ANNOTATED BIBLIORGAPHY OF PREDICTOR VARIABLES FOR WEATHER MODIFICATION APPLICATIONS

by

Nancy Westcott

Illinois State Water Survey
Urbana, Illinois

Progress Report
NSF Grant ATM 79-05007

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INTRODUCTION

Weather modification projects, both research and operationally oriented, require accurate prediction of precipitation and severe weather events, in the conduct of operations and in the evaluation of possible seeding effects. These two aspects of modification projects have been the focus of many studies. As an aide to on-going and future projects, particularly those in areas where little rain information readily exists, the following annotated bibliography has been prepared. The references include studies of variables used in weather forecasting, variables correlated with weather events and variables used in evaluating seeding effects.

The need for such a bibliography was recognized as we conducted a research project addressing the design and evaluation of operational, typically non-scientific commercial modification endeavors. The study demonstrated the value of appropriate predictor variables, both in field operations and as an important tool for any attempt to meaningfully evaluate the efficacy of modification efforts. The considerable need for readily accessible information on predictors applicable in different situations lead us to develop and publish this bibliography which encompasses a broad geographic area and many types of weather events.

One hundred and seventy-four references were collected. Meteorological journals published from 1965 to the present, provided the main source of articles (110). Other sources included preprint volumes from meteorological conferences from 1969 to the present (20), and university (22), NOAA and NWS (15), Air Force (3) and private industry (4) technical reports. Although this bibliography may seem exhaustive, some studies were likely but inadvertently

overlooked. Hopefully between the articles presented here and the reference sections of those articles, the majority of the relevant studies can be located.

The articles are alphabetized by author. The author, year of publiction, title, source and page number are given. The National Technical Information Service (NTIS) number is given for many of the reports. Those reports unavailable from NTIS or the issuing agency can be obtained from the Illinois State Water Survey Library on a loan basis (or copied at a small cost). Following the reference citation, the abstract of the article is presented. If no abstract is available, the summary, conclusion or introduction section, or an excerpt we prepared is provided. No commentary has been made upon the quality of the work.

To facilitate the use of this bibliography, the articles have been categorized by area of the country and by nation in some cases, and by the weather type which the study addressed. No attempt was made to classify the articles by meteorological variable, because of the vast number of variables examined.

The continental United States was divided into nine regions, based on topographic and climatic considerations (Figure 1). Many studies encompassed a wider area of the United States and were categorized as such (Table 1). Other nations have undertaken similar studies and are also represented in the area classification. If a study fell in more than one area, it was listed under both categories. Table 1 presents the geographic regions and the number of references included in each grouping. The Geographic Region Index follows the list of citations and the Author Index.

Table 1

Geographic Region	Total Number of Citations
Conterminous U.S.	21
U.S. east of the Rocky Mountains	23
Central U.S. (Midwest and Great Plains)	18
West Coast	10
Mountainous West	17
Great Plains	35
Midwest	12
Great Lakes	2
Gulf	10
Appalachian Mountains	2
East Coast	7
Florida	15
Australia	1
British Isles	4
Canada	5
India	2
Israel	2
Netherlands	2
Swiss Alps	1

The weather type categories selected and number of references within each are presented in Table 2. The hail and tornado alone citations are included in the severe storms list. The Weather Type Index is also found subsequent to the main text.

Table 2

Weather Type	Total Number of Citations
General rain and thunderstorms (warm months)	84
Severe storms of all types (thunderstorm, hail, tornadoes, and/or winds)	63
Hail alone	15
Tornadoes alone	24
Winter precipitation	43

The majority of these articles and reports deal with investigations where forecasts were made and verified, case studies of storms, and/or actual seeding projects. Articles dealing with numerical simulation of weather events were excluded as well as those concerned with analysis techniques. During the course of this investigation, several other bibliographies were found which dealt v?ith the more general topics of precipitation forecasting and weather modification. These provided some direction for this bibliography and may be found useful.

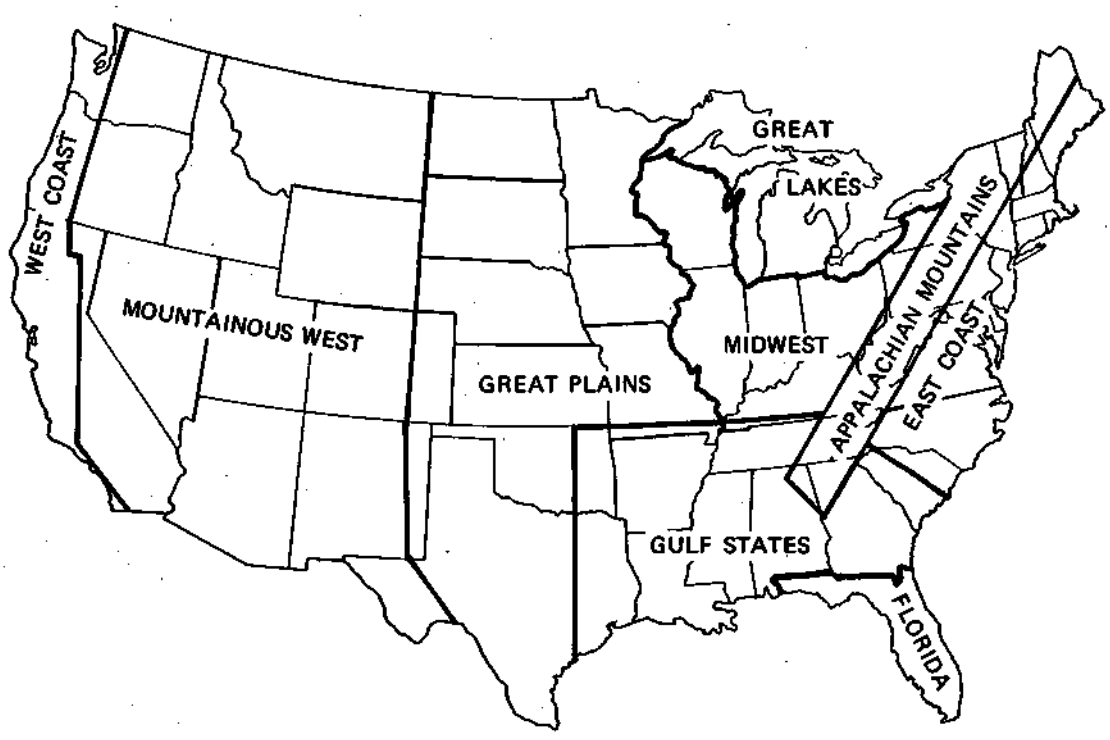

Figure 1. Regional divisions of the continental United States employed in the Geographic Index of meteorological variable studies.

ACKNOWLEGMENTS

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The opinions, findings, conclusions, and recommendation expressed in this publication are those of the author and do not necessarily reflect the views of the National Science Foundation.

1

Achtemeier, G. L., and G. M. Morgan, Jr., 1978

"A Short-Term Thunderstorm Forecast System: Step 1, Exploitation of the Surface Data"

Preprints, 9th Conference Severe Local Storms, Norman, Amer. Meteor. Soc, Boston, 18-24.

CONCLUSIONS:

The general methodology for a dynamic destabliziation model has been outlined for particular application to Illinois meteorological conditions. The model relies upon hourly monitoring of surface conditions and frequent monitoring of upper air conditions* to produce accurate 2-4 hour predictions of locations and onset times of convection. The frequent updating technique will allow circumvention of mesoscale numerical predictive models complicated by boundary and initial conditions.

2

Achtemeier, G. L., P. H. Hildebrand, P. T. Schickedanz, B. Ackerman, S. A. Changnon, Jr., and R. G. Semonin, 1978

"Illinois Precipitation Enhancement Program (Phase I) and Design and Evaluation Techniques for High Plains Cooperative Program"

Final Report, Illinois State Water Survey, Urbana, pp. 32-181, available from Illinois State Water Survey, Contract Report 210.

EXCERPT (pp. 178-179):

The sounding SPECs were found to be unimportant in explaining the daily and 6-hour rainfall variance. This was largely due to the low correlations of sounding variables to which the transience problem contributed.

The correlation of surface SPECs with rainfall were also low, but were higher than the correlations of soundings with rainfall. The upslope vertical velocity (observed wind) ranked high for both daily and 6-hour rainfall in June and August, but not in July. In general, the wind (pressure) related SPECs were best for the June and August daily rainfall. However, no SPEC ranked consistently high throughout the 3-month period. Also, no outstanding field pattern and no single physical process was identified to be productive to high plains rainfall.

The overall correlation of the surface variables with rainfall was somewhat greater than daily rainfall than for 6-hour rainfall. This may be due to the greater sparsity of hourly stations with respect to daily stations.

The factor analysis scheme was found to be useful for incorporating pattern information into the SPEC-rainfall relationships. Interpretation of the factors indicated that some factor-rainfall correlations were consistent

with known physical processes that lead to inconsistent and others were not revealing.

SPECs from the cloud model were poorly correlated with the daily rainfall and were of similar magnitude as the sounding correlations. The correlations with 6-hour rainfall were extremely low. The low correlations are likely due to the cloud model initialization which was not representative of atmospheric conditions that accompany transient weather systems.

The radar SPEC of percent areal coverage for Dodge City during 1200-1800 (i.e., the percent of the Dodge City sampling area covered by the envelope containing radar echoes) explained 25% of the rainfall variance. When the Dodge City radar SPEC was used as a dependent variable and was correlated with the surface factors, the range of correlations was .14 to .47. This range was slightly higher than the correlation of the 6-hour rainfall with the factors (range of correlation was 0-.38). The increase may be due in part to the capability of the radar to observe precipitation echoes on days when no rain fell at the hourly raingage sites.

Prewetness and the rainfall from the surrounding areas were included in the 6-hour SPEC-rainfall relationships, and the rain from surrounding areas was included in the daily SPEC-rainfall relationships. These SPECs ranked consistently high throughout the 3-month period. Overall, the prewetness and the rain from the surrounding areas were found to be the most consistent of all SPECs investigated.

The incorporation of the SPECs into the SPEC equation indicated that the amount of variance explained by the SPEC equations varies from 44.9% to 57.8% for daily data, and from 26.2% to 46.2% for precipitation during the period 1200-1800. The independent data test for the daily data in June indicated that the variance explained for the daily data might be as low as 32.8% to 44.5%. However, it is noted that the independent data test was based only on SPEC equations from the period 1965-1970. In an actual experiment, the equations could be updated each year with the inclusion of previous years into the SPEC equation. That is, 1965-1971 would be used to predict 1972, 1965-1972 would be used to predict 1973.

3

Anderson, C. E., and L. W. Uccellini, 1974

"Studies of Meteorological Factors Involved in the Formation of Severe Local Storms in the Northeast Colorado Region"

Preprints, 8th Conference Severe Local Storms, Denver, Amer. Meteor. Soc, Boston, 84-88.

SUMMARY:

Presented here are the preliminary results of the use of surface wind convergence and θ_e analyses for more accurate forecasts of severe convective storms in northeast Colorado. It is hoped that the inclusion of such analyses will provide better forecasts and extened lead time for the seeding

experiments being carried out. In general it was found that the axis of maximum θ_e favorably correlates with the area of initial cell development for both air mass and frontal cases. The convergence analysis appeared to be of some value for frontal situations. When a convergence pocket approached the axis of maximum θ_e convective storms rapidly developed. Little correlation was found between pre-existing convergence fields (as measured on a subsynoptic scale) and the air mass thunderstorms.

4

Barber, D. A., 1975

"A Contribution to the Climatology of Static Stability and Vertical Wind Shear"

Preprints, 9th Conference Severe Local Storms, Norman, Amer. Meteor. Soc., Boston, 13-17.

EXCERPT FROM INTRODUCTION:

Presented here is a statistical study of the distribution of several meteorological parameters which are related to severe storm occurrence. The study is a preliminary attempt to explain the areal distribution of tornado incidence over the contiguous United States from the viewpoint of synoptic climatology. The results of the study may also be applied to improving our knowledge of tornado climatology which is currently based on highly biased tornado reports. The selection of parameters, all computed from the standard twice-daily rawinsonde ascents, includes some which have seen long use in severe storm forecasting and analysis together with others designed by the author to fit existent knowledge of storm structure and dynamics.

5

Battan, L. J., 1967

"Silver-Iodide Seeding and Precipitation Initiation in Convective Clouds"

Journal of Applied Meteorology, 6(2): 317-322.

ABSTRACT:

Convective clouds on seeded and not-seeded days were observed by means of radar and a pair of high quality, ground-based cameras. Stereographic analysis allowed calculation of cloud-top heights, bearing, and distance from the radar set. Radiosonde data were used to convert cloud-top altitudes to summit tempertures. During the periods 1957 to 1960 (Program I) and 1961 to 1964 (Program II) the tptal number of cloud observed were 1249 and 522, respectively. The analyses indicate that on days when silver-iodide seeding was carried out from an airplane, a higher fraction of clouds developed precipitation echoes. When all the clouds in Program I with temperatures between -18 and -42C are considered, the effects of seeding were found to be

significant at the 0.07 level according to the Mann-Whitney U test. When the data for both programs are combined, the same test yields a significance level of about 0.03 for clouds with summit temperatures between -18 and -42C. The results lead to the conclusion that airborne silver-iodide seeding may influence the precipitation-initiation process in convective clouds.

6

Beebe, R. G., 1956

"Tornado Composite Charts"

Monthly Weather Review, 84(4): 127-142.

ABSTRACT:

Composite charts of height (or sea level pressure), temperature, and dew point were prepared for the surface, 850-, 700-, and 500-mb levels for tornado occurrences in 6 different areas in the United States. Cases selected for inclusion in these composite charts were mostly based upon the occurrence of 3 or more tornadoes within any one of the 6 areas during a 12-hour period. The number of cases ranged from 17 to 66 in any one area with a total of 229 cases. These charts present a mean picture of synoptic conditions from 0 to 12 hours before the outbreak of tornadoes for each of the 6 areas. In spite of seasonal and geographical differences in data, the similarity of patterns is striking.

7

Beebe, R. G. and F. C. Bates, 1955

"A Mechanism for Assisting in the Release of Convective Instability"

Monthly Weather Review , 83(1): 1-10.

ABSTRACT:

A model is proposed as one means whereby an air mass characterized by the "typical" tornado sounding is converted to one described by the type of sounding observed in the vicinity of a tornado. By considering certain indications of the vorticity equation, it is possible to analyze configurations of jet axes and jet maxima such that low-level (850 mb) convergence is surmounted by higher-level (500 mb) divergence. Thus a model of jet structures is described which assists in, or possibly in some cases effects, the release of convective instability through vertical stretching or lifting. An example is presented to illustrate the use of this tornado forecasting and methods of application are outlined.

8

Bellon, A., and G. L. Austin, 1978

"The Evaluation of Two Years of Real-Time Operation of a Short-Term Precipitation Forecasting Procedure (SHARP)"

Journal of Applied Meteorology, 17(12): 1778-1787.

ABSTRACT:

Digital weather radar data have been used with a simple pattern recognition procedure to automatically generate precipitation forecasts in the zero to three hours range. Such a technique has been in real time operation for two years. The verification of the procedure has led to a preliminary "radar climatology" for the Montreal area in the form of a map of areas showing a predominant growth or decay of precipitation patterns.

9

Belville, J., G. A. Johnson, and J. D. Ward, 1978

"A Flash Flood Aid - The Limited Area QPF"

NOAA Technical Memorandum NWS SR-97, 12 p., available from NTIS, PB-281 886.

CONCLUSIONS AND RECOMMENDATIONS:

This has proven to be an excellent program at WSFO Lubbock. The main asset is that a forecaster must systematically look at the parameters which signify a potentially heavy rain situation on a day-to-day basis. Therefore, the possibility of overlooking a situation that has flash flood potential is reduced. Also, when developing procedures for a program such as this, much is learned about the climatology of rainfall for an area. However, because a technique that works well in one part of the country may not work in another, we recommend that other WSFOs initiate similar studies.

The QPF (Quantitative Precipitation Forecast) program should improve yearly at WSFO Lubbock as more data and additional storms are studied. Also, improvements made in the LFM products should increase the accuracy of the forecasts.

10

Bermowitz, R. J., 1975

"An Application of Model Output Statistics to Forecasting Quantitative Precipitation"

Monthly Weather Review, 103(2): 149-153.

ABSTRACT:

The Model Output Statistics (MOS) technique has been applied to the prediction of quantitative precipitation. Data at 233 stations for two winter seasons are pooled to develop generalized operator equations for prediction of the probability of precipitation amount (PoPA) in categories for a 12-24 hr forecast projection. Predictors subjected to screening regression are obtained from the National Meteorological Center's (NMC) Primitive Equation Model and the Techniques Development Laboratory's Trajectory Model. The equations are developed by means of two approaches. The first, referred to an unconditional, uses both precipitation and no precipitation cases in the development sample. The second, referred to as conditional, uses only precipitation cases.

To test the system on independent data, forecasts at 58 cities in the United States are verified for October 1972. Probability forecasts are transformed to categorical forecasts by (1) maximizing the percent correct, (2) maximizing a quantitative precipitation forecast (QPF) score used to verify categorical forecasts at NMC, (3) maximizing a utility score, and (4) minimizing the categorical bias. The categorical forecasts are then compared to those obtained from (1) the Limited Area Fine Mesh Model, (2) subjective preparation at NMC, and (3) climatology. Verification scores include the percent correct, a QPF score used at NMC, and a utility score. In addition, the categorical bias is computed for each forecast method. The results indicate that the PoPA categorical forecasts obtained by minimizing the bias are, in general, slightly better than all the other forecasts. Also, "unconditional" forecasts are about as good as "conditional" forecasts.

11

Bermowitz, R. J., 1971

"Objectively Computed Surface Diagnostic Fields"

NOAA Technical Memorandum NWS TDL-38, 23 p., avaiable from NTIS, COM-71-00301.

ABSTRACT:

Hourly surface observations of temperature and wind are objectively analyzed on a grid with a gridlength of about 50 miles (1/4 that used at the National Meteorological Center). The analyses are then used to compute relatively small-scale diagnostic fields of divergence, vorticity, frontogenetical function, and temperature advection.

The results of two test cases are described. It appears that the diagnostic fields can be helpful in short range predictions. In some cases, they seem to be related to significant smaller scale features such as regions of thunderstorm and tornado activity and incipient cyclogenesis. Synoptic scale features such as frontal zones appears to be rather well represented by the diagnostic fields.

12

Biondini, R., J. Simpson, and W. Woodley, 1977

"Emperical Predictors for Natural and Seeded Rainfall in the Florida Area Cumulus Experiment (FACE), 1970-1975"

Journal of Applied Meteorology, 16(6): 585-594.

ABSTRACT:

The data obtained from the Florida Area Cumulus Experiment in the years 1970-75 are analyzed statistically. Specifically a set of empirically derived predictors for both seeded and unseeded rainfall is identified. First the experiment is briefly described and the data given. The concept of echo motion categories is presented. The responses to be predicted and the variables used as predictors are listed and described and the methods for obtaining the prediction models are give. Next comes a listing of the model equations obtained by those methods, along with some commentary on their possible physical meaning. Examples illustrate the use of some of these prediction models for estimating seeding effects and possible bias in selection of experimental days. A discussion of the echo motion covariate and the basic predictor variables, their histories, rationales and some theoretical indications of their importance completes the main body of the paper.

13

Bocchieri, J. R., and H. R. Glahn, 1976

"Verification and Further Development of an Operational Model for Forecasting the Probability of Frozen Precipitation"

Monthly Weather Review, 104(6): 691-701.

ABSTRACT:

An automated system for forecasting the conditional probability of frozen precipitation was put into operation by the National Weather Service in Novemenber 1972. The Model Output Statistics (MOS) concept was used to develop the system, and both teletypewriter and facsimile products have been distributed to field offices twice daily. In this paper, guidance forecasts from this system are compared to subjective (local) forecasts prepared at Weather Service Forecast Offices. The local forecasts have been archived since September 1973 as part of a combined aviation/public weather forecast verification program within the National Weather Service. The comparative verification between the guidance and locals for two different data samples shows the guidance has produced better forecasts for the 18, 30, and 42 h projections.

In attempting to improve the operation system, we experimented with the Regression Estimation of Event Probabilities (REEP) screening technique. The operational system had been developed with the logit model, but or logit

computer program does not objectively screen predictors as REEP does. A comparison of the REEP and logit systems on independent data shows logit to better.

We used the logit model to develop a new operational system. Five winters of developmental data were used for the new system; the old system was developed from three winters of data. A comparison between the new and the old systems on independent data shows that they are equally accurate for the short-range (12 h) projection but that the new system is more accurate for the longer-range (36 h) projection.

The predictors in the new system include the 850 mb temperature, boundary-layer potential temperature, 1000-500 mb thickness, and 1000-850 mb thickness. These variables are forecast by the National Meteorological Center's primitive equation model. The new system was made operational during the winter of 1975-76 and provides forecasts for the 12, 18, 24, 30, 36, 42, and 48 h projections twice daily.

14

Bonner, W. D., 1966

"Case Study of Thunderstorm Activity in Relation to the Low-Level Jet"

Monthly Weather Review, 94(3): 167-178.

ABSTRACT:

The relationship between the low-level jet and thunderstorm activity in the south-central United States is examined through mesoanalysis of surface data from Weather Bureau and NSSP stations. Separate squall systems moved through Kansas and Oklahoma during the night; the systems in Kansas persisted while those in Oklahoma died out. The most likely explanation for this is the synoptic-scale vertical velocities in the vicinity of the low-level jet.

15

Boyden, C. J. , 1963

"A Simple Instability Index for use as a Synoptic Parameter"

The Meteorlogical Magazine, 92(1092): 198-210.

EXCERPT FROM THE INTRODUCTION:

Most indices are designed for use in relation to thunderstorms and similar violent phenomena. They are usually computed from upper air ascents made at night and it is assumed, with fair justification in the circumstances, that the only change in the local atmosphere in the next 12 or 18 hours will arise from surface heating. This is broadly true since heat thunderstorms commonly occur where there is little advection, at least in the lower layers.

Nevertheless, about half the summer thunderstorms over the British Isles occur in the vicinity of a front, though often a weak one, and this points to a need for a method of assessing the probability of thunderstorms when the local upper air changes with time are not negligible. It is believed that an instability index is rarely, if ever, used as a synoptic parameter in the sense that instability isopleths are regularly drawn over a complete air chart and followed from day to day as are depressions and anticyclones. The nature of the components of an instability index suggests there would be no great diffuclty in doing this, but it would take time. The present paper introduces an index which appears to meet all major requirements and can be plotted on a 700 mb chart for all stations over the North Atlantic and Europe within five minutes.

16

Braham, R. R., Jr., 1966

"Project Whitetop: A Convective Cloud Randomized Seeding Project: Part I - Design of the Experiment; Part II - Summary of Operations"

Final Report, Department of the Geophysical Sciences, University of Chicago, Chicago, pp. 10-16, 115-143, available from NTIS, PB-176 622.

EXCERPT (pp. 142-143):

Although the use of the criteria results in fewer experimental days than had been originally anticipated, it has been shown that it successfully differentiated days not only in respect to the occurrence of precipitation but in respect to the fraction of the research area receiving rainfall and the avearge amount of rain falling over this area. By means of the "factors of merit" it has been shown that the likelihood of any precipitation event (fraction of area, and amount) was at least three times as large on an experimental days as on a non-experimental day and that this likelihood increased for combinations of large areas and large average amounts.

The criteria were originally chosen as a specific means for defining experimental days. However, the study suggests the value of using these, or similar criteria based on precipitable water, winds or other objective meteorological parameters as forecasting aids. Used in their present form the criteria indicate real differences in the likelihood of precipitation for days which meet the criteria compared with days which do not. It seems that further study into both the suitability of such criteria for locations other than southern Missouri and the use of other combinations of criteria would indeed bring about worthwhile results.

17

Bradley, R. A., S. S. Srivastava, and A. Lanzdorf, 1979

"Some Approaches to Statistical Analysis of a Weather Modification Experiment"

Technical Report M491, Department of Statistics, Florida State University, Tallahassee, 48 pp., available from the issuing agency or from the Illinois State Water Survey Libarary.

ABSTRACT:

This report is concerned with an evaluation of the effects of cloud seeding in Phase I of the Santa Barbara Convective Band Test Seeding Program conducted by North American Weather Consultants, 1967-71. Earlier reports summarized data on precipitation over both a Control Area and various Target Areas and provided summary data on meteorological variables, all by convective band, the chosen experimental unit. In this report, the meteorological variables are used as covariates to reduce experimental error with a view to improved precision in the examination of both direct and interactive effects of cloud seeding. Various analyses are reported with and without the use of Control Area precipitation as a covariate and with and without weighting for possibly heterogeneous error variances. A subset of the covariates was effective in the reduction of experimental error by 60-70%. No effects of cloud seeding were found.

18

Bradley, R. A., S. S. Srivastava, and A. Lanzdorf, 1978:

"An Examination of the Effects of Cloud Seeding in Phase I of the Santa Barbara Convective Band Seeding Test Program"

Technical Report M467, Department of Statistics, Florida State University, Tallahassee, 67 p., available from the issuing agency or from the Illinois State Water Survey Library.

ABSTRACT:

Data from a weather modification experiment are examined and a number of statistical analyses reported. The validity of earlier inferences is studied as are the utilities of various statistical methods. The experiment is described. The original analysis of North American Weather Consultants, who conducted the experiment, is reviewed. Data summarization is reported. A major approach to analysis is through the use of cloud-physics covariates in regression analyses. Finally, a multivariate analysis is discussed. It appears that the covariates may have been affected by treatment (cloud seeding) and that their use is invalid, not only reducing error variances but removing treatment effect. Some recommendations for improved design of similar future experiments are given in a concluding section, including preliminary trial use of blocking by storms.

19

Brandes, E. A.,and J. Spar, 1971

"A Search for Necessary Conditions for Heavy Snow on the East Coast"

Journal of Applied Meteorology, 10(3): 397-409.

ABSTRACT:

An investigation into the synoptic conditions necessary for the occurrence of heavy snow on the east coastal plain of the United States has revealed no obvious characteristic antecedent patterns either 12 or 24 hr prior to the onset of snow. The contemporaneous association of heavy snow with east coastal secondary cyclogenesis and with certain synoptic features at the 850-mb level is found to be of limited predictive value.

20

Browne, R. F., and R. J. Younkin, 1970

"Some Relationships Between 850-Millibar Lows and Heavy Snow Occurrences Over the Central and Eastern United States"

Monthly Weather Review, 98(5): 399-401.

ABSTRACT:

It is generally known that certain relationships exist between the production of heavy snow and low-level dynamic and thermodynamic parameters, such as vorticity, moisture, and temperature advection patterns. This statistical synoptic climatological study at the 850-mb level is made to understand better these relationships and also to improve operational forecasting of heavy snow over the central and eastern United States. Models relating percentage frequency of heavy snowfall in 12-hr periods to initial and subsequent 850-mb height and temperature patterns are developed. Also, considerable other statistical information is arranged in tabular form for forecaster evaluation.

21

Carlson, T. N., and F. H. Ludlam, 1968

"Conditions for the Occurrence of Several Local Storms"

Tellus, 20, 203-226.

ABSTRACT:

The technique of relative-flow analysis on isentropic surfaces is used to examine the large- ("synoptic"-) scale situations associated with selected severe local storms near southern England and over the mid-western U.S.A. (including the Horsham, Wokingham, and Geary storms whose behaviour has been described in several previous publications). The storms occur ahead of major troughs, in the vicinity of confluence-lines (usually recognised as cold fronts over western Europe but as "dry-lines" over the U.S.A.), where an increase of wind with height favours the organisation and intensification of cumulonimbus convection. Extreme instability arises where small-scale convection is confined to a lower most 1 or 2 km (leading to an abnormally

high wet-bulb potential temperature) beneath a plume of very warm air lying downwind of an extensive arid plateau (Spain or Mexico). The instability is released where the (backed) low-level flow eventually reaches the edge of the restraining plume aloft. It appears that the occurrence of severe local storms demands a peculiarly favourable combination of geographical features and atmospheric flow-pattern.

22

Chappell, C. F., L. 0. Grant, and P. W. Mielke, Jr., 1971

"Cloud Seeding Effects on Precipitation Intensity and Duration of Wintertime Orographic Clouds"

Journal of Applied Meteorology, 10(5): 1006-1010.

ABSTRACT:

The nature of precipitation changes resulting from seeding cold orographic clouds is examined by separating the observed total precipitation change into duration and intensity change components. The total precipitation change and its two components are then evaluated as functions of cloud temperature using precipitation data recorded in the primary target area during the cloud seeding experiment conducted near Climax, Colorado. The results show that the total change in observed precipitation is mainly controlled by changes in precipiation duration, rather than intenstiy. The main effects of seeding appear to be the initiation of a precipitation release for the warmer clouds during many hours when it would not have occurred naturally, and the suppression of precipitation for the coldest clouds during some hours when it would have occurred naturally. These results are consistent with the concepts of cloud microstability and cloud over-seeding.

23

Charba, J. P., 1979

"Two to Six Hour Severe Local Storm Probabilities: An Operational Forecasting System:

Monthly Weather Review, 107 (3): 268-282.

ABSTRACT:

The National Weather Service has developed an operational objective system which produces 2-6 h probability forecasts of severe local storms. The probabilities pertain to square areas of about 85 n mi (155 km) on a side which cover most of the United States east of the Rocky Mountains.

The forecast probabilities are based on multiple linear regression equations. The independent variables (predictors) are derived from objectively analyzed surface atmospheric variables observed hourly, forecasts

of atmospheric variables above the surface from a large-scale numerical predication model, manually digitized radar data, and localized climatic frequencies of the predictand. Certain predictors, such as modified forms of standard stability measures, are derived from thr latest observed temperature and moisture variables at the surface together with numerical forecasts of these same variables in the lower troposphere. Each predictor is positioned optimally (in a climatic sense) relative to the predicted areas and is derived to bear a linear relationship to the predicted relative frequency.

The severe storm regression equations are found to contain many of the predictive variables used subjectively by operational severe storm forecasters. Predictors derived partly or totally from observed surface data are especially prominent in the equations. Separate equations for two geographical regions of the United States exhibit differences in the relative importance of certain predictors. The most notable single difference is that predictors derived partly or totally from observed surface data are more important in the Midwest and High Plains than they are near the Gulf Coast. The statistical predictor-predictand analysis also yielded evidence that the technique of deriving predictors from a combination of the latest observed data at the surface together with forecast data aloft produces more predictive information than when these data are used separately.

Limited quantitative verification of the operational forecasts issued during the spring season of 1971 shows that the probabilities were superior to either climatology or persistence. However, comparison of the verification scores for this independent sample with those from the dependent sample indicates some instability in the system. This instability is evidently due to small development and verification samples used and the low frequency of occurrence of the predictand. Subjective verification of the probabilities for six randomly selected severe storm days showed that the system's ability to forecast storm occurrences is generally respectable. However, the quality of individual forecasts is related to the organization and strength of the synoptic systems that produced the storms.

24

Charba, J. P., 1977

"Operational System for Predicting Thunderstorms Two to Six Hours in Advance"

NOAA Technical Memorandum NWS TDL-64, 24 pp., available from NTIS, PB-271 147.

ABSTRACT:

We have developed and implemented in the National Weather Service an objective method yielding probabilities of thunderstorms 2-6 hr in advance. The probabilities are for square areas 40-45 nmi on a side which cover most of the United States east of the Rocy Mountains.

The probabilities are produced by mulitple linear regression equations. The independent variables or predictors in these equations are derived from routinely-observed surface atmospheric variables, manually digitized radar

data, localized climatic frequencies of thunderstorms, and large-scale numerical model output. Predictor quantities computed from these data are appropriately positioned relative to the predictand areas and "linearized" in order to enhance their correlation with the predictand.

Verification of 2-1/2 mo of operational spring season forecasts shows the forecasts to have considerable skill relative to forecasts of the climatic frequency and persistence of thunderstorms. Subjective examination of individual cases shows that the envelopes of high probability values match up well with the general patterns of thunderstorm occurrence.

25

Cimino, N. P., and L. M. Moore, 1975

"An Objective Aid to Forecasting Summertime Showers Over the Lower Rio Grande Valley of South Texas"

NOAA Technical Memornadum NWS SR-79, 14 p., available from NTIS, COM-75-10307.

ABSTRACT:

Accurate precipitation forecasts are essential to a good weather service program for the agricultural community of the Lower Rio Grande Valley of South Texas. This local forecast study involves, primarily, the short range forecasting of areal coverage of summertime airmss showers over the valley by using predictor variables extracted from the latest Brownsville atmospheric sounding. The highest correlated predictor variable with areal shower coverage was the combination of the mean relative humidity in the 850 mb to 700 mb layer and the 650 mb to 500 mb layer. In addition, these two predictors were used to construct a graph to estimate the average and maximum 24-hour precipitation amounts.

26

Connell, J. R., and L. Ey, 1977

"Wind Shear and Wet and Dry Thermodynamic Indices as Predictors of Thunderstorm Motion and Severity and Application to the AVE IV Experimental Data"

NASA Contract Report 150220, University of Tennesse Space Institute, Tullahoma, 113 p., availabe from NTIS, N77-21801.

ABSTRACT:

Two types of parameters are computed and mapped for use in assessing their individual merits as predictors of occurrence and severity of thunderstorms. The first group is comprised of equivalent potential temperature, potential temperature, water vapor mixing ratio, and wind speed. Equivalent potential temperature maxima and strong gradients of equivalent potential temperature at

the surface correlate well with regions of thunderstorm activity. The second type comprised of the energy index, shear index, and energy shear index, incorporate some ;model dynamics of thunderstorms, including nonthermodynamic forcing. The energy shear index is found to improve prediction of tornadic and high-wind situations slightly better than other indices.

It is concluded that further development and refinement of nonthermodynamic aspects of predictive indices are definitely warranted. Some specific recommendations for further work are made which involve looking at atmospheric structure in finer detail, with more physical insight, and using correlation techniques for formulating the best predictor indices.

27

Cotton, W. R., and A. Boulanger, 1975a

"On the Variability of "Dynamic Seedability" as a Function of Time and Location over South Florida: Part I. Spatial Variability"

Journal of Applied Meteorology, 14(5): 710-717.

ABSTRACT:

Using the one-dimensional cumulus model developed by Cotton, predictions of the effects of seeding Laboratory FACE 1973 Experiment. The calculations were performed with the Miami 1200 GMT soundings and soundings taken in the interior of Florida at 1400 GMT at the so-called Central Site (CS) location.

A comparison of "seedability" predictions using the Miami 1200 GMT and CS 1400 GMT soundings have shown that substantial differences between the two seedability predictions occur on a number of days in spite of the fact that the soundings are separated in time by only 2 h and in space by only 110 km. The differences can be atrributed to the frequent intrusion of dry air masses of varying height and thickness. The intensity of the dry layers is generally greatest over the higher-latitude CS location. The greatest differences between the two soundings, and hence the greatest difference between the predicted seeding effects, occurs during periods of transition from a disturbed, westerly flow regime to a well-defined, deep, easterly flow regime.

28

Cotton, W. R., and A. Boulanger, 1975b

"On the Variability of "Dynamic Seedability" as a Function of Time and Location over South Florida. Part II. Temporal Variability"

Journal of Applied Meteorology, 14(7): 1376-1382.

ABSTRACT:

Using the one-dimensional cumulus model developed by Cotton, predictions of the effects of seeding cumulus clouds were performed during the months of

July 1973 as part of the Experimental Meteorology Laboratory's Florida Area Cumulus Experiment 1973 experiment. In Part I we compared seedability predictions with the Miami 1200 GMT soundings and soundings taken over the center of the experimental area (Central Site) at 1400 GMT. It was found that substantial differences between the two predictions occurred on a number of days inspite of the fact that the soundings are separated in time by only 2 h and in space by only 110 km.

In this paper we compare seedability predictions with the MIA 1200 GMT soundings and the CS 1800 GMT soundings. The CS 1800 GMT soundings were assumed to be representative of conditions oyer the experimental area during the period of operation of the experiment. We found that the predictions with the MIA 1200 GMT soundings were, on the average, more representative of conditions over the center of the experimental area during the period of operation of the experiment than were the predictions with the CS 1400 GMT soundings. The results of this study indicate that the choice of a sounding site and sounding time to be used for prediction of seeding effects over an experimental area must be carefully considered in the design of the experiment.

29

Darkow, G. L., 1968

"The Total Energy Environment of Severe Storms"

Journal of Applied Meteorology, 7(2): 199-205.

ABSTRACT:

The distribution in time and space of the total specific energy (c_pT + gZ + Lq + $V^2/2$) of the environment of severe storms is examined. Comparisons of the total energy profiles of tornado proximity soundings with the closet check soundings show pronounced differences. The tornado proximity sounding has substantially high total energy values in the lower troposphere and lower values in the mid-troposphere than nearby stations. It is shown that the total specific energy may be approximated with negligible error by the static energy (c_pT + gZ + Lw) and that this parameter is proportional to isobaric equivalent potential temperature and is similarly conservative.

A practical application of these results to severe storm forecasting is given in the form of a "Total Energy Index." This index is readily and objectively determined from routinely transmitted upper air data. Unlike other widely used stability indices, the Energy Index indicates not only the energy release associated with the ascending, potentially warm air but also the possible contribution of the saturated descent of the evaporatively cooled, potentially cold mid-tropospheric air to the total energy release of the storm. Examples are shown of the Energy Index field on several recent tornado days.

30

Darkow, G. L., and R. L. Livingston, 1973

"Hourly Surface Static Energy as a Delineation of Thunderstorm Outflow Areas"

Preprints, 8th Conference Severe Local Storms, Denver, Amer. Meteor. Soc, Boston, 232-237.

EXCERPT FROM INTRODUCTION:

The detection and subsequent monitoring of surface outflow air from thunderstorms or thunderstorm complexes such as squall lines can play a critical role in operational mesoscale and severe storm forecasting. At times, the mesoscale outflow air from a number of thunderstorms in an area may merge and have a pronounced impact on subsequent synoptic scale developments (see for example Fujita, 1955, and Zipser, 1969).

It is the purpose of this paper to call attention to the advantages and potential for the use of hourly surface static energy ($c_pT + gz + Lw$) analysis to readily delineate thunderstorm outflow areas.

31

David, C. L., 1976

"A Study of Upper Air Parameters at the Time of Tornadoes"

Monthly Weather Review, 104(5): 546-551.

ABSTRACT:

An objective analysis routine was used to obtain the values of selected upper air parameters at the location and time of tornadoes. Parameters used were the temperature, dew point, wind direction and wind speed for the 850 mb, 700 mb, and 500 mb levels, the 200 mb wind direction and wind speed the mean mixing ratio in the lowest 100 mb layer, the tropopause temperature and pressure, and the 500-850 mb thickness. Some computed stability indices are also presented; these are the Showalter Index, Total-Totals Index, and the Air Force Sweat Index. Tables are presented giving the average value and the standard deviation for each of the parameters by states and by months. Similar information is presented for the longer track tornadoes and they are compared with very short track tornadoes.

32

David, C. L., 1974

"Objective Probabilities of Severe Thunderstorms Using Predictors From FOUS and Observed Surface Data"

NOAA Technical Memorandum NWS CR-54, 9 p., available from NTIS, COM-74-11258.

ABSTRACT:

Model Output Statistics and screening regression are used to derive equations for estimating the probability of severe thunderstorm occurrences. The predictors screened were the PE model forecast data transmitted on the FOUS teletype message and the latest observed surface data. The predictand is the occurrence of severe thunderstorms during a 12-hour period in an area 120 nm centered on a station. Two equations are derived from the 00Z FOUS data and two from the 12Z FOUS data. One is for the period 12 to 24 hours after the FOUS data time and the other is for the period 24 to 36 hours after the data time.

33

David, C. L., and J. S. Smith, 1971

"An Evaluation of Seven Probability Indices as Predictors of Severe Thunderstorms and Tornadoes"

Preprints, 7th Conference Severe Local Storms, Kansas City, Amer. Meteor. Soc, Boston, 105-109.

CONCLUSIONS:

First we will consider the five indices, as predictors of severe thundstorms, that are computed from the early radiosonde data. The Showalter Index is the best predictor, with the potential wet bulb index, the Sweat Index, total-totals and the K-value following in that order. The K-value was designed for air mass thunderstorms and the deep moist layer that gives the higher K-values is not necessary (and maybe unfavorable) for severe thunderstorms. The Sweat Index was successful in improving the total-totals, which is the stability parameter in that index, but the author is of the opinion that a more successful index can be found using the Showalter Index as the stability parameter. The addition of the wind speed terms and the wind shear term made the Sweat Index a better predictor of tornadoes than the others. A threshold value for the Sweat Index of 300 for severe thunderstorms and 425 for tornadoes is suggested by the Air Force. The screening program found 250 as the most favorable threshold for both severe thunderstorms and for tornadoes.

The good results that the Showalter Index gave in this evaluation makes it a valuable stability parameter for any prediction equation. Other factors that add to its value are that it is easy to compute and the data are available before the full radiosonde data.

Although the PE 12-hour prog index is a better predictor of severe weather than the SELS and Showalter indices, it is transmitted via facsimile during the early afternoon and too late to be a factor in the SELS morning operations. It can however, be used by the field stations to evaluate the morning severe thunderstorm outlook of SELS, by comparing the pattern of the index with the area outlooked. If a relatively unstable area of the index coincides with the area of the SELS outlook, the outlook should be more likely to verify than if the areas do not coincide. It is hoped that improvements in the time of availability of this and other PE products will be forthcoming.

34

Decker, W. L., L. N. Chang, and G. F. Krouse, 1971

"An Evaluation of the Whitetop Cloud Seeding Experiment through a Covariance Analysis"

Journal of Applied Meteorology, 10(6): 1193-1197.

ABSTRACT:

The Whitetop experiment concerning cloud seeding was conducted in southern Missouri and northern Arkansas during 1960-64. In general, the early analysis showed the rainfall in the treated areas on days with seeding to be significantly less than the rain in corresponding areas on days without seeding. In the present analysis, the rainfall for an area adjacent to the treated area was taken as a covariant. Using the analysis of covariance, the seeding effect is not statistically significant at the 5% level. At least a portion of the negative effect from treatment previously reported is associated with the high frequency of heavy rain on the days without seeding. From the covariance analysis the differences in precipitation for varying distances from the seeding line were not statistically significant.

35

Dennis, A. S., and A. Koscielski, 1969

"Results of a Randomized Cloud Seeding Experiment in South Dakota"

Journal of Applied Meteorology, 8(4): 556-565.

ABSTRACT:

A 3-year randomized crossover seeding experiment has been conducted in South Dakota to test effects of artifical nucleation upon convective clouds of spring and early summer. The associated rainfall observations have been analyzed by several statistical techniques. The principal conclusions are: 1) on days with isolated showers, rainfall has been heavier in the seeded target area than in the unseeded target area; 2) on days with widespread convective activity and southwesterly winds aloft, rainfall has been lighter in the seeded target area than in the unseeded target area, except for the regions 10-20 miles east of the Black Hills; and 3) on days with widespread convective activity and northwesterly winds aloft, rainfall has been lighter in the seeded than in the unseeded target area.

36

Dennis, A. S., J. R. Miller, Jr., D. E. Cain, and R. L. Schwaller, 1975

"Evaluation by Monte Carlo Tests of Effects of Cloud Seeding on Growing Season Rainfall in North Dakota"

Journal of Applied Meteorology, 14(5): 959-969.

ABSTRACT;

Rainfall data collected at 67 gages in a 2750 mi^2 target area during a four-year randomized cloud seeding experiment in North Dakota have been stratified in a variety of ways and subjected to several kinds of statistical tests. Some stratifications related to cloud model predictions were possible for only the last two years when a rawinsonde station was operated as part of the project. Monte Carlo experiments simulating 500 reruns of the four-year experiment have been used to establish significance levels for the tests within each data stratification.

The analysis provides significant evidence that seeding convective clouds on a determinate set of days leads to 1) an increase in the frequency of rainfall events at the individual target gages, 2) an increase in the average rainfall recorded per rainfall event, and 3) an increase in total rainfall on the target. The set of days to which this evidence applies is those days with dynamic seedability; that is, days for which a cloud model predicted in cloud top height under the influence of silver iodide seeding. Rainfall observations on days when the cloud model predicted no increase in cloud height show no significant differences between seed and no-seed days.

The possibility of bias has been checked by comparing the frequencies of wet and dry days and the averages of several meteorological variables for seed and no-seed days within each stratification, by cross-checking the stratifications, and by comparing rainfall on seed and no-seed days over an area of roughly 50,000 square miles surrounding the target area. There is no obvious bias to account for the significant differences between seed and no-seed days with dynamic seedability.

It is tentatively concluded that dynamic effects, including rainfall increases, were produced by light to moderate silver iodide seeding from below cloud base. The potential rainfall increase resulting from seeding below selected clouds on days with dynamic seedability is estimated at one inch per growing season.

37

Dennis, A. S., J. H. Hirsch, D. E. Cain, J. R. Miller, Jr., and A. Koscielski, 1975

"The Potential for Rainfall Increases from Convective Clouds in the Northern Plains"

Bureau of Reclamation Report 75-12, Institute of Atmospheric Sciences, South Dakota School of Mines and Technology, Rapid City, 60 p., available from NTIS, PB-248 920.

ABSTRACT:

This report describes a variety of investigations using data collected during the Institute's field experiments in cloud seeding over the past ten years. The particular sets of data used are the Cloud Catcher 10—cm radar for 1971-72, the rainfall records from the Rapid Project of 1966-68, and from the

North Dakota Pilot Project (NDPP) for 1971-72, and time-lapse radar photographs obtained on the NDPP in 1972. A one-dimensional, steady-state cloud model has been used extensively in all three investigations.

The 10-cm radar data from Project Cloud Catcher are analyzed for the first time in terms of individual cells rather than test cases as a whole. The Cloud Catcher cases of 1971-72 were randomly assigned to seed and no-seed categories with salt being the usual seeding agent. A comparison of 41 cells drawn from the seed population and 16 drawn from the no-seed population shows no difference in cloud depth but suggests significant differences in some other variables. In particular, the seed cells were narrower than the no-seed cells, but they yielded higher point rainfall rates and had higher precipitation efficiencies. Because of the limited nature of the Cloud Catcher data sample it is considered premature to draw firm conclusions about the effects of salt seeding on individual cells.

The Rapid Project was a randomized crossover experiment with separate target areas for southwest and northwest flow days. A previous analysis based on individual gages had shown rainfall increases on shower days and suggested rainfall decreases on storm days except for storm days with southwest flow, when rainfall increases were suggested ten to twenty miles downwind of the Black Hills. A much more detailed analysis is reported here with consideration given to average daily rainfall in each target area, to the fraction of gages in a given target reporting rain on the given day, and to the total rainfall accumulated in each target area for all days of a particular type. Stratifications based on 500-mb temperature, wind shear between 400 and 700 mb, virtual temperature excess, updraft profile types, and dynamic seedability are presented. Significance levels have been established in every case by Monte Carlo experiments. For southwest flow days, the increases previously noted on shower days are confirmed. They appear to be related to dynamic seedability. Days with dynamic seedability can be identified by requiring an indicated increase in cloud height (H) of 0.5 km or more due to silver iodide seeding for cloud model runs with updraft radius at cloud base at 1.5, 2.0, or 2.5 km. The results for northwest flow days are generally inconclusive, apart from an indication that rainfall was decreased by seeding on certain storm days. The decrease appears to affect the number of gages recording rain as well as the total rainfall accumulated. It is impossible to give results concerning the relationship between dynamic seedability and rainfall on northwest flow days because the 12 days with dynamic seedability of 500 m or more were broken down into 10 south seed and 2 north seed days, which does not yield a reliable data sample.

A renalaysis of the NDPP rainfall data tends to confirm that dynamic seedability can be identified by running the model with updraft radii in the range of 1.5 to 2.5 km and looking for days with H of more than 0.5 km.

A study of shower echoes on the North Dakota Pilot Project for 1972 shows most of the cloud depths from 4 to 10 km. Cloud model runs suggest considerable dynamic seedability for clouds 3 to 6 km deep, decreasing to negligible seedability for large clouds 10 km or more in depth. A study of the time available for precipitation to form suggests that seeding the smaller clouds not only increases their size but increases the time available for

precipitation to form within them during the ascent of embryos from cloud base. It is shown that the apparent rainfall increases on the NDPP in 1971-72 can be accounted for on the basis of dynamic seedability of individual cumulus clouds.

38

Dennis, A. S., A. Koscielski, D. E. Cain, J. H. Hirsch, and P. L. Smith, Jr., 1975

"Analysis of Radar Observations of a Randomized Cloud Seeding Experiment"

Journal of Applied Meteorology, 14(5): 897-908.

ABSTRACT:

Magnetic tape records for radar observations of 80 moving one-hour test cases in a three-way randomized (no-seed, salt, silver iodide) cloud seeding experiment have been analyzed in terms of echoing areas and radar-estimated rainfall amounts. Individual test cases ranged from non-precipitating cumulus up to moderate thunderstorms with echoing areas exceeding 100 km^2 and rainfall estimated at 3000 kT in 1 h.

Out of numerous predictor variables, cloud depth is found to be the best single predictor for both echoing area and radar-estimated rainfall. The echoing area and radar-estimated rainfall are very closely correlated. A cube-root transformation of the radar-estimated rainfall improves the correlation between cloud depth and the radar-estimated rainfall for the no-seed (control) sample to 0.91. For clouds of a given depth, both the echoing area and radar-estimated rainfall are larger in seeded than in unseeded cases. The differences between no-seed and salt cases are of marginal statistical significance, but the differences in echoing area and rainfall between no-seed and silver iodide cases are significant at the 1% level. The indicated effects, expressed as a percentage of the echoing area or radar-estimated rainfall in the no-seed cases, decrease with cloud depth.

A comparison of no-seed and Agl cases with the aid of a one-dimensional steady-state cloud model shows that Agl seeding may have led to increases in maximum cloud height averaging 600 m.

It is concluded that seeding affected the precipitation in the Cloud Catcher test cases through both the microphysical process and the cloud dynamics.

39

Dewey, K. F., 1979

"Lake Erie Induced Mesosystems - An Operational Forecast Model"

Monthly Weather Review, 107(4): 421-425.

ABSTRACT:

All Lake Erie lake-effect days for a 10-year period prior to the 1976-77 snowfall season were utilized in the development of an operational lake-effect snowfall forecast model. Upper air and surface observations were combined with overlake data and analyzed, using stepwise multiple-discriminant analysis. A nine-predictor mesoscale forecast model resulted from this statistical test and its performance was evaluated during the 1976-77 and 1977-78 snowfall seasons. The results of this evaluation indicate that it is possible to predict six intensities of the Lake Erie lake-effect snowstorm using this mesoscale model.

40

Dirks, R. A., 1969

"A Climatology of Central Great Plains Mesoscale Convective Systems"

Technical Report E-10-686, Colorado State University, Fort Collins, 60 p., available from NTIS, PB-183 988.

ABSTRACT:

Dynamic and thermodynamic factors associated with squall line development are reviewed along with proposed initiating mechanisms.

Mesoscale convective systems (100 km scale) are studied over one summer season (May-August 1966) in the central Great Plains area. Based on satellite photographs, radar observations and standard synoptic data, the spatial and temporal distributions of the formation of these systems are analyzed. The analyses show preferred regions of initial development several hundred kilometers leeward of the Colorado Rockies while in the immediate lee of the mountains convection is largely suppressed.

The synoptic conditions associated with meso-system formation are investigated and mean cases are constructed. Convective instability and a tongue of warm, moist air at low levels (850 mb) along with evidence of a short wave feature at upper levels (700 and 500 mb) are common characteristics. Other conditions such as the presence of the low-level jet, jet streams aloft, or surface fronts are found to be related to a particular type of synoptic situation.

Future studies will involve a theoretical evaluation of the various ways in which orography controls the observed leeward convective development. An Appendix presents a preliminary discussion of a mountain slope—plain numerical experiment along with some early results.

41

Druyan L. M., and Y. Sant, 1978

"Objective 12 h Precipitation Forecasts Using a Single Radiosonde"

Bulletin of the American Meteorological Society, 59(11): 1438-1441.

ABSTRACT:

Radiosonde profiles of temperature and dew point at Bet Degan, Israel, are used to develop and test an objective procedure for making 12 h forecasts of precipitation by an approach suggested by Schell (1946) and Krown (1953). Verification of 62 percent based on the procedure showed 89% to be correct, although some degree of "overforecasting" of precipitation was evident. The verified skill compares favorably to the skill of offical subjective forecasts made available to the public during the same season.

42

Eddy, A., and E. Cooter, 1979

"The Evaluation of Operational Cloud Seeding in South Dakota: Some Preliminary Findings"

Final Report to North Dakota Weather Modification Board, Amos Eddy, Inc., Norman, 43 p., available from the issuing agency or from the Illinois State Water Survey Library.

ABSTRACT:

Commerical cloud seeding operations began in North Dakota about 1950. In order to study potential benefits of this activity to the wheat farmers of the state, we have examined the rainfall climatology from several points of view. We have endeavoured to separate dry years from wet years by using growing season soil moisture as a means to represent temperature and rainfall simultaneously. The growing season averages across the state of the daily maximum and minimum temperatures, the daily rainfall, and the soil moisture were not significantly different before seeding was begun (1913-1948) from what they were after the onset of commercial seeding (1951-1976). However, the average growing season daily rainfall at a station where any rainfall was observed (over .01 inches) was 13% less from 1951-1976 than it was from 1913 to 1948; whereas the frequency of growing season rainfall occurrence was 19% greater than 1951 to 1976 than from 1913 to 1948 period. This is associated with a (statistically non-significant) 2-3% increase in post-1950 growing season rainfall over the pre-1949 period. Thus, although there has not been a significant increase in growing season rainfall since seeding began, there has been a significant change in the way the rainfall has occurred, that is, an increase in the number of days with light rainfall.

We have found that when mean rain on a rainy dat at stations in, or downwind from any target area is compared with mean rain on a rainy day at stations out of any seeded areas there is significantly more rain on a rainy day in the seeded area when the winds have a component from the West. Furthermore this difference is significant when only days with a SW wind are considered. Northwest flow produced a little more mean rain on a rainy day associated with seeded areas than with non-seeded areas, but not enough to prove significant.

As will be seen from a careful consideration of the following text, it is difficult to escape the implication that the mean rain on a growing season rainy day since operational cloud seeding started in North Dakota has been significantly influenced by the seeding activity.

43

Elliot, R. D., P. St. Amand, and J. R. Thompson, 1971

"Santa Barbara Pyrotechnic Cloud Seeding Test Results 1967-70"

Journal of Applied Meteorology, 10(4): 785-795.

ABSTRACT:

Tests of the effectiveness of ground-released pyrotechnics in enhancing precipiation in storms in Santa Barbara County were conduced during the three winter seasons of 1967-68, 1968-69, and 1969-70. The mode of operation and the type of pyrotechnic device remained fixed through the three years in order to develop a large sample of data. The observation unit employed was a convective band embedded within a general storm system. A series of pyrotechnic candles of the LW-83 formulation were ignited just prior to and during the passage of convective bands over the seeding site, located on a 3500-ft mountain ridge in the Santa Ynez mountains. : The bands were detected upwind of the test area and tracked into the test area by use of telemetered raingages and weather radar. Out of a total of 85 bands, 43 were seeded and 42 not-seeded. The selection of bands to seed was made on a random basis following declaration of the approach of a seedable band.

Over 60 recording raingages extending over an area of ~ 1500 mi^2 provided the basic evaluation data. Soundings taken with a GMD-1 system just prior to band passage into the test area provided useful air mass documentation. The cases were stratified by stability and 500-mb temperature categories.

The statistical analysis shows that there was a statistically significant difference between the distributions of seeded and not-seeded band precipitation totals for stations distributed over a several hundred square mile area downwind of the point source of nuclei. Indications were that precipitation was increased by 50% or more. The effect was greatest in the case of the warmer and more unstable categories.

When the overall precipitation is considered, including the between-band (not-seeded) component, the net increase is about 32%. Precipitation between bands was not significantly changed by seeding.

A computerized seeding-area-of-effect model was employed to predict an envelope of areas of seeding effect for the various categories of seeded bands. The bulk of the stations for which seeded precipitation distributions were significantly different from the not-seeded distributions fell within these areas.

The test results show the value of seeding winter convective orographic systems with his pyrotechnic device. The test results also demonstrate the value of employing the convection band as a natural unit of seeding and of observation. The sensitivity of the statistical evaluation was greatly enhanced through the use of this approach.

44

Elliott, R. D., R. W. Shaffer, A. Court, and J. F. Hannaford, 1978

"Randomized Cloud Seeding in the San Juan Mountains, Colorado"

Journal of Applied Meteorology, 17(9): 1298-1318.

ABSTRACT:

A five-year randomized cloud seeding program conducted in the San Juan Mountains of southwestern Colorado by the Bureau of Reclamation was completed in April 1975. The test design included randomization of the seeding by 24 h experimental days, and other features such as operation only during suitable cloud and wind conditions, and suspension to avoid adverse effects on the public and environment.

Previous experimentation by Grant near Climax, Colorado, during the 1960's had identified conditions under which clouds seeded with silver iodide would produce more snow than similar, untreated clouds. The purpose of the Colorado River Basin Pilot Project was to determine whether the experimental procedure applied at Climax would be effective in an operational mode. The objectives were twofold: 1) to test the physical concepts of weather modification potential, and 2) to test the practical weather modification potential for an operation technology in the continental weather systems that bring snow to the San Juans.

A formal statistical analysis based on precipitation data for 71 experimental treated days and 76 experimental control days found no significant difference between precipitation, gage by gage, on seeded and unseeded days, even after deletion of 22 control days suspected of contamination by previous seeding.

An a posteriori analysis, based on 6 h time blocks (in place of the 24 h day called for in the experimental design), indicates that positive seeding effects may have been achieved during periods of warm cloud-top temperatures, as expected from the Climax experiment. These positive effects may have been overbalanced in the experiment by decreases in snowfall due to seeding unfavorable cloud types.

The results of the a posteriori analysis suggest that an operational seeding program, flawlessly carried out with perfect forecasts and no periods of suspension, could increase 15 October-15 May precipitation by 10-12% in various portions of the drainage basin. The resulting average precipitation increase during the snow acculumation season, put into a hydrologic streamflow

model developed as part of the evaluation, yields a potential increase in annual runoff of the San Juan River of 197,000,000 mi^2. In the Rio Grande Basin, on the downwind side of the crest, the potential increase in annual runoff is 186,000,000 mi^3.

45

Endlich, R. M., and R. L. Mancuso, 1968

"Objective Analysis of Environmental Conditions Associated with Severe Thunderstorms and Tornadoes"

Monthly Weather Review, 96(6): 342-350.

ABSTRACT:

This study describes objective analysis of the atmospheric conditions that precede or accompany severe thunderstorms and tornadoes. The data used are standard rawinsonde observations and hourly surface reports as they are transmitted over teletypewriter. In analyzing upper air data spherical coordinates are used with grid points 2 1/2° of lat. and long, apart. Hourly observations are analyzed on a 1 1/4° grid. The vertical structure of the atmosphere is represented by seven layers between the surface and 100 mb. Observational data are averaged for these layers using all points in the soundings. By use of the nondimensional pressure term as the vertical coordinate, the three layers below 500 mb slope with the terrain, and the lowest layer contains most boundary processes.

The objective analysis procedure fits a first degree polynomial to at least five observations that are nearest to a grid point. A distance weighting factor and upstream-downstream enhancement are used. The analysis method smooths the observations lightly, but has a resolution and accuracy that appear approximately equivalent to those of hand methods. Analyzed quantities include wind components, height, temperature, and moisture. From these a number of kinematic quantities not normally available to forecasters are computed and compared with storm developments. In general, certain quantities that depend on the field of motion appear to be more directly related to storm formation than do synoptic or thermodynamic factors. Objective severe storm indicators that combine different synoptic or kinematic factors are formulated at grid points, and their patterns match areas of storm development reasonably well. The results support the belief that the foreacaster's accuracy and efficiency can be increased through greater reliance on computer methods of data processing and analysis

46

Fawbush, E. F., R. C. Miller, and L. G. Starrett, 1951

"An Empirical Method of Forecasting Tornado Development"

Bulletin of the American Meteorlogical Society, 32(1): 1-9.

ABSTRACT:

The frequency distribution of tornadoes in the United States is discussed briefly and an empirical method of forecasting these and allied severe storms is described. It is shown that the formation of such storms can be forecast by evaluating certain empirical cirtieria related to the stability of the air column, the horizontal and vertical distributions of the moisture content and the wind. A typically tornado development is discussed from a synoptic point of view. An unusual situation and the verification of 35 experimental forecasts are briefly described.

47

Fernandez-Partagas, J. J., and M. A. Estoque, 1974

"An Observational Study of Convergence and Rainfall over South Florida"

Journal of Applied Meteorology, 13(4): 507-509.

ABSTRACT:

Relationships between convergence and rainfall at subsynoptic scales of motion are studied observationally. Data are based on special surface wind and rainfall observations in the South Florida peninsula during the period 11-13 July 1971. It is shown that larger scale convergence produces smaller scale convergence which, in turn, induces rainfall. The convective rainfall lags behind the large (peninsular) scale convergence by approximately 2 hr. In addition, the smaller scale divergence associated with rainfall produces larger scale divergence. The importance of the results in relation to parameterization and short-range forecasting of convective rainfall is discussed.

48

Feteris, P. J., 1965

"Statistical Studies on Thunderstorm Situations in the Netherlands"

Journal of Applied Meteorology, 4(2): 178-189.

ABSTRACT:

Records from a network of volunteer thunderstorm observers in the Netherlands are used with routine synoptic and upper-air data to investigate relations between storm severity and almost simultaneous (just prior) meteorological parameters. The latter are derived from fields of the meteorological variables. The x^2 test and screening regression show that the ratio of storms associated with lightning damage to the total number of storms increases significantly with the surface wet-bulb potential temperature (θ_w) and the instability index, (AT), but the relations are rather weak. Hail frequency increases monotonically with the instability index, but is bimodally

distributed with respect to the potential temperature. Hailsize-windshear relations are barely significant. Additional information provided by parameter combination over that in a single best predictor is limited by fairly strong correlations among the surface wet-bulb potential temperature, the stability index and saturation deficit (D). Stratification of the data according to synoptic situation and the use of nonlinear functions of the variables improve some of the relations.

49

Flueck, J. A., 1971

"Project Whitetop: A Convective Cloud Randomized Seeding Project: Part V - Statistical Analyses of the Ground Level Precipitation Data"

Final Report, Department of the Geophysical Sciences, University of Chicago, Chicago, 294 p., available from NTIS, N72-13559.

EXCERPT from the Summary of the Principal Results within the Research Area (pp. 212-215):

The operational and wet days of the experiment were partitioned by four specialized "meteorologically based" variables (plume direction wind speed, echo height, and burner hours). The precipitation data within each of the resulting categories then were separately analyzed and the principal results were:

5. There was very strong evidence on days in which the maximum echo height was equal to or greater than 40,000 feet of a negative time and space dependent treatment effect on the amount of precipitation in the plume area. The effect appeared to be close-in to the seeding line and smaller in the hours reserved for treatment and farther downwind and larger in the post-treatment hours (Chapter 5). The differences variate of the Original Statistical design indicated that the suggested effect for the operational days was approximately -65% change in the amount of precipitation (equally weighted rainfall and radar) for the full eleven hours of the experiment, -57% (rainfall) to -46% (radar) change for the six hours reserved for treatment, and approximately a -82% change in the post-treatment hours.

6. There was evidence on the south wind days of a negative treatment effect on the amount of precipitation in the plume are in the full eleven hours of the experiment, with the suggested effect being most pronounced in the six hours reserved for treatment (Chapter 5). The Original Statistical design's difference variate indicated that the suggested 11-hour operational day treatment effect was on the order of a -38% (equally weighted rainfall) to a -49% (radar) change in the amount of precipitation and -50% to -65% change in the six hours reserved for treatment.

There was also evidence of a smaller negative treatment effect in the nonplume on these same south wind days. However, because of the indication of the presence of uncontrolled background factors (e.g. temperature, Appendix F), the nonplume treatment question was not entirely resolved.

7. There was considerable evidence on days in which the wind speed was between 12 and 24 knots of a negative time and space dependent treatment effect on the amount of precipitation in the plume area with a substantial indication that the effect was strongest close-in to the seeding line (Section 1) in the six hours reserved for treatment and strongest farther downwind (Sector 3) in the post-treatment hours (Chapter 5). The difference variate of the Original Statistical design indicated that the suggested 11-hour operational day effect was approximately -60% (equally weighted rainfall) to a -100% (radar) change in the amount of precipitation with the post-treatment hours suggesting an effect of approximately -60% to -145%.

8. There was evidence in the burner hours partitioned precipitation data of an inverse relationship between the dosage level of the treatment and the size and direction of the treatment effect on the amount of precipitation (Chapter 5), with the indication that the largest negative effect was close-in to the seeding line in the six hours reserved for treatment and farther downwind in the post-treatment hours in the larger treatment categories. The difference variate of the Original Statistical design suggested an 11-hour operational day treatment effect sequence over the burner hours categories of -9, 2, and -47% change in the amount of (equally weighted) rainfall, and 20, -26, and -59% change in the echo cover.

9. There was evidence on days in which the maximum echo height was between 20,000 and 40,000 feet of a positive treatment effect in the amount of precipitation in the plume area (Chapter 5). The differences variate of the Original Statistical design suggested that the effect for operational days was on the order of a +107 (equally weighted rainfall) to a +57% (radar) change in the amount of precipitation over the eleven hours of the experiment.

10. There was weak evidence on the west wind days of a positive treatment effect on the amount of precipiation in the plume area in the six hours reserved for treatment with an indication that the effect was strongest close-in to the seeding line (Chapter 5). The difference variate of the Original Statistical design suggested that the effect was on the order of a + 6 (equally weighted rainfall) to a +42% (radar) change in the amount of precipitation for the operational day six hour data.

11. Lastly, there was evidence on west wind days of a positive treatment effect on the frequency of days with precipitation for the plume area in the six hours reserved for treatment (Chapter 5). The size of the suggested effect was approximately +20%. In this same six hour period there was evidence on the south wind days of a negative treatment effect (only in the rainfall data) of about -40% change in the frequency of days with rainfall in the plume area.

50

Foote, G. B., and J. C. Fankhauser, 1973

"Airflow and Moisture Budget Beneath a Northeast Colorado Hailstorm"

Journal of Applied Meteorology, 12(8): 1330-1353.

ABSTRACT:

A case study is presented of a persistent thunderstorm of moderate intensity which occured in northeast Colorado, and which produced a light hailfall at the ground. The storm was intensively monitored by aircraft radar, dropsondes, and surface and upper air networks involved in the National Hail Research Experiment. The present study emphasized the measurements obtained by instrumented aircraft in examining the proper ties of the subcloud airflow.

Large-scale analysis shows that the storm formed on a surface confluence line subsequently moved toward the region of surface moisture. A brief radar analysis of the storm during the mature stage of its ~ 5-hr lifetime is presented and identified the general features as belonging to the category termed "super-cell" by previous workers. A precipitation analysis is carried out, and rain and hailfall are correlated with the track of the storm.

Liberal use of a time-space conversion technique results in detailed mesoscale pressure, temperature, moisture and wind field analyses from a network of 22 remote meteorological stations. Surface divergence of mass and moisture is computed. Surface features are related to the position and structure of the radar echo.

Wind, temperature and moisture data obtained by aircraft encircling the storm in the region below cloud base are presented. Emphasis is placed on the airflow with respect to the moving storm, and details of the subcloud circulation are examined. Analysis of relative streamlines, supported by the observed temperature and moisture structure, delineates distinct regions of inflow and outflow for the storm. Partitioning of the measured flux into inflow and outflow segments at the aircraft levels and at the surface results in estimates of the mass and moisture budgets for the storm. The ratio of rainout measured at the ground, 2×10 gm sec^{-1}, to the computed moisture influx, 13×10^{9} gm sec^{-1}, results in a precipitation efficiency of only 15%. A physical basis (following a discussion presented by Marwitz) for correlating this low efficiency with the fairly high value of vertical wind shear which existed around the storm, $\sim 5 \times 10^{-3}$ sec^{-1}, is elaborated upon, and the present results are compared with those of previous investigators. The computed mass inflow, 2×10^{12} gm sec^{-1}, is rather large, but is shown to be compatible with other measurements made of the storm. The computations indicate that, in this case, only about half of the upward flux took place in the vicinity of the "echo-free" vault," and attention is drawn to a secondary region of echo overhang where various measurements indicate that significant vertical transports also occurred. . Based on the airflow and thermodynamic measurements, some ideas concerning the energy source that drives the inflow circulation are presented.

51

Fortner, L. E., Jr., and B. E. Grubbs, 1973

"Thermal Parameters as a Predictor of Precipitation Type for Carswell AFB, Texas"

Technical Note No. 73-2, 3rd Weather Wing, Aerospace Sciences Division, Offutt AFB, NE, 15 p., available from NTIS, AD-762 289.

ABSTRACT:

This paper presents a summary of thermal parameters as predictors of precipitation type at Carswell AFB, Texas. The material presented in this paper may be used to make an objective forecast when the input data are extracted from current observations and prognastic facsimile charts. The Greater Southwest Airport (GSW), Fort Worth, TX, radiosonde data (for 0000Z and 1200Z) are correlated against precipitation type that occurred at Carswell AFB, TX, within plus or minus three hours of radiosonde time. Thermal parameter combinations used in this study are: 1000-850mb thickness, 1000-700mb thickness, 1000-500mb thickness; surface and 950mb temperatures.

52

Foster, D. S., 1964

"Relationship Among Tornadoes, Vorticity Acceleration, and Air Mass Stability"

Monthly Weather Review, 92(7): 339-343.

ABSTRACT:

Numerical computations of the local change with respect to time of the local tendency of the vertical component of the vorticity of the surface wind and a stability index were made at 3-hour intervals for fifteen tornado days during the period from February to June 1961. Average values of these two parameters were computed with reference to tornado occurrences at the center of the computation grid. These average values are shown for five time periods: 9 to 12 hr., 6 to 9 hr. , 3 to 6 hr. , 0 to 3 hr. prior to tornado occurrences, and 0 to 3 hr. after tornado occurrences. It appears the tornadoes develop within an area under the influence of increasing cyclonic vorticity tendency and characterized by a conditionally unstable air mass. These conditions apparently exist during a short time interval before tornado occurrence, with tornadoes developing only after the combined intensity reaches a critical value.

53

Frank, N. L., and D. L. Smith, 1968

"On the Correlation of Radar Echoes over Florida with Various Meteorological Parameters"

Journal of Applied Meteorology, 7(4): 712-714.

EXCERPT FROM RESULTS:

A survey of Table 1 reveals the following points:

1) The only significant correlations involve moisture. Poor correlations are obtained with the surface and 950-mb humidity because moisture is nearly always present at this level. The humidity correlations improve rapidly with height reaching a maximum of 650 mb. This means that showers are more likely with a deep moist layer. Chalker (1949) concluded the same thing in his study of air mass showers. This also supports the results of several studies cited by Carson.

2) Even thought the magnitude of the other coefficients are generally near or below the significant level, the sign often agrees with what we would expect. The following might be noted:

a. Showers at 1300 and 1600 tend to be associated with warmer surface temperatures and cooler temperatures above 850 mb. This is also supported by the 24-hr 550-mb temperture change and the 850-550 mb lapse rate.

b. Showers are more likely with cyclonic vorticity aloft.

c. Showers are directly related to surface divergence.

d. Even though the poorest correlations involve the heights, showers are more likely with a 24-hr 550-mb height fall.

3) The correlations tend to be much better with the 1300 and 1600 observations than the 1900. This is because showers are more prevalent at the earlier times.

54

Fujita, T. T., D. L. Bradbury, and C. F. VanThullenar, 1970

"Palm Sunday Tornadoes of April 11, 1965"

Monthly Weather Review, 98(1): 29-69.

ABSTRACT:

An extensive aerial survey was made over a large portion of the area effected by outbreak of tornadoes on Palm Sunday on April 11, 1965. The destruction from the tornadoes extended over parts of six Midwestern States. Aerial and ground damage surveys were combined with eyewitness reports to determine the exact location and time of each tornado occurrence and its path. Radar pictures of the squall line clouds were used to verify the direction and speed of the tornado-producing clouds. Almost simultaneously with the first tornado touchdown in eastern Iowa, TIROS IX took pictures of the Midwest United States that showed a large tongue of cloud-free dry air behind the cold front. The vertical structure of the cold dome is discussed in connection with its role in the development of the tornadoes.

Two predictive parameters, namely, the best lifted index (BLI) and material differential advection (MDA) were developed and evaluated with data gathered on this outbreak of tornadoes.

The wind speed of a tornado in relation to its parent tornado cyclone is discussed in terms of an anemometer trace showing a peak gust speed of 151 mi hr^{-1}. An indirect wind-speed estimate was also attempted by examining characteristic cycloidal marks left on the fields along the tornado paths. The ground speeds computed ranged from 166 to 180 mi hr^{-1} for one tornado.

55

Galway, J. G., 1956

"The Lifted Index as a Predictor of Latent Stability"

Bulletin of the American Meteorological Society, 37(10): 528-529.

EXCERPT:

The Lifted Index (2), as used in the SELS Center, is defined as the temperature differences betweeen the observed 500 mb temperature and the assumed 500 mb temperature of a mean parcel lifted from the modified lower 3000 foot layer next to the ground. Indices are negative for parcel temperatures which are warmer than the environment. Thus the Lifted Index is similar to the Showalter stability index except for the determination of the level from which the parcel is lifted and the fact that the Lifted Index is a forecast index whereas the Showalter Index is an observed static index.

A check on the improvement of the Lifted Index over the static stability index was made by correlating the 1500 GMT Showalter stability index with the 2100 GMT Showalter stability index for the same soundings used above. Figure 3 is a plot showing the relationship between the stability index at 1500 GMT and the stability index determined from the 2100 GMT sounding at the same station. The correlation coefficient is 0.71. Although both correlations are significantly high, an examination of the data reveals information favoring the use of the Lifted Index over the static stability index. For example, 112 cases, or almost one third of the data studied, show a positive Showalter stability index at 1500 GMT and a negative Showalter stability index at 2100 GMT. The Lifted Index correctly forecast the change from positive to negative in 107 cases, and within ±2°C in 88 of the 107 cases. Therefore, results from 339 cases considered indicates that the Lifted Index is a useful forecast tool for the prediction of latent instability that is observed during the afternoon some six hours later.

56

Georges, T. M., and G. E. Greene, 1975

"Infrasound from Convective Storms. Part IV. Is It Useful for Storm Warning?"

Journal of Applied Meteorology, 14(7): 1303-1316.

ABSTRACT:

An experiment was carried out to collect statistics on the observability of severe-storm infrasound at three stations during the 1973 storm season. The results have been evaluated with the help of four "indices of usefulness":

False-alarm rate, which tells how often infrasound from other sources is mistaken for that from storms. We devised a sorting procedure that reduces the false-alarm rate to 15-20%, and still lower rates seem achievable.

Detection rate, which tells what fraction of severe storms are detected. Here the big problems are defining what we mean by "severe storm" and verifying their occurrence; we estimate a 65% detection rate for tornadic storms, a 31% detection rate for tornadoes themselves, and a 33% detection rate for storms with radar tops above 50,000 ft.

Timeliness, which tells how much advance warning the waves give compared to dangerous storm effects. It was practical to consider only tornadoes from this viewpoint, and we found tht the emissions tend to precede tornado onset by an hour or so.

Location accuracy, which tells how Well the emissions can be used to locate and track storms. This index is hard to evaluate quantitatively, as illustrated by the six cases where storms were seen at all three stations. Propagation effects and measurements uncertainty presently prevent positive identification and tracking of a particular storm, but we see ways to improve this.

The answer to the title question is that the emissions show promise as supplement to the present warming system. A question remains about the cost-effectiveness of doing the additional required research and deploying an operational sensor network.

57

Gilhousen, D. B., 1976

"Improving Short Range Precipitation Guidance During the Summer Months"

NOAA Technical Memorandum NWS ER-61, 20 p., available from NTIS, PB-256 427.

ABSTRACT:

An objective technique has been developed for modifying 12- to 14-hour precipitation guidance forecasts from the NMC primitive equation model by using manually digitized radar and the Limited Fine Mesh Model 12- to 24-hour precipitation. Developmental data were from two stations in the eastern United States for the summer season. Constructed radar variables were entered into a stepwise multiple regression program with the PE precipitation probabilities and the LFM precipitation forecasts. The resulting equation yielded a 15-35% improvement by Eastern Region forecast offices of the National Weather Service over the PE guidance amounts to 10-15%.

58

Gilhousen, D. B., 1974

"Heavy Fall and Winter Rain in the Carolina Mountains"

NOAA Technical Memorandum NWS-ER-57, 6 p., available from NTIS, COM-74-11761.

CONCLUSION:

Eight cases of heavy fall or winter rainfall in the Carolina Mountains were examined. There were common characteristics found in the synoptic scale patterns and trajectory model forecasts available prior to the onset of heavy rain. In the future, if these features are identified in the fall and winter months, the threat of locally heavy rain is established. The extent of overwarning, however, is not known since it was not determined how often these features occurred and heavy rain did fall.

59

Glahn, H. R.,and J. R. Bocchieri, 1976

"Testing the Limited Area Fine Mesh Model for Probability of Precipitation Forecasting"

Monthly Weather Review, 104(2): 127-132.

ABSTRACT:

Experimental objective forecasts of probability of precipitation (PoP) were made and verified for a large number of United States cities in order to make preliminary tests of the usefulness of the limited area fine mesh (LFM) model. The Model Output Statistics (MOS) technique was used to derive the forecast equations for the winter and summer seasons. Predictors were selected from forecast output of the Primitive Equation (PE), Trajectory (TJ) and LFM models, and from the sine and cosine of the day of the year. Forecast equations were developed with data from only one winter and one summer season ("small sample equations") from PE predictors only, TJ predictors only, LFM predictors only, and various groupings of these. The small-sample equations were compared on independent data with each other and with operational equations developed on a much larger data sample.

It was found that the small-sample combinations that included the LFM gave better results than the operational equations in winter. However, in summer, all small-sample combinations were significantly worse than the operational equations. It was also found that adding the harmonic terms of the day of year consistently improved the forecasts. Based on these preliminary results, the LFM will be incorporated into the operational PoP equations starting in the winter of 1975-76. Further tests will be made when a larger development sample is available for the LFM.

60

Glahn, H. R., and J. R. Bocchieri, 1975

"Objective Estimation of the Conditional Probability of Frozen Precpitation"

Monthly Weather Review, 103(1): 3-15.

ABSTRACT:

A system is developed which produces objectives of conditional probability of frozen precipitation for the conterminous United States. Development of the system consists of two basic steps, in each of which the MOS (Model Output Statistics) concept is used. First, for each of 186 stations, we find a "50%" value for each of three variables predicted by the National Meteorological Center's Primitive Equation (PE) model: 1000-500 mb thickness, boundary-layer potential temperature, and 850-mb temperature. For instance, we find the value of the 1000-500 mb thickness which indicates a 50-50 chance of frozen precipitation at a particular station, provided precipitation occurs. These 50% values are determined by using the logit model to fit data from three winter seasons, September 1969 through March 1972.

Secondly, the deviations from the 50% values are determined for each station for each variable; the relative frequency (for those cases when precipitation occurred) of frozen precipitation is then computed, again with the logit model, as a function of these new variables. In order to get stable results in this last step, data for all stations are combined. In additional to the meteorological variables, we also use the first harmonic of the day of year and station elevation as predictors. Separate logit equations are determined for each of the PE run times, 0000 and 1200 GMT, and for each of four projections, 12, 24, 36, 48 hours.

This system was put into operation by the National Weather Service in November 1972. Both teletypewriter and facsimile products are being distributed to field offices twice daily.

A comparative verification on independent data for the 12- and 36-hr forecast projections shows the objective system produced better forecasts than those prepared subjectively at the National Meteorological Center.

61

Glahn, H. R., and D. A. Lowry, 1972

"The Use of Model Output Statistics (MOS) in Objective Weather Forecasting"

Journal of Applied Meteorology, 11(8): 1203-1211.

ABSTRACT:

Model Output Statistics (MOS) is an objective weather forecasting which consists of determining a statistical relationship between a predictand and variables forecast by a numerical mode at some projection time(s). It is, in

effect, the determination of the "weather related" statistics of a numerical model. This technique, together with screening regression, has been applied to the prediction of surface wind, probability of precipitation, maximum temperature, cloud amount, and conditional probability of frozen precipitation. Predictors used include surface observations at initial time and predictions from the Subsynoptic Advection Model (SAM) and the Primitive Equation model used operationally by the National Weather Service. Verification scores have been computed, and, where possible, compared to scores for forecasts from the objective techniques and for the official forecasts. MOS forecasts of surface wind, probability of precipitation, and conditional probability of frozen precipitation are being disseminated by the National Weather Service over teletype facsimile. It is concluded that MOS is a useful technique in objective weather forecasting.

62

Glickman, T. S., N. J. MacDonald, and F. Sanders, 1977

"New Findings on the Apparent Relationship between Convective Activity and the Shape of 500 mb Troughs"

Monthly Weather Review, 105(8): 1060-1061.

CONCLUSIONS:

These results support the view that the convection and heavy precipitation are a result of the 500 mb trough orientation rather than the cause of it. It could be argued, of course, that the trough orientation originally developed as a consequence of convection and then continued to support convection. We did not test this idea, but the question could be examined by evaluating the skill of the model in producing negatively tilted troughs. In any case, the association presented by MacDonald (1976) should have value in precipitation forecasting.

63

Grant, L. 0., and R. Elliott, 1974

"The Cloud Seeding Temperature Window"

Journal of Applied Meteorology, 14(3): 355-363.

ABSTRACT:

The greatest potential for seeding with artificial ice nuclei to augment preciptation should occur with cloud summit temperatures in the range from about -10C to about -25C. This is the temperature region where there may be a deficiency of natural ice-forming nuclei. This cloud-top temperature range therefore constitutes a "temperature window" for seeding effectiveness. This article considers the results from a number of cloud seeding experiments

reported in the literature with respect to this temperature window. The analysis of seven randomized experiments and references to four other experiments indicates that there is a window in the cloud-top temperature range for which precipitation increases are indicated. This extends from about -10C to about -24C for seeding conducted in the modes employed on these projects. At the coldest cloud-top temperatures, generally less than about -30C, decreases in precipitation are indicated. There are variations among the samples which appear to be explainable in terms of differences in the degree of convection present, the seeding methods used, or in the type of nucleant employed. No evidence is presented to shows that the temperature window concept applies where there are strong dynamic effects, either natural or due to seeding, such as those in relatively large and isolated cumuli.

64

Hanssen, A. W., 1965

"An Objective Method for Forecasting Thunderstorms in the Netherlands"

Journal of Applied Meteorology, 4(2): 172-177.

ABSTRACT:

An objective method has been developed for forecasting the occurrence of thunderstorms. Four parameters have been selected one of which has been derived from the 500-mb contour pattern. The other three parameters (atmospheric pressure, stability and humidity) are related to the center of the forecast area. The method which is based on relatively many observations (~ 1000) can readily be applied for the day following the 0000 GMT aerological sounding if the 500-mb flow pattern is sufficiently known. From this 500-mb flow a parameter has been derived that is combined with the atmospheric pressure at De Bilt defining a parameter X. By combination of a stability parameter and a-moisture variable - both of which have been derived from the aerological sounding at De Bilt - a second parameter, Y, has been defined. Finally, the probability of the occurrence of thunderstorms can be obtained as a function of X and Y. The system has been designed for the summer season and is based on eleven years (1949 to 1959 inclusive) of dependent data. It was tested for three years (1960 to 1962 inclusive) of independent data yielding a skill factor I = 0.48. The method shows more than 2.5 times the skill factor of the persistence forecast.

65

Harley, W. S., 1971

"Convective Storm Diagnosis and Prediction Using Two Layer Combined Indices of Potential and Latent Instability in Combination with Other Special and Standard Significators"

Preprints, 7th Conference Severe Local Storms, Kansas City, Amer. Meteor. Soc., Boston, 23-30.

INTRODUCTION;

It would be useful to have an instability index that was a measure of the energy available for the creation and intensification of convection currents within a layer. None of the indices in current use do this directly. Use of the equivalent potential temperature permits the derivation of an energy related index from routinely measured atmospheric properties. It is the purpose of this paper to obtain such an instability energy index, and to show how it may be used in conjunction with other special and standard thunderstorm significators, such as the fields of low level moisture, maximum wind, vertical motion and surface fronts, to forecast areas of general thunderstorm activity, and the location of severe storm threat areas.

66

Harley, W. S., 1965

"An Operational Method of Quantitative Precipitation Forecasting"

Journal of Applied Meteorology, 4(3): 305-319.

ABSTRACT:

A complete operational method for quantitative precipitation (Q.P.F.), is developed by combining the technique for determining large scale vertical velocities by Penner with one for determining precipitable water content using 1000-500 mb thickness lines and the Godson precipitation rate formula. Methods are included for taking into account the effects of initial unsaturation, topography, release of latent heat during condensation, friction, release of potential instability and height of cloud base. A case study is presented to illustrate the results of the method and an example is given of a complete Q.P.F. computation.

67

Henderson, T. J., 1979

"The Southeastern Illinois Weather Resources Management Program: A Summary of Cloud Seeding Activities Conducted Over Saline and Gallatin Counties in Illinois During the Period 4 August 1978 Through 4 September 1978"

Atmospheric Incorporated Report, Fresno, 37 p., available from the issuing agency or from the Illinois State Water Survey Library.

EXCERPT FROM RESULTS AND CONCLUSIONS:

On operational days during the 1978 Southeastern Illinois Program, acetate overlays were placed on the radar scope each 20-minute period, and precipitation echo data were logged for all areas of significant rainfall within operating range of the radar system. Atmospherics Incorporated has complete a case-by-case examination of the overlay data, as well as all

information on the individual flight logs and general project notes. In those cases where precipitation echo comparisons were relevant, the seeded and non-seeded echoes were examined for maximum echo intensity, areal coverage, duration of precipitation periods, growth rate characteristics, maximum echo heights and movement near and over the target areas. Of particular imporatnce was the comparison of these precipitation characteristics between seeded clouds and the simultaneously occurring non-seeded clouds adjacent to the operational area.

In all categories, the seeded precipitation echoes exhibited definite average positive effects. From these data there is a strong indication the cloud seeding program did produce average precipitation increases in the range of at least 15% - 20% above what would have fallen in the seeded areas had those clouds not been treated.

As originally stated, it is unlikely that any non-randomized short-term program could generate data in a few weeks, which would demonstrate statistically significant results at a high confidence level. The period of operation is far too short, and the numbers of seeded cases much to limited. Therefore, it is necessary to provide a cautionary note. These suggestions of a positive effect come only from a cursory examination of limited data collected during a very short time period. No other meaningful type evaluation is possible, other than a more detailed examination using the radar film footage.

68

Henz, J. F., 1972

"An Operational Technique of Forecasting Thunderstorms Along the Lee Slopes of a Mountain Range"

Journal of Applied Meteorology, 11(8): 1284-1292.

ABSTRACT:

The lee slopes of the Rocky Mountains from Montana to New Mexico have long been recognized as prime breeding grounds for lee slope thunderstorms. A simple forecast technique is introduced which models the formation of these thunderstorms. It provides the operational meteorologist with an accurate short range forecast tool. Three forecast parameters are used to model thunderstorm development. The Mountain Layer Stability (MLS) measures the stability of the mountain thermal bubbles as they are lifted in the valley breeze circulation. The Max Heating Index (MHI) measures the thermal energy on the plains to trigger lee slopes cumulus into thunderstorms at the time of maximum heating. The Filter Index is used to separate borderline occurrences into a distinct forecast.

69

Hill, G. E., 1979

"Analysis of Randomized Winter Orographic Cloud Seeding Experiments in Utah"

Journal of Applied Meteorology, 18(4): 413-448.

ABSTRACT:

Analysis is made of two radomized winter orographic cloud seeding experiments conduced in the northern Wasatch Mountains. In the first experiment seeding material was released from airborne pyrotechnics and in the second experiment, from three mountain-top generators. Precipitation was measured by a network of remotely interrogated precipitation gages. Interpretation of the results are aided in particular by the use of storm type classification, precipitation estimators based on upper level data, vertical incidence radar and aircraft icing reports.

An a priori hypothesis, that seeding of clouds would increase precipitation when the 500 mb temperature is warmer than -22°C, is rejected. Also, precipitation increases are not found in orographic clouds when the cloud-top temperature is warmer than -29°C.

An a posteriori analysis fails to show increases in precipitation when the cloud-top temperature is warmer than -24°C. On the other hand, stratification of experimental events according to degree of aircraft icing, as a measure of supercooled water concentration, indicates that marked seeding effects may be present.

70

Hill, G. E., 1978

"Development and Application of a Predictor Control for the Evaluation of a Winter Orographic Cloud Seeding Project"

Journal of Applied Meteorology, 17(4): 489-497.

ABSTRACT:

Evaluation of an operational-type winter cloud seeding project in Utah is made by developing meteorological predictors of target precipitation. Predictors (covariates) are developed by matching 1200 GMT rawinsonde data and 24 h precipitation amounts. These predictors and precipitations are summed over seven unseeded seasons to form a seasonal predictor-predictand relationship, for which the correlation is 0.975 when the average precipitation for all stations is used, and 0.879 when only the two highest altitude stations are used. Then, the predictor is found for each of the seeded seasons, and based upon the unseeded predictor-predictand relationship, the predicted preciptation is obtained. Differences between predicted and observed precipitation in seeded years are compared and tested for seeding effects. Application of the method to the first two years of the project indicates a substantial chance that little or no effect of seeding occurred. It is concluded that the method offers a promising approach to the evaluation of winter cloud seeding projects.

71

Hiser, H. W., 1973

"Sferics and Radar Studies of South Florida Thunderstorms"

Journal Applied Meteorology, 12(3): 479-483.

ABSTRACT:

A Litton System 500-kHz, SPARSA/S, 64 channel, thunderstorm-sferics sensor is coupled to the PPI scope of a 10-cm wavelength weather radar. Short vectors protrude from the center of the PPI scope indicating the direction and count rate of sferics discharges. The sferics sensor is thresholded to detect activity within approximately 200 n mi which is equal to the useful range of the weather radar. Thus, the sferics sensor is used to identify thunderstorm precipitation echoes on the radarscope and the combined presentations are photographed on time-lapse 35-mm film.

The results of three years of investigation of summer thunderstorms in South Flroida are presented. Radar PPI and directional 500-kHz sferics data within 200 n mi of Miami are analyzed for 1967-69. During the years 1968 and 1969, three-dimensional radar data to 100 mi range are also included. Relationships between thunderstorm sferics activity and precipitation echo size, height, intensity, life cycle, and geographical distribution are given. In most cases, the first sferics activity was observed after the precipitation echoes became radar-detectable; the activity intensified as, the echoes grew in size and intensity.

72

Houghton, H. G., 1968

"On Precipitation Mechanisms and their Artificial Modification"

Journal of Applied Meteorology, 7(5): 851-859.

ABSTRACT:

Natural precipitation processes are re-examined on the basis accumulated knowledge of the micro-physical aspects and field observations, with particular attention to the implications for cloud seeding. It appears that the active lifetime of a convective cell is much the same as the time required to grow precipitation and, therefore, that artificial nucleants should be inserted during the inception of the cell. The accretion process appears to be dominant in convective precipitation and there is evidence that the effectiveness of the sweeping action could be enhanced in many cases by adding more precipitation particles. The dominant precipitation mechanism in the stratiform system characteristic of extratropical cyclones is the ice crystal process. It is proposed that the uniformly high precipitation efficiencies of such systems, in the face of the great variability of the concentration of natural ice nuclei, result from the exponential increase in active ice nuclei

with decreasing temperature. It is suggested that opportunities exist for redistributing some of the precipitation by seeding if the nucleants are released into the proper cloud layer at the correct time. Orographic precipitation often involves convective clouds as well as forced uplifting and the characteristic synoptic features and topography of the particular region are of major importance. It is believed that opportunities exist for reducing the loss of condensate in the downslope flow by seeding upwind of the barrier. It is concluded that opportunities exist for the modification of each of the three general types of precipitation considered, but that their realization depends on much more complete observations and a more quantitative approach than have been typical of past cloud seeding experiments.

73

House, D. C, 1961

"The Divergence Equation as Related to Severe Thunderstorm Forecasting"

Bulletin of the American Meteorological Society, 42(12): 803-816.

ABSTRACT:

The divergence form of the equations of motion is developed and the terms of the equation are related to several local thunderstorm forecast parameters. It is found that the divergence equation provides the physical basis for evaluating the validity of several forecast rules under differing synoptic situations. In order that the magnitudes of the several terms can be compared, a numerical solution for a particular severe local thunderstorm producing synoptic situation is shown.

74

Hung, R. J., and R. E. Smith, 1978

"Ray Tracing of Gravity Waves as a Possible Warning System for Tornadic Storms and Hurricanes"

Journal of Applied Meteorology, 17(1): 3-11.

ABSTRACT:

. Gravity waves with wave periods of 13 to 15 min and horizontal phase velocities of 90 to 220 ms^{-1} were present in ground-based observations of the upper atmosphere during time periods when tornadoes were occurring and gravity waves with wave periods of 20 to 25 min and horizontal phase velocities of 100 to 200 m s^{-1} were detected when a hurricane was present. Combinations of available neutral atmosphere data and model parameter values were used with a group ray tracing technqiue in an attempt to locate the sources of these waves. Computed sources of the waves with periods of 13 to 15 min were located within 50 km of the locations where tornadoes touched down

from 2 to 4 h later. In the case of the waves with periods of 20 to 25 min it was found that the computed location of the source was roughly where the hurricane would be located 3 h after the waves were excited. The applicability of the present study to a tornado and hurricane warning system is noted.

75

Jefferson, G. J., 1963

"A Modified Instability Index"

The Meteorological Magazine, 92(1088): 92-96.

INTRODUCTION:

The instability index for the months May to August in the British Isles and near continential areas described by Rackliff[1] possesses the very desirable features for a forecasting tool of simplicity and quick computation. Some attempt has been made at London (Heathrow) Airport to use it in midsummer, especially in regard to air-mass thunderstorm activity, and to ascertain the possibility of its application to wider areas. While no comprehensive investigation of its value has so far been possible, one or two features have come to light which suggest that some modification is necessary for it to be used in this way.

76

Johnson, H. L., Jr., R. D. Hart, M. A. Lund, R. E. Powell, and J. S. Stanford, 1977

"Measurements of Radio Frequency Noise from Severe and Nonsevere Thunderstorms"

Monthly Weather Review, 105(6): 734-747.

ABSTRACT:

Thunderstorm radio noise measurements at several frequencies in the range 0.01-74 MHz have been made with specially designed remote recording stations in Iowa. The data were recorded during the spring and summer of 1974 when a series of severe storm systems produced a great number of large hail and tornado reports in Iowa. Computer analyses were made of nearly a billion bits of data, corresponding to 170 h of real-time recordings. Careful compilations of surface severe weather reports, hail damage information from insurance companies, and studies on the Des Moines WSR-57 radar echoes were compared with the analyzed radio noise data. The results include the following:

1) In agreement with earlier work, large-amplitude radio noise impulse rates were found to be generally good indicators of thunderstorm severity. Although the majority of the radio energy radiated from major lightning

strokes occurs in the 0.01 MHz range, this frequency was found to be a poor indicator of storm severity; the higher frequencies (megahertz range) were considerably better. The character of the noise appears similar at 2.5 and 74 MHz.

2) In at least five cases, tornadic events correlated in time with radio noise count rate peaks. One funnel cloud was reported equidistant at 60 km from two recording stations and coincident with count rate peaks at both stations, lending credence to the idea that the peak was associated with the storm occurrence, rather than with corona or other local effects.

3) No unusual radio noise was recorded during the lifetime of a small verified tornado at 19 km range. In addition, the count rates for its parent thunderstorm would not have indicated severity.

In spite of inherent atmospheric variableness, the radio noise technique is a useful complementary indicator of storm severity.

77

Kapoor, R. K., K. Krishna, U.S. De., K. G. S. Nair, I. C. Talwar, S. K. Sharma, and Bh. V. Ramana Murty, 1973

"Results of Operational Cloud Seeding Experiment over Rihand Catchment in Northeast India"

Indian Journal of Meteorology and Geophysics, 25(3, 4): 379-384.

ABSTRACT:

A cloud seeding experiment, on operational basis, was undertaken during August-September, 1973 over the catchment area of the Rihand reservoir in the state of Uttar Pradesh. While the intended seeding operation was done on many days, the same could not be accomplished, for unavoidable reasons, on a number of days during the above period. Considering the latter category of days as control days and the areas adjoining the catchments as control areas, the result of the experiment was evaluated. The analysis suggested rainfall increase in the catchment area, due to seeding, by over 17 percent. The increase, however, is statistically not significant.

78

Kimpel, J., L. Ruthi, B. Smull, S. George, C. Sohl, S. Young, H. Crowther, and R. Garvin, 1976

"A Severe Storm Forecast and Intercept Project"

Final Report, Department of Meteorology, University of Oklahoma, Norman, 59 p., available from NTIS, PB-269 485.

ABSTRACT:

This project addressed parameters important to improving the issuance of severe thunderstorm/tornado watches and warnings to the general public. The particular areas studied included a test of an objective forecast technique and the documentation of severe thunderstorm intercepted by mobile "chase" teams.

The participants in this program consisted primarily of students from the Department of Meteorology at the University of Oklahoma, working in close cooperation with the National Severe Storm Laboratory in Norman, Oklahoma.

Conventional forecast methods were supplemented by computerized output of objectively determined quantities of parameters thought to be important in severe storm development. These parameters included surface-equivalent potential temperature, convergence of surface-equivalent potential temperature, convergence of dewpoint temperature, and relative vorticity, all computed from conventional hourly surface data.

The quality of the resulting forecasts is evident in the large number of severe storm successfully intercepted by the chase teams. The photographs, movies, and other forms of visual documentation collected by the chase teams should prove useful in providing ground truth for the radars at the National Severe Storm Laboratory, and in photographically illustrating material used in training volunteer storm spotters across the nation.

In all 784 35 mm slides and 1335 feet of still and time lapse 16 mm movies have been turned over to the National Severe Storm Laboratory for detailed analysis.

79

Klein, W. H., 1971

"Computer Prediction of Precipitation Probability in the United States"

Journal of Applied Meteorology, 10(5): 903-915.

ABSTRACT:

The "perfect prog" method of combining numerical and statistical weather prediction is applied to develop an automated system for forecasting the probability of precipitation at 108 cities on the mainland of the United States during daytime and nighttime periods from 12-60 hr in advance. Multiple regression equations are derived from a 4-5 year sample of data by seasons for each city by screening twice-daily geographical arrays of the following predictors: initial 850 mb height, initial 850-700 mb mean dew-point spread, and previous 12-hr precipitation at the network of surface stations. Each of the three predictor fields contributes about equally toward explaining the variance of the observed precipitation, but considerable geographical variation is exhibited by the equations. The forecast system is

applied in an iterative fashion in 12-hr time steps by using as input numerical predictions of height and moisture at standard grid points as well as prior values of precipitation. The resulting computerized forecasts of precipitation probability, when applied on an operationsl basis in real time, may offer valuable guidance to the local weather forecaster.

80

Klein, W. H., D. L. Jorgensen, and A. F. Korte, 1968

"Relation Between Upper Air Lows and Winter Precipitation in the Western Plateau States"

Monthly Weather Review, 96(3): 162-168.

ABSTRACT:

A comparison is made of the relative effectiveness of the cyclonic circulation pattern at four different tropospheric levels in specifying winter precipitation over the intermountain area of the western United States. This is accomplished by developing the synoptic climatology of precipitation resulting from Lows at the 850-, 700-, 500-, and 300-mb levels. Twelve-hr. precipitation amounts (expressed as a percent of the 7-day normal) at 280 stations in the Plateau States for 13 yr are related to the positions of nearby low centers through a computer system of moving coordinates. For each level, the upper Lows are classified into three intensity categories according to the departure from normal of their central heights. Average precipitation amount, distribution, and frequency of occurrence are then calculated for the area of the grid system. The dependence of these precipitation characteristics upon the level, intensity, and location of the upper Low is described and illustrated. The geographical distribution of Lows at the four upper levels and a schematic model of their associated precipitation are also presented. It is concluded that the effectiveness of upper Lows in producing precipitation generally varies directly with their intensity and inversely with elevation.

81

Knowles, H. T., and K. H. Jehn, 1975

"A Central Texas Synoptic Climatology and its Use as a Precipitation Forecast Tool"

Monthly Weather Review, 103(8): 730-736.

ABSTRACT:

A synoptic precipitation climatology was derived for central Texas centering on Austin. Characteristics of the 500 mb wind field were combined with a surface wind parameter to "type" the 1200 GMT circulation pattern for 2327 days of study. The relative frequency of precipitation was computed for three consecutive 12 h periods following 1200 GMT for each circulation type. Use of the derived precipitation frequencies as a first estimate of the

probability of precipitation, given a predicted circulation pattern, was evaluated for its effectiveness as a forecast tool. Results indicated that for the first 12 h period, use of the synoptic climatology provided guidance inferior to that currently available to forecasters in the field. However, for the second and the third 12 h periods, the synoptic climatology provided guidance better than that available to meteorologists over teletype and the weather facsimile network.

82

Kohl, D. A., 1969

"An Analysis of SELS Forecasts and a 500-kHz Sferics Predictor"

Preprints, 6th Conference Severe Local Storms, Chicago, Amer. Meteor. Soc., Boston, 135-138.

ABSTRACT:

The sferics pulse count rates output of a standard commerical thunderstorm monitor was evaluated as a severe weather predictor in terms of STORM DATA verification and also in relation to SELS forecasts. This 3-year study included an analysis of 136 public forecasts, 155 STORM DATA listings, 1,380 thunderstorm hours of data. Early warning for 89% of severe weather event periods was obtained on a regional basis. 100% verification of early alerts for local severe weather events within 30 miles was obtained with an average lead-time of 59 mintues.

83

Koscielski, A., and A. S. Dennis, 1976

"Comparison of First Radar Echoes in Seeded and Unseeded Convective Clouds in North Dakota"

Journal of Applied Meteorology, 15(3): 309-311.

ABSTRACT:

First radar echoes on a randomized cloud seeding project in North Dakota appeared closer to cloud base and at higher temperatures on seed days than on no-seed days. The average first echo temperature was near -11C°C on no-seed days and -7°C on seed days.

84

Kreitzberg, C. W., M. L. Leach, and R. G. Rasmussen, 1978

"Convective Precipitation Prediction Tests Using a Cumulus Model"

Final Report, Drexel, Univeristy, Philadelphia, 37 p., available from the issuing agency or from the Illinois State Water Survey Library.

ABSTRACT:

Tests were conducted on the feasibility of using the sequential plume cumulus model with information from other National Weather Service forecast systems to predict summertime precipitation. Twelve stations in the southern and central United States were selected and forecasts out to 18 hours were made twice per day for six months. These forecasts, along with the precipitation forecasts from the Limited-area Fine Mesh (LFM) model were statistically verified against radar data and surface precipitation measurements. The essential conclusion is that little improvement can be made to the LFM forecasts by any simple, objective, non-iterative application of the cumulus model.

Cumulus model precipitation of occurrence of precipitation is sensitive to predictions of low-level diurnal heating and to cyclonic-scale vertical motions. Quantitative precipitation forecasts are so sensitive to the environmental vertical velocity that convection should be allowed to feed back into the numerical weather prediction model as a cumulus parameterization scheme. As an independent forecast aid, the cumulus model is expected to be of value only to an experienced user with access to other data from which large mesoscale environmental ascent on spatial scales of 50 km can be inferred. Suggestions for future research, in view of difficulties uncovered in this research, are included.

85

Kumar, S., 1972

"An Objective Method of Forecasting Premonsoon Thunderstorm Activity Over Delhi and Neighbourhood"

Indian Journal of Meteorology and Geophysics, 23(1): 45-50.

ABSTRACT:

An attempt was made to provide an objective aid for forecasting of thunderstorm/duststorm in premonsoon season over Delhi and neighbourhood. Relationships of a number of meteorological parameters to subsequent convective activity were determined and the five parameters which showed the strongest relationships were combined by graphical correlation techniques to form an objective forecasting aid.

The method was tested on independent data and the results were found to be consistent with those obtained on the developmental data.

86

Longley, R. W., and C. E. Thompson, 1965

"A Study of the Causes of Hail"

Journal of Applied Meteorology, 4(1): 69-82.

ABSTRACT:

An analysis has been made of the incidence of hail in southern Alberta during the years 1959-1963. The study has shown that warm air is necessary for major hail. An effective lower limit of -1C at 700 mb in the vicinity of the storm has been established. Other meteorological variables were examined to try to distinguish days with hail from those without hail. The best clues to the occurrence of hail were: a steep temperature gradient at low levels between Great Falls and Seattle, a high-level vortex over British Columbia, and unstable air over Great Falls. Other variables were also examined, and a relationship with hail was confirmed. Yet among the varialbes examined no necessary and sufficient conditions were isolated by which one could distinguish a day with severe hail from a day with minor hail or a day without hail.

87

Lowry, D. A., 1977

"A Synoptic Climatological Model to Specify the Probability of Precipitation"

Thesis (Ph.D.), Department of Physical Geography, University of Maryland, College Park, 169 p., available from Xerox University Microfilm, Ann Arbor.

ABSTRACT:

No dynamic model is capable of estimating precipitation in terms of probability. Until we approach perfection in categorical prediction, there is certainly a pronounced gap, a need for probability estimation as the basis for decision making. This dissertation is founded on the premise that we can bridge this gap by examining the output from existing numerical models and comparing these data with actual observations of precipitation. If this procedure is carried out over a period of time, a new type of synoptic climatology is generated, a climatology of the numerical prediction models. This climatology, in turn, can form this basis for a dynamical-statistical st of equations, or model, to specify the probability of precipitation.

Thus a model is developed. The procedure is called Model Output Statistics (MOS) and the model itself is called PEATMOS (Primitive Equation And Trajectory Model Output Statistics). When applied to specify the probability of precipitation (PoP), the model name becomes PEATMOS PoP. The necessary relationships are derived through multiple linear regression where forward stepwise screening is used.

Six reasons covering a three-year development period are discussed. Probability estimates are made for projections from twelve to forty-eight hours for the conterminous United States. The accuracy of the estimates is quite high.

Geographical areas are defined for each season. Fourteen areas are used during the sixth season (Summer 1973). Predictor categories include relative humidity, precipitation amount, precipitable water, stability indices, upper-air heights, plus vertical and horizontal wind. Profiles showing correlation

coefficients are generated for each field used these categories for each of three twelve-hour periods in each area.

A geographical analysis is presented that attempts to point out the spatial distributions and physical characteristics that support the observed relationships (profiles) between the predictors and the predicted (precipiation). In general some of the relationships leading to precipitation are: (1) High relative humidity, precipitable water, and precipitation amount estimates. (2) Upward vertical wind motion. (3) Low 850 mb heights. (4) Atmospheric instability. (5) Favorable horizontal surface winds blowing from oceans toward land, etc. Factors that help determine these relationships are latitude, station elevation, location of moisture sources, upslope terrain, and synoptic systems both moving and stationary.

The physical characteristics of the model are reflected in the predictors actually chosen through screening. Relative humidity is clearly the dominant predictor category for all time projections. Vertical velocity plays a secondary role while all other categories are reduced to minor roles.

It is concluded that the synoptic climatological model developed here to specify the probability of precipitation exhibits characteristics that are physically sound. Its place in the scientific community is justified by the results of testing and through successful performance.

88

Lowry, D. A., 1972

"Climatological Relationships Among Precipitable Water, Thickness and Precipitation"

Journal of Applied Meteorology, 11(8): 1326-1333.

ABSTRACT:

Climatolgical relationships among precipitable water, thickness and precipitation are presented in such a manner that a line of saturation thickness may be defined. One year of data were used to develop such a line and the subsequent year's data were used to check the validity of the line. The equation for this line is $h_s = 5550 + 300$ in W + 0.1 E, where the saturation thickness (h_s) is given in meters when the precipitable water (W) is in inches and the elevation (E) is expressed in meters. The equation is valid over a region east of the Rocky Mountains during all seasons of the year. A weakness in the relationship occurs under extreme cold and dry conditions. Possible applications include the use of observed (or predicted) fields to produce diagnostic (or forecast) values of atmospheric moisture, including precipitation.

89

Lund, I. A., 1971a

"An Application of Stagewise and Stepwise Regression Procedures to a Problmem of Estimating Precipitation in California"

Journal of Applied Meteorology, 10(5): 892-902.

ABSTRACT:

This paper illustrates a method of blending stagewise and stepwise regression procedures for selecting predictors and deriving equations. Only a few minutes of large-scale computer time were required to screen almost 4500 potential predictors and identify the leading contenders for use in the prediction equations. The equations developed for specifying and predicting California precipitation produced estimates of the amount of precipitation which were distinctly superior to estimates based on persistence or recurrence.

90

Lund, I. A., 1971b

"Correlations between Areal Precipitation and 850-Millibar Geopotential Height"

Monthly Weather Review, 99(9): 691-697.

ABSTRACT:

Geopotential heights of the 850-mb surface at 499 grid points over one-half of the Northern Hemisphere, extending from 10°E westward to 170°W, were correlated with daily precipitation observations over California and an area in the Eastern United States on 401 January and February days. Correlations as high as 0.69 were obtained between 850-mb heigths and California precipitation. The statistical significance of the maximum correlation obtained over the one-half hemisphere area exceeded the 5-percent level for all periods of less than 5 days. The maximum cprrelaton between heights and precipitation observed in the Eastern United States was -0.44 and the correlations were signficant at the 5-percent level for all periods of less than 3 days.

Since correlations between 850-mb heights and subsequent precipitation exceed autocorrelations except for short periods of time, it is proposed that 850-mb height observations replace or supplement persistence in conditional climatologies of precipitation.

91

Macdonald, N. J., 1976

"On the Apparent Relationship between Convective Activity and the Shape of 500 mb Troughs"

Monthly Weather Review, 104(12): 1618-1622.

ABSTRACT:

A study was made of the surface occurrence of convective activity during the late spring and summer months for an eight-year period over a region of the central United States. It was found that there was a significant increase in the amount of convective activity as measured by thunderstorms when 500 mb troughs with a northwest to southeast (negative) tilt were present in the area. The enhanced convection was significantly greater than that activity associated with the presence of 500 mb troughs with a more ordinary tilt (or shape).

An extension of the study to the winter months over a two-year period showed a similar but not so striking association between convective activity and negatively titled troughs. The observations offer some support for a theoretical argument that convection may be associated with an equatorward flux of relative angular momentum.

92

McNulty, R. P., 1977

"On the Relationship of Wind Maxima to Severe Weather and its Operational Application"

Preprints, 10th Conference Severe Local Storms, Omaha, Amer. Meteor. Soc, Boston, 352-357.

EXCERPT FROM CONCLUSIONS:

The importance of upper tropospheric divergence in severe weather occurrence has been emphasized by several authors over the past 20 years. This study provides empirical verification of this concept and reemphasizes the use of wind maxima quadrants.

An operationally viable approach to the use of wind maxima has been presented. Currently available analyses and prognoses, when used in terms of the scheme described above, can lead to refinements in the current AC forecast program. The weakest part of this scheme is the thermodynamic predictions presently available.

93

Maddox, R. A., 1976

"An Evaluation of Tornado Proximity Wind and Stability Data"

Monthly Weather Review, 104(2): 133-142.

ABSTRACT:

Over 250 torando proximity soundings have been closely studies. Emphasis was given to a detailed examination of the wind profiles and stabilities of the soundings. The uncertainties inherent in severe storm reports,, and in the positioning of proximity data relative to moving storms, were examined. It was found that the small-scale storm environment cannot be resolved with mean proximity data. On the synoptic scale a very large range of winds and stabilities was found to be associated with confirmed tornadoes. Only slight differences were found between mean tornado proximity soundings, mean soundings associated with destructive tornado outbreaks, and mean soundings associated with outbreaks of non-tornadic severe thunderstorms. Storm relative wind fields were found to be similar for all types of tornado soundings studied. The storm relative flow fields vary dramatically as thunderstorm velocity changes within a given environment.

94

Maddox, R. A., 1973

"A Severe Thunderstorm Surface Potential Index (SPOT)"

Preprints, 8th Conference Severe Local Storms, Denver, Amer. Meteor. Soc., Boston, 252-256.

INTRODUCTION:

The development and successful use of the AFGWC Severe Weather Threat (SWEAT) Index has been described by Miller et al., (1972). Since SWEAT is an upper air index (although the 850 mb data have been replaced by 900 meter above ground level (AGL) boundary layer model data, SWEAT remains a combination of upper air terms), the author felt that there was need for a complementary index based on surface parameters available hourly during the day. The index would be a combination of various terms derived from hourly surface observations. The value of an index which could specify areas of high severe thunderstorm surface potential would be its use in conjunction with SWEAT forecasts to improve both the accuracy and lead times of point warnings for severe convective activity. It would also be helpful in defining areas of high severe thunderstorm probability which are issued on the Military Weather Advisory. The idea was not to attempt to find some "magic number", but rather to devise an index which would specify the potential of each station relative to other stations surrounding it. Such an empirical index has been developed and is being programmed for computer computation and operational use by AFGWC forecasters. It has been designated the Surface Potential Index or in short, SPOT.

95

Madigan, E. F., 1959

"An Objective Technique for Forecasting Summertime Air Mass Thunderstorms at Fort Riley, Kansas"

Detachment 15, 25th Weather Squad, (AWS-MATS) USAF, Fort Riley, 13 p., available from NTIS, AD - 226721.

CONCLUSION:

Probably the most significant conclusion that may be drawn from this study concerns not the accuracy of the study itself, but the opening of a new area to objective forecast techniques. Fort Riley lies in that part of the United States known as "Tornado Alley." If it is possible to develop a purely objective technique for forecasting any single weather element at one station, it may be concluded that at other stations in the same area similar objective techniques may be developed, in some cases by using the same basic predictors. If a conclusive test continues to produce the high percentage of correct forecasts indicated by the preliminary test, it will have been proven that at least part of the thunderstorm forecast problem in the Central Plains may be solved objectively; and a step will have been taken toward the improvement of severe weather forecasting techniques.

The size of the independent data sample used in testing the technique and the fact that the preliminary test was begun prior to the specified period of applicability of the technique makes results gained to this point invalid for the purpose of drawing conclusions. However, it was pointed out in a discussion of the technique conducted to "sell" it to the forecasters at Fort Riley that the percentage of correct subjective thunderstorm forecasts declines as the tendency away from frontal activity and toward air-mass activity continues through the summer months. The objective technique, since it was devised for the months of June, July, and August, may be expected to improve its accuracy over the May and early June test period.

Strong evidence has been presented that the objective technique developed here will provide a significantly higher percentage of thunderstorm forecast verification than subjective methods used previously.

96

Magor, B. W., 1959

"Mesoanalysis: Some Operational Analysis Techniques Utilized in Tornado Forecasting"

Bulletin of the American Meteorological Society, 40(10): 499-511.

ABSTRACT:

The tornado forecast becomes a small-scale problem as the tornado-generating severe-thunderstorm area approaches a particular locality. Consequently, much of this problem can be solved by the best possible analysis of surface synoptic weather data. Various tornado occurrences were investigated and found to be associated with meso-lows. These meso-lows were depicted either by the intersection of two instability lines or by the intersection of a squall line with a northeastern boundary of rain-cooled air. An explanation is given for the formation of tornadoes along this intersection.

97

Mahrt, L., 1977

"Influence of Low-Level Environment on Severity of High-Plains Moist Convection"

Monthly Weather Review, 105(10): 1315-1329.

ABSTRACT:

Early afternoon environmental conditions preceding hail-producing thunderstorms are statistically compared with conditions for classes of less severe moist convection using only from individual radiosonde releases collected during the National Hail Research Experiment in northeast Colorado. The ensuing analyses emphasize the thermodynamic characteristics of the mixed layer and immediate overlying free flow.

On days with hail-producing thunderstorms, the mixed layer tends to be particularly thin and moist. Energy required to initiate moist convection is found to be somewhat greater than normal, while energy required to further develop moist convection is substantially less than normal. Parcel energies are found to be quite sensitive to the level of parcel origin in the mixed layer.

98

Marwitz, J. D., 1971

"Severe Storm Types in Relation to Wind Shear"

Preprints, 7th Conference Severe Local Storms, Kansas City, Amer. Meteor. Soc, Boston, 240-243.

SUMMARY:

The environmental winds surrounding supercells, multicells, and severely sheared storms have been examined. Distinctive characteristics of the environmental winds have been identified for each of the storm types. In the case of five well documented supercell storms, the environmental winds in the subcloud layer were strong (10 to 17 mps) and veered by > 60° from the mean environmental winds. There was also > 50° of veering within the subcloud layer. The environmental wind shear through the cloud layer was strong (but not severe) with values ~ 4.0×10^{-3} sec^{-1}. The distinctive characteristic of the environmental winds associated with nine well documented multicell storms was the light winds in the subcloud layer. All cases had wind speeds mps with the median being 4 mps. The shear through the cloud layer was $\leq 4.5\ 10^{-3}$ sec^{-1}. Only two storms have been documented which existed in extreme environmental wind shear ($> 7.0 \times 10^{-3}$ sec^{-1}). In both cases the storms contained large, persistent, bounded weak echo regions and evolved in a similarly slow but steadily changing manner. The observations suggest that detrainment is an important process in the case of extreme wind shear.

99

Mielke, P. W., Jr., L. 0. Grant, and C. F. Chappell, 1971

"An Independent Replication of the Climax Wintertime Orographic Cloud Seeding Experiment"

Journal of Applied Meteorology, 10(6): 1198-1212.

ABSTRACT:

An orographic cloud seeding experiment conducted in the vicinity of Climax, Colo., has been continued for five additional wintertime periods from 1965-70. A comparison of this new independent information is made with previously discussed wintertime operations of the experiment from 1950-65. As a whole agreement between these independent data sets is good. In particular, the agreement in temperature and wind partitions is consistent with a previously reported model which describes seeding effects under various physically defined conditions. These comparisons have been made using pooled groups of precipitation sensors having similar elevations and locations.

100

Miller, J. R., Jr., E. I. Boyd, R. A. Schleusener, and A. S. Dennis, 1975

"Hail Suppression Data from Western North Dakota, 1969-1972"

Journal of Applied Meteorology, 14(5): 755-762.

ABSTRACT:

Four seasons of hail data were gathered on a randomized cloud seeding project aimed at reducing hail damage and increasing rainfall in western North Dakota. Hail on seed days was generally less severe than on no-seed days. Statistical tests of data from passive hail indicators do not permit rejection of the null hypothesis at the 90% confidence level, but appliation of rank tests to crop-hail insurance loss data indicates that the seeding reduced crop damage from hail.

Post-analyses of related data indicate that 1) the ratio of rainfall amount to hail energy was greater for seed days than no-seed days, and 2) radar characteristics of seeded storms differ from those unseeded storms. In addition, case studies of 34 storms indicate that damaging hail was usually suppressed when their updraft areas were seeded continuously.

101

Miller, R. C., 1967

"Notes on Analysis and Severe-Storm Forecasting Procedures of the Militay Weather Warning Center"

Technical Report 200, AWS - USAF, 170 p., available from NTIS, AD-659 865.

ABSTRACT:

This collection of notes discusses the various types of severe-weather air masses, how severe weather systems form, which parameters best define the existence and intensity of severe weather, and how to use local information to better forecast the occurrence of phenomena at individual stations. Specifically, wind gust and hail-size forecasting techniques and the usefulness of various stability indexes are presented. Also, a chapter on severe weather in tropical air masses is included. Finally, a number of detailed case studies are in the report to help the reader visualize how forecasting concepts are applied, and to emphasize the importance of forecasting experience.

102

Miller, R. C., and R. A. Maddox, 1975

"Use of the SWEAT and SPOT Indices in Operational Severe Storm Forecasting"

Preprints, 9th Conference Severe Local Storms, Norman, Amer. Meteor. Soc., Boston, 1-6.

SUMMARY AND CONCLUSIONS:

These two examples of the performance of the SWEAT and SPOT indices demonstrate how two routine AFGWC computer products are used in severe thunderstorm forecasting. It is to be expected that indices such as SWEAT/SPOT would work well during a widespread, strong outbreak of severe storms. However, the case of 14 March demonstrates that these two products can be of great value in forecasting small scale severe outbursts occurring in localized areas. Forecasting smaller scale severe storm events is actually a much more difficult problem than forecasting super outbreaks such as that of April 3, 1974. Although these two indices cannot be used to forecast all severe storm occurrences, they have been found to valuable forecaster aids; especially so in an environment where individual forecaster ratainability is short and where the range of individual forecaster experience is very large. While specific counts have not been maintained of "false alarm" rates, it can be reported that the false alarm rate of the overlap SWEAT/SPOT forecast area is much smaller than that of either index used separately.

103

Miller, R. C., A. Bidner, and R. A. Maddox, 1971

"The Use of Computer Products in Severe Weather Forecasting (The SWEAT Index)"

Preprints, 7th Conference Severe Local Storms, Kansas City, Amer. Meteor. Soc., Boston, 1-6.

EXCERPT (pp. 1):

Case studies collected through the years at the MWWC provided the foundation for developing a Severe Weather Threat (SWEAT) Index. From a study of 328 tornadoes, and using experience gained in daily forecasting, we determined which parameters to consider. We also had a good idea of the relative weights to be assigned. Several constraints were imposed:

a. The Index must be computed from U.S. selected-level radiosonde (SLAM) data avialable approximately one hour after observation time. This allows us to have an automated plot of the SWEAT Index at one hour and 15 minutes after observations time and give us a means of rapidly appraising the current air-mass potential.

b. The Index must be computed from fields currently stored in the AFGWC prediction data base. This facilitates automated prognoses of the SWEAT Index without a major revampling of the data base.

c. The parameterization must use reported and predicted values directly, rather than relying on derived parameters or complex pattern recognition.

Under the above constraints, using our empirically derived weighting factors, the SWEAT Index was developed to the present form (Bidner, 1970):

$I = 12D + 20(T-49) + 2f8 + f_5 + 125 (S + 0.2)$ where I = SWEAT Index

D = 850 mb dew point in degress Celsius (if D is negative, the term is set to zero)

f_8 = speed of 850 mb wind in knots

f_5 = speed of 500 mb wind in knots

S = Sin (500 mb - 850 mb wind direction)

T = "Total Total" in degrees Celsius (T is the sum of the 850 mb temperature and dew point minus twice the 500 mb temperature; if T is less than 49, the term 20(T-49) is set to zero).

104

Modahl, A. C., 1979a

"Low-Level Wind and Moisture Variations Preceding and Following Hailstorms in Northeast Colorado"

Monthly Weather Review, 107(4): 442-450.

ABSTRACT:

The evolution of the mean low-level environmental wind and moisture content at Sterling, Colorado, on days preceding, during and following hail episodes has been determined from National Hail Research Experiment

soundings. Results show marked development of shallow easterlies during hail days compared to mean westerlies on no-hail days. Southerly wind components increase for thundershower and hail days as early as 24-36 h prior to the event, compared to little change during no-hail periods. Moisture content increases are in concert with increasing southerly and easterly winds. Southerly winds diminish or become northerly during the 12-24 h after hailfall event. An example of evolving low-level wind and moisture content accompanying a notable hail outbreak - including the Fleming storm - is presented.

105

Modahl, A. C, 1979b

"Synoptic Parameters as Discriminators between Hailfall and Less Significant Convective Activity in Northeast Colorado"

Journal of Applied Meteorology, 18(5): 671-681.

ABSTRACT:

Synoptic data are studied to determine which, if any, parameters representing large-scale physical processes can be used to discriminate effectively between days of insignificant convective activity and those with significant moist convection and high hail potential in northeast Colorado. Divergence, relative vorticity, vorticity advection, temperature advection, surface mixing ratio and a modified K index (George, 1960) were computed and associted with observed weather. Two methods were used to compare distributions of these parameters for their discriminative potential. The first involved ranking of the Student's t statistics for both hail versus no-hail and significant versus insignificant convection stratifications. The second method was a graphical technique for plotting cumulative relative frequencies of the stratified distributions. The most effective parameter on a comparative basis for discriminating between significant and insignificant convection was a measure of low-level and middle-level tropospheric moisture content. Moisture content at the surface provided the best discrimination between hail and no-hail.

106

Mooney, M. L., and G. W. Lunn, 1969

"The Area of Maximum Effect Resulting from the Lake Almanor Randomized Cloud Seeding Experiment"

Journal of Applied Meteorology, 8(1): 68-74.

ABSTRACT:

A randomized cloud seeding experiment was conducted on the Lake Almanor watershed near Mt. Lassen, California, during five winter seasons, 1962-1967. The target area extended approximately 20-mi east-west and 15 mi north-south, and ranged in elevation from 4500-6400 ft MSL. Silver iodide was released

from ground-based, acetone solution generators which were located between 6000 and 7400 ft MSL. Silver iodide releases were made for 12-hr periods, these seeding periods being subsequently divided into four weather categories, depending on wind direction and temperature. In three of these categories, which together produce approximately 85% of the total precipitation, no response to the seeding was observed in the target area. In the remaining category, characterized by westerly winds and cold temperatures, the increase peaked at approximately 57% between 5 and 11 mi downwind, and averaged 37% throughout the 21-mi distance. Both results were statistically significant at the 5% level.

107

Moore, P. L., and D. L. Smith, 1972:

"Updating of Numerical Precipitation Guidance"

Journal of Applied Meteorology, 11(8): 1293-1298.

ABSTRACT:

An objective technique has been developed for modifying precipitation probability guidance forecasts received from the National Meteorological Center by means of radar information which becomes available subsequent to receipt of the guidance forecasts. Tests show improvement with respect to both the centralized guidance and the official subjective forecasts. The findings also carry implications as to the resolution necessary in radar data used in such a procedure.

108

Morgan, G. M. Jr., and R. C. Beebe, 1971

"Analysis of the Time-Space Behavior of the Field of Equivalent Potential Temperature During a Severe Weather Situation"

Preprints, 7th Conference Severe Local Storms, Kansas City, Amer. Meteor. Soc, Boston, 54-59.

EXCERPT FROM CONCLUSIONS:

Surface fronts are used by analysts and forecasters to follow the motions of different air masses. Fronts are seen as the separation between air masses of different properties, and, according to the existing models, as lifting surfaces with easily determined slopes and characteristic weather phenomena. The results of this study indicate that, over a large continent, in the summer months, the picture may be quite different and more complex. Fronts are difficult to locate and may be a very misleading concept. A chart such as the θ_e min chart can be a great aid in analyzing for fronts, or could even supplant them for some purposes.

Cold air which may have been heated by rain-out of some of its moisture moves with a subsiding motion off the Rocky Mountains and spreads eastward. The subsidence warms it still more and masks its cold nature, allowing it to spread out over warmer air without over-turning. Even in the absence of such overrunning, the lowest layers are rapidly warmed and transformed and take over the characteristics of tropical air, separated from the dry air aloft by a strong subsidence inversion. The surface front begins to lose definition and meaning. Analysts tend to "hold the front back" and associate it with "dew point fronts" or "dry lines", while the real cold air moves on eastward. There may be a tendency to frontogenesis back in the rapidly warming cold air mass. A greater application of θ_e analyses , such as the chart of θ_e min, may show that during the warm season the overrunning process is more the rule than the exception. It is certainly easier to follow and analyze the motion of the cold air itself by means of this type of chart than to explain the weather by analyses of surface fronts.

109

Mulvey, G. J., 1977

"Physical Mechanisms of Extra Area Effects from Weather Modification"

Atmospheric Science Paper No. 276, Colorado State Univ., Fort Collins, 138 p., available from NTIS, N77-16568.

ABSTRACT:

One of the complexities of weather modification, namely extra area effects have long posed an opportunity for the long-term control of the earth's weather. This study investigates the physical mechanisms by which cloud seeding projects may cause extra area effects. The investigations center on one of the simplest of precipitating systems, namely the cold wintertime orographic clouds of the central Rocky Mountains. Three lines of investigation are followed: (1) field studies of seeding material movement in the atmosphere and receiver cloud characteristics, (2) numerical simulation, and (3) historical studies of the affected cloud system.

The field observation consist of case studies of the movement and dispersion of silver iodide from ground based generators. These studies, during the winters of 1974-75 and 1975-76, used nuclei counters aboard two aircraft. Aerosol silver concentration measurements were also made during the last experimental year. The surface observation made as part of the field studies included snow collection for silver analysis, radar observation and ice nuclei measurements.

The aircraft studies established the fact that regions of above background ice nuclei concentrations extend from the target cloud systems as far as 240 km downwind while exhibiting concentrations from 10 to over 700 ice nuclei per liter active at -20°C. The analysis of silver concentrations in snow confirmed above background silver concentrations exist in snow samples on days during which cloud seeding occurred in the mountains.

The numerical cloud models were used to investigate the mode of seeding and the seeding requirements of the downwind cloud systems. Case study runs using a cumulus model suggested that seeding the upslope cloud would cause little dynamic intensification. It was therefore inferred that the cloud seeding mode was static. The second cloud model, a rapid glaciation model, estimated the seeding requirements in terms of active ice nuclei or ice crystals for precipitation augmentation to be between 1.0 and 5 N_o1^{-1}. An ice crystal transport model was used to predict the survival time for a spectrum of crystal sizes under a variety of conditions. The results indicate that under certain meteorological conditions crystals typically observed in orograhic conditions can survive long enough to reach the downwind upslope cloud in concentrations between .5 and 50 N_o1^{-1}. The historical studies established characteristics of the typical upslope clouds was well as the surface features controlling their formation. The radar observations showed convective-like echoes migrating within the upslope cloud over the eastern plains of Colorado downwind of Climax. These studies show the existence of at least two feasible mechanisms through which mountain orographic clouds can affect the precipitation on the eastern plains. The studies also outline the meteorological conditions under which the mechanisms investigated are operative.

110

Neiburger, M., and H. C. Chin, 1969

"The Meteorological Factors Associated with the Precipitation Effects of the Swiss Hail Suppression Project"

Journal of Applied Meteorology, 8(2): 264-273.

ABSTRACT:

During 1957-63 a randomized experiment to test the efficacy of cloud seeding to suppress hail in the southern Alps was conducted using ground-based silver iodide generators. While the results from the standpoint of hail suppression were negative, there appears to have been a definite overall effect in increased precipitation on days with seeding. Further, Neyman and Scott discovered that the precipitation effect was strongly positive on days selected for the experiment by one forecaster, and somewhat negative on those selected by another. This paper is an attempt to identify the factors responsible for this difference.

An analysis of the meteorological conditions associated with the experiment showed that, in general, the conditions favoring convective precipitation, i.e., southerly flow and upper-level instability, were also associated with positive seeding effects. To some extend the difference between forecasters referred to above was due to accidental differences in the random selection of seeding opportunities among cases of southerly and northerly flow. Not all the difference was explained in this way.

The conditions favoring large amounts of precipitation and large seeding effects were studied. For instance, the experimental days were typed according to surface pressure pattern, and in two of the weather types strong positive seeding effects were present.

The necessity of caution in attributing to seeding differences which might be due to other factors is discussed in the light of the possibility of the process of random selection producing unequal samples from meteorological types having widely different physical characteristics.

111

Neumann, C. J., 1971

"The Thunderstorm Forecasting System at the Kennedy Space Center"

Journal of Applied Meteorology, 10(5): 921-936.

ABSTRACT:

One of the major problems concerning meteorologists at the Kennedy Space Center, Florida, involves the forecasting of thunderstorm activity and associated adverse weather phenomena. The purpose of the study is to outline some of the more successful diagnostic tools which have been developed to aid the forecaster. These involve a variety of statistical procedures including conditional probabilities, exposure-period probabilities, and systems of multiple-regression equations based on nonlinear predictors.

112

North Dakota Weather Modification Board, 1977

"Cloud Seeding Decision Models" (Volume 2) and "Weather Analysis and Forecasting" (Volume 5) of

The North Dakota Cloud Modification Project - An Operations Manual - Bismark, approximately 370 p., available from the issuing agency or the Illinois State Water Survey Library.

EXCERPT FROM FOREWARD:

The North Dakota Weather Modification Board has prepared an Operations Manual for the North Dakota Cloud Modification Project. The Manual is a series of volumes; each designed to provide a brief discussion of a particular phase of the project.

Examination of the volumes in the Manual will point out the necessity for teamwork to provide a good operation. This teamwork extends from the cooperation required between meteorologists and pilots, to the Board/Contractor relationship.

113

Notis, C., and J. L. Stanford, 1976

"The Synoptic and Physical Character of Oklahoma Tornadoes"

Monthly Weather Review, 104(4): 397-407.

ABSTRACT:

The synoptic and physical characteristics of Oklahoma tornadoes are studied for the 16-year period 1959-74. When the Oklahoma results are compared with tornadoes in Iowa (Notis and Stanford, 1973), grouping tornadoes into classes based upon direction of movement reveals a number of differences in tornado characteristics between the southern and central portions of the Midwest. In both states a strong correlation between tornado direction of movement and 500 mb flow direction is found. These results, based on 534 tornadoes in Oklahoma and Iowa, provide a statistical basis for tornado movement forecasts. Since it is widely believed by the public that tornadoes move from the southwest, such forecasts may be of greatest value in the northern portions of the Midwest, under conditions of northwesterly flow aloft.

Median and expected path lengths for Oklahoma tornadoes are found to be ~ 1 mi and 4.2 mi, respectively. A X^2 test reveals that the tornado path length distributions are not independent of 500 mb speed in the 30-70 kt range.

114

Notis, C.,and J. L. Stanford, 1973

"The Contrasting Synoptic and Physical Character of Northeast and Southeast Advancing Tornadoes in Iowa"

Journal of Applied Meteorology, 12(7): 1163-1173.

ABSTRACT:

Results are presented from a systematic study of 386 Iowa tornadoes reported over a 13-year period (1959-71). The tornado occurrences are studied as a function of time of day, date, path length, width, 500-mb flow, and their relationship to associated fronts and low-pressure centers. The data surprisingly reveal that Iowa tornadoes fall naturally into two rather distinct classes: northeast-advancing (NE) and southeast-advancing (SE) tornadoes. There also appear to be subgroups of tornadoes occurring ahead of the front and on or behind the front. Considering all the tornadoes studied, the tornado direction of movement is found to be closely tied to the 500-mb flow (statistically significant at the 99.99% level). Tornado path lengths tend to be longest during the spring.

Some contrasts found between the two main classes of Iowa tornadoes are the following:

1. NE and SE tornadoes comprise approximately 70% and 30%, respectively, of the total in Iowa.

2. NE tornadoes exhibit a bimodal annual distribution occurring predominatly in the spring and again in the fall, while SE tornadoes have a peak occurrence in the summer.

3. NE tornadoes tend to occur ahead of the front, while SE tornadoes tend to occur on or behind the front.

4. NE tornadoes are more closely associated with a low than SE tornadoes.

5. SE tornadoes tend to occur slightly later in the day than NE tornadoes.

6. The relationship between path length and width is rather complicated and is independent of direction of movement but depends upon the location of the tornado relative to the front.

Because of the results of recent tornado-damage studies which showed that first-floor rooms facing the tornado direction of approach were statistically less safe than other areas, application of some of the present results promises to lead to increased public safety in upper-Midwest tornadic storms.

115

Olsen, A. R., and W. L. Woodley, 1975

"On the Effect of Natural Rainfall Variability and Measurement Errors in the Detection of Seeding Effect"

Journal of Applied Meteorology, 14(5): 929-938.

ABSTRACT:

Natural rain variability and measurement errors are obstacles to the determination of the seeding effect in convective cloud seeding experiments. The relative importance of these problems in Florida is evaluated in this paper. Its major thrust is embodied in a computer simulation of area cloud seeding experiments for two areas (570 km^2 and 1.3×10^4 km^2) using field measurements as input. The effect of natural rain variability is studied as it relates to the power functions of selected statistical tests for seeding effect. Measurement errors for gage and radar systems are introduced by modifying the underlying distribution of area mean rainfall.

For the two Florida areas, natural rain variability is by far the major obstacle to the determination of a seeding effect. Errors are of lesser importance for the system of rain measurement used in Florida, which involves radar-rain estimates adjusted by gages. With a less accurate system of rain measurement, errors would assume greater relative importance. It is concluded that to detect a particular seeding effect with a minimum number of cases, the importance of natural rain variability must be decreased through either stratification of the experimental days or through meteorological predictors. The measured system used by the Experimental Meteorology Laboratory is adequate for the evaluation of its seeding experiments and little will be gained through the expenditure of time and effort to improve it further.

116

Peagle, J. N., 1974

"Prediction of Precipitation Probability Based on 500-mb Flow Types"

Journal of Applied Meteorology, 13(2): 213-220.

ABSTRACT:

Regression techniques are applied on stratified and non-stratified data to obtain prediction equations for the probability of precipitation over the western continental United States. The stratification is based on 500-mb winter types. The equations are tested on an independent data sample and it is found that the stratification leads to considerable improvement of the forecasts.

117

Paegle, J. N., and L. P. Kierulff, 1974

"Synoptic Climatology of 500-mb Winter Flow Types"

Journal of Applied Meteorology, 13(2): 205-212.

ABSTRACT:

An objective correlation method is used to obtain seven typical 500-mb flow patterns over the western United States and eastern Pacific Ocean. The frequency of occurrence of each type is presented. The atmospheric configurations of each type are described in terms of 850- and 300-mb heights, 850-mb dewpoint depressions, 500-mb absolute vorticities and vertical velocities, relative frequency of precipitation, and other related fields. The distinctness of the types over different geographical locations is discussed.

The relative frequency of precipitation at 42 western stations is well differentiated by the seven types. This suggests that the stratified relative frequencies could be used as a first refinement over simple climatology when other more accurate quantitative precipitation forecasts are not available.

118

Peagle, J. N., and R. P. Wright, 1975

"Forecast of Precipitation Probability Based on a Pattern Recognition Algorithm"

Journal of Applied Meteorology, 14(2): 180-188.

ABSTRACT:

A nonparametric statistical technique is developed which is capable of interfacing with dynamic atmosperhic models to produce probability of precipitation forecasts. The technique is implicitly nonlinear, utilizing an

efficient algorithm to represent joint probability densities as N-dimensional histograms. Operationally, the method can be updated on a daily basis.

The technique is tested in an atmospheric data sample. Initial predictor selection is based on a general nonlinear approach applying fields of the sample correlation ratio. An iterative algorithm optimization technique is described and utilized. The technique is tested and shown to have significant skill relative to climatology.

119

Pappas, J. J., 1962

"A Simple Yes-No Hail Forecasting Technique"

Journal of Applied Meteorology, 1(3): 353-354.

ABSTRACT:

An objective method of hail forecasting is developed, employing as predictors (1) the ratio of cloud depth below the freezing level to the cloud's estimated vertical development and (2) the height of the freezing level. Based on dependent data for Texas, Oklahoma, Kansas and Nebraska, the method showed common and Appleman skill scores +0.65 and +0.66, respectively.

120

Parton, W. J., Jr., 1968

"Application of Hourly Surface Data to the Development of Short Range Forecasting Techniques"

Part II of Development of Short Range Forecasting Techniques, Department of Meteorology, Univ. of Oklahoma, Norman, pp. 1-57, available from NTIS, PB-179 722.

ABSTRACT:

Hourly surface data are used to develop short range forecasting techniques for occurrence of precipitation. Selected rain cases from the spring seasons of 1966 and 1967 were studied to determine which surface parameters appear to be the better predictors. The results indicate that temperature advection and upstream temperature dewpoint spread area related to the precipitation probability. These parameters were used in the development of nomograms which give a probability forecast for the occurrence of precipitation at the verification hour and from one to six hours.

121

Penn, S., 1957

"The Prediction of Snow v.s. Rain"

Forecasting Guide No. 2, U.S. Department of Commerce, Weather Bureau, Washington D.C., 29 p., available from the issuing agency or the Illinois State Water Survey Library.

INTRODUCTION:

In many sections of the United States during the colder portion of the year forecasters often face the difficult decision as to whether precipitation will be in the form of snow or rain. This problem is fundamentally just one phase of the overall problem of precipitation forecasting, and perhaps for that reason has received considerably less attention in the way of research than has the basic question of the occurrence or non-occurrence of precipitation.

The problem of predicting snow vs. rain is, however, important in its own right because of the many decisions of great social and economic consequence which may hinge on the forecast. A prediction of snow amount, an extremely vital consideration to many interests, must be preceded by a decision as to the type of expected precipitation. Ordinarily, an inch or so of precipitation in the form of rain will cause no serious inconvenience. On the other hand, the same amount of precipitation in the form of snow (or sleet or freezing rain) can seriously interfere with transportation, communication, business, and the public in general. In such cases the snow-rain problem becomes a factor of the greatest economic importance. Witness the serious dislocation of normal activity resulting from the great snowstorm of December 26, 1947 in New York City, and more recently, the late March storms of 1956 in the Northeast.

The hardship and disruption which are often caused by snow can be alleviated to a great extent if the snow is correctly predicted. The most obvious countermeasures are those of snow removal, sanding, and keeping vehicles off the roads. While the forecaster may lean to the pessimistic side (i.e., forecast snow instead of rain), that, too, can be costly. The standby costs in a large city may run into thounsands of dollars. A forecast of snow also generated preparations of another sort. Skiresorts, buses and trains to the resorts, and manufacturers of certain types of wintertime clothing and equipment welcome a snow forecast.

There are also times when it is very important to know if the expected precipitation will be rain. The most serious of these situations occurs in connection with floods. Heavy rain occurring when the snow cover is deep and the water table fairly high may result in the smaller streams readily overflowing their banks.

This guide is concerned with the forecasting of snow vs. rain, assuming that precipitation can be correctly predicted. The intermediate elements, sleet and freezing rain (glaze) which often occur in the boundary zone between snow and rain, have been generally grouped with snow in most of the treatment here, although their individual prediction as differentiated from either snow or rain is frequently of great importance too. Specifically this paper surveys research and forecasting techniques which bear directly upon the snow-rain problem in the United States. However, studies for other regions are also included insofar as they are pertinent to the United States problem. The

various techniques and systems often complement and overlap each other, and the alert forecaster should be aware of the application of all methods. Two general approaches have been used; 1. synoptic circulation patterns and 2. thermal relationships (i.e., the use of temperatures at the surface and aloft in separating cases of rain from those of snow). The relative merits of the two basic approaches and of the various methods will be pointed out.

122

Perkey, D. J., 1976

"Prediction of Convective Activity Using a System of Parasitic-Nested Numerical Models"

NASA Contract Report 2761, Department of Physics and Atmospheric Sciences, Drexel Univ., Philadephia, 160 p., available from NTIS, N77-16503.

ABSTRACT:

A limited-area, three-dimensional, moist, primitive equation (PE) model is developed to test the sensitivity of quantitative precipitation forecasts to the initial relative humidity distribution. Special emphasis is placed on the squall-line region. To accomplish the desired goal, it was necessary to develop time-dependent lateral boundaries and a general convective parameterization scheme suitable for mid-latitude systems. The sequential plume convective parameterization scheme presented is designed to have the versatility necessary in mid-latitudes and to be applicable for short-range forecasts. The results indicate that the scheme is able to function in the frontally forced squall-line region, in the gently rising altostratus region ahead of the approaching low center, and in the over-riding region ahead of the warm front.

Three experiments are discussed. The first used a 1.5 km vertical grid interval and humidity analysis based on standard rawinsonde oabservations. This experiment correctly predicted the position of the precipitation maximum over Oklahoma but underpredicted its magnitude. A maximum over Kentucky-Tennessee was totally missed. The squall-line precipitation was also too light. The squall position was predicted to move eastward somewhat too rapdily. The predicted precipitation amount over Oklahoma was combined stable and convective in nature. This agrees with observations in that hourly precipitation records indicate steady rainfall rates over the forecast period, with periods of heavy rainfall. In the squall region observations show rainfall periods lasting 1 to 2 hours with high rates. This type of precipitation was also indicated by forecast.

A narrow band of moisture extending from Central Texas south along the coast was suggested by satellite cloud observations. This band was too narrow to be observed by the convectional rawinsonde observations network. The second experiment attempted to enhance the initial moisture field to reflect this narrow band. The inclusion of the moisture band enhanced the squall-line precipitation while doing little to the Oklahoma maximum. The initiation and dissipation of the squall line as well as the squall-line

precipitation amounts were affected by this narrow moisture band. Although the enhanced humidity field is not necessarily the "true" humidity field, it is a reasonable and possible field and, thus, indicates the sensitivity of short-range quantitative, precipitation amounts to changes in moisture fields.

The third experiment, which used increased low-level vertical resolution, indicates that even without more horizontal resolution, and therefore without added observational costs, better short-range precipitation forecasts can be obtained. The Olkahoma maximum was increased by 25 percent, so that it more nearly agreed with observations. Also, some increase was noted in the convective region, which also improved the forecast.

123

Pielke, R. A., R. Biondini, and G. Mullen, 1977

"Rainfall in the (Experimental Meteorology Laboratory) EML Target Area as a Function of Synoptic Parameters"

Preprints, 5th Conference Probability and Statistics in Atmospheric Sciences, Las Vegas, Amer. Meteor. Soc., Boston, pp. 196-200.

SUMMARY AND CONCLUSION:

The results presented here must be considered preliminary because of the relatively small sample size. Nonetheless, the differences in rainfall amounts for two classes of wind speeds supports Biondini's (1976) finding of differences in rain statistics depending on whether a day had radar-echo-motion or not. It also suggests that echo motions are well correlated with the surface geostrophic wind speed. This in turn suggests that the echo motion phenomenon is largely controlled by synoptic scale patterns. This had been conjectured previously, but heretofore has not been examined. All previous studies involving this phenomenon have been restricted to mesoscale (or smaller) entities.

The importance of wind direction on rainfall amounts, with its diametrically opposed differences for the two classes of wind speeds is one of the significant findings of this study. This dependence on direction supports the argument that the sea breeze circulation pattern over south Florida is crucial in regulating rainfall amounts in the EML Target Area, although this finding needs to be substantiated with additional modelling experiments.

The dependence of rainfall on the relative moistness of the lower troposphere is as one would intuitively expect for the light wind case, but the strong wind class has greater rainfall for a relatively drier lower troposphere. It is not expected that this relation can be explained by sea breeze patterning alone, but undoubtedly is dependent on cumulus dynamics and thermodynamics. The statistical evaluation of a larger sample needs to be undertaken in order to ascertain if this result is real.

Finally, the use of synoptic predictors to forecast rainfall in the EML Target Area seems to be of value. Additional work is needed to see if other

large-scale parameters, such as wind shear, and upper level winds, can improve the predictions. Indeed a statistical model, such as developed for hurricane track forecasting (i.e., Miller, et al. (1968)), may be a particularly valuable tool to quantify precipitation forecasts.

124

Quiring, R. F., 1977

"Climatolgical Predication of Cumulonimbus Clouds in the Vicinity of the Yucca Flat Weather Station"

NOAA Technical Memorandum - NWS WR-121, 20 p., available from NTIS, PB-271 704.

CONCLUSIONS:

The performance of the various climatological indices as predictors of CB activity in the vicinity of Yucca Flat is essentially as expected. There is a strong suggestion that the performance of the indices derived from the Yucca Flat 12Z sounding can be attributed mainly to the high degree of persistence of CB days. Precipitable water as an index of the probability of CB activity is little better than persistence. The K-value and Z-index are essentially equal with respect to reliability of the probability forecasts in that the relative frequency of occurrence agrees favorably with the predicted probability over the full range from 0 to 1. The contribution of reiiability to the Brier Score is small. The Z-index is distinctly better than K-value with respect to resolution; however, both indices fail to predict often enough at the high end of the probability scale.

The Z-index is very near the limit of success that can be achieved with climatological indices derived from the 12Z sounding; i.e., climatological in the sense that the index is based strictly on observed values. If one accepts the correlation coefficients from the multiple linear regression which selected the observed parameters used in the discriminant function to generate the Z-index, and there is not compelling reason not to, the Z-index accounts for 41% of the variance of the predictand in comparison with 43% for the combination of all 54 parameters offered for selection. This means, of course, that there is still 59% of the variance of the predictand which is not explained by the Z-index. This should provide some incentive for investigating the merits of introducing predicted parameters into the prediction equation. It is conceivable, however, since we are dealing with an air mass phenomenon in the summertime, which implies slow change, that there is very little hope of improving on the climatological probability provided by the Z-index. One would hope, however, that the skill and ingenuity of the forecaster with the aid of satellite pictures and the vast array of prognostic charts available to him daily would prevail in the long run. In other words, the forecaster should be able to take the guidance offered by the climatological indices and subjectively adjust the forecast probability in a manner consistent with the synoptic situation and the numerical predictions and produce a better probabilistic forecast.

125

Rackliff, P. G., 1962

"Application of an Unstability Index to Regional Forecasting"

The Meteorological Magazine, 91(1078): 113-120.

CONCLUSIONS:

It is suggested that a chart based on the instability index would assist the regional forecaster, particularly during the summer thunderstorm regime. The simple computations and objective method mean that charts can be prepared very rapidly from the 2300 GMT radiosonde data; thus the deduced information is available for the early forecast bulletins.

In non-frontal situations, an index value exceeding 30 should alert the , forecaster to the prospect of significant showers accompanied by thunderstorms.

126

Randerson, D., 1977a

"Determining the Relative Frequency of Occurrence of Local Cumulonimbus Activity through Discriminant Analysis"

Monthly Weather Review, 105(6): 709-712.

ABSTRACT:

Discriminant analysis is used to develop a cumulonimbus prediction equation (Z index) for a single station during the period June through September. Based on dependent data, the Z index explains 43% of the variance, while the more commonly used K index explains only 34% of the variance in the same data set. Verifications with 4 years of independent data demonstrate that the Z index yields a lower seasonal Brier Score than the K index, precipitable water content, persistence and the climatological average of cumulonimbus activity for June-September. It is concluded that the Z index provides a meaningful first approximation to the probable development of local cumulonimbus activity during the period June-September.

127

Randerson, D., 1977b

"Spatial Variability of Warm Season Echo Activity as a Function of Two Stability Indices Computed from the Yucca Flat, Nevada Rawinsonde"

Monthly Weather Review, 105(12): 1590-1593.

ABSTRACT:

A radar echo survey for two warm seasons is used to determine the spatial variability of the relative frequency of occurrence of an echo day in six selected areas. These areas include the Las Vegas Valley, Lake Mead and the Spring Mountains, all located in extreme southern Nevada. Also included are the Tonopah and Nevada Test Site areas as well as the Cedar City, Utah, area. The occurrence of an echo in these areas is related to both the K and Z indices, calculated from the Yucca Flat, Nev. , 1200 GMT sounding. The relative frequency of occurrence of an echo was determined for various categories of K and Z. The resulting charts should have practical value for estimating the probability of the occurrence of moist convection over mountainous terrain.

128

Reap, R. M., 1972

"An Operational Three-Dimensional Trajectory Model"

Journal of Applied Meteorology, 11(8): 1193-1202.

ABSTRACT:

A numerical model is developed to compute three-dimensional trajectories from operational wind forecasts generated by the six-layer primitive equation model of the National Meteorological Center. Detailed 14-hr forecats of temperature and dew point, designed for application to severe storm prediction, are derived by computing the 6-hr variations of potential temperature and mixing ratio for air parcels assumed to follow paths defined by the trajectories. Initial values at the trajectory origin points are provided by an objective analysis technique which reproduces detailed patterns and gradients with only light smoothing of the observations. The influence of a relatively detailed terrain is also included in the program. Verification statistics indicate a significant improvement over the primitive equation model forecasts in the lowest 150 mb, where temperature and moisture distributions are crucial to severe storm development. Output from the model for the surface, 850 and 700 mb is currently transmitted via National Weather Service facsimile and teletype circuits for use as guidance in severe storm forecasting.

129

Reap, R. M., and D. S. Foster, 1977a

"Automated Prediction of Thunderstorms and Severe Local Storms"

NOAA Technical Memorandum NWS TDL-62, 60 p., available from NTIS, PB-268 035.

ABSTRACT:

Operational probability equations were developed for predicting general thunderstorm activity and more localized severe weather such as tornadoes,

large hail, and damaging winds for periods up to 36 hours in advance. The statistical equations were derived by applying multiple screening regression techniques to predictors forecast by operational numerical models and to predictands tabulated from manually-digitized radar data and severe local storm reports.

Generalized forecast equations were developed to give thunderstorm probabilities for the April to September convective season. Key predictors in the thunderstorm equations were the stability and vertical motion fields below 700 mb and the boundary-layer wind field. The equations for severe local storms, developed for both spring and summer, predict the conditional probability of tornadoes, large hail, or damaging winds, given the occurrence of a thunderstorm. Predictors selected in the spring (April-June) equation strongly reflected the importance of low-level atmospheric circulation and dynamics to severe storm formation. The probability forecasts are routinely transmitted on facsimile and teletypewriter for use as guidance by operational forecasters.

130

Reap, R. M., and D. S. Foster, 1977b

"Operational Probability Forecasts for Major Outbreaks of Severe Local Storms"

Preprints 5th Conference Probability and Statistics in Atmospheric Sciences, Las Vegas, Amer. Meteor. Soc, Boston, 41-46.

SUMMARY;

We have developed new equations for predicting the conditional probability of major outbreaks of tornadoes, large hail, and damaging winds. These forecasts were designed to supplement existing operational probability forecasts of thunderstorms and severe local storms, a sample of which is shown in Figure 6. The conditional probabilities shown in Figure 6 predict all three categories of severe local storms and have appeared on facsimile since 1972.

The new equation for predictng the conditional probability of significant tornado outbreaks with densities of 7 or greater per 25 grid block area was operationally implemented during the 1977 spring season and is undergoing evaluation at NSSFC and TDL. Not surprisingly, all the predictors in the tornado equation contain either horizontal winds or vertical motions. This emphasis on circulation parameters is in sharp contrast t6 the current operational equations for predicting thunderstorms and severe local storms which, to a large extent, are controlled by stability indices and thermodynamic predictors.

The single best predictor for severe local storm outbreaks with densities of 9 or higher per 25 grid block area was found to be the Alaka-Reap index, which combines the convective or layer instability with the vertical motions necessary to release it.

131

Reap, R. M., and D. S. Foster, 1977c

"Operational Thunderstorm and Severe Local Storm Probability Forecasts Based on Model Output Statistics"

Preprints, 10th Conference Severe Local Storms, Omaha, Amer. Meteor. Soc, Boston, 376-381.

SUMMARY:

The key predictor in the thunderstorm equation was found to be an interactive predictor which combines the local atmospheric stratification, given by the K stability index, with climatology, given by daily thunderstorm relative frequencies obtained from MDR data. This predictor captures most of the widespread general convective activity associated with deep moist layers in the atmosphere. The remaining predictors in the thunderstorm equation severe to identify thunderstorms associated with more localized severe convective activity. The spring equation for tornadoes, large hail, and damaging winds shows the importance of predictors which reflect atmospheric circulation and dynamics, e.g., temperature advection, strong zonal winds, large-scale lifting of convectively unstable layers, ..., etc. This dependence on the large-scale circulation is even more pronounced in the probability equation for major tornado outbreaks, where all the predictors involve either horizontal winds or vertical motions.

132

Renne, D. S., and P. C. Sinclair, 1969

"Stability and Synoptic Features of High Plains Hailstorm Formation"

Preprints 6th Conference Severe. Local Storms, Chicago, Amer. Meteor. Soc, Boston, 125-130.

ABSTRACT:

The structure of a hail-producing and no hail-producing atmosphere is studied by examining rawinsondes launched at New Raymer, Colorado in the summer of 1967. It is found through examination of the convective condensation level and surface moisture values that an ample low-level moisture supply is important for hailstorms to form; The lifted index is a useful parameter for determining the degree of convective instability. A Total Energy Index is derived from energy profiles of $C_pT + gz + Lw$, and this index is also shown to be a good indicator of the degree of potential instability.

A certain increase in baroclinicity on a large scale is shown to occur when summertime hailstorms form. Furthermore, it is shown that the occurrence of hail is related to a surface convergence mechanism. The resulting cyclonic

circulation can advect moisture from the Gulf of Mexico into the region from the east and south, resulting in an increase in instability.

The results of the 1967 data are applied to the forecasting of six independent cases of hail and no hail occurrences in 1968.

133

Ruthi, L. J., and J. P. Kimpel, 1977

"Objective Analyses used in Forecasting Severe Storms During a Tornado Intercept Project"

Preprints, 10th Conference Severe Local Storms, Omaha, Amer. Meteor. Soc., Boston, 390-394.

CONCLUSIONS:

The objectively analyzed fields discussed here, combined with convectional forecasting techniques and guidance, have been useful in locating areas favorable for intercepting severe thunderstorms more than two hours in advance of the occurrence of severe activity. Emphasis was placed upon regions where patterns containing large values of $(-V \cdot V T_d)$ and $(-V \cdot V \theta_e)$ persisted. The severe storm intercept teams for the University of Oklahoma observed and documented six tornadoes during April-June 1976, and twenty tornadoes during April-May 1977. The success of the intercept teams suggests that the forecasts were, at least on these occasions, both timely and accurate.

134

Sanders, F., 1955

"Relationships Between Weather and Indicators of Vertical Motion"

Scientific Report No. 1, Department of Meteorology, Massachusetts Institute of Technology, AFCRC-TN-55-866, 19 p., available from the issuing agency or the Illinois State Water Survey Library.

ABSTRACT:

The probability of occurrence of cloudiness or precipitation at Boston is related to concurrent values of quantities which can be measured from charts of the atmospheric circulation pattern near the ground and in the middle troposphere. These quantities are considered to be indicative of the large-scale vertical motion in the troposphere. Two such quantities, the thickness advection and a quantity derived by Sutcliffe, are shown to be related to the probability of occurrence of cloud and precipitation in the expected sense.

It is found that values of the Sutcliffe expression are highly correlated with vertical velocities computed from the thermotropic numerical prediction

model, thus offering the forecaster an opportunity of assessing vertical motion from appropriate prognostic charts regardless of the method of their preparation.

Use of surface and upper-level charts at slightly different times renders the results slightly less reliable. Preliminary testing indicates that prognostic charts which predict reasonably well the large-scale features of the horizontal circulation pattern do not necessarily predict the pattern of vertical motion with equal success.

Observed thickness changes at Boston indicate that substantial warming occurs in the winter season which is not predicted by horizontal advection and adiabatic temperature changes associated with vertical motions indicated by the Sutcliffe expression. It is suggested that non-adiabatic heating is of considerable importance even in winter in some land areas.

135

Sanders, F., and K. A. Emanuel, 1977

"The Momentum Budget and Temporal Evolution of a Mesoscale Convective System"

Journal of Atmospheric Sciences, 34(2): 322-330.

ABSTRACT:

The momentum budget and temporal evolution of a convective mesosystem, originally investigated by Sanders and Paine (1975), are examined. It is found that 1) alternative analyses of the data do not substantially change the conclusions reached in the previous paper, 2) stresses due to cumulus-scale eddies produce forces which are as large as the horizontal pressure-gradient force, in the direction normal to the storm line, and 3) liquid water aloft must be taken into account in the hydrostatic computation of the pressure field. The mesoscale circulation increases substantially during the 4 h observation period, suggesting a time evolution which may be characteristic of this type of convective system.

136

Sanders, F., and A. J. Garrett, 1975

"Application of a Convective Plume Model to Prediction of Thunderstorm"

Monthly Weather Review, 103(10): 874-877.

ABSTRACT:

The numerically calculated height of a steady-state model of a convective plume, which relies on the entire sounding of temperature and humidity above the assumed cloud base, is considered to be a measure of the thermodynamic predisposition of the atmosphere to convective overturning. The plume height is evaluated as a predictor of summer thunderstorms at Tampa, Fla., and is

found to contain more forecast skill than combination of two simpler and more familiar predictors, the Showalter Index and the precipitable water depth. In absolute terms, however, the skill is modest. Skill is somewhat improved when a simple measure of the zonal geostrophic flow over the Florida penninsula is considered as a predictor together with the height of the model plume, but it is suggested that a major portion of skill, not yet within reach, resides in prediction of the mesoscale systems in which convection is organized

137

Sangster, W. E., 1979

"Warm Season Nocturnal Quantitative Precipitation Forecasting for Eastern Kansas Using the Surface Geostrophic Wind Chart"

NOAA Technical Memorandum NWS CR-64, 44 p., available from NTIS, PB-295 982.

ABSTRACT:

The surface geostrophic wind (SGWO) chart has been used to statistically derive probability of precipitation (PoP) and probability of precipitation amount (PoPA) equations for the nighttime periods for eastern Kansas and extreme western Missouri. The season of interest is May through September. The 1800 GMT SGW chart was used to obtain the predictors. The scientific basis for using this chart is that nocturnal precipitation in the forecast area is known to be related to boundary layer wind maximums.

These PoP and PoPA values were then compared for skill with Model Output Statistics (MOS) values transmitted from the National Meteorological Center. The SGW values were found to be inferior on independent data to those of MOS in all 5 scores computed; however, a consensus (average) of SGW and MOS was superior to MOS in 3 of 5 scores. Joint values were constructed and found to be superior to those of MOS in all 5 scores, but this verification of joint values was not on independent data, so further testing will have to be done.

Numerous examples with maps are given, in the belief that a dedicated forecaster could better his chances of improving upon all objective techniques by a study of these maps.

138

Sangster, W. E., 1958

"An Investigation of Nighttime Thunderstorms in the Central United States"

Technical Report No. 5, Department of Meteorology, Univ. of Chicago, Chicago, 39 p., available from the issuing agency or the Illinois State Water Survey Library.

ABSTRACT;

The vertical motion at the 700-mb level for the area of high nighttime thunderstorm frequency in the central United States is computed for four times

daily for a period of twelve consecutive days. A significant diurnal variation is found, with the maximum upward motion occurring, on the average, at 2100 CST, and the maximum downward motion at 0900 CST. The diurnal variation of vertical motion is shown to be primarily a consequence of the diurnal wind variation along the southern border of the area of study. Individual cases of nighttime thunderstorm activity are shown to be associated with a diurnal pulsation of the vertical motion at 700 mb.

139

Sartor, J. D., 1962

"Essential Factors of Thunderstorm Forecasting"

Memorandum RM-3049-PR, The Rand Corporation, Santa Monica, 23 p., available from the issuing agency or the Illinois State Water Survey Library.

ABSTRACT:

A method for formulating a mathematical relationship between the occurrence of thunderstorms and several essential prior conditions is demonstrated. A winnowing of 24 thunderstorm-forecasting parameters leads to the isolation of five essential factors and an expression demonstrating their possible relationship to thunderstorms.

140

Schaefer, J. T., 1977

"On the Applicability of the Divergence Equation to Severe Storm Forecasting"

Preprints, 10th Conference Severe Local Storms, Omaha, Amer. Meteor. Soc., Boston, 358-363.

INTRODUCTION:

At its most elemental level, the severe storm's environment is characterized by a conditionally and convectively unstable stratification and localized upward vertical velocities. During the past 30 years many theoretical, empirical, and statistical techniques have been developed to identify regions with these characteristics. Since this work of Beebe and Bates (1955), it has been assumed that the upward vertical velocities generally arise from the superpositioning of jet streams so that a region of upper level divergence overlays one of lower level convergence. McNulty (1977) reemphasized the importance of synoptic scale upper tropospheric divergent areas as inferred from isotach maxima at the 300 mb level.

However, as pointed out by House (1958), severe weather phenomena often occur with divergent areas which are not directly associated with jet streams.. Evaluation of the complete divergence equation should be one method for diagnosing the short-term develoment of such areas.

141

Schickedanz, P. T. , and S. A. Changnon, Jr., 1970

"The Design and Evaluation of Hail Suppression Experiments"

Monthly Weather Review, 98(3): 242-251.

ABSTRACT:

A statistical methodology involving the analysis of three basic types of historical hail data on an areal approach is presented for the planning and evaluation of hail suppression experiments in Illinois. The methodology was used to generate nomograms relating the number of years required to detect significant results to 1) type I error, 2) type II error, and 3) power of test for various statistical tests and experimental designs. These nomograms were constructed for various area sizes and geographical locations within the State.

Results indicate that, for an Illinois experiment, insurance crop-loss data are the optimum hail measurement if the study area has more than 60 percent insurance coverage. The optimum experimental design is the random-historical design in which all potential storms are seeded on a particular day, and 80 percent of the forecasted hail days are chosen at random to be "seeded days." The recommended statistical analysis is the sequential analytical approach. If, however, conditions for the sequential analytical approach are not fulfilled by the data sample, the nonsequential approach utilizing a one-sample test with the historical record as the control (random-historical design) should be employed.

For a significance level of 0.05 and a beta error of 0.3, the average detection time in an area of approximately 1,500 sq mi would be 11. yr for a 20 percent reduction in the number of acres damaged, 2 yr for a 40 percent reduction, and 1 yr for a 60 and 80 percent reduction. If the nonsequential analyses were required, the number of years would be 25, 5, and 1, respectively.

142

Schickedanz, P. T., and F. A. Huff, 1971

"The Design and Evaluation of Rainfall Modification Experiments"

Journal of Applied Meteorology, 10(3): 502-514.

ABSTRACT:

Storm rainfall data from dense raingage networks in Illinois were employed in a study to determine the length of time required to obtain significance for various increases in storm rainfall due to weather modification efforts. The primary purpose was to evaluate the effect of stratifying the storm data on the detection of seeding effects for a given design using highly accurate measurements of the rainfall parameters. It was also desired to evaluate the efficiency of various rainfall parameters and the efficiency of various

statistical designs in detecting various increases. Results indicate that the length of experimentation necessary for detection of seeding effects varies according to weather type, precipitation type, rainfall parameter, and statistical design employed. Results also indicate that as the seeding-induced becomes large, the choice of stratification, rainfall parameter, and statistical design becomes less important. An evaluation procedure is recommended which incorporates desirable features from several of the designs, stratification and rainfall parameters considered in this study. Although it is difficult to verify, a 20% increase in precipitation can be detected in a five-year experiment provided proper choices are made of weather types, statistical design, data stratification and rainfall parameters.

143

Schleusener, R., and A. Auer, Jr., 1964

"Hailstorms in the High Plains"

Final Report, Civil Engineering Section, Colorado State Univ., Fort Collins CER64 RAS36, 100 p., available from the issuing agency or from the Illinois State Water Survey Library.

ABSTRACT:

The instrumentation and data collection system used in hailstorm studies in northeastern Colorado for the period 1960 through 1964 is described. Basic data were derived from cooperative observers and passive hailfall indicators to obtain information on rainfall and hailfall to supplement the existing stations. Systematic efforts were made through newsletters to inform people in the area of the research work being conducted. In 1964, assistance was given by the Colorado State Highway Patrol in reporting rainfalls and hailfalls, which proved to be particularly valuable in establishing negative reports of hailfalls.

A variety of radar equipment was used to establish radar characteristics of hailstorms. Cloud seeding on selected thunderstorms was done with silver iodide generators in 1962 and 1963 in limited cases. These results are reported separately.*

The main body of the report gives a summary of project reports in abbreviated form, and detailed results are given in separate appendices. The reported results are those of a background nature on the characteristics of hailstorms and rainstorms, and the associated physical studies that have been made in the period 1960 through 1963 for the purpose of establishing the necessary background information for a scientific hail suppression experiment to be conducted in northeastern Colorado.

The data obtained indicate that such an experiment cannot be conducted on the basis of target and control areas, but must be conducted by studies of the changes in hailstorms as a function of time during their lifetime.

Additional physical studies are continuing, as well as continuation of the hail suppression experiment, which was begun in 1964.

A detailed report of the results of seeding of individual thunderstorms is being prepared as a separate report.

144

Scoggins, J. R., H. E. Fuelberg, S. F. Williams, and M. E. Humbert, 1978

"Mesoscale Characteristics of the Texas HIPLEX Area During Summer 1976"

Final Report, LP-65, Bureau of Reclamation, Texas Department of Water Resources, Austin, pp. 322-343, available from the issuing agency or the Illinois State Water Survey Library.

ABSTRACT:

This report contains an analysis for fifteen days on which mesoscale meteorological data were obtained in the Texas HIPLEX area during the period June 1 to July 15, 1976. Rawinsonde soundings were made at 3-h intervals between 1500 and 0300 GMT on nine of the fifteen days at Midland, Robert Lee, Post, and Big Spring. Surface data consisting of 10-min average values of temperature, humidity, pressure, and wind direction and speed were available from seventeen stations for all fifteen days. In addition, data were available from the National Weather Service radar at Midland.

The data were analyzed and results presented for each day separately. In addition, composite analyses of selected surface variables and atmospheric energetics are presented. Variables considered in the surface analysis include temperature, mixing ratio, velocity divergence, vertical motion, vertical flux of moisture, moisture divergence, equivalent potential temperature, vorticity, and in some cases the relative wind field. Charts of analyzed fields determined from data placed on a 15-km grid are compared with radar data coded on a similar grid. Variables considered in the upper-air analysis include mass divergence, vertical motion, moisture divergence, all terms in the total energy budget, all terms in the water vapor budget, and time changes in sounding parameters. Each upper-air variable is presented as an average vertical profile for the Texas HIPLEX area.

The results show pronounced interactions between the environment and convective activity. Marked changes in nearly all surface and upper-air variables occur in association with convective activity. The analysis of individual days as well as the composite analysis suggests that surface processes indicated by moisture divergence, vertical flux of moisture, and vertical motion are important in the formation and maintenance of convective clouds. The importance of these same variables also is reflected in the upper-air analyses as well as energy processes and time changes.

No attempt is made to reach definitive scientific conclusions because of the relatively small number of days for which data are available. However, the results are conclusive in terms of demonstrating the value of mesoscale research in the overall problem of developing the technology for systematic rainfall enhancement.

145

Showalter, A. K., 1953

"A Stability Index for Thunderstorm Forecasting"

Bulletin of the American Meteorological Society, 34(6): 250-252.

EXCERPT (pp. 250-251):

In summary, the Stability Index is offered as an extremely simple, thermodynamically sound and easily understood tool for making a very rapid check on thunderstorm possibilities. It is recommended that forecasters continue their own tried and tests techniques for more refined analyses within the areas where the stability index had a negative value or any positive value less than +5°. If negative values of -4° or larger are indicated, I suggest a quick check on the synoptic maps and weather sequences because in that case one should be on the alert for unusual thunderstorm activity.

Perhaps it should be noted that not all cases of convective instability will show a negative Stability Index since the technique selects only the more pronounced cases of convective instability. Actually it is possible to have convective instability when the index is +6° if the air is quite dry at 500 mb. However, such cases might offer more resistance to convection than can be realized by the usual lifting mechanisms.

146

Simpson, J., and W. L. Woodley, 1975

"Florida Area Cumulus Experiments 1970-1973 Rainfall Results"

Journal of Applied Meteorology, 14(5): 734-744.

ABSTRACT:

After four summer periods of randomized experimentation with dynamic cumulus seeding in a 1.3×10^4 km^2 target area in south Florida, 14 seed and 23 control cases are available, with increased documentation of radar measurement accuracy.

Seed-control rainfall comparisons are made for "floating" and total target for the 6 h period following the first seeding. On days screened as suitable for the experiments, natural rain volume varied by a factor of 62 for floating target and by a factor of 25 for total target. Area seed-control rainfall differences are not significant with six classical tests, nor is the difference between random and non-random controls.

Analysis of isolated experimental clouds obtained on days of mulitple cloud seeding produced significant findings. Results were stratified depending on whether the single clouds dissipated in the target area without merger or whether they merged with a neighbor. With the former stratification, the mean seeded rainfall exceeded the mean control rainfall by

a factor of 2, a result (one-tailed significance of 3%) that is consistent with earlier single cloud studies. No meangingful rainfall comparison was possible with the latter stratification because, on the average, the seeded clouds merged (and were dropped) 13 min earlier than the controls. This disparity inmean lifetimes before merger (two-tailed significance level of 0.5%) suggests that seeding is promoting merger in FACE as intended.

Several Bayesian approaches are used to estimate a probability distribution of a multiplicative seeding factor, based on gamma rainfall distribution, with the same shape parameter for seeded and control populations. The most general treatment assigns prior probabilities to three variables, the common shape parameters, the mean of the control distribution, and the multiplicative seeding factor. With existing data, 95% of the area under the marginal density of the seeding factor lies between about 0.7 and 1.7, with a mean just above and a mode just below 1.

After extensive search for physically meaningful covariates or predictors, radar echo motions in or near the target related to two distinct rainfall populations. Category 1 comprised those cases where echoes were "marching" across the area. Category 2 comprised those cases with growth and dissipation virtually without motion. Echo motion is shown to be a statistically significant covariate, accounting for 30% of the variation in the total rainfall. For the afternoon measurement period, the mean target rainfall in Category 2 cases exceeded that in Category 1 cases by a factor 2.5.

Separate seed-control comparisons in the two categories indicate that different effects of seeding might be sought in continued experimentation. Although the existing sample is small, there is evidence that in Category 1 (marching) the seeding effects is probably not multiplicative.

Attempts are in progress to estimate the number of further cases required to resolve a range of postulated seeding effects in this experimental context.

147

Simpson, J., J. C. Eden, and A. R. Olsen, 1975

"On the Design and Evaluation of Cumulus Modification Experiments"

Journal of Applied Meteorology, 14(5): 946-958.

ABSTRACT:

Combination of numerical simulation, many simultaneous measurements, and a large assortment of statistical tools, employed at all stages, have been found useful in design and evaluation of modification experiments on cumulus clouds. A randomized sample is essential, although non-random controls have supplemented it by providing necessary information on natural distributions.

Obstacles to definitive estimates of treatment effects are huge natural variability compounded by the expense and labor involved in obtaining an adequately large data sample. A 26 pair data set from a dynamic seeding experiment on isolated Florida cumuli is used here to illustrate both the

problems and the combined approach used to overcome them. In this data set, rain volumes from unmodified single cumuli varied by three orders of magnitude on days screened as suitable. The field phase of the experiment cost above, $250,000 requiring instrumented aircraft, calibrated radar, and several radiosondes daily.

Numerical simulation of seeded and unseeded cumulus towers defined the key screening variable "seedability", namely the predicted height difference between seeded and unseeded towers, so that only days on which the physical seeding hypothesis would be expected to work are selected for experimentation. On those days, randomization is between clouds selected by the experimenters as suitable.

Classical and Bayesian statistics are used together in the evaluation, with both univariate and multivariate analyses. Various well-known probability density distributions fitted the seeded and unseeded rainfalls. Among the best were gamma, log-normal, beta-K, and beta-P. Seed-control differences were examined with nonparametric and parametric tests (some of the latter after data transformation) and effects of random and systematic measurement errors were considered. In all tests, the seed-control rainfall difference was significant at better than 5%. A mulitplicative seeding factor of 2-3 was estimated in several ways (allowing for or getting around the bias problem with ratio estimators related to long-tailed distributions).

148

Simpson, J., W. L. Woodley, A. H. Miller, and G. F. Cotton, 1971

"Precipitation Results of Two Radomized Pyrotechnic Cumulus Seeding Experiments"

Journal of Applied Meteorology, 10(3): 526-544.

ABSTRACT:

A randomzied single-cloud, dynamic seeding experiment was conducted with airbone pyrothechnics in South Florida in 1968 with results extensively reported. In the first 40 min following seeding, large increases in rainfall (about 150 acre-ft or approximately 100% per seeded cloud) were obtained by analysis with a calibrated 10-cm radar, the accuracy of which had been tested by a raingage comparison. The statistical significance of the rainfall differences was, however, marginal, ranging from 5-20% with a series of two-tailed tests.

In the spring and early summer of 1970 an improved repeat of the experiment was conducted in two phases. Five instrumented aircraft participated in the first phase and only two in the second. Altogether 13 seeded clouds and 16 controls were obtained. All seeded clouds reached cumulonimbus stature as did 10 of the clouds. The average differences in vertical growth following seeding of seeded vs control clouds was 6200 ft, significant at the 1% level.

This paper is concerned primarily with the rainfall results of the 1970 experiment and the combined 1968 and 1970 experiments, together with the results of a detailed statistical investigation of their significance. The rainfall analyses are made with the University of Miami's calibrated 10-cm radar by the method developed and tested for the 1968 data. For the first 40 min following seeding the average seeded minus control rainfall difference is about 100 acre-ft while it is more than 250 acre-ft, or more than 100%, for the entire cloud lifetime. Significance is better than 5% for the whole cloud lifetime for the 1970 data alone and for the 1968 and 1970 data combined; it is better than 5% for the combined data for the first 40 min and better than 10% for the 1970 data alone. When the rainfall data are objectively stratified into fair and rainy days, the fair-day differences are of the order of 350-400 acre-ft and the rainy-day differences are negative. Intraday comparisons are also made, comparing seeded and control clouds on the same day. This analysis, if anything, increases seeded-control differences, which retain high significance. The main result of the statistical analysis is that for all 1968 and 1970 data combined, the positive seeding effect is not only significant but exceeds a factor of 3.

The shortcomings of the radar evaluations are discussed; it is shown that if they could be removed the rainfall conclusions would be strengthened.

149

Skaggs, R. H., 1967

"On the Association Between Tornadoes and 500-mb Indicators of Jet Streams"

Monthly Weather Review, 95(3): 107-110.

ABSTRACT:

Many studies of tornado-severe local storms outbreaks have called attention to the role of the jet stream. In fact, the jet has become an accepted part of a climatological model for tornado occurrrences in the central and southern Plains. This study undertakes to verify this acceptance by statistically testing the association between 500-mb. indications of the midlatitude and subtropical jet streams and tornado days in Kansas, Oklahoma, and Texas.

The results presented here indicate that indeed the two jet streams are associated wtih tornadoes. Further, the results are interpreted to show important spatial variations in the relative influence of the two jet streams.

150

Sly, W. K., 1966

"A Convective Index as an Indicator of Cumulonimbus Development"

Journal of Applied Meteorology, 5(6): 839-846.

ABSTRACT:

Empirical methods are used to determine a modification to Jefferson's index of instability which has a good correlation with the incidence and development of cumulonimbus clouds over Edmonton, Alberta. This results in a convective index combining a representative afternoon dew point, the maximum temperature for the day and the temperature at the 500-mb level at the time of maximum heating. A critical value for the incidence of cumulonimbus evolves. Field testing shows increased accuracy in cumulonimbus forecasting when a forecast index is used. The forecast index has been applied to other localities in western Canada and proved to be a useful tool in delineating areas of expected instability from the surface through Canada and proved to be a useful tool in delineating areas of expected instability from the surface through the 500-mb level.

151

Smith, E. J., 1970

"Effects of Cloud-Top Temperature on the Results of Cloud Seeding with Silver Iodide in Australia"

Journal of Applied Meteorology, 9(5): 800-804.

ABSTRACT:

Analysis of three cloud seeding experiments over areas of Australia suggests that results varied with cloud-top temperture, when cumulus and similar clouds had top temperatures ≤ -10C rainfall was increased by seeding, but when the cloud tops were warmer rainfall was decreased.

152

Smith, W., and R. J. Younkin, 1972

"An Operationally Useful Relationship Between the Polar Jet Stream and Heavy Precipitation"

Monthly Weather Review, 100(6): 434-440.

ABSTRACT:

The jet stream is recognized as an important atmospheric mechanism for vertical exchange processes. It follows that certain jet stream positions relative to moisture source regions bring about occurrences of extensive heavy rainfall. One type of such occurrence, mainly in the central United States, is identified with a "digging" polar jet stream. To better understand the meteorological relationships involved, we developed composite models from seven representative cases and studied one unusually heavy rainfall situation in more detail. For this type, there is a tendency for heavy rainfall to occur in an ellipsoidal pattern in advance of the polar jet stream.

153

Spieglar, D. B., and G. E. Fisher, 1971

"A Snowfall Prediction Method for the Atlantic Seaboard"

Monthly Weather Review, 99(4): 311-325.

ABSTRACT:

Melted precipitation and snowfall data from eight winters were used to develop a snow and melted precipitation predicted model associated with 850-mb cyclones along the Atlantic Seaboard. Results indicate that the major potential for heavy snow exists in a band extending from 75 to 225 mi to the left from 350 to about 1,000 mi ahead of the 850-mb cyclone in the 12-hr period beginning 6 hr after routine upper air observation time. Application of the prediction model of snow amounts to some storms from the 1968-1969 winter season indicate they provide valuable guidance to the forecaster during periods of East Coast storms.

154

Strommen, N. D., and J. R. Harman, 1978

"Seasonally Changing Patterns of Lake-Effect Snowfall in Western Lower Michigan"

Monthly Weather Review, 106(4): 503-509.

ABSTRACT:

A shift in the area of maximum lake-effect snowfall-toward Lake Michigan from an early season inland location between November and January and a return inland by March-over western lower Michigan was investigated for the period from November 1965 through March 1971. The seasonal pattern for all areas of western lower Michigan was similar, but the inland displacement of early- and late-season snowfall was nearly twice as great in the northwest section.

Lake-snow days were identified and daily maps analyzed to determine the axis of maximum snowfall; the displacement from the lakeshore was measured along three traverses, one each in southwest, west-central and northwest lower Michigan. Temperature differences between the lake water and air at the 850 mb level and geostrophic winds at the surface, 850, 700 and 500 mb levels were calculated over mid-Lake Michigan, and observed winds for Green Bay, Wisc., and Flint, Mich., were determined for each lake-snow day.

The degree of inland displacement of lake-effect snow was strongly related to wind speed at the surface and the 850 mb level. At a given wind speed, a greater lake surface - 850 mb temperature contrast was associated with snowfall nearer the lakeshore, and wind speed upstream at Green Bay was more closely correlated with lake-snow patterns than was the wind speed downstream at Flint.

155

Townsend, J. F., and R. J. Younkin, 1972

"An Objective Method of Forecasting Summertime Thunderstorms"

NOAA Technical Memorandum NWS ER-46, 9 p., available from NTIS, COM-72-10765.

CONCLUSIONS:

A thunderstorm forecast index, the MYI, has been introduced and related to the frequency of thunderstorms in the Washington metropolitan area. Forecast values of the MYI can be determined objectively. Tests on independent data show greater skill, as indicated by the threat score, obtained with forecast values of the MYI, than that obtained with either observed or forecast values of the lifted index and K-index. The MYI may be suitable for use at other locations, but tests should first be conducted to determine this. Although the emphasis in this paper has been to relate the MYI to the frequency of thunderstorms within an area, this same MYI can be related to the frequency of occurrence of thunderstorms at a point. Obviously, the point frequency would be less than the area frequency.

156

Ulanski, S. L., and M. Garstang, 1978a

"The Role of Surface Divergence and Vorticity in the Life Cycle of Convective Rainfall. Part I: Observation and Analysis"

Journal of Atmospheric Sciences, 35(6): 1047-1062.

ABSTRACT:

The role of the surface velocity fields in the formation, maintenance and decay of convective storms, is examined using approximately 90 days of measurements in a densely instrumented network (660 km^2) in south Florida. The results show statistically strong cause and effect relationships between surface convergence and onset of rain, storm intensity and duration. Short-term prediction of the onset of rain and the amount of rain produced proves possible.

The surface fields of divergence provide an estimate of storm mass and moisture transports. The size of the surface area of convergence, by governing the supply of moisture, plays a controlling role in storm intensity. Large storms are efficient (72%), in terms of moisture supplied to rain produced, compared to smaller storms (37%). Within the confines of the experiment network, weak storms are in near mass balance, while inflow greatly exceeds outflow in the intense storm. The near mass balance of the weak storm suggests cloud-to-subcloud layer interaction as a further control in storm intensity.

157

Ulanski, S. L., and M. Garstang, 1978b

"The Role of Surface Divergence and Vorticity in the Life Cycle of Convective Rainfall. Part II: Descriptive Model"

Journal of Atmospheric Sciences, 35(6): 1063-1069.

ABSTRACT:

Three stages, prerain, mature, and decay, in the life cycle of a convective storm are shown by compiling surface observations from 12 well-organized Florida summertime thunderstorms. In the mature stage, a distinction is made between stationary and moving storms. The prerain phase is characterized by cyclonic inflow, the mature phase shows cyclonic inflow and anticyclonic outflow simultaneously, while in the dissipating stage only anticyclonic outflow exists. Numerical values for the updraft and downdraft areas, upward flux of water vapor, maximum divergence and vorticity, and rainfall are presented. Moving storms last longer (by 25 min), transport roughly four times the moisture of a stationary storm and produce more rain over a larger area. These numbers provide valuable information not previously available for the surface layers of the convective storm environments.

158

Vardiman, L., and J. A., Moore, 1978

"Generalized Criteria for Seeding Winter Orographic Clouds"

Journal of Applied Meteorology, 17(12): 1769-1777.

ABSTRACT:

An a posteriroi analysis was conducted utilizing precipitation, rawinsonde and seeding generator data from seven randomized winter cloud-seeding research projects conducted in orographic settings in the Rocky Mountain West and on the Pacific Coast of the United States. Variables were developed and investigated to establish generalized seedability criteria that are applicable to a variety of meteorological and topographic conditions. The variables were divided into four general categories: time available, water available, nuclei available and mixing available. This approach established stratifications under which positive (increases) or negative (decreases) seeding effects occurred. The study showed that positive seeding effects occurred at the crest under stable or unstable conditions when a "crest" trajectory was present, moderate-to-high cloud moisture was present and the cloud-top temperature was between -10 and -30°C. Decreases occurred at the crest for unstable clouds with a "blow-over" trajectory, with low cloud moisture and cloud-top temperature colder than -30°C. The precipitation for upwind and downwind regions of a barrier was also increased or decreased depending on stability, trajectory, cloud moisture and cloud-top temperature. Other stratification are discussed in the paper.

159

Wallace, J. M., 1975

"Diurnal Variations in Precipitation and Thunderstorm Frequency over the Conterminous United States"

Monthly Weather Review, 103(5): 406-419.

ABSTRACT:

Hourly data on the frequencies of all types of precipitation events, heavy precipitation events, trace precipitation events, and thunderstorms for more than 100 stations in the United States were processed to generate statistics on the amplitude and phase of the diurnal and semidiurnal cycles at each station. Results are displayed on seasonal maps in a vectorial format that emphasizes the large scale geographical consistency of the diurnal variations.

During summer each of the four parameters listed above displays geographical pattern of diurnal variations. Thunderstorm frequency tends to be the most strongly modulated by the diurnal cycle; trace precipittion the least strongly modulated. Over the central United States the maximum frequency of severe convective storms occurs during the early evening; thunderstorms exhibit their maximum frequency around midnight, while most precipitation falls later in the night. These amplitude and phase differences offer some insight into the relative importance of thermodynamical and dynamical processes in controlling the frequency and intensity of convective activity.

During winter heavy precipitation and thunderstorms are biased toward nighttime over much of the Midwest and Atlantic seaboard. Trace precipitation exhibit a small but geographically consistent diurnal oscillation with a peak near or slightly after sunrise. It is suggested that this morning peak is associated with precipitation from low stratus decks.

The semidiurnal cycle is generally smaller than the diurnal. Effects of the S_2 pressure wave area clearly evident over much of the tropics, but over middle latitudes they are often obscured by regional and local influences.

160

Warner, A. J., 1957

"Mean Temperature from 1000 mb to 500 mb as a Predictor of Precipitation Type"

Scientific Report No. 2, Department of Meteorology, Massachusetts Institute of Technology, AFCRC-TN-57-288, 19 p., available from NTIS, AD-117 176.

ABSTRACT:

The frequency of occurrence of frozen precipitation forms relative to the frequency of occurrence of non-frozen forms is determined as a function of geographical location and of the mean temperature (or thickness) of the layer

from 1000 mb to 500 mb. The results are derived from the data for a large number of stations in the United States during two winter seasons. A map of the thickness values for equal probability of occurrence of frozen and non-frozen forms illustrates the effects of altitude and continentality.

It is found that the form of the precipitation can be specified with a confidence of 75% or more when the thickness value at a station is 100 feet or more from its "equal probability" value. Some refinements of the technqiue are discussed.

161

Wasserman, S. E., and H. Rosenblum, 1972

"Use of Primitive-Equation Model Output to Forecast Winter Precipitation in the Northeast Coastal Sections of the United States"

Journal of Applied Meteorology, 11(1): 16-22.

ABSTRACT:

The National Meteorological Center's operational primitive-equation multilayer model predictions of relative humidity and vertical velocity are found to be well correlated with relative frequency of observed precipitation in the northeast coastal section of the United States. A technique is presented for using these primitive-equation model predictions to objectively determine the probability of precipitation in each of three consecutive 12-hr periods, the first period starting 12 hr after initial data time.

162

Whitehead, D. R., 1971

"A Comparison of Objective Convective Activity Indices"

OURI-1828-71-1, Univ. of Oklahoma Research Institute, Atmospheric Research Laboratory, Norman, 66 p., available from NTIS, COM-72-10285.

ABSTRACT:

Three objective indices of convective activity are compared in an application to two case studies. The three indices are: the United States Air Force Global Weather Central SWEAT Index, the Lifted Index, and a quantity representing the vertical transport of moisture from the planetary boundary layer (qw). A variational analysis technqiue is applied to standard rawinsonde wind data to botain boundary layer grid fields of kinematic parameters while a simple objective analysis is applied to obtain boundary layer grid fields for thermodynamic air properties. In this study, the boundary layer is represented by four levels from the surface to 3000 feet above terrain elevation in 1000-foot increments. It is shown that there are

only minor differences in the areal resolution of potential thunderstorm threat areas depicted by the SWEAT Index and the Lifted Index. On the other hand, the vertical moisture transport parameter showed little or no areal correlation to either the Lifted Index patterns or the SWEAT Index patterns. This study suggests possible improvement of severe weather analyses and forecasts by simultaneously considering the vertical moisture transport parameter with the SWEAT Index. Also, the timeliness and the ease with which the SWEAT is computed makes it preferable to the Lifted Index as a severe storms indicator. The last part of this study examines the parameters involved in computing the SWEAT Index and established their relative importance.

163

Whitehead, V. S., 1968

"Determination of Rainfall Potential From Synoptic Scale Patterns"

Part I. of Development of Short Range Forecasting Techniques, Department of Meteorology, Univ. of Oklahoma, Norman, pp. 1-19, available from NTIS, PB-179 722.

ABSTRACT:

An effort to develop objective upper air short range (less than 18 hours) forecast techniques for precipitation, which can be quickly and eaily applied by local station forecasters, is described. Multidimensional diagrams that permit the determination of probability of precipitation as a function of the values of some upper air parameters have been constructed. Of the parameters tested those that appear to be the most reliable predictors are: mean relative humidty (surface to 500 mb), magnitude of wind shear (surface to 700 mb), 500 mb wind speed and direction, and 500 mb relative vorticity.

164

Whiting, R. M., 1957

"The Surface Chart as a Synoptic Aid to Tornado Forecasting"

Bulletin of the American Meteorological Society, 38(6): 353-356.

ABSTRACT:

An attempt is made to relate the occurrence and the location of Tornado activity to areas of intense surface warm advection as indicated by the isobars and isotherms on the sea level chart. The degree of cross-isotherm flow is classified by the packing of the thermal field and the temperatures in it along with the strength and direction of flow as indicated by the isobars to determine short range forecasting patterns. The method presented is limited in that it is not applicable to all tornado situations and is offered as a supplementary technique which could serve to raise the confidence level of short range tornado forecasts based on upper air patterns.

165

Whiting, R. M., and R. E. Bailey, 1957

"Some Meteorological Relationships in the Prediction of Tornadoes"

Monthly Weather Review, 85(5): 141-150.

ABSTRACT:

Synoptic surface and upper air features are analyzed in relation to tornado occurrences. The findings are incorporated into a forecasting system by means of which a preliminary alert forecast of tornado areas can be issued in the early morning hours for the period 1100-2300 CST. Basically, the forecast is derived through the prognostic locations of favorable surface parameters relative to the cold axis at 200 mb. In a test of the system on independent data, most of the multiple outbreaks of tornadoes are correctly predicted.

166

Whitney, L. F., Jr., 1977

"Relationship of the Subtropical Jet Stream to Severe Local Storms"

Monthly Weather Review, 105(4): 398-412.

ABSTRACT:

A series of five case histories illustrates the apparent effect of the subtropical jet stream on severe local storms. In these cases, the polar and subtropical jet streams are in a diffluent configuration to the east of an advancing trough. Severe storms, particularly tornadoes, are shown to occur betwen the jet streams and ahead of the surface front. The central observation is that the growth of vigorous squall lines and severe weather are sharply inhibited at and to the south of the subtropical jet. Thunderstorms do occur south of the subtropical jet but rarely produce severe weather in this synoptic configuration.

Speculations are presented which suggest how the subtropical jet might influence divergence, stability and even surface heating to contribute to an environment favorable for severe storms to the north but unfavorable to the south of the jet axis.

167

Williams, R. J. , 1976

"Surface Parameters Associated with Tornadoes"

Monthly Weather Review, 104(5): 540-545.

ABSTRACT:

Surface parameters at the location of over 5000 tornadoes from January 1968 through 15 June 1974 were computed objectively at the National Severe Storms Forecast Center. This set of conditions 0-3 h prior to tornado occurrence provides a large sample and was used to determine a variety of tornado related averages. The mean conditions associated with tornadoes include: temperature 74°F, dew point 62°F, sea level pressure 1007 mb, and wind 175°, at 7 kt. Significant seasonal and geographical variations from these averages were noted and illustrated.

168

Wills, T. G., 1969

"Characteristics of the Tornado Environment as Deduced from Proximity Soundings"

Atmospheric Science Paper No. 140, Colorado State Univ., Fort Collins, 55 p., available from the issuing agency or the Illinois State Water Survey Library.

ABSTRACT:

An observational study of 700 tornado proximity soundings is presented. Soundings were chosen that were within two hours and 100 miles from well-documented tornadoes. Data was obtained during the period of 1956-1966 and covers all areas of the U.S. east of the Rocky Mountains. Tropical storm-spawned tornado soundings are also included. Soundings were sorted by geographical region, time, and position relative to the tornado location.

A summary of the characteristics of the proximity soundings is described with regard to the tornado's environmental horizontal wind fields, vertical wind shear, and cumulus potential buoyancy. The magnitude of the lower tropospheric (below 500 mb) vertical wind shear was found to be very large—averaging 44 knots. The horizontal wind field deomonstrate a variable shear across the tornado and an apparent "blocking" of the mean wind field at upper levels created by large cumulonimbus clouds penetrating through the vertically shearing environment. When the lapse-rate and surface convergence dictate that cumulonimbus convection is likely, then the most crucial parameter for tornado occurrence is the vertical wind shear in the lower half of the troposphere.

A "tornado-likelihood" index is developed utilizing the three parameters of cumulus potential buoyancy, low-level convergence, and lower tropospheric vertical wind shear. When tested in comparison with non-tornadic days, this index appears to be a good predictor.

169

Wilson, G. S., and J. R. Scoggins, 1975

"Changes in the Structure of the Atmosphere in Areas of Convective Storms as Revealed in the Ave II Experiment"

Preprints, 9th Conference Severe Local Storms, Norman, Amer. Meteor., Soc., Boston, 143-150.

CONCLUSIONS:

This study has demonstrated the magnitude and importance of changes in meteorological parameters associated with convection over time periods as short as 3 h. Large changes in these parameters over periods less than 12 h appear to result from subsynoptic-scale systems moving through the large-scale flow pattern. As the systems move, changes in moisture and temperature over a period of 3 h are sufficient to increase the probability of convection from 10 to 80 percent or more in a given area. The results is important in the formation of convection, vertical motion is of equal importance. The probability of convection is maximized when the TTI is betwen 40 and 50 and vertical motion is positive.

170

Winston, J. S., ed., 1956

"Forecasting Tornadoes and Severe Thunderstorms"

Forecasting Guide No. 1, Severe Local Storm Forecasting Center, U.S. Department of Commerce, Weather Bureau, Washington, D.C., 34 p., available from the issuing agency or the Illinois State Water Survey Library.

INTRODUCTION:

This guide is concerned with the problem of short-range predictions (usually 12 hours or less) of the occurrence of tornadoes and severe thunderstorms over the United States. These constitute what have become known as severe local storm forecasts. Severe thunderstorm forecasts are issued by the Weather Bureau when thunderstorms are expected to result in one or more of the following:

1. Surface gusts of 75 mph (65 knots) or more,

2. Sustained surface winds of 50 mph (44 knots) or more,

3. Hail having a diameter of 3/4 inch or larger,

4. Severe or extreme turbulence.

A tornado forecast implies that the area alerted will also have severe thunderstorms. The treatment in this guide excludes tornadoes and thunderstorms associated with hurricanes, and phenomena such as waterspouts and dust devils.

The size of the severe local storms forecast area is dependent upon the type of weather expected and the season. Areas in which severe thunderstorms are predicted are usually somewhat larger than tornado forecast areas. It has been observed that an area of some 20,000 square miles will usually encompass

the severe thunderstorms or tornadoes occurring during a 6-hour period in later winter, spring, and early summer when family-type tornado outbreaks are most frequent. In other seasons (i.e., late summer, early fall) the areas are usually somewhat smaller since tornado occurrence are more isolated in these seasons.

Present severe local storms forecasts are aimed at predicting the areas which are expected to contain the maximum amount of svere weather. Various data restrictions along with the limitations in our current knowledge of the cause of severe local storms, preclude the prediction of a unique area. Thus, each forecast area is surrounded by an area having an expected lower probability of occurrence of severe local storms with the probability decreasing with distance from the predicted area. The same is also true with regard to the valid time of the forecast. It is stressed that present severe local storms forecasts are for areas and no attempt is currently made to predict the time and site of occurrence of any individual severe local storm.

With perhaps a few exceptions, it is generally believed at this time that the difference between severe thunderstorms with tornadoes and those without associated tornadoes is largely a matter of degree. One of the forecasting problems is to evaluate subjectively the various considerations to determine the expected intensity of thunderstorm activity. Thus it is impossible to describe the tornado forecasting method separately from the severe thunderstorm forcasting method without considerable repetition. For simplicity, then, this guide has been prepared in two sections. The first and more comprehensive section deals with tornado forecasting, but naturally includes most general aspects of severe thunderstorm forecasting. The second section treats the specific problems of hail size, turbulence, and surface gusts associated with severe thunderstorms.

171

Wurtele, Z. S., 1971

"Analysis of the Israeli Cloud Seeding Experiment by means of Concomitant Meteorological Variables"

Journal of Applied Meteorology, 10(6): 1185-1192.

ABSTRACT:

This paper summarizes results of a statistical analysis of the Israeli cloud-seeding experiment (1961-67) based upon precipitation data for the period of the experiment and upon 30 concomitant meteorological variables, both surface and upper air. The experiment had a crossover design in which days are allocated at random to seeding in one of two (North or Center) targets, separated by a Buffer region. Two statistical tests are used, one based upon normal theory and the other a Wilcoxon two-sample (nonparametric) test. On the basis of these tests it is reasonable to accept the hypothesis that cloud seeding affected precipitation; results are significant for two-sided tests at the 2.5% level in the case of the normal test and at the

10% level in the case of the Wilcoxon test. However, when these same test procedures were applied to the Buffer region instead of the Center target, even more significant results were obtained. Analysis of plume directions at the times of seeding to not indicate that this contamination was due to physical transport of seeding material. This result with regard to the Buffer strongly suggests the possibility of contamination of one target by seeding of the other. The meteorological assumptions underlying a crossover experiment are that contamination effects ae negligible in comparison to the effects of seeding in the target area. When such assumptions are not valid, interpretation of the results of a crossover experiment may be grossly misleading; in fact, they may be in the wrong direction.

One the assumption that this is not the case for the Israeli experiment, i.e., that crossover effects are negligible, an attempt is made to determine the differential effects of seeding under different meteorological conditions. It is estimated that in an operational year there would be about 35 days of actual seeding with increases of 1.9 mm day^{-1} in the North and 2.2 mm in the Center. No evidence of large negative effects in target areas was found, but in about 10-20% of the days there may have been moderate or slight negative effects. Meteorological conditions on such days are associated with warm surface air moving from the south. Positive effects are associated with meteorological conditions that are conducive to greater than average rainfall. Tables with details about partitionings of the data by means of meteorological variables are provided.

172

Younkin, R. J., J. A. La Rue, and F. Sanders, 1965

"The Objective Prediction of Clouds and Precipitation Using Vertically Integrated Moisture and Adiabatic Vertical Motions"

Journal of Applied Meteorology, 4(1): 3-17.

ABSTRACT:

This article describes and illustrates an objective technique of forecasting clouds, precipitation and precipitation amounts. The sytem is tailored to fit the specific operation of the National Meteorological Center in the use of data routinely available. It attempts to eliminate or to alleviate a number of difficulties which have plagued other objective techniques.

The method follows rather closely the earlier work of Frederick Sanders, but departs importantly in the method of obtaining vertical motion and in the form and manipulation of the moisture parameter. The vertical motion is computed from objective 1000-mb and 500-mb prognoses through an adiabatic approach. Saturation thickness is used as the moisture parameter in a manner which eliminates the need for reference to specific and relative humidities.

Two forecasts are illustrated in detail. The first example employs a form which obtains directly a vertical motion, field, while the second by-passes this step.

173

Zak, J. A., 1977

"Forecasting Thunderstorms over a 2- to 5-h Period by Statistical Methods"

NASA Contract Report 2934, Department of Meteorology, Texas A and M Univ., College Station, 112 p., available from NTIS, AD-A050 005.

ABSTRACT:

Classical statistical techniques, such as multiple regression with variable selection and principal component analysis, were employed to define combinations of parameters from meteorological observations which optimally discriminate between the occurrence and nonoccurrence of thunderstorms. Routine observations of weather elements at five levels in the troposphere during two spring and summer seasons were analyzed objectively onto a 65-km grid which spanned much of the central United States. A thunderstorm occurrence was defined from manually digitized radar (MDR) observations with an MDR code of four or greater as the basis. The binary variable one or zero for occurrence or nonoccurrence, respectively, was the predictand. Parameters which are measures of atmospheric moisture content, stability, and trigger mechanisms were calculated from gridded fields of surface and upper-air observed elements fo different times each morning. These parameters were candidate predictors in the variable-selection procedures. Data from all grid points and for each day were pooled in order to provide an adequate sample of thunderstorm observations.

Errors which result from usual assumptions in a regression model were quantitatively analyzed. Multicollinearity was severe but minimized through stepwise and maximum R^2 variable selection techniques. Specification and heteroskedasticity errors which result from the binary nature of the dependent variable were present but did not invalidate the overall results.

The first four variables selected in every case were surface mixing ratio, occurrence of precipitation during the morning, moisture convergence, and a stability measure. These four variables include the synoptic-scale conditions commonly recognized as prerequisites for thunderstorms. The trigger mechanism was most difficult to specify from the data, followed by stability, and then moisture. Additional parameters (up to 17) continued to reduce the total, unexplained variance of thunderstorm occurrence. Time changes in surface parameters were not selected as leading predictors. Upper-air observations added an important ingredient, the stability, which, apparently, could not be inferred adequately from surface measurements alone.

Data were grouped by surface wind component, random sampling, and for a spring and summer month. About one-third of the data was saved for a test of results. Thunderstorms were more predictable between 2000 and 2300 GMT when surface winds had a northerly component at 1800 GMT. Random sampling was a way of reducing the influence of the many observations of no thunderstorms which result from the low climatological frequency of occurrence. Predictors in April reflected the importance of kinematics, while those in July were associated with thermodynamic variables as would be expected from synoptic-scale data.

Finally, regression statistics with the predictand being occurrence of thunderstorm at 2000 to 2300 GMT did not show important differences when upper-air parameters were calculated from observations at 1200, 1500, or 1800 GMT. However, these data were available only on one day, 24 April 1975.

The results from this study are comparable with other objective forecasts and with those produced by weather station forecasters although direct comparisons are difficult to make. This technique can be applied rapidly and effectively in an operational environment at locations within the developmental area. If offers all the advantages of an objective forecast and contains no disadvantages from being tied to specific forecast models.

174

Zawadzki, I. I., and C. U. Ro, 1978

"Correlations between Maximum Rate of Precipitation and Mesoscale Parameters"

Journal of Applied Meteorology, 17(9): 1327-1334.

ABSTRACT:

Daily 5, 10 and 30 min maxima of precipitation rate determined from a raingage network and radar were correlated with parcel convective energies, upper air humidity, height of parcel convection and maxima of surface conditions. After a slection of 54 well-documented cases the correlation coefficient between the maximum of rain rate over 5 min and the maximum convective energy was p = 0.79 for all cases and p = 0.89 for 15 air mass cases. Introducing the upper air humidity further improves the correlations.

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161 Wasserman and Rosenblum (1972)

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