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STUDIES IN OBJECTIVE FORECASTING OF MESOSCALE WEATHER USING AN INTERACTIVE COMPUTER SYSTEM

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20. ABSTRACT *(Continue on reverse side if necessary and identify by block number)*

Work under this contract involving weather inference from GOES data and weather prediction is summarized. The research involved extrapolation and advection of meteorological events, a statistical study relating GOES data to surface thunderstorm observations, and investigating satellite indicators of short-term changes in surface visibility.

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1. INTRODUCTION

The purpose of this final report for work completed under support provided by Air Force Contract, "Studies in objective forecasting of mesoscale weather" (F19628-78-C-013), is to state objectives and to summarize results and conclusions. A basic objective of the research was to develop and test some methods for short range objective terminal weather forecasting through use of meteorological satellite data by itself and in combination with other routinely available data. The research entailed the application of McIDAS (man computer interactive data access systems) to process the satellite and conventional meteorological information for analysis and forecast experiments. Software was developed for mesoscale analysis and prediction primarily for local operational needs and several studies were completed. Most results from these studies have been reported previously in the annual scientific reports. These results along with other pilot studies and software development will be summarized in this final report.

The development of capabilities to merge conventional data with satellite information of high temporal and spatial resolution in order to isolate the movement of mesoscale features is a difficult task. One primary thrust was the development of methods for short range prediction of mesoscale features observed in GOES imagery and through synoptic analyses. The geosynchronous satellite data provides the high temporal resolution and accurate location of mesoscale meteorological phenomena; however, limited information is available on vertical structure and precisely what type of weather occurs with the systems viewed from space. Another primary thrust of this research was to test whether or not terminal weather conditions in terms of visibility, ceiling and severity of weather phenomena could be inferred from the geosynchronous satellite information alone. By and large the results of such tests were disappointing. To some extent, the problem of inferring terminal weather conditions from space is equivalent to the problem of determining the cloud tops and inflight conditions from surface observations. The satellite fields of information only explicitly provide information on the distribution of the characteristics such as height, type and evolution of the upper surface of clouds. No unique relationship exists between these characteristics and the actual weather occurring in terms of cloud bases, surface visibilities, slant visibilities, intensity of precipitation and/or other weather phenomena. For the most accurate specification of weather occurring in short range prediction, systems need to assimilate all types of satellite and conventional information available. The satellite information provides accurate specification of the position and movement of the phenomena while surface observations and radar provide a more accurate specification of the associated weather conditions, radar being particularly important for determining intensity and areal coverage of precipitation. The research conducted under the Air Force support, however, did not in general address the optimum system since we were charged with determining the accuracy of specifying weather conditions from satellite information alone. Thus, while the results seem somewhat disappointing, they do not establish the full potential of a system which includes both satellite and conventional information for mesoscale prediction.

2. EXTRAPOLATION OF MESOSCALE METEOROLOGICAL EVENTS

In an effort to develop methods for short-term prediction of mesoscale phenomena, procedures for the delineation and extrapolation of features qualitatively defined in GOES imagery were established.[1] Initially, a rectangle was prescribed to encompass the feature of interest along with the computation of a brightness-weighted centroid for successive images. Polynomials were then fit to the successive central positions and used for prediction of the feature position through temporal extrapolation. In later tests, the rectangle was changed to an ellipse whose location, size and orientation were adjusted by the operator.

Two types of polynomials were tested for extrapolation: the one based on a Taylor series expansion which fit the data exactly and the other based on a least squares fit that minimized the RMS differences between the curve and the data values.

Over a three month period, the extrapolation predictions were made for 493 selected cases of thunderstorms observed within real-time infrared images. Cases were classified by convection type, method of computation, magnitude of prediction errors and the number of hours forecast. Results of these experiments summarized in Table I indicate that extrapolation based on first-order polynomials generally produced the best results. Further, the consistency of moderate threat scores indicate utility in this approach.

In addition to mesoscale features found solely in satellite imagery, extrapolation was also applied to fronts, squall lines, etc., where a single line defined the position of the entity. For each time period in this method, the operator constructs a line describing the position of the feature through use of least squares polynomials which serve to smooth the line. The trends

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[1]Wash, C. H., T. M. Whittaker and D. R. Johnson, 1979: Initial Studies in Objective Forecasting of Mesoscale Weather Using an Interactive Computer System. Scientific Report No. 1, AFGL, Hanscom Air Force Base, MA, 2-7.

of the polynomial coefficients were then used to predict polynomials at future times that specified positions of the feature.

TABLE I

Error statistics for extrapolation of thunderstorms observed in IR imagery. (LS = least squares, TS = Taylor series)

ORDER	PREDICTION METHOD	DISTANCE ERROR	THREAT	BIAS	POST AGREEMENT
1	LS	56.6	.449	1.459	.675
1	TS	60.0	.439	1.321	.653
2	LS	136.6	.270	1.391	.463
2	TS	217.8	.209	1.522	.364

Experiments uncovered difficulties in defining and representing a unique pattern with a polynomial. The choice of axis orientation relative to the display screen led to problems with doubly-defined points along a particular latitudinal or longitudinal axis which could not easily be solved.

3. ADVECTION TECHNIQUES

In research on advective methods for short-range prediction, the use of a characteristic steering current to forecast the movement of surface features in mean sea level pressure analyses was examined. A steering current based on a vertically integrated density weighted wind was computed. The early portion of the work[2] concentrated on determining statistically the best layer of the

[2] Ibid

atmosphere for specifying the wind for the steering current. Experiments indicated that the mean wind within the 850 to 200mb layer generally produced the best steering current to predict the motion of surface features.[3]

Two different methods were tested for actual forecasts: the first used an advection equation and the second a trajectory-like approach. In both cases, stepping through time is required; however, due to numerical difficulties in the advection equation method, very frequent time increments were required (1-5 min). The trajectory method used 30 min increments. In addition, the trajectory method lends itself very well to single-point forecasting.

Initial work concentrated on prediction of the surface temperature advection, a field closely linked with the position of surface fronts. The prediction results for a three hour period yielded threat scores in the range of 0.5 to 0.8. In addition, the test showed that forecasts of the movement of the central axis (closely aligned with cold fronts) were reliably accurate to 6 hours.[4]

Later experiments used 3-hour radiosonde data available from the April, 1979 SESAME set to predict the lifted stability index. This index, based on parcel theory, is an empirical measure of the convective stability. In the computation, a parcel representing boundary layer thermal and moisture

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[3]Wash, C. H., R. O'Keefe, T. M. Whittaker, D. A. Edman and D. R. Johnson, 1980: Studies in Objective Forecasting of Mesoscale Weather Using an Interactive Computer System. Scientific Report No. 2, AFGL, Hanscom Air Force Base, MA, 26-39.

[4]Wash, C. H., and T. M. Whittaker, 1980: Subsynoptic Analysis and Forecasting with an Interactive Computer System. Bull. Am. Meteor. Soc., 61, 1584-1591.

conditions is lifted dry adiabatically to saturation and then moist adiabatically to 500mb. At this level, its temperature is compared with the environmental temperature. If the parcel is warmer (negative index), the parcel is buoyant and will continue to rise.

In our experiments, the surface equivalent potential temperature was advected, while the 500mb temperature field was assumed invariant. Table II summarizes the advective prediction results obtained over the Oklahoma area on the 10th of April. These results indicate a skill level commensurate with our previous work. In an operational diagnostic application, the ability to use the hourly observed surface values and 500mb temperature data to estimate the current lifted index may be of value in severe weather forecasting.

TABLE II

Threat score and post agreement statistics for lifted index prediction based on advection of surface θ_e

	3 - Hour		6 - Hour	
Verifying Time	Threat	Post Agreement	Threat	Post Agreement
10/15Z	0.67	0.76		
10/18Z	0.83	0.86	0.56	0.74
10/21Z	0.67	0.67	0.60	0.66
11/00Z	0.77	0.83	0.64	0.64

4. REGRESSION

To assess the relative skill level of extrapolation and advection predictive procedures, a simplified single-station regression forecast scheme was developed. Forecasts of visibility, wind speed, cloud amounts, temperature and dew point were accomplished using the preceeding six hours of observational data. Curves fit to the data provided the basis for temporal predictions, which were tested over several consecutive days and different regions of the country. In nearly all cases, the results displayed little skill over persistence, thus indicating that the data from surrounding observation points which implicitly include information on advection of fields is necessary for success in prediction of mesoscale fields.

5. MDR DATA BASE

In teleprinter messages, hourly radar observations in the form of azimuth and range of points define broad areas of precipitation. In recent years, the NWS has also added a form of "manually" digitized radar data to define precipitation intensities in roughly 50km square grid boxes surrounding each radar site.[5] Efforts were initiated to test the use of these data for the advection of prediction regions using the McIDAS system; however, the MDR data were not fully installed until the end of the contract. The machine instructions to decode, store, and retrieve these data were, however, among those programs delivered to AFGL at the close of the contract.

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[5]National Weather Service, 1978: Radar Code Users Guide. Silver Spring, MD, 1-16.

6. STATISTICAL STUDY OF THE RELATION OF GOES DIGITAL DATA TO SURFACE OBSERVATIONS OF THUNDERSTORMS

One initial goal of this research included the objective determination of both thunderstorm presence and severity from satellite-derived statistics.[6] Co-located surface hourly data and satellite data were obtained using a data acquisition procedure set up on McIDAS. Thirty-four hours of data were gathered in the spring and early summer of 1980, comprising 5570 station reports of which nearly 3% had thunderstorms.

Discriminant analysis routines performed on the data yielded eight statistically significant discriminant models. These models emphasized the importance of temporal and multi-spectral predictors in the thunderstorm specification. Actual accuracy ranged from 0.73 to 0.81.

7. SATELLITE INDICATORS OF SHORT-TERM CHANGES IN SURFACE VISIBILITY

An analysis of four synoptic situations during 1980 was undertaken in order to ascertain what selected GOES imagery parameters are suitable to indicating short-term changes in snowfall intensity and visibility in regions of continuous precipitation associated with extratropical cyclones.[7] A total of 210 arrays were used.

Five numerical parameters were then estimated from each array of digital IR brightness. These included the deviation of station brightness from

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[6]Wash, C. H., R. O'Keefe, T. M. Whittaker, D. A. Edman and D. R. Johnson, 1980: Studies in Objective Forecasting of Mesoscale Weather Using an Interactive Computer System. Scientific Report No. 2, AFGL, Hanscom Air Force Base, MA, 3-24.

[7]Zapotocny, J. V., D. R. Johnson and T. M. Whittaker, 1981: The Development and Testing of Methods to Infer Midlatitude Precipitation Intensity from Geosynchronous Satellite Infrared Data. Scientific Report No. 3, AFGL, Hanscom Air Force Base, MA, 82 pp.

the array average, two five-point station centered Laplacians of the brightness field (one with a 16nm horizontal scale and the other with a 32nm scale), and two-nine point Laplacians.

Results based on the distributions of the means and frequencies for a five-point Laplacian showed that for the most skillful indicator of snowfall intensity positive determination of precipitation intensity at a given locale was possible only about 10 per cent of the time. The most skillful indicator of intensity changes for a nine-point Laplacian produced a correct inference nearly 30 per cent of the time.

8. SOFTWARE DELIVERED

Software developed for Space Science and Engineering Center's McIDAS system under this contract to produce the advective predictions and decode MDR data were delivered to AFGL for use on their McIDAS system. In order to provide the functional characteristics of the advective predictions and MDR decoding, it was necessary to upgrade the existing software on the AFGL system to include SSEC's grid data base capabilities. This resulted in modifications to several programs that were in use at AFGL in addition to installation of more than one hundred routines of new support software. (See list of programs and routines in Table III.) Modifications were made primarly to the programs which produce grids and those which display them. New user-level programs were provided to manage the uniform grid data base file, and to display these data on both the graphics and alphanumeric CRT's. Installation of grid management software was also necessitated by the fact that the advective prediction and MDR software made extensive use of these capabilities in the SSEC McIDAS. In addition, to support the MDR data collection, minor changes were in the form of new keyins to manage the ingest, storage and display of MDR data.

The grid data base management routines provide the means to create, display, save and restore grid point values. These data may be from any source, locally produced grid point interpolations, forecasts, MDR data fields, numerical model output and even cloud information. While these programs were designed to fit within a distributed processing environment, such as the case at SSEC, specific adaptations to the system at AFGL were made by Mr. T. M. Whittaker for the purpose of installing the new software. Support provided by AFGL staff allowed the conversion to proceed in a timely fashion.

9. CONTRIBUTING SCIENTISTS, PROGRAMMERS AND GRADUATE STUDENTS

Scientists: D. A. Edman
D. R. Johnson, Principal Investigator
C. H. Wash

Programmers: M. Barrett
H. Mead
T. Whittaker

Graduate Students: R. O'Keefe
J. Zapotocny

TABLE III

List of Programs and Routines Sent to AFGL

INTPO	NDRRMH	FILT
SNDANL	WDTRMH	PSTN
GETREC	PUTMDD	TYPE
SVCASX	VERPLT	GETMAN
PSLL	PRERAB	RAOBGT
LLPS	SETRAB	GRDUTL*
GRFIL	E4B	GRIDWK*
VDRUMR	R4B	LSTGRD*
VDRUMW	NCH	CONTUR*
RLOCPU	OM	SACNT1*
IDCPU	OPNBFI	CONPTR*
NAMCPU	SVCMDR	WISPLT*
RSQ	OUSECT	RBCONX*
RETEST	PCHAR	IASVCA*
RETSQ	PHDIPP	IARAOB*
RREADW	PREDSK	MDRINT
GRDDOC	SCH	RAOBPT*
GRDFLL	SPLICE	
GRDNAM	TPMES	
RGDIRL	TVDIN	
RGDIR	UREAD	
RGDIRT	WHERES	
WGDIR	WHOAMI	
WGDIRU	BLKA	
WGDIRT	CTIO	
GRDERR	DESFIL	
GRDERR	DEVCOD	
GRDZSQ	FILTYP	
GRDVAL	FINDFS	
RDCWD	GETFLS	
GENGRD	GETLIN	
GNRAOB	GETWRD	
WRGRID	ICEIL	
LFGRID	IFLOOR	
GNHRLY	INSECT	
LLGRID	KCHAR	
GRDGNP	MAKFIL	
GRADD	MATCHR	
RDGRID	MOVTAP	
GRDPDE	INCH	
SVCATF	OUCH	
GETMDD	MDRMSG	
TQMESS	PRED	
MOVE	PTRAJ	
NAMGET	VXY	

*These programs actually consist of more than one routine

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COST DATA AS OF 31 JULY 1981

	Actual		Cumulative Actual		Cumulative Planned	
	1 Mar.-31 July 81		Through 31 Jul. 1981		Through 31 Jul. 1981	
	Hours	Amount	Hours	Amount	Hours	Amount
I. SALARIES AND WAGES						
Principal Invest.	105	$ 3002	672	$16886	713	$16510
Project Assoc.	185	1689	1433	14247	1239	11616
Specialist (Prog.)	412	4631	2725	26607	1909	18333
Specialist (Met.)			1379	11712	919	7244
Secretary	110	734	963	5506	1149	5583
Research Ass't.	375	2790	2889	19240	3147	20937
Student Hourly	100	423	1015	3416	1580	5656
LTE			18	88	3	14
		13269		97702		85893
II. FRINGE BENEFITS						
Academic		1893		13793		10626
Classified		188		1521		1678
Research Ass't.		120		962		792
LTE				6		3
		2201		16282		13099
III. MATERIALS AND PUBLICATIONS				3684		3762
IV. COMPUTING UNIVAC McIDAS						
		509		18136		34052
V. TRAVEL		150		1157		4576
VI. TUITION REMISSION		905		905		
VII. UNIVERSITY OVERHEAD		6774		57050		53529
		$23808		$194916		$194916

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