Paper No. 9

NUMERICAL PREDICTION EXPERIMENTS SIMULATING THE IMPACT OF MESOSCALE SATELLITE DATA*

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ABSTRACT

Recent developments in mesometeorology are summarized to place this research in perspective. Recent advances in computer analysis and forecast system development that provide the basis for the simulation tests are discussed. The impact of NIMBUS-6 humidity data on analyses off the West Coast are shown and incorporation of geopotential gradient data is discussed. Experiments to demonstrate the feasibility of incorporating satellite-derived wind fields in mesoscale severe storm models are mentioned briefly.

INTRODUCTION

A revolution in mesometeorology is taking place because of recent advances in meteorological satellites, large and small computers, and data communication and display systems (Kreitzberg, 1976). The greatest impact has been made by the GOES visible and infrared image data because of the high resolution in both space and time, and because the data are available in real-time to many meteorologists. Forecast applications are numerous and considerable research is underway to extend the applicability of the data. For example, detailed precipitation rates and wind fields can be deduced by those with adequate image analysis systems.

The launch of TIROS-N marks the beginning of a new era in mesoscale meteorology because of the multitude of remote sounding data available from the TOVS system. At the same time, digitized weather radar data are becoming available with the installation of digital video integration processor (DVIP) equipment on National Weather Service network radars. The urgency of the need for such information on an operational basis is demonstrated by actions of the Federal Aviation Administration (FAA). DVIP data from several radars are displayed in color in real-time at Air Route Traffic Control Centers (ARTCC) and Enroute Flight Advisory Service (EFAS) locations. They will put 150 high resolution color radar displays into service at 20 ARTCC and 44 EFAS locations during the next 18 months to complement the laser facsimile GOES image data.

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The mesoscale data explosion from ground-based sensors is just beginning. The National Weather Service is moving rapidly toward automation of surface observations (Klein and Haggard, 1978) and experimental networks of sensors around airports are being developed by both National Weather Service and Air Weather Service. Networks of environmental data stations and automatic data acquisition systems are being installed by the power industry (Tennessee Valley Authority, for example) and the Forest Service. Digital weather stations are available to individuals for several hundred dollars. Computer dial-up systems can collect data from these digital networks and stations, and such data can be communicated on the State and National Data Circuits associated with AFOS.

The hardware required to manipulate the mesoscale data fields has been developed in NASA's AOIPS system, University of Wisconsin's McIDAS system, and the NESS VISSR Image Registration and Gridding System (VIRGS). The communication of ground-based point observations can be handled by AFOS and the digital radar and satellite data can be communicated by land lines or communication satellites (Bristor, 1978).

Numerical weather prediction research has moved toward higher resolution numerical models (Perkey, 1976; Kreitzberg, 1978; Anthes and Warner, 1978). It has been demonstrated that these models develop more detailed patterns during the forecast than exist at the initial time. Fig. 7, p. 359, in Chang and Kreitzberg (1977) shows the detail with which squall lines can be depicted. This forecast had been initialized using only the 1200 GMT rawinsonde data and a remarkably detailed and accurate squall line is shown from 7 h to 12 h into the forecast. The papers of Perkey and Chang demonstrate further that short-range forecasts of convective precipitation amounts are often very accurate, but they are also rather sensitive to the initial relative humidity fields.

It is clear that the limiting factor on reliable detailed short-range forecasts is the initial analysis. Equally clear is the fact that much more data are being collected than are being used in weather prediction. Currently, the weak link is the composite data analysis system that uses a dynamic prediction model to provide for four-dimensional data assimilation. A very large effort has gone into data assimilation research on the large scale for the Global Weather Experiment (FGGE Advisory Panel, 1978). None of this effort has been concerned with moisture analyses, including relative humidity and cloud water concentration. The mass and motion adjustment is known to have important differences on the scale of detailed prediction models compared with hemispheric and global models.

The goal of the NASA supported research by Drexel University's Atmospheric Sensing and Prediction Project is to expand the regional scale numerical prediction <u>model</u> towards a prediction <u>system</u> that includes the composite data analysis function. This has been a small effort over several years, having begun at MSFC in 1975 and transferred to GSFC in 1977.

The principal effort during this past year has been to upgrade the set of data processing, analysis, prediction, and diagnostic computer codes into a system of codes called Limited Area and Mesoscale Prediction System (LAMPS). This system includes a preprocessor and a library of data manipulation codes, together called FLOTRAN, which has been developed in collaboration with Daniel Anderson at the National Center for Atmospheric Research. FLOTRAN has the power and flexibility to take concise, simple code that is relatively easy to write correctly, document internally, and read, and then generate FORTRAN code from it that can be compiled by most computer systems. Therefore, it is relatively easy to change when doing complex research experiments and easy to maintain in spite of its size. It is portable to other computer systems. The dynamic prediction model is the heart of LAMPS but only comprises 15% of the code (5,000 out of 35,000 statements).

Model nesting experiments have been performed to demonstrate the sensitivity of forecasts to grid resolution and the use of forecasts on a larger grid to initialize forecasts on a smaller grid. Results reported in Kreitzberg and Chang (1978) demonstrate the need for moisture profiles over the Gulf of Mexico and document the ability of smaller grid models to generate narrower, more intense squall lines using the same data as lower resolution models. It is clear that more vertical resolution near the tropopause is necessary for 35-km horizontal resolution models to reach their full potential; otherwise, convective cloud tops are limited to the model tropopause instead of the real tropopause.

DATA IMPACT STUDIES

The urgent requirement for satellite humidity data over the offshore waters lead us to investigate the potential of the NIMBUS-6 sounder data off the U. S. West Coast on August 18, 1975. Our standard relative humidity analysis scheme uses the National Meteorological Center analysis as the first guess field. The rawinsonde data averaged over the model layer (1 km in this example) and centered at the model level (as shown in Fig. 1a) is then used to refine the analysis. Our analysis with the first guess and the rawinsonde data is given in Fig. 1b. Satellite soundings from NIMBUS-6 provided by the University of Wisconsin are located at points shown in Fig. 1c. The analysis from the first guess plus the satellite and rawinsonde data is shown in Fig. 1d.

Clearly, the density of satellite data, collected between 0800 GMT and 1000 GMT, is exactly what we need off the West Coast. The satellite analysis in Fig. 1d is drastically different from the rawinsonde analysis in Fig. 1b (which is the same over the ocean as the first guess because there are no rawinsonde data there). The satellite analysis is qualitatively reasonable in view of the visible and infrared image data in this storm.

The forecast with and without satellite data will be shown at the NASA Program Review. The cloud and precipitation forecasts will be greatly different, but the gross synoptic forecasts will not be too different after 24 h.

Much more remains to be done on this NIMBUS-6 case in terms of detailed validation of the humidity analyses compared with the cloud image data. Also important will be quantitative comparison of the forecasts with and without the satellite humidity data. The most significant results will be those comparing the two forecasts with the observed evolution of cloudiness as the storm develops and moves onshore, and those comparing the forecast with the observed precipitation along the coast.

The geopotential height gradients from NIMBUS-6 are used in the pressure field and wind analyses in LAMPS. The impact of these data on the analyses and the forecasts will be examined separately and then combined with the satellite humidity analyses. It is expected that some tests and tuning will be required to properly mix the satellite geopotential gradient and the first guess geopotential data. Problems may arise along the coast where observation types change.

The insertion of wind fields derived from GOES image data is the third problem. We will be inserting real data from the Neasho and Omaha tornado cases and the May 20, 1977, severe storm case (AVE-IV, AVSSE-II, SESAME '77 cases). To demonstrate feasibility and to demonstrate dynamic response as a function of grid resolution, perturbation scales, and amplitude, a series of experiments with idealized perturbations is being conducted.

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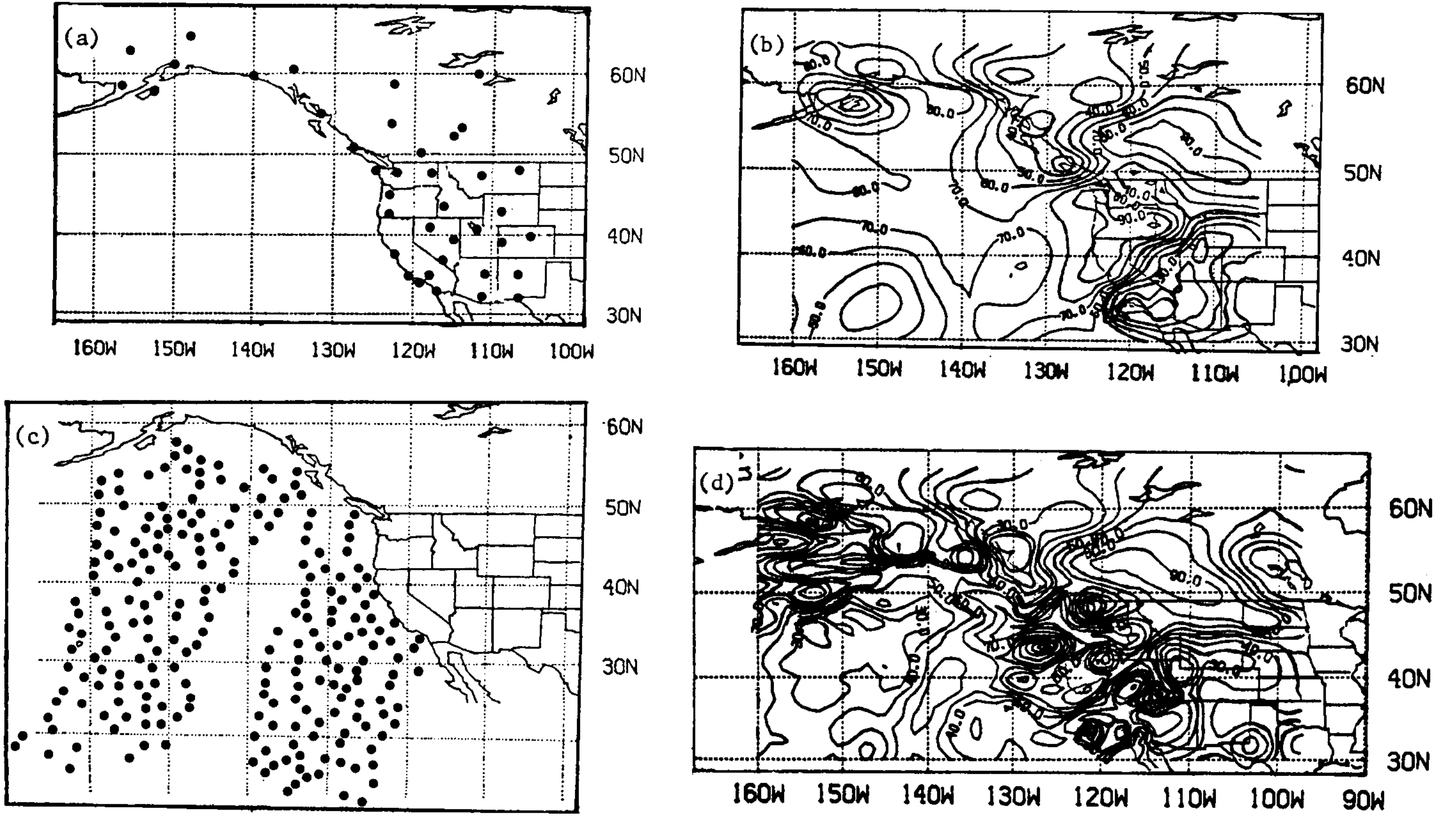

Fig. 1--Impact of relative humidity data on analyses: (a) rawinsonde data points; (b) analysis with first guess and rawinsonde data; (c) satellite data points; (d) analysis with all data.