- *Aerosol-heterogeneous chemistry*

Over the eastern and central U. S. sulfates are a major, if not dominant, aerosol particle species. Water content and optical characteristics of clouds are crucially dependent upon the NH_4^+/SO_4^{--} molar ratio. Cumulus clouds are major chemical reactors where SO_2 gas is transformed into sulfate aerosol. Anecdotal data have suggested that the sulfate is not completely neutralized; thus, field studies are necessary to evaluate the level of neutralization of the aerosol and the amount of sulfate production in nonprecipitating cumulus clouds. These processes must be further elucidated in support of the development and validation of a Regional Particulate Model that will be adapted from RADM.

3.10 Validation of mesoscale models

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Bill Kuo: Verification of mesoscale models

Tom Warner:	*Verification of cloud prediction from the PSU/NCAR mesoscale model*
Stan Benjamin:	*Results from MAPS/NGM verification comparisons and MAPS observation sensitivity tests to ACARS and profiler data*
Steve Koch:	*Systematic errors and mesoscale verification for a mesoscale model*
Andrew Staniforth:	*The COMPARE Project and the CME*

Bill Kuo opened the session by giving a review on the general methodologies used in the verification of mesoscale models. He then described the recent verification of an experimental mesoscale numerical weather prediction model during STORM-FEST, in which a 20-km version of the PSU/NCAR mesoscale model was used to provide experimental numerical guidance. His results showed that this model (which was not tuned prior to its use in support of STORM-FEST) gave a superior performance over the NMC Nested Grid Model (NGM). *This indicates that a mesoscale model which employs advanced physical parameterizations and more realistic topography has a strong potential to improve short-range local forecasting.* By verifying the model forecasts against the three-hour special rawinsondes and hourly profiler observations, Kuo was able to examine the model's systematic biases. He showed that the PSU/NCAR model has a wet bias in the humidity fields above 500 mb. By 36-h, the accumulated positive bias can be as high as 30%. He also noted that the model has a weaker diurnal variation in the surface-air temperature than that shown by the surface station observations. These results showed that *further improvement in model precipitation and planetary-boundary-layer parameterization is needed.*

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Tom Warner presented a study on the verification of cloud prediction from the PSU/NCAR mesoscale model, wherein model-predicted cloud cover (based on relative humidity and cloud water) were compared against the Air Force real-time Nephanalysis of cloud cover over 20 days. Predictions of the vertical distribution of clouds were found to contain significant biases. Although the total cloud-cover bias scores were reasonably good in general, the model has less skill for "scattered" and "broken" coverage, and higher skill for mostly clear or mostly cloudy conditions. *The use of model-predicted cloud water as a predictor of cloud fraction shows promise.*

Stan Benjamin discussed the results from verification comparisons between the MAPS (Mesoscale Atmospheric Prediction System) and NGM models, with emphasis on the impact of ACARS and profiler data on short-range forecasts. Based on verification against rawinsonde observations, he showed that MAPS 3-h and 6-h forecasts are superior to 12-h forecasts from NGM at most levels. This difference is most pronounced for wind forecasts near jet levels. Observational sensitivity tests presented also showed that ACARS-reported observations from commercial aircraft are the most important asynoptic observation for improving short-range forecasts over the United States at the current time. However, the observations from wind profilers also provide a smaller but consistent improvement to wind and height forecasts. Based on the statistical verification of a large number of cases against both point observations and grid data, Benjamin concluded that verification against point observations were less ambiguous because of independence from the objective analysis scheme used and less scale dependence. He emphasized that *the key element in verifying mesoscale forecasts is the availability of mesoscale observations.*

Steve Koch gave a presentation on systematic errors and mesoscale verification of the Mesoscale Atmospheric Simulation System (MASS). Although he conducted this assessment nearly a decade ago, it still serves as an exemplary approach to model validation, this being the first known attempt to systematically evaluate the ability of a modeling system to predict MCS activity without resorting to the usual case study "tuning" approach. Nearly 30 simulations were evaluated, first for their systematic errors at the synoptic scale, and then for their accuracy in "predicting" MCS likelihood in terms of convective predictor fields (the model at that time did not explicitly predict convective precipitation), verified against Manually Digitized Radar (MDR) data. Clearly, were one to perform a similar evaluation today, this method should be modernized to use digitized NEXRAD data and explicit model prediction of convective precipitation. Nonetheless, an important result of the model evaluation was that *systematic errors in predicted synoptic-scale fields adversely affected the model's ability to "predict" MCSs.* In particular, the evaluation revealed errors

in the model map transformation and boundary condition codes, inadequacies in the initialization of moisture over and near the Gulf of Mexico, and the need to include a convective parameterization scheme in the model to avoid systematic thickness errors. An interesting use of the temporal behavior in model forecast error statistics was shown to be uniquely capable of revealing certain systematic errors.

Andrew Staniforth described an international community effort in the verification of mesoscale models--the COMPARE (Comparison of Model Prediction and Research Experiments) Project under the auspices of the CAS/JSC Working Group on Numerical Experimentation. Recherche en Prevision Numerique of Environment Canada has taken the lead in this effort. The idea is to compare in a controlled way the results of many mesoscale models (and eventually mesoscale data assimilation systems) from both research and operational communities, on a representative testbed of cases selected primarily from Intensive Observation Periods of well-instrumented observational campaigns. Through model and data assimilation intercomparisons, they hope to improve communication among modelers, increase understanding of mesoscale phenomena and predictability, and improve the performance of various components of mesoscale models (particularly parameterizations) and mesoscale data assimilation systems, leading ultimately to improved models for both operational forecasting and research applications. The first case chosen for this project is the March 6-8, 1986 IOP of the Canadian/US CASP/GALE (Canadian Atlantic Storms Project/Genesis of Atlantic Lows Experiment) field study. The common data set (stemming from a regional reanalysis of the observed data, and using a "standardized" data-distribution format to facilitate the distribution of future cases) has recently been distributed to participants to initialize their models and make forecasts. A workshop is planned for the Spring of 1994 to discuss the ensuing results. The preparation of a second case, an IOP drawn from the Franco- Spanish PYREX field study, is underway, and the selection of further cases is under discussion. *The chairman of COMPARE ended his presentation by inviting the organizers of the CME to consider collaborating with the COMPARE project by providing a set of scientific hypotheses to be verified by coordinated numerical experimentation using data and analyses drawn from a CME IOP.*

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3.11 Techniques and resources for storm-scale numerical weather prediction

Kelvin Droegemeier: Non-hydrostatic modeling and prediction in the mid-1990's and beyond: strategies for dealing with data, parallel processors, and communication

Georg Grell: Multi-scale application of the 5th-generation PSU/NCAR mesoscale model