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Practical Limits to Atmospheric Mesoscale Predictability

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LONG-TERM GOALS

The long term goal of this project is to determine the mesoscale atmospheric predictability and how it relates to synoptic scale uncertainty due to sampling and data assimilation of incomplete samples on the larger scale.

OBJECTIVES

The objectives of this research are to determine the ability to numerically predict mesoscale coastal structures in a variety of synoptic scale situations and demonstrate for given small scale structures the time ranges under which they might be considered predictable. The answer is probably dependent on the data assimilation system and one objective is to determine this sensitivity.

APPROACH

The basic approach is to run a series of numerical model experiments with slightly different observational samples and determine the relative spread in mesoscale forecasts. Since mesoscale truth is difficult to obtain from actual observations, we use a COAMPS model forecast as a representation of a true atmosphere. Samples are generated from this true atmosphere and then put into the data assimilation system for the MM5 model and subsequent forecasts are then verified against this truth. In this manner the impact of data sample, sample size, and data assimilation can be compared. This is being done for a variety of synoptic weather regimes to see if particular weather regimes have greater mesoscale predictability than others.

WORK COMPLETED

During the past year, we have completed diagnostics of numerical experiments in which the topography has been rotated by 1 degree to assess the impact of small perturbations. These

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experiments consisted of running the numerical model with identical initial conditions with slightly rotated topography. The topography was rotated by plus/minus one degree relative to the flow ahead of a land-falling front observed during the California Landfalling Jets Experiment (CALJET). This basic experiment was reported on last year. During the present year, complete diagnostics of the impact of the perturbation in topography on the frontal structure and dynamics has been done. This consisted of examining the relationship between terrain enhanced precipitation and various dynamic mechanisms ranging from frontogenesis to mountain induced gravity wave structures. These results have been reported on in several conferences over the past year.

The other significant work completed during the past year has been to examine the use of a simple sampling strategy to target observations. This work was done by running COAMPS to simulate a true atmosphere over a two week period in January of 1999. This simulated atmosphere was then used to sample observationally using either random sampling or a simple targeting strategy based on optimal sampling for a 24 hour forecast valid at the analysis time. Multiquadric interpolation is used to iteratively determine the required points to define the structure of the 24 hour forecast. Then observations are extracted at these points and assimilated into the model and a forecast is made that is subsequently compared to a forecast based on a randomly sampled set of observations. Statistics have been compiled over the two week period of simulation.

RESULTS

The diagnostic study of the causes of differences in terrain enhanced precipitation due to slight changes in the topographic orientation have revealed that the precipitation is highly sensitive to the amplitude of moist mountain waves induced by the flow across the topography. When the flow more directly impinged upon the topography, higher amplitude mountain waves were observed. This resulted in more drying in the lee of the topography and a strong humidity gradient that forced greater precipitation in the model. When the flow was more parallel to the topography, a weaker flow across the mountain occurred and lower amplitude mountain waves. This resulted in more uniform moisture and less precipitation. The differences in cross-mountain flow were found to be the result of increased frontogenesis for the flow oriented more cross-mountain. The increased frontogenesis developed due to feedback during the preceding 12 hours. This sensitivity highlights the limits of mesoscale predictability for landfalling frontal systems.

The results from Kuypers (2000) suggested that the structure of the observational sample could substantially impact on the growth of forecast error. Consequently, experiments to test whether a sampling strategy optimized for the data assimilation system would consistently produce reduced forecast error was designed. The results of designing this sampling strategy revealed that extensive, scattered observations were necessary to define a wide variety of atmospheric structures. This highlighted the need to completely sample a wide range of wavelengths in the atmospheric structure. After extracting this optimal sample, a similar number of random observations were extracted and both sets were used to assimilate into the model to compare their impact on short term forecasts. The results show that the optimal sampling consistently reduced error compared to random sampling. This suggests that the structure of a observational sample is very important to reduce error. While the targeting was based on defining the basic thermal structure of the forecast atmosphere, optimally sampling dynamically based sensitivity patterns from adjoint sensitivity or ensemble methods could also be done. This might improve the error reduction even more.

IMPACT/APPLICATION

The impact of these studies will be in furthering our understanding of the limits to mesoscale prediction using actual numerical models and data assimilation approaches. This will greatly aid Navy forecasters in knowing how best to use forecasts from mesoscale models.

TRANSITIONS

These results have been used as classroom examples at the Naval Postgraduate School.

SUMMARY

This research has demonstrated that numerical weather forecasts on small scales are very sensitive to small differences in the analyzed structure of the atmosphere used to make the forecast. This exact nature of this sensitivity and its dependence on weather regime will be determined in the ongoing research in coming years.

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PUBLICATIONS

Nuss, W.A. and D.K. Miller, 2001: Mesoscale Predictability under Various Synoptic Regimes. *Nonlinear Proc. in Geophys.* In press.