

Determination of Mesoscale Predictability Limits with Respect to Uncertainty in the Larger-Scale Environment

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LONG-TERM GOALS

Our long-term goal is to determine the limits of predictability inherent in atmospheric forecasts due to uncertainty in their initial conditions. These uncertainties are a consequence of inaccuracies of observational data and the algorithms that produce 3-dimensional analysis. Even if a model can simulate atmospheric behavior perfectly, since atmospheric flows exhibit instabilities leading to chaos, any errors in a forecast's initial condition will tend to grow, until information content of the forecast is negligible. The result is a limit to predictability.

This predictability limit has been known for some time (Lorenz, 1963), although it continues to be ignored by some who make very optimistic claims (e.g., the U. S. Weather Research Plan goals of useful 10-day weather forecasts and 48-hour quantitative precipitation forecasts). Its character, especially regarding how various types of errors influence the predictive skill of various fields on various scales, has only been superficially explored to date (Lorenz, 1969; Errico et al., 1995). Since characterization of this limit has crucial implications regarding forecast reliability and possible observation system impacts, its determination is critical (Tribbia and Baumhefner, 1988).

OBJECTIVES

Our objective in this particular study is to determine the predictability limits of weather forecasts caused by inaccuracies in their initial conditions and to characterize the processes of forecast error growth. In particular, we will determine these limits and characterize the processes as functions of

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14. ABSTRACT Our long-term goal is to determine the limits of predictability inherent in atmospheric forecasts due to uncertainty in their initial conditions. These uncertainties are a consequence of inaccuracies of observational data and the algorithms that produce 3-dimensional analysis. Even if a model can simulate atmospheric behavior perfectly, since atmospheric flows exhibit instabilities leading to chaos, any errors in a forecast???'s initial condition will tend to grow, until information content of the forecast is negligible. The result is a limit to predictability.					
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horizontal scale. Results will depend on the fields being forecast: Although the predictability limit for forecasting 50 kPa geopotential height anomalies may be as long as 8 days with present observation and data assimilation systems, it is likely considerably shorter for forecasts of the small-scale processes that generate clouds or precipitation. Yet for many purposes, it is these more poorly determined fields that are of paramount interest.

Both the energy and variances of fields are much greater at synoptic and planetary scales than at mesoscales. Initial conditions for forecast models therefore also tend to have errors that dominate at these larger scales. It has been argued that mesoscale errors grow more rapidly or, alternately, that they are more predictable, but these have been on heuristic grounds, using either simple models (Lorenz, 1969) or flawed experimental designs (e.g., Anthes et al., 1985, as revealed by Errico and Baumhefner, 1987). One of our goals will be to perform careful experiments to characterize the interaction of mesoscale and synoptic-scale errors using the most realistic and highest resolution global model that we can presently afford to use.

APPROACH

We assume a perfect model. For this reason, the model must be carefully verified with regard to its abilities to both forecast weather and simulate climate. It must be neither overly damped nor too energetic, otherwise perturbations will not behave consistently with respect to forecast errors. Tests of version 3 of NCAR's Community Climate Model (Kiehl et al., 1998) reveal it is such a suitable model.

Initial condition perturbations are created by randomly sampling from an error probability distribution that has some assumed characteristics of analysis errors. We can only base this on "assumed" characteristics because very limited effort has been applied to revealing the true character of such errors. Estimated analysis errors reported by Daley and Mayer (1986) and from examination of differences between analyses produced at NCEP and ECMWF are used as guidance, along with knowledge about the current observation system and intuition regarding the behavior of data assimilation systems.

For selected forecast periods, ensembles of randomly perturbed forecasts are created. They are then examined using standard forecast verification tools as well as statistical tests on all the pairs of forecast differences. Scales are distinguished using spherical harmonics as basis functions. Other techniques have been applied as well, as required.

WORK COMPLETED

During the past year we have worked on 4 aspects of our problem (each described following). All this work is at the stage in which draft manuscripts have been prepared and are near ready for submission. Cross-referencing of the results of each manuscript requires coordination of the manuscript submission so that all will be submitted simultaneously.

We have completed comparison of the latest NCEP and ECMWF re-analysis for a five-year period for the purpose of characterizing the statistics of analysis error. So far, only corresponding 6-hourly analyses for a period of 5 days were examined in detail. Our attention was focused on geopotential height and wind fields, since currently the precipitation fields provided with these analysis are strictly model-forecast results, independent of any actual observations of precipitation. A more extensive statistical analysis was begun this past fall.

Characteristics of the growth of perturbations were compared for T42, T63, T106, and T170 resolutions of the CCM3. Preliminary examination of synoptic scale precipitation was begun in order to compare this to estimates of the predictability of smaller mesoscale precipitation systems. Also, unperturbed forecasts were begun for the four resolutions with topography removed and using identical initial conditions at any of the commonly resolved scales. The purpose of this experiment was to explore the effect of unresolved scales on the resolved ones. Of particular interest was the rate of transfer errors from unresolved scales to resolved and the magnitude of errors relative to the control variability.

In recognition of the importance of predictability error growth in limiting forecasts and of the lack of knowledge of the nature of this growth within the general meteorological community, we have drafted an article for the Bulletin of the American Meteorological Society characterizing what has been learned since predictability limits were first hypothesized. This article includes descriptions of how fast errors grow (doubling of rms global 50kPa geopotential height perturbations every 1.5 days) and on what scales the errors grow (planetary and large synoptic scales, peaking at total wave number 10).

RESULTS

Comparison of the NCEP and ECMWF re-analysis reveals rather large differences in oceanic locations, where current observations are of poorer quality than over Northern Hemisphere land areas. At 50kPa, average oceanic height differences are approximately 50m, corresponding to 2.5C mean temperature differences in the lower half of the atmosphere. These differences have been incorporated into the NCAR initial error simulator improving the representativeness of the simulations in physical and spectral space.

We had previously noted that the statistics of the growth of ensembles of perturbations in the T170 CCM3 are nearly identical to those in the T106 version. This includes variances of perturbations as functions of geographic location, total wave number, and time. The mean growth rate is the same as that reported by Simmons et al. (1995) for the ECMWF model. By calibrating the results from the imperfect model twin experiments which examined the error growth due to unresolved scales we have been able to independently corroborate the adequacy of T106 resolution for synoptic scale predictions. Our research indicates that unresolved errors rapidly saturate the T016 scale of motion making higher resolution essentially useless for synoptic scale forecasting.

Our nascent studies on the predictability of non-convective precipitation demonstrates the difficulties of improving quantitative precipitation forecasts. Despite the fact that non-convective precipitation is tied to synoptic structures, the detailed timing and amount of precipitation depends so sensitively on the details of the flow that predictive skill in this field is lost in about 1.5 days.

IMPACTS/APPLICATIONS

NCAR's CCM3 appears to be suitable as a forecast model, with comparable skill to ECMWF and NCEP models at the same resolutions when measured using rms 50kPa geopotential height errors. In CCM3, physical parameterizations of moist processes are apparently quite sensitive to unresolved scales and limit not only the predictability of precipitation but also the synoptic scale environment.

Insofar as this generalizes to other models, it reinforces the need for scalable and linearizable physical parameterizations.

TRANSITIONS

The initial error simulator is being tested at NRL Monterey for use in ensemble prediction.

RELATED PROJECTS

Work on various aspects of singular vectors is being performed in collaboration with Kevin Raeder at NCAR, Martin Ehrendorfer at the University of Vienna, Austria, and Carolyn Reynolds and Ron Gelaro at NRL, Monterey.

SUMMARY

This project has shown over the past three years that the nature of error growth in weather forecasts is strongly tied to error growth in the synoptic (i.e. weather map) scales. Perfect information on smaller scales is nearly useless if synoptic scales are inaccurate. We have also shown that there are rather large inaccuracies in synoptic scales over the oceanic regions. This has a significant implication for windward coastal zone forecasting. Over the next 2 years we will quantify what this means for frontal scale and smaller scale weather in the western coastal regions.

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PUBLICATIONS

Four manuscripts are in preparation.