Development of a Multi-scale Operational Weather Research and Forecasting Model Ensemble Kalman Filter

A Project Report

by

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I. Introduction

The main goal of this project is to develop and test a multi-scale WRF ensemble Kalman filter (EnKF) over the continental United States toward operational use at the National Weather Service (NWS). The NWS has recently increased their effort to produce operational, probabilistic, mesoscale analyses and forecasts, and a WRF EnKF can potentially provide these products in real time. This project specifically aims to produce a set of benchmark results in order to 1) evaluate the performance of the WRF EnKF against current NWS forecast models, and 2) to serve as a basis for comparison for future, improved WRF EnKF configurations. Although this project was supported initially for one year by the WRF DTC, it is intended that further collaboration between the Principal Investigator and the WRF DTC continue so that important results can be produced. This continued collaboration in the immediate future is necessary for such results as a major disk failure occurred on the computing resources used for this project. Details of the status of the project are described below.

II. Project Status

A. Period of work 11/24/08 – 12/12/08

The WRF DTC required 4 weeks of visitation from the Principal Investigator during the year of the project. The first 2.5 weeks of these 4 weeks were spent in late November/early December 2008. The primary goal of this first visit was to configure and compile the WRF EnKF system on the NOAA linux cluster wjet, which is the computer resource supplied for this project. The EnKF code is that of the University of Washington EnKF system (Torn and Hakim 2008), and was successfully configured and compiled during this time. The WRF EnKF system was configured to contain a large outer domain at 48-km (D1) grid spacing with a nested domain at 12-km (D2) grid spacing (Figure 1). Both domains contain 38 vertical levels. The purpose of this configuration was to supply the continental 12-km domain with boundary conditions from a larger EnKF (48-km domain), reducing errors associated with a distribution of suboptimal boundary conditions that are necessarily supplied to the outer domain (Torn et. al 2006).

Both domains of the WRF EnKF were setup to run on a 6-hour update cycle and contain 100 ensemble members. Other data assimilation parameters, such as the amount of analysis variance inflation (required to prevent lack of spread in the ensemble when using a relatively small sample size) and localization radius (distance to which assimilated observations have influence) were set to be different between the 48- and 12-km domains. The 48-km domain parameters were set to be the same as the calibrated values used with a similar system in Torn and Hakim (2008) (which used 45-km grid spacing), whereas the 12-km domain was set to use appropriately smaller analysis variance inflation and localization (as used in Ancell et al 2009). The 48-km domain was configured to produce 72-hr forecasts, and the 12-km domain was set to produce 24-hr forecasts.

The observations used for both assimilation and verification were satellite cloud-track winds, ACARS wind and temperature data, rawinsonde wind, temperature, and relative humidity data, and surface altimeter, wind, and temperature data. These observations were collected and preprocessed during this period of work to remove duplicates and observations not within 20 minutes of assimilation time. Furthermore, surface observations for which the actual terrain height and model terrain height were different by more than 200 meters were removed. The observations were preprocessed every hour for all of September and October 2008, which is the period over which the benchmark results for this project will be produced. Cloud-track wind, ACARS, and surface observations were divided into two sets at assimilation times (0000, 0600, 1200, and 1800 UTC), one set to be assimilated and the other to be verified against. Only a single set of rawinsonde data was retained at times 0000 and 1200 UTC, all of which will be assimilated. All observations were used for verification at non-assimilation times. Although most of the above tasks were completed during the first period of visitation, some were completed remotely in the weeks following the first visitation.

B. Period of work 04/27/09 – 05/05/09

The last 1.5 weeks of visitation to the WRF DTC were spent in late April/early May, and were used to create and test driver scripts to run long periods of WRF EnKF experiments on the NOAA wjet linux cluster. These scripts were written and tested successfully, and it was planned that experiments for a 2-month period during September and October of 2008 would run in the few months following this second period of visitation. Subsequently, WRF EnKF analyses and forecasts would be produced to answer the following questions:

1) How do the 48- and 12-km WRF EnKF perform against each other and the GFS, NAM, and RUC?
2) Does the surface terrain profile (e.g. flat terrain in the Midwest, complex terrain of the mountainous West) affect these results?
3) At what forecast time do the suboptimal boundary conditions on the 48-km domain adversely affect the 12-km domain?

Furthermore, these WRF EnKF results would provide a benchmark of performance statistics against which subsequent WRF EnKF configurations could be evaluated.

C. Disk Failure and Limitation of Results

At the end of May 2009, the disk /lfs0 on which all of the files associated with this work resided failed. A backup was restored from February 2009 that included none of the work completed during the second visitation described in Section B. Furthermore, files that had been altered since February 2009 and prior to the failure were also lost, which included a large number of driver scripts, observation files, and other files required to run the WRF EnKF. Efforts by NOAA's computing support staff to recover this data continue, but to this point have not been successful.

D. Future Work

NOAA Computer support staff continues to attempt to recover the data on /lfs0 that was present at the end of May 2009, and has reported that a majority of this data will likely be recovered in the near future. Should this be the case, the WRF EnKF experiments that were planned and essentially ready to run in late May 2009 could begin shortly, likely producing the expected results by the end of the year 2009. However, if the data recovery is not successful, a more significant amount of time will need to be invested to recreate the data for these experiments. Since this work will be more difficult to complete as it will not be during visitation, the expected date of results would be June 2010.

III. Summary

This project has the potential to produce very important results in concert with NOAA's vision of a United States operational, probabilistic, mesoscale analysis and forecasting system. Once the Principal Investigator is notified of the status of the final /lfs0 recovery efforts, he will make arrangements to continue this work. Due to the disk failure, The Principal Investigator hopes this work can continue beyond the initial funded year of this project. Furthermore, it is intended that improvements to the WRF EnKF beyond the initial results from the initial system configuration described here progress through further collaboration between the Principal Investigator and the WRF DTC. The eventual goal of this further collaboration is the transition of the WRF EnKF system into NWS operations.

References

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Torn, R.D., G.J. Hakim, and C. Snyder, 2006: Boundary conditions for limited-area ensemble Kalman filters. *Mon. Wea. Rev.*, 134, 2490-2502.

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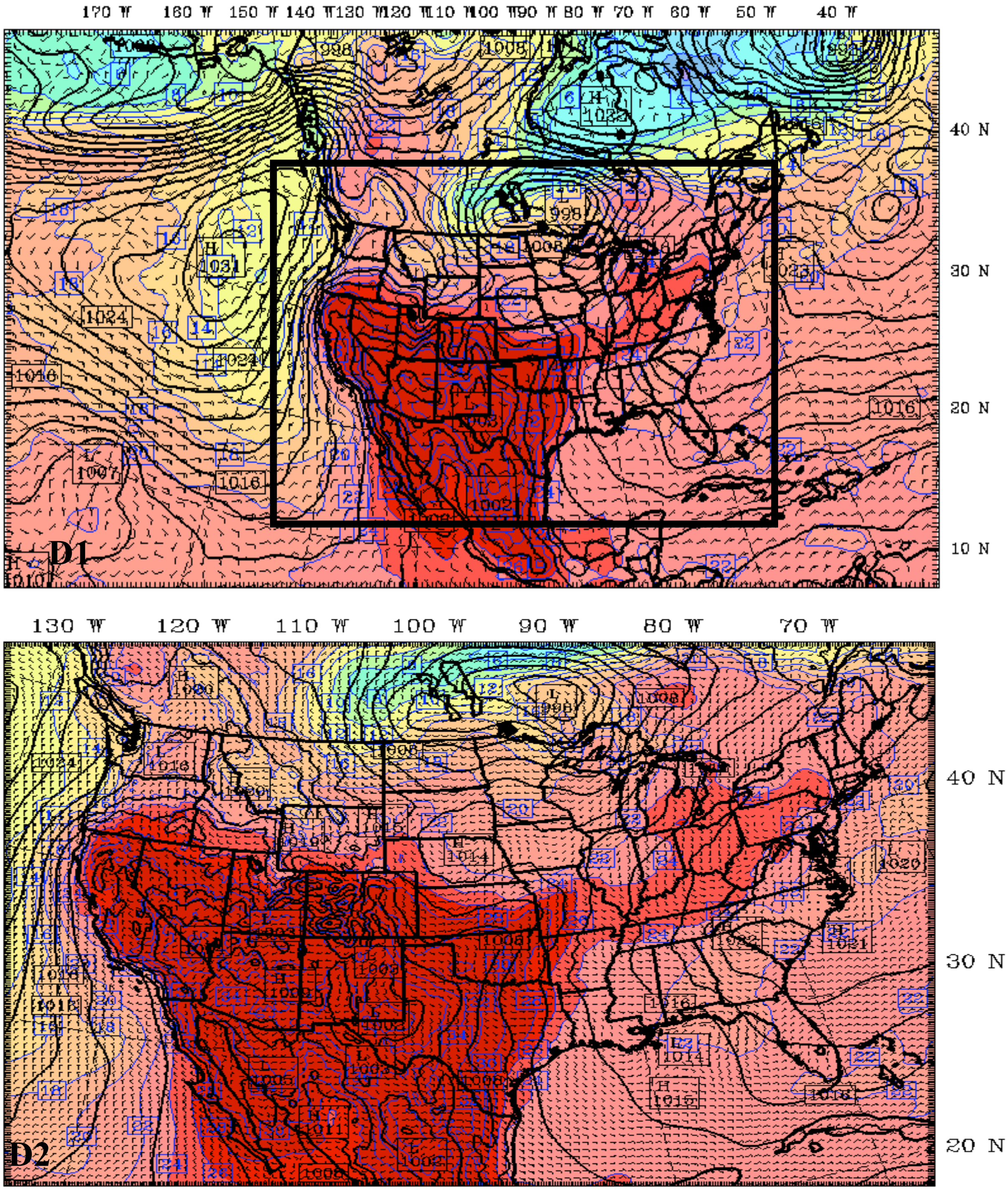

Figure 1 – Sample forecasts of sea-level pressure (black contours), 925-hPa temperature (shaded with blue contours), and surface winds on the WRF EnKF 48-km outer domain (D1, top) and 12-km nested domain (D2, below). The boundary of D2 is also shown within D1.