Challenges in Using WRF as an Operational and Research Tool for High Resolution NWP in Alaska and Montana

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Introduction

Efforts have been underway to deploy WRF in the Fairbanks and Missoula Weather Forecast Offices as a regional weather model to complement various AWIPS products. To date, we have built a software system that automates the process from the retrieval of GRIB input data to the posting of various output products. With an emphasis on portability and "rapid deployment," we have been able to produce daily output at 4km resolution for the Missoula CWA and 7.5km resolution for the Fairbanks CWA. Additionally, by request from the Alaska Volcano Observatory we have deployed a 1km resolution model around the island-volcano of Mt. Augustine in Alaska.

Real Time NWP

A constantly-evolving suite of scripts and programs has been assembled to automatically perform all of the operations necessary for a real-time model forecast.

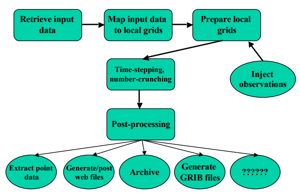

Figure 1. Flow process for automated real-time WRF simulations.

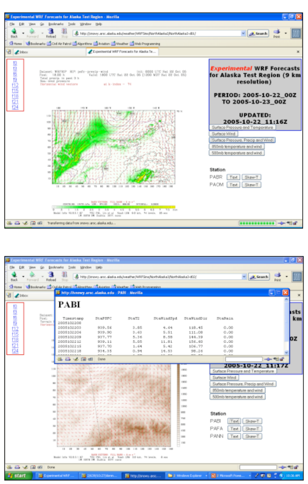

Figure 2. Web output products from automated real-time WRF simulations.

Modeling Alaska

Using the Arctic Region Supercomputing Center's Cray XD1, *nelchina*, we are currently producing two 48-hour forecasts each day on a 7.5km grid covering most of Alaska and its surrounding environment (see Figure 3). Model runs are initialized with the 45km NAM 216 grid (awipak). Using sixty CPUs, we perform a 48-hour simulation in approximately 2.5 hours. However, pre- and post-processing activities force a total time of five or more hours. Two to three hours (sometimes longer) is often spent retrieving the initial data from NCAR FTP servers, and approximately one hour is used to produce web graphics (*http://pileus.arsc.alaska.edu/weather/*) and GRIB files for eventual migration to NWS AWIPS.

As it stands now, the turnaround time is much too long to provide timely products to forecasters. For example to perform a 12Z forecast we currently wait until about 15Z until the NAM 216 grids are available, and the long downloading time prevents us from even starting the simulation until about 18Z. The simulation plus post-processing activities result in an availability of our products at approximately 22Z! Hence, work is underway to pre-fetch older initial data and to perform much of the post-processing on other machines in real-time, as WRF produces its output files. In this way, to produce a 12Z forecast we will have already downloaded the 06Z input data by 12Z and can start producing output in real-time shortly after 12Z.

Bugs in the WRF modeling system, until recently, had us performing simulations with an absence of sea ice, drastically affecting forecasts along Alaska's west and north coasts. This problem has been resolved and we have been producing more realistic forecasts since early May 2006.

At this time, one of our primary goals in the Alaska realm is to streamline the process so that we can produce two forecasts per day in timely fashion. Additionally, we are preparing to use recent observational data and assimilate it into our forecasts.

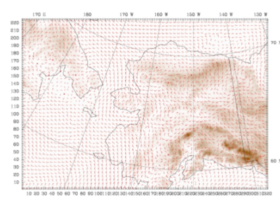

Figure 3. Surface wind fields produced from 7.5km resolution WRF simulation over Fairbanks CWA.

Volcanoes

In support of the Alaska Volcano Observatory (AVO) we are producing a daily 24-hour forecast on a 160x160 5km grid with a 100x90 1km nest around Mt. Augustine Island (see Figure 4). This was motivated by the 2006 eruption of Augustine volcano, situated on the island. Figure 5 shows a volcanic ash dispersion model run (model is called Puff) done using the WRF model data as initialization. Here, we can see three clear volcanic clouds/plumes as modeled using Puff and WRF (5km grid) wind fields. The WRF products of these forecasts are used by AVO researchers to drive their plume models and will provide essential data for the ability of such dispersion models to accurately detect volcanic ashfall during an eruption.

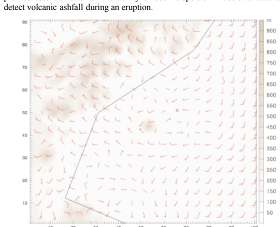

Figure 4. Surface wind fields produced from 1km resolution WRF simulation centered on volcanic island (Mt. Augustine, seen offshore in center of graphic).

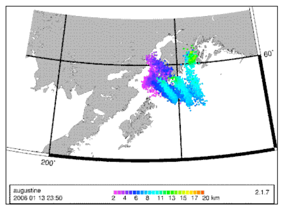

Figure 5. Volcanic ash model results of Augustine eruption clouds using WRF model data.

Modeling Western Montana

Work is concurrently being performed with the Missoula, Montana WFO with identical goals of producing timely high-resolution forecasts to be ingested into AWIPS. The overall domain is an 85x70 36km grid with a 90x90 12km nest, and a finer 150x170 4km mesh over the Missoula CWA (see Figure 6). Simulations are currently driven by the NAM 212 40km grids.

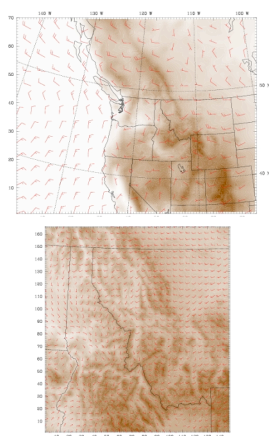

Figure 6. 36km and 4km resolution domains for Missoula WRF simulation.

Acknowledgements

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High Resolution Case Study

Due to the primary author's keen interests in outdoors and aviation activities in the western Montana region, additional work has been focused on trying to model this very rugged region at higher resolutions in an attempt to capture some of the small-scale features. A case study has been performed, recreating an arctic outbreak that slipped into the region in mid-February 2006. The region was modeled at both 1km and 5km resolution (see Figure 7) with key variables being extracted at specific locations for comparison with observations.

In particular, we were interested in determining how well our forecasts would match observations and whether there would be noticeable gains in using the high resolution. Given that the run with a 1km nest took about eight hours on 60 CPUs and a run without the 1km nest took about thirty minutes, we need to be sure that our heavy use of computer time is not done in vain!

The case study was a 54-hour simulation starting at 12Z on 15 February 2006. For the purposes of this poster we focus on three observation sites – an AWOS at Missoula International Airport, a RAWS at Ninemile, and a Univ. Montana weather station at the mouth of Hellgate Canyon (see Figure 7).

Residents of Missoula, Montana are familiar with the Hellgate Winds which tend to drain the mountains to the east of their cold air, with the flow constricting and accelerating through the narrow Hellgate Canyon on the east side of town (Figure 7). These winds frequently appear on an otherwise calm, cool morning when winds aloft are negligible. Additionally, the arctic outbreaks typically come from the east side of the Continental Divide, pouring cold air to the west, funnelling through terrain features such as Hellgate Canyon. It has been our hope to capture these localized winds with high-resolution models.

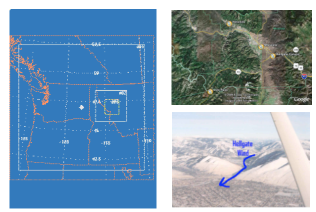

Figure 7. 25/5/1 km resolution domains for Missoula case studies (left), observation sites used in case study (upper right), easterly Hellgate Wind, Missoula, Montana (lower right).

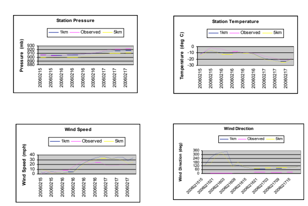

Figure 8. Comparison of 1km model, 5km model and observations at Missoula International Airport ASOS (KMSO).

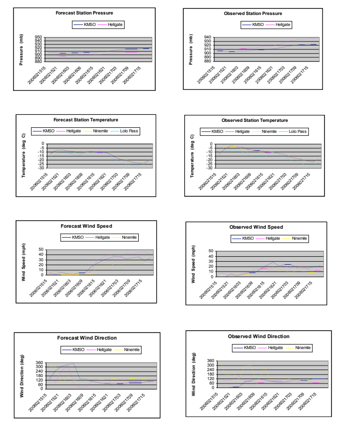

Figure 9. Comparison of 1km forecast versus observations at Missoula AWOS (KMSO), Hellgate Canyon weather station, and Ninemile RAWS.

Analysis

A very preliminary analysis of Figure 8 (comparison of 1km and 5km forecasts with observations at the Missoula ASOS) reveals that the 1km model does a much better job at capturing station pressure. The actual elevation of the ASOS is 3,200 ft MSL, and the 1km and 5km models interpolate this particular point to be 3,231 ft and 3,226 ft, respectively, so it appears that the pressure discrepancy is much more than sampling at different elevations. Although the observed wind speeds don't present a close match to the forecasts, it should be noted that during this outbreak, KMSO exhibited wind gusts up to 36 mph, which is close to that presented by the forecast – the observed wind data come from a once-hourly reading and seem low when compared to what was really happening. As has often been the case, forecast and observed wind directions seem to vary substantially when wind speeds are low, but come into closer agreement with increased velocities.

Figure 9 compares the 1km forecast at all three stations with the observations. The forecasted pressure difference between KMSO and Hellgate (both are close to 3,200 ft MSL) is significant, and further analysis reveals that the interpolated elevation at Hellgate comes out to 3,443 ft, accounting for a lower forecast pressure. This discrepancy suggests that if we really want to capture the behaviour in these narrow canyons, we need to increase the resolution, possibly by another order of magnitude.
The discrepancy between observed pressures at KMSO and Hellgate is believed to be due to instrument calibration error at the Hellgate site.

Again, forecast wind speeds appear much higher than observed, but the observed data may not be representative of what was really happening. During this outbreak, Gene Petrescu (SOO at Missoula WFO) reported hanging on to the side of his truck near the Hellgate site to measure substantially higher winds than depicted in these observations, indicating that we may need to re-visit how our observed winds are being represented.

Summary

To date, our group has been expending much effort towards the realization of robust, real-time regional weather models in areas of interest to us (Alaska and Montana). Immediate goals in this realm are to streamline the process and to begin research in the incorporation of observations to help drive the forecasts. The forecasts depicted in this poster are all driven by initial data with approximately 40km resolution, so it seems obvious that, in order to achieve high-resolution forecasts we need to ingest a number of valid observations for initial conditions. Although Alaska and western Montana are sparsely populated, there does exist a sizable number of weather stations and, one of our primary driving goals now is to determine how we can collect this data on a real-time basis and successfully use it in our forecasts. An important consideration in all of this work is that it becomes necessary to rigorously and carefully analyse the forecast vs. observed data in as objective a way as possible.