Improvement of Mesoscale Numerical Weather Prediction For Coastal Regions of Complex Terrain

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LONG-TERM GOALS

The long-term goals of this proposal are to improve the skill of mesoscale numerical weather prediction (NWP) over coastal regions of complex terrain and to evaluate the effectiveness of local NWP for civilian and military applications. An ancillary goal is to understand the structural and dynamical interactions that occur as synoptic weather systems interact with coastal terrain.

OBJECTIVES

The major scientific objectives of the project include the following:

* To complete an intensive verification of a large number of high-resolution mesoscale forecasts to determine mesoscale model skill and weaknesses for an orographic coastal zone. This work will not only quantitatively evaluate model skill as horizontal and vertical resolution is increased, but will also provide guidance for the improvement of the basic physical parameterizations of radiation, microphysics and the planetary boundary layers.

* To evaluate the benefits of mesoscale data assimilation for regional mesoscale forecasting.

* To evaluate various approaches for synoptic initialization and boundary forcing for regional numerical weather prediction for coastal regions.

* To help determine the implications of a local mesoscale forecasting capability for regional Navy operational needs.

* To complete work on coastally propagating disturbances along the west coast, gap flow in coastal orography, and the interaction of synoptic disturbances with coastal terrain.

APPROACH

Twice-daily forecasts of the Penn State/NCAR model for the west coast of North America have been made over the past two years at horizontal resolutions of 36, 12 and 4 km. These forecasts have been

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compared over the Northwest with a very dense set of mesoscale observations, taken from over a dozen separate networks.

For the mesoscale initialization studies, approximately one dozen cases have been run with and without mesoscale initialization. The results have been verified using the Northwest mesoscale verification system to determine the period over which local data initialization can have a beneficial effect.

To study the effects of various forms of synoptic initialization, we have tested nudging-based Four Dimensional Data Assimilation (FDDA), insertion of cloud fields at initialization, and Four-Dimensional Variational Data Assimilation (4DVAR) approaches.

High-resolution numerical modeling using the Penn. State/NCAR model (MM5) has been used to examine coastally trapped features such as the Catalina Eddy and Coastally trapped wind reversals. The model has also been used for sensitivity experiments in which various physical processes have been modified or removed.

COAST field experiment cases have been analyzed using both numerical simulation and observations, including the radars/flight level instrumentation of the NOAA P3 aircraft.

WORK COMPLETED AND RESULTS

Specific ONR-supported accomplishments during the past year includes:

1. Completion of observational/modeling studies of the Catalina Eddy and trapped coastal wind reversals. This work has provided detailed diagnostics of the structural and dynamical evolution of these events, and has demonstrated the potential of high-resolution mesoscale modeling to realistically simulate and forecast their development (Davis et al 1999, Mass and Steenburgh 1999).

2. Several detailed studies of the interaction of synoptic fronts with coastal terrain were completed. For example, using data from the NOAA P3 aircraft and conventional observations, the interaction of the COAST IOP2 front with the Olympics and Cascades was documented and successfully simulated (Chien et al 1999). In another study, a springtime landfalling front and accompanying onshore marine push were described and modeled (Chien et al 1997). Colle et al (1999) also explored the interaction of the COAST IOP5 front with the Olympic Mountains. An ongoing study now being completed describes the coastal effects of a major cyclone (12 December 1995) as it approached and crossed the coastal mountains.

3. The effects of gaps in coastal mountains both for near-sea level gaps (Strait of Juan de Fuca, Colle and Mass 1999) and for gaps in which elevation varies considerably (Colle and Mass 1998 a, b) have been examined. In the first study, the NOAA P3 Doppler radar described the three-dimensional flow within the gap (a first for any gap) and an excellent simulation helped explain the complex dynamics of the event. In the second study, the combination of a gap flow and downslope windstorm was described and the ability of a mesoscale model (MM5) to forecast strong downslope winds was demonstrated. The realism of high resolution modeling to forecast the intrusion of cold air through gaps in coastal orography was examined in Steenburgh et al (1997), and a student is now working on a detailed observational and modeling study of the flow through the Columbia River Gorge.

4. Two years of high resolution (26-12-4 km horizontal resolution) mesoscale forecasts by the MM5 over the Pacific Northwest have been verified in detail and several papers describing the effects of varying resolution in coastal terrain have been published (Colle and Mass 1999, Colle et al 1999). Using conventional skill scores, a clear improvement in precipitation forecasts was apparent going from 36 to 12 km, with additional skill at 4 km when the synoptic flow is well forecast. A comprehensive paper described the effects of resolution on major parameters is now being prepared. Detailed evaluation of real-time precipitation forecasts and limited microphysical data from the COAST field experiments have revealed significant deficiencies in microphysical schemes over coastal terrain.

5. Various methods of dynamic model initialization for regional mesoscale models have been tested including nudging-based Four Dimensional Data Assimilation (FDDA) and 4DVAR. The results of this work suggest that 4DVAR works well, producing a spun-up forecast on the mesoscale that is consistent with large scale guidance. A paper describing these experiments is now in preparation.

6. The value of mesoscale initialization using the considerable local assets in the Northwest has been evaluated with a number of experiments. We have found that the benefits of mesoscale initialization were only transitory, lasting 3-6 hours for most cases.

7. A high level of interaction has been fostered between the UW group and Navy operations personnel at Whidbey Island NAS and the forecast unit at Bangor. This interaction has included the provision of the MM5 real-time forecasts, frequent forecast discussions over the telephone, and several visits to Whidbey Is NAS and Bangor for lectures on regional meteorology and the use of high resolution model output. Substantial interaction has also occurred with NRL Monterey, and particularly the mesoscale modeling group. One example of this cooperation is the comparison simulations (MM5, COAMPS) made for several COAST cases.

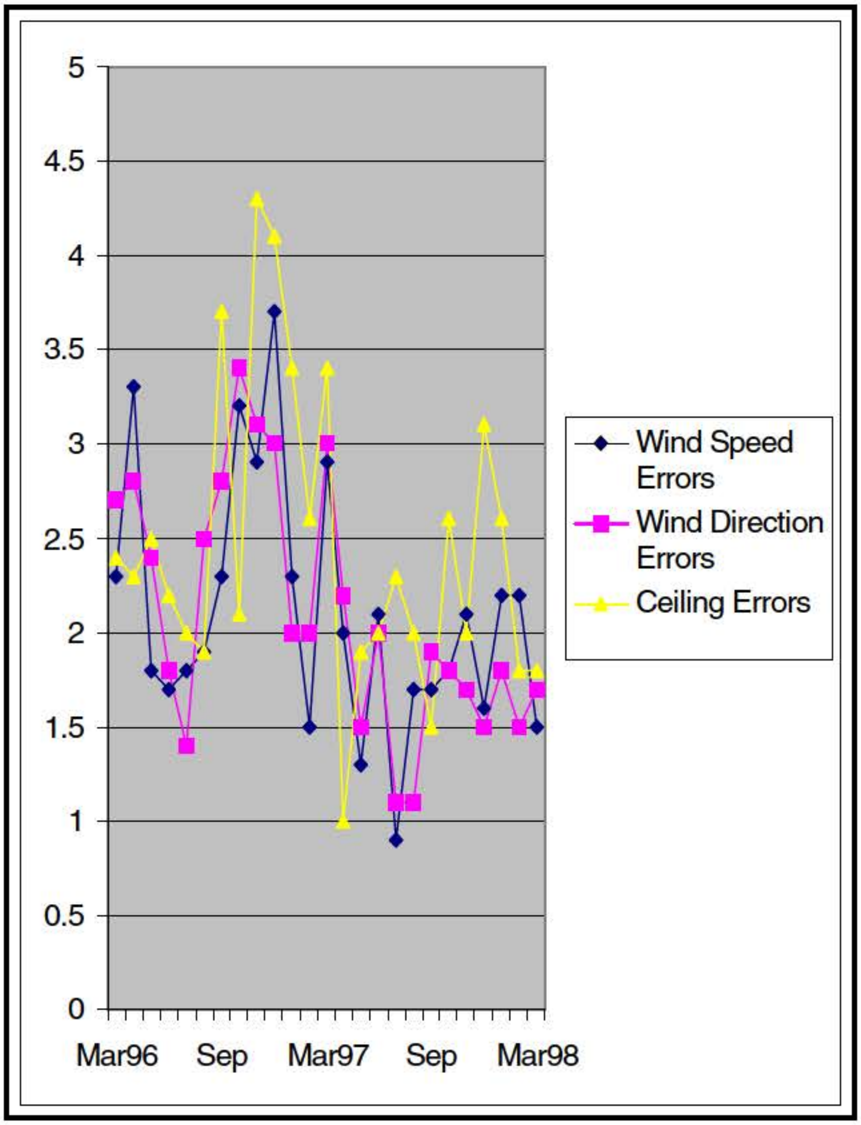

Figure 1: Wind speed, wind direction, and ceiling errors at Whidbey Island Naval Air Station. The MM5 was first introduced at Whidbey between March and May 1997. It appears that there was a noticeable improvement in forecast skill with the access to high resolution model forecasts.

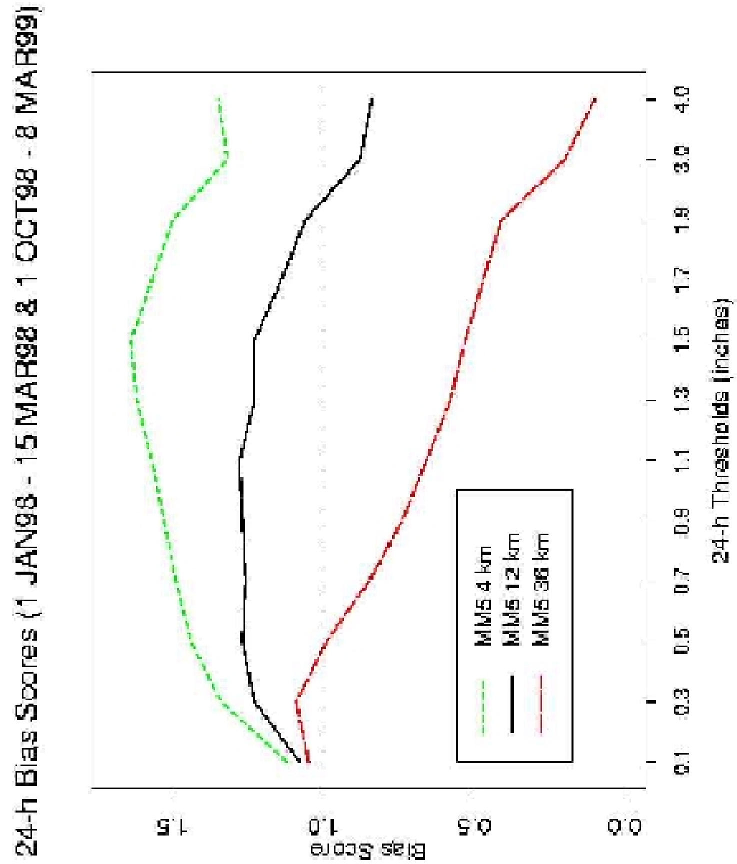

Figure 2: Precipitation biases at 36, 12 and 4 km resolution for the 1999 and 1999 winter seasons for the UW MM5 regional forecasts. Note the severe underprediction of the 36-km resolution domain, particularly for higher 24-h precipitation thresholds.

IMPACT/APPLICATIONS

This work provides the best documentation to date of the influence of horizontal resolution on the fidelity of regional numerical weather prediction, describing where the point of diminishing returns appears to be. The research demonstrates the effectiveness of various forms of mesoscale model initialization. It also substantially clarifies the structural evolution and dynamics of a number of orographically trapped features along the west coast of North America and demonstrates the potential of high resolution numerical modeling for warm and cold season events. Finally, this research provides detailed understanding of the mesoscale structures resulting from the interaction of the synoptic scale flow and coastal orography.

TRANSITIONS

Judged by citations, the above work has had a substantial influence on other groups involved in the study of coastal circulations in complex terrain. The predictions produced by this effort have been used by local Navy meteorologists in the Northwest (e.g., Whidbey, Bangor), and our experiences will be used in the development of training materials for Navy forecasters.

RELATED PROJECTS

A substantial amount of the work on coastally trapped summertime disturbances has been done in concert with an ONR-sponsored effort at the MMM Division at the National Center for Atmospheric Research.

REFERENCES

Publications sponsored in total or part by this grant during the last year include:

Chien, F.-C., C. F. Mass, and P. J. Neiman, 1999: An observational and numerical study of an intense land-falling front along the northwest coast of the U.S. during COAST IOP2, Submitted to *Mon. Wea. Rev*.

Mass, C., D. Ovens, M. Albright, B. Colle, and K. Westrick, 1999: Does increasing resolution always improve forecast skill? Submitted to Bull. Amer. Meteor. Soc.,

Davis, C., S. Low-Nam, and C. F. Mass, 1999: Dynamics of a Catalina Eddy revealed by numerical simulation. Accepted in *Mon. Wea. Rev*.

Colle, B. A. and C. F. Mass, 1999: High-resolution observations and numerical simulations of easterly gap flow through the Strait of Juan de Fuca on 9-10 December 1995. Accepted in *Mon. Wea. Rev.*

Colle, B. A. and C. F. Mass, 1999: The 5-9 February 1996 flooding event over the Pacific Northwest: sensitivity studies and evaluation of the MM5 precipitation forecasts. Accepted in *Mon. Wea. Rev.*

Westrick, K., C. Mass, and B. Colle, 1999: Is meteorological radar useful for quantitative precipitation estimation over the western U.S.? Accepted in Bull. Amer. Meteor. Soc.

Mass, C. and J. Steenburgh, 1999 An Observational and Numerical Study of an Orographically Trapped Wind Reversal along the West Coast of the U.S. Accepted in Mon. Wea. Rev.

Colle, B. A., K. J. Westrick, and C. F. Mass, 1999: Evaluation of MM5 and Eta-10 precipitation forecasts over the Pacific Northwest during the cool season . *Wear and Fo.*

Colle, B. A., C. F. Mass and B. F. Smull, 1999: An observational and numerical study of a cold front interacting with the Olympic Mountains during Coast IOP 5. *Mon. Wea. Rev.,* **127**, 1310-1334