Improvement of Mesoscale Numerical Weather Prediction For Coastal Regions of Complex Terrain FY2000

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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. Other important goals include understanding the structural and dynamical interactions that occur as synoptic weather systems interact with coastal terrain, and the nature of coastal gap flows and other coastal orographic features.

OBJECTIVES

The major scientific objectives of the project include the following:

* To evaluate the value of mesoscale ensembles using both varying initializations and model physics.

* To complete an intensive verification of a large number of high-resolution mesoscale forecasts to determine mesoscale model skill for a variety of parameters. This work will not only quantitatively evaluate model skill as horizontal resolution is increased for the whole domain, but will determine whether certain areas are more predictable than others.

* To help determine the implications of a local mesoscale forecasting capability for regional Navy operational needs, and to help train Navy personnel in the use of high-resolution model forecasts.

* 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.

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* To investigate the quality of model initialization over the Pacific of a number of modeling systems, and to determine how initialization quality affects forecast skill.

* To evaluate timing errors of troughs as they approach and interaction with the west coast of North America.

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

An ensemble prediction system has been created that runs the MM5 at 36 and 12-km resolution eight times: five runs with different initializations and lateral boundary conditions (NCEP AVN, ETA, MRF and Navy NOGAPS and Canadian GEM model) and three additional physics diversity runs (varying PBL schemes, microphysics and cumulus parameterizations). These 8 runs are made daily (0000 UTC cycle) and are being carefully verified against regional observations. The skill of the ensemble mean and the relationship of forecast skill and spread are also being examined. This system will run through the upcoming winter, and summary results will be prepared.

COAST field experiment cases have been analyzed using both numerical simulation and observations, including the radars/flight level instrumentation of the NOAA P3 aircraft. One case deals with a strong Pacific front that crossed the coastal terrain of British Columbia and Washington. Another is the 12 December 1995 event in which a deep low crossed the coast near Tatoosh Island.

We are also well into a detailed study of the flow in the Columbia River Gorge, including an evaluation of the horizontal and vertical resolutions required to realistically simulate Gorge flow. In addition, observational analyses are being made for a number of cases, using both a collection of surface networks and ACARS aircraft data from flights approaching and leaving Portland.

Another major project has been to evaluate the strength and timing errors of troughs approaching the U.S. west coast over a several year period. We have developed objective algorithms for determining MM5 and NCEP Eta model timing errors for a collection of 8 buoys over the eastern Pacific and along the coastal waters.

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 2000, Mass and Steenburgh 2000).

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 2000). 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. 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 or submitted (Colle and Mass 1999, Colle et al 1999, Mass et al 2000). 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 describing the effects of resolution on major parameters has been completed. Detailed evaluation of real-time precipitation forecasts and limited microphysical data from the COAST field experiments has revealed significant deficiencies in microphysical schemes over coastal terrain. This work has stimulated the upcoming IMPROVE field experiment, that will collect both state and microphysics data for both synoptic and orographic atmospheric features.

4. The 8 member mesoscale ensemble system has been created, made operational, and its output is available in real-time on the web. We have put into place a verification system and will be analyzing the results of a full winter. Our initial evaluation shows that mesoscale detail is apparent in the ensemble mean and that the ensemble mean has generally been more skillful than any individual member.

5. A high level of interaction has been fostered between the UW group and Navy operations personnel at Whidbey Island NAS. This interaction has included the provision of the MM5 real-time forecasts, forecast discussions over the telephone, and several meetings with Whidbey personnel. Substantial interaction has also occurred with NRL Monterey, and particularly the mesoscale modeling group.

6. Substantial progress has been made in observational and modeling studies of the flow through the Columbia River Gorge. The Gorge is an ideal test bed for the study of gap flows due to its simple geometry and substantial data assets. Our work has revealed improved simulations as horizontal resolution is increased to .3 km.

7. Our analysis of trough timing errors has revealed mean absolute timing errors of 2-4 hours for most locations along the west coast, with larger timing error near the substantial terrain of northern California/southern Oregon.

8. Our evaluation of various model initializations reveals substantial differences in initialization quality over the Pacific, with the NCEP MRF or AVN models generally being the best. The correlation between Pacific initialization quality and forecast skill downstream is significant along the Pacific coast, but decreases over the continental U.S. Summary results are available on-line and a summary paper is now being written.

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 ensemble work is probably the cleanest test of this concept yet for short-range forecasts. The project's research 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.

REFERENCES

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

Colle, B.A., C. F. Mass, and D. Ovens, 2000: Evaluation of the timing and strength of MM5 and Eta surface trough passages over the eastern Pacific. Submitted to *Weather and Forecasting*

Colle, B. A., C. F. Mass, and K. J. Westrick, 2000: MM5 precipitation verification over the Pacific Northwest during the 1977-1999 cool seasons. Submitted to *Weather Forecasting*.

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Mass, C., D. Ovens, M. Albright, and K. Westrick, 2000: Does Increasing Horizontal Resolution Produce Better Forecasts?: The Results of Two Years of Real-Time Numerical Weather Prediction in the Pacific Northwest. Submitted to Bull. Amer. Meteor. Soc.

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