Department of Atmospheric & Oceanic Sciences
University of Wisconsin–Madison
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December 30, 1996

Ms. Victoria Johnson
COMET
UCAR, PO Box 3000
Boulder, CO 80307-3000

Dear Ms. Johnson:

Enclosed is a combined progress report for the second year of our Cooperative project with the Milwaukee/Sullivan Office and a final report on Brad Hoggatt's fellowship. We have included a hard bound copy of his Master's thesis for your library. We are preparing two journal publications based on Brad's exciting thesis results.

Also included are our proposed tasks for this next year and an accompyaning budget for the next year. As you can see, Pete Pokrandt has moved off the project (to a Department Computer Systems Analyst position) and Brad Hoggatt has now taken the position formally held by Pete. In this way we continue our close relationship with the Milwaukee/Sullivan Office. We have also begun some interaction with the Green Bay and Duluth offices which have found extensive use for our mesoscale forecasts and who are interested in pursuing research studies based on our numerical simulations of interesting lake effect storms. Both offices are also interested in pursuing very small scale forecasts of wind conditions over the lakes for their summertime marine forecasts. I believe there is a great potential for local mesoscale forecasts in that area. We would like to continue our collaboration with the NWS after this project ends, continuing to expand on our lake effect winter storms emphasis into the summertime season where we can augment local boating forecasts. We would like to continue with Milwaukee/Sullivan as the focus of our collaboration, and perhaps work with Green Bay and Duluth through partners projects. As we wrote in our future plans, we have also identified a student, Dan Lennartson, as a possible candidate for a future COMET fellowship.

We see from the weather wire forecast discussions that our model forecasts are not only being used by the Milwaukee/Sullivan office, but are being utilized by NWS forecast offices throughout the entire Western Great Lakes region. We are excited to be a part of their forecast efforts and we thank COMET for making this possible.

I realize that your program funding is even more limited than ever and so we would like some guidance on how we can keep this going. We believe that these projects have been funded at a "bare bones" level all along, but they continue because of the benefits to both the NWS and University as a result of this collaboration. I hope COMET realizes that we spend far more time than we ask to be paid for because our commitment to the ideals for which COMET stands. I think all COMET participants feel this way and we sincerely hope that the NWS realizes the degree of benefits that their offices receive from these collaborations beyond the small seed money that they put toward this effort.

If you need any more materials, please let us know.

Sincerely,

Gregory J. Tripoli
Associate Professor

COMET Yearly Report

1996

University of Wisconsin-Madison

Gregory J. Tripoli and Bradley D. Hoggatt

During the past 18 months, many operational and educational endeavors were successfully completed. The COMET project in collaboration with the Milwaukee-Sullivan National Weather Service Office has been a two-pronged endeavor with both a COMET research grant lead by Professor Greg Tripoli and a COMET fellowship which funded Brad Hoggatt providing the impetus for the beneficial interaction between the operational and research communities. Our collective efforts have been concentrated upon improving and providing mesoscale numerical guidance which is distributed to the National Weather Service in Sullivan, WI as well as the surrounding National Weather Service offices. The fellowship work focused specifically upon the feasibility of accurate high resolution operational predictions of subtle, yet important variations in lake-effect snow structures using current data assimilation and model initialization techniques. In addition, we have provided seminars and discussions regarding: 1) operationally applicable diagnostic techniques including quasi-geostrophic and semi-geostrophic theory and 2) description of the usage and composition of the University of Wisconsin-Madison Nonhydrostatic Modeling System (UW-NMS) within the context of both large scale and mesoscale (lake-effect snow) forecast situations. The ensuing paragraphs describe each of the major interactive ventures in which we have participated over the past year and a half.

I. Improvements to the UW-NM Operational Model

The UW-NMS continues to be run twice per day using a three grid configuration with the inner grid possessing 27 km horizontal spacing. The operational run has historically been performed on an IBM RS-6000, but the simulations were not being completed in a timely fashion for operational use by the National Weather Service (NWS). The NWS's desire to acquire the UW-NMS mesoscale model output prompted the purchase of an HP-755 workstation by the NWS Central Region in October, 1995. The UW-NMS had previously never been configured for an Hewlett-Packard (HP) operating system, so we had to alter copious amounts of code to take full advantage of the HP architecture. The optimization was extremely labor intensive and equated to a near rewrite of many parts of the model because of the manner in which the HP executes the various scalar and vector calculations. After many UW-NMS code alterations, the operational run was transferred to the HP in February, 1996. The reconfiguration and optimization of the UW-NMS for the HP decreased our real-time, 48-hour simulation run time from approximately 10 hours after the synoptic time to 8 hours while letting us expand the size of the mesoscale grid by about 60% and thereby include more of the Chicago, Duluth, and LaCrosse forecast areas.

We also continued to maintain and upgrade the UW-NMS home page from which our model output can be downloaded in various formats. Explicit forecasts of snowfall amounts calculated from a developed snowfall accumulation algorithm as well as freezing rain accumulations have been made available on the home page. Moreover, during the past year, UW-NMS output has been made available in gridded binary format (GRIB) on all three grids for display on the advanced weather information display system (AWIPS) used by the NWS. Some difficulty, however, has been encountered decoding the GRIB data at the NWS offices. With the help of Ralph Peterson at the National Center for Environmental Prediction (NCEP), we have been actively attempting to determine a means of alleviating the decoding problems which are not allowing the NWS offices to fully utilize our model output.

UW-NMS model physics, specifically the cumulus parameterization scheme, has been upgraded within the last six months using the information extracted from the monitored performance of the operational simulations. The operational run had been using a modified Kuo convective parameterization scheme with downdrafts. The Kuo scheme is based exclusively upon the relationship between convective rainfall and large scale moisture convergence. The extreme dependence upon large scale moisture convergence and not upon instability or vertical motion occasionally creates problems where convection is initiated in the wrong location or not initiated at all. If instability and vertical motion both support convection but the cumulus parameterization does not activate, the explicit gridscale convection (nonhydrostatic dynamics allow for the explicit representation of convective processes) will activate creating a cumulus cloud which consumes all of a gridbox. On the inner 27 km grid, explicit convection does not pose serious problems. However, the 80 and

160 km domains suffer if explicit convection is allowed to proceed. The presence of a 160x160 km or a 80x80 km cumulus cloud and the accompanying latent heat release generate anomalous tropospheric flow patterns which feedback upon the large scale decreasing the integrity of the solution. To circumvent this problem, an Emanuel cumulus parameterization scheme modified by Greg Tripoli has been employed. The modified Emanuel scheme is primarily driven by both the background vertical motion and convective instability. The application of the modified Emanuel scheme has reduced the occurrences of anomalous convective complexes.

As mentioned above, the 27 km grid has been expanded during the past year to include all of the Western Great Lakes lake-effect snow belts (figure 1). The expansion was performed at the request of the Chicago, Indianapolis, Green Bay, and Duluth National Weather Service (NWS) Offices. Because of the increased model efficiency, we were able to complete our forecasts within the time window required by NWS operations. The operational 27 km grid has allowed us to simulate and study various lake-effect snow structures including shoreline-parallel bands, mesoscale vortices, the mean effects of wind-parallel rolls.

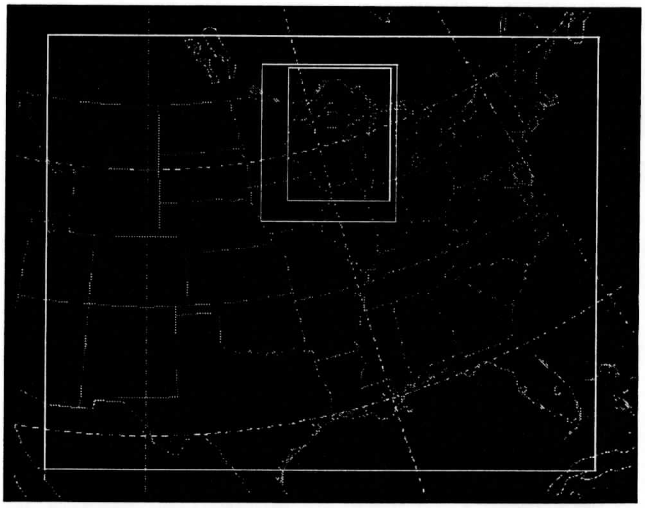


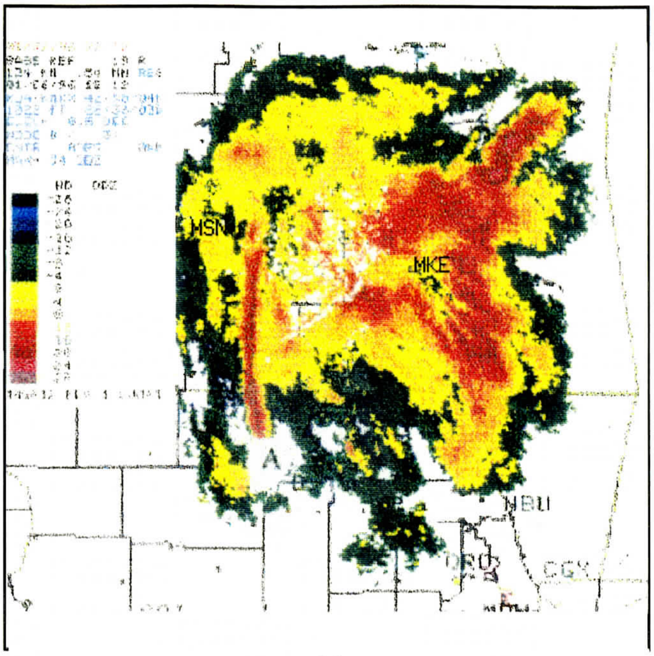
Figure 1 UW-NMS expanded 27 km inner grid with previous inner grid configuration included.

II. Lake-Effect Snow Study (Master's Thesis Completed by Brad Hoggatt June 1996)

The expanded inner grid and its ability to simulate lake-effect snow structures with skillful accuracy has created a heightened sense of interest for the UW-NMS. More specifically, both the Duluth and Green Bay offices in addition to the Sullivan office are actively communicating and participating with the UW-NMS modeling group. High resolution UW-NMS simulations (horizontal resolutions of 10 km or less) have been performed for each office attempting to achieve a greater understanding of the underlying forcing mechanisms responsible for the various modes of and variations in lake-effect snow convection.

Under the support of a COMET Fellowship and as a NWS employee, Brad completed a Master's Thesis in June 1996 on lake-effect snows. Hoggatt collaborating with the Sullivan, WI NWS office numerically investigated two lake-effect snowstorms which exhibited peculiar structural variability. Using initial and boundary conditions provided by NCEP's ETA model, high resolution multiple two-way nested UW-NMS simulations with a minimum grid spacing of 4.5 km were performed. The high resolution simulations were able to capture much of the small scale variability despite the use of initial conditions deficient in meso-β scale information. Figure 2 is a comparison between an 18 hour 4.5 km UW-NMS forecast of ageostrophic winds and vertical motion and the accompanying radar reflectivity plot. The simulated position of the quasi-linear, westward propagating precipitation band (labeled "A") accompanying the westward propagating gravity wave coincides with the observed position. The 4.5 km simulation was able to capture gravity

A)



B)

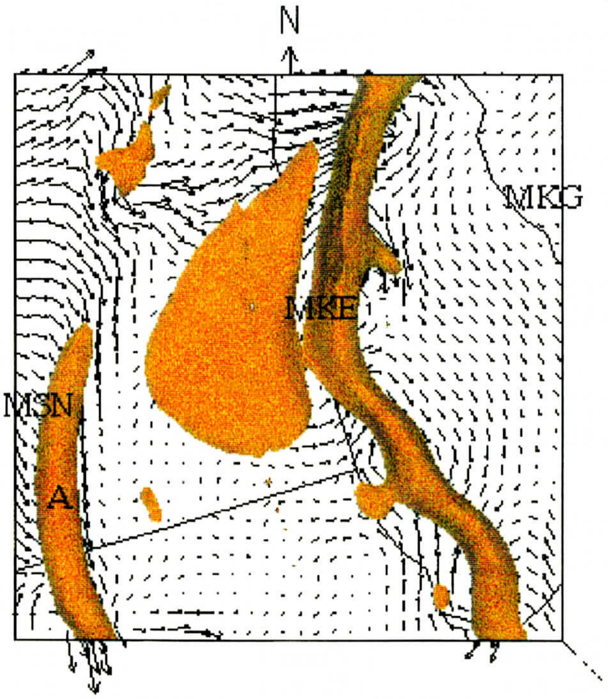


Figure 2 (A) Milwaukee-Sullivan WSR-88D reflectivity data measured at 1812 UTC using a .5 degree elevation angle in clear air mode. (B) UW-NMS simulated 10 cm/s isosurface of vertical motion and 250 m ageostrophic wind vectors. The UW-NMS simulation is valid at the same time as the radar image. Inland propagating quasi-linear precipitation structure labeled "A".

wave initiation by the deformation of the boundary layer capping inversion through an increase in the convective intensity of the shoreline parallel band. In the same simulation, the UW-NMS was able to resolve observed banded precipitation structures (not shown) oriented downwind of and parallel to the shoreline parallel band. These banded precipitation structures were shown to be forced by lee gravity waves excited by the shoreline parallel band acting as an obstacle in the large scale easterly flow.

The UW-NMS simulation in support of the second lake-effect snow case also proved to be successful as a transient sinusoidal disturbance which propagated southward along a shoreline parallel band was resolved. The dynamics responsible for the sinusoidal disturbance were linked to gravity waves initiated by northerly flow impinging upon the elevated terrain of the Upper Peninsula of Michigan. The large scale flow provided the wave trapping mechanism in the form of a sloped cold frontal zone. The vertical gradient of Brunt-Vasailla frequency provided by the cold frontal zone formed a duct in which the gravity waves were able to amplify sufficiently to induce a local wind field anomaly that perturbed the shoreline parallel band. The observed variability found in the two investigated cases was shown to evolve from the interaction of predictable large scale flows with well-resolved small scale topography and land surface differences and not upon small scale perturbations not captured by conventional initialization procedures. The results showed that lake-effect snow structures including the small scale variations are likely predictable out to several days provided the large scale forecast is accurate. The conclusions drawn from these collaborative case studies were presented by Greg Tripoli and Brad Hoggatt at the NWS Lake-Effect Snow Conferences in Washington, D.C. and Norman, OK respectively. We are also preparing two publications to be submitted to ***Weather and Forecasting*** and ***Monthly Weather Review*** on these subjects.

III. Collaborations with Duluth and Green Bay NWS Offices

Preliminary simulations (10 km horizontal simulation) in support of Green Bay and Duluth have also been performed to more conclusively determine whether lake-effect snow structures are predictable using initial data deficient in mesoscale information. Once again, the UW-NMS produced precipitation and wind fields resembling the observed with both offices being impressed. These simulations were presented by Gene Brussky (Green Bay) and Brad Bramer (Duluth) at the recent NWS Winter Weather Workshop in Michigan. We plan to submit a proposal at a later date in support of the collaborative effort between Duluth, Green Bay, and ourselves.

IV. Quantitative Precipitation Forecast Verification

Besides lake-effect snow forecasting and research, we have been developing a quantitative precipitation forecast (QPF) verification scheme in conjunction with the Sullivan NWS office. By comparing observed precipitation amounts for each of the river basins in Wisconsin with operational UW-NMS QPF for each basin, we are quantitatively determining model performance for all types of atmospheric flow patterns. The basin rainfall data is prepared at the River Forecast Center (RFC) in Minneapolis and broadcasted to us by the Sullivan office on a daily basis. The quantitative evaluation of model performance will allow us to archive and directly compare our model performance with the various other numerical models rather than simply perform subjective, qualitative , case-specific comparisons.

V. NWS Sullivan Synoptic-Dynamics Seminar

Additionally, several seminars were given by Brad Hoggatt at the Sullivan NWS office during the months of January and February, 1996. The all-day seminars were divided into two parts. The first half provided the forecasters with a review of basic thermodynamic and dynamic principals including: the equations of motion, first law of thermodynamics, geostrophy, hydrostatic balance, thermal wind, and ageostrophy. In this section, differences between hydrostatic and nonhydrostatic models were discussed with particular emphasis placed upon the ability of nonhydrostatic models, the UW-NMS, to explicitly simulate convection and capture trapped internal gravity waves. Brad Hoggatt also encouraged discussions regarding various physics packages including the use and ramifications of cumulus parameterization schemes. In the afternoon session, the rudimentary concepts discussed in the morning session were utilized to form the basis of quasi-geostrophic (QG) and semi-geostrophic (SG) theory including: QG omega and height tendency equations, **Q** vectors, QG frontogenesis, Petterson frontogenesis (SG). These various diagnostic tools were then used to rediagnose a major forecast bust which occurred on January 18, 1996 over the southeast half of Wisconsin. The participants used both hand analysis and PCGRIDDS to investigate the relevance of QG and SG theory to the case in question. It was stressed that these diagnostic tools provide a means of better understanding the fundamental forcing mechanisms and are not meant to "beat" the model using model output. By understanding the processes responsible for the evolution of vertical motion and accompanying precipitation, one is able better analyze the initial fields as well as determine whether a numerical model is consistent with itself ie. whether the cumulus, surface layer, or other parameterizations were corrupting the solution.

VI. Space Science and Engineering Center (SSEC)

The text describing the accomplishments of SSEC during the past year will be sent in a separate package.

VII. Third Year Tasks

For the next year, our collaboration with the NWS will continue to expand. We expect to implement quantitative verifications algorithms, continue to improve the model forecasts, and improve the ability of forecasters to compare model output from different NWS and local models. Moreover, we hope to participate in the NSF sponsored Lake-ICE program. The project will lead to major advances in the understanding, modeling, and forecasting of lake-effect snowstorms over Lake Michigan in particular. Through our continued collaboration with the NWS Sullivan office, new discoveries and technologies will immediately find their way into the operational environment. Our specific plans include:

- Acquisition and incorporation of gridded Great Lake temperature data
- Perform statistical analyses of the hydrological basins QPF to evaluate model performance
- Investigate possible methodologies for the sectorization and reconstruction of the cumbersome mesoscale grids for initialization and verification purposes.
- Incorporate 12 hour forecast information from the previous operational run into the initialization to provide initial mesoscale information to reduce spin-up time.
- Prepare and present seminars discussing the UW-NMS and various other models with particular emphasis placed upon the differences. The seminars also will contain an overview of the entire numerical modeling process from the observations to objective analysis to the actual integration. Various surrounding NWS offices have expressed interest in such a seminar.
- Submit two papers for publication in ***Weather and Forecasting*** and ***Monthly Weather Review*** based upon the observed lake-effect snow variability studied in Hoggatt's Masters Thesis. This endeavor is currently underway.
- Perform a case study in conjunction with the Sullivan NWS office of an interesting southeast Wisconsin lake-effect snow event for future publication.

We also hope to expand our new and exciting collaborations with the Duluth and Green Bay offices. We expect to submit a Partners Project funding request in this regard. Moreover, we currently are working with a student, Dan Lannertson, who we feel would be a good candidate for a COMET Fellowship thereby facilitating our continued collaboration with the operational community.

Budget: Cooperative Program between NWS-Sullivan and the University of Wisconsin-Madison
Year 3: 1 September 1996 - 31 August 1997

		Hours	Rate	Cost	
I.	Labor and Fringe Benefits				
	a) Co-PI (Smith)	0	n/c	$ 0	
	b) Co-PI (Tripoli)	261	42.46	11,082	
	c) Scientist-Mesoscale Modelling	440	21.12	9,293	
	d) Scientist-GOES	0	34.55	0	
	e) Scientist-ASOS	0	30.92	0	
	f) NOAA/NESDIS Scientist Support*	0	n/c	0	
	Subtotal				$20,375
II.	Travel				
	12 trips/2people/1day each/Sullivan - Madison				351
III.	University Indirect Cost at 44%				9,119
	TOTAL				$29,845

*NOAA/NESDIS support is at no cost to this grant

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