From *Preprints of the 10th Conference on Numerical Weather Prediction*, July 18-22, 1994, Portland, OR. American Meteorological Society, Boston MA, 369-371.

10B.5

THE OPERATIONAL MULTI-SCALE ENVIRONMENT MODEL WITH GRID ADAPTIVITY (OMEGA)
PART II. SIMULATIONS OF LOCAL CIRCULATIONS

Z. Boybeyi, D. P. Bacon, T. J. Dunn, Y-L. Ho, M. D. McCorcle, S. E. Peckham, R. A. Sarma,
S. Young*, and J. Zack*

Applied Physics Operation
Science Applications International Corporation, 1710 Goodridge Dr., McLean, VA 22102

1. INTRODUCTION

Current operational atmospheric simulation systems are scale specific (Hoke *et al.*, 1989) and cannot resolve the full spectrum required for the accurate forecast of local scale phenomena. The Operational Multi-scale Environment model with Grid Adaptivity (OMEGA) is a new atmospheric simulation system that merges state-of-the-art computational fluid dynamics techniques with a non-hydrostatic equation set. OMEGA is based upon an unstructured triangular prism grid that permits a horizontal resolution ranging from 100 km to 1 km and a vertical resolution from a few tens of meters to 1 km in the free atmosphere.

This paper presents an application of OMEGA to simulations of sea breezes over the Florida peninsula. Due to its unique peninsular geography, Florida provides an excellent oppurtunity to investigate the relationship between sea breeze convergence and convection. The peninsula has the highest annual number of days with thunderstorms in the United States during summer days because of sea breeze convergence caused by differential heating between the peninsula and the ocean. The prevailing large-scale flow is generally from the southwest or the southeast depending on synoptic weather.

2. MODEL DESCRIPTION

OMEGA uses a fully non-hydrostatic equation set to describe the dynamics. OMEGA physics include bulk-water microphysics, a convective parameterization scheme, and a radiation scheme which approximates the effects of carbon dioxide and water vapor on the radiation budget. OMEGA also contains an extensive planetary boundary layer package with 1st and 1.5 order $\kappa - \varepsilon$ turbulence closure schemes. Finally, embedded within OMEGA are both Eulerian and Lagrangian aerosol transport modules.

3. DISCUSSION OF RESULTS

As an example, OMEGA is applied to an idealized sea breeze simulation over the Florida peninsula.. A computational domain of roughly 600 km by 700 km by 6.5 km was defined with a grid consisting of 3929 triangles (ranging from 4 to 20 km edge length) in each of 23 layers for a total of roughly 90,000 cells (Figure 1).

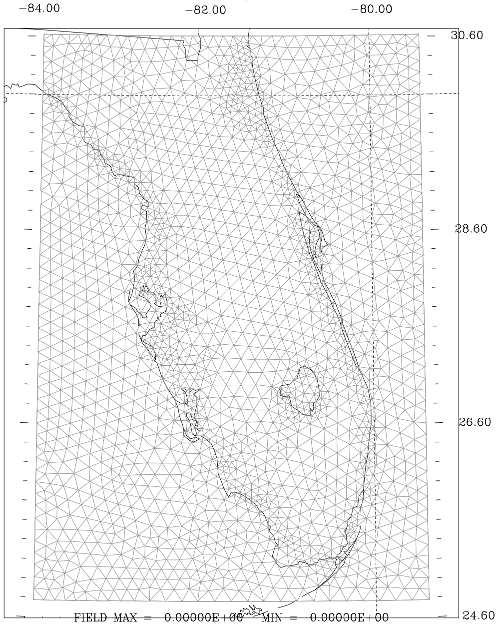

Figure 1. OMEGA grid over Florida

The unstructured triangular prism computational mesh. is unstructured in the horizontal dimension and structured in the vertical dimension. The flexibility of unstructured meshes facilitates the gridding of arbitrary surfaces and volumes in three dimensions. In particular, unstructured grid cells in the horizontal dimension can increase local resolution to better capture topography or the important physical features of atmospheric circulation flows and cloud dynamics. The grid shown in Figure 1 has high resolution in the vicinity of coastlines and surface property boundaries. Note that, for comparison, a rectangular grid with 4 km resolution would require 26,250 horizontal cells in each of the 23 layers for a total of nearly 600,000 cells.

---

* MESO, Inc., Rensselaer Tech Park, 185 Jordan RD, Troy, NY 12180

OMEGA is also naturally scale spanning because its unstructured grid permits the addition of grid elements at any point in space and time. This means that OMEGA can readily adapt its grid to stationary surface or terrain features, or to dynamic features in the evolving weather pattern.

A southwesterly uniform flow of 6.0 m/s is used for a typical summer day under the assumption that neither frontal nor tropical systems are present during the simulation. Figure 2 shows the low-level horizontal wind vectors (at about 100 m AGL) after 3, 6, 9 and 11 hours of OMEGA simulation.

During the day, the continuous differential heating between the land and the water and the resulting vertical thermal mixing in the planetary boundary layer creates a lower pressure region at the surface. In response to this pressure fall, the southwesterly winds turn inland along both east and west coasts of the peninsula and increase in speed due to the acceleration of the air towards the lower pressure region. The southwesterly flow becomes nearly easterly along the east coast and westerly along the west coast. The mesoscale easterly flow opposing the southwesterly flow causes a well defined primary sea breeze convergence zone along the east coast. A weaker secondary convergence zone along the west coast also forms due to the horizontal temperature gradient between the land and the water. This convergence zone is not as intense as the one near the east coast because the ambient wind is in the same direction as the local

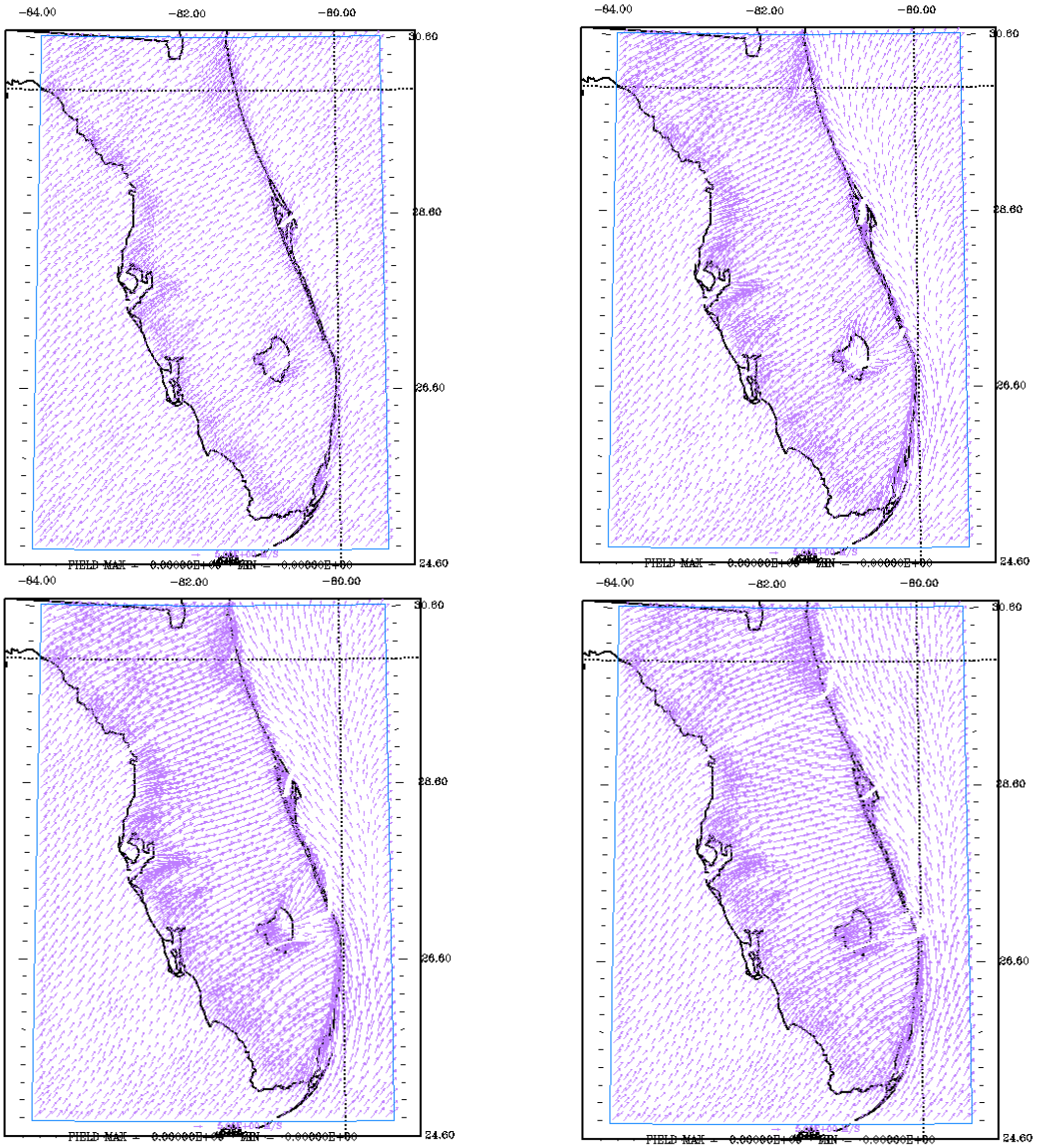

Figure 2. Low level horizontal wind vectors after 3, 6, 9, and 11 hours of OMEGA simulation.

sea breeze.

During the simulation, onshore winds along both the west and the east coasts continuously advect relatively cooler marine air over land. This results in inland advection of the temperature gradient and hence, the convergence zones. Inland penetration of the convergence zones is generally controlled by the intensity of the total heat input to the air and magnitude of the ambient wind (Pielke, 1974). The secondary convergence zone along the west coast moves inland farther than the east coast convergence zone since there is no opposing flow along the west coast, while the convergence zone along the west coast shows very little movement due to the opposing ambient flow (Boybeyi and Raman, 1992). Note that these results clearly indicate preferred regions for convective activity, such as the area surrounding the Kennedy Space Center and the east coast of Florida in general.

The model results also show that Lake Okeechobee in south Florida generates its own mesoscale circulation because of its large size. A divergent region over the lake is predicted during the simulation indicating the existence of a cloud free region over the lake.

Figure 3 shows the centroid of the series of continuos Lagrangian tracers releases from three sites after 11 hours of simulation. In addition to the Lagrangian transport, Figure 3 also shows the logarithmic contours for the Eulerian dispersion from the same release points (there is a factor of ten between the concentration contours).

The three plume configurations clearly shows the influence of the enhanced sea breeze circulation. The Eulerian transport is not an exact match to the Lagrangian situation since the source is effectively an areal as opposed to a point source. Nevertheless, the agreement between the Eulerian and Lagrangian plume trajectories is quite good.

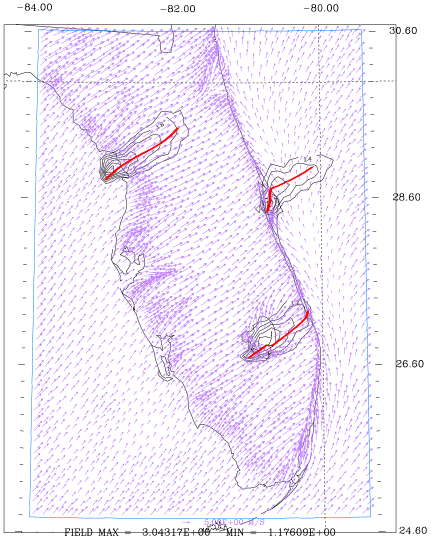

Figure 3. Simulation of Lagrangian and Eulerian aerosal transport in a Florida sea breeze circulation using OMEGA

4. CONCLUSIONS

OMEGA represents a departure from traditional methods used for atmospheric simulation. For the first time in recent years, advanced numerical methods developed by the computational fluid dynamics community have been applied to the problem. This has permitted the development of an extremely high resolution atmospheric simulation tool.

Acknowledgments

The OMEGA team wish to thank Dr. I. Lottati of SAIC for providing invaluable support in grid generation techniques and our past and present Technical Monitors, Dr. C. Gallaway, Dr. M. Byers, Dr. J. Hodge, and Dr. R. Cox of the Defense Nuclear Agency for their collaboration and support which has considerably improved the model.

This work is supported by the Defense Nuclear Agency under contract DNA001-92-C0076.

References

Boybeyi, Z., and S. Raman, 1992: A three-dimensional numerical sensitivity study of convection over the Florida peninsula. *Boundary Layer Meteorol.*, **60**, 325-359.

Dudia, J., 1993: A nonhydrostatic version of the Penn State/NCAR mesoscale model: Validation tests and simulation of an Atlantic cyclone and cold front. *Mon. Wea. Rew.*, **121**, 1493-1513.

Hoke, J.E., N.A. Phillips, G.J. DiMego, J.J. Tuccillo, and J.G. Sela, 1989: The regional analysis and forecast system of the National Meteorological Center. *Wea. Forecasting*, **4**, 323-334.

McPherson, R., 1991: 2001 - An NMC Odyssey, *Ninth Conf. on Num. Wea. Prediction*, AMS, Boston, MA.

Pielke, R. A., 1974: A three-dimensional numerical model of the sea breezes over south Florida. *Mon. Wea. Rev.*, **102**, 115-139.