1.10 INTEGRATED EFFECTS OF MESOSCALE CONVECTION ON THE DEVELOPMENT OF AN EXPLOSIVE WEST COAST MARINE CYCLONE

Douglas K. Miller and Wendell A. Nuss
Naval Postgraduate School, Monterey, California

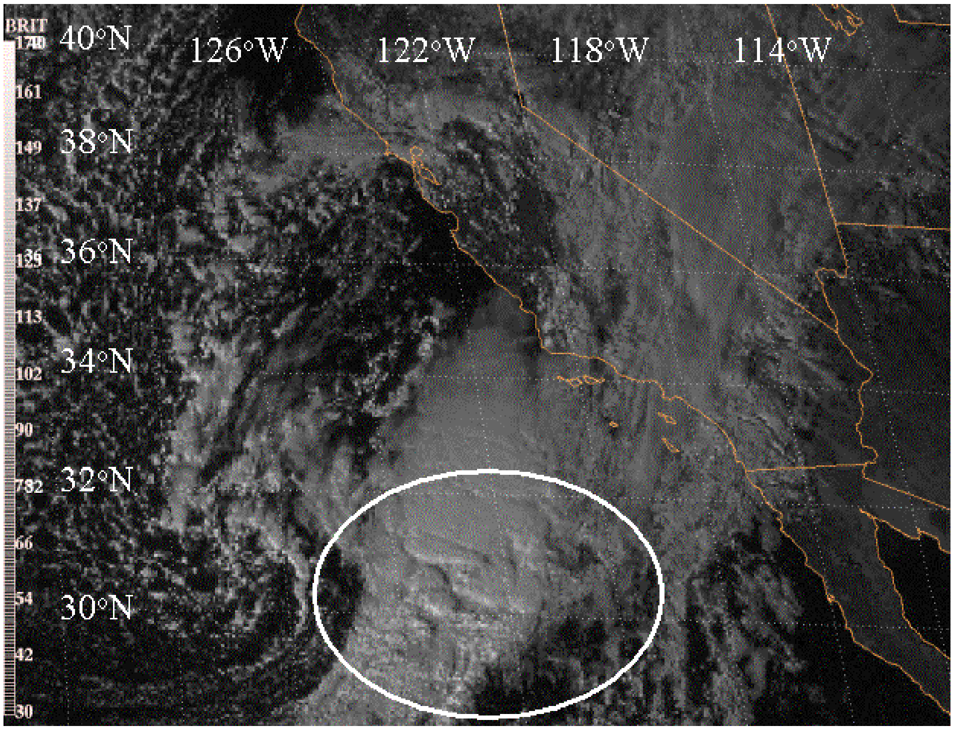

Figure 1: *GOES-10 4-km visible image valid 0000 UTC 13 Feb 2001. Oval highlights region of apparent convective activity.*

1. INTRODUCTION

A coastal winter storm developed rapidly off of Southern California on 12 February 2001 and proceeded to disrupt travel corridors in the vicinity of the California Bight region over the next day. Reports from various locations indicated significant snow accumulations occurred in the mountains surrounding the LA Basin, while significant rain accumulations within the basin itself resulted in numerous instances of urban flooding and mudslides in the lower elevations of the Santa Ana Mountains (Storm Data, 2001). Observations also indicated "a fast moving squall line behind the main frontal band knocked down trees and power lines…" (Storm Data, 2001), hinting at a significant contribution to the storm structure by mesoscale convective elements. Figure 1 shows the visible GOES-10 satellite image valid at 0000 UTC 13 Feb 2001 on which an oval has been drawn to highlight a region exhibiting convective cloud structure. Analysis of the development phase of this cyclone using observations would be impossible using the existing standard network. However, the Pacific Landfalling Jets Experiment (PACJET) had deployed fixed and mobile observing platforms that greatly assist in filling in the standard observation gaps. Supplementing the standard observations with those of the PACJET intensive observation period helps improve understanding, but gaps still remain due to the apparently strong contribution to storm development by small-scale convective effects alluded to earlier. For this reason, the full-physics mesoscale model of the U.S. Navy (COAMPS™) is applied in order to estimate the integrated effects of mesoscale convection on the development of the explosive west coast marine cyclone of 13 February 2001.

**Corresponding author address*: Douglas Miller, Department of Meteorology, Naval Postgraduate School, Monterey, CA 93943; email: dkmiller@nps.navy.mil.

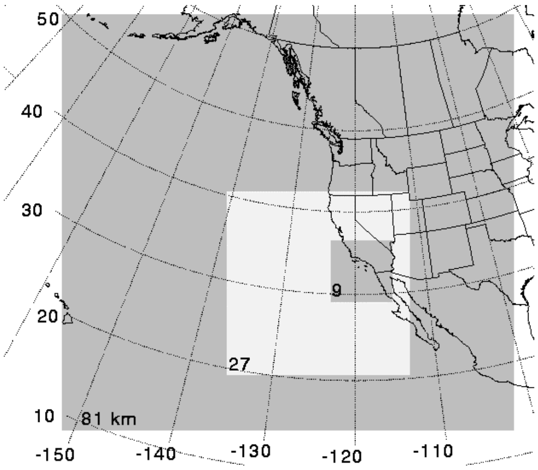

Figure 2: *COAMPS nested grid configuration with grid spacings decreasing from 81 to 9 km in multiples of 3.*

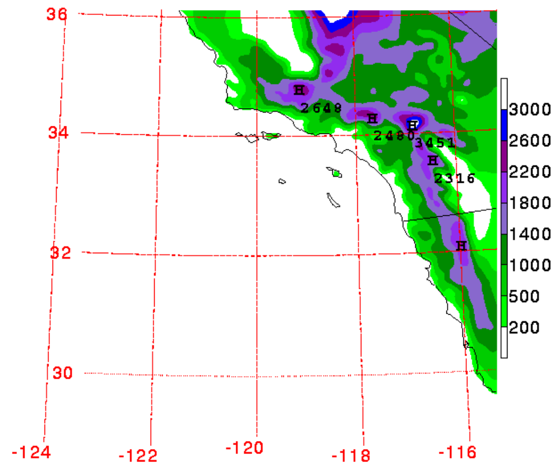

Figure 3: *COAMPS 9 km domain terrain elevation (m).*

2. BACKGROUND

The mesoscale model domain configuration, whose location is shown in Figure 2, consists of three nested domains ranging from 81 to 9 km grid spacing, with a grid spacing ratio of 3 between consecutive domains.

The model top was prescribed to be at 20 km with 47 vertical levels from the surface to model top. Each mesoscale model forecast consists of a 24-h simulation generated using a "cold-start" approach, wherein the initial conditions have been computed using two-dimensional multiquadric univariate interpolation (2DMQ, Nuss and Titley 1994) blending available National Weather Service observations with the U.S. Navy Operational Global Atmospheric Prediction System (NOGAPS) model forecast fields for creating initial and lateral boundary conditions of the outermost domain updated every 12 hours. The Kain-Fritsch convective parameterization scheme is active for only the 27 and 81 km domains. One-way nesting is prescribed so that information is communicated through the lateral boundaries of the inner domains from the mother domain.

The 9 km COAMPS^{TM} domain terrain elevation field generated for the simulations (Figure 3) shows the coastal mountains that form a wall along the California Bight southward into Mexico and whose peaks reach to nearly 3500 m above sea level.

Previous simulations intended to examine the sensitivity of the model solution to the structure of the Sea Surface Temperature (SST) field (Nuss and Miller, 2003) yielded moderate development for the full-physics simulation and explosive development for the no-flux simulation. It was hypothesized, based on the analysis of Touchton (2002), that the incipient NOGAPS cyclone was shifted too far to the east. Touchton's analysis also shed light on the complicated three-dimensional structure of the storm; multiple surface low centers and apparent "multiple fronts", seemingly confirmed in satellite IR and scatterometer observations and in PACJET flight-level and dropsonde observations.

The synoptic pattern as derived from the U.S. Navy NOGAPS model analyses blended with available standard (PACJET observations have been excluded) surface and upper-air observations valid at 0000 UTC 13 February 2001 (Figures 4 – 6) shows a positively tilted trough at the 250 hPa level (Fig. 4) which indicates a jet streak directed toward the Baja Peninsula having a maximum wind speed just above 70 m s^{-1}. North of the jet streak is a warm pool at 250 hPa (not shown) centered in the trough indicative of warm thermal advection in the upper troposphere downstream of the trough. The 500 hPa level pattern (Fig. 5) indicates positive vorticity advection occurring downstream of the trough, corresponding to the position of the developing surface cyclone (Fig. 6) located at 31^{o}N, 122^{o}W. The incipient surface cyclone is collocated with a lower-tropospheric baroclinic zone associated with the trough evident at the 250 and 500 hPa levels.

Touchton (2002) analyzed the 13 Feb 2001 case and determined that it had deepened 14 hPa from 0000 to 1200 UTC, exceeding most thresholds for categorizing this cyclone as having undergone

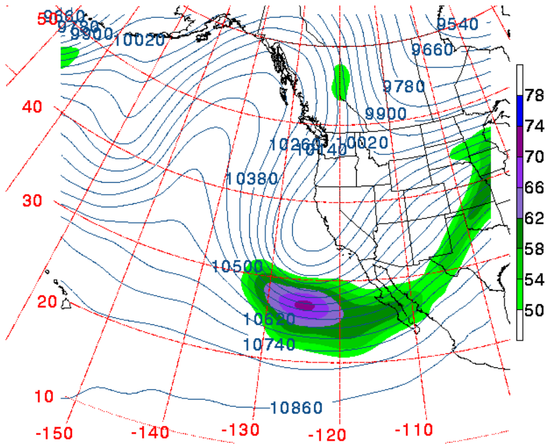

Figure 4: *Geopotential height (m, contours) and isotachs (m s^{-1}, shading) at the 250 hPa level valid at 0000 UTC 13 FEB 2001.*

rapid cyclogenesis. Most operational numerical weather prediction guidance from the National Center for Environmental Prediction and U.S. Navy global and mesoscale simulations under-predicted both the cyclone intensity and its intensification rate. The surface and upper-air analyses used to initialize the operational global and mesoscale models were consistent in depicting a surface cyclone with favorable synoptic scale upper-tropospheric/ lower-stratospheric dry dynamic and thermodynamic support for development.

Results from Nuss and Miller (2003) indicated that mesoscale model simulations of this case are quite sensitive to the influence of surface fluxes. The full-physics simulation showed (Figure 7) a broad area of 24-h accumulated precipitation amounts in excess of one inch over the ocean, a position corresponding to the location of the upper level trough. The no surface flux simulation showed (Figure 8) a reduced amount of accumulated precipitation over the ocean. These differences arise by 12 hours into the simulation, evident in the full-physics (Figure 9) and no surface flux (Figure 10) sea level pressure patterns. The differences in latent heating over the ocean resulted in a less intense upper-level trough in the full-physics simulation (Figure 11) than in the no surface flux simulation (Figure 12). These results were linked to significant differences in low-level stratification, evident in a comparison of the simulated warm sector sounding at 31.5^{o}N, 120.5^{o}W for the full-physics (Figure 13) and no surface flux (Figure 14) simulations, the former showing weaker stratification. As a result, convection was more widespread and severe in the full-physics simulation that yielded a weaker storm and smaller

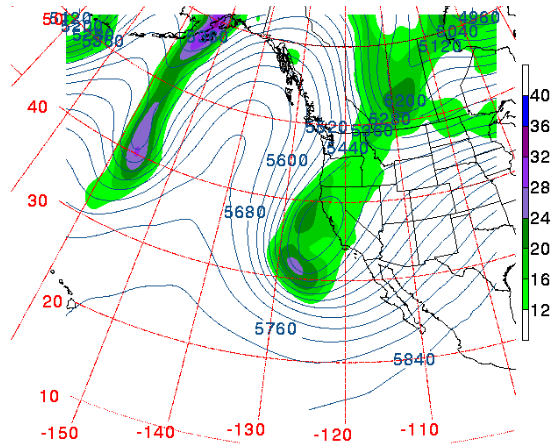

Figure 5: *As in Figure 4, except absolute vorticity (x 10^{-5} s^{-1}, shading) at the 500 hPa level.*

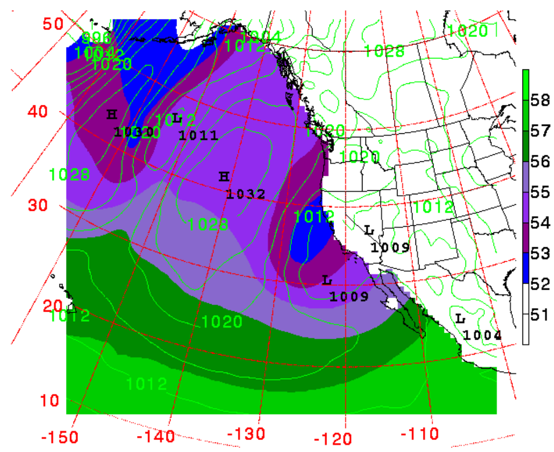

Figure 6: *Mean sea level pressure (hPa, contours) and 1000-500 hPa thickness (hm, shading) valid at 0000 UTC 13 FEB 2001.*

intensification rate.

3. PRELIMINARY NUMERICAL RESULTS

The poor performance of operational models and of the original full-physics COAMPS^{TM} simulation for this particular case study raise the concern that mesoscale convective elements generated by inaccurate intial conditions can significantly inhibit synoptic-scale cyclone development for weather regimes when moist processes play an important role.

To this end, several numerical experiments are in the process of being tested and the results will be discussed in greater detail at the oral presentation. Preliminary results for this case suggest that generating convection in the wrong temporal or spatial location undermines the favorable synoptic-scale pattern for explosive development. Several

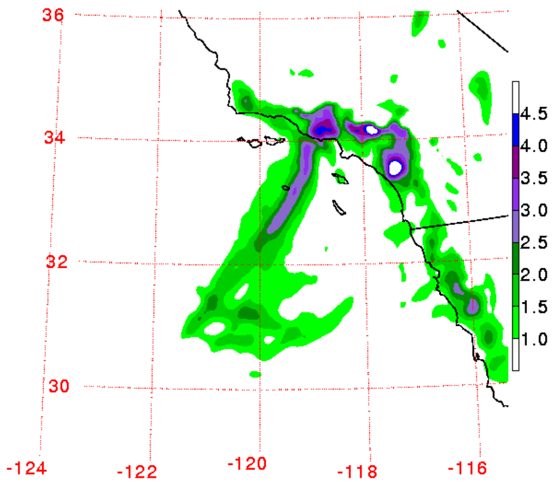

Figure 7: *Simulated full-physics 24-h accumulated precipitation (in., shading) valid at 0000 UTC 14 FEB 2001.*

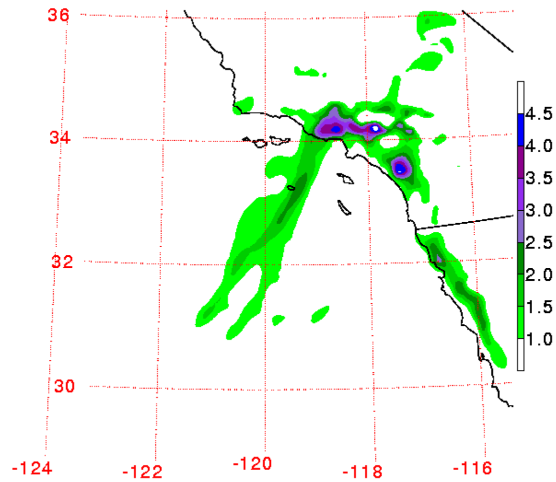

Figure 8: *As in Figure 7, except for no surface flux simulation.*

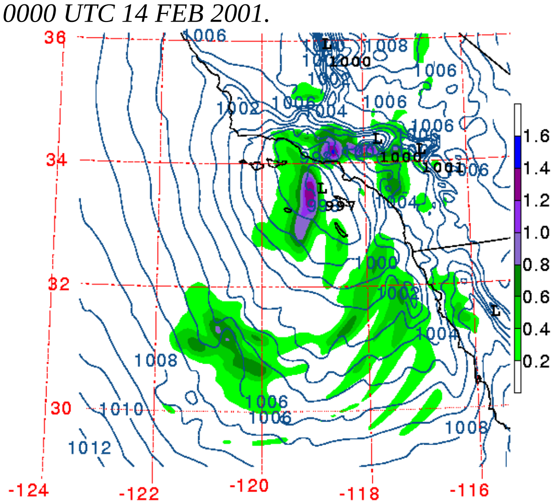

Figure 9: *Simulated full-physics mean sea level pressure (hPa, contours) and 3-h accumulated precipitation (in., shading) valid at 1200 UTC 13 FEB 2001.*

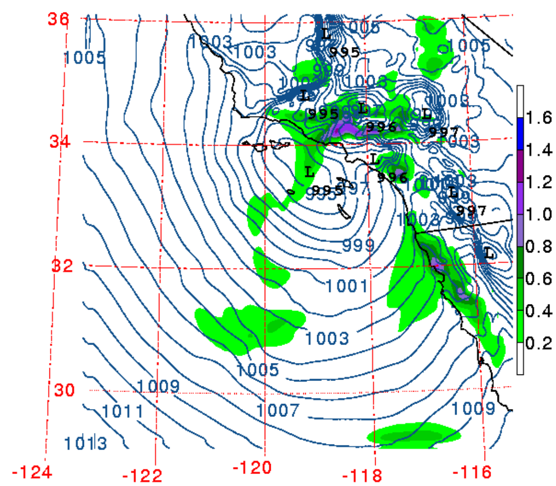

Figure 10: *As in Figure 9, except for no surface flux simulation.*

tests in which the NOGAPS atmospheric features have been shifted one, two, and three degrees in longitude toward the west for a fixed SST analysis have been examined and show no significant improvement relative to sea-level pressure and precipitation observations when compared to the original full-physics simulation.

Initial conditions created using additional observations from PACJET and cloud-track wind observations blended with the non-shifted NOGAPS analyses results in a simulation having a weak intensification rate for the 13 February 2001 cyclone.

New experiments such as uniformly increasing the atmospheric boundary layer stratification and shifting the NOGAPS analyses while blending with available PACJET and cloud-track observations remain to be tested.

4. SUMMARY

Observations and numerical simulations indicate that mesoscale convection played a significant role in the development of a case of rapid marine cyclogenesis that took place over the California Bight on 13 February 2001. Numerical simulations of this case are quite sensitive to the integrated effects of moist convection. The most realistic

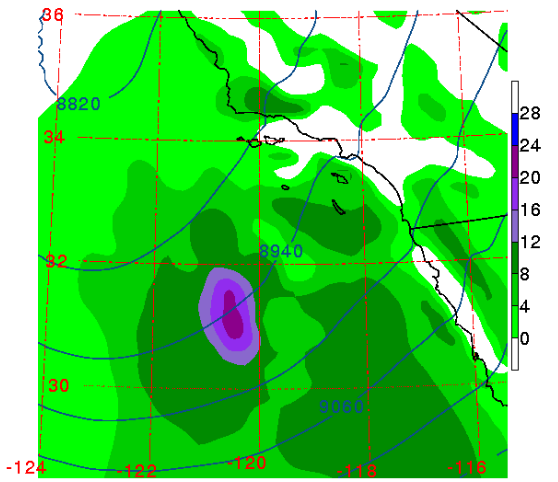

Figure 11: *Simulated full-physics 300 hPa geopotential height (m, contours) and advection of equivalent potential temperature (x10^{-5} K s^{-1}, shading) valid at 0600 UTC 13 FEB 2001.*

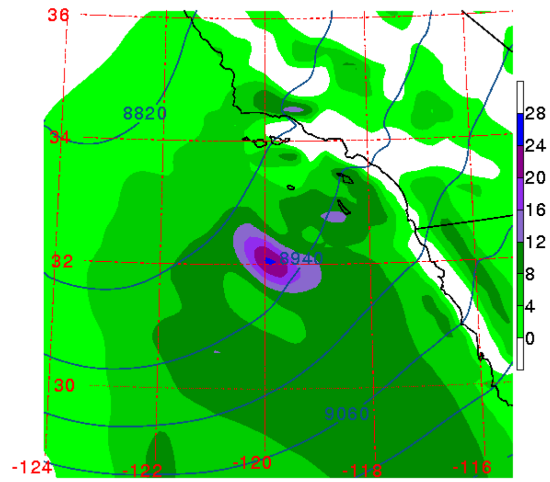

Figure 12: *As in Figure 11, except for no surface flux simulation.*

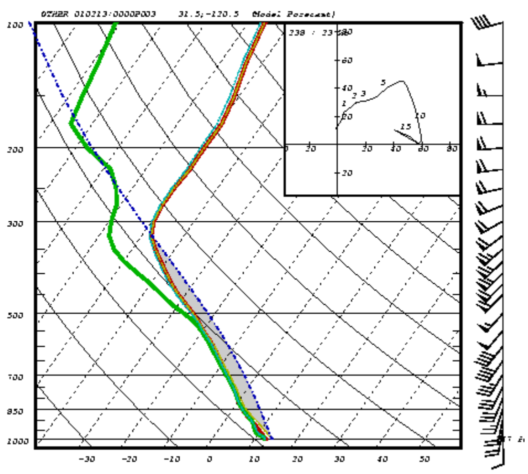

Figure 13: *Simulated full-physics skew-T at location 31.5^{o}N, 120.5^{o}W (in warm sector) valid at 0300 UTC 13 FEB 2001. Available buoyant energy for a lifted surface parcel is shaded.*

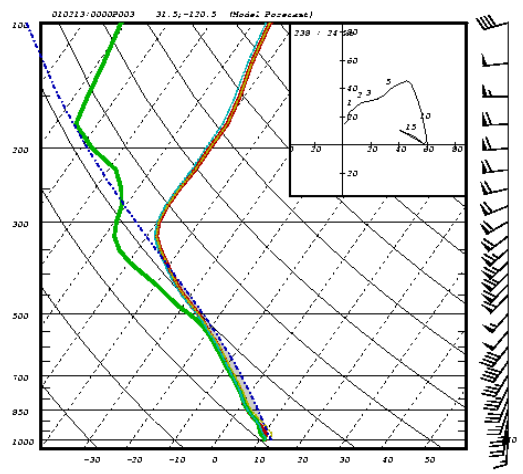

Figure 14: *As in Figure 13, except for no surface flux simulation.*

simulation to date occurs when the effects of surface fluxes have been disabled over the 24-h period of development. The implication is that convection in the full-physics simulations is being initiated in a position that damps the upper-tropospheric wave, resulting in only moderate surface cyclone intensification rates.

5. REFERENCES

Nuss, W. A. and D. K. Miller, 2003: Revisiting the effects of surface fluxes on rapid marine cyclogenesis. Preprints of the 12th Conference on Interactions of the Sea and Atmosphere, Long Beach, California, February 9 – 13.

Nuss, W. A. and D. W. Titley, 1994: Use of multiquadric interpolation for meteorological objective analysis. *Mon. Wea. Rev.,* **122,** 1611-1631.

Storm Data, 2001. National Climate Data Center, February, **43**, 2, 180pp.

Touchton, M.E., 2002: Examination of the 13 February 2001 Eastern Pacific maritime cyclogenesis. M.S. Thesis, Naval Postgraduate School, Monterey, CA, 47pp.