P3.24 DIAGNOSES AND NUMERICAL SIMULATIONS OF TURBULENCE IN THE VICINITY OF COASTAL TOPOGRAPHY

Douglas K. Miller and Donald L. Walters
Naval Postgraduate School, Monterey, California

1. INTRODUCTION

The ability to forecast turbulence using mesoscale atmospheric models has proven challenging because of the complexities of the dynamic processes responsible for its genesis. The necessity of turbulence forecasts has become clear for applications within the aviation industry, the astronomical community, and for effective laser-based defense programs. The challenge of utilizing today's mesoscale models for generating deterministic turbulence forecasts has been documented by Walters and Miller (1999). In the case presented, Walters and Miller (1999) showed that a modification of the shear and buoyancy contributions to the simulated turbulent kinetic energy (TKE) using a Mellor-Yamada 2.5 parameterization (Mellor and Yamada 1982; Yamada 1975) resulted in model predictions which had more realistic TKE magnitudes when compared to radar, balloon, and wind tunnel measurements. Walters and Miller (1999) and Miller and Walters (2001) demonstrated a methodology for computing optical turbulence (Cn^2), relevant to space observing and missile defense programs, from mesoscale model TKE predictions. This methodology proved to give reliable turbulence trends but was shown to be quite sensitive for conditions of (1) high wind shear at nighttime near the surface, (2) topographically induced gravity waves aloft, and (3) within the elevated Planetary Boundary Layer (PBL). The work presented in this study will investigate optical turbulence in the vicinity of coastal topography using a robust method for computing optical turbulence that avoids the sensitivities of the method derived from mesoscale model TKE predictions. The numerical simulations used in generating the results for this study will be defined in Section 2, the synoptic conditions for the October 2001 case study will be presented in Section 3, preliminary model results will be given in Section 4, and a summary of the study will be made in Section 5.

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

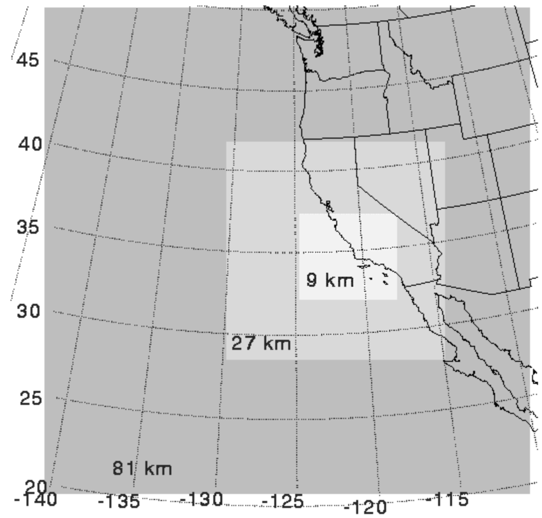

Figure 1: *COAMPS nested grid configuration with grid spacings decreasing from 81 to 9 km in multiples of 3.*

2. NUMERICAL SIMULATIONS

The simulations utilize both the U.S. Navy Coupled Ocean Atmosphere Mesoscale Prediction System (COAMPS, version 2.0.15) and Penn State-NCAR (MM5 v3.3) non-hydrostatic mesoscale models for testing the sensitivity of the simulated optical turbulence to the method presented in Miller and Walters (2001) which requires model forecasts of TKE (designated COA1) and to a Richardson number (TKE-free) method (designated COA2 and MM5). The mesoscale model domain configuration, whose location is shown in Figure 1, 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 National Center for

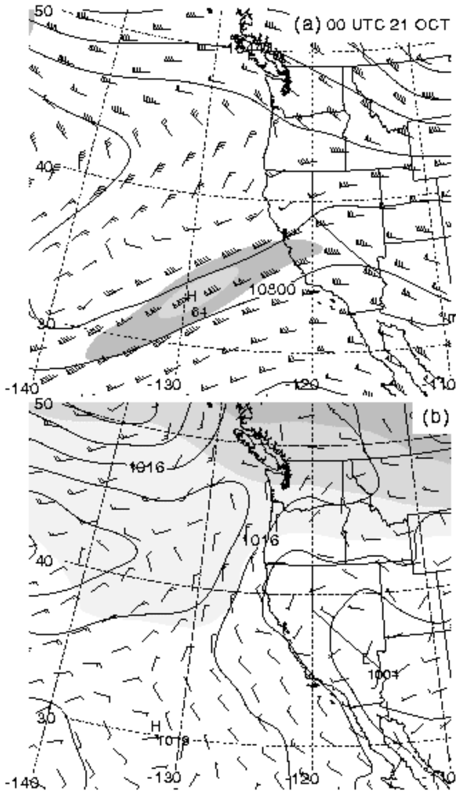

Figure 2: *Analyses from the NCEP ETA model of [a] 250 mb geopotential height (m, contours) and isotachs (m s^{-1} , shading) and [b] mean sea level pressure (mb, contours) and 1000-500 mb thickness (m, shading) valid at 0000 UTC 21 October 2001.*

Environmental Prediction (NCEP) ETA model as the analysis first guess and the U.S. Navy Operational Global Atmospheric Prediction System (NOGAPS) model forecast fields for creating lateral boundary conditions.

3. OCTOBER 2001 CASE STUDY

The synoptic pattern as derived from the NCEP ETA model analyses valid at 0000 UTC 21 October, shown in Figure 2, shows a positively tilted trough at the 250 mb level (Fig. 2a) which indicates a jet streak directed toward the central coast of California having a maximum wind speed of 64 m s^{-1} . At the surface (Fig. 2b), an inverted trough is located over the southwest United States.

The surface and upper level weather patterns four days later indicate significant zonal flow at the 250 mb level (Fig.3a) with the jet stream over the Pacific Northwest and a weakened pressure gradient over Southern California at the surface (Fig. 3b).

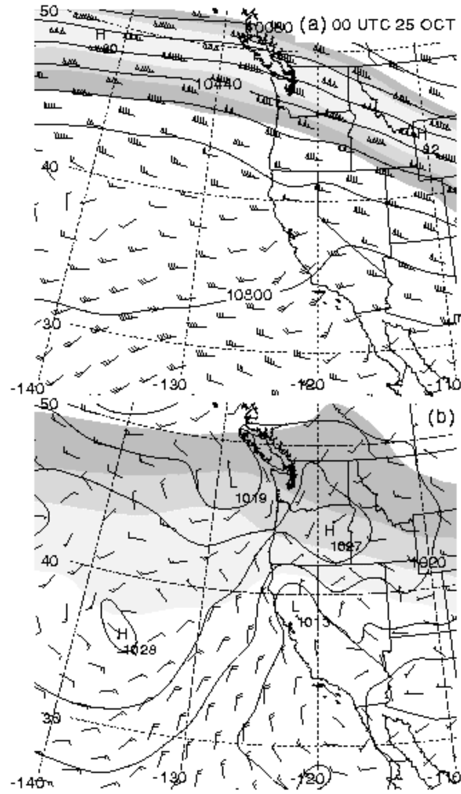

Figure 3: *As in Figure 2, except valid at 0000 UTC 25 October 2001.*

The Vandenburg (VBG), CA soundings corresponding to the 0000 UTC 21 and 25 October periods are shown in Figures 4 and 5, respectively. The wind speeds at VBG on 21 October (Figure 4) are moderate or strong throughout the entire depth of the atmosphere. Comparison of the flow direction to the position of VBG relative to the coastal topography (Figure 6) indicates a strong cross-mountain component at altitudes at and above the 650 mb level. A strong low-level inversion, associated with the marine PBL is evident near he 925 mb level and a secondary stable layer is evident in the mid-troposphere, close to the 550 mb level. By 25 October (Figure 5), the VBG wind speeds have decreased, particularly in the lower atmosphere in response to the decreased low-level pressure gradient. Drying has occurred throughout the atmosphere at VBG as high pressure has built over the eastern Pacific Ocean. The marine PBL low-level inversion persists on 25 October and a secondary inversion is evident at the 750 mb level.

4. PRELIMINARY NUMERICAL RESULTS

COAMPS and MM5 simulations of Cn^2 have been generated for the period of 20-26 October 2001 for

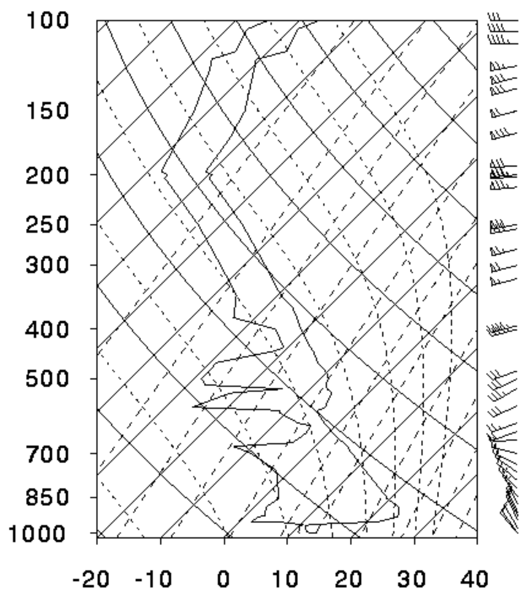

Figure 4: *Rawinsonde observations for Vandenberg, CA valid at 0000 UTC 21 OCT 2001.*

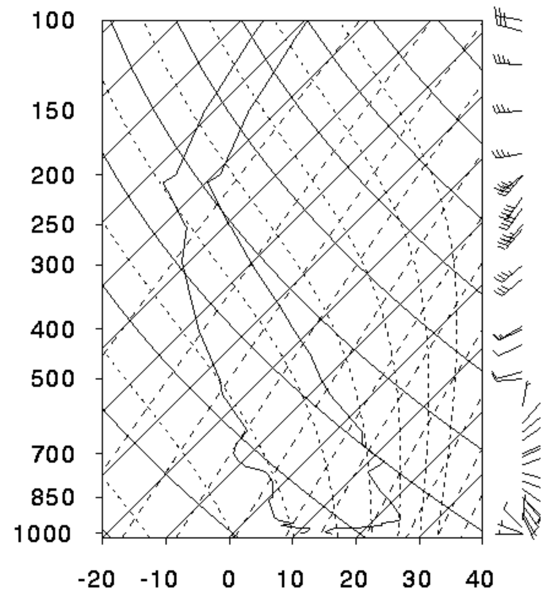

Figure 5: *As in Figure 4, except valid at 0000 UTC 25 OCT 2001.*

an innermost domain covering the area displayed in Figure 6. Simulations (15-h) of Cn^2 using the Richardson number method (COA2) are displayed in Figures 7 and 8 valid at 0300 UTC 21 and 25 October 2001, respectively. The period of strong cross-mountain flow (Fig. 7) shows four distinct layers of large optical turbulence within the 925 to 100 mb layer. Each layer corresponds to a region of relatively strong stability collocated with a region of strong speed and/or direction wind shear. Significant asymmetries in the simulated Cn^2 upstream and downstream from the crest of the mountain are not evident. The cross-mountain flow occurs at the 650 mb level, well above mountain top (850 mb level). A comparison of the simulated large optical turbulence layers to the VBG 21 October sounding (Fig. 4) indicates that the layers centered at the 600 and 125 mb levels may have verified, while those at the 725 and 400 mb levels are difficult to justify based on the observed VBG thermal and wind profiles at those levels.

The period of weak cross-mountain flow (Fig. 8) shows weaker simulated optical turbulence at the middle- and upper-tropospheric levels and enhanced Cn^2 just above the PBL, centered near the 800 mb level. This is consistent with the location at VBG on 25 October of the secondary elevated inversion. There is fair cross-mountain variability in the simulated optical turbulence, though it is not related to flow interaction with coastal topography.

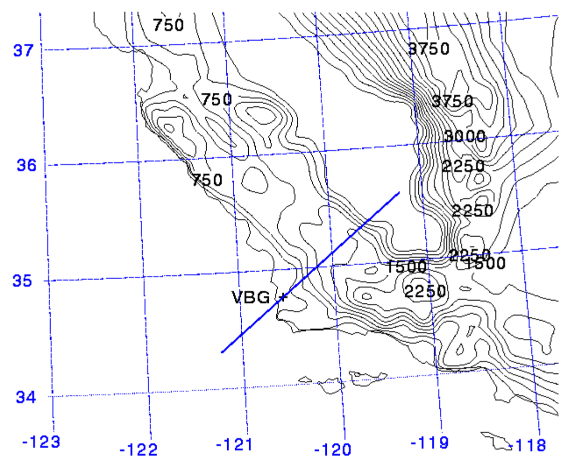

Figure 6: *COAMPS 9 km domain terrain elevation (m) plotted every 250 meters. Location of vertical cross sections in Figures 7 and 8 as well as VBG location are also plotted.*

A comparison of simulated optical turbulence profiles (15-h forecast) for TKE (COA1) and TKE-free (COA2 and MM5) methods is displayed in Figure 9 valid at 0300 UTC 21 October. Each of the methods simulate similar structures, with minor differences aloft and more significant differences within the PBL. The observed profile is plotted in the gray-colored solid line and indicates good basic agreement with each of the model simulations. The Cn^2 peak at 8 km is depicted at the proper altitude in the simulations with a tendency for over- or under-prediction by COAMPS or MM5, respectively. The disagreement between the

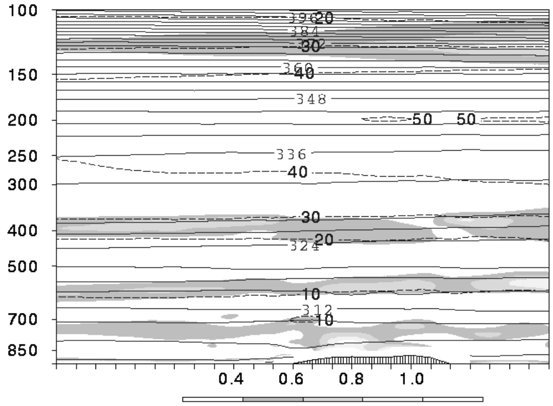

Figure 7: *Vertical cross section depicting simulated potential temperature (K, solid contours), wind speed (m s^{-1}, dashed contours) and Cn^2 (x10^{16}, shading) for COA2 along the cross-coast location plotted in Figure 6 valid at 0300 UTC 21 October 2001.*

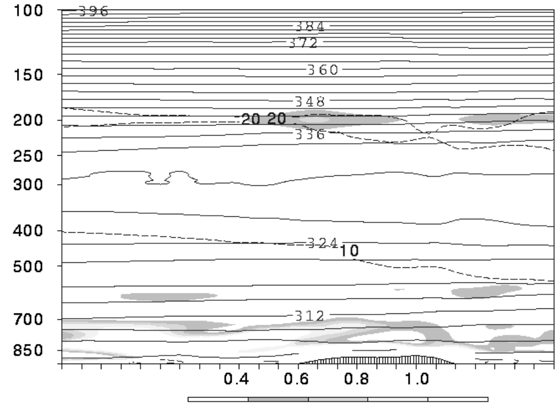

Figure 8: *As in Figure 7, except valid at 0300 UTC 25 October 2001.*

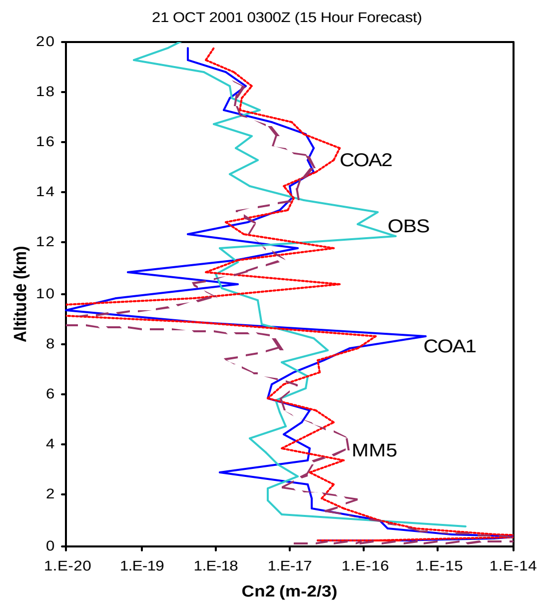

Figure 9: *Simulated and observed Cn^2 values valid at 0300 UTC 21 October 2001.*

observed and simulated elevation of the lower stratospheric Cn^2 peak is currently being investigated.

5. SUMMARY

A TKE-free method for estimating optical turbulence has been introduced which gives results as accurate as the TKE-based method described in Walters and Miller (1999) and in Miller and Walters (2001). Comparisons for simulations over the course of a year for a domain having significant orographic effects has shown the TKE-free method to be more robust, particularly in instances of (1) high wind shear near the surface at nighttime, (2) topographically induced gravity waves aloft, and (3) within the elevated daytime PBL inversion.

6. REFERENCES

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