2.3 NUMERICAL STUDY OF THE INFLUENCES ON POLLUTANT TRANSPORT DUE TO MULTIPLE CONVERGENCE ZONES IN THE SEA BREEZES OF CAPE COD AND SOUTHEASTERN MASSACHUSETTS

Nelson L. Seaman[1*], Aijun Deng[1], Glenn K. Hunter[1], Bruce A. Egan[2], and Annette M. Gibbs[1],

[1]The Pennsylvania State University
Department of Meteorology, University Park, PA

[2]Egan Environmental, Inc.
Beverly, MA

1. INTRODUCTION

In New England (NE) it is common for power plants and other large emission sources to be concentrated along the coastline, where prevailing mid-latitude westerly winds can advect effluents over the ocean. Of course, mesoscale circulations, especially the sea breeze, can dominate coastal winds when the large-scale flow is weak and land-ocean thermal contrast is large. However, irregular coastlines (bays and peninsulas) and topography lead to multiple thermally driven circulations that can interact and make it difficult to estimate exposure to harmful airborne species. Therefore, a numerical investigation has been conducted to better understand the influences on pollutant transport and diffusion due to interactions between local and mesoscale sea-breezes over Cape Cod and southeast MA. The study involves a mesoscale meteorological model (the PSU/NCAR MM5v3.4), a trajectory calculator (TRAJEC) and three plume dispersion models (CALPUFF, ISC3ST, and SCIPUFF). Transport and diffusion of plumes from two power plants (elevated sources), a highway, and Otis AFB (surface sources) were calculated. A companion paper in this volume describes the dispersion modeling results (Egan et al. 2002). This paper focuses on the meteorological modeling and trajectory calculations.

2. MODEL DESCRIPTION, METHODOLOGY AND CASE DESCRIPTION

The MM5v3.3 is a 3-D non-hydrostatic full-physics meteorological model with a terrain-following vertical coordinate (Grell et al. 1994). For this study, the model was configured with the Dudhia radiation and explicit moisture schemes, and a 1.5-order TKE turbulence scheme. Four nested domains were used with meshes of 36, 12, 4, and 1.33 km (Figure 1). All domains had 50 layers (30 below 1560 m), with the first level at ~12 m AGL. The 4-km grid over southern NE had 151 X 151 points and the 1.33-km grid over Cape Cod had 115 X 115 points. The Kain-Fritsch deep convection scheme was used, but only on the 36- and 12-km domains. Four-dimensional data assimilation (FDDA) was applied on the 36- and 12-km domains via analysis nudging to reduce large-scale errors that could affect the local sea-breeze development. NOAA EDAS analyses were used for the model's initial and boundary conditions and for FDDA. Three 48-h cases with weak synoptic-scale forcing were chosen from the summer of 2000: 1-2 July, 5-6 July, and 21-22 August. All three were post cold-frontal cases with weakening large-scale winds and a large land-sea thermal contrast that led to a sea breeze on one or both days of the episodes.

* Corresponding author: N.L. Seaman, Penn State Univ., Dept. of Meteorology, University Park, PA, 16802.
Ph.: 814-863-1583, Email: seaman@ems.psu.edu

3. RESULTS

Here, we concentrate on results on the 1.33-km grid at 1800 UTC, 1 July. Manual analysis shows a thermal low over the interior of MA with a converging regional sea-breeze front (Fig. 2). The MM5 reproduces this front, plus several convergence zones due to local sea breezes over Cape Cod (Fig. 3). Figure 4 shows 6-h trajectories initiated from four emissions sources and ending at this same time. The trajectories show strong influences due to both the regional and local sea breezes. Table 1 gives a summary of statistical results for all three cases in three layers of the atmosphere.

4. SUMMARY

The MM5 produces realistic mesoscale structures on a 1.33 km grid, in terms of both the regional sea breeze and statistical agreement with regional data. The fine-grid model also produces local sea breezes over Cape Cod that cannot be resolved by standard observations.

5. ACKNOWLDGEMENTS

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6. REFERENCES

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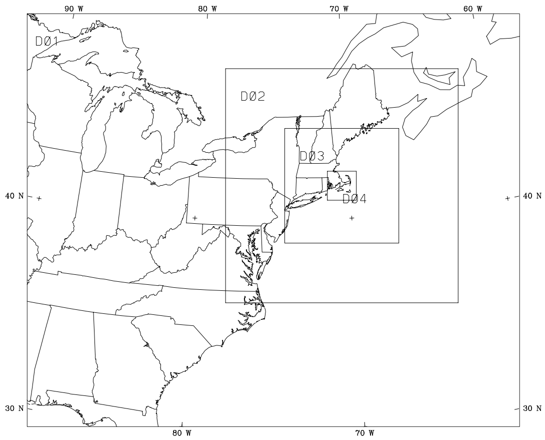

Figure 1. Location of 36, 12, 4 and 1.33-km nested domains for the MM5 configuration over Cape Cod.

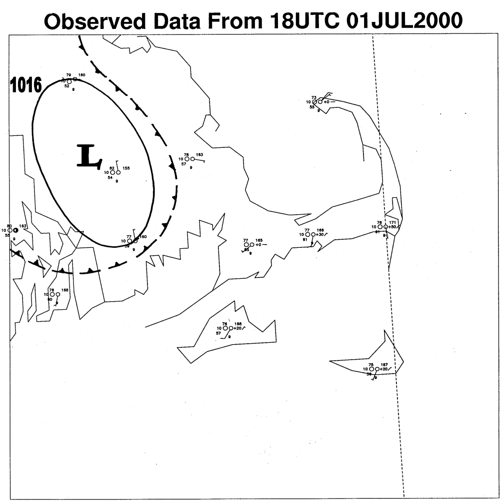

Figure 2 Manual analysis of sea-level pressure (mb) over the area of the 1.33-km MM5 domain for Case 1 at 1800 UTC, 1 July 2000. Isobar interval is 1 mb.

Table 1. Averaged MM5 statistics for three cases of the Cape Cod sea breeze. MidTrop is 1000-5000 m, PBL is 45-1000 m, SfcLayer is 12 m AGL.

Variable Layer	RMS Err	MnAbs Err	Mean Err	% Within Criteria
Speed (ms^{-1})				Cr=2.0 ms^{-1}
MidTrop	2.36	2.03	+0.42	60.3
PBL	2.78	2.34	+0.88	49.7
SfcLayer	1.55	1.30	-0.03	78.9
Direct'n (deg)				Cr=20.0deg
MidTrop	18.8	16.7	-4.3	80.0
PBL	40.9	31.1	-6.7	52.9
SfcLayer	54.8	41.8	-5.7	41.3
Temp. (C)				Cr=2.0 (C)
MidTrop	0.99	0.82	+0.14	93.4
PBL	1.21	1.00	-0.51	88.2
SfcLayer	2.41	1.97	+0.16	61.2
Mix.Rat.(g/kg)				Cr=1 (g/kg)
MidTrop	0.97	0.80	-0.13	63.4
PBL	1.38	1.16	-0.25	55.2
SfcLayer	2.46	2.46	+0.25	33.3
SLvlPrs (mb)				Cr=2.5 mb
	0.69	0.62	+0.39	100.0

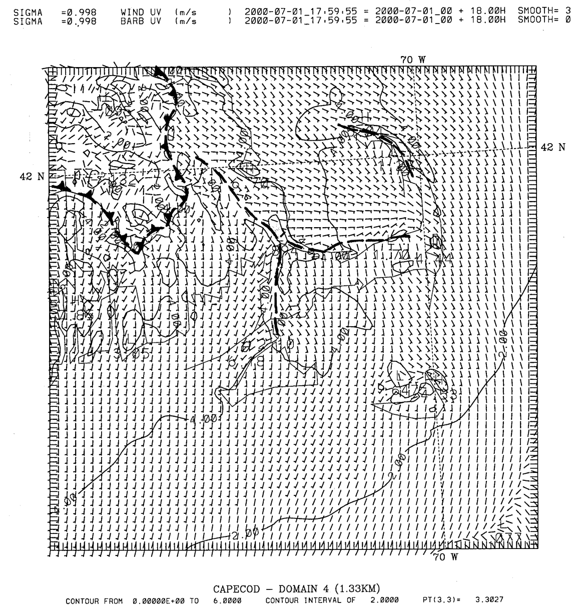

Figure 3. MM5 surface-layer wind (ms^{-1}) on the 1.33-km domain in Case 1 valid at 1800 UTC, 1 July 2000 (+18 h). Full barb is 10 ms^{-1}. Contour interval is 2 ms^{-1}. Heavy dashed line with wedges represents sea-breeze front. Dashed lines indicate convergence zones.

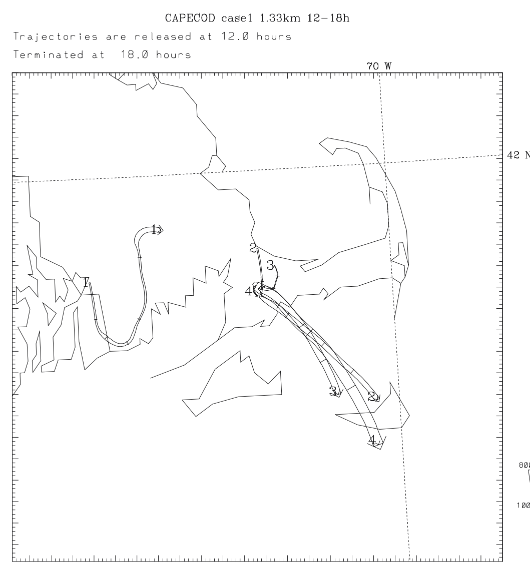

Figure 4. Six-hour TRAJEC forward trajectories based on MM5-simulated winds in Case 1. Release time is 1200 UTC, 1 July 2000 (+12 - 18 h). Parcel 1 is Brayton Point plant. Parcel 2 is Canal plant. Parcel 3 is middle of highway segment. Parcel 4 is Otis AFB. Tick marks shown on trajectories give positions at 1-h intervals, or until the parcels exit the domain.