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A NUMERICAL STUDY OF POLLUTANT DISTRIBUTIONS IN SEA BREEZE CIRCULATIONS

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Field studies in coastal locations have led to the observation that sea/lake breeze-flows may increase the air pollutant burden of a region through a recirculation of contaminants, and affect other locales with an along-shore displacement of the recirculating pollutants (Lyons and Olsen, 1973; Raynor, et al, 1974). In this paper, preliminary results of a numerical study of the effect of sea breeze circulations on air pollutant distributions are examined.

The meteorological fields are obtained using a modification of a cross-sectional model for coastal circulations developed by Tingle (1971), which simulates wind and temperature fields in the planetary boundary layer assuming a hydrostatic, compressible, and dry atmosphere. Turbulent transport in the vertical is parameterized using K-theory dependent on the local Richardson number, and is based on the Level I formulation of Mellor and Yamada (1974).

A three-dimensional Particle-in-cell model, developed by Sklarew, et al (1972), is used for the simulation of pollutant distributions for an airborne, chemically inert, non-buoyant material. In this model the diffusive components are computed as turbulent flux velocity vectors which are then added to the wind vector components to obtain a total transport wind velocity. For example, the flux velocity in the vertical is computed from

$$W_D = - \frac{K_Z}{C} \frac{\partial C}{\partial Z}$$

where C is the concentration of the cell and K_Z is computed as discussed previously.

Results are presented for zero gradient flow conditions for which well-defined sea breeze circulations are simulated to occur. At the present stage of the study we are simulating air pollutant distributions from shallow volume instantaneous surface sources situated at the coastline for a period during the day when the circulation is at its maximum intensity. The development of the circulation is shown in Fig. 1, with the corresponding turbulent diffusivities shown in Fig. 2. The simulated transport and turbulent diffusion of the puff for a 6-hour period is shown in Figs. 3-5, for which the computed sea breeze circulation as it existed at 1400 hours was used. The circulation is seen to limit the landward progression of the puff with stretching and vertical transport occurring in the sea breeze front, and seaward in the upper return flow layer. A recirculation of the material is evident, as seen in Fig. 5, although this occurs at a very slow rate. The effect of the Coriolis force for the case presented results in a circulation at an angle less than perpendicular to the coastline but the flow and the pollutant transport occurring in a near vertical plane.

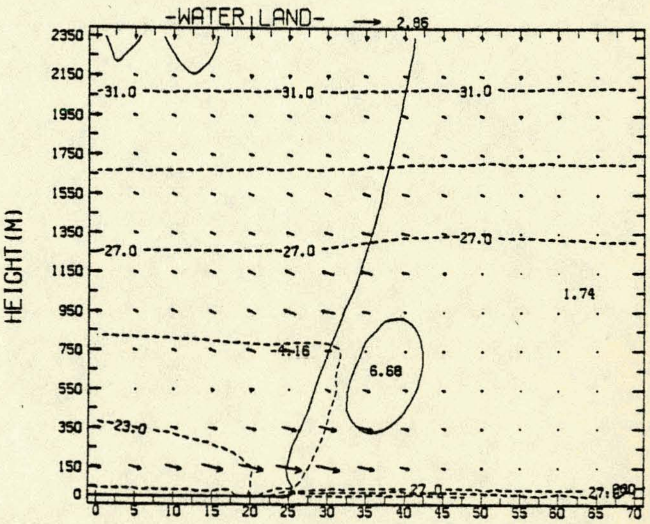

Figure 1a.

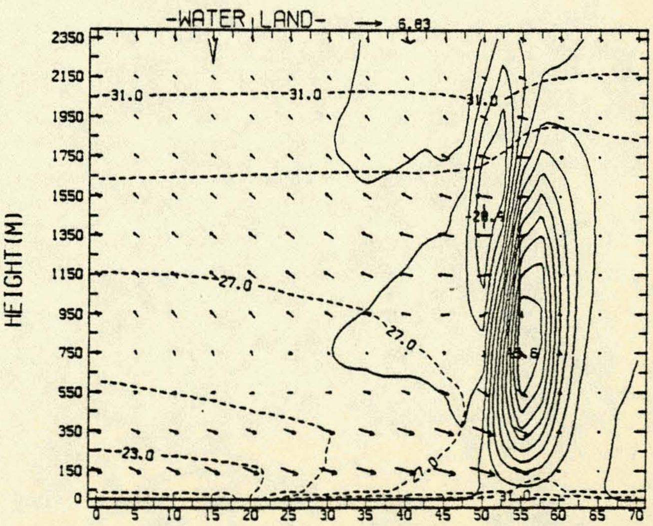

Figure 1b. Meteorological fields at (a) 1100

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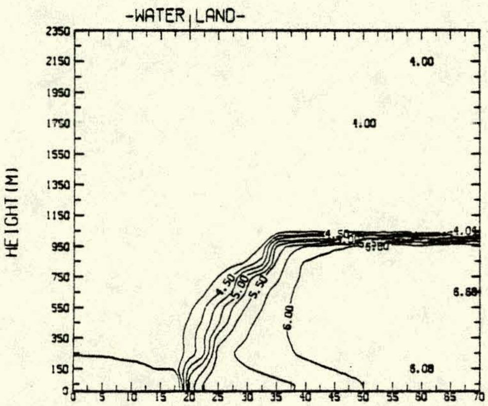
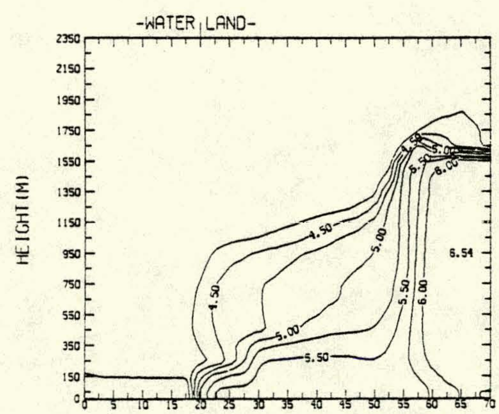
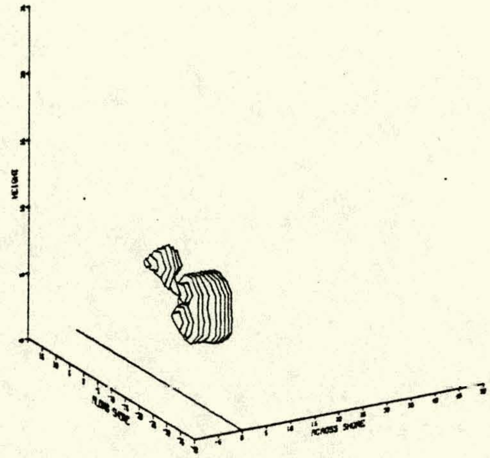
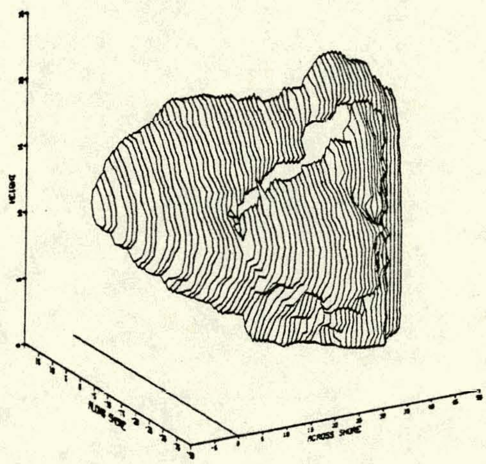
hours local time and (b) 1400 hours. Scale of the abscissa in kilometers with the land-water boundary at 20 Km. Dashed lines for potential temperature (°C), full lines for the vertical velocity field drawn in intervals of 5 cm/sec and maximum and minimum values plotted where appropriate. Vectors represent the horizontal component of the wind with the arrow centered on the grid points. An arrow parallel to the abscissa with the arrowhead pointing to the right would represent on-shore flow, an arrow pointing to the the bottom of the figure would represent flow down the shoreline, etc. Vector magnitude drawn in proportion to the maximum vector, which is shown at the top of the figures in m/sec.





Figures 2a, b. Logarithm (base 10) of computed turbulent diffusivities at 1100 and 1400 hours.





Figures 3 a, b. Three dimensional perspective of pollutant puff at (a) 1 hour and (b) 6 hours simulation time showing the $2 \times 10^{-4}\ m^{-3}$ surface. Vertical scale in hundreds of meters, horizontal scale in kilometers from the position of the source. Source is of unit intensity.

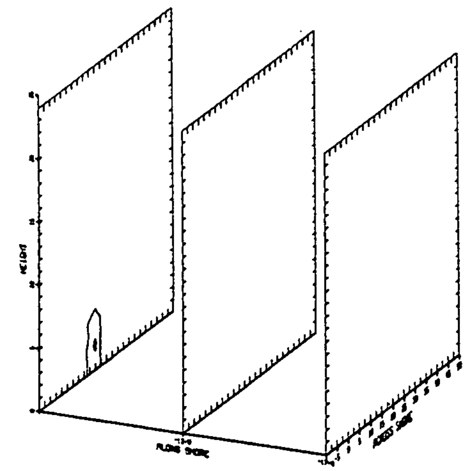


Figure 4a.

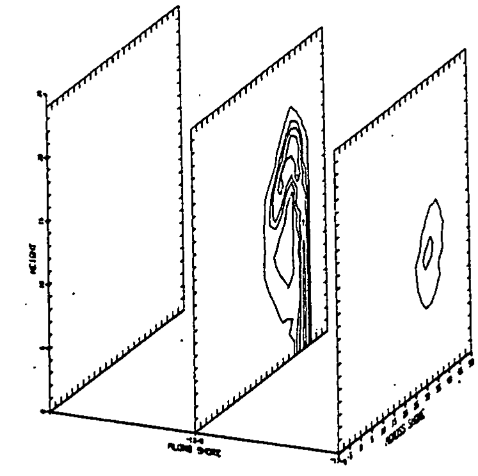


Figure 4b.

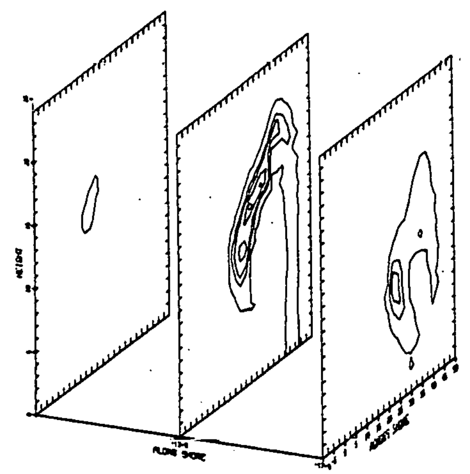


Figure 4c.

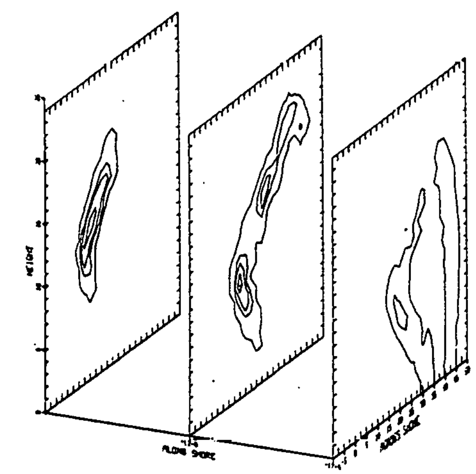
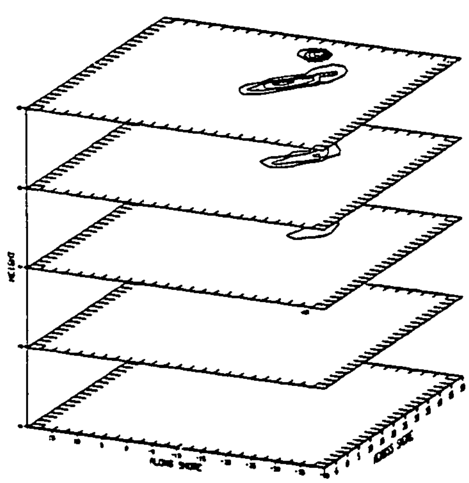
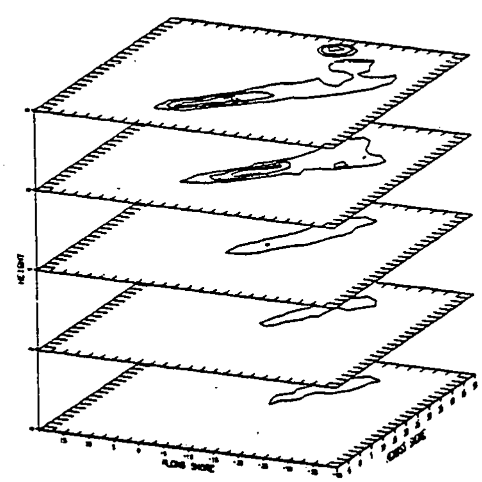


Figure 4d.

Figures 4a, b, c, d. Contours of pollutant concentration in planes perpendicular to the shoreline at (a) 1 hour, (b) 3 hours, (c) 4 hours, and (d) 6 hours simulation time. Contours plotted at 2, 25, 50, 100, 150, and 500 x 10^{-4} m^{-3}. Scale as in Figure 3.





Figures 5a, b. Contour of vertical planes for (a) 4 hours, and (b) 6 hours. Vertical planes are at the surface, 200 m, 400 m, 600 m and 800 m. Contour levels as in Figure 4.

Acknowledgements

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References

Lyons, W. A., and L. E. Olsson, 1973: Detailed mesometeorological studies of air pollution dispersion in the Chicago lake breeze. Mon. Wea. Rev., 101, 387-403.

Mellor, J. L., and T. Yamada, 1974: A hierarchy of turbulent closure models for planetary boundary layers. J. Atmos. Sci., 31, 1791-1806.

Raynor, G. S., J. V. Hayes, and E. C. Ogden, 1974: Mesoscale transport and dispersion of airborne pollens. J. Appl. Meteor., 13, 87-95.

Sklarew, R. C., A. J. Fabrick, and J. E. Prager, 1972: Mathematical modeling of photochemical smog using the PICK method. JAPCA, Vol. 22, No. 11, pp. 865-869.

Tingle, A. G., 1971: A numerical model of the Lake Michigan lake breeze. Proc. Symp. on Air Pollution, Turbulence and Diffusion, Dec. 7-10, 1971, pp. 376-383.