14B.4 DEVELOPMENT AND PROPAGATION OF A POLLUTION GRADIENT IN THE MARINE BOUNDARY LAYER DURING INDOEX (1999)

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1. Introduction

The Intensive Field Phase of the Indian Ocean Experiment (INDOEX) was carried out over the tropical Indian Ocean from 14 January to 31 March 1999. Higher marine boundary layer ozone concentrations were observed over the Indian Ocean in the northern hemisphere during the northeast monsoon season (Johnson et al., 1990). Direct transport of anthropogenic emissions resulting in sharp increases in CO, CO_2, O_3, and NO_y have been detected at distances of 1500 km from southern India (Rhoads et al. 1997).

Westward propagating cloud bands were observed using a geo-stationary satellite during INDOEX (1999) (Desalmand et al. 2002). Infrared temperatures recorded by the Meteosat-5 satellite showed cloud tops to be about 5°C colder than the sea surface temperature over the Arabian Sea, which corresponds to a cloud height of 600 to1000 m.

We argue that these cloud bands were the leading edges of pollution gradients. The pollution gradient observed over the Arabian Sea is defined as a boundary between one air mass high in aerosol and anthropogenic gas concentrations originating from the Indian subcontinent and another unpolluted marine air mass located to the southwest over the Arabian Sea. A sharp gradient in aerosol concentrations and other pollutants in the marine boundary layer occur at the leading edge of the polluted continental air mass.

2. Numerical Simulation of the Pollution Gradient

The mesoscale model used in this study is the fifth generation of the PSU-NCAR Mesoscale Model (MM5**)**. The model was integrated up to a period of 72 hours from 0500 LT on 5 March until 0500 LT on 8 March 1999.

Model simulated convergence at a height of 10 m at 1100 LT on 6 March 1999 is shown in Figure 1. The simulated convergence associated with the pollution gradient has a maximum value of 10×10^{-5} s^{-1}. Location of the simulated convergence closely corresponds to the observed location of the pollution gradient in infrared satellite images..

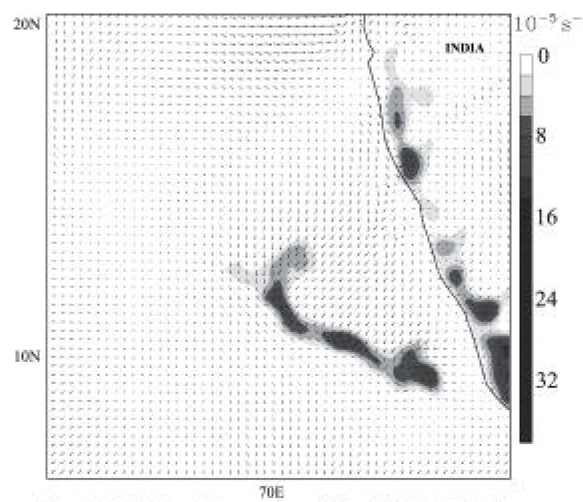

Figure 1. Model simulated convergence at 10 m height at 2300 LT at 1100 LT on 6 March 1999 showing the location of the pollution gradient.

One method of testing our hypothesis that the formation of the convergence zone and pollution gradient is related to the s ea and land breeze circulation is to plot model simulated trajectories. A simulated trajectory released at a height of 200 meters along the west coast of India (labeled A) at 0500 LT on 5 March 1999 is shown in Figure 2. Strong northeast winds aloft begin transporting the parcel offshore at around 2300 LT on 5 March 1999. As the parcel moves offshore it decreases in altitude and is at a height of 200 m by 1100 LT on 6 March. At 1700 LT on 6 March 1999 (labeled C), the parcel interacts with an area of convergence. Interaction with the convergence zone results in the parcel slowing down in speed and changing the direction of its movement. The parcel is lifted to a height of about 600 m by the positive vertical motion associated with the convergence zone. Movement of the simulated trajectory thus shows the influence of the sea and land breezes along the west coast of India in conjunction with the offshore convergence zone associated with the pollution gradient.

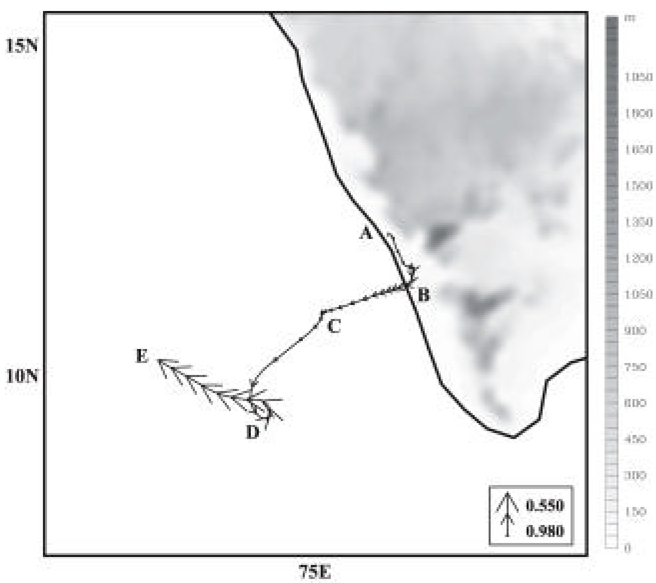

Figure 2. Model simulated trajectory released at a height of 200 m on 5 March 1999 at 0500 LT and ending on 8 March 1999 at 0500 LT.

3. Conclusions

Observations near the west coast of India during INDOEX (1999) revealed several peaks in aerosol number concentration caused by the passage of pollution gradients. Peaks in Carbon Monoxide concentration were shown to result from the passage of the pollution gradients. The timing of the occurrence of concentration peaks correlated well with the timing of the pollution gradient passage observed from infrared satellite images.

A mesoscale model was employed to verify the hypothesis of the formation and propagation of the pollution gradient. The numerical model simulated the formation of the pollution gradient and its propagation over the Arabian Sea. The gradient appears to develop as a result of the diurnal coastal circulations. As the sea breeze weakened, the pollution gradient was pushed out to sea by the large-scale easterly winds. The depth of the aerosol gradient extended to a height of 800 m above the surface. Maximum vertical velocities of about 0.22 ms^{-1} were simulated from the low level convergence associated with the pollution gradient. Stratocumulus clouds at 900 m were shown to develop as a result of the vertical velocity caused by the pollution gradient.

4. References

Désalmand, F., et. al: 2003. 'Systematic observation of westward propagating cloud bands over the Arabian Sea during Indian Ocean Experiment (INDOEX) from Meteosat-5 data', *J. Geophys. Res.*, *108*(D18), 8004.

Johnson, et. al, "Ozone in the marine boundary layer over the Pacific and Indian Oceans", J. Geophys. Res., 95, 11847- 11856, 1990.

Rhoads,K., et. al, "Composition of the troposphere over the Indian Ocean during the monsoonal transition," *J. Geophys. Res.* 102, 18981-18995, 1997.

Acknowledgements: This research was supported by the Atmospheric Sciences Division of the National Science Foundation under Grant ATM-0080088.