3.2

SEA FOG ALONG THE CALIFORNIA COAST IN RESPONSE TO SYNOPTIC FORCING

J. M. Lewis*
NOAA/NSSL and desert Research Institute, Reno, Nevada
D. Koracin
Desert Research Institute, Reno, Nevada
R. Rabin
NOAA/NSSL and Space Science and Engineering Center, Madison, Wisconsin
J. A. Businger
University of Washington, Seattle, Washington

Through examination of two successive weather systems off the California coast in mid-April 1999, we have shown the influence of the large-scale lower-tropospheric circulation pattern on surface trajectories and structure of the MBL. In subsequent discussion, we refer to the cyclone/anticyclone couplet that impacted the coast on April 7-12, 1999, as system 1, and the couplet that impacted the coast on April 12-16, 1999 as system 2.

In system 1 that was fog free, measurements at the buoy sites showed that both air temperature and dewpoint temperature increased along the trajectories. The trajectories were governed by flow out of an anticyclone positioned offshore. Since sea surface temperature (SST) was generally larger than air temperature along these trajectories, the increase in both air temperature and moisture content could be attributed to the sensible and latent heat flux from sea to air. Subsidence was weak in system 1, cloud cover was limited to stratocumulus, and the MBL height remained relatively constant at about 800 – 1000 m. Nevertheless, the modification of the air in the aftermath of the frontal passage led to an airmass along the southern California coast that could be characterized as relatively warm and moist (air temperature nearly equal to the SST and dewpoint depressions of a few degrees Celsius). This air was entrained into synoptic system 2.

The post-frontal trajectories from system 2 were controlled by a strong anticyclone that moved into the Pacific Northwest and subsequently down through the south central states over a several day period. Subsidence as high as 4 cm/s was associated with this anticyclone and the pattern of high subsidence rates progressively moved southward along the West Coast over a 24 h period. A stratus cloud deck formed in conjunction with the subsidence and its movement and extent was highly correlated with the movement of the subsidence pattern. Fog occurred with system 2 and it was obviously linked to the stratus deck. Yet, fog was more limited in areal extent than was the stratus. The foggy area was confined to the Southern California coastline (and adjoining sea based on the records at buoy sites).

Upper air soundings associated with system 2 at Oakland (OAK) (Central California) and Vandenberg AFB (VBG) (Southern California) bore strong resemblance to each other, particularly the warming above the subsiding MBL. Examination of the surface conditions and structure of these soundings led us to expect identical weather conditions at each site. This was not the case. Careful examination of the buoy records off the coast from these upper-air stations led to an explanation for fog at one site and not at the other. The interpretation relied on earlier results of numerical simulation of fog due to stratus lowering under conditions of strong subsidence and marine inversion (Koracin, et al., 2001). In essence, the presence of stratus cloud along the Lagrangian trajectory leads to radiative cooling of the MBL via buoyancy-driven turbulence (from cloud-top cooling). This cooling dominates the warming associated with sensible heat flux from sea to air and shortwave heating in the cloudy atmosphere. Those trajectories that do not come under the influence of stratus cloud display a trend of increasing air temperature in response to the sensible heat flux that is not counteracted. At the buoy near OAK (the SF buoy), we were able to show that air

---

**Corresponding author address:* John M. Lewis, Desert Research Institute, Reno, NV 89512. Email: jlewis@dri.edu temperature and dewpoint-temperature trends were tending toward a saturated state, but the southward propagation of the stratus deck and the associated Lagrangian track under clear skies reversed the trend in air temperature and led away from saturation. This was not the case for trajectories arriving in the Point Conception area.

Our synoptic analysis makes it clear that slight changes in large-scale conditions associated with cool-season cyclone/anticyclone couplets and associated fronts must be considered in forecasting fog along the California coastline. It is tempting to rely on local conditions to explain fog. Yet, in our case, it is difficult to find an explanation based on local data alone (data in the Point Conception – California Bight area). In this area, the SST is warmer than the air temperature, but the buoy records indicate a cooling of the air. Cooling could come from a land breeze (easterly flow), but the wind records at the buoy sites show no evidence of a land breeze during the period of temperature drop. Cloud was present and incoming shortwave radiation is diminished, but this would not directly cool the surface air; rather, it would diminish input of solar energy into the ocean. In short, we were compelled to look beyond the local area for a rational explanation of fog. Although the radiative cooling associated with stratus is a local phenomena, its evolution along the Lagrangian trajectories is the essential factor in understanding fog formation for this case. Our explanation relied on processes simulated in the numerical experiment. The approach, however, was strongly influenced by the work of the following early investigators: Geoffrey Ingram (“G. I.”) Taylor [1917] who realized that observations of fog over the Banks of Newfoundland could only be explained by examining the path history of the air mass, Joseph Anderson [1931] who first observed and documented the occurrence of fog at sea due to stratus lowering, and Dale Leipper [1948] who discussed fog in the context of the Pacific Anticyclone's circulation.

References

Anderson, J., 1931: Observations from airplanes of cloud and fog conditions along the southern California coast. *Mon. Wea. Rev.,* **59,** 264-270

Koracin, D., J. Lewis, W. T. Thompson, C. E. Dorman, and J. A. Businger, 2001: Transition of stratus to fog along the California coast: Observations and modeling. *J. Atmos. Sci.,* In press.

Leipper, D., 1948: Fog development at San Diego, California. *J. Mar. Res.,* **7**, 337-346

Taylor, G. I., 1917: The formation of fog and mist. *Quart. J. Roy. Met. Soc.,* **43**, 241-268