The Meteorology & Climatology of Coastal Fog

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Fog in Motion (from Simon Christen’s “Adrift”)

see full movie at - http://www.simonchristen.com/adrift.html
Synoptic Variations in SLP

[Map showing sea level pressure isobars with color scale and label: NCEP Operational Dataset]

Thu Aug 10 2006

CMSI Symposium, UC Davis
March 19, 2015
2012 BML Experiment - Synoptic Differences:

Clear Days                      Foggy Days

700 hPa

1000 hPa

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1997: Low Fog  1951: High Fog

- Deeper troughing of foggy situations leads to strong **negative vorticity advection** upwind/offshore driving strong subsidence which *depresses* the MBL and *accelerates* surface winds downwind.

- Shoaling of MBL and increased latent heat fluxes (and most likely lower nearshore SSTs) *increases* dew point temperatures & *lowers* temperature near coast, leading to coastal fog.
Coastal marine fog, a characteristic feature of climates generated at the eastern boundaries of ocean basins worldwide, evokes different feelings in those who experience it (see Figure 1). Authors and poets use fog to represent mystery, bleakness, and confusion. Film directors seek out fog to shroud scenes in eerie gloominess. Tourists visiting beaches bemoan the cool and damp conditions that create a striking contrast to the sunny warm conditions typically found less than a few kilometers inland. Airline passengers delayed by fog impatiently wait for the skies to clear. Residents get used to the Sun “rising” in midday after fog dissipates.

To climate scientists, fog’s physical opacity symbolizes how much remains to be discovered about it. They know the importance of the summertime shade and moisture provided by the onshore transport of fog arriving as a wall of marine cloud. However, empirical data or physical models capable of characterizing fog as a climatological phenomenon are surprisingly sparse.

One pressing question involves how global climate change will influence fog and how fog may be affected by rising surface temperatures and secondary effects such as coastal wind strength, inland marine layer intrusion, and increased evaporation. For example, a recent study of coastal fog in the eastern Pacific, which relied on long-term airport records, indicated that the occurrence of summertime fog has declined by 33% over the course of the 20th century [Johnstone and Dawson, 2010]. How representative is this finding of worldwide changes in fog patterns that may come? Can long-term cycles in ocean temperature such as the Pacific Decadal Oscillation explain the centennial trend?

These questions, and others like them, are not purely academic: Changes in fog frequency have implications for a wide range of sectors, including coastal ecology, agriculture, urban energy and water consumption, and public health. To help coastal communities, many climate scientists are taking a close look at fog with the aim of developing models of future fog patterns.

Forming Marine Fog

The frequency of marine coastal fog events and the extent of inland penetration depend on both simultaneous and sequential processes across an extremely broad range of the planet’s spatial and temporal scales [Kora et al., 2014]. Semipermanent anticyclones (high surface pressures), which tend to develop on the eastern sides of the world’s ocean basins, result in alongshore surface wind stresses. These alongshore stresses act in concert with the Coriolis force to drive offshore oceanic (Ekman) transport that in turn pumps deep, cold water up to the coastal margins. These ocean upwelling conditions occur beneath a complementary downwelling branch of the atmosphere’s Hadley circulation—a planetary-scale flow pattern in both hemispheres that takes humid air ascending at low latitudes, heats and desiccates it in deep precipitating tropical clouds, and then sinks it at midlatitudes, where it is considerably warmer and drier than it was.

The cold nearshore waters couple with the descending, adiabatically warmed air aloft to form a stable lower atmosphere with a strong temperature inversion, which has long been linked to a prevalence of low stratiform clouds. As this sinking air mass weighs on the marine layer, the latter compresses into a thin layer with a relatively high concentration of water vapor. This process also warms and dries the top of the marine layer, establishing a delicate balance with the moistening ocean below. If the dew point temperature of the trapped moisture rises to the surface temperature of the ocean, then fog can form like condensation on a cold windowpane.

Ecological and Societal Value of Coastal Marine Fog

Declines in fog frequency may be good news for Sun-seeking tourists and for air traffic controllers at coastal airports, but the trend seen in the eastern Pacific alarmed the global community.

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Fog = Stratocumulus Clouds & Radiative Budget

- Earth’s albedo ~ 30% (15-20% due to clouds)
- Cloud forcing (W/m²) ≡ Net radiation – Cloud-free conditions
- Global influence est.: -13 to -21 W/m², net cooling (~ 4W/m² for CO₂ doubling)