Ship observations of southeastern tropical Pacific stratocumulus clouds along 20°S

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Introduction
High-albedo marine stratocumulus clouds cool the top-of-atmosphere and surface radiation budgets over the eastern subtropical and tropical Oceans. Most models used for the IPCC 4th Assessment overpredicted net radiative warming by 10-30 W m⁻² in the 20°S, 85-75°W region, partly explaining warm SST errors (de Szoeke et al. 2010). We measured clouds in the southeastern tropical Pacific along 20°W, describing their geometry and radiative forcing. Radar observations from EPIC and the VAMOS Ocean Clouds Atmosphere Environment (VOCALS) Regional Experiment supplied unique observations that help determine to what degree drizzle controls radiation fluxes.

Radiative fluxes
Figure 4 shows the mean downwelling (a) solar and (d) longwave radiation (filled circles) for 2.5-degree longitude bins, observed on the 7 years of research cruises. Shortwave radiation is daily averaged to avoid aliasing the diurnal cycle. Radiation changes less with longitude than sampling standard deviation in each longitude bin (open circles show modeled clear-sky radiations).

Using overhead cloud fraction from the laser ceilometer, radiation is conditionally averaged for cloudy (Fig. 4b,e) and cloudy (Fig. 4c,f) skies. 67% of scenes have cloud fraction of 1, so cloudy averages are similar to those of full-sky. For clear skies radiative fluxes collapse to the clear-sky model. Figure 5 shows the solar transmissivity ratio, color coded by clear (magenta), cloudy (blue), and partly cloudy (black) skies diagnosed from the ceilometer. Curves show hourly lowpass filtered diurnal composites. Clear skies have transmissivity near one. Cloudy skies had maximum transmissivity in the afternoon at 13 local, and a minimum after sunrise.

Diurnal cloud decoupling
Cloud base–LCL displacement is composited on local hour in Fig. 6 (shaded). The mode of the displacement is small and constant at night, and rises steadily after sunrise, to several 200-500 m in the evening (17 h). The aggregate distribution regardless of hour (curves at left) show both rising peak displacement and a broader distribution of displacement with longitude. Figure 7 shows scatter plots of cloud base height vs. LCL. Correlation between displacement is only strong in the afternoon, notably at 85°W (Fig. 7c).

Cloud radar
Radar observations in 2008 from the NOAA 94 GHz cloud radar (Moran et al. 2010) remotely sense cloud and drizzle profiles. Figure 8 shows reflectivity and vertical velocity for 3.5 hours on 2008 Nov 20 intersecting a strongly drizzling cell. Joint histograms (Fig. 9) show the empirical relationships between Doppler velocity and reflectivity at different heights. The resolved velocity distribution width is ~1 m s⁻¹. At cloud top the mode of Doppler velocity is zero, while at and below cloud base downward velocities prevail. In weakly drizzling clouds (Fig. 9), the joint distribution resembles that at the top of the strongly drizzling cloud. Doppler velocity of rain on Nov 20 shows a quadratic dependence on dBZ.

The Doppler width is roughly half the velocity, implying a lognormal size distribution width of c₃=0.25-0.5 (Frisch et al. 1995). Doppler velocity modeled from a lognormal size distribution with N₃=1.5x10³ m⁻¹ and c₃=0.35 is indicated by the red line.

References

November 20 11-14 UTC has strong drizzle.

November 18, 4-8 UTC has little drizzle.

November 18, 4-8 UTC has little drizzle.