Southeast Pacific Stratocumulus Cloud Top Heights

1. Introduction

Marine boundary layer height observations, or its proxy, cloud top height, serve as a critical test of cloud simulations, and to deductions of mean cloud top entrainment. Stratocumulus cloud top heights in the southeast Pacific (SEP) are known to exceed those of Californian stratus, which has consequences for how diabatically the clouds are characterized and evolve in detail. The difference in cloud top heights that STEM and other Earth Observation satellite sensors observe are known to be due to differences in the surface temperature and cloud base height, which in turn is a proxy for surface temperature and cloud base height in different regions. SEP stratocumulus cloud top height diurnal variations are also more pronounced than those of the Californian stratus because of diurnal variations in the free-tropospheric subsidence. This has consequences for the mean cloud deck radiative impact, although the connection between boundary layer depth variability and the associated cloud properties is not yet well characterized.

Despite the utility of well-characterized cloud top heights for southeast Pacific stratocumulus, its spatial structure has not yet been observationally assessed. Satellite data provides an efficient observational approach. For our study we selected MODIS data because of its high radiometric accuracy, 4x/ times daily overpasses, and wide (~2300 km) swath. In addition, MODIS overpasses with six month-long cruises that included high-quality data (Rosa 90° to 60°N) were available. These allow an empirical deduction of a depth-varying lapse rate, to account for the decoupling that may be present within the deeper SEP boundary layer. The cruises (tracks shown in Fig. 1) were spread over 6 years and sampled a range of conditions, adding robustness to their parameterization. All combined, the cruises launched about 180 radiosondes at times close to the 4x/ daily MODIS overpasses.

2. Cloud top height parameterization

We use daily MODIS Collection-5 cloud top temperatures from both the Terra and Aqua platforms, derived from the 11 km equal brightness temperatures. The Level 2 data first determines the cloudy pixels, then subsamples these from the original 1 km spatial resolution at nadir to a 5 km spatial resolution. First we compare the MODIS extracted cloud top temperatures to the cloud-capping inversion base temperature (Fig. 2).

For the completely overcast (5-km-scale areas), the MODIS-derived cloud top temperatures are less than the sonde-derived inversion base temperatures by a mean value of 1.3 K (a height difference of about 150 m).

We lack an explanation. The sondes (RS-90 series except for 2001) possess improved temperature sensor responses capable of delineating sharp thermal changes to ~100 m. For the dry subtropical subsiding atmosphere, uncertainty in the correction for the overlying water vapor path by the MODIS algorithm is thought to be ~0.5 K (Dong et al., 2008). Although cloud tops do extend above the inversion base at times, as shown by wind profiles that indicate maximum humidity and temperature gradients occur ~100 m above inversion base (de Snoo et al., 2008), the mean, radar derived cloud top heights are most closely associated with the inversion base minimum temperature. We welcome suggestions.

A best fit line relates the inversion base height $z_{inv}$ to $T_{inv}$ and the 3-day mean TIM SST according to $T_{inv} = 0.0699F_{inv} + 1.05$. This relationship is an empirical estimate $z_{inv}$ as well as the 3.5 K offset between $T_{inv}$ and $T_{inv}$. We find $z_{inv} = (SST_{tmi} - f(T_{inv}) - 2.35)/0.0069$ (with $SST_{tmi}$ and $T_{inv}$ $K$, $z_{inv}$ in m, applicable to cloud tops between 800 and 2000 m (Fig. 3). The comparison between $z_{inv}$ and $z_{inv}$ has a correlation coefficient of 0.73, rmses of 275 m and a bias of ~14 m for overcast pixels (N=156). Values from each cruise follow the same tendency. Cloud top heights are slightly underestimated for inversion bases ~900 m. Note the buoy mean cloud top height for Terra, a warm ENSO phase year, is ~300 m higher than for other years.

References


