Environmental controls on the evolution of cloud droplet concentration in subtropical Stratocumulus clouds from a Lagrangian perspective

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I. Droplet Concentration ($N_d$) from MODIS

Daytime-only droplet concentration is derived from MODIS-observed cloud droplet effective radius ($r_d$) and cloud liquid water path (LWP) using the relationship seen below. Results are for four Stratocumulus (Sc) regions in the eastern subtropical oceans.

$$N_{o_{eff}} = \sqrt{\frac{3}{4}}NF_{\alpha_{eff}}^{1/2}\frac{LWP^{1/2}}{r_{\alpha(h)}}$$

$\rho_l$ = Density of liquid water
$F_\alpha = F_\alpha + f_{nu}$
$F_\alpha = \text{adiabatic rate of increase in liquid water content with respect to height}$
$h_{nu} = \text{estimate of the degree of adiabaticity}$
$LWP = \text{Liquid Water Path (MODIS)}$
$N_{o_{eff}} = \text{estimate of cloud thickness}$
$k = 0.8$ for marine Sc

II. Lagrangian Framework

This Lagrangian routine samples cloud scenes that originate in our four Sc regions and advect offshore and equatorward. Winds driving the trajectories come from the ERA-Interim reanalysis. Trajectories are run for 48 hours. Sampling occurs at ~1:30 and ~13:30 local times as the A-train passes over each scene. Droplet concentration is only sampled at 13:30, in daylight. Around 160,000 trajectories were run from 2007-2010.

III. Cloud Controlling Variables

Planetary Boundary Layer (PBL) depths are derived from the difference between MODIS cloud top temperature and ERA-Interim SST using a parameterized lapse rate and a tuning algorithm based on co-located CALIPSO-observed cloud top heights.

Rain rates are estimated using AMSR/E 89 GHz Brightness Temperatures and a tuning algorithm based on co-located CloudSat-observed rain rates.

Lower tropospheric stability (LTS) is the difference in potential temperature between 700 and 1000 hPa. Potential temperatures are sourced from the ERA-Interim reanalysis.

Entraining specific humidity (q) is the specific humidity directly overlying the inversion that separates the PBL and the free troposphere. Both q and the inversion height (used for this calculation) are sourced from the ERA-Interim.

10-meter wind speeds are also sourced from the ERA-Interim reanalysis.

IV. Mean Lagrangian Behavior

The 48-hour Lagrangian evolution of $N_d$ cloud cover, and our five predictor variables in the Sc-Cu transition regions AND trade Cu regions offshore shows:

- Declines in $N_d$, LTS, and cloud cover.
- Increases in entraining q, and PBL depth.
- Spikes in rain rate and wind speed.

V. Effects of Predictor Variables on $N_d$ Evolution

Predictor variables are converted to anomalies ($\Delta$) with respect to their seasonal and diurnal cycles. Variability for all predictor variables is normalized. Residual $\Delta N_d$ is defined as the Lagrangian change in $N_d$ relative to the mean evolution expected along each trajectory, and is calculated for trajectories within each $\sigma$-bin of our predictor variables. Predictor variables are measured at night, between both daytime $N_d$ observations.