

Marine Stratus Analysis and Parameterization using MODIS Observations

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1. MOTIVATION AND OBJECTIVE

Marine boundary layer clouds are important for the planetary energy balance because they cover large regions of the oceans and possess albedos that are much greater than the underlying ocean. Their radiative impact is influenced by cloud micro- and macrophysical properties that are not fully understood and a their realistic representations are essential to obtain realistic climate model simulations.

Climate models typically ignore the horizontal variability of cloud liquid water path within these clouds, and previous studies indicate that this variability may have an important impact on cloud albedo. We use four full years of cloud retrievals from MODIS for five prominent marine stratus regions to compile statistics of stratus cloud properties to assess the regional and seasonal impact of cloud horizontal variability on albedo.

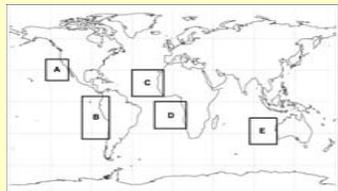


Figure 1. Study Regions. The five prominent marine stratus regions analyzed, referred to as: A= California, B=Peru, C=Canary, D=Angola, E=Australia.

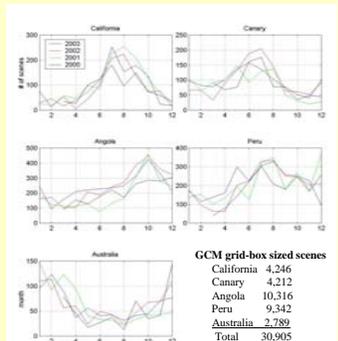


Figure 2. Number of Stratus Scenes Identified. 30,905 GCM grid-box sized scenes are identified from March 2000 to December 2003. Each region shows a seasonal cycle in the number of scenes identified, which may be considered a proxy for stratus cloud occurrence. Some interannual variability is evident within the seasonal cycle, but peak stratus months can be identified for each region.

4. CLOUD ALBEDO EFFECTS OF HORIZONTAL VARIABILITY

The horizontal variability of the cloud optical depth is quantified via a probability distribution function (PDF). The PDF is fit using a gamma distribution (Barker et al., 1996), where the variability is quantified in terms of the mean cloud optical depth and the gamma parameter. The gamma parameter is inversely related to the width of the distribution; thus large gamma values are associated with the most horizontally homogeneous clouds.

The effect of horizontal variability on the cloud albedo is computed as a difference between the plane-parallel albedo and the albedo when the full gamma distribution of cloud optical depth is used: $\text{Albedo}(\text{plane-parallel}) - \text{Albedo}(\text{gamma})$

The retrieval of cloud properties from partly cloudy pixels can be problematic if not accounted for (Coakley et al. 2005), and inclusion of these pixels might introduce false variability in our results. We assume that these pixels are most likely located at the edge of clouds, and we analyze their potential effects on our results by removing them via successive 'rings', as illustrated in Figures 5 and 6.

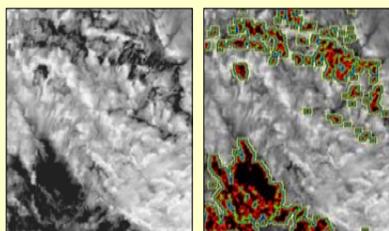


Figure 5. Cloud Edge Ring-Removal Analysis.

Cloudy pixels near cloud edges are removed via successive rings to evaluate the potential effects of contamination by partly cloudy pixels. Color coding shows successive cloud 'rings' removed where: 1=red, 2=green, 3=blue, 4=yellow.

Figure 6. Distributions After Ring Removal.

a) Frequency histograms of cloud optical depth for the pixels remaining after ring removal. Three months of California data are used. The largest change occurs when one ring is removed (difference between "No Rings" and "1 Ring").
b) Gamma parameter effect of ring removal. The gamma parameter systematically increases with ring removal, indicating a tightening (enhanced uniformity) in the cloud pixel distributions.

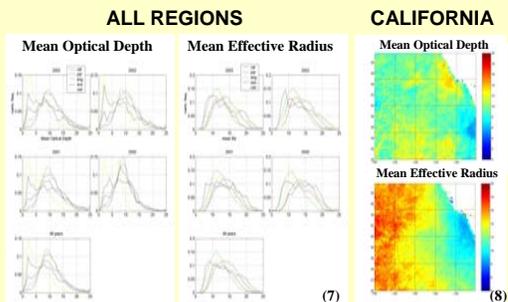
5. REGIONAL AND TEMPORAL VARIABILITY

Figure 7. Inter-Regional and Temporal Variability.

For the 300 km x 300 km scenes, histograms of the mean optical depth and effective radius indicate little difference in cloud properties in the same region for different years; however significant differences exist between the five stratus regions. Stratus clouds in the Canary region tend to have lower optical depth compared to the other regions. Peru stratus have the largest effective radii, probably related to a greater incidence of drizzle.

Figure 8. Intra-Regional Variability.

To understand the intra-region spatial variability in MODIS-observed cloud properties, we processed the peak months (July, August, September) for the California region for all years using an analysis window size of 10 km. These plots indicate a general increase of mean effective radius as we move away from the coast. Optical depth shows a bimodal structure with a maximum near the coast and then a secondary oceanic maximum.



6. METEOROLOGICAL ANALYSIS & PARAMETERIZATION

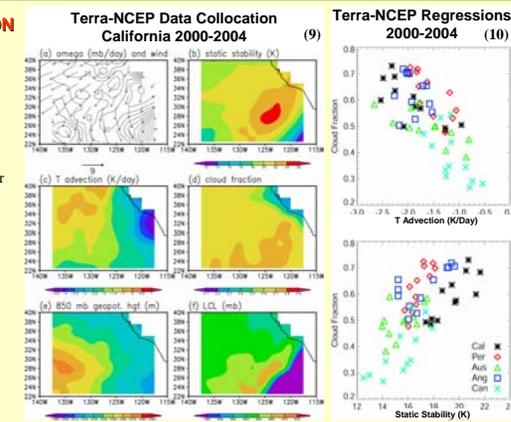
Meteorological analyses are conducted to parameterize the observed variability in the MODIS cloud properties (e.g., liquid water path and its gamma parameter). The cloud properties are related to prevailing meteorological parameters using the NCEP/NCAR 4-times daily reanalysis product, for which the 2.5° x 2.5° meteorological data are collocated with each independent 300 km x 300 km MODIS region. The meteorological fields considered include vertical velocity, temperature advection, lifting condensation level (LCL) of the surface air and sea surface temperature, and dry static stability (defined here as the potential temperature difference between 700 and 1000 mb).

Figure 9. MODIS-NCEP Collocation Example.

MODIS-Terra data are collocated with NCEP/NCAR data for 2000 to 2004. The regional variations are given for several meteorological properties and the MODIS-determined cloud fraction.

Figure 10. MODIS-NCEP Regression Example.

Regressions for the collocated data are given for the dependence of MODIS cloud fraction on temperature advection and static stability. All five stratus regions are presented, where each point is a monthly mean for the data from 2000 to 2004.



7. REGIONAL ALBEDO EFFECTS

Cloud albedo inhomogeneity effects (Plane-parallel minus Gamma) for cloud albedos and scene albedos, which include the cloud fraction.

TERRA 0 RING RESULTS

Including subgrid scale horizontal variability can decrease the cloud albedo (relative to plane parallel) by beyond 0.10.

Approximately 20% of the scenes have cloud albedo differences > 0.06.

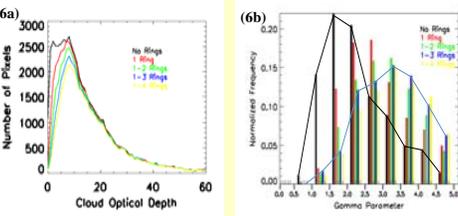
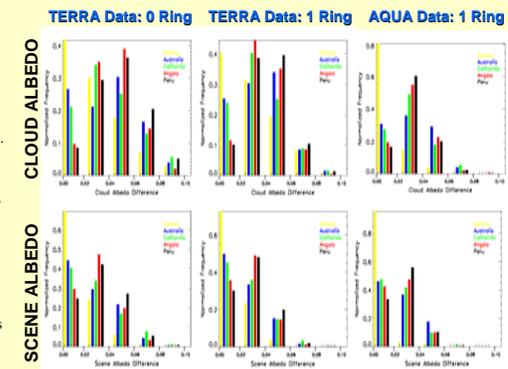
The larger cloud albedo differences tend to correlate with small cloud fractional cover so the net effect on the scene albedo is reduced. Less than 10% of the scenes have scene albedo differences greater than 0.06.

TERRA 1 RING RESULTS

Eroding only one pixel from the cloud edges significantly reduces the variability difference in cloud albedo and scene albedo.

AQUA 1 RING RESULTS

The sun-synchronous orbit of the Terra and Aqua spacecrafts result in overpasses at approximately 10:30 and 1:30 local time, which allows us to sample different parts of the diurnal cycle at a given location. Aqua results suggest that the clouds are far more homogeneous than during the Terra viewing time.



8. REFERENCES & ACKNOWLEDGEMENTS

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