1. Estimating the PBL depth from clouds seen by CALIPSO and MODIS

The Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIPSO) satellite provides an along-track vertical profile of cloud cover in the Vertical Feature Mask (VFM) product. We use returns in the lowest 3 km to identify boundary layer clouds just beneath the inversion, who’s altitude represents the depth of the Planetary Boundary Layer (PBL). Frequency distributions are analyzed to identify the PBL (the highest low cloud top) when multiple cloud layers are present.

The Moderate Resolution Imaging Spectroradiometer (MODIS) provides cloud top temperature (CTT) histograms for sub-pixels within 1° x 1° grid boxes, concurrent with CALIPSO observations, allowing for simultaneous, overlapping measurements. An iterative approach is applied using concurrent MODIS CTT and CALIPSO VFM measurements to tune the histogram sampling based on cloud cover, allowing us to estimate PBL depth for cloud amounts as low as 30%. Depth is based on the difference between sea surface temperature and CTT assuming a parameterized lapse rate.

The MODIS/CALIPSO PBL product is currently only calculated for clouds in these four regions of persistent Stratocumulus (Sc) cloud cover. Annual mean 95mb wind vectors are also shown. Daily grids will soon be available for years 2007-2010. This product produces values that match well with previous observations and shows the expected pattern of increasing PBL depth offshore in these regions. A Lagrangian study is currently underway to determine which environmental factors have the strongest effects on the subtropical Sc topped PBL.

2. Annual Mean PBL depths in the eastern subtropical oceans

3. Estimating the PBL depth using COSMIC GPS radio occultation

The Constellation Observation for Meteorology, Ionosphere, and Climate (COSMIC) project uses Global Positioning System (GPS) satellites in concert with Low Earth Orbiting (LEO) satellites to measure atmospheric profiles. Radio signals between GPS and LEO satellites are occulted (bent) depending on atmospheric density, which in turn varies with humidity and temperature. As an LEO satellite ‘sets’ behind the Earth relative to a GPS satellite, the line-of-sight between the two approaches the surface. The position of the LEO and GPS satellites relative to each other and to other nearby GPS satellites can be used to determine the degree of Radio Occultation (RO). The PBL is associated with a strong increase in humidity (hydrolapse) as one observes downward in the profile. The PBL in this dataset is assigned to the maximum vertical gradient in refraction, indicated by sudden jumps in RO, most likely associated with the strongest hydrolapse.

The COSMIC/CALIPSO product in

4. The seasonal cycle of PBL depths over the oceans from COSMIC GPS RO

The PBL depth is calculated as an annual mean for the equatorial Pacific and Atlantic regions. Seasonal cycles in PBL depth appear strongest in the eastern subtropical and extratropical ocean basins, showing a stronger magnitude than in the eastern subtropical basins.

5. Comparing MODIS and COSMIC PBL measurements in overlapping regions

On the left, time series of monthly mean PBL depth are shown for each product as well as the correlation coefficient between time series. The annual cycle in PBL depth is shown on the right. Each individual year is shown by a faint line. A curve is fit to the mean annual cycle and shown as the thick line.

6. Possible causes of disagreement

In the NE Pacific and SE Atlantic there is a discrepancy in the average PBL depths during the ‘shallow’ season with the COSMIC PBL noticeably deeper. This may be caused by the relatively abrupt profiles of water vapor, as shown in these vertical profiles taken during the shallow PBL season in the NE Pacific (CET) shown below. It is likely that the COSMIC product is seeing one of many hydrolapses above the temperature inversion. Agreement is better in the SE Pacific where the mid-troposphere is much drier.

In the E Indian region the PBL appears much deeper in the MODIS-CALIPSO product. In this deep region the COSMIC product may be assigning the PBL depth to the height of the sub-cloud mixed layer, or the parameterized lapse rate used in the MODIS-CALIPSO product may be inappropriate for boundary layers of this depth. The MODIS-CALIPSO data also relies on a high cloud filter to remove CTT returns that are below freezing. The PBL may show subtle differences when high clouds are present. Further work using both products lead to improvements in both techniques, allowing for even better sampling of the marine PBL in time and space.

References