Remote Sensing of the Thermal Structure of Marine Boundary Clouds in the Southeast Pacific using COSMIC, CALIOP, and Radiosonde Data

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1. Introduction

Accurate characterization of the evolution of the planetary boundary layer (PBL) height is critical to the exchange of energy and moisture from the Earth surface to the free troposphere, which in turn impacts the formation of clouds and water and energy cycles. Recent studies have shown that the high-resolution Global Positioning System (GPS) radio occultation (RO) data from FORMOSAT-3/CO-Orbit Satellite Observing System for Meteorology, Ionosphere, and Climate (COSMIC) are very useful to detect the PBL heights. However, due to lack of high vertical resolution in situ observations, validation of RO PBL height especially over the oceans is difficult. In this study, the PBL heights derived from COSMIC RO data are compared to those derived from the Cloud-Aerosol Lidar with Orthogonal Polarization (CALIOP) measurements.

Characteristics of GPS RO Data
- Measurement of time delay: no calibration needed
- High precision (~400 m) (He et al., 2001, 2004, He et al., 2004, 2012)
- Inversion of clouds and precipitations (vertical resolution ~10 km)
- Detection of cloud top height using RO data (Blondel et al., 2012, ACP; Blondel et al., 2013 GCR)

2. MBL height detection using COSMIC RO Data over the Southeast Pacific during the VOCALS-REx

In this study, COSMIC bending angle, refractivity, and water vapor pressure profiles are used to derive the MBL height. In a neutral atmosphere the refractivity (N) is related to pressure (P) in mbar, temperature (T) in K, and water vapor pressure (v) in mbar according to the following equation

\[ N = 77.6 \frac{P}{T} + 3.73 \times 10^3 \frac{P}{T} \]

1) Minimum Gradient method (MG)

\[ X(Z) = \frac{X(Z) - X(Z_n)}{Z - Z_n} \]

2) Break Point (BP) method: Sokolovsky et al. [2009] and Guo et al. [2011] estimated the MBL height by finding the “break point” in the N profile. This is an approximation of the second derivative of the N profile and is the so-called “break point” in the profile.

The spatial and temporal variability of the MBL over the Southeast Pacific is studied using radiosonde data from the VAMOS Ocean-Clouds-Aerosol-Land Study Regional Experiment (VOCALS-REx) and COSMIC RO data with the MG and BP methods.

3. Collocation of CALIPO and COSMIC data

CALIPO data onboard Cloud-Aerosol Lidar and Infrared Pathfinder Satellite Observation (CALIOPSO) satellite. CALIPO is a two-wavelength (532 nm and 1064 nm) polarization-sensitive lidar that provides high-resolution vertical profiles of aerosols and clouds. CALIPO data are used to study the collocated PBL height with CALIOP.

4. Statistical comparisons of MBLH from COSMIC and co-located CALIOP Cloud-top Observations

Figure on the left depicts the scatter plots for the 77 RO-CALIOP pairs for MBLHmin, MBLHmax, and MBLH using breaking point method with the corresponding CALIOP MBLH, respectively. In general, the RO-defined MBL heights from bending angles, refractivity, and water vapor profiles are more similar to the CALIOP cloud tops than the heights estimated from the Break Points in refractivity. The mean differences for MBLHmin, MBLHmax, and MBLH are similar.

5. Diurnal and inter-annual MBLH Variations

Figure on the right depicts the diurnal variation of the binned MBLHmin, MBLHmax, and MBLH from co-located CALIOP. The MBLHmin, MBLHmax, and MBLH from CALIOP are slightly lower than the mean MBLHmin, MBLHmax, and MBLH from RO-CALIOP.

6. Conclusions

- The spatial and temporal variability of the MBL over the Southeast Pacific is studied using RO data from the VAMOS Ocean-Clouds-Aerosol-Land Study Regional Experiment (VOCALS-REx), and CALIOP.

The seasonal variation of the RO MBLH and the CALIOP MBLH data from September 2007 to March 2010.

References:

The mean longitudinal variation of RO derived MBLH in the VOCALS-REx region is shown. This shows that the MBLHmin, MBLHmax, and MBLH from CALIOP increase from around 1 km near 90° W to 1.5 km at 86° W.