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Abstract Schedule:
Date: Monday, January 11, 2021
Time: 1:30 p.m. - 1:35 p.m.

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VIRTUAL | 10-15 January 2021

Planetary Boundary Layer Height Retrievals from COSMIC-2

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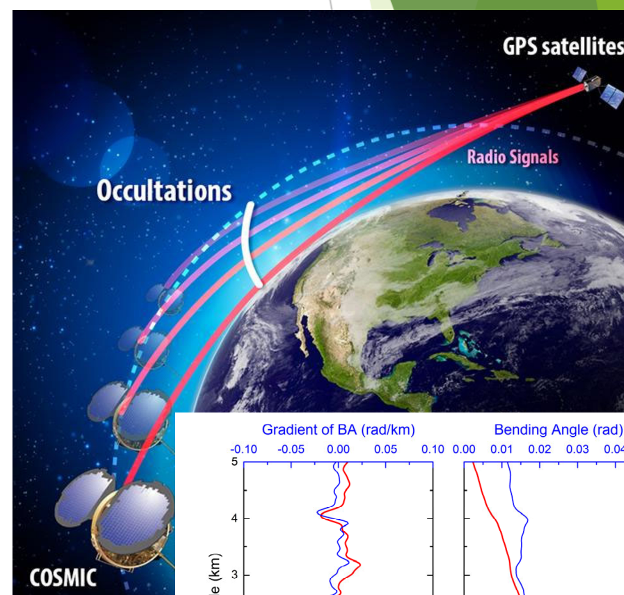
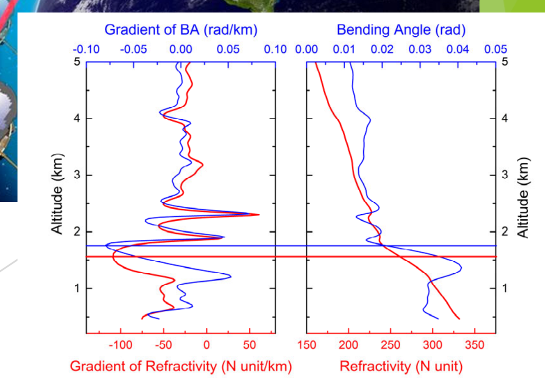
COSMIC2 Introduction

- A receiver on low Earth orbit tracks the change in the phase of radio signals(1-2GHz) transmitted from GNSS constellations(e.g., GPS, GLONASS, Galileo) as the signals pass through different atmospheric layers
- The phase delay measurement is directly related to the refractivity index of the medium, which a function of temperature, pressure, and specific humidity
- Observable: bending angle or refractivity profile
- PBL Height: derivable from vertical gradient of bending/refractivity
- Resolution: vertical ~100 meter
- Cloud penetration: all weather, all surface conditions
- The NOAA National Centers for Environmental Prediction (NCEP) operational numerical weather prediction system has started to assimilate COSMIC-2 data since early 2020.

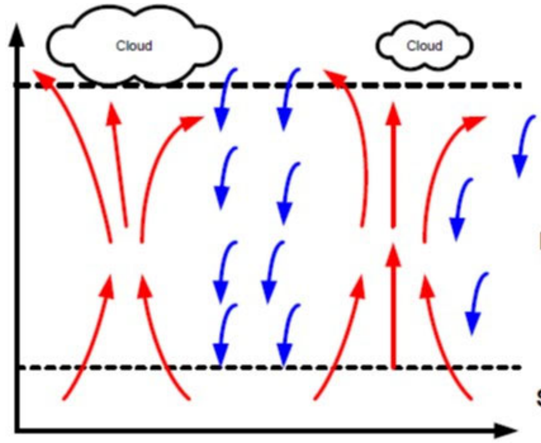




Motivation I

- Planetary boundary layer (PBL) is the key component of the weather and climate system and air quality, It is an interface between earth's surface and the free troposphere through affecting energy and mass flux
- The characteristic and changes with time of PBLH also indicates the evolution of low clouds
- Mixing height given by PBLH is the fundamental parameter to characterize the vertical extent of mixing within the boundary layer and the level at which exchanges with the free troposphere occurs

During a clear day, it consists of ***a roughness sublayer*** (air flows around individual roughness elements-grass, plants, trees, or buildings), ***a surface boundary layer***, ***a well-mixed layer*** and ***capping entrainment layer***



Entrainment Zone : The atmospheric boundary layer (ABL) is capped by temperature inversion, which inhibits mixing and confines pollution bellow it.

Mixed Layer: Potential temperature and other quantities are constant with altitude, Earth's rotation becomes important and the wind direction veers with height

Surface Layer : Formerly known the constant flux layer, ~100m thick or 10% of the PBLH

MBL height detection using COSMIC RO Data-Minimum Gradient method (MG)

- To remove sharp vertical structures between layers resulting from local perturbations, we first apply LOWESS(**locally weighted scatterplot smoothing) to smooth all bending angle**
- To estimate the PBL height, the Minimum Gradient method(MG) was used. the first and second derivative of bending angle was calculated

First derivative: $X'(Z_i) = \frac{X(Z_i) - X(Z_{i-1})}{Z_i - Z_{i-1}}$

Second derivative: $X''(Z_i) = \frac{X'(Z_i) - X'(Z_{i-1})}{Z_i - Z_{i-1}}$

The second derivative was used to find the minimum position of first derivative height

Data Set

- UCAR COSMIC2 atmPrf from 10/1/2019 to 10/31/2019
- CALIPSO v4.20 cloud layer from 10/1/2019 to 10/31/2019

- The ERA5 PBLH were collocated with COSMIC2 occultation position and time
- CALIPSO v4.20 cloud layer were collocated with COSMIC2 profiles

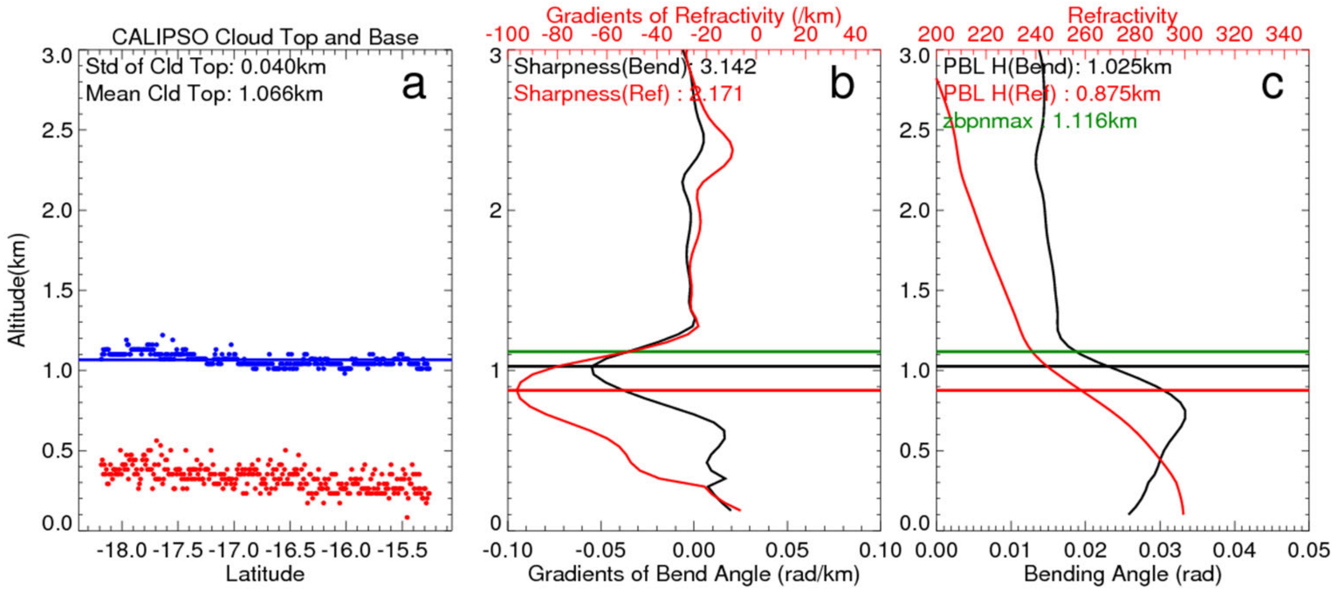
  Collocation condition

  - Time: < T_0 hours
  - Distance: $< D_0$ km
  - Developed a Normalized Pairing Parameter which defined as:

$$Total_{\Delta} = \frac{\Delta \mathrm{T}}{2\mathrm{hours}} + \frac{\Delta S}{200km}$$

  - choose the smallest "$Total_{\Delta}$" when searching the spatio-temporal closest pairs
- Only the profiles which penetrated deeper than 500 meter were considered

Comparison of CALIPSO-CALIOP Cloud Top Heights and COSMIC ABL Heights

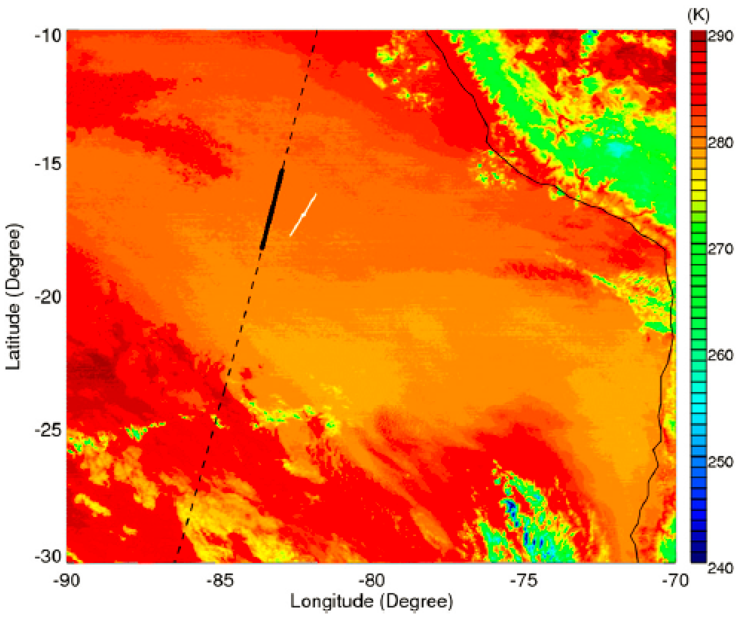


The gradient of the bending angle profile is a good indicator of ABL cloud height.

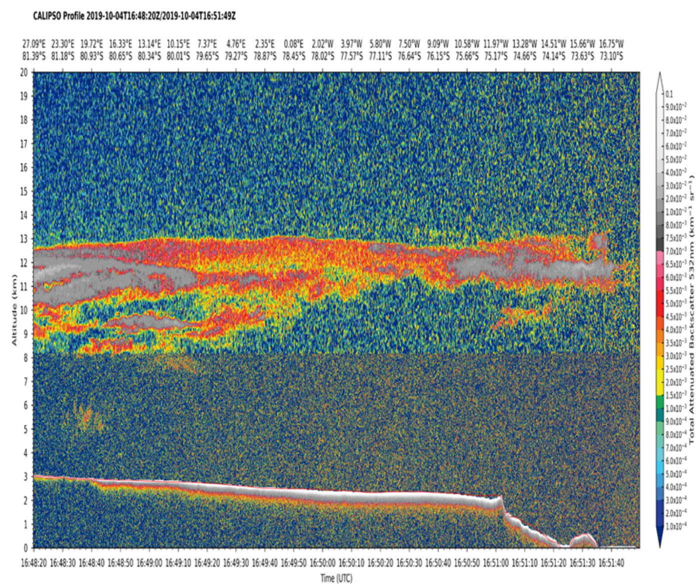
Results

- Compared COSMIC2 PBL height with CALIOP low cloud
- Compared COSMIC2 PBL height with ERA5 PBLH

Collocated CALIOP and GNSS-RO track



Courtesy of Ho, Shu-peng, et al. 2015

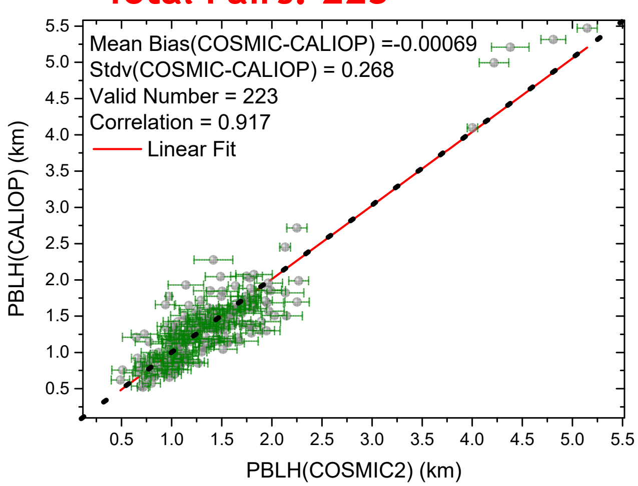


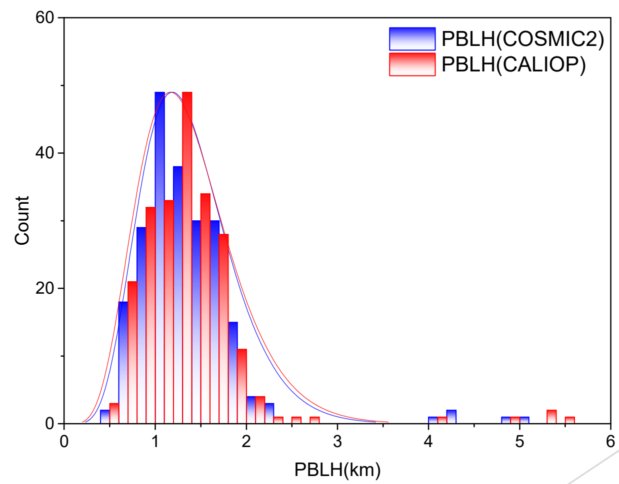
After Quality Control of CALIOP Low Cloud Height when pairs with COSMIC2 PBLH

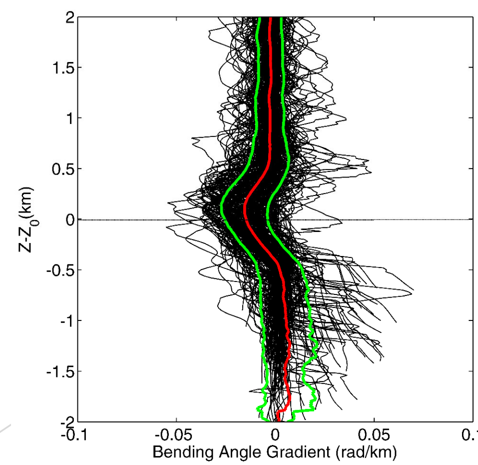
- Boundary Layers are usually shallow, cloud-capped and has a well-mixed appearance; the cloud layer, however, is often decoupled
- To reduce possible uncertainties associated with the variability of CALIOP cloud-top heights within the 200-km and 2-h window
- only those RO-CALIOP pairs that contain more than 150 CALIOP pixels and where the standard deviation of the CALIOP cloud-top heights in the ensemble relative to its mean is less than 0.1 km are paired.

After Quality Control

Total Pairs: 223

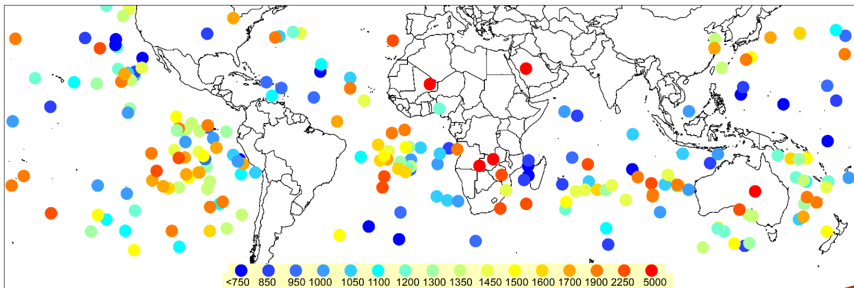




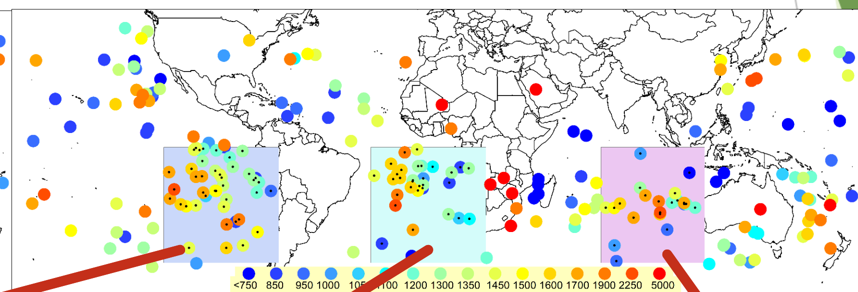


Geographical distribution of the paired CALIOP low cloud top height and COSMIC2 PBLH

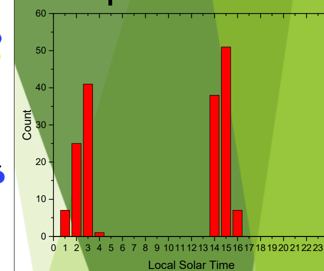
COSMIC2 PBLH

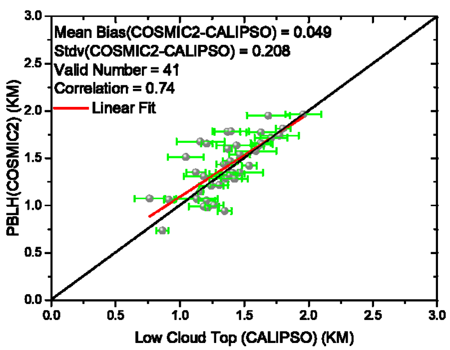


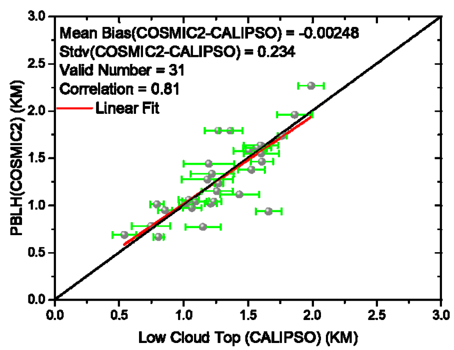
CALIOP Low Cloud

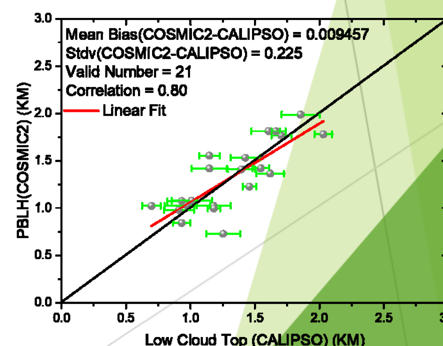


local solar time of pairs



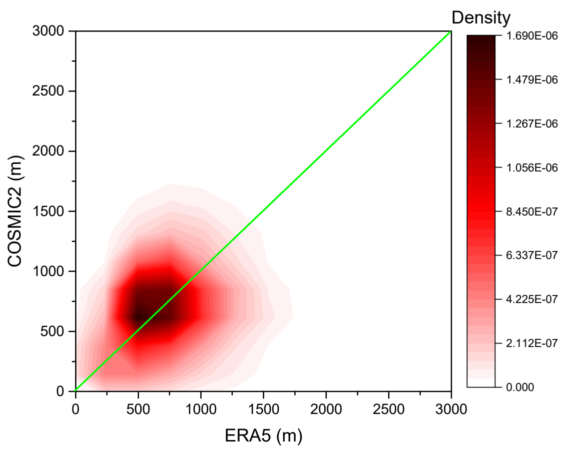




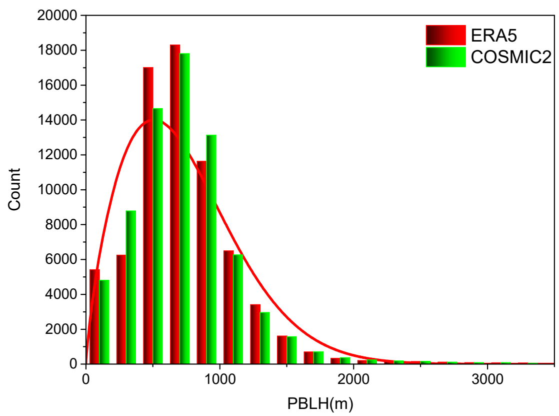


COSMIC2 PBLH VS ERA5 PBLH

scatter density plot



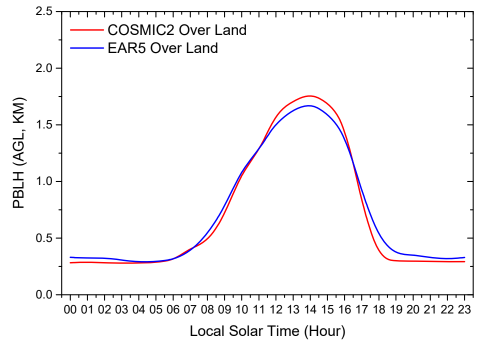
Histogram Plot



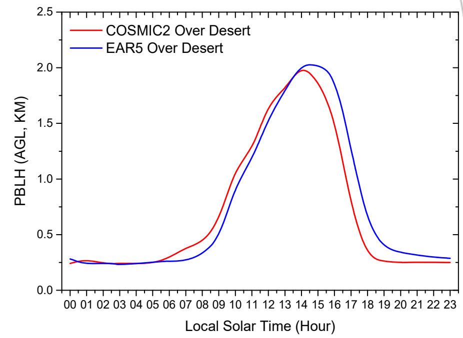
Comparison between COSMIC2 and ERA5 PBLH on different land surface type

- The PBLH over water doesn't show the obvious diurnal variation on the global average
- But the PBLH over land shows very obvious diurnal cycle
- The PBL depth is generally greater in arid regions because of clear skies and low substrate water content, which allow higher surface temperatures, resulting in stronger sensible-heat fluxes to the atmosphere and deeper turbulent mixing.

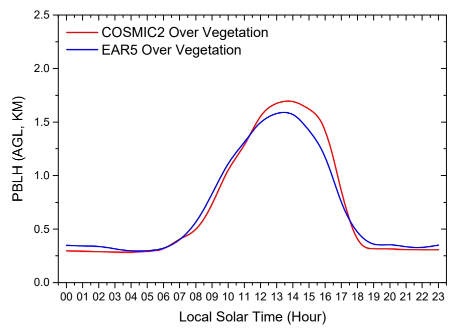
land



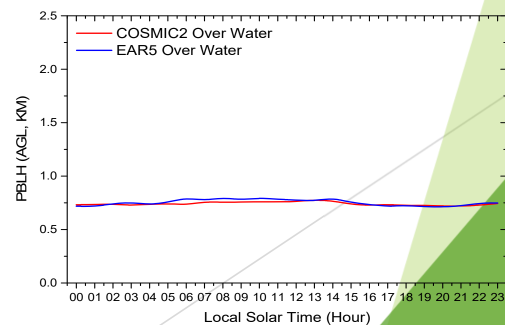
Desert



Vegetation



Water



Conclusion

- On average, the COSMIC2 PBLH is consistent with CALIOP low cloud top height and also consistent with ERA5 PBL height. The mean PBL heights from COSMIC2 have similar diurnal variations with that of ERA5; The PBL height over desert has deeper variation than that over vegetation regions. But PBLHs over Ocean show non-clear diurnal cycles in terms of global average
- GNSS RO measurements has fine vertical resolution, cloud-penetrating ability, and moist thermodynamics information about the **PBL**. The observation of refractivity/bending angle is function of temperature, pressure, and specific humidity in lower troposphere. It provides a new opportunity in detecting PBL heights.
- Especially, recently launched COSMIC-2 which provides more than 4,000 atmospheric Bending Angle (BA) and refractivity profiles each day, the signals have higher Signal-Noise-Ratio (SNR) compared to other Global Navigation Satellite System (GNSS) Radio Occultation (RO) missions and a deeper penetration than those from other RO missions
- But we have to notice that current GNSS data are not very well-suited in **identifying** and **determining** the depths of the shallower PBLs due to the data quality near the surface

Thanks