1st ever ARM Summer Training

Boundary Layer Structure: a comparison between methods and sites

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July 24 2015

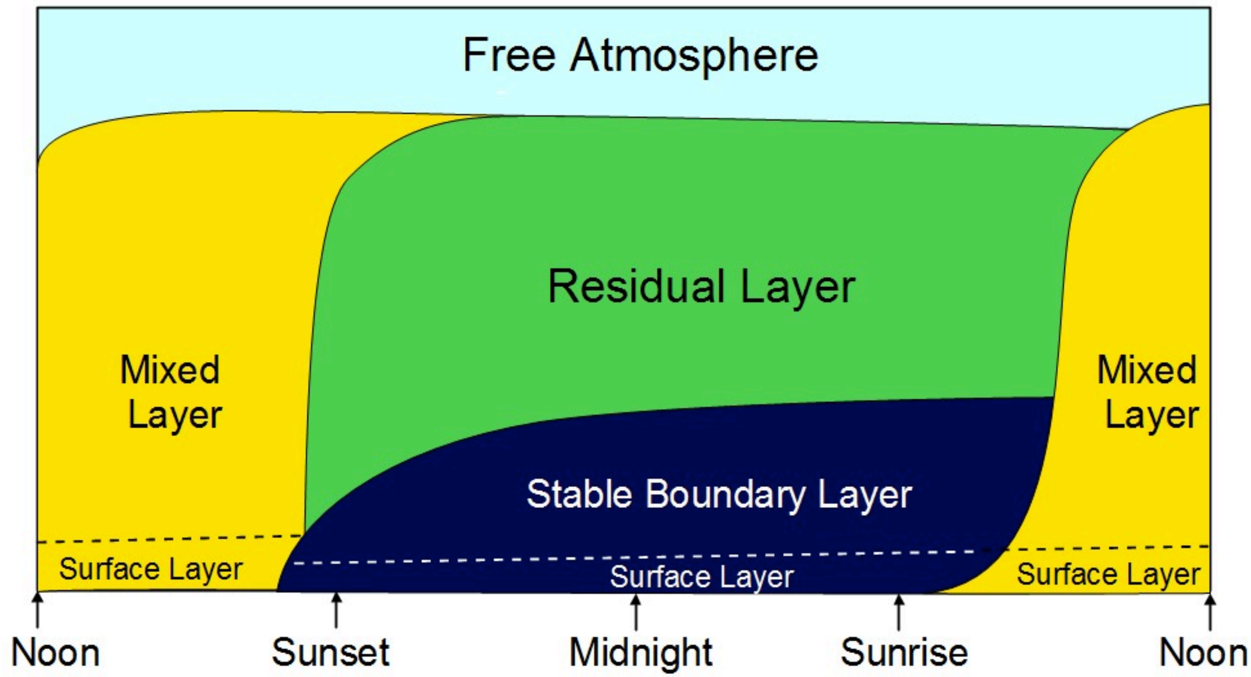
Outline

- Introduction
- Methodology
- Results
  - SGP
  - MAO
  - Comparison between the 2 sites
- Conclusions

INTRODUCTION

Focus: estimates of PBL height

Boundary Layer: “The bottom layer of the troposphere that is in contact with the surface of the earth.” (AMS, Glossary of Meteorology)



Importance

- Impacts on cloud formation
- Aerosol studies
- Improving weather numerical modelling

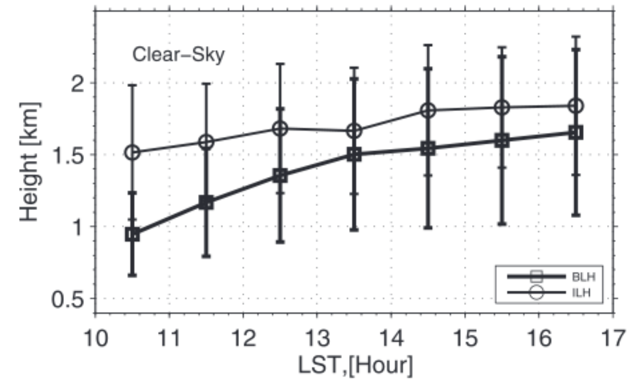
Sites

SGP – Southern Great Plains, US

MAO – Manacapuru, Brazil

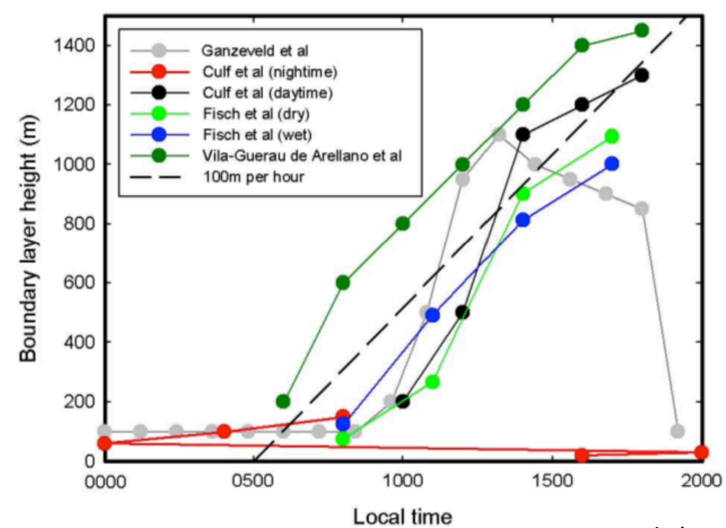
Sites

SGP – Southern Great Plains, US



Chandra et al. (2010)

MAO – Manacapuru, Brazil



Pearson et al. (2010)

Goals

- Evaluation of the methods for PBL height estimation for each site
- Intercomparison of the PBL structure between the two sites

METHODOLOGY

Instrumentation and Data

Instrument	Variable	Spatial resolution	Temporal resolution
Doppler Lidar	Backscatter, velocity	30m	0.3s
Radiosonde	T, P, RH, wind speed	23~30m	6h
Ceilometer	backscatter	30m	15s
Radar Wind Profiler	SNR of reflectivity	60m	15s
ECOR	Sensible heat flux latent heat flux	-----------	30m

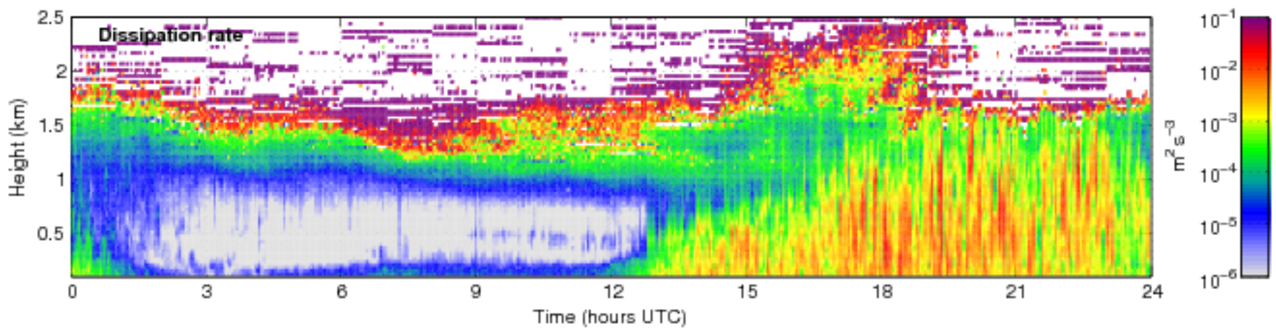
PBL Retrieval using Doppler Lidar

- TKE dissipation rate **ε**

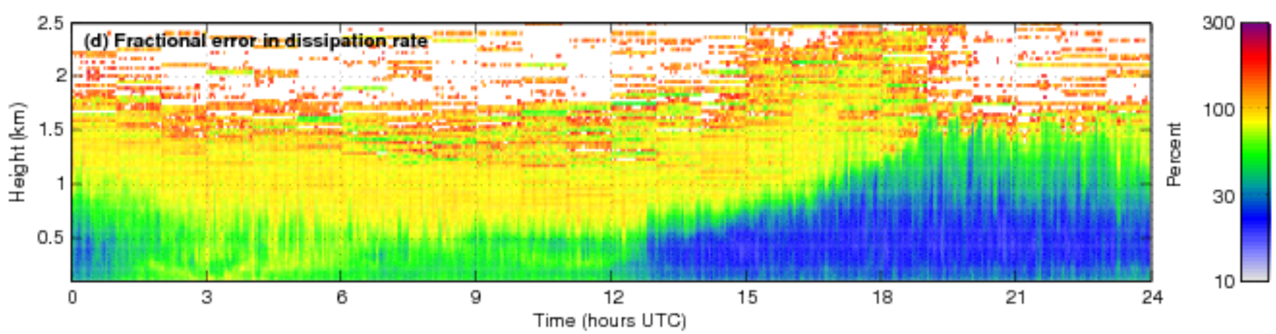
O'Connor et al. (2010)

$$\varepsilon = \left(\frac{2}{3a}\right)^{3/2} \sigma_{\bar{v}}^{\;3} \left(k_1^{-2/3} - k_2^{-2/3}\right)^{3/2}$$

Dissipation Rate



Fractional Error



- Use dissipation threshold of $3\times10^{-5} m^2 s^{-3}$
- Use fractional error threshold 80% to filter the data

PBL from Radiosondes

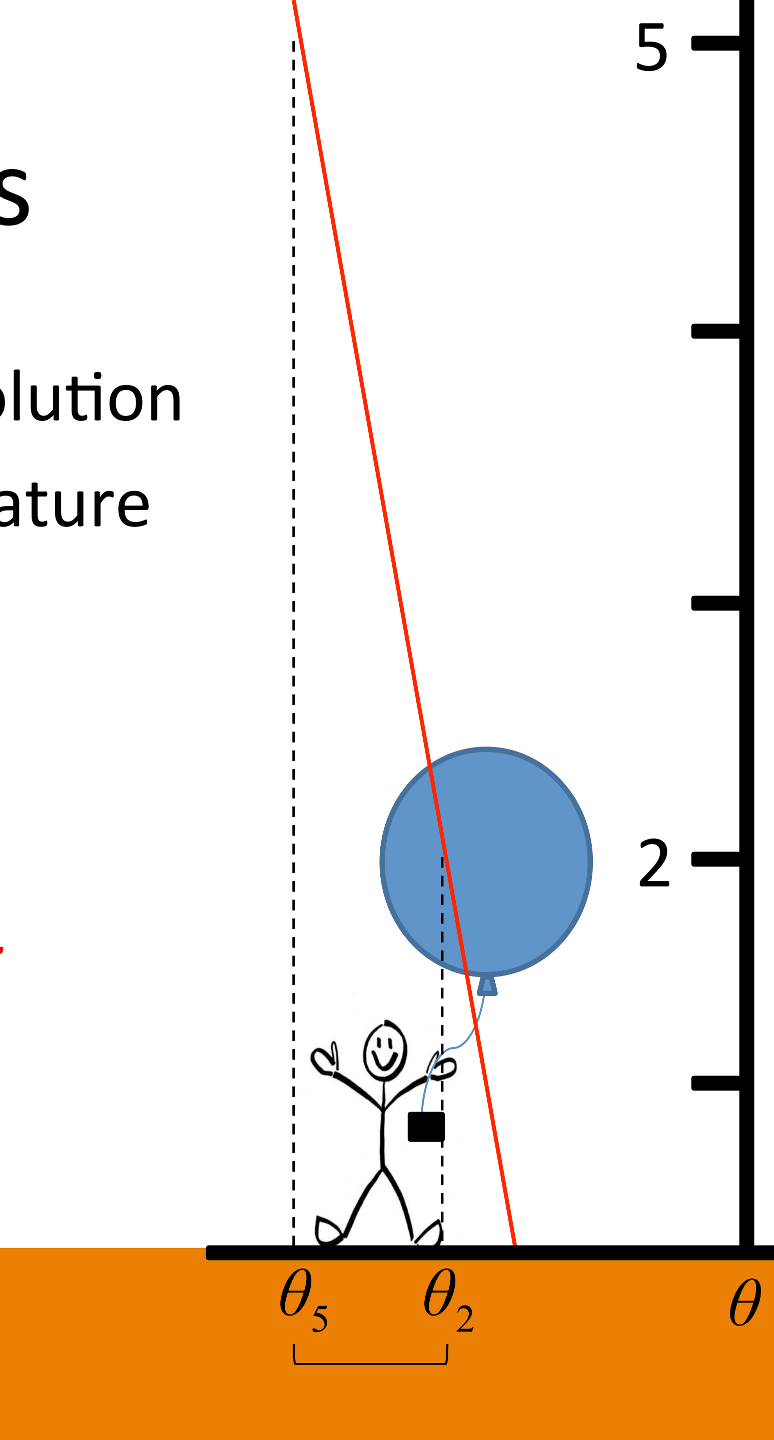
- Data is subsampled at 5mb resolution
- Calculation of potential temperature

$$\theta = T\left(\frac{p_0}{p}\right)^{R/c_{pd}}$$

- Determination of PBL regime

$$\theta_5 - \theta_2 < -\delta_s$$

Convective BL



– Over land, δ_s = 1 K

PBL from Radiosondes

- Data is subsampled at 5mb resolution
- Calculation of potential temperature

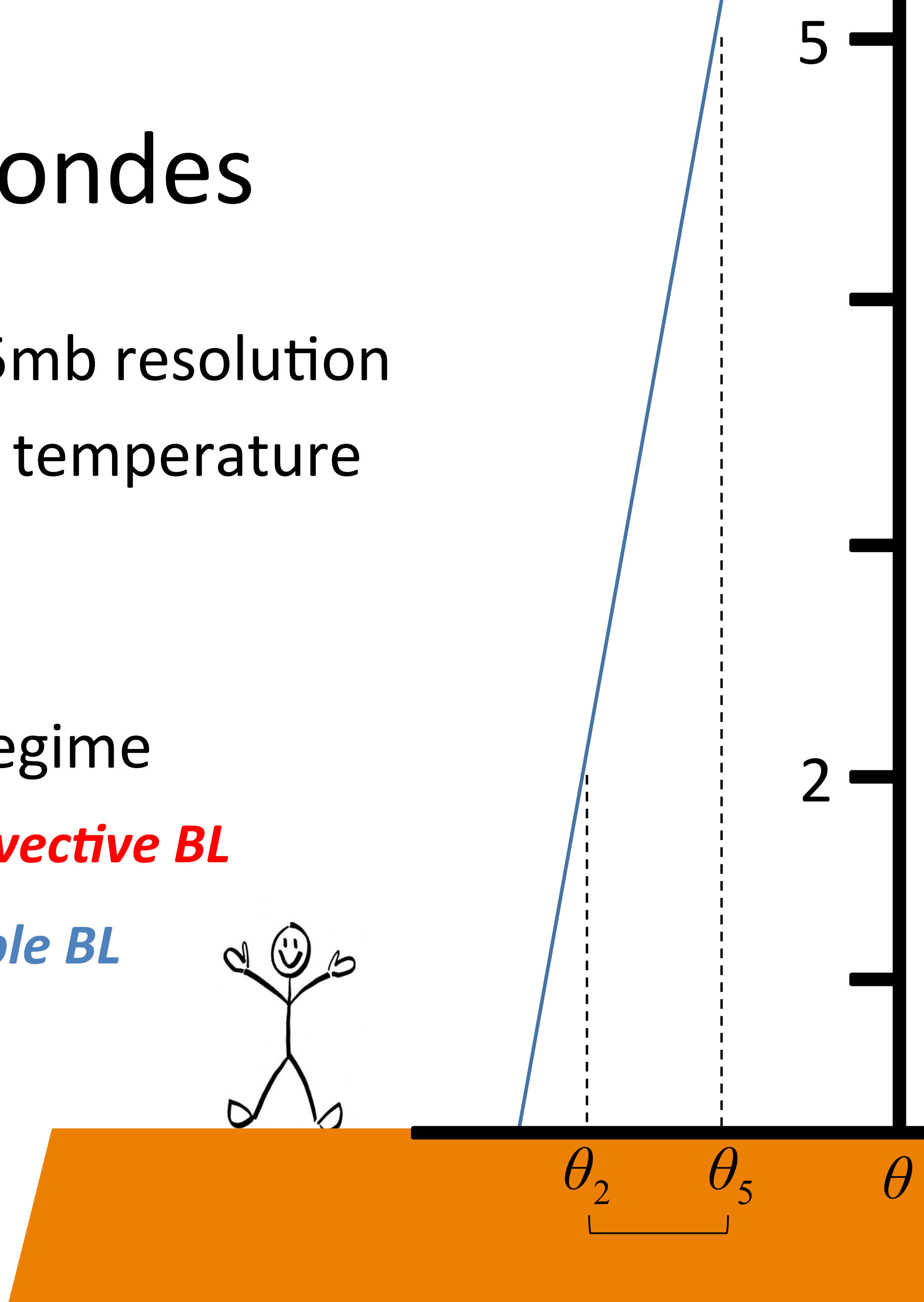
$$\theta = T\left(\frac{p_0}{p}\right)^{R/c_{pd}}$$

- Determination of PBL regime

$\theta_5 - \theta_2 < -\delta_s$ **_Convective BL_**

$\theta_5 - \theta_2 > \delta_s$ **_Stable BL_**

  – Over land, δ_s = 1 K



PBL from Radiosondes

- Data is subsampled at 5mb resolution
- Calculation of potential temperature

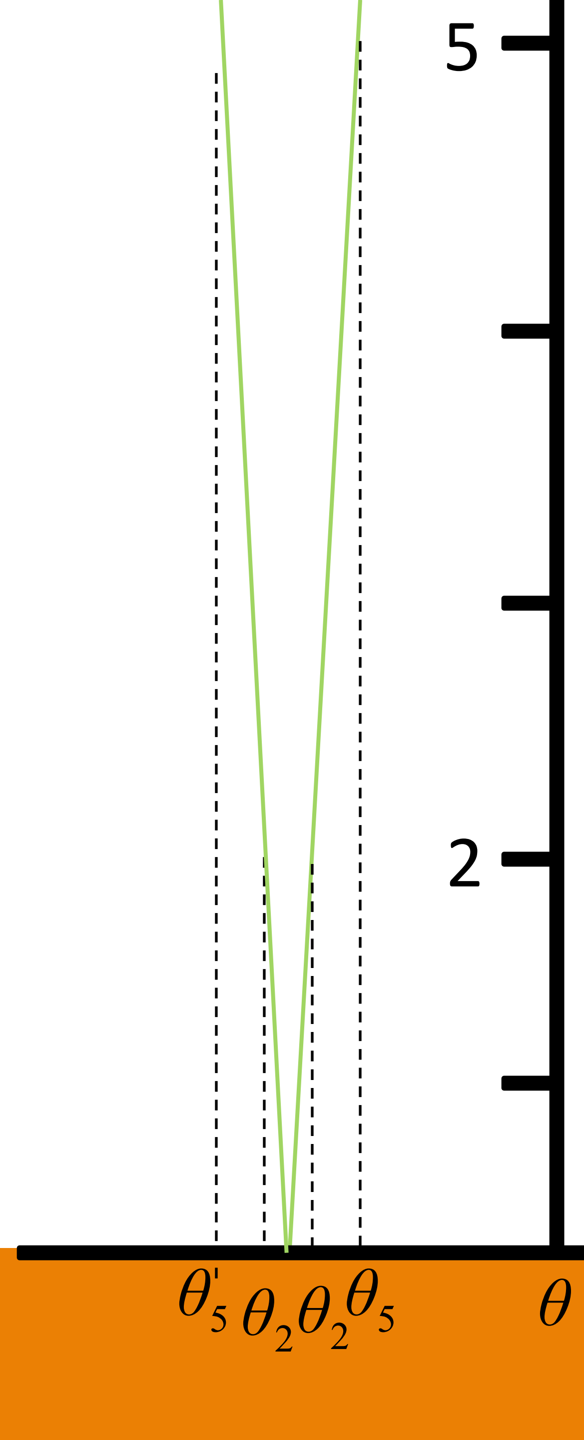
$$\theta = T\left(\frac{p_0}{p}\right)^{R/c_{pd}}$$

- Determination of PBL regime

$\theta_5 - \theta_2 < -\delta_s$ *Convective BL*

$\theta_5 - \theta_2 > \delta_s$ *Stable BL*

$-\delta_s \le \theta_5 - \theta_2 \le \delta_s$ *Neutral BL*

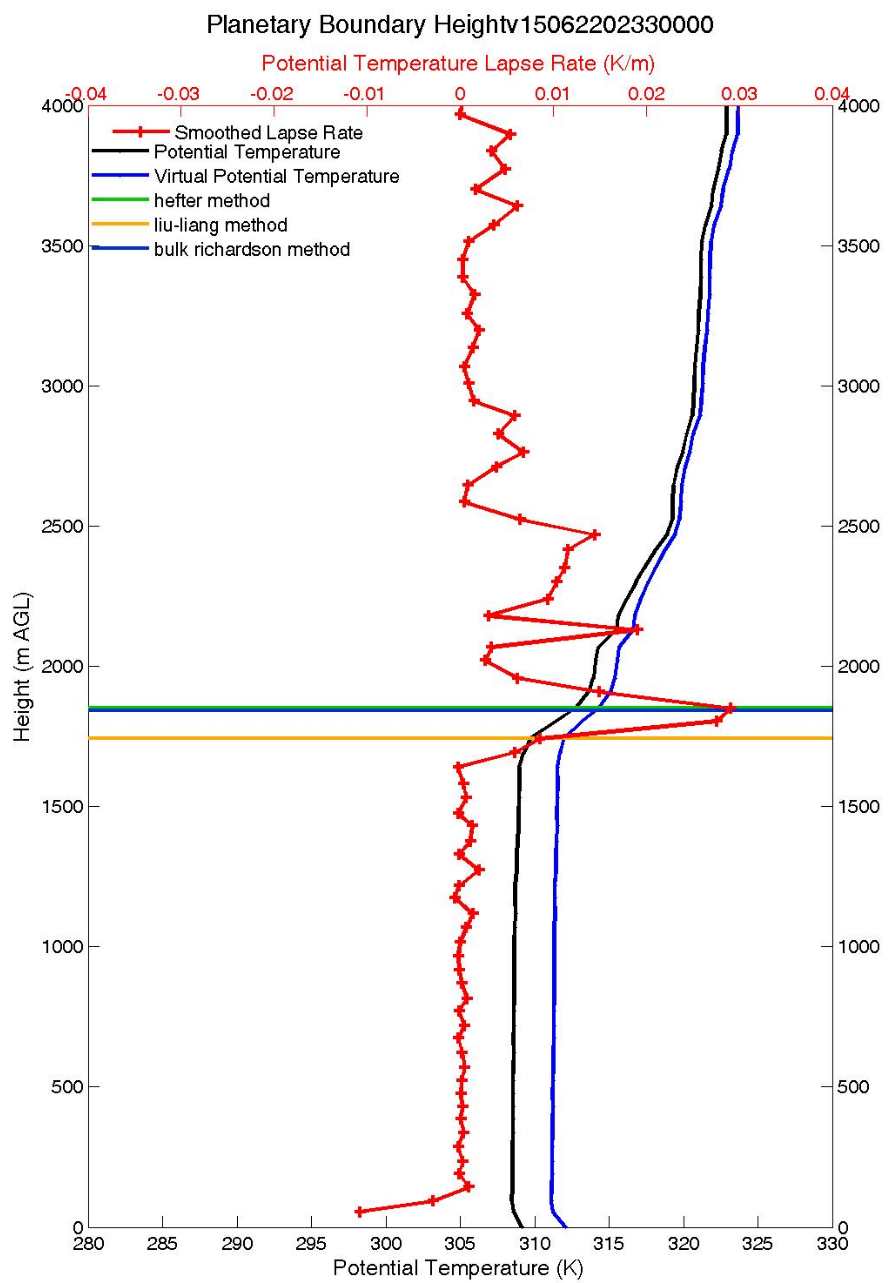


– Over land, δ_s = 1 K

PBL from Radiosondes

Method: Liu and Liang

- Convective or neutral: "height at which an air parcel rising adiabatically from the surface becomes neutrally buoyant."
  - Find lowest level k where:
    (0.5 K)
  - Upward scan to determine lowest level where: $\frac{\partial \theta_k}{\partial z} \geq \frac{\partial \theta_r}{\partial z}$ (0.004 K/m)
- Stable: more uncertain definition, may be based on stability or wind shear criteria.



PBL from Radiosondes

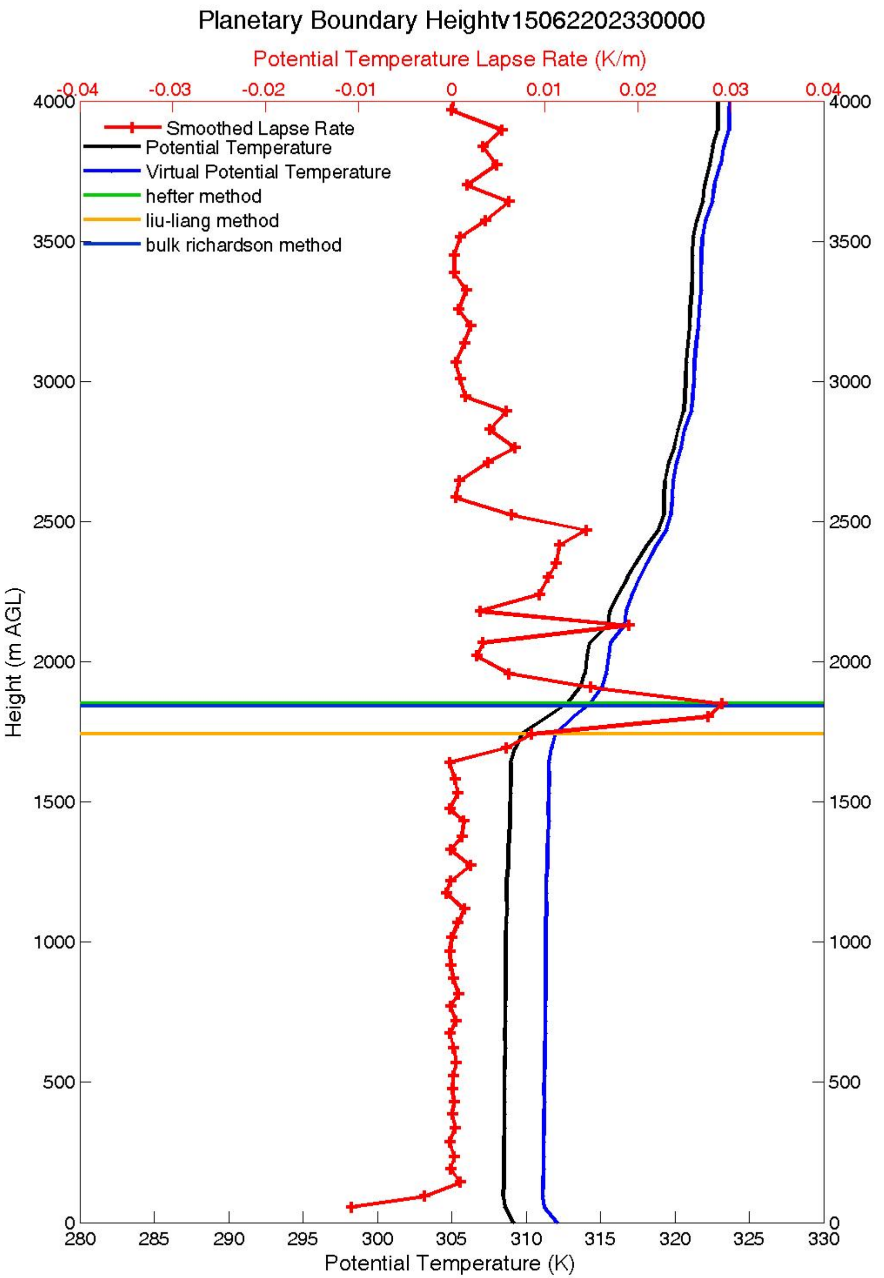
Method: Heffter

- Looks at the strength of the inversion layers:
  - Smooth data to avoid identification of spurious layers (15mb)
  - Identify up to 5 inversion layers:

  consecutive heights where

  $$\frac{\partial \theta_k}{\partial z} > 0.005K/m$$

  - Identify the lowest inversion layer in which $\Delta\theta > 2$ K

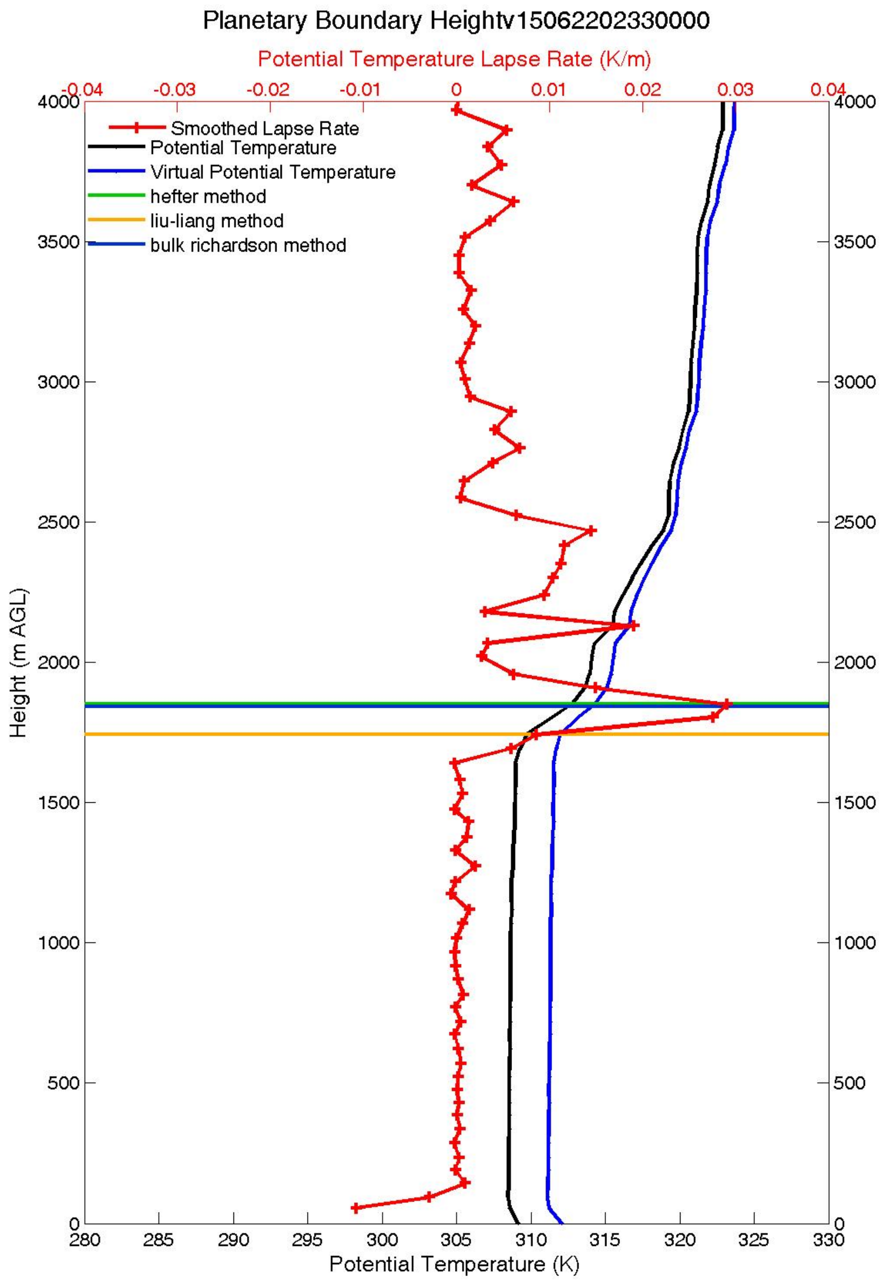


PBL from Radiosondes

Method: Bulk Richardson number

$$Ri_b = \left(\frac{gz}{\theta_{v0}}\right)\left(\frac{\theta_{vz}-\theta_{v0}}{u_z^2+v_z^2}\right)$$

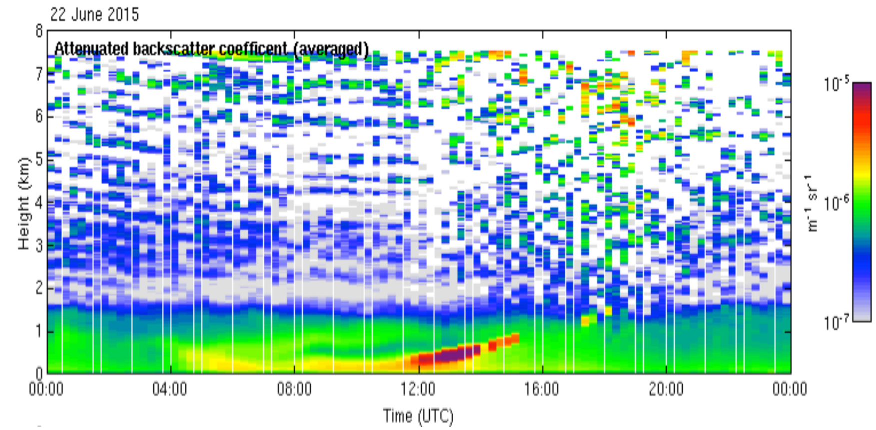
- Represents the ratio of turbulence produced by thermal gradient to that produced by vertical shear
  - PBL height: $Ri_b > Ri_c = 0.25$ or 0.50

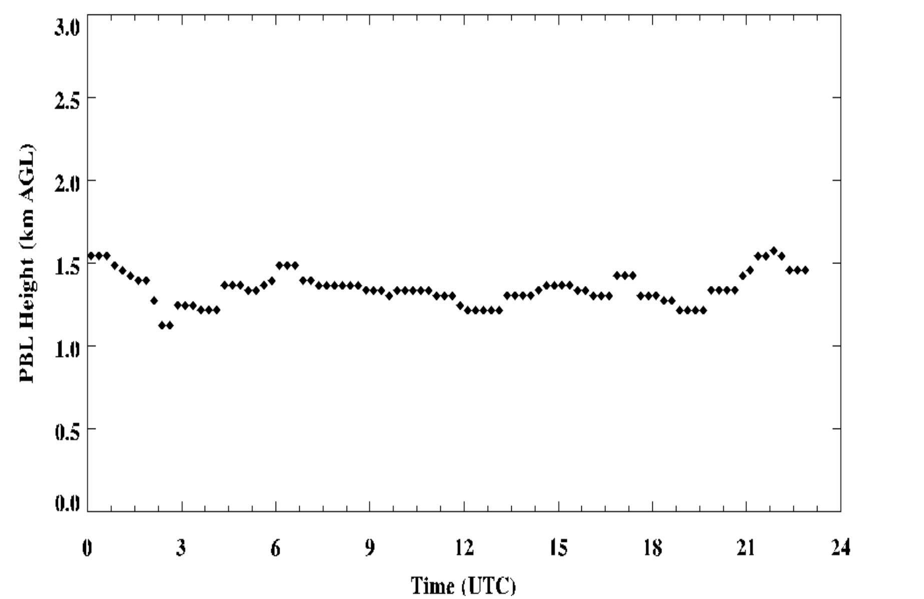


PBL Retrieval using Ceilometer

- Aerosol
  - scatters ceilometer beam.
  - is mixed in BL
  - can be tracer of BL
  - Threshold = $5\times10^{-7}\ m^{-1}sr^{-1}$

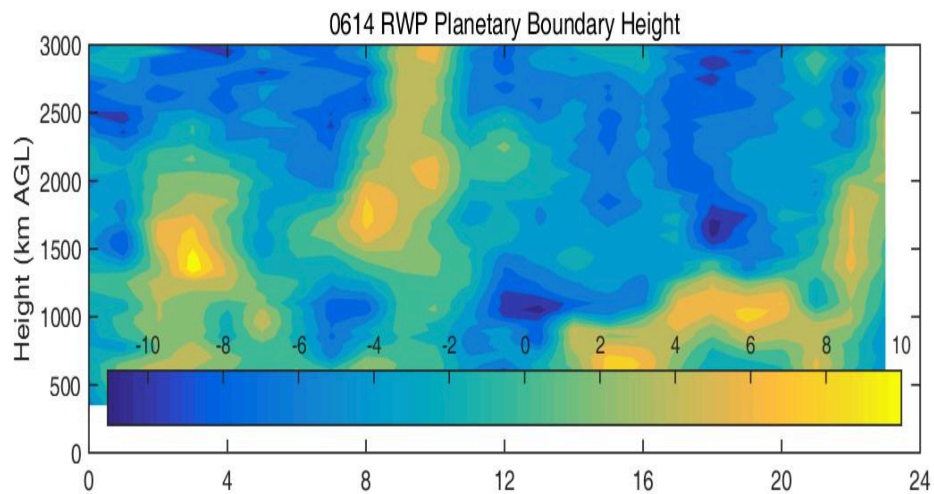
- Constraints
  - Not always



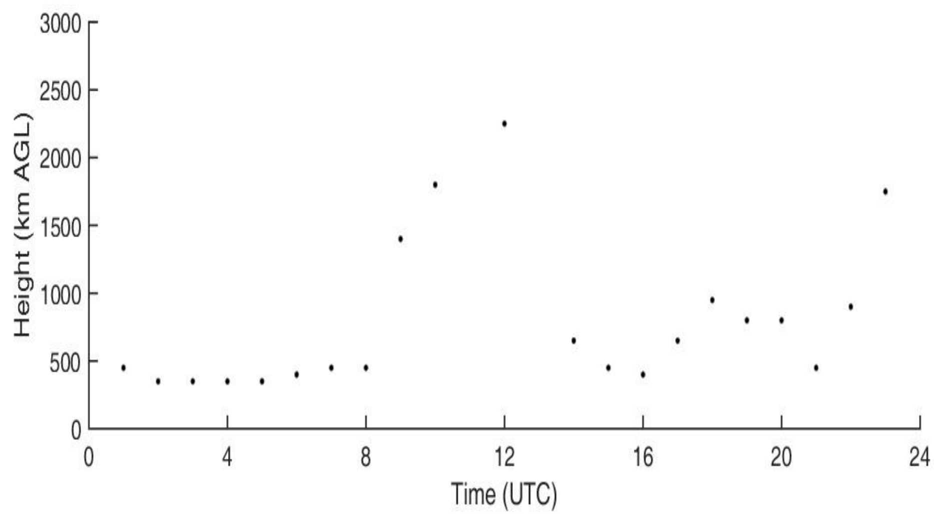


PBL Retrieval using Radar Wind profiler

- Bragg scattering
  - related to T,q change
  - Threshold = 2dB



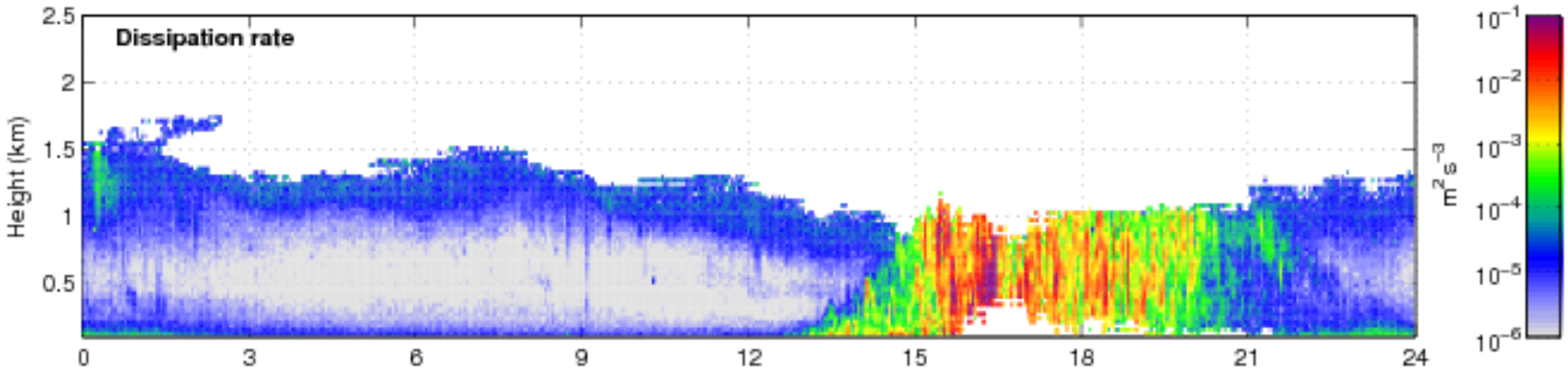
- Constraints
  - cloud edge effect

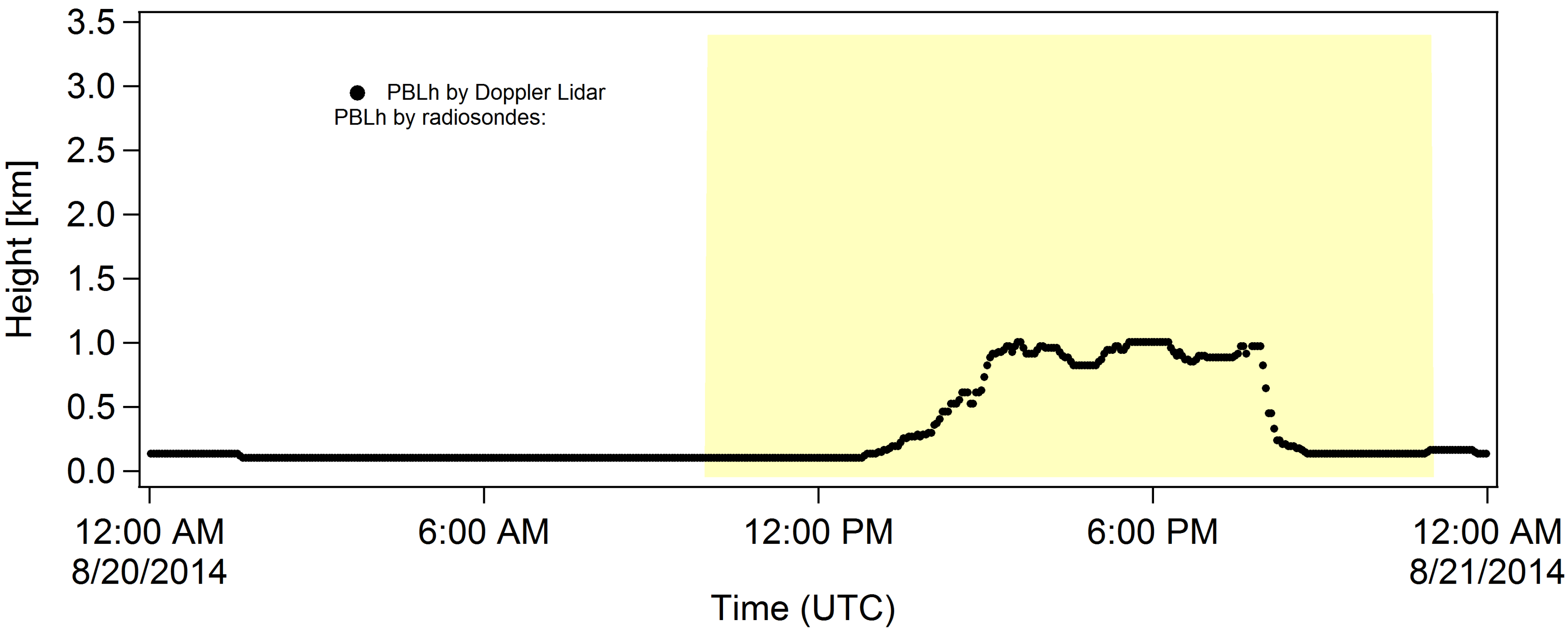


RESULTS

MAO (Amazon)

Amazon: clear sky case (very rare!)





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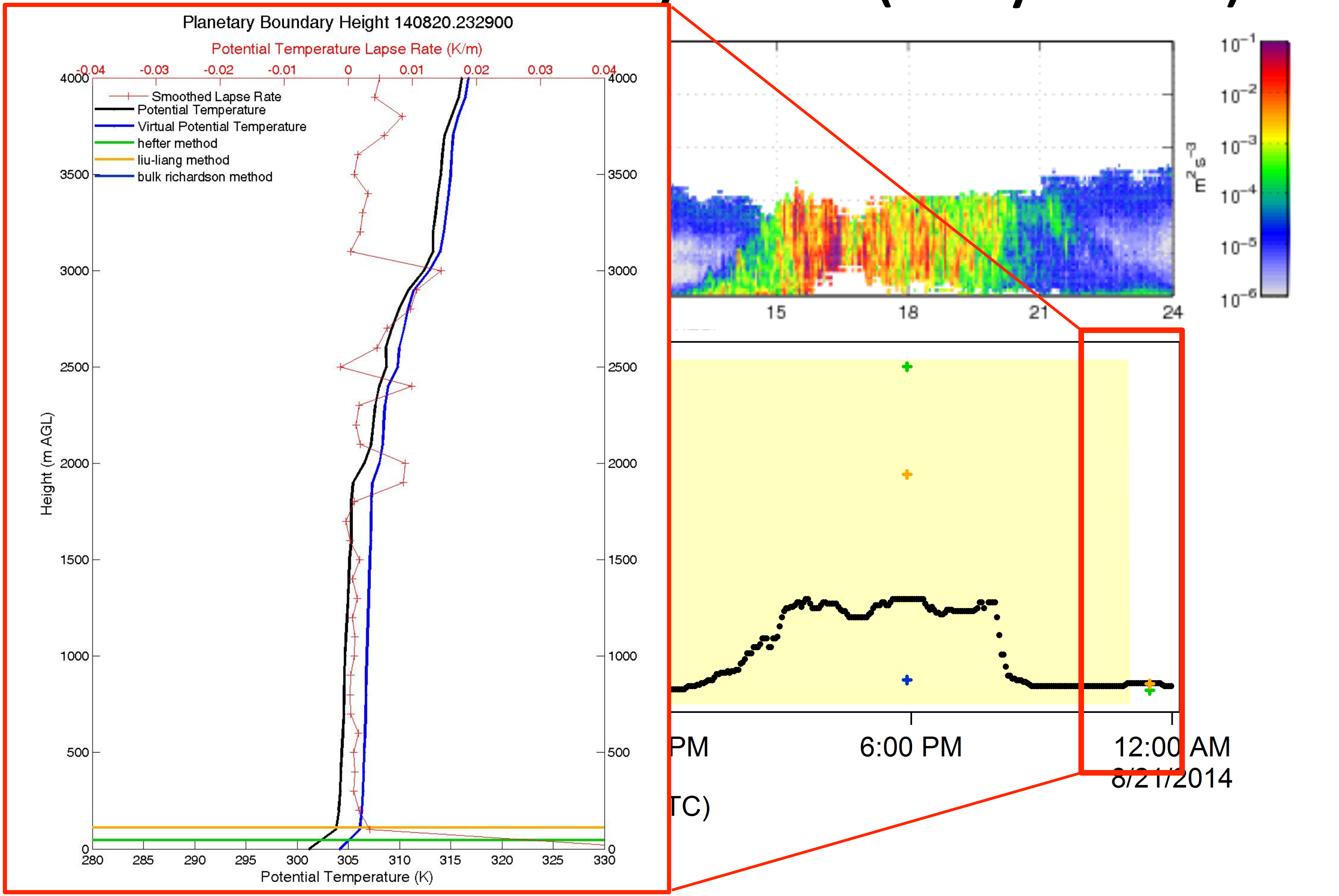

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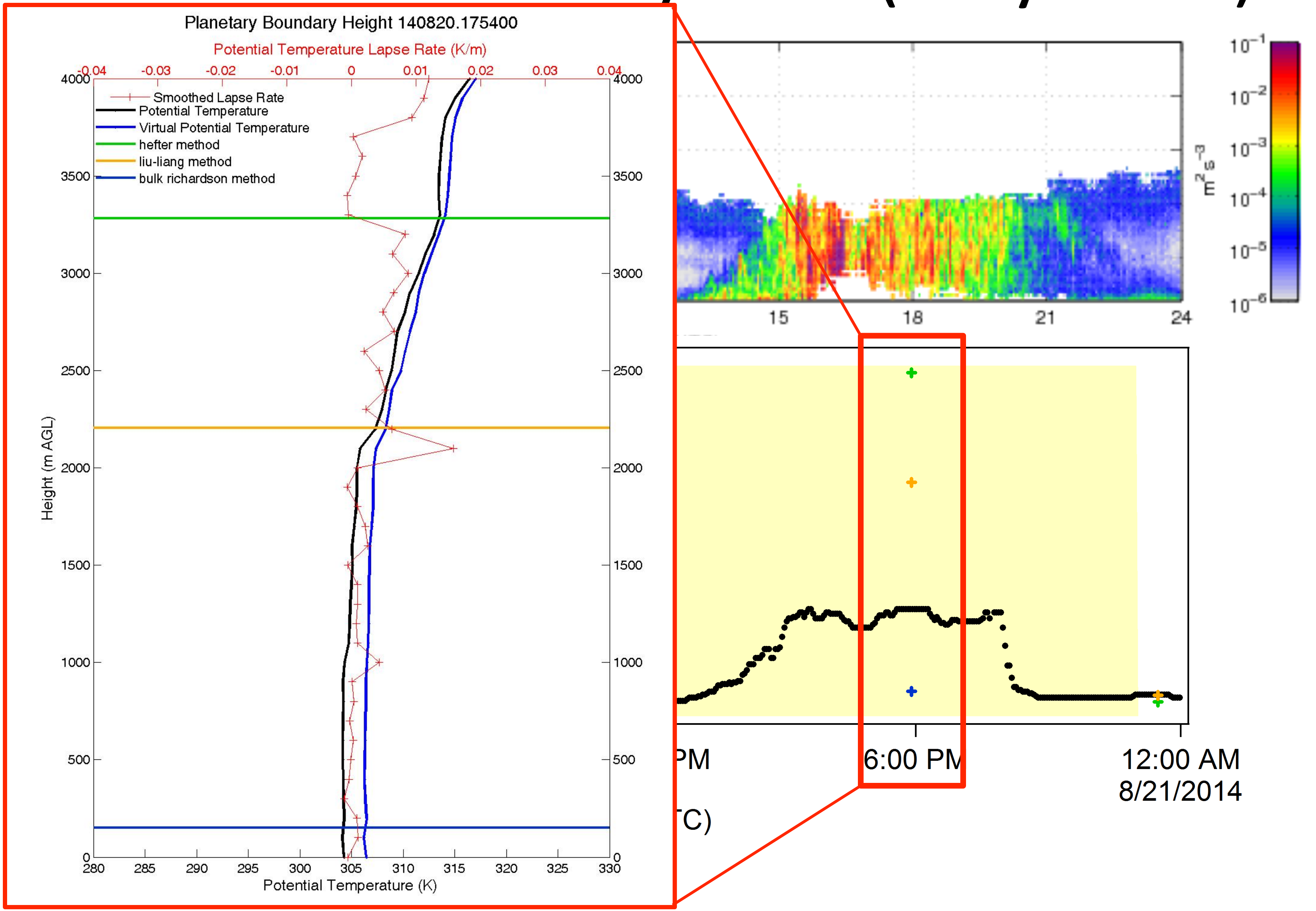

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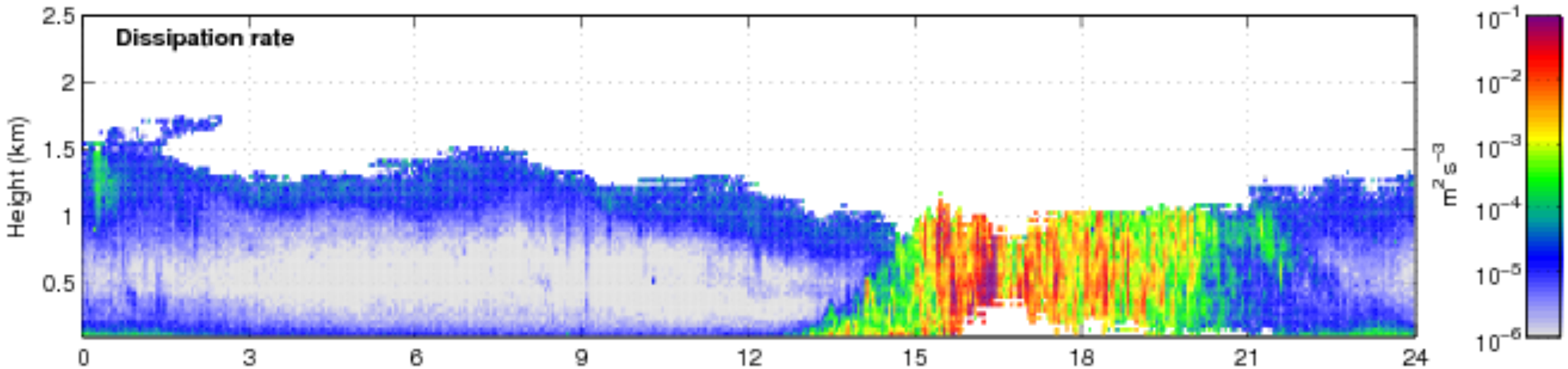

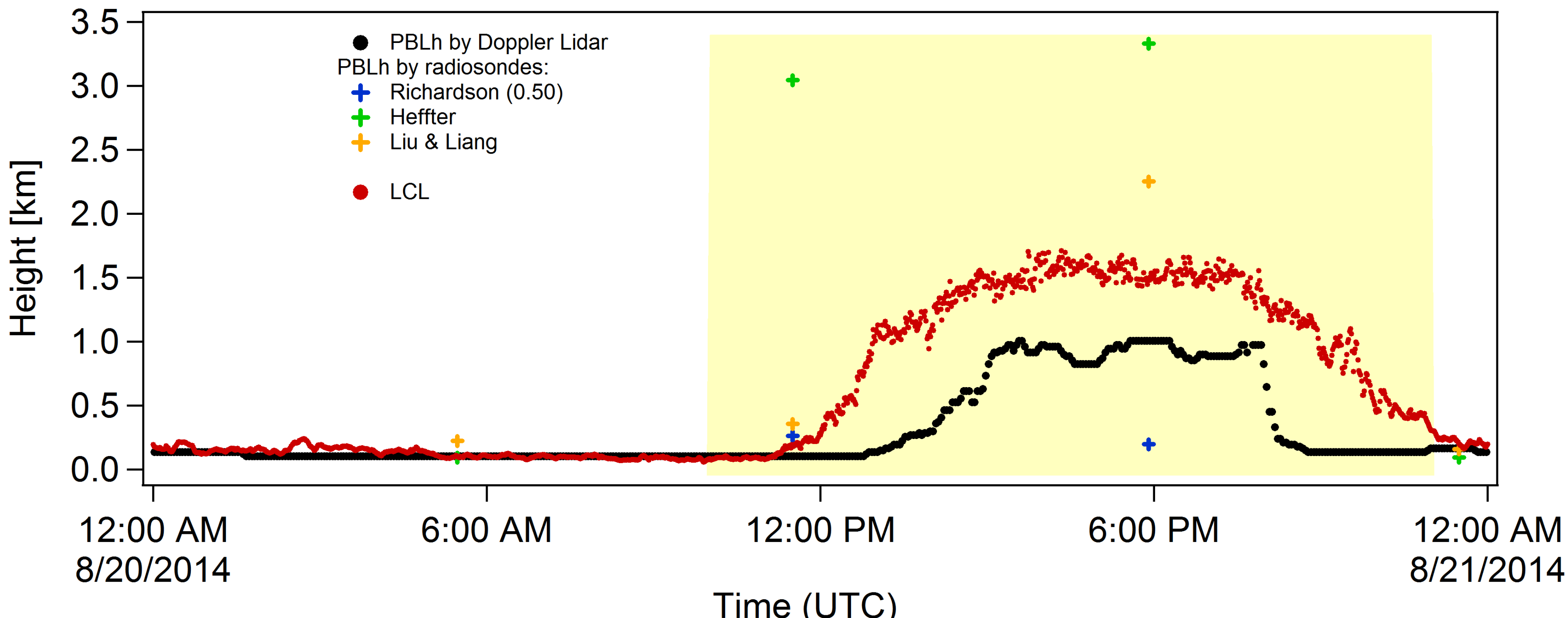

$$h_{LCL} = (20 + \frac{T}{5})(100 - RH)$$

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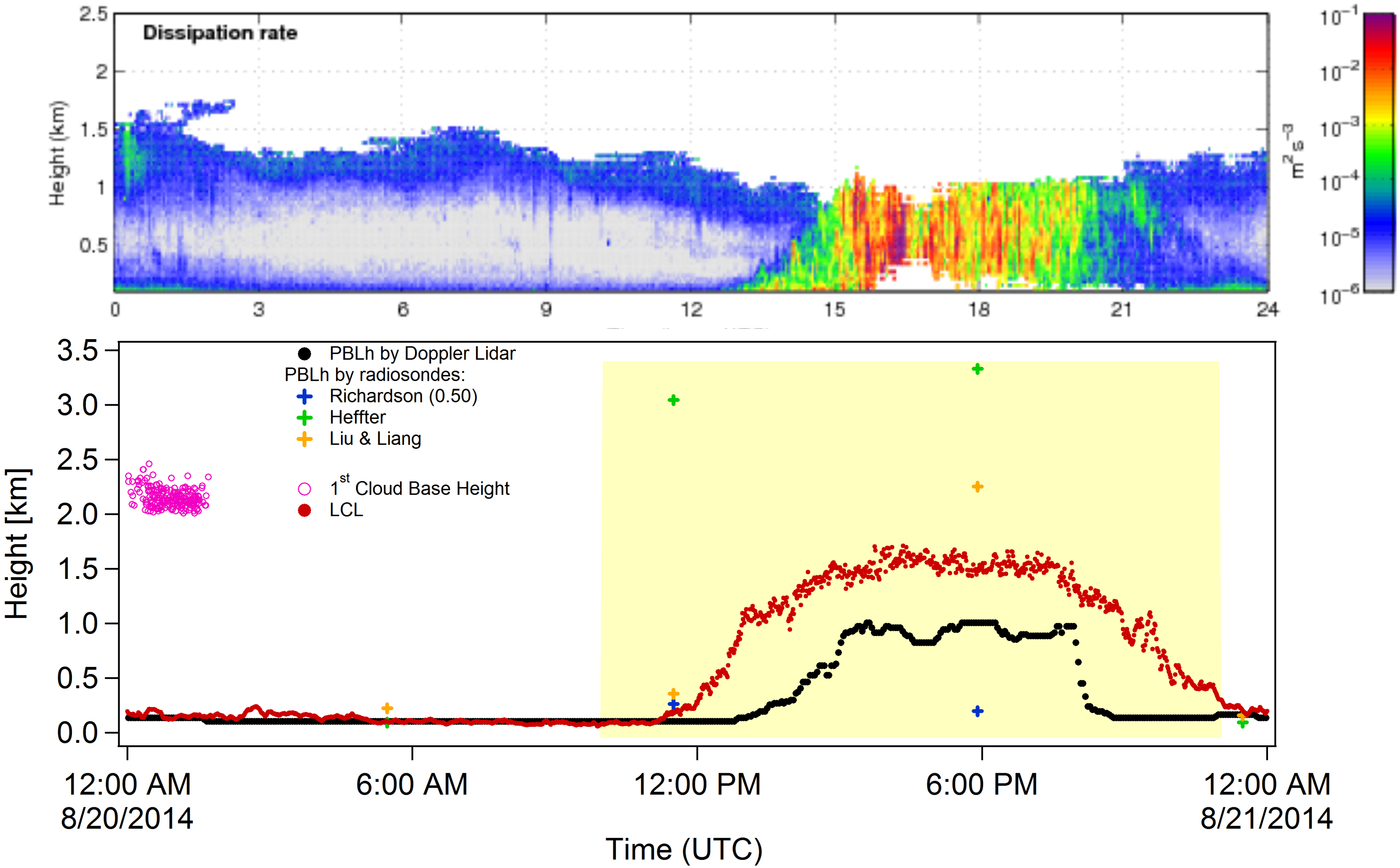
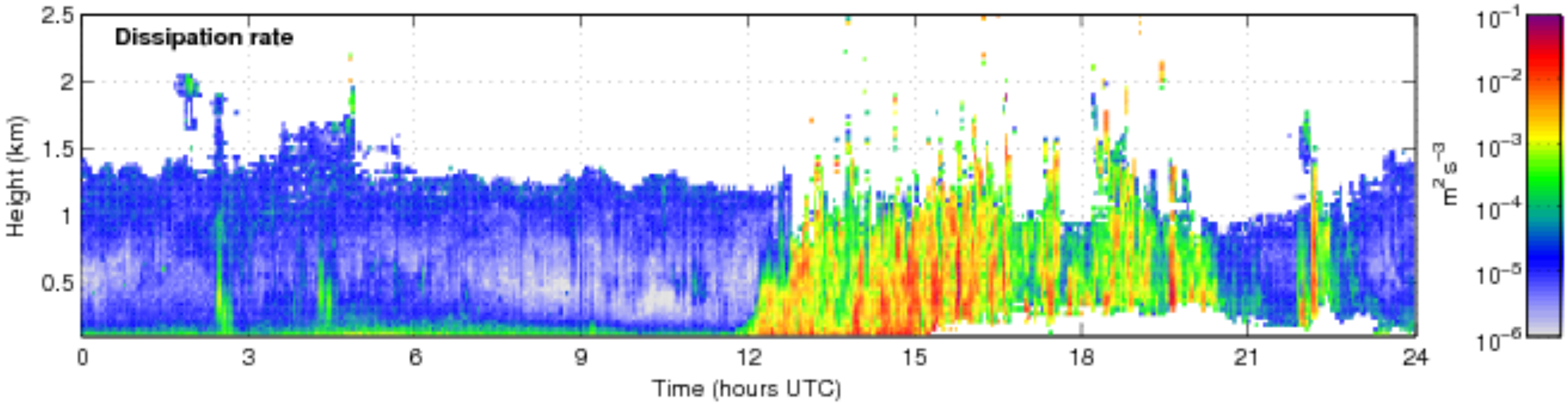
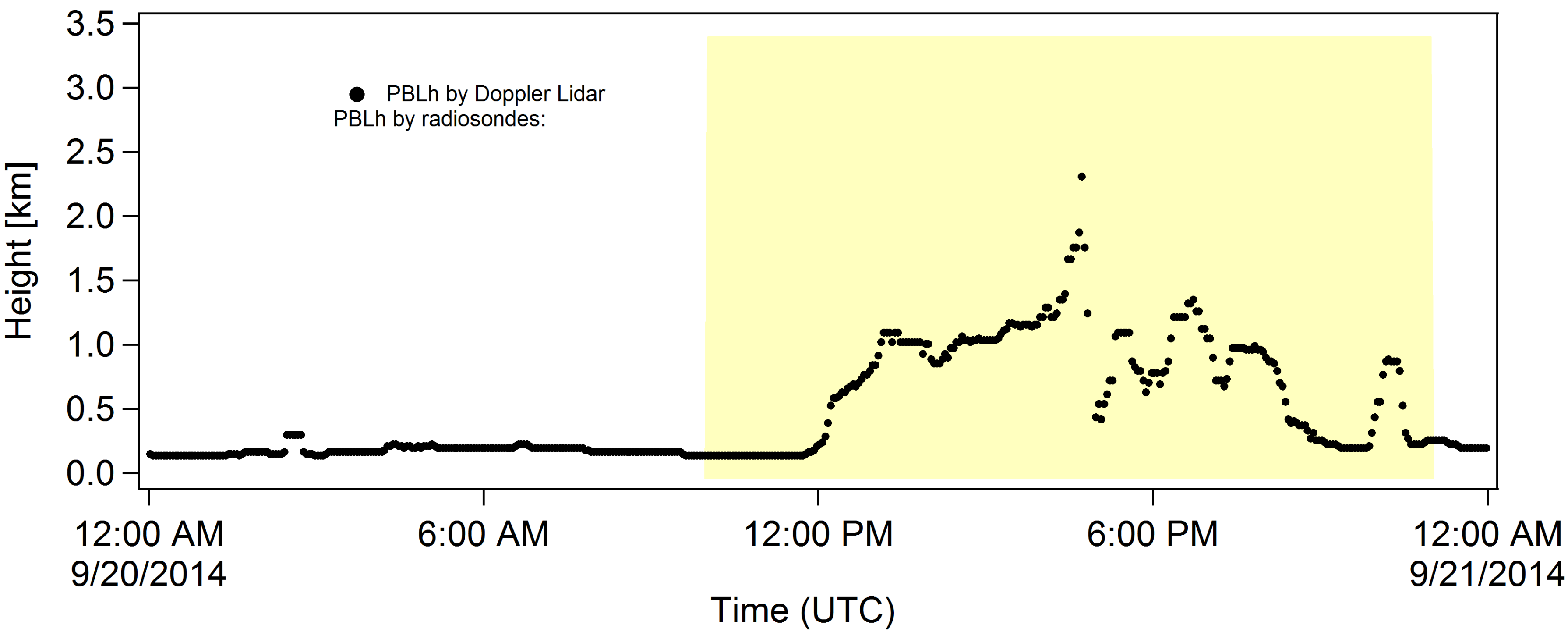


Amazon: cloudy sky case (typical)





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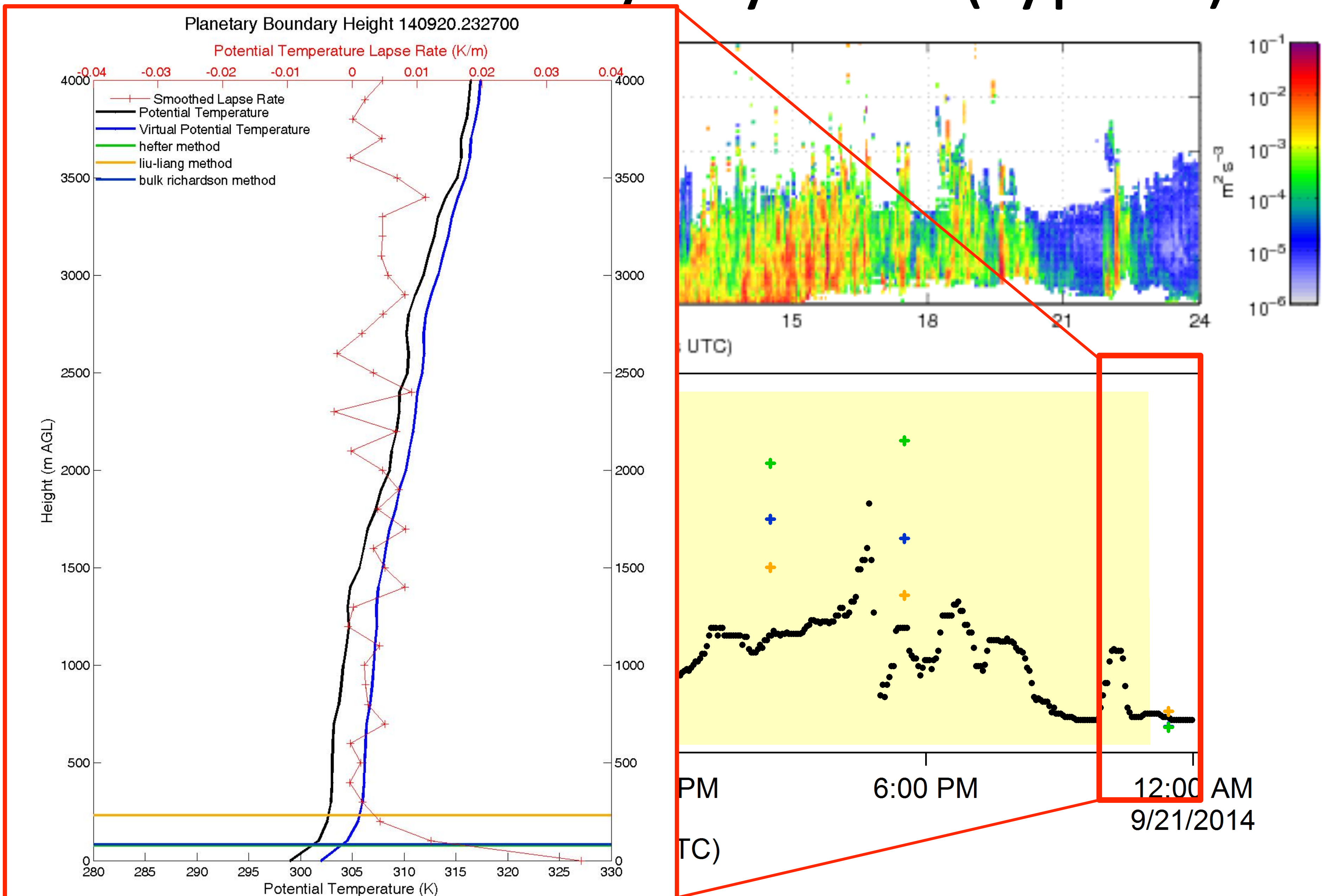

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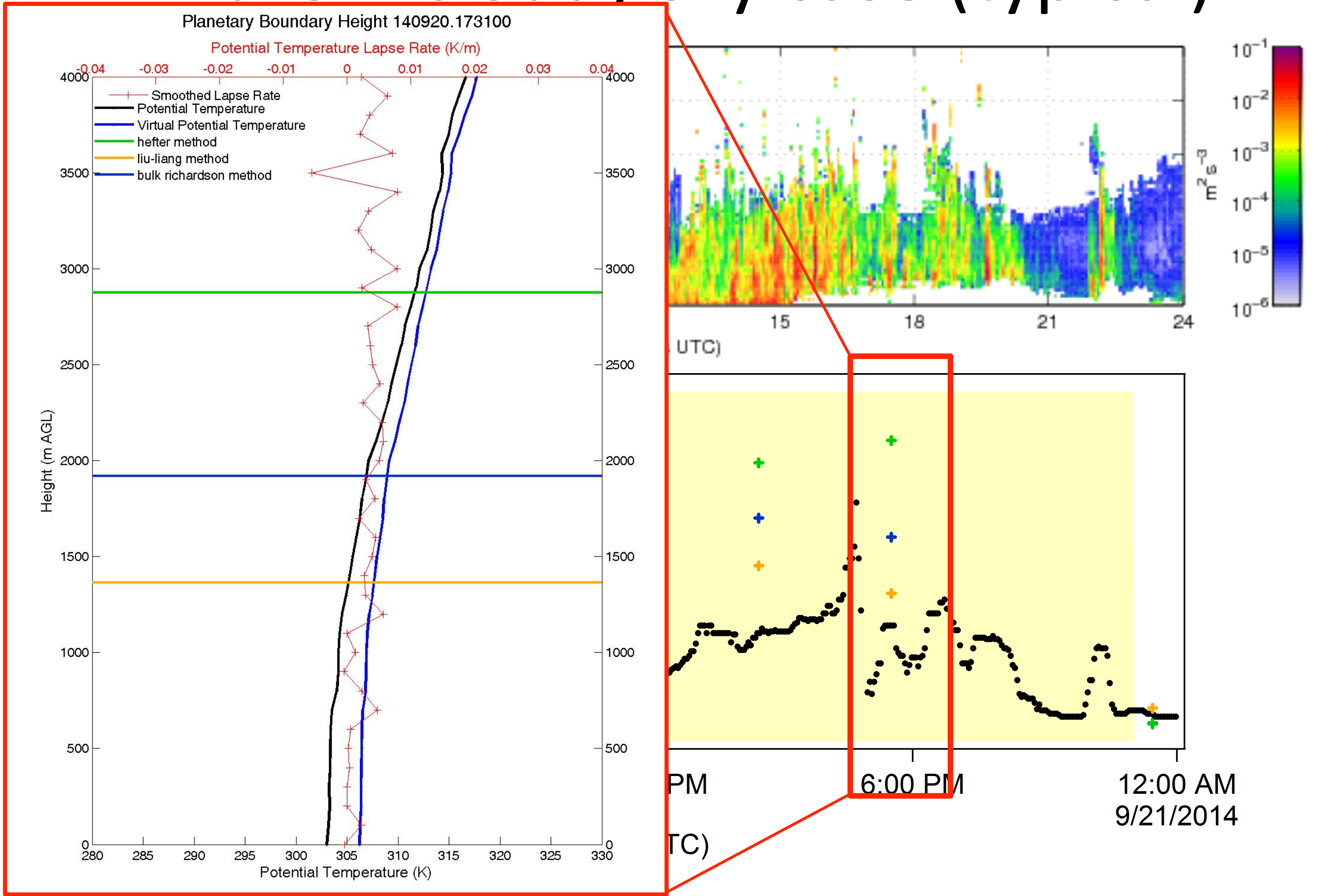

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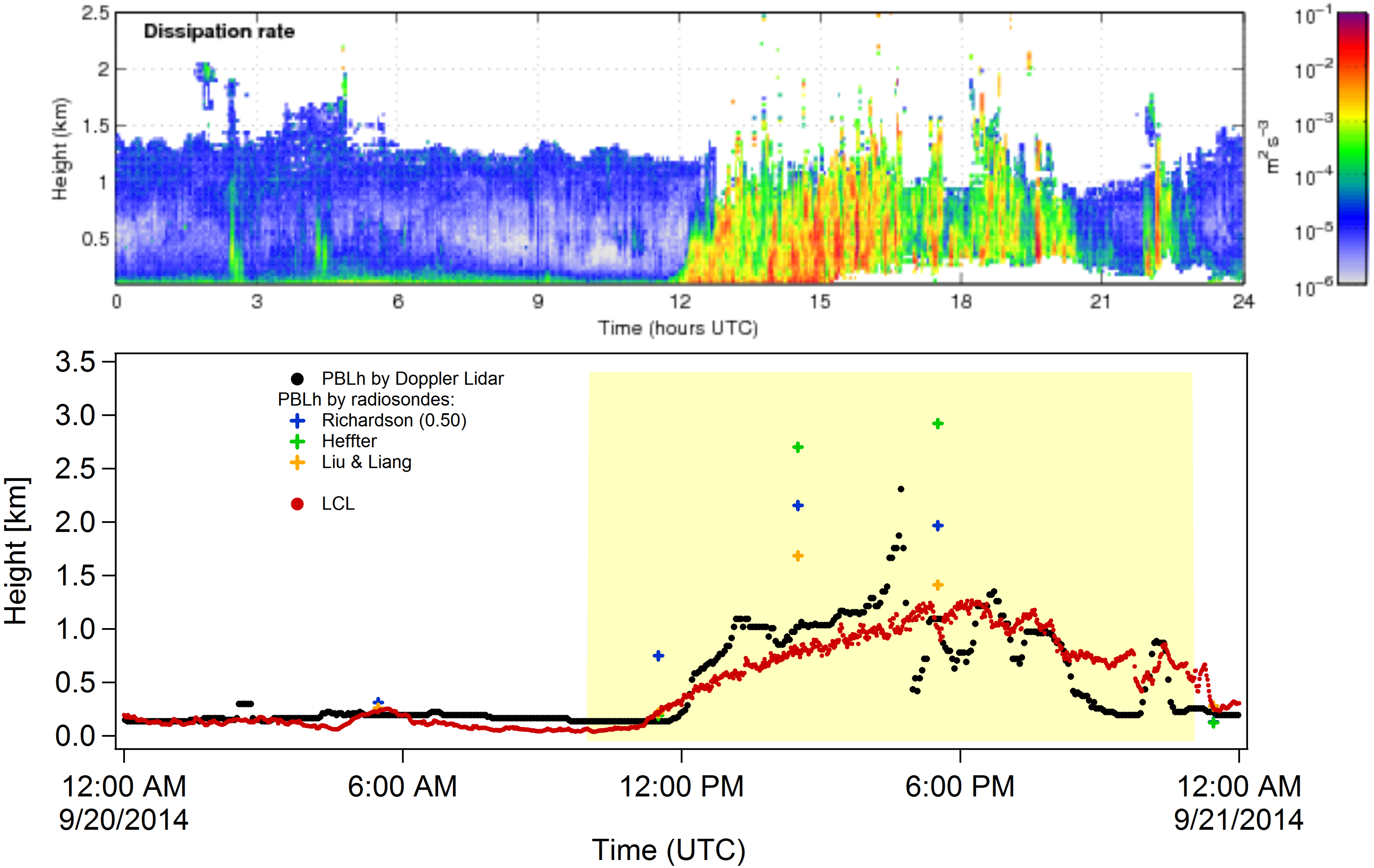

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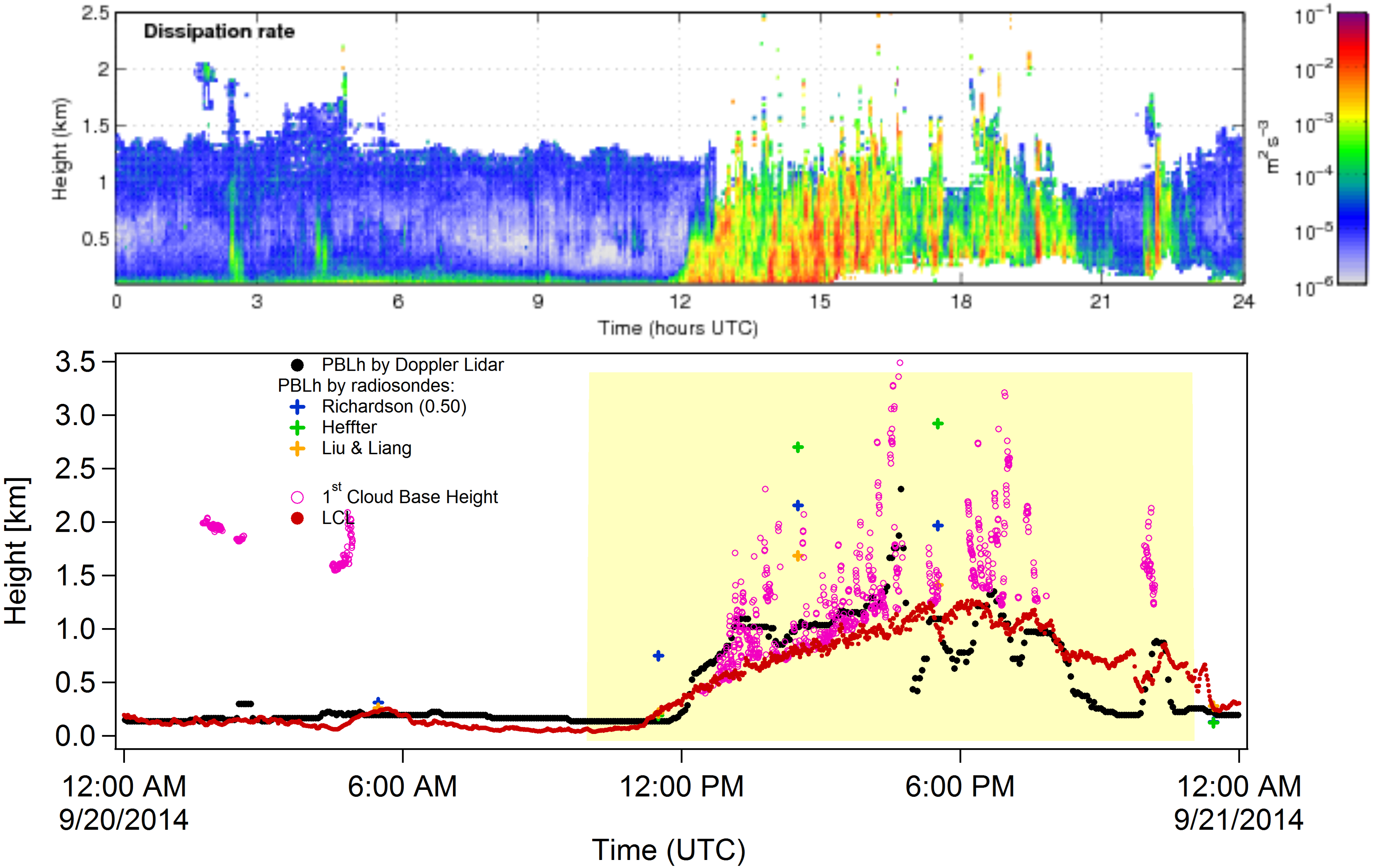
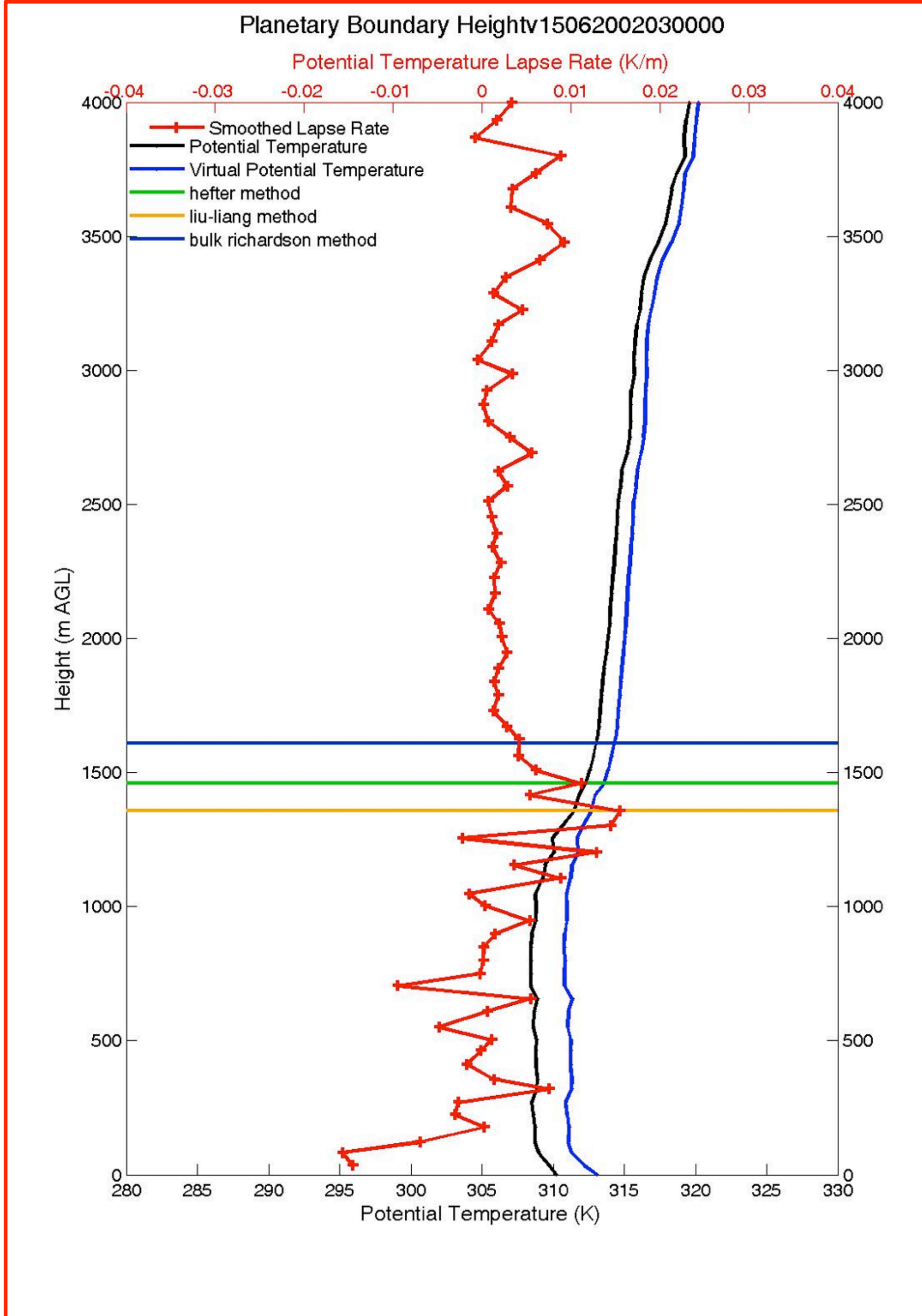
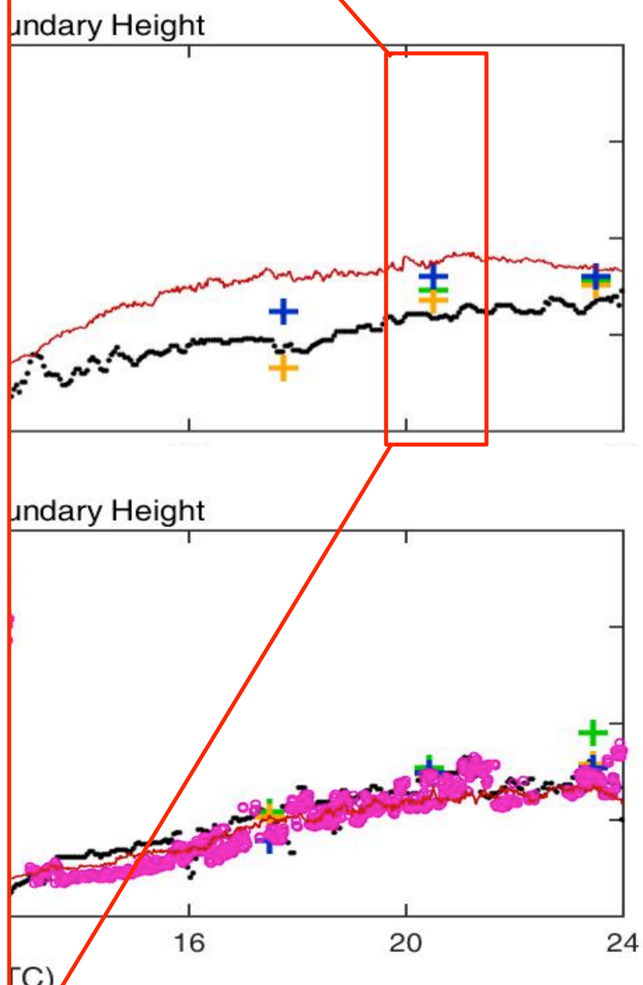


RESULTS

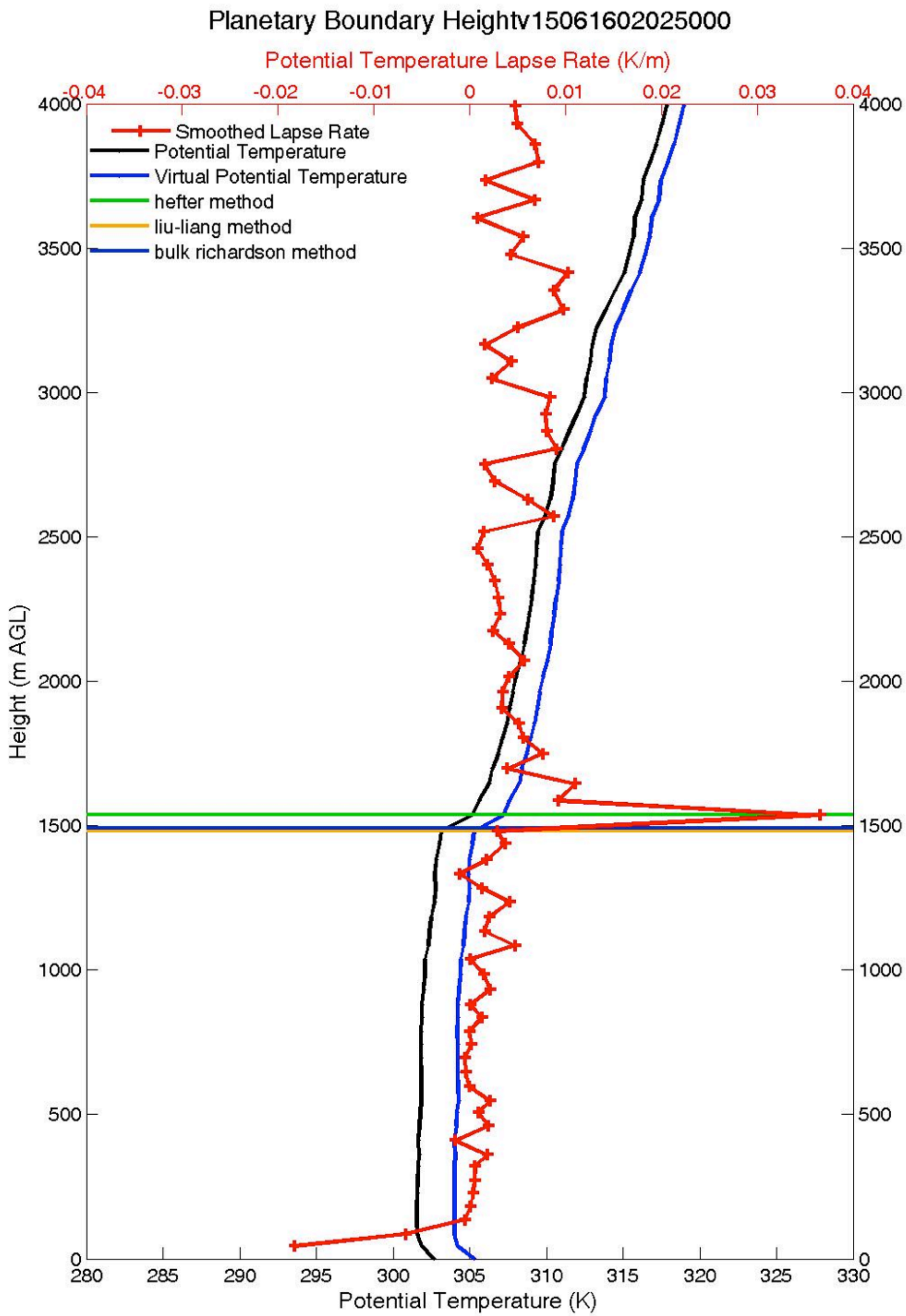
SGP (Oklahoma)

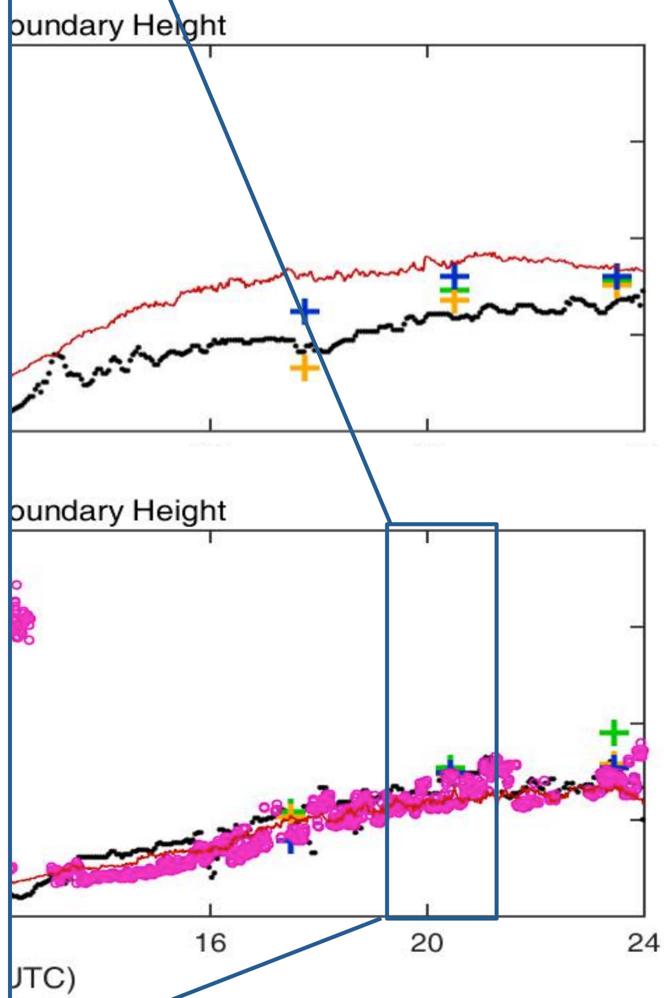
n PBL retrievals



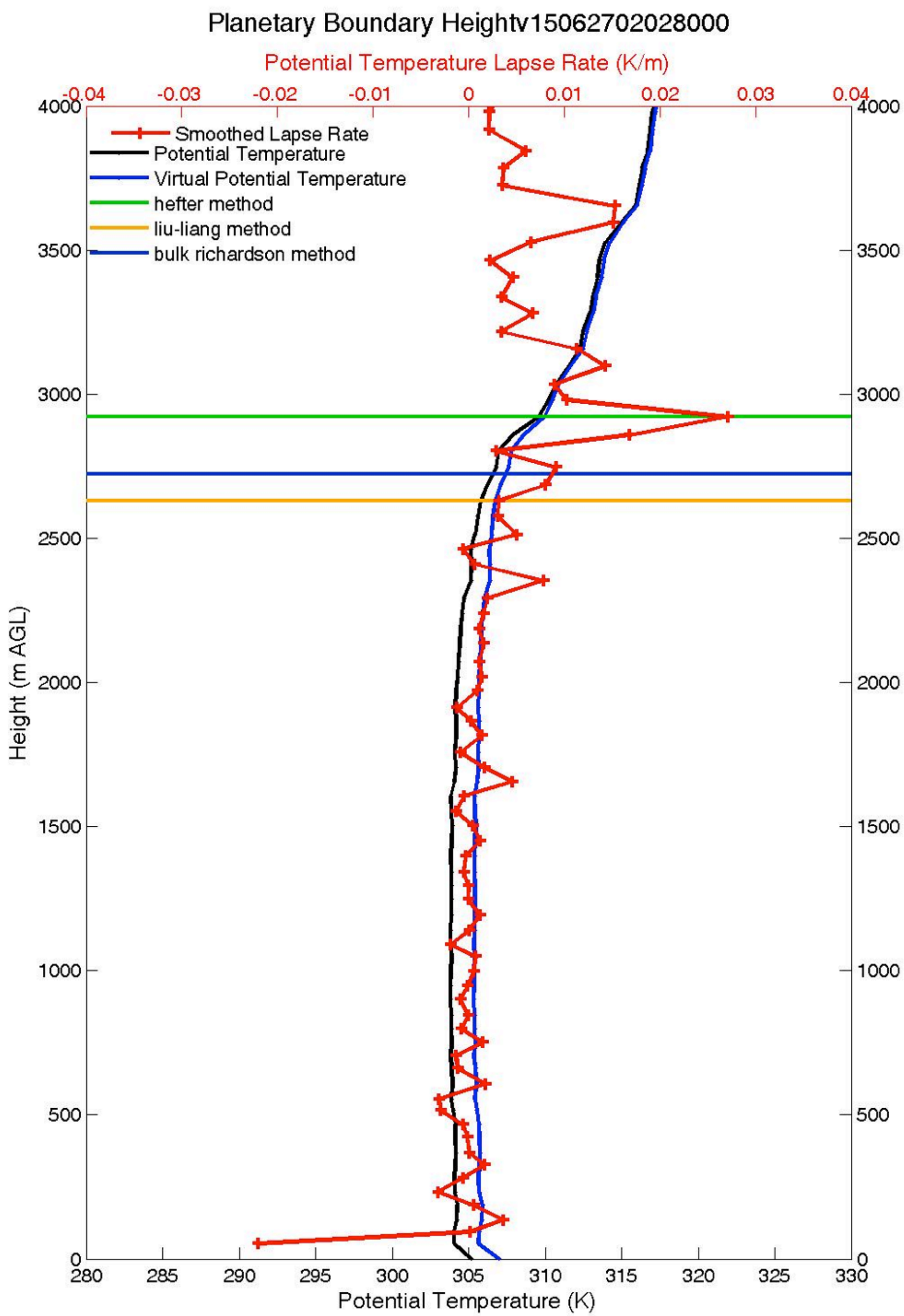


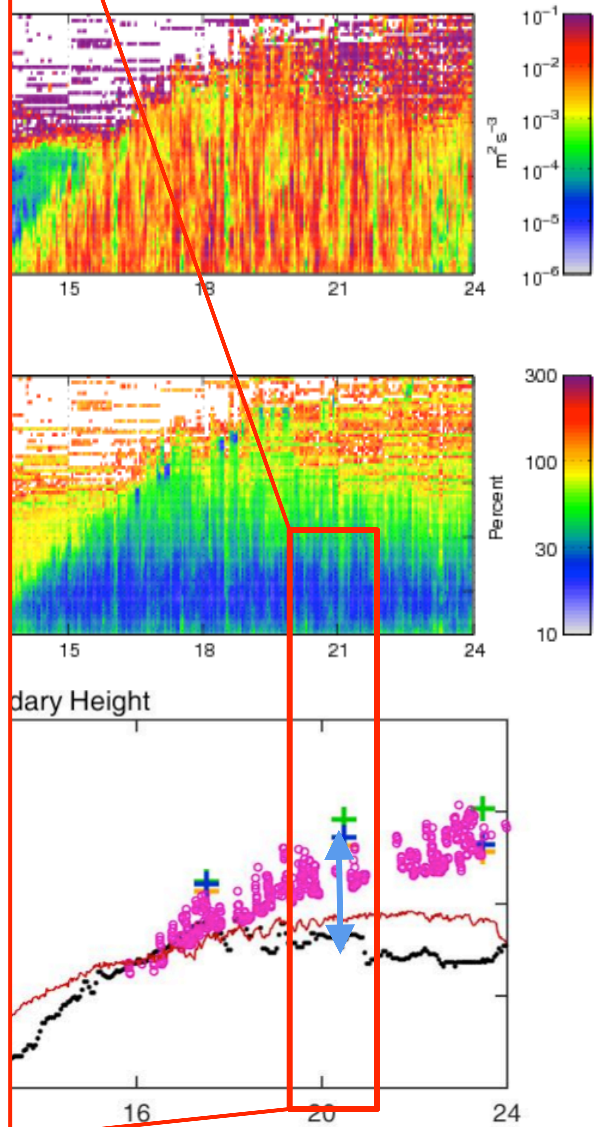
on PBL retrievals



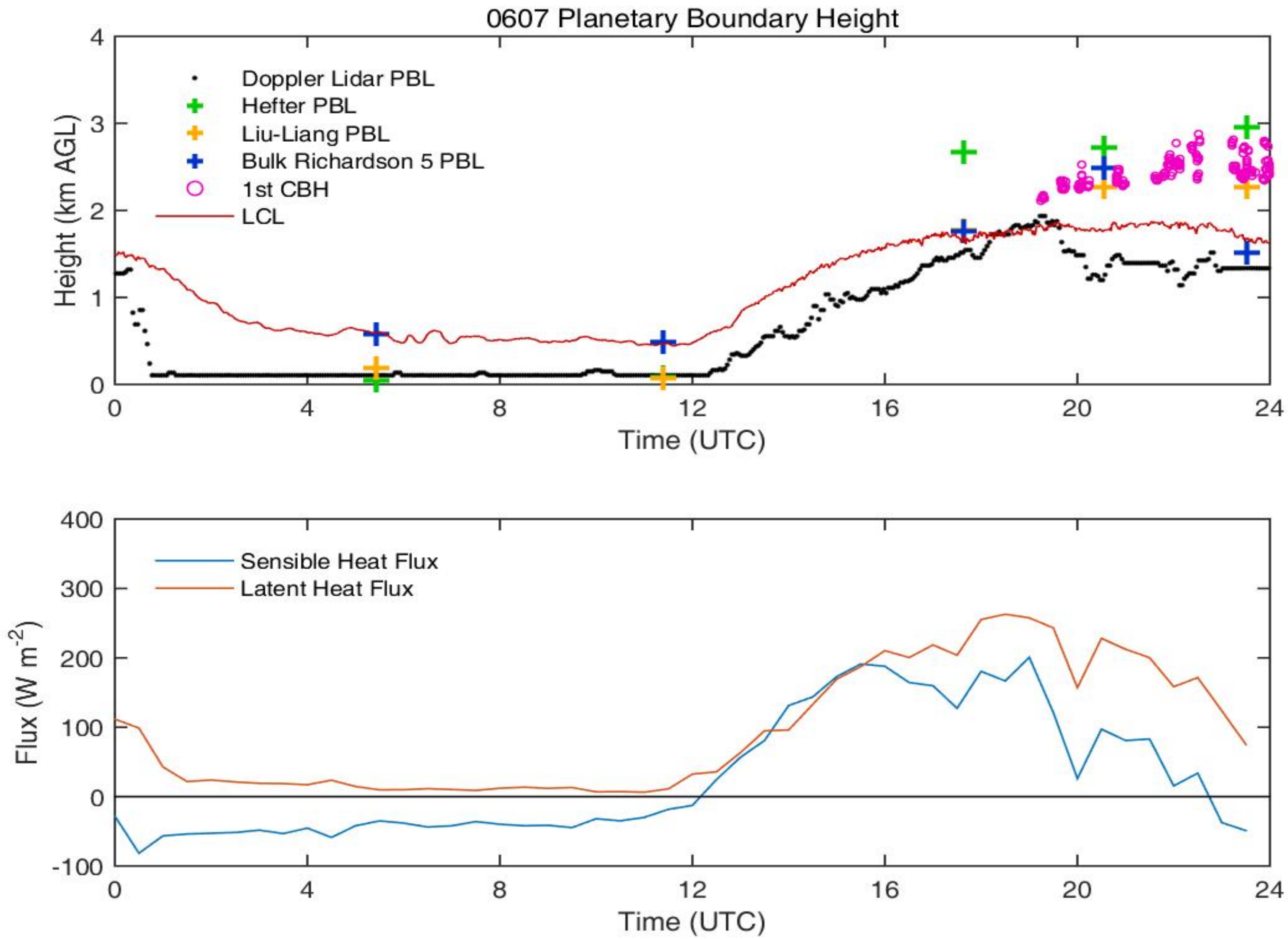


Doppler Lidar

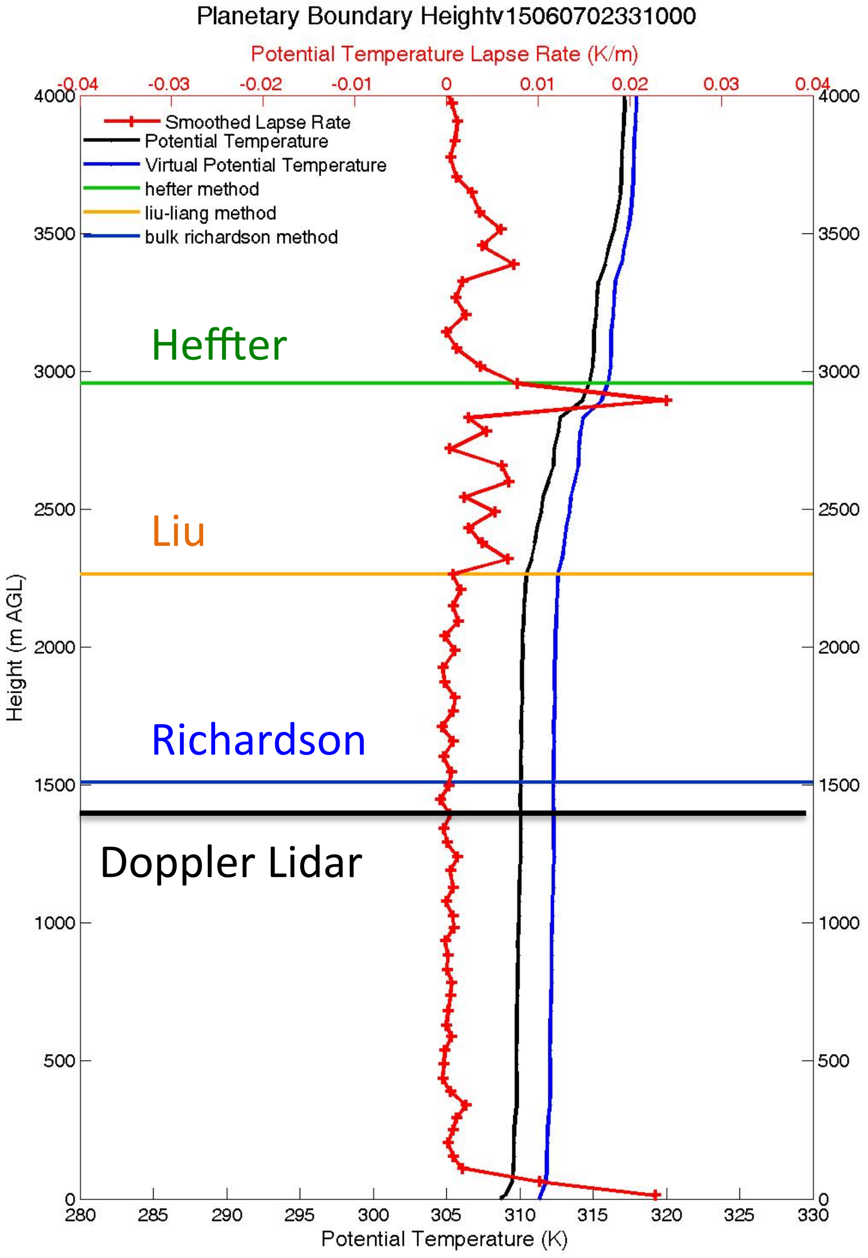




Case 3: June 5th 2015
-- retrieval not agree



Case 3: June 7th 2015, 23:31 (UTC) -- retrieval not agree

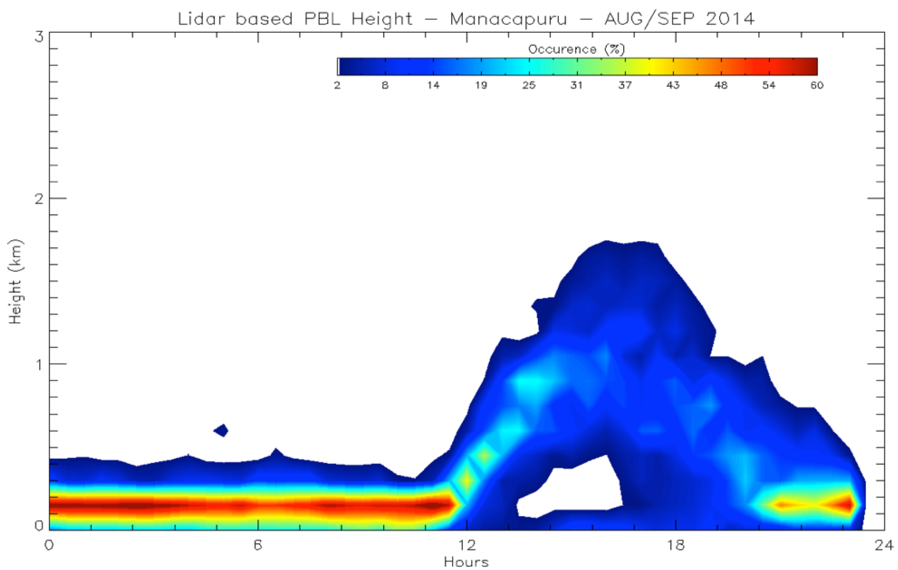


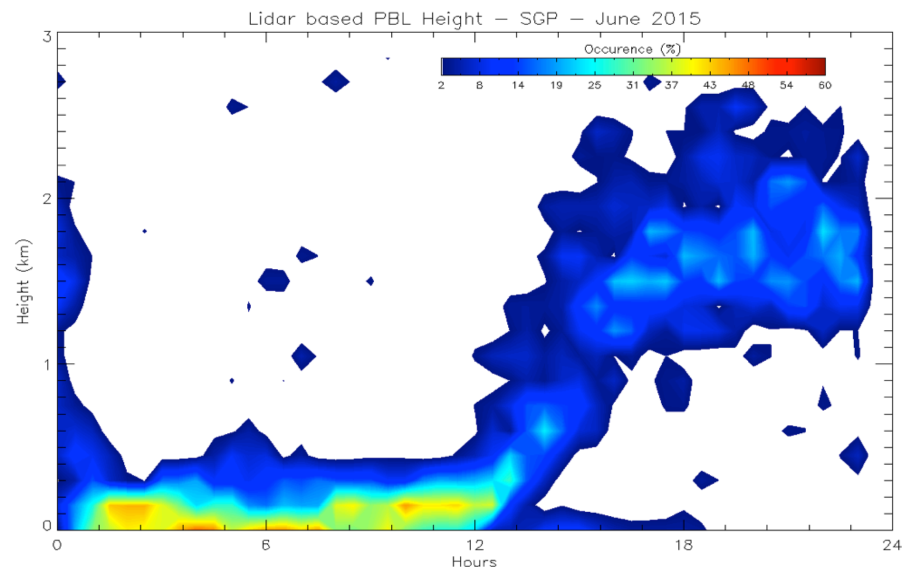
- Neutral boundary condition with several small inversions
- More strict threshold for Heffter method ($\Delta\Theta > 2K$) than Liu and Liang, higher PBL height

RESULTS

SGP vs MAO

Intercomparison of sites





Well defined PBL during the night, high dispersion during the day, probably due to cloud formation leading to retrieval errors

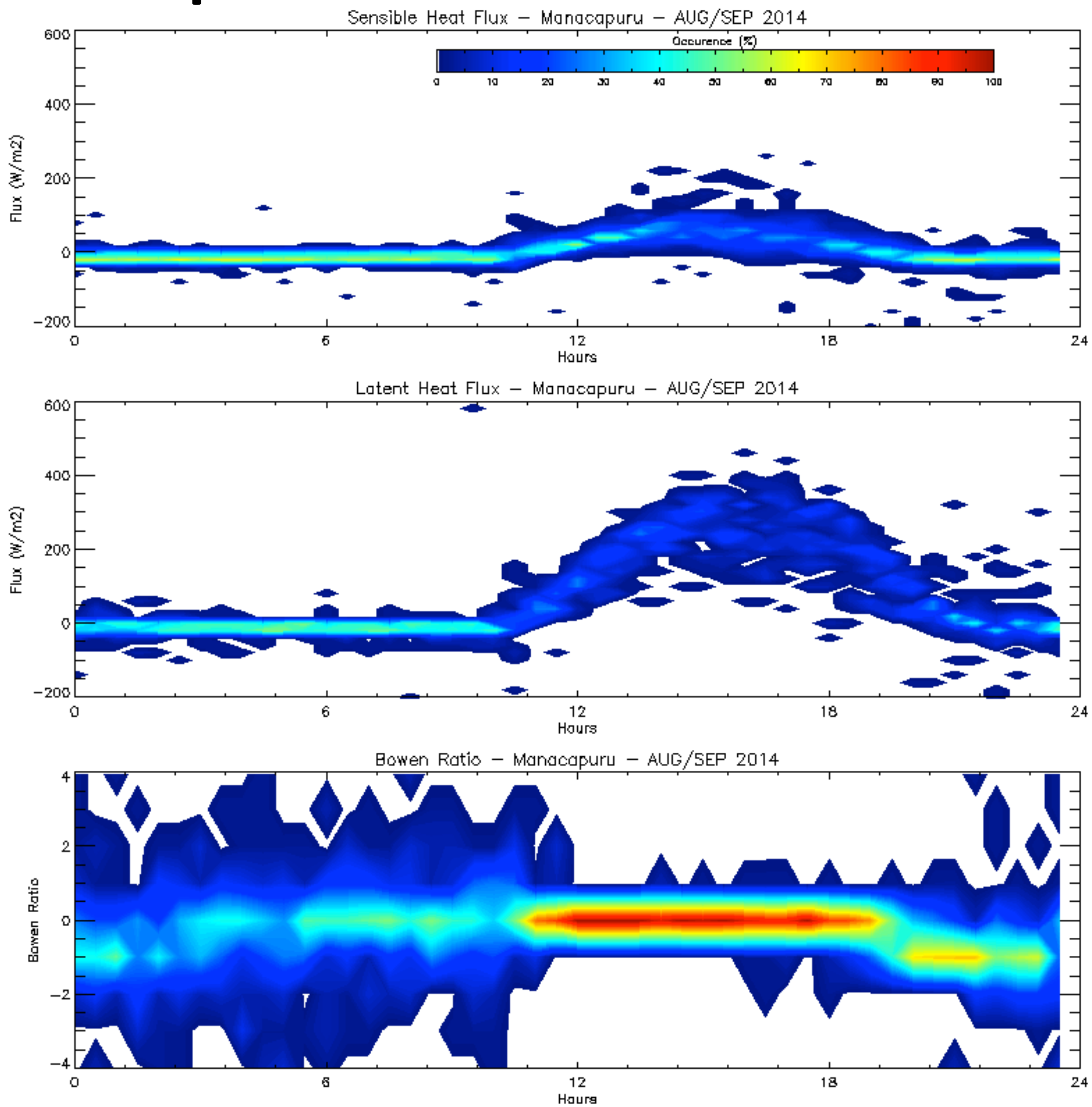
More dispersion during the night than MAO

Intercomparison of sites

Low values of sensible heat flux

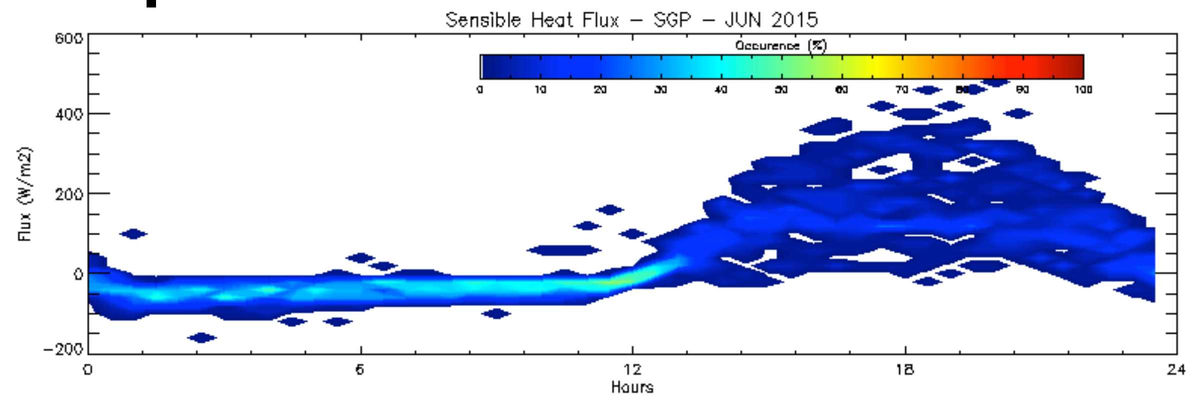
High values of latent heat flux

Indetermination due to low values of H and LE during the night, low values during the day

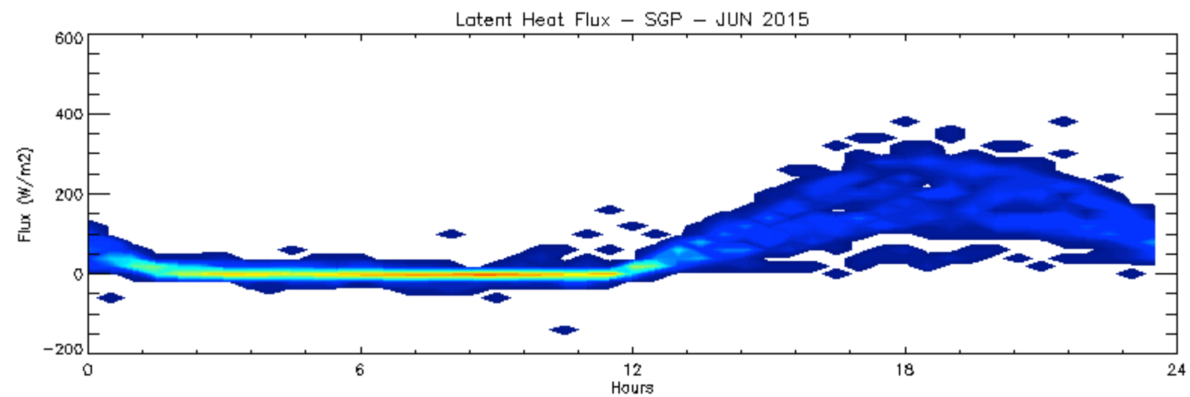


Intercomparison of sites

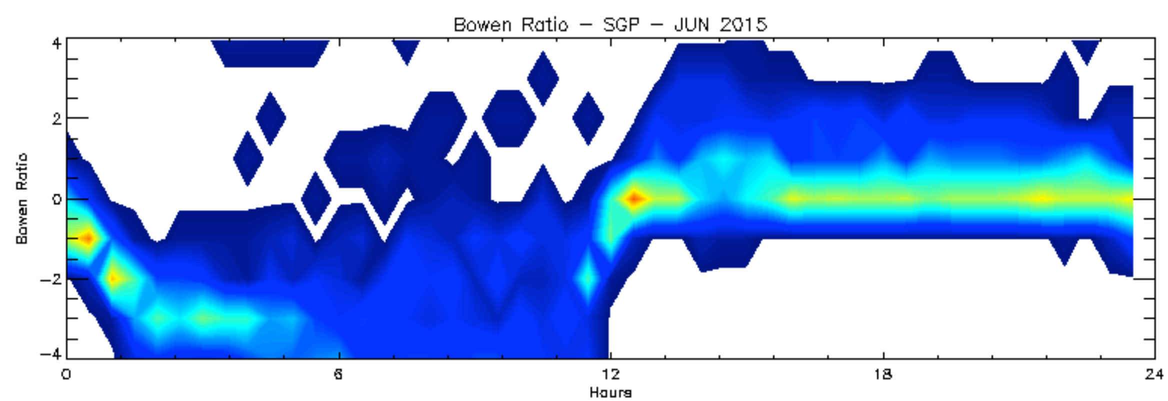
High values of sensible heat flux during daytime and high radiative loss during the night



Low values of latent heat flux



Bowen ratio higher than the MAO site (consistent with the soil tye)



Conclusions

- Dissipation rate derived from Doppler lidar provides direct measurements of turbulence and therefore better retrieves PBL height (but, maximum range of 2km)
- Large differences between the 3 sounding methods, especially for the Amazon
- SHF and LHF consistent with the PBL height dispersion for both sites

Thank you!