Characterization of the *Atmospheric Boundary Layer* Over Aburrá Valley Region Using *Remote Sensing and Radiosonde* Data

Laura Herrera Mejía MSc
Advisor : Carlos David Hoyos PhD

Con el apoyo de:

Un proyecto de:

Geographical context

A low-latitude highly complex mountainous terrain located between Colombian west and central ***mountain ranges***, home of about 4.5 million people over an extension of *1152 km*^{2}

Channel slope 0.73 %
Basin mean slope 29 %
10% basin has slopes > 55 %

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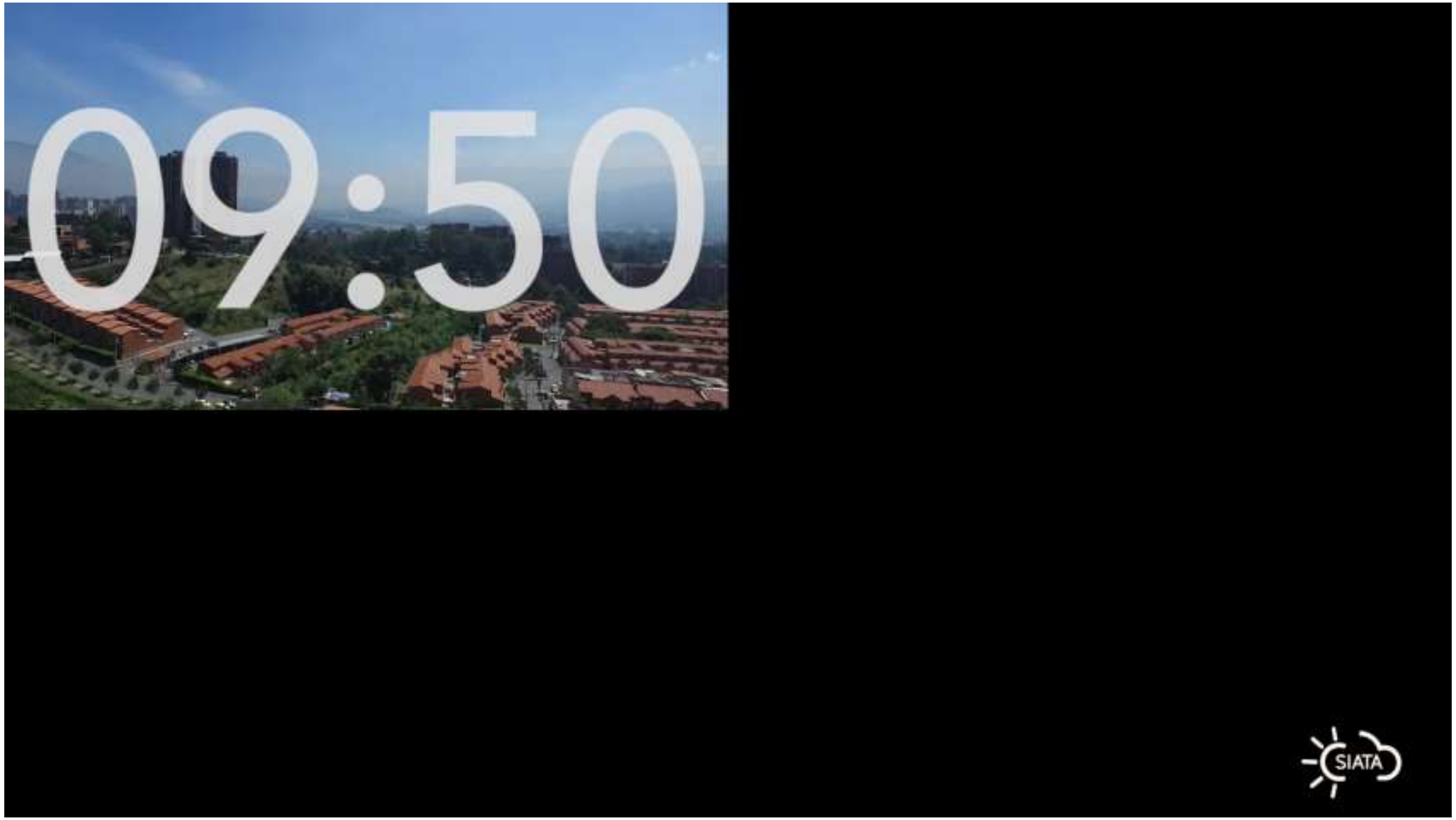

Atmospheric stability is considered a key and a governing factor for ***pollutant vertical dispersion***, determining the efficiency of the exchanges between the surface and the lower troposphere

Monitoring Atmospheric Stability
October 3rd - 2016

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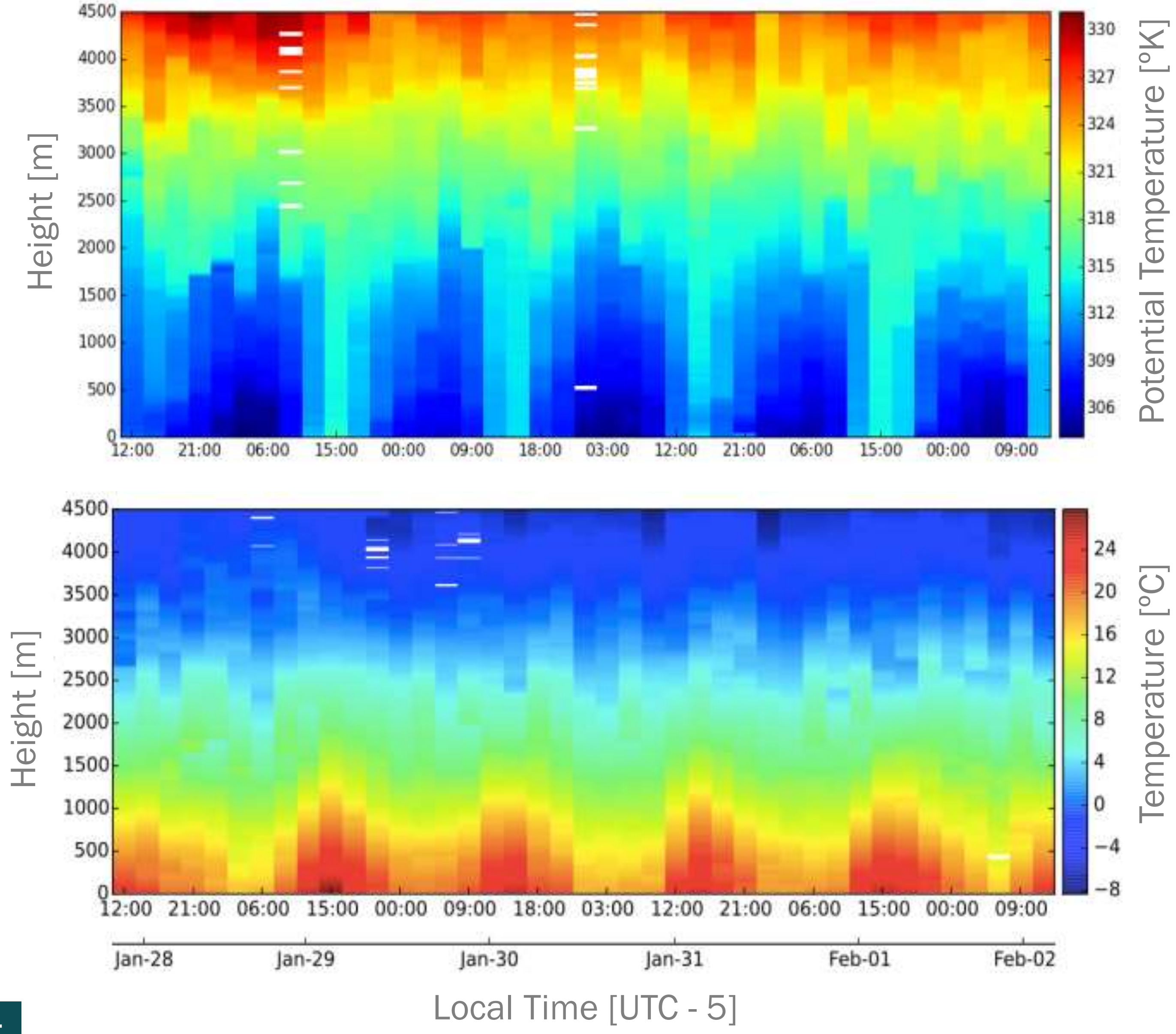


The Atmospheric Boundary Layer

"The part of the troposphere that is directly influenced by the presence of the earth's surface, and responds to surface forcings with a timescale of about an hour or less"

Stull (1988)

Structure and spatio-temporal variability

<u>Air quality dynamics</u>

Local deep convection

Urban meteorology

SISTEMA DE ALERTA TEMPRANA DE MEDELLÍN Y EL VALLE DE ABURRÁ

Medellín and Aburrá Valley Early Warning System

Radiosondes IOP’s

Currently there have been ***three*** intensive campaigns for ***five days*** conducted on three different time periods between:

- January 28 to February 2 - **2015**
- March 24 to March 28 - **2015**
- May 4 to 8 - **2015**

120 Launches

InterMet sondes working at a 403 MHz frequency.

3 Lidar Ceilometers
Vaisala CL51

October 2014 –2017
Temporal Resolution: every 16 seconds
Vertical scope: 4.5km
Resolution: 10m

Radar Wind Profiler
RAPTOR VAD-BL

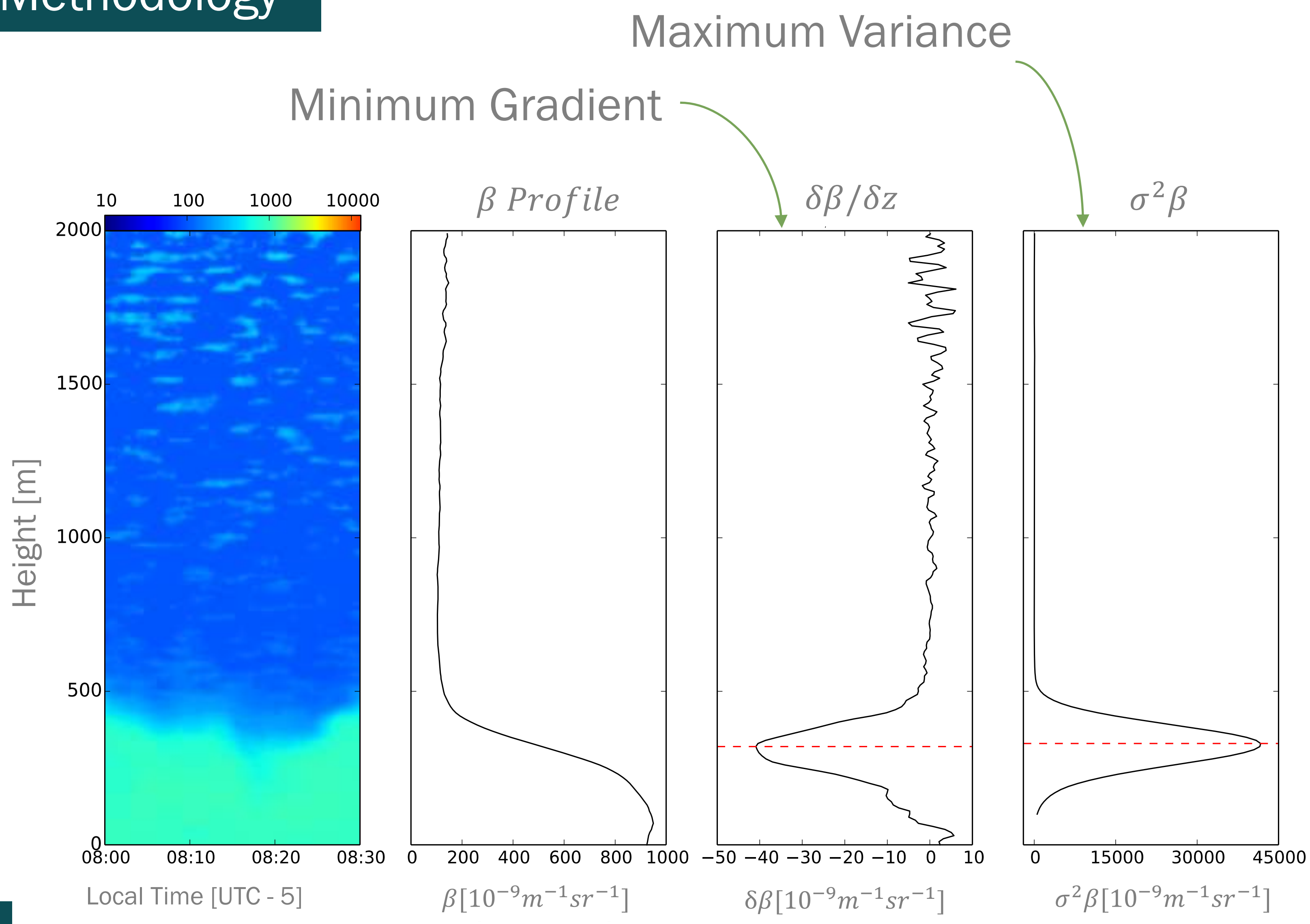
January 2015 – October 2017
Temporal Resolution : every 5 minutes
Vertical scope: 8km
Resolution: 77m

Microwave Radiometer
Radiometrics MP-3000A

January 2015 – October 2017
Temporal Resolution: every 2 minutes
Vertical scope: 10km
Resolution: XXXX

Methodology

Ceilometer *Retrievals*
Backscattering Profiles



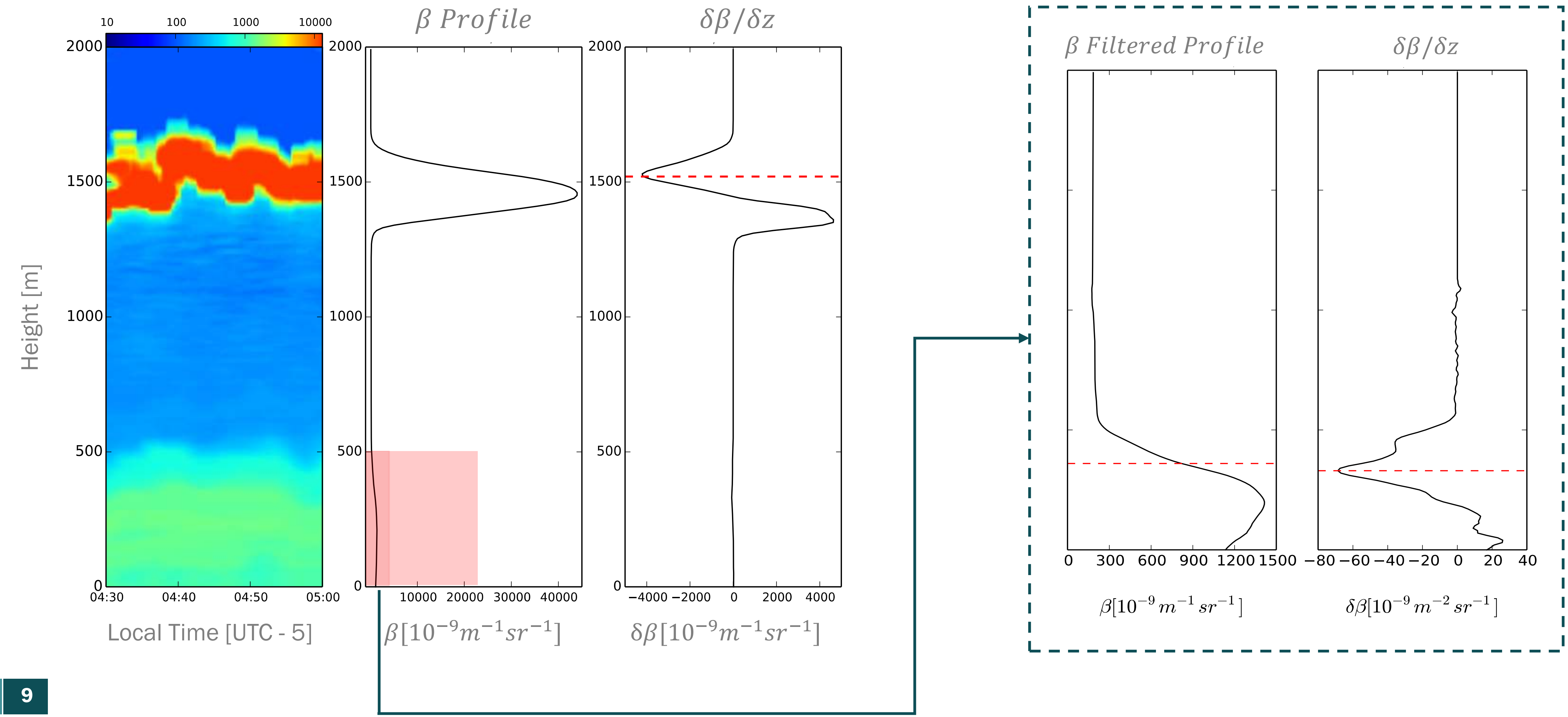
$$\frac{\partial x}{\partial z} \approx \frac{x(z_i + \Delta(z)) - x(z_i - \Delta(z))}{2\Delta z}$$

$$\sigma^2 = \frac{\sum_{i=1}^{n} \left(\beta(z_i) - \bar{\beta}(z)\right)^2}{N}$$

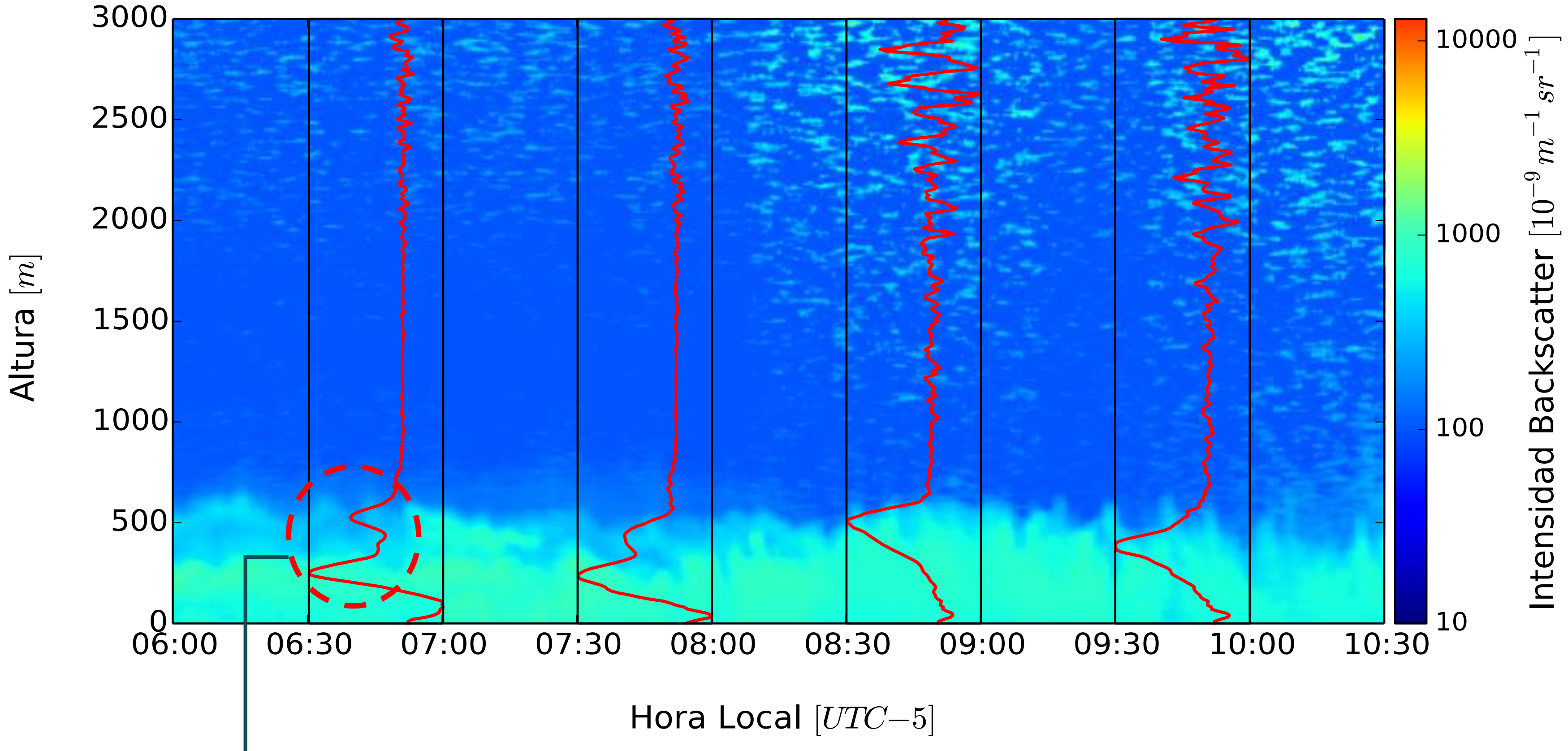
ABL retrievals from ceilometer backscatter profiles are based on the assumption that a ***significant aerosol concentration reduction takes place at the top of the ABL***

Methodology

Cloud Filter



Methodology

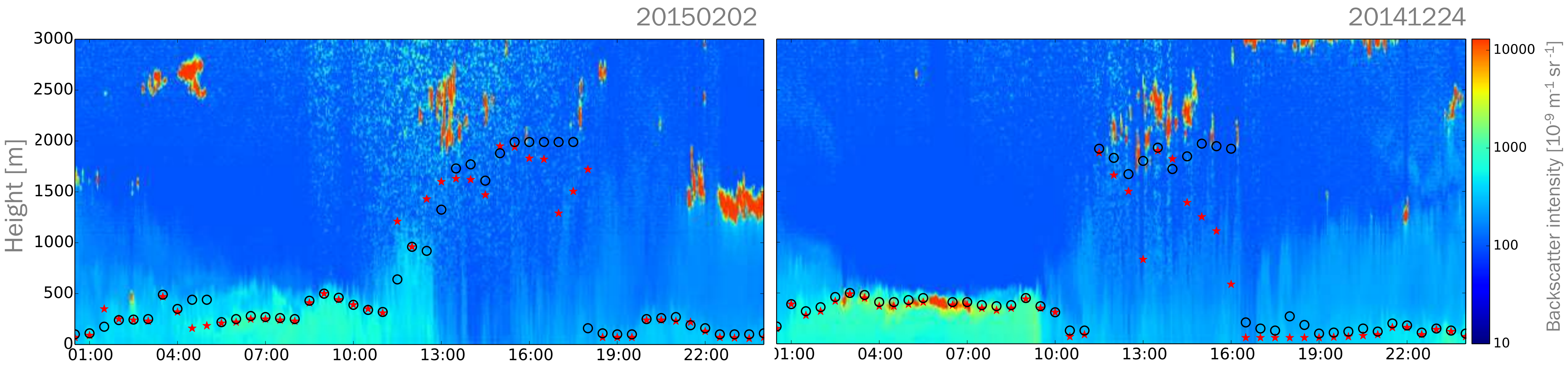


The methods developed ***detect the highest change on each profile*** in order to find the ABL height. These methods also allow ***identifying internal layers*** caused by weak mixing and stratification, providing information about processes that occurs within the layer

Detection of Residual layers

ABL Retrievals
Ceilometer profiles

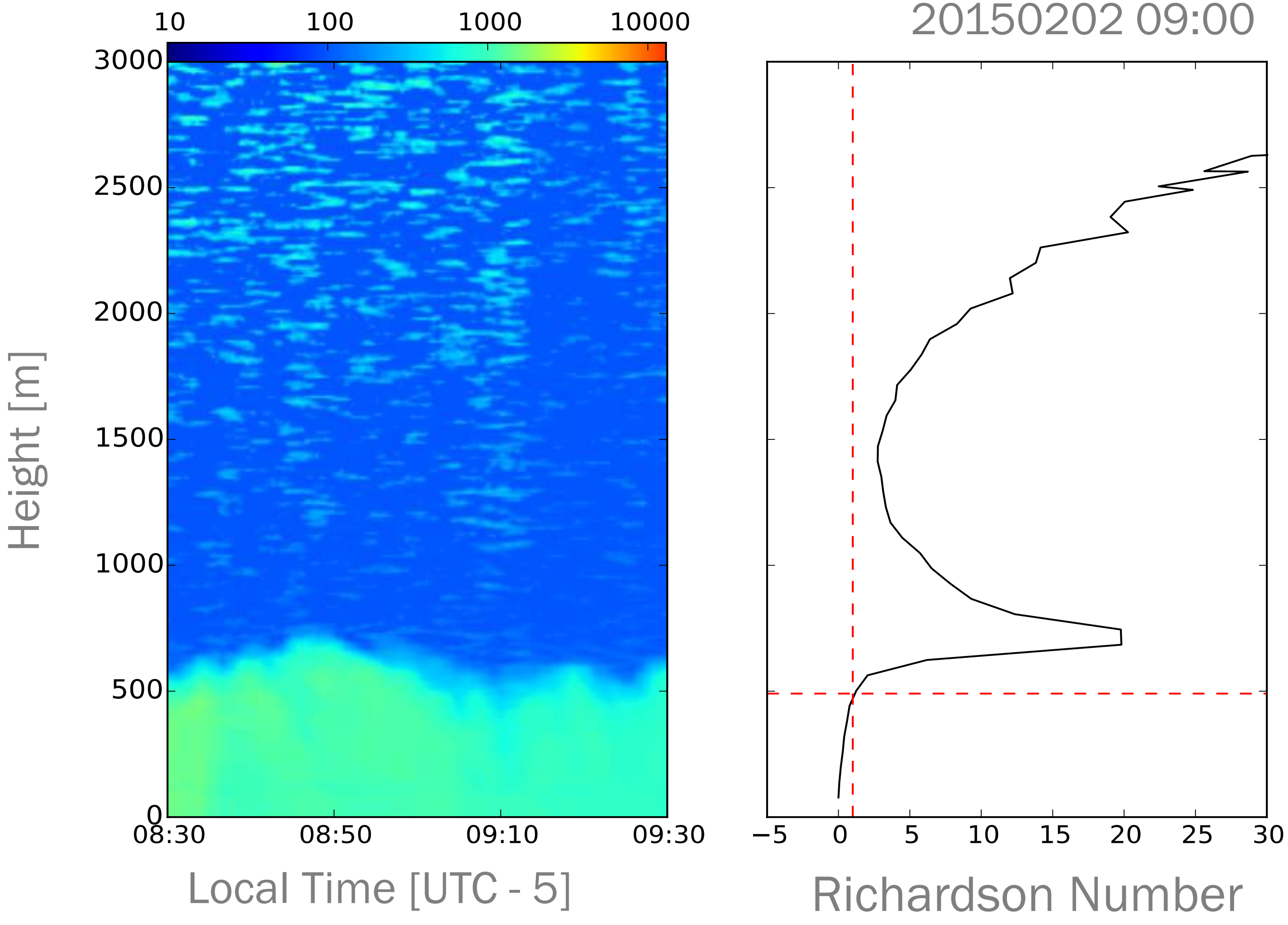
Results



★ Minimum Gradient Retrievals

○ Maximum Variance Retrievals

Methodology



Multi-sensor *Retrievals*
Richardson Number

$$Ri_b(z) = \frac{g}{\theta_s} \frac{(\theta(z) - \theta_s)}{(u(z)^2 - v(z)^2)} z$$

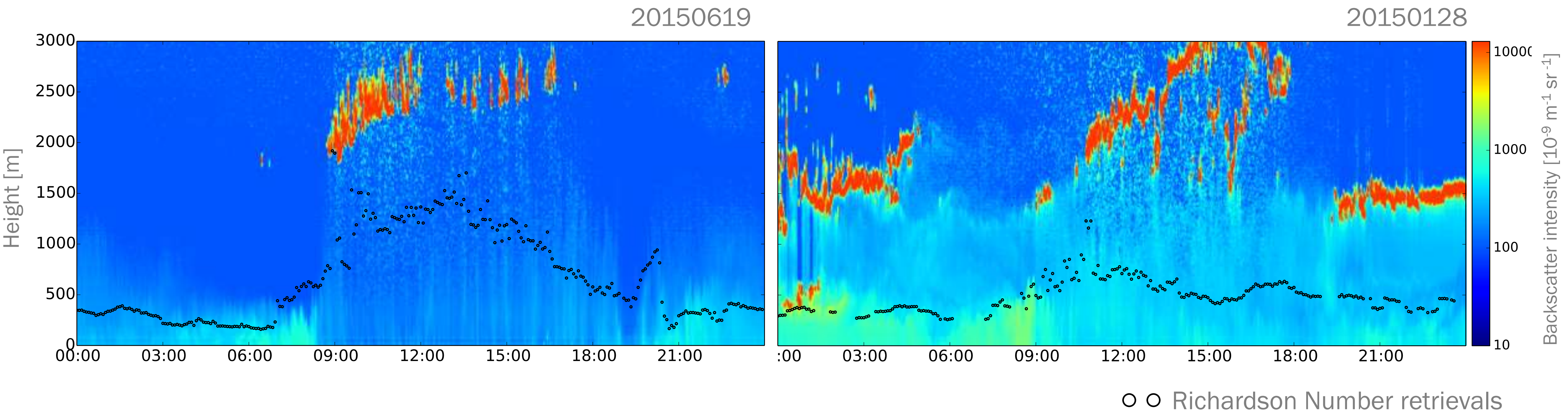
Stull, (1988)

$$R_{ibc} = 1$$

A Multi-Sensor technique was developed ***combining information from the RWP and the MWR***. The profiles obtained from these two sensors were integrated to estimate ABL height by means of calculating the ***bulk Richardson number (Rib)***

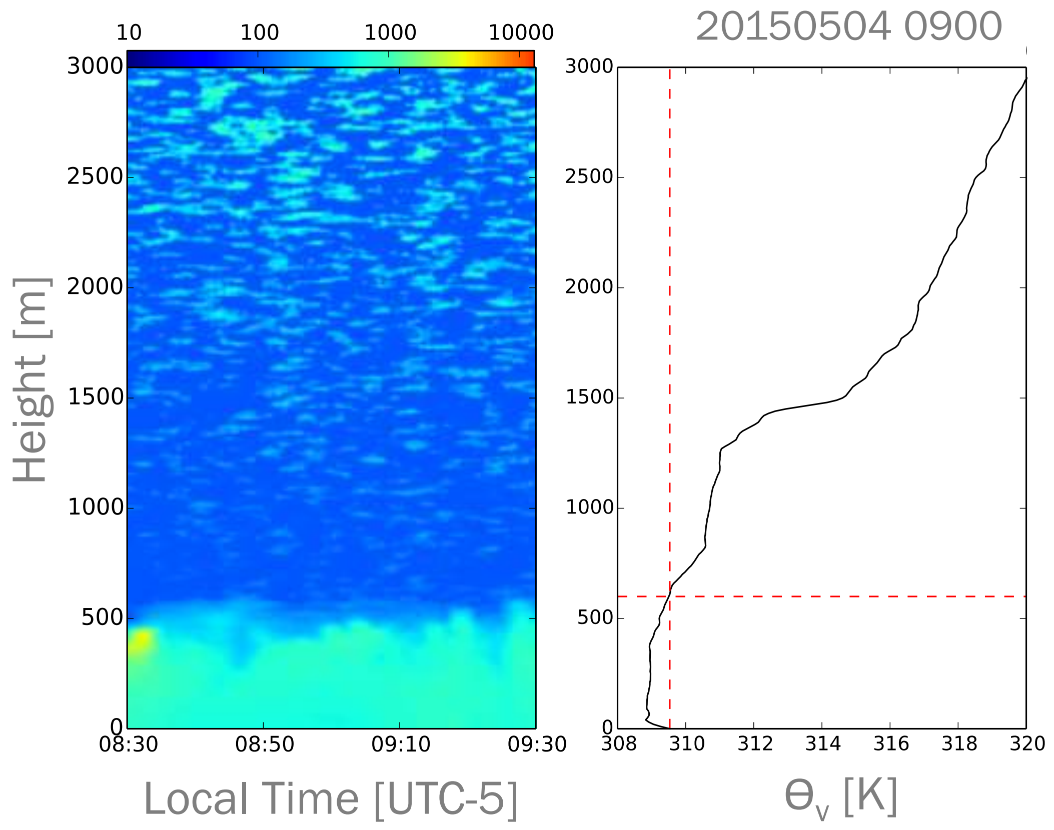
ABL Retrievals
Richardson Number

Results



Methodology

Holzworth Method



The first interception between the θ_v profile and the dry-adiabatic line starting from the surface,

"The parcel will be on ***equilibrium*** with its environment"

Gradient Method

Gradients or significant changes in the troposphere due to the transition between the ABL and the free atmosphere

Mixing Ratio profile

Potential temperature profile

Relative Humidity profile

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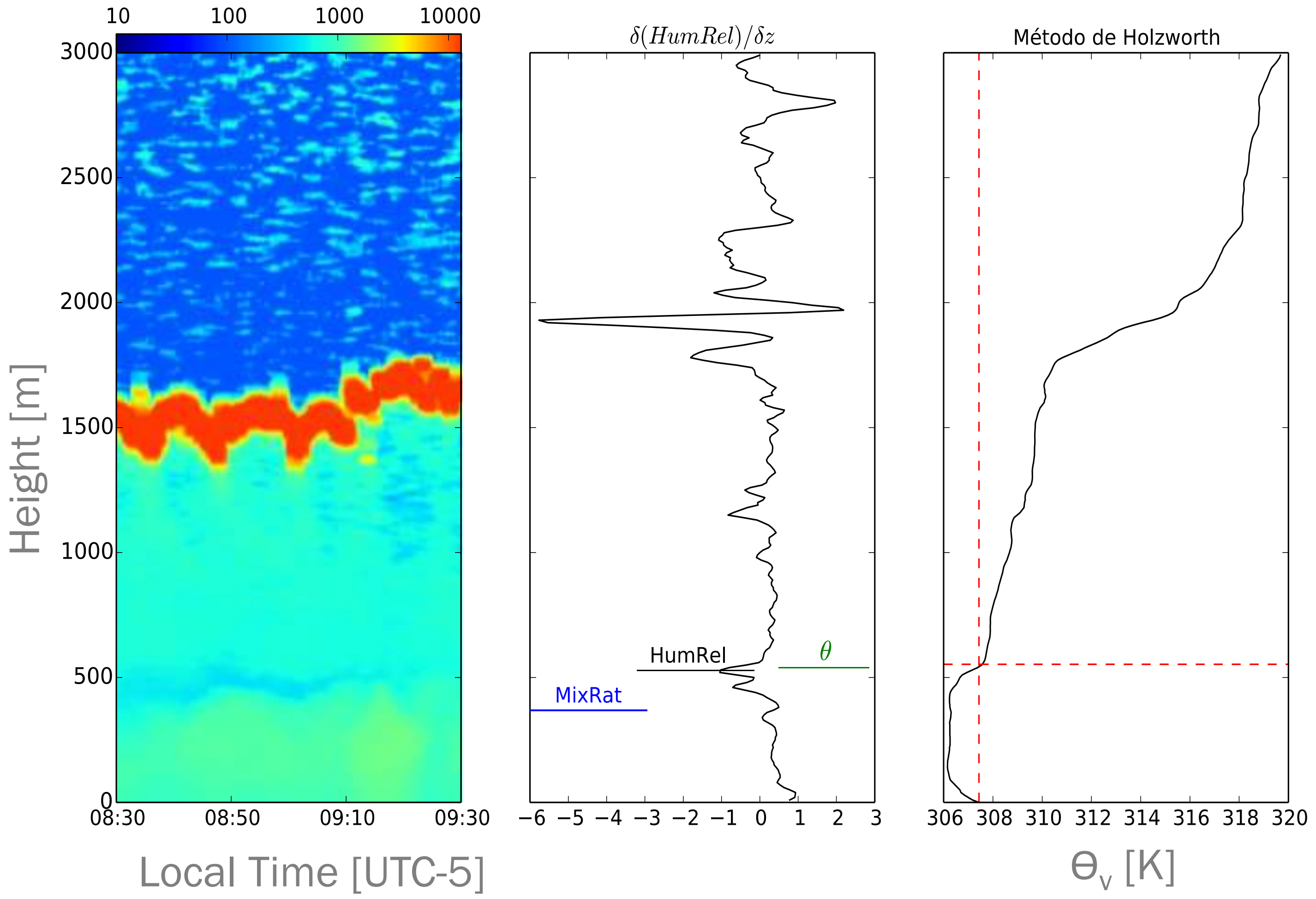
Radiosondes Retrievals (1)

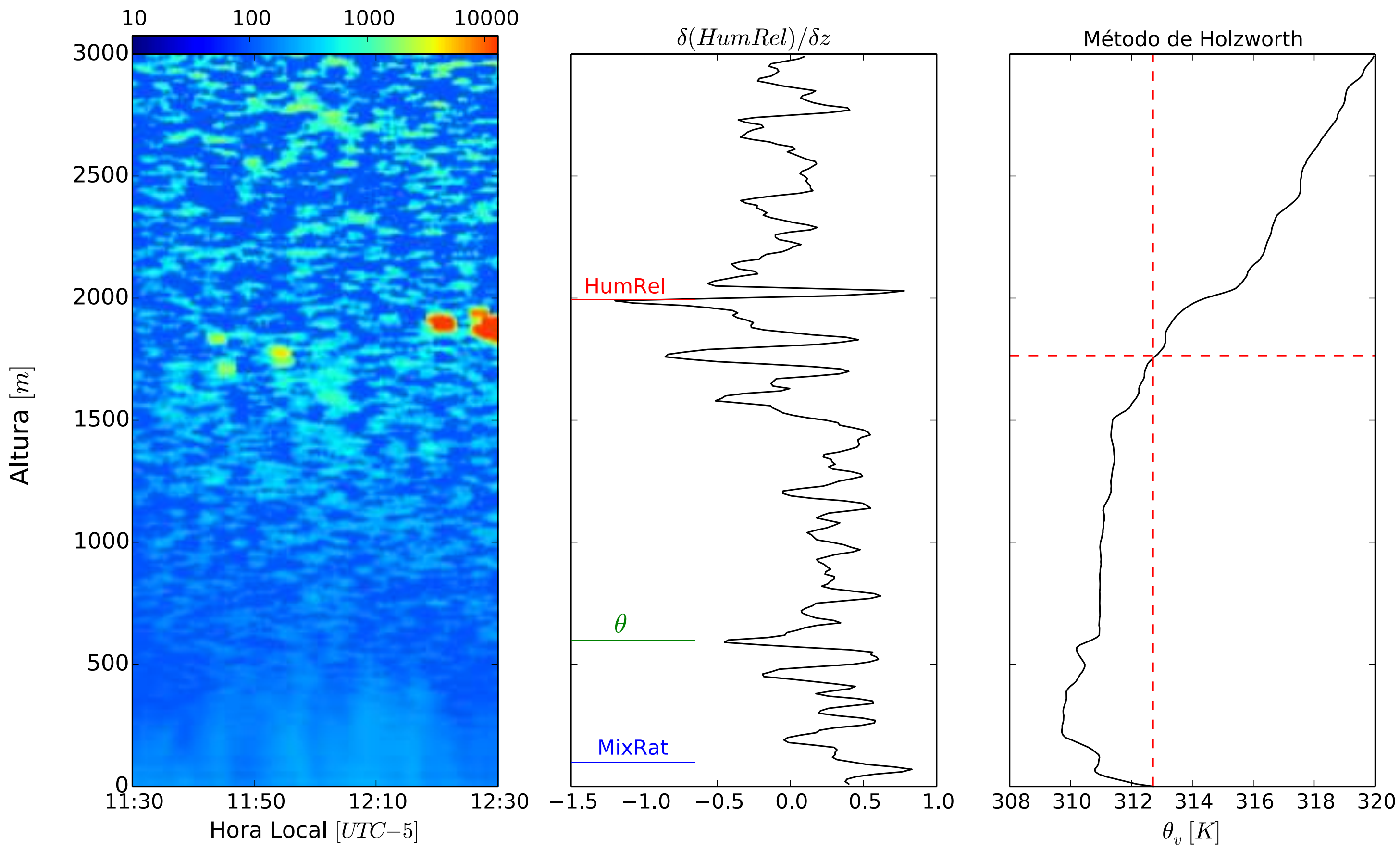
Results



Retrievals match

Radiosondes Retrievals (2)

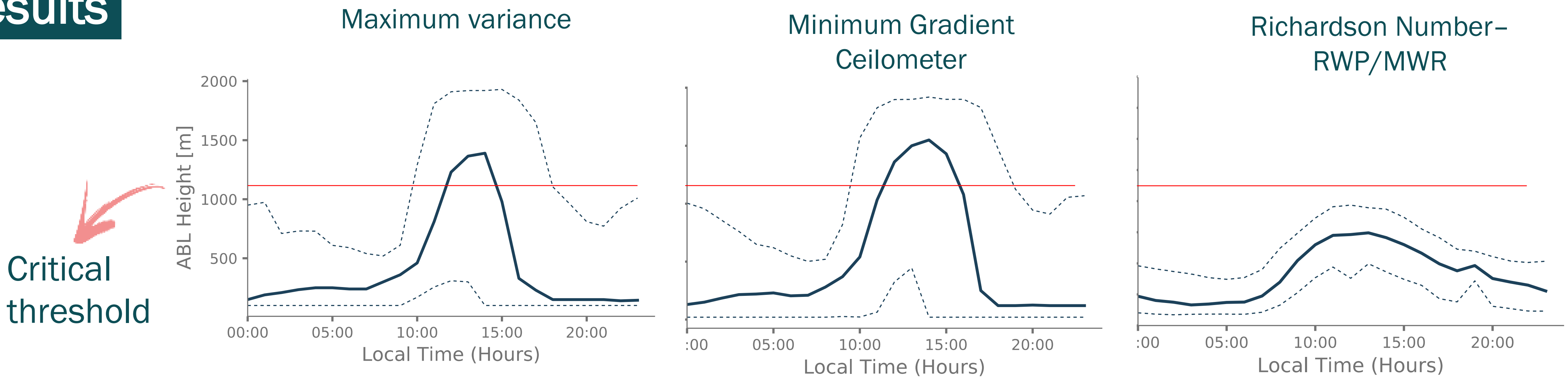
Results

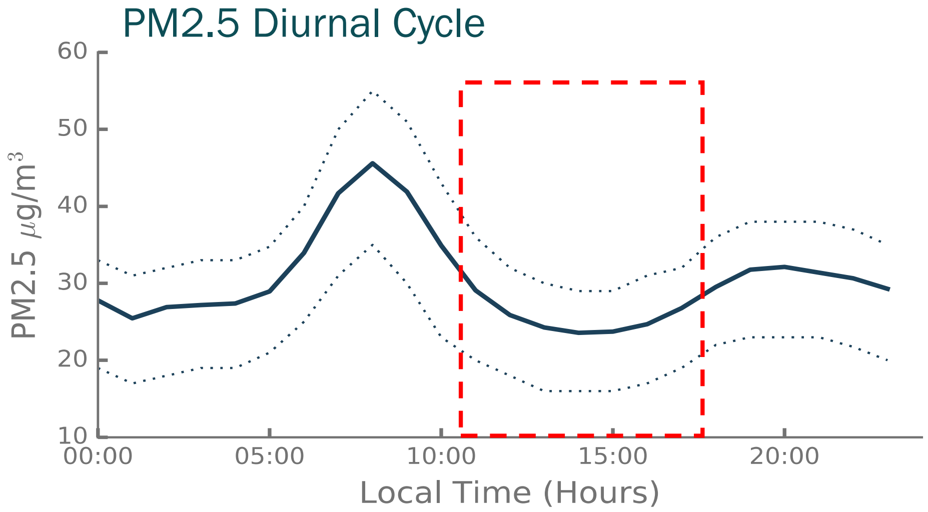


Retrievals don't match

Diurnal Variability

Results



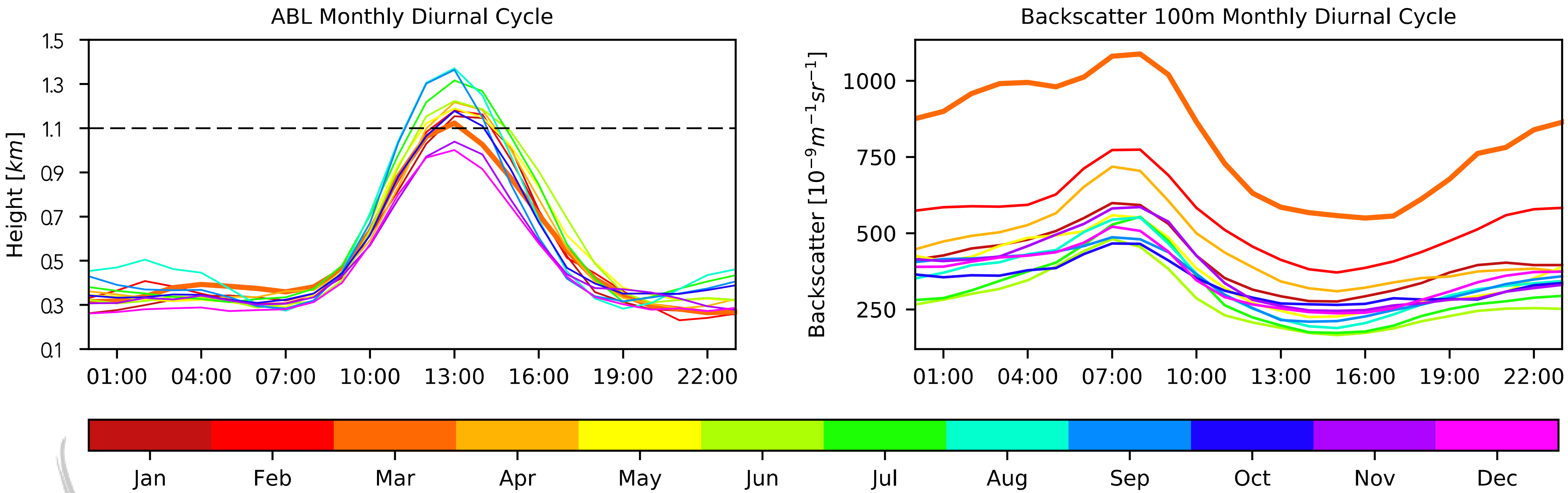


On the valley floor, the ***thermal turbulence triggered by the incoming solar radiation activates convective fluxes*** and, in consequence, the mixing processes, causing the ***layer to growth.***

The pollutants suspended inside the layer get mixed and ***vertical dispersed***, leading the ***concentrations to decrease***

Results

Seasonal and Annual Variability



Significant differences between the curves for each month suggest a strong ***annual forcing*** possibly associated with the migration of the Intertropical Convergence Zone (ITCZ) and its strong surface ***radiation forcing.***

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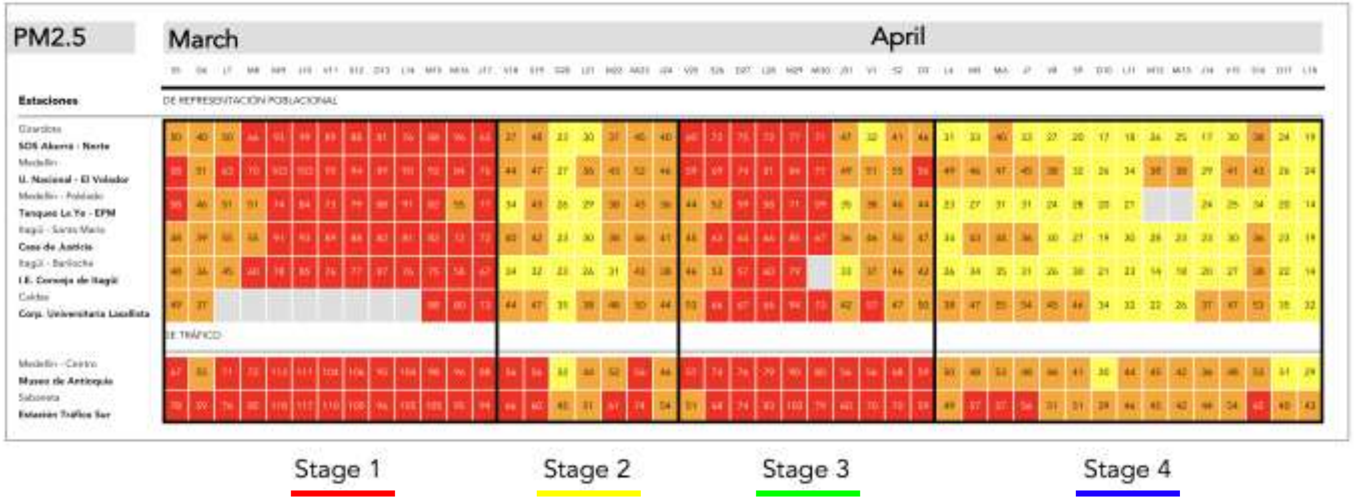
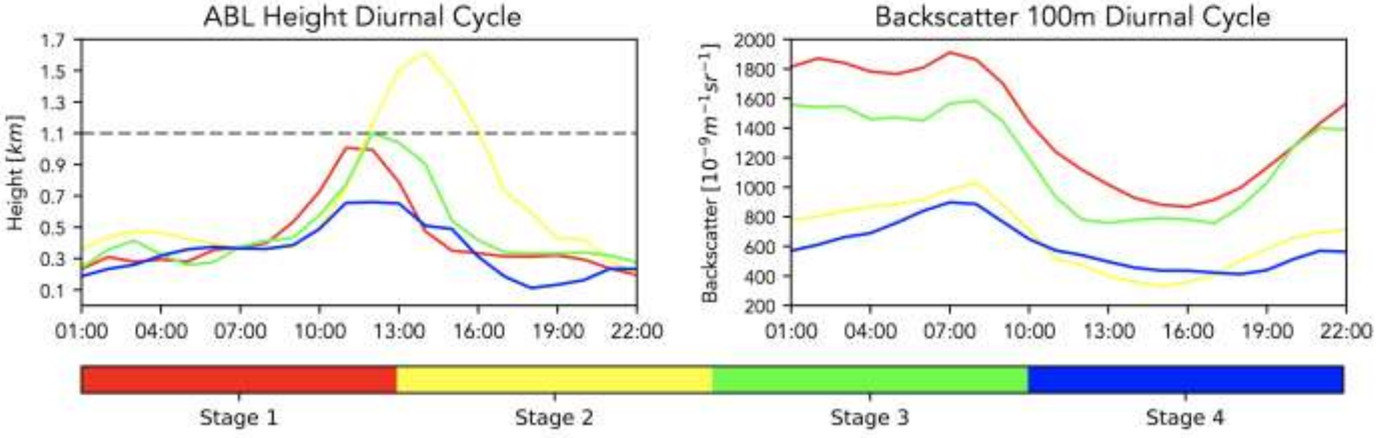
Results

Intra - Seasonal Variability

March 2016 - Air Pollution Episode





In March 2016 an air pollution episode took place in the Aburrá valley. PM2.5 concentrations rose to historical levels.

Within the episode, apparently dominated by ***large scale*** tropical dynamics, there was clear ***intra-seasonal*** variability.

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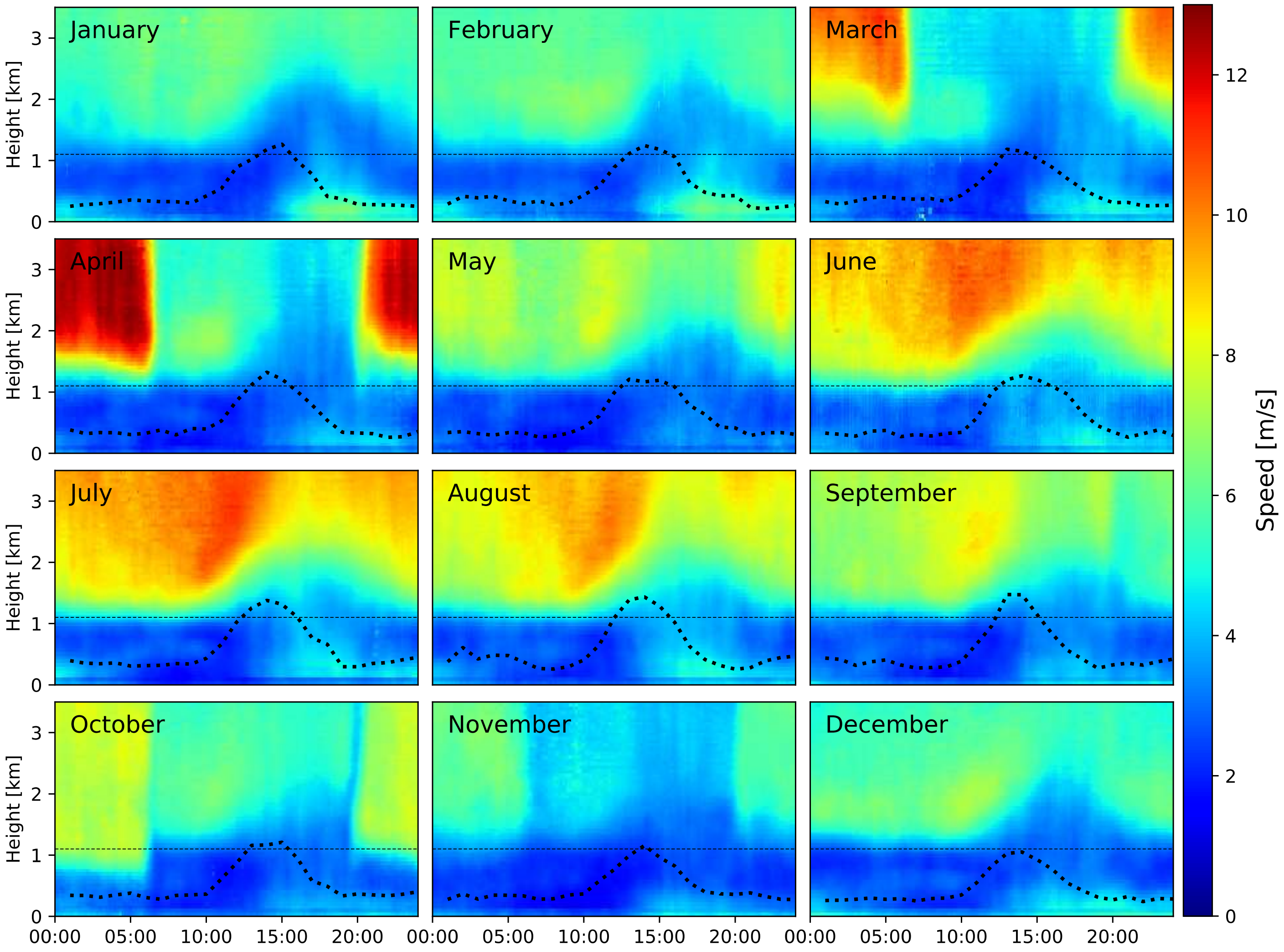
January
February
March
April
May
June
July
August
September
October
November
December
Height [km]
0
1
2
3
00:00
05:00
10:00
15:00
20:00
Speed [m/s]
0
2
4
6
8
10
12

Conclusions

Temperature gradient between the surface and the lower troposphere, are one of the main modulator of the ABL structure and variability, forcing the air parcels to ascent and descent and in consequence, activating the mixing and turbulence processes

Significant differences in the annual cycle suggest a strong ***forcing*** possibly associated with the migration of the Intertropical Convergence Zone (ITCZ) and its strong surface ***radiation forcing.***

Retrievals obtained individually, from the different thermodynamic and dynamic profiles represent the diurnal evolution and the ABL mono-modal regime in the Aburrá Valley, according to their magnitude and variability.

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Stull, R. B. (1988), An Introduction to Boundary Layer Meteorology, vol. 13, 666 pp., doi:10.1007/978-94-009-3027-8.

Thank you!!