Monitoring the depth of the atmospheric boundary layer by FORMOSAT-3/COSMIC

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Outline:

Effects of the atmospheric boundary layer (ABL) on radio occultation (RO) signals

Different definitions of the ABL top from RO

Comparisons of the variabilities of the ABL depth derived from bending angle and water vapor from FORMOSAT-3/ COSMIC RO data 2007-2009

Structural uncertainty of the determination of the ABL depth from RO

ABL is the layer directly affected by the Earth's surface

Turbulently mixed layer underlying stably stratified free atmospehere

Separated from the free atmosphere by the interfacial layer (temperature inversion and decrease of humidity)

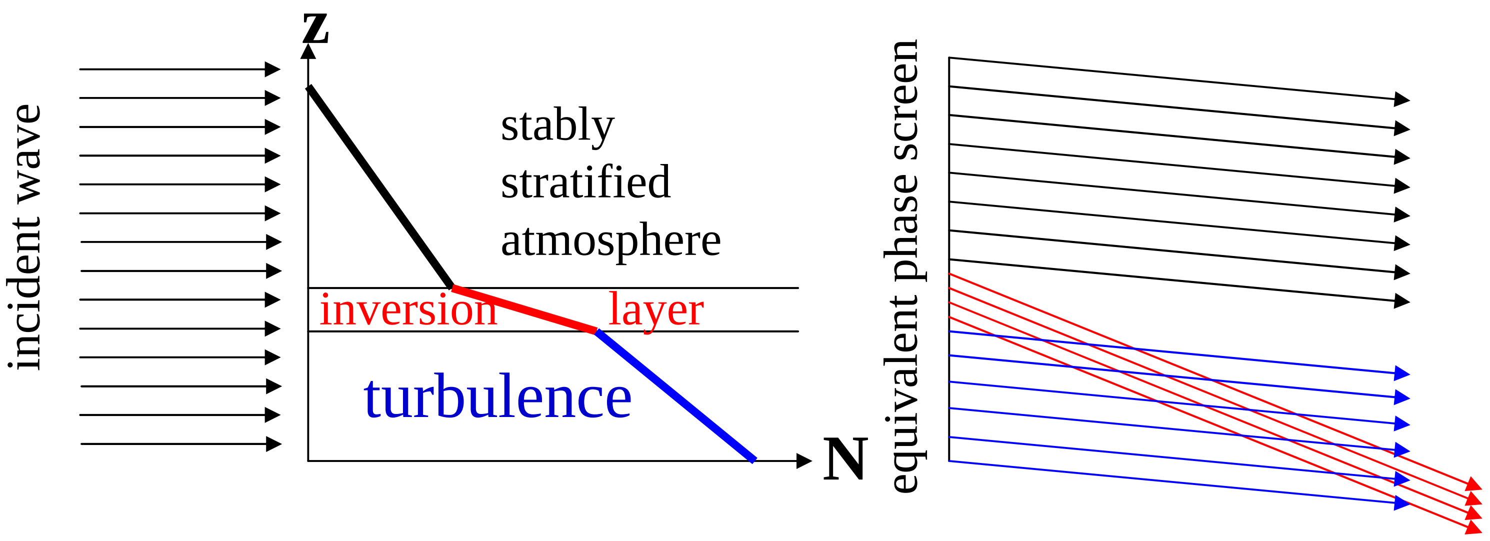
$$N = 77.6\frac{P}{T} + 3.73 \cdot 10^5 \frac{P_w}{T^2}$$

Main effect: decrease of humidity =>
=> decrease of refractivity =>
=> effect on propagation of RO signals =>
=> used for determination of the ABL depth from RO

Effects of the ABL on propagation of RO signals

The ABL top results in the strong increase of bending angle and fading of amplitude due to defocusing

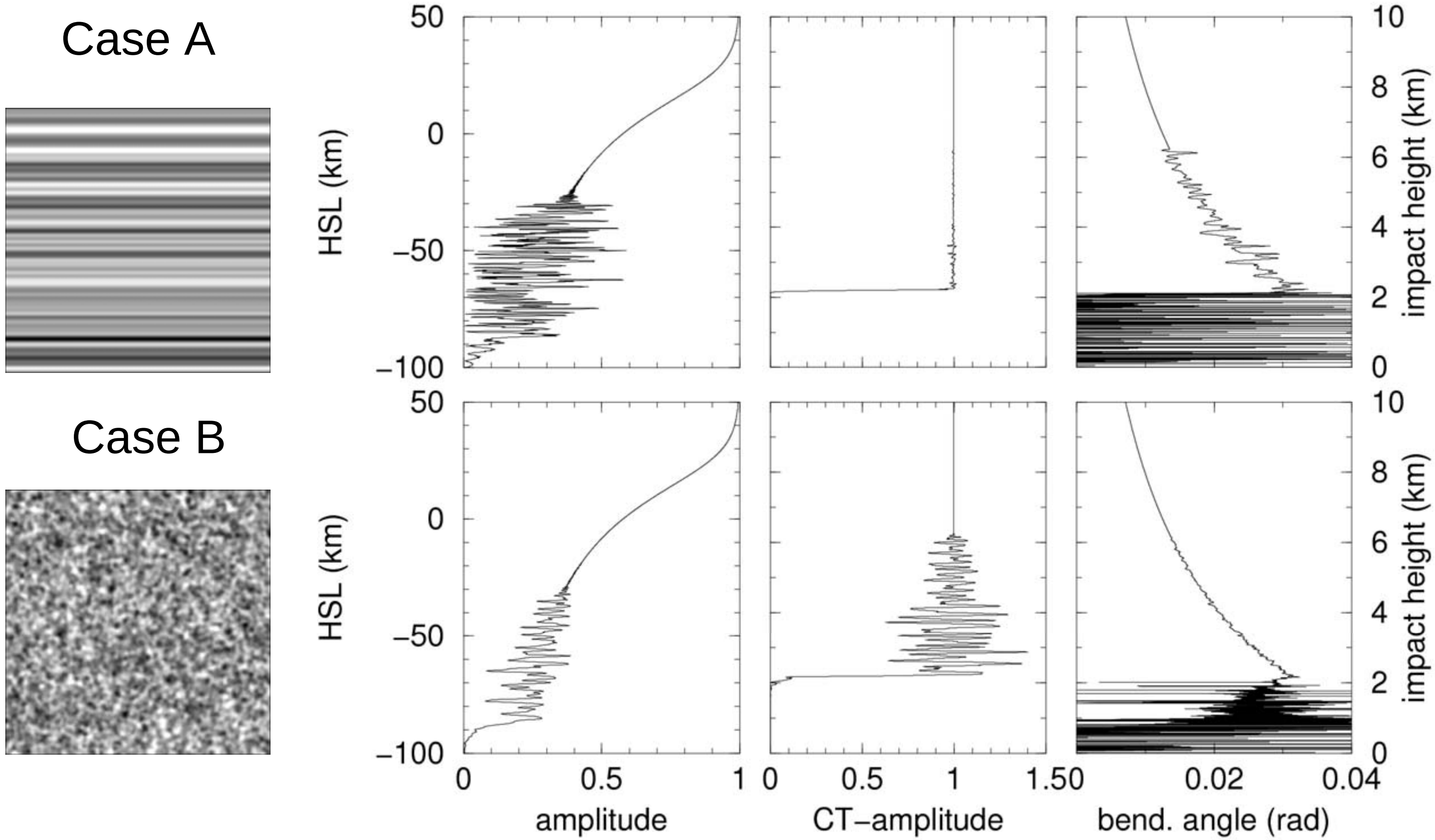
At lower heights - fluctuation due to: (1) multipath propagation, (2) turbulence



The effects (1) and (2) are different in the observed RO signals and after transforming to impact parameter representation by WO methods

Numerical modeling:

	CT amplitude fluctuation	CT phase (BA) fluctuation
Case A (horizontal irregularities)	weak	strong
Case B (isotropic irregularities)	strong	weak

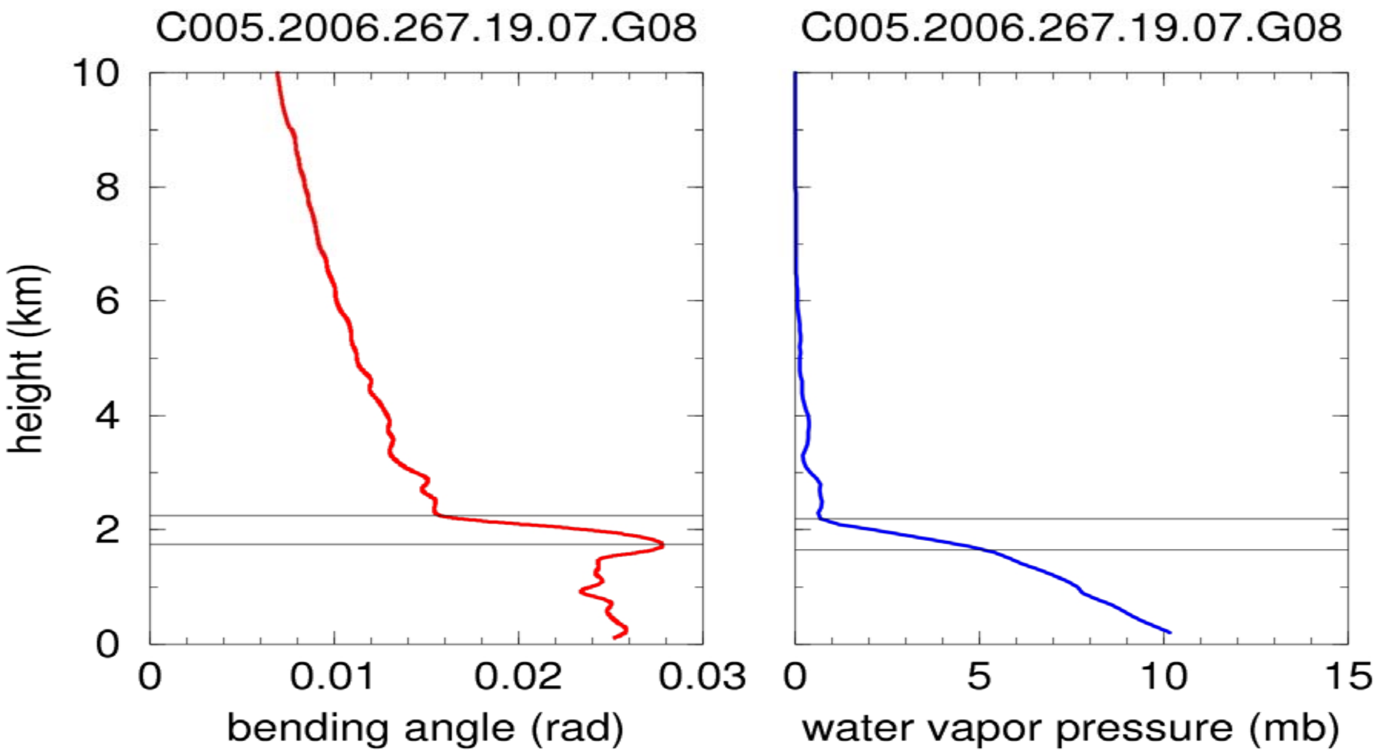


Amplitude fluctuation of WO-transformed RO signal ~ convection

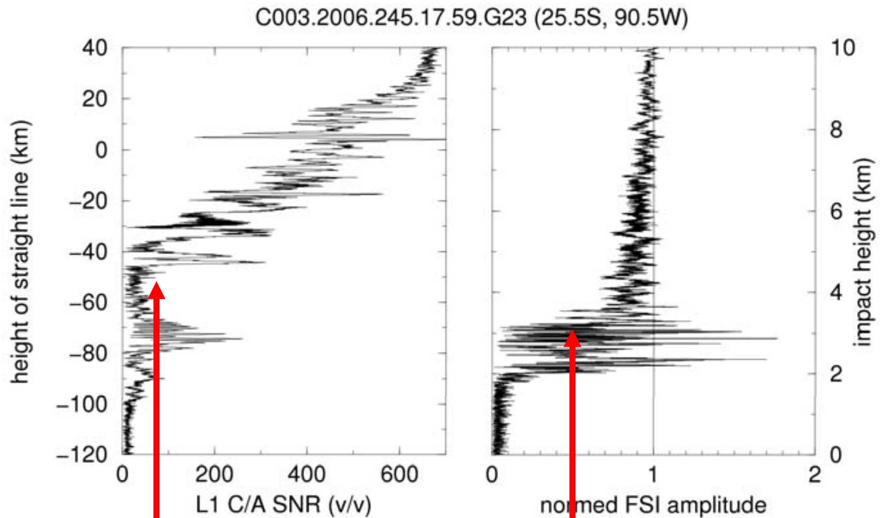
Determining the top of ABL (or strong inversion layer)

Maximum bending angle lapse

Maximum lapse of water vapor pressure retrieved from refractivity



examples FORMOSAT-3/COSMIC occultations, sharp ABL top



Transform to impact parameter representation allows vertical localization of turbulent layers

defocusing

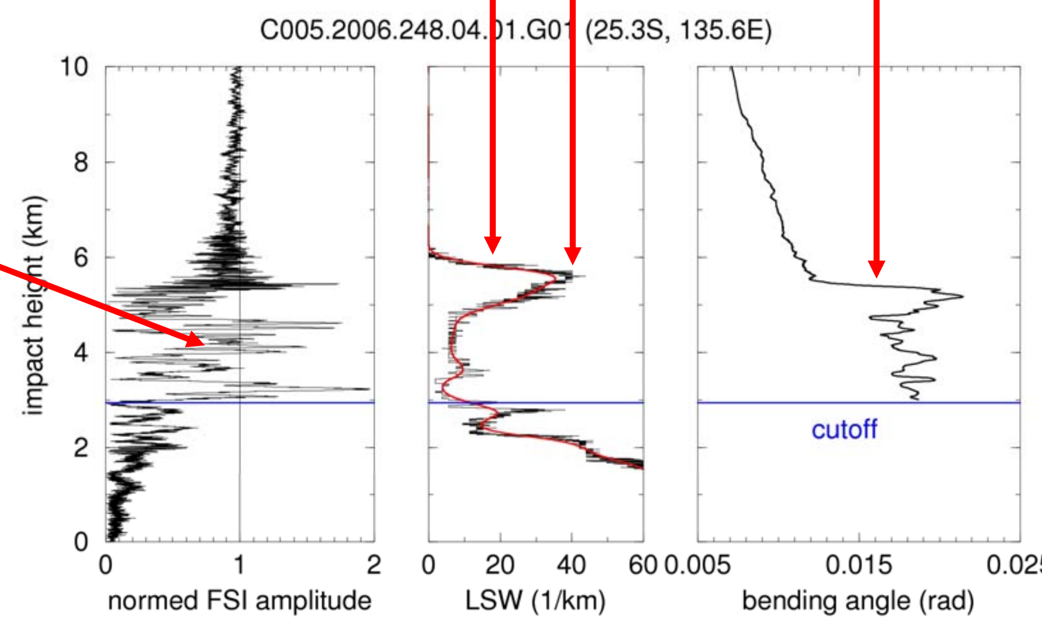
fluctuation due to turbulence

max. lapse of LSW

max. LSW

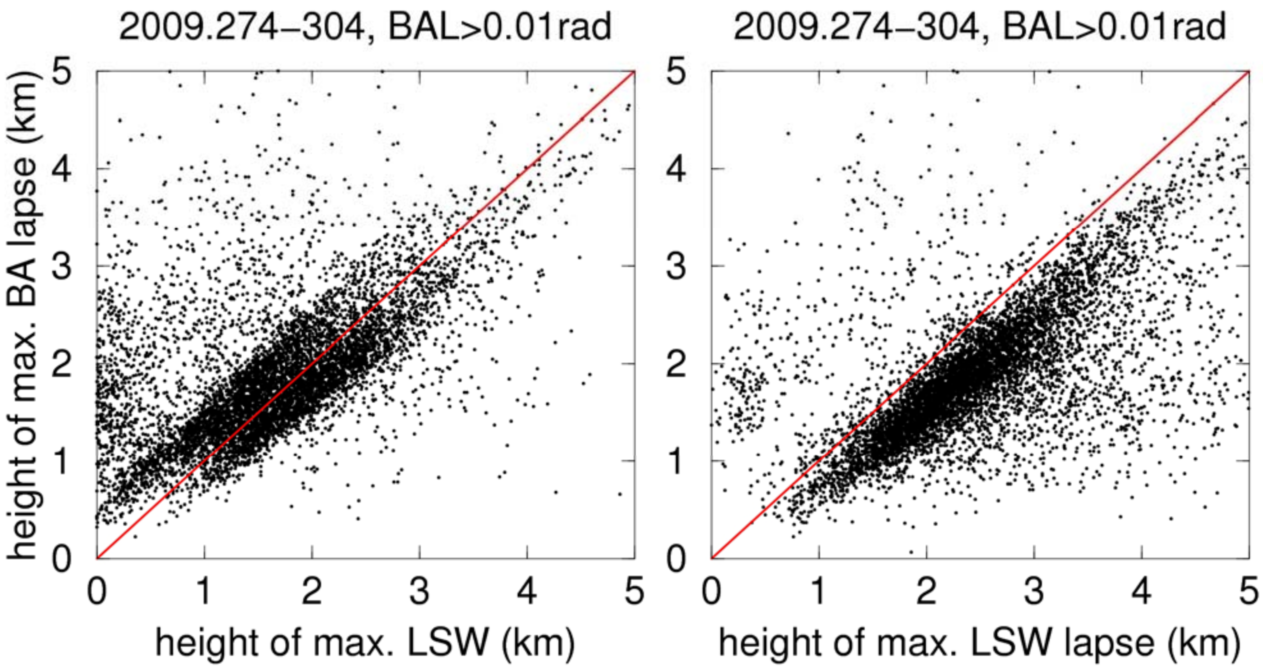
max. lapse of BA

Fluctuation of the amplitude of the transformed RO signal can be characterized by scintillation index (S4) or by local spectral width (LSW)



It is known that in the case of well defined ABL top the strongest turbulence is observed near the top (Wyngaard and LeMone, 1980)

Correlation of the max. BA lapse (or max. water vapor lapse) with the height of max. LSW and max. lapse of LSW



This establishes a statistical relation between the main physical definition of the ABL top (capping turbulence) and the definition based on BA or WV lapse (more convenient for practical use).

ABL depth from BA lapse, FORMOSAT-3/COSMIC

(only profiles penetrating below 0.3 km)

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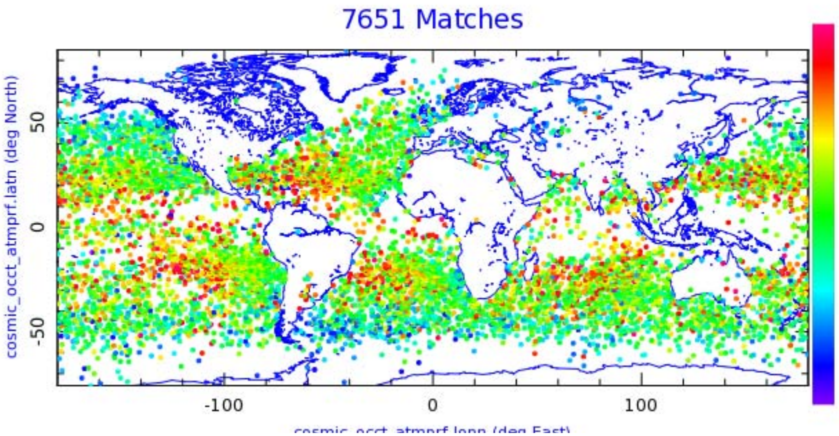
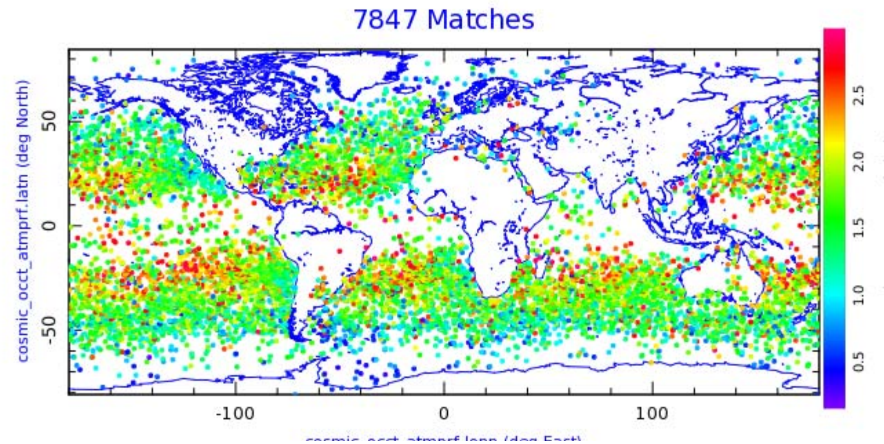


M A M



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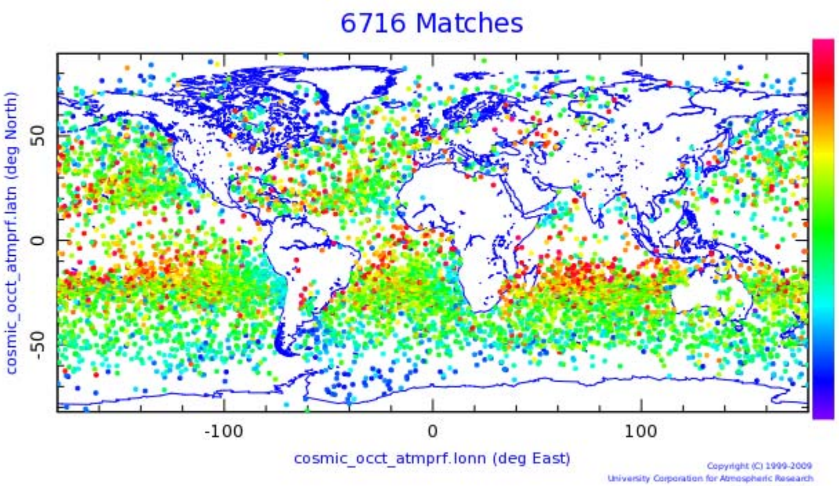
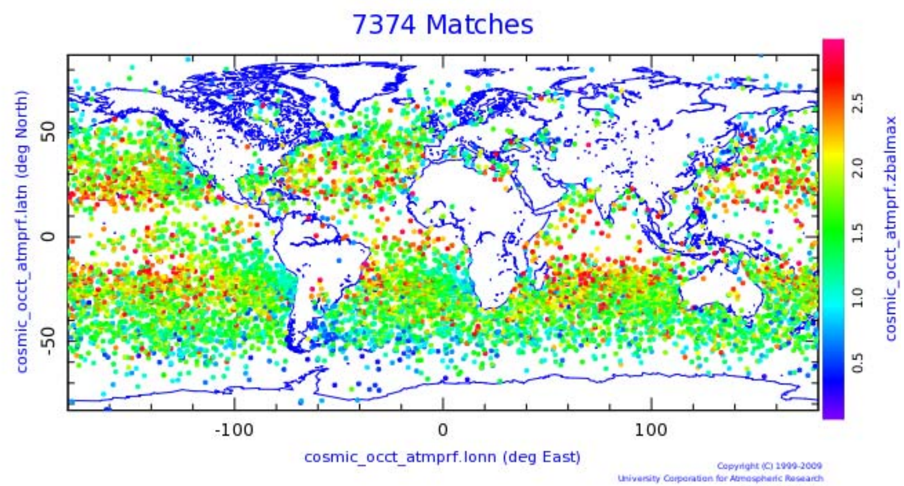
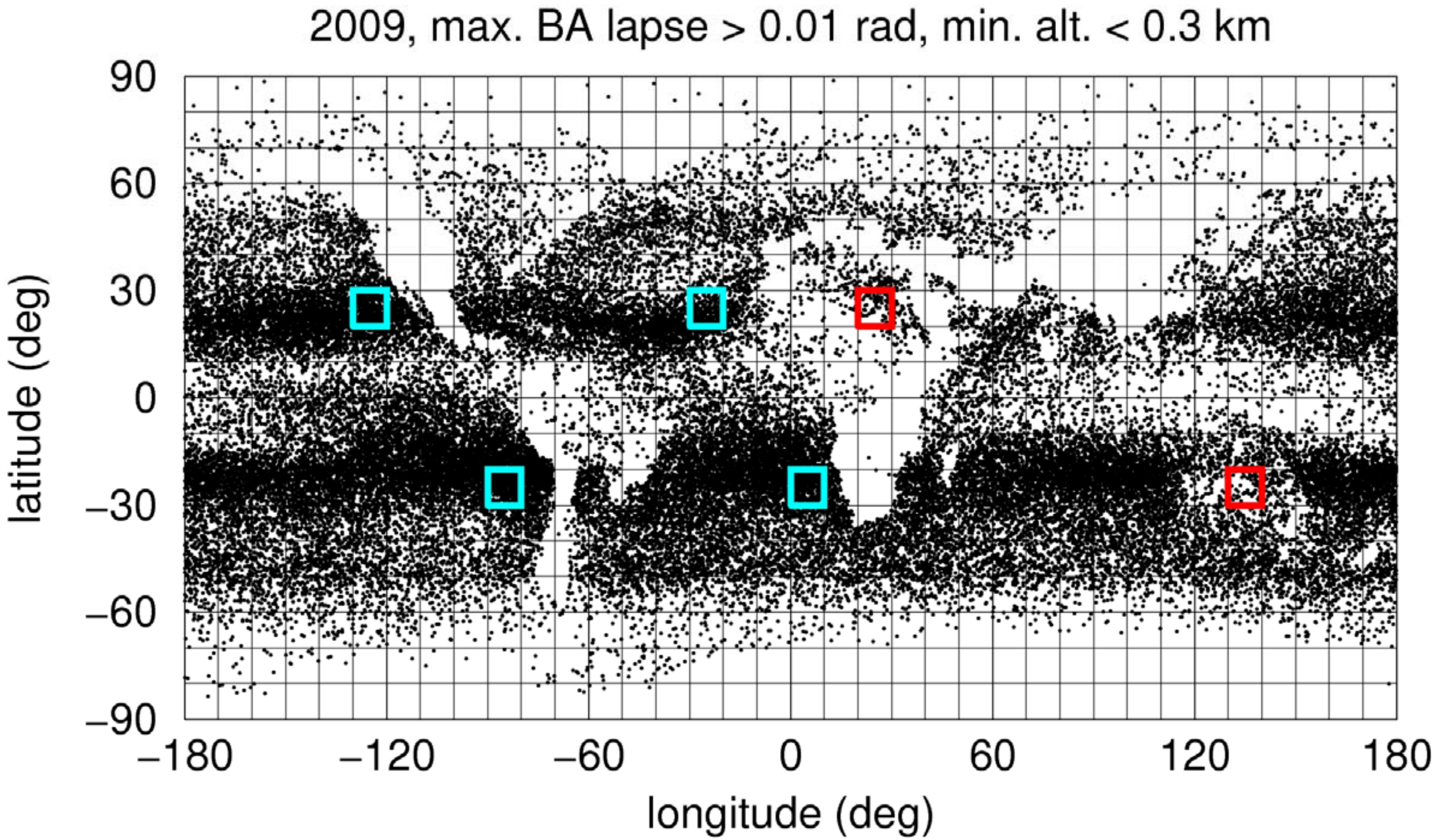


S O N



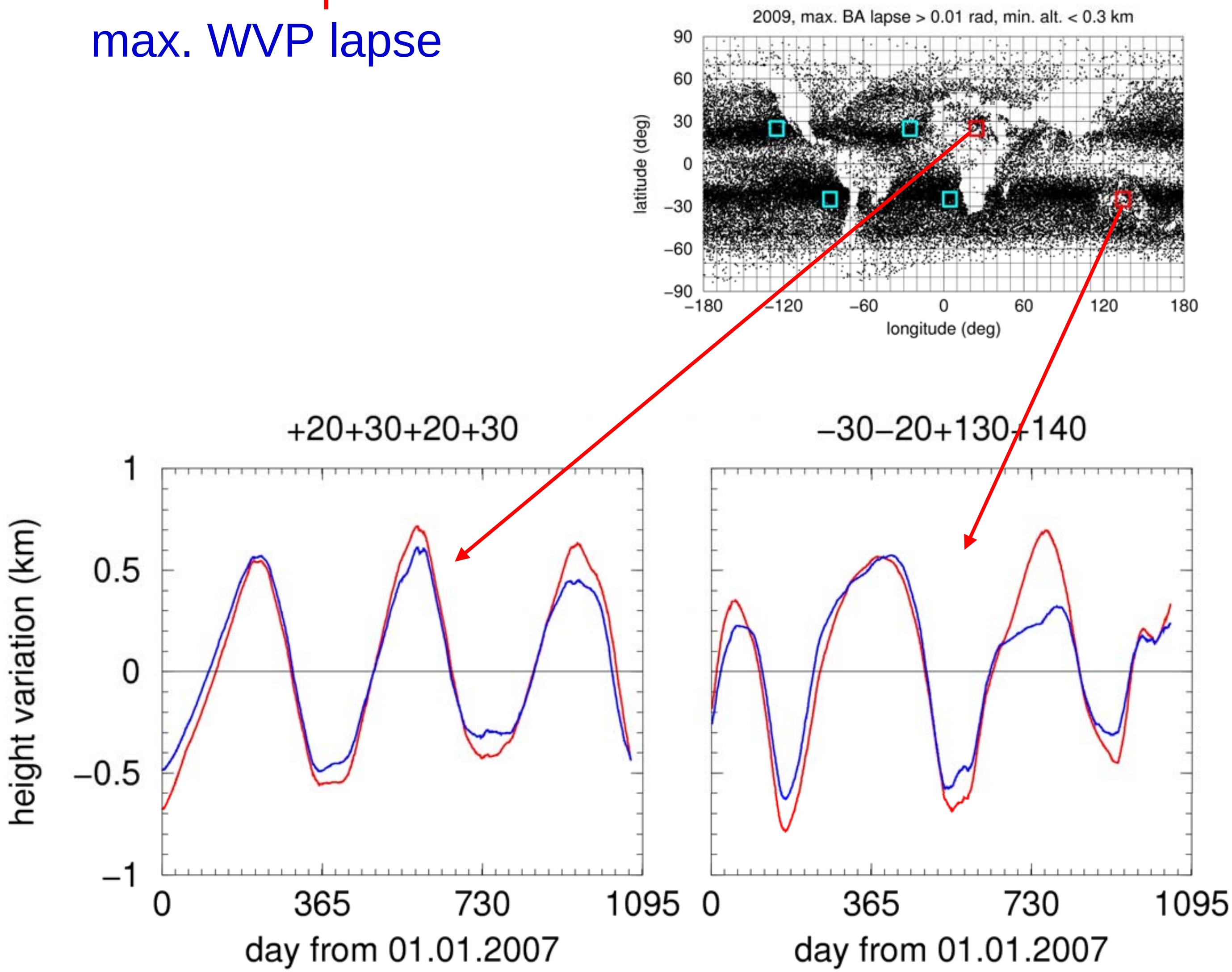
Study of the variability of the ABL depth (by BA and WV) from FORMOSAT-3/COSMIC RO data, 2007-2009



boxes - regions selected for the study

Interannual variation of the ABL depth (land)

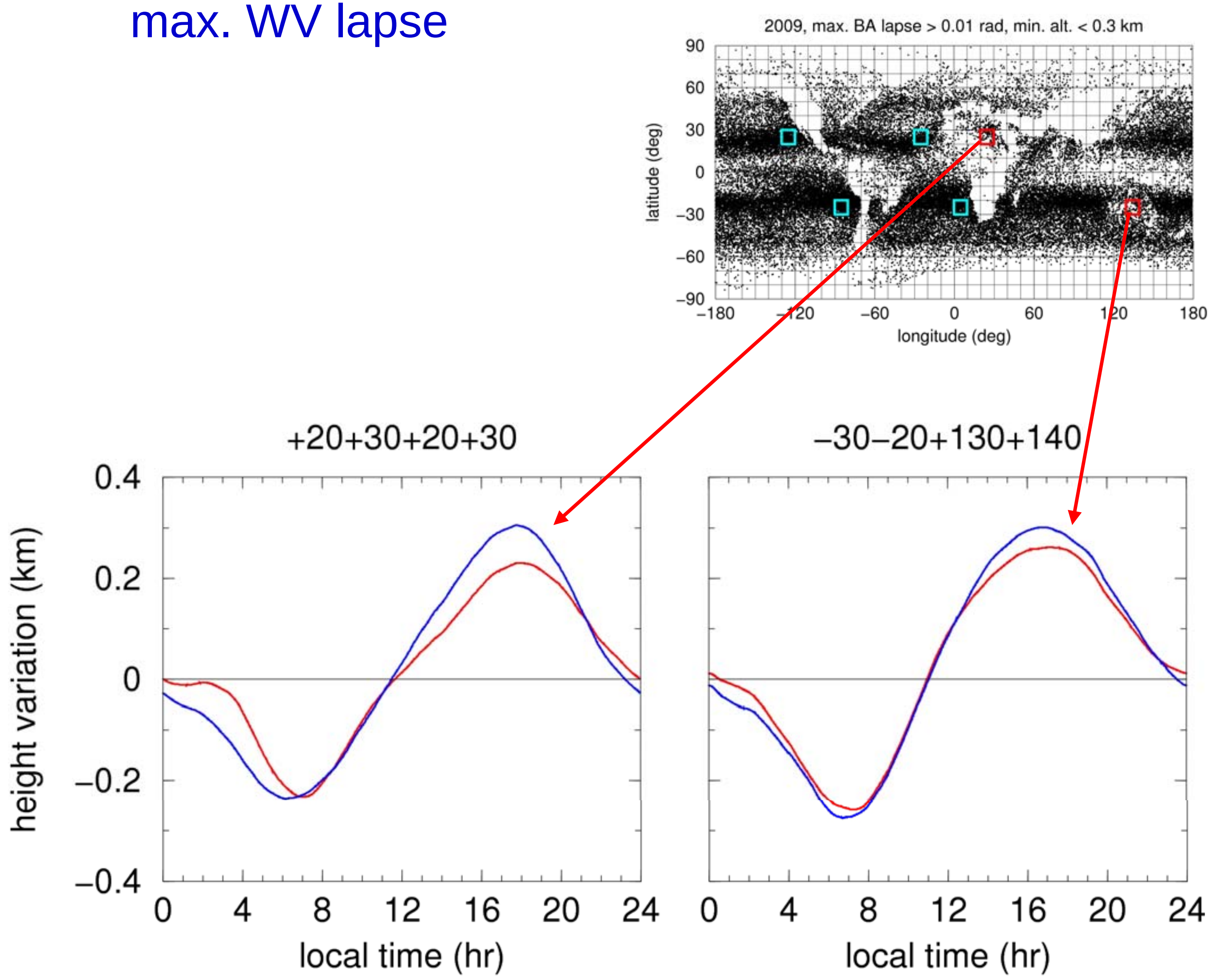
max. BA lapse
max. WVP lapse



Diurnal variation of the ABL depth (land)

max. BA lapse

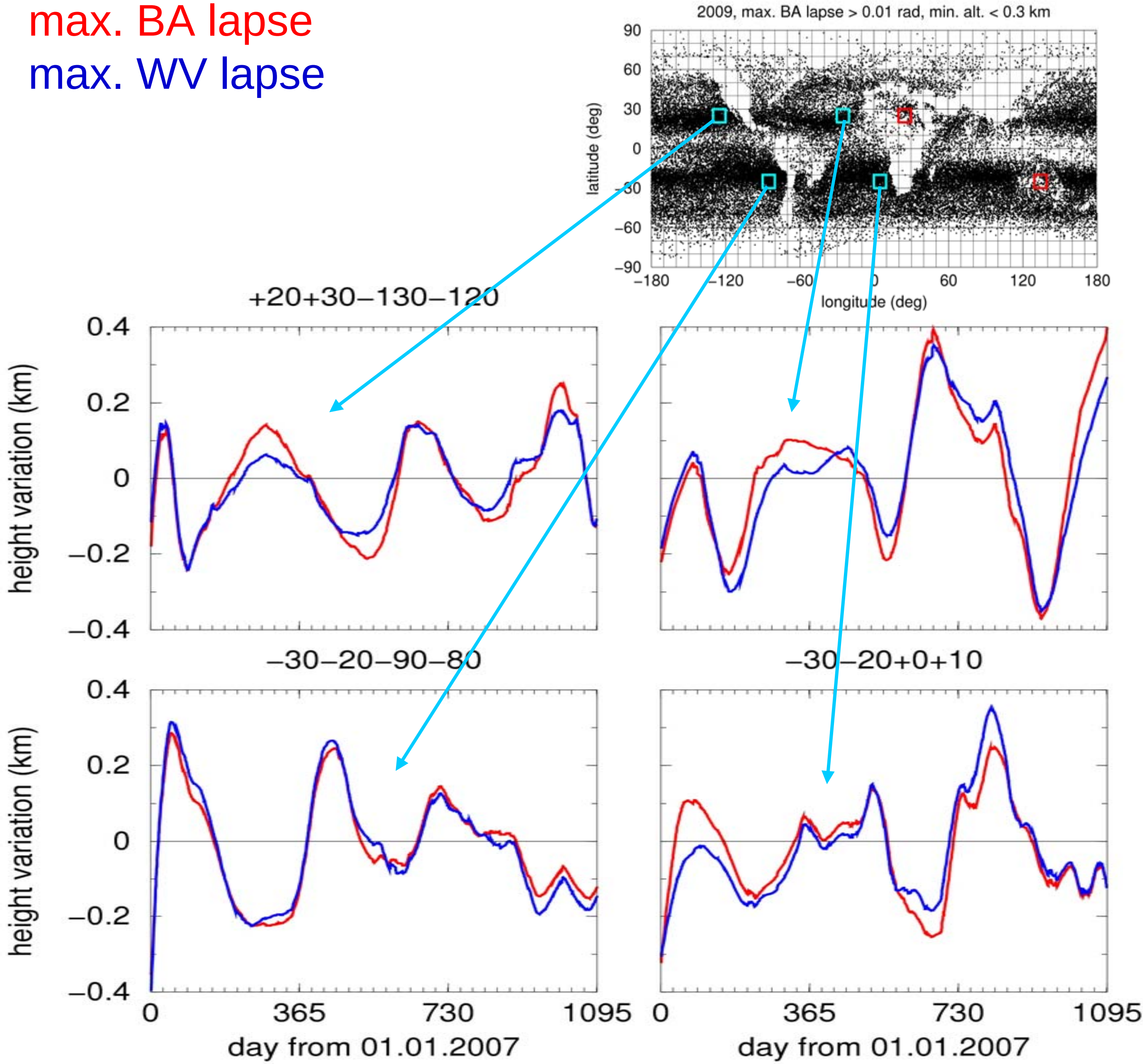
max. WV lapse



Interannual variation of the ABL depth (oceans)

max. BA lapse

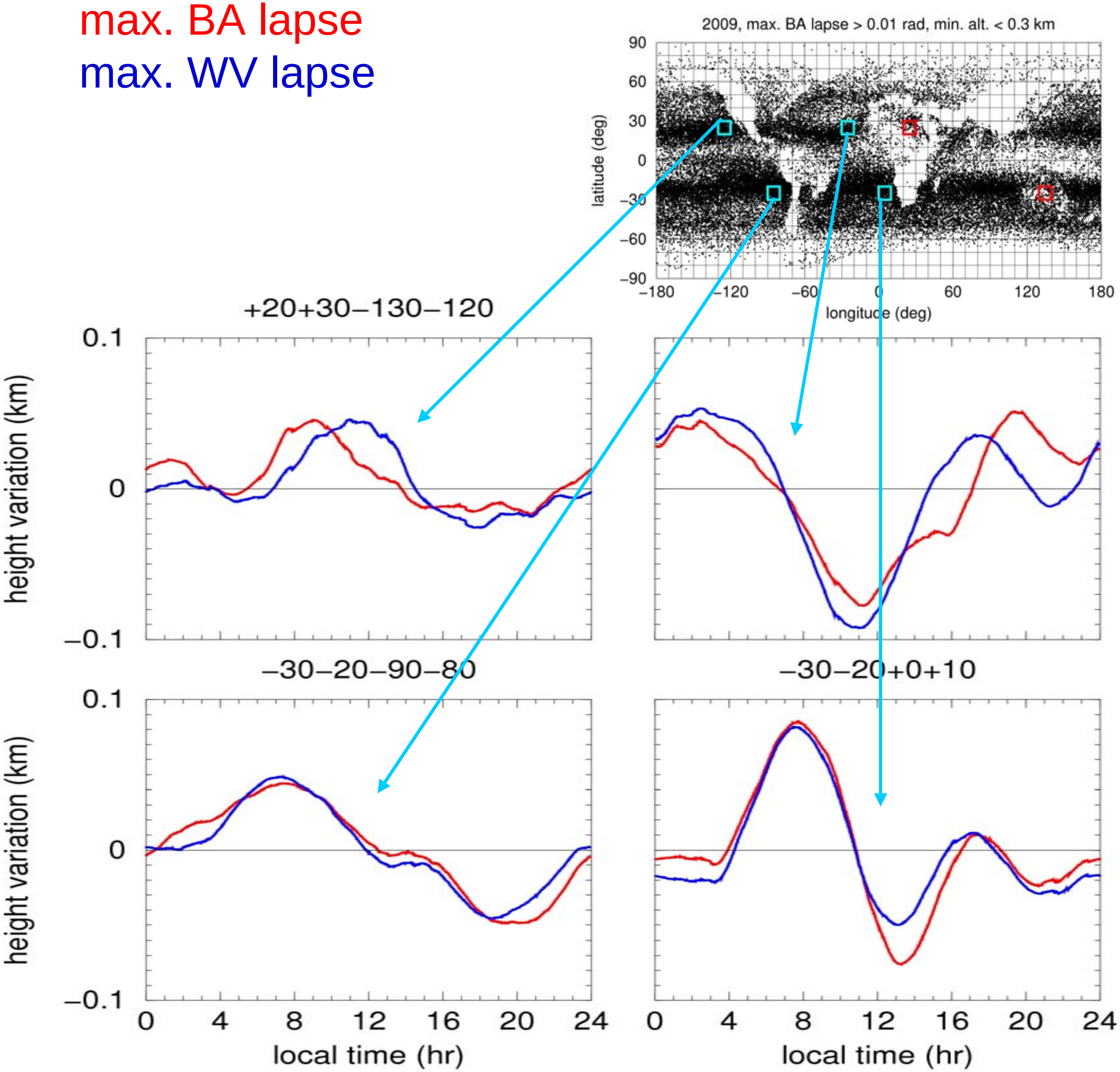
max. WV lapse



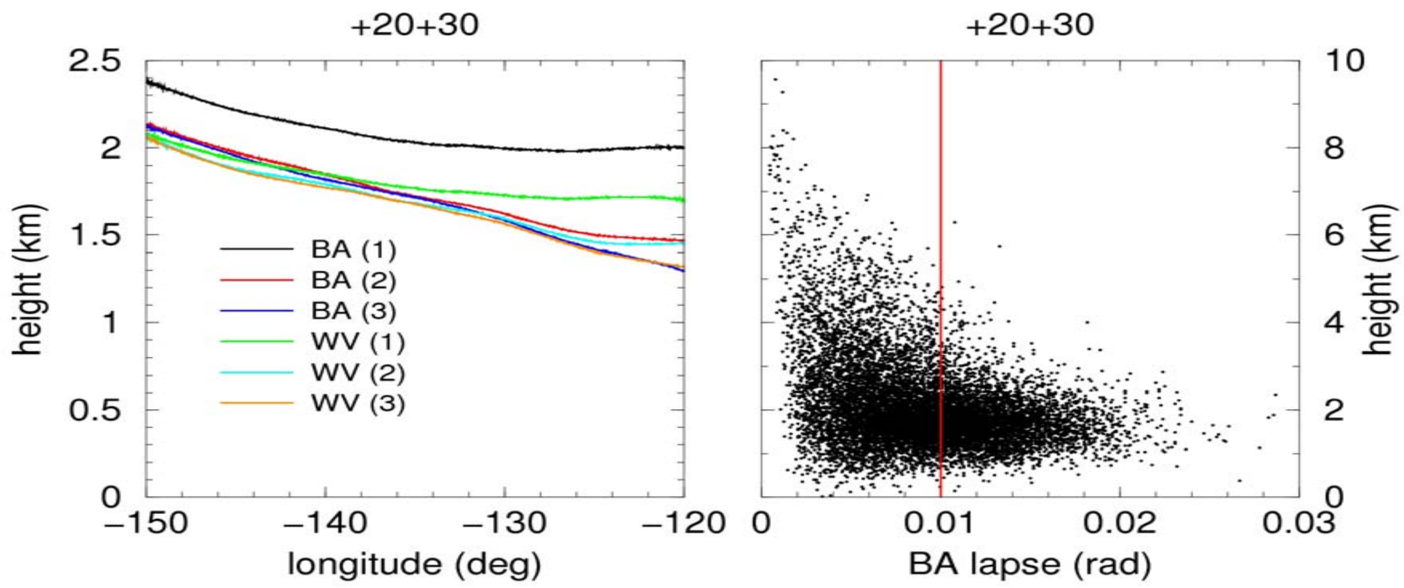
Diurnal variation of the ABL depth (oceans)

max. BA lapse

max. WV lapse



Structural uncertainty

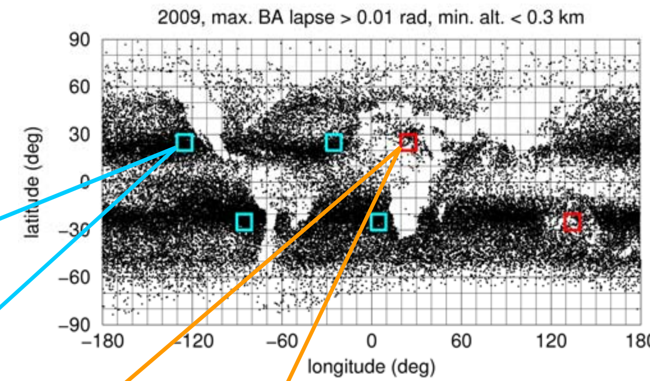


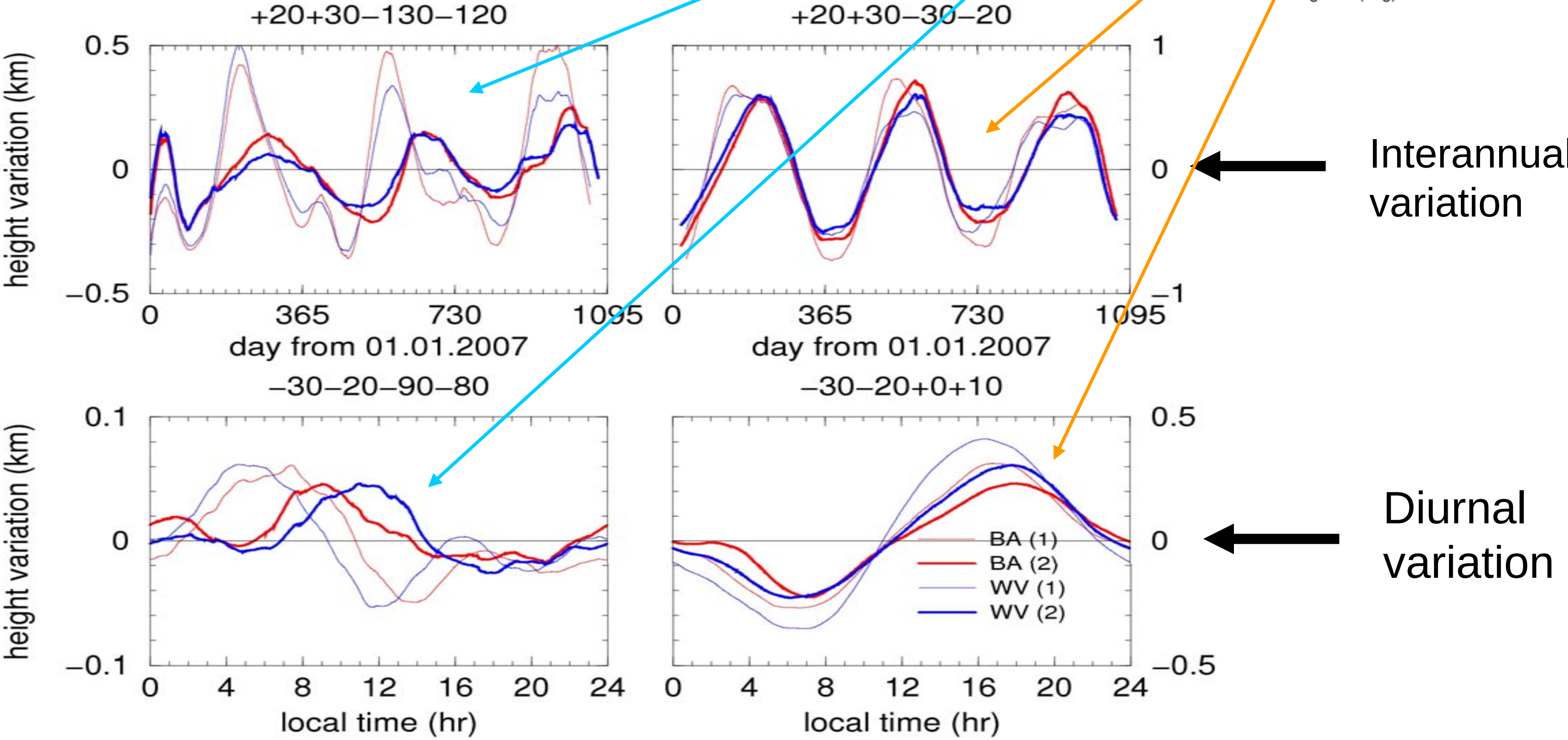
BA - from bending angle lapse; WV - from water vapor lapse
(1) - all data; (2) - BA lapse > 0.01 rad; (3) add. min. ret. alt. < 0.3 km

Small BA lapse may not necessarily correspond to the ABL top.
May introduce bias in averaging. Possible constraints:
- magnitude of the BA or WV lapse
- ABL depth
- percentile of lapse, ratio first/second maxima (Ao et al. 2008)
- median instead of mean (no tunable parameters)

Structural uncertainty

On the other side:
deeper ABL - smaller BA lapse - larger variability

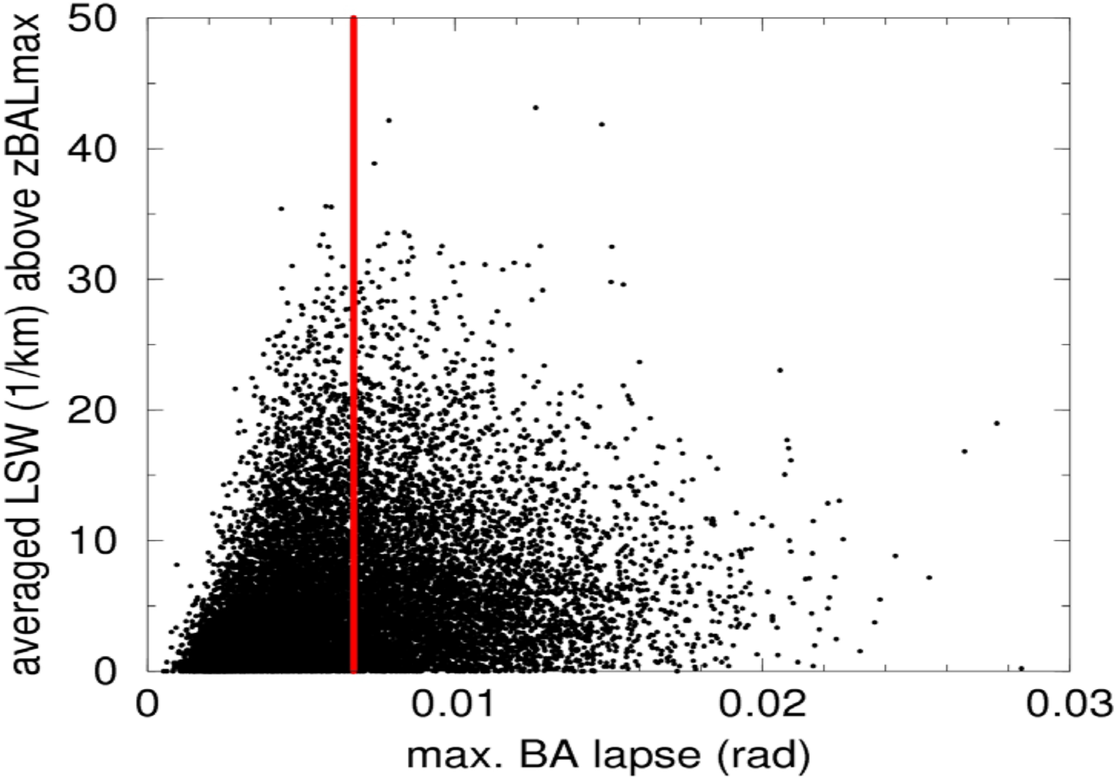




BA - from bending angle lapse; **WV** - from water vapor lapse
(1) - all data; (2) - BA lapse > 0.01 rad (ocean), 0.005 rad (land)

How to come up with a justified constraint?

When max. BA lapse is larger than a certain value, the averaged LSW above the layer decreases, i.e. the inversion layer is capping turbulence. This is consistent with the main physical definition of the ABL top. That value (different for different regions) can be used as a constraint.



Summary

Determination of the ABL top from RO based on strong gradient of BA is consistent with the main physical determination based on turbulence.

Any of the RO-retrieved profiles (BA, N, WVP, etc.) can be used for monitoring the ABL depth.

Existing RO data allow studies of the geographical, seasonal, interannual and diurnal variations (diurnal variations over the oceans have never been observed before).

For statistical studies, it is important to consider the structural uncertainty. Constraining on sharpness of the ABL top yields lower estimates of the mean ABL depth and magnitude of the variations.