Organized structures in the Sahelian boundary layer during the transition period between the wet and dry seasons

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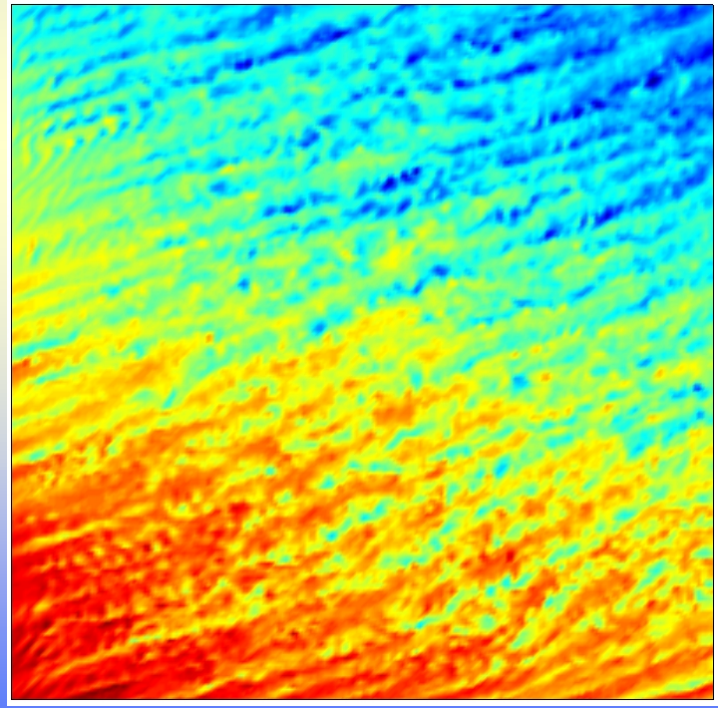
Organized structures can make the measurement of heat fluxes a very difficult challenge.

Use of a numerical simulation of one HAPEX-SAHEL case with a meso-scale model at 250 m horizontal resolution to show further evidence of the possible impact of the coherent structures on aircraft flux measurements.



Introduction: issue

Start of this study:

- **under-estimation of fluxes measured with aircraft during HAPEX-SAHEL**
- **airplane measurements give too small heat fluxes: a persistent problem with airplane measurements of fluxes**
- **General difficulty to measure fluxes in well-organized PBL versus homogeneous fully-turbulent PBL**

Embedded issues:

- **Sampling issues**

  “How long is long enough ?” (Lenschow, 1994)

- **2D or 3D structures versus line-measurement with an aircraft or from the ground**

$\Rightarrow$ Ongoing study about the impact of coherent structures on 1D flux measurement, links with processes in sahelian PBL

Context: HAPEX-SAHEL 1992

October 8 1992 case

Numerical simulation
with MesoNH model

3 domains centered on Hamdallay
With 37 levels

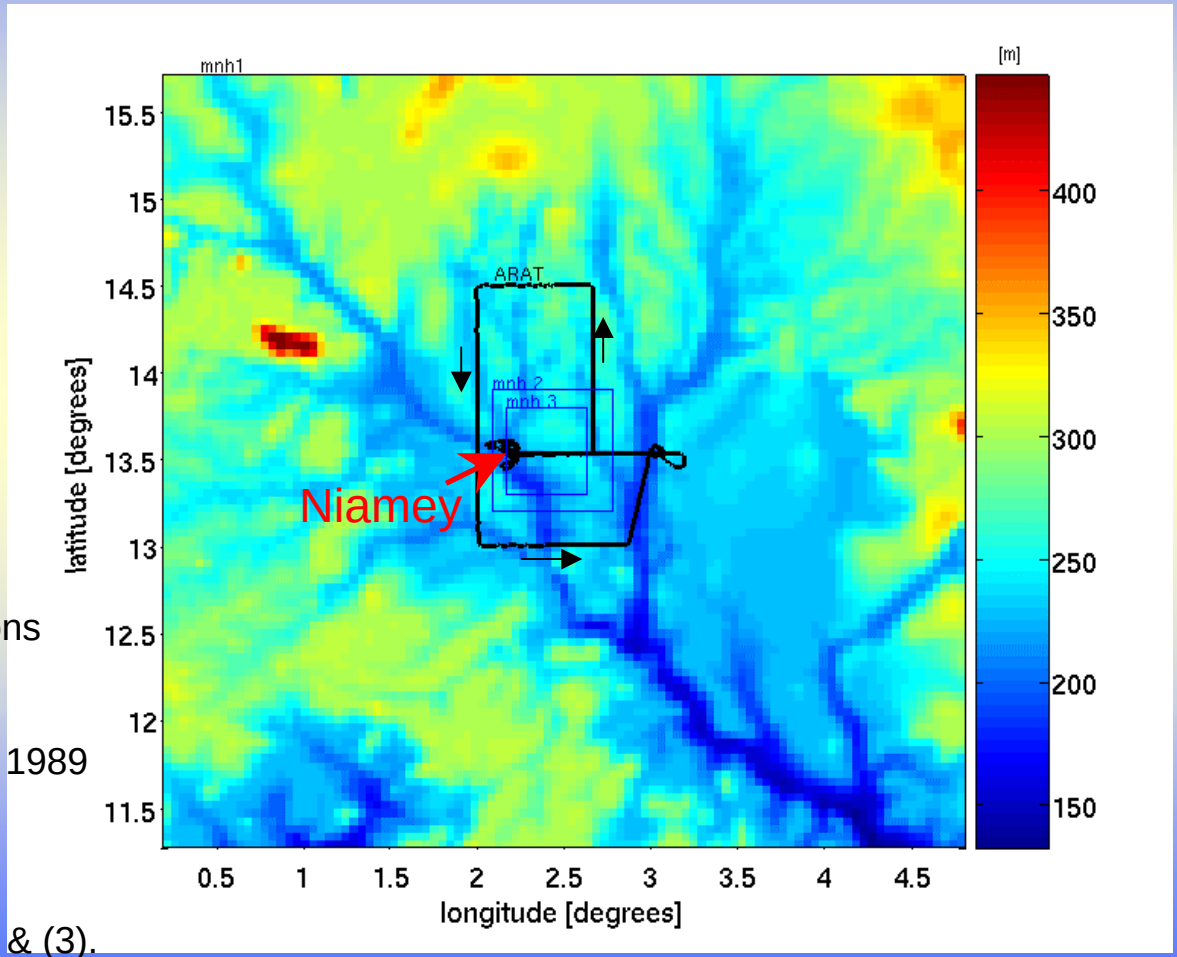
(1): 5 km hor. res.
(2): 500 m
(3): 250 m

Initiation: ERA15 reanalyses

Soil moisture modified with observations
and physiographical characteristics

Continental surface scheme : Noilhan 1989

Turbulence schemes:
Bougeault et Lacarrère 1989 for (1)
Deardorff 1972 3D turbulence for (2) & (3).



Context: HAPEX-SAHEL 1992

October 8 1992 case

ARAT aircraft measurements

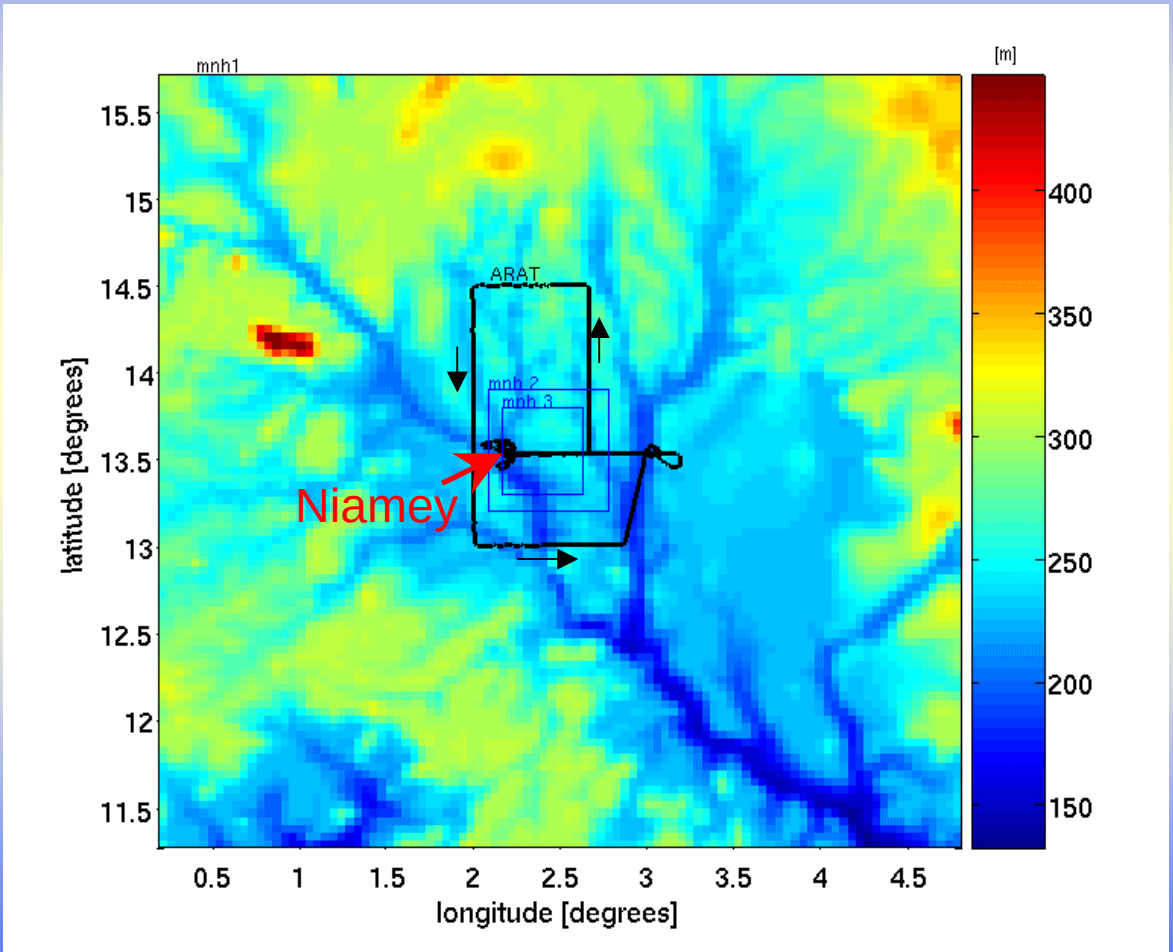
- Flight level: 300 m between 0930 and 1200 UTC

- Two soundings made at the beginning and the end

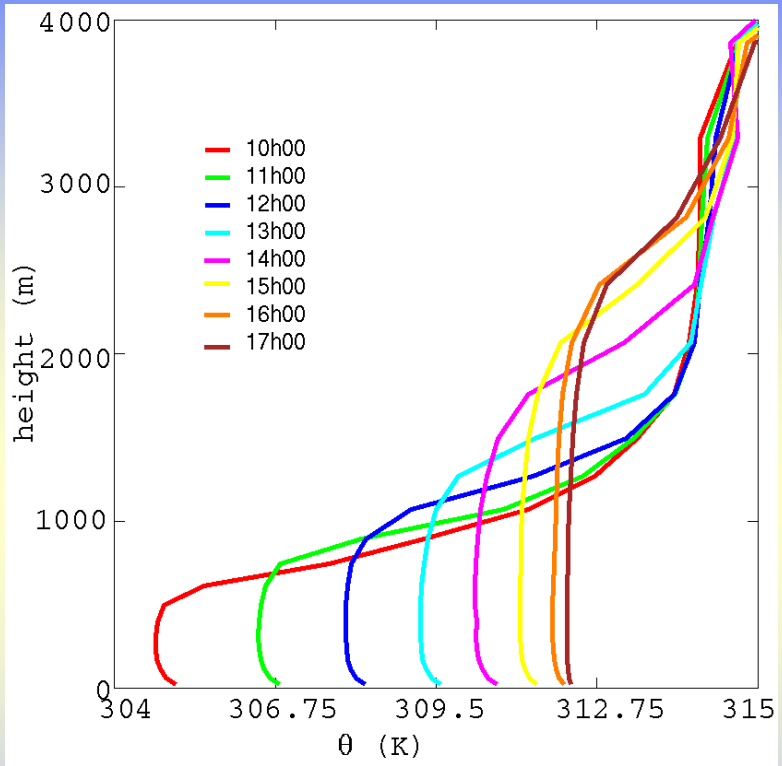
- Sampling rate: 16Hz

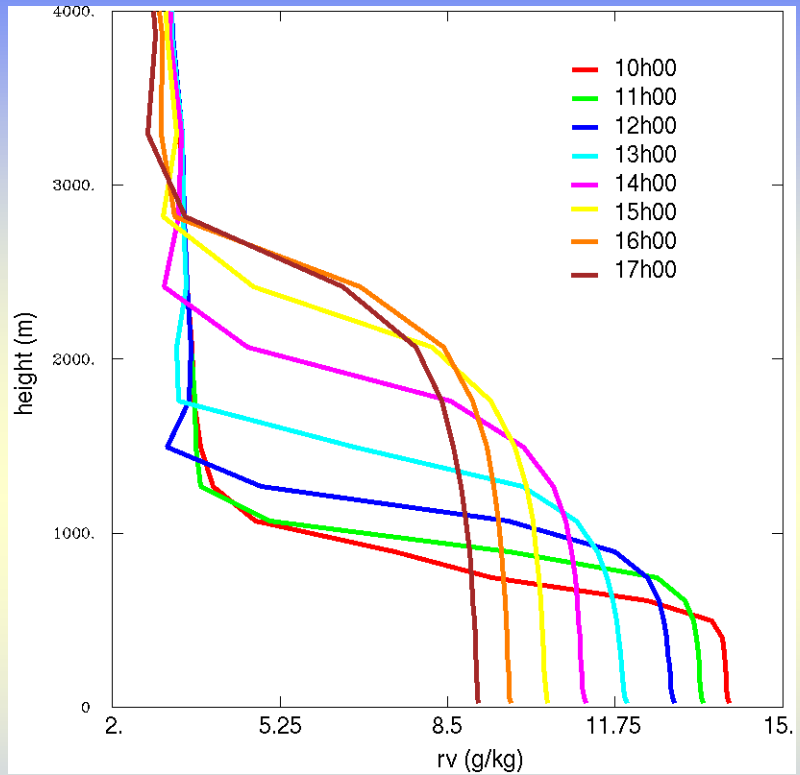
- Stabilized legs divided into twenty-four 30-km segments for turbulence analysis

- high pass filter at ~5 km used to remove the mesoscale trend.



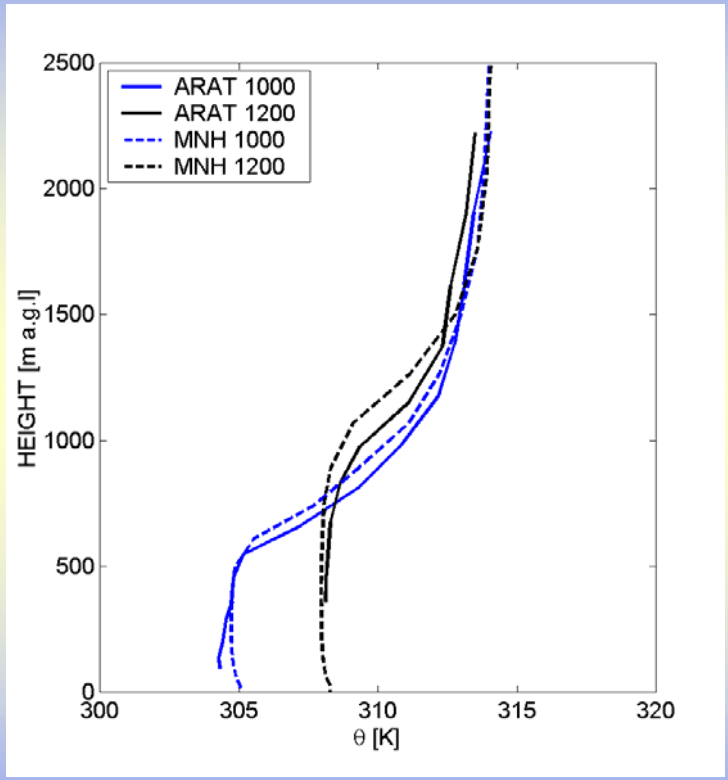
Evolution of the PBL along the day

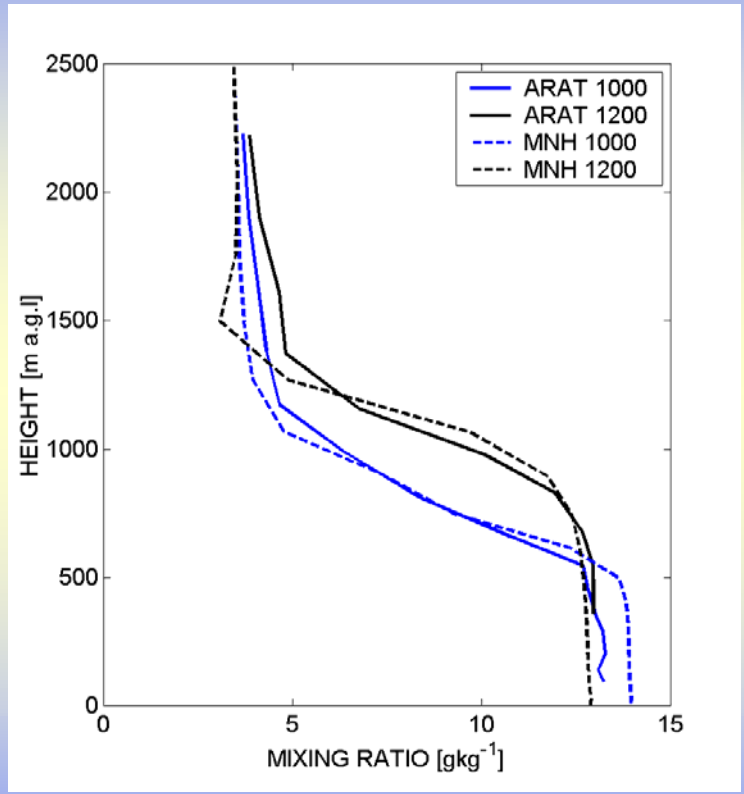




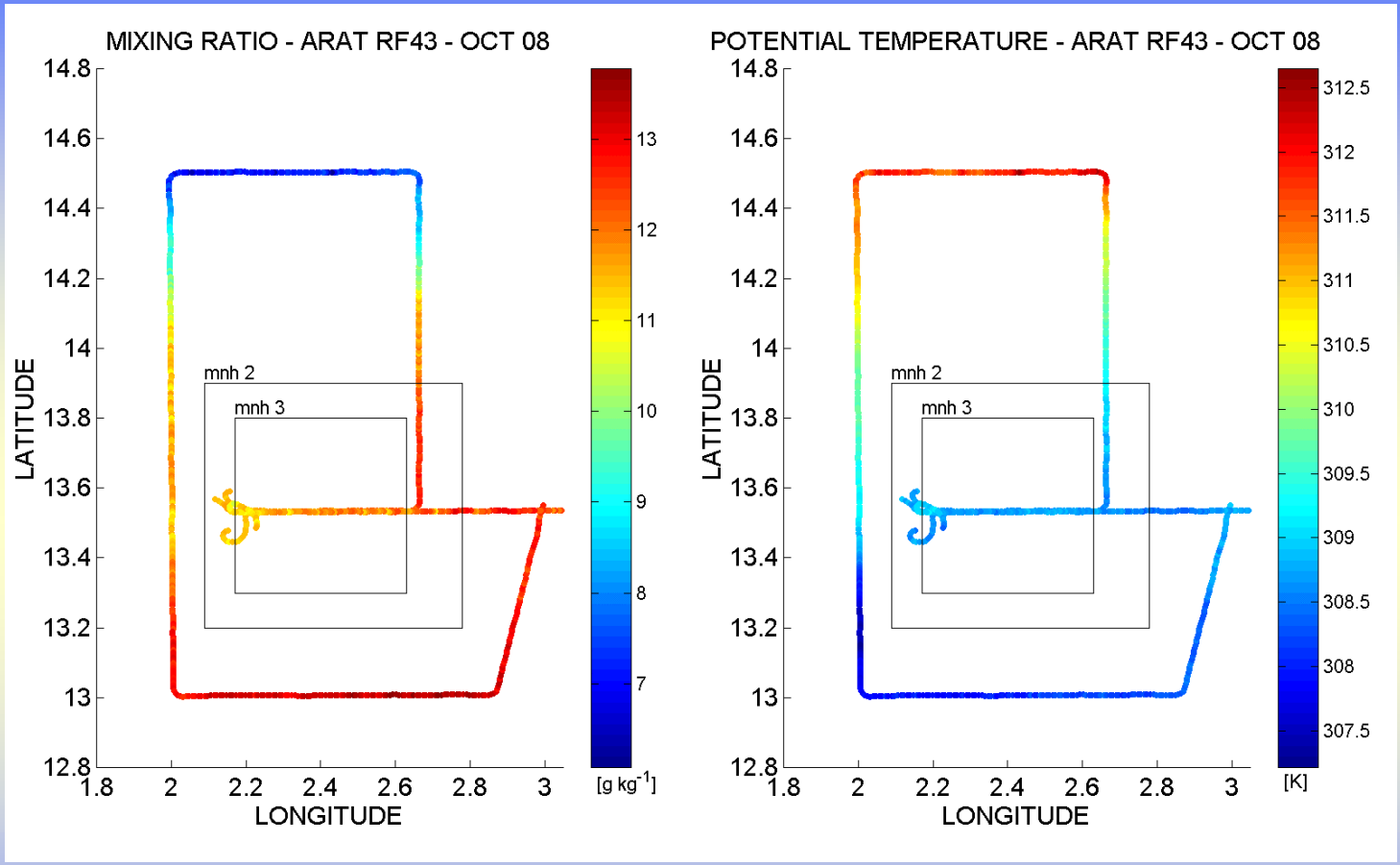
PBL growth: 400 m at 900 UTC to 2400 m at 1700 UTC.
Warming: 307 K to 313.5 K
Drying: 14 gkg^{-1} to 8.5 gkg^{-1}
Large gradients at the PBL top: 5 K, 7 gkg^{-1}
Small wind speed: 2 to 5 ms^{-1}
Typical conditions of October = transiton between wet and dry season

Validation : vertical profiles



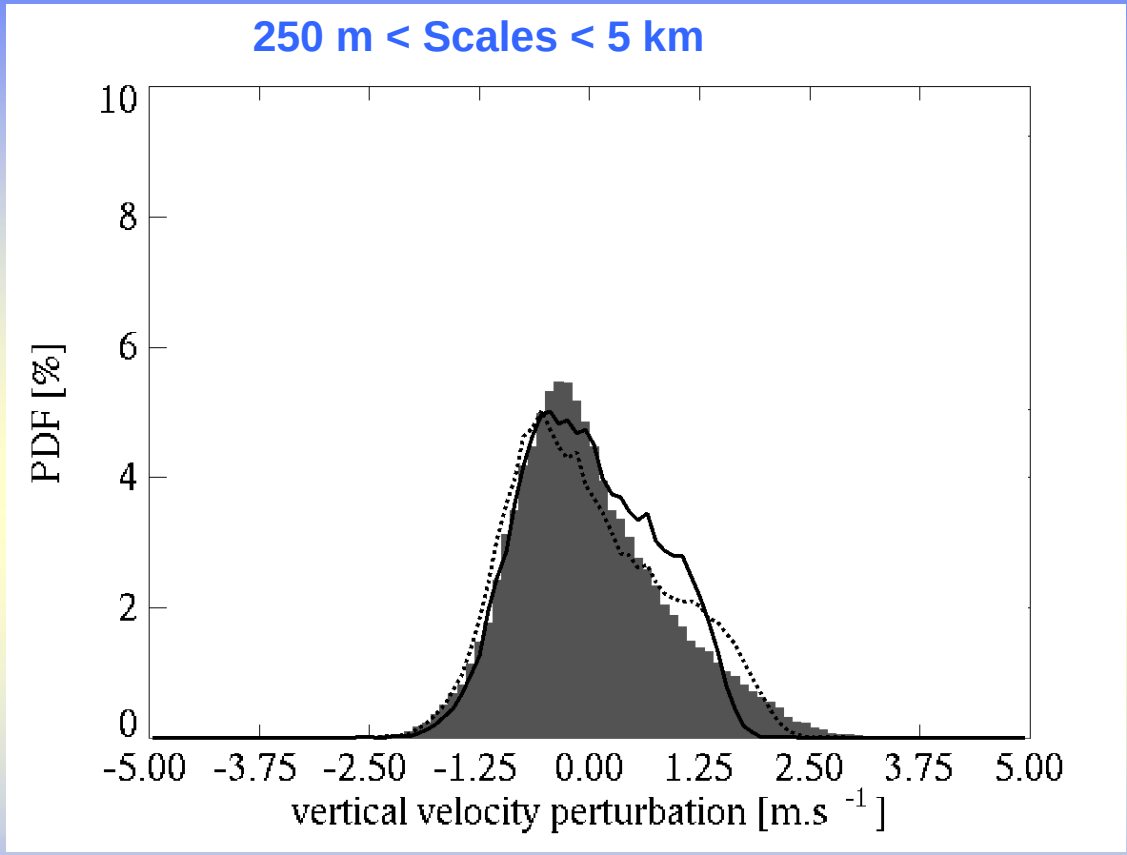


Validation: horizontal and temporal gradient



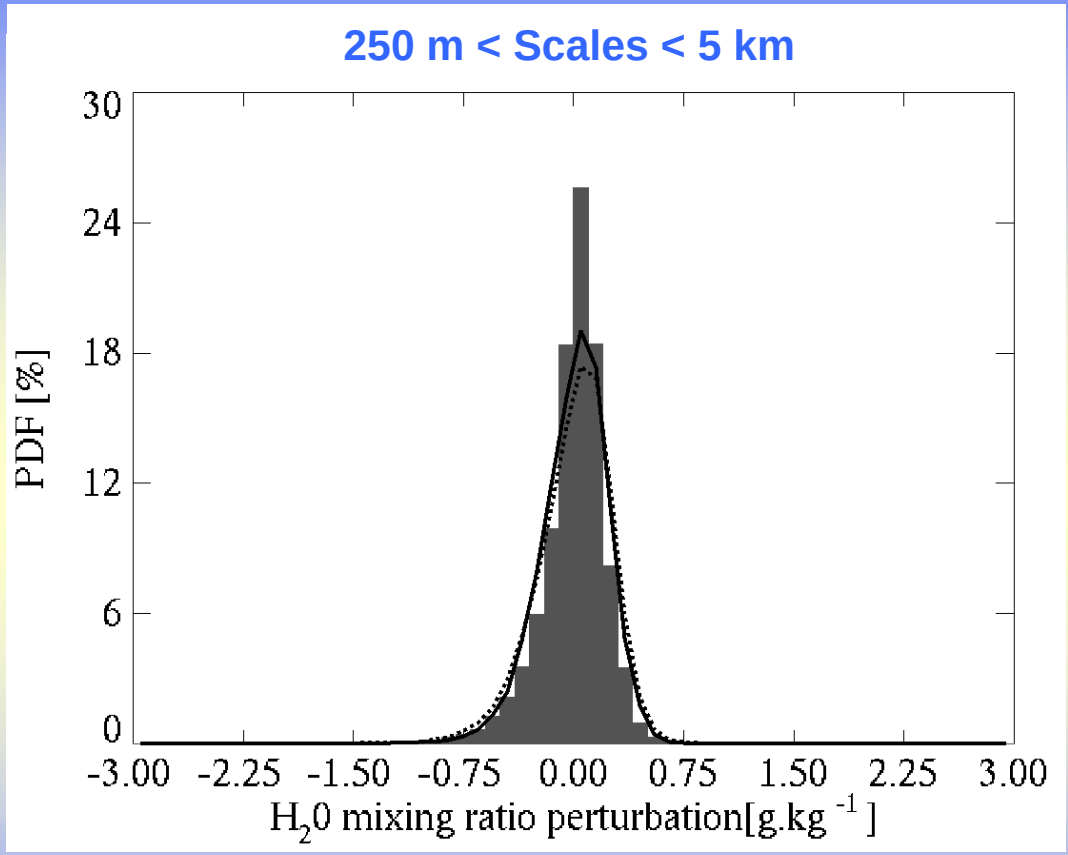
ARAT	MNH
2.7K per 200km (along Y-axis)	1.5 K per 200 km (along Y-axis)
-5.5 gkg^{-1} per 200 km (along Y-axis)	-4.6 gkg^{-1} per 200 km (along Y-axis)
1.5°C/h	1.8°C/h
-0.6 gkg^{-1}/h	-0.5 gkg^{-1}/h

Validation : distribution of the variables



ARAT	MNH
$0.40 < \sigma^2_w < 1.25$ m^2s^{-2}	$0.41 < \sigma^2_w < 1.22$ m^2s^{-2}
$0.08 < S_w < 1.12$	$-0.11 < S_w < 0.62$

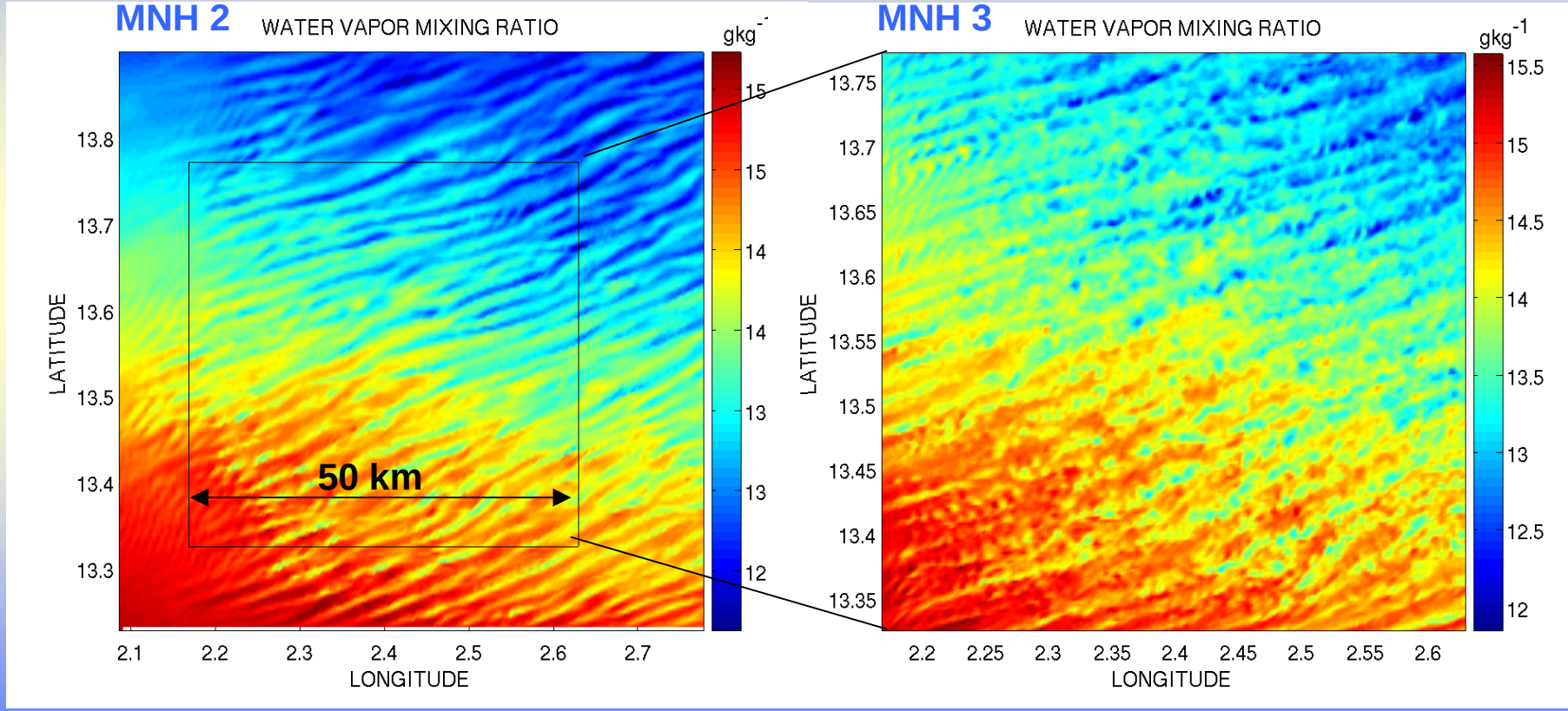
Validation : distribution of the variables



ARAT	MNH
$0.0142 < \sigma^2_q < 0.1498$ g^2kg^{-2}	$0.032 < \sigma^2_q < 0.1470$ g^2kg^{-2}
$-1.60 < Sq < -0.53$	$-0.69 < Sq < -0.53$

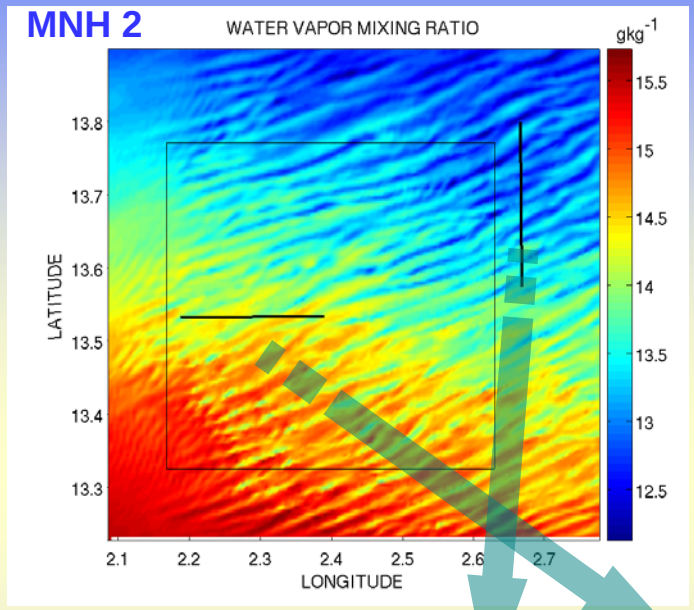
Persistent characteristic of the PBL during HAPEX: Negative skewness

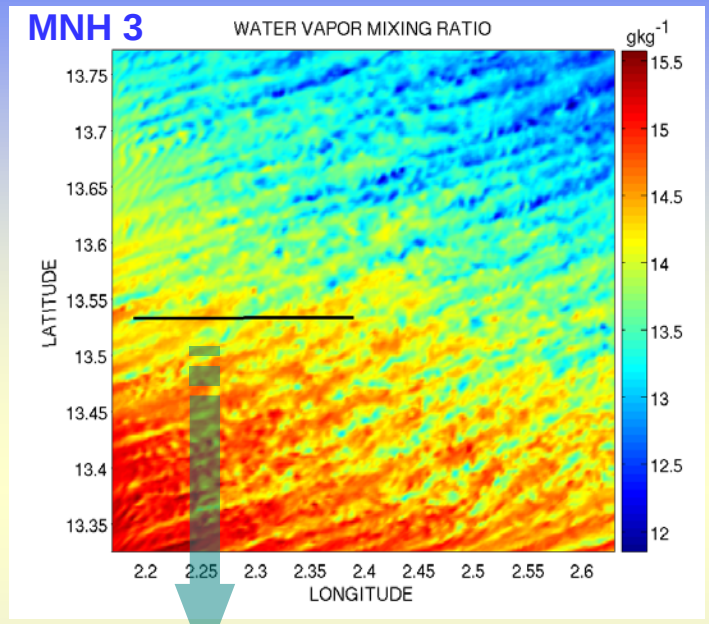
Structures: evidence

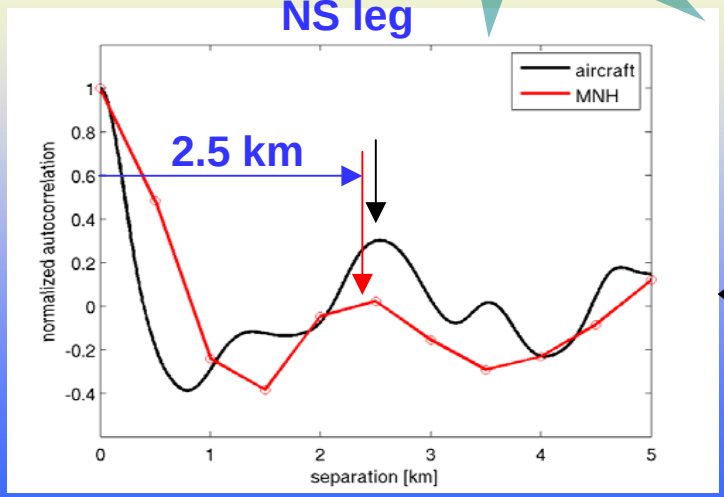


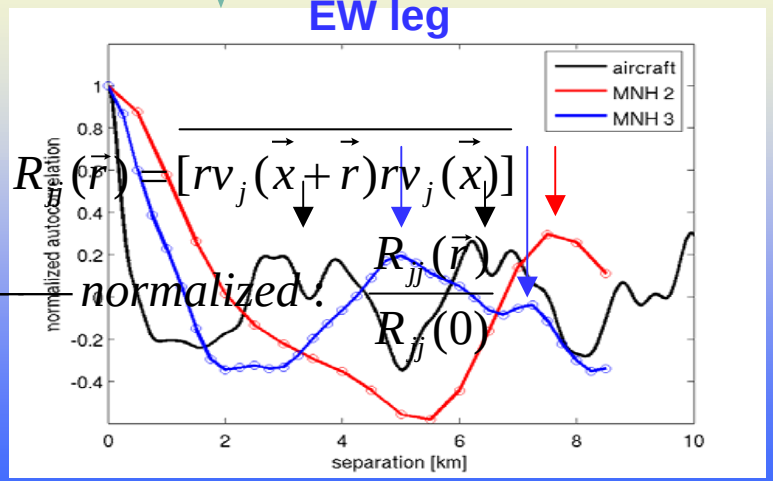
75 km

Structures: evidence





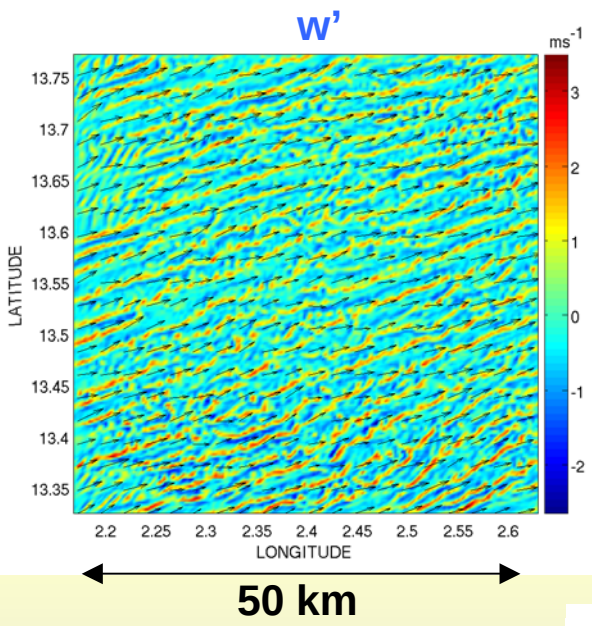


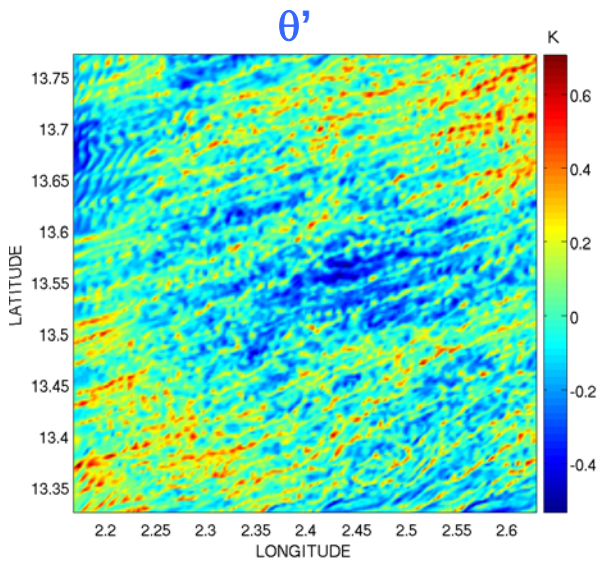


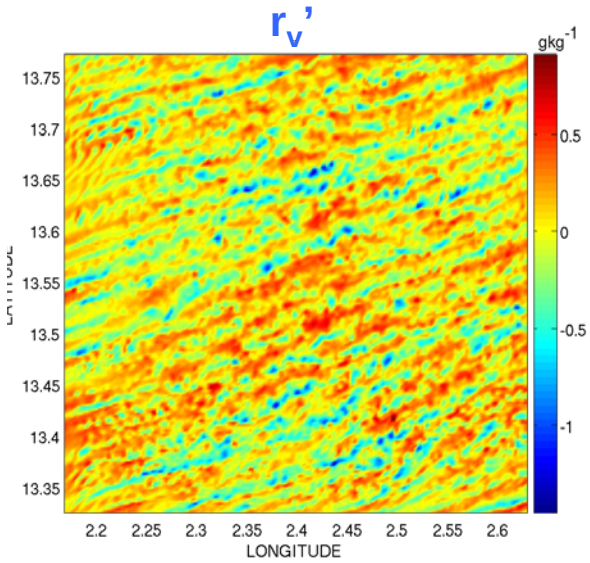
$$R_{jj}(\vec{r}) = \overline{[rv_j(\vec{x}+\vec{r})rv_j(\vec{x})]}$$

normalized: $\dfrac{R_{jj}(\vec{r})}{R_{jj}(0)}$

Structures: evidence - role

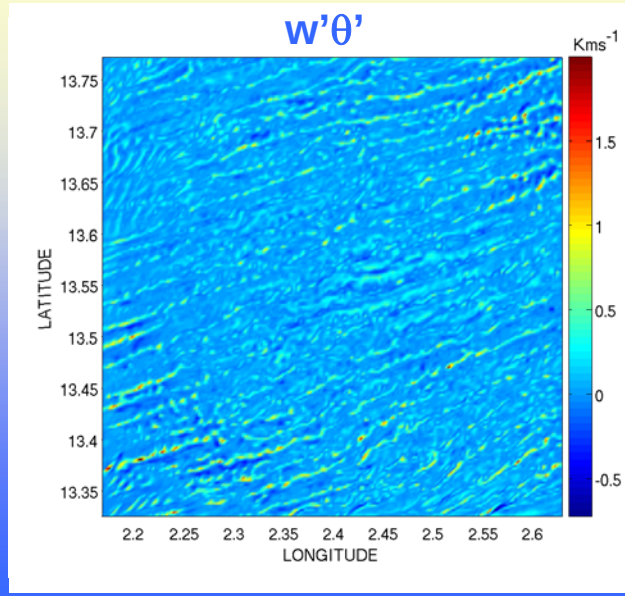


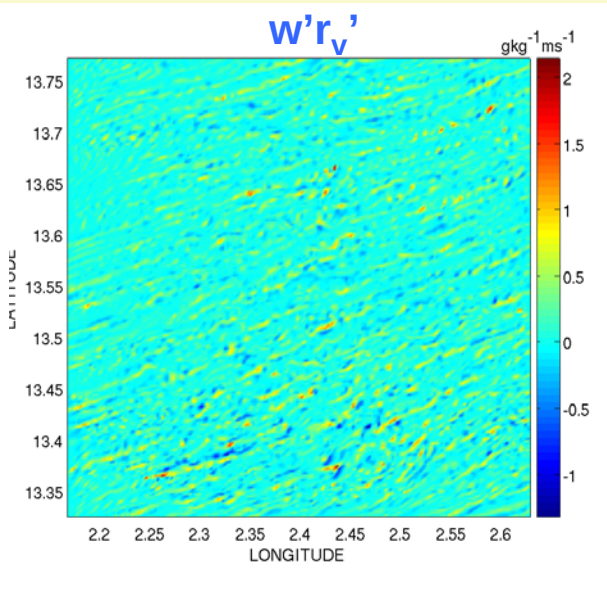




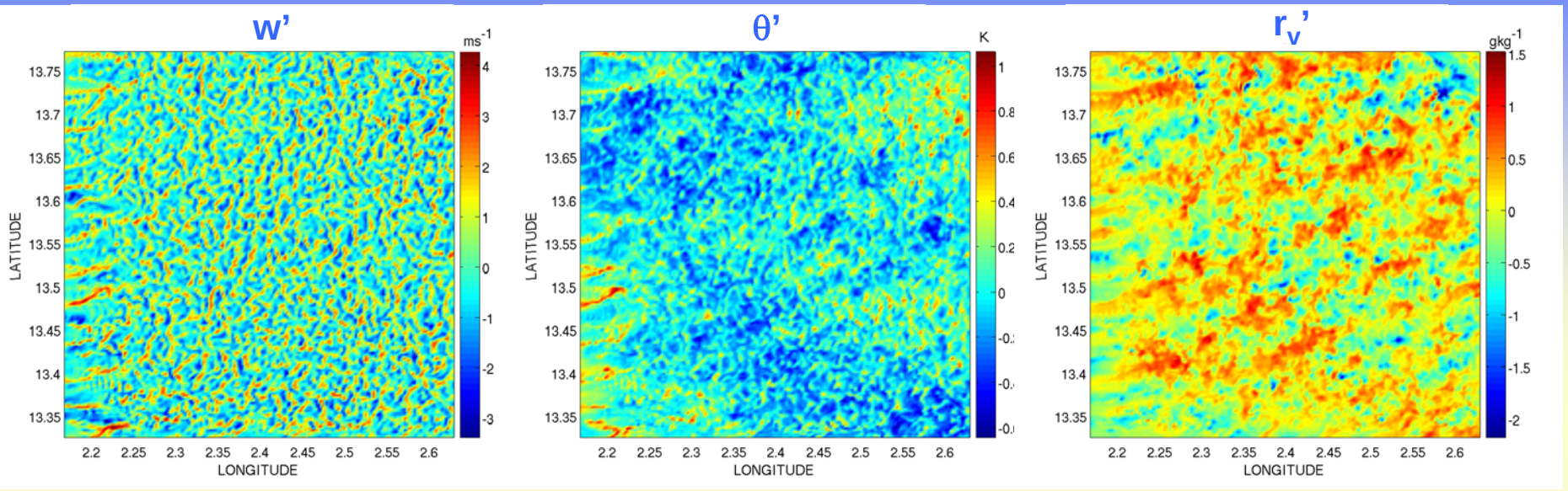
1000 UTC

300 m a.g.l



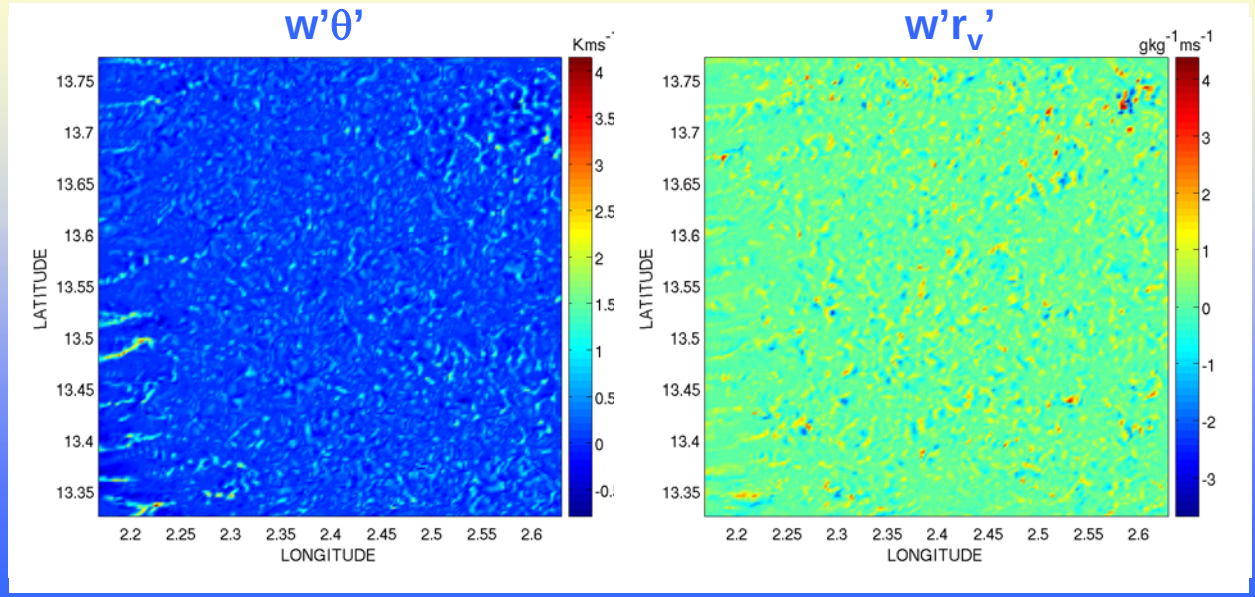


Structures: role / evolution

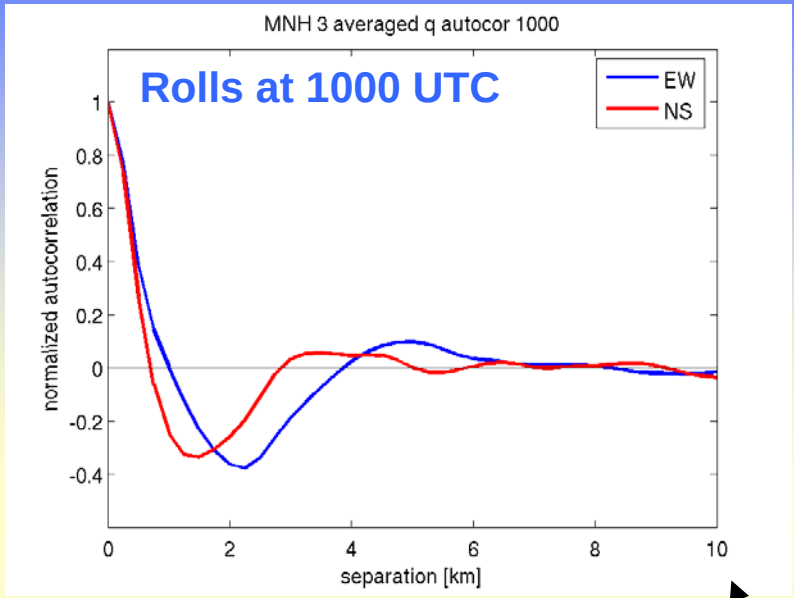


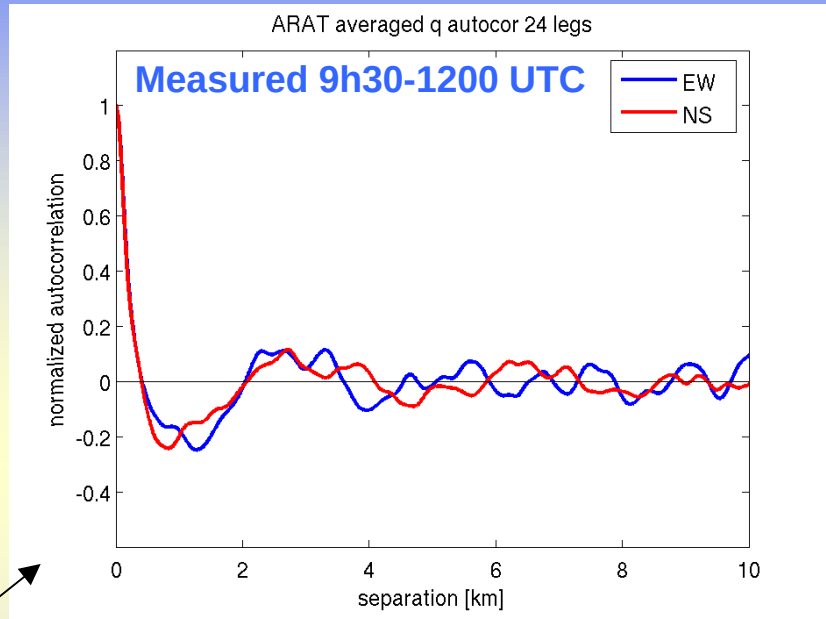
1200 UTC

300 m a.g.l.

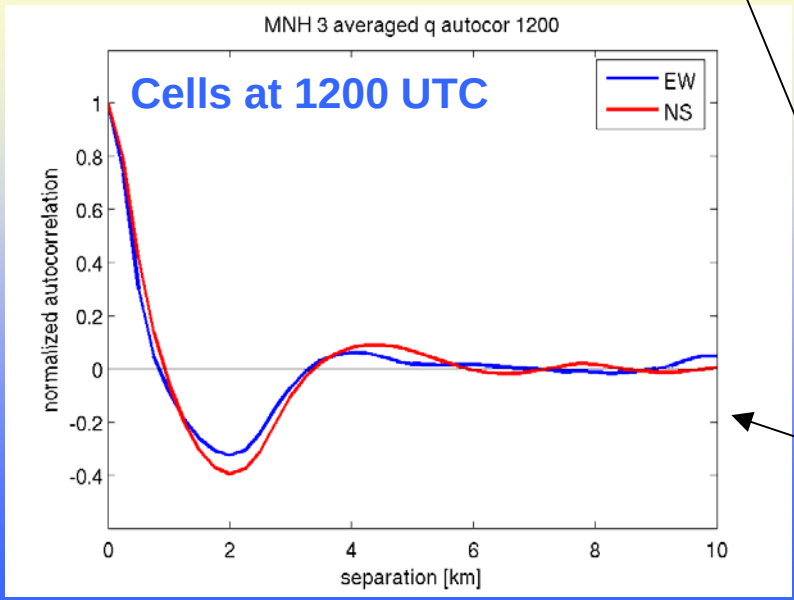


Structures: evolution



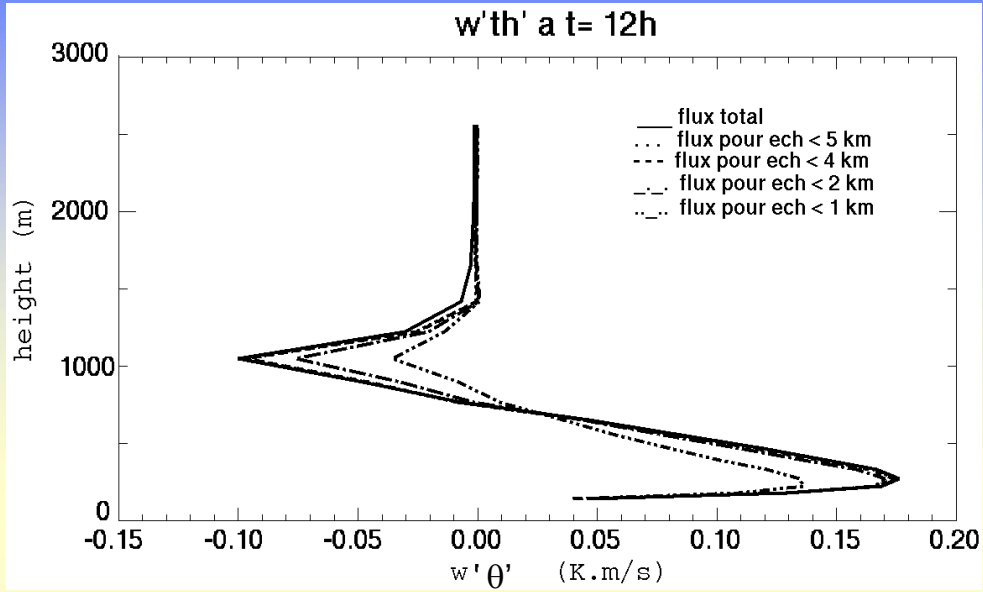


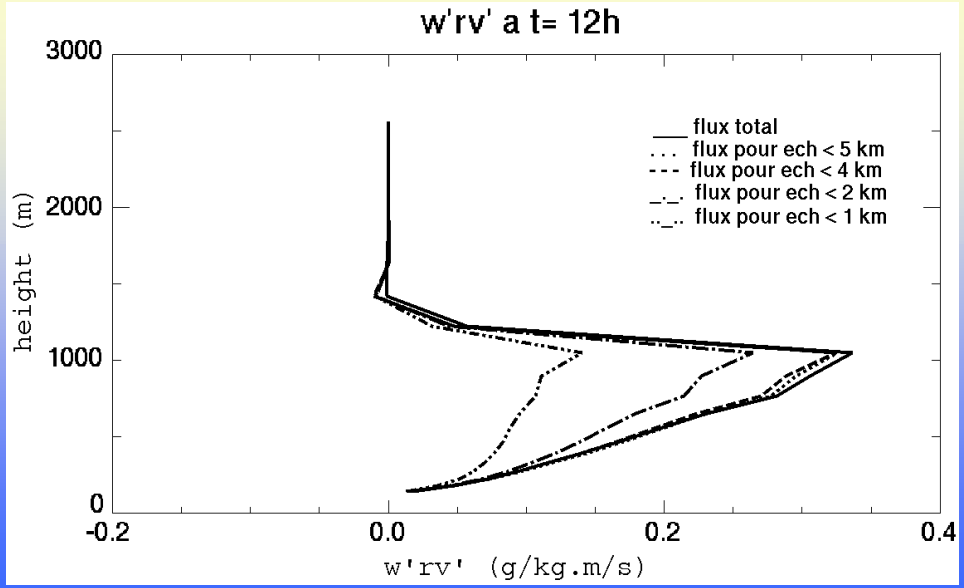
Averaged over the all 24 legs of ARAT aircraft, flown beteween 9h30 and 1200 UTC



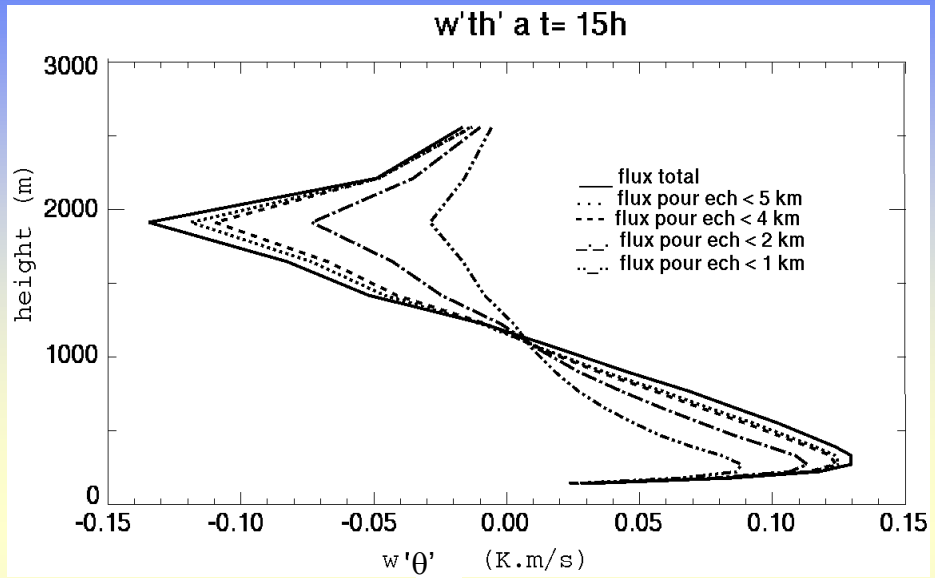
Averaged over the entire 2D field at 300 m of model 3, at two different times.

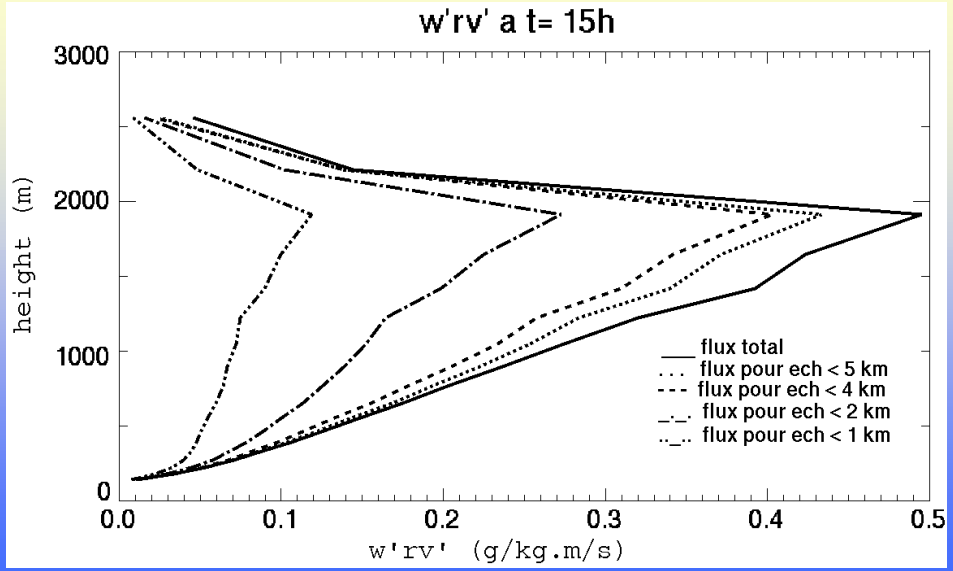
Structures: role





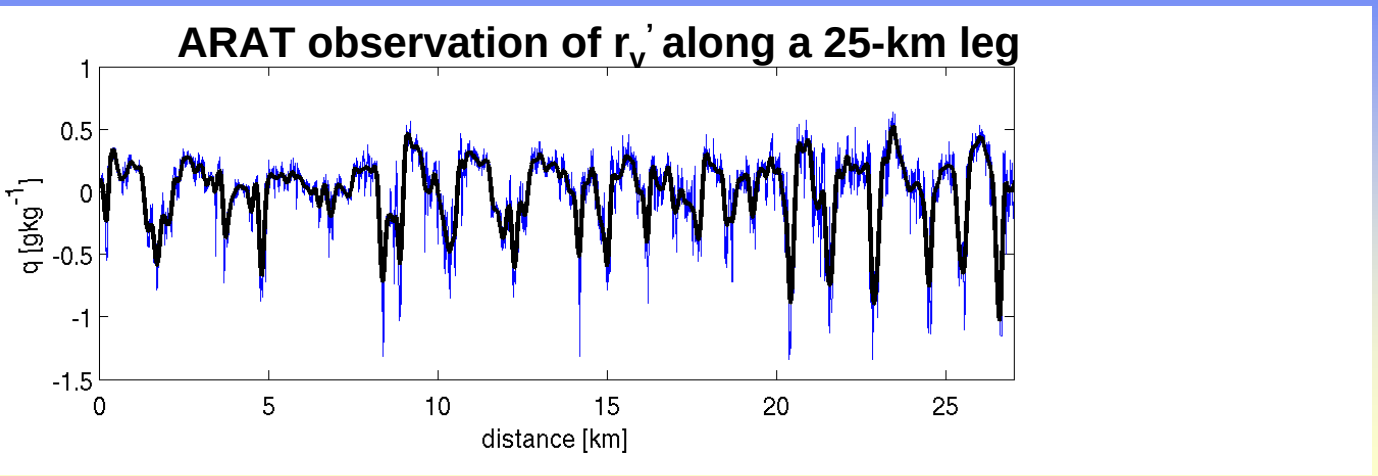
Structures: role

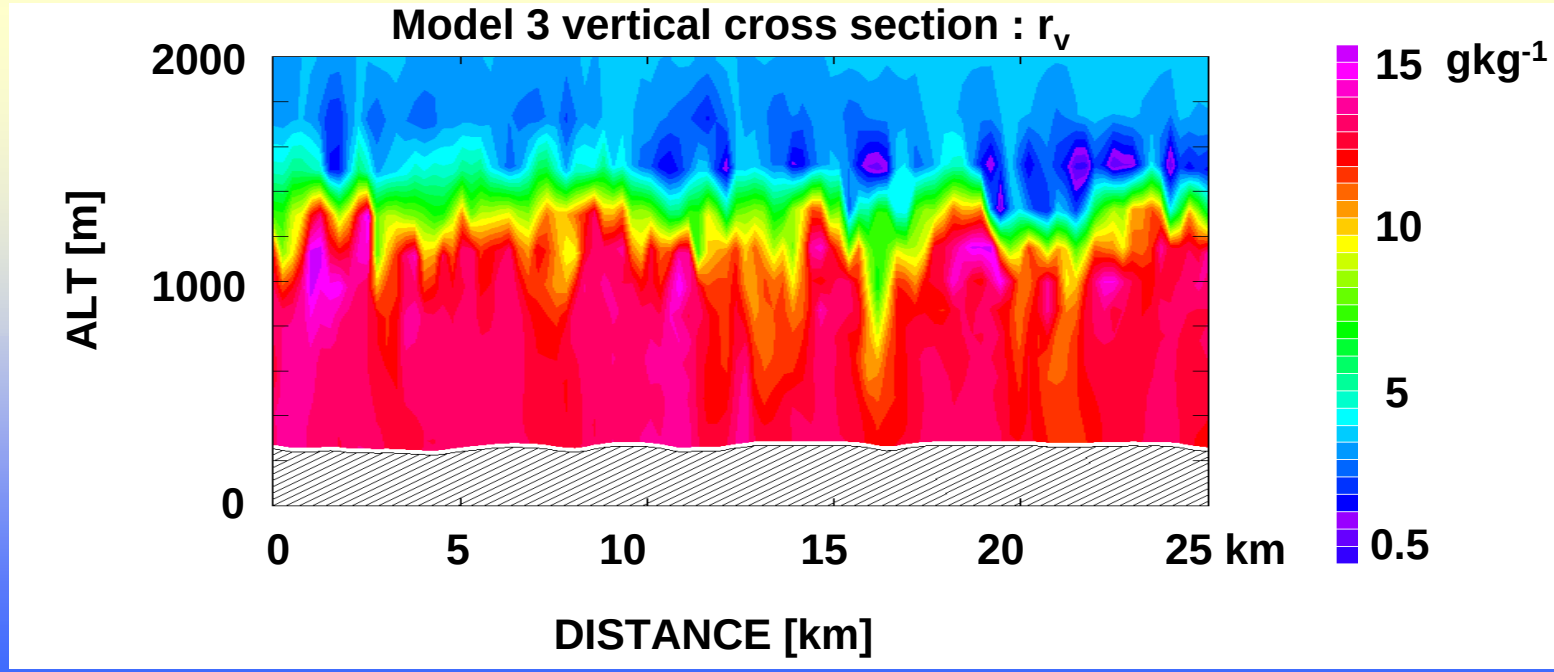




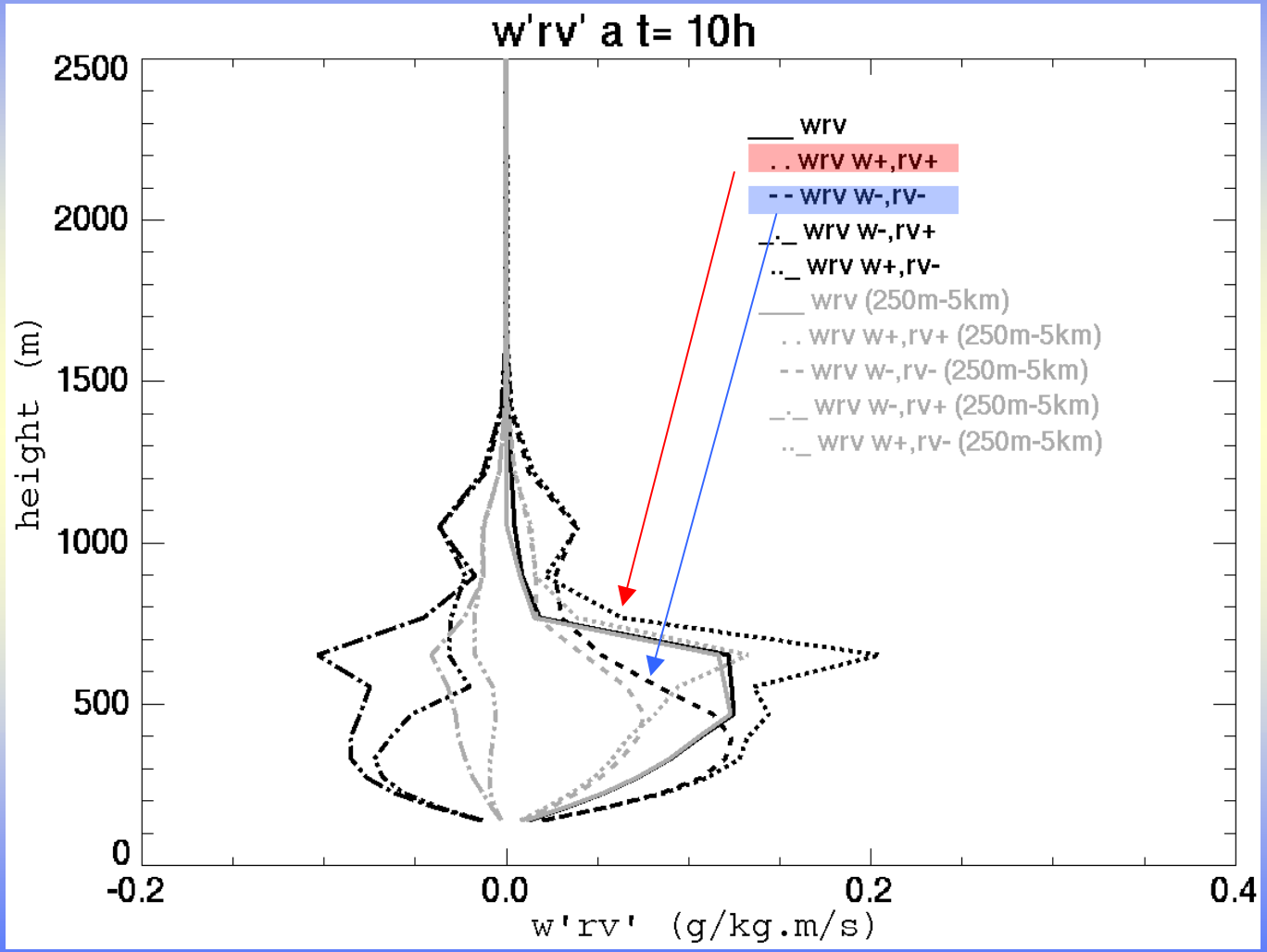
Significant contribution of scales ranging from 1 to 4 km

Dry intrusions: evidence



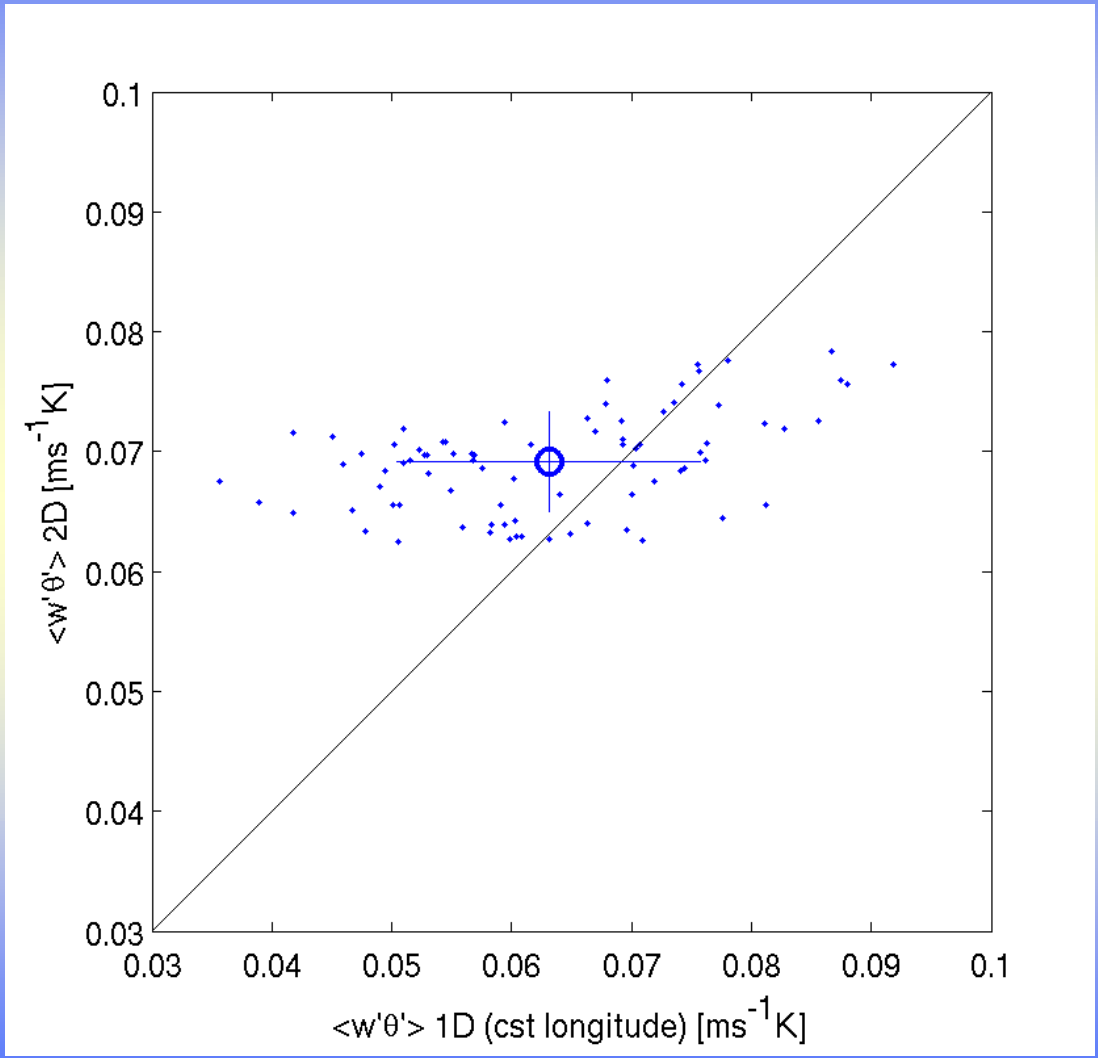


Dry intrusions: role



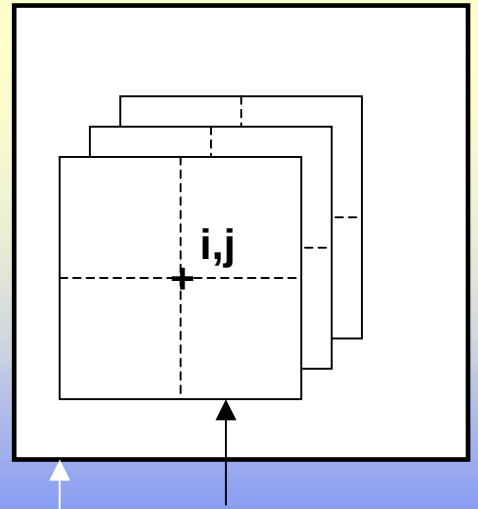
Significant contribution of ‘dry intrusion’ relative to ‘thermals’

A line measurement in a 2D field



Random error 3 times larger in 1D than in 2D

Possible bias (10% here) but not systematic



30x30 km domain at 300 m

model 3 domain

Conclusions and prospectives

Several explanations that work together:

- **Scale of structures large for the sampling method, given the hypothesis necessary for the calculation of the turbulent fluxes**
- **Dry intrusions are another source of heterogeneity**

Some important results about the PBL processes:

- **Coherent structures and dry intrusions contribute significantly to the total fluxes**
- **But respective contribution impossible here to estimate, because scales smaller than 250 m are important for fluxes and not considered here.**
- **Observed skewness of water mixing ratio is due to dry intrusion and directly linked to entrainment.**

Conclusions and prospectives

Next step:

- **LES study is required to go further in the study. Limitation: high resolution will be gained at the expense of the mesoscale structure. Ongoing work using a LES simulation of a case of IHOP (F. Couvreux).**
- **Spectral analysis of the different contributions in fluxes (thermals, dry intrusions…)**
- **More about 1D versus 2D approaches**

Notes for AMMA:

- **2D and 3D exploration with lidars and radars along with 3D numerical simulation will be necessary to complement the aircraft 1D measurements in organized PBL.**
- **Important coupled role of dry intrusion / entrainment / organized structures / shear between Monsoon and Harmattan to be explored and better understood**
- **$\Rightarrow$ Relevance of vertical exploration coupled with remote sensing observations**

('ITF exploration' flight plan) .