Impact of atmospheric turbulence on the accuracy of LST measurements

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IMPACT OF ATMOSPHERIC TURBULENCE ON THE ACCURACY OF LST MEASUREMENTS

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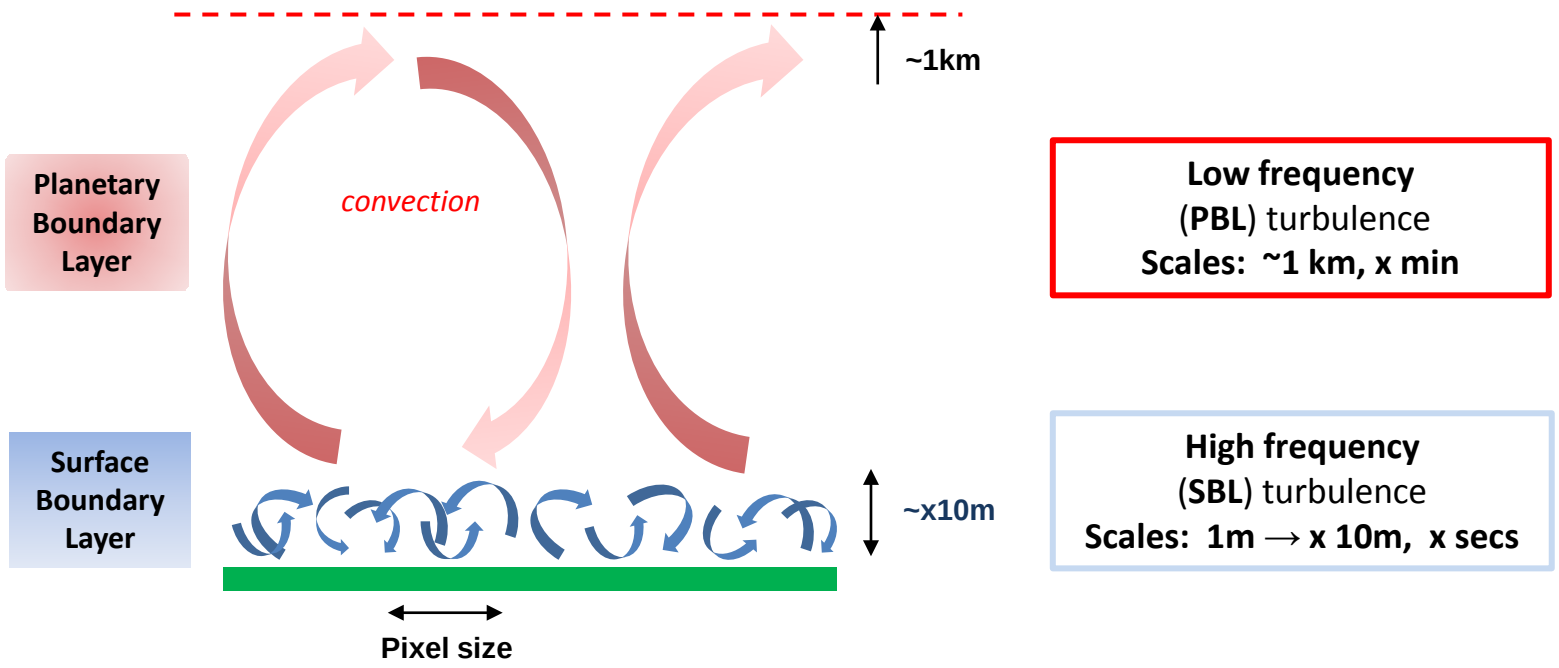
Land Surface Temperature and Atmospheric Turbulence



- **LST is governed by surface energy budget and displays temporal fluctuations generated by both SBL and PBL turbulence**

- **What do a instantaneous satellite measurement mean?**

At high resolution ? for designing new missions in the TIR such as MISTIGRI, Hyspiri, THIRSTY…

At moderate resolution ? MODIS, VIIRS…

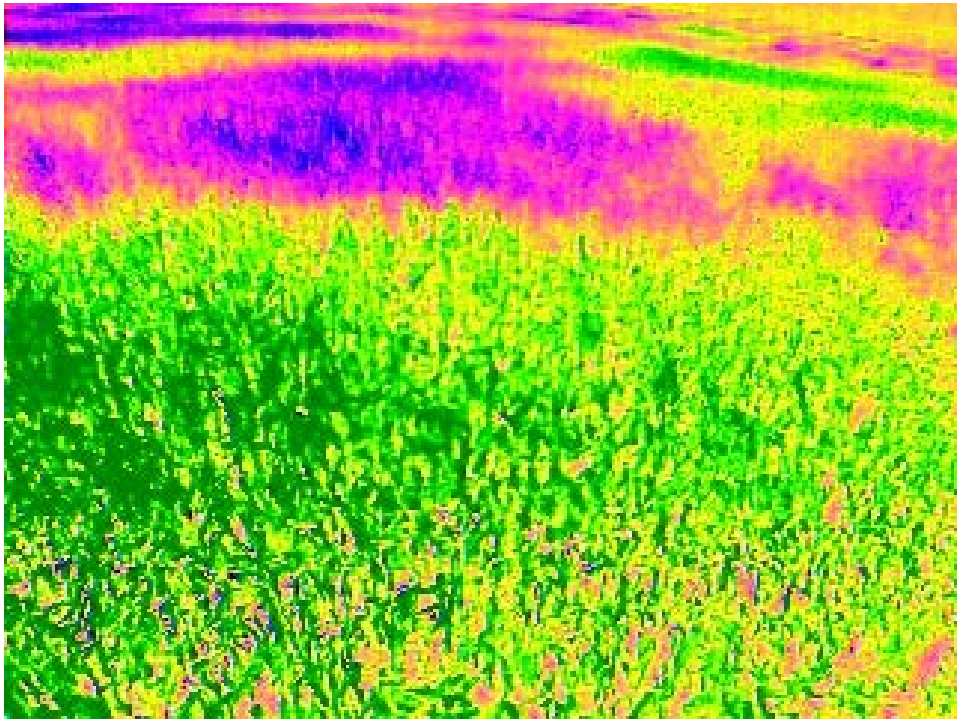
Land Surface Temperature and Atmospheric Turbulence

Mechanical interactions between the surface and atmosphere are well known….

Land Surface Temperature and Atmospheric Turbulence

Bilos 44° 30' 03''N
0° 57' 20''W
SW France

…but they also exist in the thermal domain



- **TIR camera A40-M FLIR**
- **80° x 64.4° wide FOV**
- **Incl. ~60°/nadir**
- **NeDT 0.08 K at 30°C**
- **Acquisition: 12.5 Hz, 18mn**

- **3D Young 81000V sonic anemometer**

Analysis of LST fluctuations : methodology

2 approaches followed:

Experimental

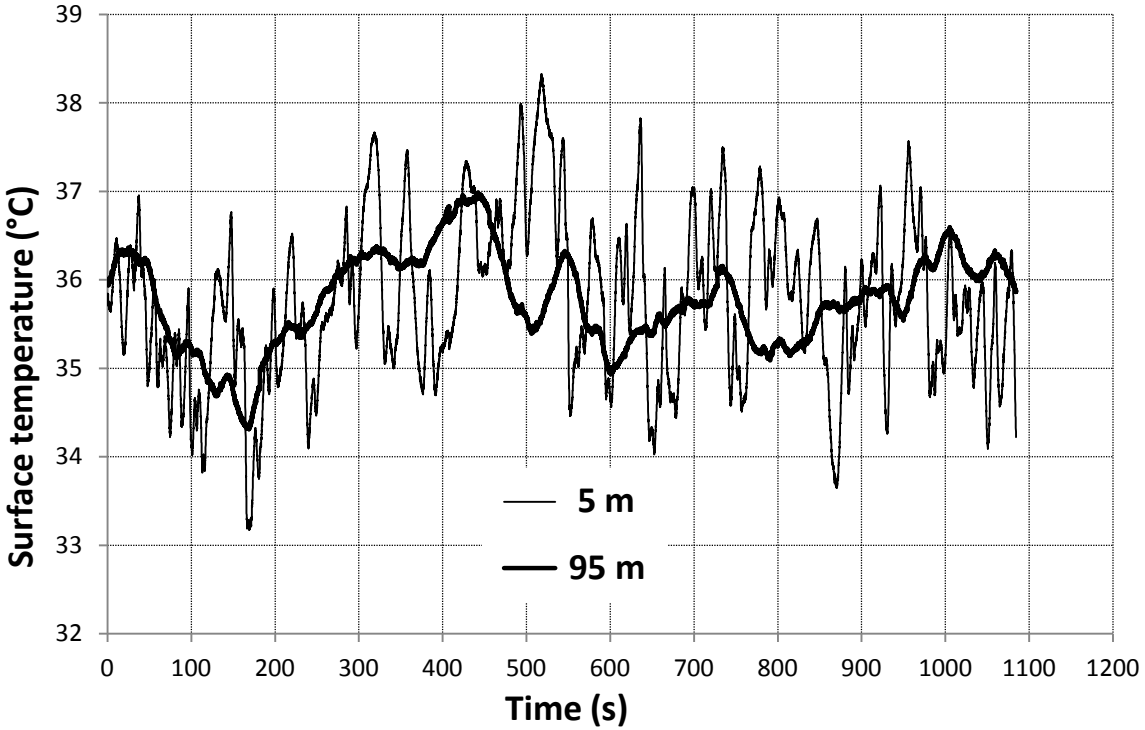
- Acquisition of high frequency time series at high spatial resolution from TIR cameras placed on masts or helicopter-borne
- Working with **brightness** surface temperatures
- Geometric rectifications to superpose all images (with helicopter) → stacks of TIR images
- Reconstructing time series at different spatial resolution by agregation according to T^4 scheme
- Analysis of temporal fluctuations according to resolution

Modelling

- Use of a Large Eddy Simulation atmospheric model (ARPS) coupled with a SVAT model (MuSiCA)
- Equivalence between LST spatial variability within a domain and temporal variability at a given point within the domain
- Pine canopy

Experimental set-up over agricultural crops

Maize

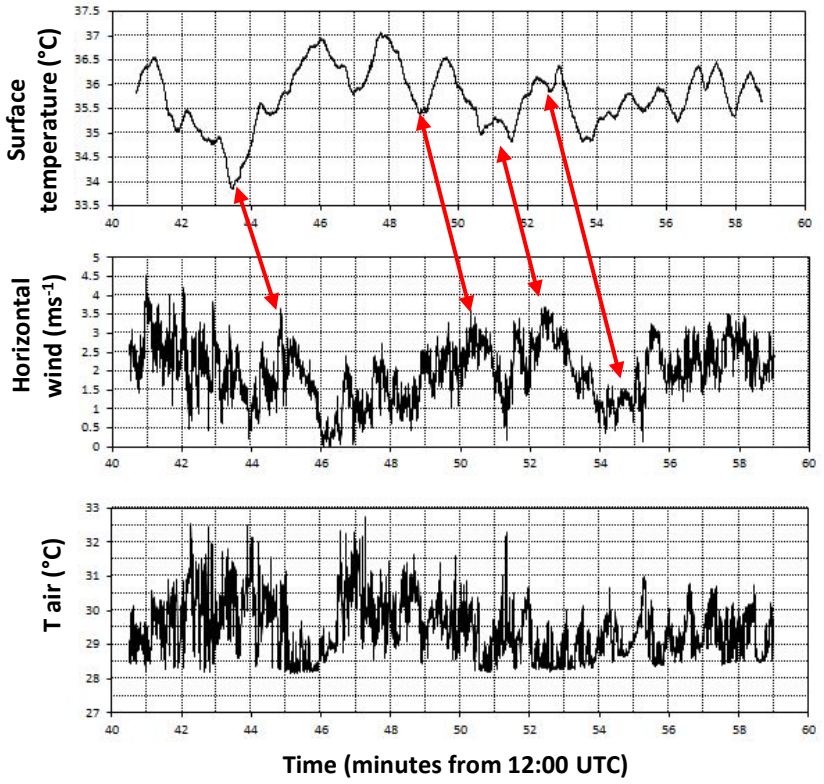


Spatial integration of small-scale fluctuations

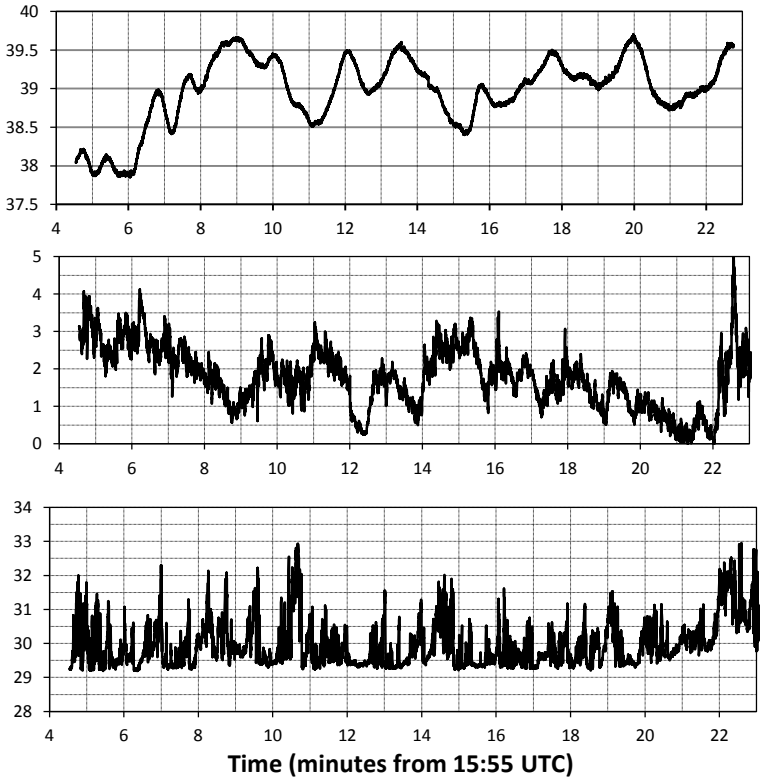
→ The amplitude of the LST temporal fluctuations decreases with spatial resolution

Experimental measurements (agricultural crops): results

Maize (50m aggregation)



Bare soil (50m aggregation)



Analysis of maximum cross correlation coefficient between LST and windspeed
→ **prevailing effect of wind on LST temporal fluctuations**

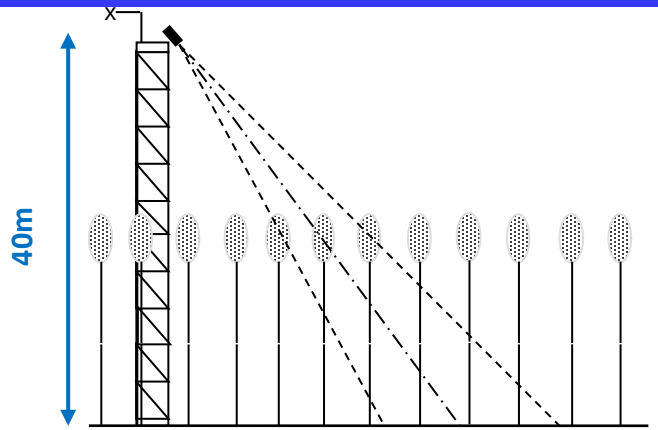
No correlation with air temperature found

Experimental measurements over pine stands

INRA **Le Bray** site 44° 43' 01.50”N
0° 46' 09.00”W

- **Flux tower**
- **Gill R3 3D sonic anemometer**

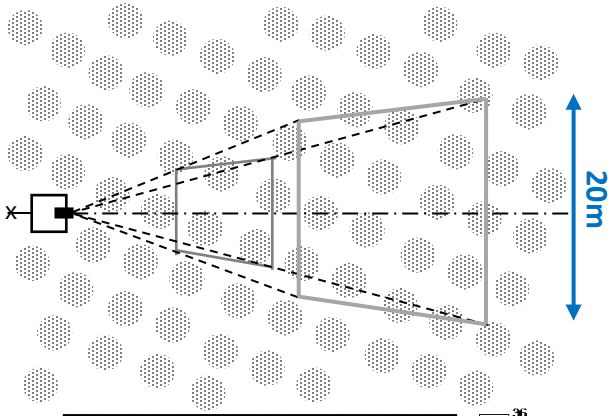
Experimental measurements over pine stands

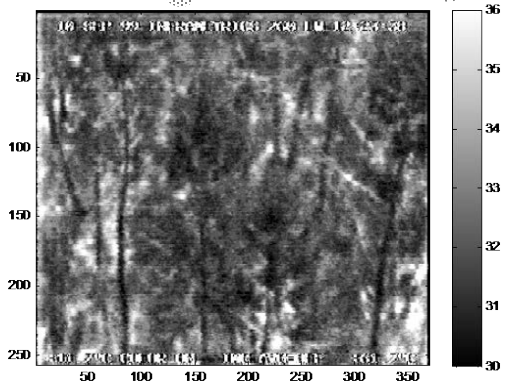


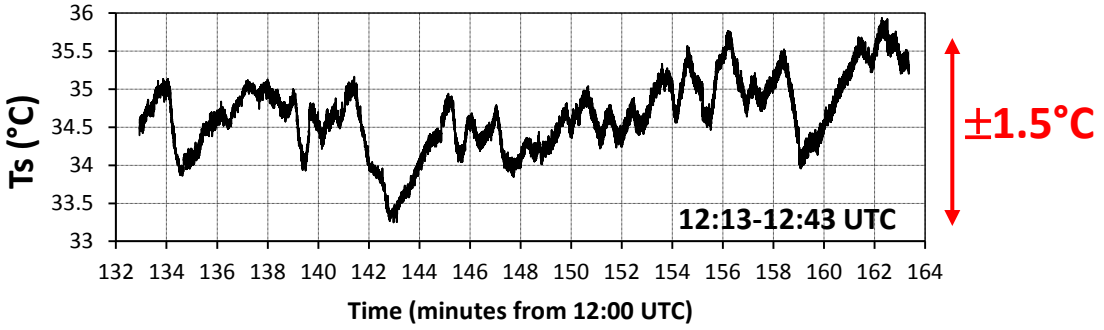
- Sept. 10, 1999
- Inframetrics M760
- 17 x 22° FOV
- NeDT < 0.2°C

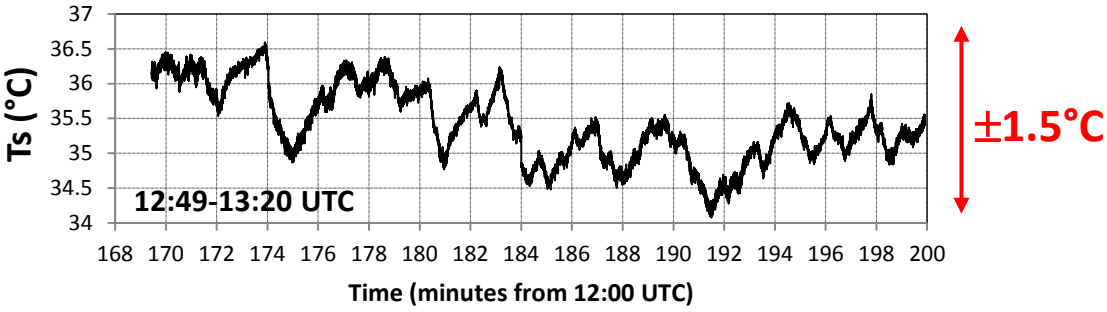
- 2 acquisitions:
  30mn, 10 Hz
  2 directions (E, S)

Resolution : **~20m**

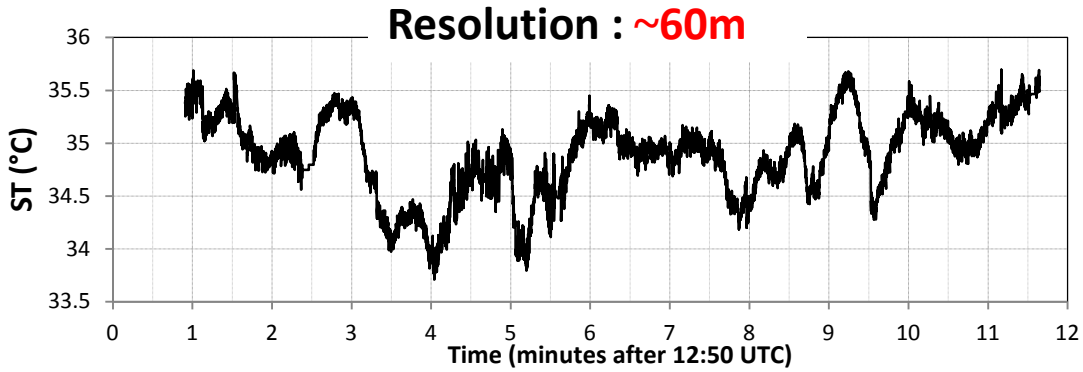


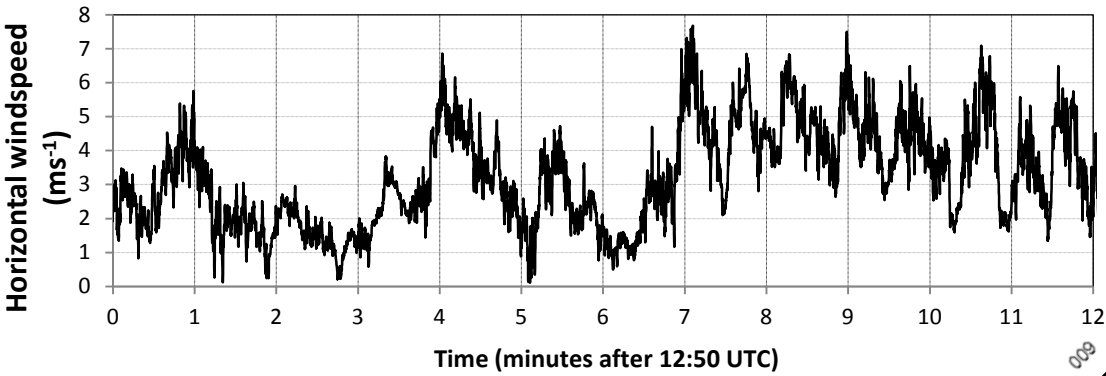


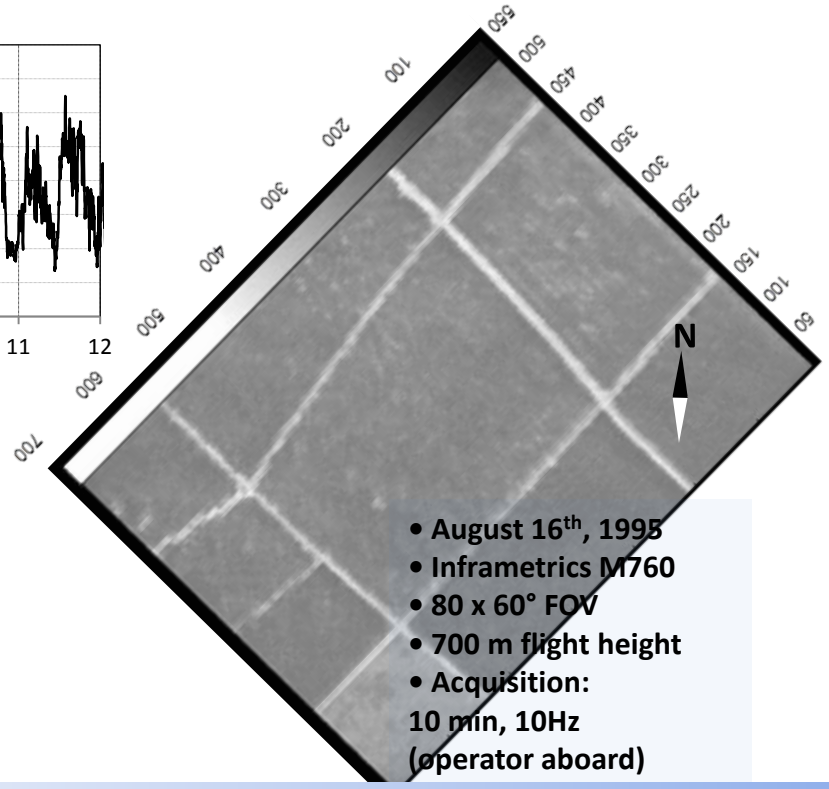




Experimental measurements over pine stands







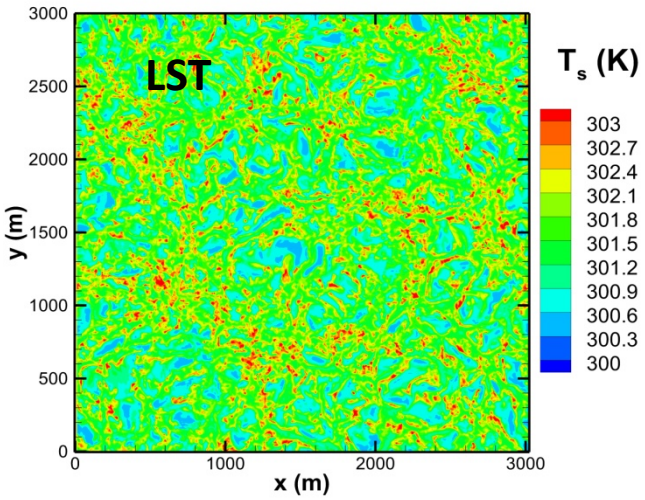
Measurements from helicopter over le Bray (pixel at tower site)

Cross correlation : ~ 6s lag ⇒ ~60m vith u ~3m^{s-1}

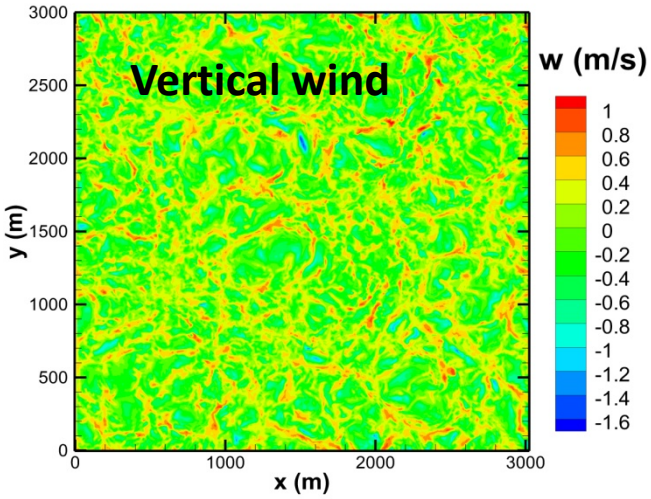
→Wind effect confirmed

LES simulation

(a)

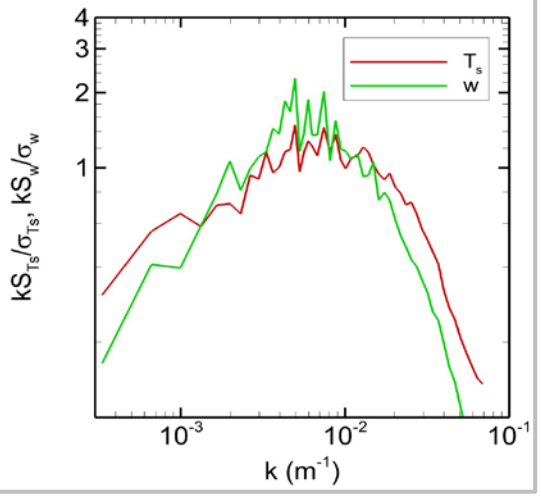


(b)

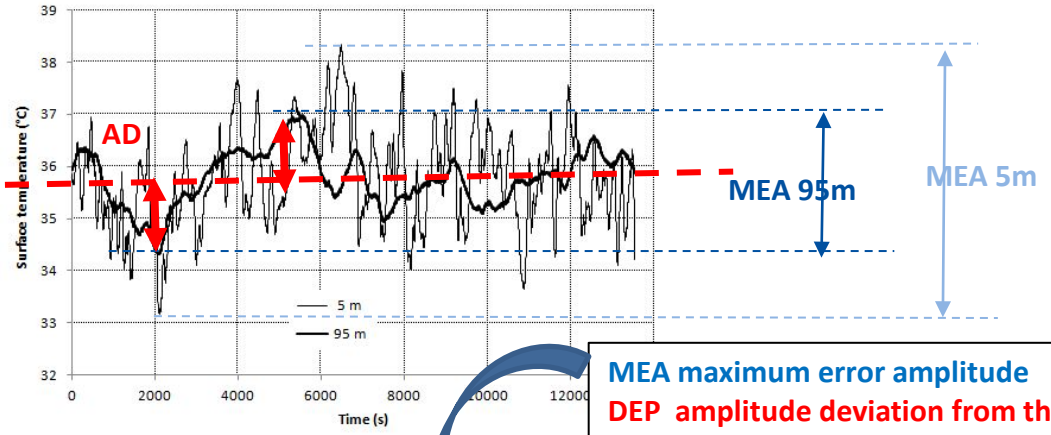


- LES ARPS modem coupled with MuSICA SVAT
- 3000x3000m x 2.5km
- Simulation of a pine stand surface
- Equivalence between temporal fluctuations at a given location and spatial variability within the domain

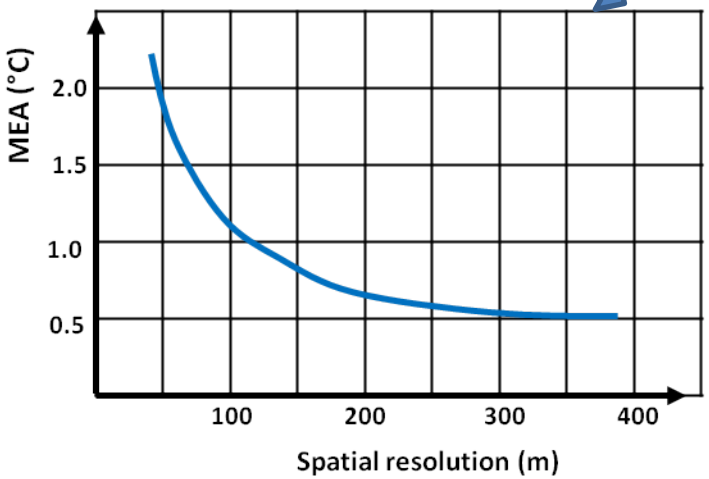
- Spectral analysis confirms the prevailaing effect of wind on LST fluctuations



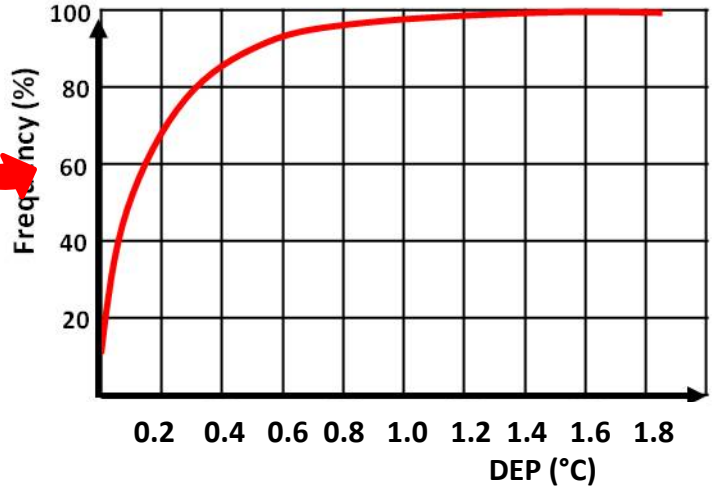
Key interpretation parameters



MEA maximum error amplitude
DEP amplitude deviation from the mean temperature (absolute value)

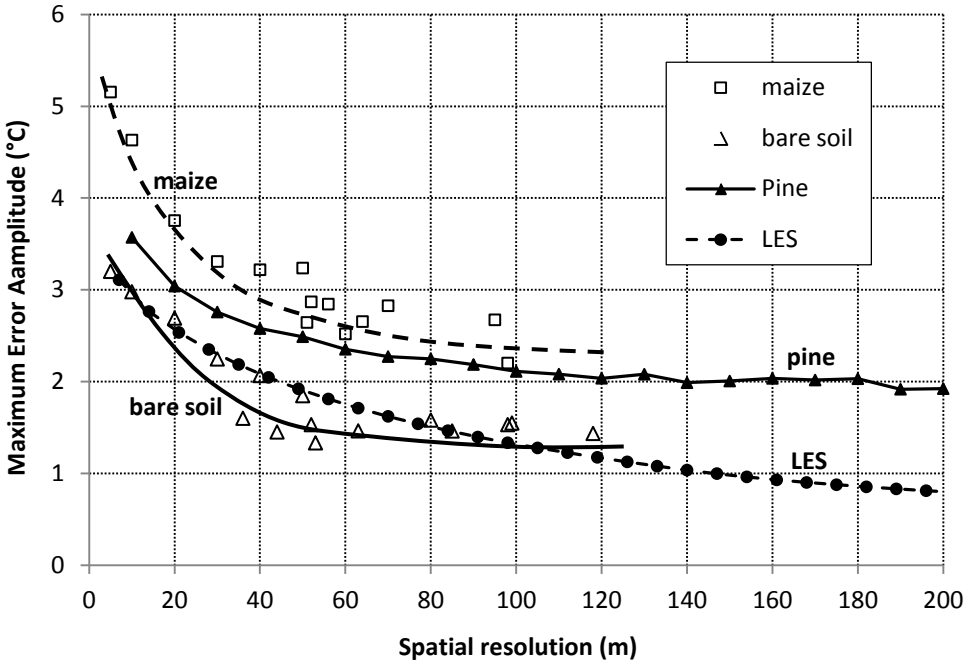


LST amplitude



Statistics of the deviation from mean LST

Results



Decrease of amplitude of fluctuations for high spatial resolutions explained by integration effect of small size SBL eddies over the pixel

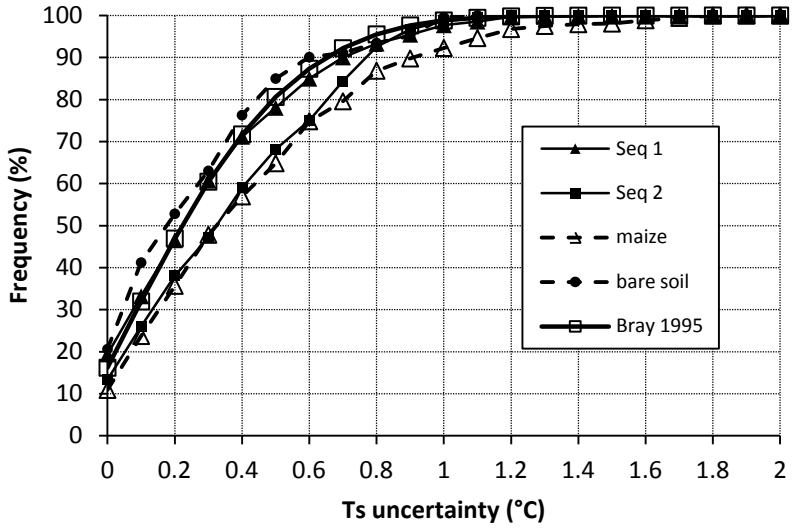
Larger PBL eddies contribute to LST uncertainty for resolutions > 50-100m

Uncertainty :

< ±0.6 °C for ~70% measurements

< ±0.8 °C for ~85% measurements

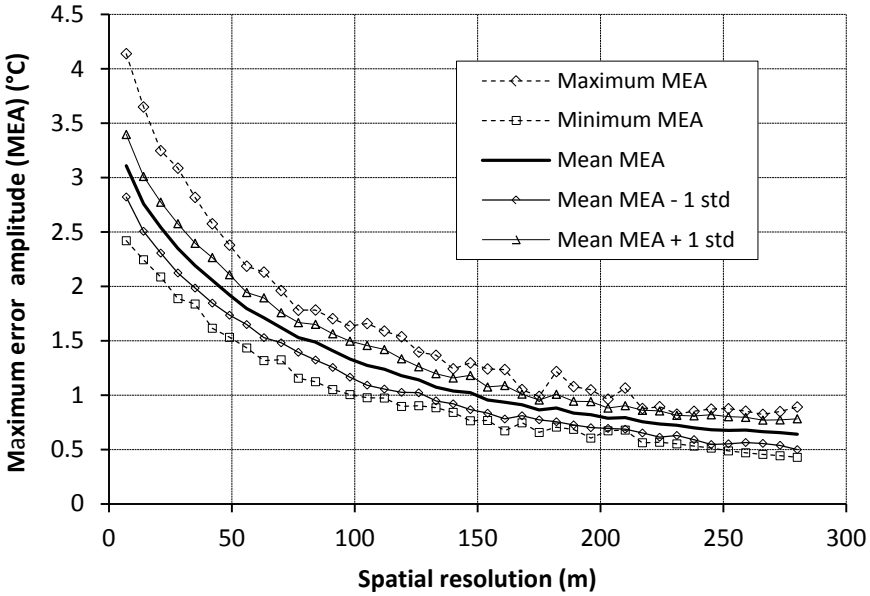
at 50m resolution

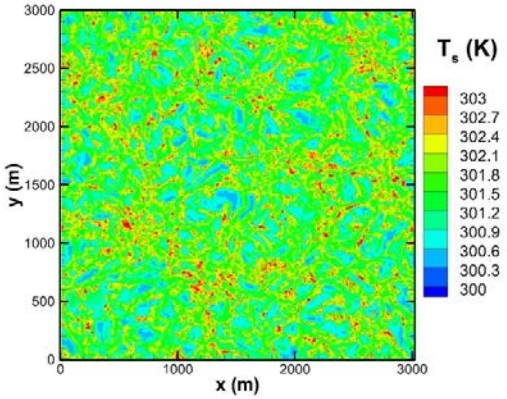


Lagouarde et al., RSE 2013

Lagouarde et al., RSE 2014 submitted

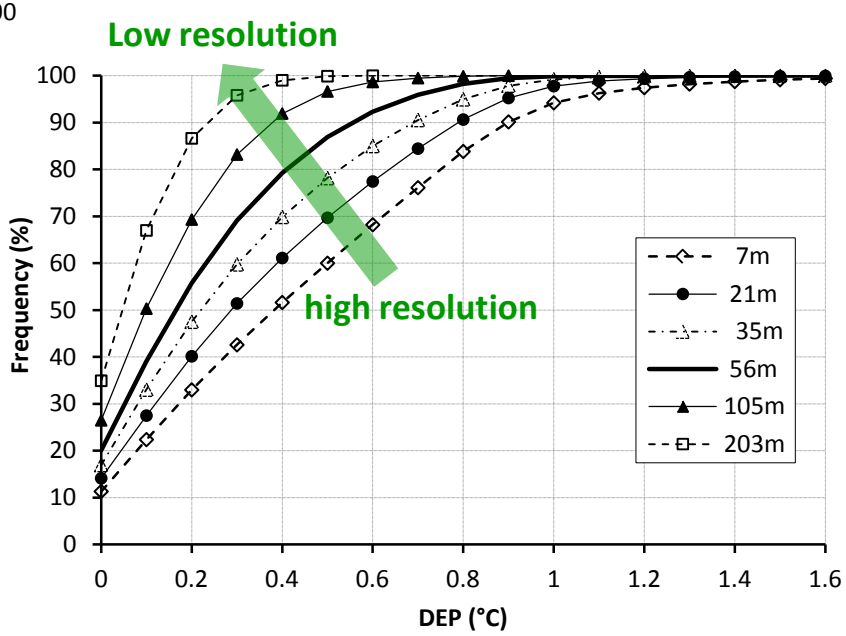
Results





LES simulation confirms experimental results → decrease of MEA with spatial resolution

Impact of spatial resolution on DEP illustrated



Summary of results

- **LST measurements are prone to uncertainties due to atmospheric turbulence.**
- **The uncertainty depends on spatial resolution : high resolution is dramatically affected by SBL turbulence**
- **At 50-60 m resolution, for measurements over vegetation :**

  LST error > ± 0.6K for 20-25%

  LST error > ± 0.8K for 10-15%

- **Generalization to other surfaces and metorological conditions needed**
- **Case of water bodies to be investigated**

Recommandations

For using satellite data…

1. Care must be brought when using satellite data in combination with SVAT models (which generally have 30 mn to 1 hour time steps)

2. Uncertainty both on satellite data and ground measurements to be taken into account when performing validation exercises

For designing future TIR missions…

3. Is it necessary to aim at very high resolution in the TIR (<50m) for continental biosphere sutdies?

4. Possibility of relaxing the NeDT specification (0.2 K for vegetation?)

5. Need of high revisit fo future TIR systems