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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...

\[ \text{Pixel size} \approx 10 \text{m} \]

\[ \text{Low frequency (PBL) turbulence} \]
\[ \text{Scales: } \sim 1 \text{ km, } x \text{ min} \]

\[ \text{High frequency (SBL) turbulence} \]
\[ \text{Scales: } 1 \text{ m} \rightarrow \times 10 \text{ m, } x \text{ secs} \]
Mechanical interactions between the surface and atmosphere are well known....
...but they also exist in the thermal domain

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

- 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) $\rightarrow$ stacks of TIR images
- Reconstructing time series at different spatial resolution by aggregation 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
Spatial integration of small-scale fluctuations

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

- ±1.5°C

GlobTemperature meeting UCM#3, 11-12 June 2015, Reading
Experimental measurements over pine stands

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

Cross correlation: $\sim 6s$ lag $\Rightarrow \sim 60m$ with $u \sim 3m^{-1}$

$\rightarrow$ Wind effect confirmed
LES simulation

- 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 prevailing effect of wind on LST fluctuations
Key interpretation parameters

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

Statistics of the deviation from mean LST

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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:
- $\pm 0.6 \, ^\circ\text{C}$ for $\sim$70% measurements
- $\pm 0.8 \, ^\circ\text{C}$ for $\sim$85% measurements

at 50m resolution

Lagouarde et al., RSE 2013
Lagouarde et al., RSE 2014 submitted

GlobTemperature meeting UCM#3, 11-12 June 2015, Reading
Results

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

Impact of spatial resolution on DEP illustrated
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 meteorological conditions needed.

Case of water bodies to be investigated.
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 studies?

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

5. Need of high revisit for future TIR systems.