HARMONIOUS

UAS Techniques for Environmental Monitoring

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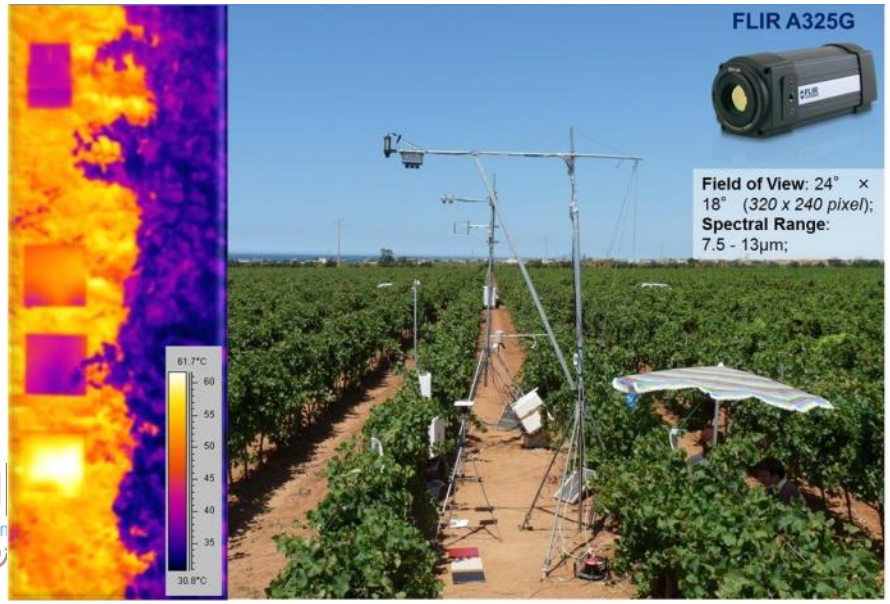
Session 3 – UAS for Hydrological Monitoring [Convener Prof. Bob Su]

Surface soil water content mapping using thermal images: limits and advantages

Proximity sensing facilities



Proximity sensing facilities

TRADITIONAL METHODS FOR SOIL WATER CONTENT ASSESSMENT

In field measurements:

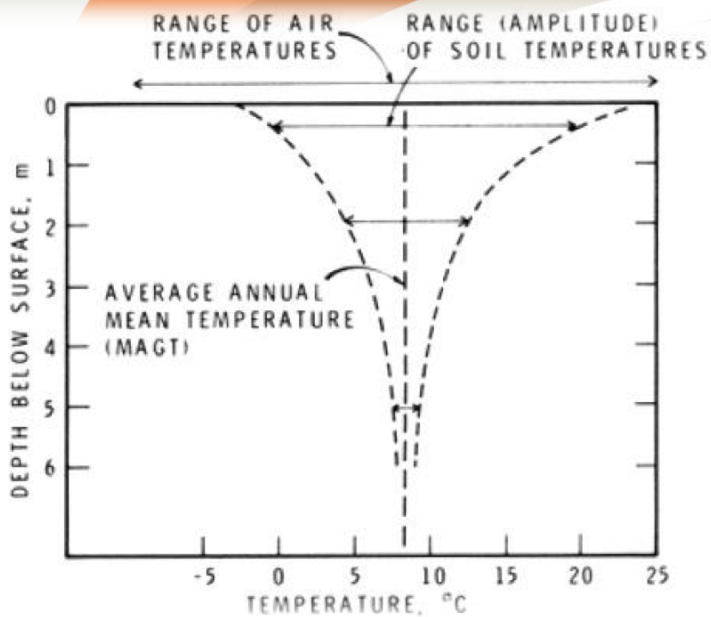
- **Gravimetric method**
- **TDR (*Time-Domain Reflectrometry***
- **FDR (*Frequency Domain Reflectometry*)**

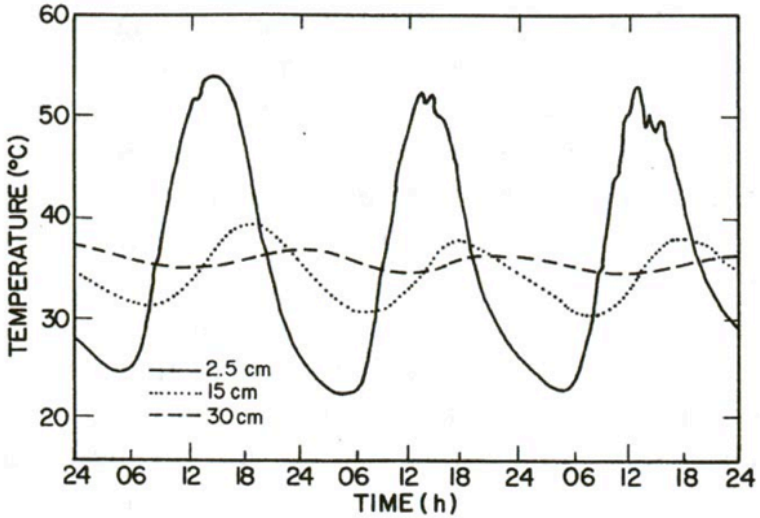
REMOTE SENSING METHODS

Spectral field	MODEL	Advantages	Disadvantages
SW [VIS (~ 4-6* 10^2 nm), NIR (7* 10^2 nm)], **LW [TIR (~ 10^4 nm)]**	- **Triangle method** (Carlson, 1995); - **Thermal Inertia** (Xue and Cracknell, 1995)	- High spatial resolution	- Atmospheric conditions
MW (micro-onde) **(~10^6 nm)** **-Active (3.5-6 GHz);** **-Passive (3.5-8 GHz).**	-The Dubois model (1995) (active); - The PSEM Oh model (2002) (activo); - Microwave Polarization Difference Index (Owe *et al.*, 2001) (passive)	- All time - Medium-Highspatial resolution (activo)	-Low spatial resolution(passive); - Vegetation influence (act. and pass.) and texture influence (act.)

Thermal inertia

Short theoretical background





$$T(z,t) = -\frac{A_c}{B} + (1-\alpha_{SW})E_{Sun}\tau_{SW}\sum_{n=1}^{\infty} A_n \frac{e^{(-k_0\sqrt{nz})}\cdot\cos(n\omega t - k_0\sqrt{nz} - \delta_n)}{\sqrt{\omega P^2 + \sqrt{2\omega}PB + B^2}}$$

T_{AVG} daily average

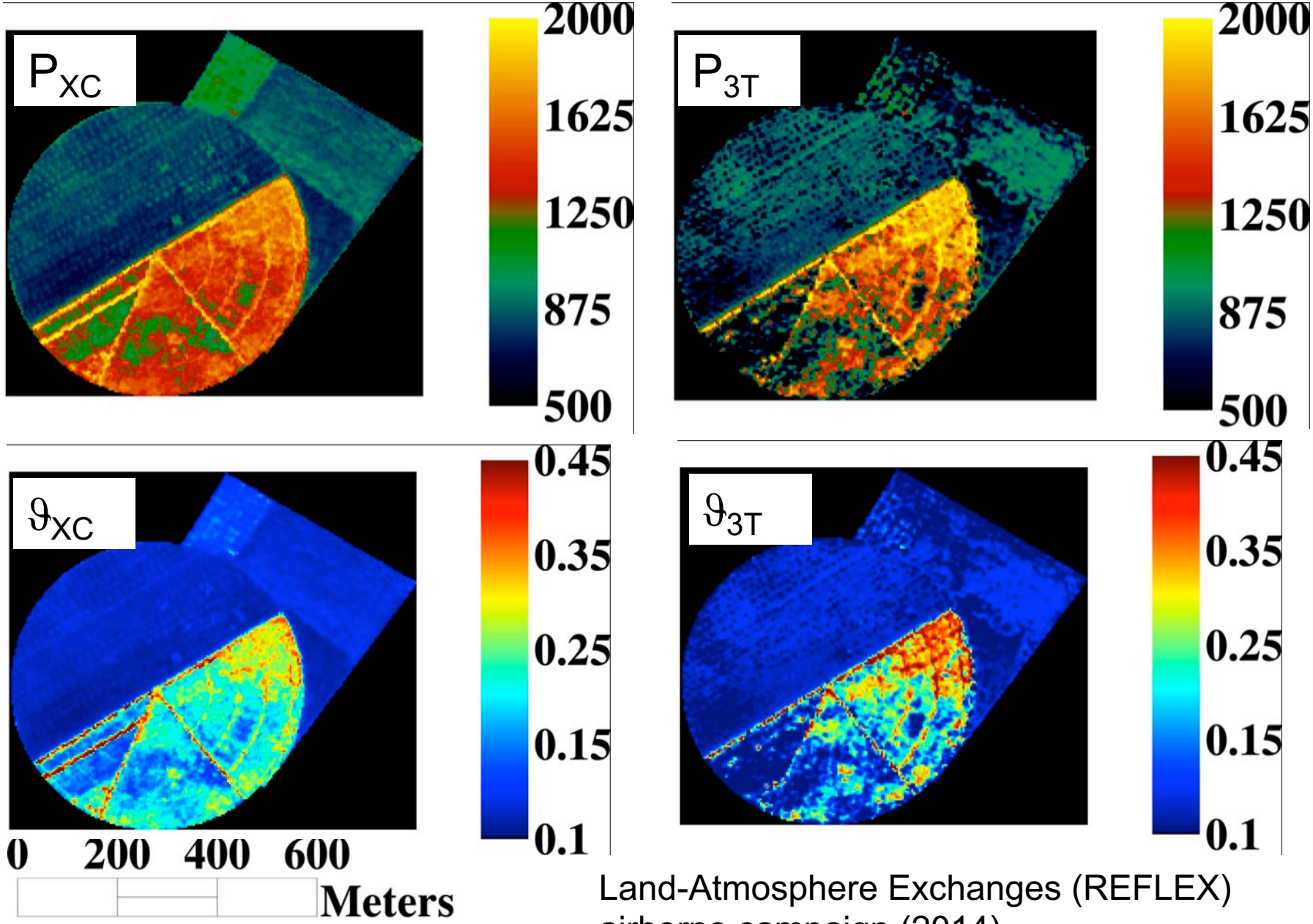
Temperature amplitude

dumping

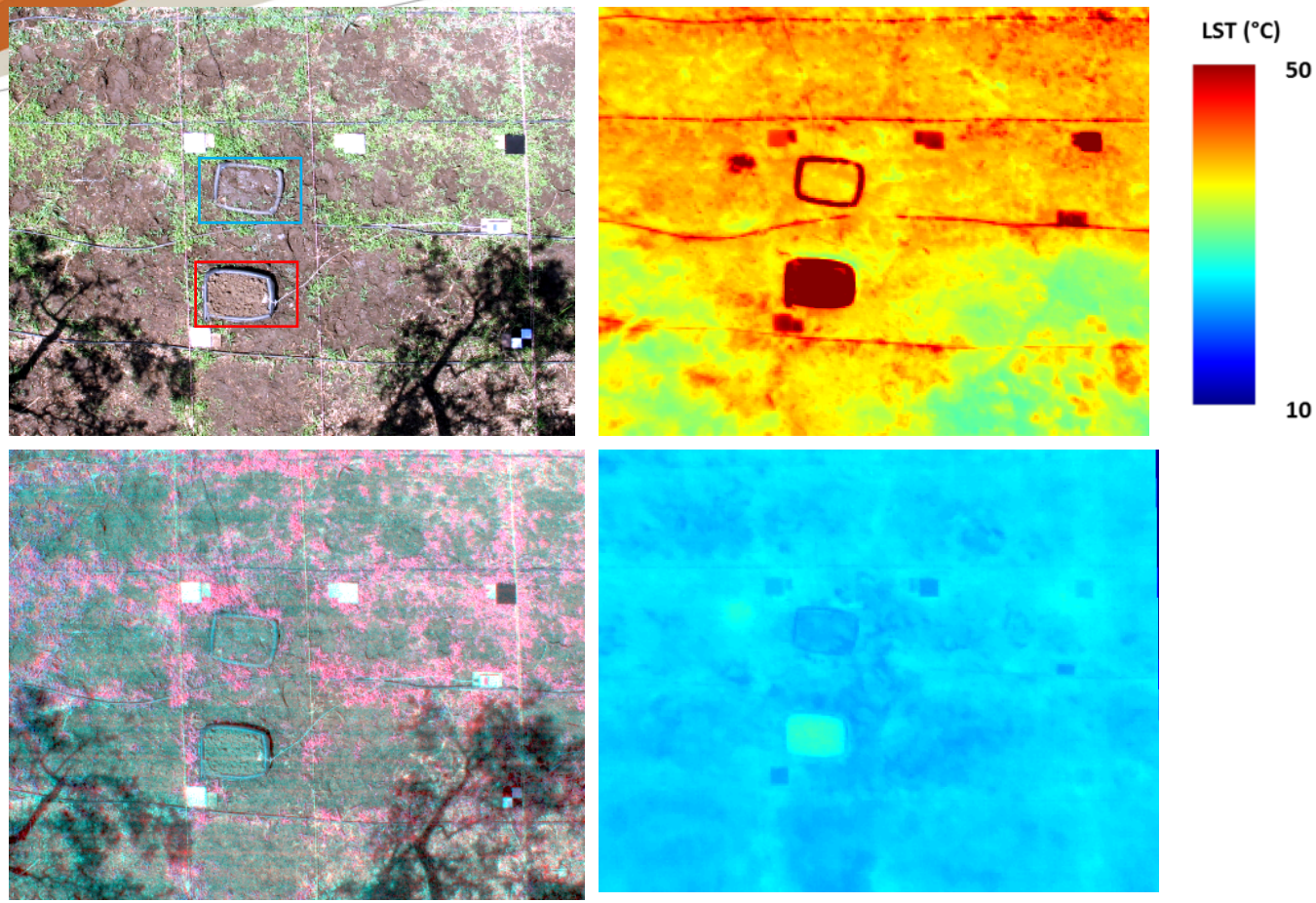
Oscillation

Phase

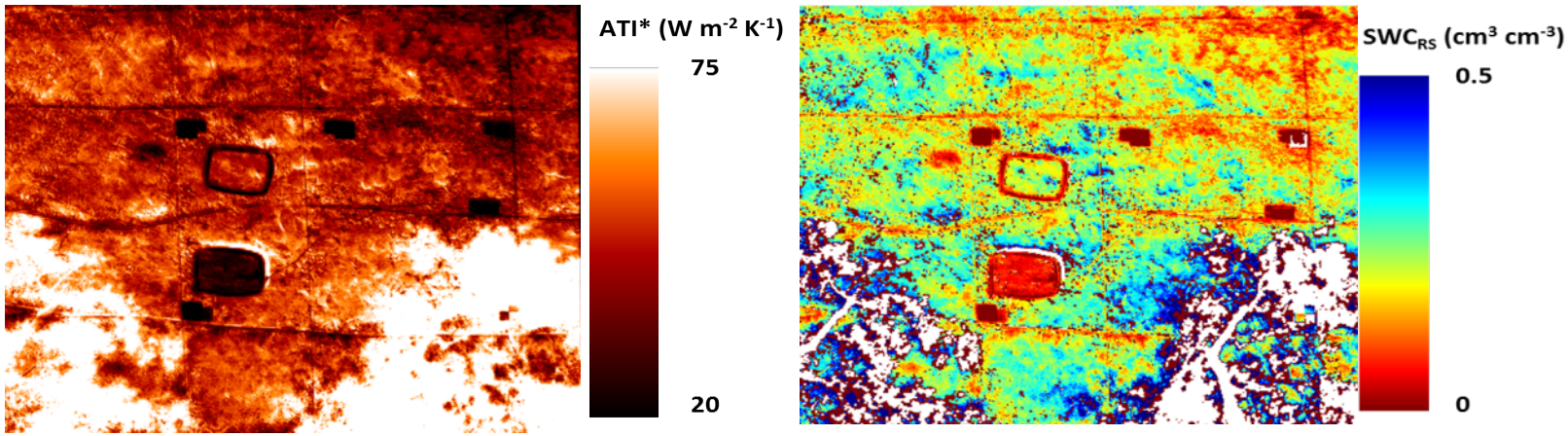
THERMAL INERTIA and SOIL WATER CONTENT – XC approximation and 3ST METHOD



Land-Atmosphere Exchanges (REFLEX) airborne campaign (2014)



Canon optical image and Tetracam *ADC* multispectral image. *Thermal images acquired at 13.21 (upper right panel) and 18.34 (lower right panel) solar time.*



*ATI** spatial distribution (left panel). Pseudo colour composition showing the SWC_{RS} distribution. Shadowed pixels are masked (in white) (right panel).

Thermal inertia

Advantages

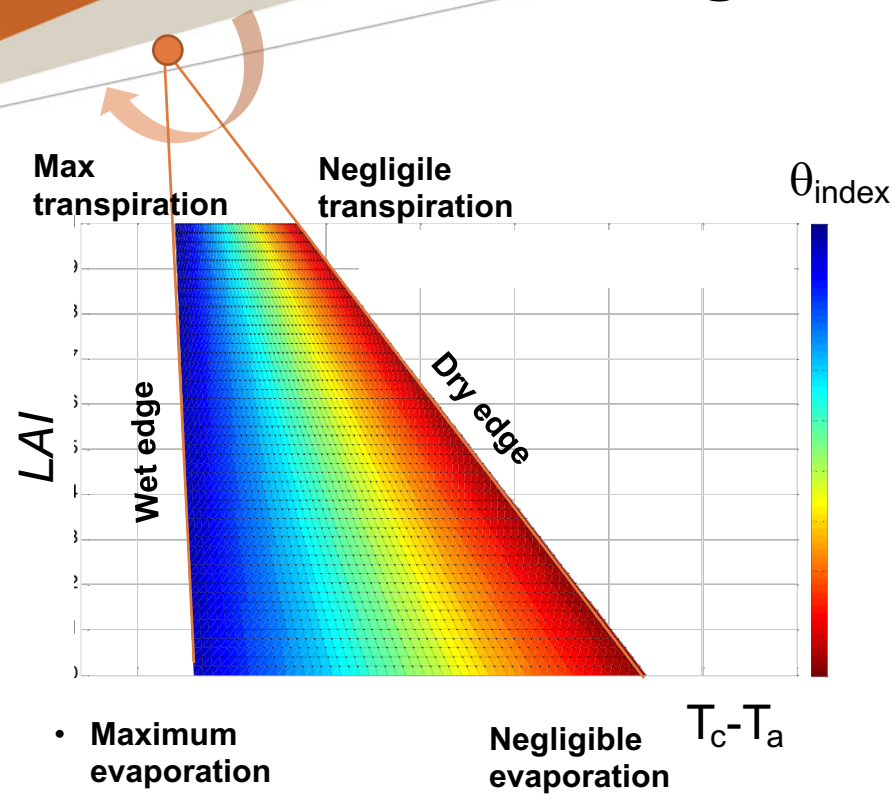
- Applicability to bare soil or sparsely vegetated, almost independently of the pedology; actually it depends on soil porosity and textures.
- The first order approximation lead straightforward to the solution

Limits

- A least two thermal images are required, that should be acquired in suitable moments of the day
- VIS/NIR images are required in order to quantify the shortwave albedo
- Thermal diffusivity does not vary with soil depth
- Soil water content is representative of the layer of the soil where daily temperatures oscillations occur
- Upper layers contribute more than lower layers
- The second order approximation requires an iterative approach

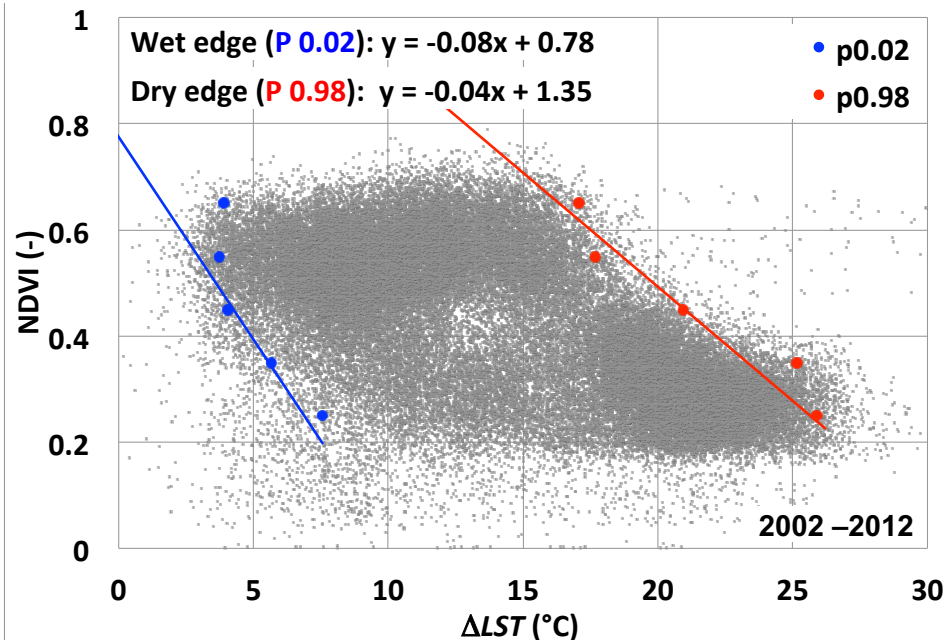
Triangle method

Short theoretical background

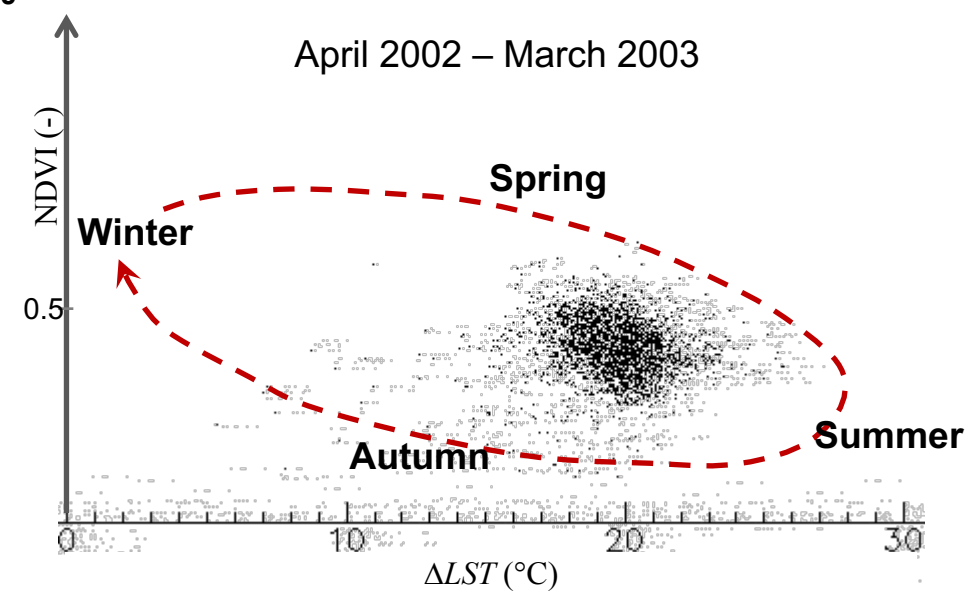


$$T_c - T_a = \frac{r_a\left(R_N - G_0\right)}{\rho c_p} \cdot \frac{\gamma\left(1+\frac{r_a}{r_c}\right)}{\Delta + \gamma\left(1+\frac{r_a}{\frac{r_s}{LAI}}\right)} - \frac{e_a^* - e_a}{\Delta + \gamma\left(1+\frac{r_a}{\frac{r_s}{LAI}}\right)}$$

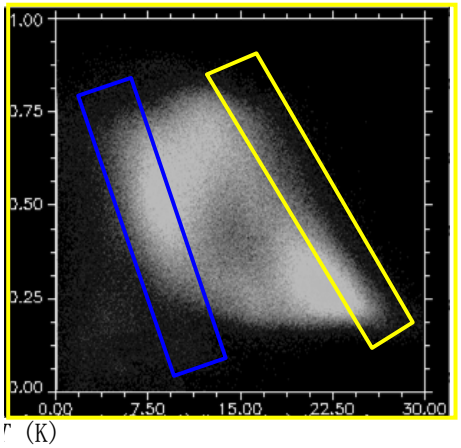
TRIANGLE METHOD admittance version

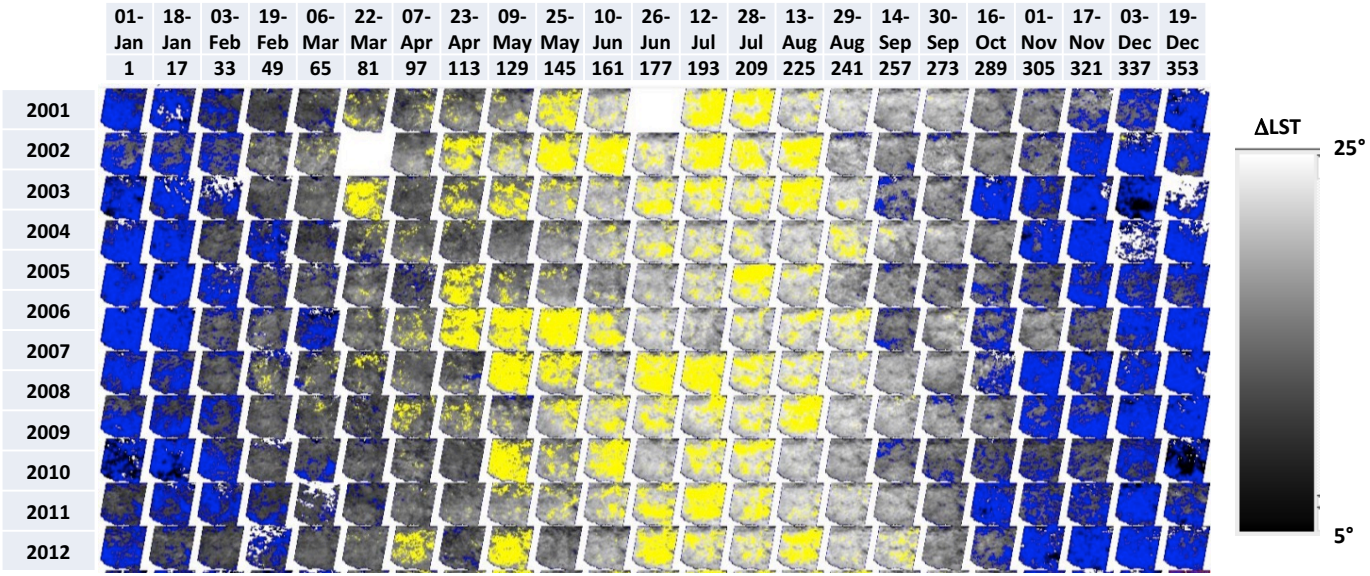


Empirical approach → wet and dry edges directly from images

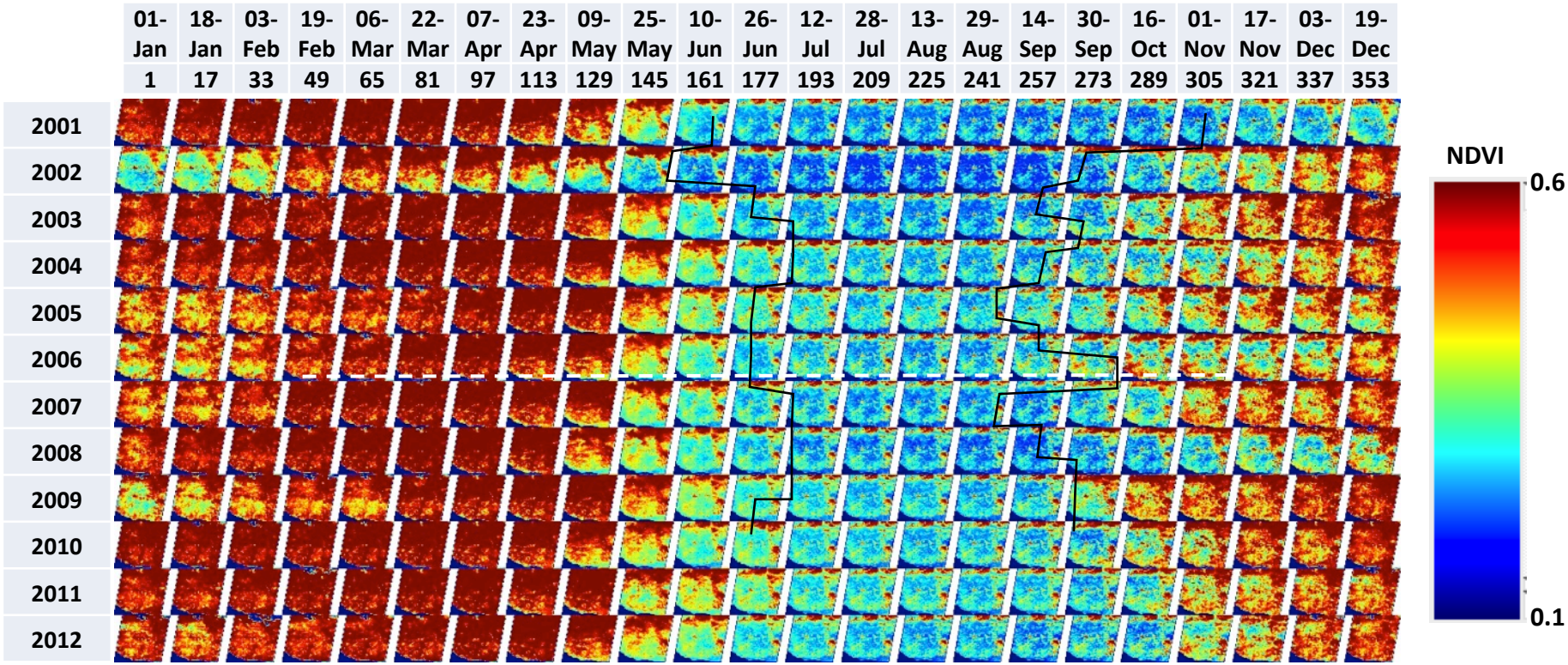


Diachronic analysis

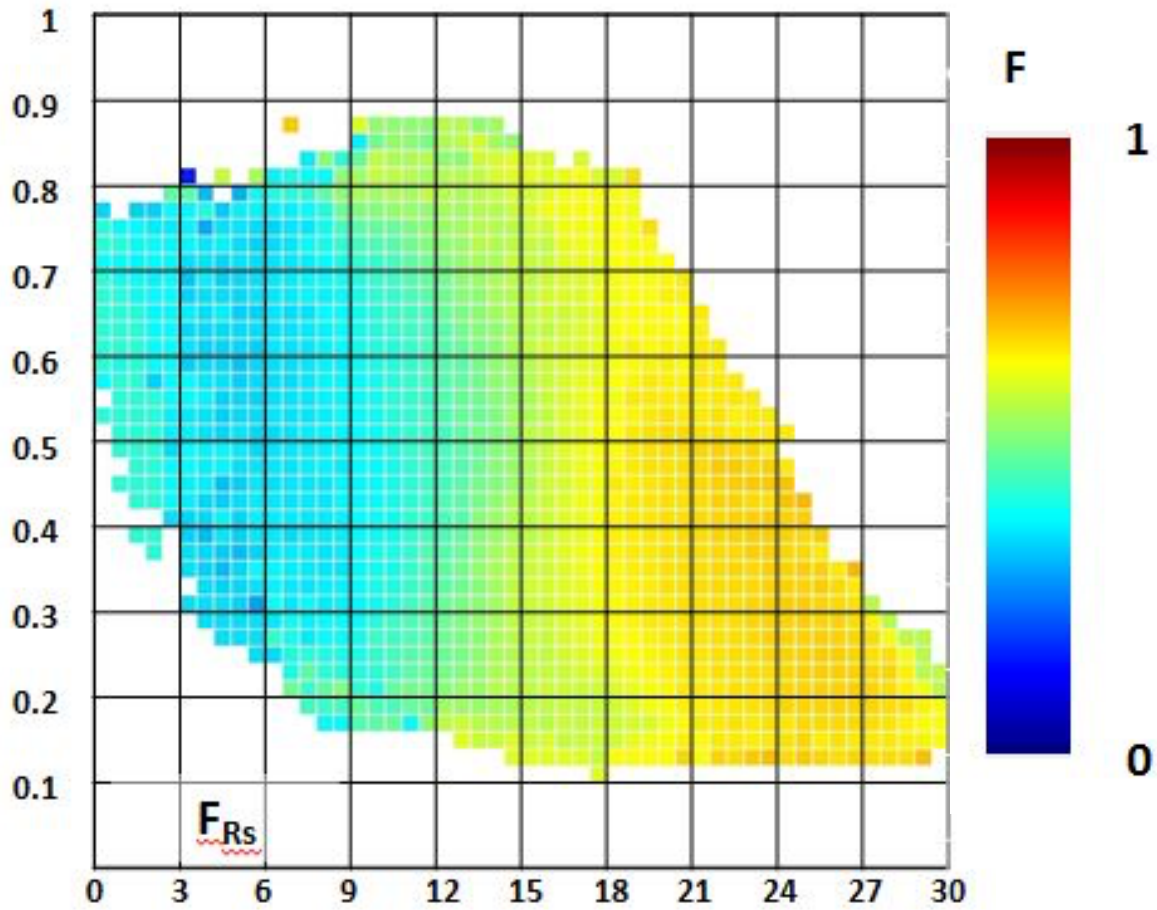




Diachronic analysis



NDVI (upper panel). DOYs and years are reported in x-axis and y-axis respectively.


1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
3
6
9
12
15
18
21
24
27
30
F
1
0
F_{Rs}

Triangle method

Advantages

- Applicability to vegetated soil.
- Soil water content is representative of the root zone where transpiration occurs and/or the upper layer of the soil where evaporation occurs;
- We need just two temperatures: a thermal image and air temperature
- The empirical approach is straightforward to apply: we can determine both the dry and the wet edges directly from the images

Limits

- VIS/NIR images are required in order to quantify the LAI or a vegetation index
- The theoretical approach is difficult to apply (we need vegetation stomatal resistance)
- Limits in the multitemporal applications due to other stress factors (eg., excessive incoming solar radiation, air temperature, air humidity)

Thermal inertia vs. Triangle method

Thermal inertia

1. Applicability to bare soil or sparsely vegetated soils.
2. Two thermal acquisitions are required
3. Soil water content is representative of the layer of the soil where daily temperatures oscillations occur.

Triangle method

1. Applicability to vegetated soil.
2. We need just two temperatures: a thermal image and air temperature
3. Soil water content is representative of the root zone where transpiration occurs and/or the upper layer of the soil where evaporation occurs.

Thanks to the remote sensing group, including F. Capodici, G. La Loggia.