Improving continuous monitoring of evapotranspiration by combining data from future thermal infrared missions

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Preparation of the future missions

TRISHNA

LSTM @ esa

Context

- Evapotranspiration (ET) is a major component of the water cycle and monitoring ET has a lot of interest for monitoring water stress of ecosystem and water management in agriculture

- ET can be estimated using thermal infrared data from satellite

- However, satellite revisit is low when considering applications at field scale
  - applications require a continuous monitoring of ET
  - best present revisit is
    - -> 16 days with Landsat (8 days with two platforms) at ~100 m resolution
    - -> 1 day with MODIS at 1 km resolution

- Cloud coverage may have a large impact on data availability

Context

- **Solutions:**

  -> implement interpolation procedures between available ET estimations

  ex:
  Delogu et al. 2012
  Alfieri et al. 2017
  Ma et al. 2018
  Guillevic et al. 2019
  Delogu et al. 2021
  Allies et al. 2022
  Awada et al. 2022
  …

-> develop satellite missions with a better revisit

- **TRISHNA (CNES/ISRO, 2026)**
- **LSTM (ESA/Copernicus, 2028)**
- **SBG (NASA, 2028)**

Revisit study / new TIR missions: objectives

- analyze the impact of the new missions revisit on the uncertainty in deriving continuous daily ET

- revisit studies are usually based on surface flux data (typically from flux towers)
  - not a large quantity of data
  - data for agricultural surfaces are usually discontinuous

  => we used a land surface model for generating ET over a large range of agricultural situations

- revisit studies are not usually accounting for errors in remote sensing estimation of ET

  => different levels of errors in estimating ET from remote sensing were inserted in the analysis: (white noise [with std 0.3 mm d^{-1}, 0.6 mm.d^{-1}, 0.9 mm.d^{-1}…], proportional to ET, systematic…)

- Revisit studies usually analyze the uncertainty related to deriving continuous daily ET in terms of 'seasonal' errors (RMSE, Bias…)

  => we developed an analysis to evaluate the uncertainty and evaluate the risk of daily errors, in particular large daily errors

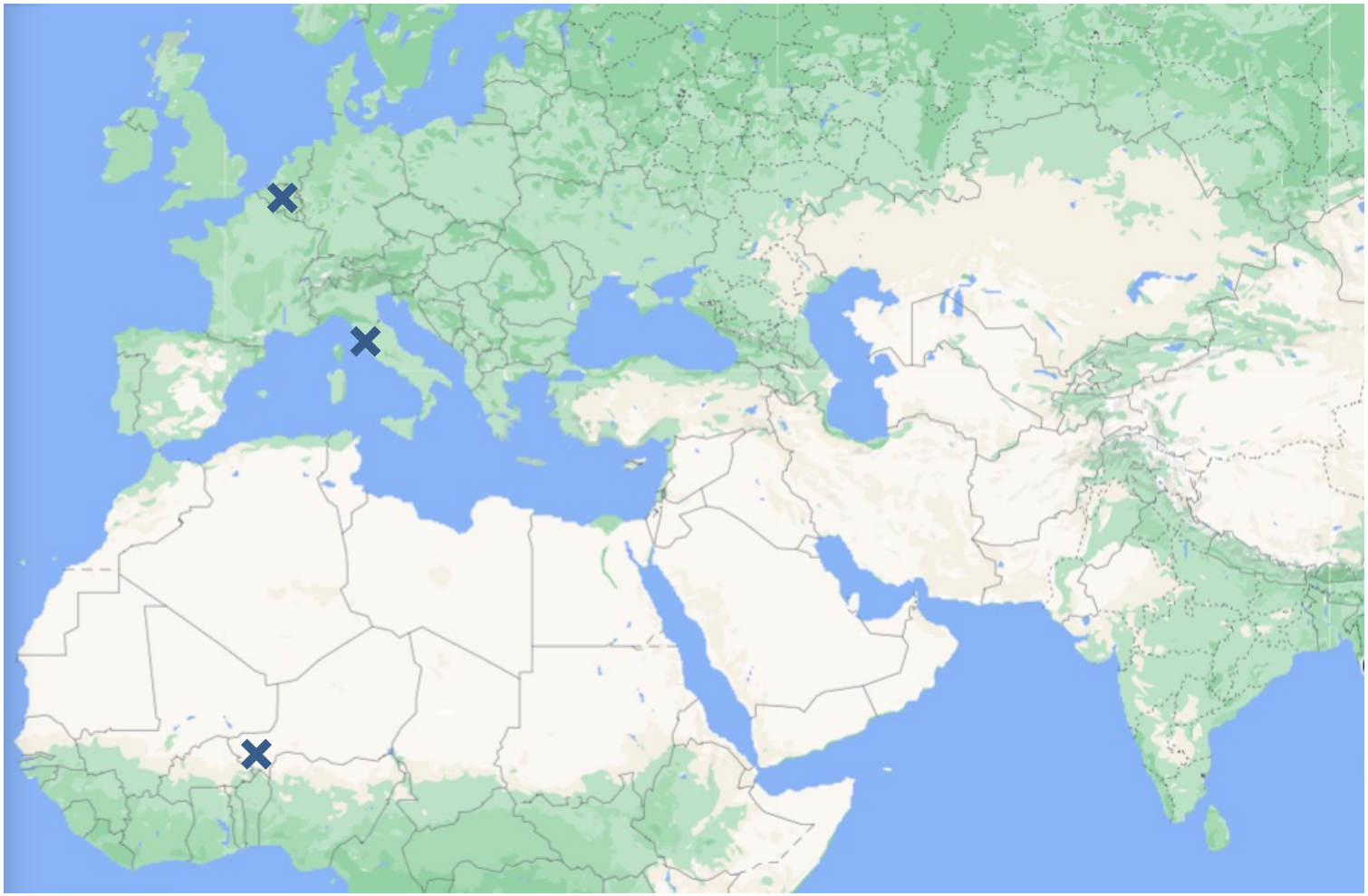
Agricultural sites

- **Lonzée in Belgium (ICOS surface flux monitoring site)**
- **Grosseto in Italy (airborne experiment site by ESA)**
- **Wankama in Niger (AMMA-Catch surface flux monitoring site)**

Lonzee, Belgium
Latitude 50.55159° N Longitude 4.74613° E

Grosseto, Italy
Latitude 42.82° N Longitude 11.07° E

Wankama, Niger
Latitude 13.645° N Longitude 2.63° E



Satellite revisit

At equator		Belgium
-> Landsat :	1/16 days	-> 1/16 days
-> TRISHNA :	3/8 days	-> 5/8 days
-> SBG :	1/3 days	-> 2/3 days
-> LSTM :	1/4 days	-> 2/4 days
-> LSTM A & B:	1/2 days	-> 4/4 days

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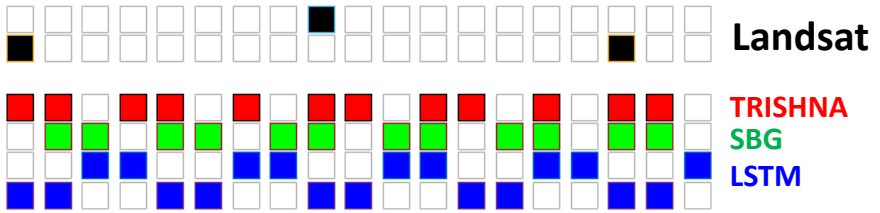

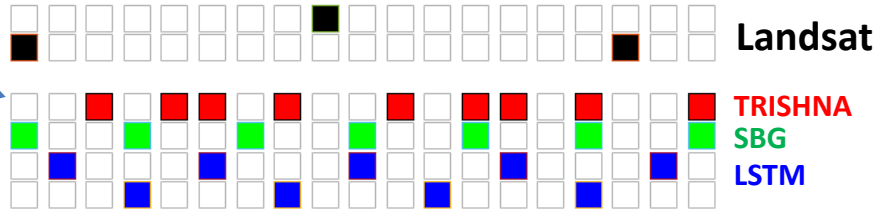

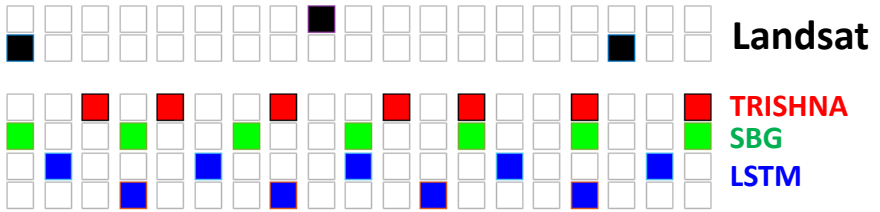

Agricultural sites

- ❑ **Cloud occurrence (evaluated from ERA5 solar radiation, calibrated on MODIS and S2 cloud masks)**

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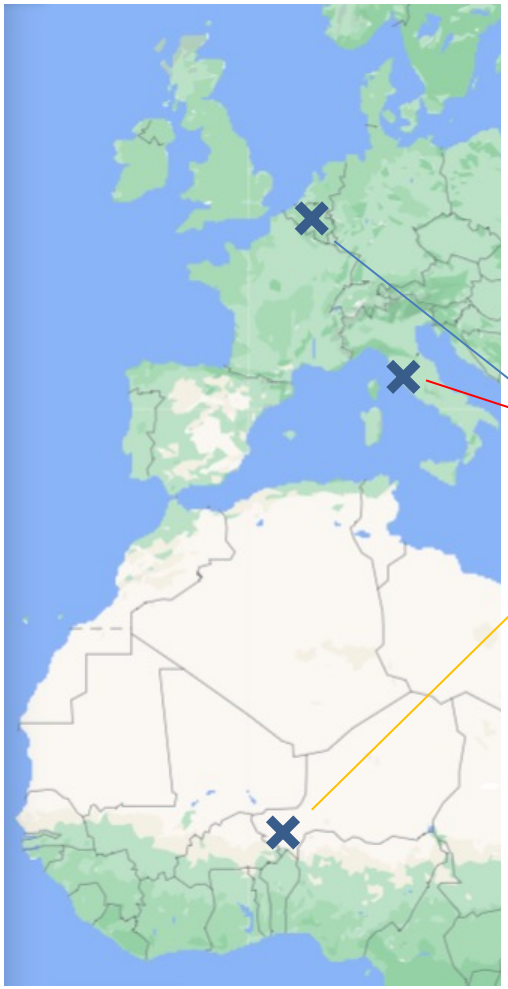

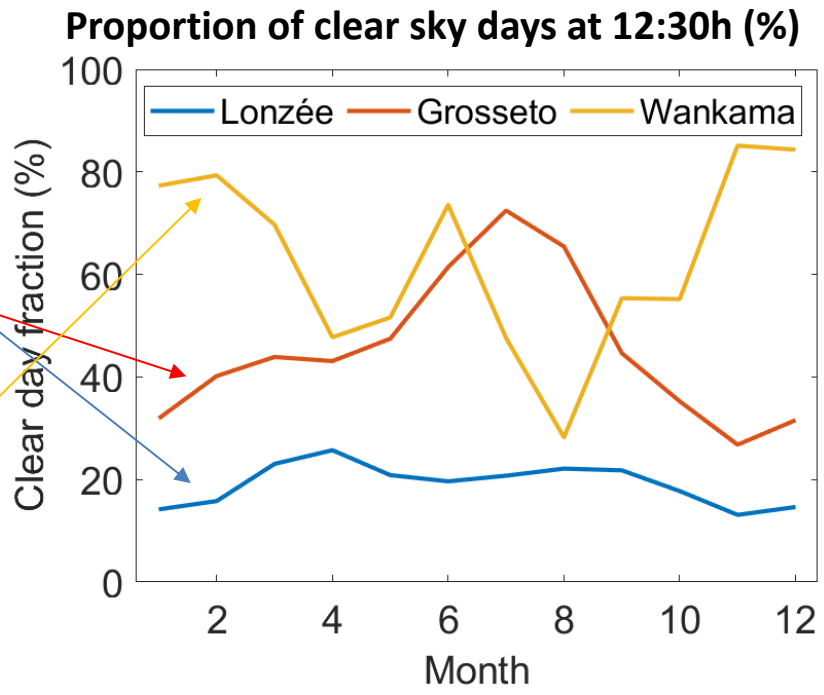

Evapotranspiration (ET) simulations with ISBA-A-gs

(Land Surface Parameterization at MeteoFrance ISBA-A-gs : Calvet et al. 1998, 2008)

- ❑ **Different types of crops: C3 crops, C3 grass, C4 crops, irrigated / non-irrigated crops**
- ❑ **20 sequences of 19 years (2000-2018) for each sites**
- ❑ **Plant and soil parameters were chosen randomly in possible ranges for each type of crops**

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corn
winter wheat
sugar beet
seed potato
…

irrigated corn
winter wheat
grassland
alfalfa
tomato
…

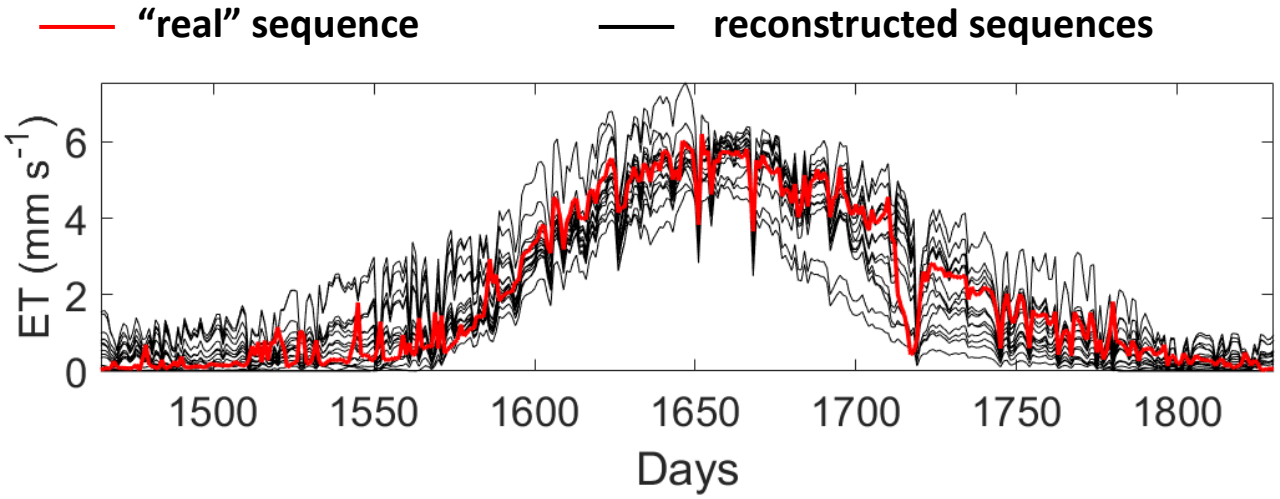
millet
fallow
…

Examples of interpolated ET sequences

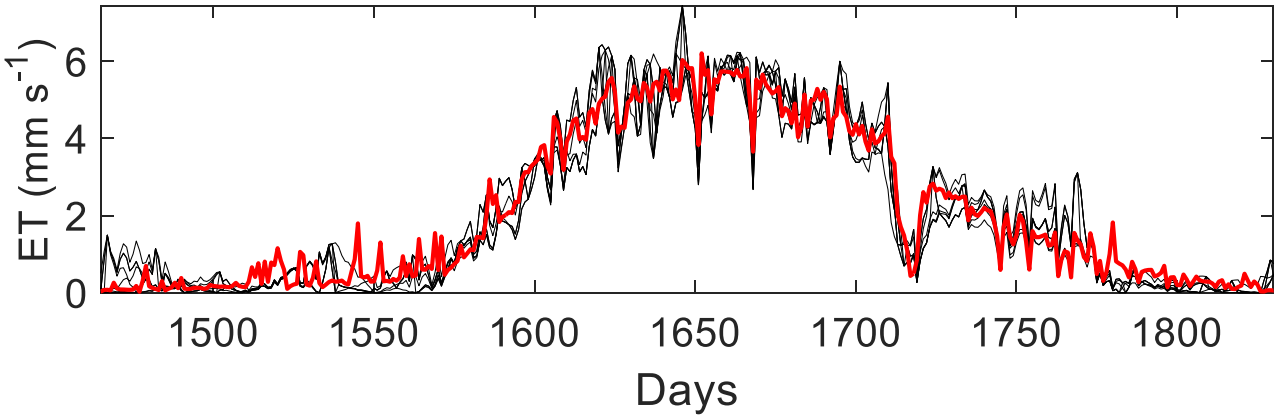
Grosseto – Summer C3 crop (sunflower) - RS error: std = 0.6 mmd^{-1}

Reconstruction based on interpolating the daily evapotranspiration to daily solar radiation ratio

One LANDSAT platform
=> 16 reconstructed ET sequences



TRISHNA
=> 8 reconstructed ET sequences

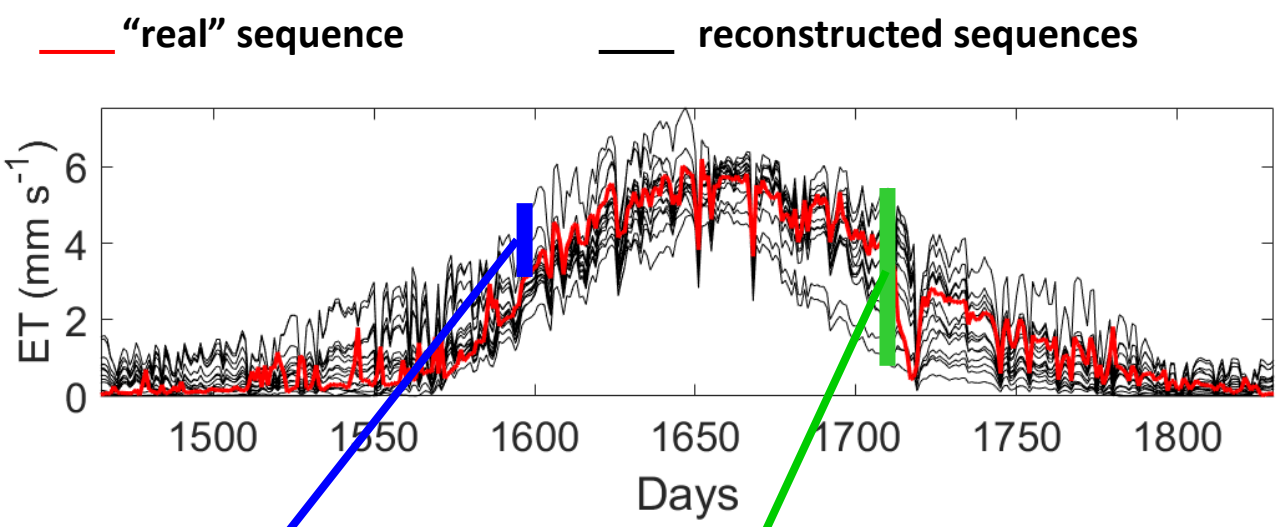


Examples of interpolated ET sequences

Grosseto – Summer C3 crop (sunflower) - RS error = 0.6 mmd^{-1}

Reconstruction based on interpolating the daily evapotranspiration to daily solar radiation ratio

Landsat: one platform

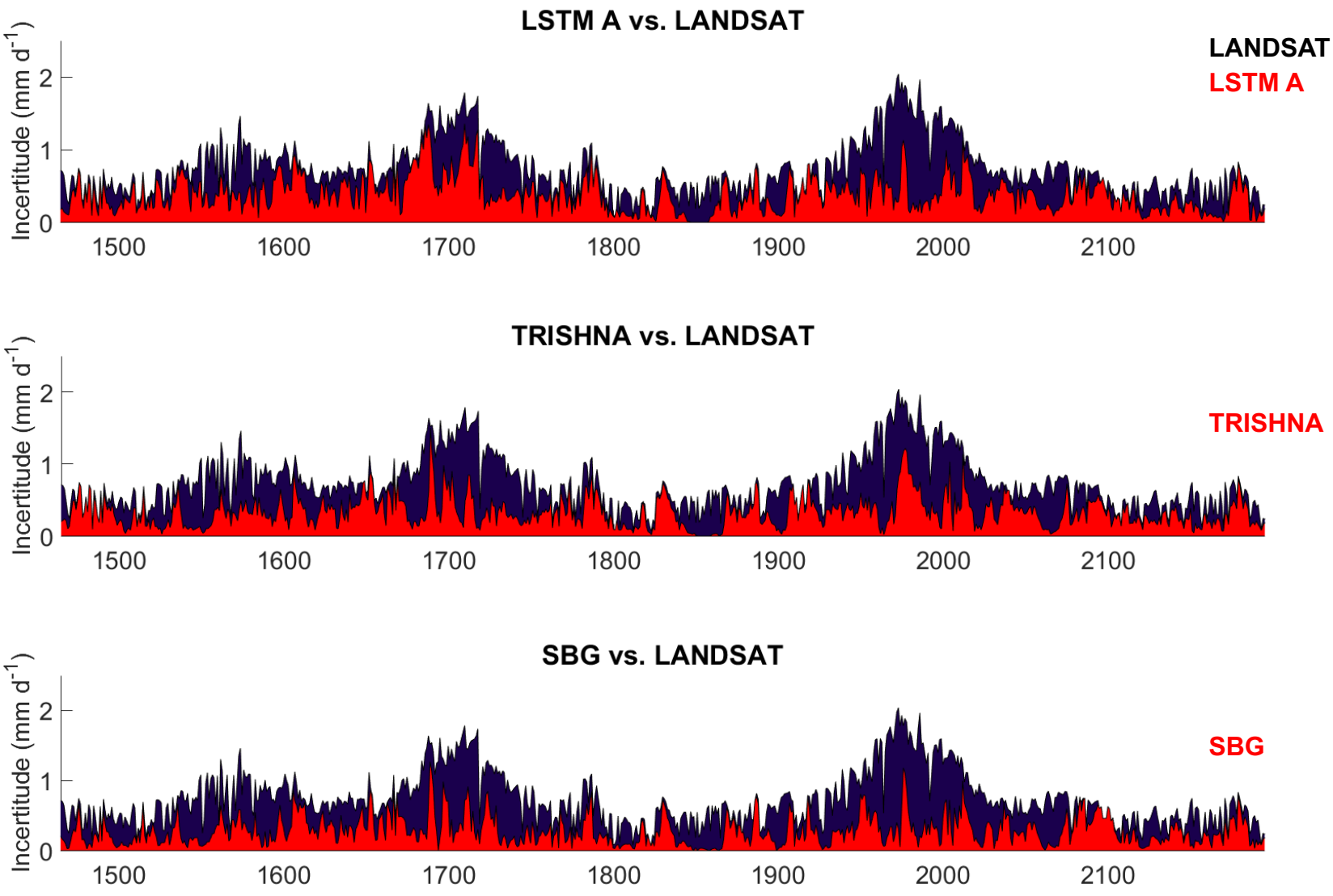


Error = difference between reconstructed ET and "true" ET

Range of reconstructed ET = Uncertainty X 2
(= zero for daily revisit and no cloud)

Example of results

Uncertainty for C3 summer crops in Grosseto over 2 years (with RS error = 0.6 mm d^{-1})



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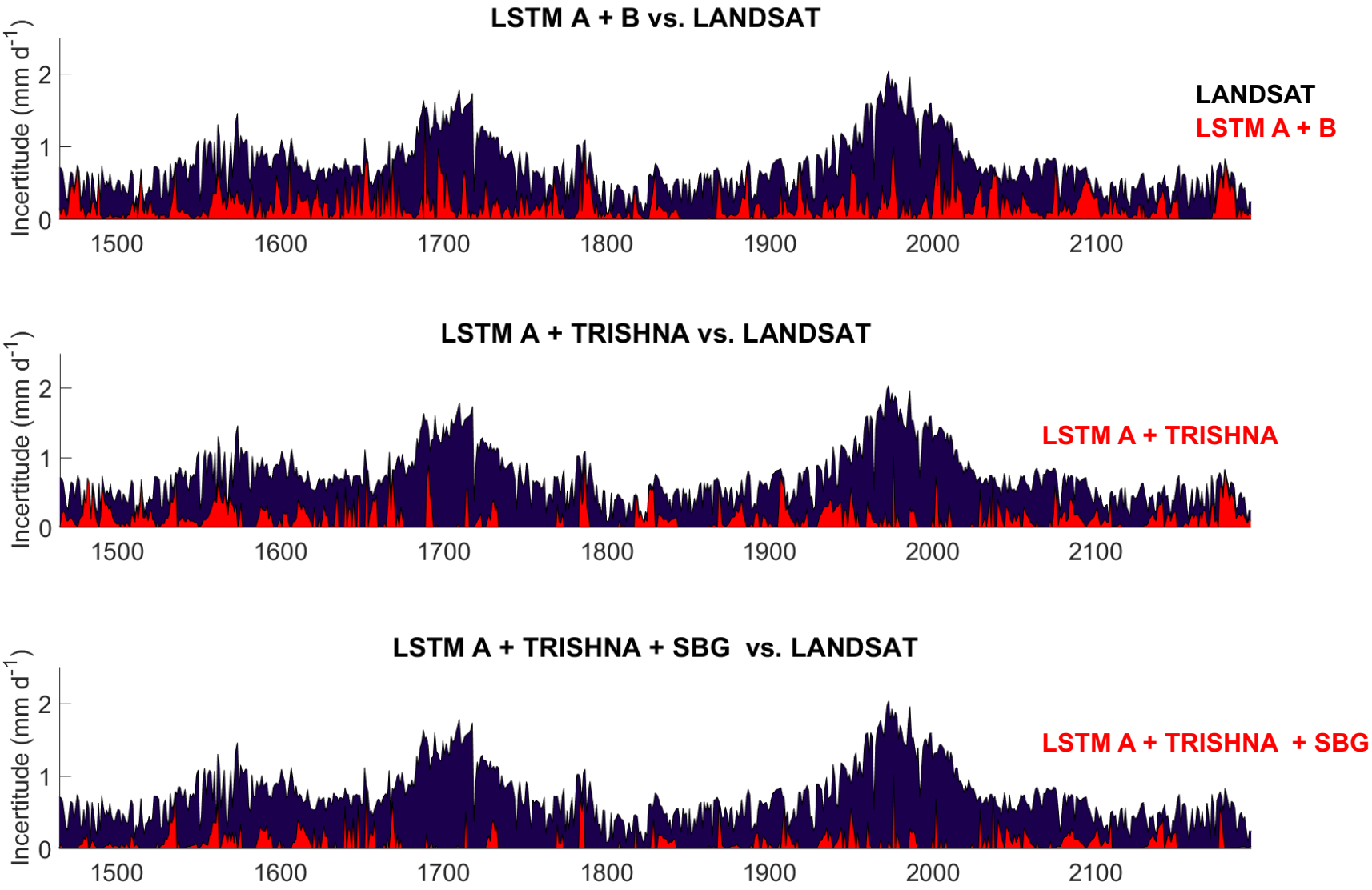
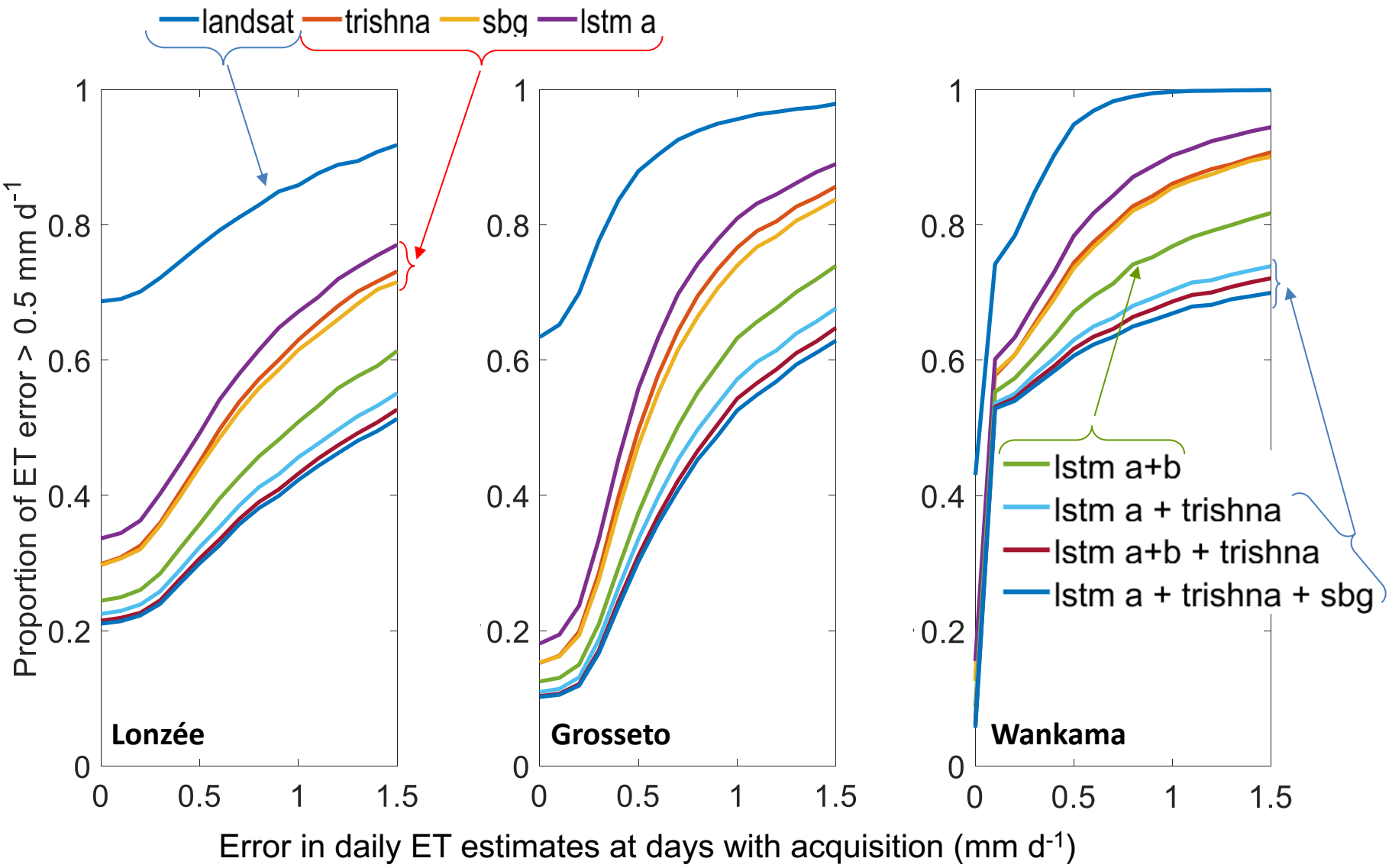


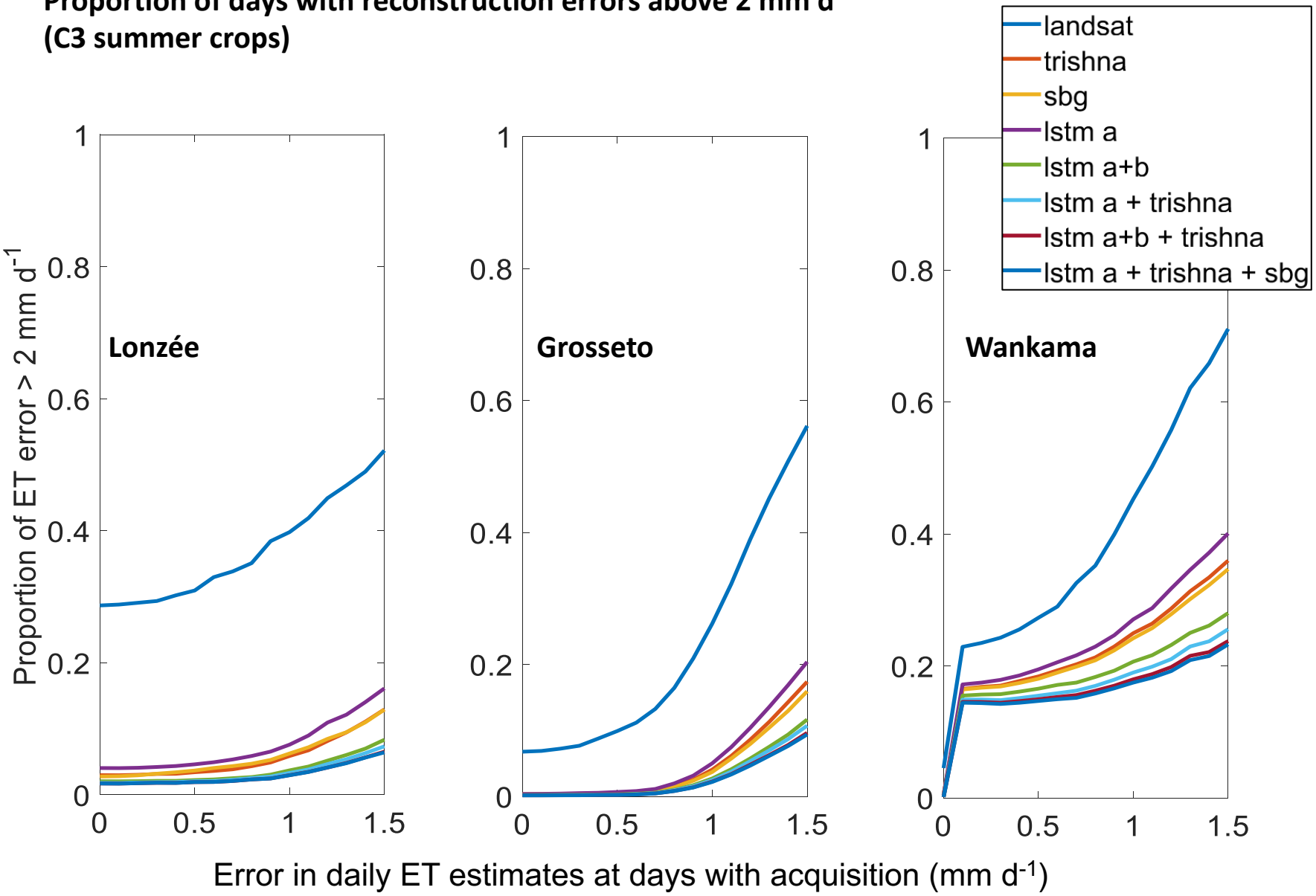
Example of results

Proportion of days with reconstruction errors above 0.5 mm d^{-1} (C3 summer crops)



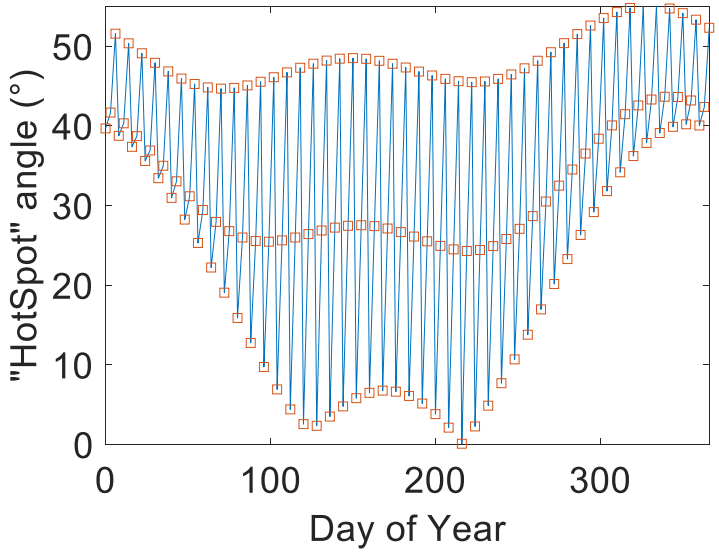
Example of results

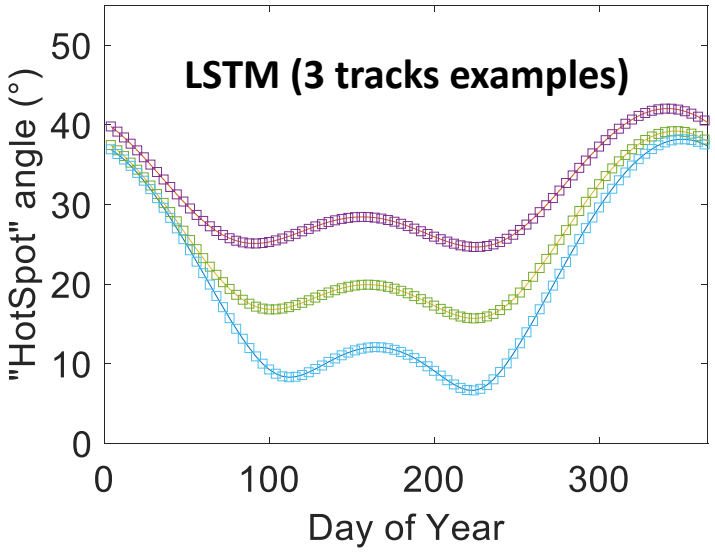
Proportion of days with reconstruction errors above 2 mm d^{-1} (C3 summer crops)

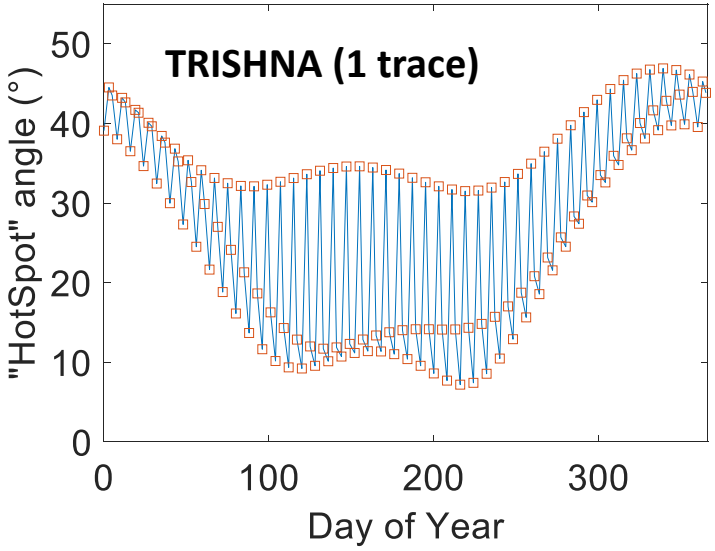


Specificity of tropic areas: the hotspot issue

Wankama: acquisition cycle from TRISHNA (2 traces are presented) and LSTM B (3 traces)







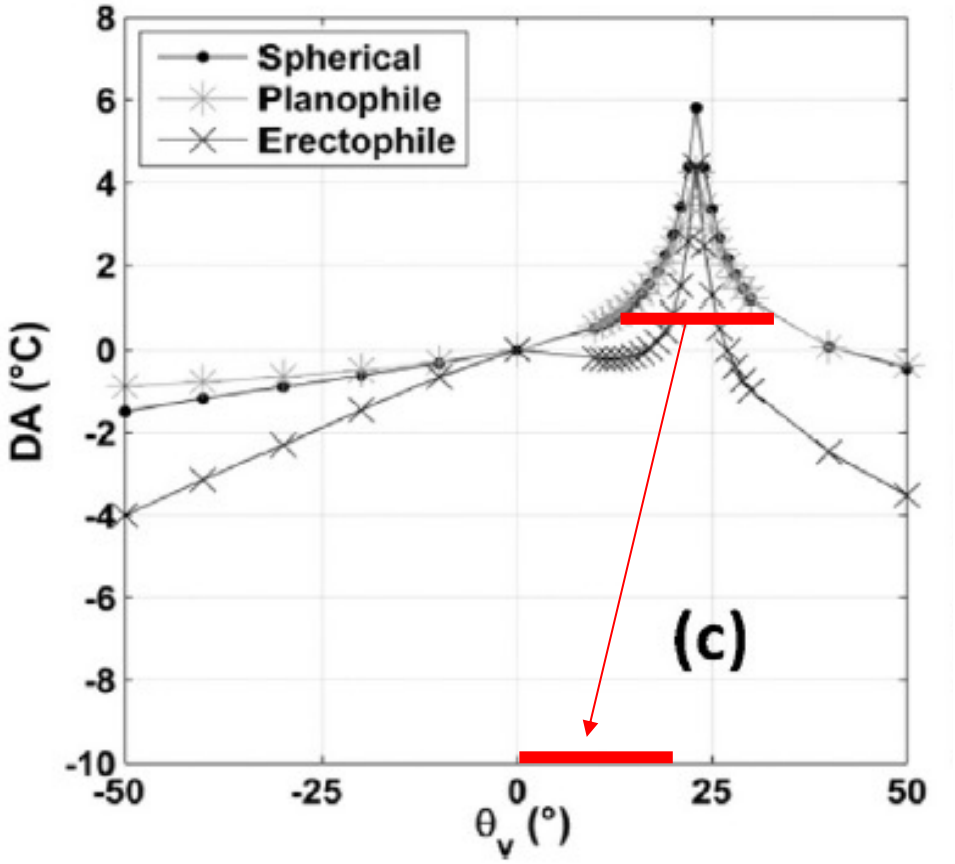
HotSpot angle =
angle between sun and viewing directions

Specificity of tropic areas: the hotspot issue

The directional anisotropy of a thermal signal was simulated by Duffour et al. (2015) using the SCOPE model (van der Tol et al.)

Showing a hotspot that can represent +/- 10°

(DA = temperature difference with nadir)



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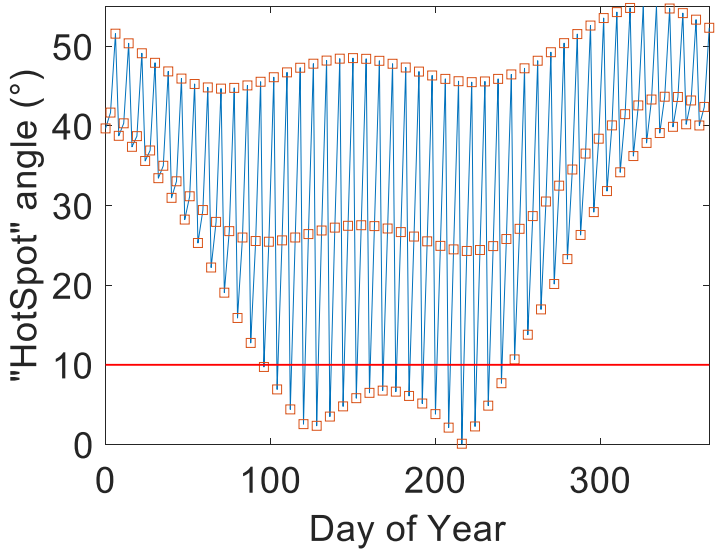
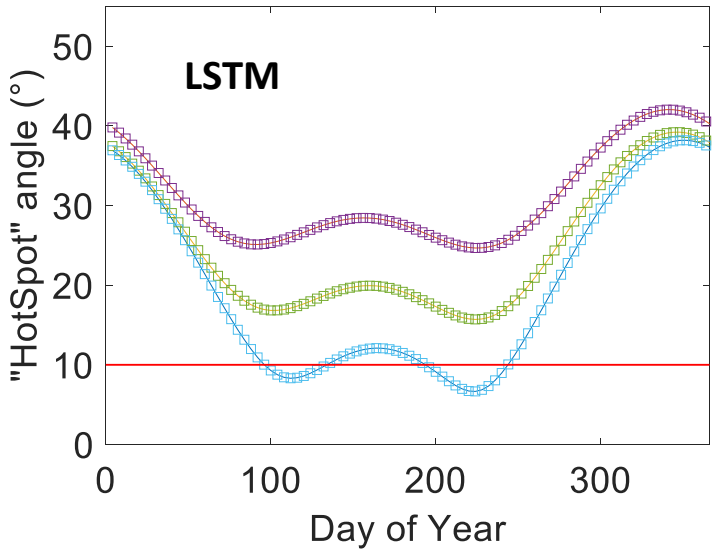
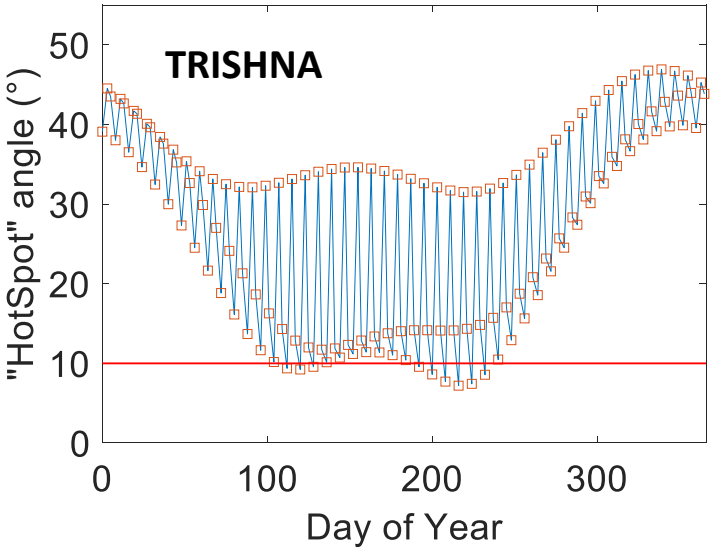
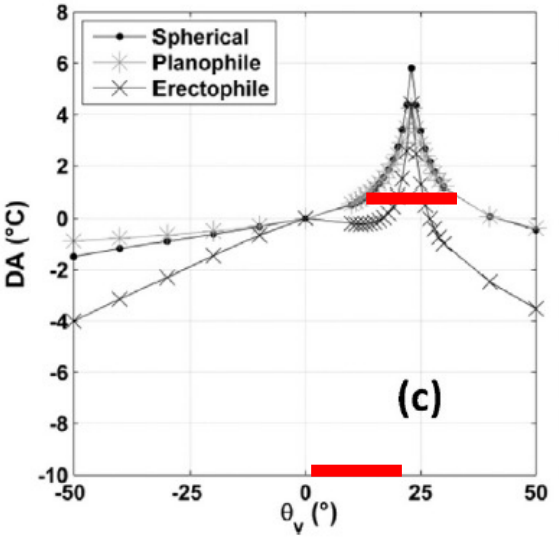








Summary

Uncertainty

- **uncertainty decreases when revisit improved**
- **uncertainty increases with cloud coverage**
- **revisit increases with latitude => partially compensates the increase in cloud coverage**
- **differ from one type of crop to another (and on the irrigation calendar)**
- **the primary error on remote sensing estimates of ET has a high impact on the global uncertainty and on the risk of high interpolation errors**
- **the hotspot issue can be a problem on some parts of the tropics**

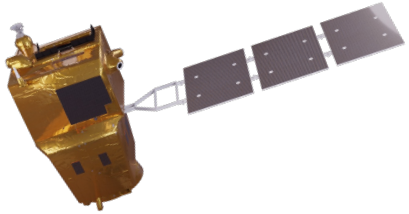
The methodology can be applied to examine uncertainty in continuous estimates of ET in any area based on land surface model simulations (here ISBA-A-gs / ERA5) and hypothesis on errors in ET models

- **calculation of a priori uncertainties by crop types**
- **evaluation of risk of errors by sites**
- **test of interpolation methodologies**

A coordination between future missions will improve revisit, helping in reducing uncertainties in ET up to at least 7 acquisitions every 8 days by combining TRISHNA, LSTM A and SBG

Thank you

LSTM @ esa



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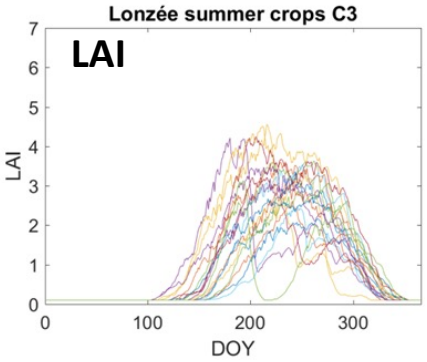
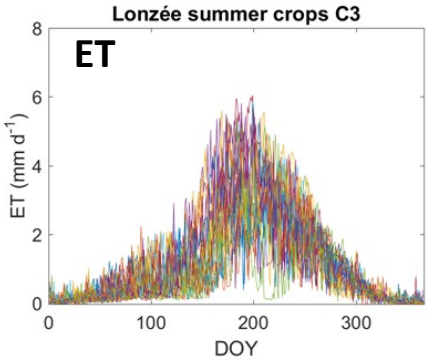
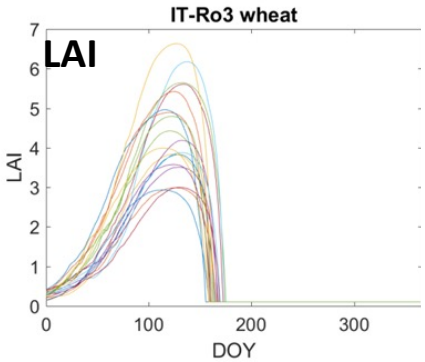
ET simulations with ISBA-A-gs + error of estimation of ET from remote sensing

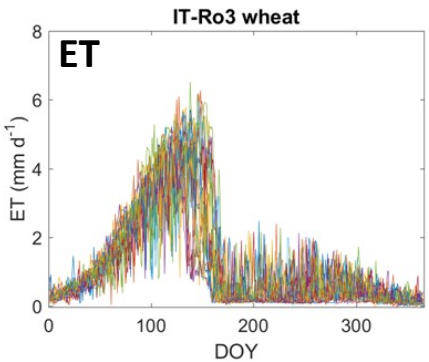
- **Examples of LAI and ET simulations (2000 – 2019)**

Ex: sugar-beet in Lonzée and wheat in Grosseto









- **Errors on ET estimation from remote sensing data were set to**
  - **white noise**
  - **proportional**
  - **systematic**
  - **0.3 mm d^{-1}**
  - **0.6 mm.d^{-1}**
  - **0.9 mm.d^{-1}**
  - **…**

Ex: error proportional to ET with std = 0.6 mm d^{-1}