Uncertainty in evapotranspiration mapping from thermal infrared remote sensing data with EVASPA

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Evapotranspiration (ET) can be derived using various models based on thermal infrared data

- -> uncertainty in Ts:
  - instrument
  - atmosphere
- -> large number of models -> diversity of algorithms => uncertainties
- -> lots of other data required :
  - albedo
  - vegetation density
  - meteorological data

  various sources of data => uncertainties

Many unknowns remain concerning the uncertainties in the derivation of ET, in particular for discriminating uncertainties from input data and models

Models of Latent Heat Flux (LE)

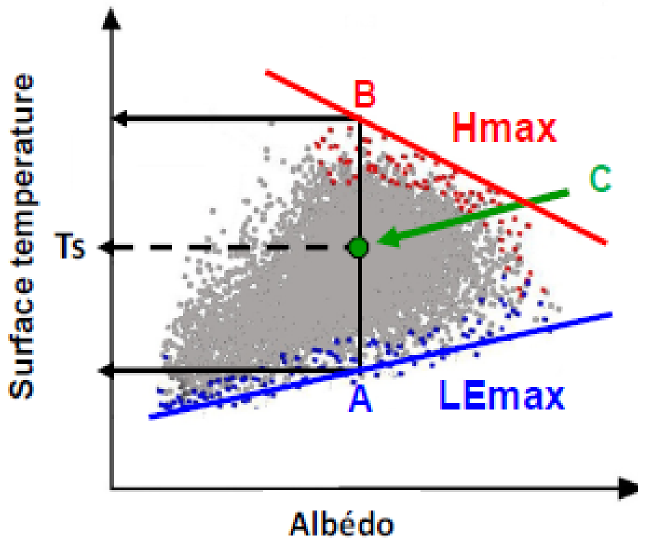
[see Lagouarde and Boulet 2016]

-> Contextual model : *LE ~ EF x (Rn – G)*

EF = evaporative fraction <- *Ts* vs. *albedo or NDVI*

Rn = net radiation <- albedo, emissivity, Ts, solar irradiance, atmospheric irradiance

G = ground heat flux <- *Rn, NDVI, fCOVER*

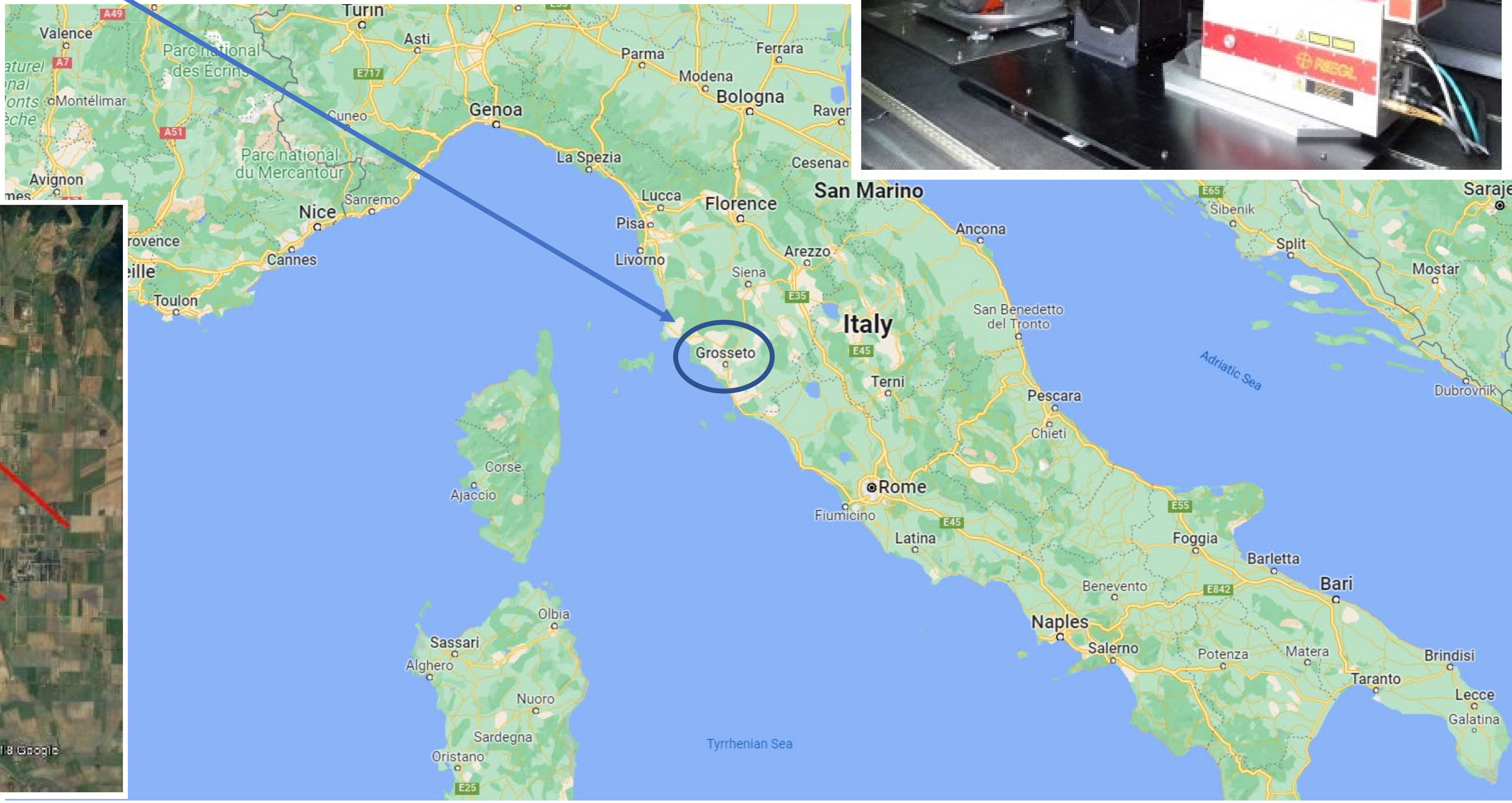


ex: S-SEBI (Roerink et al. 2000)

ESA experiment in Grosseto (Italy) in support of the LSTM program : July 2018

Airborne acquisition with TASI (TIR) and HyPLANT (VNIR, SWIR) sensors
3.5 m resolution at the ground

Agricultural area (~10 X 10 km)



Data: Grosseto experiment, July 2018

Surface temperature and emissivity :
- –> TASI data provided by ESA
- –> TASI data re-processed at Univ. of Valencia

Surface spectral reflectances : –> HyPlant data
- –> NDVI
- –> albedo
- –> LAI
- –> roughness

Incident radiations
- –> ERA 5 reanalysis (ECMWF – COPERNICUS Climate change Service)
- –> SoDa Meteosat (COPERNICUS Atmosphere Monitoring Service)
- –> COSMO6-REA Reanalysis (Bohn University)
- –> in situ data (2 instruments)

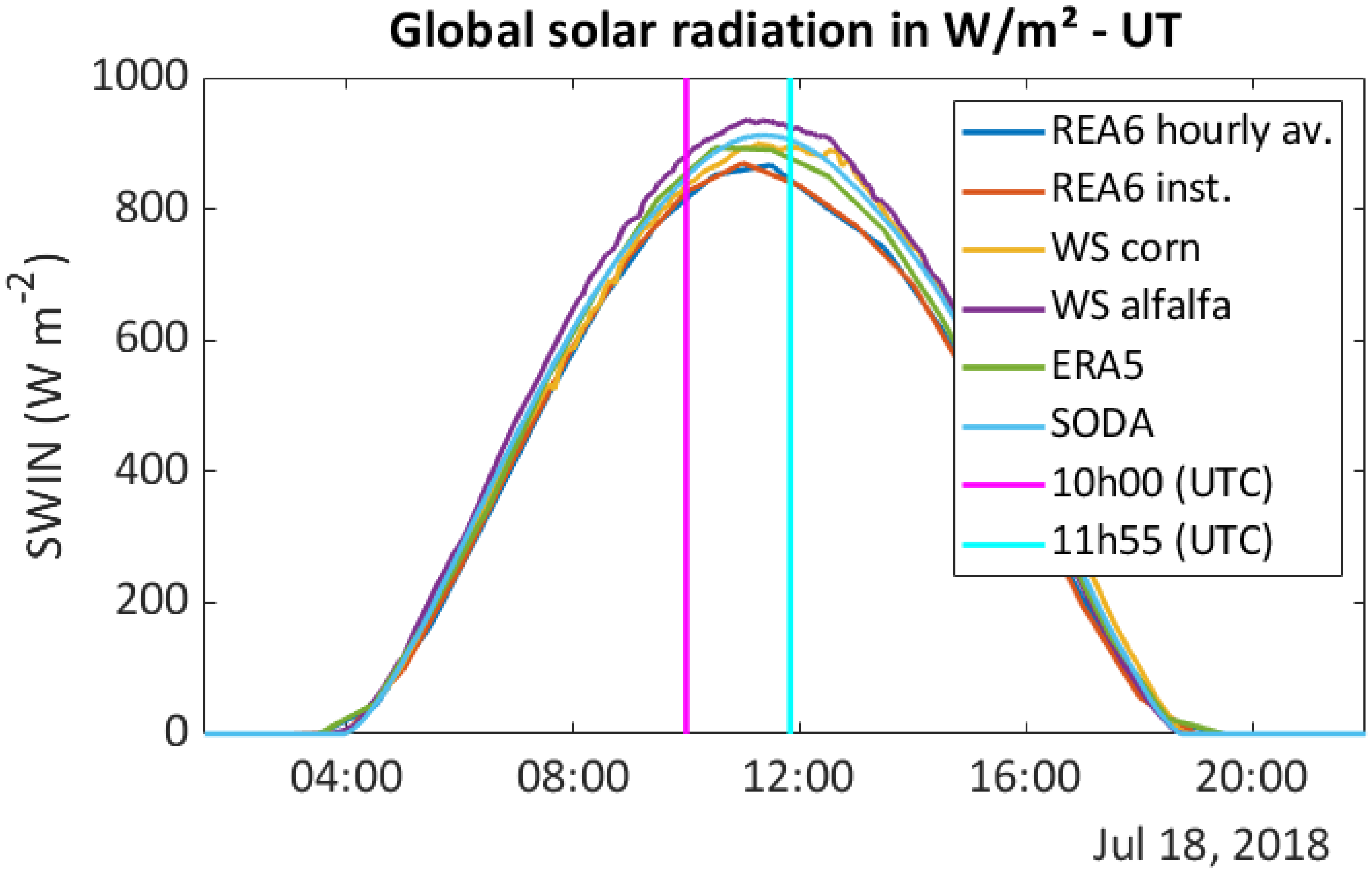
Air temperature and wind speed
- –> ERA 5
- –> COSMO6-REA Reanalysis (Bonn University)
- –> in situ data (2 locations)

Uncertainty analysis : **we use the EVASPA concept** (Gallego et al. 2013, Olioso et al. 2018, Allies et al. 2020)

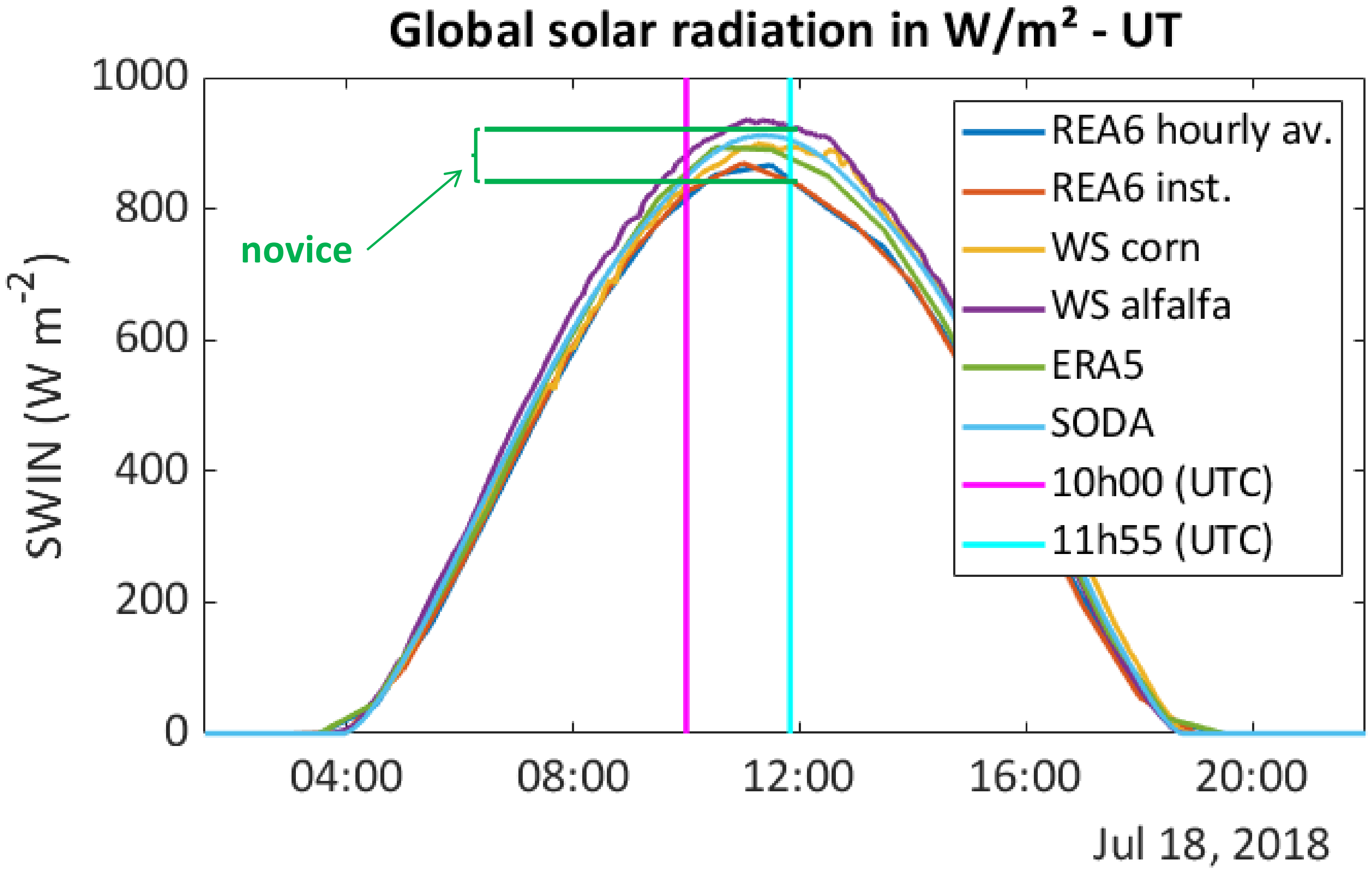
- **-> computes ET as an ensemble estimate (ensemble mean)**
  - **-> from various sources of data**
  - **-> by combining various model**
- **-> computes uncertainties from the variability of calculated ET depending on**
  - **-> model**
  - **-> inputs**

- **-> Uncertainty is defined as the standard deviation of the ensemble simulations (or the range of variations as in Mira et al., RSE 2016)**
- **-> Uncertainty related to the impact of one variable or model is computed by keeping only the variations related to this model or variable**
- **-> We compute two levels of uncertainty:** (Allen et al., 2011, Blatchford et al., RSE 2019).
  - **- novice uncertainty = full range of variations**
  - **- expert uncertainty = reduced range of variations depending on prior-information on accuracy**

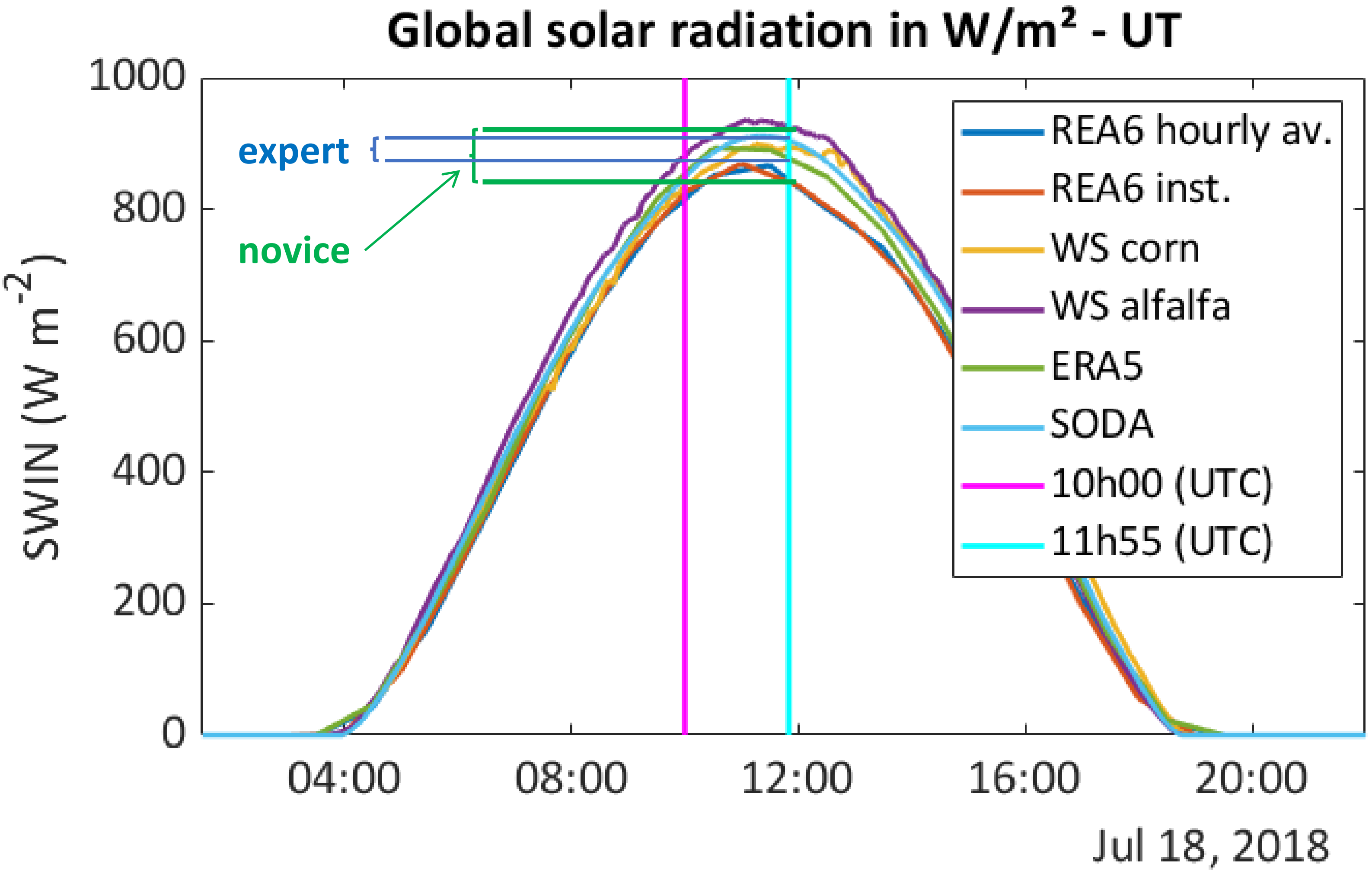
Example -> Meteorological variables : solar radiation



Example -> Meteorological variables : solar radiation



Example -> Meteorological variables : solar radiation



Uncertainties

variability in input data source and algorithms

<table>
<tr><th></th><th></th><th colspan="6">Novice case</th><th colspan="6">Expert case</th></tr>
<tr><td></td><td colspan="13">common inputs</td></tr>
<tr><td>Surface temperature</td><td>T_s</td><td colspan="12">4 2 atmospheric corrections (Un. Valencia & CzechGlobe)</td></tr>
<tr><td></td><td>NDVI</td><td colspan="12">2 calculations (different spectral windows)</td></tr>
<tr><td></td><td>albedo</td><td colspan="6">13 models</td><td colspan="6">11 models</td></tr>
<tr><td></td><td>emissivity</td><td colspan="6">20 models</td><td colspan="6">5 models</td></tr>
<tr><td>Incident solar radiation</td><td>R_g</td><td colspan="2">2 reanalysis</td><td colspan="2">1 satellite product</td><td colspan="2">2 in situ stations</td><td colspan="2">1 reanalysis</td><td colspan="2">1 satellite product</td><td colspan="2">1 in situ station</td></tr>
<tr><td>Atmospheric radiation</td><td>$L\downarrow$</td><td colspan="3">2 reanalysis</td><td colspan="3">2 in situ stations</td><td colspan="3">2 reanalysis</td><td colspan="3">2 in situ stations</td></tr>
<tr><td>G to Rn ratio</td><td>$\xi\ (G/Rn)$</td><td colspan="6">7 equations</td><td colspan="6">6 equations</td></tr>
<tr><td></td><td colspan="13"></td></tr>
<tr><td></td><td colspan="13">Evaporative fraction model</td></tr>
<tr><td>Evaporative fraction</td><td>EF</td><td colspan="6">5 algorithms</td><td colspan="6">5 algorithms with slope limitations</td></tr>
</table>

Surface temperature data from TASI

Two sets of data were provided based on the TES algorithm

- one directly from ESA (CzechGlobe processing)
- three processing at University of Valencia :
  - -> LIRE radiosoundings (on site)
  - -> GSW profile (atmospheric model …)
  - -> NCEP profile (US model)

We used data on the 18th and the 20th at :

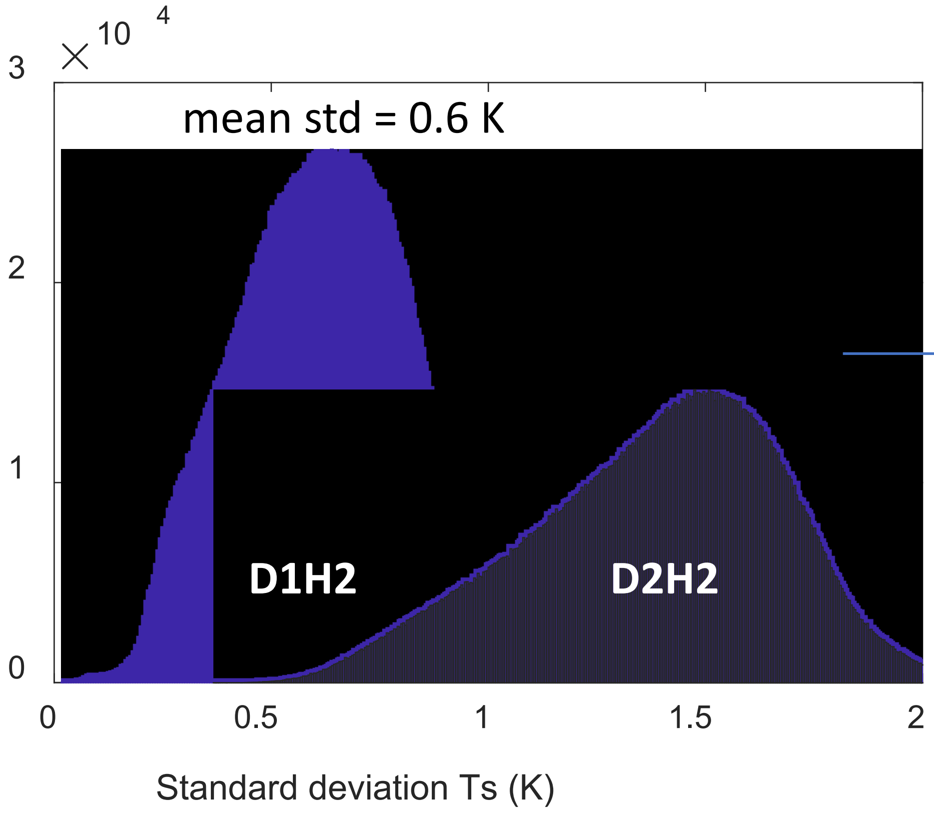
- around 10h UTC (= 12h CEST) -> morning
- around 12h UTC (= 14h CEST) -> midday

notation: D1H1, D1H2, D2H1, D2H2

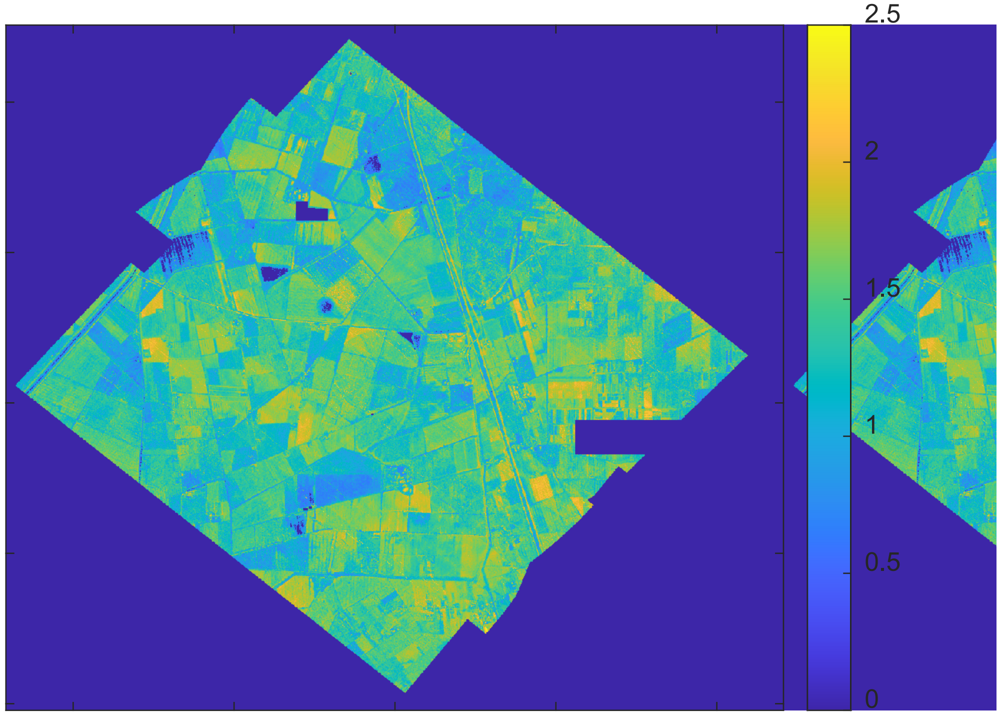
However, results were very similar for each days (and even each acquisition time) -> D2H2

Uncertainty in Ts

Standard deviation of the 4 Ts maps



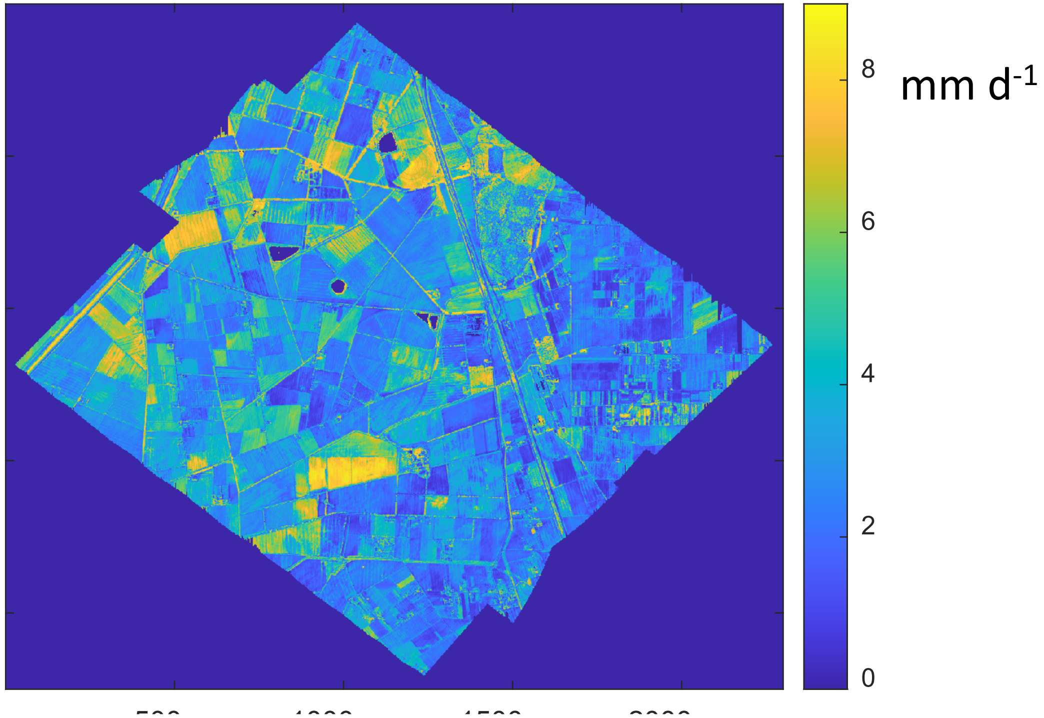
Ts standard deviation map D2H2 (K)



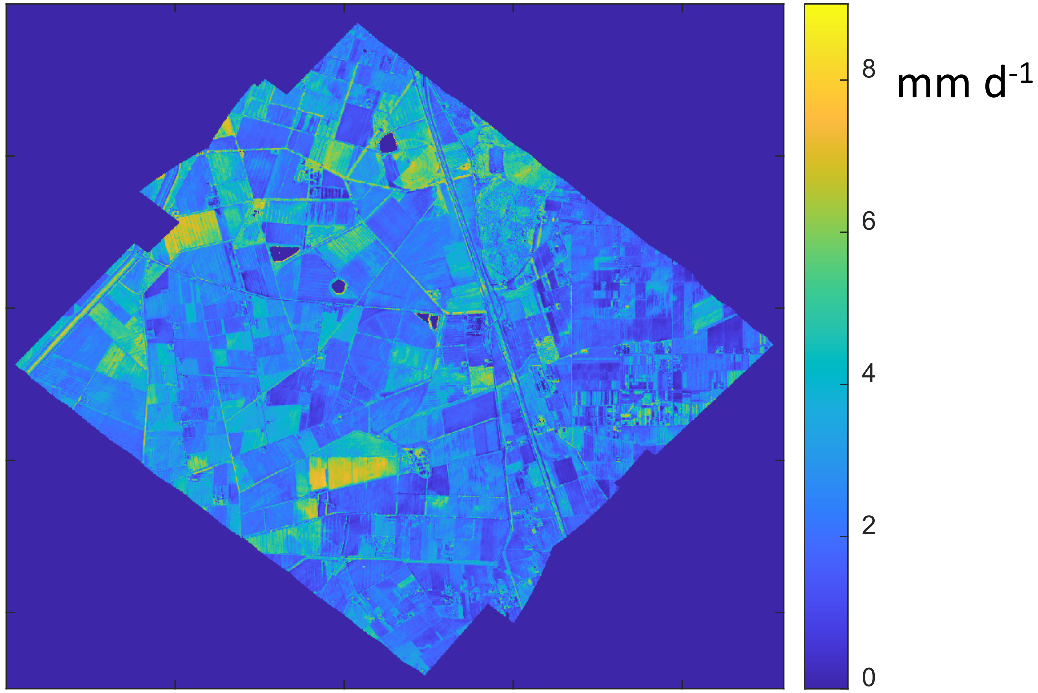
Evapotranspiration map

Average of all the calculations for D2H2

Novice case – average ET =3.4 mm d^{-1}



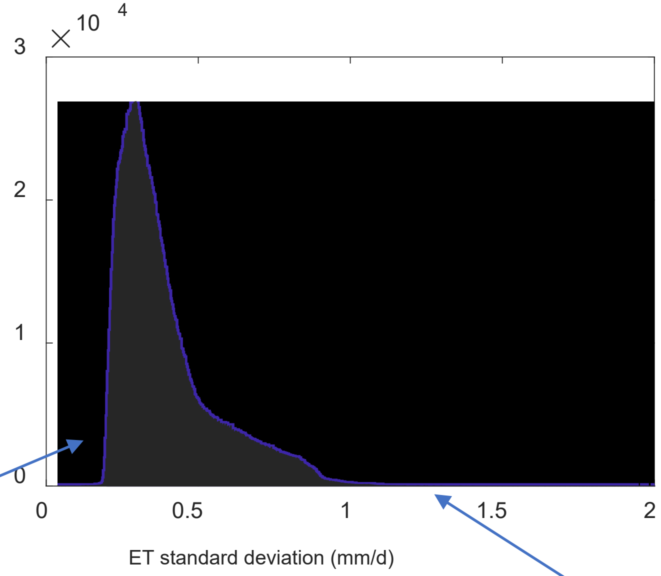
Expert case - average ET =2.8 mm d^{-1}



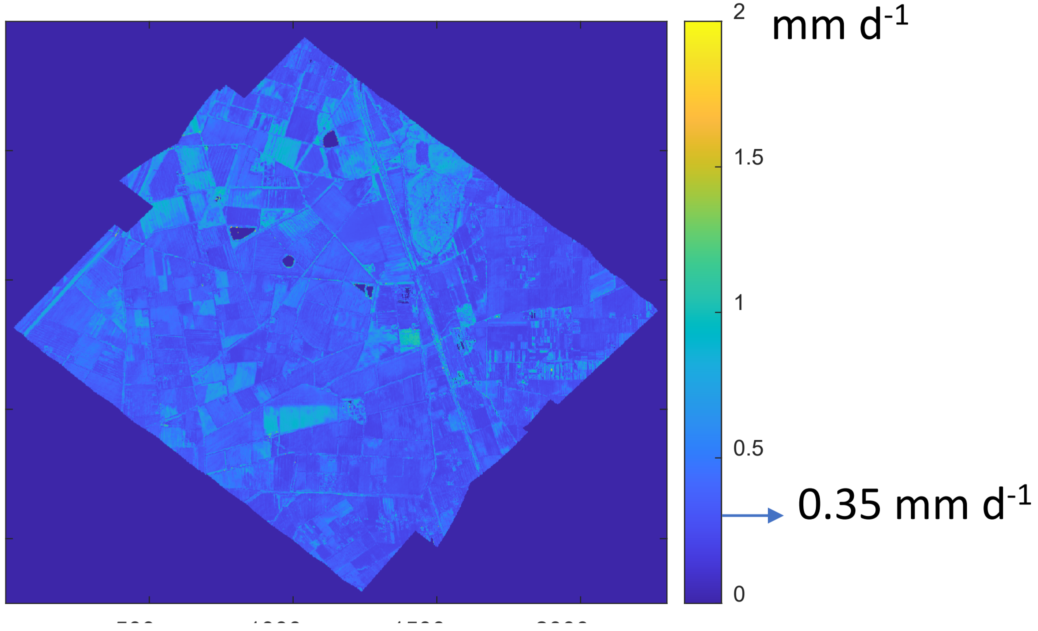
Uncertainty in ET

(standard deviation mm d^{-1})

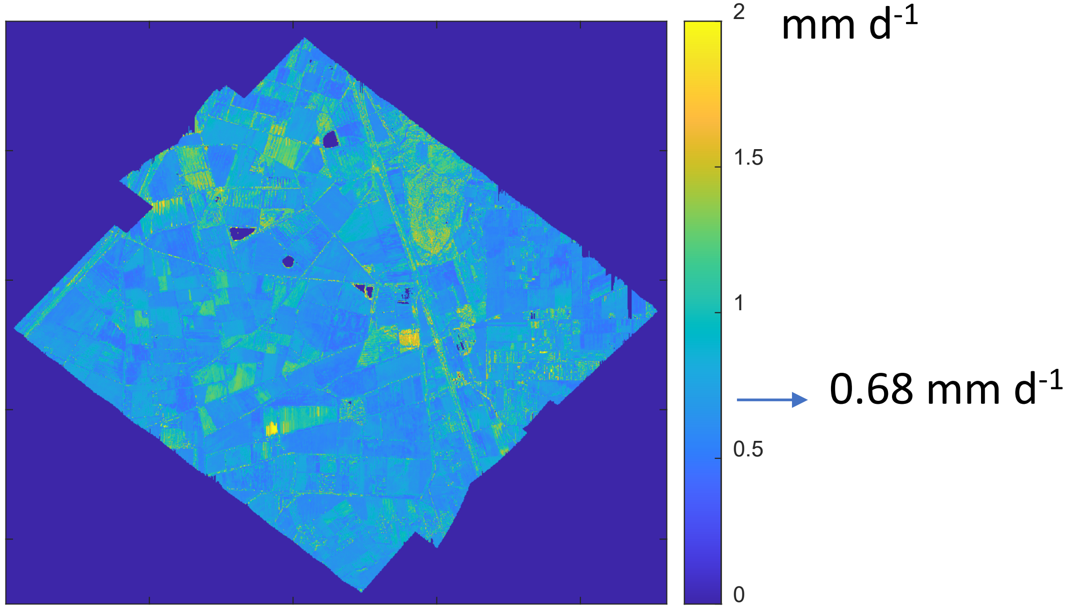
D2H2 case



Expert case



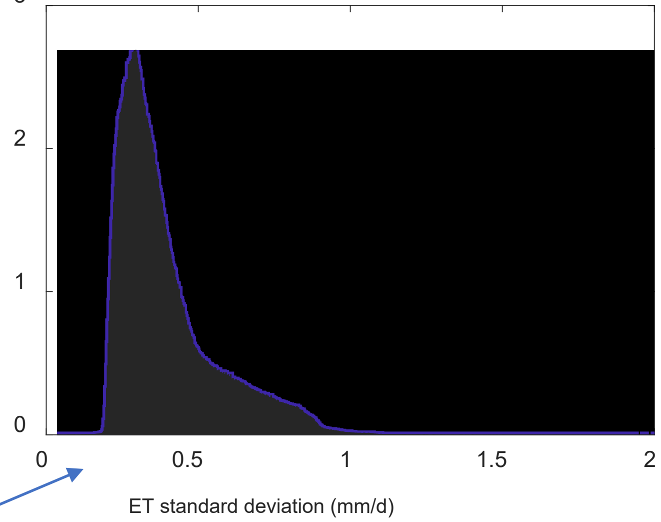
Novice case



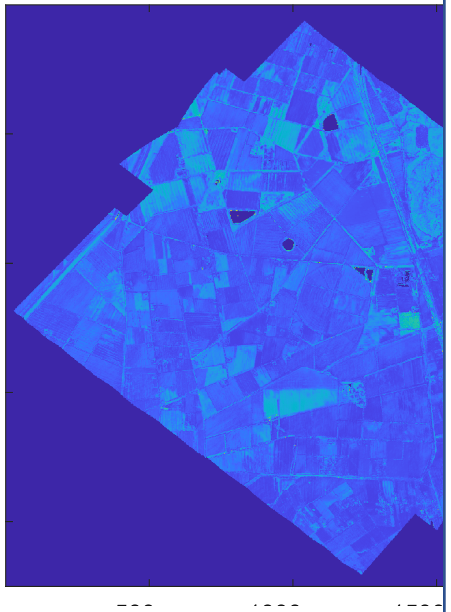
Uncertainty in ET

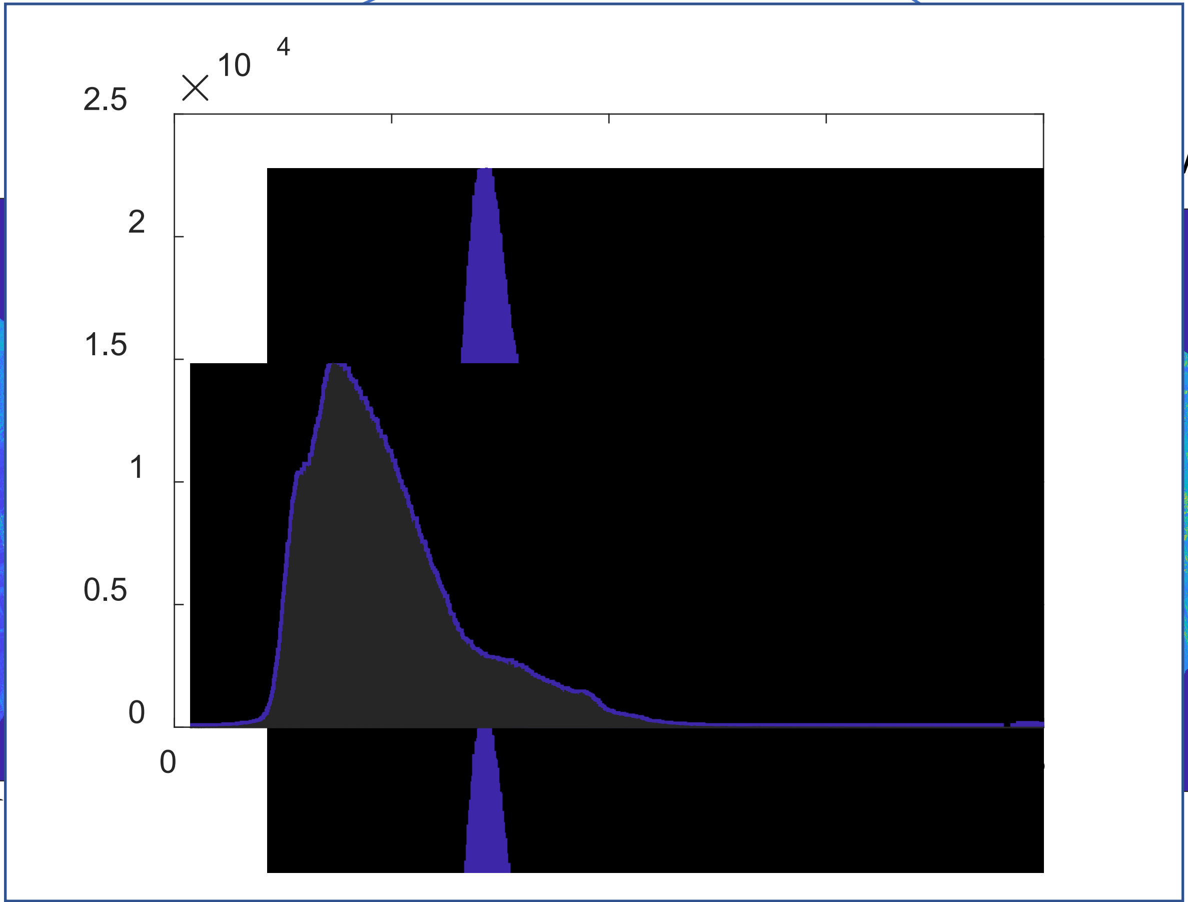
(standard deviation mm d^{-1})

D2H2 case

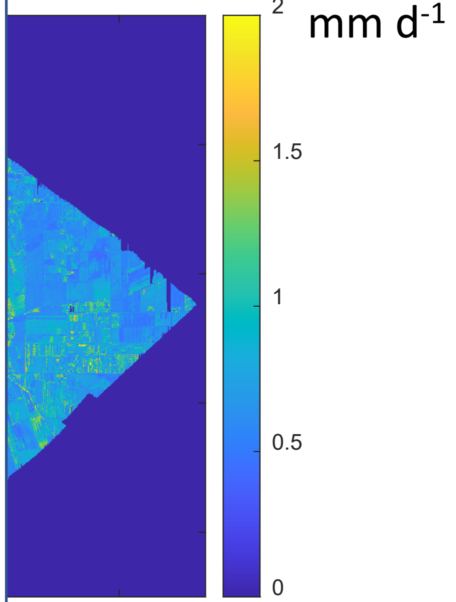


Expert case



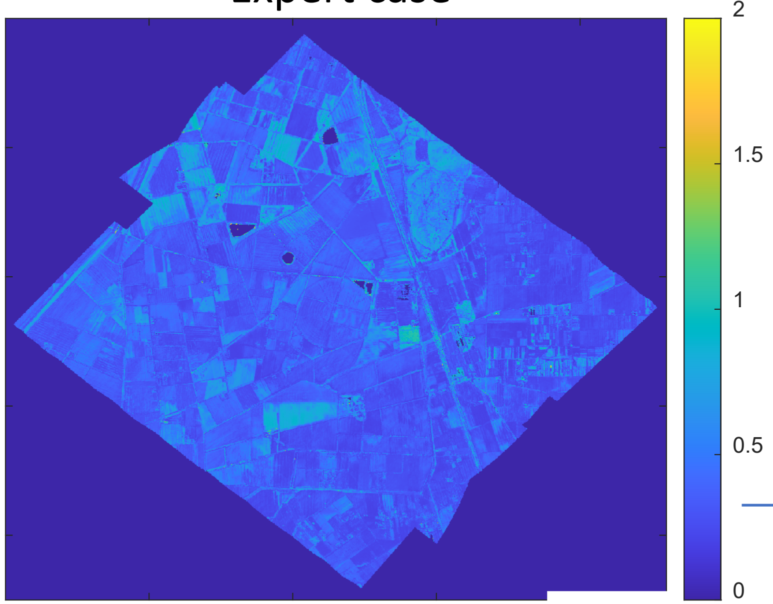


vice case



Uncertainty in ET (mm d^{-1}) D2H2 case

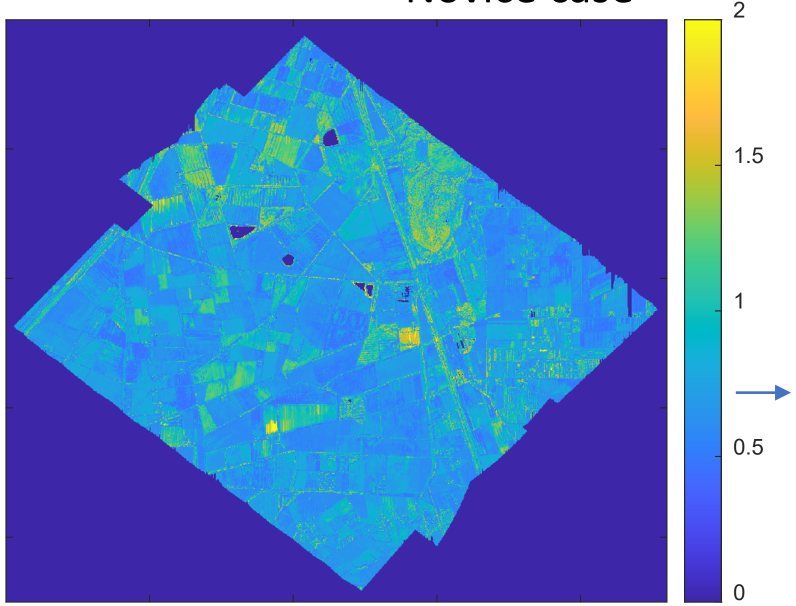
Expert case



(mm d^{-1})

0.35 mm d^{-1}

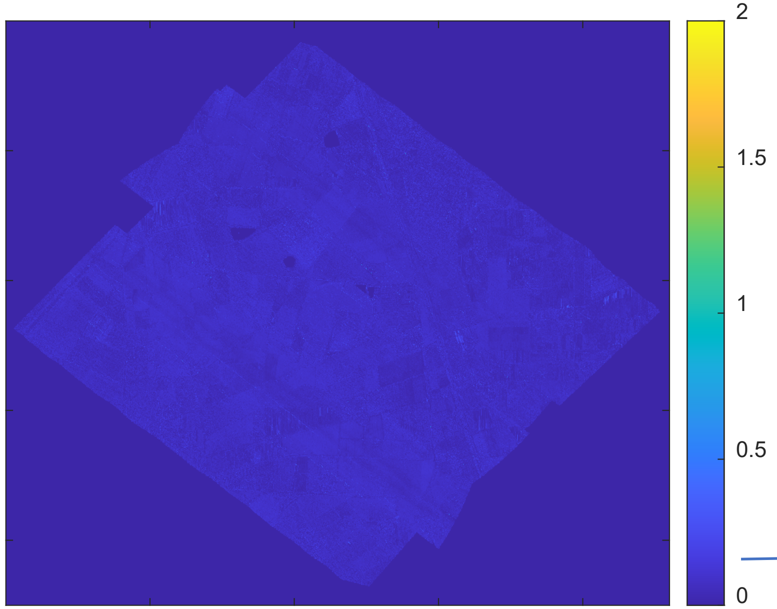
Novice case



(mm d^{-1})

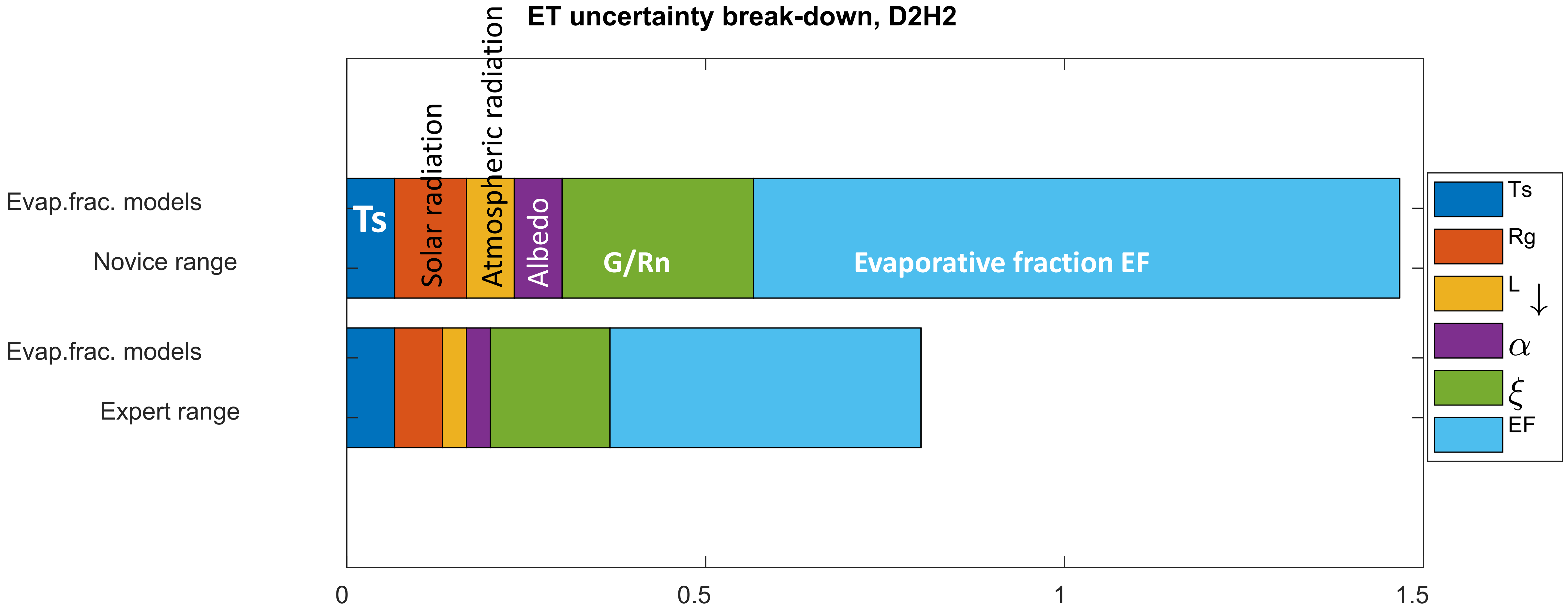
0.68 mm d^{-1}

Uncertainty related to Ts:



(mm d^{-1})

0.07 mm d^{-1}



Cumulated standard deviation (mm d^{-1})

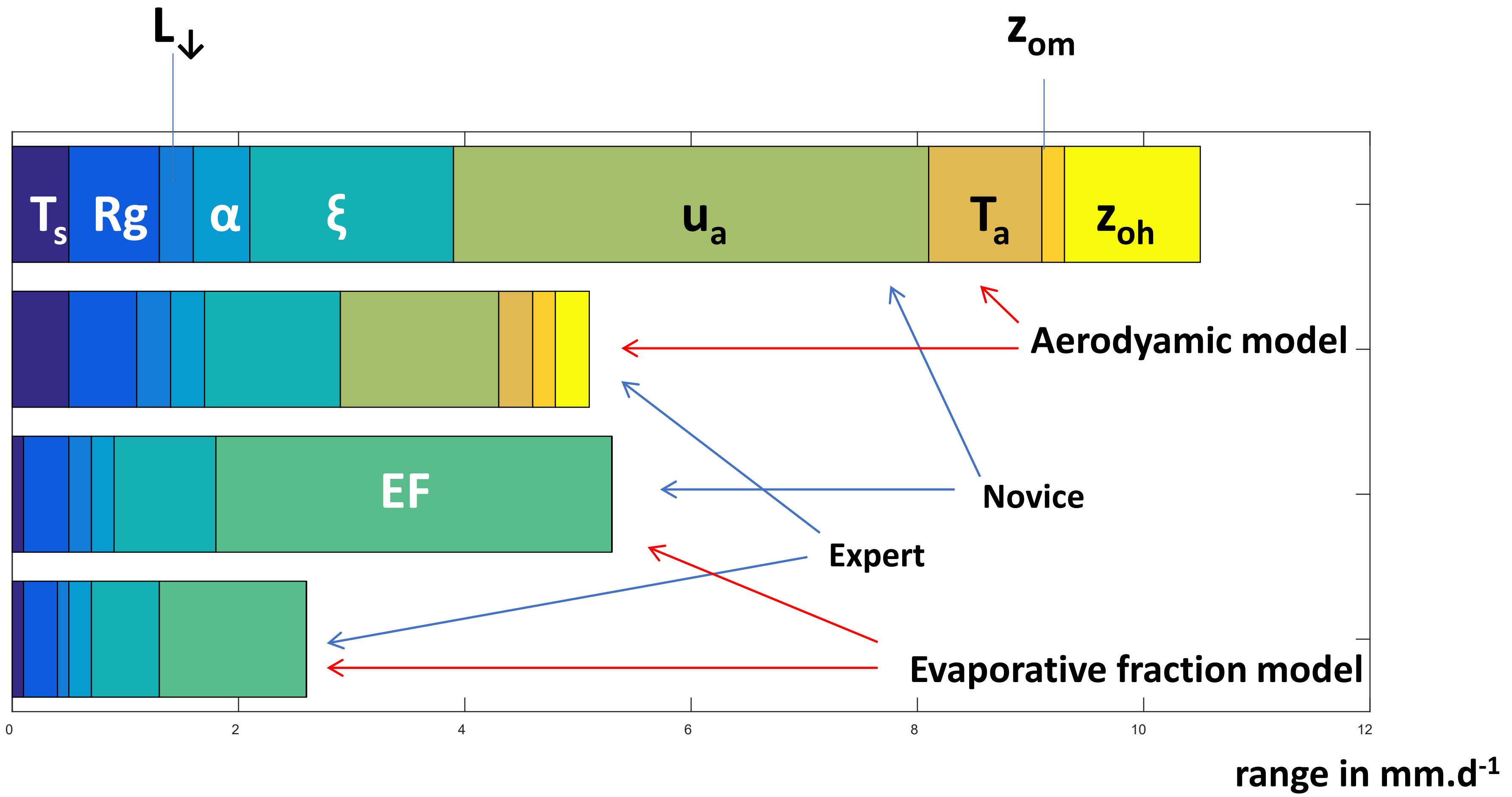
Summary

- uncertainty in ET is large, up to 1.5 $mm.d^{-1}$ (for D2H2 and when expressed as standard deviation)
- uncertainty is significantly lower in the expert case than in the novice case
- ranking of uncertainty sources highlights
  - impact of Ts is low
  - largest impacts: evaporative fraction, G/Rn ratio (**ξ**)
  - model formulations have a larger impact than input data

Perspectives

- work on other situations
- extending to aerodynamic one-source and two source-models (TSEB, SPARSE…)
- transfer to time serie processing (ex. using MODIS data)
- derive an uncertainty algorithm to be used in the TRISHNA data processing for associating uncertainty to ET

Ranking of uncertainty sources



Uncertainty ranking for D2H1 (July 20th morning)