Evapotranspiration mapping from remote sensing data: uncertainties and ensemble estimates based on multimodel – multidata simulations

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(* Previous affectation)

Preparation of the future missions TRISHNA

LSTM @ esa

Context

- ET is a major component of the hydrological cycle, but
  - → in many situations, ET and its evolution are not well known
  - → there is a lot of uncertainties in ET monitoring

- Many models exist, but none looks satisfactory in every situations (season, type of climate, type of surfaces…

  → ensemble modelling

  Ensemble modelling approaches were developed in various field of research (ex. Climate, hydrology, agronomy…) assuming they are providing an optimal or suboptimal solution

- Work done in the frame of TRISHNA and LSTM mission preparations

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
- → time integration
  - - instantaneous measurements
  - - intermittent data (revisit, clouds)

  } → daily values => uncertainties

No consensus on a best model => ensemble averaging considering both models and data sources

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

ET estimate = average of ensemble members

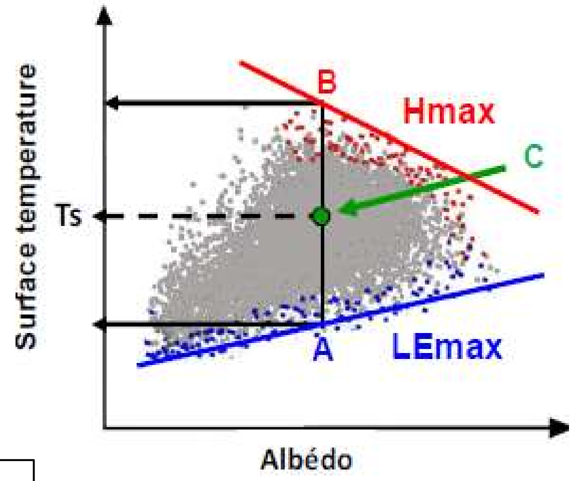
Uncertainty =
standard deviation of ensemble members

Models of Latent Heat Flux (*LE*) [see Lagouarde and Boulet 2016]

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

with *EF* = BC / BA

- *EF* = evaporative fraction <- *Ts* vs. *albedo or NDVI or fraction cover*
- *Rn* = net radiation <- albedo, emissivity, Ts, solar irradiance, atmospheric irradiance
- *G* = ground heat flux <- *Rn, NDVI, fCOVER*



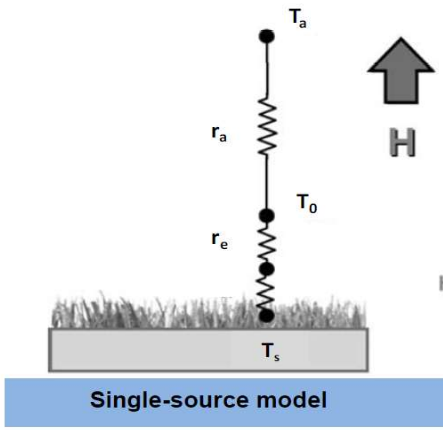
ex: S-SEBI (Roerink et al. 2000)

Upscalling to daily level based on

ET ~ LE X Rgd / Rgi

-> Residual aerodynamic equation: *LE = Rn – H – G*

- *H* = sensible heat flux <- Ts, Ta (air temperature), ua (wind speed), zom, zoh (roughness)

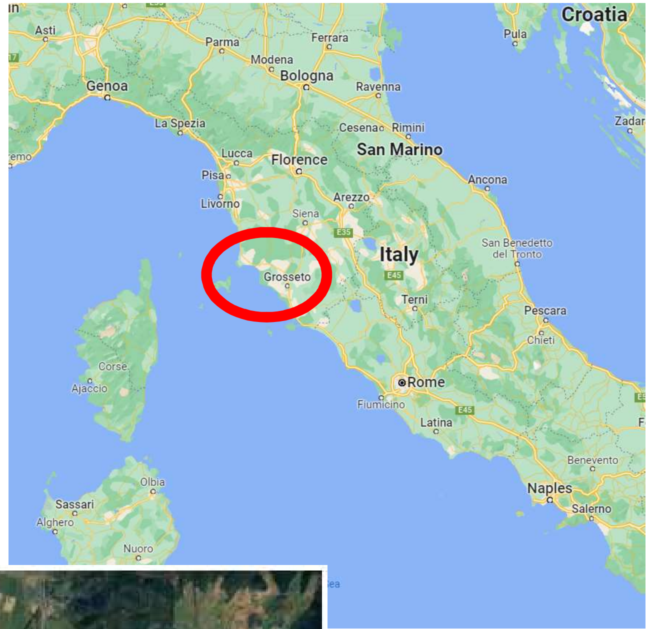


ex: SSEBE (Olioso et al. 2006)

Application:

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

Airborne images in the solar and the thermal domains on two different days



Various sources for input data :

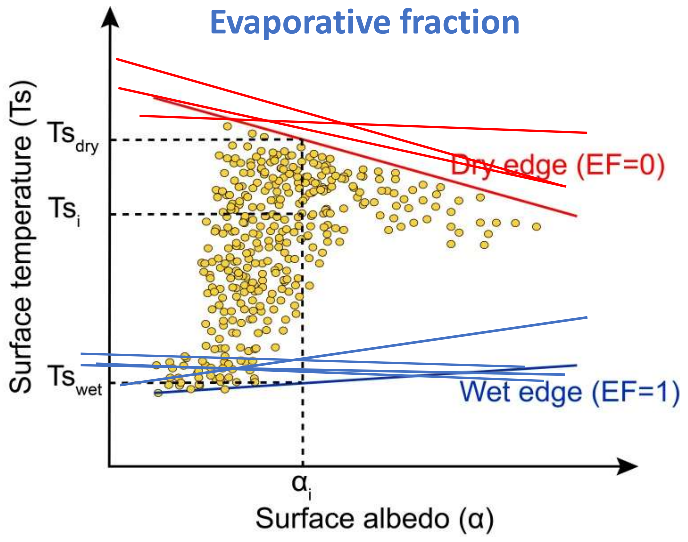
- incident radiations,
- LAI,
- fCOVER,
- surface temperature…

Various « models » for

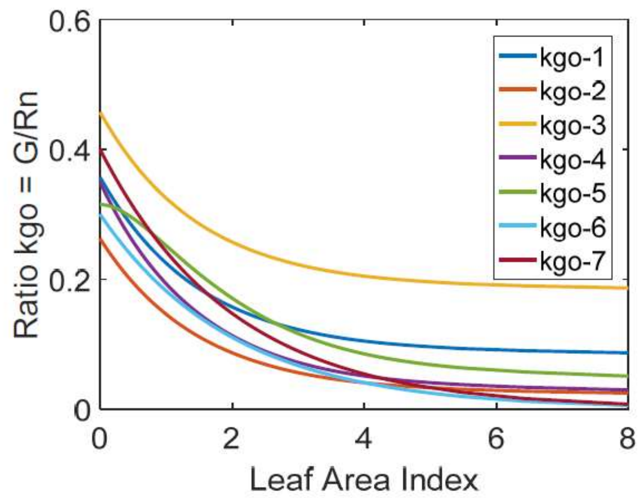
- Ground heat flux
- Evaporative fraction EF
- albedo

Example of variations (=> uncertainties) in data sources and models

Evaporative fraction



Ground heat flux ratio to Rn



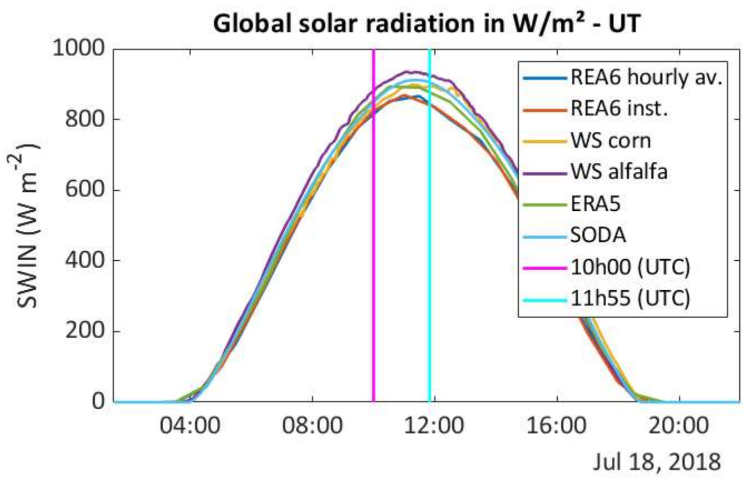
Uncertainty

Novice case -> all available data or models are used

Expert case -> previous knowledge => { some of the data sources and algorithms are dropped

Global uncertainty -> standard deviation of ET (pixel basis) all together, ~400 000 cases (*ET*)

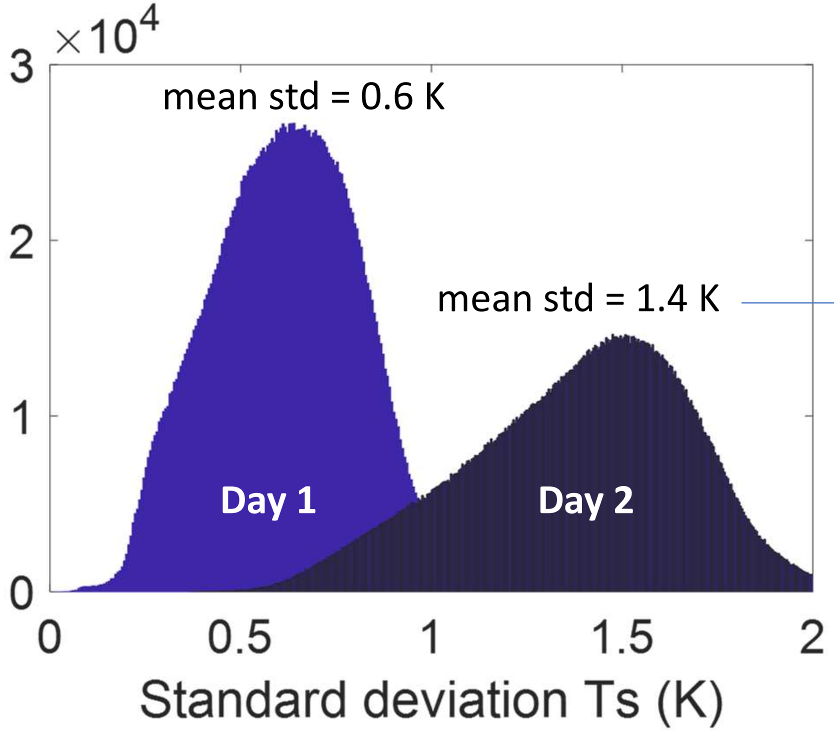
Factor uncertainty -> standard deviation of ET for variations of one factor only



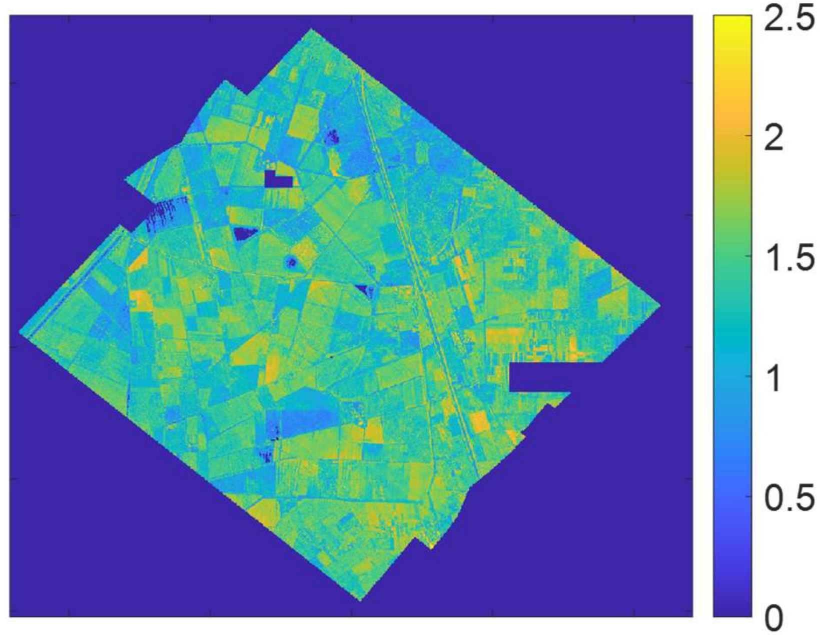
Uncertainty in Ts:

several processings were performed mainly differing in the atmospheric profiles used for the atmospheric corrections

Standard deviation of the 4 Ts maps (at pixel level)



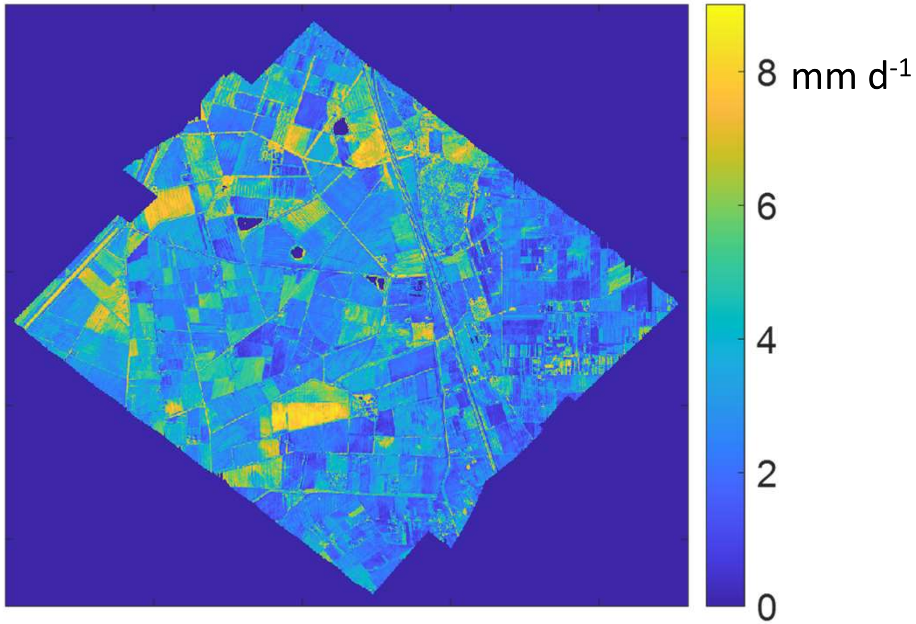
Ts standard deviation map Day 2 (K)



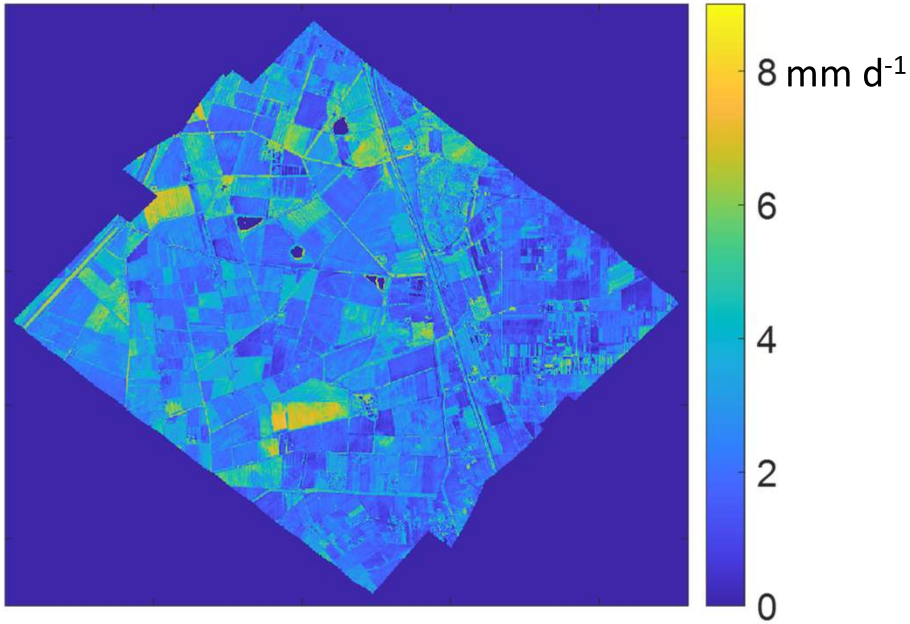
Evapotranspiration map

Average of all the calculations for Day 2

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



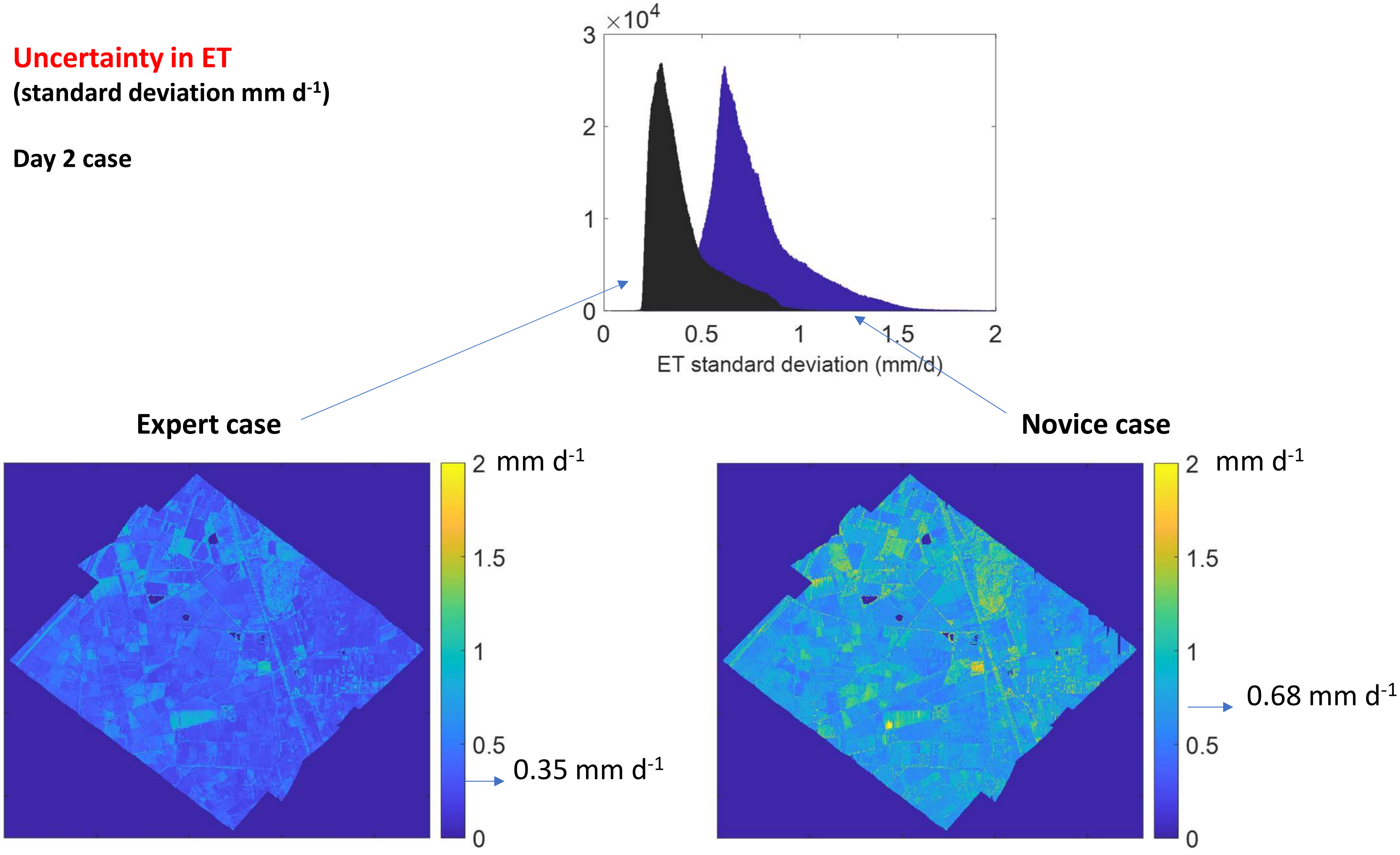
Expert case - average ET =2.8 mm d^{-1}



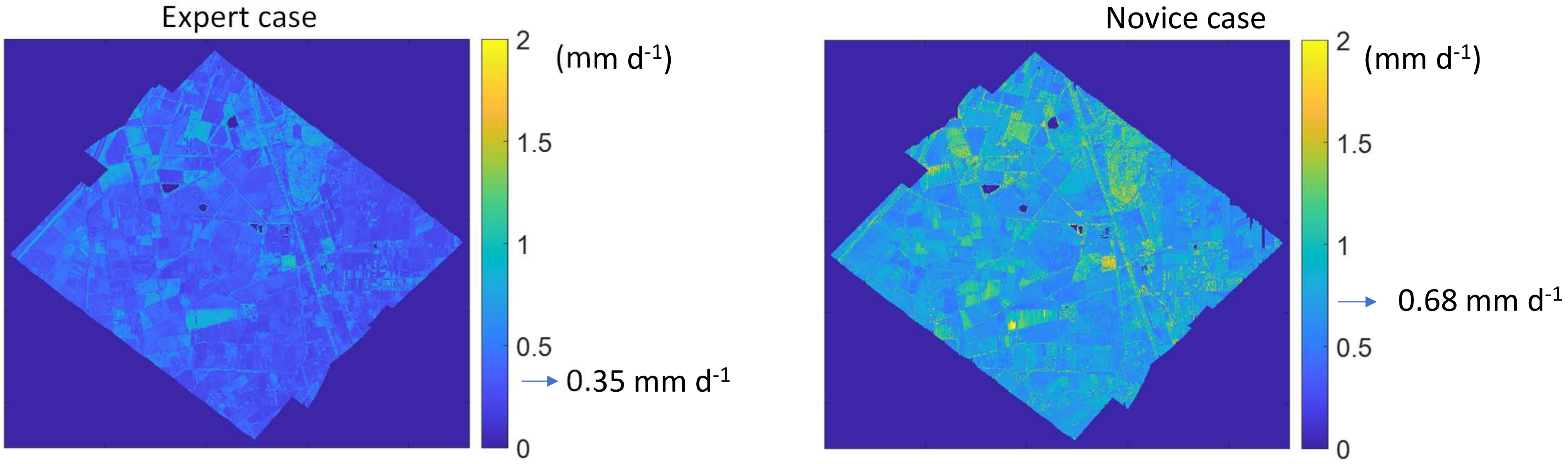
Uncertainty in ET

(standard deviation mm d^{-1})

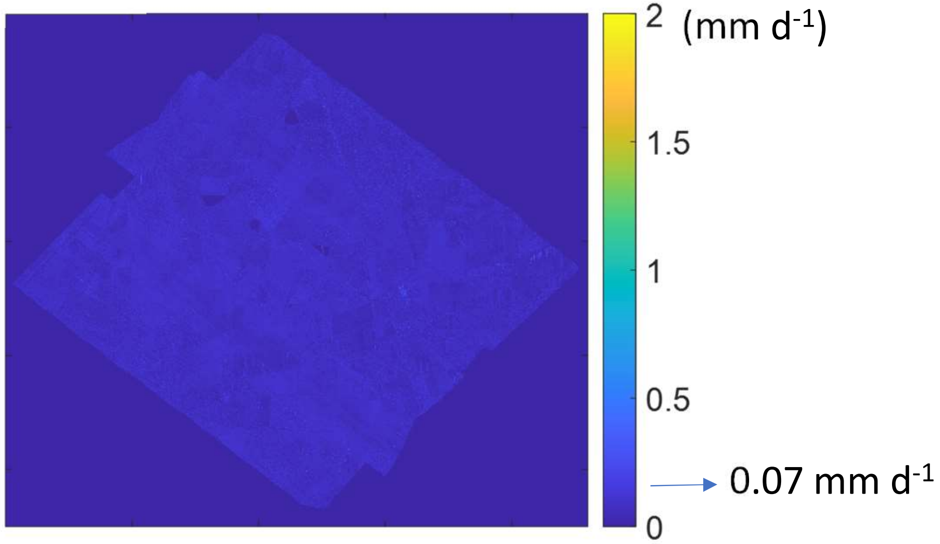
Day 2 case

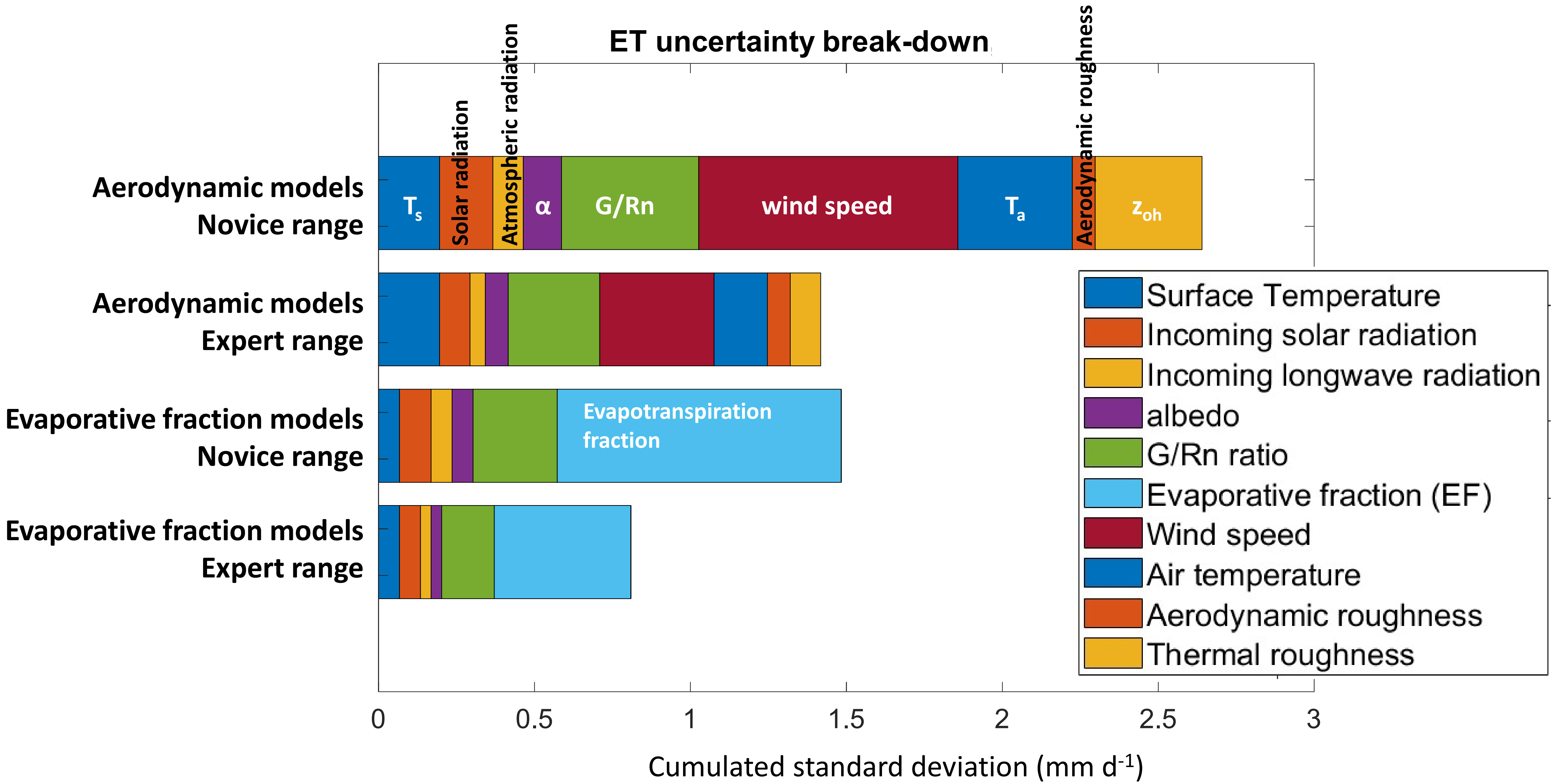


Uncertainty in ET (mm d^{-1}) Day 2 case

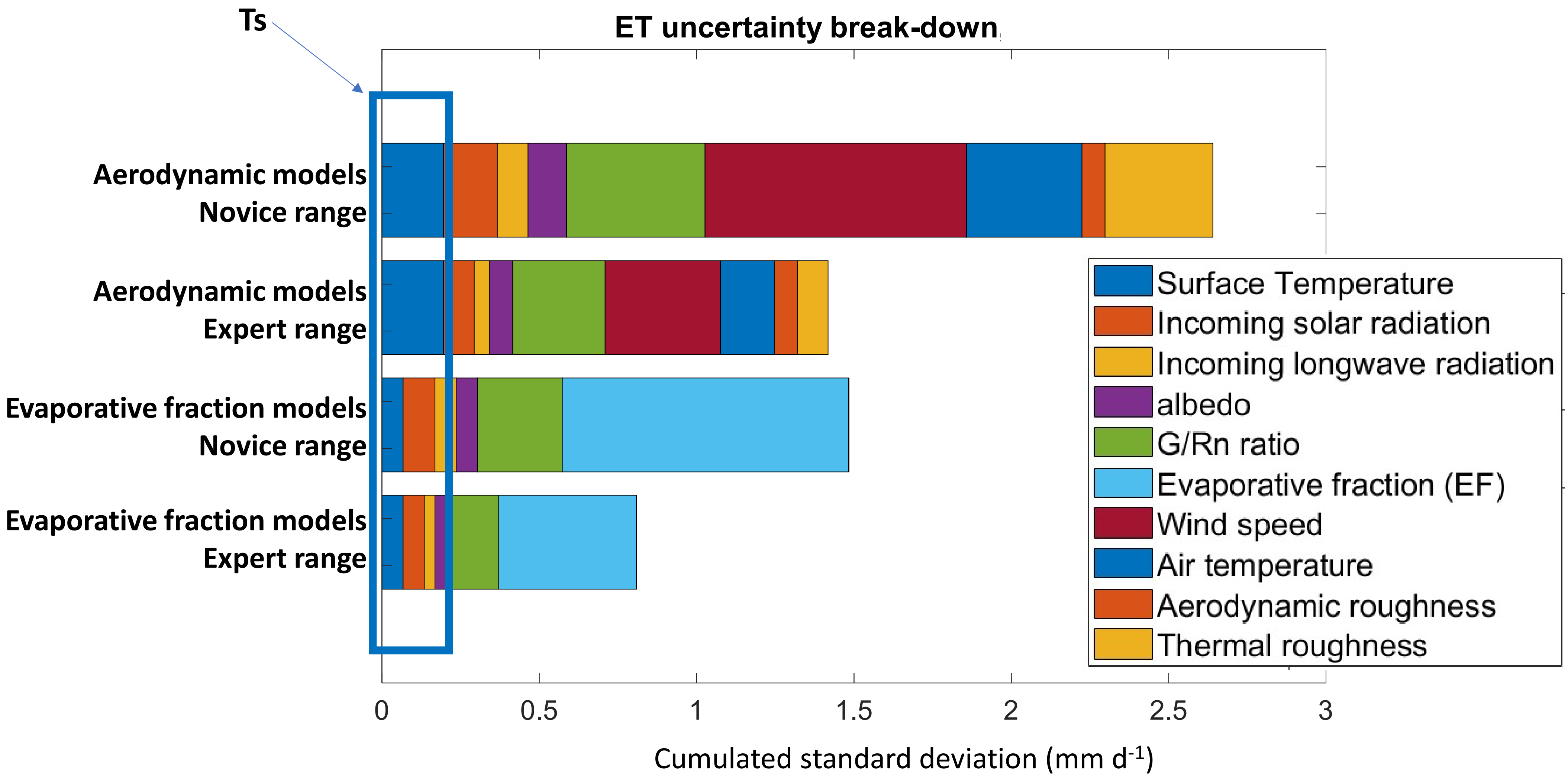


Uncertainty related to Ts:





ET uncertainty break-down
Aerodynamic models
Novice range
Aerodynamic models
Expert range
Evaporative fraction models
Novice range
Evaporative fraction models
Expert range
Ts
Solar radiation
Atmospheric radiation
α
G/Rn
wind speed
Ta
Aerodynamic roughness
zoh
Evapotranspiration fraction
Surface Temperature
Incoming solar radiation
Incoming longwave radiation
albedo
G/Rn ratio
Evaporative fraction (EF)
Wind speed
Air temperature
Aerodynamic roughness
Thermal roughness
0
0.5
1
1.5
2
2.5
3
Cumulated standard deviation (mm d-1)


Ts
ET uncertainty break-down
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Novice range
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Expert range
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Surface Temperature
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Incoming longwave radiation
albedo
G/Rn ratio
Evaporative fraction (EF)
Wind speed
Air temperature
Aerodynamic roughness
Thermal roughness
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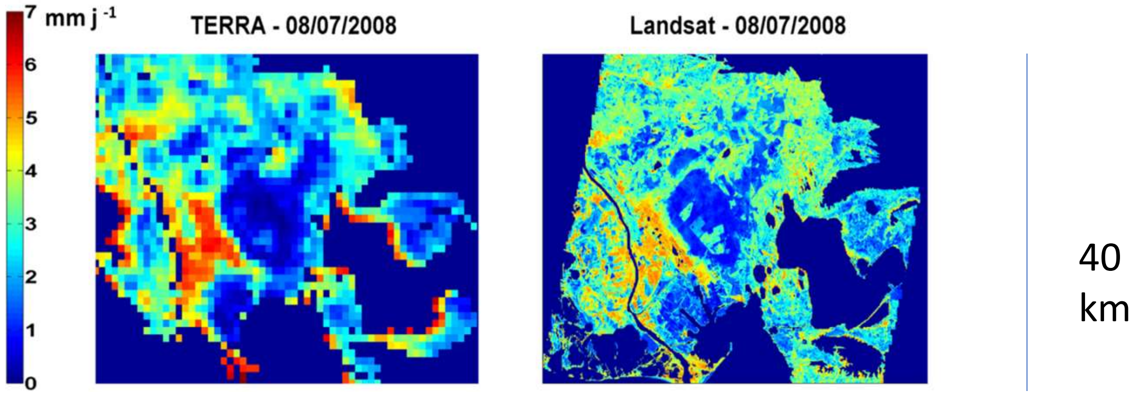
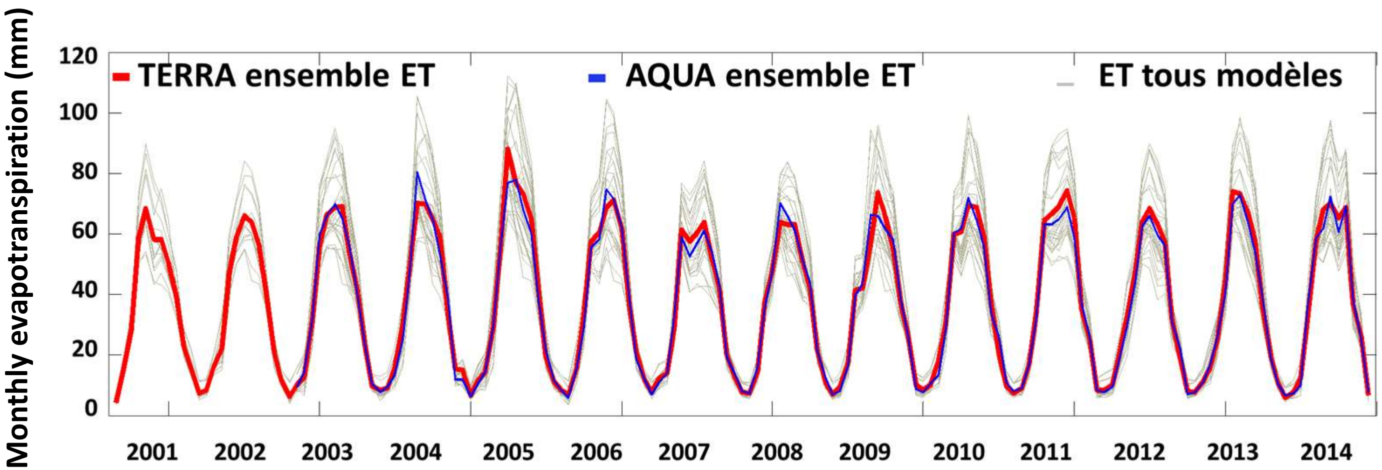
0.5
1
1.5
2
2.5
3
Cumulated standard deviation (mm d-1)

Applications of EVASPA to the Crau area

EVASPA is an implementation of the method that will be used for the level 2 ET product for TRISHNA (together with the STIC model (Mallick et al.))



Monthly ET obtained over the Crau aquifer (600 km^2) with the evaporative fraction models for MODIS TERRA and AQUA data :



Summary

Ensemble modelling applied to multi-data source – multi-model (or algorithm) may be used for:

- **monitoring ET**
- **providing uncertainty in the estimates**

  (however this uncertainty is only epistemic and does not include estimation errors)
- **providing information on the main uncertainty factors:**
  - in all analysed cases, surface temperature was not the main limitation in ET estimations
  - for contextual models, the main sources of uncertainty concern algorithm (EF and ground heat flux)
  - for other models, including aerodynamic equations, meteorological forcing of wind speed and air temperature have also a strong impact

The EVASPA algorithm is a simple algorithm that will be the basis for implementing ET products in the frame of the TRISHNA program