Evapotranspiration from canopy LST distribution: forward & inverse Surface Energy Budget models

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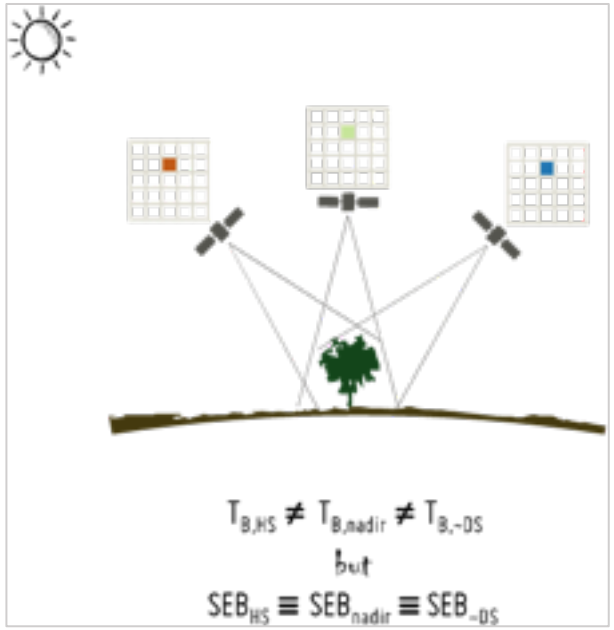
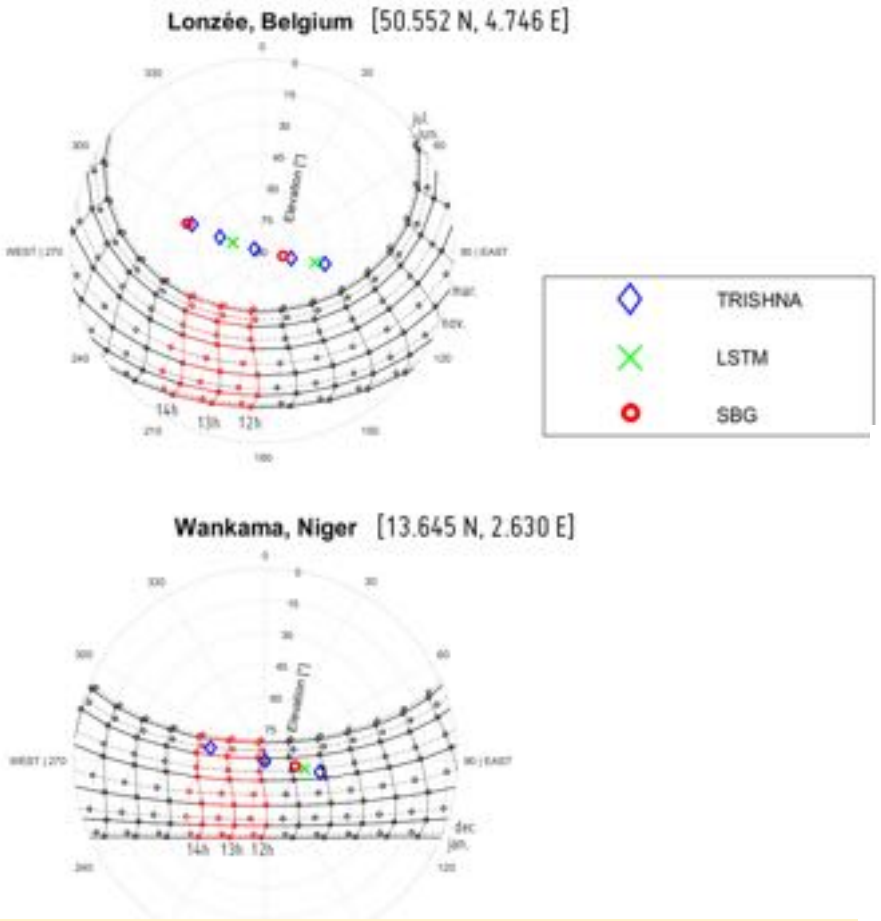
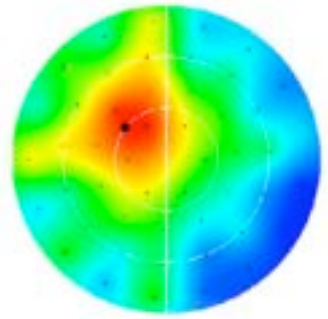
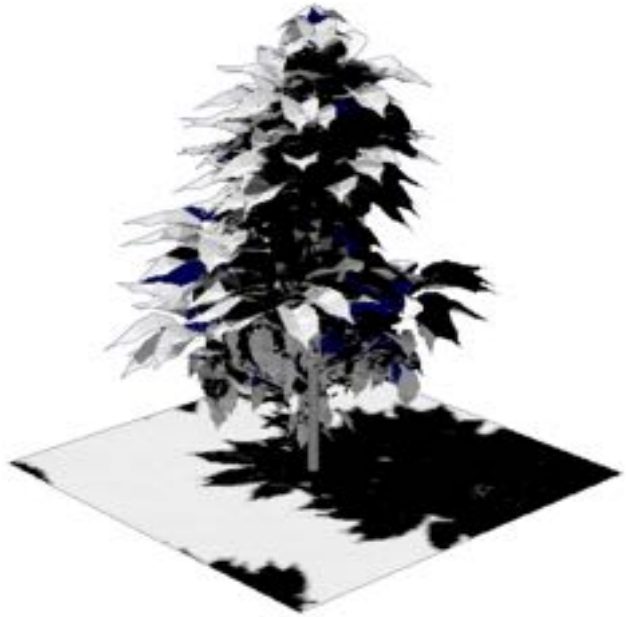
LST will be observed over various view angles







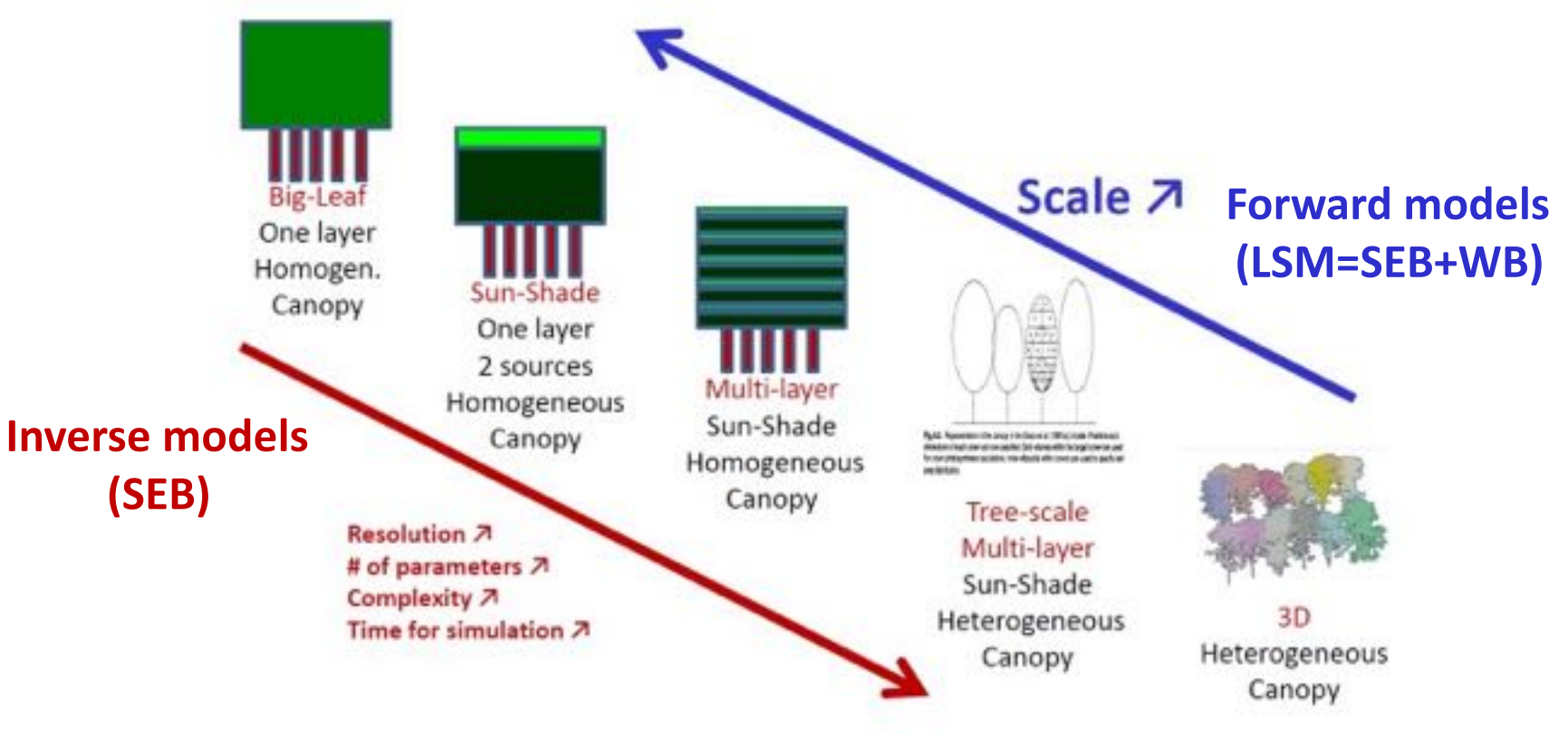


Main question of the talk:

Can we relate the Surface Energy Budget formulation (including latent heat/evapotranspiration) to the Sun-Target-Sensor viewing geometry ?

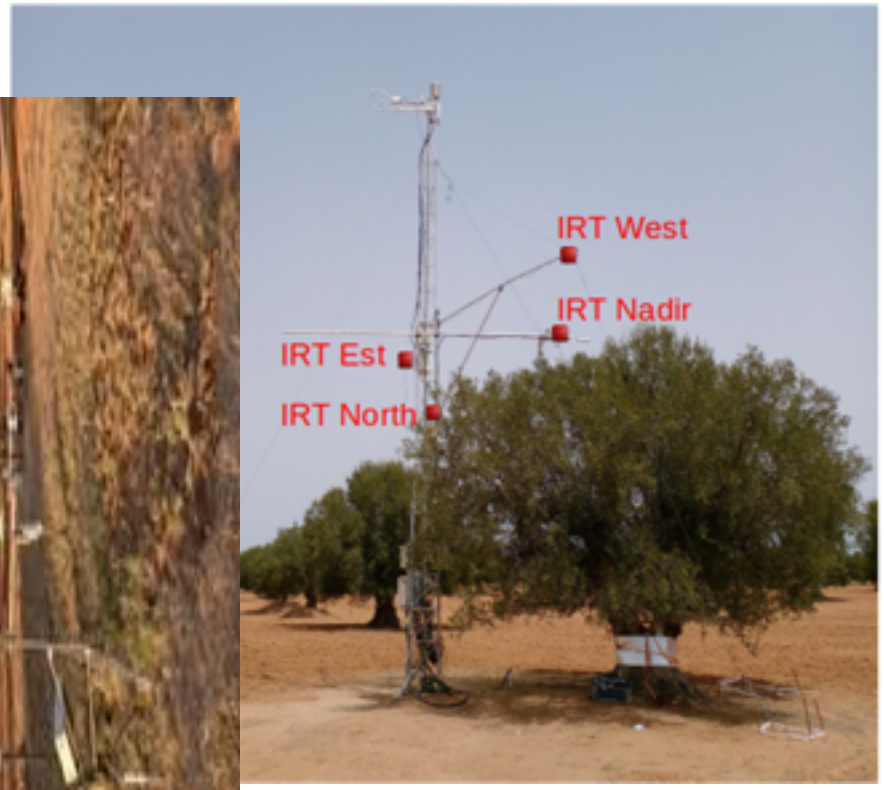
LSM (SEB+Water Budget, forward) & SEB (inverse)

Land Surface Model: Data Assimilation of LST (main target: monitoring plant health; adhoc for rainfed agroecosystems)
Surface Energy Budget: LST as main input (main target: monitoring plant water stress; adhoc for irrigation scheduling)



DART 3D RTM Vis>TIR

FORWARD MODE: isolated rainfed olive tree (Tunisia)



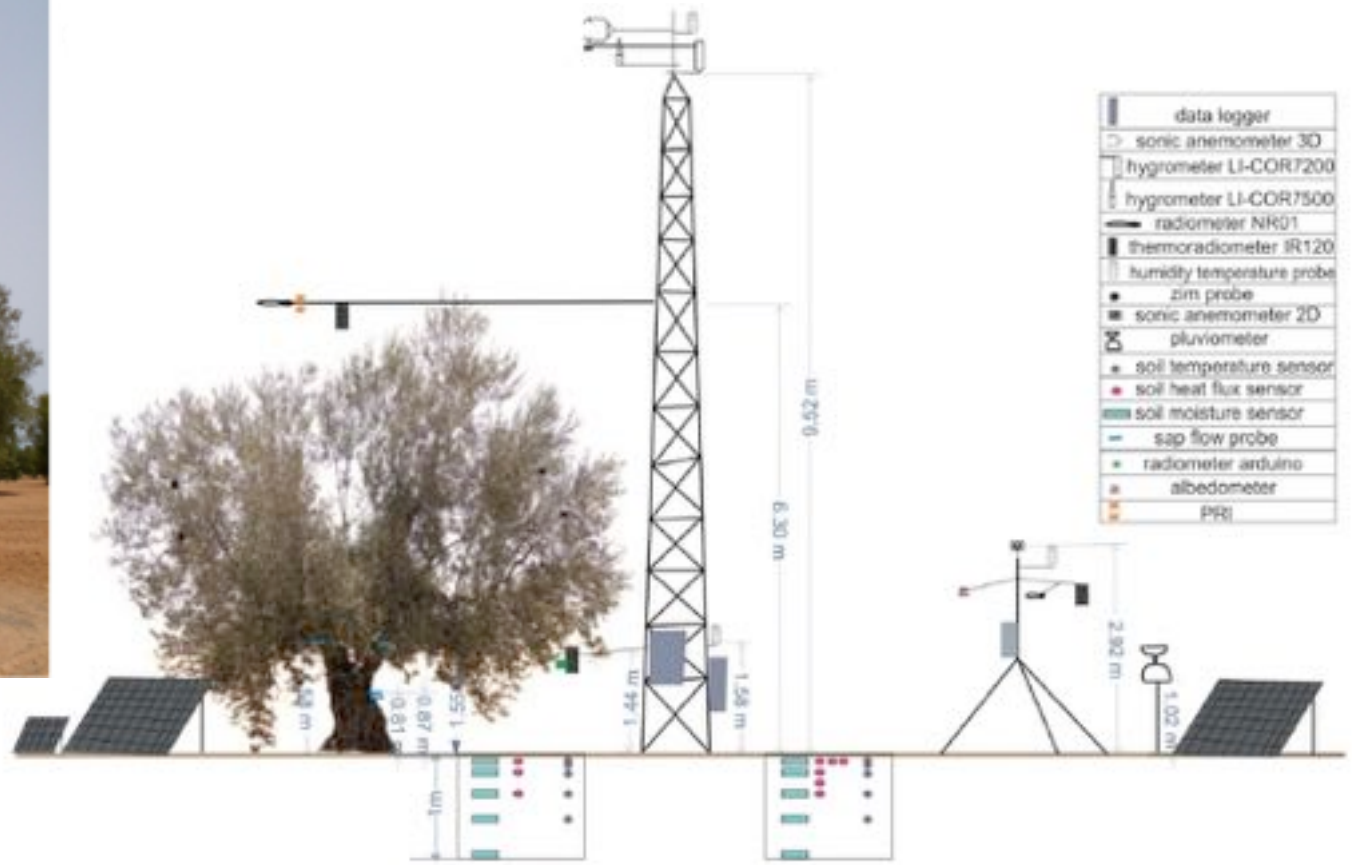
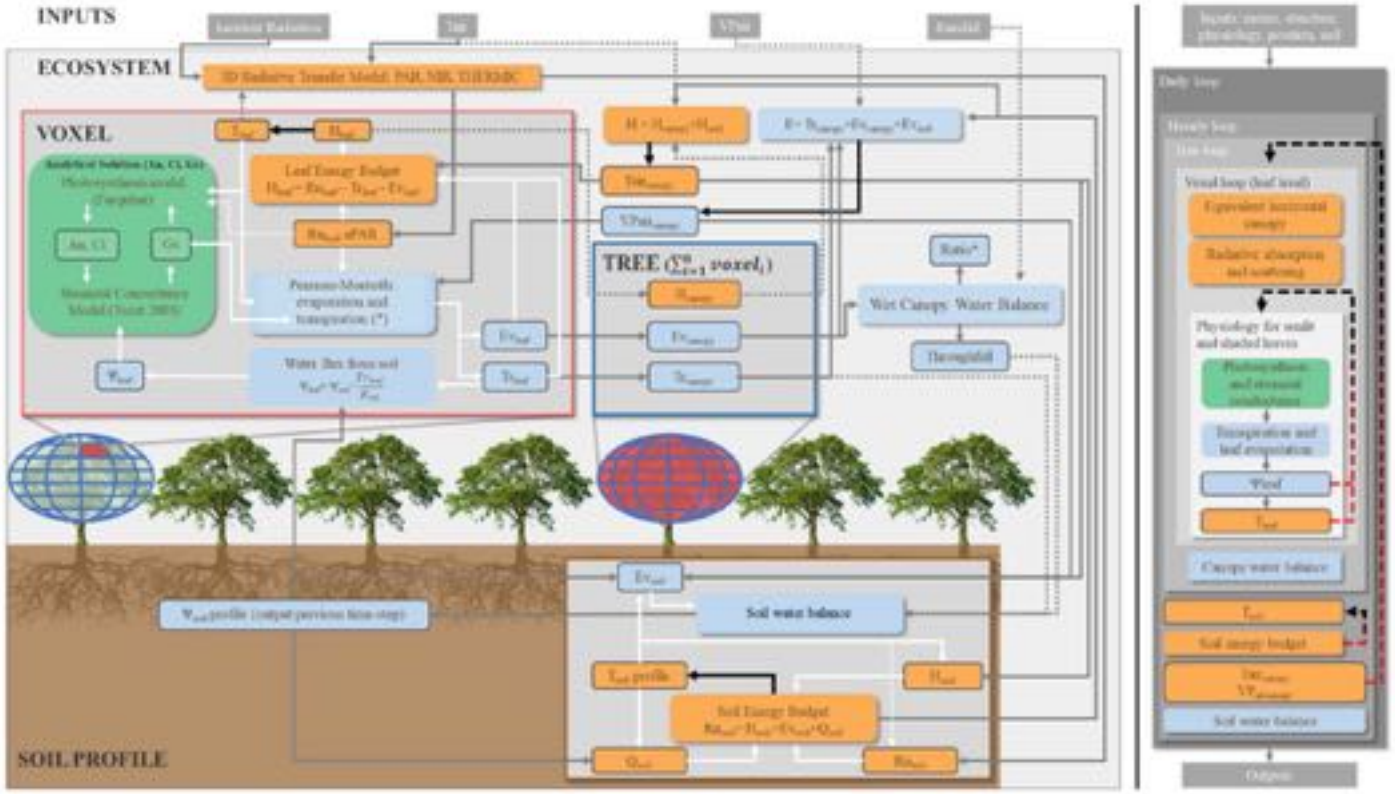
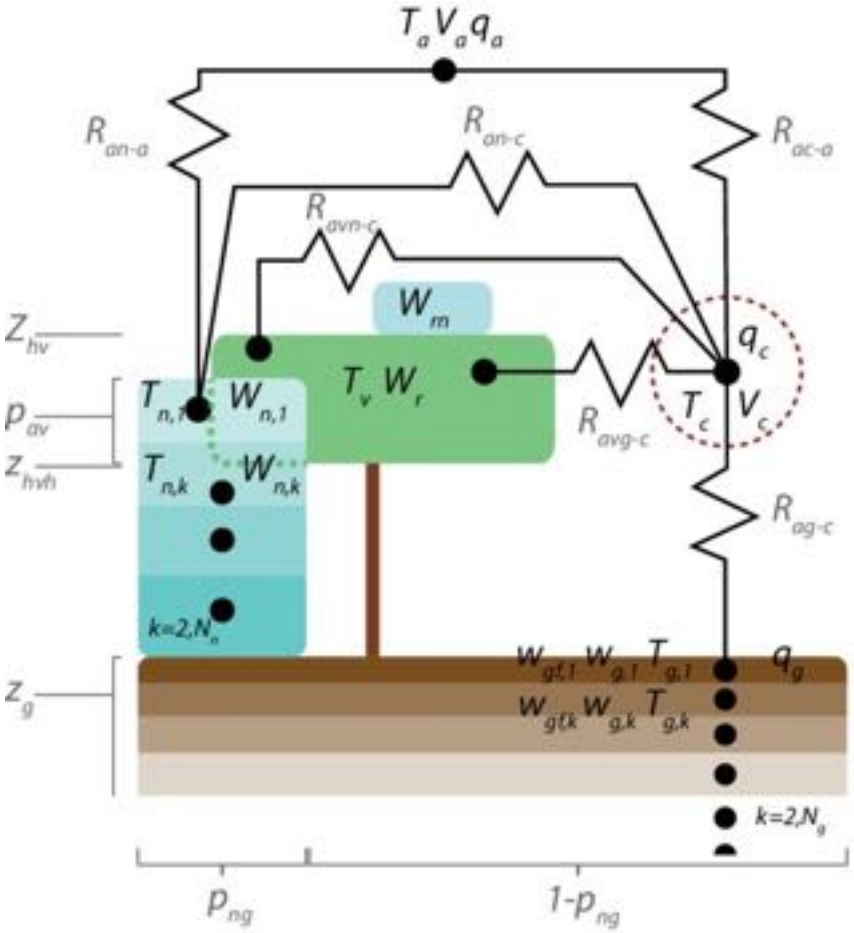


Fig. 1. Schematic of the study area and the site instrumentation.

2 Land Surface Models: 1D and 3D canopies

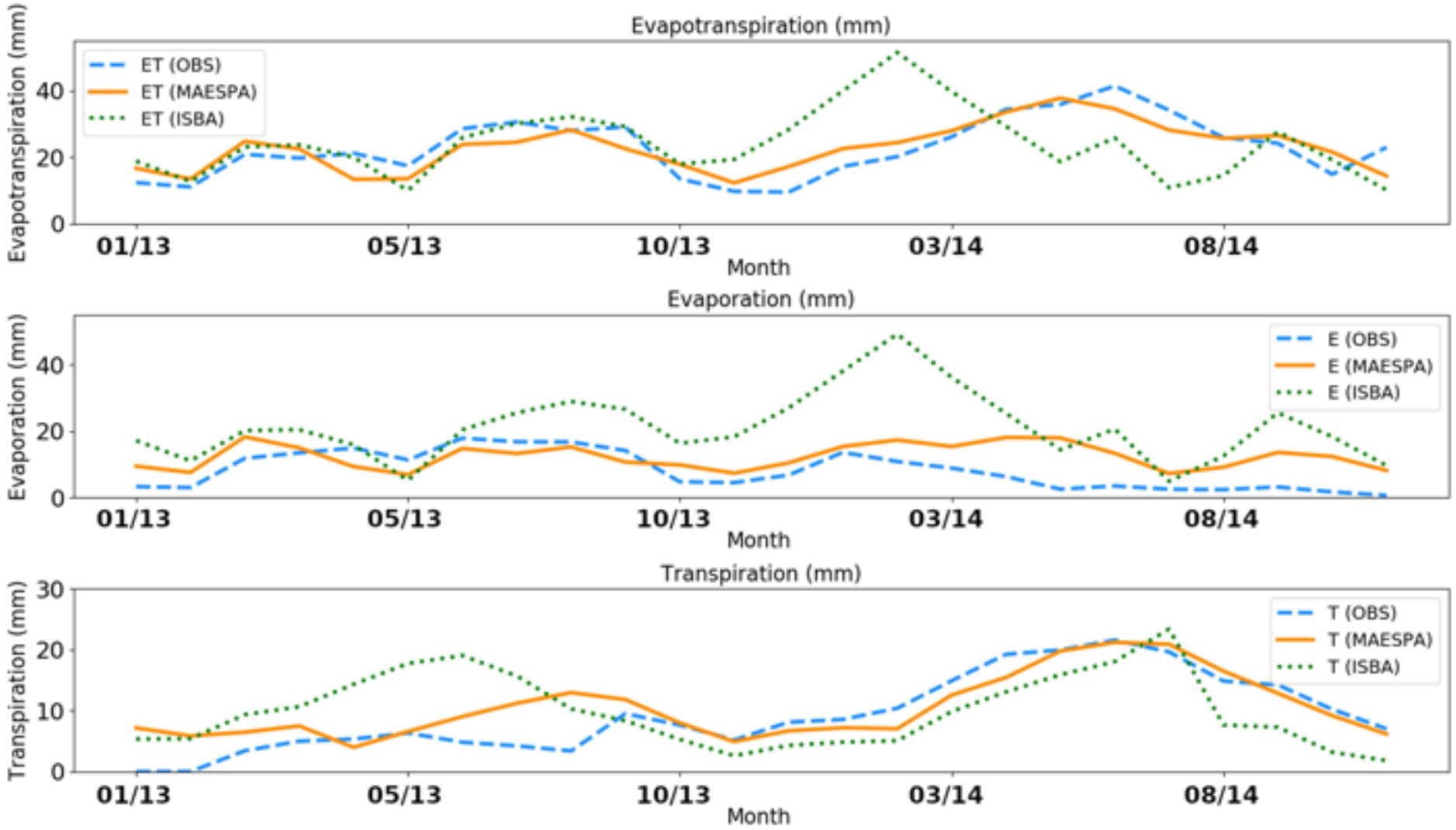


MAESPA LSM with a 3D canopy SEB module

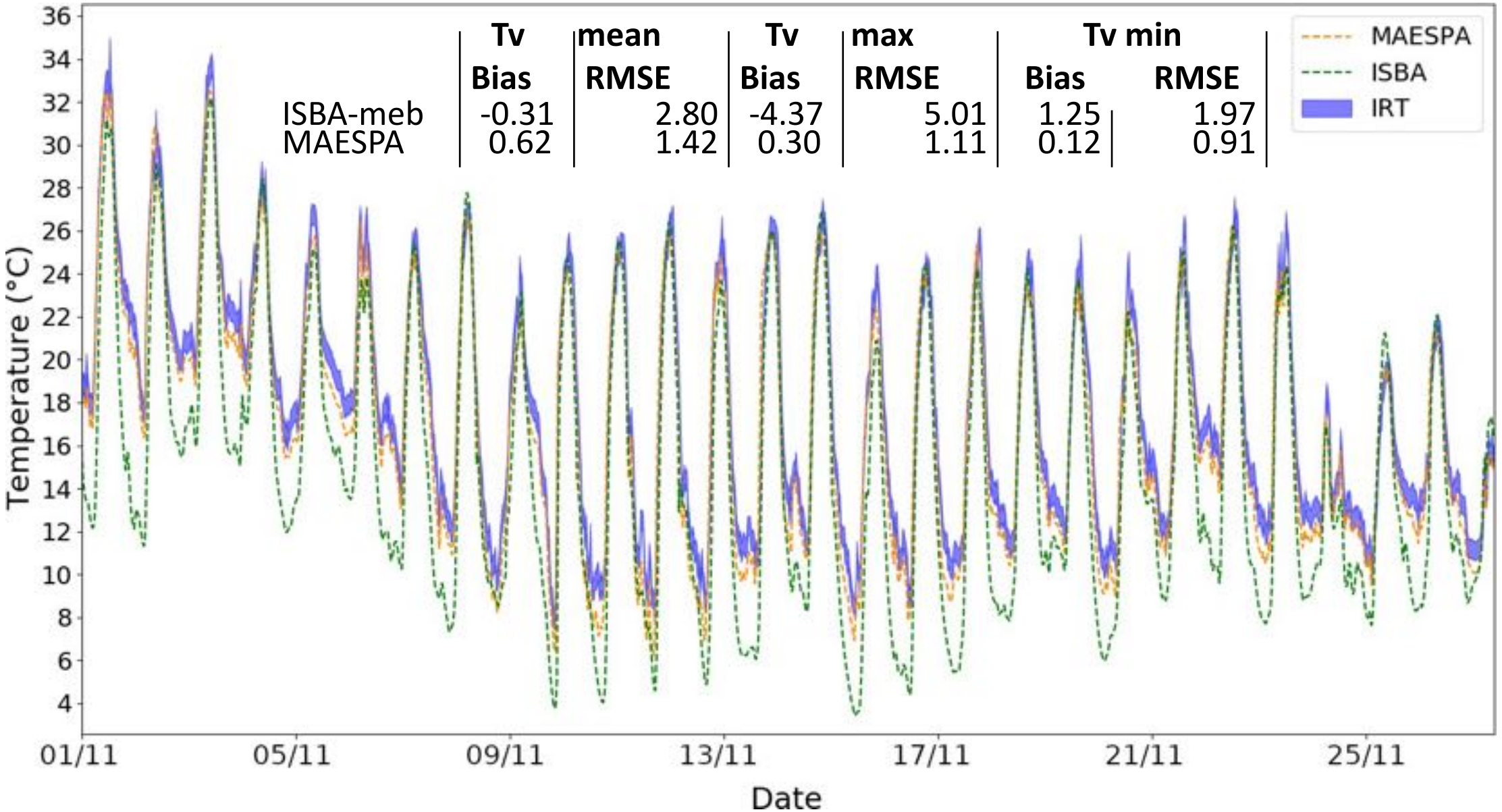


ISBA LSM with its two-source interface

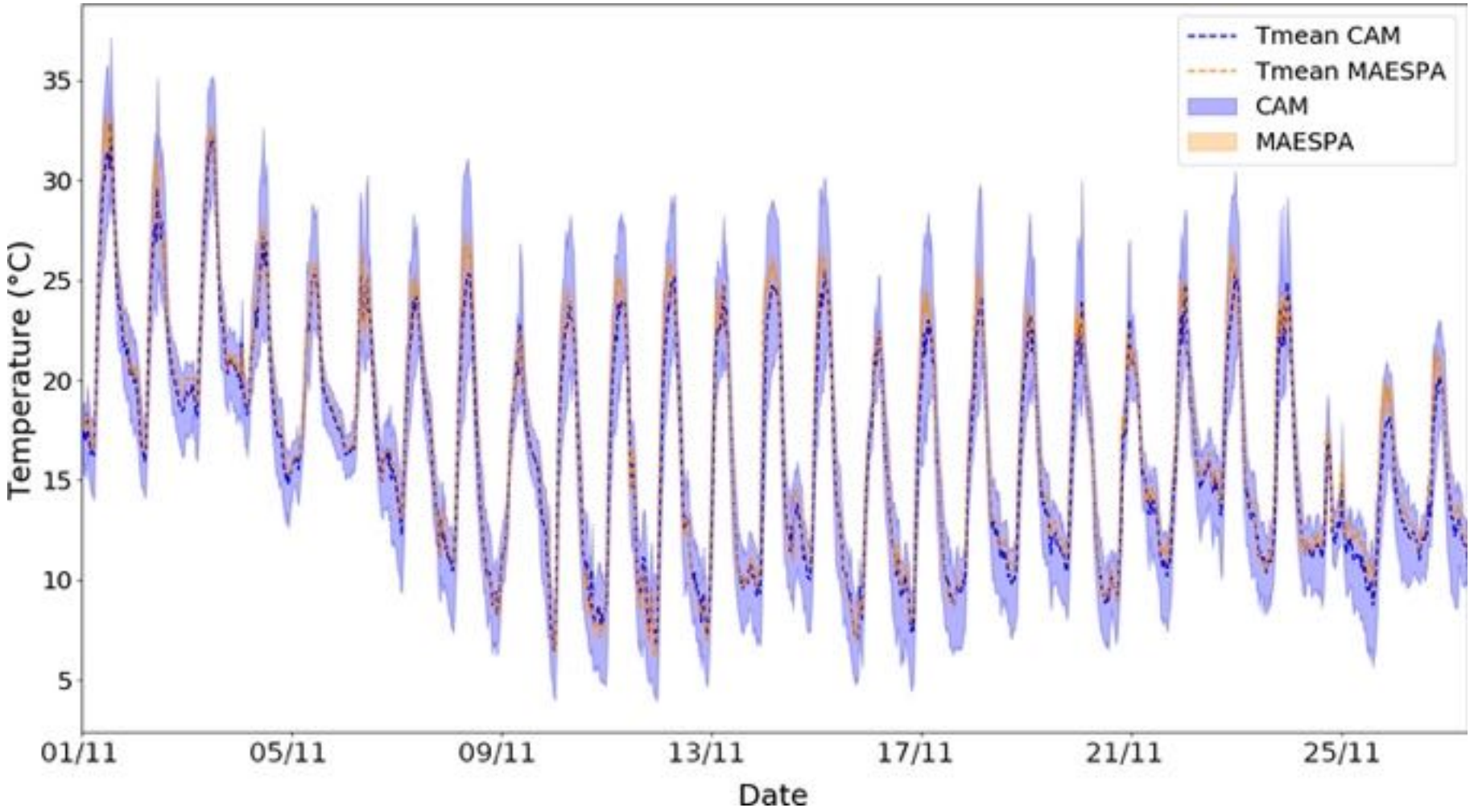
Performance of MAESPA and ISBA models for total and component (evaporation, transpiration) fluxes



Average canopy temperature



Discrepancy between the range of canopy temperatures from MAESPA and those observed by the TIR cameras



INVERSE MODE: LST min/max retrieved from SEB model

Sun direction:
zenith, azimuth

View direction:
Zenith : 0-90;
Azimuth : 0-360

- *Row geometry;*
- *canopy variables;*
- *elemental temps.*

reconstruction of T_B

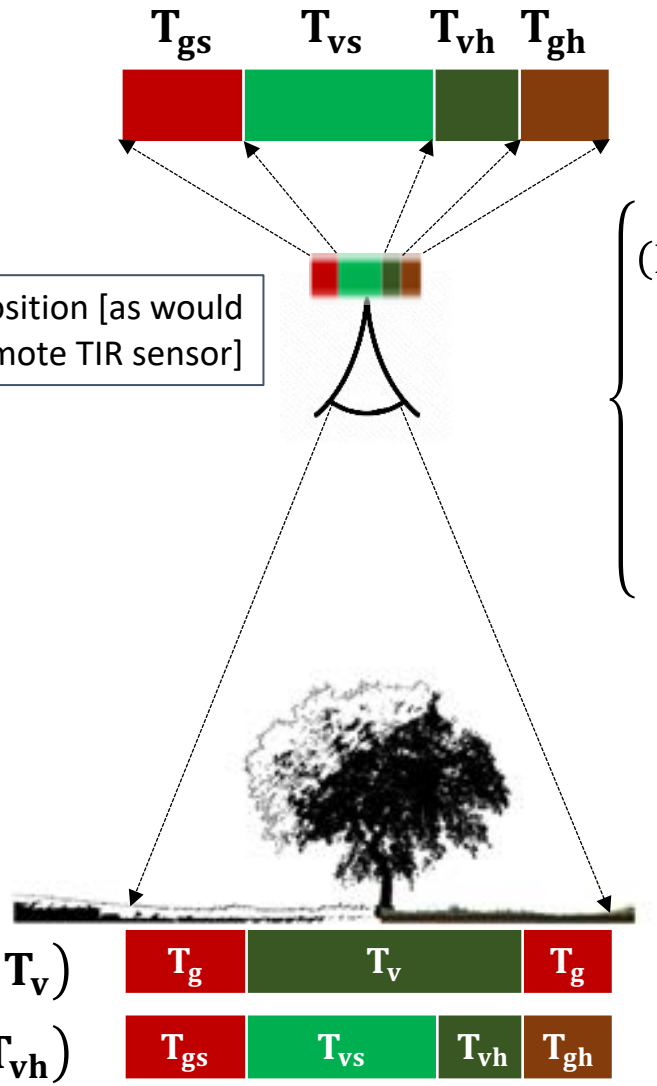
Illum./shd. Soil/vegetation contribution coefficients, …
UFR97, DART

"directional surface temp." → SPARSE | SPARSE4 [LE, H, Rn-G, …]

① ID1 observing the 'sunlit' soil
② ID2 viewing the 'shaded' veg.
③ ID3 observing the 'sunlit' veg.

LIAISE Verdu drip irrigated vineyard (Spain)

2 (SPARSE) vs 4 (SPARSE4) source SEB retrieval



Hypothetical pixel composition [as would be captured by a remote TIR sensor]

g,v – ground, vegetation
s,h – sunlit, shaded

$$\begin{cases} (R_n - G) - (H + \lambda E) = \sum_{xx} R_{n,xx}(1- \xi) - (H_{xx} + \lambda E_{xx}) = 0 \\ \rho C_p \dfrac{T_0 - T_a}{r_a} = H = \sum_{xx} H_{xx} \\ \dfrac{\rho C_p}{\gamma} \dfrac{e_0 - e_a}{r_a} = \lambda E = \sum_{xx} \lambda E_{xx} \end{cases}$$

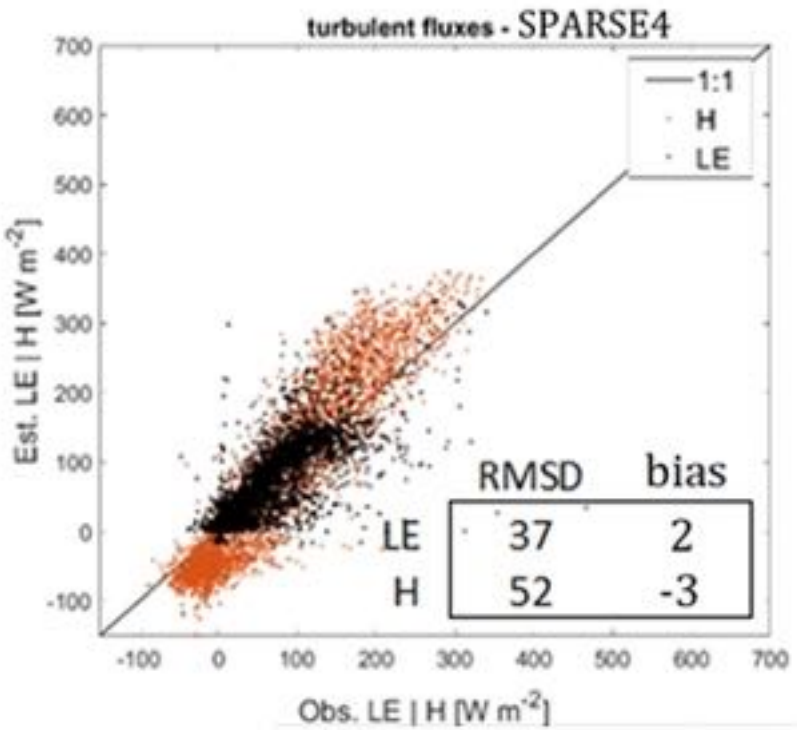
R_n - net radiation ; G – soil heat flux ; H – sensible heat flux ; λE – latent heat flux

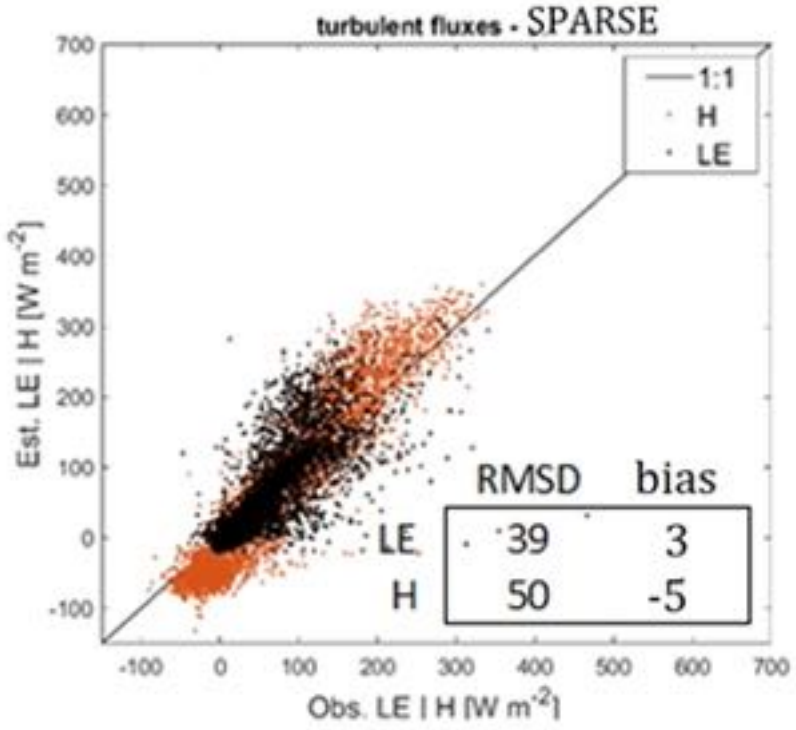
$xx = \text{soil/veg. (g/v) for SPARSE}$
$xx = \text{sunlit/shaded(s/h),soil/veg. (g/v) for SPARSE4}$
$\xi = G/R_{n,g}$ ratio ; ξ = 0 for vegetation elements

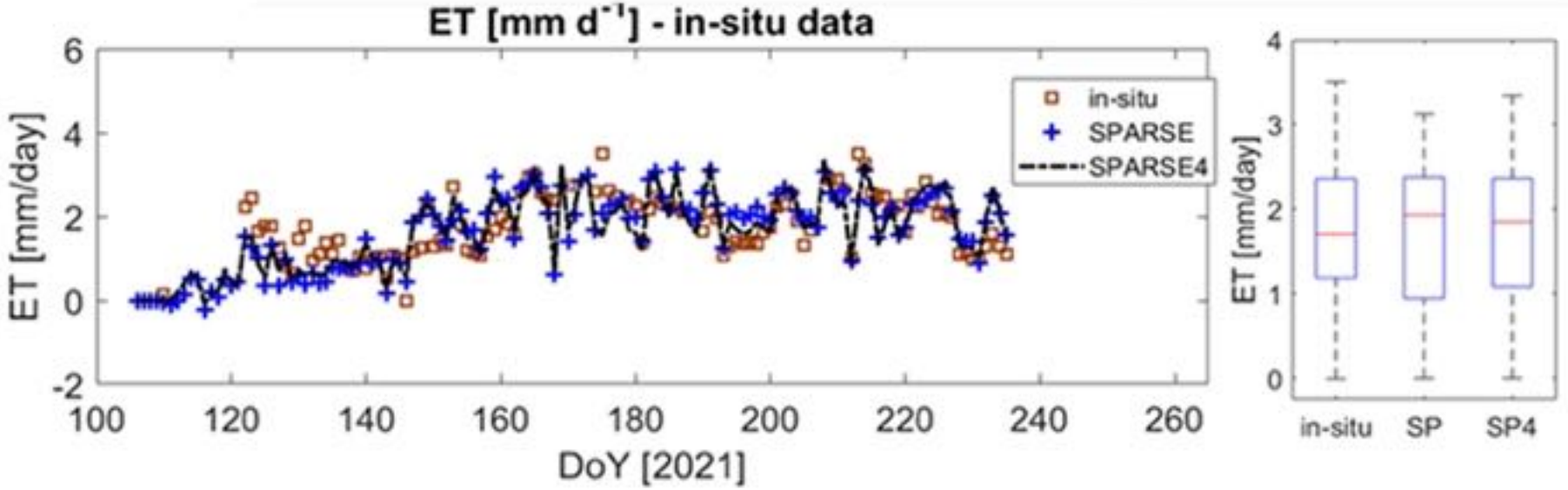
$$L_\lambda \uparrow (\theta_v) = f(T_g, T_v)$$

$$L_\lambda \uparrow (\theta_v, \Phi_v) = f(T_{gs}, T_{gh}, T_{vs}, T_{vh})$$

NADIR

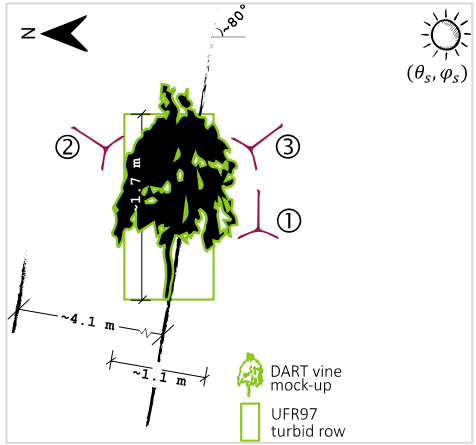

turbulent fluxes - SPARSE4
1:1
H
LE
Est. LE | H [W m-2]
Obs. LE | H [W m-2]
RMSD bias
LE 37 2
H 52 -3

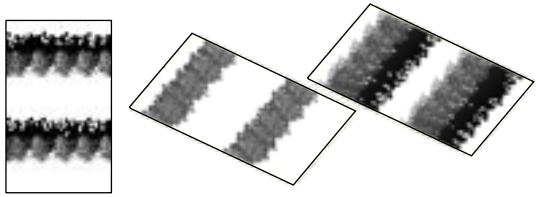

turbulent fluxes - SPARSE
1:1
H
LE
Est. LE | H [W m-2]
Obs. LE | H [W m-2]
RMSD bias
LE 39 3
H 50 -5


ET [mm d-1] - in-situ data
in-situ
SPARSE
SPARSE4
ET [mm/day]
DoY [2021]
ET [mm/day]
in-situ
SP
SP4

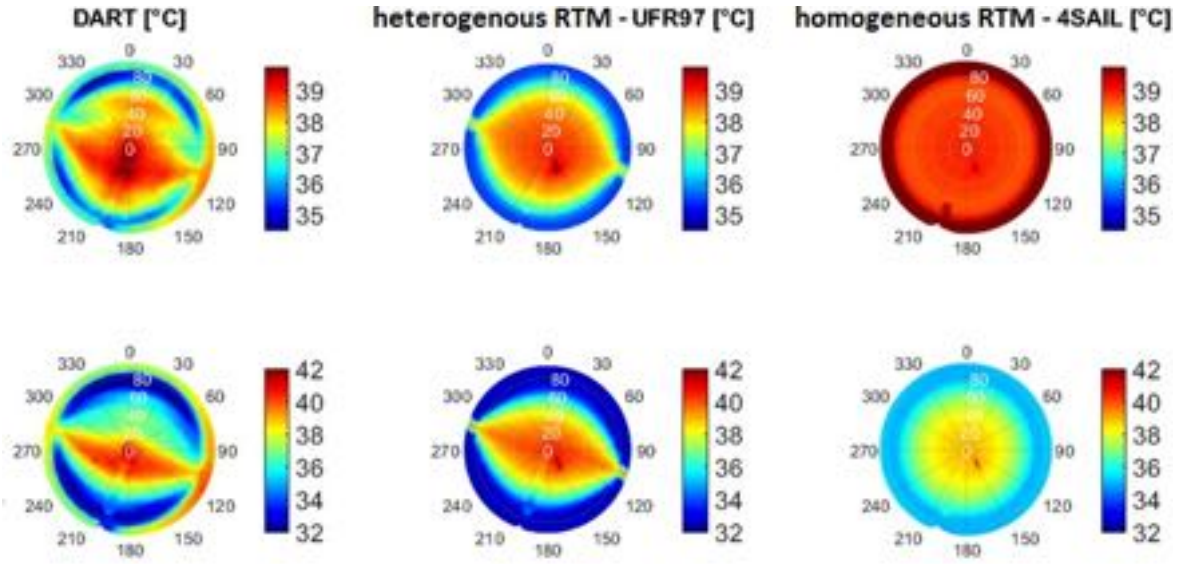
Directional LST reconstruction: RTMs

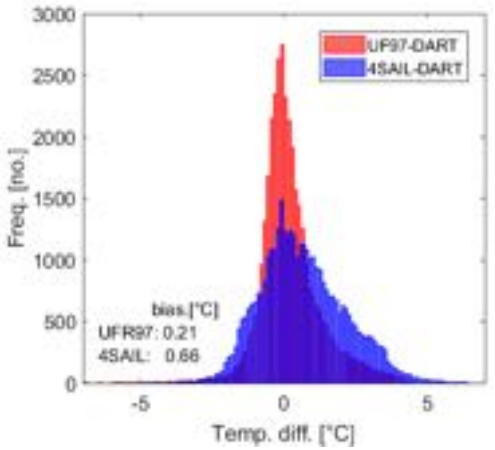
- Overall shape/distribution of simulated directional temperatures simulated by UFR97 similar to DART
- Some phenomena not reproduced however

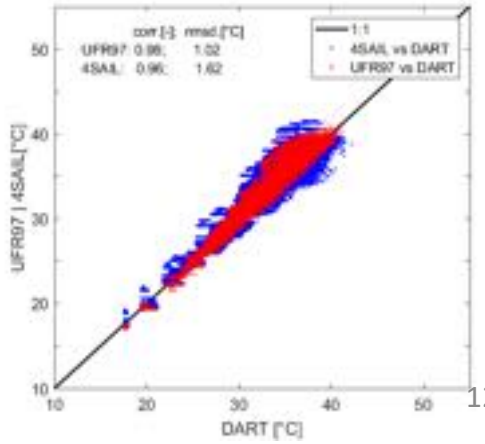




Nadir **Hot spot** **Anti hot spot**





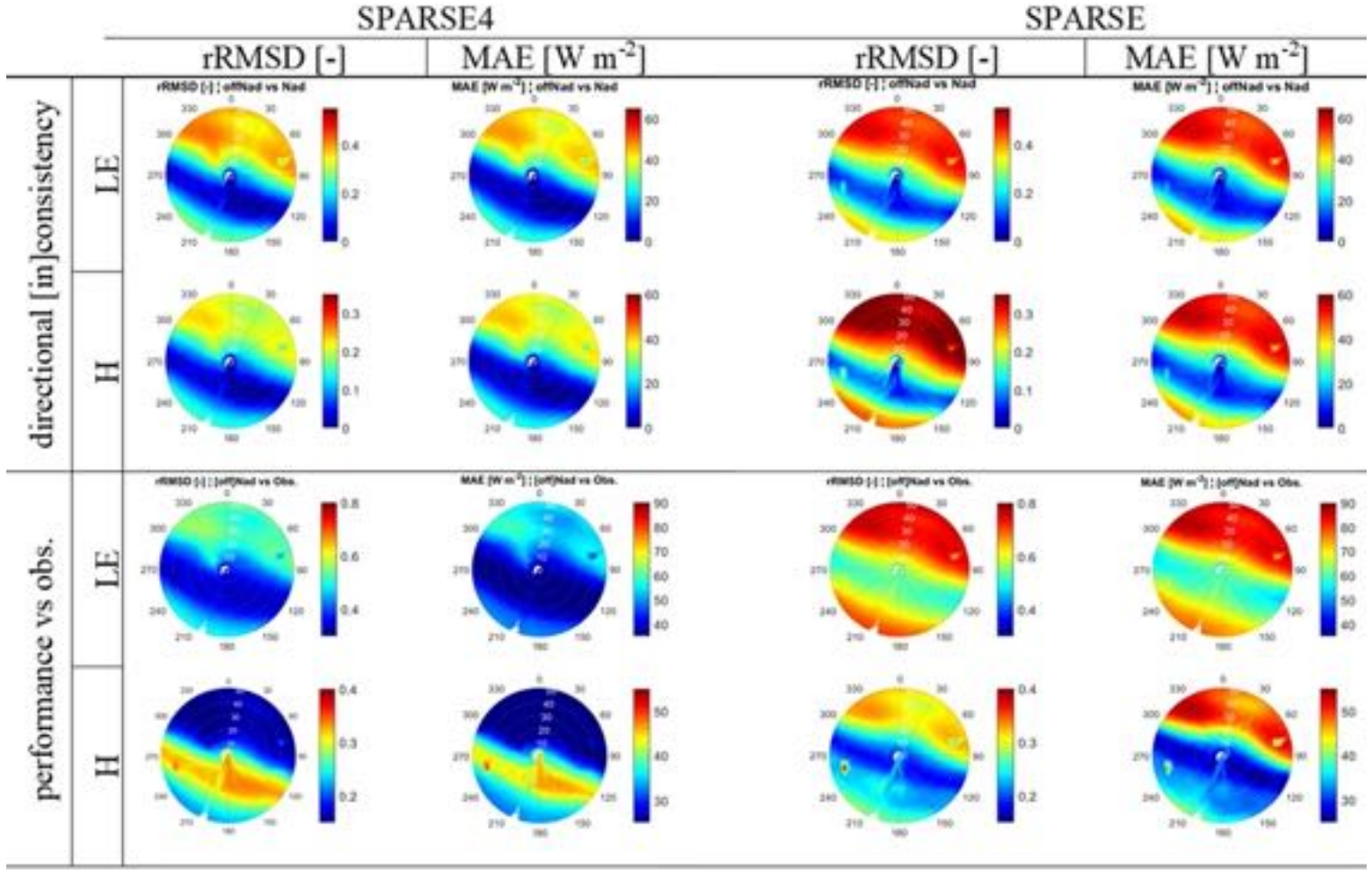


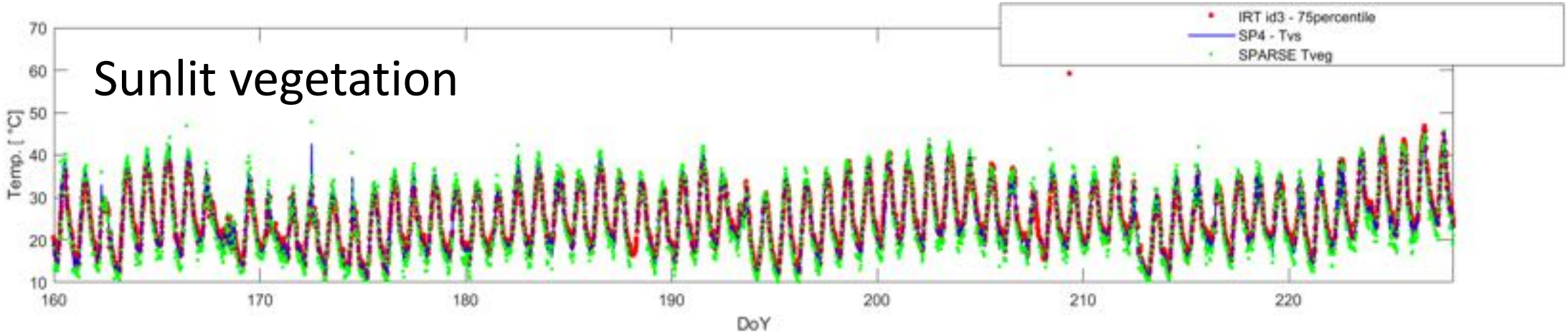
H and LE retrieval from directional LST

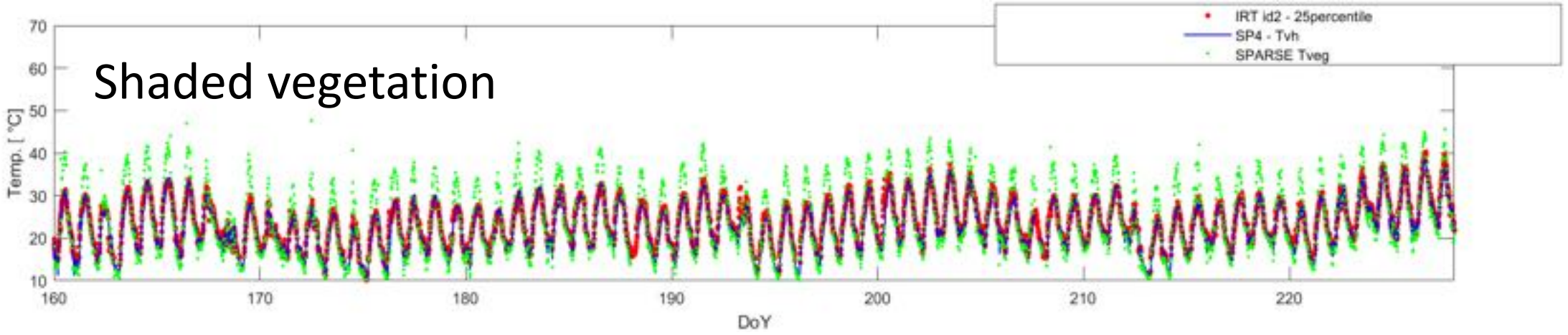
- Directional [in] consistency

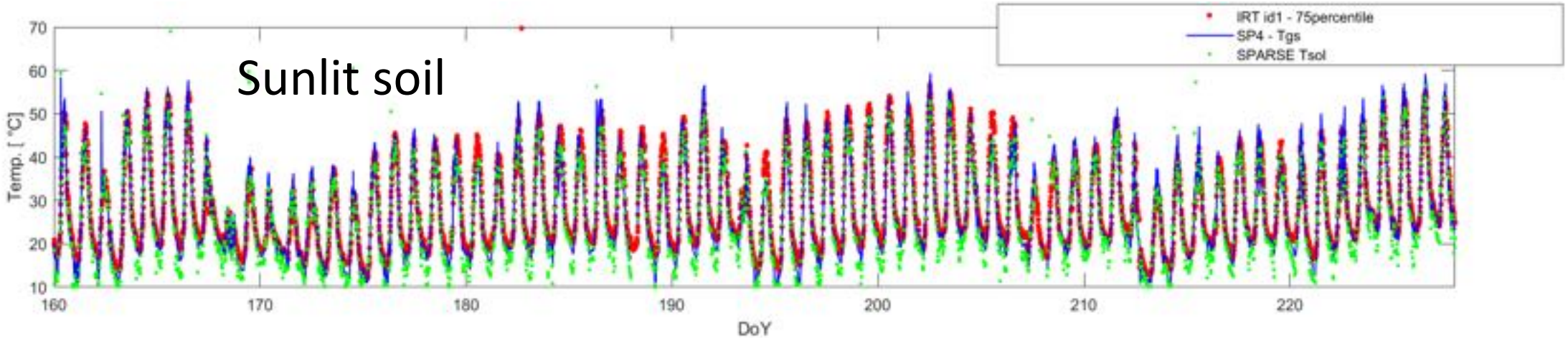
  Inversion of the SPARSE/SPARSE4 SEB using DART temperature data

  Better directional consistency does not necessarily imply better model performance [i.e., w.r.t. observations]




Sunlit vegetation
IRT id3 - 75percentile
SP4 - Tvs
SPARSE Tveg
Temp. [°C]
DoY


Shaded vegetation
IRT id2 - 25percentile
SP4 - Tvh
SPARSE Tveg
Temp. [°C]
DoY


Sunlit soil
IRT id1 - 75percentile
SP4 - Tgs
SPARSE Tsol
Temp. [°C]
DoY

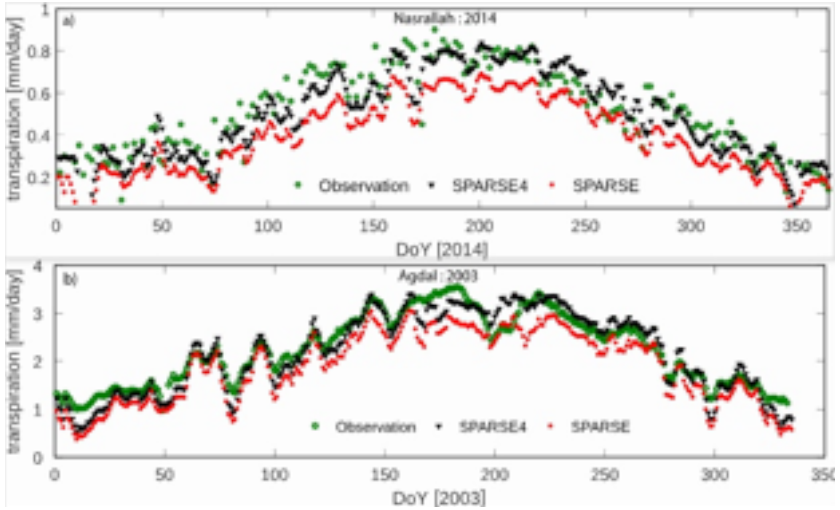
Conclusion and future work

- Difficult to build a full 3D demonstrator for TIR (LSM+RTM)

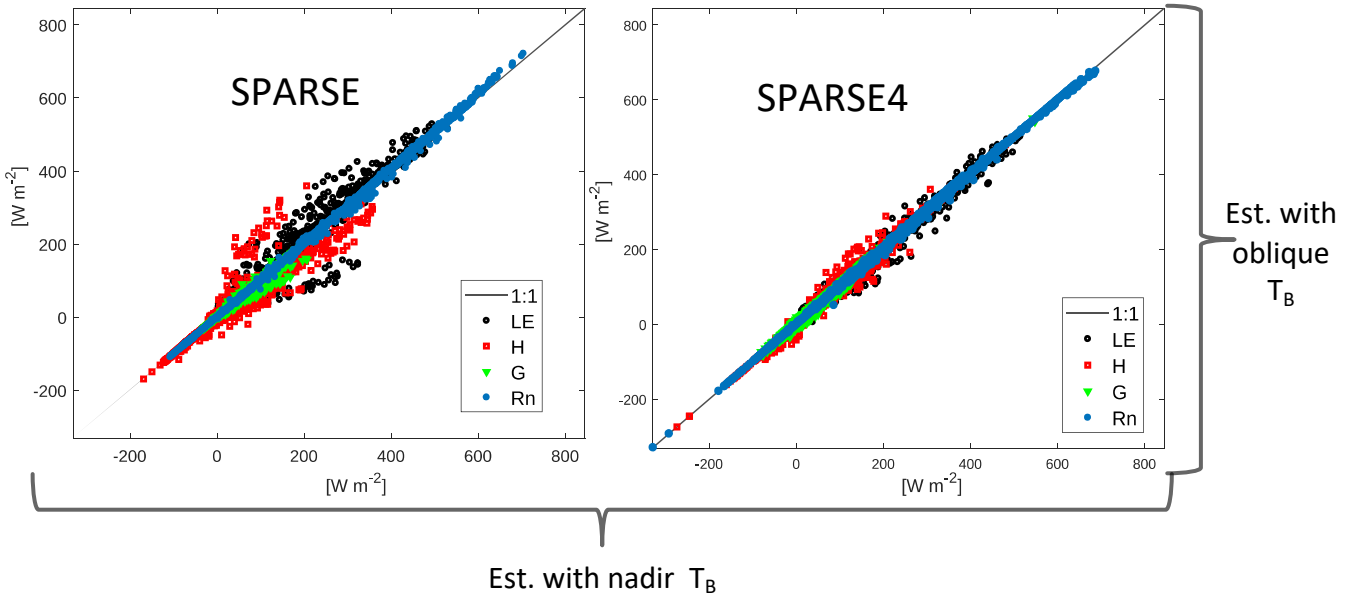
> Current work on developping DART_EB model (missing part = 3D turbulent fluxes > LES ?)

- Consistency of SEB retrievals improved when using a 4 component model with accurate crop geometry, probably also for the partitioning into evaporation and transpiration

> Not for a product, but usefull for stake holders with local info (TRISHNA knowledge hub)



Partitionning: transpiration

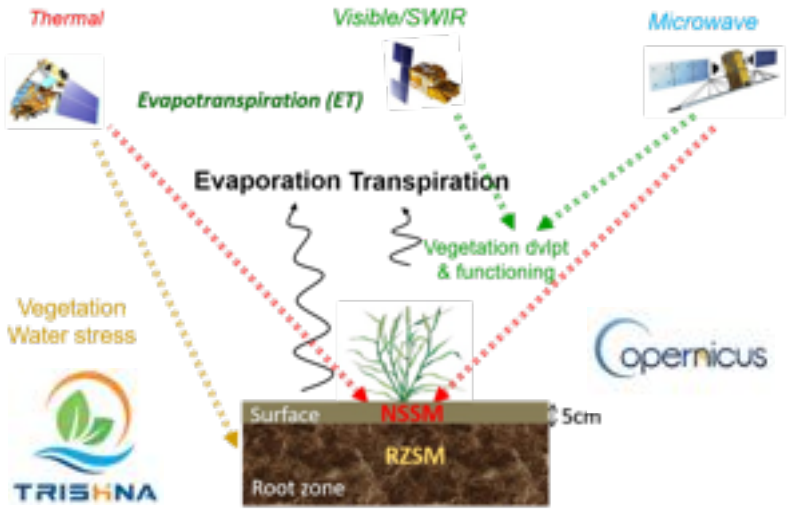


Nadir/off nadir **consistency**

Target = daily high resolution (<100m)
Evaporation + Transpiration products

HiDRATE (2023-2027) PI G. Boulet (CESBIO) & K. Mallick (LIST)

integrating **High resolution** Data from **Remote sensing** And **land surface models** for **Transpiration** and **Evaporation** mapping



Multi-wavelength remote sensing retrievals

Specific design for complex canopies

Models / Area	Forward 1D / plot	Forward 3D / plot	Retrieval / landscape scale
Radiative Transfer	PROSAIL / LIST+CESBIO+URFM	DART / CESBIO	S2MP / CESBIO
Surface Energy Balance (SEB)	SCOPE / LIST+CESBIO+URFM		SPARSE4 / CESBIO, STIC / LIST, SEN_ET / CESBIO, SEB4S / CESBIO
Water Budget (WB)			SimKcET / URFM, PAMEAS / HSM
Land Surface Models (SEB+WB)	SiSPAT / CESBIO+HSM, SISPAT_RS / HSM, SiSPAT_isotope / Jülich	MAESPA / CESBIO	**HiDRATE Demonstrator (Task 3.2)**

Complex models in forward mode used to transform retrieval models combining water and energy budgets, evaluated over sites in France, Germany, Tunisia & India

H_2O/CO_2 flux partitioning

Sapflow

SIF

µlysimeters

isotopes

UAV flying over SM+TIR low cost stations

M-TROPICS