living planet symposium | BONN 23–27 May 2022

TAKING THE PULSE OF OUR PLANET FROM SPACE

1 km evaporation and soil moisture simulations across Europe based on GLEAM and the Sentinel constellation

Dominik Rains, Darren Ghent, Isabel Trigo, Emanuel Dutra, Sofia L. Ermida,
Petra Hulsman, Akash Koppa, Jose Gómez-Dans, Diego Miralles

27/05/2022

EVAPORATION – GLEAM

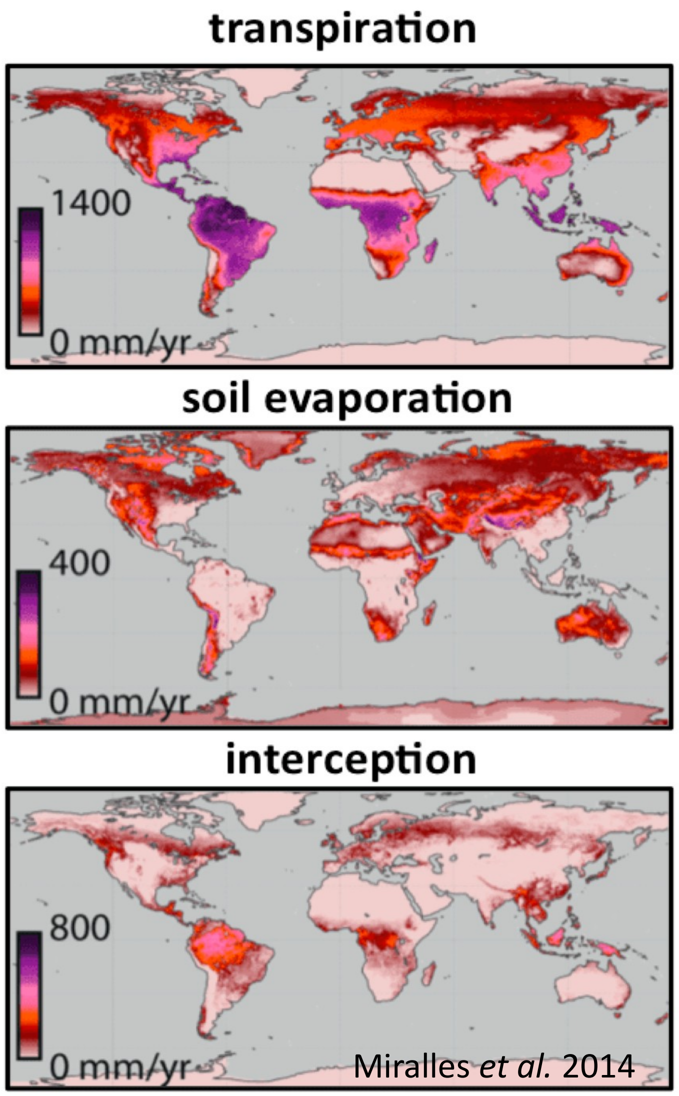
Interception Model
Gash model driven by observed rainfall

Potential Evaporation
Priestley and Taylor driven by observed meteo

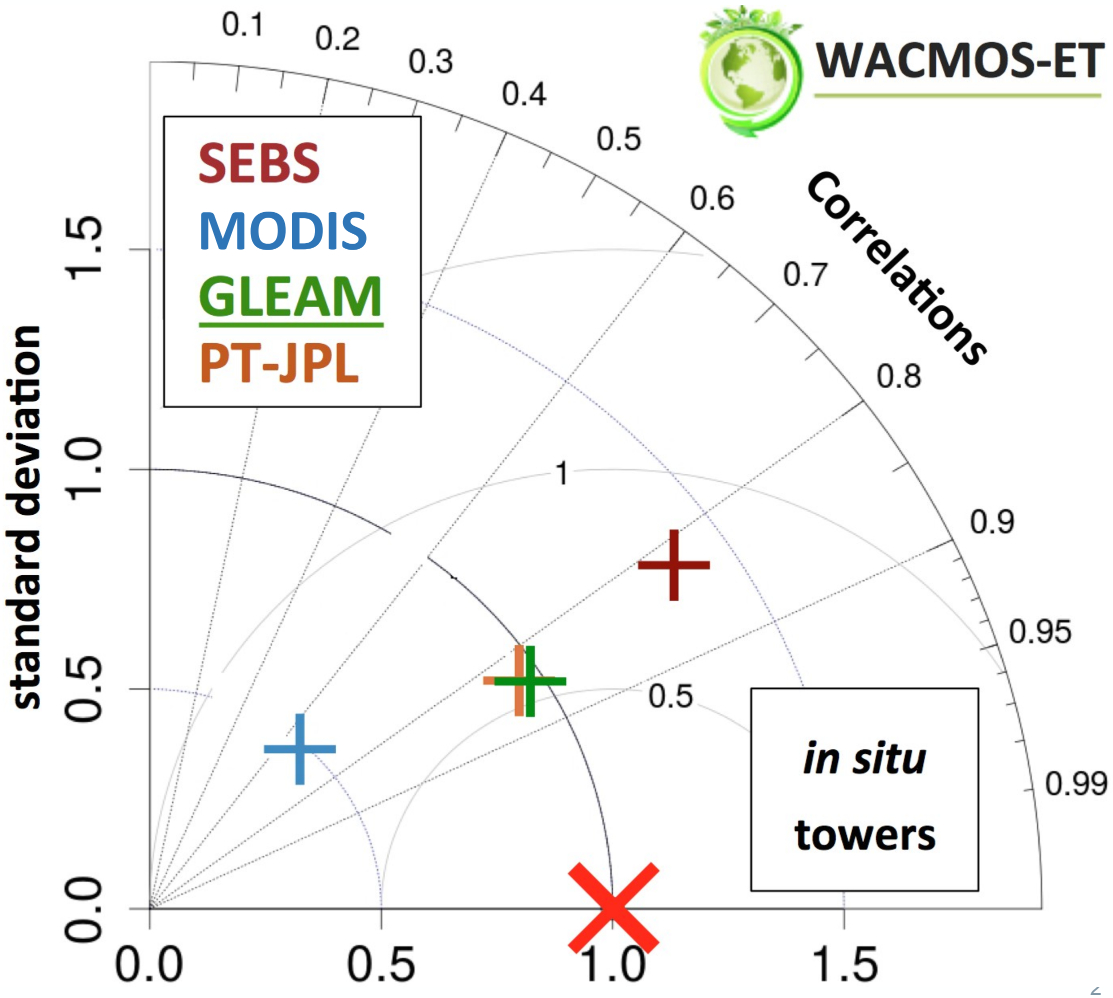
$$E = E_p \times S + E_i$$

Stress Module
Semi-empirical relationship to root-zone moisture and VOD

Soil Module
Multi-layer profile driven by precipitation and soil moisture

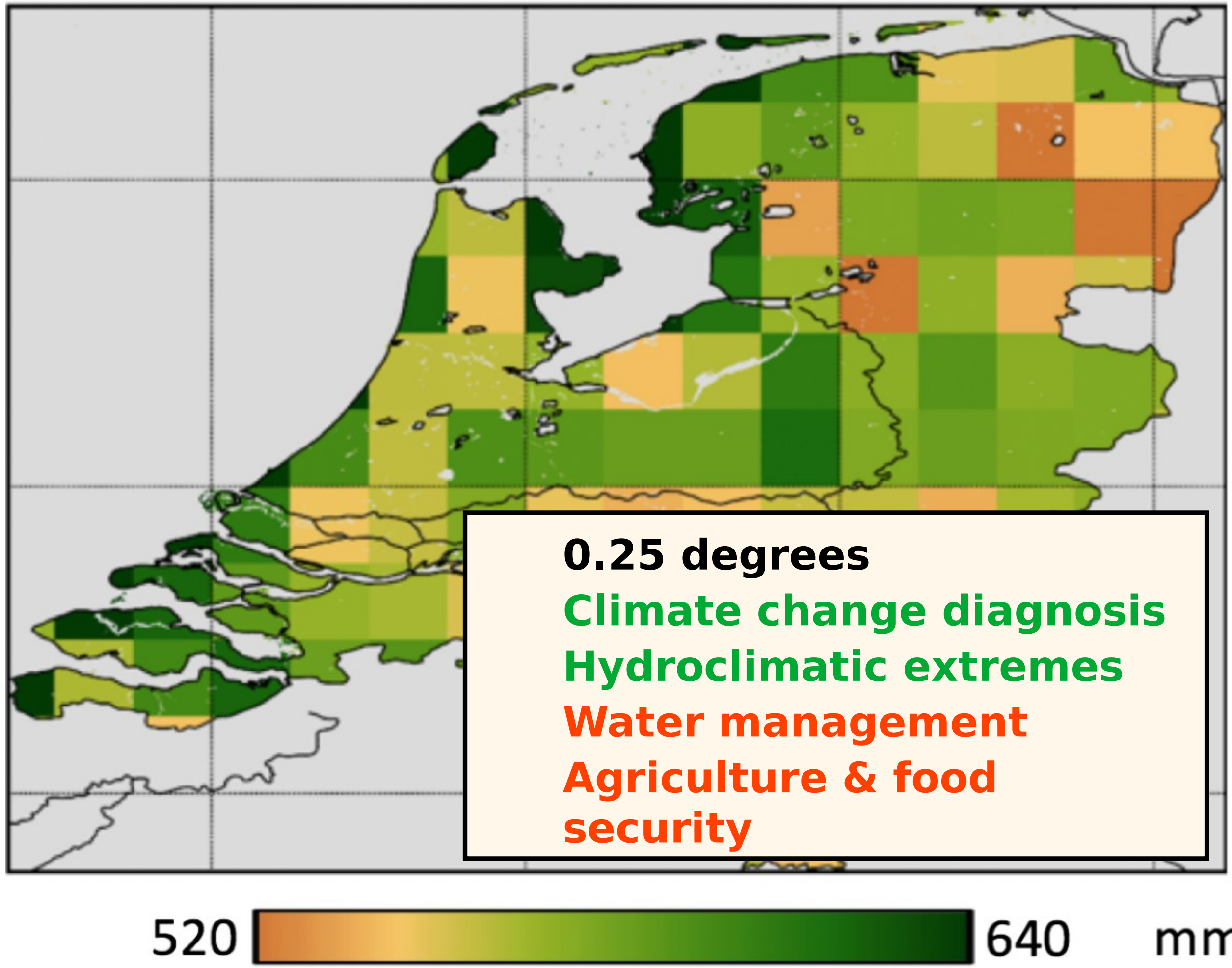


WACMOS-ET



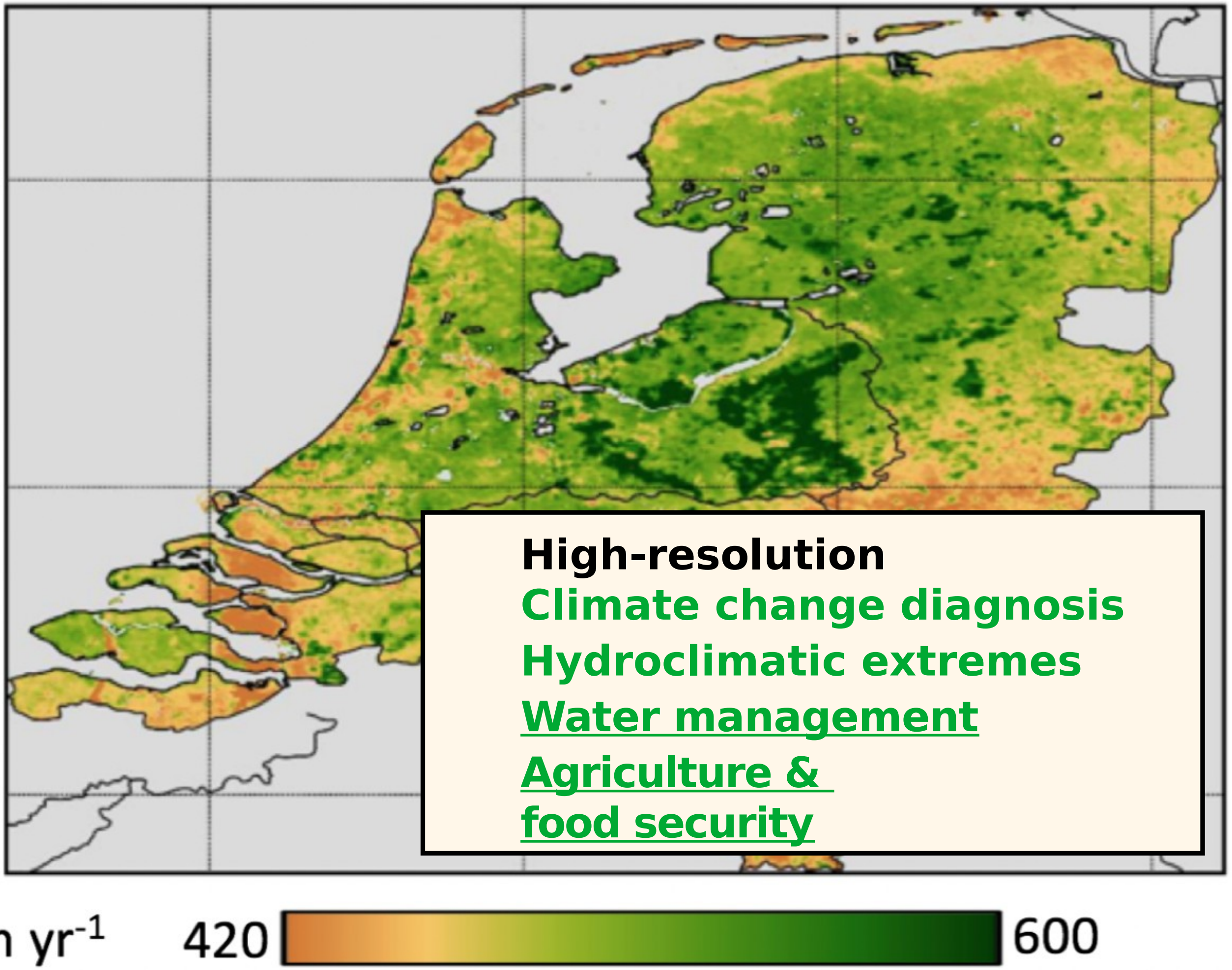
1 km evaporation and soil moisture simulations across Europe

EVAPORATION – GLEAM – GLEAM-HR



0.25 degrees
Climate change diagnosis
Hydroclimatic extremes
Water management
Agriculture & food security

mm yr^{-1}



High-resolution
Climate change diagnosis
Hydroclimatic extremes
Water management
Agriculture & food security

Martens el al., 2018

1 km evaporation and soil moisture simulations across Europe

EVAPORATION – GLEAM – GLEAM-HR

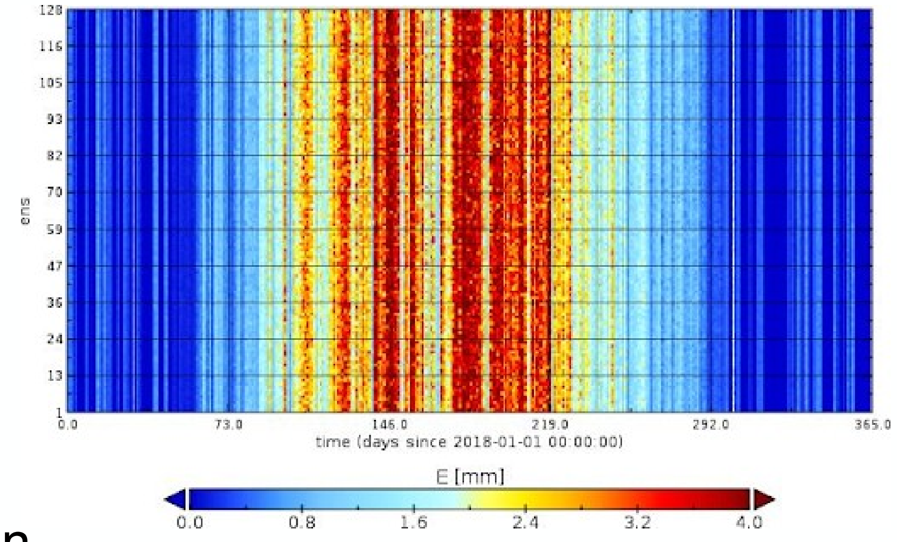
- Reimplementation in Python
- Version control with test branches, DL hybrid-branch etc.

Article | Open Access | Published: 08 April 2022

A deep learning-based hybrid model of global terrestrial evaporation

Akash Koppa, Dominik Rains, Petra Hulsman, Rafael Poyatos & Diego G. Miralles

Nature Communications **13**, Article number: 1912 (2022)

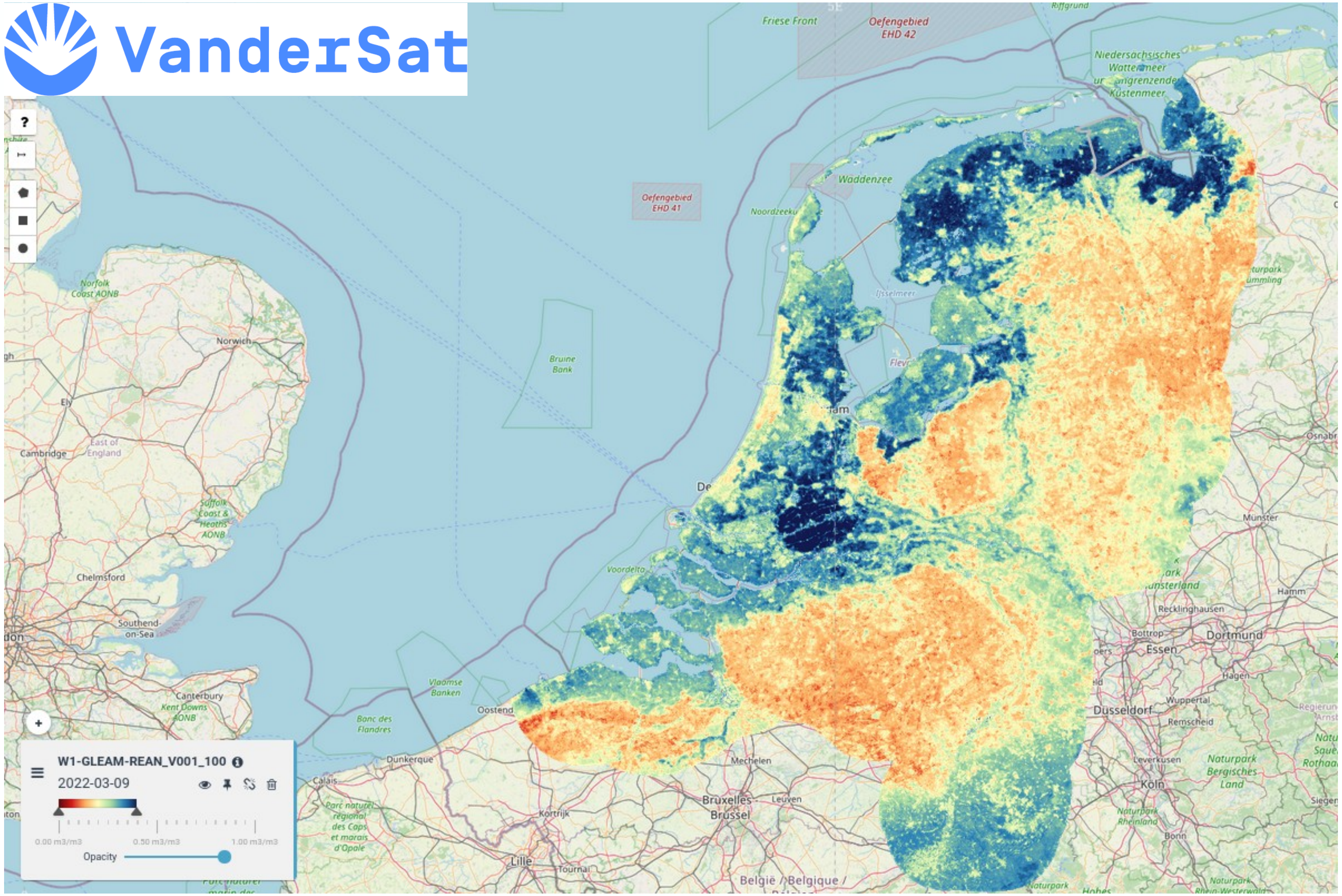


Name	Last commit	Last update
docs	Remove unsupported documentation theme options	3 months ago
examples	Merge branch 'feature/data-assimilation' into 'develop' Feature/data as...	3 weeks ago
src/pygleam	Fix condensation distribution for bare soil	2 weeks ago
tests	removed print statement in test_model.py	3 weeks ago
.coveragerc	Change project structure using PyScaffold 3.2.2 Goal is to convert pygle...	3 months ago
.gitignore	Add interactive sensitivity analysis example	1 month ago
.gitlab-ci.yml	Specify dependencies exclusively in setup.cfg Goal is to have one obvio...	3 months ago
AUTHORS.rst	Update AUTHORS.rst	2 months ago
CHANGELOG.rst	Change project structure using PyScaffold 3.2.2 Goal is to convert pygle...	3 months ago
LICENSE.txt	Change project structure using PyScaffold 3.2.2 Goal is to convert pygle...	3 months ago
README.md	added blankline to README.md	3 weeks ago
setup.cfg	Change documentation theme	3 months ago
setup.py	Change project structure using PyScaffold 3.2.2 Goal is to convert pygle...	3 months ago

- DTE-Hydrology (Po valley, ESA) and DTE-Hydrology Evolution (Mediterranean basin, ESA)
- 4DMED (Mediterranean basin, ESA)
- **ET-Sense (BELSPO, Stereo III)**
  1km on European domain

SATDATA project

- providing operational data to Dutch water authorities
- pyGLEAM implementation with local forcing data
- Implemented in Cloud environment



→ THE EUROPEAN SPACE AGENCY

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Stress Module
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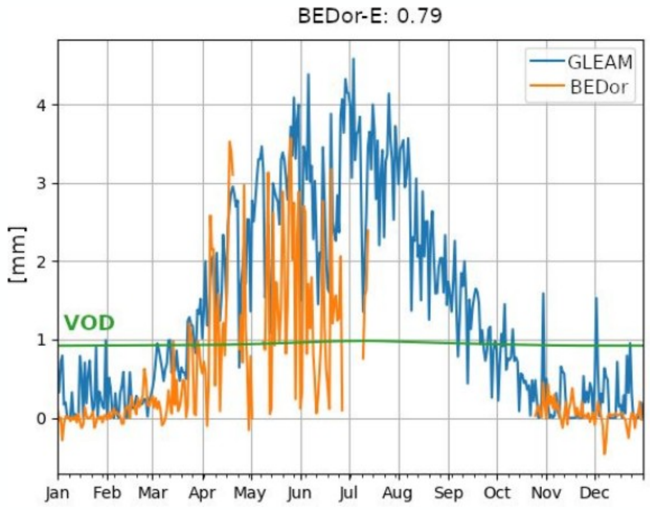
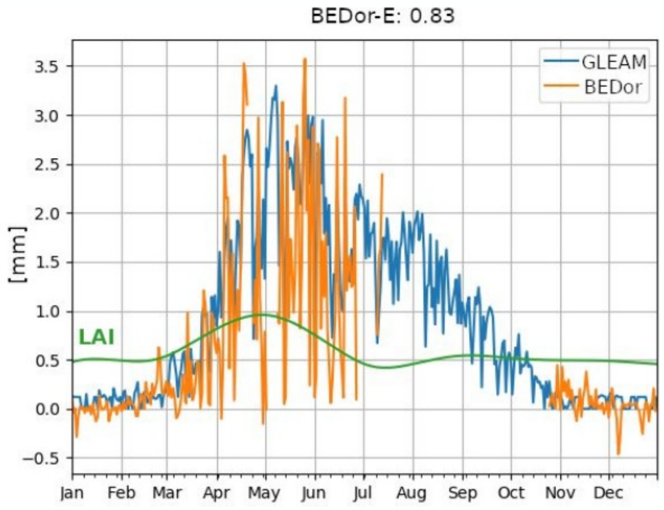
Soil Module
Multi-layer profile driven by precipitation and soil moisture

Surface Net Radiation	CERES	1°	LSAF | Sentinel 3	1 km
Outgoing Shortwave	CERES	1°	LSAF | Sentinel 3	1 km
Soil Moisture (DA)	AMSR-E | SMOS	0.25°	Sentinel 1	1 km
Precipitation	MSWEP v1	0.25°	MSWEP v2	0.10°
Skin Temperature	AIRS	0.5°	Sentinel 3	1 km
Vegetation Optical Depth	AMSR-E | SMOS	0.25°	AMSR-E | SMOS	0.25°
Snow Water Equivalent	GlobSnow	0.25°	Sentinel 1	1 km
Lightning Frequency	LIS/OTD	5 km	LIS/OTD	5 km
Leaf Area Index	–	–	Sentinel 3	1 km
Solar Induced Fluorescence	–	–	Sentinel 5P	5 km
Soil Properties	SoilGrids	0.25°	SoilGrids	250 m
Land Cover Fractions	MODIS	250 m	MODIS	250 m

EVAPORATION – GLEAM – GLEAM-HR – ET-SENSE – LAI – S1 – S3 LST

- Vegetation phenology (VOD) input for vegetation stress module
- Empirical relationship based on scaled, not absolute, values
- LAI a direct substitute for VOD
- Postprocessed ProbaV product





- ! Work on stress module with e.g. hybrid approach and new use of vegetation phenology within GLEAM

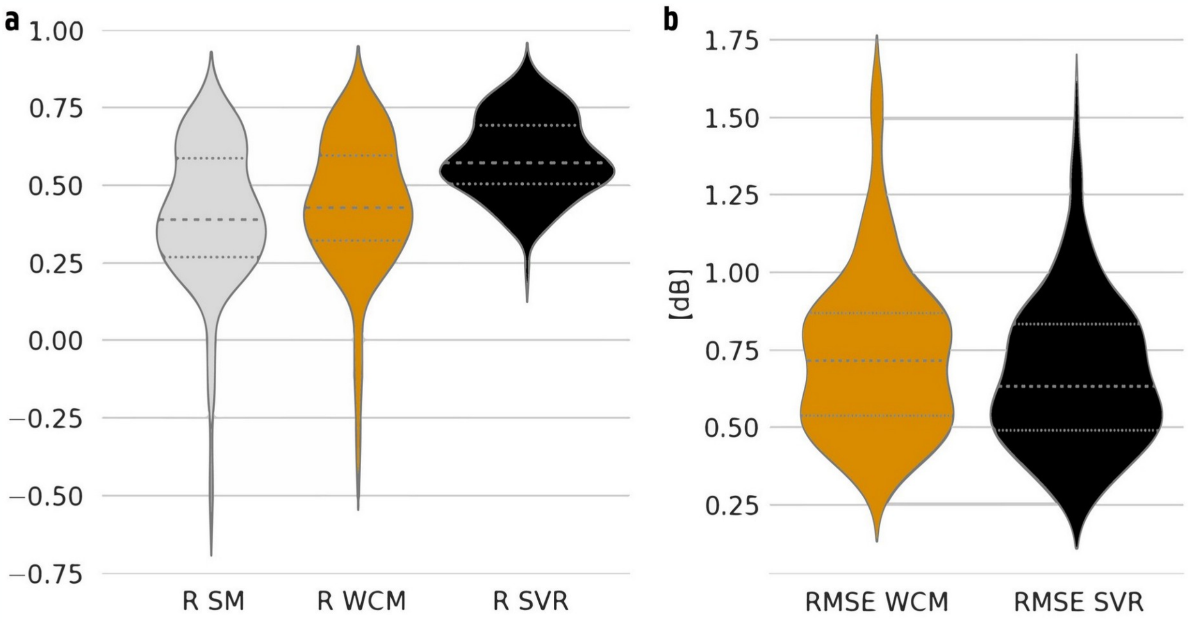
- Assimilation of Sentinel-1 backscatter observations requires forward simulations from model to observation space
- Water Cloud Model takes into account roughness, vegetation state and soil moisture, needs calibration
- Explore Support Vector Regression as alternative
- Assimilation using Ensemble Kalman Filter (32 ens)

$$x^a = x^b + K(y - h(x^b))$$

$$K = PH^\intercal(HPH^\intercal + R)^{-1}$$

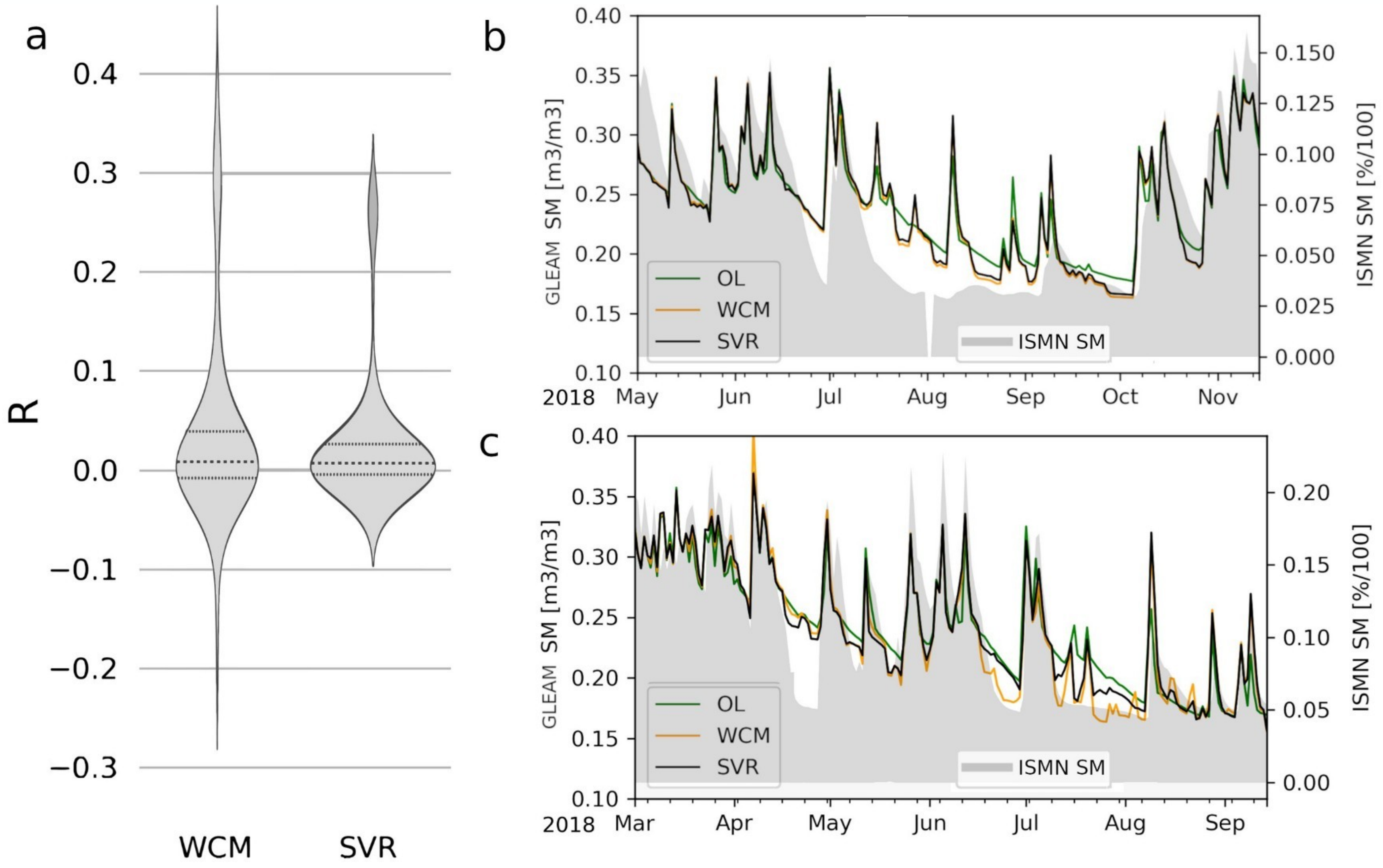
Sentinel-1 Backscatter Assimilation Using Support Vector Regression or the Water Cloud Model at European Soil Moisture Sites

Dominik Rains, Hans Lievens, Gabriëlle J. M. De Lannoy, Matthew F. McCabe, Richard A. M. de Jeu, and Diego G. Miralles



For all considered ISMN sites: (a) R between GLEAM soil moisture and S1 backscatter observations, as well as between the WCM or SVR forward simulations and S1 backscatter; (b) RMSD between the WCM or SVR forward simulations and S1 backscatter.

EVAPORATION – GLEAM – GLEAM-HR – ET-SENSE – LAI – S1 – S3 LST



(a) Distribution of the assimilation impact (ΔR) for all considered ISMN sites when using the WCM or SVR forward simulations.

Temporal subset of soil moisture time series for the open-loop run and both assimilation experiments together with ISMN soil moisture for (b) Acqui Grandcal and (c) SMOSMANIA Sabres.

- Key forcing variable for GLEAM is net radiation, but also use of outgoing shortwave and air temperature
- Higher-resolution, gap-free, products challenging → Downscaling of all-sky LSAF products using albedo and LST
- Combine advantages of geostationary temporal resolution with spatial resolution of retrievals from polar-orbiting platforms.

$$SNR = (SW_{in} + LW_{in}) - (SW_{out} + LW_{out})$$

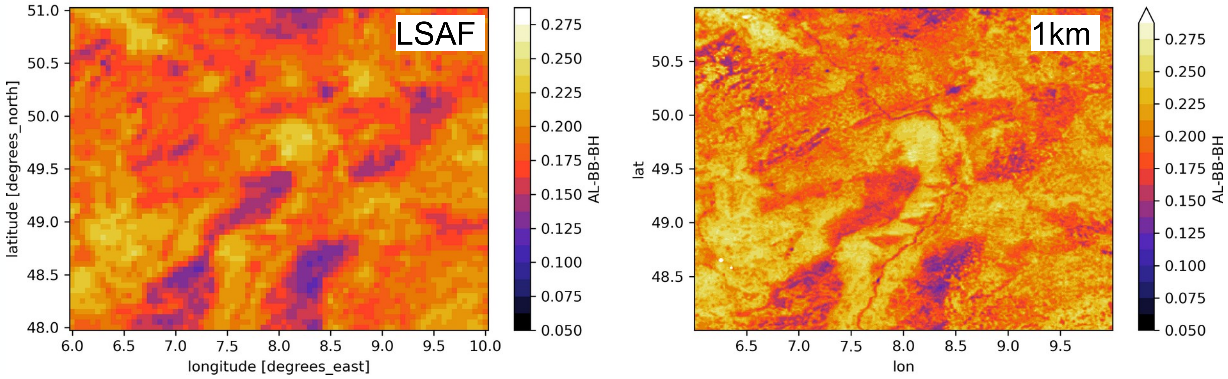
$$SW_{out} = SW_{in} * \alpha$$

$$LW_{out} = \varepsilon * \sigma * LST^4 + (1 - \varepsilon) * LW_{in}$$

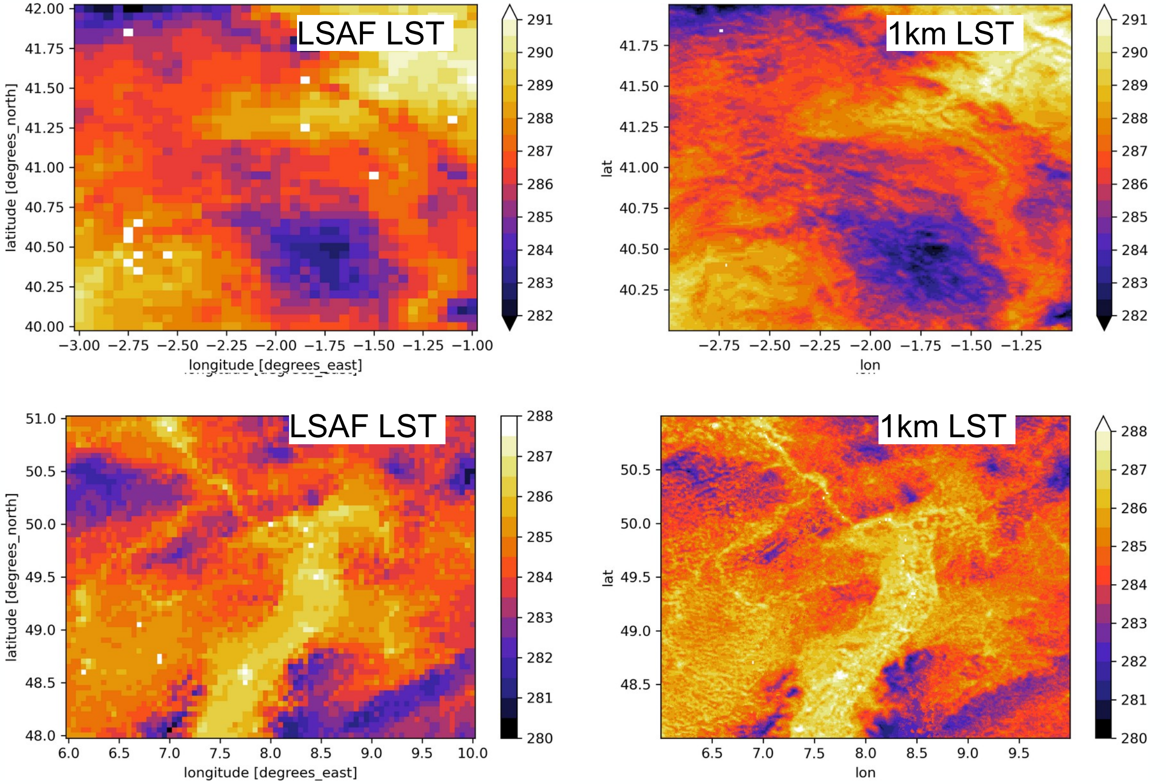
Variable	Satellite	Orbit	temporal	spatial	clear-sky/all-sky
SW_{in}	MSG	geostationary	hourly	5–7 km	all-sky, clear-sky+model
LW_{in}	MSG	geostationary	hourly	5–7 km	all-sky, clear-sky+model
LST	MSG	geostationary	hourly	5-7 km	all-sky, clear-sky+model
LST	Sentinel 3 A	polar	2–3 days	1 km	clear-sky
ε	MSG	geostationary	hourly	5–7 km	clear-sky composite
α	MSG	geostationary	hourly	5–7 km	clear-sky composite
α	ProbaV	polar	daily	1 km	clear-sky composite

- Albedo downscaled through simple bias-correction using albedo from ProbaV

$$SW_{out} = SW_{in} * \alpha$$



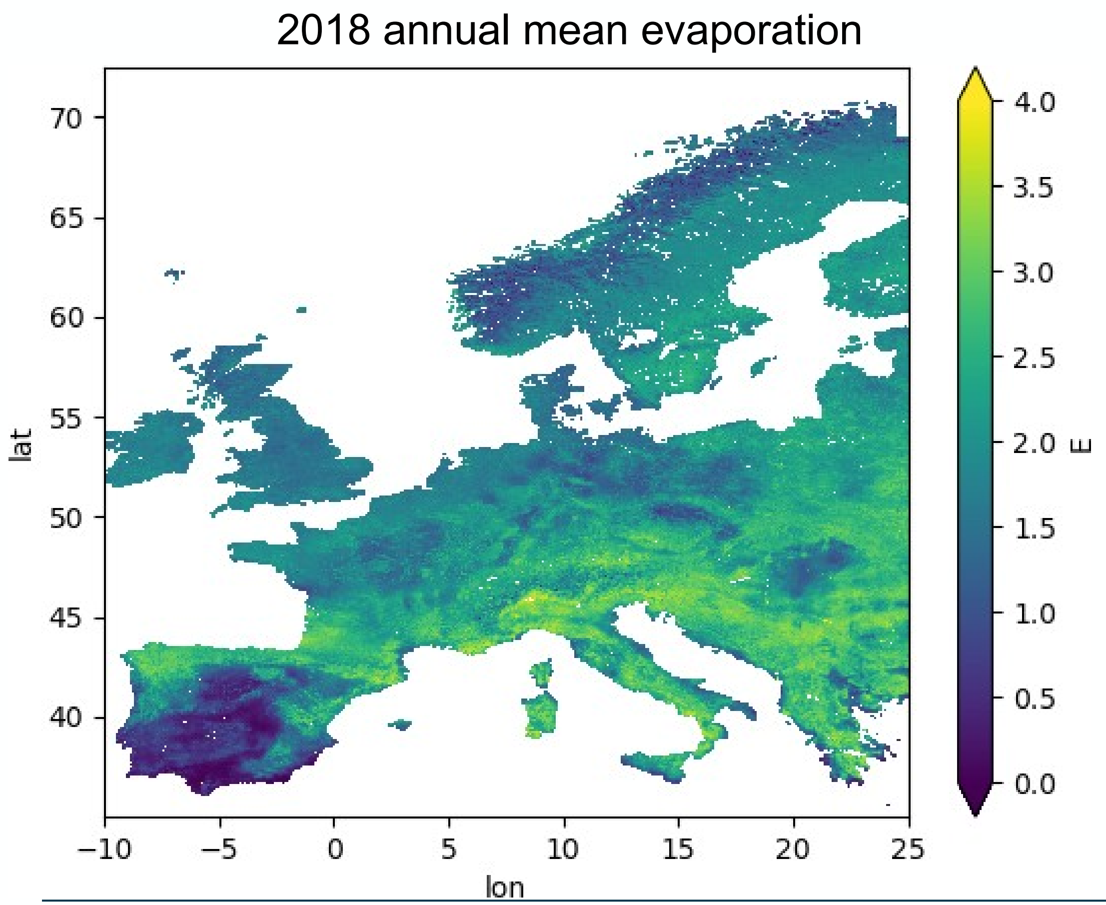
$$LW_{out} = \varepsilon * \sigma * LST^4 + (1 - \varepsilon) * LW_{in}$$

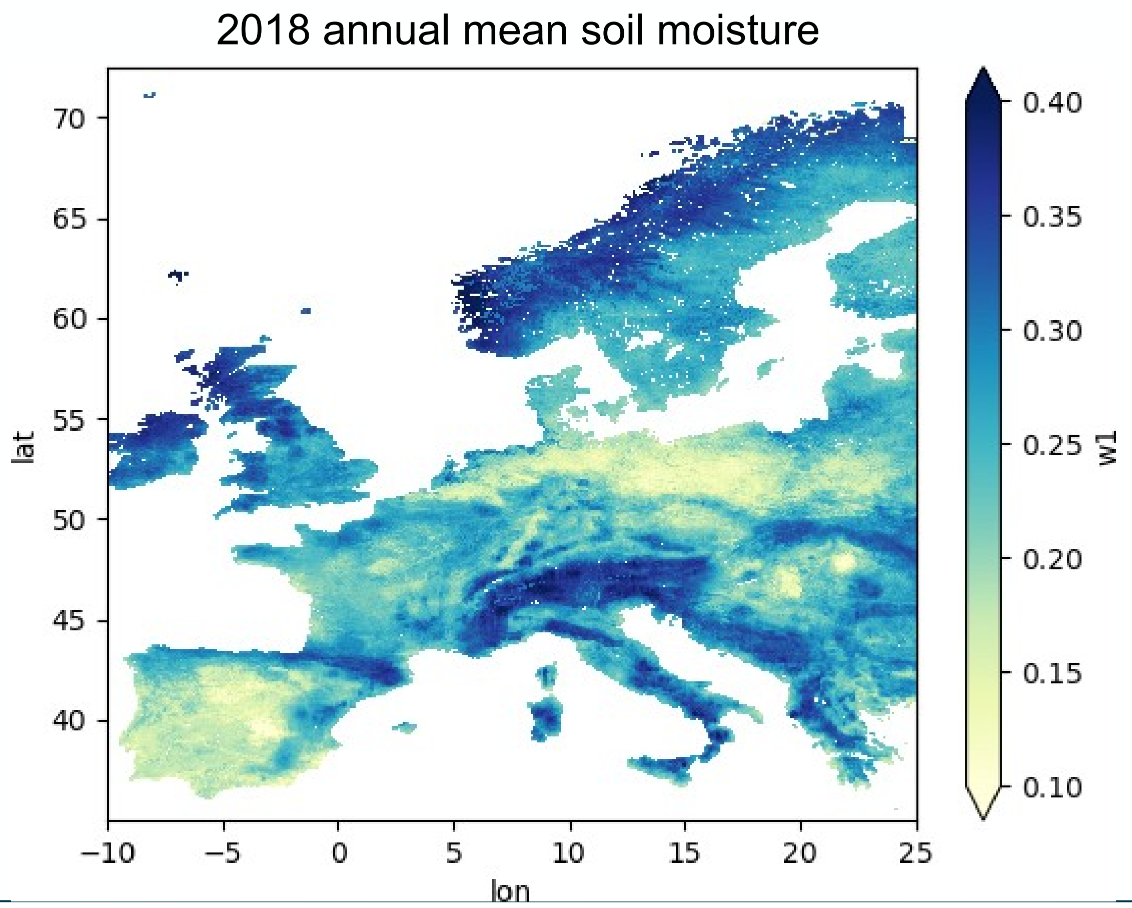


- 1) Normalisation of S3 LST (~2-3 days) to nearest full hour using diurnal cycle from LSAF LST hourly data
- 2) Bias correction of LSAF LST towards normalised S3 LST per pixel
- 3) Assimilate normalised S3 LST observations into time series from 2) to generate 'Sentinel-like' gap-free time series

- Publication in preparation!

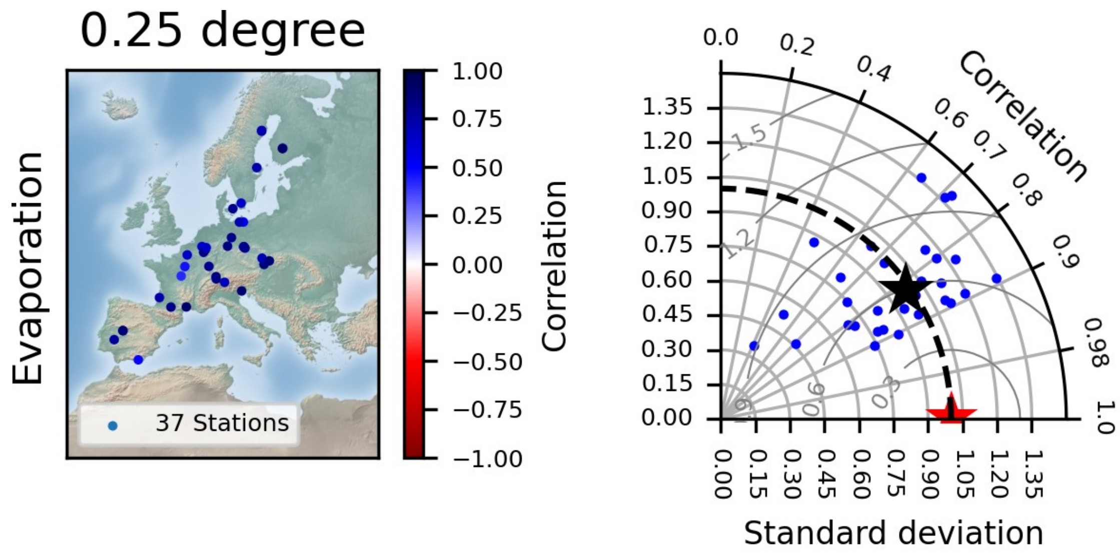
- First simulation runs for 2018 – 2019 ongoing using 1km net radiation



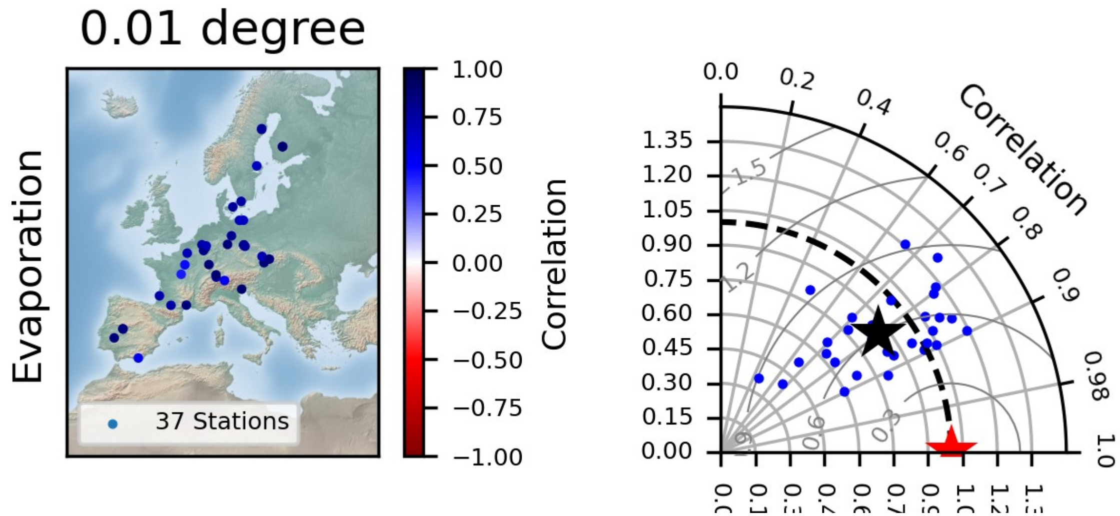


1 km evaporation and soil moisture simulations across Europe

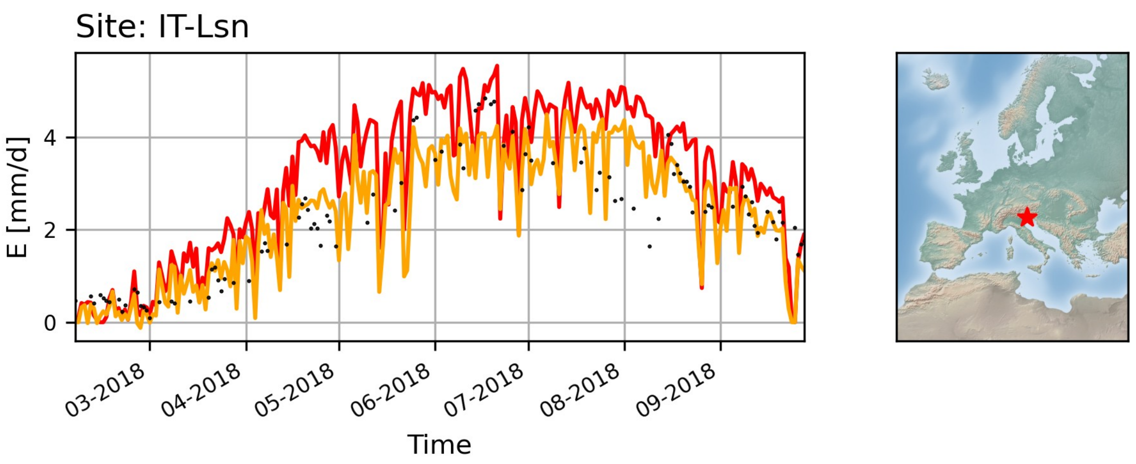
EVAPORATION – GLEAM – GLEAM-HR – ET-SENSE – LAI – S1 – S3 LST / ALB – First Runs

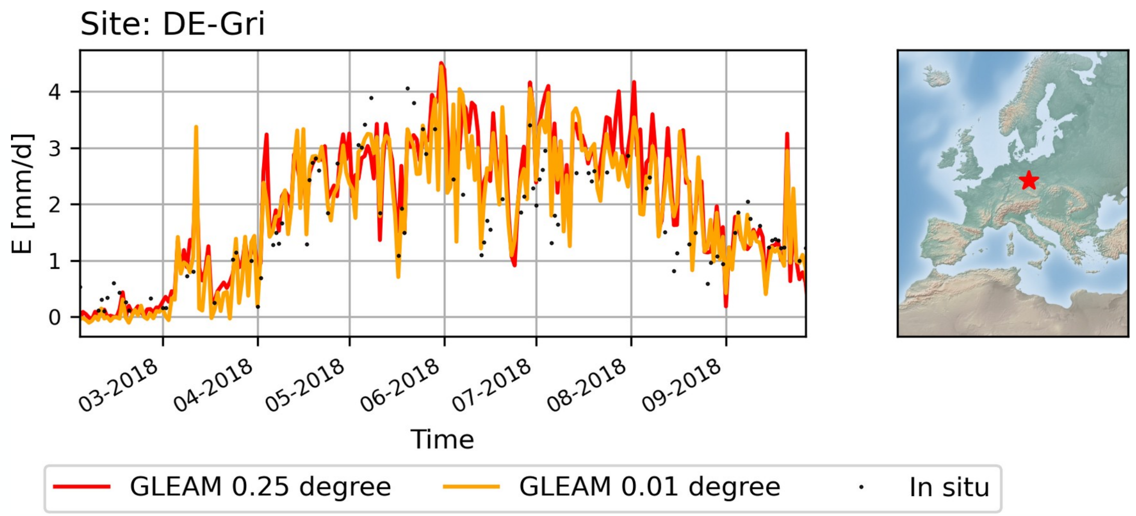


R	0.80
RMSE	1.00
KGE	0.57
NS	0.31
MARE	0.43
pBias	-7.65



R	0.79
RMSE	0.92
KGE	0.59
NS	0.44
MARE	0.34
pBias	1.29





- **Conclusions:**
- Use of LAI as VOD replacement works well (although use of vegetation phenology will change)
- S1 assimilation using WCM/SVR improves soil moisture simulations within expectations
- Use of geostationary and polar-orbiting radiation and LST/Albedo retrievals for increased spatial heterogeneity in radiation forcing
- First simulations (without S1) show satisfactory results both in terms of validation and spatial patterns
- **Next steps:**
- Comprehensive sensitivity analysis with different forcing updates/combinations
- Release 2018–2019 test dataset both for E as well as merged LST/Rnet radiation