An integrative information aqueduct to close the gaps between global satellite observation of water cycle and local sustainable management of water resources

iAqueduct

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Ruisdael Science Day, 19 June 2019, KNMI

Water Works 2017

Water JPI

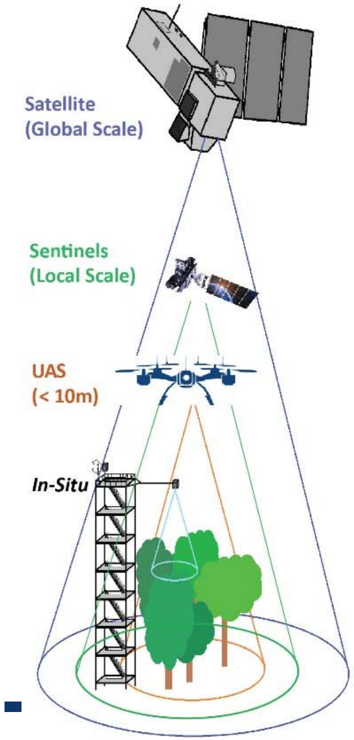
OBJECTIVES

iAqueduct will integrate the various components ***from the global water cycle observation to local soil and water states*** in an open-source water information system and test and demonstrate their utility on pan-European scale at a set of carefully selected research sites for sustainable management of water resources.

CONSORTIUM DESCRIPTION

WP DESCRIPTION

Site1. Twente, NL	Temperate, Dry Winter, Hot Summer
Site2. Zala, HU	Cold, Humid, Warm Summer
Site3. Alento, IT	Temperate, Dry Hot Summer
Site4. Corleto, IT	Temperate, Dry Warm Summer
Site5. Barranco del Carraixet, ES	Arid, Steppe, Cold
Site6. Haogen , IL	Arid, Dry Hot Summer



Feedback Loop to Improve iAqueduct

WP1
From Global satellite water cycle products to field scale satellite water states

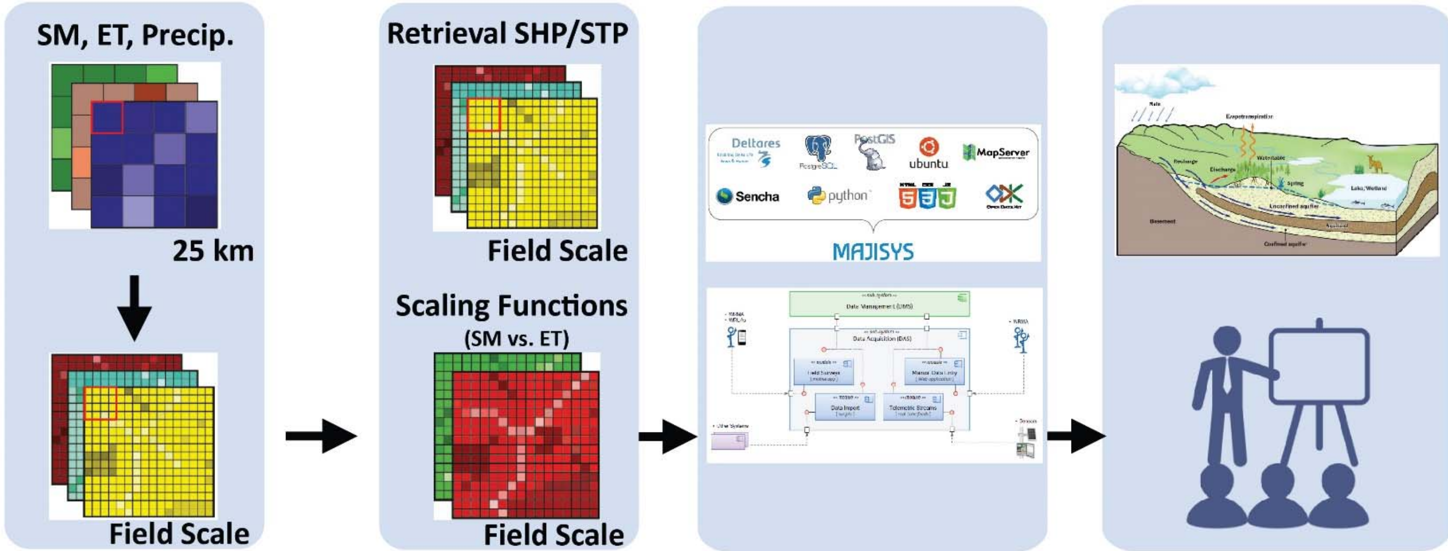
WP2
Retrieval of soil properties (SHP/STP)

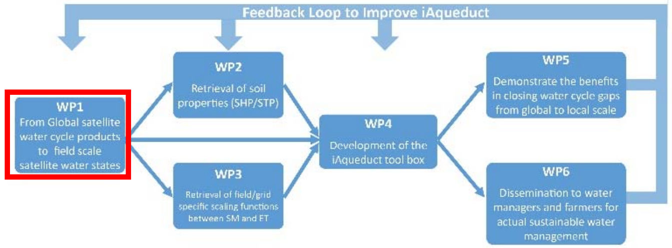
WP3
Retrieval of field/grid specific scaling functions between SM and ET

WP4
Development of the iAqueduct tool box

WP5
Demonstrate the benefits in closing water cycle gaps from global to local scale

WP6
Dissemination to water managers and farmers for actual sustainable water management





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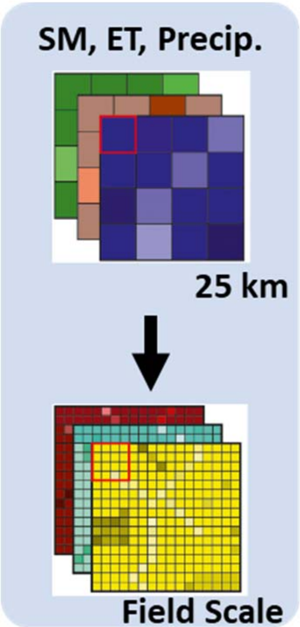
WP1 From Global satellite water cycle products to field scale satellite water states



Task 1.1 Spatial downscaling procedures and data products

1) Bayesian statistical bias correction of satellite data based on in-situ observation;
2) Development of downscaling methods by the use of Copernicus Sentinel1-2-3 data (concerning evapotranspiration and soil moisture);
3) Generation of high resolution water cycle products of soil moisture, vegetation patterns and vegetation stress, using UASs;
4) Characterization of the spatio-temporal distribution of soil moisture and evapotranspiration processes (UAS results vs. in-situ measurement);
5) Downscaling of the remote sensing data up to the field scale.

Task 1.2 Derive profile soil water content from surface soil moisture information

1) Prediction of root-zone SWC with the SMAR-EnKF, from Satellite and UASs;
2) The STEMMUS model to analyze the sensitivities of the predicted root-zone SWC.

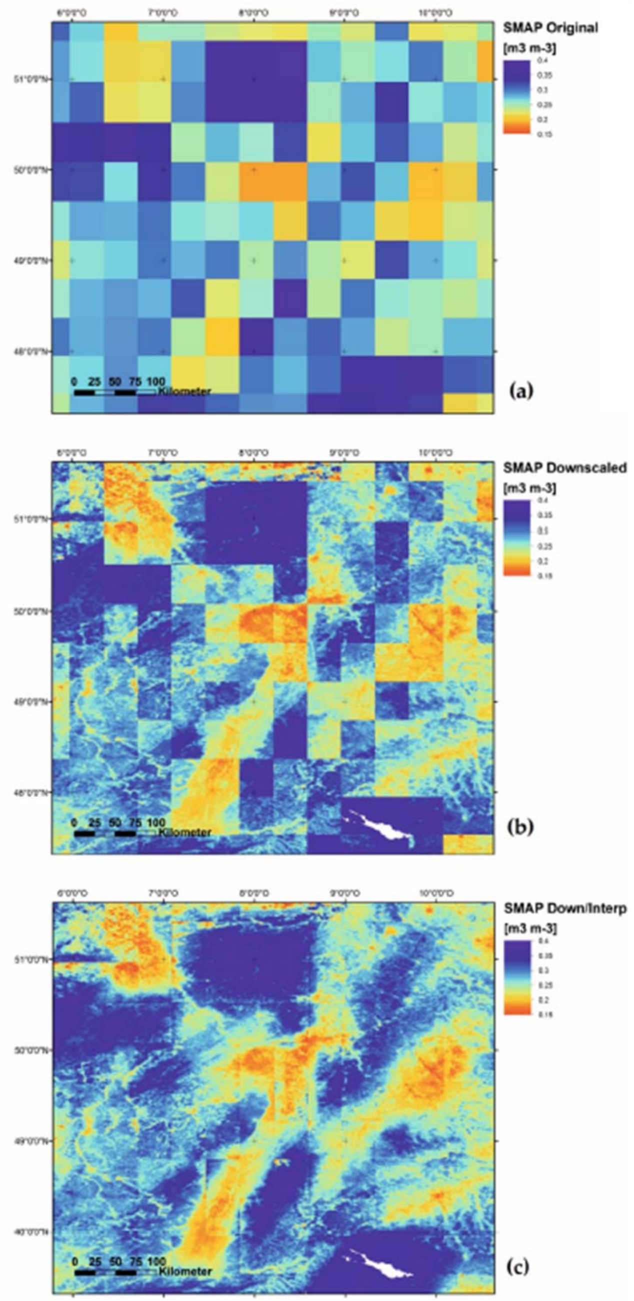
Sub-Grid Soil Moisture Variability Data for Downscaling

Earth observation data with a proven relationship to soil moisture variability such as surface temperature, vegetation, a combination of both, radar backscatter, or even soil texture.

$$\widehat{\theta_{i,j}} = \overline{\theta} + \sigma_{\theta}\left(\overline{\theta}\right)\frac{P_{i,j} - \overline{P}}{\sigma_P}$$

where $P_{i,j}$ is the proxy data at fine scale sub-grid y-location i and x-location j, P is the mean of the proxy, and σ_P is the standard deviation of the proxy

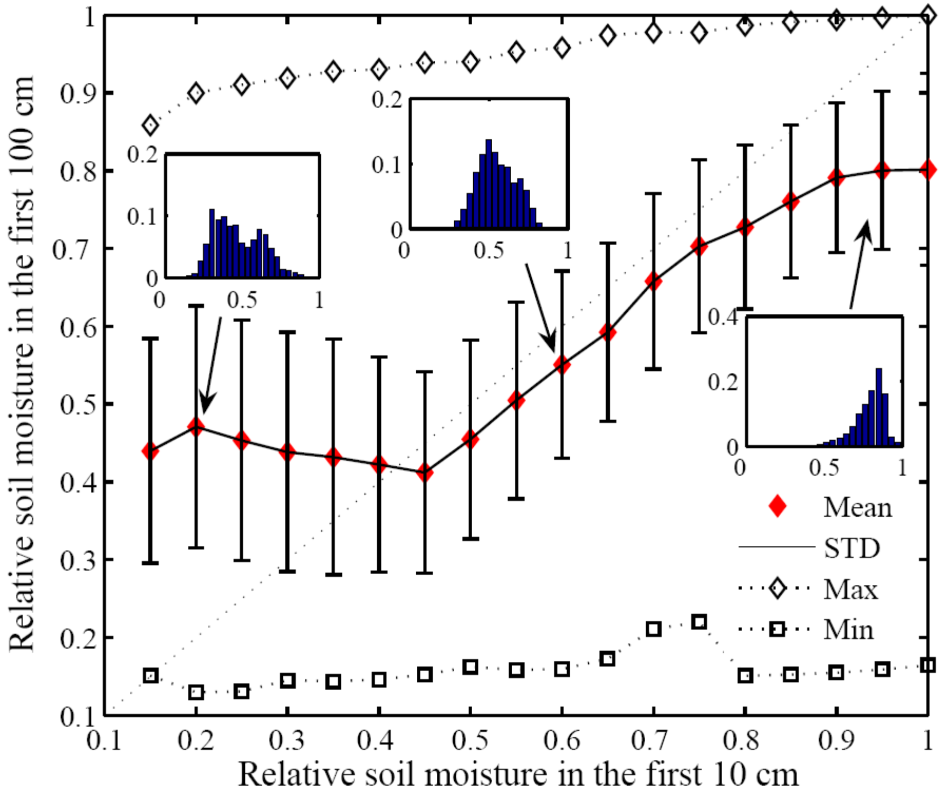
Based on Qu et al. Predicting subgrid variability of soil water content from basic soil information. Geophys. Res. Lett. 2015, 42, 789–796. [CrossRef]



Characteristics of relative soil moisture in deep and shallow layers

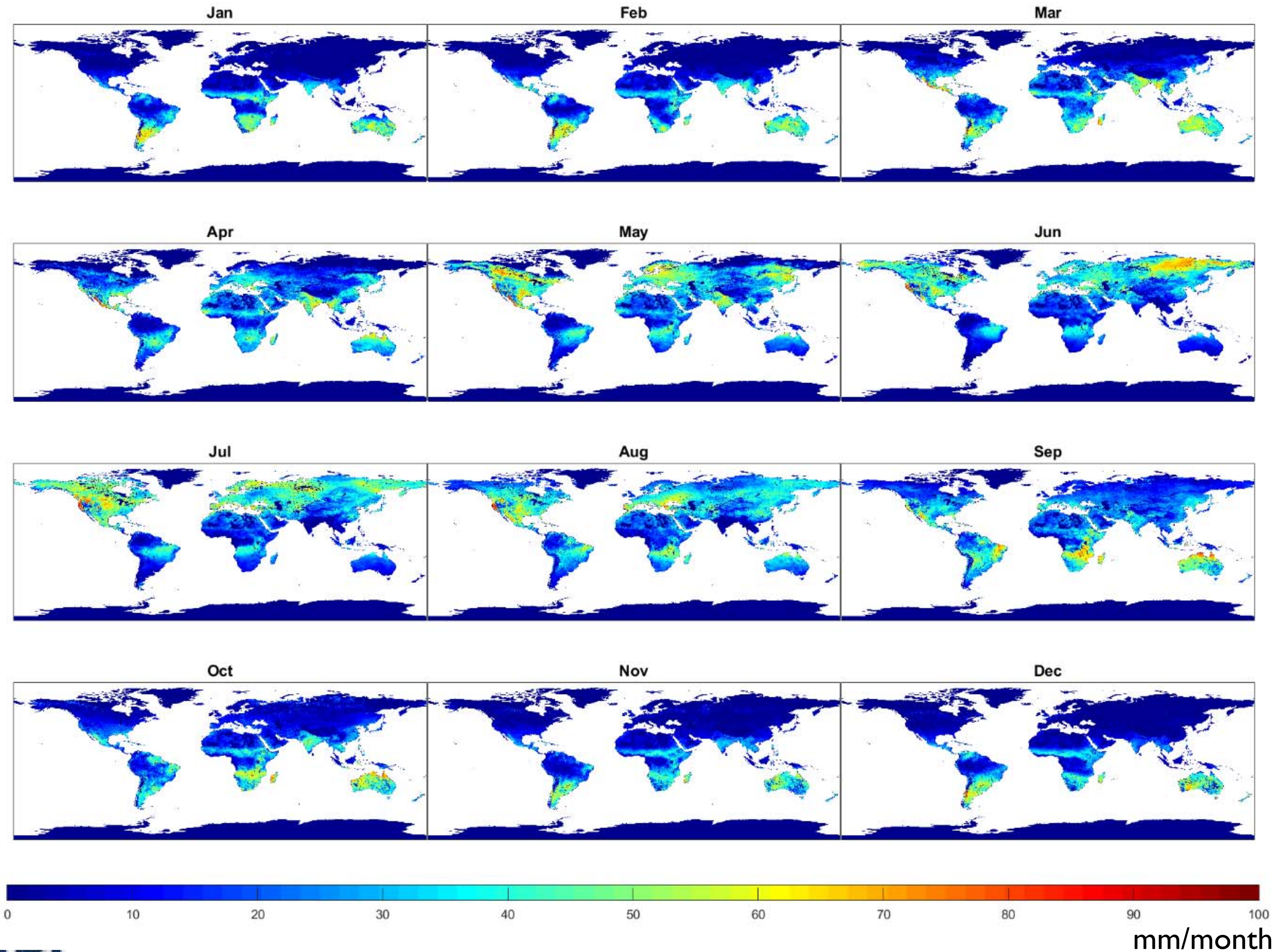
- Developing a relationship between the relative soil moisture at the surface to that in deeper layers of soil would be very useful for remote sensing applications.

- <u>This implies that prediction of soil moisture in the deep layer given the superficial soil moisture, has an uncertainty that increases with a reduced near surface estimate.</u>



Manfreda et al. (AWR – 2007)

SEBS-Derived Monthly ET (MODIS + ERA5, 2018)

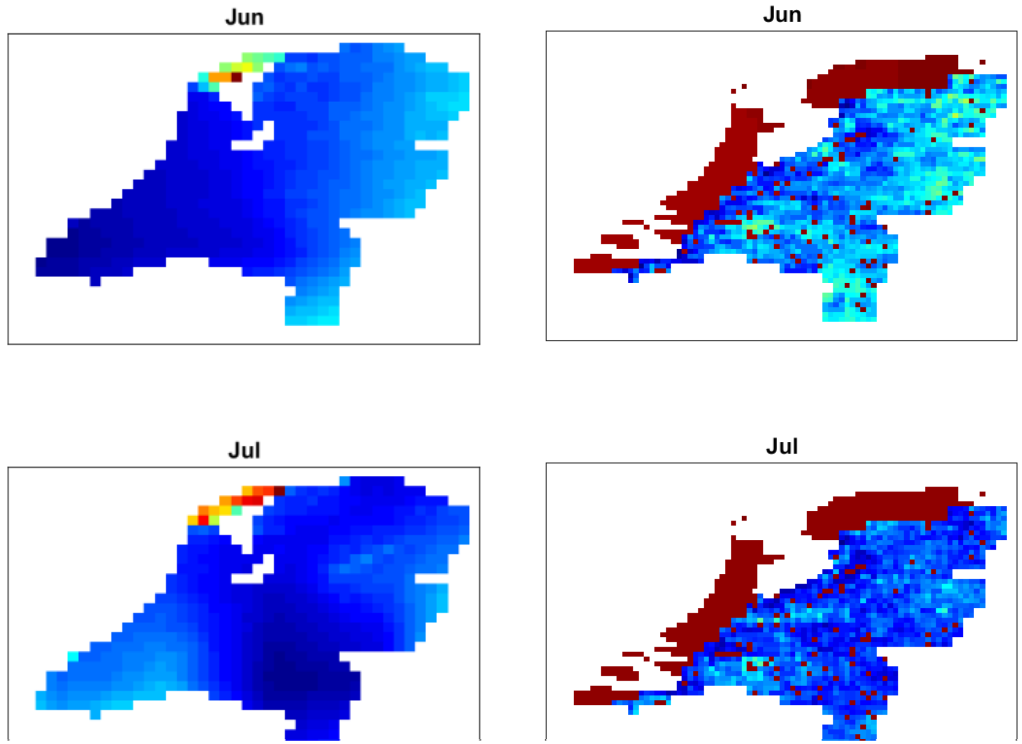


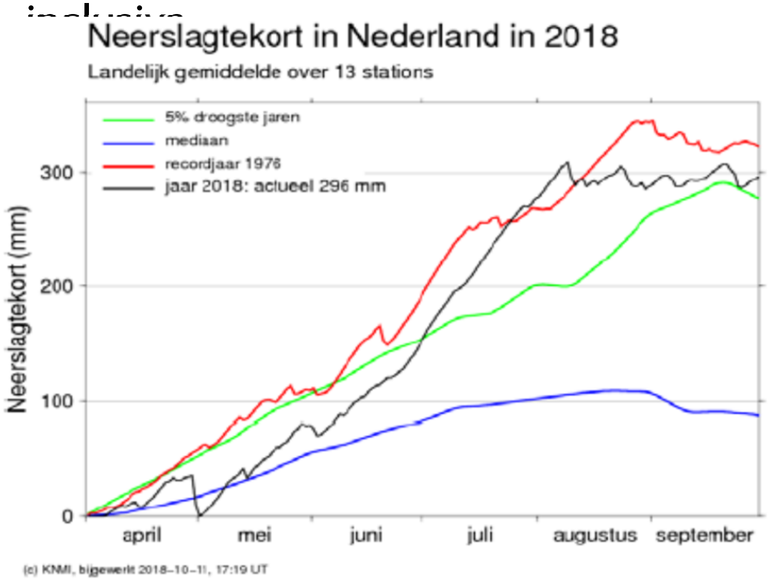
The Netherlands experienced a heat wave of 13 days starting with 15 July and to 27 July inclusive.
The country's longest since the European heat wave of 2006.

In many parts of the country authorities were planning for measures in case of water shortages.

A second heat wave started on 29 July, lasting 10 days until 7 August inclusive

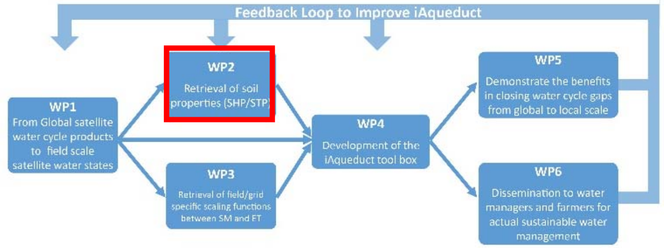
Monthly IMERG(GPM) | P-E





Source: KNMI.nl

Photo: Akkerwijzer.nl



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Pursuing the Unknown

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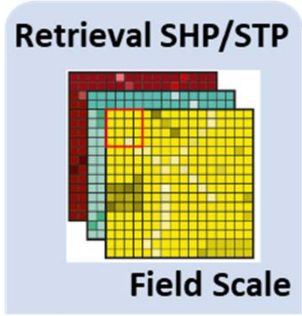
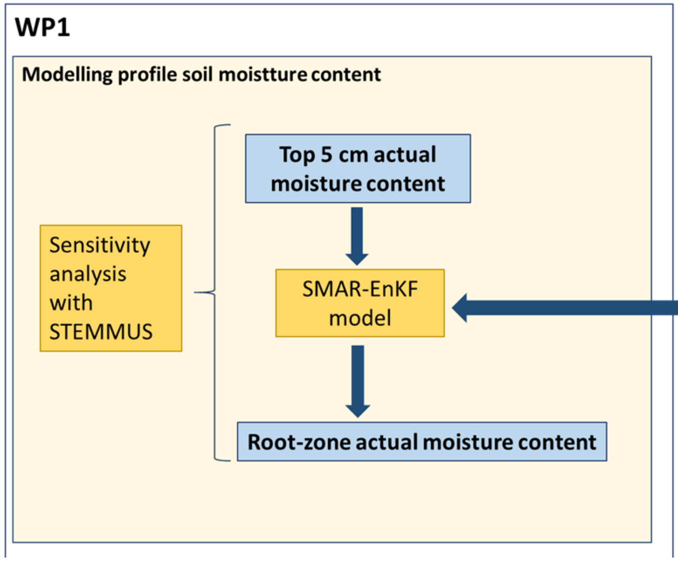
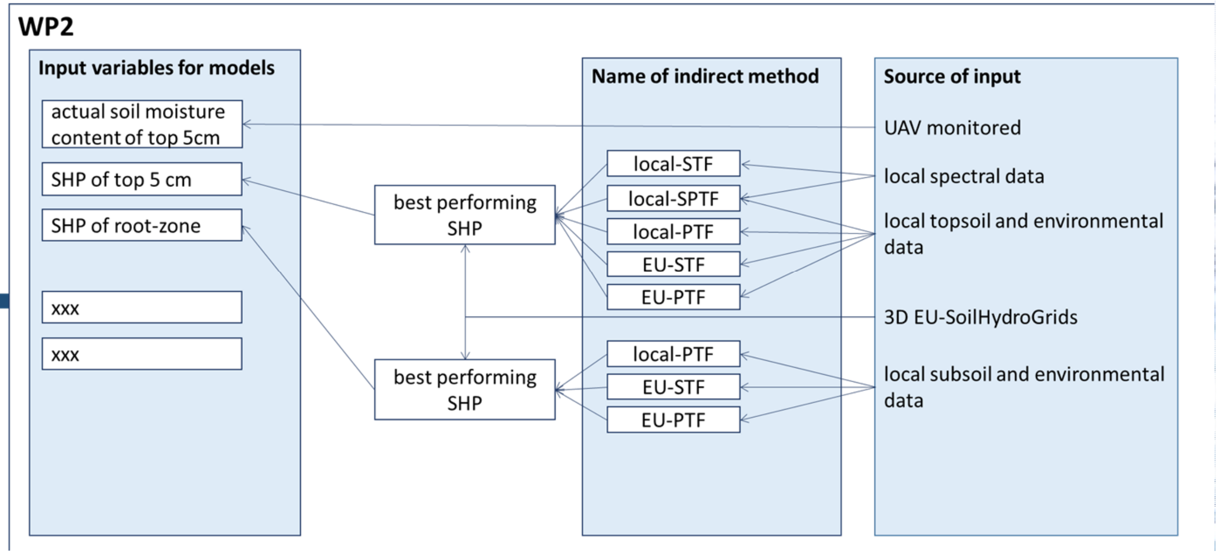
WP2
Retrieval of soil properties (SHP/STP)

- **Task 2.1 Collection of field scale data**
- **Task 2.2 Soil spectroscopy and hyperspectral remote sensing**
- **Task 2.3 Basic PTF functions**
- **Task 2.4 Advanced PTF functions**



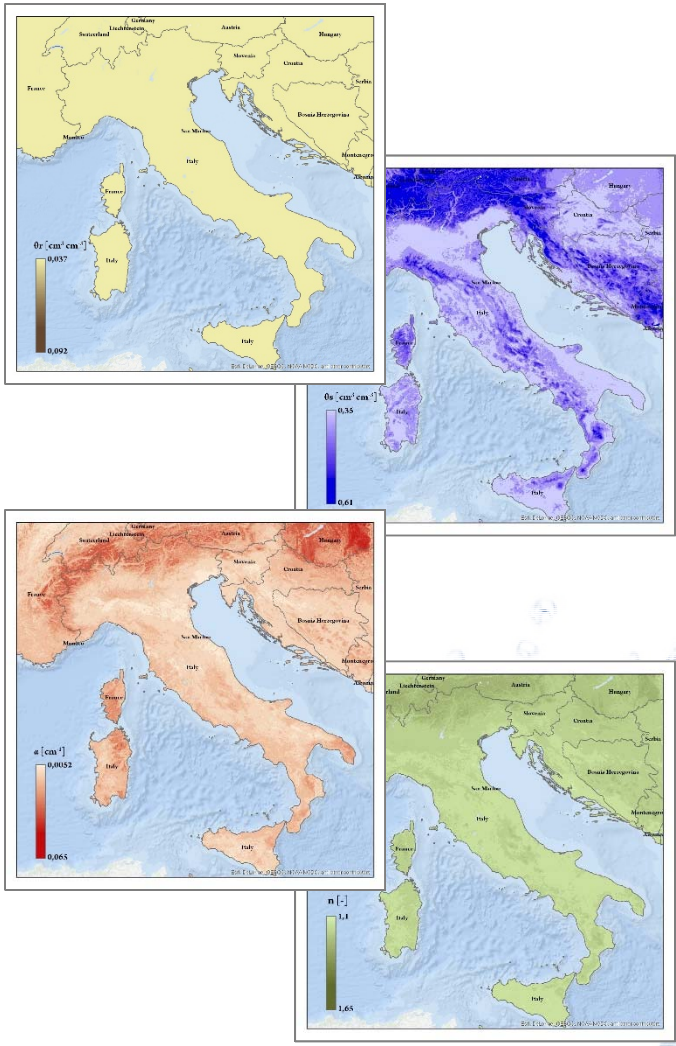
STF - spectrotransfer functions
SPTF - spectral pedotransfer functions
PTF - Pedotransfer functions
EU-STF - LUCAS
EU-PTF - EU-HYDI



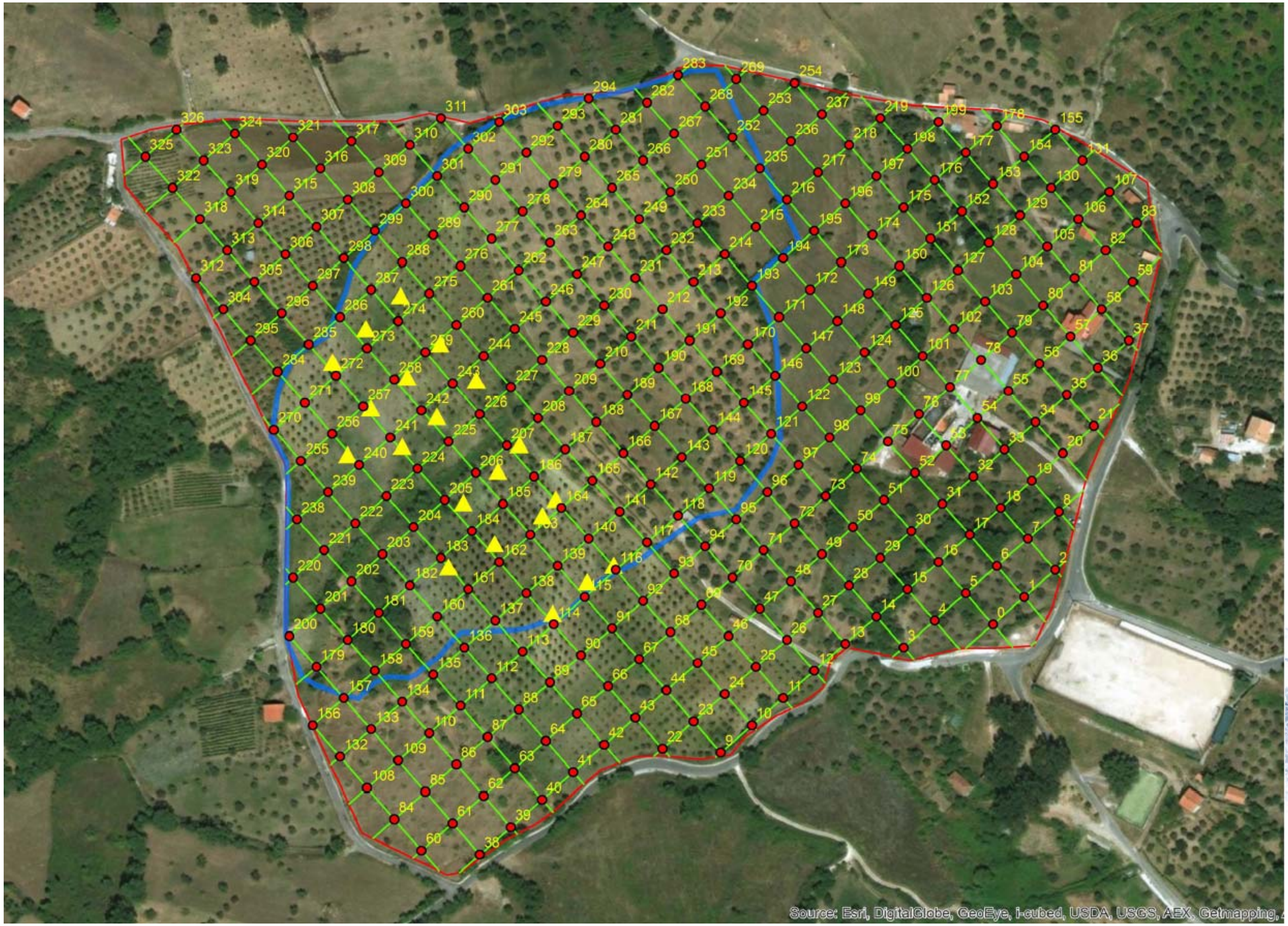


a) 3D Soil Hydraulic Database of Europe at 250 m resolution

	EU-SoilHydroGrids
Predicted soil hydraulic property	THS, FC, WP, KS, MRC (VG), MRC + HCC (MVG)
Horizontal coverage	Europe
Vertical coverage	0, 5, 15, 30, 60, 100, 200 cm
Resolution	250 m, 30 arcseconds (~ 1 km at the Equator)
Projection	ETRS-LAEA
Format	GeoTIFF
Input soil information	SoilGrids 250 m and 1 km (Hengl et al., 2017)
Soil property considered for the calculations	clay, silt and sand content, organic carbon content, bulk density, pH in water, depth to bedrock
Pedotransfer functions (PTFs) used for the calculations	EU-PTFs: PTF6 (THS), PTF9 (FC), PTF12 (WP), PTF16 (KS), PTF22 (MRC), PTF 19 (MRC+HCC) (Tóth et al., 2015)
Database used to derive PTFs	EU-HYDI (Weynants et al., 2013)
Availability of the dataset	http://mta-taki.hu/en/eu_soilhydrogrids_3d https://esdac.jrc.ec.europa.eu/
Information about the dataset	Tóth et al. (2017)



► To provide soil physico-chemical and hydraulic parameters for running models of different complexity. (Nunzio Romano, 2019)



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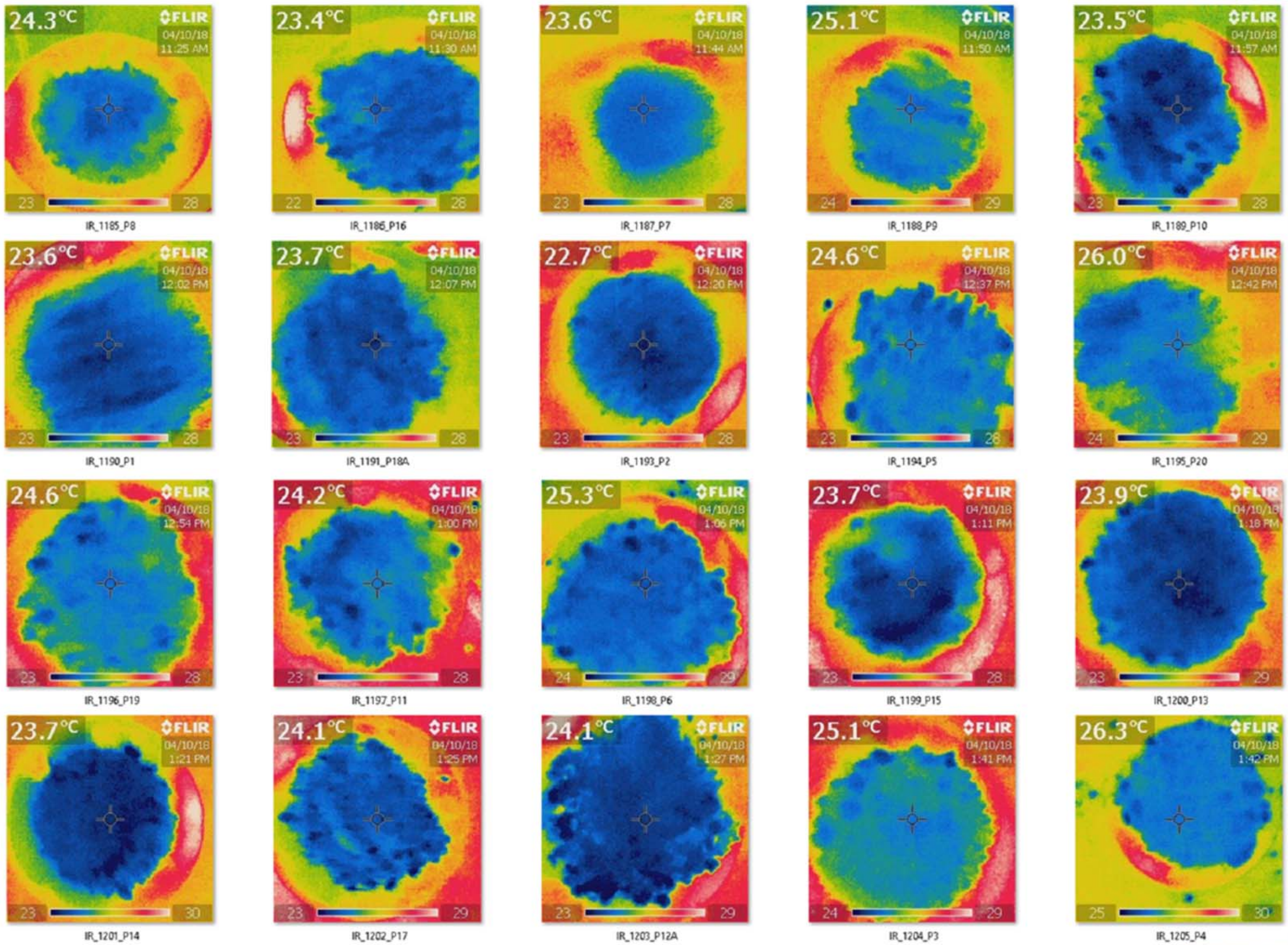
- *a) shows a Spectral Measurement through ASD spectrometer, and b) shows a measurement of Temperature using a FLIR camera* (Eyal et al, 2019)

Water JPI

www.waterjpi.eu

iAqueduc



The thermal images and the temperature of the soil samples (Eyal et al, 2019)

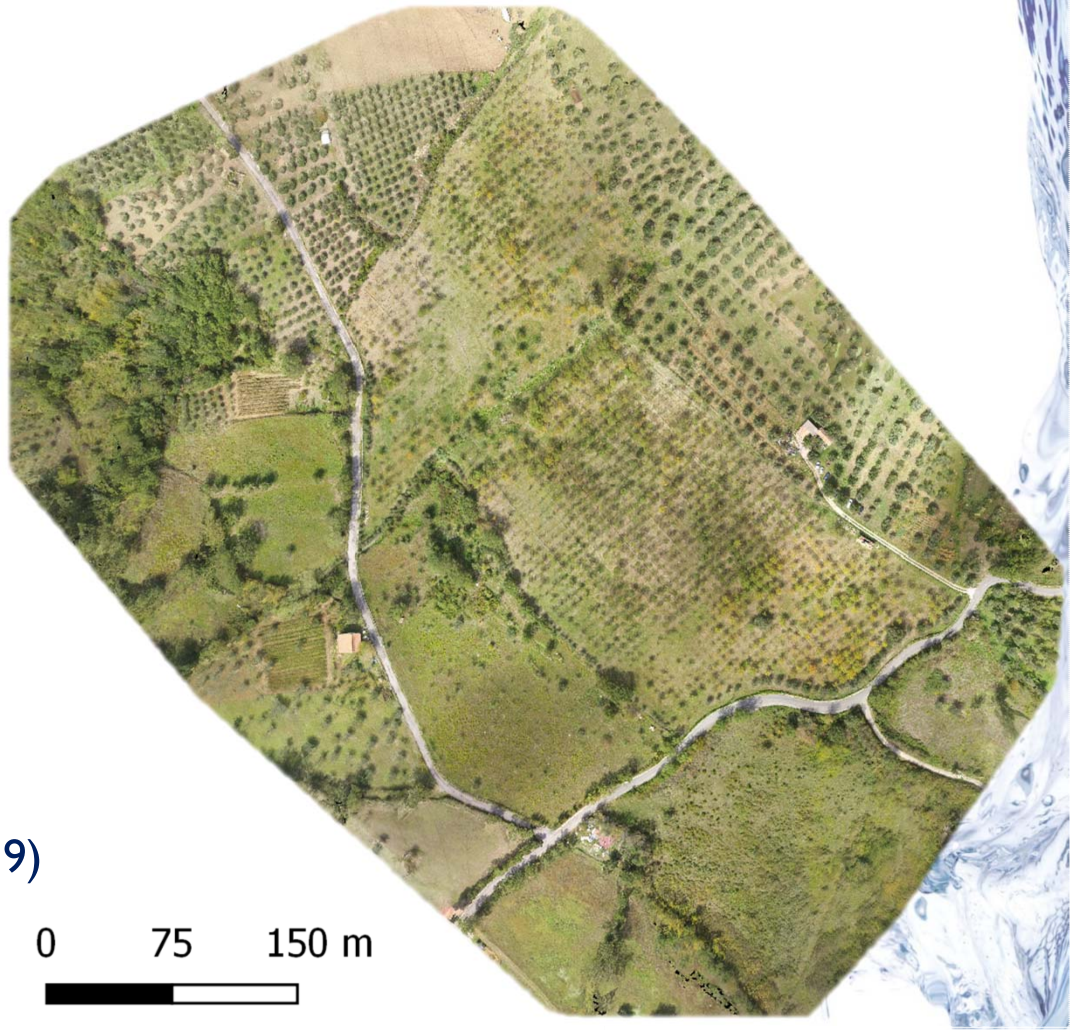
Water JPI

www.waterjpi.eu

Application:

Orthomosaic Monteforte

RGB Orthomosaic
4 cm resolution

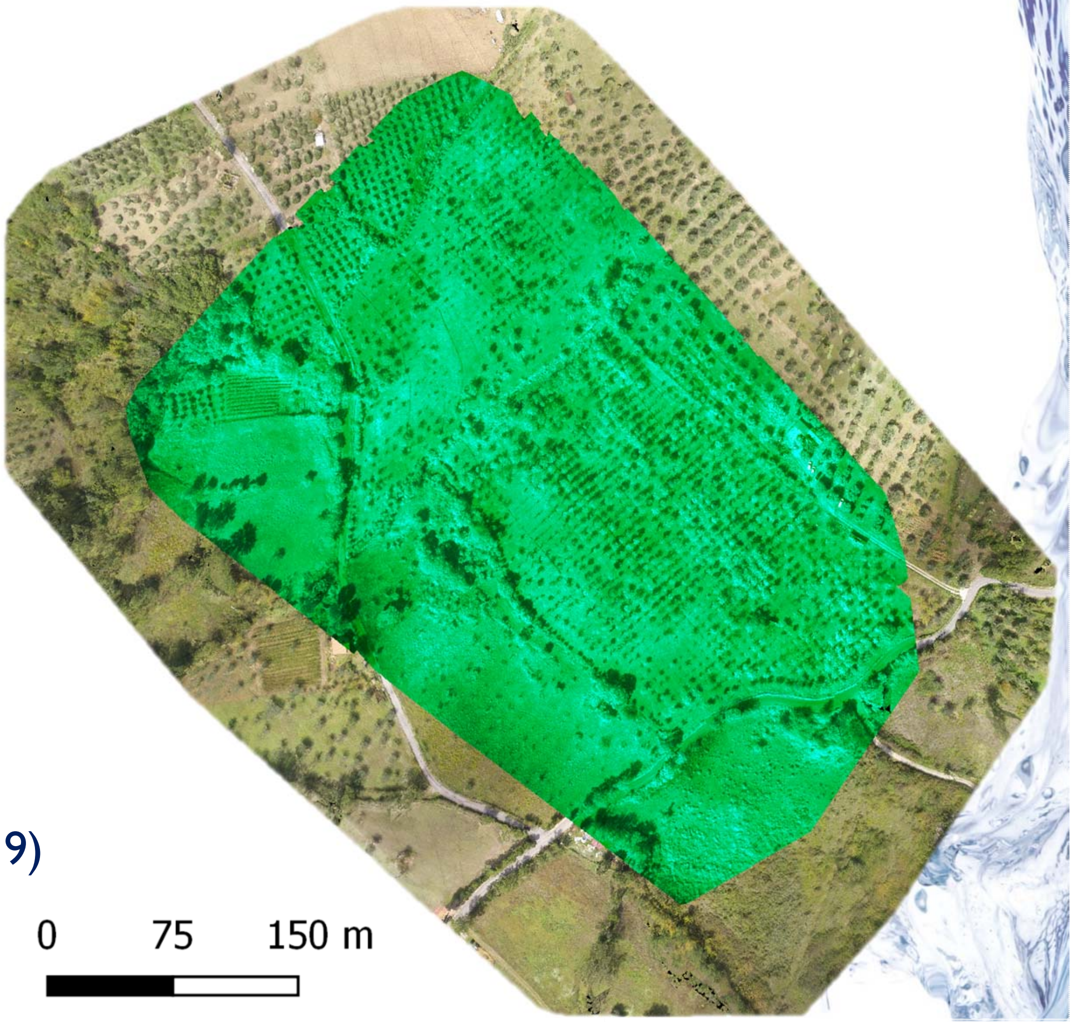


(Manfreda et al, 2019)

Example of Application: Orthomosaic Monteforte

Multi-spectral mosaic
5 cm resolution

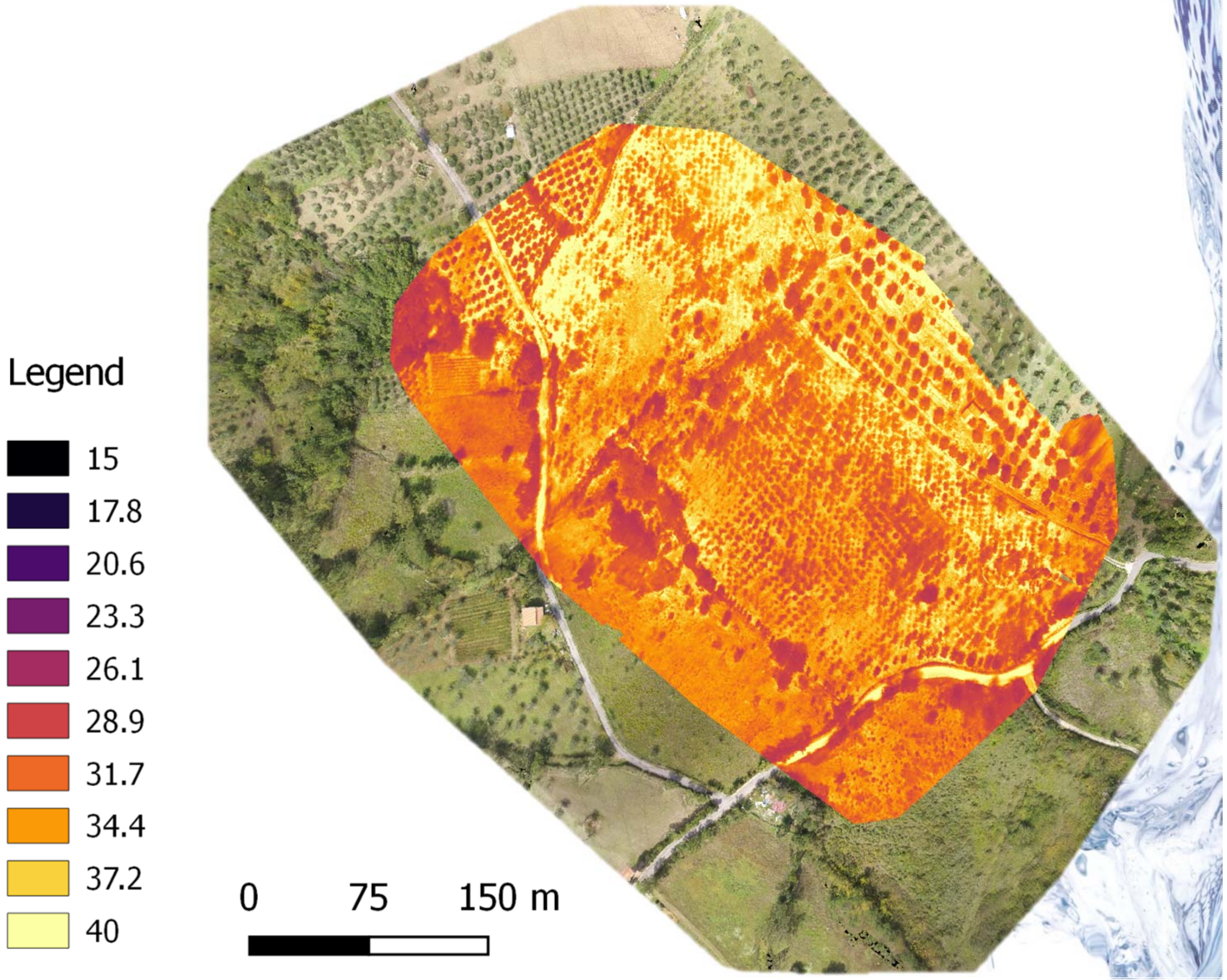
(Manfreda et al, 2019)



Example of Applications:

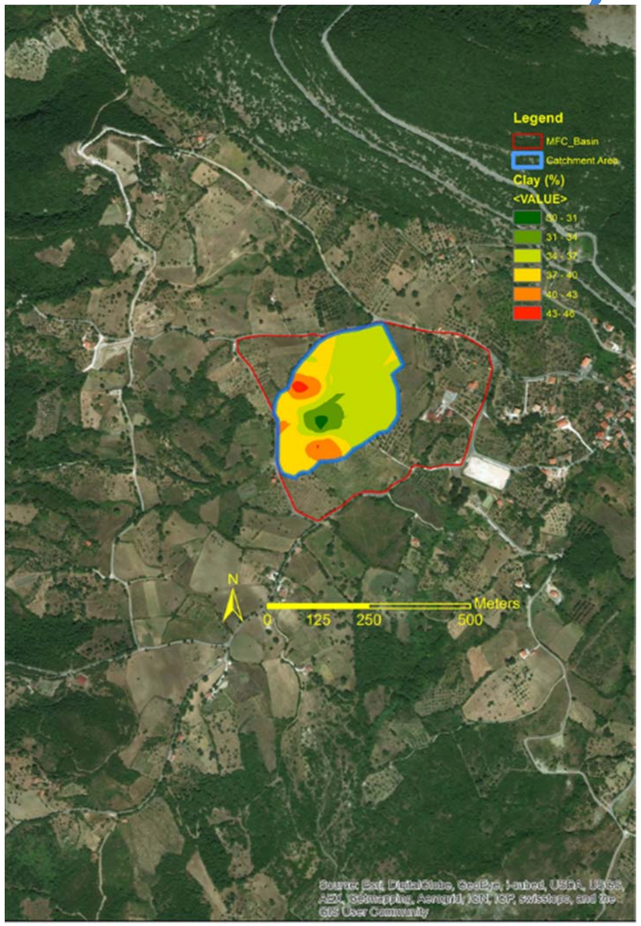
Orthomosaic Monteforte

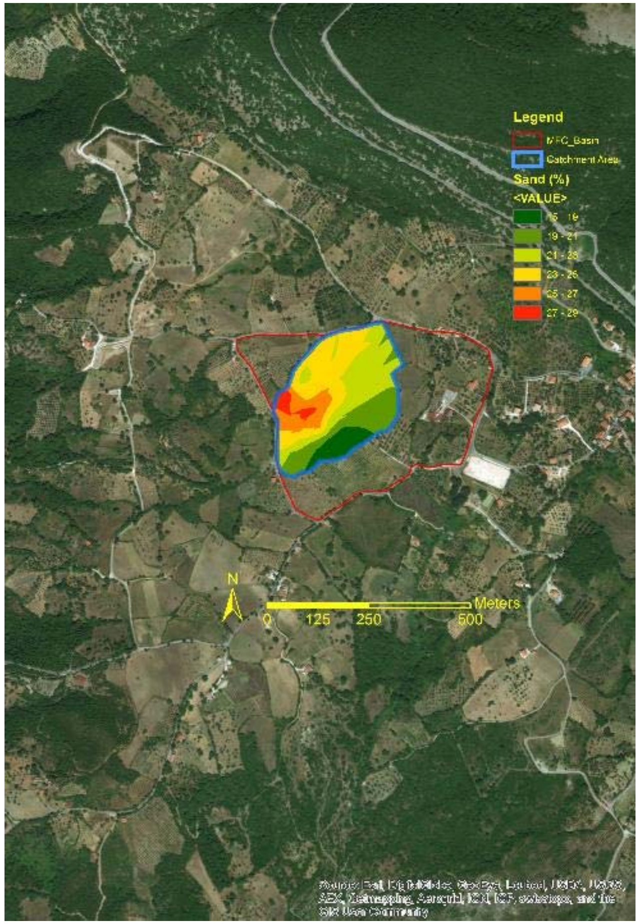
Thermal mosaic
17 cm resolution

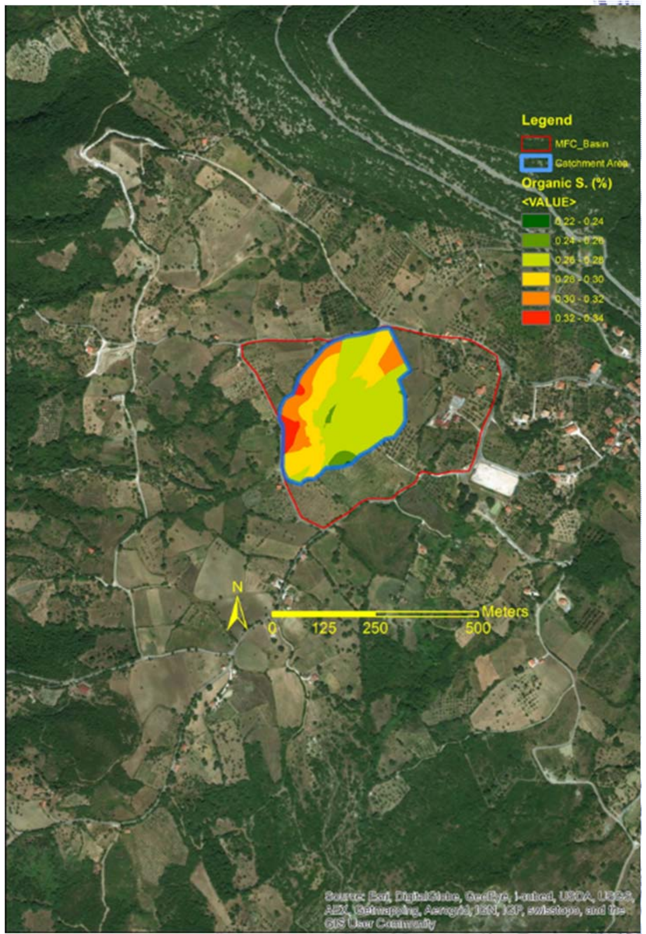


(Manfreda et al, 2019)

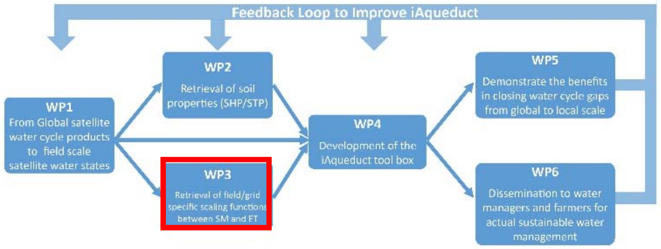
Preliminary Results: Soil Texture







(Romano et al, 2019)



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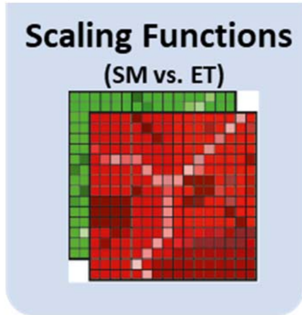
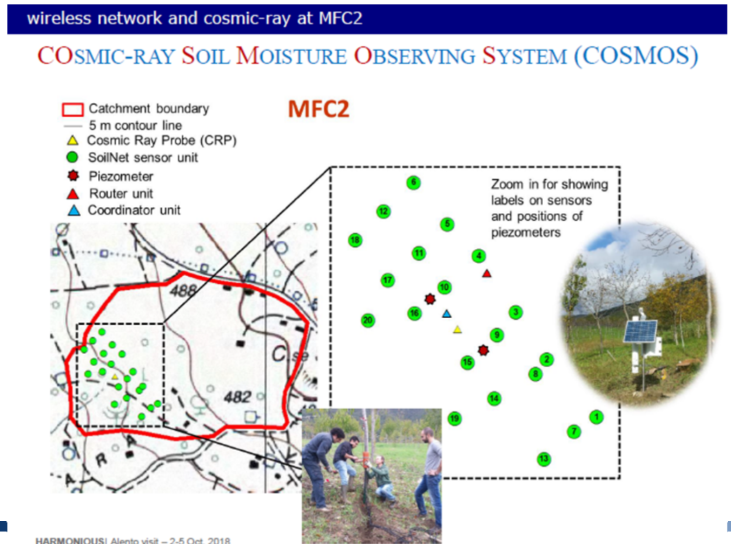
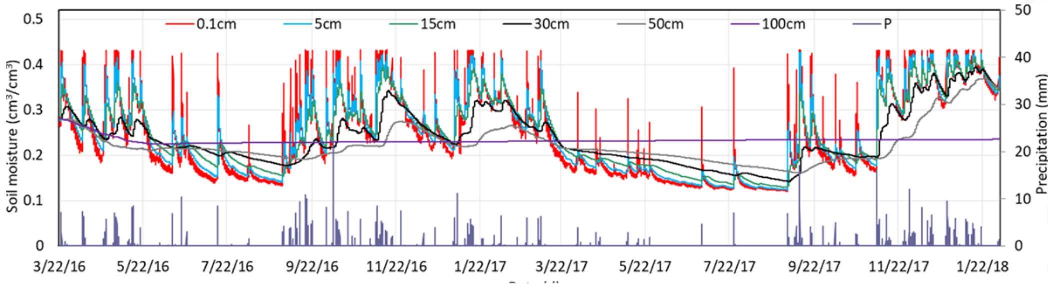
WP3
Retrieval of field/grid specific scaling functions between soil moisture and evapotranspiration

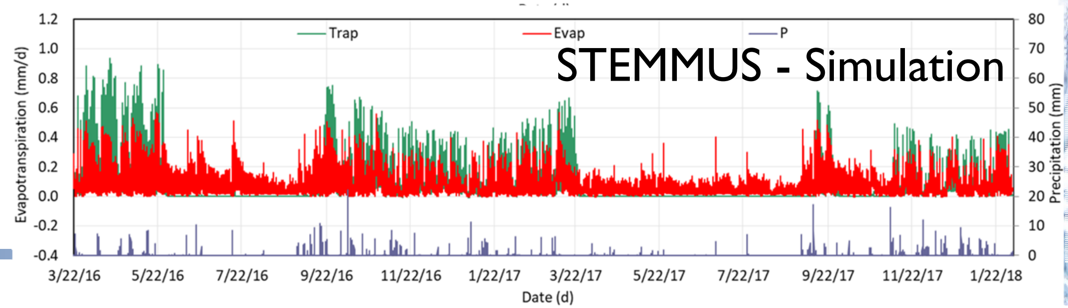
Task 3.1 Field/grid specific scaling functions between soil moisture and evapotranspiration

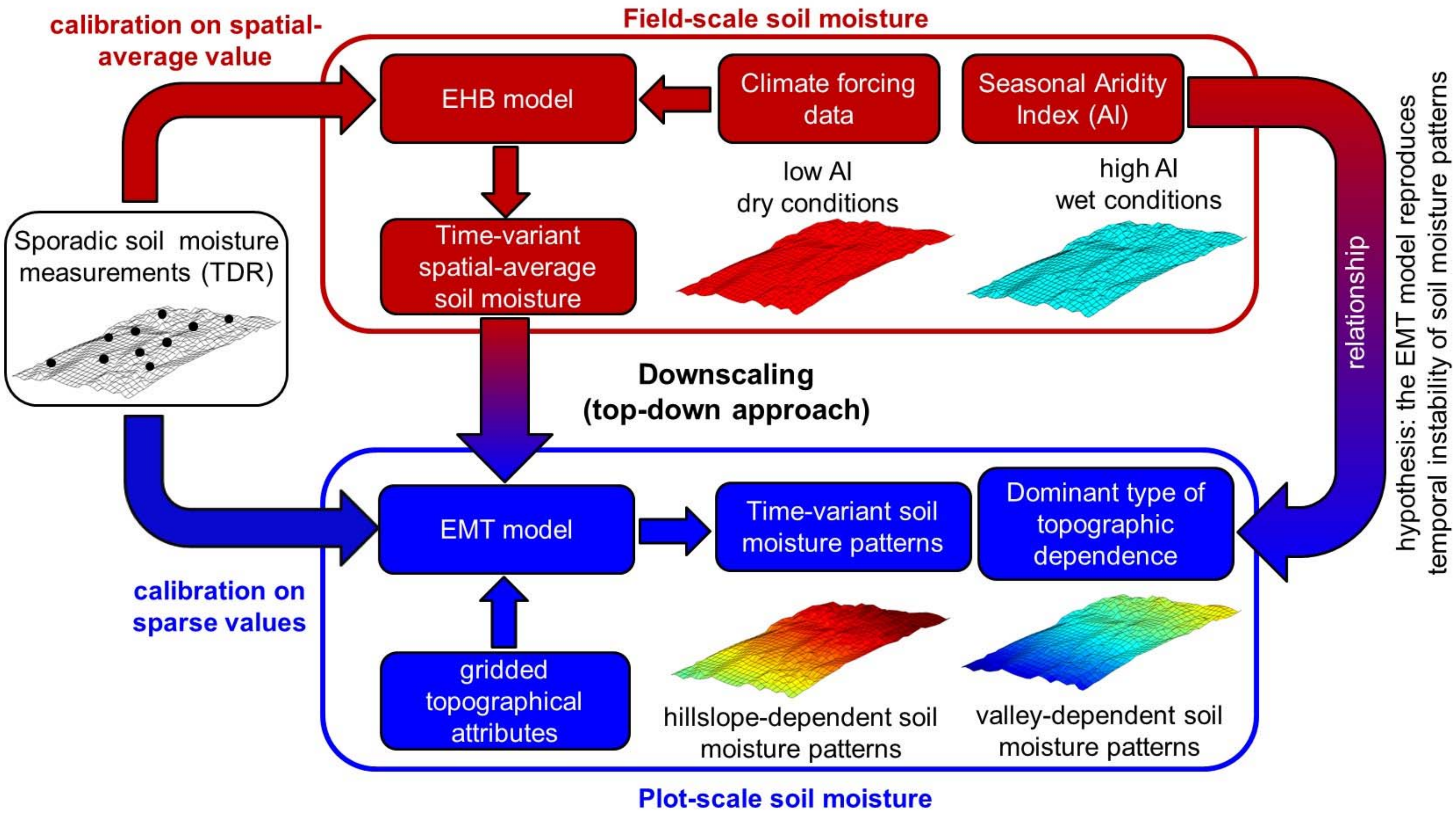
Task 3.2 Generalizing scaling functions between soil moisture and evapotranspiration







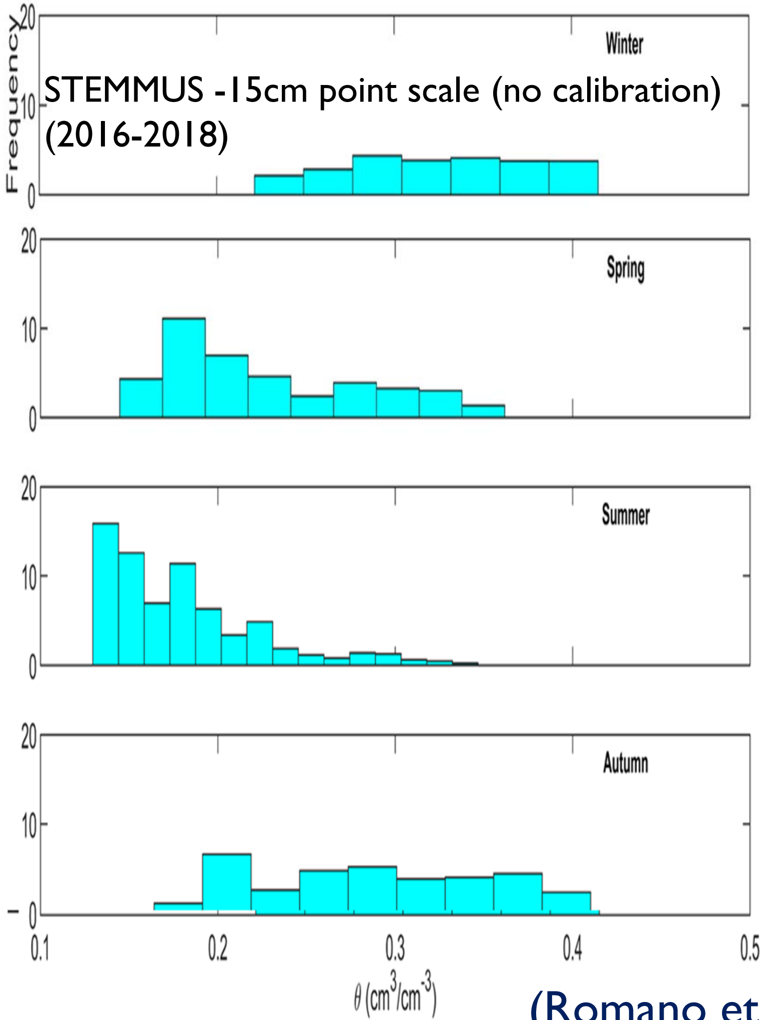


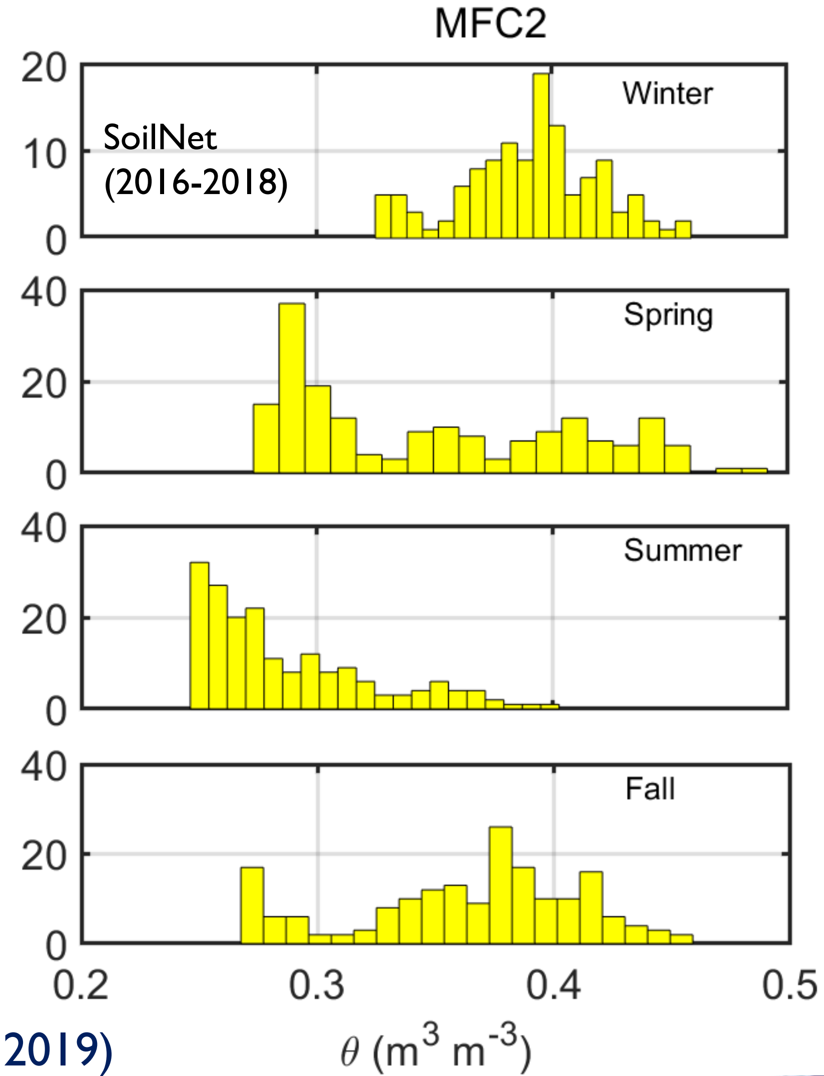


(Romano et al, 2019)

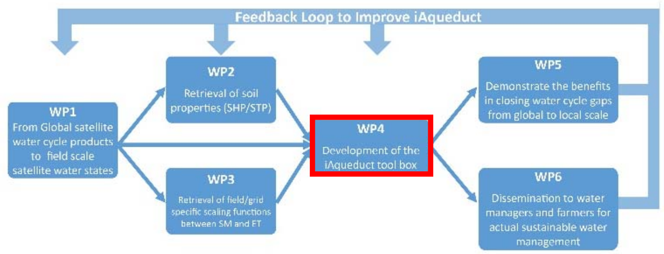
STEMMUS Preliminary Simulation Results:

Spring : 20 Mar – 20 June
Summer: 20 June – 23 Sep.
Autumn : 23 Sep. – 22 Dec.
Winter : 22 Dec. – 20 Mar





(Romano et al, 2019)



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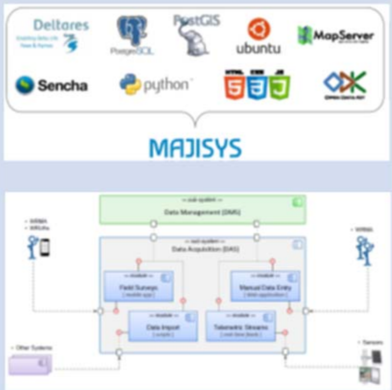
WP4 Development of the generic (iAqueduct tool box)

Task 4.1 Intercomparison of models, soil and vegetation parametrizations and soil parameters

1) A minimalist soil-vegetation-atmosphere model will be developed;
2) The coupling of the soil moisture dynamics and plant activities (ET and carbon fixation);
3) For crops, yield will be determined from the total accumulated crop biomass employing the harvest index, with biomass growth rate depending on the growing conditions;
4) Machine leaning algorithms will be experimented to speed up the usually computational intensive process-based computations.



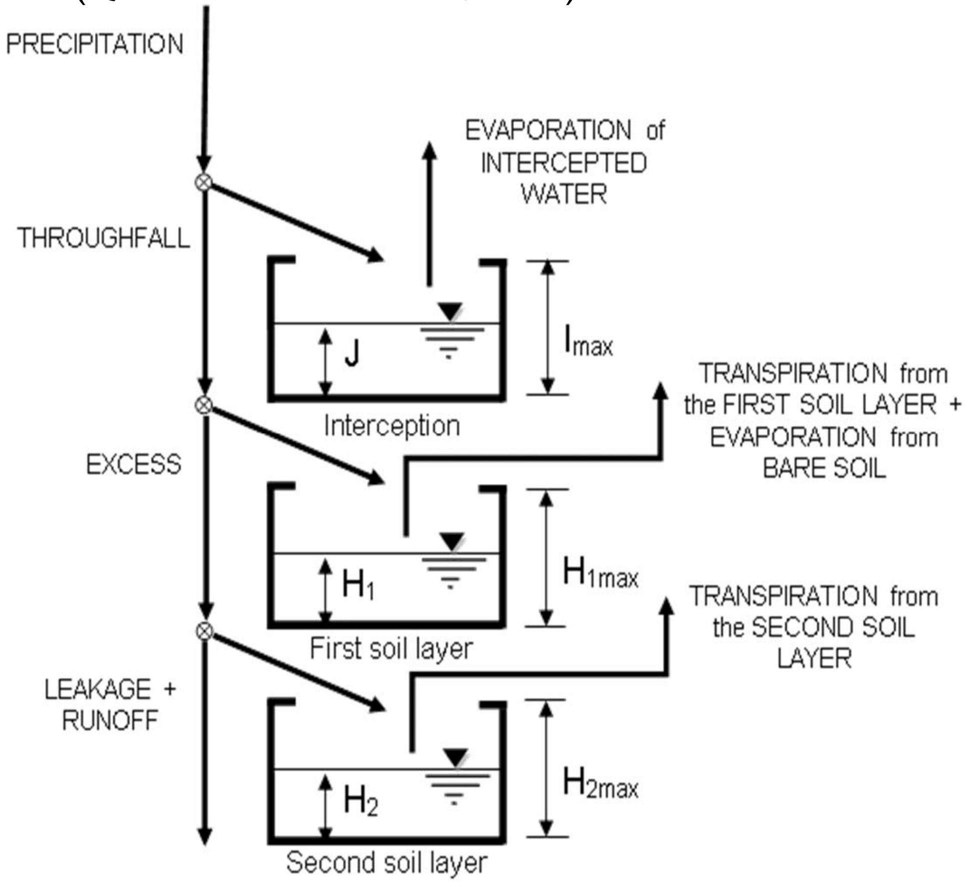
Task 4.2 iAqueduct toolbox

1) The existing open–source software system MajiSys water information system as the core ;
2) The iAqueduct toolbox which consists of water flow processes in relations to the models, soil and vegetation parametrizations and soil parameters as well as forcing fields.

What is the State-of-the-Art?

SPAC MODELS III – Minimalist approach

Hydrological sub-model
(Quevedo and Francés, 2012)



Dynamic Vegetation sub-model (Pasquato et al., 2014)

Based on the Light Use Efficiency

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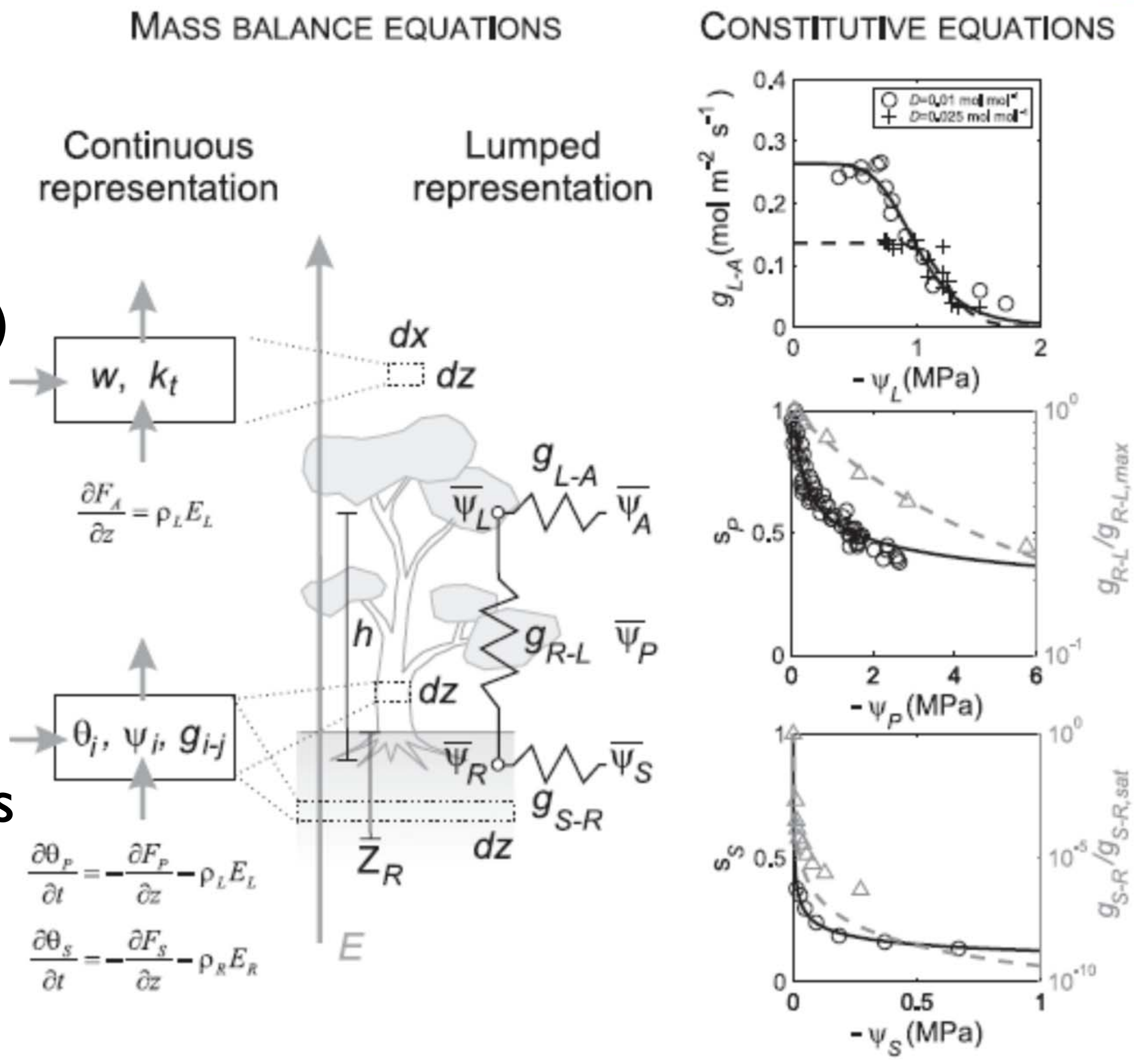
What is the State-of-the-Art?

SPAC MODELS II – Leaf-to-plant, layered

Focus on water balances and fluxes

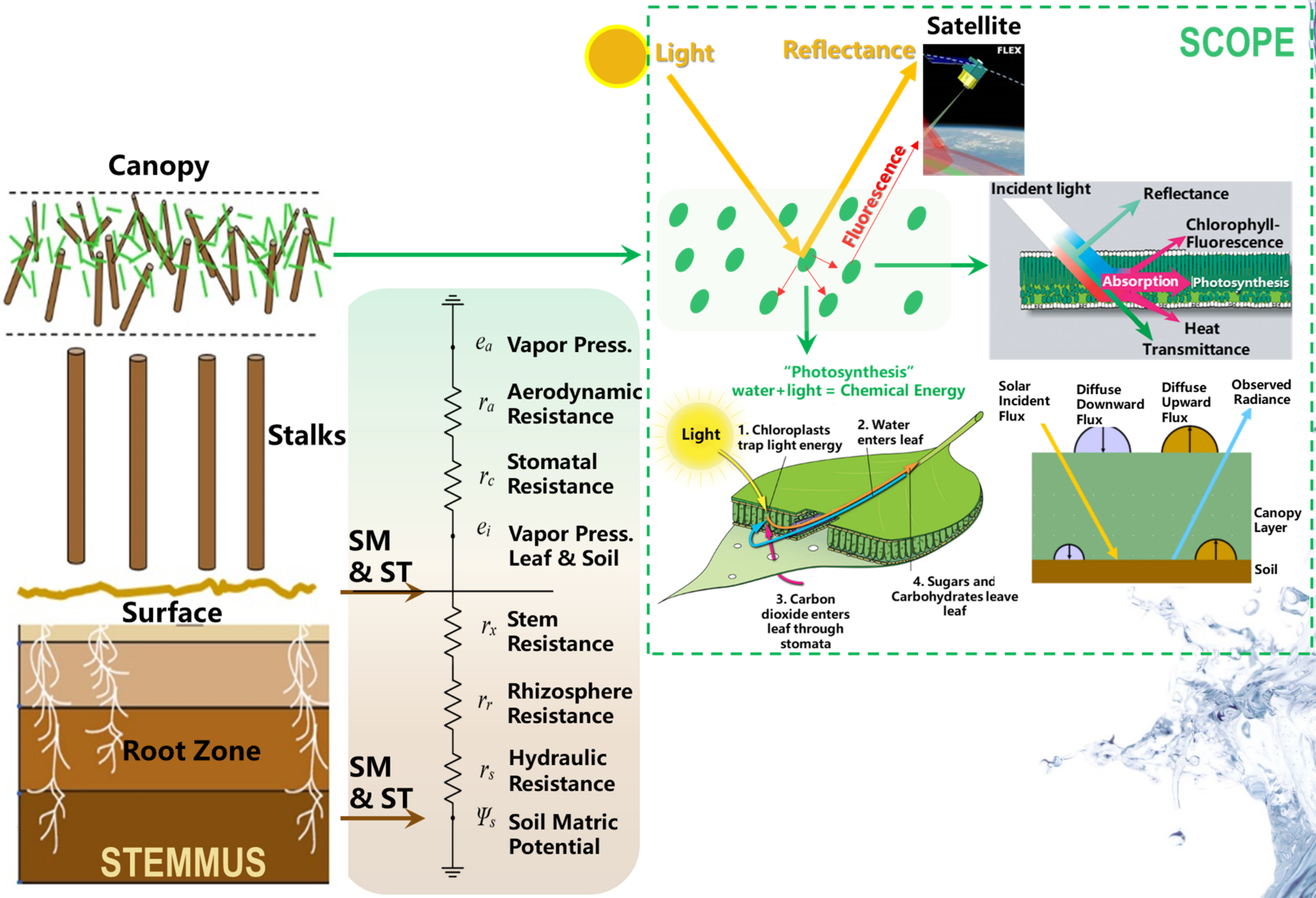
Energy in some (stomatal) models

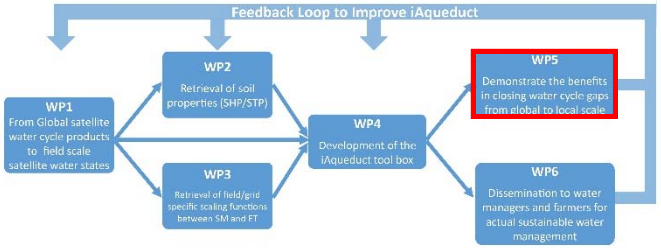
Can be lumped (big leaf + soil bucket models) or resolved layers wise (two big leaves or canopy layers + soil layers)



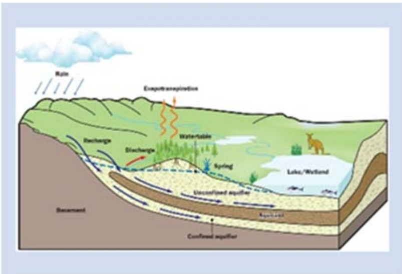
(Manzoni, Vico, Porporato, Katul, 2013 AWR)

STEMMUS + SCOPE





WP5
Demonstrate the benefits in closing water cycle gaps from global to local scale



- The aim of this WP is closing water cycle gaps by improving hydrological model implementations using spatial information;
- Discharge provides only limited insight on the spatial behavior of the catchment (Conradt et al., 2013 HESS);
- The development of distributed hydrological models and the availability of spatio-temporal data (WP1-3) appear as key alternative to overcome those limitations and can facilitate a spatial-pattern-oriented model calibration (Ruiz-Pérez et al., 2017 HESS);
- This WP will advance how to effectively handle spatio-temporal data when included in model calibration and how to evaluate the accuracy of the simulated spatial patterns;
- Numerical experiments will be conducted for calibration of a parsimonious distributed ecohydrological daily model in ungauged basins using exclusively spatio-temporal information obtained from WP1 and other remotely sensed information.

Introduction

- General research question for hydrological modelling: **is it profitable to use RS info for model calibration?**
  - NDVI at plot scale:
  - NDVI at catchment

Hydrol. Earth Syst. Sci., 12, 1175–1187, 2008
www.hydrol-earth-syst-sci.net/12/1175/2008/

Hydrology and Earth System Sciences

A conceptual dynamic vegetation-soil model for arid and semiarid zones

D. I. Quevedo[1] and F. Francés[1]
[1]Institute for Water Engineering and Environment, Polytechnical University of Valencia, Spain

ECOHYDROLOGY
Ecohydrol. 8, 1024–1036 (2015)
Published online 6 October 2014 in Wiley Online Library
(wileyonlinelibrary.com) DOI: 10.1002/eco.1559

Comparing two approaches for parsimonious vegetation modelling in semiarid regions using satellite data

Marta Pasquato,[1*] Chiara Medici,[1,3] Andrew D. Friend[2] and Félix Fra
[1] *Research Institute of Water and Environmental Engineering, Universitat Politècnica de València, Valenc*
[2] *Geography Department, University of Cambridge, Cambridge, UK*
[3] *Civil and Environmental Engineering, Princeton University, Princeton, NJ, USA*

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Research article

Managing low productive forests
biomass and fire risk to achieve e

María González-Sanchis[a,*], Guiomar Ruiz-
Félix Francés[c], Cristina Lull[a]

Hydrol. Earth Syst. Sci., 21, 6235–6251, 2017
https://doi.org/10.5194/hess-21-6235-2017

Hydrology and Earth System Sciences
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Calibration of a parsimonious distributed ecohydrological daily model in a data-scarce basin by exclusively using the spatio-temporal variation of NDVI

Guiomar Ruiz-Pérez[1,6], Julian Koch[2,3], Salvatore Manfreda[4], Kelly Caylor[5], and Félix Francés[6]

Temporal efficiencies

- Nash-Sutcliffe Efficiency index (NSE) (Frances et al, 2019)

$$1 - NSE = \frac{\sum_{t=1}^{T}\left(Q_{sim}^{t} - Q_{obs}^{t}\right)^{2}}{\sum_{t=1}^{T}\left(Q_{obs}^{t} - \overline{Q_{obs}}\right)^{2}}$$

where Q_{sim}^{t} is modelled discharge at time t, Q_{obs}^{t} is observed discharge at time t, $\overline{Q_{obs}}$ is the mean of observed discharges

- Balance Error in % (BE)

$$BE = \frac{\sum_{t=1}^{T}\left(Q_{sim}^{t} - Q_{obs}^{t}\right)}{\sum_{t=1}^{T}\left(Q_{obs}^{t}\right)}$$

where Q_{sim}^{t} is modelled discharge at time t, Q_{obs}^{t} is observed discharge at time t

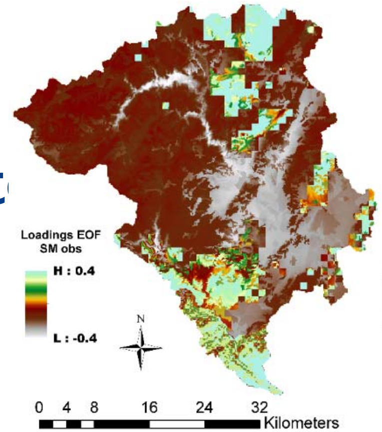
Spatio-temporal efficiency (STE)

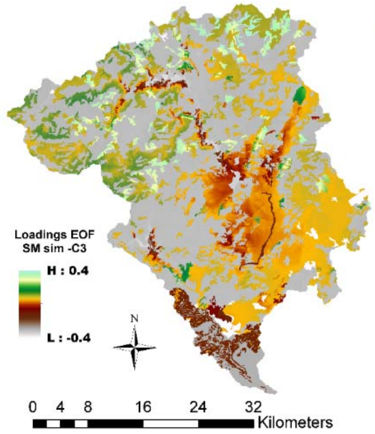
(Frances et al, 2019)

$$STE = \frac{\sum_{p=1}^{N}[w_p * NSE(loadings(EOF)_p^{obs}\ , loadings(EOF)_p^{sim})]}{N}$$

- STE (and any other metric) tries to incorporat
  - Spatial pattern
  - Temporal dynamics, without consi

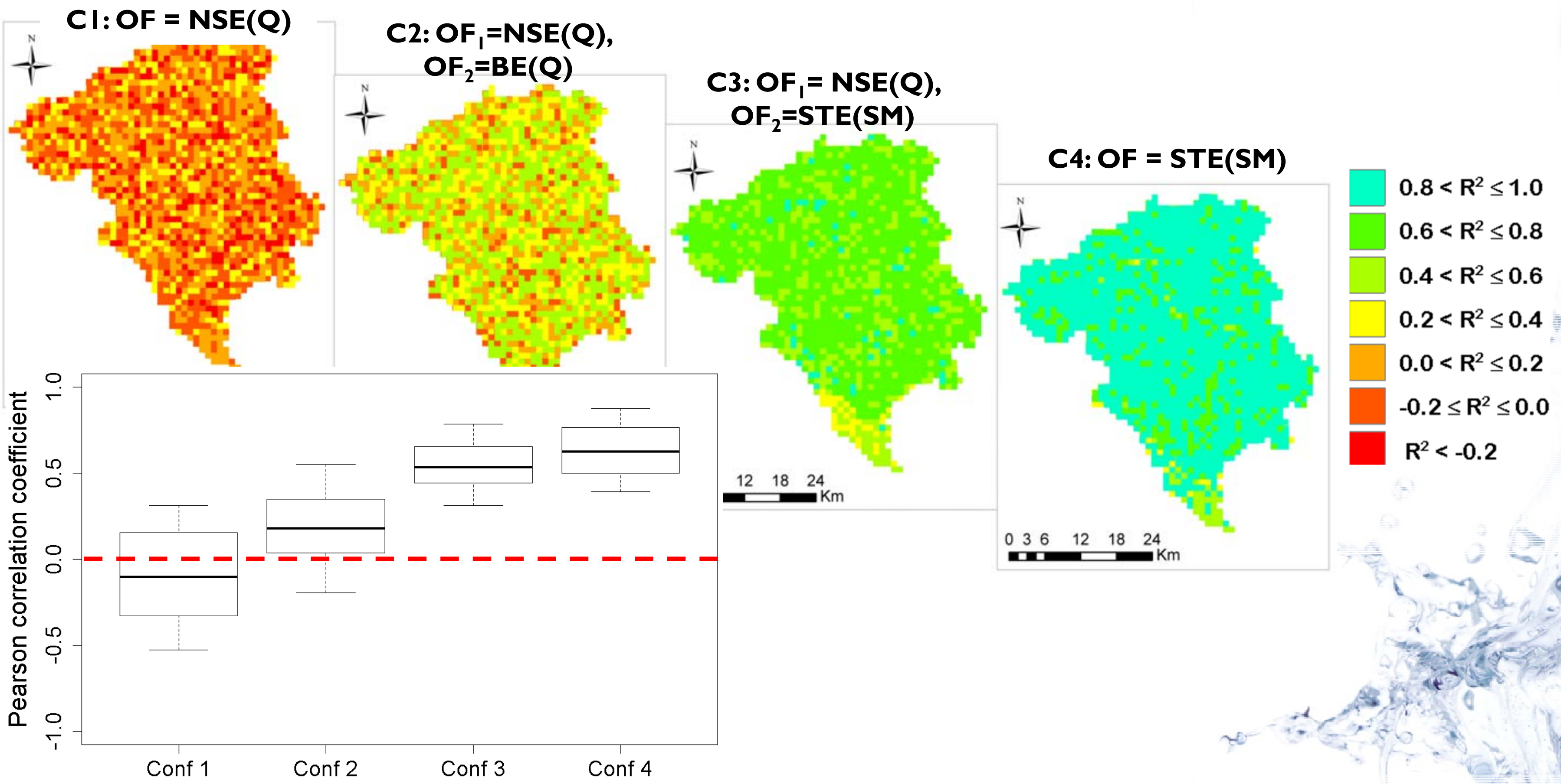
  the exact values of the satellite





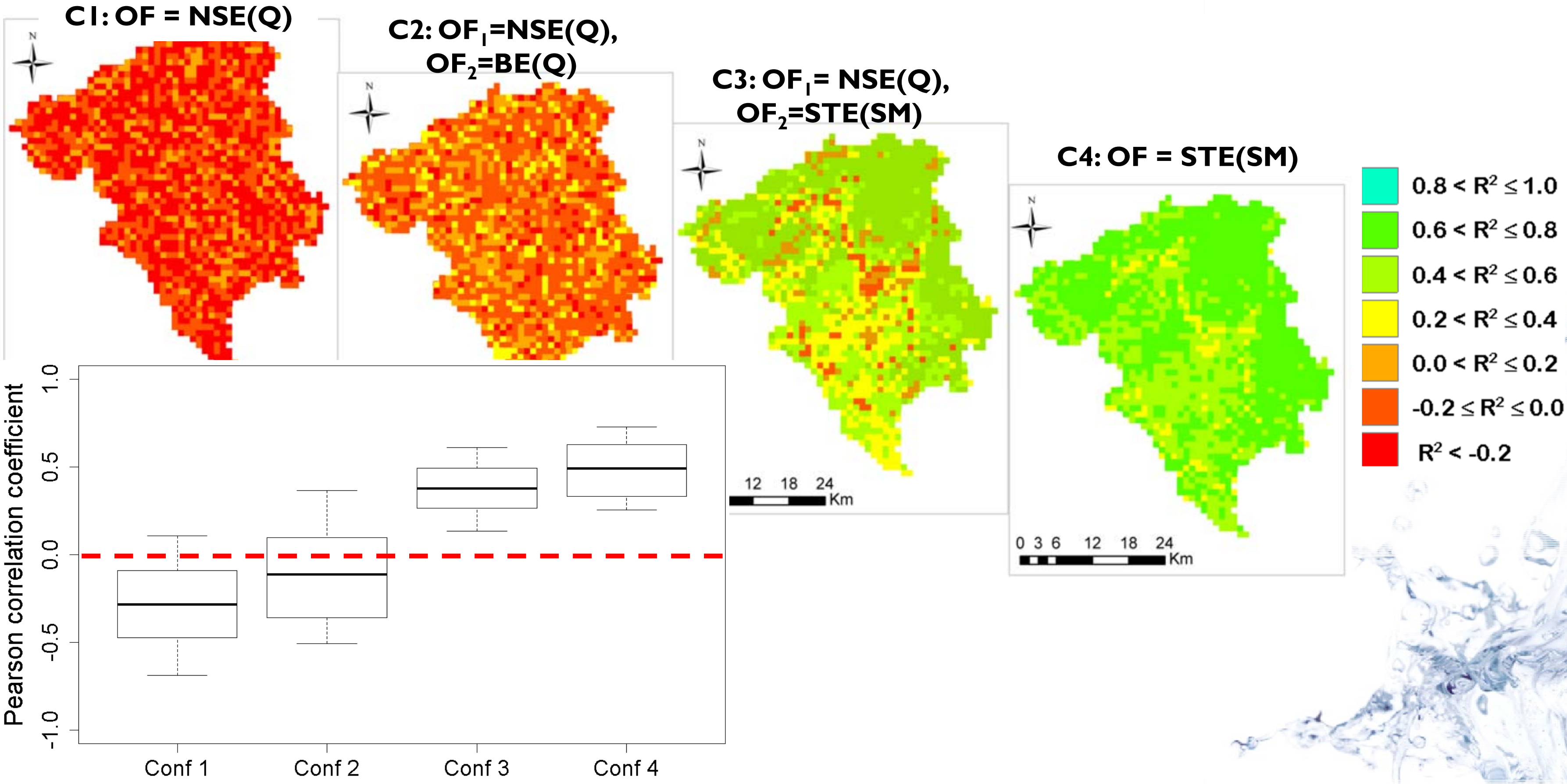
Soil Moisture R^2 maps: calibration period

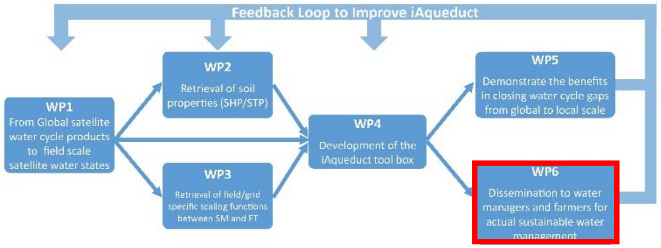
(Frances et al, 2019)



LAI R^2 maps: calibration period

(Frances et al, 2019)





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WP6
Disseminate generated knowledge and tools for actual sustainable water management

- The aim of WP6 is to disseminate and communicate the generated knowledge and tools to water managers, companies and farmers for actual sustainable water management.
- In order to be effective, stakeholders will be engaged in the entire project for the effective transfer of the project achievements and will be consulted for the actual needs for real life water management.
- We will use the 2018 summer European drought as a concrete retrospective application to demonstrate the advantage of using detailed water cycle information for water management.

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Potential links to Ruisdael Observatory?

- Micro-scale soil physical processes?
- Micro-scale biophysical processes?
- Potential coupling with micro-physics on the ground?

Thanks for your attentions