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

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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

WB1 (section 3.1) Downscaling of Satellite Water Cycle Products with UAS

WB2 (section 3.2) Retrieval of soil Hydraulic and Thermal Properties

WB3 (section 3.3) Linking Soil Properties, Soil Moisture and Evapotranspiration

WB4 (section 3.4) Developing Plant- and Plot-Level Ecological Models Using Remote Sensing Information

WB5 (section 3.5) Improving Distributed Catchment-Scale Ecological Models using Spatial Information

WB6 (section 4) Towards Sustainable Water Management with iAqueduct Toolbox

(Su et al. 2020, Water, under review)
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.
Example 1: 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.

\[
\hat{\theta}_{i,j} = \overline{\theta} + \sigma_\theta(\overline{\theta}) \frac{P_{i,j} - \overline{P}}{\sigma_P}
\]

where \( P_{i,j} \) is the proxy data at fine scale sub-grid y-location i and x-location j, \( \overline{P} \) is the mean of the proxy, and \( \sigma_P \) 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]
Example 1: Sub-Grid Soil Moisture Variability Data for Downscaling, Maasai Mara, Kenya

ASCAT SMI (12.5km) → SMOS (25km) → SMAP (9km) → ASCAT SM

Porosity → SM variability for coarse pixel → Close-from expression model → Upscale to coarse resolution → Downscaling

Downscaled SM products (1km) → In-situ datasets → Validation

Soil map (1km) → Soil content → Clay content → Silk content → Sand content → Bulk density → Soil organic carbon content

PTF → VGM model

Field capacity (1km) → Hydraulc parameters

Kenya Maasai Mara Park

CRNP site

A01

SMOS

ASCAT

SMAP
Example 1: Sub-Grid Soil Moisture Variability Data for Downscaling, Maasai Mara, Kenya

(Liu, et al. 2019, ITC, University of Twente)
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.

- 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.

Manfreda et al. (AWR – 2007)
Example 3: RZSM over Tibetan Plateau

(Zhuang et al. 2020, Remote Sensing)
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

Retrieval SHP/STP
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

<table>
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<tr>
<th>EU-SoilHydroGrids</th>
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<tr>
<td>Predicted soil hydraulic property</td>
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<td>Horizontal coverage</td>
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<td>Vertical coverage</td>
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<td>Resolution</td>
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<td>Format</td>
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<td>Input soil information</td>
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<td>Soil property considered for the calculations</td>
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<td>Pedotransfer functions (PTFs) used for the calculations</td>
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<td>Database used to derive PTFs</td>
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<td>Information about the dataset</td>
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To provide soil physico-chemical and hydraulic parameters for running models of different complexity. (Nunzio Romano, 2019)
Preliminary Results: Soil Texture

(Romano et al, 2019)
a) shows a Spectral Measurement through ASD spectrometer, and b) shows a measurement of Temperature using a FLIR camera (Eyal et al, 2019)
The thermal images and the temperature of the soil samples (Eyal et al, 2019)
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
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 learning 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

The ultimate goal is to explore the advantages and disadvantages of the different approaches to modelling soil-vegetation-atmosphere interactions when aiming at reducing the reliance on in-situ observations and at taking full advantage of UAS, airborne and satellite observations.
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)

(Fatichi, et al. 2016)
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.
General research question for hydrological modelling: is it profitable to use RS info for model calibration?

- NDVI at plot scale:

- NDVI at catchment scale:
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.
- Growth
  - biomass production (kg/ha)
  - CO2 intake (kg/ha)
  - leaf area index LAI (m² leaf/m² ground)
  - vegetation index NDVI

- Moisture
  - evaporation shortage (mm/week)
  - current evaporation (mm/week)
  - surplus rain (mm/2 weeks)
  - reference evaporation

EXAMPLE
Thanks for your attentions!

https://www.costharmonious.eu/iaqueduct-water-jpi/