WATERWORKS 2017 RDI FUNDED PROJECTS BOOKLET

Project: 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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Project structure (WPs description):

WP1. From global satellite water cycle products to field scale water states *(Uni. Basilicata, Uni. Twente, UPV)*

This WP will focus on the monitoring and downscaling of soil moisture data based on remotely sensed data. It is divided into two main trajectories: one aimed at the spatial description of soil moisture and the second focusing on the prediction of soil moisture in the root-zone. The WP will be developed in close connection with the activities of WP2.

Task 1.1 Spatial downscaling procedures and data products

Task 1.1 will develop and test a number of procedures to downscale remotely sensed water cycle products to scales suitable for water management purposes:

1) Bayesian statistical bias correction of satellite data based on in-situ observation - calibration and validation at selected field sites with in-situ observation will form an integral part of this task (at kilometer scale but corrected for spatio-temporal error, e.g. due to topography, soil texture and climate, cf. those by Kimani et al., 2018 RS, for precipitation; Chen et al., 2014 ACP, for evapotranspiration and Zeng et al., 2016 RS, for soil moisture);
2) Development of downscaling methods by the use of Copernicus Sentinel data (from kilometer to hectometer scale). This task concerns evapotranspiration and soil moisture (by assuming the precipitation is homogeneous at kilometer scale). Downscaling will be achieved by combined use of optical, thermal and radar data from Sentinel-1,2,3;
3) Generation of high resolution water cycle products of soil moisture, vegetation patterns and vegetation stress ((sub)meter spatial scale and daily interval). High resolution maps will be provided with UAS equipped with thermal cameras, multispectral and hyperspectral cameras. Such data will support the development of downscaling procedures linking satellite to point measurements for calibration and validation in the selected field sites;
4) Characterization of the spatio-temporal distribution of soil moisture and evapotranspiration processes will be conducted after validations of the high resolution imagery from UAS with outcomes of field measurements and outputs from other models. The proper description on the controlling factors for the spatial variability of soil moisture is crucial to further advance the potential of downscaling methodologies;
5) Downscaling of the remote sensing data up to the field scale (from hectometer to plot scale) using a Bayesian approach exploiting the predicted variance and spatial correlation of soil moisture process along with the ancillary data derived from UAS and WP2 activities on the physical characteristics of soil and vegetation. In particular, WP2 will support the development of new strategies aimed at the mapping of soil hydraulic and physical characteristics that will enhance the capabilities of soil moisture downscaling procedures (see e.g. Nasta et al., 2018, JH; Montzka et al., 2018, RS).

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

While downscaling coarse scale remotely sensed water cycle products to fine spatial scales is achieved in Task 1.1, the remote sensing products typically refer to surface information that needs to be transferred to the depth, at least to the root-zone and be linked up in a consistent physical framework that will be accomplished in this task.

1) Prediction of root-zone SWC with the SMAR-EnKF (Manfreda et al., 2014 HESS; Baldwin et al., 2017 JH). Such an approach derives SWC based on the relative fluctuations of surface soil moisture retrieved from satellite or UAS. Given the physically based nature of the model, it will benefit from the information collected on the hydraulic characteristics of the soil (see WP2). The use of such methodology will provide a strategy to derive useful

information on dynamics of vegetation (e.g. evapotranspiration);

2) The STEMMUS numerical soil-water-atmosphere model (Zeng and Su, 2013 ITC; Yu et al., 2016 HESS; Yu et al., 2018 JGR) will be applied to analyze the sensitivities of the predicted root-zone SWC at sites with detailed observation of soil and water properties (soil hydraulic and thermal parameters) and states (profiles of soil moisture and soil temperature and surface radiation, sensible, and latent heat flux, precipitation and other meteorological forcing).

This task will provide high resolution spatio-temporal pattern of root-zone SWC that can be linked to the patterns of soil (see WP2) and evapotranspiration (see WP3) in the different catchments.

WP2. Retrieval of soil properties (SHP/STP) *(CAR-HAS, TAU, Uni. Naples)*

WP2 will retrieve soil hydraulic and thermal parameters (SHP/STP) from spectral signatures and knowledge of near-surface soil moisture dynamics. This WP will initially employ commonly used pedotransfer functions (PTFs) for regional applications and then locally calibrate them using readily measurable surface soil spectral features. The world Soil Spectral Library (SSL, Rossel et al. 2016, ERS), European Spectral Soil Library (LUCAS, Toth et al., 2013, EMA) and some local SSL (e.g. the GEO-CRADLE Mediterranean Balkan SSL) will be used to generate global to local spectral based models to assess soil properties. A harmonized protocol will be developed from the selected sites.

Task 2.1 Collection of field scale data

This task aims to collect and complete relevant data for selected sites (e.g. as those for the Alento River Hydrological Observatory (ARHO, Romano et al., 2018 VZJ) for Tasks 2.2, 2.3 and 2.4). Information on soil physical and hydraulic properties, terrain and environmental attributes (topographical, geological, pedological, and land-use/land-cover information together with hydro-meteorological datasets and soil physical and hydraulic properties), and topsoil spectral data will be collected. Whereas needed, similar activities will be carried out also at other sites (e.g. at the Twente site such field data are collected routinely as the site is used as a SMAP cal/val site (Colliander et al., 2017 RSE)).

Task 2.2 Soil spectroscopy and hyperspectral remote sensing

This task aims at harmonizing standards and protocols for hyperspectral remote sensing in the laboratory, field, air and space domains for soil mapping (Ben Dor, 2012 CPR Press). Existing world SSL with local ones will be utilized for developing spectral based models for soil hydrophobicity, soil hydraulic properties, soil texture, carbonate and organic matter content (Ben Dor et al., 2009 RSE). Attempts will be made to extend the knowledge in hyperspectral remote sensing to the thermal region.

Task 2.3 Basic pedotransfer functions

Application and evaluation of already established PTFs (Toth et al., 2015, EJSS) will be carried out at selected field sites using the 3D Soil Hydraulic Database of Europe at 250 m resolution (Toth et al., 2017, HP) as a baseline dataset. This task will explore if and to what extent the prediction capability of these basic PTFs can be suitably improved through in-situ remote measurements, via both UAS and satellite, of spatial patterns of land cover for mapping soil hydraulic and thermal properties (Zhao et al., 2018 ESSD).

Task 2.4 Advanced pedotransfer functions

Hyperspectral data will be used to derive spectrotrasfer functions (STF) and spectral pedotransfer functions (SPTFs) (Babaeian et al., 2016, RSE) using soil and environmental data as well. Such function will be used for the description and mapping of topsoil hydraulic properties with high level of details. Further to the site specific STFs the relationship between SSLs and hydraulic properties will be analysed on European datasets (LUCAS, EU-HYDI, Weynants et al., 2013 EUR-STR). Hyper- and multi-spectral sensors on ground and UAS will be employed for in-situ prediction of soil organic carbon (SOC), soil sealing and soil particle size distribution by vis–NIR spectroscopy. Soil hydraulic properties will be mapped for the study sites with SPTFs, STFs based on the available data, similarly to Task 2.3. Validation will be performed using measured values obtained in Task 2.1. Such task will support the downscaling procedures described in WP1 - Task 1.1.

WP3. Retrieval of field/grid specific scaling functions between soil moisture and evapotranspiration *(SLU, Uni. Naples, Uni. Twente, UPV)*

This WP concerns the retrieval of field/grid specific scaling functions (task 3.1) and their generalisation (task 3.2).

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

This task will provide soil moisture datasets measured in two sub-catchments of ARHO at two different scales: at local scale (by the wireless sensor network) and at field scale (by the cosmic-ray neutron probe). With the availability of hierarchical information of soil moisture (from satellite, UAS, cosmic-ray probe, and capacitance probe) both upscaling and downscaling relationships will be developed to link soil moisture and evapotranspiration (as obtained from Task 1.1). Tests will be done at other sites that will be used to validate the proposed procedure (see next Task 3.2).

Task 3.2 Generalizing scaling functions between soil moisture and evapotranspiration

The STEMMUS numerical soil-water-atmosphere model (Zeng and Su, 2013, ITC; Yu et al., 2016, HESS) will be used as a numerical toolbox to examine the field/grid derived scaling functions between soil moisture and evapotranspiration (Task 3.1) in order to link the states of soil moisture to evapotranspiration products on regional scale, while pertaining to the physical consistency. The derived scaling relationship will be compared and used as benchmark for simplified parametrizations in other operational hydrological models (see WP4, WP5).

WP4: Development of the generic (iAqueduct tool box) *(Uni. Naples, and all model groups)*

WP4 intercompares different models, soil and vegetation parametrizations and parameters (Task 4.1) and integrates the results into the iAqueduct toolbox (Task 4.2).

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

Analysis of water flow processes will be made, with the different models used in the different sites, e.g. in the soil-vegetation-atmosphere (SVA) system making use of the detailed field observations available in ARHO and integration of the data into a process-based ecohydrological model, considering also validation and output uncertainties. To facilitate the integration of models into the iAqueduct toolbox (Task 4.2), particular attention will be devoted to identify models that provide robust realistic results, while at the same time having low parameter requirements and easy transferability across sites. To this aim, a minimalist soil-vegetation-atmosphere model will be developed and its applicability across sites assessed, employing the data collated within this project. The model will be based on the coupling of the soil moisture dynamics and plant activities (chiefly transpiration and carbon fixation; Manzoni et al, 2013). 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 (Vico and Porporato, 2013 WRR; Manzoni et al., 2013 AWR). For more computationally-intensive models, machine leaning algorithms will be experimented to speed up the usually computational intensive process-based computations.

Task 4.2 iAqueduct toolbox

The results of analysis in previous WPs will be integrated into a library as 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. The existing open–source software system MajiSys water information system at University of Twente will serve as the integration platform. Such a toolbox will then be used for robust application (incl. machine learning algorithms) to other sites and also for use by stakeholders (See WP5 and WP6).

WP5: Demonstrate the benefits in closing water cycle gaps from global to local scale (case studies) (*UPV and all groups operating sites*)

The aim of this WP is closing water cycle gaps by improving hydrological model implementations using spatial information. The calibration of a hydrological model has traditionally only relied on the temporal variation of the discharge at the catchment outlet. But 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, so as to bridge the scales from plant to plot, subcatchment, and catchment/basin respectively with the representative size of 1-10 m^2 to 50-500 m^2, 1-10 km^2, and >100 km^2, as derived by means of TDR observations, to cosmic ray/drone observations, drone/satellite, and satellite observations, respectively. Findings will be implemented in the iAqueduct toolbox and easily tested at other sites.

WP6. Disseminate generated knowledge and tools for actual sustainable water management (*Univ. Twente, and all groups operating sites*)

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. The aim here is connecting science to society in order to experiment approaches to influence stakeholders (in particular citizens) towards desirable behaviour. Besides the traditional activities of dissemination such as the project website and newsletters, a series of three workshops will be planned at each year of the project, working in close collaboration with the COST Action HARMONIOUS in order to disseminate our results over a larger audience that includes researchers, stakeholders and private companies. Stakeholders will be expected to take active role in the project, and specific actions will be focused on depending on the local circumstances. For the selected specific sites, detailed actions will take place as follows.

- University of Twente will involve the water authority Vechtstromen (for which lasting collaboration exists, https://www.vechtstromen.nl/). The developed scaling functions and soil and water datasets will be used by the company Cosine to develop machine learning algorithms. University of Twente and Deltares are in further development of the MajiSys water information system (developed in a joint project), which will serve as the information backbone of the iAqueduct project and the new development will be readily taken up by Deltares for application in the national Delta plan for water management under climate change;
- University of Naples will collaborate with the “Velia” Consortium Authority of Land Reclamation (which manages the dams and the irrigation district) and the “Cilento and Diano Valley” National Park (the largest park in Italy);
- The Confederacion Hidrografica del Jucar (CHJ) as the Spanish Water Authority for part of the Mediterranean basins of Spain will use the case study by the Universitat Politecnica de Valencia to help solve the climatic, environmental and socio-economic problems in the practice of water management. The Spanish company with European experience in UAS, Geosystem, will uptake the project results in developing services;

Scenarios will be worked out for each of the selected sites using a technique developed in the EC CORE-CLIMAX project (Su et al., 2018 BAMS) whereby the distribution of forcings will be derived from the 2018 summer European drought period and by replacing the distribution with that of another site, mimicking potential future climate changes and impact to water resources. For example, the observed climate in the Twente region during the drought of 2018 summer will be replaced by that of the Spanish or Italian site and the spatio-temporal water situation in the Twente region be simulated. In collaboration with the water authority Vechtstromen, potential management scenarios will be developed and citizens will be invited to propose additional measures (e.g. water saving measures) as a preparation for such a scenario, thus connecting science to the society more effectively and influencing citizens towards desirable behaviour. For example, a first response to the water crisis experienced toward the end of eighties and beginning of nineties in the Alento catchment in Italy was the construction of the earthen dam at Piano della Rocca, which has been operating since 1994. Would the citizens in the Twente region welcome a similar measure? What else would be needed in order to cope with future drought events? These and other questions by the water authorities and citizens alike could then be worked out in the chosen scenarios.
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