Work Package 3

QUANTIFICATION OF STORAGE COMPARTMENTS

Work package 3 encompasses the quantification of all four storage compartments, namely: snow, glaciers, soil moisture and surface water. Below, activities are described per individual compartment.

DESCRIPTION OF THE ACTIVITIES

SNOW

The snow water equivalent (SWE) describes the amount of liquid water in the snowpack that would be formed if it were completely melted. SWE is an important measure of availability of water resources since it relates to the runoff of rivers and variations in groundwater levels. The snowpack that accumulates during the winter has a significant role in groundwater recharge during spring. In turn, water stored in the snowpack is one component that needs to be removed from TWS in order to resolve for groundwater storage in higher latitudes and mountainous regions across the world. However, a global-scale observation-based harmonized product on Snow Water Equivalent (SWE) does not yet exist.

To address this issue, currently existing data products will be extended, methods and lessons learnt from earlier projects will be utilized, and a harmonized data product with global coverage will be produced.

Three key steps will be carried out:

1. Development of an Enhanced SWE Retrieval Algorithm
The retrieval methodology will combine satellite passive microwave measurements with ground-based weather station observations. The retrieval algorithm enhancements include improved emission modelling through the utilization of an advanced model, taking into account the presence of sub-grid lake ice and an improved forest transmissivity model. Out of this process, a temporally and spatially variable snow density field will be developed. Furthermore, a sensitivity analysis to assess the influence of land cover variability on snow depth and effective grain size used within the retrieval process will also be carried-out to increase the preciseness of the product.

2. Merging EO-Based SWE Fields with Third Party Products
This step consists in filling the gaps of the Enhanced Copernicus Global Land Service SWE just developed. To do so, it is proposed to use Snow Extent (SE) measurements and EO-based SWE estimates to reach full coverage.

According to the Copernicus Global Land Service, SE is highly sensitive to changes in temperature (freezing/thaw) and precipitation (snowfall, rain, hail). Snow stores a significant mass of water and has a strong effect on regional and global energy and water cycles. Up-to-date knowledge about the snow cover extent is an important information for hydrological runoff modelling, together with the Snow Water Equivalent (SWE) product from passive microwave sensors, that provides information on the water content in the snow on plain areas, with limitations in mountainous areas.

More specifically, the passive microwave's technique used within CGLS SWE for the snow detection scheme has a proneness to uncertainty during the snow melt season and will thus be replaced by a SE product. Further data gaps that need addressing occur in mountain areas, and this will be covered by using Earth Observation- based SWE estimates with Land Surface Model (LSM) SWE fields.

3. Spatial Expansion of the Snow Water Equivalent (SWE) Product
The current Copernicus Global Land service (CGLS) SWE spatial coverage will be expanded to full global coverage (i.e. extending to full Northern Hemisphere and full Southern Hemispheric coverage).

GLACIERS

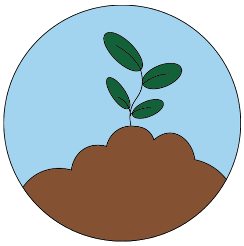
Retreating and thinning glaciers are icons of climate change and impact regional hydrology and global sea level rise. The World Glacier Monitoring Service (WGMS), hosted at the Department of Geography of UZH, is in charge of compiling standardized data on glacier changes in length, area, volume, and mass. Starting in 2017, the WGMS was integrating a global glacier inventory (RGI 2017) as well as glaciological and geodetic mass change series with annual updates into the C3S Climate Data Store. Based on these data-sets, Zemp et al. (2019, 2020) developed a new method to combine the temporal variability from the glaciological sample with the glacier-specific values of the geodetic sample. The new approach allowed assessing annual glacier mass changes from 1961 to 2016 for all glacierized regions as well as the corresponding contribution to global sea-level rise, including corresponding uncertainties. For the development of G3P the Zemp et al. (2019) approach will be further developed:

Combination of C3S services into global glacier mass-change product with annual updates.
Implementation of the methodology by Zemp et al. (2019, 2020) updated to the latest version of C3S glacier datasets and focused on the GRACE period (2000 – 2018/19).

Reprocessed glacier mass-change product on a regular grid.
Development of a new methodological approach to combine the C3S glacier datatset inspired in Zemp et al. (2019, 2020) resolving for an ameliorated spatial resolution of glacier changes, from previous regional estimates to a gridded dataset, as required for the global groundwater product.

Reprocessed glacier mass-change product with increased temporal resolution.
Further development of the methodological approach, options involving different levels of statistical and glacier change modelling will be evaluated to increase the temporal resolution (currently annual means) of the glacier mass-change product to the requirements of the global groundwater product.

SOIL MOISTURE



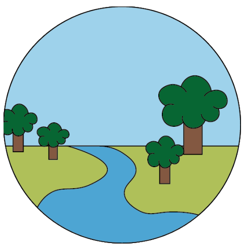
Since 2011, long-term variability of soil moisture is systematically mapped within the European Space Agency (ESA)'s Climate Change Initiative (CCI). ESA CCI Soil Moisture combines multiple soil moisture products from passive and active microwave satellites into harmonized Climate Data Records spanning the period 1978-near present at a 0.25° spatial and daily temporal resolution. In 2017, the operational production of ESA CCI Soil Moisture was transferred to the Copernicus Climate Change Service C3S, where the near-real time data are now routinely distributed through the Climate Data Store with approximately 10-day latency. Every year, the C3S production algorithm is updated with the latest scientific and methodological insights. To develop an enhanced global C3S-based surface and root-zone soil moisture datasets, a daily gap-filled process will be carried out to the soil moisture product from C3S data, which will then be used to develop a root-zone soil moisture product to cover the unsaturated zone. Data will then be validated with in situ measurements and other references.

Development of a gap-filled soil moisture product from C3S data
Using the C3S processing algorithm as a basis, a spatially and temporally gap-filled soil moisture product will be produced. Temporary gaps in the time series will be filled using methods based on Gaussian processes and permanent gaps will be filled using multi-model soil moisture data from other sources. The task will include the assessment of different methods and different soil moisture and ancillary datasets.

Development of a root-zone soil moisture product
Using the gap filled dataset and the original C3S data, a soil moisture product representative for the unsaturated zone will be developed based on the methodology initially proposed by Wagner et al. (1999). The methodology will be thoroughly assessed throughout development, for example, over different soil types and climates, to ensure the best quality dataset is produced.

Validation of soil moisture products
The gap-filled daily soil moisture product and root-zone soil moisture product will be validated using in-situ measurements from the ISMN and other reference data. This will be achieved through the use of the online soil moisture validation service QA4SM (http://qa4sm.eodc.eu/). All three of the new products will be validated and an inter-comparison to the original C3S soil moisture data will be undertaken.

SURFACE WATER STORAGE



The assessment of surface water storage variations is complex and requires a multi-sensor approach together with the use of hydrological and hydraulic models. The space sensors of interest (altimeters and optical and/or SAR - Synthetic Aperture Radar) are already on-board of satellites of the Copernicus program. The approach considers a different methodology for quantifying surface water storage for large lakes and for large rivers.

Altimetry for large lakes
This includes extending the number of lakes monitored by the altimetry component of HYSOPE processing baseline to a global coverage as required by G3P.

Hypsometry functions and storage calculation for large lakes
It is also planned to compute and/or benchmark hypsometry functions from external sources (e.g. CCI-Lake: https://climate.esa.int/en/projects/lakes/) to extend the network of lakes monitored by the lake water storage component of HYSOPE (HYdrométrie Spatiale OPErationnell, an operational processing center for lake and river observation) to the areas of interest for G3P. In addition, lake storage time series will be computed.

Modelo de Grandes Bacias or Large Basins model (MGB model) forcing and assimilation data

The MGB forcing data (e.g., rainfall observations, air temperatures, relative humidity) required as model input into the MGB model and the assimilation products (altimetric water levels) are specified and converted from external formats to the MGB model format. This task will be carried out for each study area (Niger, Congo and Danube river basins). As the MGB modelling system will be designed so that it can assimilate data from various sources, it will enable to consider the integration of newly produced altimetry data.

River discharge simulation and storage estimation

Application of the MGB model to the study areas. This will be performed through calibration using in-situ discharge observations to be collected thanks to partnerships and a thorough analysis of the basin hydrology cycle and specific events (floods, droughts). The outputs will be validated by comparison to a set of in situ gauges (or time-periods) that have not been used in the model. Finally, the river water storage variations will be estimated from the discharge.

Validation and merging of lake and river surface water storage products

The global surface water storage variation product for lakes and rivers will be validated and the consistency of both products is assessed. The lake water storage variation product will be evaluated by comparison of lake water levels to in-situ data, and the hypsometry relationships by agreement with theoretical models. If lake water extent or storage datasets from other methodologies are available, they will be considered in the validation process. The river water storage variation product will be evaluated through comparison of discharge and water level with in-situ data and other hydrological models such as GloFAS. The consistency of the lake and the river water storage products will be assessed thanks to the comparison of storage for lakes within the specific river basins: Lake Kainji in Niger basin, Lake Tanganyika and Mweru in Congo basins.

DELIVERABLES

3.1: Improved Global Snow Water Equivalent Product and Quality Assessment Report
3.2: Global glacier mass-change product Report
3.3: Surface soil moisture product and summary document
3.4: Unsaturated zone soil moisture product and summary document
3.5: Surface Water Storage Variations – Lakes Product and Quality Assessment Report
3.6: Surface Water Storage Variations - Rivers Product and Quality Assessment Report

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