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Quantifying errors of multiple gridded soil moisture products in Sweden using triple collocation analysis and traditional evaluation method with ICOS data

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Soil moisture is an Essential Climate Variable (ECV) that plays an important role in land surface-atmosphere interactions. Accurate monitoring of soil moisture is essential for many studies in water, energy and carbon cycles. However, soil moisture is characterized with high spatial and temporal variability, making conventional point-based in-situ measurements difficult to sufficiently capture these variabilities given the often lack of dense in-situ network for most regions. Considerable efforts have been made to explore satellite remote sensing, hydrological and land surface models in estimating and mapping soil moisture, leading to increasing availability of different gridded soil moisture products at various spatial and temporal resolutions. The accuracy of an individual product varies between regions and needs to be evaluated in order to guide the selection of the most suitable products for certain applications. Such evaluation will also benefit product development and improvements. The most common (traditional) evaluation method is to calculate error metrics of the evaluated products with in-situ measurements as ground truth. The triple collocation (TC) analysis has been widely used and demonstrated powerful in evaluation of various products for different geophysical variables when ground truth is not available.

The Integrated Carbon Observation System (ICOS) is a research infrastructure with aim to quantify the greenhouse gas balance of Europe and adjacent regions. A standardized network of more than 140 research stations in 13 member states has been established and is operated by ICOS to provide direct measurements of climate relevant variables. The ICOS Carbon Portal offers a 'one-stop shop' freely for all ICOS data products at <https://www.icos-cp.eu/observations/carbon-portal>.

This study evaluates for the first time a large number of different satellite-based and reanalysis surface soil moisture products at varying spatial and temporal resolutions using ICOS measurements from 2015 over Sweden. Evaluated products include ESA CCI, ASCAT, SMAP, SMOS, Sentinel-1 derived, ERA5 and GLDAS products. In order to quantify spatial patterns of errors of each individual product, TC analysis is applied to different combinations of gridded products for spatial evaluation across entire Sweden. The performance of products in different seasons and years is evaluated. The similarity and difference among different products for the drought period in the year 2018 is particularly assessed. This study is expected to improve our understanding of the applicability and limitations of various gridded soil moisture products in the Nordic region.