SHORT TERM SCIENTIFIC MISSION (STSM) SCIENTIFIC REPORT

This report is submitted for approval by the STSM applicant to the STSM coordinator

Action number: ES1404
STSM title: Validation study of satellite snow products using Sentinel-2 and webcam data
STSM start and end date: 03/09/2018 to 19/10/2018
Grantee name: Gaia Piazzi

PURPOSE OF THE STSM:
(max.200 words)

This Short Term Scientific Mission aims at assessing the potential of using Sentinel-2 (S-2) data to validate moderate-resolution products of snow extent and snow fraction, that are the snow-related quantities most commonly used as input for hydrologic, meteorological and climate modelling. S-2 imagery is used to validate H10 – Snow detection (SN-OBS-1) and H12 – Effective snow cover (SN-OBS-3) supplied by the European Organization for the Exploitation of Meteorological Satellites (EUMETSAT) Satellite Application Facility on Support to Operational Hydrology and Water Management (HSAF). The interest in HSAF snow products is focused on investigating the potential and suitability of these datasets for hydrological purposes. However, even though the high-resolution imagery can be reasonably used to establish reliable ground truth, it is noteworthy that a finer spatial resolution does not necessarily entail a higher accuracy of the satellite product. Furthermore, since no existing study supplies detailed information on the accuracy of S-2 imagery in detecting snow, this dataset is firstly validated against in-situ observations and measurements in order to guarantee the reliability of the validation analysis. With the aim of properly assessing the satellite snow products under different climatological and topographic conditions, three study areas are analysed, located in Finland, Italian Alps, and Turkey.

DESCRIPTION OF WORK CARRIED OUT DURING THE STSMS
(max.500 words)

The analysis period extends throughout two winter seasons, namely 2016/2017 and 2017/2018. In each country, eight S-2 tiles are selected to ensure a sizeable sample of satellite images. The selection of S-2 tiles targets those providing significant datasets over the validation period and those where in-situ snow monitoring instruments are located, by still minimizing possible overlapping. Since this study is focused on snow cover, only S-2 images with cloud cover lower than 20% are analysed. The resulting dataset of S-2 imagery consists of 219, 336, and 105 images over Italian Alps, Finland and Turkey, respectively. Because of the significant impact of vegetation on satellite snow detection, ancillary information on the vegetation cover of each S-2 tile is derived from ESA GlobCover 2009.
S-2 L1C data are downloaded from the Copernicus Open Access Hub and then processed through the Sentinel-2 Level-2A Prototype Processor (Sen2Cor, version 2.5.5) provided by ESA. Sen2Cor supplies Scene Classification (SCL) maps at a spatial resolution of 20 m.
In order to properly perform the comparison analysis, all the satellite snow products have been preliminarily reprojected to the same common image projection (WGS84/UTM). Since the analysis is tile-based, maps over the geographic extension of each selected S-2 tile are derived from the original full images of both HSAF products.

To validate HSAF products, firstly binary snow masks are derived. According to the original classification of SCL map, bare-soil, water and vegetation pixels are classified as no-snow pixels. Consistently, HSAF-based snow masks are derived by considering snow and bare-soil pixels. While unclassified pixels are discarded, cloud-contaminated pixels are flagged and neglected in the comparison of snow maps. Since the satellite products are differently gridded, the comparison is performed at the coarser spatial resolution of the HSAF products. For each HSAF grid cell, the percentage of snow cover is determined according to the S-2 observations by counting the number of S-2 snow pixels versus the total number of S-2 pixels in the coarser cell. Coarse S-2-based pixels where more than the 50% of fine S-2 pixels are classified as cloud are neglected in order to not compromise the analysis results. This computation results into S-2-based maps of fractional snow cover area (FSC). While FSC maps derived from S-2 data are directly comparable with HSAF H12 product, the validation of HSAF H10 requires to restore binary snow masks. Therefore, each resulting coarse S-2-based pixel is classified as snow if FSC is higher than 50%, otherwise it is classified as soil.
In Finland and in Italy the validation of S-2 imagery is performed by using in-situ webcam photography. From webcam observations the effective snow cover is assessed through visual inspection by several experts. The resulting sample of estimates is compared with maps of effective snow cover from S-2 data over the field of view of each webcam.
In Turkey S-2 snow mapping is validated against in-situ measures of snow depth supplied by 75 stations. A threshold of 5 cm is set to define snowy and snowless conditions, according to the ground-based observations.

DESCRIPTION OF THE MAIN RESULTS OBTAINED
(max.500 words)

A pixel-to-pixel analysis is performed for both HSAF snow products, over mountain (Italian Alps, Turkey) and flat (Finland) areas. Three different periods are separately assessed, namely early winter (October, November), winter (December-March), and melting period (April-June).
The validation of HSAF H10 is analyzed through several evaluation metrics, namely Probability Of Detection (POD), False Alarm Ratio (FAR), Probability Of False Detection (POFD), Accuracy (ACC), Critical Success Index (CSI) and Heidke Skill Score (HSS). The results show that HSAF H10 product generally ensures ACC values ranging around 0.8 - 0.9. Except for the early winter, the consistency between S-2-based and H10 snow masks is higher over flat areas than over mountain region, mainly due to the impact of complex orography.This issue is further confirmed through POD values, which are equal to 0.92 in Finland and only to 0.64 in Italy. As well as POD, also FAR values are significantly worse over Alps (0.40) than over flat region (0.18). The same difference in product performances is detected through HSS, whose satisfying value of 0.03 in Finland increases up to 0.40 in Italy.
To assess the S-2-based validation of HSAF H12 product, the Root Mean Square Error (RMSE) is evaluated.
During the melting season, when patchy snow cover is generally present, RMSE values significantly increase. Consistently with H10 validation, over mountain areas S-2 and H12 snow masks reveal a slightly lower matching. Indeed, while in Finland the RMSE is equal to 0.15 throughout the whole analysis period, in Turkey its value increases to 0.21 and up to 0.33 over the Italian Alps.
As regards the validation of S-2 imagery against in-situ measurements of snow depth in Turkey, the results are very promising, as revealed by the high values of POD and ACC, equal to 0.82 and 0.79, respectively, and the low FAR value of 0.078.
The use of in-situ webcam photography allows to appreciate the consistency of S-2 imagery over large areas, especially in Finland. The ensemble of visual inspections of S-2 images performed by a sample of around 10 experts reveals a RMSE lower than 15%, in terms of FSC.

FUTURE COLLABORATIONS (if applicable)

This study has been carried out through collaboration of several international institutes, namely Finnish Meteorological Institute (Finland), CIMA Research Foundation (Italy), Middle East Technical University (Turkey), Çankırı Karatekin University (Turkey), and National Civil Protection Department (Italy).
This work has been recently presented at the COST ES1404 HARMSNOW Worshop (Budapest, 30-31 October 2018).
Currently a joint paper focused on the study is being drafted and it will soon be submitted to an international scientific journal.