Short Time Scientific Mission (STSM) - Scientific Report

Action Number: ES1404
Host institute: Middle East Technical University (METU), Ankara, Turkey
In collaboration with: Turkish State Meteorological Service (TSMS). Ankara, Turkey
Visiting Institute: Finnish Meteorological Institute (FMI), Helsinki, Finland
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Introduction

Validation of satellite based fractional snow cover (FSC) products is challenging due to the lack of reference in-situ data. Often these products are validating using measurements as proxy, for example using snow depth measurements to validate FSC. In-situ measurements of fractional snow cover exists on a very limited level, both for the spatial coverage and temporal coverage. Also, the measurements are done by visually inspecting an area, which is expected to have a large subjective error. Another method for validating FSC products is to compare them with other satellite based FSC products as case studies. This type of comparison includes the errors of the reference data itself, but provides an estimation of reliability using the data available.

Digital image photography is a new method to retrieve snow cover information on high spatial and temporal resolution. It is possible to get FSC from digital images either by visual observations or automated processing. Although the spatial coverage of established digital cameras are much lower than satellites, they provide a large amount of data compared to in-situ measurements, which can be used in validation of snow cover products.

Sentinel-2 is an earth observation satellite constellation that carries a multispectral imager as the main instrument. The satellite is maintained by Copernicus programme and offers 20 to 60 m resolution imaging of the globe in multiple bands from 400 nm to 2.2 µm wavelength. Current constellation of 2 satellites has a revisit time of 5 days. With Sentinel satellites, some free to use software tools are also offered by ESA. Sen2Cor is a standalone program that can process Sentinel-2 Level 1C images, which are disseminated from Copernicus data hubs, to Level 2 scene classification data, which has snow presence information. The very high resolution snow cover maps produced with the tool using Sentinel-2 data is used for the intercomparison of the snow product to be validated in the mission.

The aim of the mission is to study the performance of different data sources for the validation of snow products in an operational, automated and harmonized way. New satellite data (Sentinel-2) and ground level high resolution optical data (webcam) will be used as reference data source for validation case studies. New toolboxes will be used and modified if necessary to establish the automated validation for different sources of validation data.

Materials and Methods

Snow cover product

The product to be validated for the study is “Effective snow cover by VIS/IR radiometry (H12)” of the "EUMETSAT Satellite Application Facility on Support to Operational Hydrology and Water Management (H-SAF)." The product is based on multi-channel analysis of the AVHRR instrument onboard NOAA and MetOp satellites and provides FSC (0-100%) on a equirectangular projection of H-SAF area with 0.01 degree resolution. The product is pre-operational, due to the lack of reference data to be used in the validation.

Digital imagery

A camera network consisting of 28 cameras in 15 research sites over Finland is established under “Climate Change Indicators and Vulnerability of Boreal Zone: Applying Innovative Observation and Modeling Techniques” (MONIMET) project (http://monimet.fmi.fi). The cameras are capturing images about every half an hour from the field of views targeted at different parts of different ecosystems, for example a peatland or canopy, crown or understorey of a spruce forest. The images are available via FTP access and from Zenodo repositories.

Extracting FSC information from the images is previously studied by Arslan et al. It is shown that FSC can be calculated using a histogram based snow detection algorithm developed by Salvatori et al. and georectification algorithm studied by Corripio. For the validation of the algorithm, a dataset was produced by visual observations on images by project partners. In this dataset, FSC over the scene was estimated by visual observation separately for open areas and forested areas. The subjective error of the estimation, which was about 10%, was calculated by using observations on a subset of images by 6 more different experts. Assumed as much closer to the truth, this dataset is used in the study, rather than the automated processing. Observations from 3 sites are used in the comparison:

- Sodankylä site: FSC for both open and forested areas
- Sodankylä peatland site: FSC for open area
- Kenttärova site: FSC for both open and forested areas

Field of view of the cameras in different FSC conditions can be seen in Figure 1.

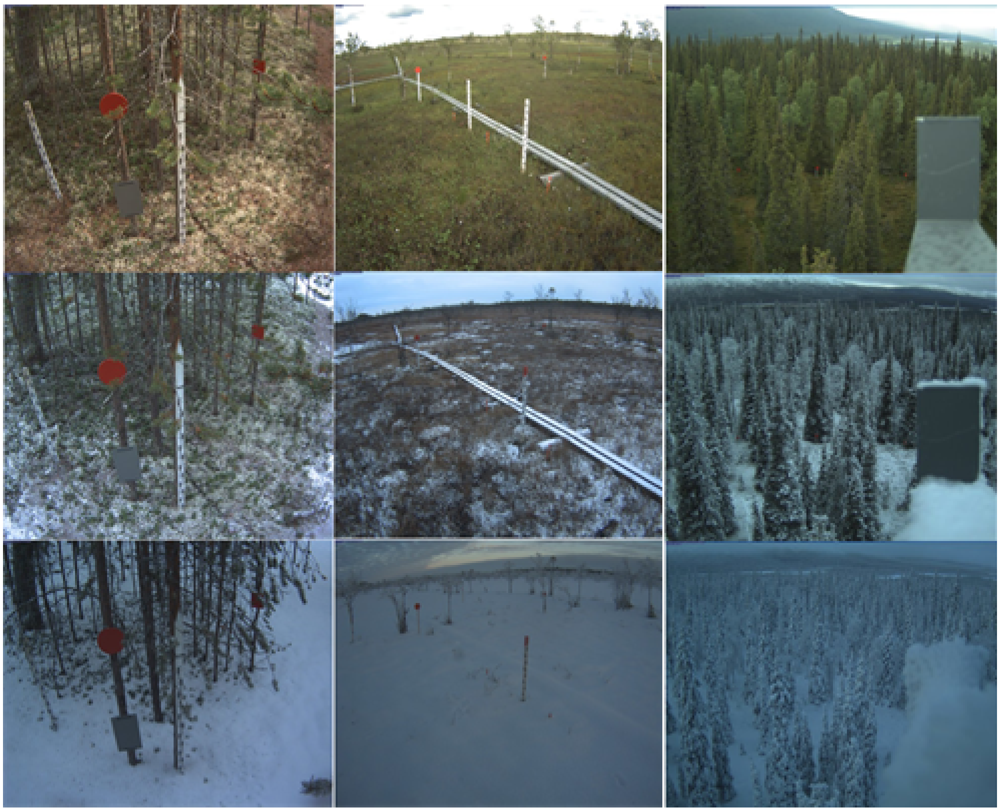

Figure 1 Field of view of the cameras for different FSC conditions. From left to right: Sodankylä ground camera, Sodankylä peatland camera, Kenttärova canopy camera.

In total, the comparison from the digital imagery includes 5 values for each day. The representativeness of the observations is assumed to be 100m x 100m. Resampled onto the H12 grid using Gaussian distribution, each observation corresponds to 1 pixel for Sodankylä site and 2 pixels for two others. Depending on the cloud and non-classified pixels for those locations, number of pixels compared for each day changes between 0 and 8. From October 2014 to December 2017, for 52 of 792 daily products, at least one pixel in the comparison had a valid value to be compared. In total 218 value pairs are compared.

Satellite data

An Intercomparison study has been conducted for the 2017-2018 validation period between H12 and Sentinel-2 level-2A data. Comparison is done by assuming Sentinel-2 L2A Scene Classification as reference data. Study area is Sentinel-2 tile T34VFN, which is a region of approximately 100 km x 100 km located in Southern Finland. Downloading and processing of Sentinel-2 data is done previously in FMI by a project colleague as a part of the validation efforts for H12. All of the data is downloaded from Copernicus Open Access Hub (https://scihub.copernicus.eu/) as level-1C and processed to level-2A with Sen2Cor 2.5.5 standalone version. With this processing Sen2Cor, atmospheric correction and scene classification is applied to the input, level-1C, data and as result, scene classification of the tile in 20m resolution is obtained. For further details and documentation on sen2cor processor, please see http://step.esa.int/main/third-party-plugins-2/sen2cor/. Location and Sentinel-2 RGB composite image of the tile is shown in Figure 2 and Figure 3.

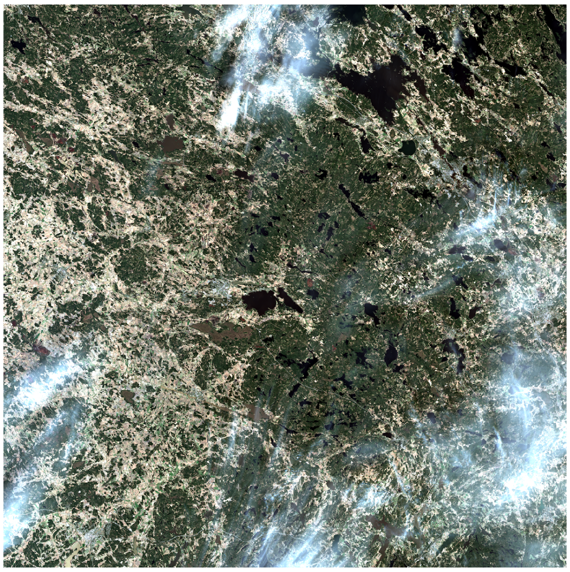

Figure 2 The RGB composite of Sentinel-2 data of T34VFN tile

Figure 3 Location of the T34VFN tile in Finland

Due to the problem of difficulty of finding usable H12 and Sentinel-2 data on the same date, comparison was done on 12 of the 75 dates that Sentinel-2 data had collected. 5 of these 12 dates was in-season days, meaning that snow and vegetation/bare ground was present at the same time. By taking in-season dates, misleading results of 0% and 100% snow covered images are eliminated.

Image processing toolbox

For every new data source to be used as reference data for the validation, new scripts and programs needed to be designed for the comparison of the data with the product. A software tool is created to be used with different sources of data for the comparison of the snow product. This tool is designed and implemented on an existing image processing toolbox. The data format in the toolbox is used as a basis for the geospatial and point data so that new types of data produced by the toolbox in the future versions can be used in the validation for further efforts.

Finnish Meteorological Institute Image Processing Toolbox (FMIPROT) is a software designed to process digital image series from cameras and camera networks. It can acquire and process images from multiple camera networks on a single platform by adding connection information of the image repositories. It provides a graphical user interface to set up configurations and parameters to be used in the acquisition and processing of the images. The analysis can be run either using the GUI or via CLI with a single action that triggers a processing chain. The toolbox performs necessary tasks to acquire images from image repositories of the camera networks, process them and generate HTML reports with interactive plots along for visualization of the output data. The design allows using the toolbox with a job scheduler to run analysis for creating operational monitoring systems. Detailed information about the toolbox can be found in FMIPROT website (http://fmiprot.fmi.fi). The software is developed under the MONIMET Project, funded by EU Life+ Programme (2013-2017).

During a visiting scientist activity in H-SAF project, FMIPROT is modified to compare Sentinel-2 data with H12 product for the same purpose. The tool is designed so that the comparison parameters can be set up from the same interface for different data sources. The interface for the comparison setup can be seen in Figure 4. For the study, a different time and region of interest is used. The details of the methodology can be found in the activity report. For the STSM, this tool is further improved to be able to read and compare new format of Sentinel-2 data and the data format of the output of the toolbox itself (webcam processing data). Also, linear regression analysis is added and comparison value pairs are stored for creating scatter plots. The comparisons in the STSM are done using the toolbox. (Those features are not yet available to public in the current version of the toolbox.)

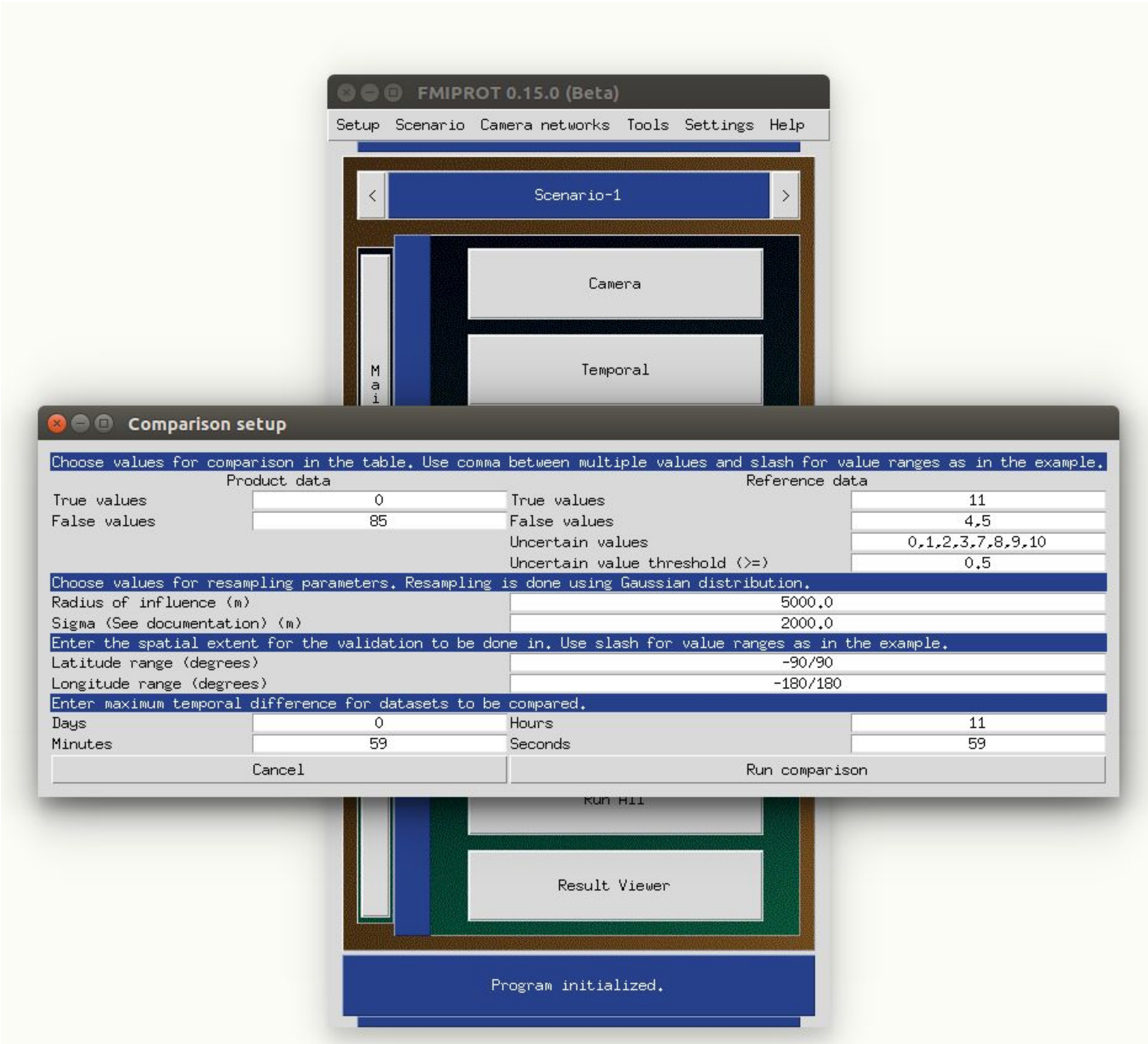

Figure 4 Comparison setup menu interface in FMIPROT

Results

Daily and total RMSE is calculated from the comparison with digital imagery and linear regression is applied for each compared value pair. Results are seen in Figure 5 and Figure 6. In the figures, values are normalized to 0 – 1 range.

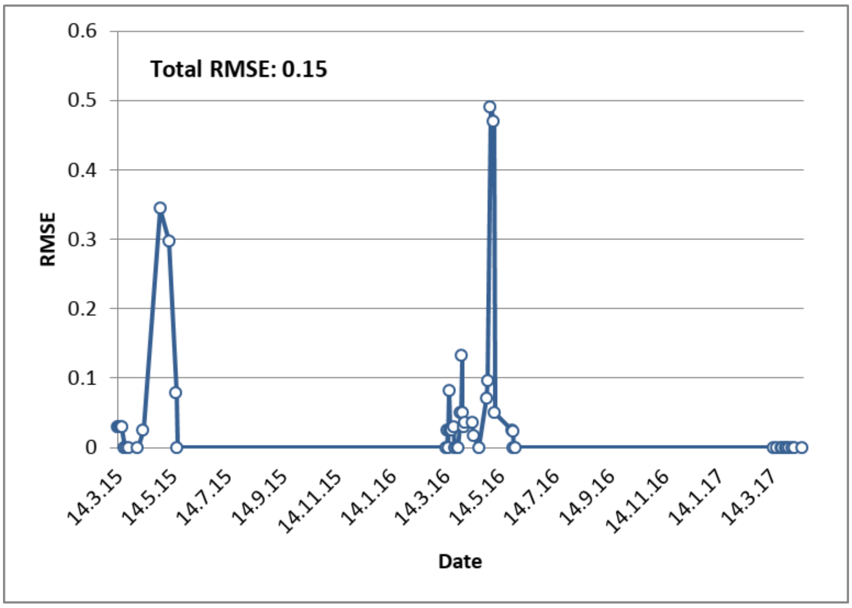

Figure 5 Daily and total RMSE for the validation with digital imagery (Values are normalized to 0 – 1 range)

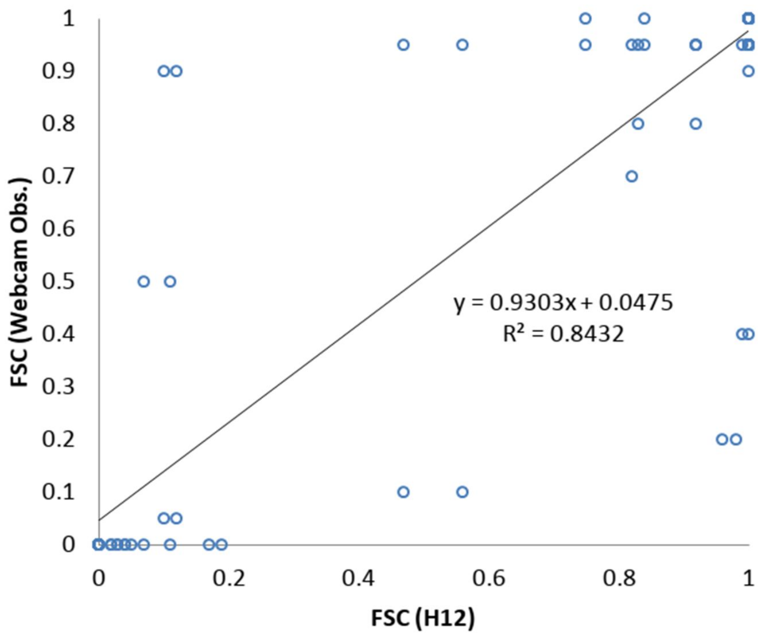

Figure 6 Linear regression for the compared value pairs in the validation with digital imagery (Values are normalized to 0 – 1 range)

The daily RMSE values are sufficiently low to judge the product as reliable. Total RMSE is between optimal and target requirement. Clouds and darkness should also be noted as a challenge in this comparison, as seen from the comparison, early season and mid-winter has no comparable values, although the comparison is done only for few locations.

Linear regression has a good fit with an R2 of 0.84 and no more than 12 outliers out of 218 points. In general the product overestimates the FSC.

In Table 1, results of the comparison with Sentinel-2 data of 5 in-season dates are shown.

Date	**RMSE**	**Number of Observations**
04-03-2018	0.35	189
18-03-2018	0.48	1438
27-03-2018	0.43	1309
03-04-2018	0.21	3028
13-04-2018	0.37	8653

Table 1 RMSE and number of observations for 5 in-season dates

In Figure 7, RMSE and number of observations are shown for all 12 available dates. As we have expected, when there is full snow cover or no snow cover, results are extremely well.

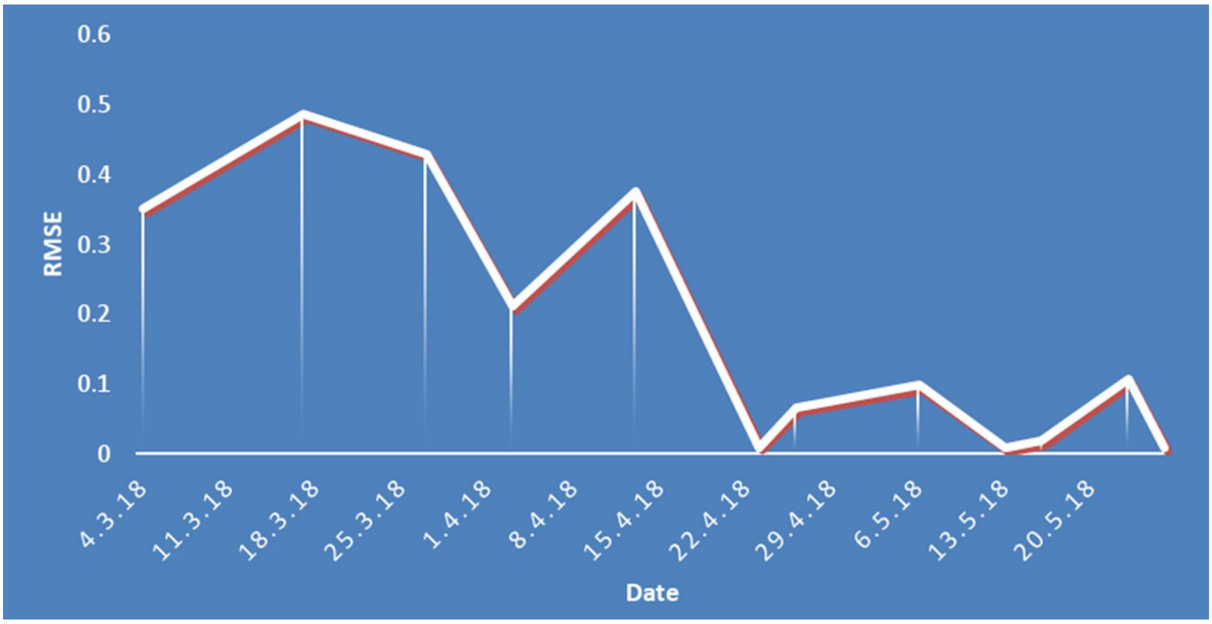

Figure 7 RMSE values for all available dates

As the results shown above indicate, RMSE value does not exceed the 50% threshold requirement, as stated in the Product Requirement Document, in any of the compared dates. In conclusion, comparison of H12 and Sentinel-2 L2A classified data on tile T34VFN for 2017-2018 validation period meets the 50% threshold requirement of H12.

Conclusions

Two case studies to validate a satellite based snow product using digital imagery and satellite data is done in the STSM. New toolboxes are modified and used for validation as a feasibility example for a harmonized way of using different sources of data for geospatial intercomparison. Results are presented and reported to the project coordinator to be used in the validation document of the snow product.

The experience about the digital imagery and satellite data are shared between partners. Further possible studies and efforts are proposed and discussed. One concrete outcome is that the current infrastructure in the host institute and collaborating institute can be used to start using webcams for monitoring snow cover with digital imagery.

The colleagues in the host institute and the collaborating institute who could not participate to the action meetings are acquainted. The STSM was a great opportunity for the networking between the institutes.

References

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