Satellite inspired hydrology in an uncertain future:
an H SAF and HEPEX workshop
Reading, 25-28 November 2019

Operational validation of H SAF snow products

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Operational validation of H SAF snow products

Goals:

- Monitor the progress of products quality
- Provide validation service and quality control to end-users
- To assess the benefits of the products on hydrological applications and to improve products and their usability in operational hydrology

Features:

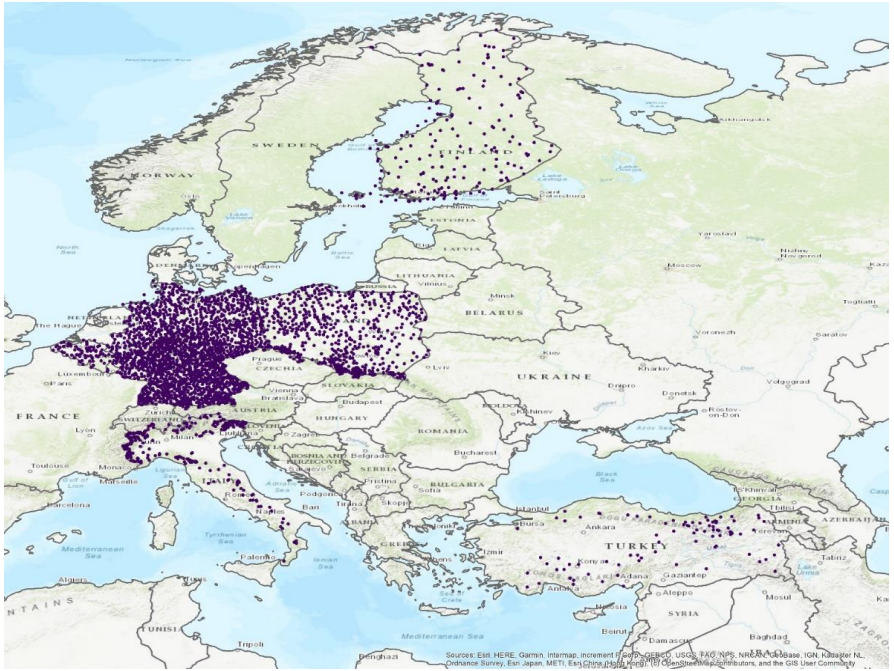
- Continuous in time (every year)
- Include the direct validation of the product and hydrological-validation
- Consistent over years and in space
- Reliant upon robust procedures

- **SE-E-SEVIRI**: Snow detection (snow mask) by VIS/IR radiometry [H10]
- **WS-E**: Snow status (dry/wet) by MW radiometry [H11]
- **FSC-E**: Effective snow cover by VIS/IR radiometry [H12]
- **SWE-E**: Snow water equivalent by MW radiometry [H13]

Operational validation of H SAF snow products

Products **SE-E-SEVIRI (H10)**, **WS-E (H11)** and **SWE-E (H13)** are validated using ground station data over the European area.

Country	Type	N. snow depth stations
Finland	Synoptic	190
Turkey	Synoptic	85
Italy	Snow/Avalanche	264
Poland	Synoptic	595
Germany	Synoptic	1863
Belgium	Teleclim	84
TOTAL		3081



Operational validation of H SAF snow products

Winter period (1 October – 1 May) to produce large statistic (multi-categorical and continuous), and case study analysis.

Large statistics → identifying existence of systematic errors, mainly derived from inhomogeneity of snow cover in complex terrain (spatial inhomogeneity) and rapid snow melting in some areas (mainly in southern and costal near the sea).

Case studies → useful to identify the roots of errors.

Score	Threshold	Target	Optimal
POD	0.80	0.85	0.99
FAR	0.20	0.15	0.05

Product requirements SE-E-SEVIRI (H10) in Flat/Forest areas

Score	Threshold	Target	Optimal
POD	0.60	0.70	0.99
FAR	0.30	0.20	0.05

Product requirements SE-E-SEVIRI (H10) in Mountainous areas

Score	Threshold	Target	Optimal
POD	0.60	0.80	0.90
FAR	0.20	0.10	0.05

Product requirements WS-E (H11)

Area	Threshold	Target	Optimal
flat (RMSE)	40 mm	20 mm	10 mm
mountain (RMSE)	45 mm	25 mm	15 mm

Product requirements SWE-E (H13)

		Reference dataset	
		Snow	No snow
Analyzed dataset	Snow	a	b
	No snow	c	d

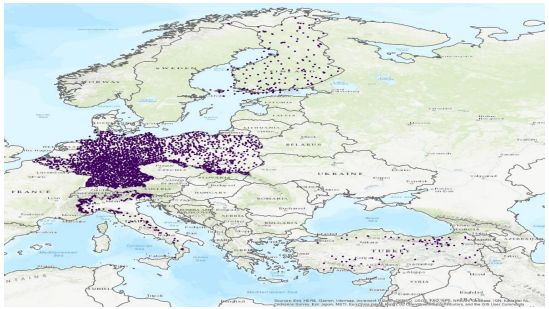
Probability of detection: $POD = {}^{a}/_{(a+c)}$

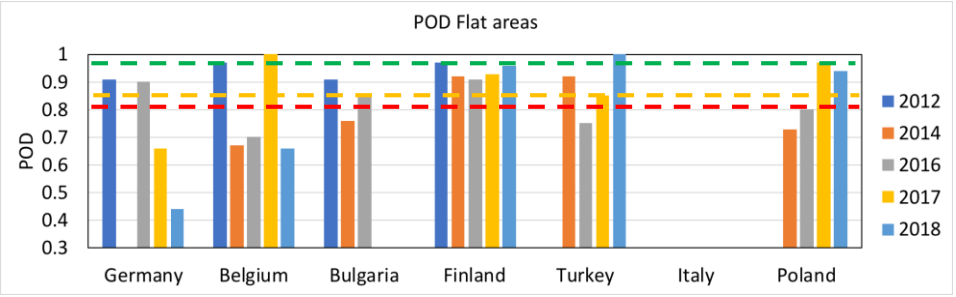
False alarm ratio: $FAR = {}^{b}/_{(a+b)}$

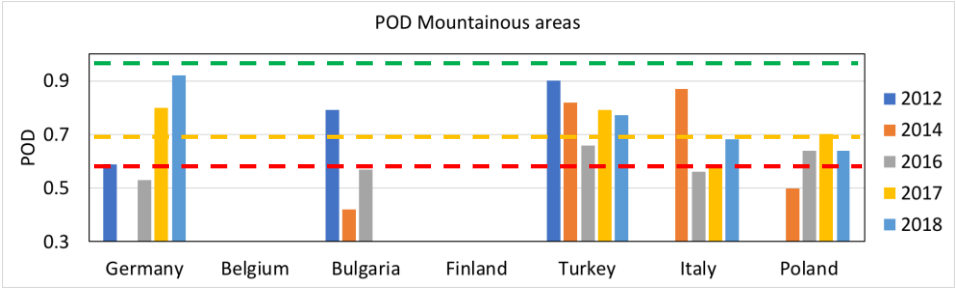
Accuracy: $ACC = {}^{(a+d)}/_{(a+b+c+d)}$

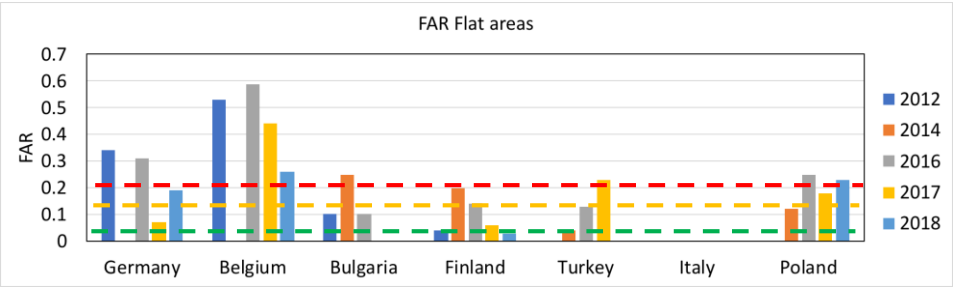
SE-E-SEVIRI (H10)

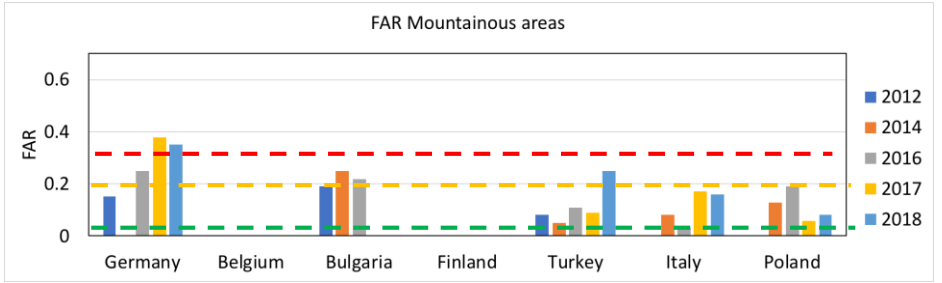
The measurement is considered as ‘snow occurrence’ if the snow depth SD ≥ 2 cm.



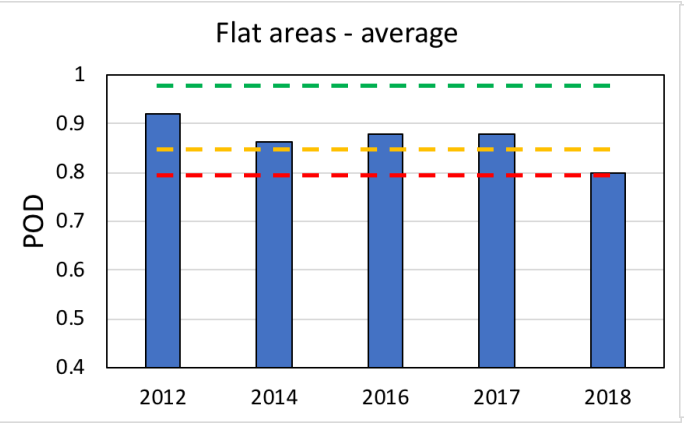


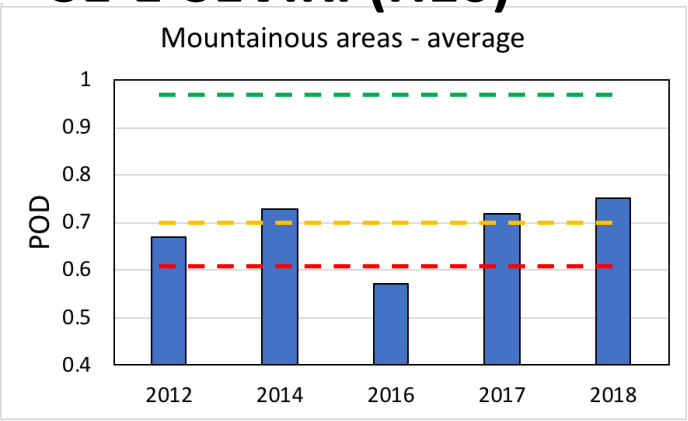


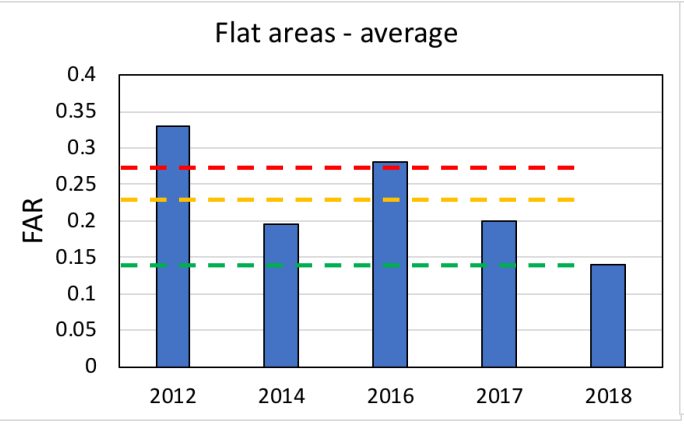


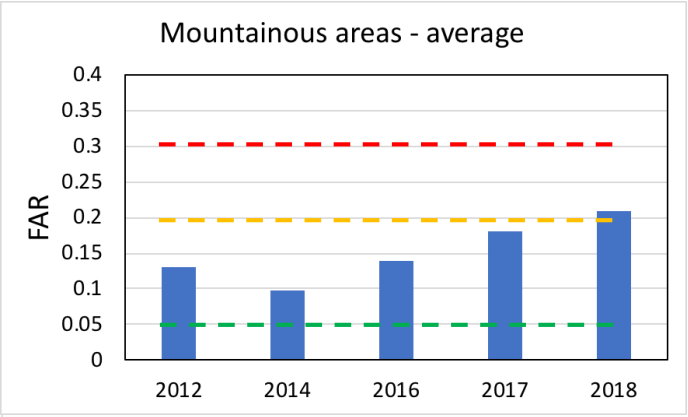


SE-E-SEVIRI (H10)







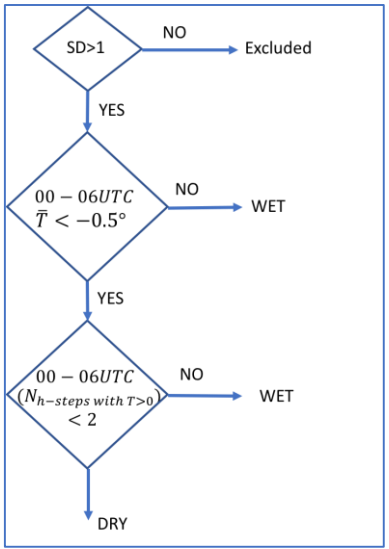


In both flat and mountainous areas the Probability Of Detection (POD) and False Alarm Rate (FAR) are generally good and between threshold and target.

WS-E (H11)

Validation of H11 is restricted to flat areas in Nordic countries - **Finland**

Snow Status is validated by and indirect temperature-based validation procedure.
This approach is **based on air temperature** data, which does not directly describe the status of the snow pack. Secondly, the calibration of the thresholds is based on data for whole Finland over several years, but is still validated for a single country only and might not hold for places with very different winter conditions.



H-SAF Accuracy requirements for H11				
Product requirements				H11
Score	threshold	target	optimal	total
POD	0.60	0.80	0.90	0,97
FAR	0.20	0.10	0.05	0,04

validation period 2017-2018

Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

FSC-E (H12)

Product **FSC-E (H12)** is validated using high resolution satellite Data from COPERNICUS Sentinel2 satellites.

geosciences

MDPI

Article

Cross-Country Assessment of H-SAF Snow Products by Sentinel-2 Imagery Validated against In-Situ Observations and Webcam Photography

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Collaboration with European Cooperation in Science and Technology (COST) ES1404 Harmosnow Action.

- Validate moderate-resolution H SAF products using Sentinel-2
- High-resolution image of Sentinel-2 data are assumed as ground truth
- to guarantee the reliability of the validation analysis the accuracy of Sentinel-2 snow maps validated against in-situ snow measurements and webcam photography.

FSC-E (H12)

Use of Sentinel-2

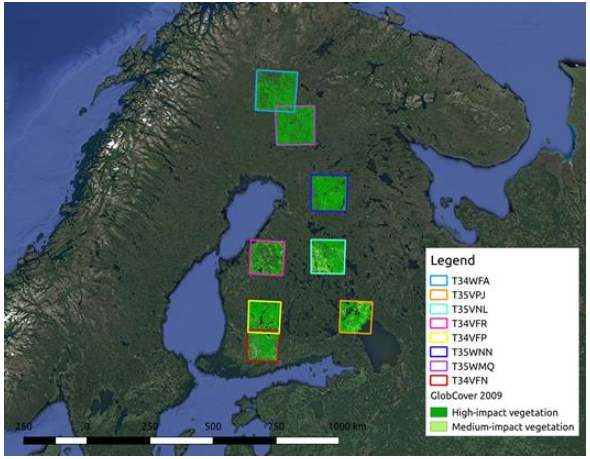
8 Sentinel-2 tiles selected over Finland, Italian Alps and Turkey.

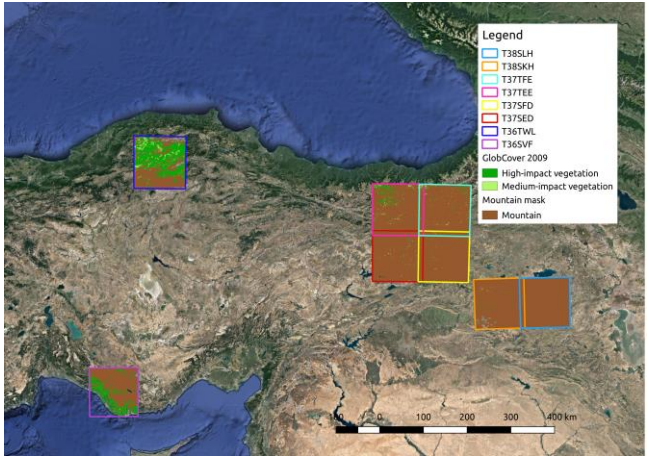
Ancillary information on vegetation cover derived from ESA GlobCover 300-m map

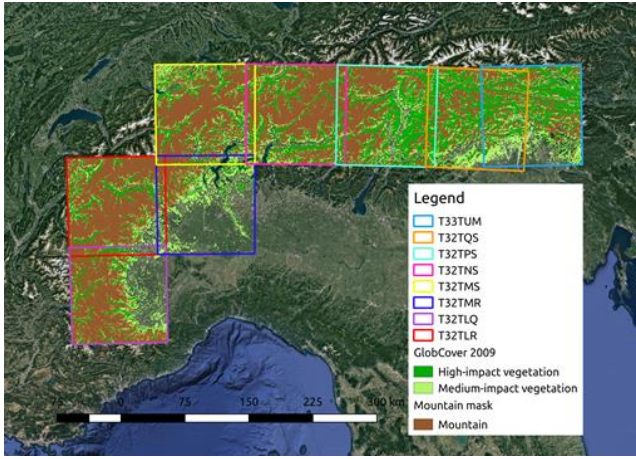
- High-impact vegetation (V_1): evergreen forest
- Medium-impact vegetation (V_2): deciduous forest

Analysis period: winter seasons 2016/2017 and 2017/2018.

Cloud free scenes or scenes with minor cloud cover (lower than 20%) are analyzed.







Validation of Sentinel-2 snow maps

Turkey
- In situ measurements of snow depth

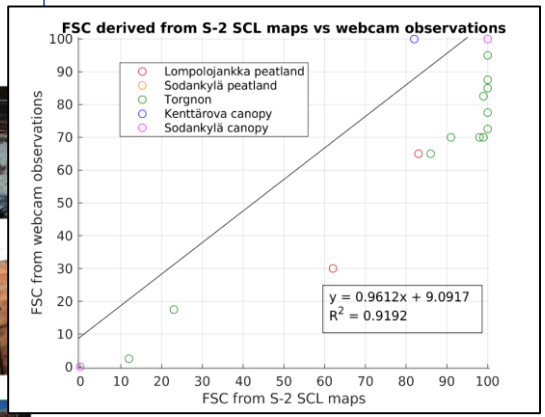
Significant consistency of satellite imagery, as evidenced by the highest number of hits and lower values of false alarms and misses

POD	0.82
FAR	0.08
POFD	0.40
ACC	0.79
CSI	0.77
HSS	0.33

Italy and Finland
- FSC by Webcam images

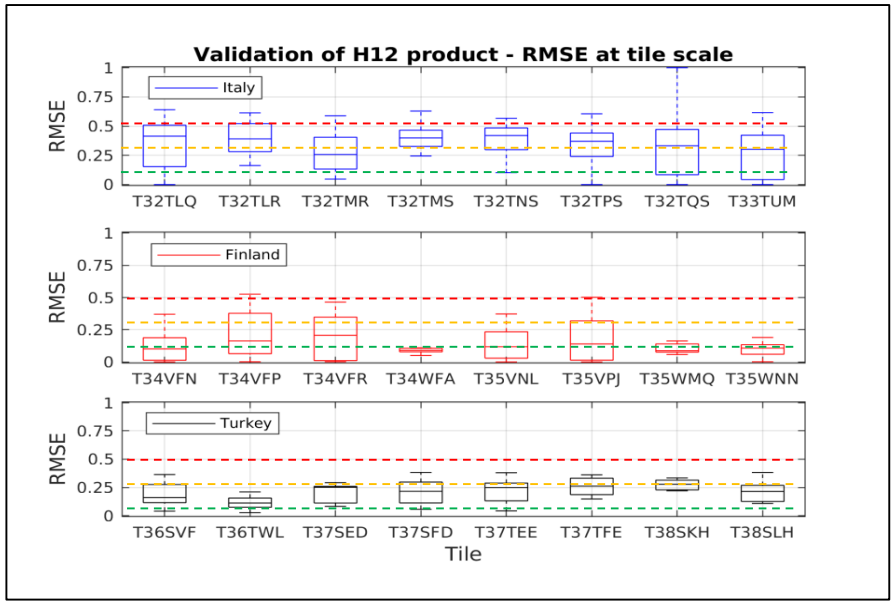
Camera name	No. of analyzed images
Torgnon	24
Sodankylä peatland	22
Sodankylä canopy	22
Lompolojankka peatland	23
Kenttärova canopy	23

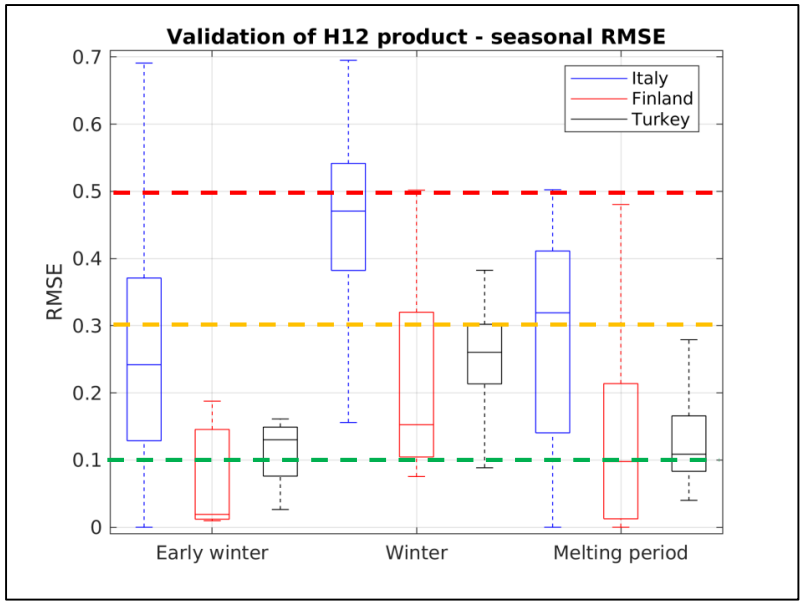
Figure 7. Webcam field of views: (a) Kenttärova canopy camera, (b) Lompolojankka peatland camera, (c) Sodankylä canopy camera, (d) Sodankylä peatland camera, (e) Torgnon camera.



- RMSE 12%
- Tendency of S2 to over-estimation
- Scenes having the highest error are those affected by higher cloud cover fraction
- During the melting period (meltwater and patchy snow cover) S2 overestimation tendency

FSC-E (H12)





- RMSE scores are generally lower than 0.4.
- Complex topography in mountainous areas affects the consistency between H12 product and Sentinel-2 snow maps, especially over the Italian Alps.

Region	RMSE
Finland	0.15
Italian Alps	0.33
Turkey	0.21

- higher RMSE in winter (H12 overestimates respect to S2) especially in mountainous region.

	Threshold value	Target value	Optimal value
RMSE (in SCA units)	50%	30%	10%

FSC-E (H12)

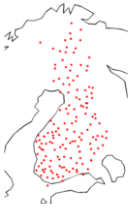
About Sentinel-2

- Can be properly used for continuous validation of medium/coarse resolution satellite snow products, have a significant consistency with both ground-based snow measurements and in-situ webcam photography.
- Dense cloud cover can undermine the reliability of Sentinel-2 snow maps
- Patchy snow cover and melting period may lead to an overestimation of snow cover.

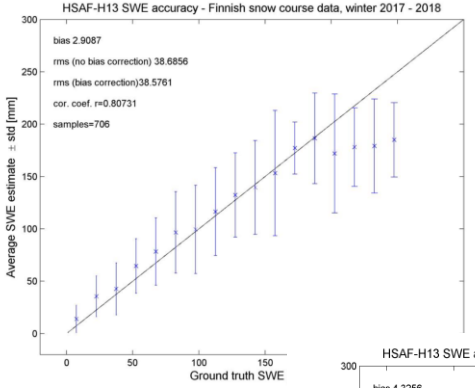
About H SAF snow product

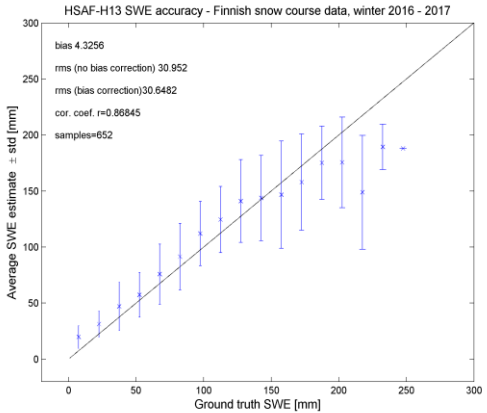
- Highly consistent with S-2 imagery with a higher agreement over flat areas than in mountainous regions
- Complex topography significantly hinders snow detection.
- Vegetation cover has less relevant impact on the consistency among remotely-sensed observations, even in presence of dense evergreen forest.

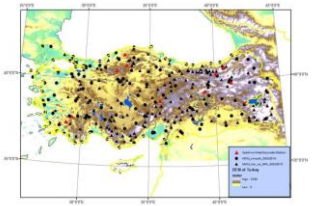
SWE-E (H13)



Finland
150 snow stations
October-May

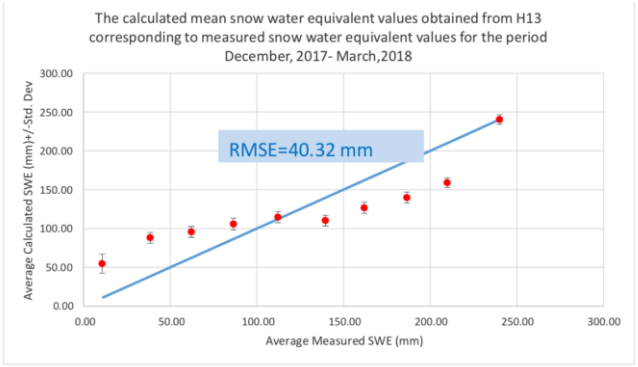


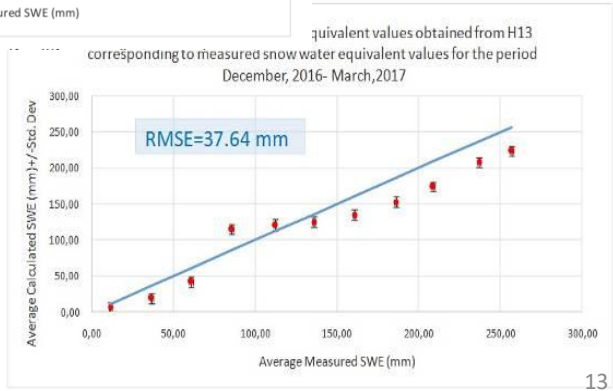




Turkey
66 snow stations
December-March

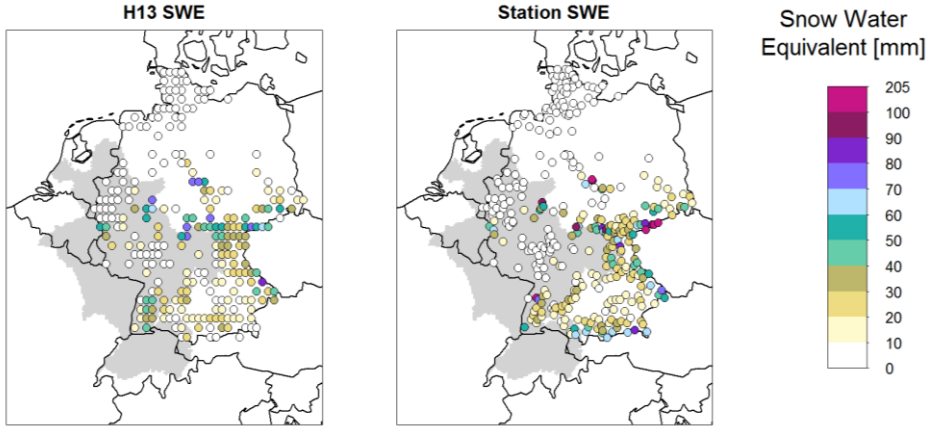
$|Elev_{SnowSt} - Elev_{Sat}| < 400$

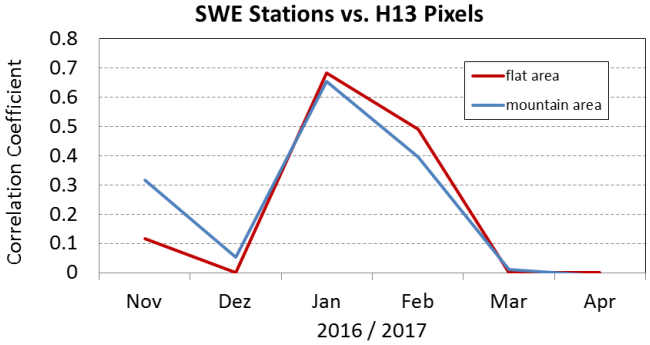




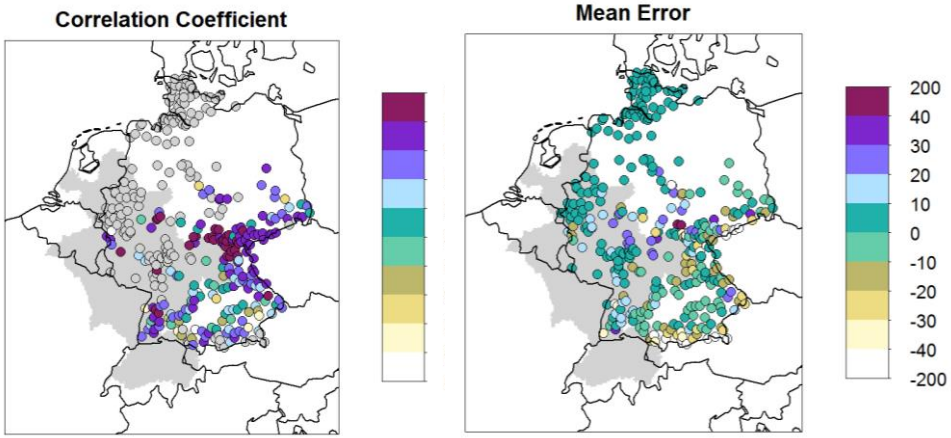
SWE-E (H13)

January 2017, monthly means





Grey shaded area: International River basins Rhine and Maas



- Small correlation due to low amount of snow or “wet snow” conditions (months: N, D, M, A)
- **January** & February 2017:
  Snow cover for several weeks
  - dry and cold weather conditions
  - several stations with SWE > 200 mm

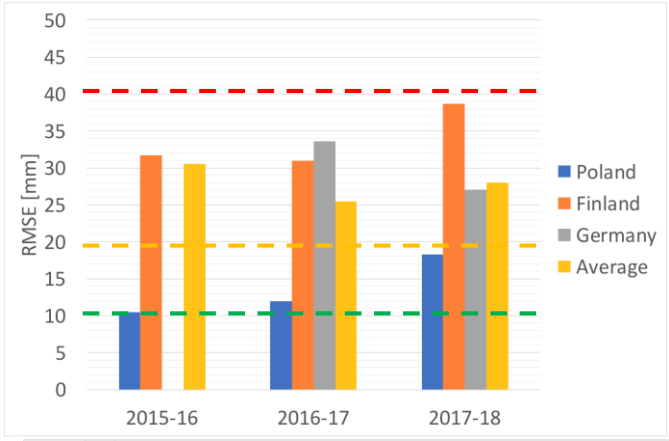
SWE-E (H13)

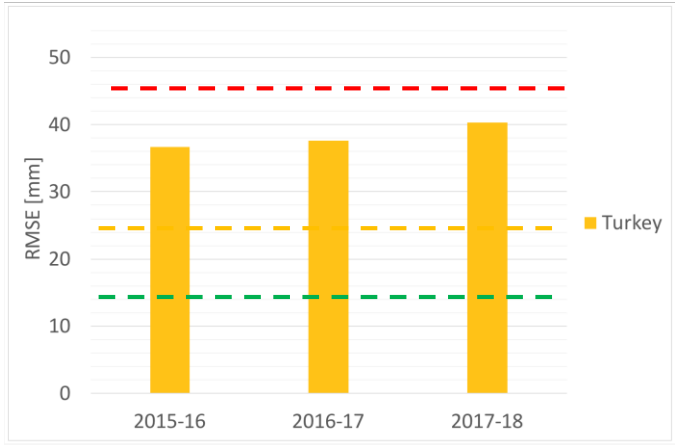
SWE- E product is developed for dry snow conditions, performance decrease for wet snow (different validation period for each country)

SWE-E satisfies the Product Requirements, with RMSE between threshold and target values

Best performance are obtained in the flat areas

General underestimation of SWE when values are larger than about 150 mm.





Operational validation of H SAF snow products

Hydro-validation

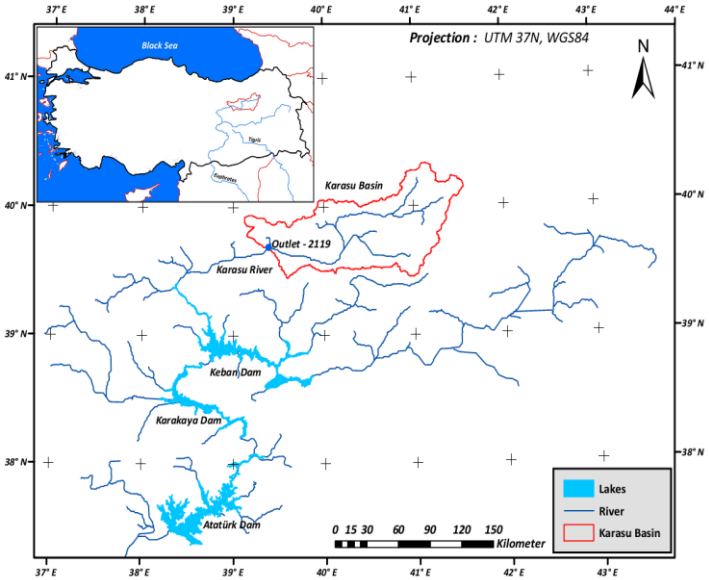
Hydro-validation concerns the use of H SAF snow products for hydrological applications (e.g. floods, water balance)

Hydro-validation is complicated from the impact of additional variables on the final performance of the products: models, quality of discharge observations, assimilation technique

The activities have been carried out by single case studies mainly related to assimilation of the products into different rainfall-runoff models for different study periods with different data assimilation techniques (case specificity)

Operational validation of H SAF snow products

Hydro-validation

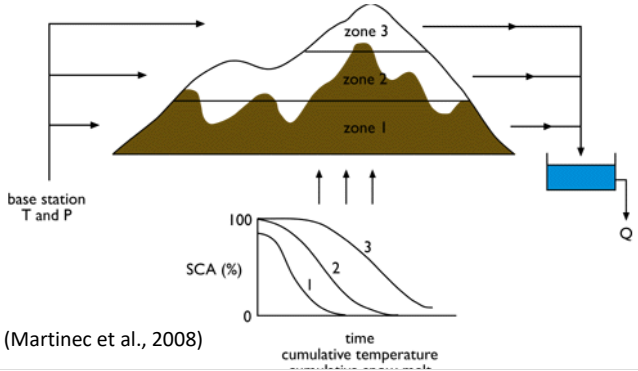


Karasu catchment, Turkey:
mean average discharge: 84.4 m^3/s
area: 10275 km^2
elevation between 1125 and 3487 m

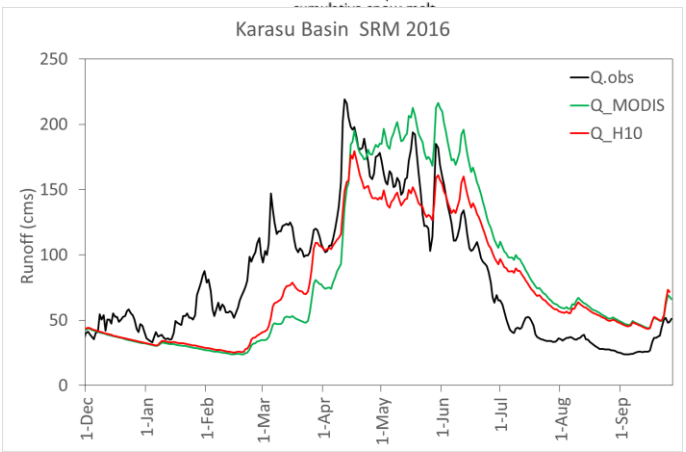
HydroVal Studies in Turkey
Upper Euphrates Basin

Impact Analysis and Hydrovalidation (SRM)

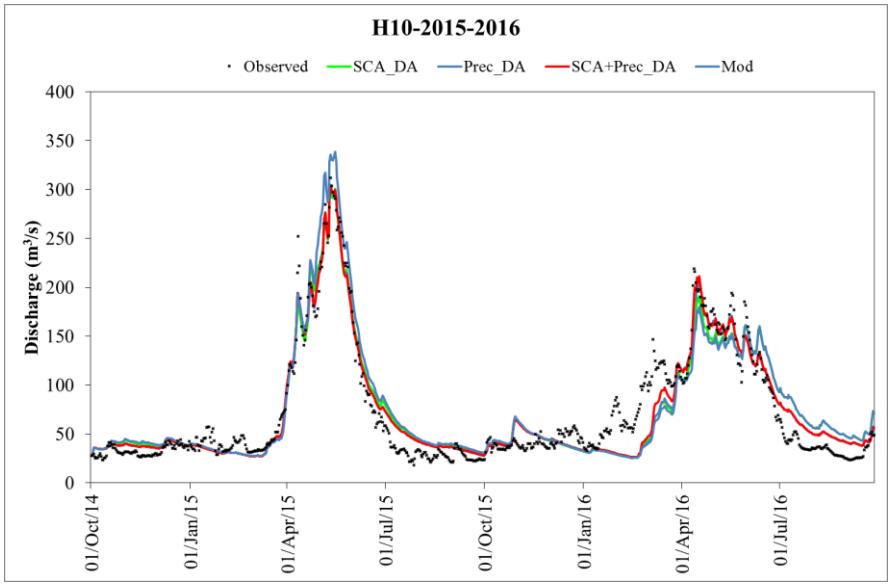
SRM (Snowmelt-Runoff Model)



(Martinec et al., 2008)



Impact analysis of snow depletion curves on runoff

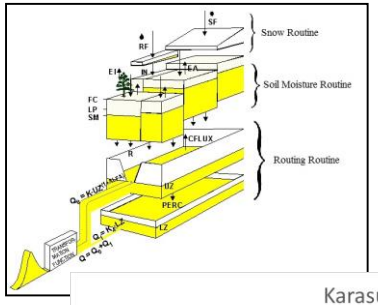


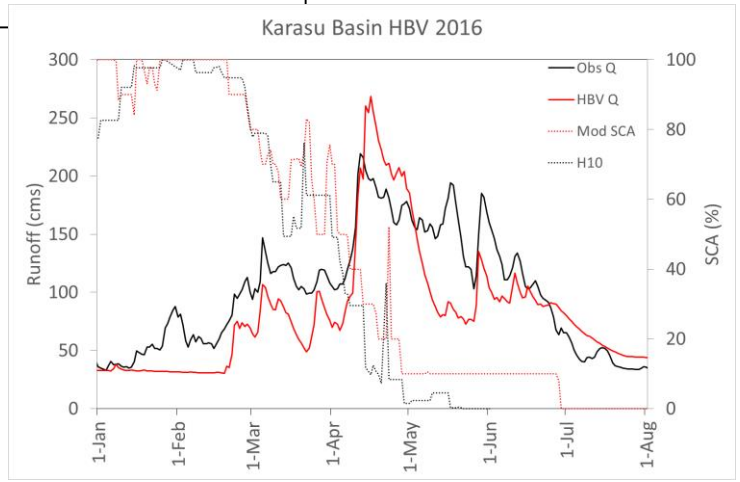
Hydrological modeling results for 2015 and 2016 water years with SN OBS-1 product and data assimilation study

DA of SCA (H10) improves discharge prediction

Hydrovalidation and DA through HBV

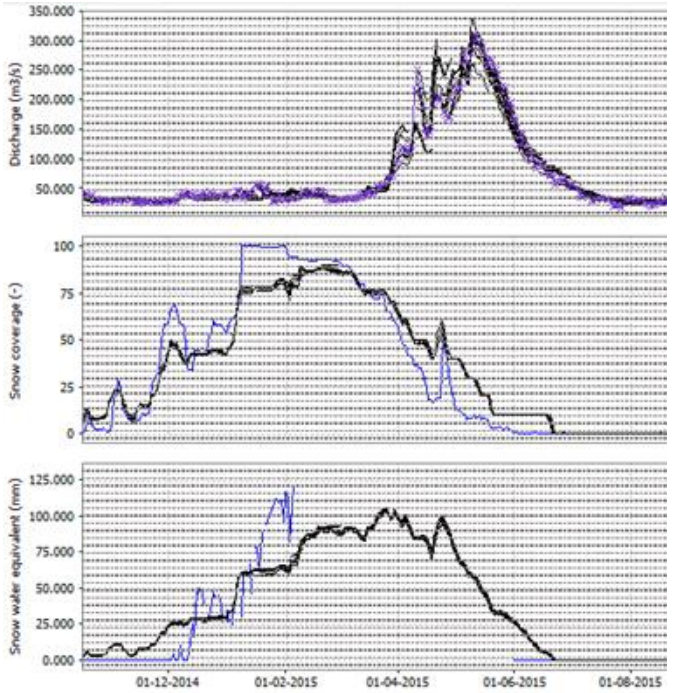
HBV (Hydrologiska Byråns Vattenbalans)





Hydrovalidation analysis for snow depletion curve and/or snow water equivalent

DA with runoff, SCA (H10) and SWE (H13)



Thursday, 28 November

Session 5: Novel hydrological data sources and assimilation techniques

"Sequential and variational assimilation of satellite snow data through a conceptual hydrological model in a mountainous catchment" Dr. G. Uysal

Operational validation of H SAF snow products

Conclusions

Performances of snow products validation using snow stations are generally good, scores are generally between threshold and target

Extend the validation in more countries

Hydrological validation should be strengthened by implementing more case study involving different catchments, snow conditions, hydrological models and assimilation techniques

Thank you for your attention