VALIDATION of H-SAF SNOW PRODUCTS

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SUMMARY

- **Snow Products in H-SAF Operative-Preoperative**
- **Validation results, performances with some case study**

Snow Products in H-SAF

Legacy products over European area - operational

- H10 Snow detection – Snow cover
- H11 Snow status (wet/dry)
- H12 Effective (Fractional) Snow Cover FSC
- H13 Snow Water Equivalent - SWE

Global and hemispherical products:

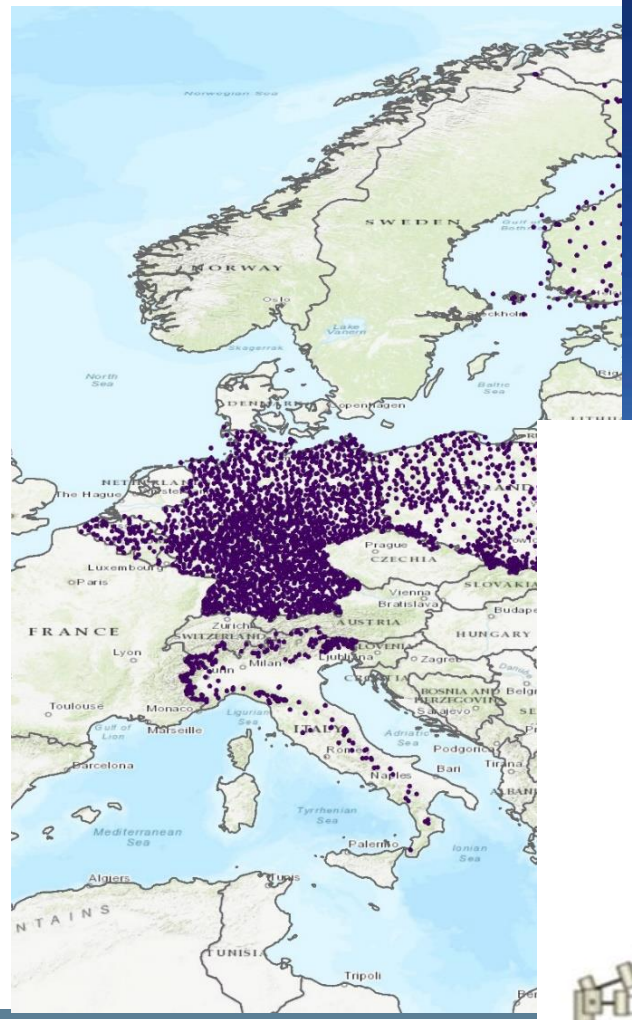
- H34 and H35 new products (Snow det. and FSC) Pre-op
- H31 and H32 ex L-Saf products (Snow det.) Oper

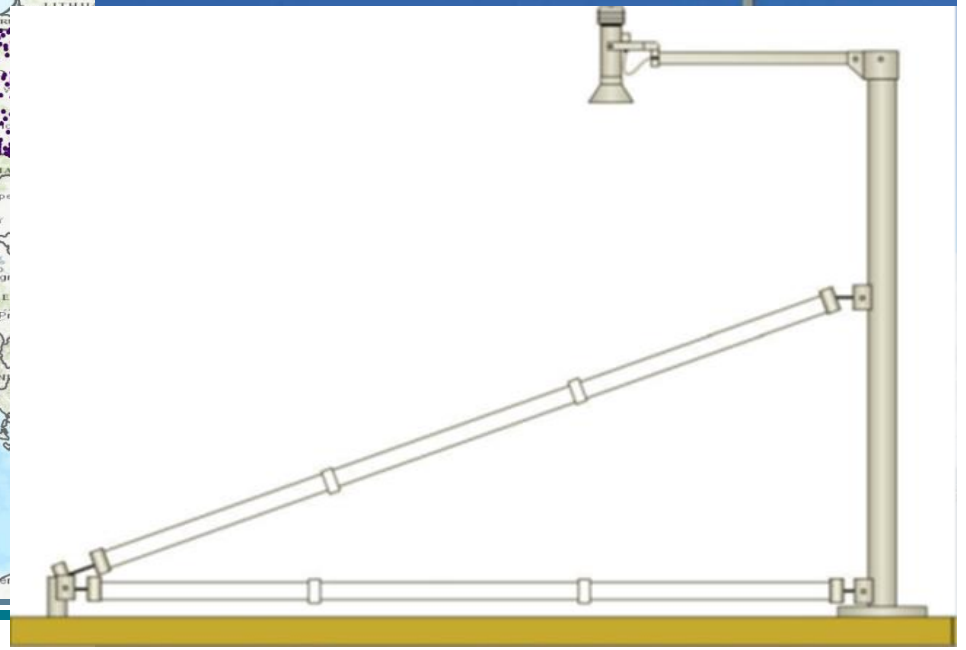
Ground Station Network

Weather stations and snow detection: manual and automatic

SWE Stations

Country	Type	Number of Stations
Finland	Synoptic	190
Turkey	Synoptic	85
Italy	Snow/Avalanche	264
Poland	Synoptic	595
Germany	Synoptic	1863
Belgium	Teleclim	84
TOTAL		3081





Validation – Snow detection

- H10 (H31) H32 and H34:

Validation methodology - Confusion matrix:
Hits n11, False alarms n01
Misses n10, Correct negatives n00

$$\begin{bmatrix} n_{11} & n_{01} \\ n_{10} & n_{00} \end{bmatrix}$$

POD

FAR

$$POD = \frac{n_{11}}{n_{11} + n_{10}} \quad (1)$$

$$FAR = \frac{n_{01}}{n_{11} + n_{01}} \quad (2)$$

$$POFD = \frac{n_{01}}{n_{01} + n_{00}} \quad (3)$$

$$ACC = \frac{n_{11} + n_{00}}{n_{11} + n_{00} + n_{10} + n_{01}} \quad (4)$$

$$CSI = \frac{n_{11}}{n_{11} + n_{10} + +n_{01}} \quad (5)$$

$$HSS = \frac{2 \times (n_{11} \times n_{00} - n_{01} \times n_{10})}{[(n_{11} + n_{10}) \times (n_{10} + n_{00}) + (n_{11} + n_{01}) \times (n_{01} + n_{00})]} \quad (6)$$

Validation results H10

•H10 in OR10 snow season 2019-20:

POD slightly out of spec for Flat/Forest areas, but fully compliant for Mountainous areas. Problems arise in H10 if snow is scarse and snow cover is not homogeneous in space and time, as was in winter 2019/20 in central Europe.

Statistical scores for H10 over mountainous and flat areas period 1.10.2019-31.5.2020

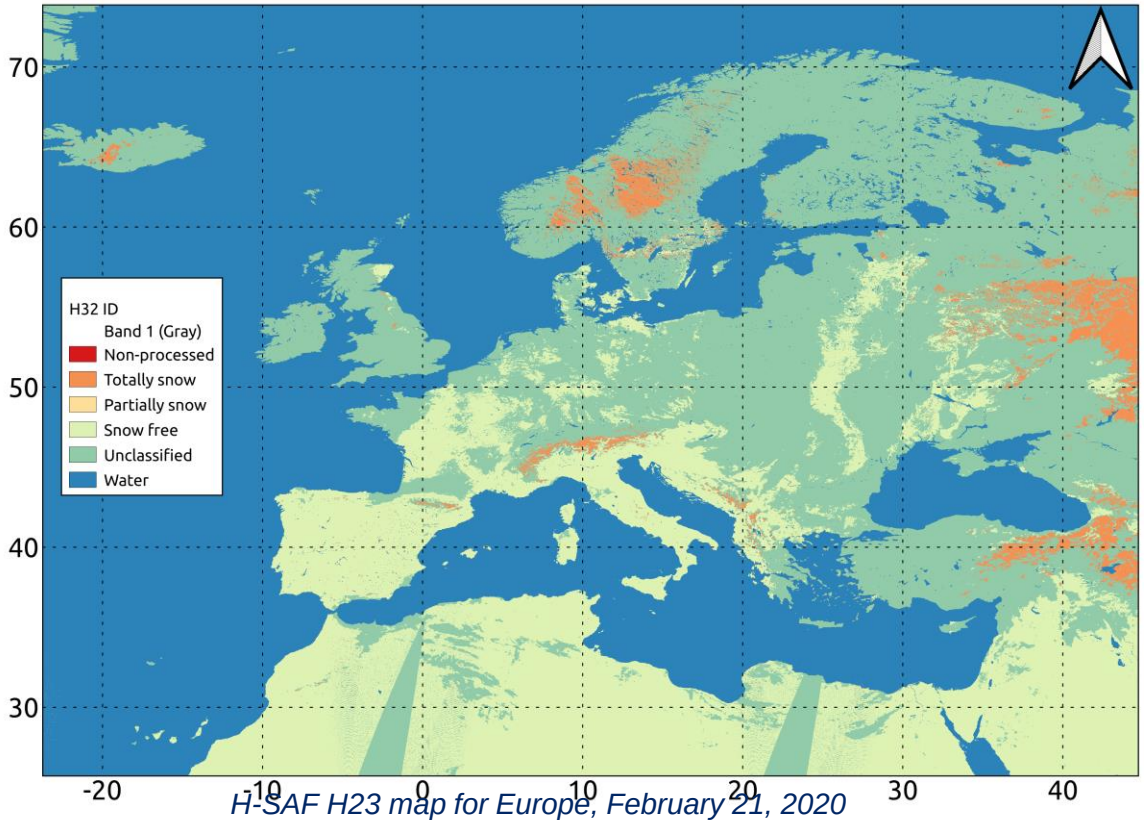
Between target and optimal	Between threshold and target	Threshold exceeded by < 50 %	Threshold exceeded by ≥ 50 %

H-SAF Accuracy requirements for H10 in Flat/Forest areas				
Product requirements				H10
Score	threshold	target	optimal	total
POD	0.80	0.85	0.99	**0.74**
FAR	0.20	0.15	0.05	**0.27**

H-SAF Accuracy requirements for H10 in Mountainous areas				
Product requirements				H10
Score	threshold	target	optimal	total
POD	0.60	0.70	0.99	**0.70**
FAR	0.30	0.20	0.05	**0.22**

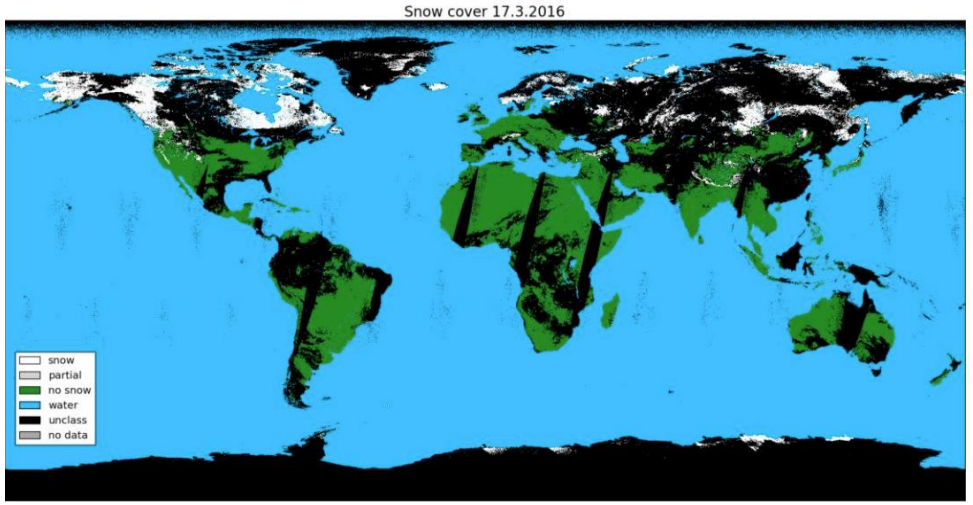
Validation H32

Validation of the SE-G-AVHRR (H32) snow product



H-SAF H23 map for Europe, February 21, 2020

SE-G-AVHRR (H32): global snow-cover data (SCA) based on measurements from the Advanced Very High Resolution Radiometer (AVHRR) on-board EUMETSAT polar system satellites, the Metop series.
Daily, ~1 km



Validation of the SE-G-AVHRR (H32) snow product

Statistical scores over European areas with ground data in the period 1.10.2019-31.5.2020

Validation area	Finland	Italy	Germany	Poland	Turkey	Average
pod	0.98	0.77	0.63	0.80	0.91	**0.82**
far	0.12	0.01	0.37	0.41	0.05	**0.19**

Statistical scores over Extra-European areas with Satellite data in the period 1.10.2019-31.5.2020

Validation area	California	Siberia	Japan	Average
pod	0.93	0.99	0.93	**0.95**
far	0.06	0.01	0.01	**0.03**

Validation H34

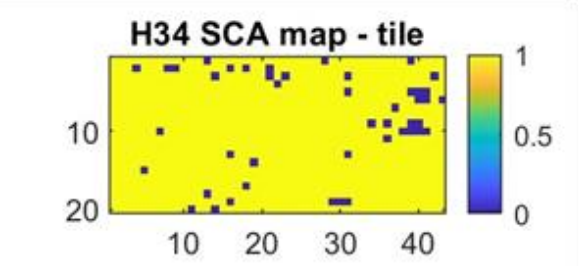
Statistical scores for H34 over mountainous and flat areas with ground station data relatively period 1.10.2018-31.5.2019 (except Finland)

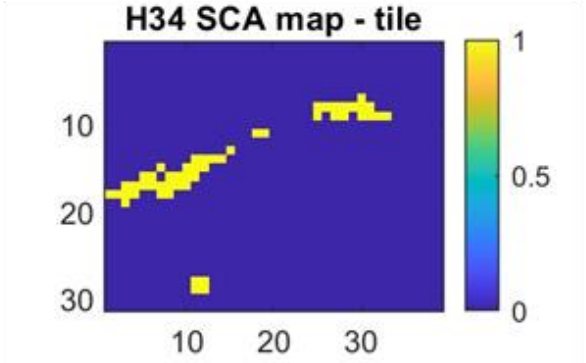
validation area	Belgium	Finland (2017-18)	Finland	Italy	Turkey
pod	0.94	0.95	0.94	0.72	0.66
far	0.39	0.01	0.09	0.05	0.00
csi	0.59	0.95	0.86	0.07	0.66
acc	0.98	0.97	0.92	0.80	0.66

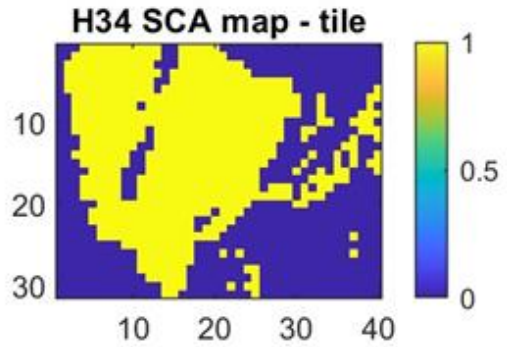
Statistical scores for H34 over mountainous and flat areas with Sentinel2 data relatively period 1.10.2018-31.5.2019

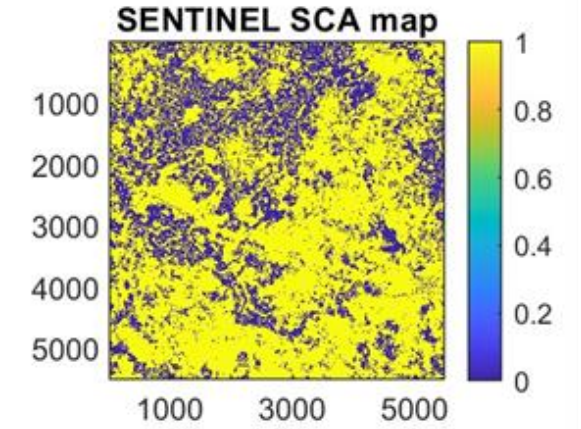
Validation area	Caucasus	Belarus	Turkey	Lebanon	Atlas
pod	0.75	0.98	0.89	0.96	0.73
far	0.15	0.00	0.11	0.59	0.95
csi	0.66	0.98	0.81	0.41	0.04
acc	0.83	0.99	0.90	0.87	0.72

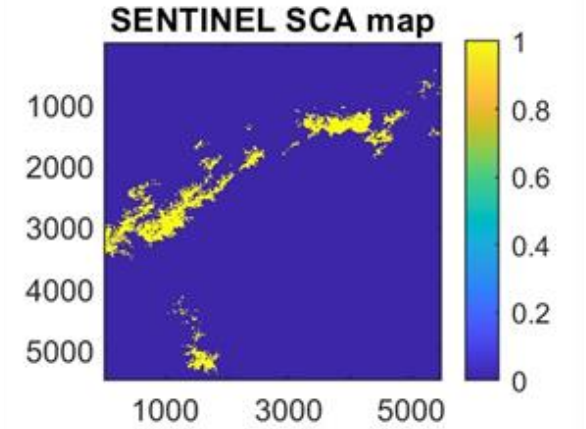
Validation H34: 3 case studies

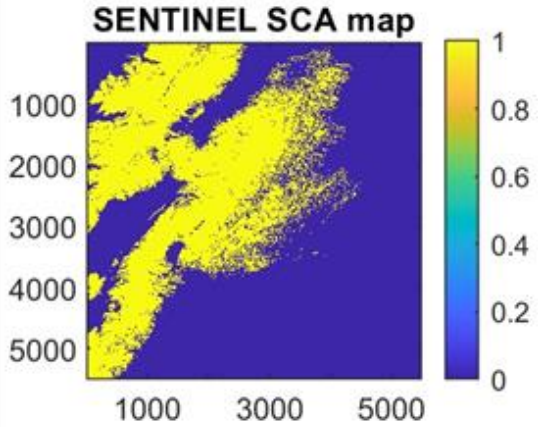












Comparison between H34 and Sentinel-2 snow-covered area in Belarus (February 18, 2019, tile 35UPB), Mount Atlas (November 28, 2018, tile 29RPQ), and Lebanon (January 21, 2019, tile 37SBT).

Validation H10, H32, H34 discussion

Problems arise in H10 if snow is scarse and snow cover is not homogeneous in space and time, as was in winter 2019/20 in central Europe.

H 34: full disk extension of H10 (to superseed H10)
validation strategy as in H10 is used, with ground data of the same countries. For extra H-SAF areas a new validation scheme using Sentinel2 data with European and extra-European target areas is used (CIMA).

H32: hemispherical Snow Detection Product ex L-SAF
Same strategy as in H34, with ground data over Europe and Satellite data (CIMA) over extra-European areas. Results are very good (High resolution)

Validation H11 Snow status (wet/dry)

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

Finland	ott-19	nov-19	dic-19	gen-20	feb-20	mar-20	apr-20	mag-20	Total
numbers of obs	121	248	516	342	367	465	323	261	2643
pod	**0.90**	**0.99**	**1.00**	**1.00**	**0.93**	**0.81**	**0.74**	**0.24**	**0.87**
far	**0.71**	**0.11**	**0.19**	**0.13**	**0.02**	**0.12**	**0.10**	**0.23**	**0.12**
csi	0.08	0.88	0.81	0.87	0.91	0.73	0.69	0.23	0.78
pofd	0.69	1.00	1.00	1.00	0.53	0.65	0.49	0.10	0.63
acc	0.99	0.88	0.81	0.87	0.91	0.74	0.71	0.51	0.79

H11 is validated with a temperature proxy – so no measure about snow wetness is made.

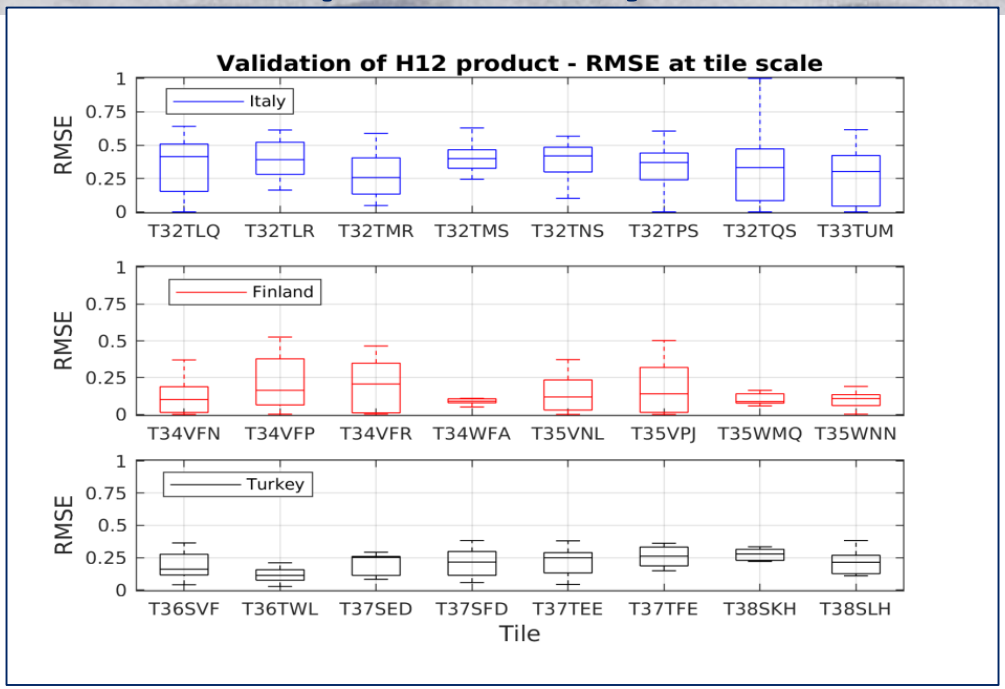
In areas where there is a homogenous and stable snow cover product H11 can be considered reliable.

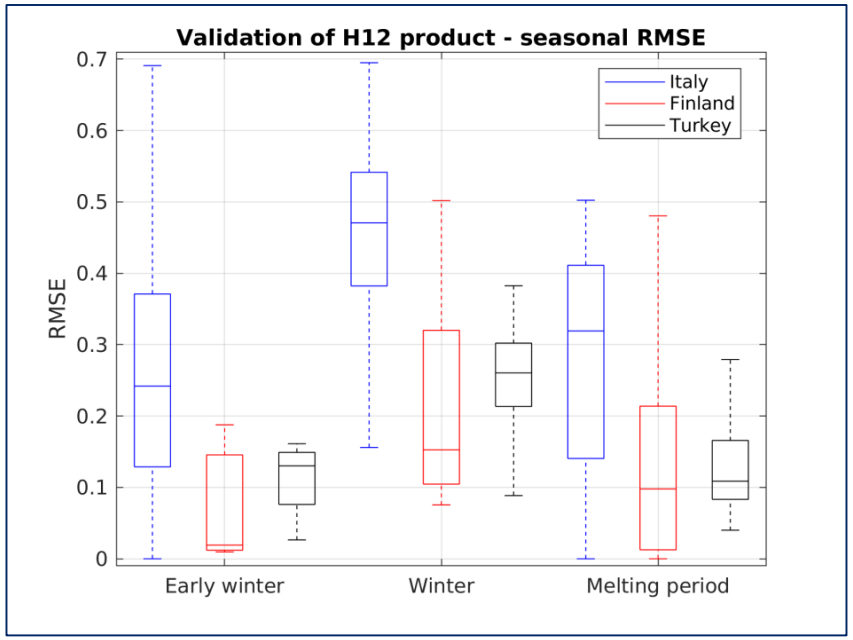
If a clear snow melting period - that is areas with snow cover going from dry to wet in H11 - is detected by the product, the data is valuable and usable for those hydrological applications, in which snow melting is an important factor.

Validation H11 discussion

- H11 is restricted to flat areas in Nordic countries. Validation is performed only in in Finland, with an updated validation scheme since 2018.
- In the mean, product H11 satisfies the requirements, with results of POD between target and optimal and FAR between threshold and target.
- Validation group strongly recommends using product H11 in Nordic areas only during the winter and if snow cover is known to be sufficiently homogenous.

Validation of H12 product by Sentinel-2



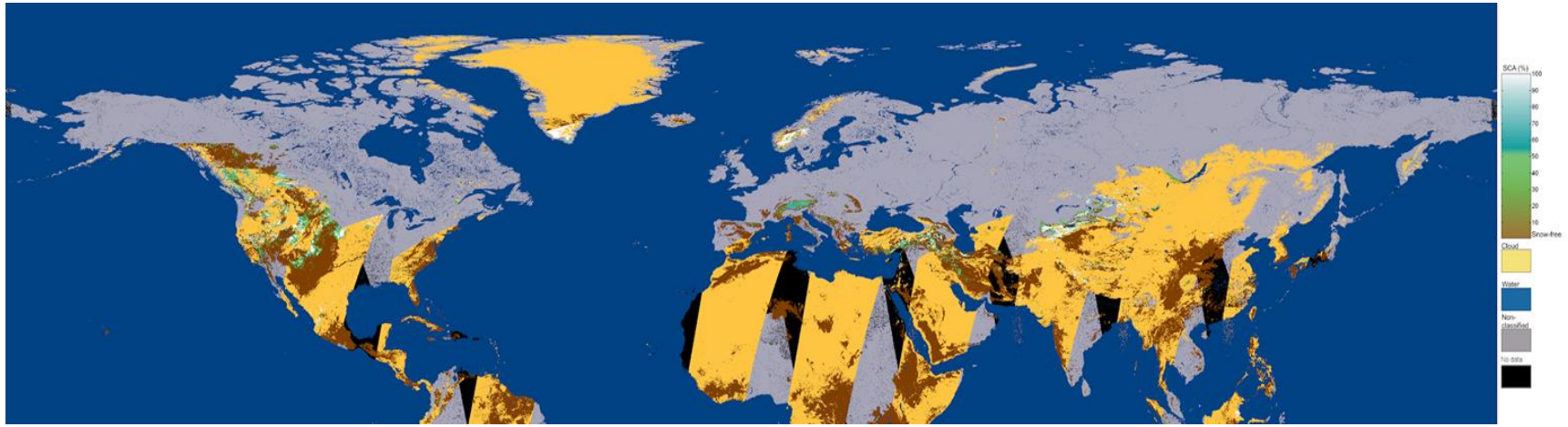


- RMSE scores are generally lower than 0.4.
- Complex topography in mountainous areas affects the consistency between H12 product and Sentinel-2 snow maps, especially over the Italian Alps.

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.

Validation of the ESC-H (H35) snow product

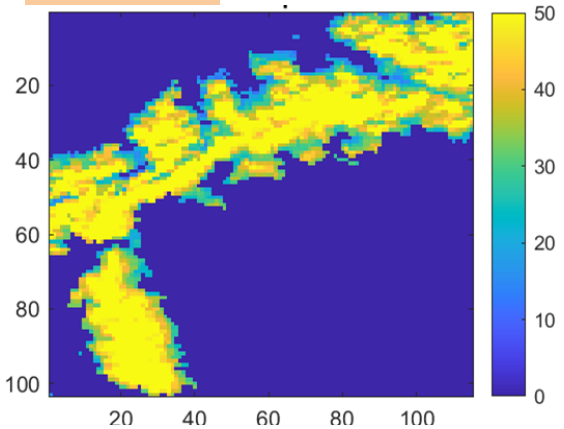


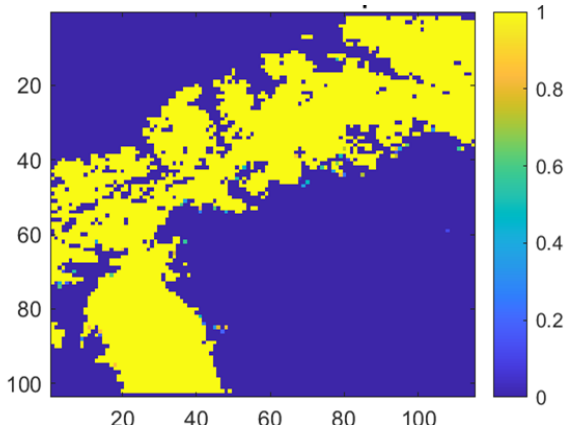
ESC-H (H35): daily FSC maps for the northern Hemisphere, by VIS/IR radiometry is based on multi-channel analysis of the AVHRR instrument onboard MetOp satellites

Validation of the ESC-H (H35) snow product

We compared H35 to Sentinel-2 Scene Classification Maps, following results by Piazzi et al. 2019

Atlas





Step 1 — **Download S2 data**

We directly downloaded Level-2 SCL maps

Step 2 — **Resampling S2 data**

For each map-tile, we resampled S2 according to the HSAF grid

Step 3 — **Comparison**

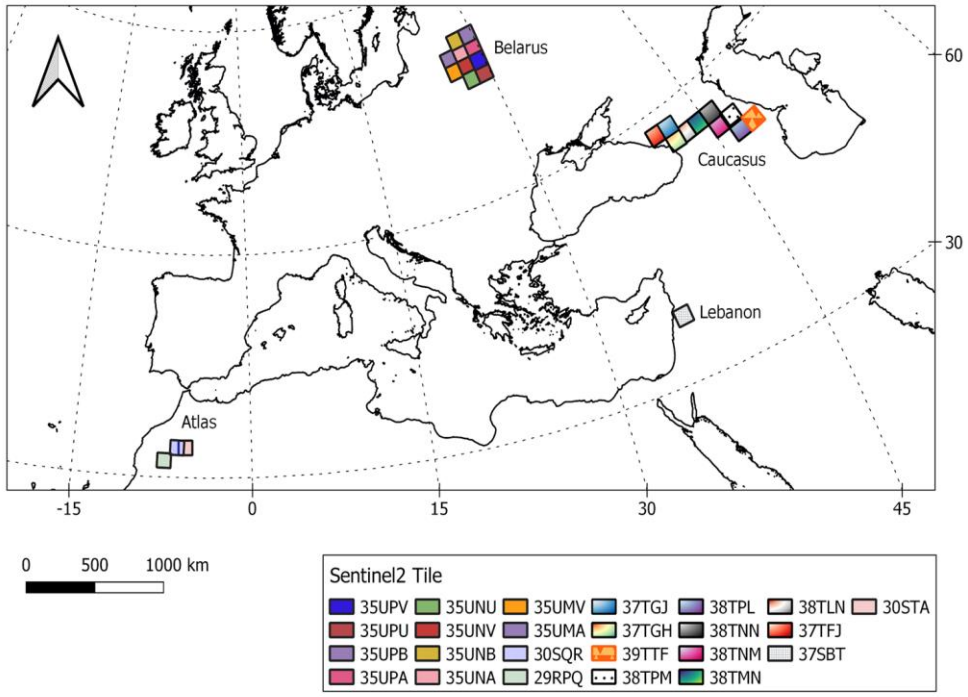
H35, S2 resampled maps were converted to FSC

Step 4 — **Evaluate performance**

performance for H35 was evaluated using RMSE and bias.

Validation of the ESC-H (H35) snow product

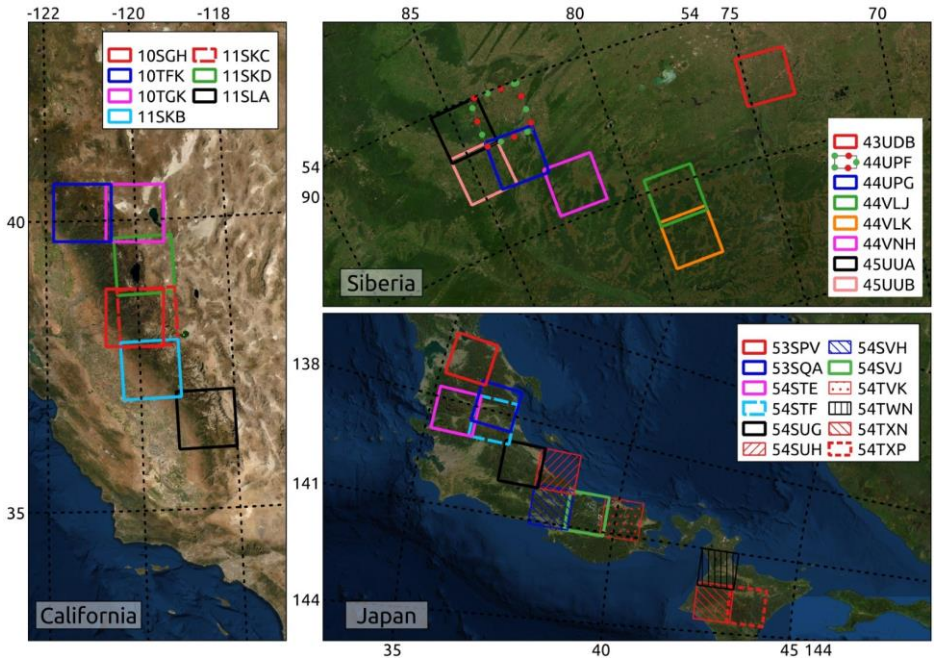
H35: Oct. 1 2019 - Jan. 31 2020



We considered S2 tiles across:

- Siberia
- Japan
- California
- Belarus
- Caucasus
- Lebanon
- Atlas

H35: Oct. 1 2019 - May 31 2020



H35: Caucasus, Lebanon, Atlas, Belarus

RMSEs and biases for all areas of interest were below thresholds (50% and 40%, respectively).

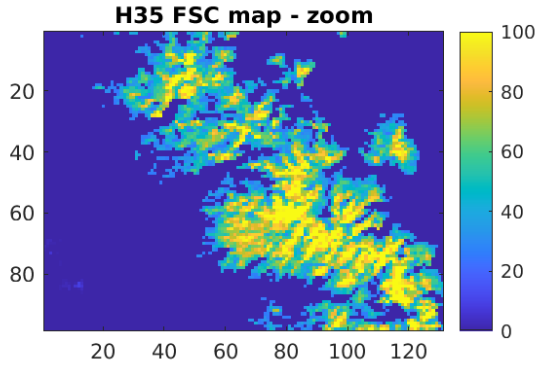
Area of interest	RMSE	Bias
Caucasus	38%	-20%
Belarus	3%	0.25%
Atlas	19%	-6%
Lebanon	22%	-6%

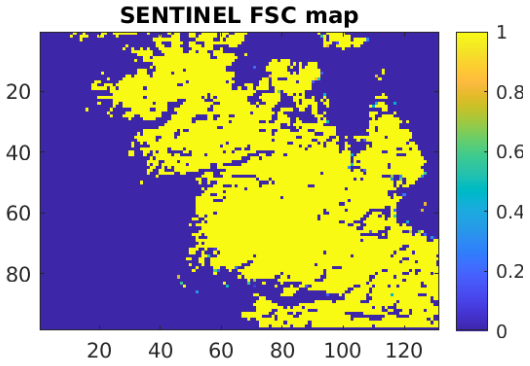
Thresholds for Fractional Snow Cover products (H12, H35)

H-SAF Accuracy requirements FSC Products			
Product requirements *Root Mean Square Error*			
Score	threshold	target	optimal
Flat/ Forested areas RMSE	40%	20%	10%
Mountainous areas RMSE	50%	30%	10%

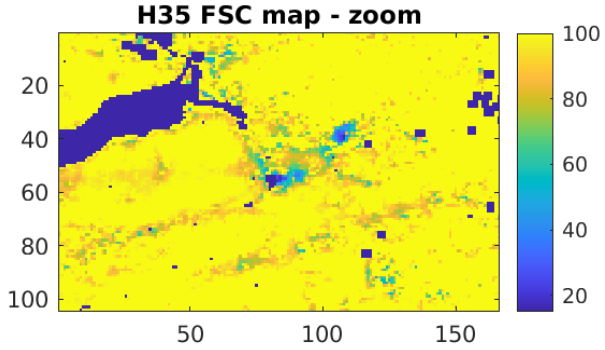
Validation of the ESC-H (H35) 3 case studies

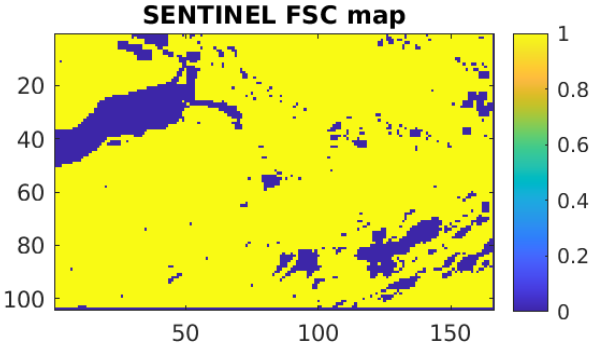
California (February 06, 2020, tile 11SKC)



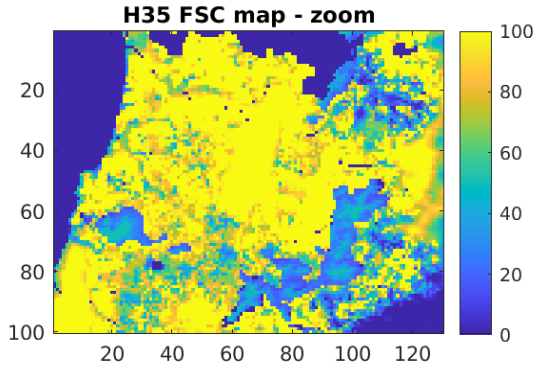


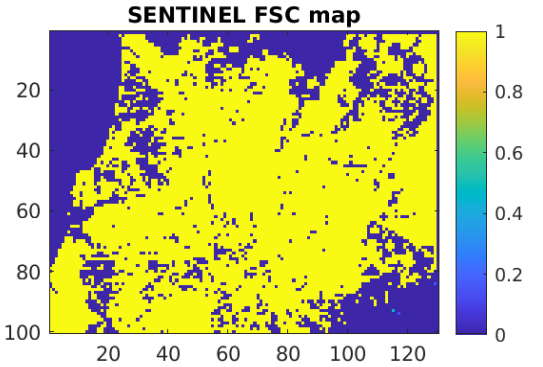
Siberia (March 23, 2020, tile 44UPF)





Japan (February 12, 2020, tile 54SVJ).

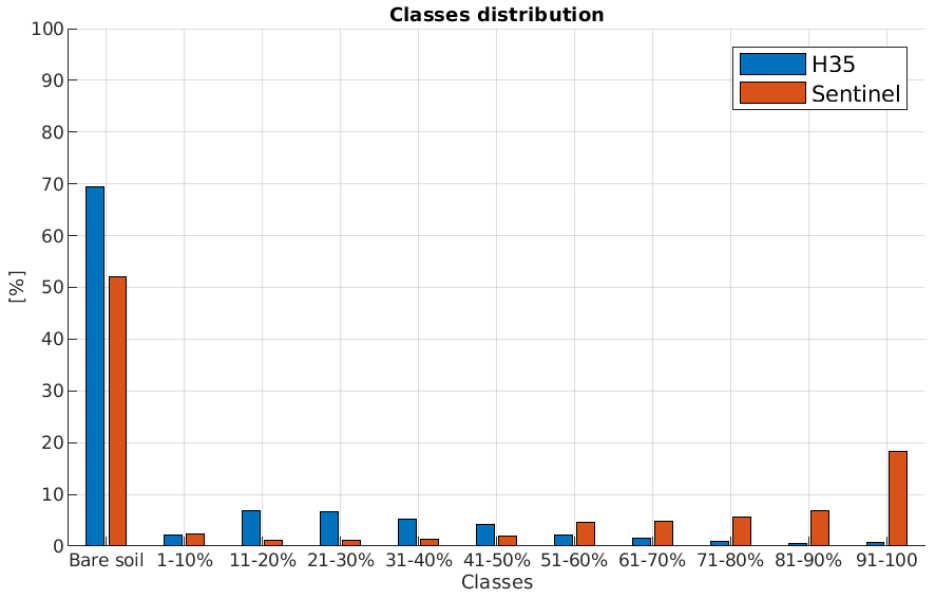


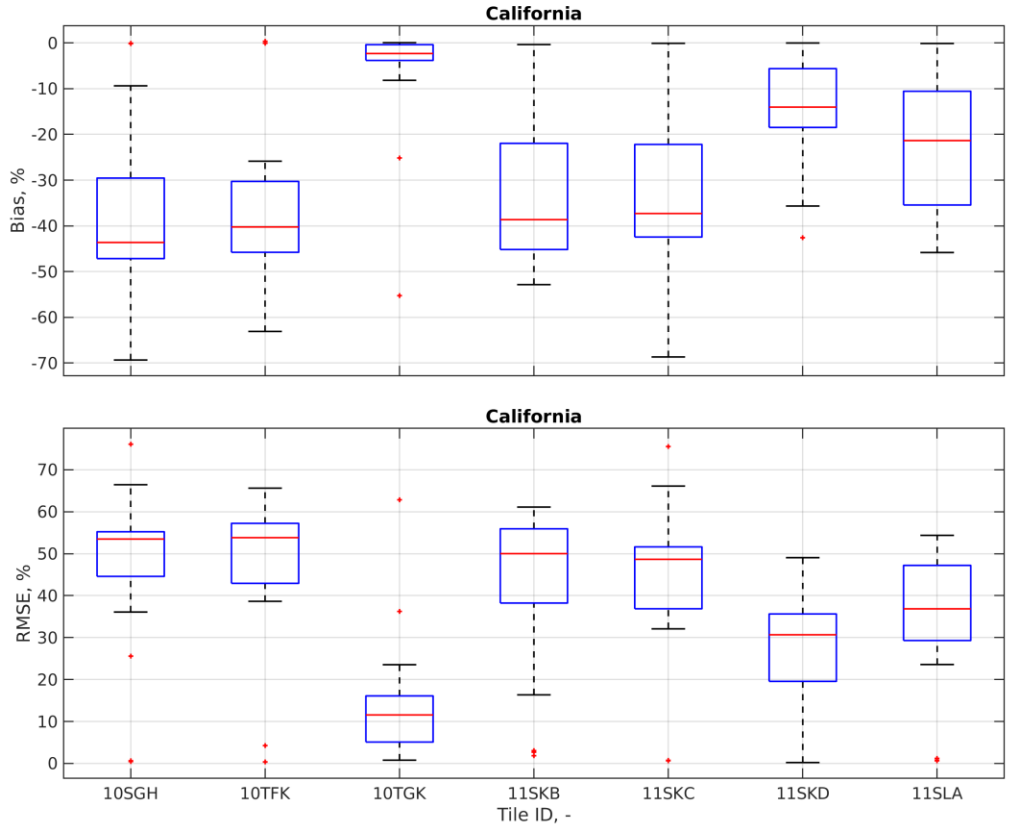


Qualitatively, snow patterns estimated by H35 and by Sentinel 2 are consistent.

H35: California (mountain region)

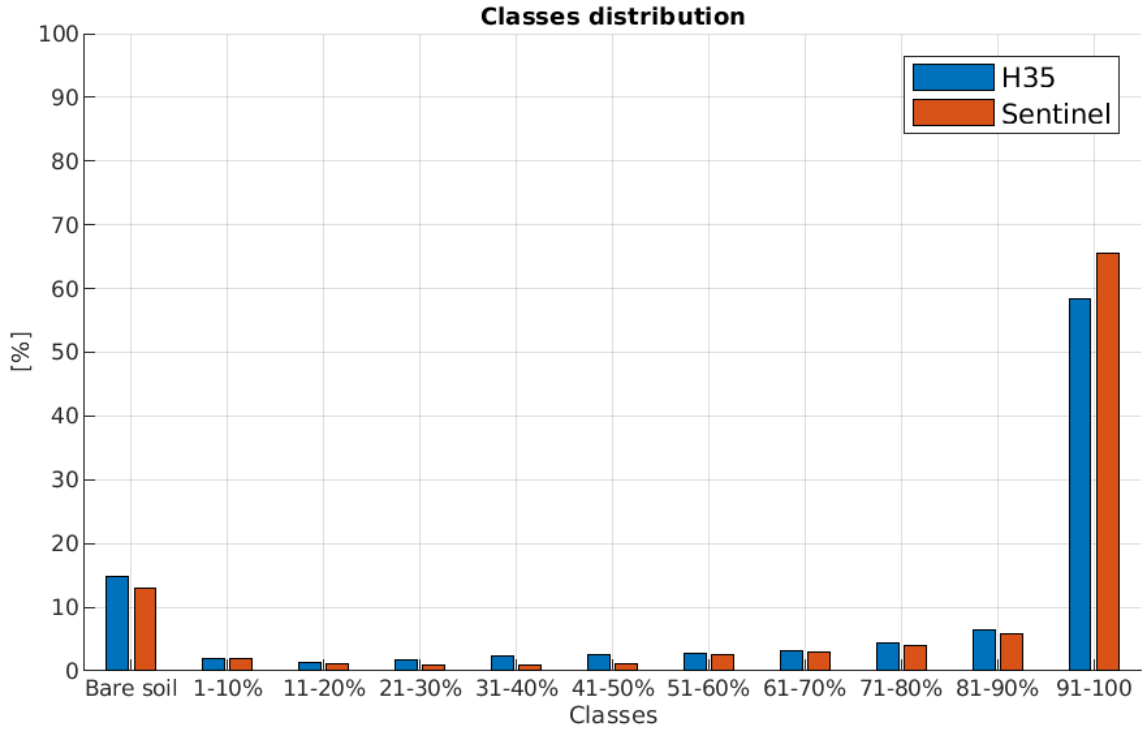
RMSE 40%, BELOW THRESHOLD

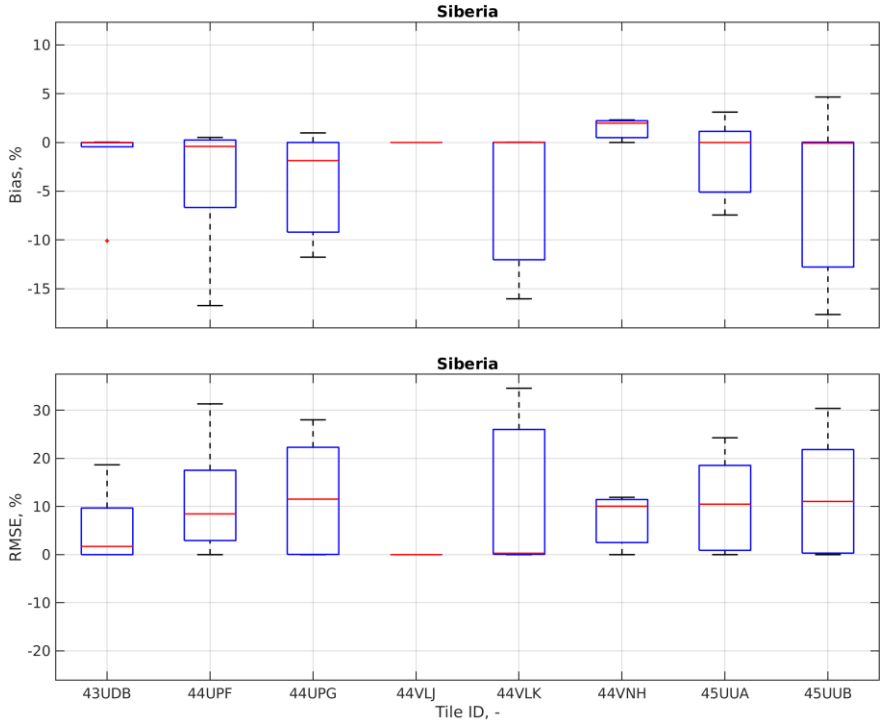




H35: Siberia (flat region)

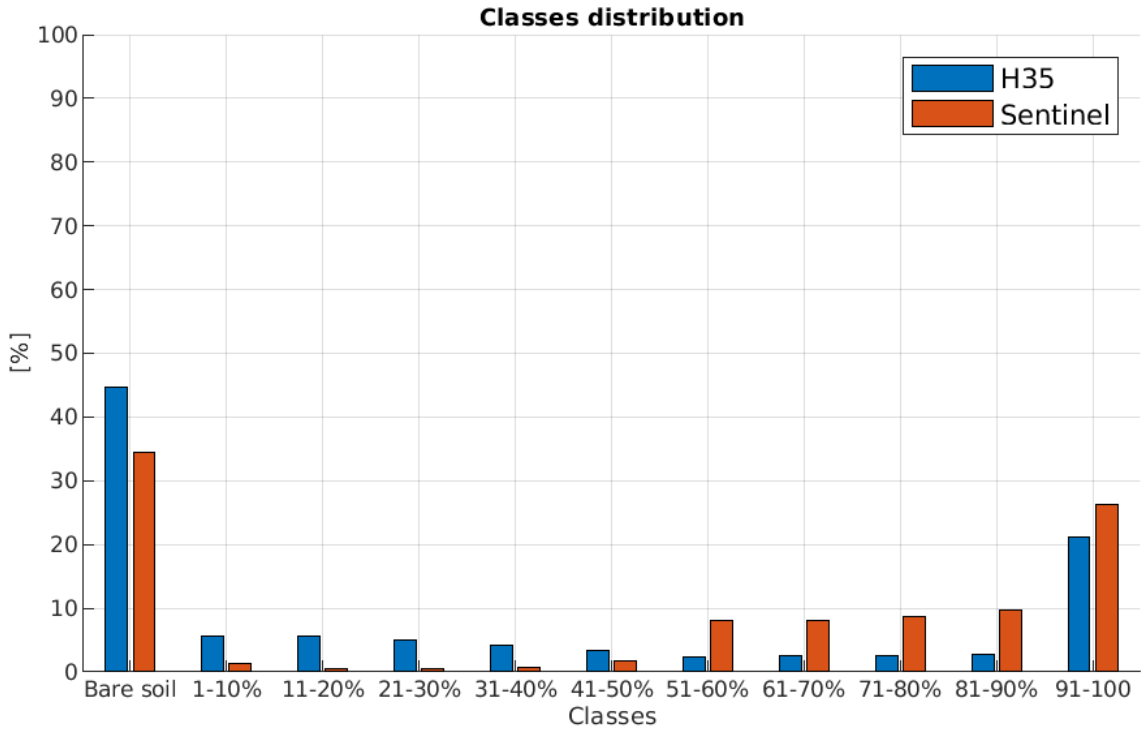
RMSE 17.5%, BETWEEN TARGET AND OPTIMAL

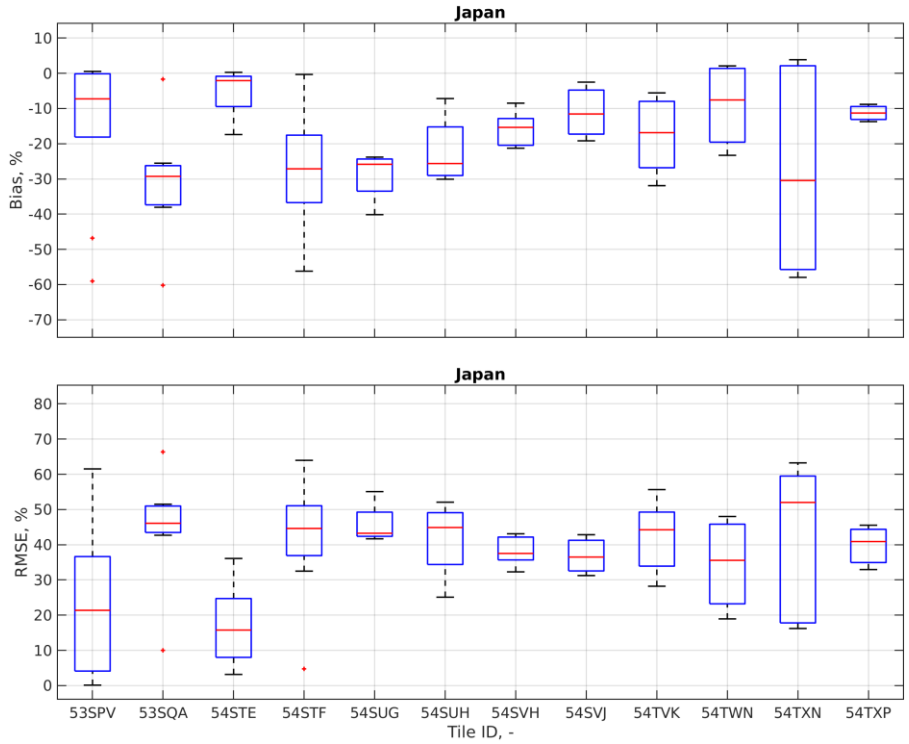




H35: Japan (mountain region)

RMSE 39%, BELOW THRESHOLD





Validation H12 and H35 discussion

- In all areas H12 product meets the RMSE-based accuracy requirements.
- CIMA study: threshold RMSE for mountainous areas not exceeded in any validation area, but values are just above threshold (very difficult mountainous terrain selected).
- Turkey study: values are much better and are between target and optimal. In areas where snow cover is more homogeneous in space and in time, H12 product has better performances, even in mountainous areas.

H 35: northern hemispheric extension of H12 (to superseed H12 in the next years)
Same validation strategy of H12 (CIMA)

Validation H13 Snow Water Equivalent

H13: operational

Data from Poland, Finland, Turkey, Germany. Thresholds are RMSE in mm of SWE.

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

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

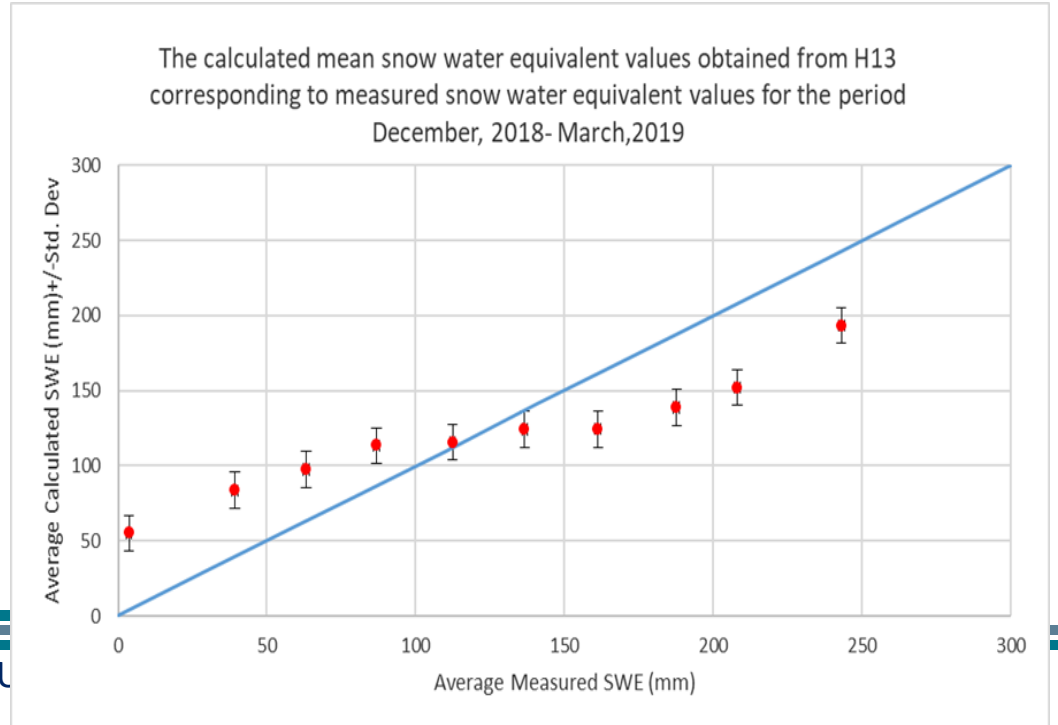
Validation in 2021 OR10

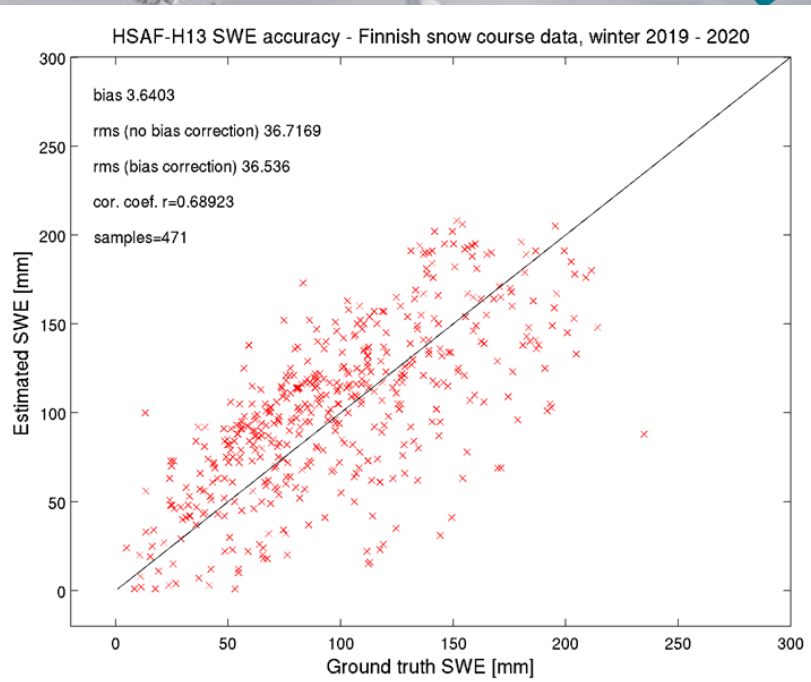
H-SAF Accuracy requirements for H13								
Product requirements				RMSE (mm)				
	threshold	target	optimal	AVERAGE	Poland	Finland	Turkey	Germany
N. samples					441	597	2848	1637
Mountainous	45 mm	25 mm	15 mm	39.2 mm			39.2 mm	
Flat Area	40 mm	20 mm	10 mm	23.5 mm	9.5 mm	36.7 mm		24.2 mm

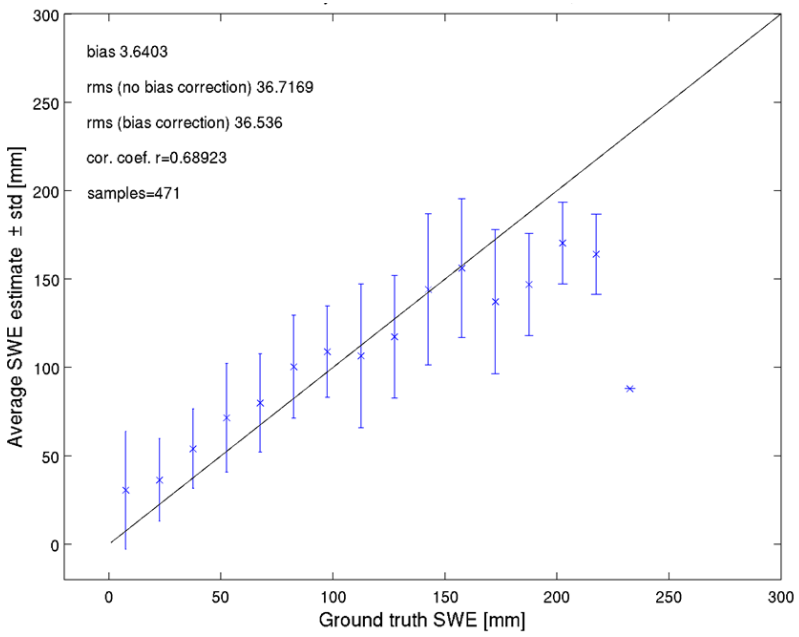
Validation H13 case study

Detail over Finland and Turkey

<u>General underestimation</u> of SWE when values are larger than 150 mm.







Validation H13 discussion

- H13 satisfies the Product Requirements, with RMSE between threshold and target values.
- Since the SWE product is developed for dry snow conditions, validation period is selected as December to March (or to April). In Finland, where snow cover is more stable, the whole period October-May is evaluated.
- Best performance are obtained in flat areas.
- Turkish and Finnish studies: general underestimation of SWE when values are larger than 150 mm, slight overestimate below.

RECAP

1. Snow Detection Products (Snow Cover) H10, H34, H32
   - Best performances in flat areas, were snow cover is more homogeneous
   - Problems arise in non homogeneous snow cover (space and time)
   - Validation with ground data very difficult (filtering needed). Better performances with high resolution satellite data (CIMA), especially for H32 (high resolution)

2. Snow Status (Dry/Wet) H11: Validation suggest to use the product only in Nordic areas (flat). Validation very difficult due to proxi data (temperature)

3. Fractional/Effective Snow Cover H12 and H35: Validation results good in flat areas, acceptable in mountainous areas, due to problems of resolution (complex terrain) and not homogeneous snow cover in complex orography.

4. SWE Products H13: Performances are better in flat areas (RMSE 10-20 mm), in mountainous areas RMSE around 30-40 mm. Underestimation if more than 100 cm snow.


EUMETSAT
H SAF
Thank You!
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