THE SATELLITE SNOW PRODUCTS INTERCOMPARISON AND EVALUATION EXERCISE

SNOWPEX CCN2

Evaluation of Snow Cover Extent products against in-situ snow depth measurements within ESA SnowPEx+

EARSeL 10th Workshop on Land ice and Snow, 2023, Bern

Sari Metsämäki, Sakari Väkevä (SYKE)

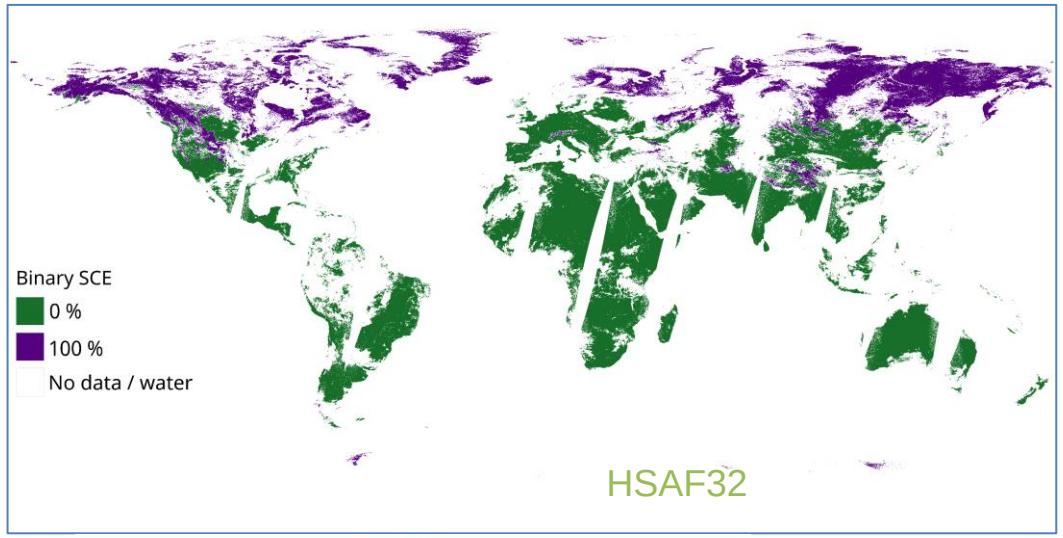
Thomas Nagler, Gabriele Schwaizer, Lars Keuris (ENVEO)

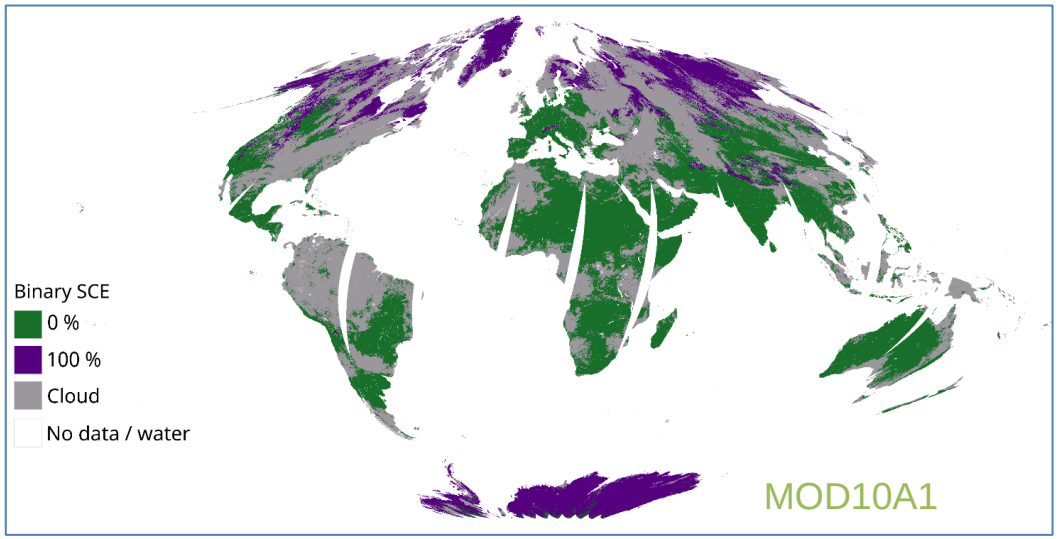
Kari Luojus, Mikko Moisander, Pinja Venäläinen (FMI)

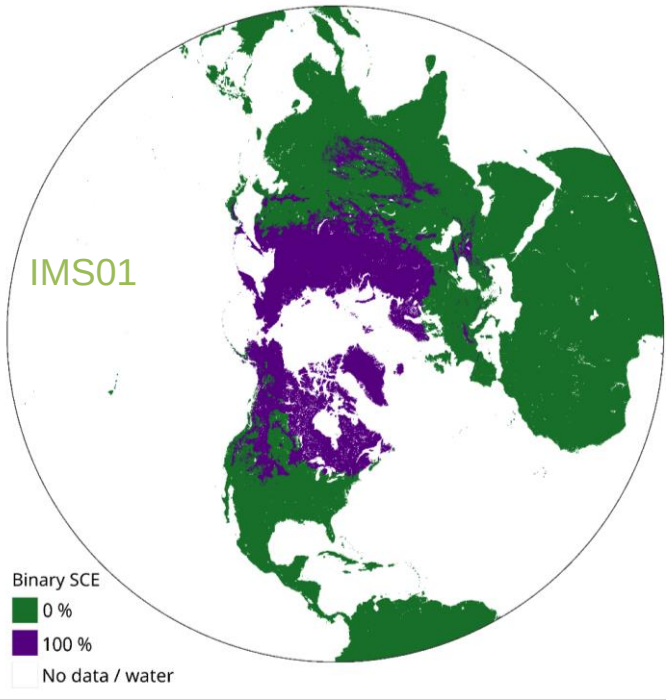
Colleen Mortimer (ECCC)

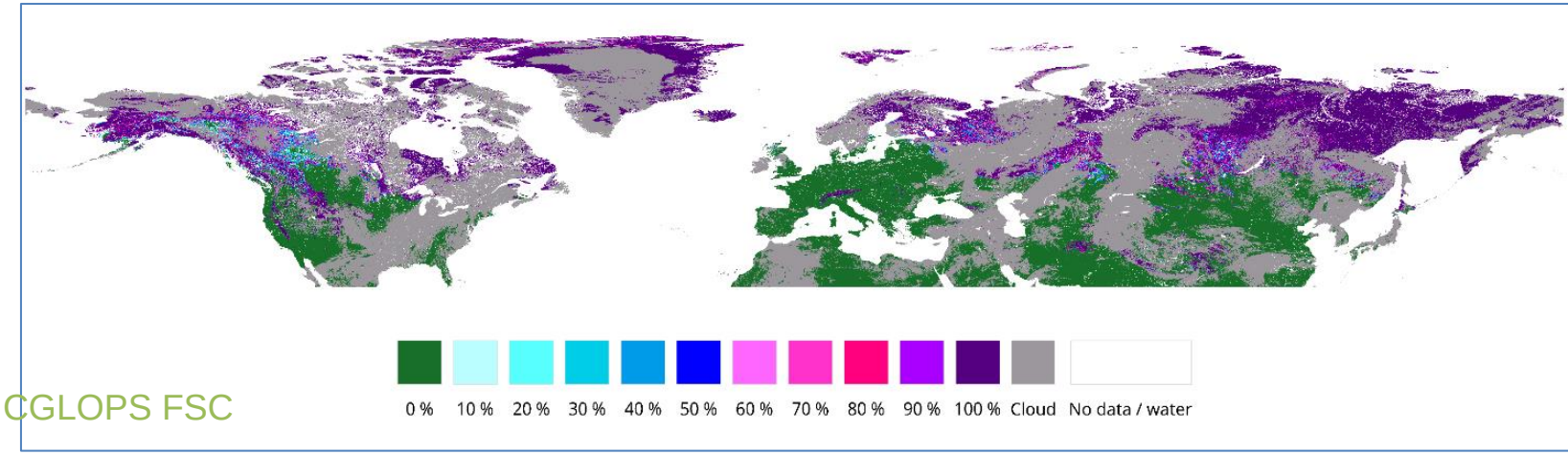
SnowPEx Consortium:

Validation of Snow Cover extent products against Snow Depth in situ-observations: examples of the products









SnowPEx Validation concept

- 11 Global/Hemispherical products for years 2015-2020 (some products do not cover all these years)
- The observability of the products varies, due to the different consideration of clouds and polar darkness
- Validation is based on the established SnowPEx-protocol: all products as well as Snow depth observations were converted to binary 'snow/on-snow' information → confusion matrices → binary metrics
  - **Most of the products provide binary observations initially**; only SNOWCCI and CGLOPS provide Fractional Snow Cover (FSC, %) → converted to binary applying FSC-threshold of 15%
  - Most of the products provide top-on-canopy snow (Viewable snow) while Snow Depth in-situ observations are made at ground level → **focus on non-forested or sparsely forested areas (NFSF)**
  - Spatially and temporally matching data were exctrated from the products in their **original projection**
  - **Homogeneity rule**: the product pixel at the weather station was extracted only if its neighbourhood is homogenous (either snow or non-snow)
  - Validation made for quarterly seasons

SnowPEx Validation concept

- 1 step: conversion to binary information (both in-situ snow depth and product data)
- 2 step: identification of matching in–situ / product pairs (for product pixels overlaying the weather stations, on the same day)
- 3 step: a contingency table for binary data are generated and several binary metrics are calculated.

Criteria for snow products
if SCF≥50% then ”snow” else ”no snow"
if SCF≥15% then "snow" else "no snow"

Criteria for in-situ
if SD>0cm then ”snow” else ”no snow"
if SD≥2cm then "snow" else "no snow"
if SD≥15cm then "snow" else "no snow"

in-situ	Product	
	snow	No-snow
snow	True Positive (TP)	False Negative (FN)
no-snow	False Positive (FP)	True Negative (TN)

Statistical metrics

Statistical metrics as output from validation

Measure	*Equation*	*Description*
Precision	TP / (TP+FP)	The ratio of correct snow identifications to all snow identifications. Describes the certainty of snow identifications.
Recall	TP / (TP+FN)	Product's ability to identify snow out of all true snow cases. Products ability to find snow.
F-score	2 * TP / (2 * TP + FP + FN)	A metric accounting for both the Recall and False Alarm rate.
Omission error	FN / (TP + FN)	Probability of falsely identified snow free cases.
False Alarm Rate, Comission error	FP / (FP+TN)	The ratio of cases falsely identified as snow to all true snow-free cases. Product's tendency to overestimate snow.

Cohen's Kappa: A metric that excludes the random accuracy part from total accuracy. Commonly considered as a most descriptive metric.

$$\kappa = \frac{2 \times (TP \times TN - FN \times FP)}{(TP + FP) \times (FP + TN) + (TP + FN) \times (FN + TN)}$$

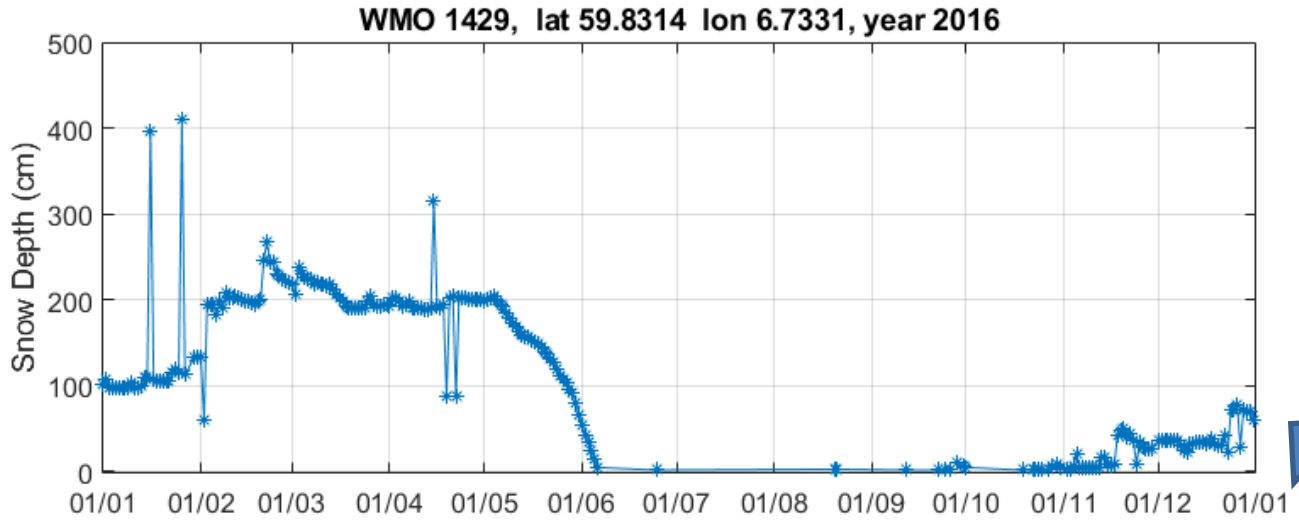
Validation of Snow Cover extent products against Snow Depth in situ-observations: in-situ data

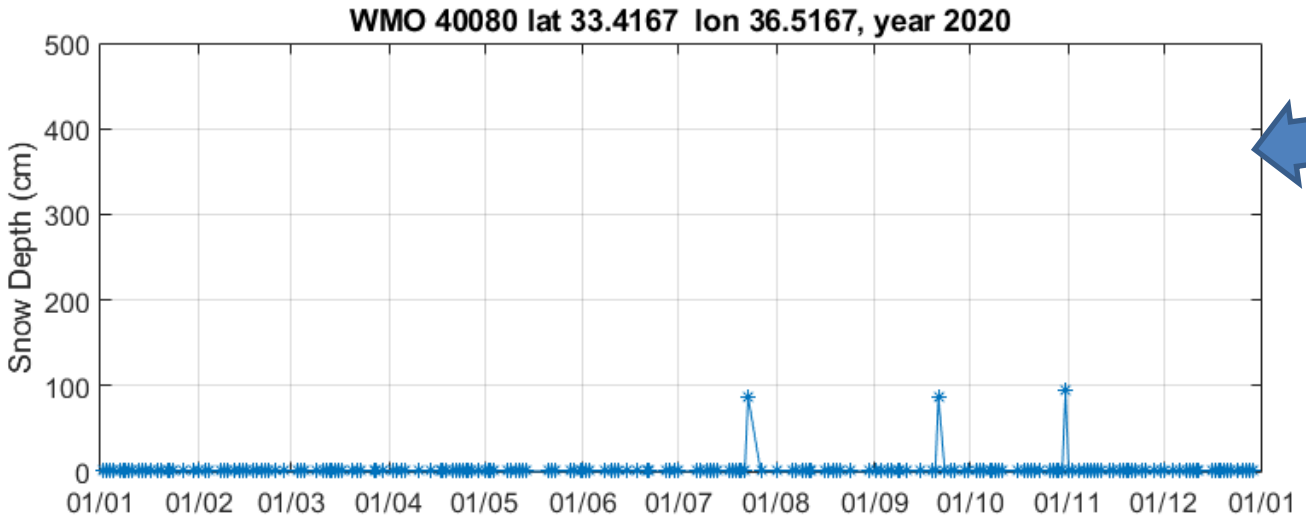
The point-wise snow depth datasets are collected from five separate sources:

- European Centre for Medium-Range Weather Forecasts (ECMWF),
- Russian Research Institute for Hydro-meteorological Information (RIHMI-WDC)
- NOAA Global Historical Climatology network (GHCN)
- Finnish Meteorological Institute (FMI)
- Chinese Academy of Science

Dataset	Spatial coverage	Temporal coverage
ECMWF weather stations	Eurasia	01/2014-12/2020
RIHMI weather stations	Eurasia	01/2014-05/2020
GHCN- daily	North America	01/2014-12/2020
FMI-obs	Northern hemisphere	01/2014-12/2020
Chinese Academy of Science	China	01/2017-06/2019

Validation of Snow Cover extent products against Snow Depth in-situ observations: in-situ data after quality check

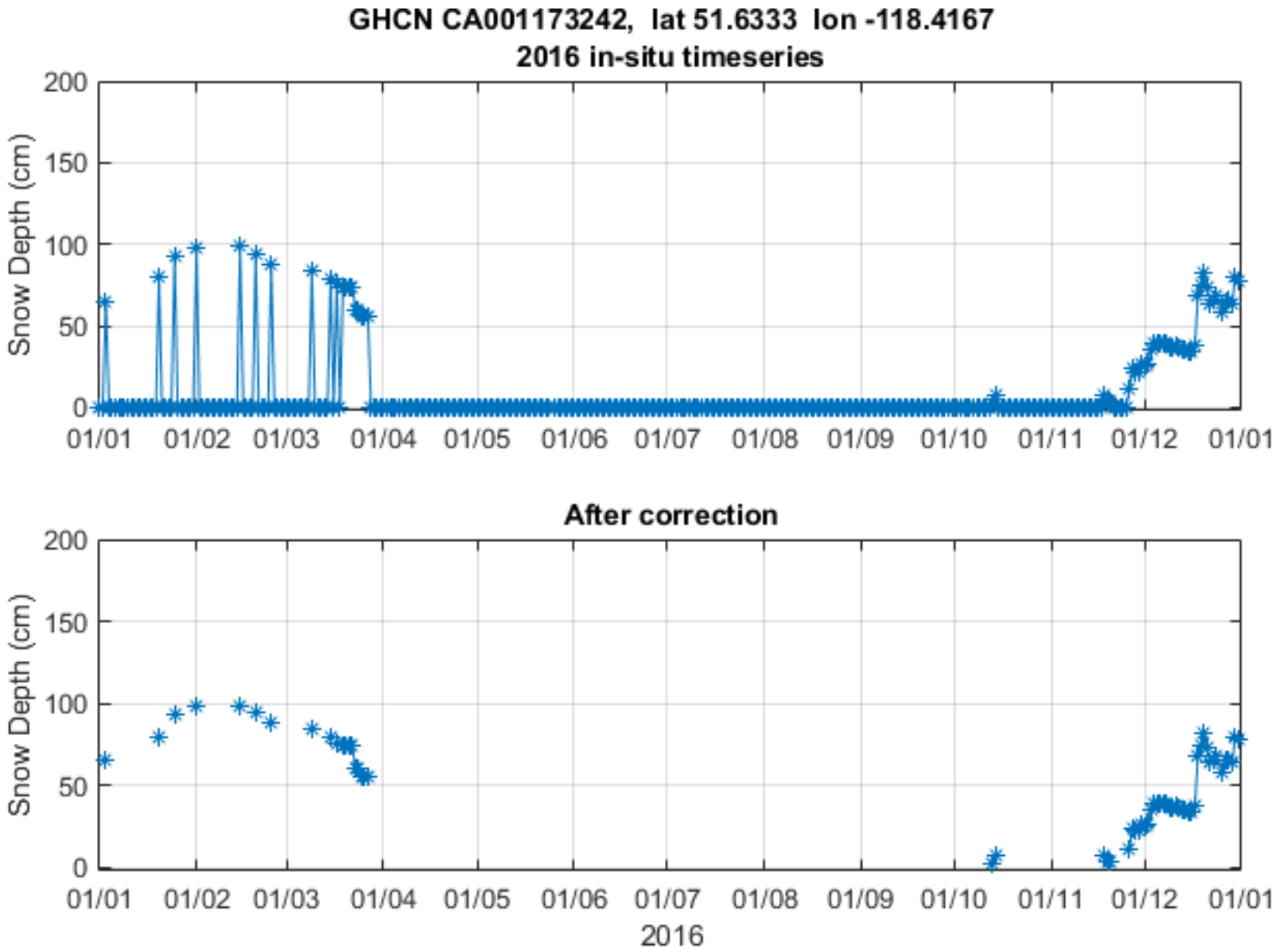




Severe problems with the Snow Depth time series:

- Different practises in data reporting even within the same datasource:
  - Often impossible to know whether 0 means a real observation or missing observation → a large number of stations reporting mainly 0cm snow were discarded (particularly when the station clearly represents an area with seasonal snow cover)
- Sudden strong peaks (up or down) were removed as unrealistic
- Station reporting mainly 0cm cannot be trusted even when there are observations > 0cm
- Duplicate observations in different sources, must be tracked

Validation of Snow Cover extent products against Snow Depth in-situ observations: in-situ data after quality check



Tracking of false zeros and correcting the time series:

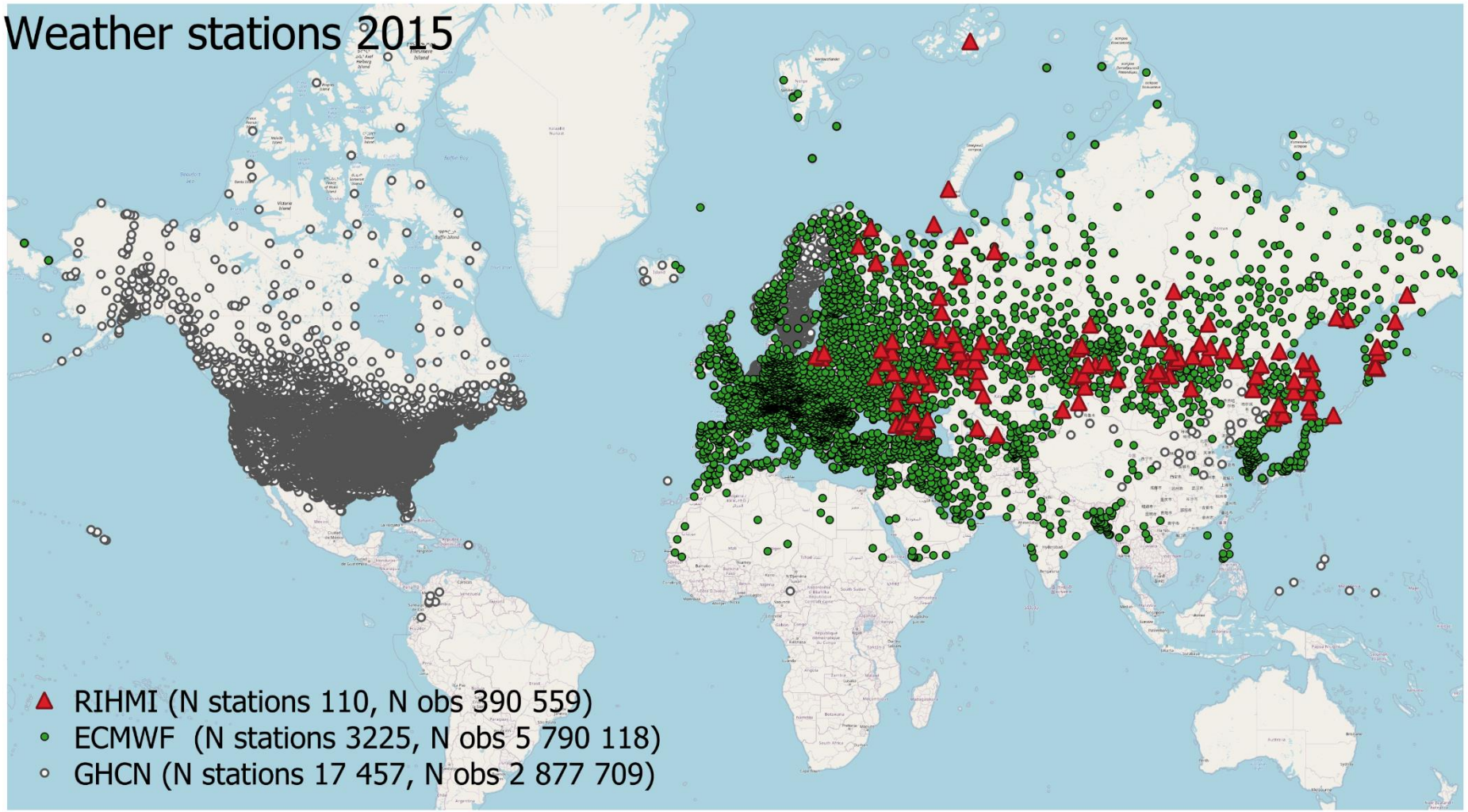
- Which ones are not true observations?

- Sudden decrease from higher SD indicates 'no-data'

→ How to discriminate these from real 0cm observations? You cannot not → remove all zeros

Sometimes we cannot know if this is a correct thing to do (should we remove the peaks instead?) Depends on a case…

Example: Weather stations 2015



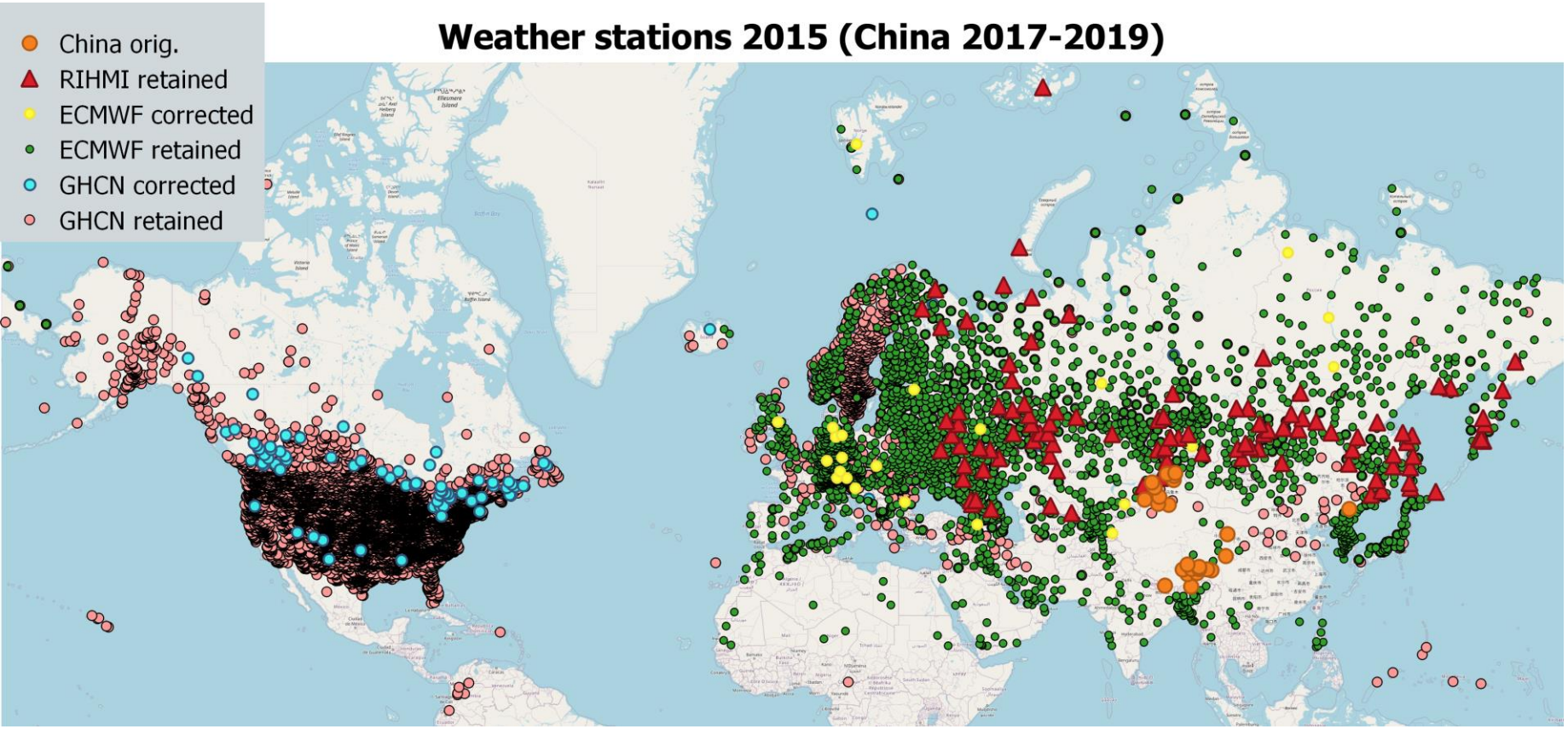
Slight variation between different years: some sites are non-active, new sites may be established etc)

USA is dominating, but many of the stations do not cover whole year or introdude obviously erroneous observations

Seemingly, SnowDepth of 0 cm is often reported although the mesurement is not done.

Identification and removal of these is essential as they have a strong effect on the validation results

Validation of Snow Cover extent products against Snow Depth in-situ observations: in-situ data after quality check



Large part of the stations in Canada removed according to information from ECCC

Stations (Latitude >37° N) regularly reporting >80% of zero snow depth throughout the year are removed.

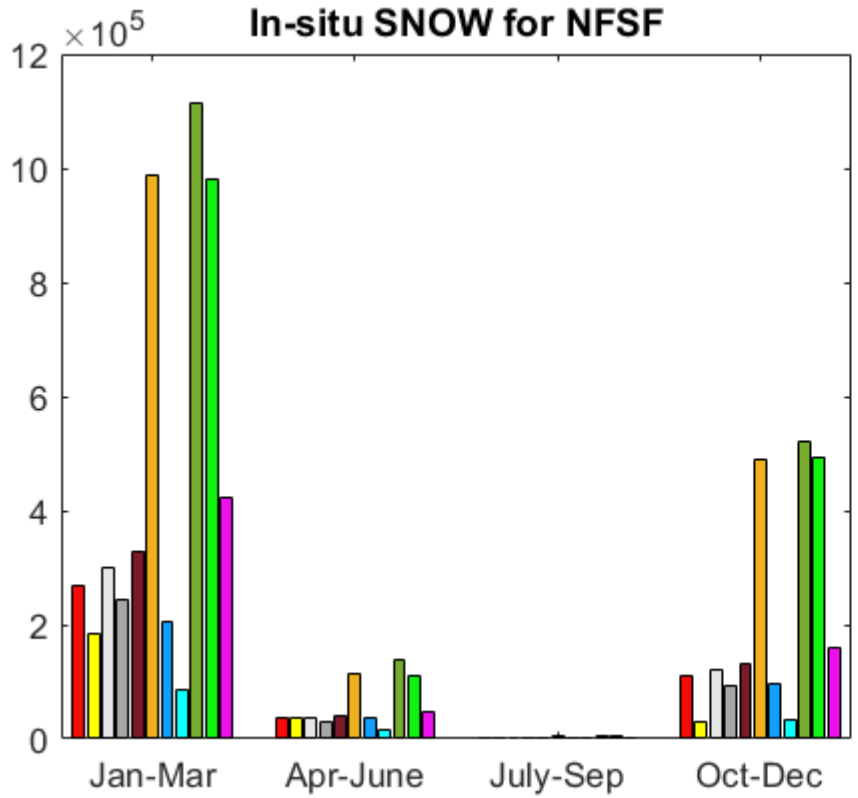
For the other stations, check for erroneous observations (peaks, sudden large drops) is made. When identified, these single observations (not the total station) are discarded

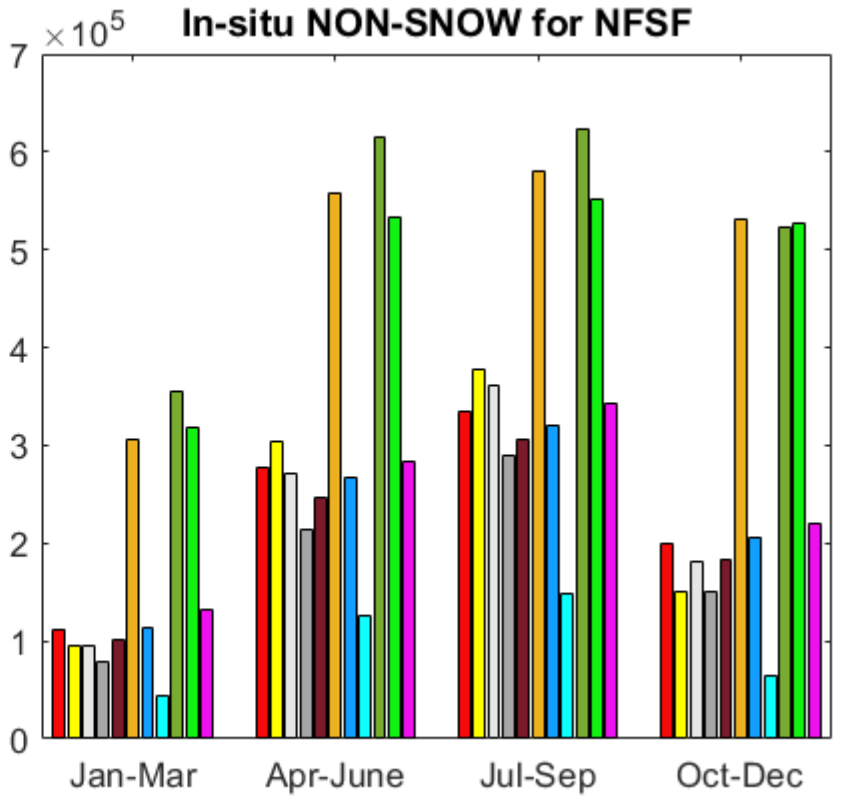
Effect of Quality check on the number of cases

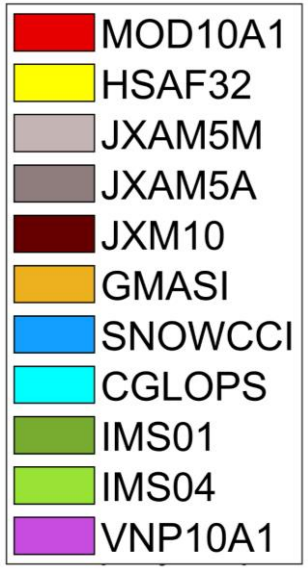
Database	Before quality check		After quality check		
	Number of total observations	Number of 0cm snow depth observations	Number of total observations	Number of 0cm snow depth observations	Reduction of the number of stations (in 2015)
ECMWF	3 946 318	2 446 001	1 659 382	278 748	4216 → 1654
GHCN	21 121 630	16 375 458	8 124 581	4 467 526	29252 → 6608
RIHMI	260 131	155 688	224 624	123 234	129 → 95

Number of in-situ/product cases for years 2015-2020

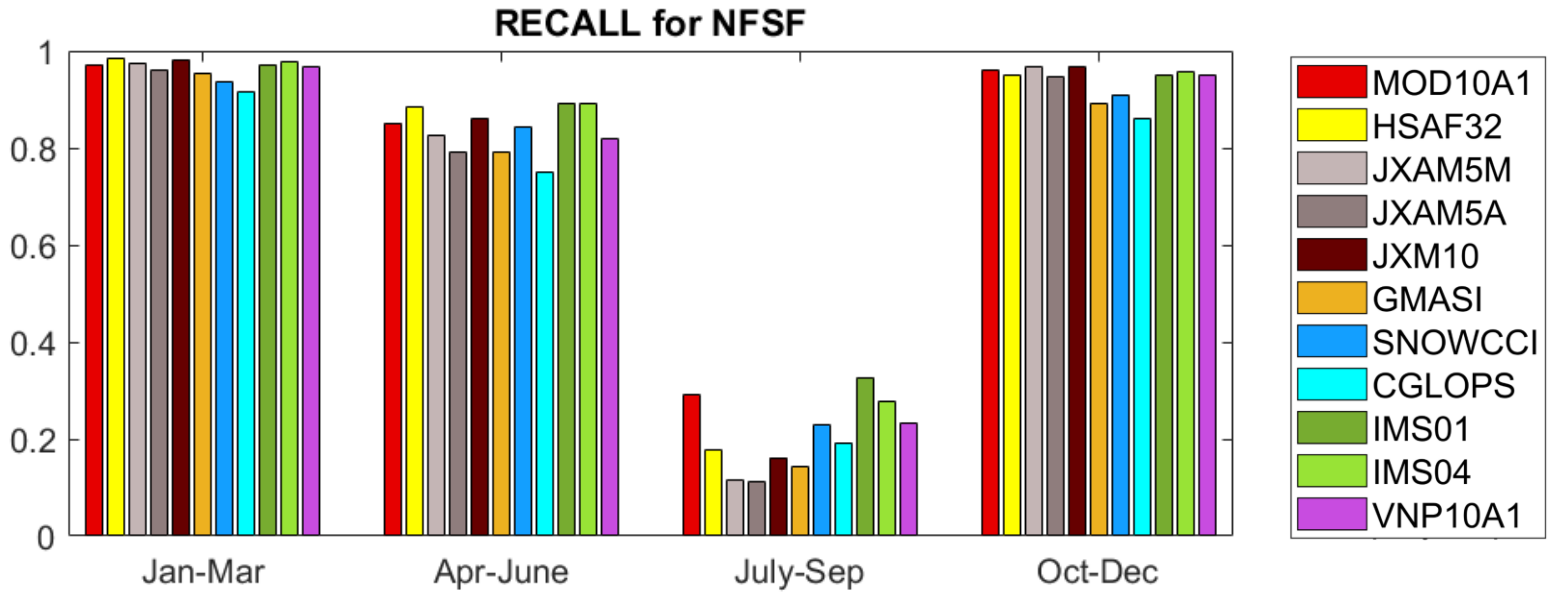
- Obviously, products without cloud cover introduce more data pairs (IMS01, IMS04 and GMASI)
- CGLOPS started only in 2017 → fewer cases

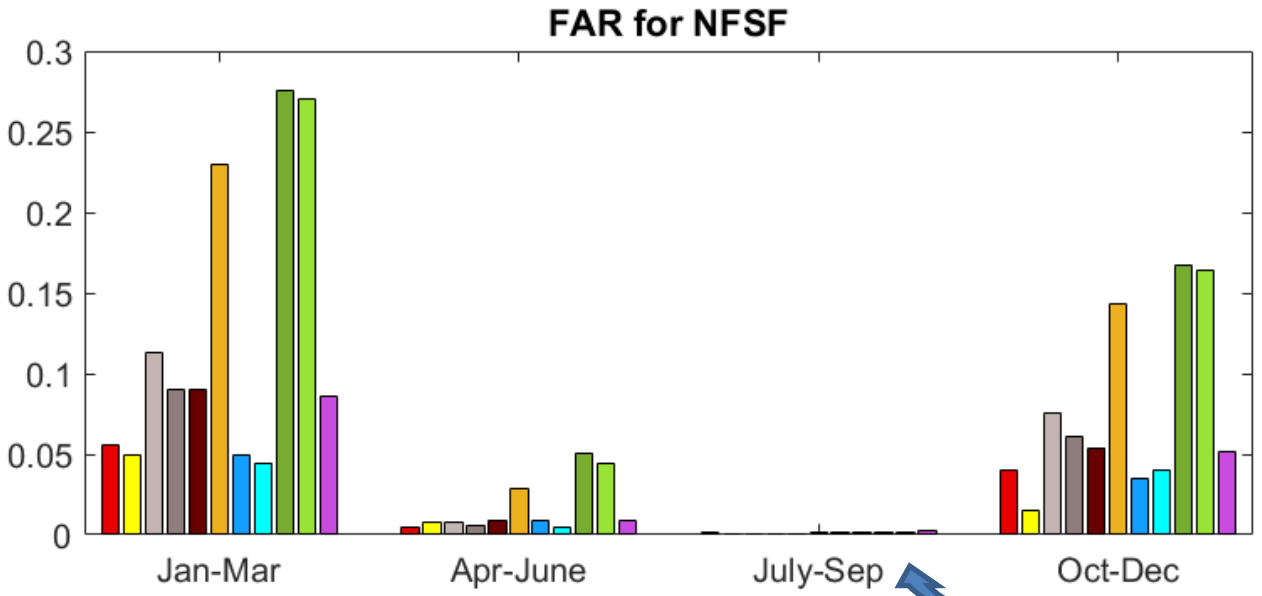


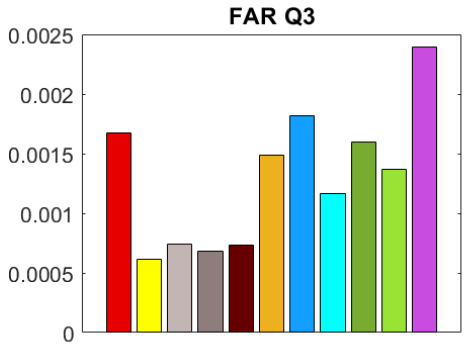




Results for nonforested/sparsely forested areas (viewable snow)

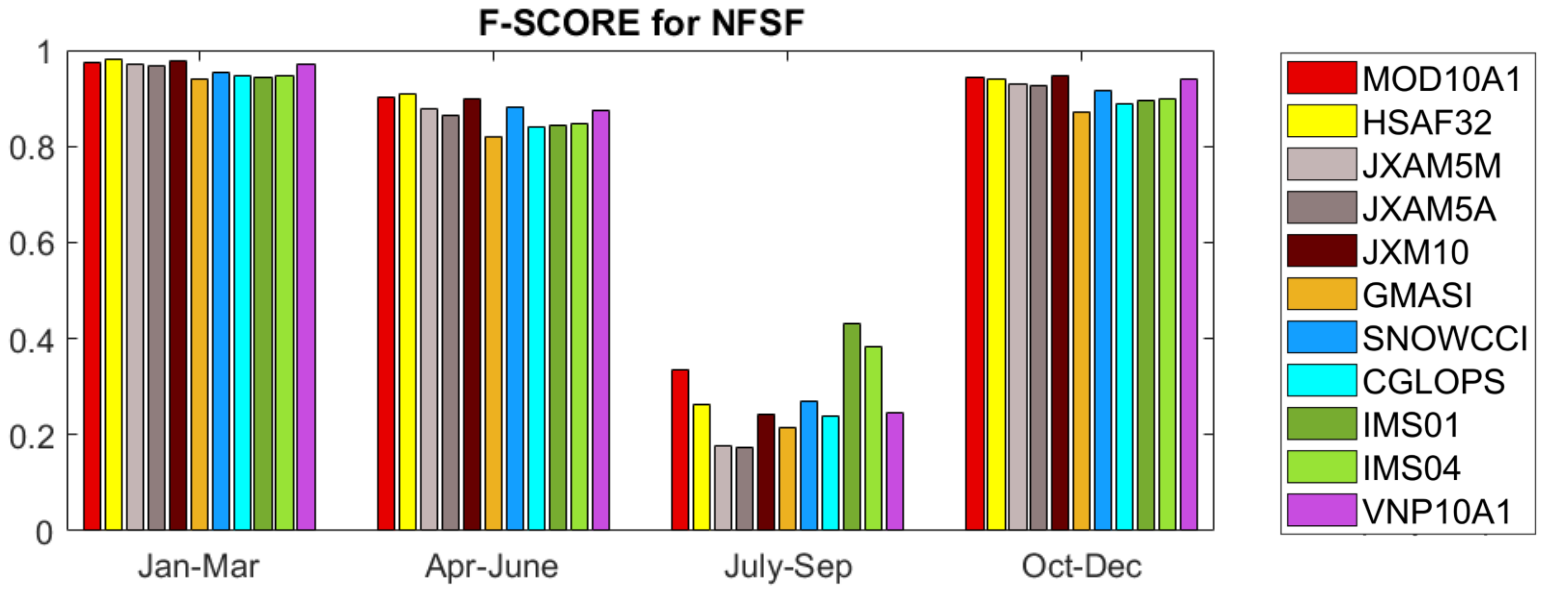


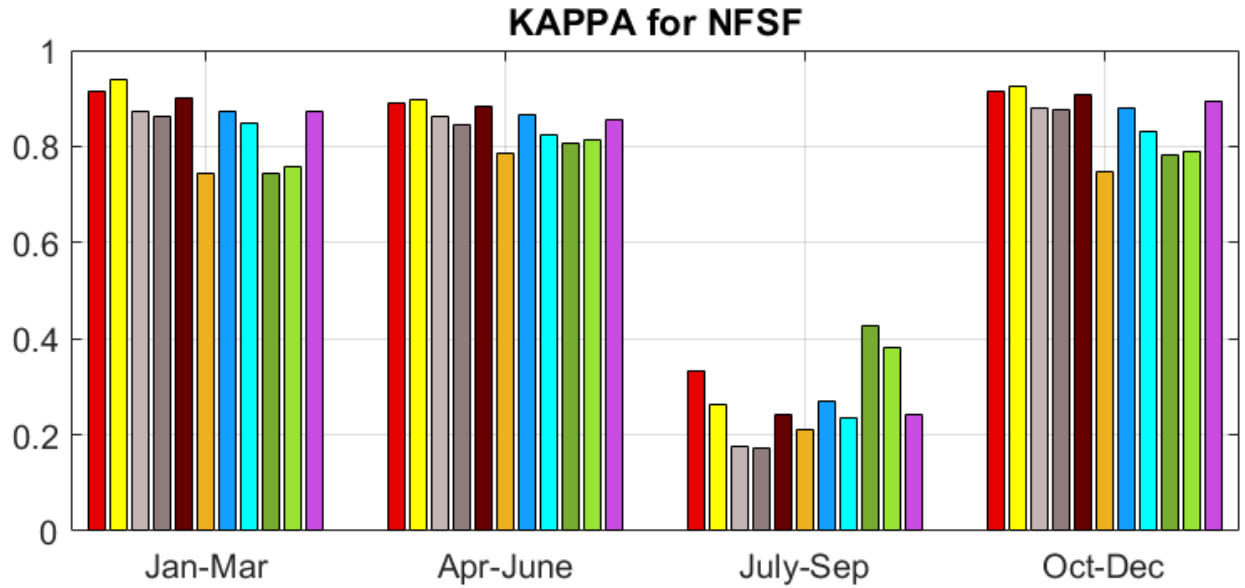




- **IMS-products detect most of the snow (high RECALL) but at the expense of false snow alarms (high FAR)**
- **Other products show generally rather similar performance:**
  - Deep winter seems to be ideal for all the products
  - Melting period and summer increase variation
  - FAR is extremely low in summer for all products

Results for nonforested/sparsely forested areas (viewable snow)





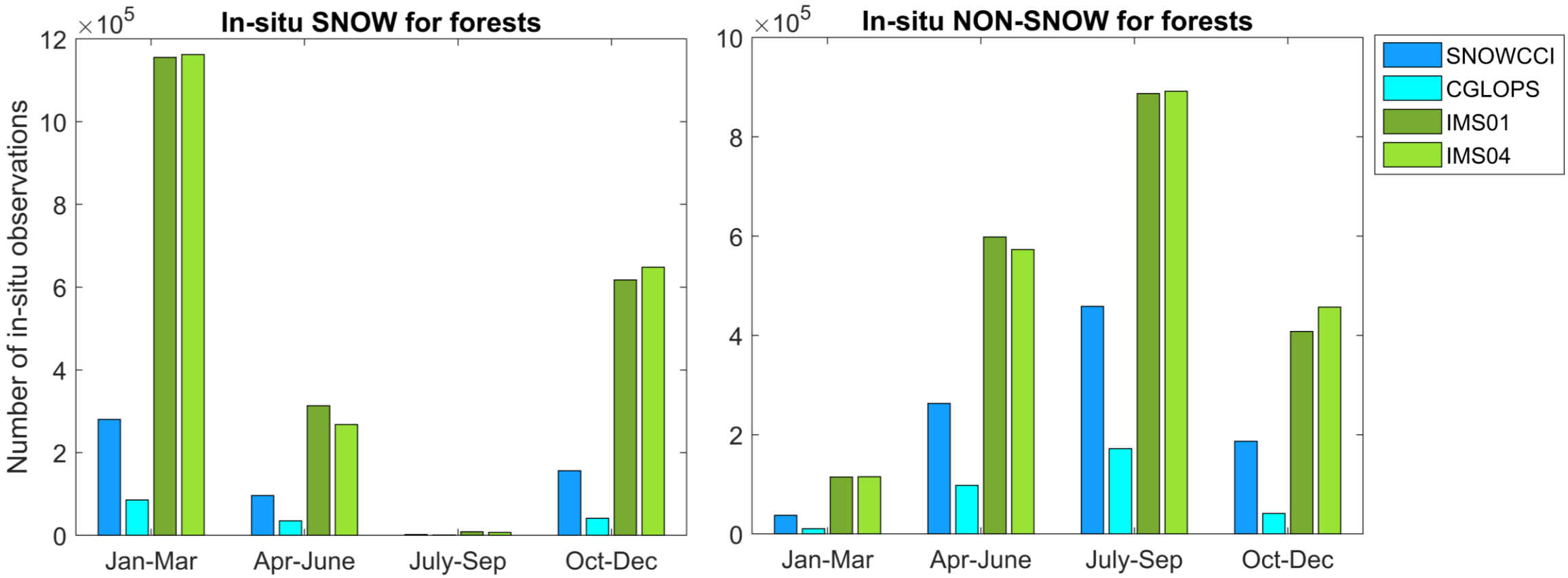
F-score and **Kappa-coefficient** describe the results with consideration of unbalanced number of 'snow'/non-snow in-situ data and accounts for Precision and Accuracy at the same time.

Kappa indications:

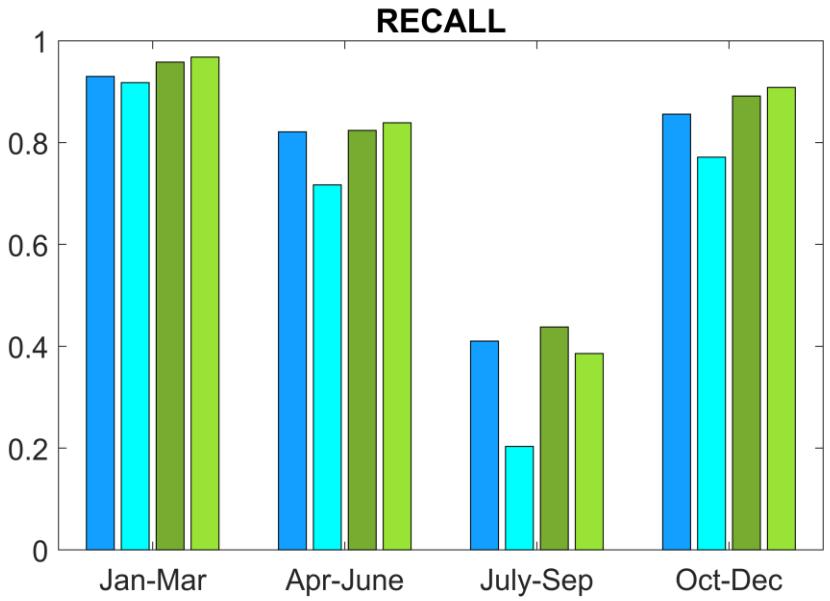
- HSAF shows the best performance outside summer
- MOD10A1, JXM10, SNOWCCI and VNP10A1 are in the top five (outside summer)
- IMS products do a good job in summer
- GMASI has problems in all seasons
- All in all, there are not very big differences in the metrics between different products

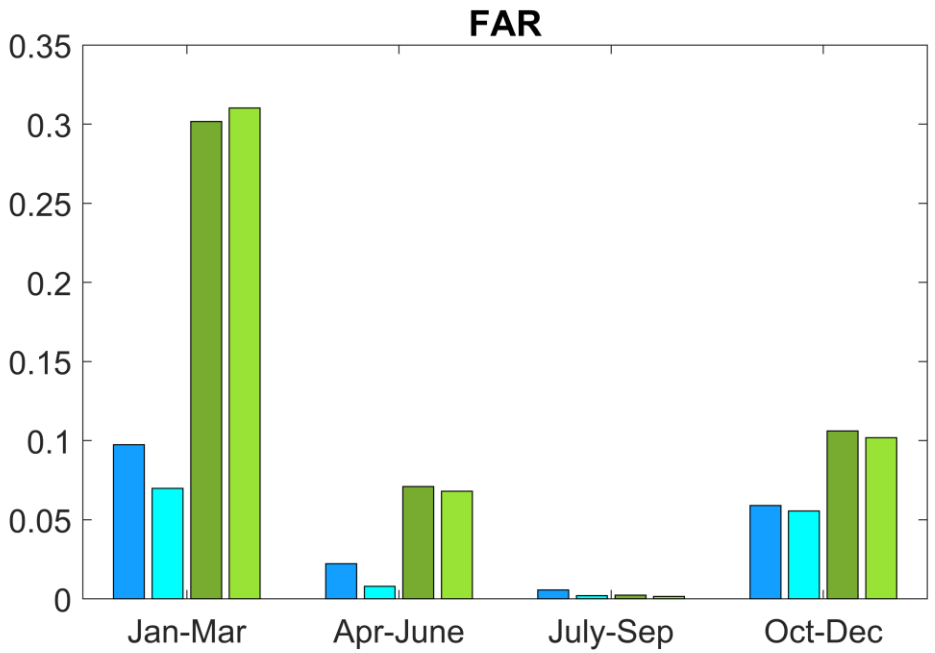
Results for forested areas (snow-on-ground, SCEG): number of datapairs

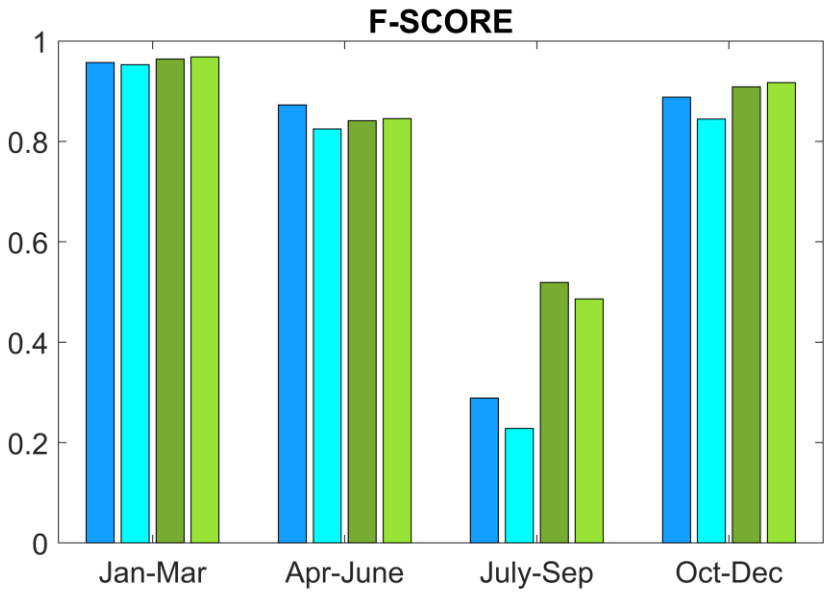
- Again, IMS products without cloud cover introduce more data pairs
- Also, CGLOPS started only in 2017 → fewer cases



Results for forested areas (snow-on-ground, SCEG)

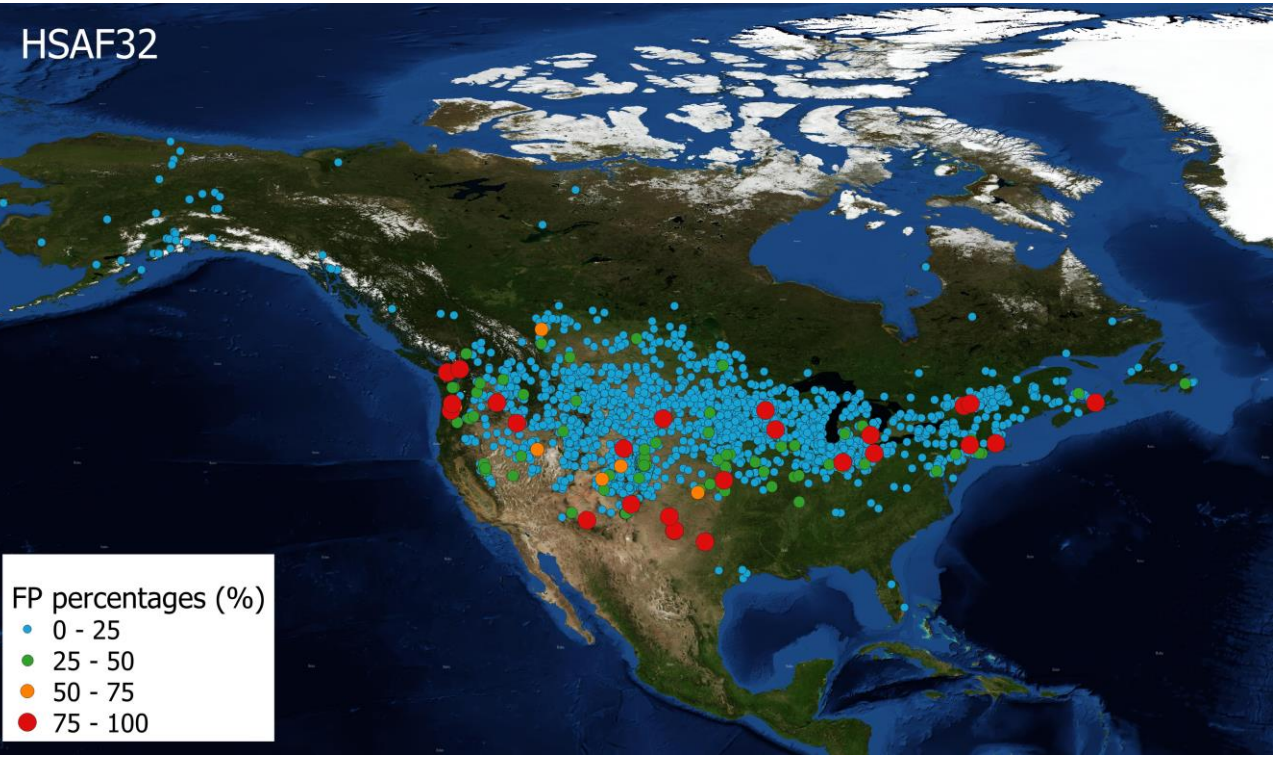


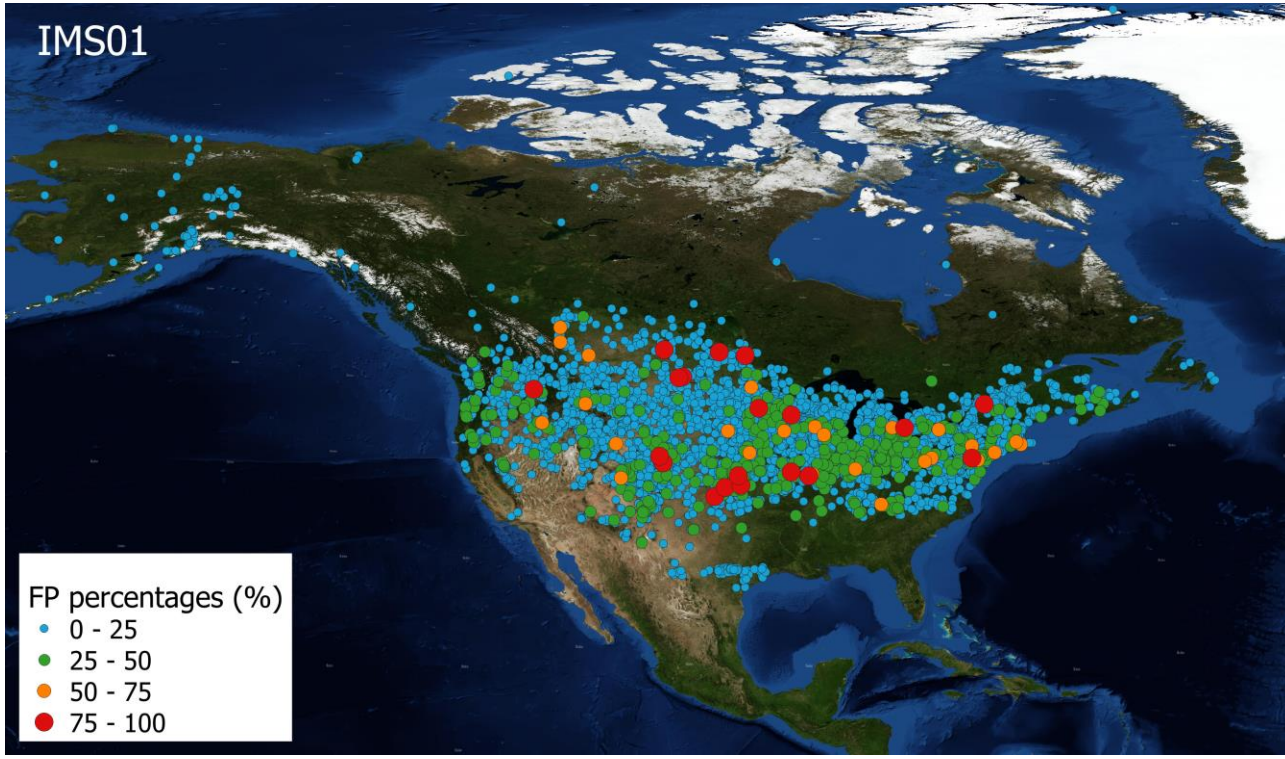




- Like for NFSF, in forested areas IMS overestimates the snow (high RECALL, high FAR) except for summer season.
- F-score indicates the highest perfomance for SNOWCCI in melting period
- In general, these products behave rather similarly in forests and over non-forested areas

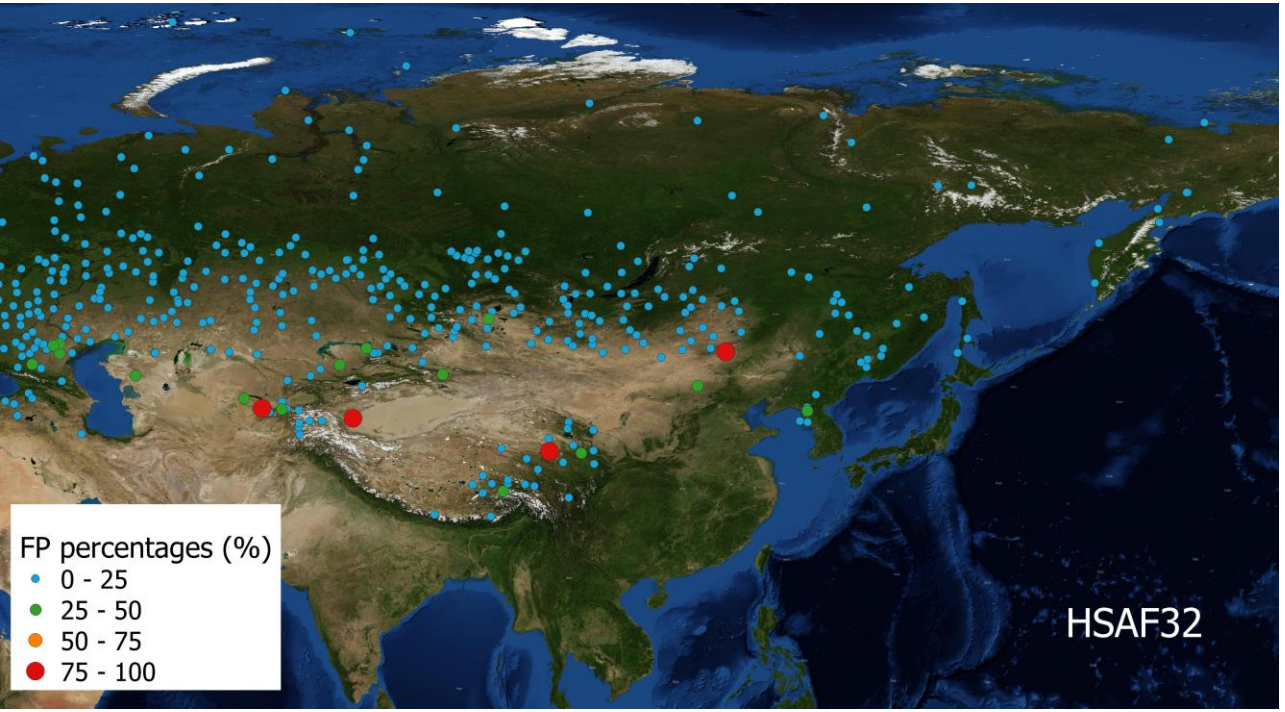
Locations and frequency of False snow commissions (FP) for HSAF32 and IMS01

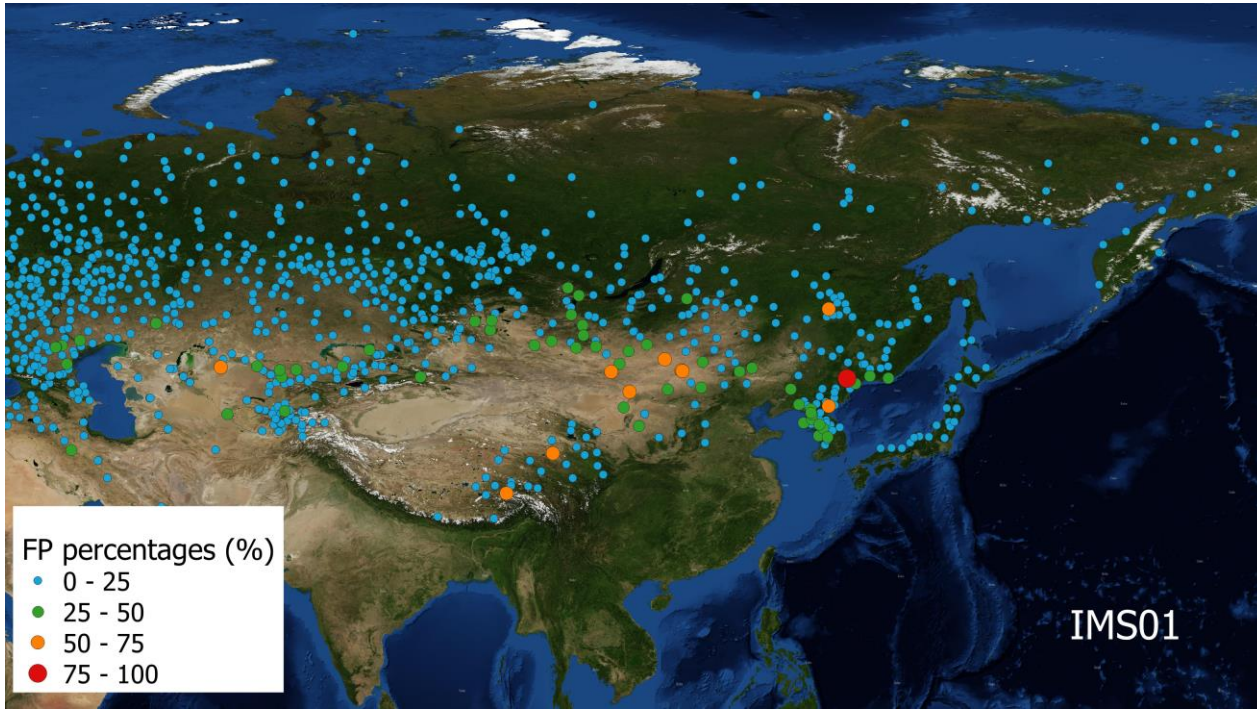




- **Maps show the locations of the False snow commissions (FAR) for North America for HSAF32 and IMS01**
  - percentage of all data pairs is illustrated
- **Demonstrates the higher FAR of IMS01**
  - may be partly due to bad-quality data which remained in the in-situ dataset despite the quality check

Locations and frequency of False snow commissions (FP) for HSAF32 and IMS01





- **Maps show the locations of the False snow commissions (FAR) for Asia for HSAF32 and IMS01**
  - percentage of all data pairs is illustrated
- **Demonstrates the higher FAR of IMS01**
  - may be partly due to bad-quality data which remained in the in-situ dataset despite the quality check

Please visit also Nagler et al.:

” SnowPEx+: Results of the Intercomparison and Validation of Northern Hemispheric Snow Extent Products 2015-2020) “ at the poster session

Thanks for your attention !