# Recent Developments Towards the Upcoming Snow Cover Fraction Climate Research Data Package V3.0 from Terra MODIS And Sentinel-3 SLSTR data within ESA CCI+ Snow



snow cci

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5 esa

*EARSeL LISSIG Workshop,*
*06-08 February 2023,*
*Berne, CH*

| snow cci | User requirements | Product specifications |
|---|---|---|
| **Parameter** | Fractional snow extent [%] | Fractional snow extent [%] |
| **Description** | Viewable Snow + Snow on Ground and attached Uncertainty Maps | Viewable Snow + Snow on Ground and attached Uncertainty Maps |
| **Spatial Coverage** | Global land areas without ice sheets (Antarctica / Greenland) | Global (without Antarctica, Greenland icesheet, land ice, open water) |
| **EO Data** | Medium Resolution Optical satellite data | Medium Resolution Optical satellite data |
| **Spatial Resolution** | 0.01 deg to 0.05 deg meets the majority of needs | Ca. 5 km (0.05 deg)<br>Ca. 1 km (0.01 deg) |
| **Period** | User requirement for multi-sensor homogenized dataset | 1982 – onwards (5 km) / AVHRR<br>2000 – onwards (1 km) / MODIS + SLSTR |
| **Frequency** | Daily | Daily |
| **Map Projection** | Geographic Grid (Lat/Lon) | Geographic Grid (Lat/Lon) |
| **Format** | netCDF | netCDF |
| **Uncertainty Metric** | Unbiased RMSE | Unbiased RMSE |

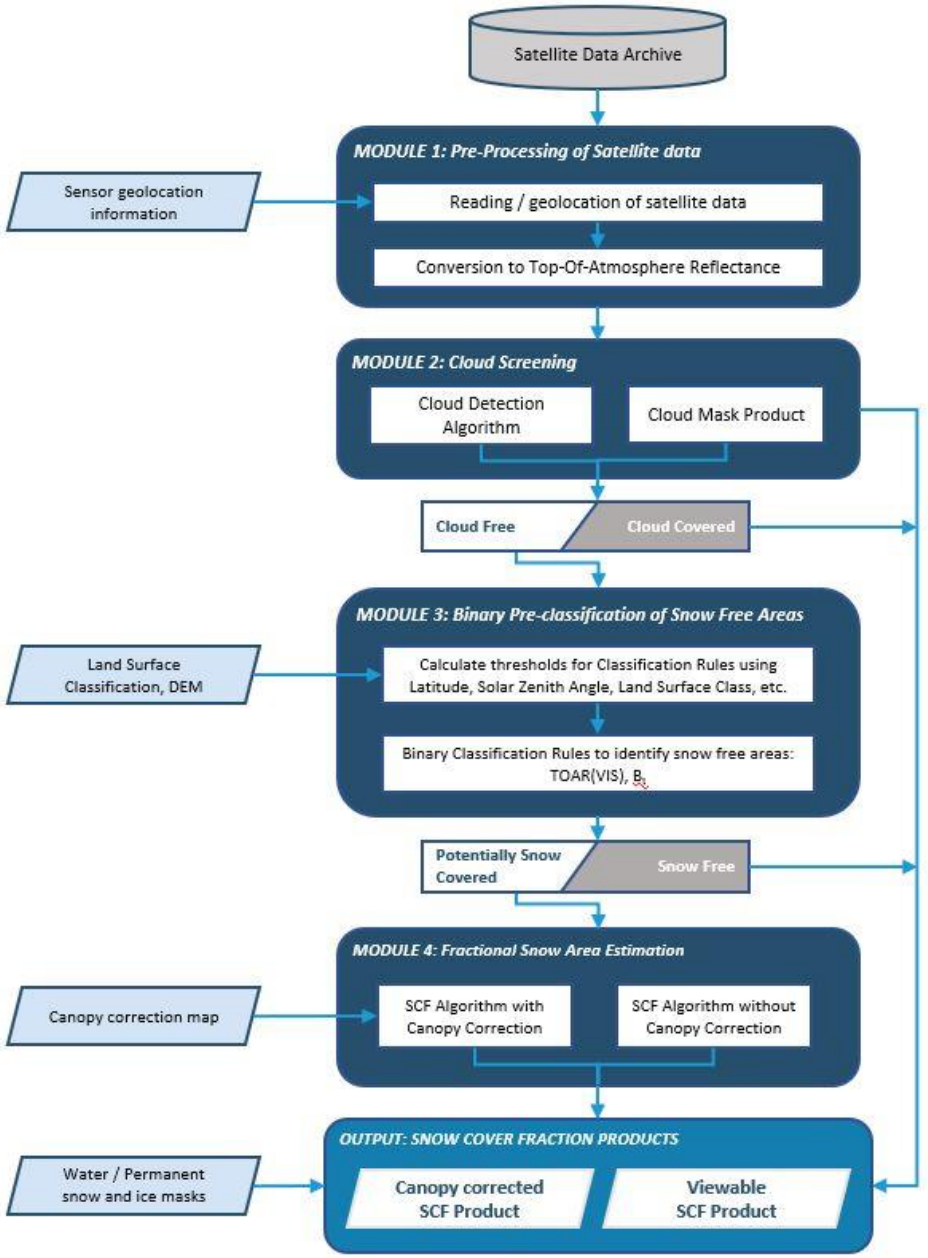
# Processing chain for Snow Extent Product

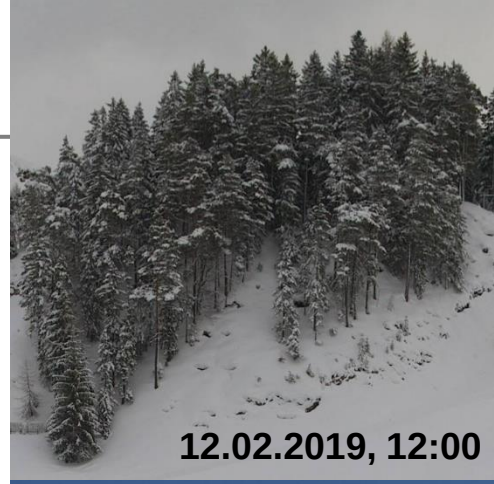
The procedure provides the generation of homogenized products for

- viewable snow
- snow on ground (canopy corrected)
- associated uncertainty maps

## Canopy Correction:

Forest Transmissivity derived from Land Cover CCI products and Tree Cover Density (Hansen et al., 2013)





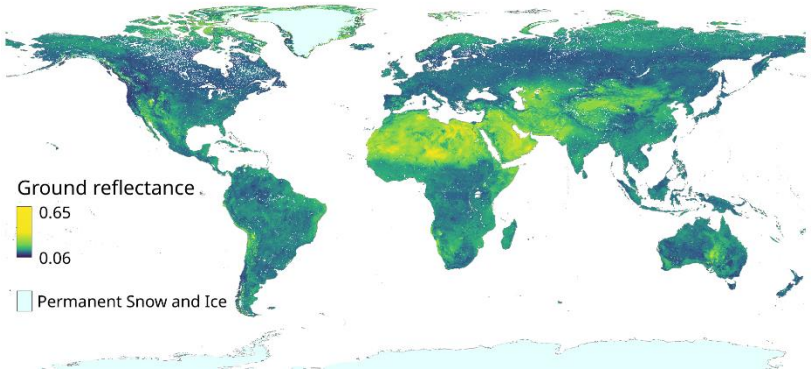




# SCF algorithms for MODIS & SLSTR

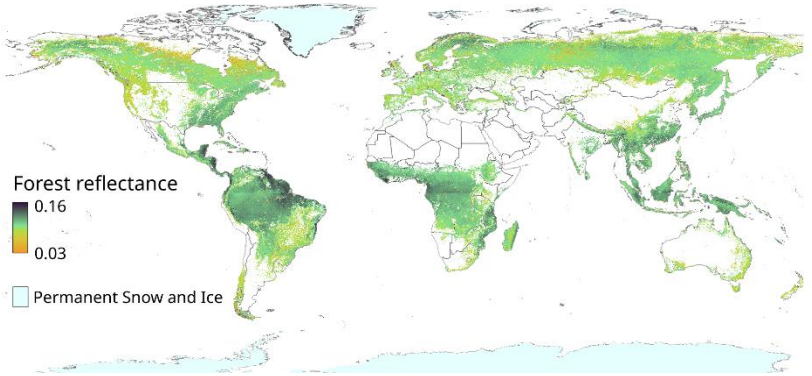
## SCFG retrieval (adapted from SCAmod):

$$SCFG = \frac{\frac{1}{t^2} * \rho_{\lambda,obs} + (1 - \frac{1}{t^2}) * \rho_{\lambda,forest} - \rho_{\lambda,ground}}{\rho_{\lambda,snow} - \rho_{\lambda,ground}}$$



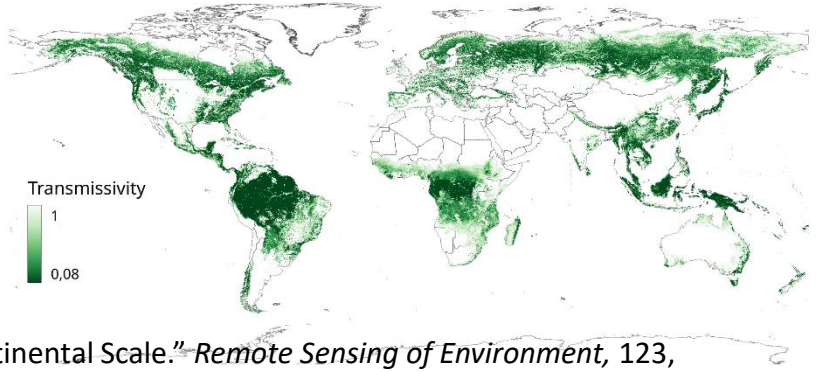

## SCFV retrieval (adapted from SCAmod):

$$SCFV = \frac{\rho_{\lambda,obs} - \rho_{\lambda,snowfree_background}}{\rho_{\lambda,snow} - \rho_{\lambda,snowfree_background}}$$




Based on first 10 days with snow free conditions per year 2000 - 2015:

- $\rho_{\lambda,forest}$ map of MODIS band 4 (555 nm) for forested area
- $\rho_{\lambda,ground}$ map of MODIS band 4 (555 nm) for open land
- $\rho_{\lambda,snowfree_background} = (1 - t^2) * \rho_{\lambda,forest} + t^2 * \rho_{\lambda,ground}$
- $\rho_{\lambda,\mathrm{snow}}$ based on reflectance analysis of selected test sites




Metsämäki, S., et al. 2012. "An Optical Reflectance Model-Based Method for Fractional Snow Cover Mapping Applicable to Continental Scale." *Remote Sensing of Environment,* 123, doi:10.1016/j.rse.2012.04.010.

# SCF uncertainty estimation

Variance of SCF estimate based on error propagation approach:

$$S^2_{FSC} = E^2_{forest} + E^2_{ground} + E^2_{snow} + E^2_{t^2}$$

With the variance contributions:

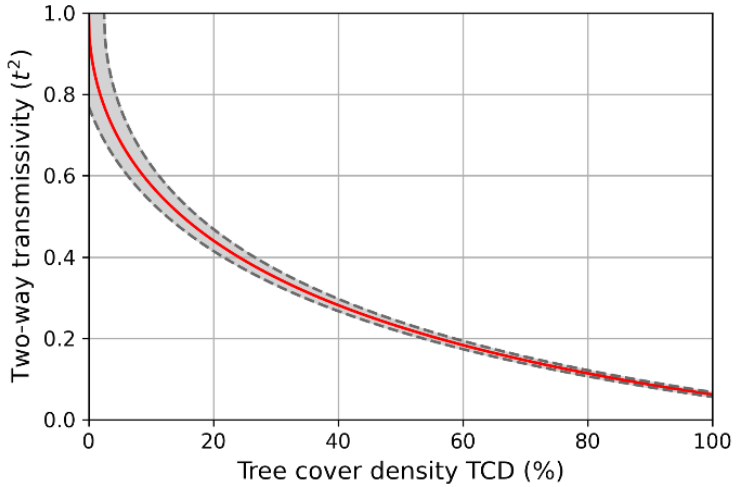
$$E^2_{forest} = \left(\frac{1 - \frac{1}{t^2}}{\rho_{snow} - \rho_{ground}}\right)^2 S^2_{forest} \quad \text{with } S^2_{forest} = (0.014)^2$$

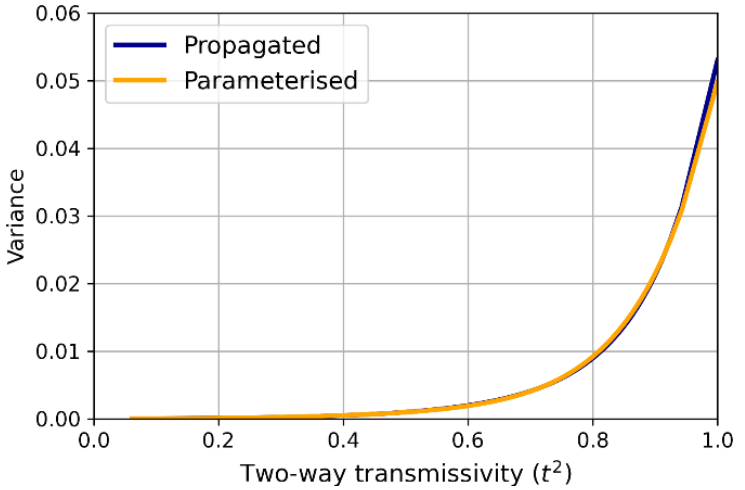
$$E^2_{ground} = \left(\frac{FSC - 1}{\rho_{snow} - \rho_{ground}}\right)^2 S^2_{ground} \quad \text{with } S^2_{ground} = (0.042)^2$$

$$E^2_{snow} = \left(\frac{FSC}{\rho_{snow} - \rho_{ground}}\right)^2 S^2_{snow} \quad \text{with } S^2_{snow} = (0.040)^2$$

$$E^2_{t^2} = \left(\frac{1}{t^2}\frac{\left(\rho_{forest} - \rho_{ground}\right) + FSC\left(\rho_{ground} - \rho_{snow}\right)}{\rho_{snow} - \rho_{ground}}\right)^2 S^2_{t^2}$$

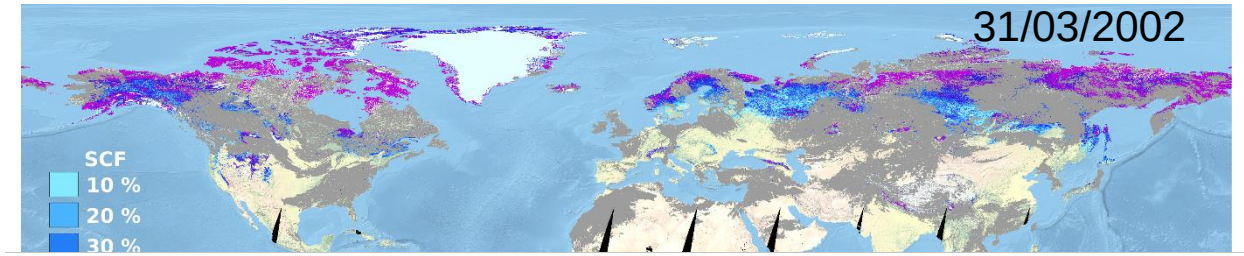
with $S^2_{t^2} = \left(0.006892 - (0.029547 * t^2) + (0.345379 * (t^2)^2) - (0.655364 * (t^2)^3) + (0.554611 * (t^2)^4)\right)^2$

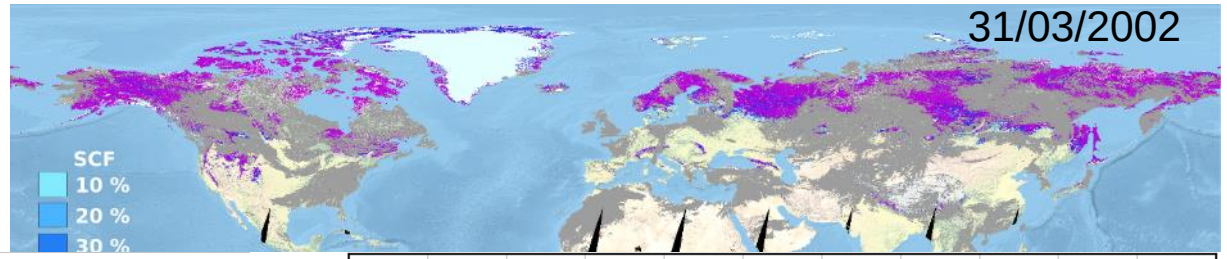


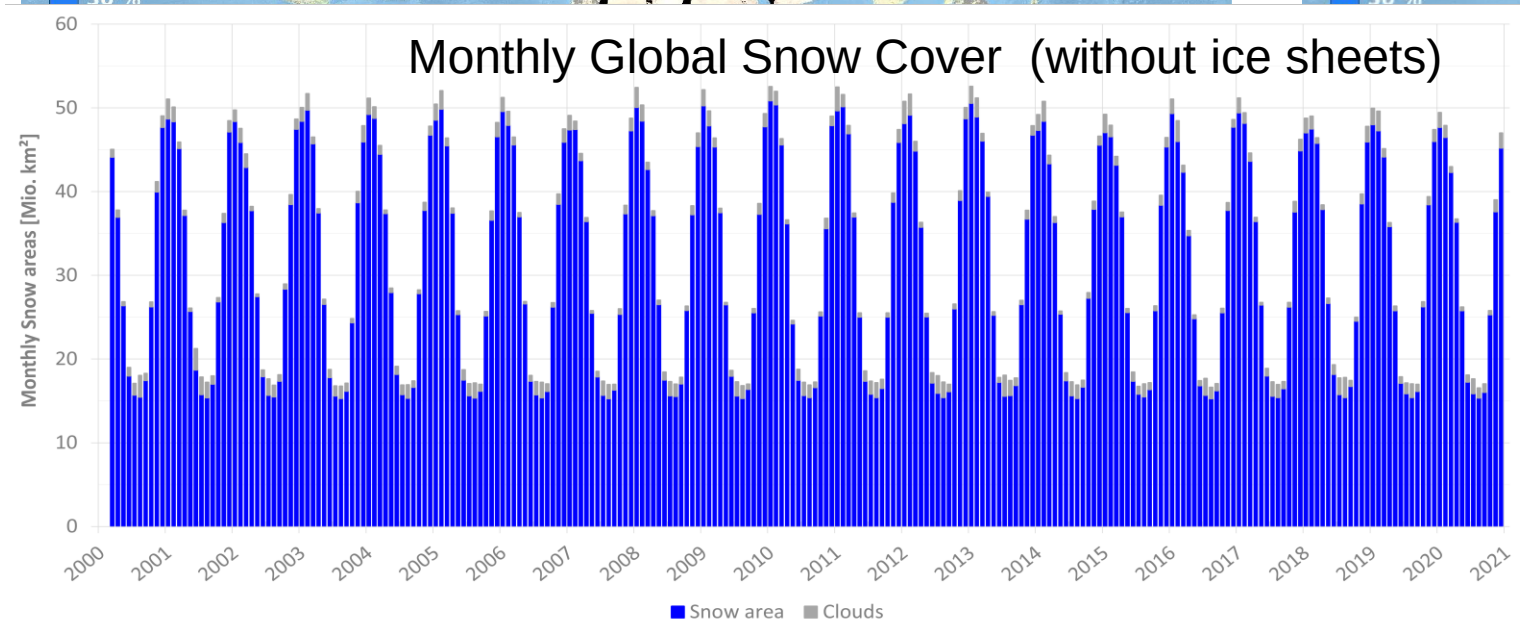



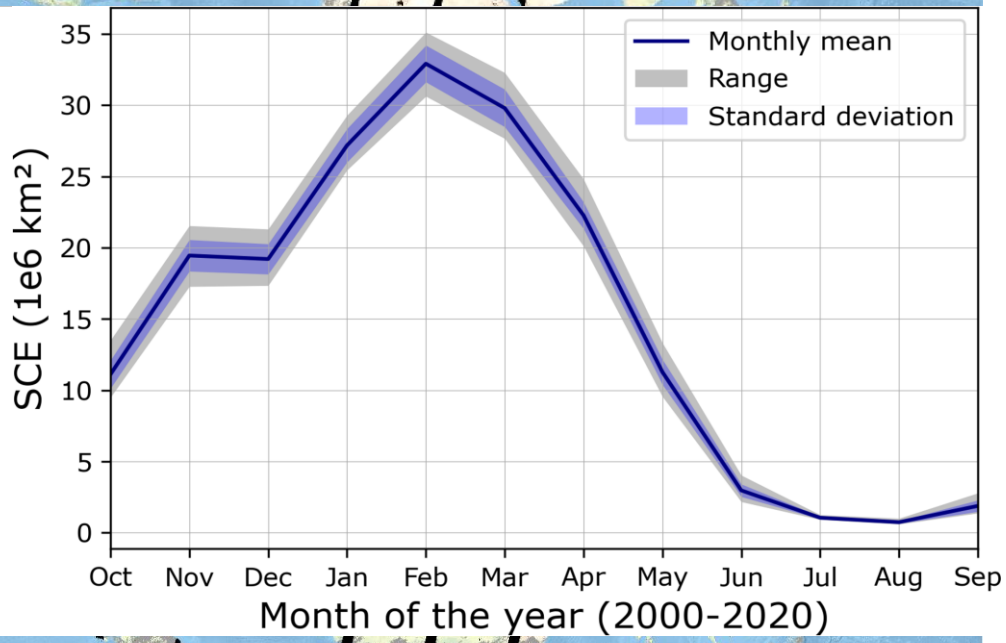

Salminen, M., et al. (2018). Determination of uncertainty characteristics for the satellite-based estimation of fractional snow cover. *Remote Sensing Environ.*, 212, 103-113.

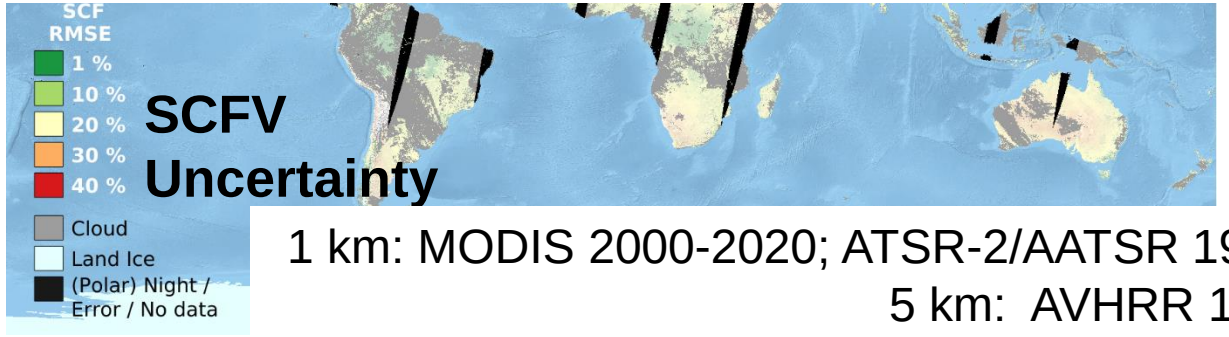
# Snow Extent CRDP V2 – global, daily, 1982-2020



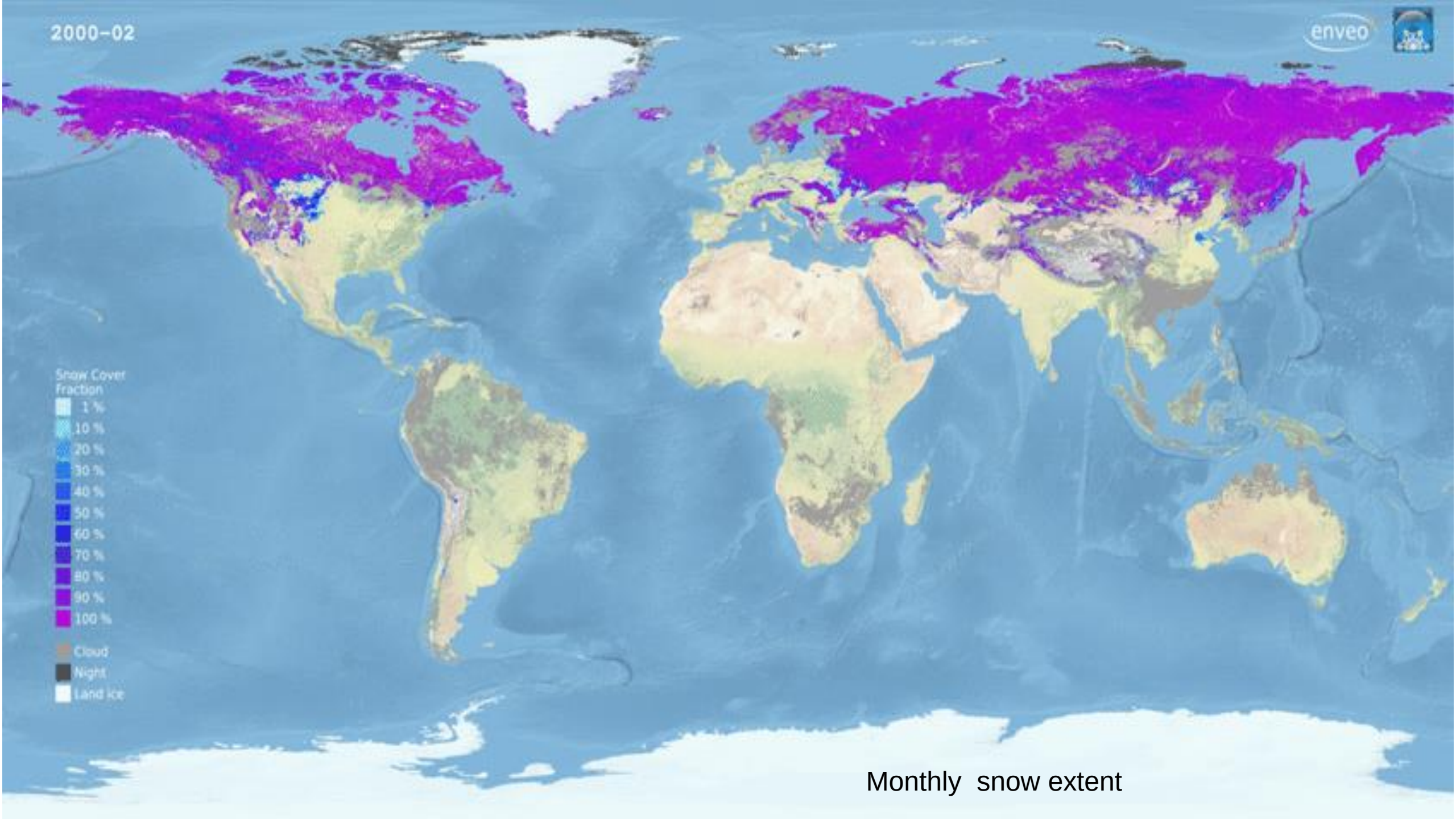







1 km: MODIS 2000-2020; ATSR-2/AATSR 1995-2012; S3 SLSTR 2020 (prototype);
5 km: AVHRR 1982 -2018

**MODIS data processed at HPC of Sigma2, NO**

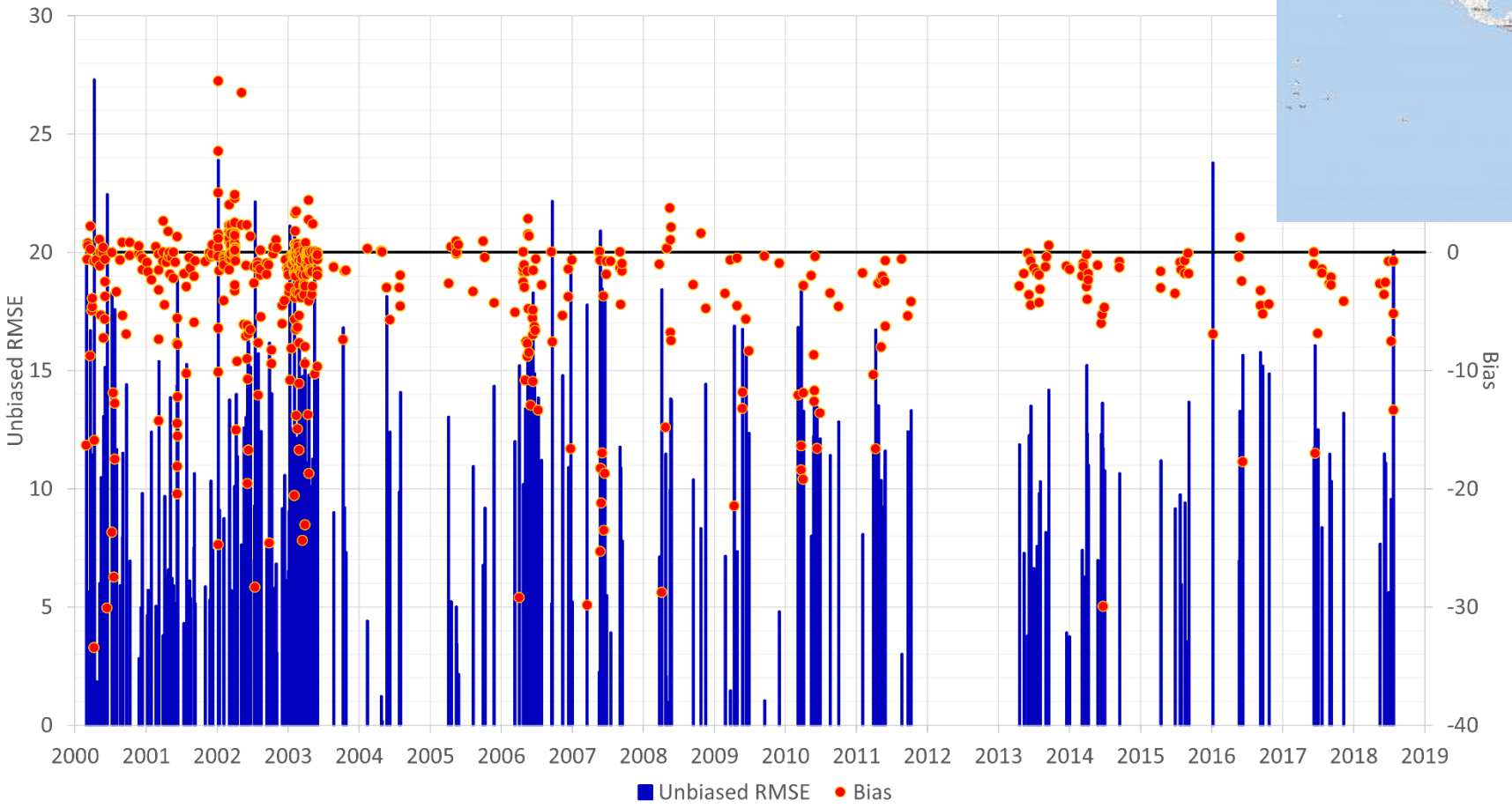



Monthly snow extent

# Validation with high resolution snow reference data

- Snow reference data set consisted of 545 Landsat scenes acquired between 2000 – 2018.
- Snow reference data set was generated following SnowPEx protocols.
- validation performed for open land





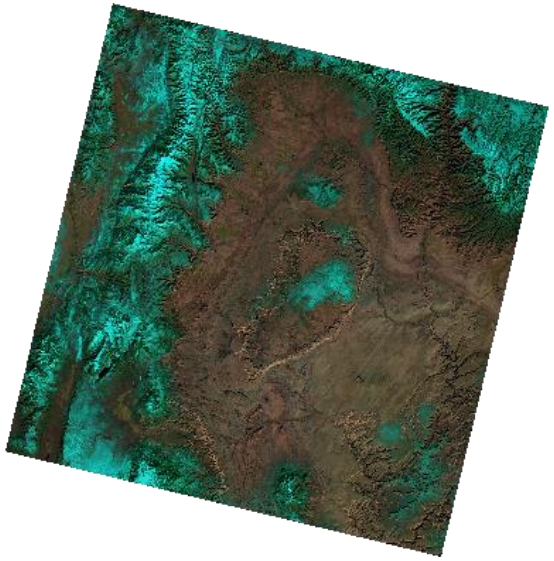

**For 1km SCF CRDP from MODIS/SLSTR**

Mean Unbiased RMSD: 8%

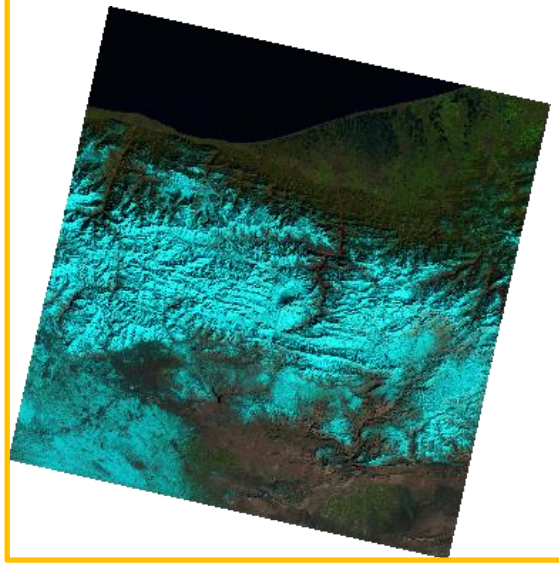
Mean BIAS: -4 %

# Local product performance assessment

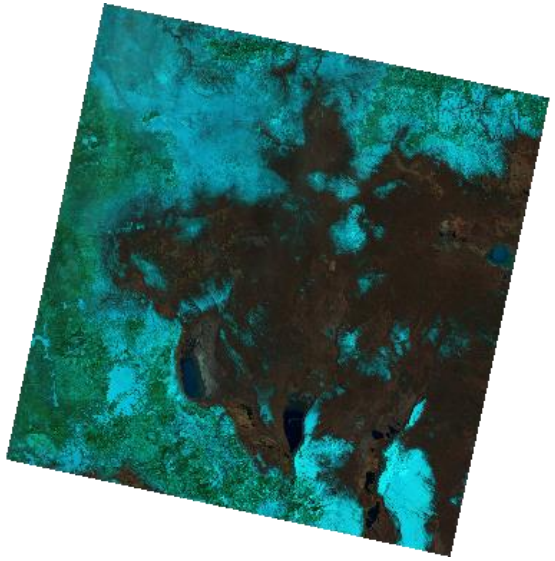
LC08, 037/033, 20151201



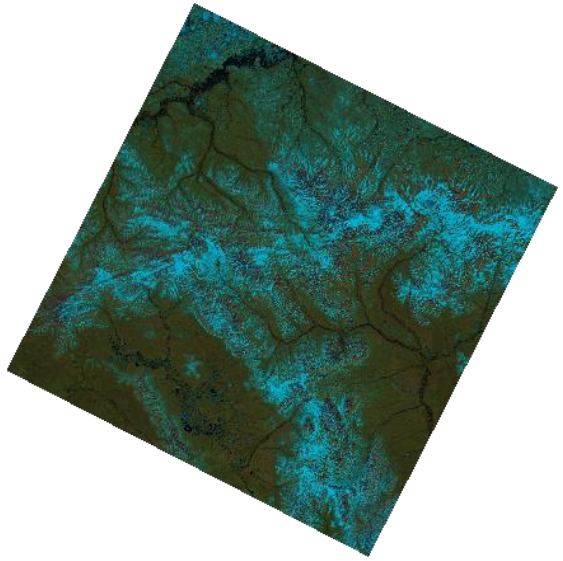
LC08, 164/035, 20180202

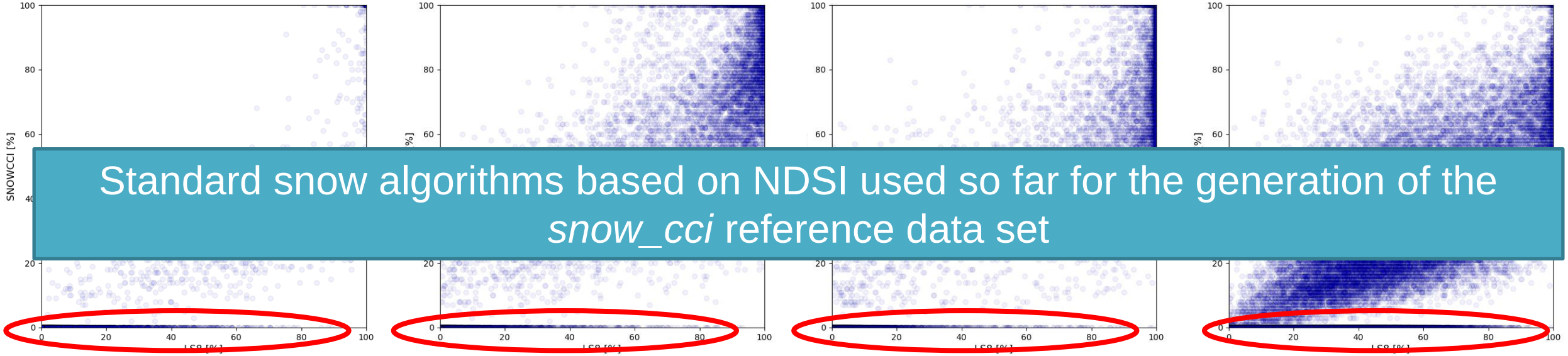


LC08, 044/030, 20190316



LC08, 120/011, 20180606

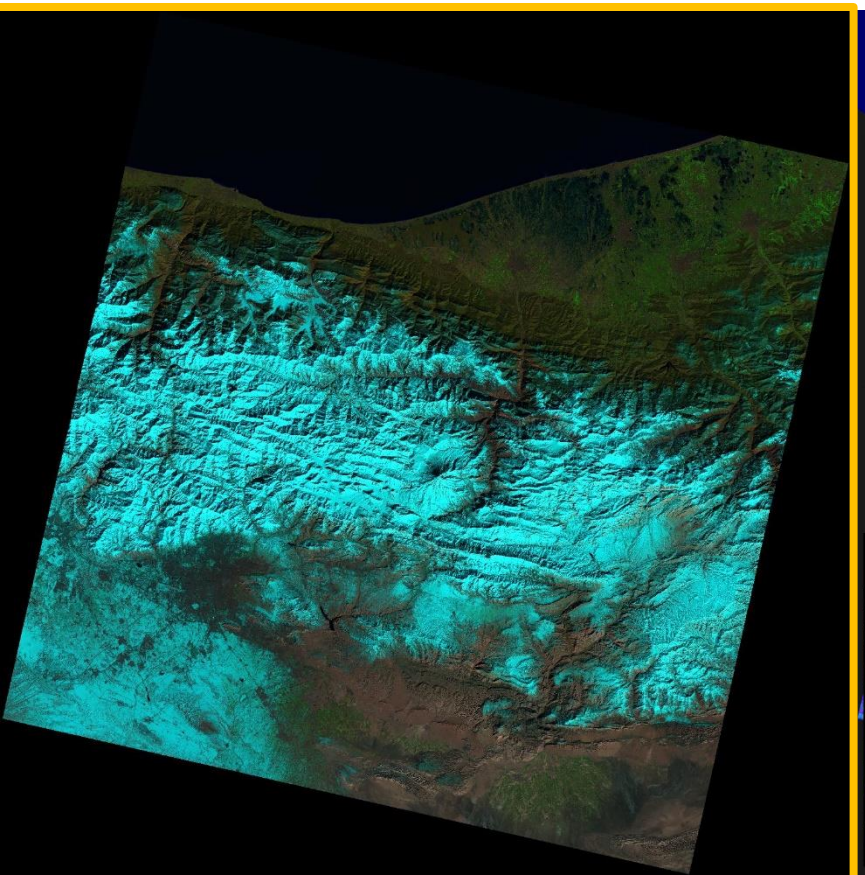


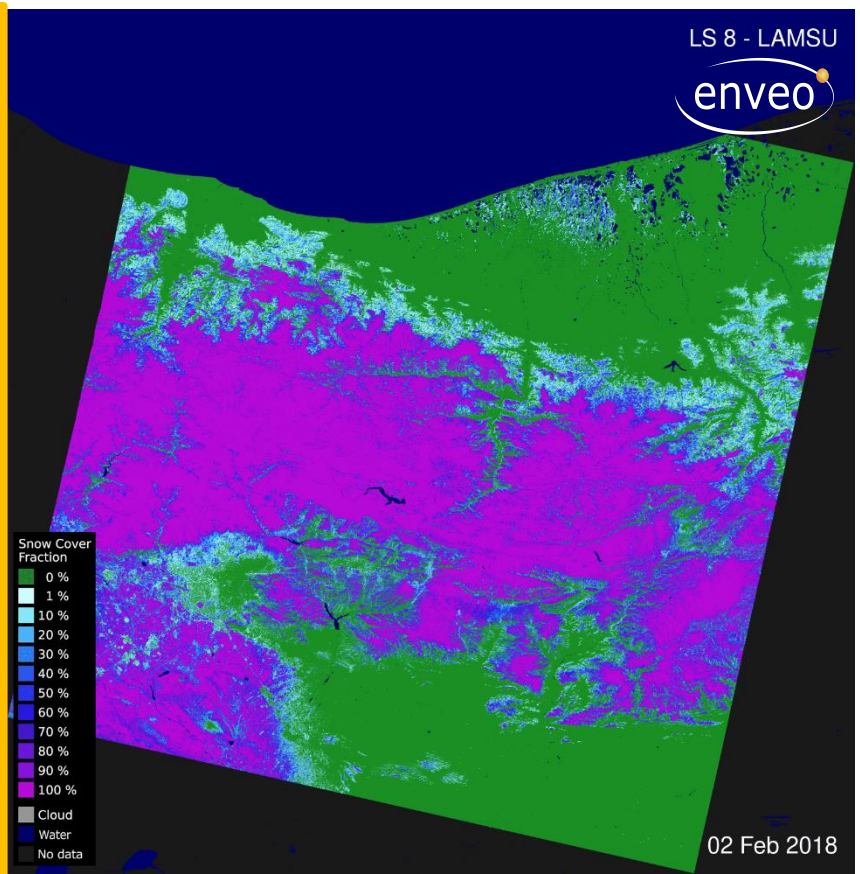


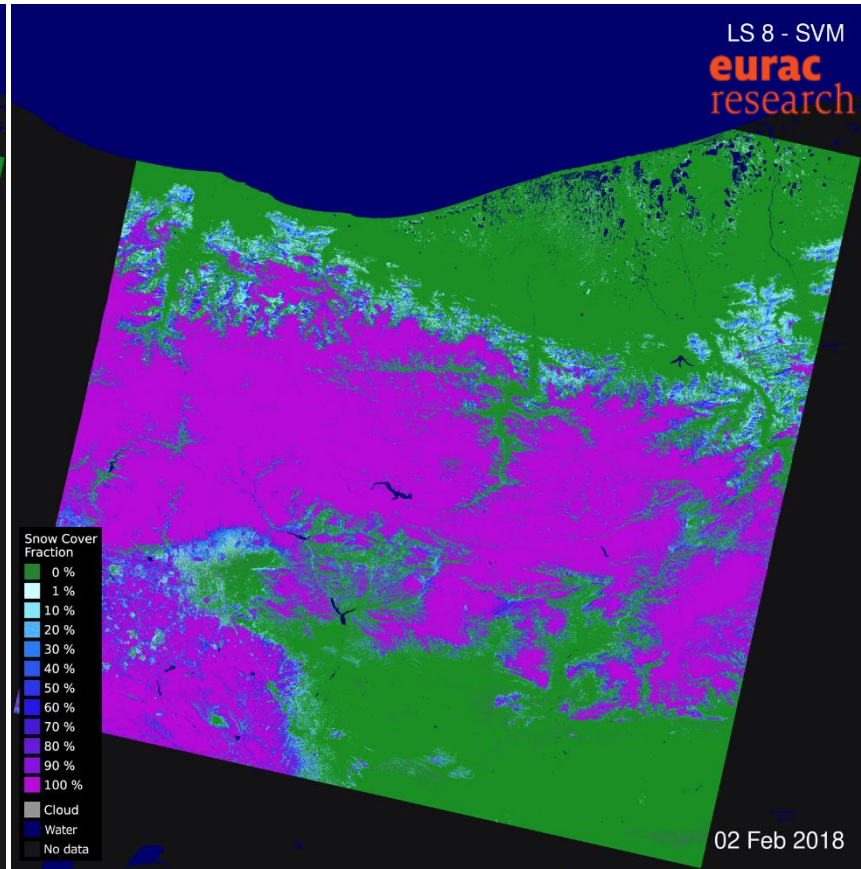

Standard snow algorithms based on NDSI used so far for the generation of the *snow_cci* reference data set

# Generation of high quality reference data set

- Selection of cloud free Landsat scenes
- Focus on open land
- Different snow conditions
- Different climate zones
- Advanced snow retrieval algorithms for the generation of the reference snow maps (presentation by Keuris et al, Tuesday 07.02.2023, 17:20)





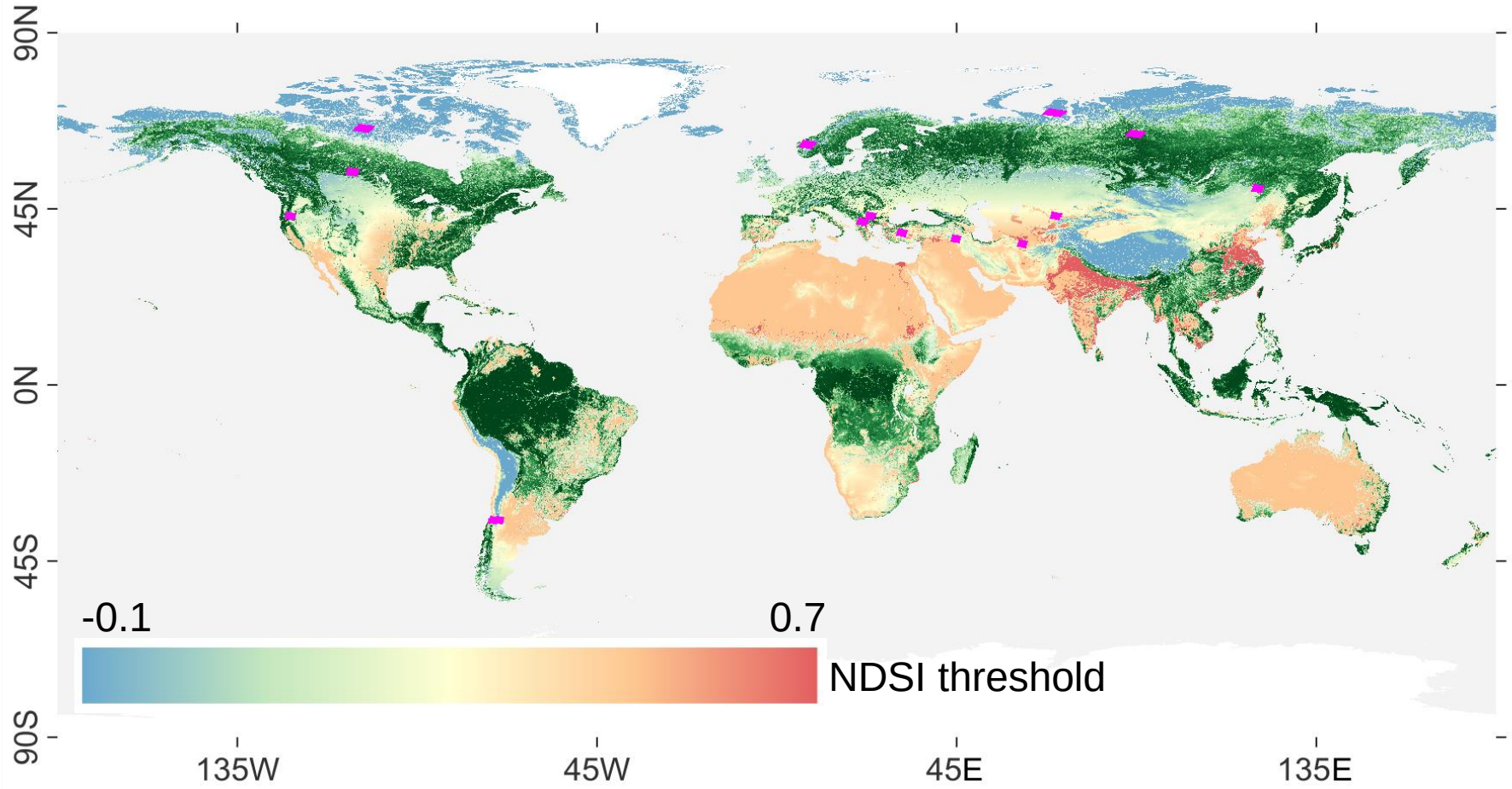



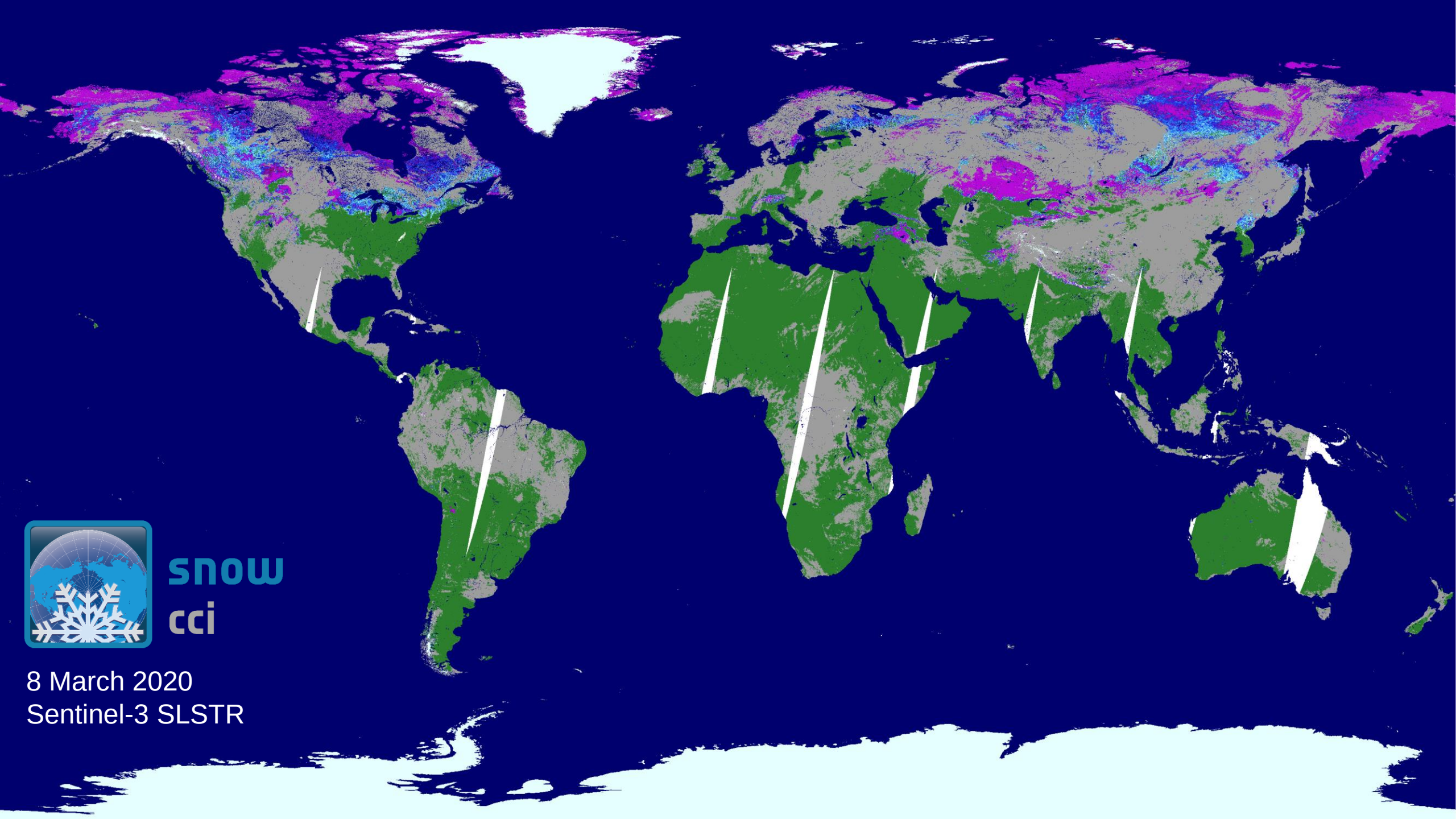
# Towards snow_cci SCF CRDP v3.0 from MODIS and SLSTR data

- Improve pre-classification module to identify snow free pixels
- Review and improve SCFV/SCFG classification
- Adjust per pixel uncertainty estimation

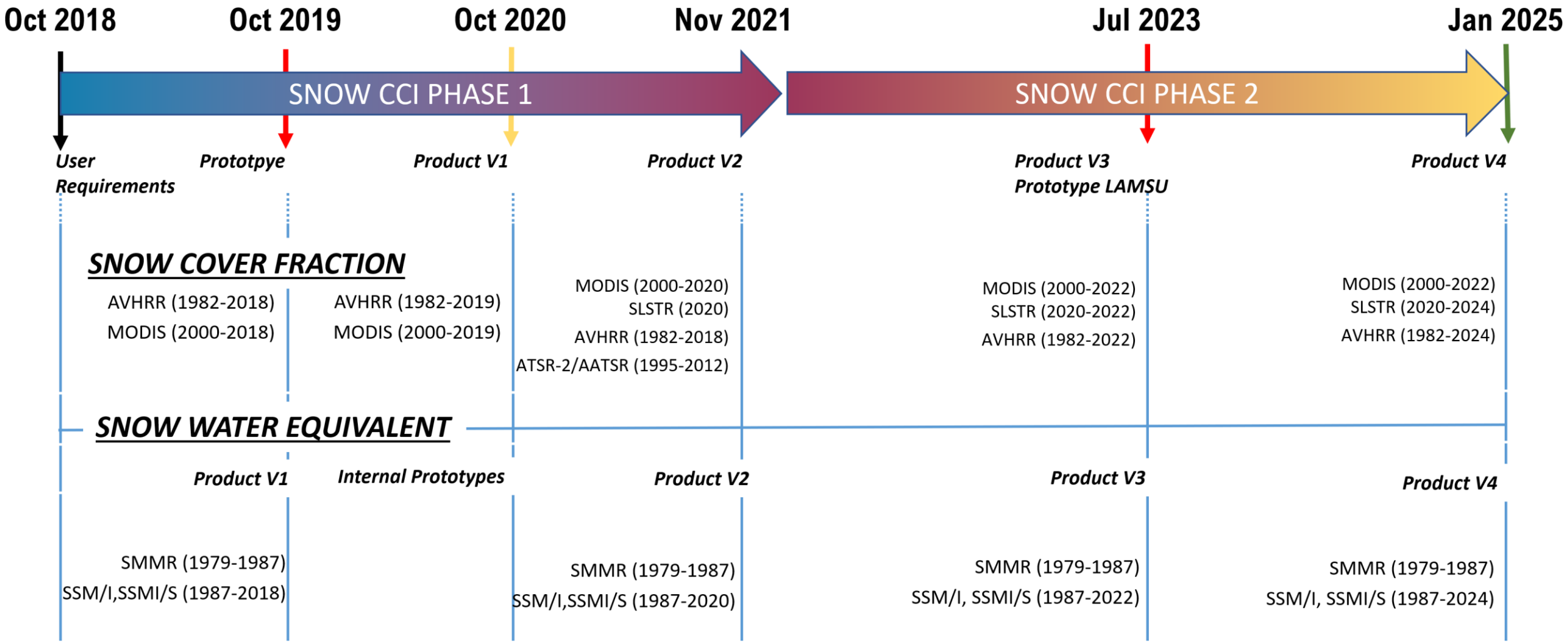
→ for all steps: sensor specific adjustments as needed for SLSTR data

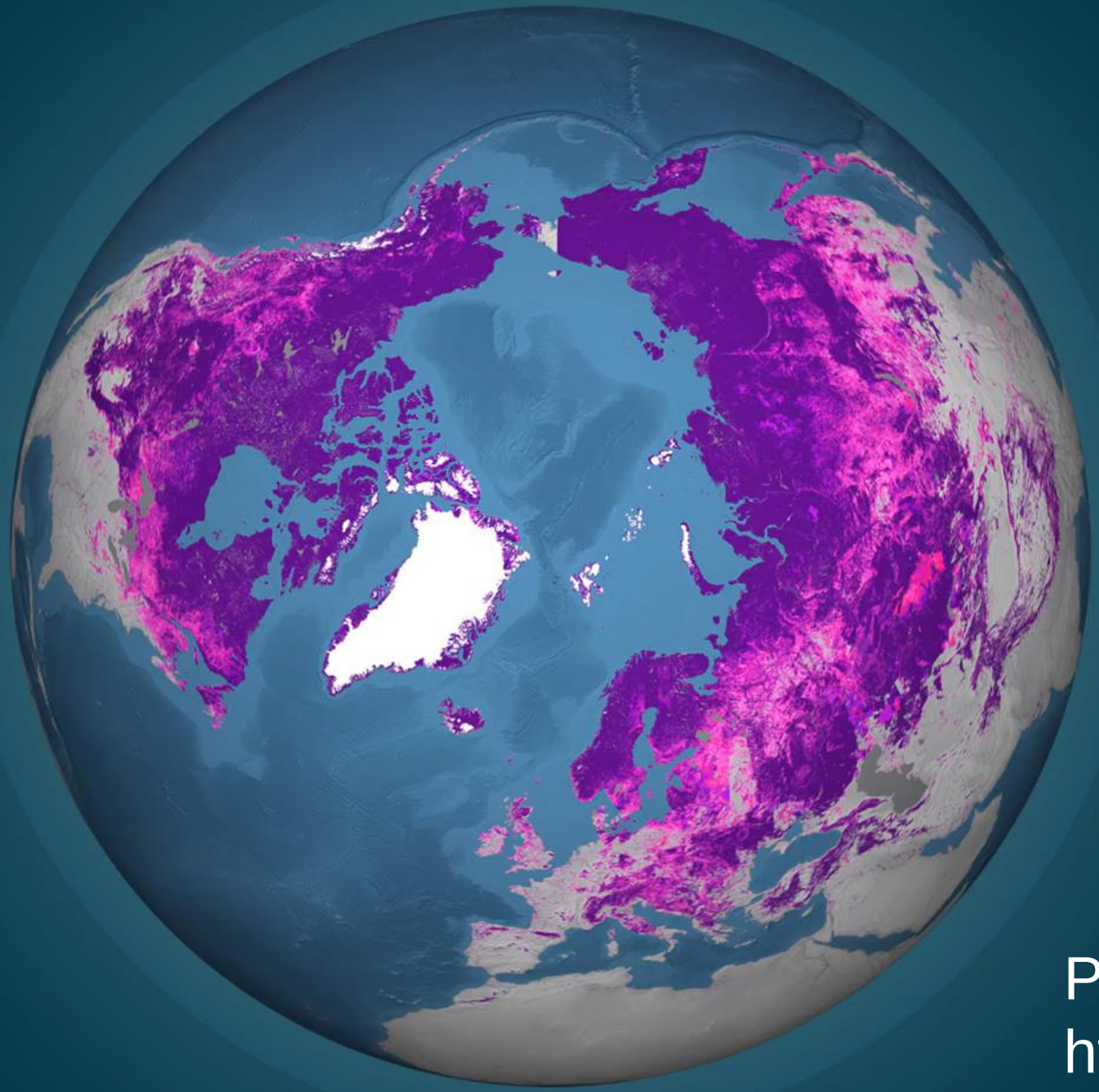
*Additional R&D ongoing:*
Testing of multi-spectral unmixing algorithm for global application




snow
cci
8 March 2020
Sentinel-3 SLSTR

# Release schedule of Snow CCI Products





Stay tuned
http://snow-cci.enveo.at

Products available at CEDA
https://catalogue.ceda.ac.uk/