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Remote Sensing of the Cryosphere – an overview

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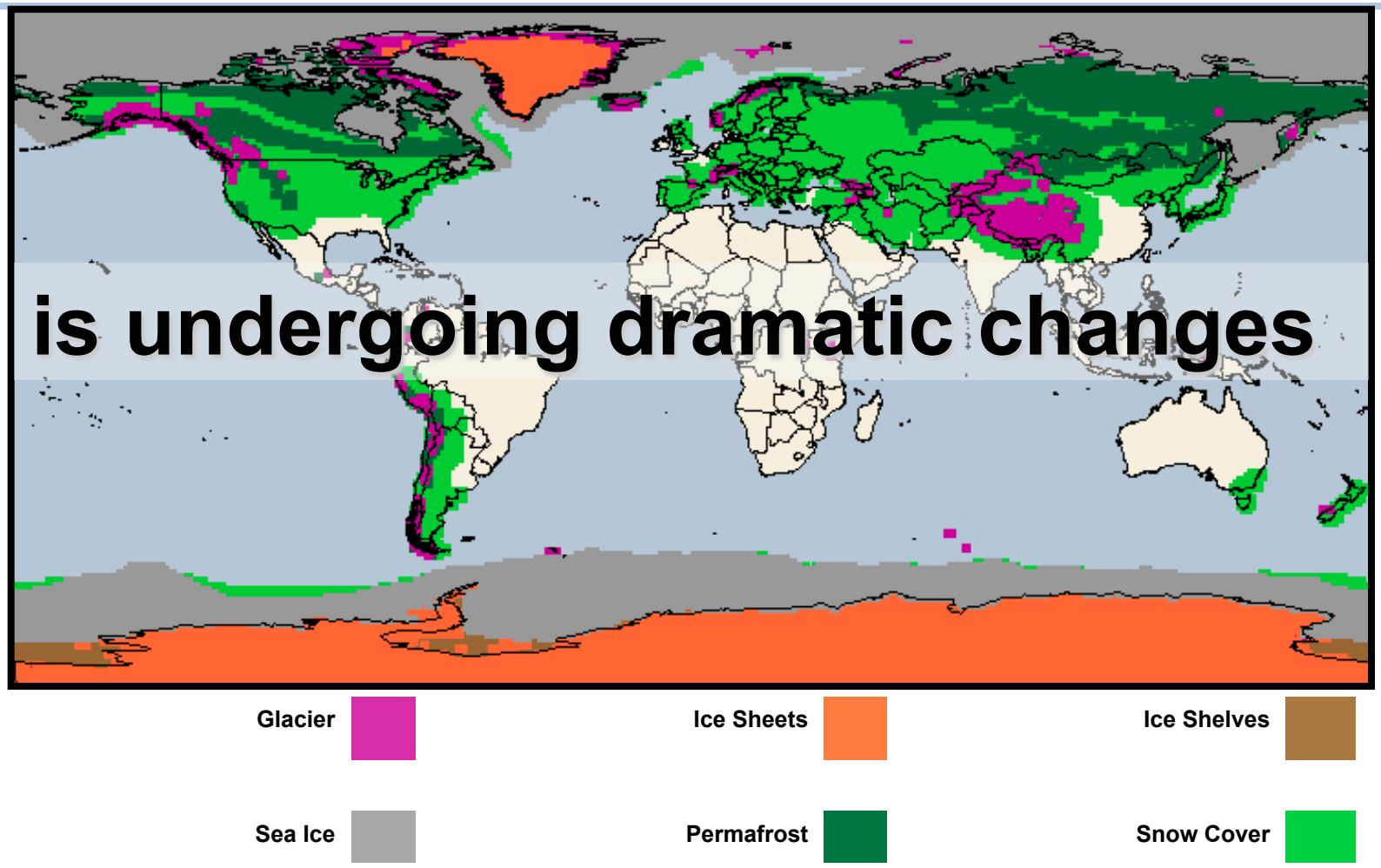
Global Cryosphere



© Vladimir Ryabinin, WMO-WCRP; ESA-Globsnow workshop; Feb. 14, 2008

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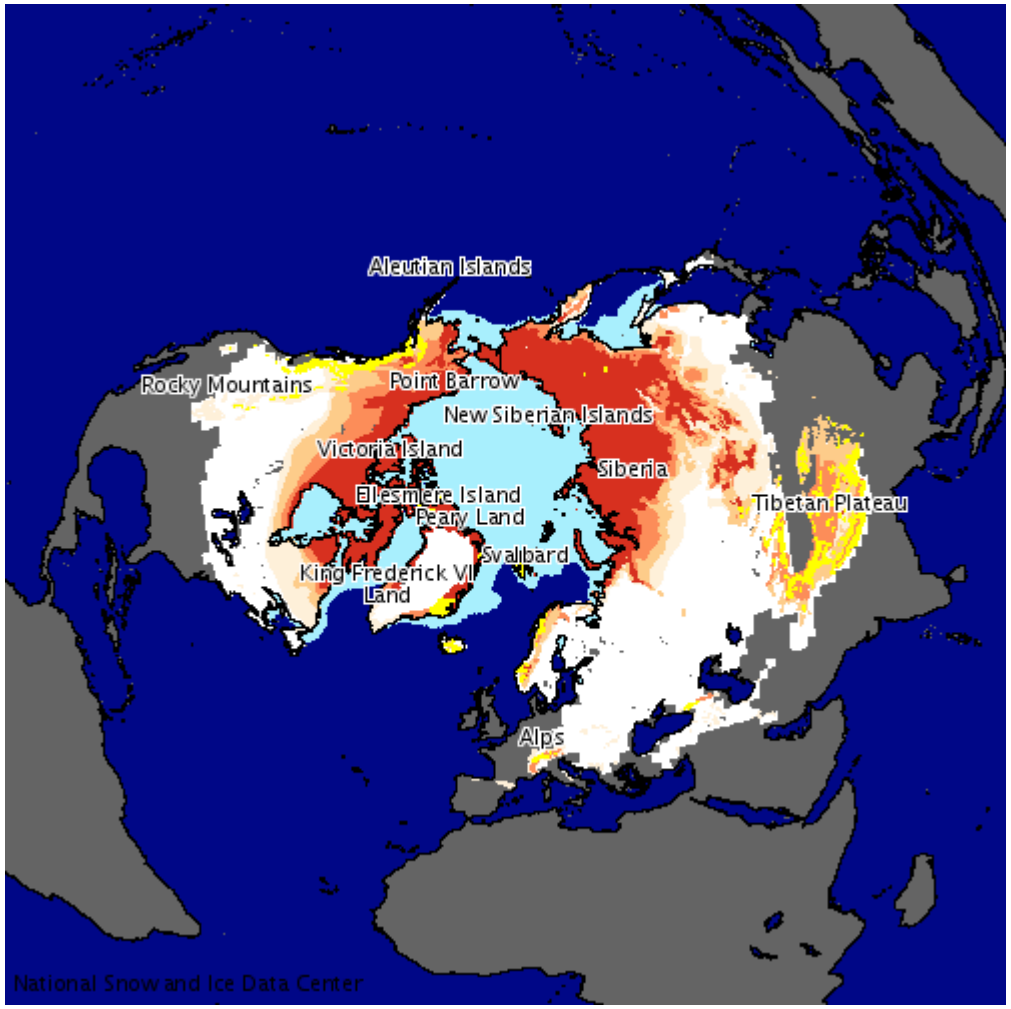
Cryosphere of Northern Hemisphere (January 2014)

- Permafrost (red)
- Glacier (yellow)
- Snow (white)
- Sea ice (blue)



NSIDC, Atlas of the Cryosphere

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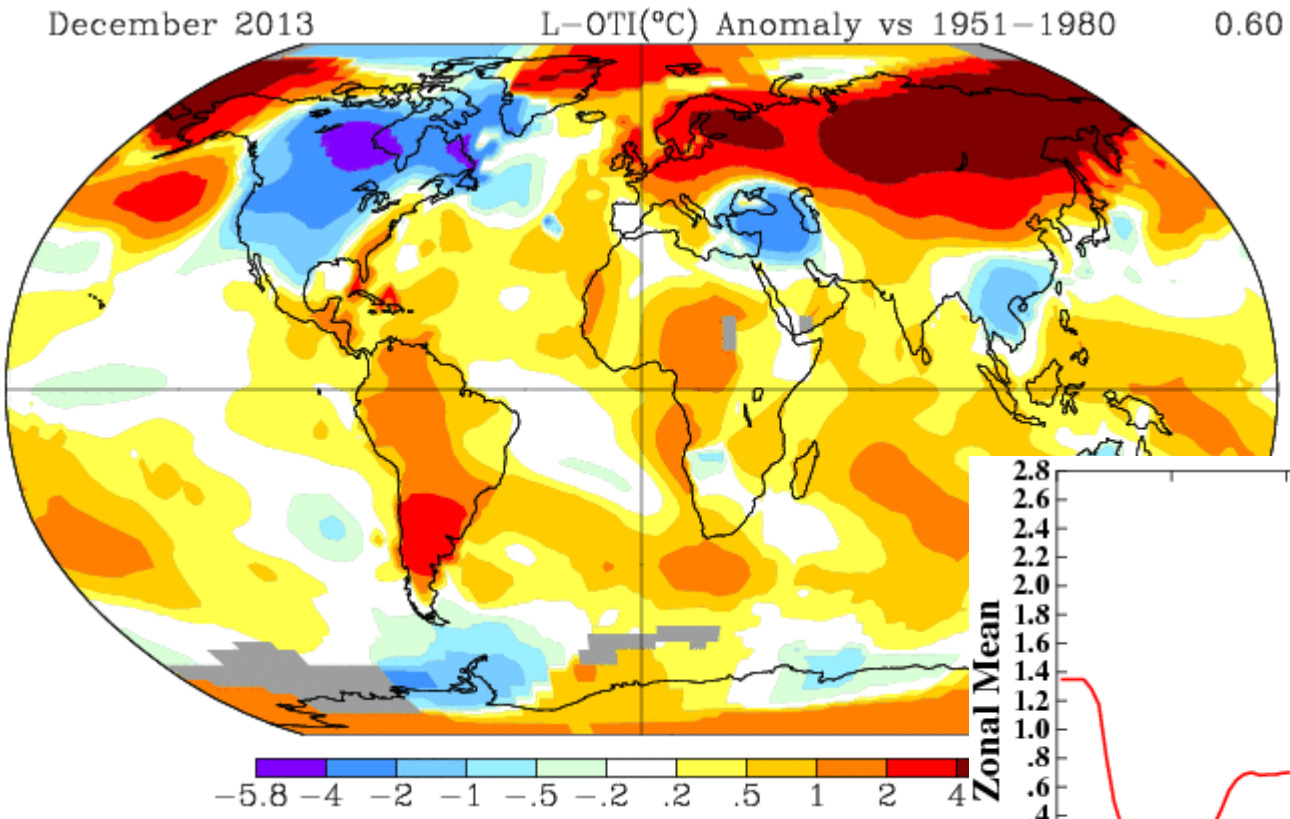
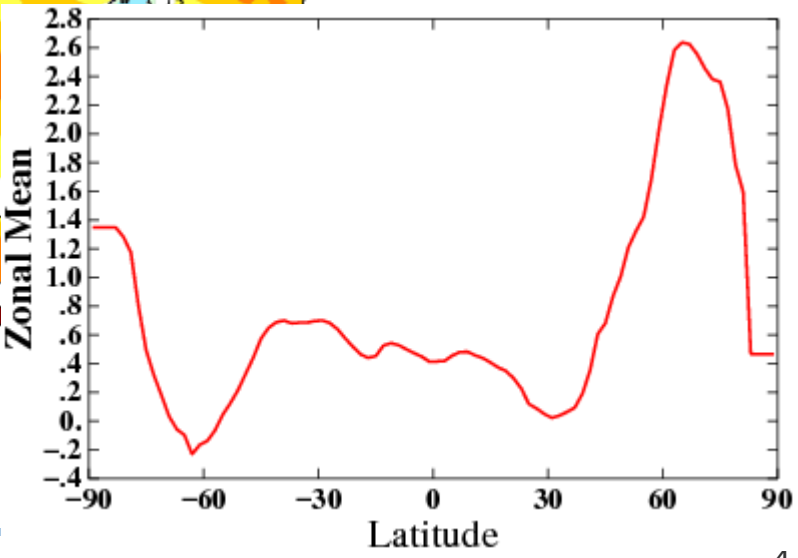
GISS Surface Temperature Analysis (NASA)





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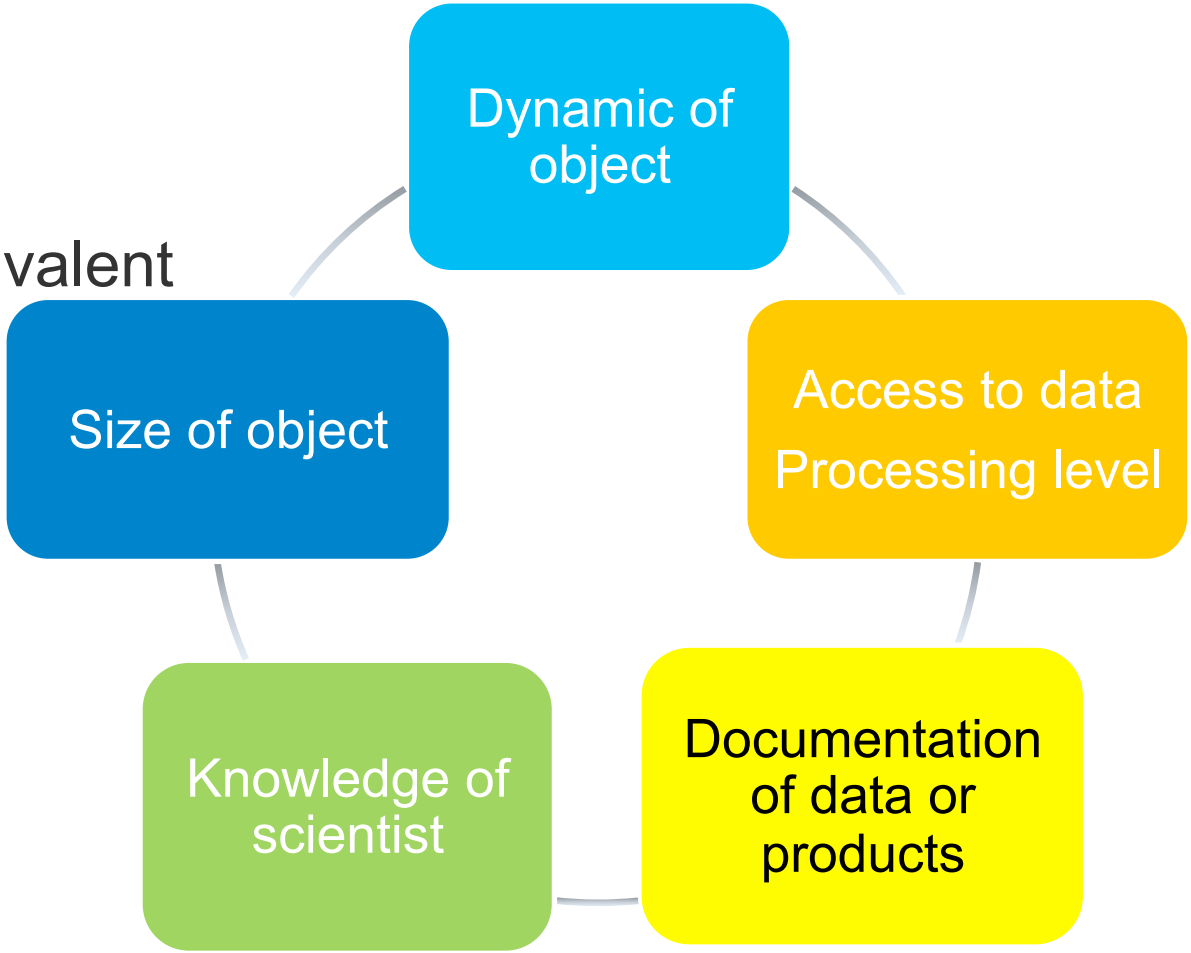
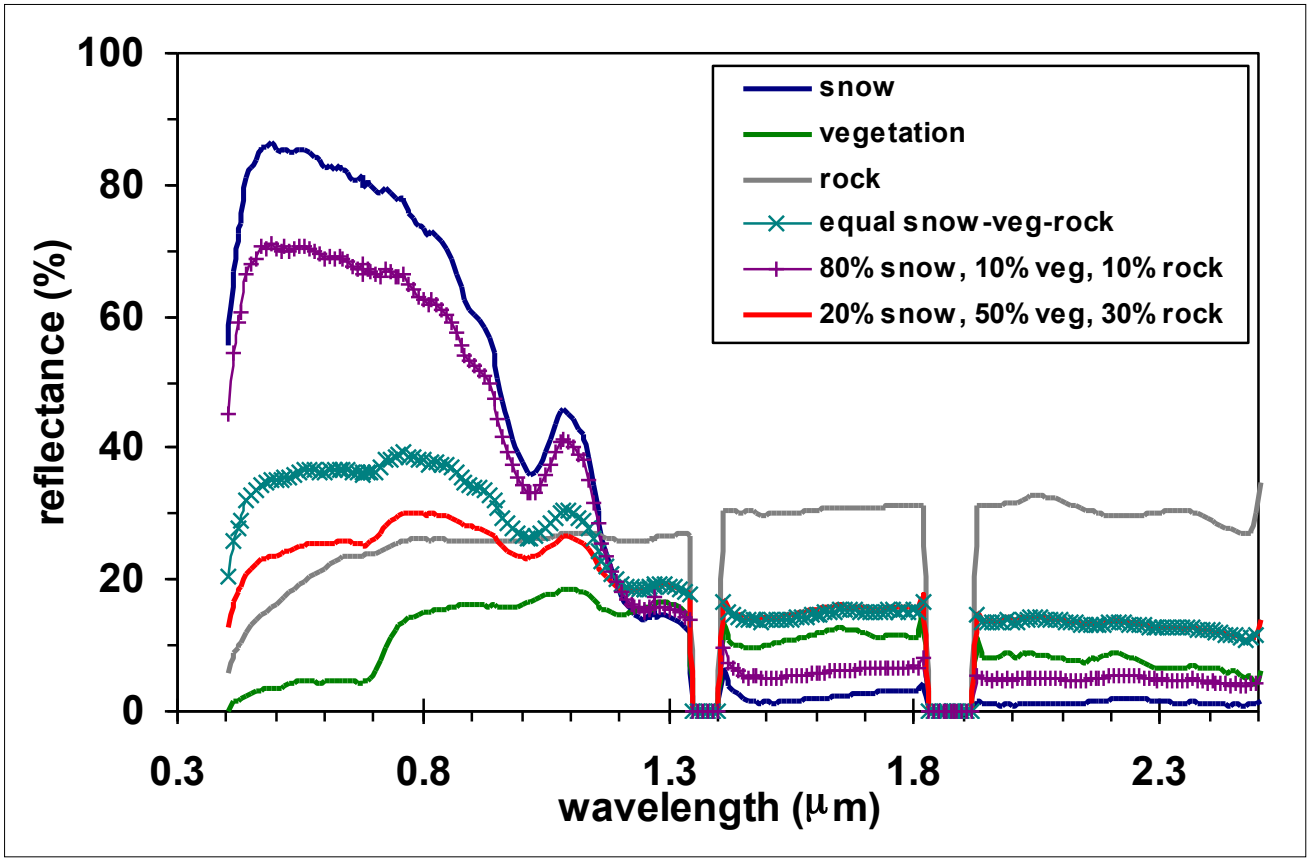
Selection of sensor depends on:

- **Surface types of Cryosphere**
  - Snow extent
  - Snow water equivalent
  - Snow melt
  - Glacier extent
  - Glacier dynamic
  - Ice caps
  - Ice sheets
  - Permafrost
- **Climate, change detection or NRT**



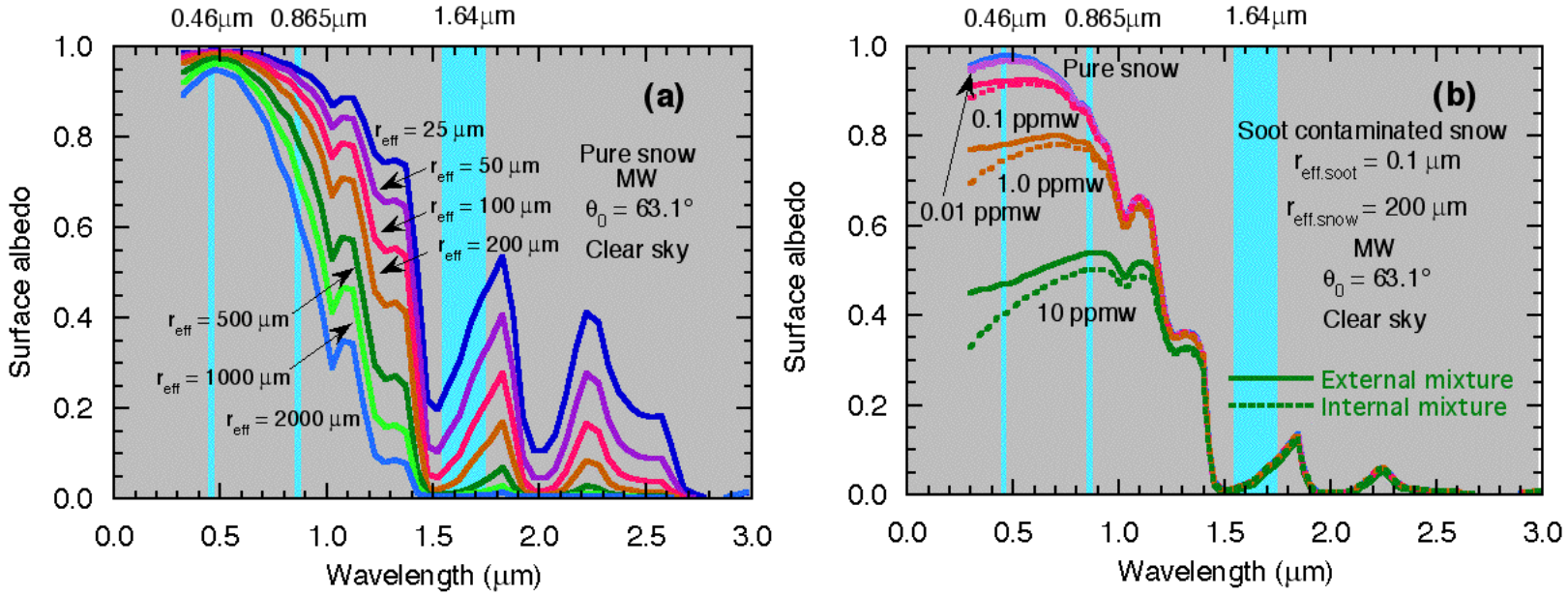
Remote Sensing of Snow

- Optical remote Sensing of the Cryosphere is an easy task because
  - High reflectance of snow and ice in the solar spectra



AVIRIS-spectra, JPL

Reflectance depends on grain size and contamination



From Teruo Aoki,
EARSeL WS 2005

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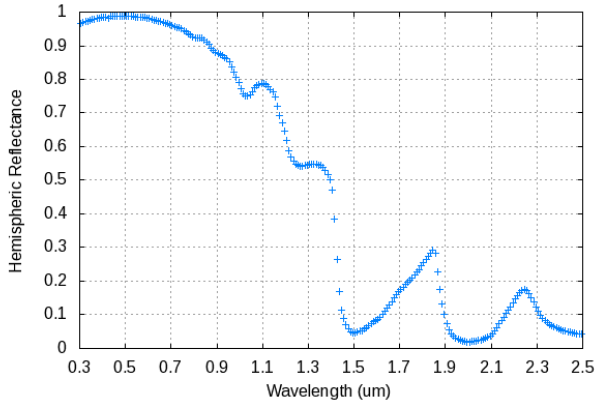
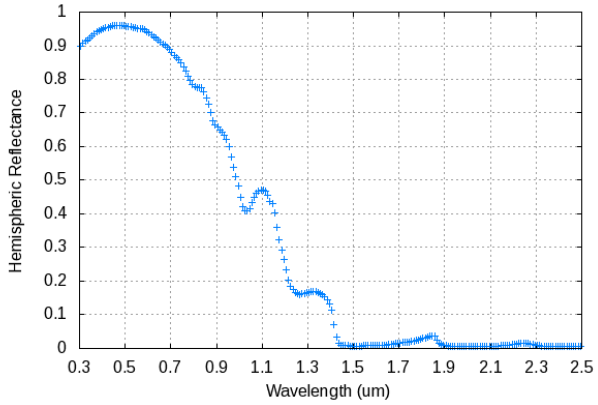
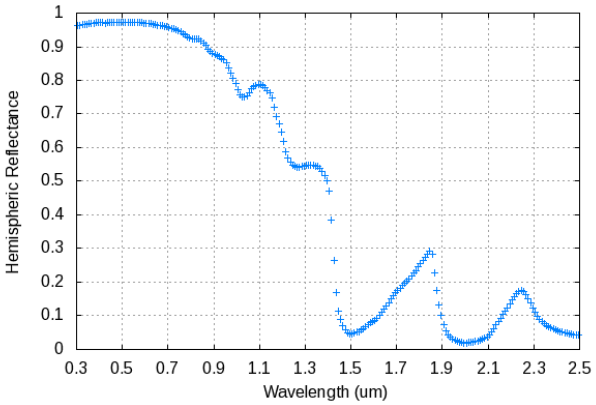
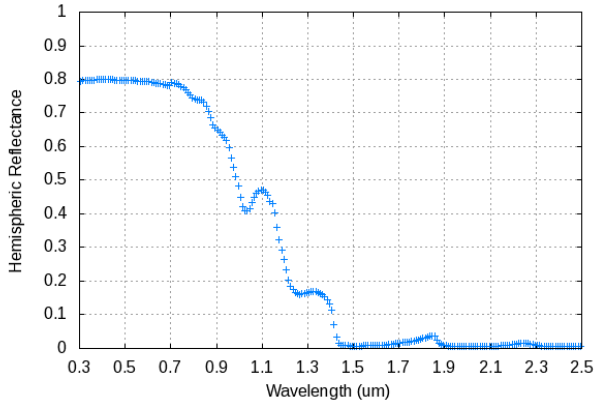
Influence of grain size and thickness on spectral reflectance

- Snow layer (1m vs. 0.1m, 100 microns, no impurities) left
- Snow layer (1m vs. 0.1m, 1000 microns, no impurities) right



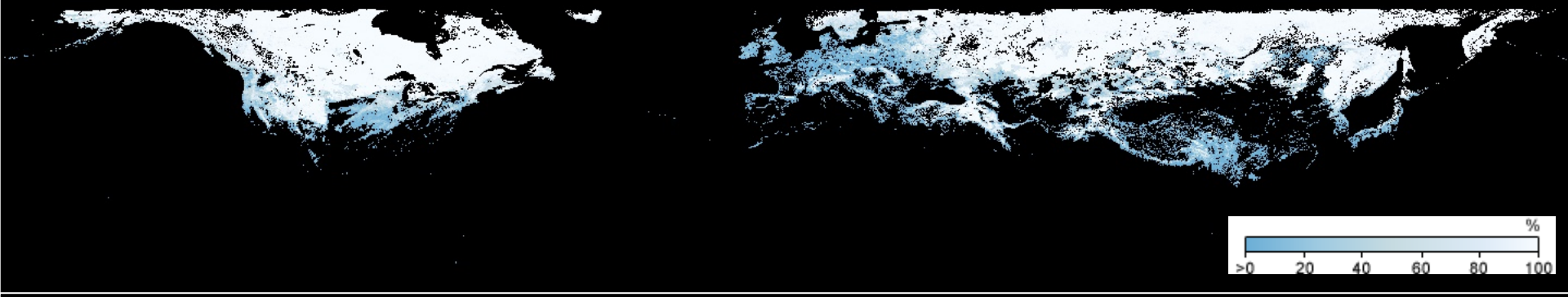




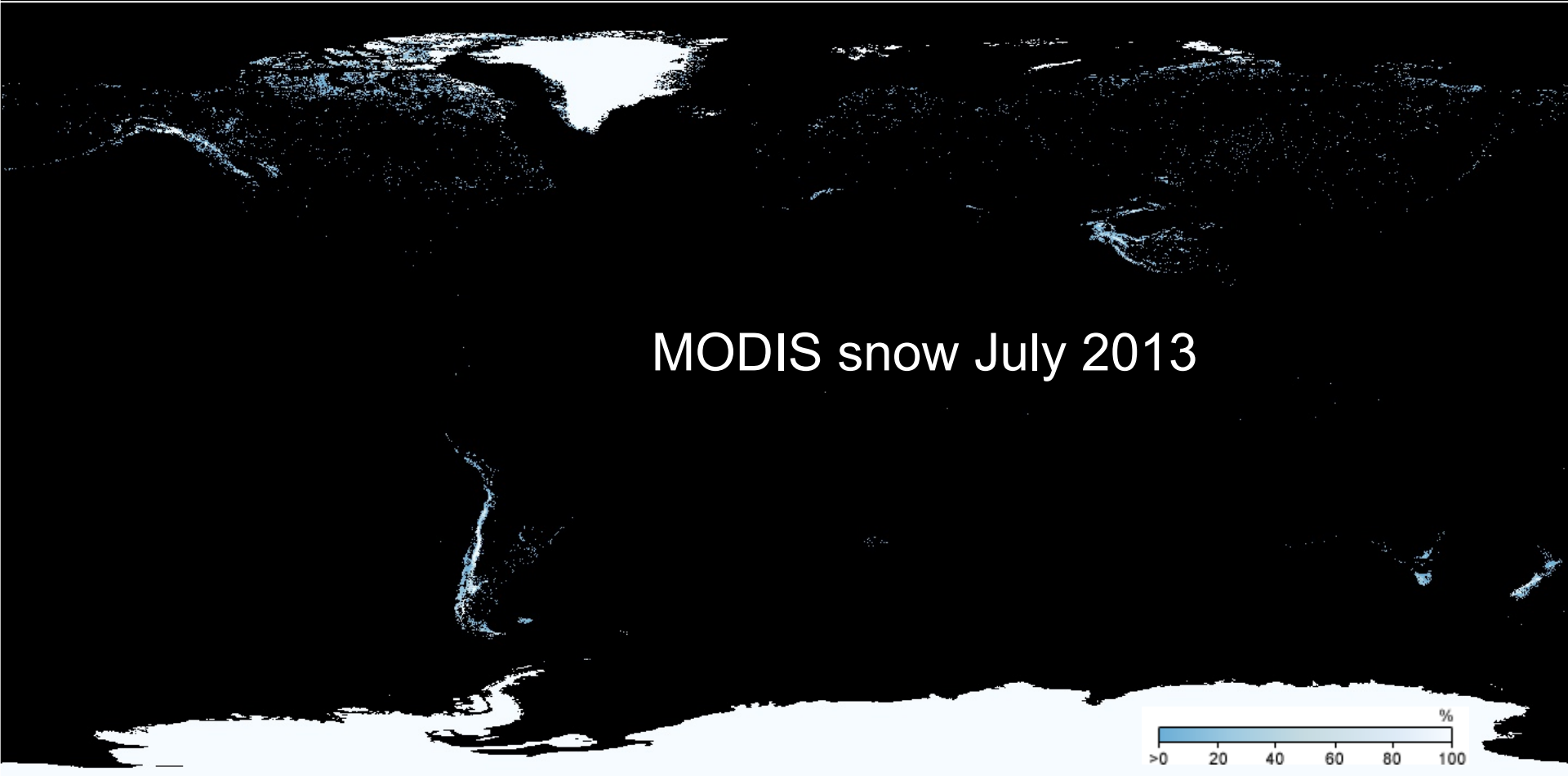


http://snow.engin.umich.edu/

MODIS snow Dec. 2013



MODIS snow July 2013



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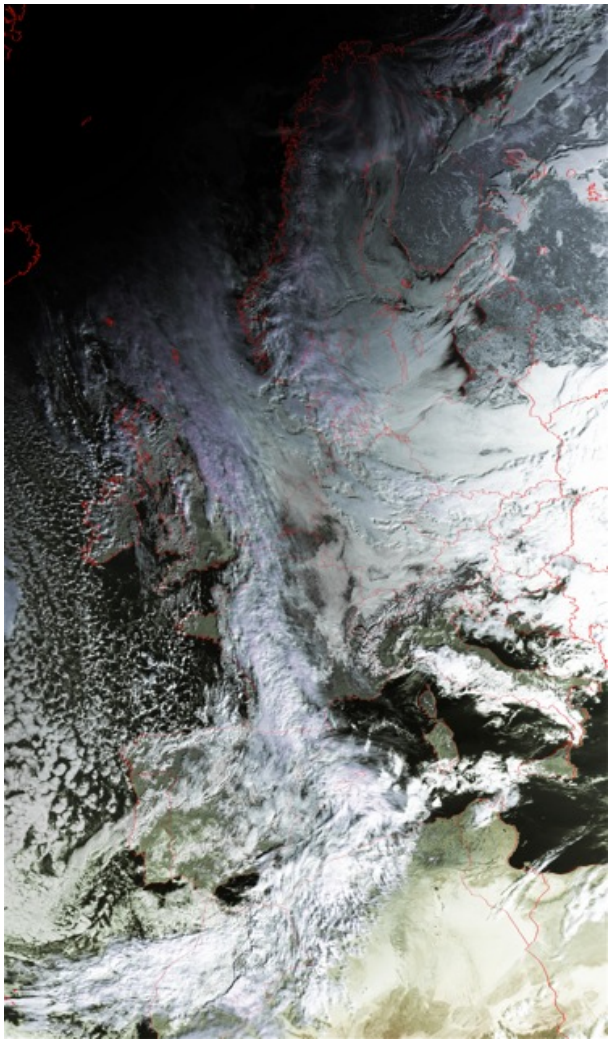
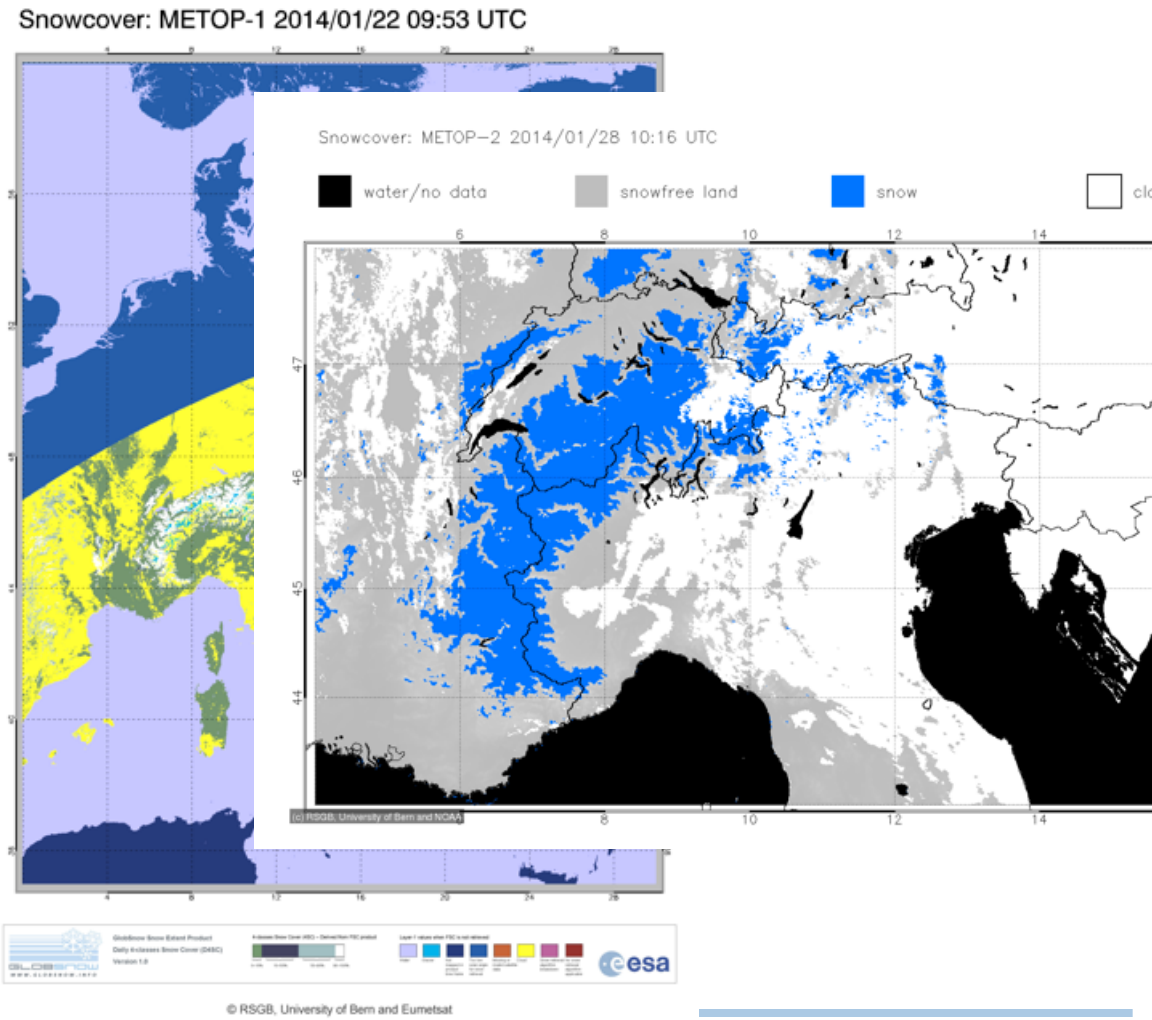
Advanced Very High Resolution Radiometer AVHRR on NOAA- and MetOp-satellites





MetOp-Image received at UniBe

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ESA DUE Globsnow products February 17, 2012 and April 2012

GLOBSNOW WWW.GLOBSNOW.INFO

GlobSnow Snow Extent Product

Daily 4-classes Snow Cover (D4SC)

Version 2.0

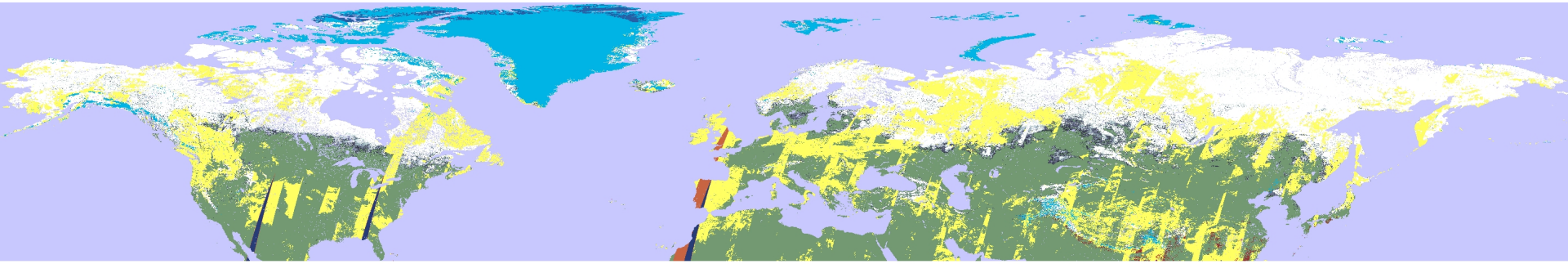
4-classes Snow Cover (4SC) – Derived from FSC product

0–10% 10–50% 50–90% 90–100%

Layer-1 values when FSC is not retrieved

Water | Glacier | Not mapped in product time frame | Too low solar angle for snow retrieval | Missing or invalid satellite data | Cloud | Snow retrieval algorithm breakdown | No snow retrieval algorithm applicable

esa



GLOBSNOW WWW.GLOBSNOW.INFO

GlobSnow Snow Extent Product

Monthly Aggregated Fractional Snow Cover (MFSC)

Version 2.0

Fractional Snow Cover (FSC) - Steps of 1% in product

100% 75% 50% 25% 0%

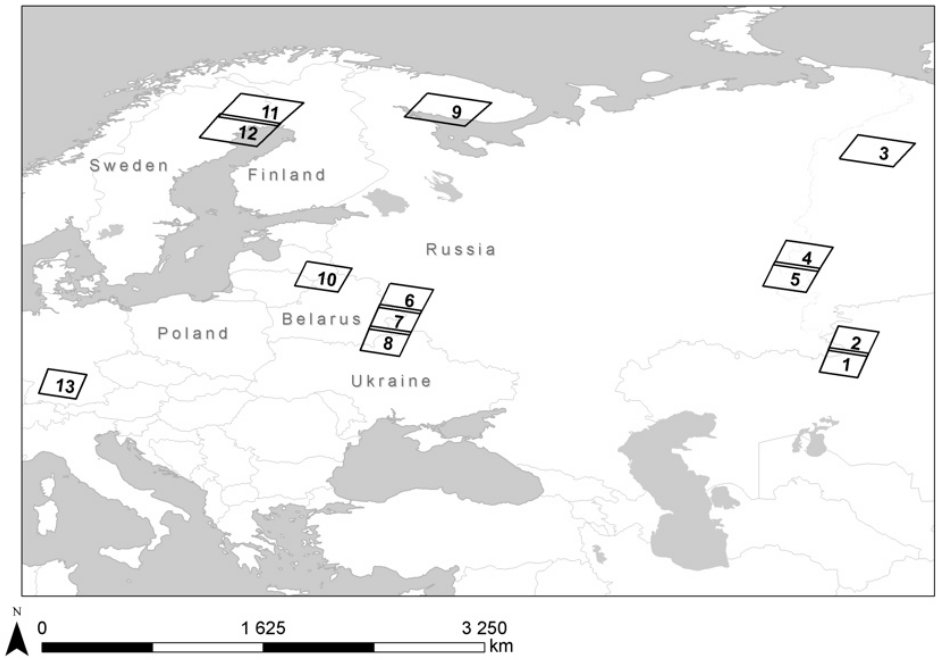
Layer-1 values when FSC is not retrieved

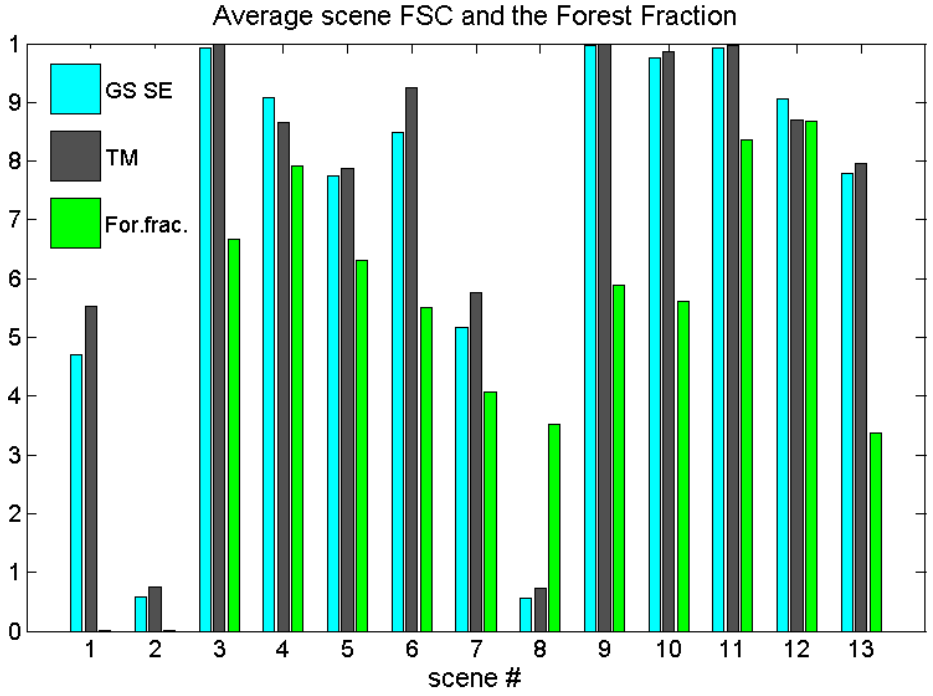
Water | Glacier | Not mapped in product time frame | Too low solar angle for snow retrieval | Missing or invalid satellite data | Cloud | Snow retrieval algorithm breakdown | No snow retrieval algorithm applicable

esa

Accuracy of snow extent (binary or fractional)

- Validation based on:
  - Station data (cm snow depth)
  - Model data
  - Satellite data with higher spatial resolution





ESA Globsnow consortium; Sari Metsämäki,SYKE

Snow extent (binary or fractional)

- **The spatial and temporal resolution varies as well as the accuracy**
- **Critical issues**:
  - Cloud cover / sub-pixel clouds
  - Forest
  - Geocoding accuracy
  - Influence of topography
  - Calibration
  - Atmospheric effects

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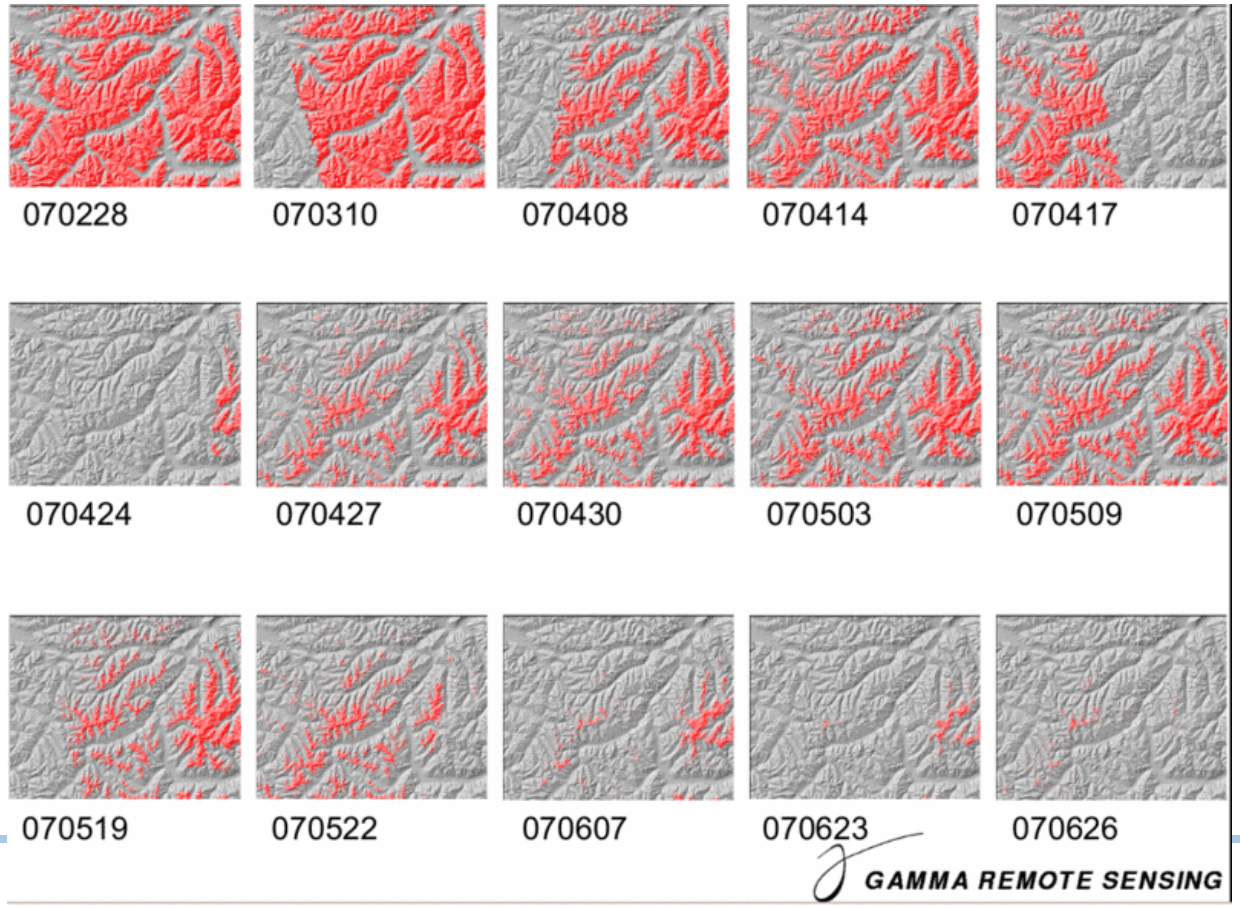
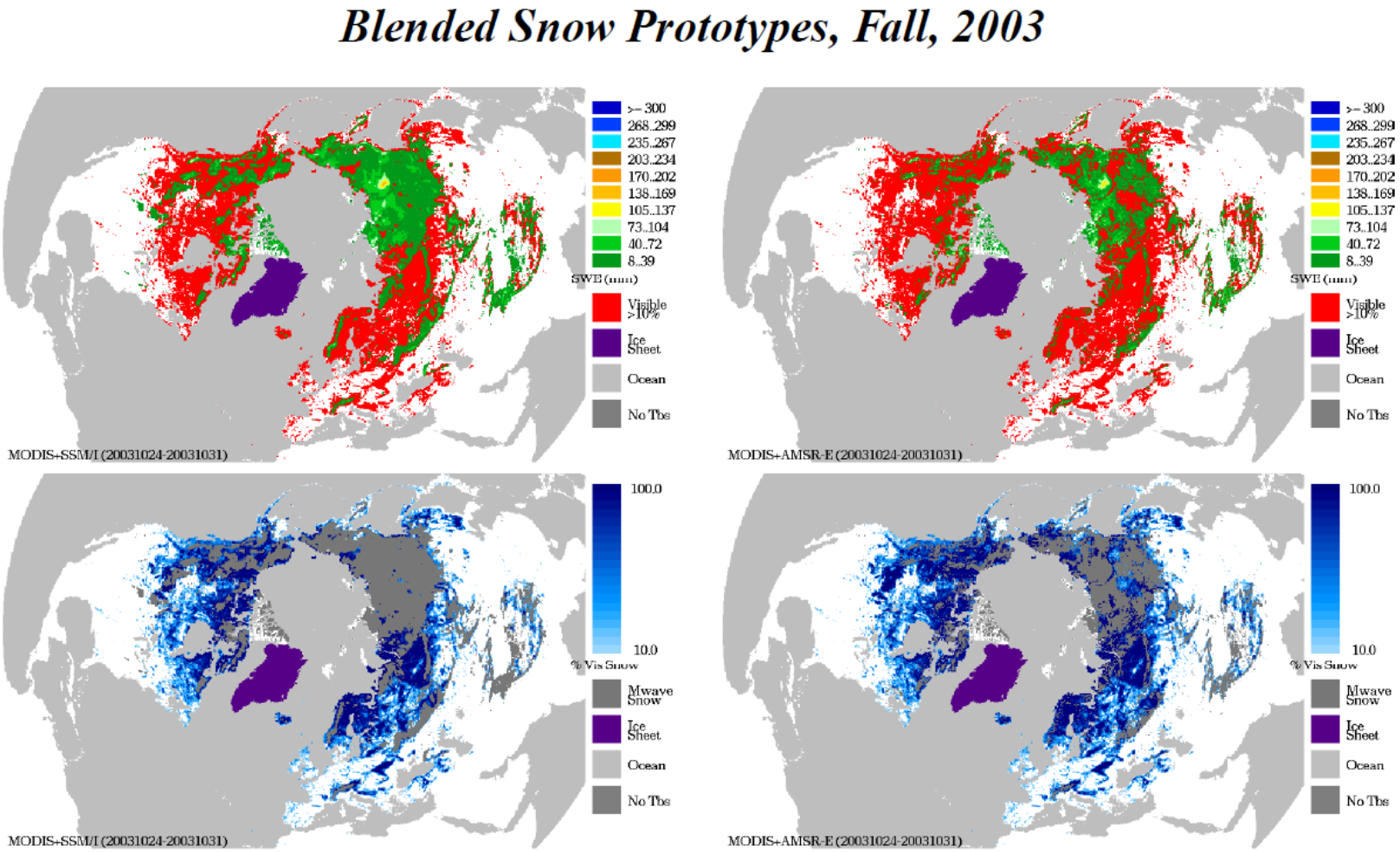
Detection of wet snow with C-band SAR (gamma remote sensing)

- Dry snow is highly transparent for this frequency
- Wet snow strongly reduces backscattering → wet snow vs. snow free
- Extrapolation of dry snow above the altitude of wet snow



MODIS – SSM/I snow product



Armstrong, R. et al. 2003: Poster presentation availabe at NSIDC

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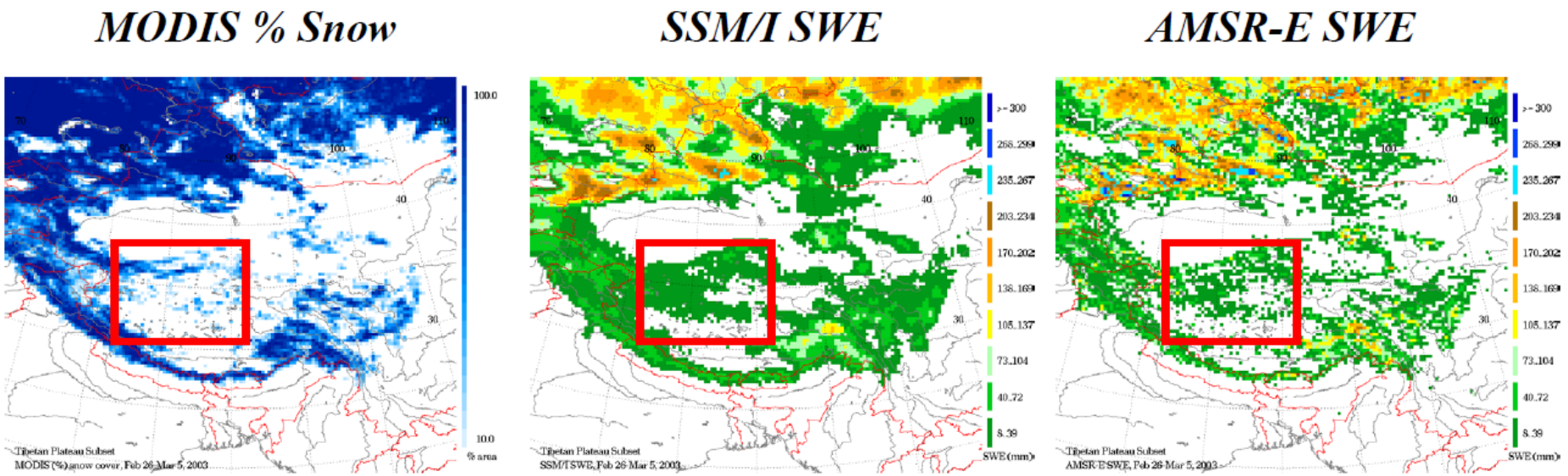
Snow coverage vs. snow water equivalent

> Significant difference between optical and coarse resolution microwave



Tibetan Snow Cover, February 26 - March 5, 2003, left to right: percent area with MODIS snow, SWE derived from SSM/I and SWE derived from AMSR-E. Red box outlines area of patchy visible snow (MODIS) that is "smeared" by SSM/I but better resolved by AMSR-E's improved spatial resolution.

Armstrong, R. et al. 2003: Poster presentation availabe at NSIDC

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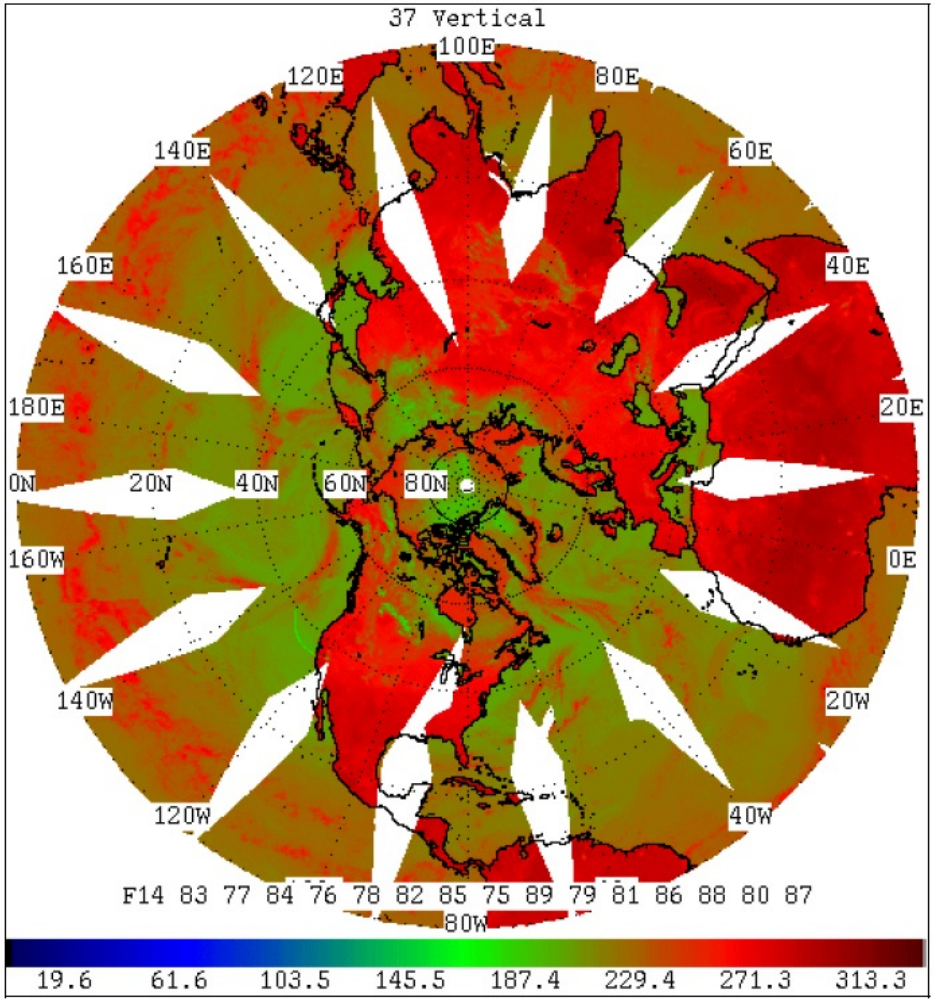
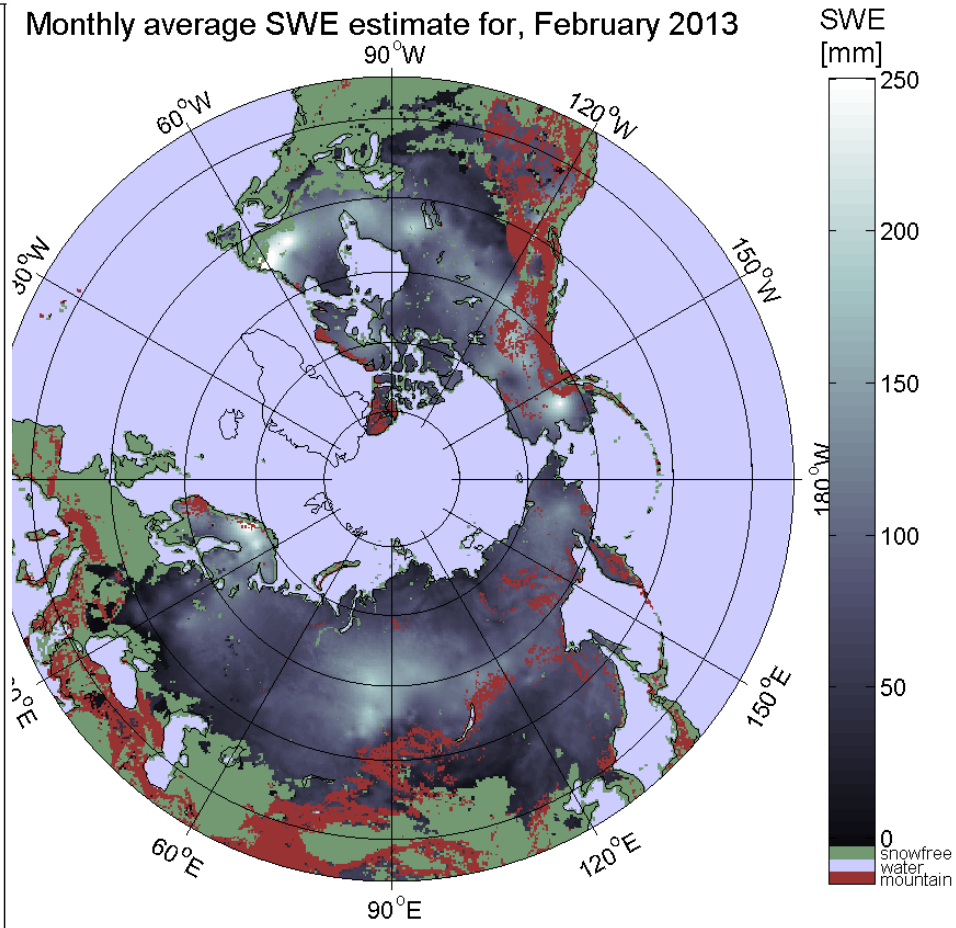
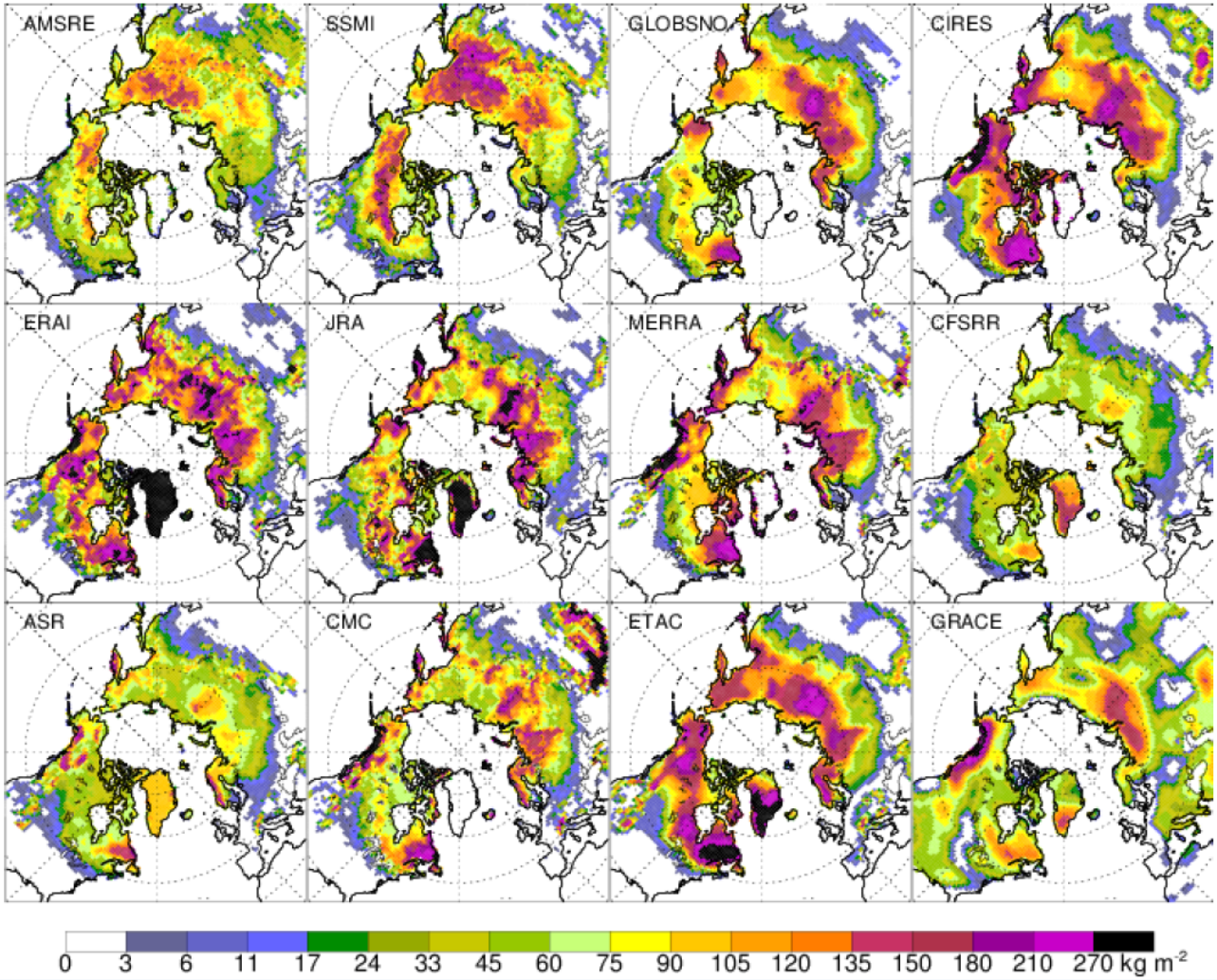
Passive microwave (SSM/I, AMSR-E, etc.) - Retrieval of Snow Water Equivalent (SWE)



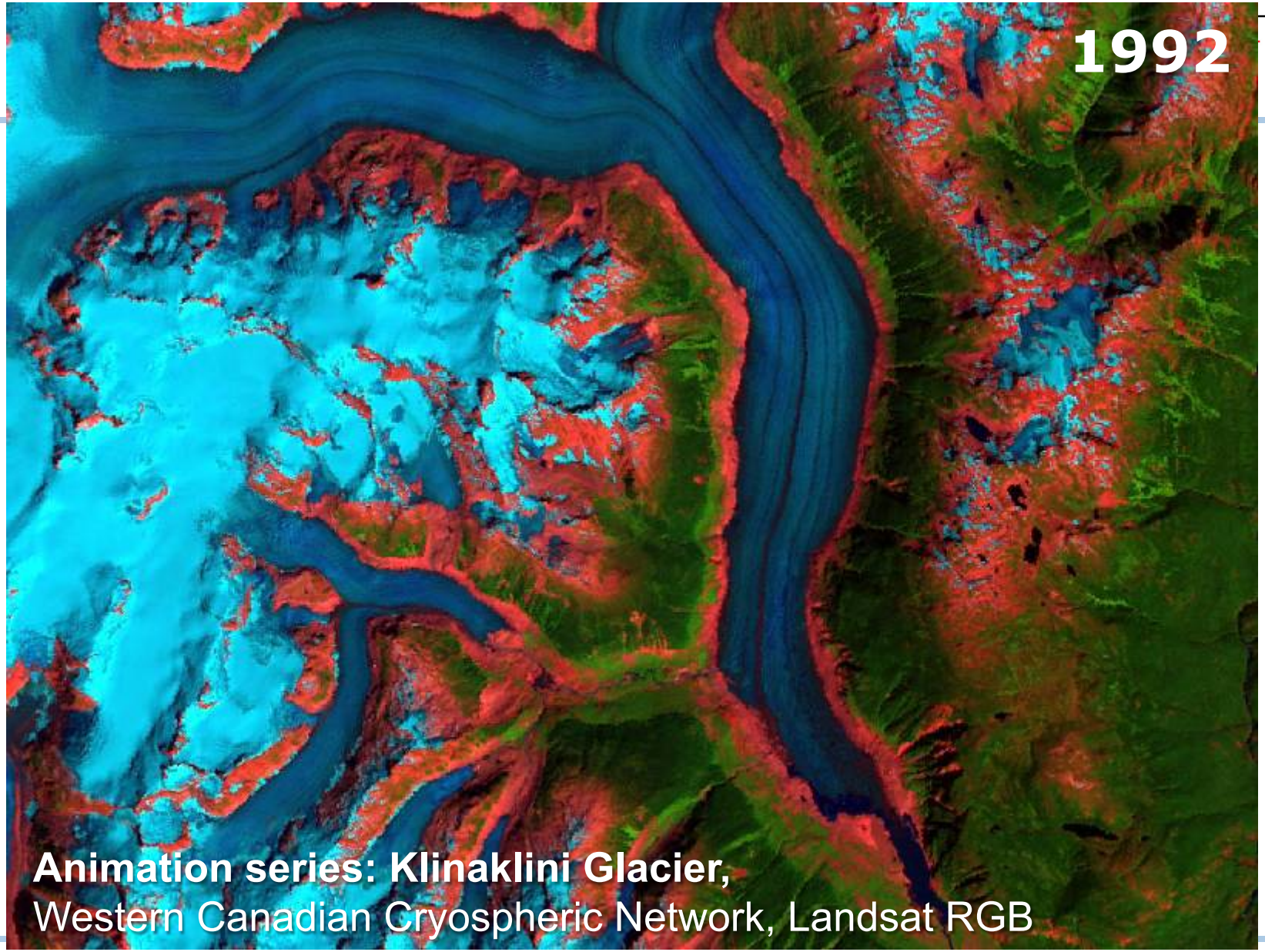


ESA Globsnow SWE

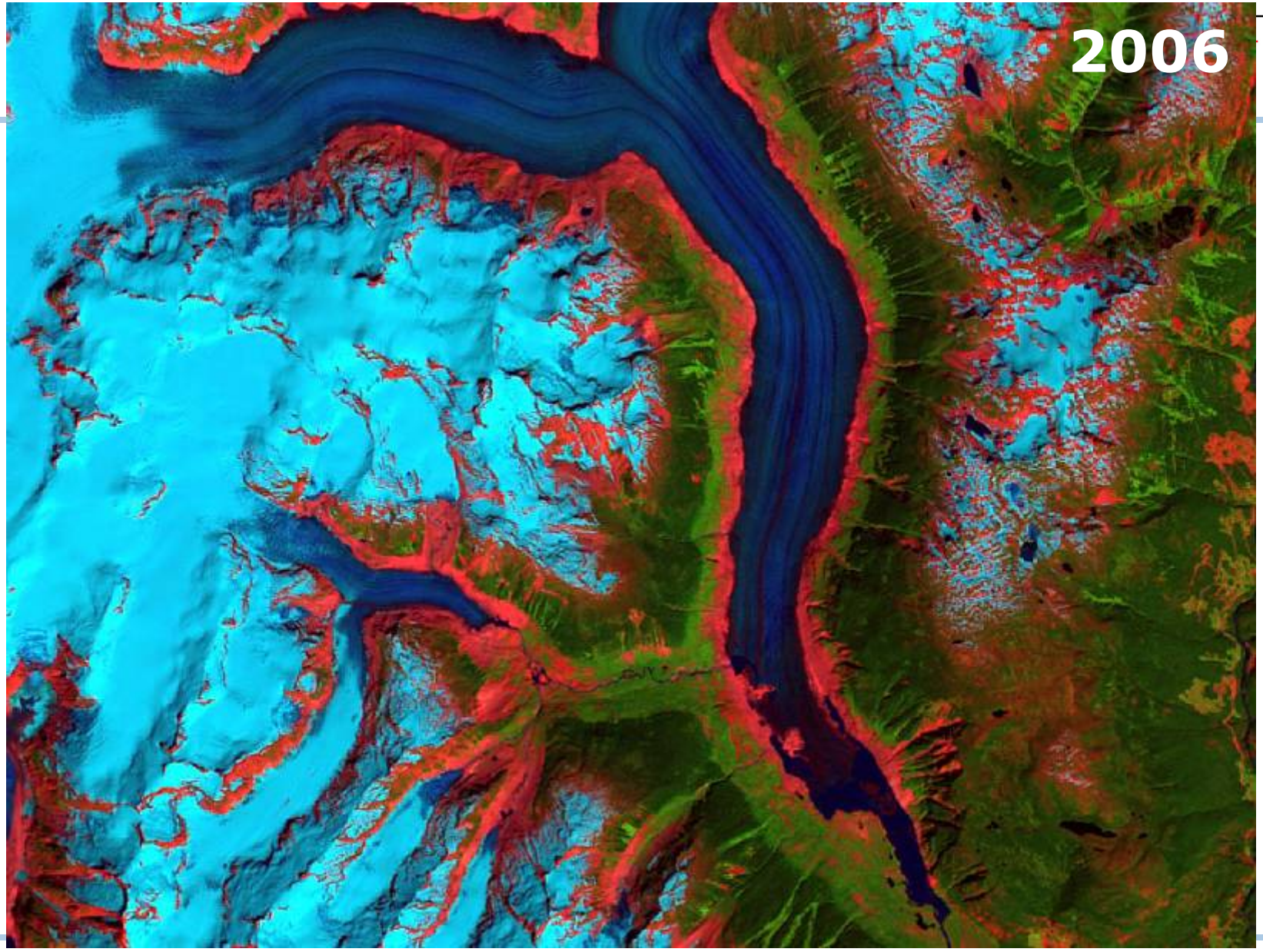
Mean March SWE (~2000-2009)

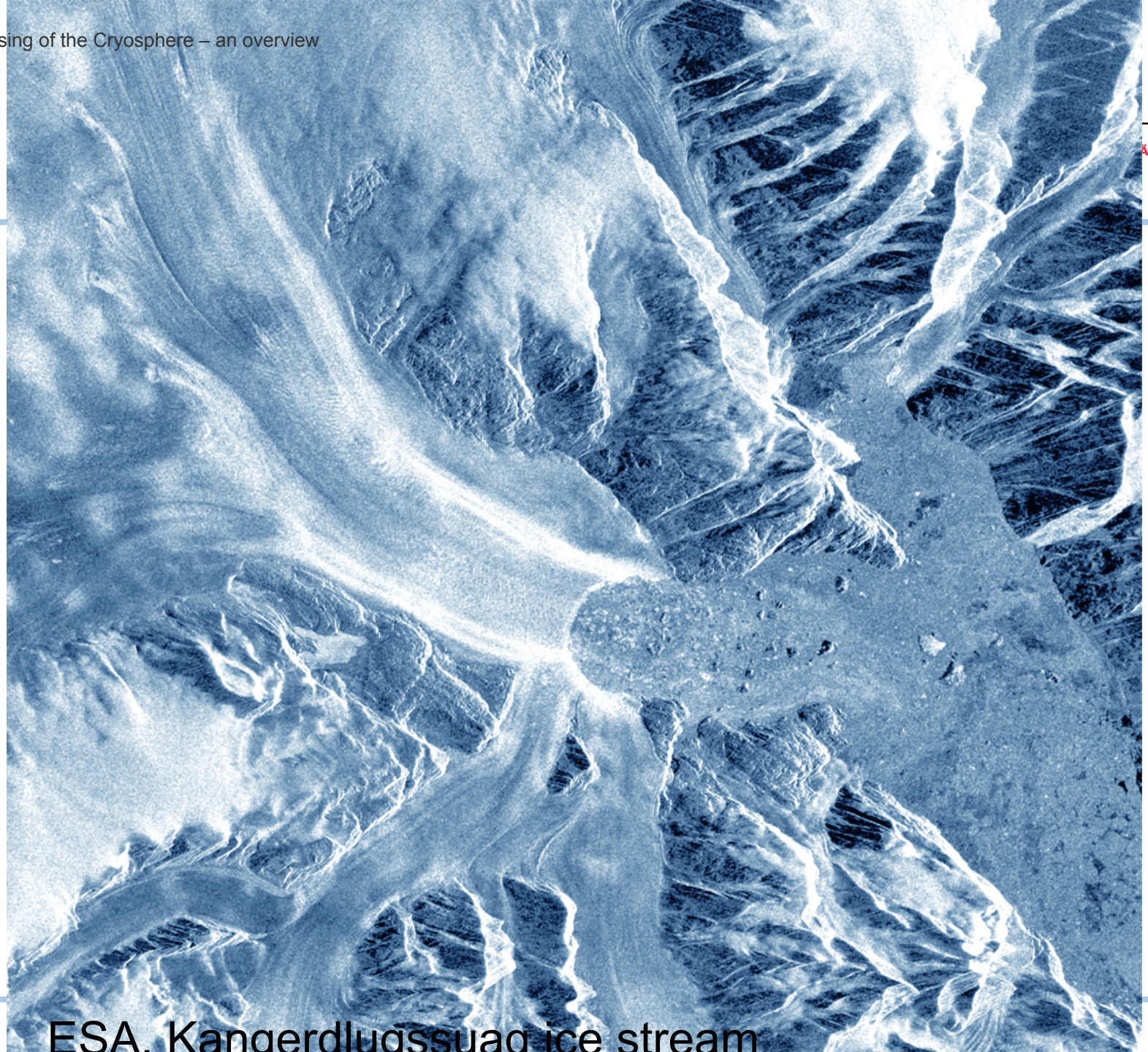


aslater@nsidc.org



Animation series: Klinaklini Glacier,
Western Canadian Cryospheric Network, Landsat RGB

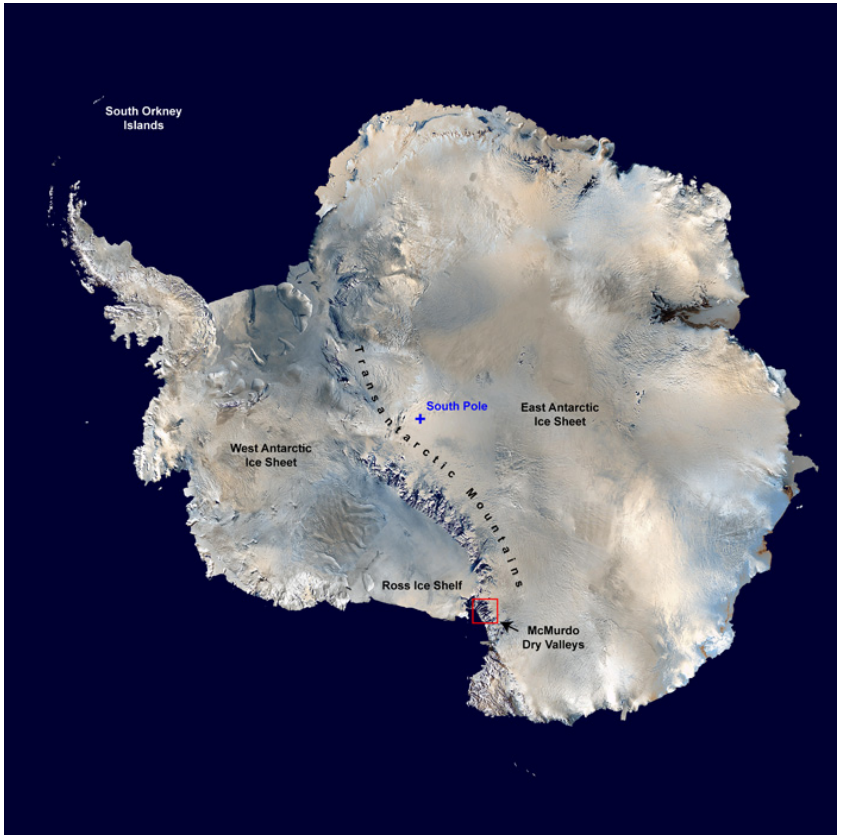

2006



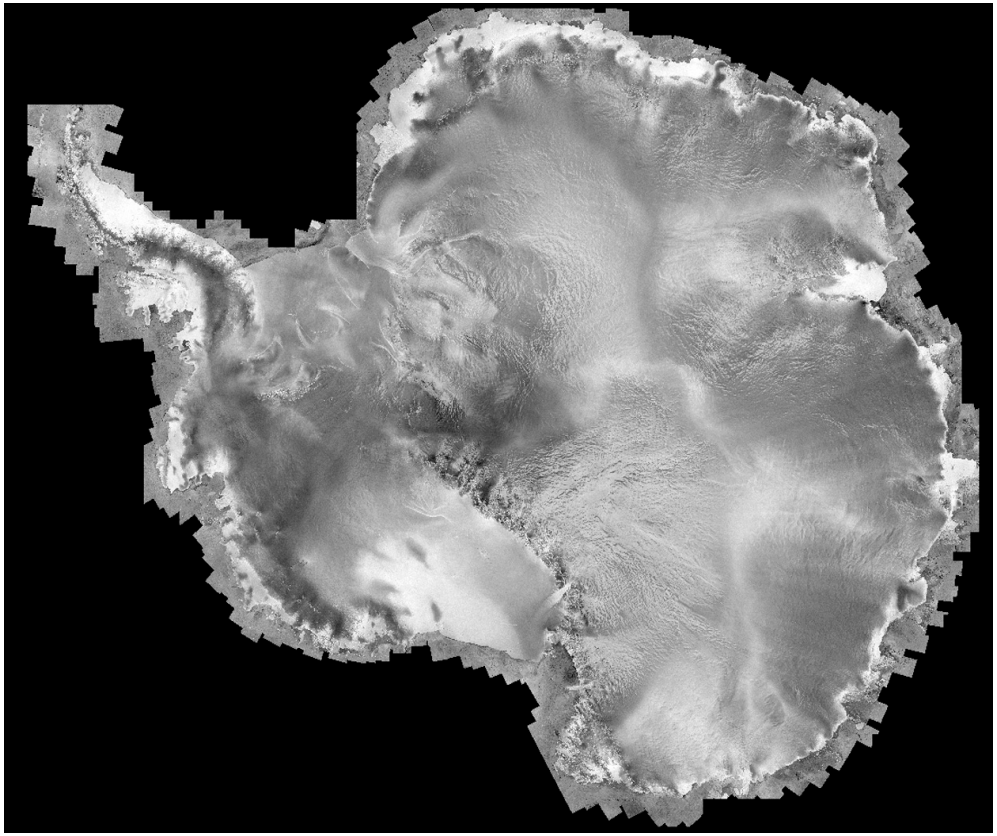
ESA, Kangerdlugssuaq ice stream

Landsat and SAR mosaic of Antarctica

> LIMA (Landsat Mosaic of Antarctica) filled with MODIS



RAMP (SAR Mosaic)



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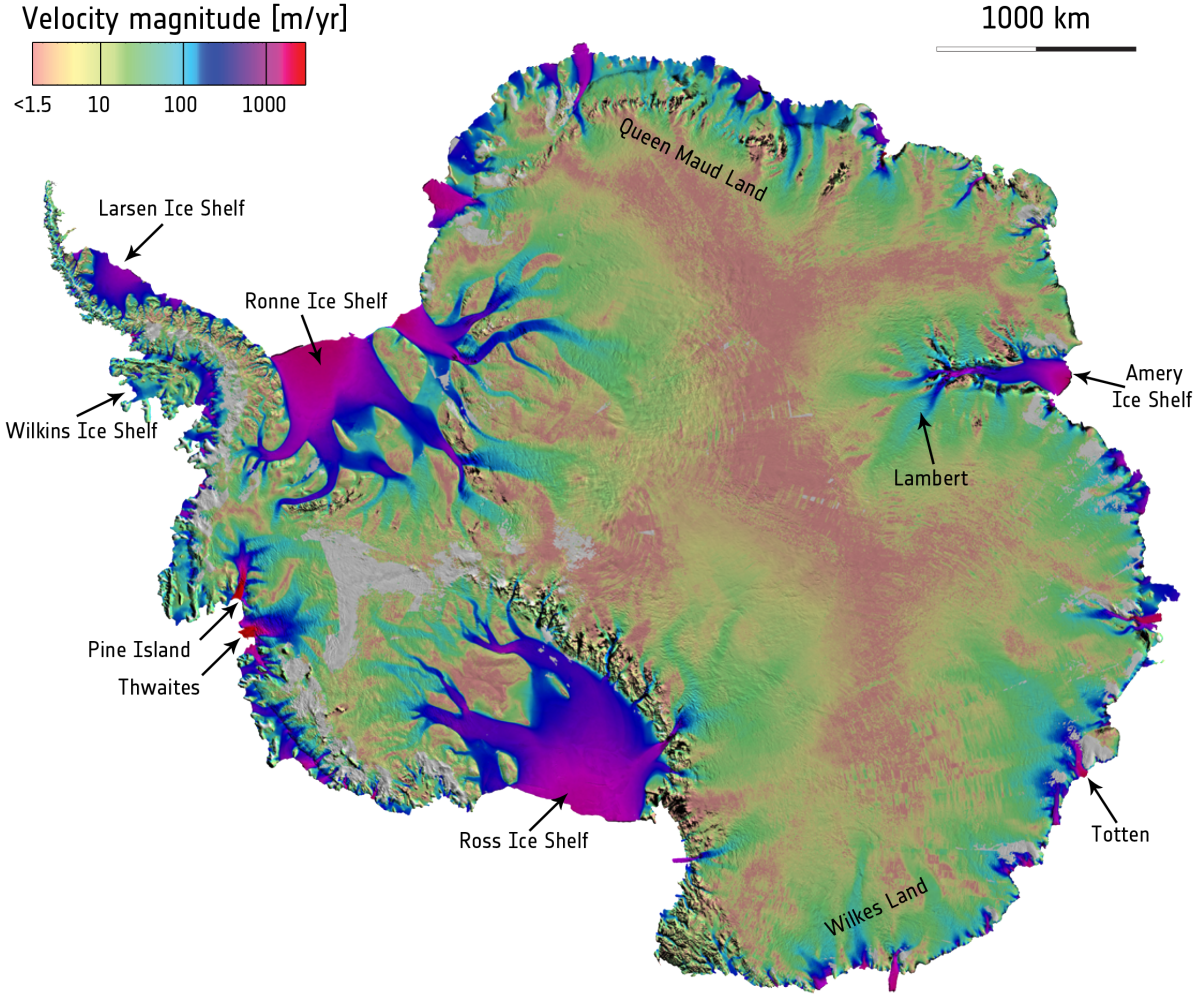
Ice velocity over the entire continent of Antarctica

- Derived from ALOS PALSAR, ESA Envisat ASAR, Radarsat-2, ERS-1 and ERS-2 satellite radar interferometry overlaid on a MODIS mosaic of Antarctica. E.Rignot et al. 2011



Summary

- There are many products available to monitor the extent and behavior of the Cryosphere.
- Every product has its own advantage and limitation. Therefore, the user (climate, hydrology, hazards) needs a clear recommendation for the best product for their application.
- There is a need to include :
  - Probability for retrieval accuracy
  - Confidence interval for product accuracy
  - Error budget shall be included
- There is a need for an inter-comparison and careful validation of snow products for different scales (global – regional).

Outlook

- Future of snow and ice monitoring in Europe
  - ESA Glacier Climate Change Initiative (CCI) is ongoing (phase 2)
  - ESA Globsnow-2 project is terminated for June 2014
  - EU CryoLand will be finished in summer 2014
- After mid-2014 there will be no European project to continue with snow remote sensing beside Eumetsat H-SAF.
  - Time series of SE for climate research will depend on small research projects (regional – continental scale)
  - SE and SWE used for hydrological purpose (i.e. run-off forecast) can not be tailored for these applications. Interaction of user and data provider is needed.
- **There is a strong need to continue snow monitoring in the frame of CCI Snow.**