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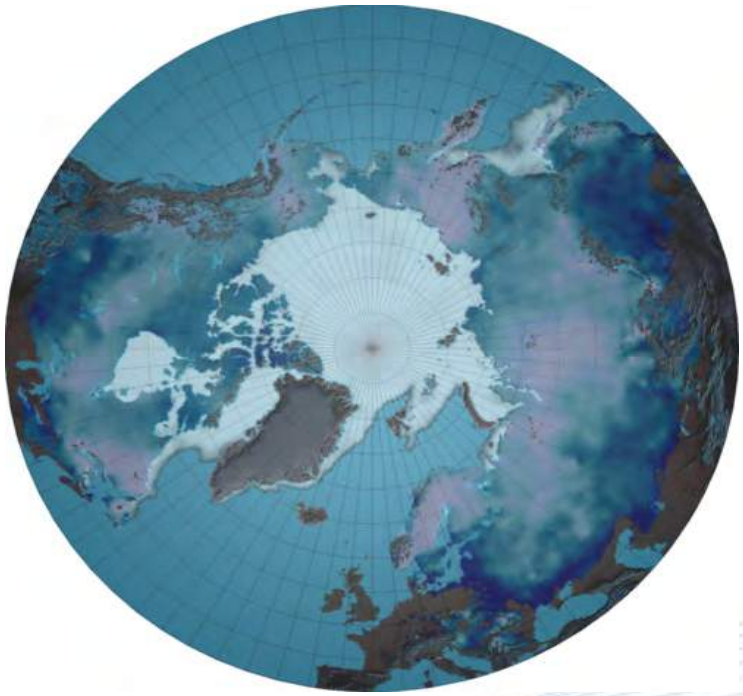
Remote Sensing Capacity in the Arctic



Johanna Tamminen

CGOS Science Day
Helsinki
22.10 2018

Image Credit: media.mnn.com

Image Credit: AP

Image Credit: Katey Walter Anthony/
University of Alaska Fairbanks

Image Credit: sovcomflot

Image Credit: media.mnn.com

Image Credit: AP

Observation needs in the Arctic:

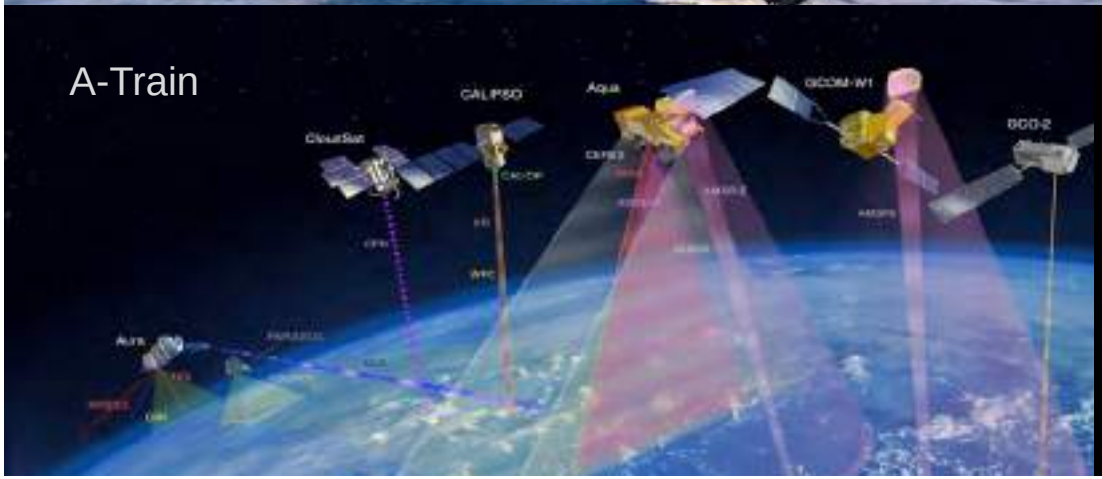
- **Climate** related variables
- **Safety:** communications**,** meteorology, ocean, environment
- **Sustainable development:** energy, CleenTech, land use…

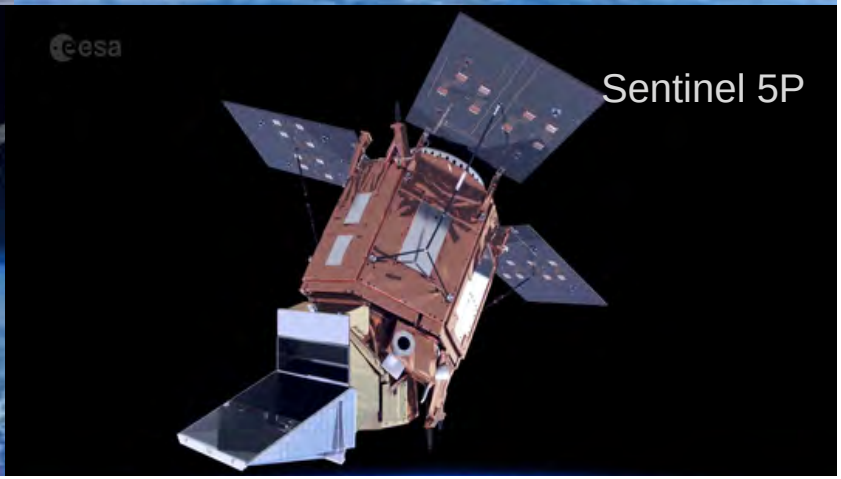
Image Credit: Katey Walter Anthony/
University of Alaska Fairbanks

Image Credit: sovcomflot


SMOS


Sentinel 1

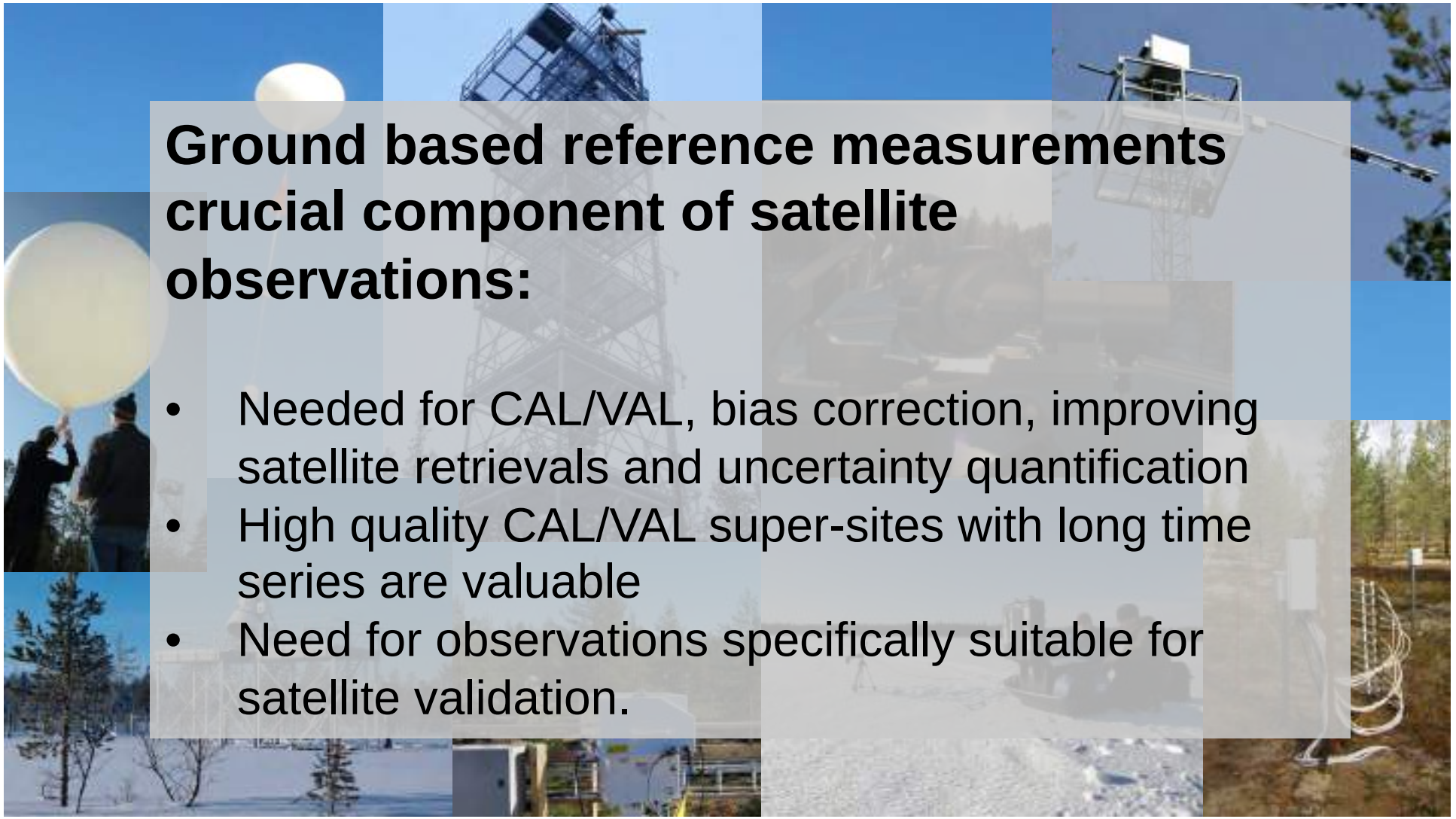

A-Train
CALIPSO
Aqua
GCOM-W1
GCO-2


esa
Sentinel 5P

Satellite observations:

- Coverage, frequency, availability, reliability
- Coordination with ground based observations maximizes the benefits


Images FMI



Ground based reference measurements crucial component of satellite observations:

- Needed for CAL/VAL, bias correction, improving satellite retrievals and uncertainty quantification
- High quality CAL/VAL super-sites with long time series are valuable
- Need for observations specifically suitable for satellite validation.

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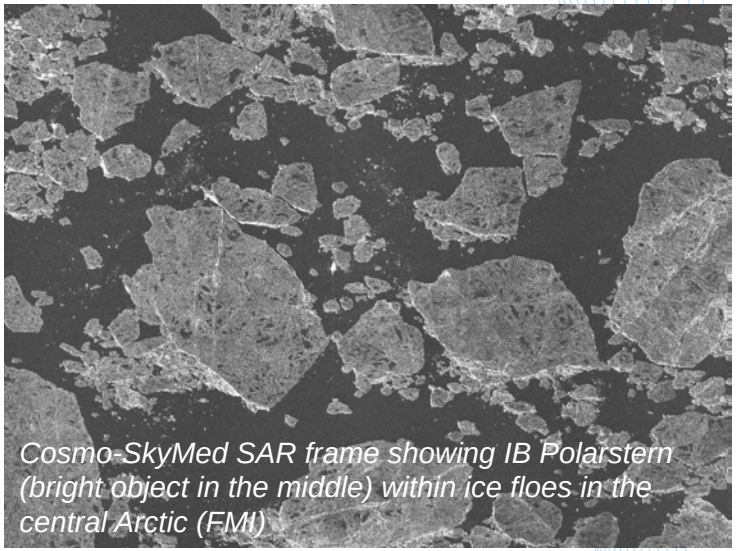
Arctic Sea Ice

Support for operations in ice

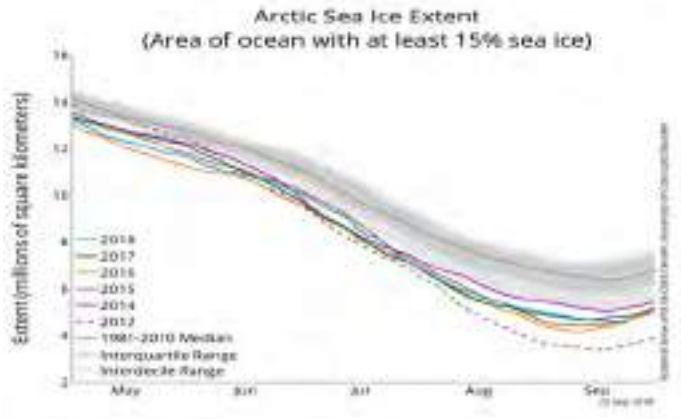
- (Almost) completely based on Satellite SAR
- Ice services benefit from more data

Climate research

- Call for long time series
- Concentration and extent measured using passive microwave observations.



Cosmo-SkyMed SAR frame showing IB Polarstern (bright object in the middle) within ice floes in the central Arctic (FMI)



NSIDC sea ice extent plot based on PMW data

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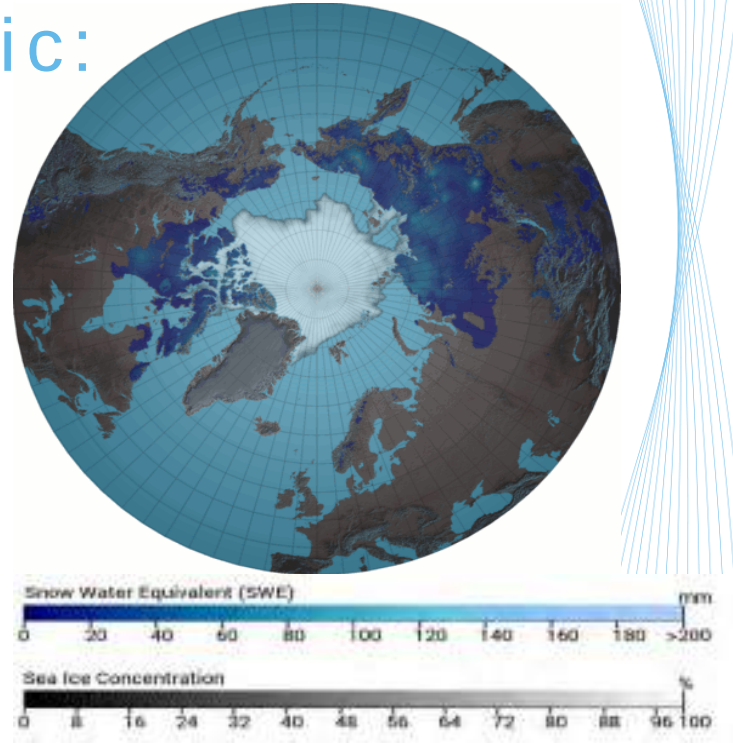
Snow and ice in the Arctic:

Space-borne data-derived information for climate research and NRT-applications

- Snow covered area
- Snow water equivalent
- Hydrology
- Hydropower

- Atmospheric phenomena and their interaction with biosphere and cryosphere



Snow Mass and Ice Cover (12 Oct. 2017-6 Dec. 2017)

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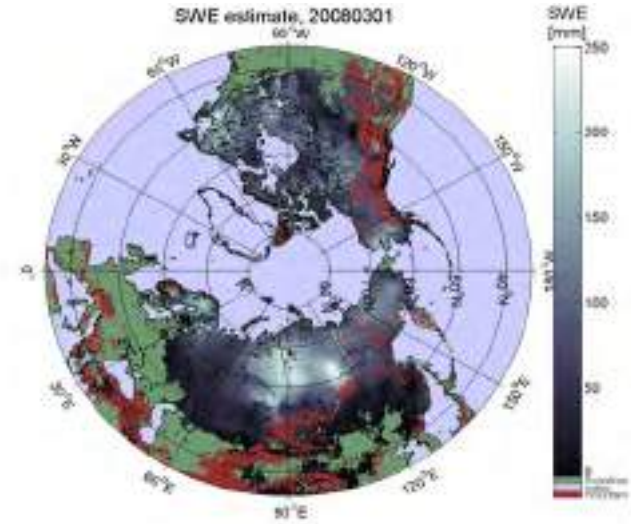
GlobSnow Climate Data Records

Snow Water Equivalent (SWE) & uncertainty

- **Passive microwave radiometer data combined with ground-based synoptic snow observations in variational data-assimilation**
- 25 x 25 km grid; daily, weekly, monthly products
- **Hemispheric data record 1980 – 2018 (and onwards)**

Snow Extent (SE) & uncertainty

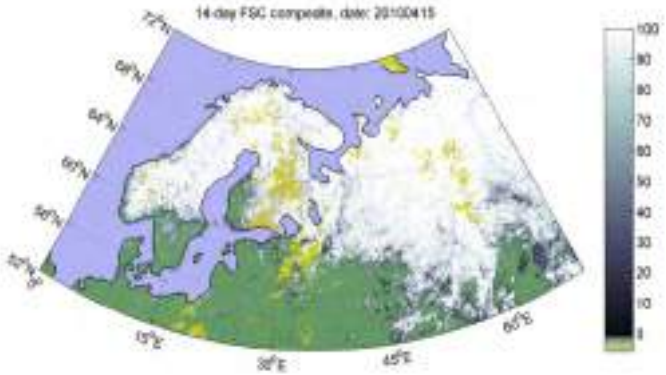
- Optical sensors, mitigation of forest cover and clouds.
- 0.01° (~1 km) products starting 1995

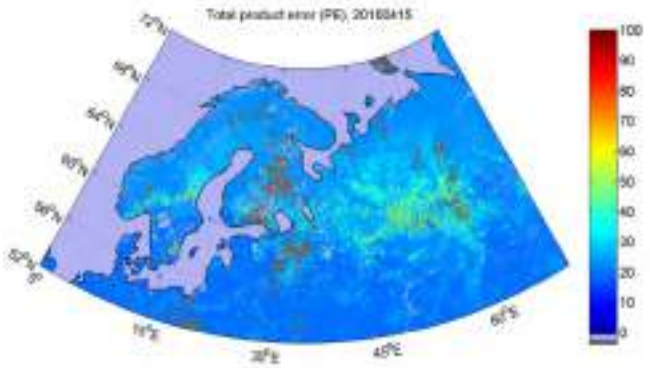


Takala et al., 2011

GlobSnow 25 km Hemispheric SWE product

GlobSnow Snow Extent as Fractional Snow Covered area (0.01°, 14-day composite)





Pulliainen et al., TGRS, 1999
Pulliainen & Hallikainen, TGRS, 2
Metsämäki et al., 2005 Pulliainen, RSE, 2006
Metsämäki et al., 2012 Lemmetyinen et al., TGRS, 2010
Salminen et al., 2013 Lemmetyinen et al., TGRS, 2011
Metsämäki et al., 2015 Takala et al., TGRS, 2011
Salminen et al., 2018 Takala et al., JSTARS 2016

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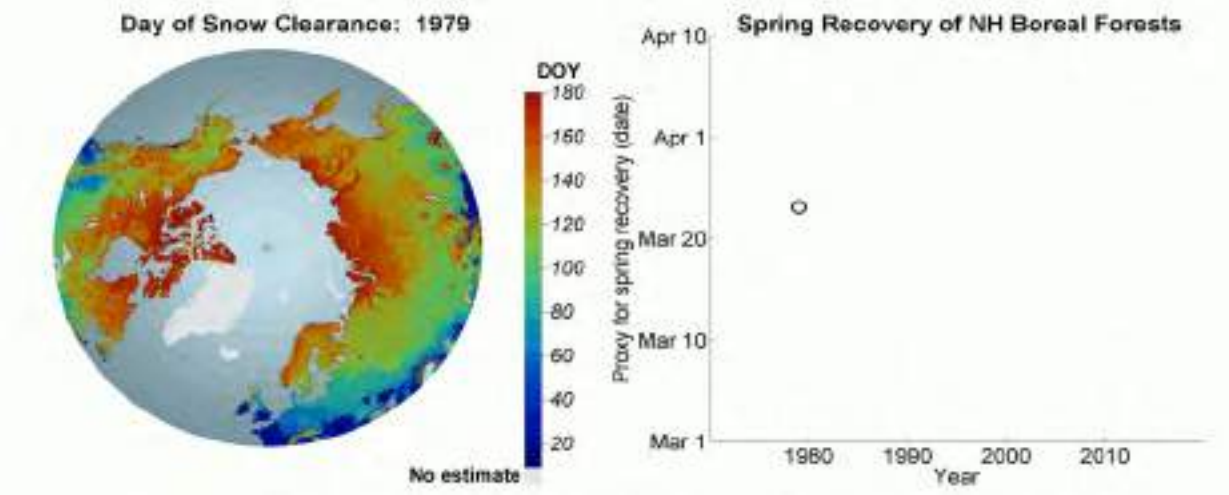
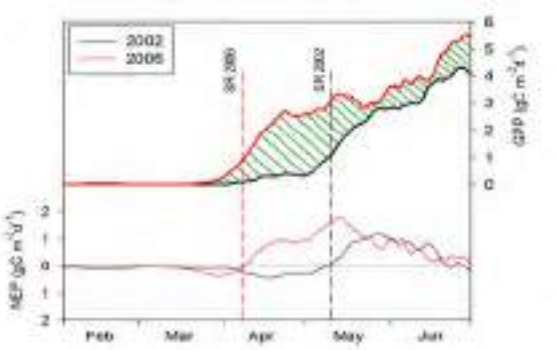
Carbon Cycle: Earlier spring has increased carbon uptake in boreal forests

Pulliainen et al., PNAS, 2017



Snow clearance date from passive microwave observations (Takala et al., 2009)

Trend of boreal forest Spring recovery 1979-2015 estimated from snow clearance



Relation between spring recovery date (SR) and carbon uptake of boreal forests in terms of GPP (thick lines) and NEP (thin lines).

- 38 years of satellite data shows that the spring recovery has occurred earlier by 2 days / decade.
- Increase in springtime cumulative GPP of carbon was 4-7% per decade

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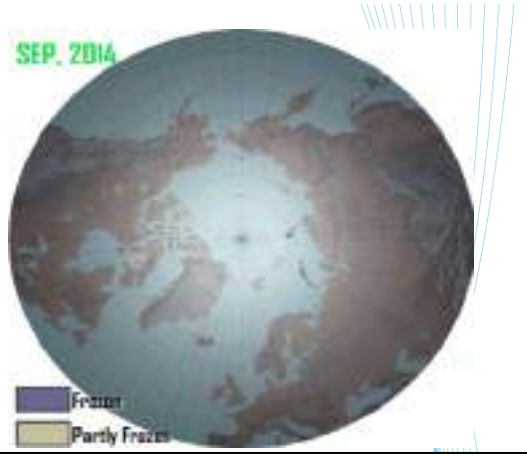
Soil Freeze/Thaw product

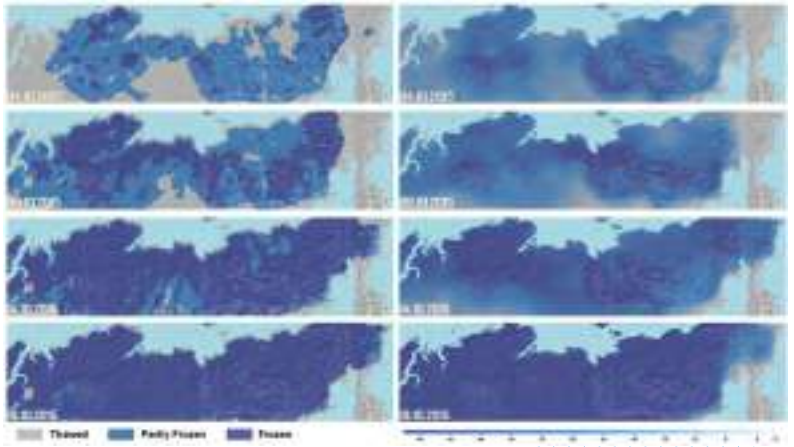
- **F/T needed to understand exchange processes between Earth's surface and atmosphere and to improve weather and climate models**

- Daily information on soil freeze/thaw state based on SMOS satellite observations

- Spatial resolution: 25x25km (EASE grid)
- Three levels: "frozen", "partially frozen", "thaw"
- Current dataset: 2010 – 2017 => operational product under development



Soil state for winter period 2014-15



Soil freezing in Siberia (left), and a 5-day cumulative surface temperature sum (ECWMF) an example for October 2015

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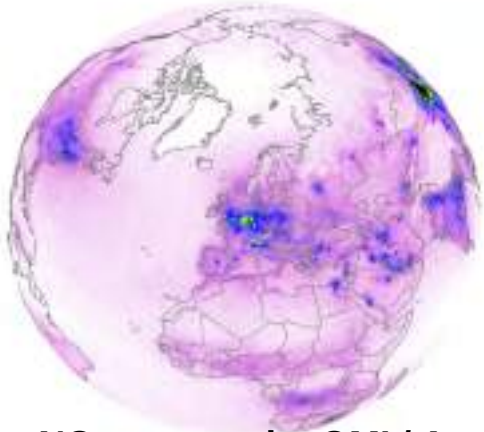
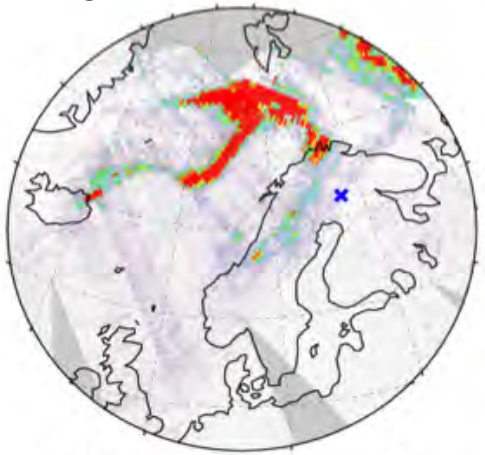
Air Quality: safety, health, tourism, CleenTech

- Spectral UV-VIS observations provide information of ozone layer, air quality including volcanic eruptions, air pollution emissions and transport of air pollution

- Challenges in cloudy conditions and low sun.
- Improved interpretation of satellite observations in challenging conditions (snow, clouds) would be useful.



NO_2 as seen by OMI / Aura
Fig. Sundström, FMI.



SO_2 emissions from the Iceland eruption 10.9. 2014. Fig: Ialongo, FMI.

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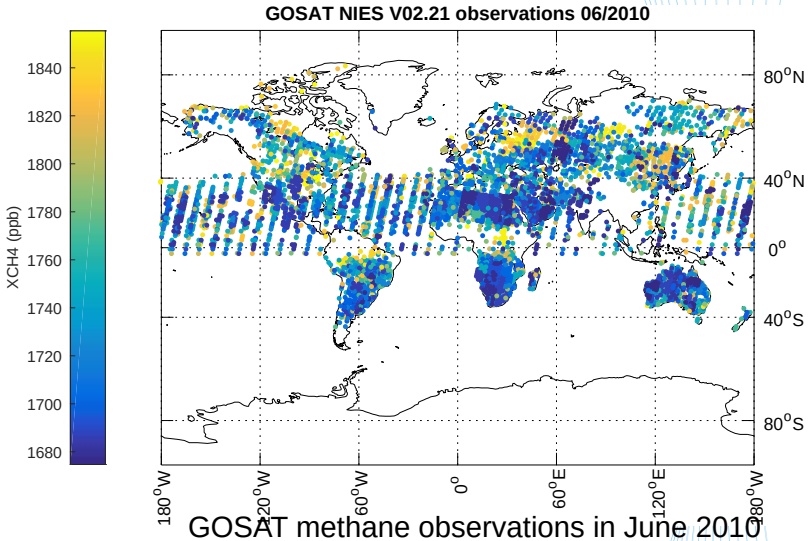
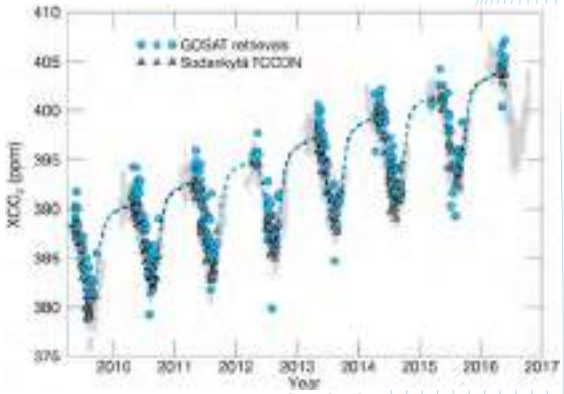
Greenhouse gas observations using SWIR

- Short wave infrared observations best suited for estimating sources and sinks of greenhouse gases**: carbon dioxide and methane**
- High latitudes challenging due to frequent clouds and low sun in winter time.

- Observations at present sparse, 90% rejected due to clouds
- Anthropogenic CO_2 mission studied by ESA / Copernicus.



GOSAT methane observations in June 2010



GOSAT vs Sodankylä CO_2
Figure from Lindqvist et al, 2016

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Highly Elliptic Obit - HEO

The Atmospheric Imaging Mission for Northern Regions: AIM-North

Canadian mission under consideration (Phase 0) consisting of 2 HEO satellites with accuracy and precision linked to GEO Air Quality and GHG missions.
"Quasi-geostationary" coverage of high latitudes (~40-80°N) including the Arctic.
NIR-SWIR Spectrometer: CO_2, CH_4, CO, solar induced fluorescence (SIF), aerosol
UV-Vis Spectrometer: O_3, NO_2, aerosol, BrO, HCHO, SO_2, SIF & more
Imaging ~3x3 km^2 pixels, < 90 min. revisit during daylight, over land, where cloud permits

Frequent imaging yields movie-like views of daytime atmospheric composition!

Overlap with GEO coverage gives intercalibration opportunities beyond LEO

Cloud Imager: for intelligent pointing and real-time day and night, hourly cloud data ~1x1 km^2

www.aim-north.ca
ray.nassar@canada.ca

Environment and Climate Change Canada | Environnement et Changement climatique Canada

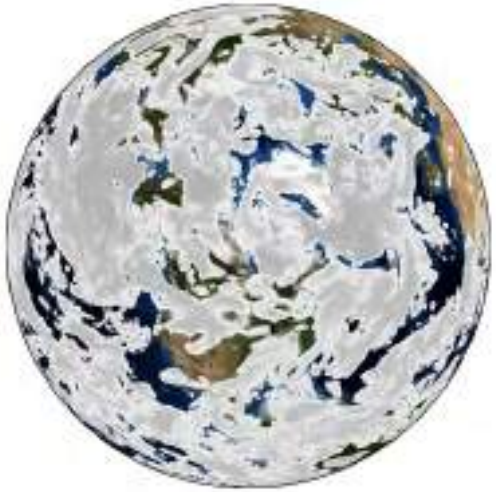
Figure by Cameron MacDonald (U. Waterloo)

Canada

AIM-North Intelligent Pointing

- Current GHG missions reject ~90% of data due to clouds!
- Japan's GOSAT-2 (launching Oct 29, 2018) will use 'intelligent pointing' from LEO
- AIM-North plans to use a small low-cost cloud imager (< 10 kg) to inform pointing and provide real-time cloud data for other applications
- From the HEO or GEO vantage point, essentially every location is cloud-free at some time, and there is typically somewhere cloud-free to view at any time
- Smarter pointing could focus on clear regions or just events/regions or interest

MERRA2 cloud cover for 2015-06-21 17:30 UT



15 potential Field of View (240x240, 3x3 km^2) positions

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Summary

- Satellite remote sensing is an important component in monitoring and studying Arctic where **climate** change effects are stronger than average.
- Observations are also needed for ensuring **safety** and suppporting **sustainable developments** in the Arctic.
- Coordination with ground based observations is important for maximizing the overall observing capacity.

- Dedicated CAL/VAL observations and activities are a crucial component of satellite observations

- Research and ground based validation needed to improve interpretation of satellite observations at high latitudes, e.g. snow & cloudy conditions.

- Observations from Highly Elliptic Orbit (HEO) would ensure similar service for high latitudes that GEO provides for lower latitudes.


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