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FINNISH METEOROLOGICAL INSTITUTE

# FMI – ARCTIC SPACE CENTRE AND COPERNICUS ACTIVITIES

Jyri Heilimo

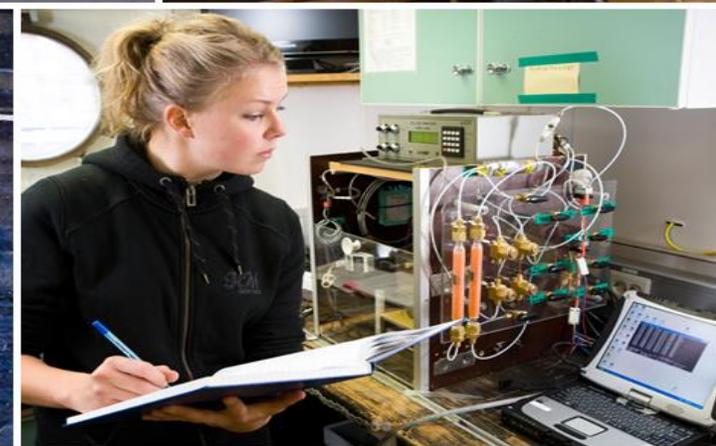
Head of Arctic Space Centre

26.10.2020



# FINNISH METEOROLOGICAL INSTITUTE

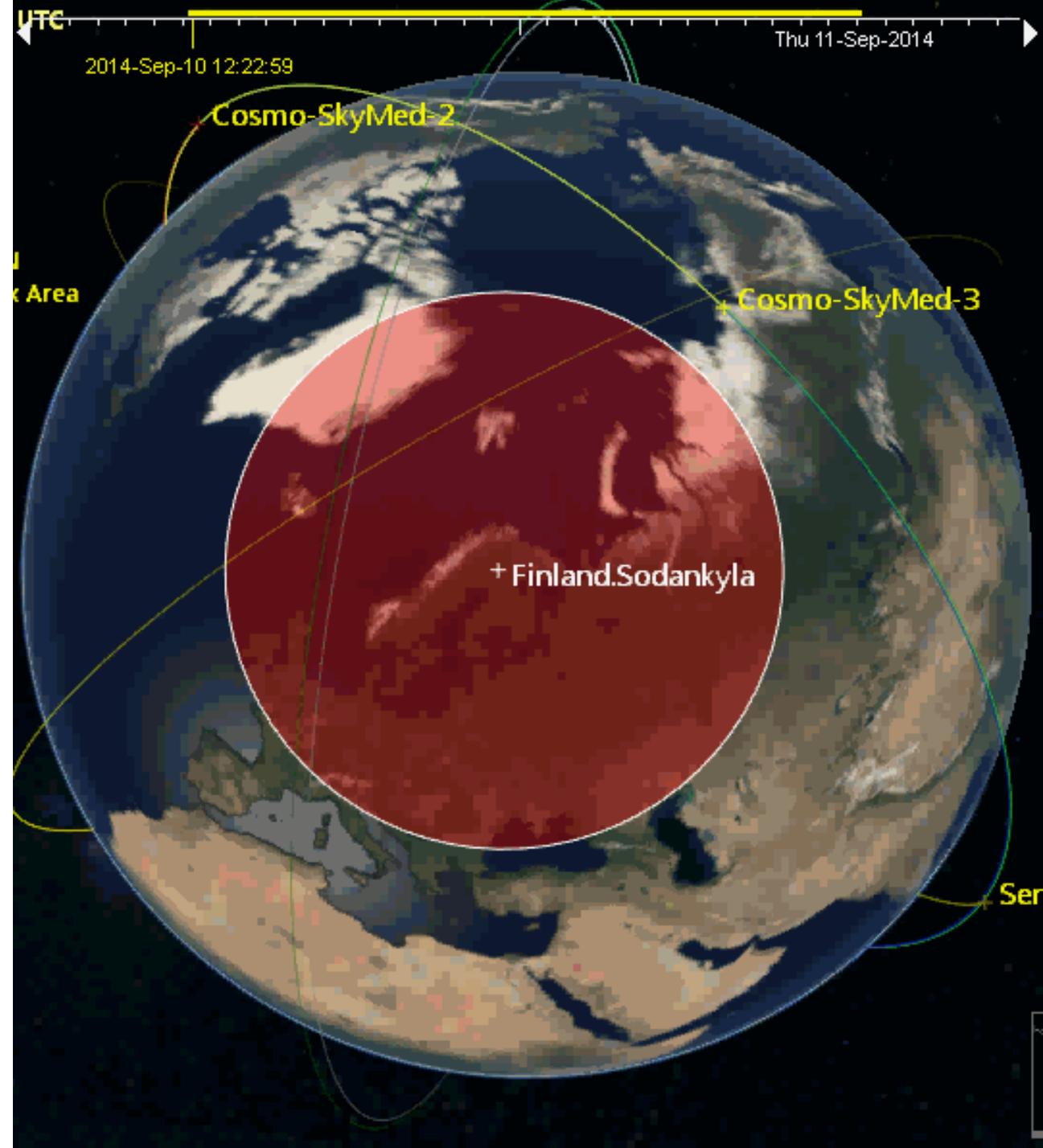
- The Finnish Meteorological Institute (FMI) is a research and service agency under the Ministry of Transport and Communications.
- FMI produces weather services and physical marine services to meet the needs of public safety, transport, businesses and people in the country
- FMI produces sector-related services, particularly aviation weather services, to safeguard national defense and ensure the viability of other operations of the Finnish Defense Forces in both normal conditions and in emergencies and exceptional circumstances



# FMI – ARCTIC SPACE CENTRE

The Arctic Space Centre of the Finnish Meteorological Institute (FMI-ARC) is Finland's primary infrastructure for utilization, calibration and validation of data by Earth Observation (EO) satellites. This includes direct data reception from polar orbiting EO satellites, processing and archiving of satellite data products, and the housing of satellite instrument's ground-based reference systems (e.g. SMOS, OCO-2).

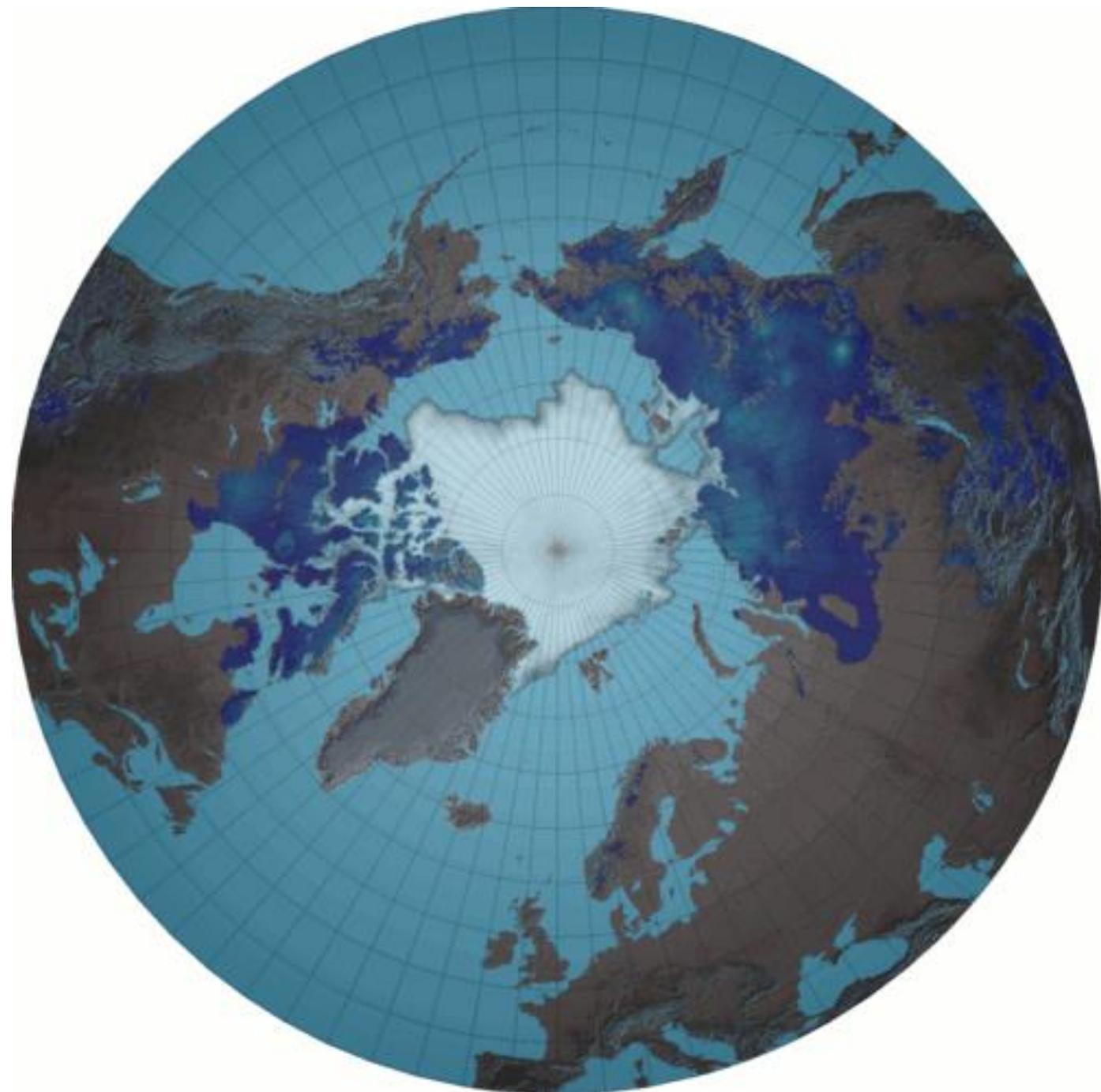
The FMI's Arctic Space Centre operates satellite ground station focusing on fast delivery of remote sensing products. FMI-ARC, located north of the Arctic Circle in Sodankylä lies in an excellent location for receiving data from all polar orbiting spacecraft.



# SNOW AND ICE IN THE ARCTIC

Space-borne data-derived information  
for climate research and near real time  
applications

- Atmospheric phenomena and their interaction with biosphere and cryosphere
- Snow covered area
- Snow water equivalent
- Seasonal frost / thaw
- Permafrost
- Sea ice cover
- Hydrology





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# GROUND STATION SERVICES



# NATIONAL SATELLITE DATA CENTRE

## ESA Sentinel Collaborative Ground Station

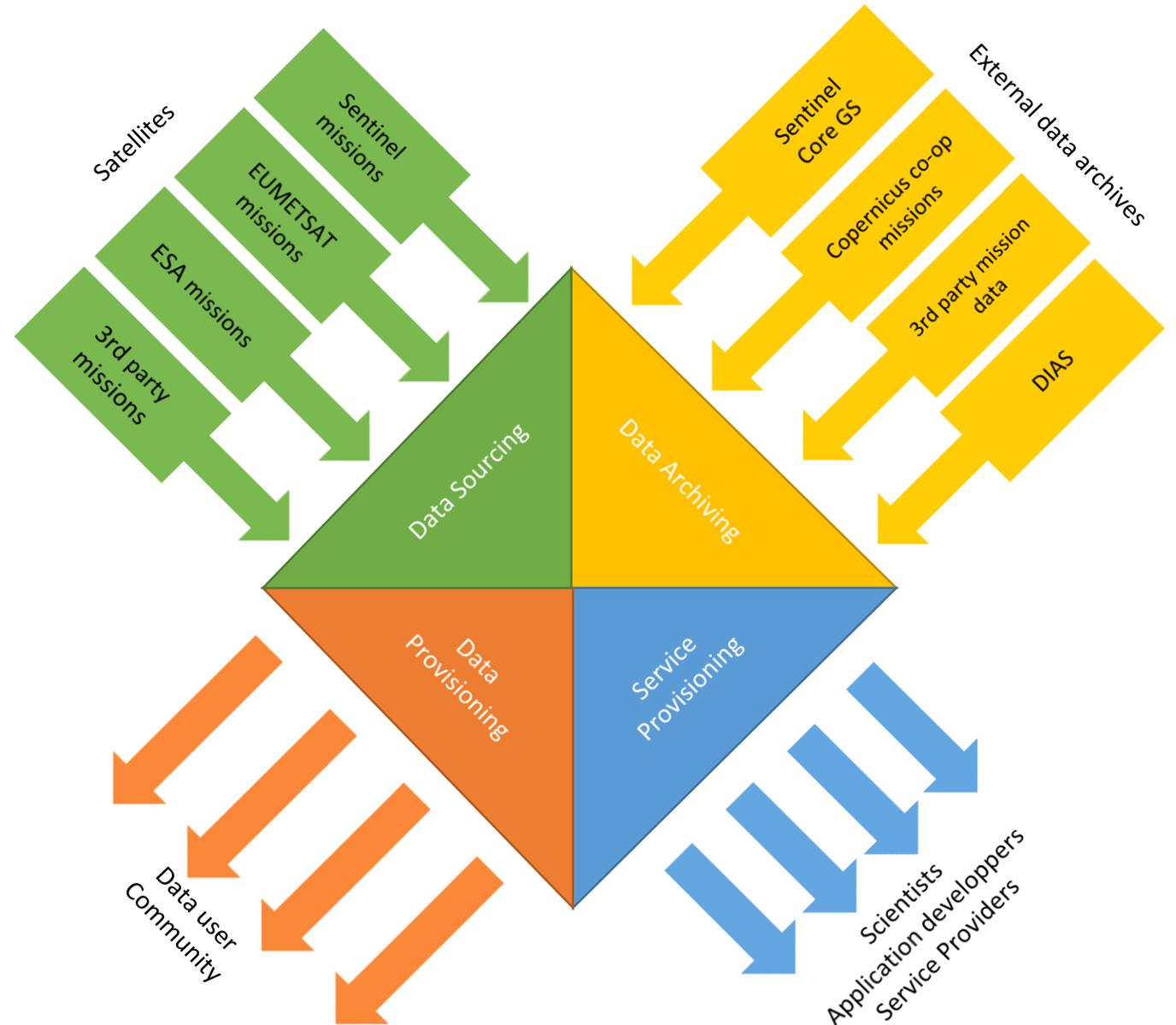
- Local reception of Sentinel-1 Direct Broadcast
- Focus on NRT and Quasi-Real-Time products

## Sentinels' data local mirror site

- Safe long-term archive of scientific data
- Long-term data archive
- Automated data processing lines for specific products
- Bulk processing
- Sentinels data dissemination: <https://finhub.nsdci.fmi.fi>

## Data processing services

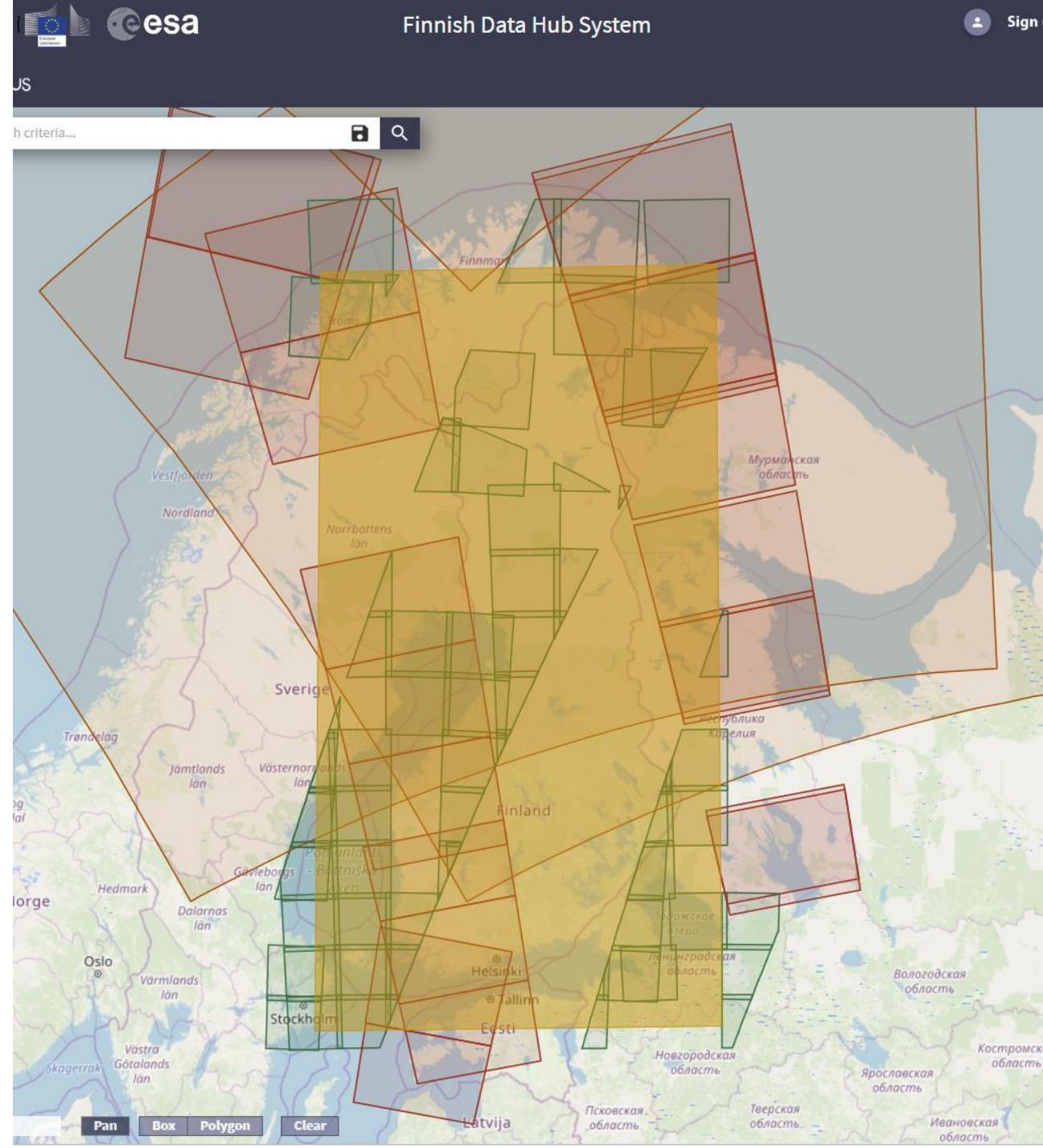
- Virtualization environment for operational product processing
- Hosted processing (IaaS, PaaS)
- Calvalus – Processing Cluster for efficient Remote sensing data storage and processing



# FINHUB

## Finnish Sentinel-data portal

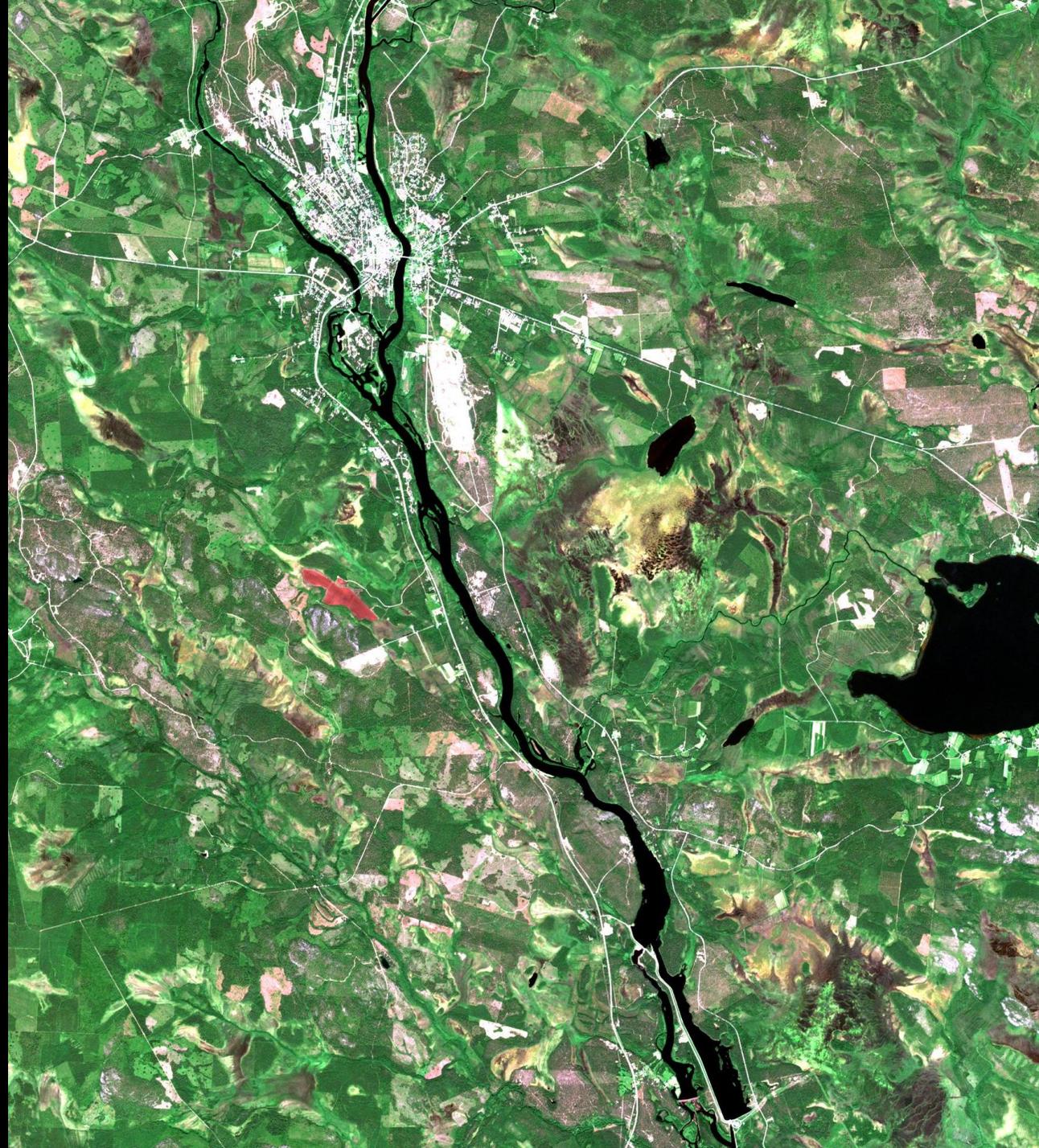
- Sentinels' data dissemination system
- Utilizes the ESA developed DHuS system
  - Same Graphical user interface
  - Same M2M interface (curl)
- No self-registration
  - > Controlled number of users
- No limitation in parallel downloads
- Both graphical user interface (GUI) and machine readable IF (ODATA)
- <https://finhub.nsdcm.fmi.fi>





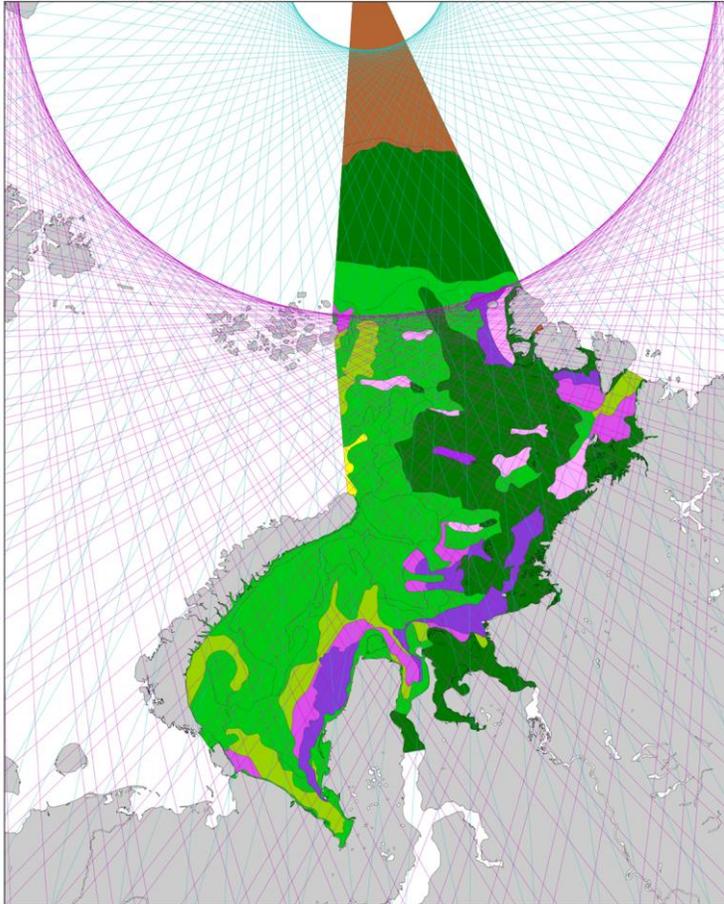
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# COPERNICUS RESEARCH ACTIVITIES

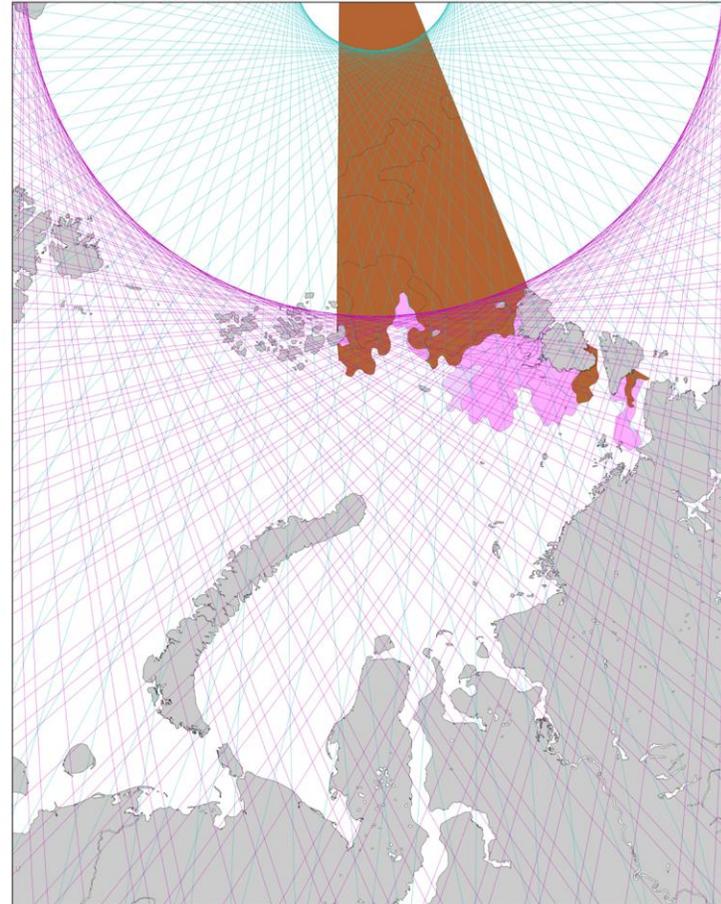


# Support studies for CRISTAL

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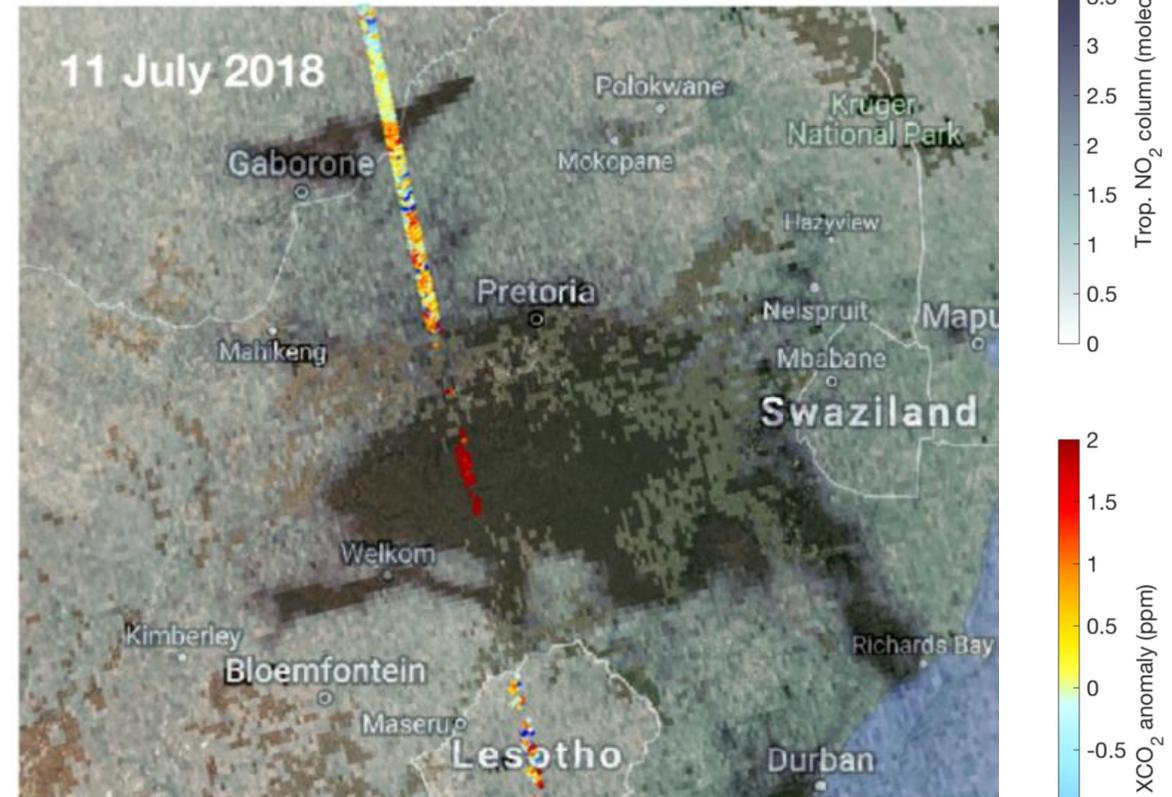
FMI is involved in the preparation for the Copernicus Polar Ice and Snow Topography Altimeter mission.

FMI's experience in ice charting has been used in assessing different CRISTAL orbit candidates. Figures show a typical winter (left) and summer (right) ice chart for Kara Sea with CRISTAL (cyan) and Sentinel-3 (magenta) orbits overlain. Summer figure underlines the importance of high inclination orbit of CRISTAL since most of the ice lies north of the Sentinel-3 coverage.



# Research supporting preparations for the high-priority candidate mission CO2M: Anthropogenic CO<sub>2</sub> analysis using existing satellites

- We participate in the **EU CoCO2** consortium that builds towards the CO<sub>2</sub> Monitoring and Verification Support Capacity.
  - FMI tasks: plume analysis from atmospheric satellite data, greenhouse gas inverse modelling.
- Other related ongoing projects:
  - **ESA DACES** (2018–2022): detection of anthropogenic CO<sub>2</sub> emissions from space
  - **Academy of Finland CitySpot** (2020–2024): developing methods for a reliable estimation of CO<sub>2</sub> over urban and polluted areas. Compile a database of urban emission signatures.



**11 July 2018, South Africa:** Positive OCO-2 XCO<sub>2</sub> anomalies indicate higher CO<sub>2</sub> (yellow-red colors) over the plumes with the largest NO<sub>2</sub> enhancements from S5P TROPOMI (dark gray areas). Figure: J. Hakkarainen, FMI (Hakkarainen et al., 2019).



# SCIPPER: Shipping Contributions to Inland Pollution Push for the Enforcement of Regulations

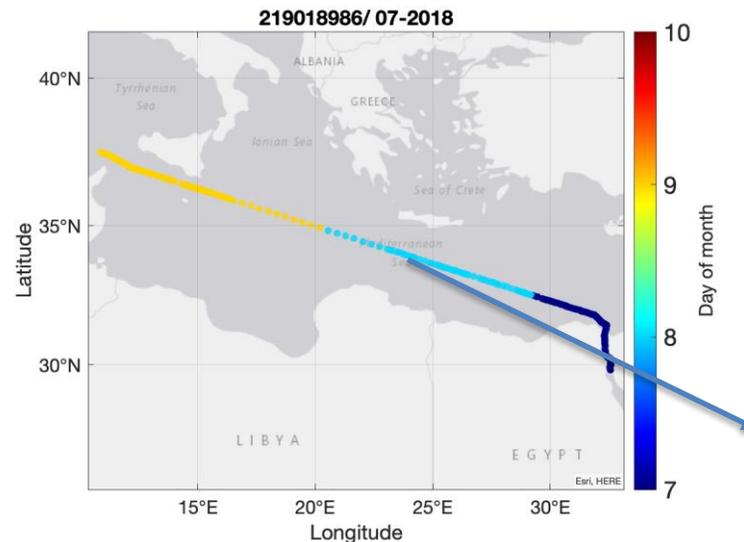
**Project aim:** deploying state-of-art and next-generation measurement techniques to monitor emissions of vessels under their normal operation.

**Copernicus Sentinel 5p TROPOMI** observations are used in SCIPPER to study NO<sub>2</sub> signatures from ships within the European sea areas.

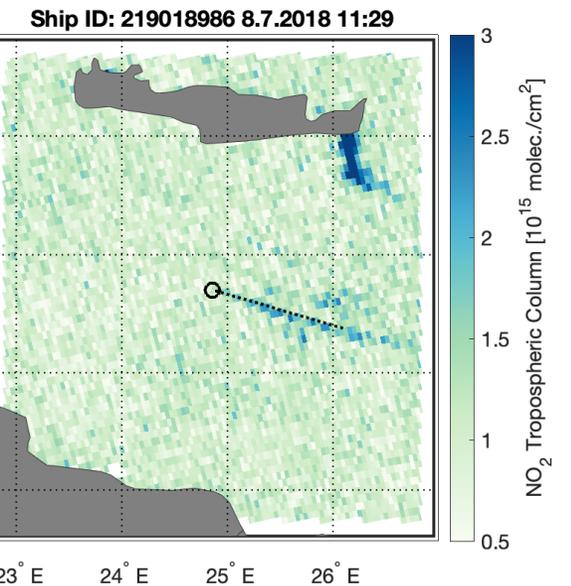
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## Ship route



## TROPOMI NO<sub>2</sub>





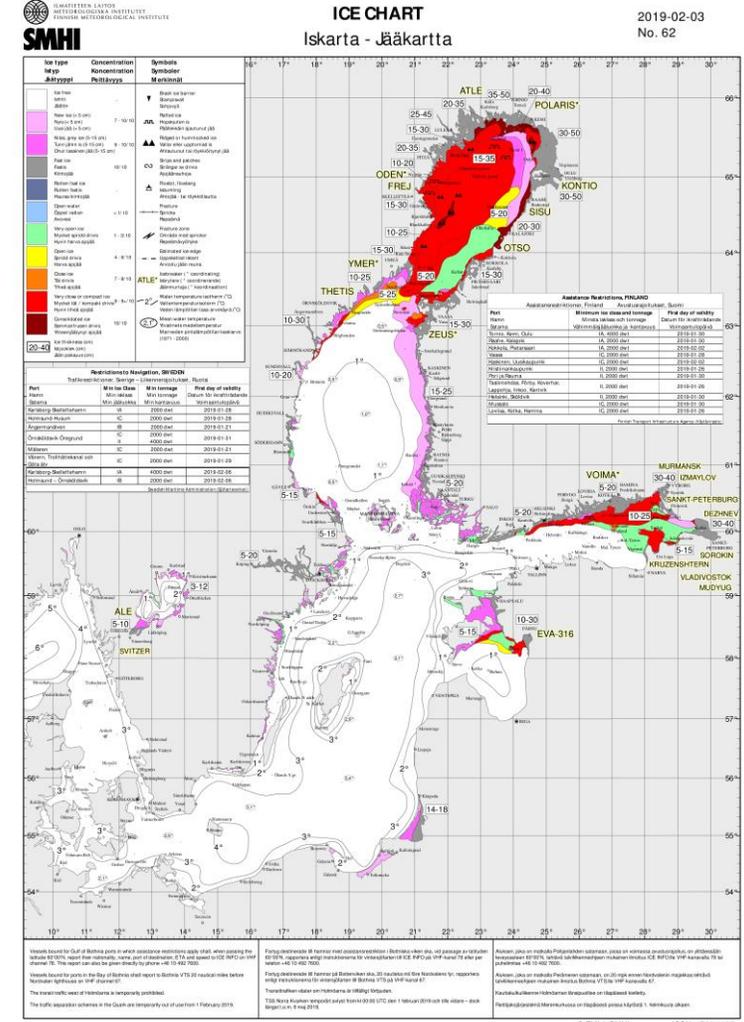
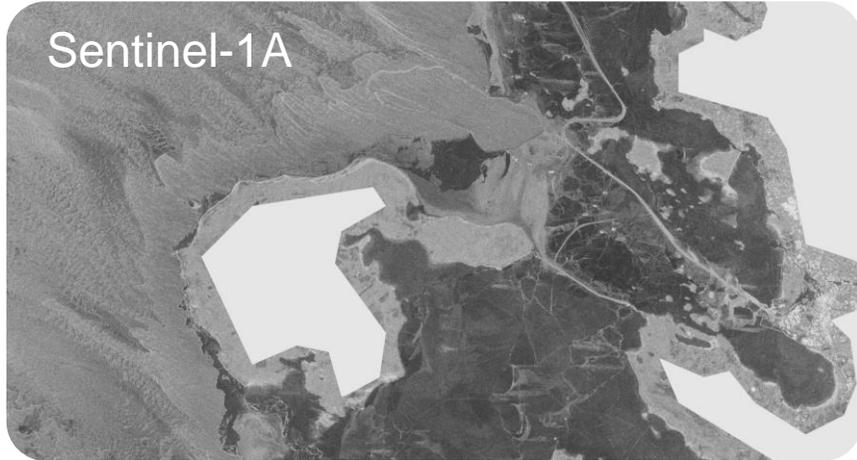
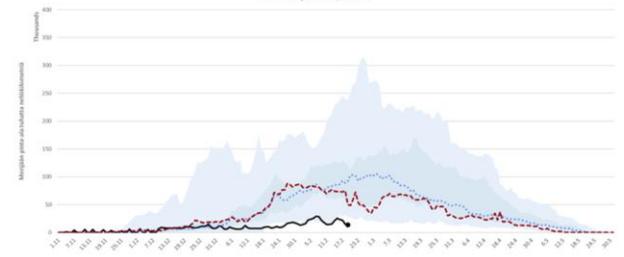
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# OPERATIONAL SERVICES UTILIZING COPERNICUS DATA



# Finnish Ice Service

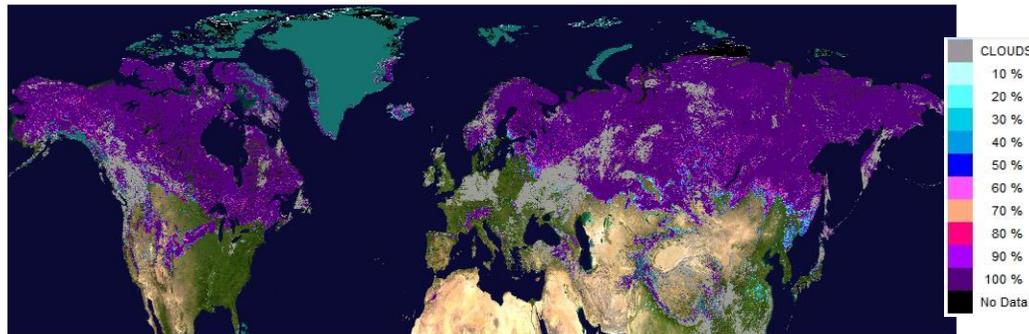
- Finnish ice service is providing sea ice information to the users to ensure safe and efficient sea transportation
- Main products are daily ice chart and report, forecasts and statistics.
- Several hundreds of Sentinel-1, Sentinel-2, Radarsat-2, COSMO-Skymed and Terrasar-X images are analysed and provided in near real time to ice breakers annually.



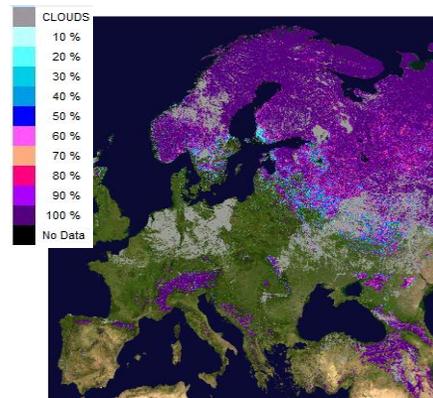
# Copernicus Global Land Service

## – Cryosphere theme led by FMI

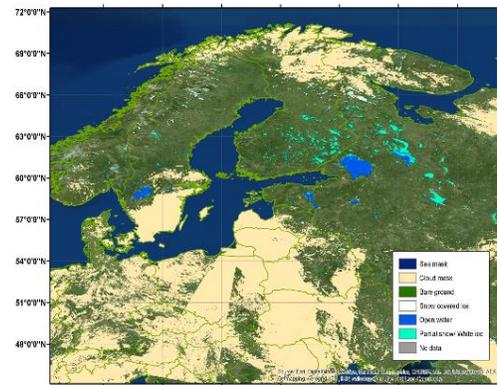
**Daily NRT: Snow Cover Extent, Snow Water Equivalent, Lake Ice Extent**



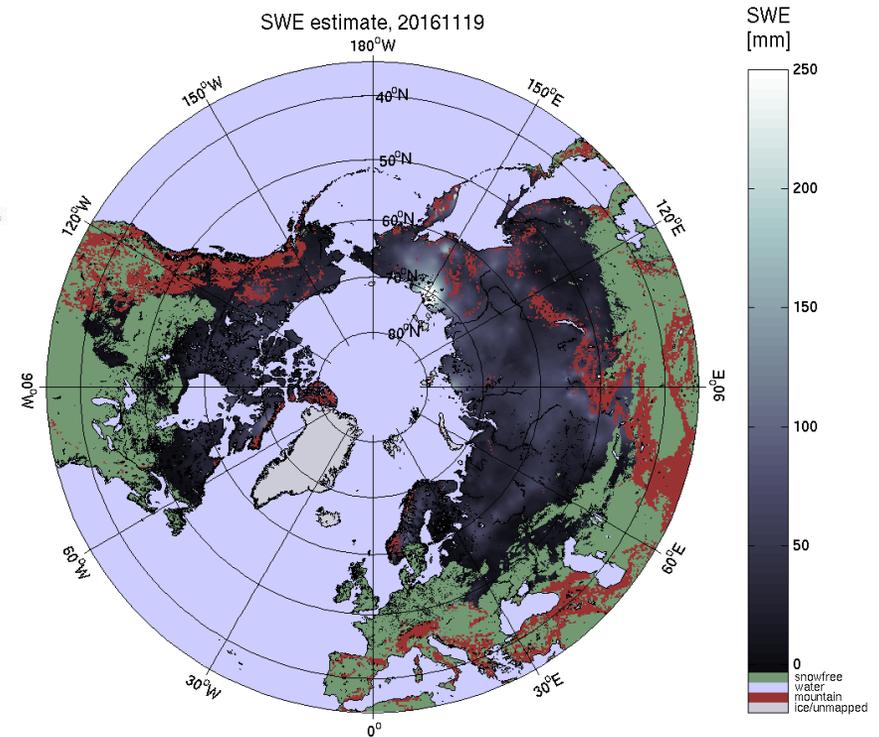
Northern-Hemisphere Snow Cover Extent (SCE)



Pan-European Snow Cover Extent (SCE)



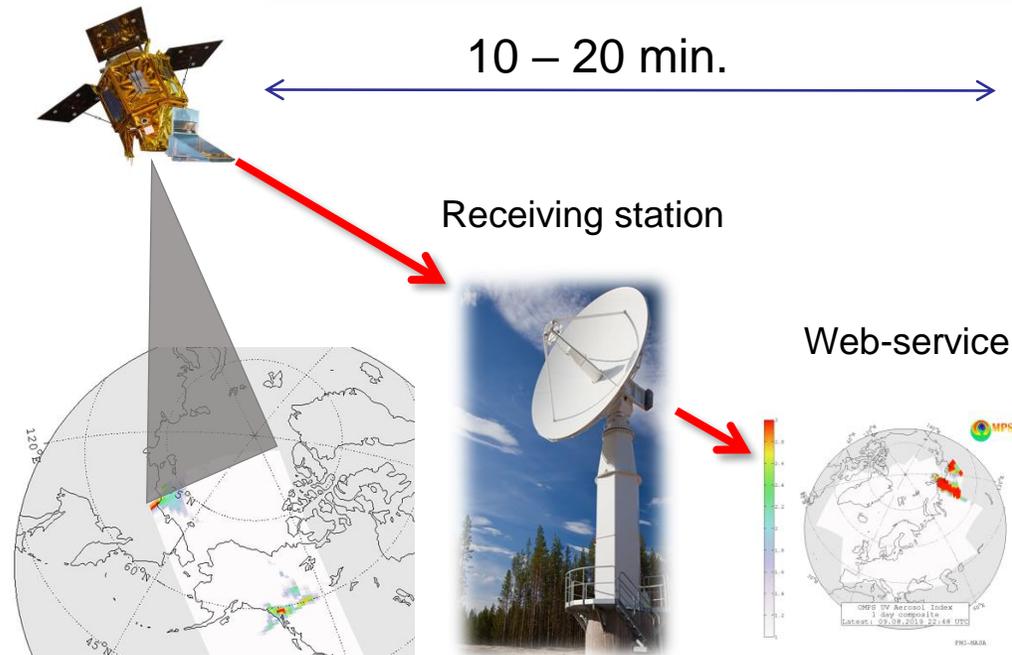
Lake Ice Extent (LIE) for Baltic Sea area



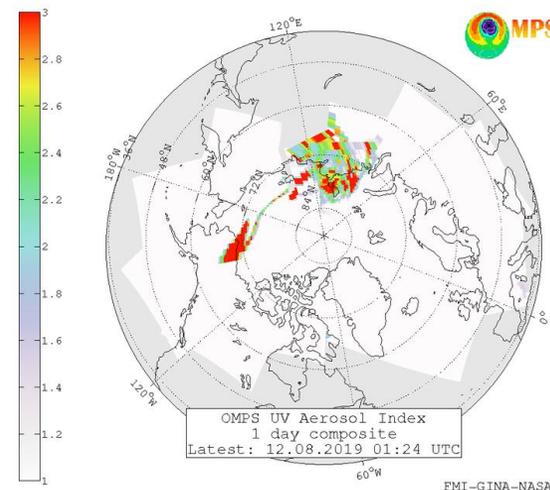
# ATMOSPHERIC DATA PRODUCTS AND SERVICES

**SAMPO**

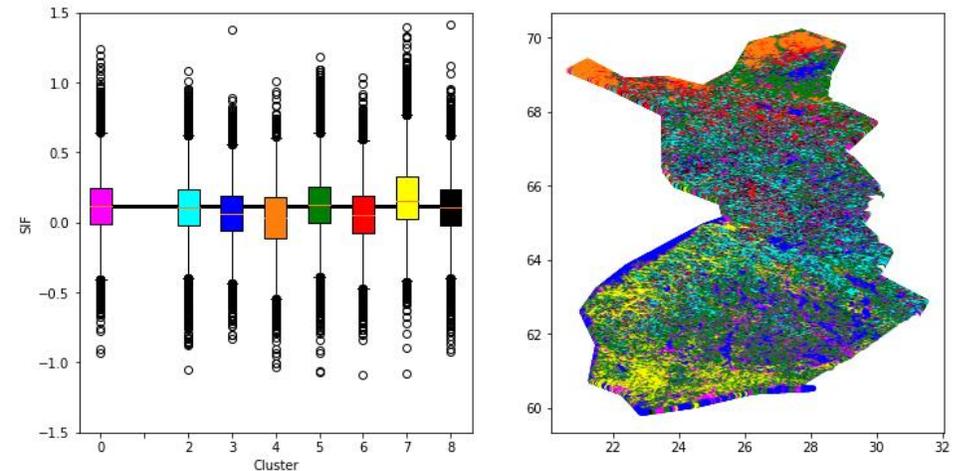
Satellite Measurements from Polar Orbit  
- Instantly delivered Direct Readout products



- Service maintained by Finnish Meteorological Institute, in co-operation with NASA and KNMI.
- Very fast processing and delivery of OMI and OMPS O<sub>3</sub>, SO<sub>2</sub>, aerosol and UV products.
- Spatial coverage: focusing on Northern / polar regions
- Reception in Sodankylä and Alaska as Direct Readout (DR), processing and dissemination within 10-20 minutes after reception.
- <http://sampo.fmi.fi>



# Copernicus FPCUP DG Clima Action: Developing support for monitoring and reporting of GHG emissions and removals from land use, land use change and forestry



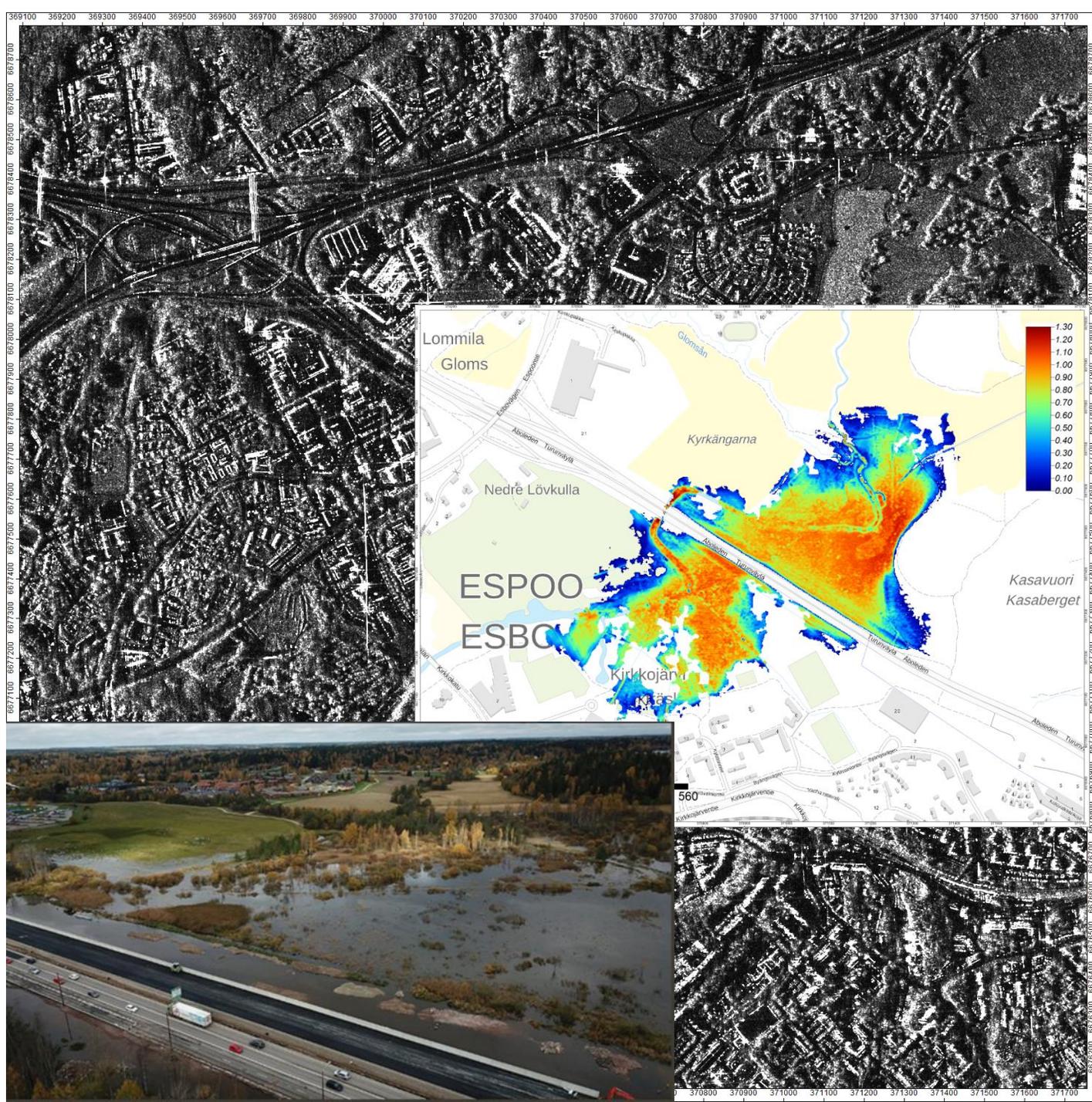
OCO-2 satellite retrievals of solar-induced fluorescence aggregated over different land use clusters reveal a higher than average photosynthesis over agricultural-dominated land use (yellow) in Finland. Preliminary result from the Action. Figure: O. Lamminpää and H. Lindqvist, FMI.

Together with SYKE and Luke, we assess the potential of Copernicus data (both land and atmospheric) and top-down approaches for LULUCF emission monitoring through the following tasks:

- Description of the current GHG inventory and reporting methods for LULUCF in Finland
- Comparison of results of Finnish national inventory report and Copernicus Land Monitoring Services datasets
- Testing top-down approaches for monitoring LULUCF related emissions
- Organizing a national-level meeting with relevant stakeholders

# FLOOD MONITORING

- Annual flooding of rivers in Bothnia
  - Spring floods due snow melt
  - Autumn floods due heavy rain
- Use of Synthetic Aperture Radar (SAR) provides weather independent observation
- Detection of Flooded areas both in open areas and forested regions
- Operational service for regional authorities in collaboration with SYKE
  - Flood covered area, Flood depth
  - Forest floods





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# CONNECTING EARTH OBSERVATION WITH IN-SITU



# Long term times series from the meteorological observatory

- First thermo-/barometer based records in **1856**
- Met station during the 1st IGY **1882/83**
- Continuous homogenized synoptic weather records from **1908** onwards
- Upper air soundings from **1949** onwards
- Solar radiation observations since **1957/58** (1st IPY)
- Radioactivity monitoring since **1963**
- Air quality observations since **1970s**
- Ozone and UV-observations **1988**
- Stratospheric Aerosol/Humidity mid **1990s**
- Micrometeorological tower **1999**
- Weather radar at Luosto **2000**
- Satellite data processing **1998**
- Satellite data reception **2003**
- Large capacity satellite data reception & archiving **2011**
- WMO hosted comparative instrument set of snow/rain observations **2013**
- **WMO GAW** and **GCW** primary site
- **ICOS** primary site



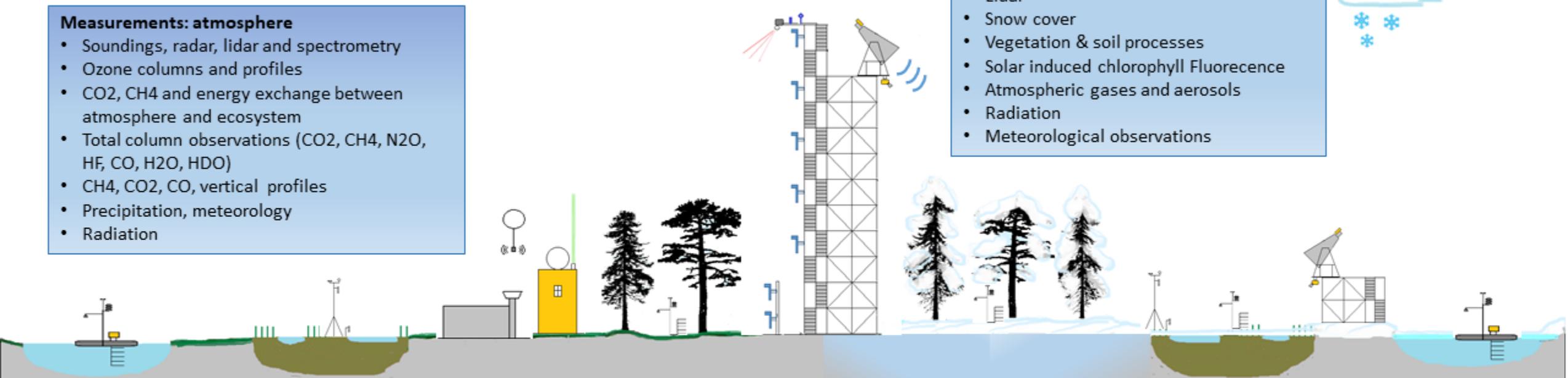


### Measurements: atmosphere

- Soundings, radar, lidar and spectrometry
- Ozone columns and profiles
- CO<sub>2</sub>, CH<sub>4</sub> and energy exchange between atmosphere and ecosystem
- Total column observations (CO<sub>2</sub>, CH<sub>4</sub>, N<sub>2</sub>O, HF, CO, H<sub>2</sub>O, HDO)
- CH<sub>4</sub>, CO<sub>2</sub>, CO, vertical profiles
- Precipitation, meteorology
- Radiation

### Measurements: Satellite cal/val

- Ground-based, drones and sounding
- Passive microwave (radiometer)
- Active microwave (radar)
- Optical/IR
- Lidar
- Snow cover
- Vegetation & soil processes
- Solar induced chlorophyll fluorescence
- Atmospheric gases and aerosols
- Radiation
- Meteorological observations



### Ecosystem processes (summer)

#### Water bodies (lake/river)

- CO<sub>2</sub>/CH<sub>4</sub> exchange
- Water level
- Surface temperature
- Sensible and latent heat exchange

#### Wetland

- CO<sub>2</sub>/CH<sub>4</sub> exchange
- Long-term greening
- Plant phenology
- Water level
- Sensible and latent heat exchange

#### Forest

- CO<sub>2</sub> exchange
- Long-term greening
- Plant phenology
- Soil humidity
- Sensible and latent heat exchange

### Ecosystem processes (winter)

#### Forest

- Snow-soil-forest interactions
- Snow Water Equivalent
- Soil freezing

#### Wetland

- Snow-soil-vegetation interactions
- Snow Water Equivalent
- Soil freezing

#### Water bodies (lake/river)

- Snow-ice interactions
- Freezing

# SATELLITE INSTRUMENT CALIBRATION AND PRODUCT VALIDATION AT ARCTIC SPACE CENTRE

## Sodankylä FTIR (Fourier Transform Infrared Spectrometer)

- Validation and calibration of JAXA GOSAT and NASA OCO-2 carbon monitoring satellites
- Column amounts of CO<sub>2</sub>, CH<sub>4</sub> and N<sub>2</sub>O

## ESA Elbara-II for SMOS satellite CAL-VAL

- L-band (1.4 GHz) microwave radiometer
- Continuous SMOS reference measurement
- Ground moisture/frost algorithm development
- Also reference for NASA SMAP mission





Arctic  
Environment  
Research

Earth  
Observation  
data  
processing

In-situ  
Measurements

Arctic Space  
Centre

Ground Station  
Services

Satellite  
Instrument  
CALVAL

Satellite  
Remote  
Sensing

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