

ESA Arctic-Boreal Earth Science, calibration and validation supersite (Sodankylä EO Supersite by FMI)

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FMI space activities: focus on the Arctic

The largest space R&D unit and public service provider in Finland

FMI Arctic Space Centre at Sodankylä

Co-operation with EU, EUMETSAT, ESA, NASA, NOAA, ECCO/CSA

Public-Private-Partnership and shared systems with Finnish and international R&D institutes

Sustained long-term *in situ* observations and satellite CAL-VAL

Earth observation research and operational products

Atmospheric composition, air quality, meteorology

Monitoring of carbon exchange, wildfires, risks to aviation

Unique products on cryosphere for research and operational applications (hemispheric snow cover; soil freeze-thaw state; regional products e.g., for hydropower industry)

Space technology, space weather and planetary research

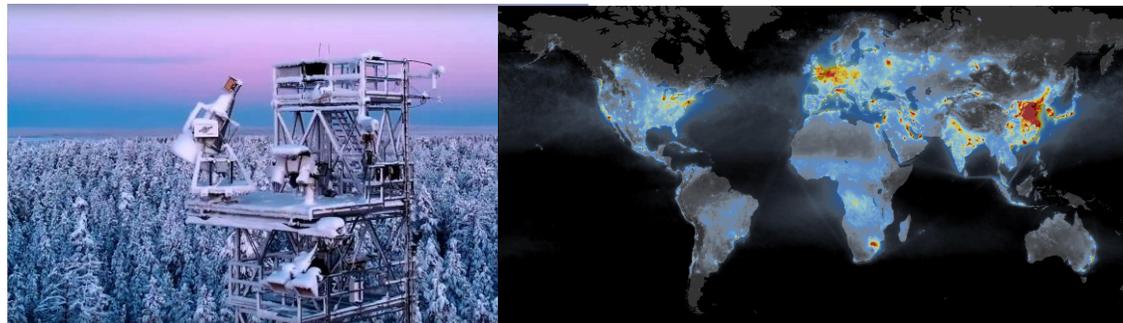
Coordinator of Pegasus space weather service for global civil aviation (ICAO)

Responsible for the Finnish participation to EU-SST partnership (space surveillance and tracking, related to space traffic and security)

Strong co-operation with NASA and ESA in planetary exploration



Sodankylä's Arctic Space Centre: Ground segment for polar orbiting EO satellites



FMI Arctic Space Centre at Sodankylä (FMI-ARC)

National Satellite Data Centre (NSDC) as a key function

Co-operation with satellite operators

Services to national security and FMI weather and ice services

Public-Private-Partnership and shared systems with R&D institutes, ***Sodankylä Space Campus with Sodankylä Geophysical Observatory, SGO (University of Oulu)***

Reception of data and products from Earth Observation satellites

Part of Collaborative Ground Segment for EU Copernicus Sentinels

Near-real-time Sentinel data (**S1 SAR**): Ice services of FMI and SMHI, Finnish Food Authority through co-operation with CGI Inc.

Satellite data reception and processing services:

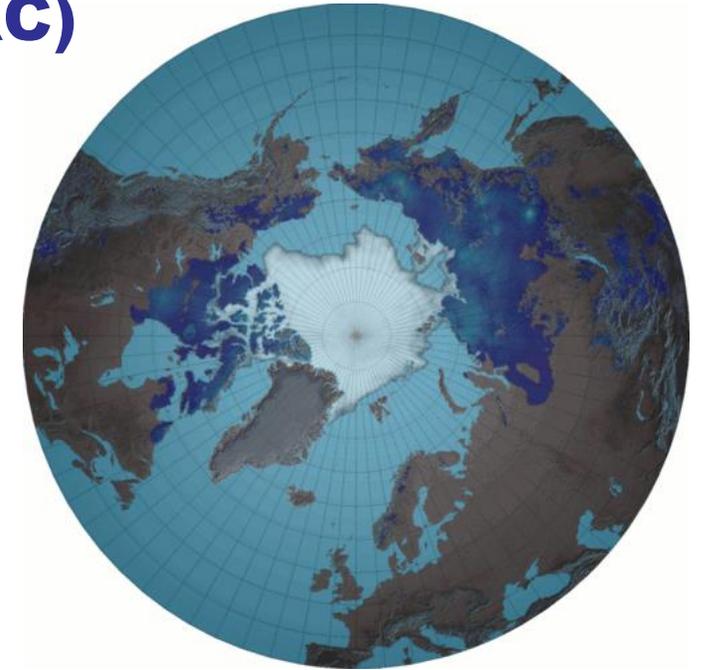
NSOAS ocean monitoring satellite data for EUMETSAT (for ECMWF global weather prediction)

Radio-occultation data for NOAA through co-operation with U.S. company Atlas Space Operations Inc.

Italian CosMo-SkyMed SAR reception and delivery (including EU-Copernicus; ice services of FMI and SMHI), co-operation with e-GEOS and Telespazio

Data/product archives and **real-time situational awareness**

Products for EU: Cryosphere information for Copernicus Land Monitoring Service, wildfire detection/alarm service (Northern Europe)

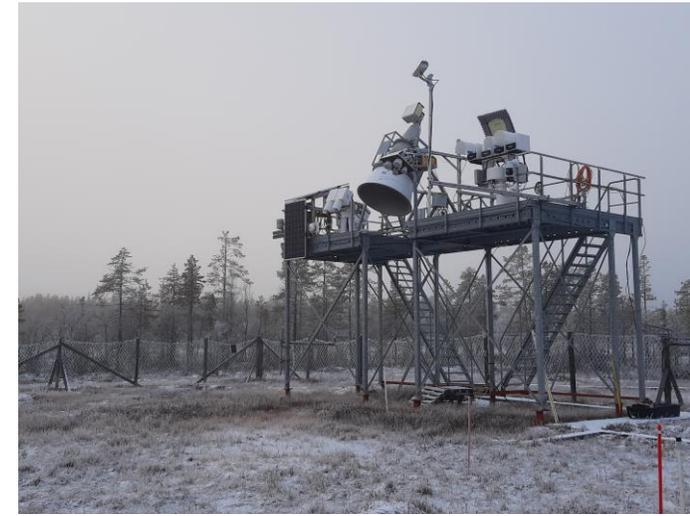
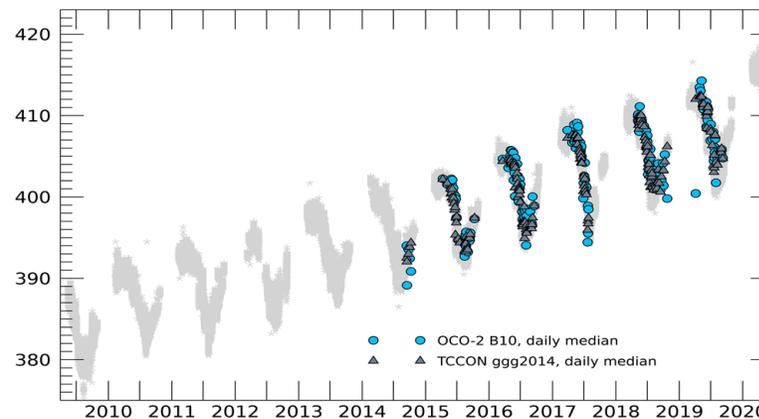
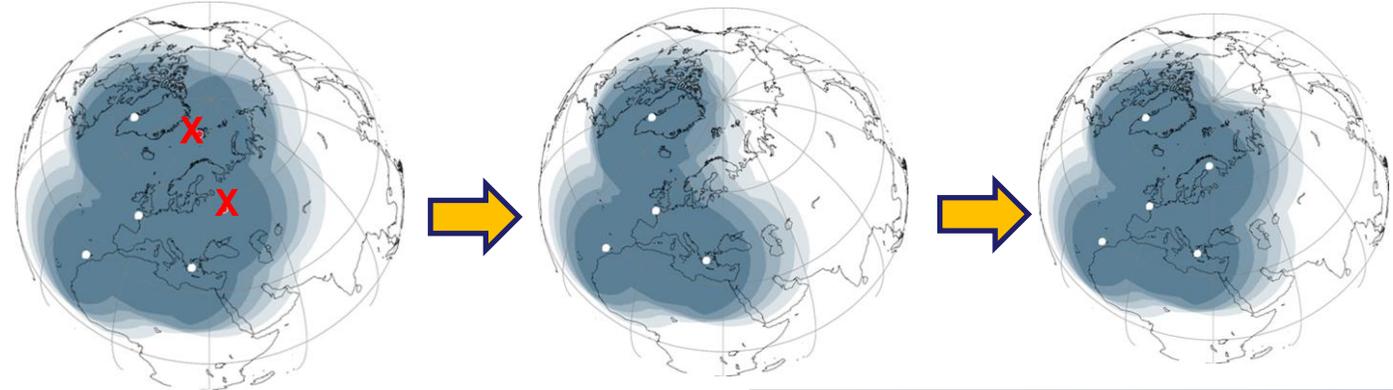
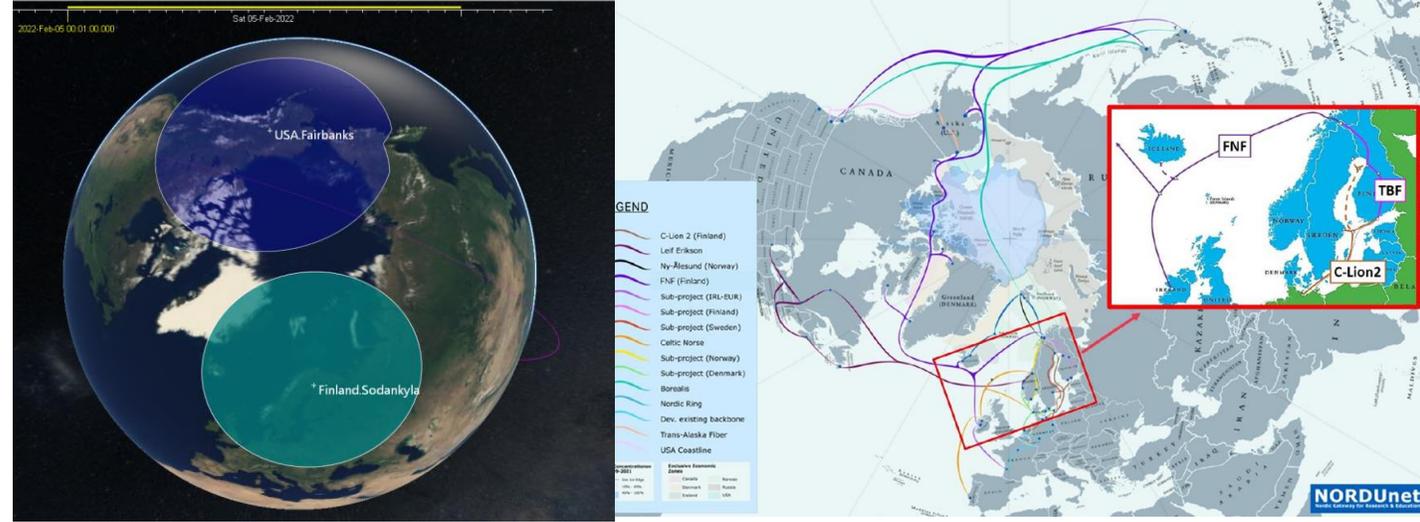


Hemispheric snow mass and Arctic sea ice (autumn 2017) **NRT service in EUMETSAT H-SAF**



Sodankylä Satellite Ground Segment and satellite cal-val

- Ground station collaboration with international partners
- Ground station support for EUMETSAT
- Reference data and instruments for current satellite missions of ESA, EU, EUMETSAT, NASA, Jaxa, CSA
- Reference for future EU Copernicus missions Cal/Val (e.g., CO2M, CIMR, ROSE-L)
 - Artic Pixel – Use Sodankylä in-situ measurement networks
- Nordic G/S collaboration on EPS-Sterna regional data access
 - Focus on regional NWP and Nowcasting at high latitudes and Arctic
 - Build upon Nordic MetCoOp collaboration



Hosting external satellite ground stations (GS) at Sodankylä

- Current status of GS implementation for an Italian company:
 - Construction of infrastructure for a two-antenna system
 - Access road and hardstands
 - Electrical power supply
 - Internet connection and LAN
 - Housing of indoor equipment
- Maintenance and hosting of GS
 - Maintenance of GS facility
 - First level maintenance of GS equipment
 - Support for Second level and corrective maintenance



Sodankylä site: a unique resource for Earth Observation

Sodankylä centre northern location and infrastructure provides an ideal base for satellite-based observations

- Local ecosystem and climate representative of wider circum-polar forest-tundra ecotone (including Canada and Russia)
- Existing infrastructure and operational monitoring programmes managed through FMI
- Ideally located to enable frequent coverage through multiple spaceborne acquisition opportunities
- Track-record in providing ground-based measurements in support of ESA missions and calval (SAR, Optical and passive microwave missions such as Sentinel-1, FLEX, SMOS and others)



New project: Develop ESA Arctic-Boreal Earth Science, calibration and validation supersite

- Implement major 3-year ESA project with FMI, Science Institutions and Industry partners funded through ESA's FutureEO programme
- Build on and expand on existing infrastructure and previous ESA experience with Sodankyla (campaigns, instruments)
- Address three main overarching science themes relevant to satellite-based monitoring of the Arctic
 - Boreal forest ecosystems
 - Seasonal snow for hydrology
 - Greenhouse Gases and atmospheric composition
- Develop reference ground observations to improve satellite products and services for EU/ESA Copernicus Sentinel satellites, ESA Earth Explorers and third-party missions in the Arctic
- Provide R&D platform for the Finnish and European Space industry in Sodankylä to test new environmental sensing technology, develop new satellite missions and satellite-based applications relevant to the arctic.



ESA Arctic-Boreal Earth Science, calibration and validation supersite

- Reference data for EO satellite sensors: Validation for Arctic-Boreal and global applications;
- Support to EU Copernicus Sentinels, ESA Earth Explorers and third-party missions with the scientific focus on (a) boreal forests, (b) hydrology/snow, and (c) greenhouse gases
- Co-operation with the Finnish and European space industry; R&D platform
- **Sodankylä EO-supersite diminishes a major serious data gap** hindering the exploitation of EO satellites for Arctic-Boreal terrestrial areas and the atmosphere.



Current and planned co-operation with the Finnish and European Space industry

Relevant Finnish companies that participated the **exhibition and launch of the ESA supersite** during the ESA PB-EO visit to Sodankylä on 5 Feb. 2025:

- **Vaisala PLC:** In situ sensors to support GHG missions (global leader in meteorological instruments)
- **Harp Technologies Ltd:** Micro- and millimeter wave technology and remote sensing systems
- **Kelluu Ltd:** Advanced aerial measurements
- **KuvaSpace Ltd:** Optical-range satellite constellations and technology
- **ICEYE Ltd:** X-band SAR constellations and technology
- **CGI PLC:** Remote sensing application development
- **PhiLab network:** ESA network in Finland to enhance EO industry



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FINNISH METEOROLOGICAL INSTITUTE

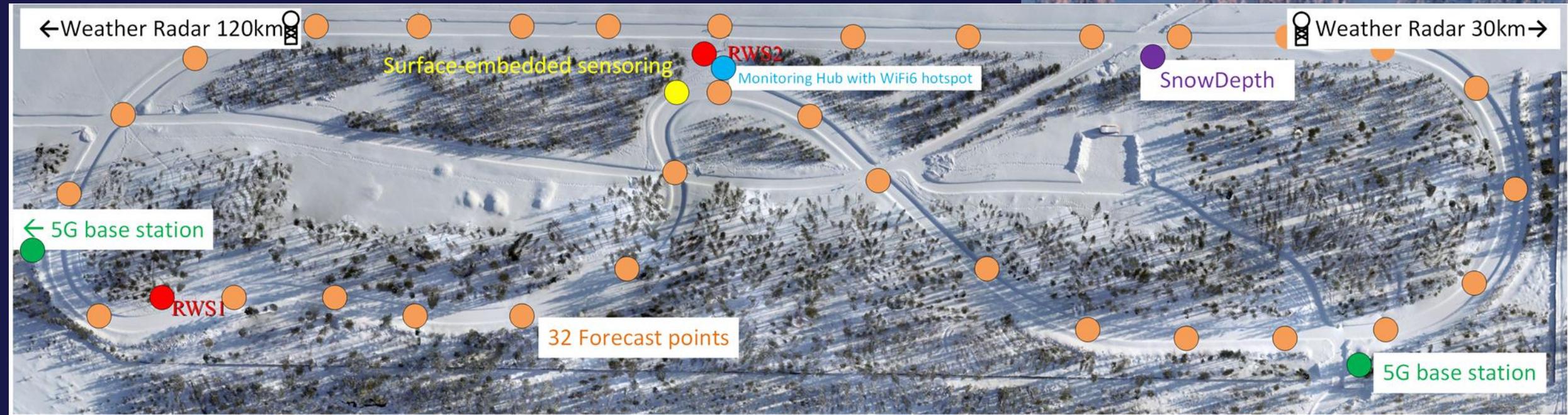
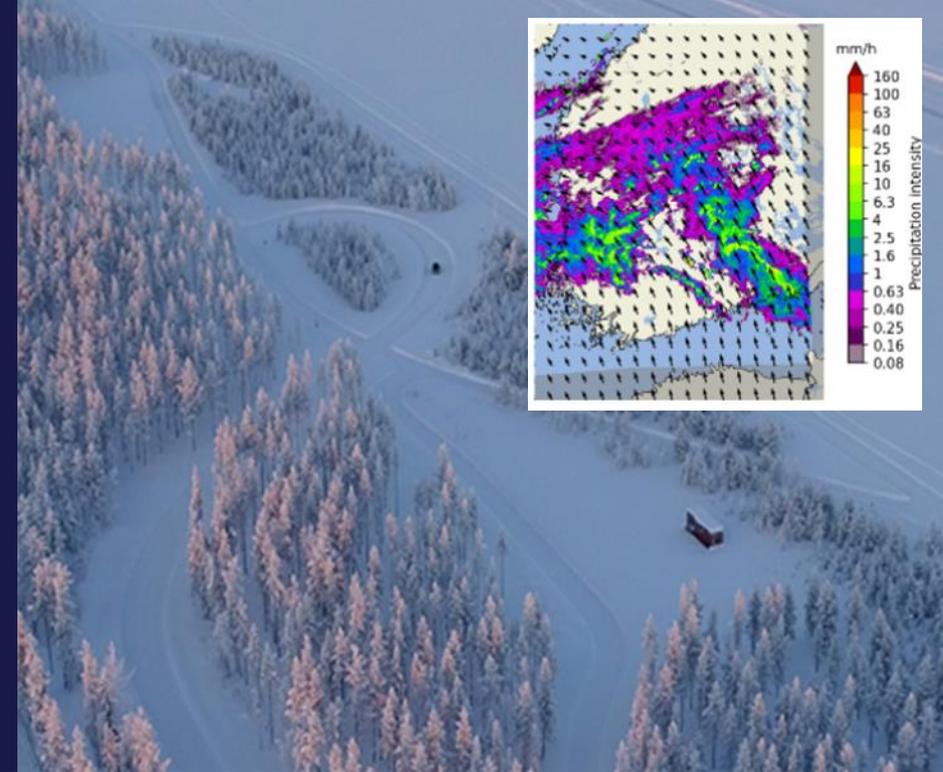


Sodankylä test track for Intelligent Traffic road weather services (contributes to NATO Diana testbed of Univ. Oulu)

- 5G, ITS-G5, C-V2X, WiFi6, Starlink in Arctic Environments
- 5(6)TGN
- Road weather stations, surface-embedded sensors and on-board mobile friction sensors
- LiDAR + camera –assisted weather monitoring
- Autonomous miniature robot vehicle
- Weather radars in Luosto and Kaunispää
- Digital Twin (Unity/Unreal) from test track

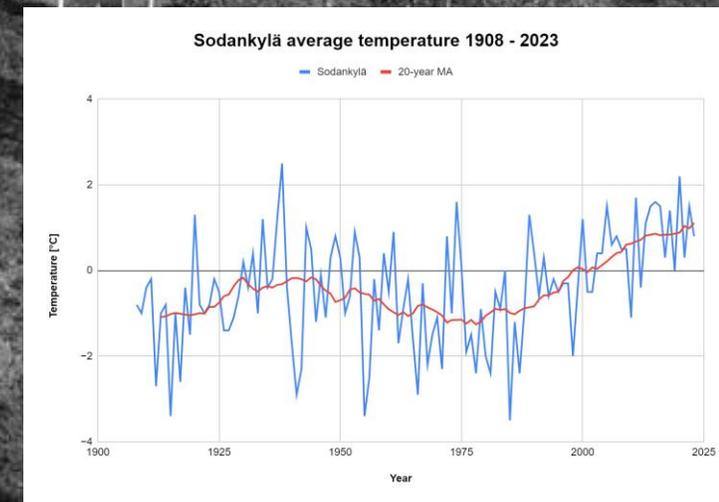
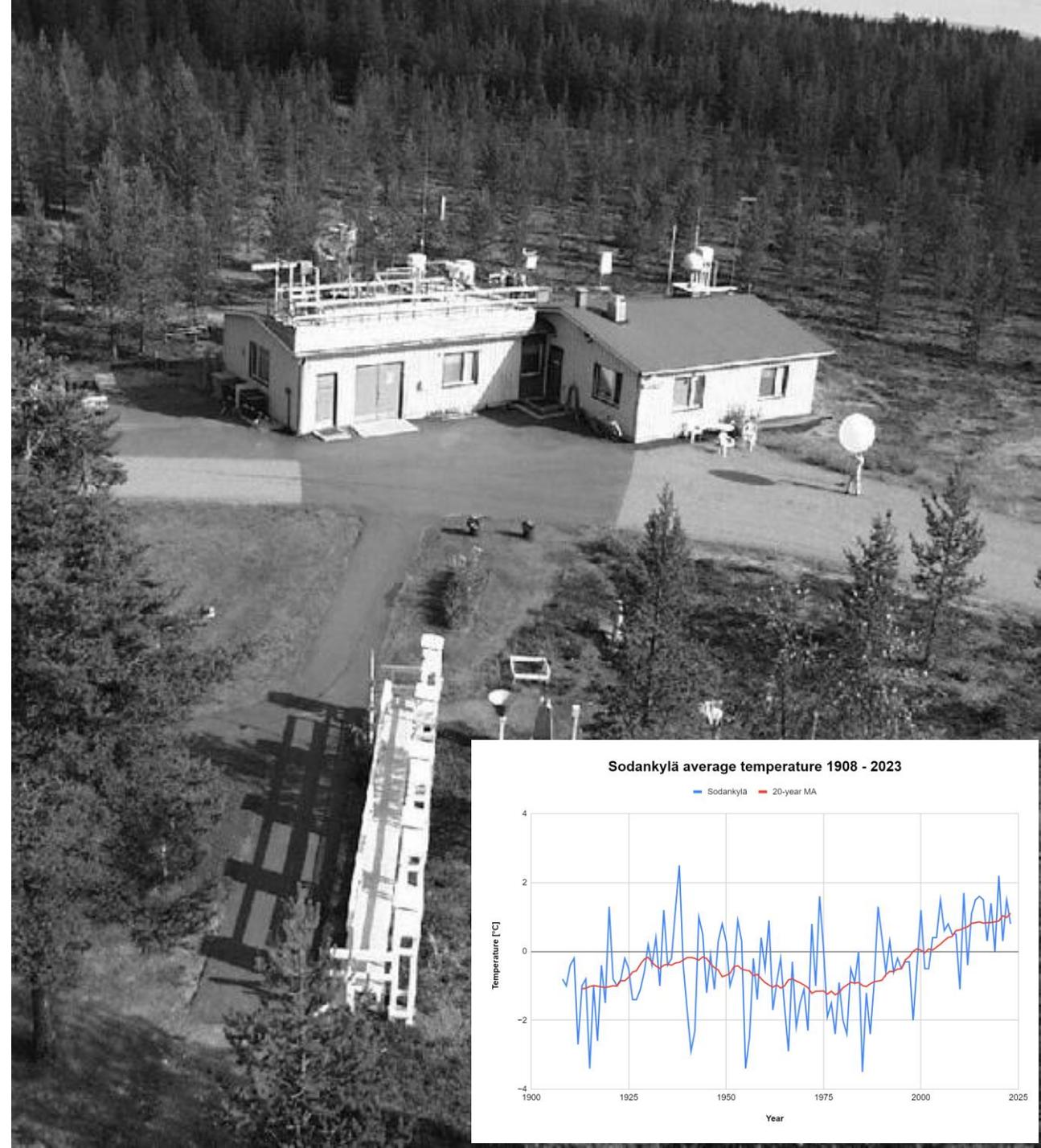


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FINNISH METEOROLOGICAL INSTITUTE



Long term times series from the meteorological observatory

- First thermo-/barometer-based records in **1856**
- Met station during the 1st IPY **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
- CO₂, CH₄ and energy exchange between atmosphere and ecosystem
- Total column observations (CO₂, CH₄, N₂O, HF, CO, H₂O, HDO)
- CH₄, CO₂, 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)

- CO₂/CH₄ exchange
- Water level
- Surface temperature
- Sensible and latent heat exchange

Wetland

- CO₂/CH₄ exchange
- Long-term greening
- Plant phenology
- Water level
- Sensible and latent heat exchange

Forest

- CO₂ 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

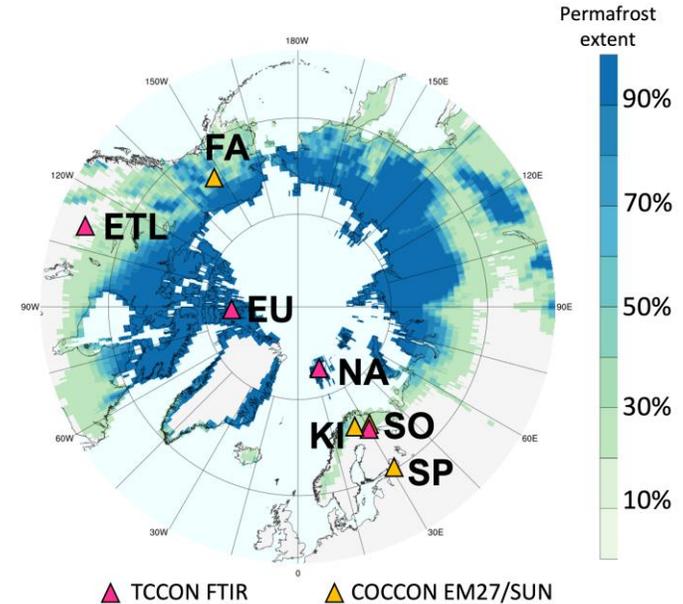
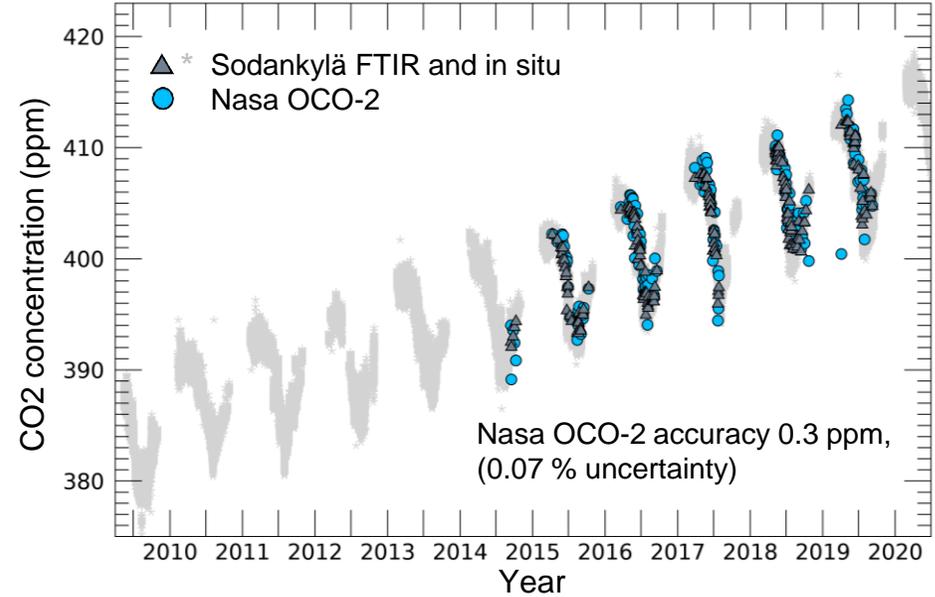
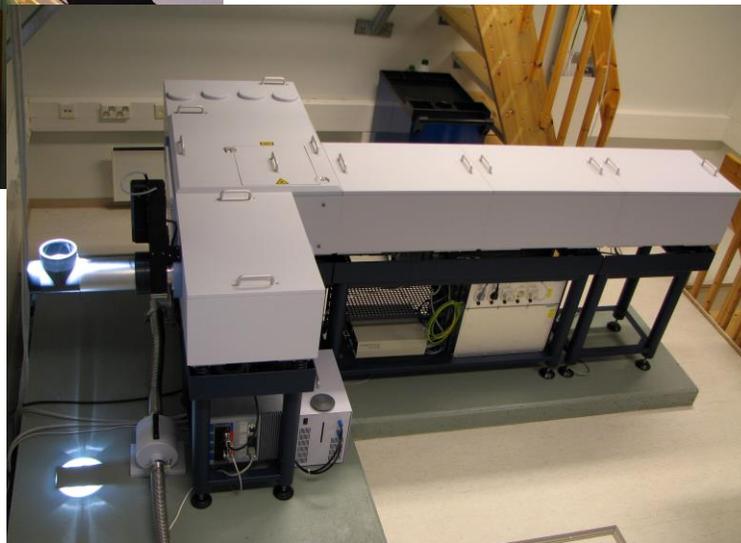
- Snow-soil-vegetation interactions
- Snow Water Equivalent
- Soil freezing

Water bodies (lake/river)

- Snow-ice interactions
- Freezing

Fourier-transform spectrometer (FTIR) of Sodankylä

- An essential system for calibrating NASA OCO-2 and future Copernicus CO2M global observation data of atmospheric CO₂
- Part of NASA/JPL TCCON network



Copernicus Anthropogenic CO₂ Monitoring Mission (CO2M)

Assessment of national emissions can be enhanced through global satellite observations

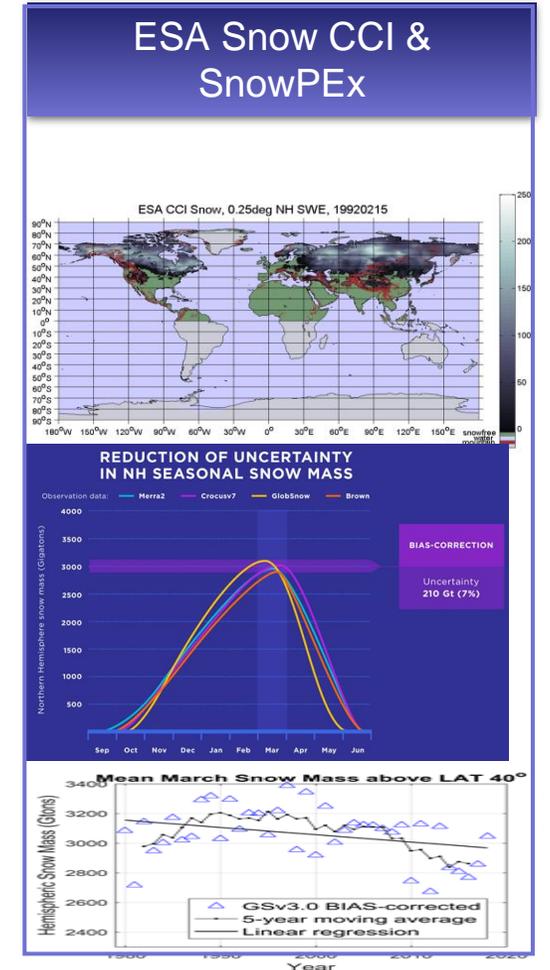
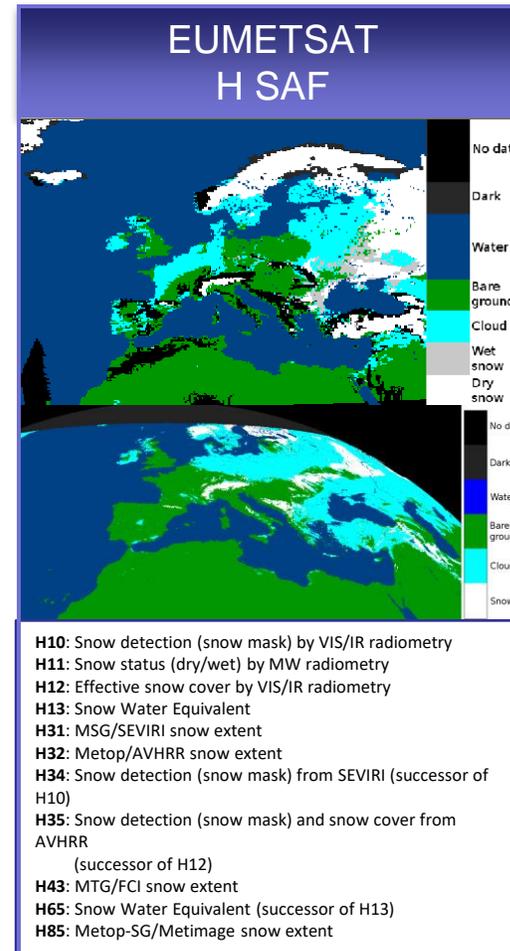
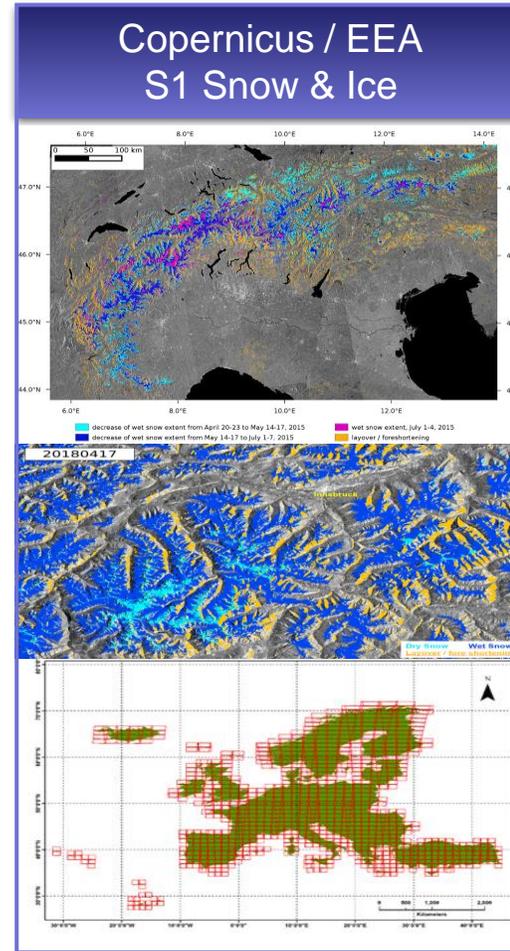
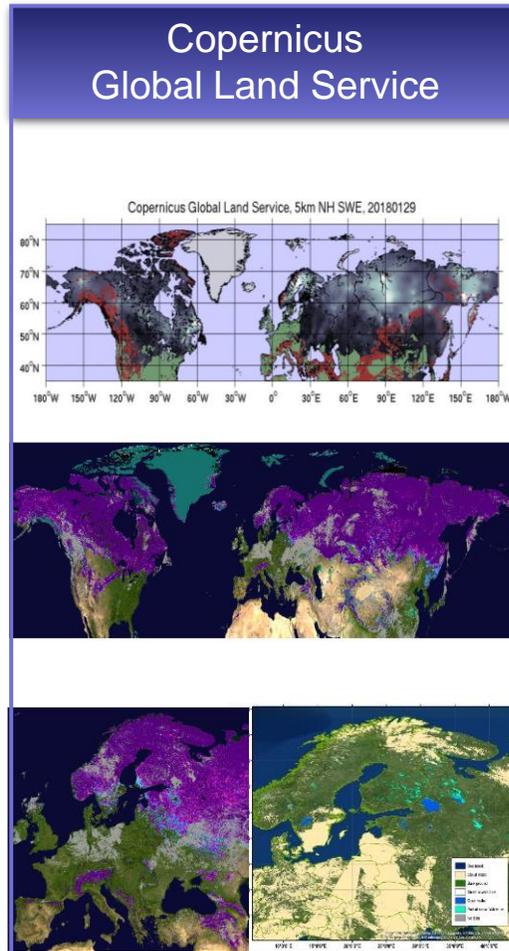
Monitoring the goals of Paris climate agreement already from 2026 onwards.

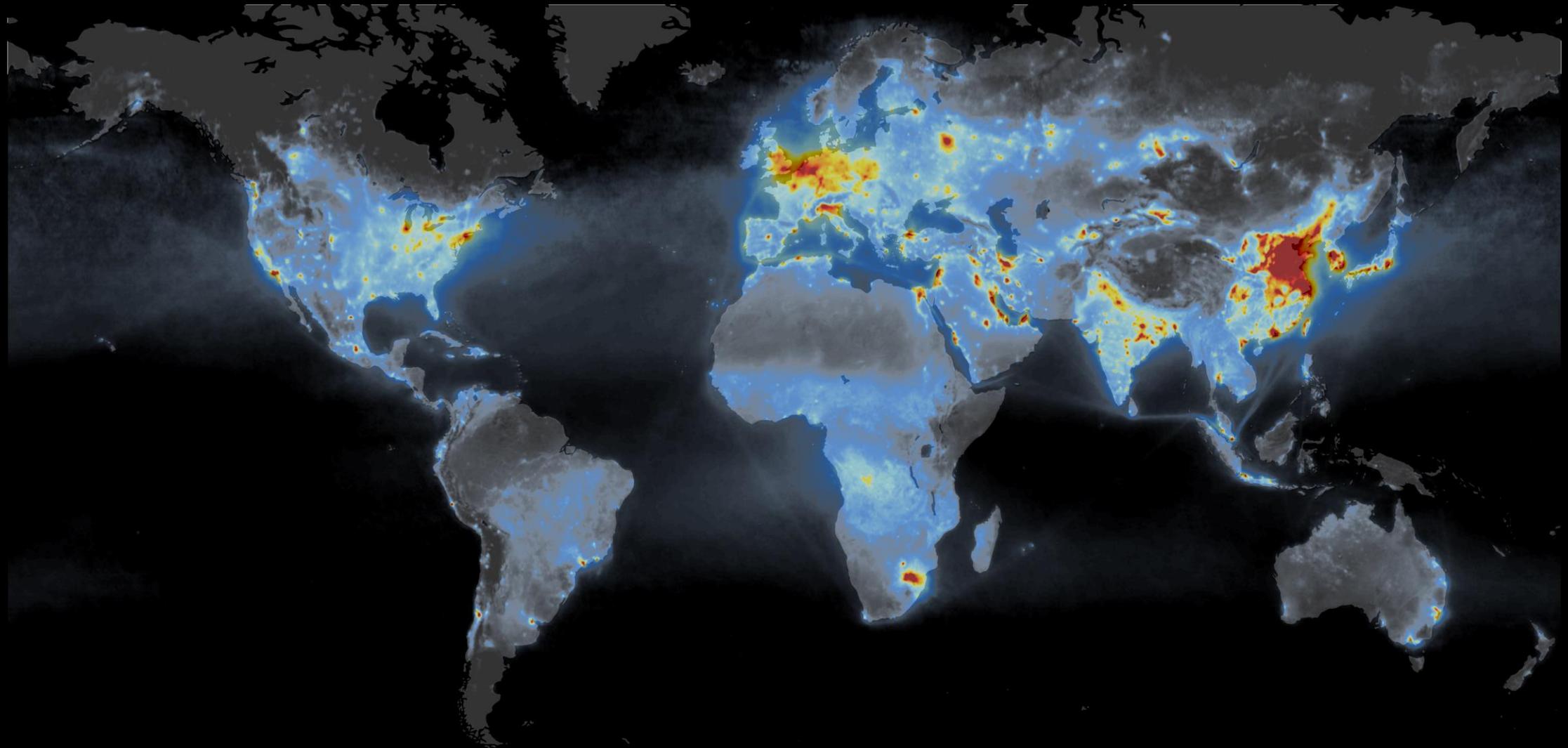
FMI supports CO2M-mission:

1. Application to Finland
2. Reference measurements in Sodankylä including unique instrumentation (FTIR-reference spectrometer, already in use for NASA OCO-2)
3. Method development for assessing emissions and sinks
4. Participation to ESA CO2M Mission Advisory Group.

FMI – satellite-based global and regional snow services

- Daily NRT Snow services from Sodankylä processing centre for Copernicus & EUMETSAT; with climate aspects for ESA.





Tropospheric NO₂, average in 2018, TROPOMI / Sentinel 5P

FIG: A-M. Sundström, FMI

Earth Observation at FMI

Data reception



Processing Archiving Distributing

SATELLITE DATA

SATELLITE PRODUCTS

SWE

FSC

SMOS Level 3

Sentinel 1 Freeze/Thaw

Merged AOD

Sentinel-5P

SSPI 10 days

SSPI 30 days

SuperSWE map

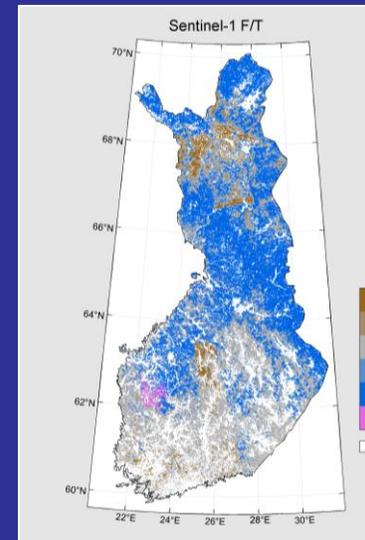
SUNLIT

Volcano monitoring

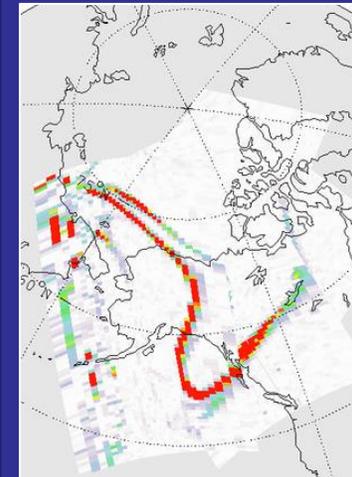
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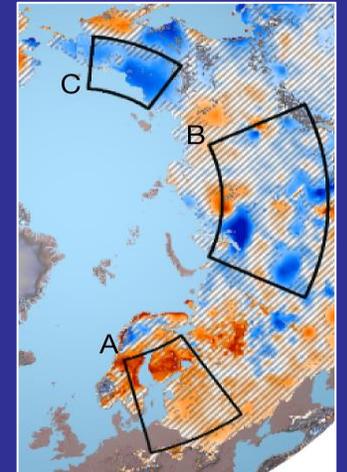
Product and sensor development



Service development



Research



Arctic Space Centre in Sodankylä is also a partner international monitoring programs:

WMO GAW (Global Atmosphere Watch), WMO GCW (Global Cryosphere Watch), ICOS (Integrated Carbon Observation System), TCCON (Total Carbon Column Observing Network), GRUAN (GCOS Reference Upper-Air Network), ISMN (International Soil Moisture Network), COCCON (Collaborative Carbon Column Observing Network), NDACC (Network for the Detection of Atmospheric Composition Change)

Thank you for your
attention!

