

The Arctic - ESA Earth Observation Activities and ESA Task Force Roadmap

Maurice Borgeaud, Chair of the ESA Arctic Task Force

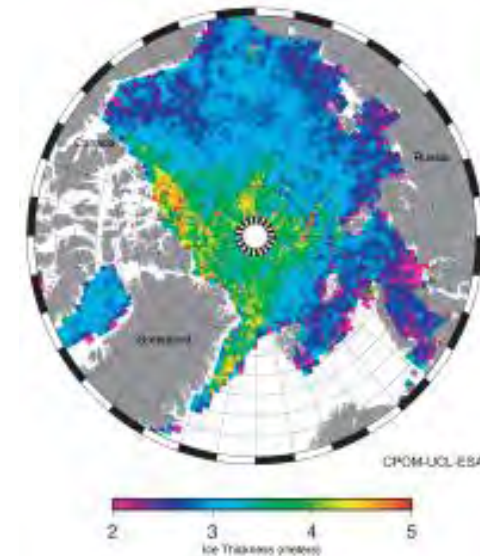
Harwell, 4 November 2016

Outline

- Background and strategic importance
- On-going ESA Earth Observation activities dealing with the Arctic
 - Science and applications
 - Preparation for future missions and campaigns
- ESA Arctic Task Force
- Plans for the Arctic at the CM-16
- Roadmap for “Arctic and Space”
- Way Foreward

Background

- Operational needs
 - Increased demand for SAR (Synthetic Aperture Radar) operations / capabilities
 - Increased pressure to exploit Arctic natural resources (oil and gas, mining, fisheries) demanding environmental baseline and tactical information
 - New trans-Arctic shipping highways
- Climate change / Science
 - A more variable and unpredictable Arctic sea-ice regime
 - Accelerating Greenland glaciers, increased glacier calving, increased production of ice-bergs
 - Improved predictability of Arctic weather and climate



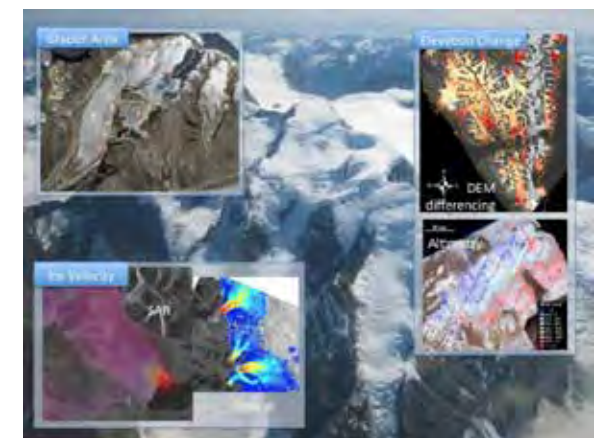
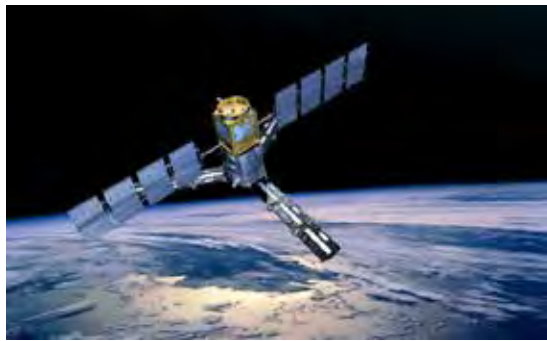
Strategic importance of polar regions monitoring for Europe

- EC communication on “An integrated European Union policy for the Arctic” in April 2016
- Importance of monitoring the Polar regions stressed in EUMETSAT Strategy “Challenge 2025” released in May 2016
- Polar and Snow Cover Applications User Requirements Workshop convened by EC in June 2016:
<http://www.copernicus.eu/events/polar-and-snow-cover-applications-user-requirements-workshop>
- Importance of monitoring the Polar regions, specifically the Arctic for sea ice, snow and weather was emphasized by EC at Copernicus Committee in October 2016
- Envisioned in-orbit deployment timeframe is from ~2025 for Copernicus Space Component Evolution, for additional capabilities in support of currently identified needs

Science and Applications



On-going ESA activities - EOP

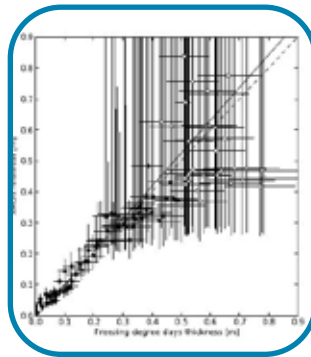


ESA UNCLASSIFIED - For Official Use

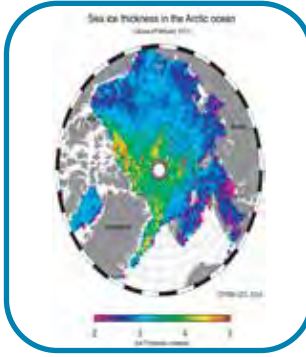
ESA EO Arctic Activities | 4 Nov. 2016 | Slide 6



ESA EO Arctic Initiative



Advancing Science



Climate Change



Novel Applications



Training & Open Tools



Data Infrastructure



Campaigns



Future Missions



PSTG: EO Data Coordination

Next Generation Polar missions & Science

STSE Polaris

- Gather information requirements for the polar regions
- Establish these requirements with key user representative bodies
- Identify information gaps considering space and non-space based systems

EOPA Polaris Mission Concepts

Explore & select mission concepts based on Polaris user needs outcomes
 Input to programme proposal for new infrastructure



DUE GlobPermafrost

- Addressing priorities identified in the ESA-CLIC-GNTP-IPA user workshop;
- PSTG White Paper in response to the needs of the permafrost community;

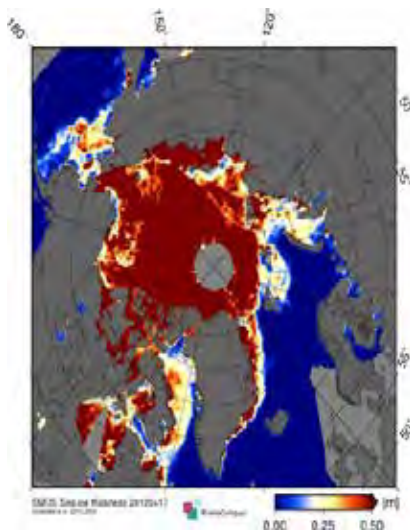
STSE Arctic+ Initiative

- Response to the needs of the Arctic community;
- Addressing major priorities identified in the ESA-CLIC Arctic Science Agenda;
- Preparing future activities coordinated with H2020.

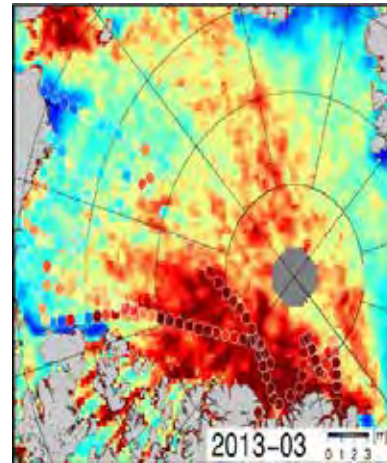


ESA-CLIC workshop on EO and Arctic Science
 Priorities, Tromsø, 20th January 2015
 ESA EO Arctic Activities | 4 Nov. 2016 | Slide 8

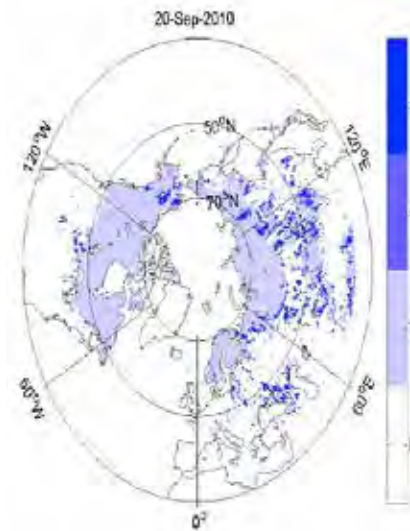
Advancing Science: Some achievements



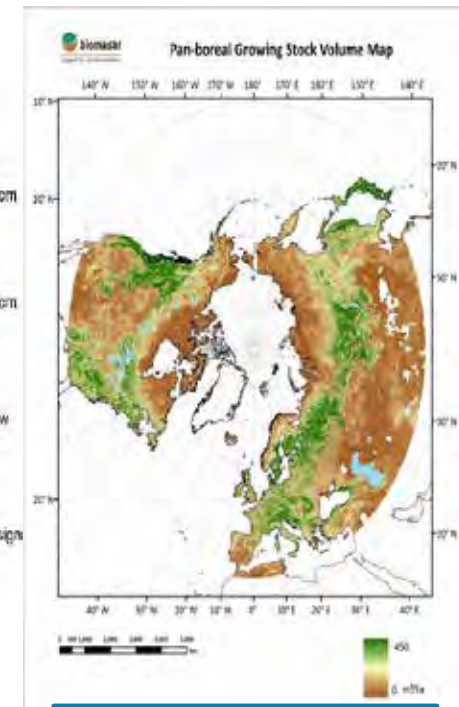
SMOS very thin sea ice measurements (<0.5m) complementing CryoSat measurements



Novel merged CryoSat + SMOS product covering the full thickness range (dots are NASA Icebridge airborne measurements)

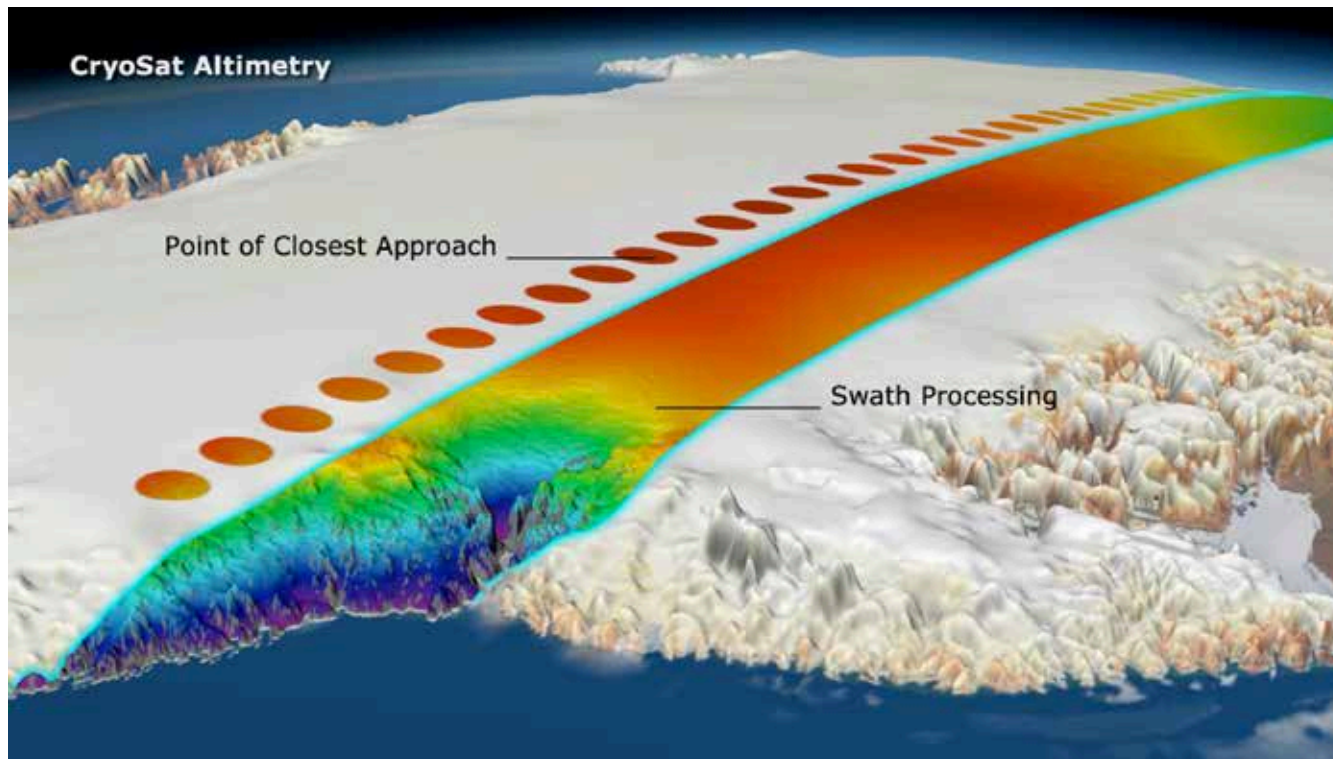


Novel pan-Arctic frozen soil estimates from SMOS



Novel pan-Arctic growing stock volume from hyper-temporal SAR (ASAR) processing

Advancing Science: Recent Results



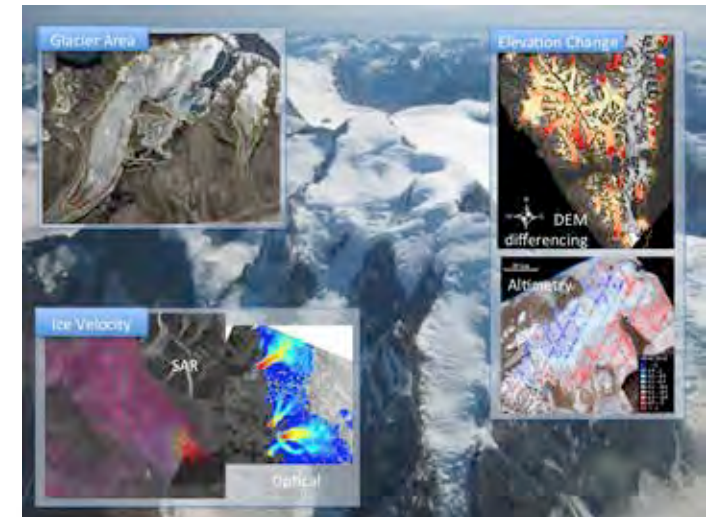
STSE CryoTop:
First Greenland DEM at
500m pacing by exploiting
the SARIN swath
processing potential of
CryoSat;

SARIN Swath processing
technique:

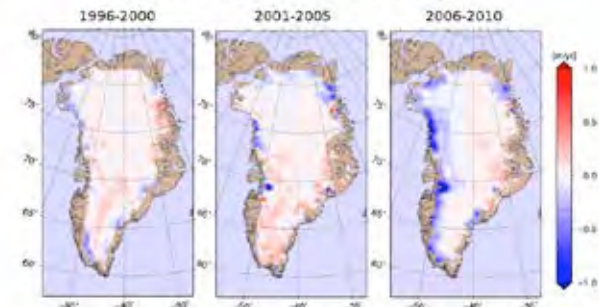
- Enhance the number of elevation samples by several orders of magnitude;
- Enhance DEM resolution down to <500m;
- Allows retrieval of elevation on areas uncovered by traditional altimetry

Polar Activities in CCI

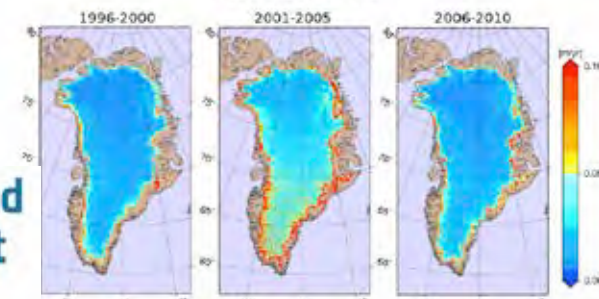
- Four key ECV projects: **Greenland Ice Sheet, Antarctica Ice Sheet, Glaciers, Sea Ice** (long time series surface elevation change, area, ice velocity, grounding line, calving front, mass balance).
- Improved sea level ECV estimates for the Arctic ocean.
- International coordination of activities with NSIDC, NASA, WGMS, IACS, Randolph Glacier Inventory (IPCC AR5), GCOS.
- ESA-NASA ice-sheet mass balance inter comparison exercise (**IMBIE**), also in IPCC AR5.
- Antarctic Ice Shelf Fellowship.



Mean 5-year surface elevation changes



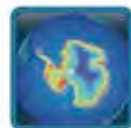
Associated errors



sea ice
cci



glaciers
cci

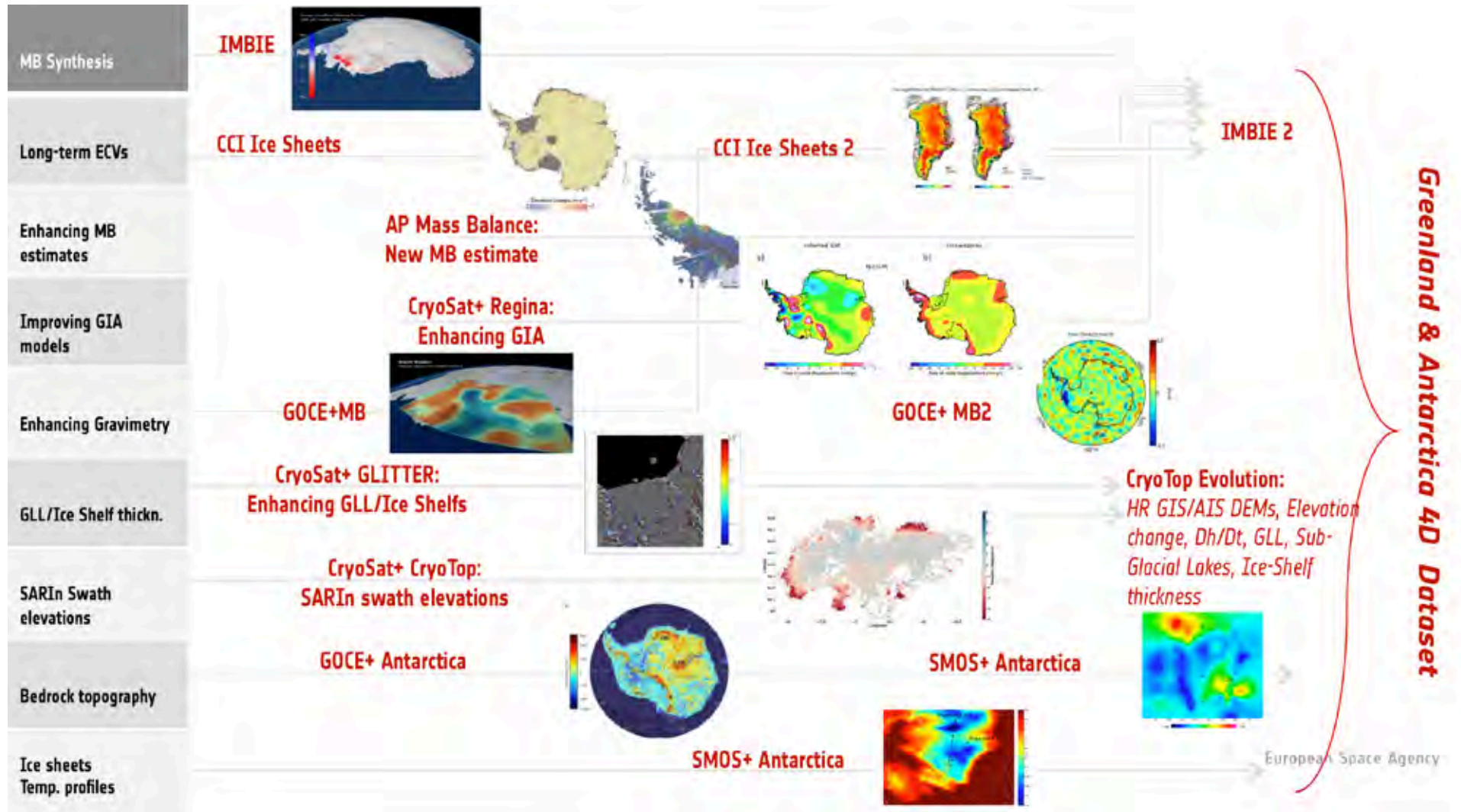


antarctic
ice sheet
cci



greenland
ice sheet
cci

Arctic & Polar Science: Ensuring coherence

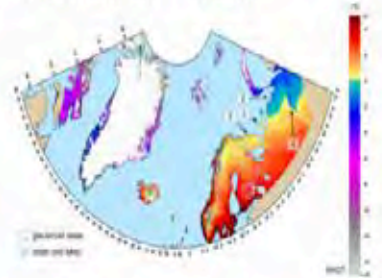


GlobPermafrost Products

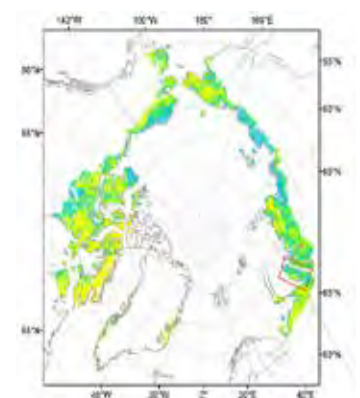
Permafrost Information System (PerSys)
Open Access Data Catalog



Permafrost extent



Local "cold spots"

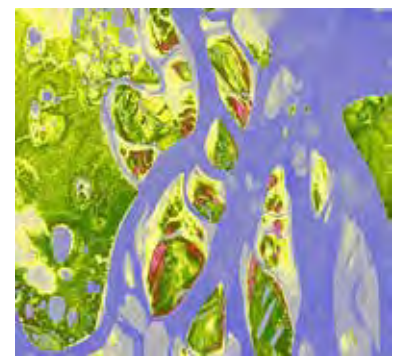


Wetness levels

Permafrost dedicated land cover class prototypes

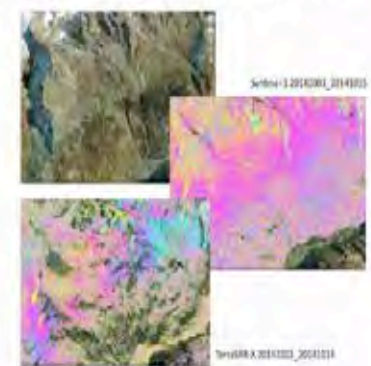


Lakes and periglacial processes



Hotspot trend analysis

Mountain permafrost areas



InSAR signals related to rockglaciers dynamic in TerraSAR-X 11 days and Sentinel-1 12 days interferograms over part of the Oberwallis region in Switzerland.

Wetland classes based on C-Band SAR

Transects for identification of hotspot regions of permafrost change



➔ www.globpermafrost.info



Preparation for Future Missions and Campaigns



Polar Ice, Snow and Sea Topography by Interferometric SAR Altimetry

Main objectives:

- Monitor critical and direct climate change signals: ice cap melting and sea level
- Support monitoring Arctic ice, snow and sea conditions
- Support applications related to coastal and inland waters
- Support Arctic policies for environmental protection, sustainable development and international cooperation, operational services

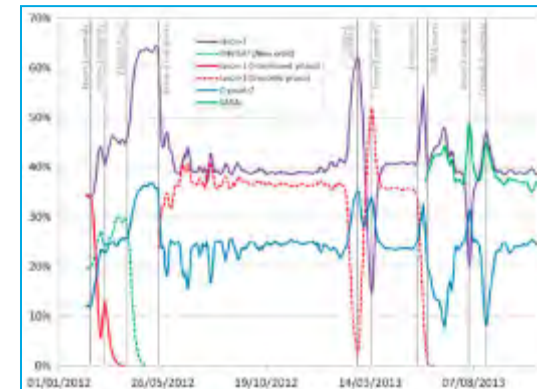
Application areas (examples):

- Climate (ice and snow monitoring, ocean circulation, sea state, sea level,..)
- Weather, climate and seasonal forecasting
- Coastal and marine environment
- Global marine and inland water resources incl. glaciers
- Emergency management (hydrology, ocean monitoring)

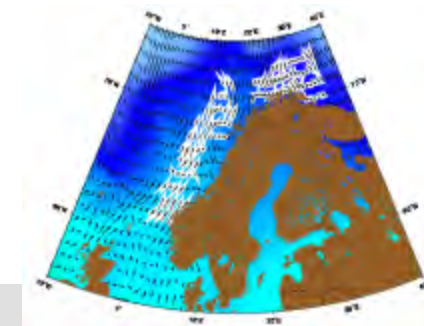
Required observations:

- Enhanced continuity of ice thickness
- Snow depth and snow cover
- High-latitude ocean circulation
- Lakes, rivers, glaciers, and coastal water levels

ESA UNCLASSIFIED - For Official Use



In blue: relative contribution of CS-2 to sea level maps (source: GODAE OceanView)



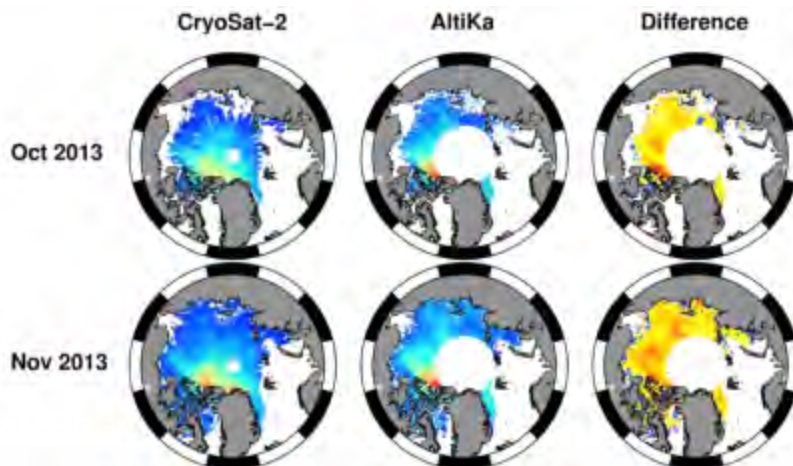
Slide 15

Dual-band Radar Altimeter

Cryosat2 (Ku-band altimeter)

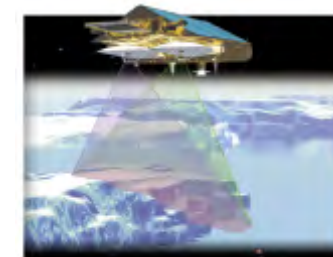


Altika (Ka-band altimeter)



$$d = \frac{\Delta F_r^{(sat)}}{(d+h_c)\Delta f} \approx \frac{\Delta F_r^{(sat)}}{1.22\Delta f}$$

Dual Band
Radar
Altimeter



Ku+Ka-band Synergy Campaign

Objectives

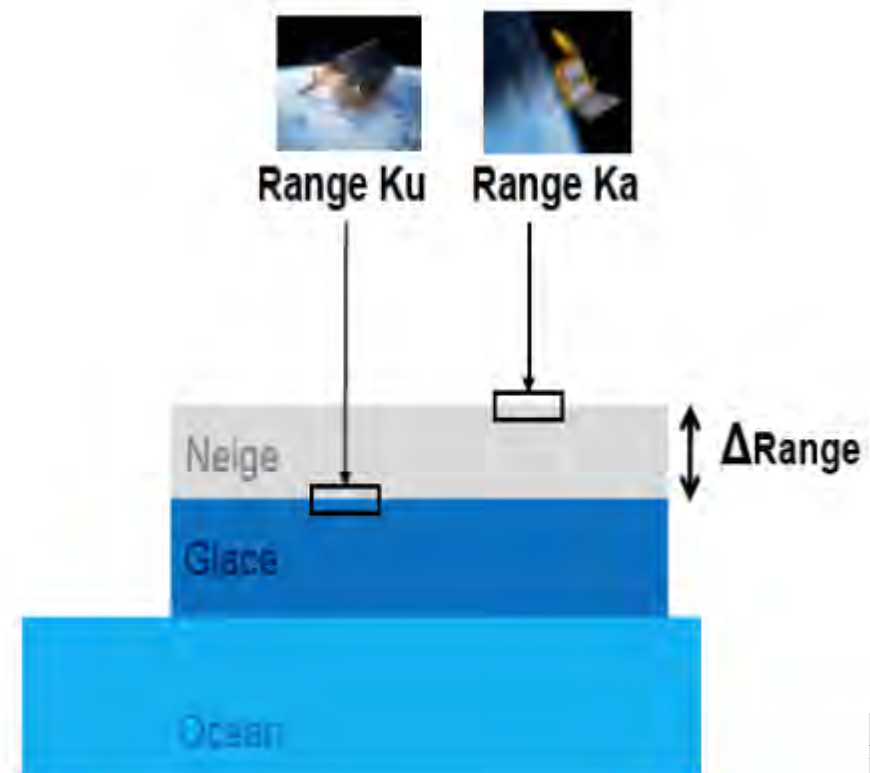
- Document additional value of coincident Ka- and Ku-band acquisitions in cryosphere
- Support detailed investigations into signal properties (e.g. penetration into snow cover, signal strength)
- Technical inputs to Ku- and Ka-band mission feasibility studies with industry

Campaign Details

- First measurement campaign: October 2016 (Greenland). Follow-on in 2017.
- Prime Contractor: DTU (DK)
- Ku-band RA ASIRAS (RST-CH)
- Ka-band RA (Metasensing – NL)
- Ground teams (Univ. Leeds – UK)



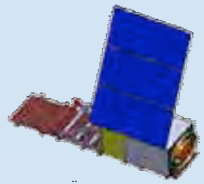
In addition:

- Arctic+ STSE Study starting
- Other science / user oriented activities also in planning
- Technical definition (antenna, HPA,..)



Polar Sea Ice: Polar-Train Bistatic, High Resolution Wide Swath (HRWS)

Other potential future SAR missions are also deemed interesting by users

L-Band "P-Train" Dual-Frequency, S1 Convoy	C-Band HRWS Full-pol, S1 enhanced continuity	C-band Passive InSAR XTI, S1 Convoy
		
Dual-Frequency emulation	High-resolution, High-repeat, full polarisation	Across-Track Interferometry (XTI), vertical information
Summer ice characterization	Iceberg detection & tracking	3D sea ice topography
Charting automation	Charting automation	Fine structure, edges

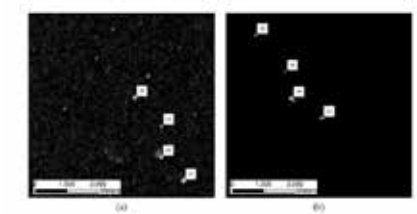
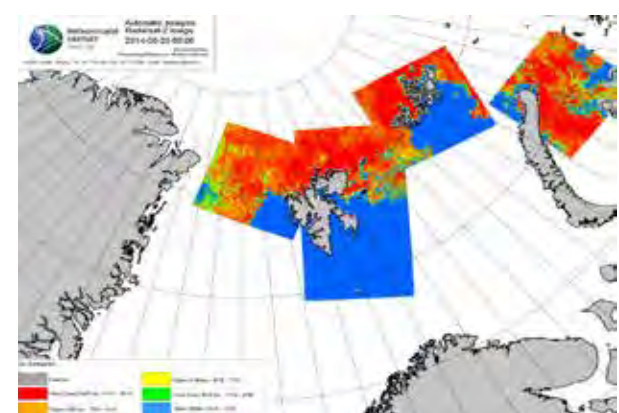
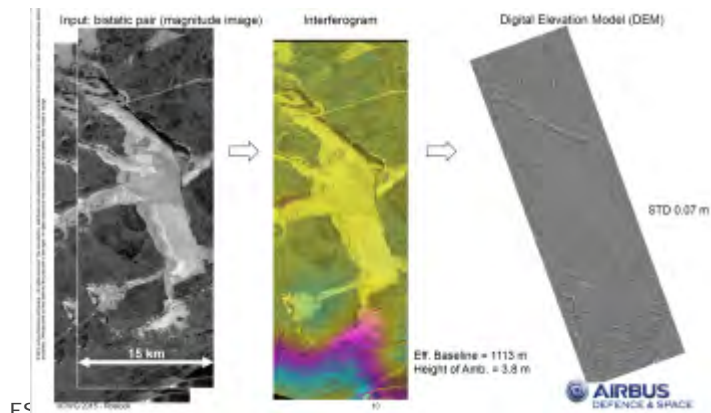


Figure 14: Iceberg 27-28 as they appear in RadarSat-2 from 28 Sept 2013 1100 UTC (a) and Landsat-8 from the same date 17:26 UTC (b)

Iceberg detection using RadarSat High-res SAR

ESA Evidence-based for climate

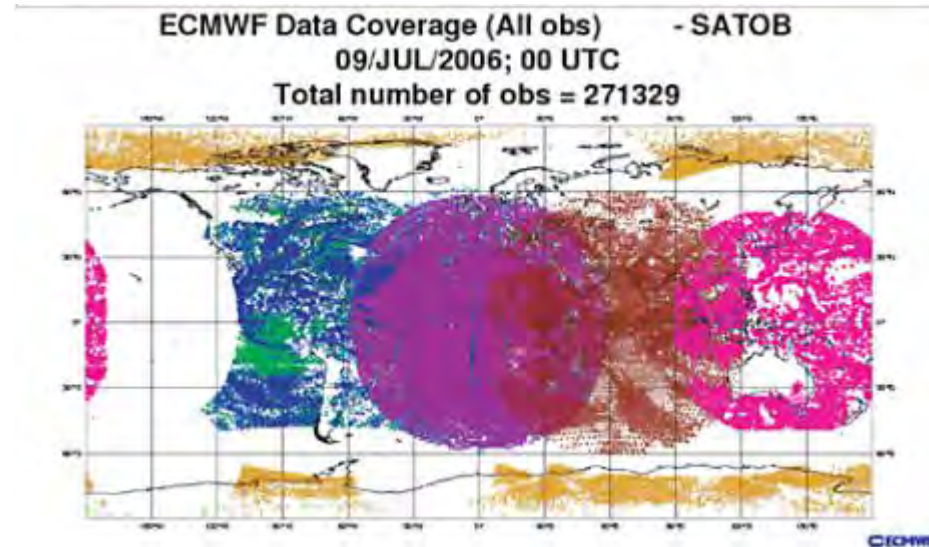
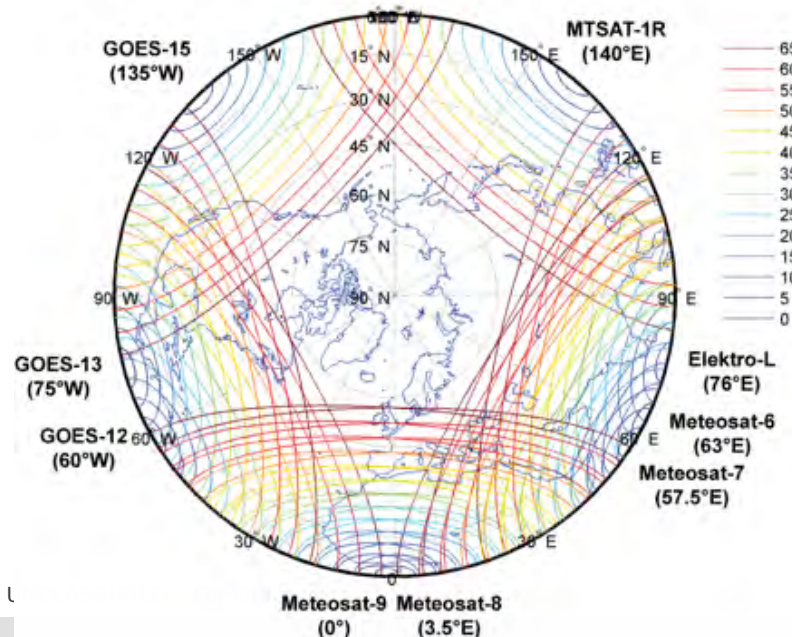
Example of bistatic SAR use for Sea Ice

Polarisation-based sea ice automatic classification



Polar Atmosphere: Polaris Hosted Arctic Imager (HAI)

- One of the concepts (with strong heritage) in ESA's Polaris studies
- Current meteorological observations based on GEO stop at 55-60° latitude
- WMO identified filling this gap as 2025 priority, but past attempts (CAN's PCW) are stalled
- GEO gap common to EO and telecom, hence a Joint Arctic Mission to HEO makes sense, relying on a constellation of two satellites embarking a suite of telecom, navigation and EO payload
- Synergistic mission relevant to EU Arctic Policy needs: Mobile Comms, EO, NAV
- EOP contribution Concept: HAI in Highly Elliptical Orbit (50,000 km max altitude)

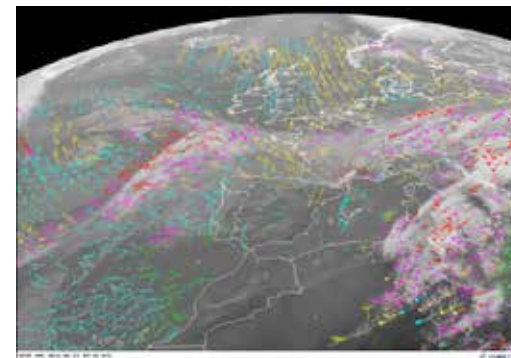
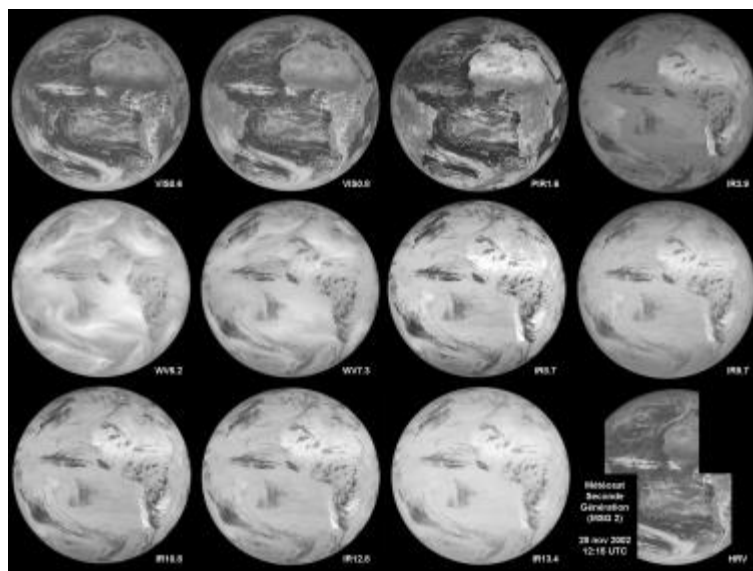


Weather sats GEO & LEO coverage

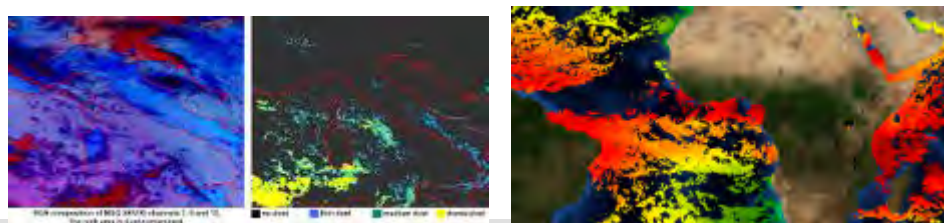
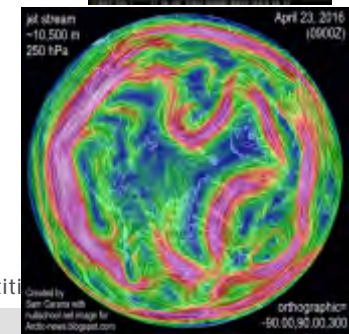
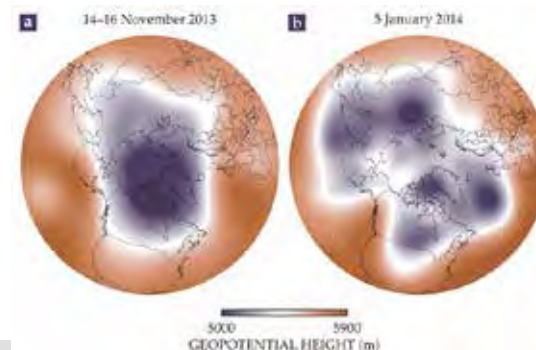
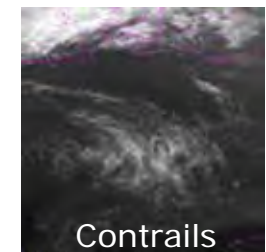
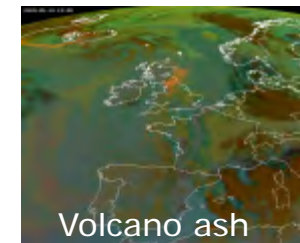
ESA EO Arctic Activities | 4 Nov. 2016 | Slide 19

Polar Atmosphere – Polaris HAI

- Data for weather and climate (and crucial for extreme events at mid-latitudes), but applications also for e.g. land and emergency management
- Imager like SEVIRI on MSG: ~12 channels, 3 km resolution, imaging every 15 min, flying in HEO orbit → specifications adapted to hosted telecom platform



Atmospheric Motion Vector (AMV)



Aerosol Optical Depth Land/Sea surface temperature

Couplings ice-arctic weather-extreme events

ESA Arctic Task Force



The ESA internal “Arctic Task Force”

- ESA DG decision to setup an Arctic Task Force (ATF) in April 2016
- To respond to the needs of four Nordic countries (DK, FIN, NO, SE) and broaden the scope to all ESA MS interested
- Almost all ESA Directorates involved with key participation from EO, COM, and NAV
- Points of contact (PoC) identified in several ESA Member States
- ATF supports pro-active industrial policy management
- Targeting primarily the Arctic, with Antarctic when relevant
- ATF to consolidate all ESA-wide activities so to establish concrete proposals to be presented at the Council meeting at Ministerial Level (CM-16) in December 2016

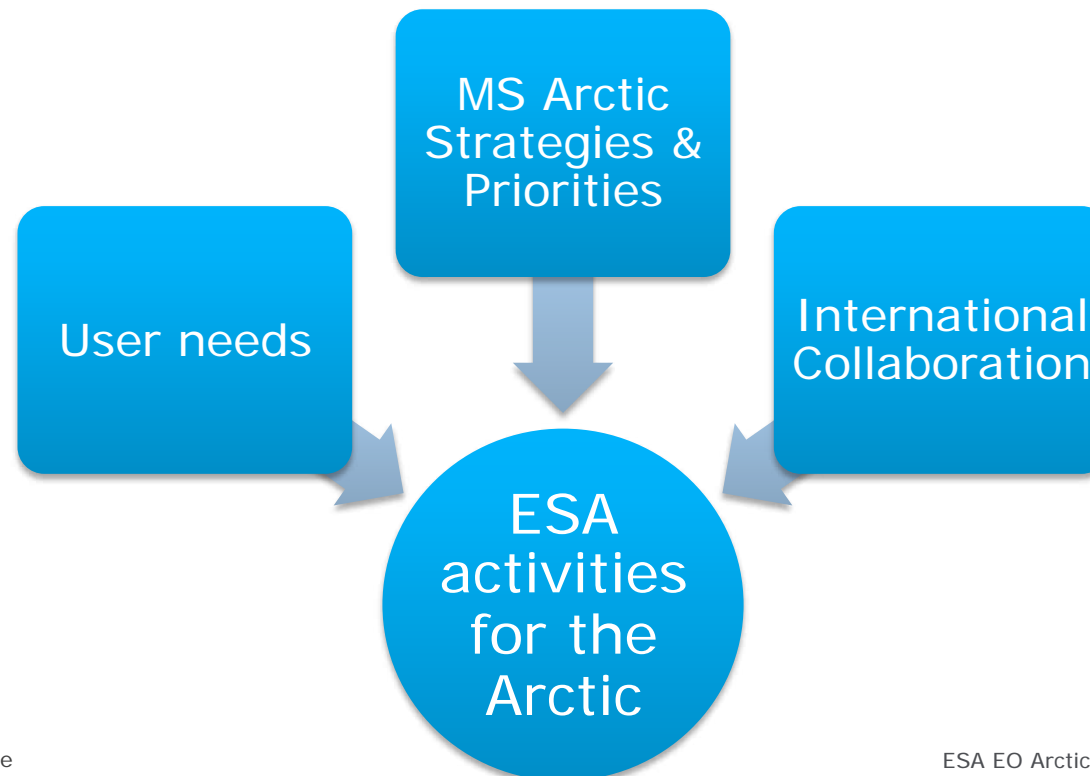
Identification of some opportunities

- Continuity of CryoSat and SMOS
 - Polar mission (Copernicus Evolution)
 - Automatic Identification System (AIS) – extension of Vessel Traffic and Vessel Monitoring Systems to the Arctic
 - Hosted payloads on Highly Elliptical Orbit satellites
 - VHF Data Exchange System (VDE System)
 - Polar-orbiting Synthetic Aperture Radars
 - Automatic Dependent Surveillance –Broadcast (ADS-B) - extending coverage
 - SatCom Payload for secure communications
 - Testing the PROSPECT drill for the Moon
- *Note that most opportunities would also support activities in the Antarctic*

ESA Roadmap for the Arctic (1)

Taking into account:

- User needs (science, operational, environmental, industrial)
- Member States Arctic strategies and priorities
- Activities to be proposed at the CM-16



ESA Roadmap for the Arctic (2)



Roadmap based on three main axes:

- Large missions (phase AB1 -feasibility studies for future Arctic missions)
- Small/medium missions and micro-launchers
- Exploitation activities using existing data and space infrastructure (science, services, and fostering innovation via Business Incubators)

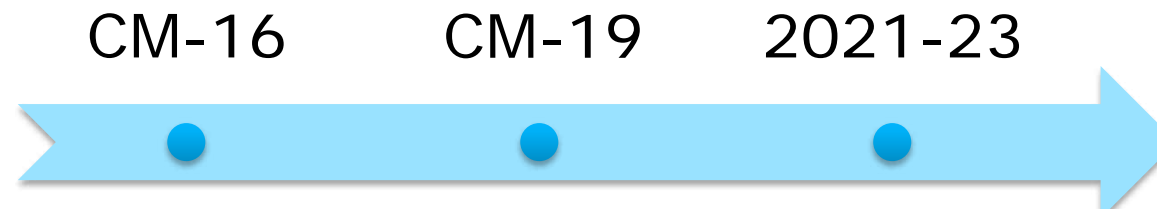
ESA Roadmap for the Arctic (3)

Timeline

- Assessment of current ESA Arctic activities (EOP, NAV, TIA, TEC and potentially OPS, HRE, SCI, LAU)
- New activities to be proposed at CM-16 to fill gaps and better answer to the needs of ESA (Nordic) Member States

Milestone and deliverables

- CM-16: activities approved in the different Directorates + Arctic roadmap
- CM-19: first results for Axes 2+3, decision to implement large missions of Axis 1
- 2021-23: missions of Axis 1 launched



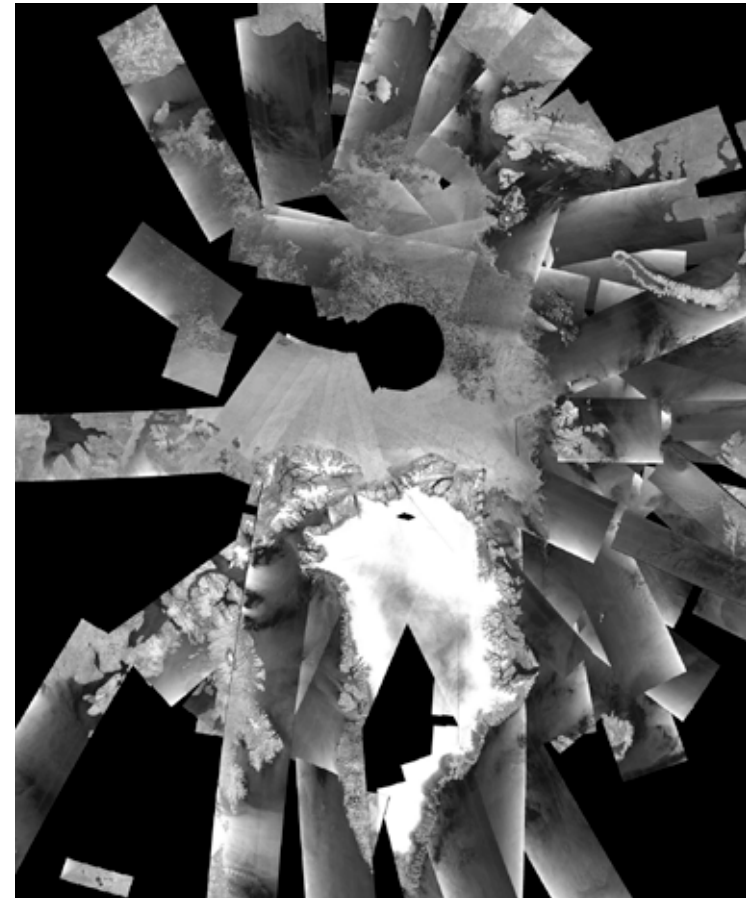
ESA proposed Arctic Activities at CM-16

- Earth Observation (EOEP-5, CCI+):
 - POLARIS preparatory activities, including hosted payloads
 - Preparation of Copernicus Space Component Evolution (Enhanced interferometric altimetry)
 - New ECV's in CCI+
- Telecommunications:
 - Partnership with private Satcom operator (payloads)
 - GovSatCom Precursors
 - VDE or ADS-B capability
- Technology:
 - Polar Satellite Launch Service
 - Sirius nanosatellites
- Science:
 - Solar wind Magnetosphere Ionosphere Link Explorer (SMILE)
- Navigation:
 - Evolution of Arctic Test Bed
 - Polar hosted payloads for GNSS augmentation systems
- Applications:
 - IAP continuation
 - call for ideas for Arctic and sub-Arctic services and applications



Way Foreward

- Many past / actual programmes at ESA serve the Arctic
- The Arctic is already identified in a certain number of programme proposals for Ministerial Council in December 2016
- Most/all ESA Member States have shown interest for the Arctic
- Specific activities are already identified and need validation from users and from Member States
- In discussion with EC (DG-GROW) about Copernicus evolution – EC considers a polar mission to support EU policies



S1a 3-day mosaic image 5 Sep 2016