# ESA Earth Observation and Polar Areas

[ESA and International Polar Year 2007-2008]

*Henri Laur and Mark Drinkwater*

ESA Earth Observation Programmes Directorate

# Background

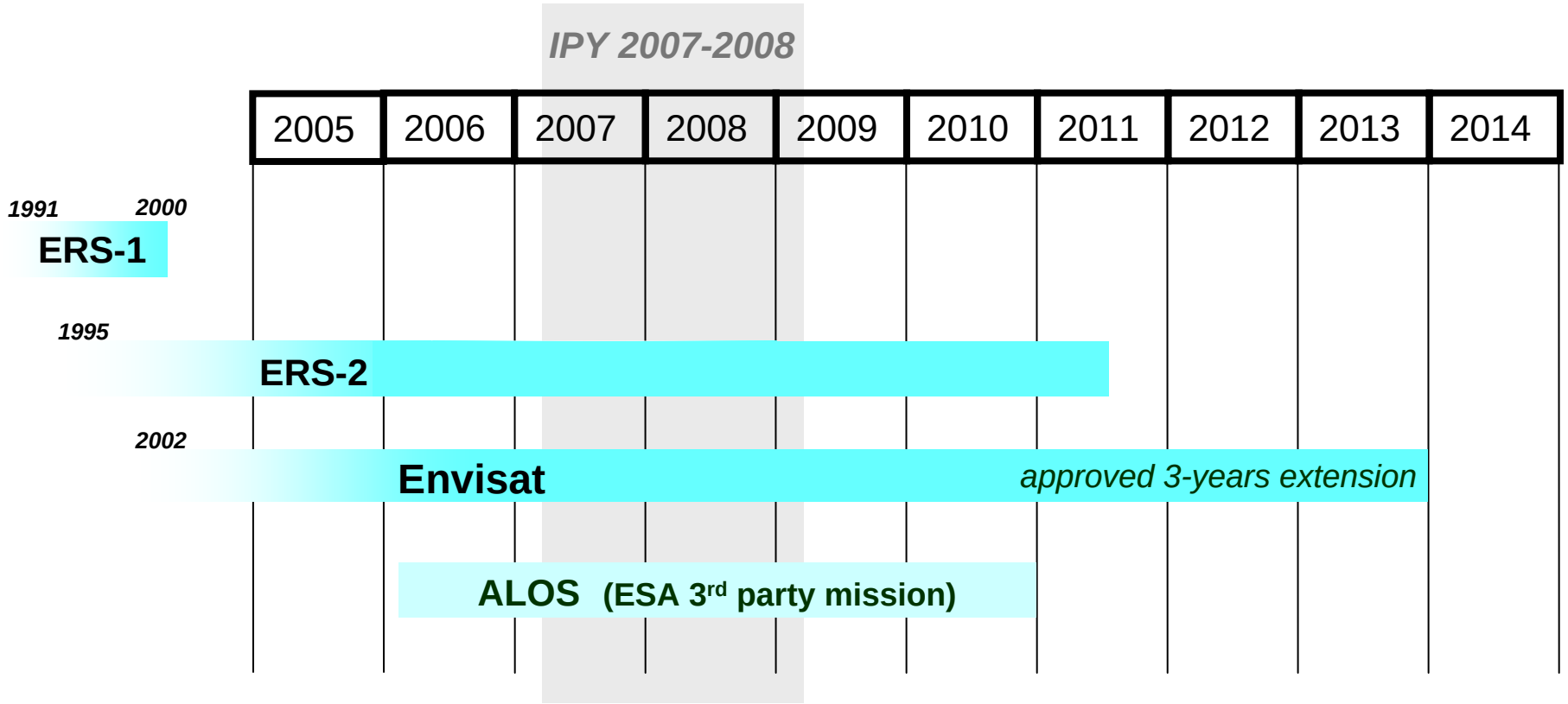
Since 20+ years, ESA is increasingly supporting the Cryosphere communities with the provision of Earth Observation data:

- in the 80's, with Landsat (European Arctic),
- since 1991, through ***ERS-1*** *and* ***ERS-2*** (SAR, Altimetry, Ozone monitoring),
- from 2002, with an increased capacity provided by ***Envisat*** (SAR, Altimetry, Atmospheric Chemistry, Imaging Spectrometer).

→ ESA was the initiator of the space agencies contribution to International Polar Year 2007-2008 (GIIPSY initiative).

→ importance of legacy data acquisition.

# ESA EO missions contributing to polar observations



# ESA and International Polar Year

ESA supported the International Polar Year activities:

❑ dedicated Announcement of Opportunity (AO) for EO data provision in support of IPY with data provision to 48 scientific projects.

❑ in the framework of the IPY Space Task Group (GIIPSY), several activities to ensure the acquisition of an increased amount of EO data over polar areas:

→ ***ESA legacy EO data portfolio for IPY***

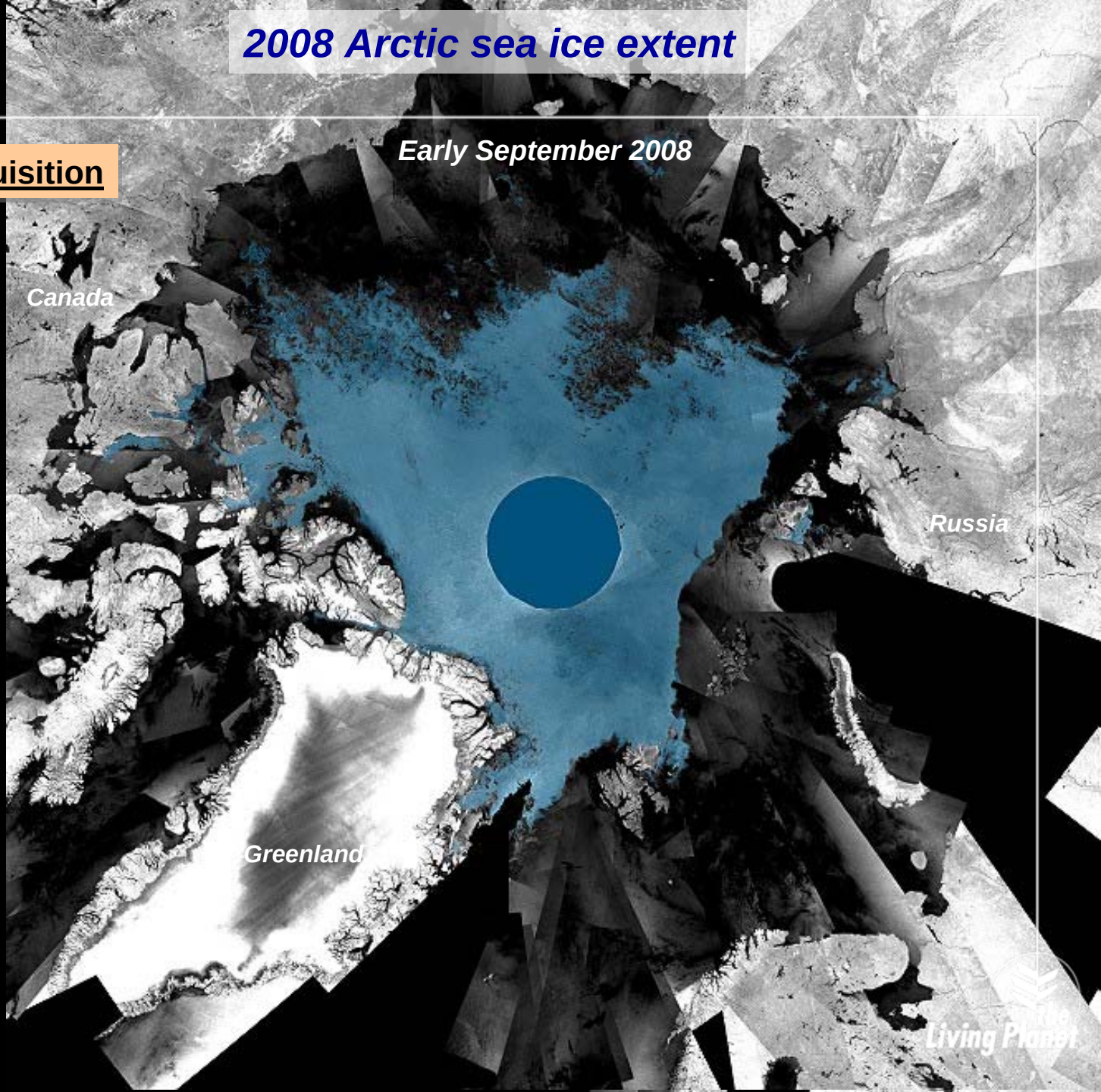
# *SAR Sea-Ice Mosaics*

## Legacy SAR data acquisition

**Envisat ASAR for polar applications (e.g. sea ice, support to polar expedition):**

1- Systematic coverage of Antarctica, Antarctica seas and Arctic seas, using ASAR Wide Swath Mode (150 m resolution) or Image Mode (25 m res.)

2- Supplementary coverage of all polar areas using ASAR Global Monitoring Mode, (1000 m resolution) when ASAR not operated in Wide Swath Mode or Image Mode.



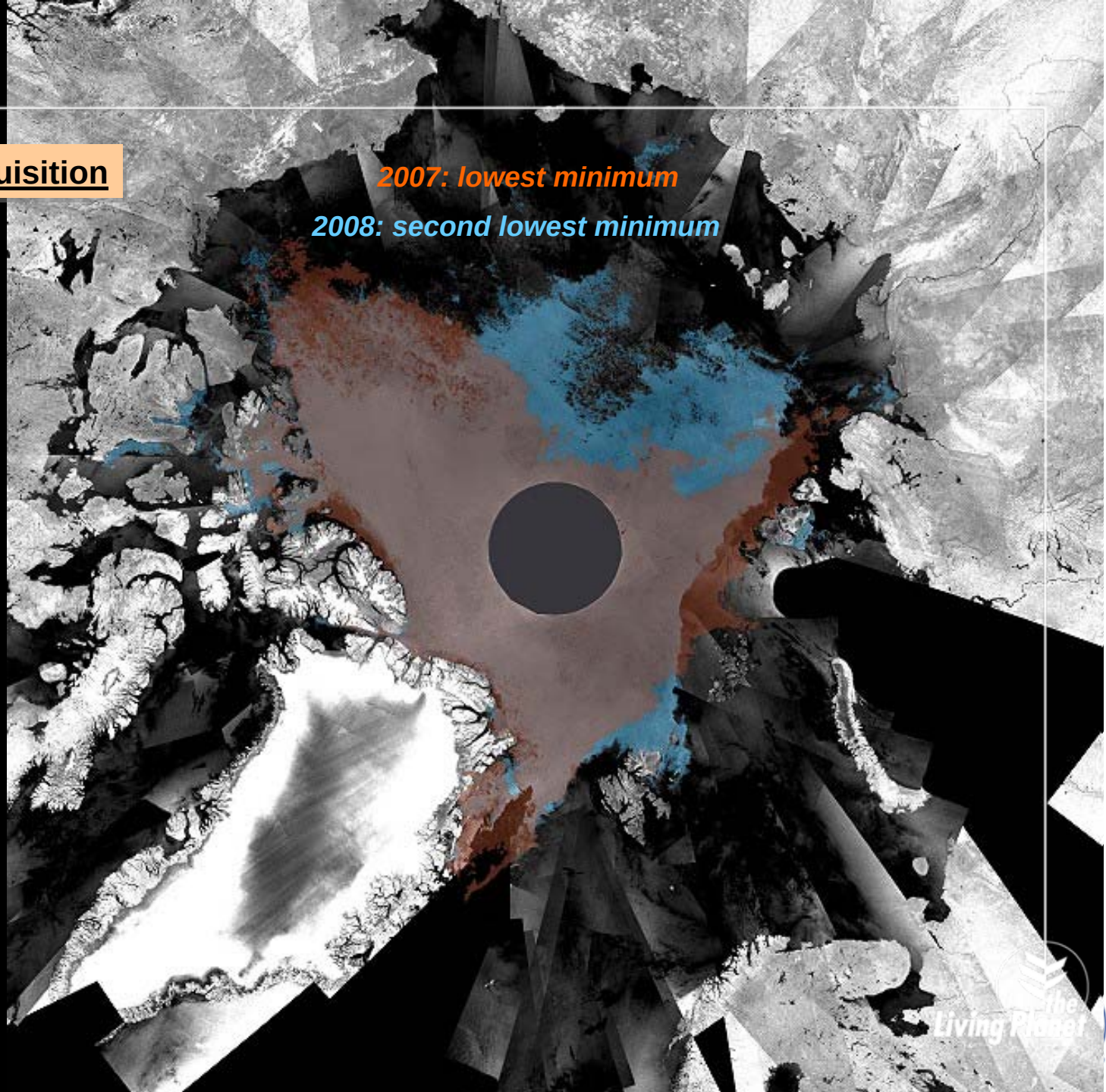
esa

## Legacy SAR data acquisition

*2007: lowest minimum*

*2008: second lowest minimum*

# *Arctic sea ice extent 2008*



*Envisat ASAR mosaic*

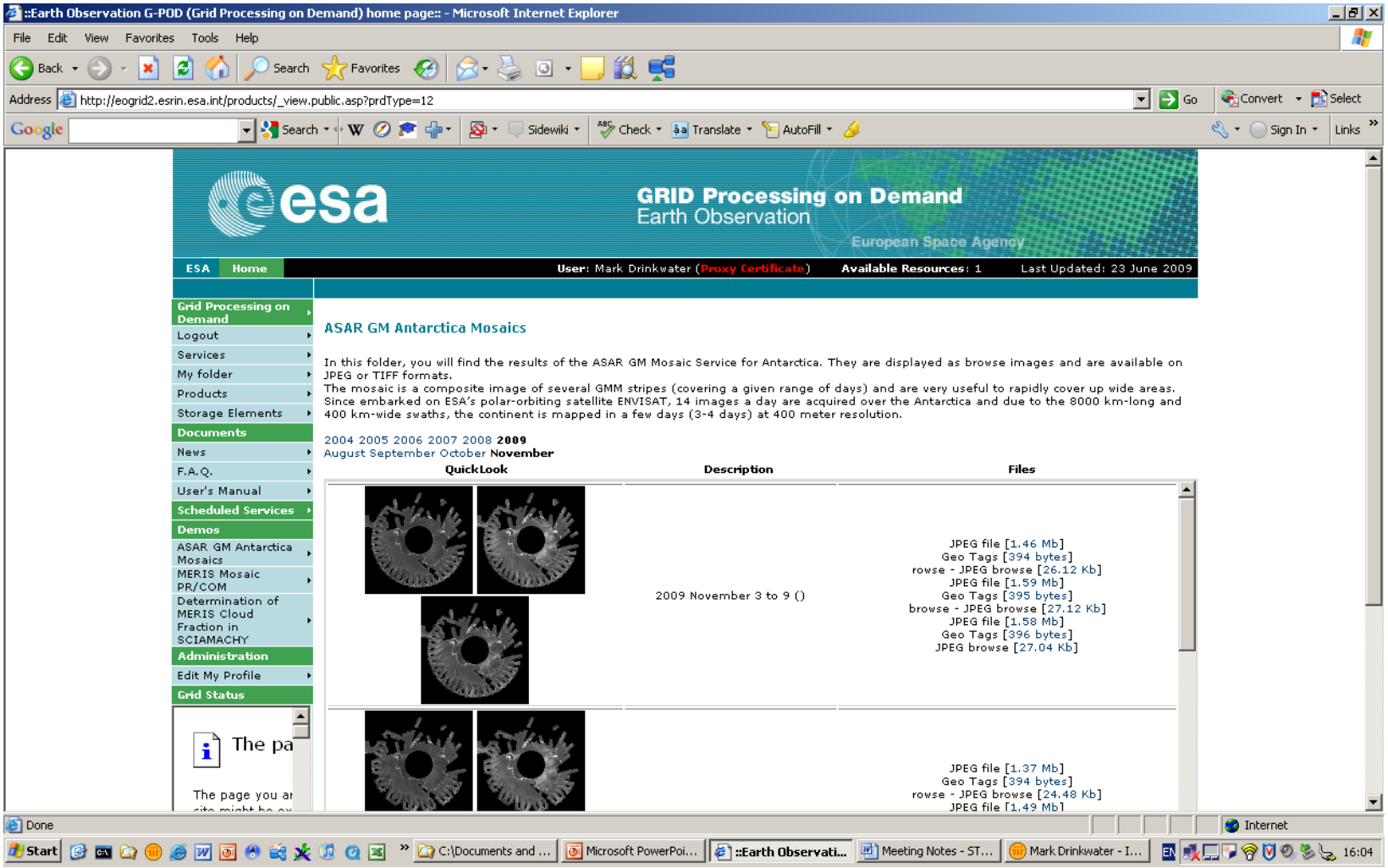
European Space Agency
Agence spatiale européenne

the Living Planet

esa
N
Envisat ASAR - 31 August 2007
Direct North West Passage open
This type of Envisat ASAR products were freely available for IPY use
European Space Agency
Agence spatiale européenne
the Living Planet

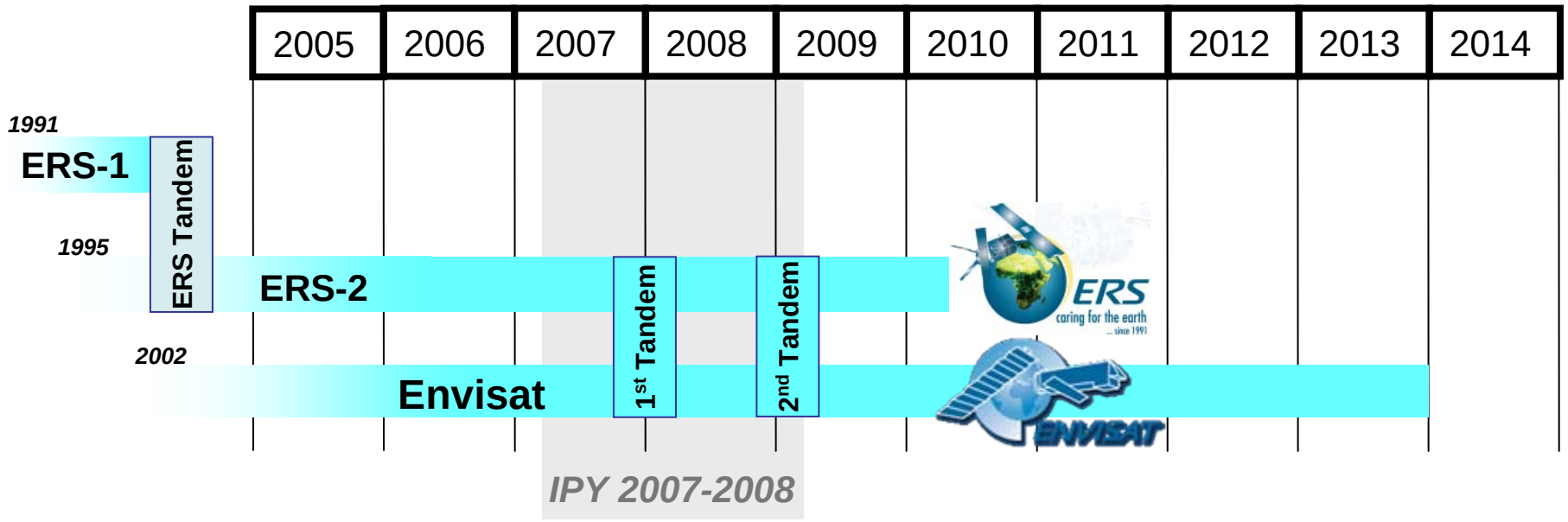
# *SAR Mosaic Processing*

# GRID Processing On Demand (G-POD)
## Mosaic Processing



# *Cross-Interferometric SAR (CInSAR)*
# *ERS-2 – Envisat InSAR*
# *IPY Legacy Data*

# Legacy SAR data acquisition for IPY



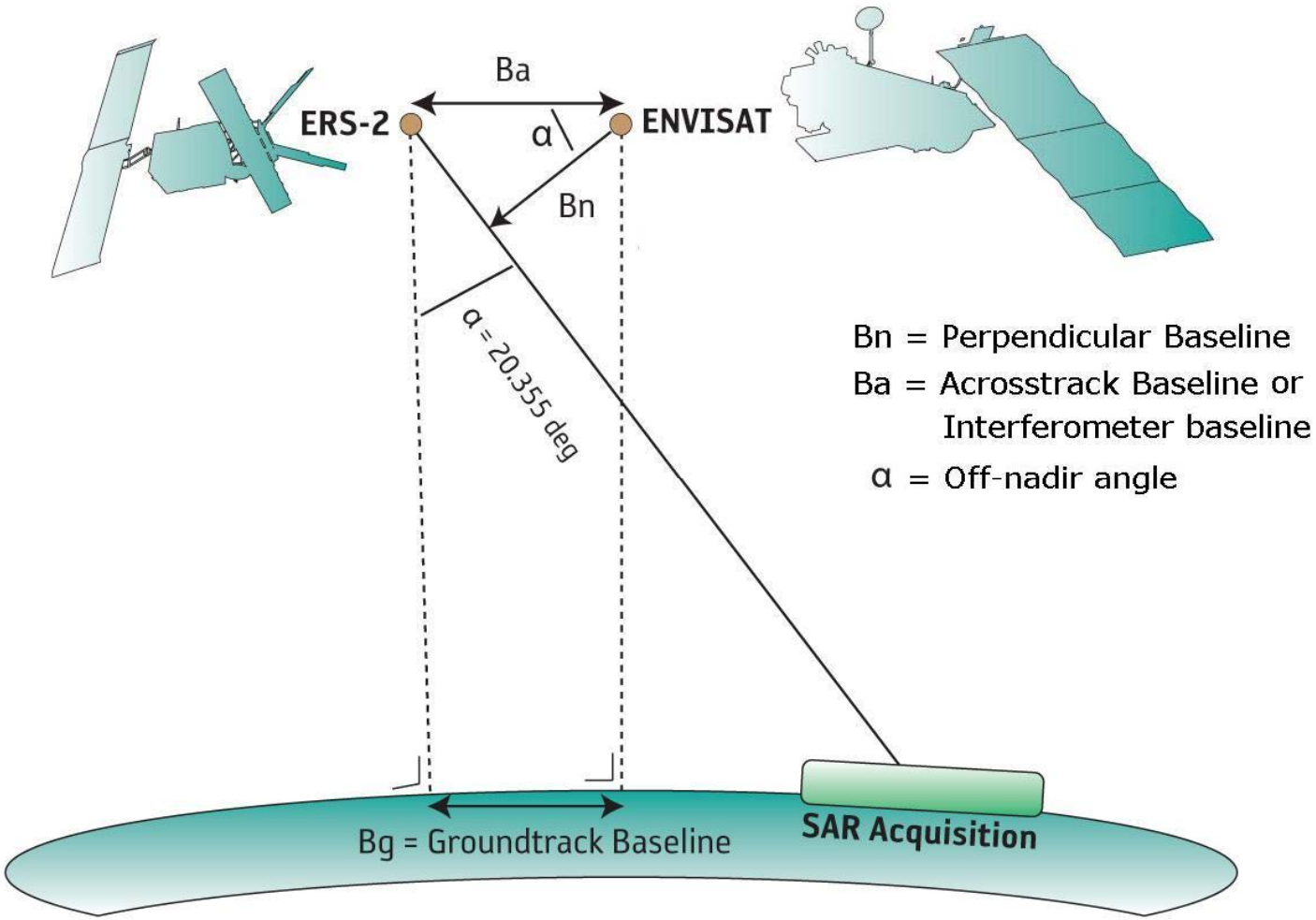

- The **ERS-2 / Envisat SAR Tandem campaigns** aimed to:
  - ✓ Measure *velocity of fast moving northern polar glaciers* (> 200 m/year). ERS/Envisat SAR data should be suited to map velocities of 1 cm between the two 30-minutes passes.
  - ✓ Generate accurate *low relief Digital Elevation Models*. This is of particular interest for many low elevation delta regions, in particular for polar areas (North Canada, North Russia) where there is no available SRTM DEM's.

- Temporary modification of ERS-2 orbit (2 km off-set versus nominal ground track) to have optimal SAR interferometric baselines between ERS-2 and Envisat (30 min. separation) over Northern latitudes.

# Inter-satellite SAR interferometry

- Thanks to the common ground-track of ERS-2 and Envisat, the two sensors could revisit the same areas on the Earth's surface with a time delay of approximately 30 minutes but…
- There is a difference of 35 MHz in the carrier frequencies of the two SAR systems. Until 2007 few cross-interferograms had been generated…
- The frequency gap can be compensated by tuning the baseline: a **perpendicular baseline of 2.1 km** makes the inter-satellite interferometry possible.

# Inter-satellite SAR interferometry



# Tandem constellation

Target: Change the orbit control of ERS-2 in order to achieve a flying formation that leads to:

Perpendicular baseline of 2.1 km = GT deviation of 2.0 km

# Previous campaigns. Overview

- First campaign
  - Duration: 2007/09 – 2008/02 (4 repetition cycles)
  - Targets achieved:
    ERS-2/Envisat latitudes at [60,81] deg North at the descending arc
    ERS-2/ERS-2 Equator (low latitudes) for cycles 1 and 2 and
    latitudes [30,40] deg North for cycles 3 and 4 wrt cycle 1 and 2
- Second campaign
  - Duration: 2008/11 – 2009/01 (2 repetition cycles)
  - Targets achieved:
    ERS-2/Envisat latitudes in [60,81] deg North descending
    ERS-2/ERS-2 Equator (low latitudes) within nominal dead-band
- Second campaign (extension)
  - Duration: 2009/01 – 2009/04 (2 repetition cycles)
  - Targets achieved:
    ERS-2/Envisat latitudes in [30,70] deg North descending
    ERS-2/ERS-2 latitudes in [20,50] deg North ascending kept within
    nominal dead-band

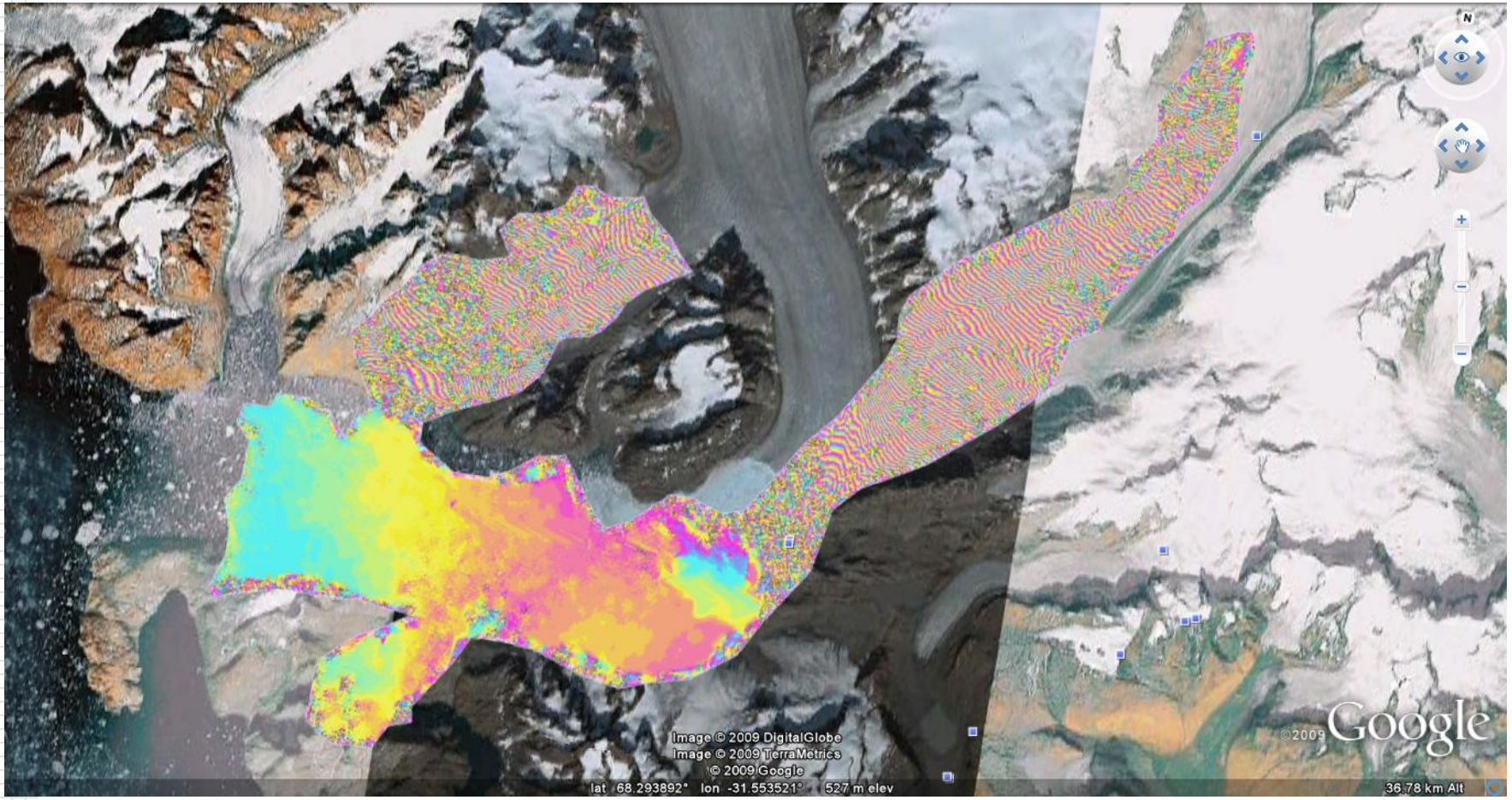
# New campaign 2010/02 – 2010/??

- First half (two repetition cycles):
  - Targets: Antarctica
  - Orbit control: 2 km ERS-2/Envisat GT deviation at minimum latitude would provide (in combination with a proper in-plane control) a 2.1 km interferometric baseline at low latitudes, [70,81] deg South.
- Second half (?):
  - Targets: **To be defined**. High latitudes assumed (incl Greenland).
  - Orbit control: For the high latitudes assumption, 2 km ERS-2/Envisat GT deviation at the maximum latitude of the orbit.
- Common requirements:
  - Keep the ERS-2/ERS-2 nominal dead-band at given latitudes: Etna, Vesuvius, Southern California and around the Equator.
  - Natural drift of the inclination used as the only means of inclination decrease =>No out of plane manoeuvres (OCM) to reduce the inclination! This minimizes the operational risk in terms of gyros usage and utilization of non calibrated thrusters.

# Examples of CInSAR Results from first 3 Tandem Campaigns

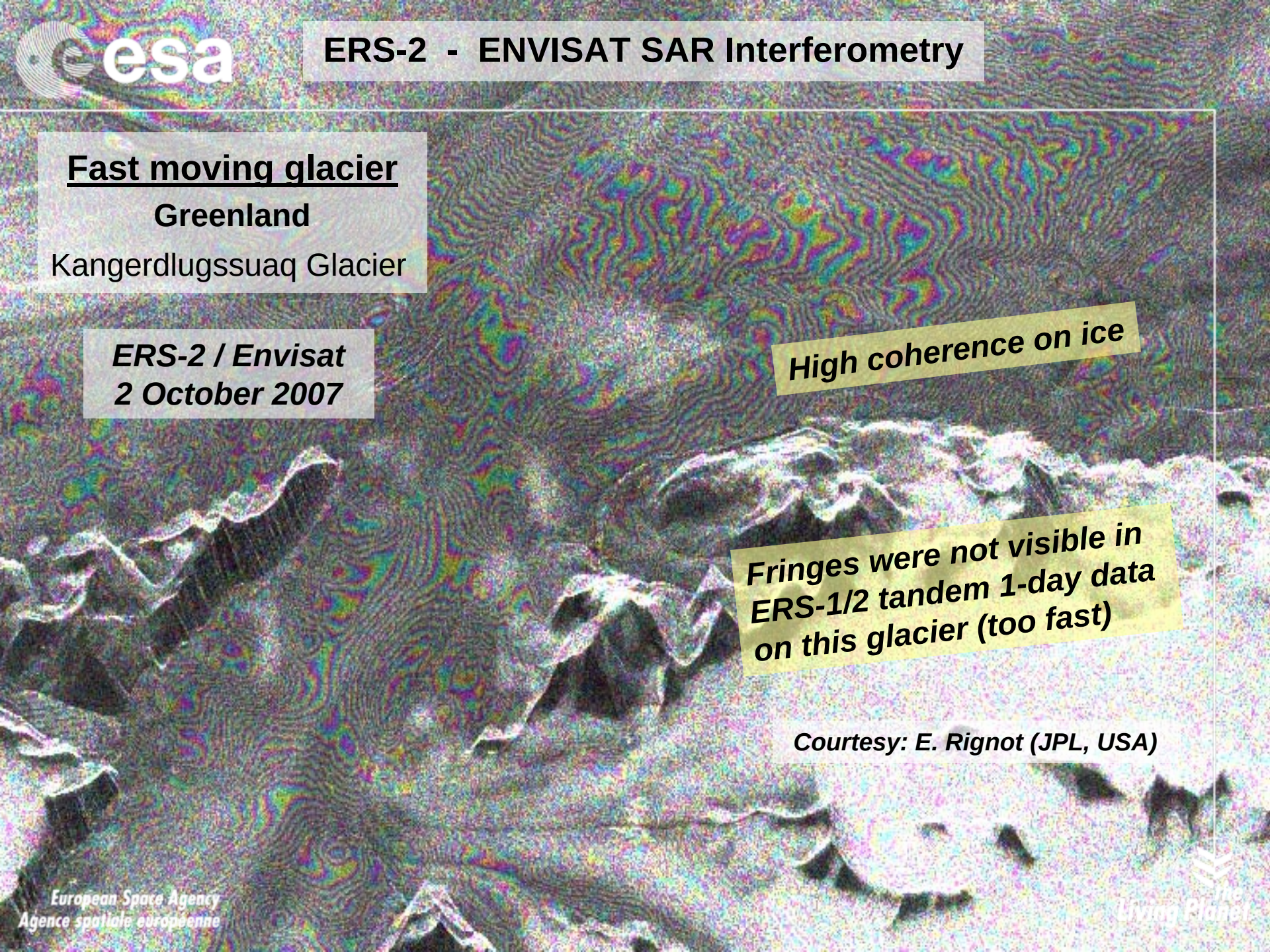
sarmap
your information gateway

# CInSAR processing results over ice



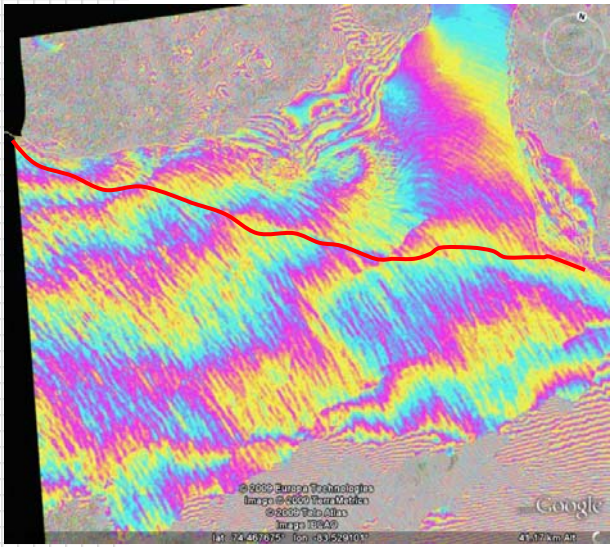

Glaciers in east Greenland, Mount Gunnbjørn area

# ERS-2 - ENVISAT SAR Interferometry

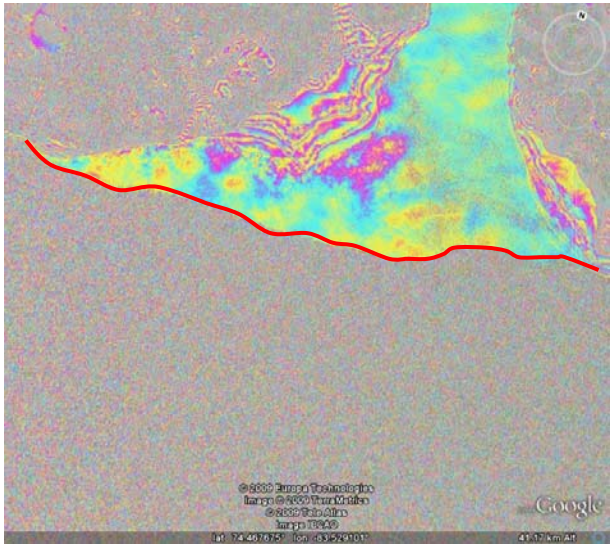


# Identification and monitoring of the grounded ice border

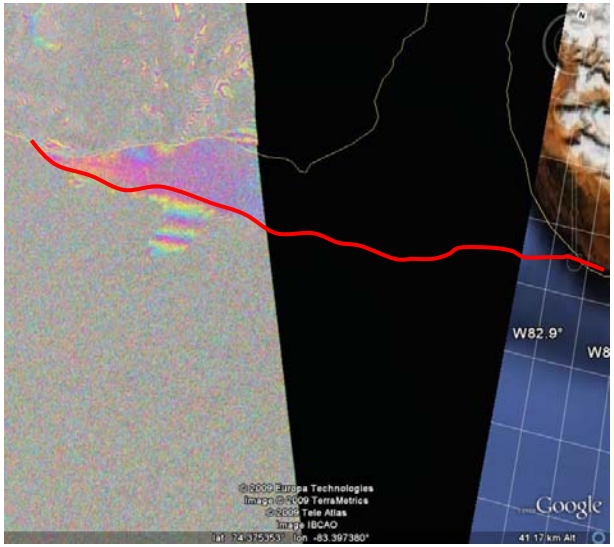
January 4th



January 7th



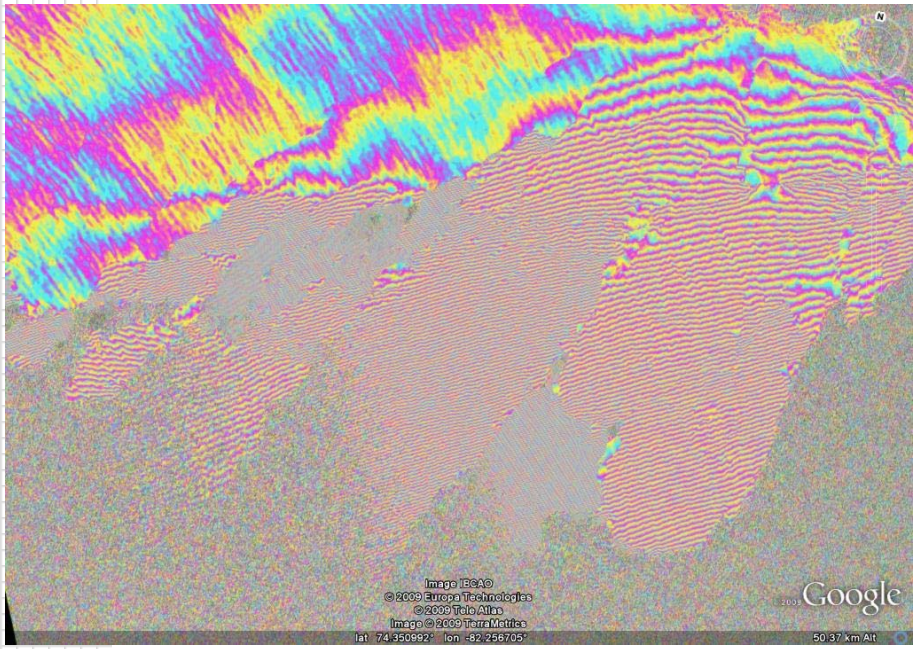
January 10th




North-west channel, Northern Canada

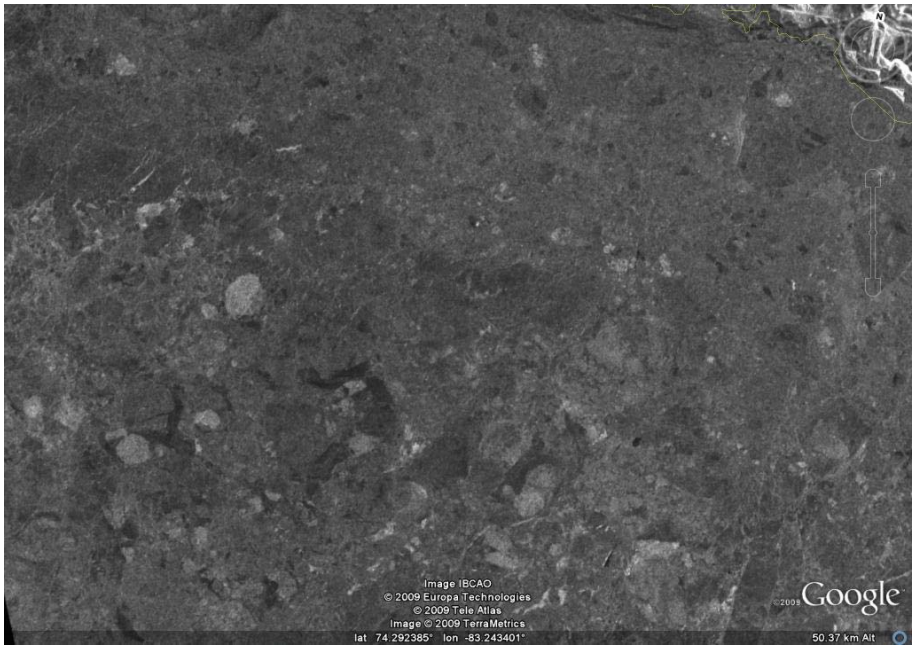
# Monitoring sea ice displacement

Flattened interferogram




Several fragments of pack moving with different speed / direction

ASAR Amplitude

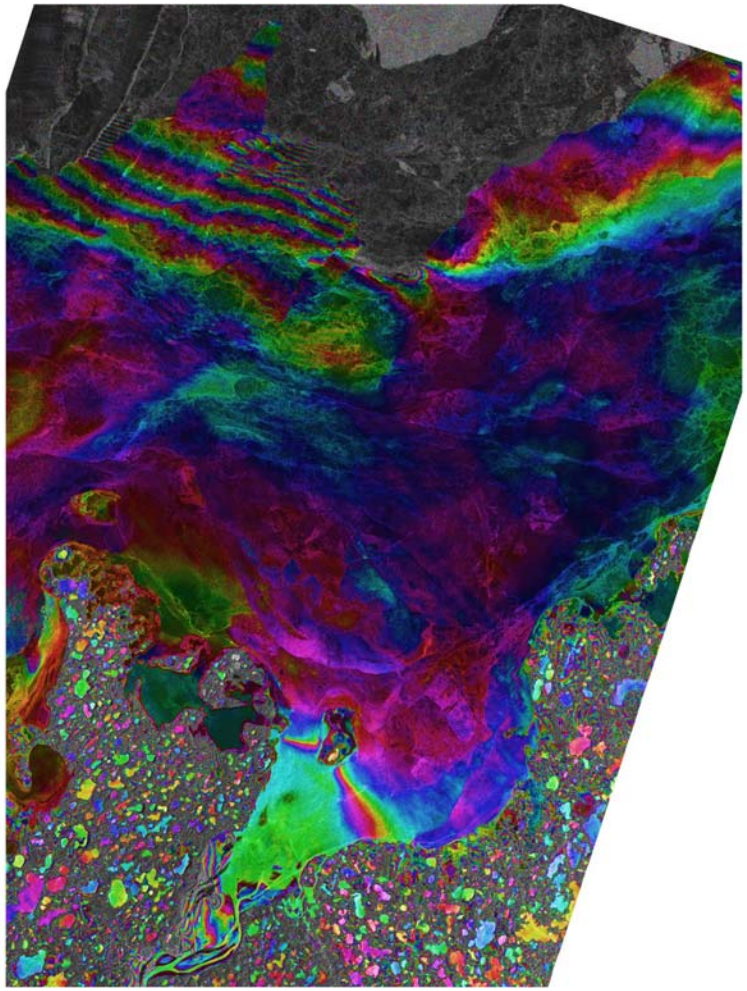



No evidence of the different fragments from the SAR amplitude

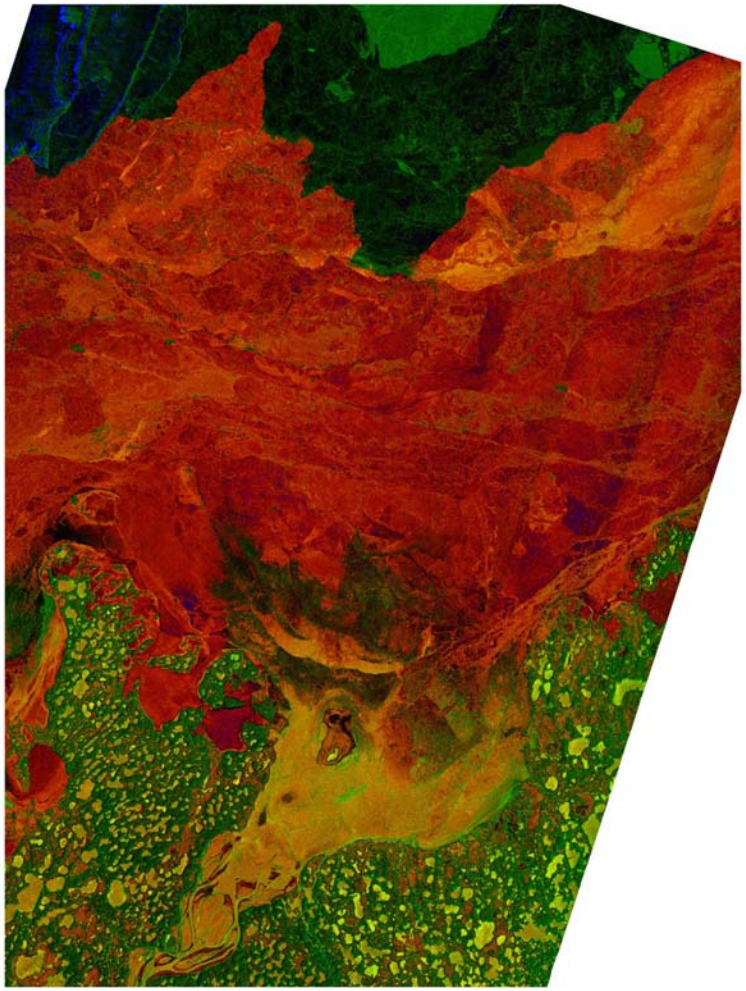
North-west channel, Northern Canada

# Kugmallit Bay, Canada

ERS-ENVISAT Cross-Interferogram, 10-March-2009, $B_{\perp}$=2247m, dt=28min.



0 $2\pi$ phase



Coherence product

R = coherence
G = backscatter
B = backscatter change

# *Medium Res. Optical IPY Legacy Data*

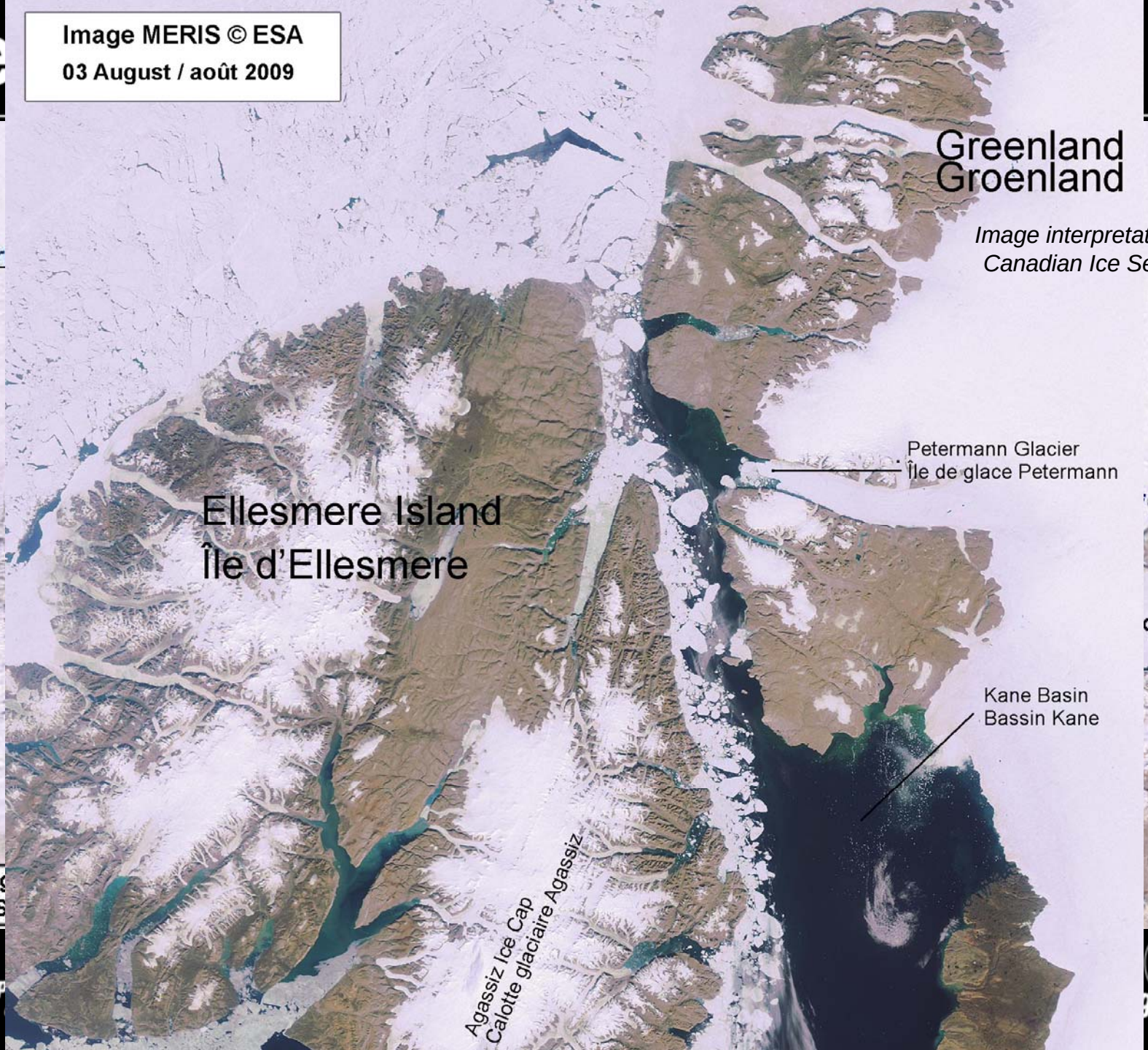
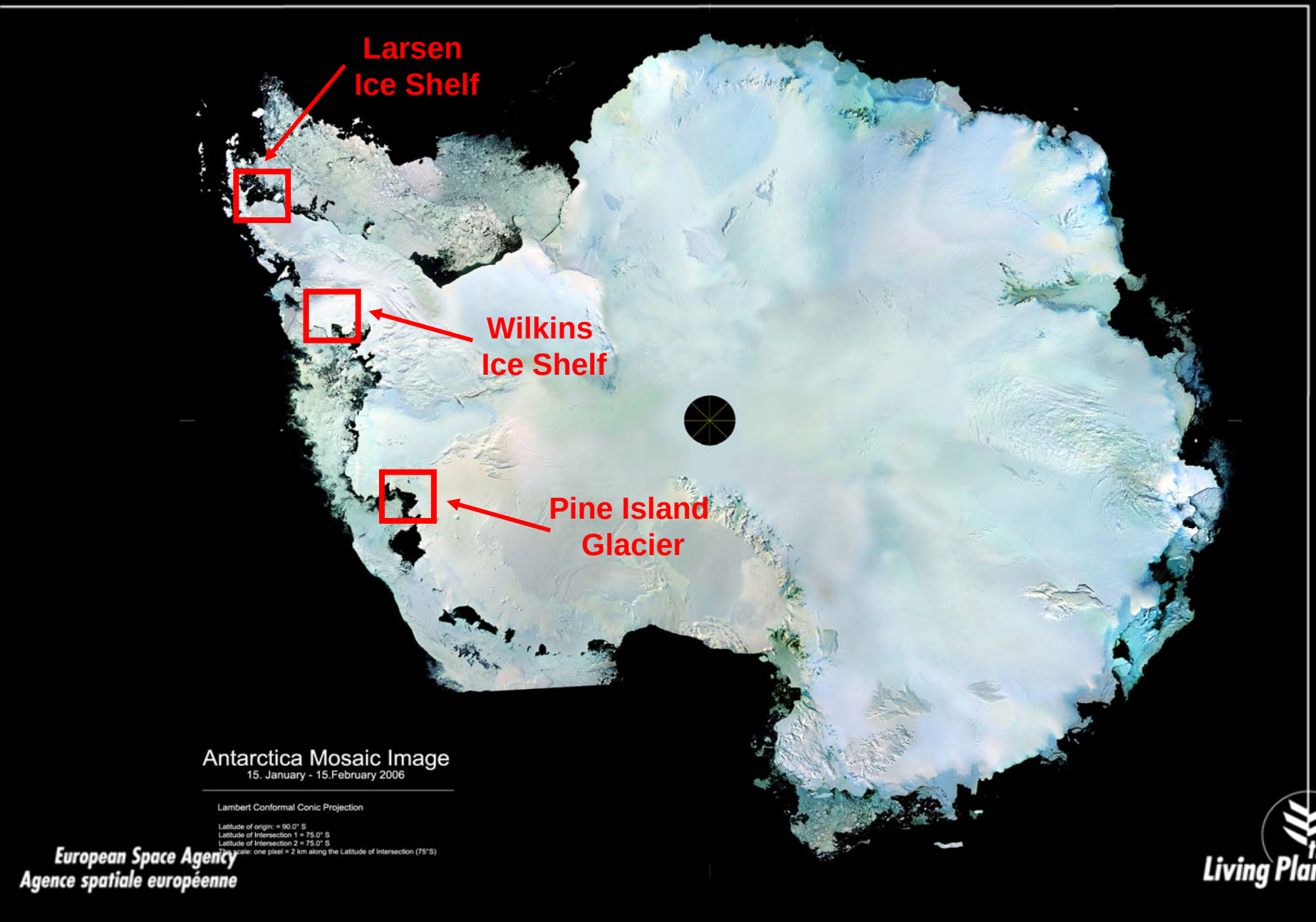
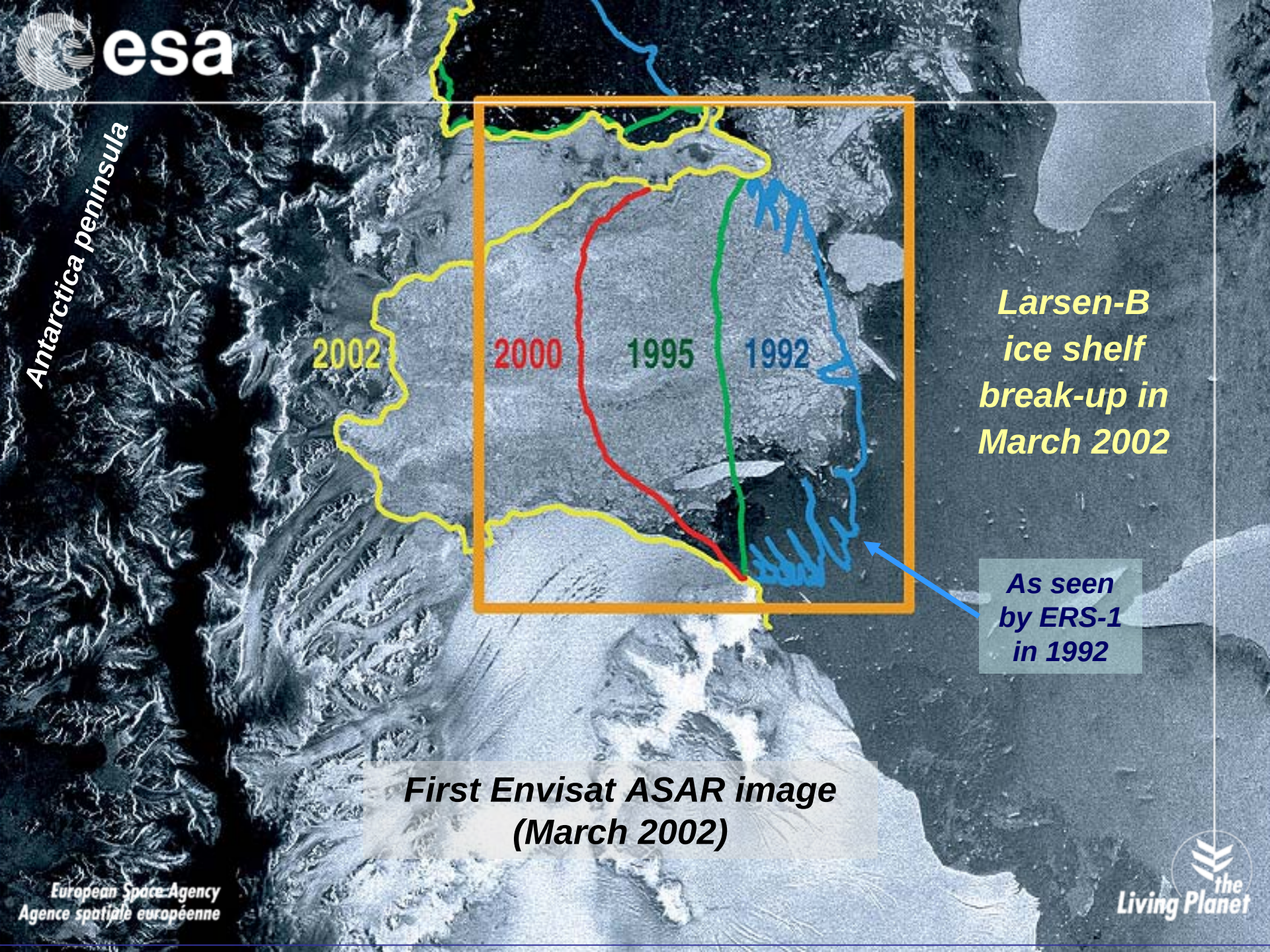


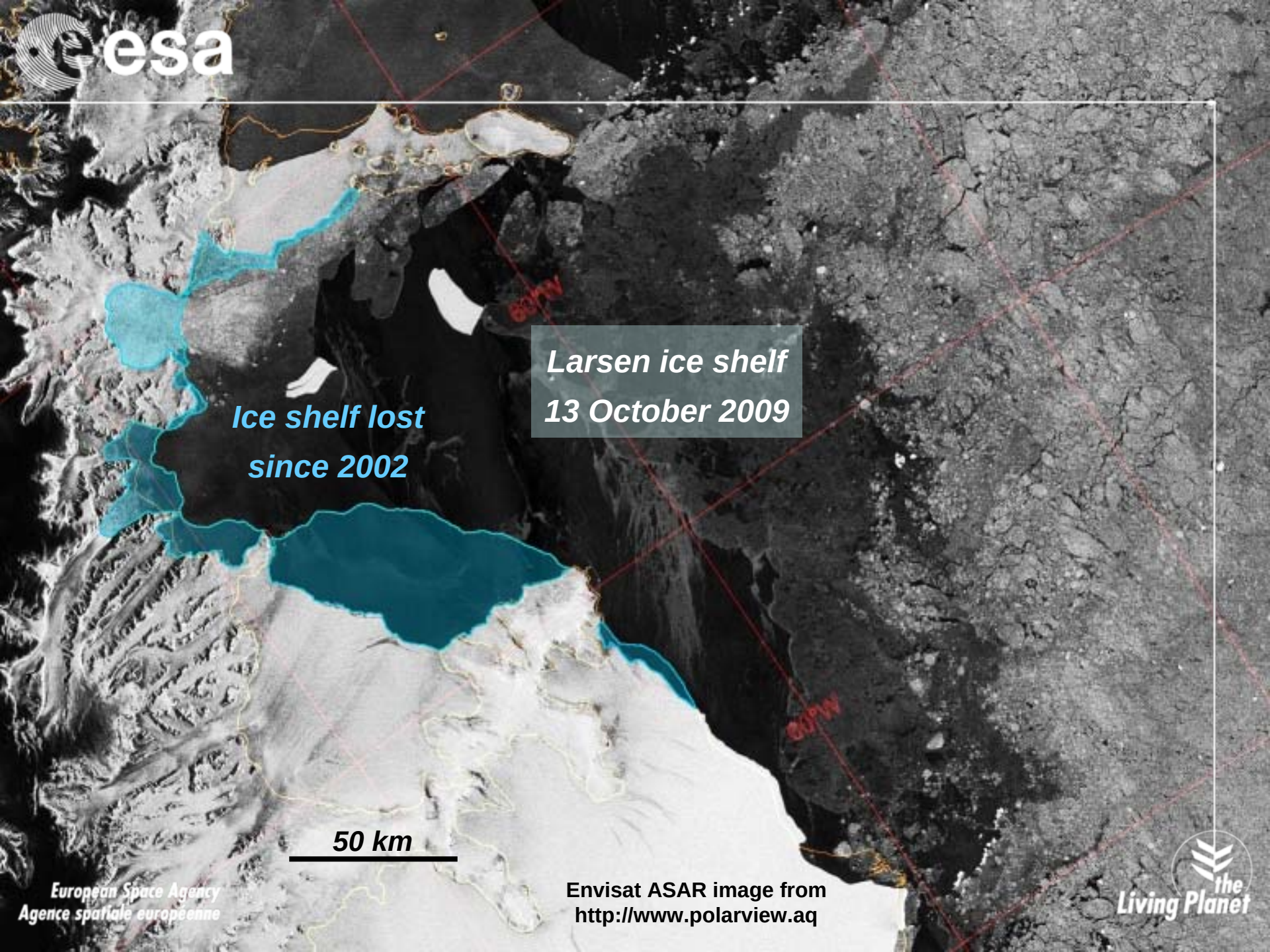
Image MERIS © ESA
03 August / août 2009
Greenland
Groenland
Image interpretation by
Canadian Ice Service
Petermann Glacier
Île de glace Petermann
Ellesmere Island
Île d'Ellesmere
Kane Basin
Bassin Kane
Agassiz Ice Cap
Calotte glaciaire Agassiz

# *Ice Shelf Monitoring*
# *IPY Legacy Data*

# Legacy SAR data acquisition for IPY (Antarctica)




esa
Antarctica peninsula
2002
2000
1995
1992
Larsen-B
ice shelf
break-up in
March 2002
As seen
by ERS-1
in 1992
First Envisat ASAR image
(March 2002)
European Space Agency
Agence spatiale européenne
the
Living Planet


esa
Larsen ice shelf
13 October 2009
Ice shelf lost
since 2002
50 km
European Space Agency
Agence spatiale européenne
Envisat ASAR image from
http://www.polarview.aq
the
Living Planet

ENVISAT

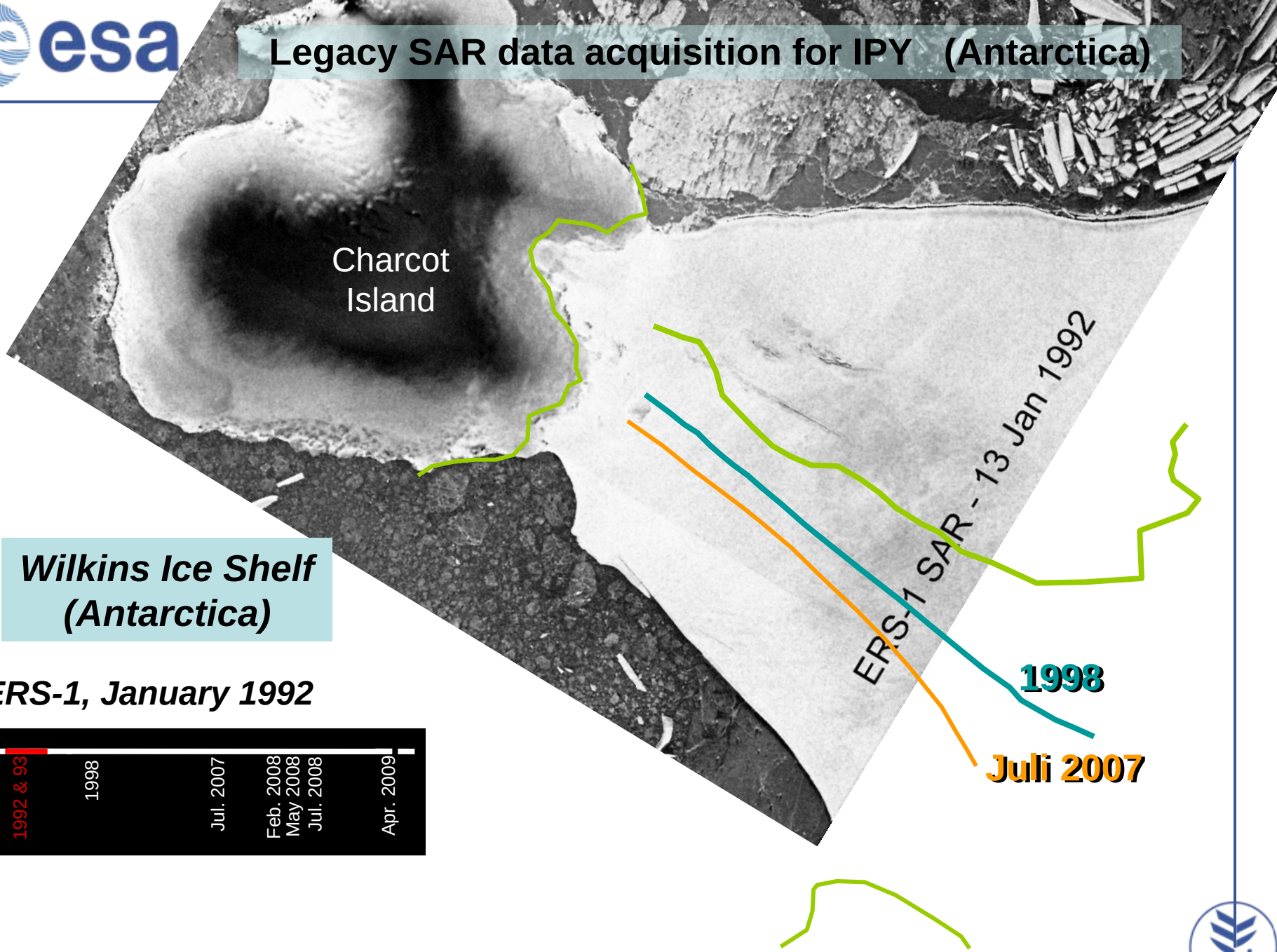
**Birth of a giant iceberg that has broken off from the Pine Island Glacier in West Antarctica**

**Length: 34 km**
**Width: 20 km**

**ASAR**
**Wide Swath,**
**150 m res.**

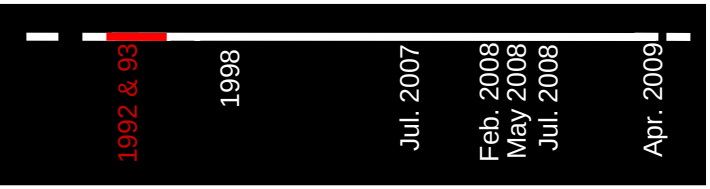
The Living Planet

# Legacy SAR data acquisition for IPY (Antarctica)



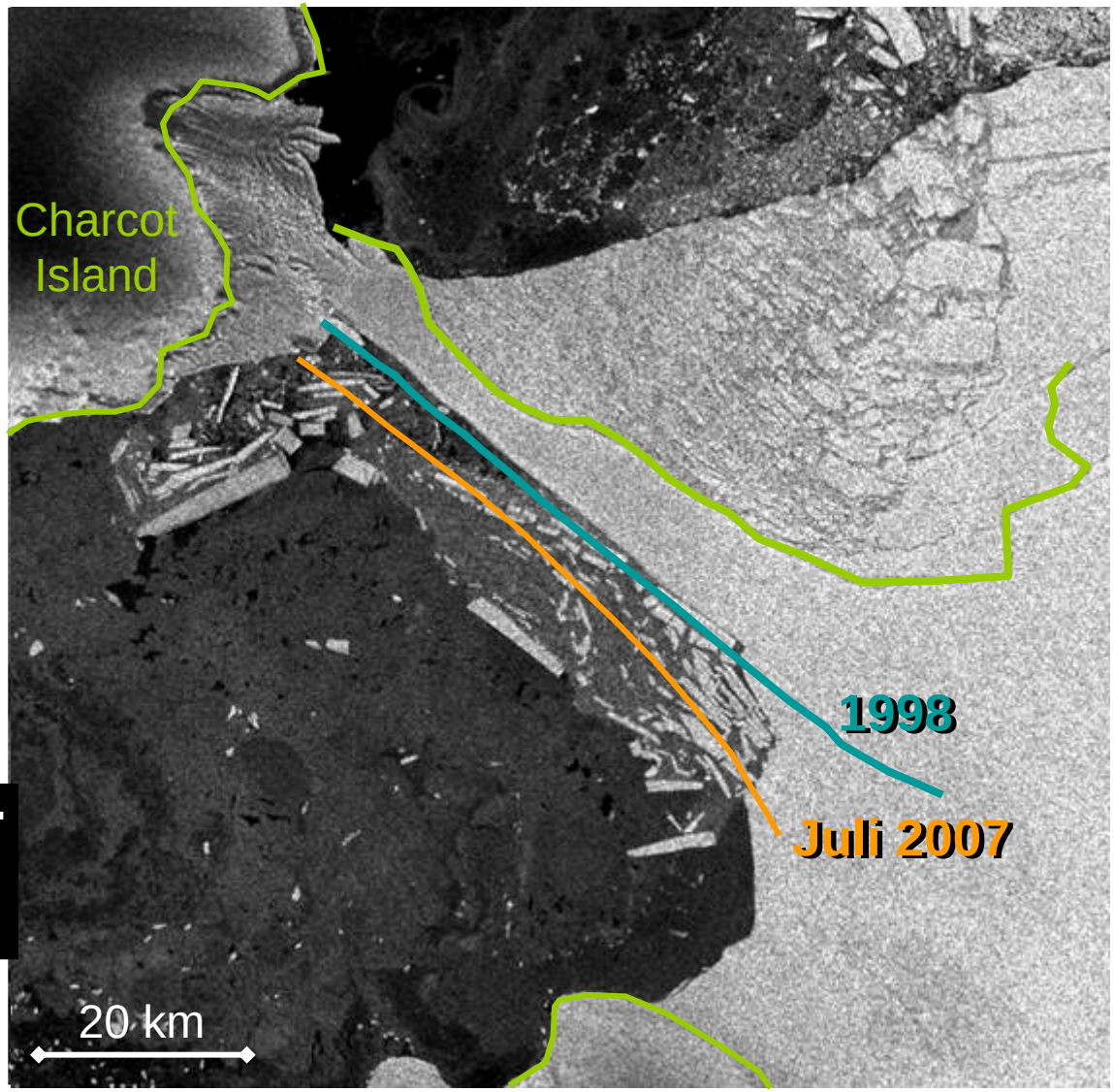

***Wilkins Ice Shelf (Antarctica)***

***ERS-1, January 1992***

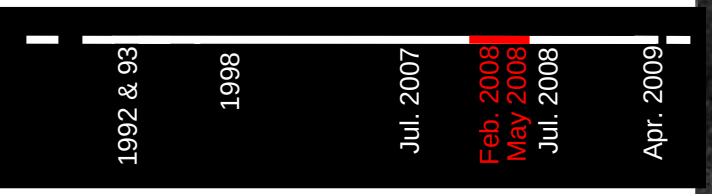


# Legacy SAR data acquisition for IPY (Antarctica)

***Wilkins Ice Shelf (Antarctica)***




***February & May 2008***



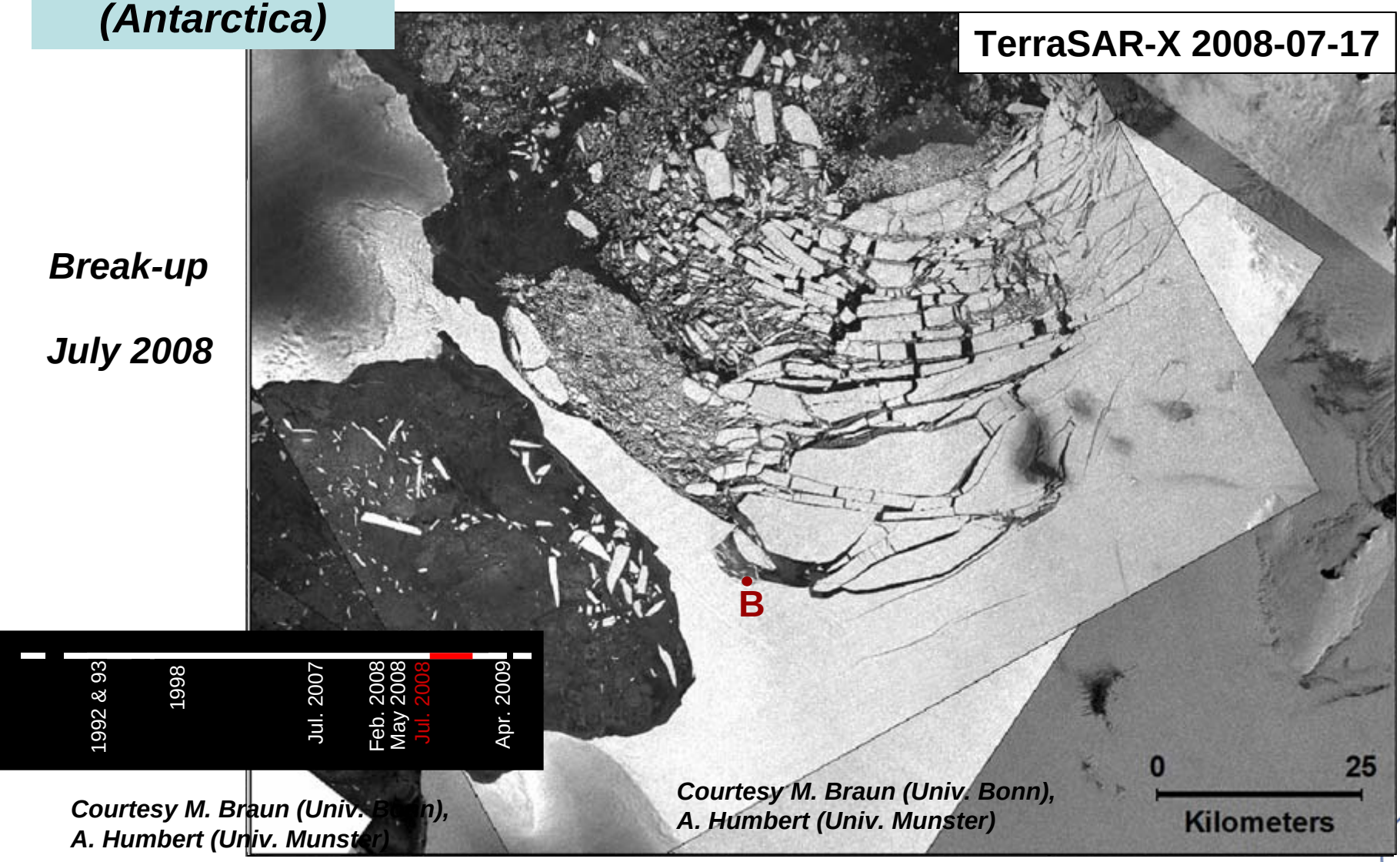

***Courtesy M. Braun (Univ. Bonn), A. Humbert (Univ. Munster)***

# Legacy SAR data acquisition for IPY (Antarctica)

## *Wilkins Ice Shelf (Antarctica)*

***Break-up***

***July 2008***



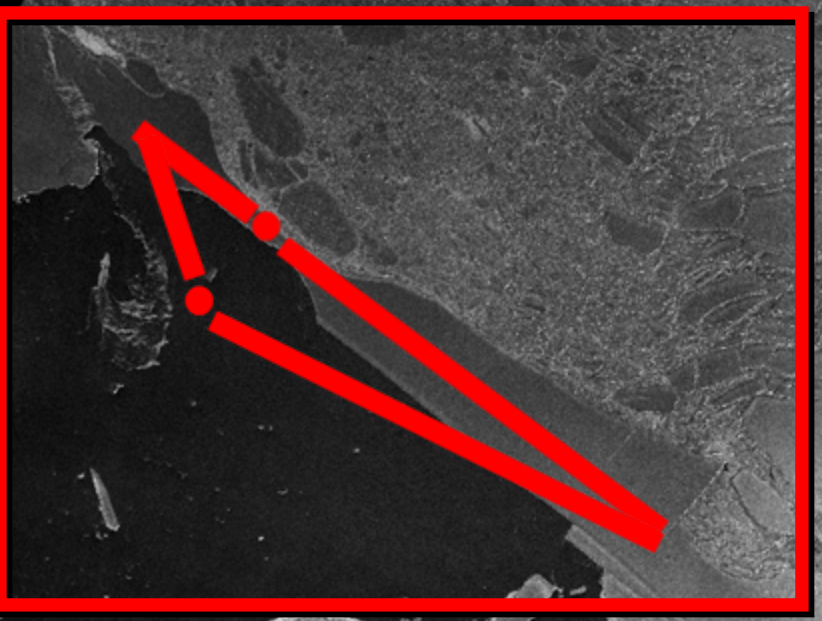

*Courtesy M. Braun (Univ. Bonn), A. Humbert (Univ. Munster)*

*Courtesy M. Braun (Univ. Bonn), A. Humbert (Univ. Munster)*

# Legacy SAR data acquisition for IPY (Antarctica)

*Collapse of the ice bridge*

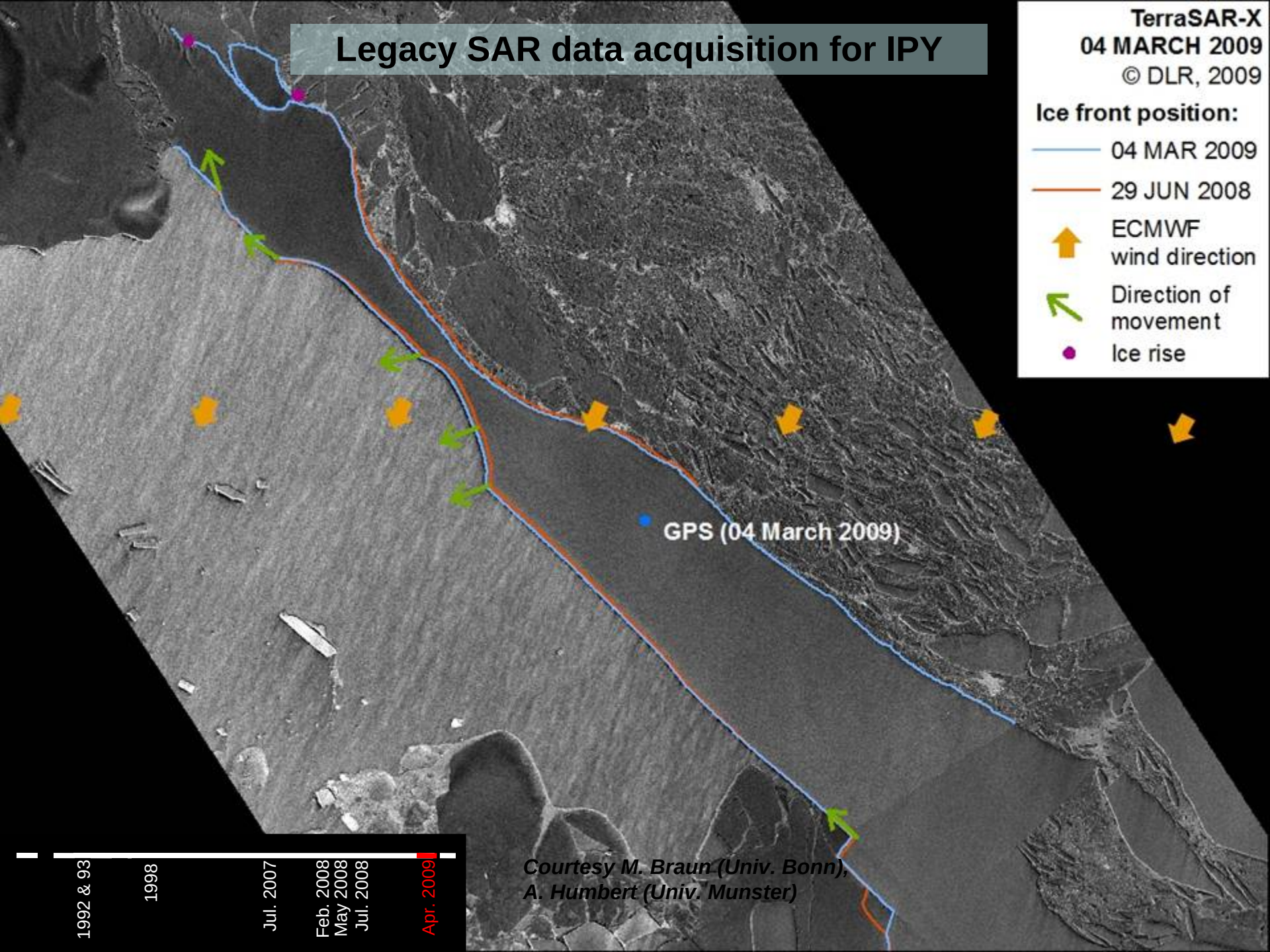
***Wilkins Ice Shelf (Antarctica)***



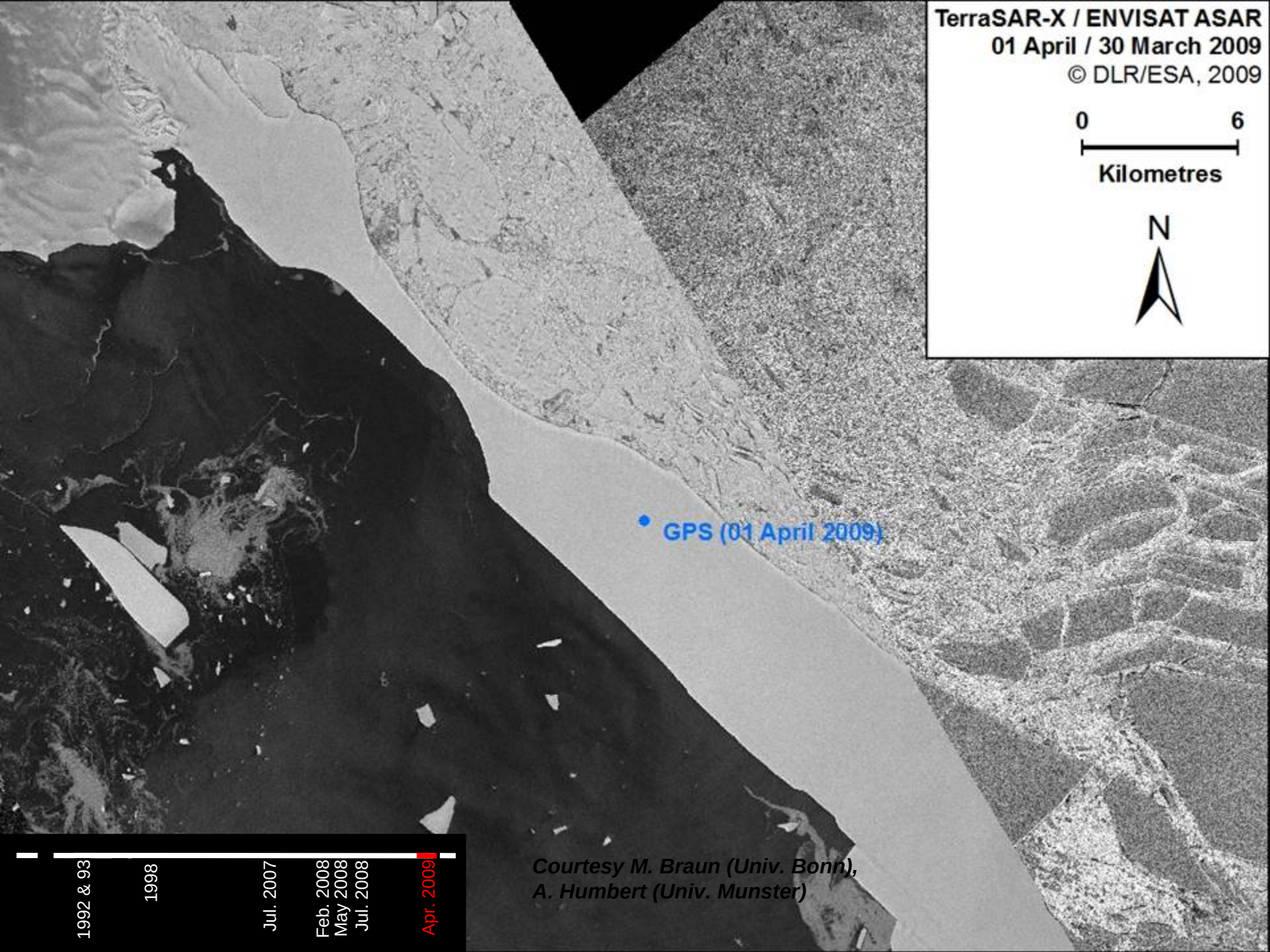
***Courtesy M. Braun (Univ. Bonn), A. Humbert (Univ. Munster)***

**TSX scansar – 10 March 2009**

# Legacy SAR data acquisition for IPY

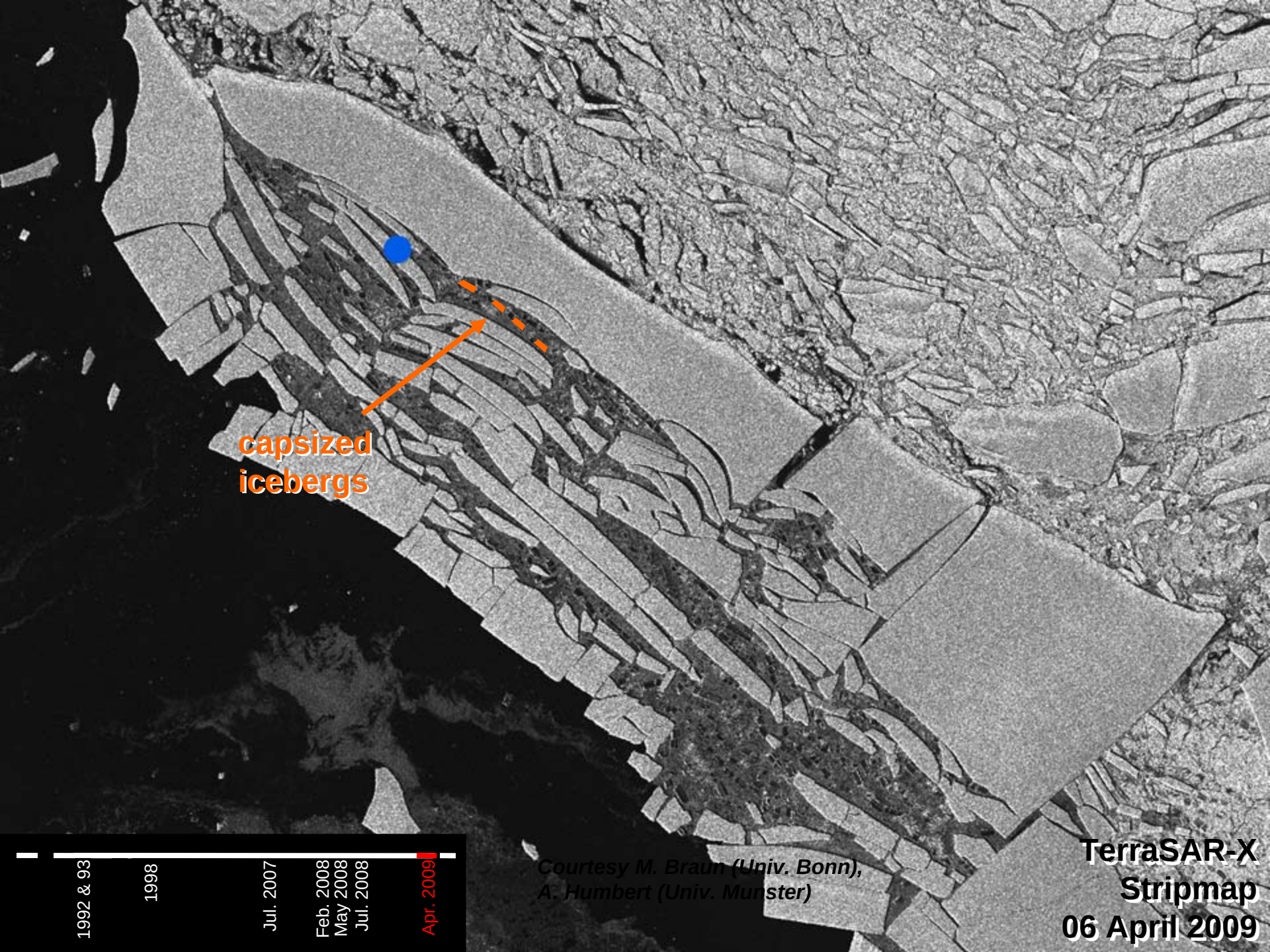



*Courtesy M. Braun (Univ. Bonn), A. Humbert (Univ. Munster)*




*Courtesy M. Braun (Univ. Bonn), A. Humbert (Univ. Munster)*

ENVISAT ASAR
02 April 2009
© ESA, 2009
0
6
Kilometres
N
GPS (02 April 2009)
1992 & 93
1998
Jul. 2007
Feb. 2008
May 2008
Jul. 2008
Apr. 2009


capsized
icebergs
1992 & 93
1998
Jul. 2007
Feb. 2008
May 2008
Jul. 2008
Apr. 2009
Courtesy M. Braun (Univ. Bonn),
A. Humbert (Univ. Munster)
TerraSAR-X
Stripmap
06 April 2009

# Legacy SAR data acquisition for IPY

ENVISAT ASAR
03 July 2009
© ESA, 2009

**Proposed best case scenario (May 2008)**

**Proposed worst case scenario (May 2008)**

*Strong general public and media interest:*
*→ **Webcam from Space***
*on ESA web portal*

*Courtesy M. Braun (Univ. Bonn), A. Humbert (Univ. Munster)*

# *IPY Logistics Portal*

# ESA IPY Activities – ESA projects

Polar View:

- Project supported by ESA, EC and CSA

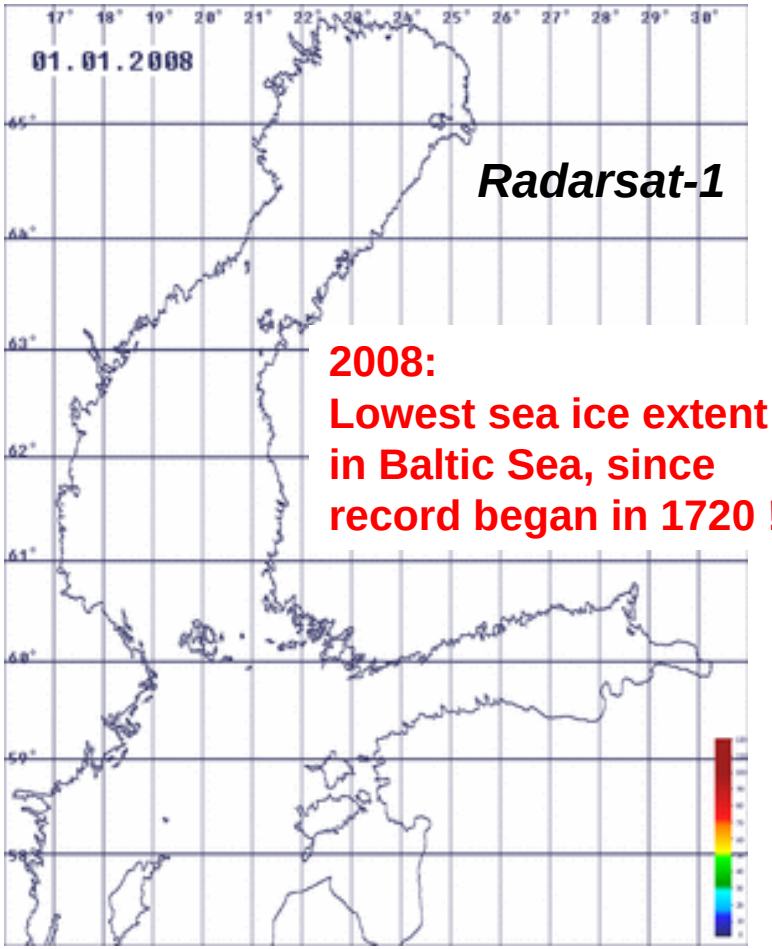
- Promotes the utilization of satellites in the areas of sustainable economic development, marine safety, and the environment.

- Polar View's objective is to provide products for environmental monitoring and safety in the ***polar regions***

**http://www.ipy-ice-portal.org**

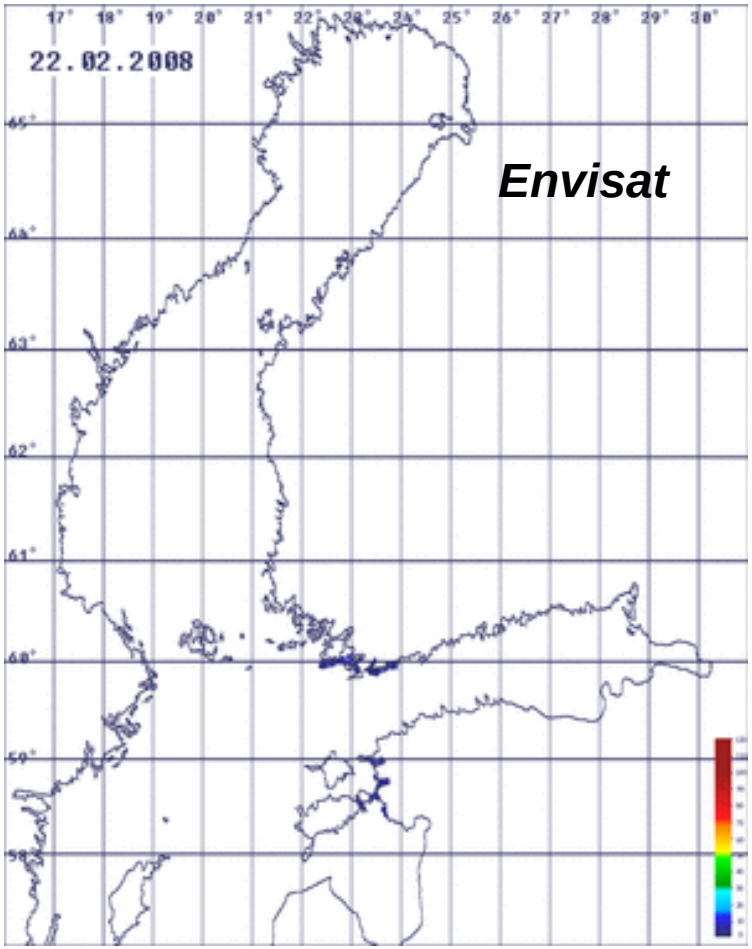
# Operational use of Envisat ASAR WS for ice chart

## *Winter 2007-2008*




**2008:**
**Lowest sea ice extent in Baltic Sea, since record began in 1720 !**

## *Winter 2008-2009*

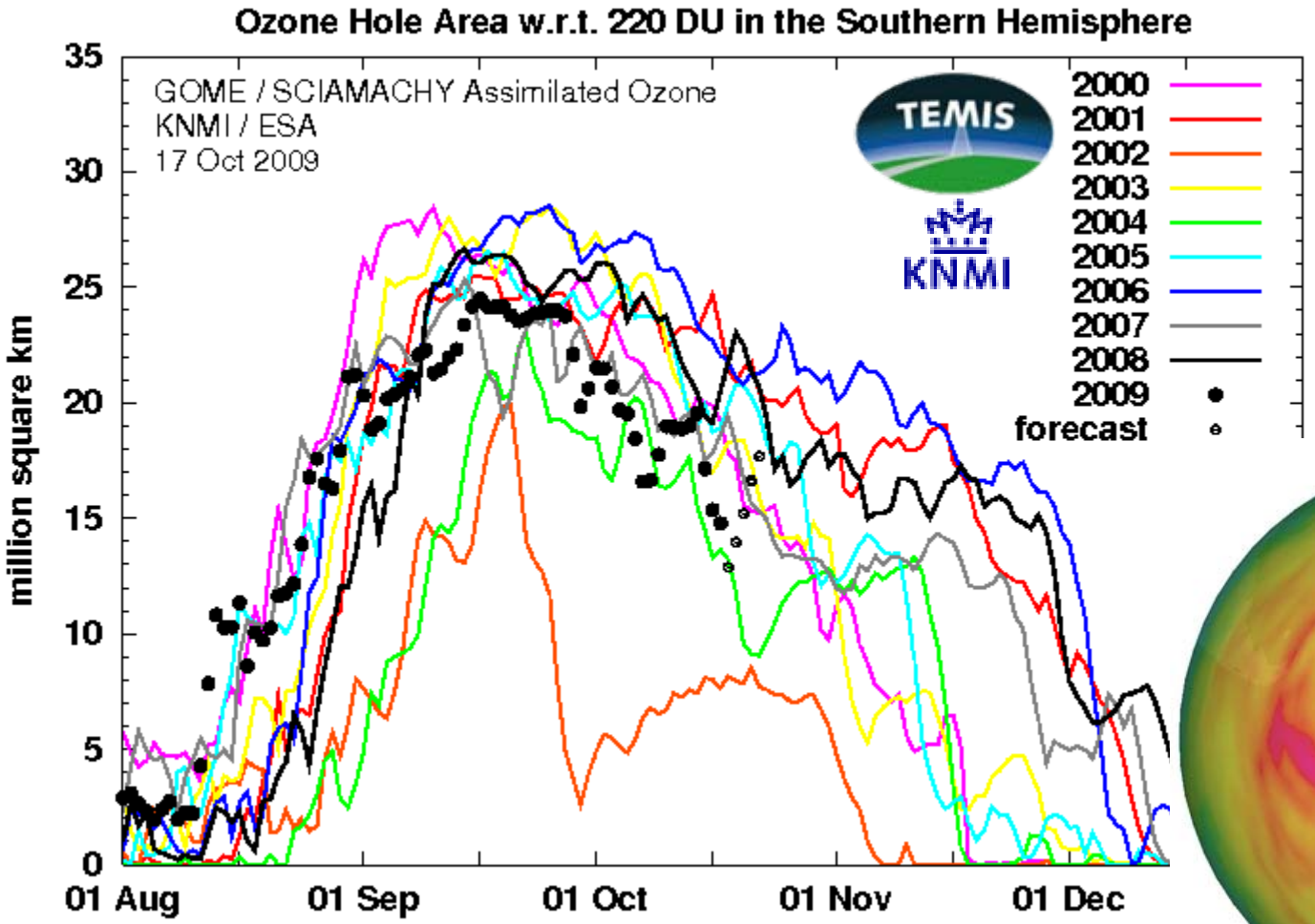



***Credit: Finnish Institute of Marine Research***

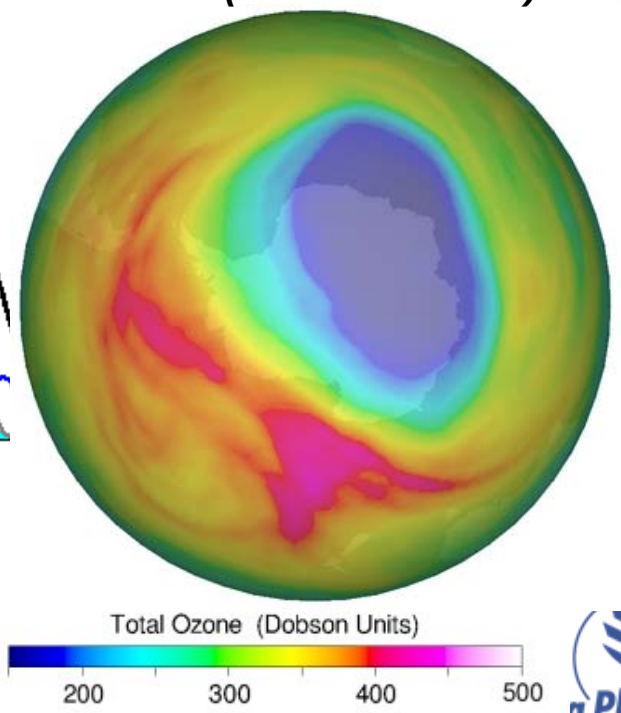
# *Atmospheric IPY Legacy Data*

# Other data acquisition for IPY

## Legacy Atmospheric data acquisition




***Forecast for today***
***(20 October 2009)***

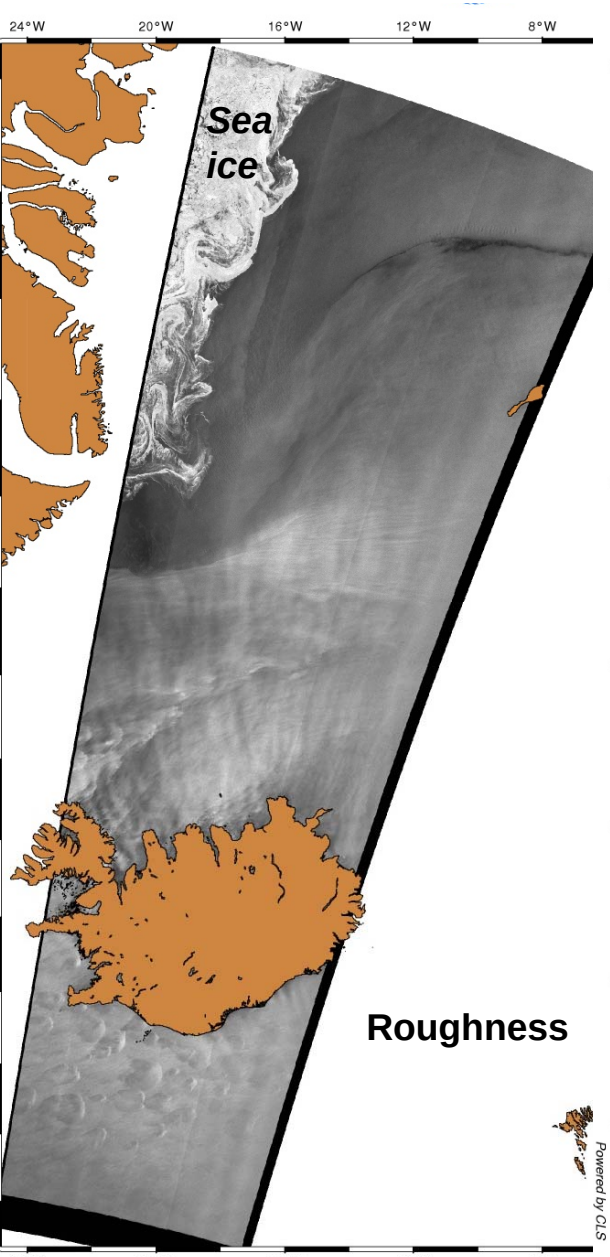


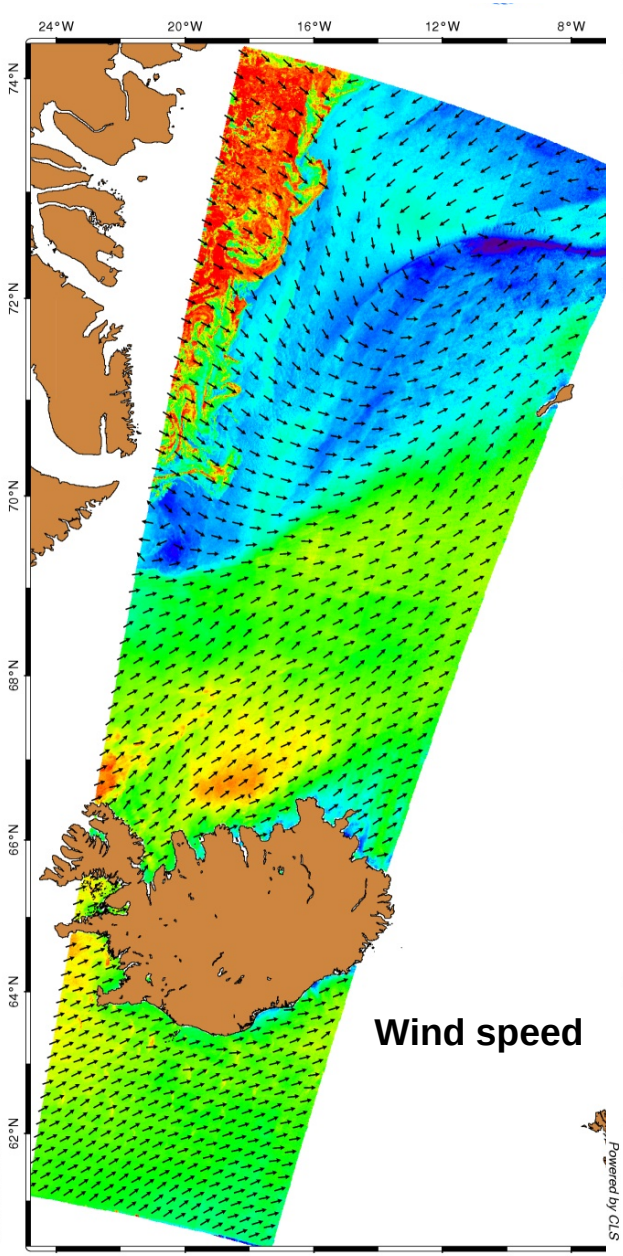
# *New Products*

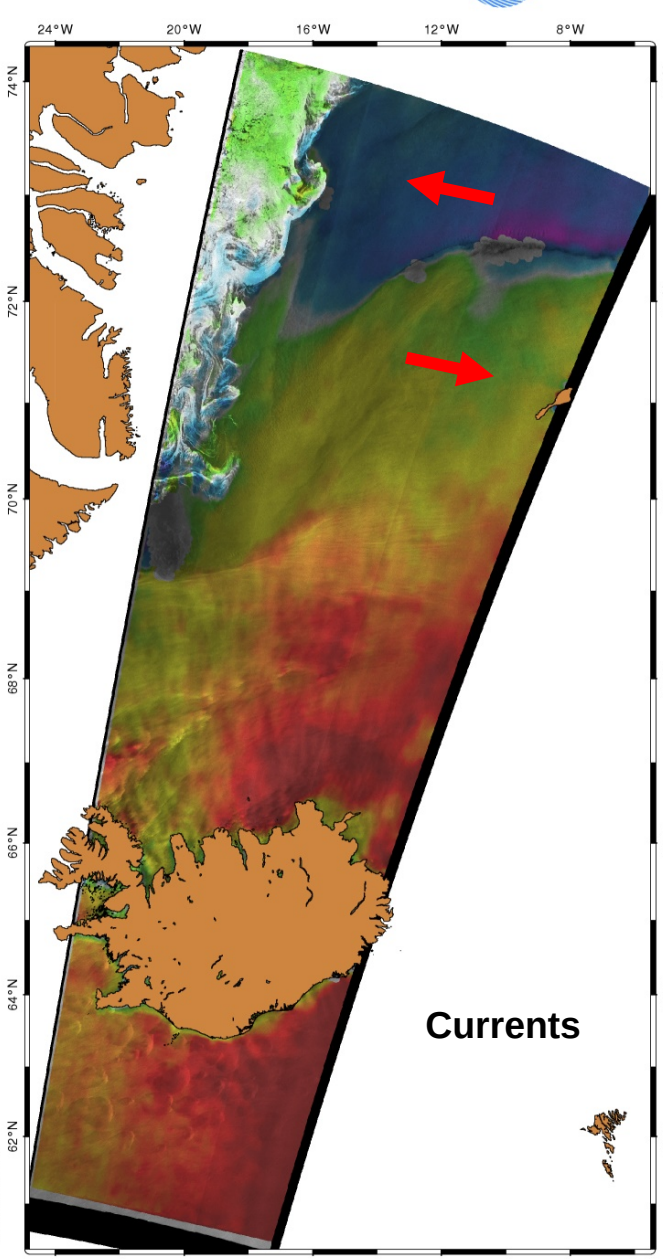
-October-2009 11:51:24 (UTC)
VISAT WSM Product

15-October-2009 11:51:24 (UTC)
ENVISAT WSM Product

15-October-2009 11:51:24 (UTC)
ENVISAT WSM Product




European Space Agency
Agence spatiale européenne

Wind Speed [m.s$^{-1}$]

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19

Radial Surface Velocity [m.s$^{-1}$]

−2.5 −2.0 −1.5 −1.0 −0.5 0.0 0.5 1.0 1.5 2.0 2.5

# Facilitating access to Earth Observation data

**A constant objective:**

**→ *ease access to Earth Observation data***

- **Common objective for all missions data handled by ESA:**
  Envisat, ERS, Earth Explorers, and Third Party Missions

- **New ESA EO data policy in preparation:**
  - **→ open and free of charge for most data (user registration)**
  - **→ some restrictions for some SAR data and some 3rd Party Missions**

- **Internet access to Near Real Time (NRT) data and to archived data**

- **Development of alternative ways to provide data (e.g. processing on demand, toolboxes)**

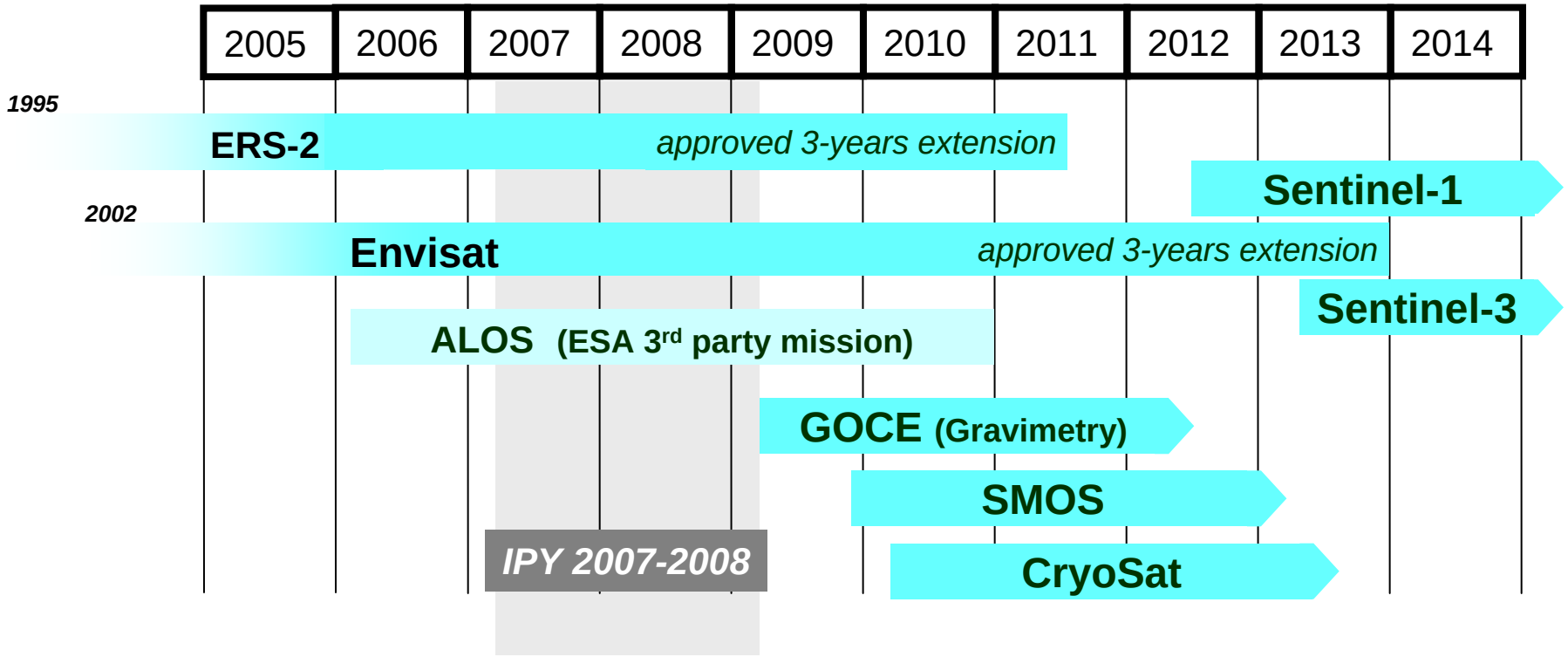
- **Maintain effort in improving quality of products (algorithms, validation)**

- **Maintain effort in exploiting data (e.g. ESA Climate Change Programme)**

# *Life Beyond IPY*

# After IPY 2007 - 2008

## ESA EO missions contributing to polar observations



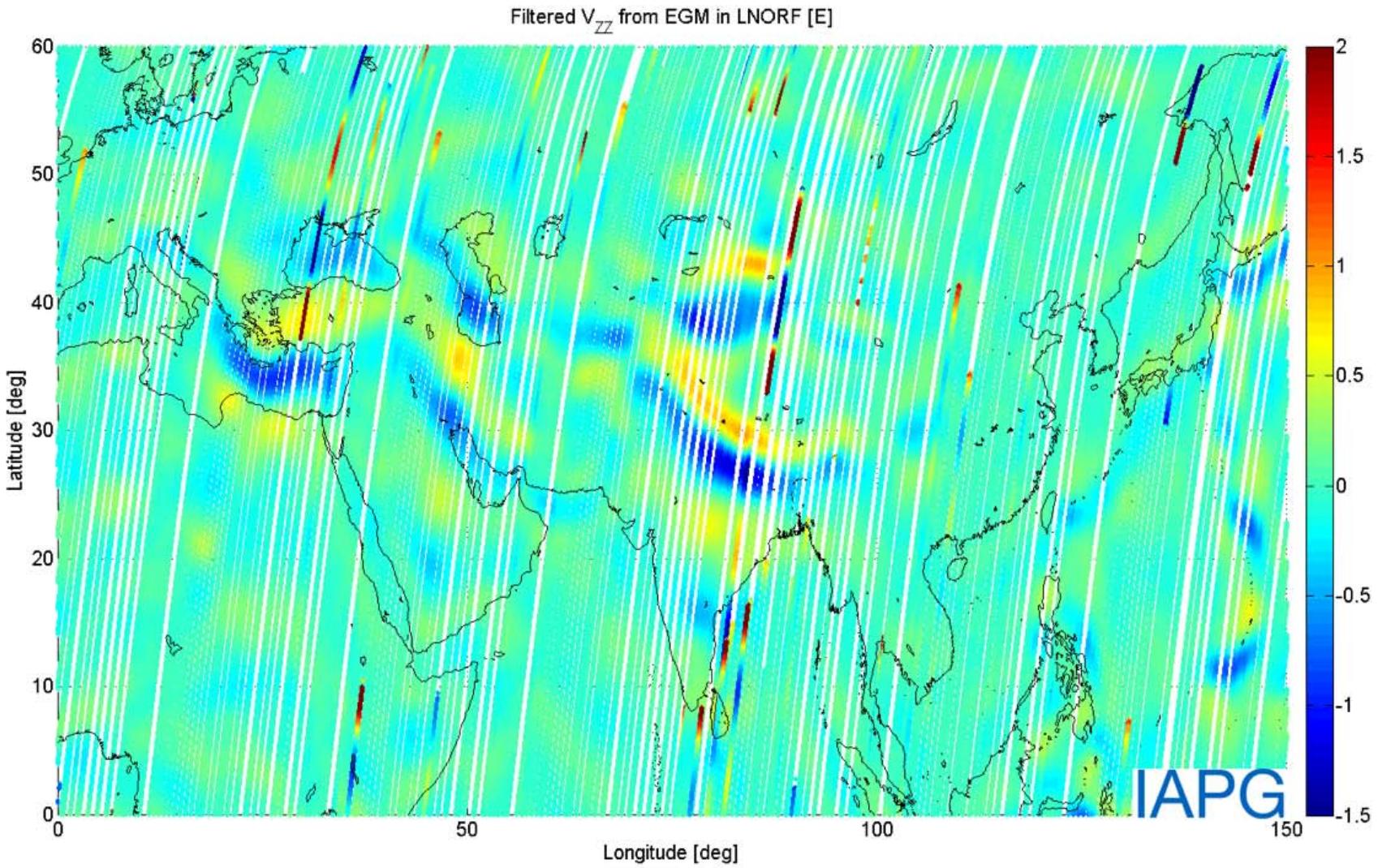

- Envisat satellite is in <u>good health</u> and with an expected reasonable evolution.
- Efficient consumption of on-board hydrazine allows operating nominally Envisat until 2010. But most of hydrazine will be consumed by 2010.
- Envisat 3-yr extension requests 2010 modification of orbital parameters to be able to operate the satellite with minimum hydrazine.

# *GOCE Status*

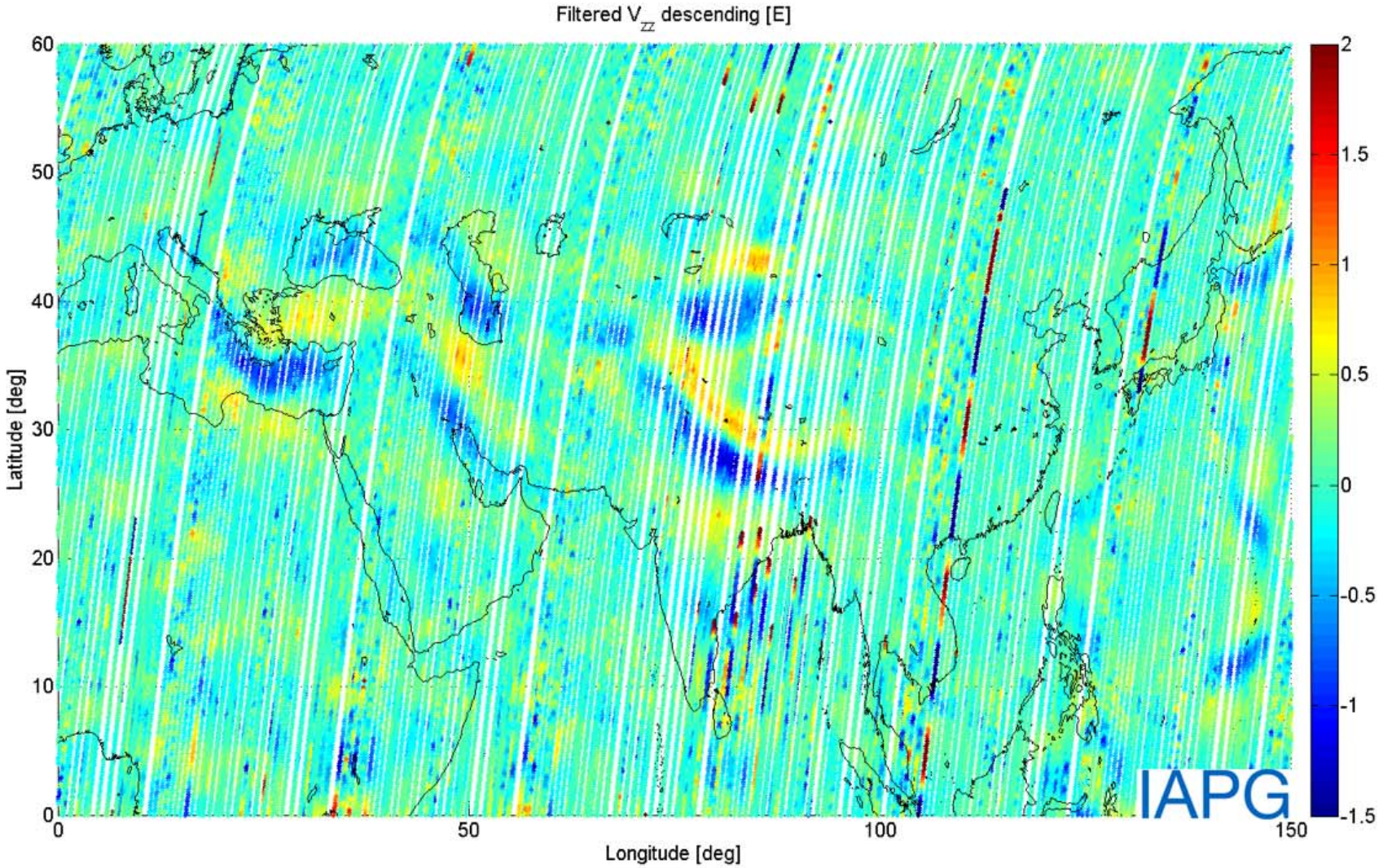
# GOCE Status

- Functional satellite commissioning completed by end of June. All units performing excellently. No failures on-board.
- Calibration activities required full drag-free mode, and therefore the natural decay to an altitude where air drag was within ion engine thrust envelope (a result of the extremely low solar activity)
- Measurement altitude of 254.9 km (979:61 repeat) reached on 13 September
- Drag-free control system performance is excellent, about one order of magnitude better than spec
- GOCE in full measurement mode since 30 September
- Continuous measurements now expected until end of mission; concept of “measurement operations phases” out of eclipse only is no longer needed
- Resources on-board for approximately 5 years continuous mission
- Performance is excellent. Gravity field products expected to serve all mission objectives within the duration of the nominal mission.
- Release of first data to the community in spring. First gravity field at ESA’s Living Planet symposium in Bergen, 28 June - 02 July 2010

# Vertical gradient measurements vs. model



# Vertical gradient measurements vs. model



# Satellite-to-Satellite Tracking Instrument

- Top class precise orbit determination products!
- **Current positioning accuracy is at 1-2 cm level** in each of the three orthogonal directions (and in most cases better than 2 cm 3D RMS)!
- Rapid science orbits (<1 day latency) at 3-4 cm accuracy
- Independently validated by Satellite Laser Ranging

# *SMOS*

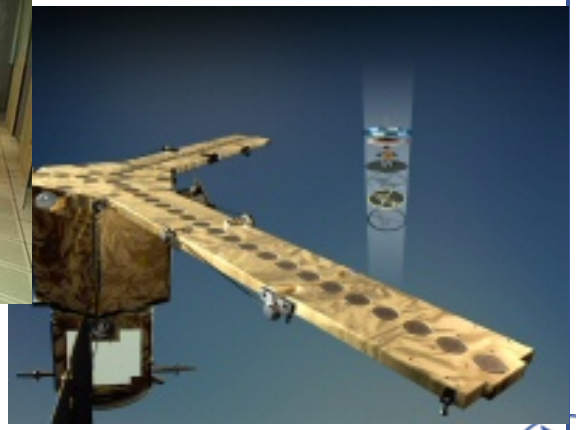
# The first three weeks of SMOS …

**2 November: Launch from Plesetsk, Russia**

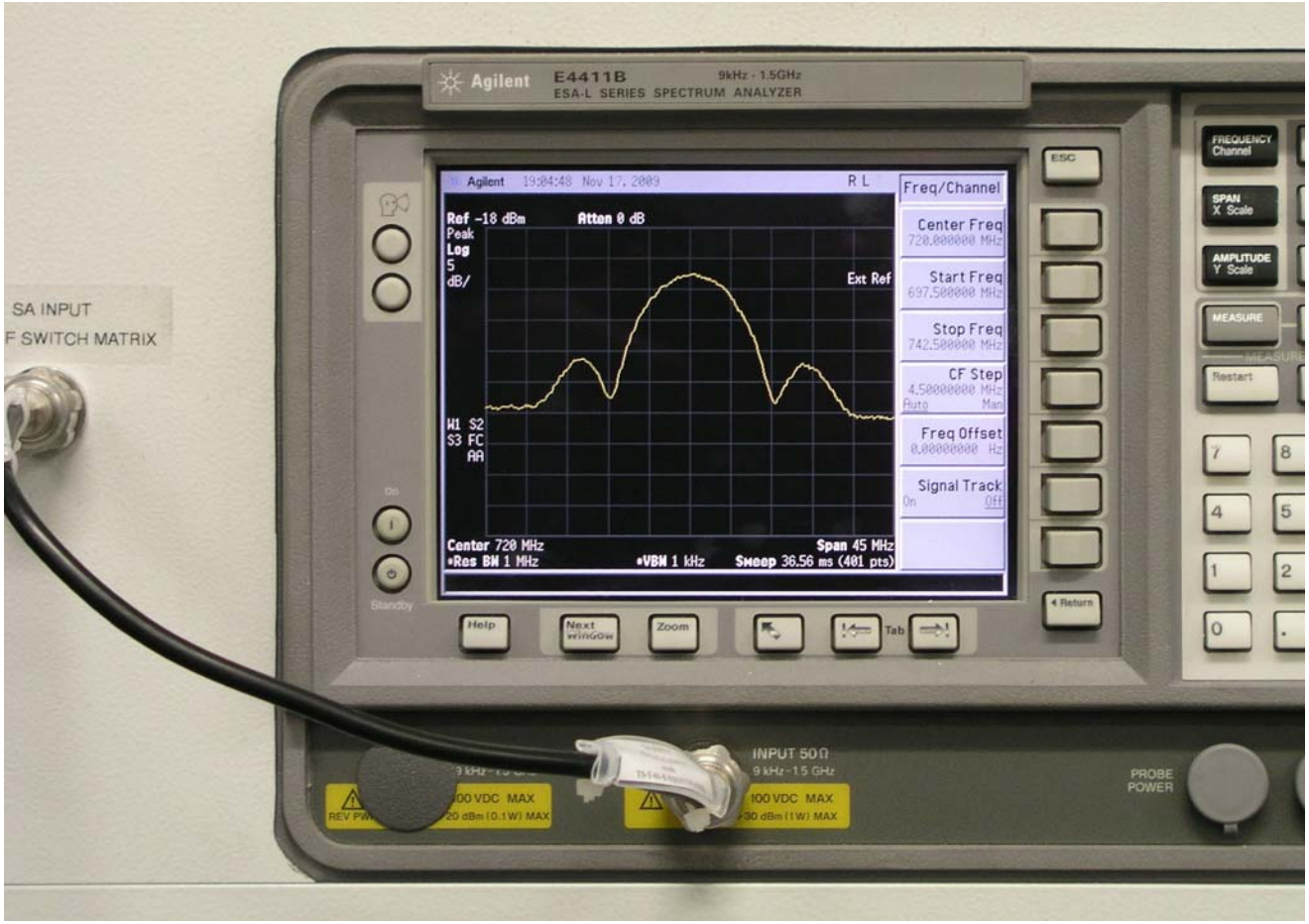
**3 November: Antenna deployment**

**Commissioning of SMOS platform**

**17 November: Instrument switch-on 1st download over ESAC**



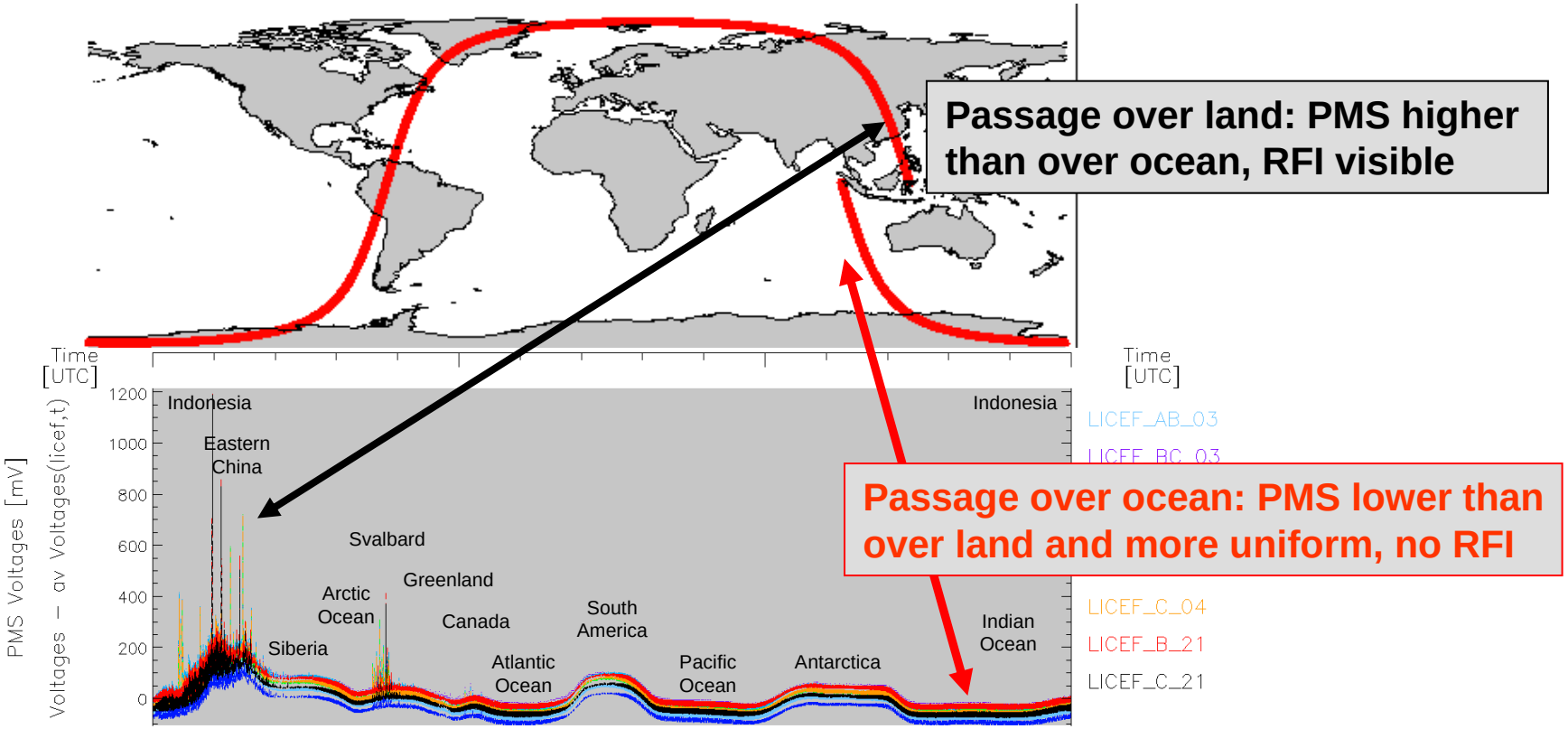
# First signal of SMOS at antenna in ESA



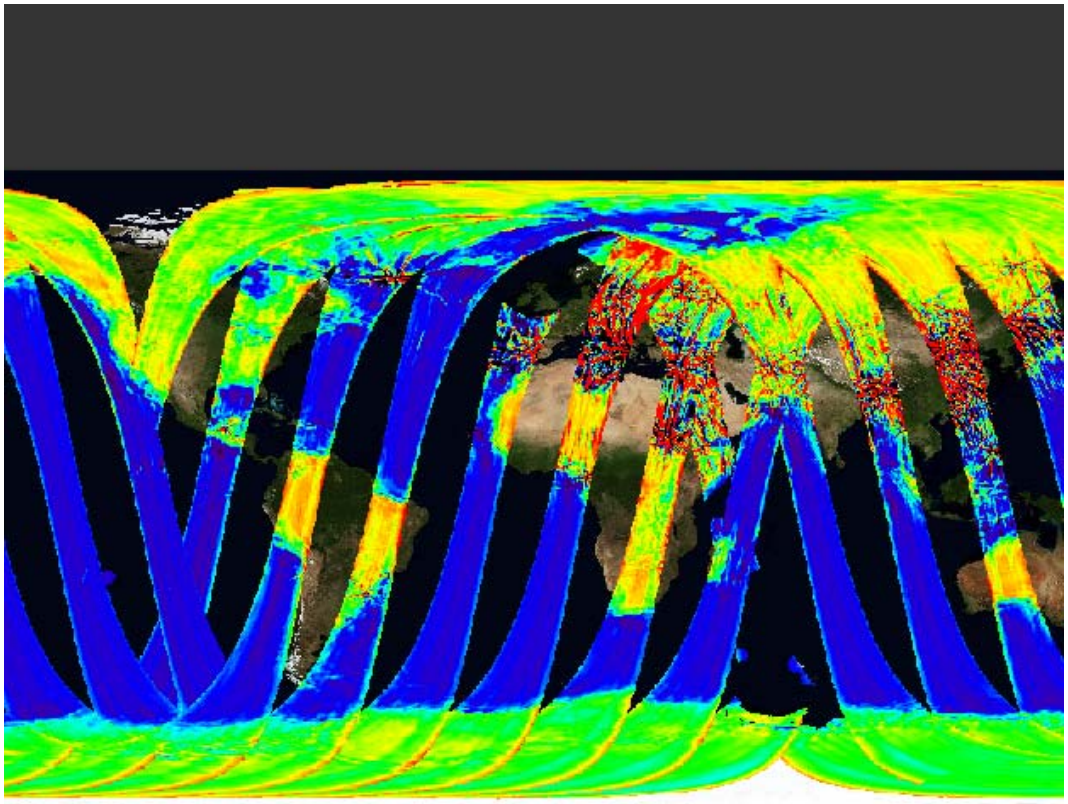
# First assessment of payload switch-on

**MIRAS is working very well!**
The LICEFs'(= Receivers of the SMOS instrument MIRAS) Power Measurement System voltages are well within expected range and responding to the scene content

All key subsystems – optical fibres and correlation units - are working well; the NIR antenna brightness temperatures are just within 2-5 K from one another, in both polarisations



# First L1 image – without calibration



19-Nov-2009

The MIRAS instrument is working very well –

We have been able to produce reasonable images even without any in-orbit calibration data (not yet available – task for next few weeks)

Red areas are contaminated by RFI from just a few powerful radars (TBC).

# CryoSat mission objectives

- To determine fluctuations (rates of change) in the Earth's ice fields
  - sea-ice thickness
  - mass balance of ice-sheets and ice-caps
  - variations in major glaciers

- Technique: advanced radar altimeter – SIRAL
  - high pulse repetition with interferometric capability
  - operates in several modes adapted to surface type
  - supported by additional instrumentation (DORIS, Star Trackers, Laser Retro-Reflector)

***- Higher spatial resolution***
***- Factor 10 improvement in sampling over sea ice***
***- Sampling of dynamic ice sheet margins***
***- Measurements to 88° latitude***

# Arctic GOCE + CryoSat-2

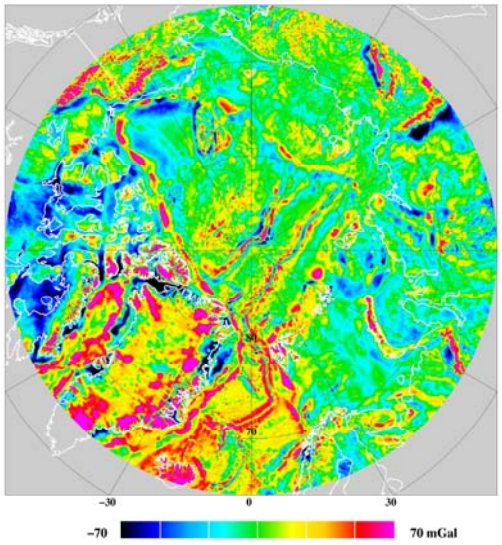



*Fig.1.. ArcGP grid, January 2006 release. Units: mGal.*

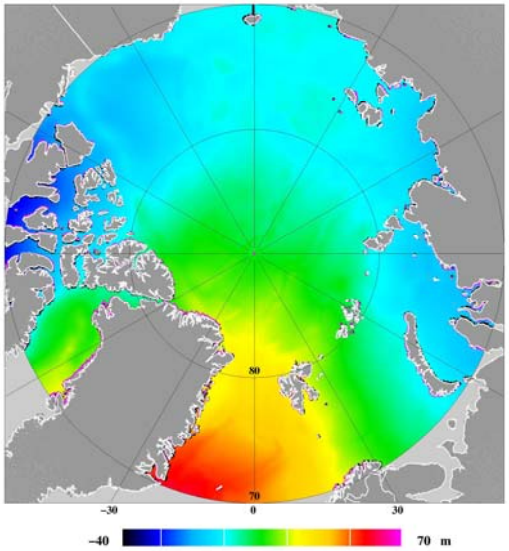
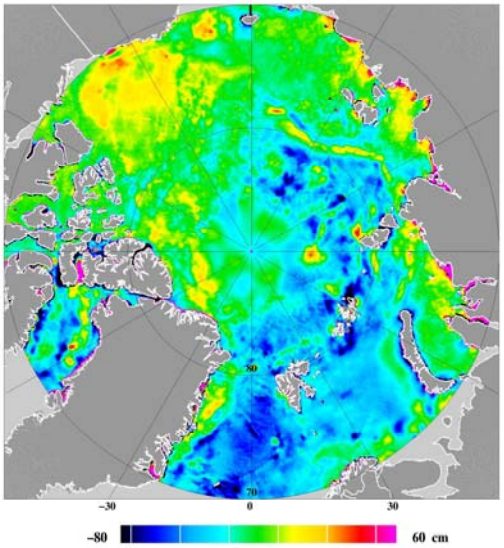
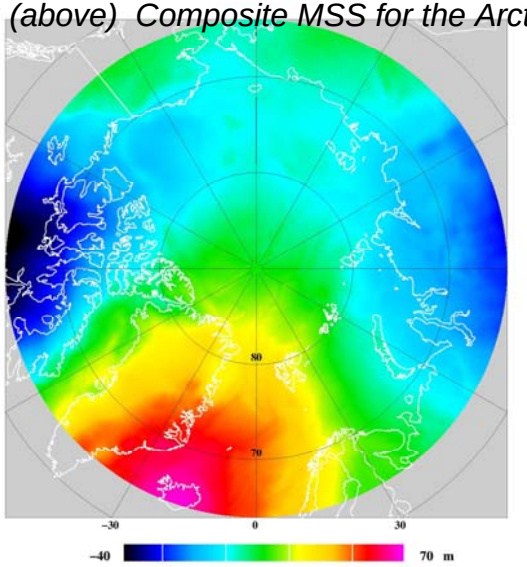



*Fig. 2 (above) Composite MSS for the Arctic Ocean region;*




*Dynamic Topography Units metres.*




*and (below) new ArcGP geoid. Units metres.*

# GMES dedicated missions: Sentinel-1

## Sentinel-1:

## C-band

## SAR mission

**Applications:**

- monitoring sea ice zones and the arctic environment
- surveillance of marine environment
- monitoring land surface motion risks
- mapping in support of humanitarian aid in crisis situations

**4 nominal operation modes:**

- strip map (80 km swath, 5X5 m res.)
- interferometric wide swath (250 km swath, 20X5 m res.)
- extra wide swath (400 km swath, 25X100 m res.)
- wave (5X20 m res.)

**2300 Kg spacecraft mass**

**Sun synchronous orbit at 693 Km mean altitude**

**12 days repeat cycle**

**7 years design life time, consumables for 12 years**

**Sentinel-1A: launch 2012**

**Sentinel-1B: foreseen 2015**

# GMES dedicated missions: Sentinel-3

## Sentinel-3:

## ocean & global land mission

**Applications:**

- **sea/land colour data and surface temperature**
- **sea surface and land ice topography**
- **coastal zones, inland water and sea ice topography**
- **vegetation products**

**1198 kg spacecraft mass**

**Sun synchronous orbit at 814.5 km mean altitude over geoid**

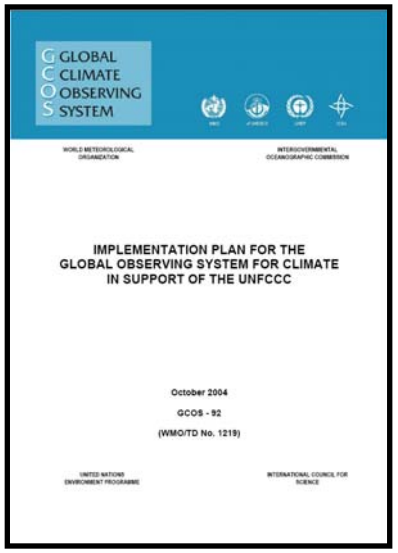
**27 days repeat cycle**

**7 years design life time, consumables for 12 years**

# *ESA Climate Change Initiative*

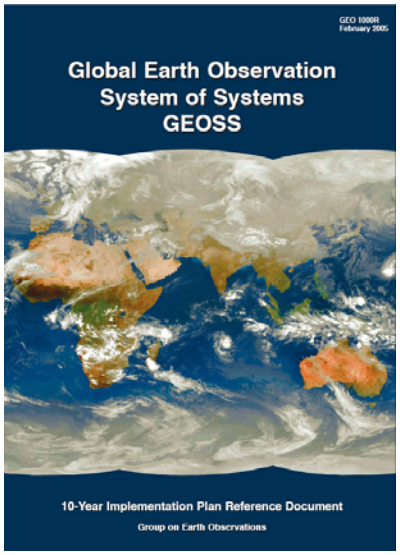
# The ESA Climate Change Initiative

GCOS IP 2004

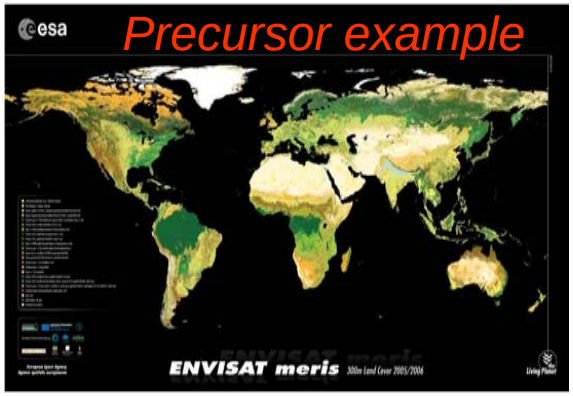



Part of GEO task CL-06-01

GEOSS IP 2005




ESA CCI: Production of Essential Climate Variables (ECV) according to GCOS requirements




***ESA Ministerial Council, Nov 2008***:

Approval of 75 M€ for a six year programme that will contribute to about twenty satellite-based ECVs. A strong interaction with the scientific community is an essential part of the programme.

The CCI initative will ensure that ESA can play a full role in deriving relevant ECVs specified by GCOS, based on ESA current and archived EO data. ESA will work with CEOS agencies to ensure as complete a coverage of the entire suite of ECVs as possible.

# Climate Change Initiative (CCI)

**INPUT FROM**

*Long Term Archiving Programmes*

*Multi-mission infrastructure*

**Re-processing ex archive (e.g. calibration)**

"Gather"

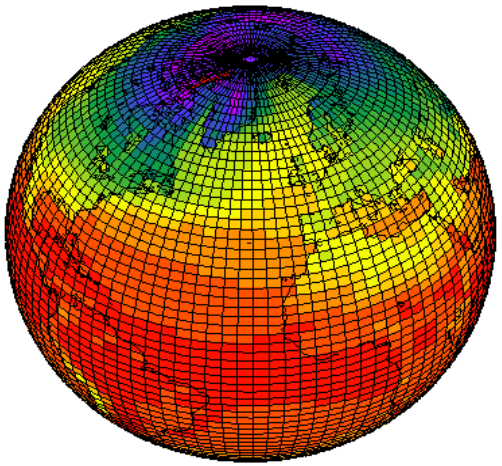
**ECV generation (e.g. validation & bias)**

"Deliver"

**ECV assimilation & assessment**

"Exploit"

***Active Feedback Loop***



**OUTPUT TO**

*International Climate Programmes*

*EC & MS R&D Programmes*

*IPCC Process, UNFCCC*

**Education & Awareness**

"Show"

# Satellite-based ECVs

| | | |
|---|---|---|
| **Atmosphere** | **Surface** ( 0, 0, 6 ) | *Air Temperature; Precipitation ; Air pressure; Water vapour; Surface radiation budget; Wind Speed & direction;* |
| | **Upper air** ( 1, 1, 3 ) | ***Cloud properties,*** ***Wind speed & direction*** *Earth radiation budget; Upper-air temperature; Water vapour;* |
| | **Composition** ( 3, 0, 0 ) | ***Carbon dioxide Methane & other GHGs; Ozone; Aerosol properties*** |
| **Ocean** | **Surface** ( 4, 2, 1 ) | ***Sea-surface Temp; Sea-level; Sea-ice; Ocean colour; Sea state; Sea-surface salinity*** *Carbon dioxide partial pressure* |
| | **Sub-surface** ( 0, 0 , 7 ) | *Temperature; Salinity; Current; Nutrients; Carbon; Ocean tracers; Phytoplankton* |
| **Terrestrial** ( 3, 7, 4 ) | ***Glaciers & ice caps; Land Cover; Fire disturbance*** ***Fraction of absorbed photo-synthetically active radiation; LAI , Albedo Biomass, Lake levels, Snow cover, Soil moisture*** *Water use, Ground water, River discharge Permafrost and seasonally-frozen ground* | |

**CCI First Steps (11 ECVs) : Later in CCI (10 ECVs) : Not in CCI (24 ECVs)**

esa
http://www.esa.int
http://earth.esa.int
eohelp @ esa.int
European Space Agency
Agence spatiale européenne
the Living Planet