The ESA Earth Observation Missions and their Exploitation for Science and Applications

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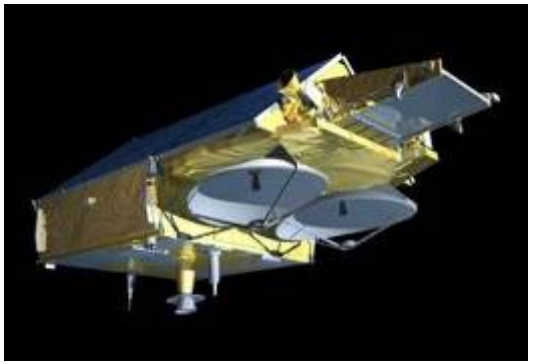
European Space Agency
ESRIN, FRASCATI, ITALY

In Orbit: ESA Earth Observation satellites

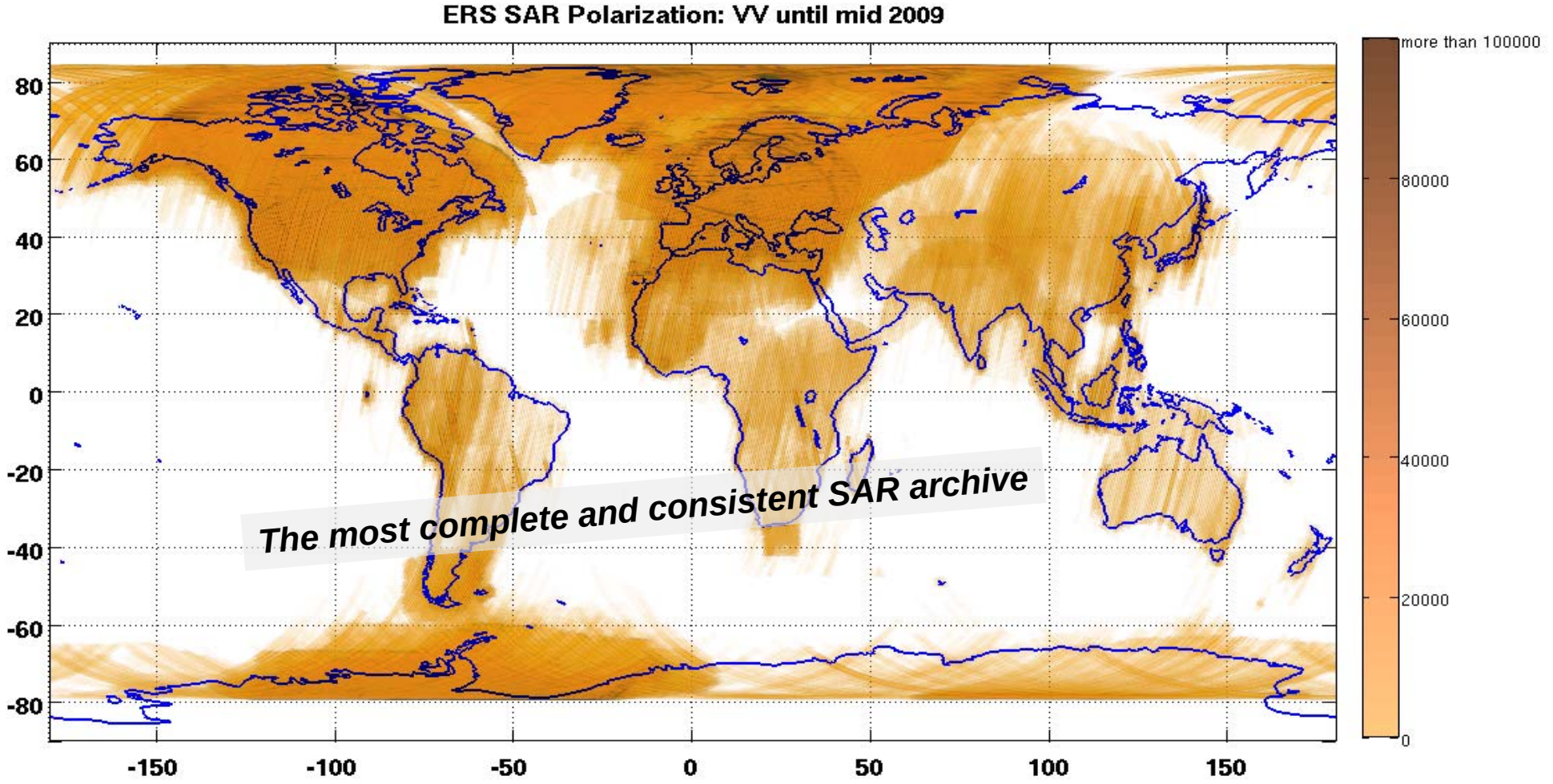


- **Six EO missions in operation**
  - 5 more currently operated by Eumetsat
- **5000** data user projects worldwide– increasing further
- **100 Terabytes/yr** of data
- **30 partner missions** for which data disseminated to European users

ERS Missions

ERS-1 and ERS-2 missions

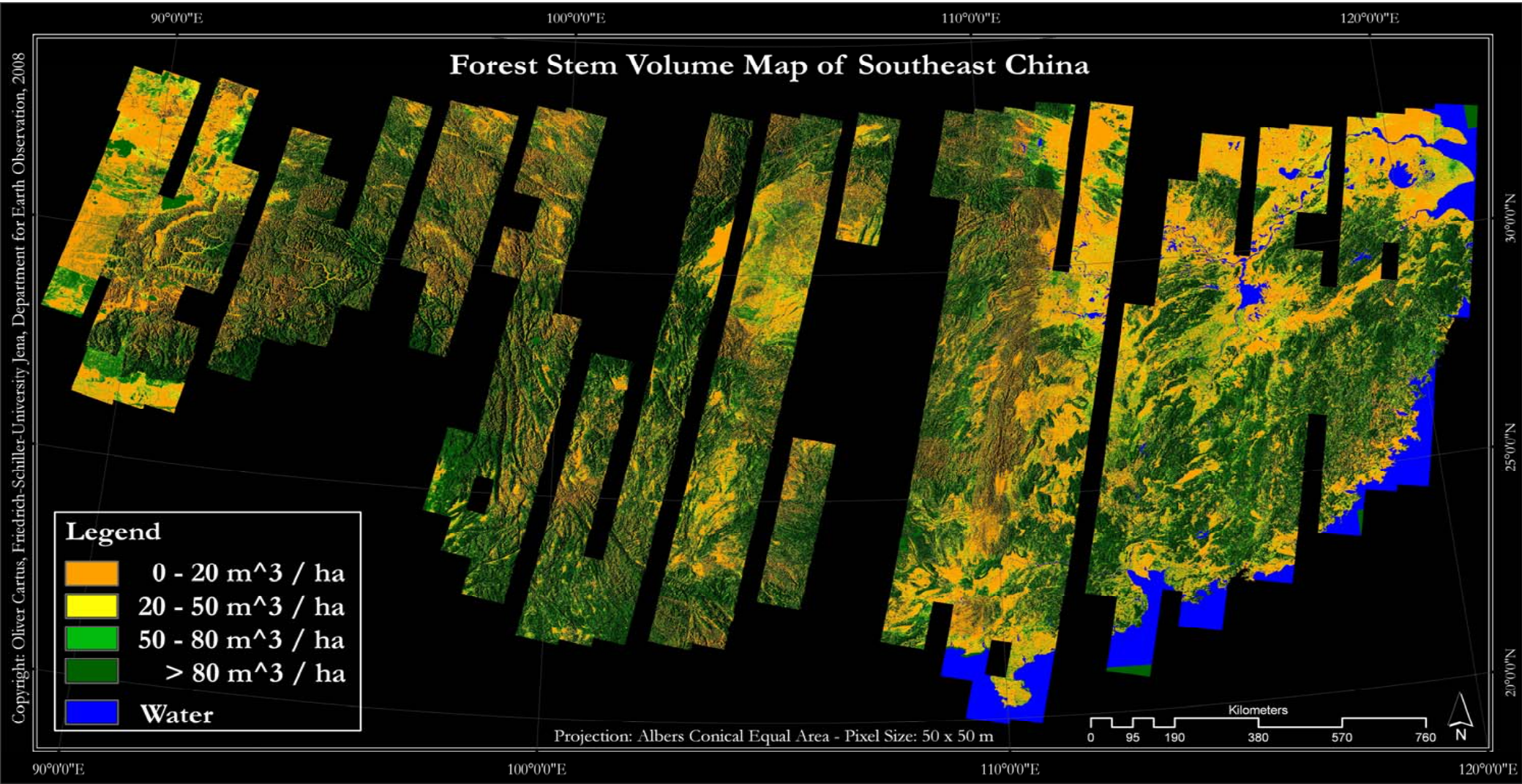
20 years of ERS-1/2 SAR data in the archive



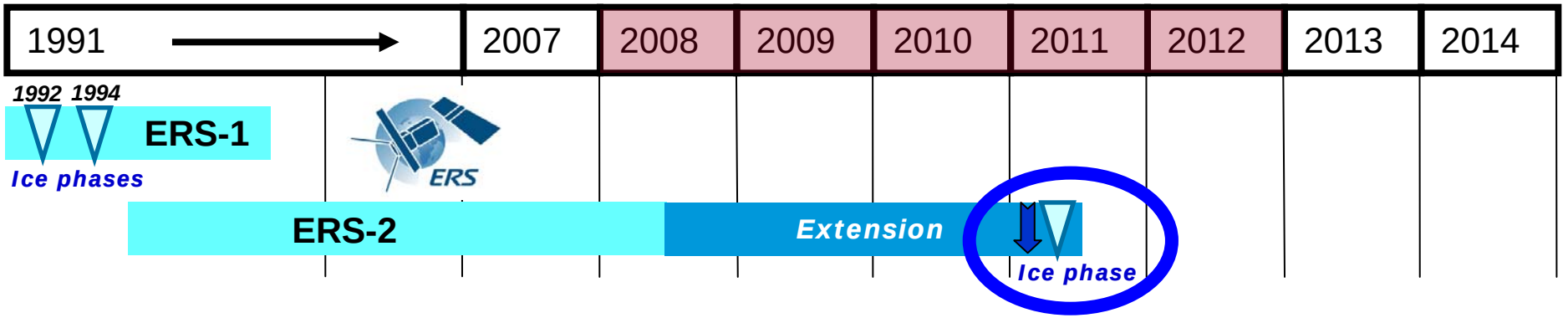
Forest Biomass Retrieval

ERS-1/2 tandem coherence data from 1995 to 1998

Author: Mr. Oliver Cartus, FSU Jena



SCIENTIFIC EXCELLENCE
The last months of ERS-2 mission



• The ***ERS-2 Ice Phase*** (February to May 2011) is a ***3-day repeat cycle*** configuration identical to the ERS-1 Ice Phases (1992, 1994).

• ***Recommended*** by the scientific community (e.g. Fringe recommendations), it shall provide a unique science opportunity in several domains. It allows exploiting the newly acquired data in synergy with the historical dataset, taking advantage of the existence of GPS networks.

• Science domains addressed by the ERS-2 Ice Phase:

- ***sea-stream dynamics*** (SAR): determination of polar glacier grounding lines; identification of the outlet ice-streams and model improvement; contribution to sea-level rise projection
- ***ice caps*** (SAR): ice velocity, equilibrium line location
- ***synergy with CryoSat***: combination of altimetry & InSAR: thickness & velocity changes
- ***tectonics, volcanology*** (InSAR): e.g. post-seismic deformation
- ***InSAR coherence*** of targets with 6 & 12 days repeat (Sentinel-1 preparation)

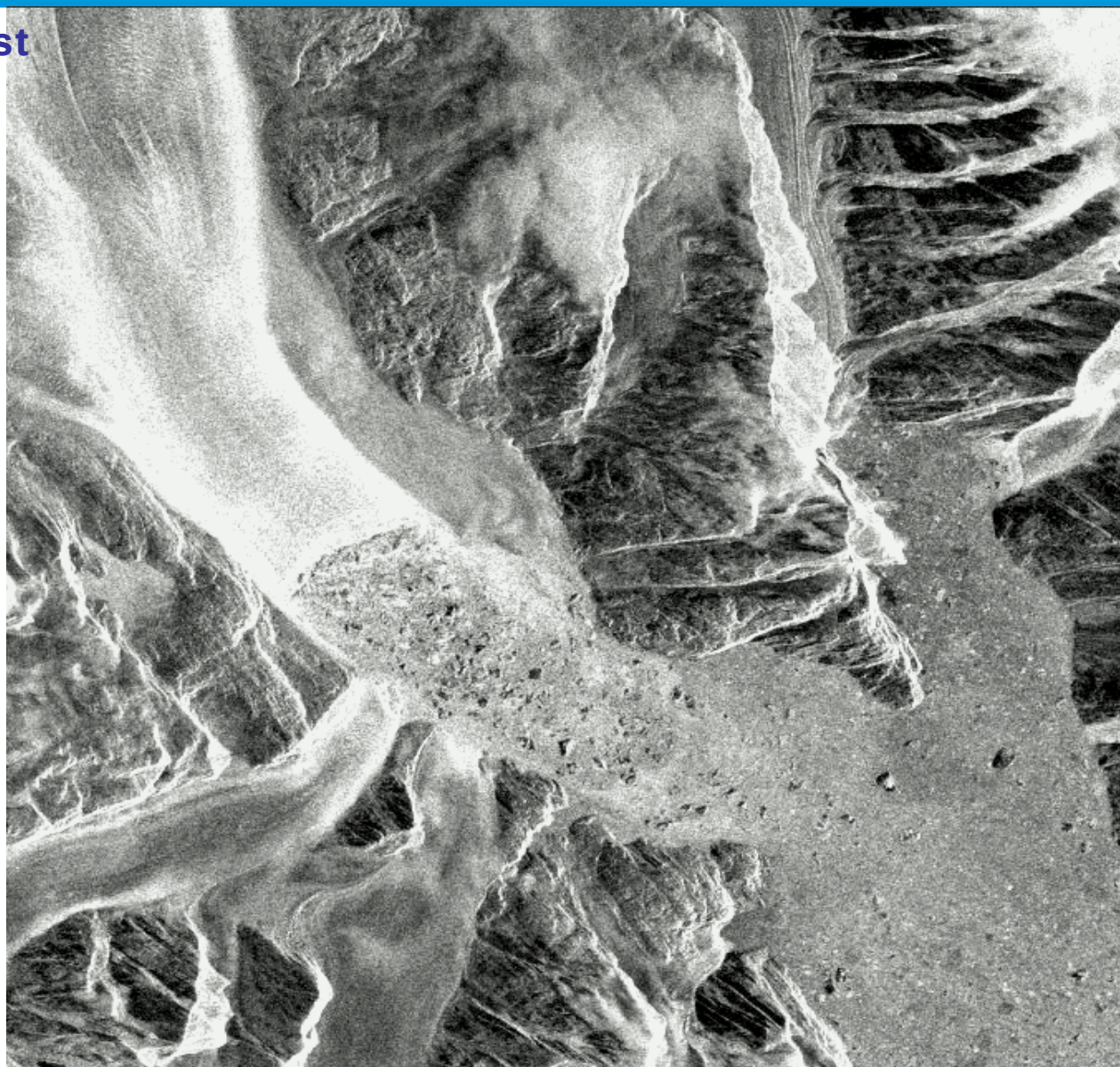
Ice Stream Tracking with SAR
ERS-2 Ice Phase

Kangerdlugssuaq Ice Stream (East Greenland)

ERS-2 Ice-Phase
- 3-day repeat cycle
- March - June 2011 (until deorbit)

13 SAR scenes from 2011
- 11,17,20 & 23 March
- 01,04,07,10,13,19,22 & 28 April
- 01 May

Calving front advances ~1.8km



Ice Stream Tracking with SAR
Comparison between 1992 and 2011

Kangerdlugssuaq Ice Stream

ERS-1 1st Ice-Phase
- 07 Feb 1992 (SAR)

ERS-2 Ice-Phase
- 11 Mar 2011 (SAR)

Calving front receded by ~5.5km

Notable thinning of glaciers and ice streams in the area.

Greenland glaciers' discharge

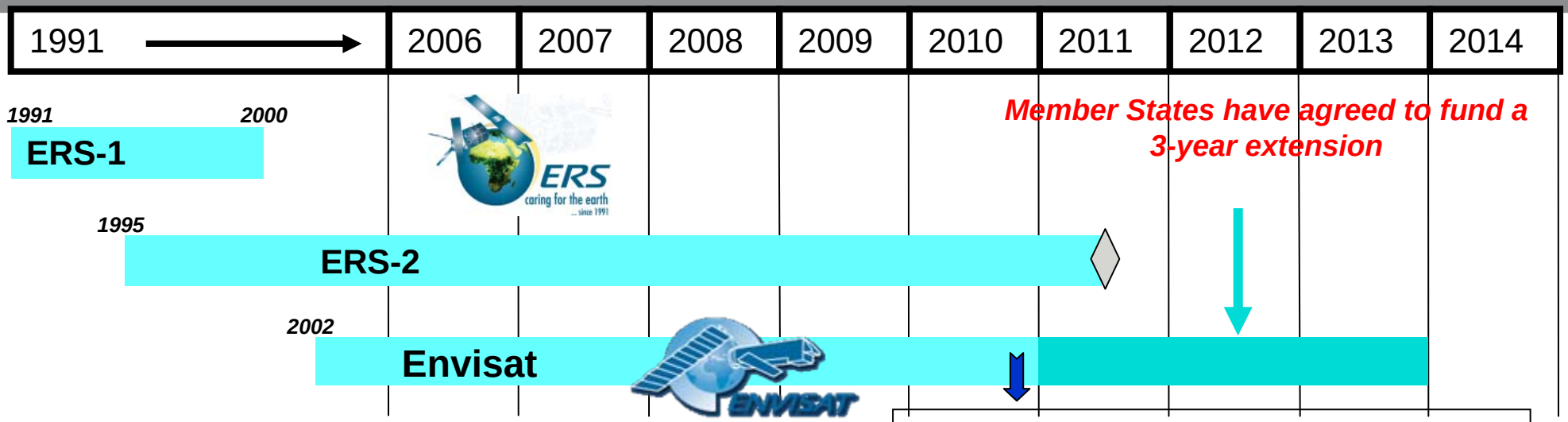
New ERS2 3-day mission allows for re-assessment of ice discharge measured during the 1st ice phase (1990's)

Here over the Petermann glacier, north-west Greenland

ENVISAT

envisat.esa.int

Envisat mission extension



The new orbital parameters allow:

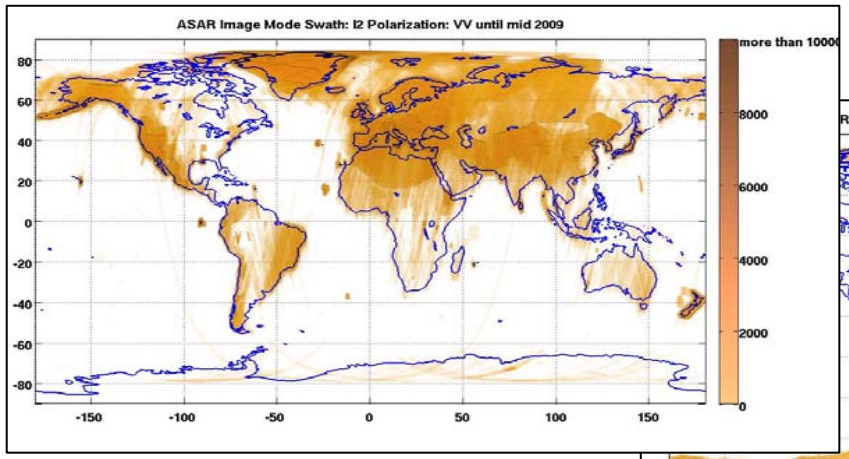
1. to keep current nominal mission until 2010,
2. to extend the mission beyond 2010,
3. to allow operations of all instruments with small or no degradation of their measurements, and minor impact on data quality, *excepted for InSAR*
4. to commit with the satellite disposal rules.

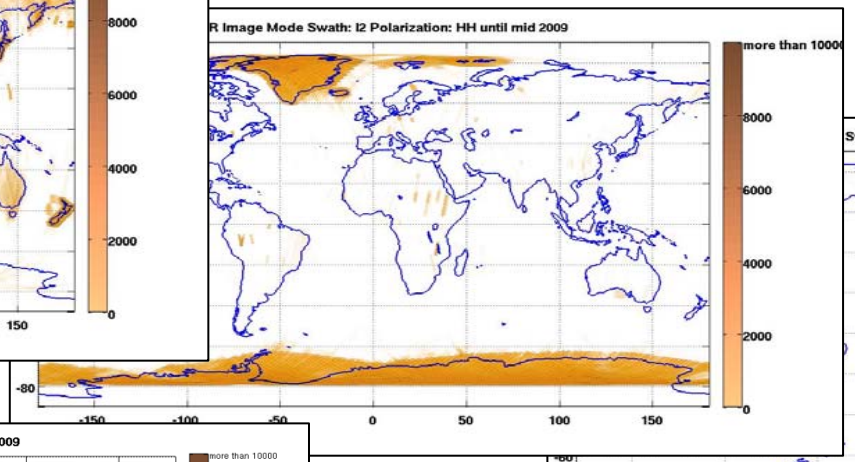
GROUND SEGMENT ACTIVITIES IN SUPPORT OF SCIENCE

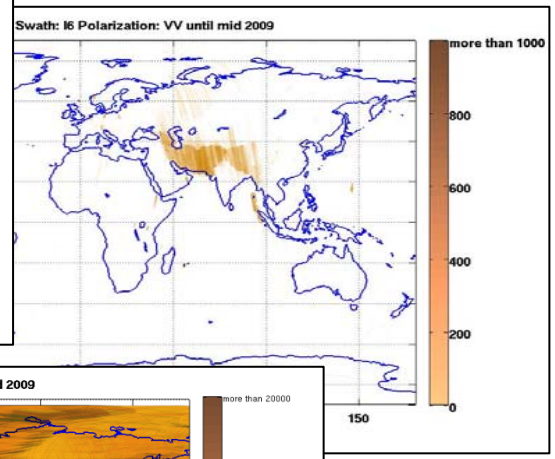
INCREASED AMOUNT of ACQUIRED DATA

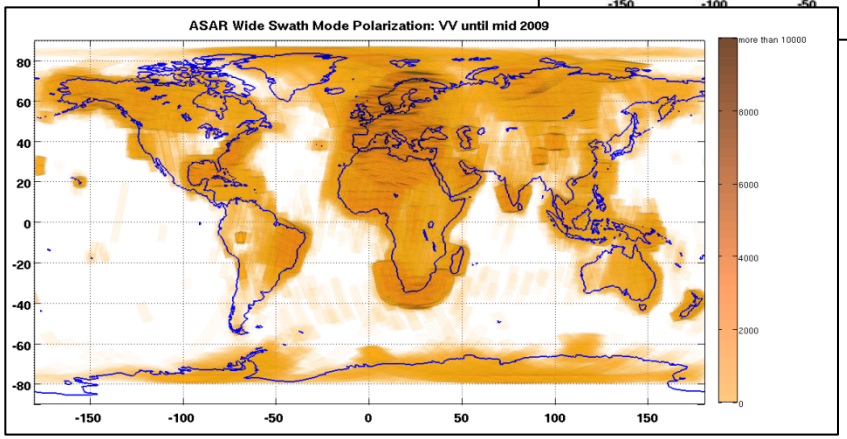
Background missions use the extra capacity of sensor and ground segment acquisition. It has allowed acquiring useful data, e.g. SAR Interferometry (InSAR) data.

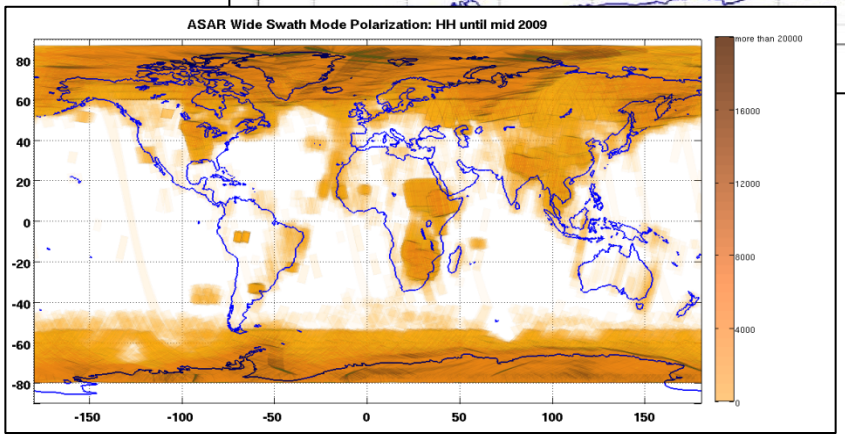
Example with Envisat ASAR data (a large archive dedicated to InSAR):

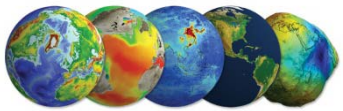










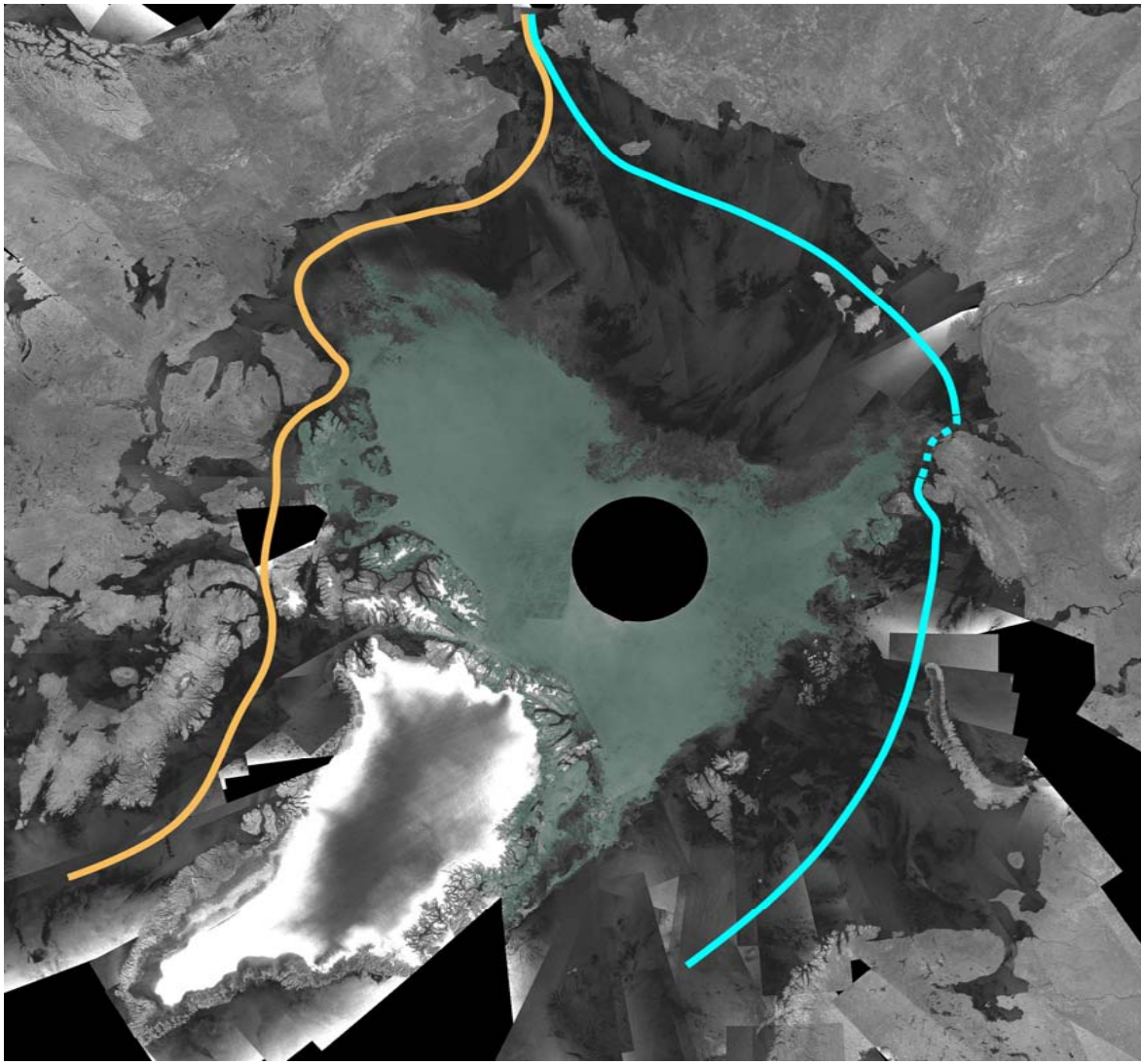


LOWEST ARCTIC ICE COVERAGE IN HISTORY

Arctic sea ice extent

–Northwest Passage open (orange line) and Northeast passage only partially blocked (blue line).

–the record reduction in 2007 stunned the international operational ice charting community

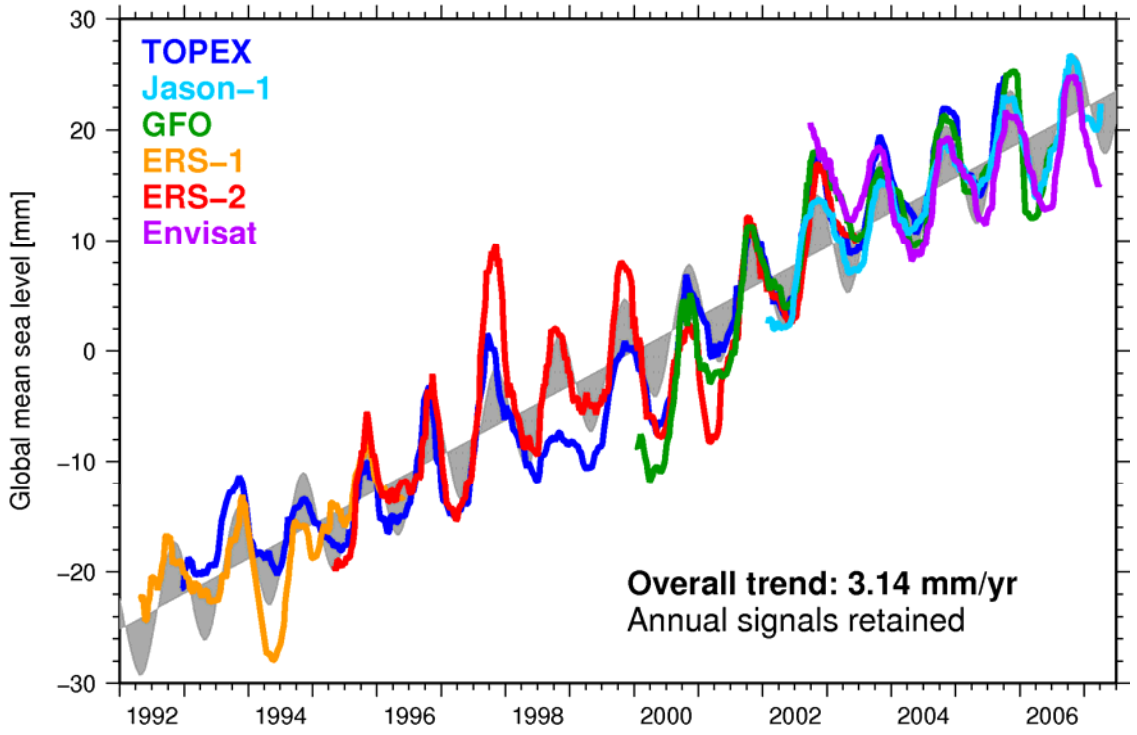


SEA LEVEL RISE

THE ENVISAT ALTIMETER PROVIDES CONTINUITY TO THE MEASUREMENTS INITIATED IN THE EARLY 1990

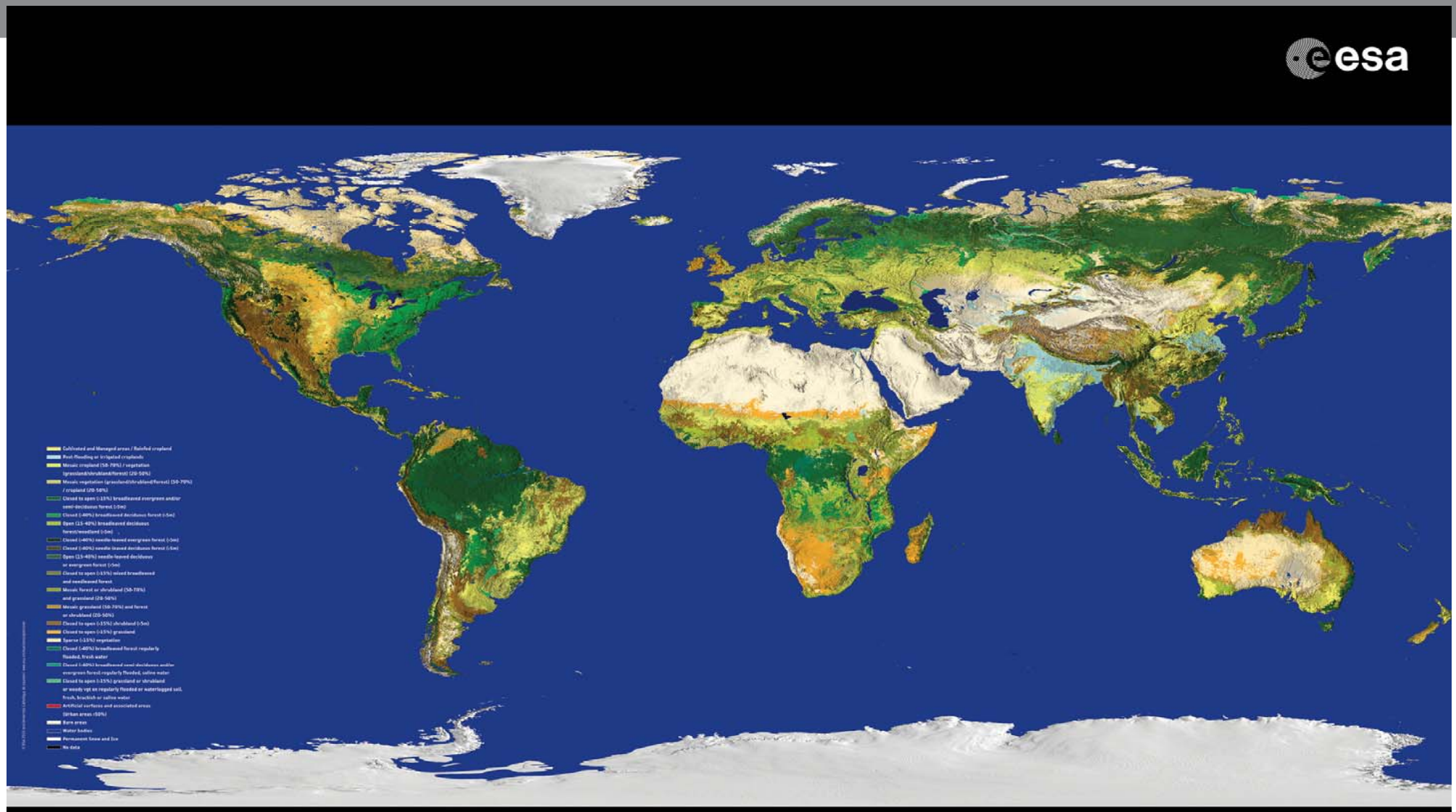
Sea level rise

Trend: +3.1 mm/yr



> COURTESY OF REMKO SCHARROO, NOAA,US

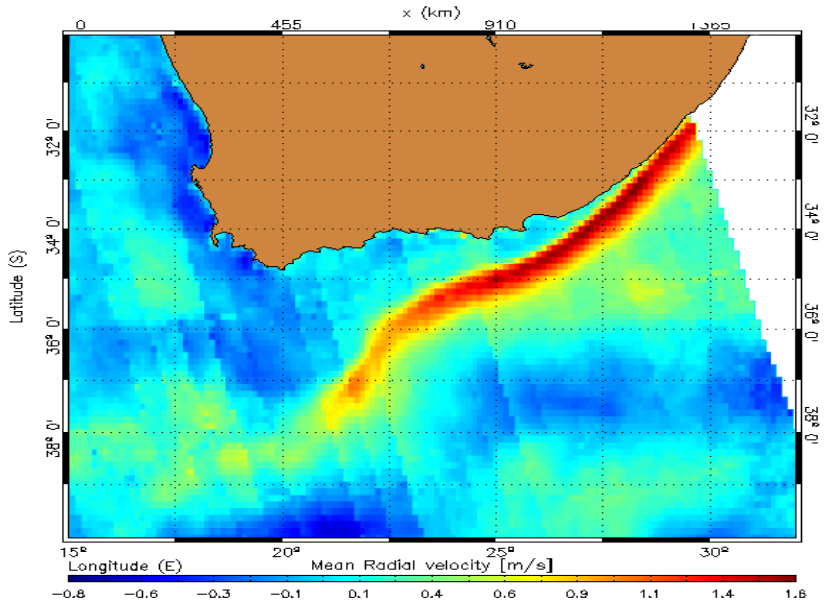
GLOBCOVER: NEW PORTRAIT OF EARTH SHOWS LAND COVER AS NEVER BEFORE

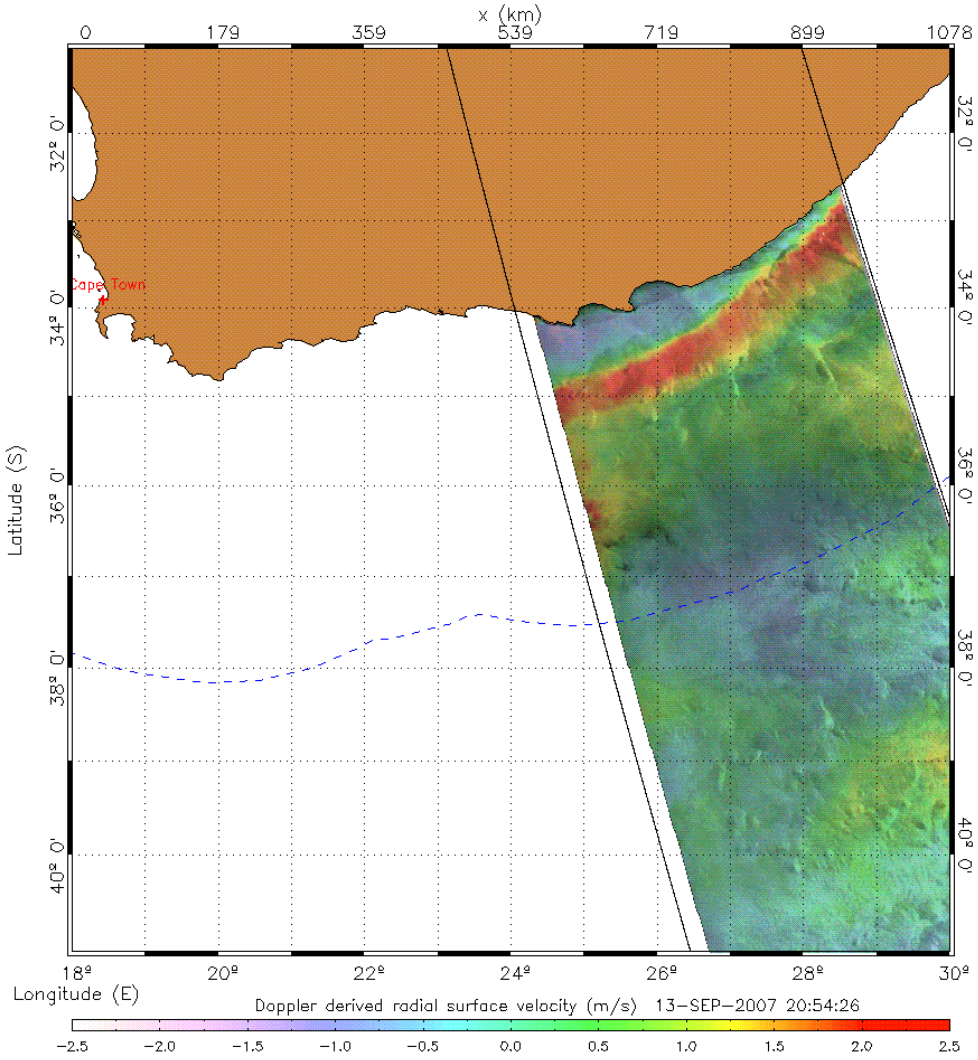


→ GLOBCOVER 2009 | MERIS 300m

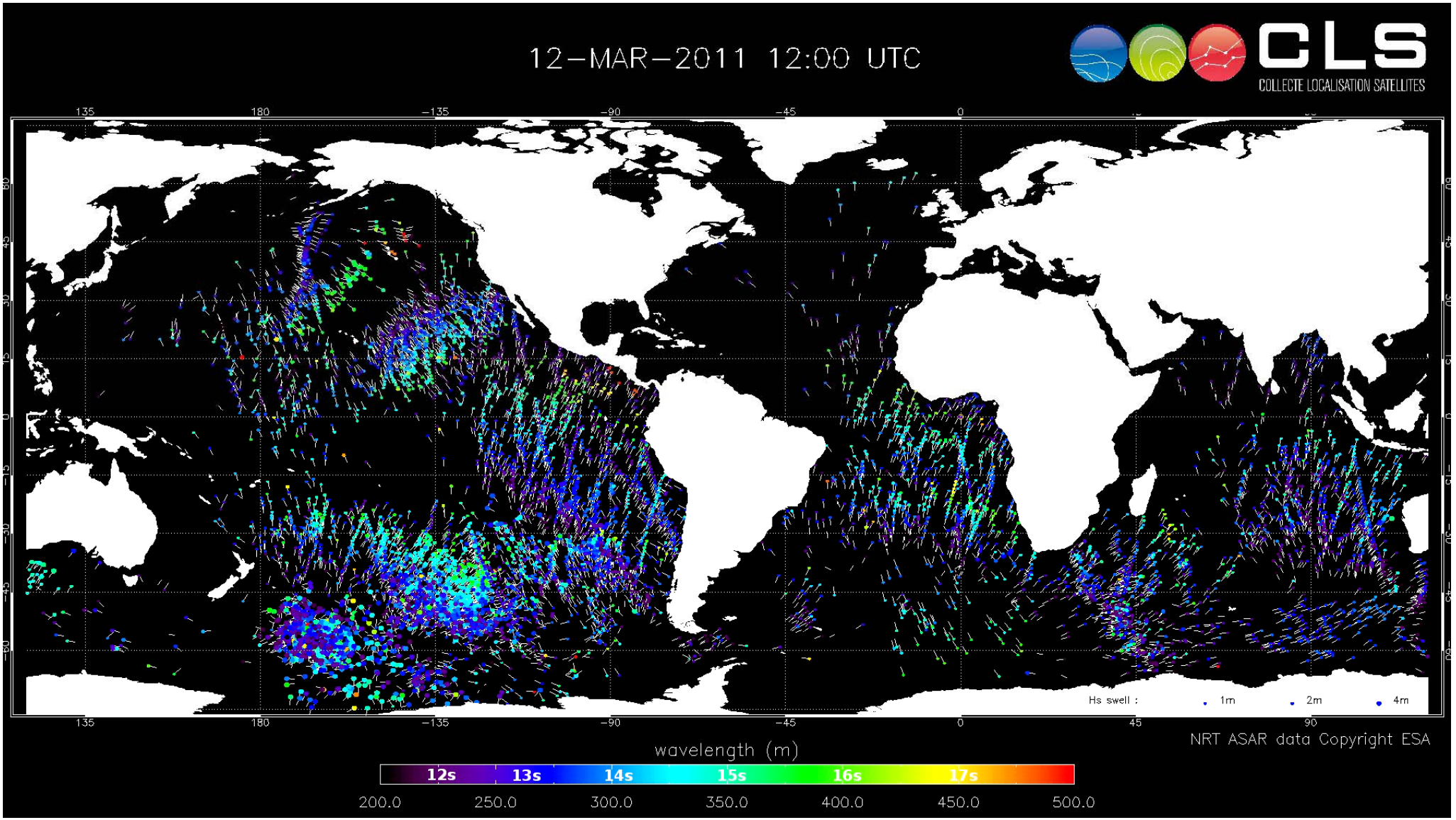
ocean current dynamics

- Direct measurements of upstream surface flow of the Greater Agulhas Current as obtained from ASAR Wide Swath Mode on 13, 16, 19 and 22 September 2007. The radial surface velocity is marked in the colour bar in metres per second.
  See http://www.esa.int/esaEO/SEMZRQEMKBF_index_1.html
- Credits: ESA - BOOST Technologies





SWELL PROPAGATION



Dragon 2 Project id. 5305
Lead Investigator Dr. Sun Jianbao, China Earthquake Administration

backstory

Revealing ruptures

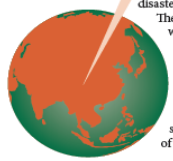
Zheng-Kang Shen and colleagues discovered an unusual cure for car-sickness while trying to understand the mechanics of fault deformation during the Wenchuan earthquake.

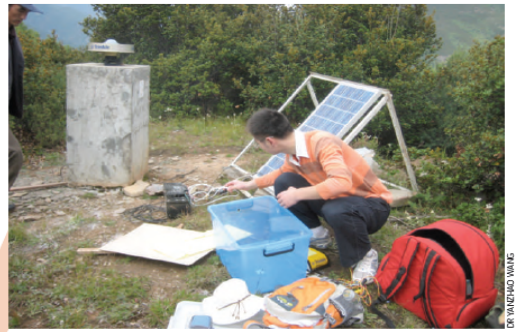
What was the objective of the work?
We wanted to understand the mechanics of the fault rupture of the 2008 Wenchuan earthquake in China, which killed more than 80,000 people. The earthquake took place along the Longmen Shan fault. The rupturing of this fault reflects ongoing tectonic stress build-up that results from the eastward movement of the Tibetan plateau thrusting over the relatively stable Sichuan basin. We hoped that by measuring crustal deformation during and after the Wenchuan earthquake, we could better understand the geometry and extent of the fault rupture, as well as the mechanism of the earthquake and its associated tectonic processes.

Why did you choose this particular location for the fieldwork?
The earthquake chose the location for us, providing an exceptionally rare opportunity for study. Scientifically, few (if any) Earth scientists anticipated an event of this magnitude in this locality, even though the steep western margin of the Sichuan basin is known to be seismically active.

What sorts of data were you after?
We collected GPS data, together with radar data obtained from satellites. We used this data to measure crustal deformation resulting from the earthquake, and to determine fault geometry and slip distribution during the earthquake.

Did you encounter any difficulties?
We encountered most of our difficulties during the early phase of our fieldwork, which was carried out immediately after the quake. We came across roads that had been buried by landslides, collapsed bridges, vehicles hit by fallen rocks and a traffic accident in a congested road lined up with disaster-relief trucks. The living conditions were poor, with a lack of adequate food and water supplies at some camping grounds, and no power supply. Several of us suffered from altitude sickness while climbing mountains to survey sites. And there was the psychological trauma of seeing so much destruction.




DR WENZHAO WANG

A crew member setting up GPS survey instruments at a mountain-top site after an hour-long hike. He is being watched by a local villager who helped carry survey equipment to the site.

Did you have any encounters with dangerous animals?
One of our team members was stung by a hornet when working at a survey site. He had to run down a half-hour-long trail before being rushed to hospital.

Any low points?
On many occasions we were shocked by the scale of the devastation that the quake had caused. Among all the emotional lows, the one that stood out the most was when we had just finished a day of work and sought lodging assistance at a local government office. A lady in her thirties quietly arranged tents and meals for us. Afterwards, she asked, with a gentle and quiet voice: "Didn't you know such a big one was coming?" We learnt later on that she had lost her husband in the earthquake.

What was the highlight of the expedition?
Having overcome all sorts of difficulties and hazards, we were elated when — two weeks after the quake — we had our instruments up and running at the first field site.

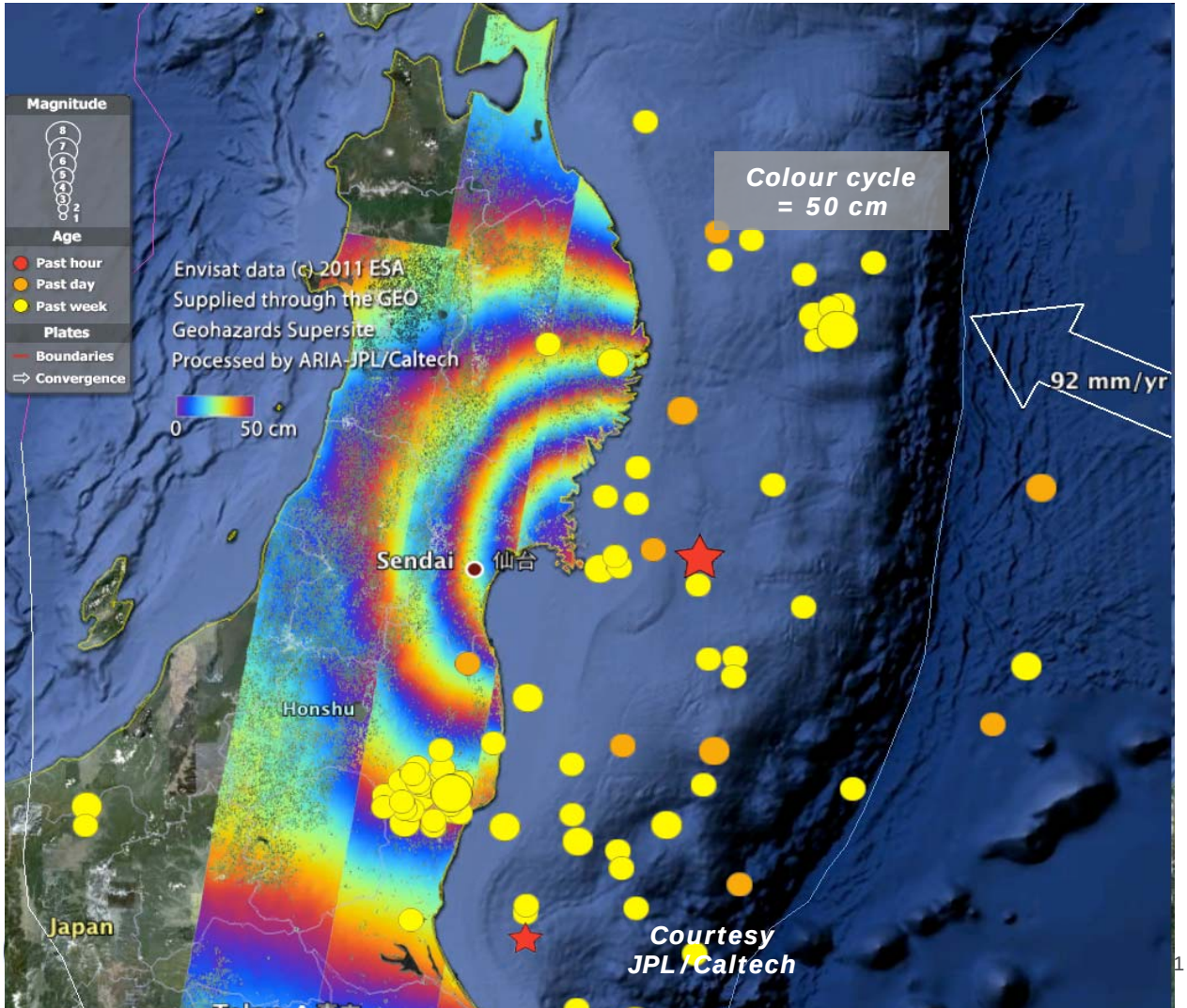
Did you learn anything new about yourself or your team members?
One of our crew members got car-sick while sitting in the back seat of a four-wheel-drive Toyota Land Cruiser, following a long drive along a treacherous rural road. With no other cure available, we put him in the front seat of a small and shaky pick-up truck, with tiny wheels and thin body parts. Bumping up and down, he sat in the car for the next several days, and never got car-sick again. We learnt that expensive and comfortable vehicles can still offer great discomfort, and that cheap uncomfortable vehicles are sometimes the best cure.

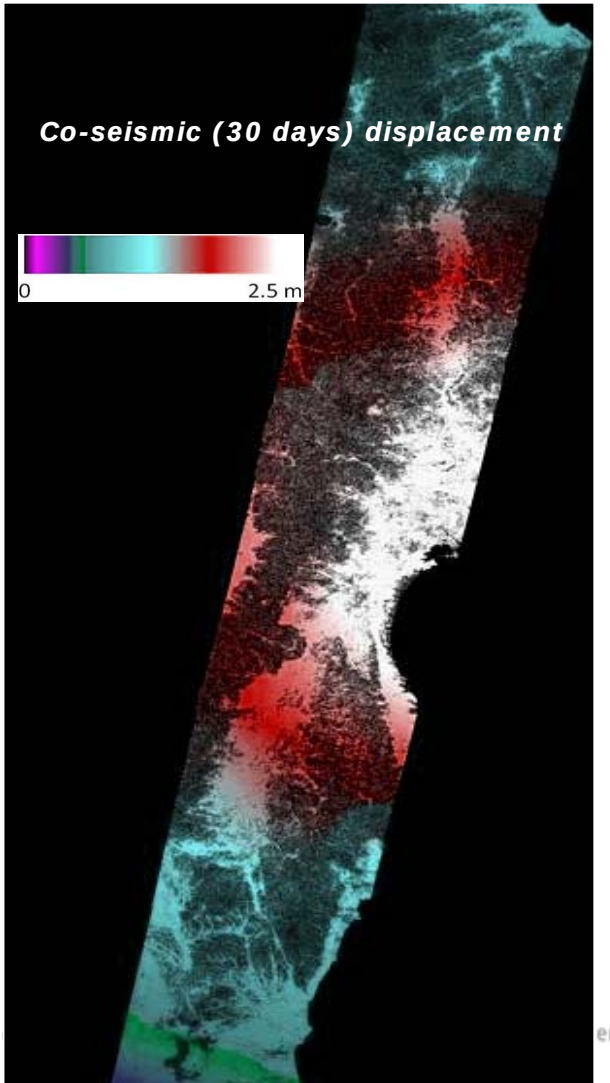
This is the Backstory to the work by Zheng-Kang Shen and colleagues, published on page 718 of this issue.

10 public media reported the work after Publication, BBC, ABC , CNN, Xinhua etc.

Japan earthquake (March 2011)

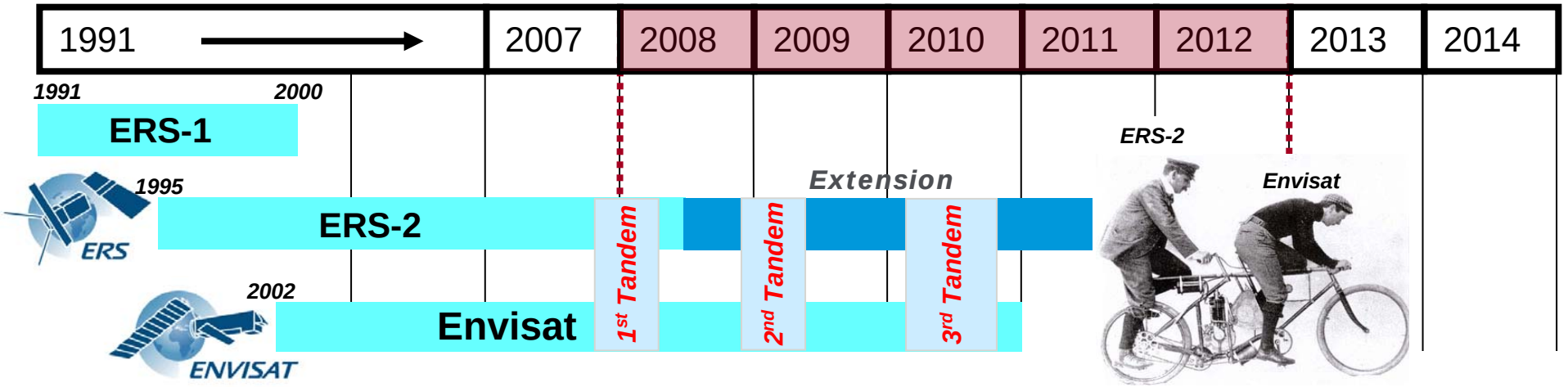
Thanks to the background data acquisitions (several pre-seismic acquisitions in February 2011), it is possible to generate an Envisat ASAR interferogram (combining with several post-seismic acquisitions in March 2011) which provides a detailed estimation of the terrain movement on a very large scale.





ENVISAT ERS-2
Tandem Mission

SCIENTIFIC EXCELLENCE
ERS-2 MISSION



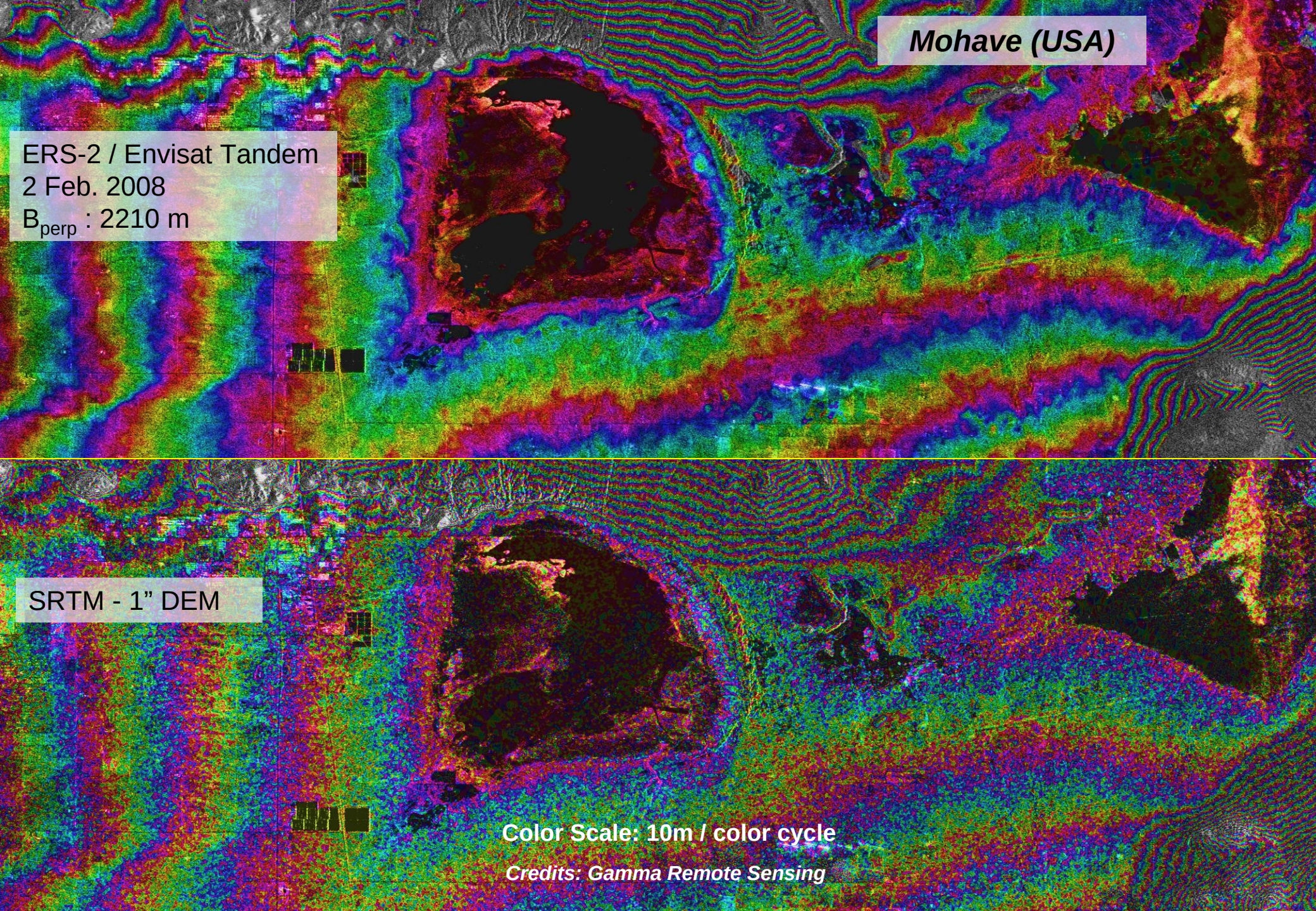
The EOEP-3 proposal included the provision for operating ERS-2 until mid-2008.

However the ERS-2 mission lifetime was ***extended by 3 years*** in 2008 thanks to:

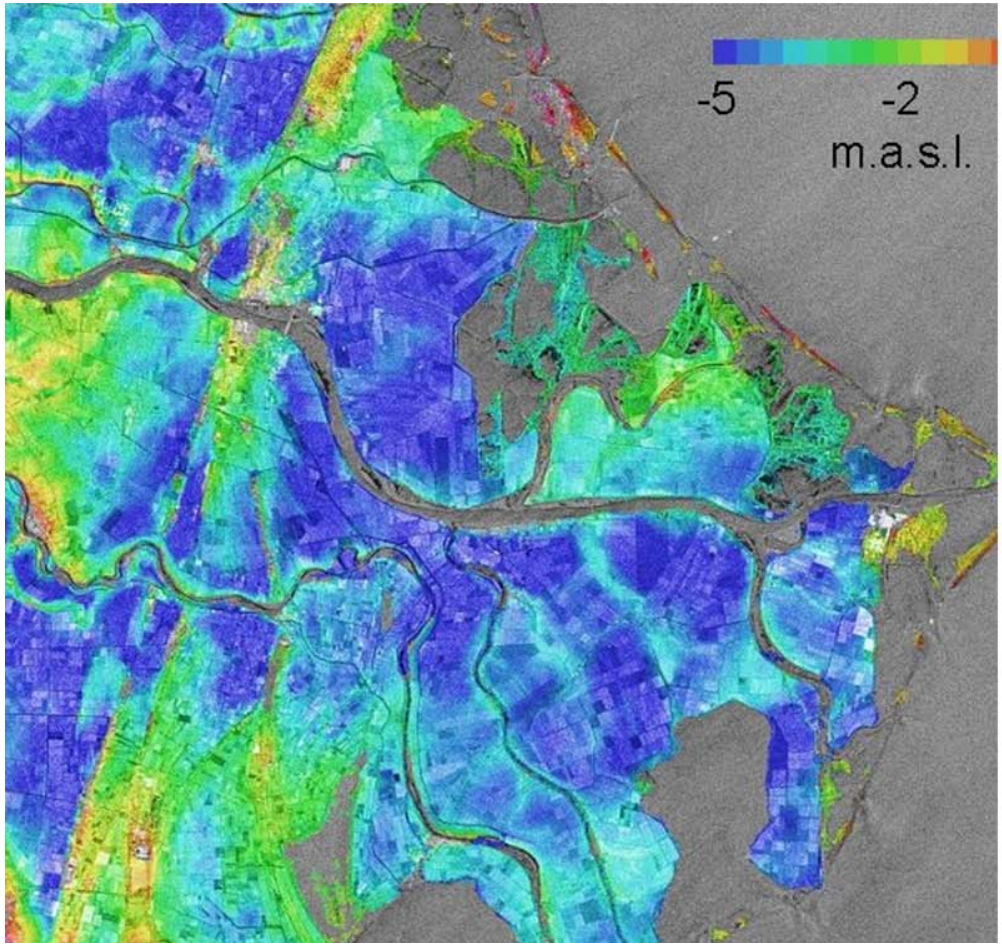
- the flexibility of the Envelope Programme
- the overall satisfactory status of the satellite
- the scientific demand (in particular InSAR) as well as demand for operational applications

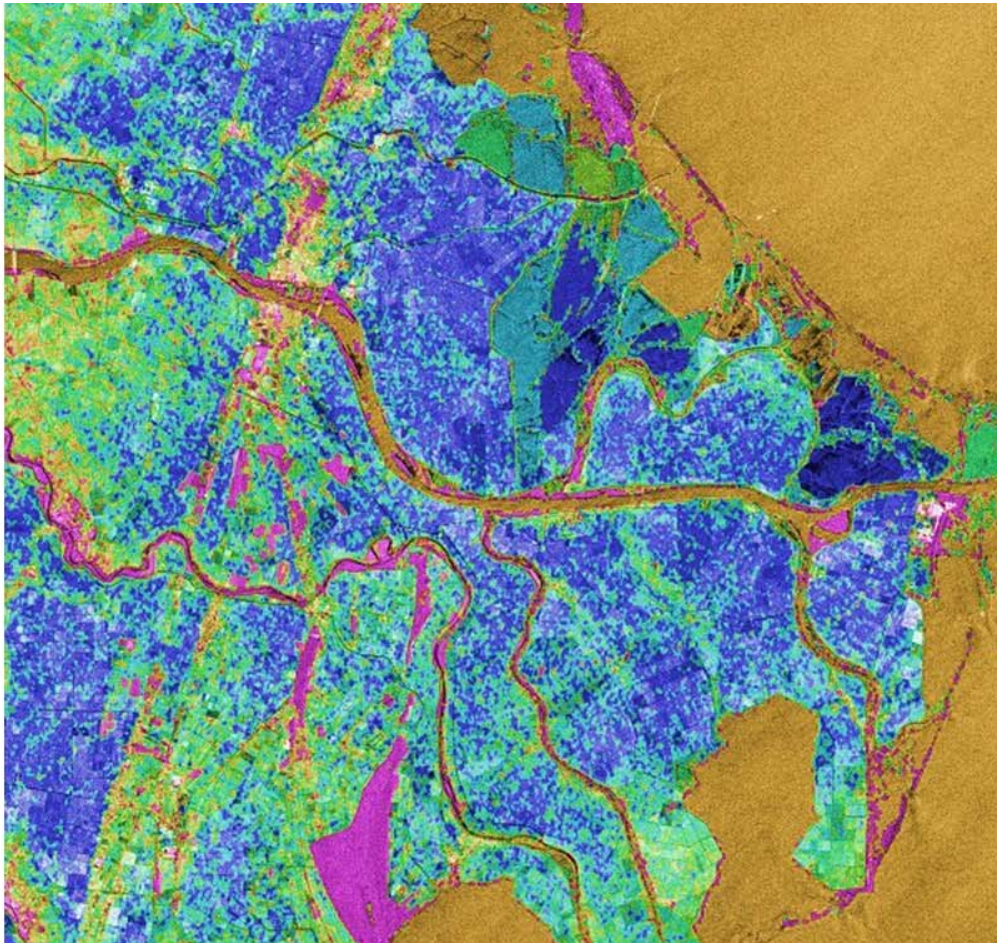
Amongst the benefits of the ERS-2 mission extension:
→ Three ***ERS-2 / Envisat SAR tandem campaigns***, exploiting the synergy between the 2 missions (30 min. time interval on the same orbit) until Envisat orbital change at end 2010.

After 16 years of operations, ERS-2 mission will complete its prolonged mandate at mid-2011 and will be de-orbited.


Mohave (USA)
ERS-2 / Envisat Tandem
2 Feb. 2008
B_{perp} : 2210 m
SRTM - 1” DEM
Color Scale: 10m / color cycle
Credits: Gamma Remote Sensing

ENVISAT-ERS Tandem DEM





- Comparison of Digital Elevation Models (DEMs) for a 50km x 35km area of the Po river delta, Italy.
- The DEM shown in the left image was derived from highly accurate interferometric data gathered during tandem observations by ESA's ERS-2 and Envisat (7 Nov 2007).
- The image to the right shows the interpolated Shuttle Radar Topography Mission (SRTM) DEM heights over the same area using the identical very fine color scale.

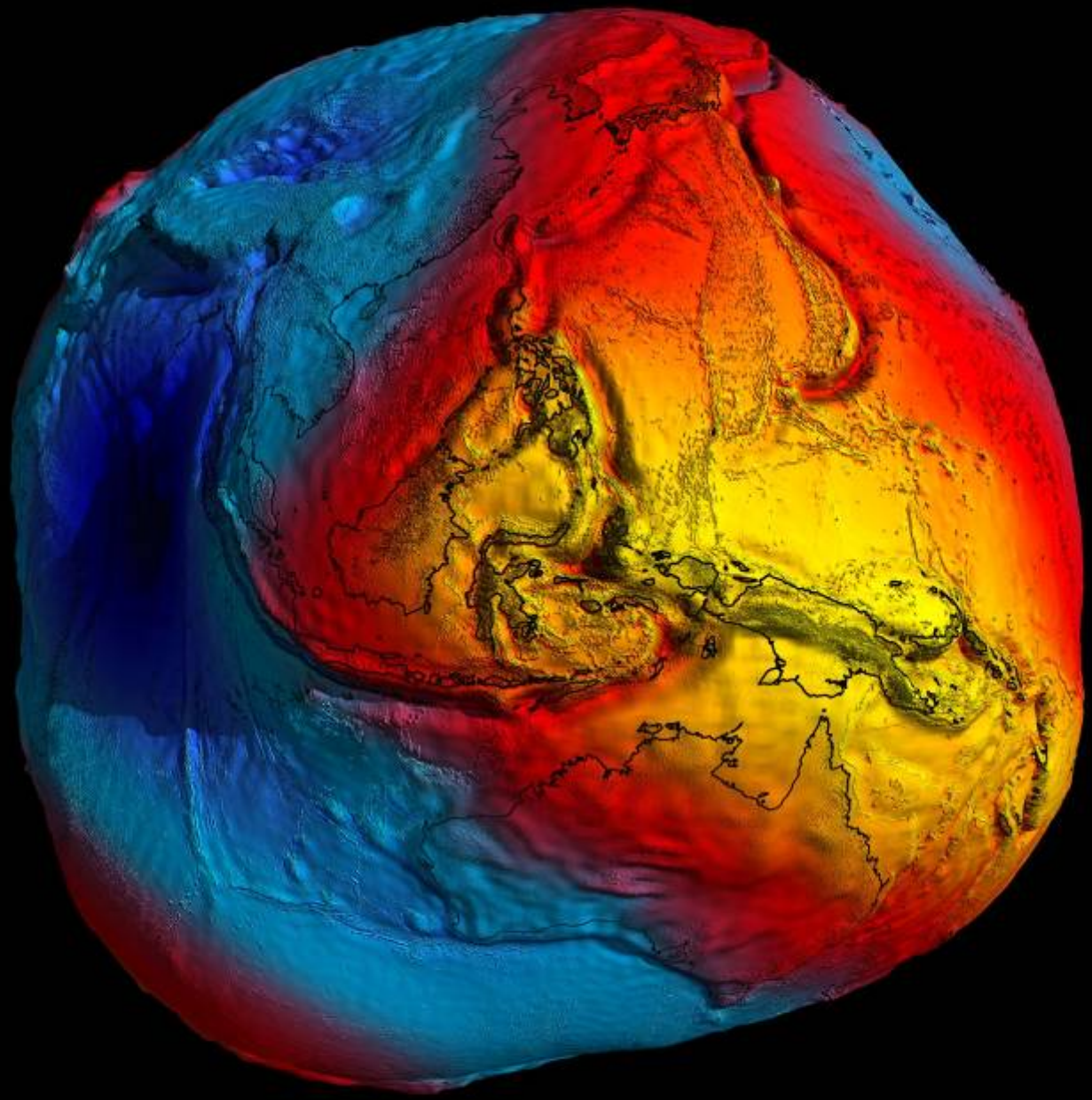
Earth Explorers

GOCE – *the gravity mission*

- **Launched in March 2009**
- **GOCE successfully finished its nominal mission in March 2011**

A unique mission:

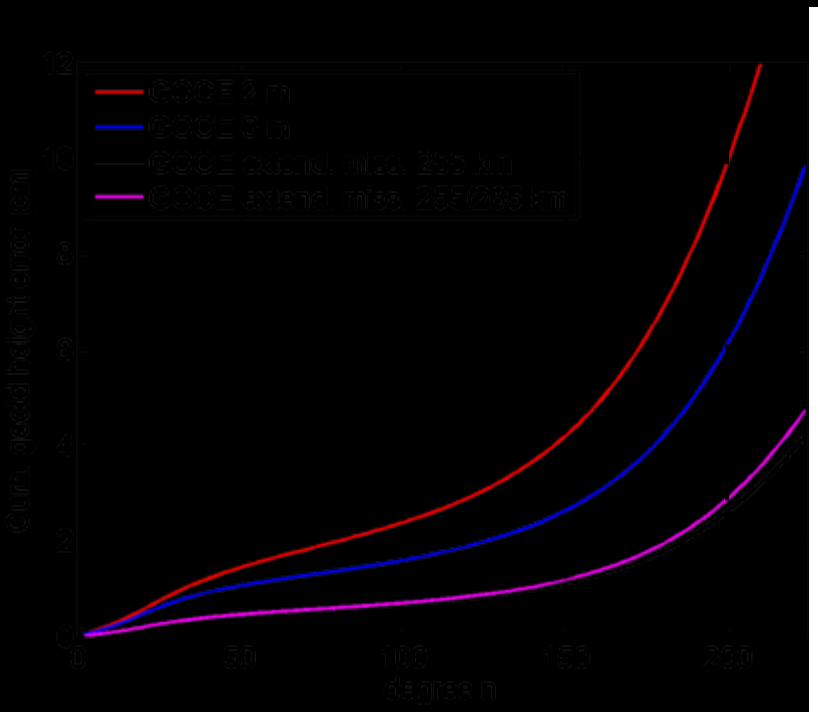
- First gradiometer in space
- Very low orbit (255 km)
- Active air drag control (ion engine)
- Perfectly quiet environment

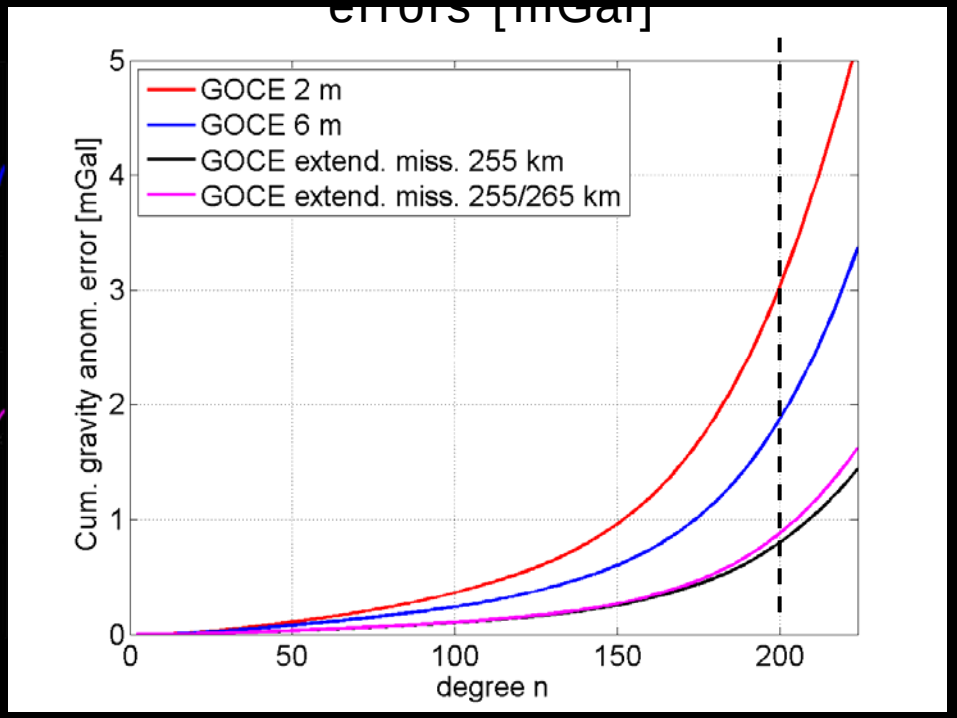


GOCE gravity field – newest geoid

- *Based on 3 cycles / 6 months of data*
- *Geoid based on full nominal*

Full achievement of all mission objectives in extended mission with no aid from other data





→ Performance estimates for **GOCE stand-alone** solutions

→ Combination solutions make perfect sense; GRACE now also ESA TPM

→ Already now: 2 cm global geoid error at spatial resolution of ca. 150 km

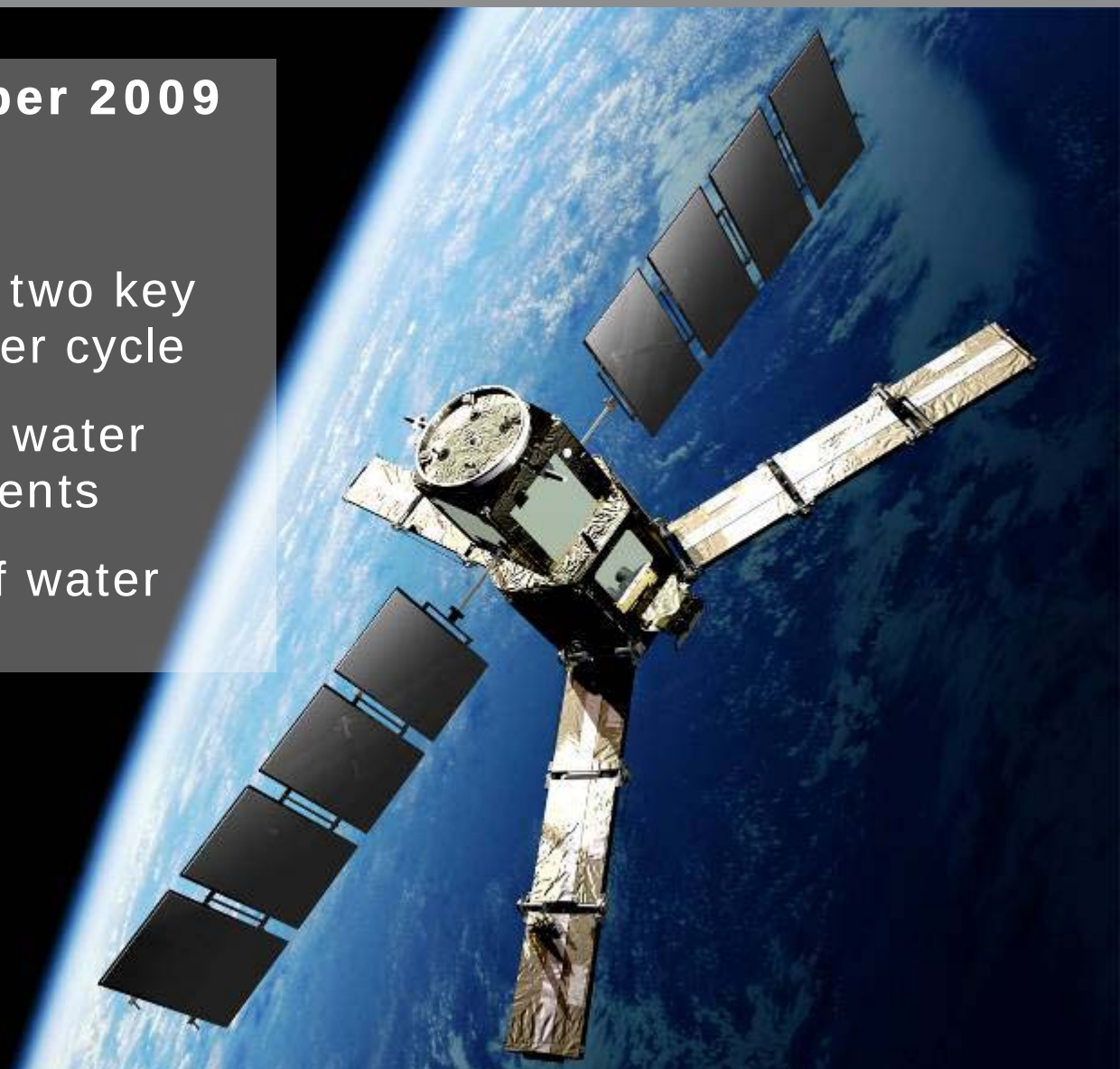
SMOS – *The ESA water mission*

In space since 2 November 2009

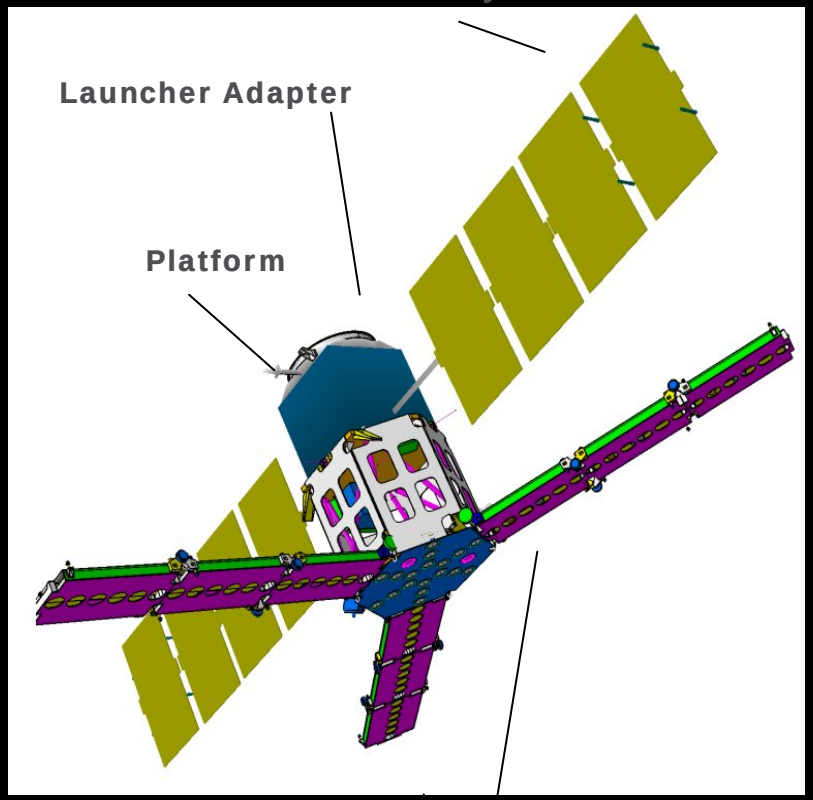
Applications:

First <u>global</u> observations of two key variables of the Earth's water cycle

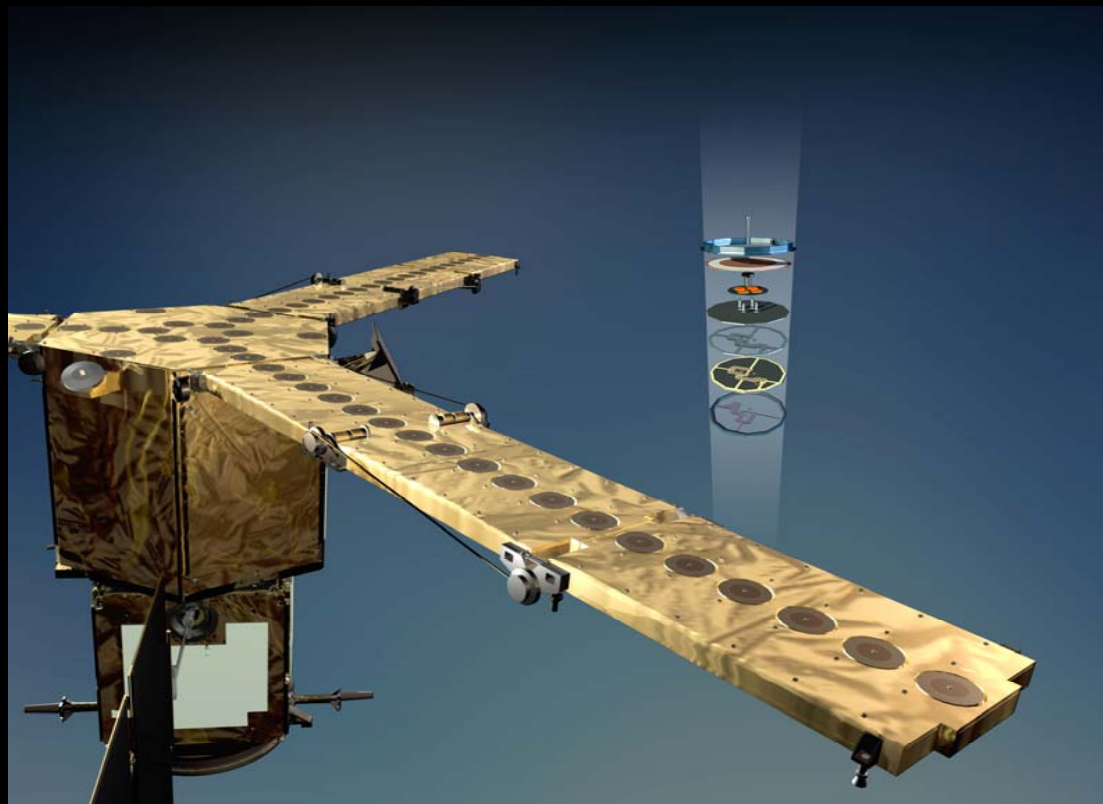
- Improve *models* of global water cycle and global ocean currents
- Improved management of water resources



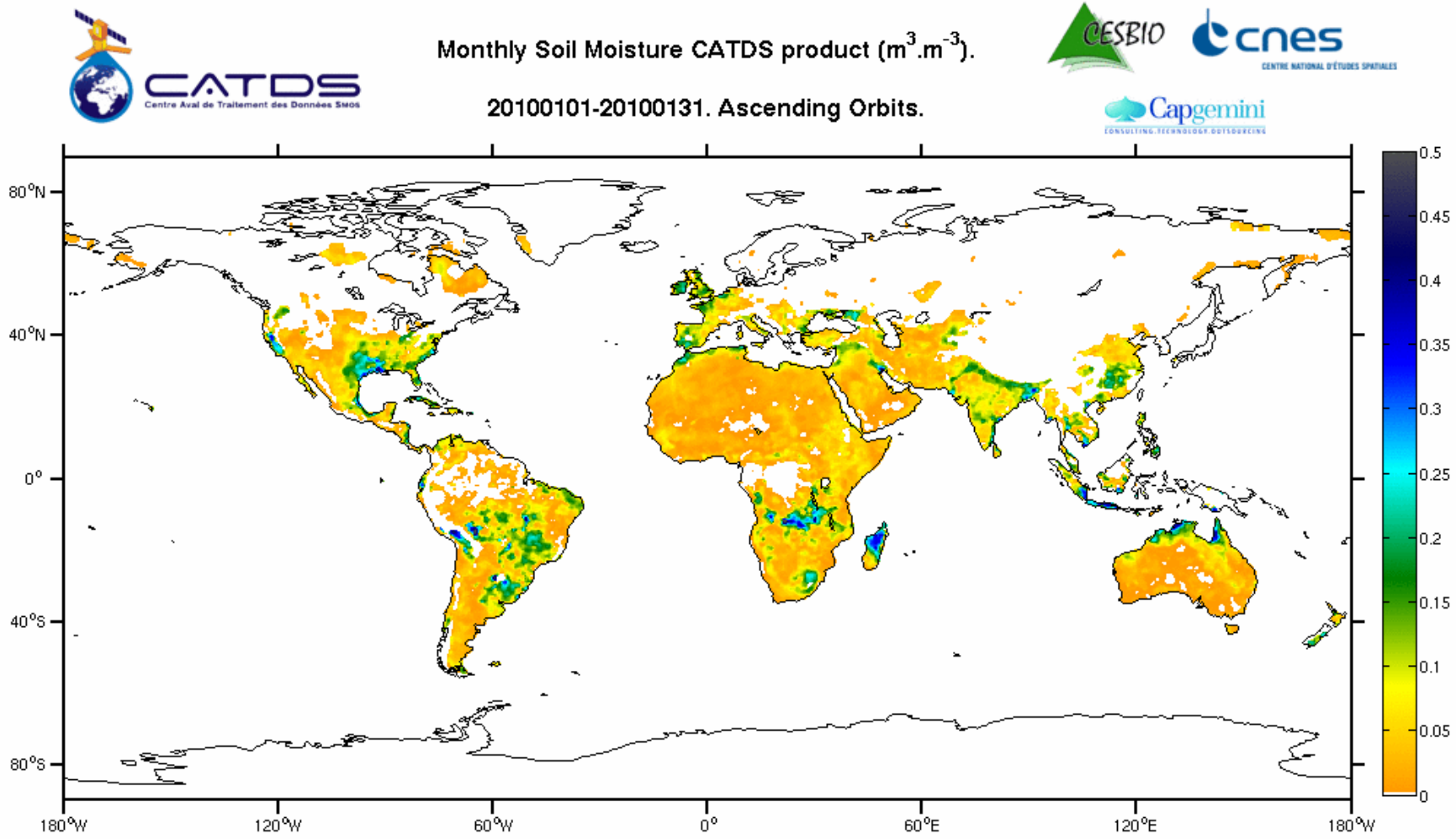
SMOS: RADIOMETRY WITH APERTURE SYNTHESIS



microwave radiometer
at L band: 1.4 GHz
2D interferometry (from 72 receivers)
multi-incident angles (0°- 55°)
polarimetric observations

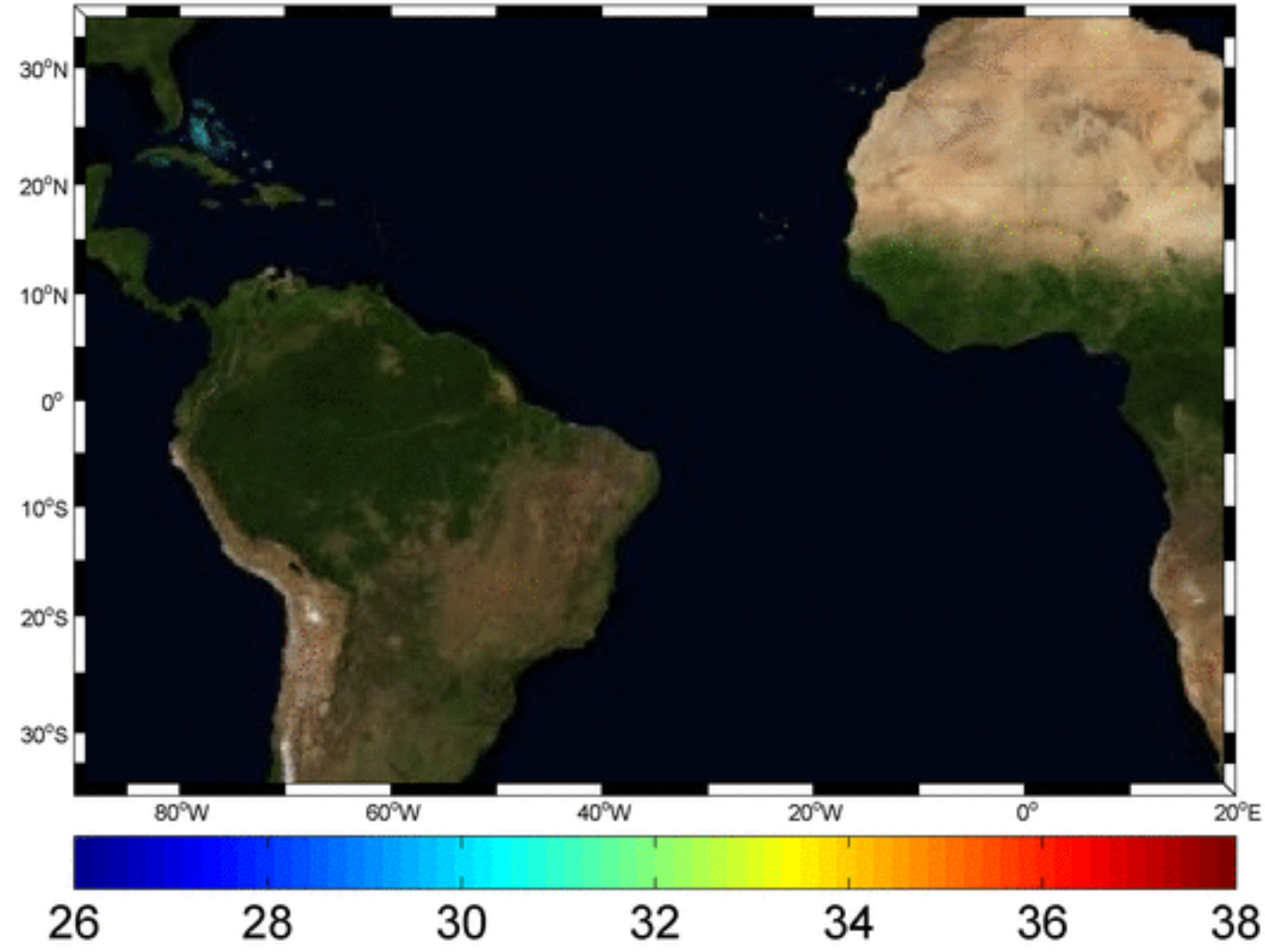


SMOS Global Soil Moisture Map
(Monthly mean year 2010)



SMOS Ocean Salinity

SSS products evolution over the Tropical Atlantic region combining both ascending and descending passes from January to December 2010



Space Agency

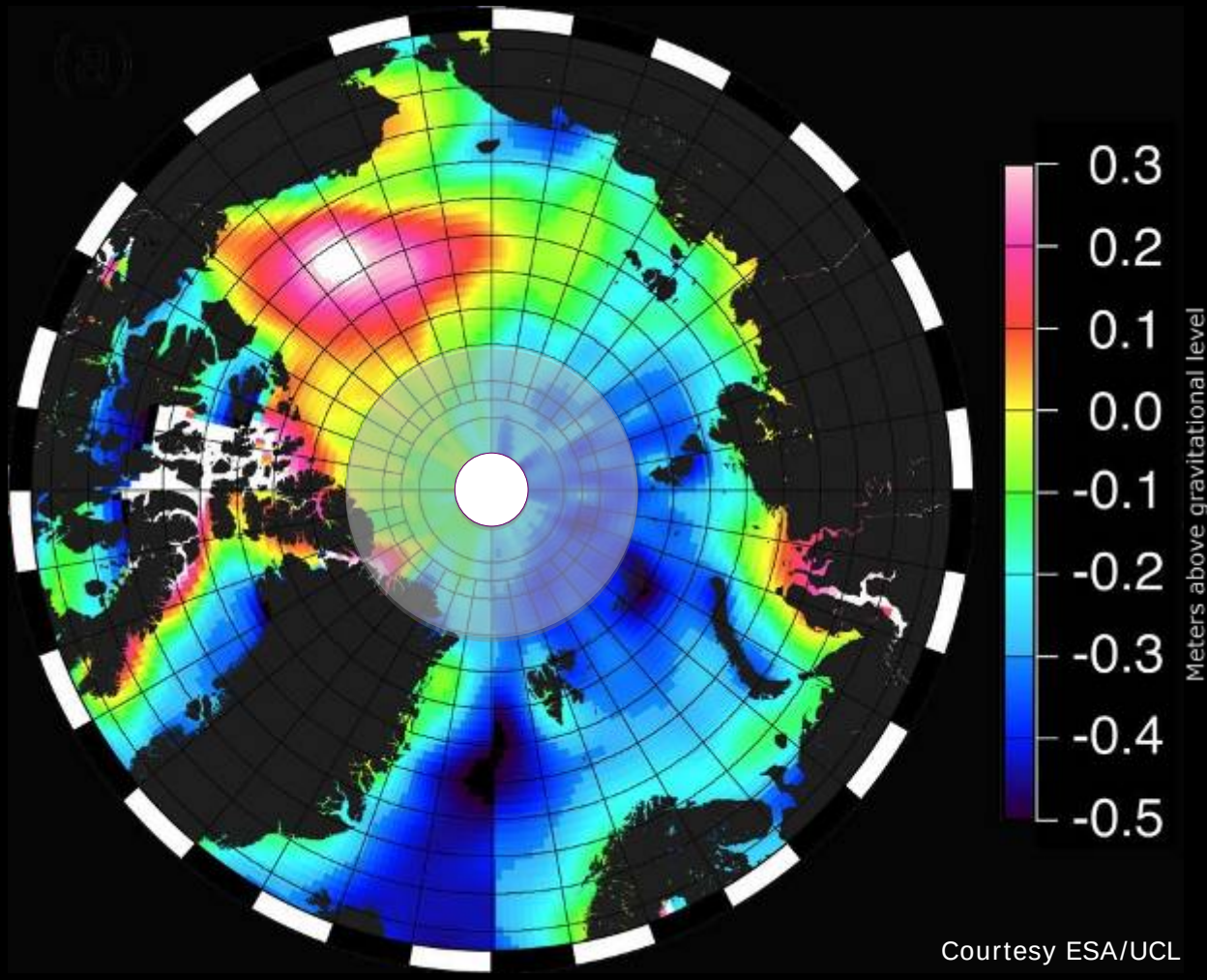
CryoSat-2 – *ESA's ice mission*

- monitoring precise changes in the thickness of the polar ice sheets and floating sea ice, reaching latitudes of 88°
- Launch 8 April 2010

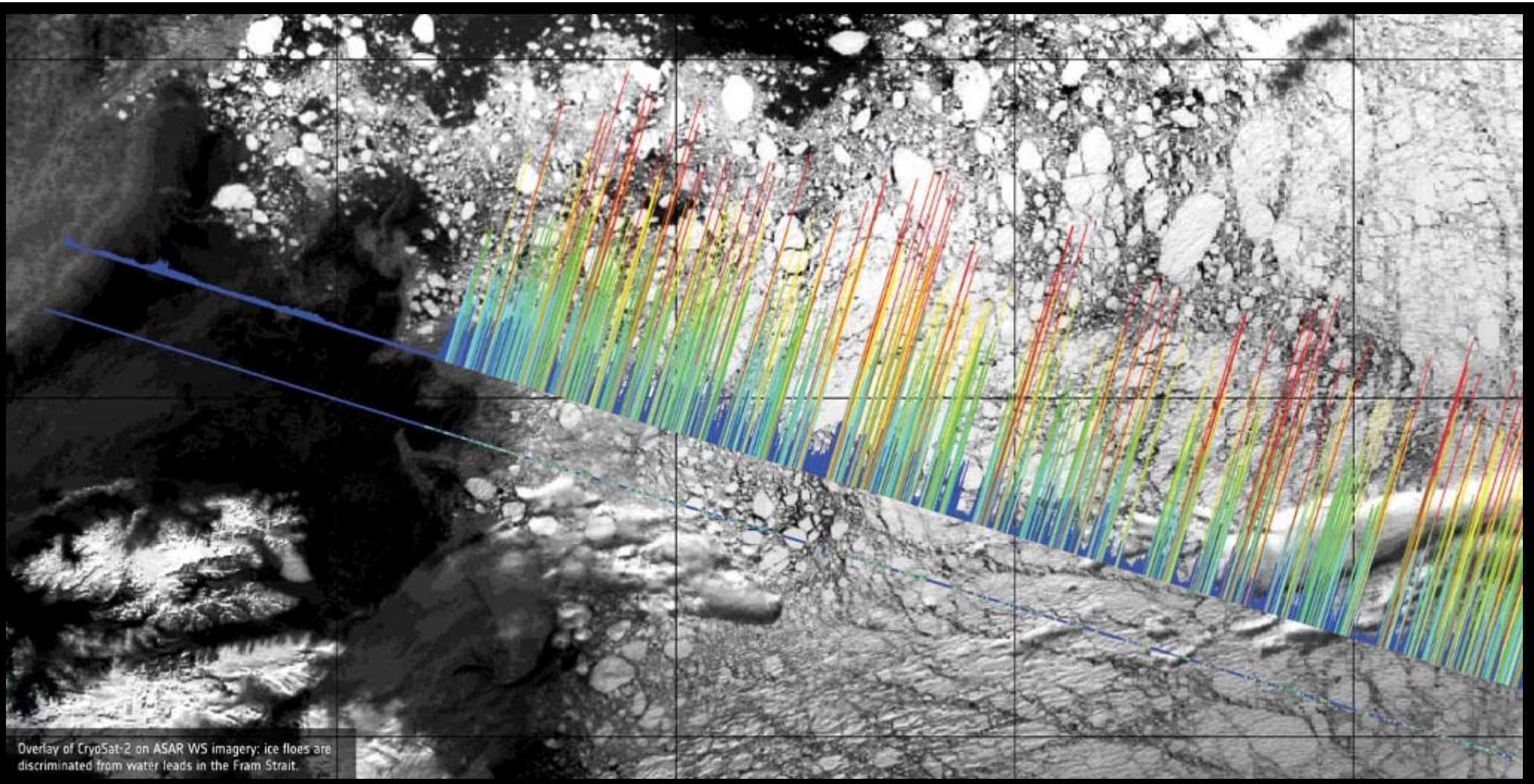
European Space Agency

CryoSat returns first science

Revealed the first complete picture of ocean Dynamic Topography in the Arctic Ocean up to 88° latitude



Preparing for sea-ice thickness measurements



Overlay of CryoSat-2 on ASAR WS imagery: ice floes are discriminated from water leads in the Fram Strait.

Ice floes

Water Leads

Courtesy ESA/UCL

SWARM – ESA‘s magnetic field mission

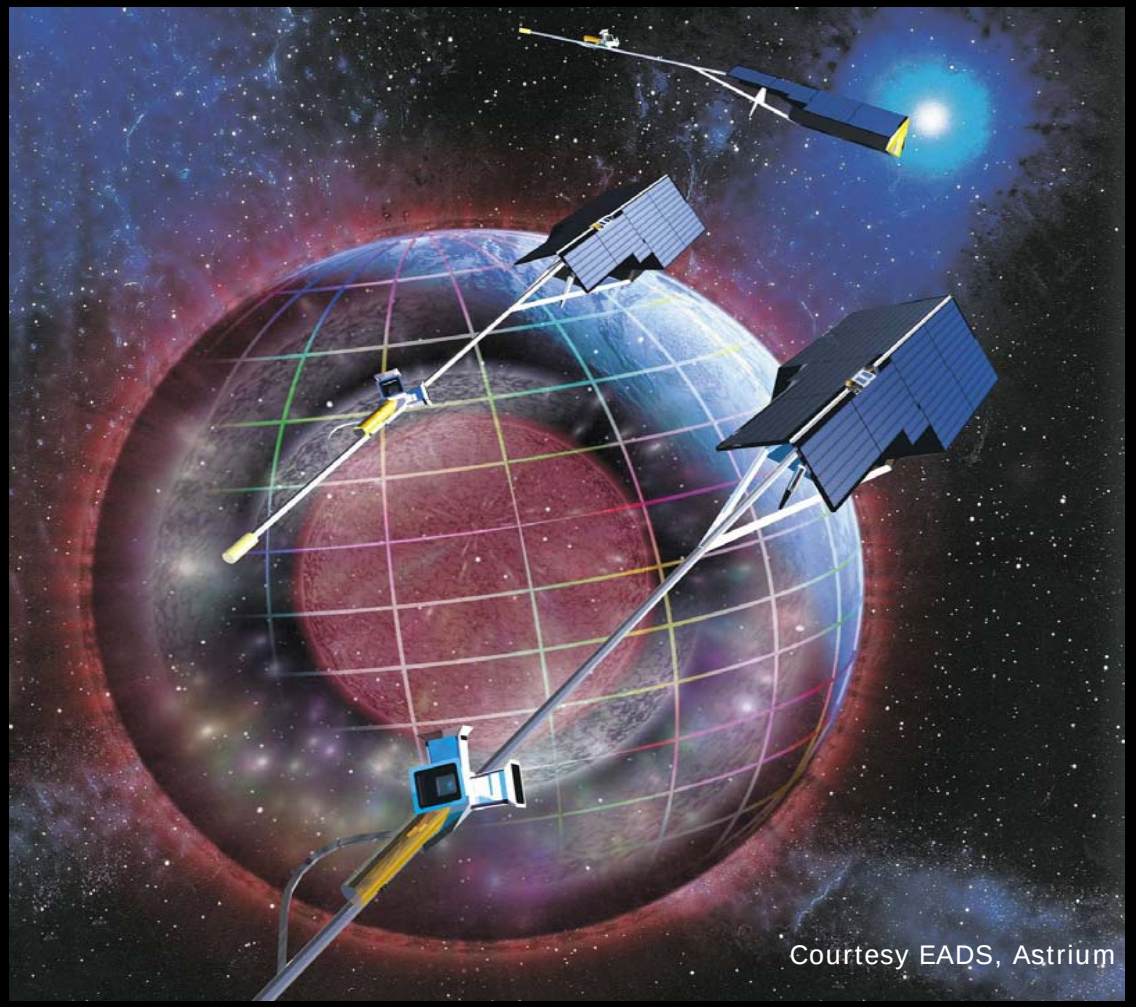
- to provide the best-ever survey of the Earth’s geomagnetic field and its variation in time
- to gain new insight into the Earth’s interior and climate.

Status:

Satellites manufacturing, components integration and testing ongoing

GS development progressing

Launch scheduled for July 2012



ADM-Aeolus – ESA‘s wind mission

- **to provide global observations of wind profiles from space**
- to improve the quality of weather forecasts and our understanding of atmospheric & climate processes

Status:

Implementation of the continuous mode of the ALADIN instrument ongoing

Satellite platform back in storage

Satellite acceptance review planned by mid 2013

EarthCARE – ESA‘s aerosol mission

- for a better understanding of the interactions between cloud, radiative and aerosol processes that play a role in climate regulation.

Status:

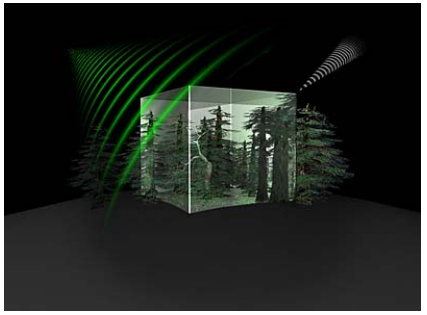
Preparation of Phase C/D

Launch in 2015-16

EARTH EXPLORER 7 phase A studies

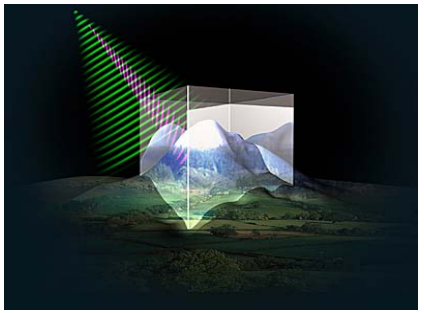
BIOMASS

A single satellite carrying a P-band SAR to provide continuous global interferometric and polarimetric radar observations of forested areas



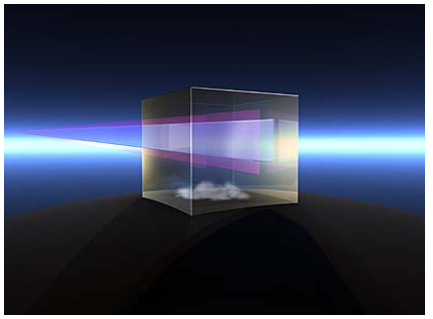
CoReH2O

single satellite with dual frequency (X, Ku), dual-polarisation SAR to observe snow / ice at high spatial resolution

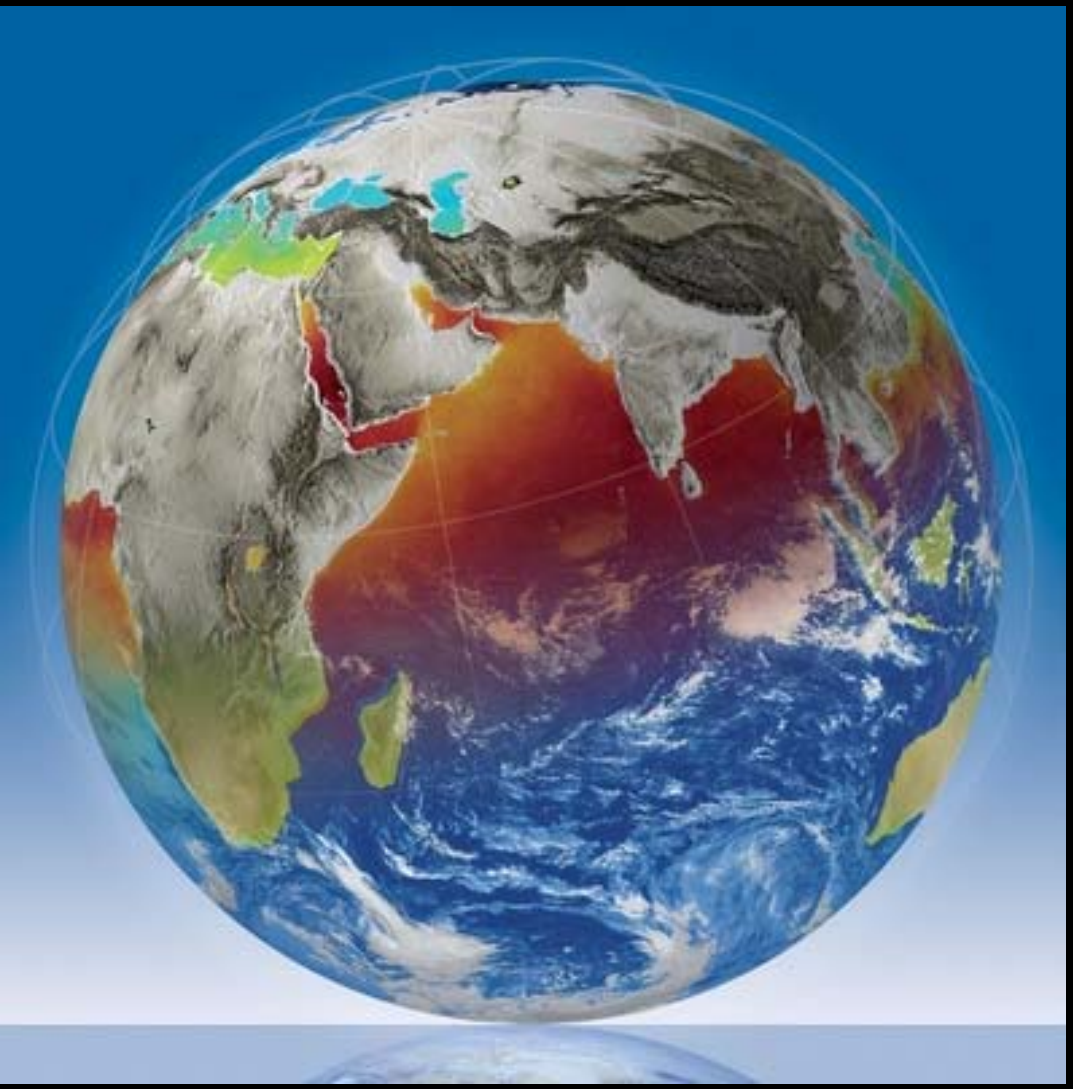


PREMIER

3D fields of atmospheric composition in upper troposphere and lower stratosphere. The instrumentation will consist of an infrared limb-imaging spectrometer and a mm-wave limb-sounder



Earth Explorer 8



- **FLEX: to provide global maps of vegetation fluorescence, which can be converted into an indicator of photosynthetic activity** -> to improve our understanding of how much carbon is stored in plants and their role in the carbon and water cycles

- **CarbonSat: to quantify and monitor the distribution of carbon dioxide and methane** -> for a better understanding of the sources and sinks of these two gases and how they are linked to climate change.

Global Monitoring for Environment and Security

European **independence** in data sources for environment and security monitoring

and

The European **contribution** to the Global Earth Observation System of Systems (GEOSS)

GMES Overall View

USERS

Policy Makers & Public & Private, Commercial

What is their need?

Farming

Oil Spill Tracking

Air Quality

Flood

Surveillance

Example Services Provided

Land | Marine | Atmosphere | Emergency | Security

Core Services

Space Infrastructure & In Situ Infrastructure

Information Service

OBSERVATION

ESA’s role in GMES

- **Coordinator** of the overall GMES Space Component
- **Development and procurement Agency** for dedicated space infrastructure
- **Ad-interim operator** of Sentinel 1, -2 and Sentinel-3 (land) missions

GMES Space Component infrastructure




Sentinel missions

SAR – Multi-spectral – Ocean/Land – Atmospheric (LEO and GEO); launched from 2013 onwards





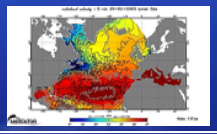



Contributing missions

Free & Open Data Policy

USERS

SERVICES

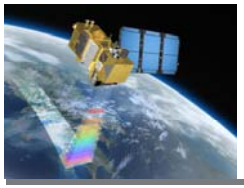



Distributed Ground Segment

GMES dedicated missions: Sentinels

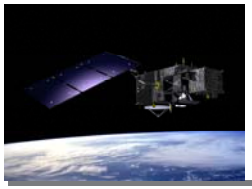
Sentinel 1 – SAR imaging
All weather, day/night applications, interferometry

2013 / 2015



Sentinel 2 – Multi-spectral imaging
Land applications: urban, forest, agriculture,..
Continuity of Landsat, SPOT

2013 / 2016

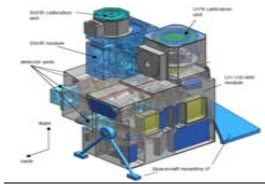


Sentinel 3 – Ocean and global land monitoring
Wide-swath ocean color, vegetation, sea/land surface temperature, altimetry

2013 / 2017

Sentinel 4 – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution

2019



Sentinel 5 – Low-orbit atmospheric
Atmospheric composition monitoring
(S5 Precursor launch in 2014)

2020+

+ Ground Segment and Coordination

Sentinel Data Policy Principles

FREE and OPEN

Anybody can access Sentinel data; no difference is made between public, commercial and scientific use

→ open access

Sentinel data will be made available to the users via a 'generic' online access mode

→ free of charge


SENTINEL-1
esa
P.CARRIL 2007

Sentinel-1
Mission Highlights

C-band SAR Mission

Launch : May 2013

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:

High Bit Rate 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.)

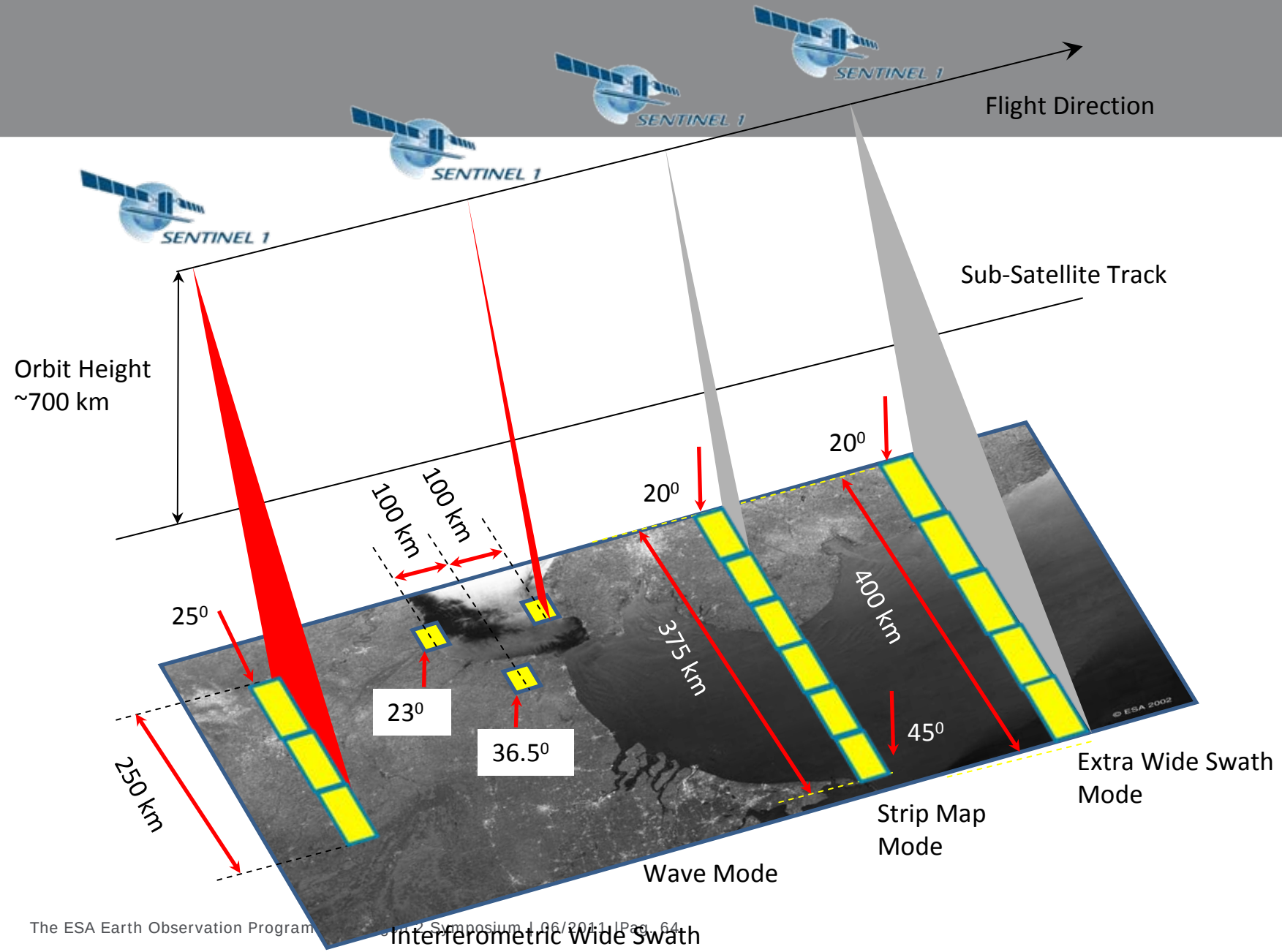
Low Bit Rate Mode
- Wave (5X5 m res.)

Duty Cycle: 25 min in HR mode per orbit in HBR mode & rest of the orbit in LBR

Sun synchronous orbit at 693 Km mean altitude

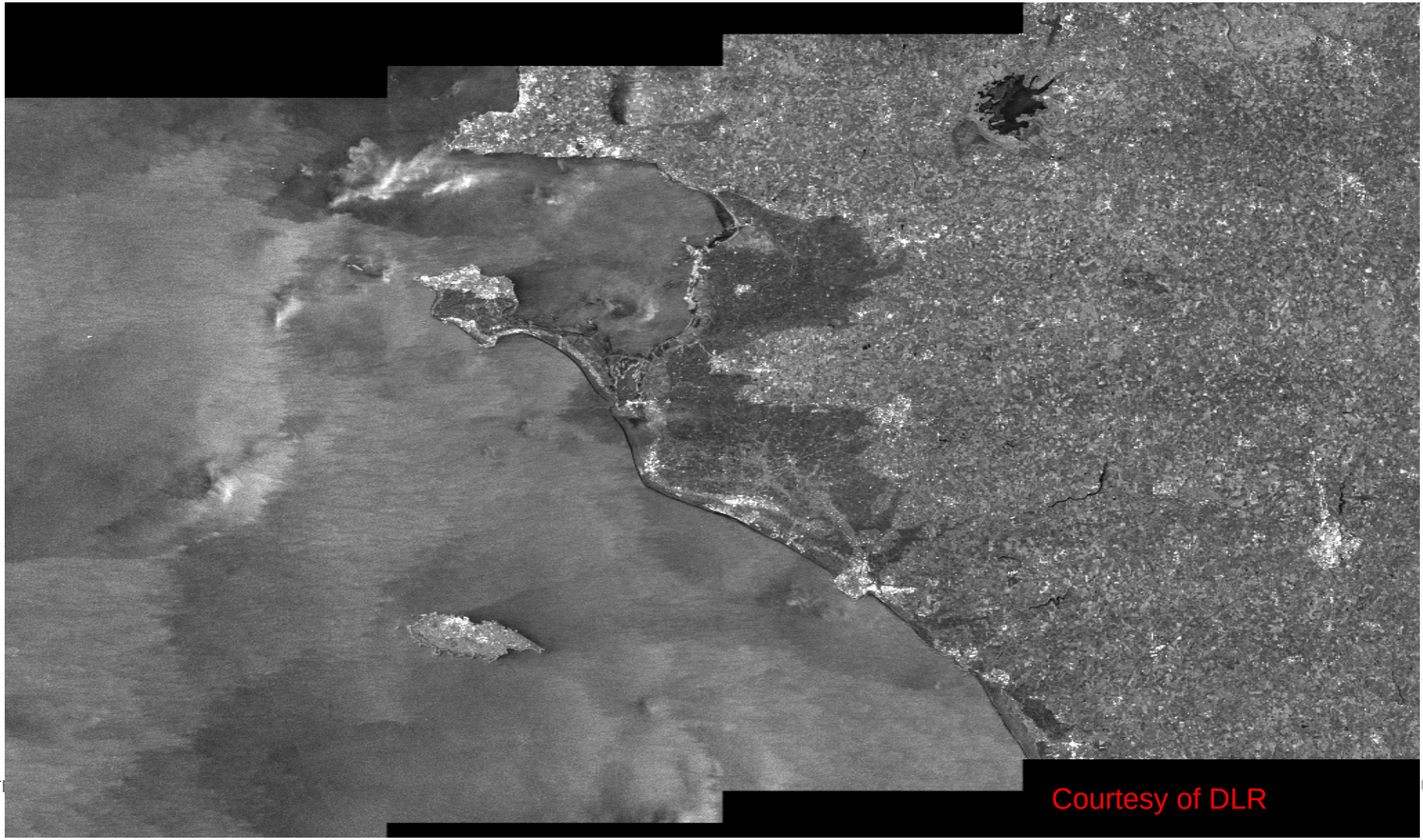
12 days repeat cycle

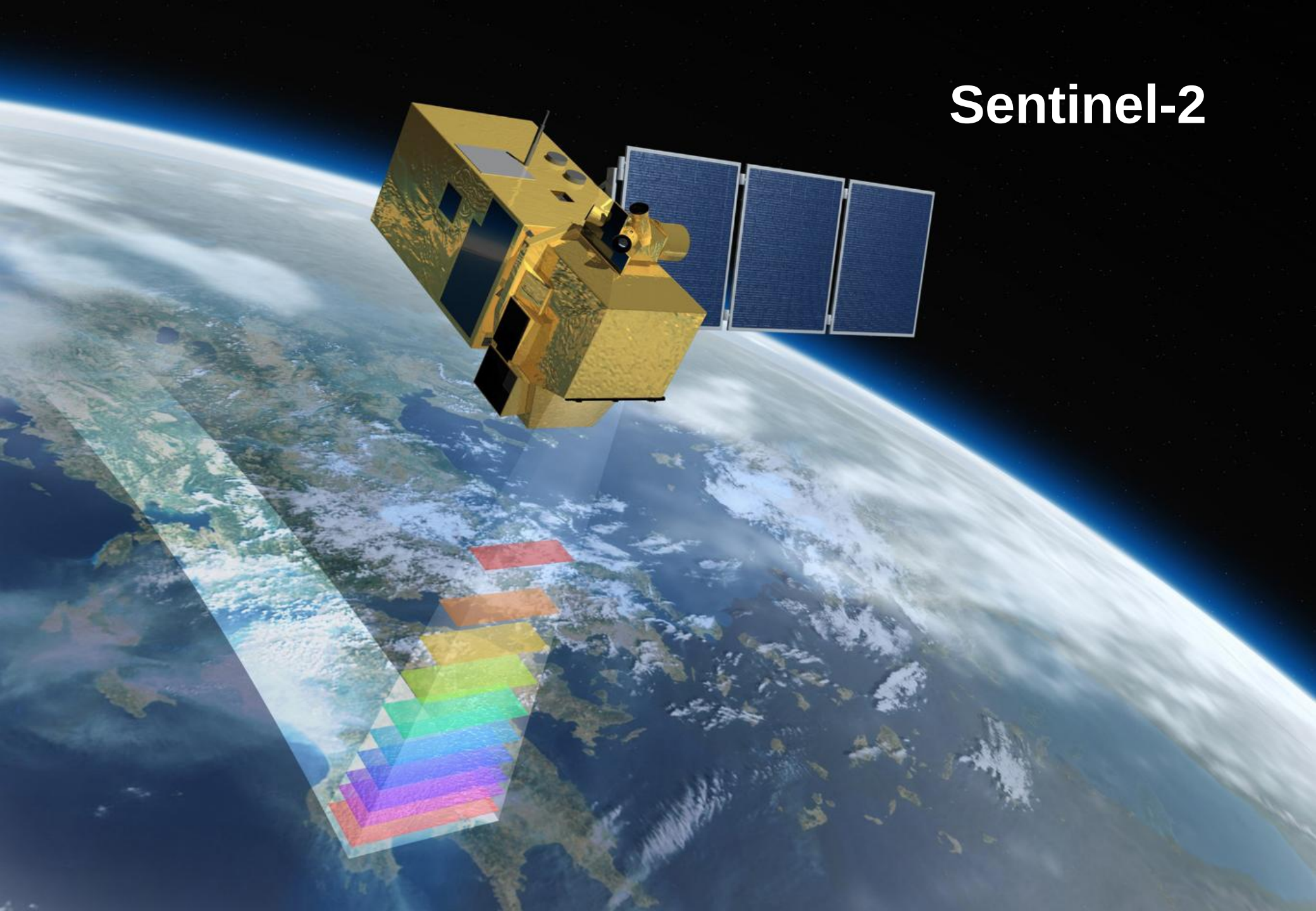
7 years design life time, consumables for 12 years


SENTINEL 1
SENTINEL 1
SENTINEL 1
SENTINEL 1
Flight Direction
Sub-Satellite Track
Orbit Height
~700 km
100 km
100 km
20⁰
20⁰
25⁰
23⁰
36.5⁰
375 km
400 km
45⁰
250 km
© ESA 2002
Wave Mode
Strip Map
Mode
Extra Wide Swath
Mode
Interferometric Wide Swath
Mode

Challans: TOPSAR image

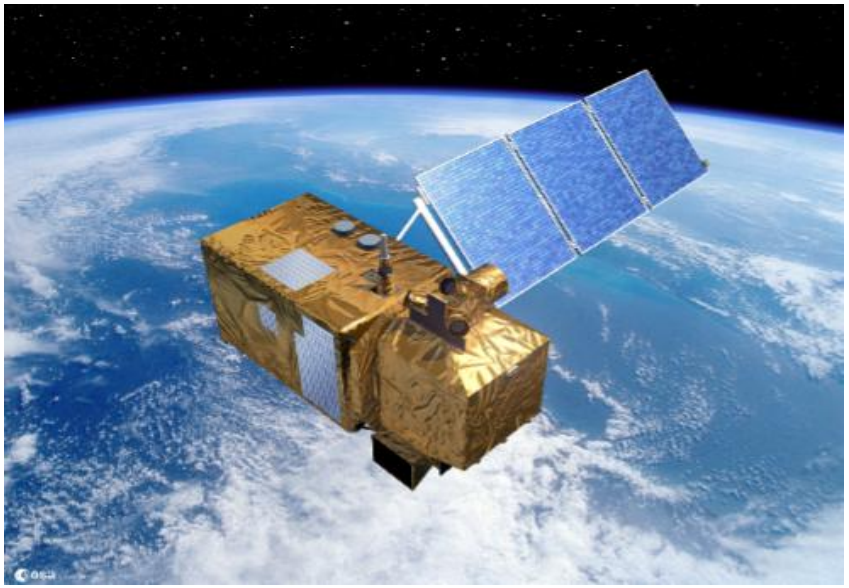
Time acquisition: July 9th, 2007 at 6.26 am




Sentinel-2

Sentinel-2
Mission Highlights

Super-spectral Imaging Mission



Launch : mid 2013

Applications:
- **Generic land cover maps**
- **Risk mapping and fast images for disaster relief**
- **generation of leaf coverage, leaf chlorophyll content and leaf water content**

Push-broom filter based multi spectral imager with 13 spectral bands (VNIR & SWIR)

Spatial resolution: 10, 20 and 60 m

Field of view: 290 km

2 x 280Mbps concurrent channels
~18 min downlink required per orbit for data playback

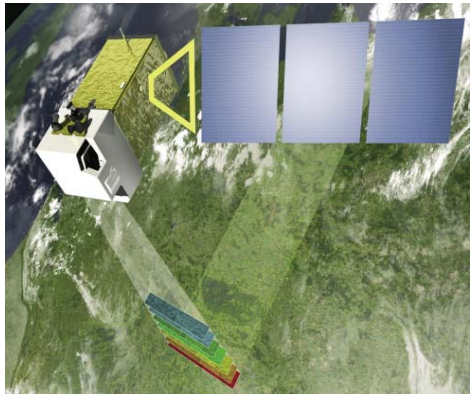
5 days repeat cycle (in twin spacecraft configuration)

Sun synchronous orbit at 786 km mean altitude

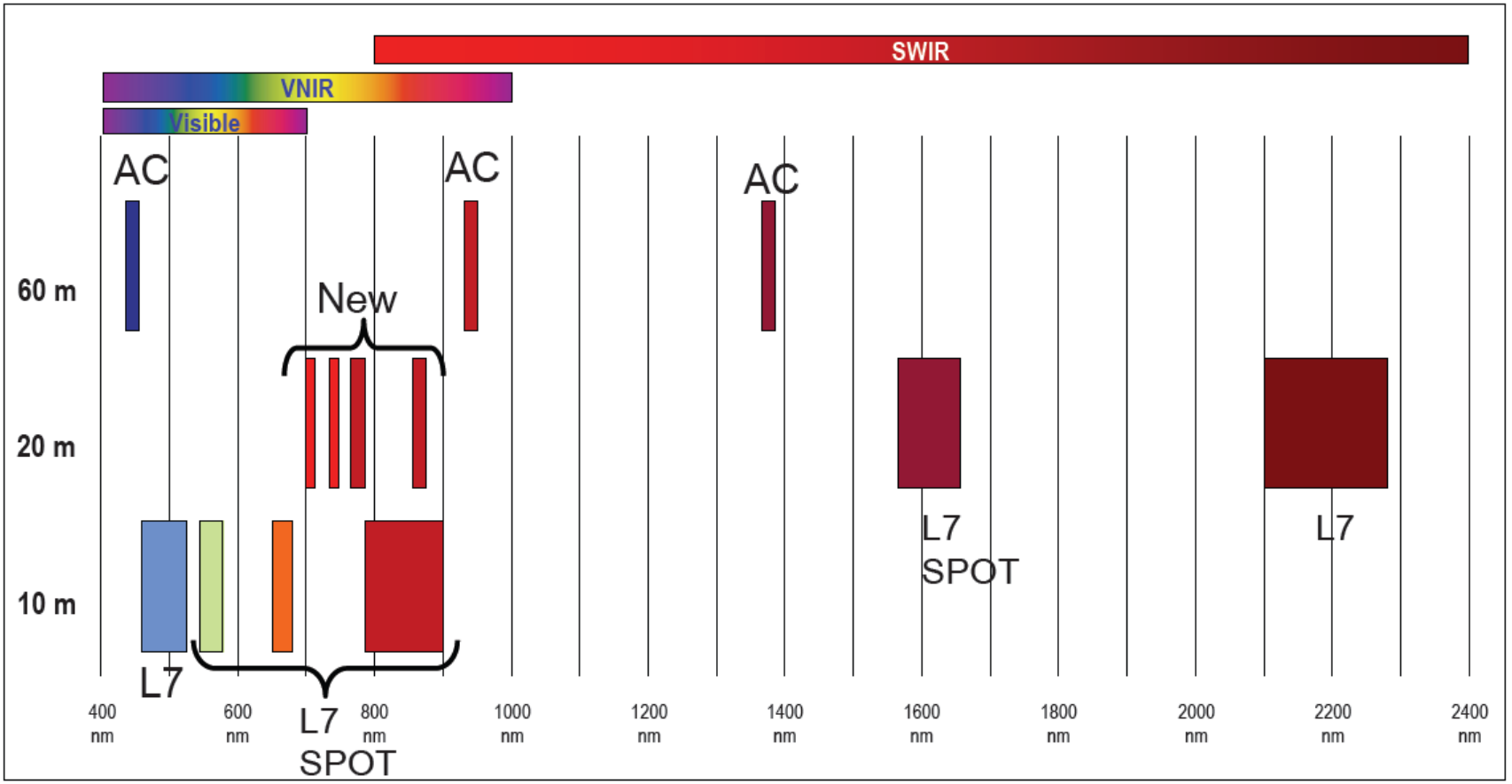
7 years design life time, consumables for 12 years

S2 - Swath

SPOT4 60 x 60 km x 2
IRS P6 LISS III 141x141 km
Landsat ETM+ 180 x 172 km
Sentinel-2 290 x 290 km

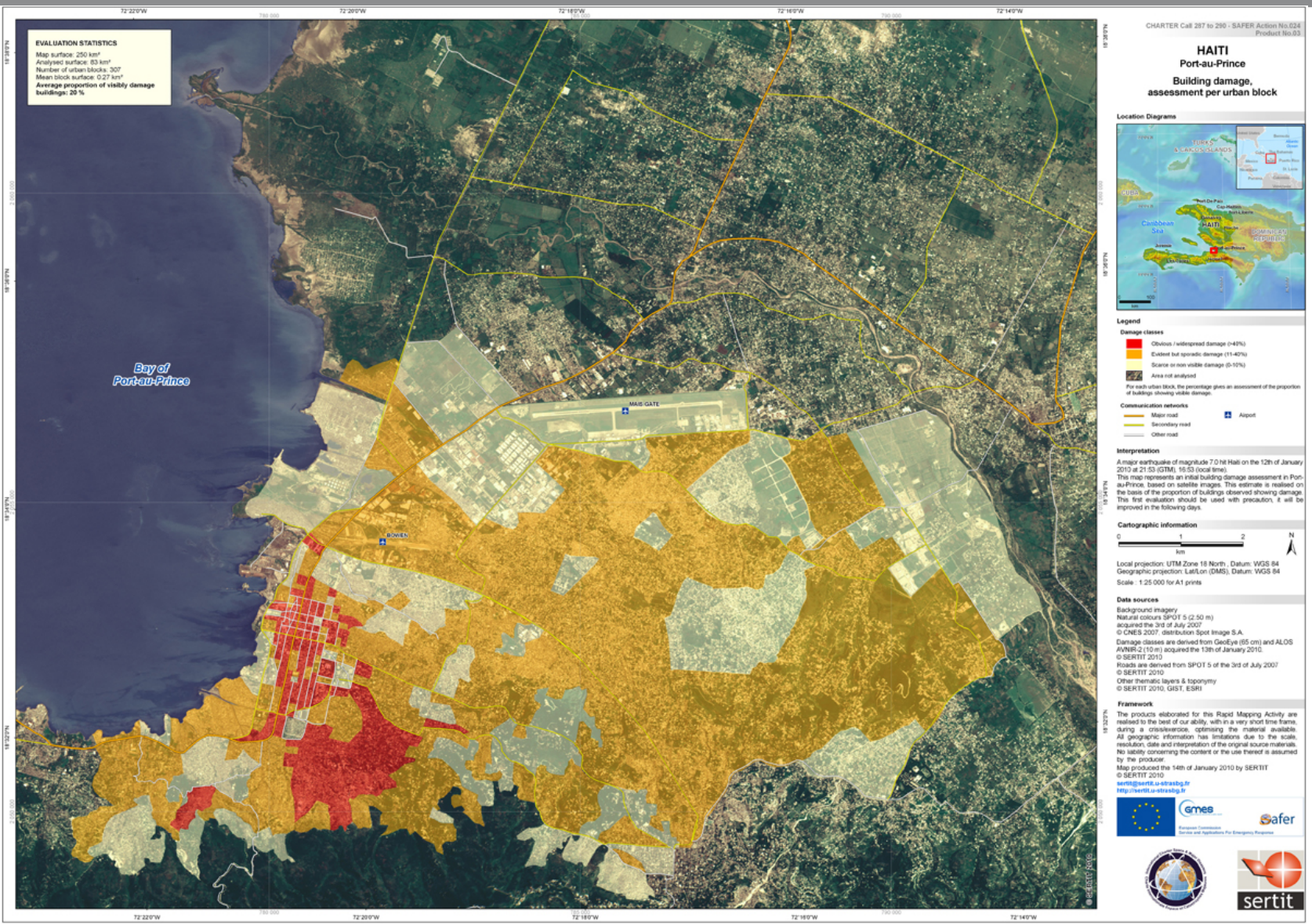


SENTINEL-2



13 spectral bands versus spatial sampling distance

Emergency management: Earthquake



Earthquake management at Port-au-Prince, Haiti – 13 January 2010

Data: ALOS, SPOT-5, GeoEye

Credits: SERTIT/SAFER

GMES
We care for a safer world


Sentinel-3

Sentinel-3
Mission Highlights

Launch : mid 2013

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

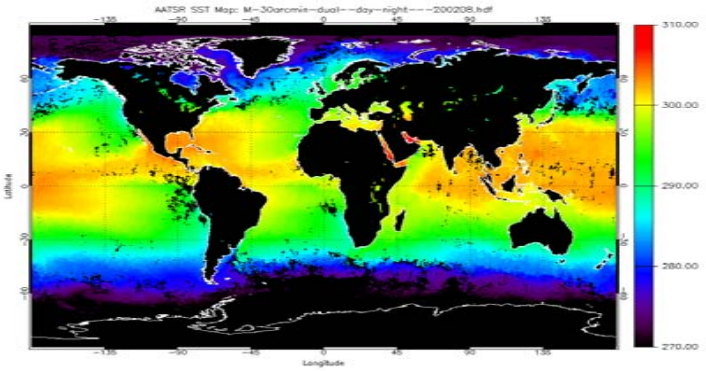
7 years design life time, consumables for 12 years

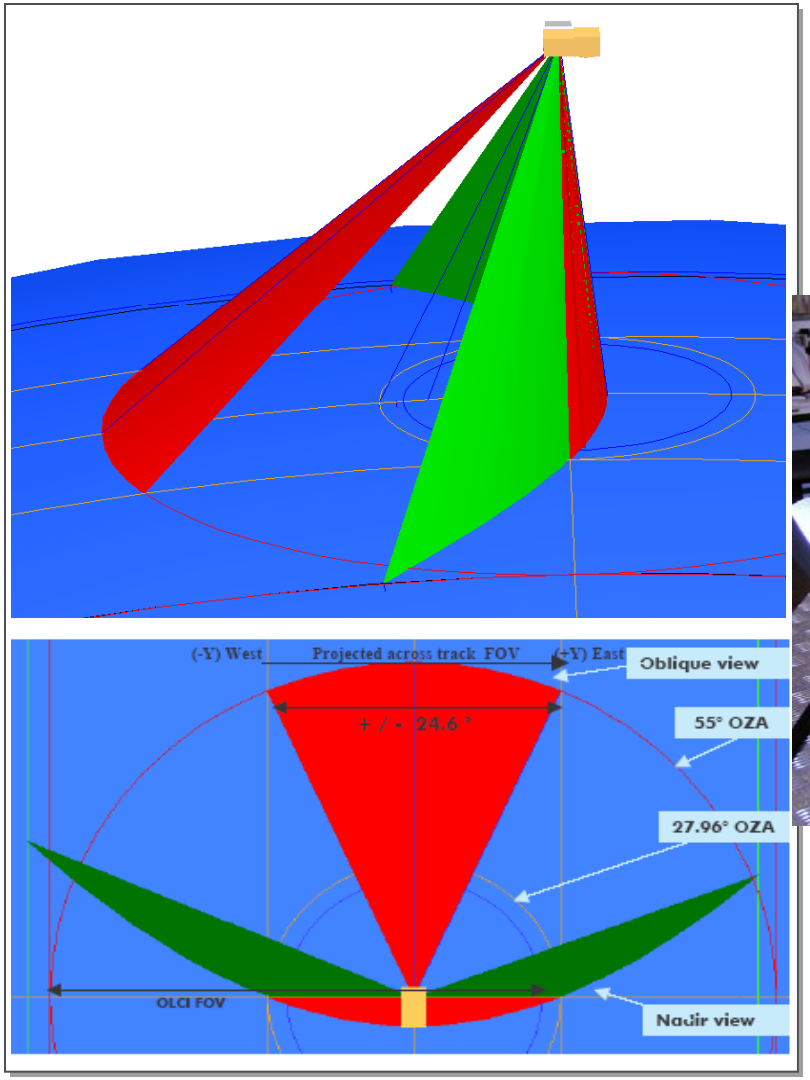
SENTINEL-3

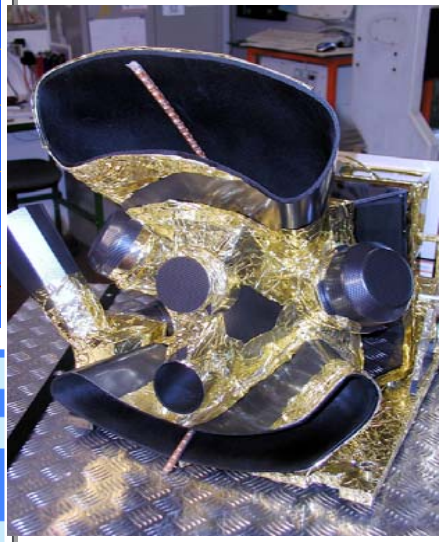
- Topography Mission
  - Bi-frequency Synthetic Aperture Radar Altimeter
  - Microwave Radiometer
  - Precise Orbit Determination (POD) including
    - GNSS Receiver
    - Laser Retro-Reflector
- Optical Payload
  - Ocean and Land Colour Instrument (OLCI)
  - See and Land Surface Temperature (SLST)

Sentinel-3 SLSTR

- **Heritage from AATSR, dual view (nadir and backward) required for aerosol corrections:**
  - Nadir swath: 74° (1420 km typ)
  - Dual view swath: 49° (750 km typ)
  - Nadir swath covering OLCI swath
- **9 spectral bands:**
  - Visible: 555–659–865 nm
  - SWIR: 1.38–1.61–2.25 µm
  - TIR : 3.74–10.85–12 µm





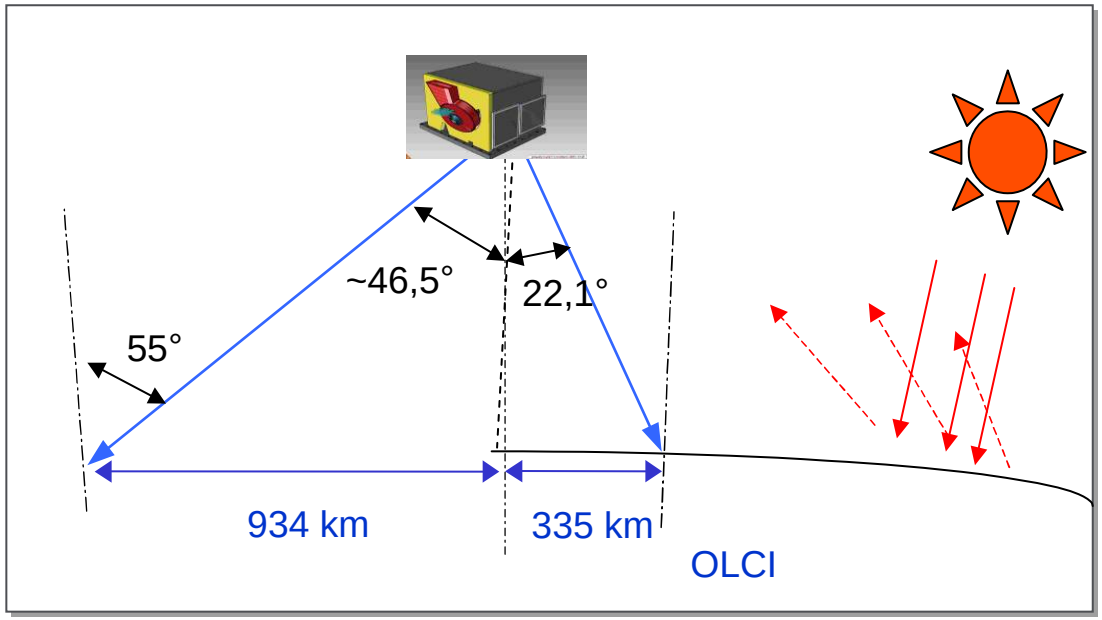


Sentinel-3
OLCI

- **5 cameras, 21 programmable spectral bands (incl. channels for MERIS & VGT legacy products)**
- **Absolute radiometric accuracy < 2% (to the sun)**
- **Minimisation of sun-glint by design**
- **Spatial Resolution: 300m (at nadir)**

  - 1200m open Ocean, after L1 processing

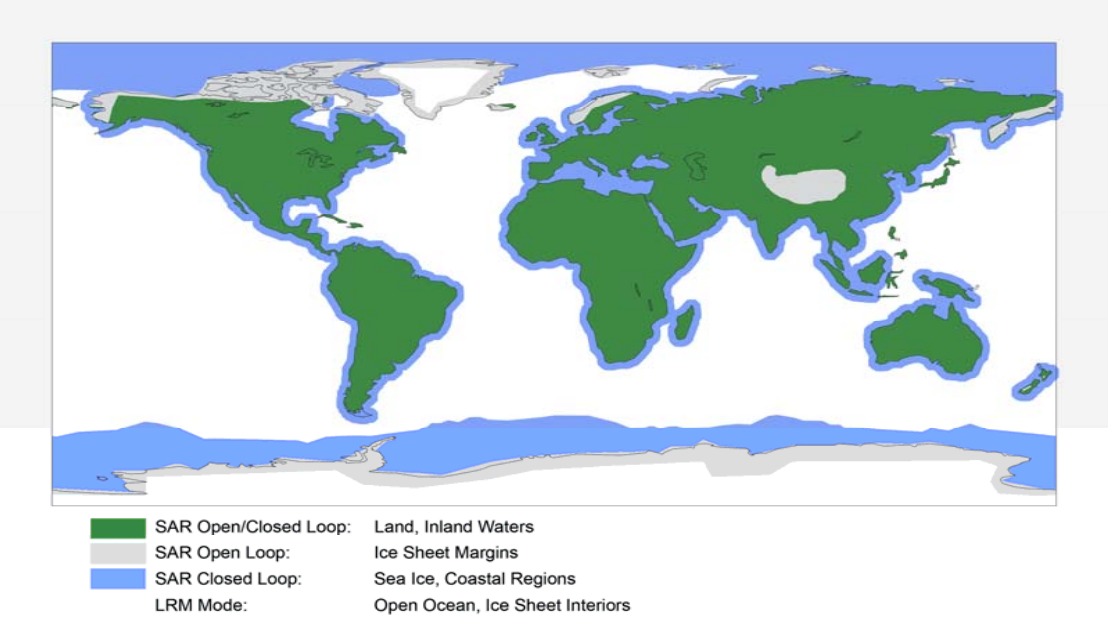
  - 300m over Land & Coastal Ocean



Heritage from MERIS

Sentinel-3
Topography Package

- **SRAL**
  Dual frequency Ku/C band Radar Altimeter, with SAR mode and open loop tracking (CryoSat/Jason heritage)
- **MWR**
  Dual channel microwave radiometer
- **Precise Orbit determination**
  - GPS receiver
  - Doris navigation receiver
  - Laser retro-reflector



Climate Change Initiative

CCI objectives

Realize the full potential of the long-term global EO archives that ESA, together with its Member states, has established over the last thirty years.....

..... as a significant and timely contribution to the ECV databases required by the United Nations Framework Convention on Climate Change

6 Years / 75 M

GCOS Essential Climate Variable (ECVs)

OCEANS	O.1	Sea Ice
	O.2	Sea Level
	O.3	Sea Surface Temperature
	O.4	Ocean Colour
	O.5	Sea State
	O.6	Ocean Reanalysis
	O.7	Ocean Salinity

TERRESTRIAL	T.1	Lakes
	T.2	Glaciers & Ice Caps, and Ice Sheets
	T.3	Snow Cover
	T.4	Albedo
	T.5	Land Cover
	T.6	fAPAR
	T.7	LAI
	T.8	Biomass
	T.9	Fire Disturbance
	T.10	Soil moisture

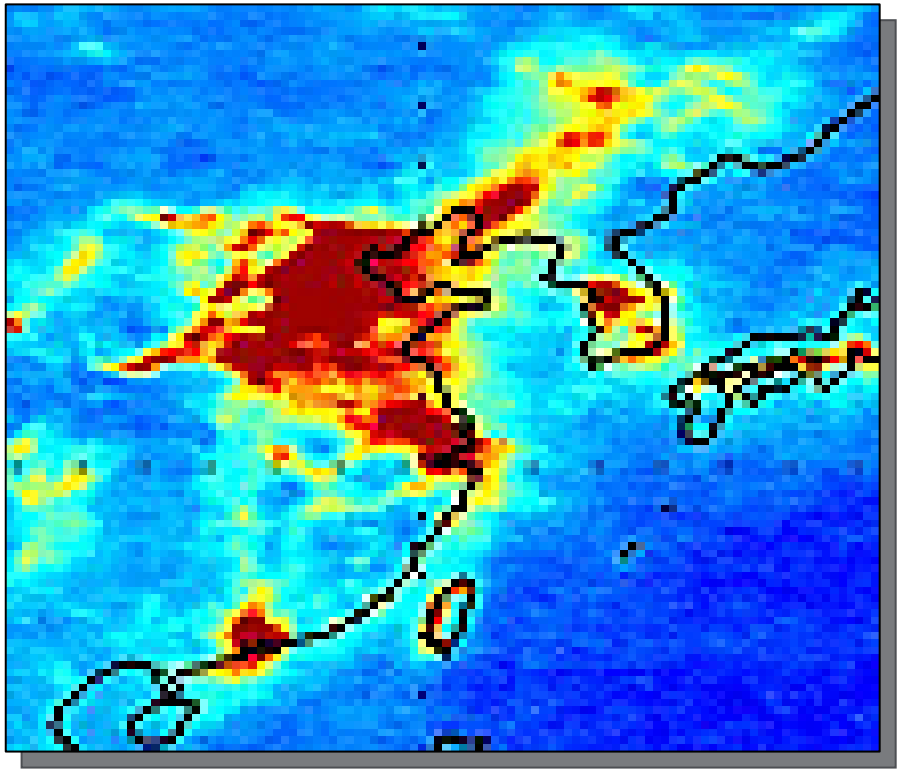
ATMOSPHERE	A.1	Surface Wind Speed and Direction
	A.2	Upper-air Temperature
	A.3	Water Vapour
	A.4	Cloud Properties
	A.5	Precipitation
	A.6	Earth Radiation Budget
	A.7	Ozone
	A.8	Atmospheric reanalysis (multiple ECVs)
	A.9	Aerosols
	A.10	Carbon Dioxide, Methane and other Greenhouse Gases
	A.11	Upper-air Wind

CCI First Steps (11 + 2ECVs)

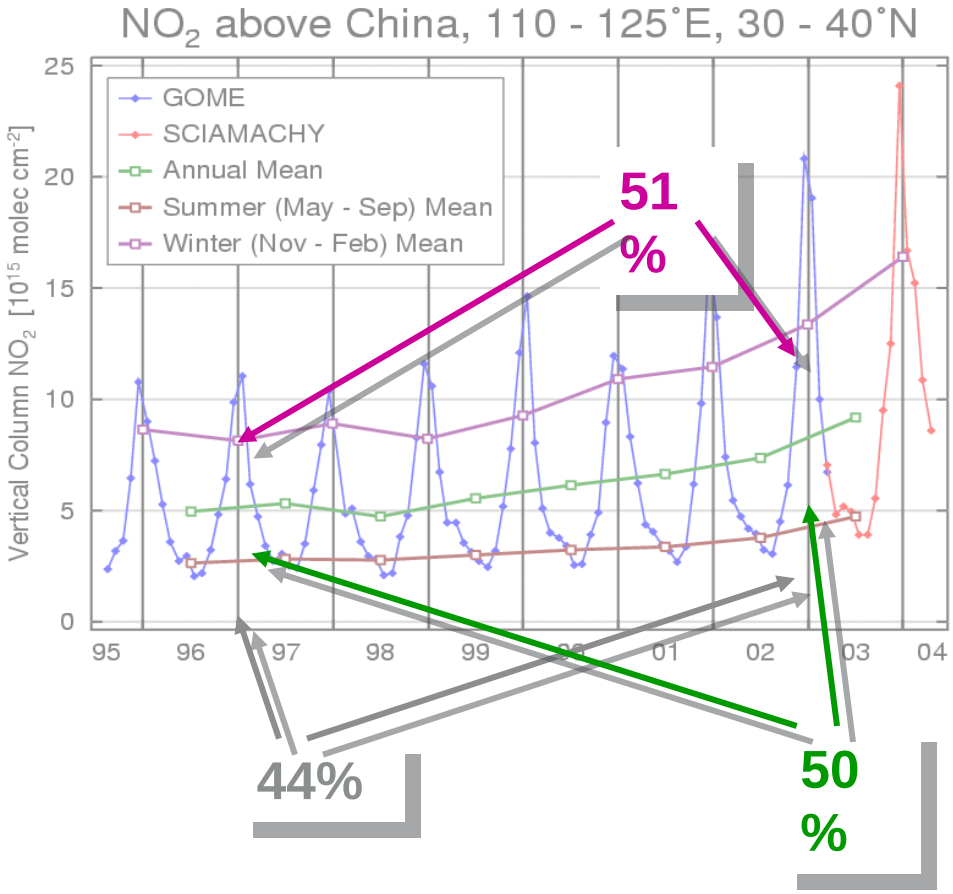
Later in CCI (8 ECVs)

GCOS – 107 Systematic Observation Requirements for Satellite-Based Product for Climate Page 12 and 13

NO_2 concentration increase by 50% over China



Combined with ERS-2 GOME data

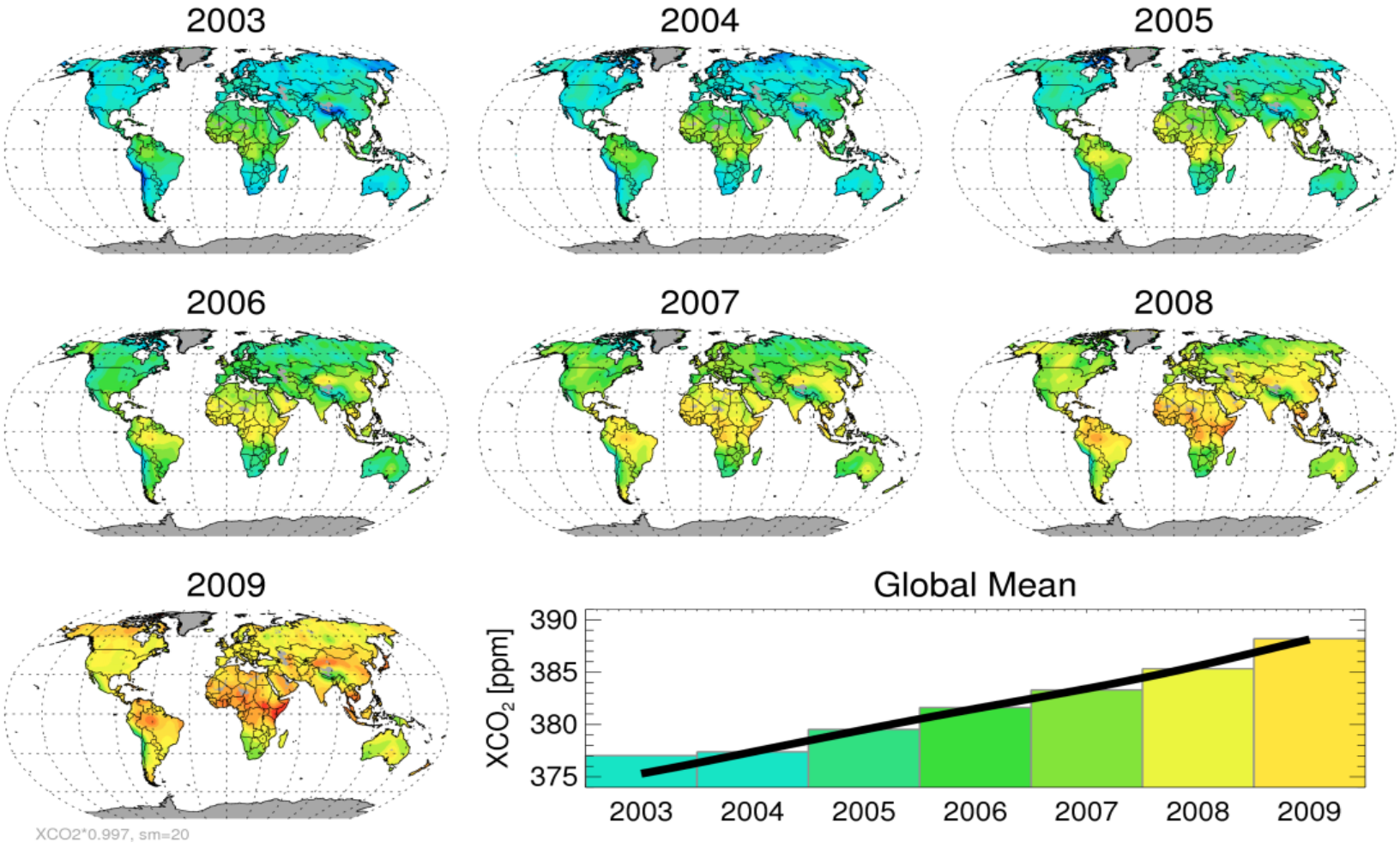


Courtesy of John Burrows, Univ. Bremen, D

R & D— Recent Results

GreenHouseGases Monitoring – GHG_cci project

Global CO2 increase as measured by SCIAMACHY



CCI: International coordination



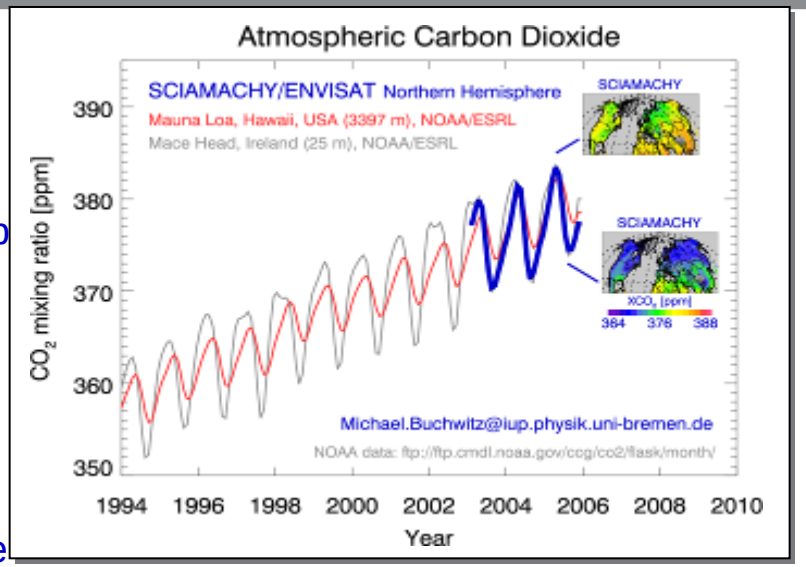


- UNFCCC which coordinates the interests and decisions of its Parties on Climate Policy,
- GCOS which represents the scientific and technical requirements of the Global Climate Observing System on behalf of UNFCCC,
- CEOS which serves as a focal point for Earth Observation related activities of Space Agencies (e.g NOAA, NASA, JAXA, EUMETSAT)
- Individual Partner Space Agencies with whom ESA cooperates bilaterally (e.g. EUMETSAT)
- International Climate Research Programmes, which represent the collective interests and priorities of the worldwide climate research,
- EC and National Research Programmes which establish research priorities and provide resources for climate research community within Europe (e.g. DG Research, DG-JRC)
- GMES Partners: DG Enterprise and Industry, user DGs ENV, EEA…

next 3 years => CCI phase 1

Cardinal Requirements:

- Develop and validate algorithms to meet GCOS ECV requirements for (consistent, stable, error-characterized) glob satellite data products from multi-sensor data archives
- Optimize impact of ESA EO missions data on climate data records
- Produce, within R&D context, most complete and consistent possible multi-sensor global satellite data products for climate research and modelling
- Generate complete specifications for an operational production system
- Strengthen inter-disciplinary cooperation between international earth observation, climate research and modelling communities, in pursuit of scientific excellence



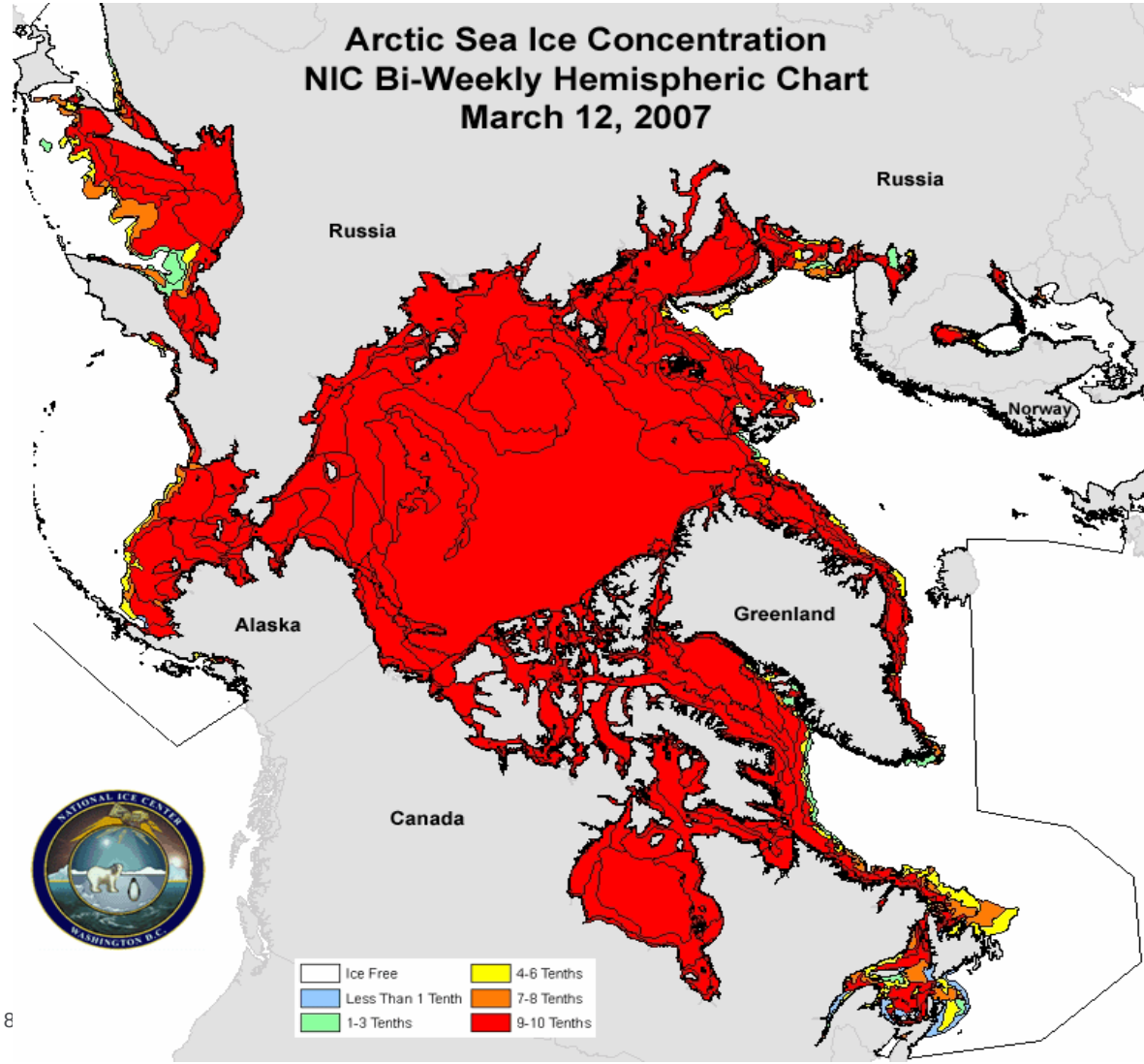
Annual variability of carbon dioxide mixing ratio in parts per million
(Univ. Bremen)

Discrepancy Models / Satellites Observations

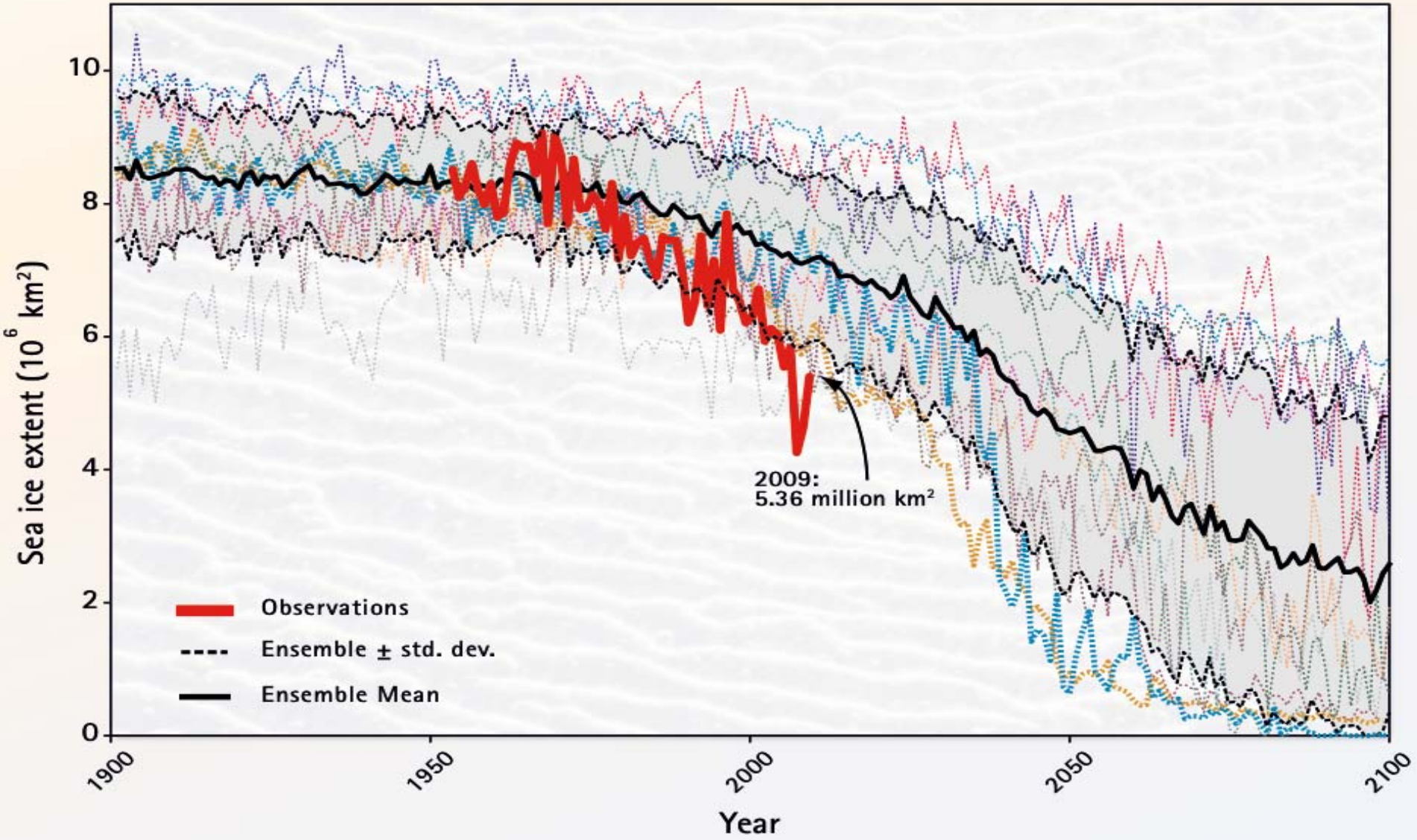
Arctic sea ice extent

Douglas Bancroft, Director of the Canadian Ice Service, the record reduction in 2007 stunned the international operational ice charting community:

"The overall extent was similar to what some of the models envisioned but decades in advance of when they expected that would occur. In fact, the summer of 2007 looked very similar to some climate model forecasts for 2030 to 2050."



Discrepancy between sea ice extent models (IPCC) and satellite observations...



THANKS FOR YOUR ATTENTION

Maurice.Borgeaud@esa.int
European Space Agency ESRIN