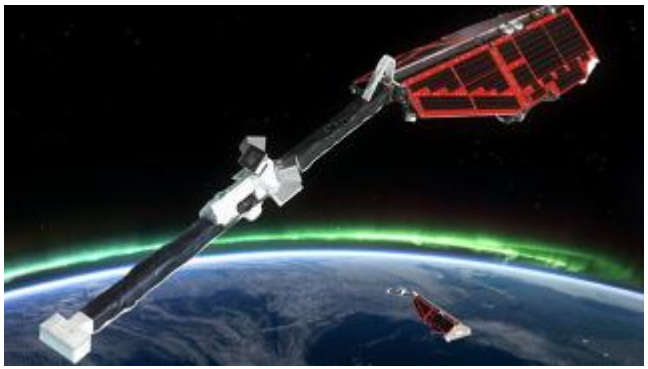
12th EMS Annual Meeting &
9th European Conference on Applied Climatology

Earth Observation in Support of Climate Services:

The European Earth Observation Programme




Prof. Michael Rast

Łódź, 10 September 2012

European Space Agency

Earth Observation: *recognition of an imperative tool for science and society*

"Providing earthlings with a reliable, continuous record of their planet's condition would seem a **sensible** aim in any circumstances. With the state of the atmosphere and oceans upset in ways whose consequences are not easily foreseen, and may well prove catastrophic, it becomes an **imperative**."

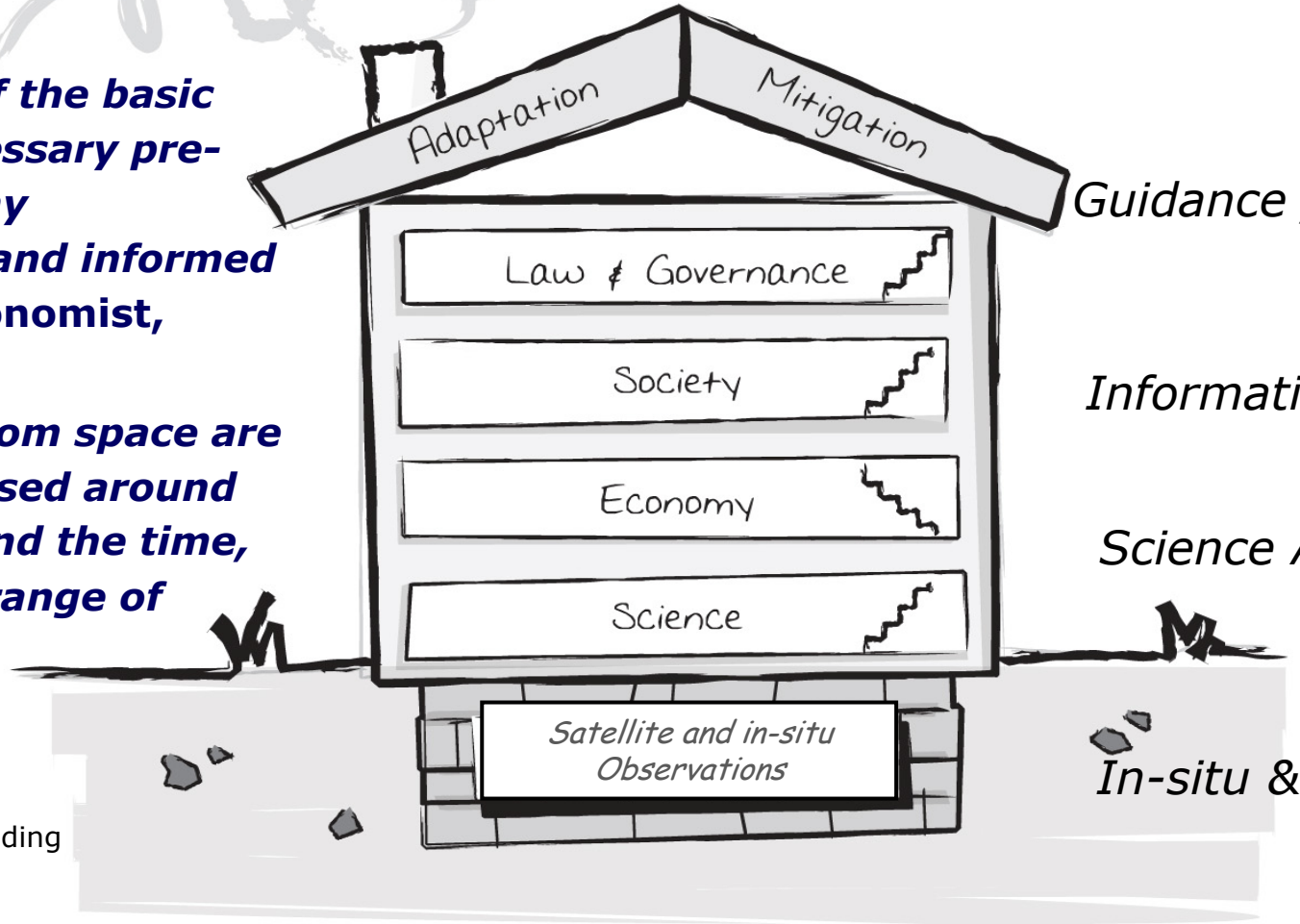
The Economist, 12 May 2012

European Space Agency

Observation: Foundation of Science & Services

Climate House WITH Observations

- ***"A firm grasp of the basic trends is a necessary pre-condition for any understanding and informed policy"*** **(the Economist, 2012)**
- ***Observations from space are delivered and used around the globe, around the time, around a wide range of subjects***



Guidance / Knowledge

Information services

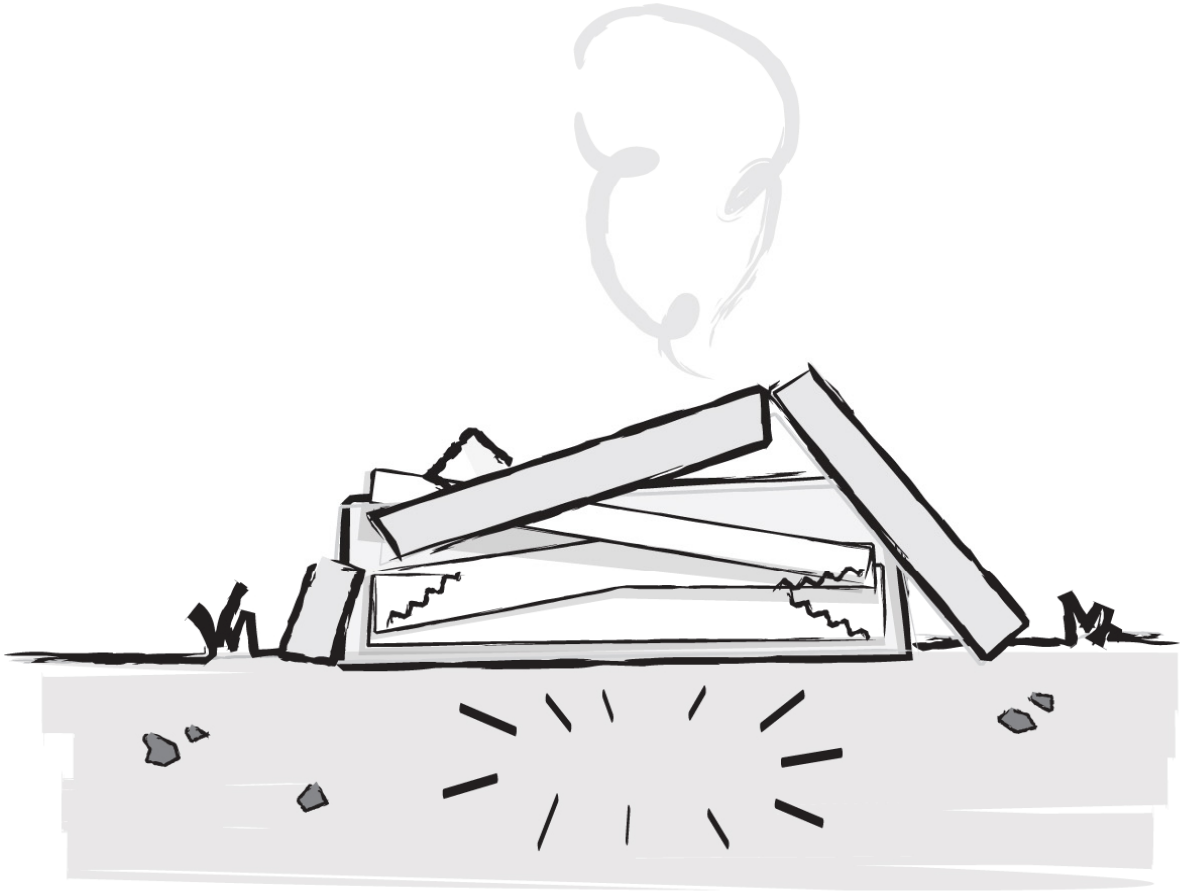
Science Assessment

In-situ & Space data

Adapted from
DiploFoundation
Climate Change Building

Observation:
Foundation of Science & Services

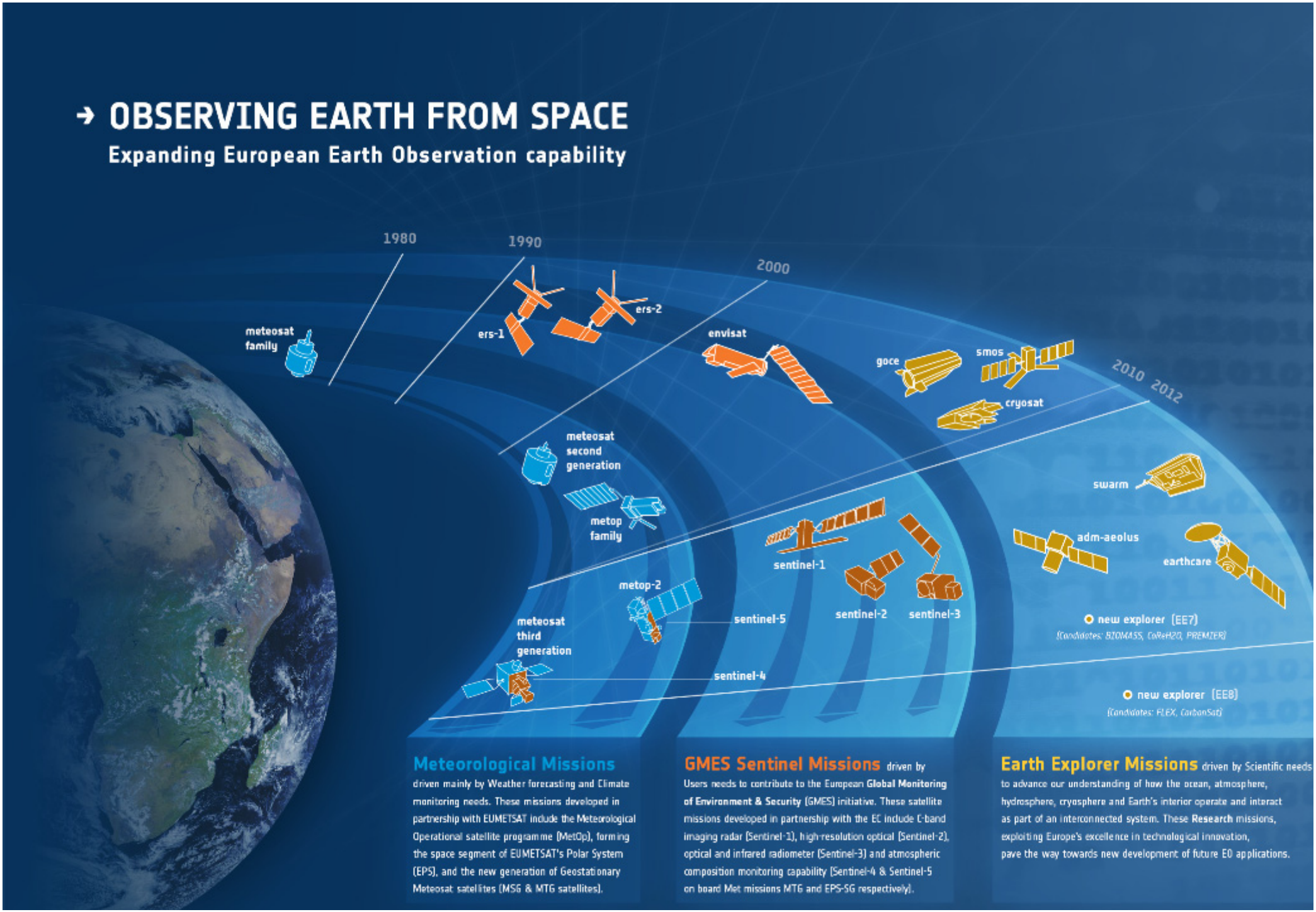
Climate House WITHOUT Observations



Courtesy Marco, ESA

→ OBSERVING EARTH FROM SPACE

Expanding European Earth Observation capability



Meteorological Missions driven mainly by Weather forecasting and Climate monitoring needs. These missions developed in partnership with EUMETSAT include the Meteorological Operational satellite programme (MetOp), forming the space segment of EUMETSAT's Polar System (EPS), and the new generation of Geostationary Meteosat satellites (MSG & MTG satellites).

GMES Sentinel Missions driven by Users needs to contribute to the European **Global Monitoring of Environment & Security** (GMES) initiative. These satellite missions developed in partnership with the EC include C-band imaging radar (Sentinel-1), high-resolution optical (Sentinel-2), optical and infrared radiometer (Sentinel-3) and atmospheric composition monitoring capability (Sentinel-4 & Sentinel-5 on board Met missions MTG and EPS-SG respectively).

Earth Explorer Missions driven by Scientific needs to advance our understanding of how the ocean, atmosphere, hydrosphere, cryosphere and Earth's interior operate and interact as part of an interconnected system. These **Research** missions, exploiting Europe's excellence in technological innovation, pave the way towards new development of future EO applications.

ENVISAT – The end of an era

- Sunday 8 April: loss of communication between 13:09 and 14:28 CEST. Activation of extended network of ground stations to send commands, but unsuccessful so far.
- Last Envisat data transmitted in Ka-band was received at ESA/ESRIN on 8 April at 13:05 CEST though direct Artemis transmission (MERIS image depicting Portugal and Spain)
- The last Envisat data transmitted in X-band was received at Santa Maria station in the Azores, Portugal, at 13:09 CEST (ASAR image depicting Canary Islands).
- On 8 May, the termination of Envisat was declared

10 years of ENVISAT: an impressive heritage

- A total of **1 Petabyte** of data have been delivered by Envisat during its lifetime.
- In the past ten years, some **15.000 scientific publications** referenced the Envisat mission
- The **exploitation of 10-years Envisat** data archive will continue

10 years of exploitation:

Envisat was designed for 5 years nominal lifetime

Ground segment:

80+ types of operational products

280 GBytes data per day

Earth sciences users:

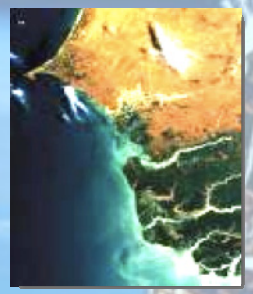
4000 science projects

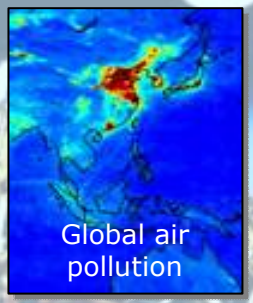
Operational users:

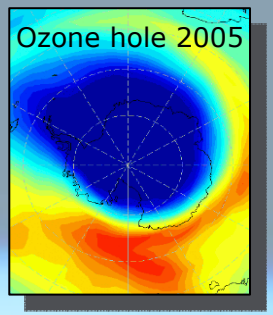
strongly used by GMES Services

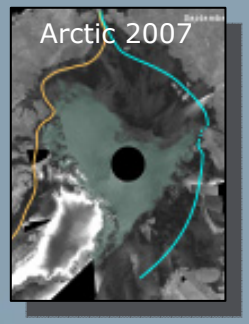
European Space Agency

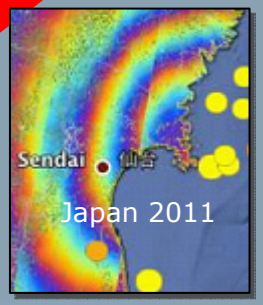
ENVISAT mission: 10 years

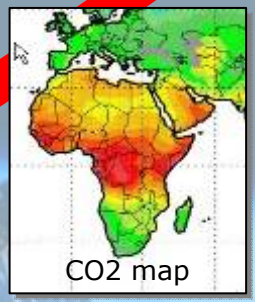


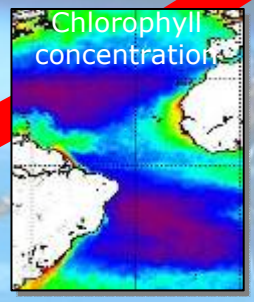


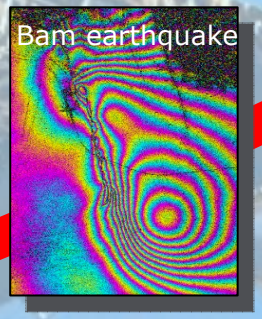












Serving
4000 scientific projects
and
many operational users

Envisat Symposium
Salzburg (A)

Envisat Symposium
Montreux (CH)

Living Planet Symposium
Bergen (N)

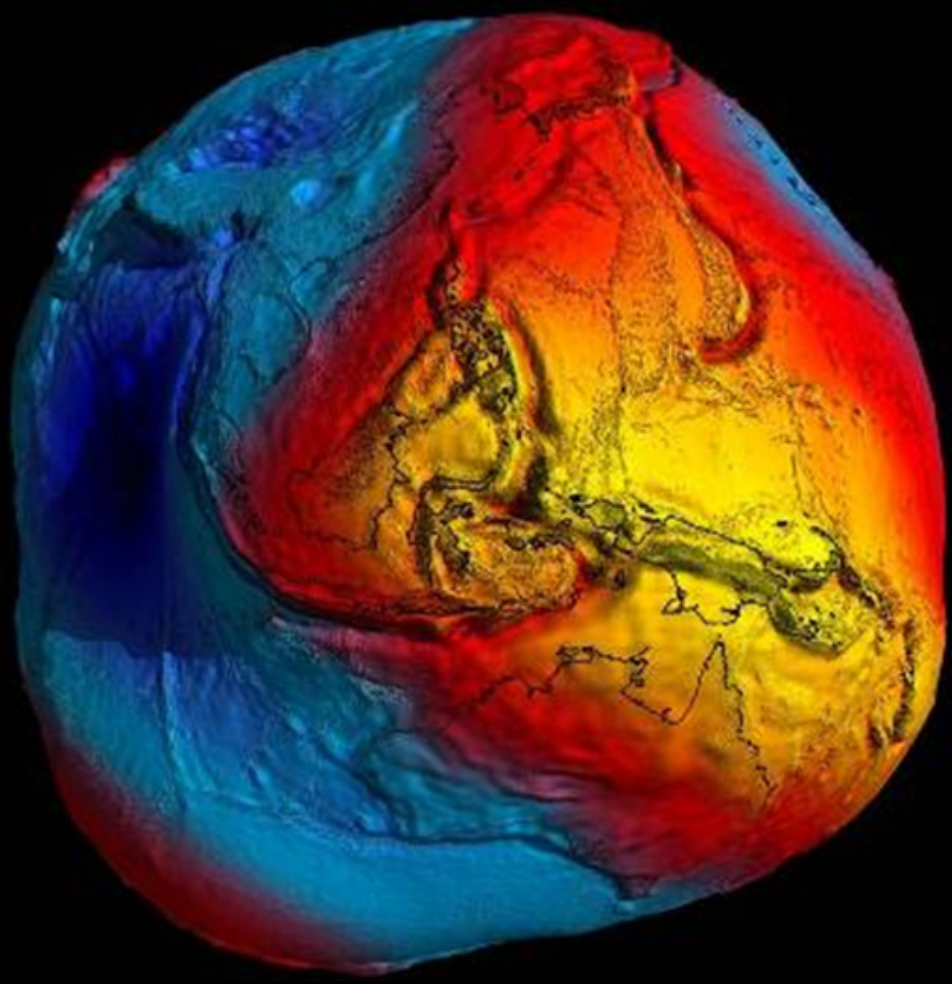
Mar 02 — **Sep 04** — **Apr 07** — **Jun 10** — **July 12**

and many workshops dedicated to specific Envisat user communities

Earth Explorer satellites

ESA's GOCE mission has delivered the most accurate model of the 'geoid' ever produced

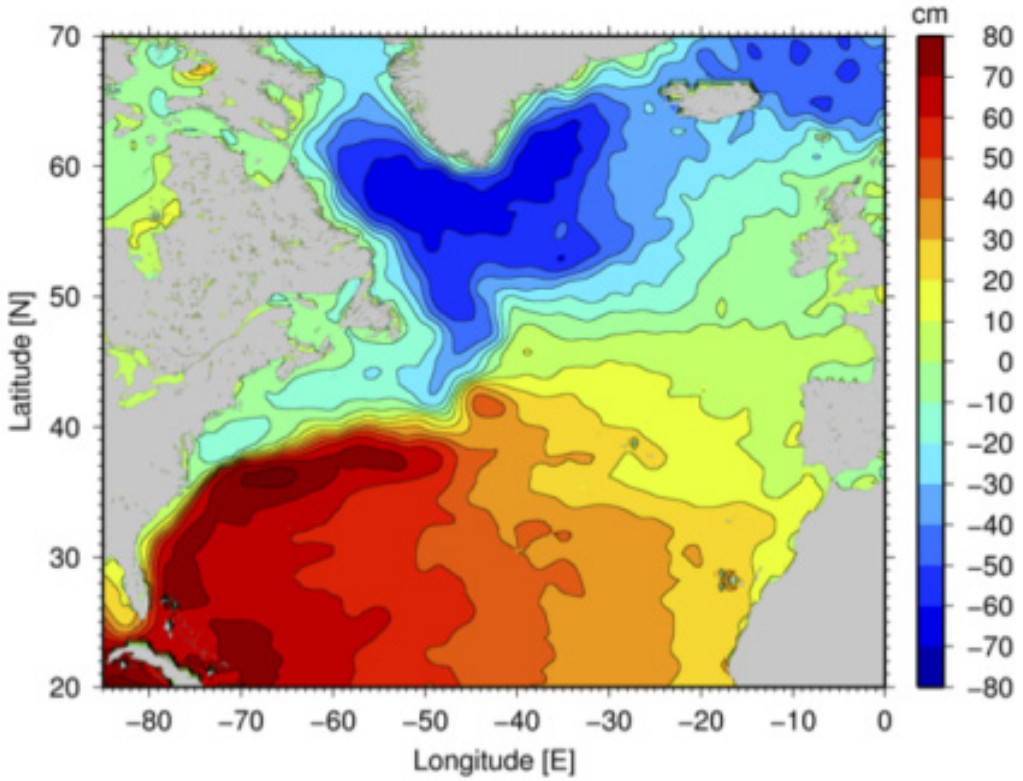
- GOCE's **third-generation geoid** has been created using more than 50 million measurements of slight variations in gravitational attraction from 255km altitude
- **The mission goals will be accomplished:**
- *Gravity anomalies: a figure of less than 1 mGal*
- *Geoid accuracy: a figure of 2-3 cm at 100 km resolution*



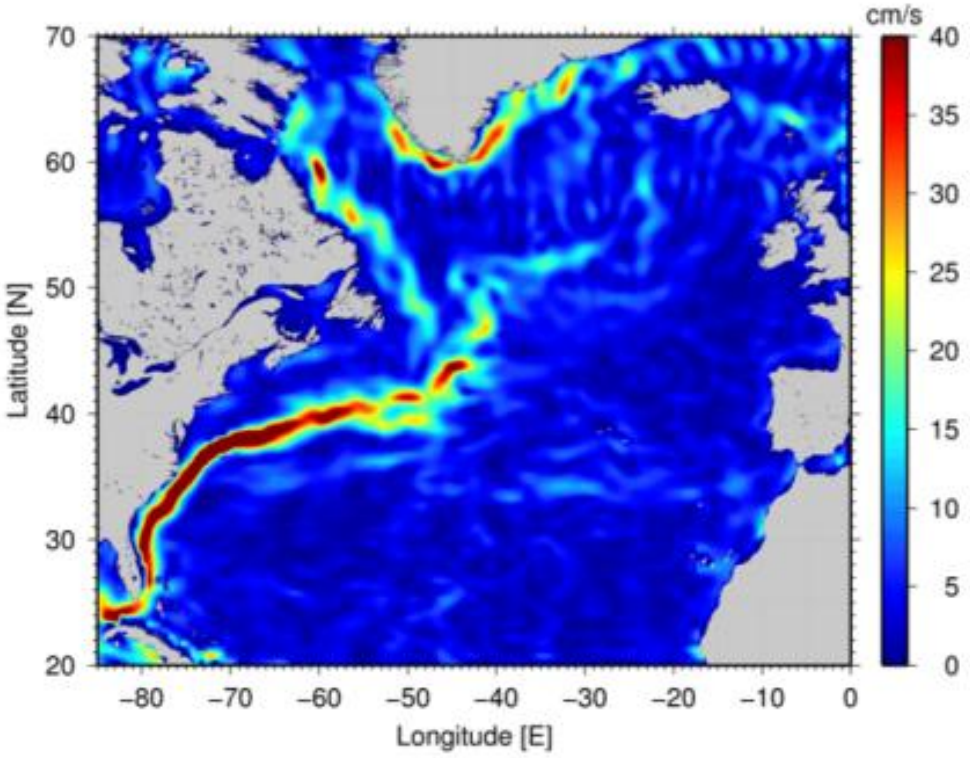
GOCE: accurate ocean currents map

- With GOCE geoid, for the first time, global currents can be extracted directly from satellite altimetry data.

Ocean Dynamic Topography

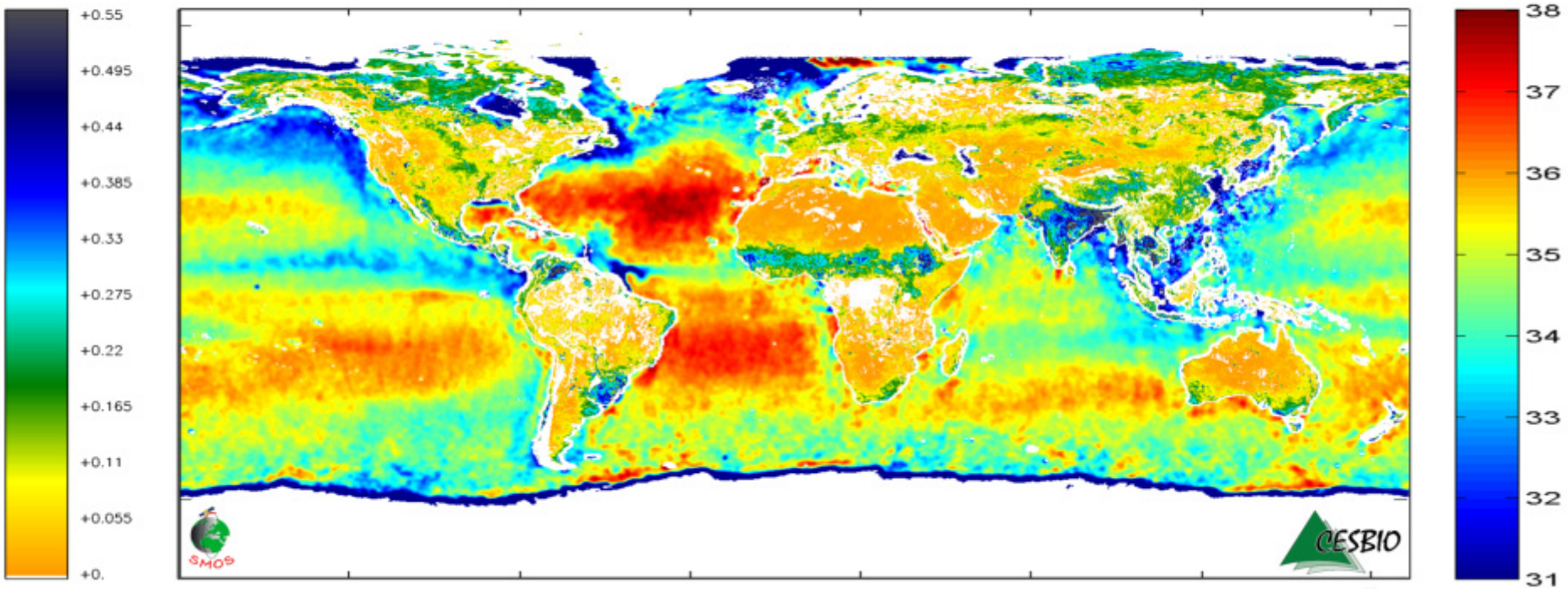


Water Surface Velocity



SMOS: 2 1/2 years in orbit

- **SMOS provides the first global measurements of two key variables in the water cycle – soil moisture and ocean salinity**

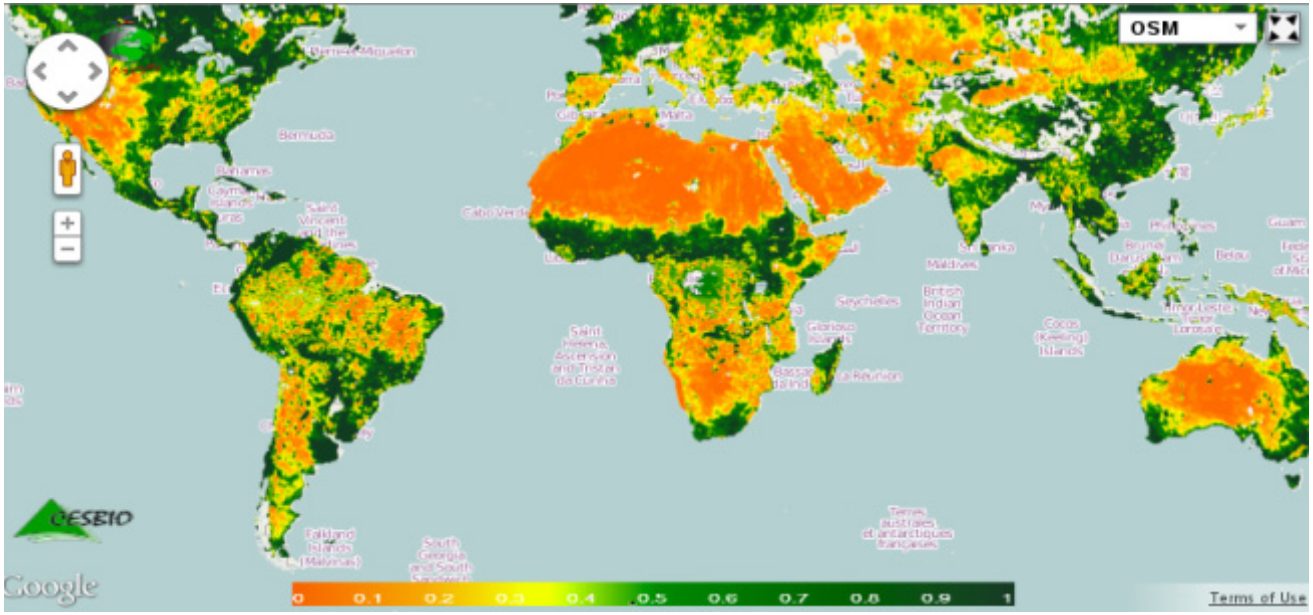


Merged global maps of soil moisture (August 2011) and sea surface salinity (August 2010), morning orbits. © CESBIO, IFREMER, CATDS

European Space Agency

SMOS: from science to applications

- Global maps of Soil Moisture and Sea Surface Salinity are the **basis for a variety of applications** over land and ocean, to the benefit of society:
  - *Drought monitoring*
  - *Hydrological forecasting*
  - *Prediction of ocean circulation pattern important for climate research*



SMOS monitors droughts:
The **SMOS Global Drought Monitor** uses SMOS soil moisture data combined with hydrological models to predict available water in the soil. This is an important planning tool for national water authorities to prevent the negative impact of droughts.

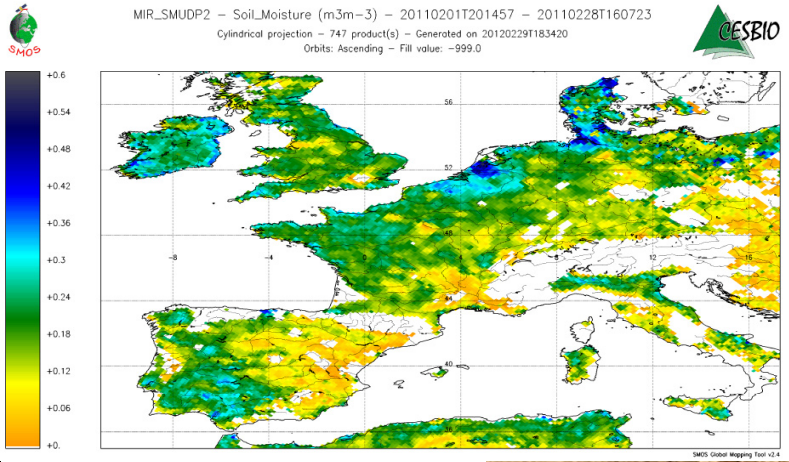
Left: latest interactive map of SMOS drought root zone soil moisture index;

European Space Agency

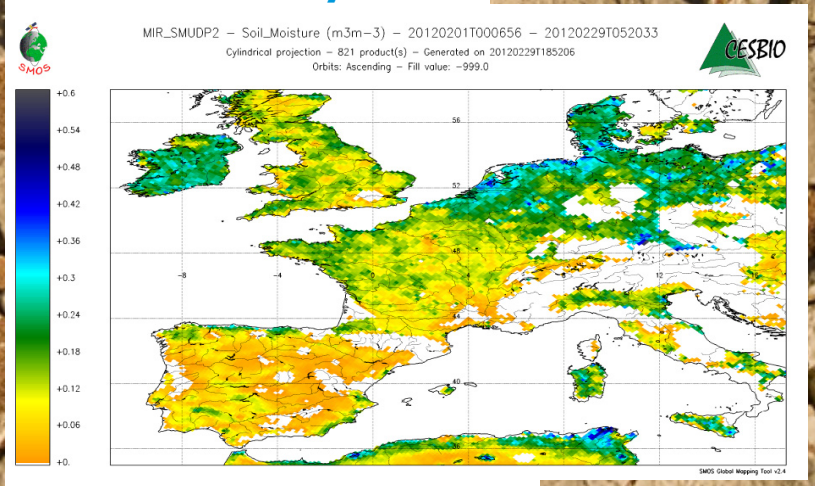
SMOS: 2011 Drought in Europe

- Western Europe: severe lack of water due to less than average rainfall
- Absence of sufficient water resources: diminishing food supply, shortage of water for households and industry, shipping routes can fall dry

Inter-annual variation of water available in soils across Europe (images CESBIO):



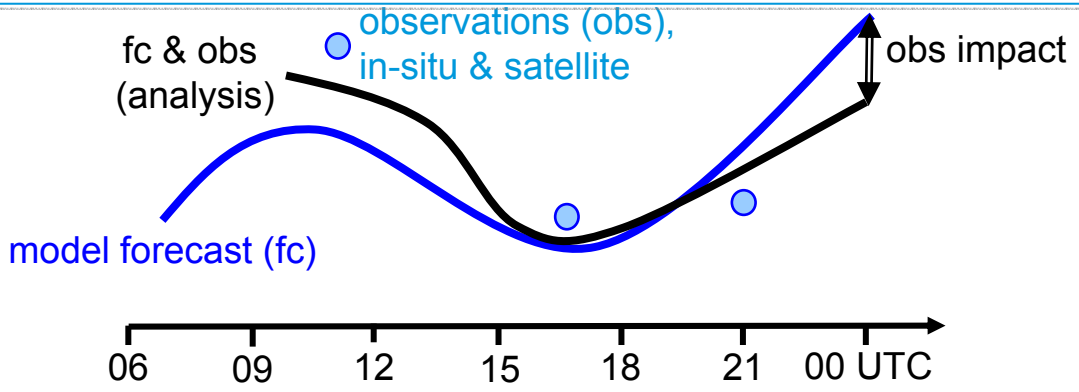
SMOS February 2011



SMOS February 2012

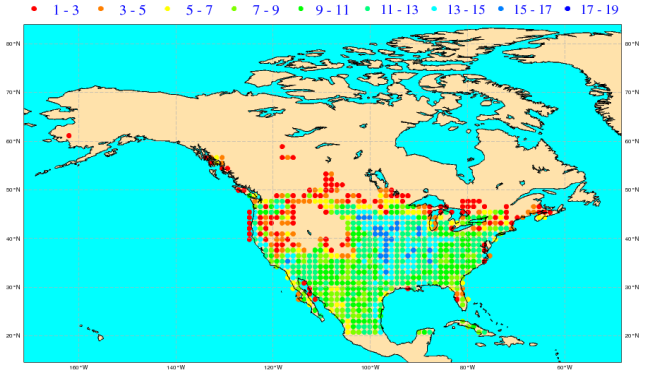
SMOS & NUMERICAL WEATHER PREDICTION AT ECMWF

- Numerical Weather Prediction is an initial value problem.
- Satellite data are being used to infer the true state at the beginning of the forecasting period.
- SMOS is being used to obtain the best soil moisture field possible.

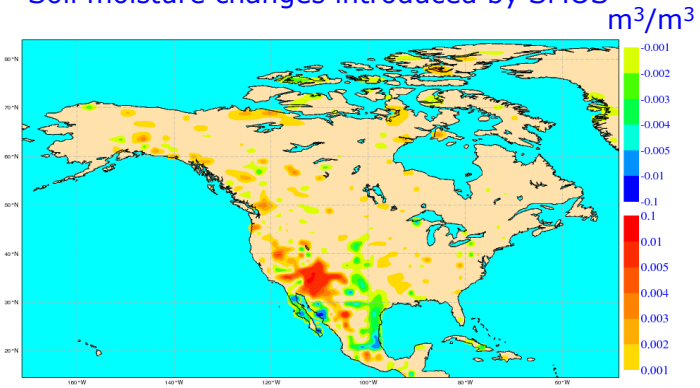


7-day experiment 4.4.2011-10.4.2011 using the Integrated Forecasting System

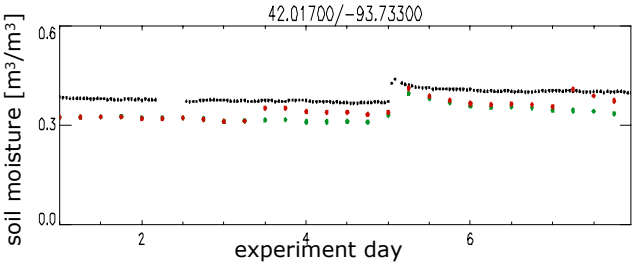
Number of assimilated SMOS observations



Soil moisture changes introduced by SMOS



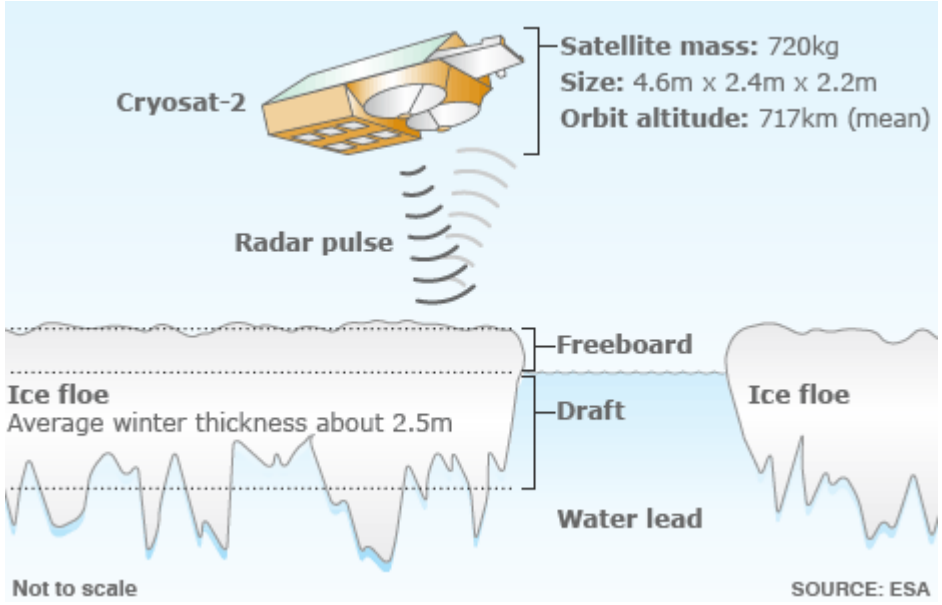
In-situ verification using Iowa data

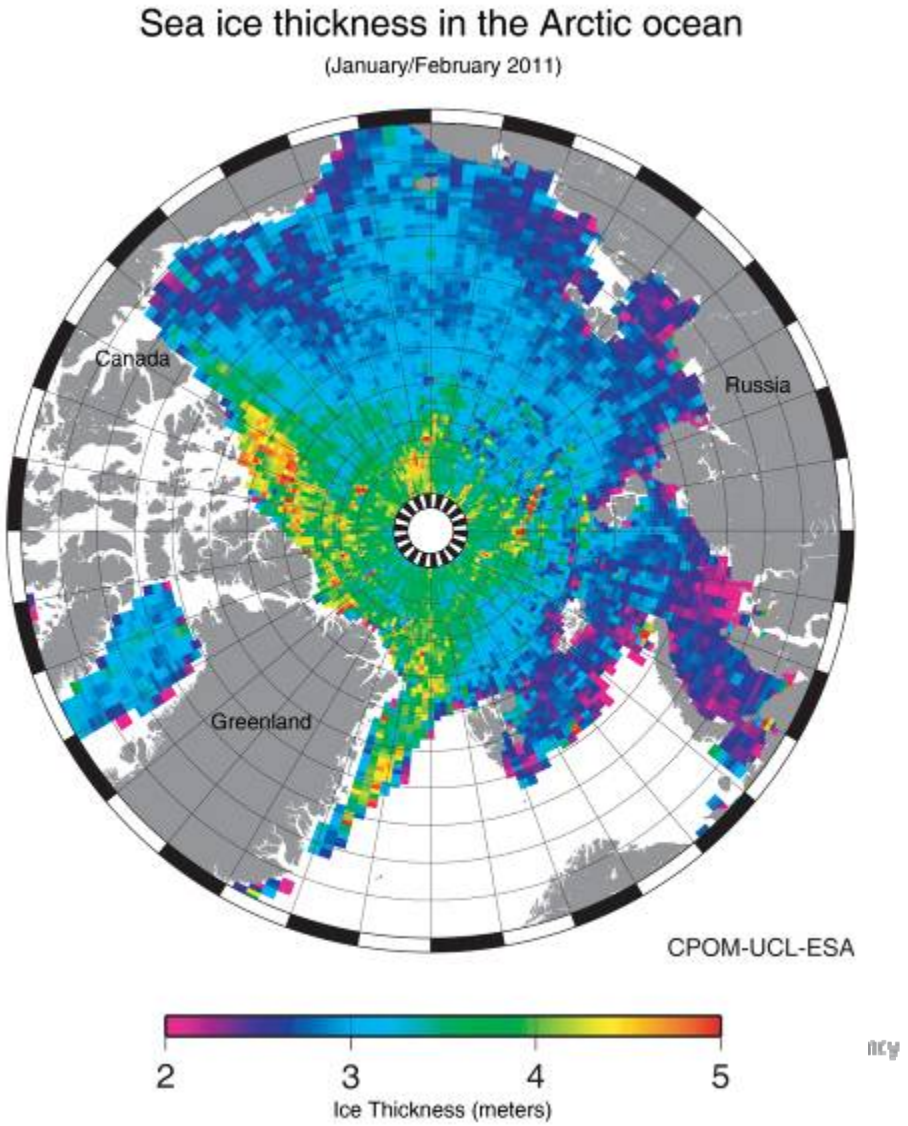


Black: soil moisture observations
Green: fc & 2m T & 2m rH (no SMOS)
Red: fc & 2m T & 2m rH & SMOS

CryoSat ice thickness map of the Arctic (June 2011)

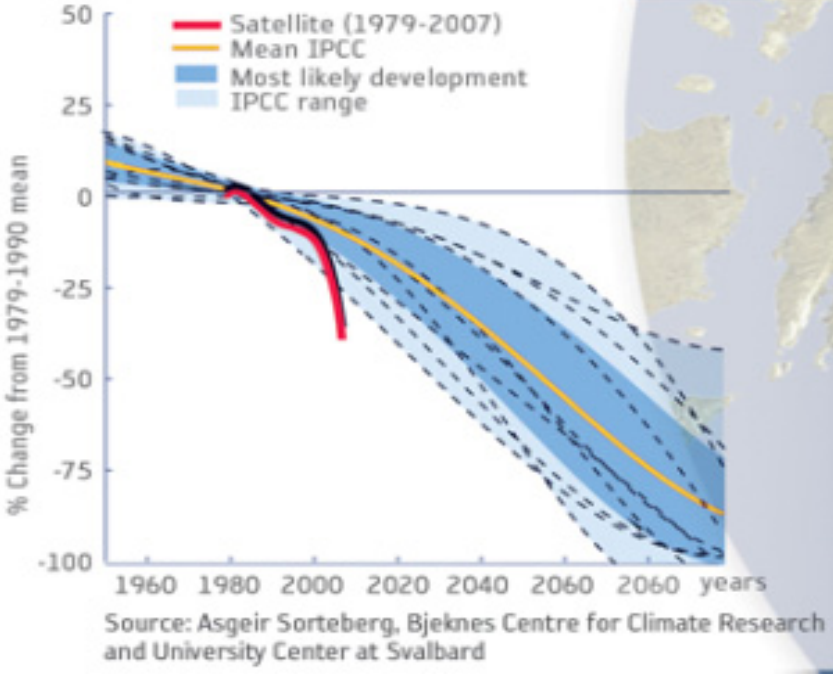
- 1st map of sea-ice thickness from ESA's CryoSat mission was revealed in June 2011
- New understanding of the complex relationship between ice & climate





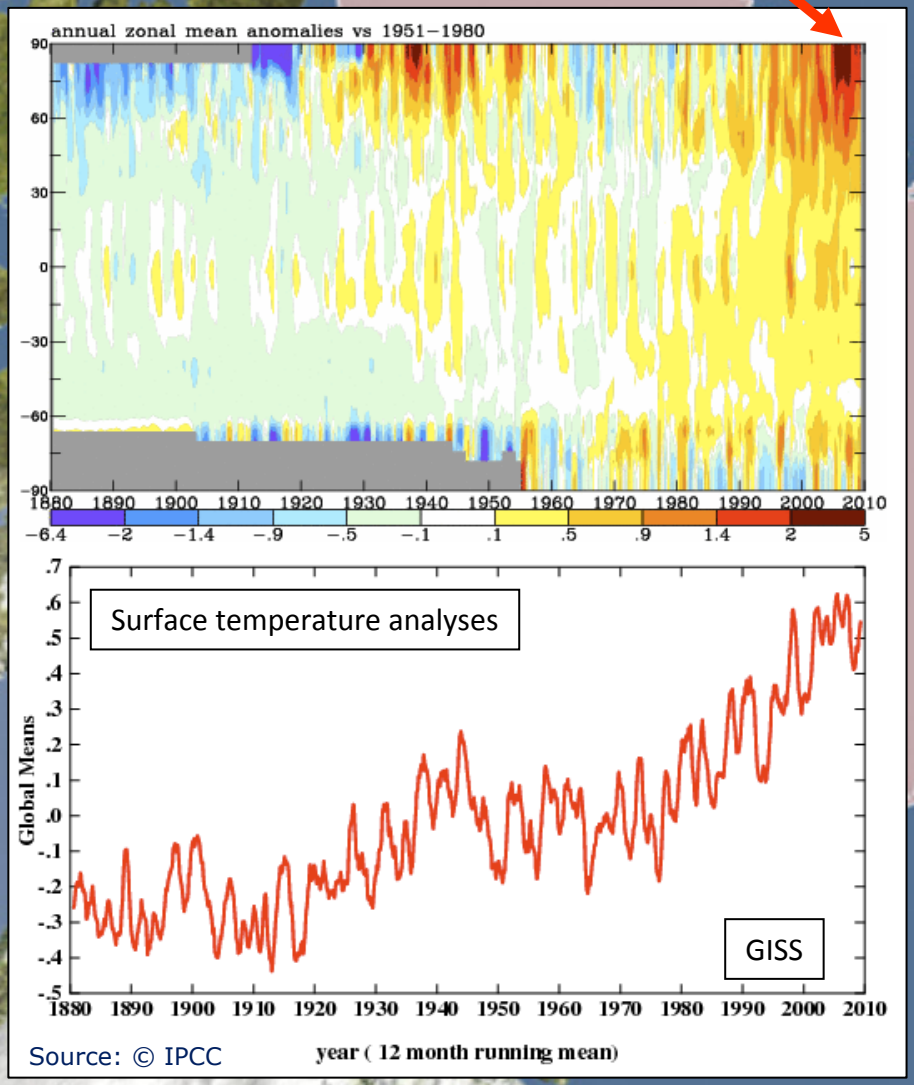
Satellites reveal a changing Arctic:
from climate science to daily ice mapping

- Arctic sea-ice extent (September) has shrunk by 12% per decade since 1978
- The Arctic increasingly becomes an arena of high geopolitical relevance

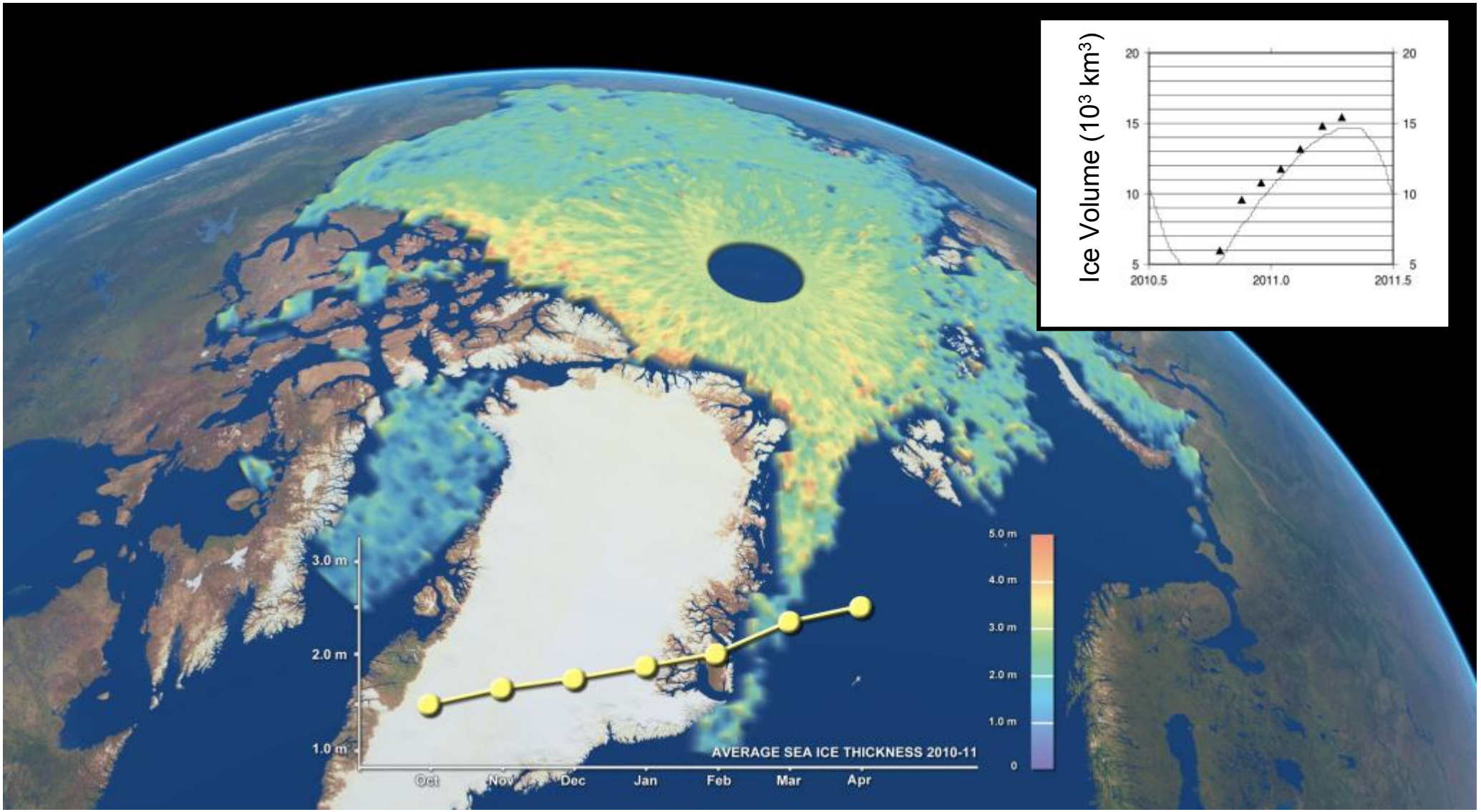


Source: Asgeir Sorteberg, Bjeknes Centre for Climate Research and University Center at Svalbard

Arctic region

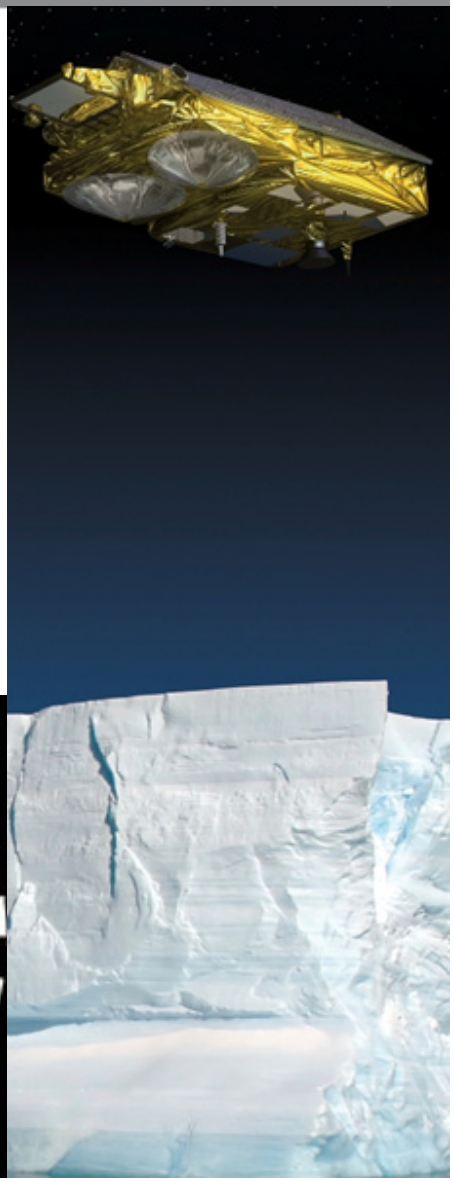


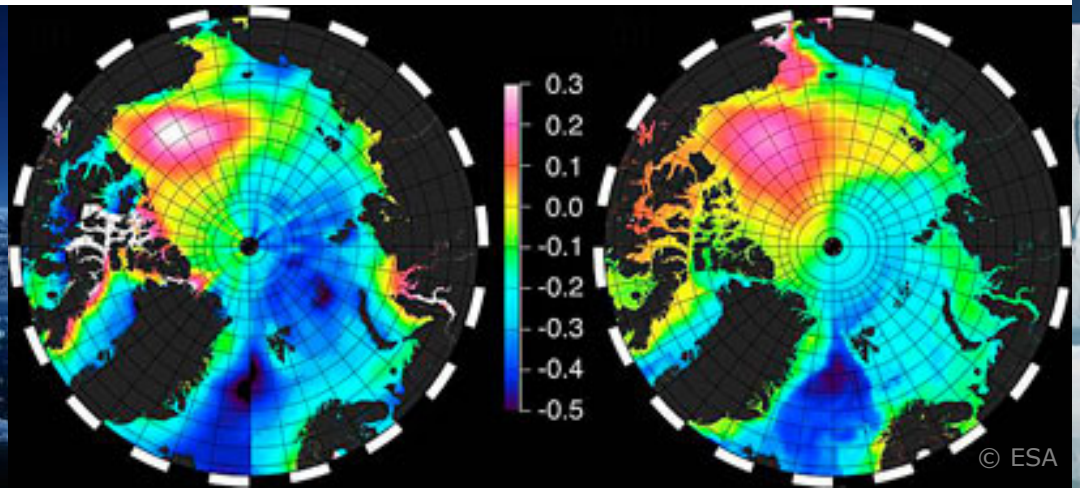
CryoSat *Seasonal cycle of arctic ice thickness* - October 2010 to April 2011 *(published April 2012)*



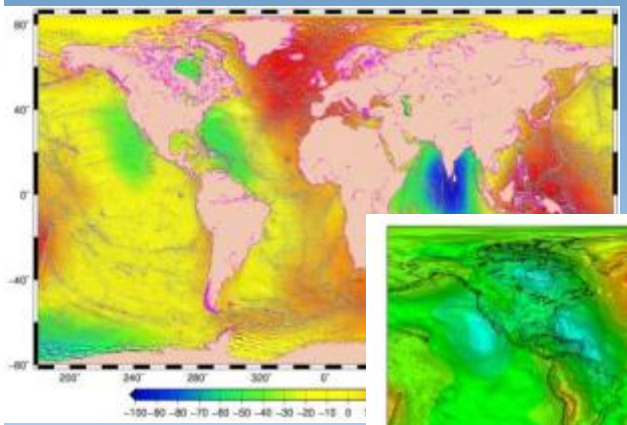
CryoSat is set to meet and exceed its primary mission goals

- CryoSat provides **Arctic-wide ice volume** in unprecedented detail and determine the accuracy of predictions of an ice free Arctic
- CryoSat provides **coverage of continental ice** sheets with unequalled accuracy
- CryoSat contributes to other geophysical goals like the **dynamics of the Arctic ocean** and the determination of the **marine geoid in the global oceans**

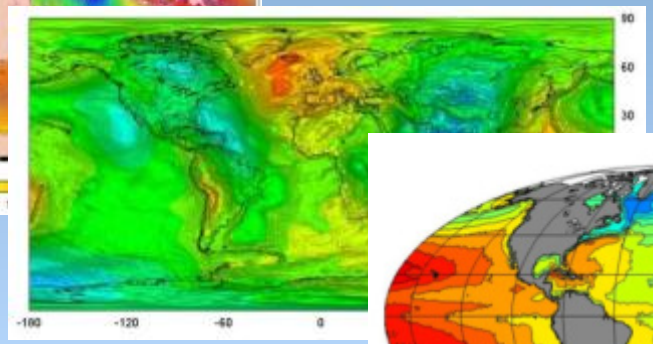




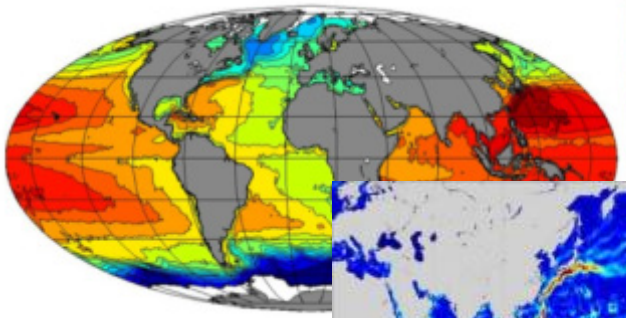
ESA mission synergies



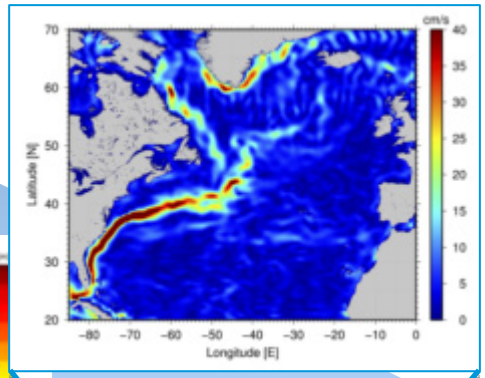
Altimetry map *(Envisat, Jason)*

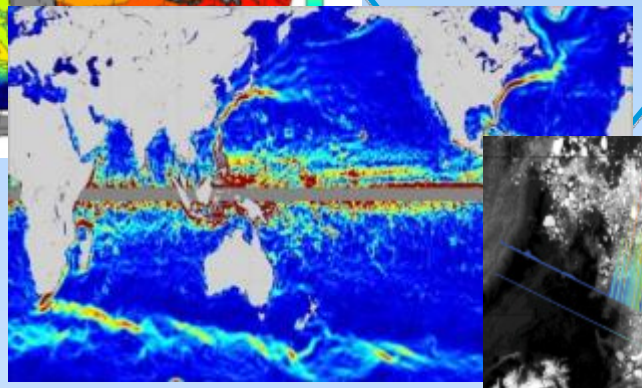


High precision Geoid (GOCE)

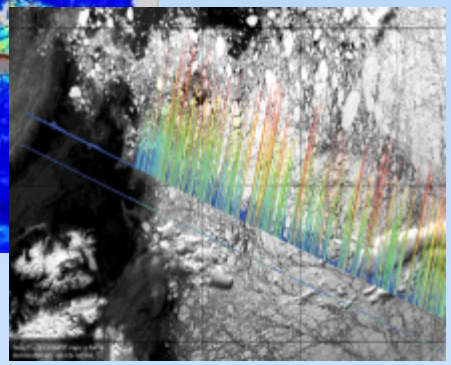


Ocean Dynamic Topography





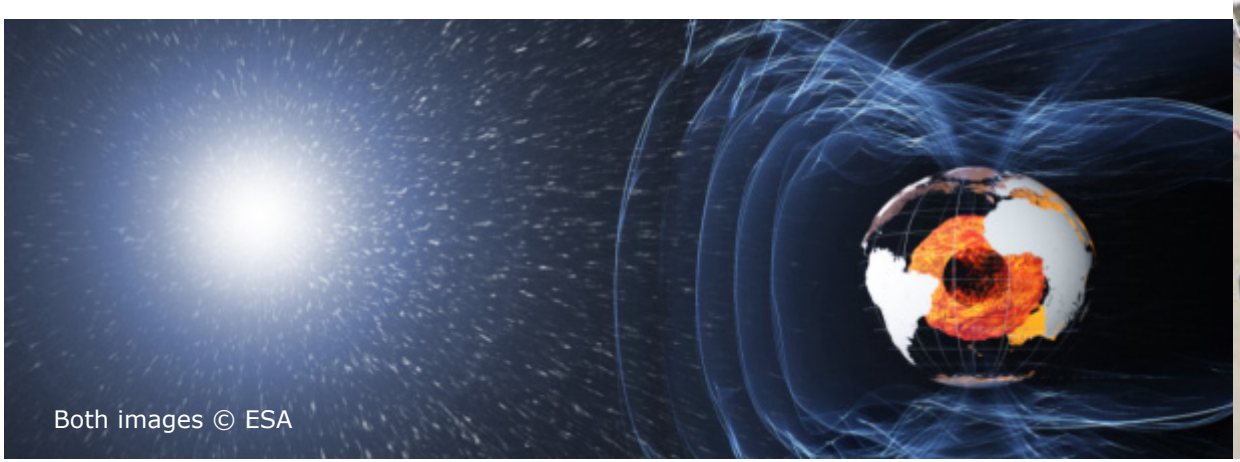
Ocean currents (GOCE)



CryoSat Data of Ice/Water surface

Next in line: Swarm – ESA's magnetic field mission

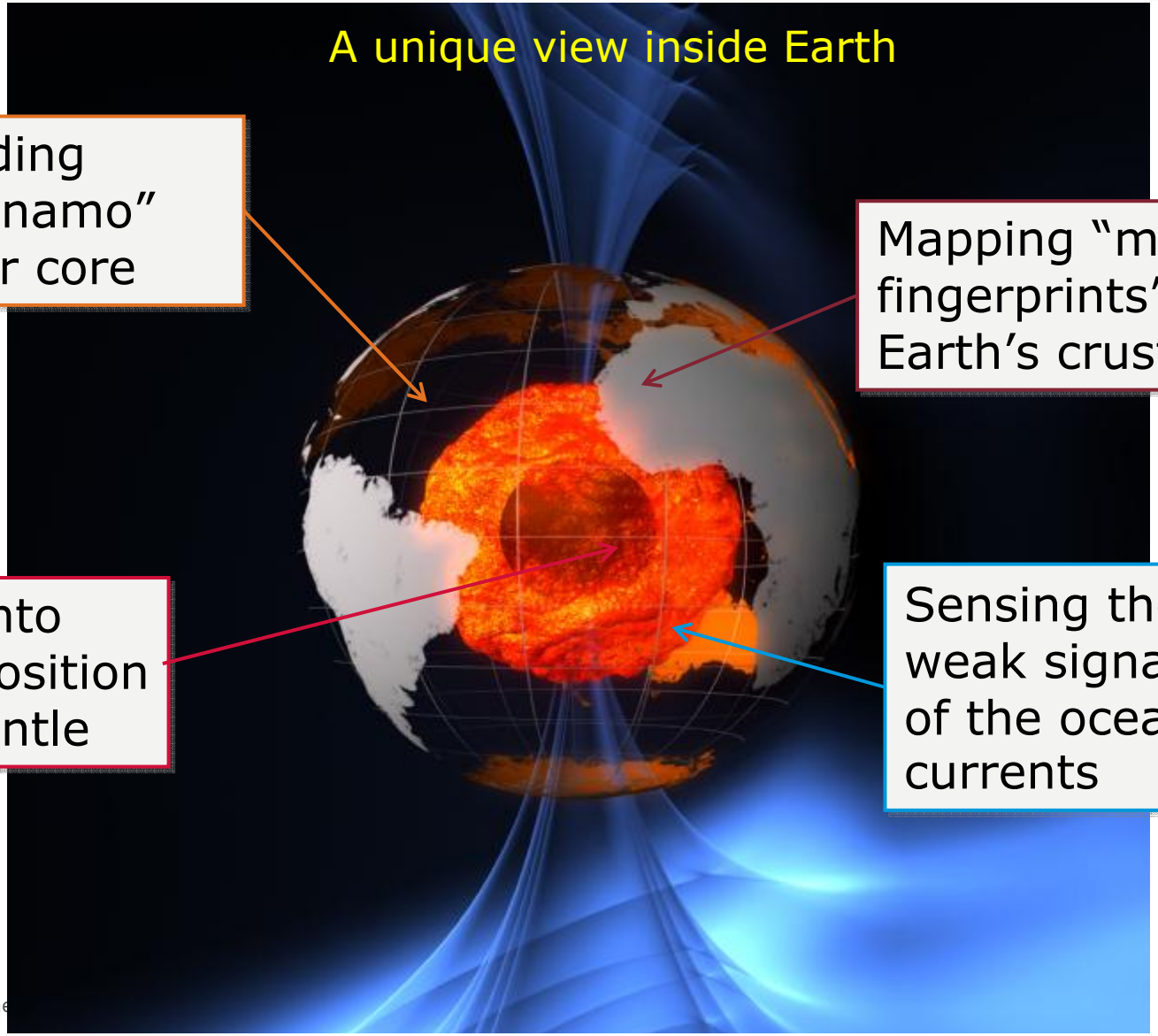
- Swarm will provide the **best-ever survey of the Earth's geomagnetic field** and its variation in time
- Swarm will allow to gain new **insights into the Earth's interior** and climate
- Launch scheduled for October 2012



Both images © ESA

Swarm in February 2012 at ABG Ottobrunn, Germany.

Swarm: revealing Earth's inner secrets



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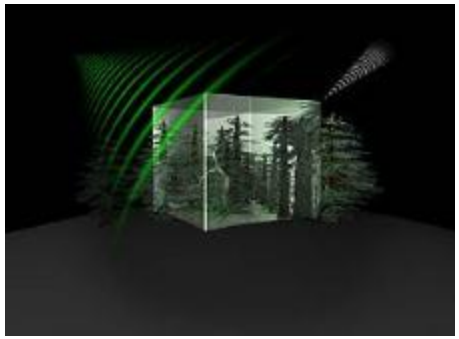
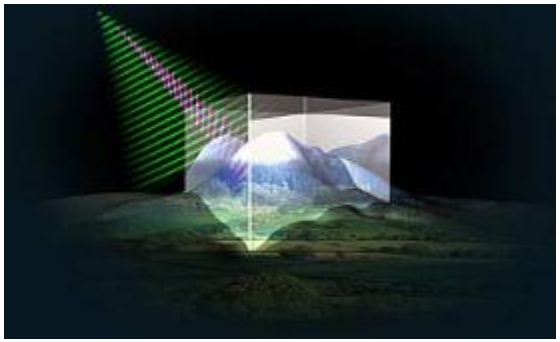
ESA, together with the science community, selects the next Earth Explorer missions (1)

- One of the **Earth Explorer 7** three candidate missions will be selected for implementation beginning of 2013.

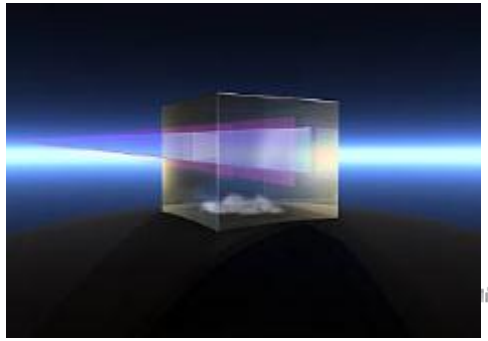


- **BIOMASS:** single satellite carrying a P-band SAR to provide continuous global interferometric and polarimetric radar observations of forested areas.



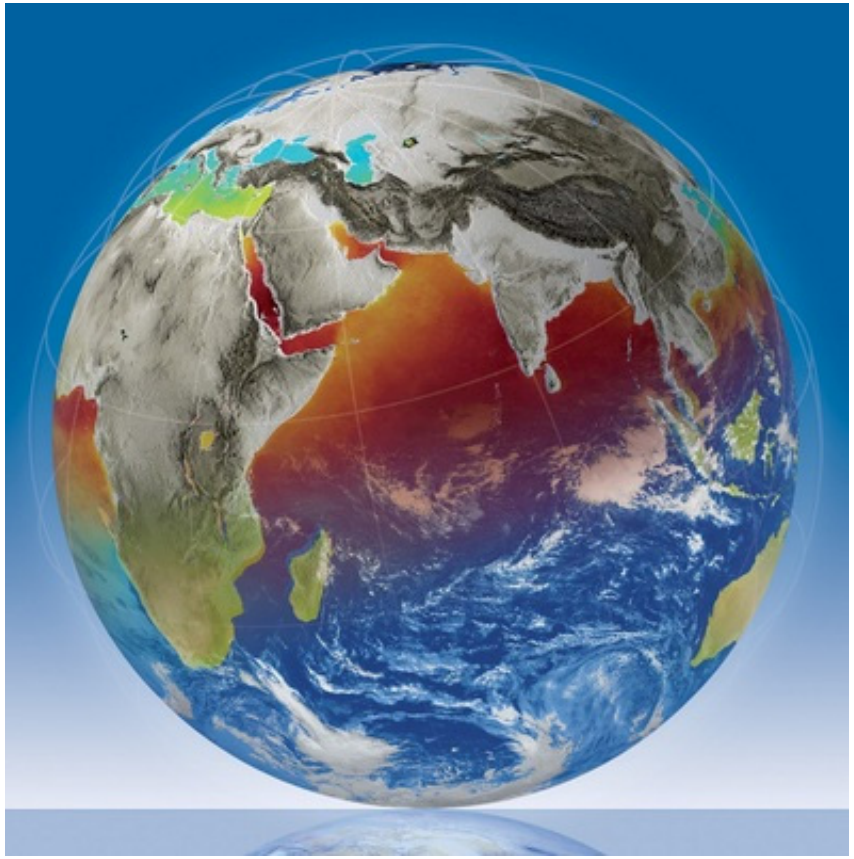
- **CoReH2O / Snow mission:** single satellite with dual frequency (X, Ku), dual-polarisation SAR to observe snow / ice at high spatial resolution

- **PREMIER:** 3D fields of atmospheric composition in upper troposphere and lower stratosphere with an infrared limb-imaging spectrometer and a mm-wave limb-sounder.



ESA, together with the science community, selects the next Earth Explorer missions (2)

– Phase A/B1 studies for two **Earth Explorer 8** candidate missions have been kicked off.



- **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.

European Space Agency

ESA Climate Change Initiative

- **EO satellites deliver global, consistent and long-term data of ECVs,** constituting the foundation supporting Climate Research & Applications *(e.g. Understanding, Attribution, Modelling, Re-Analysis, Budget Analysis, Prediction, Services)*
- **GMES Sentinels** will provide long-term continuity for monitoring our planet
- Gaps in time series => irreversible damage to the foundation underpinning Climate Research

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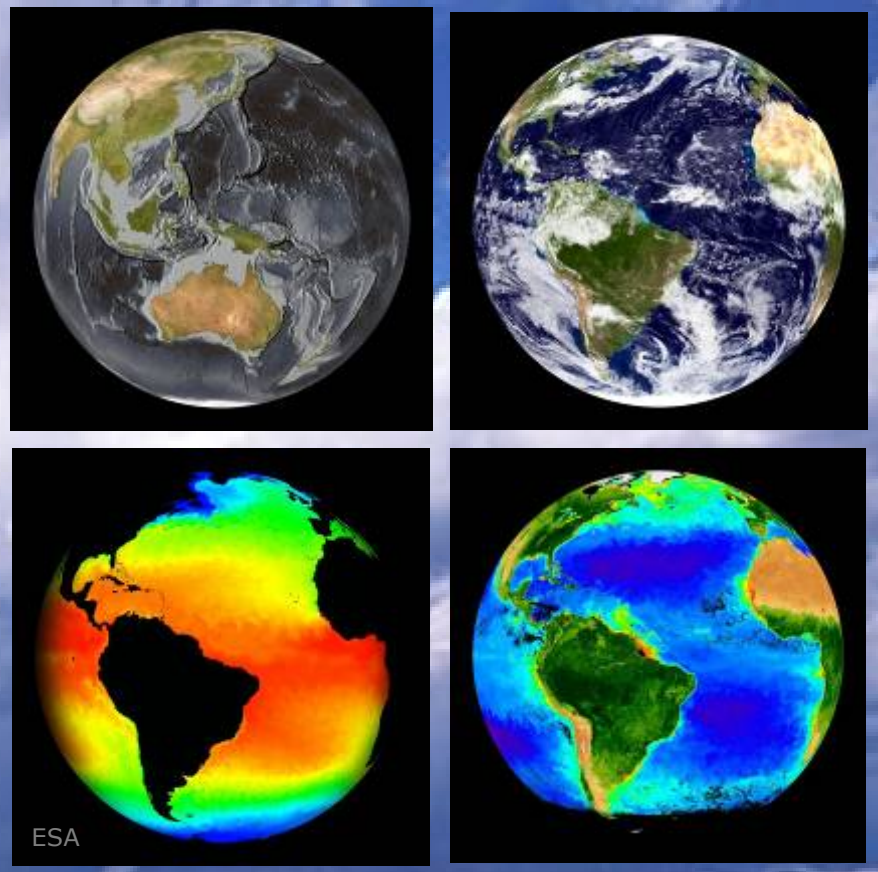
European Space Agency

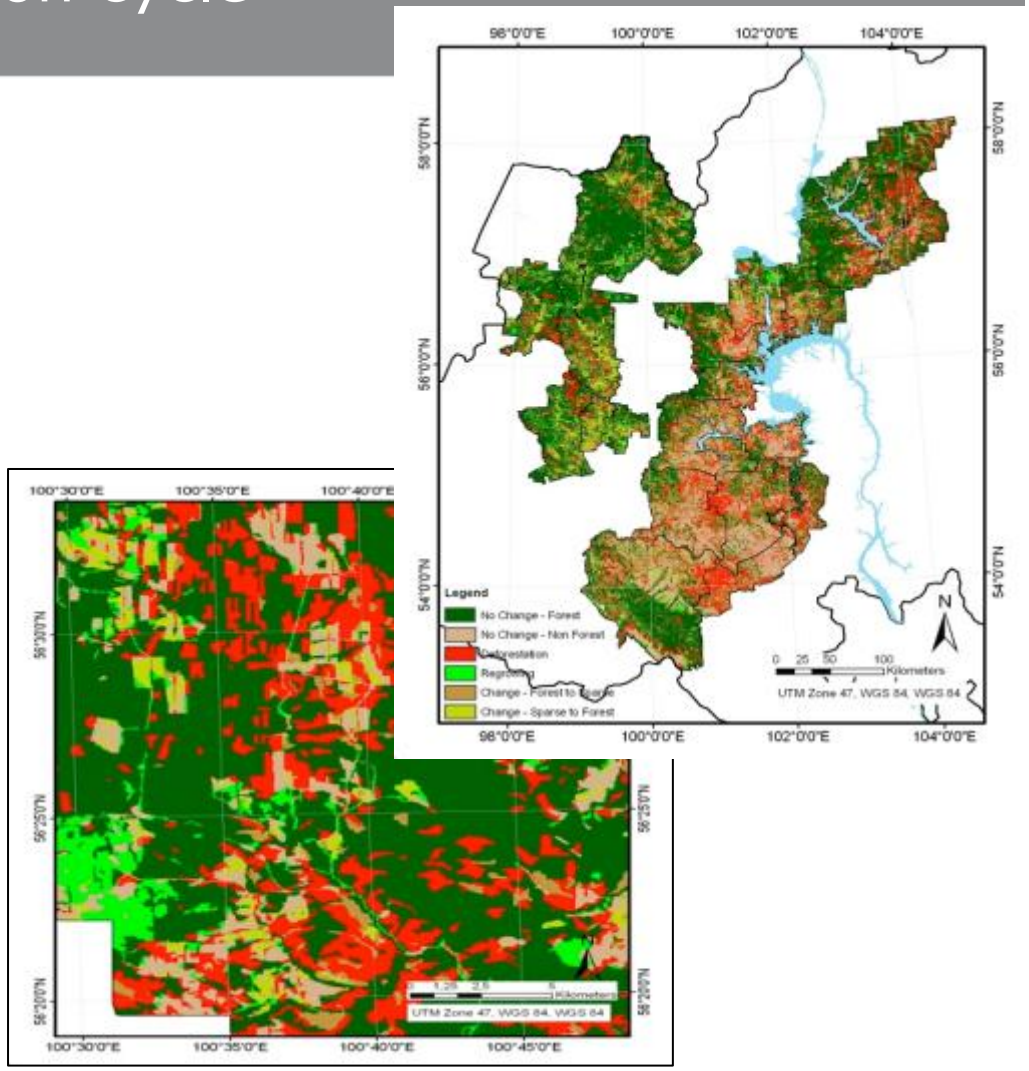
Essential Climate Variables under the ESA CCI programme

- Cloud Properties
- Carbon Dioxide, Methane & other GHGs
- Ozone
- Aerosol properties
- Sea Surface Temperature
- Sea Level; Sea Ice
- Ocean Colour
- Glaciers and ice caps
- Land cover
- Fire disturbance
- Soil moisture



Satellites conquer new applications:
The example of the global carbon cycle

- EO data reduce uncertainties by up to 80% in carbon cycle source and sink distribution
- Eliasch Review (2008) estimates global economic cost of climate change impacts of deforestation to rise up to US$ 1 trillion p.a. by 2100.
- A reduction of uncertainty of 10% on land data can be worth of about 2 billion US$ p.a. (Fuss et al., 2012, GEOCARBON)



Satellite analysis of forest stands: Final Map Product of ESA-Project GSE Forest Monitoring

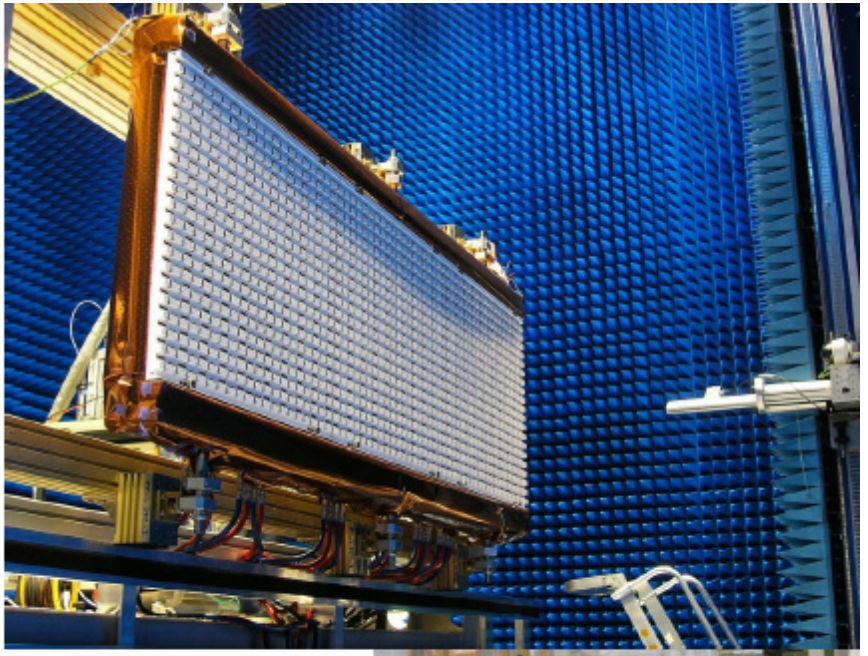
European Space Agency

Securing a sustainable future for European EO: the **GMES** programme

- The Sentinels (1A/B, 2A/B, 3A/B, 4A/B und 5"Precursor") under development; Sentinel-5, Jason-CS in definition
- Satellite launches as of 2013
- Ground segment (data reception, processing and distribution) is being implemented
- Sustainability of operational GMES is the biggest political challenge

Sentinel-1A getting ready for launch in 4th Quarter 2013

S/C Structure without external panels
(Courtesy of TAS-I, I)

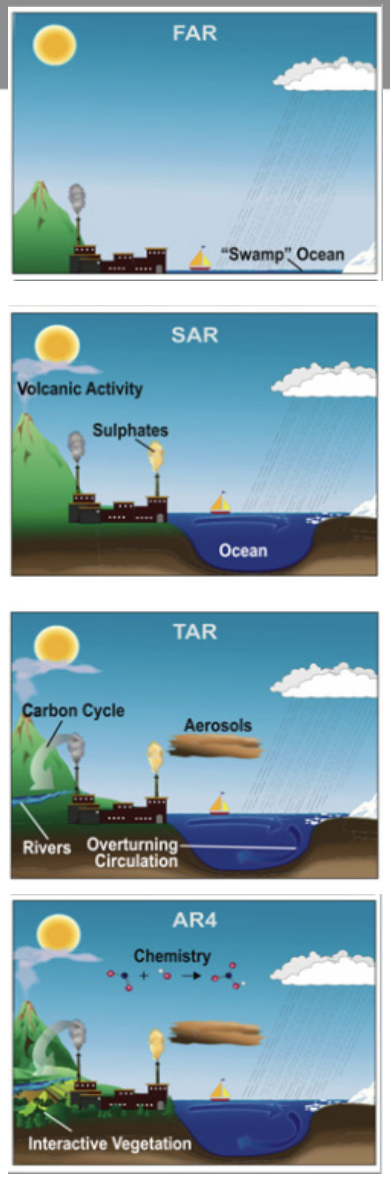


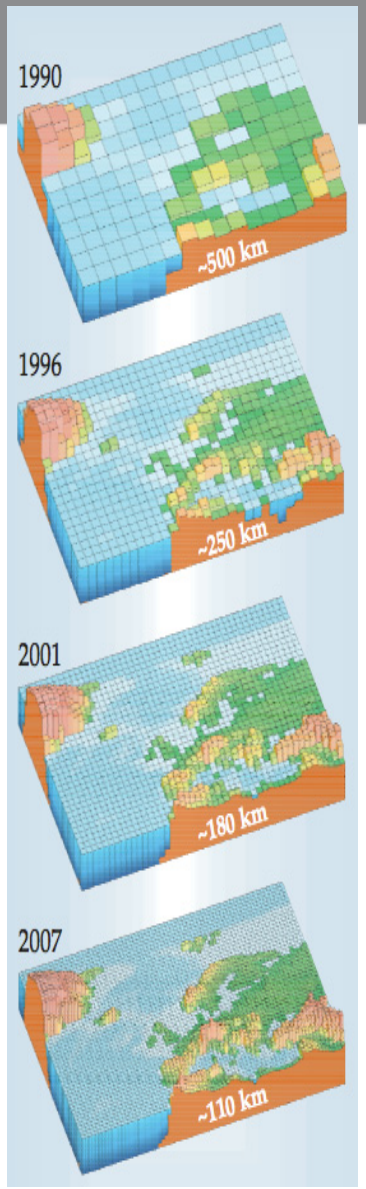
SAR Antenna Panel A during Antenna Pattern Tests
and
SAR Antenna Panel Frames D and E during integration of Deployment Mechanisms
(Courtesy of Astrium GmbH, D)

Sentinel missions: foreseen launch dates

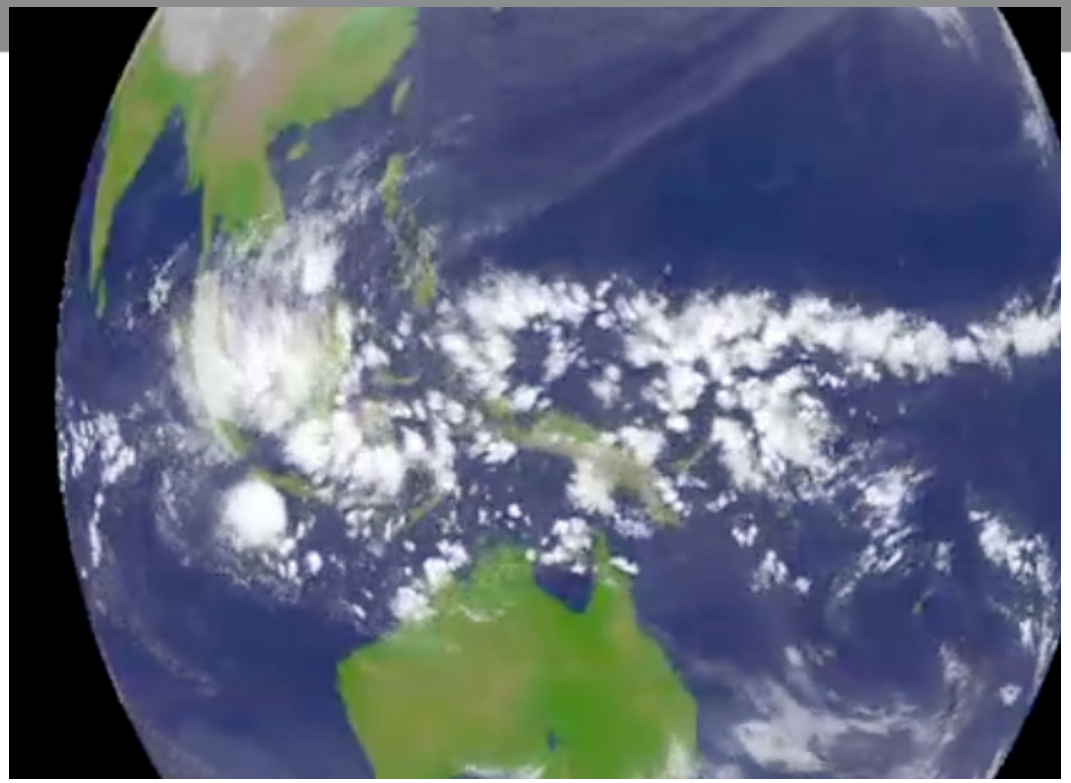
SENTINEL	LAUNCH DATE
Sentinel-1A	Oct-Dec 2013
Sentinel-2A	June 2014
Sentinel-3A	April 2014
Sentinel-5P	March 2015
Sentinel-1B	FAR in 2015
Sentinel-2B	FAR in 2015
Sentinel-3B	FAR in 2015

Modelling Climate – Towards better prediction



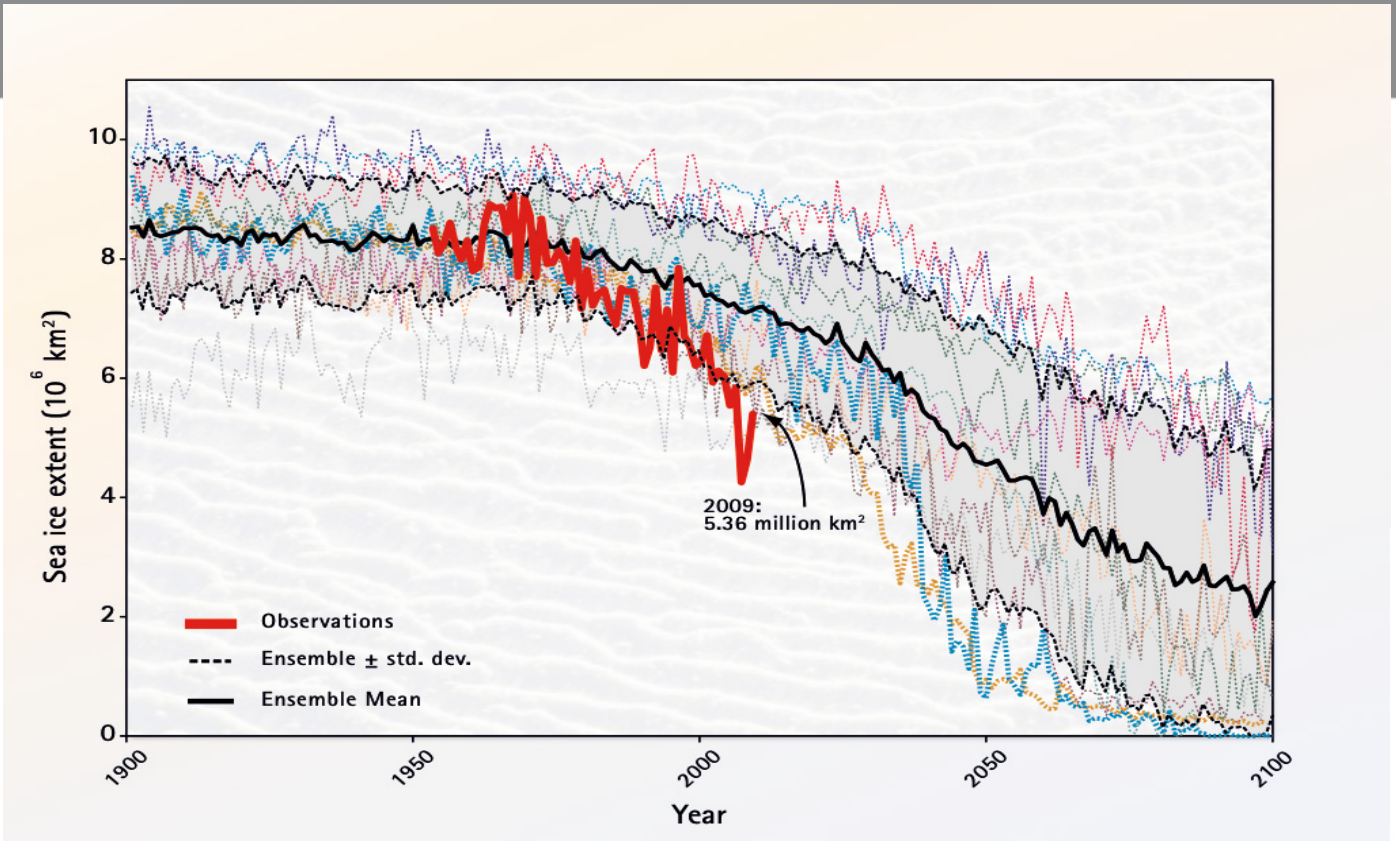


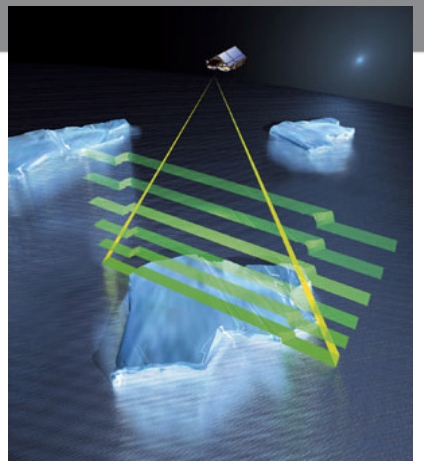
Complexity Resolution

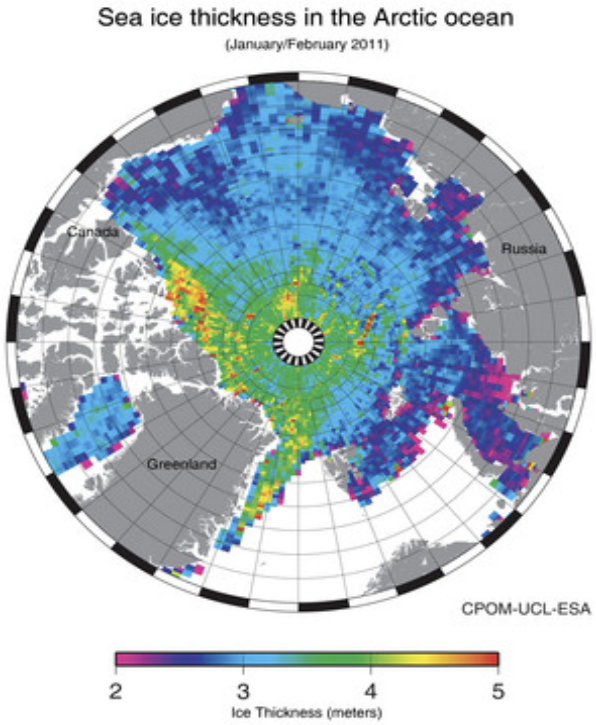


Grand Challenge of Climate Modelling. 1km resolution by the end of the decade.
The new generation climate models will be able to resolve clouds, e.g. global NICAM model run on Earth Simulator. Courtesy M. Satoh, Jamstec.

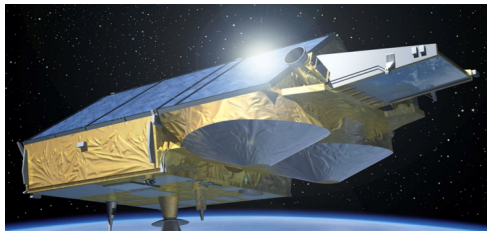
Improving Sea-Ice Modelling





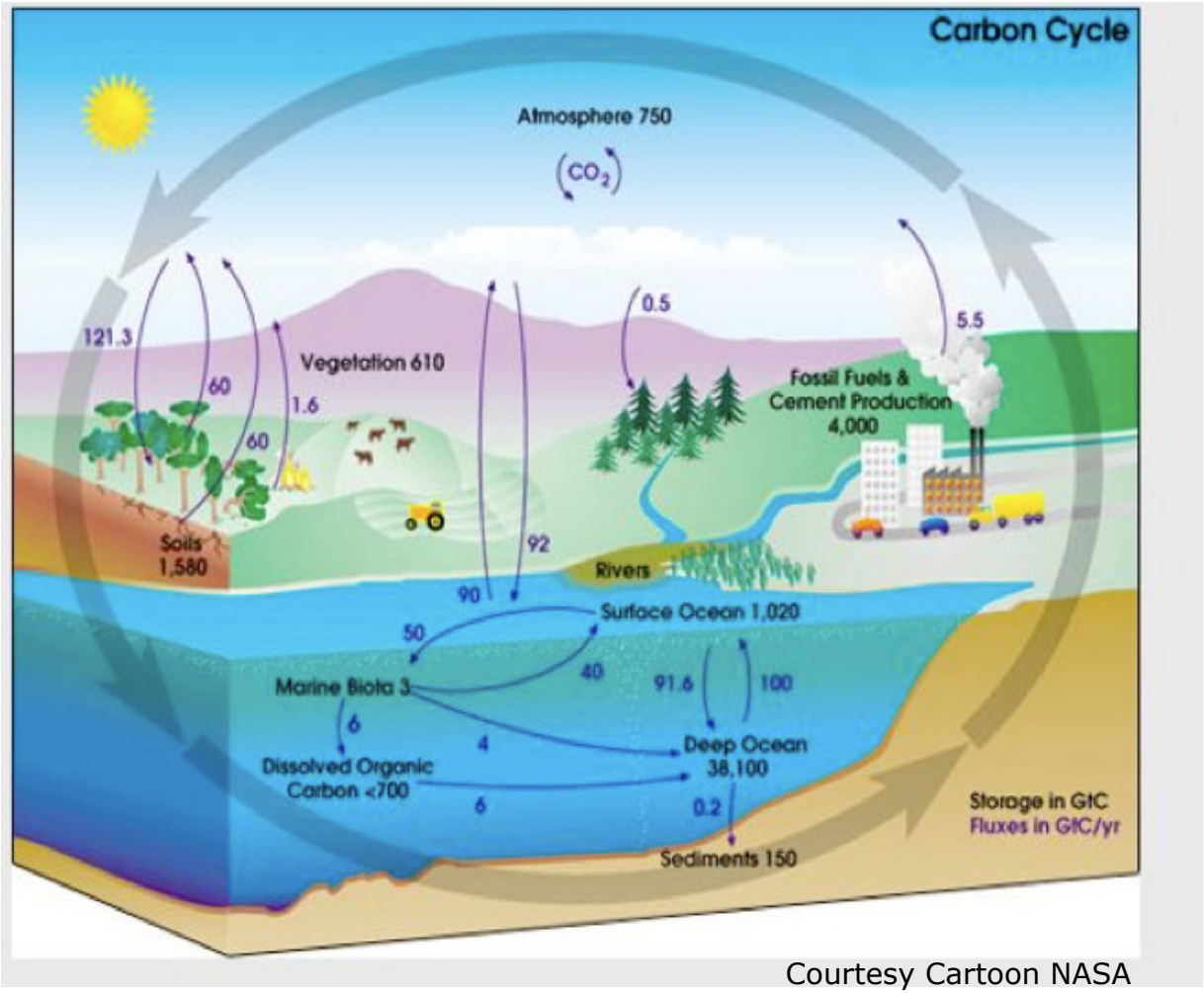


Ice Thickness from Cryosat will help modellers to better initialise, validate and constrain their models.



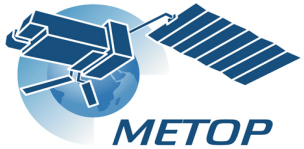
Improving Carbon Cycle Modelling

Making sense of the carbon jigsaw with different independent measurements .. of land, oceanic, and atmospheric parameters ..



Courtesy Cartoon NASA

Sentinel 4

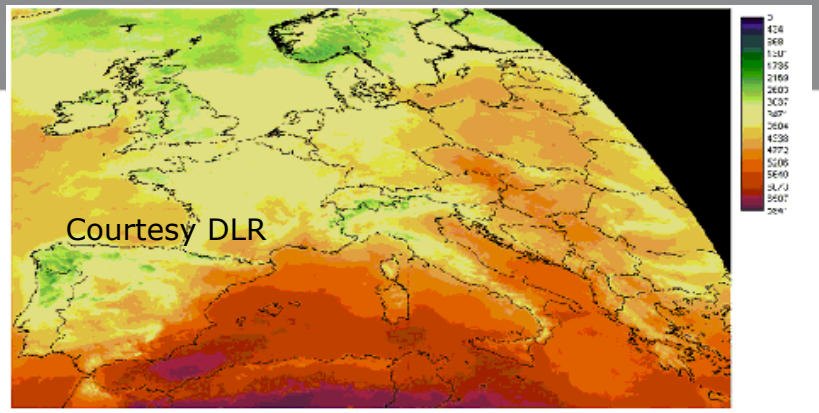


Sentinel 5

European Space Agency

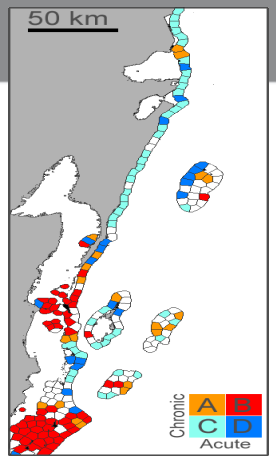
Climate Services

Mitigation



Long-term data sets of solar energy from Meteosat missions help solar energy manager siting and optimising solar power plants.

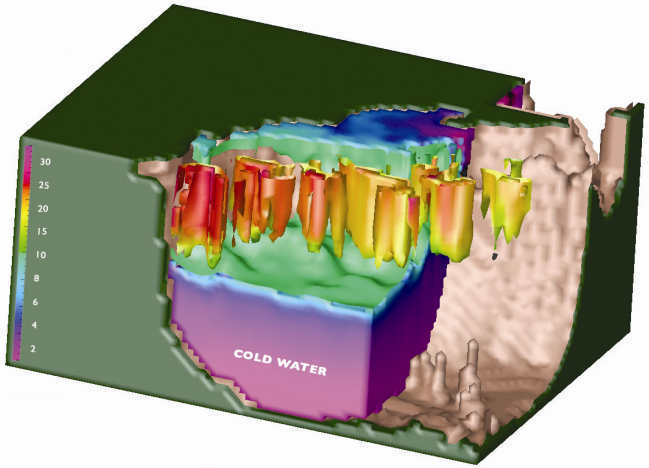
Adaptation



Met-ocean data help Coral Reef managers To quantify risks

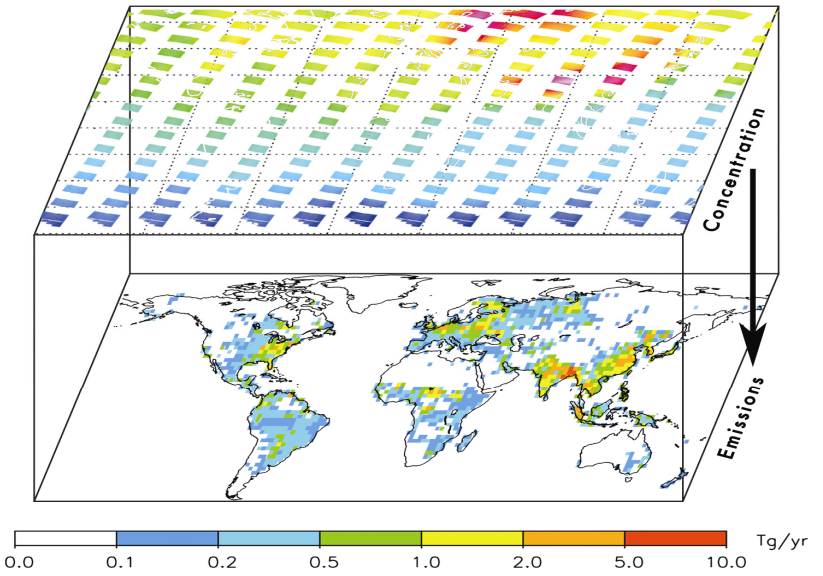
Courtesy Peter Mumby

Re-Analysis



Building a 4D picture of the Earth System through Data Assimilation.

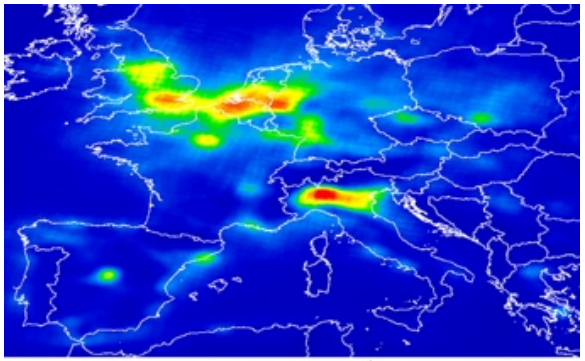
Attribution



Quantifying carbon emissions sources / sinks from concentration

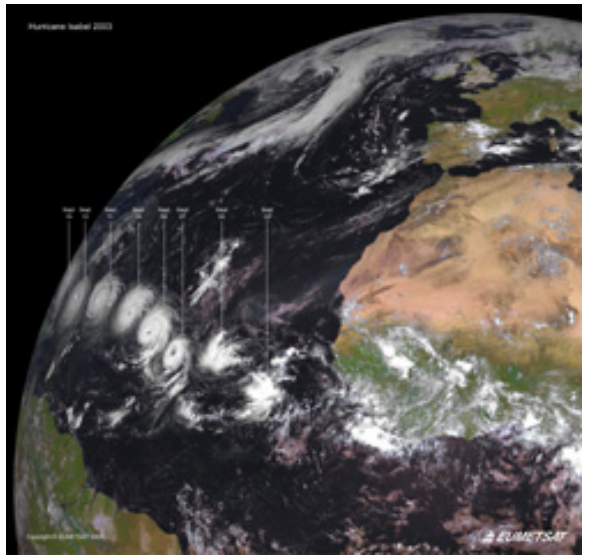
Satellites for weather forecasting:
Only space gives a global view

- Weather forecasting, air quality and atmospheric chemistry are dependent on satellite observations from polar and geostationary orbits
- **Europe: world-leading capability in development of payloads and instruments**
- Successful translation of R&D in ESA to EUMETSAT *(a process unique to Europe)*
- Estimates of Metop-SG economic benefits from 16 Bn Euro to 63 Bn Euro over 20 years



GOME-2 (MetOp): hourly info on NO2 in troposphere

Meteosat-8 hurricane composite



Outlook

- US / NASA interim Decadal Plan review: reduction of instruments
- In Europe the situation is only kept stable with:
  - *Deployment of a fully operational GMES programme*
  - *The addition of Sentinel-5 and Jason-CS*
  - *A strong EOEP programme to progress science*
- To reach this goal, two key events are
  a) the budget decision with the EU and
  b) the ESA Ministerial Conference in November 2012