



ESA's Earth Observation Programmes: recent achievements and perspectives

ICES Biennial Workshop
Geneva, 12 November 2013
Michael Rast, ESA-ESRIN

www.esa.int

European Space Agency

21st Century: New Societal Challenges



- Population Growth
- Food Security
- Energy
- Pollution
- Geo-Hazards
- Climate Change



Challenge Population Growth



1992

1960 

2012 

2040 

one symbol represents 1 billion people;
numbers from UN, World Population Prospects,
2012 revision, medium variant

Challenge Population Growth - Food Security

- Majority of food calories from 37% of the land surface
- Food production to be increased by 70% to feed 9 bn people

Challenge Population Growth: Mega-Cities



- Rapid increase: 2 Mega-Cities in 1979, up to 37 in 2025
- Cities will hold most of population increase
- 3 Mio people move to cities each week in developing countries
- Mega-Pollution, Mega-Stress, Mega-Risks

Challenge Population Growth: Vulnerability



The 10 coastal cities at greatest flood risk in terms of overall cost

New Opportunities – The Information Age



New boundary conditions for gathering, processing, exploiting, searching and storing data:

- Crowd Sourcing/Crowd Mapping
- Sensor Web/Internet of Things
- Cloud Computing
- Big Data
- New Generation Mapping Tools
- Social Networks

New Opportunities – The Information Age



© Thinkstock by Getty Images

Increased IT availability:

- Global mobile cellular penetration at 96%
- Global household internet penetration at 41%
 - Europe: 77%
 - Africa: 7%

Reference: The World in 2013 – ICT Facts and Figures, ITU, Geneva, 2013



Space Based Earth Observation



Essential tool to tackle global challenges

- Reliable assessment of human activity
- Coverage over space and time
- Long observation intervals
- Large scale observations

First EO Revolution:

- WWW, broadband data networks, GIS, desktop processing

Second EO Revolution:

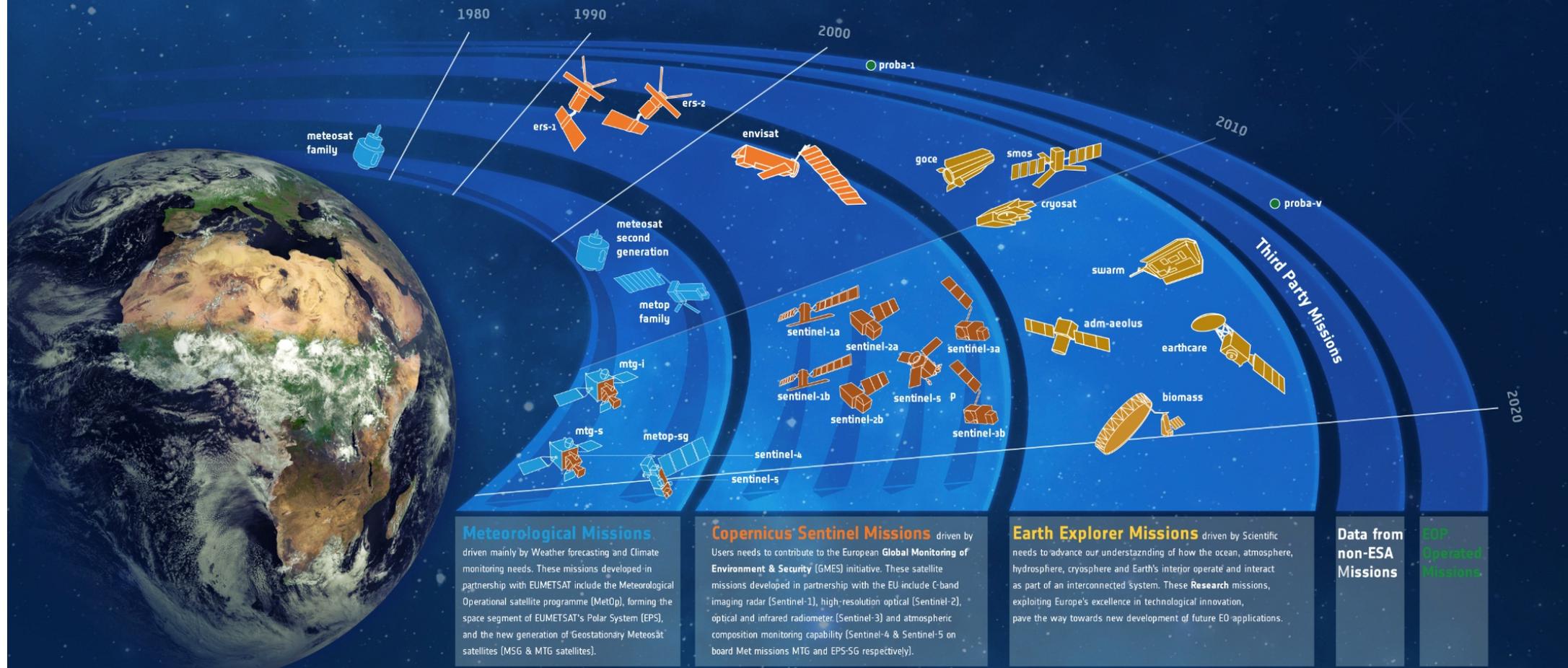
- cloud computing, crowd sourcing, big data, new generation mapping tools
- Coverage over space and time
- Long observation intervals
- Large scale observations



What is at our hands?



→ THE ESA EARTH OBSERVATION PROGRAMME



Ten Years of Envisat Science

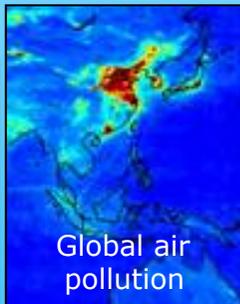


5000 scientific projects using Envisat data

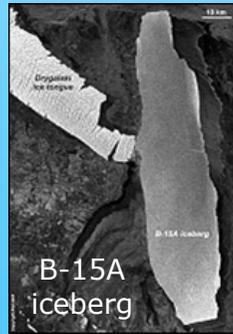
First images



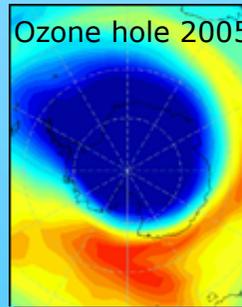
Global air pollution



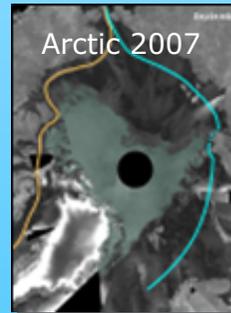
B-15A iceberg



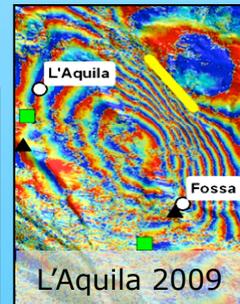
Ozone hole 2005



Arctic 2007



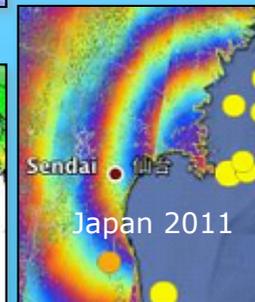
L'Aquila 2009



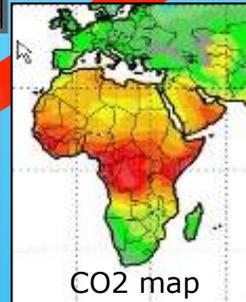
Iceland 2010



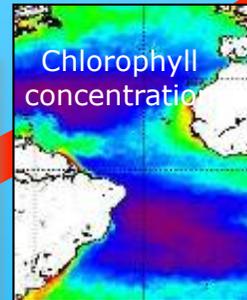
Sendai Japan 2011



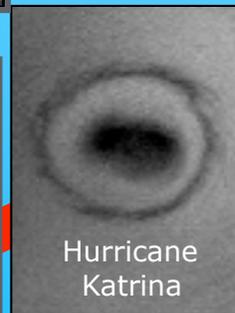
CO2 map



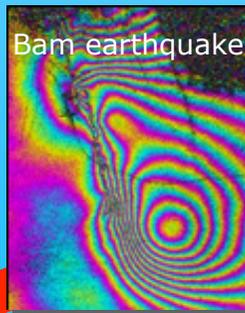
Chlorophyll concentration



Hurricane Katrina



Bam earthquake



Prestige tanker oil slick



Launch



Numerous presentations based on Envisat data during the Symposium

Envisat was the Sentinel "precursor" for many operational users

Envisat Symposium Salzburg (A)

Envisat Symposium Montreux (CH)

Living Planet Symposium Bergen (N)

Living Planet Symposium Edinburgh (UK)

Mar 02

Sep 04

Apr 07

Jun 10

Sep 13

and many workshops dedicated to specific Envisat user communities

Science – the Earth Explorers



GOCE: A Wealth of Applications



Gravity Anomalies

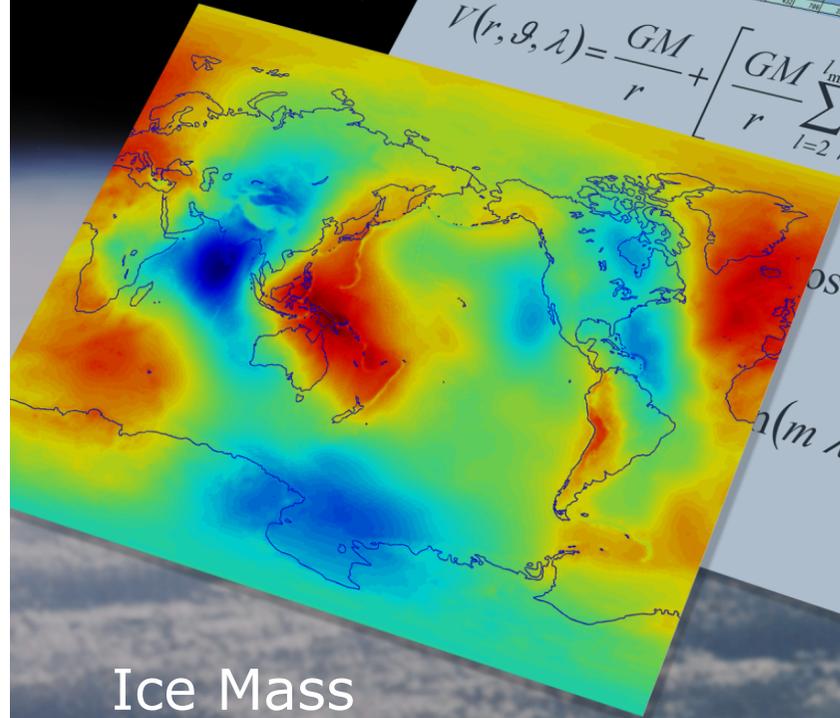
Topography

Geoid

Altimetry

Positioning

Unified Height Systems



$$V(r, \vartheta, \lambda) = \frac{GM}{r} + \left[\frac{GM}{r} \sum_{l=2}^{l_{\max}} \sum_{m=0}^l \left(\frac{a}{r} \right)^l P_{lm} \right]$$

$$\left[\begin{matrix} \cos(m\lambda) \\ \sin(m\lambda) \end{matrix} \right]$$

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4	93	0.00000000000000000000	10	100	0.00000000000000000000

Ice Mass Balance

Mean Ocean Circulation

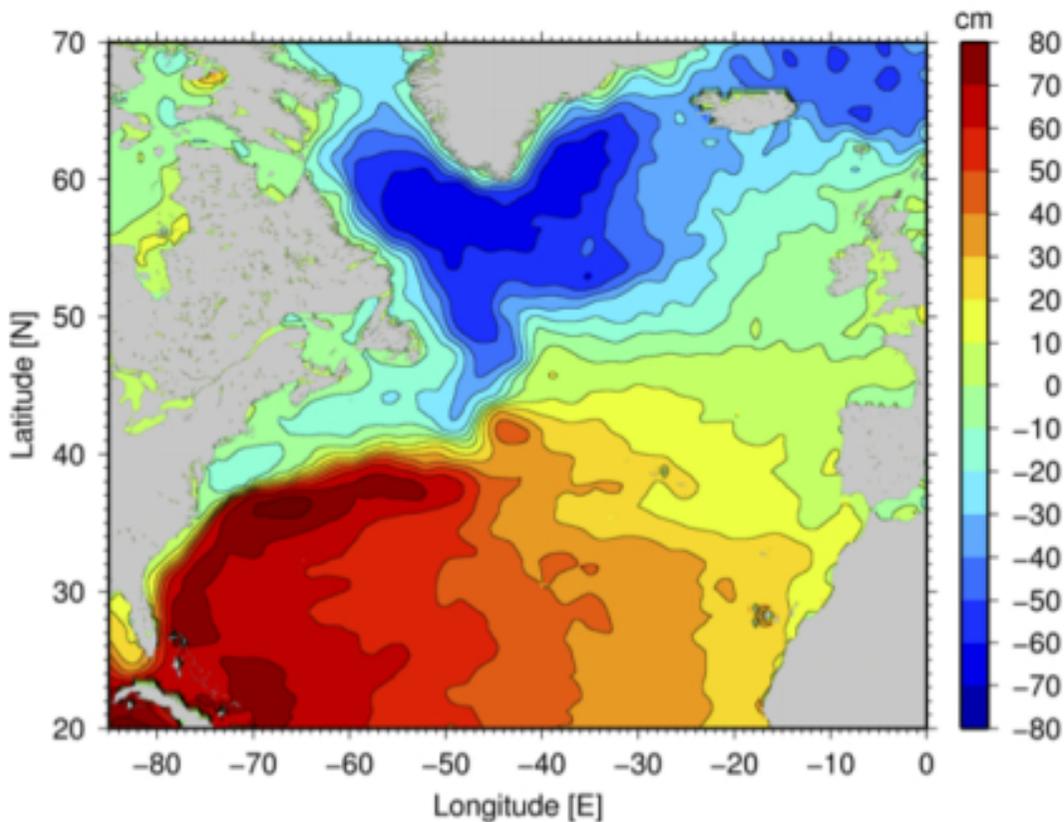
Oil and Gas Exploration

Post Glacial Rebound

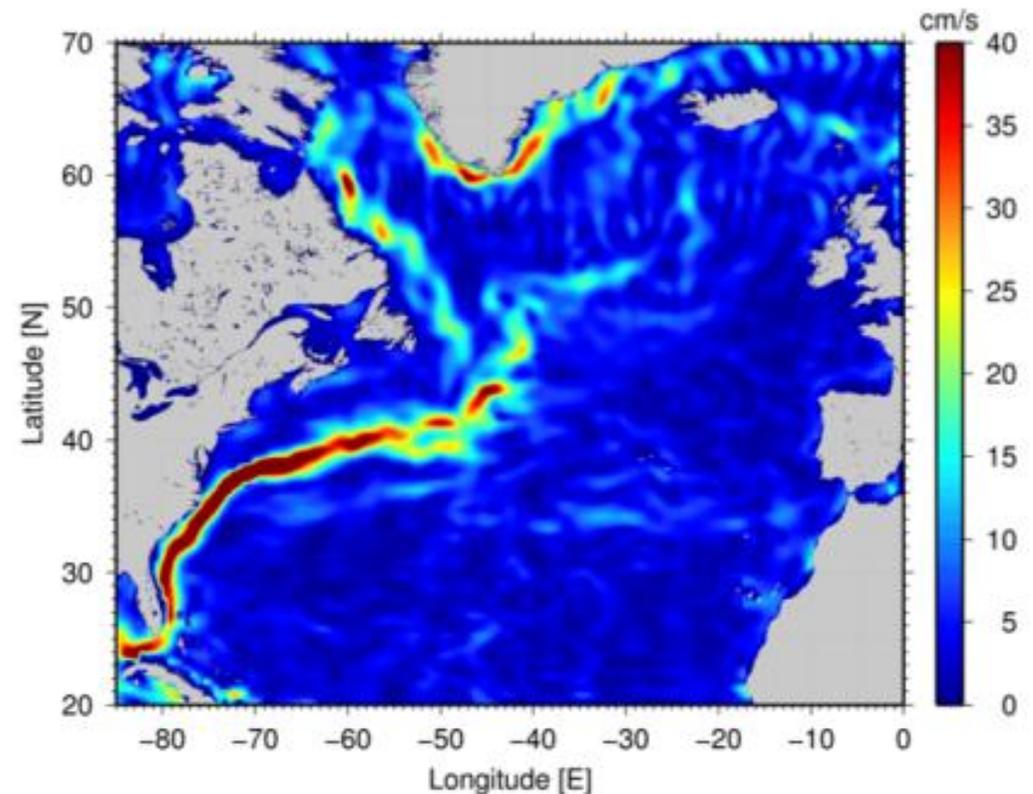


- With GOCE geoid, for the first time, global currents can be extracted directly from satellite altimetry data.

Ocean Dynamic Topography

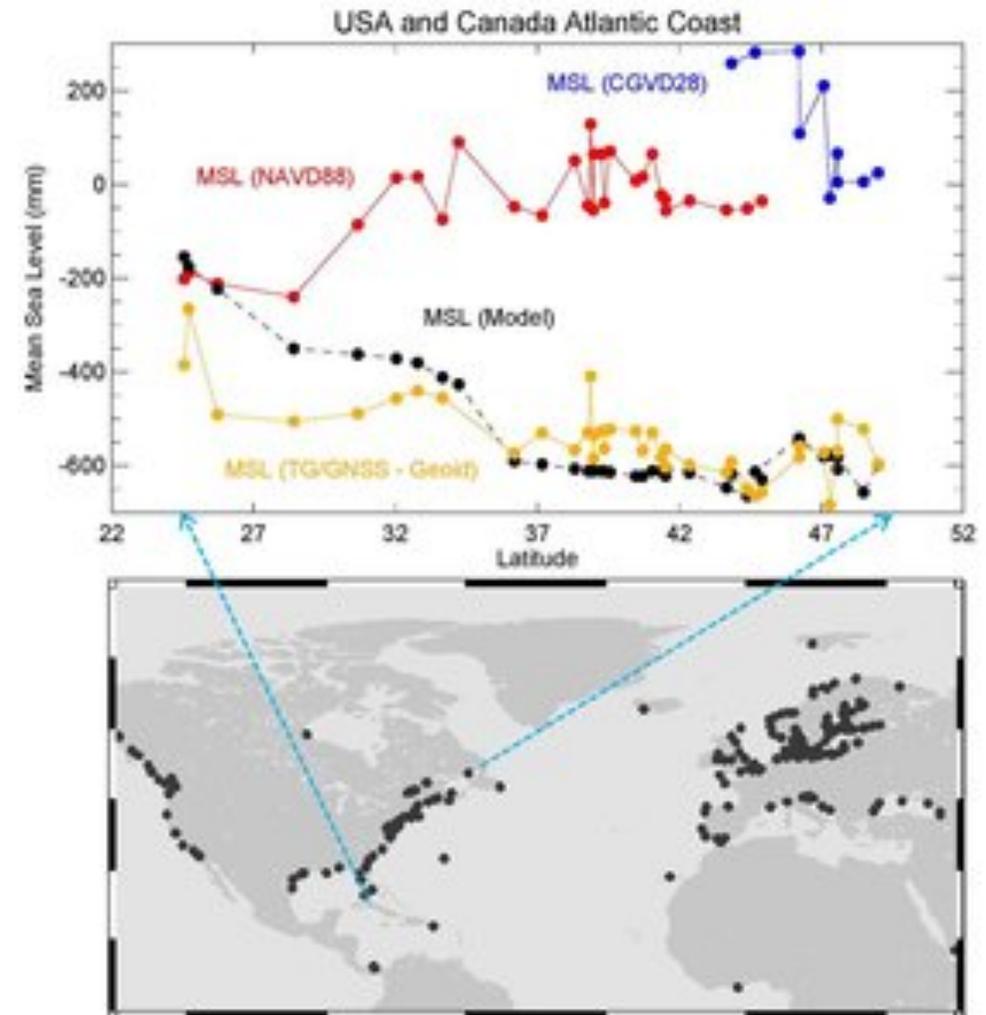


Water Surface Velocity



GOCE: Debate on Sloping Sea

- Science has been dealing with the question whether the sea is higher or lower heading north along the east coast of North America
- Wind, currents, tides and different temperatures cause seawater to pile up in some regions and dip in others
- GOCE measurements, together with GPS heights, showed that the sea level decreases going north along the North American coastline
- Through ESA's Support to Science Element programme, new reference level surfaces have been determined



GOCE – Tohoku Earthquake



Air Density Perturbation



SMOS – Soil Moisture and Ocean Salinity



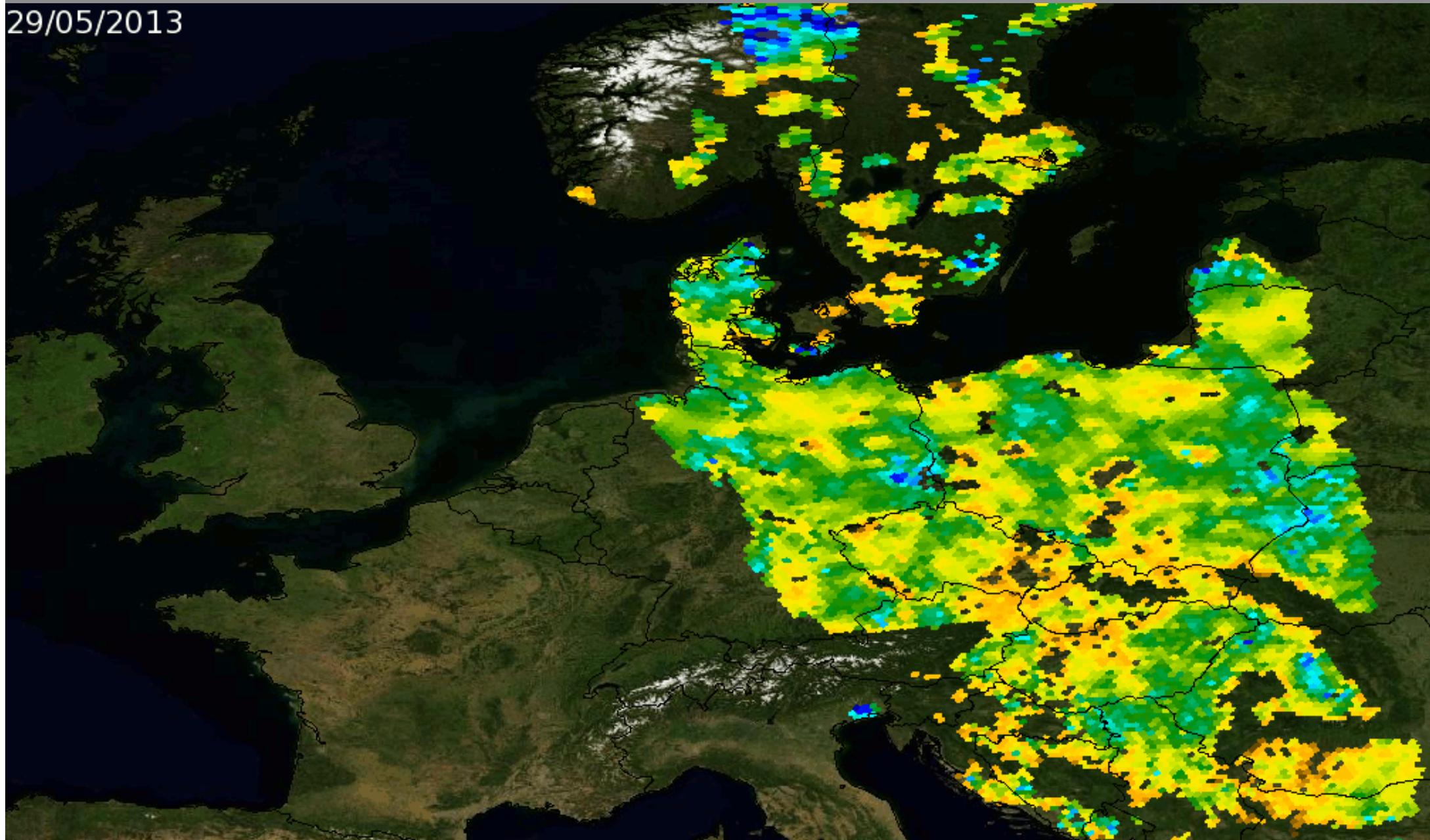
- Complete Earth coverage within three days
- Radio Frequency Interference (RFI) mitigation continues
- Outstanding international cooperation
- Mission extension until 2017 likely



SMOS AND HYDROLOGY: *Floods in Europe May/June 2013*



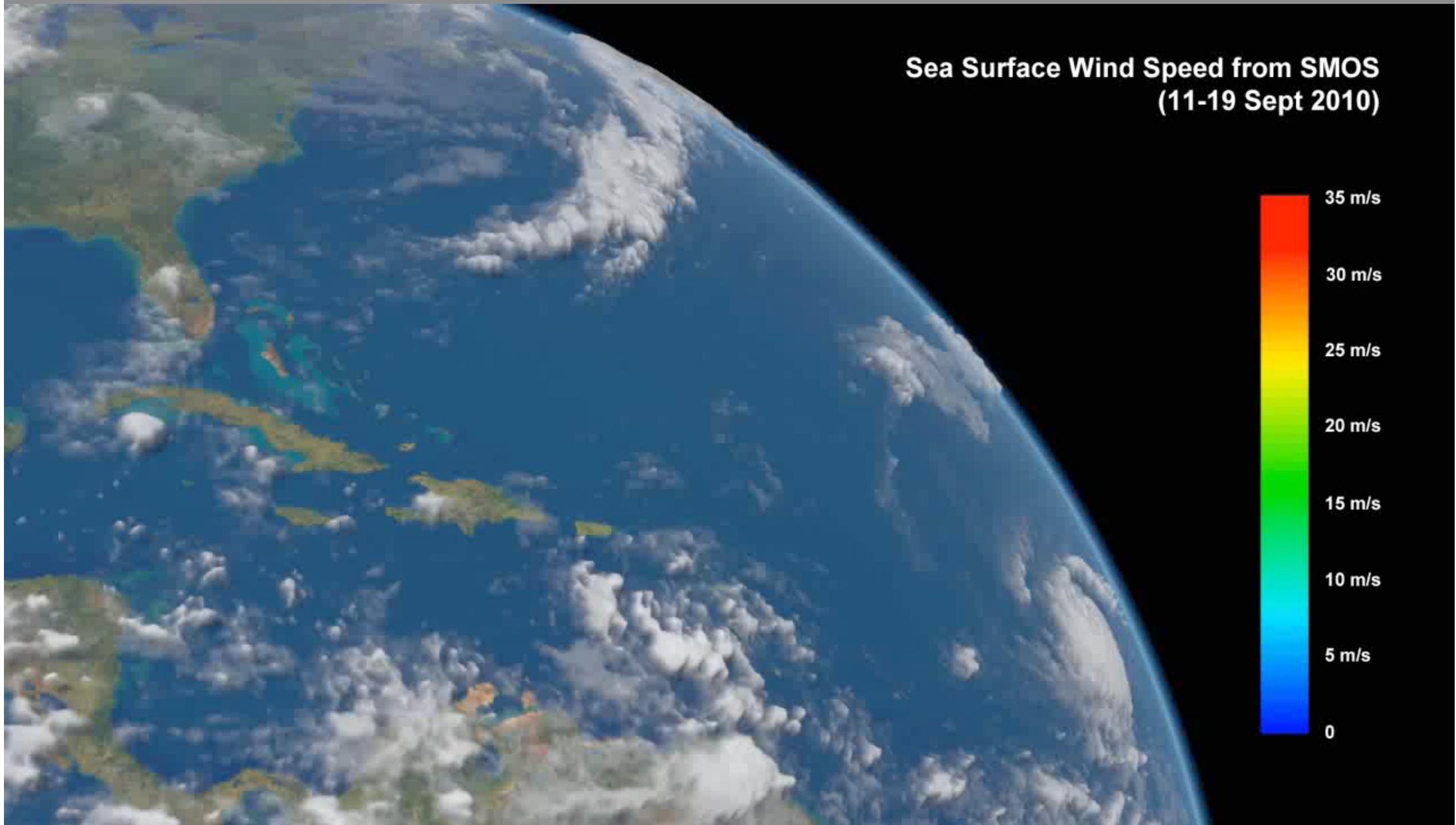
29/05/2013



SMOS - Hurricane Igor



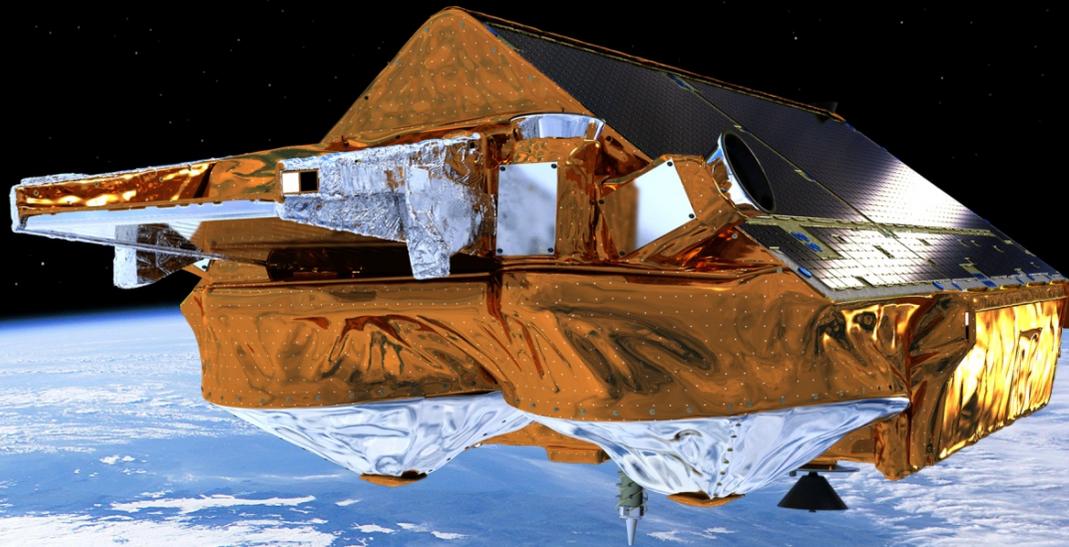
Sea Surface Wind Speed from SMOS
(11-19 Sept 2010)



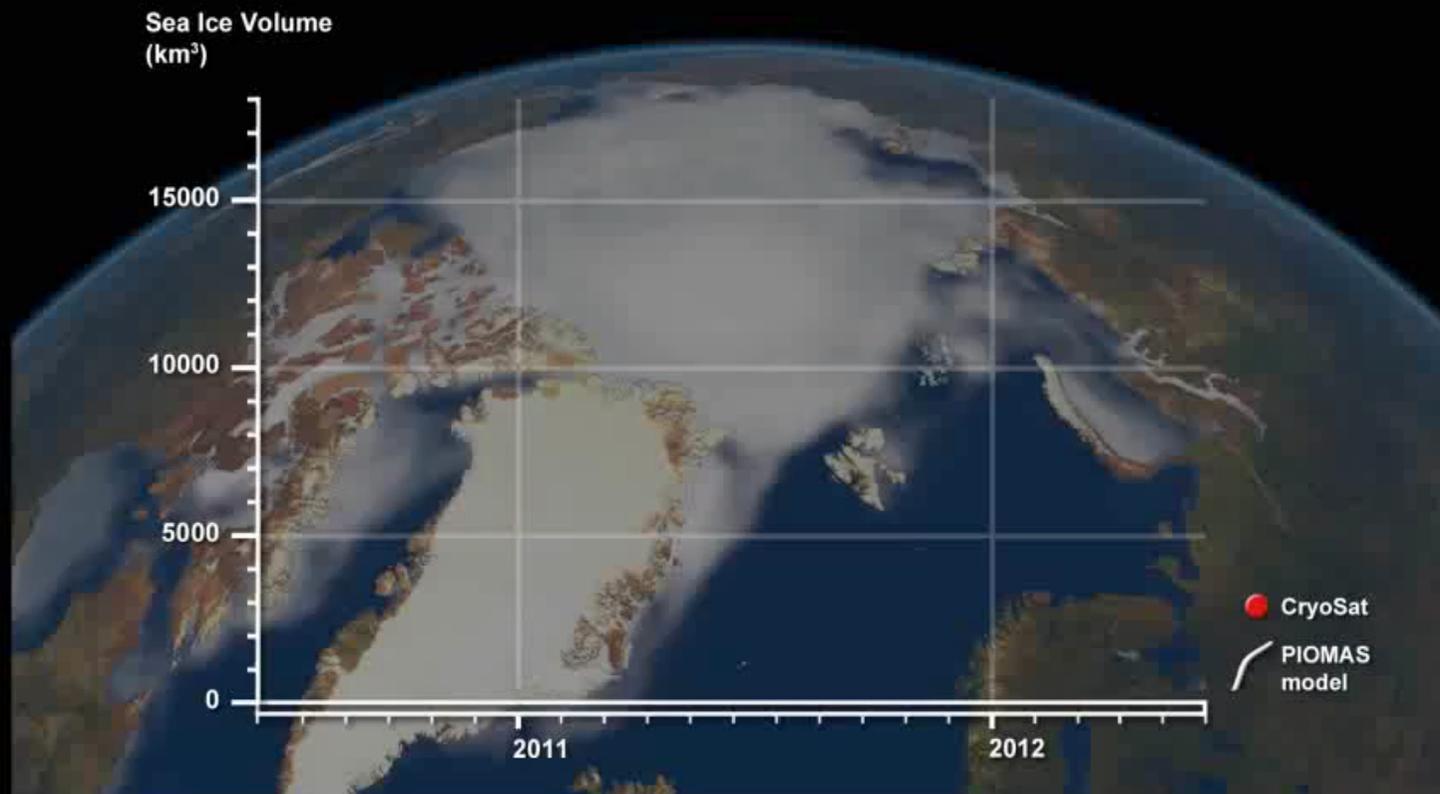
CryoSat: The Ice Mission



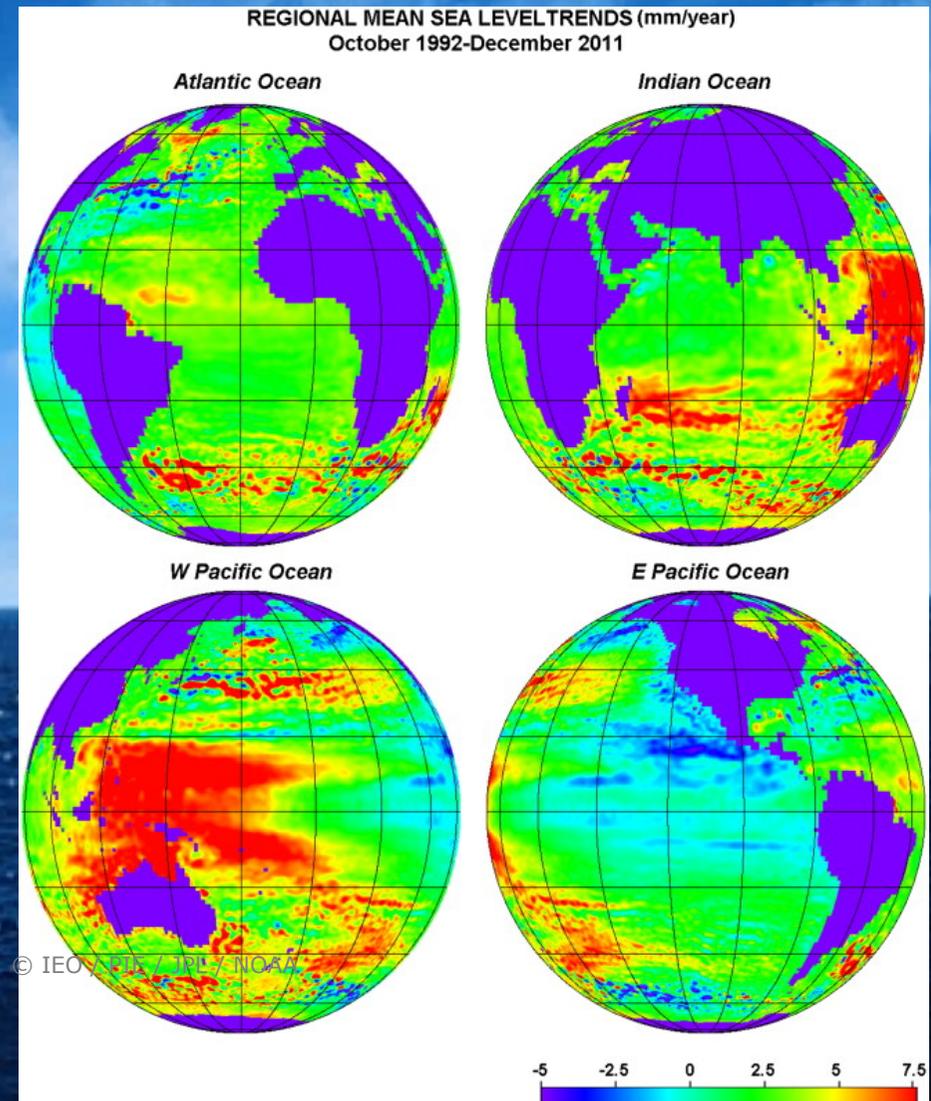
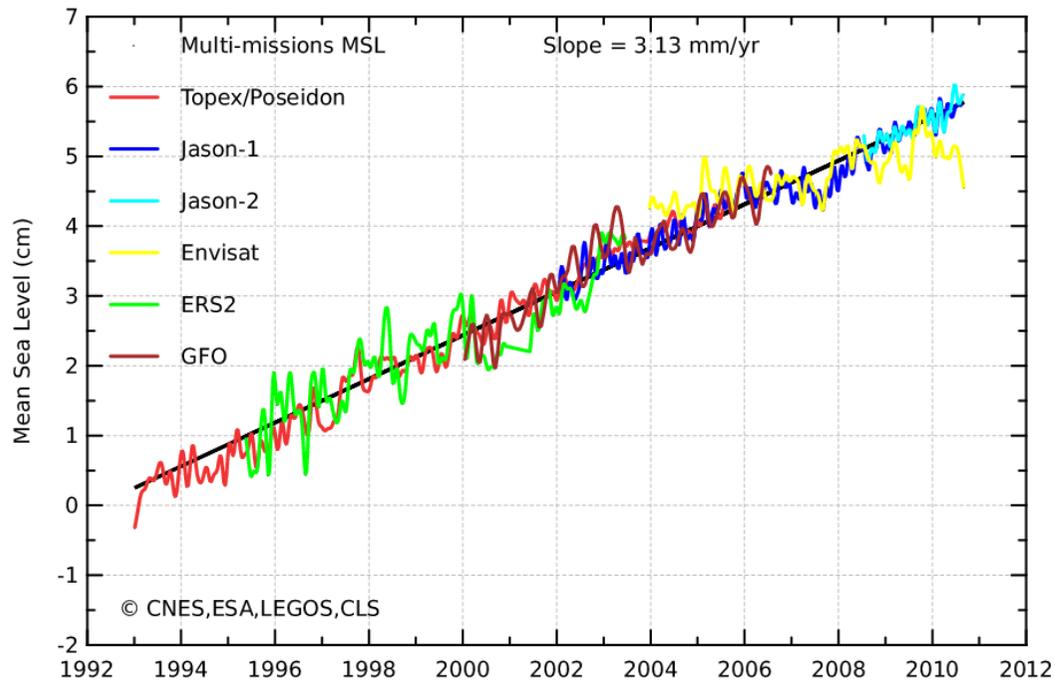
- First interferometric altimeter in space
- Global sea ice thickness measurements
- Data used for ice research, but increasingly also for oceanography
- Mission extension until 2017 likely



CryoSat – Arctic Sea Ice Volume



Satellites show global sea-level rise: 20 year-trend



Next in line: Swarm



- 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 22 November 2013

Swarm Science Objectives



understanding the weakening of Earth's protective shield

understanding the "Earth's dynamo" in the outer core

mapping magnetic fingerprints in Earth's crust/ Composition of the mantle

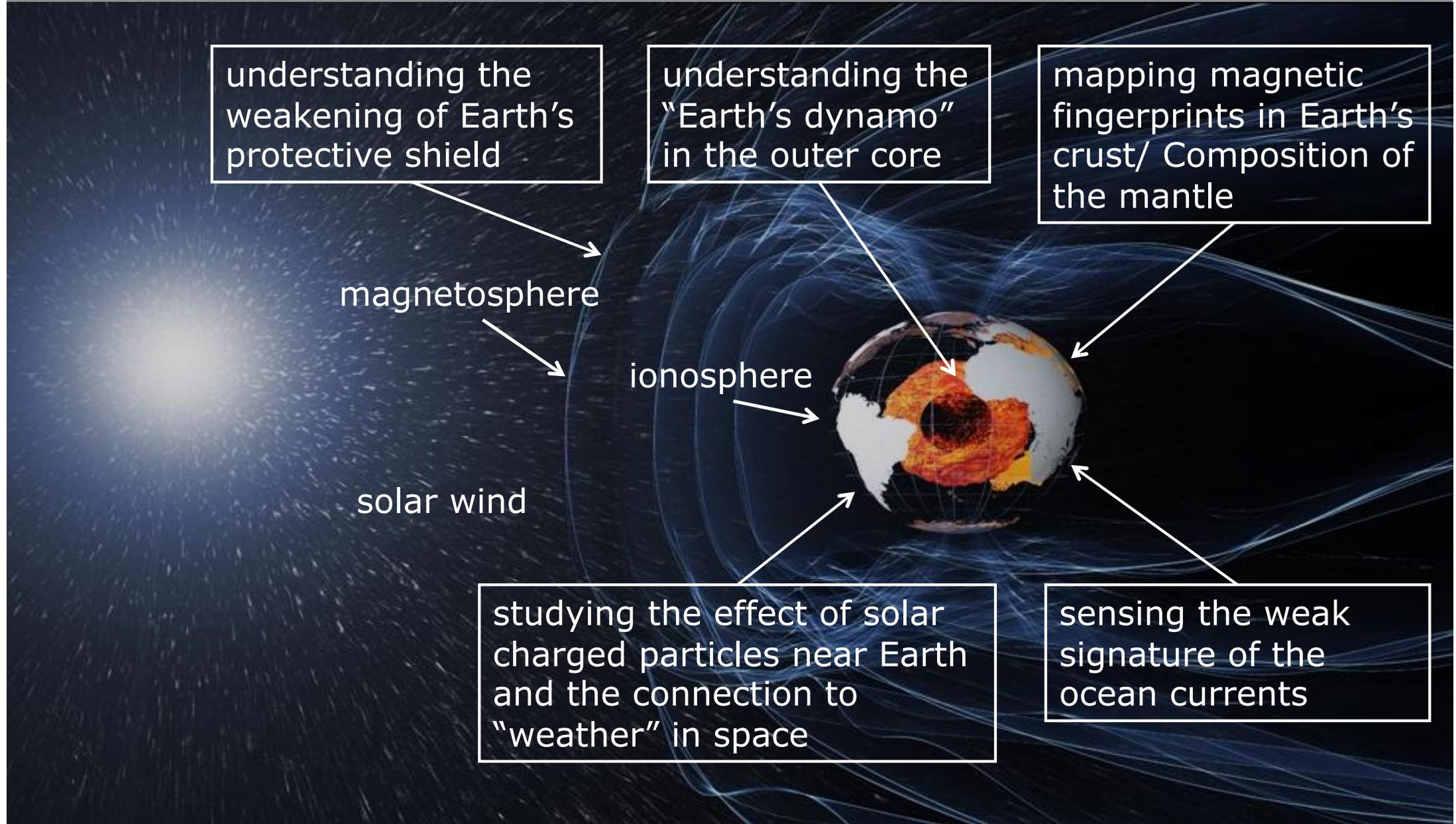
magnetosphere

ionosphere

solar wind

studying the effect of solar charged particles near Earth and the connection to "weather" in space

sensing the weak signature of the ocean currents



Meteorological missions



- Cooperation model: ESA is developing and launching the European meteorology missions, EUMETSAT is operating them
- Currently Meteosat Second Generation (MSG) missions in GEO and MetOp missions in LEO
- Two successful launches in 2012: MSG-3 and MetOp-B
- MeteoSat Third Generation (MTG) and MetOp Second Generation under development



First image of Europe's "youngest" meteorological satellite, MSG-3 (7 August 2012)

Copernicus: A New Generation of Data Sources



Sent-1A/B



Sentinel-2A/B



Sentinel-3A/B



Sentinel-4A/B



Sentinel-5/5P



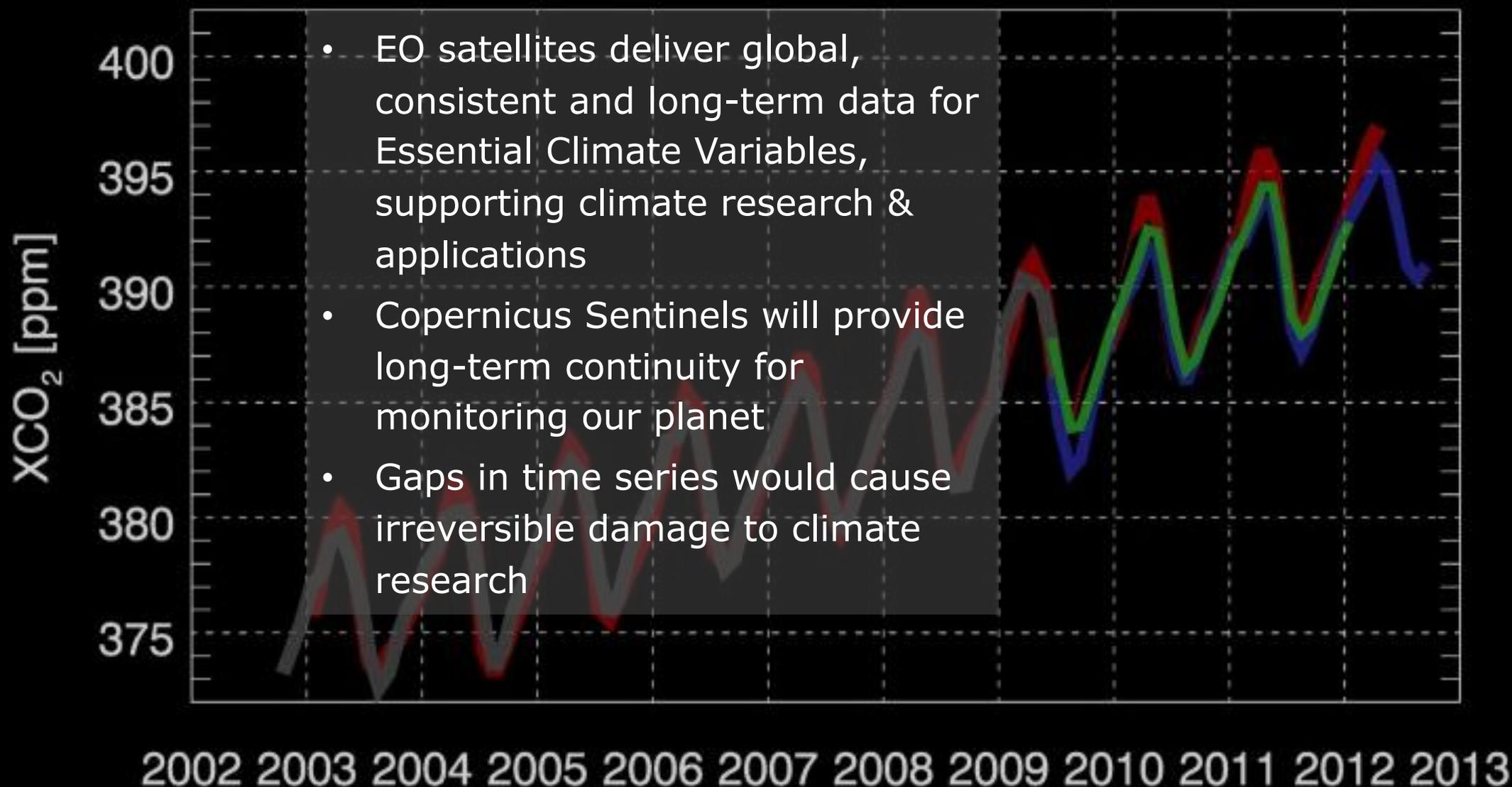
Jason-CS



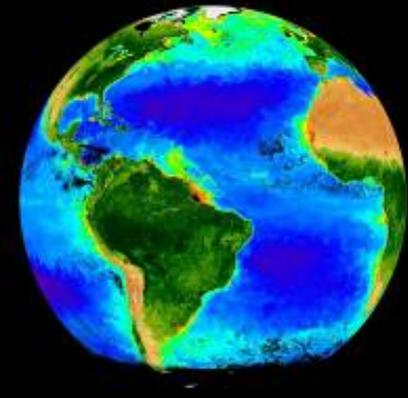
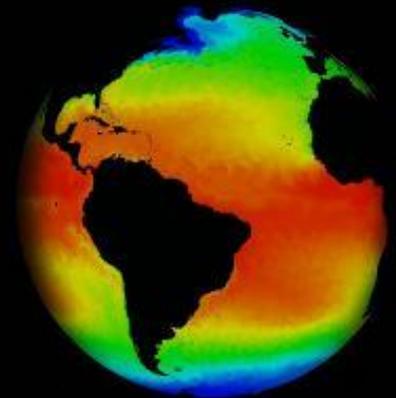
- Copernicus is a European space flagship programme led by the European Union
- ESA coordinates the space component
- Copernicus provides the necessary data for operational monitoring of the environment and for civil security



The ESA Climate Change Initiative (CCI)



- 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



The Big EO Data challenges



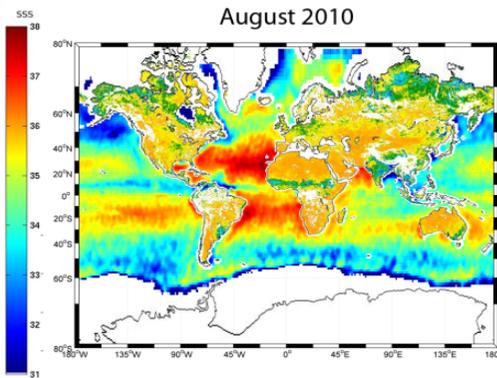
Definition of BIG DATA includes:

1. The **size** (volume) of the data sets
2. The degree of **diversity** and **complexity** within the data sets
3. The *amount of value* that can be derived from innovative analysis techniques applied to diverse and complex data sets

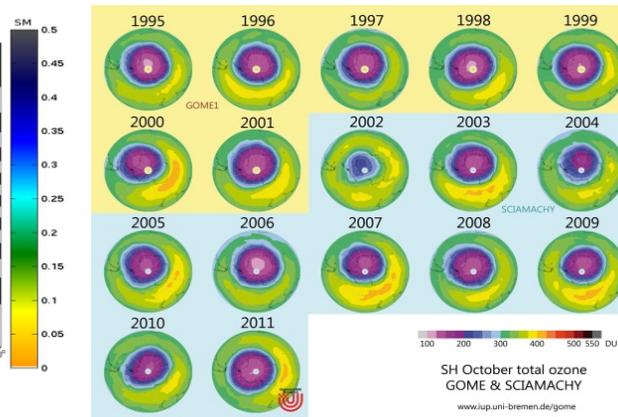
Aspects relevant for Earth Observation :

- A. Increasing **amount** of **EO space data** (past, current and new satellite data)
- B. Increasing **diversity** of **EO space data** (in media, formats and processing)
- C. Increasing **amount and diversity** of **non-space data** used in conjunction with EO space data (e.g. ground GPS measurements, marine buoys measurements, atmospheric plane measurements, etc...)

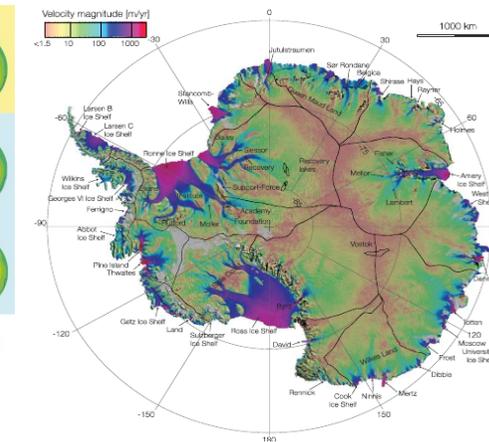
Variety of EO Data Challenges



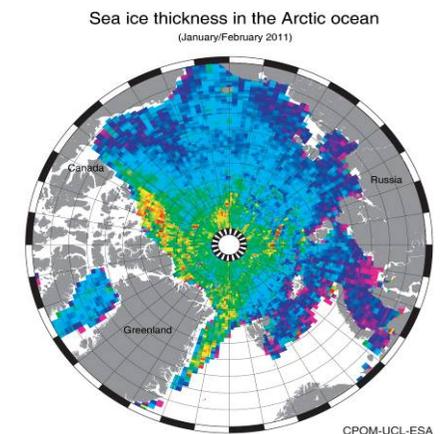
Data volume



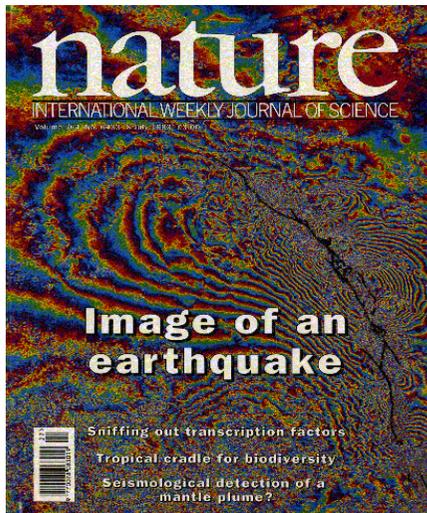
Data continuity



Data sharing



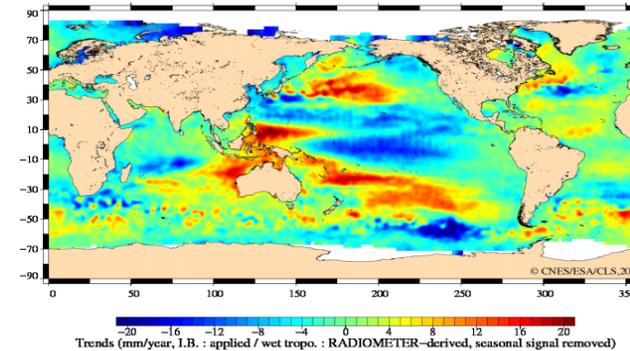
Data quality



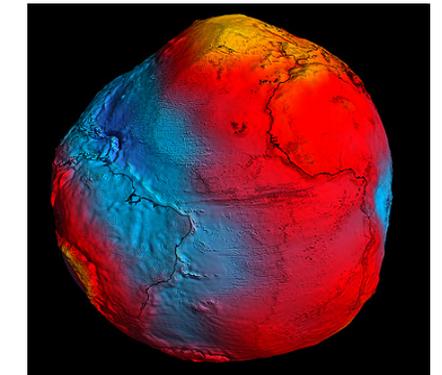
Innovation



Timeliness



Synergy with other missions

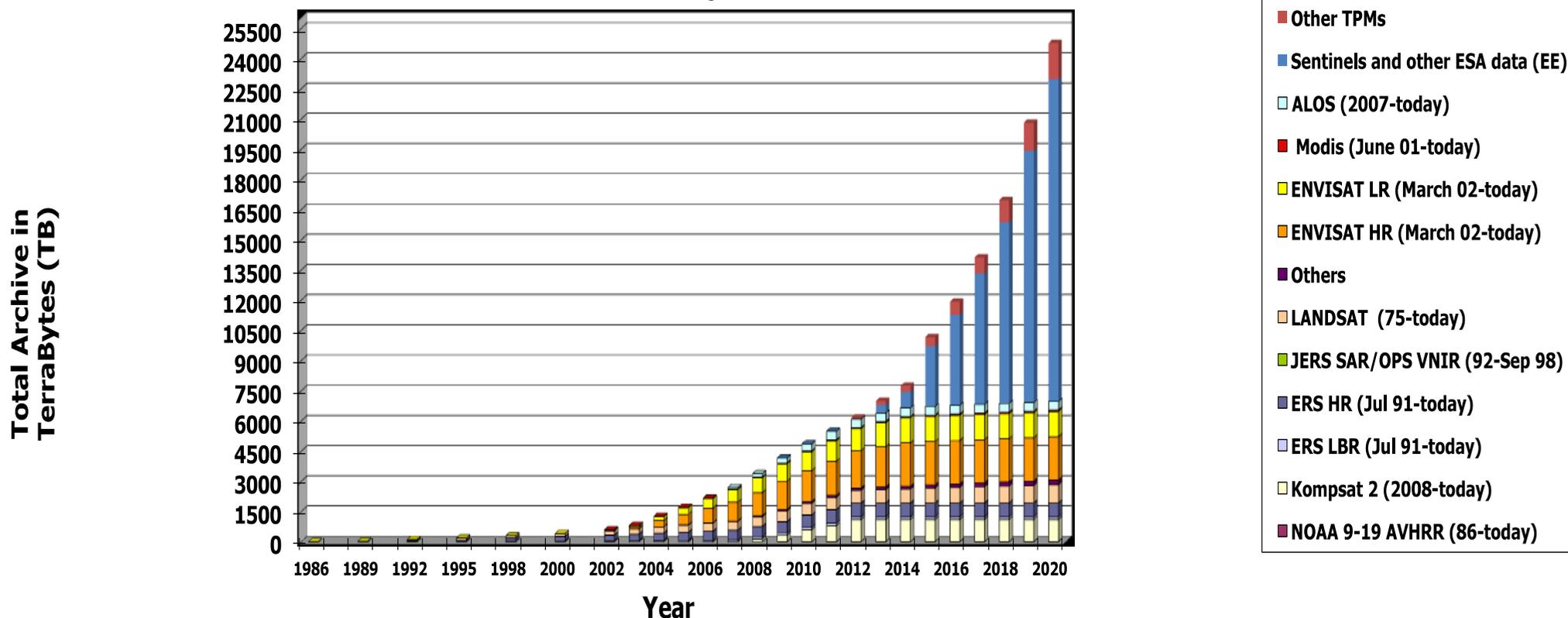


Uniqueness

Increasing Volume of EO space data



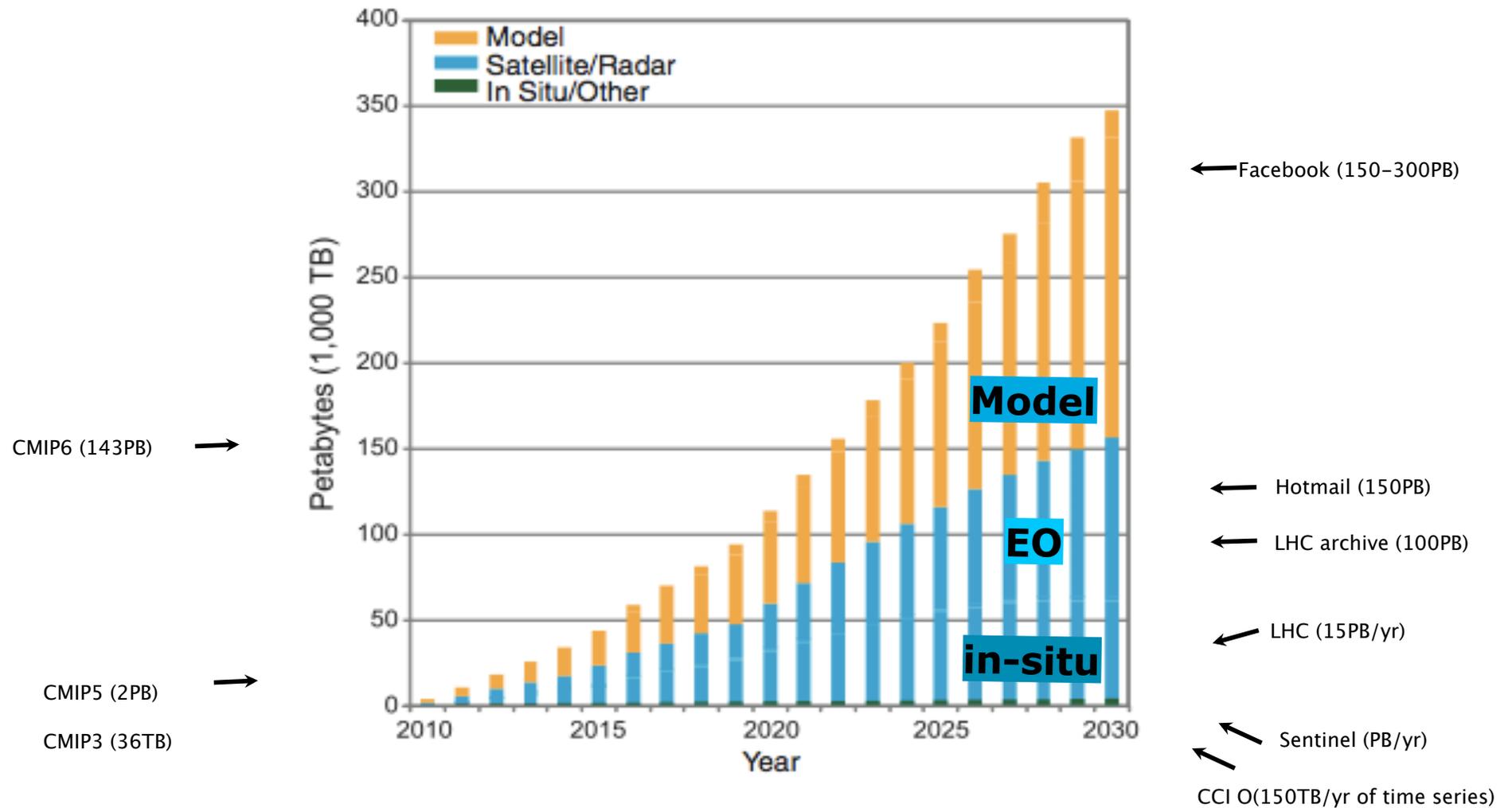
Evolution of ESA's EO Data Archives between 1986-2010 and future Projections



→ New data volume increasing fast

→ Old data gaining value (e.g. climate change studies)

Climate Data Deluge



Increasing diversity of EO data media



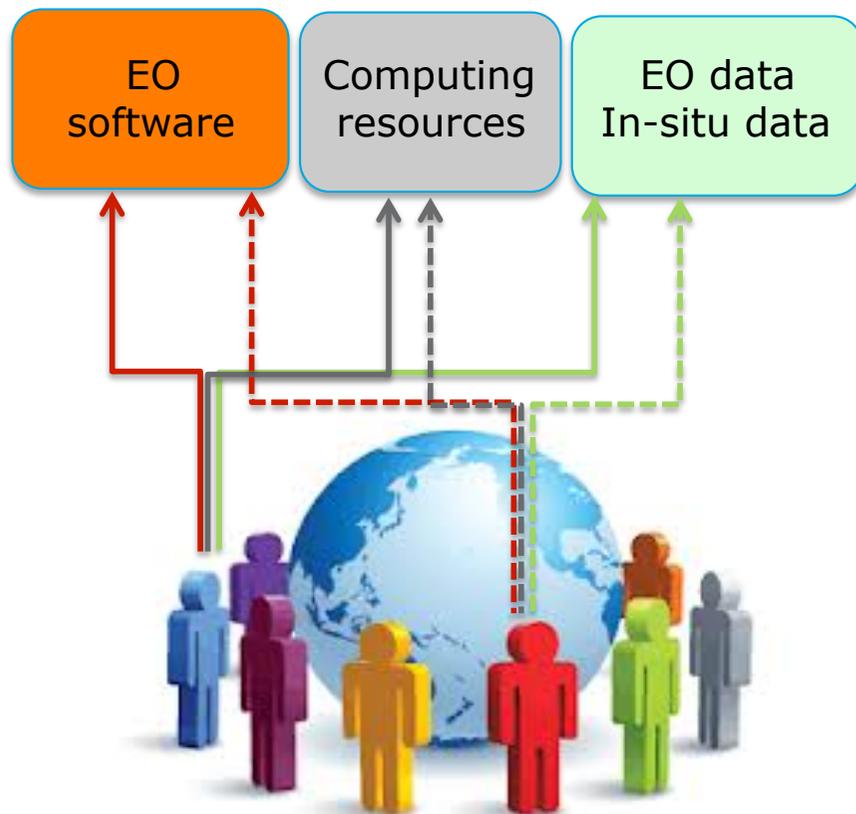
Data from some 30 different EO missions from 15 owners for >50 instruments

Transcription
Reformatting
Reprocessing

→ **Diversity of Historical Data is the challenge not new data**



Legacy model: Move the data to users' computers



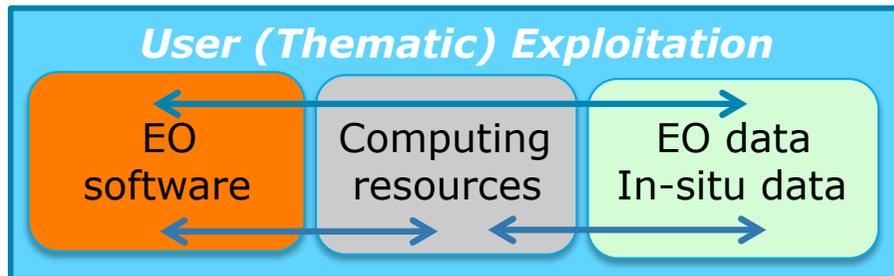
Legacy model: data and software distributed to users. Transferred many times; replicated in many places; loose user network.

But usage of large amount of data opens big opportunities for research and requires new approaches and services (e.g. exploitation platforms for e-collaboration)

New Paradigm of Exploitation Platforms



New model: Move the users' computers to the data



Legacy model: data and software distributed to users. Transferred many times; replicated in many places; loose user network.

New model: users access a platform work environment containing the data and resources required, as opposed to downloading and replicating the data 'at home'.

A scenario for data intensive scientific exploration (but not only) - complementing - but not replacing - the traditional model.

Exploitation Platform = Virtual Environment bringing together Data Center + Computing Resources + Third Party Tools + Workflows + Integrated User Interface + Documentation + Collaborative Tools + Help desk (social network) around a thematic domain.

ESA Super Sites Exploitation Platform - archive



GEO Geohazards Supersite :: OpenSea... x Helix Nebula - The Science Cloud, Re... x +

eo-virtual-archive4.esa.int

geo supersites

GEO Geohazards Supersite

Group on Earth Observations

Search Search

Found 56360 results in 15 digital repositories From 1 Jan, 1992 to Jan 11, 2013

Orbits from to
Tracks from to
Frames from to
Paths All

About Search My Data

ASAR Image Mode source packets Level 0 (ASA_IM_OP)
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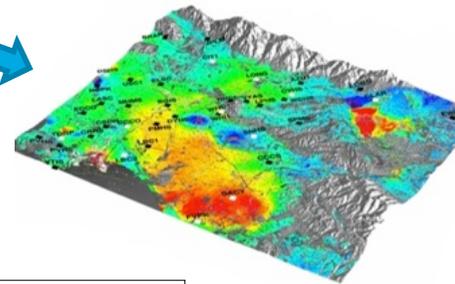
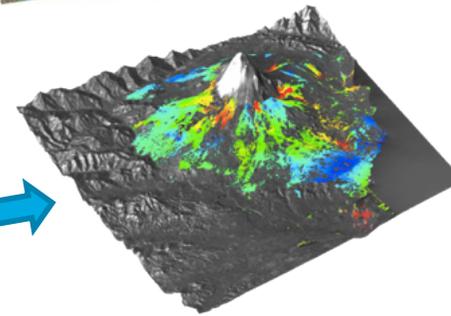
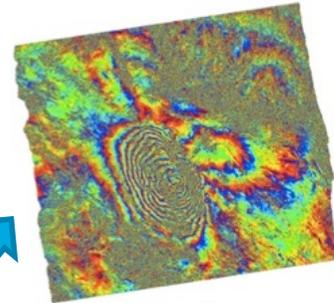
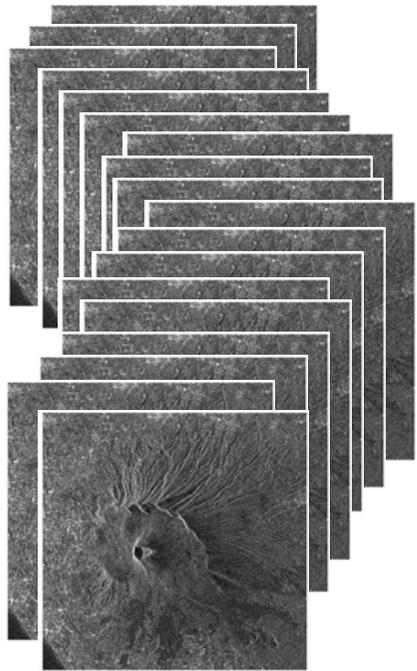
ERS-2 SAR Image SAR Annotated Raw Data Product Level 0 (ER02_SAR_RAW_OP)
[Found 12234 results] [Showing from 0 to 19] first next last

ER02_SAR_RAW_OP_20100118T174929_20100118T174945_ESR_77106.
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The download of products requires a EO Single Sign On username/password. You can log in when accessing the data or login [here](#). To register go [here](#).

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ESA Super Sites Exploitation Platform - processing



Earthquakes



Volcanoes



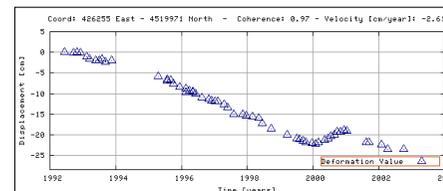
Oil & Gas



Water Resources
European Space Agency

Cloud Processing

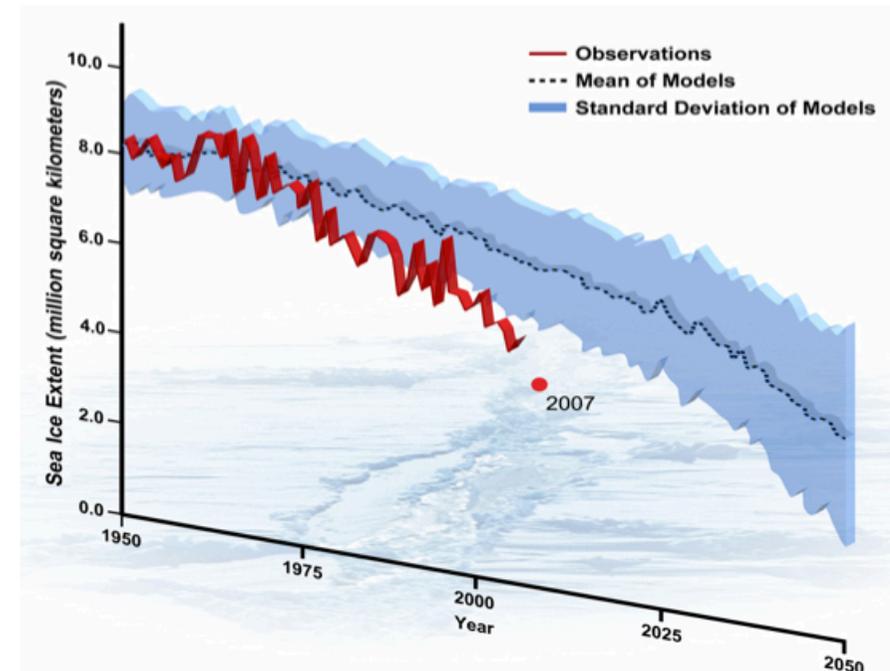
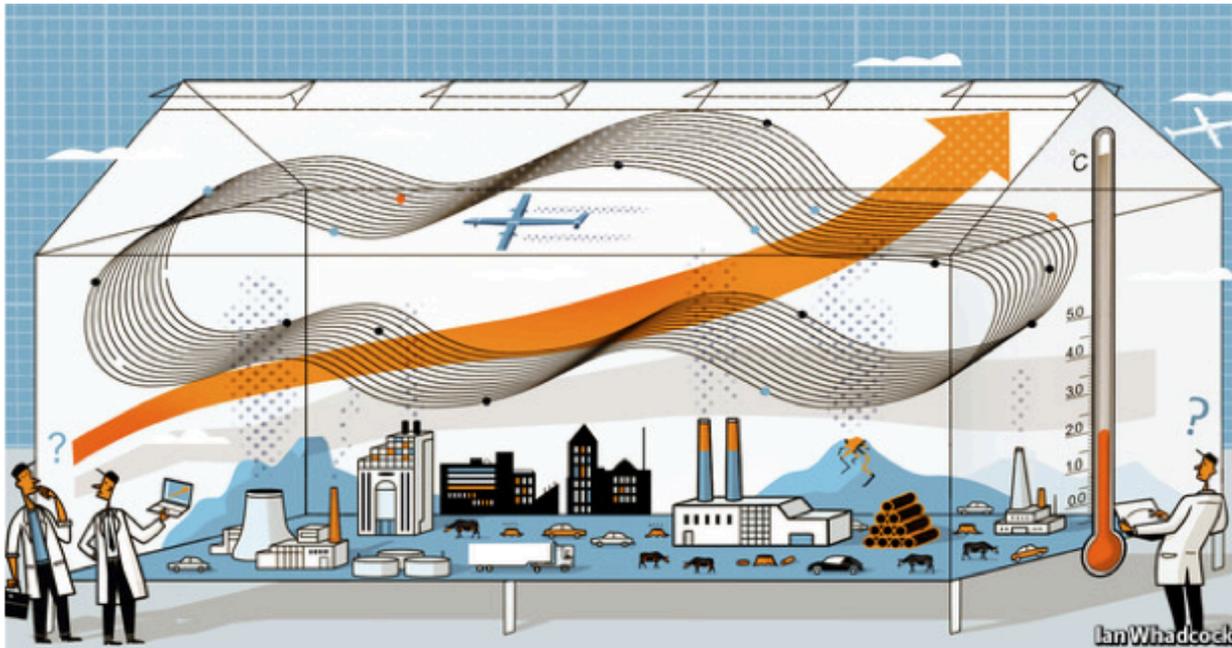
~150 Satellite images/250 GB (per area)



Confronting Data & Models

Climate science

A sensitive matter





"Data can be equated with money that has value only if it is used and circulated. As the different currencies can be stored in the globally interrelated bank infrastructures, we need persistent, highly available and compatible data infrastructures where data from various disciplines can be stored and fetched from."

PARADE - Partnership for Accessing Data in Europe14.

European Space Agency