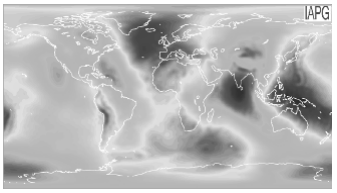
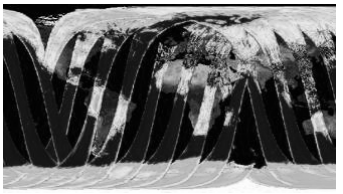
Satellite Missions for Climate Observations





Prof. Volker Liebig

Director, ESA Earth Observation Programmes

Alpbach, Austria, 27 July 2010

Earth Observation: *headlines 2009 / 2010*

BBC Home News Sport Weather TV Radio More...

NEWS Watch ONE-MINUTE WORLD NEWS

'Tuned' images from Esa's Smos water mission

Glacier-melting debate highlights importance of satellites

1 February 2010

The intense public debate on

5.19.2010 12:22 pm

BP Gulf Oil Spill Visible from Space (Pictures)

Telegraph.co.uk

Envisat keeping an eye on the Eyjafjallajoekull volcano

21 April 2010

Shocking new satellite images of Haiti show scale of earthquake devastation

FEATURES & SPECIAL REPORTS

Satellites help conserve Egypt's wildlife

BBC NEWS 2 WEEKS AGO

Cryosat-2 focuses on ice target

Cryosat has to be able to distinguish the floes from the leads The Cryosat-2 mission is delivering on its promise to make high-precision radar measurements of polar ice. The first data from the European spacecraft has been presented at... FULL ARTICLE AT BBC NEWS

Satellite Data Instrumental In Combating Desertification

Science Daily 2009

Science News

Value Of Satellites Recognized For Conserving Wetlands

ScienceDaily (Nov. 25, 2008) — Wetlands contribute to our lives in remarkable ways by

enlarge

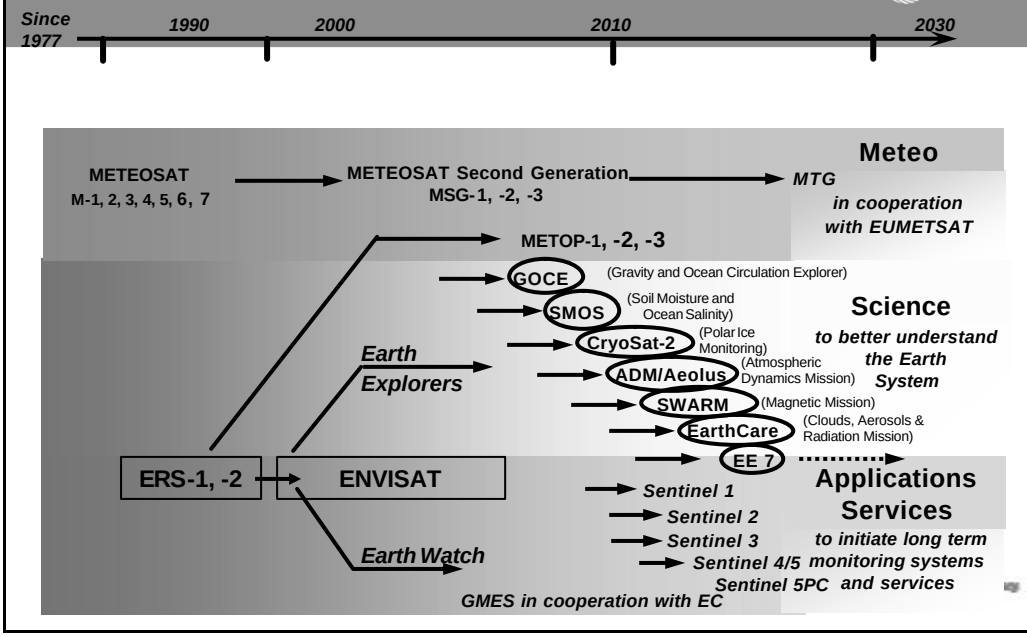
September 21, 2009 | 1 comments

http://www.scientificamerican.com/article.cfm?id=ozone-layer-depleti

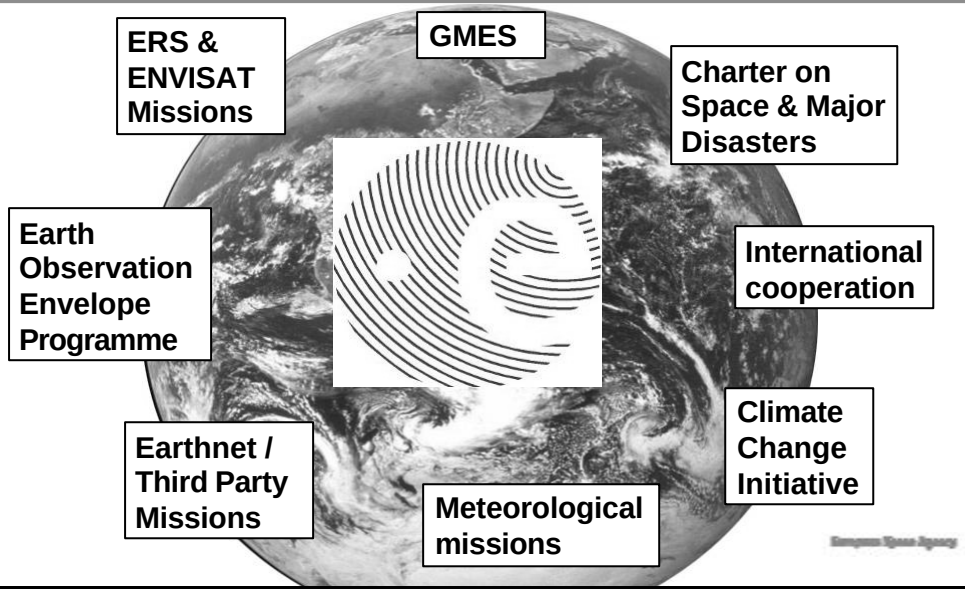
Ozone layer depletion levelling off

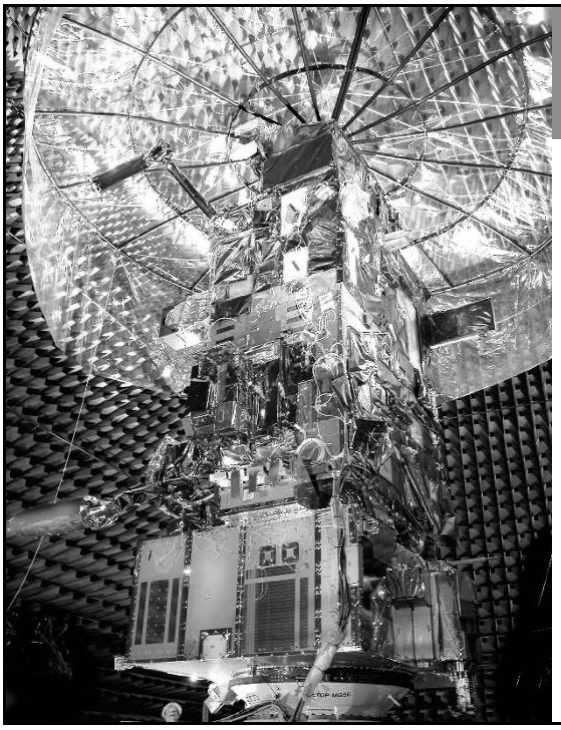
By merging more than a decade of atmospheric data from European satellites, scientists h compiled a homogeneous long-term ozone record that allows them to monitor total ozone trends on a global scale - and the findings look promising.

EO development

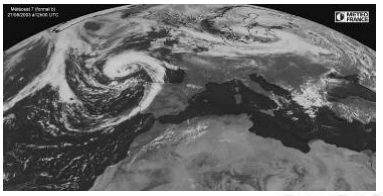


ESA Earth Observation

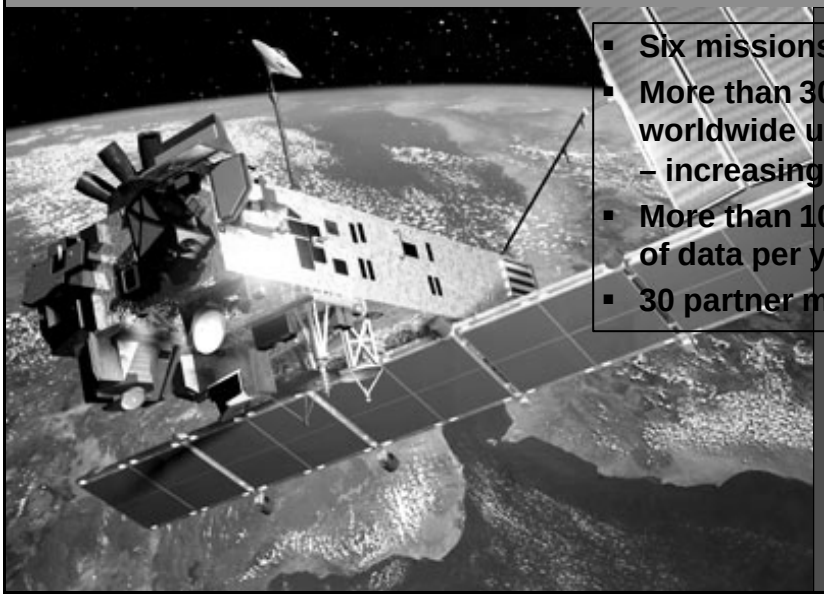




- **Weather satellites -> first “operational” field of EO**
- **MeteoSat series since 1978, now in second generation, soon MTG**
- **Cooperation with EUMETSAT**

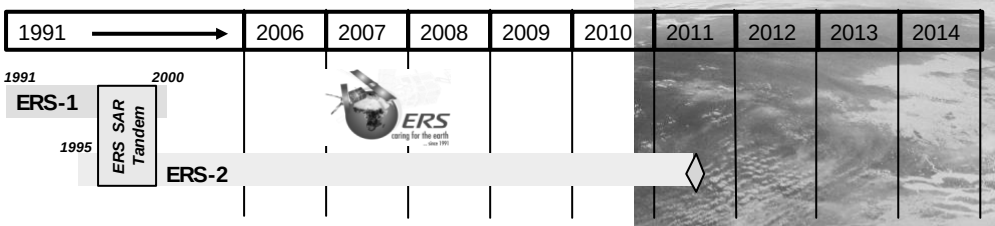


In orbit: ESA Earth Observation missions



- **Six missions in space**
- **More than 3000 projects worldwide use their data – increasing further**
- **More than 100 Terabyte of data per year**
- **30 partner missions**

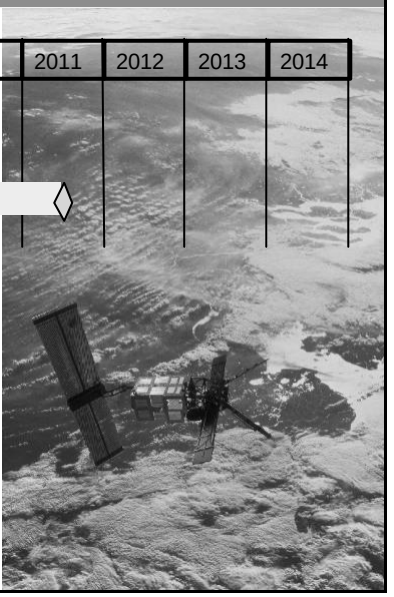
In orbit: 15 years of ERS-2



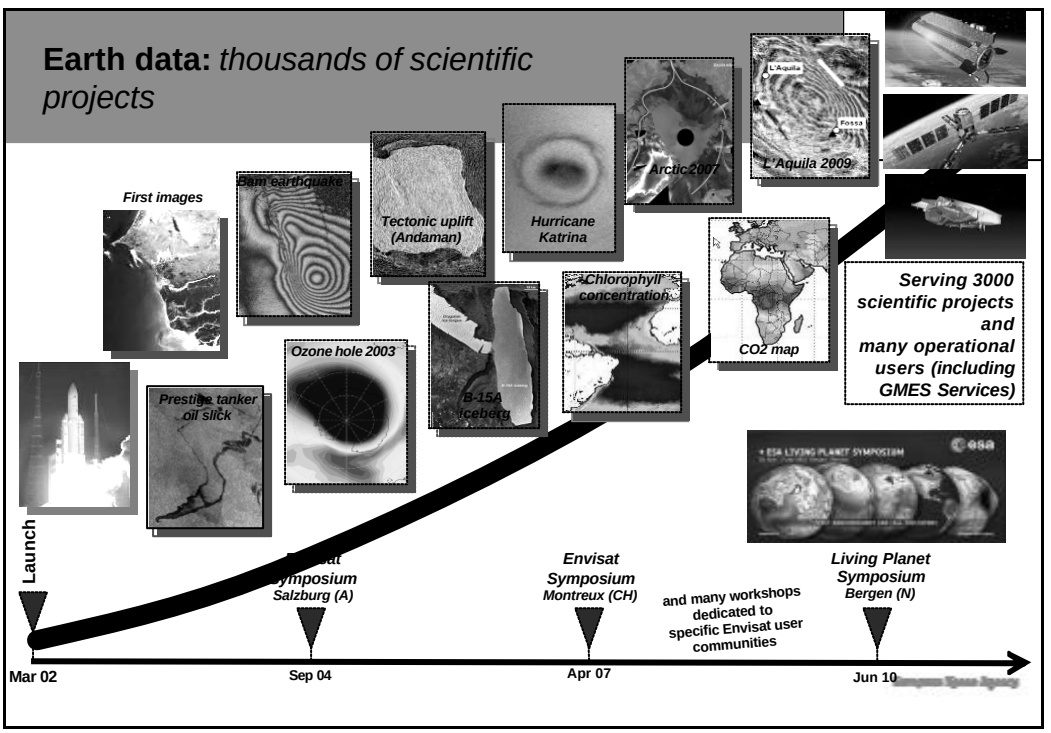
ERS-2 reached <u>15 years</u> of operations in April 2010

- ✓ *designed for 3 years nominal lifetime*
- ✓ *no gyroscopes since 2001: gyro-less operations*
- ✓ *no on-board recorders: network of acquisition stations provides a good coverage*
- ✓ *all instruments (but ATSR) work satisfactorily*

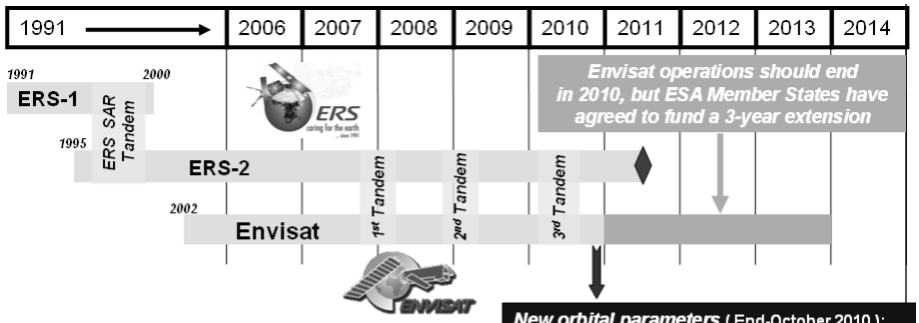
➔ ***ERS-2 mission should be operated until mid-2011***



Earth data: *thousands of scientific projects*



Envisat mission **extension**



Envisat operations should end in 2010, but ESA Member States have agreed to fund a 3-year extension

New orbital parameters (End-October 2010):
- Altitude change: -17.4 km
- Repeat cycle: 30 days / 431 orbits
- Orbit control: altitude control with inclination drift
- Mean Local Solar Time variation: +/- 10 min.

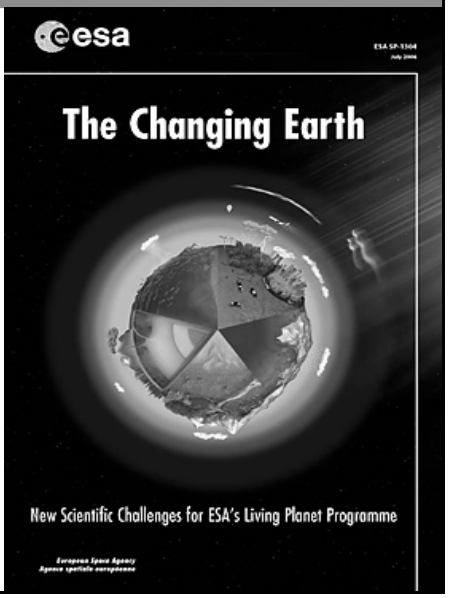
Efficient consumption of on-board hydrazine allowed operating nominally Envisat until 2010 (nominal 5-years lifetime ended in Feb. 2007), but most of hydrazine is now consumed.

The Envisat 3-years extension requests a modification of the orbital parameters in October 2010 to be able to operate the satellite with minimum hydrazine.

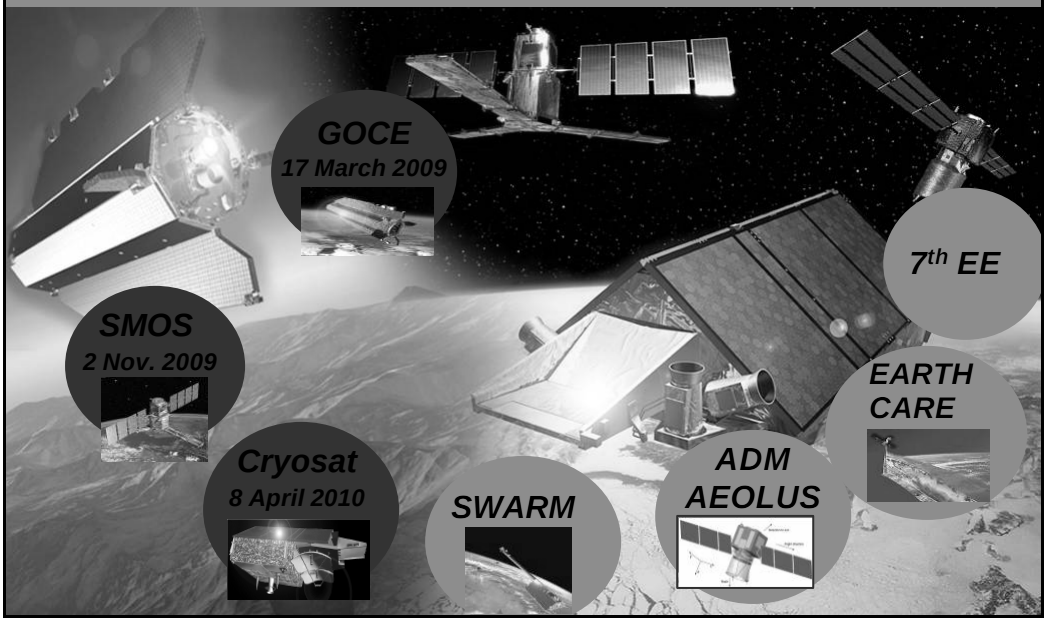
ESA's Science Strategy

The science strategy for ESA's Living Planet Programme:

- **Launch a steady flow of missions addressing key science issues**
- **Provide an infrastructure to allow quick and efficient satellite data exploitation**
- **Contribute to global Earth Observation capabilities**
- **Provide an efficient and cost-effective process for science priorities to be rapidly translated into space missions**



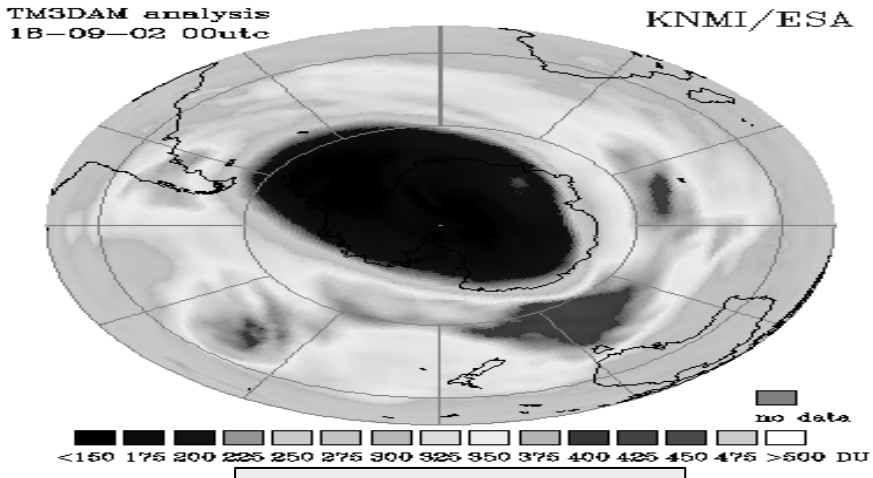
The Earth Explorer Missions



The atmosphere from space

- Our atmosphere **supplies** us with air and **protects** us against harmful radiation
- Satellite sensors can **map** the atmosphere's composition, **detecting** holes in the ozone layer, plumes of aerosols and pollutants, burning forests and exhaust trails left by aircraft
- Satellites can map changes in our atmosphere that provide **reliable indicators** for **global warming**

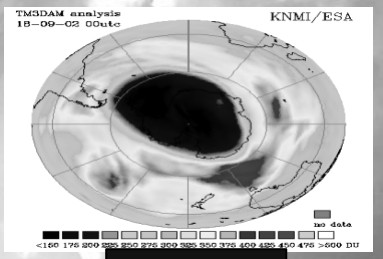
Ozone hole seen from Envisat

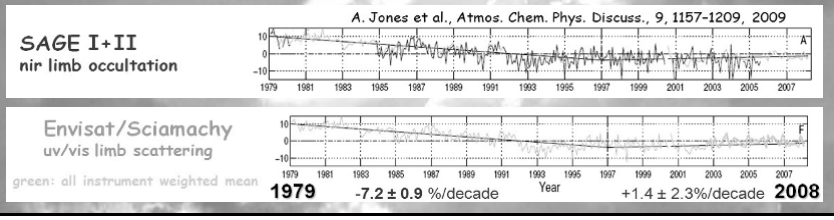


Recent scientific headlines of Earth Observation: Ozone

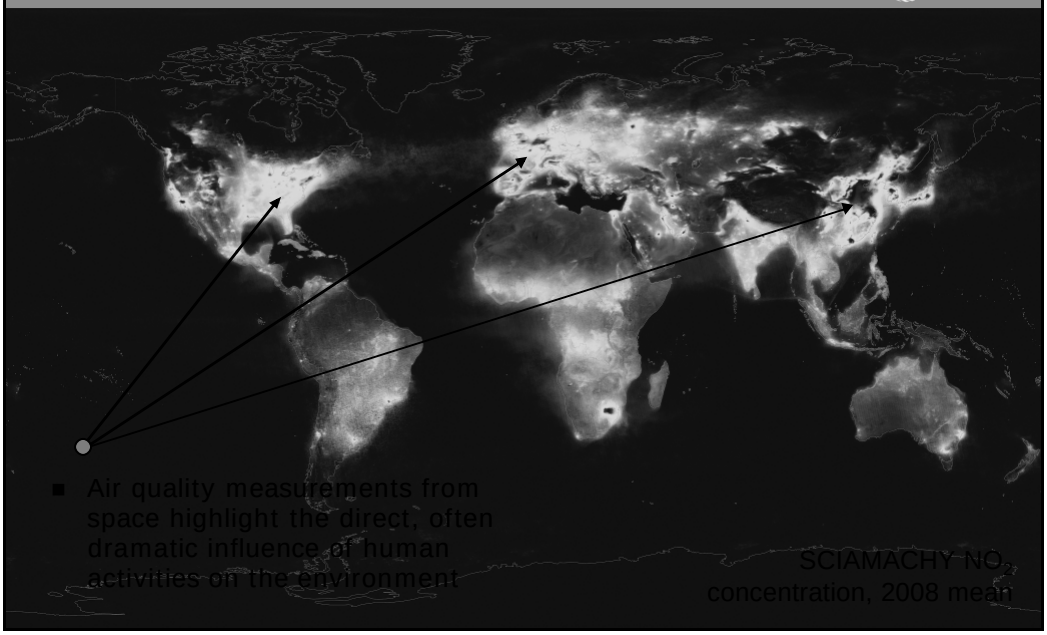
Ozone layer depletion levelling off

Slightly positive trend of global ozone increase of almost 1% per decade in the total ozone from the last 14 years
(result confirmed by comparisons with ground-based measurements)





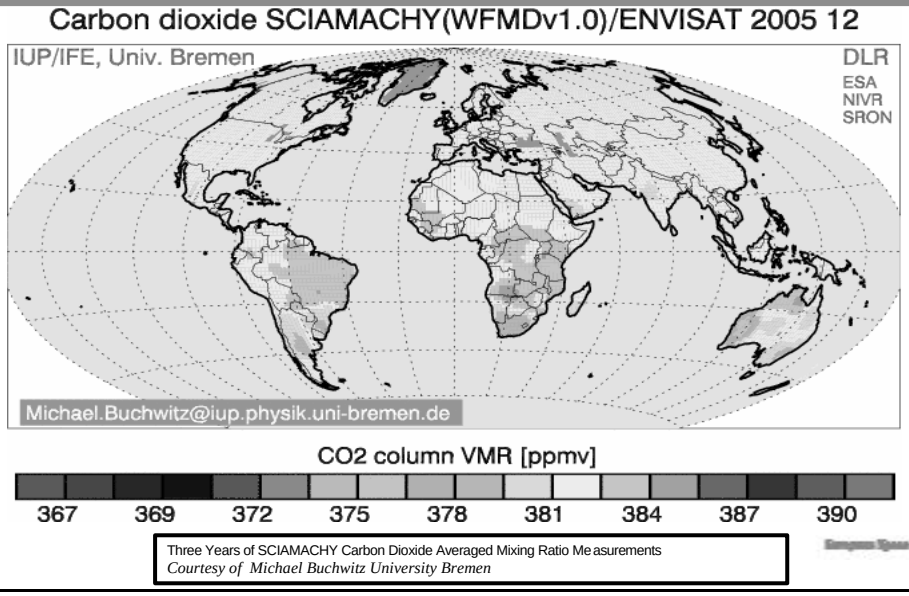
The changing air quality



- Air quality measurements from space highlight the direct, often dramatic influence of human activities on the environment

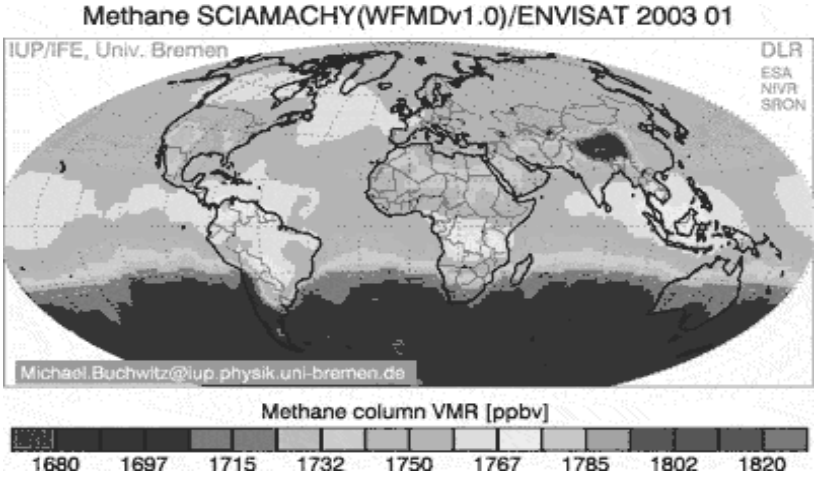
SCIAMACHY NO_2 concentration, 2008 mean

CO2 seen from Envisat



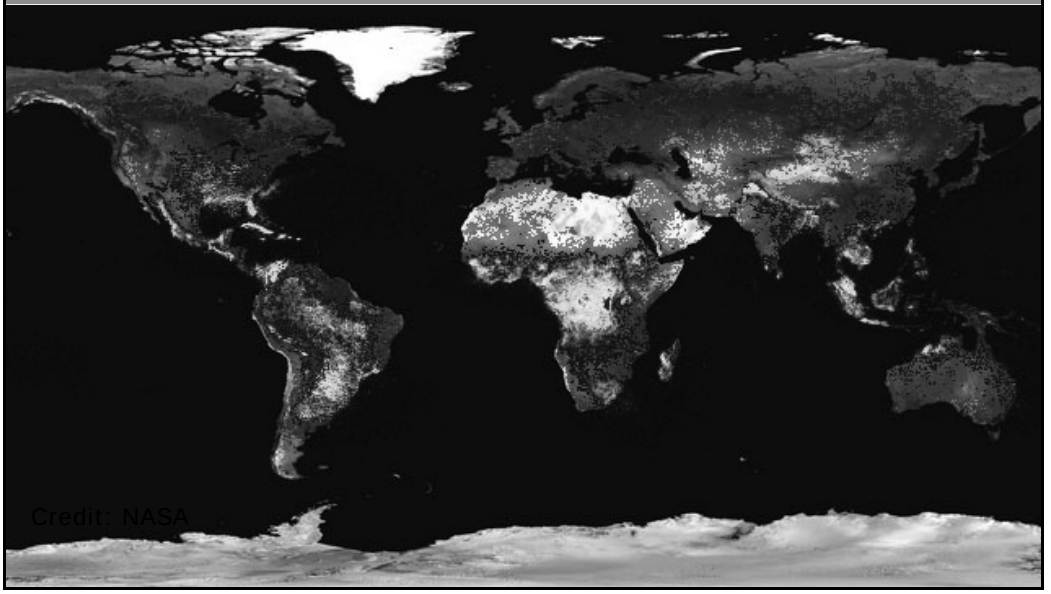
Three Years of SCIAMACHY Carbon Dioxide Averaged Mixing Ratio Measurements
Courtesy of Michael Buchwitz University Bremen

Methane seen from Envisat



Three Years of SCIAMACHY Methane Column Averaged Mixing Ratio Measurements
Courtesy of Michael Buchwitz University Bremen

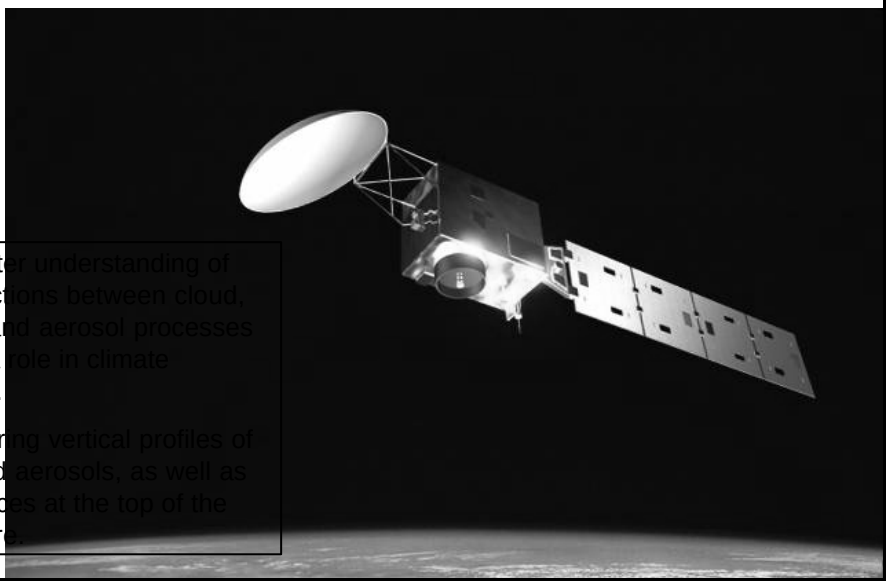
Global lightning map



ADM-Aeolus – ESA‘s wind mission

- **to provide global observations of wind profiles from space** *(+ cloud top heights, vertical distribution of cloud, aerosol properties and wind variability)*
- to improve the quality of weather forecasts and our understanding of atmospheric & climate processes
- ADM-Aeolus will utilise the **active Doppler Wind Lidars (DWL)** method.
- This is the only method that can provide the required data globally.

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.
- by acquiring vertical profiles of clouds and aerosols, as well as the radiances at the top of the atmosphere.

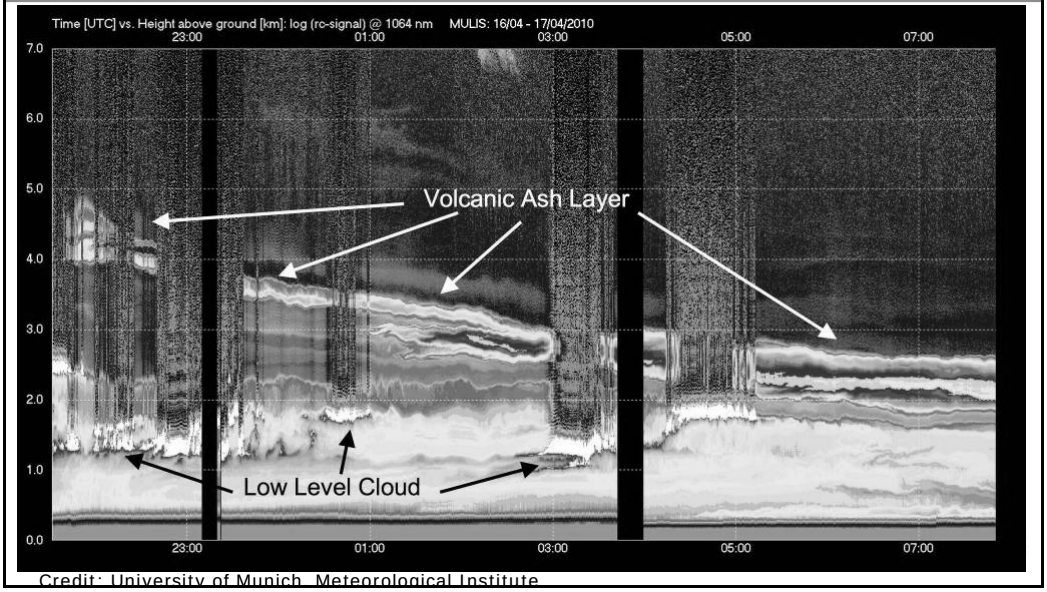
Volcanic ash cloud monitoring

Eruption of the Icelandic volcano Eyjafjallajoekull (April-May 2010):

- *Optical images from space (Envisat)*
- *Ground-based network of LIDAR stations (Earlinet)*
- *ADM-Aeolus and EarthCARE will provide essential new information*

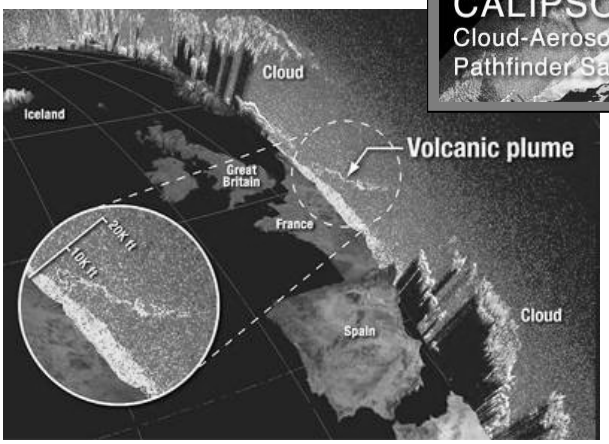
Volcanic plume from FALCON aircraft [redacted]

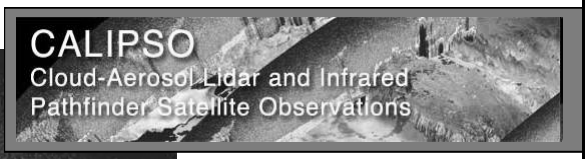
Volcanic ash cloud monitoring: ground-based LIDAR (Munich, Germany, 16-17 April)



Credit: University of Munich, Meteorological Institute

Volcanic plume from space – NASA CALIPSO





CALIPSO is a joint NASA (USA) and CNES (France) mission (launched in 2006)

Passive and active instruments onboard the CALIPSO satellite monitor aerosols and clouds 24 hours a day.

Credit NASA

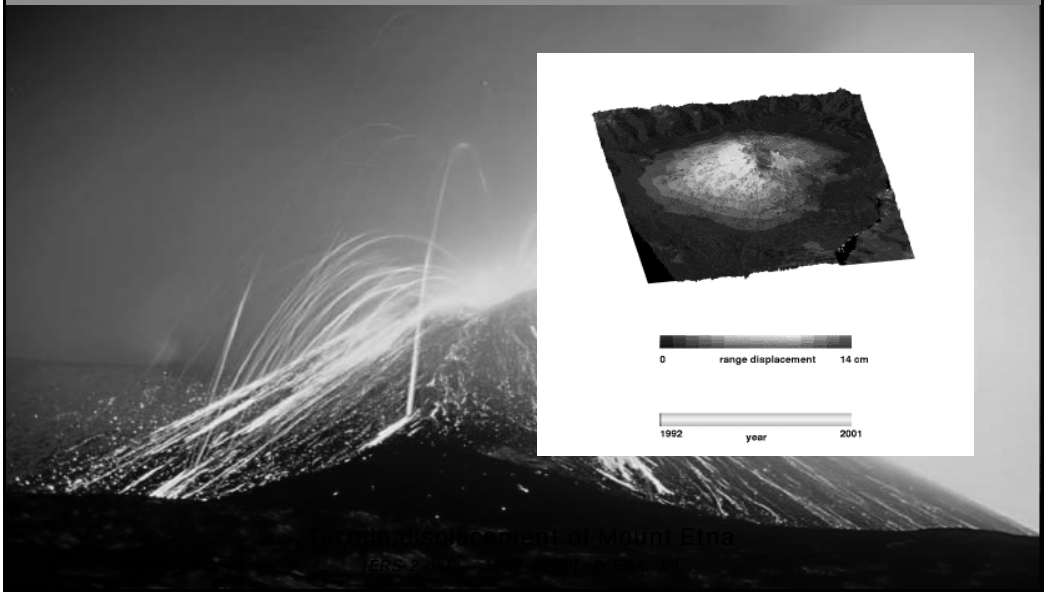
Earth Surface Monitoring

me Ground

- Satellite observations let us know our **home planet in greater detail** than ever before
- They enable the objective **global classification** of surface land cover, mapping the distribution of forests, deserts, water bodies, agricultural land and human settlements
- They can also be used to **precisely measure** surface topography

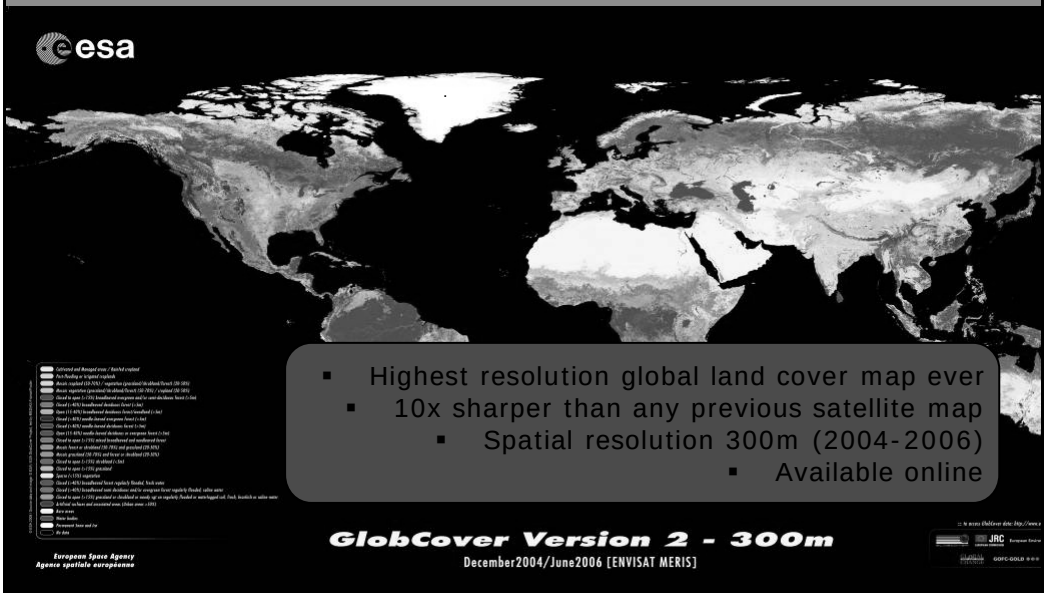
Ground Motion Monitoring from Space

The breathing of a vulcano



Terrain displacement of Mount Etna

ESA Global Land Cover Map



- Highest resolution global land cover map ever
- 10x sharper than any previous satellite map
- Spatial resolution 300m (2004-2006)
- Available online

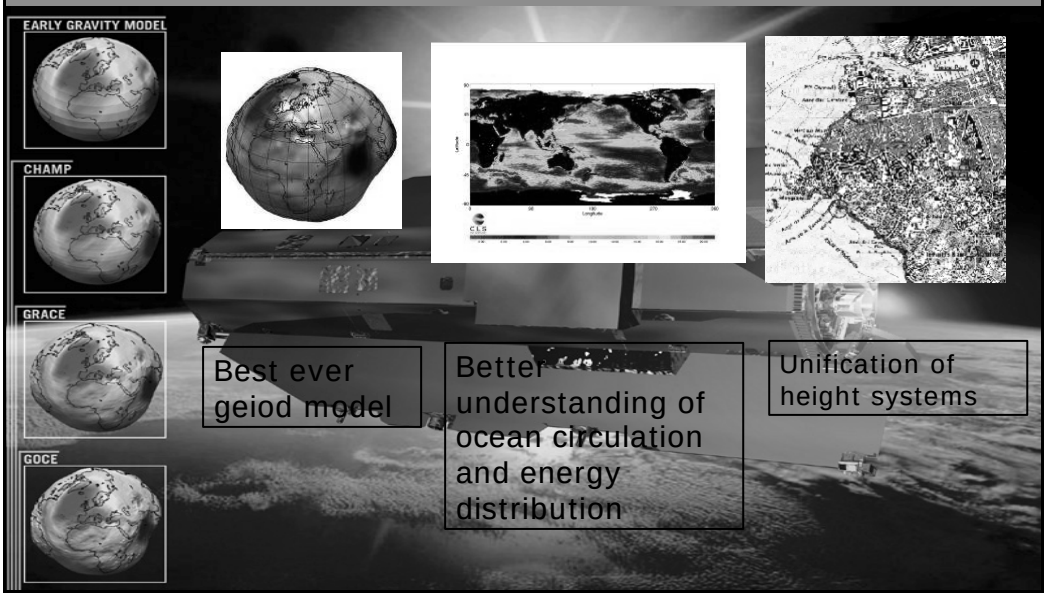
GOCE – *the gravity mission*

- **In space since March 2009**
- **Third measurement cycle of the Earth's gravity field**

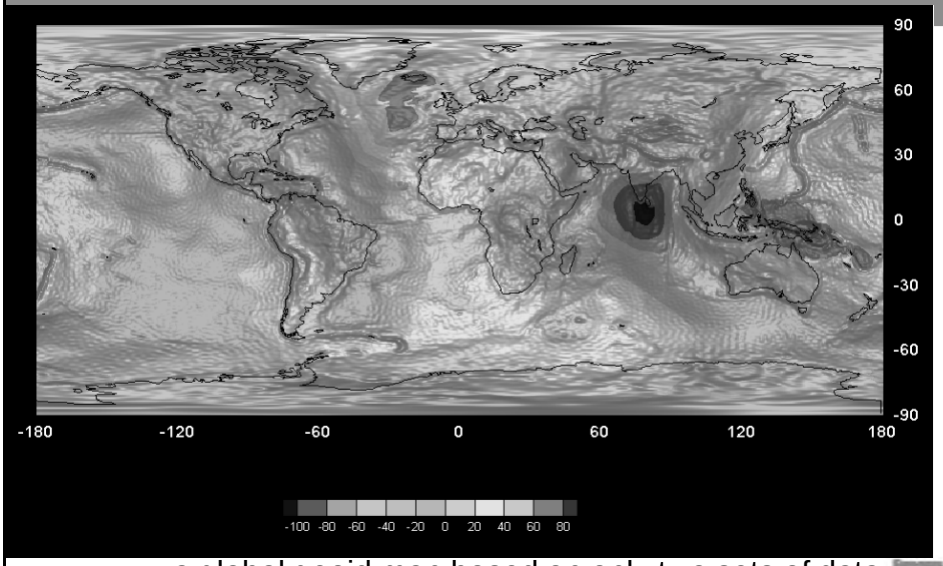
A unique mission:

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

GOCE – *applications*



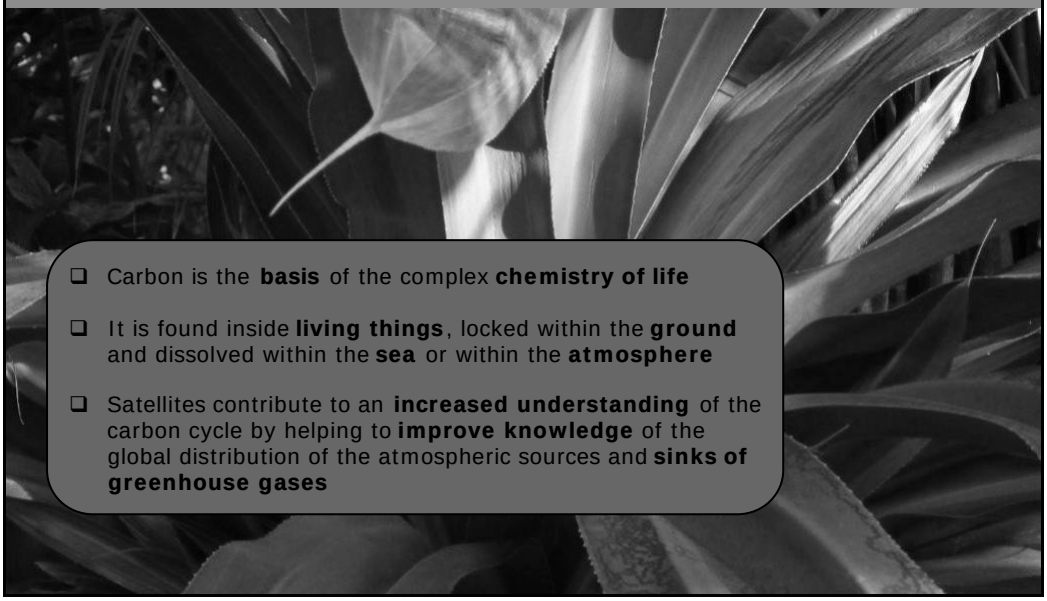
GOCE gravity field



a global geoid map based on only two sets of data

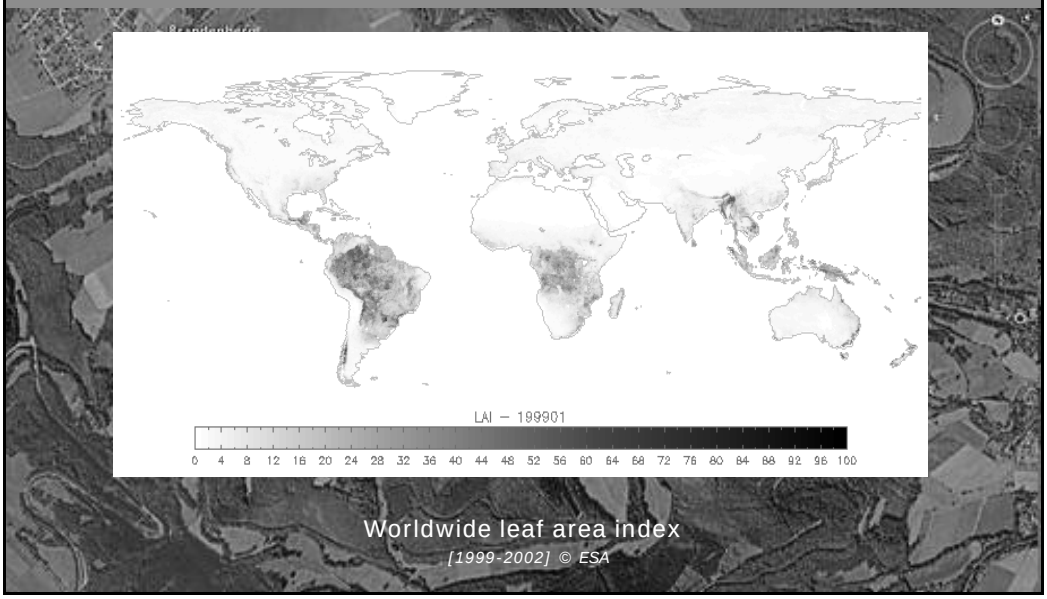
Urban development

Carbon counting from space



- Carbon is the **basis** of the complex **chemistry of life**
- It is found inside **living things**, locked within the **ground** and dissolved within the **sea** or within the **atmosphere**
- Satellites contribute to an **increased understanding** of the carbon cycle by helping to **improve knowledge** of the global distribution of the atmospheric sources and **sinks of greenhouse gases**

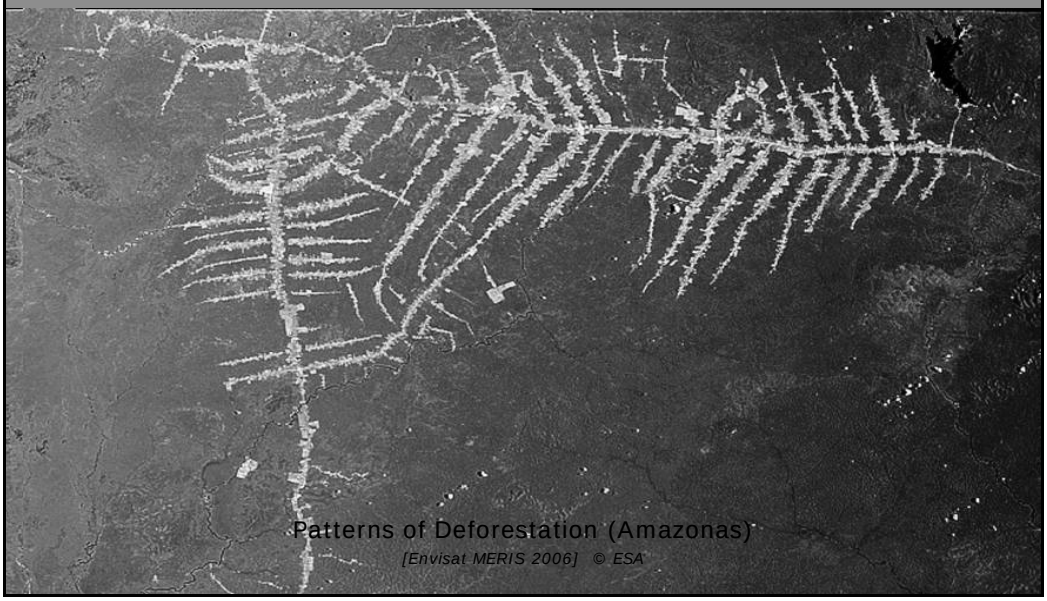
Worldwide leaf area seen from space



Worldwide leaf area index

[1999-2002] © ESA

Land use & human impact

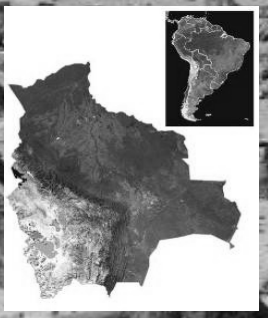


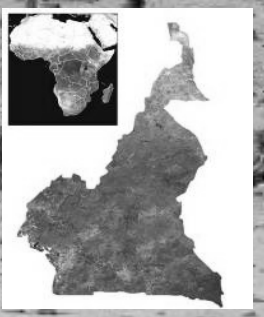
Patterns of Deforestation (Amazonas)

[Envisat MERIS 2006] © ESA

Reduction of Emission from Deforestation & Degradation *(REDD)*

- Tools to account for national Deforestation and Degradation emissions
- Opportunities for national incentive schemes and strengthened forest governance





Providers: GAF, GOFC-GOLD
Users: KfW, GTZ, governmental, UNFCCC

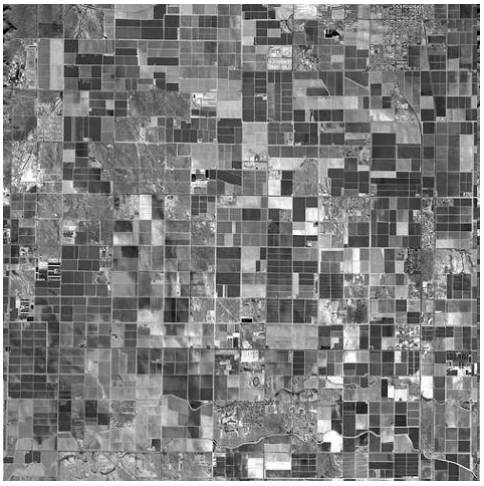
GEO Forest Carbon Tracking

- Global network of national forest carbon monitoring, reporting and verification systems

Providers: GAF, GOFC-GOLD
Users: KfW, GTZ, governmental, UNFCCC

Land use & human impact

PHOENIX

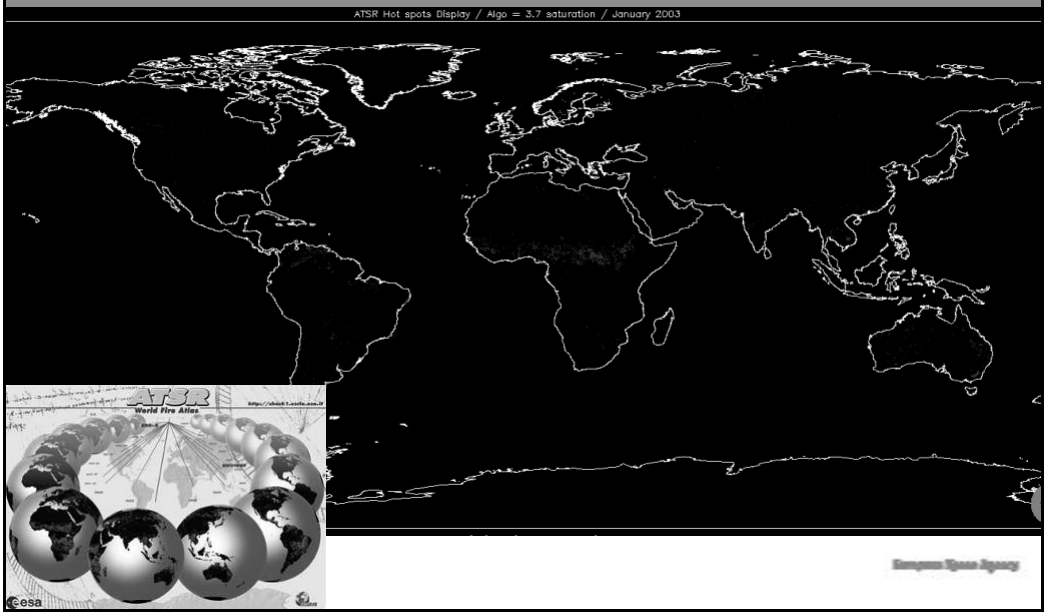


IMPERIAL VALLEY

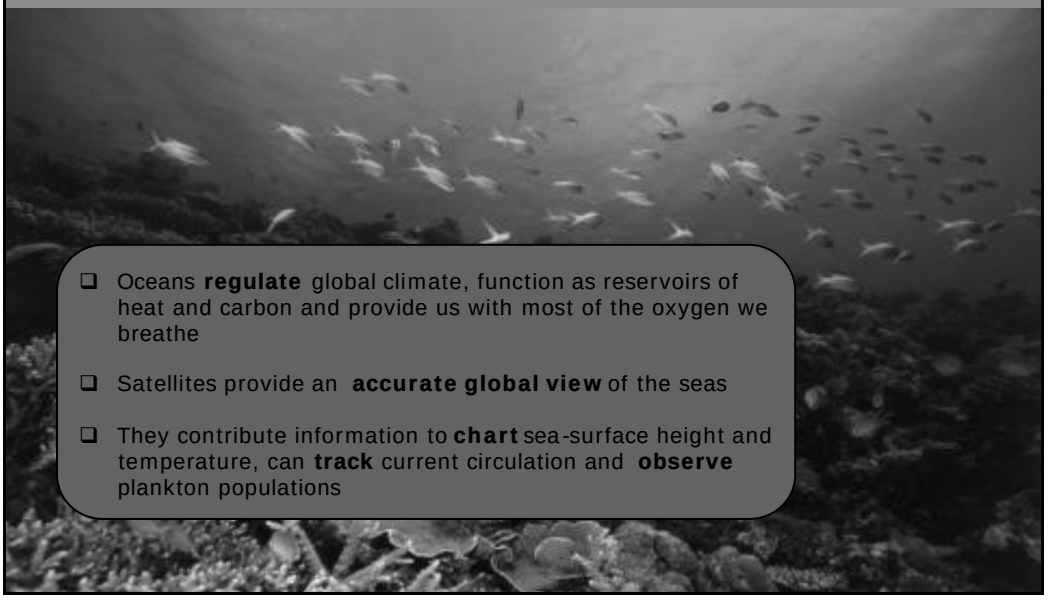
Agricultural patterns in the United States

[SPOT 2007/2008] © Spotimage

Worldwide fires seen from space

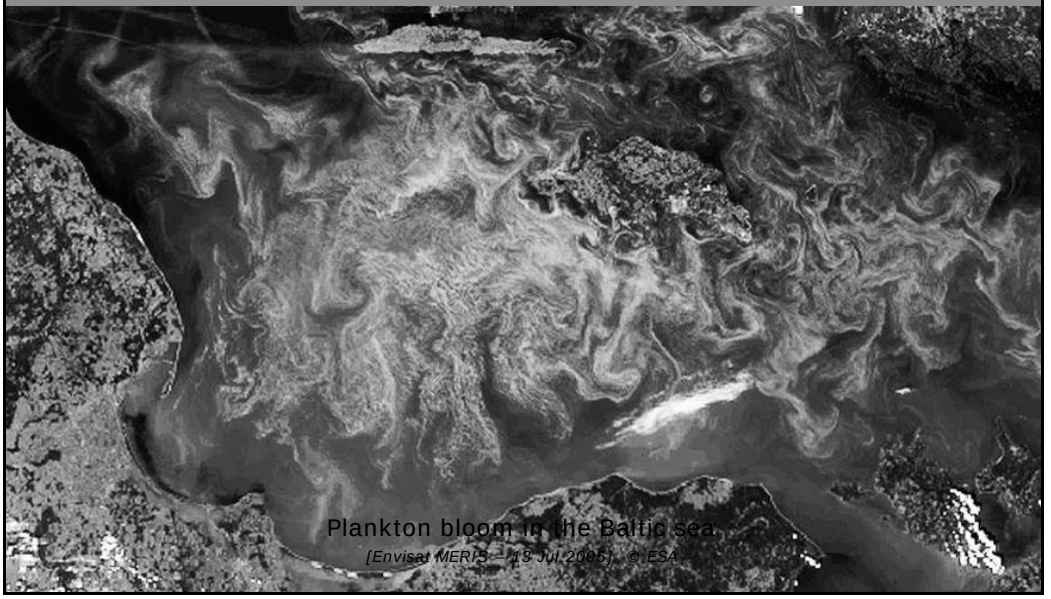


Understanding our oceans



- Oceans **regulate** global climate, function as reservoirs of heat and carbon and provide us with most of the oxygen we breathe
- Satellites provide an **accurate global view** of the seas
- They contribute information to **chart** sea-surface height and temperature, can **track** current circulation and **observe** plankton populations

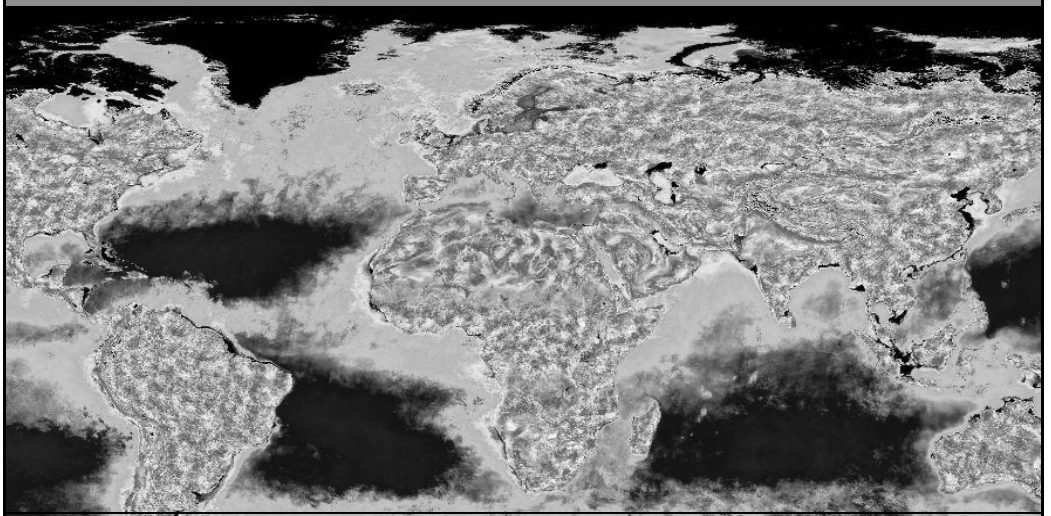
Biomass monitoring from space



Plankton bloom in the Baltic sea.

[Envisat MERIS – 18 Jul 2005] © ESA

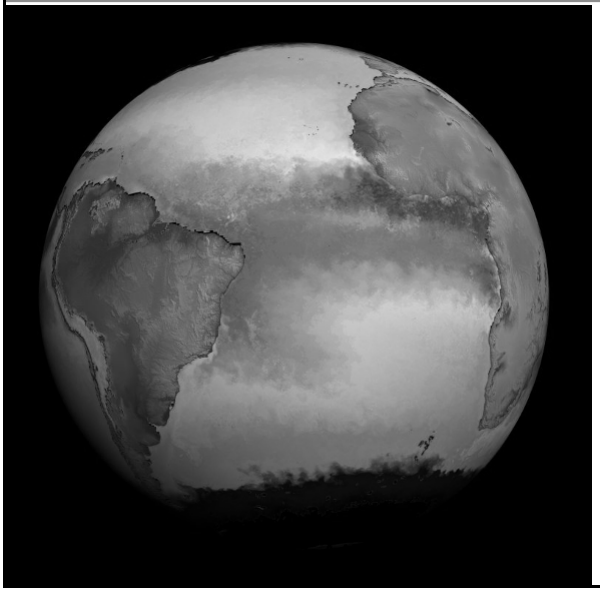
Chlorophyll monitoring from space



Chlorophyll- global concentration map

[Envisat MERIS - Mean 2008] © ESA, ACRI

Sea Surface Temperature



Working like thermometers in the sky, different satellite instruments measure SST on an ongoing basis.

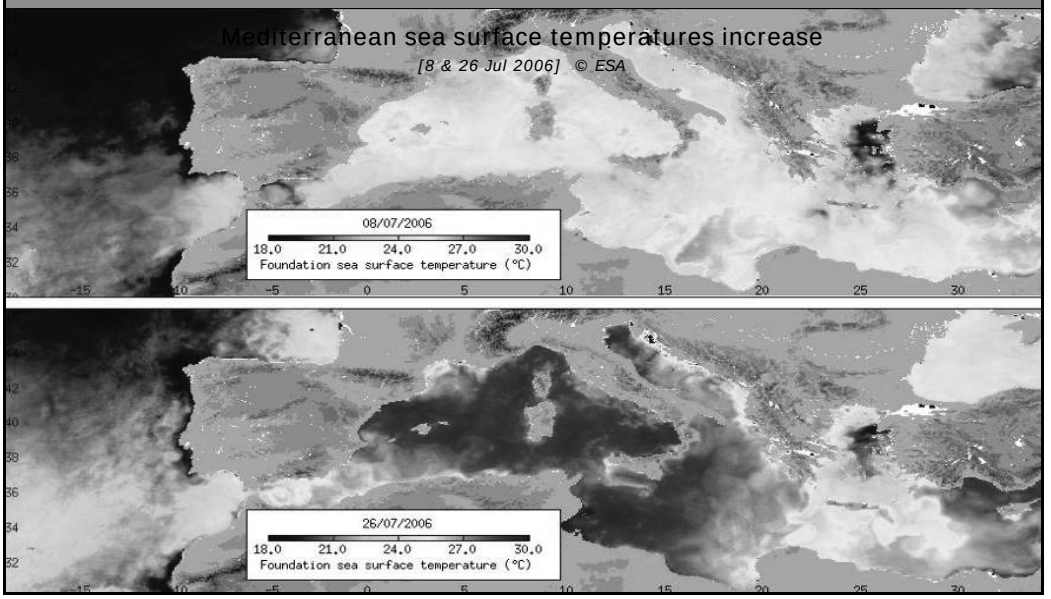
The Advanced Along-Track Scanning Radiometer (AATSR) aboard Envisat uses infrared wavelengths to acquire SST across a square kilometre of ocean to an accuracy of 0.2 °C.

Comparable data sets are availbale since 1991 (ERS-1)

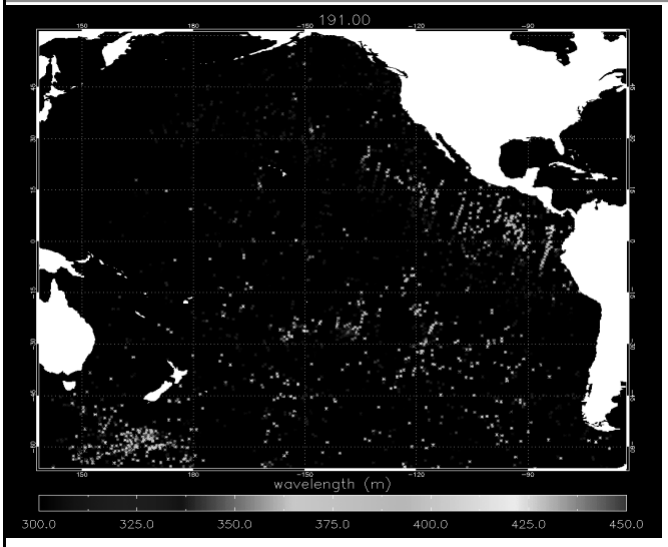
Sea Surface Temperature

Mediterranean sea surface temperatures increase

[8 & 26 Jul 2006] © ESA



Wave tracking from space



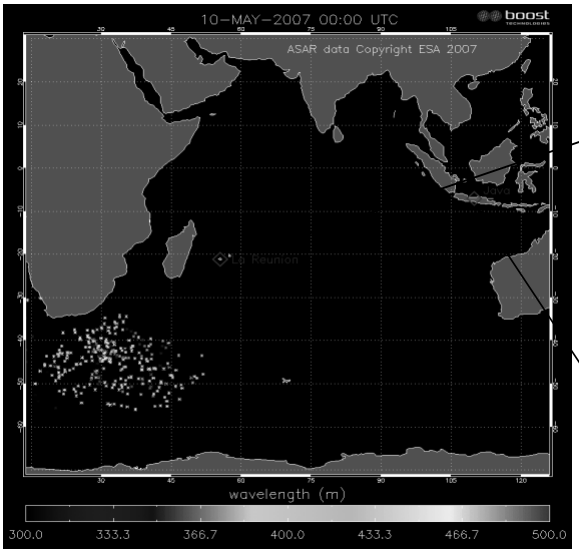
ENVISAT ASAR monitors SWELL

Courtesy of B.Chapron IFREMER and F. Collard BOOST Technologies BREST

ASAR Wave Mode tracks long swell propagating across the Pacific during 12 days

- 6 hour time step
- Wavelength from 300 to 450m
- Wave period from 13 to 17 seconds
- Time period from 8 to 20 July 2004

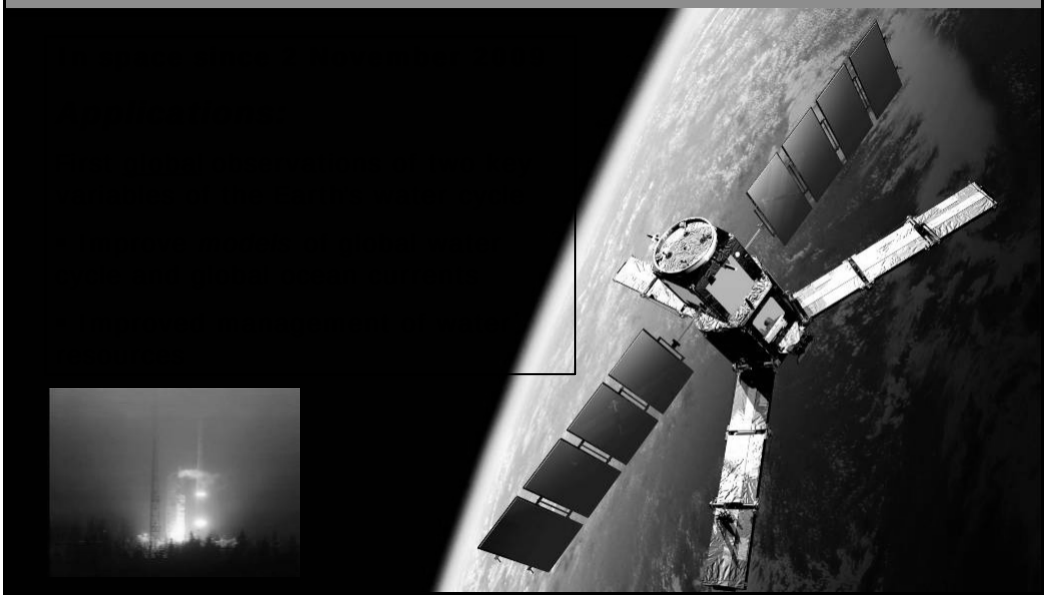
Headline news: Envisat tracking the long swell that hit La Reunion and Indonesia



A first giant wave of 11meter hit La Reunion island on 12th May

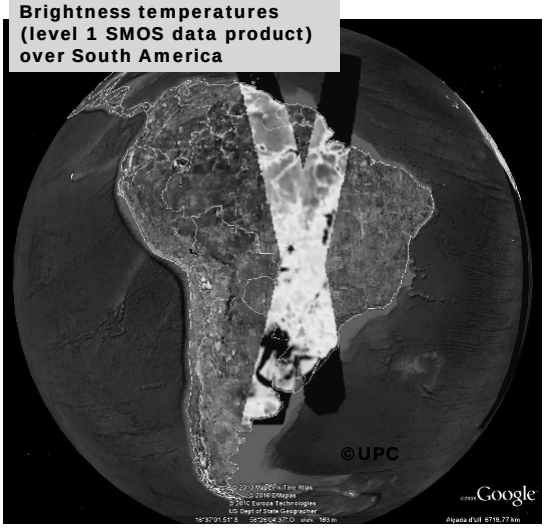
•A subsequent Giant wave of 7 meter hit Indenosia on 17th and 18th May

SMOS – *The ESA water mission*



SMOS – *First results*

Brightness temperatures (level 1 SMOS data product) over South America



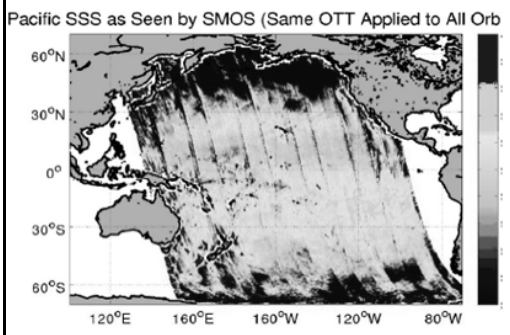
<u>Release of data</u>

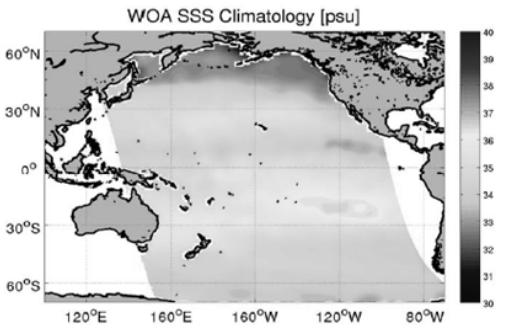
First Level 1C products (and some data sets for level 2) released to cal & val PIs mid April

General release of level 1C (= brightness temperature) by 9 July 2010

General release of Level 2 (=soil moisture and ocean salinity) in September 2010

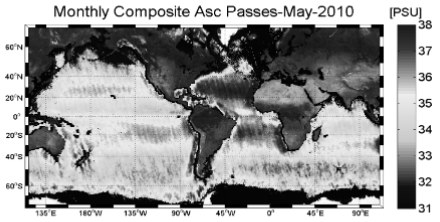
First SMOS Salinity Map

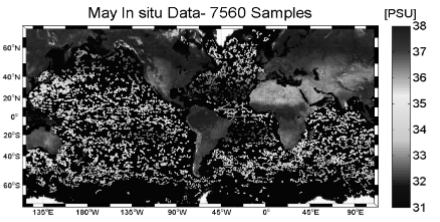




Comparing SSS map generated with 3 days of SMOS data (ascending orbits 29-31, January 2010) and World Ocean Atlas climatology for January [J. Tenerelli, CLS, Brest]

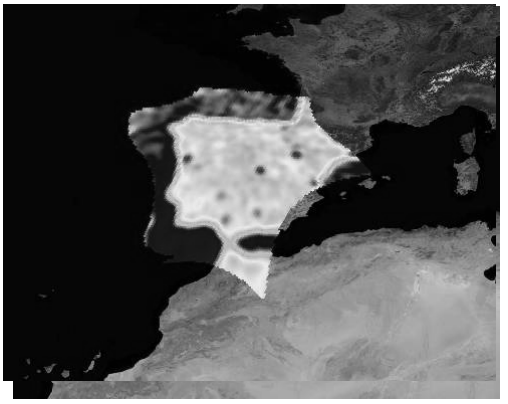
Validation of SMOS L2 products





March 2010: comparison of SMOS data composite with 7296 in situ salinity values (Argo floats) [IFREMER, Brest]

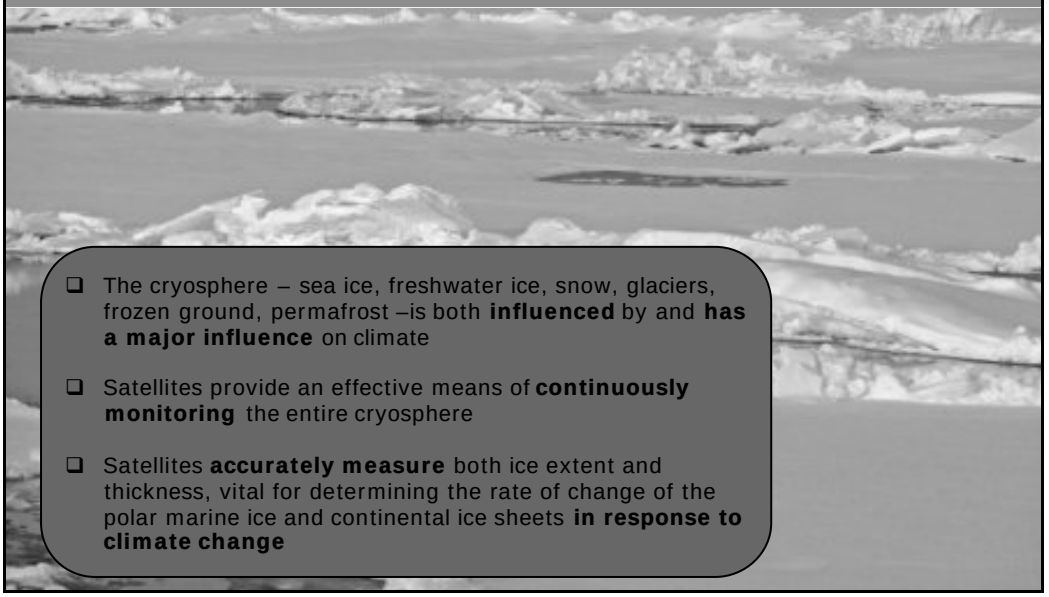
SMOS – *RFI*



First image: March, Second image: 25 May after switch-off of several sources

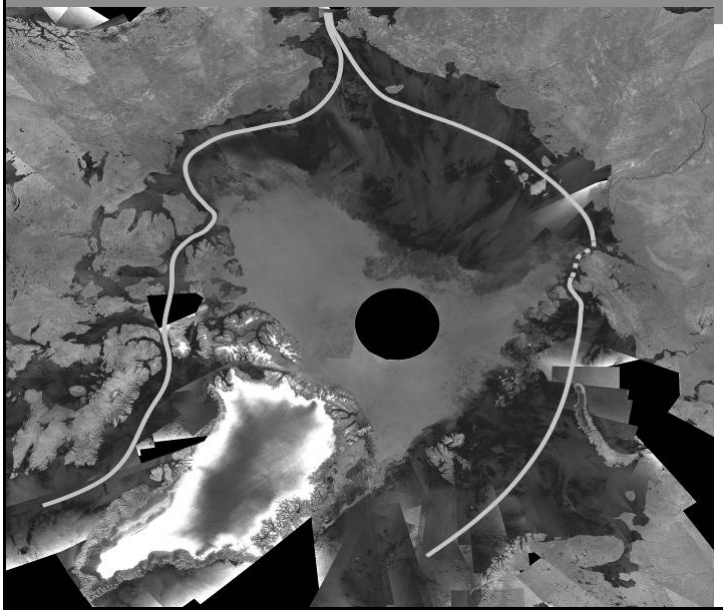
- → Radiofrequency Interference found in SMOS data even though L-Band is a protected band for EO missions
- → Working closely with international organisations and national authorities to rectify the situation
- → Major success in Spain: Identification and characterisation of RFI sources and their elimination working closely with national authorities

Charting the cryosphere



- The cryosphere – sea ice, freshwater ice, snow, glaciers, frozen ground, permafrost –is both **influenced** by and **has a major influence** on climate
- Satellites provide an effective means of **continuously monitoring** the entire cryosphere
- Satellites **accurately measure** both ice extent and thickness, vital for determining the rate of change of the polar marine ice and continental ice sheets **in response to climate change**

Arctic Sea Ice coverage (ENVISAT)

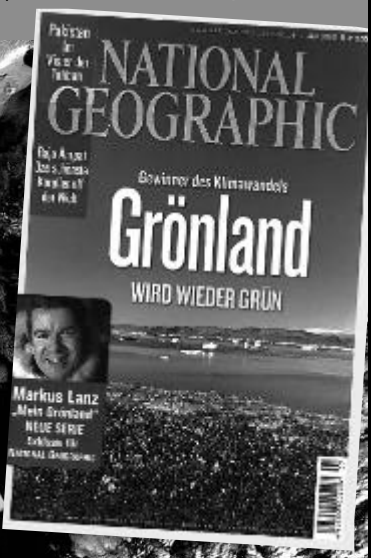


NW Passage

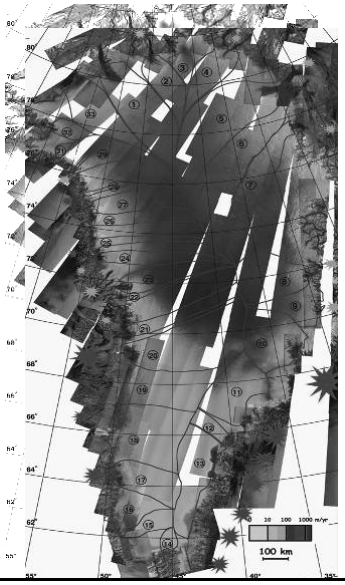
NE Passage

South Greenland

[Envisat MERIS – 16 Feb 2006] © ESA



Greenland mass balance 1996-2005

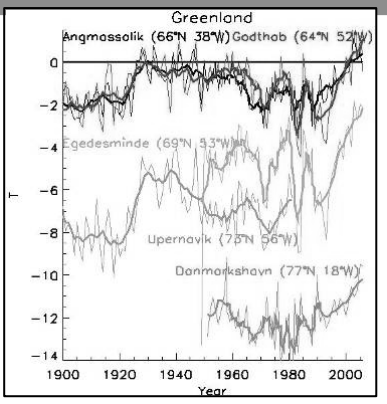


Mass deficit:

83±30 Gt/yr in 1996

205±37 Gt/yr in 2005

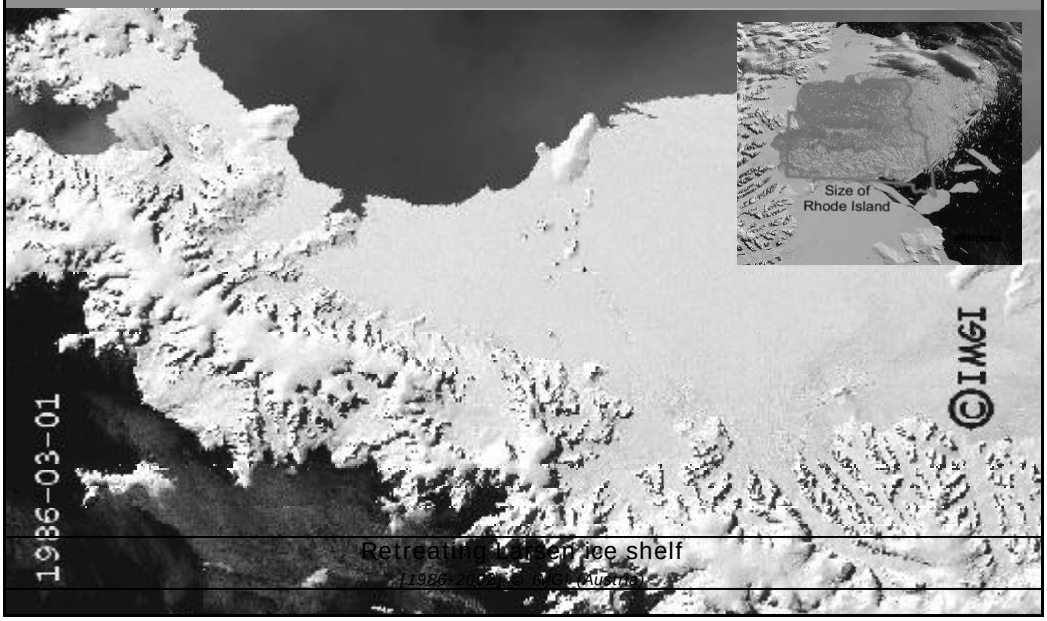
2/3rd of loss due to dynamic thinning



"Greenland's contribution to sea level rise has been doubling between 1995 and 2005" – Eric Rignot, JPL

Changes in the Velocity Structure of the Greenland Ice Sheet, Science vol. 311 no. 5763, pp. 986-990 *Courtesy of Rignot & Kanagaratnam,*

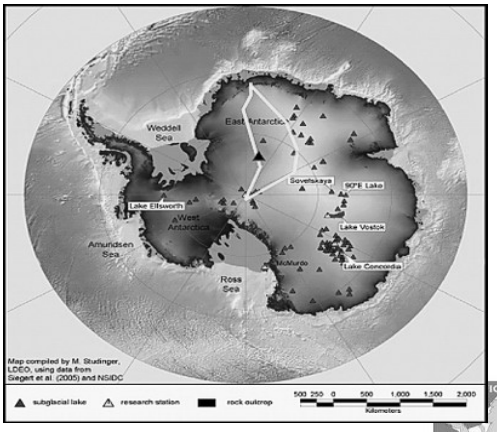
Ice shelf loss - Antarctica

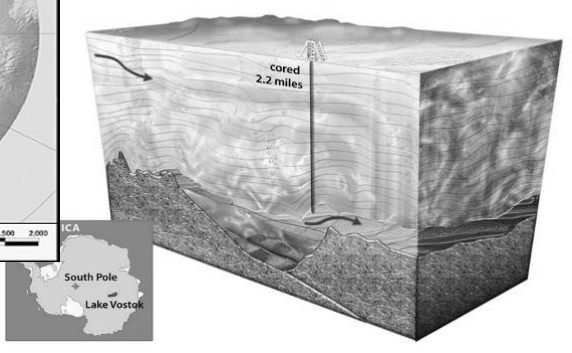


Retreating Larsen ice shelf

[1986-2002] (NASA Aqua/Terra)

Subglacial Lakes in Antarctica

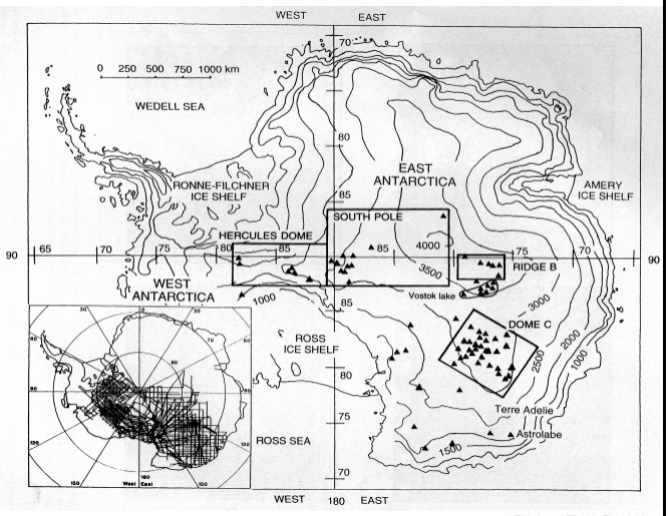




Credit: The Daily Galaxy

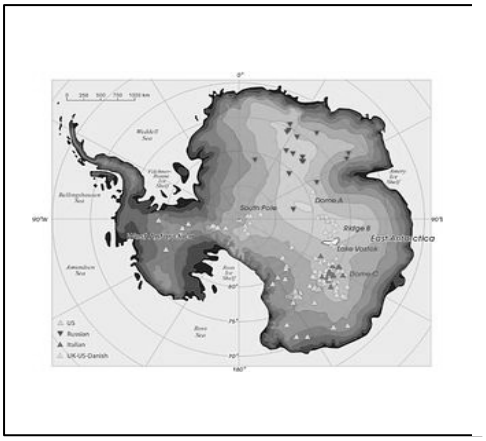
Subglacial Lakes in Antarctica

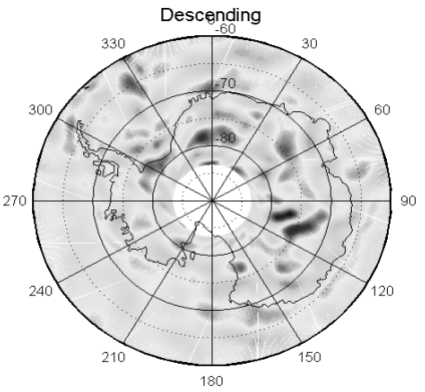
- Total volume of water held beneath the ice sheet is estimated between 4000 and 12,000 km3 in about 70 subglacial lakes
- The largest, and most well documented is Lake Vostok
- Subglacial lakes were first identified with airborne radio-echo sounding



Credit: Bristol Glaciology Centre

GOCE gravity field over Antarctica





Map compiled by M.Studinger, LDEO,
Using data from Siegert et al. (2005) and NSIDC

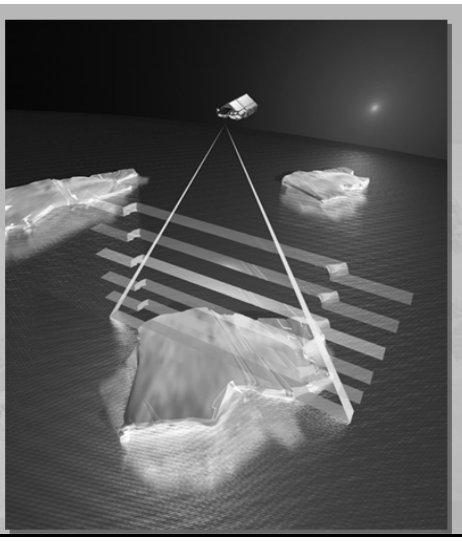
CryoSat-2 – *ESA's ice mission*

- Launch 8 April 20

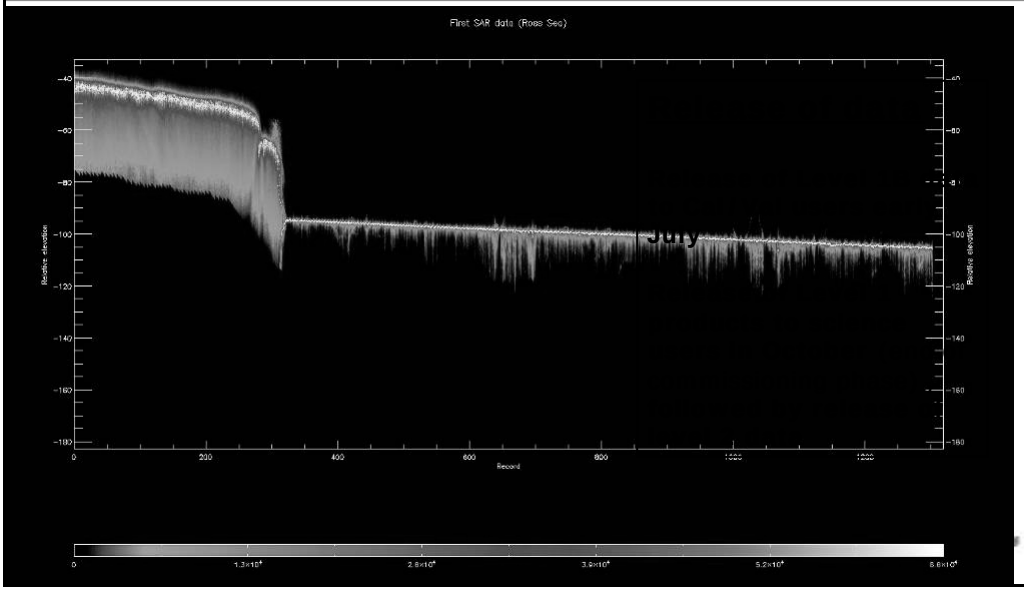
CryoSat-2 – *ESA's ice mission*

CryoSat Sea Ice Measurements

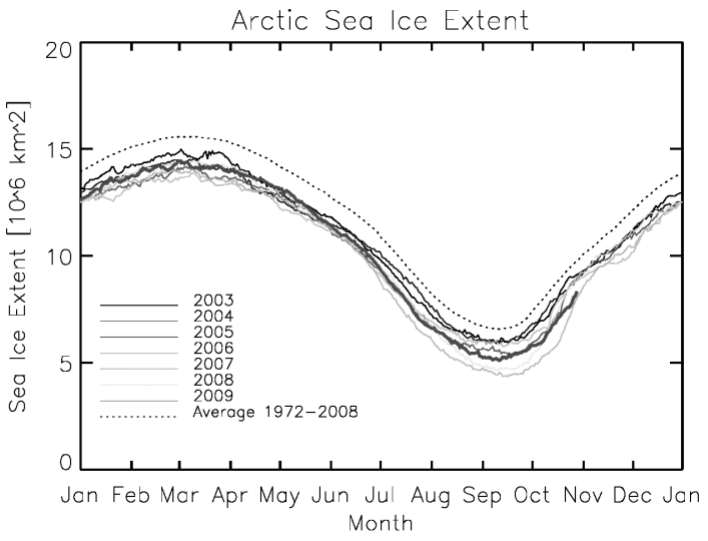
- SAR mode provides 250 m along-track resolution
- Improves discrimination between floes and leads
- Allows small floe detection



L1b Stacking: Ross Ice Shelf & Ross Sea, 11th April



Arctic Sea Ice extend – seasonal and annual change



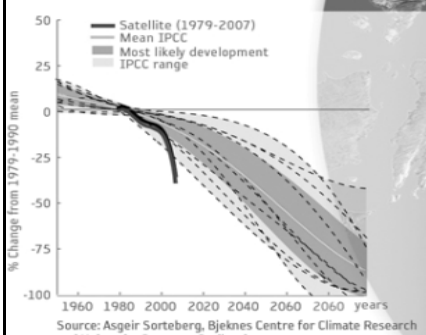
©University of Bremen

Climate, environment & human life

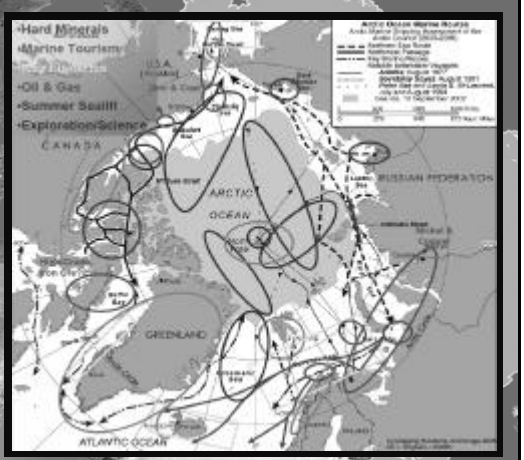
- **The environment and human activities influence each other**
- The value of Earth Observation from space: not only science, but politics, economy and daily life of citizens profit from data

The Changing Arctic

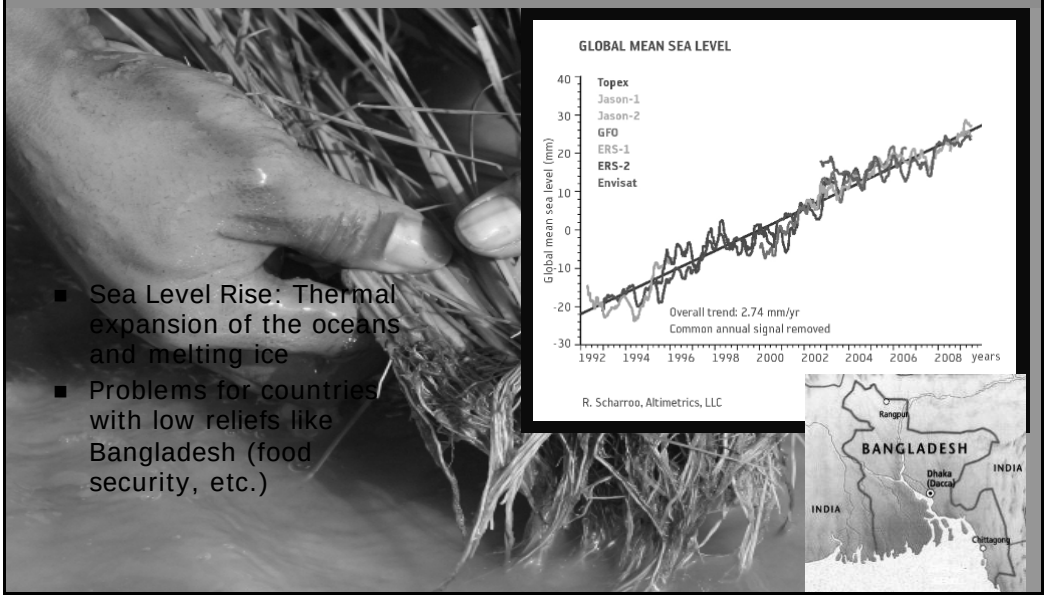
- Arctic sea-ice extent (September) has shrunk by 12% per decade since 1978
- The Arctic increasingly becomes an arena of high geopolitical relevance



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

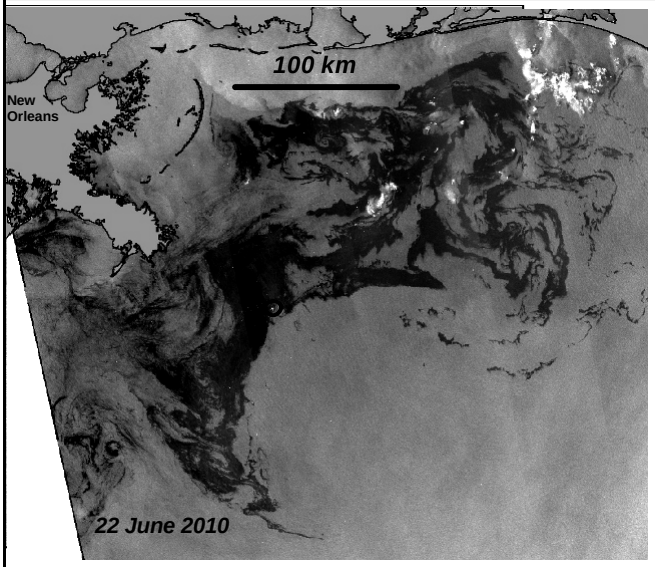


The changing oceans

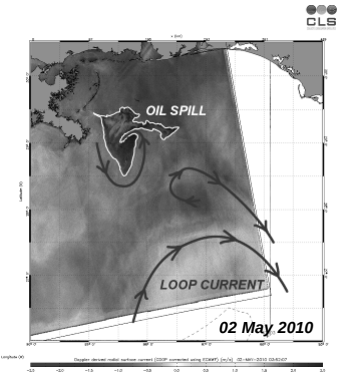


- Sea Level Rise: Thermal expansion of the oceans and melting ice
- Problems for countries with low reliefs like Bangladesh (food security, etc.)

Disaster management with a help from space



The Louisiana Oil Spill disaster from space
(Envisat ASAR)



ESA Climate Change Initiative

- ESA EO programmes **essential** for Climate Change monitoring
- **30 years** of EO data archived
- **20 new satellites** launched over next 10 years

Programme goal:

to systematically generate and distribute long-term series of **"Essential Climate Variables" (ECV)** to meet needs of UNFCCC and IPCC

The "ESA Climate Change Initiative"

- **The work of science communities and ESA for 11 selected ECVs has started**
- **ESA is coordinating the programme at international level,** e.g. with EUMETSAT and EU
- **The Climate Change Summit in Copenhagen has underlined the importance of this activity**

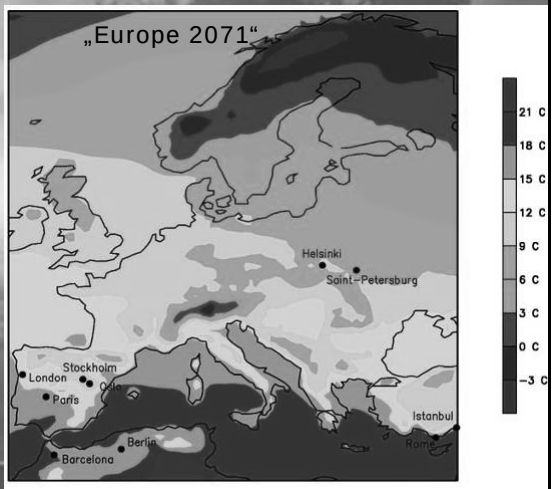
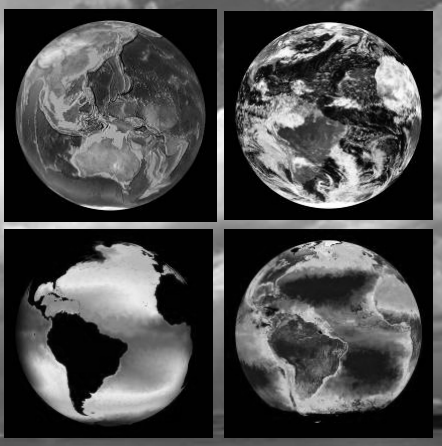


Image: Centre International de Recherche sur l'Environnement et le Développement and Ecole Nationale de la Météorologie, Météo-France

Source: guardian.co.uk

11 Essential Climate Variables

- 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



Essential Climate Variables

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)

International cooperation

- **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…**

New Earth observation missions in space
(selection)

- **GOCE (Europe)**
- **GOSAT (Japan)**
- **Cosmo-SkyMed (Italy)**
- **NOAA-N' (USA)**
- **OCO (USA)** – failed
- **RISAT-2 (India)**
- **Oceansat-2 (India)**
- **SMOS (Europe)** – 2 Nov
- **DMC 2 (UK)**
- **MEGHA-TROPIQUES (France / India)** – end 2009
- **CryoSat-2** (April 2010)
- **Tandem-X (Germany)** (June 2010)

ESA EO missions – launch schedule

ID	Task Name
1	EO Programmes
2	GOCE
3	SMOS
4	Cryosat 2
5	Swarm
6	Aeolus
7	MSG 3
8	Metop B
9	GMES Sentinel 1a- 1b
10	GMES Sentinel 2a- 2b
11	GMES Sentinel 3a- 3b
12	GMES Sentinel 5P
13	MSG 4
14	SEOSAT
15	EarthCare
16	Earth Explorer 7
17	Metop C
18	MTG I-1 - 2 - 3 - 4
19	MTG S-1 - 2
20