ESA's Living Planet Programme

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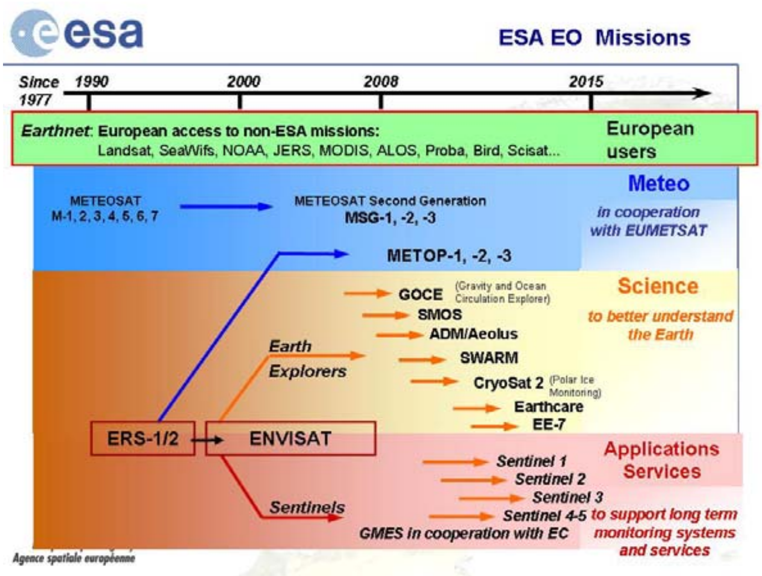

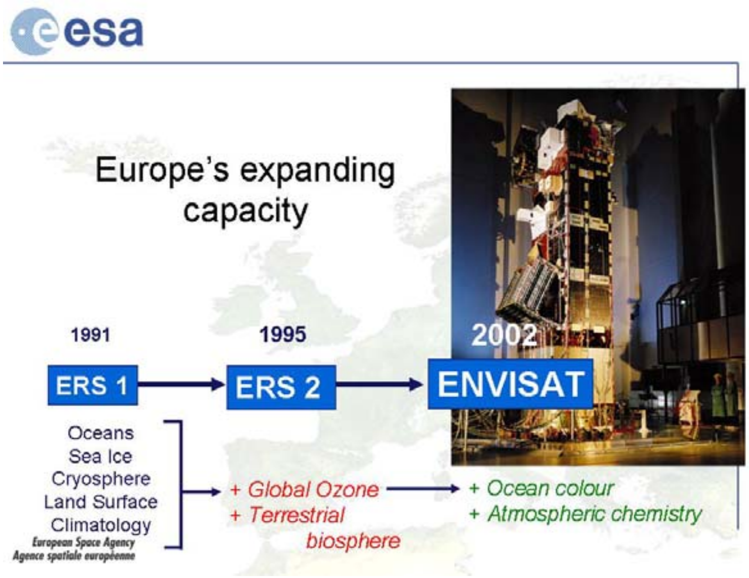
esa
Europe's expanding capacity
1991
1995
2002
ERS 1
ERS 2
ENVISAT
Oceans
Sea Ice
Cryosphere
Land Surface
Climatology
+ Global Ozone
+ Terrestrial biosphere
+ Ocean colour
+ Atmospheric chemistry
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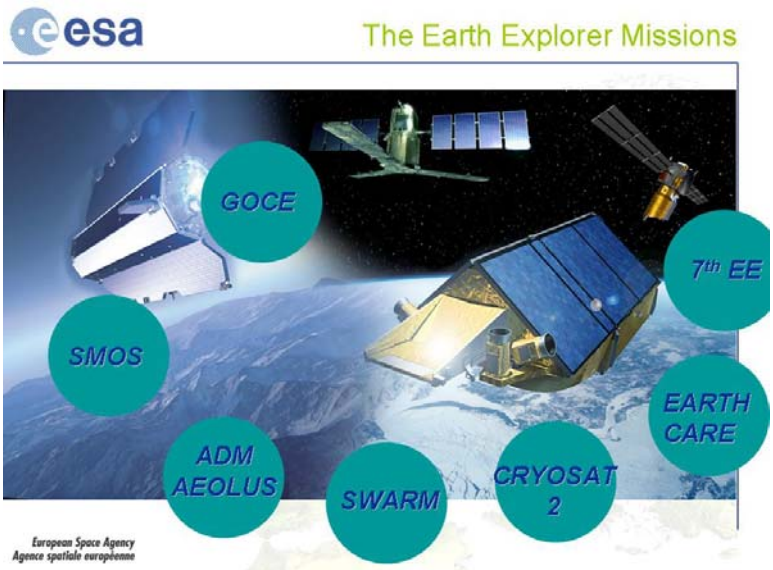
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The Earth Explorer Missions
GOCE
7th EE
SMOS
EARTH CARE
ADM AEOLUS
SWARM
CRYOSAT 2
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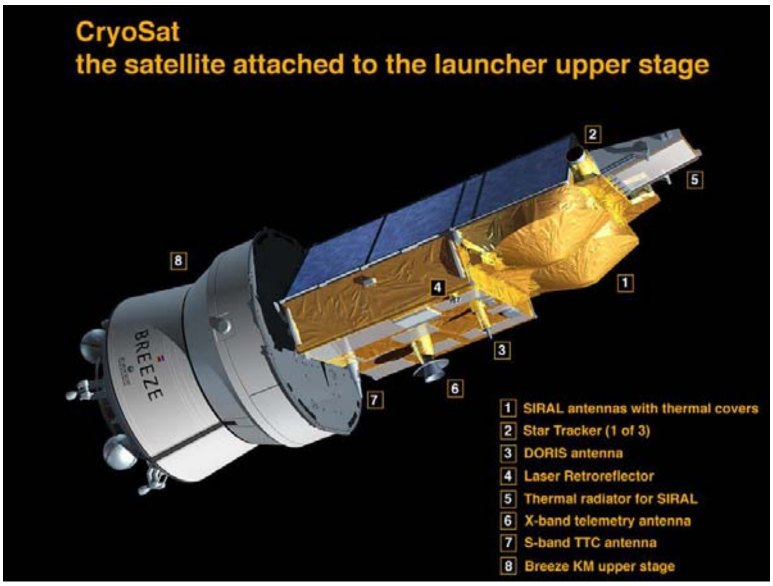
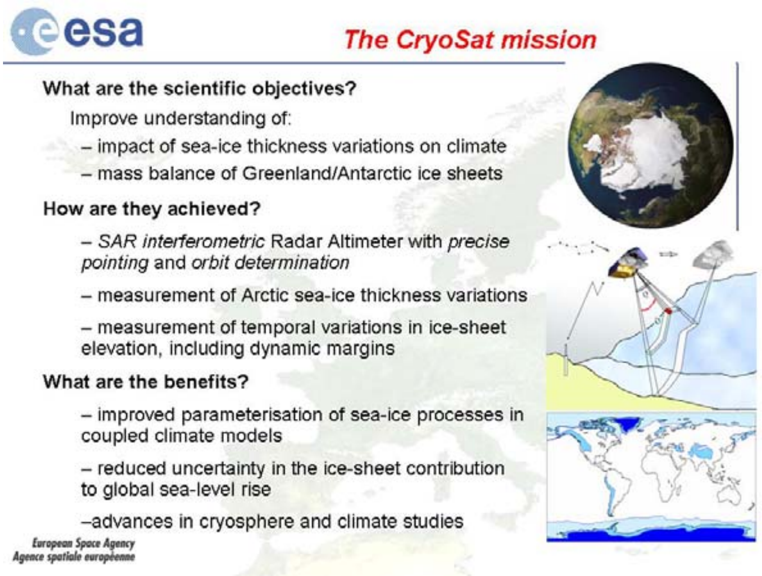

CryoSat
the satellite attached to the launcher upper stage
BREEZE
1 SIRAL antennas with thermal covers
2 Star Tracker (1 of 3)
3 DORIS antenna
4 Laser Retroreflector
5 Thermal radiator for SIRAL
6 X-band telemetry antenna
7 S-band TTC antenna
8 Breeze KM upper stage


esa
The CryoSat mission
What are the scientific objectives?
Improve understanding of:
– impact of sea-ice thickness variations on climate
– mass balance of Greenland/Antarctic ice sheets
How are they achieved?
– SAR interferometric Radar Altimeter with precise pointing and orbit determination
– measurement of Arctic sea-ice thickness variations
– measurement of temporal variations in ice-sheet elevation, including dynamic margins
What are the benefits?
– improved parameterisation of sea-ice processes in coupled climate models
– reduced uncertainty in the ice-sheet contribution to global sea-level rise
–advances in cryosphere and climate studies
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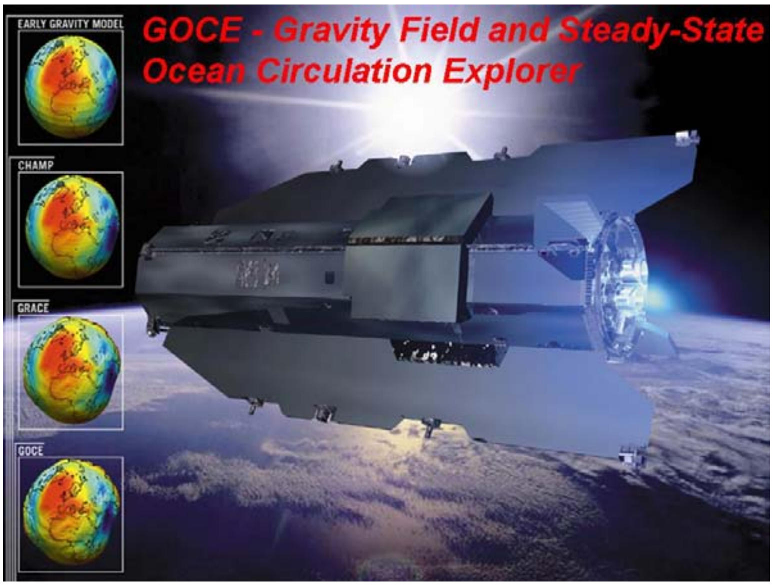
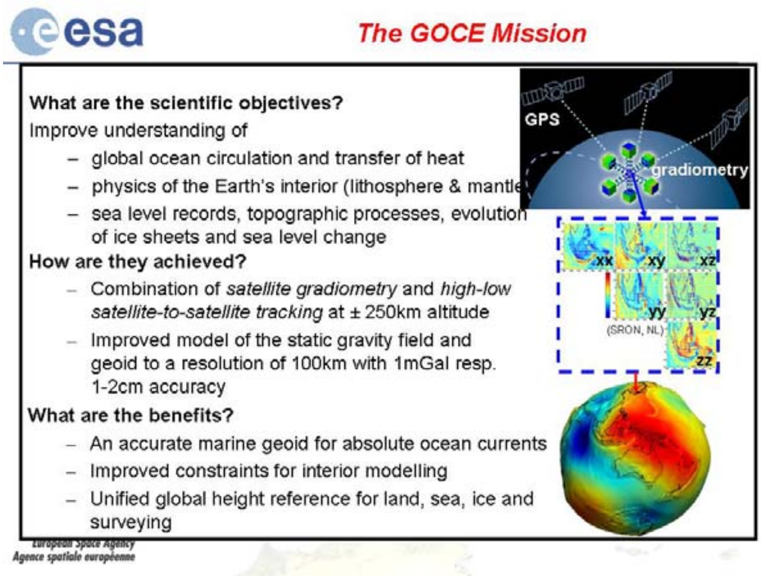

GOCE - Gravity Field and Steady-State Ocean Circulation Explorer
EARLY GRAVITY MODEL
CHAMP
GRACE
GOCE


esa
The GOCE Mission
What are the scientific objectives?
Improve understanding of
– global ocean circulation and transfer of heat
– physics of the Earth's interior (lithosphere & mantle
– sea level records, topographic processes, evolution of ice sheets and sea level change
How are they achieved?
– Combination of satellite gradiometry and high-low satellite-to-satellite tracking at ± 250km altitude
– Improved model of the static gravity field and geoid to a resolution of 100km with 1mGal resp. 1-2cm accuracy
What are the benefits?
– An accurate marine geoid for absolute ocean currents
– Improved constraints for interior modelling
– Unified global height reference for land, sea, ice and surveying
GPS
gradiometry
xx
xy
xz
yy
yz
zz
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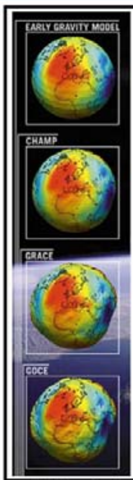
esa

GOCE: Uniqueness and Relevance



- Only mission with satellite gradiometry (3D) and drag-free control in low orbit (250km)
- GOCE will provide global static gravity field with homogeneous quality of unprecedented accuracy and resolution
- Key step in improving ocean, solid Earth and sea level modelling
- Large impact on national height systems and surveying applications on land and sea
- Essential benchmark technique for understanding mass distribution and change
- Element of IGGOS (Integrated Global Geodetic Observing System) and essential for WOCE, WCRP and CLIVAR

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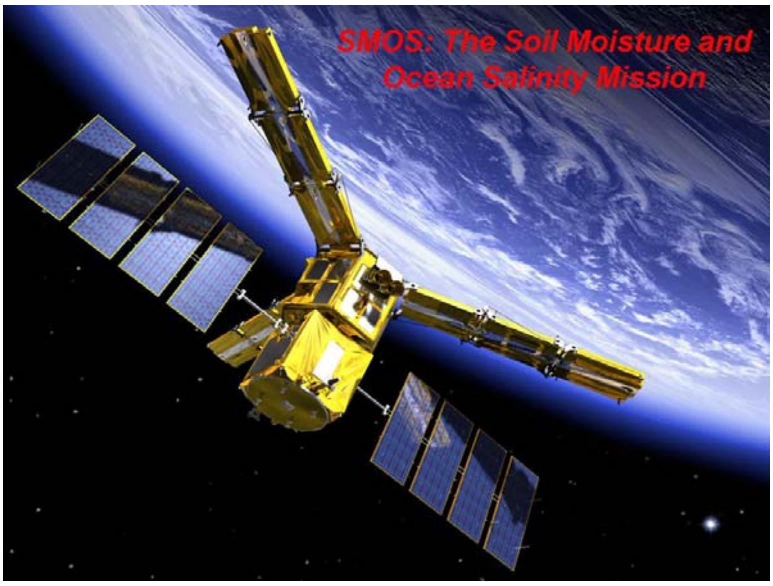

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The SMOS Mission

What are the scientific objectives?:

To improve understanding of:

- the water cycle (and the Energy and Carbon Cycle), and
- its representation in mesoscale models (Hydrology, Oceanography and Climate).

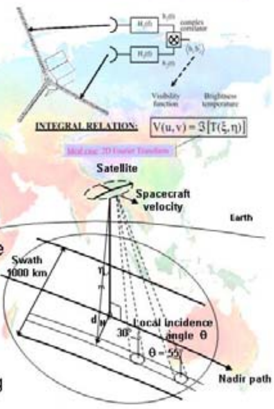
How are they achieved?:

Constraining models by global soil moisture and ocean salinity observations estimated from dual-pol., multi-angular, L-band brightness temperature measurement acquired by a 2D interferometer.

What are the benefits?:

Enhancement of the model parameterisation will:

- improve the weather prediction
- improved ocean circulation/hydrology modelling
- better extreme event forecasting



$$Tb = f(\nu, p, \theta, T, sm/s, \sigma^0, ...)$$

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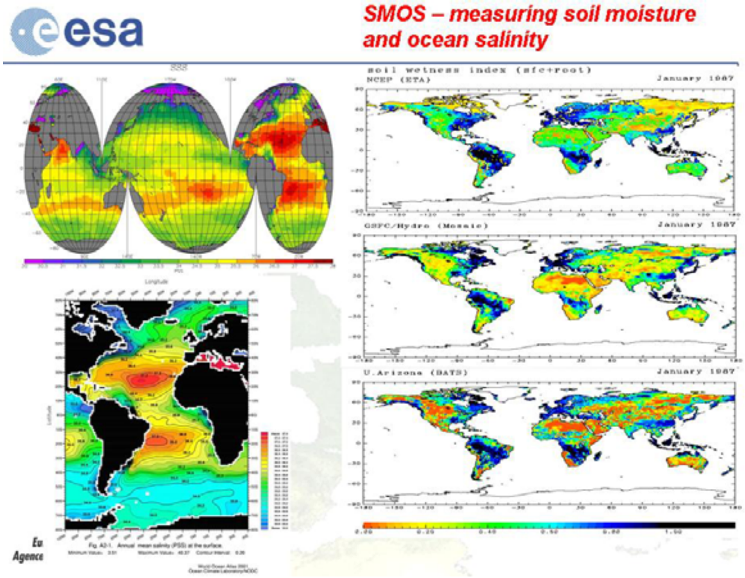
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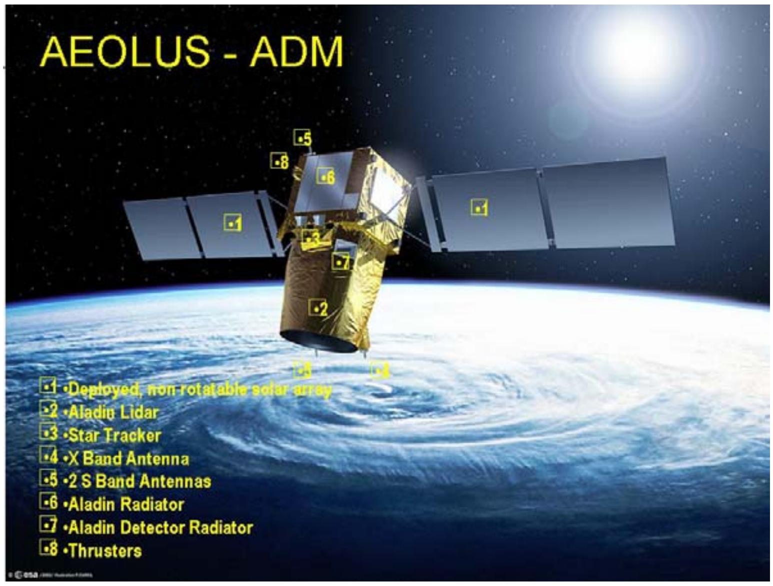
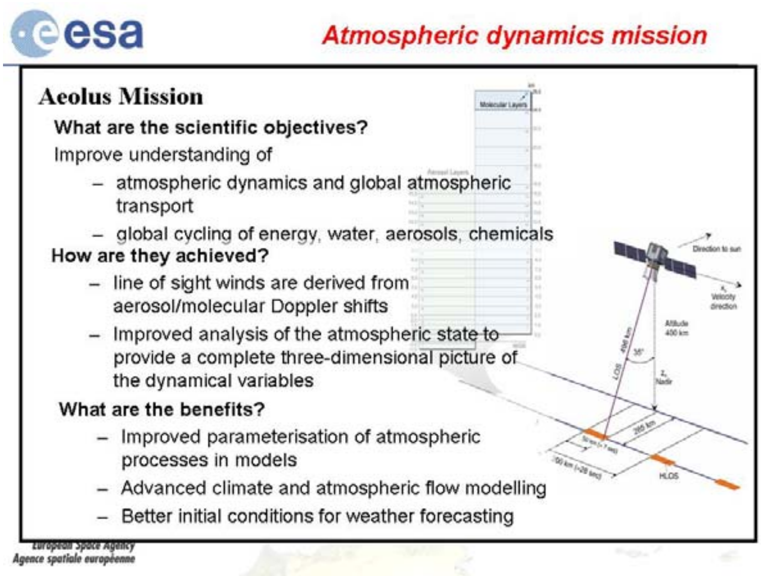
SMOS – measuring soil moisture and ocean salinity


AEOLUS - ADM
1 •Deployed, non-rotatable solar array
2 •Aladin Lidar
3 •Star Tracker
4 •X Band Antenna
5 •2 S Band Antennas
6 •Aladin Radiator
7 •Aladin Detector Radiator
8 •Thrusters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Atmospheric dynamics mission
Aeolus Mission
What are the scientific objectives?
Improve understanding of
– atmospheric dynamics and global atmospheric transport
– global cycling of energy, water, aerosols, chemicals
How are they achieved?
– line of sight winds are derived from aerosol/molecular Doppler shifts
– Improved analysis of the atmospheric state to provide a complete three-dimensional picture of the dynamical variables
What are the benefits?
– Improved parameterisation of atmospheric processes in models
– Advanced climate and atmospheric flow modelling
– Better initial conditions for weather forecasting
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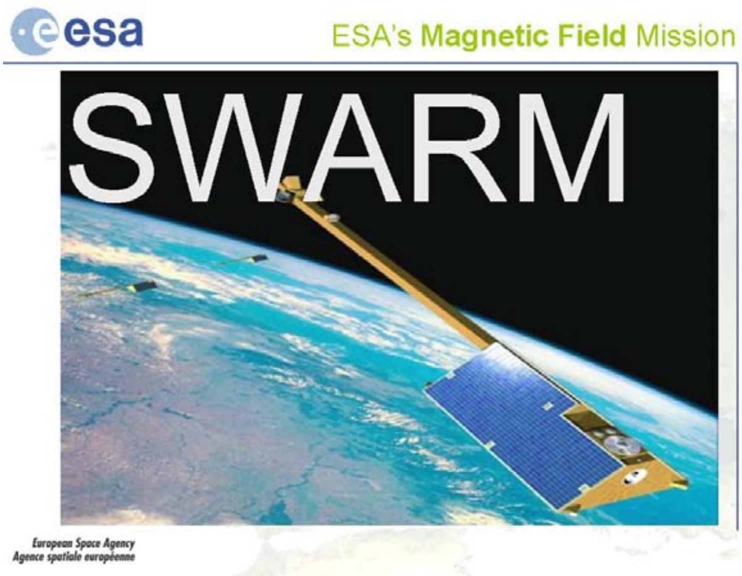
esa
ESA's Magnetic Field Mission
SWARM
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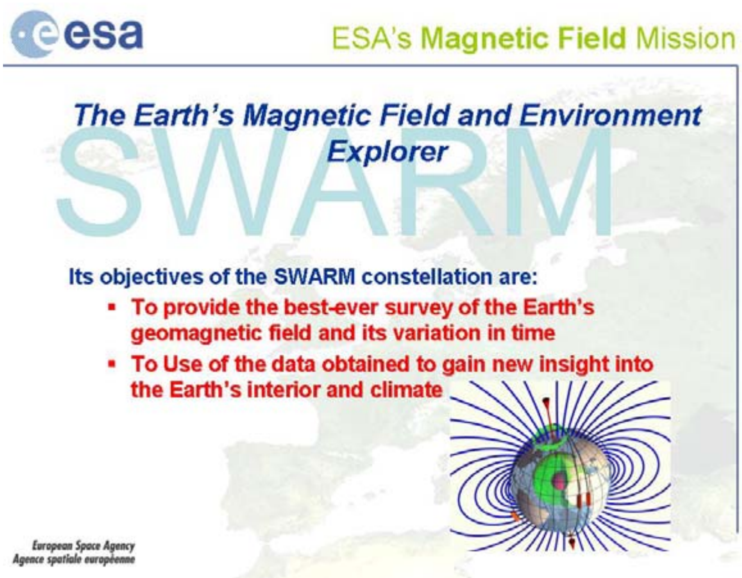
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ESA's Magnetic Field Mission
The Earth's Magnetic Field and Environment Explorer
SWARM
Its objectives of the SWARM constellation are:
▪ To provide the best-ever survey of the Earth's geomagnetic field and its variation in time
▪ To Use of the data obtained to gain new insight into the Earth's interior and climate
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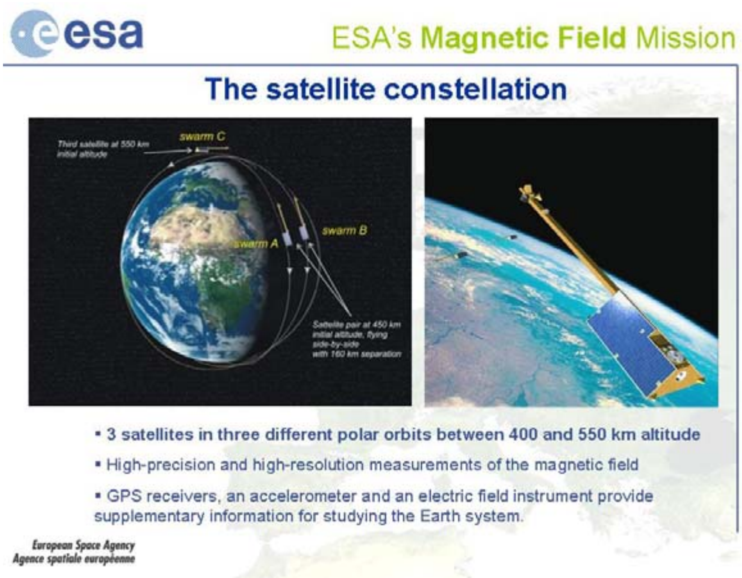
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ESA's Magnetic Field Mission
The satellite constellation
Third satellite at 550 km initial altitude
swarm C
swarm A
swarm B
Satellite pair at 450 km initial altitude, flying side-by-side with 160 km separation
▪ 3 satellites in three different polar orbits between 400 and 550 km altitude
▪ High-precision and high-resolution measurements of the magnetic field
▪ GPS receivers, an accelerometer and an electric field instrument provide supplementary information for studying the Earth system.
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esa

ESA's **Ice** Mission

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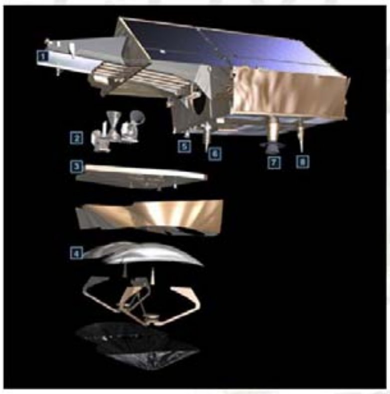
esa

ESA's **Ice** Mission

The satellite and its instruments



1 Radiator: a heat-radiating panel at the top of the nose structure which houses the SIRAL electronics under the solar array.

2 Star tracker

3 Antenna bench: stable and rigid support structure isostatically mounted to satellite nose.

4 SIRAL antennae

5 Laser retroreflector: reflects tracking pulses back to ground-based laser station.

6 DORIS antenna: receives signals from a global network of radio beacons for orbit determination.

7 X-band antenna: transmits the huge volume of SIRAL measurement.

8 S-band helix antenna: receives telecommands from the ground.

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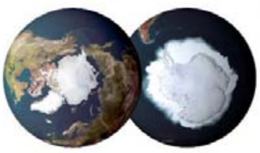
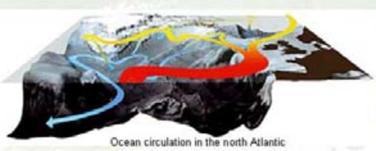
ESA's **Ice** Mission

Cryosat – the ice mission of ESA

Its objectives are to improve understanding of:

- **Thickness and mass fluctuations of the Earth's continental ice shields and marine ice cover**
- **To quantify rates of thinning and thickening of ice due to climate variations**





Ocean circulation in the north Atlantic

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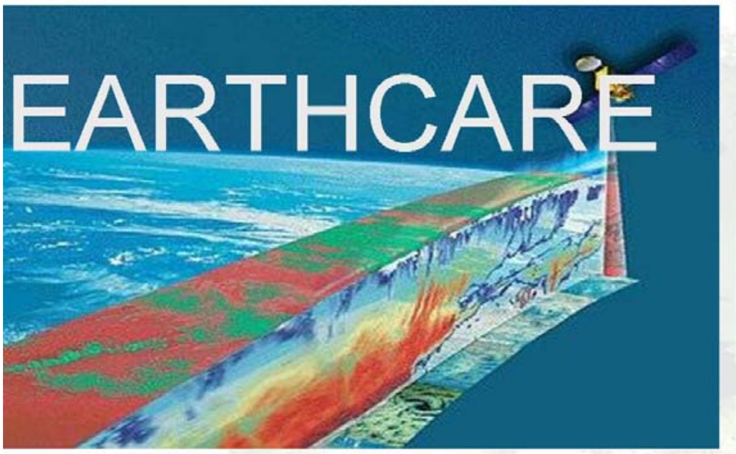
ESA's Cloud & Aerosol Mission



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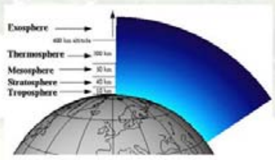
ESA's Cloud & Aerosol Mission

The Earth Clouds, Aerosols and Radiation Explorer

EarthCARE is a joint European (ESA) – Japanese (JAXA) mission with the objective:

- to quantify and thus improve understanding of cloud-aerosol-radiation interactions
- to include such parameters correctly and reliably in climate and weather prediction models



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The 7th Earth Explorer Mission

Six candidate missions

BIOMASS – global measurements of forest biomass.

TRAQ monitor air quality and long-range transport of air pollutants.

PREMIER to understand processes that link trace gases, radiation, chemistry and climate in the atmosphere.

FLEX observe global photosynthesis through the measurement of fluorescence.

A-SCOPE improve our understanding of the global carbon cycle and regional carbon dioxide fluxes.

CoReH2O make detailed observations of key snow, ice and water cycle characteristics.

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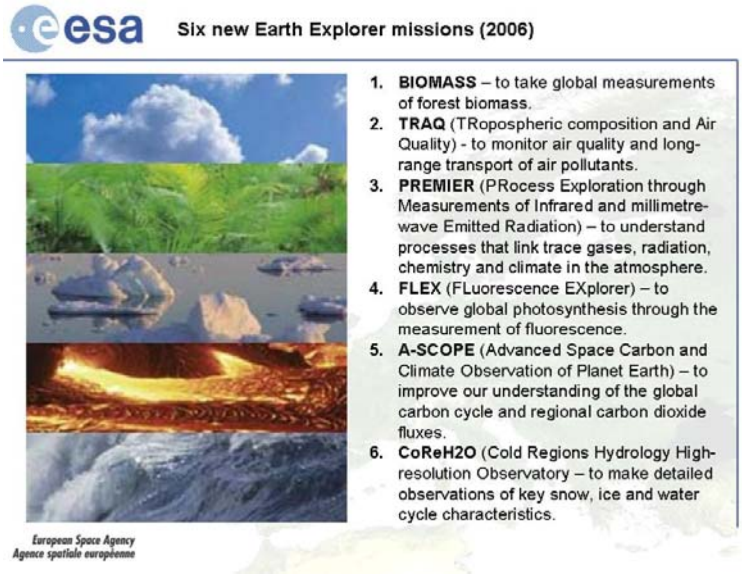
esa
Six new Earth Explorer missions (2006)
1. BIOMASS – to take global measurements of forest biomass.
2. TRAQ (TRopospheric composition and Air Quality) - to monitor air quality and long-range transport of air pollutants.
3. PREMIER (PRocess Exploration through Measurements of Infrared and millimetre-wave Emitted Radiation) – to understand processes that link trace gases, radiation, chemistry and climate in the atmosphere.
4. FLEX (FLuorescence EXplorer) – to observe global photosynthesis through the measurement of fluorescence.
5. A-SCOPE (Advanced Space Carbon and Climate Observation of Planet Earth) – to improve our understanding of the global carbon cycle and regional carbon dioxide fluxes.
6. CoReH2O (Cold Regions Hydrology High-resolution Observatory – to make detailed observations of key snow, ice and water cycle characteristics.
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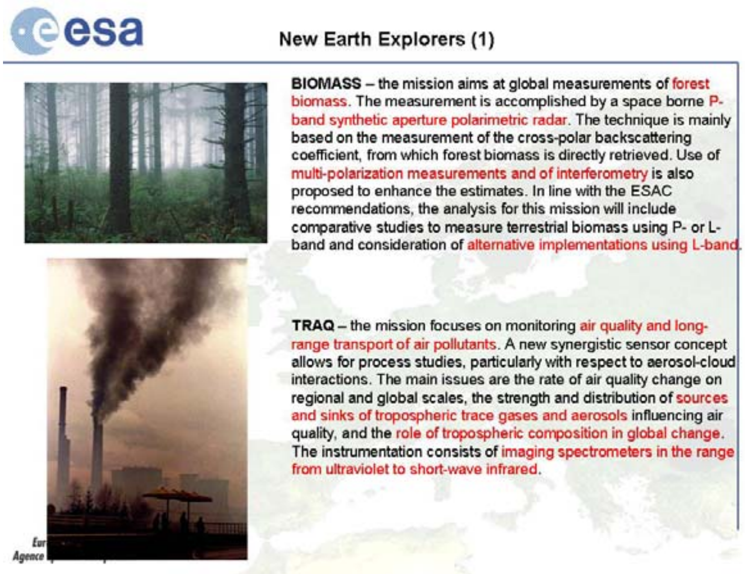
esa
New Earth Explorers (1)
BIOMASS – the mission aims at global measurements of forest biomass. The measurement is accomplished by a space borne P-band synthetic aperture polarimetric radar. The technique is mainly based on the measurement of the cross-polar backscattering coefficient, from which forest biomass is directly retrieved. Use of multi-polarization measurements and of interferometry is also proposed to enhance the estimates. In line with the ESAC recommendations, the analysis for this mission will include comparative studies to measure terrestrial biomass using P- or L-band and consideration of alternative implementations using L-band.
TRAQ – the mission focuses on monitoring air quality and long-range transport of air pollutants. A new synergistic sensor concept allows for process studies, particularly with respect to aerosol-cloud interactions. The main issues are the rate of air quality change on regional and global scales, the strength and distribution of sources and sinks of tropospheric trace gases and aerosols influencing air quality, and the role of tropospheric composition in global change. The instrumentation consists of imaging spectrometers in the range from ultraviolet to short-wave infrared.


esa
New Earth Explorers (2)
PREMIER – Many of the most important processes for prediction of climate change occur in the upper troposphere and lower stratosphere (UTLS). The objective is to understand the many processes that link trace gases, radiation, chemistry and climate in the atmosphere – concentrating on the processes in the UTLS region. By linking with MetOp/ National Polar-orbiting Operational Environmental Satellite System (NPOESS) data, the mission also aims to provide useful insights into processes occurring in the lower troposphere. The instrumentation consists of an infrared and a microwave radiometer.
FLEX – The main aim of the mission is global remote sensing of photosynthesis through the measurement of fluorescence. Photosynthesis by land vegetation is an important component of the global carbon cycle, and is closely linked to the hydrological cycle through transpiration. Currently there are no direct measurements available from satellites of this parameter. The main specification is for instruments to measure high spectral resolution reflectance and temperature, and to provide a multi-angular capability.
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New Earth Explorers (3)

A-SCOPE – The mission aims to observe total column carbon dioxide with a nadir-looking pulsed carbon dioxide Differential Absorption Lidar (DIAL) for a better understanding of the global carbon cycle and regional carbon dioxide fluxes, as well as for the validation of greenhouse gas emission inventories. It will provide a spatially resolved global carbon budget combined with diagnostic model analysis through global and frequent observation of carbon dioxide. Spin-off products like aerosols, clouds and surface reflectivity are important parameters of the radiation balance of the Earth. A contribution to Numerical Weather Prediction is foreseen in connection with accurate temperature profiles. Investigations on plant stress and vitality will be supported by a fluorescence imaging spectrometer.

CoReH2O – The mission focuses on spatially detailed observations of key snow, ice, and water cycle characteristics necessary for understanding land surface, atmosphere and ocean processes and interactions by using two synthetic aperture radars at 9.6 and 17.2 GHz. It aims at closing the gaps in detailed information on snow glaciers, and surface water, with the objectives of improving modelling and prediction of water balance and streamflow for snow covered and glacierised basins, understanding and modelling the water and energy cycles in high latitudes, assessing and forecasting water supply from snow cover and glaciers, including the relation to climate change and variability.

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EE-7 candidate missions - summary

Mission	Proposers	Objective	Instrumentation and orbit	Evaluation
BIOMASS	T. Le Toan (F) and S. Quegan (UK) + 32 researchers from I, F, A, S, CDN, FIN, D, NL, US, Br, JP	Forest biomass & extent, deforested areas, flooded forests, subsurface imaging in arid areas, Antartic ice cover, soil moisture, sea surface characteristics (salinity, low frequency surface roughness)	P-band (432-438 Mhz) SAR, fully polarimetric or HH/HV polarizations Sun-synchronous, dawn-dusk orbit at 580 km	Unique long wavelength sensor Need process models for above ground biomass assimilation Concerns about ionospheric effects, biomass levels above 150 ton/ha, and radio frequency interference
TRAQ	P. Levelt (NL) and C. Camy-Peyret(F) + 125 researchers from A, B, CDN, CH, D, DK, F, FIN, GR, IE, IT, N, NL, UK, US, CHN, JP	Air quality: megacities emissions, long range transport, diurnal cycle, long-term trends, forecast Sources and sinks of trace gases and aerosols influencing air quality Climate impact of change in tropospheric composition	UV-VIS-NIR nadir grating imaging spectrometer TIR+SWIR FTS cloud imager multi-viewing polarization-resolving imaging radiometer Drifting low Earth orbit	Innovative mission concept with new orbit and new strategy for synergistic use of multiple sensors for retrieval of tropospheric gas-phase and aerosol compounds; great potential for understanding air chemistry and processes; information on air quality for users and decision makers
PREMIER	B. Kerridge (UK) + 60 researchers from D, B, UK, F, S, CH, Gr, I, CDN, Pol, US, Bul, Ind	Convective transport, thin cirrus, tropical tropopause layer, stratosphere troposphere exchange; gravity waves and global circulation; UT humidity and cirrus; radiative forcing by tropospheric O3 and CH4, stratospheric O3 and water vapour; chem-climate interaction (OH chemistry); processes linking clouds and aerosols to atmospheric chemistry and global climate	Limb imaging FTIR for trace gases and particles Push-broom mm/sub-mm wave limb-sounder Sun-synchronous orbit, loose formation flight with Metop to support tropospheric applications	The mission offers greatly improved understanding of UTLS chemistry and climate processes Synergy with MetOp/NPOESS data The timely availability of the Swedish contribution of STEAM-R is mandatory
FLEX	J. Moreno (E) + 77 researchers from B, NL, UK, D, F, E, FIN, CDN, I, CH, AUS, US, JP, Czech	Chlorophyll fluorescence for photochemical processes and terrestrial carbon sequestration. bio/geophysical quantities from reflectance and thermal infrared measurements to get vegetation variables for interpretation of fluorescence measurements, and to monitor vegetation health, using fluorescence as an early indicator of stress.	Imaging Spectrometer (480-780nm), resolution 0.1nm, Multi-Angular Vegetation Imaging Spectrometer (400-2400nm), dual-view TIR spectrometer with 3 channels in the 8.8-12 µm band Sun-synchronous orbit	Ambitious proposal on chlorophyll fluorescence, multispectral and thermal remote sensing Highly precise atmospheric correction together with sub-pixel cloud masking is mandatory
A-SCOPE	P. Flamant (F) + 19 researchers from NL, F, UK, D, E, I, US	Mapping sources and sinks of CO2 Global carbon cycle and regional CO2 fluxes Low bias CO2 data, aerosol and cloud information Contribution to NWP in connection with accurate T profiles Plant stress and vitality	Laser Absorption Spectroscopy (LAS) sensors for CO2 and O2 column soundings ATLID type DIAL for CO2, canopy height, aerosol/clouds layers Fluorescence imaging spectrometer for photosynthesis, plant stress and vitality. Camera for cloud and ground backgrounds Sun-synchronous orbit	Would eliminate three sources of bias for OCO and GOSAT: measure by night as well as by day (sampling time bias); will measure at high latitude; lidar will provide a clear indication of scattering material in the optical path. Potentially significant sources of bias remaining, such as surface pressure and terrain variability Programmatic assumptions of the NASA contribution need to be clarified.
CoReH2O	H. Rott (A) + 33 researchers from D, F, UK, N, I, FIN, US, CDN, A, NL, DK	Estimation of snow and ice masses and their temporal variations for climate modelling and hydrological and NWP modelling	2 SAR instruments in Ku-band (17.2 GHz) and X-band (9.6Ghz) on 2 different satellites with VV + VH polarization Dawn/dusk orbit	Snow water equivalent and snowcover of unique importance Cost boundary condition may be met only by implementing the mission with a single satellite

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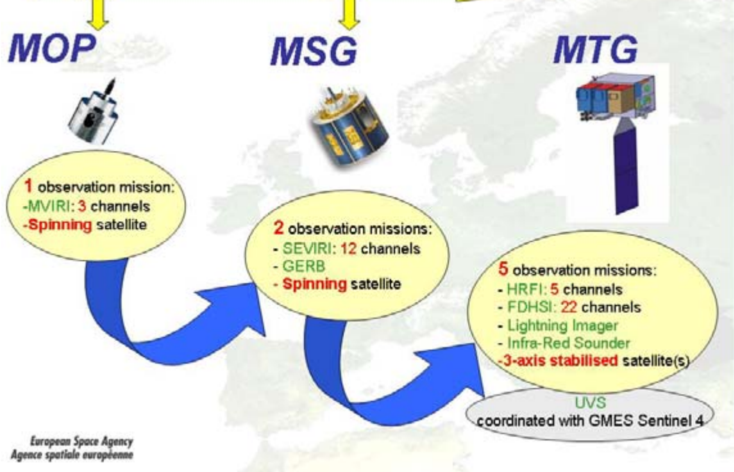
Towards Meteosat Third Generation (MTG)



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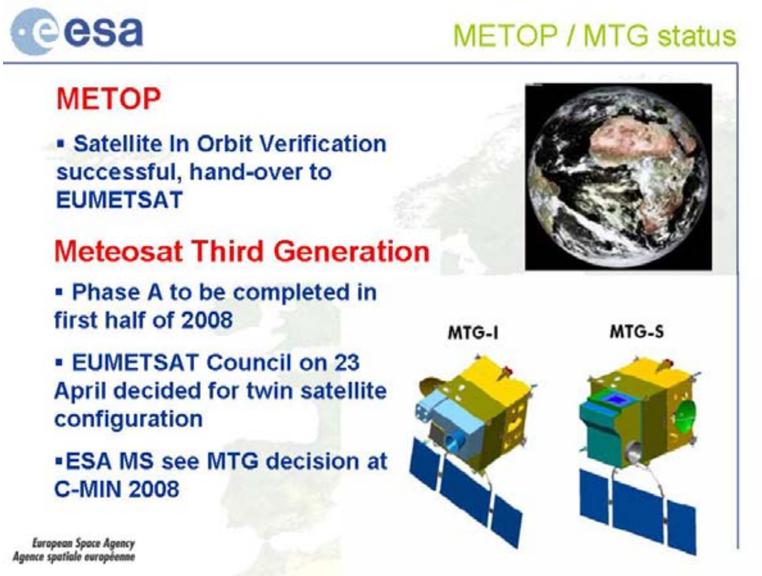
esa
METOP / MTG status
METOP
▪ Satellite In Orbit Verification successful, hand-over to EUMETSAT
Meteosat Third Generation
▪ Phase A to be completed in first half of 2008
▪ EUMETSAT Council on 23 April decided for twin satellite configuration
▪ESA MS see MTG decision at C-MIN 2008
MTG-I
MTG-S
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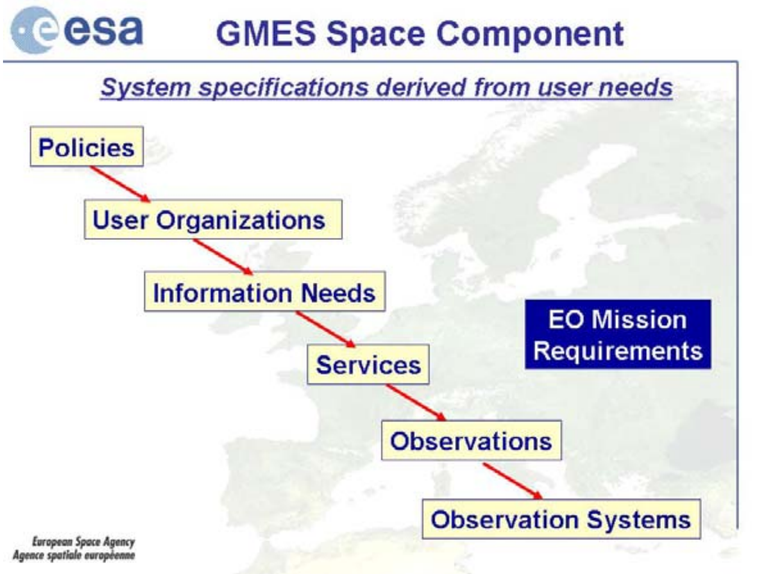
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GMES Space Component
System specifications derived from user needs
Policies
User Organizations
Information Needs
Services
Observations
Observation Systems
EO Mission Requirements
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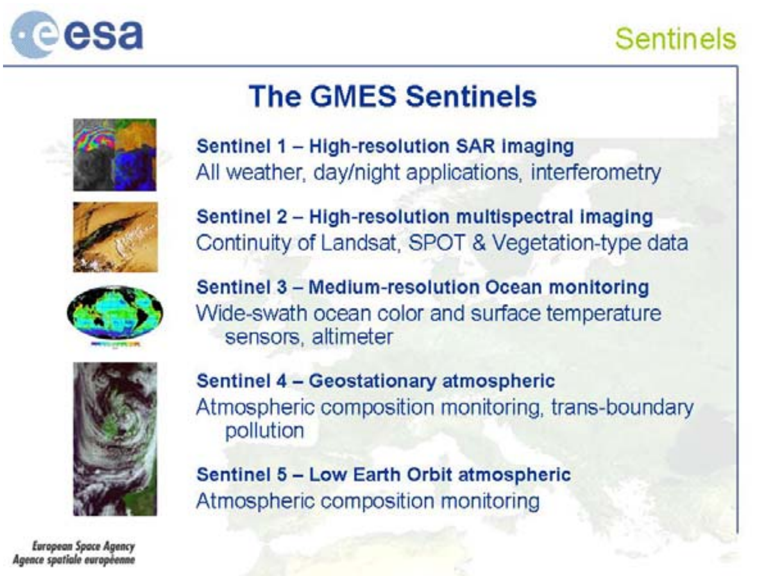
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Sentinels
The GMES Sentinels
Sentinel 1 – High-resolution SAR imaging
All weather, day/night applications, interferometry
Sentinel 2 – High-resolution multispectral imaging
Continuity of Landsat, SPOT & Vegetation-type data
Sentinel 3 – Medium-resolution Ocean monitoring
Wide-swath ocean color and surface temperature sensors, altimeter
Sentinel 4 – Geostationary atmospheric
Atmospheric composition monitoring, trans-boundary pollution
Sentinel 5 – Low Earth Orbit atmospheric
Atmospheric composition monitoring
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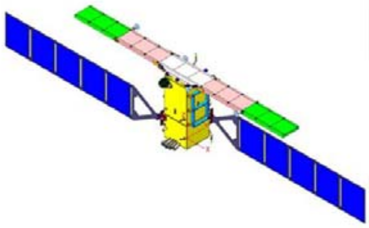
Sentinel-1



- European Radar Observatory: C-band Synthetic Aperture Radar
- Main operational mode: SAR imaging (Interferometric Wide Swath)
- Prime task: Continuity of operational SAR applications including interferometry

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Sentinel-1 Instrument Performance

- C-Band multi-mode SAR with selectable dual polarisation.
- Sensitivity (noise equivalent sigma-zero)
  better than -22dB (ASAR: -20 dB)
- Radiometric Accuracy (3σ)
  better than 1dB (ASAR: 1.2 dB)
- Ambiguity ratio (for distributed targets)
  better than -22dB (ASAR: -17 dB)
- Spatial resolution (Strip-map mode)
  better than 5x5m (ASAR: 28m x 28 m)

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Sentinel-1 Nominal Modes

Sentinel-1 has four nominal operational modes designed for inter-operability with other systems:

- Stripmap Mode (SM) with 80 km swath and 5x5 metre spatial resolution
- Interferometric Wideswath Mode (IW) with 250 km swath, 5x20 meter spatial resolution and burst synchronisation for interferometry
- Extra-wide Swath Mode (EW) with 400 km swath and 25x100 meter spatial resolution (3-Looks)

These modes are available with selectable dual polarisation (VV+VH, or HH+HV)

- Wave Mode (WV) with 20x20km swath. Sampled image mode with low data rate and 5x20 meter spatial resolution.

This mode is available with selected single polarisation (VV or HH)

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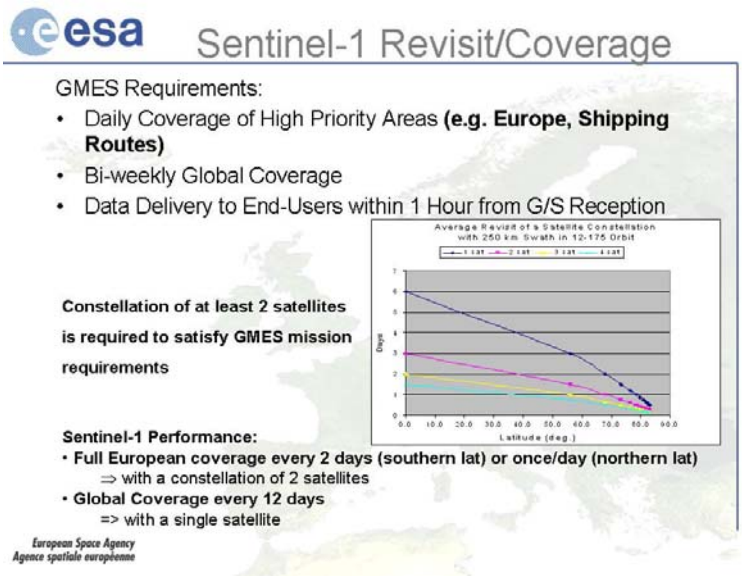
esa
Sentinel-1 Revisit/Coverage
GMES Requirements:
• Daily Coverage of High Priority Areas (e.g. Europe, Shipping Routes)
• Bi-weekly Global Coverage
• Data Delivery to End-Users within 1 Hour from G/S Reception
Constellation of at least 2 satellites is required to satisfy GMES mission requirements
Sentinel-1 Performance:
• Full European coverage every 2 days (southern lat) or once/day (northern lat)
⇒ with a constellation of 2 satellites
• Global Coverage every 12 days
=> with a single satellite
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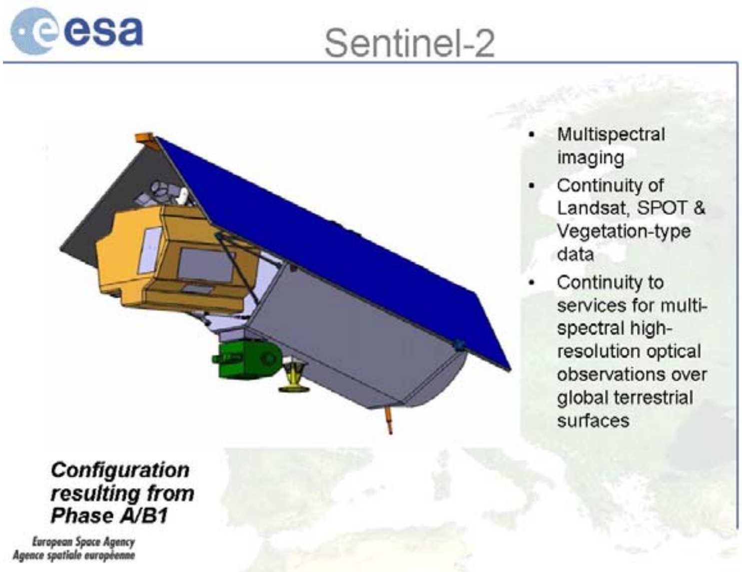
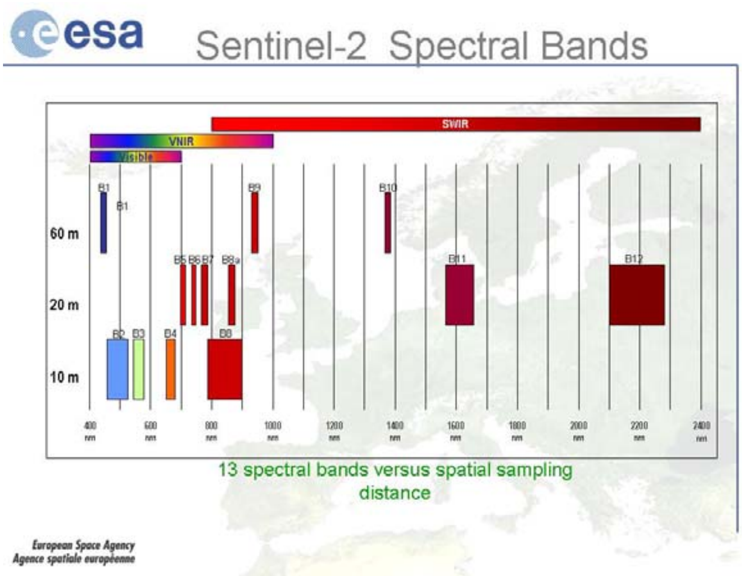

esa
Sentinel-2
• Multispectral imaging
• Continuity of Landsat, SPOT & Vegetation-type data
• Continuity to services for multi-spectral high-resolution optical observations over global terrestrial surfaces
Configuration resulting from Phase A/B1
European Space Agency
Agence spatiale européenne


esa
Sentinel-2 Spectral Bands
SWIR
VNIR
Visible
60 m
20 m
10 m
B1
B2
B3
B4
B5 B6 B7
B8a
B8
B9
B10
B11
B12
13 spectral bands versus spatial sampling distance
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esa

Spectral Coverage

As shown in the previous chart, the MSI's spectral coverage has been evolved to provide
- 4 Bands @ 10 m resolution
- 6 Bands @ 20 m
- 3 Bands @ 60 m

This evolution has been driven by the following mission goals:
- enhanced continuity to Spot and Landsat
- spectrally narrow bands for better feature identification
- channels in the red-edge spectral domain addressing vegetation,
- dedicated channels for improved atmospheric corrections and cirrus cloud detection

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esa

Sentinel-2 Spectral Bands

(Wavelength nm/Width nm/SSD m)

MSI spectral bands	Mission objective	Measurement or Calibration
B1(443/20/60), B2(490/65/10) & B12(2190/180/20)	Aerosols correction	Calibration bands
B8(842/115/10)/B8a(865/20/20), B9(940/20/60)	Water vapour correction	
B10(1375/20/60)	Cirrus detection	
B2(490/65/10), B3(560/35/10), B4(665/30/10), B5 (705/15/20), B6(740/15/20), B7(775/20/20), B8(842/115/10)/B8a(865/20/20), B11(1610/90/20), B12(2190/180/20)	Land cover classification, Leaf chlorophyll content, leaf water content, LAI, FAPAR, snow/ice/cloud, mineral detection.	Land measurement bands

In comparison, SPOT5 bands: 4 multi-spectral channels + 1 panchromatic channel between 0.49 um and 0.69 um.

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Instrument Features

- Swath: 285 Km
- 13 Bands @ 10-60 m resolution
- Radiometric Resolution 12 bit
- Onboard calibration
- Pushbroom technology
- VNIR (Very Near Infrared) focal plane: CMOS or CCD
- SWIR (Short-wave Infrared) focal plane: cooled MCT (Mercury Cadmium Telluride) detector hybridised on CMOS read-out circuit
- Shutter provided for launch contamination and sun view

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Mission Aspects

Coverage:

- Aim is to provide full land coverage (-56° to +83°)
- With 2 operational satellite, a 5 day revisit time is achieved (<<Landsat (16d) or Spot (26d))
- This then should provide global cloud free products every 15-30d
- A roll-tilt manoeuvre capability has been included in the design, allowing a more rapid (1-3d) access for disaster monitoring

Processing/Distribution

- Accurate geo-location (<20m) will be produced automatically
- Automatic data processing for pre-defined areas/time windows, made available on-line for subscribing users

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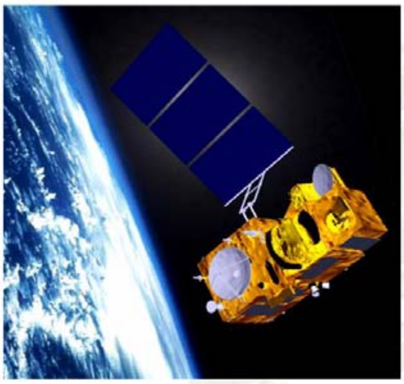
Sentinel-3



- Consistent, long-term collection of remotely sensed marine and land data
- Operational ocean state analysis, forecasting and service provision
- Advanced Radar Altimeter concept
- Multi-channel optical imager (VIS, IR)

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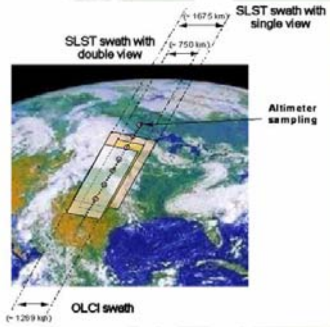
Sentinel-3 Payload Complement

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



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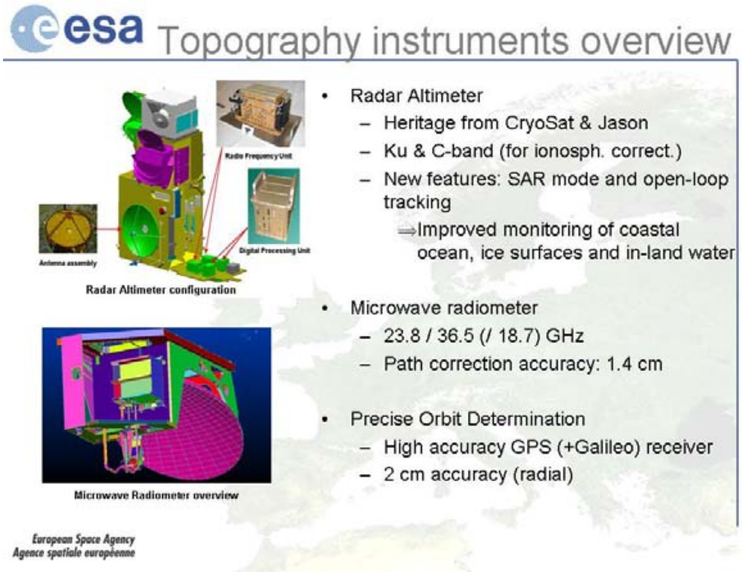
esa
Topography instruments overview
Radar Altimeter configuration
Microwave Radiometer overview
• Radar Altimeter
– Heritage from CryoSat & Jason
– Ku & C-band (for ionosph. correct.)
– New features: SAR mode and open-loop tracking
⇒Improved monitoring of coastal ocean, ice surfaces and in-land water
• Microwave radiometer
– 23.8 / 36.5 (/ 18.7) GHz
– Path correction accuracy: 1.4 cm
• Precise Orbit Determination
– High accuracy GPS (+Galileo) receiver
– 2 cm accuracy (radial)
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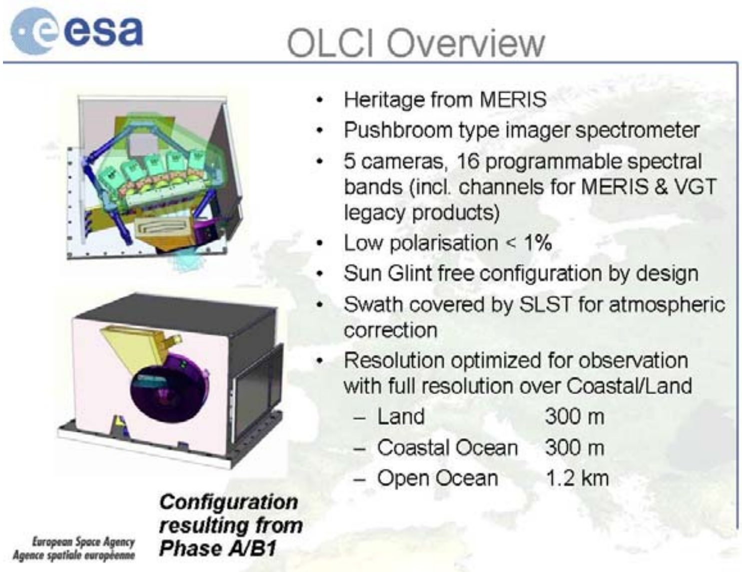
esa
OLCI Overview
• Heritage from MERIS
• Pushbroom type imager spectrometer
• 5 cameras, 16 programmable spectral bands (incl. channels for MERIS & VGT legacy products)
• Low polarisation < 1%
• Sun Glint free configuration by design
• Swath covered by SLST for atmospheric correction
• Resolution optimized for observation with full resolution over Coastal/Land
– Land 300 m
– Coastal Ocean 300 m
– Open Ocean 1.2 km
Configuration resulting from Phase A/B1
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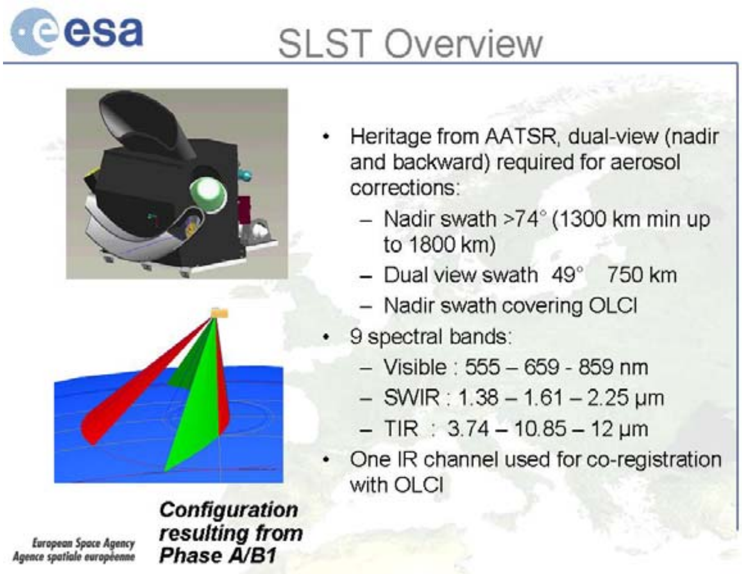
esa
SLST Overview
• Heritage from AATSR, dual-view (nadir and backward) required for aerosol corrections:
– Nadir swath >74° (1300 km min up to 1800 km)
– Dual view swath 49° 750 km
– Nadir swath covering OLCI
• 9 spectral bands:
– Visible : 555 – 659 - 859 nm
– SWIR : 1.38 – 1.61 – 2.25 µm
– TIR : 3.74 – 10.85 – 12 µm
• One IR channel used for co-registration with OLCI
Configuration resulting from Phase A/B1
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Mission Performance

- Revisit time (optical observations):
  - Full performance is met with 2 satellites. Significant improvement wrt to Envisat achieved with 1 satellite: wider instrument swath and optimised orbit.
  - Vegetation products, with approx. 1-day revisit are derived from OLCI (visible/NIR bands) and SLST (SWIR bands) over the overlapping part of their swaths.

		Revisit at Equator	Revisit for latitude > 30°	Requirement
Ocean Colour (sun-glint free)	1 Satellite	< 3.8 d	< 2.8 days	< 2 days
	2 Satellite	< 1.9 d	< 1.4 days	
Land Colour (and vegetation)	1 Satellite	< 2.2 d	< 1.8 days	< 2 days (goal 1d)
	2 Satellite	< 1.1 d	< 0.9 day	
SLST dual view	1 Satellite	< 1.8 days	< 1.5 days	< 4 days
	2 Satellite	< 0.9 day	< 0.8 day	

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Mission Performance (cont'd)

- Ocean Topography:

Error type	Value
Altimeter random	*1.3 cm*
Sea model	*2.0 cm*
Ionosphere	*0.7 cm*
Dry troposphere	*0.7 cm*
Wet troposphere	*1.4 cm*
Total range error (rms)	3.0 cm
POD (rms)	2.0 cm
Sea Surface Height (rms)	3.6 cm

- Products
  - Near Real Time L2 optical and topography products, available within 3 hours following acquisition.
  - Highest quality, Non-time critical L2 products, available within 1 month.

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Status of Sentinels 1-3

- Sentinel-1
  - Phase B2 start: April 2007
  - Preliminary Design Review: February 2008
  - Critical Design Review: March 2009
  - Flight Acceptance Review: August 2011
  - Launch: November 2011
  - Commissioning Review: February 2012
- Sentinel-2
  - Industrial proposals TEB selection process: May-July 2007
  - Phase B2 start: October 2007
  - Preliminary Design Review: October 2008
  - Critical Design Review: Mid 2010
  - Flight Acceptance Review: January 2012
  - Launch: April 2012
  - Commissioning Review: July 2012
- Sentinel-3
  - Industrial proposals TEB selection process: May-July 2007
  - Phase B2 start: October 2007
  - Preliminary Design Review: August 2008
  - Critical Design Review: February 2010
  - Flight Acceptance Review: April 2012
  - Launch: August 2012
  - Commissioning Review: January 2013

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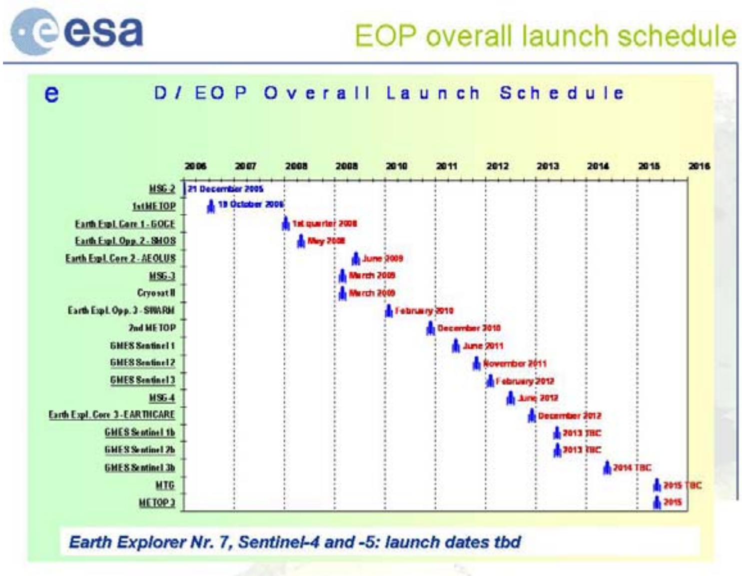
esa
EOP overall launch schedule
e
D / EOP Overall Launch Schedule
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
MSG-2
21 December 2005
1stMETOP
19 October 2006
Earth Expl. Core 1 - GOCE
1st quarter 2008
Earth Expl. Opp. 2 - SMOS
May 2008
Earth Expl. Core 2 - AEOLUS
June 2009
MSG-3
March 2009
Cryosat II
March 2009
Earth Expl. Opp. 3 - SWARM
February 2010
2nd METOP
December 2010
GMES Sentinel 1
June 2011
GMES Sentinel 2
November 2011
GMES Sentinel 3
February 2012
MSG-4
June 2012
Earth Expl. Core 3 - EARTHCARE
December 2012
GMES Sentinel 1b
2013 TBC
GMES Sentinel 2b
2013 TBC
GMES Sentinel 3b
2014 TBC
MTG
2015 TBC
METOP 3
2015
Earth Explorer Nr. 7, Sentinel-4 and -5: launch dates tbd


esa
Earthnet and Third Party Missions
Third Party Missions
Missions not operated by ESA
for which ESA assumes some responsibility / contributes financially (sharing of Ground Segment facilities or operations cost)
for which ESA assumes a data distribution responsibility, mainly towards the European Scientific User Community
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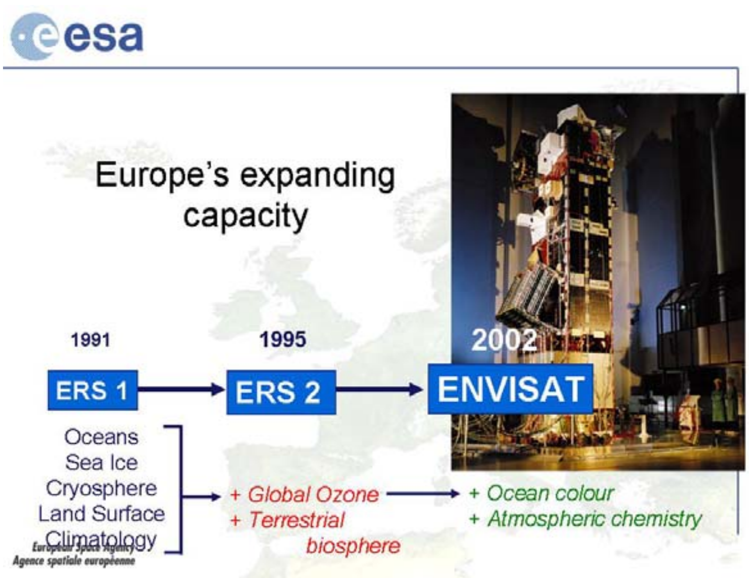
esa
Europe's expanding capacity
1991
1995
2002
ERS 1
ERS 2
ENVISAT
Oceans
Sea Ice
Cryosphere
Land Surface
Climatology
+ Global Ozone
+ Terrestrial biosphere
+ Ocean colour
+ Atmospheric chemistry
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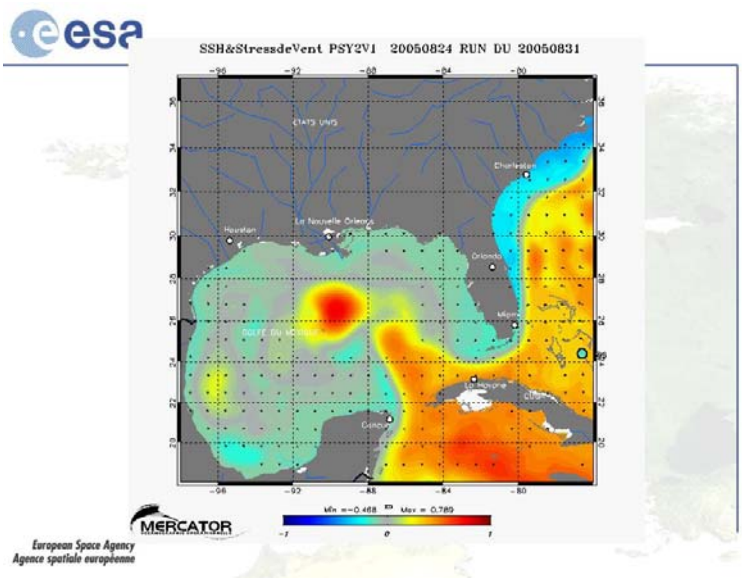
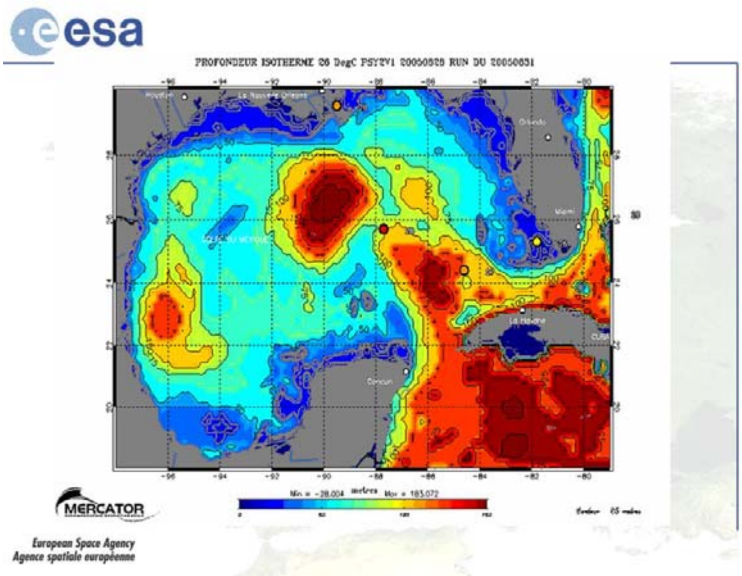
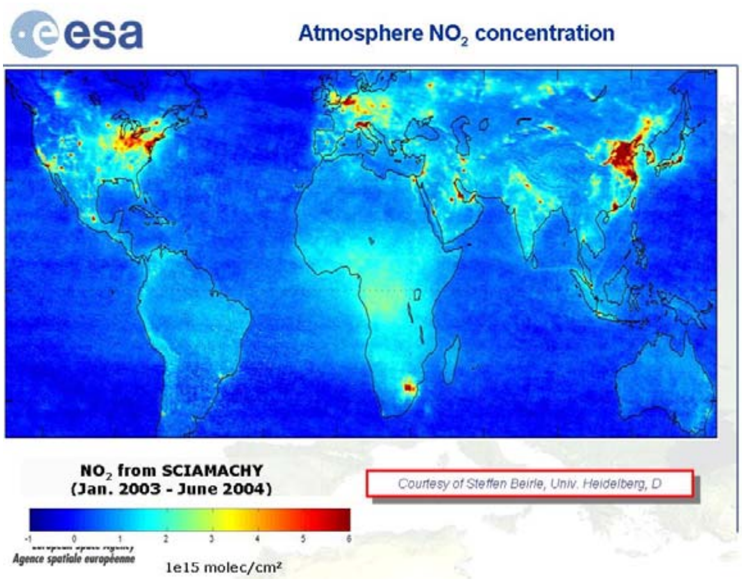
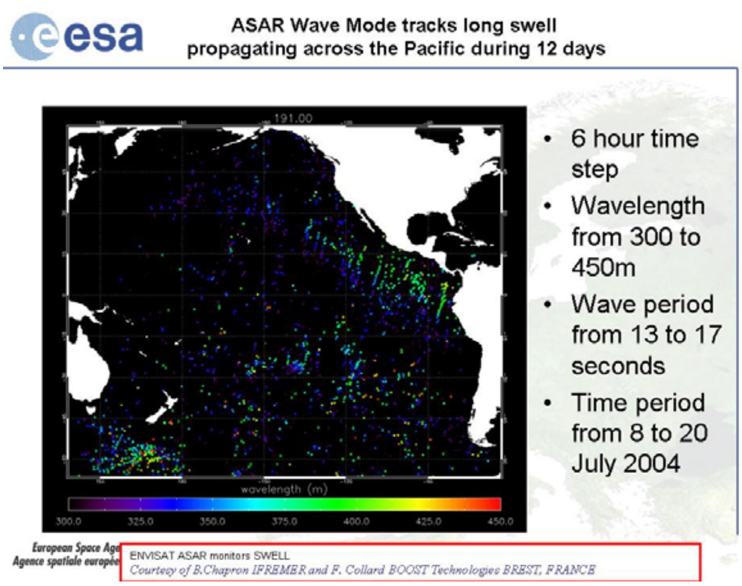
esa
Achievements: Science Exploitation
nature
EARTHQUAKE FORECASTING
Science
CASSINI
TITAN
IEEE TRANSACTIONS ON GEOSCIENCE AND REMOTE SENSING
Geophysical Research Letters
▪ 2000+ scientific teams worldwide provided with data from ERS-1/2, Envisat and TPM
▪ users are provided free of charge software toolboxes that ease their work
▪ a versatile multi-mission ground segment, also drawing on MS facilities
▪ a large number of workshops and training courses
▪ growing number of scientific publications basing their results on data provided by ESA
▪ scientific results as basis for implementation of new applications and services


esa
Achievements: Exploitation
dup
Information
Service
User
• develop user communities for both institutional and commercial applications
• support European companies to develop and demonstrate information products
• support value adding and servicing companies in establishing useful and cost effective services.
EARTHOBSERVATION MARKETDEVELOPMENT
• building industrial partnerships to conduct pre-commercial service trials with customers
• marketable service portfolios developed with non-EO service suppliers engaged
• better understanding of the prospects for EO in emerging market sectors
• the GMES service element has established service partnerhips
• builds largely on scientific achievements
• forms the space basis for the GMES component

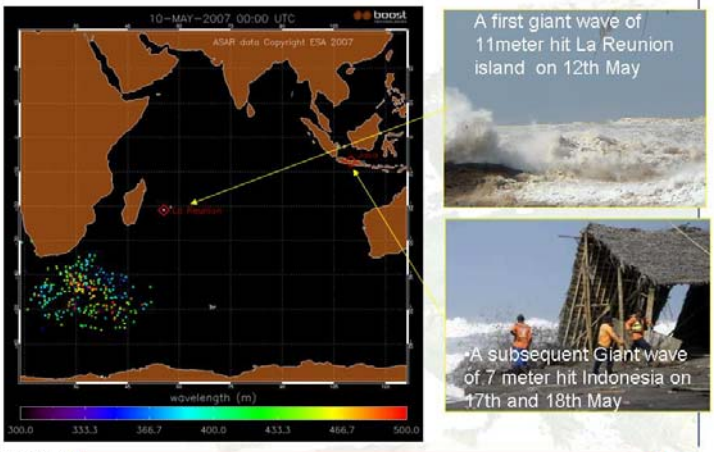

esa
SSH&StressdeVent PSY2V1 20050824 RUN DU 20050831
Charleston
Houston
La Nouvelle Orleans
Orlando
Miami
MERCATOR
European Space Agency
Agence spatiale européenne


esa
PROFONDEUR ISOTHERME 26 DegC PSY2V1 20050829 RUN DU 20050831
MERCATOR
European Space Agency
Agence spatiale européenne


esa
Atmosphere NO_2 concentration
NO_2 from SCIAMACHY
(Jan. 2003 - June 2004)
Courtesy of Steffen Beirle, Univ. Heidelberg, D
Agence spatiale européenne
1e15 molec/cm²


esa
ASAR Wave Mode tracks long swell
propagating across the Pacific during 12 days
191.00
wavelength (m)
300.0
325.0
350.0
375.0
400.0
425.0
450.0
• 6 hour time step
• Wavelength from 300 to 450m
• Wave period from 13 to 17 seconds
• Time period from 8 to 20 July 2004
ENVISAT ASAR monitors SWELL
Courtesy of B.Chapron IFREMER and F. Collard BOOST Technologies BREST, FRANCE

Headline news: ASAR Wave Mode tracking the long swell that hit La Reunion and Indonesia



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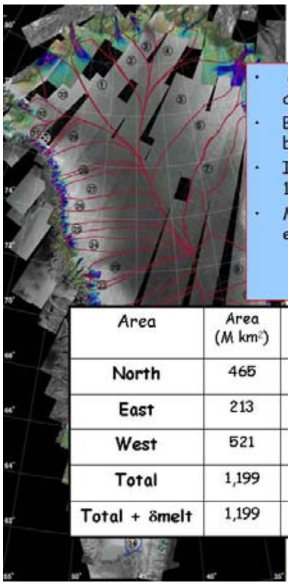
ENVISAT ASAR monitors SWELL
Courtesy of B.Chapron IFREMER and F. Collard BOOST Techenolgies BREST, FRANCE



Ice sheet mass balance

- Greenland ice sheet loss from ice dynamics increased by a factor 3 in 10 years.
- Enhanced melt from Hanna et al. JGR 2005 increases loss by 35 to 57 km³/yr.
- Ice dynamics contributes 2/3 of Greenland ice loss vs 1/3 for enhanced surface melt.
- Monitoring ice dynamics and progression further north is essential.

Area	Area (M km²)	Discharge (km³/yr)	Input (km³/yr)	Balance (96 | 00 | 05) (km³/yr)
North	465	49.5	50.0	-4.8 | +0.5 | -2.4
East	213	160.8	110.0	-31.8 | -50.8 | -118.4
West	521	168.0	145.0	-21.5 | -23.0 | -36.8
Total	1,199	378 ±12	305 ±30	-58 ±32 | -73 ±32 | -158 ±32
Total + δmelt	1,199			-93 ±34 | -119 ±34 | -215 ±35

Antarctic ice velocity: ERS-1/2 (1996), RSAT-1 (2000)

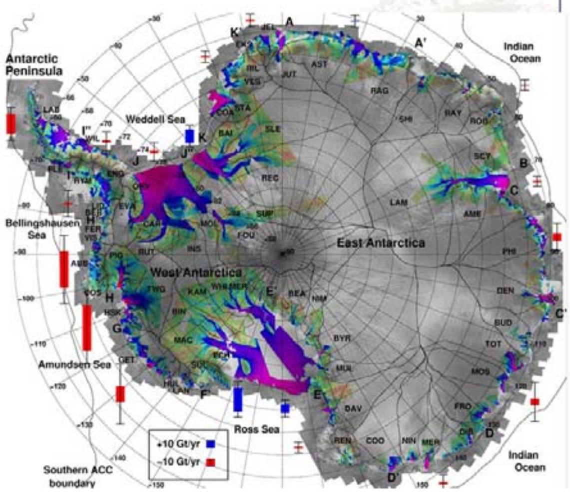
Mass deficit of 140±50 Gt/yr,

Mostly West Antarctica Ice Shelf & Antarctic Peninsula.

Entire Admundsen Sea/Bellingshausen Seas sector thinning dynamically.

East Antarctic Ice Shelf ~ balance

Rignot et al., Subm. 2007



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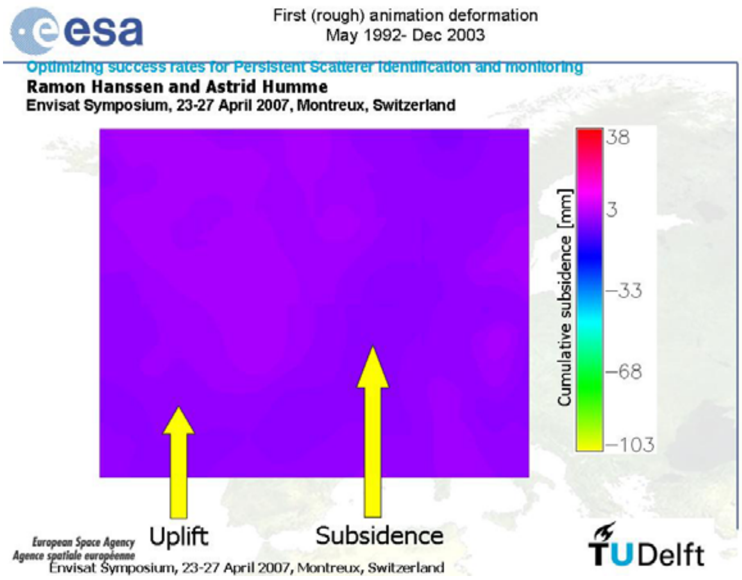
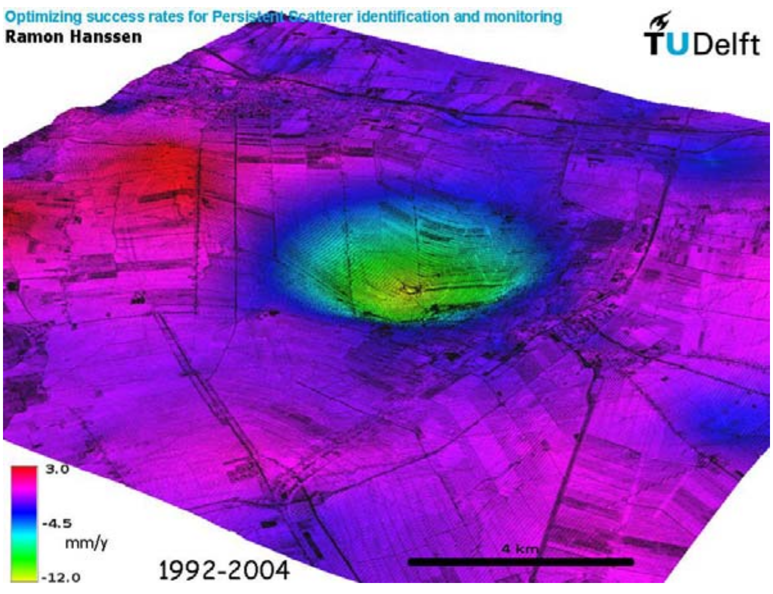
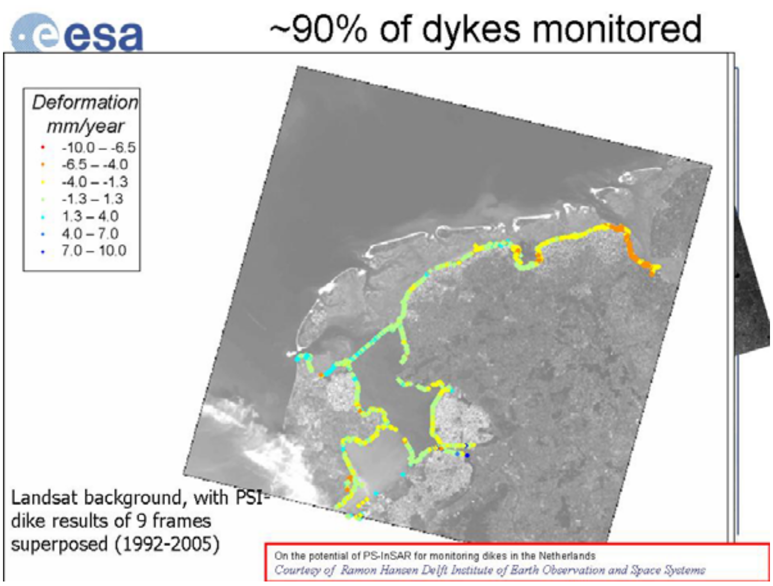
Veendam Salt Mining
4 km
Optimizing success rates for Persistent Scatterer identification and monitoring
Ramon Hanssen and Astrid Humme
Envisat Symposium, 23-27 April 2007, Montreux, Switzerland
TUDelft

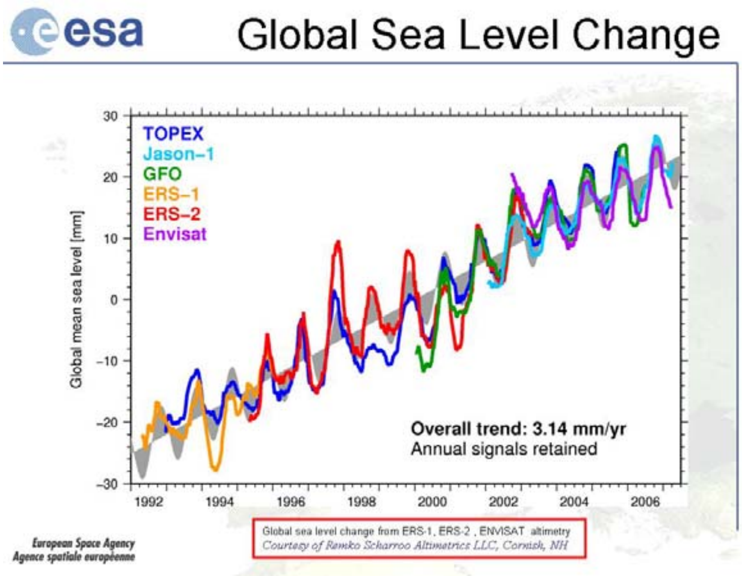

esa
First (rough) animation deformation
May 1992- Dec 2003
Optimizing success rates for Persistent Scatterer identification and monitoring
Ramon Hanssen and Astrid Humme
Envisat Symposium, 23-27 April 2007, Montreux, Switzerland
38
3
-33
-68
-103
Cumulative subsidence [mm]
Uplift
Subsidence
European Space Agency
Agence spatiale européenne
Envisat Symposium, 23-27 April 2007, Montreux, Switzerland
TUDelft

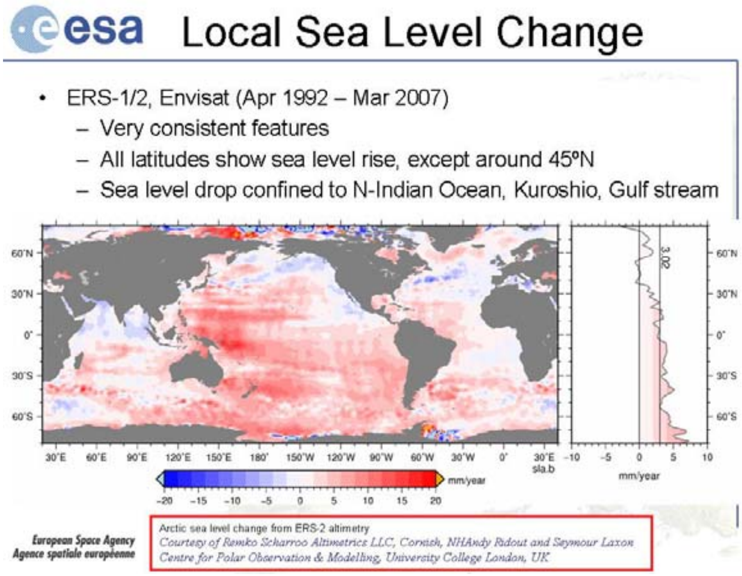

Optimizing success rates for Persistent Scatterer identification and monitoring
Ramon Hanssen
TUDelft
3.0
-4.5
mm/y
-12.0
1992-2004
4 km


esa
ENVISAT for monitoring dykes in the Netherlands
History: Zeeland, 31 Jan 1953
•Evacuation of 72000 people
•Thousands of buildings destroyed
N Noordzee
On the potential of PS-InSAR for monitoring dikes in the Netherlands
Courtesy of Ramon Hanssen Delft Institute of Earth Observation and Space Systems


esa
Can we monitor this from space?
Overflowing
Sliding inner slope
Overtopping
Plastic horizontal sliding
Piping
Nipping ice
17000 km of water barriers:
– 3565 km primary water barriers (big rivers, sea, IJsselmeer, Markermeer),
– >14000 km regional water barriers
On the potential of PS-InSAR for monitoring dikes in the Netherlands
Courtesy R. Hanssen Delft Institute of Earth Observation and Space Systems


esa
~90% of dykes monitored
Deformation mm/year
-10.0 – -6.5
-6.5 – -4.0
-4.0 – -1.3
-1.3 – 1.3
1.3 – 4.0
4.0 – 7.0
7.0 – 10.0
Landsat background, with PSI-dike results of 9 frames superposed (1992-2005)
On the potential of PS-InSAR for monitoring dikes in the Netherlands
Courtesy of Ramon Hanssen Delft Institute of Earth Observation and Space Systems


esa
Global Sea Level Change
TOPEX
Jason-1
GFO
ERS-1
ERS-2
Envisat
Global mean sea level [mm]
Overall trend: 3.14 mm/yr
Annual signals retained
Global sea level change from ERS-1, ERS-2 , ENVISAT altimetry
Courtesy of Remko Scharroo Altimetrics LLC, Cornish, NH
European Space Agency
Agence spatiale européenne


esa
Local Sea Level Change
• ERS-1/2, Envisat (Apr 1992 – Mar 2007)
– Very consistent features
– All latitudes show sea level rise, except around 45ºN
– Sea level drop confined to N-Indian Ocean, Kuroshio, Gulf stream
3.02
mm/year
Arctic sea level change from ERS-2 altimetry
Courtesy of Remko Scharroo Altimetrics LLC, Cornish, NHAndy Ridout and Seymour Laxon
Centre for Polar Observation & Modelling, University College London, UK
European Space Agency
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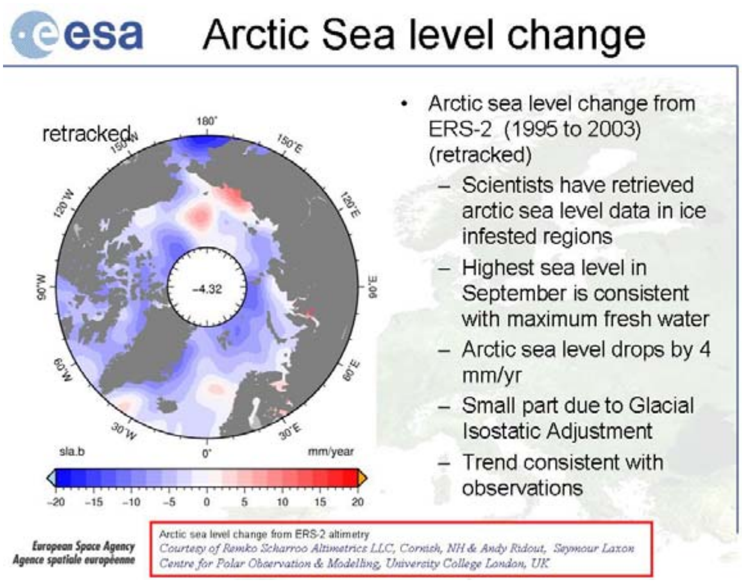
esa
Arctic Sea level change
retracked
-4.32
sla.b
mm/year
• Arctic sea level change from ERS-2 (1995 to 2003) (retracked)
– Scientists have retrieved arctic sea level data in ice infested regions
– Highest sea level in September is consistent with maximum fresh water
– Arctic sea level drops by 4 mm/yr
– Small part due to Glacial Isostatic Adjustment
– Trend consistent with observations
Arctic sea level change from ERS-2 altimetry
Courtesy of Remko Scharroo Altimetrics LLC, Cornish, NH & Andy Ridout, Seymour Laxon
Centre for Polar Observation & Modelling, University College London, UK
European Space Agency
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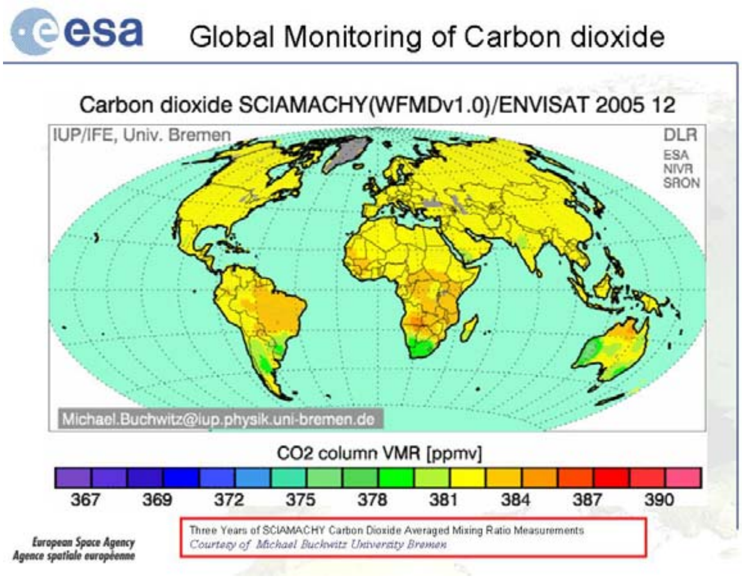
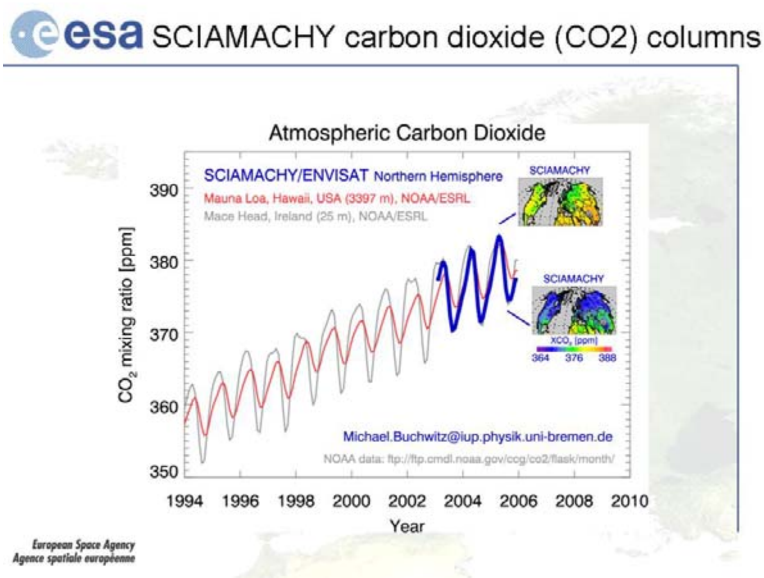

esa
Global Monitoring of Carbon dioxide
Carbon dioxide SCIAMACHY(WFMDv1.0)/ENVISAT 2005 12
IUP/IFE, Univ. Bremen
DLR
ESA
NIVR
SRON
Michael.Buchwitz@iup.physik.uni-bremen.de
CO2 column VMR [ppmv]
367 369 372 375 378 381 384 387 390
Three Years of SCIAMACHY Carbon Dioxide Averaged Mixing Ratio Measurements
Courtesy of Michael Buchwitz University Bremen
European Space Agency
Agence spatiale européenne


esa SCIAMACHY carbon dioxide (CO2) columns
Atmospheric Carbon Dioxide
SCIAMACHY/ENVISAT Northern Hemisphere
Mauna Loa, Hawaii, USA (3397 m), NOAA/ESRL
Mace Head, Ireland (25 m), NOAA/ESRL
SCIAMACHY
SCIAMACHY
CO2 mixing ratio [ppm]
390
380
370
360
350
Michael.Buchwitz@iup.physik.uni-bremen.de
NOAA data: ftp://ftp.cmdl.noaa.gov/ccg/co2/flask/month/
1994 1996 1998 2000 2002 2004 2006 2008 2010
Year
European Space Agency
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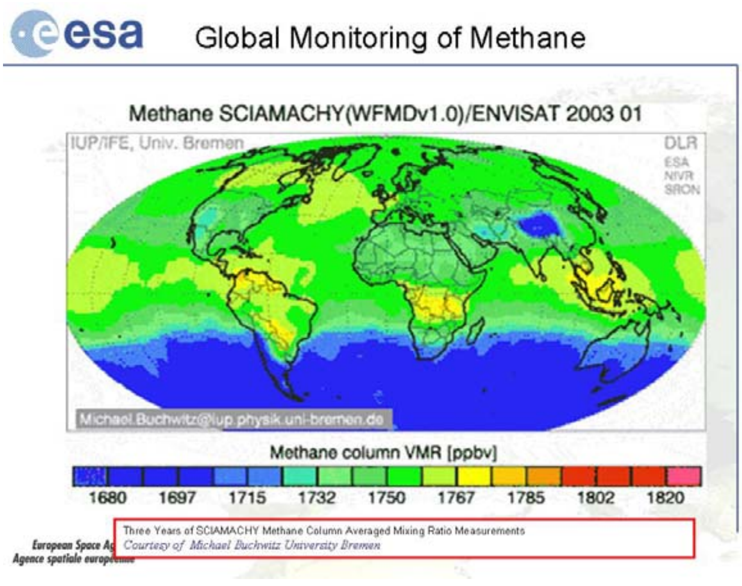
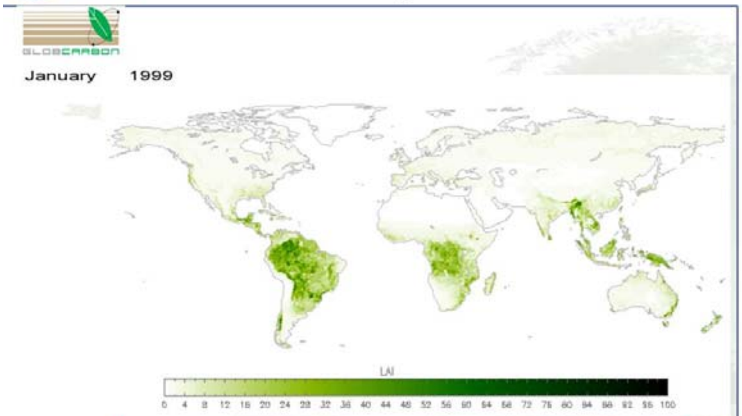

esa
Global Monitoring of Methane
Methane SCIAMACHY(WFMDv1.0)/ENVISAT 2003 01
IUP/IFE, Univ. Bremen
DLR
ESA
NIVR
SRON
Michael.Buchwitz@iup.physik.uni-bremen.de
Methane column VMR [ppbv]
1680 1697 1715 1732 1750 1767 1785 1802 1820
Three Years of SCIAMACHY Methane Column Averaged Mixing Ratio Measurements
Courtesy of Michael Buchwitz University Bremen

Leaf Area Index for global terrestrial carbon studies



4 years 1999 to 2002 measurements with ATSR-2, AATSR, MERIS, VEGETATION
Courtesy of Deng, F. et al., 2006, **Algorithm for global leaf area index retrieval using satellite imagery,** *IEEE Transactions on Geoscience and Remote Sensing,* 44(8), 2219-2229.

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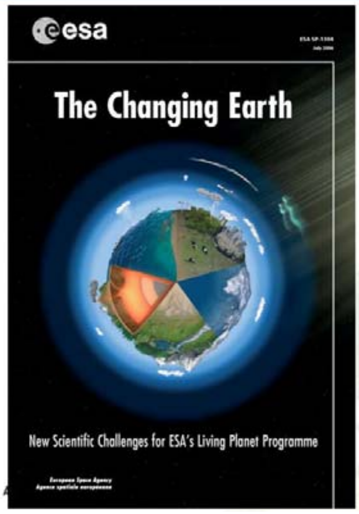
Scientific challenges for ESA's LPP



- an updated science strategy for ESA's Living Planet Programme has been formulated under the guidance of the Earth Science Advisory Committee
- a wide consultation on the strategy with the scientific community was undertaken at a workshop in February 2006
- the document addresses Earth science through the five topics: oceans, atmosphere, cryosphere, land and solid Earth and identifies the challenges for each of these
- particular emphasis is put on the Earth system approach, and on the effect of humankind on that system

Conclusion

- The updated strategy will provide the scientific guidance for activities to be undertaken in ESA's Living Planet Programme
- Future calls for mission ideas and proposals will solicit responses that address challenges presented in the report
- The Earth Science Advisory Committee will have full visibility into how the strategy is implemented and will provide continuous guidance
- ESA will actively cooperate with its Member States and partner agencies and organisations in order to implement the strategy
- A strong scientific programme is a guarantee and prerequisite for development of new applications and operational services using space data

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