ESA’s Living Planet Programme

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Europe’s expanding capacity

1991 ERS 1
1995 ERS 2
2002 ENVISAT

- Oceans
- Sea ice
- Cryosphere
- Land Surface
- Climatology
- + Global Ozone
- + Terrestrial biosphere
- + Ocean colour
- + Atmospheric chemistry

The Earth Explorer Missions

- GOCE
- SMOS
- ADM AEOUS
- SWARM
- CRYOSAT 2
- 7th EE
- EARTH CARE

CryoSat
the satellite attached to the launcher upper stage
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

What are the scientific objectives?
- 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 a 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
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GOCE: Uniqueness and Relevance

- Only mission with satellite gravimetry (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 IGOS (Integrated Global Observing System) and essential for WOCE, WCRP and CILVAR

SMOS: The Soil Moisture and Ocean Salinity 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-polar, 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

$$T_h = f(v, p, \theta, T, sm, s, \sigma, ...)$$
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**SMOS – measuring soil moisture and ocean salinity**

**AEOLUS - ADM**

**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’s Magnetic Field Mission**

**SWARM**

**The Earth’s Magnetic Field and Environment Explorer**

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

**The satellite constellation**

- 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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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: a flexible and rigid support structure isostatically mounted to the satellite nose.
4. SIRAL antenna.
5. Laser retroreflector: reflects tracking pulses back to ground-based laser stations.
6. DORIS antennas: 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 telecommunication from the ground.

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 Earth-Atlantic
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**ESA’s Cloud & Aerosol Mission**

**EARTHCARE**

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 Earth Clouds, Aerosols and Radiation Explorer**

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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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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.

New Earth Explorers (1)

**BIOMASS** – the mission aims at global measurements of forest biomass. The measurement is accomplished by a space-born, pointed aperture polarimetric radiometer. The technique is mainly based on the measurement of the cross-polar backscattering coefficient, from which forest biomass is directly retrieved. Use of multi-polarisation 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.

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’s 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 for instruments to measure high spectral resolution reflectance and temperature, and to provide a multi-angular capability.

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A-ECOPE – 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 distributed 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 1.6 and 1.2 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 ice-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.

EE-7 candidate missions - summary

Towards Meteosat Third Generation (MTG)

1977 2002 2015

MOP MSG MTG

1 observation mission: MWR: 3 channels
2 observation missions: - SEVIRI: 12 channels
- GCOM: - Spinning satellite

3 observation missions:
- IMP: 5 channels
- FDH: 22 channels
- Lightning Imager
- Infrared Red Sounder
- 2-axis stabilised satellite

DVS coordinated with GMES Sentinel-4

European Space Agency Agency seatel programme compliance

European Space Agency Agency seatel programme compliance

European Space Agency Agency seatel programme compliance

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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

**Sentinel-1 Instrument Performance**

- C-Band multi-mode SAR with selectable dual polarisation.
- Sensitivity (noise equivalent sigma-zero) better than -22 dB (ASAR: -20 dB)
- Radiometric Accuracy (3σ) better than 1 dB (ASAR: 1.2 dB)
- Ambiguity ratio (for distributed targets) better than -22 dB (ASAR: -17 dB)
- Spatial resolution (Strip-map mode) better than 5x5 m (ASAR: 26 m x 28 m)

**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 Wide swath 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 (VH, VH, or HH)

- Wave Mode (VV) with 20x20 km 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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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)
- Global Coverage every 12 days
  - with a constellation of 2 satellites
  - with a single satellite

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

Sentinel-2 Spectral Bands

13 spectral bands versus spatial sampling distance
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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

Sentinel-2 Spectral Bands

<table>
<thead>
<tr>
<th>MSI spectral bands</th>
<th>Mission objective</th>
<th>Measurement or Calibration</th>
</tr>
</thead>
<tbody>
<tr>
<td>B1(443/20/60), B2(490/65/10)</td>
<td>Aerosol’s correction</td>
<td>Calibration bands</td>
</tr>
<tr>
<td>B12(2190/180/20)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B8(642/115/10)/B9(865/20/20)</td>
<td>Water vapour correction</td>
<td></td>
</tr>
<tr>
<td>B9(940/20/40)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B10(1375/20/20)</td>
<td>Cirrus detection</td>
<td></td>
</tr>
<tr>
<td>B2(490/65/10), B3(560/395/10), B4(665/20/20), B5(705/15/20), B6(740/15/20), B7(775/20/20), B8(842/115/10)/B8a(865/20/20), B11(1610/10/20), B12(2100/180/20)</td>
<td>Land cover classification, leaf chlorophyll content, leaf water content, LAI, FAPAR, snow/ice/cloud, mineral detection.</td>
<td>Land measurement bands</td>
</tr>
</tbody>
</table>

In comparison, SPOT5 bands: 4 multi-spectral channels + 1 panchromatic channel between 0.45 um and 0.88 um.

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
Mission Aspects

Coverage:
- Aim is to provide full land coverage (-56° to +83°)
- With 2 operational satellites, a 5 day revisit time is achieved
  (-<Landsat (16d) or Spot (26d))
- This then should provide global cloud-free products every 15-30 days
- A roll-and-bend 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

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)

Sentinel-3 Payload Complement

- Topography Mission
  - Bi-frequency Synthetic Aperture Radar Altimeter
  - Microwave Radiometer (8- or Three-frequency)
  - Precise Orbit Determination (POD) including
    - GNSS Receiver
    - Laser Retro-Reflector
- Optical Payload
  - Ocean and Land Colour Instrument (OLCI)
  - Sea and Land Surface Temperature (SLST)
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Topography Instruments Overview

- Radar Altimeter
  - Heritage from CryoSat & Jason
  - Ku & C-band (for ionospheric correct.)
  - New features: SAR mode and open-loop tracking
    - Improved monitoring of coastal ocean, ice surfaces and inland 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)

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

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 - 869 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
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.

<table>
<thead>
<tr>
<th>Ocean Colour (sun-glint free)</th>
<th>Revisit at Equator</th>
<th>Revisit for latitude &gt; 30°</th>
<th>Requirement</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Satellite</td>
<td>&lt; 5.9 d</td>
<td>&lt; 2.6 days</td>
<td>&lt; 2 days</td>
</tr>
<tr>
<td>2 Satellite</td>
<td>&lt; 1.9 d</td>
<td>&lt; 1.4 days</td>
<td></td>
</tr>
<tr>
<td>1 Satellite</td>
<td>&lt; 2.2 d</td>
<td>&lt; 1.8 days</td>
<td></td>
</tr>
<tr>
<td>2 Satellite</td>
<td>&lt; 1.1 d</td>
<td>&lt; 0.9 days</td>
<td></td>
</tr>
<tr>
<td>1 Satellite</td>
<td>&lt; 1.8 days</td>
<td>&lt; 1.5 days</td>
<td></td>
</tr>
<tr>
<td>2 Satellite</td>
<td>&lt; 0.8 day</td>
<td>&lt; 0.8 day</td>
<td></td>
</tr>
</tbody>
</table>

Mission Performance (cont'd)

- Ocean Topography:

<table>
<thead>
<tr>
<th>Error type</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Altimeter random</td>
<td>1.3 cm</td>
</tr>
<tr>
<td>Sea model</td>
<td>2.0 cm</td>
</tr>
<tr>
<td>Ionosphere</td>
<td>0.7 cm</td>
</tr>
<tr>
<td>Dry troposphere</td>
<td>0.7 cm</td>
</tr>
<tr>
<td>Wet troposphere</td>
<td>1.4 cm</td>
</tr>
<tr>
<td>Total range error (rms)</td>
<td>3.0 cm</td>
</tr>
<tr>
<td>POD (rms)</td>
<td>2.0 cm</td>
</tr>
<tr>
<td>Sea Surface Height (rms)</td>
<td>3.6 cm</td>
</tr>
</tbody>
</table>

- 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.

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 proposal 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 proposal 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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**EOP overall launch schedule**

Earth Explorer Nr. 7, Sentinel-4 and -5 launch dates tbd

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**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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**Europe’s expanding capacity**

ERS 1  →  ERS 2  →  ENVISAT

- Oceans
- Sea ice
- Cryosphere
- Land Surface
- Climatology

- + Global Ozone
- + Terrestrial biosphere
- + Ocean colour
- + Atmospheric chemistry
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Achievements: Science Exploitation

- 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

Achievements: Exploitation

- 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
- 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 partnerships
- builds largely on scientific achievements
- forms the space basis for the GMES component

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Atmosphere NO₂ concentration

NO₂ from SCIAMACHY

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

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

A subsequent giant wave of 7 meter hit Indonesia on 17th and 18th May.

European Space Agency
Agency satellite component

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        | Discharge (km³/yr) | Input (km³/yr) | Balance (96 | 00 | 05)     |
|-------------|--------------------|----------------|---------------|-----------|
| North       | -468               | 49.8           | 90.0          | -4.8 | -0.5 | -2.4 |
| East        | 233                | 160.9          | 110.0         | -31.8 | -50.8 | -118.4 |
| West        | 621                | 168.0          | 148.0         | -21.3 | -23.0 | -36.8 |
| Total       | 1,999              | 378±12         | 306±30        | -58±22 | -73±22 | -158±22 |
| Total + melt| 1,999              | 378±12         | 306±30        | -93±24 | -119±24 | -215±28 |


Mass deficit of 140±50 Gt/yr;
Mostly West Antarctica Ice Shelf & Antarctic Peninsula.
Entire Admudsen Sea/Bellinghausen Sea sector thinning dynamically.
East Antarctic Ice Shelf ~ balance
Rignot et al., Subm. 2007
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First (rough) animation deformation
May 1992 - Dec 2003

Optimizing success rates for Persistent Scatterer identification and monitoring
Ramon Hansen and Astrid Humme
Envisat Symposium, 23-27 April 2007, Montreux, Switzerland

Uplift Subsidence

Optimizing success rates for Persistent Scatterer identification and monitoring
Ramon Hansen

European Space Agency
Envisat Symposium, 23-27 April 2007, Montreux, Switzerland

1992-2004

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**ENVISAT for monitoring dykes in the Netherlands**

**History: Zeeland, 31 Jan 1953**

- Evacuation of 72000 people
- Thousands of buildings destroyed

17000 km of water barriers:
- 3565 km primary water barriers (e.g., rivers, sea, IJsselmeer, Markermeer)
- >14000 km regional water barriers

**Can we monitor this from space?**

~90% of dykes monitored

Landsat background, with PSI dikes results of 9 frames superposed (1992-2005)
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Global Sea Level Change

- **TOPEx**, **GFO**, **ERS-1**, **ERS-2**
- Overall trend: 3.14 mm/yr
- Annual signals retained

Local Sea Level Change

  - Very consistent features
  - All latitudes show sea level rise, except around 45°N
  - Sea level drop confined to Ni-Indian Ocean, Kuroshio, Gulf stream

Arctic Sea Level Change

- Arctic sea level change from **ERS-2** (1995 to 2003)
  - 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
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**Leaf Area Index for global terrestrial carbon studies**

January 1999

- A year 1999 to 2002 assessment with [ASTER–MODIS, MERIS, VEGETATION]

**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 2008
- 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