ESA EO Satellite Missions for Oceanography

From Science to Applications and Services

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Head R&D section
EO Science and Applications Department
European Space Agency ESRIN
Frascati - ITALY
OUTLINE

- ESA Earth Observation PIs
- ERS-1 and 2 missions
- ENVISAT mission
- Third Party Missions
- GMES-1 services
Earthnet: European access to non-ESA missions:
Landsat, SeaWifs, NOAA, JERS, MODIS, ALOS, Proba, Bird, Scisat...

Meteo
in cooperation with EUMETSAT

Science
to better understand the Earth

Applications Services
to initiate long term monitoring systems and services

EO Missions handled by EOP
Earth Observation Principal Investigator Portal (to apply for ESA EO data)

http://eopi.esa.int
All the Announcements of Opportunity and the Calls for Proposals since 1998
Third Party Missions available through the Category 1 scheme

Currently open AOs and Calls
An increasing number of **worldwide** scientific users

Category-1 and AO statistics

* Estimates for 2006

<table>
<thead>
<tr>
<th>Year</th>
<th>No of Proposals</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>17</td>
</tr>
<tr>
<td>2001</td>
<td>98</td>
</tr>
<tr>
<td>2002</td>
<td>201</td>
</tr>
<tr>
<td>2003</td>
<td>350</td>
</tr>
<tr>
<td>2004</td>
<td>544</td>
</tr>
<tr>
<td>2005</td>
<td>768</td>
</tr>
<tr>
<td>2006</td>
<td>1070</td>
</tr>
</tbody>
</table>

* Year 2006 estimates.
ENVISAT mission: 4 years of activity

First images

Global air pollution

Bam earthquake

Tectonic uplift (Andaman)

Hurricane Katrina

Chlorophyll concentration

Prestige tanker

First Image via Artemis

Ozone hole 2003

ENVISAT Symposium 2007

Environmental Satellite Symposium and 23-27 April

Scientific publications

Launch
Calibration Review
Validation Workshop
MERIS Workshop
FRINGE workshop
Envisat Symposium Salzburg (A)
MERIS / (A)ATSR Workshop
FRINGE SESAR
ALTIMETRY Symposium
Atmospheric Science Conference

Mar 02 Sep 02 Dec 02 Nov 03 Dec 03 Sept 04 Sep 05 Dec 05 Jan 06 Mar 06 May 06 Apr 07
Workshops and Symposia for PIs
Scientific exchange, Reporting results/progress, Collecting PI feedback
Evolution of PI demand to multi-missions event

Papers and presentations available on-line
• Software ‘Toolboxes’ instigated by ESA contracts.
• Each Toolbox is a collection of software tools to help the remote sensing community to exploit ESA-TPM data.
• New generation to contain Scientific tutorials prepared with Universities and practical case studies using real EO data.
<table>
<thead>
<tr>
<th>Mission Compatibility</th>
<th>Multi-Mission User Toolboxes</th>
</tr>
</thead>
</table>

- **SMOS Toolbox**
  - SMOS
  - GOCE
  - Cryosat 2

- **BRAT**
  - RA2

- **GUT**
  - RA

- **SMOS** Toolbox
  - AIRSAR
  - EMI SAR
  - E-SAR
  - P3 SAR
  - SAR 580
  - RAMSES

- **TPM**
  - MODIS
  - TOMS
  - OMI
  - GOME2
  - TES
  - MLS

- **BRAT**
  - ASAR
  - MERIS
  - AATSR
  - ASAR

- **GUT**
  - MIPAS
  - OOMOS
  - SCIAMACHY
  - ASAR AP

- **SMOS Toolbox**
  - RA2
  - RA2

- **TPM**
  - Jason-1
  - Topex/Posidon
  - PALSAR
  - TerraSAR-L
  - TerraSAR-X
  - SIR-C
First Advanced Training Course on Land Remote Sensing

**Dates:** 2-7 September 2007

**Venue:** Instituto Superior de Estatística e Gestão de Informação, Universidade Nova de Lisboa (ISEGI-UNL), Lisbon, Portugal

**Audience profiles:** PhD students, postdoc/research scientists from Europe and Canada

**Number of participants:** 60

**TOPICS:** SAR (INSAR, Polarimetry, POLINSAR), OPTICAL, THERMAL theory and land applications focused on GMES priority themes

**Organizers:** Y-L Desnos ESA, Mário Caetano (IGP, Marco Painho (ISEGI-UNL)

**Website:** [http://earth.esa.int/Landtraining07](http://earth.esa.int/Landtraining07)
ERS Missions
• 15 years of ERS-1/2 data in the archive
  (suitable for applications requiring long term series products)

• ERS-2 achieved 11 years in orbit in April 2006
  (was designed for 3 years nominal lifetime)

• Some problems with the platform
  (gyroscope in 2001, tape recorder in 2003)
• but all instruments still functioning well
  ◊ engineering solutions have been developed:
    - new 'gyro-less' working mode
    - set up of a station network for Low Bit Rate data recovery

• Operations funding expected until 2008
### ERS-2 satellite and payload status

<table>
<thead>
<tr>
<th>Mission elements</th>
<th>Expected evolution</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Service Module</td>
<td>Good</td>
<td><strong>Relaxed attitude control</strong> +/− 2 deg, all other subsystems with full redundancy. SPOT-1 platform flown for 17 years before de-orbiting.</td>
</tr>
<tr>
<td>Propulsion and Hydrazine</td>
<td>Excellent</td>
<td>1/3 of hydrazine has been consumed within 11 years</td>
</tr>
<tr>
<td>Payload Equipment Bay</td>
<td>Fair</td>
<td><strong>Tape Recorders Failed</strong>, Realtime mission only with some 40% global coverage. Transmission Tube redundancy available.</td>
</tr>
<tr>
<td>SAR Image Mode</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>SAR Wave Mode</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>Scatterometer</td>
<td>Fair</td>
<td>Sub System on redundant side</td>
</tr>
<tr>
<td>RA &amp; MWR</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>ATSR</td>
<td>Good</td>
<td>Scan Mirror problem has been overcome by patches on ground</td>
</tr>
<tr>
<td>GOME</td>
<td>Good</td>
<td>Calibration lamp problem overcome by using sun measurements</td>
</tr>
<tr>
<td>PRARE</td>
<td>Excellent</td>
<td>Reduced surface transponders covering North &amp; South Poles and Europe only; no redundancy</td>
</tr>
</tbody>
</table>
PI publications and workshops within the framework of ESA missions ERS-1&2 exploitation and ENVISAT mission preparation and exploitation:
Greenland Ice Sheet velocity structure

“Study of glacier velocity over the Greenland ice sheet has shown significant acceleration of outlet glaciers during the last few years, doubling Greenland’s contribution to sea level rise between 1995 and 2005” – Eric Rignot, JPL
Contribution to sea level rise is 0.65 mm/yr in 2005.

Global Marine Geoid from Radar Altimetry (1 to 12 km resolution). The ERS-1 Geodetic Mission offered to scientists an unprecedented view of the Marine Gravity Anomalies. The ERS-1 GM offered a dense mesh of ground tracks with 8 km cross-track resolution at the Equator.
Global Bathymetry from Satellite Altimetry

From Smith and Sandwell (1997)
ENVISAT Mission
ENVISAT: 10 instruments to monitor the Earth

- Michelson Interferometric Passive Atmospheric Sounder (MIPAS)
- Medium Resolution Imaging Spectrometer (MERIS)
- Global Ozone Monitoring by Occultation of Stars (GOMOS)
- Advanced Along Track Scanning Radiometer (AATSR)
- Scanning Imaging Absorption Spectrometer for Atmospheric Cartography (SCIAMACHY)
- Microwave Radiometer (MWR)
- Ka-band Radar Altimeter 2 (RA-2)
- X-band Radar Altimeter (XRA)
- Advanced Synthetic Aperture Radar (ASAR)
- Doppler Orbitography and Radio-positioning Integrated by Satellite (DORIS)
- Data Relay Satellite Artemis
- Ground Stations

**Launch**
- 1st March 2002

** Orbit**
- 800 km, sun synchronous
  - 10:00 am, i.e. 30 minutes before ERS-2
ENVISAT mission

- Largest European satellite & largest worldwide EO satellite:
  - unique combination of 10 instruments addressing land, ocean, ice and atmosphere studies,
  - instruments working nominally, in particular ASAR
  - some concern with altimeter instrument

- Satellite OK with long-term operations capabilities:
  - 57% of fuel available
    (i.e. about 4 years assuming same orbit control strategy: +/- 1 km)

- Operations funding until 2010

- 78 different types of ESA data products (27 types of ASAR products)

- 250 Gigabytes of data products generated per day at ESA (+ telemetry)
### Expected Envisat evolution

<table>
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<tr>
<th>Mission elements</th>
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<tr>
<td>Service Module</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>Propulsion and Hydrazine</td>
<td>Fair</td>
<td>Main limiting factor of the mission</td>
</tr>
<tr>
<td>Payload Equipment Bay</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>ASAR</td>
<td>Fair</td>
<td>Sub-system on redundant side</td>
</tr>
<tr>
<td>MERIS</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>AATSR</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>RA-2</td>
<td>Fair</td>
<td>Recent anomaly with altimetric range measurement On ground correction tables</td>
</tr>
<tr>
<td>MWR</td>
<td>Good</td>
<td></td>
</tr>
<tr>
<td>DORIS</td>
<td>Fair</td>
<td>Instrument on redundant side</td>
</tr>
<tr>
<td>SCIAMACHY</td>
<td>Excellent</td>
<td></td>
</tr>
<tr>
<td>MIPAS</td>
<td>Bad</td>
<td>Progressive mechanical degradation in non redundant part. Used on campaign basis.</td>
</tr>
<tr>
<td>GOMOS</td>
<td>Fair</td>
<td>Instrument on redundant side. New operations scenario is satisfactory.</td>
</tr>
</tbody>
</table>
• ASAR Level 1 product derived from Single Look Complex imagettes using cross-spectra methodology
  • Publication *(Engen et al., 1995, TGARS)*
  • Users - scientists consultation 1995
  • Prototype 1996
  • Implementation in PF-ASAR 1997

• Improvements:
  • Improved signal-to-noise ratio
  • Wave propagation ambiguity resolvable
  • Improved spectral resolution
New algorithm developed for ESA by ESL (NORUT & IFREMER)

Meteo Users & scientists consultation 1997-1999

Prototype 2001

PF-ASAR September 2002

Properties:

- Optimal utilization and processing of the SLC data
- No a priori information
- Provide SAR ocean wave spectra and local wind speed estimate
  - Wave spectra, wind speed, wave height, radar cross section, azimuth cut-off, orbital velocity variance, non-linear spectral width
Alaska SAR Demonstration

ENVISAT ASAR Wide Swath Mode, 02 Dec 2005 06:43 UT

William PICHEL et al. (ENVISAT-AO Project 431)
Doppler centroid anomaly:
a direct measurement of ocean surface currents from space

Radial component of sea surface scatterers overlaid on sea surface roughness – Straits of Florida
New Measurements exploitation

Doppler centroid anomaly
Envisat monitors Ice-Sea Ice in Antarctica

LARSEN B collapse observed in 2002 by ERS /Envisat

Envisat Radar monitoring Antarctica Ice and Sea-Ice extent (April-to June 2004)

Courtesy of H.Rott, Univ Innsbruck, AU
Global Level 3 products

MERIS chlorophyll-a

http://envisat.esa.int/level3/
Global Level 3 products

MERIS aerosol optical thickness (865nm)

http://envisat.esa.int/level3/
Global Level 3 products

MERIS water vapor

http://envisat.esa.int/level3/
Envisat and ERS measure Sea Surface Temperature rise

ATSR/AATSR measurements
Trend 0.13±0.03°C/decade

Courtesy of David Llewellyn Jones, Univ. Leicester, UK
Merging of the sea level time series of all six altimeters. The time series are filtered using a 3-month boxcar filter. A common annual cycle and trend was estimated, along with a bias for each altimeter.

**Top:** Annual signals retained, estimated trend and annual variation shown in grey.

**Bottom:** Common annual signals removed.

Reference: GLOBAL AND REGIONAL SEA LEVEL CHANGE FROM MULTI-SATELLITE ALTIMETER DATA Remko Scharroo1 and Laury Miller21 Altimetries LLC, Cornish, New Hampshire, USA 2 NOAA Laboratory for Satellite Altimetry, Silver Spring, Maryland, USA
The World from Radar Altimetry

S&S/ACE DEM (RESOLUTION = 30sec)
Third Party Missions
### ESA selected Third Party Missions

#### Research and Applications Opportunities

<table>
<thead>
<tr>
<th>Year</th>
<th>Missions</th>
</tr>
</thead>
<tbody>
<tr>
<td>2004</td>
<td>OMI Cat-1, ERS, ENVISAT, OMI</td>
</tr>
<tr>
<td></td>
<td>ALOS AO, ERS, ENVISAT, All TPM</td>
</tr>
<tr>
<td></td>
<td>Proba Cat-1, ERS, ENVISAT, All TPM</td>
</tr>
<tr>
<td></td>
<td>Landsat Cat-1, ERS, ENVISAT, All TPM</td>
</tr>
<tr>
<td></td>
<td>Kompsat Cat-1, ERS, ENVISAT, All TPM</td>
</tr>
<tr>
<td></td>
<td>Scisat Cat-1, ERS, ENVISAT, All TPM</td>
</tr>
<tr>
<td></td>
<td>Orbview-2 Cat-1, ERS, ENVISAT, All TPM</td>
</tr>
<tr>
<td></td>
<td>Spot-4 Cat-1, ERS, ENVISAT, All TPM</td>
</tr>
<tr>
<td></td>
<td>IRS-P6 Cat-1, ERS, ENVISAT, All TPM</td>
</tr>
<tr>
<td>2005</td>
<td>+ Kompsat-2, Bird, CBERS, DMC….</td>
</tr>
</tbody>
</table>
Mission Objectives

- Develop digital elevation models (DEM)
- Perform regional observation for sustainable development
- Conduct disaster monitoring around the world
- Survey natural resources
- Develop sensor and satellite technology

Launch

- ALOS launch 24th Jan 2006 successfully by an H-IIA rocket
- First data: 14th Feb (PRISM), 15th (PALSAR), 17th (AVNIR-2)
- First complete downlink with data at Kiruna 28th April

PALSAR

*Phased Array type L-band Synthetic Aperture Radar*: an active microwave sensor which enables all-weather, 24-hours observations. The sensor has a steerable beam in elevation and the ScanSAR mode. PALSAR has also fully polarimetric capabilities.
First PALSAR Images acquired in Kiruna

Product Type Code: PSR_FLSensor
Instrument: PALSAR
Acquisition Station: KS
Start: 2006-05-01T10:20:46

Product Type Code: PSR_FLSensor
Instrument: PALSAR
Acquisition Station: KS
Start: 2006-04-28T09:53:57

First PALSAR Images acquired in Kiruna.
Support to Scientific Exploitation
POLinSAR 2007

The 3rd International Workshop on Science and Applications of SAR Polarimetry and Polarimetric Interferometry

ANNOUNCEMENT & CALL FOR PAPERS

ESA-ESRIN Frascati, Rome, Italy • 22-26 January 2007

web site: http://earth.esa.int/pollinsar2007 • e-mail: envmail@esa.int

THEMES

The workshop will focus on theory and methods in the fields of SAR Polarimetry and Polarimetric Interferometry around the following themes:

1. SAR Polarimetric Interferometry (Pol-InSAR)
2. Theoretical Modelling
3. Applications
   - Forestry
   - Land-Agriculture
   - Snow and Ice
   - Ocean
   - Other
4. Polarimetry and Persistent Scatterer Interferometry (PSI)
5. ALOS PALSAR first results
6. Spaceborne missions for Pol-InSAR
   - TerraSAR-X, Radarsat-2
   - Cosmo-Skymed and others
7. Airborne Pol-InSAR campaigns
POLARIMETRY Application for Sea Ice: alpha-anisotropy classification

Newly forming ice  
Smooth first year ice  
Ridged first year ice  
Compressed first year ice  
Multiyear ice floes  

Entropy-alpha-anisotropy classification

R & D for future mission exploitation
Polarimetric SAR Data Processing and Educational Tool (POLSARPRO)

http://earth.esa.int/polsarpro

~530 registered users

Polarimetric Target Signatures
GMES Services
Geographic coverage – baseline service

Oil pollution

Water Quality & Algal Bloom
Oil Spill detection
Service Examples: Spain & North Sea
MarCoast Drift Forecasting

SST, SLA & OC

Data assimilation

In-situ

Ocean forecast

Oil slick location & extent

Oil slick drift forecast

NRT SAR
Polar View Services

• Polar View services address user requirements in the following areas:

§Safe Shipping
– Ship and iceberg monitoring
– Ice charting
– Ice forecasting
– Floe edge monitoring

§Water and Environment
– Glacier monitoring
– Snow mapping
– River and lake ice monitoring
– Ice trajectories and pollution transport

§Adapting to Climate Change
– Floe edge monitoring
– Glacier and snow monitoring
– River and lake ice monitoring
– Climate change adaptation indicators
Snow Services: Fractional Snow Covered Area

Examples of Snow maps during melting period 2006

No snow Full snow cover Cloud Water
High-Resolution Ice Thickness Charts over Baltic Sea

- Ice thickness chart is based on SAR and ground truth.
- Spatial resolution 500 by 500m = product for ships and in ships’ scale.
- End users: shipping
Met-Ice-Ocean Regional Forecasting at FIMR

- End users: shipping
- resolution 1 nautical mile
- 6 parameters:
  - ice concentration and drift
  - ice ridge thickness
  - ice ridge concentration
  - compress region
  - deformed ice fraction
  - mean ice thickness
- published once a day