ERS

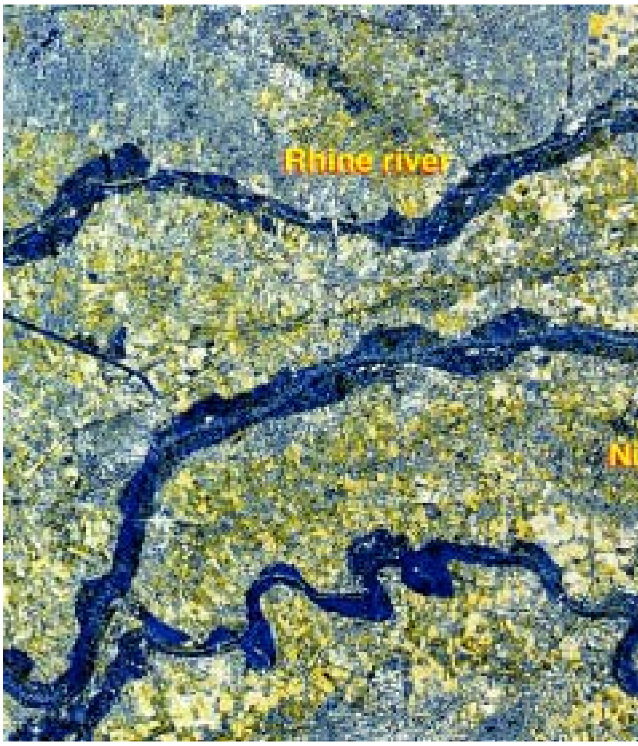
Achievements: first European radar satellites, first long-duration civil radar satellites
Launch dates: ERS-1 17 July1991; ERS-2 21 April 1995
Mission end: ERS-1 10 March 2000; ERS-2 continues full operations. 3-year projected lives
Launch vehicle/site: Ariane-4 from Kourou, French Guiana
Launch mass: ERS-1 2384 kg on-station BOL (888 kg payload, 318 kg hydrazine); ERS-2 2516 kg on-station BOL
Orbit: ERS-1 782x785 km, 98.5° Sun-synchronous with 35-day repeat cycle during most of operational phase; ERS-2 784x785 km, 98.6° Sun-synchronous, phased with ERS-1 for 1-day revisits
Principal contractors: Dornier (prime), Matra (bus), Marconi Space Systems (AMI), Alenia Spazio (RA), British Aerospace (ATSR); ERS-2 added Officine Galileo (GOME)

The European Remote Sensing (ERS) satellite is the forerunner of a new generation of environmental monitoring satellites, employing advanced microwave techniques to acquire measurements and images regardless of cloud and lighting conditions. Such techniques had been used previously only by NASA's short-lived Seasat mission in 1978, and during brief Space Shuttle experiments.

ERS is unique in its systematic and repetitive global coverage of the Earth's oceans, coastal zones and polar ice caps, monitoring wave heights and wavelengths, wind speeds and directions, precise altitude, ice parameters, sea-surface temperatures, cloud-top temperatures, cloud cover and atmospheric water vapour content. Until ERS appeared, such information was sparse over the polar regions and the southern oceans, for example.

ERS is both an experimental and a pre-operational system, since it has had to demonstrate that the concept and the technology have matured sufficiently for successors such as ESA's Envisat, and that the system could routinely deliver to end users some data products such as sea-ice distribution charts within a few hours of the satellite observations.

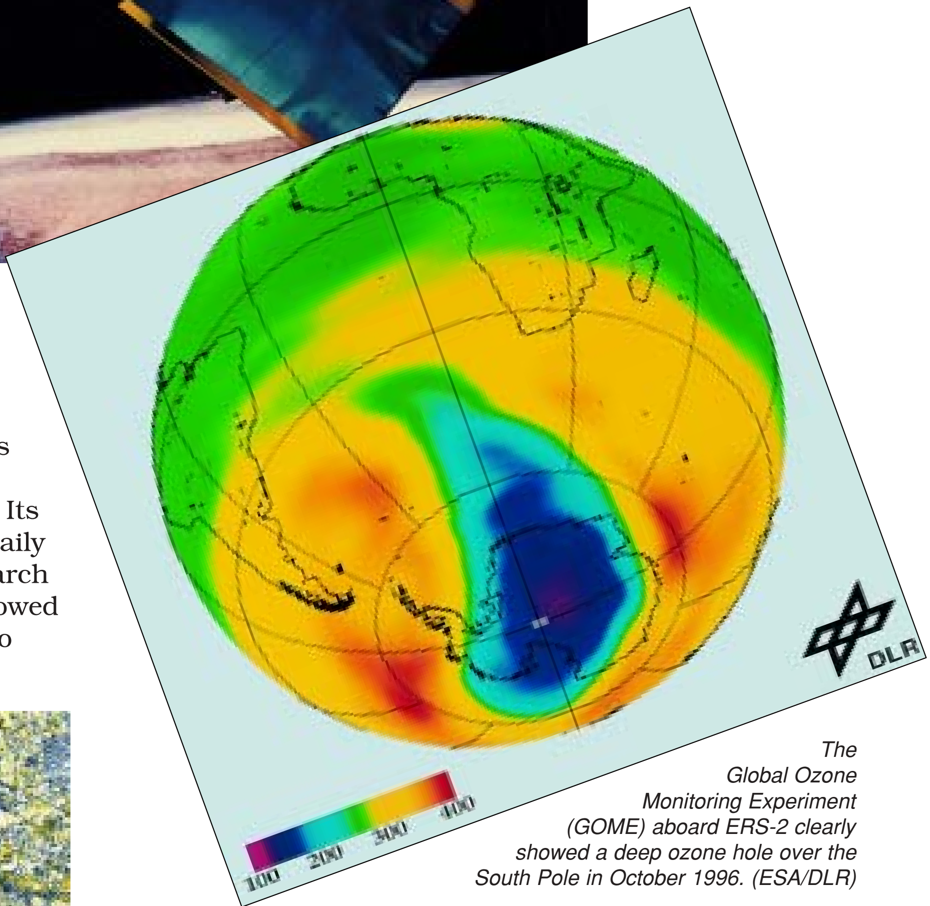
ESA launched ERS-2 to ensure continuity of service until Envisat's appearance in 2001, and the pairing with ERS-1 made new demonstrations possible. The two satellites operated simultaneously from August 1995 to May 1996 – the first time that two identical civil Synthetic Aperture Radars (SARs) had worked in tandem. The orbits were carefully phased for 1-day revisits, allowing the collection of



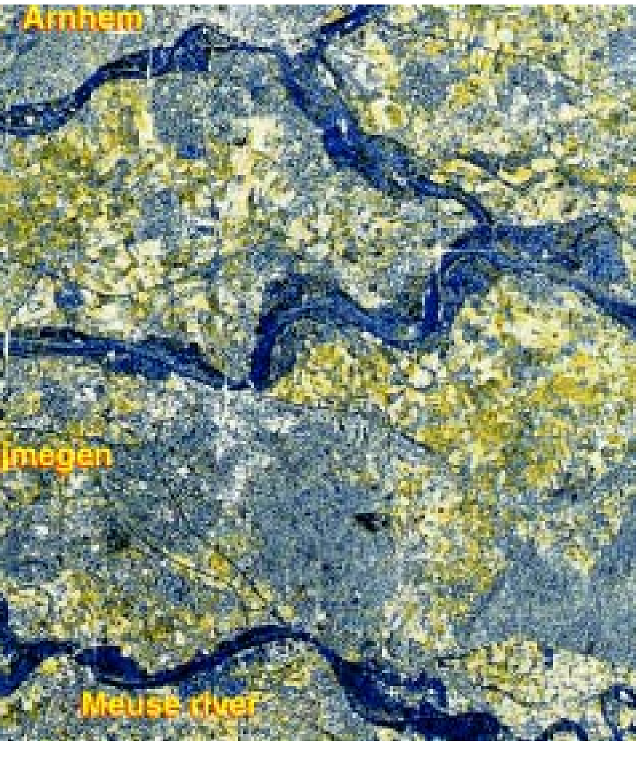
ERS in orbital configuration. During its remarkable career, ERS-1 generated about 1.5 million SAR scenes. More than 3500 scientists have published more than 30 000 scientific papers based on ERS data. (Dornier)

'interferometric' image pairs revealing minute changes.

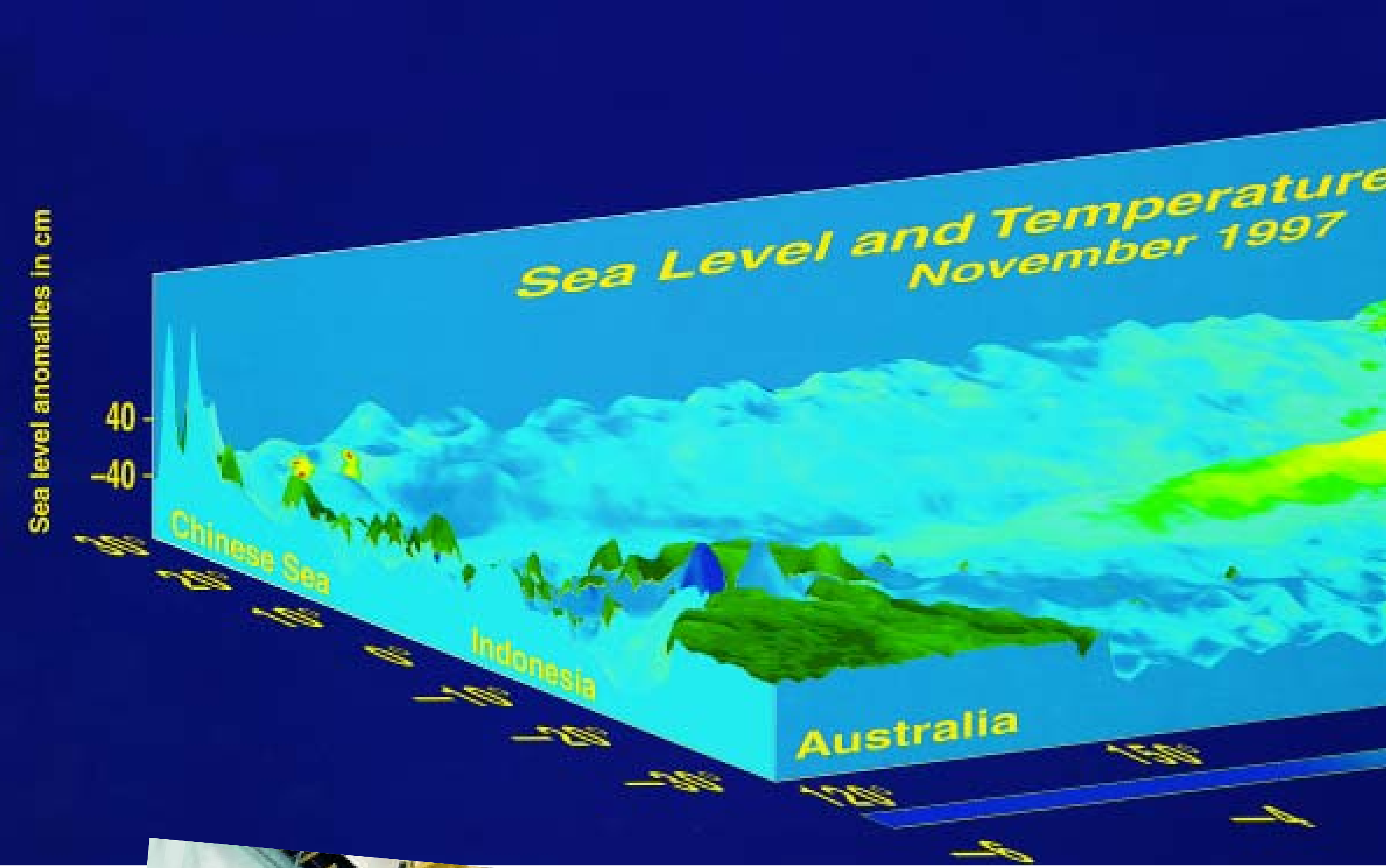
ERS-1 was held in hibernation as a backup from June 1996, while ERS-2 continued full operations. Its SAR Image mode was activated daily for battery conditioning. On 8 March 2000 a computer failure was followed the next day by an unrelated gryo control failure, leading to battery depletion on 10 March. During its remarkable career, major progress was made in environmental and geophysical applications such as disaster monitoring and risk management. It is hoped that ERS-2 will continue operations until at least Metop-1 is commissioned in 2006.



The Global Ozone Monitoring Experiment (GOME) aboard ERS-2 clearly showed a deep ozone hole over the South Pole in October 1996. (ESA/DLR)

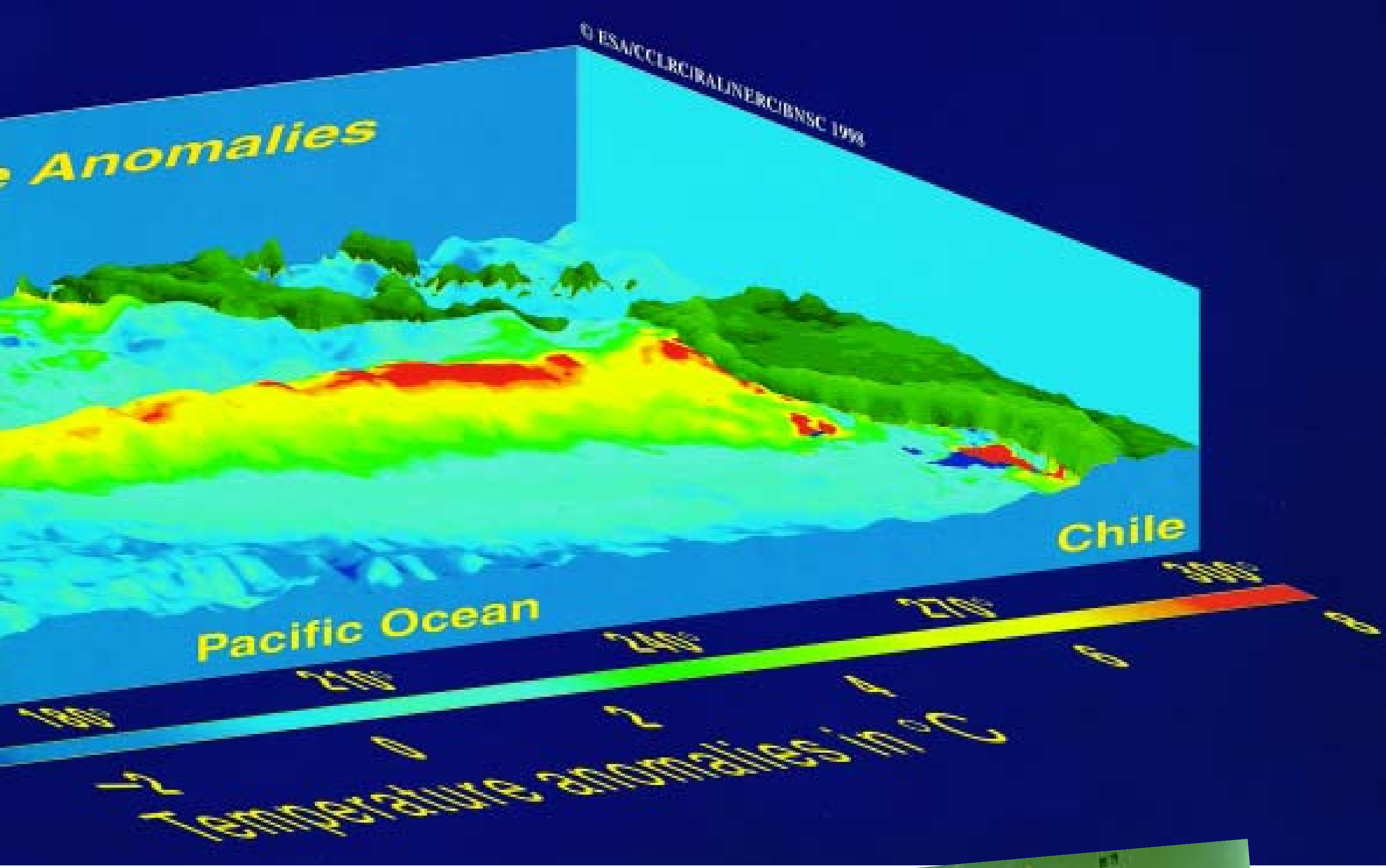


ERS view of flooding in Northern Europe in January 1995. This image was created by superimposing two Synthetic Aperture Radar images and assigning different colours to each. The first image was acquired on 21 September 1994 and the second on 30 January 1995. Flooded areas appear in blue.



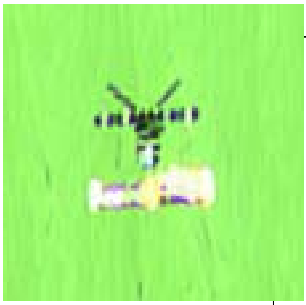
El Niño is a disruption of the ocean-atmosphere in the tropical Pacific that affects weather around the globe. The 1997-98 El Niño is one of the strongest this century, with increased rainfall causing destructive flooding in the US and Peru, and drought in the western Pacific, also associated with devastating fires. The phenomenon is characterised by a rise of up to 40 cm in sea level and up to 8°C in sea-surface temperature in the eastern equatorial Pacific and falls of up to 40 cm/6°C in the western equatorial Pacific. They are closely monitored by the ERS Radar Altimeter and Along-Track Scanning Radiometer. The image above shows the state of the Pacific Ocean in November 1997. The height of this 3D image represents sea-level anomalies, ranging from -40 cm to +40 cm; the colours indicate sea-surface temperature anomalies ranging from -6°C (blue) to 8°C (red).

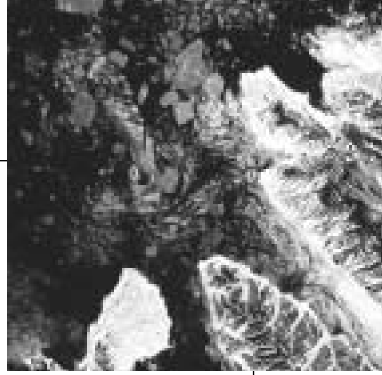
ERS-2 undergoing final launch preparations at Kourou, French Guiana. (ESA/CSG/Arianespace)

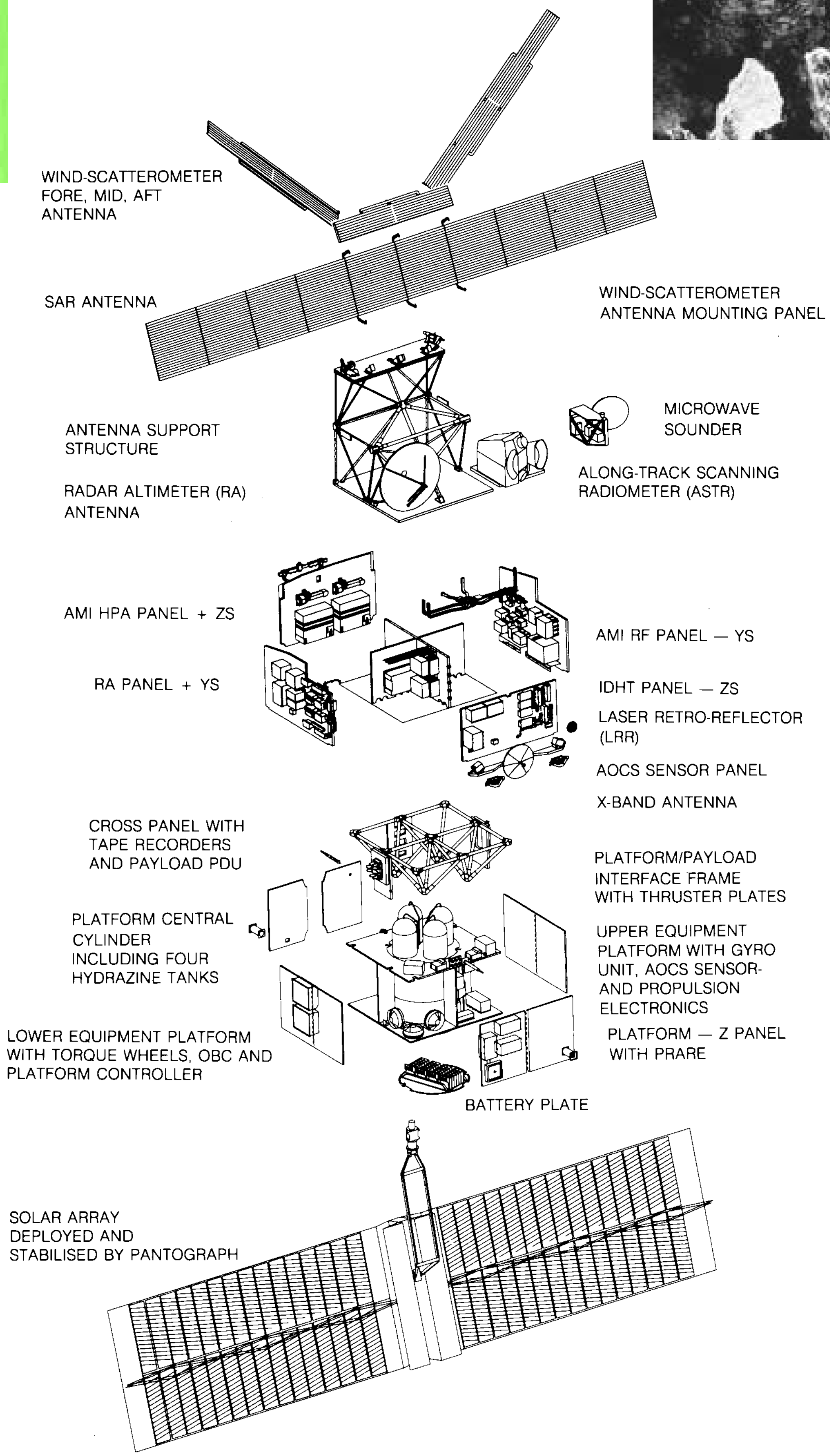


The 'normal' state of the ocean is such that the sea level on the western side is higher than on the eastern side. This difference is due to the Trade Winds blowing constantly from east to west, causing the waters to pile up at the western side. Also due to the Trade Winds, the surface water on the eastern side is constantly transported westward, and replaced by cold, nutritious water rising from deeper layers. So generally along the South American coast, cold and nutritious waters prevail, while on the western side there is warm surface water. During an El Niño event the Trade Winds relax, and become very weak (and may even reverse). This causes the warm surface waters to flow back eastward, and stops the upwelling on the eastern side. No more upwelling means that the sea-surface temperatures rise, implying a sea level rise.

ERS-2 in the Large European Acoustic Facility at ESTEC.






WIND-SCATTEROMETER FORE, MID, AFT ANTENNA
SAR ANTENNA
WIND-SCATTEROMETER ANTENNA MOUNTING PANEL
ANTENNA SUPPORT STRUCTURE
MICROWAVE SOUNDER
RADAR ALTIMETER (RA) ANTENNA
ALONG-TRACK SCANNING RADIOMETER (ASTR)
AMI HPA PANEL + ZS
AMI RF PANEL — YS
RA PANEL + YS
IDHT PANEL — ZS
LASER RETRO-REFLECTOR (LRR)
AOCS SENSOR PANEL
X-BAND ANTENNA
CROSS PANEL WITH TAPE RECORDERS AND PAYLOAD PDU
PLATFORM/PAYLOAD INTERFACE FRAME WITH THRUSTER PLATES
PLATFORM CENTRAL CYLINDER INCLUDING FOUR HYDRAZINE TANKS
UPPER EQUIPMENT PLATFORM WITH GYRO UNIT, AOCS SENSOR- AND PROPULSION ELECTRONICS
LOWER EQUIPMENT PLATFORM WITH TORQUE WHEELS, OBC AND PLATFORM CONTROLLER
PLATFORM — Z PANEL WITH PRARE
BATTERY PLATE
SOLAR ARRAY DEPLOYED AND STABILISED BY PANTOGRAPH

ERS principal features (ESA). Inset left: ERS-1 imaged from 41 km above by France's Spot-4 Earth observation satellite on 6 May 1998 over the Tenere Desert of Niger, Africa (CNES). Inset right: the first recorded SAR image (at Kiruna) from ERS-1, taken at 11:50:32 UT 27 July 1991 and centred on 79.99°N/15.01°E (ESA).

Satellite configuration: payload support module, 2x2 m, 3 m high, above a platform derived from Matra's 3-axis Spot platform providing power, AOCS and overall operational management. Total 11.8 m high, 11.7 m deployed span.

Attitude/orbit control: primary attitude control by reaction wheels, unloaded by magnetorquers. Hydrazine thrusters provide orbit adjust and further attitude control. Pitch/roll information from Digital Earth Sensor, yaw reference from Sun sensor; supported by 6 gyros. ERS-2 began 1-gyro control in Feb 2000, and switched to gyroless control (using DES and X-axis RW) in Feb 2001 to preserve remaining good gyro for critical operations.

Power system: twin 2.4x5.8 m Si-cell solar wings sized for 2.2 kW after 2 years, supported by four 24 Ah nickel cadmium batteries.

Communications: controlled from ESOC at Darmstadt, Germany with ESA ground receiving stations at Salmijärvi, near Kiruna (Sweden, primary station, also for TT&C), Fucino (I), Gatineau (CDN), Maspalomas (E), Prince Albert (CDN), plus national & foreign stations e.g. at Fairbanks (Alaska, US), Neustrelitz (D), West Freugh (UK), Alice Springs (Australia). SAR's 105 Mbit/s image data returned in realtime only, available only when the wave/wind modes are inactive (other data recorded onboard, thus providing global coverage). ESA's ESRIN ERS Central Facility (EECF) facility at Frascati (I) is the user service and data management centre and prepares the mission operation plan for ESOC, with processing/archiving facilities at Brest (F), Farnborough (UK), DLR Oberpfaffenhofen (D) and Matera (I). Some products, such as from the wind scatterometer, are available within 3 h of observation.

ERS Earth Observation Payload

Active Microwave Instrument *(AMI)*

Incorporates two separate 5.3 GHz C-band 4.8 kW-peak power radars: a Synthetic Aperture Radar using a 1x10 m antenna for the image and wave modes; a 3-beam scatterometer for the wind mode. *SAR imaging:* 30 m resolution, linear-vertical polarisation, 37.1 µs transmit pulse width, 105 Mbit/s data rate, 100 km swath width, with 23° incident angle at mid-swath (up to 35° using experimental roll-tilt attitude control system mode). *SAR wave mode:* operates at 200 km intervals along-track for 5x5 km images to provide ocean wave speed and directions. *AMI Wind Scatterometer:* three antennas (fore/aft 360x25 cm, mid 230x35 cm) providing fore/mid/aft beams sweep 500 km swath in 50 km cells for surface wind vectors: 4-24 m/s, 0-360±20°.

Radar Altimeter *(RA)*

The 120 cm-diameter nadir-viewing, 13.8 GHz, 1.3°-beamwidth altimeter measures, in Ocean Mode, wind speed (2 m/s accuracy), 1-20 m wave heights (50 cm accuracy, 2 km footprint), and altitude to 5 cm. Ice Mode operates with a coarser resolution to determine ice sheet topography, ice type and sea/ice boundaries.

Along-Track Scanning Radiometer and Microwave Sounder *(ATSR-M)*

An experimental 4-channel IR radiometer for temperature measurements and a 2-channel nadir-viewing microwave sounder for water vapour measurements. *IR Radiometer:* scanning at 1.6/3.7/10.8/12 µm, 0.5 K resolution over 50x50 km, 1 km spatial resolution; 500 km swath. ERS-2 added 0.55/0.67/0.78 µm visible channels to improve monitoring of land applications, such as vegetation moisture. *Microwave Sounder:* 23.8/36.5 GHz channels measuring the vertical column water vapour content within a 20 km footprint, providing corrective data for ATSR sea-surface temperature and RA measurements.

Global Ozone Monitoring Experiment *(GOME, ERS-2 only)*

Near-UV/visible scanning spectrometer measuring backscattered Earth radiance in 3584 pixels over four channels, 240-316/311-405/405-611/595-793 nm, to determine ozone and trace gases in troposphere and stratosphere.

Precise Range/Range Rate Experiment *(PRARE)*

For precise orbit determination with ranging accuracy of 3-7 cm using 8.5 GHz signals transmitted to a network of mobile ground transponders. ERS-1 PRARE failed within 3 weeks because of radiation damage, but ERS-2's improved design remains operational.

Laser Retroreflector

Also permits precise range/orbit determination, but less frequently than PRARE, and RA calibration.

Further information on ERS and other ESA Earth observation projects can be found at http://earth.esa.int