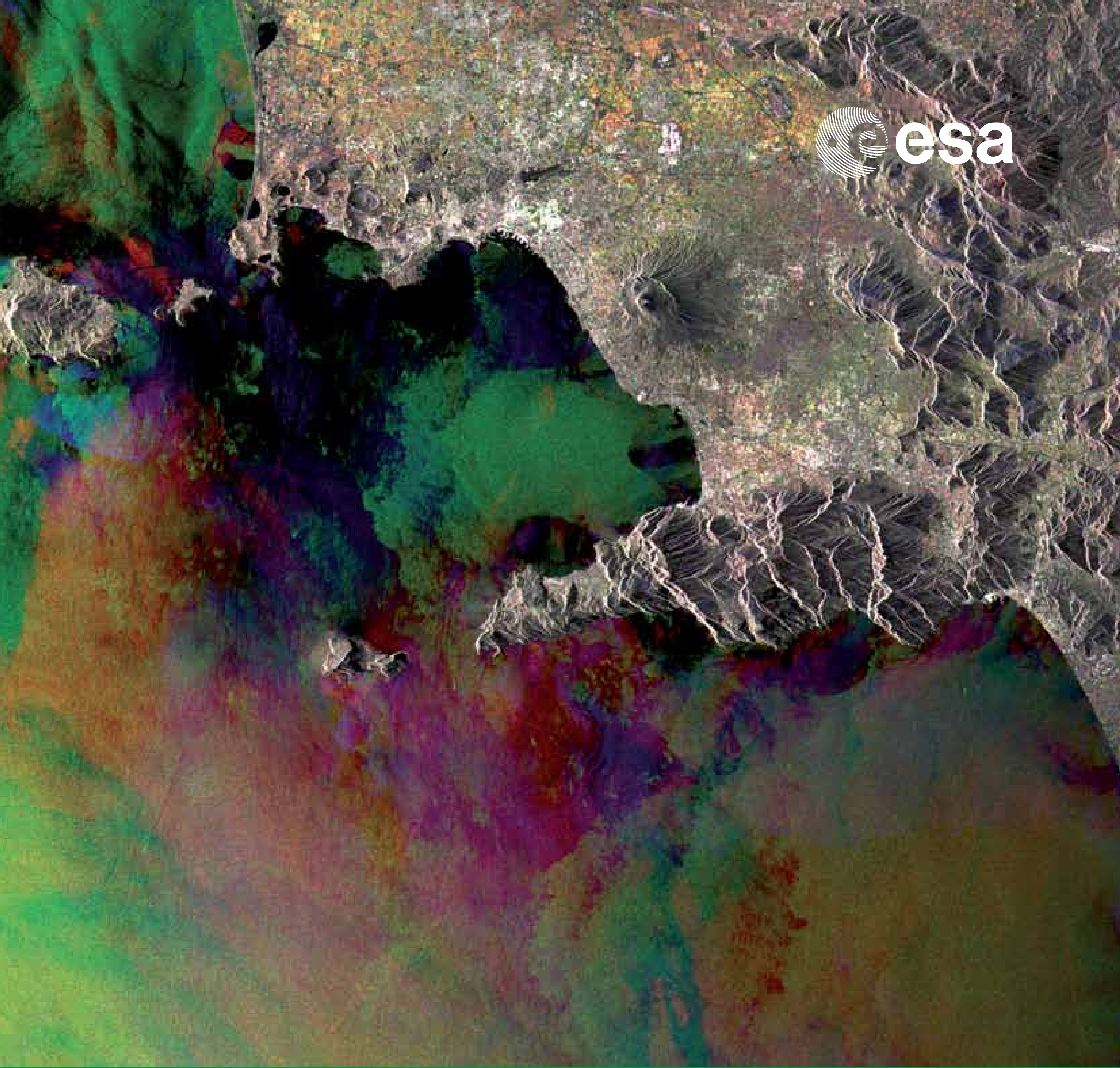

→ ERS MISSIONS

20 Years of Observing Earth

SP-1326
July 2013

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20 Years of Observing Earth

European Space Agency

Cover: Synthetic Aperture Radar multitemporal colour composite image showing Naples and its bay. Naples, the largest city in southern Italy and capital of the Campania Region, can be seen as the large bright area on the northern tip of the Bay of Naples. The bay lies within an important volcanic province, with the volcano Mount Vesuvius and the Phlegrean Fields (Campi Flegrei) area being its active and ancient primary testimonies. The different colours shown by the sea in the bay indicate sea surface roughness caused by the winds which occurred during the dates of acquisition. The colour patches to the north of Naples represent crop fields. The image is made from three ERS-2 SAR Precision Radar Image images acquired on different dates. A different RGB colour is assigned to each date of acquisition: Red: 11 February 2004, Green: 21 April 2004, Blue: 30 June 2004. (ESA)

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Foreword

Scientific and commercial remote sensing was still in its early stage when the first European Remote Sensing satellite, ERS-1, was launched in 1991, leading to the outstanding achievements described in this book.

ERS-1 was the most advanced and complex satellite of its day, carrying three instruments (ERS-2 had four instruments) and delivering what was at the time an enormous volume of data to Earth. Ensuring the timely delivery of products was a great challenge because of the low computing capacities and the weak performance of telephone lines featuring 'modern ISDN' technology. It should be considered that at the time, information technology for digital data processing was very expensive and the majority of products were disseminated using postal services. Consequently, the ERS programme was built with exploitation goals based on the available 'ground' technology of the late 1980s targeting specific user communities.

Concomitant with the development and launch of ERS-1 a revolution took place in computer and information technology. Computers and workstations doubled in speed and capacity every year, and the World Wide Web took off, boosting internet utilisation, supporting easy access to ERS data and bringing computing costs down to a mass market level. The mission operations benefited strongly from this technological revolution, removing processing limitations and bottlenecks in accessing data and making them freely available online. Earth observation applications based on space data also profited from these developments as they could suddenly be processed on the desks of users instead of only in computer centres.

Throughout the 20 years of ERS, special emphasis has been given to the calibration of instruments, validation of products, cross-calibration of instrumentation, information retrieval evolution, and to the documentation of these processes. This has been a joint effort with specialised labs, user communities and partner space agencies, keeping the mission an innovative asset for research and services.

By enabling the dissemination of high-quality data and building on continuous technological progress driven by the computer and internet revolution, the 'free and open' data policy has been the ultimate accelerator in ensuring the full exploitation of ERS data. Allowing an ever-growing community to have easy and free access to satellite data enormously facilitated the transformation of these unique data into valuable information, far beyond the original scope of the programme.

The outstanding robustness of both satellites and instrumentation has facilitated long time series of data overlapping with successor instrumentation flown on ERS-2, Envisat and MetOp, enabling the creation of 'one mission' across several platforms.

The environment of high-quality data being available easily to all users has been the essence of an outstanding return on investment for ESA stakeholders, and has also led to new national satellites and the Global Monitoring for Environment and Security (GMES) programme, recently renamed Copernicus. ERS has served as a precursor mission in Europe for acquiring key industrial expertise in areas like radar technology and scientific application fields like interferometry. There are thousands of projects throughout the world relying on ERS data.

This book describes the exceptional success of a pioneering satellite, starting in a different technological era and founding communities that have significantly advanced our knowledge of planet Earth, while bringing research to operational services and business. The Sentinels will carry on this heritage, making remote sensing a commodity for all citizens.

Volker Liebig
Director of Earth Observation Programmes

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→ INTRODUCTION

Introduction

The first European Remote Sensing (ERS-1) satellite was launched in July 1991 and was followed by ERS-2 in April 1995. Carrying suites of sophisticated instruments to study the complexities of the atmosphere, land, oceans and polar caps, these two missions were the most advanced of their time. Over 20 years the two satellites delivered a continuous stream of data and information that changed our view of the world and placed Europe firmly at the forefront of Earth observation.

In September 2011 ESA organised a scientific workshop to celebrate the outstanding achievements of the ERS mission after 20 years of successful operations. The main themes of the discussions are captured in each of the chapters of this publication. Comprising contributions from key scientists and their colleagues involved in the mission exploitation, this publication highlights the outstanding scientific achievements unique to the ERS mission. The authors also provide their personal perspectives on the mission, addressing the human angle of the mission preparation and of its scientific exploitation, as well as recalling successes and wider impacts resulting from the unique achievements of the ERS mission and its exploitation.

The first chapter deals with the history of ERS from its conception in the 1970s, through the hectic days of the launches, the experiments that paved the way for new research, the adaptations of ESA data policy and the deorbiting phase. In particular it recalls the proactive role of ESA mission management for the provision of data to the science community, the deployment of a worldwide network of ground stations and early steps in international cooperation, as well as the support to campaigns like the first ever ERS-1/2 tandem campaign and pilot projects for precursor applications demonstration.

The second chapter focuses on the Along-Track Scanning Radiometer instruments, ATSR and ATSR-2, which were capable of measuring land and sea surface temperatures with unprecedented accuracy. The first Sea Surface Temperature measurements from ATSR proved to be better than actual buoy measurements. The scientific exploitation results extended to global land surface temperatures and cloud or aerosol measurements. ESA initiated an innovative exploitation of the ATSR infrared channel properties to produce a regularly updated world fire atlas. Thanks to the ERS ATSR/ATSR-2 instrument data, we have a unique and continuous set of Sea Surface Temperature measurements going back to 1991, which is used today in climate research.

The third chapter discusses the history of the development of the Global Ozone Monitoring Experiment (GOME), including exploitation results. GOME was the only new instrument on ERS-2 as compared to the ERS-1 payload, adding atmospheric chemistry monitoring capabilities. Having a high spectral resolution and broad-wavelength coverage, GOME measured ozone, but also known ozone-depleting substances such as chlorine and bromine, clouds and aerosols, and chemically reactive factors of air quality such as nitrogen and sulphur dioxide. Based on the success of GOME, follow-on instruments such as GOME-2 on MetOp and the Ozone Monitoring Instrument (OMI) on the Earth Observing System satellite Aura have been realised, which are extending the provision of long-term ozone data for the World Meteorological Organization's *Scientific Assessment of Ozone Depletion*. In addition, GOME has enabled the development of air-quality applications based on satellite data.

The fourth chapter illustrates the contribution to science and operations over land, sea and ice by observations made with the ERS Active Microwave Instrument (AMI) scatterometer mode. The ERS scatterometer measures the speed and direction of winds over the surface of the ocean. This information is used for operational weather and wave forecasting, as well as climate research. Other applications of ERS scatterometer backscatter measurements include sea ice age, extent and melt. Over land the scatterometer is being used operationally to retrieve soil moisture and soil water index globally. Follow-on instruments are now carried on the European operational meteorology MetOp satellites operated by Eumetsat.

The impact of the information provided by the ERS AMI wave mode on oceanography, meteorology and climate research is discussed in the fifth chapter. This chapter describes the motivation for incorporating the Synthetic Aperture Radar (SAR) wave mode in the ERS-1 instrument, in particular thanks to its capability to image globally ocean waves and to the development of numerical two-dimensional wave spectral models. The SAR wave mode has become an established component of operational wave prediction and has been continued on follow-on satellites such as Envisat and Sentinel-1. Finally, the recent cross-spectral analysis of SAR wave data has allowed major improvements in wave product inversion and subsequently a new application on swell tracking has been demonstrated for operational use.

The sixth chapter reports some of the advances in studies of the upper ocean, its monitoring and understanding with the use of ERS AMI Image Mode and Radar Altimeter. SAR imaging over the ocean has enabled significant advances in physical oceanography such as the observation of mesoscale fronts and eddies, monitoring and understanding of internal waves, the detection of oil spills and the measuring of wind speed. This period saw the development of the first operational services in near-realtime, such as oil spill monitoring and ship detection in the Norwegian Sea.

The ERS altimetric mission objective was to map global ocean wave heights, roughness, ocean circulation and associated transfers of energy including ocean–atmosphere interactions. With its 35-day repeat orbit and therefore denser ground tracks, the ERS mission was an indispensable complement to the NASA–CNES Topex–Poseidon altimetric mission, bringing high-resolution mesoscale variability into the picture.

The seventh chapter illustrates the contribution of the Radar Altimeter to geodetic research, ice and sea-ice studies, improvements in Digital Elevation Models (DEMs), coastal oceanography, and river and lake hydrology. While ERS-2 was in the final stage of development, the scientific community requested that ERS-1 be flown in a very dense orbit. The so-called geodetic phase, which lasted from April 1994 to March 1995, made it possible to map the mean sea surface and derive the marine geoid and seafloor bathymetry at unprecedented resolution and accuracy. The ERS-1 geodetic phase data acquired over land were used to correct existing DEMs and led to the release of a new global and accurate DEM called Altimetry Corrected Elevation (ACE). A new application emerged, based on the capability to extract river and lake levels globally and in particular in regions that are difficult access and poorly monitored. Ice sheet topography was a key target of the ERS mission and was mapped with unprecedented coverage and accuracy. Finally, the level of the sea ice above the water level could be estimated and sea surface topography measurements extended in the coastal zone.

The eighth chapter explains the steps that have led to the birth of modern SAR interferometry. Although not known at the time, and therefore not specified in the ERS-1 imaging radar development, scientists discovered that it was possible to exploit the phase difference in radar pixels from consecutive overpasses, which could be directly related to terrain height. ESA teams developed a new processor to generate a new phase-preserved product, organised a fringe group of science users, distributed new products widely and set up proof-of-concept validation campaigns.

Today, SAR interferometry is used in most imaging radar applications such as land cover classification, DEMs, surface deformation, earthquake and volcano monitoring and ice flow velocity measurements. In addition, the property of the radar over specific point targets to preserve the phase information allowed measurements of local subsidence of a few millimetres. Value-adding companies processed entire datasets from the ERS archive and generated subsidence maps at regional and national scales.

In the ninth chapter the authors highlight the value of the ERS SAR compared with optical imaging. SAR can image in all weather conditions, irrespective of day or night, and is particularly useful for agriculture/forest monitoring and snow and ice studies in the polar regions. In addition, the ERS SAR demonstrated particular sensitivity to surface roughness, allowing geological or topography mapping. Also sensitive to dielectric properties, it allowed for soil moisture or biomass mapping. New applications such as rice crop mapping and tropical forest monitoring were also developed using multitemporal ERS imagery. Finally, combining radar interferometry and the measurement of radar reflectivity allowed for biomass retrieval at regional scales, such as the boreal forest Siberia project or the Chinese forest under the Dragon cooperation.

In conclusion, we invite readers to evaluate whether ERS has fulfilled the objective set at the origin of the mission: ‘ERS-1 will be the European Space Agency's first satellite devoted entirely to remote sensing from a polar orbit. It will be a forerunner of a new generation of space missions planned for the 1990s which will make a substantial contribution to the scientific study of our environment.’

Our opinion is a clear YES!

The contributions of the ERS missions to science, applications and operational services is well illustrated by the more than 2000 scientific papers exploiting the ERS data that have been published so far. The ERS archive is freely and openly available for further exploitation – from science to climate research – thus ensuring that the success story will continue.

We wish you all pleasant reading and look forward to the opportunity to meet you at the next ESA Living Planet Symposium.

The organisers of the scientific workshop '20 years of ERS missions'