ERS-1: A Cautionary Tale of Data Overload

In a storeroom at Britain's National Remote Sensing Centre (NRSC), in row upon row of shelves, magnetic tapes and optical discs are piling up. The tapes and discs are packed with data from ERS-1, the European Earth-observing satellite, which each day rains down data equivalent to 2500 copies of the *Encyclopaedia Britannica*. In the 2 years since the satellite's launch, NRSC has accumulated some 5000 high-density computer tapes and 3000 discs, with about 60 tapes and 34 discs being added to the stash each week.

But of this flood of data, only a trickle is actually being used by scientists. It's not that scientists are uninterested. On the contrary, the detailed images of Earth's surface and information on winds, waves, and ocean temperature are extremely valuable to a wide range of researchers, from oceanographers and meteorologists to environmental scientists and agricultural planners (*Science*, 18 June, p. 1742). Yet the 13-nation European Space Agency (ESA) has stumbled on numerous difficulties in processing the data and getting them to eager scientists.

Data, data everywhere. But only 5% of the synthetic aperture radar data has been put to work.

Of course, some such hiccups are to be expected whenever a complex ground system is set up for a new satellite, but with ERS-1 the problems are larger and the stakes higher. The satellite, which carries three radar sensors as well as a passive radiometer, serves many research communities at once and is a prototype for the large multisensor satellites that will be filling the skies towards the end of the decade. The space agency's difficulties in coping with the data flood offer a cautionary tale for the planners of ERS-1 successors, particularly the coming Earth Observing System (see main story). The moral: Sometimes getting the data can be the easy part.

The problems start with simply transporting the data. Europe does not yet have high-capacity fiber-optic networks capable of handling the prodigious amount of data produced by the satellite, so after they are received at one of ESA's two main receiving stations in Sweden and Italy, the data are recorded on tape and shipped to the NRSC in Britain and three other processing centers in France, Germany, and Italy. After making the 500-mile journey from satellite to ground in milliseconds, the data can take a week to cover the next few hundred miles.

That is not good enough for some users, such as meteorologists, who need the data within hours, and so some of the data are dispatched via telecommunications satellite to a few centers equipped with suitable dishes. But first the data must be processed—very quickly—and that, too, can be difficult.

Unlike optical images, the reflected microwave pulses from ERS-1's radar sensors need a lot of processing to provide meaningful information. The wind scatterometer, for example, looks at how wind roughens the sea surface. With the right processing, the raw scatterometer data yield the wind's speed and direction—information that is of great value to meteorologists. But when ESA tried to supply that information, it discovered that its computer algorithm did not quite work: The program could narrow down the wind vector at any point to two choices, pointing in opposite directions, but could not decide whether, say, east or west was correct. Only this year was the algorithm made trustworthy enough for meteorologists to start using the data.

Most of the satellite data do not need such on-the-fly processing, but even having days instead of hours does not solve all the problems. ERS-1's radar altimeter, for example, can chart the hills and valleys of the ocean surface and ice caps to within a few centimeters by measuring the round-trip time of radar pulses bounced off the surface, but achieving that accuracy requires between 15 and 20 corrections to the data: for curvature of the Earth, orbit of the satellite, moisture in the atmosphere, solar activity, and so on. The scientists in charge of this processing underestimated just how complicated it would be, and some researchers only began receiving regular batches of altimeter data this year.

ESA says most of these teething troubles are now sorted out, but the rapidly filling shelves at the NRSC illustrate that there is a yet bigger hurdle to overcome: letting scientists know what data is available and getting it to them. A prime example is the images produced by the satellite's synthetic aperture radar (SAR), a sort of microwave "camera" that can see through clouds and darkness to produce detailed images of the Earth's surface. These images are processed at the NRSC, but so far less than 5% of SAR data archived at the center has actually been converted into images in response to user requests.

The meager demand partly reflects researchers' unfamiliarity with SAR radar images and what can be done with them. But SAR images, like other types of ERS-1 data, also need to be made accessible to more researchers, says Huw Hopkins, manager for Earth observation data policy at ESA's Paris headquarters. At the outset, ESA chose about 300 research groups to receive data for free. Everyone else must pay, and SAR images, in particular, are expensive. To ensure the most complete use of the data, Hopkins says, they should be available to all scientists equally, at only a nominal fee.

Even if this is done, there will remain one more major hurdle to clear before useful information from ERS-1 is widely disseminated. Because of restrictions in its charter, ESA can do no more than "engineering processing" of data—converting the output of sensors into accurate physical quantities or plain images. Further processing, such as combining images of the same place taken at different times to highlight changes or combining satellite data with information from other sources, can create new results valuable to a wide variety of researchers. This additional processing must be done by individual users—but their data processing techniques may be incompatible, making it difficult to share data.

Because constructing a centralized, automated system for processing and distributing data is beyond Europe's means, the European Commission plans to set up the Centre for Earth Observation, which would develop search software, draw up standard formats for data, compile catalogues, and set up communications networks across the continent in partnership with existing institutes. The plans depend on Europe's governing bodies agreeing to foot the bill, and in the meantime the data will continue to pile up.

–Daniel Clery