The Along Track Scanning Radiometer

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ABSTRACT

The Along Track Scanning Radiometer (ATSR) is a new-generation infrared radiometer which was built specifically to supply accurate measurements of sea surface temperatures (SST) for environmental and climate applications. The instrument has been operating for almost four years and there have been a variety of applications developed for the data. The main product (an averaged SST for climate applications) has been validated against accurate surface measurements, and is now available to the research community for use in global and regional climate models. A replacement instrument (ATSR-2) has just been successfully launched on the ERS-2 satellite. This instrument includes three visible/near infrared channels to enhance the use of the data over land surfaces.

INTRODUCTION

The European Space Agency's First Remote-sensing Satellite (ERS-1) was launched from their Kourou facility in French Guyana during 1991. The instruments on this new satellite have a prime objective of studying the earth's oceans using active and passive remote sensing. Included in the payload is a new-generation infrared radiometer that has been specifically designed to measure the surface temperature of the global oceans with an accuracy of about 0.3K. This is the accuracy desired by scientists who require the data for studies of the earth's climate and climate change. The instrument is the Along Track Scanning Radiometer (ATSR) which has been supplied to the European Space Agency (ESA) by a consortium of laboratories in the U.K., France and Australia.

During the latter half of 1991 several ship cruises were undertaken in Australian waters to collect data for the ATSR scientific program which includes geophysical validation, atmospheric absorption correction, cloud classification and instrument performance assessment. For studies of the land surface several ground stations have been deployed to assess the potential of ATSR data in determining land surface properties. The unique scan mechanism of the ATSR provides two (almost) simultaneous views of the earth's surface from two different angles.

THE ATSR INSTRUMENTS

The ATSR now flying on ERS-1

The ATSR instrument that was launched in 1991 has been described in the literature (See list of ATSR references). Operational estimates of sea surface temperature (SST) are currently derived using the AVHRR instruments on the NOAA operational meteorological satellites. ATSR has the same infrared wavelengths as AVHRR (3.7, 10.8 and 11.9 micrometres) but contains several innovations which have been included to ensure that the ATSR can supply surface temperatures with the improved accuracy. A comparison of the two instruments is given in Table 1.

Table 1. ATSR and AVHRR specifications.

	ATSR	AVHRR/2
Infrared bands (μm)	3.7 10.8 11.9	3.7 10.8 11.9
Vis.NIR bands (μm)	1.6	0.6 0.9
Surface views	Double	Single
Calibration black bodies	2	1
Space views	0	1
Aperture (cm)	10	20
Integration time (μsec)	80	20
Detector temp. (K)	80	105
Digitisation (bits)	12	10
Detector NEDT (K)	0.03	0.12
Passive microwave channels	Yes	No
Surface swath (km)	500	2800
Nadir pixel size (km)	1.1	1.1

The ATSR incorporates active cooling of the infrared detectors to near 80K using a Stirling cycle cooler developed in the U.K. by Oxford University and the Rutherford Appleton Laboratory. This is the first such cooler to fly on a civilian satellite and is now performing well within its specifications. Two on-board black body cavities provide an accurate absolute calibration of the radiometer at the upper and lower ends of the expected sea surface temperature range. A dual-angle view of the surface is provided by an offset conical scan which provides a near nadir cross track scan swath of 500 km and a second scan about 900 km ahead of the sub-satellite point, again with a swath of 500 km. The combination of these two views enable an improved atmospheric correction for the data which reduces the errors in sea surface temperature estimates. The complicated scan geometry of the ATSR is well described by Prata et al. in the IEEE Trans. Geosci. Rem. Sensing (see references).

The combination of actively cooled detectors and longer integration times give the ATSR infrared channels extremely low noise temperatures. This allows the useful digitisation of the data to 12 bits. These two features are also complemented with high quality black body calibration targets which provide a stable absolute calibration. These three features are all required to provide an accurate radiometric measurement - if one of the three is not present then the value of including the other two is greatly diminished!

The instrument also includes a channel at a wavelength of 1.6 micrometres to assist in the discrimination between clouds, ice and snow. A dual channel microwave radiometer is also included to supply estimates of the water vapour column in the atmosphere. Both these attributes are included to improve the quality and accuracy of the global SST product.

The ATSR-2 just launched on the ERS-2 satellite

The ERS-2 satellite, launched on April 21, 1995, is a "carbon copy" of ERS-1 with two additions; an instrument (GOME) for monitoring global ozone levels is included, and the ATSR instrument includes three extra channels situated in the visible/near infrared band at wavelengths of 550, 670 and 870 nanometres. ESA has provided the extra data rates required for 12-bit transmission of data in all channels in almost all cases. An on-board calibration unit for these new channels is also included - a feature that hitherto has been absent from many satellite instruments sampling in this spectral region.

Global and regional remote sensing of vegetation is currently undertaken with AVHRR and the thematic mapper on the LANDSAT satellites. ATSR-2 has significant advantages over these instruments and will be ideal for mapping vegetation and monitoring any changes in the land surface. When combined with the high temperature resolution of the thermal channels many new techniques are expected to develop pertaining to agriculture and land use management. Some instruments proposed for future EOS programs have bi-directional views of the earth's surface, but the ATSR-2 will, for several years be the only instrument providing high quality bi-directional information on a global basis.

The Advanced ATSR (AATSR) for ESA's ENVISAT

The AATSR has been accepted by ESA for flight on its polar platform, ENVISAT. This instrument is now in the construction phase and is basically identical to the previous ATSRs. This reproduction of design is desirable as the major justification for inclusion of the instruments in the payloads is to produce a long term data set for climate modelling. Thus any differences in instrument performance or characteristics lead to questions about the continuity of the data set.

ATSR INSTRUMENT PERFORMANCE

Since the ATSR was turned on several weeks after launch it has supplied almost continuous data for deriving global sea surface temperatures. The initial assessment of ATSR performance indicates that the instrument is supplying raw data with a quality that meets the design specifications. Image data show that the optics is well aligned and that there is no blurring or de-focussing of the data. Unfortunately the 3.7 μm detector failed after ten months, but the SST products are still generated within the design specifications.

Several validation cruises have been undertaken in Australian waters and elsewhere, and the results show that the ATSR can supply sea surface temperatures with the design accuracy. Detailed comparisons between ATSR, AVHRR and ship measurements all taken on the same day, have shown that ATSR data and derived products exhibit less noise than those of the

AVHRR, as well as agreeing well with the ship data.

THE ATSR SCIENCE PROGRAM

The ATSR data are finding many applications in oceanography, meteorology, agriculture, climate research, and other geophysical sciences. Included below is a collection of some of these applications.

Oceanography

Detailed ATSR images of the infrared radiance leaving the ocean surface show many finescale features that provide information on surface currents and eddies. When combined with altimeter data (ERS-1 and-2 both carry altimeters) the ATSR data give surface currents and some measure of the thermal structure of the oceanic mixed layers.

Climate research

The high spatial resolution SST data are averaged over half degree latitude by half degree longitude boxes. These data are available for each orbit and can be used to derive global data sets with different temporal resolutions. Future averaged data sets will also include averages over ten arc-minutes cells (i.e. one ninth the area of the previous data). This will give a spatial resolution close to 15 km in the tropics.

Land surfaces

Instrumented ground sites have been used to assess the ability of the ATSR to provide land surface temperatures (LST). The extra information supplied by the dual view capability of the ATSR can supply a more accurate estimate of the surface emissivity, and thus an improved surface temperature. Improved (over AVHRR) results are obtained when a single channel of data is used with two different view angles. The use of these data reduces any emissivity variations in the analysis.

Land surface topography

The stereoscopic view of ATSR allows the determination of the height of the targets in the scenes. This ability has been tested in cloud free scenes where land surface topography can be assessed. This is probably not of any practical use as there are far better ways of obtaining elevation data from space - but it does provide a degree of confidence in the estimation of the height of water, ice, and volcanic clouds.

Volcanology

The stereoscopic view allows the determination of volcanic cloud heights. This should be of operational use to the aviation industry, as well as providing valuable information to climatologists and volcanologists. Previous attempts to estimate volcanic cloud heights have been difficult due to the spectral differences between volcanic and water/ice cloud signatures. Also the temperature of a volcanic cloud is not an indication of its height as they can exist well into the stratosphere.

The different signature in the ATSR infrared channels is being used to assess the amount and distribution of volcanic aerosol from the Pinatubo eruption which occurred just one month before launch.

Cloud physics

Cloud heights. The stereoscopic view can be used to assess cloud heights.
Cloud optical depths. The extra information supplied by the different channels of the ATSR (six channels - three wavelengths at two angles) can be used to estimate the infrared optical depth of high clouds. This information is valuable to climatologists, and cannot be provided with any degree of confidence from existing satellite instruments.
Cloud height winds Pattern recognition in the two ATSR views can be used to assess the cross-track winds at cloud height.

Water vapor distribution

The six infrared "channels" have a different response to water vapor in the lower atmosphere. The use of these channels to determine water vapor profiles is under investigation. A knowledge of the water vapor vertical distribution will allow an improved determination of SST as well as providing vital measurements for climate research. Current vertical profilers (TOVS on the NOAA satellites and VAS on the GOES satellites) have an extremely poor height resolution in the lower atmosphere.

CONCLUSIONS

The ATSR series of instruments will provide a valuable global data set of accurate SST over a twelve year period. The first instrument is nearing the end of its life, the second has just been launched and the third is under construction. The instrument has been most successful - mainly due to the philosophy of defining an instrument for a single specific purpose. However, the data are also finding many uses in a wide range of applications. Future studies of climate and climate change will undoubtedly use much of the information being supplied by the ATSR series of instruments.

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