Sea-surface temperatures from ATSR

August 1991 – July 1995

Jo Murray *

Space Science Department
Rutherford Appleton Laboratory

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*Telephone (01235) 446705; Fax (01235) 445848; e-mail jo.murray@rl.ac.uk.

Contents

List of Figures

List of Tables

1 Introduction

The first Along-Track Scanning Radiometer (ATSR-1) is a four-channel, dual-view, self-calibrating, infrared radiometer with spatially coregistered spectral channels centred at 1.6μm, 3.7μm, 10.8μm and 12.0μm. The instrument's innovative design has enabled the remote sensing of Sea-Surface Temperature (SST) to unprecedented levels of accuracy (better than 0.3K). The instrument was launched on board ESA's first remote-sensing satellite, ERS-1, on 21st July 1991, and has performed well since that time with the only serious setback being the failure of the 3.7μm channel in May 1992.

The instrument design is described in Edwards *et al.* (1990) and the results from the validation programme are reported in Mutlow *et al.* (1995) and Barton *et al.* (1995). A short description of the novel aspects of ATSR is given in Appendix A.

Suffice to say here that the on-board calibration and the use of the along-track scanning technique enable the accurate retrieval of ocean skin temperature.[1] Unlike the AVHRR SST retrieval al-

[1] Infrared radiometers measure the radiant temperature of a water layer less than 0.1 mm thick; this is typically 0.5K cooler than the bulk temperature measured at 1 m depth.

gorithms which are empirically adjusted using *in situ* bulk measurements (McClain *et al.*, 1985) the ATSR scheme results in the determination of very accurate SSTs without recourse to ground-based observations. Therefore the data presented here represent an independent set of measurements of global SST.

The second instrument in the ATSR series, ATSR-2, was launched on board ESA's second remote-sensing satellite, ERS-2, on 21st April 1995. ERS-2 is currently (September 1995) in a similar orbit but trailing one day behind ERS-1. ATSR-1 has already operated beyond its three-year design lifetime but is likely to remain in operation at least until the end of 1995. This will enable comparison of data from the two ATSRs, and data from both instruments will be made available on a future CD-ROM set.

Four years of data, August 1991 – July 1995 inclusive, are supplied on this CD-ROM set. Updates to the data, documentation and software presented here will be made available on the anonymous ftp account `sstaxp.ag.rl.ac.uk` (username `anonymous`, and please supply your e-mail address as the password). The `atsr1` directory on this account has a subdirectory structure which reflects the CD-ROM layout as described in Section 1.2.

1.1 ATSR data products

A variety of products are derived from ATSR data, but this CD-ROM set comprises only two types of data.

- The spatially-Averaged Sea-Surface Temperature (ASST) product. These data comprise half-degree, spatially-averaged SSTs with associated temporal, positional and confidence information as described in Section 2.
- Time-averaged global maps.
    1. A monthly average at half-degree spatial resolution as described in Section 3.1.
    2. A five-day average at one-degree spatial resolution as described in Section 3.2.

Other data products from ATSR include: high-resolution (*i.e.* 1km$\times$1km) 'brightness temperature' products for each thermal channel; high-resolution SSTs, and products containing results from cloud identification tests performed during processing. A complete description of these and other ATSR data products is given in Bailey (1993).

1.2 CD-ROM layout

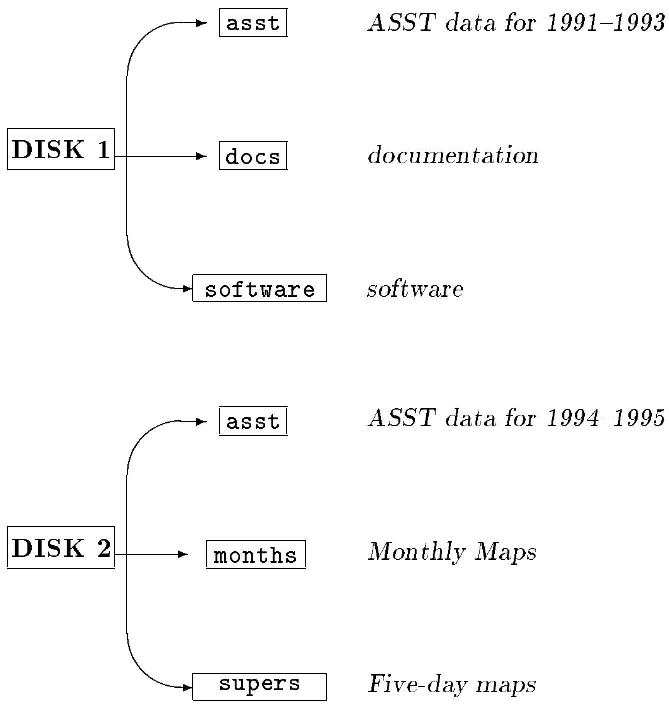
This CD-ROM set is written to the ISO 9660 standard with no record format specified for the files. Each end of line in the text files is marked by a line-feed character. On VMS systems where the default action is to use carriage-return to indicate ends of lines, the line structure of text files will look strange and the text will contain embedded control characters. However the files will remain readable. Advice for dealing with this and other complications on VMS systems is given in the file `vms.txt` in the [**docs**] directory.

The structure of the CD-ROM set is summarised in Figure 1. In addition to those containing data, there are directories for software and documentation.

Software: – the [**software**] directory contains programs to assist in reading the supplied datasets as described in Section 4. All data are stored as 2-byte or 4-byte integers in fixed-length records for maximum portability and ease of use. Details of the actual formats are given in Sections 2 and 3 for the ASST data and time-averaged global maps respectively.

Documentation: – as described in Section 5, the [**docs**] directory contains the LaTeX source for this booklet and various other useful text files.

Figure 1: Arrangement of data on CD-ROM set



2 The spatially-Averaged Sea-Surface Temperature (ASST) product

The ASST product contains half-degree, spatially-averaged SSTs with associated temporal, positional and confidence information. These data are generated using SADIST (Synthesis of ATSR Data Into Sea-surface Temperatures), the Rutherford Appleton Laboratory's ATSR data-processing scheme (Závody *et al.*, 1994, 1995). This software is under continuous development and the data described herein were produced by SADIST, Version 500, hereafter SADIST v500 (Bailey, 1993). See Appendix B for a discussion of planned changes to SADIST and the ASST product.

2.1 ASST derivation

As described in Appendix B, SST retrieval involves a linear combination of single-channel brightness temperatures from both forward and nadir views. Derivation of half-degree ASSTs is accomplished in two steps:

1. Single-pixel (1km$\times$1km) brightness temperatures are averaged into ten-arcminute brightness temperatures. SSTs are

then derived from these brightness temperatures via the usual retrieval algorithm.

2. These ten-arcminute SSTs are then averaged to obtain a half-degree SST. Nine ten-arcminute cells are contained in each half-degree (thirty-arcminute) cell.

A proportion of the ten-arcminute, nadir-view brightness temperatures is without associated forward-view values. This is usually a result of cloud coverage affecting only the forward scene, but may occur because for sections of most orbits, the forward and nadir scenes are stored on different raw data tapes. Including such nadir-only data compromises the SST accuracy, whereas omitting these data results in reduced coverage.

Rather than attempt a single solution to this problem, three different SSTs are provided for each half-degree cell as described below.

Nadir-view SSTs: SSTs derived using the nadir-view data only.

Dual-view SSTs: SSTs derived using both nadir- and forward-view data.

Mixed SSTs: SSTs derived using a dual-view retrieval if possible, and nadir-only retrieval otherwise. This will coincide with the nadir-view SST when no forward data are available for a half-degree cell, and with the dual-view SST in the case where all the contributing ten-arcminute cells have associated forward data.

The choice of SST type to use will vary with application. Dual-view SSTs represent the most accurate retrieval, and are least likely to be affected by cloud contamination. However exclusive use of these data will restrict coverage. For example in 1992, a dual-view SST was present for only 85% of those half-degree cells for which an SST had been evaluated.

2.2 Arrangement of ASST data on CD-ROMs

The ASST data are stored in the directory [**asst**] on the CD-ROM set. Disk 1 contains data from 1st August 1991 to 31st December 1993 inclusive. Data for the period 1st January 1994 to 31st July 1995 are contained in the [**asst**] directory on Disk 2.

Each day's data is in a separate file; the filenames have the form:

`day` *y mm dd*`.dat`

where *y* is the (year−1990), *mm* is the month of the year, and *dd* is the day of the month. Thus `day20304.dat` contains data for 4th March 1992.

Each file contains a number of 32-byte records, each of which is associated with a single half-degree cell. The number of records per day is highly variable, and lies in the range $0 - 31624$. Days on which no reliable data were obtained (usually due to instrument operations) are associated with files of zero length. The variation in daily data volume during normal operation reflects differences in the proportion of a day's coverage that was over cloud-free water.

2.3 ASST product format

The contents of the 32-byte record product are shown in Table 1 and described in full below. Each record contains SSTs and associated information for a single half-degree cell. The information is stored as two- or four-byte integers, but as an example, a textual representation of the first five records for 1st January 1992 is shown below:

```
15340  202  59 333  4   27130  -1  27143  -1   27136  -1  11   9351
15340  203  59 334  4   27123   4  27153   6   27153   6  29  43655
15340  221  60 337  2   27118  13  27165   6   27154  21  48  26759
15340  236  62 340  0   27141   7  27158  -1   27149   8  23   9863
15340  237  62 334  3   27127  -1  27161  -1   27161  -1  34   8839
```

The first two numbers give the time (in days and seconds as described below), the third and fourth give the position of the half-degree cell (again, see below), and the fifth number is associated with the position of the cell within the ATSR swath.

The sixth, eighth and tenth values are ASST values in centiKelvin, and the seventh, ninth and eleventh represent the associated root-mean-square (rms) deviations of the contributing ten-arcminute SSTs in each case.

The last two values represent the mean view-difference and the confidence word as described below. Any parameter that cannot be evaluated is represented as -1 (see Table 3). A description of each parameter is given below, and the format summarised in Table 1.

Time of data (days). This is given as the number of days since 1st January, 1950 (Modified Julian Day) and does not include the current, incomplete day. Dates in the (*y mm dd*) format (as described in Section 2.2) are given for the relevant day numbers in the text file `daydates.dat` in the [**docs**] directory on Disk 1 (see Section 5).

Time of data (seconds). The integer value containing the time in seconds within the current day. Note that the time used within each record is the time of the first ATSR nadir-view

Table 1: **ASST product record format**

Byte range	**Parameter description**	**Type**	**Unit**
0 – 3	Time of data (days since Jan 1st 1950)	Integer	Days
4 – 7	Time of data (secs within current day)	Integer	Secs
8 – 9	Latitude cell number	Integer	Cell
10 – 11	Longitude cell number	Integer	Cell
12 – 13	Mean across-track band number	Integer	None
14 – 15	Nadir-only ASST	Integer	K/100
16 – 17	RMS deviation of ten-arcmin SSTs contributing to nadir-only ASST	Integer	K/100
18 – 19	Dual-only ASST	Integer	K/100
20 – 21	RMS deviation of ten-arcmin SSTs contributing to dual-only ASST	Integer	K/100
22 – 23	Mixed nadir/dual ASST	Integer	K/100
24 – 25	RMS deviation of ten-arcmin SSTs contributing to mixed nadir/dual ASST	Integer	K/100
26 – 27	Mean view-difference of nadir/dual ten-arcminute SST	Integer	K/100
28 – 31	Confidence word associated with ASST derivation	None	None

scan to contribute to the ASST derivation. The variable nature of cloud-cover makes it impossible to predict the position of this scan relative to the centre of the half-degree cell. Under any circumstances, this time cannot be more than approximately six seconds from the time at which the centre of the cell is scanned by the nadir view.

Latitude. The latitude is provided as a cell number. The edges of half-degree cells are sections of parallels and meridians. The latitude cells are numbered from the South Pole to the North Pole, in the range 0 to 359. Latitude cell number 0 extends from 90°S to 89.5°S; latitude cell number 359 extends from 89.5°N to 90°N. The latitude of the cell centre may be derived by:

$$latitude = ((lat\_cell\_num - 180.0)/2.0) + 0.25.$$

The latitudes which are implied by the product cell numbers are geocentric. Geodetic latitudes may be derived using:

$$geodetic = tan^{-1}(1.0067451 \times tan(geocentric))$$

Longitude. The longitude is provided as a cell number. The edges of half-degree cells are sections of parallels and meridians. The longitude cells are numbered from 180°W to 180°E, in the range 0 to 719. Longitude cell number 0 extends from 180°W to 179.5°W; longitude cell number 719 extends from 179.5°E to 180°E. The longitude of the cell centre may be derived by:

$$longitude = ((lon\_cell\_num - 360.0)/2.0) + 0.25.$$

Mean across-track band number. The five across-track bands are numbered 0 to 4 from left to right, and are centred on the ground-track. Each band is 50 km wide, except the fifth, which is 62 km wide, and extends to the edge of the swath.

Nadir-only SST and rms deviation. These are the mean and the rms deviation of ten-arcminute cell SSTs derived using only nadir-view data. Note that the rms deviation is set to -1 if fewer than three ten-arcminute cells contributed.

Dual-only SST and rms deviation. These are the mean and the rms deviation of ten-arcminute cell SSTs derived using nadir- and forward-view data. Note that the SST is set to -1 if dual-view retrieval was not possible for any ten-arcminute cell, and that the rms deviation is set to -1 if fewer than three ten-arcminute cells contributed.

Mixed SST and rms deviation. These are the mean and the rms deviation of ten-arcminute cell SSTs derived using the best available combination of nadir- and forward-view data. Note that the rms deviation is set to -1 if fewer than three ten-arcminute cells contributed. If no ten-arcminute cells were used by the dual-view retrieval, these values will be identical to the nadir-only SST and rms deviation.

Mean view-difference. This is the mean difference between the ten-arcminute cell SSTs derived using dual-view and nadir-only retrieval algorithms. This value is set to -1 if no dual-view retrieval was possible.

Confidence word. Table 2 describes the contents of the ASST product confidence word. Bits 0 to 8 are set if, within all of the contributing ten-arcminute cells, at least 90% of the contributing pixels have the characteristic defined in Table 2. Bits 9 to 12 contain the number of ten-arcminute cell SSTs contributing to the nadir-only half-degree SST, and (the number is necessarily the same) to the mixed nadir-only/dual-view half-degree SST. Bits 13 to 16 contain the number of ten-arcminute cell SSTs contributing to the dual-only half-degree SST. This number may be zero.

Table 2: **ASST product confidence word**

Bits	Meaning if set
0	12.0μm channel present in source data
1	11.0μm channel present in source data
2	3.7μm channel present in source data
3	1.6μm channel present in source data
4	Cloud-identification used 1.6μm histogram reflection cloud test
5	1.6μm histogram reflectance cloud test used a dynamic threshold
6	Sunglint detected by 1.6μm reflectance reflectance cloud test
7	3.7μm channel used in SST retrieval
8	SST derivation used day-time data (night-time if zero)
9 – 12	Number of ten-arcminute cell SSTs derived using nadir-only retrieval (1 – 9)
13 – 16	Number of ten-arcminute cell SSTs derived using dual-only retrieval (0 – 9)
17 – 31	Unused

Table 3: **ASST product exceptional values**

Parameter	**Value**	**Reason**
Dual-only SST	-1	No ten-arcminute cells used a dual-view SST retrieval
RMS deviations	-1	Fewer than 3 ten-arcminute cells contributed to the half-degree ASST
Mean view-difference	-1	No ten-arcminute cells used a dual-view SST retrieval

Exceptional values within the ASST product are described in Table 3.

2.4 Quality control of ASST data

The quality of SSTs from ATSR data can be compromised by a number of causes. These can be classified broadly into two groups as follows:

1. ATSR or ERS-1 instrument operations.
2. Inadequate cloud-clearing or atmospheric correction.

Clearly data which are unreliable as a result of the first cause should not be included in this archive, and the quality-control procedure described below is addressed to removing these data.

However some data affected by cloud-contamination or high aerosol levels remain in the archive. Removal of these data would be inappropriate as the selection process would require arbitrary choices and would exclude the use of the archive for many purposes, such as studying the effect of aerosols or the effectiveness of the ATSR cloud-clearing scheme[2]. See Appendix B for more information on the ATSR cloud-identification scheme.

Data arising from periods when ATSR-1 was not in nominal operation have been identified in two ways:

[2] Jones *et al.* (1995) have recently suggested a useful scheme for identifying cloud-contaminated ASST data.

Inspection of the ATSR operations log: – various instrument operations affect data quality. For example, periodically the instrument cooler is turned off to allow residues which have accumulated on the detectors to boil off. During this 'outgassing' procedure, the thermal detectors lose their sensitivity and the associated data are of little value. Orbit manoeuvres also affect data quality with the forward-view data being particularly affected. The ATSR operations log is stored in **atsrops.txt** in the [**docs**] directory. Note that not all suspicious data have been discarded. For example data from the commissioning phase (from launch until 14th September 1991) are regarded as non-nominal, but most of these data remain in the archive.

Inspection of the deviation from climatology: – less serious instrument operations can also affect the data, and these cannot always be identified from the instrument log[3]. Therefore it is necessary to compare data with climatological values in order to identify such compromised observations.

GOSTA monthly one-degree climatology was used (see Bottomley *et al.*, 1990) with unfilled locations being assigned a value by taking

[3] In versions of the processing software previous to SADIST v500, an occasional orbit was mis-geolocated due to an incorrect time being associated with the data; this problem has been corrected in the SADIST v500 software.

the first of these to provide a value:

1. the average of 8 adjacent points;
2. the average of 16 next-most adjacent points;
3. the zonal mean for that latitude;
4. 271.5K (only Arctic and Antarctic regions have no zonal mean).

Linear interpolation was used to generate a half-degree grid for comparison with the ASST data.

Data have been discarded from periods where:

- more than 10% of the day-time ASSTs fell outside climatological values.
- more than 40% of the night-time ASSTs fell outside climatological values.

These thresholds were chosen after inspection of the percentage of data per 100-minute orbit which was more than 6K from climatological values. The higher threshold selected for night-time observations arises as these are more likely to be depressed as a result of incomplete cloud-clearing (in the absence of the 1.6μm data at night).

The identification of a 'bad' orbit did not necessarily result in the discarding of 100-minutes worth of data. Rather, for each such orbit, the deviation of individual ASSTs from climatology was examined to establish when normal operation ceased and resumed. All data from periods which failed the aforementioned quality criteria have been removed from the archive. All other data remain, including individual ASSTs widely deviant from climatology.

In general this test discriminated well and less than 0.3% of ASST data has been discarded. Figure 2 shows the results from comparing day-time data with climatology for each month in 1993. The percentage of data in a 100-minute period (corresponding to one orbit) is shown as a function of time. Note there is little sign of bad data until late June, when a bad period is clearly identifiable. This corresponds to an outgassing which was scheduled for 29th June to 1st July, and the affected data have been removed. However the data also exhibit a marked increase in deviation from climatology throughout July; this is due to the effects of Saharan dust during that month, and, of course, such data remain in the archive.

The time ranges which have been removed from the supplied data set are given in `baddata.txt` in the [**docs**] directory.

Figure 2: ATSR comparison with climatology in 1993

2.5 Removal of duplicates from ASST archive

A duplicate is defined to occur when more than one day-time observation or more than one night-time observation is recorded for a particular half-degree cell on a particular day. Such duplicates arise in several ways as described below.

1. The same data have reached the RAL ASST archive more than once, for example, after having been received from different ground stations. In this case, the ASST records are identical.

2. More than one observation actually occurred. This is possible at high latitudes.

3. Data division – ATSR raw data are downlinked to a ground station about once per orbit, giving rise to a break in the data stream as presented to the processing software. No attempt is made to unite divided data for processing. Therefore data which are associated with a single half-degree cell can be separated, and give rise to two distinct ASSTs, constructed with complementary fractions of the complete data associated with the cell. Such duplicates tend to occur at characteristic

latitudes associated with data downlink and usually several adjacent cells at that latitude are affected.

4. Due to a minor bug in the processing software, occasionally two records are generated for a single half-degree cell. In such cases, more than 90% of the data is used for the first record and less than 10% for the second.

In all these cases, the observation associated with the earlier time is retained and any subsequent record is removed. Thus a maximum of one day-time and one night-time observation is stored for each half-degree cell for any day. Clearly this is appropriate in the first case above where the same data are represented more than once. However in the second case (two distinct observations) both records are equally valid. In the third and fourth cases, the later data are useful but do not have equal weight with the first observation.

The duplicates arising from the latter three causes are stored in files in the [**asst**] directories. These are in the same format as the ASST files, with all the duplicates for 1991–1993 in `dups9193.dat` on Disk 1, and those for 1994–1995 in `dups9495.dat` on Disk 2, that is, the same temporal division used for the ASST data.

3 Time-averaged global maps

Global maps with averaged SSTs are provided at two spatial and temporal resolutions as described below.

1. Monthly maps at half-degree resolution.
2. Maps averaged over five-day periods at one-degree resolution. This is chosen to match the 'superobservation' grid of the U.K. Meteorological Office (UKMO), see Bottomley *et al.*, 1990.

'Mixed' ASSTs as described in Section 2.1 were used. Each averaged SST value is a simple unweighted mean of the day-time and night-time data associated with the appropriate half-degree or one-degree cell during the time period. However only ASSTs which fell within 6K of climatology (from Bottomley *et al.*, 1990) contributed to the averaged SSTs supplied in these files.

Note that ATSR-1 does not achieve complete global coverage when ERS-1 is in a three-day repeat cycle. The repeat cycle history and the associated global coverage are discussed in Appendix C.

3.1 Monthly-averaged maps

Data averaged over calendar months are stored on Disk 2 of the CD-ROM set in the directory [**months**].

The filenames have the form:

`month` *y mm*`.dat`

where *y* is the (year−1990) and *mm* is the month of the year. Thus `month203.dat` contains data for March 1992.

Each file contains a two-byte-integer array of dimensions 720×360. Each array element represents an averaged SST in centiKelvin for a half-degree cell. The terrestrial position associated with each SST is implicit in its array position as described below. (The array is stored as 360 1440-byte records, with the 720 two-byte values for a particular latitude stored in each 1440-byte record. Thus the first record contains values for the half-degree cells centred at 89.75°S *etc.*)

Considering the array to be numbered $0 \leq i \leq 719$, $0 \leq j \leq 359$, the position of the cell centre of `element`[**i,j**] is given by:

$$longitude = ((i - 360.0)/2.0) + 0.25$$

$$latitude = ((j - 180.0)/2.0) + 0.25$$

The latitudes which are implied by the product cell numbers are geocentric.

The exceptional value of -1 is used to indicate that no data were available to generate an ASST for a particular half-degree cell. Such a value will apply to all cells over land, over ice, under cloud when observed, or not observed at all during the month.

3.2 Five-day averaged maps

Data averaged over five-day periods at one-degree resolution are stored on Disk 2 of the CD-ROM set in the directory [**supers**]. This temporal and spatial resolution was chosen to match the UKMO's 'superobservation' grid (Bottomley *et al.*, 1990). In leap years, data for 29th February are included with the previous five days, thus the superobservations start on the same dates from year to year.

The filenames have the form:

`sup` *y mm dd*`.dat`

where *y* is the (year$-$1990), *mm* is the month of the year, and *dd* is the day of the month corresponding to the first day of the five-day period. Thus `sup20307.dat` contains data for the five-day period starting on 7th March 1992.

Each file contains a two-byte-integer array of dimensions 360×180. Each array element represents an averaged SST in centiKelvin for a one-degree cell. The terrestrial position associated with each SST is implicit in its array position as described below. (The array is stored as 180 720-byte records, with the 360 two-byte values for a particular latitude stored in each 720-byte record. The first record contains values for the one-degree cells centred at 89.5°S *etc.*)

Considering the array to be numbered $0 \leq i \leq 359$, $0 \leq j \leq 179$, the position of the cell centre of `element`[**i,j**] is given by:

$$longitude = ((i - 180.0)/2.0) + 0.5$$

$$latitude = ((j - 90.0)/2.0) + 0.5$$

The latitudes which are implied by the product cell numbers are geocentric.

The exceptional value of -1 is used to indicate that no data were available to generate an ASST for a particular one-degree cell. Such a value will apply to all cells over land, over ice, under cloud when observed, or not observed at all during the five-day period.

4 Software

Software to help with accessing the data on this CD-ROM set is stored on Disk 1 in the directory [**software**]. Routines written in Fortran, C and IDL[4] are provided as described below.

`readasst.c` – a C program to read an ASST file and print the contents of the first record.

`disasst.pro, dismonth.pro, dissuper.pro` – IDL procedures to display the contents of ASST, monthly average and 'superobservation' files respectively as global maps.

`avgasst.for` – a FORTRAN program to produce a time-averaged half-degree SST array for any date range.

`rdmonth.for, rdsuper.for` – FORTRAN programs to read the monthly and superobservation files respectively, and print some simple statistics about the data.

These programs are provided as templates from which the user can develop more specialised software as required. Whilst portability

[4] IDL is a registered trademark of Research Systems, Inc.

has been the main programming consideration, inevitably small alterations to the software will be necessary. In particular, the filenames of the input data must be changed to reflect the actual location of the CD directory on the local system.

The other likely change is associated with the byte-ordering used by the computer system. As mentioned earlier, the data are stored as 2-byte or 4-byte integers in fixed-length records. Byte ordering within values follows the DEC/VMS[5] standard; that is, bytes are ordered in increasing significance (*little-endian*). This byte-ordering is also used on most PCs. However, swapping of bytes will be necessary on those platforms where the contrary convention is used (*big-endian*). All the programs supplied incorporate a byteswap flag, and will perform byte-swapping if this flag set to true. Note that the programs will warn the user if the data values suggest the wrong choice regarding byteswapping has been made.

A complete description of the programs is provided in the source code and in `aareadme.txt` in the [**software**] directory.

[5] VMS is a registered trademark of Digital Equipment Corp.

5 Documentation

Useful documentation stored in the [**docs**] directory includes:

booklet.tex, booklet.ps – the LaTeX source and PostScript[6] file for this booklet.

sad500.ps, sad2.ps – the PostScript files for the SADIST v500 and SADIST 2 products documents.

atsrops.txt – a text file containing the ATSR operations log.

baddata.txt – a text file summarising the time ranges which have been removed from the ASST data set for quality control purposes (see Section 2.4).

ftp.txt – a text file describing the anonymous ftp account where updates to the data, software and documentation will be made available.

vms.txt – a text file with VMS-specific advice.

daydates.dat – dates in the (*y mm dd*) format (as described in Section 2.2) are given for the day numbers as used in the ASST data.

[6] PostScript is a registered trademark of ADOBE.

A The ATSR Instrument

ATSR-1 is a dual-view, self-calibrating, infrared radiometer with spectral channels centred at 1.6μm, 3.7μm, 10.8μm and 12.0μm (Edwards *et al.*, 1990). Several aspects of the ATSR design enable the measurement of high-precision SSTs.

On-board calibration – two highly-precise, ultra-stable, on-board calibration targets are maintained at around 265K and 305K. Radiation from each of these is measured during every scan, and these data are used to continually calibrate the instrument, enabling the determination of single-channel equivalent temperatures correct to within 0.05K.

Low-noise detectors – a Stirling-cycle cooler maintains the detectors below 100K. At the start of the mission, noise temperatures lower than 0.05K (for scene temperatures up to 300K) were achieved for each channel.

Dual-view – ATSR's conical scanning technique results in two views of the Earth's surface, one close to nadir and one at 55^o to nadir. As these views are associated with different atmospheric path lengths, a correction for atmospheric absorption can be determined.

B SADIST – the ATSR data processing scheme

The tasks performed by the ATSR data-processing scheme include:

Geolocation and Collocation of data: – the Earth location of acquired ATSR data is determined with an accuracy of better than 2 km, and the collocation (matching of forward and nadir data) has a similar accuracy (Závody, 1995).

Cloud clearing: – the cloud-clearing scheme extends that developed by Saunders and Kriebel (1988) for use with AVHRR data over the North Atlantic. Additional tests involve: consistency checks on forward and nadir brightness temperatures for individual channels; consistency checks on nadir-view brightness temperatures from different channels, and the use of the 1.6μm channel in daytime. Note that the requirements of the nadir/forward-view difference test have been relaxed from the ideal in order to avoid rejecting large quantities of data affected by aerosols from the 1991 Mount Pinatubo eruption. This can result in SSTs depressed by up to 1K from their true value (and also in the admission of genuinely cloudy data). The error is greater in nadir-only SSTs than in dual-view SSTs by an amount which is correlated with the degree of atmospheric aerosol contamination. See Zavody *et al.* (1995) for a discussion of this and a description of the cloud tests.

SST retrieval: – the SST retrieval scheme follows that demonstrated by McClain *et al.* (1985), where SST is given by a linear combination of brightness temperatures.

$$\mathrm{SST} = a_0 + \sum_{i=1}^{N} a_i T_i$$

where a_i is a constant linear regression coefficient and T_i is the cloud-free scene brightness temperature observed by ATSR. The coefficients are derived using global radiosonde sets and an atmospheric radiative transfer model; three different sets of coefficients are used depending on latitude range (polar, mid-latitude or tropical). Day-time SST retrieval uses the 11μm and 12μm brightness temperatures; night-time SST retrieval also uses the 3.7μm brightness temperature when available (that is, for data acquired previous to the May 1992 failure). Therefore a maximum of six brightness temperatures can contribute to an SST derivation, *i.e.* forward and nadir values from the 11, 12 and 3.7μm channels. This calculation is performed independently for each pixel when evaluating SSTs at 1 km$\times$1 km resolution, or on averaged ten-arcminute brightness temperatures when evaluating half-degree ASSTs (see Section 2.1). A complete description of the SST retrieval is given by Závody *et al.* (1994, 1995).

All data contained on the CD-ROM set discussed here were produced using SADIST v500. However, a radically-revised version of the processing software, SADIST-2 is in the final stages of development. In the new ASST product, SSTs averaged over a ten-arcminute cell will be stored; that is, nine values for each half-degree cell. The implications of SADIST-2 for the ASST product and the new ASST format made necessary by this change are discussed in Bailey (1995). Later versions of the ASST archive produced using SADIST-2, will be made available on future CD-ROM sets.

C Global coverage and the ERS-1 orbit

ERS-1 is in a near-polar, Sun-synchronous orbit, of inclination 98.5° and mean altitude 785 km. The ATSR swath is approximately 256 km each side of the sub-satellite track; this gives rise to near-global coverage in three days during the basic ERS-1 three-day repeat cycle, although some regions at tropical latitudes are never observed. Complete global coverage is achieved during the alternative 35-day and 168-day repeat cycles which have also been employed by ERS-1.

The result of a month's observation in January 1992 and January 1993 are shown in Figure 3; these months were associated with a 3-day and a 35-day repeat cycle respectively. Note the characteristic gap pattern evident in the earlier map compared to the full coverage exhibited by the later one.

Figure 3: Global coverage during 3-day and 35-day repeat cycles

Table 4: **ERS-1 Repeat Cycles**

Date range	**Repeat Cycle**
31 July 1991 – 10 December 1991	3-day (Commissioning Phase)
10–26 December 1991	ERS-1 orbit manoeuvres
26 December 1991 – 30 March 1992	3-day (Ice Phase)
30 March 1992 – 14 April 1992	ERS-1 orbit manoeuvres
14 April 1992 – 17 December 1993	35-day (Global Phase)
17–21 December 1993	ERS-1 orbit manoeuvres
21 December 1993 – 10 April 1994	3-day (Second Ice Phase)
10 April 1994 – 19 March 1995	168-day (Geodetic Phase)
19–21 March 1995	ERS-1 orbit manoeuvres
21 March 1995 –	35-day (Global Phase)

A record of ERS-1 repeat cycles is given in Table 4. Note that the different three-day repeat cycles were associated with different global coverage, that is, the data voids were in different places.

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Further information on ATSR can be obtained from:

Dr. Chris Mutlow,
ATSR-1 Principal Investigator,
Space Science Department,
Rutherford Appleton Laboratory,
Chilton, Didcot,
OX11 OQX,
United Kingdom.

Tel: 01235-446525
Fax: 01235-445848.

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