# VALIDATION OF THE AATSR METEO PRODUCT SEA-SURFACE TEMPERATURE AGAINST IN SITU OBSERVATIONS AND ANALYSES

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## ABSTRACT/RESUME

The AATSR Meteo product became available in near-real time as BUFR formatted files updated on an ESA ftp server from 19 August 2002. Since that time, data have been downloaded in near-real time and a series of routine monitoring and validation activities have been performed at the Met Office, UK. The Meteo product SST was compared to point measurements of SST from buoys, to in situ observations averaged on a 5° grid, and to a monthly 1° climate SST analysis field. Daily, weekly and monthly comparisons for August–November show that the Meteo product SST raises no serious concerns: the AATSR instrument and pre-launch SST retrieval algorithms seem to be performing adequately. The global monthly mean differences between Meteo product SST and the climate SST analysis were -0.07 K ($\sigma = 0.79$ K) and -0.08 K ($\sigma = 0.77$ K) for September and October, 2002, respectively. While these statistics show that the AATSR is providing a measure of SST close to expected values, it has been difficult to confirm the absolute accuracy of the product with the available data. There has been no evidence of an AATSR–in situ bias arising from the skin effect, even in night time data, suggesting that the Meteo product dual-view 3-channel SST may be ~0.1–0.2 K too warm.

## 1. INTRODUCTION

The primary purpose of the AATSR is to continue the record of climate accuracy global SST established by ATSR-1 and -2 (on board ERS-1 and -2). For this reason, a crucial part of the AATSR validation programme is to carry out comparisons between newly acquired AATSR SST data and the in situ observations and analyses that are currently used in climate research. The ATSR series were designed to deliver SST to better than 0.3 K accuracy, as required for climate datasets.

We have performed near-real time monitoring and validation of the AATSR Meteo product SST against three different data sources, since the Meteo product became available on 19 August 2002. As described in [1], this monitoring in near-real time has provided a gross check on instrument performance so far. AATSR observations have been collocated with reports from drifting and moored buoys to provide point comparisons. The Met Office Historical SST (MOHSST, [2]) is a 5° resolution gridded in situ dataset, generated every 5 days from quality-controlled ship and buoy reports. To match this temporal frequency, AATSR data have been averaged every 5 days to the same 5° resolution for broader comparisons. Finally, we have compared AATSR SST averaged monthly to 1° resolution, with the Hadley Centre sea-ice and SST (HadISST1, [3]) climate analysis. Here we report on the results of these comparisons carried out for the period 19 August–30 November 2002.

In all cases, the alternative data sources are measures of bulk SST, whereas the AATSR is sensitive to the radiometric skin SST. Real physical differences between skin and bulk SST are known to exist, and these are summarised in section 2.4. It is necessary to take into account these expected differences in assessing the Meteo product validation results.

## 2. DATA AND METHODOLOGY

### 2.1 AATSR Meteo Product

The AATSR Meteo product (ATS_MET_2P, [4]) is a fast-delivery Level 2 product designed for use by meteorological agencies, and contains averaged channel brightness temperatures and SSTs in 10 arc minute cells. The contents of this product are extracted from the 10 arc minute averaged surface temperature product (ATS_AR_2P, [4]), for clear, sea views. Land and cloudy-sea records are also included, but with measurement fields set to "missing" values. SST is retrieved using the pre-launch coefficient set, both for the nadir view only and for the dual-view combination. In each

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case, only 11 μm and 12 μm data are used during the day, but at night, valid 3.7 μm data are also included. All of the product validation described here has used only the dual-view SST, for both day and night time, unless indicated otherwise.

For near-real time use, each Meteo product orbit file is BUFR encoded and placed on an ftp server. There are some inconsistencies between the data available in the product and in the BUFR version, as noted in Table 1. For quality control purposes, it is desirable for the number of clear pixels in nadir and forward views to be included in any upgrade of the BUFR version.

Table 1. Data available in AATSR Meteo product (ATS_MET_2P) and BUFR version for the Envisat Validation Phase.

| Parameter in Meteo product | Unit | in BUFR? | Comments |
|---|---|---|---|
| Nadir UTC date/time | MJD | Y | Provided as year, month, day, hour, minute, second in BUFR |
| Record quality indicator | | N | Set to -1 if all measurement values are invalid |
| Spare field | | N | |
| Latitude of 10' cell | μ° | Y | Provided in units of ° in BUFR |
| Longitude of 10' cell | μ ° | Y | Provided in units of ° in BUFR |
| Nadir-view 12 um BT | mK | Y | 10' cell average BT of all clear pixels in nadir. Units of K in BUFR |
| Nadir-view 11 um BT | mK | Y | 10' cell average BT of all clear pixels in nadir. Units of K in BUFR |
| Nadir-view 3.7 um BT | mK | Y | 10' cell average BT of all clear pixels in nadir. Units of K in BUFR |
| Forward-view 12 um BT | mK | Y | 10' cell average BT of all clear pixels in forward. Units of K in BUFR |
| Forward-view 11 um BT | mK | Y | 10' cell average BT of all clear pixels in forward. Units of K in BUFR |
| Forward-view 3.7 um BT | mK | Y | 10' cell average BT of all clear pixels in forward. Units of K in BUFR |
| Mean across-track pixel number | | Y | Mean pixel index of the nadir view clear sea pixels within cell |
| Mean nadir view SST | cK | Y | Mean SST retrieved from nadir-view BTs. Units of K in BUFR |
| Nadir number of pixels | | N | Number of clear nadir view pixels contributing to mean SST |
| Mean dual view SST | cK | Y | Mean SST retrieved from dual-view BTs. Units of K in BUFR |
| Dual-view number of pixels | | N | Number of clear pixels contributing to mean dual-view SST |
| AST confidence flagtable | | Y | see [4] for description. Note that flag order reversed in BUFR version |

The Meteo product BUFR files have been made available on the Kiruna ftp server from 19 August 2002, with some gaps, resulting from technical problems. Table 2 summarises gaps encountered during the period up to end-November 2002. Aside from the outages listed in Table 2, data coverage has sometimes been incomplete (e.g., 25–31 October) with fewer orbits than expected on the server, or fewer valid data within the files. Since we process these data in near-real time, if outages in provision are not back-filled within approximately 3–4 days, we experience a permanent gap in our archive.

Envisat makes ~14 orbits of the globe each day; of these, up to 10 can be downloaded directly to the Kiruna receiving station, while ~4 are “blind” from Kiruna. These blind orbits have resulted in an absence of night-time observations over most of the Atlantic and part of the east Pacific Oceans (and a corresponding lack of daytime data across parts of the Indian and the west Pacific Oceans). The blind orbits started to become available from mid-November, 2002, with the introduction of the Svalbard receiving station into the data distribution chain. However the data included in this report are from Kiruna only. When all of the data gaps since the start of the mission, including the blind orbit data, have been released by ESA, we intend to reprocess AATSR data offline, to provide a complete AATSR SST archive for climate monitoring purposes.

Table 2. Gaps in Meteo product availability on Kiruna ftp server

| Dates | Days lost | Reason for gap |
|---|---|---|
| 25 August | 1 | no data available to ftp |
| 8-12 September | 4 + ½ | Envisat manoeuvre |
| 28-30 September | ½ + 1 + ½ | Kiruna hardware failure |
| 11-12 October | ½ + 1 | changes to BUFR tables |
| 22-24 October | 3 | technical problems at Kiruna |
| 1-3 November | ¾ + 1 + ¾ | technical problems at Kiruna |
| 8-9 November | ½ + ¼ | data supplied to ESRIN but not Kiruna |
| 9 November | ¾ | unknown |
| 18-20 November | 2 + ¾ | Envisat protection during Leonids |

## 1.2 Buoy data

Many marine buoys report in near-real time onto the Global Telecommunications System (GTS). These data are collected at the Met Office, and throughout the period of study, we have collated them into daily datasets. A weekly quality control of individual buoys was performed, in which the mean difference between reported SST and the Met Office NWP background SST field was considered. Buoys which showed a mean weekly bias of more than 1.2 K or standard deviation of greater than 0.6 K compared to NWP were screened out. Additionally, each single buoy SST report was required to agree within gross limits (8 K) with climatology. On the basis of these tests, up to 25 % of the buoy reports received each week could be filtered out.

AATSR data were matched up to buoy observations collocated within the 10 arc minute cell. The observations were required to be coincident to within 3 hours. Where more than one AATSR observation was matched to the same buoy report (e.g., if the buoy was located on the edge of a 10 arc minute cell), only the matchup with the smallest time difference was used. Careful screening of duplicate matchups (for cases where the same AATSR observation matched with consecutive reports from a single buoy) was performed. We obtained ~140 matchups per week across the global domain, although the numbers were highly variable due to gaps in AATSR data provision, and changes in the numbers of buoy reports received.

## 1.3 Climate datasets

The Hadley Centre produces a number of climate datasets for global SST, ranging from gridded observations to globally-complete analysed fields. The MOHSST dataset consists of quality-controlled in situ observations from ships and buoys meaned at 5° spatial resolution, as described in [2]. A 5-day (pentad) average version of this dataset, available in near-real time, was intended to be compared with the Meteo product SST to provide a gross indication of AATSR every 5 days. However, recent investigations, initiated as a result of comparisons with AATSR, have highlighted potential errors in the pentad resolution MOHSST data required for this routine validation. In contrast, monthly average MOHSST fields are fully reliable, and so AATSR SSTs were validated for each month against this dataset, instead.

The HadISST dataset is a globally-complete 1° spatial resolution sea-ice and SST analysis field, produced on a monthly basis. The SST data which contribute to HadISST come from ships, buoys and AVHRR: the AVHRR SSTs are bias-corrected to tie in with local in situ SSTs. Gaps in coverage are filled using reduced-space optimal interpolation, and the full analysis is described in [3]. Comparison to HadISST provided a more stringent validation of the Meteo product SST over a monthly period. Over timescales of a year or more, monthly comparisons could be used to identify regional or seasonal anomalies. For each of these comparisons, AATSR data were first gridded into the appropriate spatial resolution, and then averaged over the appropriate time period, before differences from the validation dataset were computed.

## 1.4 Skin–bulk SST differences

Each of our validation datasets are measures of the “bulk” SST, the temperature of the surface waters at depths of ~1 m or more. In contrast, AATSR is sensitive to the temperature of the ocean’s radiative skin, and retrieval coefficients have been derived via radiative transfer modelling so that skin SST is retrieved from the measured brightness temperatures. Because of the size and direction of net heat flow from the ocean, a thermal gradient exists across the molecular skin layer, so that the skin SST is cooler than the temperature immediately below the skin layer. Numerous studies have shown that the magnitude of this skin–bulk temperature difference is ~0.1–0.2 K at wind speeds higher than ~7 $ms^{-1}$, with values up to ~0.6 K when wind speeds are very low (e.g., [5, 6, 7]).

While small, this skin-bulk difference is not negligible, given the high accuracy constraints of AATSR (<0.3 K for SST). For this reason, where comparisons between the Meteo product SST and bulk SST datasets are made, we expect that in the absence of shallow diurnal warming effects (i.e., at night), the Meteo product should be 0.1–0.2 K cooler, if the instrument and SST retrieval work well.

During the day, where insolation is strong and wind energy is low, thermal stratification builds up in the top few metres of the ocean, reaching a maximum at mid-afternoon (e.g., [8]). The resulting diurnal thermocline may mean that SST measured just below the skin layer becomes as much as 1–3 K warmer than the SST at depths of ~1 m or more [9].

Thus, although the cool skin effect across the molecular surface layer persists at all times, it can sometimes be masked by the stronger signal from diurnal warming. Since AATSR observes the Earth's surface at ~1000 (and 2200) LST, this gives only a short time for diurnal thermocline development. However, under the right calm cloud-free conditions, we may occasionally expect the Meteo product SST to be warmer than the in situ measurement.

## 3. METEO PRODUCT RESULTS

### 3.1 Dual-view sea-surface temperatures

Global plots of daily and monthly dual-view SST from the Meteo product have been produced throughout the study period. Fig. 1 shows the maximum daily coverage during most of the study period.

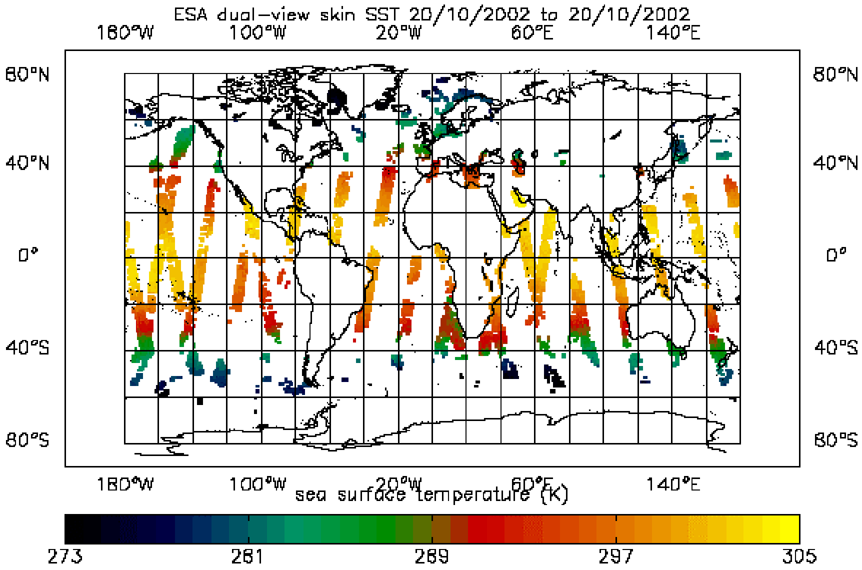

Fig.1. Meteo product dual-view SST on 20 October 2002.

Monthly mean SST averaged at 0.5° resolution are shown in Fig. 2 for the four months covered in this study, although data for August cover only 19–31 of the month. A number of features are worth noting. SST is cool to the west of southernmost America and Africa, as expected due to the large scale oceanic gyres. With the onset of Northern Hemisphere winter, cooler SST in the North Atlantic can be seen encroaching further south, while warmer SST advances south in the Southern Oceans (compare November and August). Areas of persistent cloud cover show up as data gaps in Fig. 2, such as off the western seaboard of South America and in the west North Pacific.

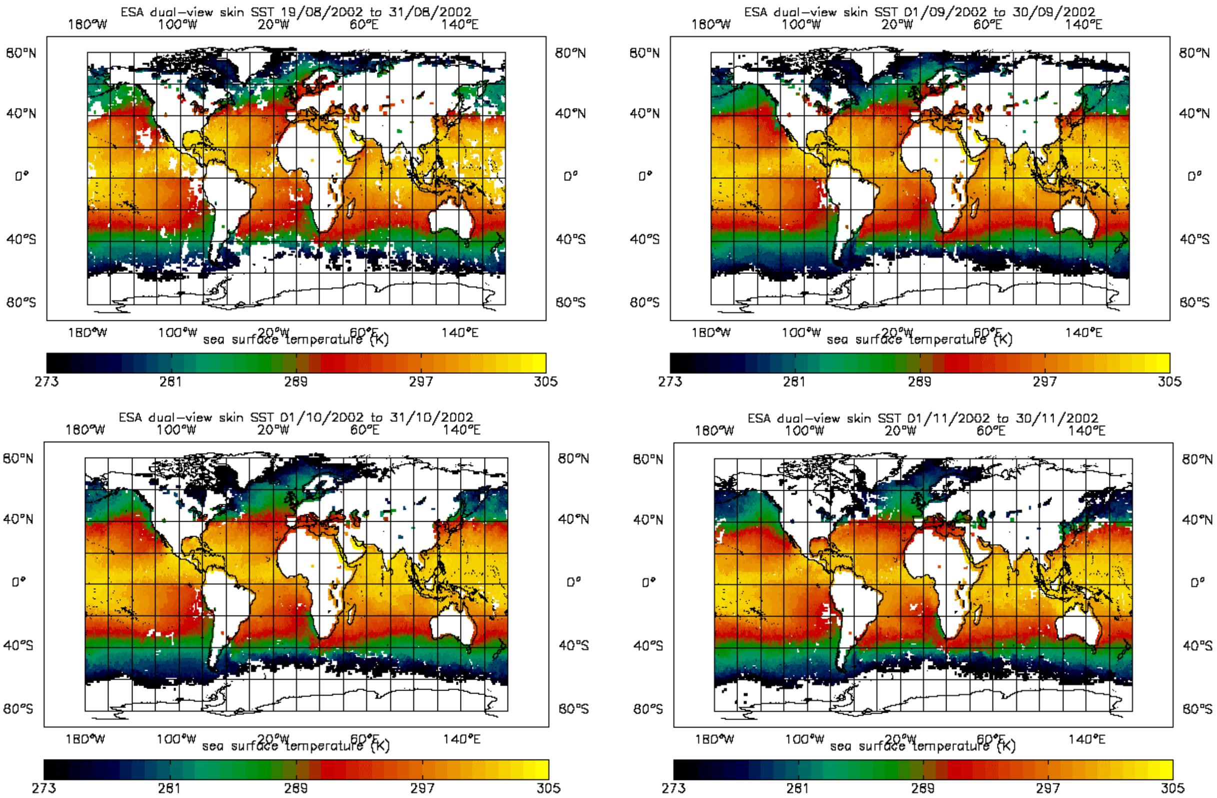

Fig. 2. Mean monthly Meteo product SST averaged to 0.5° spatial resolution, for August (top left), September (top right), October (bottom left) and November (bottom right) 2002.

Daily mean SST has been computed globally and for several regional domains. Time-series of the global mean and the mean in UK waters (latitudes 40N to 60N, longitudes 20W to 10E) are shown in Fig. 3. Erratic trends in the global time series from mid-October to mid-November are artefacts due to inconsistent data coverage during that period (see Table 2). For UK waters, Fig. 3 shows a decreasing SST, which is real and expected with the onset of winter.

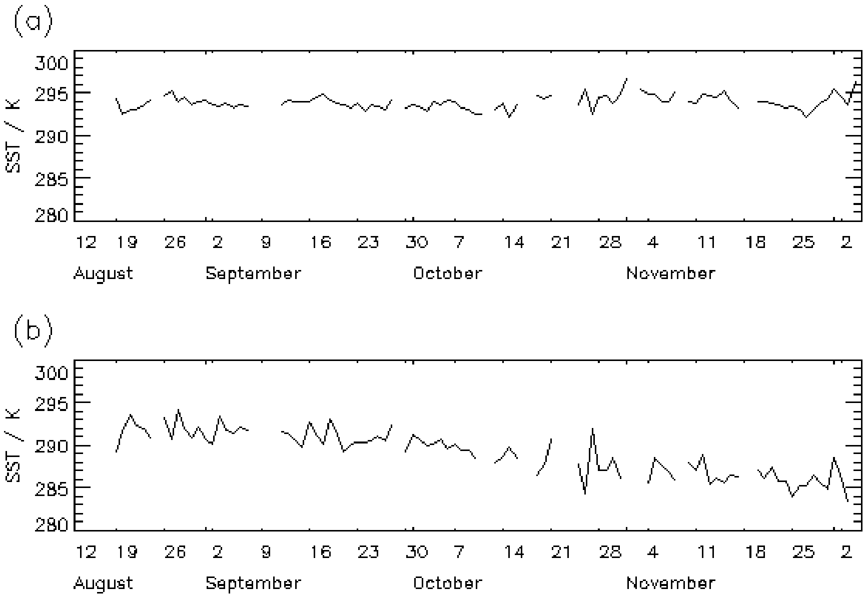

Fig. 3. Time series of daily mean SST for (a) global domain, and (b) UK waters.

## 3.2 SST algorithm comparisons

As an independent check on the performance of the SST retrieval algorithms, we retrieved SST from the brightness temperature data provided in the Meteo product, using the pre-launch coefficients set that was used in the AATSR Operational Processor (IPF). Histograms of the difference between the Meteo product SST and the independent SST retrieval are shown in Fig. 4. For a typical day, the mean difference between these independent calculations of SST was -0.004 K ($\sigma = 0.012$ K) for night time, dual-view 3-channel retrievals, and -0.007 K ($\sigma = 0.025$ K) for day time, dual-view 2-channel retrievals, with no large outliers. These discrepancies are negligible, and indicate that the dual-view SST retrieval is consistent with the brightness temperatures provided in the Meteo product.

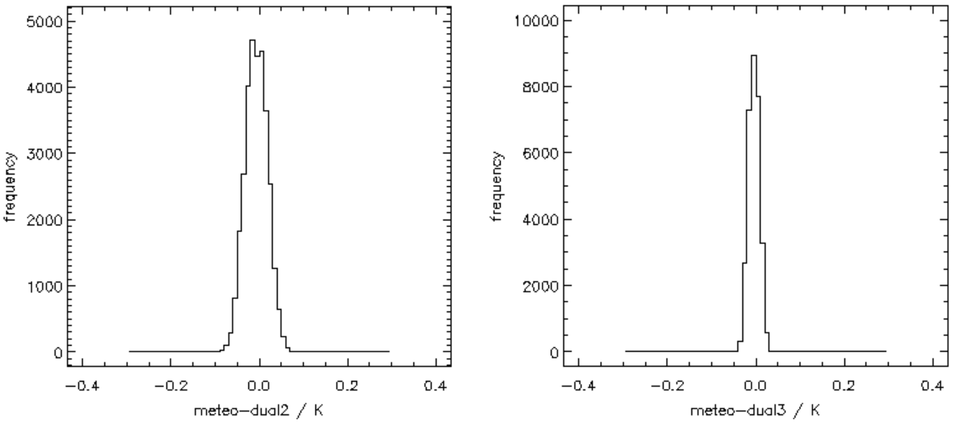

Fig. 4. Histograms of the difference between the Meteo SST and an independent retrieval of SST from Meteo product brightness temperatures, for day-time data using the dual-view 2-channel algorithm (left), and for night time data using the dual-view 3-channel algorithm (right). Data from 13 November 2002.

We then compared SSTs retrieved using different algorithms. Fig. 5 shows histograms of the differences between SSTs retrieved with the dual-view algorithms for night time AATSR and ATSR-2 data. In both cases, the dual-view 2-channel SST was ~0.2 K cooler than the dual-view 3-channel SST. This is consistent with previous work on ATSR-2 data, which showed that dual-view 2-channel retrievals may be 0.1–0.3 K cooler than corresponding dual-view 3-channel retrievals, with the magnitude of the offset apparently dependent on latitude [10, 7].

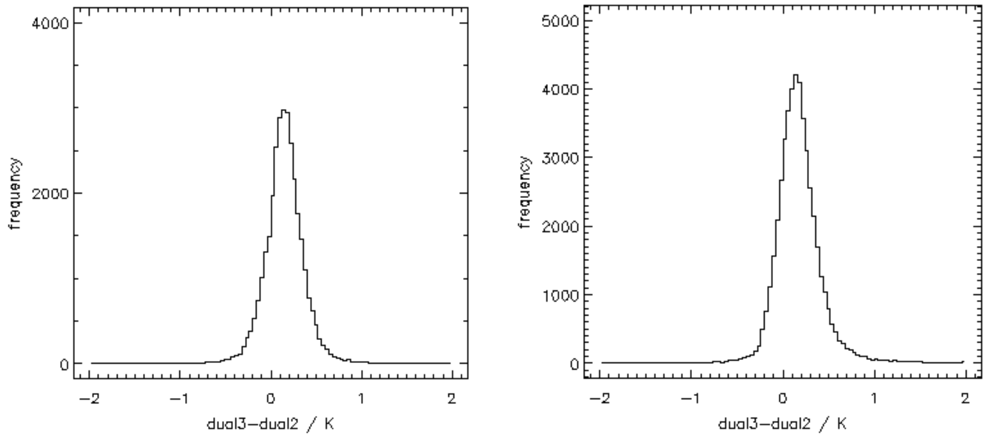

Fig. 5. Night time dual-view 3- channel SST minus dual-view 2-channel SST for AATSR data (left) on 12 November 2002, with the pre-launch coefficients set; and for ATSR-2 data (right) on 21 April 1998, with coefficients from [11].

This bias between the dual-view algorithms has been a feature of all ATSR-series SST retrievals, and appears to result from constraints in the accuracy of radiative transfer modelling, perhaps coupled with non-linearities in the relationship between brightness temperature and atmospheric water vapour burden. The bias could be removed through the addition of an empirical offset, and work is in progress for the case of ATSR-2 as to how best to define such a correction. Since the dual-view SST in the Meteo product consists of a 3-channel retrieval at night and 2-channel retrieval for day time data, this bias, if unaccounted for by the user, will cause small systematic differences between night time and day time SSTs. The Meteo product SST has not been corrected for this in the comparisons presented below.

## 4. VALIDATION RESULTS

Comparisons between Meteo product SST and alternative SST data were produced routinely in near-real time throughout the study period, in order to monitor the performance of the AATSR.

### 4.1 Comparison against SSTs from buoys

The coverage provided by the full set of AATSR–buoy matchups for August–November 2002 is shown in Fig. 6. All the major oceans are well-represented, with the exception of the western North Pacific, and the Southern Oceans. Reasons for gaps in data coverage include persistent cloud coverage (which reduces the number of available AATSR data, and may account for gaps off the western coast of the Americas) as well as low numbers of buoy deployments in some areas.

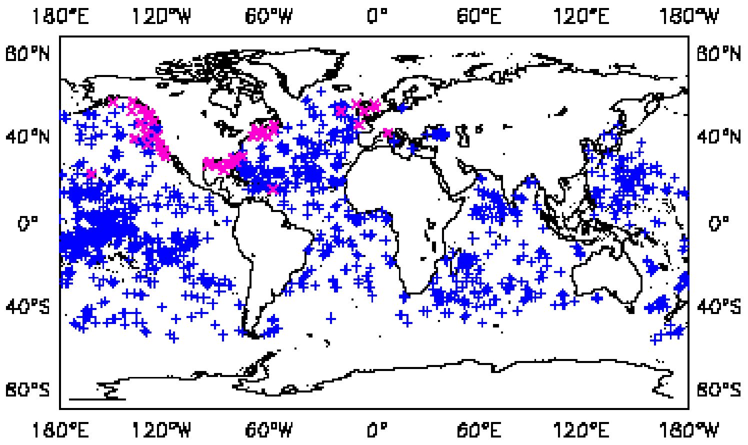

Fig. 6. Locations of 1863 matchups between AATSR Meteo product SST and reports from drifting (blue) and moored (pink) buoys between 19 August and 27 November 2002. (Note that some of the moored buoys in the TAO array report as drifters on the GTS.)

A time series of the daily global mean difference between Meteo product SST and buoy SST is presented in Fig. 7, along with time series of the daily number of matchups and standard deviation of the mean differences. With one exception, the magnitude of the mean daily AATSR-buoy SST difference remained less than 0.3 K, and predominantly it was less than 0.2 K. Similarly, the standard deviation was generally below 1 K. There was a downward trend in the number of matchups available through time. This was partly due to erratic AATSR data supply, and partly due to a reducing trend in the number of drifting buoy reports received via the GTS (probably due to a higher rate of device failures in the Northern Hemisphere in winter).

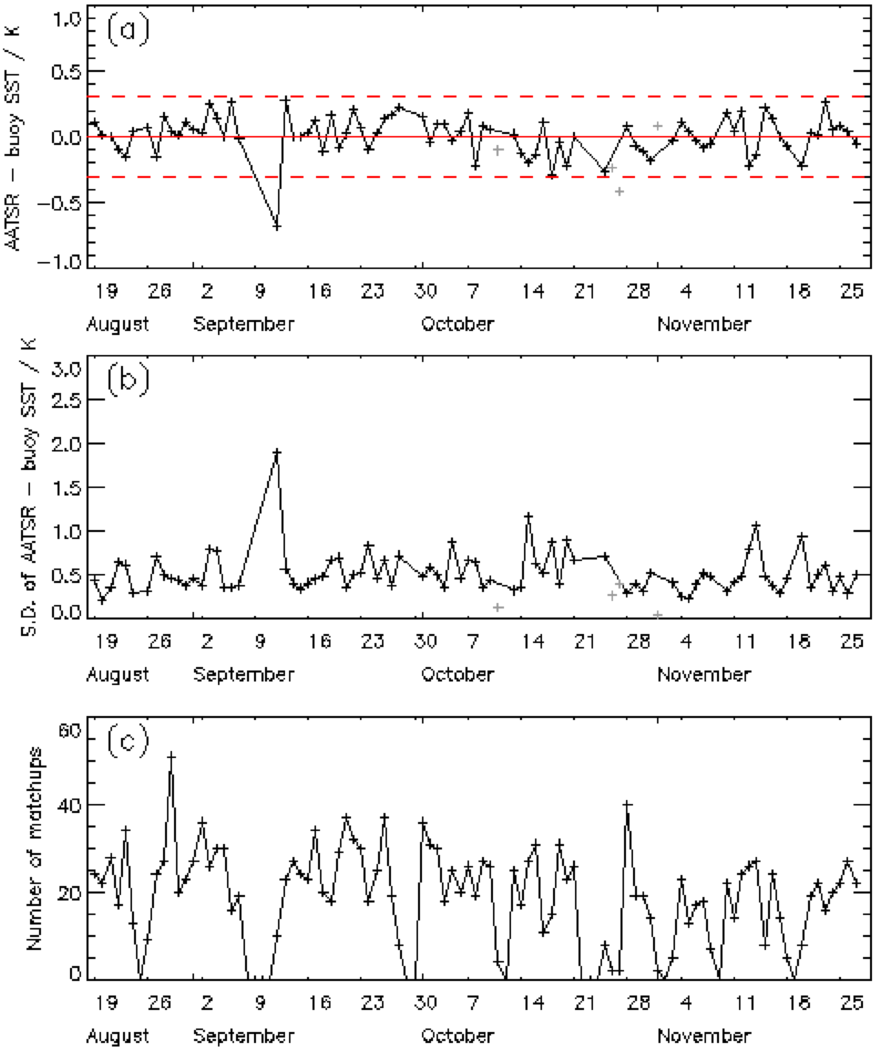

Fig. 7. Time series of daily global statistics from AATSR-buoy matchups. (a) Mean difference (AATSR SST minus buoy SST); (b) standard deviation of the mean difference; (c) number of matchups contributing to the mean.

The obvious anomaly in Fig. 7a on 12 September has been investigated. The daily mean SST difference was -0.68 K, and the high magnitude of this result arose from the contribution of 2 out of the 10 matchups for that day. These two were located off the coast of San Francisco. AATSR and buoy SSTs are given in Table 3, with the corresponding SST from the Met Office daily SST analysis used in operational NWP. In both cases, the buoy SST matches the NWP SST analysis most closely, and the Meteo product SST is significantly cooler. Geostationary satellite imagery for that day shows a large area of low-level cloud off the California coast. We assume therefore that the cool AATSR SSTs result from undetected stratocumulus cloud in the instrument's field of view.

Table 3. SST data for two AATSR–buoy matchups near San Francisco on 12 September 2002.

| Buoy SST / K | Meteo SST / K | NWP SST / K |
|---|---|---|
| 286.40 | 282.22 | 286.77 |
| 287.20 | 282.96 | 290.06 |

For 1860 matchups in the study period, (excluding the two erroneous data on 12 September, and a third matchup where the buoy SST appeared anomalously warm) the mean AATSR–buoy SST difference was 0.03 K, with standard deviation of 0.53 K. When only the matchups for night time AATSR data were considered, the mean was little different at 0.02 K (standard deviation = 0.42 K). At night time, the AATSR–buoy bias should reflect only the skin–bulk SST difference resulting from the skin effect. Since the night time bias was close to zero, when we expect a mean of between -0.1 and -0.2 K for the skin effect, it may be that the AATSR dual-view 3-channel SST retrieval (used at night only) was too warm by this amount.

This suspicion is further illustrated by consideration of the night time AATSR–buoy difference as a function of wind speed (Fig. 8). Wind speed data were obtained at 6-hourly intervals from the Met Office global NWP model analysis and interpolated to each AATSR observation location. As expected, the largest skin-bulk differences occur at the lowest wind speeds. However, the difference is close to zero or even positive at higher wind speeds, where the AATSR (skin) SST should be consistently 0.1–0.2 K cooler than the buoy (bulk) SST. In comparison, the blue line in Fig. 8 shows the skin effect predicted by the parameterisation of [5]. This model skin effect was calculated for each AATSR observation using heat flux and wind speed data from the Met Office NWP analysis, following the validation presented in [7]. The parameterisation is likely to underestimate the skin effect at very low wind speeds partly due to lack of representativity of the extremes of wind speed, and partly because the radiative fluxes which dominate at low wind are difficult to model accurately in an NWP model. However the prediction provides an indication of the skin-bulk differences that are to be expected, and shows that the dual-view 3-channel SST is probably slightly warm. Considering the mean bias between the dual-view algorithms (Fig. 5), the cooler dual-view 2-channel algorithm may provide SSTs closer to the true skin temperature than the dual-view 3-channel SST.

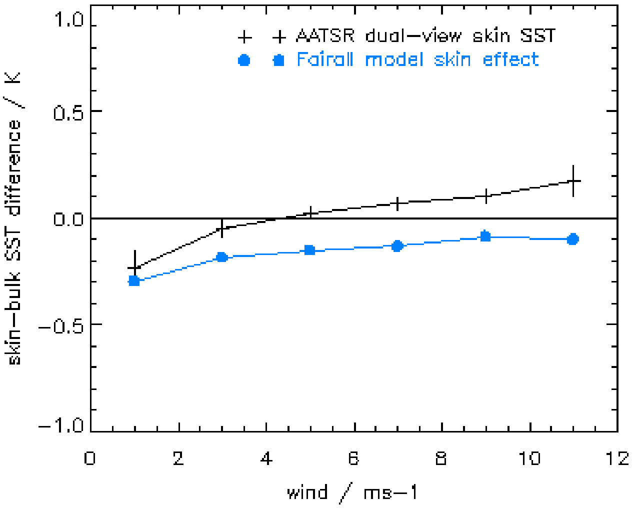

Fig. 8. Night time AATSR skin SST minus buoy SST shown as a function of wind speed, with standard error bars. Wind speed data from Met Office global NWP model analyses, interpolated to AATSR observation locations. Blue line shows the skin effect predicted for each AATSR observation, using the model of [5].

For daytime data, diurnal warming can make a variable contribution to the observed AATSR–buoy SST difference: we expect AATSR SSTs to be relatively warmer, with a larger standard deviation. For the day time subset, the mean AATSR-buoy SST difference was 0.03 K (standard deviation = 0.60 K). Since the day time SST in the Meteo product is the dual-view 2-channel SST, this result implies that the variability introduced by diurnal warming has increased the skin SST by ~0.2 K in the mean (the mean relative bias between the two dual-view algorithms), over the night time skin SST.

## 4.2 Comparison against MOHSST

AATSR skin SSTs (both day and night time data) were converted to an estimate of bulk SST through the use of physical parameterisations for the skin effect and diurnal thermocline. The bulk SST was calculated by adding a skin effect temperature difference (predicted using [5], forced by heat fluxes and wind speeds obtained from the Met Office global NWP model) to the retrieved AATSR skin SST. The model of [12], again forced by heat flux and wind speed data from the same source, was used to predict day time observations likely to have been affected by diurnal warming to the extent that skin SST might be more than 0.2 K warmer than a 1-m bulk SST. These observations were excluded from the analysis (usually ~0.5 % of the day time data). The remaining night time and day time bulk SSTs were then averaged to form monthly fields at 5° resolution and compared to monthly MOHSST. Fig. 9 shows the difference between monthly mean bulk SST derived from AATSR and monthly mean MOHSST for October 2002.

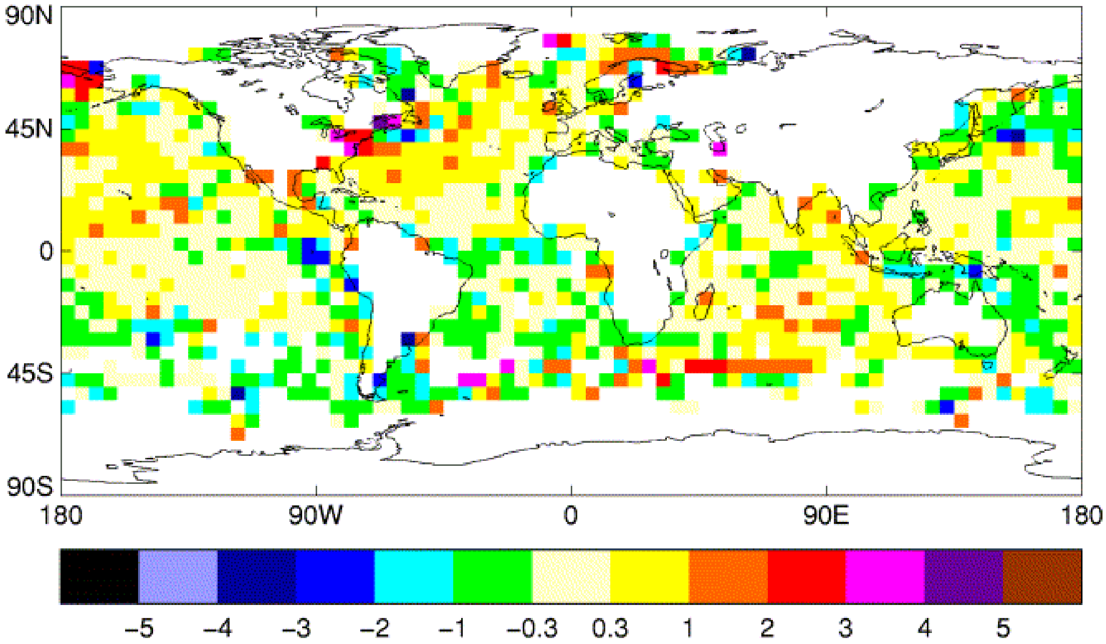

Fig. 9. Global map showing the monthly 5° mean difference between AATSR SST and MOHSST for October 2002. Differences are given in K. The AATSR SST is an estimate of bulk SST (see text for details).

Although at coarse resolution, Fig. 9 confirms that there were no areas of serious concern in the AATSR data. The global averages for the monthly comparisons were -0.00 K, 0.04 K and -0.01 K for September, October and November, respectively. These results are encouraging, and indicate that skin SSTs retrieved from AATSR data can be usefully converted to an estimate of bulk SST comparable with in situ data. The largest differences were found in areas of strong SST gradient (e.g, the Gulf Stream), or where only limited numbers of in situ data contributed to MOHSST (e.g., Southern Oceans). Where AATSR appears cooler than MOHSST in the NW Pacific, this could be related to remnant cloud contamination in the satellite data, or to warm-biased ship measurements of SST in this region.

## 4.3 Comparison against HadISST

The HadISST dataset provides a monthly SST analysis at 1° resolution. Meteo product SSTs (skin SST for both day and night time observations) were averaged to form 1° resolution monthly fields for comparison. Computation of HadISST completes mid-way through the following month; so we have only two full months available at the time of writing (September and October 2002). Fig. 10 shows the monthly AATSR – HadISST difference for October (September looked very similar). The global monthly mean SST differences were -0.07 K (standard deviation = 0.79 K) and -0.08 K (standard deviation = 0.77 K) for September and October, respectively.

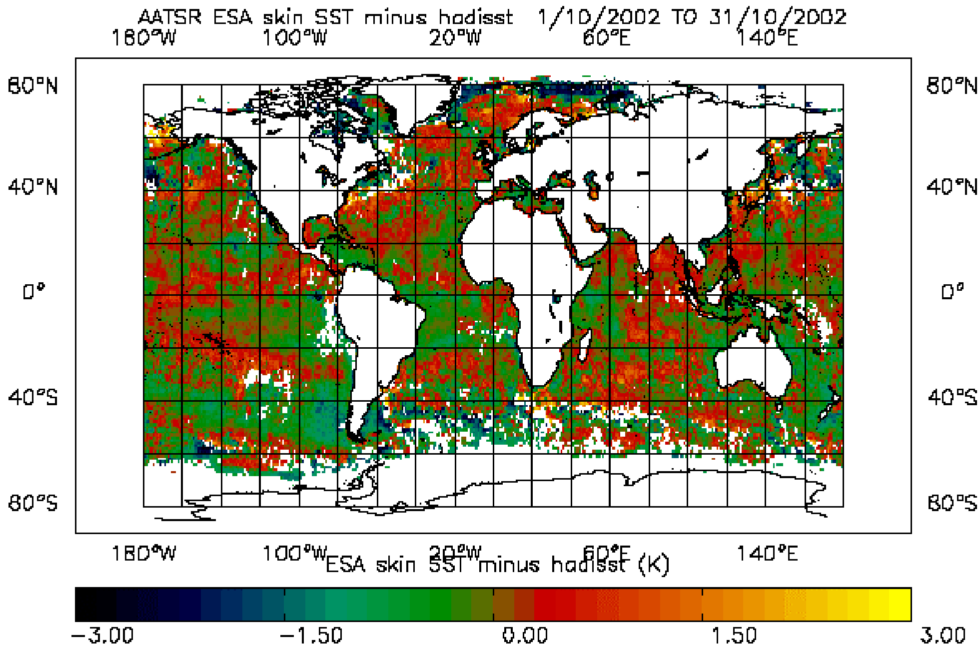

Fig. 10. Monthly mean SST difference between AATSR and HadISST in October 2002. Differences in K.

The AATSR data included in this analysis contain a few observations that may be affected by diurnal warming, and makes no correction for the dual-view interalgorithm bias. However, in keeping with the validation against buoy SSTs, the mean global difference between AATSR skin SST and the bulk SST represented by HadISST is close to zero. Fig. 10 shows that across the globe differences are generally well below ±1 K. Strong differences close to the ice edge in the Northern Hemisphere may relate to an incomplete SST–sea-ice analysis in this version of HadISST, which will be updated in the near-future. Areas where AATSR is significantly cool compared to HadISST tend to fall close to regions where cloud-detection has resulted in data gaps (e.g., South Atlantic), and therefore may be linked to remnant cloud contamination in the AATSR data.

## 5. DISCUSSION AND CONCLUSIONS

Comparison of the AATSR Meteo product to the three in situ datasets has provided firm evidence that both the instrument and pre-launch retrieval algorithms are performing consistently, and in the range of accuracy that was expected. In the mean, AATSR SSTs have shown excellent correspondence with the in situ measurements, agreeing to well within 0.3 K. There have been no issues of serious concern during the period of study from mid-August to end-November 2002. For the few cases of noticeable discrepancy, reasonable explanations have been found.

A bias of ~0.2 K in the mean between dual-view 3-channel SSTs and dual-view 2-channel SSTs has been confirmed, similar to the interalgorithm differences encountered previously with ATSR-2. There was no attempt in this work to remove this bias, and day–night differences therefore included the effect of algorithm differences as well as the diurnal cycle. Comparison of the day time and night time buoy matchups indicates that the dual-view 2-channel SST may be closer to reality. The dual-view 3-channel retrieval is a few tenths of a Kelvin too warm, but without a larger validation dataset, it is difficult to quantify the error accurately.

A priority for future work should be the provision of a Meteo product SST which is unbiased between day and night. In order to achieve this, theoretical and empirical studies are required, first to quantify and understand the interalgorithm differences fully, and then to provide a scientifically robust means of correcting them.

The short duration of this validation period has hindered the strength of quantitative conclusions that might be drawn. Without several months of further validation activities (and preferably a full year of AATSR data) it is difficult to provide an assessment of accuracy with certainty. Similarly, there are insufficient data to draw conclusions about potential seasonal or regional problems.

Further work on AATSR validation at the Met Office is planned. First, the routine validation activities described here will continue for the foreseeable future, and at least until a full year of AATSR data can be evaluated. Second, for climate purposes it is essential that the overlap between ATSR-2 and AATSR is properly calibrated. Finally, we expect to make useful comparisons between AATSR and SST from satellite-based microwave radiometers, with a view to assessing AATSR cloud detection.

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