Ongoing Validation of ATSR SST Products

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Abstract

Between August 1996 and March 1999 six ATSR-2 validation campaigns were undertaken in the oceans adjacent to Australia. The varied results from these campaigns are presented and the results indicate that the instrument is providing accurate SST values over a wide range of climatic conditions. The results demonstrate the extreme difficulty of assembling a large validation data set based on coincident ATSR and ship-based radiometer measurements under clear sky conditions. No useful validation data were collected during two of these campaigns. The possibility of SST validation using bulk SST measurements with supporting ship-based data is explored. The results also show that ship-based measurements can also be used to validate the theoretical transmission model used to derive the coefficients used in the operational ATSR SST algorithms.

1 INTRODUCTION

The SST products derived from ATSR data require ongoing validation to ensure that the global data sets are useful for applications in climate research. Early validation results for the SST derived from the first ATSR instrument on ERS-1 have been presented by Mutlow et al. (1994) and Barton et al. (1995). High quality radiometers are needed to measure the sea surface skin temperature for comparison with the satellite-derived product from ATSR-2. Bulk temperatures can only be used for validation when surface conditions enable an accurate assessment of the skin-bulk temperature difference. In the future, identification of such conditions may enable the careful use of bulk temperature measurements in the validation of ATSR SST estimates. This technique is now gaining some recognition as several ship campaigns in which bulk and radiometric measurements have been made suggest that, under some conditions, the skin effect may be sufficiently predictable to enable bulk temperature measurements to be used for SST validation purposes. Some ancillary data will be required to enable the viable application of this technique.

2 CAMPAIGNS

All the validation data obtained from the six campaigns are given in Table 1. This table includes the SST estimated using the different pre-launch algorithms derived for ATSR-2. The values of the ATSR brightness temperatures are given in Table 2 and, when radiosonde data are available, the model-derived brightness temperatures are given in Table 3. These brightness temperatures are generated by the model with the assumption that the surface skin temperature is that measured by the ship radiometer. Table 4 shows the differences between the ATSR brightness temperatures and those derived using the atmospheric transmission model.

2.1 Tropical Indian Ocean - August 1996

During this voyage of the RV FRANKLIN a TASCO radiometer was used to measure the surface temperature throughout the voyage. The use of these TASCO radiometers in the collection of SST validation data has been extensively discussed by Donlon et al. (1998). During this voyage the radiometer was regularly calibrated by viewing a blackened copper cone which was surrounded by a stirred water bath. The bulk temperature was measured by the ship's thermosalinograph which samples water at a depth of about 1 m and a towed thermistor at some 0.05 m below the surface. In well mixed conditions the temperatures measured by these two instruments were in good agreement. No radiosondes were launched during the voyage and the reflected sky radiance correction was estimated from regular measurements of the down-welling radiance using the TASCO radiometer. Several ATSR images were obtained over the study area and clear sky coincidences were found on two separate occasions.

2.2 Townsville CEOS Pilot Project - July 1997

A small vessel (15 m length) was used to collect data some twenty kilometres off the north-east coast of Australia near Townsville. The campaign was sponsored by CEOS and was aimed at an inter-comparison of infrared satellite data obtained from a selection of satellite instruments including ATSR-1 and ATSR-2. Only the results for ATSR-2 are reported here. During the one-week campaign four coincidences of clear sky ship data and ATSR overpasses were recorded. Radiometric measurements of the surface temperature were taken with two TASCO radiometers and one Everest radiometer. Continuous sky measurements were also taken with an upward-looking TASCO radiometer. Bulk SST measurements were made using two platinum resistance thermometers at a depth of 0.05 m. Wind speed was obtained from nearby stations on the coast and the Great Barrier Reef. The three radiometers were regularly calibrated with a portable hand-held calibration target. For each ship excursion a radiosonde was launched from a nearby weather station and the data made available by the Australian Bureau of Meteorology.

Table 1: Validation data collected during the ship campaigns. SST2, SST4, SST6 refer to the satellite derived SST using two (T11N,T12N), four (T11N,T12N,T11F,T12F), and six (T11N,T12N,T37N,T12F,T11F,T37N) brightness temperatures.

Date	Time (UTC)	Lat.	Long.	Wind speed m/s	Bulk SST (°C)	Rad. SST (°C)	SST2 (°C)	SST4 (°C)	SST6 (°C)
21/08/96	1423	5.43S	95.56E	4.0	28.63	28.32	28.01	27.42	28.13
26/08/96	0322	2.85S	92.41E	3.9	29.25	29.23	29.16	28.72	
27/07/97	0028	19.00S	146.90E	4.4	21.11	20.94	21.07	20.96	
27/07/97	1252	19.00S	146.90E	4.7	21.54	21.32	20.73	21.17	20.94
30/07/97	0034	19.00S	146.90E	6.4	21.52	21.29	21.54	21.21	
30/07/97	1258	19.00S	146.90E	7.5	21.67	21.42	21.42	21.71	21.83
02/12/97	0011	42.38S	148.62E	10.3	13.78	14.00	14.20	15.02	
08/12/97	0023	39.66S	143.75E	5.1	14.81	14.75	14.15	14.53	
15/03/99	1218	28.01S	156.79E	3.7	25.71	25.55	25.81	25.46	25.54
18/03/99*	1224	26.35S	154.73E	7.2	26.19	26.02	26.16	25.99	26.80

* May be affected by cloud. See discussion section.

2.3 Tasman Sea - September-October 1997

During this voyage of the RV FRANKLIN radiometric data were collected using the high quality CSIRO radiometer (Serial No. DAR009). This instrument has two accurate in-built calibration targets for near-continuous calibration, has a noise temperature of better than 0.05 K, and is described in detail by Bennett (1998). During 1998 the instrument was calibrated against the USA NIST standard radiance and found to have an absolute accuracy of better than 0.1 K. Four coincidences of ATSR and surface data were obtained, but all were partly cloudy at the vessel and none were deemed to be useful for SST validation purposes.

2.4 Australian coastal waters - December 1997

Two TASCOs and one Everest radiometer were deployed during this voyage of the FRANKLIN in December of 1997. One TASCO was used to view the undisturbed sea surface outside the ship's wake while the second was used to monitor the down-welling sky radiance. Two daytime coincidences of ship and satellite data were obtained during this voyage. Bulk temperatures were obtained from the ship's thermosalinograph instrument. This instrument is regularly calibrated against the ship’s CTD instrument

2.5 Southern Ocean - July 1998

A new high quality CSIRO radiometer (DAR011) was deployed for the first time on this voyage of the RSV Aurora Australis between Hobart and Antarctica. This radiometer has also been calibrated against the NIST standard radiance and found to have similar performance to the radiometer (DAR009) described above. Unfortunately this voyage was cut short due to a serious engine room fire which crippled the vessel. No clear-sky coincidences were recorded on either the southbound or the return journey. During the one day of successful measurements of ice-surface temperature the radiometer performed extremely well in ambient temperature conditions of –20°C.

2.6 Coral Sea - March 1999

During this most recent voyage of the RV FRANKLIN radiometric measurements were taken with both the DAR011 radiometer and two TASCO radiometers. Only the data from the first half of the voyage are reported here - the latter data from the ATSR are not yet available. Two clear sky coincidences are reported although there is some doubt about the clarity of the sky for one of these episodes. This matter is discussed further in a later section.

Table 2: ATSR brightness temperatures (K) for the validation data set. The 3.7 μm channel value is only given for night-time data. T12N and T12F refer to the 12 μm nadir and forward channels, etc.

Date	Time	T12N	T11N	T37N	T12F	T11F	T37F
21/08/96	1423	290.75	293.94	297.73	287.43	291.09	296.17
26/08/96	0322	290.47	294.09		286.19	290.32	
27/07/97	0028	289.72	291.30		287.61	289.59	
27/07/97	1252	290.22	291.56	291.37	288.29	289.87	289.56
30/07/97	0034	289.55	291.31		285.87	288.32	
30/07/97	1258	290.02	291.61	292.24	286.77	288.83	290.26
02/12/97	0011	282.75	284.41		280.30	282.32	
08/12/97	0023	286.15	286.83		284.38	285.59	
15/03/99	1218	292.91	294.93	295.90	290.32	292.74	294.28
18/03/99	1224	292.83	294.97	296.26	289.54	292.32	293.68

3 DISCUSSION

3.1 Validation of ATSR-2 SST estimates

For these data sets the skin-bulk temperature differences lie between +0.22 and -0.31 K with a typical value around -0.2 K. All three ATSR SST algorithms (six-channel SST6, four-channel SST4, and two-channel, SST2) appear to perform well with a common standard error of 0.3 K, and a mean bias of less than 0.1 K. The results shown for 18 March 1999 show some discrepancy between the SST6 and radiometer values. For this case the upward viewing radiometer shows some fluctuations suggesting the presence of thin cloud. At night it can be quite difficult to detect the presence of cloud, both from surface observations by eye and by viewing satellite imagery. In this case the ATSR image shows little evidence of cloud, and, without the upward viewing radiometer measurements this coincidence would have been classified as clear-sky. This case thus suggests that, at night, an upward viewing radiometer may be the best method of detecting thin clouds in the sky overhead.

Table 3: Theoretical brightness temperatures (K) obtained using An atmospheric transmission model with co-located radiosonde data.

Date	Time	T12N	T11N	T37N	T12F	T11F	T37F
27/07/97	0028	289.80	291.22	291.47	287.66	289.35	289.94
27/07/97	1252	290.17	291.59	291.90	288.18	289.85	290.45
30/07/97	0034	289.71	291.24	291.51	287.34	289.28	290.03
30/07/97	1258	290.24	291.66	291.89	288.06	289.82	290.44
15/03/99	1218	292.95	294.90	295.68	290.34	292.67	294.01
18/03/99	1224	292.75	294.86	295.90	289.96	292.47	294.13

Table 4: Differences between the real and model-derived brightness temperatures (K), (ATSR-Model).

Date	Time	T12N	T11N	T37N	T12F	T11F	T37F
27/07/97	0028	-0.08	0.08		-0.05	0.24	
27/07/97	1252	0.05	-0.03	-0.53	0.11	0.02	-0.89
30/07/97	0034	-0.15	0.07		-1.47	-0.96	
30/07/97	1258	-0.22	-0.05	0.35	-1.29	-0.99	-0.18
15/03/99	1218	-0.04	0.03	0.22	-0.02	0.07	0.27
18/03/99	1224	0.09	0.11	0.36	-0.42	-0.15	-0.45

3.2 Brightness temperature variations

The Indian Ocean data collected during 1996 show that the ATSR delivers an accurate SST value in high water vapour situations (see Table 1). The T37N-T12N brightness temperature difference is 7.0 K while the remainder of the validation data give differences that are less than half this value. The brightness temperature differences for July 1997 indicate a low level of atmospheric water vapour even though the data are for the tropical regions near Townsville (19°S).

3.3 Model-ATSR-2 brightness temperature comparison

Table 4 shows that for the data collected on 27 July there is very good agreement between the model and ATSR brightness temperatures for the 11 and 12 μm channels but for the 3.7 μm channel at night (1252 UTC) the model underestimates the effect of the atmospheric absorption (model temperature warmer than ATSR). For July 30 the nadir measurements at 11 and 12 μm again show good agreement but the forward-view ATSR temperatures are much cooler than the model results. The 3.7 μm channel in the nadir shows the opposite effect to that for July 27. The 1999 values show more reasonable agreement.

4 CONCLUSIONS

The results from the most recent set of validation data suggest that simple off-the shelf infrared radiometers sensing the down-welling radiance from the sky may be the best method of identifying cloud-contaminated data during validation campaigns, especially at night.

The several ship campaigns reported here indicate the difficulty in collecting accurate SST validation data at sea. However, it is now becoming apparent that useful validation may be possible using measurements of bulk temperature with sufficient ancillary measurements to ensure that a reasonably accurate estimate of the skin effect (skin-bulk temperature difference) is possible. Ongoing comparisons of skin and bulk temperature measurements from high quality instruments suggest that the skin effect can be estimated with an accuracy of better than 0.1 K. Ancillary measurements should include wind speed to ensure that the upper ocean layer is well mixed, upward looking infrared radiometers to detect thin cloud at night, and surface air temperature to ensure that the surface heat fluxes are not extreme. Adopting this approach will provide a significant increase in the number of data sets available for the validation of SST derived from ATSR-2 and AATSR in the future.

In spite of the comments made above, there is an ongoing need to collect more radiometric data at sea along with measurements of the state of the atmosphere using radiosondes. These data are required to further investigate the performance of the atmospheric model used to derive SST algorithm coefficients. Existing data sets suggest that there may still be some uncertainties in the specification of the water vapour absorption in the infrared region of the spectrum. For satellite data applications, these data sets may provide the best method of investigating these anomalies. Barton (1991) provides further details on the application of satellite data to the estimation of the water vapour continuum absorption.

Acknowledgments: Many colleagues have assisted with the collection of the radiometer data from the different vessels. In particular, William Skirving from the Australian Institute of Marine Science, Alison Walker, Ken Suber, Frank Bradley and Stuart Godfrey from CSIRO, Rob Massom and Clemente Hungria from the IASOS Department at the University of Tasmania, and Bill Emery from the University of Colorado, have provided valuable contributions. The Bureau of Meteorology at Townsville have supplied the radiosonde data for the CEOS inter-comparison.

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