Sea Surface Temperature Validation Results from the MUBEX'97 Experiment

Thomas Sheasby, Isabelle Parkes, David Llewellyn-Jones
Earth Observation Science, Department of Physics and Astronomy, University of Leicester, Leicester, UK
Tel: +44 116 2525264, fax +44 116 2525262, Email: tns1@le.ac.uk

Tim Nightingale
Rutherford Appleton Laboratory, Didcot, Oxfordshire, UK

Ryuzo Yokoyama, Sumio Tanba
Department of Computer and Information Science, Iwate University, 4-3-5 Ueda, Morioka, Iwate 020 Japan

The Mutsu Bay Experiment (MUBEX) was a series of detailed *in situ* field experiments devised to investigate the physical behaviour of the sea and its relationship to satellite observations, particularly sea surface temperature. This paper describes preliminary results from measurements obtained in Mutsu Bay, Japan during July and August 1997. *In situ* radiometric sea surface temperatures, taken using the SISTeR instrument, are compared with ATSR-2 sea surface temperatures. The ATSR-2 SSTs are found to agree with the *in situ* measurement of radiometric temperature to within 0.15 K.

1. Introduction

This paper is concerned with the validation of the sea surface temperature (SST) measured by the along track scanning radiometer (ATSR-2) on board the European Remote Sensing Satellite (ERS-2). This paper follows on from the two papers written by Parkes et. al. (1997) and the data presented in this paper are the continuation of this work. A comparison is made between the standard ATSR-2 gridded sea surface temperature (GSST) product, obtained from the Rutherford Appleton Laboratory, and the *in situ* radiometric measurements of SST. Radiometers measure the temperature of the top fraction of a millimetre of the sea surface (the skin). The temperature of the surface skin can be typically several tenths of a degree cooler or warmer than the bulk temperature a few centimetres deeper. This temperature difference is known as the skin effect (see Donlon 1994 for a discussion). Since ATSR-2 measures the radiometric SST, so also should the *in situ* temperature measurements used for comparison. The data used to validate ATSR-2 were taken using the Scanning Infrared Sea-surface Temperature Radiometer (SISTeR) designed and built by Tim Nightingale at the Rutherford Appleton Laboratory in Didcot, Oxford. The *in situ* data were collected during the last of the Mutsu Bay Experiments (MUBEX'97) that took place in Mutsu Bay, Japan from the 18th July to the 25th August 1997.

2. In situ data - the Mustu Bay Measurement System

The measurements in this paper were obtained a part of the Mutsu Bay Experiment (MUBEX). MUBEX was a three-year research project designed to establish and verify relationships between important physical processes acting at the sea surface and the measurements made by satellites. MUBEX was an international collaboration

between the Universities of Leicester, Southampton, Iwate, and Tokyo along with RAL (the Rutherford Appleton Laboratory). MUBEX'95 was carried out during the summer of 1995, MUBEX'96 took place in July/August 1996, and MUBEX'97 during July/August 1997. Mutsu Bay is situated in the north of Honshu Island, Japan at roughly 41°N and 140°E (see Figure 1).

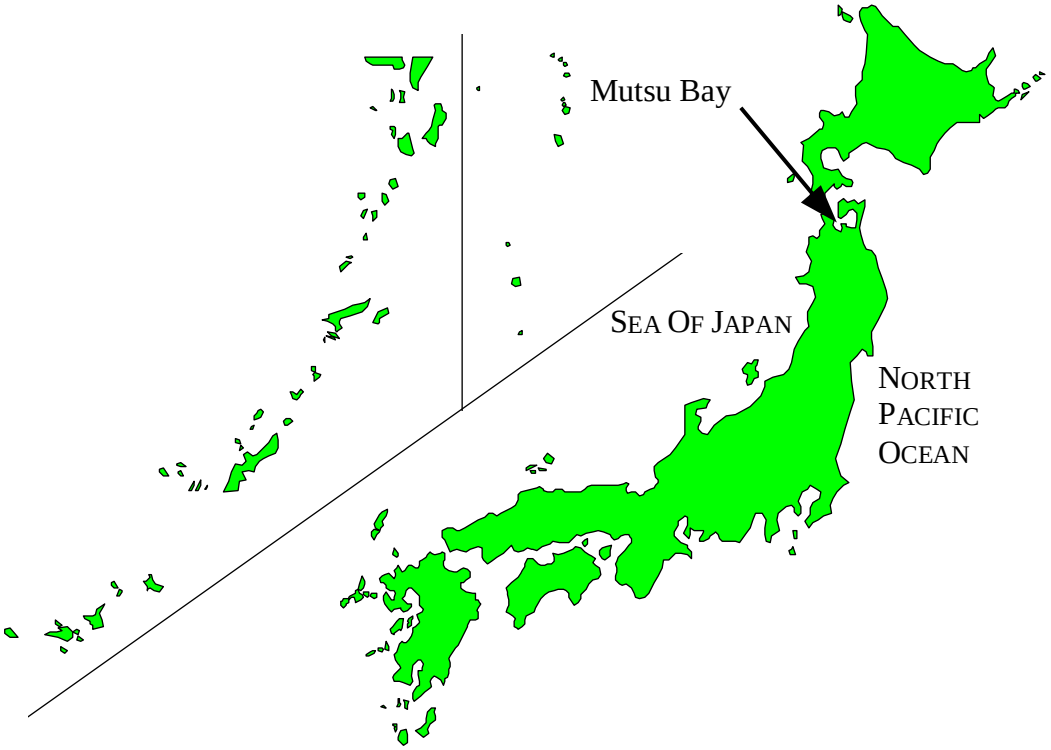

Figure 1. Map of Japan showing location of Mutsu Bay in the North of Honshu Island

Mutsu Bay covers an area of 1600 km^2 to a mean depth of 35m. Over the last 20 years considerable investment has been made in the area by the Japanese fishing industry producing a network of measuring systems. This extensive marine and meteorological data is available to the programme.

In addition to these facilities the team operate a research boat, the Dai-Ni-Misago, chartered for day and night use on which the main instruments of the project are mounted. This is an aluminium-hulled vessel, 16.5m long, 3.5m wide (see Figure 2).

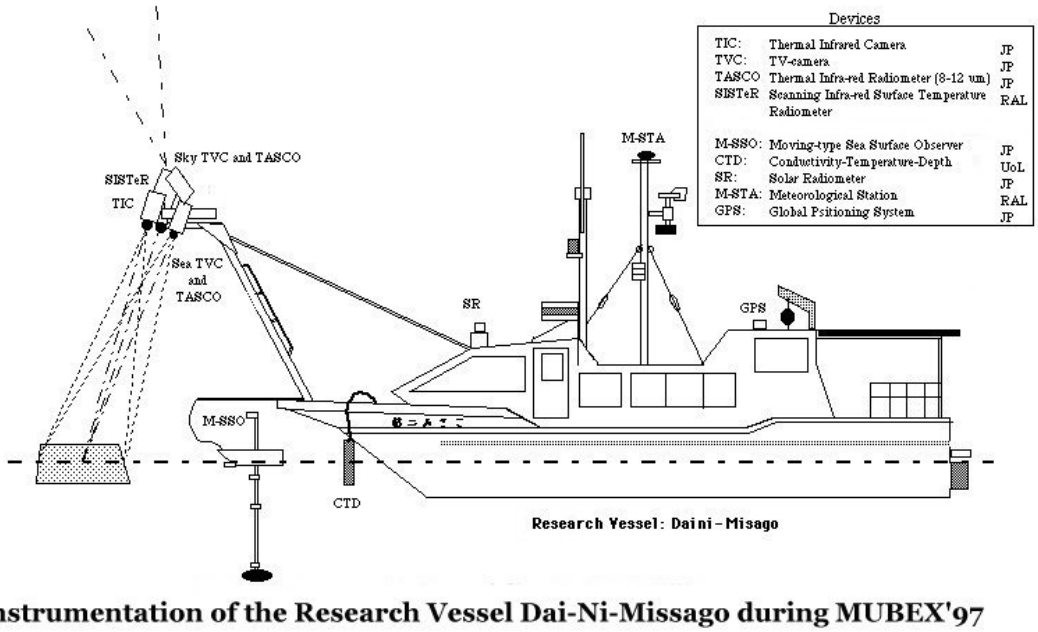

Figure 2. Schematic of the MUBEX campaign vessel the Dai-Ni-Misago

Radiometric temperature was recorded using four different systems - SISTeR, a high accuracy self-calibrating radiometer, a thermal camera NECTH3100, for studying spatial structure, and two low cost radiometer systems. These radiometers were deployed from a bow mount installed 5m above the sea surface giving the instruments an uninterrupted view of clear water. The mount was high enough to significantly reduce the risk of sea spray interfering with the operation of the instruments.

The Dai-Ni-Misago was also equiped with a Meteorological station (located well clear of the body of the boat) and video cameras recording sky and sea state. A conductivity, temperature and depth probe (CTD) was deployed on a fixed line from the foredeck of the Dai-Ni-Misago, giving a bulk water temperature at a nominal depth of 0.5m with vertical variation of approximately +/-0.1m (depending on sea state).

The meteorological and marine data were provided by four well instrumented buoys tethered at selected positions in the Bay (see Figure 3). The buoys record air temperature, short wave solar radiation, wind speed, wind direction, salinity and the temperature structure of the water column. Additional meteorological data around the coast of the Bay is provided by the Automatic Meteorological Data Acquisition System (AMEDAS), a nation-wide Japanese meteorological observation system. Six of the AMEDAS stations have been selected as appropriate for MUBEX (see Figure 3). The stations collect and distribute hourly measurements of meteorological variables such as air temperature, wind speed, solar radiation and rainfall.

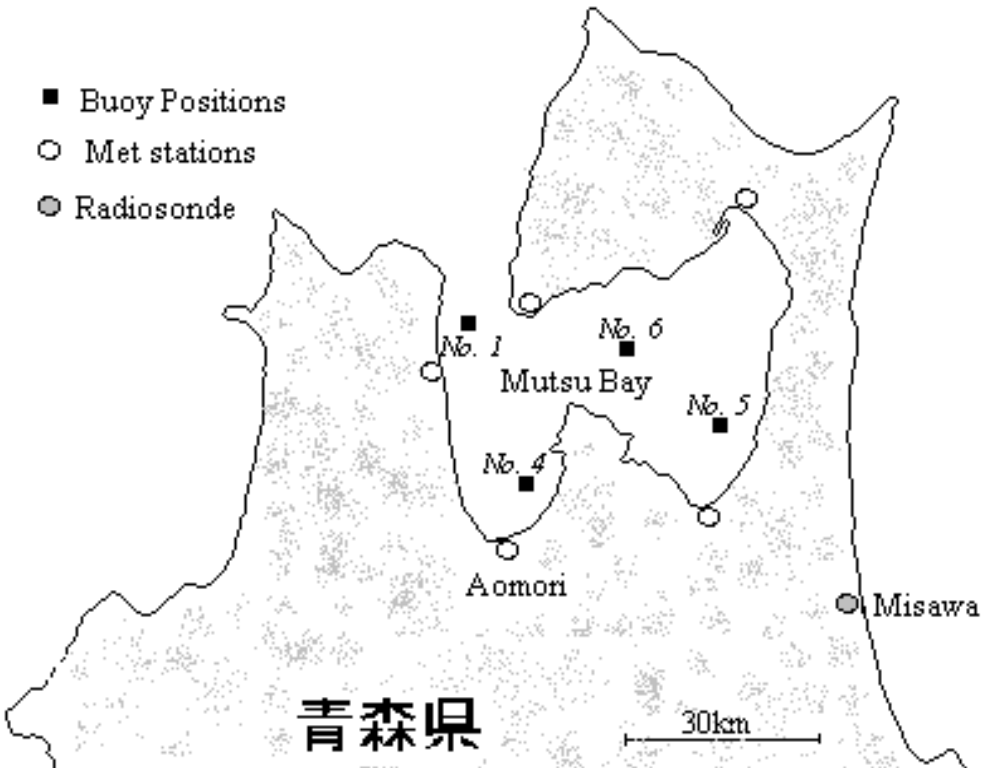

Figure 3. Schematic Of Mutsu Bay showing locations of buoys and meteorological stations. Land is shaded.

3. The SISTeR radiometer

The SISTeR (Scanning Infrared Sea-surface Temperature Radiometer) was designed and built by Dr. T.J. Nightingale at R.A.L. (Rutherford Appleton Laboratory) in Didcot, Oxfordshire. It is an internally calibrated infrared radiometer designed for the validation of ATSR-2. The radiometer was designed to have a range of possible channels, based on the ATSR-2 channels. During the MUBEX campaigns only one channel was available centred on 10.8μ. The instrument was designed to have an accuracy of better than 0.1 K and a r.m.s. error of 0.03 K for a 1 second sample. In a single scan, the instrument views first the sea, then an internal blackbody calibration source (with emissivity > 0.999), then the sky, and finally a second blackbody calibration source. One of the blackbody sources is at ambient temperature the other maintained at 10^{o}C above ambient. The target radiometric brightness temperature is calculated by comparing the signal counts of the target to that of the two internal black-bodies. The sea surface temperature was generated from the brightness temperature following Thomas et. al. (1995) using a value of 0.99246 for the emissivity of the sea - calculated from Sidram (1981) weighted for the SISTeR filter profile.

4. Validation Transects

In situ data coincident with ATSR-2 overpasses were obtained from the Dai-Ni-Misago under clear sky conditions on four separate occasions. For each overpass, the Dai-Ni-Misago made a transect across the Bay at a speed of approximately 1 knot for 0.5-1.0 hours either side of overpass. Meteorological, radiometric and bulk temperature data was logged continuously, typically at 1 Hz. In most cases the transect was chosen such that the boat was close to one of the instrumented buoys at

the time of overpass. Transects into the sun were avoided to minimise effects of sun-glint.

5. Results and discussion

Preliminary results from the comparison of ATSR-2 SSTs with the SISTeR SSTs are given in Table 1. A more complete analysis will be published in the open literature. SISTeR data are tabled as the mean during each overpass. All temperatures are given in degrees Kelvin.

Date	A - Night D - Day	ATSR SST	Nadir Cloud Flags	Forward Cloud Flags	SISTeR SST	ATSR-SISTeR	Bulk	ATSR -Bulk	Skin
24/07/97	D	294.87	4	10	294.97	**-0.10**	294.23	0.64	0.74
25/07/97	A	296.25	0	0	296.37	**-0.12**	296.56	-0.31	-0.18
31/07/97	A	297.57	0	0	298.22	**-0.65**	298.37	-0.80	-0.15
25/08/97	D	295.36	4	0	295.30	**0.06**	Too Rough	N/A	N/A

Table 1. Preliminary results showing the comparison between ATSR-2 SST and the in situ radiometric SST measured using the SISTeR radiometer. Ascending (night) overpasses are marked with an 'A', descending (day) passes with a 'D'. The bulk temperatures shown were measured with the CTD probe. All temperatures are given in degrees Kelvin.

In all but one case the *in situ* SST agrees with the ATSR-2 SST to within 0.15 K. The erroneous point is included to highlight the problem of pixel geolocation errors in the ATSR-2 data. Examination of the ATSR-2 data shows a steep east-west temperature gradient across Mutsu Bay. In areas with sharp temperature gradients care must be taken to insure that the latitude and longitude of each pixel is correct. In cases such as Mutsu Bay this can be done using the shape of the bay to geolocate the image. In the open ocean however this is not possible.

Also included in Table 1 are the skin-bulk temperature differences. A warm skin is observed during the daytime and a small cool skin is observed during the night time overpasses. The observed values of skin-bulk temperature difference (0.7K to -0.2K) are within the range observed by other authors (e.g. Donlon 1999).

6. Conclusions and Summary

Preliminary comparisons have been made between *in situ* radiometric measurements of the sea surface temperature and ATSR-2 SSTs in mid-latitude coastal waters. The *in situ* site is an area of potentially high variability in atmospheric conditions and sea surface temperature. Measurements were made under conditions of high humidity i.e. water vapour content. Nevertheless, even in these demanding conditions the ATSR SSTs agree to within 0.15K with the *in situ* measurement of radiometric temperature. The data is currently being analysed further to incorporate other data collected during the MUBEX campaigns. More complete results will be published in open literature at a future date.

7. References

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