Australian Government
Bureau of Meteorology

Spatial and Temporal Biases in MTSAT-1R SST

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Sea Surface Temperature uses and applications within the Australian Bureau of Meteorology

Sea Surface Temperature (SST) is an Essential Climate Variable that is routinely used within the Bureau of Meteorology. The primary application is within weather prediction and forecasting, and is particularly important for monitoring the development of tropical cyclones and the forecasting of fog events.

SST is assimilated by the Bureau's operational Ocean Modelling and Prediction system OceanMAPS and used within climate studies. It is also used to monitor the distribution of coral bleaching events.

Researchers have used observations of SST from polar orbiting sensors to study the diurnal warming of the ocean surface . However, the ability of these studies to depict the diurnal variation is limited by the low temporal resolution of the constellation of polar orbiting satellites.

Sensors in geostationary orbit provide observations on an hourly or sub-hourly time scale. These observations commonly have lower spatial resolution and greater uncertainty than observations from polar orbiting sensors. The use of geostationary SST observations for diurnal warming studies is investigated below.

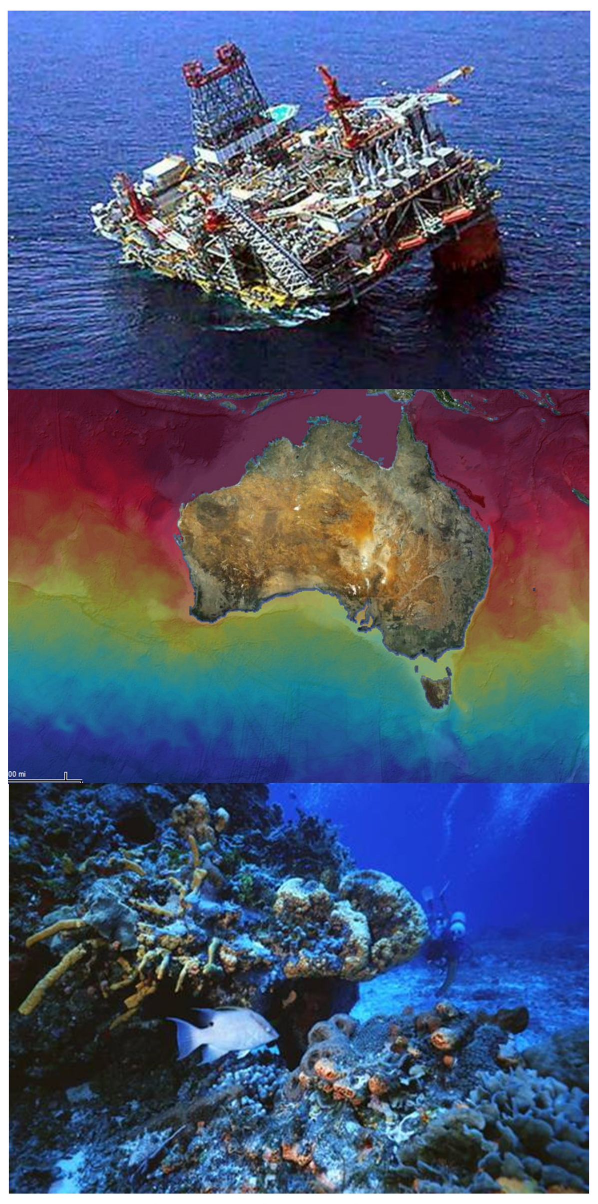

Figure 1. Applications of Sea Surface Temperature

JAMI observations of Sea Surface Temperature

The MTSAT-1R satellite is in geostationary orbit above 140°E and carries the Japanese Advanced Meteorological Imager (JAMI) on board. JAMI captured full-disc imagery on an hourly basis during the period 2005-2010 in five spectral channels (0.6-12.0 µm). The observations from spectral channels centred at 3.7, 10.8 and 12.0 µm can be used to calculate SST.

A three-way comparison [O'Carroll et. al. 2008] with the network of drifting buoys and AVHRR derived SST indicated good agreement between all platforms (Table 1). However, a spatial analysis of the difference between MTSAT and drifting buoy observations reveals significant differences (Figure 2).

Table 1. Results of a three-way comparison [O'Carroll et. al. 2008] between AVHRR, drifting buoys and MTSAT SST observations over the period 2006-2010, between 20N-60S, 100E-160W, binned by local hour.

MTSAT has the highest uncertainty of the three platforms, especially during the day (9am and 2pm), suggesting possible changes in calibration across the day.

	Standard Deviation [C]			
	9am	2pm	11 pm	1 am
No. Samples	832	1139	814	799
AVHRR	0.363	0.332	0.165	0.172
Buoy	0.269	0.334	0.213	0.210
MTSAT	0.543	0.474	0.363	0.325

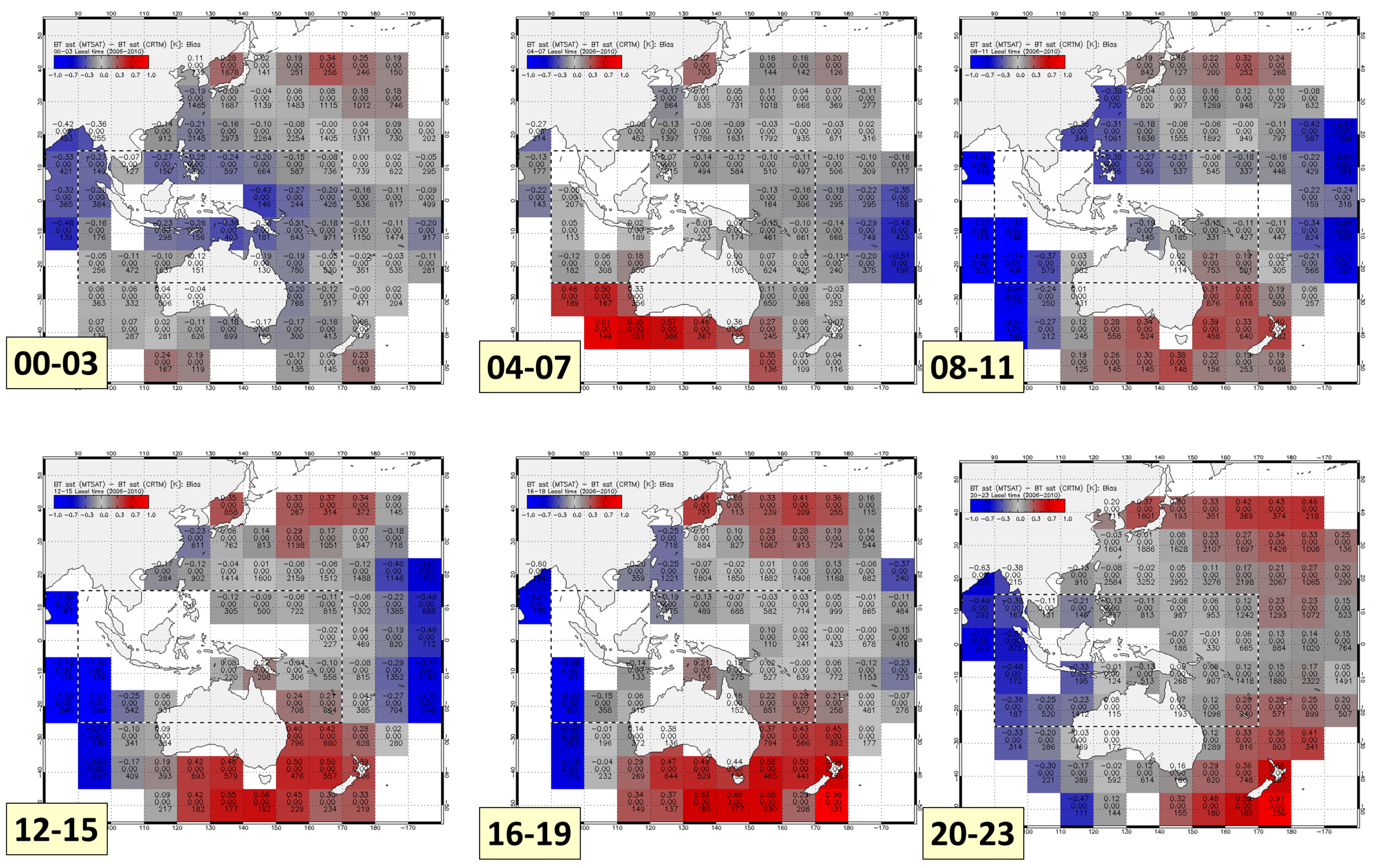

Figure 2. Difference between MTSAT SST (pre-correction) and SST from the network of drifting buoys, binned by observation hour at 3-hourly intervals in 10x10° spatial bins, over the period 2006-2010. Note the North-South and East-West biases vary across the day (UTC times).

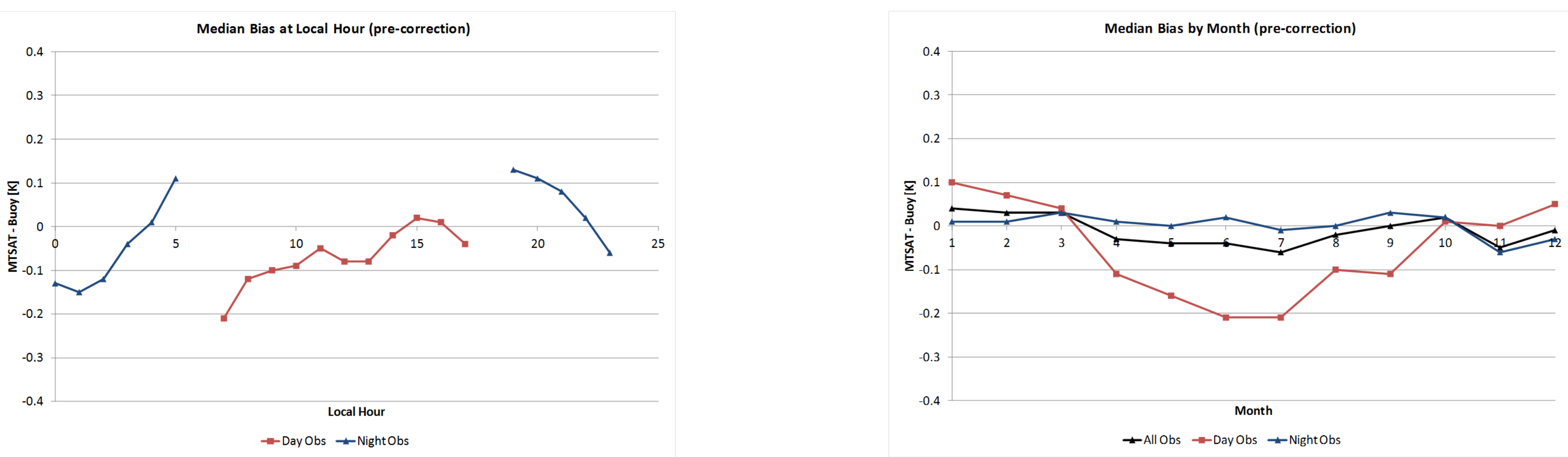

Figure 3. Pre-correction validation results. Left) The median bias between MTSAT and observations from drifting buoys as a function of local hour. Note the significant differences and discontinuities between day and night observations. Right) The median bias between MTSAT and observations from drifting buoys as a function of month. Note the difference between day and night observations, particularly from April-September, where the difference is greater than 0.2K.

Hypothesis

The spatial and temporal biases in retrieved SST may be reduced by accounting for the scanning geometry of the sensor (Figure 4) and Earth/platform and Sun/platform geometry.

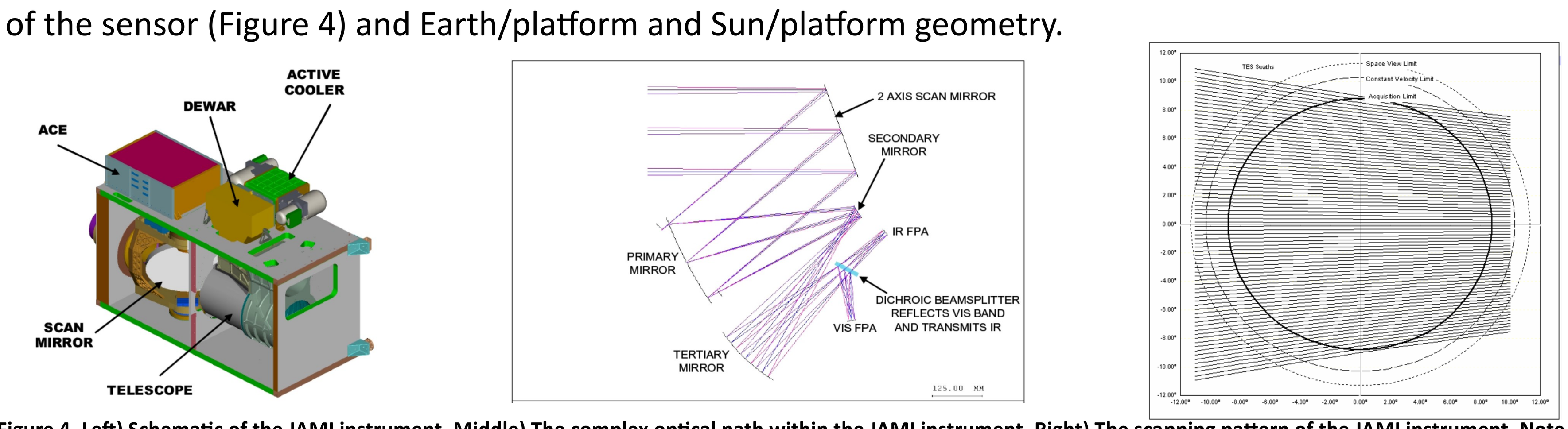

Figure 4. Left) Schematic of the JAMI instrument. Middle) The complex optical path within the JAMI instrument. Right) The scanning pattern of the JAMI instrument. Note the change in angle across the image, caused by the complex mirror system. [Puschell et al 2006]

References

O'Carroll, A.G., J.R. Eyre, R.W. Saunders, 2008: Three-Way Error Analysis between AATSR, AMSR-E, and In Situ Sea Surface Temperature Observations. J. Atmos. Oceanic Technol., 25, 1197–1207.

Puschell, J.J., et al. 2006: In-flight performance of the Japanese Advanced Meteorological Imager, Proc. SPIE 6296, Earth Observing Systems XI, 62960N; doi:10.1117/12.683505;

Modelling the Spatial and Temporal Correction Factors

In order to reduce the temporal and spatial biases in the MTSAT-1R SST data, the following correction factors were developed from a number of geometric and temporal properties, including pixel/line position, observation hour, solar declination and Earth-Sun distance (Figure 5).

$$Corrected\ \ SSTskin = SSTskin + GFAC + DFAC + TFAC$$

GFAC is a correction associated with the scan pattern;
DFAC is the SST correction caused by the solar declination/Earth-Sun distance;
TFAC is a correction for the time of day.
These correction factors are parameterised as:

$$SSTskin = p_0 T_4 + p_1 (T_4 - T_5) + p_2 (T_4 - T_5)\sec\theta$$

$$GFAC = p_3 (XIDX - p_4)^2 + p_5 YIDX^2$$

$$DFAC = p_6 DECL + p_7 (ESDIST - 1)$$

$$TFAC = p_8 \sin(\pi OBSHOUR/12) + p_9 \sin(2\pi OBSHOUR/12)$$

Where:
T_4 = Brightness temperature of Channel 4 (11 micron channel),
T_5 = Brightness temperature of Channel 5 (12 micron channel),
θ = satellite zenith angle, XIDX = pixel number in longitude direction, YIDX = pixel number in latitude direction,
DECL = solar declination, ESDIST = distance between Earth and Sun, OBSHOUR = Integer hour of observation in UTC

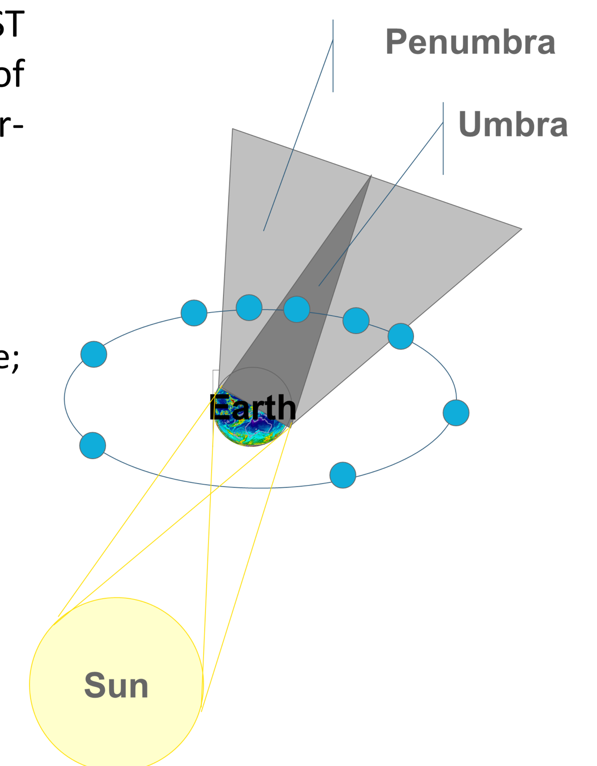

Figure 5. Simple representation of the changing solar/sensor geometry that may affect sensor performance.

Results

Parameters P[0] - P[9] were determined through cost minimisation (Levenberg–Marquardt), where the cost term was composed of the difference between MODEL and Buoy SST at a combination of time steps: instantaneous, hourly and monthly time scales. Figure 6 displays the retrieved parameterisation, while Figure 7 and 8 demonstrate the improvement in retrieved SST (compare to Figure 2 and 3).

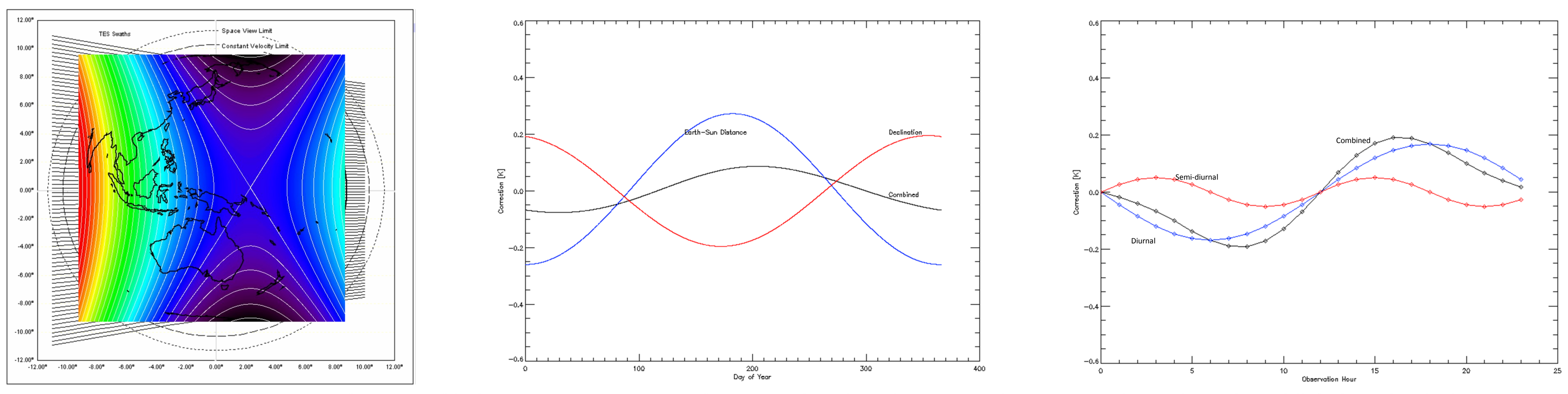

Figure 6. The optimised correction factors. Left) The geometric correction factor overlayed on the MTSAT observation scheme (GFAC). Middle) The solar declination and Earth-Sun difference factors (DFAC). Right) The diurnal and semi-diurnal correction factors (TFAC).

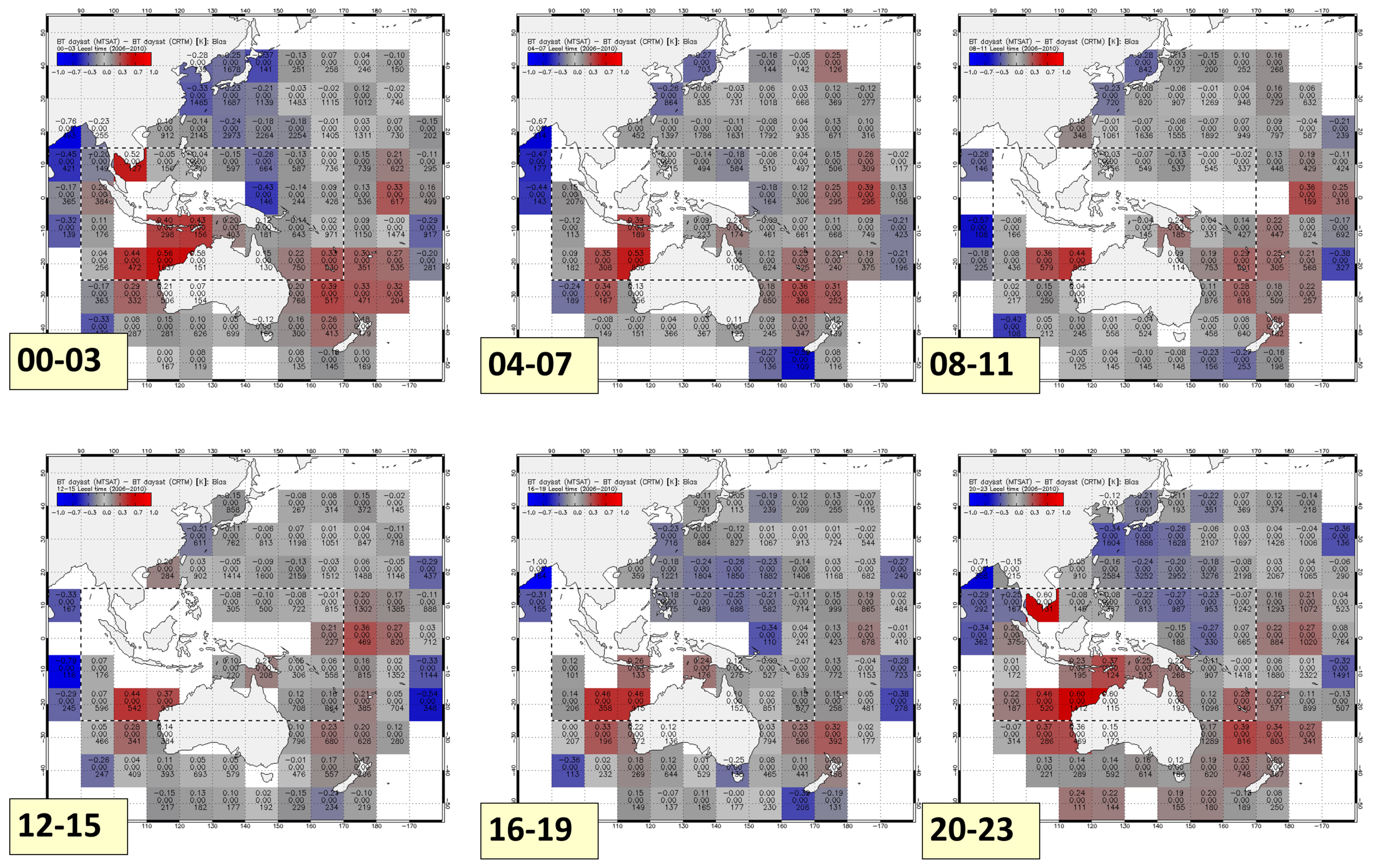

Figure 7. Difference between MTSAT SST (post-correction) and SST from the network of drifting buoys, binned by observation hour in 10x10° spatial bins, over the period 2006-2010. Note that much of the systematic bias has been removed and that the bias in corresponding bins varies only slightly across the day (UTC times).

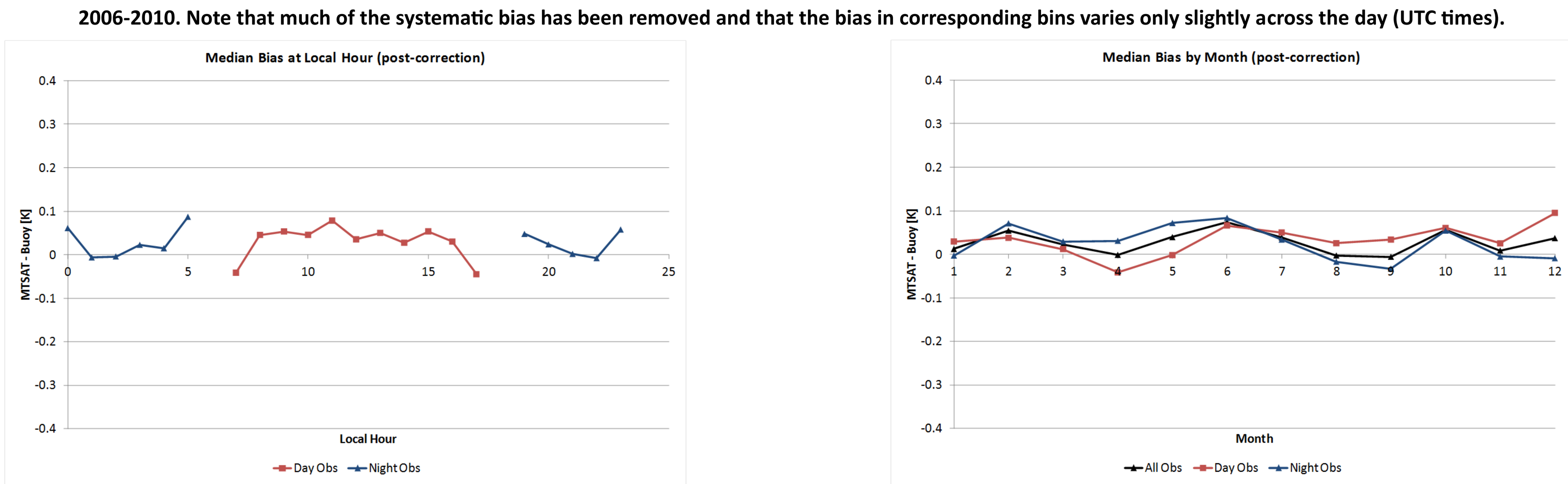

Figure 8. Post-correction validation results. Left) The median bias between MTSAT and observations from drifting buoys as a function of local hour. Note that the bias is within 0.1 K at all observation times. Right) The median bias between MTSAT and observations from drifting buoys as a function of month. Note the difference between day and night observations has reduced and that the median difference is less than 0.1 K for all months.

Conclusions

After applying corrections for scanning geometry, Earth/platform and Sun/platform geometry, the resulting bias in MTSAT SST, when compared to drifting buoys, is < 0.1 K with a standard deviation of ~0.7 K. Hour-to-hour differences in SST are also < 0.1 K, with the exception of day/night transitions (< 0.2 K).

Further Work

The use of a physical model along with mirror temperatures could lead to improved calibration of JAMI brightness temperatures, leading to improvements in stability and accuracy of SST and other derived products.

This improved data set will now be used for diurnal warming studies, including the Group for High Resolution SST Tropical Warm Pool Diurnal Variability Project. Further details can be found at the GHRSST and TWP+ experiment websites:

- Group for High Resolution Sea Surface Temperature (GHRSST): http://www.ghrsst.org/
- TWP+ Project: https://www.ghrsst.org/ghrsst-science/science-team-groups/dv-wg/twp/

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IMOS Integrated Marine Observing System