Sino-Australian Research Centre for Coastal Management
中澳海岸带管理研究中心

Seasonal Patterns of SST Diurnal Variation over the Tropical Warm Pool

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1 Introduction

- A better understanding of SST diurnal variation (DV) events is essential to better represent the air-sea interaction in weather/climate models (e.g. *Clayson and Bogdanoff*, [2013]).
- Tropical Warm Pool (TWP, 90ºE-170ºE, 25ºS-15ºN) region is considered to be an excellent area to conduct DV studies because of its: (1) globally highest annual average SST, (2) calm winds, (3) strong solar shortwave insolation (SSI), and (4) frequent, large-amplitude DV events.
- Detailed description of the SST DV seasonal patterns using long-term satellite observations is needed in order to better facilitate DV modelling and to better understand DV features over the TWP region.
- Besides, validation of the new satellite SST product produced by the Bureau of Meteorology is considered necessary before the SST data can be used with confidence in DV studies. In-situ validation against drifting buoy SST data is conducted.

2 Data & Method

Major data sets (temporal coverage for five years: Jan. 2010 – Dec. 2014):

- Satellite SST data: Bureau of Meteorology produced daily, 0.02º resolution, version 2 ("fv02") High-Resolution Picture Transmission (HRPT) Advanced Very High Resolution Radiometer (AVHRR) SSTs from NOAA-19, as a contribution to the Integrated Marine Observing System (IMOS; www.imos.org.au); SST field: **experimental hybrid SST_Day_Night** (*Griffin et al.* [2016]).
- Drifting buoy SST data: the In-situ SST Quality Monitor (iQuam; www.star.nesdis.noaa.gov/sod/sst/iquam/).
- Hourly wind speed, SSI, and latent heat flux (LH) data: the Bureau's hourly Australian Community Climate and Earth System Simulator-Regional (ACCESS–R) 24-hour forecasts (*Puri et al.*, [2013]). Spatial resolution: 0.375º (0.11º) before (after) 17th Apr. 2013.

Quality control and Method:

- Only the highest quality level AVHRR SSTs (QL=5) and buoy SSTs (QL=5) are retained;
- SST DV amplitude (dSST) = local daytime SST (~14 local solar time, LST) – local night-time SST (~2 LST).

3 In-situ Validation

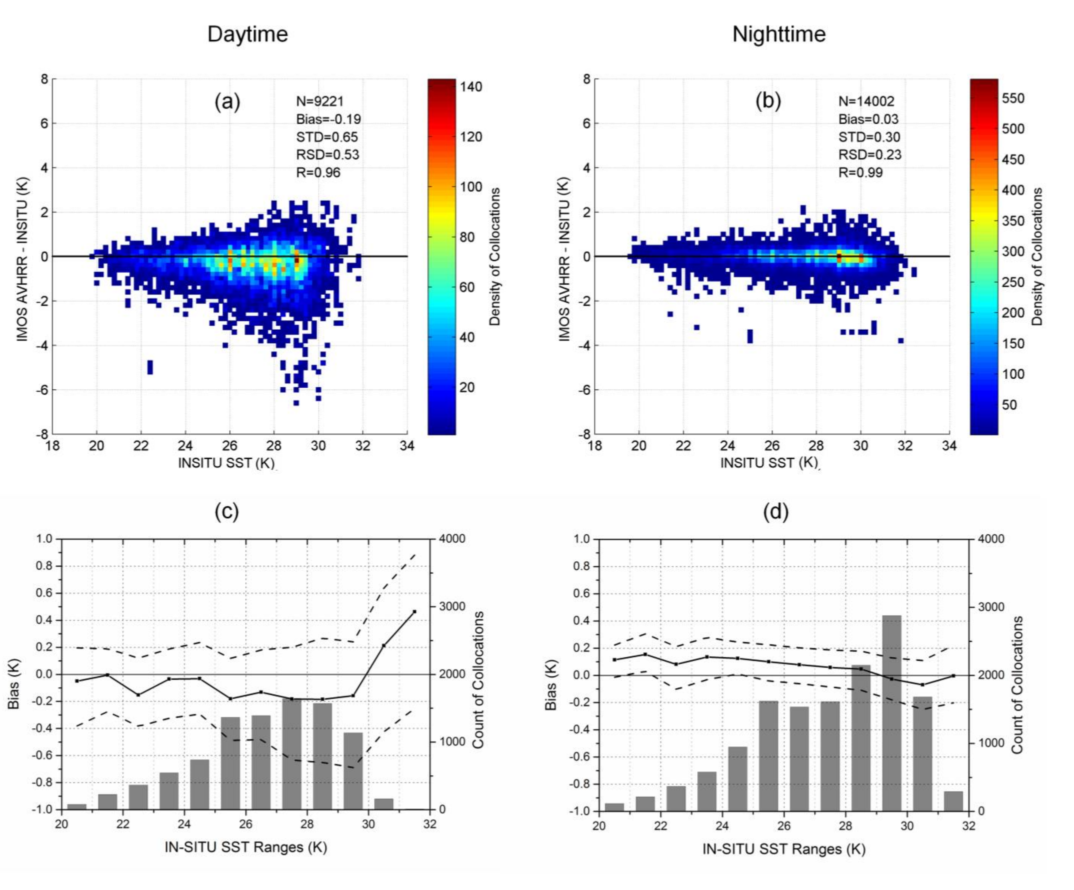

Fig.1 In-situ validation results: (a) density plot of the **daytime** (~14 LST) collocations within each 0.2 K × 0.2 K bin for winds > 6 m/s; (b) same as (a) but for **night-time** (~2 LST) collocations for winds > 2 m/s; Please note the Y axes in (a) and (b) are the differences between the satellite and in-situ SSTs. (c) **daytime** collocation numbers, median bias (solid line), 25th/75th percentiles of the biases (below/above dashed line) over each in-situ SST 1 K range; (d) same as (c) but for **night-time** collocations. RSD stands for robust standard deviation, R for correlation coefficient.

- An average **0.19 K underestimation** is found for **daytime** IMOS AVHRR SSTs;
- **Night-time** AVHRR data quality is **better**, as indicated by the near zero bias, smaller STD and RSD, larger R, and smaller 25th/median/75th percentiles of the biases over most in-situ SST ranges.

4 Seasonal Patterns of SST DV Events

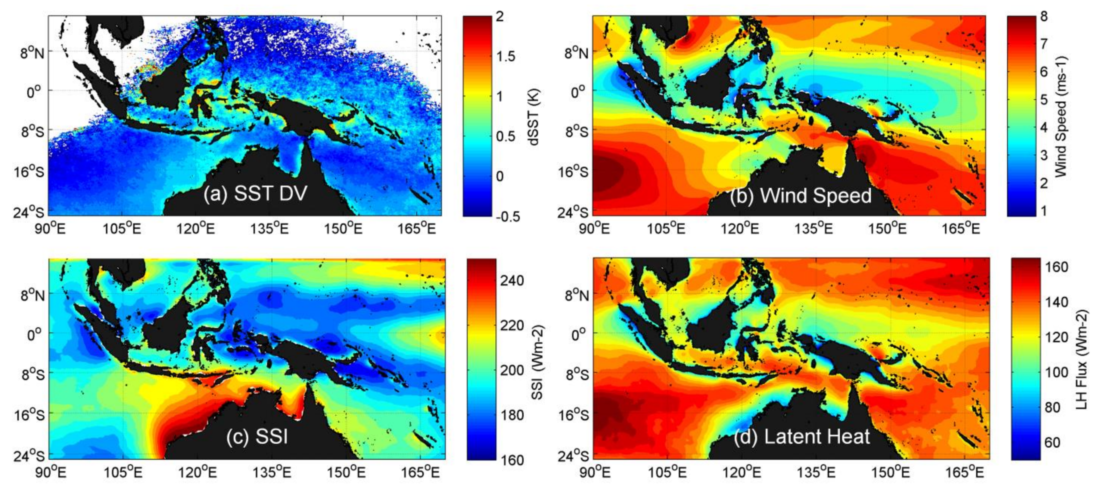

Fig.2 Spatial distributions of the **five-year average** (a) SST DV, (b) wind speed, (c) SSI, and (d) LH flux. The blank areas in (a) are due to lack of data as the IMOS AVHRR SST data set is derived only from direct broadcast (HRPT) data received at Australian and Antarctic ground stations.

- The largest five-year average SST DV amplitudes can reach **1–2 K**, mainly observed close to the equatorial Indonesian islands and Papua New Guinea (PNG) (Fig. 2a), where low wind speeds dominate (Fig. 2b).
- DV events have average amplitudes of around 0.5 K to the north of the north-western Australian coast (NWAC), due to both low winds and high SSI over this region.

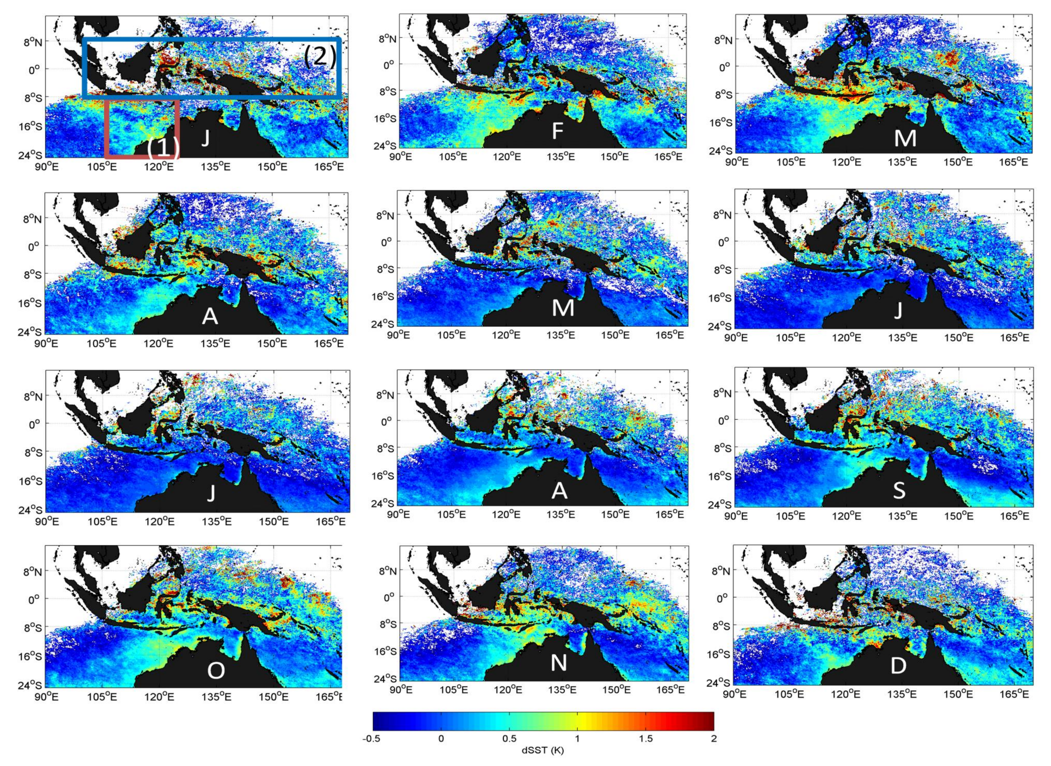

Fig.3 Spatial distributions of the five-year **monthly average SST DV amplitudes**. From left to right and from top to bottom: J stands for January, F February,…, and D December. The red and blue boxes in January panel indicate the two areas described in more detail below.

- **Double-peak** seasonal pattern is observed for most of the study domain: **maximum** DV in **Feb – Mar** and **Oct – Nov; minimum** DV in **Jun.**
- **Strong** seasonal pattern is seen in **area 1** (**red box**) due to its relatively **high latitudes** in the study domain.
- **Weak** seasonal pattern is observed in **area 2** (**blue box**) but with year-long scattered large DV events.

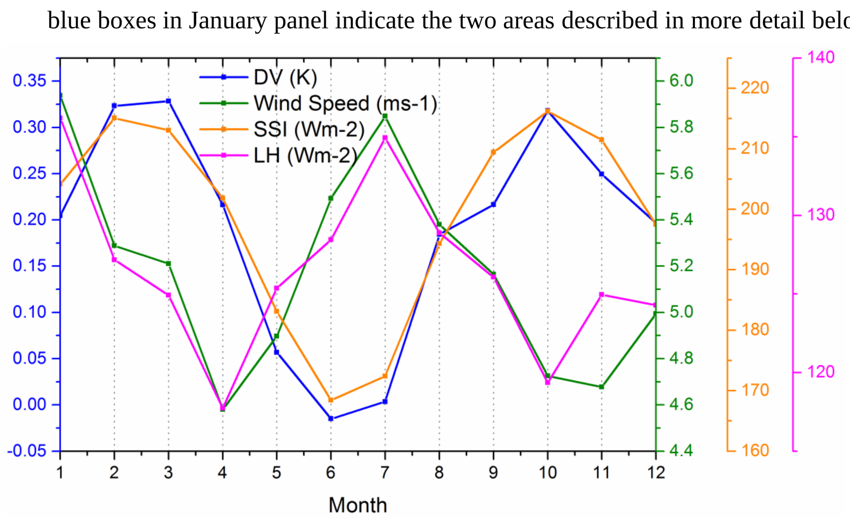

Fig.4 **Monthly average** DV, wind speed, SSI, and LH over the whole study domain and the whole five-year time period.

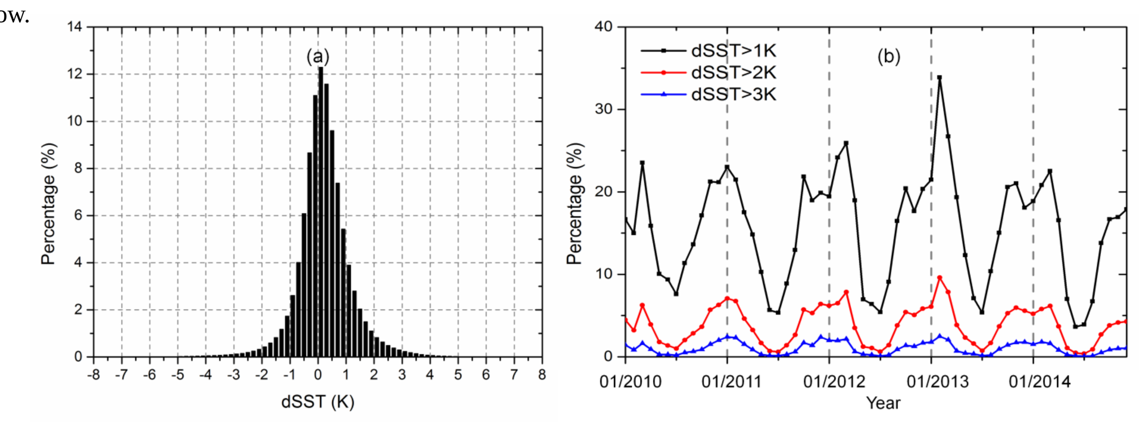

Fig.5 Statistical results of the pixels with different DV amplitudes over the whole study domain and time period. The distribution of the DV amplitudes are shown in (a). The percentages of DV > 1 K, > 2 K, and > 3 K against all pixels that have available DV amplitudes in each month are shown in (b).

- Double-peak (double-trough) pattern is observed for DV and SSI (wind speed and LH).
- The maximum monthly average DV of **0.33 K** occurs in **March**. The **minimum** DV amplitude is found in **June**. In **October**, a second peak DV amplitude can be seen with an amplitude of **0.32 K**.
- The trend for **SSI** is very closely correlated with that of DV. The **wind speed** trend exhibits good negative correlation with that of DV but for all extreme values, **a one-month lag** has been found.

- The most frequently seen DV amplitudes are within the **0–0.2 K range**, which is different from previous studies (e.g. *Clayson and Weitlich* [2007] and *Zhang et al.* [2016]) in which the peak DV is in the 0.2–0.4 K range. Reasons: (1) hourly SST data are used in the above two papers, yielding full diurnal cycles and reflecting maximum DV amplitudes; (2) daytime IMOS AVHRR SSTs tend to underestimate the true measurements by ~0.2 K.
- The double-peak pattern is revealed in most years for the dSST > 1 K and > 2 K conditions.

5 Sensitivity Tests

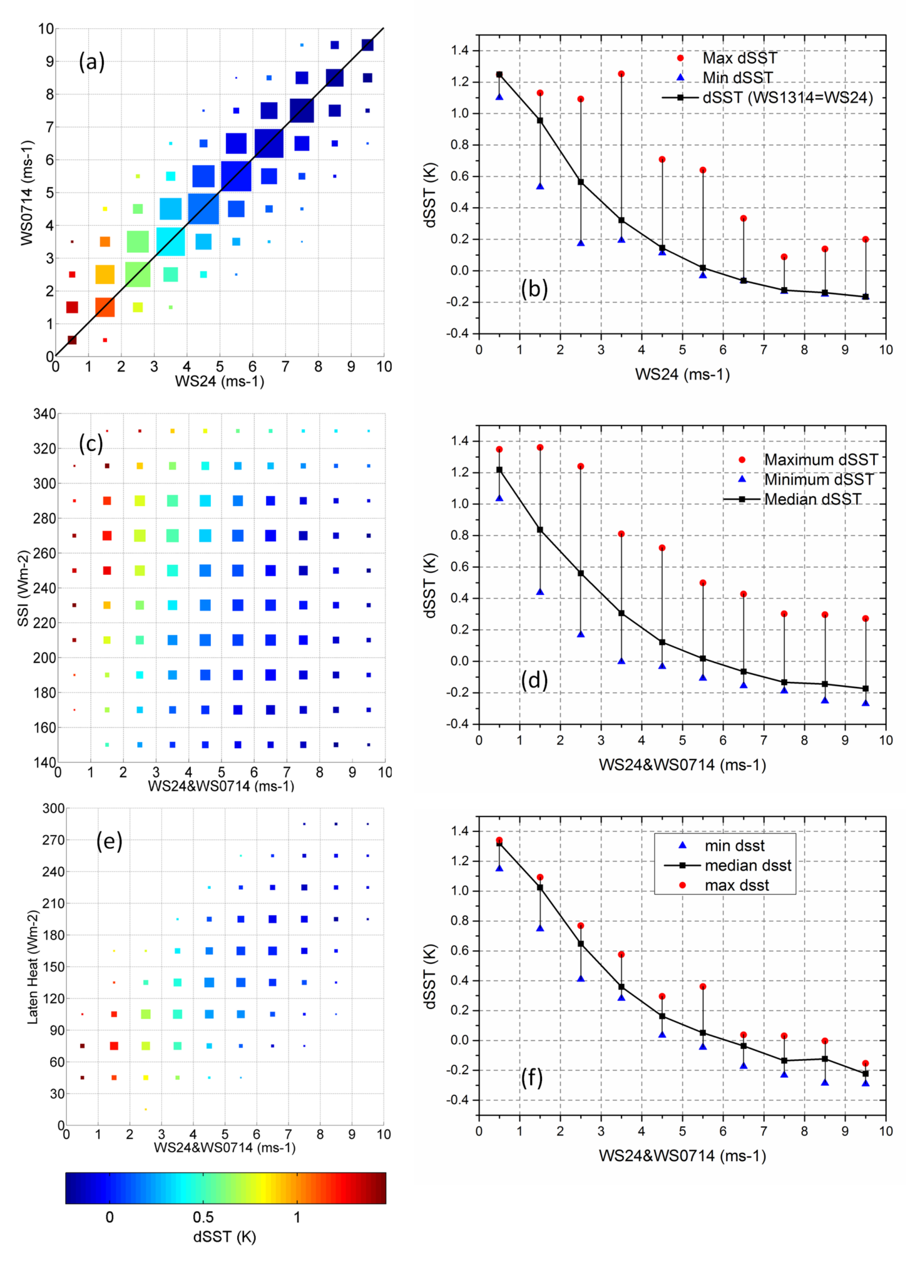

Fig.6 (a) and (b): Sensitivity test of DV amplitudes to the **WS0714** (average wind speed of local morning and early afternoon from 7-14 LST). WS24 means the daily average wind speeds. (c) and (d): Sensitivity of DV amplitudes to **SSI** levels against different wind speeds. (e) and (f): Sensitivity of DV amplitudes to different **LH** levels under fixed wind speeds and SSI condition (230 Wm^{-2} < SSI < 280 Wms^{-2}). In a, c, and e panels, the sizes of the squares are proportional to the counts of the pixels under that specific condition. The pixel count of the maximum square in a (c, e) is 15238 (7336, 5064) and of the minimum square is 124 (117,120). In b, the max (min) dSST within each 1 ms^{-1} WS24 range basically corresponds to the weakest (strongest) WS0714 condition within that WS24 range. In d and f panels, the max (min) dSST basically corresponds to the strongest (weakest) SSI and the weakest (strongest) LH condition within that wind speed range. The wind speed condition in SSI and LH sensitivity tests applies to both WS24 and WS0714.

- For the very weak (WS24<1 ms^{-1}) and the very strong daily average wind speeds (WS24>6 ms^{-1}), the effects of morning winds on dSSTs are small (± 0.2–0.4 K). However, for the **low-middle range daily wind speeds** (1 ms^{-1}<WS24<4 ms^{-1}), a calm or very windy morning can affect the DV amplitude up to **± 0.4-0.6 K**.
- When the winds are **<** 1 ms^{-1}, the DV amplitudes are large regardless of the SSI level. The most significant effects (± 0.5 K) that different SSI levels can have are found when the wind speeds are **between 1–5 ms^{-1}**.
- Over a fixed wind speed and SSI level, **low (high)** LH conditions very slightly **enhance (reduce)** the DV amplitude by **no more than ± 0.2 K**.

6 Conclusions

- The Bureau produced fv02 IMOS HRPT AVHRR SST (**experimental hybrid SST_Day_Night field**) from NOAA-19 are of good quality and are suitable for SST DV studies.
- The double-peak seasonal pattern is observed for most of the study domain with **maximum** DV events found in **Feb – Mar** and **Oct – Nov** and **minimum** DV events in **Jun**.
- Sensitivity tests of DV amplitudes to morning and early afternoon (7-14 LST) wind speeds indicates the need of combining daily average winds and the morning winds together in a DV model that only estimates the daily maximum dSST, especially under the conditions when the daily average wind speed is **low-middle** (1 ms^{-1} < WS24 < 4 ms^{-1}).

7 References

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