Himawari-ANU: A recalibrated geostationary land surface temperature dataset based on MODIS spatiotemporal characteristics

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Abstract

The geostationary Himawari-8 satellite offers a unique opportunity to monitor sub-daily thermal dynamics over Asia and Oceania, and several operational land surface temperature (LST) retrieval algorithms have been developed for this purpose. However, studies have reported inconsistency between LST data obtained from geostationary and polar-orbiting platforms, particularly for daytime LST, which usually shows directional artefacts and can be strongly impacted by viewing and illumination geometries and shadowing effects. To overcome this challenge, Solar Zenith Angle (SZA) serves as an ideal physical variable to quantify systematic differences between platforms. Here we presented an SZA-based Calibration (SZAC) method to operationally calibrate the daytime component of a split-window retrieved Himawari-8 LST (referred to here as the baseline). SZAC describes the spatial heterogeneity and magnitude of diurnal LST discrepancies from different products. The SZAC coefficient was spatiotemporally optimised against highest-quality assured (error < 1 K) pixels from the MODerate-resolution Imaging Spectroradiometer (MODIS) daytime LST between 01/Jan/2016 and 31/Dec/2020. We evaluated the calibrated LST data, referred to as the Australian National University LST with SZAC ($\mathrm{ANU_{SZAC}}$), against MODIS LST and the Visible Infrared Imaging Radiometer Suite (VIIRS) LST, as well as *in-situ* LST from the OzFlux network. Two peer Himawari-8 LST products from Chiba University and the Copernicus Global Land Service were also collected for comparisons. The median daytime bias of $\mathrm{ANU_{SZAC}}$ LST against Terra-MODIS LST, Aqua-MODIS LST and VIIRS LST was 1.52 K, 0.98 K and -0.63 K, respectively, which demonstrated improved performance compared to baseline (5.37 K, 4.85 K and 3.02 K, respectively) and Chiba LST (3.71 K, 2.90 K and 1.07 K, respectively). All four Himawari-8 LST products showed comparable performance of unbiased root mean squared error (ubRMSE), ranging from 2.47 to 3.07 K, compared to LST from polar-orbiting platforms. In the evaluation against *in-situ* LST, the overall mean values of bias (ubRMSE) of baseline, Chiba, Copernicus and $\mathrm{ANU_{SZAC}}$ LST during daytime were 4.23 K (3.74 K), 2.16 K (3.62 K), 1.73 K (3.31 K) and 1.41 K (3.24 K), respectively, based on 171,289 hourly samples from 20 OzFlux sites across Australia between 01/Jan/2016 and 31/Dec/2020. In summary, the SZAC method offers a promising approach to enhance the reliability of geostationary LST retrievals by incorporating the spatiotemporal characteristics observed by accurate polar-orbiting LST data. Furthermore, it is possible to extend SZAC for LST estimation by using data acquired by geostationary satellites in other regions, e.g., Europe, Africa and Americas, as this could improve our understanding of the error characteristics of overlapped geostationary imageries, allowing for targeted refinements and calibrations to further enhance applicability.

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Introduction

- Himawari-8 satellite offers a unique opportunity to monitor sub-daily thermal dynamics over Asia and Oceania (Fig. 1).
- Inconsistency were reported between LST data obtained from geostationary and polar-orbiting platforms, particularly for daytime LST (e.g., 12 K).
- Solar Zenith Angle (SZA) serves as an ideal physical variable to quantify systematic differences between platforms.

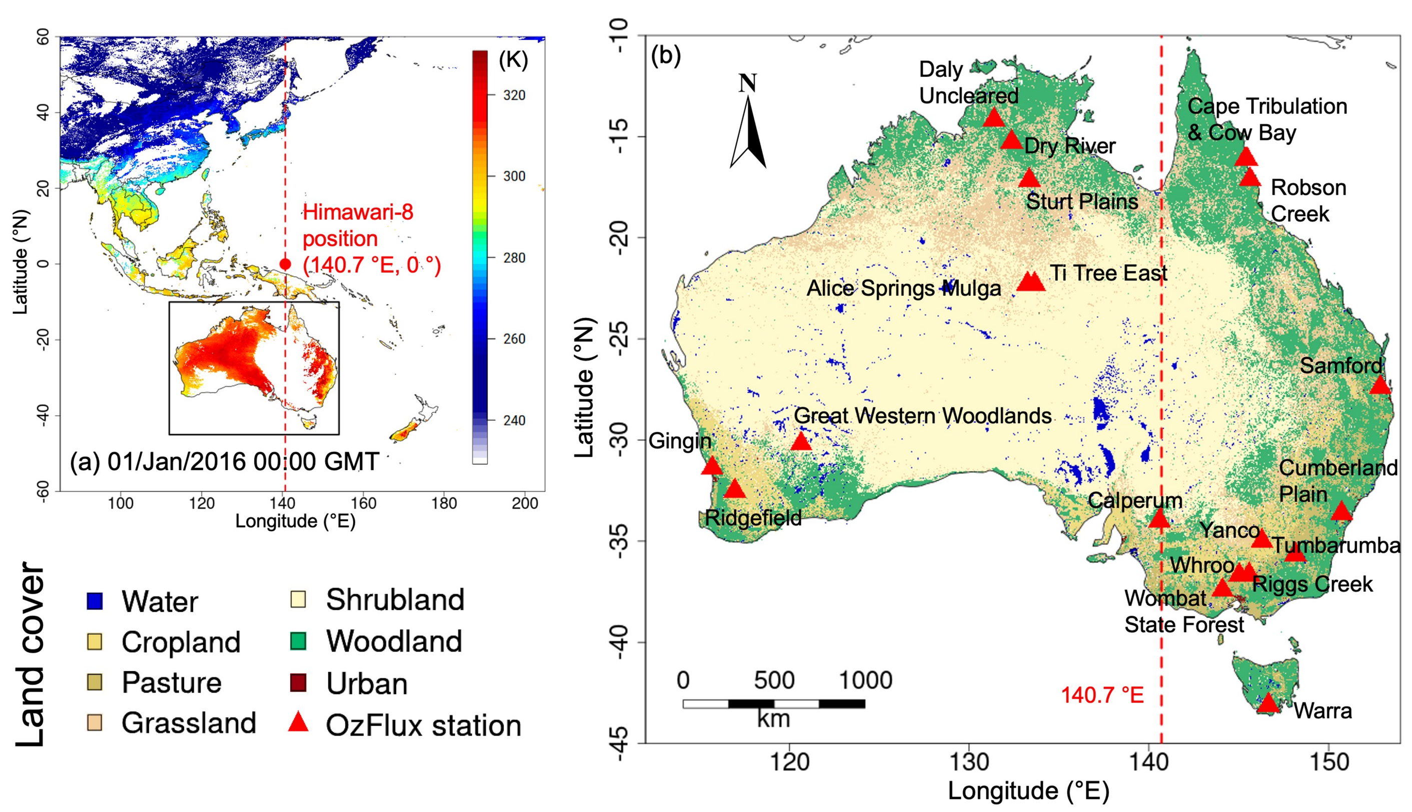

Fig. 1. (a) LST of the full-disk Himawari-8 observation area on 01/Jan/2016 00:00 GMT with clouds and oceans masked out; and (b) the land cover map of Australia and the distribution of 20 OzFlux sites.

Data and method

- $SZAC(x_i, y_i, t) = Coeff(x_i, y_i) \times log(cos\theta_{solar}(x_i, y_i, t) + 1)$
- where $SZAC$ is the calibration factor (K); (x_i, y_i) is the geolocation of a given pixel i; t is the given time; $Coeff$ is coefficient (K); θ_{solar} is SZA (°).

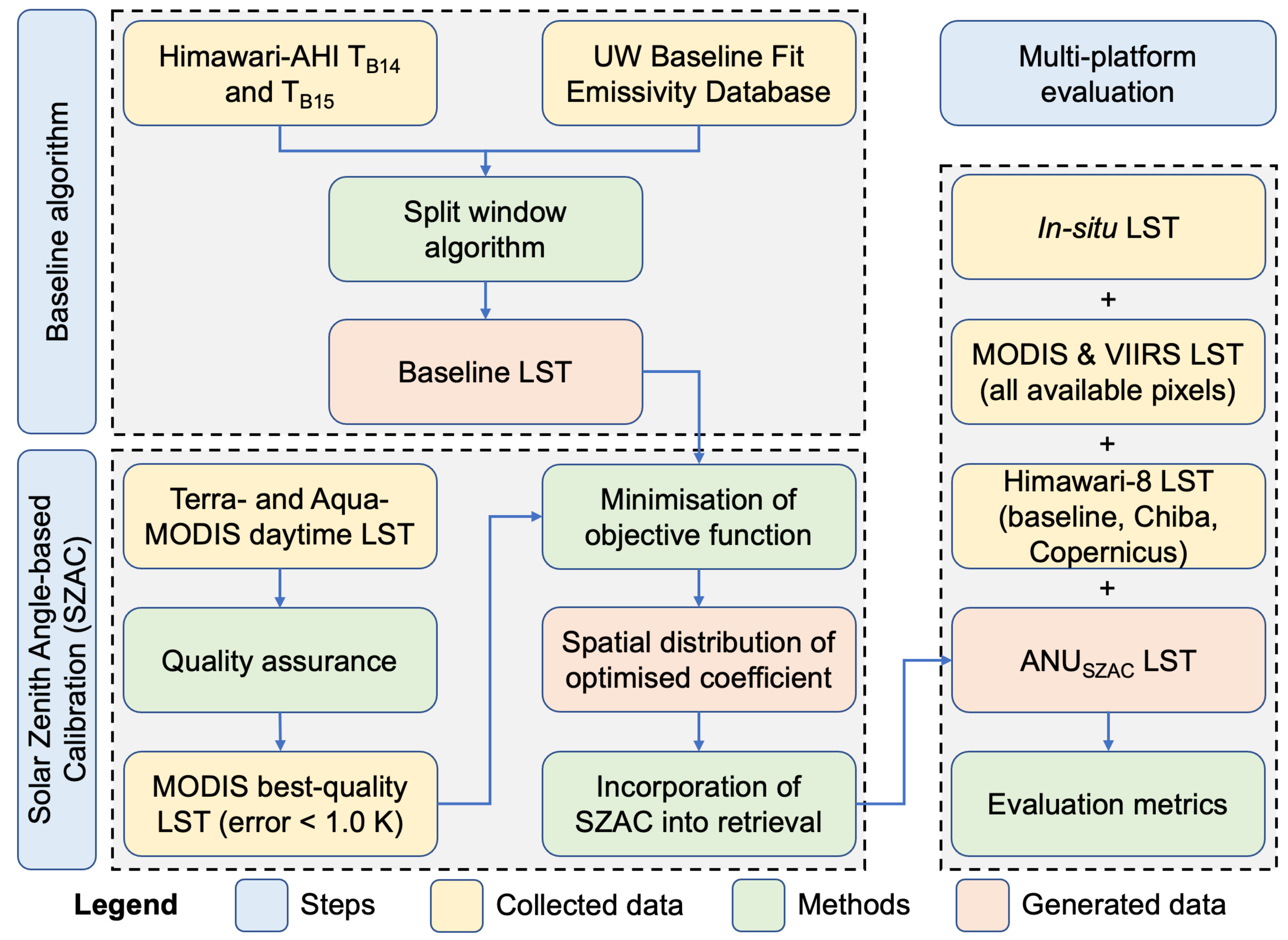

Fig. 2. Experimental design herein.

Snapshots

- SZAC variation signifies that the disparities between the baseline LST and MODIS LST were most pronounced in the summer when incoming radiation peaks and necessitate a stronger correction.
- The differences between the baseline and MODIS LST in inland and northern Australia were always higher than other regions.

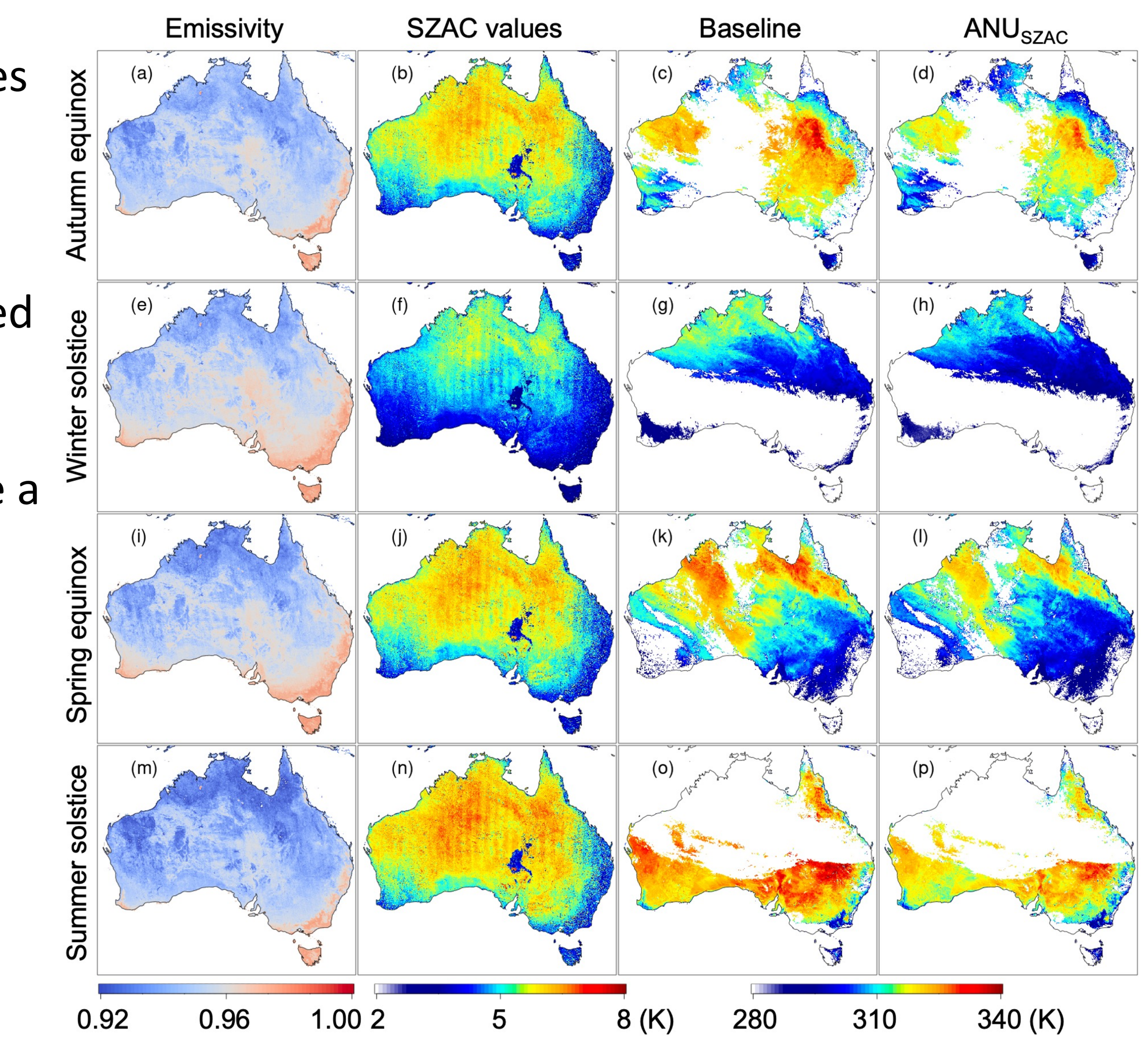

Fig. 3. Snapshots of emissivity, SZAC values, baseline and ANU_{SZAC} LST.

- Both input emissivity (Fig. 3; first column) and SZAC values (Fig. 3; second column) exhibited artefacts associated with MODIS scanning effects.

Spatial pattern of SZAC coefficient

- The SZAC coefficient revealed negative associations with vegetation cover characteristics and exhibited a greater degree of uniformity within inland regions, where calibration effects exerted a more pronounced influence (Fig. 4).
- Pixels along the eastern coastlines exhibited greater heterogeneity (Region A and C; Fig. 4 e-h and q-t), characterised by denser vegetation and relatively mountainous terrain.
- For both EVI and LAI, the SZAC coefficient exhibited similar decreasing trend with increasing vegetation indices (Fig. 5).

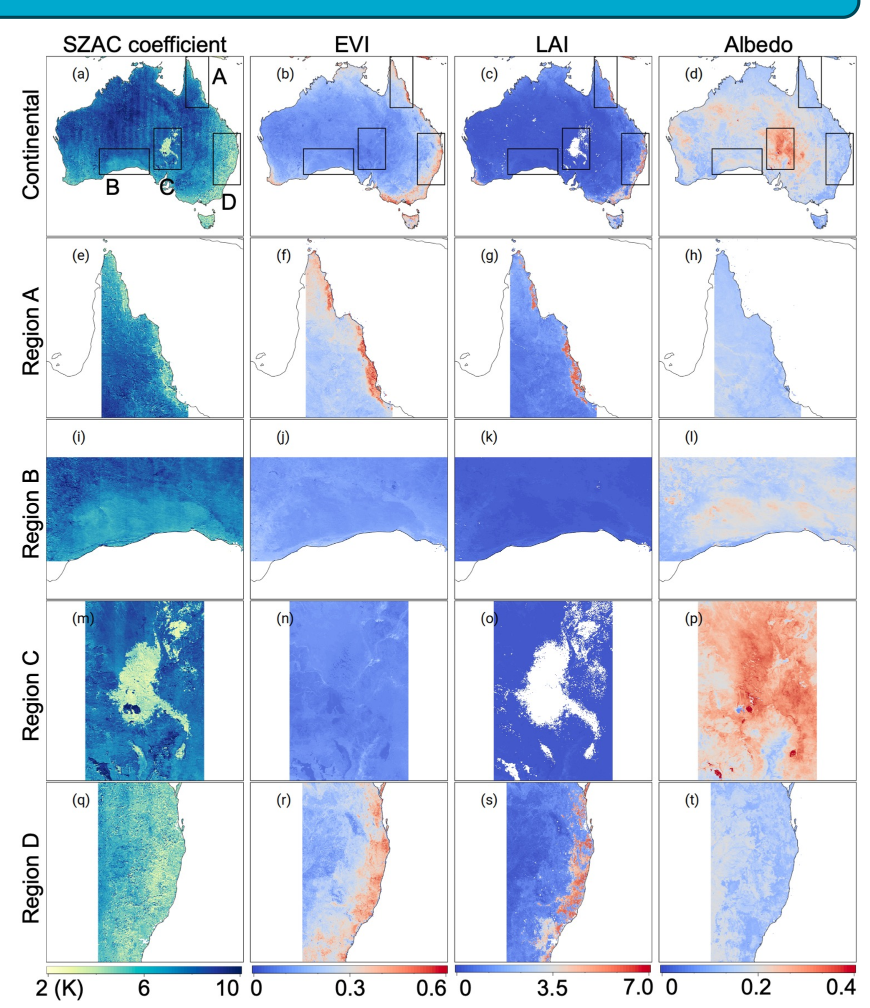

Fig. 4. (a-d) Continental-scale and (e-t) zoomed comparisons.

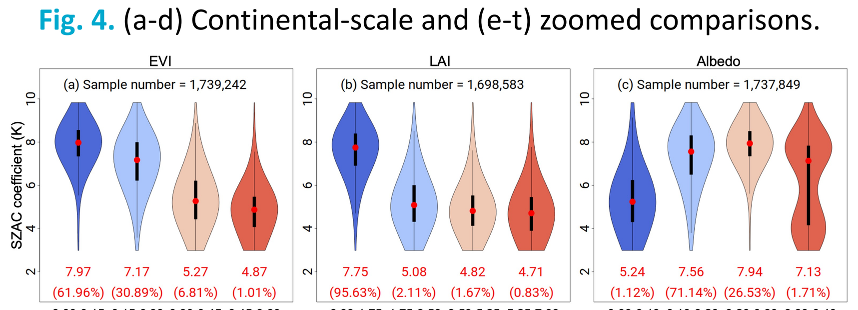

Fig. 5. Violin plots within four equal-value-range quantiles.

Cross-satellite evaluation

- The median bias (ubRMSE) of baseline, Chiba, Copernicus and ANU_{SZAC} LST against Aqua-MODIS LST for Australia was 4.85 (2.42), 2.90 (2.37), 2.28 (2.48) and 0.98 (2.44) K, respectively (Fig. 6).
- The median bias (ubRMSE) of baseline, Chiba, Copernicus and ANU_{SZAC} LST against VIIRS LST was 3.02 (3.07), 1.07 (2.84), 0.33 (2.92) and -0.63 (2.94) K, respectively (Fig. 7).
- Both VIIRS and Aqua-MODIS have an overpass time of ~ 13:30 local solar time making this comparison essentially free of diurnal cycle influences.

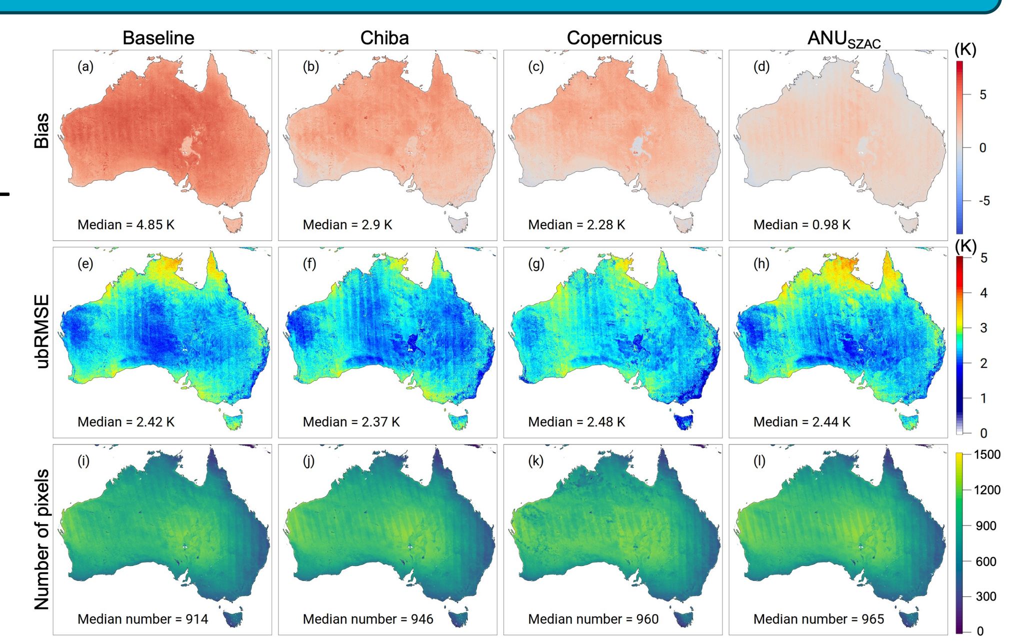

Fig. 6. Comparisons against Aqua-MODIS (i.e., MYD11A1) for Australia.

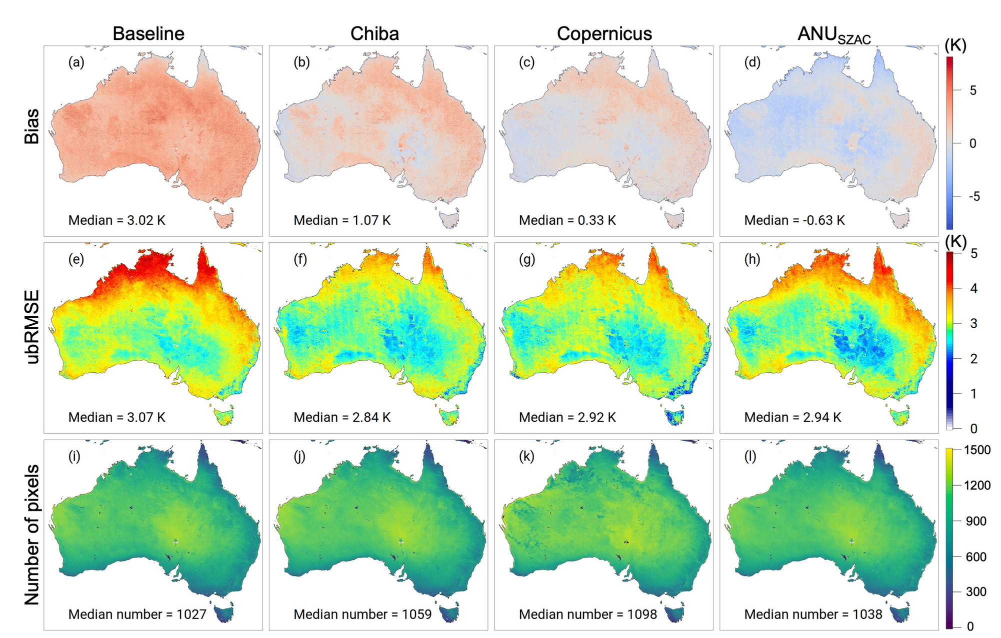

Fig. 7. Comparisons against VIIRS (i.e., VNP21A1D) for Australia.

Ground-based evaluation

- The biggest improvement in bias of ANU_{SZAC} LST was observed around midday (i.e., 10:00-12:00 local standard time; Fig. 8).

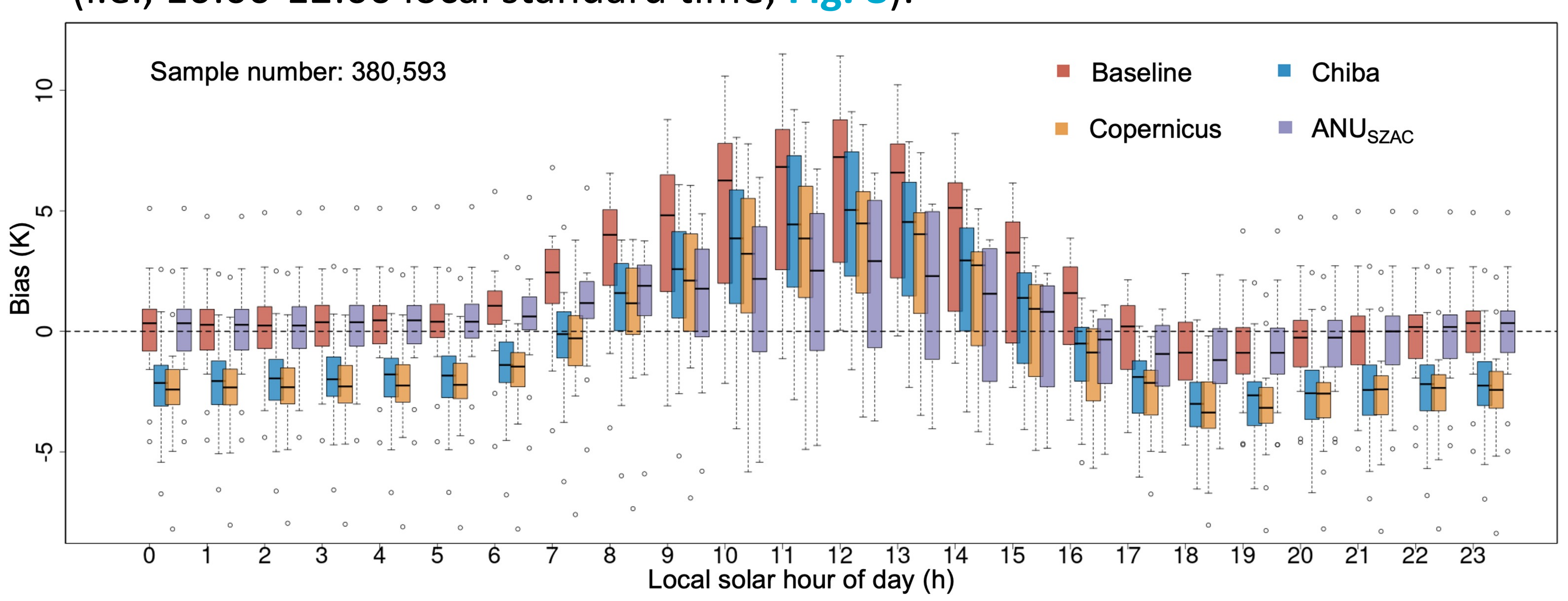

Fig. 8. Diurnal bias boxplots against OzFlux LST.

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