THE UNIVERSITY OF MELBOURNE

GHRSST
GROUP FOR HIGH RESOLUTION SEA SURFACE TEMPERATURE

Cool Skin Signals Observed from Infrared and Microwave Sea Surface Temperature Retrievals

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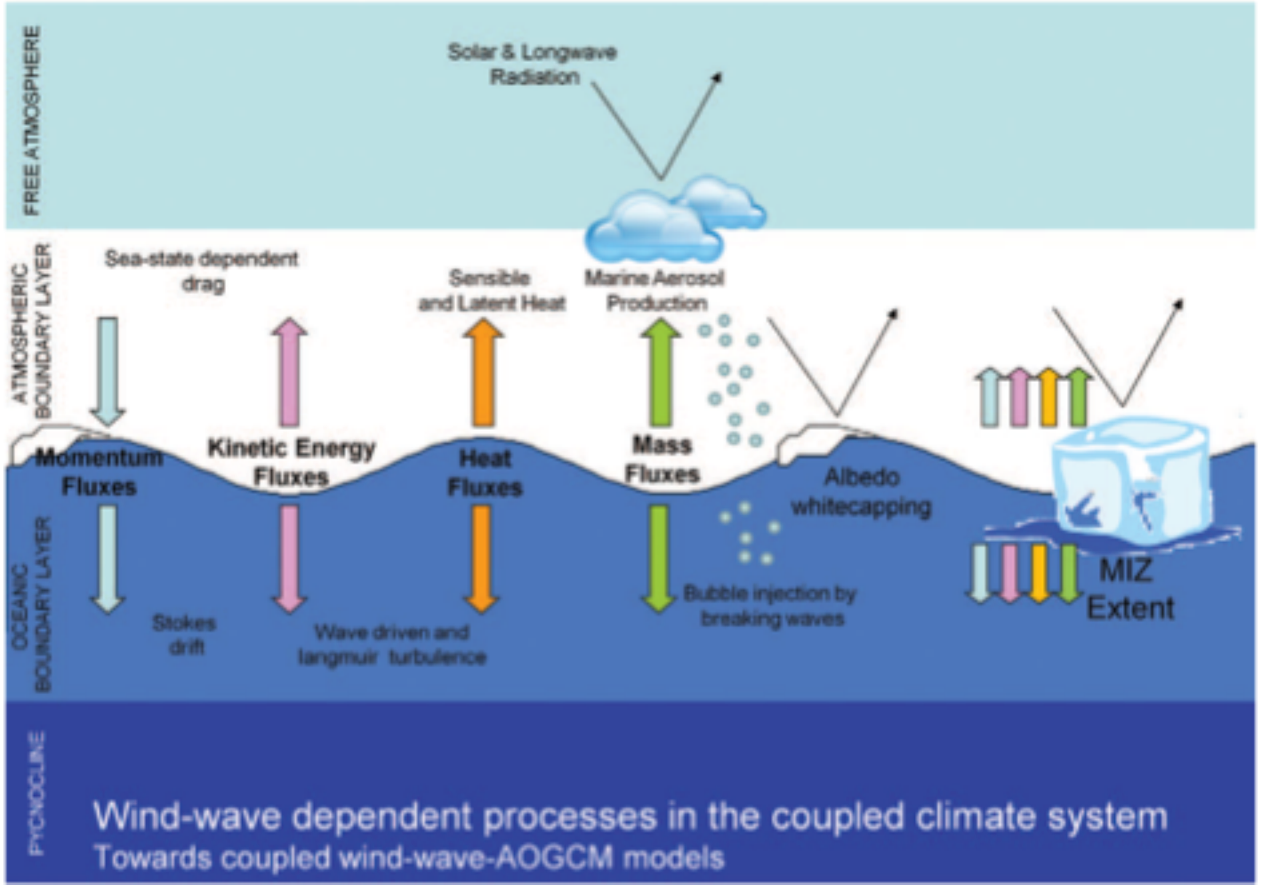
OUTLINES

- PART A: Project Introduction – Investigating Wave Breaking Using Satellite SST Data
  - Background
  - Approaches
  - Aims
  - Challenges

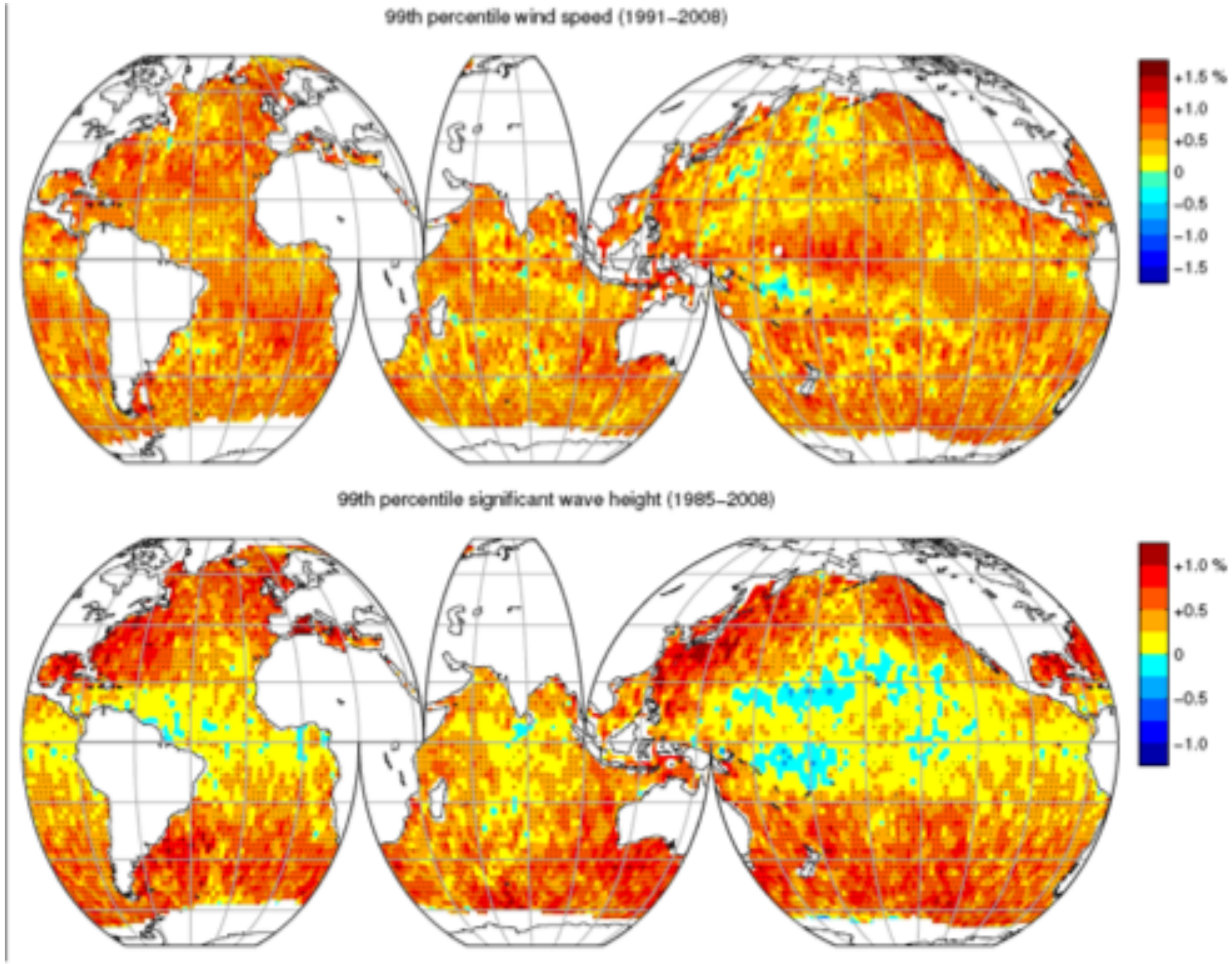
- PART B: Cool Skin Signals from Infrared (IR) and Microwave (MW) SST Data
  - Section 1: In Situ Validation of IR and MW SST Data + Quality Control
  - Section 2: Cool Skin Signal Characteristics
    - Section 2.1: Statistics
    - Section 2.2: Dependencies on Environmental Variables

Project Introduction - Background



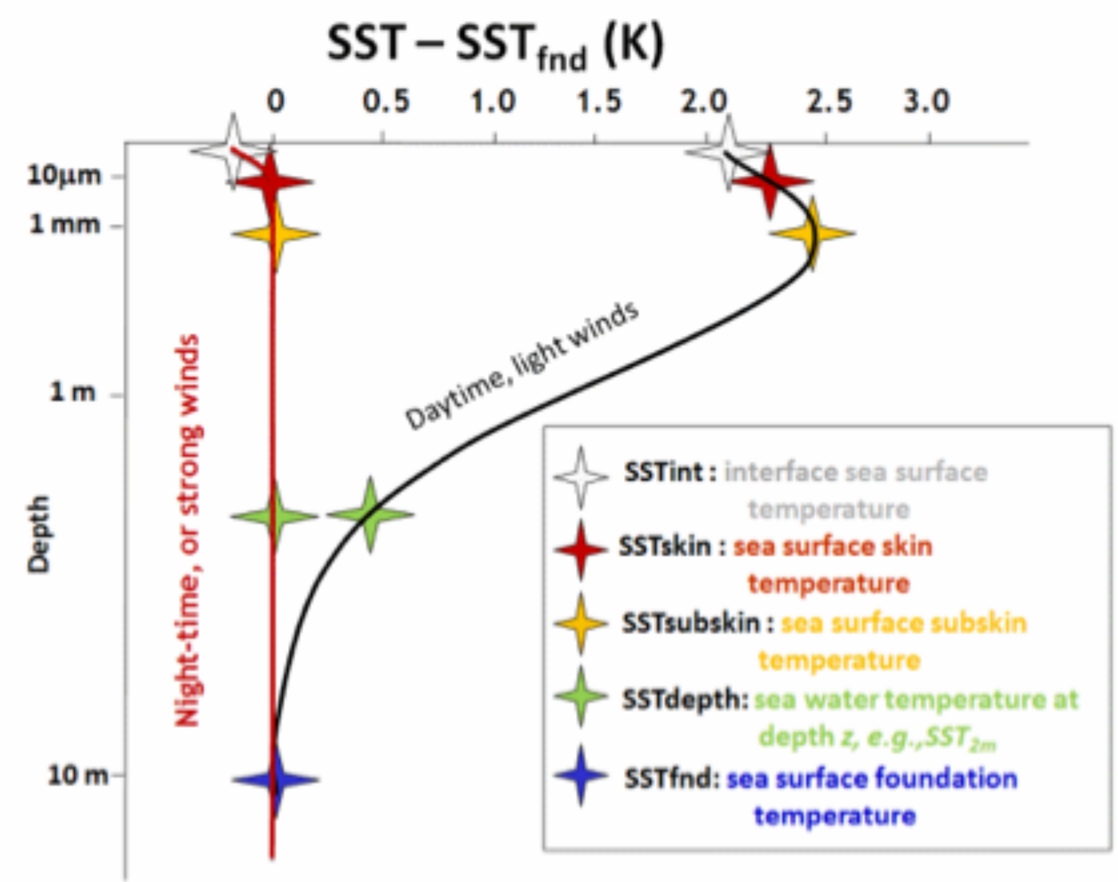
- Wave breaking in air-sea coupled system [*Cavaleri et al.,* 2012] and ocean/coastal engineering

Project Introduction - Background



➢ Global increasing trends for extreme SWH (Significant Wave Height) and wind speed [*Young et al.*, *Science,* 2011]

Project Introduction - Approaches



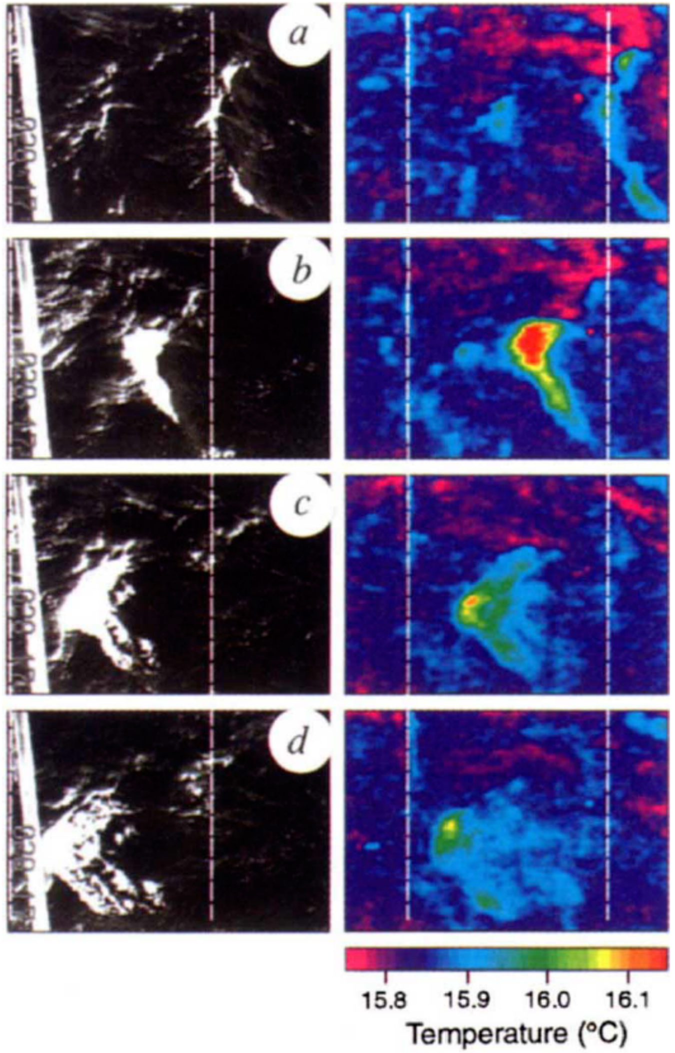
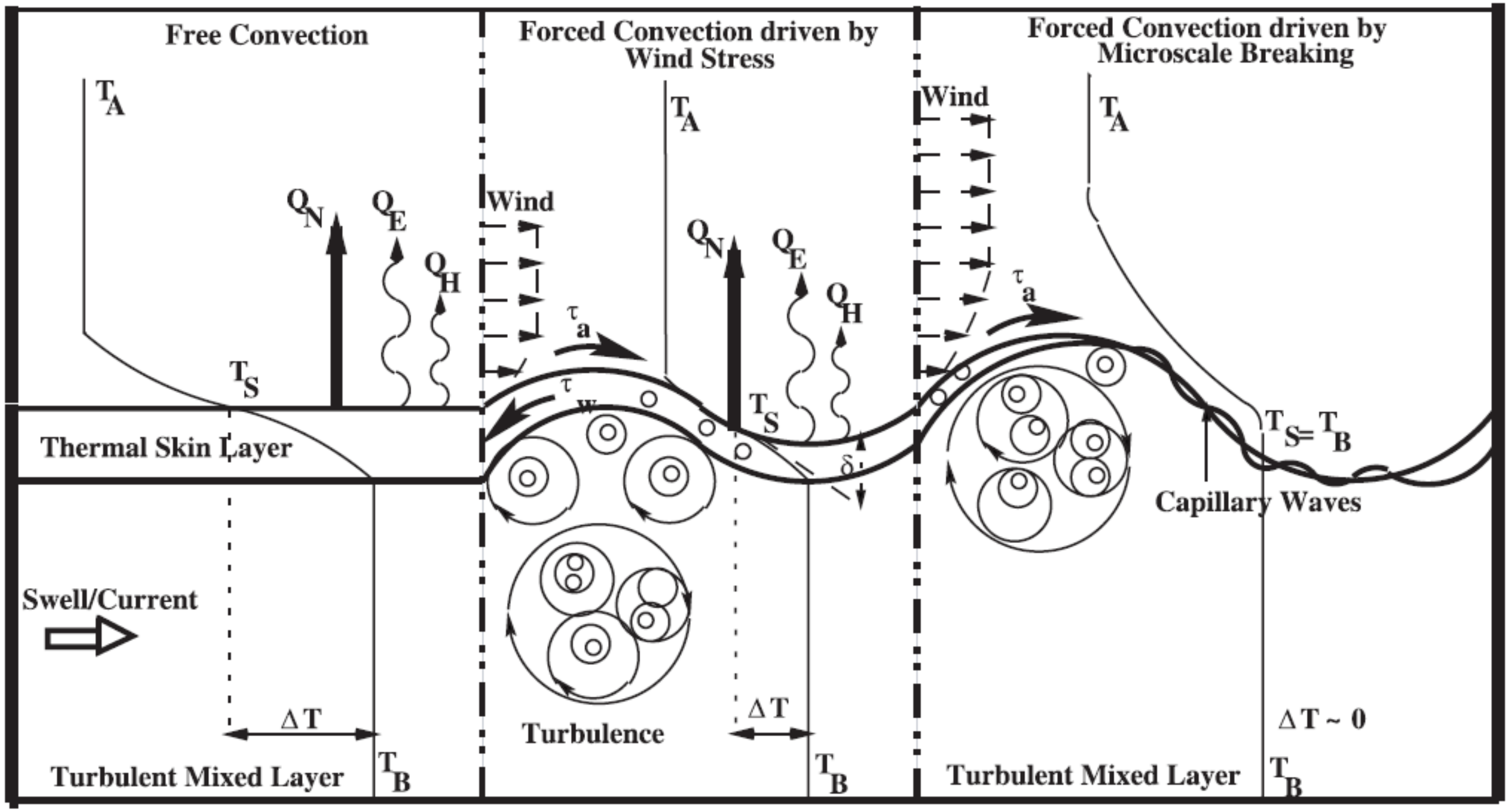


FIG. 1 Sequence of simultaneous, co-located video images (left) and infrared images (right) of a breaking wave in the open ocean. Image size is approximately 5 m × 10 m. The breaking wave is propagating from right to

- ➢ Link between SST cool skin and wave breaking [*GHRSST website; Jessup et al., Nature,* 1997]
- ➢ Both wave breaking probability and severity can be measured.

Project Introduction - Approaches



- Physical processes affecting the cool skin layer [*Castro et al.*, 1997]
- Theoretically, if the cool skin is simultaneously measured along with all other meteorological variables, wave breaking information can be extracted.

$$\Delta T \propto W_{conv}\,\Delta T_{conv} + W_{shear}\,\Delta T_{shear} + W_{shearsat}\,\Delta T_{shearsat} + W_{capil}\,\Delta T_{capil} + W_{\mu sb}\,\Delta T_{\mu sb} + W_{lsb}\,\Delta T_{lsb}\,,$$

Project Introduction – Aims & Challenges

- Aims:
  - A new method to investigate wave breaking
  - First global estimate of wave breaking probability & severity
  - Global and regional trends for wave breaking for over two decades
- Challenges:
  - The large uncertainty of IR and MW SST data, and other variables
  - Collocation between IR and MW SST measurements
  - ……

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- PART B: Cool Skin Signals from Infrared (IR) and Microwave (MW) SST Data
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  - Section 2: Cool Skin Signal Characteristics
    - Section 2.1: Statistics
    - Section 2.2: Dependencies on Environmental Variables

Section 1: In Situ Validation

- Data Sets (9 years: Oct. 2002 – Sep. 2011)
  - IR SST: MODIS (Moderate Resolution Imaging Spectroradiometer) onboard Aqua
    - Non-GSD formatted L3; 13:30/01:30 day/night local crossing time
    - Institution: NASA Goddard Space Flight Centre, Ocean Ecology Laboratory, Ocean Biology Processing Group;
    - Regression algorithm: University of Miami Rosenstiel School for Marine and Atmospheric Science group
    - Cool skin correction: -0.17 K constant
  - MW SST: AMSR-E (Advanced Microwave Scanning Radiometer for EOS, Earth Observation System) onboard Aqua
    - L3U with spatial resolution of 0.25*0.25;
    - Institution: Remote Sensing Systems; version v7a; physically retrieved
    - AMSR-E wind & water vapor data
  - In Situ SST data
    - iQuam SST: drifting buoy, tropical/coastal moored buoy data
  - NCEP (National Centres for Environmental Prediction) Re-analysis data
    - Ta, latent heat, sensible heat, specific humidity

Section 1: In Situ Validation

➢ Validation Statistics

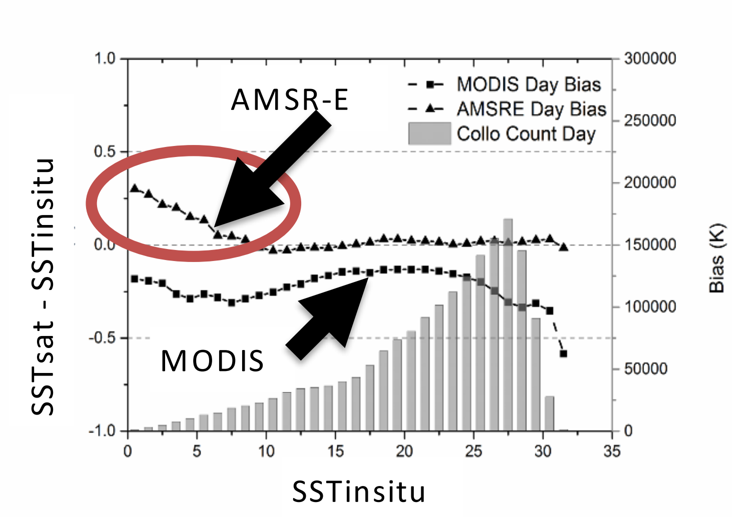
	Num	Bias	SD	RSD
MODIS - SSTinsitu				
daytime	1631156	-0.22	0.52	0.39
night-time	2337201	-0.37	0.54	0.40
AMSR-E - SSTinsitu				
daytime	1631156	0.02	0.45	0.38
nighttime	2337201	-0.05	0.46	0.38

➢ IR MODIS: larger cold bias (-0.37 K) for night-time MODIS than daytime bias (-0.22 K)

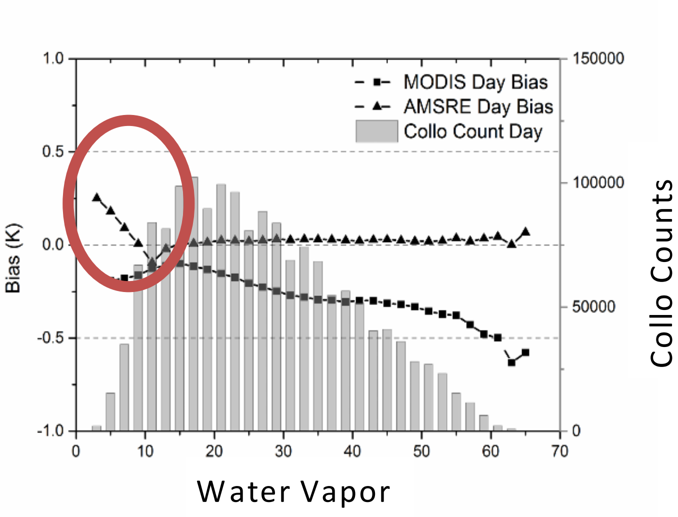
➢ MW AMSR-E: near zero biases between MW and in situ SSTs, as expected

- In Situ validation against different environmental conditions – SST ranges & water vapor.

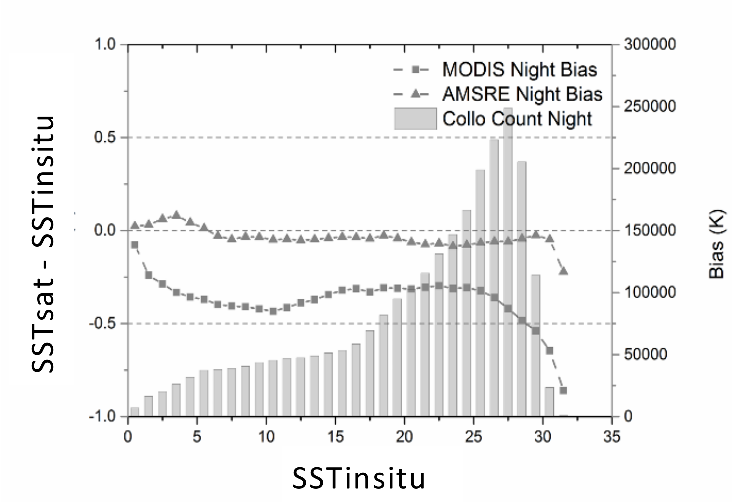
(a) Dependence on SSTinsitu – Daytime



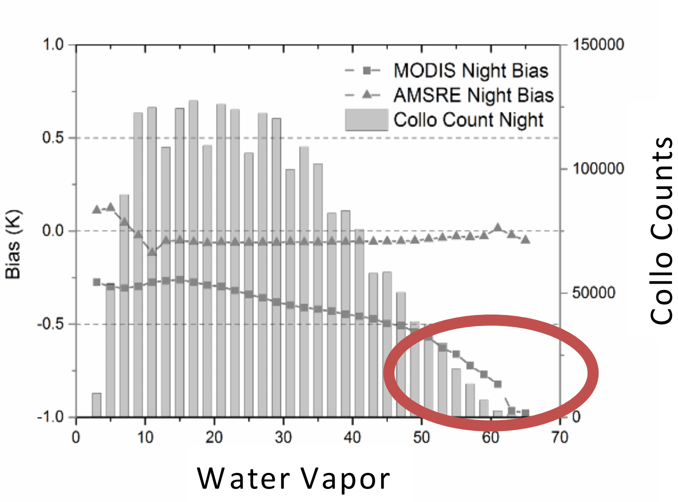
(c) Dependence on TCWV – Daytime



(d) Dependence on SSTinsitu – Night-time



(f) Dependence on TCWV – Night-time



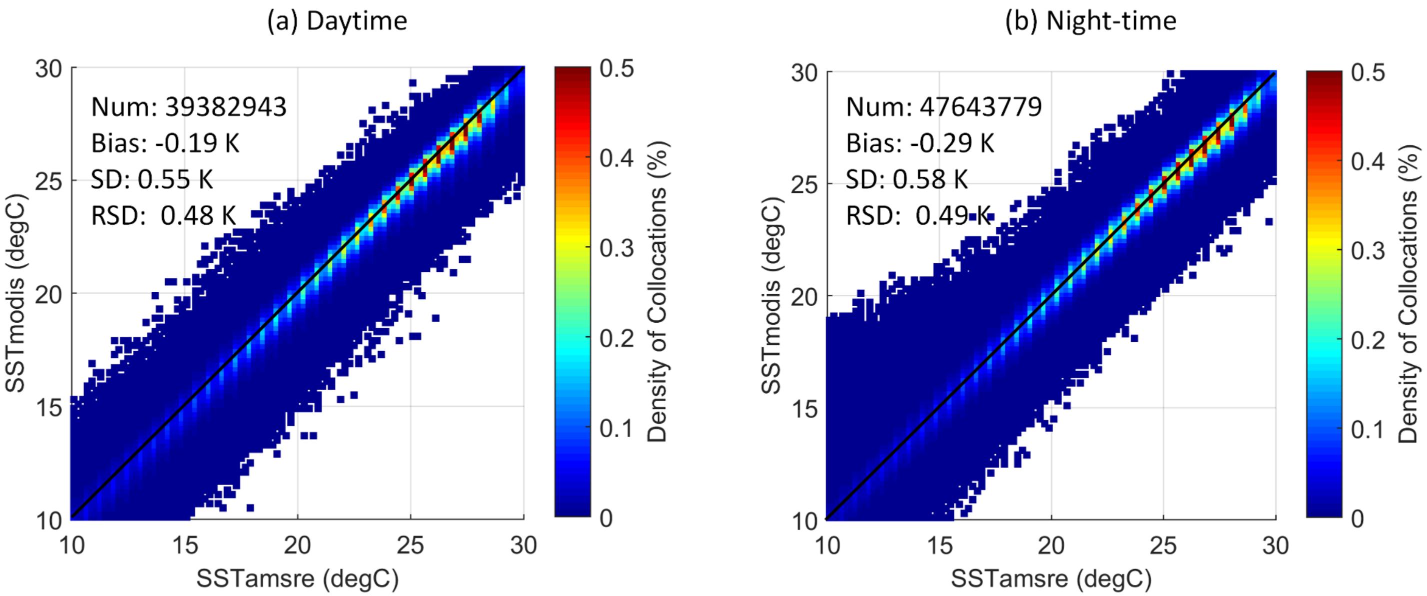
- AMSR-E: Daytime – warm bias for SSTinsitu < 10 degC and TCWV < 12 kgm^{-2}; Night-time – warm bias for TCWV < 12 kgm^{-2}

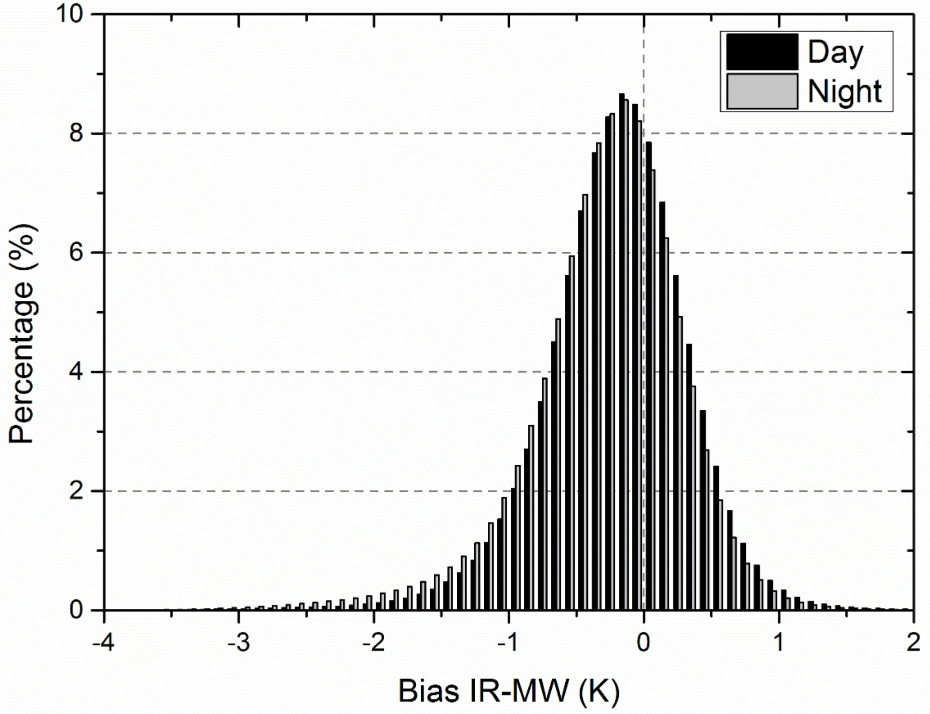
- MODIS: cold biases for TCWV > 50 kgm^{-2}, which basically correspond to very warm waters (> 30 degC) in the tropical areas.

- Quality control before moving on:
  - A. 12 < TCWV < 50 kgm^{-2};
  - B. 10 < SSTamsre < 30 degC;

Section 2.1: IR – MW Differences Characteristics – Statistics

- Distribution of IR – MW differences

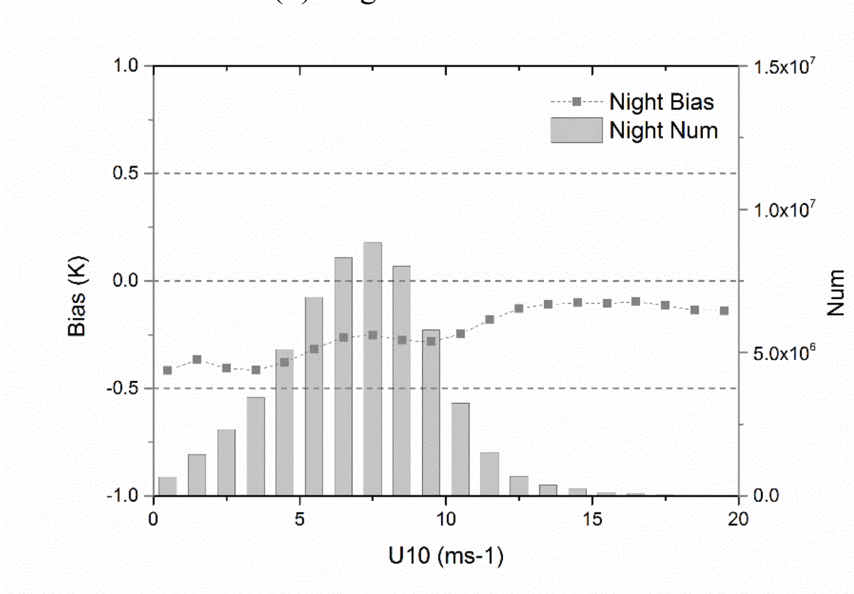




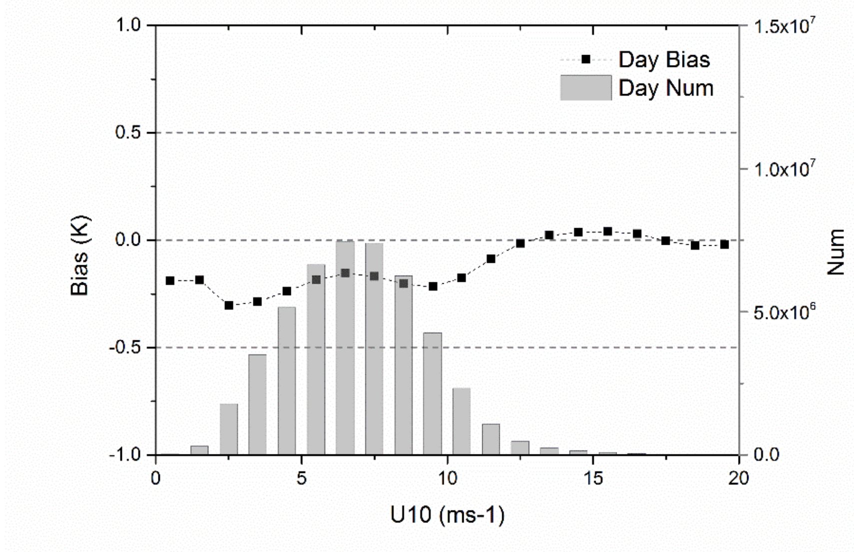
- Day bias -0.19 K and night bias -0.29 K
- Peak values are both within -0.1 – -0.2 K
- More colder skin values in the night-time

Section 2.2: IR – MW Differences Dependency on U10

(a) Night-time



(b) Daytime



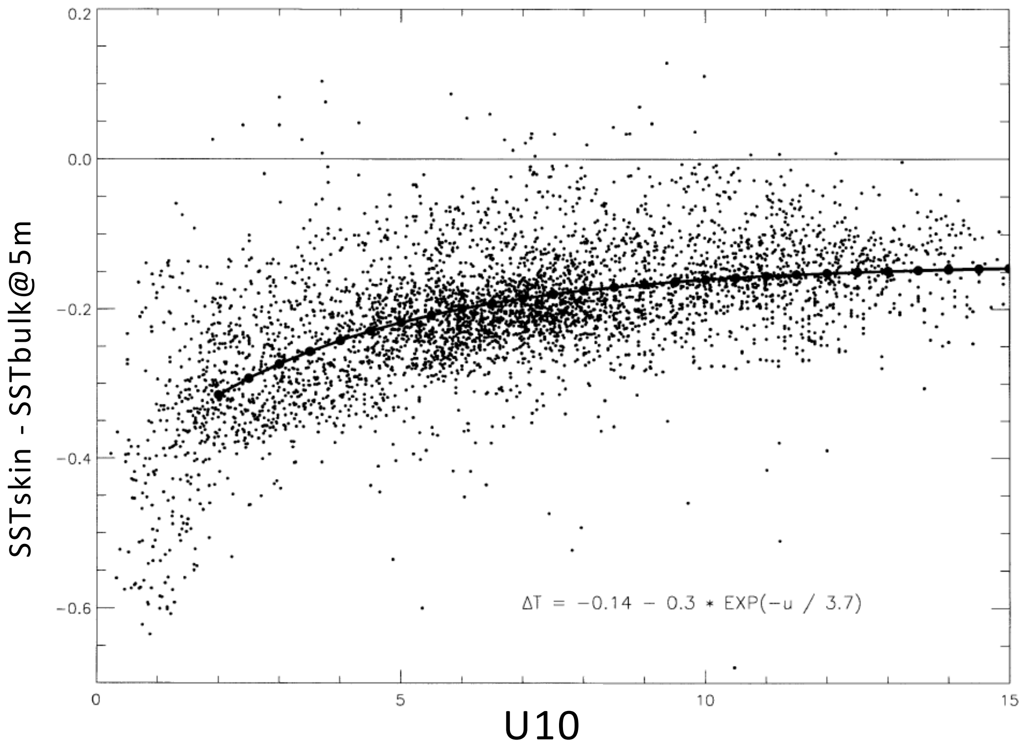
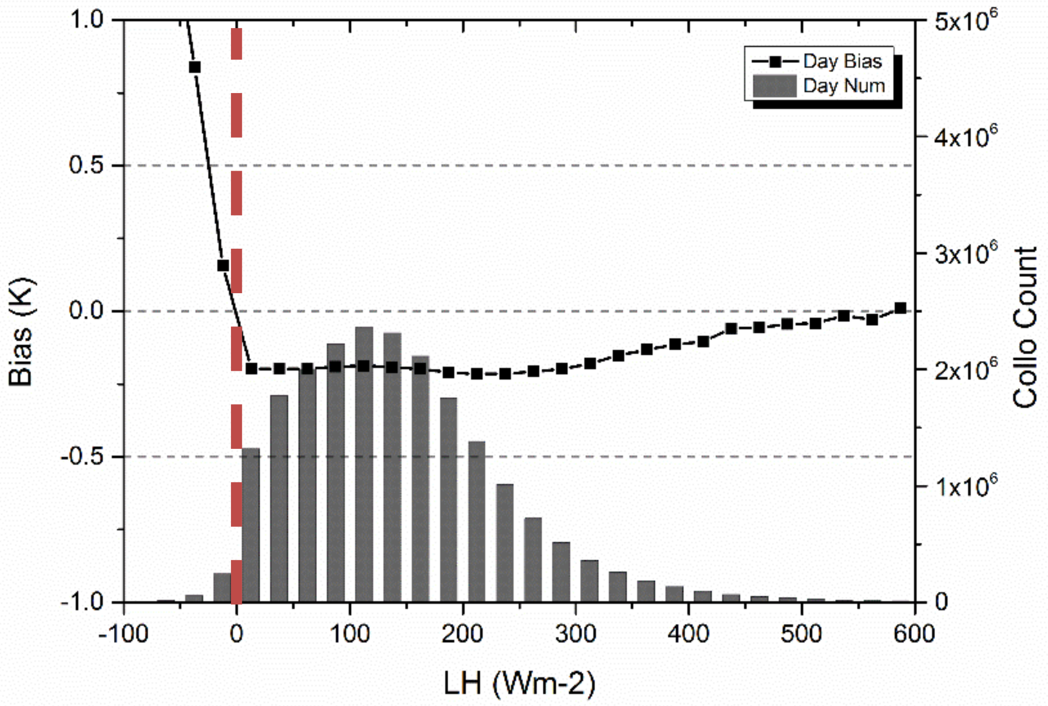


FIG. 5. All nighttime only $\Delta T_{depth\ 5\ m}$ data (as shown in Fig. 4) plotted as a function of wind speed.

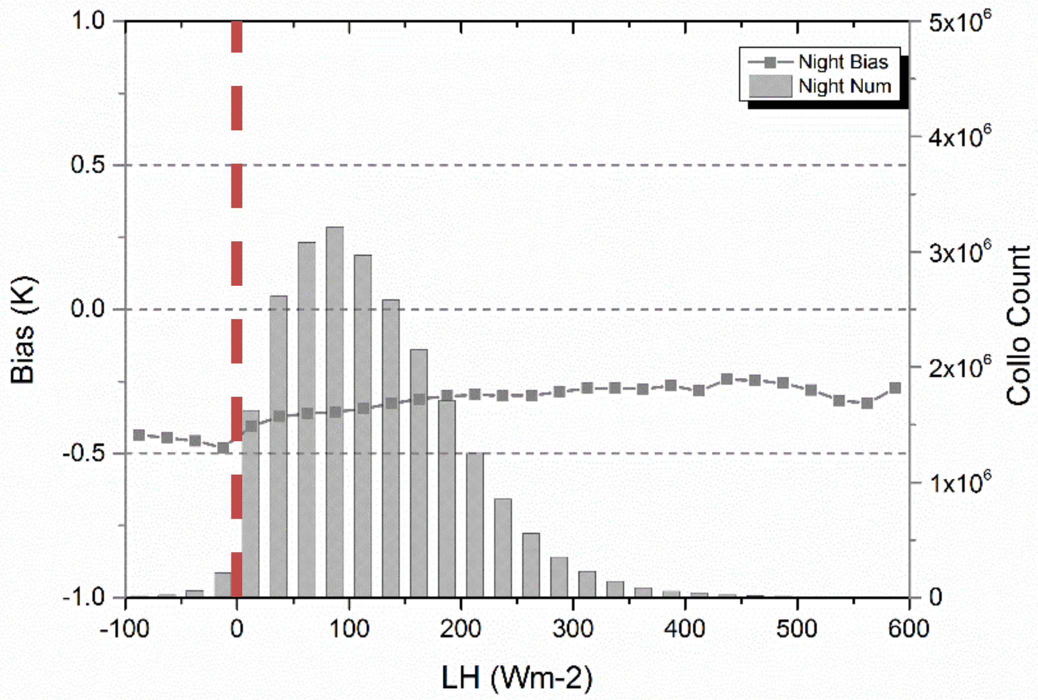
- ➢ Stronger winds leads to near-zero differences – more mixing and wave breaking
- ➢ Similar pattern with an empirical cool skin model in [*Donlon et al.*, 2002]
- ➢ More complicated due to DV for calm winds in the day

Section 2.2: IR – MW Differences Dependency on Latent Heat

(a) Daytime

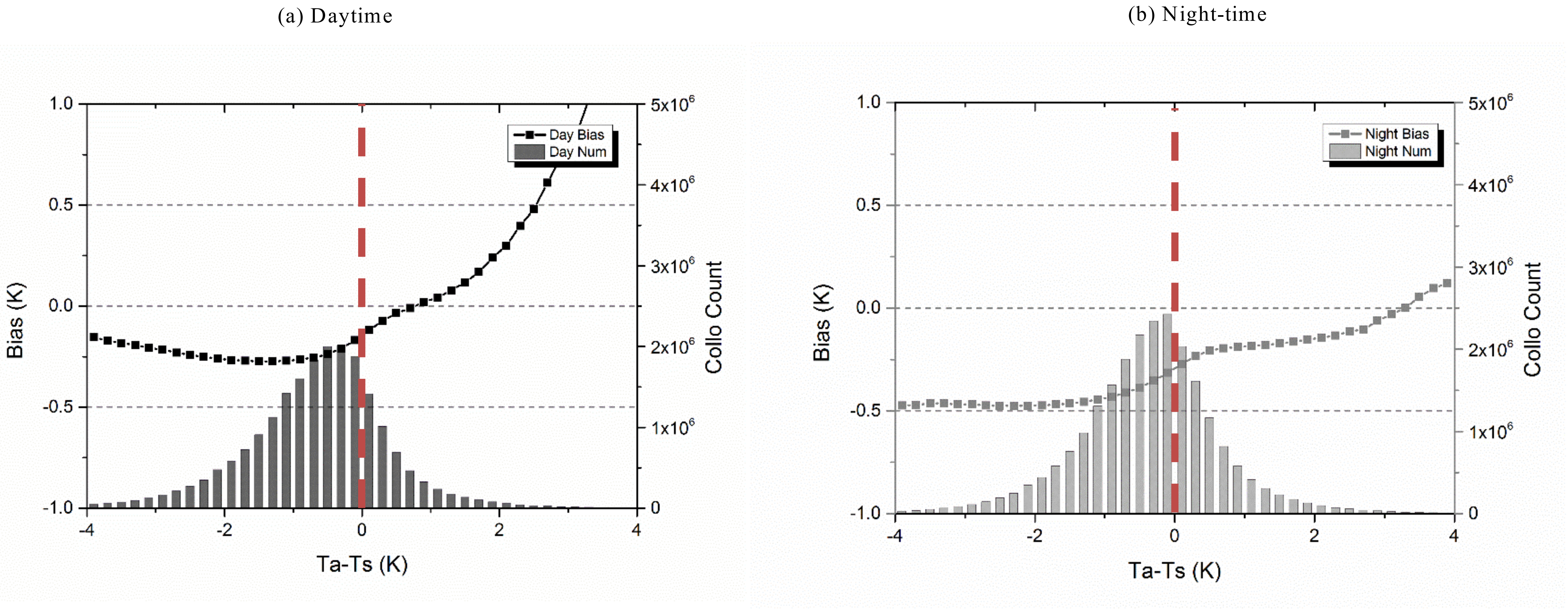


(b) Night-time



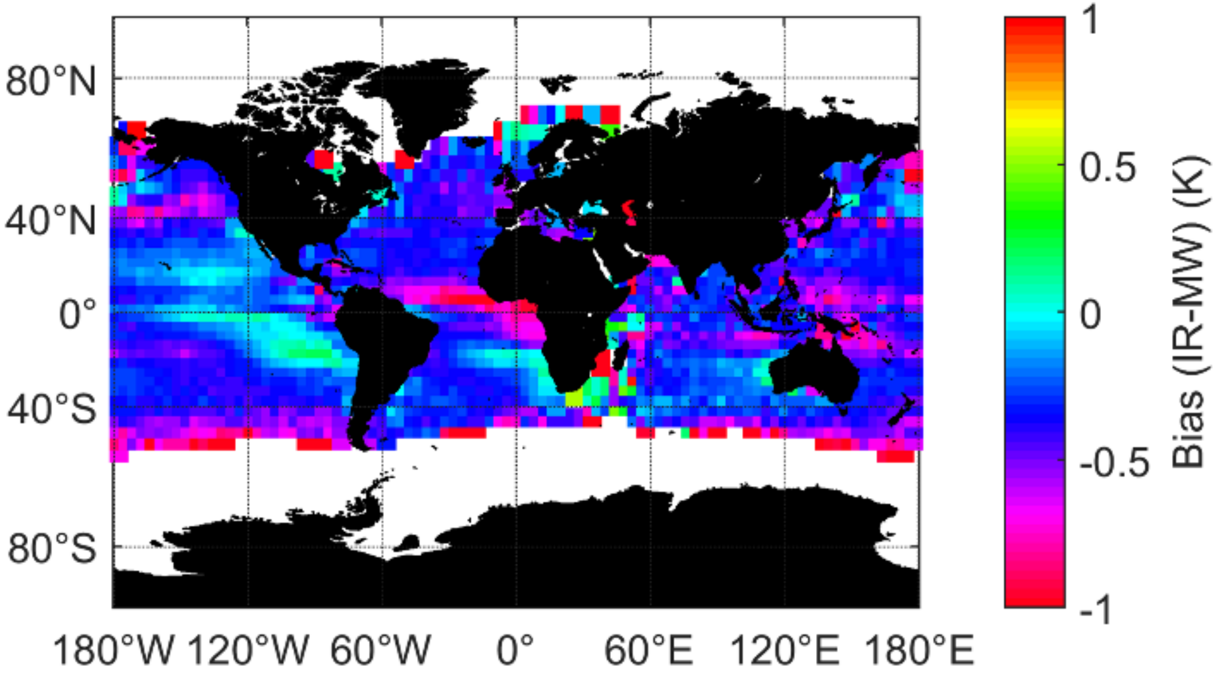
- Day: negative latent heat (heat flux into the ocean) results in positive differences
- Night: relatively minor effect

Section 2.2: IR – MW Differences Dependency on Ta-Ts



- ➢ Warmer air results in near-zero or even warm skin in the daytime
- ➢ Similar trend in the night but with smaller amplitudes

Section 2.2: IR – MW Differences Spatial Distribution



- Areas with IR-MW differences < -0.5 K in the Tropical Warm Pool – high TCWV, calm wind, warm SST, maybe also partly a degraded IR SST quality

- Areas with biases < -0.5 K in the tropical Atlantic Oceans – Saharan dust cooling effect.

Conclusions & Future Work

- Conclusions
  - Statistically, cool skin signal can be observed from MODIS – AMSR-E data. MAYBE??
  - Strong winds lead to near-zero skin-subskin difference – due mainly to mixing and wave breaking. MAYBE??
  - Saharan dust cooling effect on IR SST retrievals over the tropical Atlantic ocean.
  - Could there be warm skin in the day over the high latitudes, where LH and/or SH are negative & Ta-Ts positive?
- In the future
  - Physically retrieved IR SST. Maybe try in situ IR and bulk SSTs??
  - Try using a cool skin model, such as *Castro et al. 1997*, to extract wave breaking contribution.

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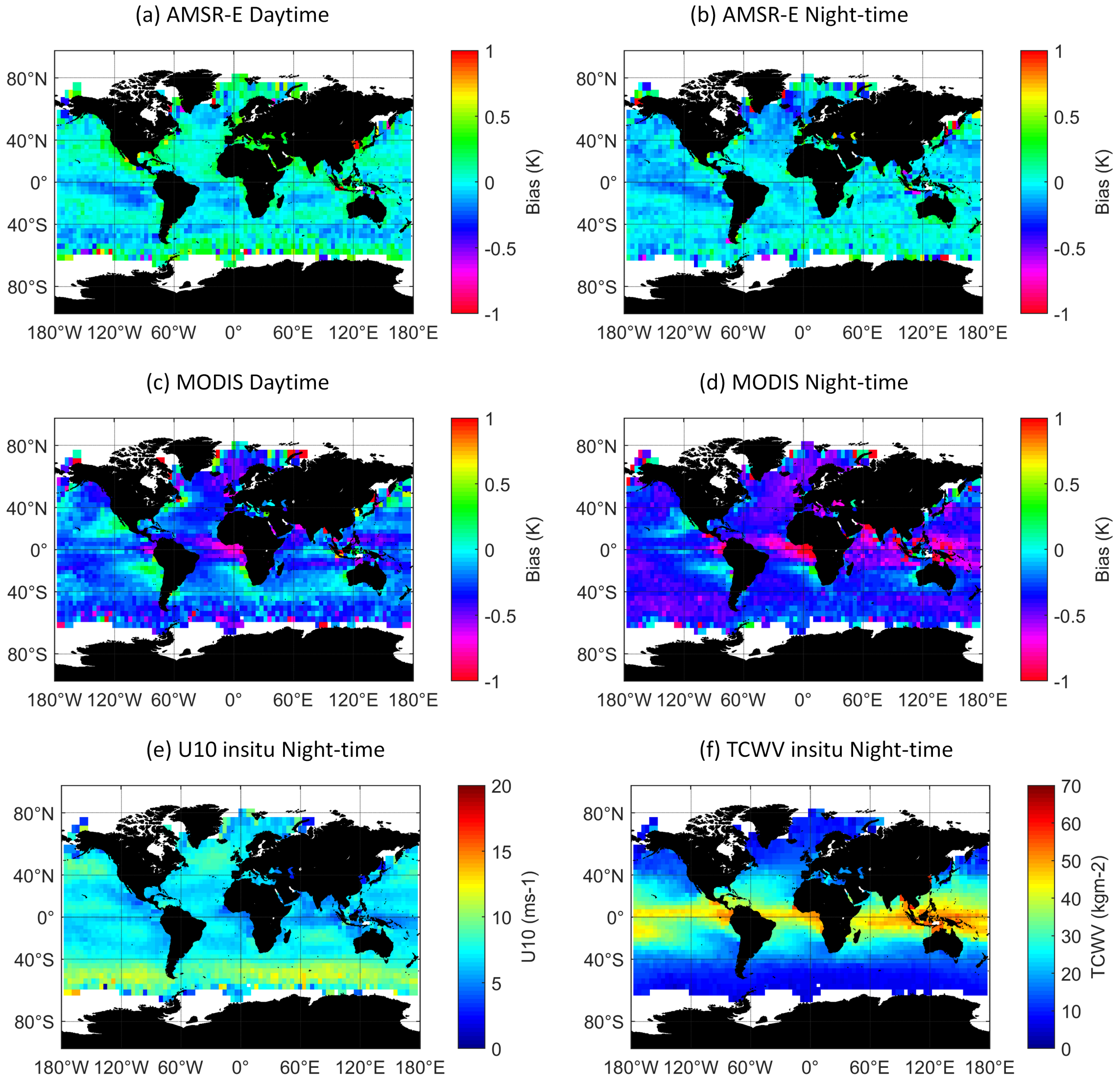
THANK YOU!

Questions?

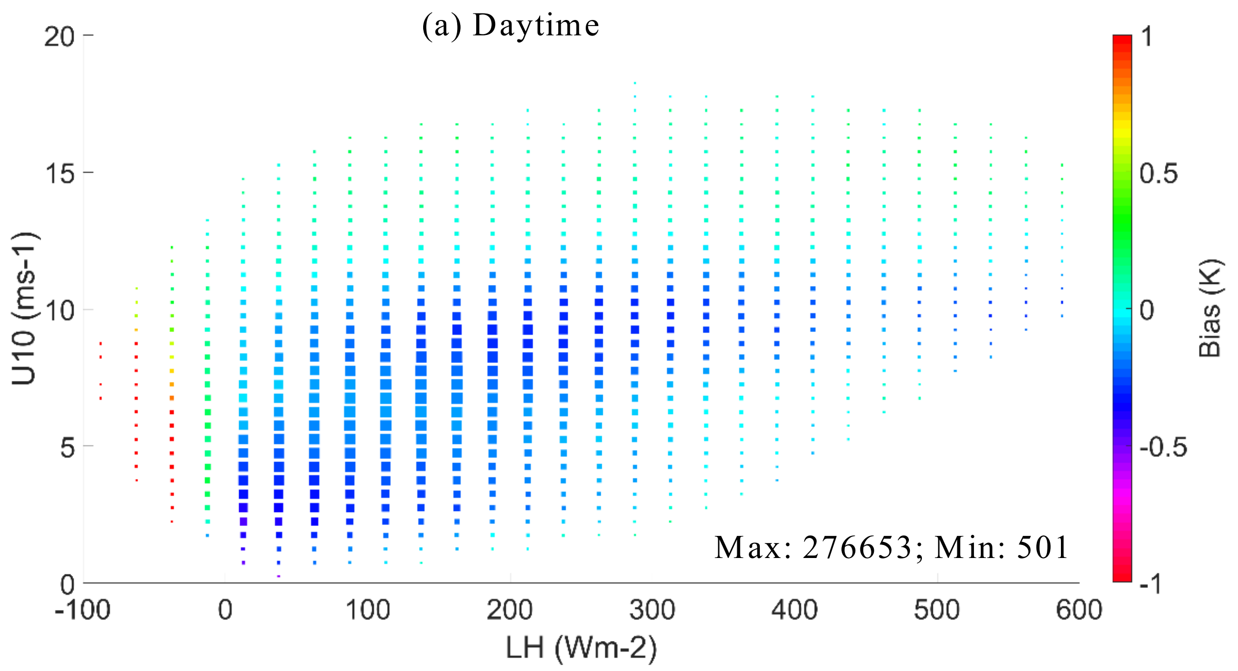
Section 1: In Situ Validation

➢ Spatial distribution

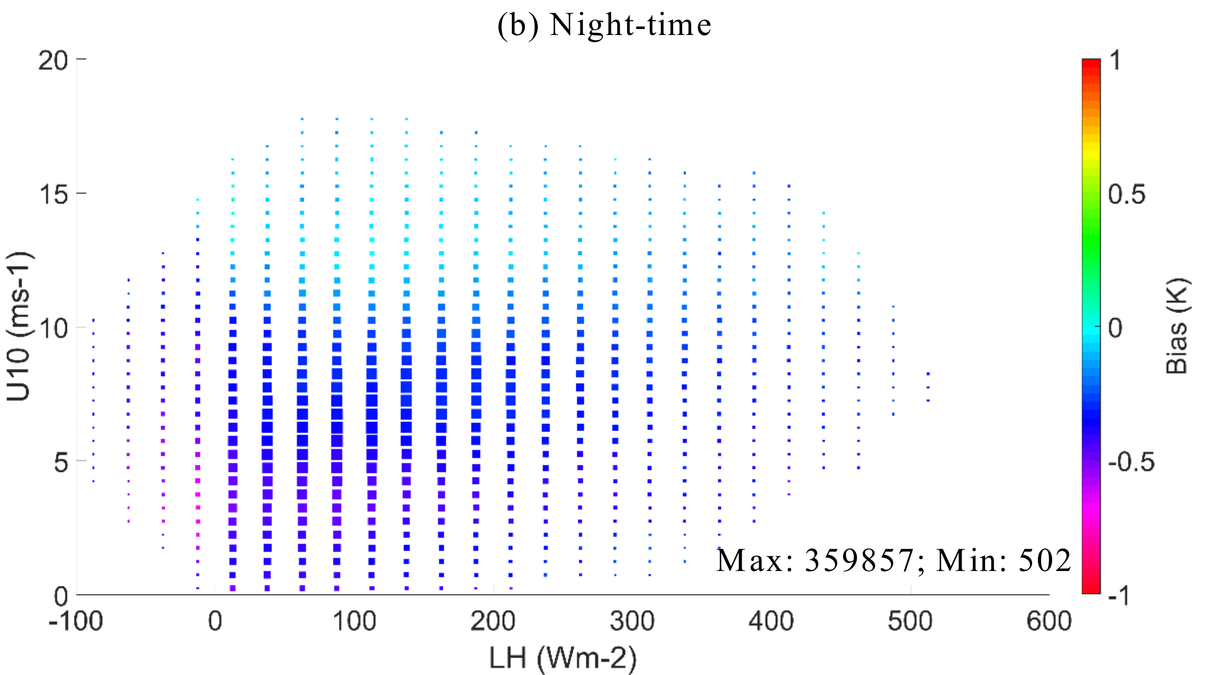


➢ Nighttime MODIS has a strong cold bias for high TCWV conditions, i.e. in the tropics.

- U10 + Latent Heat

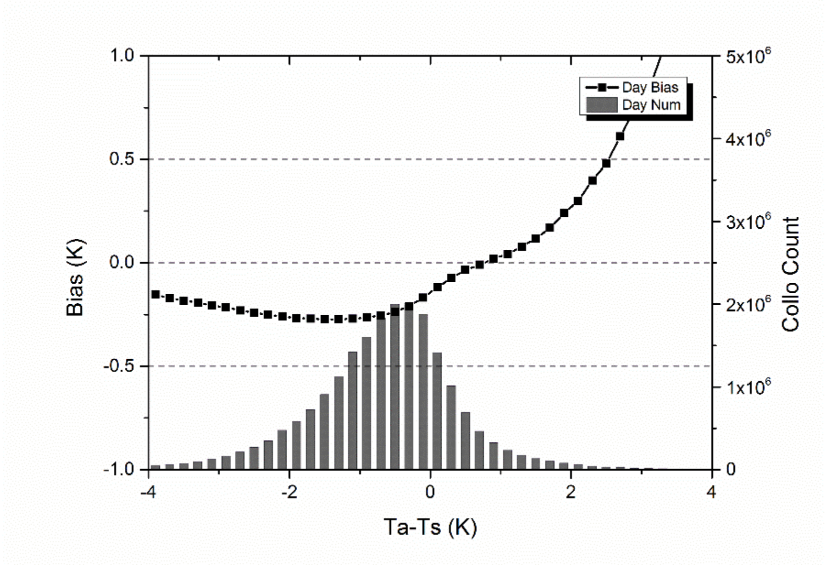


- U10: two-fold effects in daytime – through mixing and cooling; U10 < 6 or > 12 ms^{-1} all leads to near-zero differences.
- Latent Heat: effects are relatively minor and the pattern follows that of U10.

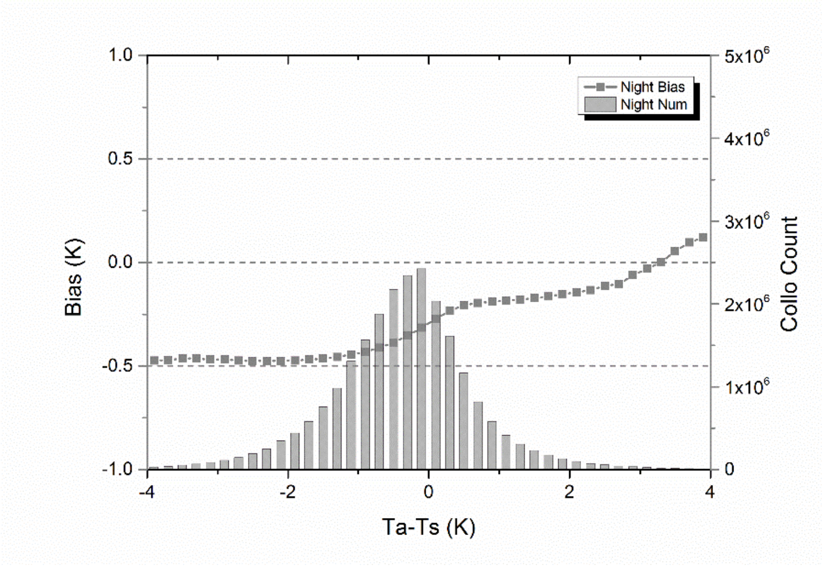


Section 2.2: IR – MW Differences Dependencies on Ta-Ts & SH

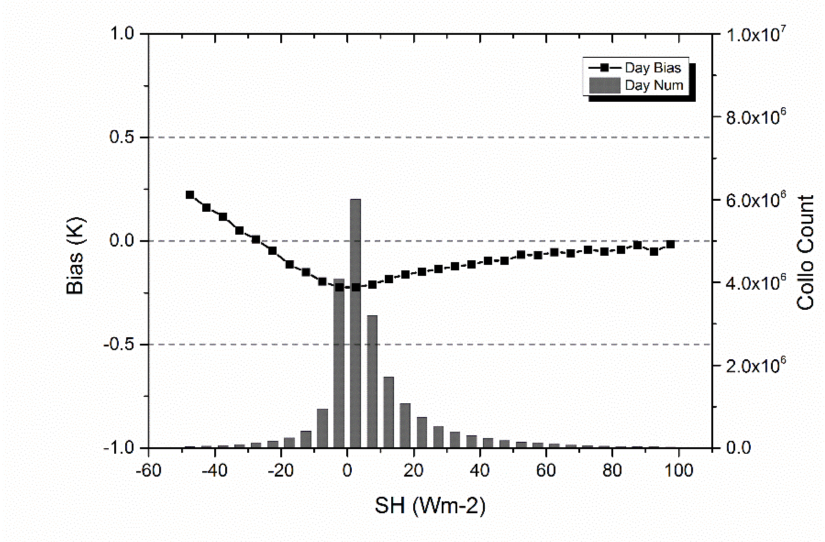
(a) Daytime Ta-Ts



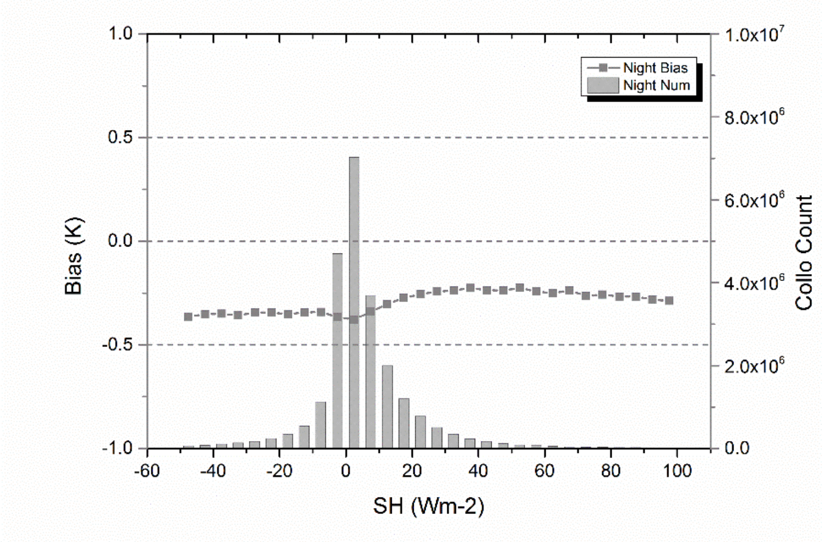
(b) Night-time Ta-Ts



(c) Daytime SH



(d) Night-time SH

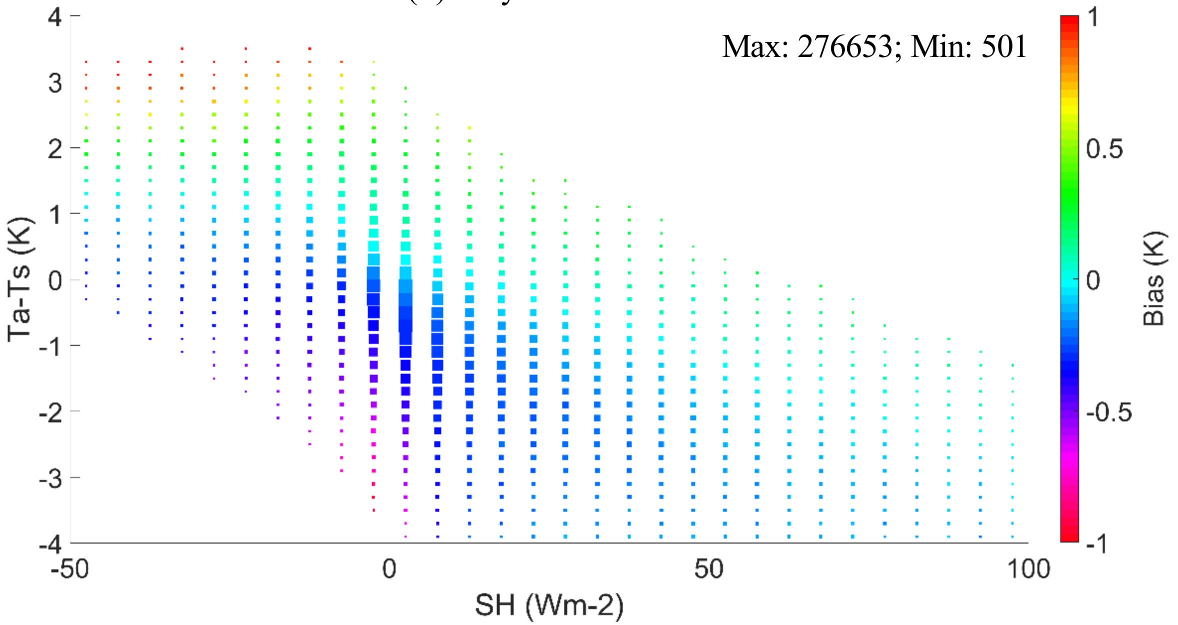


- Ta-Ts: warmer air results in near-zero or even warm skin in the daytime
- Sensible Heat: negative latent heat (into the ocean) results in warm differences; effect is minor in the night-time.

Section 2.2: Dependencies on Environmental Variables

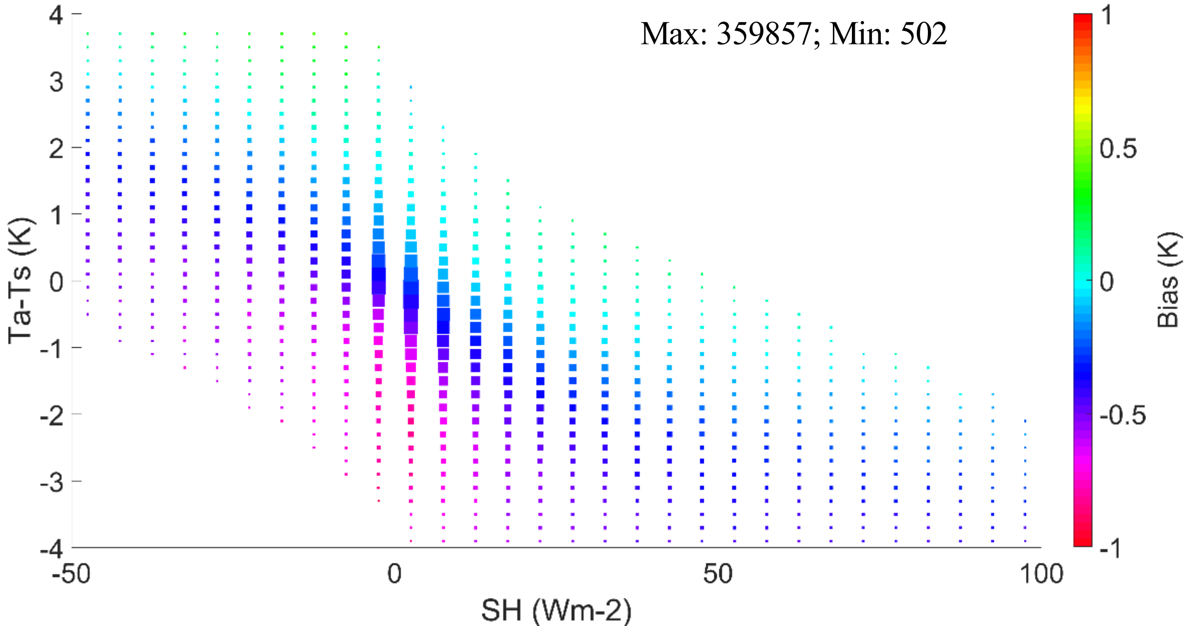
- Ta-Ts + Sensible Heat

(a) Daytime



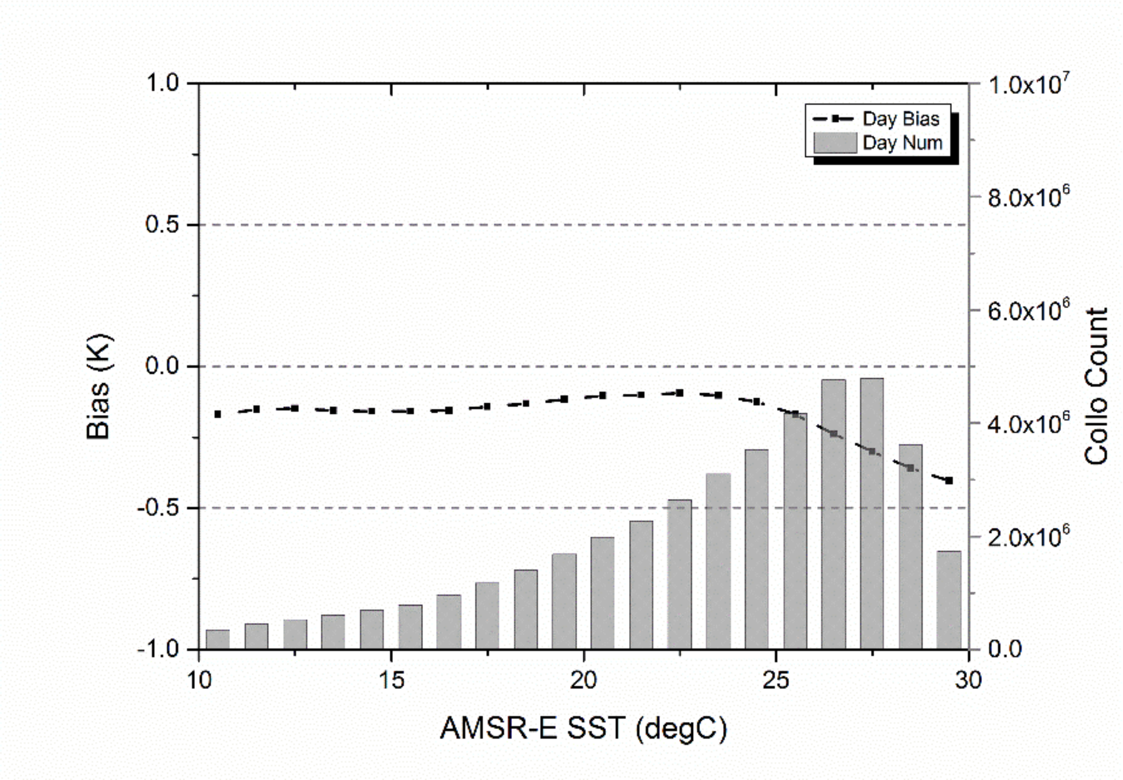
- Ta-Ts: under fixed SH, warmer air typically leads to smaller differences
- Sensible Heat: negative SH are seen for warmer air conditions; effects are also secondary to Ta-Ts.

(b) Night-time

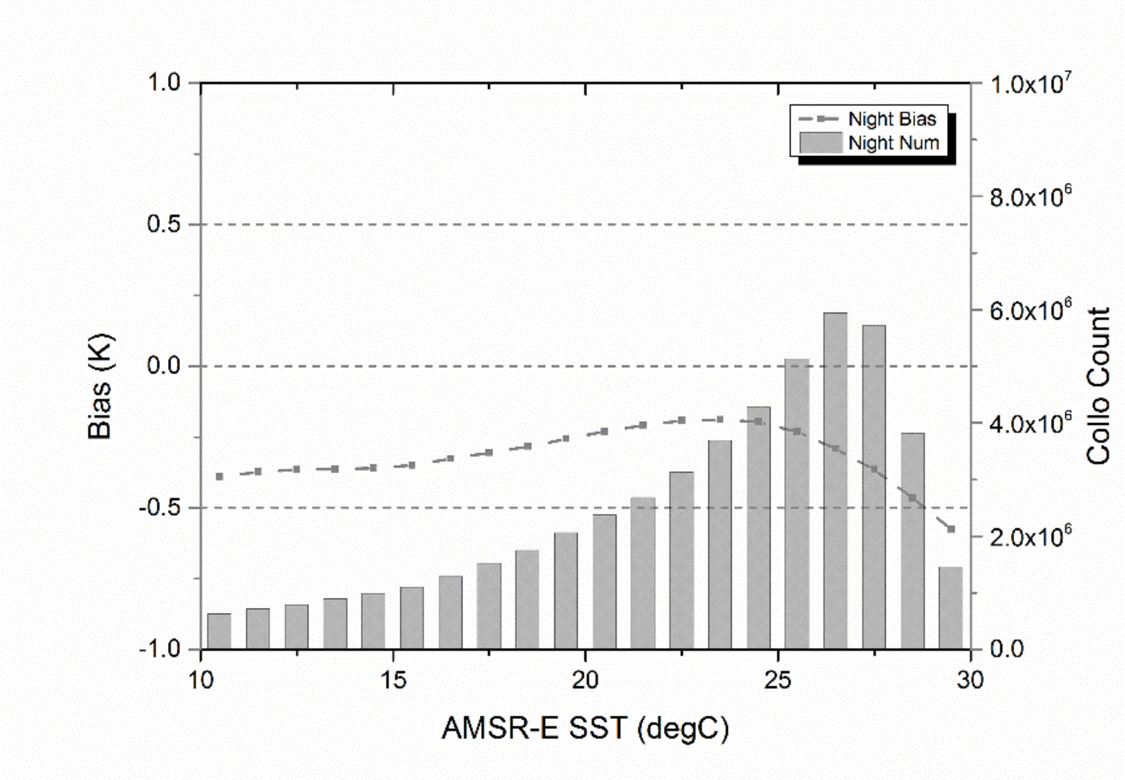


➢ SST Ranges

(a) Daytime SSTamsre



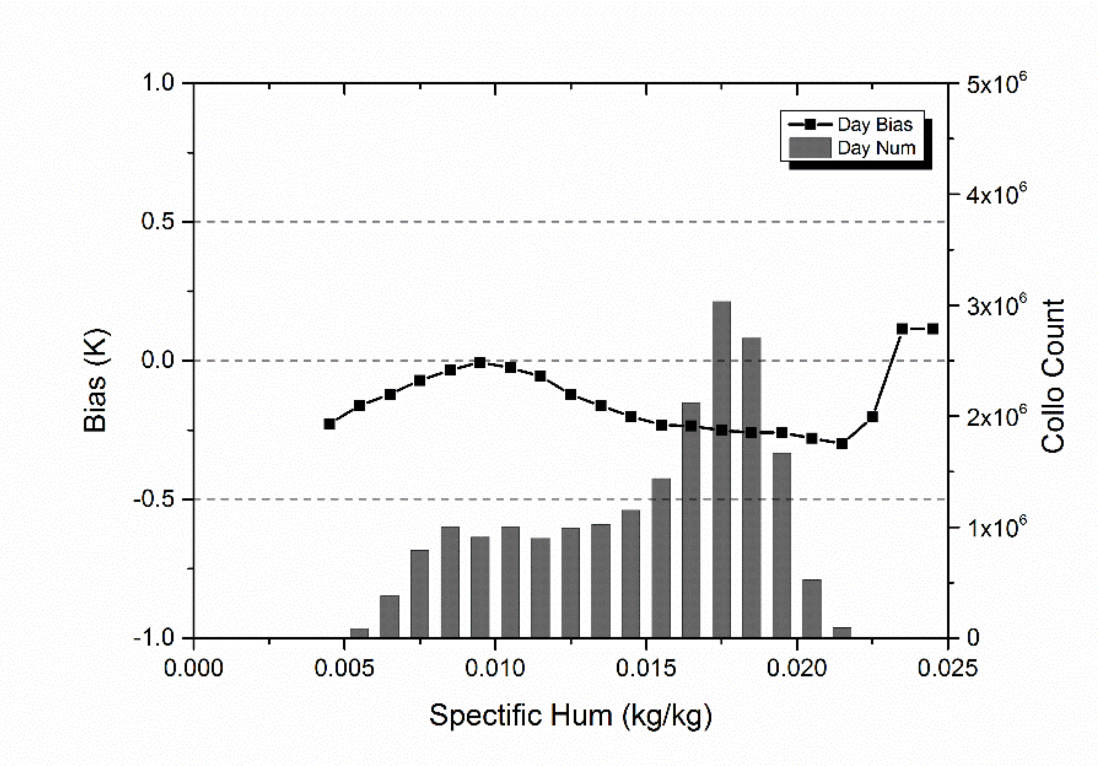
(b) Night-time SSTamsre



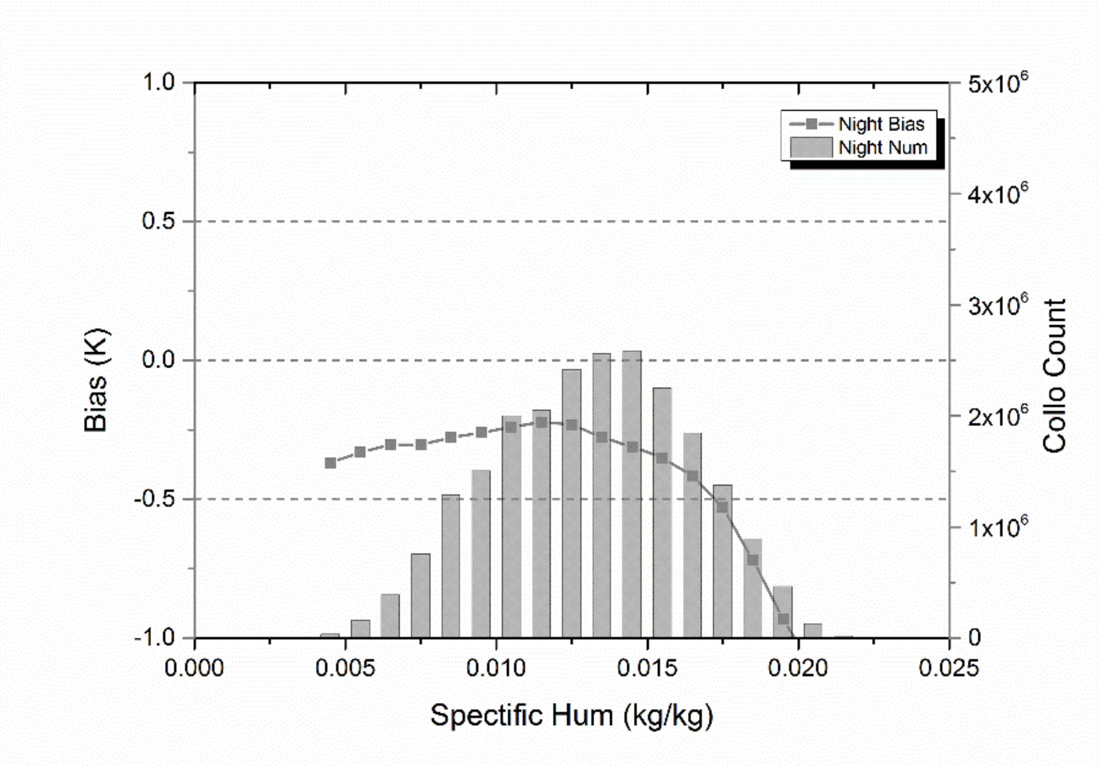
➢ SST: biases are independent of SST ranges from 10 – 25 degC, when warmer SST starts to lead more negative differences. This could also be a MODIS quality issue.

➢ Specific Humidity

(a) Daytime Specific Humidity

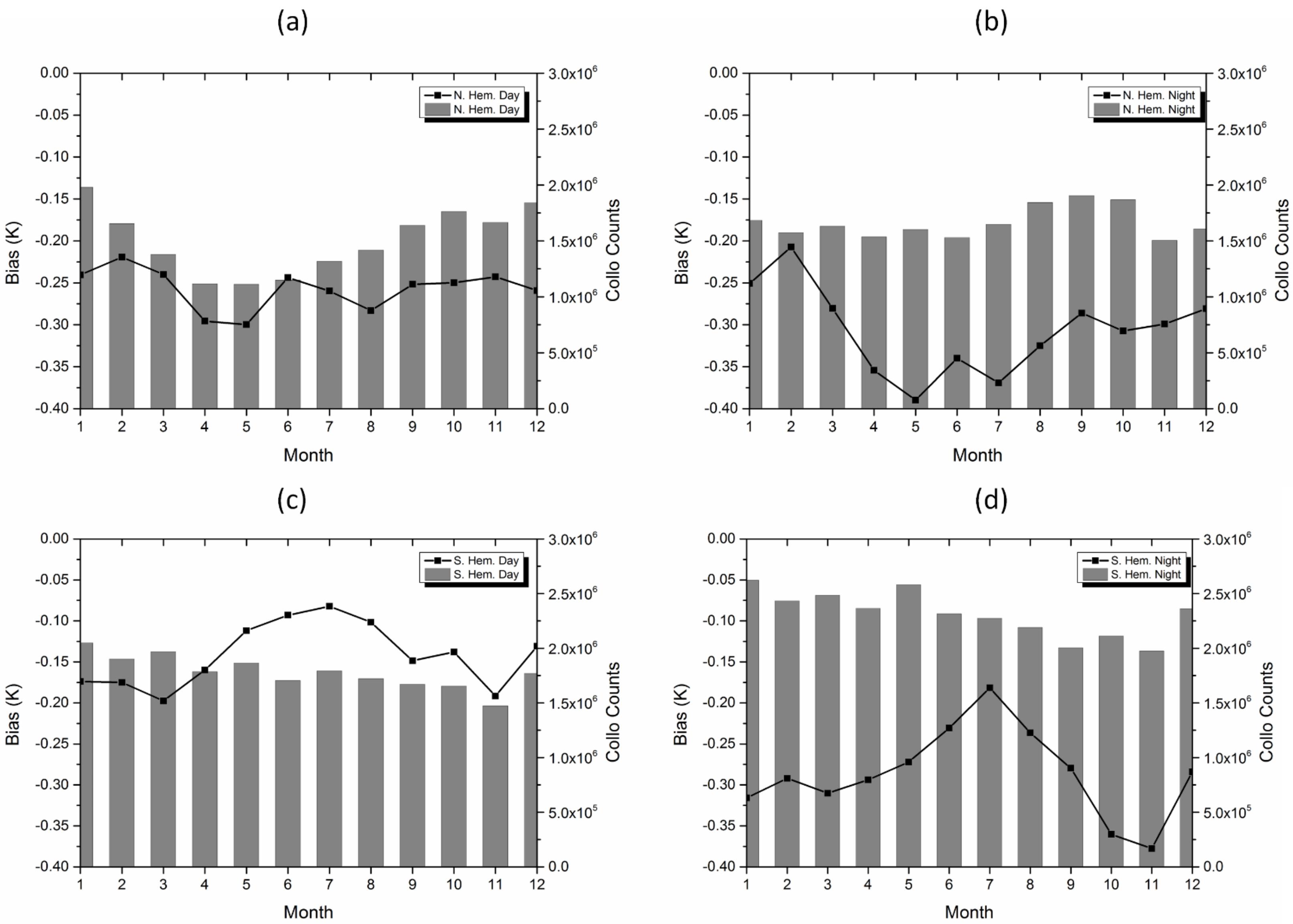


(b) Night-time Specific Humidity



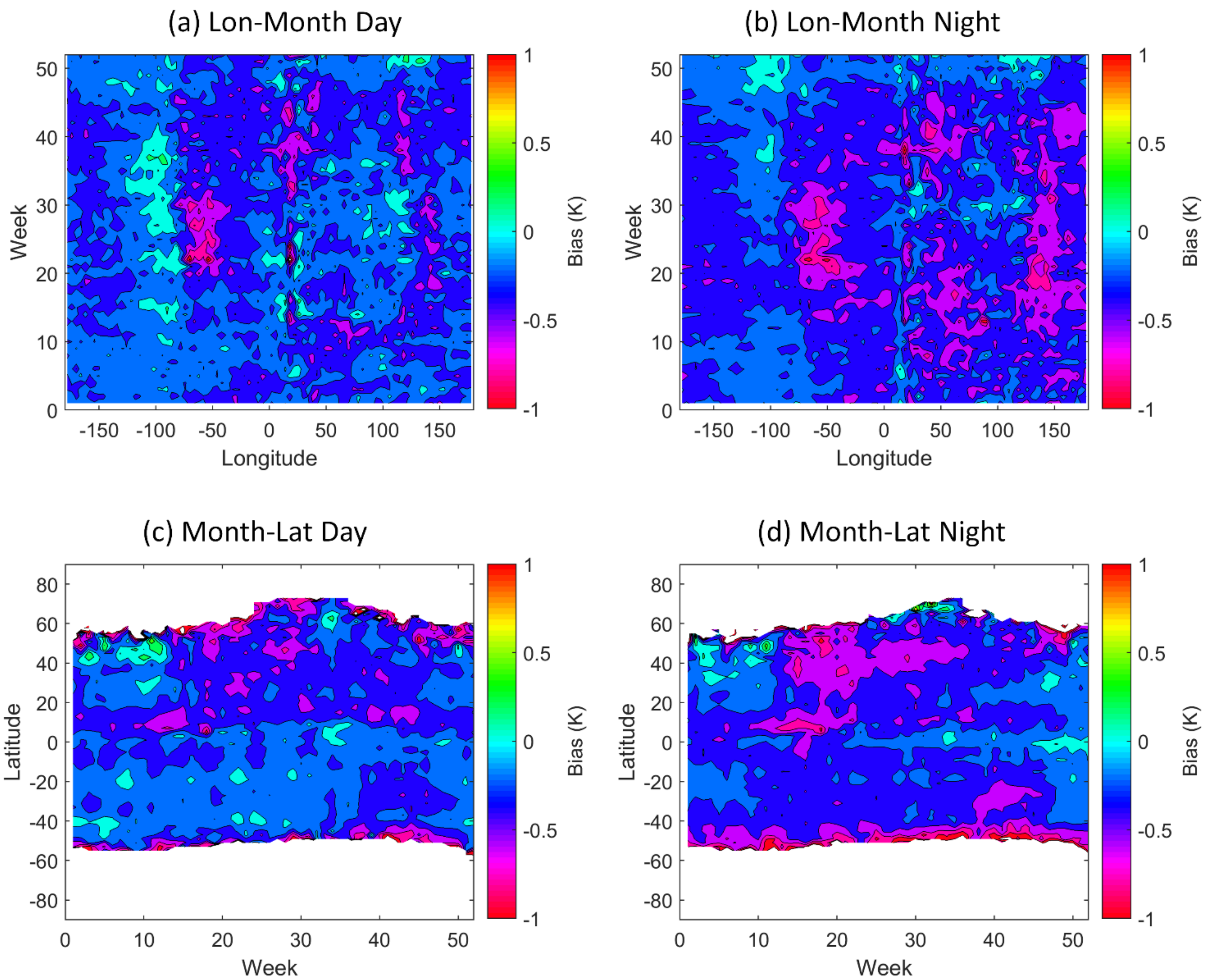
➢ Specific Humidity: large humidity leads to rapid cold skin, which corresponds to the warm waters with high TCWV.

Section 2.4: Seasonal Patterns



- ➢ Stronger/weaker cool skin in summer/winter for both hemispheres, more so for night-time.
- ➢ Could be partially due to the higher TCWV in summer times.

Section 2.4: Seasonal Patterns



- ➢ Saharan dust cooling effect from May to August over the tropical Atlantic Oceans;
- ➢ More negative differences in summer in the northern hemisphere.