Eighth WMO International Workshop on Monsoons

CLOUD AND CONVECTION PATTERNS DRIVEN by DIURNAL OCEAN WARMING

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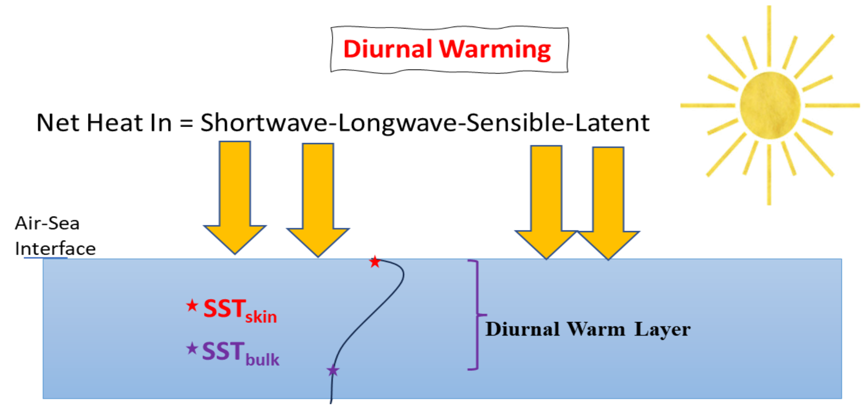
Diurnal Surface Ocean Variability

1. Diurnal Warming:

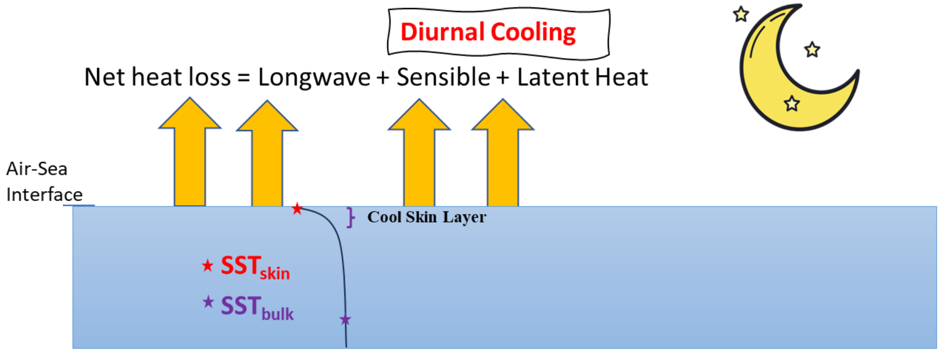
- In light wind surface temperature can warm by several degrees (called as warm layer temperature correction) and diurnal warm layer may be less than a meter deep.
- With the increasing wind speed the surface warming gets mixed down and its effect may become negligible on the computed bulk fluxes.



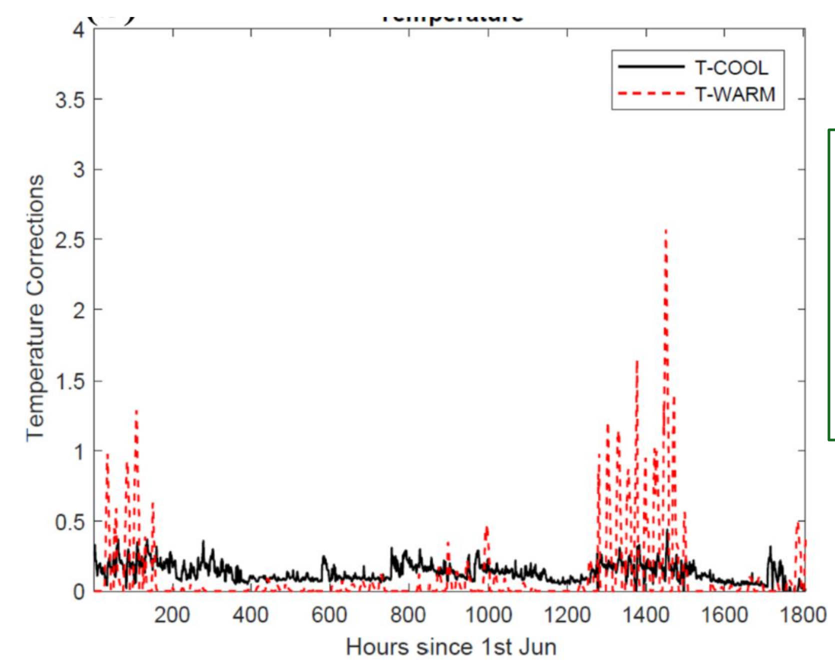
Factors
Seasonality Solar Insolation
Wind/Current Cloud Cover

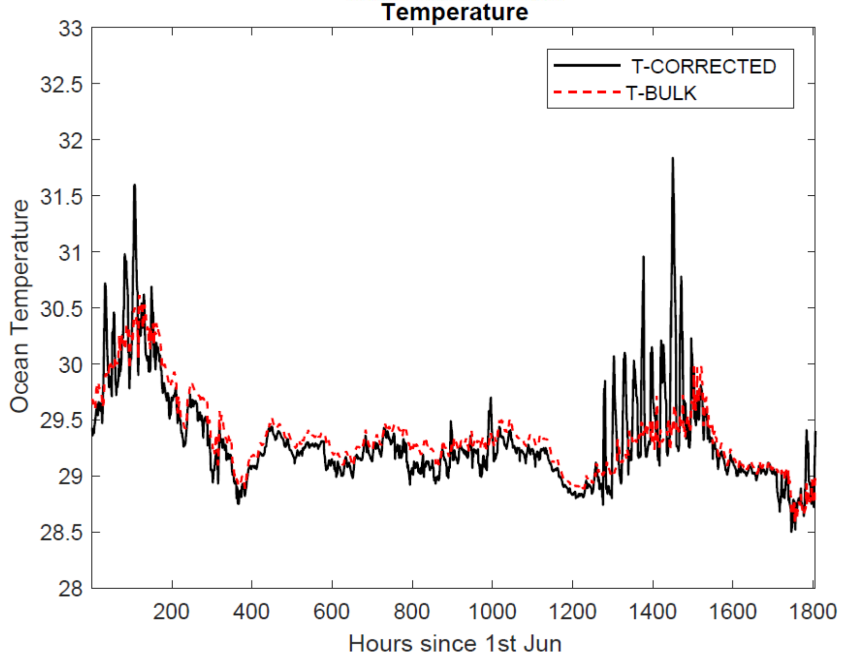
2. Diurnal Cooling:

- Effect of sensible, latent and longwave radiation loss at upper fractions of a millimeter of surface
- The interface is about 0.2-0.5K cooler than the water an mm below the surface.



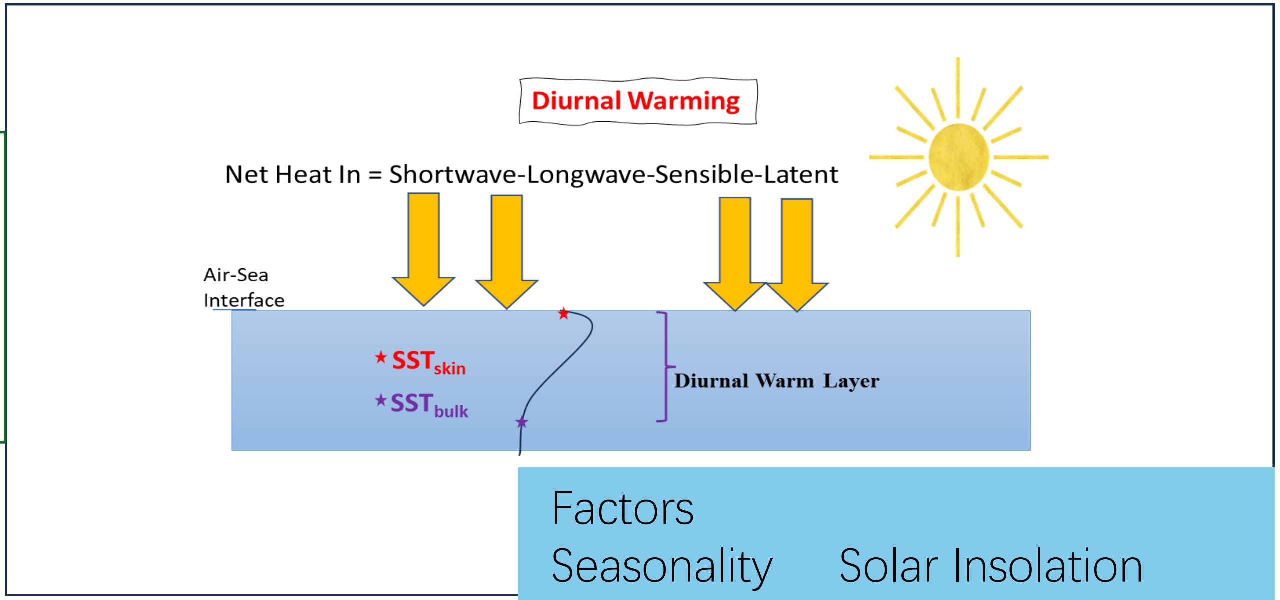
present almost every time



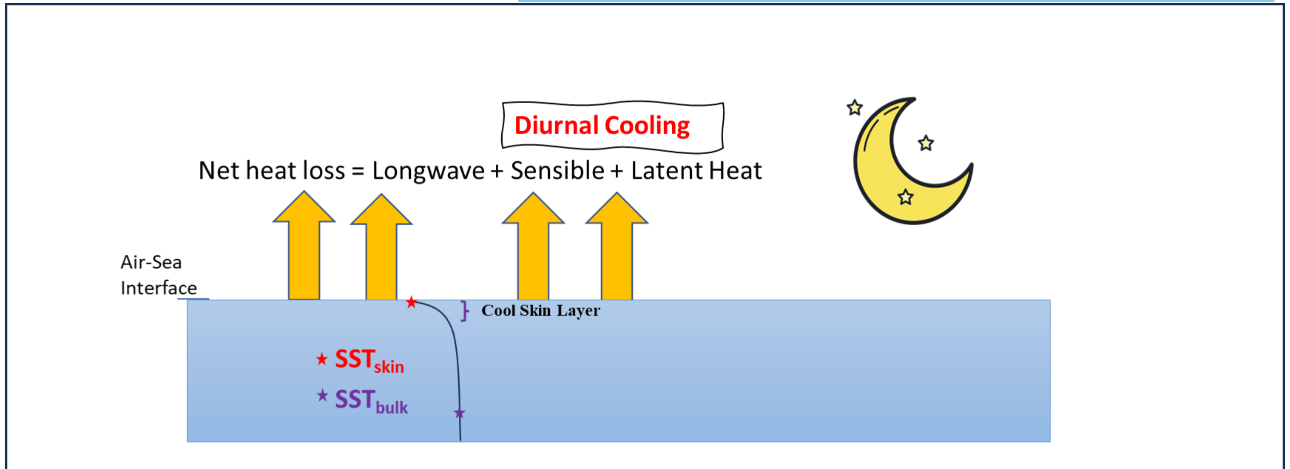


ΔT_w high as 3°C.

ΔT_c ~0.2 to 0.3°C.



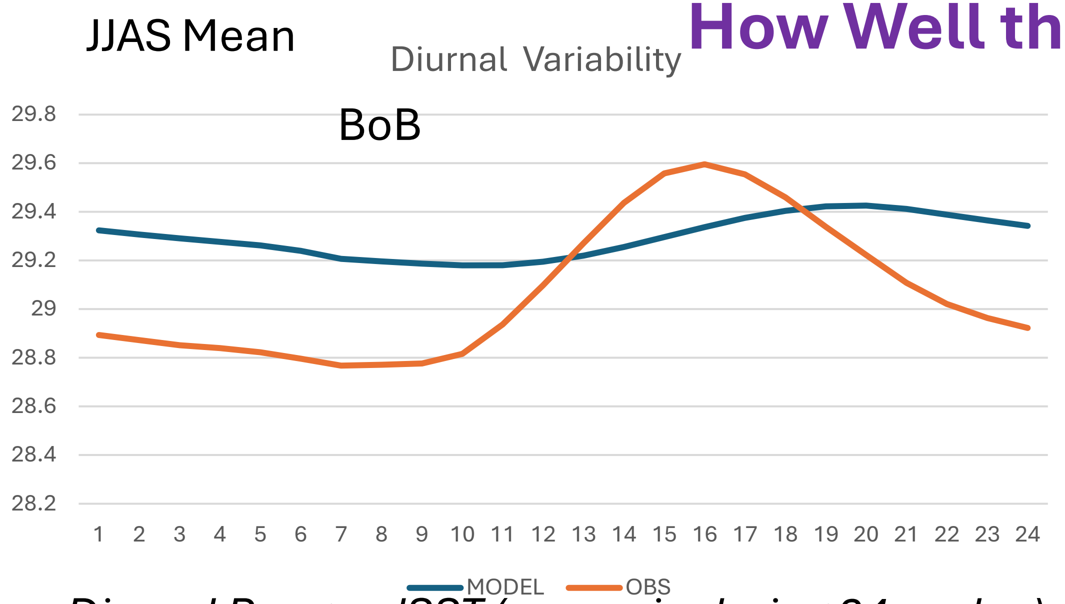
Factors
Seasonality Solar Insolation
Wind/Current Cloud Cover



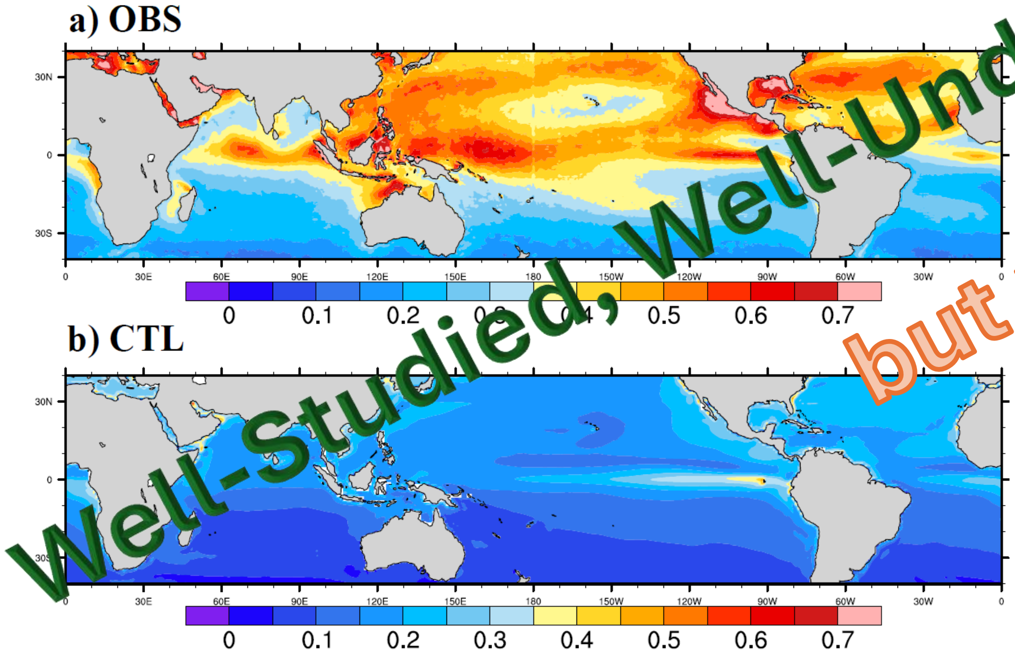
present almost every time

$$T_s = T_m(z_r) + \Delta T_w(z_r) - \Delta T_c$$

How Well the Models Represent Diurnal Variability

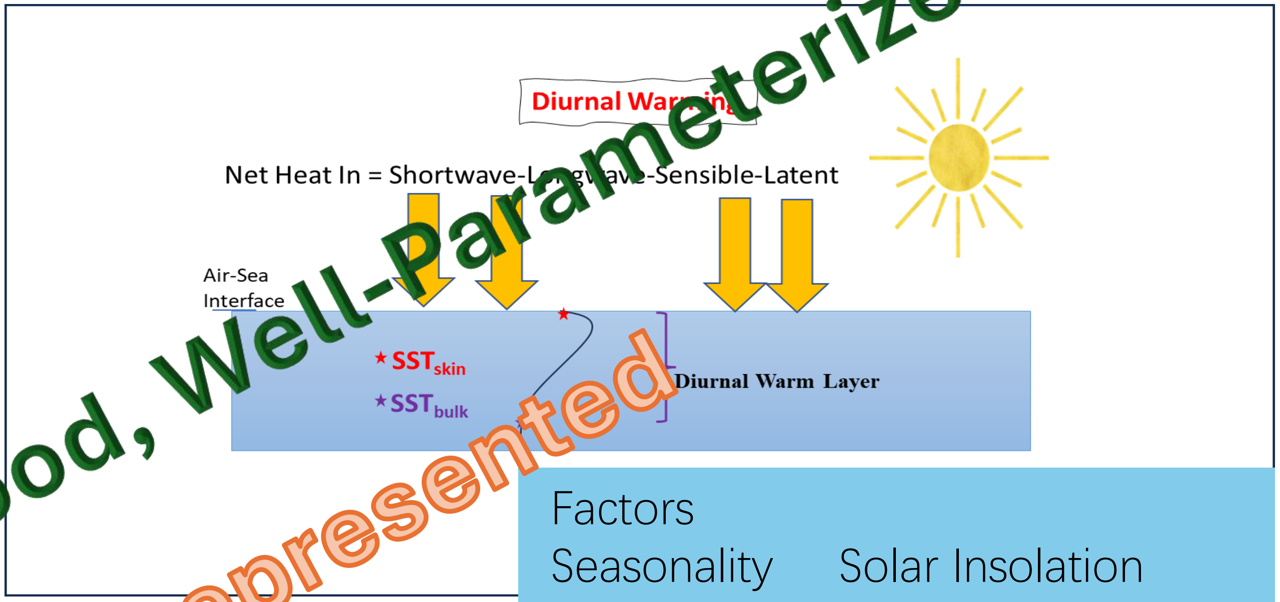


Diurnal Range: dSST (max-min during 24 cycles)



Well-Studied, Well-Understood, Well-Parameterized,

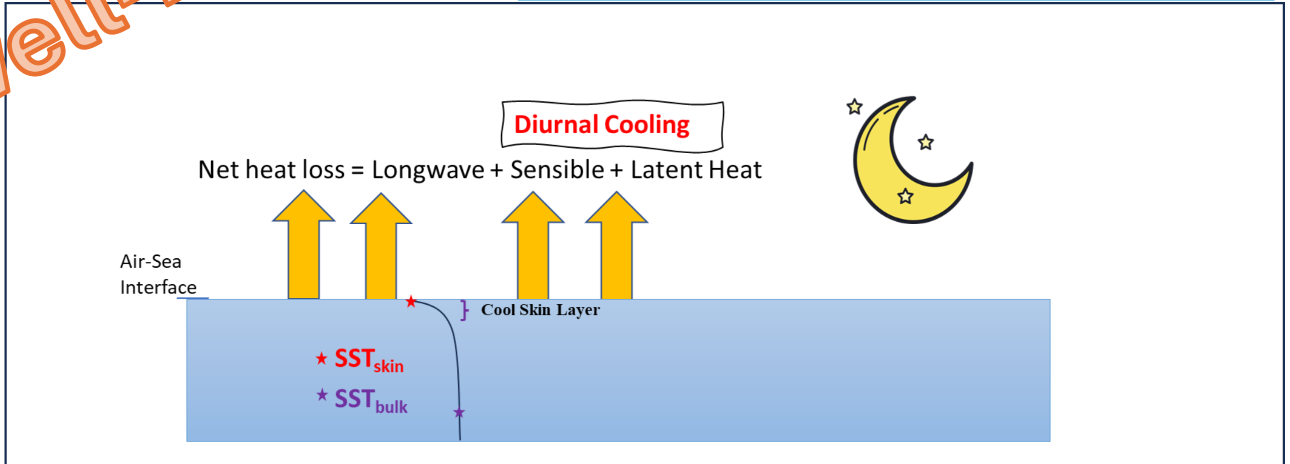
but not well-represented



Factors

Seasonality Solar Insolation

Wind/Current Cloud Cover



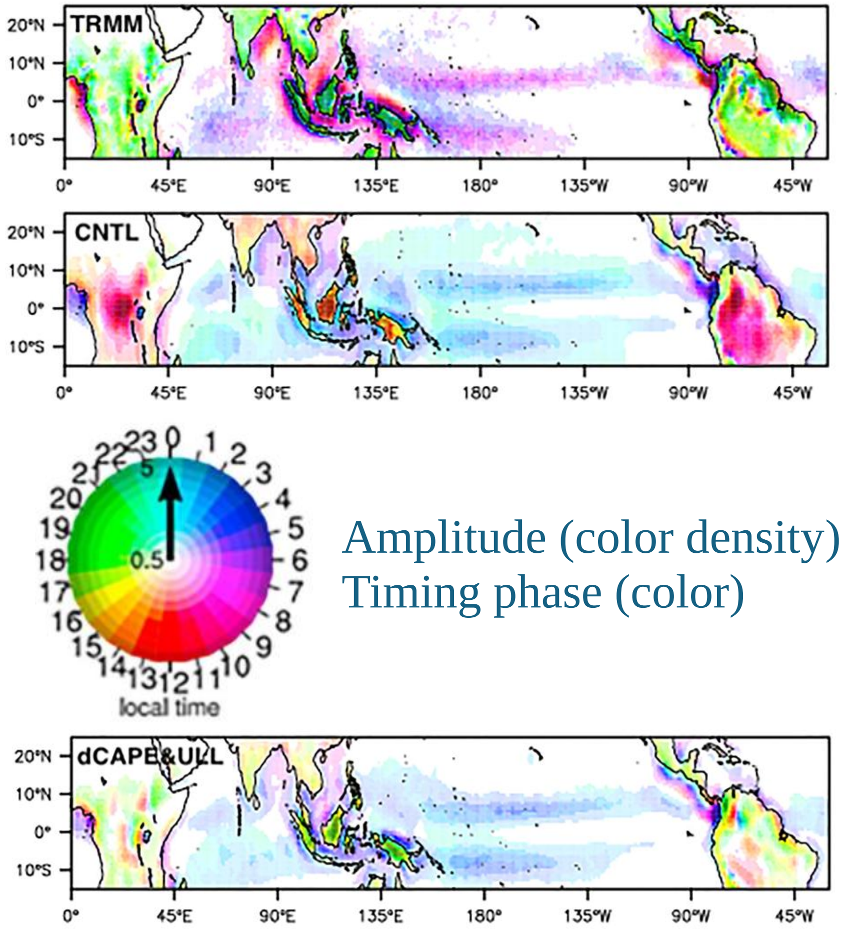
present almost every time

Improper phase and amplitude of diurnal SST

Why to improve Air-Sea Interaction?

There are several challenges using models as forecasting/prediction tool.

Models' inability to simulate realistic phase and amplitude of diurnal cycle in precipitation



Amplitude (color density)
Timing phase (color)

I. Precipitation occurs earlier than reality
II. Diurnal amplitude is underestimated

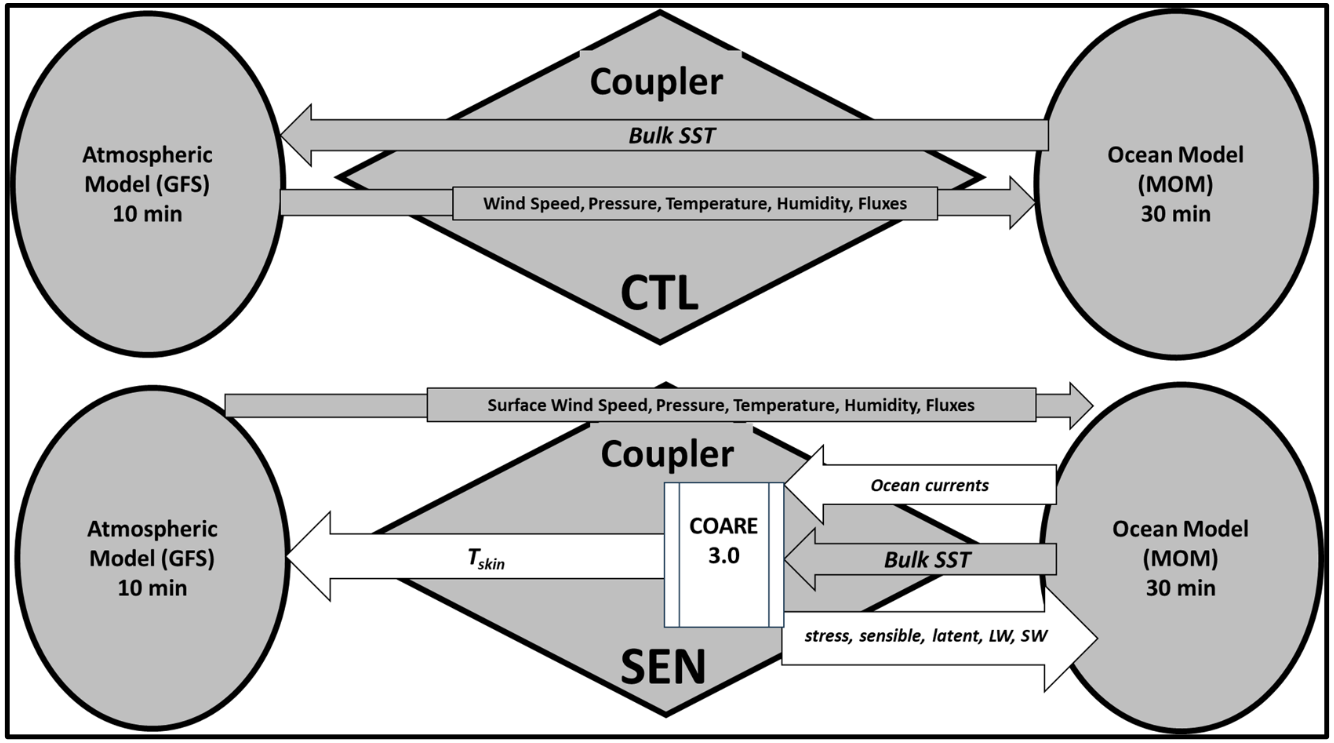
Xie et al., (2019): Improved Diurnal Cycle of Precipitation With a ***Revised Convective Triggering Function.***

- ✓ **Timing of diurnal precipitation has shown improvements.**
- ✓ **No significant improvement in diurnal amplitude of precipitation**

- **Chakraborty and Krishnamurti, (2008):** Improving diurnal cycle in the tropics by ***unified cloud parameterization scheme (multi-model super-ensemble)***
- **Ganai et al., (2016):** Impact of revised simplified Arakawa-Schubert ***(RSAS) convective parameterization***

- **Representation of diurnal air-sea interaction for organized convection** Dai and Trenberth (2004)
- **Atmospheric model is sensitive to diurnal variations in SST, and flux** Clayson and Chen (2002)

Representation of Sea Surface Temperature in Models



(a) *Cool skin and Warm layer Corrections: Atmospheric boundary condition*

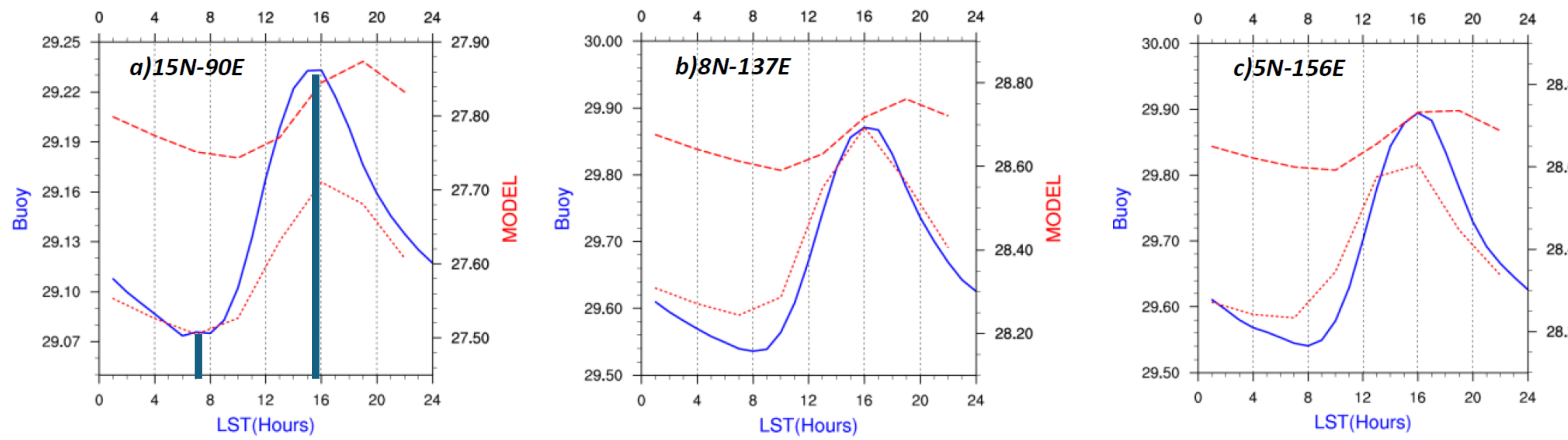
- One of the major changes between CTL and SEN
- The corrected ocean temperature is then passed to atmospheric model as the boundary forcing.

(b) *Fluxes from COARE: Oceanic Boundary Conditions*

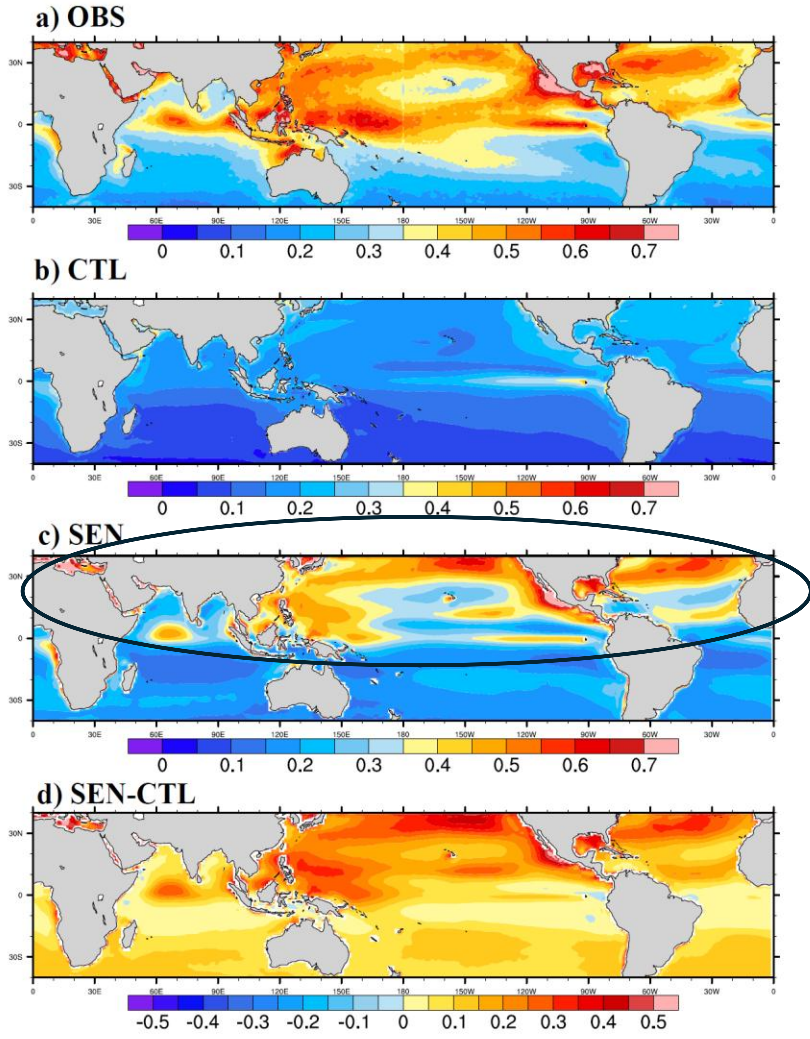
- COARE computed fluxes are used as a boundary forcing for the Ocean Model.

Representation of Diurnal Cycle

Study Period 1998-2008 JJAS



*Climatological Variation of SST w.r.t. Local Solar Time (LST) in moored buoy (blue solid line), CTL (**red dashed line**), and SEN (red dotted line) run.*



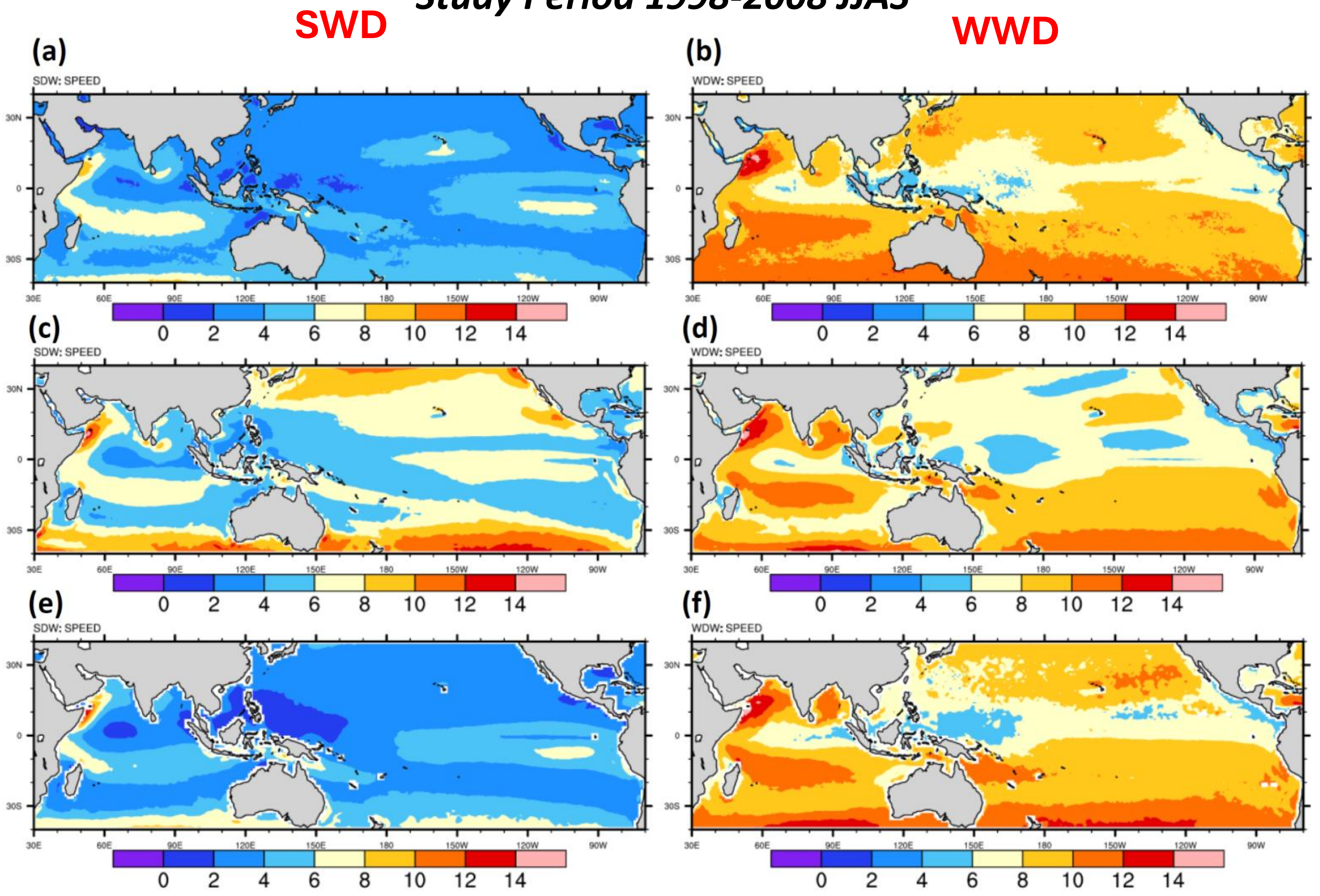
- **Phase: Timing of Maxima and Minima**
- **Amplitude (range) of diurnal SST (maxima-minima)**

Can be improved through diurnal skin temperature parameterization.

Mean dSST (max-min during 24 cycle)

Ocean Diurnal Warming and the Atmosphere

Study Period 1998-2008 JJAS



SDW : *When dSST > (mean + 1 STD) dSST*
WDW: *When dSST < (mean - 1 STD) dSST*

- SWD are events when diurnal warming > 1 STD of seasonal mean warming
- WWD are events when diurnal warming < -1 STD of seasonal mean warming

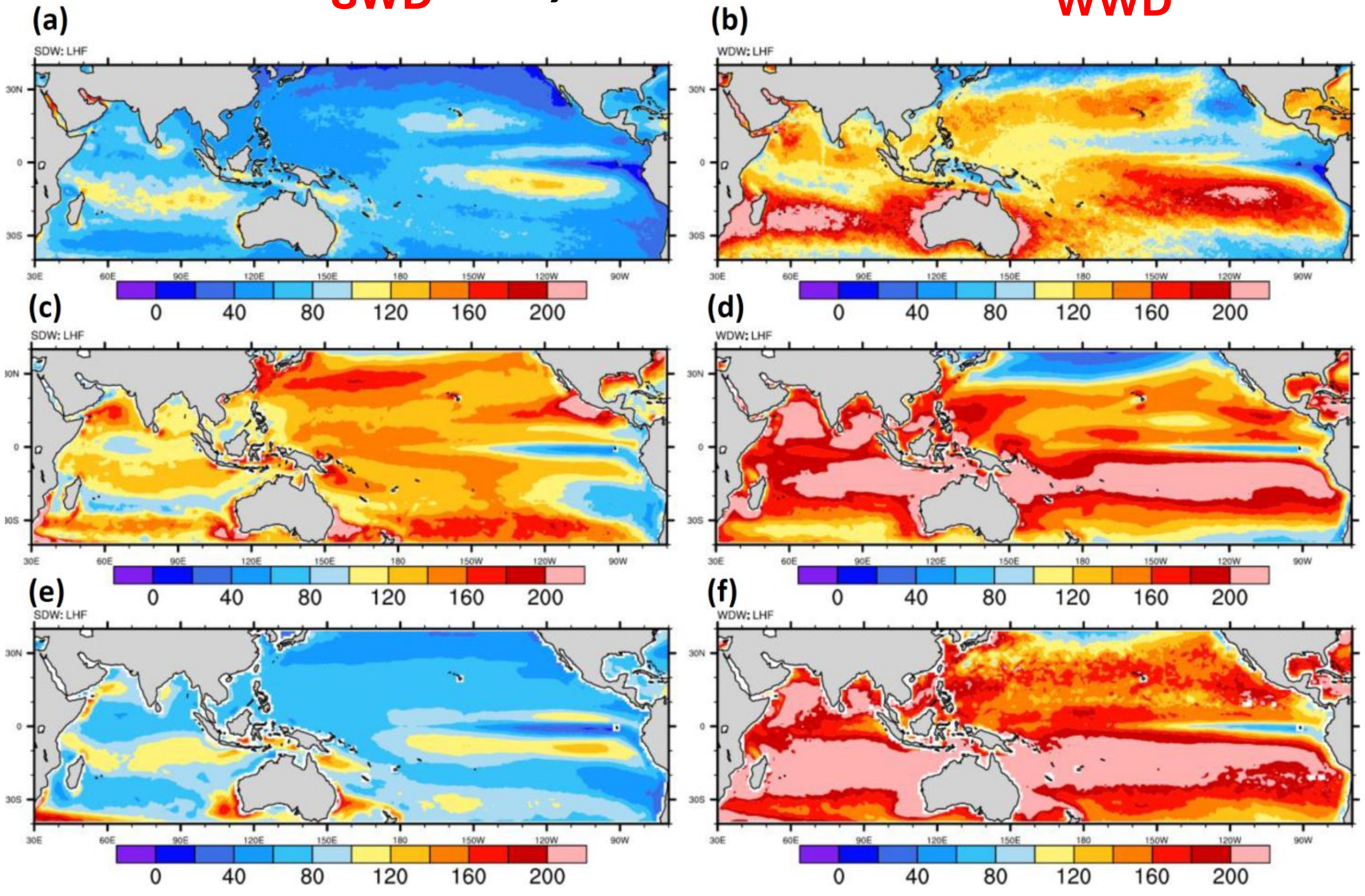
- JJAS average(Composite) horizontal wind (m/s) speed during SWD and WWD are plotted here.

10m WIND SPEED (m)

❖ **Whenever diurnal warming is higher, CTL doesn't simulate the wind speed properly. Wind speed is largely overestimated**
❖ **Whenever diurnal warming is lower, CTL and SEN simulations are closer. But CTL underestimate at few locations**

Ocean Diurnal Warming and the Atmosphere

SWD ***Study Period 1998-2008 JJAS*** **WWD**



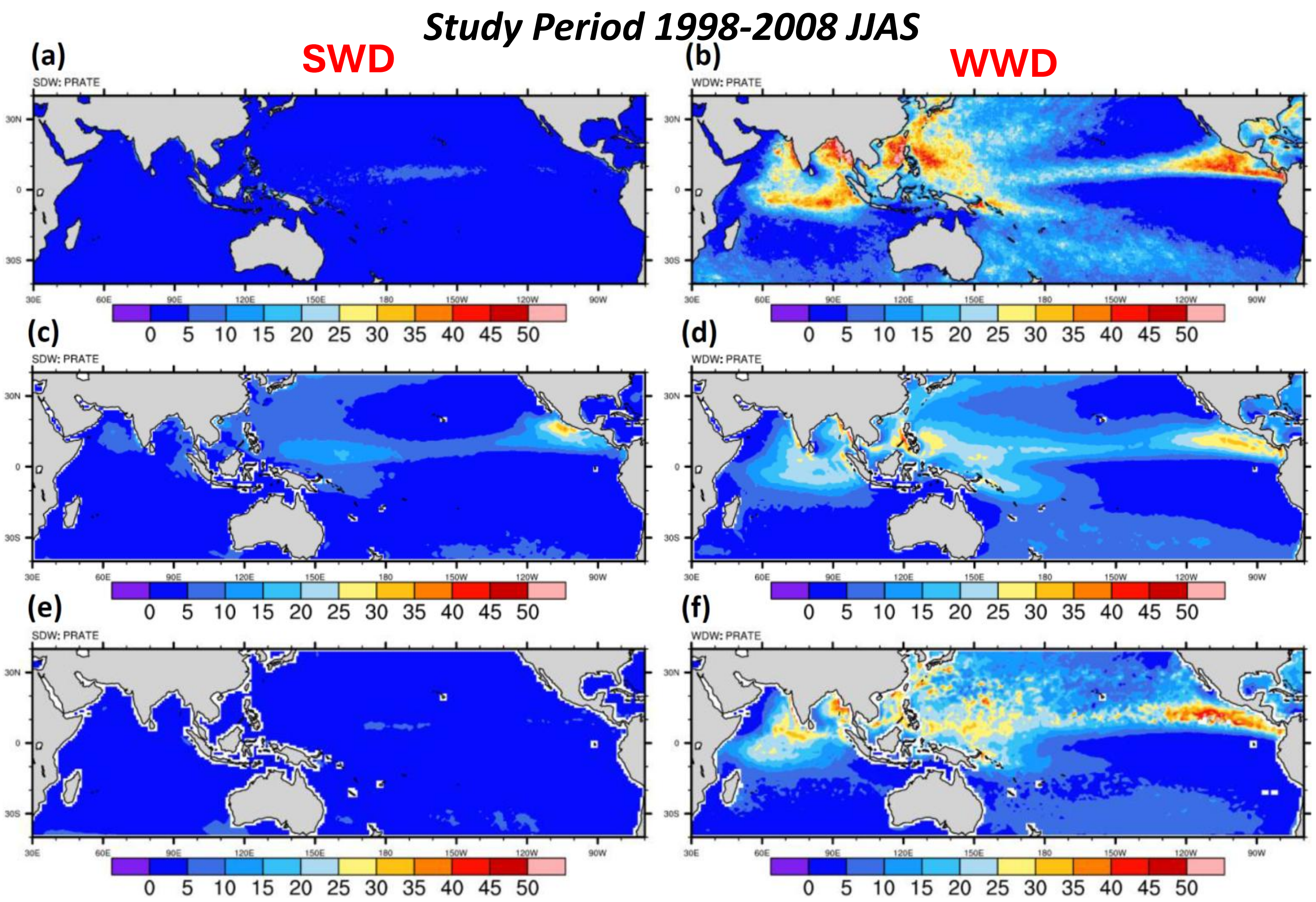
SDW : *When dSST > (mean + 1 STD) dSST*
WDW: *When dSST < (mean - 1 STD) dSST*

- JJAS average(Composite) surface latent heat (W/m^2) during SWD and WWD are plotted here.

Latent Heat Flux (W/m^2)

- **Whenever diurnal warming is higher, CTL produces higher outgoing LHF most of the oceans which is not realistic.**
- **SEN run produces a realistic LHF because of the revised SST and flux scheme.**

Ocean Diurnal Warming and the Atmosphere



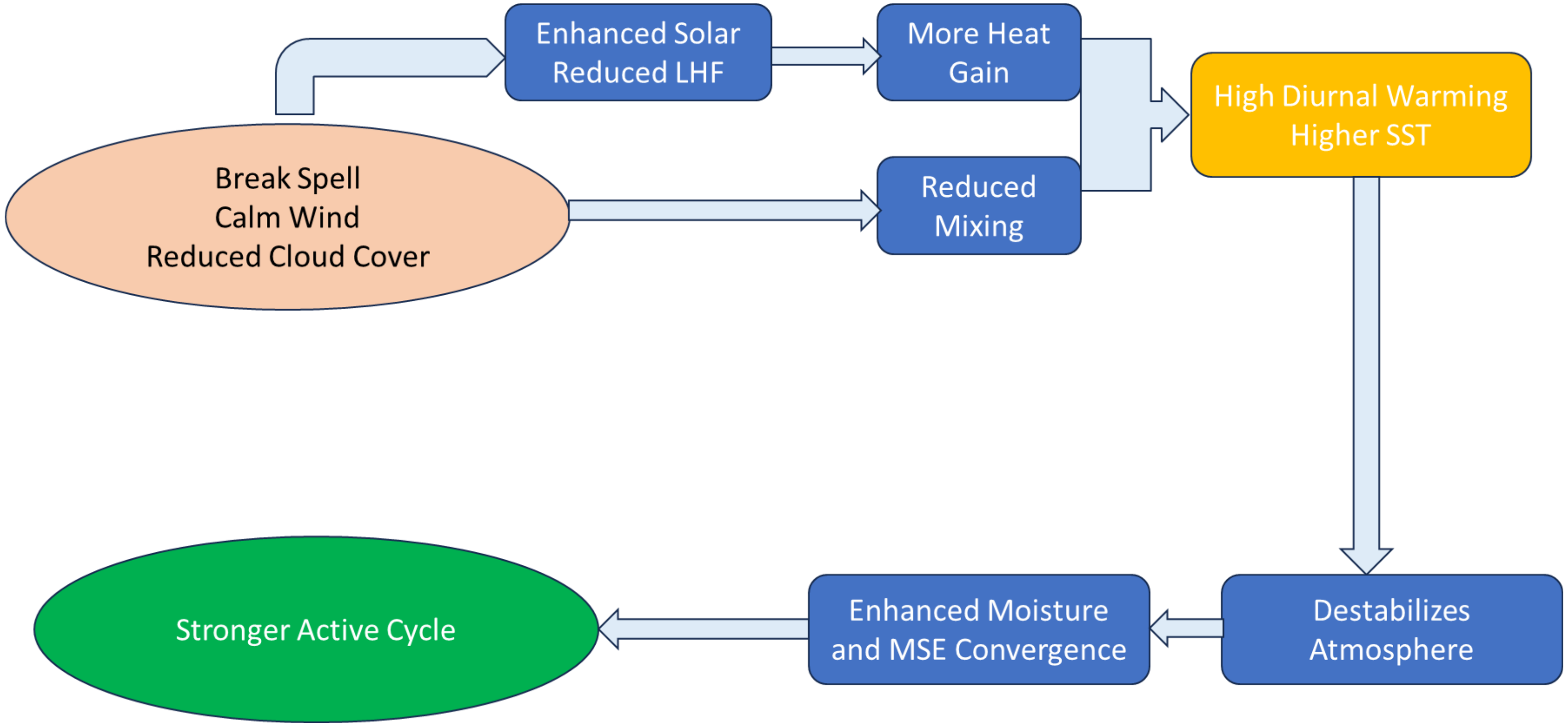
SDW : *When dSST > (mean + 1 STD) dSST*
WDW: *When dSST < (mean - 1 STD) dSST*

- JJAS average(Composite) precipitation (mm/hr) during SWD and WWD are plotted here.

Rainfall (mm/day)

- **Whenever diurnal warming is higher, CTL produces higher rainfall over eastern and western Pacific and BoB which is not realistic. Also the magnitude of rainfall is overestimated at most of the locations.**

Ocean Diurnal Warming and Atmosphere/Convection



- This suggests that the SST diurnal variations may act to (i) destabilize the atmosphere through surface fluxes, (ii) deepen the atmospheric mixed layer, and (iii) help air parcels to overcome the convective inhibition.

Bellenger et al., (2010)

Home > Climate Dynamics > Article

Towards a realistic MISO simulation: impact of rectification

Original Article | Published: 08 January 2024

Volume 62, pages 3089–3107, (2024) Cite this article

Ocean Diurnal Warming and Cloud

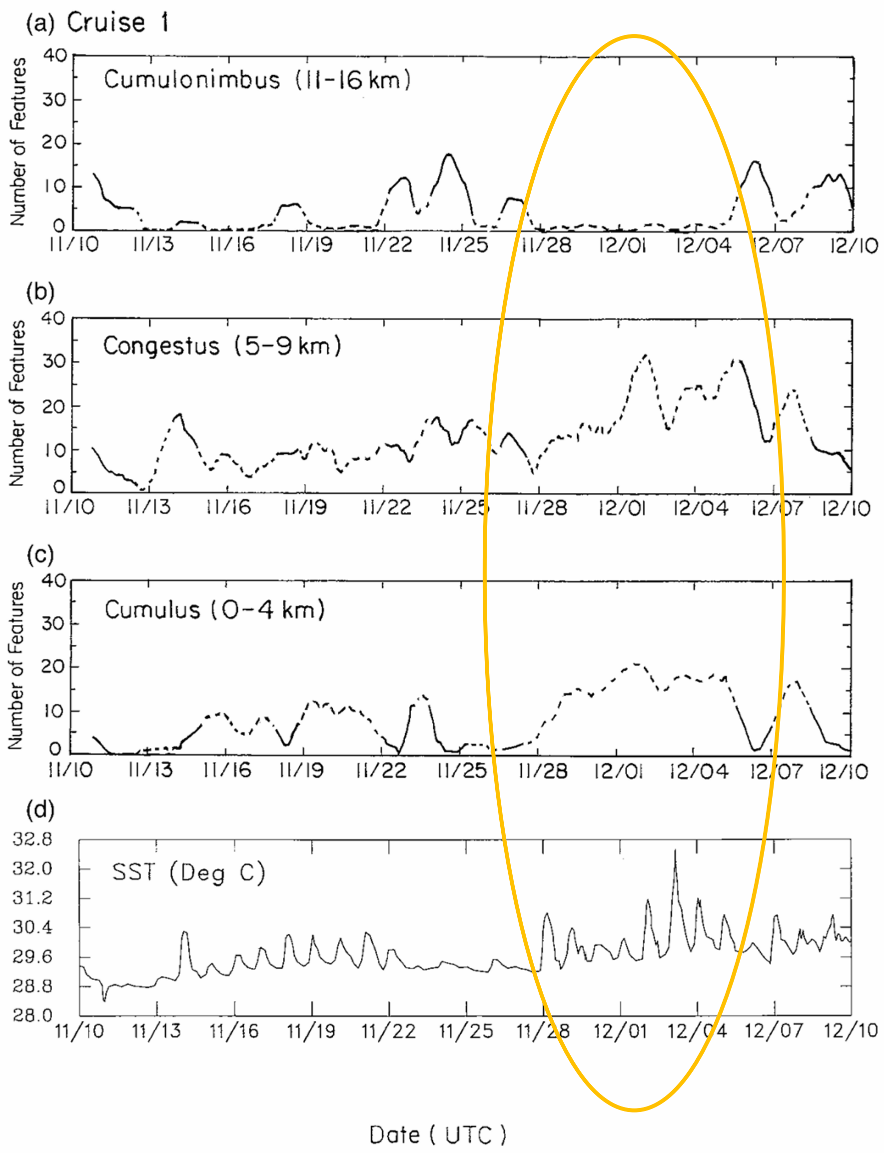
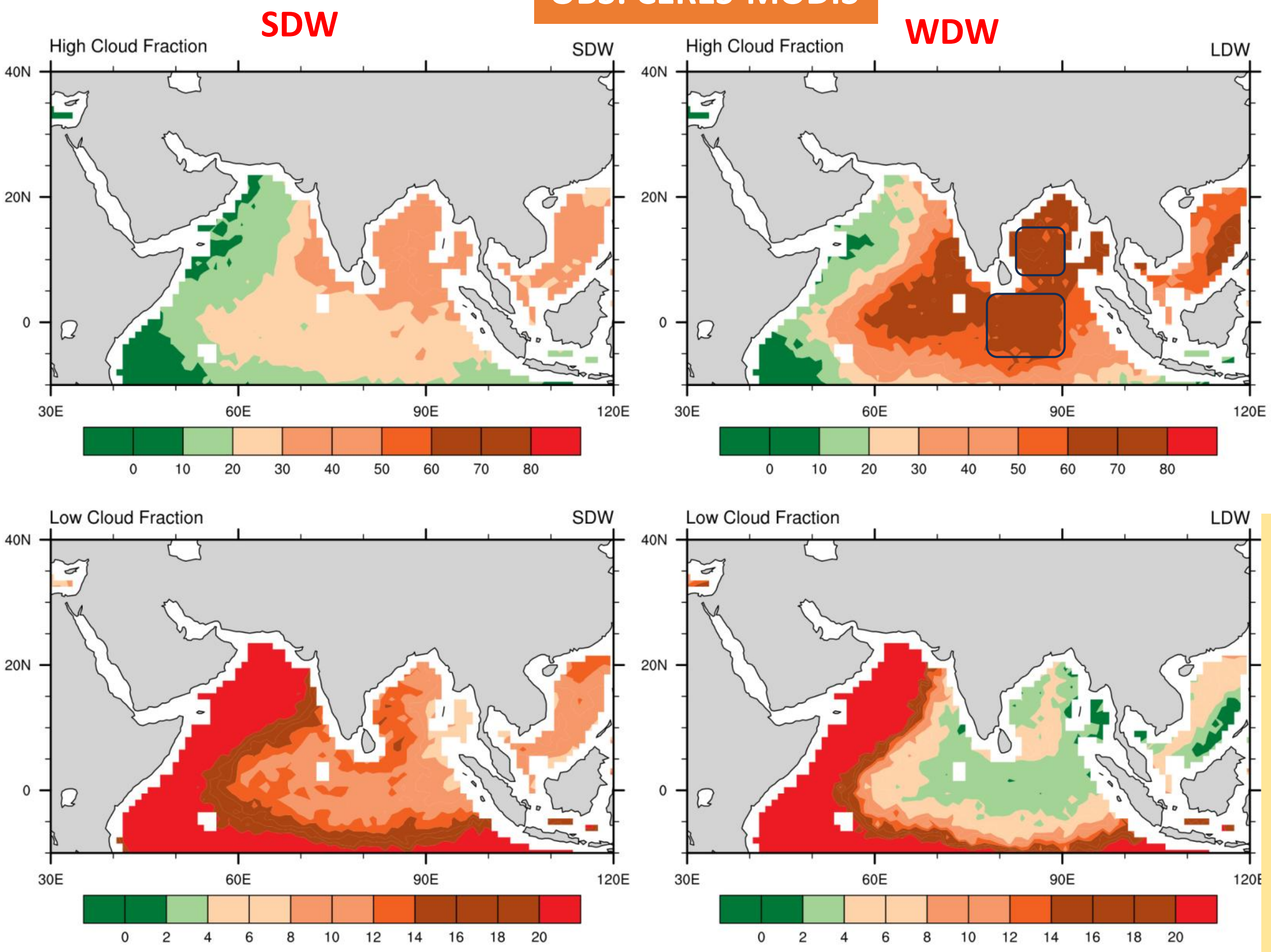


FIG. 9. Daily-averaged number of low or cumulus (0–4 km), middle or congestus (5–9 km), and high or cumulonimbus (11–16 km) radar-echo tops for cruise 1 of the R/V *Vickers*, and SST at IMET buoy at 2°S, 156°E. In upper three panels, solid curve segments refer to periods when convective echoes organized on the MCS scale (>100 km) and dotted segments to periods when only sub-MCS or isolated cells existed.

- Johnson et al. (1999) showed that cumulus (0-4 km) congestus (5-9 km) clouds are most prevalent during light wind conditions in the presence of a strong diurnal cycle in SST.
- These clouds occur most frequently in the late afternoon, with a behavior that resembles more closely the diurnal cycle inland convection, suggesting that they may be triggered by the diurnal cycle in SST

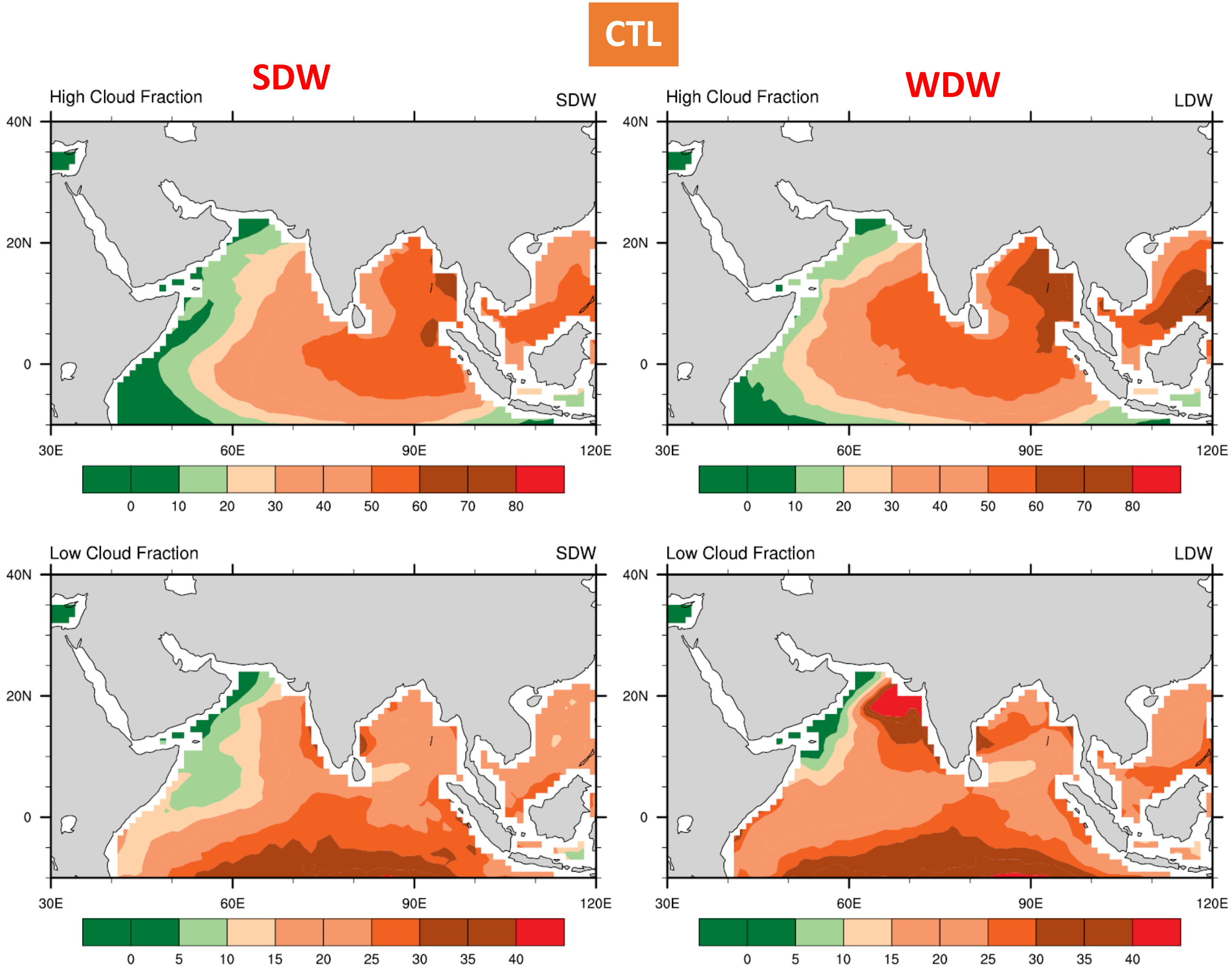
SDW : *When dSST > (mean + 1 STD) dSST*
WDW: *When dSST < (mean - 1 STD) dSST*

OBS: CERES-MODIS

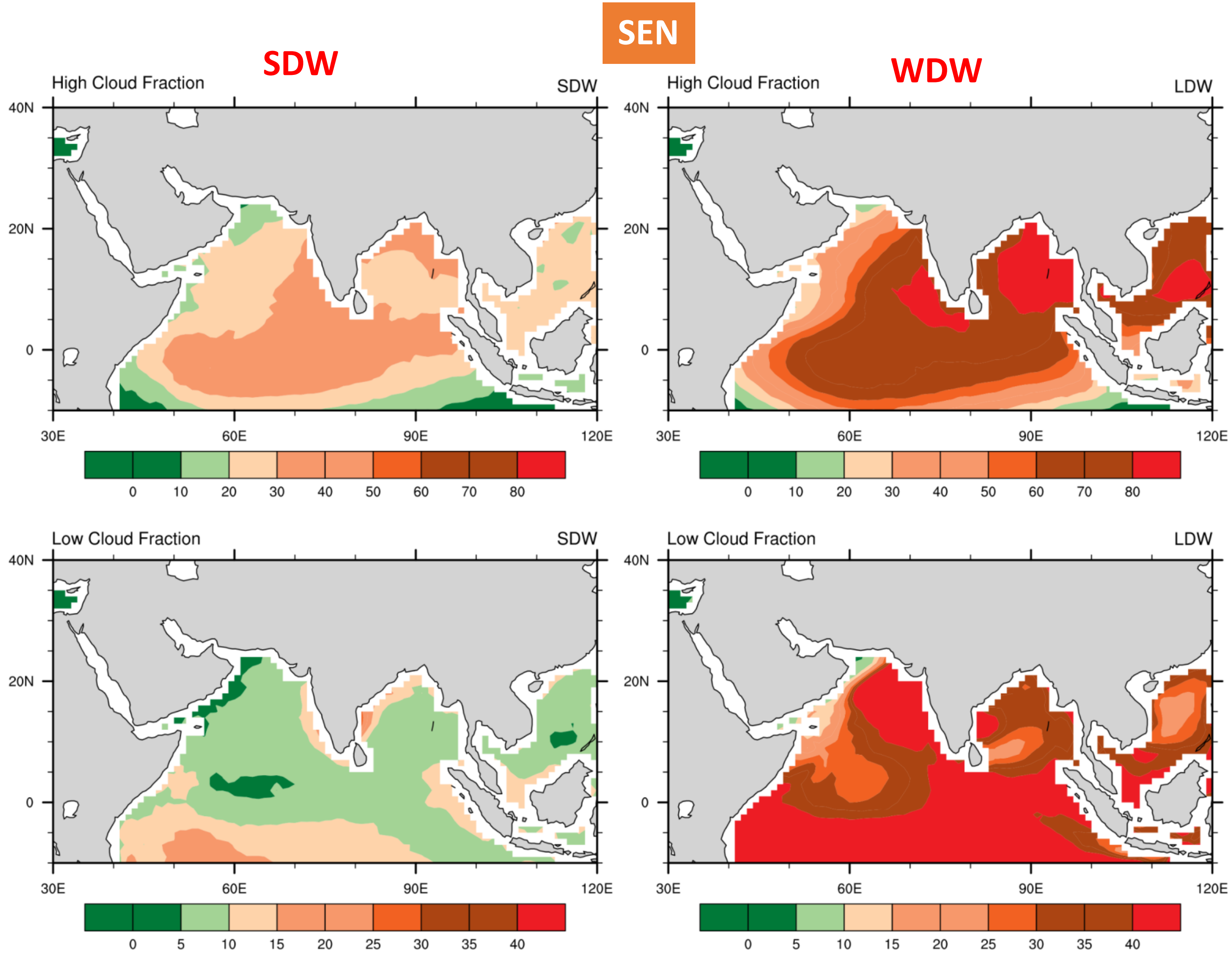


- Reduced high cloud fraction during SDW days. SDW days are accompanied by weak winds and increased solar insolation (suppressed phase).
- Abundance of high cloud during WDW days. WDW days are accompanied by strong winds and reduced solar insolation (active phase).

- During SDW days, a higher fraction of low clouds as compared to WDW days.
- Therefore, strong diurnal ocean warming triggers shallow convection with increased low clouds.
- These clouds gradually moisten the lower atmosphere, creating favorable conditions for the growth of deeper clouds and an active phase of convection.



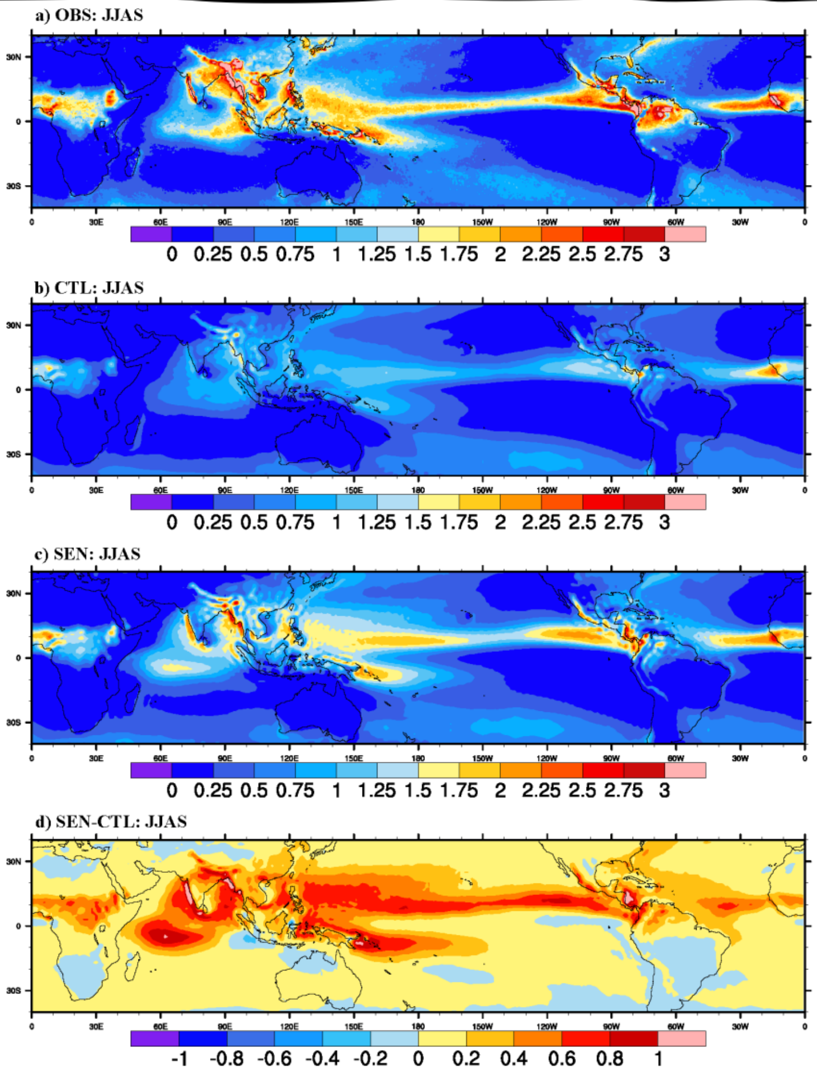
- The model could not reproduce the variability of high cloud or low cloud fraction during SDW and WDW.
- No significant increase in high cloud fraction during WDW days.
- But the variability of low cloud fraction is exactly opposite to that in observation.



- Model reproduced the variability of high cloud fraction during SDW and WDW well.
- But the variability of low cloud fraction is exactly opposite to that in observation.
- During SDW, the low cloud fraction is smaller than that during WDW, unlike the increased low cloud fraction during SDW in observation.
- Also, low cloud fractions during WDW days are unexpectedly high. *What is the origin?*

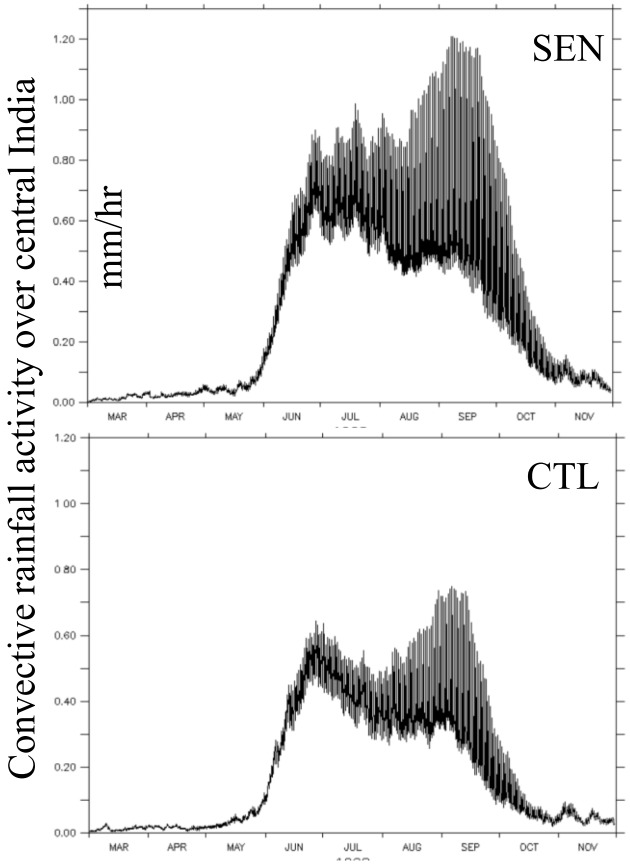
Therefore, in the current configuration of the model, although the enhancement in cloud cover happens during WDW day, the conversion of low to high clouds is not reproduced.

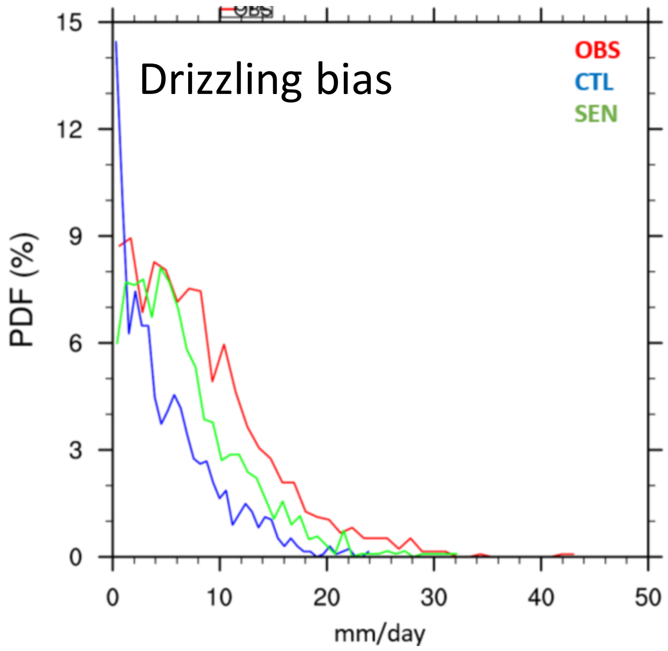
Impact on Rainfall



Seasonal (JJAS) Mean diurnal range of prate (dPRATE=maximum-minimum during 24-hour cycle in mm/hr) for the period 1998-2008.

- Diurnal Range in rainfall is enhanced
- Convective Rainfall Activity is strengthened
- Drizzling Bias is reduced

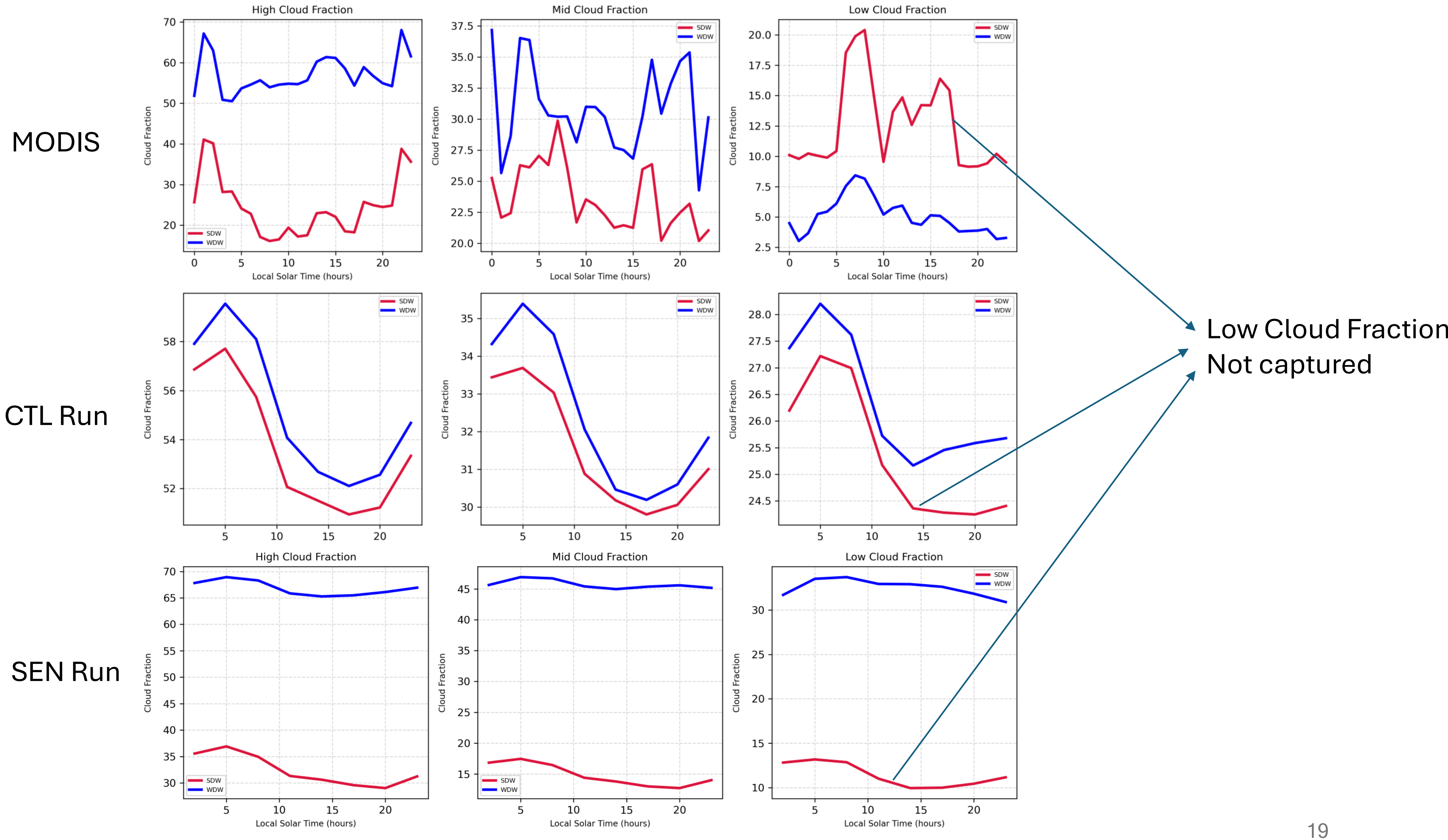




Summary

- The implementation of a suitable diurnal skin temperature parameterization helps the coupled model improve
    - The response of ocean skin temperature and surface fluxes to moisture convergence and convection.
    - The modulation of cloud fraction/base height/temperature to diurnal warming.
- Gap Areas: Still, the diurnal variability of low clouds (shallow convection) in response to diurnal warming is not realistic, which can/may be improved by tuning the convection/cloud parameterizations in the coupled models.

- Applications:
    - Analyses Products, Short-Range Forecasts for extreme weather,
    - Sub-seasonal forecasts: MISO/MJO
    - Seasonal Forecasts: Dry/Wet Bias, ENSO-IOD-ISMR teleconnections


MODIS
CTL Run
SEN Run
High Cloud Fraction
Mid Cloud Fraction
Low Cloud Fraction
Cloud Fraction
Local Solar Time (hours)
SDW
WDW
Low Cloud Fraction
Not captured

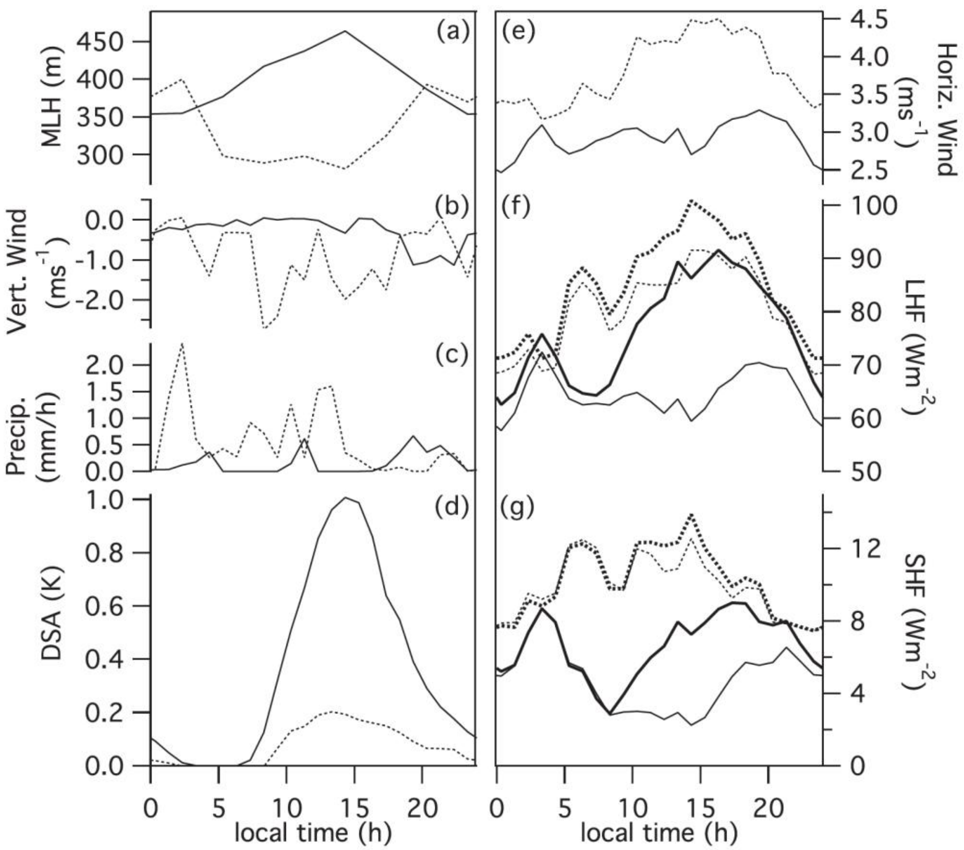


FIG. 3. Average diurnal evolution for days with (solid) and without (dashed) strong DWL of (a) the mixed-layer height (m, see text for details) from R/V *Mirai* soundings, (b) the 300–800-m height average vertical wind (m s^{-1}) from SB-LTR, (c) R/V *Mirai* precipitation rate (mm h^{-1}), and the average from R/V *Mirai* and the two m-TRITON buoys of (d) DSA (K) due to DWL formation, (e) horizontal wind (m s^{-1}), (f) surface latent, and (g) sensible heat fluxes (W m^{-2}). For surface fluxes thick lines represent heat fluxes computed with DWL-induced SST variations and thin lines represent heat fluxes computed with measured bulk SST from which the DWL effect has been removed; during the day SST is simply linearly interpolated.

Bellenger et al., 2010

- During this increase in DSA, the atmospheric mixed layer deepens, reaching a maximum of around 1400–1700 LT.
- This suggests that the SST diurnal variations may act to (i) destabilize the atmosphere through surface fluxes, (ii) deepen the atmospheric mixed layer, and (iii) help air parcels to overcome the convective inhibition.

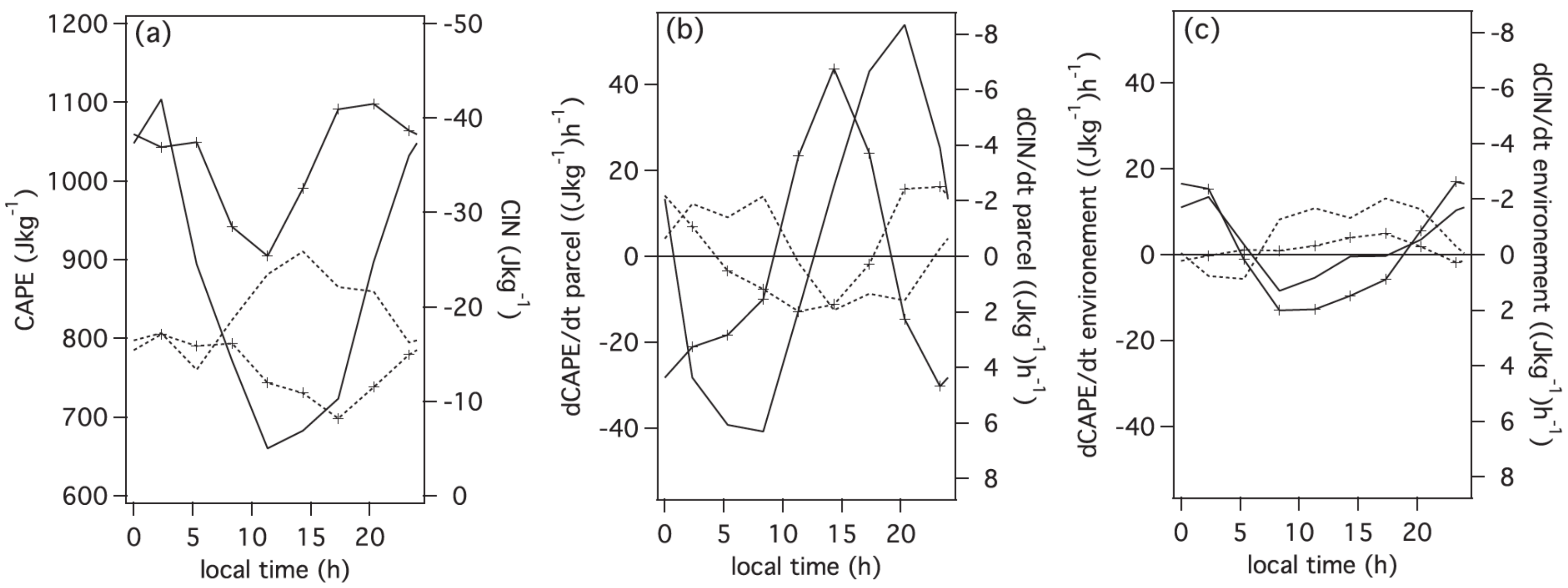


FIG. 4. Average diurnal evolution of (a) CAPE (solid) and CIN (dashed) for days with (crosses) and without strong DWL; (b) as in (a), but for CAPE and CIN generation rate from changes in boundary layer parcel (averaged between 100 and 400 m) characteristics and (c) from changes in environment characteristics. The time series are smoothed over 3 consecutive time steps (one sounding every 3 h).

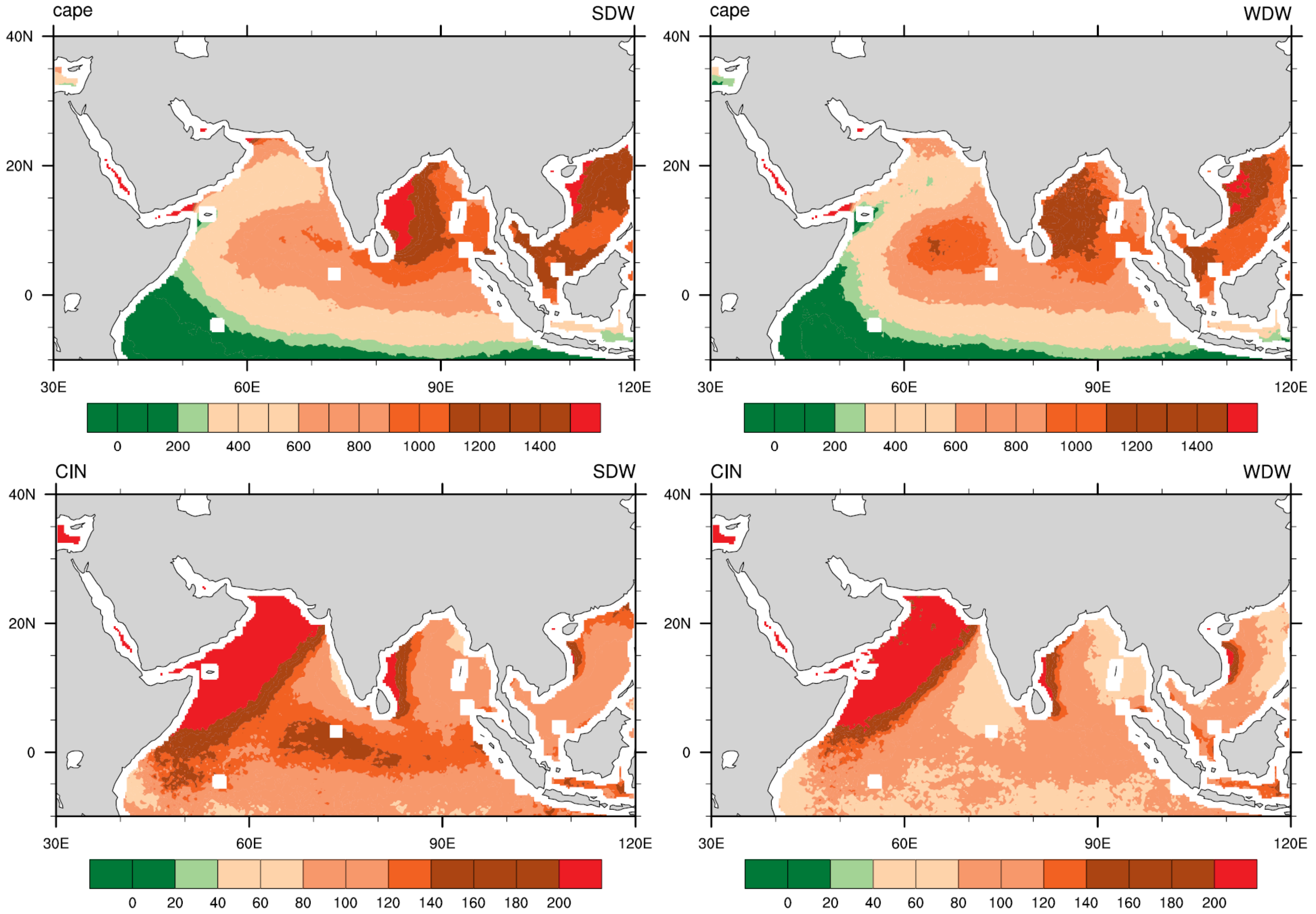
Bellenger et al., 2010

- Variability in Cape is smaller during DWL days as convection is weaker ➔ Higher Mean Cape during days with DWL than without DWL.
- CIN is higher during days without DWL suggesting processes other than static instability (e.g. low-level convergence)

- For days with DWL, CAPE increases, and CIN decreases from 100 to 1500-1700 LT in association with the DWL-induced increases in surface heat flux.
- CAPE remains high during the night while CIN increases in association with the triggering of downdrafts.

- For days without DWL, CAPE and CIN evolve out-of-phase with each other.
- CAPE (CIN) maximum (minimum) around 0300 LT (0500 LT) before the maximum convection and a minimum (maximum) around 1200–1500 LT

ERA5


cape
SDW
cape
WDW
40N
20N
0
30E
60E
90E
120E
0
200
400
600
800
1000
1200
1400
CIN
SDW
CIN
WDW
0
20
40
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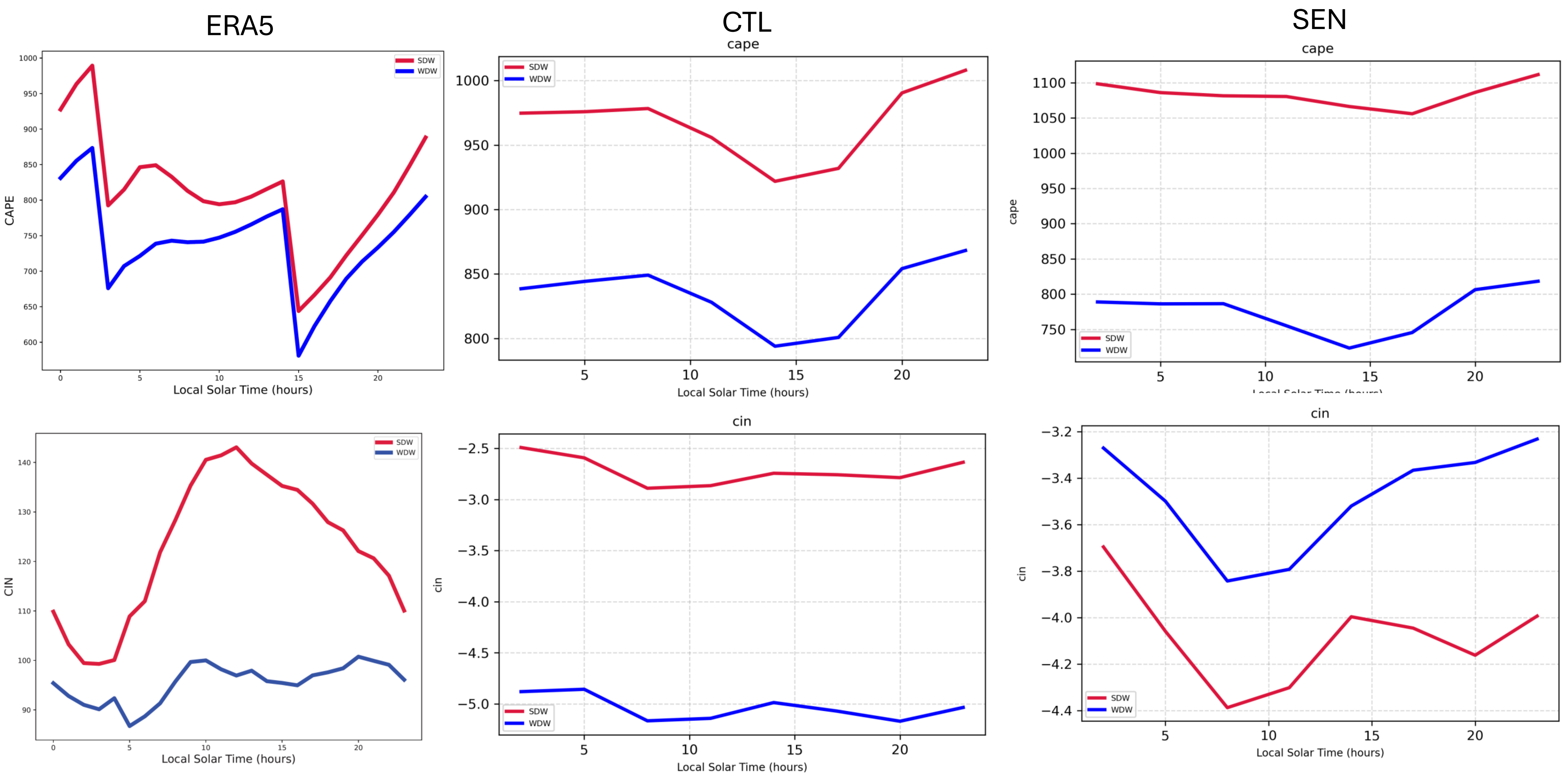
140
160
180
200


ERA5
CTL
SEN
cape
cin
CAPE
CIN
SDW
WDW
Local Solar Time (hours)