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Tropical cyclones in the past, present, and future climates using ultra-high resolution CESM simulations

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Tropical cyclones(TCs) in future warmer climate – IPCC report

More major tropical cyclones

Wetter, Winder Tropical storms

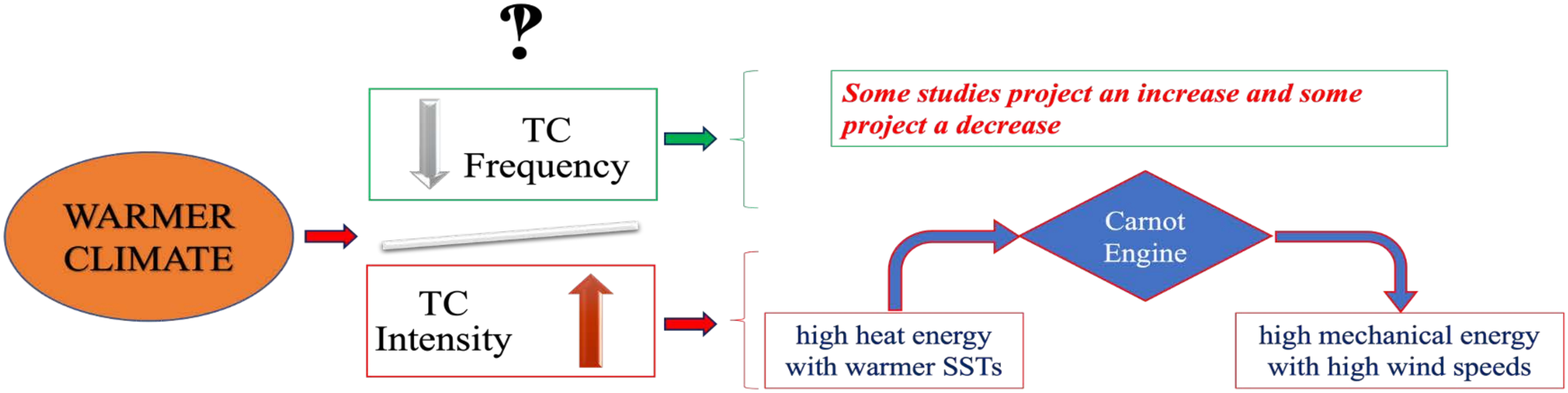
Tropical storms are shifting north

More explosive TCs - more rapidly intensifying TC

Slower TCs that can do more damage - meanders and stalls in tropical cyclone paths

TCs and Climate

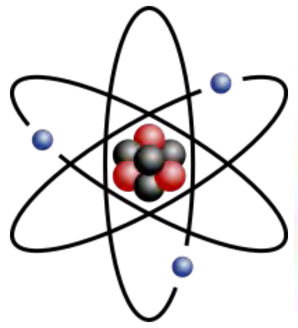
Lack of Climate theory of TC formation



Potential changes in the TC frequency under warmer climate is crucial for accurate assessment of the Hurricane induced risks under the background of increased TC intensity

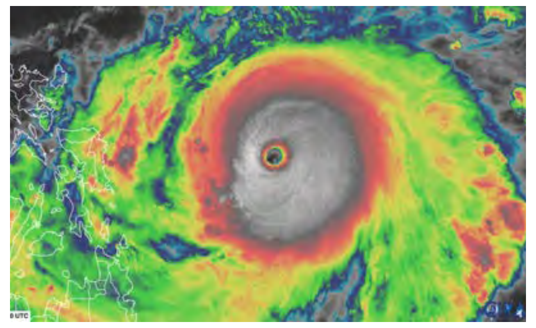
Important to understand the large-scale climate controls on the TC frequency using different model warmer climates

Objectives



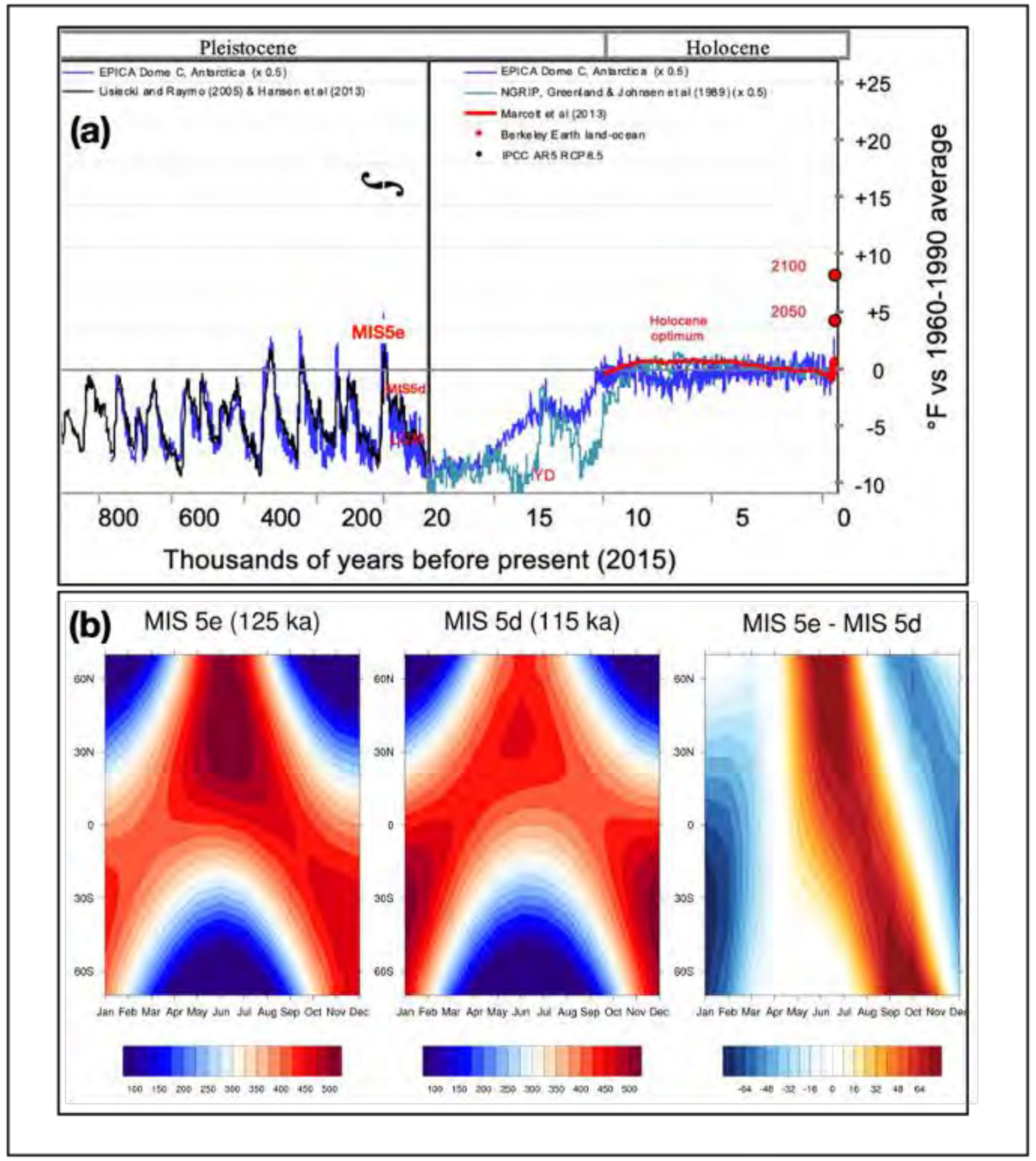
How different are the orbital forcing and greenhouse gas forcing derived large-scale climates?

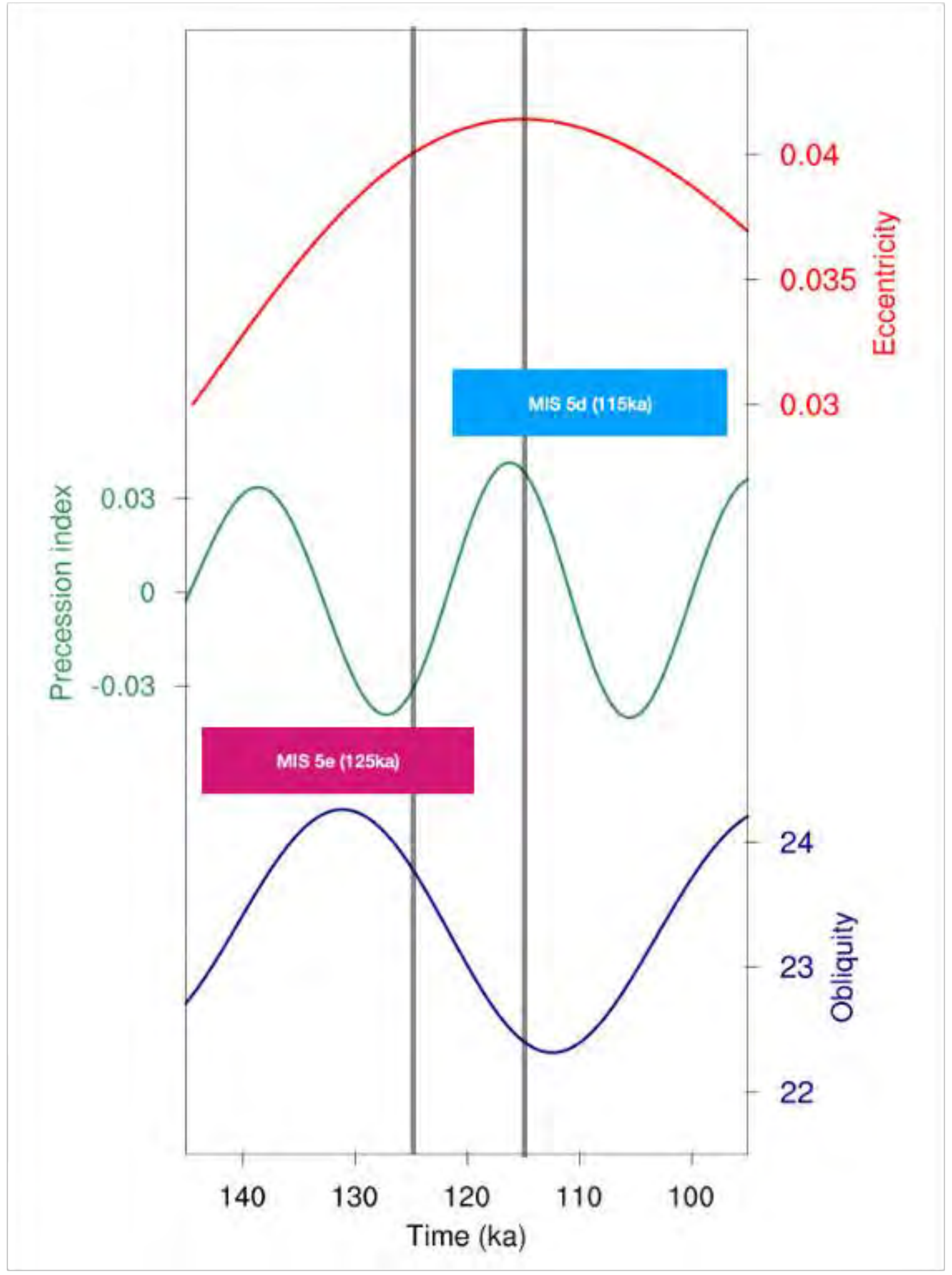
What is the effect of varied background climate states on frequency and intensity of TCs ?

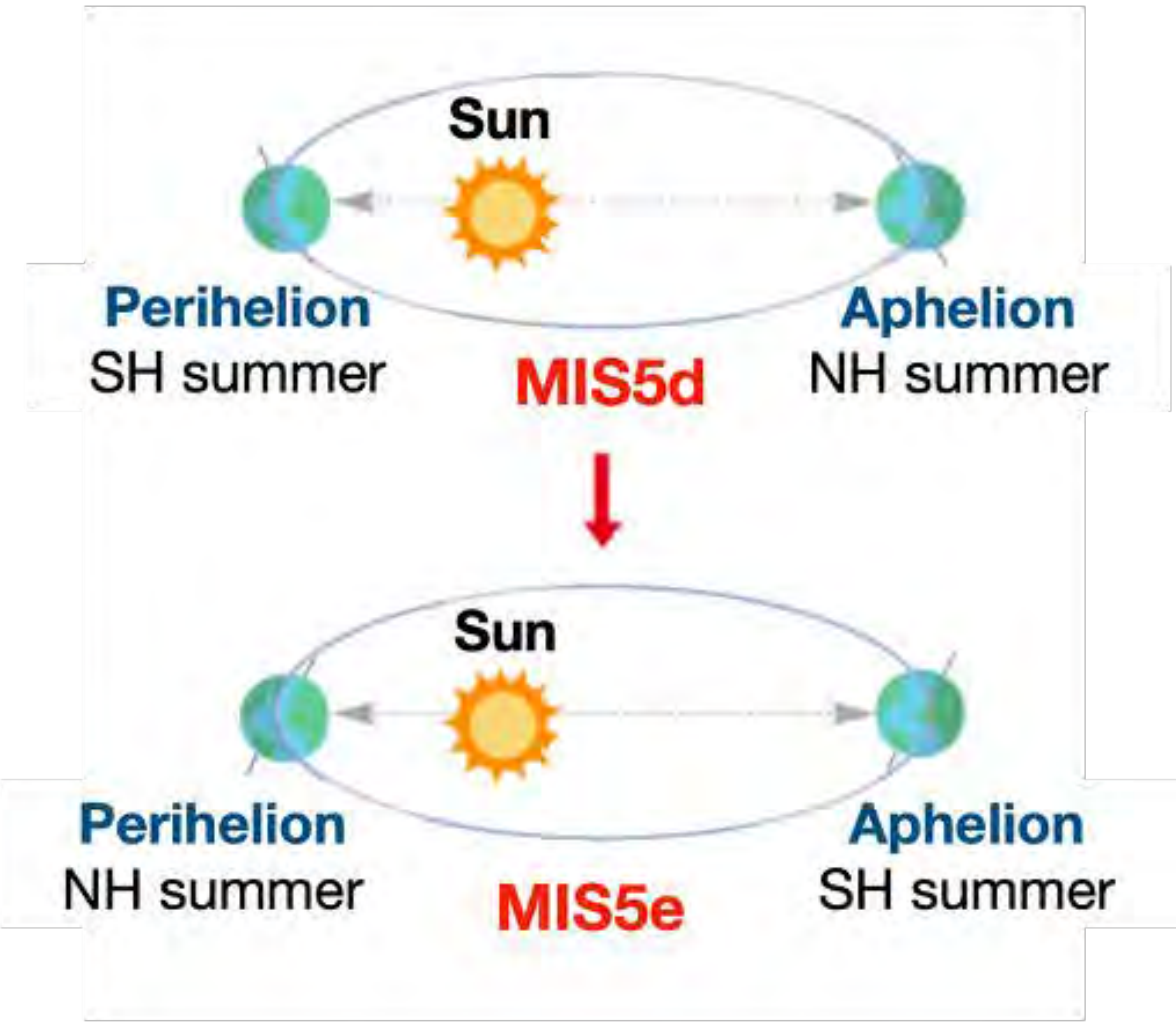


Is there a common relationship between large-scale environment and changes in TC characteristics from past to future?

Past climate - Changes in Precession Index & Solar Insolation
Future climate - Changes in the CO2 concentration levels







Model Experimental Specifications

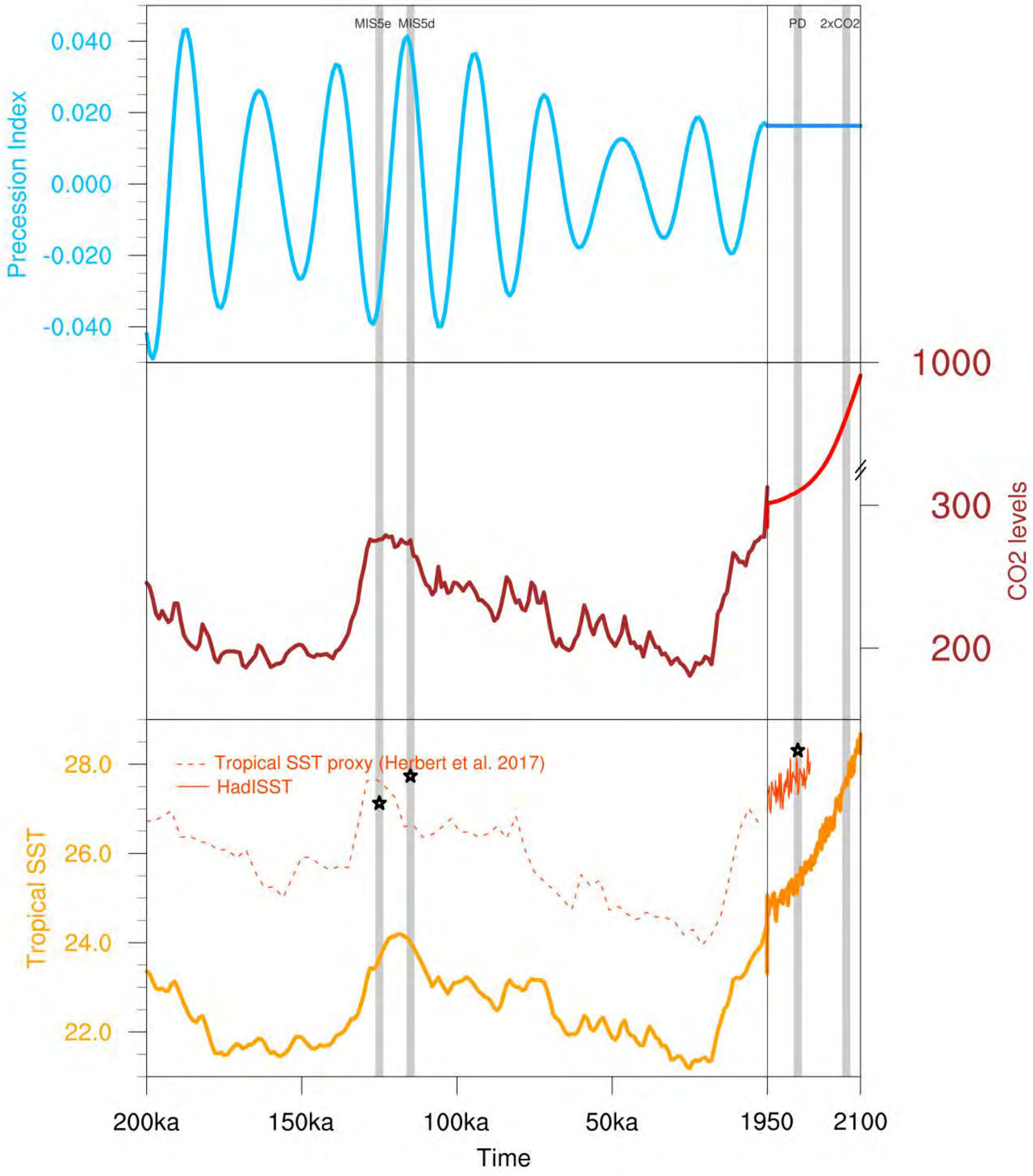
CESM1.2.2 with ATM~0.25°, OCN~0.1° resolution

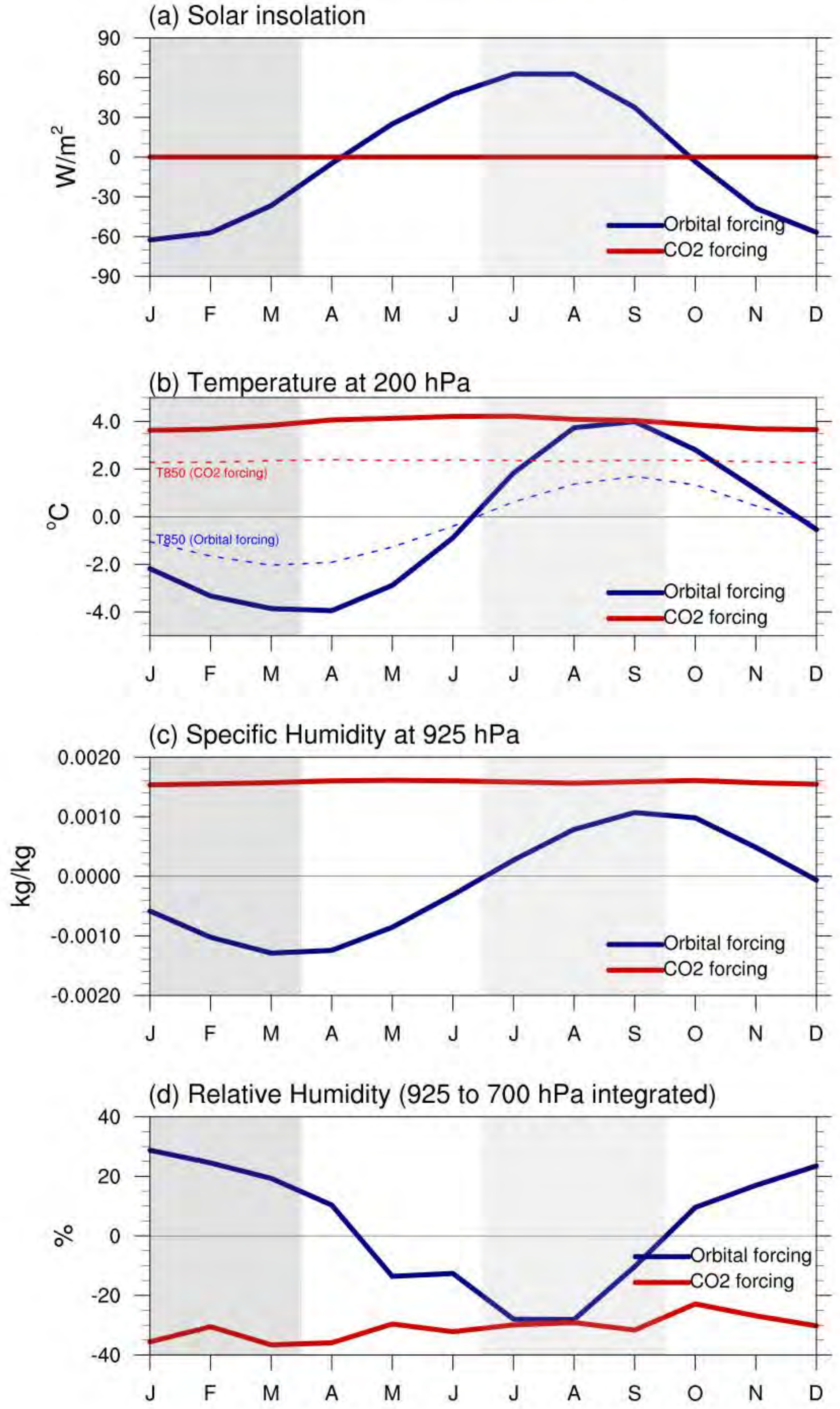
	Effect of orbital forcing		Effect of greenhouse forcing	
	MIS 5e (Eemian)	MIS 5d	Present-day	2xCO2
Orbital year	**125 ka**	**115 ka**	1990	1990
CO2	co2vmr = 276.016e-6	co2vmr = 275.623e-6	**367.0e-6**	**734.0e-6**
Other GHG gases	ch4vmr = 640.417e-9 f11vmr = 0.0 f12vmr = 0.0 n2ovmr = 263.084e-9	ch4vmr = 472.015e-9 f11vmr = 0.0 f12vmr = 0.0 n2ovmr = 251.334e-9	ch4vmr = 1760.0e-9 f11vmr = 653.45e-12 f12vmr = 535.0e-12 n2ovmr = 316.0e-9	ch4vmr = 1760.0e-9 f11vmr = 653.45e-12 f12vmr = 535.0e-12 n2ovmr = 316.0e-9
Aerosol forcing	PI condition		PD condition	
Surface data	PI condition		PD condition	
Urban effect	No		Yes	
Crop	No		Yes	

Tropical cyclone (TC) tracking schemes

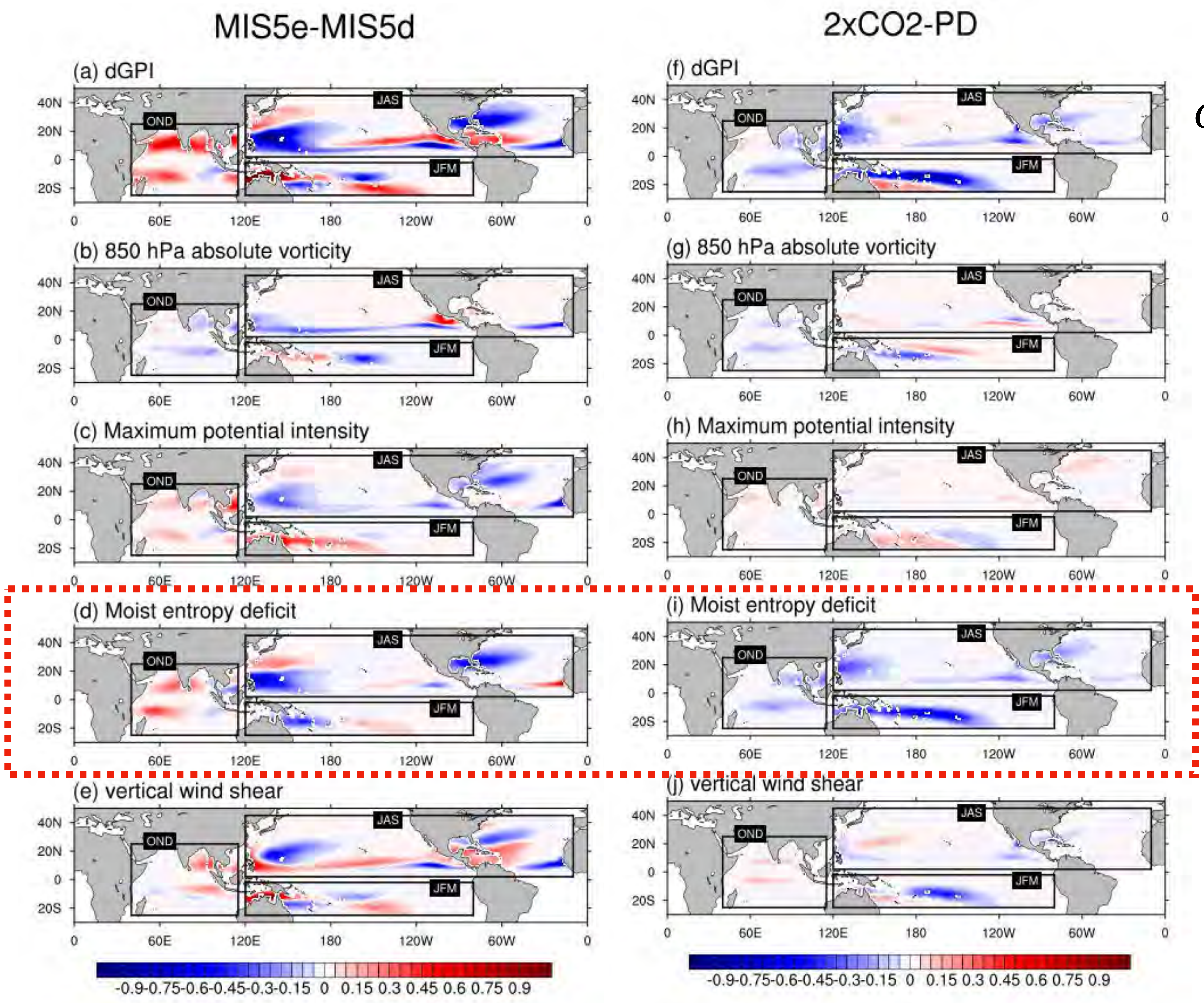
Traditional TC tracking scheme	Phenomenon-based TC tracking scheme
Detects TC like Vortices	Detects the potential locations for TC formation within large-scale disturbances
Uses resolution-dependent thresholds	Uses resolution-independent thresholds
Surface pressure, 850 hPa absolute vorticity, 10m wind speed, duration thresholds	Okubo-Weiss Zeta Parameter (850 & 500 hPa), 700 hPa relative humidity, Vertical wind shear, 950 hPa specific humidity, duration thresholds
Works well in high-resolution climate models (better simulation of TC wind speeds)	Works well in both high and Low- resolution global climate models

Changes in Large-scale environmental variables





Comparison of Genesis potential Index in Orbital forcing and Future climate model simulations



$$GPI = \alpha min(|\eta|, 4\times10^{-5})^3 max(PI-35,0)^2 \chi^{\frac{-4}{3}} (VWS+25)^{-4}$$

Term1: **absolute vorticity**

Term2: **Potential intensity**

Term3: **Moist energy deficit**

Term4: **vertical wind shear**

where a=1e^15

Korty et al. (2012)

Individual component analysis

$$\delta GPI = \delta Term1 \times (\overline{Term2 \times Term3 \times Term4}) +$$
$$\delta Term2 \times (\overline{Term1 \times Term3 \times Term4}) +$$
$$\delta Term3 \times (\overline{Term1 \times Term2 \times Term4}) +$$
$$\delta Term4 \times (\overline{Term1 \times Term2 \times Term3})$$

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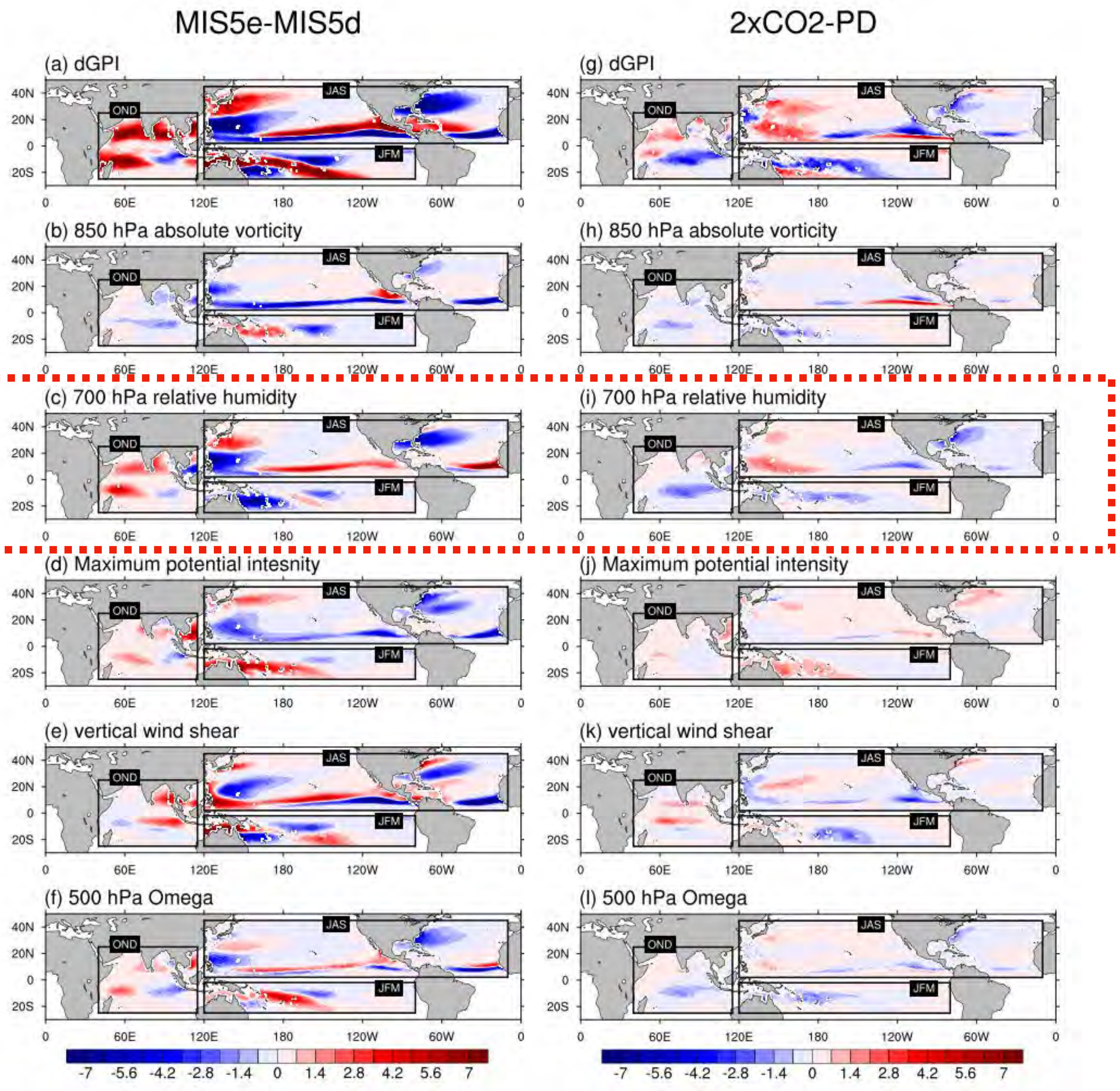
Comparison of Genesis potential Index in Orbital forcing and Future climate model simulations

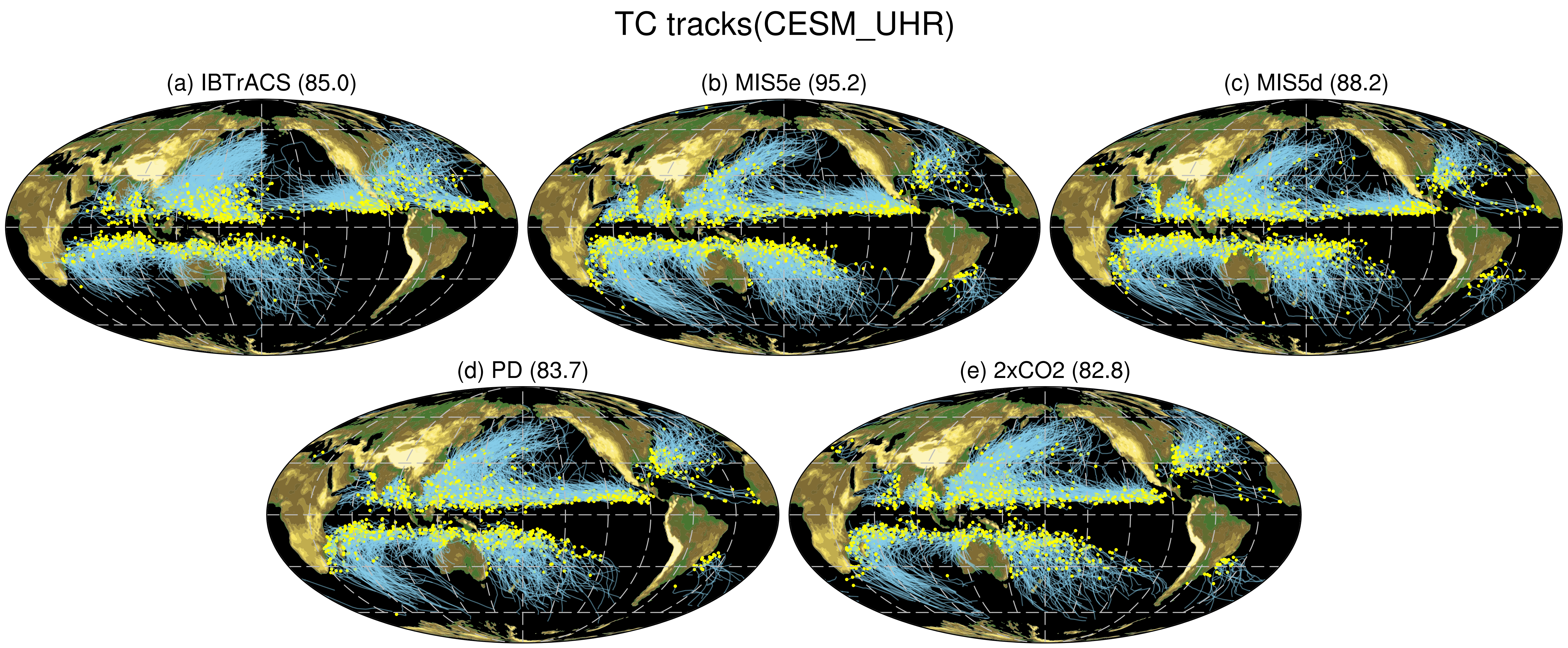


$$GPI = 10^5(|\eta|)^{3/2}(RH/50)^3(PI/70)^3(1+0.1VWS)^{-2}(-\omega+0.1/0.1)$$

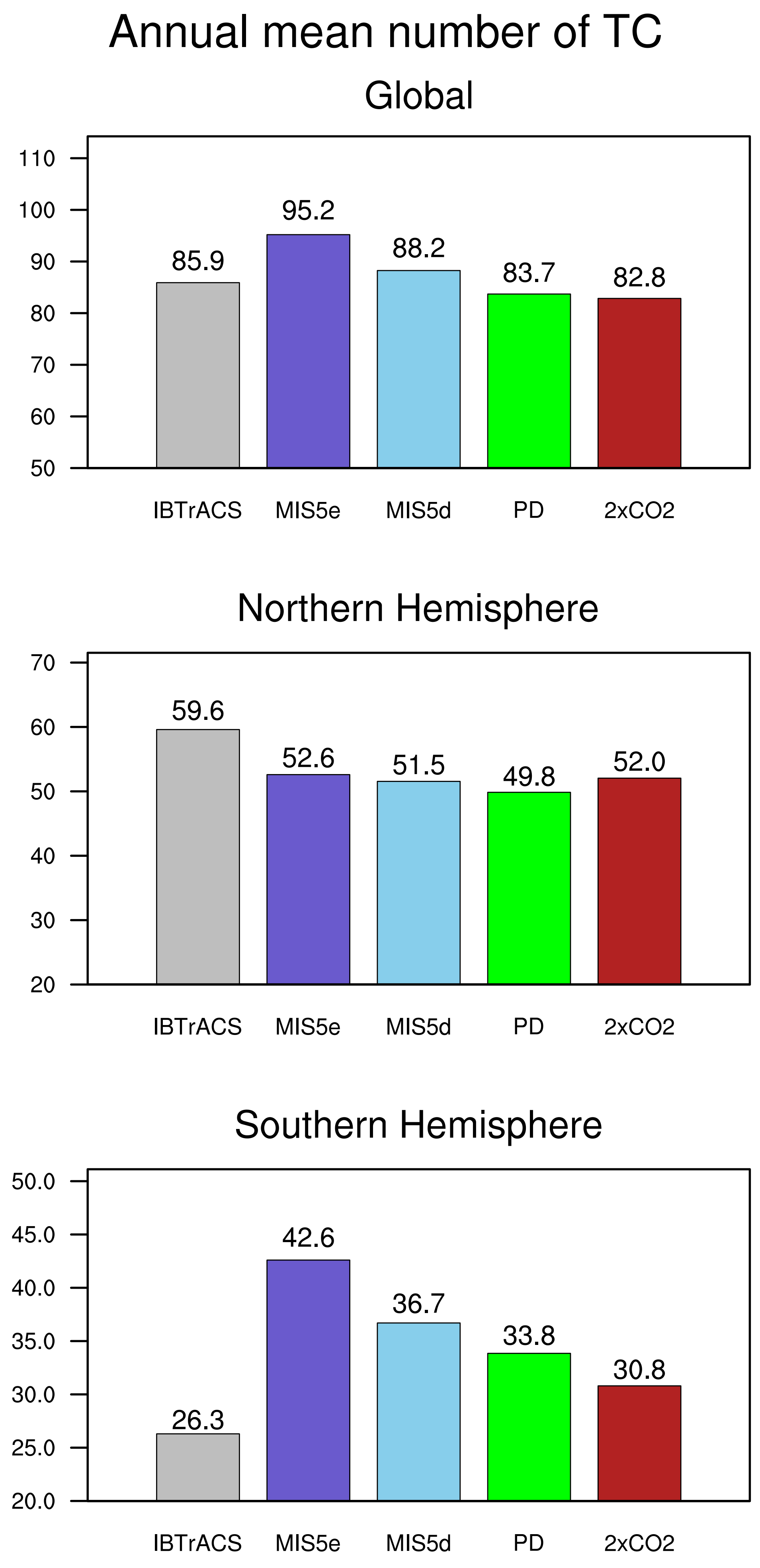
Term1	Term2	Term3	Term4	Term5
Absolute vorticity	**Relative Humidity**	**Potential Intensity**	**Vertical wind shear**	**Vertical velocity**

Murakami & Wang (2010)

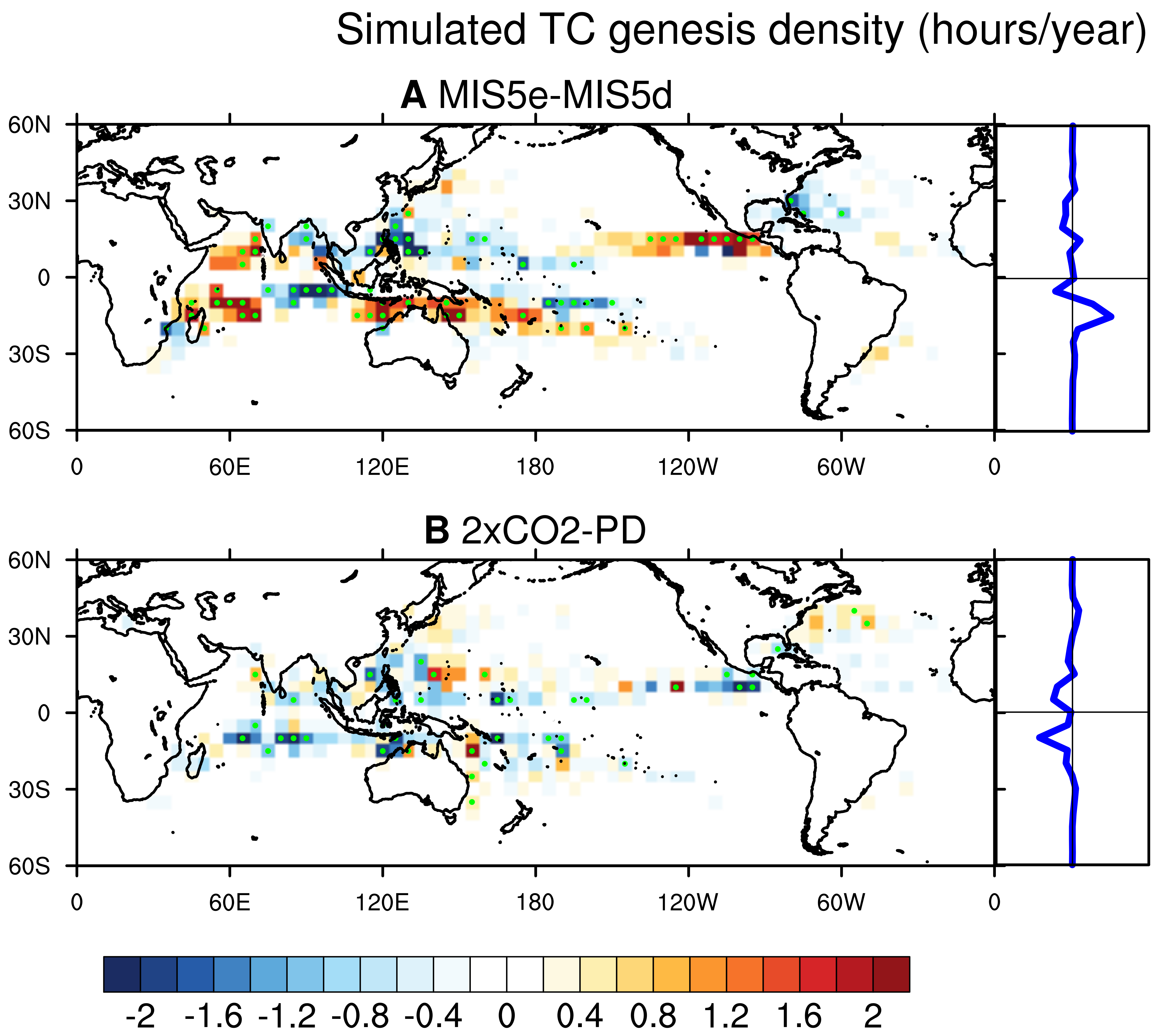
TC genesis and tracks



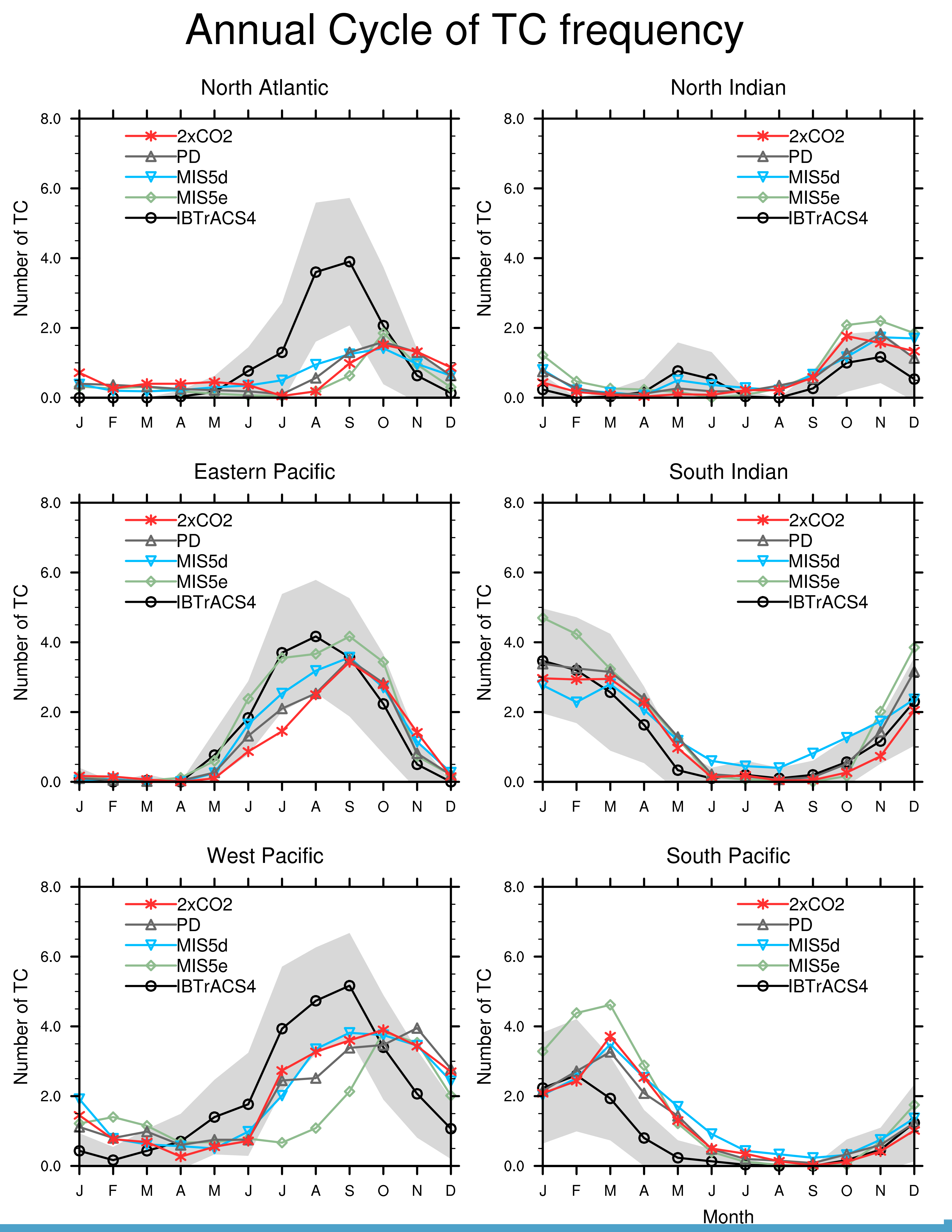
TC annual frequency



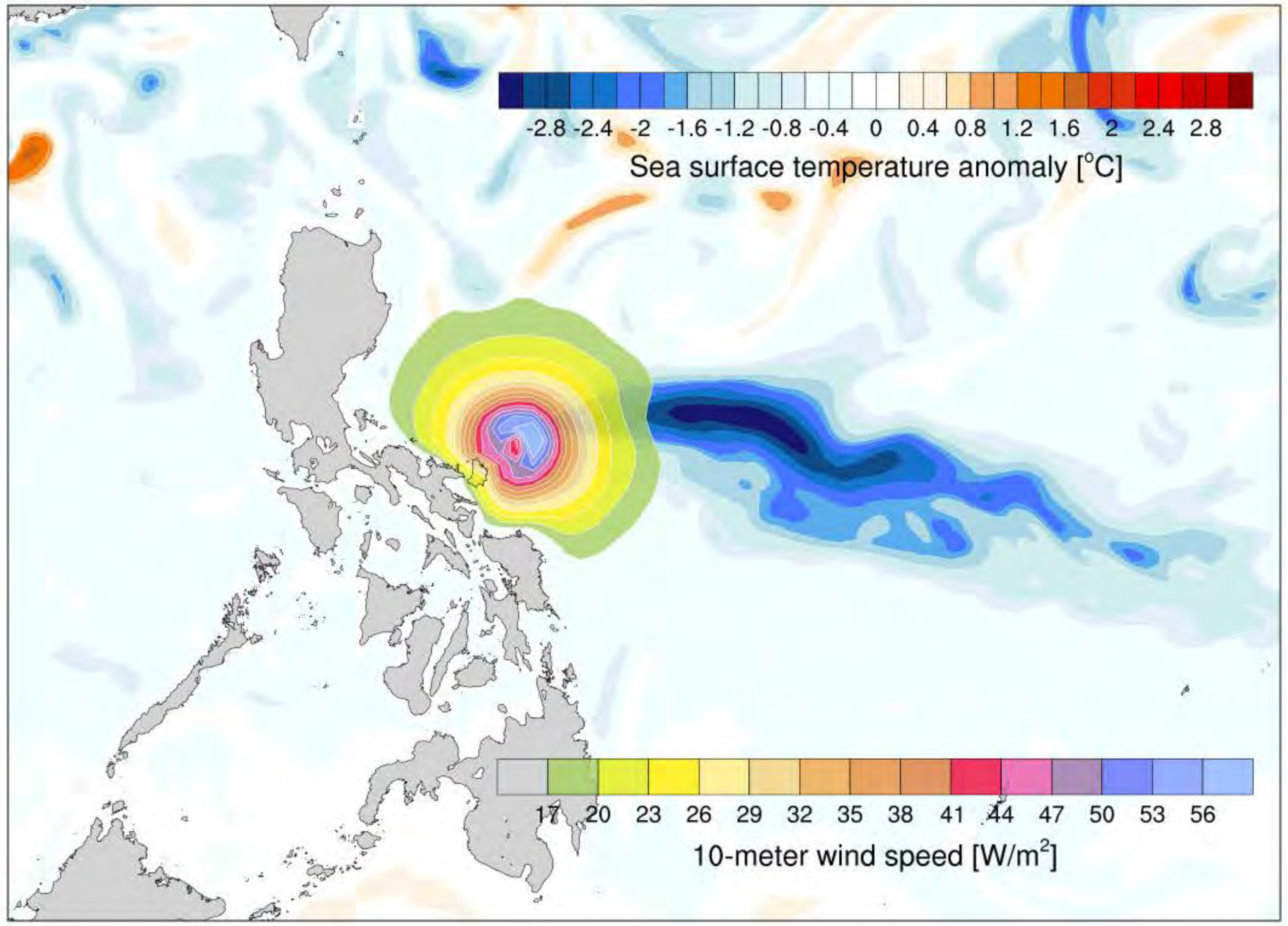
TC genesis density Differences



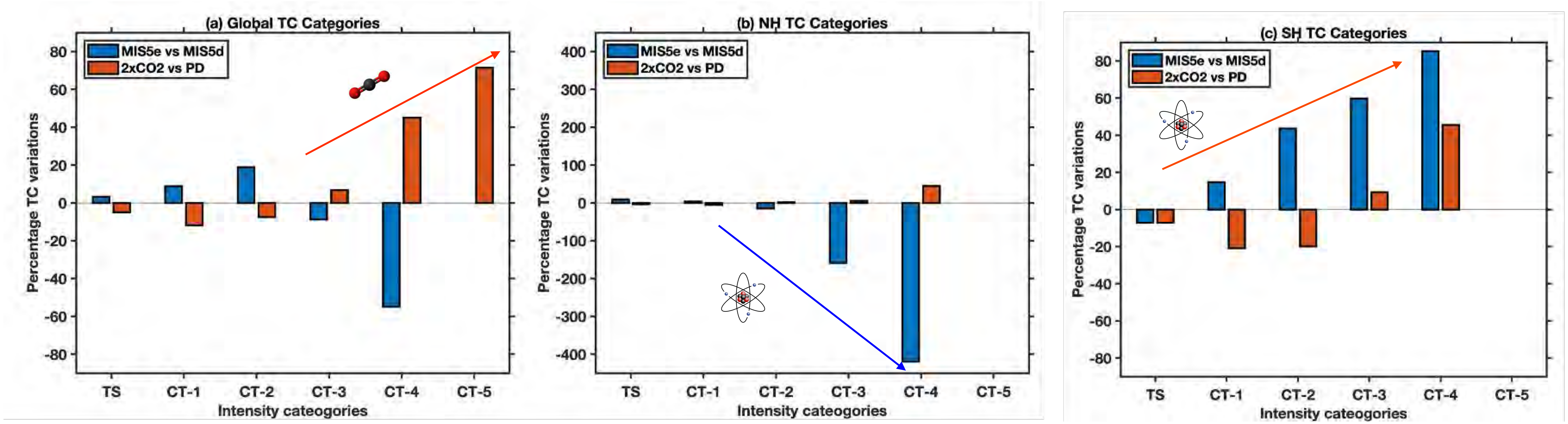
TC seasonal cycle



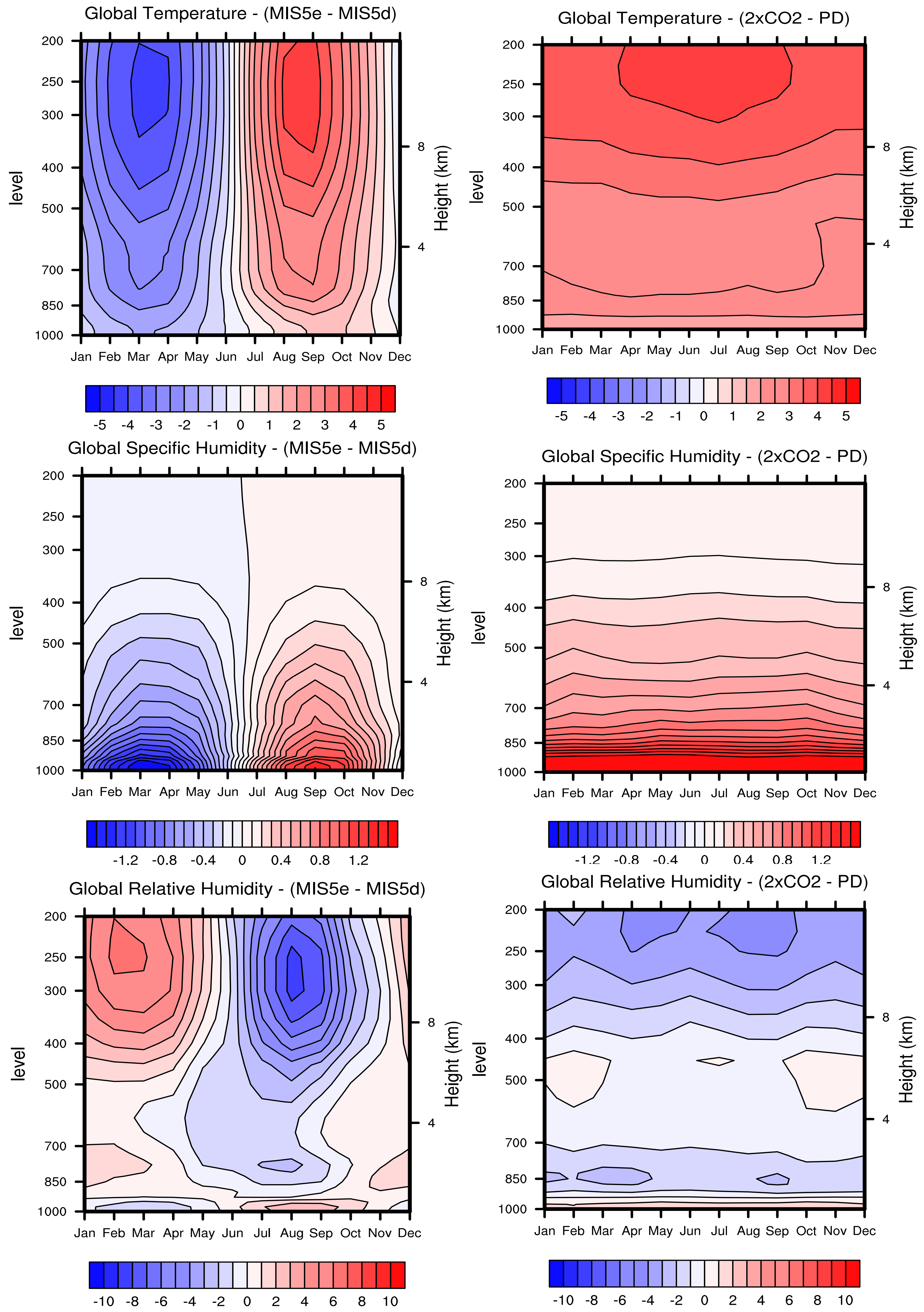
Category-4 test case in MIS5e Simulations

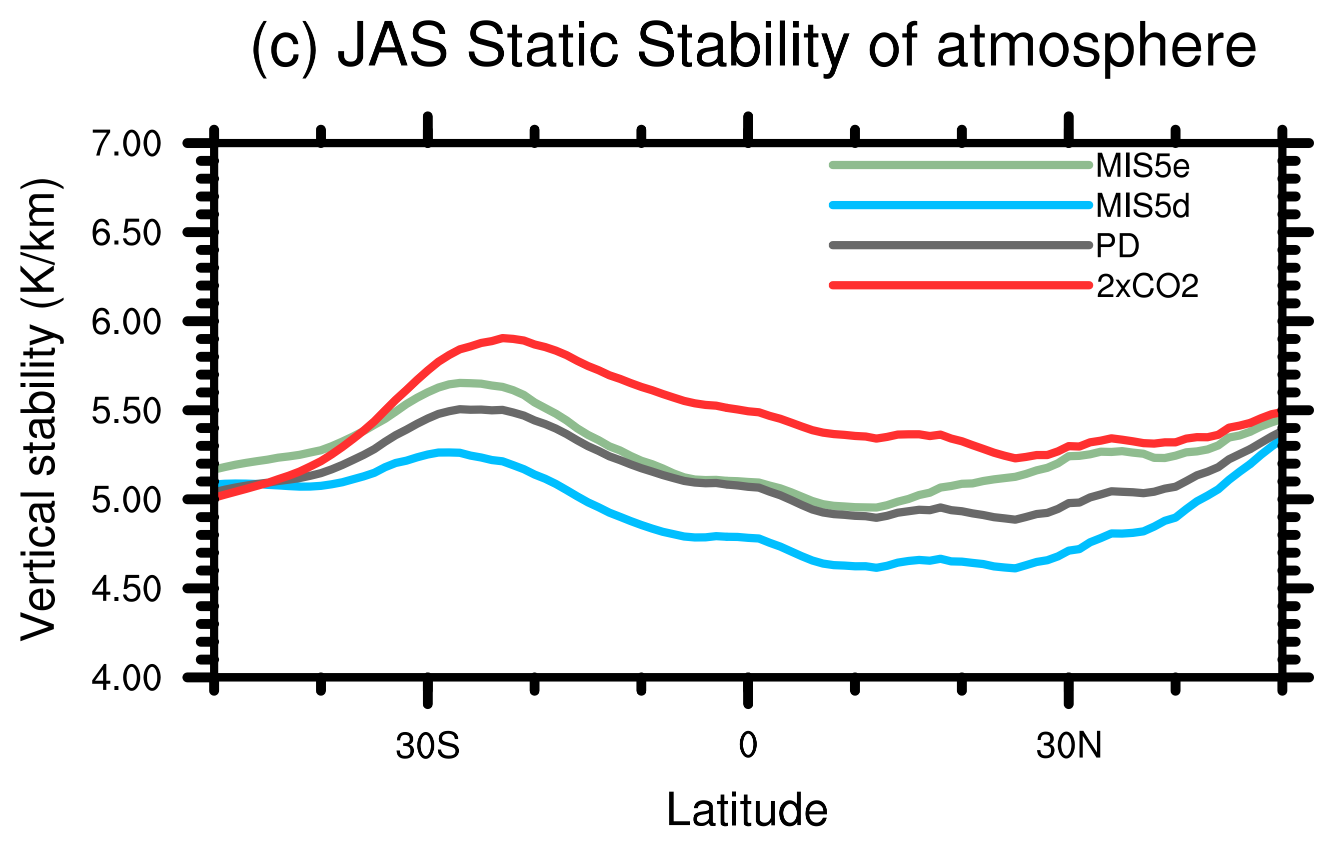


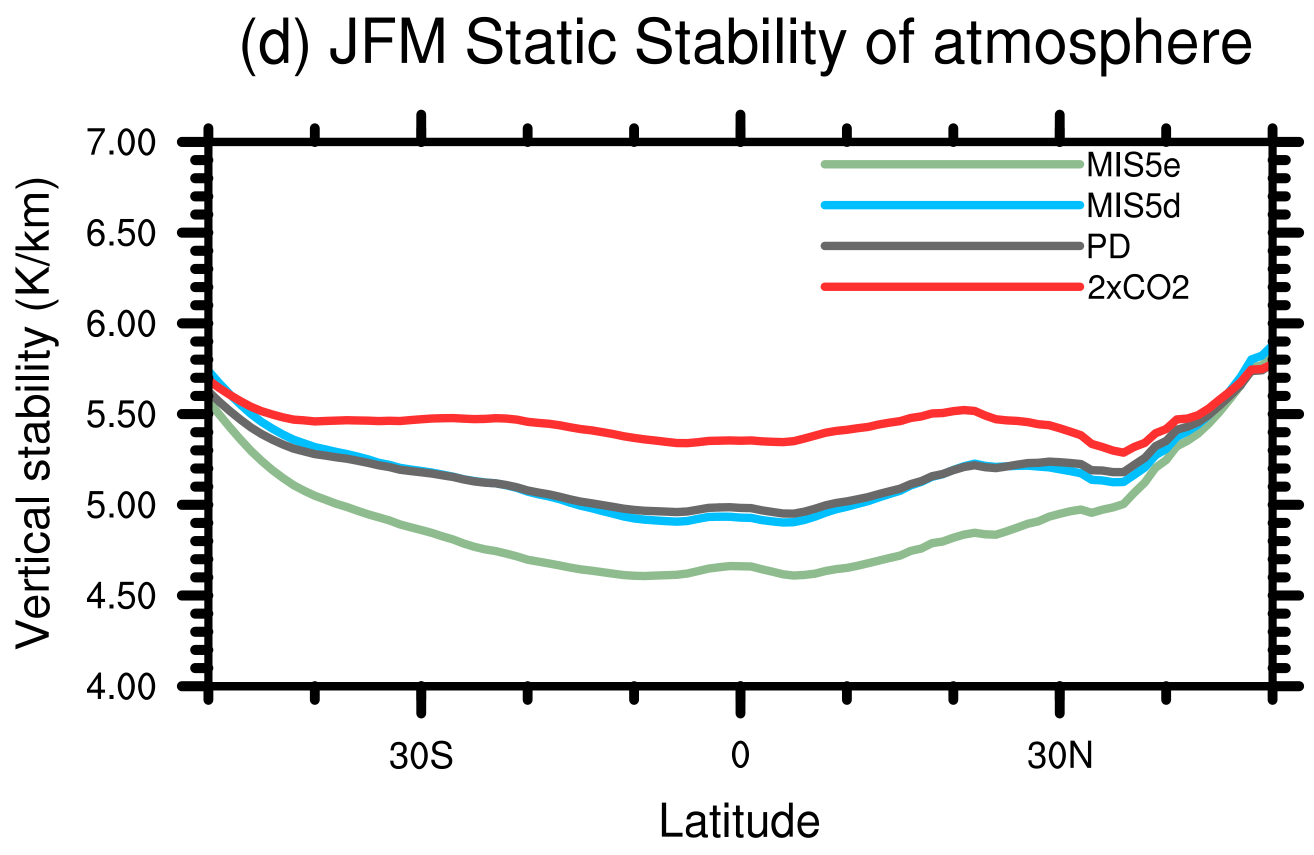
TC intensity changes



Changes in the vertical air-temperature and moisture conditions







Conclusion

Varied response of TC frequency and intensity due to Orbital and CO_2 forcing

NH summer in MIS5e cannot be an analogue to the CO_2 forcing conditions

Moisture related variables explains the Changes in the TC frequency in the past and future warmer climates

Tropospheric changes in the temperature and moisture control the TC intensity changes