The Abdus Salam International Centre for Theoretical Physics

WCRP CORDEX

Future projections in tropical cyclone activity over multiple CORDEX domains using RegCM4.7

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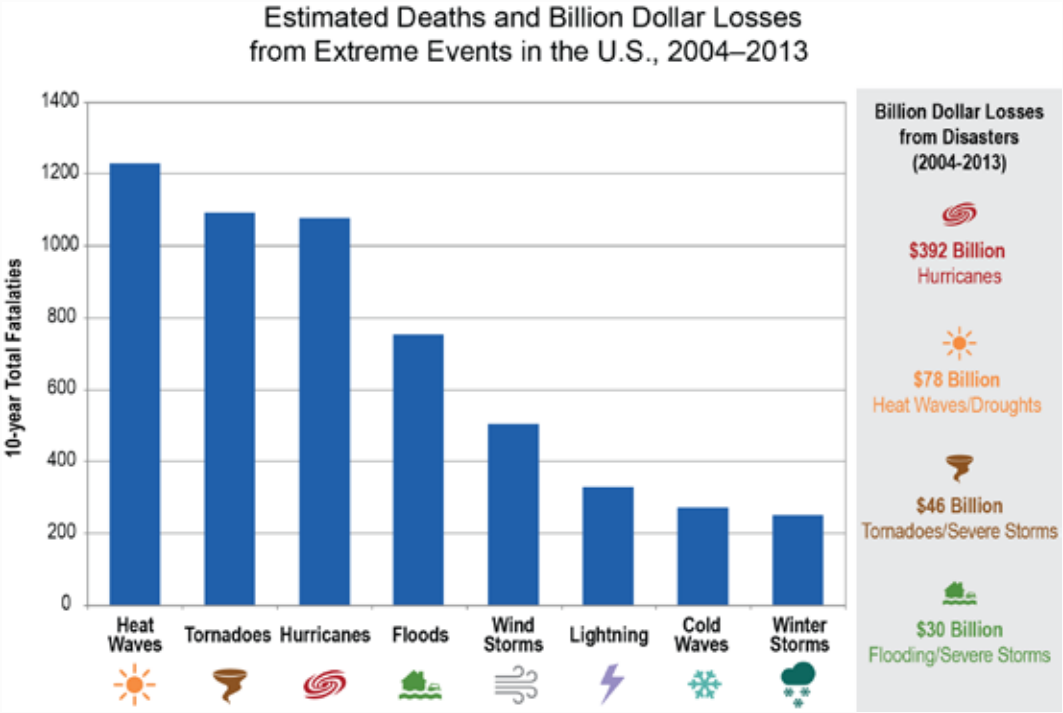
Introduction

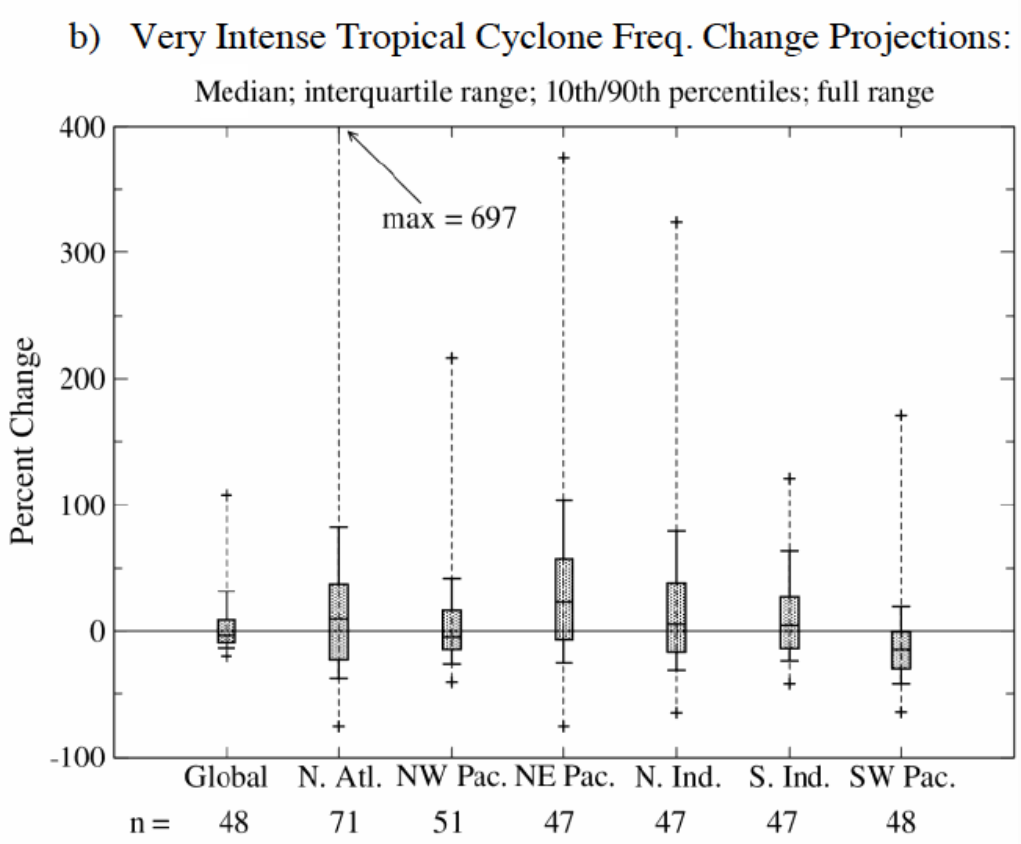
- The question of how tropical cyclones (TCs) could change with future anthropogenic warming is an important issue, particularly because of the large societal impacts from TCs and their damage (Knutson 2019).



Mendelsohn et al. 2012

Introduction

- Although several studies have addressed this topic, there remains much uncertainty about changes in TC intensity and TC rainfall on the regional scale, calling for further regional investigations.

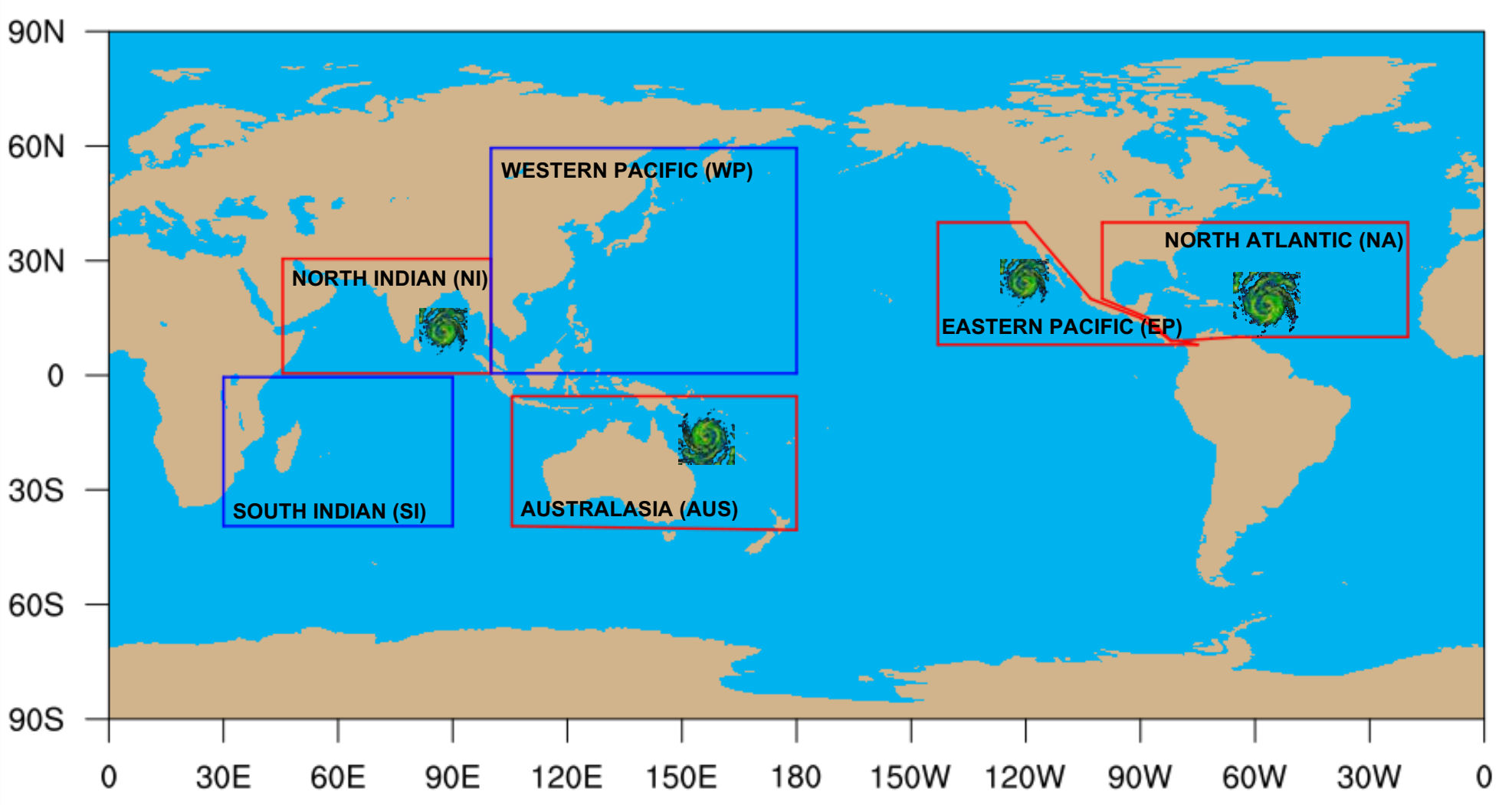


Knutson et al. 2019

Objective

To investigate the potential changes in tropical cyclone (TC) activity for future climate conditions over three CORDEX domains, using the latest version of the ICTP Regional Climate model (RegCM4.7).

Regions of study



From Cavazos- Perez T.

Method

Observations:

International Best Track Archive for Climate Stewardship (IBTrACS, Knapp et al. 2018)

Simulations:

RegCM4.7 at a spatial resolution of 25 km.

Periods analyzed:

- *Historical*: 1995-2014

RCP2.6 and RCP8.5

- *Mid-future*: 2041-2060
- *Far-future*: 2080-2099

List of GCMs

- MPI-ESM-MR (all basins)
- HadGEM2-ES (AUS, EP, NA)
- NorESM1-M (AUS, NI)
- MIROC5 (NI)
- GFDL-ESM2M (EP, NA)

Method

The TC detection method employed here is the objective-tracking algorithm, TRACK (Hodges 1999).

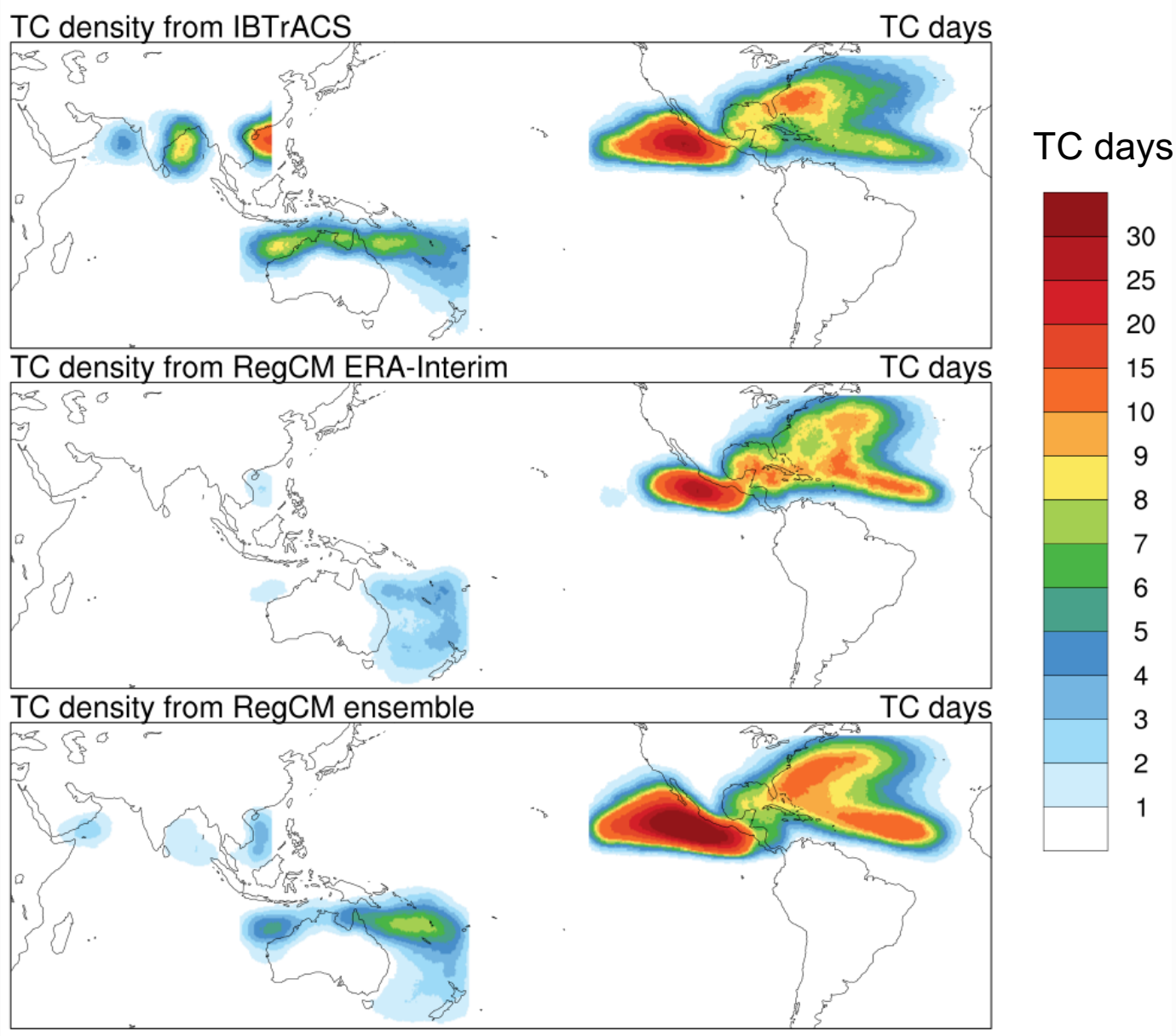
The results presented here are only for the ensemble mean.

Here we analyze:

- Geographical distribution
- Intensity (maximum wind speed)
- Precipitation-associated TCs
- Genesis potential index (GPI) and potential index (PI)

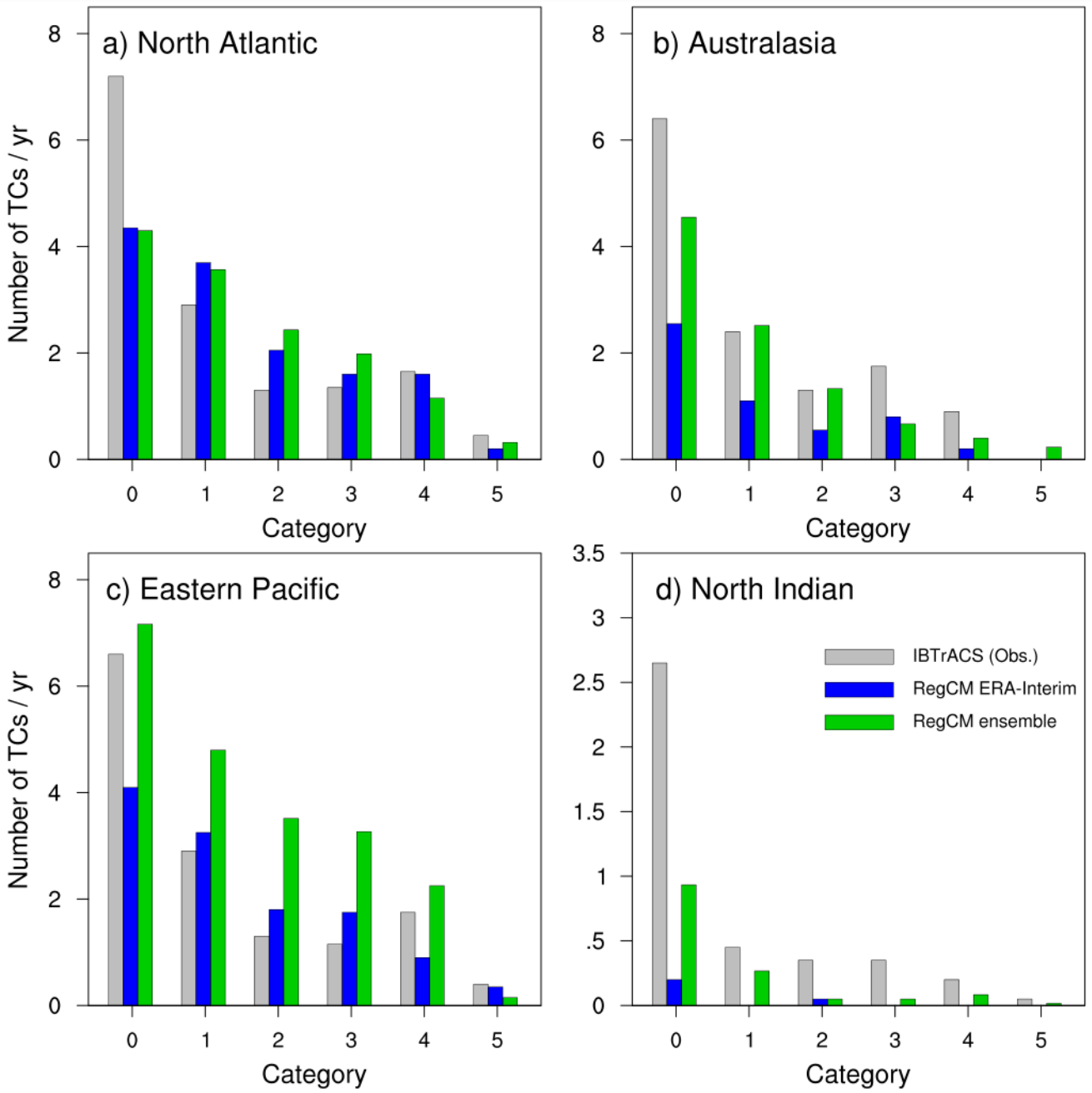
How well does RegCM represent the TC features?

Validation: Track density



RegCM is able to capture the geographic distribution of TC frequency.

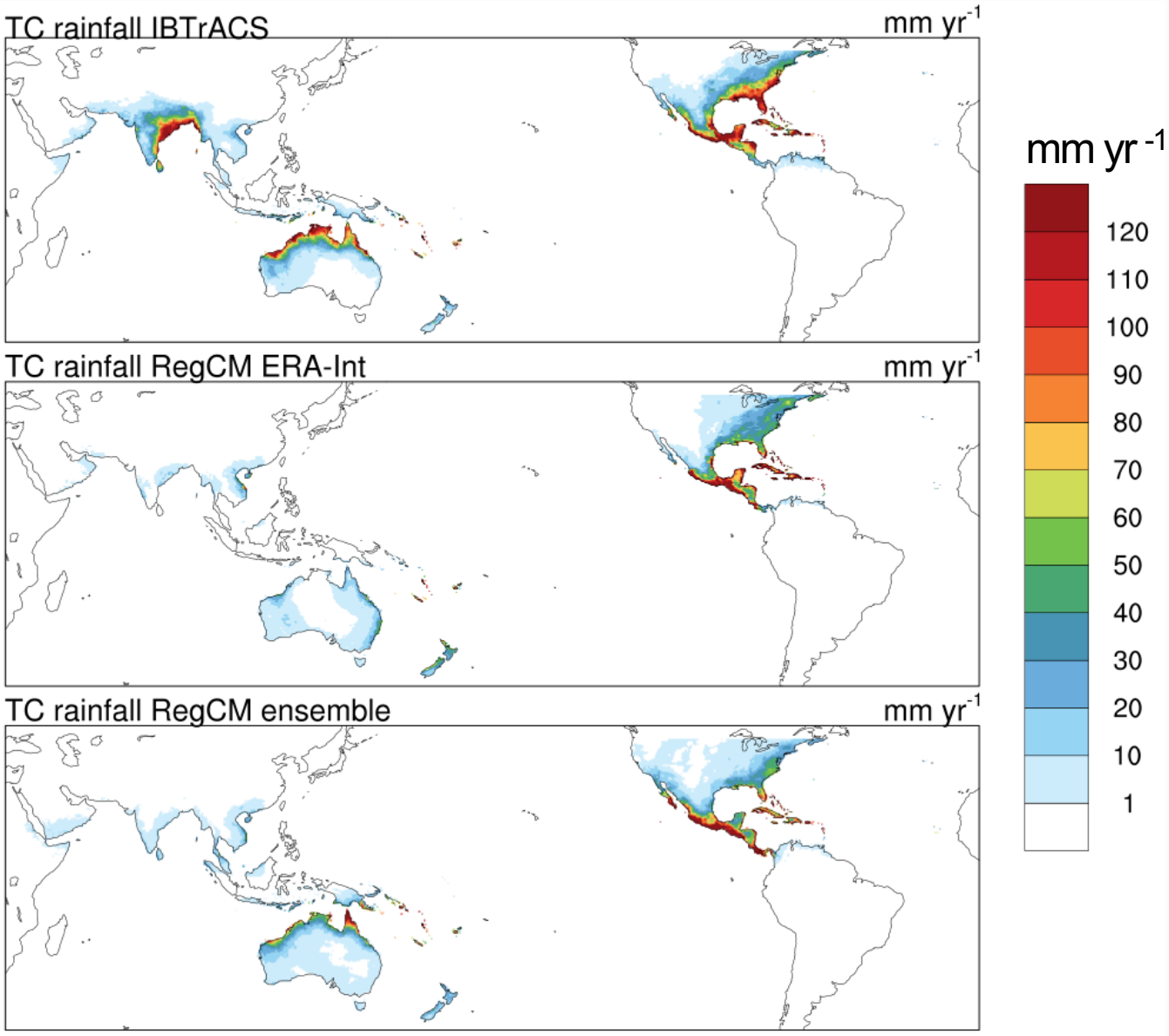
Validation: Annual number of TC by Saffir-Simpson scale



The peak value of the maximum 10m wind speed over the TC lifetime is used.

The statistical method of bias correction used is similar to the method used by Zhao and Held (2010).

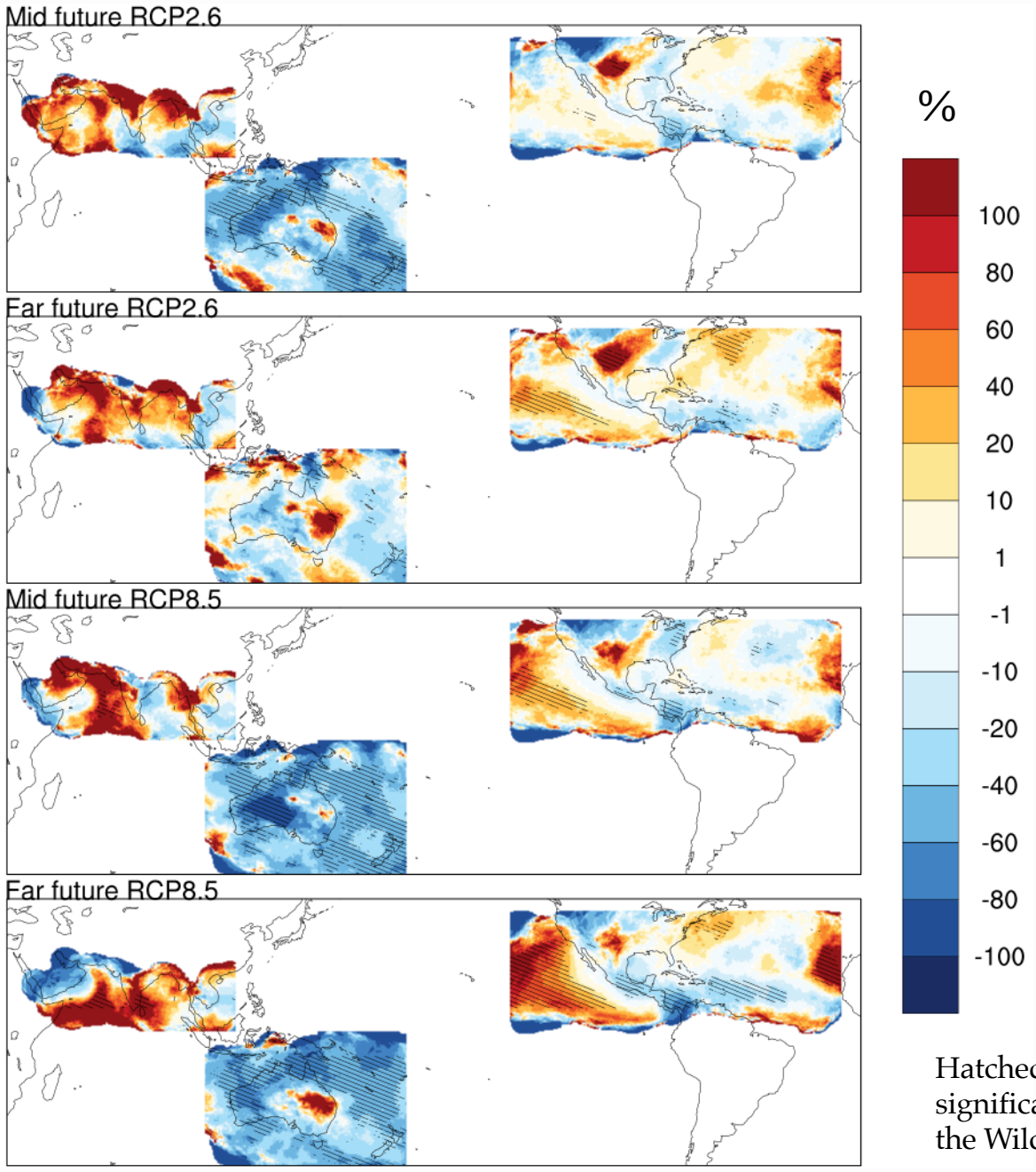
Validation: TC rainfall



RegCM simulations underestimate rainfall magnitudes.

Future projections of TC characteristics

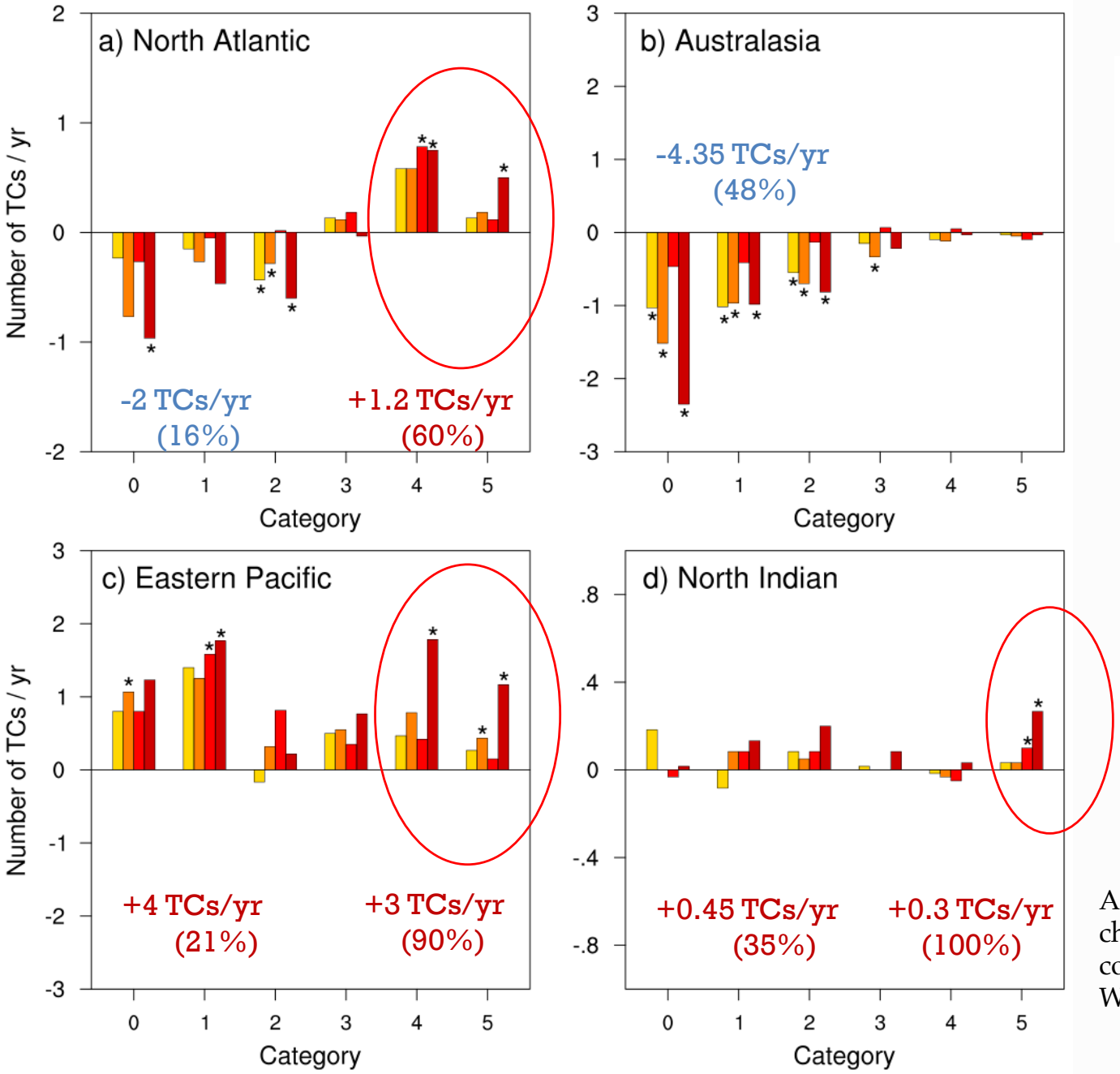
Future projections: Changes in track density



The simulations project a consistent decrease of TC density in Australasia and an increase in North Indian Ocean and Eastern Pacific.

Hatched areas show where changes are significant at a 95% confidence level, based on the Wilcoxon rank-sum test.

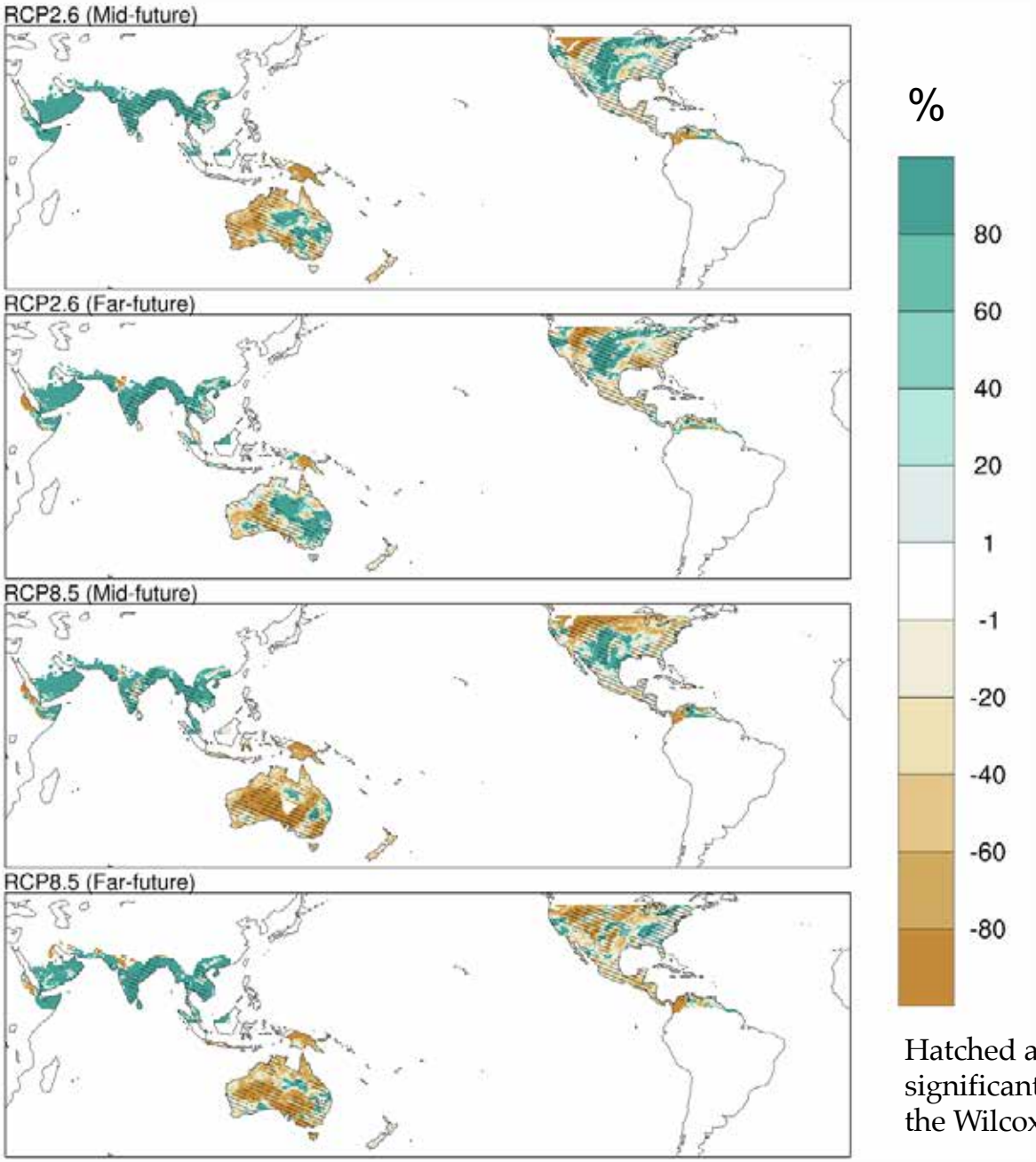
Future projections: Changes in the intensity



The model shows an increase in very intense TCs.

Asterisk symbols show where changes are significant at a 95% confidence level, based on the Wilcoxon rank-sum test.

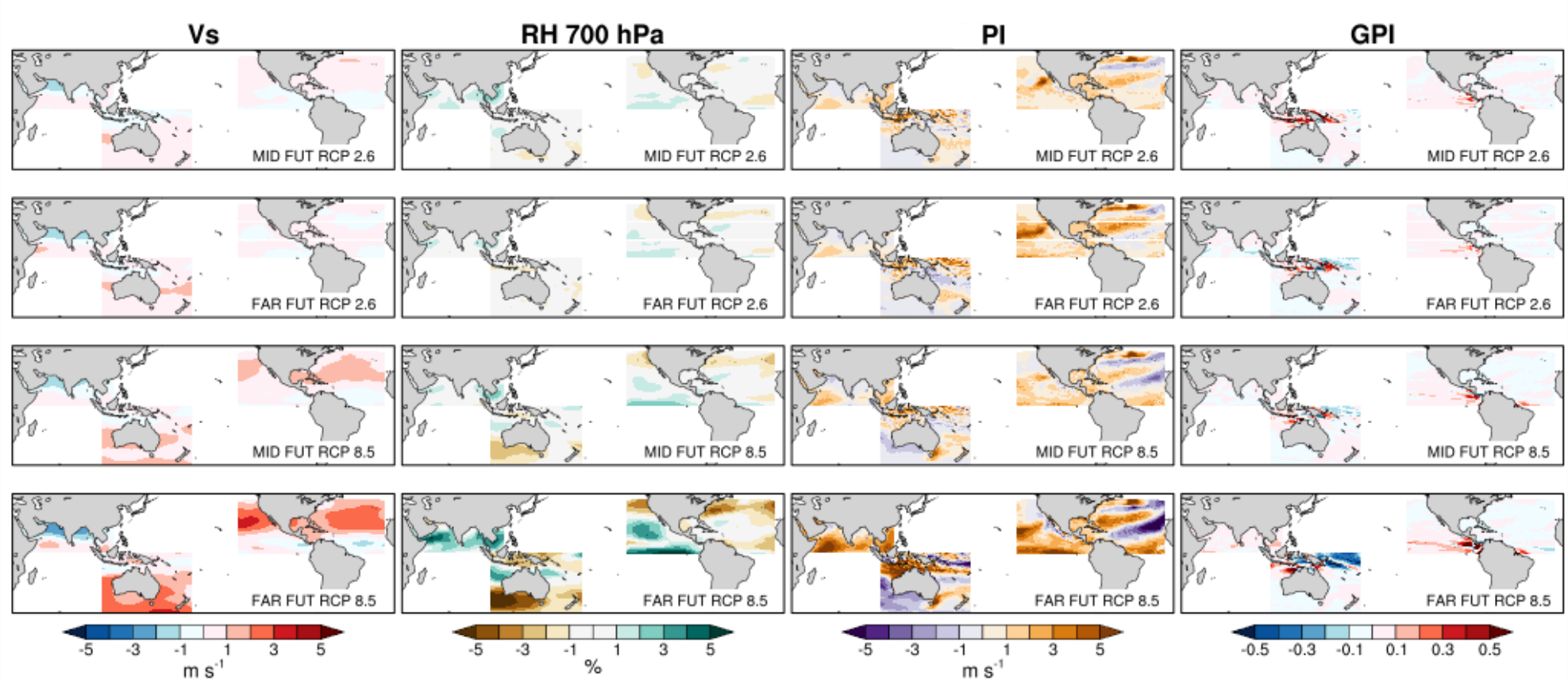
Future projections: Change in TC total rainfall (%)



RegCM shows reduced TC precipitation over Australasia, Mexico and Central America

Hatched areas show where changes are significant at a 95% confidence level, based on the Wilcoxon rank-sum test.

Future projections: Changes in GPI and the three main genesis factors



Concluding remarks

- The RegCM4.7 captures most of the features of the observed TC climatology.

- RegCM4.7 projects significant increases of TC frequency in much of the eastern United States and India and decreases in Australia and Mexico.

- The projections show an increase in the frequency of the strongest TCs over the Eastern Pacific, the Northern Atlantic and the North Indian Ocean.

- The change in TC rainfall exhibits a statistically significant decrease over Australia, Mexico and Central America.

Thank You!

Questions?

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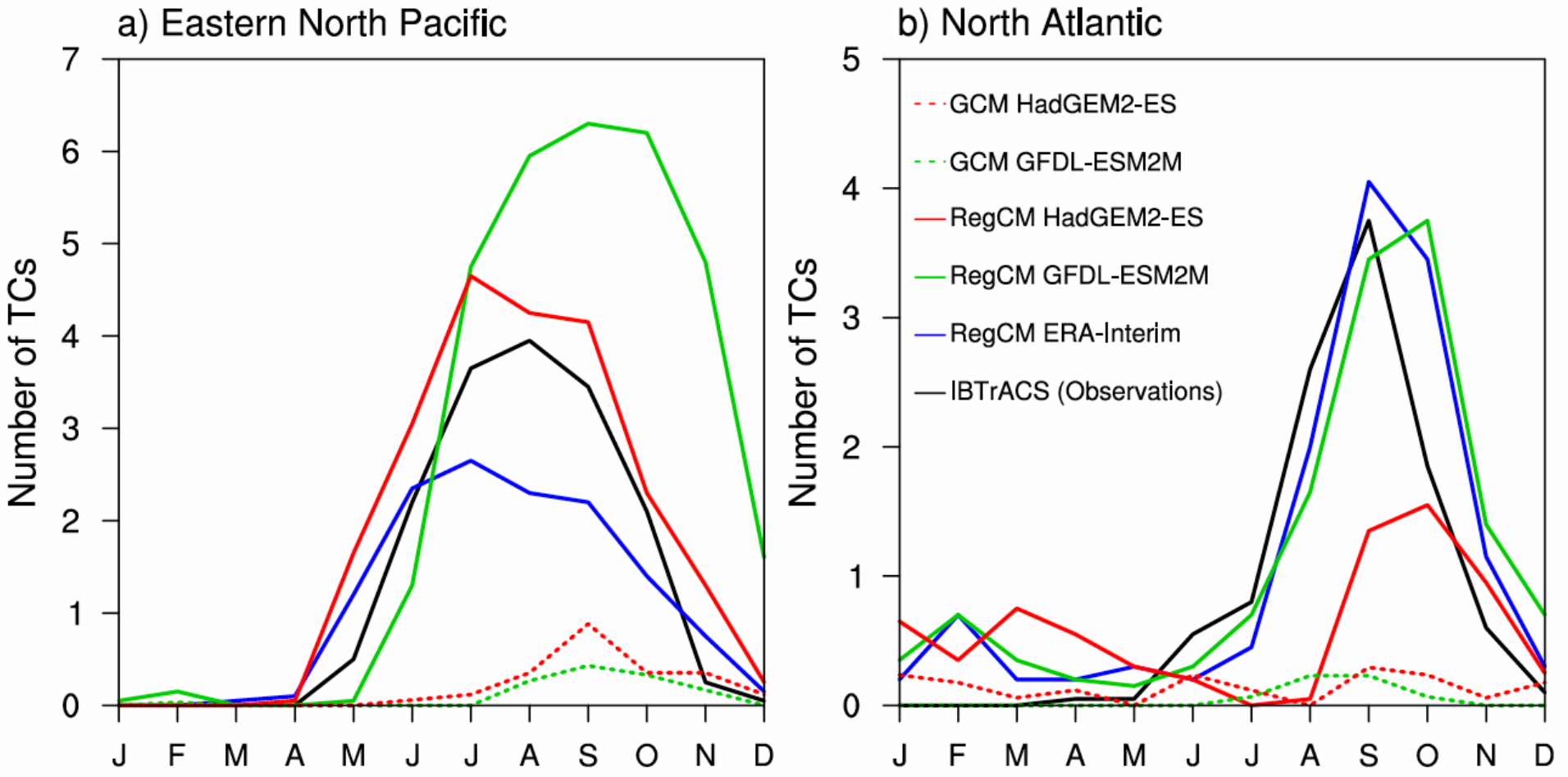
References

- Hodges, K. I. (1999) Extension of spherical nonparametric estimators to nonisotropic kernels: An oceanographic application. Monthly Weather Review, 127 (2). pp. 214-227.

- Knutson, T., S.J. Camargo, J.C. Chan, K. Emanuel, C. Ho, J. Kossin, M. Mohapatra, M. Satoh, M. Sugi, K. Walsh, and L. Wu: Tropical Cyclones and Climate Change Assessment: Part II. Projected Response to Anthropogenic Warming. Bull. Amer. Meteor. Soc., 0, https://doi.org/10.1175/BAMS-D-18-0194.1

- Zhao, M. and I.M. Held, 2010: An Analysis of the Effect of Global Warming on the Intensity of Atlantic Hurricanes Using a GCM with Statistical Refinement. J. Climate, 23, 6382–6393, https://doi.org/10.1175/2010JCLI3837.1

Added value


a) Eastern North Pacific
Number of TCs
0
1
2
3
4
5
6
7
J F M A M J J A S O N D
b) North Atlantic
Number of TCs
0
1
2
3
4
5
J F M A M J J A S O N D
GCM HadGEM2-ES
GCM GFDL-ESM2M
RegCM HadGEM2-ES
RegCM GFDL-ESM2M
RegCM ERA-Interim
IBTrACS (Observations)

GPI and PI

$$GP = \left|10^5 \eta\right|^{3/2} \left(\frac{\mathcal{H}}{50}\right)^3 \left(\frac{V_{\text{pot}}}{70}\right)^3 (1 + 0.1 V_{shear})^{-2},$$

$$\text{PI} = V_m^2 = \frac{T_s}{T_0} \frac{C_k}{C_D} [CAPE^* - CAPE]|_m \qquad (3)$$

where $CAPE^*$ is the convective available potential energy of air lifted from saturation at sea level in reference to the environmental sounding, and $CAPE$ is that of boundary layer air. Both quantities are evaluated near the radius of maximum wind. Note that the effect of dissipative heating

Tropical cyclone identification method

The objective tracking algorithm, TRACKS, Hodges 1999.
Detection criteria:

a. The T63 relative vorticity maxima at 850 hPa must be $>5\times10-5s^{-1}$.

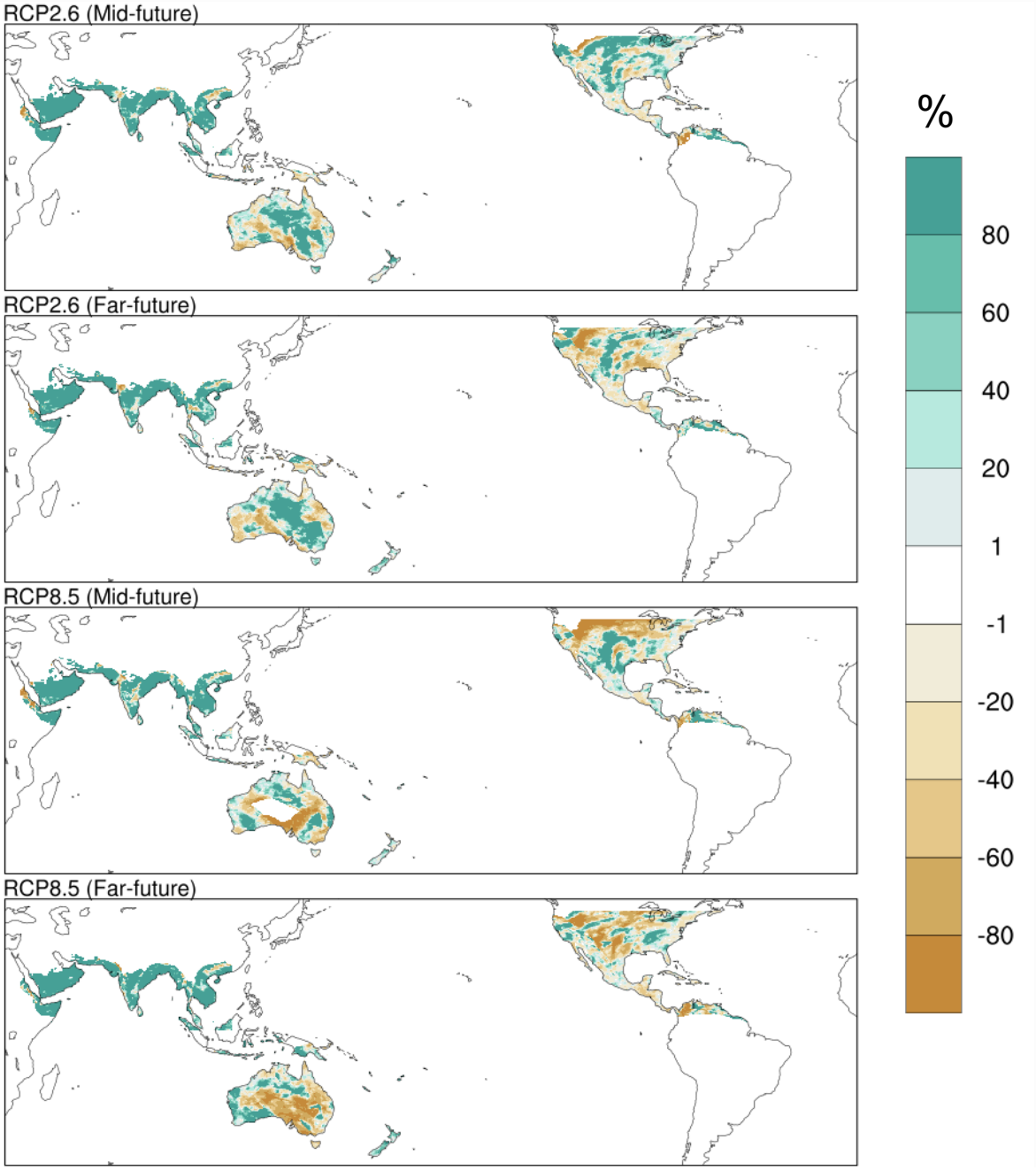
b. The vorticity maxima must exist at 850, 700, 500, and 200 hPa.

c. The difference in vorticity between 850 and 250 hPa must be $>6\times10-5s^{-1}$.

d. The 10-m wind-speed maxima must be $>17.5ms^{-1}$.

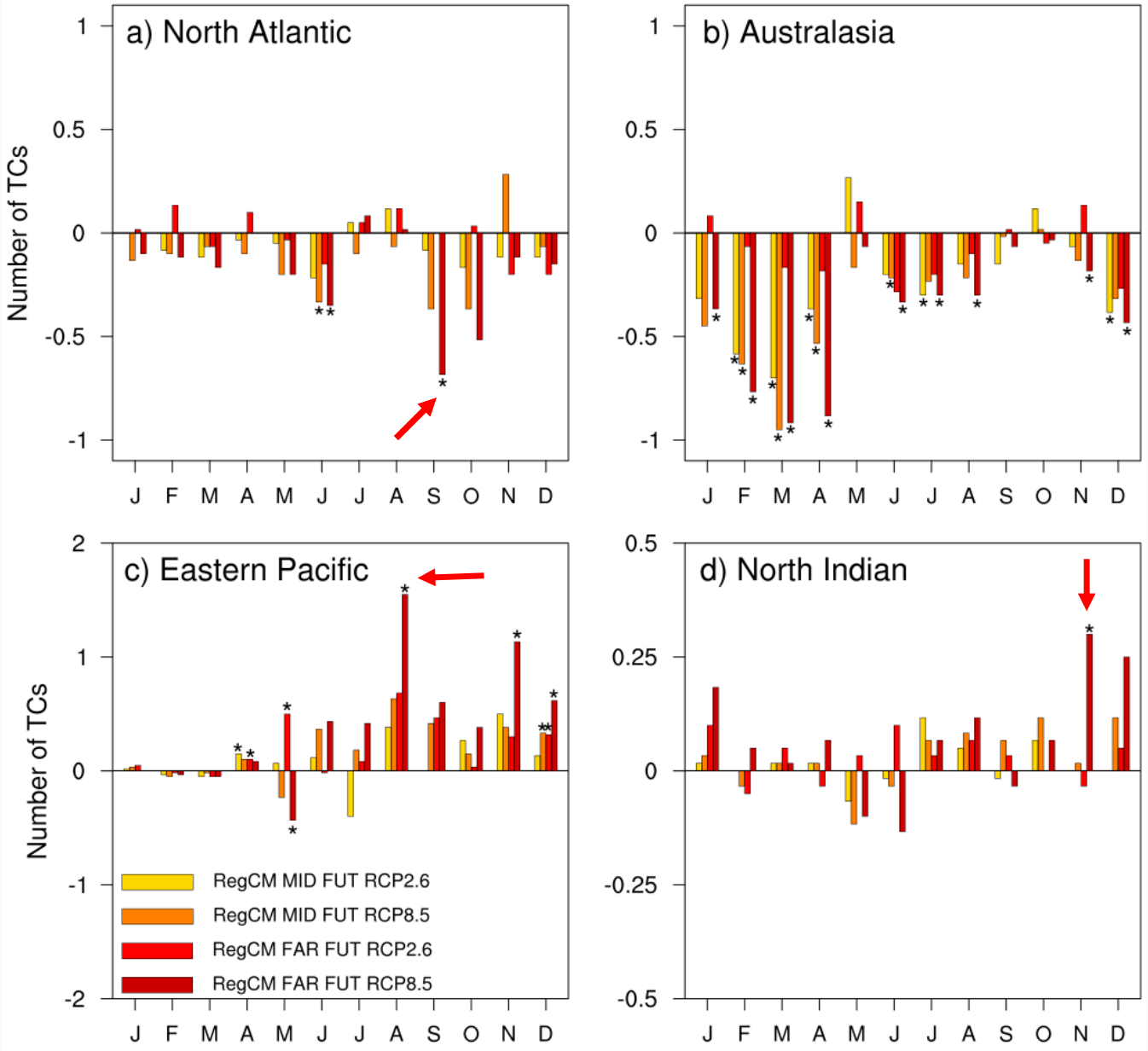
e. Criteria a, b, c and d must exist for at least four consecutive (1 day) time steps over the ocean only.

Future projections: Change in the storm rain-rate (%)



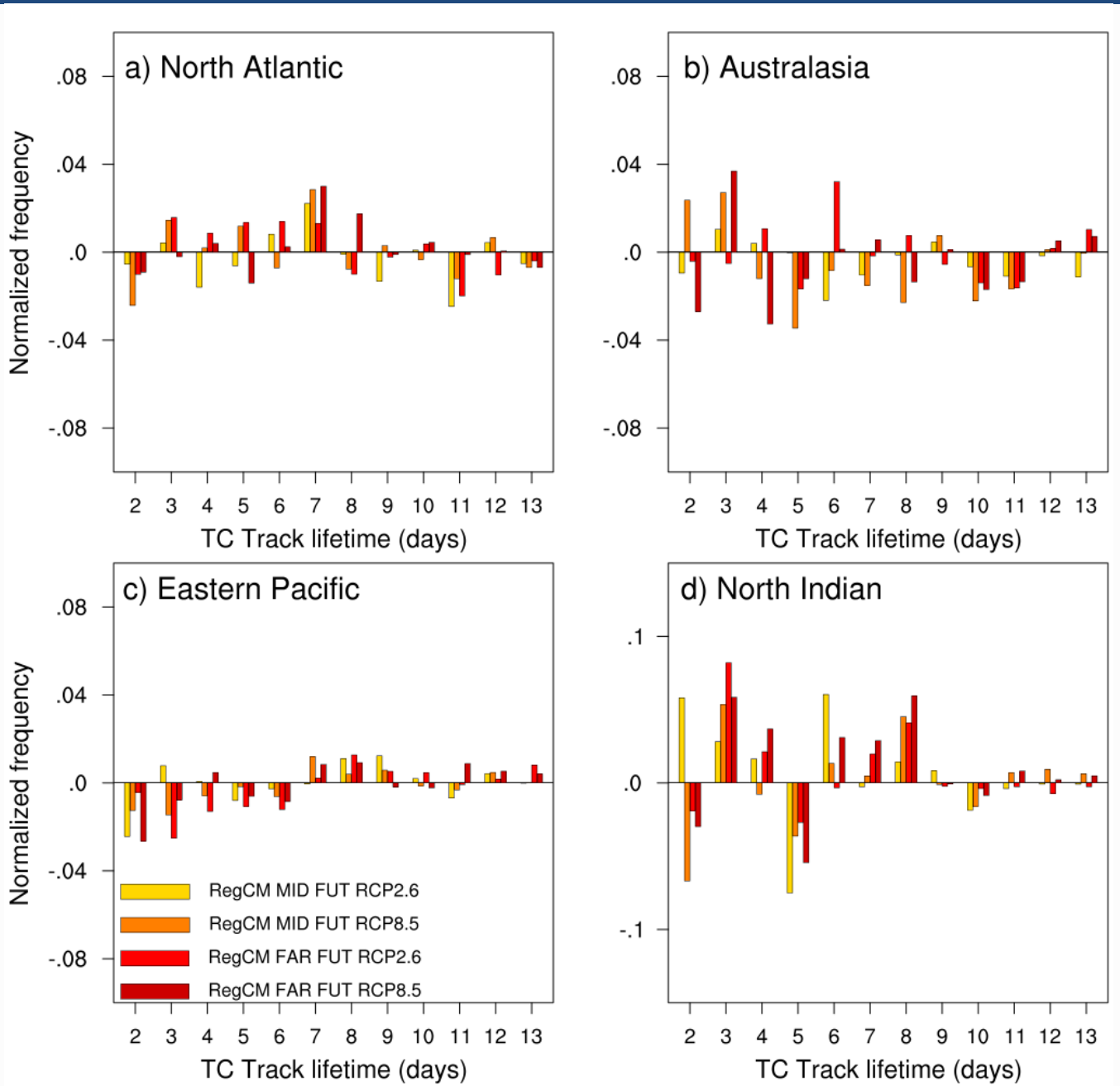
Considering daily rainfall to be TC induced if the center of circulation of the storm is located within 500 km radius from the grid point.

Future projections: Changes in the annual cycle

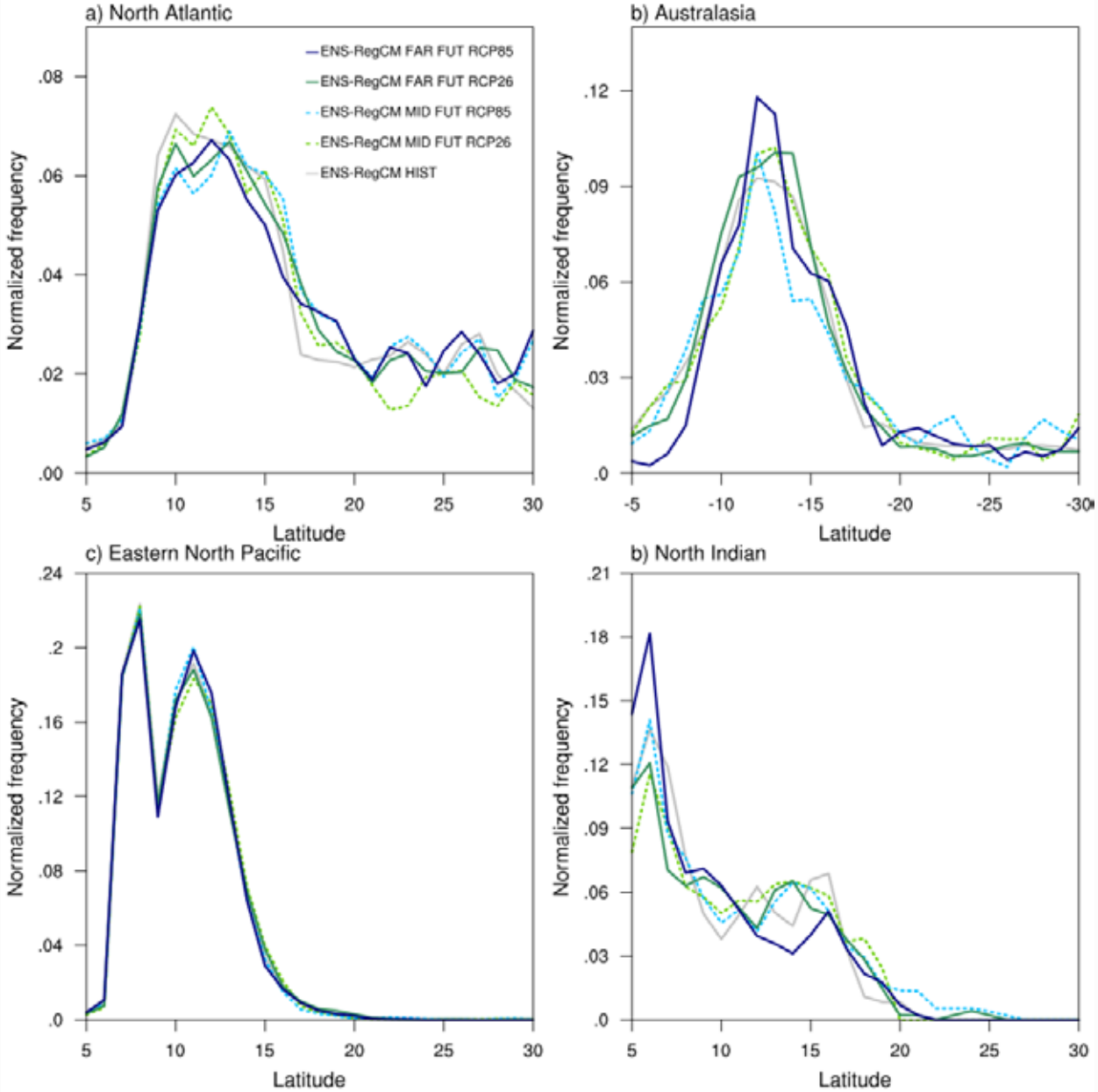


Asterisk symbols show where changes are significant at a 95% confidence level, based on the Wilcoxon rank-sum test.

Distribution of TC track life



Changes in genesis location



Pr data and SS scale

Classification	1-minute sustained wind speed (m/s)
Tropical depression (TD)	< 17 m/s
Tropical Storm (TS)	17 – 32 m/s
Category 1 (TC1)	32 – 42 m/s
Category 2 (TC2)	42 – 49 m/s
Category 3 (TC3)	50 – 58 m/s
Category 4 (TC4)	58 – 70 m/s
Category 5 (TC5)	> 70 m/s

In terms of observed precipitation, we use the Multi-Source Weighted-Ensemble Precipitation (MSWEP) V2, which is based on a combination of rain gauge measurements, satellite products and reanalysis data (Beck et al. 2017a, b).

Annual number of TC by Saffir-Simpson scale for the a) Eastern Pacific and b) Northern Atlantic for the period, 1981-2000. A statistical bias correction was applied to the simulated maximum surface wind speed