Sub-seasonal and seasonal predictions of West Pacific tropical cyclones

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1. Motivation

Tropical cyclones (TCs) are a substantial natural hazard, particularly in the West Pacific, where many of the strongest TCs form. The Philippines are struck more frequently by TCs than any other country. The combination of intense storms, a long coastline and steep topography make the Philippine population particularly vulnerable to TC impacts.

Forecast biases in TC position and intensity are often greater in the West Pacific than in any other basin (Fig. 1). These biases are related to coarse horizontal resolution and errors in large-scale circulation, for example in the West Pacific subtropical high.

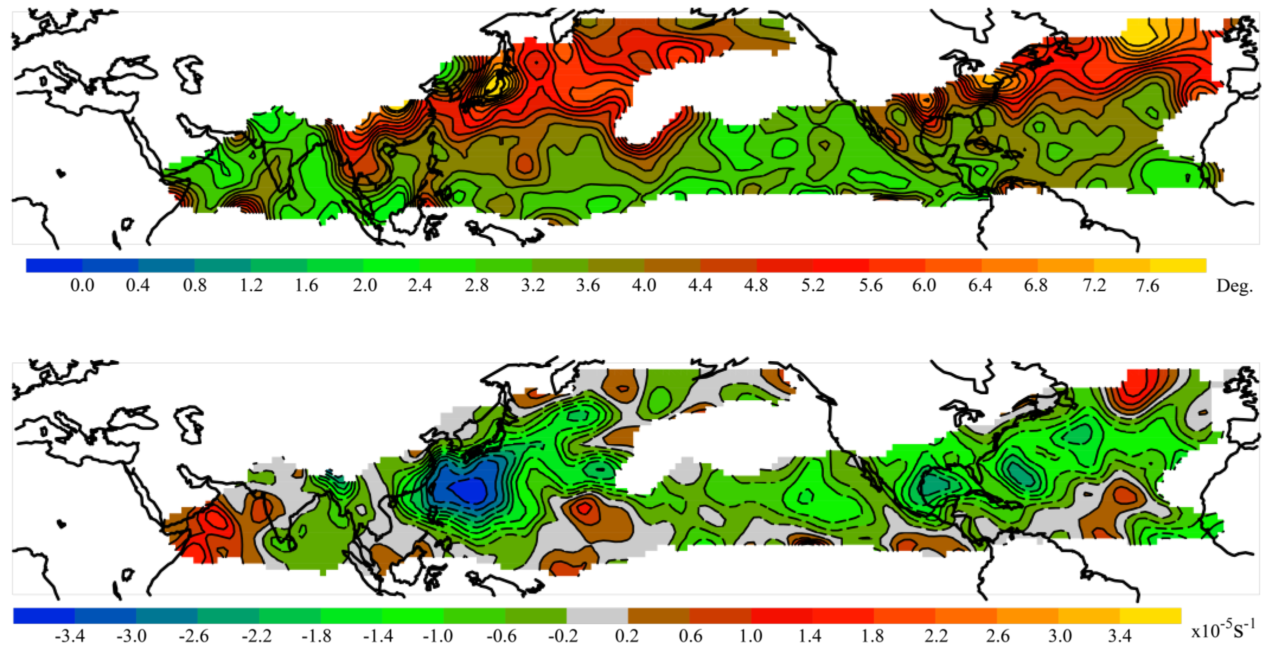


Figure 1: Errors in day-5 predictions of tropical cyclone (top) position and (bottom) intensity (by vorticity) in the Met Office Numerical Weather Prediction (NWP) model, using forecasts for 2006-2017.

2. Datasets

We tracked TCs using an objective algorithm (TRACK; Hodges et al., 2017) in

- ERA-Interim reanalysis (1979-2017)
- Met Office operational atmosphere-only NWP forecasts (7 days; 2006-2017)
- Met Office trial coupled forecasts with dynamical (3D) ocean (15 days, 2016-2017)
- Met Office trial coupled forecasts with mixed-layer (1D) ocean (15 days, 2016 only)
- Met Office coupled seasonal re-forecasts from GloSea5 (six months, 1993-2015)

For NWP, tracks are retained only if they "match" a track from the Best Track database, using a minimum distance threshold.

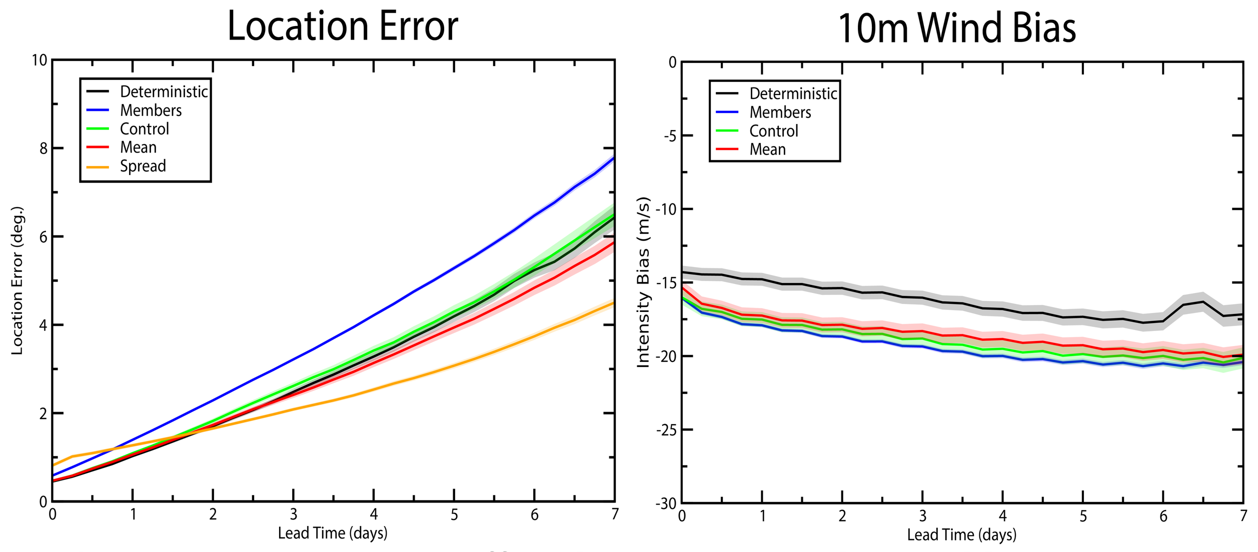


Figure 2: Errors in Met Office deterministic and ensemble NWP systems for West Pacific TCs for 2006-2017 against Best Track data.

3. Effect of MJO on TC predictions

The initial MJO phase has a considerable effect on errors in TC intensity, with **West Pacific** and **Western Hemisphere** phases outperforming **Indian Ocean** and **Maritime Continent** phases.

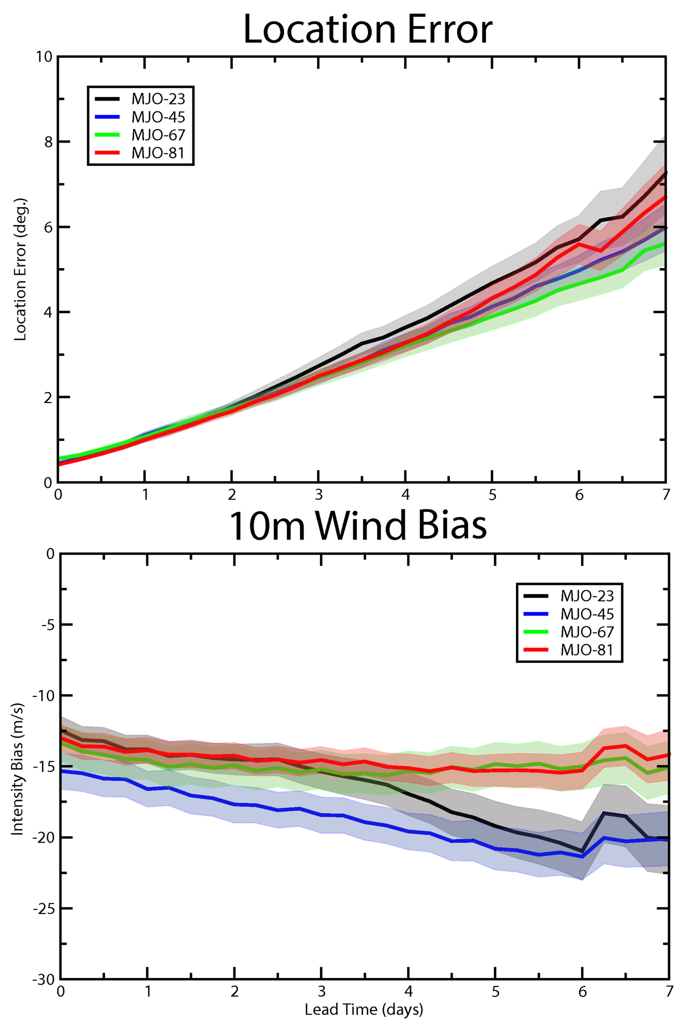


Figure 3: As in Figure 2, but with tracks separated by the MJO phase at the start of the forecast.

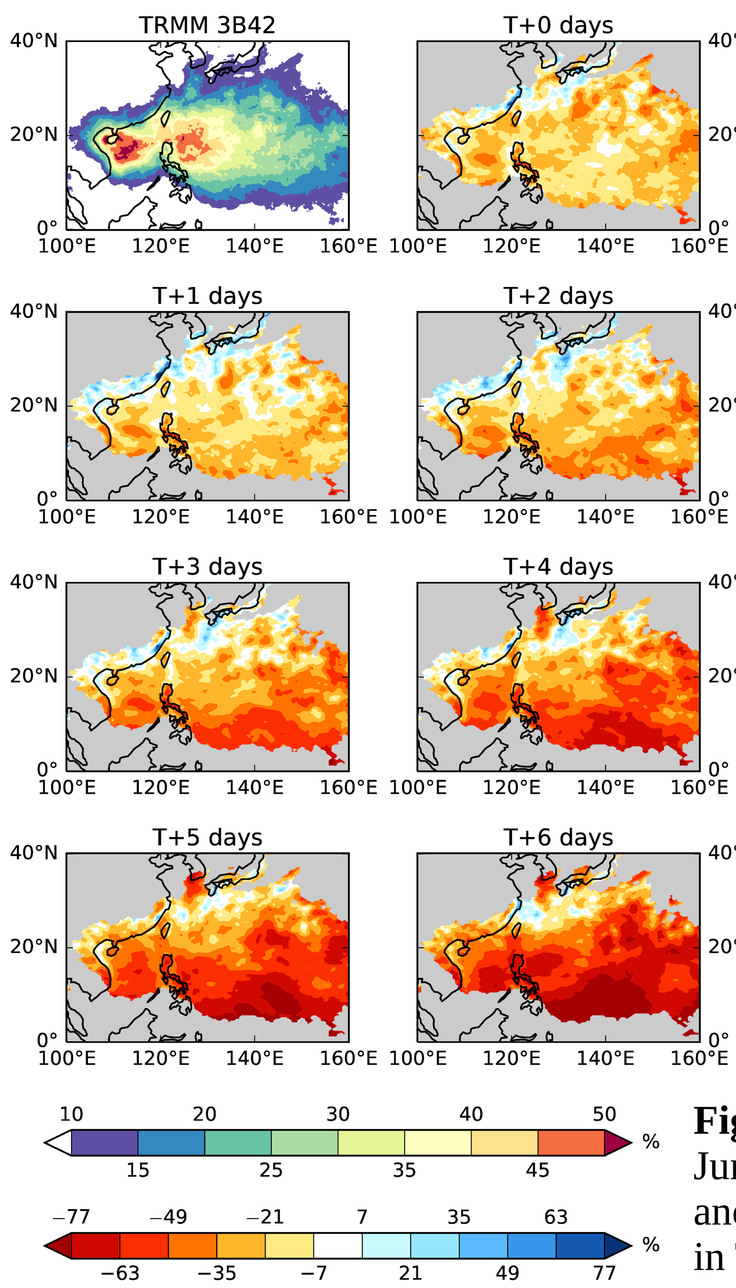
Phases 2-3 (black): Indian Ocean.

Phases 4 and 5 (blue): Maritime Continent

Phases 6 and 7 (green): West Pacific

Phases 8 and 1 (red): Western Hemisphere.

4. Predictions of TC rainfall



- We define "TC rainfall" as any rain falling within 5° of the TC centre.

TRMM rainfall and Best Track TC tracks show that up to 50% of June-November rainfall comes from TCs.

- Met Office NWP underestimates this contribution by about 20% at short lead times (0-2 days), increasing to 70% at long leads (4-6 days).

Figure 4: Top-left shows percentage of Jun-Nov rainfall from TCs in TRMM and Best Track. Other panels show bias in TC rainfall contribution from NWP.

Conclusions

- Active MJO conditions in the West Pacific improve forecasts of TC intensity, but not TC location.
- Air-sea coupling strengthens the too-weak subtropical high in atmosphere-only forecasts, improving TC tracks.
- Seasonal forecasts over-estimate TC counts in the subtropical Pacific, associated with a northward ITCZ shift and a weak subtropical high. ENSO teleconnections are under-estimated, but show a realistic spatial pattern.

5. Effect of air-sea coupling on TC prediction

There is little overall effect of coupling on 2016-17 West Pacific Tcs (Fig. 5).

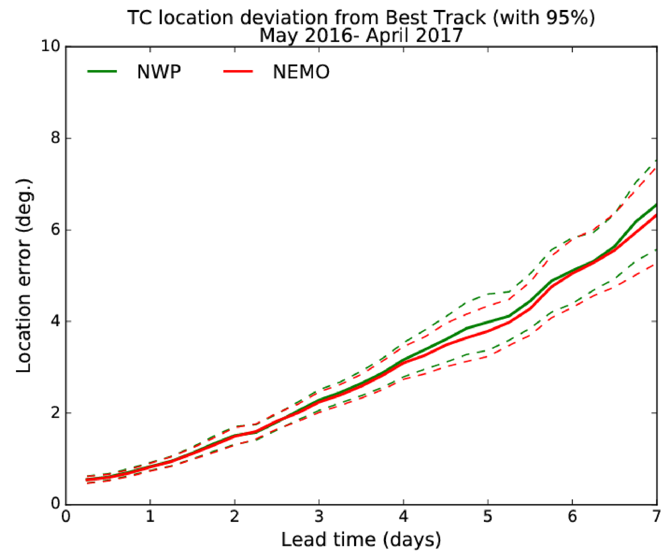


Figure 5: Location errors in uncoupled (green) and coupled (green, 3D ocean) forecasts for May 2016 to April 2017.

Coupling systematically improves TC tracks near the edge of the subtropical high (Fig. 6).

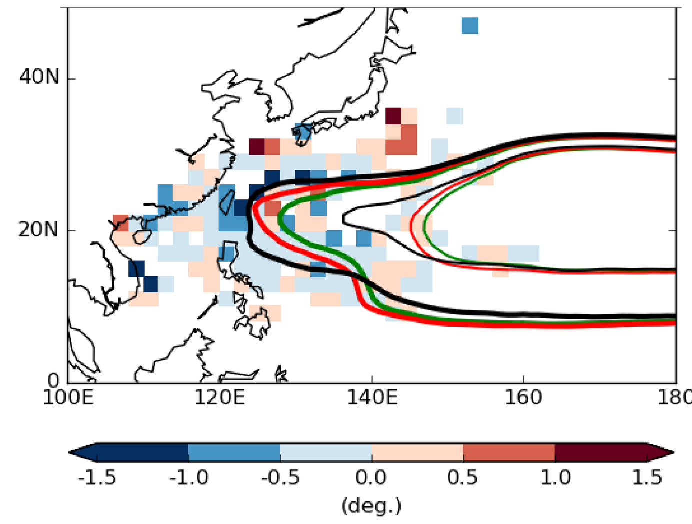


Figure 6: TC track differences (2°x2° boxes) coupled minus uncoupled; **negative:** coupled is better. Lines: edge of subtropical high in **ERA**, **coupled** and **uncoupled**.

The subtropical high is stronger and extends further west in coupled forecasts.

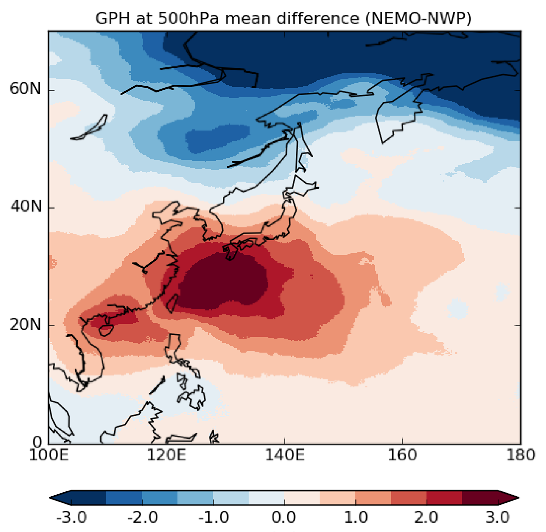


Figure 7: Mean difference in 500 hPa geopotential height between coupled and uncoupled forecasts.

The track of Typhoon Haima was improved substantially with coupling.

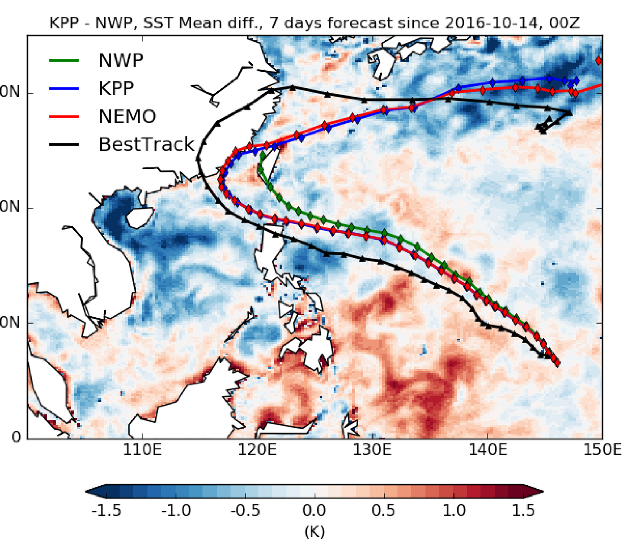


Figure 8: Track of Typhoon Haima from 14/10/16 0Z forecasts. Shading: mean SST difference, coupled minus uncoupled.

6. Seasonal prediction skill and ENSO teleconnections

GloSea5 produces too many TCs in the subtropical Pacific and not enough around the perimeter of the basin. High bias is collocated with low skill (Fig. 9).

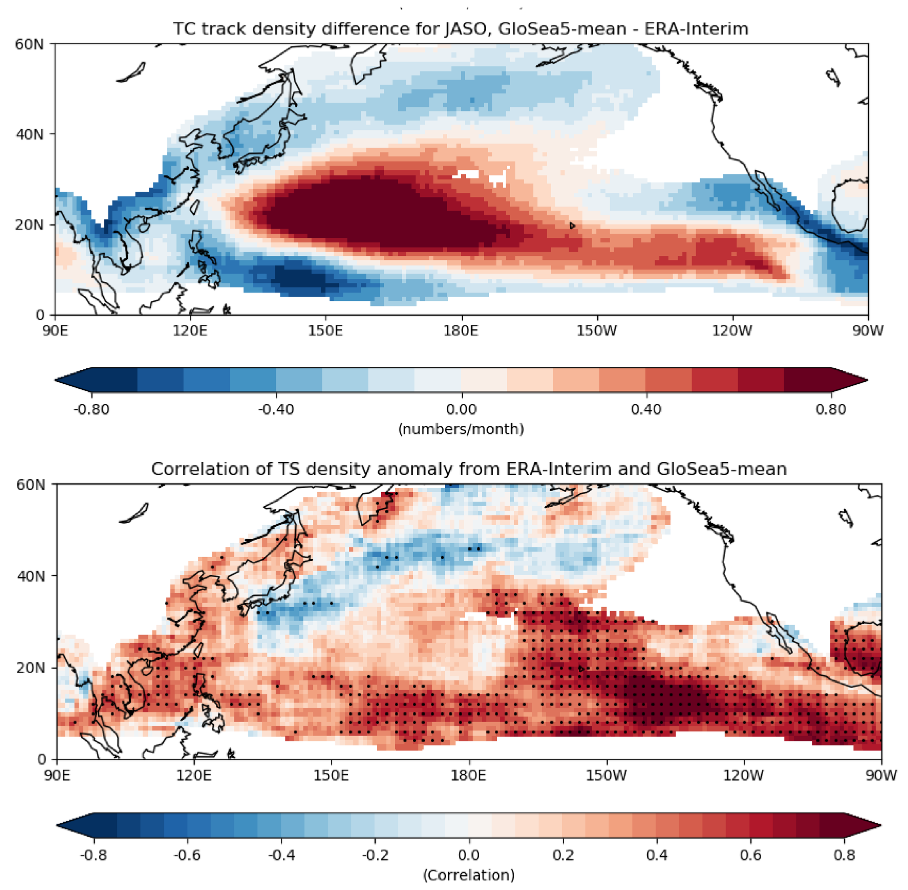


Figure 9: Top panel shows bias in TC track density for GloSea5 minus ERA-Interim (TCs/month); bottom panel shows anomaly correlation coefficient of TC track density between GloSea5 and ERA-Interim (stippling indicates significance at 5% level). Forecasts initialised in June for July-October.

These biases are related to a northward ITCZ shift, intense West Pacific convection and a weaksubtropical high (Fig. 10).

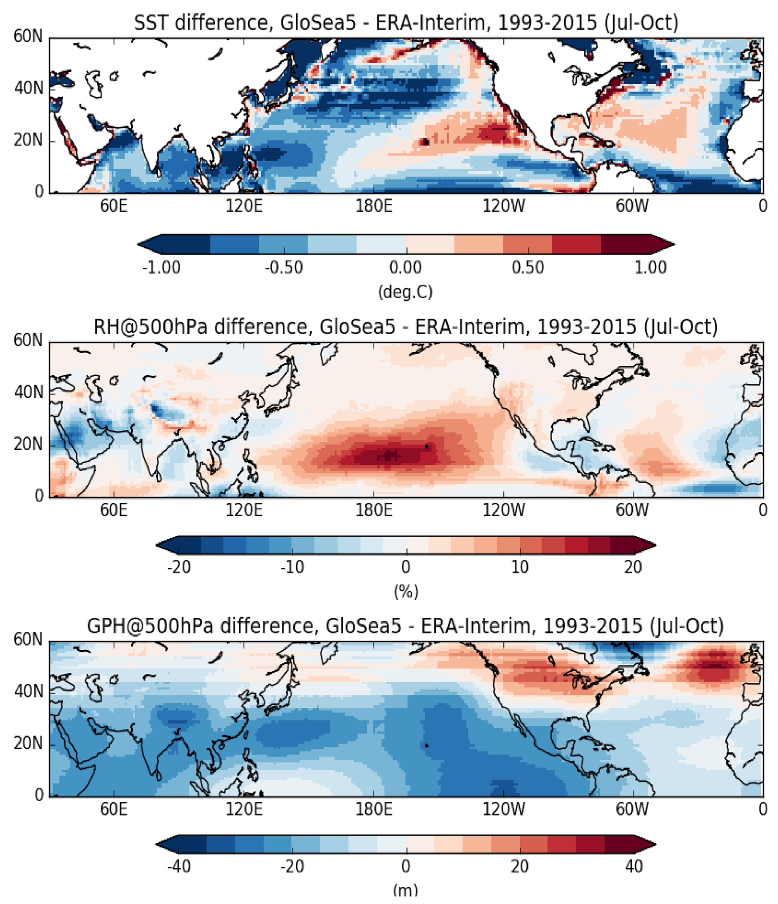


Figure 10: Mean-state biases in GloSea5 (June forecasts, July-October verification) against ERA-Interim reanalysis. Top: SST; middle: relative humidity at 500 hPa; bottom: geopotential height at 500 hPa.

GloSea5 underestimates the correlation between ENSO and TC activity, but the spatial pattern is similar to the correlation from ERA-Interim (Fig. 11).

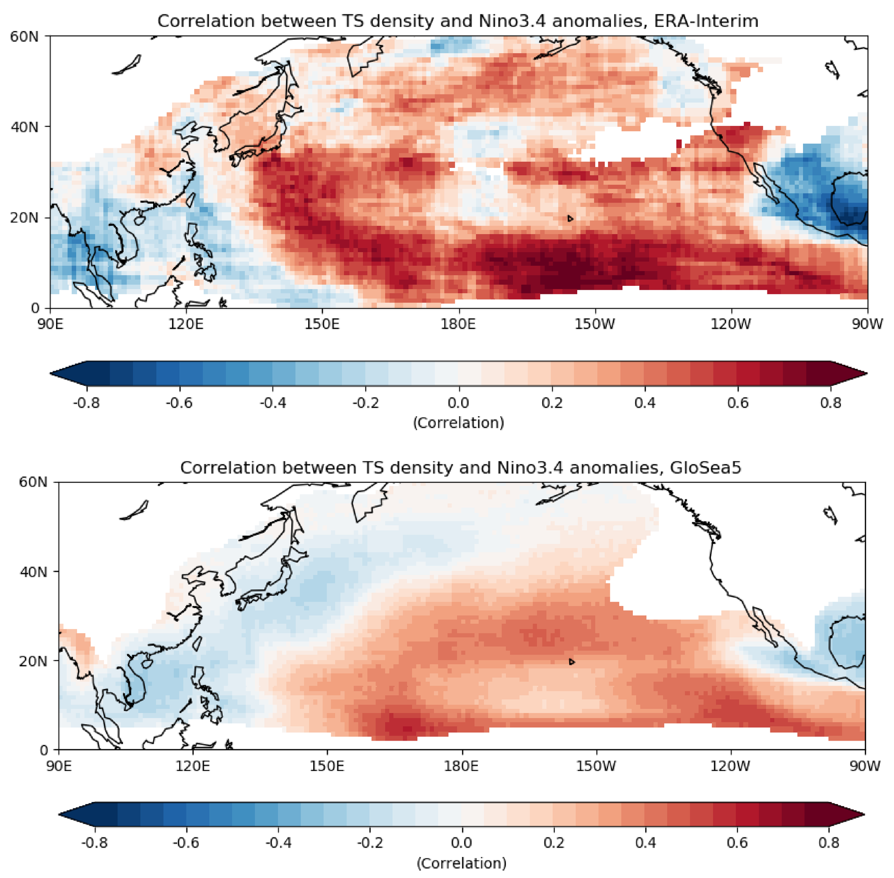


Figure 11: Correlations between Nino 3.4 and TC track density in (top) ERA-Interim and (bottom) GloSea5. The GloSea5 correlation is computed by resampling all re-forecasts 2,000 times to create 23-year timeseries (to match the length of the 1993-2015 baseline period; Johnson et al., 2017).

References

Hodges et al. 2017: How Well Are Tropical Cyclones Represented in Reanalysis Datasets? J. Climate, https://doi.org/10.1175/JCLI-D-16-0557.1
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