Teleconnections between ENSO and Southwest Pacific tropical cyclones in a high-resolution GCM

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Objectives

(1) To evaluate the ability of a high-resolution GCM to reproduce the observed teleconnection between ENSO and Southwest Pacific tropical cyclones.

(2) To understand the physical mechanisms responsible for the teleconnection in observations and in the high-resolution GCM.

1. Observed ENSO-cyclone teleconnection

A well-known relationship exists between the El Niño-Southern Oscillation (ENSO) and the paths of tropical cyclones in the Southwest Pacific: La Niña (El Niño) events are associated with a westward (eastward) shift in cyclone tracks, towards (away from) the Australian coast (Fig. 1).

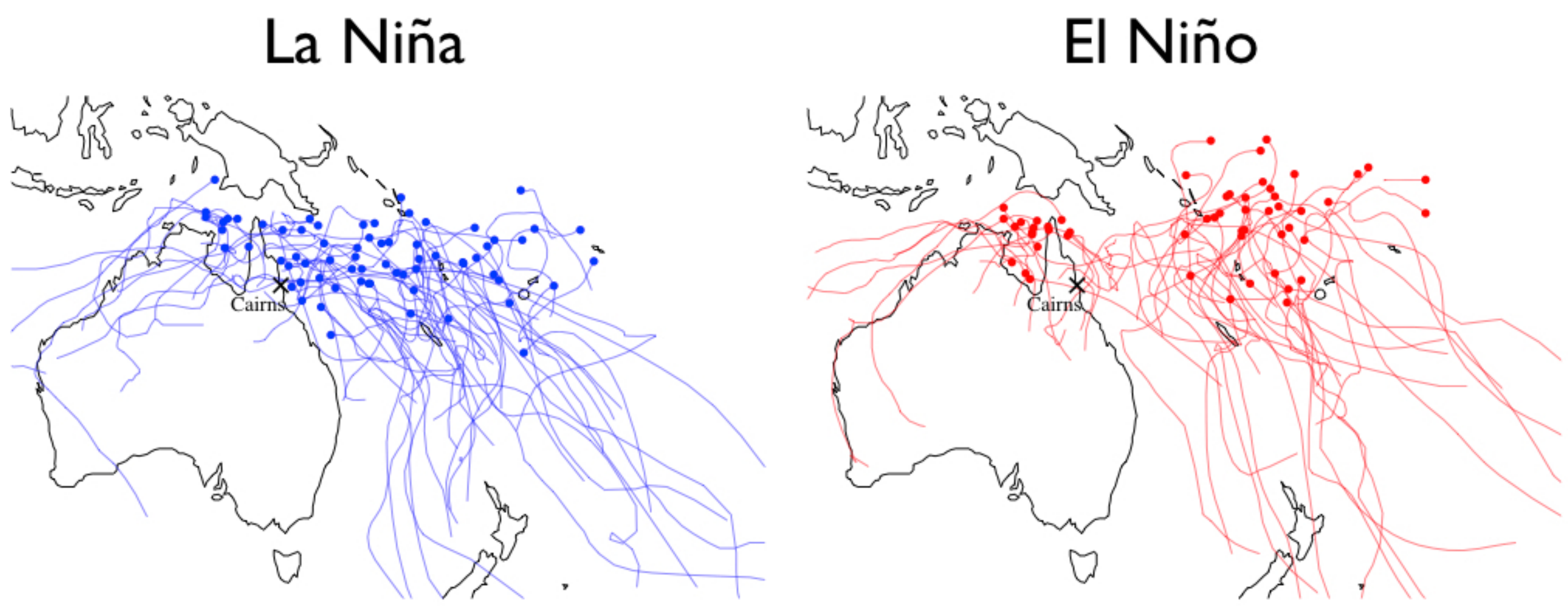


Figure 1: Tropical cyclones from IBTrACS for the seven La Niña and El Niño events since 1979.

A general circulation model (GCM) that could reproduce this observed relationship could be useful for seasonal forecasting of cyclone activity, as well as for understanding how climate change may affect the teleconnection.

2. Model simulations and tracking method

The ENSO-cyclone teleconnection is evaluated in atmosphere-only and coupled simulations of the high-resolution (~90 km atmosphere, ~30 km ocean) HiGEM GCM (Shaffrey et al., 2009; Table 1). HiGEM is based on the Hadley Centre HadGEM1, but at finer horizontal resolution in the atmosphere and ocean.

Simulation	Length	Compared to
Atmosphere-only (AMIP-type)	1979-2002	IBTrACS for 1979-2002
Coupled (present-day CO2)	150 years	IBTrACS for 1950-2008

Table 1: HiGEM simulations analyzed in this study.

HiGEM cyclones are tracked by the feature-tracking method of Hodges (1995), refined to detect only warm-core tropical cyclones. Cyclones are tracked for their entire life, from genesis to lysis, including extra-tropical transition.

3. Cyclone climatologies

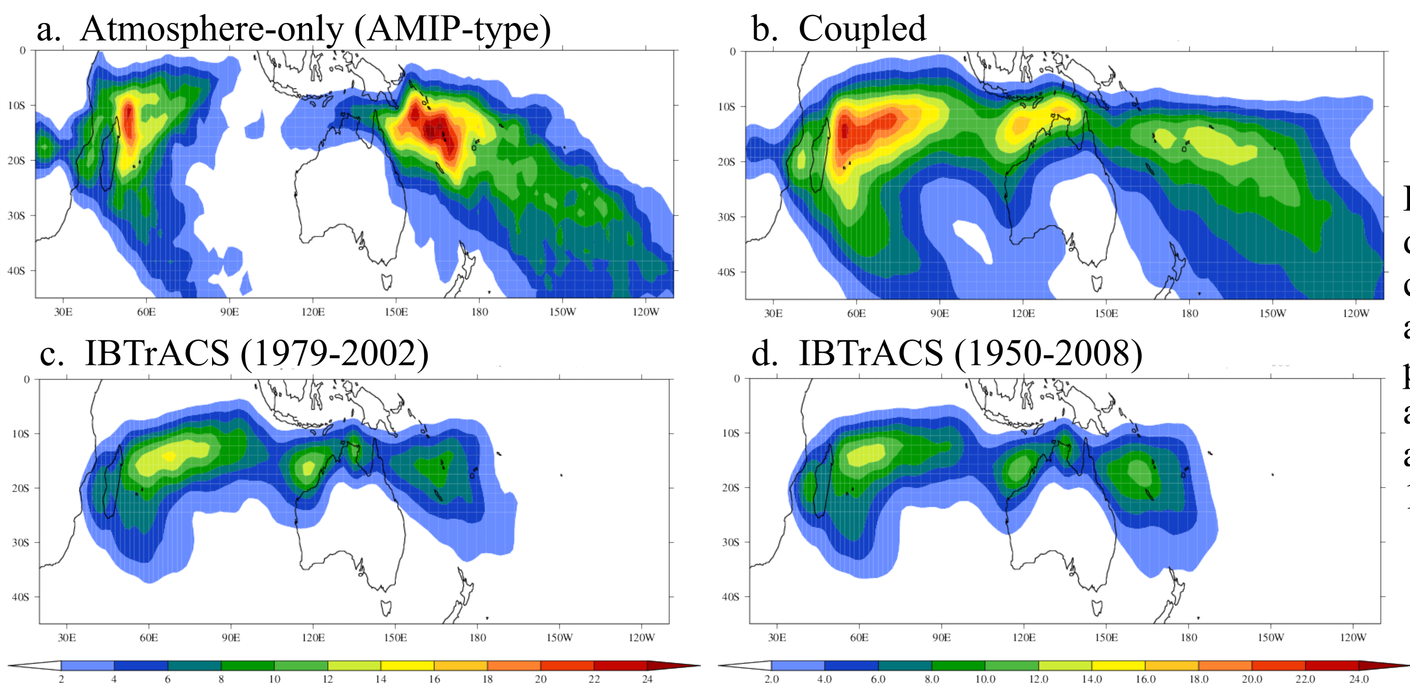


Figure 2: Track densities of tropical cyclones, expressed as cyclones per year per nominal unit area (a circle approximately 10^6 km^2).

Many more Southern Hemisphere cyclones are tracked in HiGEM than are present in IBTrACS (Fig. 2). The AMIP simulation has larger biases than the coupled one, particularly in the Coral Sea and Gulf of Carpentaria. The relative roles of model error, the tracking method and observational uncertainty in these biases are unclear.

Conclusions

(1) The atmosphere-only simulation reproduces the spatial structure of the ENSO cyclone teleconnection, although too many weak storms are tracked overall.

(2) The climatological number of cyclones and their spatial pattern is improved in the coupled model, but the teleconnection structure suffers from an overly westward extension of equatorial SST anomalies.

4. Simulated ENSO-cyclone teleconnection

The AMIP simulation reproduces the northeast (southwest) displacement of cyclone activity in El Niño (La Niña), in cyclone tracks (Fig. 3a) and genesis locations (Fig. 4a). The coupled model has an overly meridional shift (Figs. 3b, 4b), with more cyclones near northern Queensland in El Niño, contrary to IBTrACS (Figs. 3d, 4d).

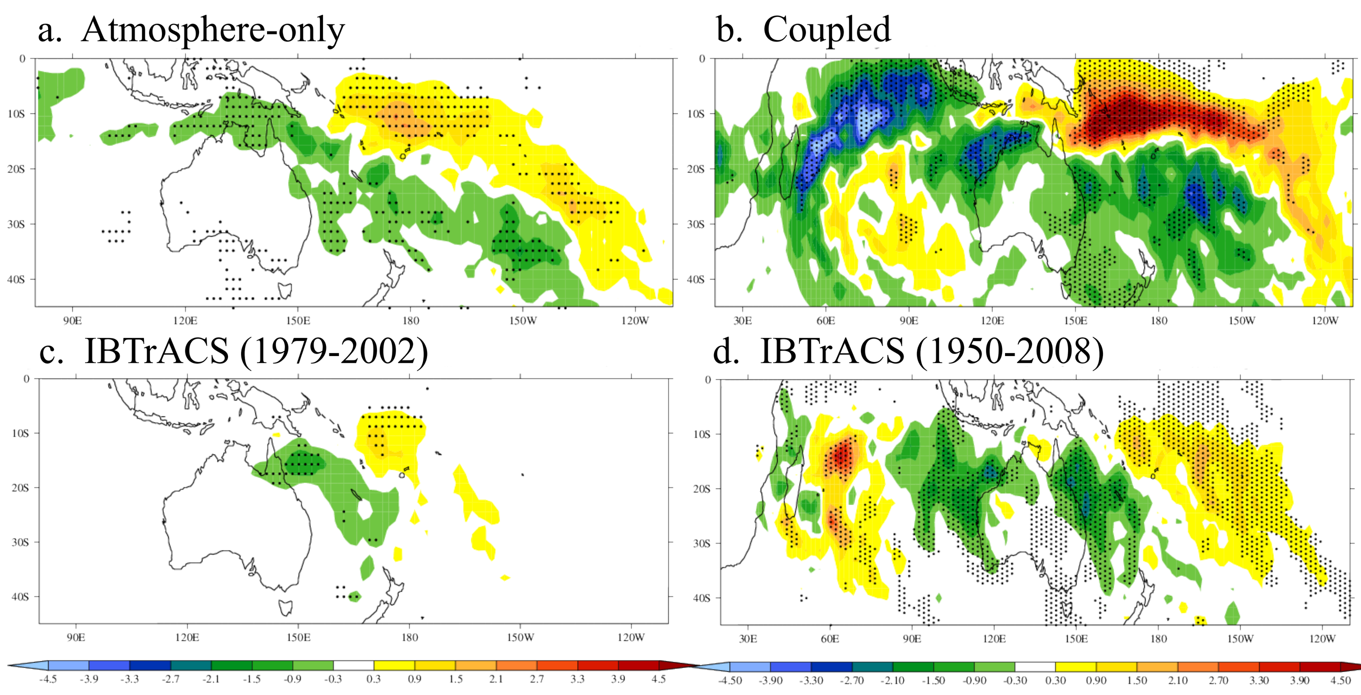


Figure 3: Linear regressions of **track density** on Niño 4 SSTs, normalized by the standard deviation of Niño 4. The atmosphere-only simulation and the IBTrACS are regressed on HadISST SSTs; the coupled simulation is regressed on its own Niño 4 index.

Note: As shown, the 1979-2002 IBTrACS [panels (c)] includes only the Southwest Pacific.

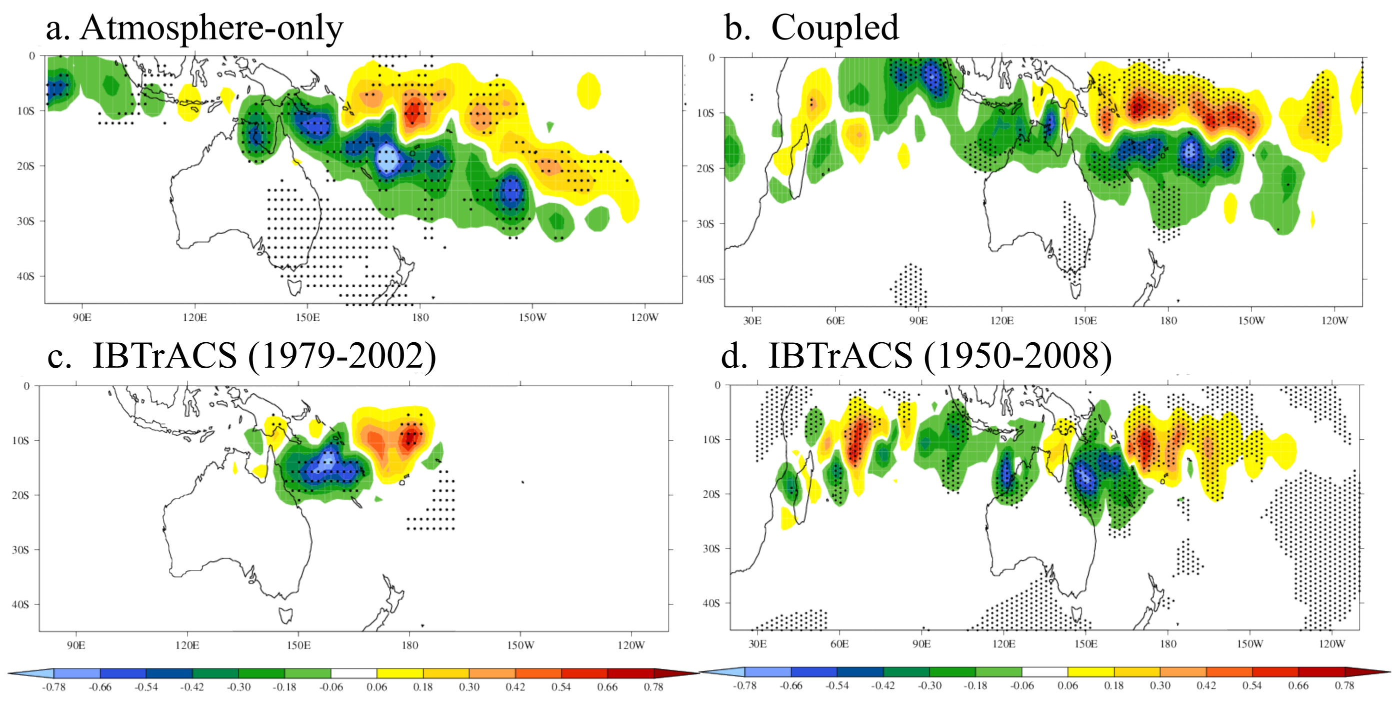
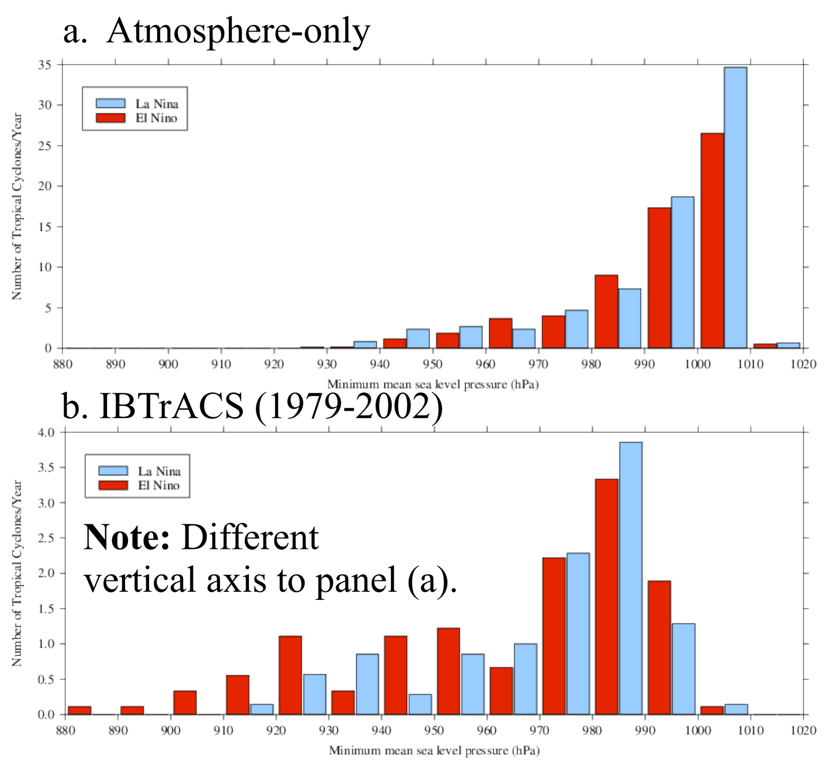


Figure 4: As in Fig. 3, but for **genesis density**. Units of genesis density are storms generated per season within a nominal unit area (a circle approx. 10^6 km^2)

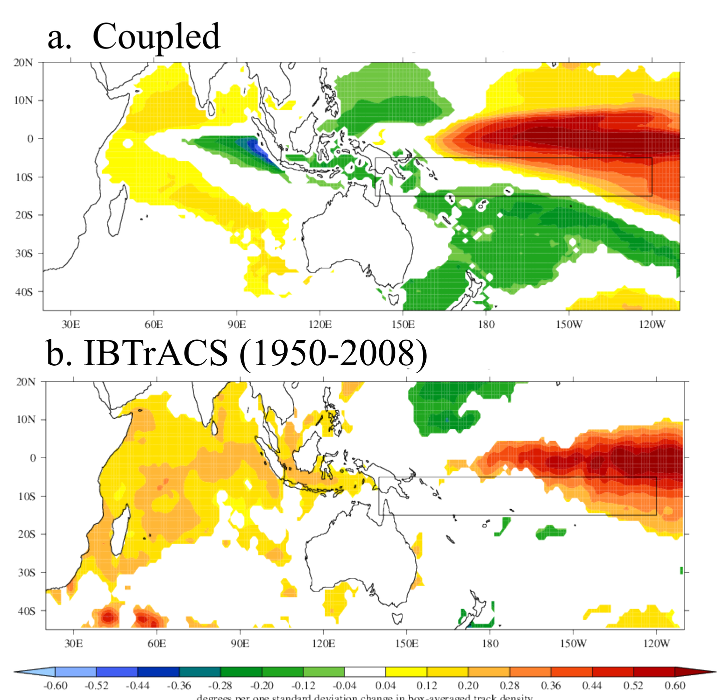
5. Cyclone intensity



The overestimate of cyclone activity in the AMIP simulation is due largely to the detection of many weak systems, which do not attain central pressures below 990 mb (Fig. 5a). These systems are much more rare in IBTrACS (Fig. 5b). Further work is necessary to determine whether (a) the structures of these weak systems in HiGEM resemble observed tropical cyclones or (b) the tracking criteria need to be refined.

Figure 5: Histograms of the minimum central pressure attained by cyclones within the Southwest Pacific (120°E-160°W, 25°S-0°).

6. Westward extension of ENSO



The overly meridional displacement of tropical-cyclone activity in the coupled model may be the result of a westward extension of ENSO SST anomalies (Fig. 6). High TC activity northeast of Australia is associated with warm SSTs that reach nearly to the Maritime Continent (Fig. 6a), potentially promoting erroneous enhanced cyclone activity near Cape York in El Niño (Fig. 3b).

Figure 6: Normalised regressions of DJF-mean SSTs on area-averaged track densities in the black rectangle. Regressions are shown only where significant at 5%.