Impact of sea surface temperature changes on tropical cyclone activity in a global atmospheric climate model

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Introduction

It is widely known that the frequency and intensity of tropical cyclones (TCs) depend on sea surface temperature (SST). However, the study of Swanson (2008) revealed the so-called nonlocality effect. By this effect the relative SST (SST – tropical mean SST) represents a better indicator for TC activity. Therefore, the SST of remote basins plays also an important role for the development and intensity of TCs. This teleconnection can only be established via the atmosphere. To investigate the nonlocality mechanism and the impact of global warming on TC activity we performed idealized simulations with the Planet Simulator (PlaSim) developed at the University of Hamburg (Fraedrich et al. 2005).

Model and experiment setup

The PlaSim includes an atmospheric spectral general circulation model along with models for other climate system compartments. In the vertical 28 Sigma-levels are adopted. The ocean SST is prescribed and the sea ice model is switched off. First of all the model is integrated at a low resolution (T42) for 10 years. The produced final state forms the initial condition of a one year simulation at a higher resolution (T170).

In the first series of experiment two idealized continents were placed in the model. Fig. 1 shows the SST for the experiments REF, WARMBASIN and COLDBASIN. In the latter two experiments positive and negative SST anomalies of 2.5K are added in the north-eastern ocean basin.

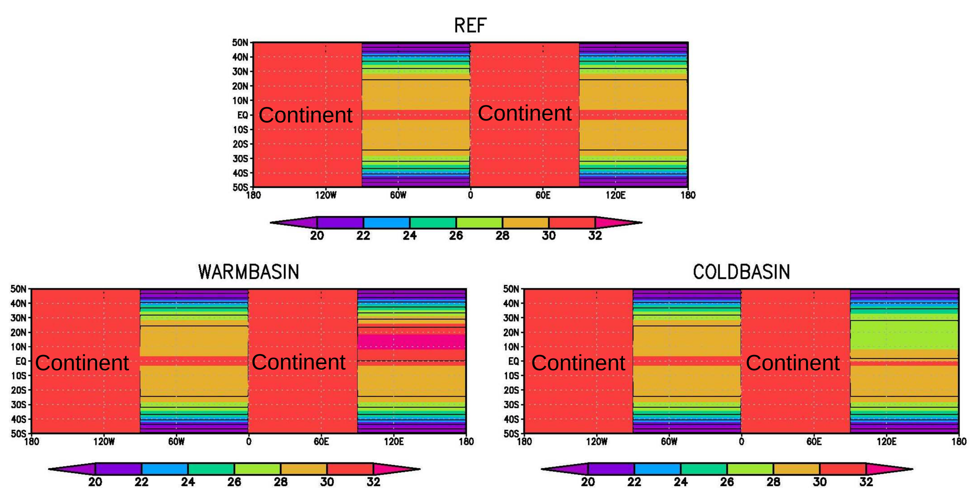

Figure 1. Prescribed SST (℃) for the basin experim ents REF, WARMBASIN and COLDBASIN.

An aquaplanet is assumed in a second set of experiments. Fig. 2 displays the meridional profiles of SST for the experiments COLD, REF and WARM. Experiment COLD and WARM mimic global warming and cooling by 5K respectively. To investigate the impact of solar absorption in the atmosphere additional experiments have been performed in which the short wave radiation scheme is switched off.

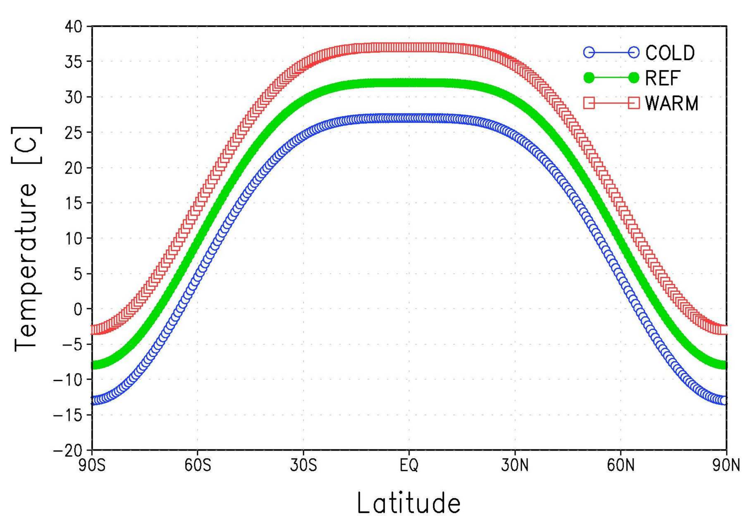

Figure 2. Prescribed SST (℃) as a function of lati tude for the aquaplanet experiments COLD, REF and WARM.

Basin experiments

For each run TC tracks (Fig. 3) have been detected by an objective method. TC tracks occur in all ocean basins but do not develop over land. Indeed, a nonlocality effect is already deducible in Fig. 3.

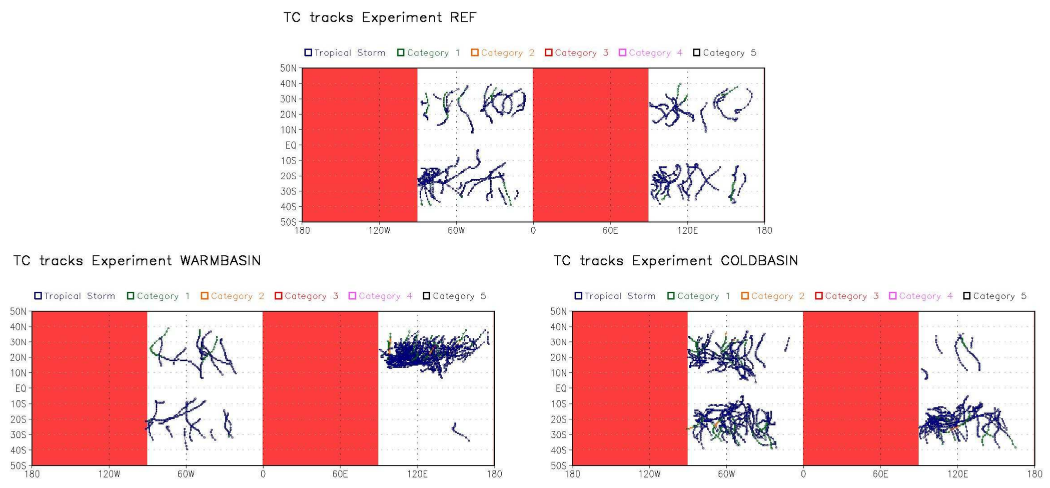

Figure 3. Detected TC-tracks in the experiments REF, WARMBASIN and COLDBASIN. The color refers to the Saffir-Simpson scale in the legend.

Table 1 contains values of the Accumulated Cyclone Energy (ACE)-Index for the various ocean basins. The ACE index measures the TC activity by taking both intensity and frequency into account (Bell et al. 2000). The table reveals the nonlocality effect in all ocean basins, i.e. the ACE increases (decreases) with increasing (decreasing) relative SST.

	REF		WARMBASIN		COLDBASIN	
	West	East	West	East	West	East
North	80	60	74 (-6)	542 (+482)	200 (+120)	21 (-39)
South	113	87	50 (-63)	3 (-84)	232 (+119)	202 (+115)

Table 1. ACE-Index in the various basin experiments. The number in brackets is the difference to experiment REF.

The modification of the planetary scale tropical circulation in terms of 200hPa velocity potential has been analyzed (Fig. 4) to examine the cause for the nonlocality effect. It can be seen that a local increase (decrease) of SST leads to an upper level divergent (convergent) flow anomaly. This is compensated by descent (ascent) above remote regions.

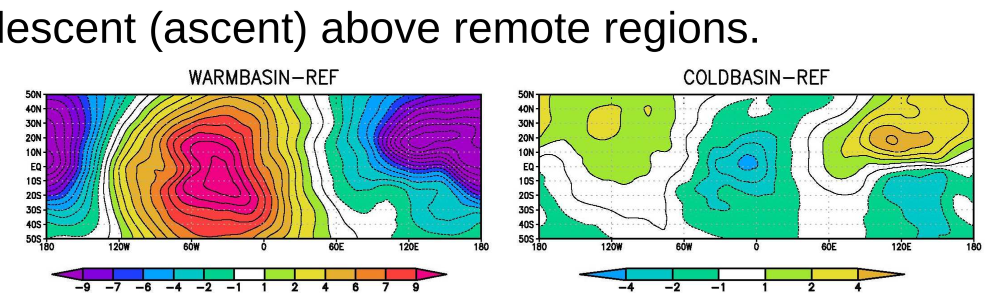

Figure 4. 200hPa velocity potential difference to REF [$10^6 m^2/s$] for WARMBASIN (left panel) and COLDBASIN (right panel).

Vertical motion induces vorticity and adiabatic temperature changes. The latter modifies the convective available potential energy (CAPE). It is known that both low level vorticity and CAPE enhance TC activity (Gray 1979). Fig. 5 reveals a change of these quantities in accordance with the nonlocality effect in most but not all remote regions.

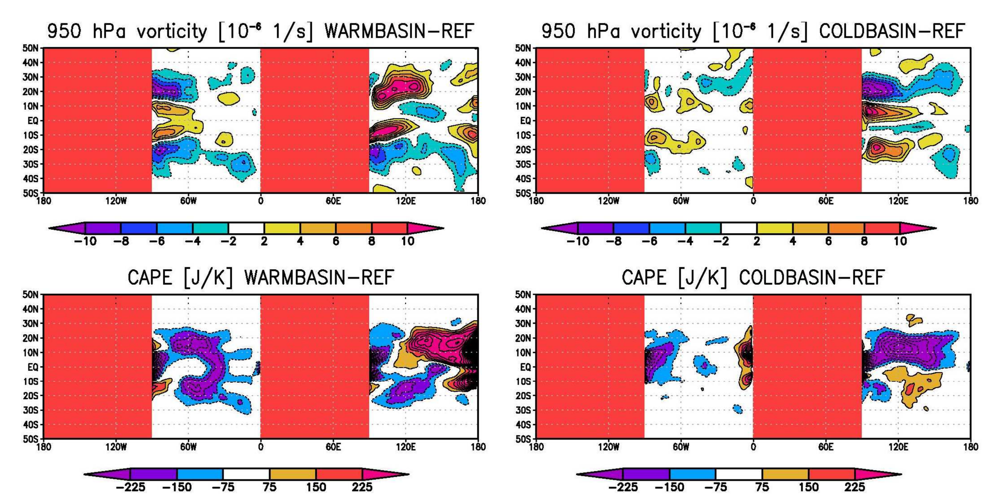

Figure 5. 950hPa vorticity (upper panels) and CAPE (lower panels) differences to REF for WARMBASIN (left panels) and COLDBASIN (right panels).

Aquaplanet experiments

Fig. 6 shows the TC tracks and table 2 the ACE index for the aquaplanet experiments. The TC activity changes only slightly between COLD and REF but a large decrease is observed when the experiments with short wave radiation are compared to those without. Thus solar absorption severely suppresses TC activity. Comparing WARM with REF shows a dramatic rise of TC activity in both cases indicating the presence of a tipping point in the model.

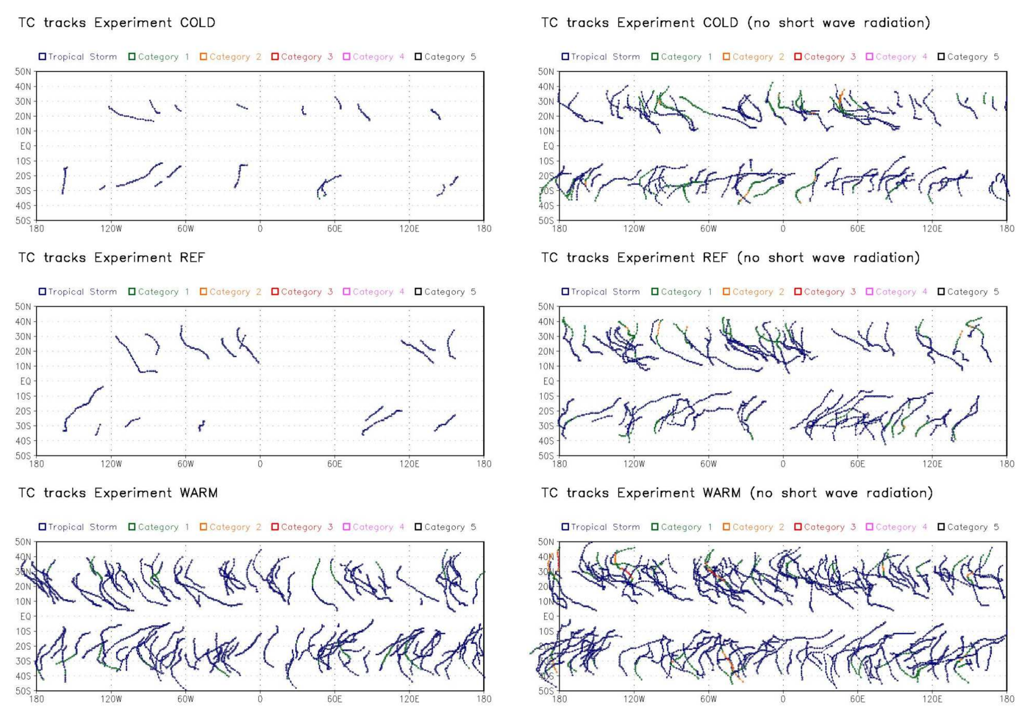

Figure 6. As in Fig. 3 but for the aquaplanet experiments.

	COLD	REF	WARM
short wave radiation	59	64	890
no short wave radiation	630	579	1178

Table 2. ACE-Index in the various aquaplanet experiments.

The seasonal genesis parameter (SGP, Gray 1979) and the genesis potential index (GPI, Emanuel and Nolan 2006) are shown in Fig. 7. Obviously, the SGP fails to predict the high sensitivity to the short wave radiation. On the other hand the GPI cannot explain the large differences between experiment WARM and COLD. Further analysis are necessary for a better understanding of these results.

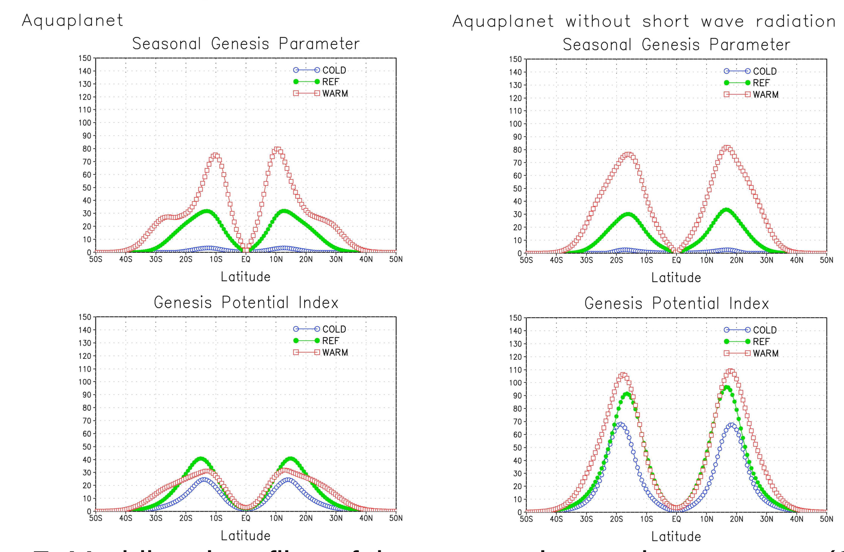

Figure 7. Meridional profiles of the seasonal genesis parameter (SGP) and the genesis potential index (GPI) for the aquaplanet experiments.

Acknowledgement

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