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VARIABILITY OF TROPICAL STORMS IN AGCMS

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The presence of tropical storms in Atmospheric General Circulation models (AGCMs) with properties similar to observed ones has been first noted by Manabe et al. (1970). The climatology and structure of the models storms was studied by Bengtsson et al. (1982, 1995). Wu and Lau (1992) explored the interannual variability of tropical storms in AGCMs, with a emphasis on the relation of model tropical storms and the El Niño-Southern Oscillation (ENSO). Vitart et al. (1997) used an ensemble of integrations to study tropical storms in AGCMs and studied their relation to the large scale circulation (Vitart et al., 1999) and sea surface temperature variability (Vitart and Anderson, 2001).

Variability of tropical storms is investigated here in low-resolution versions of the ECHAM3 and ECHAM4.5 Atmospheric General Circulation Models (AGCMs). Model tropical storms were detected and tracked in 50-year simulations (1950–2000) with 10 and 24 ensemble members, respectively. The detection and tracking algorithms are described in Camargo and Zebiak (2002) and were also used to study cyclogenesis of model tropical storms in the Western North Pacific (Camargo and Sobel, 2002).

The two models correctly simulate the annual cycle of tropical storm frequency in most regions, with the exception of the North Indian Ocean where they do not reproduce the May and October peaks of tropical storm activity; the models have a peak in August similar to the Western North Pacific. The maximum of South Pacific storm activity in the ECHAM4.5 occurs in March rather than in January as observed. In general, the models produce fewer tropical storms in the most active periods of the year than observed with the exception of ECHAM4.5 in the Western North and South Pacific. The largest model bias in the number of storms occurs in the Atlantic with ECHAM4.5.

Both AGCMs best simulate interannual tropical storm variability in the Pacific and Atlantic, and have their weakest skills over the Indian Ocean. In some periods, model variability of the follows quite well observed variability, while in others it does not, suggesting that some signals which are not being correctly simulated in the models are influencing the observed variability. By calculating the correlations of the frequency of storms in both models with observations in different ocean basins one notes that there is a large variation of skill in the models, but in general the ENSO influence seems to be the source of skill in the ocean basins where the correlations are significant.

ENSO has a large influence on tropical cyclones around the globe. In some basins, such as the Atlantic (Gray, 1984) and the Eastern Pacific, the main effect of ENSO is to modify the frequency of storms, while in others, such as the Western Pacific (Chia and Ropelewski, 2001) and South Pacific (Basher and Zeng, 1995), there is a shift on the cyclogenesis region on the basin. An important issue for forecasting tropical storm frequency is the ability of the models to reproduce the observed variability due to ENSO.

The correlation of the number of tropical storms in each basin with Nino3.4 in the models is, in general, stronger than observed. For instance, in the Western North Pacific where the correlation of the observed number of tropical storms with Nino3.4 is not significant, ECHAM3 storm frequency has a strong correlation with Nino3.4. In the Australian Basin ECHAM3 produces more storms when there is an El Niño event, while the opposite happens in the observations and in ECHAM4.5. Another interesting case is the North Indian Ocean, where the ECHAM4.5 tropical storms are much more related to ENSO, than happens in reality. As we are dealing with ensemble means, the model-based correlations are expected to be larger then the observed ones, where there is only one realization and a much smaller ratio of signal to noise, however values nearer to the observations could be expected. Most basins where the interannual variability is much different from the observed coincide with the regions where the correlation with Nino3.4 is too strong, such as the South Indian Ocean, Australian Basin and Western North Pacific (ECHAM3) and North Indian Ocean (ECHAM4.5).

An important effect of ENSO in the Western North Pacific is a shift of the genesis position (Chia and Ropelewski, 2001). Both models are able to simulate the longitudinal and latitudinal shifts in El Niño and La Niña years, although the average initial position in the models has a bias to the east. Due to the ability of the models to simulate this signal and size of the Western Pacific Basin we divided the Western Pacific in four sub-basins. The first sub-basin encompasses the South China Sea (100°W–120°W), the second and the third are respectively: (120°W-150°W) and (150°W–180°W), finally the fourth sub-basin is east of the dateline (180°W–160°E). Both models have skill in the middle basins, have a bias on producing too many tropical storms near the dateline and too few on the South China Sea. Therefore, in order to better use the models' skill, we are now concentrating our analysis of the models in the middle of the Western North Pacific Basin. Collins and Mason (2000) also divided the Eastern North Pacific in two sub-basins to enhance their understanding of the observed climatological factors involved in tropical cyclone formation.

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Both models capture the change of frequency in the North Atlantic and the Eastern Pacific related to the ENSO phase, with less model tropical storms than average happening in the North Atlantic during an El Niño year and more storms than average in a La Niña year. In the Eastern North Pacific, the frequency dependency of ENSO is opposite from the Atlantic and this signal is well simulated by both models despite a large model bias of too few storms in both the Atlantic and the Eastern Pacific. There is also a shift in the location of model tropical storms in the Eastern Pacific, with model storms genesis spreading to the west during an El Niño year. In the Southern Pacific and the Australian region, both models are able to simulate the shift of genesis and tracks due to ENSO. In an El Niño year tropical storms genesis and tracks are nearer the equator and are located more to the east of Australia then in a La Niña year.

Recently, a study on the causes of the drought on the Central and Southwest Asia concluded that the sea surface temperature on the warm pool could change the character of La Niña influences on precipitation in the Indian Ocean (Barlow et al., 2002). We are looking into the combined effects of ENSO and warm pool conditions on typhoons. Preliminary results show that composites according to the ENSO phase and the temperature anomaly in the warm pool, lead to differences in the characteristics of typhoon season in the observations. The same analysis was performed in both models and they do not seem to have the ability to reproduce these changes.

Goldenberg et al. (2001) reported a recent increase in Atlantic Hurricane Activity and related this to Atlantic sea surface temperature anomalies in the warm north Atlantic tropical region and the far North Atlantic. We are currently investigating if the models have skill in reproducing this decadal variability in the Atlantic, similar to the analysis of Vitart and Anderson (2001).

Following Vitart et al. (1999), we are also examing the effects of different wind shear patterns related to the sea surface temperature anomalies cited above and their effect on the model tropical storms. A similar dynamically based analysis will be applied in future GCM tropical storm analysis as was used by Thorncroft and Pytharoulis (2001) in the North Atlantic.

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