Variability of Indo-Pacific tropical cyclone activity and related socioeconomic disasters

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I. INTRODUCTION

The primary goal of our investigation is to improve seasonal and multiseasonal forecasts of tropical cyclone (TC) activity and finally of TC-related socioeconomic disasters in the Pacific and Indian Ocean region, whereby the focus is on the western North Pacific (WNP). Natural disasters are loss events with socioeconomic as well as natural causes. One group of causal factors is hazardous events like TC-related winds and floods. Other groups are exposure and vulnerability characteristics of the exposed elements (i.e., people, infrastructure, and economic activities) that make them susceptible to damage from the occurrence of a specific type of hazard. Like climate-related hazard events, value concentration and damage susceptibility are dependent on both space and time. Interannual variations of TC activity over the Indo-Pacific region can be associated with the El Niño-Southern Oscillation (ENSO), as was shown by previous studies. Using disaster data from Munich Re's NatCatSERVICE database, one of the most comprehensive global natural catastrophe databases, and TC best-track and Tropical Rainfall Measuring Mission (TRMM) precipitation data, two questions are considered: Do TC activity anomalies become more extreme or widespread during ENSO extremes? To what extent do TC-related socioeconomic disasters change during El Niño/La Niña conditions? Furthermore, it is very important to study the interdecadal variability of TC activity, which may be helpful in reducing human and monetary damages through proper preparation before the TC season. In this work, interdecadal ENSO variability is linked with observed interdecadal variations of TC activity over the WNP. Finally, possible changes in this interdecadal variability of ENSO respectively of WNP TC activity due to greenhouse global warming are examined.

II. TC ACTIVITY

In this study, the accumulated cyclone energy (ACE) index is employed to describe TC activity. ACE is a quantity that combines the number, lifetimes, and intensities (i.e., maximum wind speed) of TCs. It is derived from the Joint Typhoon Warning Center (JTWC) best-track data set (TC center locations and intensities at 6-hour intervals). On the other hand, TC track information is directly associated with global data of lightning and precipitation (rainfall for 0.25°x0.25° grid boxes every 3 hours) obtained from instruments onboard the TRMM satellite. This allows evaluation of lightning and precipitation rate in tropical storms, as alternate measures of cyclone intensity. Furthermore, disaster data from Munich Re's NatCatSERVICE database is used, representing the direct social and economic impacts of TCs.

III. INTERANNUAL AND INTERDECADAL VARIATIONS OF TC ACTIVITY

ENSO varies on both interannual and interdecadal timescales (e.g., Wang (1995)). In the wavelet analysis of the monthly mean Niño-3.4 index (sea surface temperature (SST) anomaly averaged over 5°S-5°N, 170°W-120°W), from 1970 to 2006, the variance changed on two timescales that are significant at the 5 % level: 1.3-6.6 years and 9.3-15.6 years (Fig. 1). In this work, it is shown that the interannual variability of

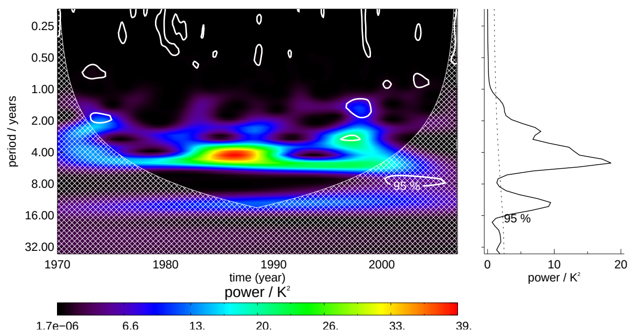

FIG. 1: Wavelet analysis of monthly mean Niño-3.4 index from 1970 to 2006. Left: Local wavelet power spectrum using the Morlet wavelet. The left axis is the wavelet period (in yr). The bottom axis is time (yr). The shaded contours are the wavelet power (in K^2). The thick white contour encloses regions of greater than 95 % confidence. Cross-hatched regions indicate the "cone of influence" (COI), where edge effects become important. Right: Global wavelet spectrum. The left axis is the wavelet period (in yr). The bottom axis is the wavelet power (in K^2). The dotted line is the 95 % confidence level for the global wavelet spectrum.

Indo-Pacific TC activity can be largely associated with the interannual ENSO variability (Fig. 2). Peculiarities in climate and disaster data are linked with dynamic and thermodynamic conditions in the atmosphere. For example, during El Niño conditions, anomalous westerlies over the East China Sea and Sea of Japan would likely steer a TC that forms east of the Philippines northward instead of moving into the Asia mainland. As a result, TC activity in Japan and in the areas to its east is likely enhanced. In contrast, less TCs follow the westward track across the Philippines and the South China Sea. Consequently, TC activity is likely decreased there. During La Niña the dynamic conditions in the atmosphere are almost reversed. This corresponds well with preceding studies (e.g.,

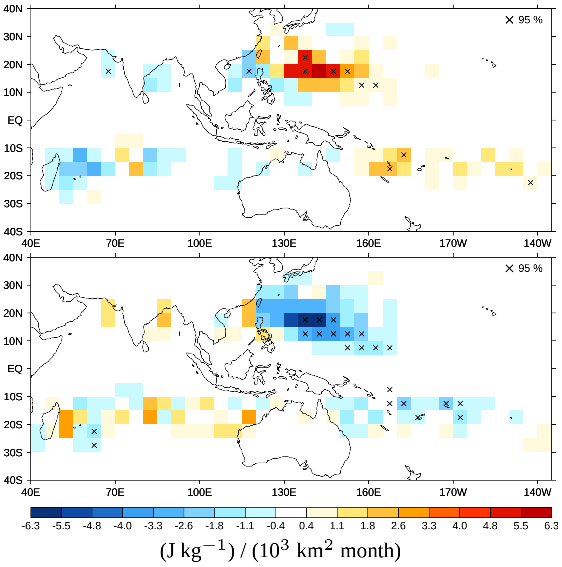

FIG. 2: Anomaly of the ACE index in J kg^{-1} per 10^3 km^2 and month, 1980-2005 (sample period and climatology): El Niño (above) and La Niña (below). El Niño and La Niña months are defined according to the monthly mean Niño-3.4 index from 1950 to 2007. The upper and lower 25 % of the distribution delimit ENSO extremes (El Niño and La Niña). Remaining months are classified as neutral. The nonparametric Wilcoxon Rank-Sum test is used to test the hypothesis that the respective samples for each 5°x5° grid box have significantly (i.e., significant at the 5 % level) different means of distribution in comparison with the whole population. Significant grid boxes are marked with "x".

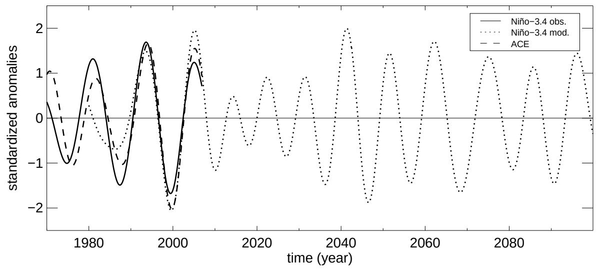

FIG. 3: Reconstruction of the monthly mean Niño-3.4 index from 1970 to 2006 (solid), of the monthly mean HadGEM1 SST averaged over the Niño-3.4 region from 1980 to 2099 (dotted), and of the monthly mean ACE-Index for the WNP from 1970 to 2006 (dashed) for periods 9.3-15.6 years. Standardization is done in the usual way, i.e., by dividing all values of the respective variable by its standard deviation.

Chan (2000)). Different measures of TC activity, like TC-related winds, rainfall, and socioeconomic disasters, are correlated. For instance, in the South China Sea and during El Niño (La Niña), not only the anomaly of the ACE index is negative (positive) (as shown in Fig. 2) but also the rain rate in TCs is significantly decreased (increased) and the number of TC-related loss events in this region is below (above) the longtime average. Interdecadal variability of WNP TC activity can be linked with interdecadal ENSO variability (Fig. 3): The correlation between the reconstructed time series of the monthly mean Niño-3.4 index and the reconstructed time series of the monthly mean ACE over the WNP basin (0°N-50°N, 100°E-160°E) for the period from 1970 to 2006 and the 9.3-15.6-year time scale amounts to approximately 90 % with a confidence of 94 %. To estimate the statistical significance of a correlation, a bootstrap technique is used.

IV. FUTURE DECADAL CYCLES OF TC ACTIVITY

Future SST projections are taken from UK Met Office HadGEM1 general circulation model (GCM) simulations. The HadGEM1 simulations had historical anthropogenic forcing from December 1970 to November 1999 (simulation started in December 1859), excluding volcanic eruptions and the solar cycle. From December 1999 to December 2099, the simulations followed the IPCC SRES scenario A1B. The interdecadal variability of HadGEM1 SST averaged over the Niño-3.4 region from 1980 to 2099 is shown as a dotted line in Fig. 3. The correlation between this curve and the observed interdecadal ENSO variability (solid) for the overlapping period from 1980 to 2006 amounts to around 84 % with a confidence of 92 %. Consequently, the interdecadal ENSO variability is well simulated in the HadGEM1 model. The reconstructed monthly mean HadGEM1 SST averaged over the Niño-3.4 region and the reconstructed monthly mean ACE index over the WNP (dashed) for periods 9.3-15.6 years are highly correlated: The linear correlation between both wavelet-filtered time series for the period from 1980 to 2006 is 90 % and significant at the 5 % level. Thus, the HadGEM1 SST simulations can be used in modeling future interdecadal cycles of TC activity over the WNP basin.

V. SUMMARY AND CONCLUSIONS

TC-related winds, precipitation, and socioeconomic loss events were employed to describe TC activity, with the main emphasis on TC-related losses. ENSO is the dominant mode of interannual variability of Indo-Pacific TC activity. Furthermore, interdecadal variations of TC activity over the WNP are associated with the interdecadal ENSO variability. HadGEM1 SST simulations are appropriate in estimating future interdecadal cycles of ENSO and finally of WNP TC activity. We regard this approach as a promising method of predicting multiseasonal TC activity and related socioeconomic disasters over the WNP.

VI. REFERENCES

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