11C.5 LARGE-SCALE SIGNALS ASSOCIATED WITH TROPICAL CYCLONE ACTIVITY IN THE WESTERN NORTH PACIFIC

Adam H. Sobel* and Suzana J. Camargo†
International Research Institute for Climate Prediction, Palisades, NY

1. Introduction

What controls the total level of tropical cyclone (TC) activity — by which we mean, loosely, some integrated measure of both TC number and intensity — occurring in a given year in a given basin? We consider here the western north Pacific (WNP). In the WNP, the annual number of named storms has a standard deviation of 5, less than 20% of the climatological mean of 27. This variation seems small when we consider that there is, presumably, a large stochastic component to tropical cyclogenesis, and that (particularly in the WNP) TCs often form in pairs or even threes, with a typical spacing and dynamical signature indicative of Rossby wave dispersion (e.g., Briegel and Frank 1997, Li et al. 2003). This tends to indicate that one TC has positively influenced the genesis of the next, a positive feedback which we might expect to increase the interannual variability in storm number.

Given the relatively small interannual variation in storm number in the face of these factors, it seems worth considering the possibility that negative feedbacks — mechanisms by which one TC tends to inhibit the genesis of future ones, presumably through its impact on the large-scale environment — are playing a role. An obvious candidate mechanism is the local reduction in SST which is known to be induced by virtually every tropical cyclone. This SST reduction, due primarily to wind-induced turbulent deepening of the ocean mixed layer, has been studied for its immediate influence on the tropical cyclone which induces it (e.g., Schade and Emanuel 1999), and Emanuel (2002) has proposed that it may play a major role in controlling global climate. Although the SST reduction is small in spatial scale, adjustment mechanisms in the ocean and atmosphere can be expected to spread it to larger scales, making a larger scale (though smaller in magnitude) reduction which we expect to reduce the genesis potential of a broader region. Other stabilization mechanisms, perhaps operating in the atmosphere only, might also be imagined.

In this study, we begin to investigate this hypothesis in a naive way. We construct a time series, with weekly resolution, that represents the net intensity of all tropical cyclones active in the WNP at a given time, the accumulated cyclone energy (ACE). We then compute the lag-regressions between this ACE time series and other dynamical variables over the whole region. Compositing of cases with high ACE is also used to verify that the qualitative results are not sensitive to the statistical method used. As discussed above, we are particularly interested in the impact of TCs on their environment, which appears in the signals at zero and positive lags in the figures below. However, the same analysis also may provide useful information on large-scale precursors to genesis in the WNP, in the signals at negative lags.

*Department of Applied Physics and Applied Mathematics, Department of Earth and Environmental Sciences, Columbia University, New York, NY, 10027, *email*: ahs129@columbia.edu

†IRI, Lamont-Doherty Earth Observatory of Columbia University, 61 Route 9W, PO Box 1000, Palisades, NY 10964-8000, *email*:suzana@iri.columbia.edu

2. Data

We use NOAA's ACE index, which incorporates both the duration and strength of named tropical cyclones (Bell et al. 2000), as our measure of TC activity. The ACE is computed by summing the squares of the estimated 6-hourly maximum sustained wind speed, in knots, for all storms in the basin, during all periods that each given storm has either a tropical storm or hurricane strength. For our purpose, an index which better represents the total area-integrated storm intensity rather than just the maximum wind (i.e., including some measure of storm size) would be better than ACE, but constructing such an index from existing data would be difficult because of the lack of reliable data on storm size, and we have not attempted it. Here, we computed ACE from the Joint Typhoon Warning Center's best track data set in the period 1950-2002. The other data sets we use are Reynolds SST, available from 1981, NOAA outgoing longwave radiation (OLR), available from 1979, and several meteorological variables from the NCEP/NCAR Reanalyses, available from 1950 (all references standard).

3. Results

Fig. 1 shows the lag-regression of anomalous SST vs. anomalous ACE (in both cases, the anomalies are computed with respect to the climatological seasonal cycle over the available data record), with negative lags indicating that ACE leads. Thus the figure can be interpreted as the typical SST anomaly two weeks before, during, and two weeks after a week of above-average (compared to climatology) tropical cyclone activity. One feature that is immediately noticeable in all three panels is the high SST centered on the equator in the eastern part of the domain. ACE is positively correlated with ENSO indices such as Nino 3.4 SST; this feature simply represents that long-timescale correlation, plus a short-timescale change — an equatorial warming after the ACE maximum — over 5 weeks. The pattern here is not exactly an El Niño pattern, having a bit more warm signal further off the equa-

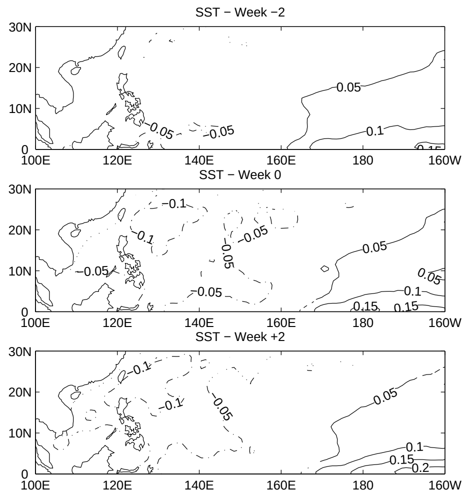

Figure 1: Regression of SST on ACE (^oC). Negative lag means that ACE leads.

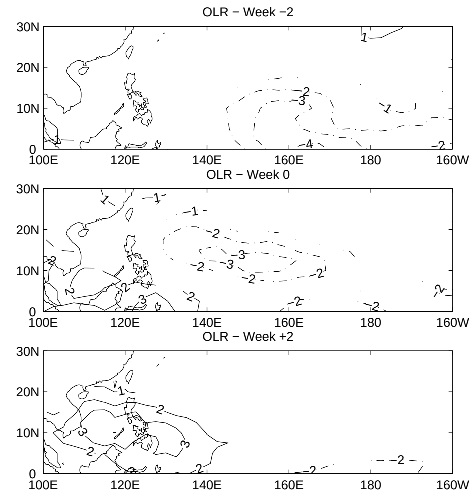

Figure 2: Lag-regression of OLR on ACE ($W\ m^{-2}$).

tor. Superimposed on this long-timescale correlation, in any case, is a pronounced cooling in the region of typical TC activity in week +2, clearly an immediate result of the anomalous TC activity.

Fig. 2 shows the lag-regression of anomalous SST vs. anomalous OLR. In all three weeks, we see a negative OLR anomaly in the eastern region on the equator, associated with ENSO. During week 0, we see the negative OLR anomaly indicative of the TCs themselves. Afterwards, in week +2, we see a positive OLR anomaly, suggestive of suppressed convection following the TC activity, in the South China and Philippine seas. This suppressed convection does not appear to be a simple consequence of the SST reduction, because it occurs somewhat to the south and west of the latter. A reduction in total column water vapor (not shown) is found to be collocated with the OLR increase in a lag-regression of the NCEP Reanalysis data.

4. Concluding Remarks

Just after the time of maximum ACE, lag-correlations show an SST cooling along the typical TC track. An OLR increase, indicating suppressed convection, and an associated drying of the troposphere, are found somewhat to the south and west of the SST cooling, in the South China and Philippine seas. It is straightforward to see how the SST reduction would negatively influence future TC genesis (or intensity). Similar roles for the OLR and water vapor signals are perhaps less obvious because those signals, though of the right sign to suppress genesis, don't occur exactly in the main genesis region. Interestingly, there is also a hint of an SST warming on the equator near the date line after the ACE maximum, which could be a result, via ocean dynamics, of enhanced equatorial westerlies associated with TCs (and the associated large-scale low-level cyclonic circulation that often accompanies them in the WNP).

The signals shown above are small in amplitude, about 0.1^oC for SST and a few Wm^{-2} for OLR, but the main features are statistically significant at the 95% confidence level. To calibrate, notice that the OLR signal associated with the peak TC activity itself (lag 0) is only a few $W\ m^{-2}$, though it is surely "real". In assessing the total effect of TCs on the environment, keep in mind that the signals here are associated only with *anomalous* ACE — the climatology has a significant signal also — and that the signals shown here are essentially those associated with one week of ACE one standard deviation above climatology. The signals persist for several weeks, and effects from subsequent or prior weeks will be additive.

References

1. Bell, G. D., and Co-authors, 2000: Climate assessment for 1999. *Bull. Amer. Meteor. Soc.*, **81**, S1-S50.

2. Briegel, L. M., and W. M. Frank, 1997: Large-scale influences on tropical cyclogenesis in the western North Pacific. *Mon. Wea. Rev.*, **125**, 1397-1413.

3. Emanuel, K. A., 2002: A simple model of multiple climate regimes. *J. Geophys. Res.*, **107**, 10.1029/2001JD001002.

4. Li, T., B. Fu, X. Ge, B. Wang, and M. Peng, 2003: Satellite data analysis and numerical simulation of tropical cyclone formulation. *Geophys. Res. Lett.*, **30**, 10.1029/2003GL018556.

5. Schade, L., and K. A. Emanuel, 1999: The ocean's effect on the intensity of tropical cyclones: results from a simple coupled atmosphere-ocean model. *J. Atmos. Sci.*, **56**, 642-651.