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PREDICTABILITY OF HURRICANE ACTIVITY AND IMPACTS

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1. INTRODUCTION

Economic losses to hurricanes arise from convolution of the geophysical threat with the geographical distribution and vulnerability of assets at hazard. It is intriguing that US damage normalized for inflation, population, and individual wealth exhibits zero trend from 1900 through 2008 (Pielke et al. 2008). Analysis of stationary time series is a powerful tool in geophysical science, and the power spectrum of this "Normalized Damage" provides insight into the century-scale climatology of the hurricane threat.

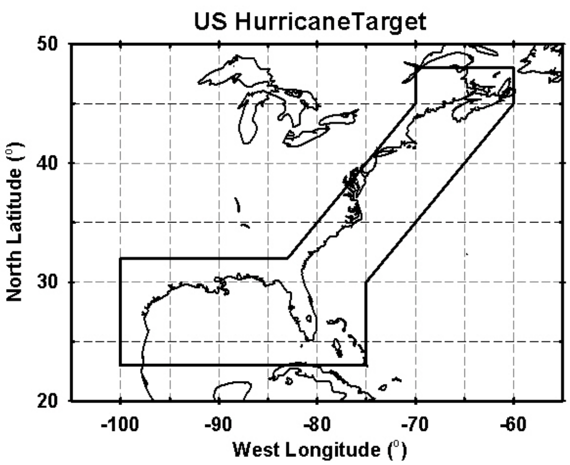

Figure 1. "US Waters" subdomain for ACE computations.

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2. ANALYSIS

Here we treat 128-yr time series of Normalized Damage for the US Mainland and ACE (Accumulated Cyclone Energy, the summed squares of the 6-hourly maximum winds in HURDAT) for both the entire Atlantic Basin and for a "US Waters" subdomain (Fig. 1). The whole Atlantic series was detrended, but the US Waters series exhibited no significant trend.

One would expect the time series and spectra to reflect El Niño (Gray 1984) and the Atlantic Multidecadal Oscillation (AMO, Goldenberg et al. 2001). However the prevalence of large-amplitude spikes in both time series implies that they should contain a substantial amount of white noise in which all Fourier components have essentially the same amplitude. The ACE spectra (Fig. 2) have significant peaks at the second harmonic (i.e., 64-year period). They also exhibit peaks corresponding roughly to the 3, 5 and 6 year El Niño return periods. Since the 128-year record spans only two cycles of the nominal AMO and only the whole-basin peak is significant, characterization of this spectral component is questionable. The spectrum itself resembles a textbook case of faulty detrending (e.g. Warner 1998). Moreover, a 500-yr proxy record of the AMO (Gray et al. 2004) does not show any well-defined periodicity. Thus, one would not necessarily expect a different sample of ACE, or of any time series modulated by the AMO, to exhibit the 64-year cycle. Nonetheless, the extant 128-yr record of ACE for the entire basin seems to show a credible low frequency component.

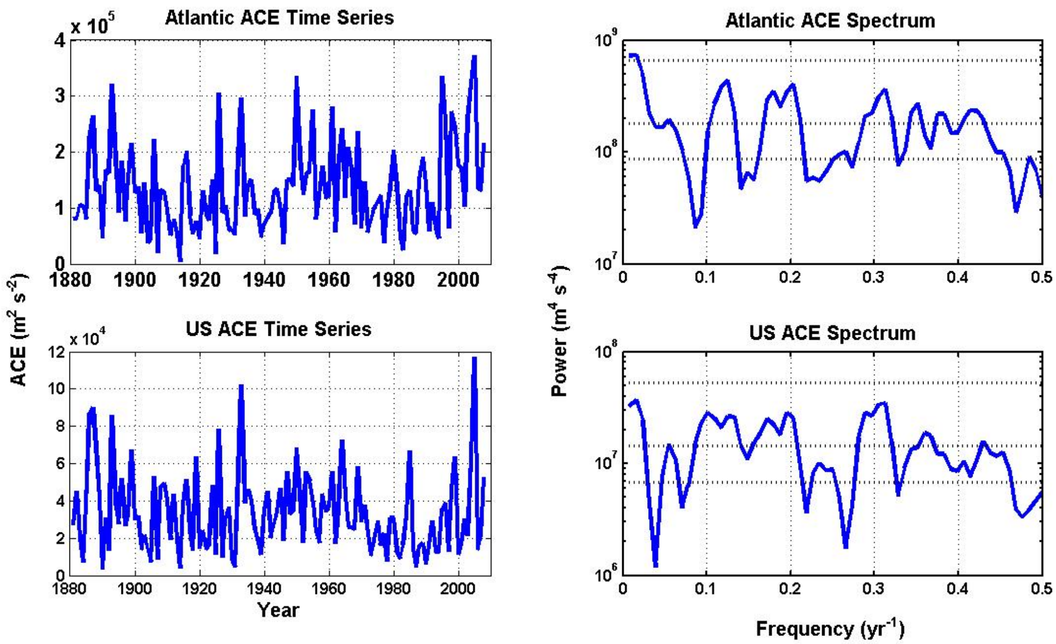

Figure 2. Time series of Accumulated Cyclone Energy (left) for the entire Atlantic basin (top) and for the US Waters subdomain (bottom) and the corresponding power spectra (right). Dashed horizontal lines indicate 95% confidence interval, mean power for white noise with the same variance, and 5% confidence interval.

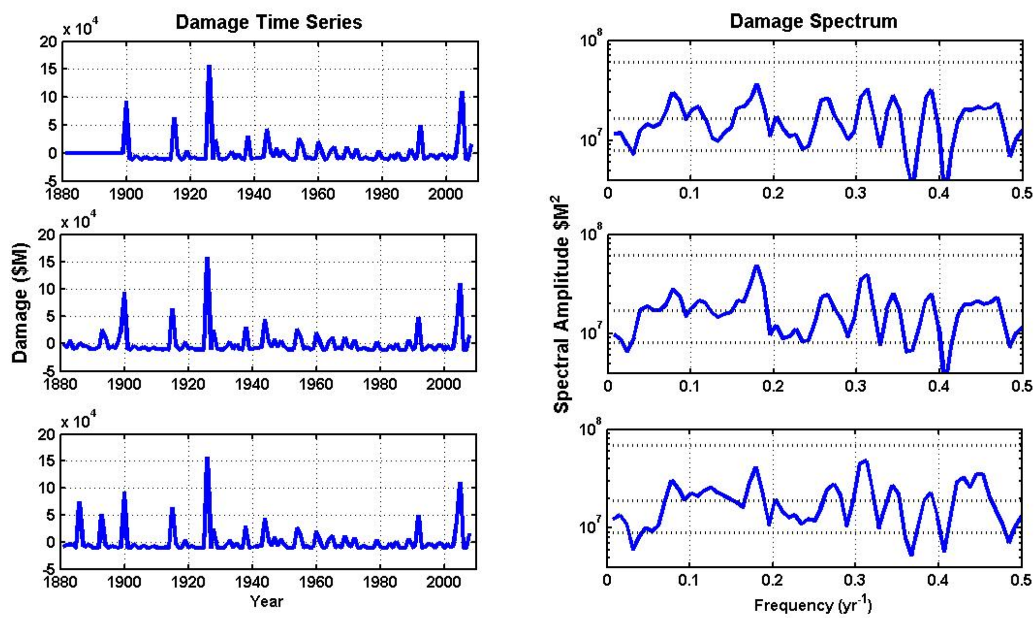

Figure 3. As in Figure 2, but for Normalized damage. The top time series is padded with zeros before 1900. The middle and bottom time series before 1900 are filed with analog damages computed as described in the text.

The Normalized Damage Time Series (Fig. 3) is extended to 128 years by adding damage from analog storms during the years 1881-1899. Each 1881-1900 landfall was identified with several 1900-2008 landfalls (for which the normalized damage is known) by calculating the "distance" between the historical and analog landfalls, $S^2 = D^2 + [(V_{19} – V_a)/20 \text{ kt}]^2$. D is the great-circle separation of the landfall positions in degrees of latitude, V_{19} is the landfall maximum wind of the 19th Century storm at landfall, and V_a is that of each analog storm. The second term is essentially the difference in intensities expressed as Saffir-Simpson categories so that a geographical separation of a degree of latitude affects S^2 as much as a difference in intensity of one category. The closest analog landfalls are those with the smallest values of S^2. A copy of the original time series was padded with zeros during 1881-1900, and two additional copies were padded with storms randomly selected from the five closest analogs.

The spectra of the Normalized Damage time series were all relatively flat for frequencies from 1/20 yr^{-1} to the Nyquist Frequency, 1/2 yr^{-1}, apart from unimpressive (and not significant) peaks that may be identifiable with the 2-to-5-year ENSO cycle and a hint of a peak (also not significant) that seems to line up with the 11-year sunspot cycle (e.g. Elsner et al. 1999). The relatively uniform amplitude across this range is more or less what one would expect for a time series where much of the variance arises from isolated, large-amplitude impulses, and it implies limited year-to-year predictability. At periods longer than 20-30 years the spectral power drops off significantly, in contrast with spectra of ACE. One might describe these as "cyan noise"---white noise for periods shorter than ~20 years and less power than one might expect under the a white-noise null hypothesis for periods longer than 20 years. Thus, the long-period variability in tropical cyclone activity does not translate into a detectable signal in normalized damage.

3. CONCLUSIONS

When the effect of the Atlantic Multidecadal Oscillation (AMO) on hurricanes was first hypothesized (Goldenberg et al. 2001), the investigators argued that it modulated normalized damage, and comparison of El Niño and non-El Niño years shows that normalized damage in the latter is about half as great in the former (Pielke and Landsea 1999). Alternatively, papers published during the hyperactive 2005 hurricane season (Emanuel 2005, Webster et al. 2005) fostered the perception that the monumental destruction and mortality during the 2004 and 2005 seasons were immediate consequences of anthropogenic global warming. These interpretations, and virtually any others that one might advance for climate signals in hurricane impacts, have been controversial (e.g., Mann and Emanuel 2006, Landsea 2007, Pielke 2005, Vecci et al., 2008). The spectra shown here are dominated by year-to-year variability and rare large impacts.

The lack of secular trends in US-Waters ACE or normalized damage contradicts a century-scale increase in the hurricane threat. This interpretation is consistent with recently published modeling results (Bender et al. 2010) and the emerging consensus among the factions in the debate over the effect of anthropogenic planetary warming (Knutson et al. 2010). Similarly, the absence of a low-frequency "red-noise" in the damage spectrum undermines meaningful short-term (~5 yr) prediction, even if based upon persistence alone.

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