Title

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Journal

Geophysical Research Letters, 42(15)

ISSN

0094-8276

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Publication Date

2015-08-16

DOI

10.1002/2015GL064505

AGU PUBLICATIONS

Geophysical Research Letters

RESEARCH LETTER

10.1002/2015GL064505

Key Points:

- North Atlantic tropical cyclones and Amazon fires are significantly correlated
- The two phenomena are coupled to atmosphere-ocean interactions in the tropical North Atlantic
- This relationship leads to an inter-hemispheric synchronization of forest carbon losses

Supporting Information:

- Table S1 and Figures S1–S4

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Citation:
Chen, Y., J. T. Randerson, and D. C. Morton (2015), Tropical North Atlantic ocean-atmosphere interactions synchronize forest carbon losses from hurricanes and Amazon fires, *Geophys. Res. Lett.*, *42*, 6462–6470, doi:10.1002/2015GL064505.

Received 12 MAY 2015
Accepted 14 JUL 2015
Accepted article online 4 AUG 2015
Published online 12 AUG 2015

Tropical North Atlantic ocean-atmosphere interactions synchronize forest carbon losses from hurricanes and Amazon fires

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Abstract We describe a climate mode synchronizing forest carbon losses from North and South America by analyzing time series of tropical North Atlantic sea surface temperatures (SSTs), landfall hurricanes and tropical storms, and Amazon fires during 1995–2013. Years with anomalously high tropical North Atlantic SSTs during March–June were often followed by a more active hurricane season and a larger number of satellite-detected fires in the southern Amazon during June–November. The relationship between North Atlantic tropical cyclones and southern Amazon fires ($r = 0.61$, $p < 0.003$) was stronger than links between SSTs and either cyclones or fires alone, suggesting that fires and tropical cyclones were directly coupled to the same underlying atmospheric dynamics governing tropical moisture redistribution. These relationships help explain why seasonal outlook forecasts for hurricanes and Amazon fires both failed in 2013 and may enable the design of improved early warning systems for drought and fire in Amazon forests.

1. Introduction

Forests in eastern North America, Central America, and the Amazon region of South America cover more than 1 billion hectares and store more than 160 petagrams (Pg) of carbon in living biomass [*Pan et al.*, 2011]. For these ecosystems, hurricanes and fires are two important disturbance processes that can have considerable ecological and socioeconomic impacts [*Boose et al.*, 1994; *Bowman et al.*, 2009]. Hurricanes and fires modify carbon budgets in these regions directly through their immediate influence on tree mortality, decomposition, and combustion-driven fluxes and indirectly by means of their impacts on community composition and stand age [*Bowman et al.*, 2009; *Chambers et al.*, 2007; *Fisk et al.*, 2013]. Climate change will modify many aspects of hurricane dynamics [*Knutson and Tuleya*, 2004] and may contribute to increasing precipitation extremes in North and Central America during the 21st century [*Collins et al.*, 2013]. The precise nature of warming-induced changes in hurricane activity remains an area of active research [*Shepherd and Knutson*, 2007]. There is also a growing appreciation that interactions between land use and climate in tropical ecosystems of South America are increasing the vulnerability of forests to drought and fire [*Betts et al.*, 2008; *Davidson et al.*, 2012].

North Atlantic SSTs are a key regulator of hurricane activity and intensity. Higher SSTs in the hurricane major development region of the tropical North Atlantic can increase the energy available for convection and cyclone development [*Trenberth and Shea*, 2006]. As a consequence, the number, duration, intensity, and destructiveness of hurricanes have been found to covary with SSTs in tropical North Atlantic on different temporal scales [*Emanuel*, 2005; *Webster et al.*, 2005].

In parallel, tropical North Atlantic SSTs also have been identified as a driver of interannual variability in fire activity in the southern Amazon region [*Chen et al.*, 2011; *Fernandes et al.*, 2011]. Warmer North Atlantic SSTs (relative to South Atlantic SSTs) during the boreal spring tend to modify the atmospheric circulation by shifting the intertropical convergence zone (ITCZ) to the north, thereby reducing tropical North Atlantic easterlies and moisture transport from ocean to land [*Yoon and Zeng*, 2010]. This shift in circulation decreases precipitation and terrestrial water storage during the middle to the end of the wet season and limits evapotranspiration (ET) fluxes during the following dry season.

Land management is the dominant source of fire activity in the southern Amazon [*Aragao and Shimabukuro*, 2010; *Kumar et al.*, 2014; *Morton et al.*, 2008], yet climate conditions contribute to interannual variability in total burned area [*Giglio et al.*, 2013] and satellite detections of thermal anomalies from active fires [*Chen et al.*, 2013b].

Fire spread and termination are strongly influenced by climate regulation of fuel moisture [*Nepstad et al*., 2008; *Ray et al*., 2005], and tree mortality in fire-affected areas is enhanced during periods of drought [*Brando et al*., 2014]. Therefore, reduced ET fluxes associated with warmer North Atlantic SSTs may contribute to lower surface humidity favoring fire activity in this region, including the escape of agricultural fires into intact forests [*Morton et al*., 2013], higher fire severity [*Brando et al*., 2014], and greater viability of conditions for fire-driven deforestation [*Le Page et al*., 2010].

Here we investigate the hypothesis that landfall tropical cyclones (including hurricanes and tropical storms) in North and Central America and fires in the southern Amazon are positively correlated because of their shared linkages to ocean-atmosphere interactions in the North Atlantic. We assessed how this relationship may lead to an interhemispheric synchronization of forest carbon losses on seasonal and interannual time scales using SST, tropical cyclone, and fire time series. Modulation of tropical cyclone and Amazon fire disturbance by North Atlantic SSTs described here is arguably a separate mode of climate forcing of the carbon cycle, apart from other well-established relationships between El Niño–Southern Oscillation (ENSO) and terrestrial and marine ecosystems [*Bacastow*, 1976; *Behrenfeld et al*., 2001; *Keeling et al*., 1995]. Our analysis may help to explain why seasonal outlook forecasts for hurricanes and Amazon fire risk simultaneously failed in 2013 and has implications for continental scale forest conservation efforts as climate change accelerates.

2. Data and Methods

2.1. Sea Surface Temperatures

We used SST data from version 2 of the NOAA's optimum interpolation sea surface temperature dataset [*Reynolds et al*., 2002]. This time series consist of monthly observations at a 1° × 1° spatial resolution. To compare with time series of North Atlantic tropical cyclones and Amazon fires, we averaged SSTs in the Atlantic within the region of 15°W–90°W and 0–25°N. During the study period, years with SSTs exceeding the mean by an amount equivalent to one half of the 1995–2013 standard deviation were defined as high SST years. Similarly, years with SSTs lower than the mean by at least one half of the 1995–2013 standard deviations were defined as low SST years.

2.2. North Atlantic Tropical Cyclones

We obtained the number, location, and intensity of North Atlantic tropical cyclones from version 2 of the National Hurricane Center's North Atlantic hurricane database (HURDAT2) [*Landsea et al*., 2004]. HURDAT2 provided the latitude, longitude, landfall status, and the maximum sustained wind speed along cyclone tracks at a 6-hourly time step. We limited our analyses to cyclones that formed from the 0–30°N belt of North Atlantic Basin (including the North Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea) that reached hurricane or tropical storm status for at least one 6-hourly interval. In our primary analysis, we combined the number of landfall hurricanes and tropical storms because these high-intensity cyclones are most likely to inflict damages and carbon losses in forests [*Zeng et al*., 2009]. As another metric of cyclone impact, we calculated the accumulated cyclone energy index (ACE) [*Camargo et al*., 2007] for each hurricane and tropical storm track by summing the squares of the 6-hourly maximum sustained surface wind speed for all records over land.

2.3. Satellite-Detected Fire Thermal Anomalies

Satellite data were used to quantify monthly fire activity in the southern Amazon (75°W–55°W and 5°S–15°S) during 1995–2013. From 2001–2013, 1 km thermal anomaly detections from NASA's Moderate Resolution Imaging Spectroradiometer (MODIS) sensor onboard the Terra satellite were aggregated to a 1° × 1° spatial resolution and a monthly time step [*Giglio et al*., 2006]. The MODIS data (MCD14ML) were screened to remove low confidence detections and nonfire hotspots and further adjusted for cloud conditions following *Chen et al*. [2013b]. In the preMODIS era, active fire data from the European Space Agency Advanced Along Track Scanning Radiometer (ATSR) sensor were used to characterize monthly fire activity. ATSR data from algorithm 2 were linearly scaled to MODIS fire counts in each 1° × 1° grid, based on the monthly relationship between MODIS and ATSR during the common period when both observations were available (2001–2011). Annual fire counts were calculated as the sum of fire detections during the North Atlantic hurricane season (June–November). We derived Pearson's correlation coefficients between annual

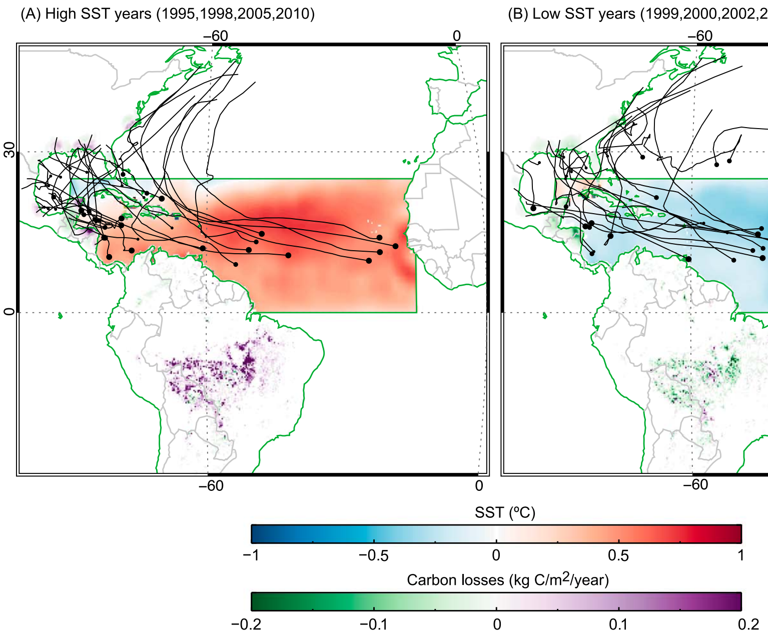


Figure 1. SST anomalies during March–June in the tropical North Atlantic during (a) high SST and (b) low SST years. On land, carbon flux anomalies from hurricanes and tropical storms in North and Central America and fire emissions in South America are shown concurrently at a 0.5° spatial resolution. Black dots and lines mark the origins and tracks of all hurricanes and tropical storms recorded during high or low SST years. The dot size represents the highest category attained during the lifetime of each storm. Small dots are tropical storms, medium dots are hurricanes, and large dots are major hurricanes.

time series of North Atlantic SST, the number of North Atlantic tropical cyclones, and active fires in the southern Amazon for 1995–2013 ($n = 19$). The data were linearly detrended before correlation analyses to remove long-term trends from climate change and human impacts.

To investigate relationships between North Atlantic tropical cyclones and fires in different vegetation types in the southern Amazon, we used MODIS data during 2001–2013. For this shorter interval, it was possible to use the MODIS global land cover type product to attribute fires to different land cover classes. Each active fire detection from Terra MODIS was assigned to a land cover class using the 500 m MODIS land cover product (MCD12Q1). We additionally separated active fires in evergreen forest areas into those overlapping with substantial deforestation, defined as 2000–2005 cumulative forest area lost fraction greater than 5% in 0.05° × 0.05° maps derived from PRODES (Program for the Estimation of Deforestation in the Brazilian Amazon) [*Chen et al.*, 2013b].

2.4. Estimating Monthly Carbon Losses From Tropical Cyclones and Fire Emissions

Forest carbon losses from North Atlantic hurricanes and tropical storms were estimated using HURDAT2 storm tracks, maps of above ground biomass (AGB), and an empirical model relating cyclone wind speeds with forest damages. Two maps of forest biomass were combined to estimate carbon stocks in Central [*Saatchi et al.*, 2011] and North America [*Blackard et al.*, 2008] (Figure S1 in the supporting information). The empirical monthly carbon loss model was based on a linear correlation between fractional change in nonphotosynthetic vegetation (ΔNPV) and field-measured tree mortality and damage (N_T) [*Chambers et al.*, 2007], and a forest impact model that connects ΔNPV with cyclone wind speed [*Zeng et al.*, 2009]. Our estimates of carbon losses, which were approximated as the product of AGB and N_T, represented only the potential losses due to tree damage and mortality by hurricanes and tropical storms. The timing of carbon losses from decomposition of coarse wood debris, as well as the additional carbon releases due to indirect effects of the storms [*Zeng et al.*, 2009], were not quantified in this study.

Monthly fire emissions were estimated using data from the Global Fire Emissions Database version 4 (GFED4). Improvements in GFED4 relative to GFED3 [*van der Werf et al.*, 2010] include emissions from small fires that are below the detection limit of MODIS burned area product [*Randerson et al.*, 2012] and several other adjustments to fuel loads and combustion completeness [*van Leeuwen et al.*, 2014]. To maintain

Table 1. Differences in North Atlantic Tropical Cyclone Activity and Southern Hemisphere South American Fires for Years With High or Low SSTs (Averaged in the Tropical North Atlantic During March–June, as Shown in Figure 2)[a]

	Parameter (unit)	Region of Origin or Impact	High SST Years	Low SST Years	All Years
Hurricanes and tropical storms	Total number (#/year)	Whole basin	18.2	11.4	12.8
		North Atlantic Ocean	11.8	8.2	8.4
		Gulf of Mexico	2.2	1.6	1.9
		Caribbean Sea	4.2	1.6	2.5
	Landfall number (#/year)	Whole basin	10.0	6.0	6.9
		North Atlantic Ocean	4.0	3.2	2.9
		Gulf of Mexico	2.2	1.4	1.8
		Caribbean Sea	3.8	1.4	2.1
	Landfall number of major hurricanes (#/year)	Whole basin	3.8	1.6	2.1
		North Atlantic ocean	2.2	0.8	1.4
		Gulf of Mexico	0.0	0.2	0.1
		Caribbean Sea	1.5	0.6	0.7
	ACE over land (10^5 knots^2/yr)	Whole basin	1.98	0. 91	1.23
		North Atlantic ocean	1.16	0.54	0.75
		Gulf of Mexico	0.08	0.09	0.10
		Caribbean Sea	0.74	0.28	0.38
	Carbon loss (Tg C/yr)	North and Central America	47	11	35
Fires	Active fires (# × 10^4/yr)	Southern Amazon	7.3	4.0	5.0
		Southern hemisphere South America	25.7	17.4	20.1
	Carbon loss (Tg C/yr)	Southern Amazon	153	78	89
		Southern hemisphere South America	391	210	245

[a] Using the origins of cyclone tracks provided in the HURDAT2 data set, hurricanes and tropical storms in the tropical North Atlantic basin were further divided into storms originating from the North Atlantic Ocean, the Gulf of Mexico, and the Caribbean Sea. The southern Amazon region is shown in Figure 3a. High SST years were 1995, 1998, 2005, and 2010. Low SST years were 1999, 2000, 2002, 2009, and 2012.

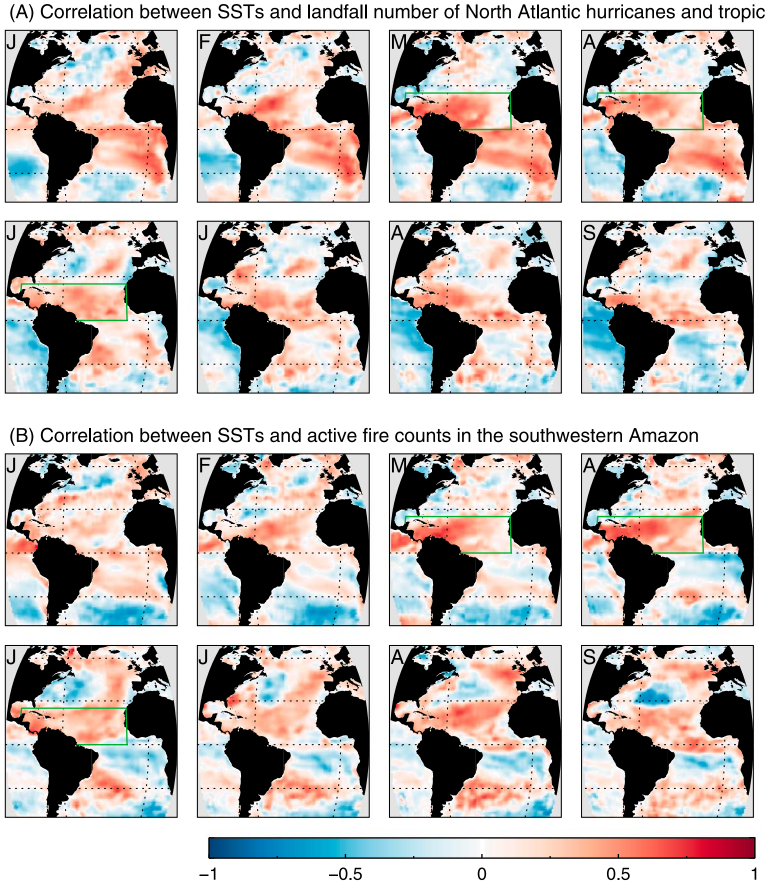
consistency with our assessment of tropical cyclone impacts on carbon stocks, the fire emissions from GFED4 included only the direct carbon losses during the combustion process.

3. Results

The number of landfall hurricanes and tropical storms was considerably higher in years with anomalously warm SSTs in the tropical North Atlantic (Figure 1 and Table 1). The strength of the correlation between SSTs and the annual number of landfall cyclones varied for SSTs in different ocean regions (Figure 2a), and was strongest for March–June SSTs in the western part of the domain (40–70°W). Tropical North Atlantic SSTs during spring and early summer were similarly correlated with the number of landfall tropical cyclones reaching hurricane status and ACE over land (data not shown).

SSTs in the tropical North Atlantic during boreal spring and early summer also influenced year-to-year variability in the number of satellite-detected fires in the southern Amazon (Figure 2b). The spatial-temporal pattern of the correlation was similar to the pattern for North Atlantic hurricanes and tropical storms, with some of the highest correlations observed during March and April in the western part of the tropical North Atlantic.

Given the relationships described above linking landfall North Atlantic tropical cyclones, and separately southern Amazon fires to tropical North Atlantic SSTs, we hypothesized that a significant positive correlation may exist between the two phenomena. Figure 3a shows areas in southern hemisphere South America where the annual number of landfall hurricanes and tropical storms was significantly correlated with the annual sum of active fires. The correlation was most significant in the southern Amazon, where northward displacement of the ITCZ associated with warm tropical North Atlantic SSTs is known to reduce the precipitation (and terrestrial water storage) and where ENSO influence is relatively weak [*Chen et al.*, 2013a; *de Linage et al.*, 2013]. Fires within a broad region in southern Amazon (for the box shown in Figure 3a) were significantly correlated with the number of landfall hurricanes and tropical storms ($r = 0.61$, $n = 19$, $p < 0.003$, Figure 3b). The relationship with fires was also robust considering the number of landfall tropical cyclones reaching hurricane status ($r = 0.56$, $p < 0.007$) or ACE over land ($r = 0.66$, $p < 0.002$). The strength of the relationship between North Atlantic tropical cyclones and southern Amazon fires exceeded direct correlations between SSTs and cyclones ($r = 0.44$, $p < 0.03$) or SSTs and fires ($r = 0.57$, $p < 0.006$).


(A) Correlation between SSTs and landfall number of North Atlantic hurricanes and tropical storms

(B) Correlation between SSTs and active fire counts in the southwestern Amazon

Figure 2. (a) Correlation between monthly SSTs (January–October) and annual number of North Atlantic hurricanes and tropical storms that made landfall in North or Central America. (b) Correlation between monthly SSTs and annual number of active fires in the southern Amazon (15°S–5°S, 75°W–55°W; region delineated in Figure 3a). Green boxes mark the area and the time interval of SSTs that were averaged in subsequent time series analyses.

To further explore the role of the tropical North Atlantic in modulating tropical cyclones and Amazon fires, we separated the influence of these disturbance agents during high SST years (1995, 1998, 2005, and 2010) and low SST years (1999, 2000, 2002, 2009, and 2012). Landfall hurricanes and tropical storms were more numerous and destructive during years with high tropical North Atlantic SSTs, with ACE over land more than double that observed in low SST years (Table 1 and Figure S2). Taken together, the number of landfall hurricanes and tropical storms and ACE over land provided evidence of an enhancement in cyclone destructiveness from warmer SSTs. In parallel, active fire detections were significantly elevated during high SST years compared to low fire years, by 83% in the southern Amazon and by 48% for all of southern hemisphere South America.

Both landfall tropical cyclones and fires accelerated carbon losses from terrestrial ecosystems. The largest increase in carbon loss from hurricanes and tropical storms during high SST years occurred in the coastal areas of Nicaragua, Honduras, the Yucatan peninsula of Mexico, and the state of North Carolina and the Gulf Coast in the US (Figure 1). Carbon losses from hurricanes and tropical storms during high SST years (47 Tg C/yr) were fourfold higher than in low SST years (11 Tg C/yr) and were consistent with differences in tropical cyclone number and ACE over land observed for these sets of years (Table 1). Similarly, carbon emissions from fires in southern hemisphere South America during high SST years (391 Tg C/yr) were almost double the carbon emissions in low SST years (210 Pg C/yr; Table 1 and Figure S3), primarily as a consequence of increased drought stress in the southern and western Amazon (Figure 1). High SSTs in the tropical North Atlantic increased carbon losses due to hurricanes and tropical storms during the primary hurricane season (June–November), as well as carbon loss from fires during the dry season in the southern

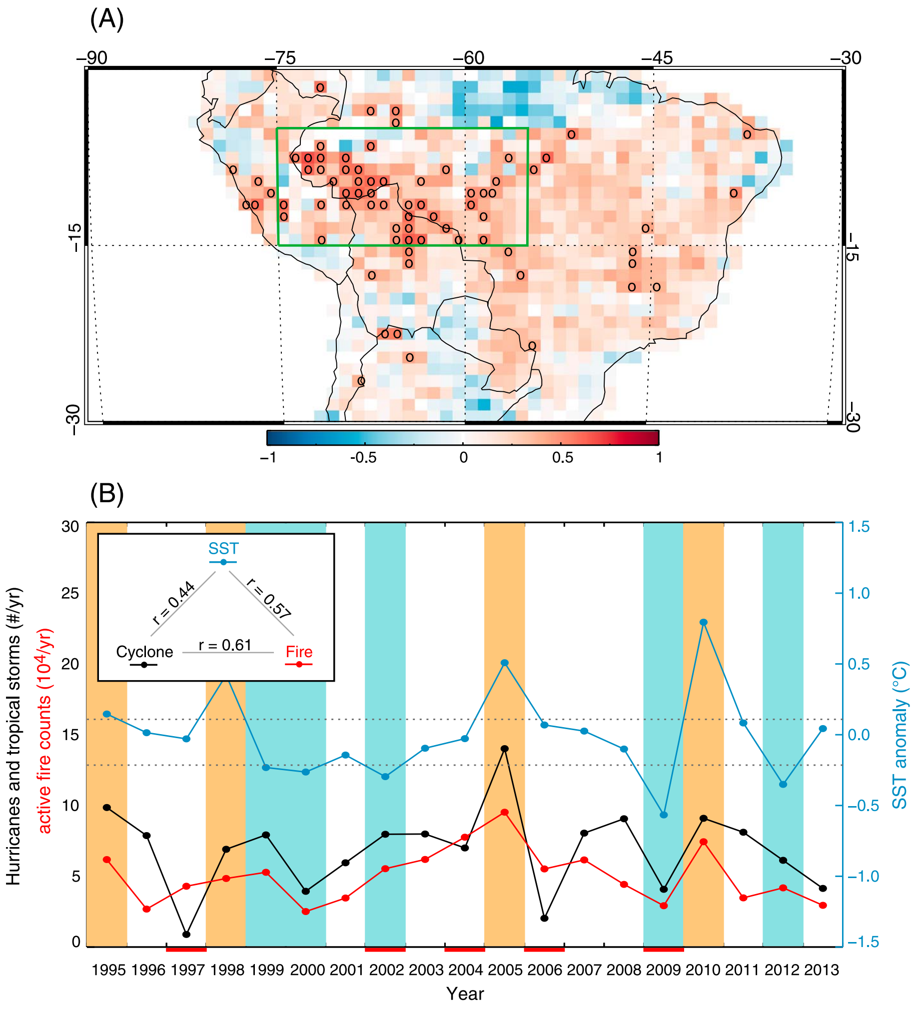


Figure 3. (a) Correlation between annual number of North Atlantic tropical cyclones (hurricanes and tropical storms) and southern hemisphere South American active fires. Grid cells with a significant correlation ($p < 0.05$) are marked with black circles. (b) Time series of annual landfall hurricanes and tropical storms in the North Atlantic, total active fire counts in the southern Amazon (within the green box denoted in Figure 3a), and mean SSTs in the tropical North Atlantic during March–June (see Figure 2). Orange and blue shades indicate high and low SST years. Two horizontal dashed lines denote SSTs falling within ±0.5 standard deviation of the mean. Red bars mark years with ENSO episodes during the boreal fall.

Amazon (June–November). Thus, mortality and carbon fluxes from these two disturbance agents also were synchronized on seasonal time scales across North and South America (Figure S3).

During the MODIS era, we investigated the strength of the correlation between North Atlantic tropical cyclones and fires in different land cover types in the southern Amazon. For fires in evergreen broadleaf forests the relationship was significant ($p < 0.05$) for all three metrics of tropical cyclone activity, including the annual number of landfall hurricanes and tropical storms, the number of landfall hurricanes, and ACE over land (Table S1). These relationships were generally stronger for fires in shrublands and savannas. Collectively, the significant correlations indicate that atmosphere-ocean interactions synchronized the variability of several very different fire classes and that the cyclone-fire relationship was important for fires influencing forest disturbance and diversity.

The relationship between North Atlantic tropical cyclones and Amazon fires identified here may help explain why seasonal outlook forecasts for these two phenomena overestimated activity in 2013. In the spring of 2013, both NOAA (http://www.cpc.ncep.noaa.gov/products/outlooks/hurricane.shtml) and Colorado State University (http://tropical.atmos.colostate.edu/forecasts/) predicted a very active hurricane season, yet poststorm analysis of tropical cyclones revealed that 2013 was the quietest Atlantic hurricane season in recent decades [*Fogarty and Klotzbach*, 2014]. This overestimation has been attributed to a significant weakening of the Atlantic thermohaline circulation during late spring and early summer [*Fogarty and Klotzbach*, 2014]. Concurrently, fire season severity in the southern Amazon also was substantially overestimated in 2013 (https://webfiles.uci.edu/ychen17/data/SAMFSS2013.html) with a SST-based statistical model [*Chen et al*., 2011]. Figure S4 shows this low fire season was accompanied by a rapid shift from above-normal SSTs from March to May to below-normal SSTs in June and July. These sudden changes in atmosphere-ocean interactions in the tropical North Atlantic triggered anomalously high precipitation across South America during June of 2013, after the end of the period used for outlook assessment. This precipitation increase, in turn, may have contributed to positive terrestrial water storage anomalies observed during late dry season (August–October, see Figure S4), thereby maintaining higher levels of evapotranspiration and suppressing fires.

4. Discussion

4.1. Implications for Seasonal Fire Forecasts in the Amazon and Forest Conservation

The relationship described here between tropical cyclones and fires may have implications for the development of early warning systems for the Amazon. Empirical seasonal outlook algorithms for hurricanes, for example, may contain information that can improve the predictability of statistical models used to make seasonal predictions of Amazon fire risk. A next step is to explore whether information about ocean-atmosphere processes used in the hurricane outlooks increases the predictive skill of seasonal fire forecasts [e.g., *Chen et al*., 2011]. A multiple linear regression analysis provided some indication of this potential: adding the number of North Atlantic tropical cyclones to SSTs as a predictor of southern Amazon fires during our study interval increased the correlation from 0.57 to 0.69.

In terms of international forest conservation, the cyclone-fire coupling also suggests that extreme climate events originating in the North Atlantic can simultaneously inflict widespread economic damages in many countries in North, Central, and South America, thus taxing available resources to manage ecosystems sustainably. A notable example is the co-occurrence of flooding in New Orleans by hurricane Katrina [e.g., *Chambers et al*., 2007] and the "once-in-a-century" Amazon drought that has been linked to anomalously warm SSTs in the North Atlantic during spring and summer of 2005 [*Marengo et al*., 2008]. An important next step is to investigate how the strength of the coupling identified here may change on longer time scales.

4.2. A Mechanism for Synchronized Interhemispheric Carbon Losses

The high degree of correlation between North Atlantic tropical cyclones and southern Amazon fires suggests these two phenomena were closely coupled to the same set of atmospheric dynamics governing tropical atmospheric moisture redistribution. In years with anomalously warm North Atlantic SSTs, trade winds across the tropical North Atlantic weaken [*Yoon and Zeng*, 2010] and likely inhibit interhemispheric moisture flow onto the South American continent during boreal spring. By combining a water accounting model with ERA-interim reanalysis, *van der Ent and Savenije* [2013] found that evaporation and water vapor transport from the tropical North Atlantic accounts for a significant fraction of precipitation in South America and that this source region is most active during December through May. The seasonal maximum in the coupling strength for this source region closely matches the timing observed reported here for the maximum in the SST-fire relationship. Concurrently, the northward movement of the intercontinental convergence zone and the reduced continental sink for atmospheric moisture may contribute to atmospheric conditions that promote the formation of hurricanes [*Merlis et al*., 2013] and landfall risk [*Dailey et al*., 2009].

The covariance between tropical cyclones and Amazon fires cannot be solely explained by their shared linkages with tropical North Atlantic SSTs. With the observed correlations reported above for SSTs and cyclones, and separately SSTs and fires (Figure 3b), a Monte Carlo analysis can be used to assess the distribution of expected correlation between cyclones and fires assuming the other processes governing these two phenomena are independent. Using this approach with 5000 trials, we obtained a median expected correlation between cyclones and fire of 0.25 and a distribution that was significantly lower than our observed value of 0.61 ($p < 0.025$). This analysis provides a quantitative basis for arguing that atmospheric dynamics interact with tropical North Atlantic SSTs in synchronizing these disturbance agents.

Ocean-atmosphere interactions in other regions and during different seasons also may help explain why the tropical cyclone-fire coupling identified here is stronger than the individual one-way couplings of these processes with boreal spring SST in the tropical North Atlantic. The Atlantic meridional mode (AMM) [*Kossin and Vimont*, 2007], for example, is a more general ocean-atmosphere circulation pattern that integrates information from SSTs, surface winds, and displacement of the ITCZ over tropical Atlantic in both the northern and southern hemispheres. The AMM variability, whose amplitude is at its maximum during boreal spring, explains twice as much the year-to-year variance of Atlantic hurricane compared with local SSTs in the hurricane development region [*Vimont and Kossin*, 2007]. The boreal spring AMM, at the same time, also plays a central role in determining the environmental conditions for severe drought and fire season severity in the southern Amazon [*Nobre and Shukla*, 1996].

Tropical Pacific SST variability characterized by ENSO can amplify or dampen the influence of tropical North Atlantic SSTs on Atlantic tropical cyclones or Amazonia drought. ENSO and AMM also may interact over a range of time scales [*Giannini et al*., 2001; *Ham et al*., 2013], contributing to the tropical cyclone-fire coupling identified here.

4.3. Implications for the Carbon Cycle

Terrestrial ecosystems remain one of the most uncertain components of the contemporary global carbon budget. ENSO-driven changes in terrestrial ecosystem fluxes are major driver of the interannual variability of carbon dioxide concentrations in the atmosphere, yet the balance of proximal mechanisms driving this variability, including fire, primary production, and respiration responses to climate variability, remains uncertain. Here we provide evidence of synchronized tree mortality and carbon losses from disturbance agents in North, Central, and South America. Although ocean-atmosphere coupling in the Atlantic and Pacific is not completely independent, the relationship between tropical North Atlantic SSTs, tropical cyclones, and fires described here is different from the well-established influence of ENSO on global patterns of temperature and precipitation. Recent work investigating ENSO-related forcing, for example, has focused on canopy-scale responses of net primary production and respiration to temperature [*Cox et al*., 2013; *Wang et al*., 2013] and drought stress [*Wang et al*., 2014]. In contrast, the climate-carbon cycle mode identified here operates through the influence of disturbance agents on forest dynamics. The interhemispheric coupling of these processes suggests that future changes in ocean-atmosphere interactions in the North Atlantic may affect forest conservation and carbon mitigation policy across multiple continents.

Acknowledgments
We are grateful for the support from the Gordon and Betty Moore Foundation (GBMF3269), the Regional and Global Climate Modeling (RGCM) Program in the Climate and Environmental Sciences Division (CESD) of the Biological and Environmental Research (BER) Program in the U. S. Dept. of Energy Office of Science, and NASA's Terrestrial Ecology Program.

The Editor thanks three anonymous reviewers for their assistance in evaluating this paper.

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