Active Atlantic hurricane era at its end?

To the Editor — The Atlantic hurricane seasons in 2013 and 2014 were quieter than average, and there are indications that hurricane activity in 2015 will also be below normal. Here we investigate whether the active Atlantic hurricane era that began in 1995 may have ended. To this end, we assess hurricane variability in the Atlantic since 1878, along with a proxy for the Atlantic multidecadal oscillation (AMO), whose positive phases have been noted to be closely linked to active periods for Atlantic hurricanes. We find that the AMO proxy values are currently at their lowest values since the early 1990s, when Atlantic hurricane activity was well below average.

The Atlantic entered an active hurricane period in 1995[1–2]. From 1995 to 2012, accumulated cyclone energy (ACE)[3] in the Atlantic basin averaged 140×10^4 knot^2 compared with 68×10^4 knot^2 from 1970 to 1994, a statistically significant increase at the 5% level. High ACE is also observed from 1878–1899 (108×10^4 knot^2) and 1926–1969 (101×10^4 knot^2) compared with low values from 1900–1925 (65×10^4 knot^2) and 1970–1994 (68×10^4 knot^2) (Fig. 1a). A limited observational network may have led to an underestimate in ACE during the earlier part of the record.

The AMO, an indicator of sea surface temperature (SST) variations in the North Atlantic, has been argued to arise from natural climate variations in the thermohaline circulation[1,2,4]. Alternatively, it could be primarily driven by alterations in levels of sulfate aerosols[5]. We argue that the weight of the evidence points towards natural oceanic variability being the principal driver of the AMO[1,4,6]. The AMO phase was classified as being positive from 1878–1899, 1926–1969 and 1995–2012, and negative from 1900–1925 and 1970–1994[2]. Positive AMO phases are characterized by above-average far North and tropical Atlantic SSTs, below-average tropical Atlantic sea level pressures (SLPs), and reduced levels of tropical Atlantic vertical wind shear. All three of these conditions are known to create a more favourable environment for Atlantic hurricane formation and intensification[1].

Following an active 2012 Atlantic hurricane season, most predictions indicated another active season in 2013[7]. A strong temporary weakening of the AMO was observed during 2013[8], which may have been one of the reasons for the season being quieter than expected. Activity during the 2014 hurricane season was also below normal. The combined ACE of 103×10^4 knot^2 registered in 2013–2014 was the lowest value that had been recorded since the ACE of 71×10^4 knot^2 in 1993–1994. And following this marked reduction in activity over the past two years, a below-average season is now expected for 2015[9].

Random resampling of three-year periods of positive AMO phase gives a 1% chance of an ACE of 155×10^4 knot^2 or lower during the positive AMO phase. It is therefore unlikely, if 2015 turns out to be as quiet as predicted, that we are in a positive AMO phase. Borderline weak El Niño conditions in 2014 and strong El Niño conditions predicted for this year's hurricane season may, however, also have contributed to observed below-average hurricane activity in 2014 and predicted below-average hurricane activity in 2015.

A proxy using a combination of North Atlantic SSTs from 50–60° N, 50–10° W and SLPs from 0–50° N, 70–10° W has been utilized to monitor the strength of the AMO in real time[10]. When the AMO is positive, SSTs in the far North Atlantic tend to be warmer, while SLPs throughout the tropics and subtropics tend to be lower[2]. This index has decreased since 2012 (Fig. 1a): SST anomalies in the tropical and far North Atlantic have become cooler and SLP anomalies throughout most of the Atlantic have increased. The decrease in far North Atlantic SSTs in the past three years has been associated with a weaker thermohaline circulation[6]. Annual mean SSTs in the North Atlantic have cooled in 2013 and 2014 compared with values averaged from 1995 to 2012 (Fig. 1b).

During the most recent 25 positive AMO years (1963–1969 and 1995–2012), 204.5 major hurricane days (MHD) were observed in the Atlantic, compared with 63.25 during the most recent 25 negative AMO years (1970–1994), a ratio of 3.2 to 1. Marked differences are also observed in tropical cyclone tracks in the deep tropics between the positive versus negative AMO phase (Fig. 1c). For example, in the Caribbean (south of 20° N, west of 60° W), 16.25 MHD occurred during the most recent

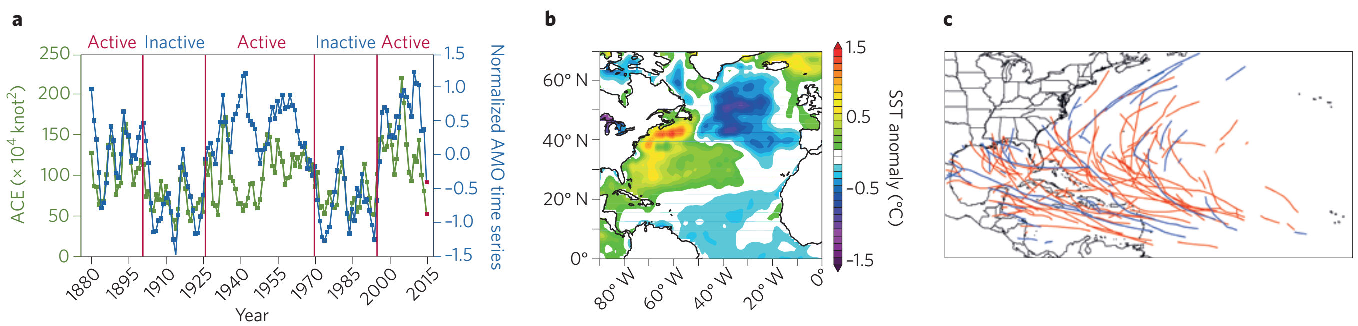

Figure 1 | Analyses of Atlantic multidecadal variability. **a**, Three-year-averaged ACE (green line) and three-year-averaged standardized normalized AMO (blue line) from 1880–2014 with predicted value for 2015 (red squares). The 2015 AMO value is the January–June-averaged value. The year listed is the third year being averaged (for example, 1880 is the 1878–1880 average). Correlation between the two time series is 0.61. **b**, Annual North Atlantic SST from 2013–2014 differenced from annual SST values from 1995–2012. **c**, Tracks of major (maximum one-minute sustained winds >96 knots) hurricanes during the 25 most recent positive AMO years (1963–1969, 1995–2012) (red lines) and tracks of major hurricanes during the 25 most recent negative AMO years (1970–1994) (blue lines). The past two years have been left out of the analysis as more confidence in the switching of the AMO phase is needed.

25 years in the negative AMO, compared with 46.75 MHD during the most recent 25 years in the positive AMO (a ratio of 2.9:1). Similar large differences are seen when examining MHD in the tropical Atlantic (south of 20° N, east of 60° W). A total of 30.75 MHD occurred during the positive AMO, compared with only 9.5 MHD during the negative AMO (a ratio of 3.2:1).

A transition of the AMO to its negative phase implies that the frequency of storms that make landfall along the east coast of the US should decrease significantly[1]. We subdivide the US coastline into the Gulf Coast/Florida Panhandle on the one hand and the Florida Peninsula/East Coast on the other hand (breaking at Tarpon Springs, Florida). The frequency of landfalling major hurricanes, based on historical data from 1878–2012 along the Florida Peninsula and East Coast decreases from 0.35 to 0.16 events per year between a positive and a negative AMO phase, while the frequency of landfalling major hurricanes remains virtually constant (0.32 in positive AMO vs. 0.35 in negative AMO) for the Gulf Coast and Florida Panhandle. The lack of change along the Gulf Coast may be due to the minimal impact of the AMO on tropical cyclone formation in the Gulf of Mexico (not shown).

A large variety of other climatic factors have also been shown to be linked to phase changes of the AMO including frequency and intensity of El Niño[10] and likelihood of Sahelian drought. Consequently, the impacts of a potential phase change of the AMO extend well beyond its impacts on Atlantic basin hurricane activity. ❐

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Additional information

Supplementary information is available in the online version of the paper.

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