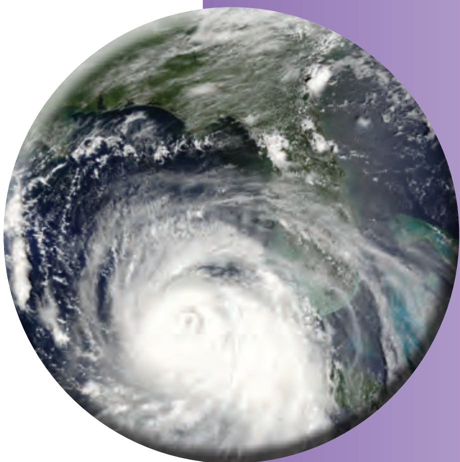

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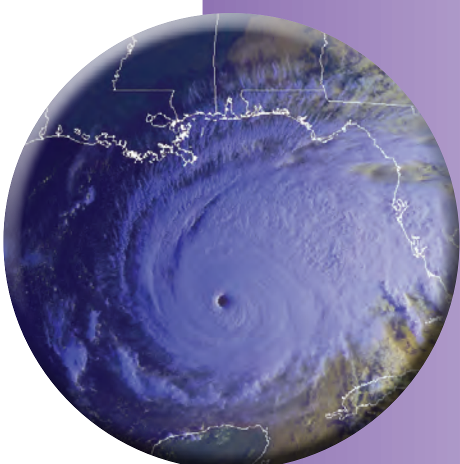
Chapter Two: The Storms of 2005

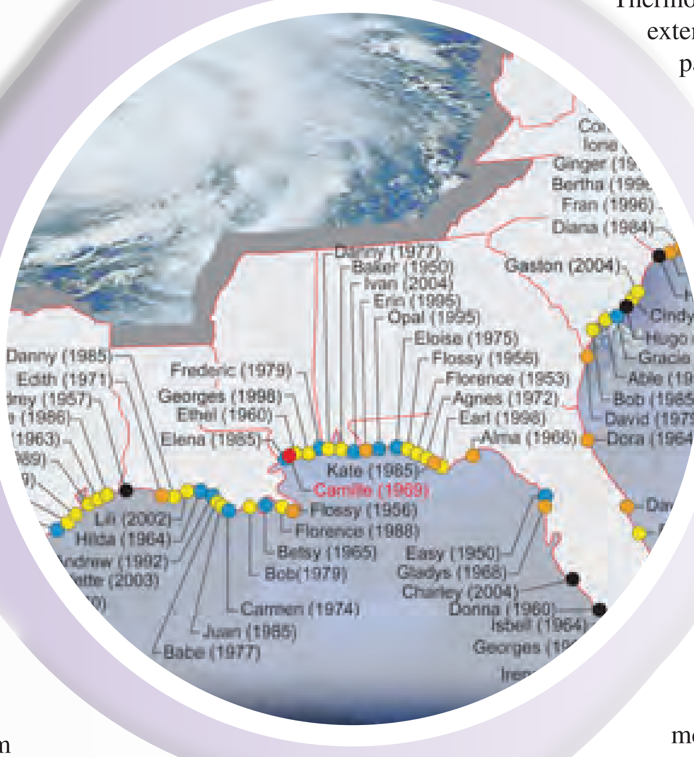


This chapter presents a few hurricane facts (hurricane terminology and categories, lists of 2005 storms, brief descriptions of Hurricanes Dennis, Katrina, Rita, and Wilma along with maps of their paths) and discusses a link between U.S. hurricane landfalls and the persistent above-average surface temperature of the North Atlantic Ocean.

Cycles of Hurricane Landfalls on the Eastern United States Linked to Changes in Atlantic Sea-surface Temperatures

By Richard Z. Poore, Terry Quinn, Julie Richey, and Jackie L. Smith

The occurrence of hurricane landfalls on the United States may be related to alternating intervals of persistent above-average and below-average surface temperature of the North Atlantic Ocean. The cycle of temperature variations, known as the Atlantic Multidecadal Oscillation (AMO), has been identified by study of records based on thermometer readings that go back to the late 1800s. These records do not cover a large enough span of time to adequately test the stability and persistence of the AMO. Better understanding of the AMO and its possible link to hurricane landfalls requires extending our knowledge of the ocean-surface temperature to periods before these thermometer readings were recorded.



Introduction

Historical observations suggest that the very active hurricane seasons of 2004 and 2005 may be part of a natural cycle in Earth's climate system that is related to changes in mean sea-surface temperature (SST) in the North Atlantic Ocean. Thermometer-based SST records only extend back to approximately the past 150 years. Compilations and analyses of these thermometer, or instrumental, records from around the world (e.g., Schlesinger and Ramankutty, 1994) have identified alternating intervals of persistent above-average and below-average ocean SST. These alternating intervals are most evident in the North Atlantic Ocean temperature records and have been named the Atlantic Multidecadal Oscillation (AMO) (Kerr, 2000). The AMO is usually represented by an index that measures departure from the long-term mean ocean temperature. The duration of a full AMO cycle of oscillation is on the order of 60–80 years (Enfield and others, 2001), which offers only a limited number of observations of a complete cycle in the instrumental record. Details of the AMO cycle and its impact on hurricane frequency remain poorly known because the instrumental record of SST is discontinuous in time and space, especially prior to the second half of the 20th century.

Landfalls Common in Warmer Phase

The historical record of major hurricane landfalls on the U.S. east coast from 1903 to 2000 shows that landfalls are generally more common during warm phases of the AMO than they are during cold phases of the AMO (fig. 1). The AMO index from 1880 to 2001 oscillates between warmer (positive phase) and cooler (negative phase) modes several times (fig. 2). The one complete warm phase present over this period is longer than either of the two complete cool phases, suggesting that warm phases of the AMO may be longer than cool phases; however, longer records are required to verify this inference. There is a general correspondence between increased number of hurricanes per decade and warm phases of the AMO (fig. 2). A very low number of hurricanes was associated with the last cold phase of the AMO. Thus, the increase in hurricanes observed in the last 5 years stands in contrast to a long interval of abnormally low hurricane occurrences.

The AMO is also linked with other changes in the climate system. For example, during the AMO warm (or positive) phase, summer rainfall over most of the United States is below normal (Enfield and others, 2001). Major droughts in the Midwestern United States during the 1930s (the Dust Bowl) and the 1950s occurred during warm phases of the AMO. In contrast, summer rainfall increases in the Sahel region of north Africa during warm phases of the AMO. The AMO also influences temperature on the continents. Surface air temperature in summer is above normal in the Eastern United States and Central Europe during warm phases of the AMO (e.g., Enfield and others, 2001; Sutton and Hodson, 2005). Future variations in the AMO may reinforce or counter temperature and precipitation changes associated with human-related changes.

Cause of the AMO

The cause of the AMO is unknown, but most researchers infer that the AMO represents an internal oscillation of the atmosphere-ocean climate system (e.g., Schlesinger and Ramankutty, 1994). The current thought is that AMO variability is related to variation in density-driven, global ocean circulation patterns that involve movement of warm equatorial surface waters into high latitudes of the North Atlantic Ocean and the subsequent cooling and sinking of these surface waters into the deep ocean (thermohaline circulation). Warm phases of the AMO represent intervals of faster thermohaline circulation, which transports more warm equatorial waters to high latitudes of the North Atlantic. Cold phases of the AMO represent intervals of slower thermohaline circulation and thus less transport of warm equatorial waters to high latitudes of the North Atlantic (Enfield and others, 2001). In general, warmer North Atlantic SST favors development of hurricanes.

To obtain longer records of the AMO for study, scientists are developing records of past temperature changes in and around the North Atlantic Ocean by studying features such as the width of tree rings and the chemistry of fossil shells, the variability in which is considered to be related to temperature. These proxy records of past temperature allow researchers to extend their knowledge beyond the period of the instrumental temperature records and permit investigations into the long-term variability of the AMO. Proxy temperature records developed from tree-ring sequences from the Southeastern United States and northern Europe show that AMO-like cycles in surface-air temperature adjacent to the North Atlantic Ocean have been present in the climate system for at least the last 400 years (Gray and others, 2004). Variability in the AMO-like cycles present in these proxy records is similar to the variability in the instrumental record of the AMO.

Extending the Record

Scientists from the USGS and collaborators are conducting research to extend the record of the AMO back in time by developing records of past SSTs from analyses of marine sediment cores from the North Atlantic Ocean and the Gulf of Mexico. The gulf is a promising study area for several reasons. First, the gulf is an extension of the North Atlantic. The warm Gulf Stream in the North Atlantic is fed by waters from the gulf that pass through the Straits of Florida, and variations in gulf and North Atlantic SSTs are highly correlated. Second, sediments in the northern gulf contain abundant marine microfossils (fig. 3), and the composition of the microfossil populations and changes in the chemistry of these microfossil shells are related to changes in ocean-surface conditions, including SST. Third, marine sediments are deposited very rapidly in the gulf, and radiocarbon dating has shown that the sedimentary record of climate variability in these cores extend back thousands of years. Initial results from the analysis of a sediment core raised from the Pigmy Basin on the Louisiana continental slope demonstrate that ocean-surface conditions over the last 1,400 years have changed in a cyclic pattern every 60–80 years. Detailed analysis is continuing on the sediment cores from the Pigmy Basin and other basins in the gulf. Future results will provide additional estimates of past ocean-surface conditions in this climatically sensitive region.

A more extensive record of the persistence and periodicity of the AMO over a longer period of time is an important step in anticipating and modeling future climate, including changes in hurricane frequency.

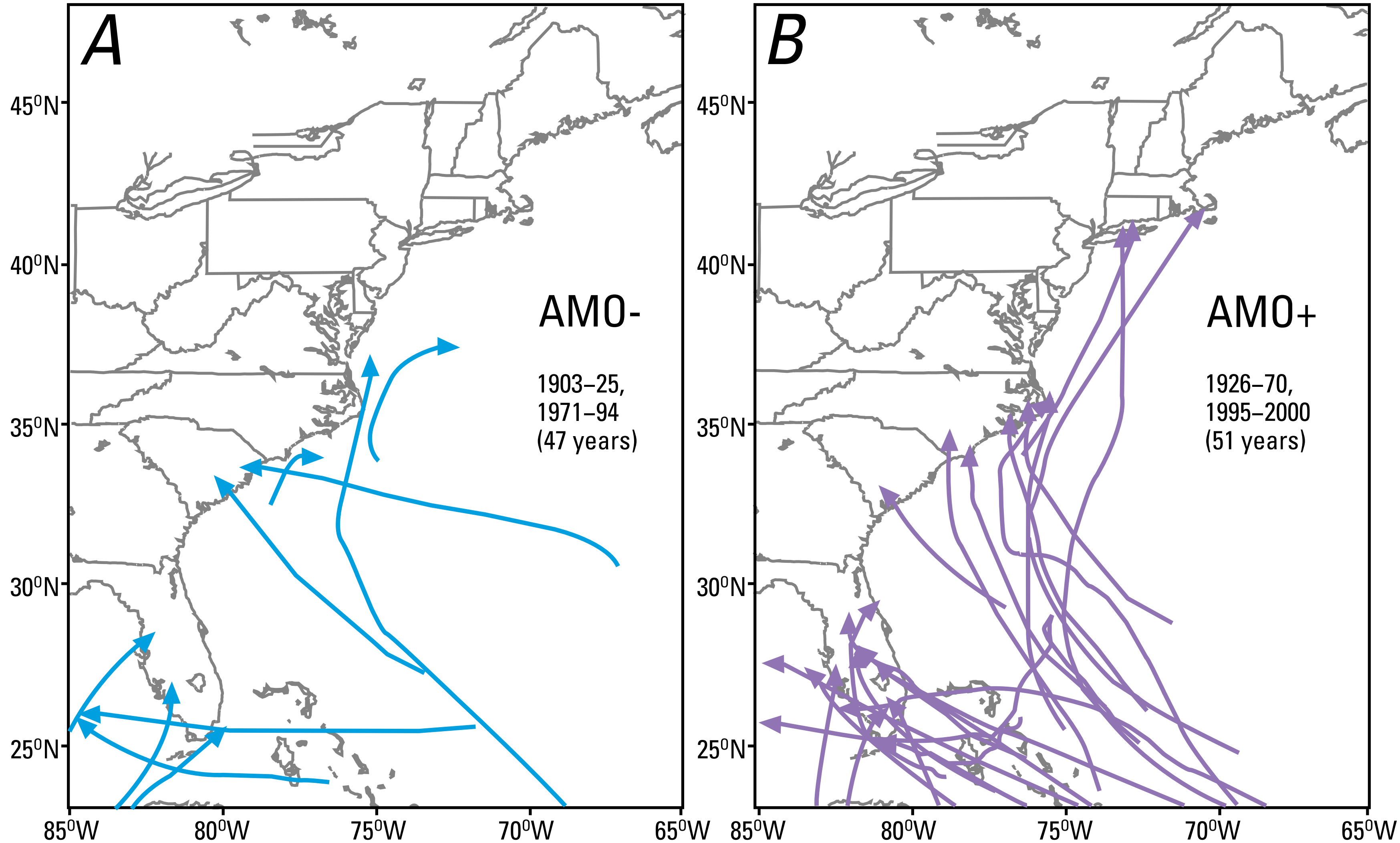


Figure 1. Map showing landfalls of major (categories 3, 4, and 5) hurricanes on the east coast of the United States during intervals of time representing cold (AMO-, *A*) and warm (AMO+, *B*) phases of the Atlantic Multidecadal Oscillation (AMO). Figure is from Goldenberg and others (2001).

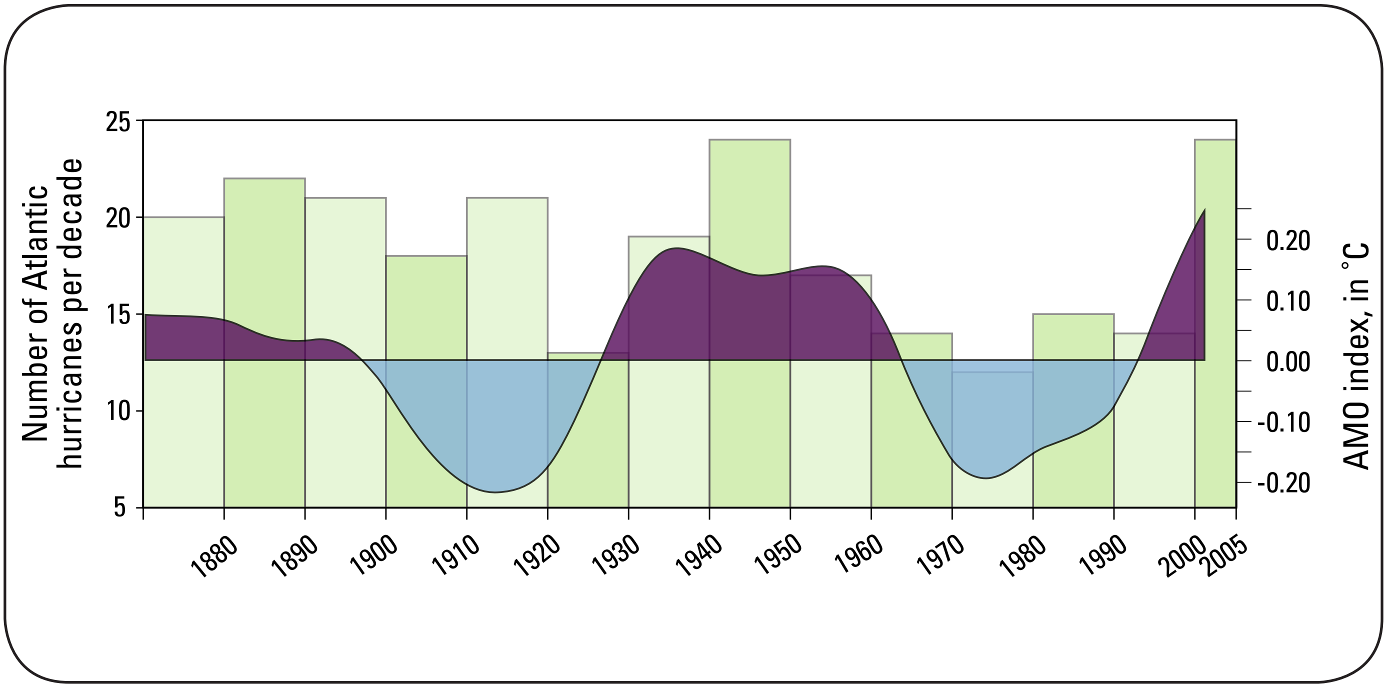


Figure 2. Comparison between the index of the Atlantic Multidecadal Oscillation (line graph, from Sutton and Hodson, 2005) and the occurrence of Atlantic hurricanes (bar graph). The bar graph was constructed from data provided by the National Hurricane Center (*http://www.nhc.noaa.gov/pastdec.shtml*). The total number of hurricanes per decade is plotted at the midpoint of the decade. The last bar represents total number of hurricanes for the 5 most recent years (2001–05). Note that the number of hurricanes in the last 5 years (24) is the same as the previous maximum number that occurred during a single decade (1940s).

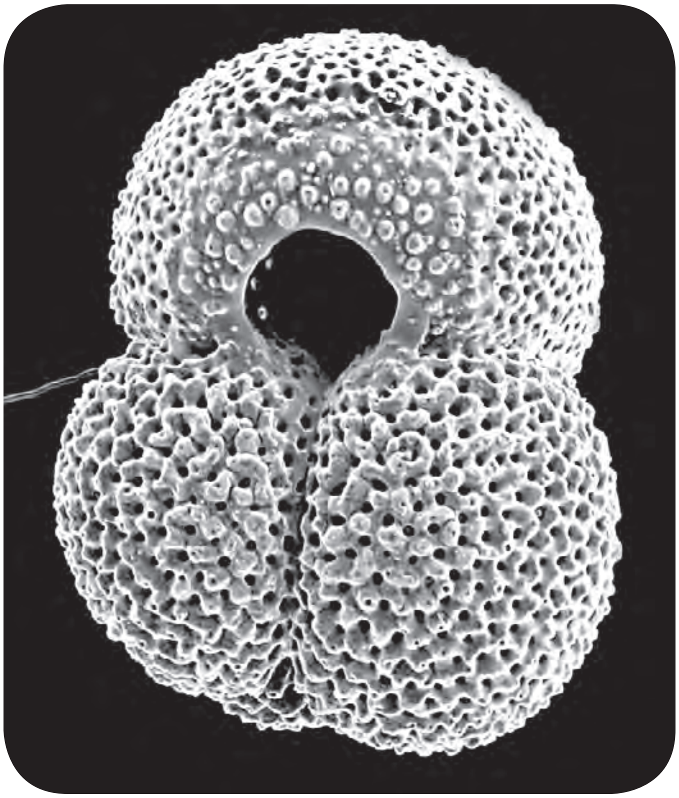


Figure 3. Photograph of the shell of *Globigerinoides ruber*, a planktic foraminifer common in surface waters of the Gulf of Mexico. The shells of planktic foraminifers are about the size of a grain of sand and are referred to as microfossils. Microfossils are common in marine sediments of the Gulf of Mexico, and changes in the population of microfossils in the sediments and the chemical composition of the microfossil shells are related to surface-water characteristics at the time the shells are formed. For example, the ratio of magnesium to calcium in the microfossil shells is dependent on the temperature of the water when the shell was formed. Researchers can construct a record of past temperatures by measuring the ratio of magnesium to calcium of shells and using radiocarbon dating to determine the age of the level sediment cores that contain the shells.

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