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6.5. Precipitation Variability

The IPCC contends that global warming is responsible for causing greater variability in precipitation, leading to more droughts and floods. In this section we review empirical research on precipitation patterns in Africa, Asia, and North America.

Additional information on this topic, including reviews on precipitation not discussed here, can be found at http://www.co2science.org/subject/p/subject_p.php under the heading Precipitation.

6.5.1. Africa

Nicholson and Yin (2001) described climatic and hydrologic conditions in equatorial East Africa from the late 1700s to close to the present, based on histories of the levels of 10 major African lakes. They also used a water balance model to infer changes in rainfall associated with the different conditions, concentrating most heavily on Lake Victoria. This work revealed “two starkly contrasting climatic episodes.” The first, which began sometime prior to 1800 and was characteristic of Little Ice Age conditions, was one of “drought and desiccation throughout Africa.” This arid episode, which was most extreme during the 1820s and 1830s, was accompanied by extremely low lake levels. As the two researchers describe it, “Lake Naivash was reduced to a puddle ... Lake Chad was desiccated ... Lake Malawi was so low that local inhabitants traversed dry land where a deep lake now resides ... Lake Rukwa [was] completely desiccated ... Lake Chilwa, at its southern end, was very low and nearby Lake Chiuta almost dried up.” Throughout this period, they report that “intense droughts were ubiquitous.” Some were “long and severe enough to force the migration of peoples and create warfare among various tribes.”

As the Little Ice Age’s grip on the world began to loosen in the mid to latter part of the 1800s, however, things began to improve for most of the continent. Nicholson and Yin report that “semi-arid regions of

Mauritania and Mali experienced agricultural prosperity and abundant harvests ... the Niger and Senegal Rivers were continually high; and wheat was grown in and exported from the Niger Bend region.” Across the length of the northern Sahel, maps and geographical reports described the presence of “forests.” As the nineteenth century came to an end and the twentieth century began, there was a slight lowering of lake levels, but nothing like what had occurred a century earlier (i.e., variability was much reduced). And then, in the latter half of the twentieth century, things once again began to pick up for the Africans, with the levels of some of the lakes rivaling the high-stands characteristic of the years of transition to the Current Warm Period.

Concentrating on the more recent past, Nicholson (2001) says the most significant climatic change has been “a long-term reduction in rainfall in the semi-arid regions of West Africa,” which has been “on the order of 20 to 40% in parts of the Sahel.” There have been, she says, “three decades of protracted aridity,” and “nearly all of Africa has been affected ... particularly since the 1980s.” However, she goes on to note that “the rainfall conditions over Africa during the last 2 to 3 decades are not unprecedented,” and that “a similar dry episode prevailed during most of the first half of the 19th century.”

Describing the situation in more detail, Nicholson says “the 3 decades of dry conditions evidenced in the Sahel are not in themselves evidence of irreversible global change,” because a longer historical perspective indicates an even longer period of similar dry conditions occurred between 1800 and 1850. This remarkable dry period occurred when the earth was still in the clutches of the Little Ice Age, a period of cold that is without precedent in at least the past 6,500 years, even in Africa (Lee-Thorp *et al.*, 2001). There is no reason to think that the most recent two- to three-decade Sahelian drought was unusual or that it was caused by the higher temperatures of that period.

Also taking a longer view of the subject were Nguetsop *et al.* (2004), who developed a high-resolution proxy record of West African precipitation based on analyses of diatoms recovered from a sediment core retrieved from Lake Ossa, West Cameroon, which they describe as “the first paleohydrological record for the last 5500 years in the equatorial near-coastal area, east of the Guinean Gulf.” They reported that this record provides evidence for alternating periods of increasing and decreasing precipitation “at a millennial time scale for the last 5500 years,” which oscillatory behavior they

interpret as being “a result of south/northward shifts of the Intertropical Convergence Zone,” specifically noting that “a southward shift of the ITCZ, combined with strengthened northern trade winds, was marked by low and high precipitation at the northern subtropics and the subequatorial zone, respectively,” and that “these events occurred in coincidence with cold spells in the northern Atlantic.”

Most recently, Therrell *et al.* (2006) developed “the first tree-ring reconstruction of rainfall in tropical Africa using a 200-year regional chronology based on samples of *Pterocarpus angolensis* [a deciduous tropical hardwood known locally as Mukwa] from Zimbabwe.” This record revealed that “a decadal-scale drought reconstructed from 1882 to 1896 matches the most severe sustained drought during the instrumental period (1989-1995),” and that “an even more severe drought is indicated from 1859 to 1868 in both the tree-ring and documentary data.” They report, for example, that the year 1860, which exhibited the lowest reconstructed rainfall value during this period, was described in a contemporary account from Botswana (where part of their tree-ring chronology originated) as “a season of ‘severe and universal drought’ with ‘food of every description’ being ‘exceedingly scarce’ and the losses of cattle being ‘very severe’ (Nash and Endfield, 2002).” At the other end of the moisture spectrum, they report that “a 6-year wet period at the turn of the nineteenth century (1897-1902) exceeds any wet episode during the instrumental era.”

Additional information on this topic, including reviews of newer publications as they become available, can be found at <http://www.co2science.org/subject/p/variabilafrika.php>.

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6.5.2. Asia

Pederson *et al.* (2001) developed tree-ring chronologies for northeastern Mongolia and used them to reconstruct annual precipitation and streamflow histories for the period 1651-1995. Working with both standard deviations and five-year intervals of extreme wet and dry periods, they found that “variations over the recent period of instrumental data are not unusual relative to the prior record.” They note, however, that their reconstructions “appear to show more frequent extended wet periods in more recent decades,” but they say that this observation “does not demonstrate unequivocal evidence of an increase in precipitation as suggested by some climate models.” Spectral analysis of the data also revealed significant periodicities around 12 and 20-24 years, which they suggested may constitute “possible evidence for solar influences in these reconstructions for northeastern Mongolia.”

Kripalani and Kulkarni (2001) studied seasonal summer monsoon (June-September) rainfall data from 120 east Asia stations for the period 1881-1998. A series of statistical tests they applied to these data revealed the presence of short-term variability in rainfall amounts on decadal and longer time scales, the longer “epochs” of which were found to last for about three decades over China and India and for approximately five decades over Japan. With respect to long-term trends, however, none was detected. Consequently, the history of summer rainfall trends in east Asia does not support claims of intensified monsoonal conditions in this region as a result of CO₂-induced global warming. As for the decadal variability inherent in the record, the two researchers say it “appears to be just a part of natural climate variations.”

Taking a much longer look at the Asian monsoon were Ji *et al.* (2005), who used reflectance spectroscopy on a sediment core taken from a lake in

the northeastern part of the Qinghai-Tibetan Plateau to obtain a continuous high-resolution proxy record of the Asian monsoon over the past 18,000 years. This project indicated that monsoonal moisture since the late glacial period had been subject to “continual and cyclic variations,” among which was a “very abrupt onset and termination” of a 2,000-year dry spell that started about 4,200 years ago (yr BP) and ended around 2,300 yr BP. Other variations included the well-known centennial-scale cold and dry spells of the Dark Ages Cold Period (DACP) and Little Ice Age (LIA), which lasted from 2,100 yr BP to 1,800 yr BP and 780 yr BP to 400 yr BP, respectively, while sandwiched between them was the warmer and wetter Medieval Warm Period, and preceding the DACP was the Roman Warm Period. Time series analyses of the sediment record also revealed several statistically significant periodicities (123, 163, 200, and 293 years, all above the 95 percent level), with the 200-year cycle matching the de Vries or Suess solar cycle, implying that changes in solar activity are important triggers for some of the recurring precipitation changes in that part of Asia. It is clear that large and abrupt fluctuations in the Asian monsoon have occurred numerous times and with great regularity throughout the Holocene, and that the sun played an important role in orchestrating them.

Also working on the Tibetan Plateau were Shao *et al.* (2005), who used seven Qilian juniper ring-width chronologies from the northeastern part of the Qaidam Basin to reconstruct a thousand-year history of annual precipitation there. In doing so, they discovered that annual precipitation had fluctuated at various intervals and to various degrees throughout the entire past millennium. Wetter periods occurred between 1520 and 1633, as well as between 1933 and 2001, although precipitation has declined somewhat since the 1990s. Drier periods, on the other hand, occurred between 1429 and 1519 and between 1634 and 1741. With respect to variability, the scientists report that the magnitude of variation in annual precipitation was about 15 mm before 1430, increased to 30 mm between 1430 and 1850, and declined thereafter to the present.

Based on analyses of tree-ring width data and their connection to large-scale atmospheric circulation, Touchan *et al.* (2005) developed summer (May-August) precipitation reconstructions for several parts of the eastern Mediterranean region (Turkey, Syria, Lebanon, Cyprus, and Greece) that extend back in time anywhere from 115 to 600 years. Over the latter length of time, they found that May-

August precipitation varied on multiannual and decadal timescales, but that on the whole there were no long-term trends. The longest dry period occurred in the late sixteenth century (1591-1595), while there were two extreme wet periods: 1601-1605 and 1751-1755. In addition, both extremely strong and weak precipitation events were found to be more variable over the intervals 1520-1590, 1650-1670, and 1850-1930. The results of this study demonstrate there was nothing unusual or unprecedented about late twentieth century precipitation events in the eastern Mediterranean part of Asia that would suggest a CO₂ influence.

Last, Davi *et al.* (2006) used absolutely dated tree-ring-width chronologies obtained from five sampling sites in west-central Mongolia to derive individual precipitation models, the longest of which stretches from 1340 to 2002, additionally developing a reconstruction of streamflow that extends from 1637 to 1997. In the process of doing so, they discovered there was “much wider variation in the long-term tree-ring record than in the limited record of measured precipitation,” which for the region they studied covers the period from 1937 to 2003. In addition, they say their streamflow history indicates that “the wettest 5-year period was 1764-68 and the driest period was 1854-58,” while “the most extended wet period [was] 1794-1802 and ... extended dry period [was] 1778-83.” For this part of Mongolia, therefore, which the researchers say is “representative of the central Asian region,” there is no support to be found for the contention that the “unprecedented warming” of the twentieth century has led to increased variability in precipitation and streamflow.

These several findings suggest that either there is nothing unusual about Asia’s current degree of warmth, i.e., it is not unprecedented relative to that of the early part of the past millennium, or unprecedented warming need not lead to unprecedented precipitation or unprecedented precipitation variability ... or both of the above. We conclude that the findings of this study and of others reviewed in this section provide no support for the contention that global warming leads to greater and more frequent precipitation extremes in Asia.

Additional information on this topic, including reviews of newer publications as they become available, can be found at <http://www.co2science.org/subject/p/variabilasia.php>.

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6.5.3. North America

Cronin *et al.* (2000) studied salinity gradients across sediment cores extracted from Chesapeake Bay, the largest estuary in the United States, in an effort to determine precipitation variability in the surrounding watershed over the prior millennium. They discovered there was a high degree of decadal and multidecadal variability in moisture conditions over the 1,000-year period, with regional precipitation totals fluctuating by between 25 percent and 30 percent, often in extremely rapid shifts occurring over about a decade. They also determined that precipitation was generally greater over the past two centuries than it was over the eight previous centuries, with the exception of a portion of the Medieval Warm Period (AD 1250-1350), when the climate was extremely wet. In addition, they found that the region surrounding Chesapeake Bay had experienced several “mega-droughts” lasting from 60-70 years, some of which the researchers say “were more severe than twentieth

century droughts.” Likewise, across the continent, Haston and Michaelsen (1997) developed a 400-year history of precipitation for 29 stations in coastal and near-interior California between San Francisco Bay and the U.S.-Mexican border using tree-ring chronologies; their work also revealed that “region-wide precipitation during the last 100 years has been unusually high and less variable compared to other periods in the past.”

Crossing the continent yet again, and dropping down to the Caribbean Sea, Watanabe *et al.* (2001) analyzed delta $^{18}\text{O}/^{16}\text{O}$ and Mg/Ca ratios in cores obtained from a coral in an effort designed to examine seasonal variability in sea surface temperature and salinity there during the Little Ice Age. In doing so, they found that sea surface temperatures during this period were about 2°C colder than they are currently, while sea surface salinity exhibited greater variability than it does now, indicating that during the Little Ice Age “wet and dry seasons were more pronounced.”

In Canada, Zhang *et al.* (2001) analyzed the spatial and temporal characteristics of extreme precipitation events for the period 1900-1998, using what they describe as “the most homogeneous long-term dataset currently available for Canadian daily precipitation.” This exercise indicated that decadal-scale variability was a dominant feature of both the frequency and intensity of extreme precipitation events, but it provided “no evidence of any significant long-term changes” in these indices during the twentieth century. Their analysis of precipitation totals (extreme and non-extreme) did reveal a slightly increasing trend across Canada during the period of study, but it was found to be due to increases in the number of non-heavy precipitation events. Consequently, the researchers concluded that “increases in the concentration of atmospheric greenhouse gases during the twentieth century have not been associated with a generalized increase in extreme precipitation over Canada.”

Dropping down into the Uinta Basin Watershed of northeastern Utah, Gray *et al.* (2004) used cores extracted from 107 piñon pines at four different sites to develop a proxy record of annual (June to June) precipitation spanning the period AD 1226-2001. They report that “single-year dry events before the instrumental period tended to be more severe than those after 1900,” and that decadal-scale dry events were longer and more severe prior to 1900 as well. In particular, they found that “dry events in the late 13th, 16th, and 18th centuries surpass the magnitude and duration of droughts seen in the Uinta Basin after

1900.” At the other end of the spectrum, they report that the twentieth century contained two of the strongest wet intervals (1938-1952 and 1965-1987), although the two periods were only the seventh and second most intense wet regimes, respectively, of the entire record. Hence, it would appear that in conjunction with twentieth century global warming, precipitation extremes (both high and low) within the Uinta Basin of northeastern Utah have become attenuated as opposed to amplified.

Last, we come to the study of Rasmussen *et al.* (2006), who had previously demonstrated that “speleothems from the Guadalupe Mountains in southeastern New Mexico are annually banded, and variations in band thickness and mineralogy can be used as a record of regional relative moisture (Asmerom and Polyak, 2004).” In their new study, they continued this tack, concentrating on “two columnar stalagmites collected from Carlsbad Cavern (BC2) and Hidden Cave (HC1) in the Guadalupe Mountains.”

The three researchers report that “both records, BC2 and HC1, suggest periods of dramatic precipitation variability over the last 3000 years, exhibiting large shifts *unlike anything seen in the modern record* [our italics].” Second, they report that the time interval from AD 900-1300 coincides with the well-known Medieval Warm Period and “shows dampened precipitation variability and overall drier conditions” that are “consistent with the idea of more frequent La Niña events and/or negative PDO phases causing elevated aridity in the region during this time.” Third, they indicate that the preceding and following colder centuries “show increased precipitation variability ... coinciding with increased El Niño flooding events.”

Clearly, moisture extremes in North America much greater than those observed in the modern era are neither unusual nor manmade; they are simply a normal part of earth’s natural climatic variability. In this regard, North America is like Africa and Asia: Precipitation variability in the Current Warm Period is no greater than what was experienced in earlier times.

Additional information on this topic, including reviews of newer publications as they become available, can be found at <http://www.co2science.org/subject/p/variabilnortham.php>.

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6.6. Storms

Among the highly publicized changes in weather phenomena that are predicted to attend the ongoing rise in the air's CO_2 content are increases in the frequency and severity of all types of storms. Many researchers have examined historical and proxy records in an attempt to determine how temperature changes over the past millennium or two have affected this aspect of earth's climate. This section reviews what some of them have learned about storm trends, focusing on Europe and North America.

A number of studies have reported increases in North Atlantic storminess over the last two decades of the twentieth century (Jones *et al.*, 1997; Gunther *et al.*, 1998; Dickson *et al.*, 2000). Since the IPCC claims this period was the warmest of the past millennium, this observation might appear to

vindicate their view of the subject. When much longer time periods are considered, however, the storminess of the twentieth century is found to be not uncommon and even mild compared to times when temperatures and CO_2 levels were lower.

Dawson *et al.* (2002) searched daily meteorological records from Stornoway (Outer Hebrides), Lerwick (Shetland Islands), Wick (Caithness), and Fair Isle (west of the Shetland Islands) for all data pertaining to gale-force winds over the period 1876-1996, which they used to construct a history of storminess for that period for northern and northwestern Scotland. This history indicated that although North Atlantic storminess and associated wave heights had indeed increased over the prior two decades, storminess in the North Atlantic region "was considerably more severe during parts of the nineteenth century than in recent decades." In addition, whereas the modern increase in storminess appeared to be associated with a spate of substantial positive values of the North Atlantic Oscillation (NAO) index, they say "this was not the case during the period of exceptional storminess at the close of the nineteenth century." During that earlier period, the conditions that fostered modern storminess were apparently overpowered by something even more potent, i.e., cold temperatures, which in the view of Dawson *et al.* led to an expansion of sea ice in the Greenland Sea that expanded and intensified the Greenland anticyclone, which in turn led to the North Atlantic cyclone track being displaced farther south. Additional support for this view is provided by the hypothesis propounded by Clarke *et al.* (2002), who postulated that a southward spread of sea ice and polar water results in an increased thermal gradient between 50°N and 65°N that intensifies storm activity in the North Atlantic and supports dune formation in the Aquitaine region of southwest France.

The results of these two studies suggest that the increased storminess and wave heights observed in the European sector of the North Atlantic Ocean over the past two decades are not the result of global warming. Rather, they are associated with the most recent periodic increase in the NAO index. Furthermore, a longer historical perspective reveals that North Atlantic storminess was even more severe than it is now during the latter part of the nineteenth century, when it was significantly colder than it is now. In fact, the storminess of that much colder period was so great that it was actually decoupled from the NAO index. Hence, the long view of history suggests that the global warming of the past century