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## 6.2. Floods

In the midst of 2002's massive flooding in Europe, Gallus Cadonau, the managing director of the Swiss Greina Foundation, called for a punitive tariff on U.S. imports to force cooperation on reducing greenhouse gas emissions, claiming that the flooding "definitely has to do with global warming" and stating that "we must change something now" (Hooper, 2002). Cadonau was joined in this sentiment by Germany's environment minister, Jurgen Trittin, who implied much the same thing when he said "if we don't want this development to get worse, then we must continue with the consistent reduction of environmentally harmful greenhouse gasses" (Ibid.).

The IPCC seems to agree with Cadonau and Trittin. Its authors report "a catastrophic flood occurred along several central European rivers in August 2002. The floods resulting from extraordinarily high precipitation were enhanced by the fact that the soils were completely saturated and the river water levels were already high because of previous rain. Hence, it was part of a pattern of weather over an extended period" (IPCC, 2007-I, p. 311). While admitting "there is no significant trend in flood occurrences of the Elbe within the last 500 years," the IPCC nevertheless says the "observed increase in precipitation variability at a majority of German precipitation stations during the last century is indicative of an enhancement of the probability of both floods and droughts" (Ibid.)

In evaluating these claims it is instructive to see how flood activity has responded to the global warming of the past century. In the sections below we review studies of the subject that have been conducted in Asia, Europe, and North America.

Additional information on this topic, including reviews on floods not discussed here, can be found at [http://www.co2science.org/subject/f/subject\\_f.php](http://www.co2science.org/subject/f/subject_f.php) under the heading Floods.

### 6.2.1. Asia

In a study that covered the entire continent, Cluis and Laberge (2001) analyzed the flow records of 78 rivers distributed throughout the Asia-Pacific region to see if there had been any enhancement of earth's hydrologic cycle coupled with an increase in variability that might have led to more floods between the mean beginning and end dates of the flow records:  $1936 \pm 5$  years and  $1988 \pm 1$  year, respectively. Over this period, the two scientists determined that mean river discharges were unchanged in 67 percent of the cases investigated; where there were trends, 69 percent of them were downward. In addition, maximum river discharges were unchanged in 77 percent of the cases investigated; where there were trends, 72 percent of them were downward. Consequently, the two researchers observed no changes in both of these flood characteristics in the majority of the rivers they studied; where there were changes, more of them were of the type that typically leads to less flooding and less severe floods.

Two years later, Kale *et al.* (2003) conducted geomorphic studies of slackwater deposits in the bedrock gorges of the Tapi and Narmada Rivers of central India, which allowed them to assemble long chronologies of large floods of these rivers. In doing so, they found that "since 1727 at least 33 large floods have occurred on the Tapi River and the largest on the river occurred in 1837." With respect to large floods on the Narmada River, they reported at least nine or 10 floods between the beginning of the Christian era and AD 400; between AD 400 and 1000 they documented six to seven floods; between AD 1000 and 1400 eight or nine floods; and after 1950 three more such floods. In addition, on the basis of texture, elevation, and thickness of the flood units, they concluded that "the periods AD 400-1000 and post-1950 represent periods of extreme floods."

What do these findings imply about the effects of global warming on central India flood events? The post-1950 period would likely be claimed by the IPCC to have been the warmest of the past millennium; it has indeed experienced some extreme floods. However, the flood characteristics of the AD 400-1000 period are described in equivalent terms, and this was a rather cold climatic interval known as the Dark Ages Cold Period. See, for example, McDermott *et al.* (2001) and Andersson *et al.* (2003). In addition, the most extreme flood in the much shorter record of the Tapi River occurred in 1837, near the beginning of one of the colder periods of the

Little Ice Age. There appears to be little correlation between the flood characteristics of the Tapi and Narmada Rivers of central India and the thermal state of the global climate.

Focusing on the much smaller area of southwestern Turkey, Touchan *et al.* (2003) developed two reconstructions of spring (May-June) precipitation from tree-ring width measurements, one of them (1776-1998) based on nine chronologies of *Cedrus libani*, *Juniperus excelsa*, *Pinus brutia* and *Pinus nigra*, and the other one (1339-1998) based on three chronologies of *Juniperus excelsa*. These reconstructions, in their words, “show clear evidence of multi-year to decadal variations in spring precipitation,” with both wet and dry periods of 1-2 years duration being well distributed throughout the record. However, in the case of more extreme hydrologic events, they found that all of the wettest five-year periods preceded the Industrial Revolution, manifesting themselves at times when the air’s carbon dioxide content was largely unaffected by anthropogenic CO<sub>2</sub> emissions.

Two years later, Jiang *et al.* (2005) analyzed pertinent historical documents to produce a 1,000-year time series of flood and drought occurrence in the Yangtze Delta of Eastern China (30 to 33°N, 119 to 122°E), which with a nearly level plain that averages only two to seven meters above sea level across 75 percent of its area is vulnerable to flooding and maritime tidal hazards. This work demonstrated that alternating wet and dry episodes occurred throughout the 1,000-year period, with the most rapid and strongest of these fluctuations occurring during the Little Ice Age (1500-1850).

The following year, Davi *et al.* (2006) developed a reconstruction of streamflow that extended from 1637 to 1997, based on absolutely dated tree-ring-width chronologies from five sampling sites in west-central Mongolia, all of which sites were in or near the Selenge River basin, the largest river in Mongolia. Of the 10 wettest five-year periods, only two occurred during the twentieth century (1990-1994 and 1917-1921, the second and eighth wettest of the 10 extreme periods, respectively), once again indicative of a propensity for less flooding during the warmest portion of the 360-year period.

The year 2007 produced a second study of the Yangtze Delta of Eastern China, when Zhang *et al.* (2007) developed flood and drought histories of the past thousand years “from local chronicles, old and very comprehensive encyclopaedia, historic agricultural registers, and official weather reports,”

after which “continuous wavelet transform was applied to detect the periodicity and variability of the flood/drought series” and, finally, the results of the entire set of operations were compared with 1,000-year temperature histories of northeastern Tibet and southern Tibet. This work revealed, in the words of the researchers, that “colder mean temperature in the Tibetan Plateau usually resulted in higher probability of flood events in the Yangtze Delta region.”

Contemporaneously, Huang *et al.* (2007) constructed a complete catalog of Holocene overbank flooding events at a watershed scale in the headwater region of the Sushui River within the Yuncheng Basin in the southeast part of the middle reaches of China’s Yellow River, based on pedo-sedimentary records of the region’s semiarid piedmont alluvial plains, including the color, texture, and structure of the sediment profiles, along with determinations of particle-size distributions, magnetic susceptibilities, and elemental concentrations. This work revealed there were six major episodes of overbank flooding. The first occurred at the onset of the Holocene, the second immediately before the mid-Holocene Climatic Optimum, and the third in the late stage of the mid-Holocene Climatic Optimum, while the last three episodes coincided with “the cold-dry stages during the late Holocene,” according to the six scientists. Speaking of the last of the overbank flooding episodes, they note that it “corresponds with the well documented ‘Little Ice Age,’ when “climate departed from its long-term average conditions and was unstable, irregular, and disastrous,” which is pretty much like the Little Ice Age has been described in many other parts of the world as well.

The history of floods in Asia provides no evidence of increased frequency or severity during the Current Warm Period. Additional information on this topic, including reviews of newer publications as they become available, can be found at <http://www.co2science.org/subject/f/floodsasiasia.php>.

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### 6.2.2. Europe

Nesje *et al.* (2001) analyzed a sediment core from a lake in southern Norway in an attempt to determine the frequency and magnitude of floods in that region. The last thousand years of the record revealed “a period of little flood activity around the Medieval period (AD 1000-1400),” which was followed by a period of extensive flood activity that was associated with the “post-Medieval climate deterioration characterized by lower air temperature, thicker and more long-lasting snow cover, and more frequent storms associated with the ‘Little Ice Age’.” This particular study suggests that the post-Little Ice Age warming the earth has experienced for the past century or two—and which could well continue for some time to come—should be leading this portion of the planet into a period of less-extensive floods.

Pirazzoli (2000) analyzed tide-gauge and meteorological data over the period 1951-1997 for the northern portion of the Atlantic coast of France, discovering that the number of atmospheric depressions and strong surge winds in this region “are becoming less frequent.” The data also revealed that “ongoing trends of climate variability show a decrease in the frequency and hence the gravity of coastal flooding,” which is what would be expected in view of the findings of Nesje *et al.*

Reynard *et al.* (2001) used a continuous flow simulation model to assess the impacts of potential climate and land use changes on flood regimes of the UK’s Thames and Severn Rivers; and, as might have been expected of a model study, it predicted modest increases in the magnitudes of 50-year floods on these rivers when the climate was forced to change as predicted for various global warming scenarios. However, when the modelers allowed forest cover to rise concomitantly, they found that this land use change “acts in the opposite direction to the climate changes and under some scenarios is large enough to fully compensate for the shifts due to climate.” As the air’s  $\text{CO}_2$  content continues to rise, there will be a natural impetus for forests to expand their ranges and grow in areas where grasses now dominate the landscape. If public policies cooperate, forests will indeed expand their presence on the river catchments in question and neutralize any predicted increases in flood activity in a future high- $\text{CO}_2$  world.

Starkel (2002) reviewed what is known about the relationship between extreme weather events and the thermal climate of Europe during the Holocene. This review demonstrated that more extreme fluvial activity was typically associated with cooler time intervals. In recovering from one such period (the Younger Dryas), for example, temperatures in Germany and Switzerland rose by 3-5°C over several decades; “this fast shift,” in Starkel’s words, “caused a rapid expansion of forest communities, [a] rise in the upper treeline and higher density of vegetation cover,” which led to a “drastic” reduction in sediment delivery from slopes to river channels.

Mudelsee *et al.* (2003) analyzed historical documents from the eleventh century to 1850, plus subsequent water stage and daily runoff records from then until 2002, for two of the largest rivers in central Europe: the Elbe and Oder Rivers. The team of German scientists reported that “for the past 80 to 150 years”—which the IPCC claims was a period of unprecedented global warming—“we find a decrease in winter flood occurrence in both rivers, while

summer floods show no trend, consistent with trends in extreme precipitation occurrence.” As the world has recovered from the global chill of the Little Ice Age, flooding of the Elbe and Oder rivers has not materially changed in summer and has actually decreased in winter. Blaming anthropogenic CO<sub>2</sub> emissions for the European flooding of 2002, then, is not a reasoned deduction based on scientific evidence.

On September 8 and 9, 2002, extreme flooding of the Gardon River in southern France occurred as a result of half-a-year’s rainfall being received in approximately 20 hours. Floods claimed the lives of a number of people and caused much damage to towns and villages situated adjacent to its channel. The event elicited much coverage in the press; in the words of Sheffer *et al.* (2003), “this flood is now considered by the media and professionals to be ‘the largest flood on record’,” which record extends all the way back to 1890. Coincidentally, Sheffer *et al.* were in the midst of a study of prior floods of the Gardon River, so they had data spanning a much longer time period. They report that “the extraordinary flood of September 2002 was not the largest by any means,” noting that “similar, and even larger floods have occurred several times in the recent past,” with three of the five greatest floods they had identified to that point in time occurring over the period AD 1400-1800 during the Little Ice Age. Commenting on these facts, Sheffer *et al.* stated that “using a longer time scale than human collective memory, paleoflood studies can put in perspective the occurrences of the extreme floods that hit Europe and other parts of the world during the summer of 2002.”

Lindstrom and Bergstrom (2004) analyzed runoff and flood data from more than 60 discharge stations scattered throughout Sweden, some of which provide information stretching to the early- to mid-1800s, when Sweden and the world were still experiencing the cold of the Little Ice Age. This analysis led them to discover that the last 20 years of the past century were indeed unusually wet, with a runoff anomaly of +8 percent compared with the century average. But they also found that “the runoff in the 1920s was comparable to that of the two latest decades,” and that “the few observation series available from the 1800s show that the runoff was even higher than recently.” What is more, they note that “flood peaks in old data are probably underestimated,” which “makes it difficult to conclude that there has really been a significant increase in average flood levels.” In addition, they say “no increased frequency of floods

with a return period of 10 years or more, could be determined.”

With respect to the generality of their findings, Lindstrom and Bergstrom say that conditions in Sweden “are consistent with results reported from nearby countries: e.g. Forland *et al.* (2000), Bering Ovesen *et al.* (2000), Klavins *et al.* (2002) and Hyvarinen (2003),” and that, “in general, it has been difficult to show any convincing evidence of an increasing magnitude of floods (e.g. Roald, 1999) in the near region, as is the case in other parts of the world (e.g. Robson *et al.*, 1998; Lins and Slack, 1999; Douglas *et al.*, 2000; McCabe and Wolock, 2002; Zhang *et al.*, 2001).”

It is clear that for most of Europe, there are no compelling real-world data to support the claim that the global warming of the past two centuries led to more frequent or severe flooding. Additional information on this topic, including reviews of newer publications as they become available, can be found at <http://www.co2science.org/subject/f/floodseuro.php>.

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### 6.2.3. North America

Lins and Slack (1999) analyzed secular streamflow trends in 395 different parts of the United States that were derived from more than 1,500 individual streamgauges, some of which had continuous data stretching to 1914. In the mean, they found that “the conterminous U.S. is getting wetter, but less extreme.” That is to say, as the near-surface air temperature of the planet gradually rose throughout the course of the twentieth century, the United States became wetter in the mean but less variable at the extremes, which is where floods and droughts occur, leading to what could well be called the best of both worlds, i.e., more water with fewer floods and droughts.

In a similar but more regionally focused study, Molnar and Ramirez (2001) conducted a detailed analysis of precipitation and streamflow trends for the period 1948-1997 in the semiarid Rio Puerco Basin of New Mexico. At the annual timescale, they reported finding “a statistically significant increasing trend in precipitation,” which was driven primarily by an increase in the number of rainy days in the moderate rainfall intensity range, with essentially no change at the high-intensity end of the spectrum. In the case of streamflow, there was no trend at the annual timescale, but monthly totals increased in low-flow months and decreased in high-flow months, once again reducing the likelihood of both floods and droughts.

Knox (2001) identified an analogous phenomenon in the more mesic Upper Mississippi River Valley, but with a slight twist. Since the 1940s and early 1950s, the magnitudes of the largest daily flows in this much wetter region have been decreasing at the same time that the magnitude of the average daily baseflow has been increasing, once again manifesting simultaneous trends towards lessened flood and drought conditions.

Much the same story is told by the research of Garbrecht and Rossel (2002), who studied the nature of precipitation throughout the U.S. Great Plains over the period 1895-1999. For the central and southern Great Plains, the last two decades of this period were found to be the longest and wettest of the entire 105 years of record, due primarily to a reduction in the number of dry years and an increase in the number of wet years. Once again, however, the number of very wet years—which would be expected to produce flooding—“did not increase as much and even showed a decrease for many regions.”

The northern and northwestern Great Plains also experienced a precipitation increase near the end of Garbrecht and Rossel’s 105-year record, but it was primarily confined to the final decade of the twentieth century. And again, as they report, “fewer dry years over the last 10 years, as opposed to an increase in very wet years, were the leading cause of the observed wet conditions.”

In spite of the general tendencies described in these several papers, there still were some significant floods during the last decade of the past century, such as the 1997 flooding of the Red River of the North, which devastated Grand Forks, North Dakota, as well as parts of Canada. However, as Haque (2000) reports, although this particular flood was indeed the largest experienced by the Red River over the past

century, it was not the largest to occur in historic times. In 1852 there was a slightly larger Red River flood, and in 1826 there was a flood that was nearly 40 percent greater than the flood of 1997. The temperature of the globe was colder at the times of these earlier catastrophic floods than it was in 1997, indicating that one cannot attribute the strength of the 1997 flood to higher temperatures that year or the warming of the preceding decades. We also note that Red River flooding is also linked to snow melt and ice jams because it flows northward into frozen areas.

Olsen *et al.* (1999) report that some upward trends in flood-flows have been found in certain places along the Mississippi and Missouri Rivers, which is not at all surprising, as there will always be exceptions to the general rule. They note that many of the observed upward trends were highly dependent upon the length of the data record and when the trends began and ended. They say of these trends that they “were not necessarily there in the past and they may not be there tomorrow.”

Expanding the scope of our survey to much longer intervals of time is Fye *et al.* (2003), who developed multi-century reconstructions of summer (June-August) Palmer Drought Severity Index over the continental United States from annual proxies of moisture status provided by 426 climatically sensitive tree-ring chronologies. This exercise indicated that the greatest twentieth century wetness anomaly across the United States was a 13-year period in the early part of the century when it was colder than it is now. Fye *et al.*'s analysis also revealed the existence of a 16-year pluvial from 1825 to 1840 and a prolonged 21-year wet period from 1602 to 1622, both of which anomalies occurred during the Little Ice Age, when, of course, it was colder still.

St. George and Nielsen (2002) used “a ringwidth chronology developed from living, historical and subfossil bur oak (*Quercus macrocarpa* (Michx.)) in the Red River basin to reconstruct annual precipitation in southern Manitoba since A.D. 1409.” Their analysis indicated, in their words, that “prior to the 20th century, southern Manitoba's climate was more extreme and variable, with prolonged intervals that were wetter and drier than any time following permanent Euro-Canadian settlement.”

Also working with tree-ring chronologies, Ni *et al.* (2002) developed a 1,000-year history of cool-season (November-April) precipitation for each climate division in Arizona and New Mexico, USA. In doing so, they found that several wet periods comparable to the wet conditions seen in the early

1900s and post-1976 occurred in 1108-20, 1195-1204, 1330-45 (which they denominate “the most persistent and extreme wet interval”), the 1610s, and the early 1800s, all of which wet periods are embedded in the long cold expanse of the Little Ice Age, which is clearly revealed in the work of Esper *et al.* (2002).

Doubling the temporal extent of Ni *et al.*'s investigation, Schimmelmann *et al.* (2003) analyzed gray clay-rich flood deposits in the predominantly olive varved sediments of the Santa Barbara Basin off the coast of California, USA, which they accurately dated by varve-counting. Their analysis indicated that six prominent flood events occurred at approximately AD 212, 440, 603, 1029, 1418, and 1605, “suggesting,” in their words, “a quasi-periodicity of ~200 years,” with “skipped” flooding just after AD 800, 1200, and 1800. They further note that “the floods of ~AD 1029 and 1605 seem to have been associated with brief cold spells,” that “the flood of ~AD 440 dates to the onset of the most unstable marine climatic interval of the Holocene (Kennett and Kennett, 2000),” and that “the flood of ~AD 1418 occurred at a time when the global atmospheric circulation pattern underwent fundamental reorganization at the beginning of the ‘Little Ice Age’ (Kreutz *et al.*, 1997; Meeker and Mayewski, 2002).” As a result, they hypothesize that “solar-modulated climatic background conditions are opening a ~40-year window of opportunity for flooding every ~200 years,” and that “during each window, the danger of flooding is exacerbated by additional climatic and environmental cofactors.” They also note that “extrapolation of the ~200-year spacing of floods into the future raises the uncomfortable possibility for historically unprecedented flooding in southern California during the first half of this century.” Consequently, if such flooding does occur in the near future, there will be no need to suppose it came as a consequence of what the IPCC calls the unprecedented warming of the past century.

Once again doubling the length of time investigated, Campbell (2002) analyzed the grain sizes of sediment cores obtained from Pine Lake, Alberta, Canada, to provide a non-vegetation-based high-resolution record of streamflow variability for this part of North America over the past 4,000 years. This work revealed that the highest rates of stream discharge during this period occurred during the Little Ice Age, approximately 300-350 years ago, at which time grain sizes were about 2.5 standard deviations above the 4,000-year mean. In contrast, the lowest

rates of streamflow were observed around AD 1100, during the Medieval Warm Period, when median grain sizes were nearly 2.0 standard deviations below the 4,000-year mean.

Further extending the temporal scope of our review, Brown *et al.* (1999) analyzed various properties of cored sequences of hemipelagic muds deposited in the northern Gulf of Mexico for evidence of variations in Mississippi River outflow over the past 5,300 years. This group of researchers found evidence of seven large megafloods, which they describe as “almost certainly larger than historical floods in the Mississippi watershed.” In fact, they say these fluvial events were likely “episodes of multidecadal duration,” five of which occurred during cold periods similar to the Little Ice Age.

Last, in a study that covered essentially the entire Holocene, Noren *et al.* (2002) employed several techniques to identify and date terrigenous in-wash layers found in sediment cores extracted from 13 small lakes distributed across a 20,000-km<sup>2</sup> region in Vermont and eastern New York that depict the frequency of storm-related floods. They found that “the frequency of storm-related floods in the northeastern United States has varied in regular cycles during the past 13,000 years (13 kyr), with a characteristic period of about 3 kyr.” Specifically, they found there were four major peaks in the data during this period, with the most recent upswing in storm-related floods beginning “at about 600 yr BP [Before Present], coincident with the beginning of the Little Ice Age.” In addition, they note that several “independent records of storminess and flooding from around the North Atlantic show maxima that correspond to those that characterize our lake records [Brown *et al.*, 1999; Knox, 1999; Lamb, 1979; Liu and Fearn, 2000; Zong and Tooley, 1999].”

Taken together, the research described in this section suggests that North American flooding tends to become both less frequent and less severe when the planet warms, although there have been some exceptions to this general rule. We would expect that any further warming of the globe would tend to further reduce both the frequency and severity of flooding in North America.

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

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### 6.3. Tropical Cyclones

The IPCC contends that global warming is likely to increase the frequency and intensity of hurricanes. For example, it states “it is *likely* that future tropical cyclones (typhoons and hurricanes) will become more intense, with larger peak wind speeds and more heavy precipitation associated with ongoing increases of tropical sea surface temperatures [*italics in the original*]” (IPCC, 2007-I, p. 15). However, numerous peer-reviewed studies suggest otherwise. In the following sections we examine such claims as they pertain to hurricane activity in the Atlantic, Pacific, and Indian Ocean basins, and the globe as a whole.

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#### 6.3.1. Atlantic Ocean

##### 6.3.1.1. Intensity

Free *et al.* (2004) write that “increases in hurricane intensity are expected to result from increases in sea surface temperature and decreases in tropopause-level temperature accompanying greenhouse warming (Emanuel, 1987; Henderson-Sellers *et al.*, 1998; Knutson *et al.*, 1998),” but that “because the predicted increase in intensity for doubled CO<sub>2</sub> is only 5%-20%, changes over the past 50 years would likely be less than 2%—too small to be detected easily.” They report that “studies of observed frequencies and maximum intensities of tropical cyclones show no consistent upward trend (Landsea *et al.*, 1996; Henderson-Sellers *et al.*, 1998; Solow and Moore, 2002),” and set out to find increases in what they call “potential” hurricane intensity, because, as they describe it, “changes in potential intensity (PI) can be estimated from thermodynamic principles as shown in Emanuel (1986, 1995) given a record of SSTs [sea surface temperatures] and profiles of atmospheric temperature and humidity.” Using radiosonde and SST data from 14 island radiosonde stations in the tropical Atlantic and Pacific Oceans, they compare their results with those of Bister and Emanuel (2002) at grid points near the selected stations. They report that their results “show no significant trend in potential intensity from 1980 to 1995 and no consistent trend from 1975 to 1995.” What is more, they report that between 1975 and 1980, “while SSTs rose, PI decreased, illustrating the hazards of predicting changes in hurricane intensity from projected SST changes alone.”

In the following year, some important new studies once again promoted the IPCC’s claim that warming would enhance tropical cyclone intensity (Emanuel, 2005; Webster *et al.*, 2005), but a new review of the subject once again cast doubt on this contention. Pielke *et al.* (2005) began their discussion by noting