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Climate Change 2001:

Working Group I: The Scientific Basis

2.3.3 Was there a "Little Ice Age" and a "Medieval Warm Period"?

The terms "Little Ice Age" and "Medieval Warm Period" have been used to describe two past climate epochs in Europe and neighbouring regions during roughly the 17th to 19th and 11th to 14th centuries, respectively. The timing, however, of these cold and warm periods has recently been demonstrated to vary geographically over the globe in a considerable way (Bradley and Jones, 1993; Hughes and Diaz, 1994; Crowley and Lowery, 2000). Evidence from mountain glaciers does suggest increased glaciation in a number of widely spread regions outside Europe prior to the 20th century, including Alaska, New Zealand and Patagonia (Grove and Switsur, 1994). However, the timing of maximum glacial advances in these regions differs considerably, suggesting that they may represent largely independent regional climate changes, not a globally-synchronous increased glaciation (see Bradley, 1999). Thus current evidence does not support globally synchronous periods of anomalous cold or warmth over this timeframe, and the conventional terms of "Little Ice Age" and "Medieval Warm Period" appear to have limited utility in describing trends in hemispheric or global mean temperature changes in past centuries. With the more widespread proxy data and multi-proxy reconstructions of temperature change now available, the spatial and temporal character of these putative climate epochs can be reassessed.

Mann et al. (1998) and Jones et al. (1998) support the idea that the 15th to 19th centuries were the coldest of the millennium over the Northern Hemisphere overall. However, viewed hemispherically, the "Little Ice Age" can only be considered as a modest cooling of the Northern Hemisphere during this period of less than 1°C relative to late 20th century levels (Bradley and Jones, 1993; Jones et al., 1998; Mann et al., 1998; 1999; Crowley and Lowery, 2000). Cold conditions appear, however, to have been considerably more pronounced in particular regions. Such regional variability can be understood in part as reflecting accompanying changes in atmospheric circulation. The "Little Ice Age" appears to have been most clearly expressed in the North Atlantic region as altered patterns of atmospheric circulation (O'Brien et al., 1995). Unusually cold, dry winters in central Europe (e.g., 1 to 2°C below normal during the late 17th century) were very likely to have been associated with more frequent flows of continental air from the north-east (Wanner et al., 1995; Pfister, 1999). Such conditions are consistent (Luterbacher et al., 1999) with the negative or enhanced easterly wind phase of the NAO (Sections 2.2.2.3 and 2.6.5), which implies both warm and cold anomalies over different regions in the North Atlantic sector. Such strong influences on European temperature demonstrate the difficulty in extrapolating the sparse early information about European climate change to the hemispheric, let alone global, scale. While past changes in the NAO have likely had an influence in eastern North America, changes in the El Niño phenomenon (see also Section 2.6), are likely to have had a particularly significant influence on regional temperature patterns over North America.

The hemispherically averaged coldness of the 17th century largely reflected cold conditions in Eurasia, while cold hemispheric conditions in the 19th century were more associated with cold conditions in North America (Jones et al., 1998; Mann et al., 2000b). So, while the coldest decades of the 19th century appear to have been approximately 0.6 to 0.7°C colder than the latter decades of the 20th century in the hemispheric mean (Mann et al., 1998), the coldest decades for the North American continent were closer to 1.5°C colder (Mann et al., 2000b). In addition, the timing of peak coldness was often specific to particular seasons. In Switzerland, for example, the first particularly cold winters appear to have been in the 1560s, with cold springs beginning around 1568, and with 1573 the first unusually cold summer (Pfister, 1995).

The evidence for temperature changes in past centuries in the Southern Hemisphere is quite sparse. What evidence is available at the hemispheric scale for summer (Jones et al., 1998) and annual mean conditions (Mann et al., 2000b) suggests markedly different behaviour from the Northern Hemisphere. The only obvious similarity is the unprecedented warmth of the late 20th century. Speleothem evidence (isotopic evidence from calcite deposition in stalagmites and stalactites) from South Africa indicates anomalously cold conditions only prior to the 19th century, while speleothem (records derived from analysing stalagmites and stalagtites) and glacier evidence from the

Southern Alps of New Zealand suggests cold conditions during the mid-17th and mid-19th centuries (Salinger, 1995). Dendroclimatic evidence from nearby Tasmania (Cook et al., 2000) shows no evidence of unusual coldness at these times. Differences in the seasons most represented by this proxy information prevent a more direct comparison.

As with the "Little Ice Age", the posited "Medieval Warm Period" appears to have been less distinct, more moderate in amplitude, and somewhat different in timing at the hemispheric scale than is typically inferred for the conventionally-defined European epoch. The Northern Hemisphere mean temperature estimates of Jones et al. (1998), Mann et al. (1999), and Crowley and Lowery (2000) show temperatures from the 11th to 14th centuries to be about 0.2°C warmer than those from the 15th to 19th centuries, but rather below mid-20th century temperatures. The long-term hemispheric trend is best described as a modest and irregular cooling from AD 1000 to around 1850 to 1900, followed by an abrupt 20th century warming. Regional evidence is, however, quite variable. Crowley and Lowery (2000) show that western Greenland exhibited anomalous warmth locally only around AD 1000 (and to a lesser extent, around AD 1400), with quite cold conditions during the latter part of the 11th century, while Scandinavian summer temperatures appeared relatively warm only during the 11th and early 12th centuries. Crowley and Lowery (2000) find no evidence for warmth in the tropics. Regional evidence for medieval warmth elsewhere in the Northern Hemisphere is so variable that eastern, yet not western, China appears to have been warm by 20th century standards from the 9th to 13th centuries. The 12th and 14th centuries appear to have been mainly cold in China (Wang et al., 1998a,b; Wang and Gong, 2000). The restricted evidence from the Southern Hemisphere, e.g., the Tasmanian tree-ring temperature reconstruction of Cook et al. (1999), shows no evidence for a distinct Medieval Warm Period.

Medieval warmth appears, in large part, to have been restricted to areas in and neighbouring the North Atlantic. This may implicate the role of ocean circulation-related climate variability. The Bermuda rise sediment record of Keigwin (1996) suggests warm medieval conditions and cold 17th to 19th century conditions in the Sargasso Sea of the tropical North Atlantic. A sediment record just south of Newfoundland (Keigwin and Pickart, 1999), in contrast, indicates cold medieval and warm 16th to 19th century upper ocean temperatures. Keigwin and Pickart (1999) suggest that these temperature contrasts were associated with changes in ocean currents in the North Atlantic. They argue that the "Little Ice Age" and "Medieval Warm Period" in the Atlantic region may in large measure reflect century-scale changes in the North Atlantic Oscillation (see Section 2.6). Such regional changes in oceanic and atmospheric processes, which are also relevant to the natural variability of the climate on millennial and longer time-scales (see Section 2.4.2), are greatly diminished or absent in their influence on hemispheric or global mean temperatures.