Evidence for global climate reorganization during medieval times

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A synthesis of global climate model results and inferences from proxy records suggests an increased sea surface temperature gradient between the tropical Indian and Pacific Oceans during medieval times.

A range of in-situ proxy records indicate that tropical eastern and central Pacific sea surface temperatures (SSTs) were relatively cool during the Medieval Climate Anomaly (MCA, ca. 900-1350 AD; e.g., Cobb et al., 2003; Rein et al., 2004; Conroy et al., 2008). This idea is supported by hydroclimate changes indicated by proxy records from extra-tropical western North and South America (e.g., Swetnam et al., 1993; Stine et al., 1994; Jenny et al., 2002; Cook et al., 2004; see Fig. 1). At the same time, indications of a distinct MCA appear in proxy records distributed around the planet, many far removed from the Pacific sector (also Fig. 1). Many of the climate shifts inferred from these latter records are inconsistent in strength or character of the changes expected on the basis of a cooler tropical Pacific alone (at least as judged from observations and model results) suggesting an important role for SST changes in other tropical oceans (Seager et al., 2007; Graham et al., 2007; Graham et al., 2010). Among such "inconsistent" shifts are indications of a more "positive NAO"-like circulation pattern during boreal winter, with impacts on European climate (e.g., Lamb, 1965; Mangini et al., 2005; Trouet et al., 2009), North Atlantic SST and sea ice (e.g., Keigwin, 1996; Jensen et al., 2004; Sicre et al., 2008; Wanamaker et al., 2008; Massé et al., 2009), aridity in equatorial Africa (Verschuren et al., 2004; Russell et al., 2007; Shanahan et al., 2009) and in parts of southwest Asia (Hassan, 1981; von Rad et al., 1999; Fleitmann et al., 2003), and increased monsoon rainfall in parts of south-central and eastern Asia (Sinha et al., 2007; Tan et al., 2008; Zhang et al., 2008; Buckley et al., 2010).

Model simulations of the climate and circulation changes ensuing from the late 20th century warming of the Indian Ocean (e.g., Bader and Latif, 2003; Hurrell et al., 2004; Hoerling et al., 2004; Bader and Latif, 2005) show some of the "inconsistent" features noted above. To explore the possibility that similar warming may have occurred during the MCA, simulations were performed with a full-physics global coupled model (NCAR CCSM) in which tropical Indian, or tropical Indian and western Pacific, SSTs were increased over the range ~0.2-0.8°C. The simulated global climate and circulation shifts for boreal winter (Figs. 1 and 2; see Graham et al. (2010) for the corresponding results for boreal summer) show many of the climate changes inferred from global proxy records for the MCA, including many of those not well explained by a cooler tropical Pacific alone. These include a systematically stronger NAO during boreal winter, with associated changes in North Atlantic SSTs and sea ice, and European/North African precipitation. The simulated changes also include cooling and reduced rainfall in the equatorial eastern Pacific (boreal winter), seasonal aridity in equatorial and northeast Africa and into southwest Asia, transitioning towards relatively more moist conditions proceeding east across the Indian subcontinent, southeast Asia and into parts of China.

Overall, the findings support the general pattern of tropical SST changes seen in a recent statistical reconstruction (Mann et al., 2009), with a stronger zonal SST gradient between the Indo-Pacific Warm Pool and the eastern/central tropical Pacific during medieval times, relative to subsequent centuries.

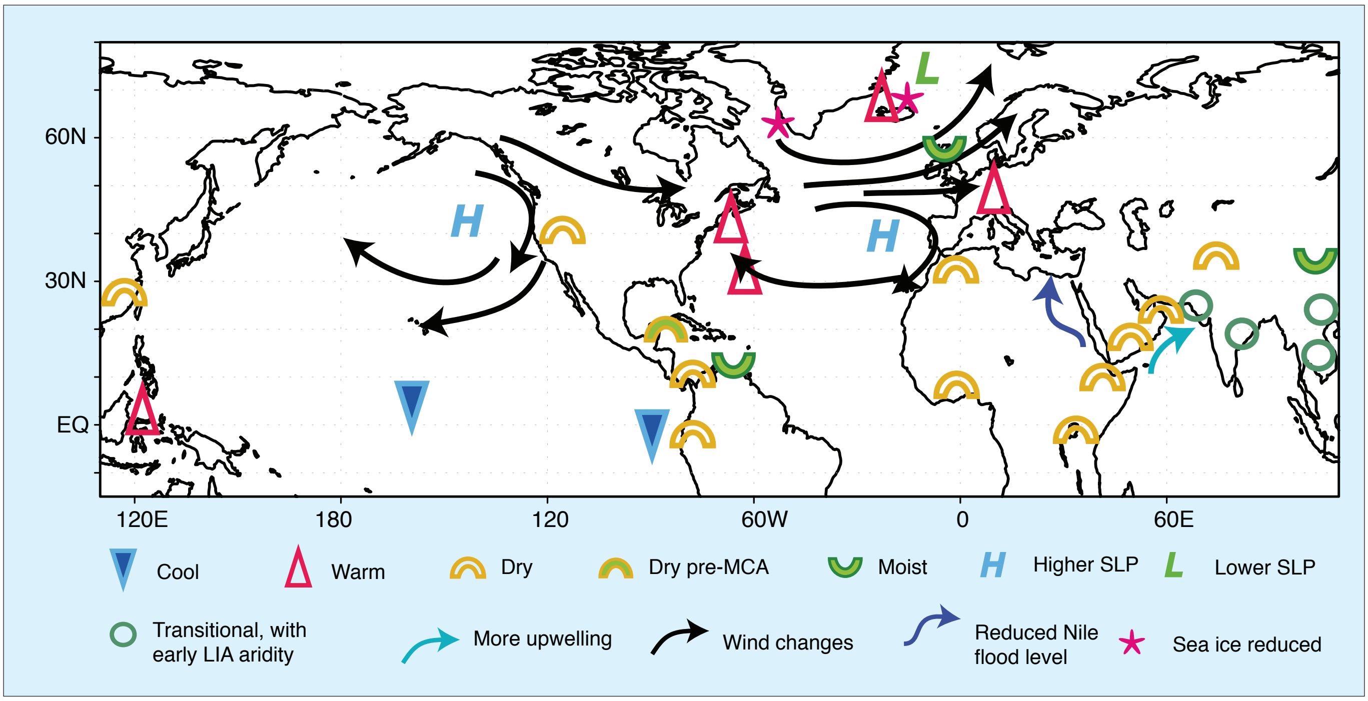

Figure 1: Schematic diagram of MCA vs LIA climate shifts as seen in a range of globally distributed proxy records

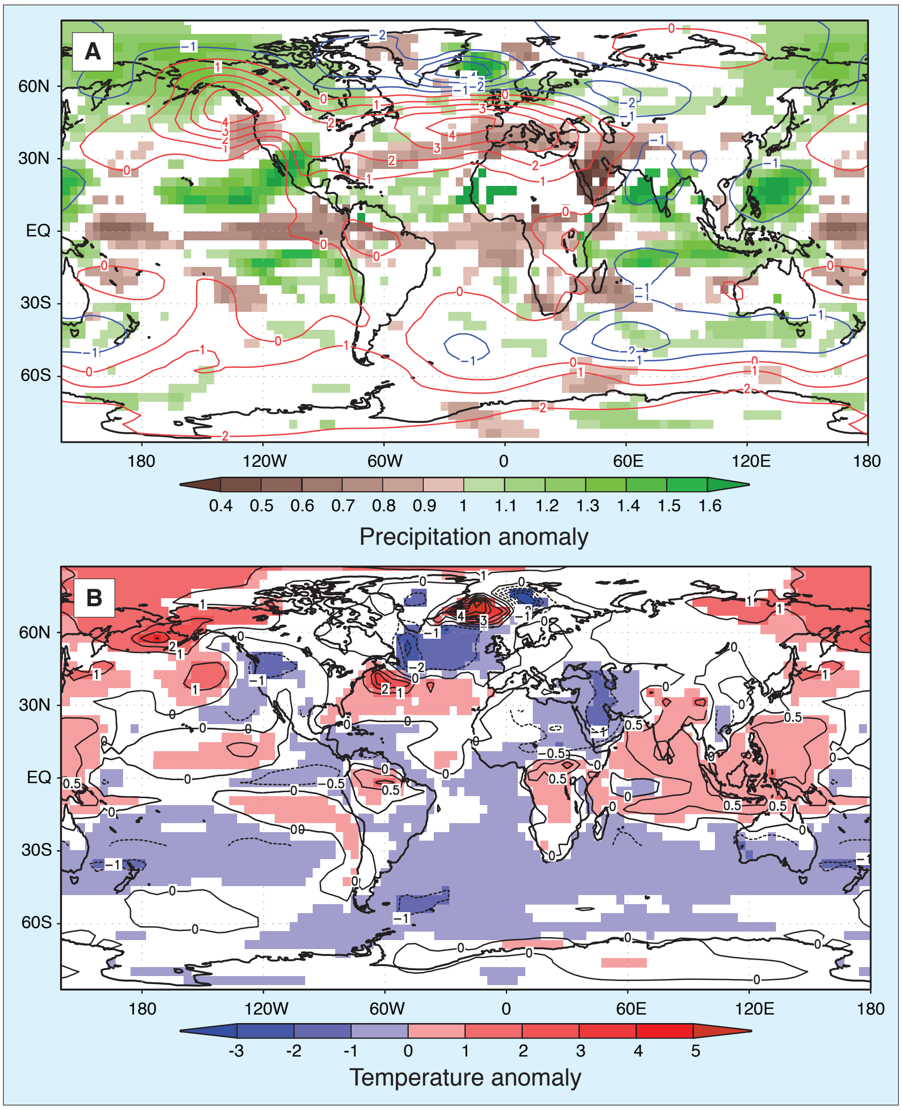

Figure 2: ***A****) Changes in December-March precipitation (fraction of control simulation climatology; color) and sea level pressure (difference with control simulation climatology; hPa, contours) for a simulation with increased tropical Indian and western Pacific SST; precipitation changes are shown only where the differences exceed the 95% confidence level.* ***B****) As in (A), but for December-March temperature (°C, color; values are SST over ocean and 2-meter temperature over land). Colors are shown only where temperature differences exceed the 95% confidence level. Lined contour interval is 0.5°C between 30°N and 30°S and 1°C elsewhere. Global average temperature change has been subtracted.*

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Medieval hydroclimate revisited

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Can the global pattern of Medieval hydroclimate be explained by a persistent La Niña-like state and a persistent positive North Atlantic Oscillation (NAO) and, if so, why did this happen?

North American megadroughts

The hydroclimate of the Medieval period (here loosely defined as the period from about the 9th Century to the end of the 15th Century) features some dramatic anomalies with respect to the modern climate. Perhaps the most remarkable are the series of multidecadal "megadroughts" that struck vast areas of Southwest North America which combined to create a generally more arid climate in the region that lasted centuries. These are well documented from tree-ring records (Herweijer et al., 2007; Cook et al., 2007, 2010). In addition, there is evidence for a strong Asian monsoon during the Medieval period, wet conditions over much of tropical South America, dry conditions in equatorial East Africa, wet in South Africa, a dry western Mediterranean region and wet northwest Europe (see compilation of proxy data in Seager et al., 2007, Burgman et al., 2010 and Figure 1). What could have caused such a global reorganization of hydroclimate for such a long period of time? The North American megadroughts immediately suggest a link to tropical ocean sea surface temperatures (SSTs). Climate modeling has clarified that the historical droughts of the 19th and 20th centuries were forced by small variations in tropical SSTs. All were forced, wholly or in part, by a cold, La Niña-like tropical Pacific Ocean. In addition, a warm subtropical North Atlantic Ocean played a role in forcing the 1930s and 1950s droughts. The tree-ring data clarified that the spa-