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Causes of Northern Hemispheric temperature change over the last millennium

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Reconstructions of past climate have shown substantial decadal and centennial scale climate variability in northern hemisphere temperature records. Here we use both a new ensemble of simulations of the HadCM3 coupled atmosphere/ocean general circulation model as well as simulations taken from the CMIP5/PMIP3 archive to understand changes in temperatures over the last millennium. We compare the simulations to a wide range of available reconstructions of hemispheric temperature to attribute causes of temperature variability from 850 to 1950. Our results show that external forcing contributed significantly to the reconstructed long-term variability of hemispheric temperatures irrespective of the reconstruction used. We have derived estimates of internal climate variability from the reconstructions since 850AD and have found that the 1960-2010 northern hemisphere temperature trend is far outside the range of variability as estimated from all reconstructions used, confirming the unusual nature of the recent warming. Reconstructions generally show smaller forced response than the models. This mismatch may be explained by non-linearities in the response of tree-ring proxies to temperature. By comparing model-derived fingerprints with reconstructions we find that the two key drivers of pre-industrial temperature variability are changes in greenhouse gases and explosive volcanic activity.