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Holocene simulations to investigate the role of low frequent solar irradiance changes and stratospheric processes for climate

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A coupled climate model including the middle atmosphere is used to investigate the role of changes in solar irradiation for selected periods of the Holocene climate. One period of interest is the Maunder Minimum (MM) from 1645 - 1715. Telescope based observations indicate that the MM is characterised by a nearly complete absence of sunspots. Sunspot based reconstructions of the solar activity reveal a reduction of the total solar irradiance (TSI) compared to present day values that is in the range of 0.1% whereas larger changes are found for the UV part of the solar spectrum. Proxy based temperature reconstructions reveal a negative NAO like pattern with a cooling over northern Europe and a warming over the western North Atlantic. Model studies indicate that changes in solar irradiance and stratosphere-troposphere coupling processes may lead to a corresponding shift of the NAO during the MM. Here the question arises if transient simulations with a fully coupled ocean-troposphere-stratosphere GCM can reproduce the reconstructed temperature pattern.

The EGMAM (ECHO-G with Middle Atmosphere and MESSy interface) AO-GCM is based on the ECHO-G model (ECHAM4 T30/L19 atmosphere and HOPE-G T42/ L20 ocean). The atmosphere model (ECHAM4 T30/L39) reaches up to 0.01 hPa compared to the top level located at 10 hPa in ECHO-G and includes a sophisticated representation of middle atmosphere dynamics. The ocean model HOPE-G remains unchanged in the new model. Long control simulations reveal EGMAM to simulate a somewhat warmer climate and reduced variability on interannual and longer timescales. The new model has only a minor drift and can be used for multi century climate simulations.

A transient simulation is performed with EGMAM that covers the time period from

the MM until present. A significant tropospheric cooling is simulated for the MM compared to a pre-industrial time period that can be attributed to the reduced TSI and volcanic eruptions. A significant change of the large scale atmospheric circulation is not found. Therefore the internal variability of the coupled system plays a major role for the simulated changes in NAO during the pre-industrial era. Comparison of the MM period with a present day time period reveals the well known greenhouse gas induced tropospheric warming and stratospheric cooling signal. Here a significant shift of the NAO is found with lower NAO values during the MM. For a better assessment of the solar signal an idealised experiment with a sinusoidal solar forcing mimicking the low frequent solar Gleissberg cycle is performed. This simulation also includes prescribed time dependent changes in stratospheric ozone concentrations. To take into account the changes in the UV part of the solar spectrum a sophisticated narrow band short wave radiation scheme is currently implemented into the EGMAM model.

The model will be used to investigate the effect of changes in solar irradiance on centennial to millennial time scales by simulation of selected episodes of the earlier Holocene. These simulations will also include changes in orbital parameters.