



## **Natural forcing of climate during the last millennium: Fingerprint of solar variability**

Didier Swingedouw (1), Terray Laurent (2), Cassou Christophe (2), Voldoire Aurore (3), Salas-Mélia David (3), and Servonnat Jérôme (1)

(1) IPSL, LSCE, Gif-sur-Yvette, France (didier.swingedouw@lsce.ipsl.fr), (2) CERFACS, 42 Av. G. Coriolis, 31057 Toulouse, France, (3) CNRM, 42 Av. G. Coriolis, 31057 Toulouse, France

The variability of the climate during the last millennium is partly forced by changes in total solar irradiance (TSI). Nevertheless, the amplitude of these TSI changes is very small so that recent reconstruction data suggest that low frequency variations in the North Atlantic Oscillation (NAO) and in the thermohaline circulation may have amplified, in the North Atlantic sector and mostly in winter, the radiative changes due to TSI variations. In this study we use a state-of-the-art climate model to simulate the last millennium. We find that modelled variations of surface temperature in the Northern Hemisphere are coherent with existing reconstructions. Moreover, in the model, the low frequency variability of this mean hemispheric temperature is found to be correlated at 0.74 with the solar forcing for the period 1001-1860. Then, we focus on the regional climatic fingerprint of solar forcing in winter and find a significant relationship between the low frequency TSI forcing and the NAO with a time lag of more than 40 years for the response of the NAO. Such a lag is larger than the around 20-yr lag suggested in other studies. We argue that this lag is due, in the model, to a northward shift of the tropical atmospheric convection in the Pacific Ocean, which is maximum more than 4 decades after the solar forcing increase. This shift then forces a positive NAO through an atmospheric wave connection related to the jet-stream wave guide. The shift of the tropical convection is due to the persistence of anomalous warm SST behind the anomalous precipitation, associated with the advection of warm SST by the North Pacific subtropical gyre in a few decades. Finally, we analyse the response of the Atlantic meridional overturning circulation to solar forcing and find that the former is weakened when the latter increases. Changes in wind stress, notably due to the NAO, modify the barotropic streamfunction in the Atlantic 50 years after solar variations. This implies a wind-driven modification of the oceanic circulation in the Atlantic sector in response to changes in solar forcing, in addition to the variations of the thermohaline circulation.