Project no. GOCE-CT-2003-505539

Project acronym: ENSEMBLES

Project title: ENSEMBLE-based Predictions of Climate Changes and their Impacts

Instrument: Integrated Project

Thematic Priority: Global Change and Ecosystems

Milestone M4.2.3: Preliminary assessment of changes in large-scale, low-frequency modes of variability under anthropogenic climate change based on scenario and time-slice experiments

Due date of milestone: August 2007 (M36)
Actual submission date: 9 August 2007 (M36)

Start date of project: 1 September 2004 Duration: 60 Months

Organisation name of lead contractor for this milestone: **CERFACS**

Revision [draft, 1, 2, ..]

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)		
Dissemination Level		
PU	Public	
PP	Restricted to other programme participants (including the Commission Services)	
RE	Restricted to a group specified by the consortium (including the Commission Services)	
CO	Confidential, only for members of the Consortium (including the Commission Services)	

Preliminary assessment of changes in large-scale, low-frequency modes of variability under anthropogenic climate change based on scenario and time-slice experiments

Laurent Terray (terray@cerfacs.fr)

The nature of the future climate change due to increasing anthropogenic emissions of greenhouse gases is still a topic of considerable debate. Analyses of both the observed record and transient integrations with climate models forced by scenarios of increasing greenhouse gases concentrations have suggested that anthropogenic climate change may manifest itself as a projection onto the dominant modes of natural variability (Monahan et al. 2000, Hsu and Zwiers 2001, Stone et al. 2001). Support for this paradigm arises from evidence of recent observed trends in the North Atlantic Oscillation (NAO) (Hurrell et al. 2003, Thompson et al. 2000, Feldstein 2002) as well as its linear response in several anthropogenically forced transient integrations (Gillett et al. 2002a). A non linear perspective of the projection has also been proposed, in which the climate system response to greenhouse forcing would be reflected in a shift of the residence frequency of the system in certain quasi-stationary regimes (Palmer 1999, Corti et al. 1999). In this preliminary study, we use a standard clustering analysis approach based on the *k*-means partitioning algorithm (Michelangeli et al. 1995) to describe possible changes at the end of the 21st century in the North Atlantic European winter large-scale atmospheric circulation due to anthropogenic influence. The algorithm seeks preferred or recurrent atmospheric patterns (weather types or regimes hereafter) in the atmospheric state space. Given a prescribed number of clusters *k*, the algorithm iteratively finds the partition that minimizes the ratio of the variance within clusters to the variance between cluster centroids. Standard reproducibility and classifiability tests are then used to objectively define *k* and to assess the robustness and the consistency of the partition

(Michelangeli et al. 1995). The algorithm is applied to mean sea level pressure (MSLP) anomalous winter (DJF) daily means for the current (1961-2000) and future (2081-2100) climates and for all models (having the relevant daily data) from the ENSEMBLES Stream 1/IPCC AR4 database. In order to account for the different simulated seasonal means, the models data are projected onto the daily regimes estimated from the NCEP reanalysis. The results are shown in figure 1 for all the individual models and for the ensemble mean.

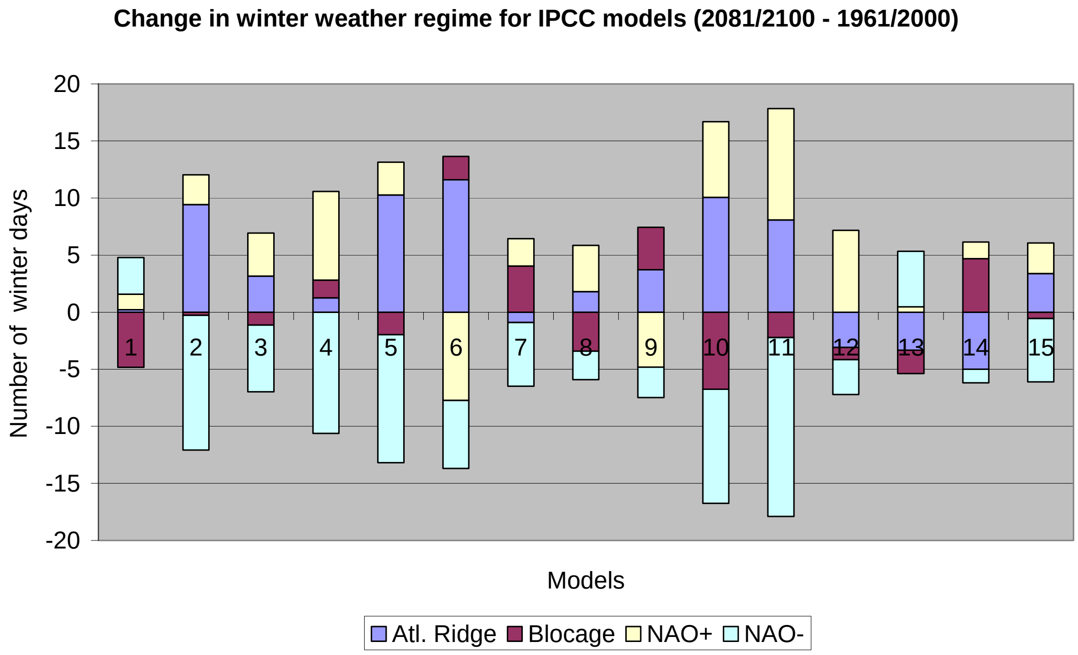

Figure 1: change in the occurrence of the standard winter weather regimes for the North Atlantic European sector (units are in days). Each bar represents an individual model (with the bar labelled 15 being the multimodel mean). Each colour represents a different weather regime.

Most models show a significant increase in the occurrence frequency of the NAO+ and Atlantic Ridge weather regimes and a decrease in the NAO- regime while changes in blocking occurrence strongly vary between models. These results suggest that changes in circulation (as represented by weather regimes) do explain a large fraction of the winter precipitation changes as simulated by the IPCC multi-model ensemble mean (strong increase over northern Europe and Scandinavia in particular, decrease over the Mediterranean area). This can be seen in figure 2 which shows the observed links between the weather regimes (from the NCEP reanalysis) and precipitation (from the CRU dataset). The two increasing regimes favour enhanced and reduced precipitation over northern and southern Europe, respectively. The decreasing one has the opposite effect on precipitation which strengthens the above influence.

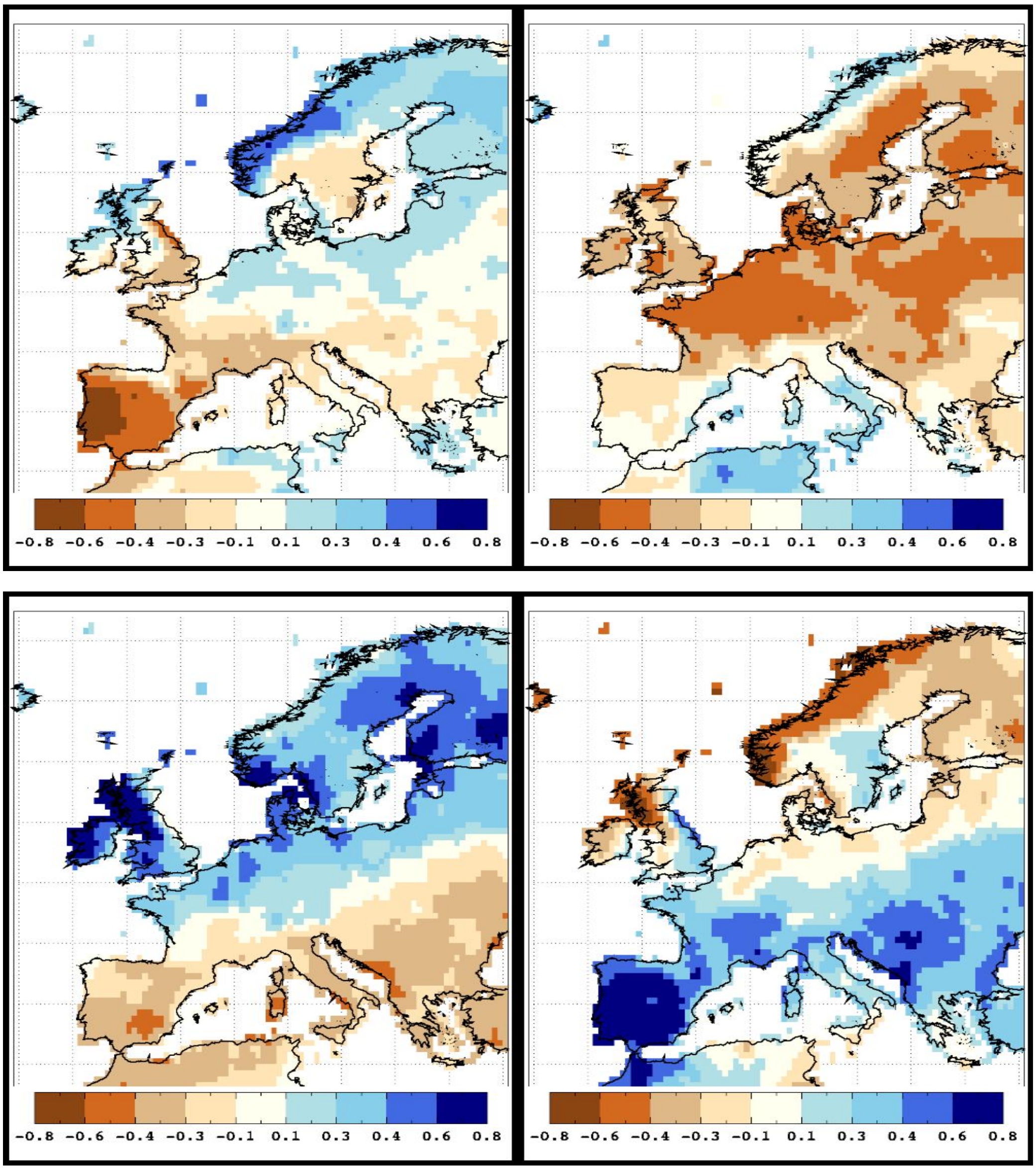

Figure 2: correlation between mean seasonal winter precipitation and the mean winter occurrence of the standard weather regimes for the North Atlantic European sector. Each panel represents a different weather regime (top left: Atl.Ridge, bottom left: NAO+, top right: blocking, bottom right: NAO-).

Changes in precipitation over Europe can thus be explained to a large extent by the variations in occurrence frequency of the pre-existing weather regimes. The simulated changes in circulation of the IPCC multimodel are in line with previous results using higher resolution models (Terray et al., 2004, Coppola et al., 2005). The methodologies used here can be applied to other tropospheric and stratospheric variables (Z500, Z50, uv850 …) and simulations such as the ones performed within the stream 2 of ENSEMBLES.

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