Mediterranean convection and climate change

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There are a few places in the world ocean where surface water sinks due to buoyancy loss and contributes to the global thermohaline circulation. They are located in the polar regions and the recycling time scale is millennial. This phenomenon is named oceanic convection, as it is the symmetrical phenomenon of atmospheric convection. The Mediterranean Sea is also a place where surface Atlantic water entering through the Gibraltar Strait is transformed into deep water and sent back one century later to the Atlantic with modified characteristics. According to IPCC projections, the Mediterranean basin would become warmer and drier by the end of the 21st century. A radiative warming would stabilize the surface layers and reduce convection (water density decreases with temperature), whereas an increase of the fresh water deficit would increase convection (a higher salinity implies a higher density). An important question is the resulting effect of these two competing phenomena. Indeed, convection plays a major role in the Mediterranean Sea ecosystems.

A 140-year numerical simulation has been conducted with a climate version of the ARPEGE/IFS atmospheric model. This global model has a maximum resolution of 0.5° in the Mediterranean basin (Gibelin and Déqué, 2003). The simulation covers the 1961-2100 period. Up to 2000, sea surface temperature (SST) as well as greenhouse gas and aerosol concentration are imposed from observed values. Then, an IPCC-A2 scenario is prescribed. SST is calculated by adding to observed monthly values an anomaly evaluated through a former ARPEGE simulation coupled to a global ocean and sea-ice model (OPA/GELATO). The horizontal resolution of the coupled model is 2.8° for the atmosphere, a little higher for the ocean. The numerical drift (estimated through a control experiment), and the systematic error of the SST are removed. This regional simulation is part of the Météo-France contribution to the European PRUDENCE project.

Daily fluxes of momentum, heat, and water over the Mediterranean Sea from the above-mentioned simulation have been used as a forcing for a regional ocean model OPAMED8 covering the whole Mediterranean Sea with a resolution of about 10 km. This model has a buffer zone in the near Atlantic in which a relaxation of temperature and salinity is applied. The relaxation fields come from the above-mentioned coupled global scenario with ARPEGE in low resolution. River run-off (including the fresh water inflow at the Dardannelles Strait) is calculated from a routing scheme (TRIP) using the grid-point run-off of the variable resolution scenario with ARPEGE. Thus, in comparison with earlier studies, no relaxation is imposed in the Mediterranean Sea, except the unavoidable adaptation of surface heat flux to SST. In particular there is no constraint on salinity other than the A2 scenario.

The time scales of an ocean model are much longer than those of an atmosphere model. As there is no relaxation, a numerical drift could occur in the simulation and could be misinterpreted as a climate signal. For this reason, a control oceanic simulation has been performed, in which the fluxes of the 1981-2100 period are those of the 1961-1980 period (with a 20-year loop).

Our results clearly show that the thermal effect dominates the salinity effect, and that the convection intensity decreases significantly. Figure 1 shows the mixed layer depth in winter and in the western basin south of the French coast (a place and a season with maximum convection). The pattern is stable after 100 years in the control simulation, but the mixing vanishes in the scenario.

In this study the feedback of regional scale SST anomalies on the atmosphere is neglected. This is also the case of the feedback from the Atlantic Ocean, but the time scale is much larger than a century. The next step in this study of possible evolution of the Mediterranean oceanic circulation during the 21st century is to couple OPAMED8 with ARPEGE. This has been done with a 30-year control simulation, but the coupled system needs to be improved before attempting centennial simulations.

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Gibelin, A.L., and Déqué, M., 2003: Anthropogenic climate change over the Mediterranean region simulated by a global variable resolution model. Clim. Dyn., 20,327-339.

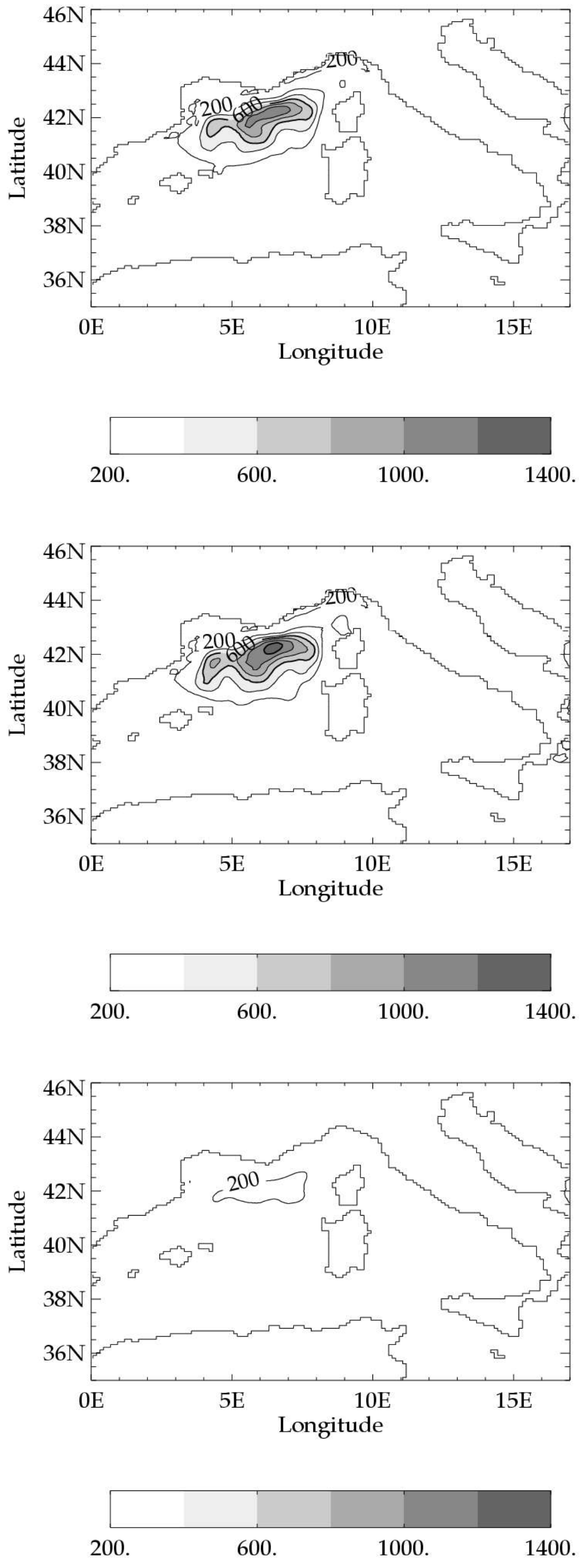

Figure 1: Winter (JFM) mixed layer depth (m) in the western Mediterranean basin convection area: beginning of the control run 1961-2000 (top), end of the control run 2071-2100 (middle) and end of the IPCC-A2 scenario 2071-2100 (bottom).