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Acidification of the Mediterranean Sea during the 21st century

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We modeled the carbon cycle in the Mediterranean Sea to study how its changes due to climate change and rising levels of atmospheric CO_2 may differ from those typical of the global ocean. More specifically, we coupled offline an ocean biogeochemical model (PISCES) to a regional eddy-permitting model of the Mediterranean Sea (NEMO-MED8, 1/8° nominal horizonal resolution) using forcing from coupled regional climate model simulations of which the ocean circulation component was identical. Here we describe the simulated changes in pH and the associated carbonate system during the 21st century. Separate simulations were made with climate forcing for a hindcast (1965-2008) and for the future (2000-2100). For the former, climate and CO_2 forcings were based on observations; for the latter, both climate and CO_2 were driven by the IPCC SRES-A2 scenario. Our hindcast simulation over the period 1965-2008 allowed us to evaluate the model and assess recent variability of the carbonate system. In our future simulation, we used separate tracers to distinguish (1) the change due to climate change and the increase in atmospheric CO_2 (from 370 to 800 ppm) and (2) the change due only to climate change (holding atmospheric CO_2 to the year-2000 level of 370 ppm). By difference, we isolated the geochemical effect (anthropogenic CO_2 perturbation). The hindcast simulation demonstrates that the model captures the amplitude and phase of the annual cycle of temperature, pCO_2 and pH, in agreement with data from the DYFAMED station. That seasonal variability of surface pCO_2 is everywhere driven by variations in temperature. These results lends support that the model is able to quantify the acidification of the Mediterranean Sea during the industrial period and for the future. However, they do not constrain the model's simulated effects of future climate change on ocean circulation and ocean biology, both of which in turn influence the carbon cycle. Similar to estimates for the global ocean, the future simulation predicts a reduction in surface pH (acidification) of the Mediterranean Sea between 2000 and 2050 of 0.1 units (total scale); however, that change is not identical everywhere. It is 0.02 units less where there is strong mixing with deep waters (Gulf of Lyon, Rhodes Gyre and south Adriatic Sea), which are impoverished in anthropogenic CO_2. It is also less, but only by 0.005 units, in regions most affected by incoming water from the Atlantic Ocean (near the Strait of Gibralter). Conversely, acidification is more intense (the magnitude of the pH change is larger) by 0.03 units in coastal areas such as the Dardanelles Strait, and near outflow from the Rhone and Po rivers, whose waters are more acidic and less able to buffer the increase in CO_2. The simulated changes in surface pH in the Mediterranean Sea are almost entirely driven only by the direct geochemical effect from rising atmospheric CO_2.