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Influence of external climate forcing on coastal upwelling systems analysed in ensemble of past millennium climate simulations

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Eastern Boundary Upwelling Systems are highly productive coastal ocean areas where nutrient rich, cold water upwells by the action of favorable winds. Observations over the 20th century and ocean sediment records, which may be indicative of upwelling, display an intensification due to stronger external climate forcing, such as increasing greenhouse gas concentrations or changes in solar irradiance. This intensification is compatible with the hypothesis put forward by Bakun (1990) that a stronger external radiative forcing should lead to a more intense coastal upwelling. Here, we analyze ensemble of simulations covering the past millennium with the aim of identifying and quantifying the role of external climate forcing on upwelling in the major Eastern Boundary Upwelling System.
We analyse the decadal variability and centennial trends of upwelling in ensemble of simulations with the global climate model MPI-ESM covering the past millennium, the last 150 years and the next 100 years. The future simulations were driven by three IPCC scenarios of concentrations of anthropogenic greenhouse gases, RCP2.5, RCP4.5 and RCP 8.5.
For the past millennium and the last 150 years, coastal upwelling does not show any imprint of external forcing. This result indicates that chaotic internal variability has dominated upwelling intensity in major upwelling regions over the last thousand years and even since industrialisation up to present.
For the 21st century, all ensemble members show a consistent and significant intensification of upwelling in the strongest scenario RCP8.5 for the Benguela upwelling region, consistent and significant weakening for Morocco and California, and no significant change for the Peruvian upwelling. Weaker scenarios do not produce consistent long-term trends that are replicated in all ensemble members.
The results are confirmed by analysing another ensemble of past millennium simulations with the model CESM-CAM5 (Community Earth System Model-Community Atmosphere Model5, Last Millennium ensemble).
We conclude, therefore, that although coastal upwelling in the EBUS may intensify in the future under the strongest emissions scenarios, either the variations of external forcing in the past have not been strong enough or the internal climate variations have been large enough to mask the effect of the external climate forcing.