Geophysical Research Abstracts
Vol. 18, EGU2016-10735, 2016
EGU General Assembly 2016

Uncertainties in sea level projections on twenty-year timescales

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Regional decadal changes in sea level are governed by various processes, including ocean dynamics, gravitational and solid earth responses, mass loss of continental ice, and other local coastal processes. In order to improve predictions and physical attribution in decadal sea level trends, the uncertainties of each processes must be reflected in the sea level calculations. Here we explore uncertainties in predictions of the decadal and bi-decadal changes in regional sea level induced by the changes in ocean dynamics and associated redistribution of heat and freshwater (often referred to as dynamic sea level). Such predictions are typically based on the solutions from coupled atmospheric and oceanic general circulation models, including a suite of climate models participating in phase 5 of the Coupled Model Intercompasion Project (CMIP5). Designed to simulate long-term ocean variability in response to warming climate due to increasing green-house gas concentration ("forced" response), CMIP5 are deficient in simulating variability at shorter time scales. In contrast, global observations of sea level are available during a relatively short time span (e.g., twenty-year altimetry records), and are dominated by an "unforced" variability that occurs freely (internally) within the climate system. This makes it challenging to examine how well observations compare with model simulations. Therefore, here we focus on patterns and spatial characteristics of projected twenty-year trends in dynamic sea level.

Based on the ensemble of CMIP5 models, each comprising a 240-year run, we compute an envelope of twenty-year rates, and analyze the spread and spatial relationship among predicted rates. An ensemble root-mean-square average exhibits large-scale spatial patterns, with the largest uncertainties found over mid and high latitudes that could be attributed to the changes in wind patterns and buoyancy forcing. To understand and parameterize spatial characteristics of the uncertainties, we also analyze a full covariance matrix between the rates among all locations over the globe. The results are discussed in terms of spatial correlation between dynamic sea level trends, possible physical mechanisms behind the patterns, sensitivity to emission scenarios and model physics, and whether the emerged dominant patterns relate to well-established modes of climate variability