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Stochastic low-frequency variability emerging from the North Atlantic ocean

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Global NEMO simulations in the eddying regime spontaneously generate a Low-Frequency Chaotic Intrinsic Variability (LFCIV) under climatological forcing. The LFCIV reaches regional-to-basin scales and 1-100 year timescales, with strong imprints on climate-relevant variables like SLA, SST, Oceanic Heat Content (OHC), Meridional Heat Transport (MHT) and AMOC in the Atlantic. The LFCIV is almost zero in laminar ocean models used in recent climate projections (CMIP5, AR5 IPCC report) but provides a marked stochastic flavor to the low-frequency variability in eddying ocean models, which are being coupled to the atmosphere for the CMIP6 exercise (and future IPCC climate projections).

Whether this LFCIV may be damped, paced or enhanced under a full (reanalyzed) forcing motivated the OCCIPUT project, which adopts a fully-probabilistic NEMO-based approach: we performed a long (1960- 2015), large (50-member) ensemble of global ocean/sea-ice 1/4° hindcasts, and two North Atlantic ensembles; the ensemble members were driven by the same reanalyzed atmospheric forcing, but started from slightly different initial conditions. Resulting ensemble statistics give access to the atmospheric constraint on the ocean chaos over a wide range of spatiotemporal scales, and to the forced and chaotic oceanic variabilities. They confirm that the ocean behaves as a non-autonomous random dynamical system, that its variability should be seen as a broadband atmospherically-modulated “chaos”, which might then impact the atmosphere in coupled mode.

Instantaneous PDFs of physical variables are modulated by the atmospheric forcing in contrasting ways, with non-gaussian shapes in certain regions. In several regions, the oceanic "chaos" has more impact than the forcing on the variability of SLA, AMOC, SST or OHC up to decadal and longer periods: in such regions, the interannual-to-decadal OHC/SLA variability, and regional 20/30-year OHC/SLA trends, have a substantial ensemble spread: they cannot be unambiguously attributed to the forcing. This ensemble run hence provides insights into the causes of the ocean variability, and raise new detection/attribution issues.