FINAL REPORT PROGRAM LEFE

Program LEFE/IMAGO	ICARE Influence du Chaos océanique sur la variabilité de la glace de mer Arctique: approche Régionale Ensembliste	Years 2017-2021
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Context: The role of ocean mesoscale activity on the variability of Arctic sea ice is largely unknown. Indeed, internal ocean variability can be either forced by atmospheric changes or arise spontaneously from chaotic non linear processes. The complex bathymetry in the Arctic favors the development of baroclinic instabilities. The existence of mesoscale eddies can also be a source of intrinsic oceanic variability in the Arctic and can possibly contribute to the observed interannual variability of sea ice and in the ocean.

Objectives: The objective of ICARE was to provide a first estimate of intrinsic variability in the Arctic and characterize its influence on interannual sea ice variability.

Main Results: Our work relies on the use of the regional Arctic-North Atlantic high-resolution model configuration named CREG12, which is a seamless regional extraction (i.e., the "north-fold" discontinuity of the global grid is removed) of the ORCA12 configuration developed jointly by the Drakkar consortium and Mercator-Ocean, encompassing the Arctic and parts of the North Atlantic down to 25°N. The version used in ICARE is based on the NEMO 3.6 and LIM3.5 numerical models for the ocean and sea ice components. The configuration has a high vertical (75 levels) and horizontal (~3-4km) resolution in the Arctic Ocean. A major part of the project has consisted in running a 10-member ensemble covering the 2005-2014 period. The ensemble run starts from a 26-yr one member spin up simulation which is part of a 1979-2014 reference simulation run at LOPS. The 10 members of the ensemble are generated in 2005 by activating a small stochastic perturbation in the equation of state within each member. The small perturbations simulate the unresolved fluctuations of potential temperature and salinity and are activated for only one year in 2005. They are generated using random walks as described in Brankart et al. (2015). Each member is forced by the Drakkar Forcing Set (DFS) 5.2 based on the ERA-40 and ERA-Interim reanalysis. This protocol is similar to that used in the ANR/PRACE OCCIPUT project (2014-2018, PI T. Penduff), which was based on the NEMO 0.25º global configuration and which allowed to demonstrate the importance of intrinsic variability in several key regions including western boundary currents extensions (Sérazin et al. 2017), the Atlantic ocean (Leroux et al. 2018), the southwestern Pacific Ocean (Cravatte et al. 2021), and the Southern Ocean (Sérazin et al. 2017). However, the 1/4º resolution used in the OCCIPUT ensemble simulations did not allow to properly represent ocean mesoscale activity in the Arctic ocean and in the Arctic gateways with the North Atlantic and Pacific oceans, hence the motivation to run a novel albeit smaller ensemble using the CREG12 configuration. In Figure 1, we have quantified the magnitude of the so-called forced and intrinsic contributions of seasonal sea ice variability following the definitions of Leroux et al. (2018). The atmospherically forced component is defined by the ensemble mean of the 10 members and the intrinsic component resulting from the oceanic chaotic variability is defined by the standard deviation from the ensemble mean. We find that while forced atmospheric variability dominates September sea ice concentration in all Arctic regions, oceanic intrinsic variability reaches its maximum in the regions of largest Eddy Kinetic Energy and its contribution can reach up to 80% of sea ice interannual variability in the marginal ice zone (Figure 1 a-c). We further show that chaotic intrinsic variability contributes up to 60% to interannual variability of the upper ocean heat content in the northeastern part of the North Atlantic subpolar gyre and at the North Atlantic-Arctic gateways. Note that the contribution of intrinsic variability can even be higher for given years of the selected period. This study shows that chaotic ocean variability can have an imprint on interannual ocean and sea ice changes in the Arctic, which questions the use of coarse models and single-member simulations to attribute observed changes in this region.

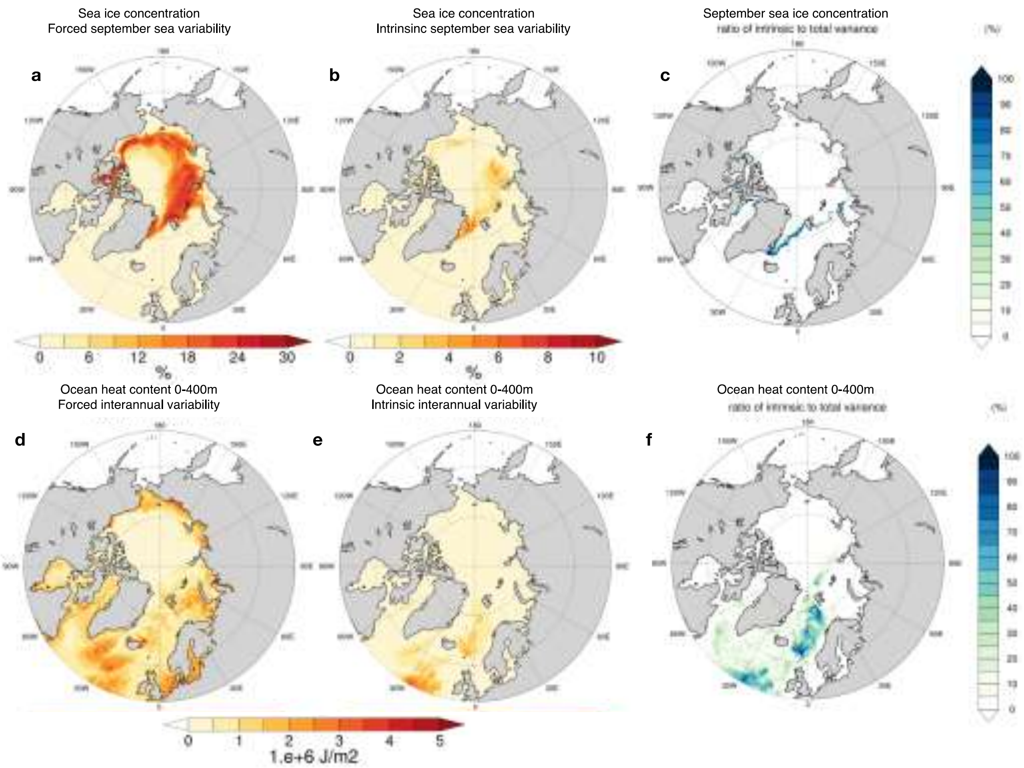

Figure 1: Estimated forced (a-d) and intrinsic (b-e) interannual variability for September sea ice concentration (top) and for the upper 400m ocean heat content (bottom) in the Arctic. Rightmost panels show the ratio of intrinsic over total (intrinsic+forced) variability for sea ice concentration (c) and ocean heat content (f).

References:

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Future of the project: Following this project, the model used in this study has been used to enhance national collaboration in particular between CECI and LOPS. This collaboration has paved the way for the organization of the workshop “Sea ice in the Earth System: a multidisciplinary perspective” funded by INSU/LEFE and Ifremer (https://lefe-ice.sciencesconf.org) in 2019 as well as the submission of the CLIMArcTIC PPR project on Arctic climate changes (funded in 2022 for 6 years). A PhD thesis co-advised between CECI and LOPS on Arctic sea ice variability is planned in the coming years.