FINAL REPORT PROGRAM LEFE

Program LEFE/ IMAGO	**Project Title: MesOVarClim** **Oceanic Mesoscale and Climate Variability**	**Years 2016-2018**

PI: Olivier Arzel (LOPS) Participating Laboratories : LOPS, LMD, LOCEAN	Contribution to *Nom des programmes internationaux* Other funding sources : GENCI (HPC at IDRIS)

Context (2-3 lignes)

Sea surface temperature (SST) anomalies associated with large-scale oceanic fronts have been shown to affect upper tropospheric circulation (e. g. midlatitude storm tracks). On the other hand, mesoscale SST anomalies affect the atmospheric boundary layer, but no study has examined their role for the upper atmosphere. Atmospheric synoptic variability associated with weather patterns provides a stochastic forcing that significantly impacts the low frequency variability of the ocean, in particular in the Atlantic sector. In this project, new diagnostics have been proposed to explicitly separate the contribution of the ocean and the atmosphere (including air-sea coupling) to the low-frequency variability of SST in both coupled ocean-atmosphere and purely oceanic contexts.

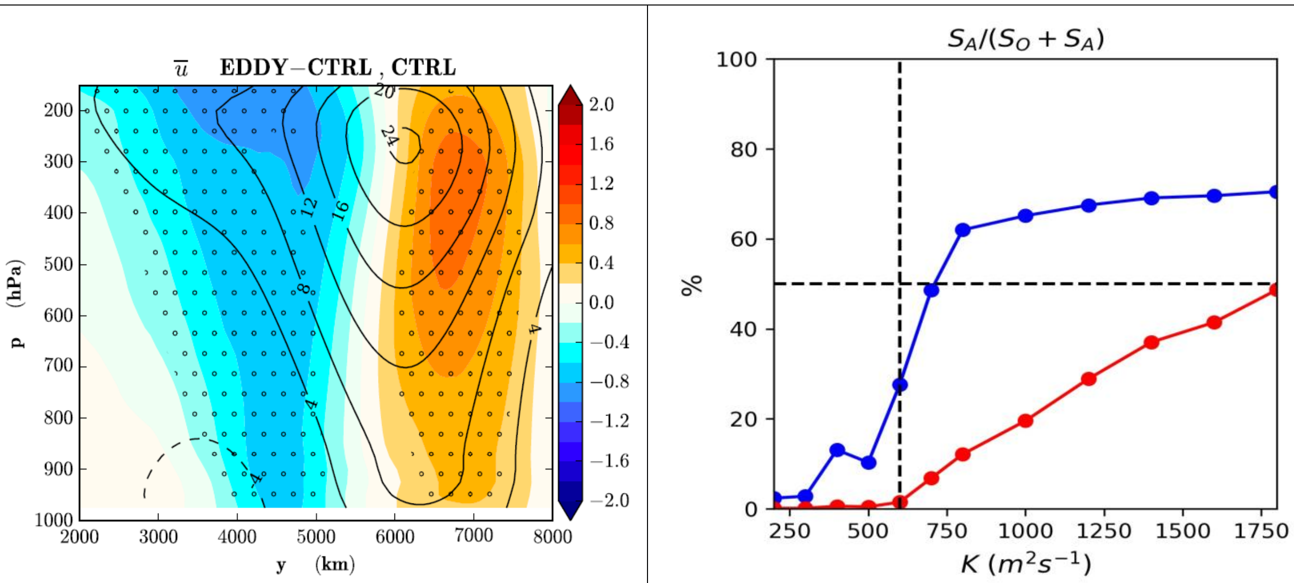
Objectives / scientific questions (2-3 lignes)

We first aim to assess whether oceanic mesoscales (scales of the order of 200km) at midlatitudes affect the tropospheric storm tracks. In that case, climate models will need to resolve such processes in the future. We also aim to assess how ocean-atmosphere coupling, intrinsic ocean dynamics and atmospheric stochastic forcing contribute to oceanic low-frequency (decadal) variability.

Main results

Part 1-: Atmosphere. We have performed different numerical simulations of an idealized storm track (a midlatitude channel of large size) in the presence of a fixed ocean (represented by its SST field). Two cases were contrasted : in addition to a large-scale SST gradient, an eddy SST field was superposed or not (simulations EDDY and CTRL). We have found that the presence of oceanic mesoscales favoured a poleward displacement of the upper-tropospheric jet and the storm-track (see figure). We have proposed a mechanism explaining such a behavior : the principal effect of the presence of the eddies is to increase the surface evaporation, hence the water vapor in the lower atmosphere. As storms tend to carry humidity upward and poleward, latent heat release (associated with condensation) occurs at higher altitude and latitude, modifying the upper tropospheric temperature distribution and the circulation as well.

Part 2 : Ocean. We have analysed IPSL-CM5A simulations and showed that the North Atlantic low-frequency (20 years) variability (LFV) in this model is sustained by intrinsic ocean dynamics. This result is confirmed by both ocean-only experiments (ORCA 2°) forced by climatological surface fluxes derived from the coupled integrations and a diagnostic approach based on the buoyancy variance budget (Gastineau et al. 2018). Atmospheric stochastic forcing is shown to increase the LFV by about 30 %. Meanwhile, we have studied the characteristics of the LFV arising in ocean-only numerical experiments at 1° resolution under climatological forcing (Arzel et al. 2018). We then considered the impact of realistic atmospheric stochastic forcing on the LFV with the objective of determining the respective contributions of the atmosphere and the ocean to the production of temperature variance in the western subpolar area of the North Atlantic (see figure). We show that in the regime where the ocean mode is damped (i.e when the eddy diffusivity K is larger than a critical value) about 2/3 of the SST variability is driven by atmospheric stochastic forcing, whereas upper ocean heat content variability is driven by internal ocean dynamics (Arzel and Huck 2020).



Left. Results of simulations diagnosing the effect of oceanic eddies on the storm track. Zonal mean zonal wind as a function of latitude and pressure (m/s). In colors differences between EDDY and CTRL. In contours, CTRL. Right. Relative contribution (%) of atmospheric stochastic forcing to the total production of the western subpolar North Atlantic temperature variance by the ocean-atmosphere system [$S_A/(S_O+S_A)$] at the surface (blue) and averaged in the upper 1000 m (red), and as a function of the eddy diffusivity K.

Future of the project :

We are now planning to examine the interaction of the storm track and an eddying ocean in realistic and coupled simulations (A. Le Gal PhD, LOPS). We are also examining in details the impact of the oceanic mesoscale on the internal generation of oceanic temperature variance at large scales and multidecadal periods (Hochet et al., submitted).

Nombre de publications, de communications et de thèses (max 5)

Foussard, A., G. Lapeyre and R. Plougonven (2019) Storm tracks response to oceanic eddies in idealized atmospheric simulations, J. Climate, 32, 445-463.

Foussard, A., G. Lapeyre and R. Plougonven (2019) Response of surface wind divergence to mesoscale SST anomalies under different wind conditions, J. Atmos. Sci., 76, 2065-2082.

Gastineau, G., J. Mignot, O. Arzel, T. Huck (2018) North Atlantic ocean internal decadal variability: role of the mean state and ocean-atmosphere coupling, J. Geophys. Res., Oceans, doi:10.1029/2018JC014074.

Arzel, O., T. Huck and A. Colin de Verdière (2018) The internal generation of the Atlantic Ocean interdecadal variability, Journal of Climate, 31, 6411-6432.

Arzel, O. and T. Huck (2020) Contributions of atmospheric stochastic forcing and intrinsic ocean modes to North Atlantic ocean interdecadal variability, Journal of Climate, 33, 2351-2370.