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Influence of oceanic fine scales on ocean/atmosphere covariability

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1 Context

Until 20 years ago, the coupling of the ocean and the atmosphere at mid-latitudes was assumed to occur only at scales larger than 1000km with a relatively mild influence of the mid-latitude oceans (Kushnir et al. 2002). Since then, high-resolution observations and numerical simulations have shown that mesoscale (50-300km) oceanic fronts and eddies modulate air-sea interactions, which impact both the ocean (e.g. Hogg et al. 2009) and the atmosphere (e.g. Deremble et al. 2012).

Surface winds are affected by oceanic mesoscales, through the role played by sea surface temperature (SST) anomalies on the stability of the atmospheric boundary layer (Wallace et al. 1989): warm SST anomalies tend to destabilize the air column and enhance surface winds, contrary to cold anomalies which decelerate the winds (Lambaerts et al. 2013, Foussard et al., 2019a).

Oceanic eddies are affected by the surface wind stress which is proportional to the difference between the wind and oceanic current (Dewar and Flierl 1987). This tends to transfer mechanical energy downwards impacting the mesoscale and the large-scale flows (Renault et al. 2016).

While mechanisms of air-sea coupling at mesoscale are beginning to be clarified, they have so far only been examined in the light of the modulation of the mechanical energy exchange between the ocean and the atmosphere. The underlying assumption was that the thermodynamical energy exchanges play a minor role in the modification of the dynamics of the coupled system.

However, we have more and more evidence that suggest that the thermodynamical energy exchanges could be a key component in the ocean-atmosphere coupling. Studies suggest that an SST anomaly of 1K gives rise to air-sea heat exchanges with values of the order of 20W/m^2 (e.g. Bourras et al. 2004). This typically represents 10% of the mean air-sea heat fluxes at midlatitudes. Such an effect has been shown to explain how mesoscale oceanic eddies affect the upper troposphere and the atmospheric storm tracks (Foussard et al. 2019b). The study of Su et al. (2018) using state-of-the-art global simulations at 2km resolution (at NASA/JPL) goes even further by indicating that oceanic scales below 30km (the submesoscales), as well, give rise to vertical heat fluxes of the order of 20 to 100W/m^2 in active energy regions of the ocean.

The aim of the PhD project is to better understand **the role of surface heat fluxes at meso and submesoscales in the coupling between the ocean and the atmosphere**, with a particular focus on the atmosphere. Up to now, coupled numerical models resolving oceanic mesoscales mainly examined the oceanic response from a mechanical point of view (e.g. Ma et al. 2016, Renault et al. 2019). From the atmospheric side, the thermodynamical response clearly prevails with the destabilization of the atmospheric boundary layer (ABL) due to meso and submesoscale SST anomalies. Instead of examining the response to an uni-dimensional SST front or to a single oceanic eddy, we propose to see **how the heat fluxes impact the coupled variability of the ocean/atmosphere in an eddying ocean**.

This PhD project can be placed into the context of the SWOT satellite mission that will measure sea surface height (SSH) and surface wind speeds at horizontal scales of about 30km, thus offering a unique capability to simultaneously describe the local interactions and couplings between ocean and atmosphere. A better understanding of the coupling by taking into account both the thermodynamical and mechanical interaction between the ocean and the atmosphere will serve for the interpretation of the data that will be obtained.

2 Scientific questions

First of all, we aim to evaluate the impact of the oceanic mesoscales on the air-sea heat fluxes at the scale of the North Atlantic basin in the observations and in high-resolution global simulations. This will be done by analyzing surface turbulent heat flux datasets, such as those provided by IFREMER (Bentami et al. 2013), in conjunction with SSH from SSALTO-DUACS and SST from GHRSST. Different techniques will be used to separate the signal due to oceanic eddies in the observations. This will allow to see how the mesoscale activity affects the net heat budget of the ocean, in particular in the North Atlantic.

A focus will be made in particular on the modulation of the fluxes by weather and oceanic large-scale conditions. We will also rely on the newly coupled global simulation that is being performed at JPL and Goddard with a resolution of 1/48° in the ocean and 3km in the atmosphere (MITgcm ocean model and GEOS atmospheric model). This will be possible through a collaboration with Patrice Klein (at CalTech, Pasadena, US).

Secondly, we aim to understand the implications of the thermodynamical coupling for the relation between SST, SSH and surface winds, by running idealized numerical simulations representative of the situations found in the first part. We will examine what are the time and spatial scales involved in the air-sea coupling and how they modulate the SSH/wind co-variations at submesoscales. It will allow us to interpret how the SSH at small scales is representative of balanced motions (i.e., filaments and mesoscale eddies), or unbalanced dynamics (inertio-gravity waves, tides). This will be done through a new framework of a coupled atmosphere-ocean system for idealized studies using oceanic CROCO and atmospheric WRF models, that is developed in collaboration with Lionel Renault (LEGOS, Toulouse).

3 General information

3.1 Profile of the candidate

The candidate will have a Master in Physical Oceanography, Dynamical Meteorology, Physics or Mathematics. Knowledge of computer languages such as Matlab, python or Fortran is needed for data analysis or numerical modeling.

3.2 Thesis location

The thesis will be prepared at Laboratoire de Météorologie Dynamique at Ecole Normale Supérieure in Paris, under the supervision of Guillaume Lapeyre (Directeur de Recherche CNRS).

3.3 Funding

In addition to the funding of the CNES, the candidate will apply to the funding provided by Ecole Doctorale des Sciences de l'Environnement, ED129 (Ile de France).

3.4 Contact

For any information, contact Guillaume Lapeyre (`glapeyre@lmd.ens.fr`).

4 Bibliography

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