Latitudinal shifts versus pulses of the eddy-driven jet in an aquaplanet general circulation model

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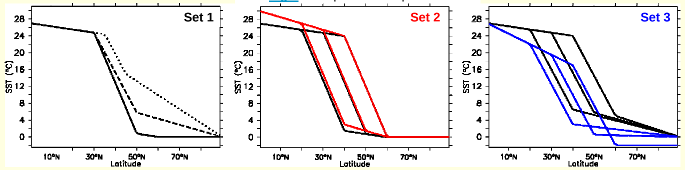
I. Motivation

Recent studies showed that mid-latitudes SSTs can impact the whole troposphere (Minobe et al. 2008) and determine in large part the location and intensity of the storm-track and eddy-driven jet (EDJ). While the dependence of the EDJ position on various SST profiles was the focus of many studies, the EDJ variability did not draw much attention (Nakamura et al., 2008). To analyze that aspect, we used an aquaplanet version of a climate model. It constitutes a mid-way numerical approach between idealized GCMs experiments and CMIP experiments which has been less intensively adopted to study the EDJ variability.

II. Model and numerical set-up

The aquaplanet version of the climate model developed at CNRM / Météo-France is used (same version as for CMIP5) with a spectral truncation T127 and 31 vertical levels. Simulations are performed under perpetual equinoctial solar insolation and forced by zonally-uniform fixed SSTs which are symmetric relative to the equator (Fig.1). Each simulation lasts 10 years. Statistics are made over the last nine years and by concatenating both hemispheres.

Fig.1 Examples of SST profiles.



III Climatologies

Fig.2 Time-mean spatially-averaged high-frequency kinetic energy ($m^2 s^{-2}$) as function of the SST front mean latitude.

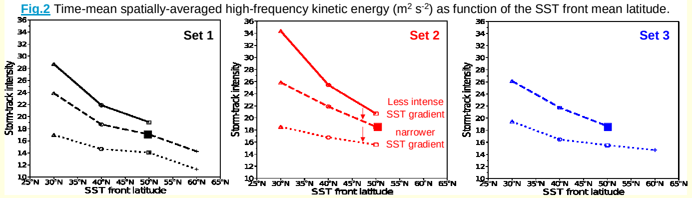


Fig.3 Vertical cross-sections of the zonal mean of the high-frequency kinetic energy (shading; $m^2 s^{-2}$) and momentum fluxes (contours; int: 5 $m^2 s^{-2}$) for an SST front at 50°N.

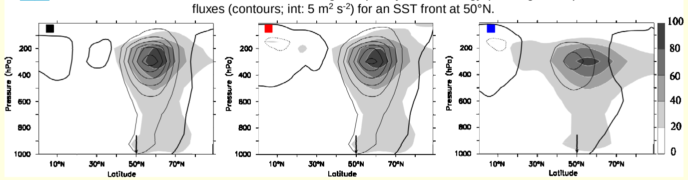


Fig.4 Vertical cross-sections of the zonal mean baroclinicity Eady parameter ($0.31\frac{f}{N}\frac{\partial U}{\partial z}$ in shading; $10^{-6} s^{-1}$) and zonal wind (contours; int: 5 $m s^{-1}$) for an SST front at 50°N.

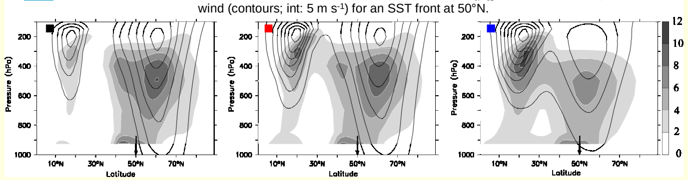
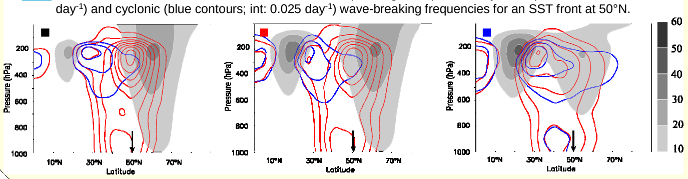


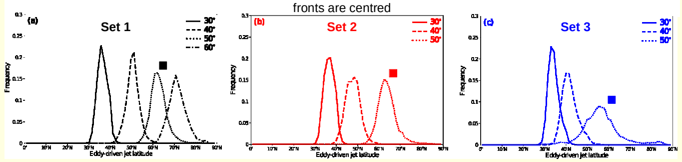
Fig.5 Vertical cross-sections of the zonal mean zonal wind (shading; $m s^{-1}$) and anticyclonic (red contours; int: 0.025 day^{-1}) and cyclonic (blue contours; int: 0.025 day^{-1}) wave-breaking frequencies for an SST front at 50°N.



- A stronger SST gradient or a wider SST front leads to a stronger storm track (Fig.2).
- A stronger subtropical jet with the same SST front (compare **set 1** with **set 2**) leads to a stronger storm track (see Fig.2) especially for a more equatorward SST front.
- **Set 3** (smaller SSTs and stronger subtropical jet) shows a slightly weaker storm track (Fig.3; it can be explained by a weaker baroclinicity above the SST front as shown in Fig.4) but covers a wider range of latitude than the other two sets.
- **Set 1** and **set 2** exhibit similar wave breaking frequencies of occurrence (Fig. 5).
- **Set 3** presents much less poleward momentum fluxes (Fig.3). There is a significant reduction in the vicinity of the eddy-driven jet of anticyclonic wave-breaking events (Fig.5).

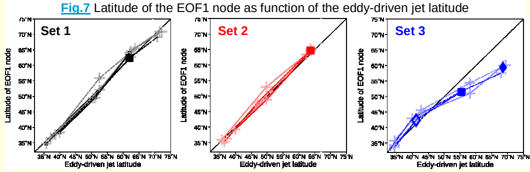
IV. Eddy-driven jet variability

Fig.6 Histograms of the eddy-driven jet daily latitude. The various line styles refer to various latitudes at which SST fronts are centred



- Cases forced by a more equatorward SST front present smaller latitudinal fluctuations than cases forced by a more poleward SST front probably because of the vicinity of the storm-track to the subtropical jet.

Fig.7 Latitude of the EOF1 node as function of the eddy-driven jet latitude



- For set 1 and **set 2**, the leading EOF of the vertical-average zonal-mean zonal wind is always characterized by a latitudinal shifting of the EDJ.
- For **set 3** and a more equatorward SST front, the leading EOF is characterized by a latitudinal shifting of the EDJ whereas for a more poleward SST front, it is more characterized by a pulsing of the EDJ intensity (Fig. 7).

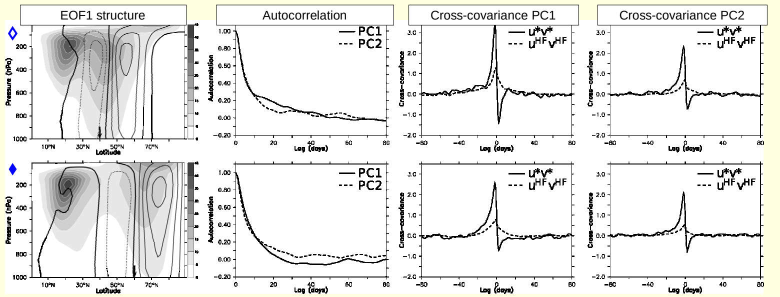


Fig 8: Comparison between two experiments of set 3 with SST front latitudes centred at 40°N and 60°N.

- First column: Zonal-mean zonal wind regressed on PC1 (contours) and time-mean zonal-mean zonal wind (shadings).
- Second column: Autocorrelation of PC1 (solid line) and PC2 (dashed line) as function of the time lag.
- Third and fourth columns:Lagged cross-covariance between the total eddy forcing $P_i^*(t)$ and PCi (solid line) and lagged cross-covariance between the high-frequency eddy forcing $P_i^{HF}(t)$ and PCi (dashed line) for i=1,2

$$P_i^*(t)=\sum_\varphi -\frac{1}{\cos^2\varphi}\frac{\partial}{a\partial\varphi}\left(\cos^2\varphi\left[u^*v^*\right]\right)EOF_i(\varphi)$$

$$P_i^{HF}(t)=\sum_\varphi -\frac{1}{\cos^2\varphi}\frac{\partial}{a\partial\varphi}\left(\cos^2\varphi\left[u^{HF}v^{HF}\right]\right)EOF_i(\varphi)$$

- For **set 3** and a front at 40°N (Fig. 8 first line), the shifting regime dominates the variability because it has a slightly stronger positive eddy feedback (from lags +10 days to +30 days) and is more excited than the pulsing regime (see the cross covariances).
- For **set 3** and a front at 60°N (Fig. 8 second line), the pulsing regime dominates the variability although it is less persistent than the second mode of variability. While a negative eddy feedback is into play for the pulsing regime, it appears to be the leading mode of variability because it is more excited by the eddies.

V. Conclusion

The latitudinal shifting regime dominates the variability for low-latitude fronts and much less for high-latitude fronts, partly because the positive eddy feedback is less active for the latter fronts. It confirms previous studies (Barnes and Hartmann, 2011) showing the dependence of the EDJ variability onto the mean position of the EDJ. However, it shows that the EDJ latitude does not explain everything since the shifting and pulsing regimes may appear for the same EDJ latitude (Fig. 7). Future work will be needed to identify the other parameters controlling the EDJ variability.

References

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