Non-orographic and orographic sources of gravity waves above Antarctica and the Southern Ocean

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Introduction

Context and motivation: Importance of gravity waves for the stratosphere:

- **locally**: temperature fluctuations, turbulence when breaking occurs;
- **globally**: contribution to the stratospheric circulation (momentum fluxes, *Alexander et al 2010*).

Vorcore campaign (Sept. 2005 - Feb. 2006): 27 superpressure balloons in the stratospheric polar vortex (16-19km) → 150,000 independent observations (*Hertzog et al 2007, 2008*).

Ongoing project: Worcore: Complement data analysis from Vorcore by mesoscale simulations, to investigate sources in particular. Implementation:

1. case study of a large-amplitude mountain wave (*Plougonven, Hertzog & Teitelbaum 2008*);
2. sensitivity study for simulations in a large domain (*Plougonven et al 2010*);
3. comparisons between the simulations and the observations: (**present study**);

Numerical setup

The Weather Research and Forecast Model (*Skamarock et al 2005*) is used with:

- a large domain: 10,000 × 10,000 km with $dx = 20$ km, 120 vertical levels (about every 300m) up to 5 hPa;
- runs lasting 3 days, with 1 day of spin-up;
- 29 runs, yielding 58 days to be investigated, from 21/10/2005 to 18/12/2005 (output every 6 hours);
- sponge layer in the last 6 km;

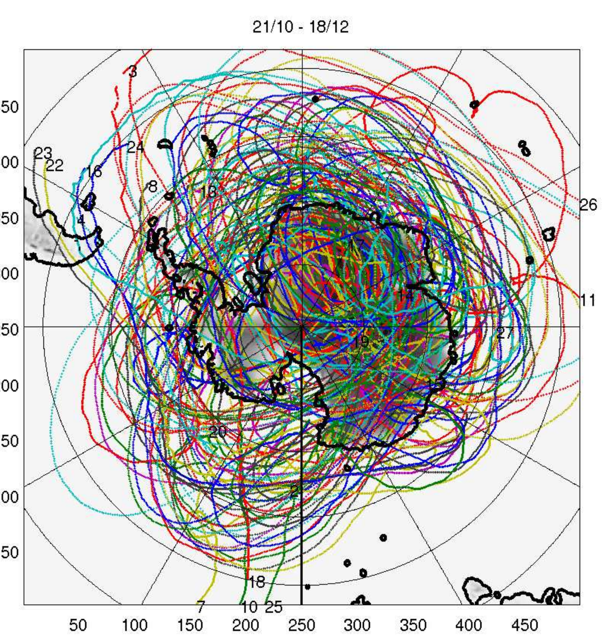

FIG. 1: *Domain for the mesoscale simulations, topography of Antarctica and trajectories of the balloons during the simulated period, from 21/10/2005 to 18/12/2005.*

Time average and comparison with the balloons

First step to assess the realism of the simulations: comparison of the simulated and observed **momentum fluxes** ($\overline{u'w'}$, Fig. 2, and $\overline{v'w'}$, Fig. 3):

- similar orders of magnitude;
- comparable overall structure, with dominance of topographic regions;
- some overestimation above topography, significant underestimation (by about a factor 2) over oceanic regions.

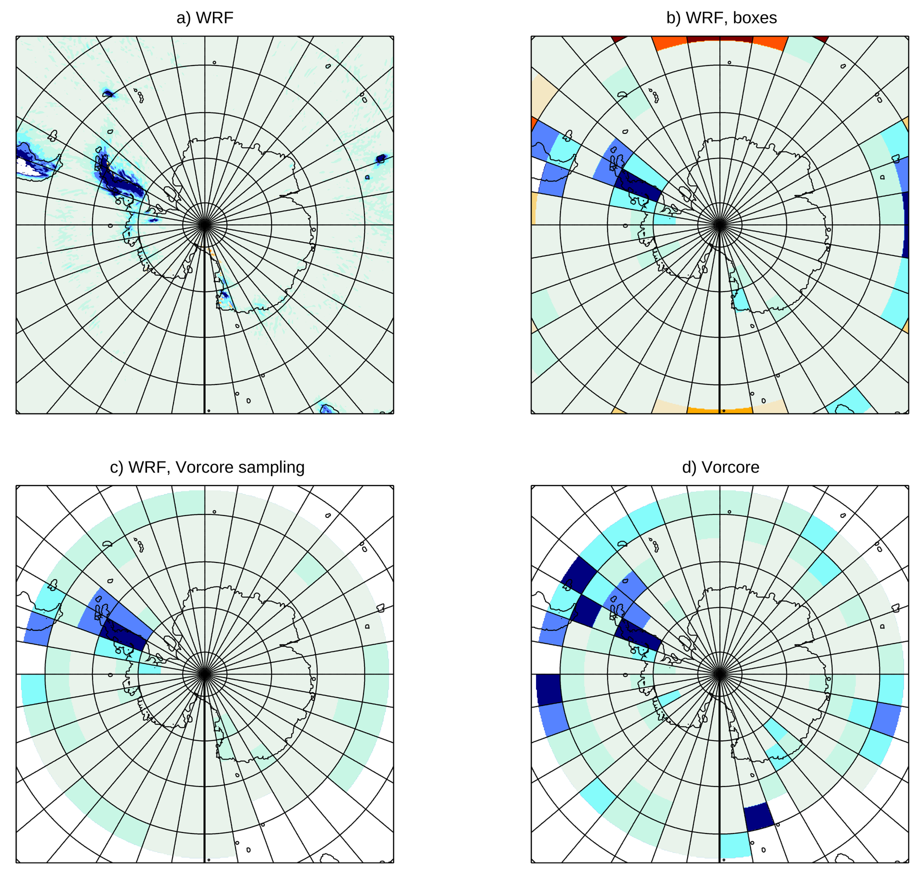

FIG. 2: *At $z = 19$km, zonal momentum fluxes in the simulations (full resolution: a); in boxes 10°×5°in longitude - latitude b); and sampled only at times when a balloon was present c)) and observations (panel d). Color range: -10 to 10mPa.*

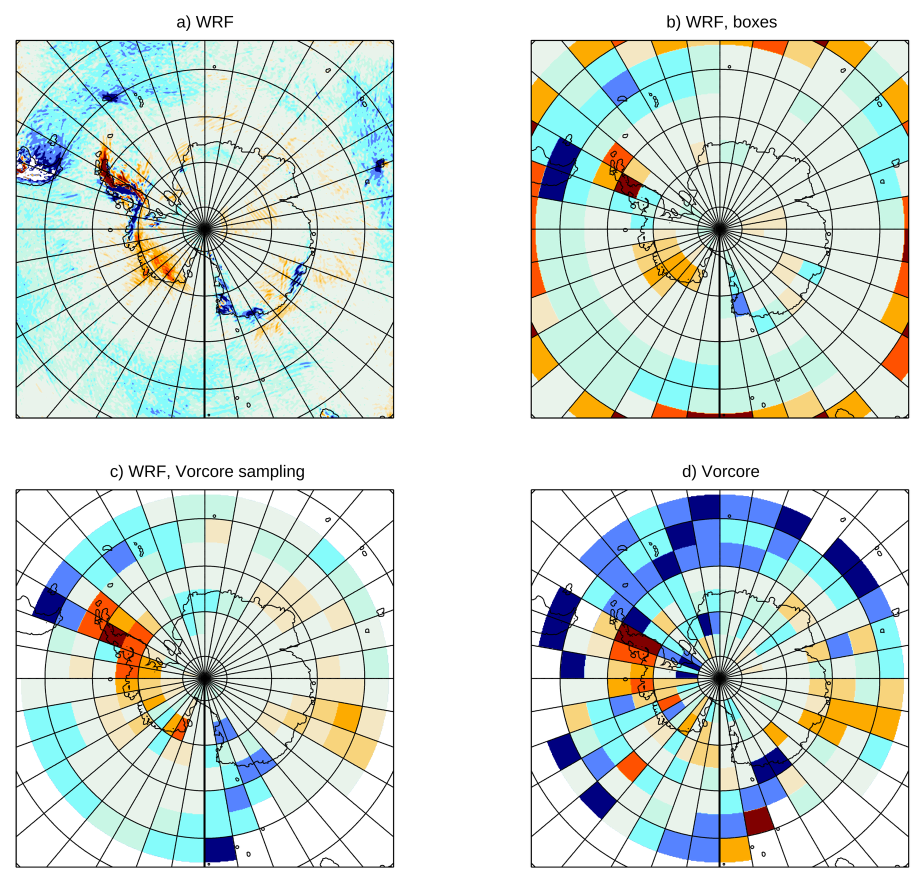

FIG. 3: *Same as Fig. 2, but for the meridionalonal momentum fluxes. Color range: from -2 to 2mPa).*

Variations in time

7 regions are defined as shown in **Figure 4**.

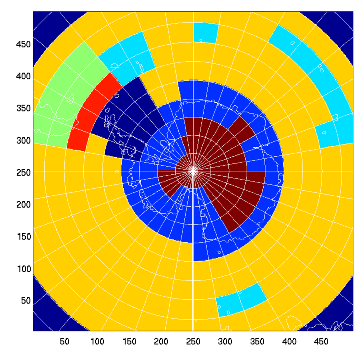

FIG. 4: *Regions into which the domain has been subdivided:* **1**: *(dark blue) Antarctic Peninsula,* **2**: *(blue) Antarctic coastline,* **3**: *(Islands),* **4**: *(tip of the Andes),* **5**: *(Southern Ocean),* **6**: *(Drake Passage),* **7**: *(Plateau).*

The time series of the domain-averaged zonal momentum fluxes (**Figure 5**) show that:

- significant intermittency during the first month, much less during the second, and an overall decrease in time as the winds decrease;
- two main contributions: the Antarctic Peninsula (small region 1), and the Southern Ocean (vast region 5);
- intermittency dominated by the strong intermittency over the Antarctic Peninsula.

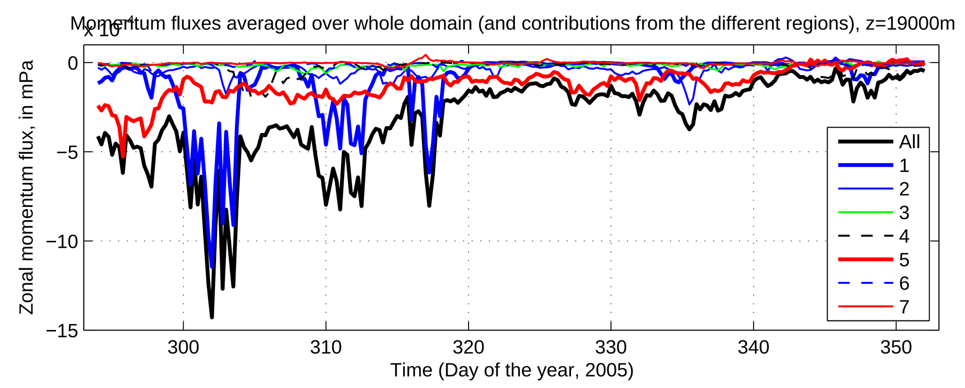

FIG. 5: *Time series of the zonal momentum fluxes averaged over the whole domain (black curve), and of the contributions from the seven different regions shown in Fig. 4.*

Zonal average

Figure 6 confirms the **comparable importance of orographic and non-orographic** regions found in the observations (*Hertzog et al 2008*).

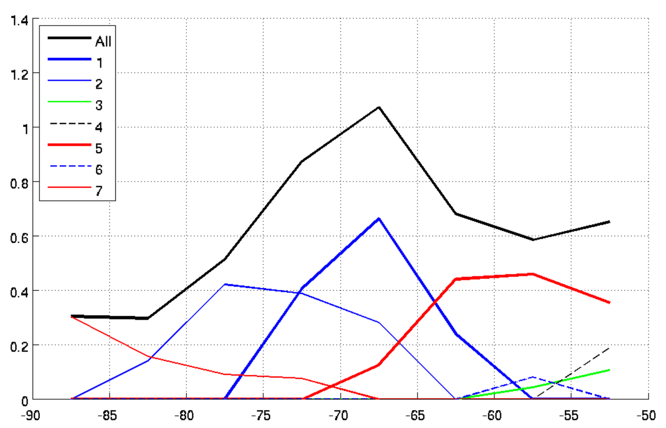

FIG. 6: *Zonal average of the absolute momentum fluxes and of the contribution to these of the different regions.*

Intermittency

Two definitions are used:

- as in *Hertzog et al 2008*, the ratio of the 50th to the 90th percentile of the timeseries, left panel in **Fig. 7**;
- the percentage of time containing the strongest values, amounting to 50% of the total, right panel in **Fig. 7**.

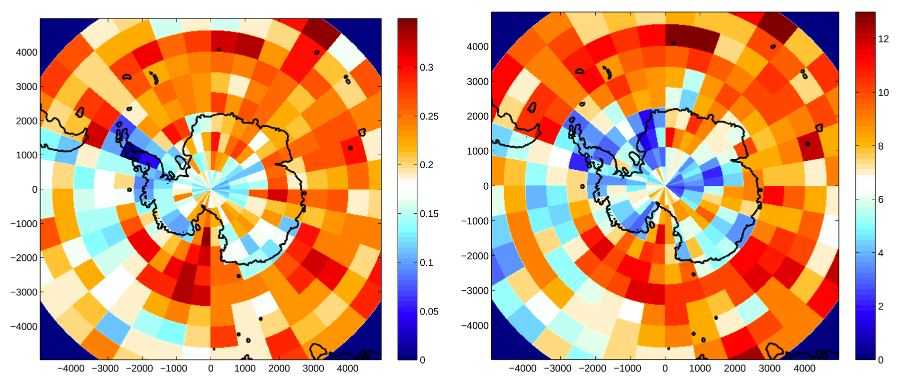

FIG. 7: *Intermittency of absolute momentum fluxes estimated in two different ways.*

Structure of the average gravity wave field over the oceans

The fine structure of the gravity wave field due to non-orographic waves is revealed in plots of the logarithm of the average absolute momentum fluxes (**Figure 8**). Such plots and movies suggest a strong correlation between the waves and the background winds (polar vortex) in which the waves propagate.

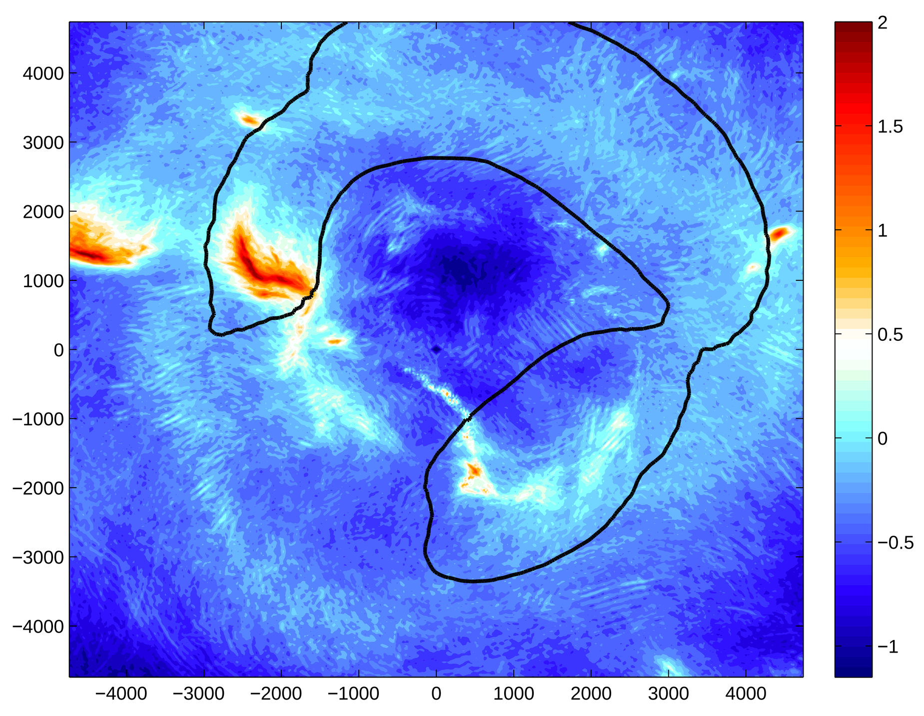

FIG. 8: *Logarithm of the mean of the absolute momentum fluxes, averaged over the whole period. Also shown is the 40$m\,s^{-1}$ average windspeed isotach.*

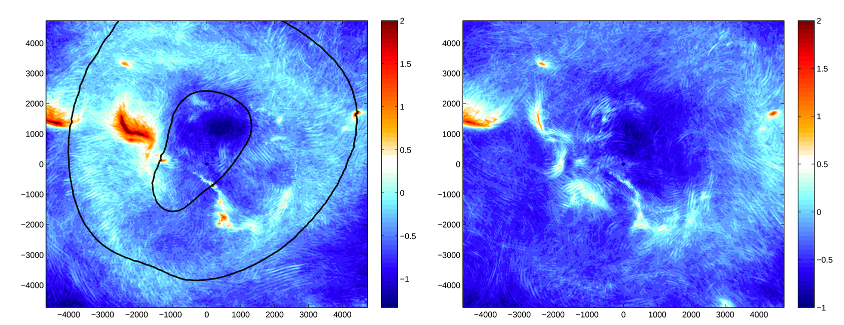

FIG. 8 (continued): *During the first month (21/10-19/11/2005, left) and during the second month (19/11 - 18/12/2005, right).*

Conclusions

Simulations show fair agreement with observations, though momentum fluxes due to non-orographic waves are underestimated, roughly by a factor 2.

Dominance of very strong, intermittent events above the Antarctic Peninsula, with local momentum fluxes reaching a few Pa (*Plougonven et al 2008*).

Nevertheless, the contribution from non-orographic waves over the Southern Ocean is comparable, corresponding to weaker, less intermittent waves.

Perspectives

The simulations will be further analyzed to investigate:

- vertical variations of the wave field, and implied forcing of the background flow;
- specific sources of the non-orographic waves, through both statistical and case studies;
- relevance of the mechanisms highlighted by idealized studies (e.g. wave capture, *Plougonven and Snyder 2005, 2007*);
- new ways to characterize the gravity wave field and relate it to the background flow (e.g. probability distribution function of momentum fluxes, in model and observations, **figure 9**).

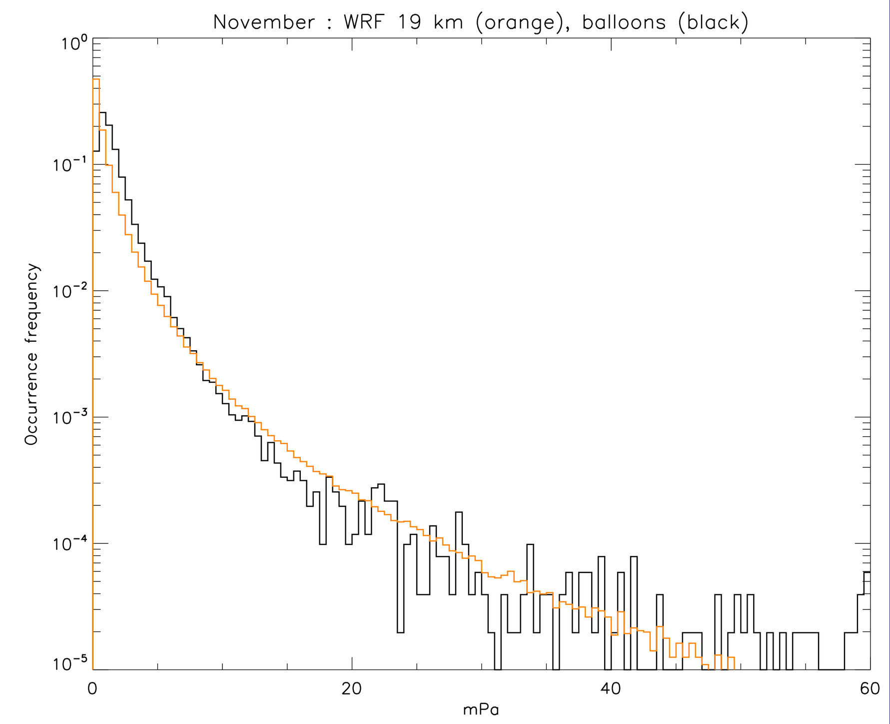

FIG. 9: *Probability Distribution Function of absolute momentum fluxes over ocean regions, for November: balloons (black) and simulations (orange).*

References

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