Can we improve gravity wave parameterizations by imposing sources at all altitudes in the atmosphere?

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Motivation :

Observations often show that in the middle atmosphere a good part of the Gws have quite small horizontal phase speed
(Constant level balloons in the low stratosphere Plougonven et al. JAS17, Inertio gravity waves at mesospheric levels in lidar Reichter et al. AMT19)

Problem :

These waves are likely to be strongly filtered by the background winds, the journey from tropospheric sources to the mesosphere might be extremely annoying for them… May be the observed waves do not all have their primary source in the troposphere.

Purpose :

See if parameterization can include such waves by considering sources at all levels in the atmosphere.
Source will be based on the spontaneous adjustment theory developped in Lott et al~(JAS10,12)

GWs parameterizations with sources at all altitudes

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Subgrid scale gravity waves represented by a stochastic Fourier series
N being launched each time step :

$$\left(\boldsymbol{u}'_n(\boldsymbol{x},z,t),T'_n(\boldsymbol{x},z,t)\right)=\sum_1^N C_n\left(\hat{\boldsymbol{u}}_{\boldsymbol{n}}(z),\hat{T}_n(z)\right)e^{i(\boldsymbol{k}_n\cdot\boldsymbol{x}-\omega_n t)}$$

Wavevector $\boldsymbol{k}_{\boldsymbol{n}}$, and frequency w_n chosen Randomly, C_n intermittency coefficients
MF flux amplitude spontaneously emitted at a given level zk:

$$F_l=G_0\frac{\Delta z\,dz_l}{f_0}\rho(z_l)N(z_l)\left[f\tanh\left(\frac{\xi_l}{f}\right)\right]^2 e^{-\pi\sqrt{J(z_l)}}$$

Spontaneous adjustment theory, ξ is the gridscale vorticity (Lott et al. 2010, 2012)

Scenario LW : F_l averaged over the *L* model levels and launched from the troposphere (as in de la Camara and Lott 2015), $C_n^2=1/N$
Large intrinsic phase speed randge (Δc=50m/s)

Scenario SW : Scenario 1 with smaller intrinsic phase speed range (Δc=10m/s)

Scenario SW² : N levels chosen randomly among the L total levels each launching its own F_l , Cn2=L/N

Very unexpensive implementation !

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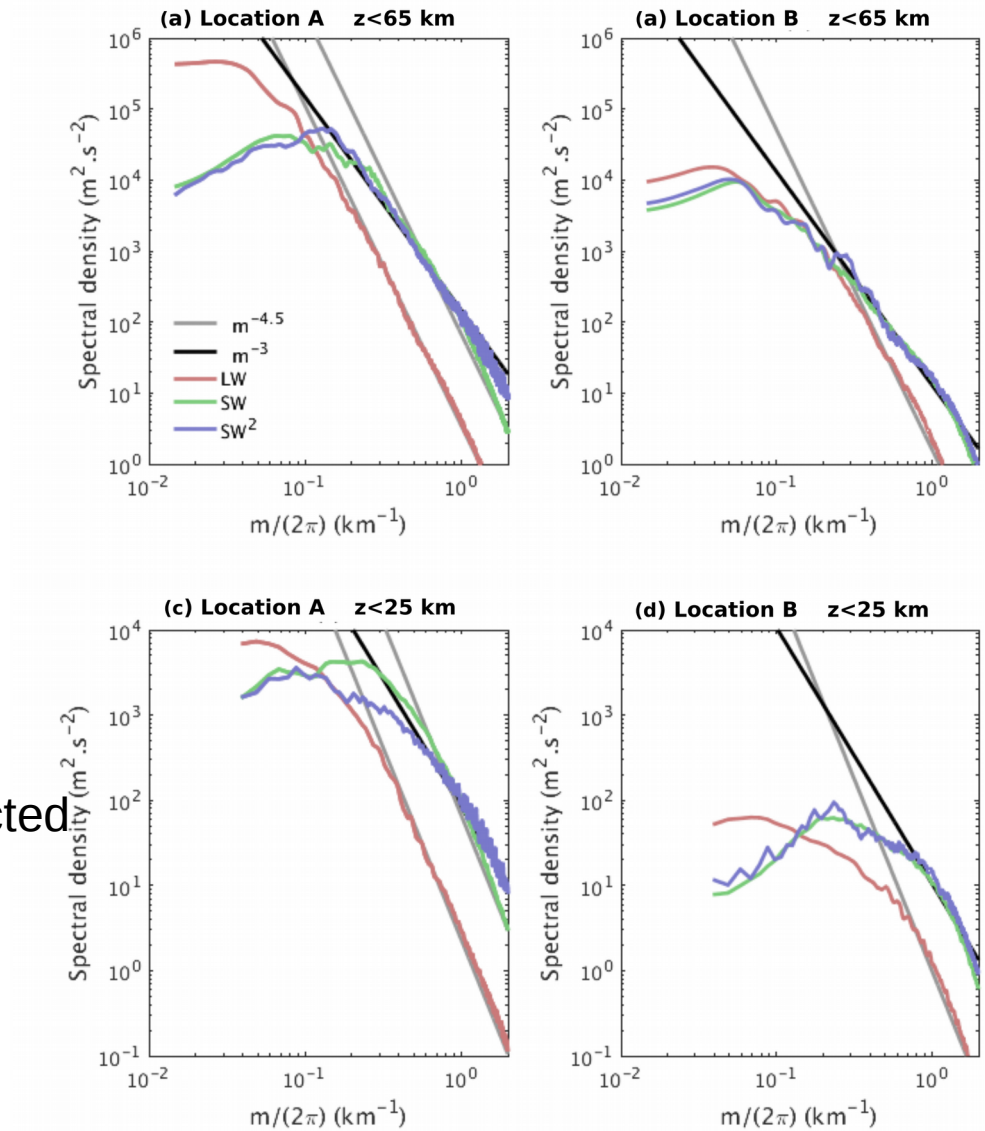
Reconstruction and off line tests : Breaking evaluated harmonics by harmonics, permits to evaluate an amplitude functior $\phi_n(z)$

$$\boldsymbol{u}_n = \frac{-\boldsymbol{k}_n \hat{\omega}_n - i f \boldsymbol{e}_z \times \boldsymbol{k}_n}{\hat{\omega}_n^2 - f^2} \phi_n(z) e^{i \int_{z_i}^{z} m_n(z') dz'}$$

Remark : the parametrization also include Coriolis



Slow waves emitted from all levels (SW^2) produces a more realistic k^{-3} tail

Here the KE vertical spectra are constructed using re-analysis data

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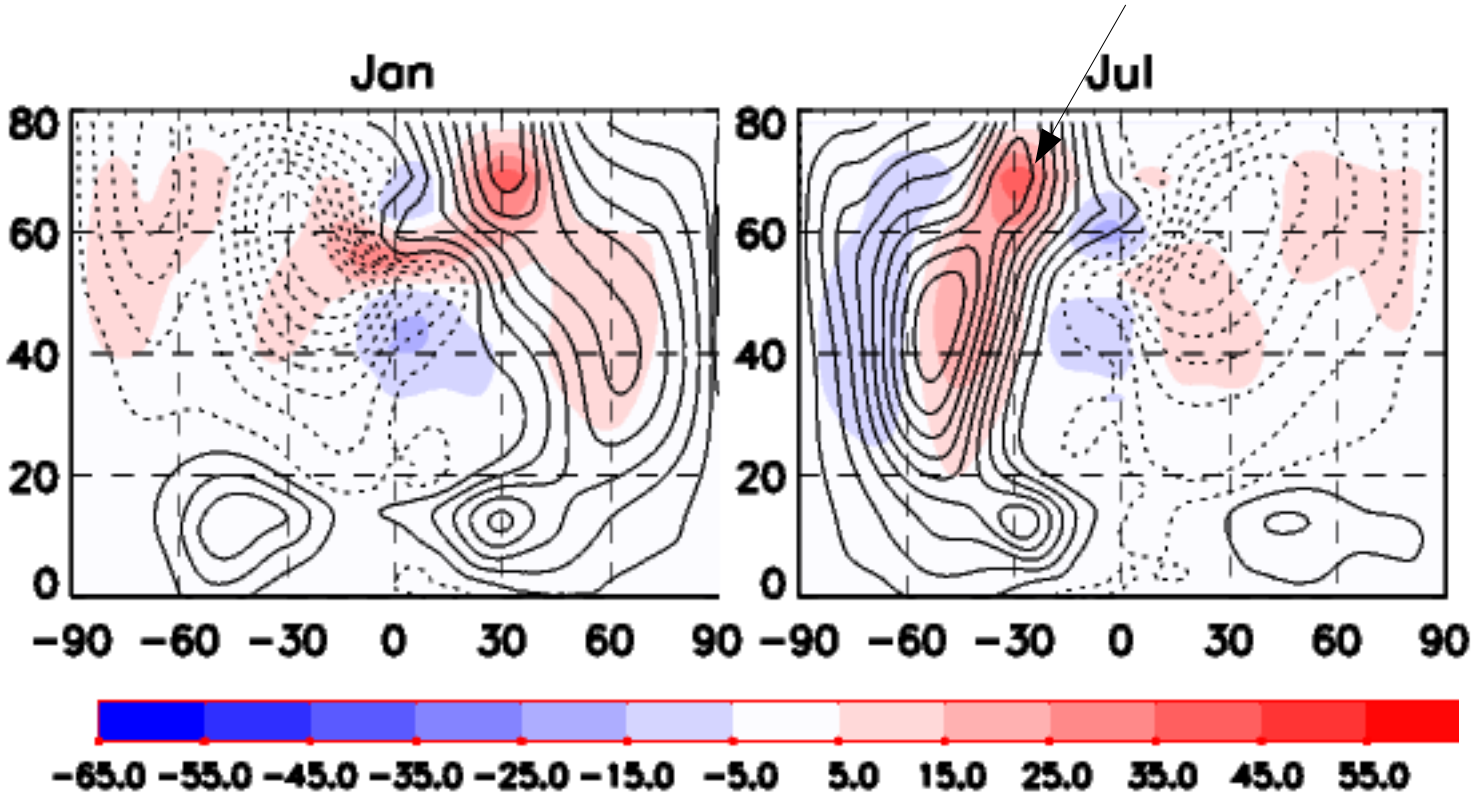
On line tests with the LMDz GCM :

Climatologies as good as with the operational de la C*ámara and Lott (2015)* scheme

With some improvement to represent the tilt of the SH jet in winter ?



Difference between scenario 2 (slow waves launched from all altitudes) and operationnal scheme. 15 years run (1980-1995)