The relevance of parameterized momentum flux intermittency during the austral stratospheric final warming as simulated by LMDz

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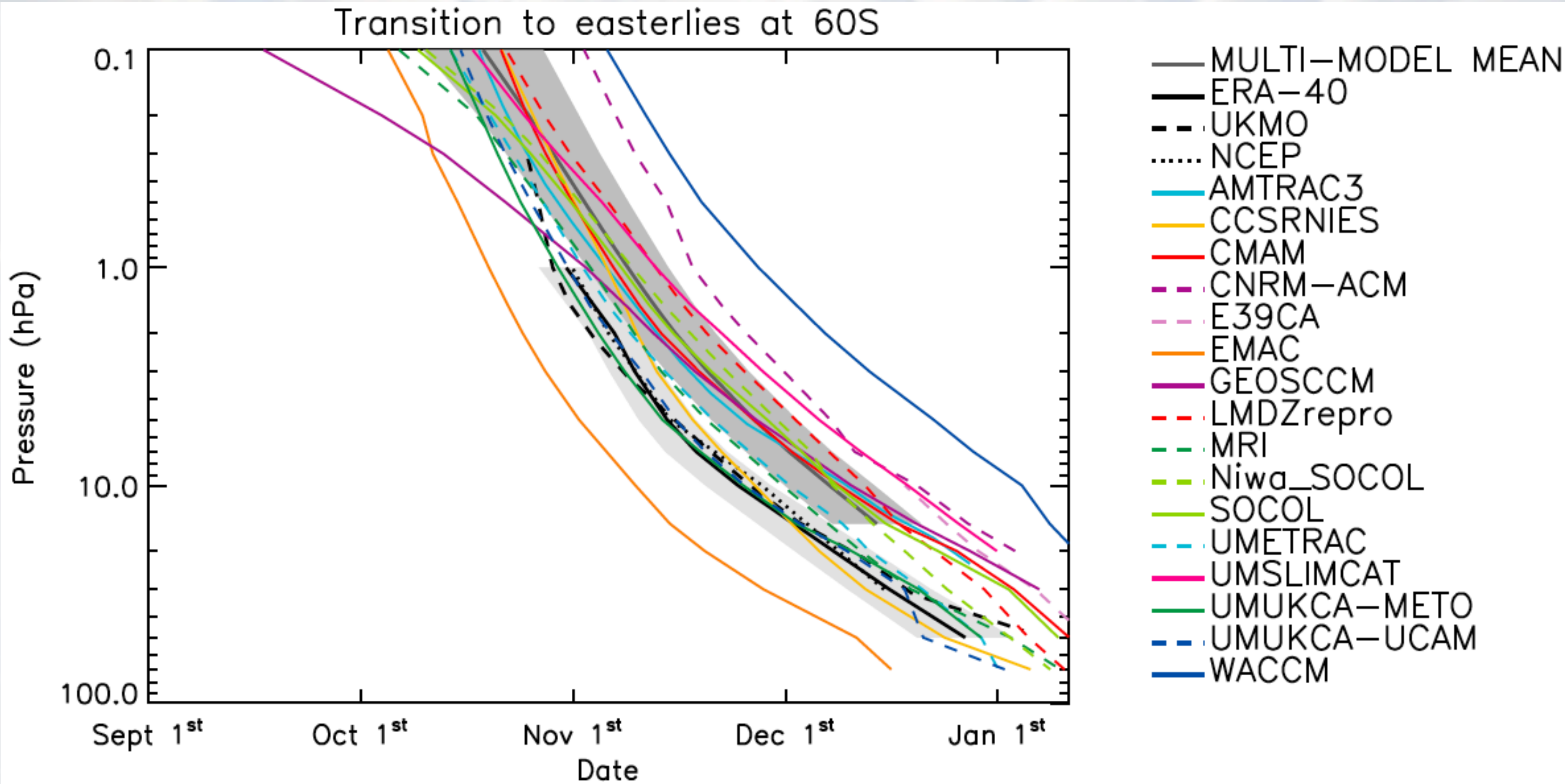
de la Cámara et al. (2016), *J. Atmos. Sci.*, doi: 10.1175/JAS-D-15-0377.1, in press.

Stratospheric final warming bias in the SH

Butchart et al. 2011, *JGR*

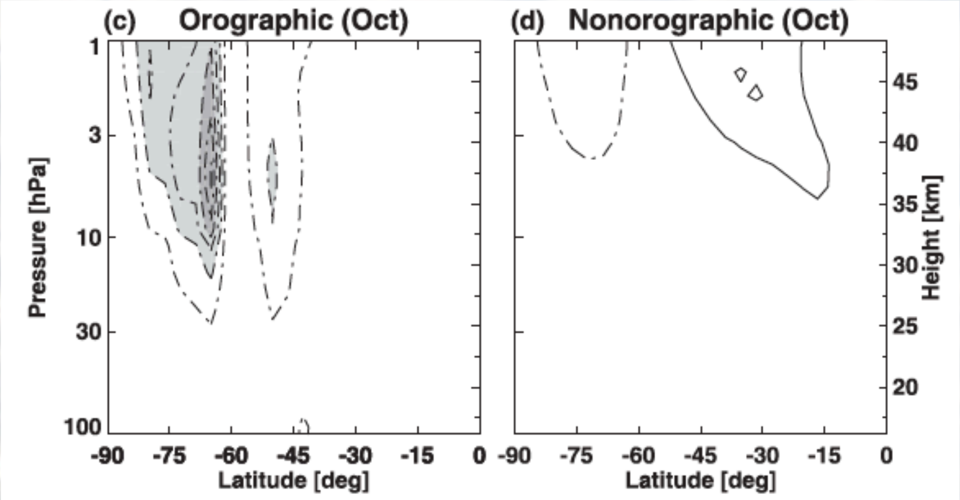


Insufficient parameterized GW drag at 60°S as cause of late final warming bias

(McLandress et al., 2012 *JAS*)

What can we do about it?
(from a 1-D parameterization perspective)

Parameterized GW drag (McLandress et al 2012 JAS)



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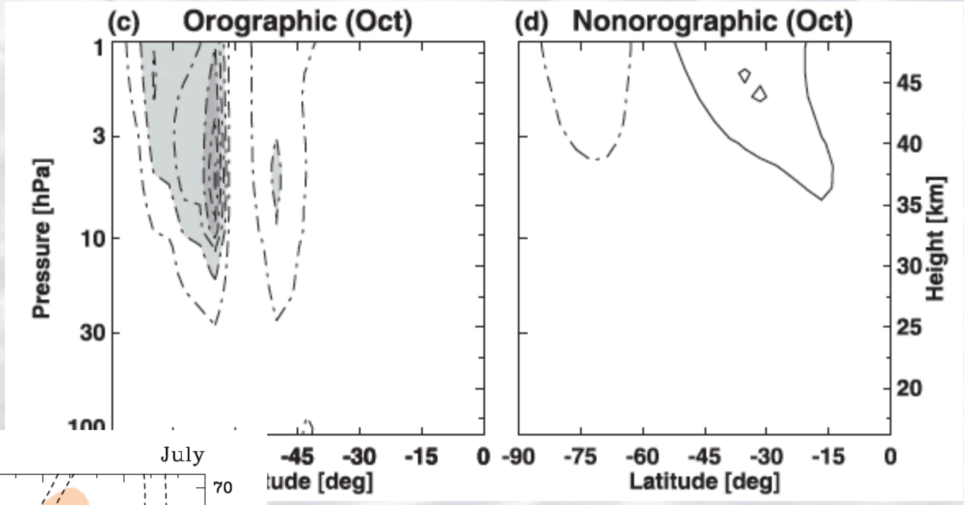
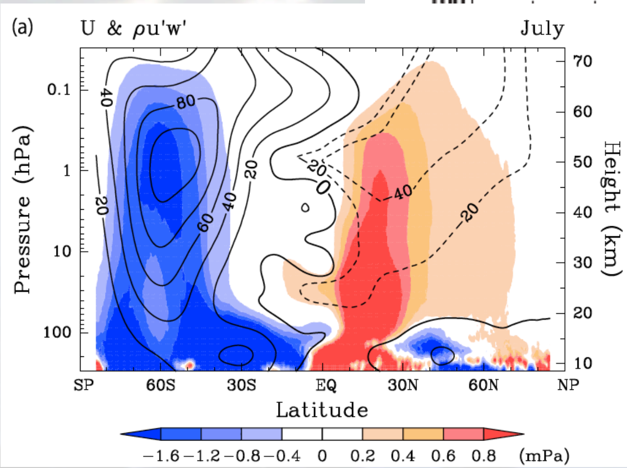
Parameterized GW drag (McLandress et al 2012 JAS)





Latitudinal propagation towards the jet
(Sato et al. 2009, 2012)

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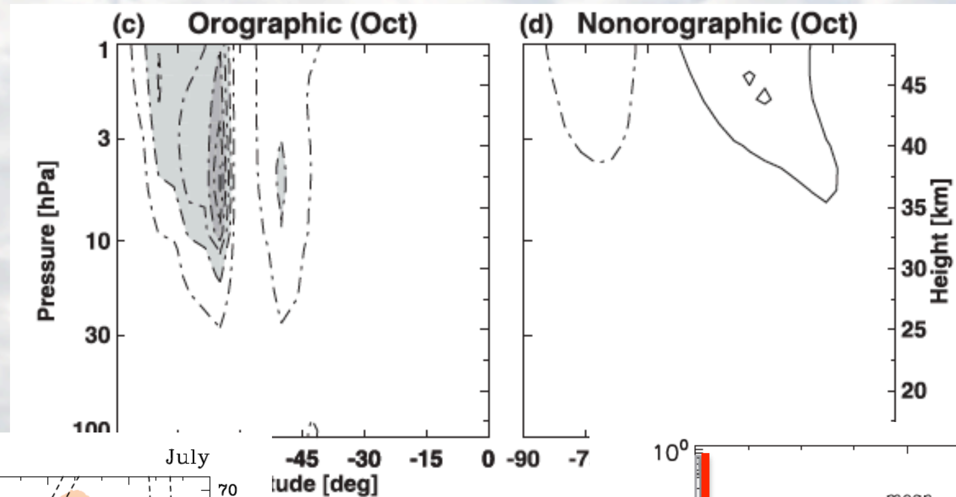
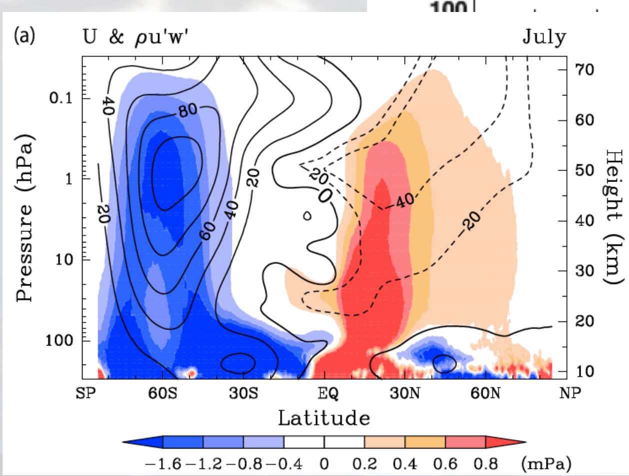
Parameterized GW drag (McLandress et al 2012 JAS)





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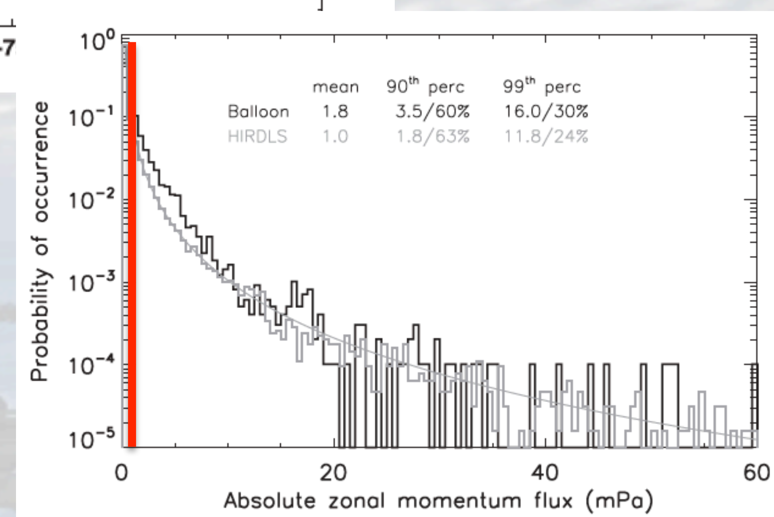


Large, intermittent momentum fluxes
(Hertzog et al., 2012 *JAS)*

Source-related GW parameterizations in LMDz

Convective GW

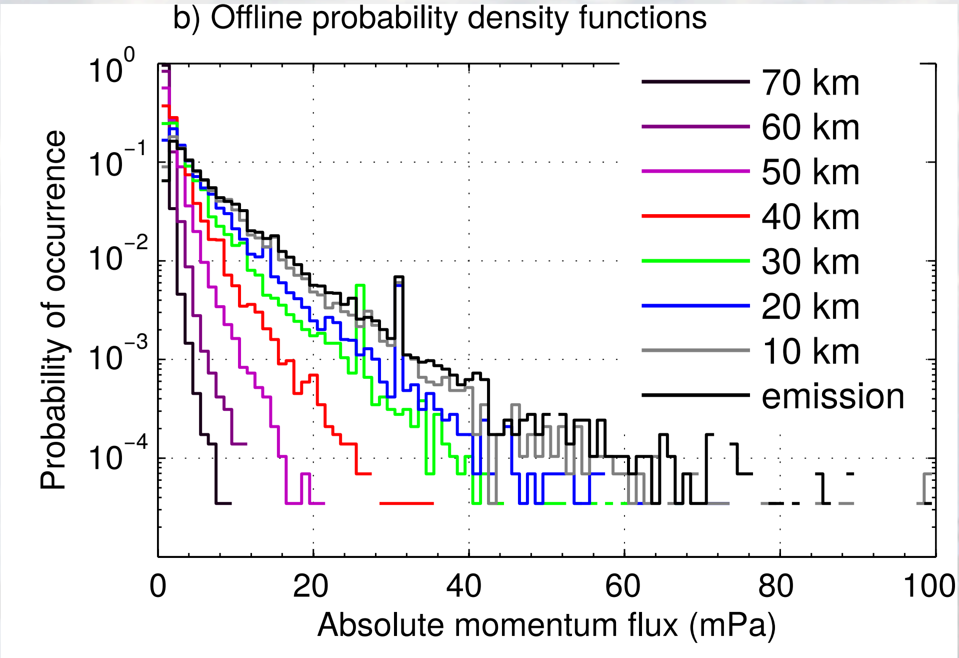
Lott and Guez, 2013 JGR

$$F_{zl} \propto precip^2$$

GW from jets/front systems

de la Cámara and Lott, 2015 GRL

$$F_{zl} \propto \zeta^2 e^{-\pi\sqrt{Ri}}$$

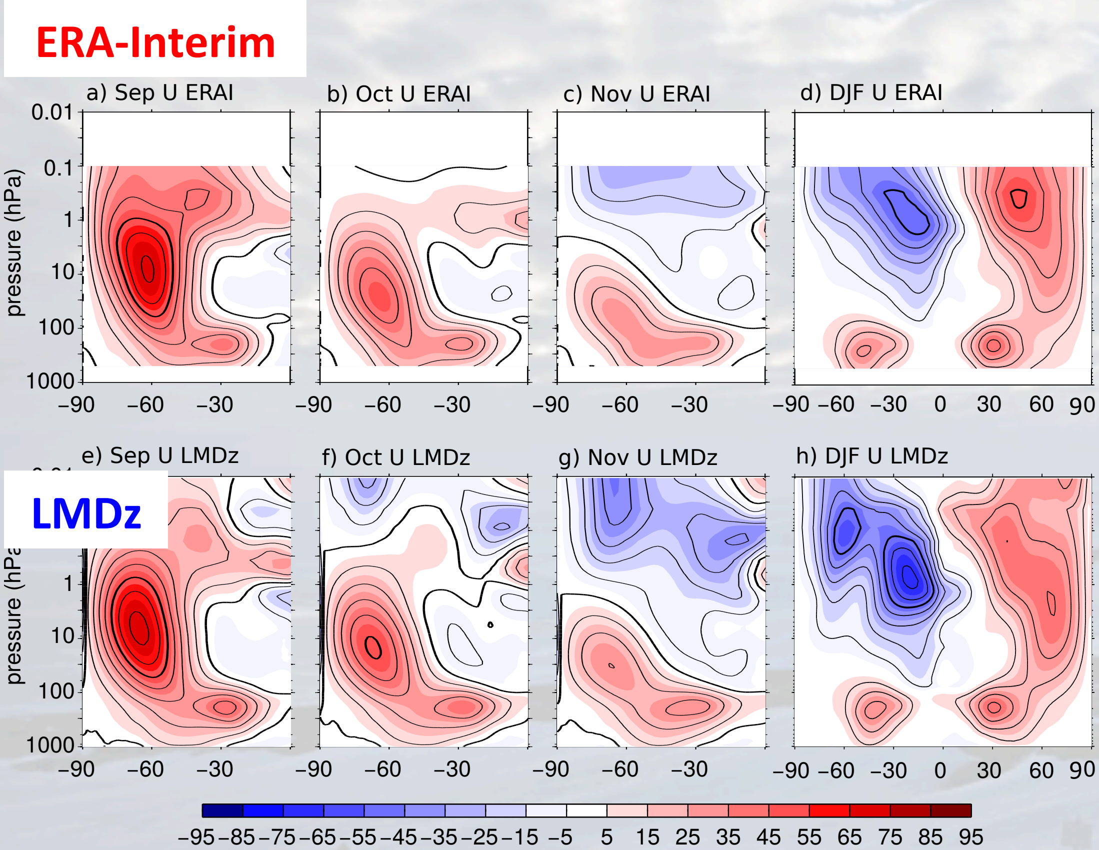


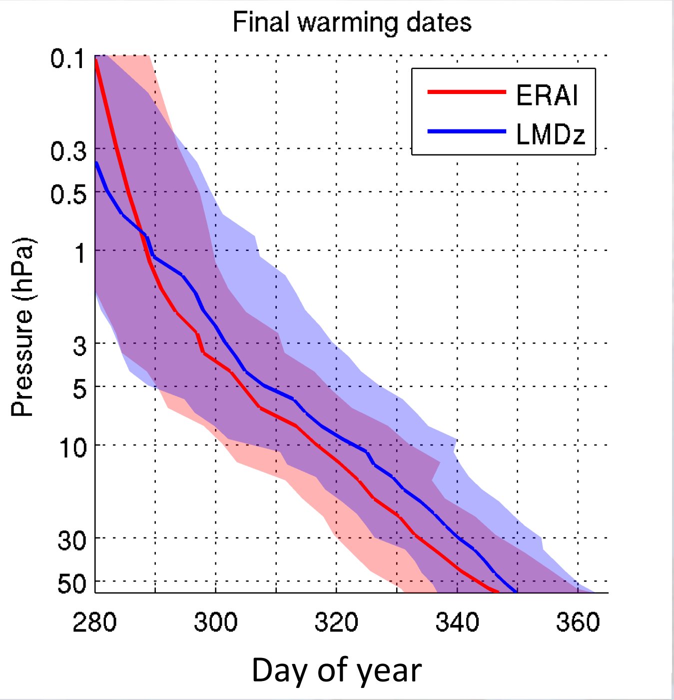
90°S – 40°S

Final warming in LMDz

<u>LMDz GCM</u>

- 3.75°lon x 2.5° lat, 72 levels (top at 0.01 hPa)
- 20-year run, ozone monthly climatology (1997-2006)



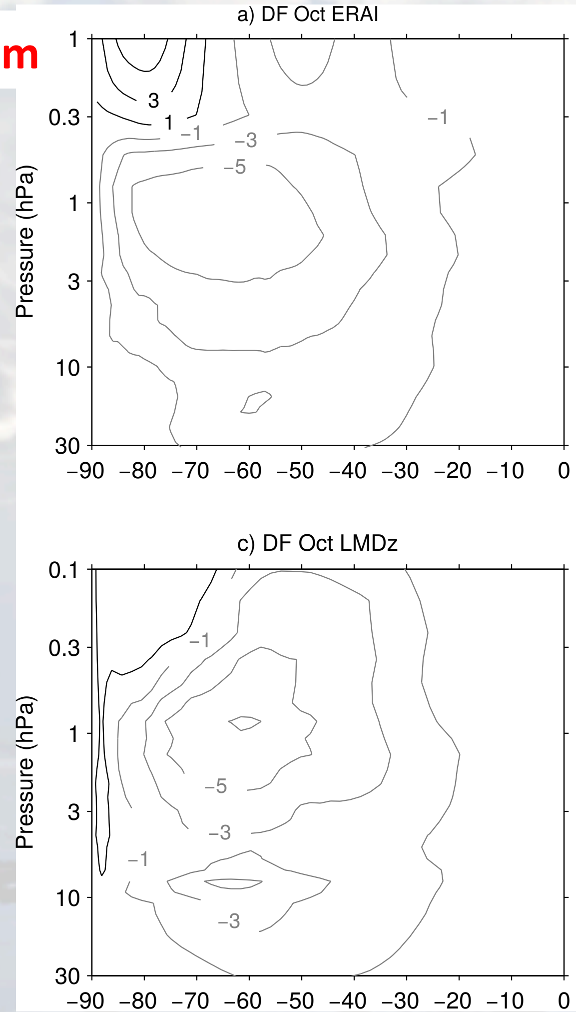


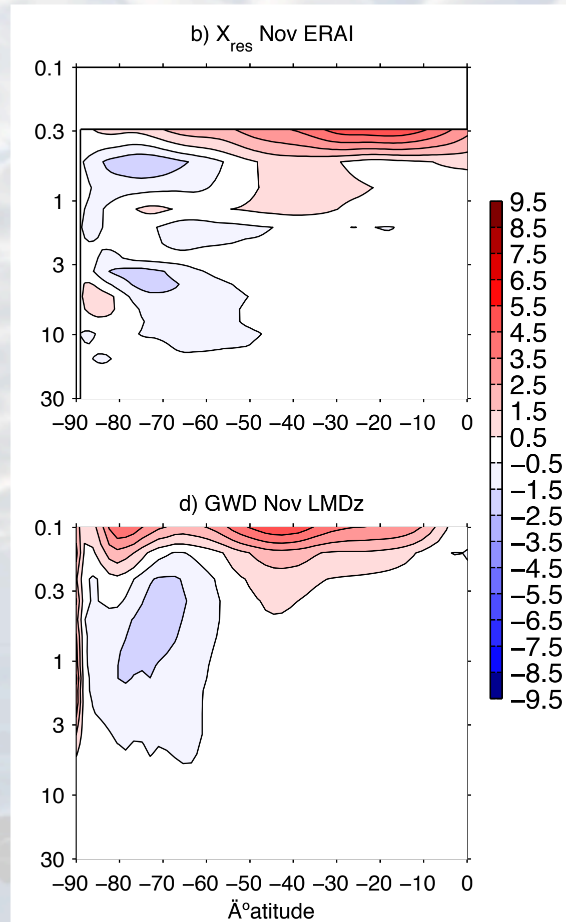
Resolved and unresolved wave drag

EP flux divergence | **Unresolved drag** | Units m/s/day

ERA-Interim

LMDz



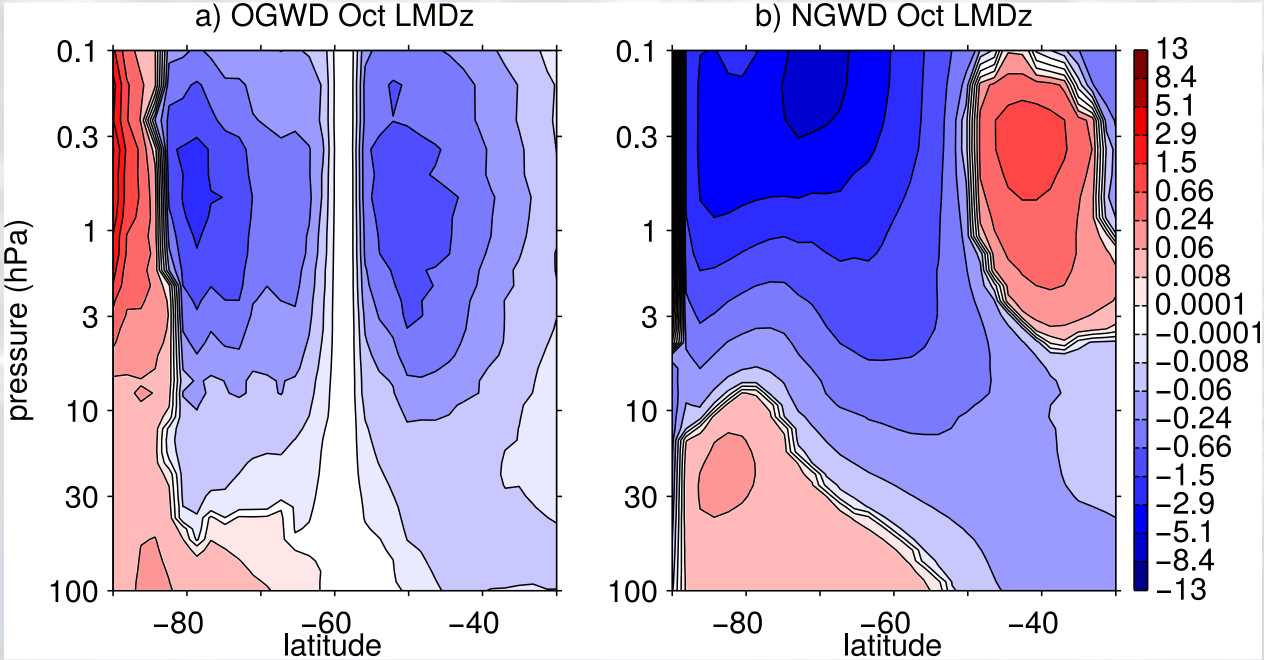


$$\bar{X}_{res} = \frac{\partial \bar{u}}{\partial t} - \frac{\vec{\nabla}\cdot\vec{F}}{\rho_0 a\cos\phi} - \left\{\bar{v}^*\hat{f} - \bar{w}^*\frac{\partial \bar{u}}{\partial z}\right\}$$

Orographic vs non-orographic GW drag

Orographic GW drag

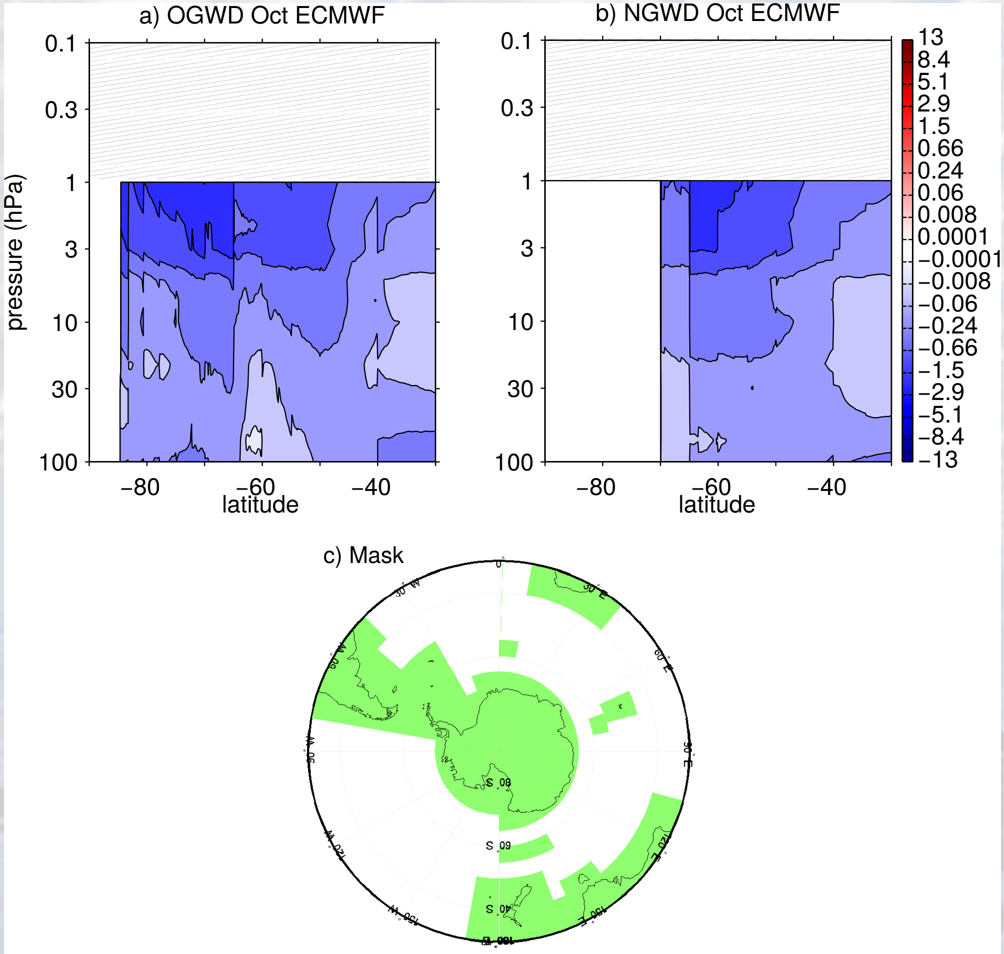
Non-orographic GW drag



The magnitude orographic and non-orographic GW drag are similar at stratospheric levels.

Orographic vs non-orographic GW drag

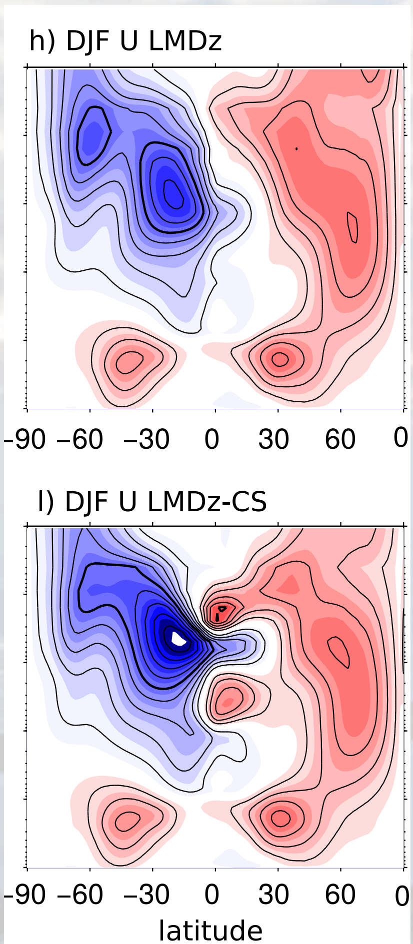
GW resolved forcing from the ECMWF operational analysis model (T1279)



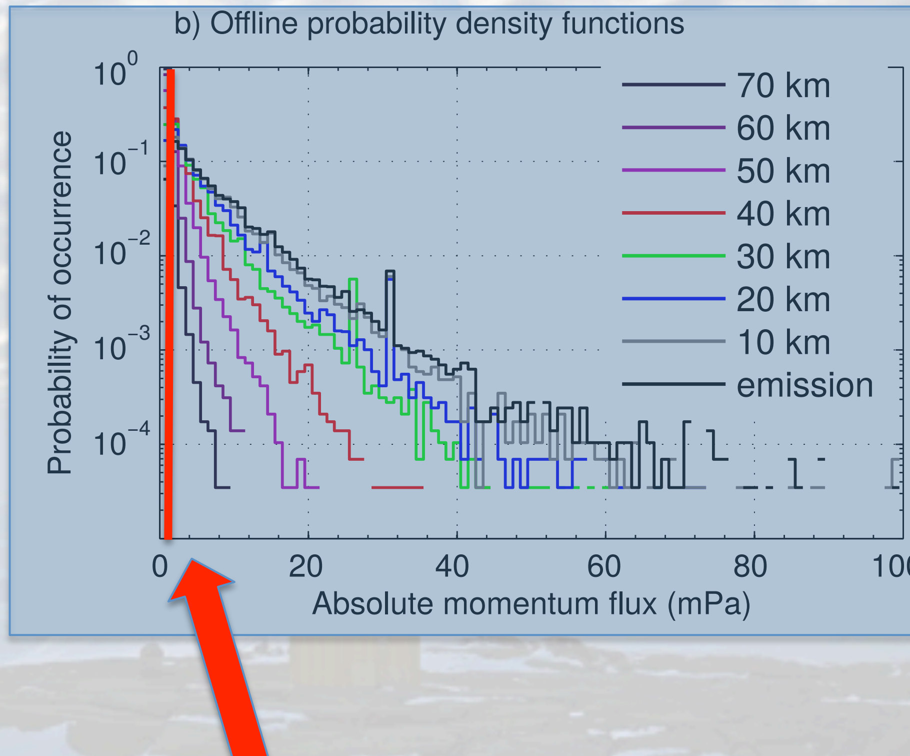
Role of GW momentum flux intermittency

Model experiment: We **remove MF intermittency** in the NGWD parameterization.

With NGW intermittency



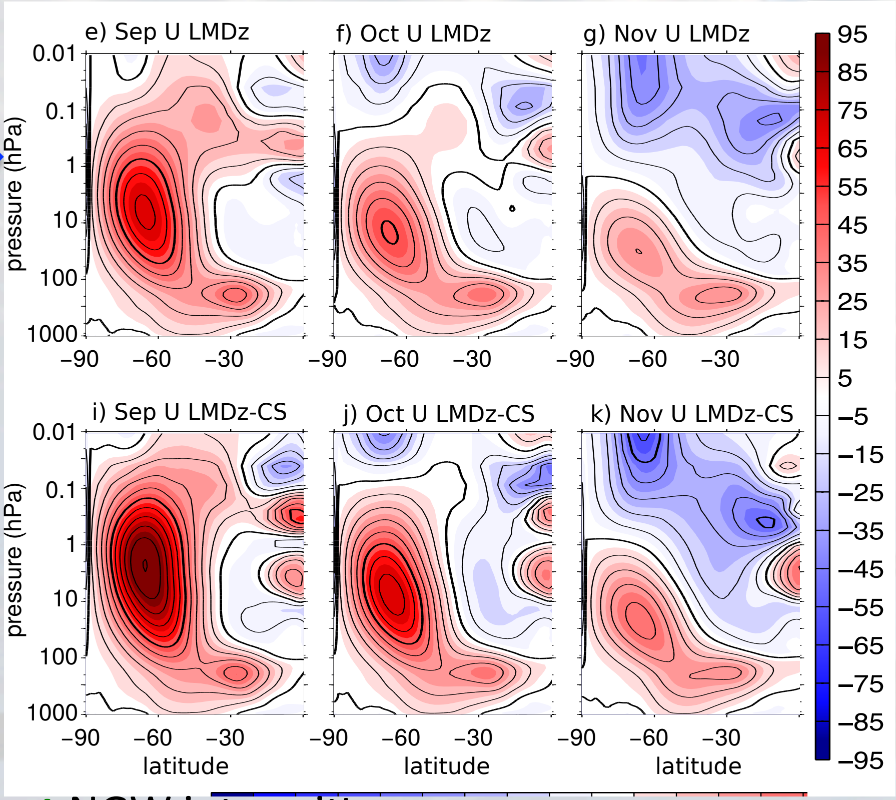
Without NGW intermittency



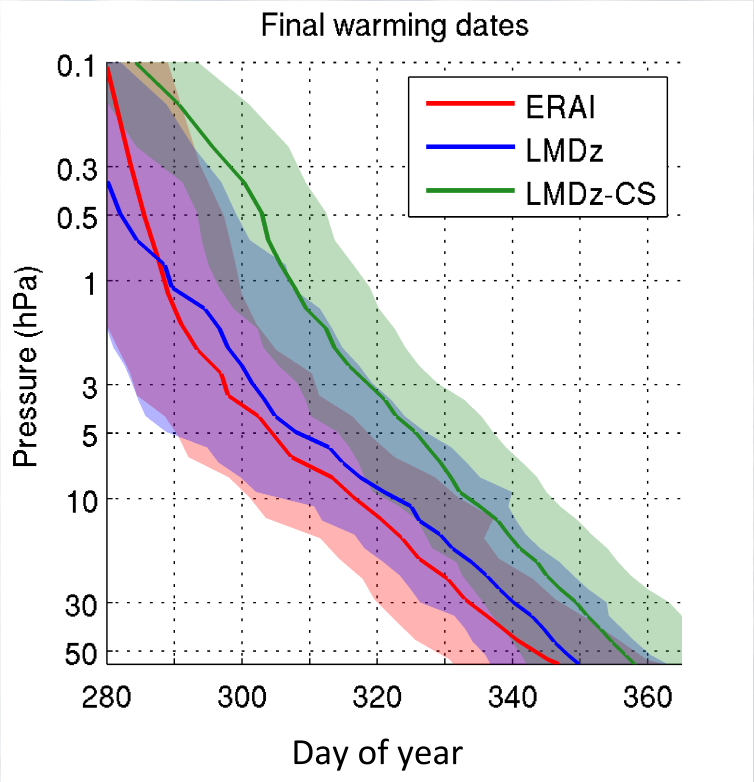
Launched stress = 1 mPa

Role of GW momentum flux intermittency

With NGW intermittency



Without NGW intermittency



Conclusions

- Including **MF intermittency in nonorographic GW** drag parameterizations helps simulating **the SH final warming with a good timing**.

Intermittency via relating the stress to the intensity of the sources:

- Convection: **Lott and Guez (2013, JGR)**
- Jets/front systems: **de la Cámara and Lott (2015, GRL)**

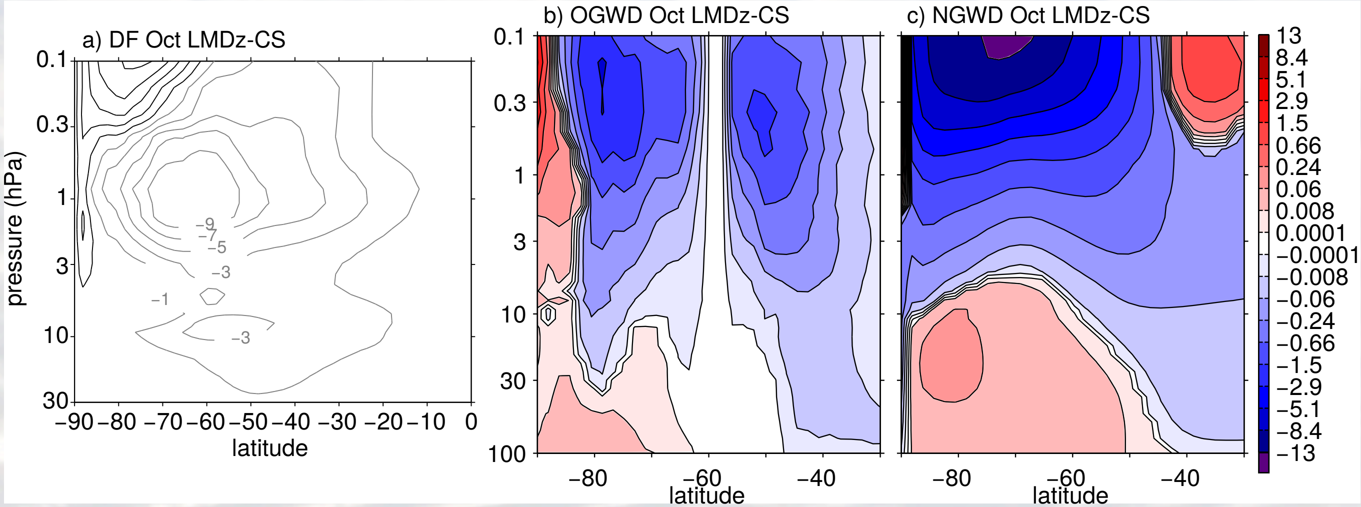
To further explore…

- At 20km height, GW stress 3-5 times smaller than Concordiasi balloon data

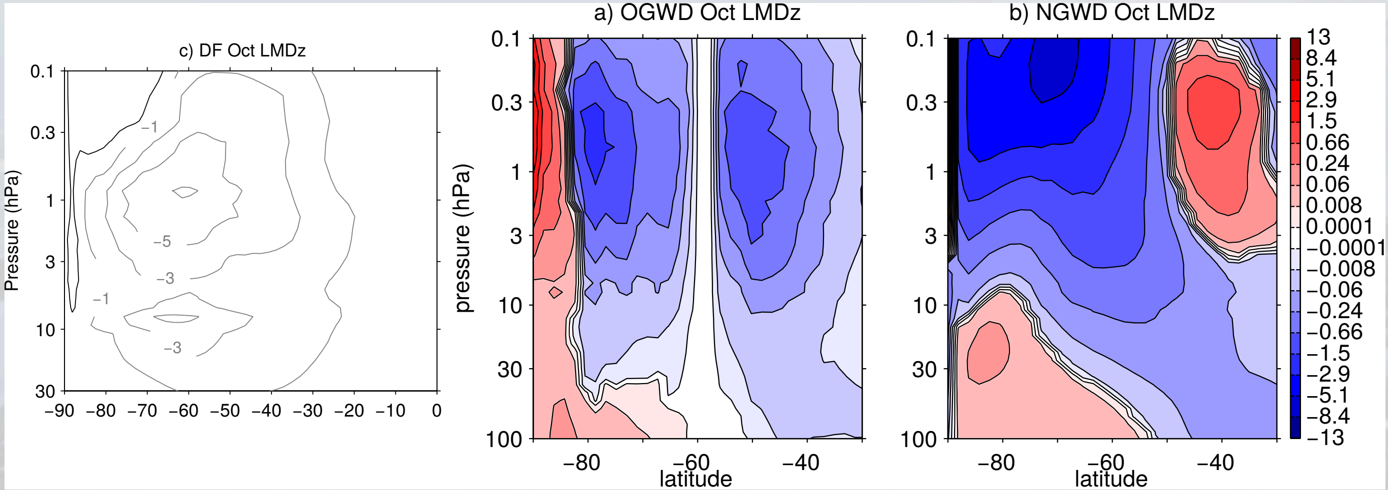
de la Cámara, A., F. Lott, V. Jewtoukoff, R. Plougonven, A. Hertzog (2016), *J. Atmos. Sci.*, doi: 10.1175/JAS-D-15-0377.1, in press.

Extra slide

Without source-induced NGW intermittency:



With source-induced NGW intermittency:

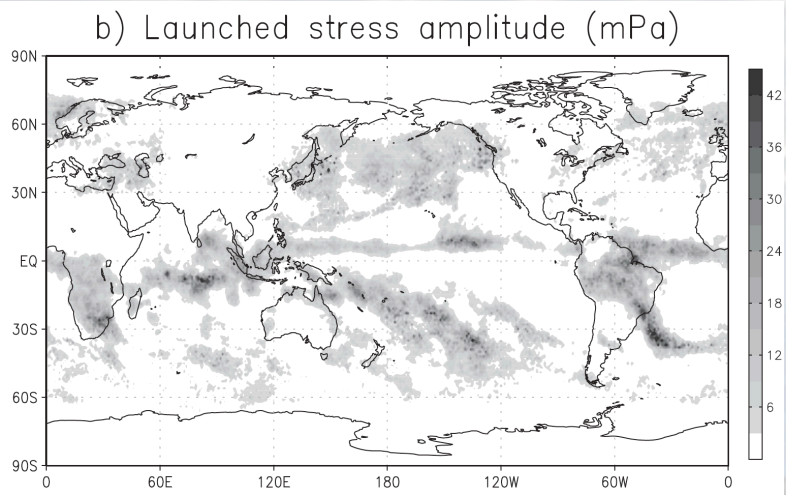


Extra slide

Emitted stress

Convective GW

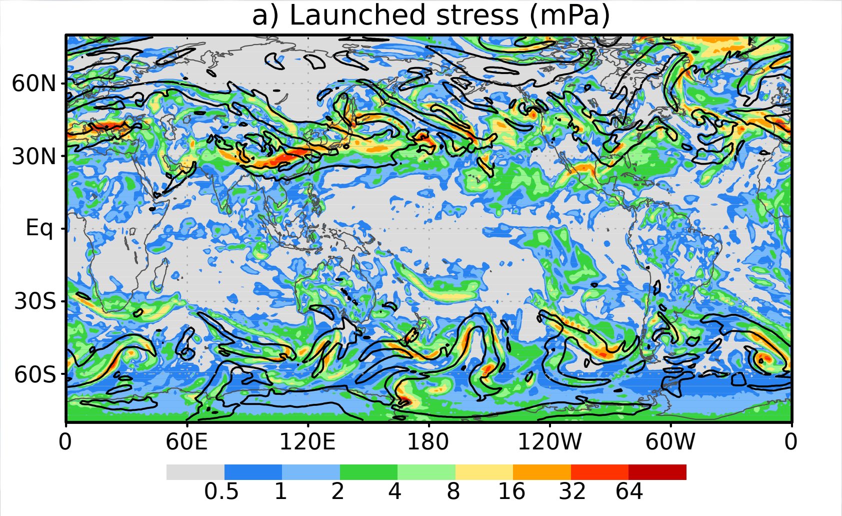
$$F_{zl} \propto precip^2$$



Lott and Guez, 2013 JGR

GW from fronts and jet imbalances

$$F_{zl} \propto \zeta^2 e^{-\pi\sqrt{J}}$$



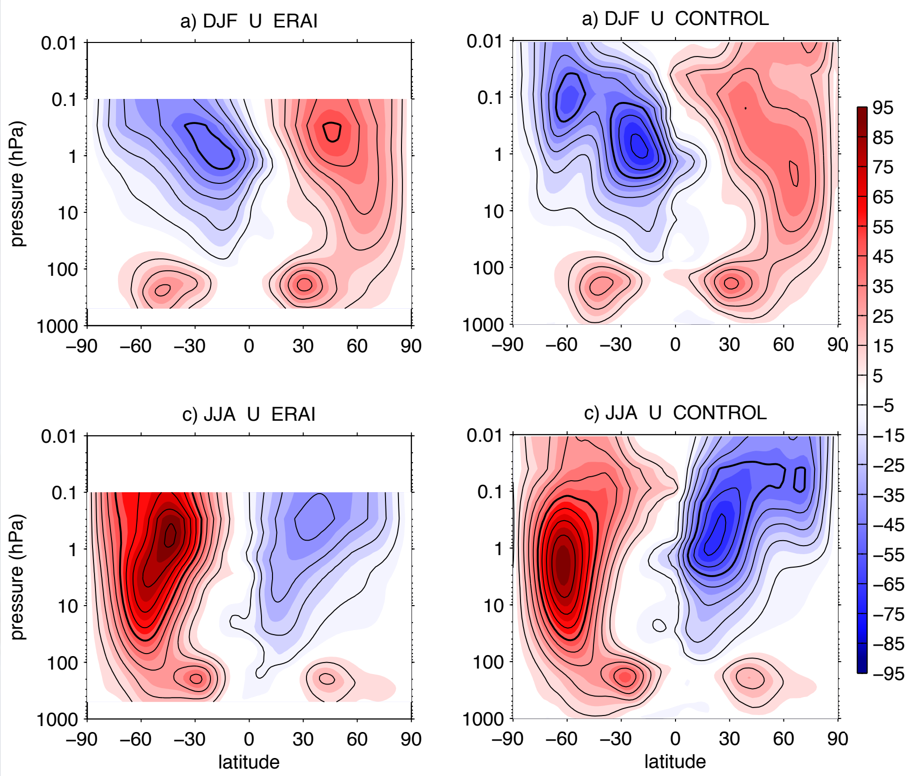
de la Cámara and Lott, 2015 GRL

Extra slide

LMDz GCM, 3.75°lon x 2.5° lat, 72 levels (top at 0.01 hPa)

- Mountain GWs (Lott 1999)
- Convective GWs (Lott and Guez 2013)
- Frontal GWs (de la Cámara and Lott 2015)

Zonal mean zonal winds



Sudden stratospheric warmings in the NH winter