The relation between gravity wave momentum fluxes and background wind speed

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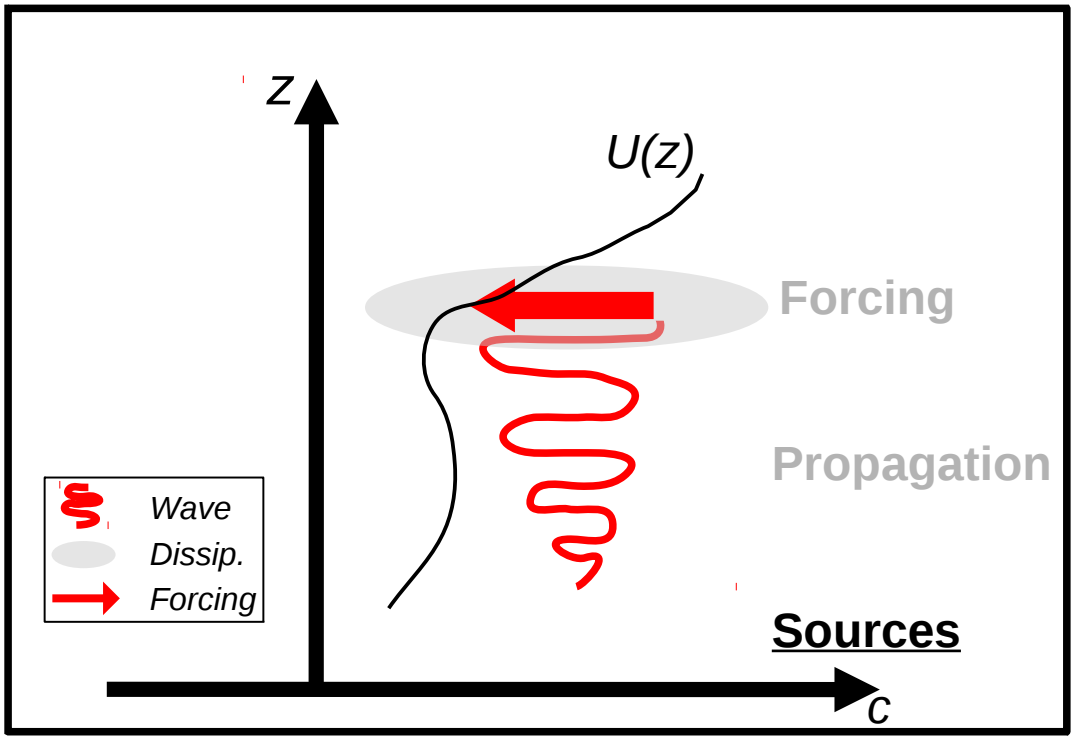
Parameterization framework



Motivations

Aiming to better describe sources of **mid-latitude non-orographic waves**

Looking for **simple, robust** relations between GW momentum flux and the large-scale flow

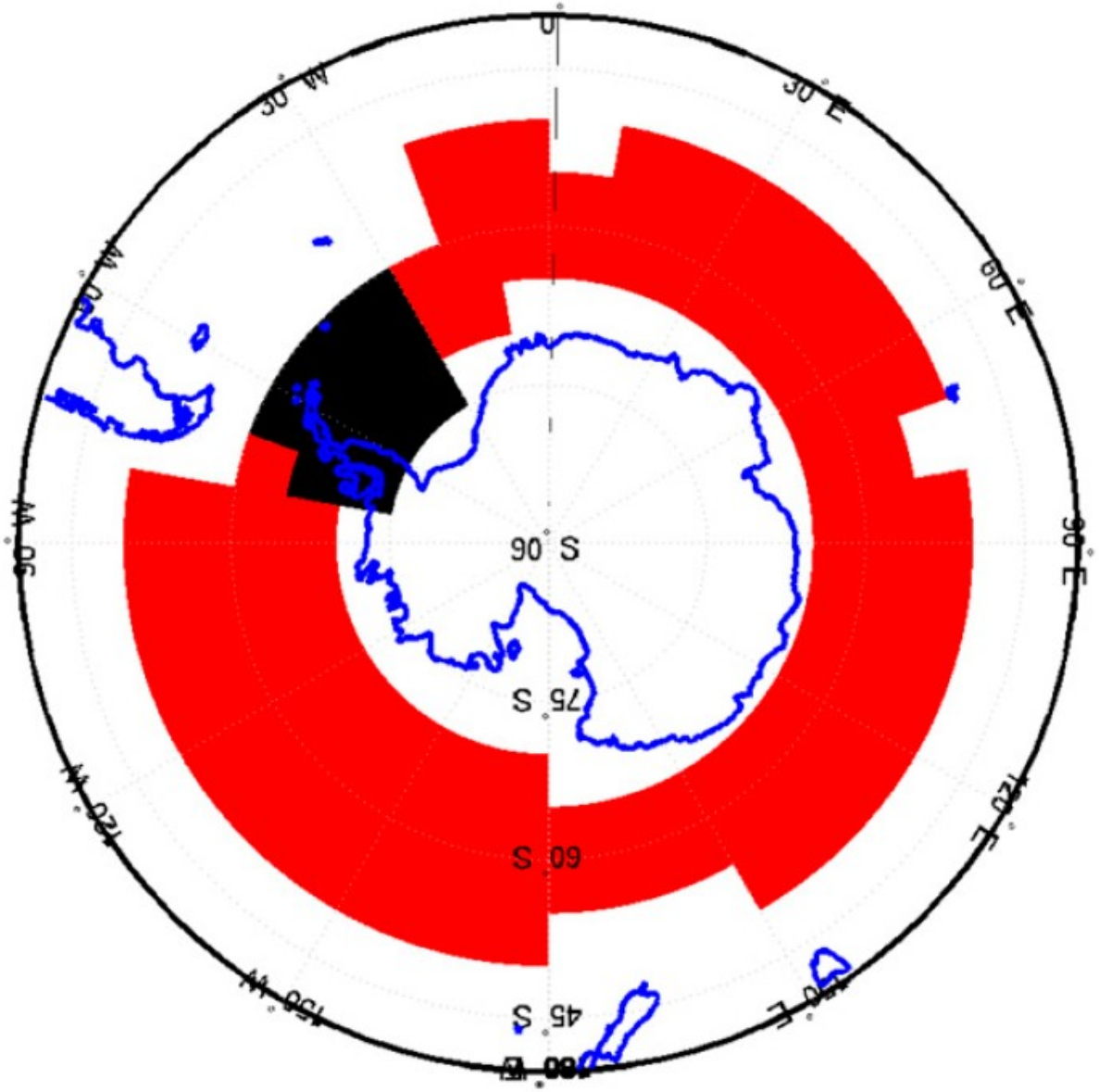
Data

Numerical **simulations** in parallel of stratospheric **balloon campaigns** around Antarctica

NB : only non-orographic waves

Over ocean, red region below

Plougonven et al 2013, Jewtoukoff et al 2015



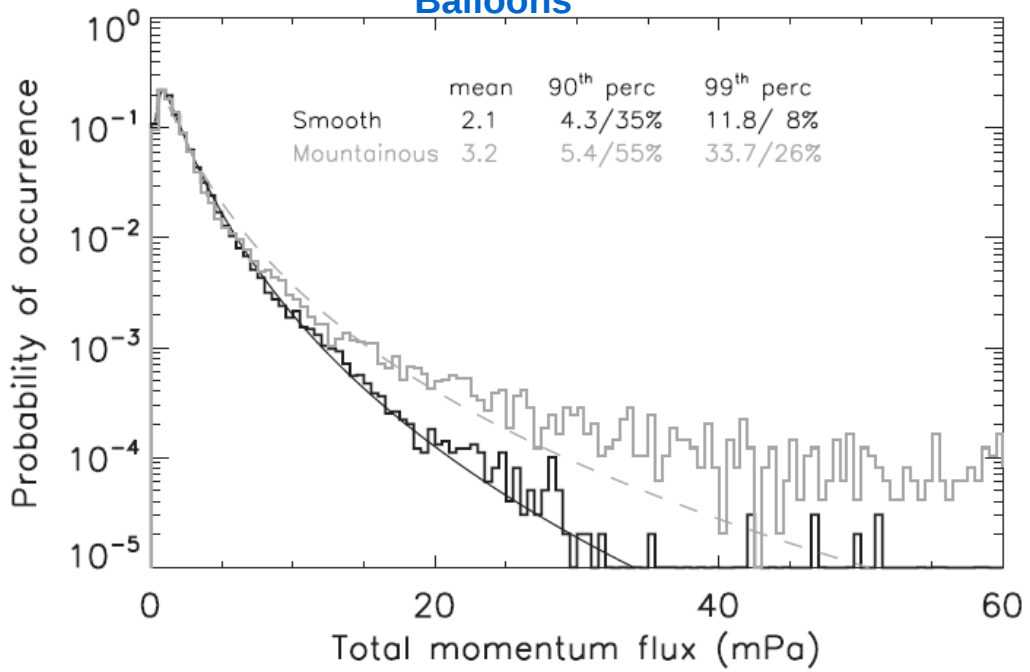
Approach

GW are intermittent → useful to describe their **Probability Distribution Function** (PDF)

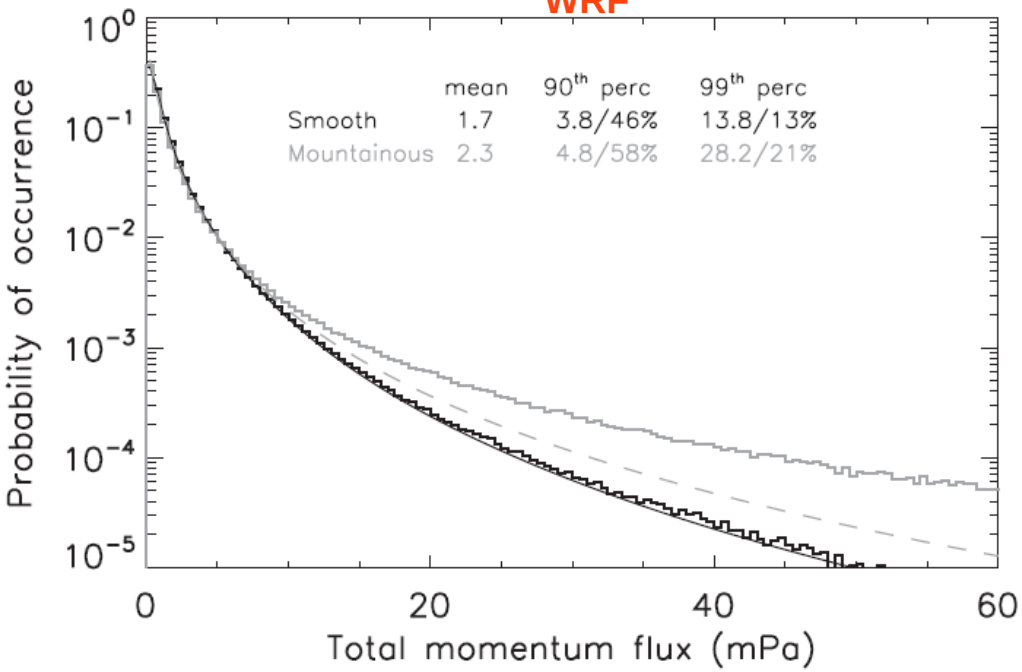
Non-orographic waves follow a **lognormal** distribution

Alexander et al 2010, Hertzog et al 2012

Balloons



WRF

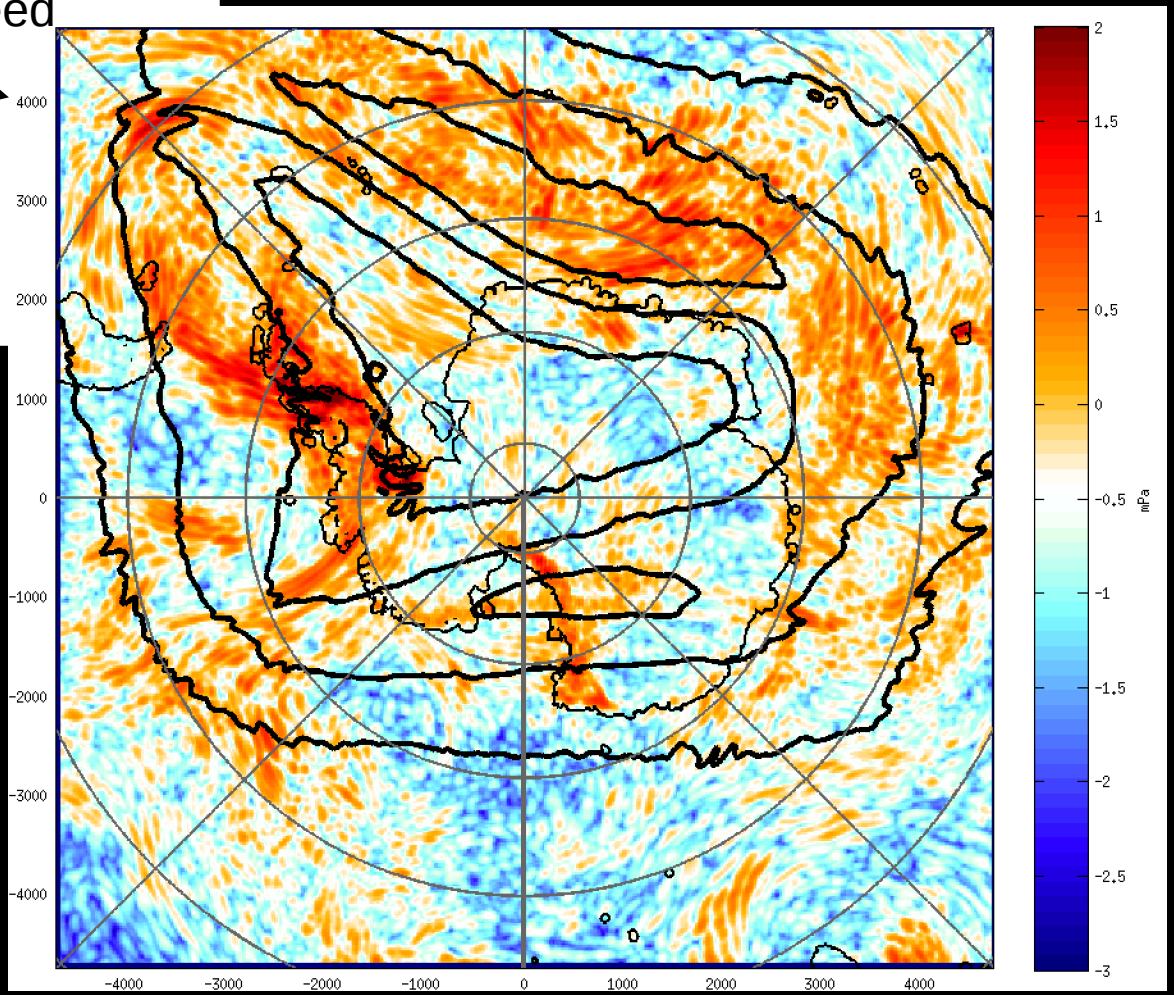


1. WRF simulations

Dx = 20 km, 2 months :
Oct. 2005 → Dec. 2005

Example of a snapshot of absolute GW mom. flux at z=20km (logarithmic scale), and wind speed (c.i. 20 m/s)

Larger values of GW mom. flux seem more likely in the jet

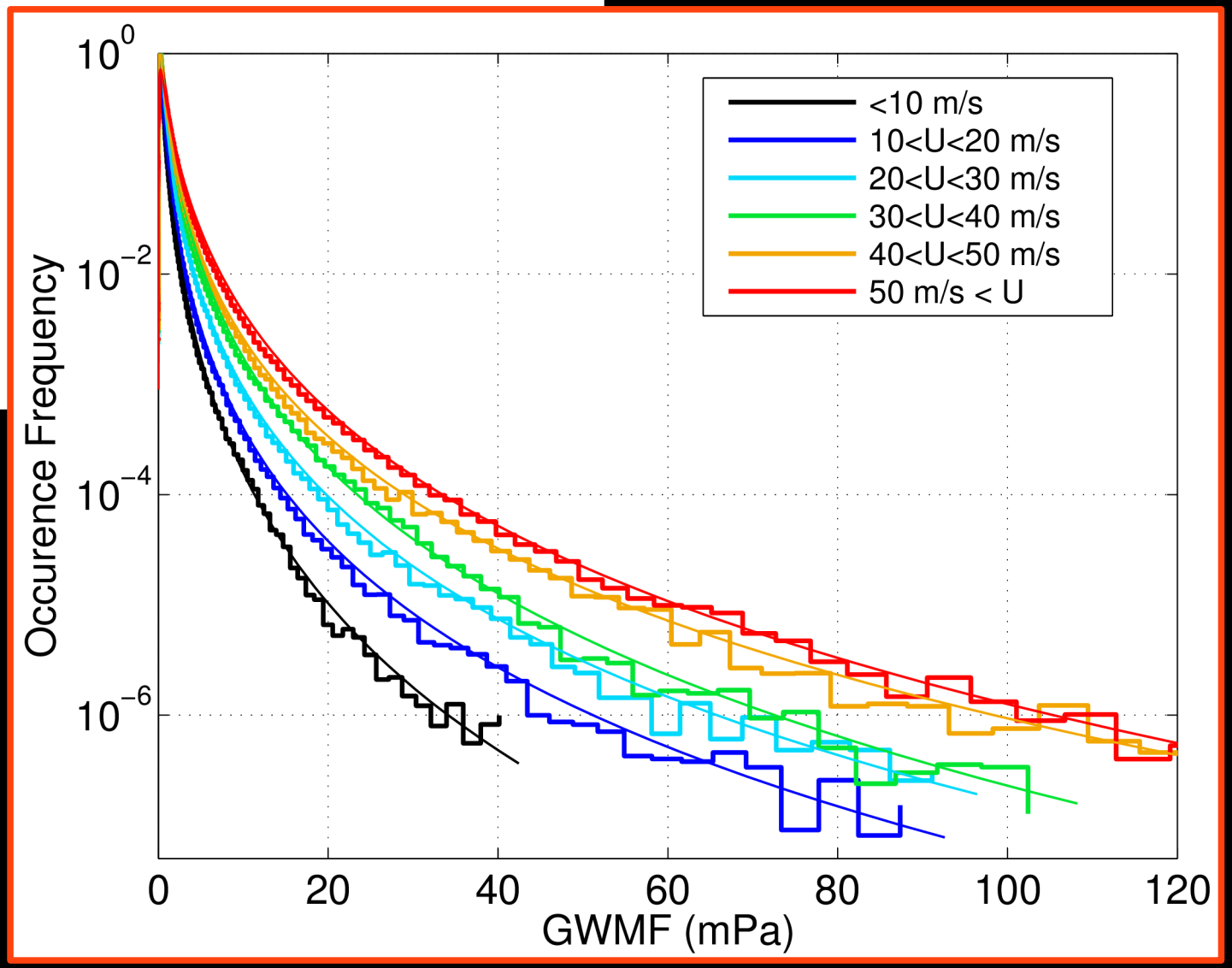


Is the PDF of the GW momentum fluxes sensitive to the local background wind ?

→ plots of the **PDFs conditional on the background wind**
(|U| < 10 m/s,
10 < |U| < 20 m/s, ...)

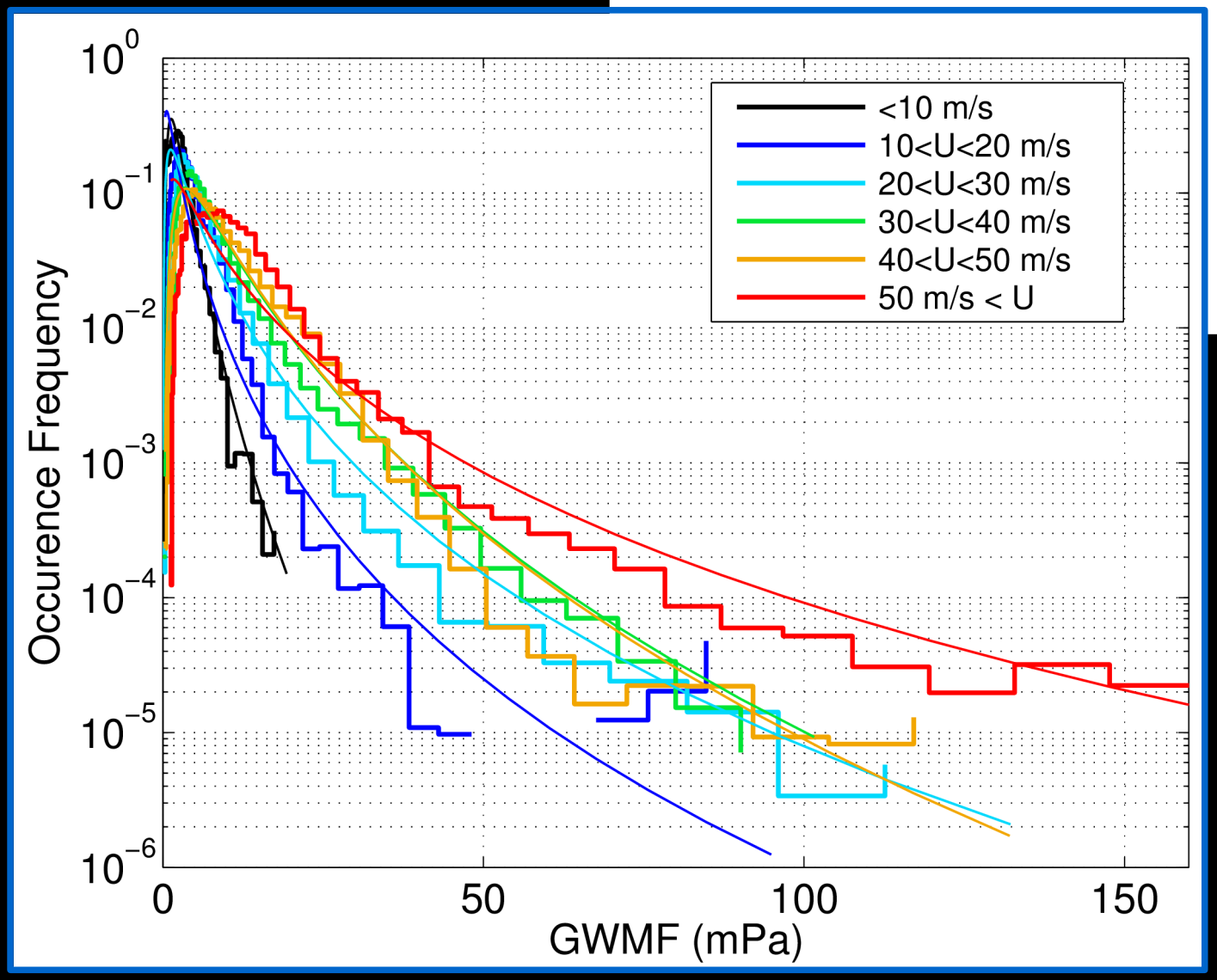
1.a WRF simulations

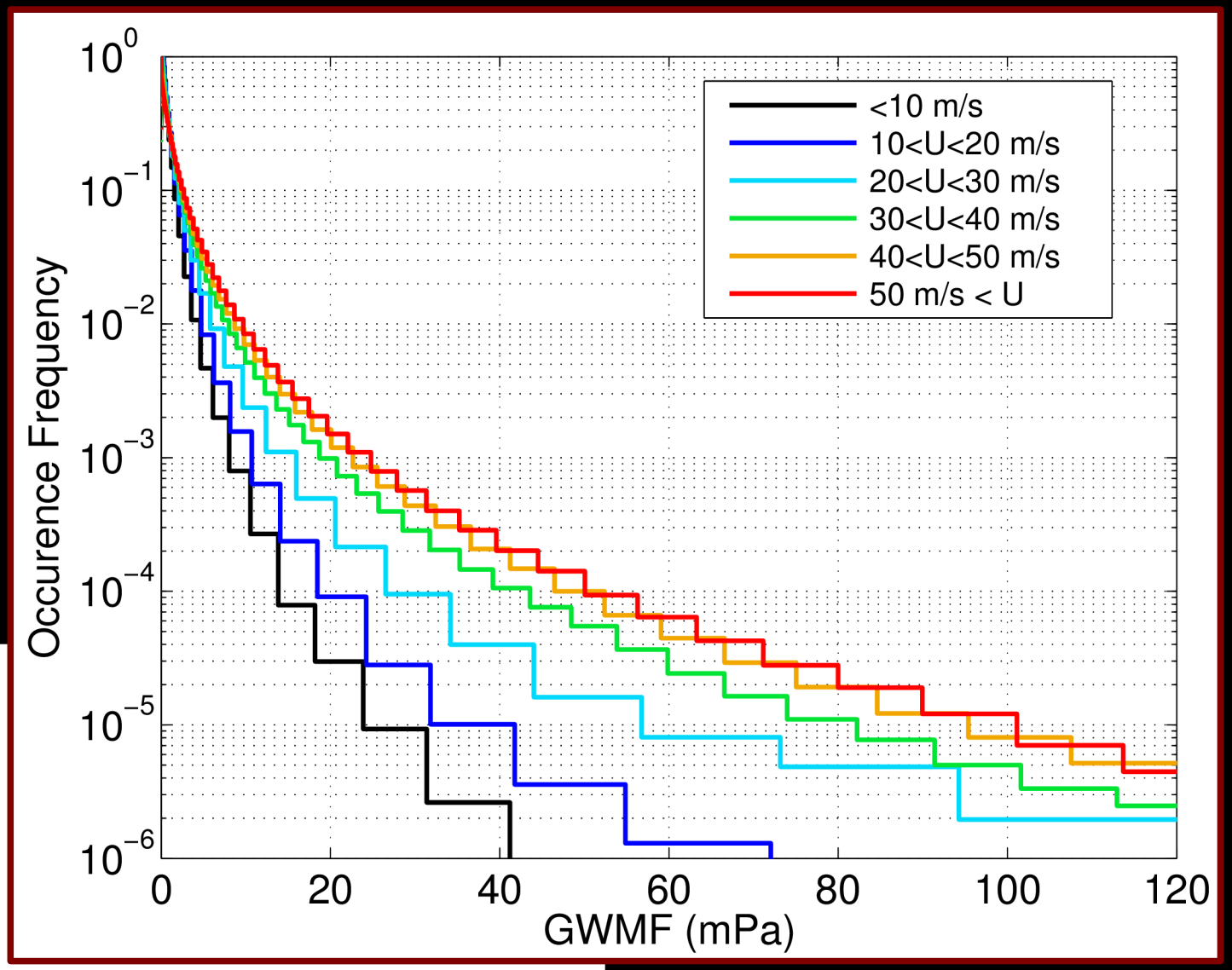
PDFs very sensitive to knowledge on the background wind



1b. Concordiasi superpressure balloons

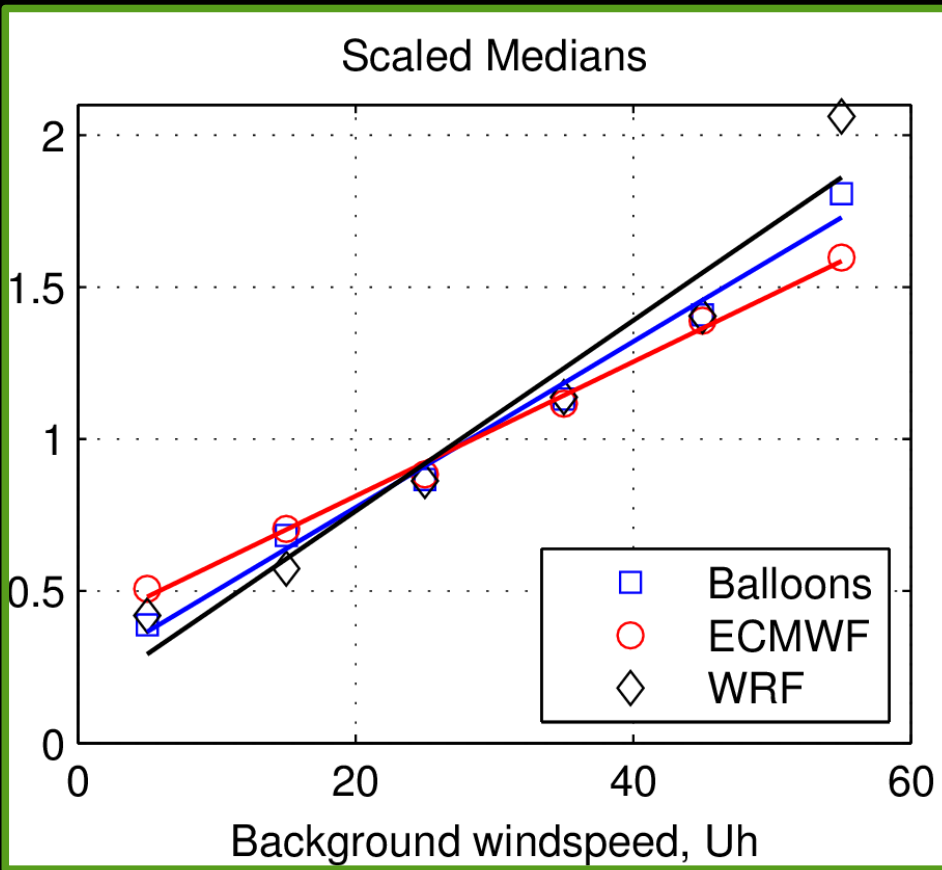
2010 – austral spring
Very Good time resolution → Whole spectrum of GW

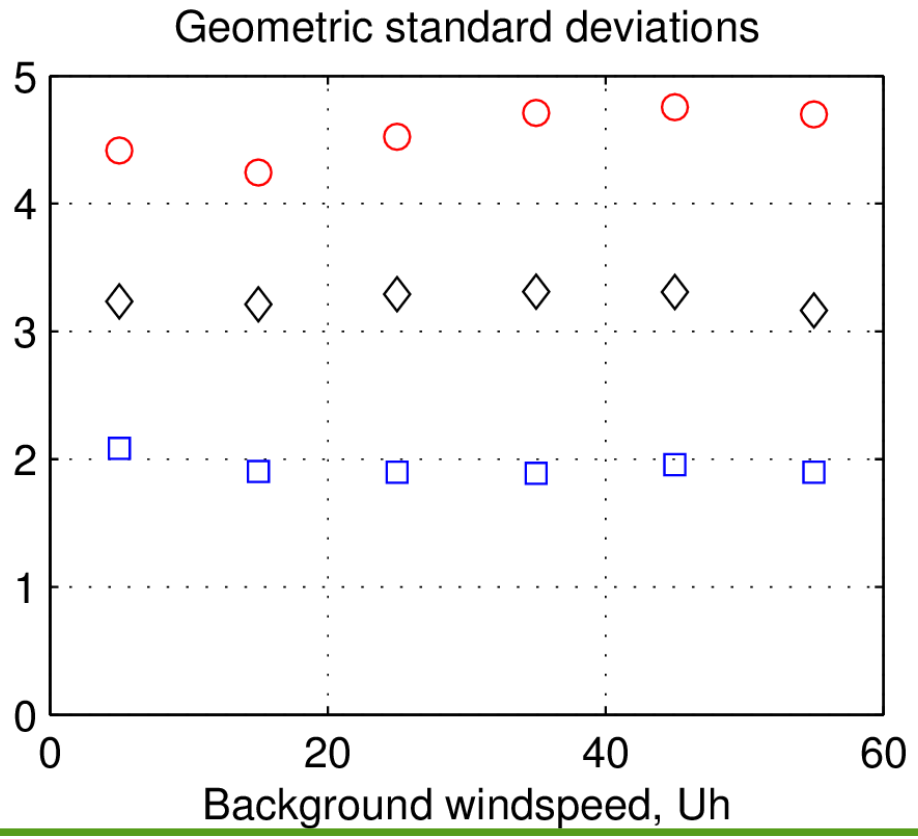




1.c ECMWF analyses

2010 – austral spring
Good agreement found with Concordiasi balloons (*Jewtoukoff et al 2015*)



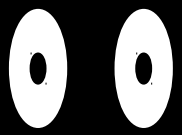


1.d Summary

Knowledge of **local wind *U*** significantly **constrains the PDF** of GW mom. Fluxes

Robust across three very different datasets

Can be summarized by the median flux as a function of *U* **(~4 times larger fluxes for U > 50 m/s than U<10 m/s)**



2. Interpretation

Candidate processes :

a. Co-location of sources and stratospheric jet

b. Shear as a source of waves *(Lott et al 2010, 2012)*

c. Wind filtering

d. Lateral propagation *(Dunkerton 1984, Sato et al 2009, 2012, Senf & Achatz 2011)*

Approach :

Use existing data (output from WRF and ECMWF) to

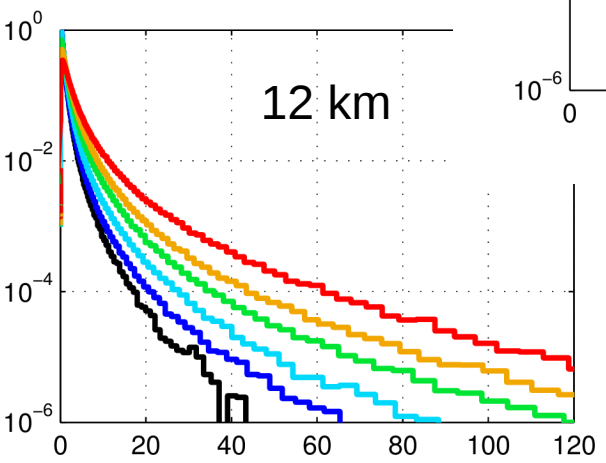
+ further investigate the relation between GW mom. fluxes and local wind
  e.g. variation with height

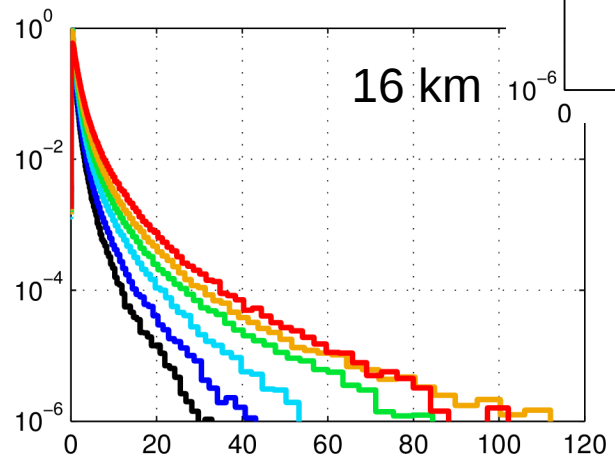
+ test implications of processes above

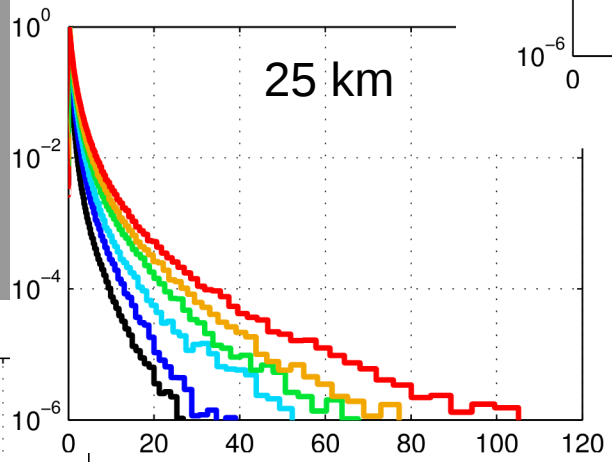
Fluxes in general decrease with height, as expected

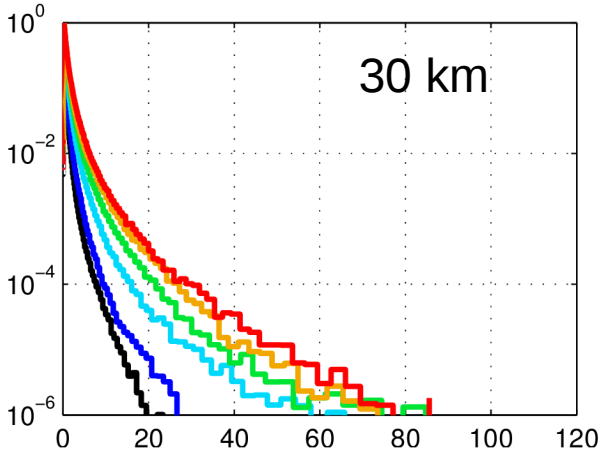
(Hertzog et al 2012, Geller et al 2013)

Relation to local wind present at all levels



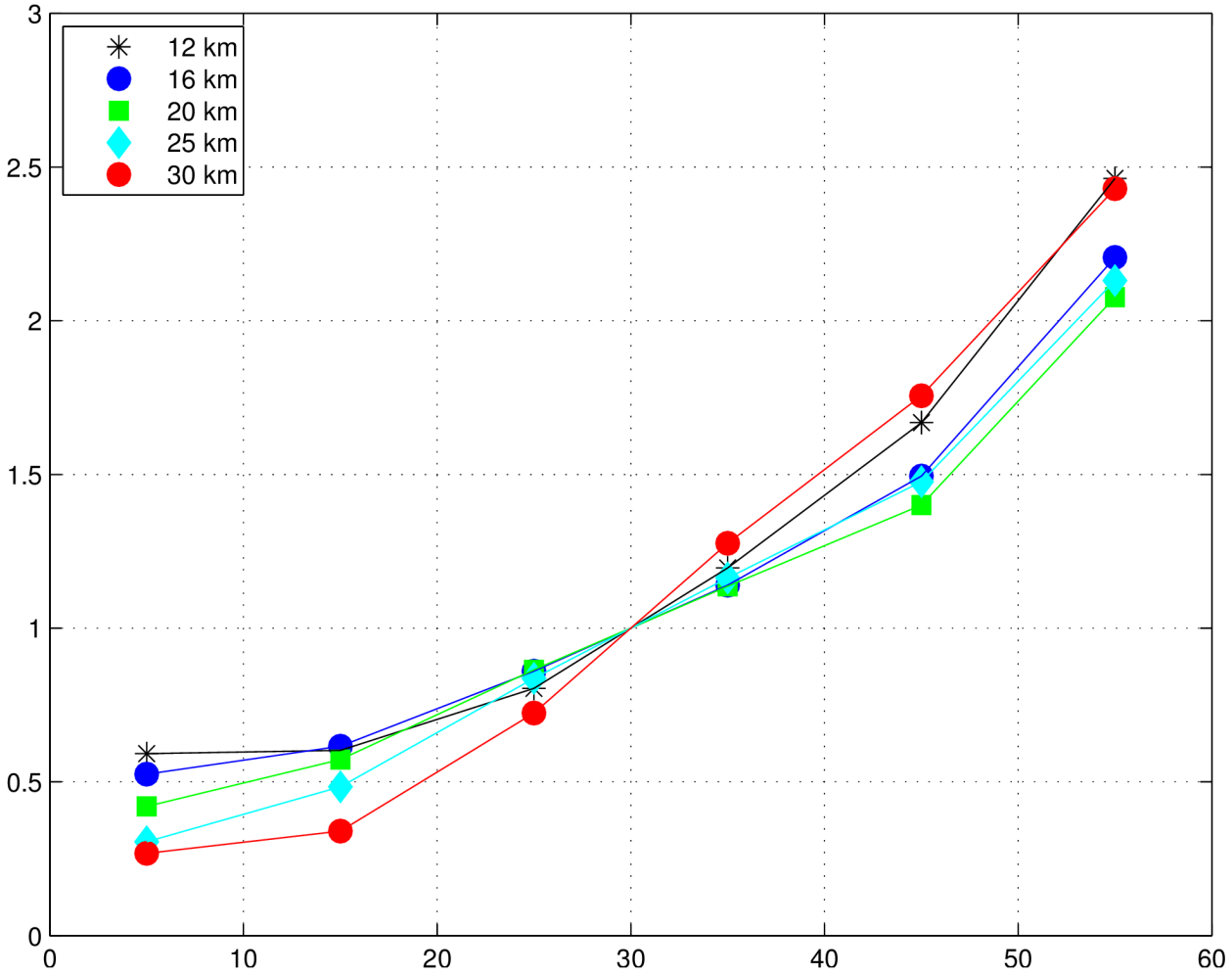






WRF simulations

Summary : variation of the median fluxes relative to *U*, at different heights



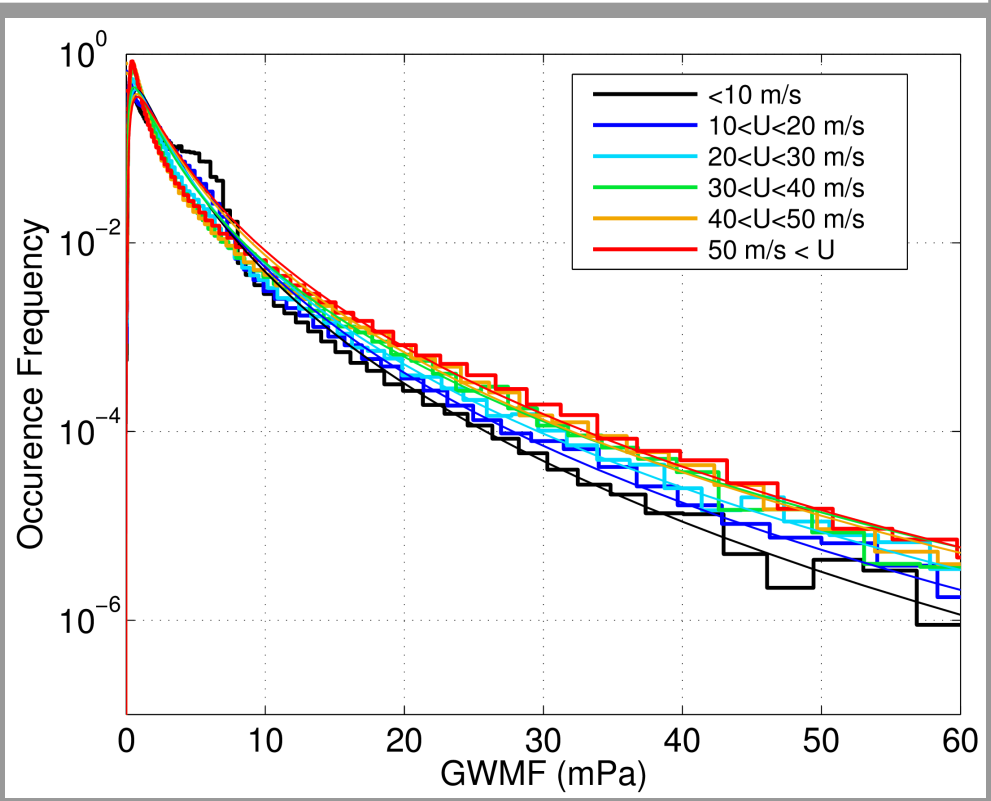
Similar overall,
stronger at 30 km altitude than at 20 km

Similar for ECMWF output

Is the relation present in a parameterization of gravity waves ?

Tested with the **LMDz parameterization run offline**, for which the sources are stochastic and tied to the tropospheric flow (Lott et al 2010, 2012, 2013, de la Camara et al 2014, 2015)

Standard phase speeds



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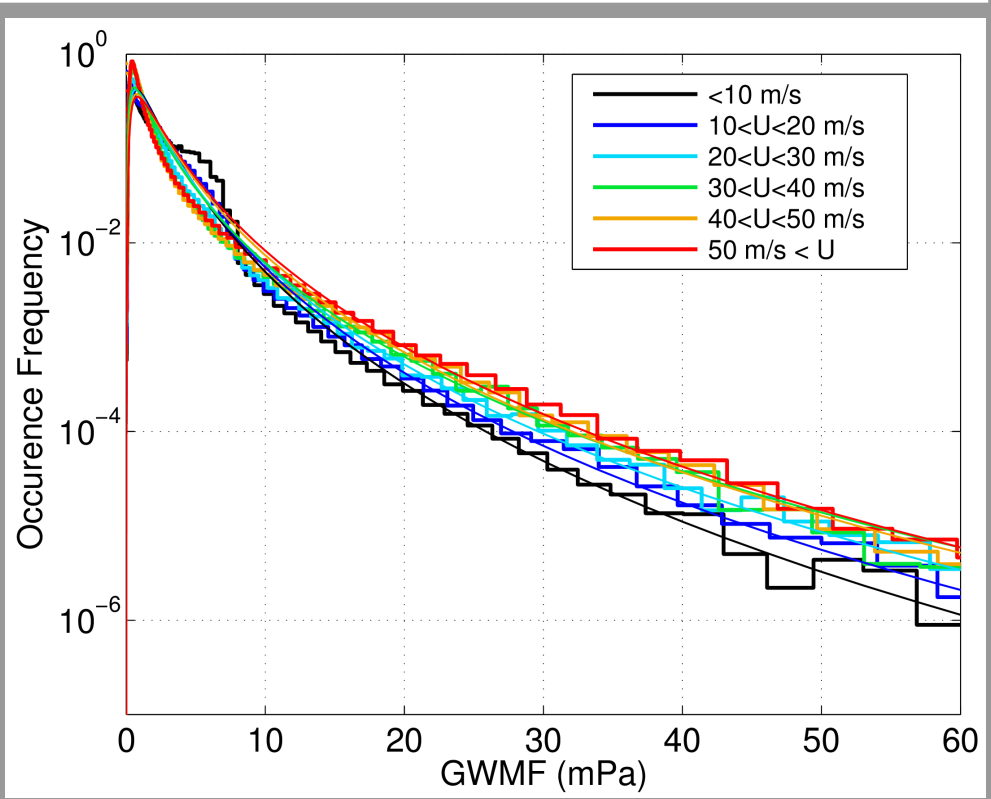
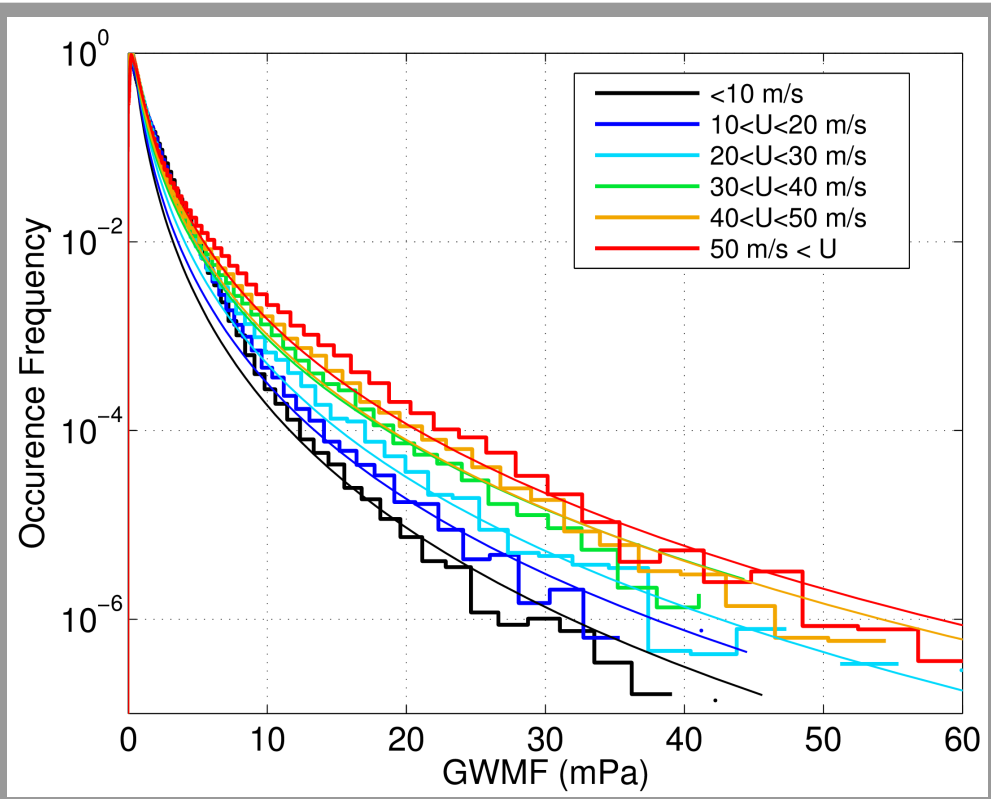


Phase speeds / 4

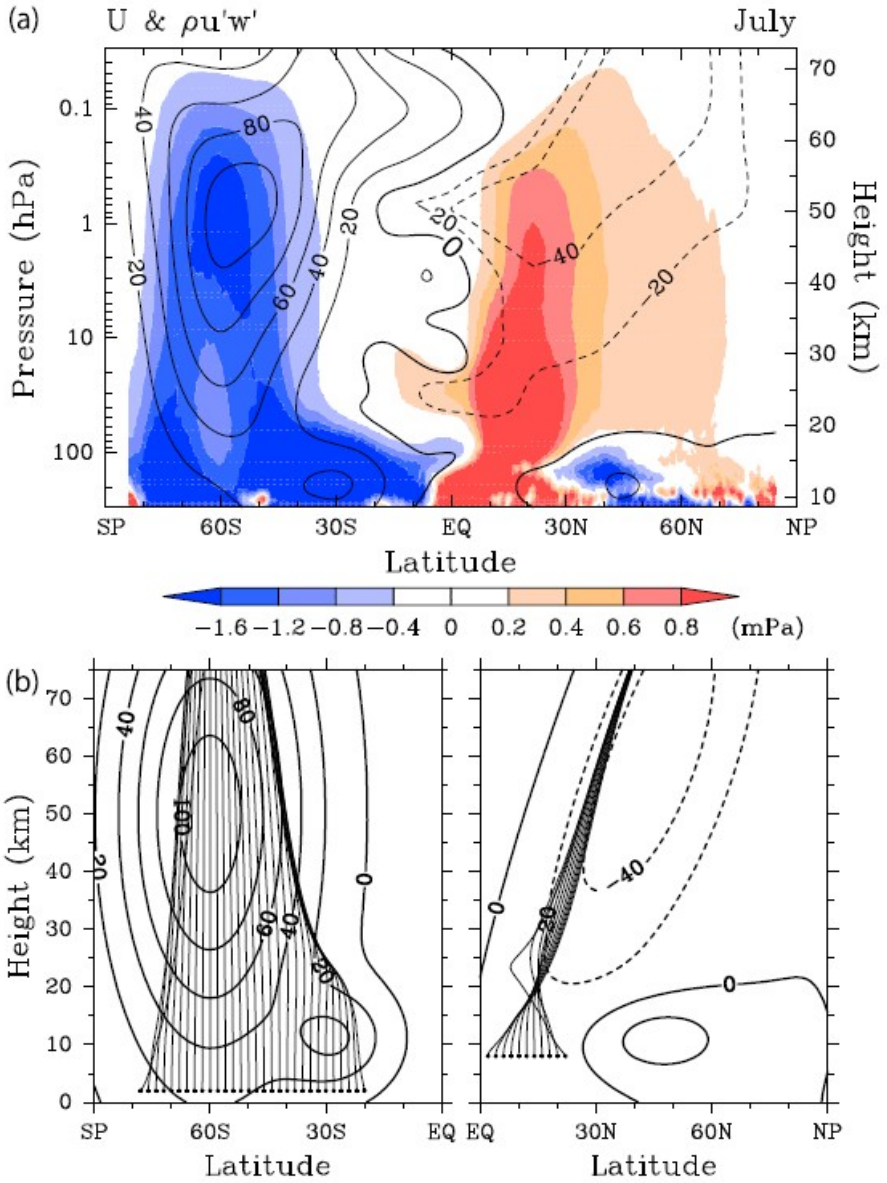


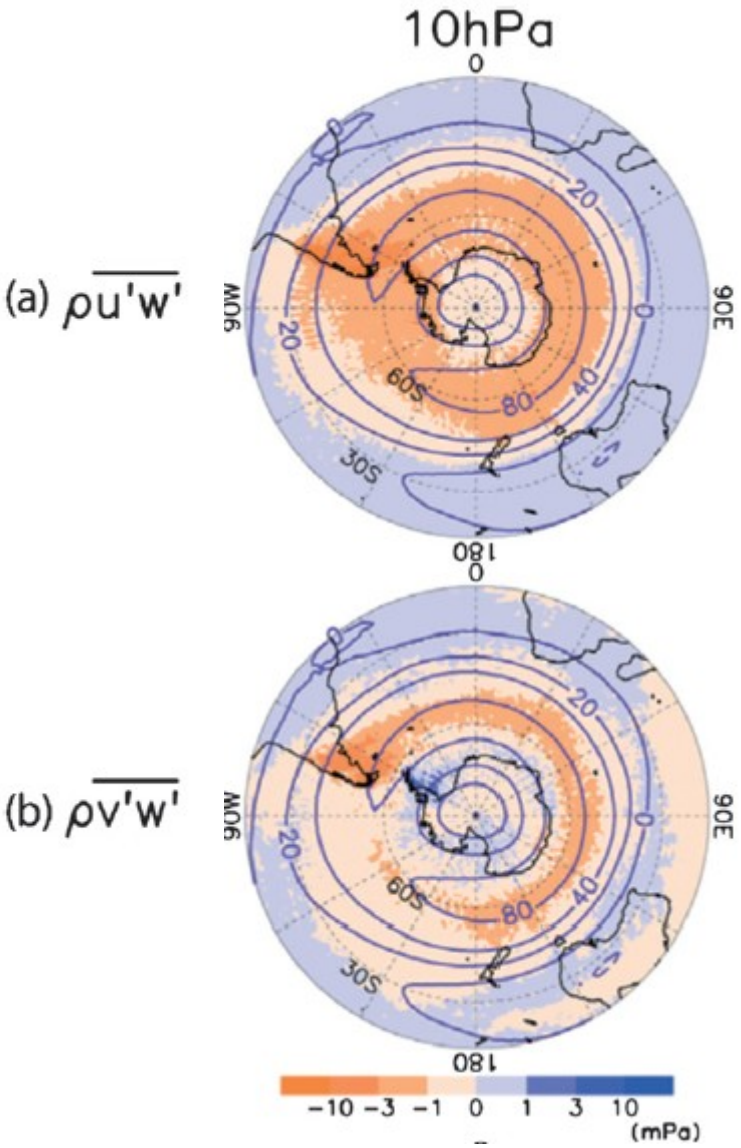
Parameterization can only reproduce the relation at the price of a very strong (unrealistic) change in GW characteristics

Evidence for lateral propagation

Lateral propagation has been known for long and stressed before

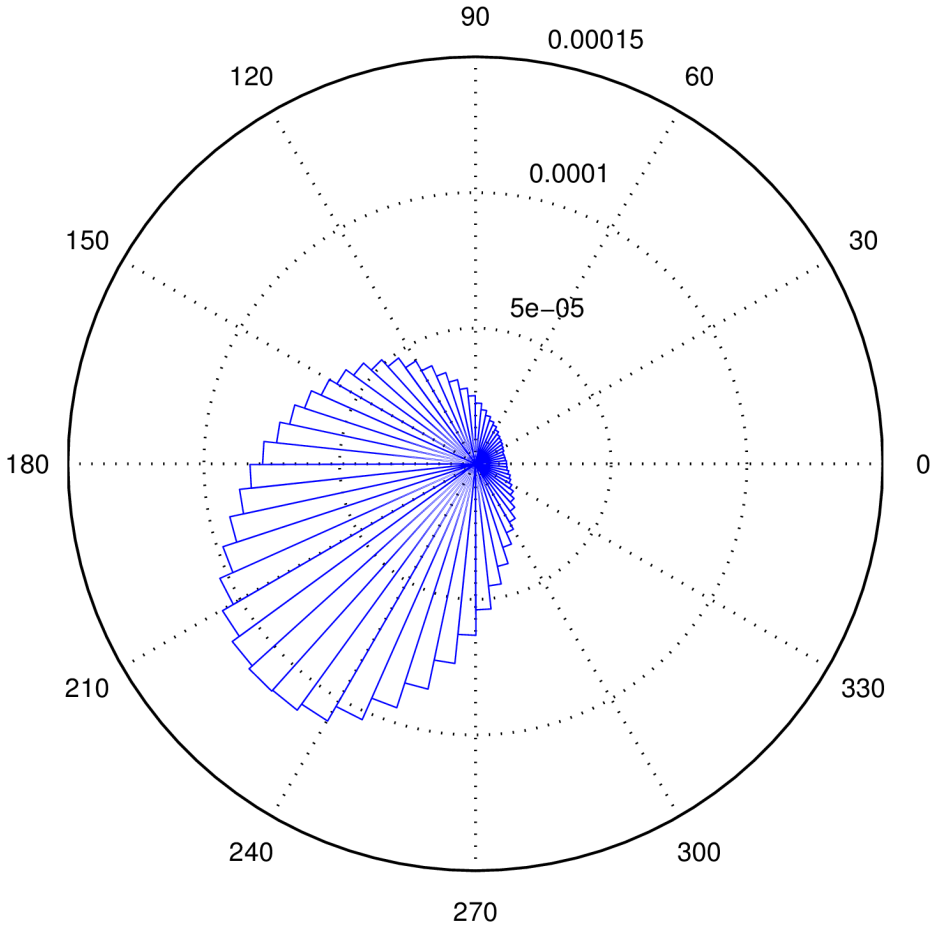
Dunkerton 1984, **Sato et al 2009, 2012**, Senf & Achatz 2011



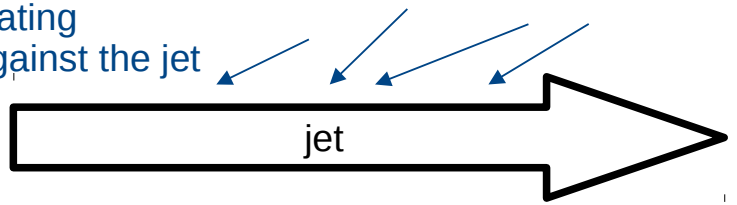


Further evidence for lateral propagation :

PDF of the orientation of momentum fluxes relative to the local wind, at z = 20 km.



GW propagating
poleward against the jet



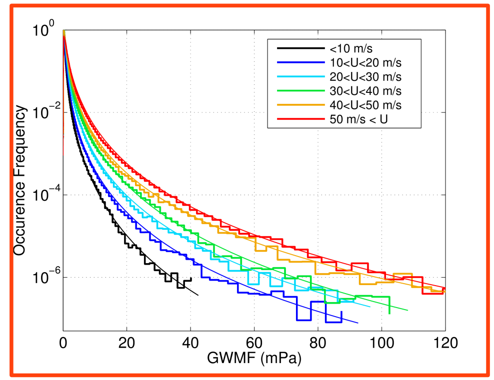
Conclusion, discussion

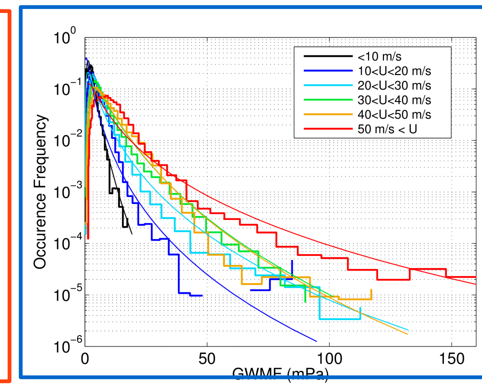
Non-orographic GW mom. fluxes larger where wind is stronger

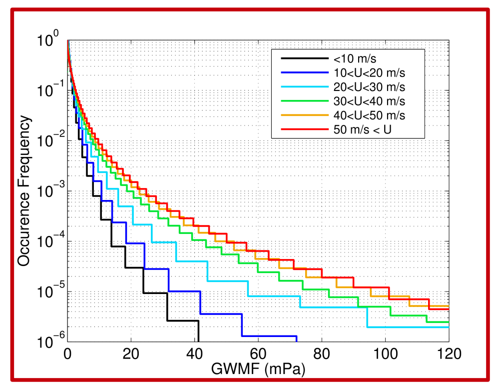
Valid at least for **10 < *z* < 30 km**

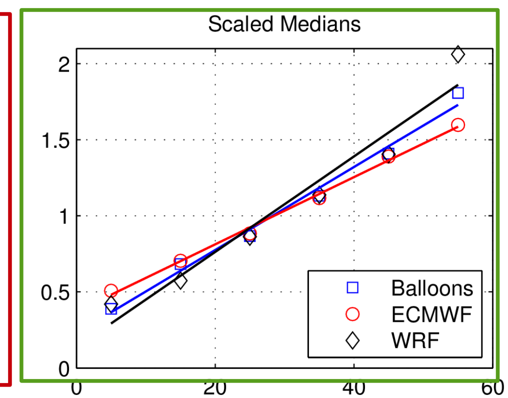
Robust : found in 3 v. different datasets (WRF, Concordiasi balloons, ECMWF)

Median for *U* > 50 m/s is ~4 times larger than for *U* < 10 m/s.









Interpretation

Several processes active to produce this relation :

Upper-tropospheric sources are tied to the jet

Lateral propagation

Significant information is known on likely GW from the knowledge of the local wind speed

Simple relation probably **not captured by parameterizations**

Implication

How high, on the list of priorities for improving GW parameterizations, should lateral propagation be ?

How important is lateral propagation ?

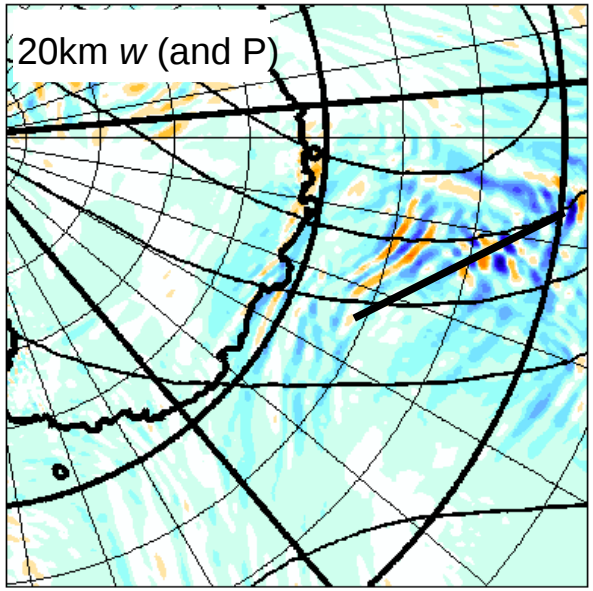
Does the omission of lateral propagation affect the climatological winds ? The variability ?

What intermediate solutions could be thought of, not requiring much communication between columns in a parallelized code ?

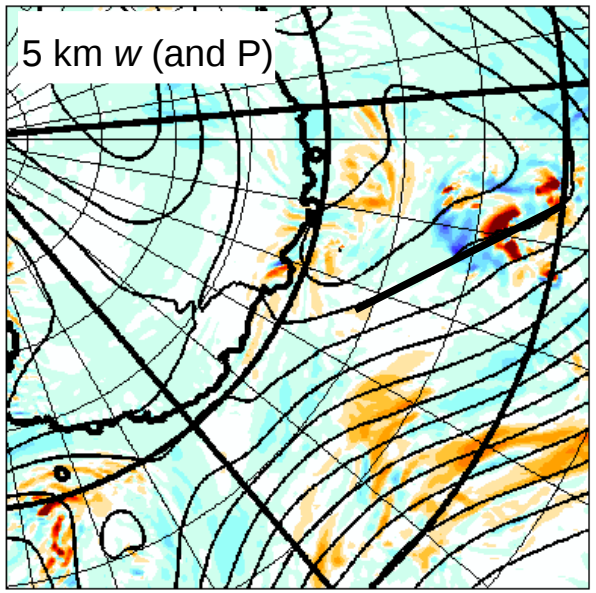
Thank you for your attention.

A preliminary remark :

Waves emitted from jet-front systems are complicated (cf Monday morning's talks)
Role of moisture emphasized, but also strong winds

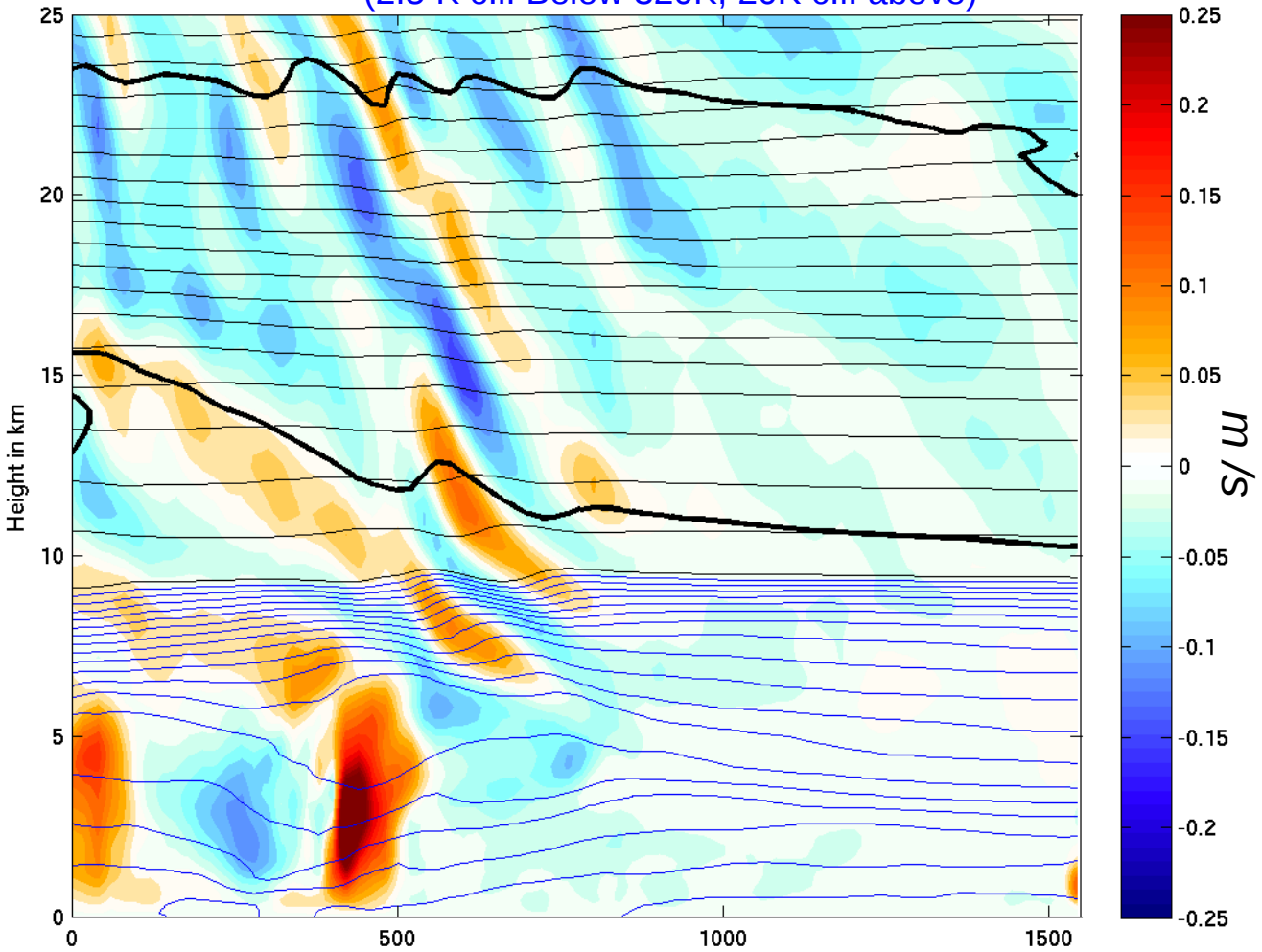


November 15, 2005, 06:00



w, wind speed (35 *m/s* isotach) and θ

(2.5 K c.i. Below 320K, 20K c.i. above)



Plougonven et al 2015

Expectations :

0. In the upper-troposphere
In fact, GW mom. fluxes are expected, at tropopause levels, to show such a relation to the local wind because the upper-trop. jet is a major source

1. In the stratosphere

a. Co-location of sources and stratospheric jet :
- relation should decrease with height
- stronger relation to tropospheric indicators of sources

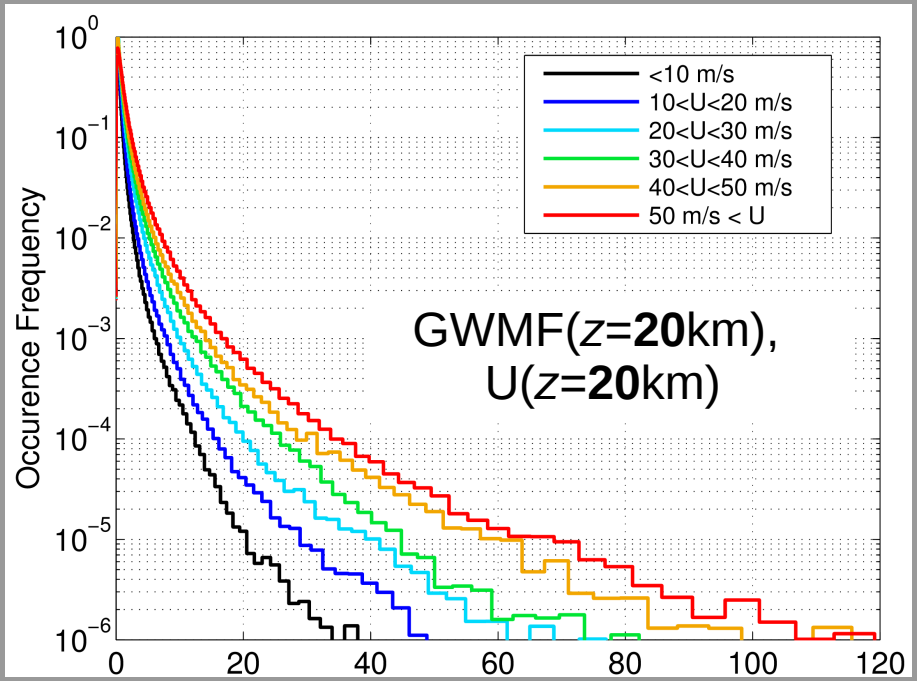
b. Shear as a source of waves :
- stronger relation using shear

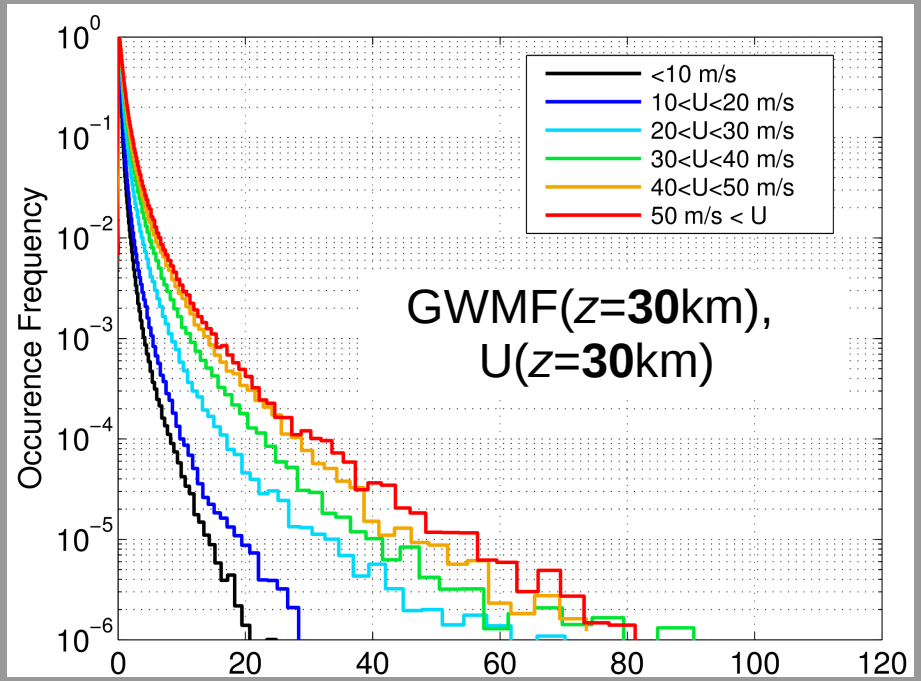
c. Wind filtering :
- relation should increase with height

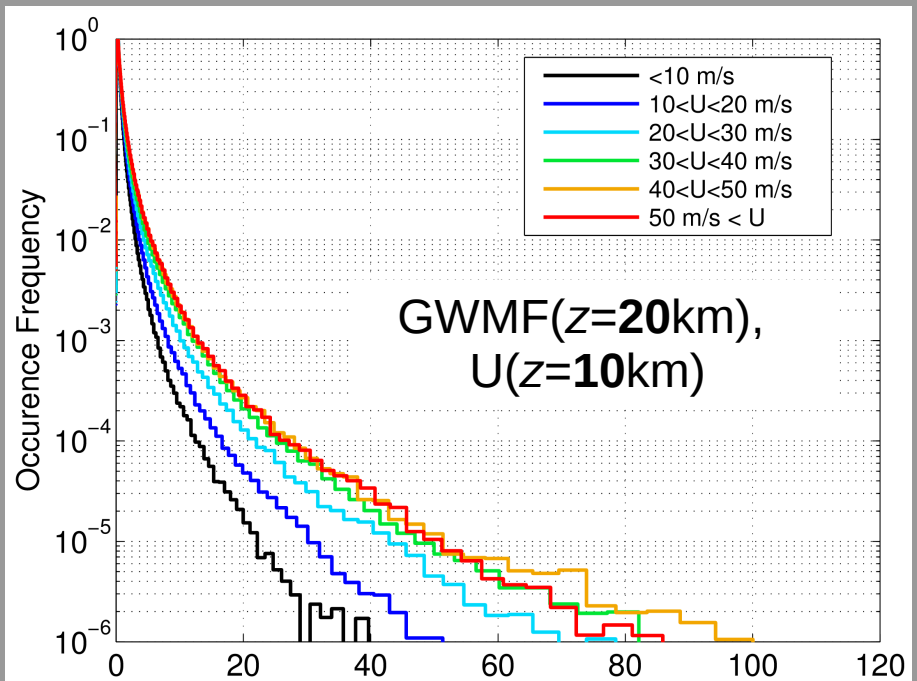
d. Lateral propagation :
- relation should increase with height

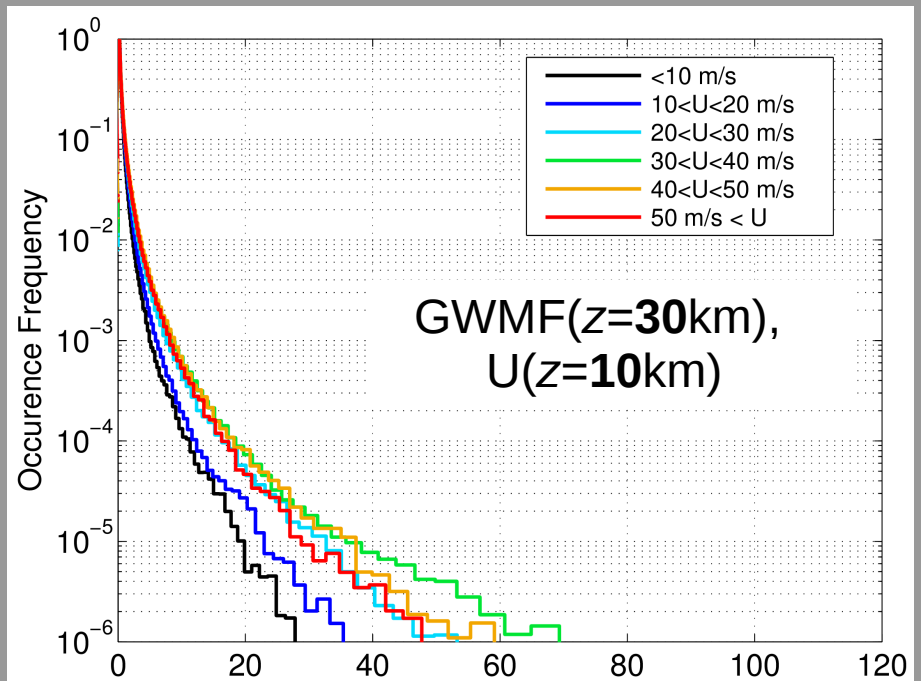
Simply a co-location of sources and stratospheric jet above ?

No.

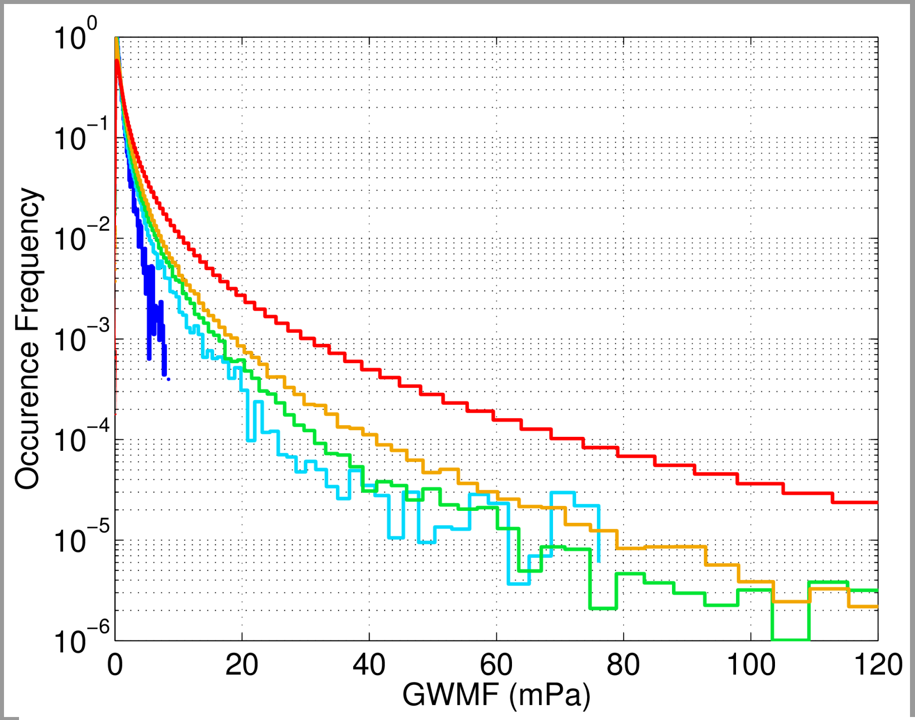


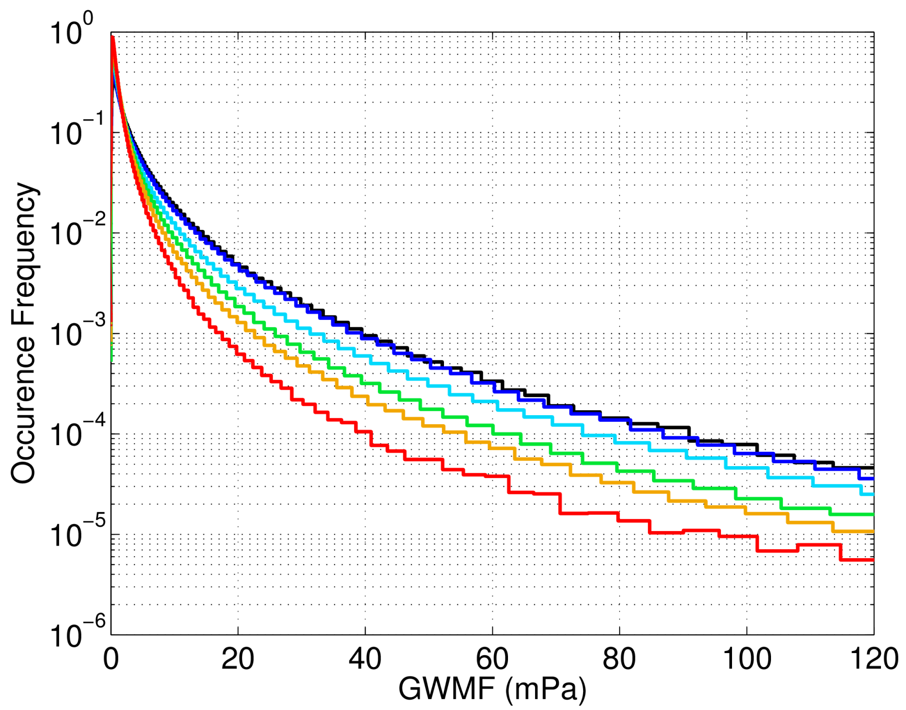


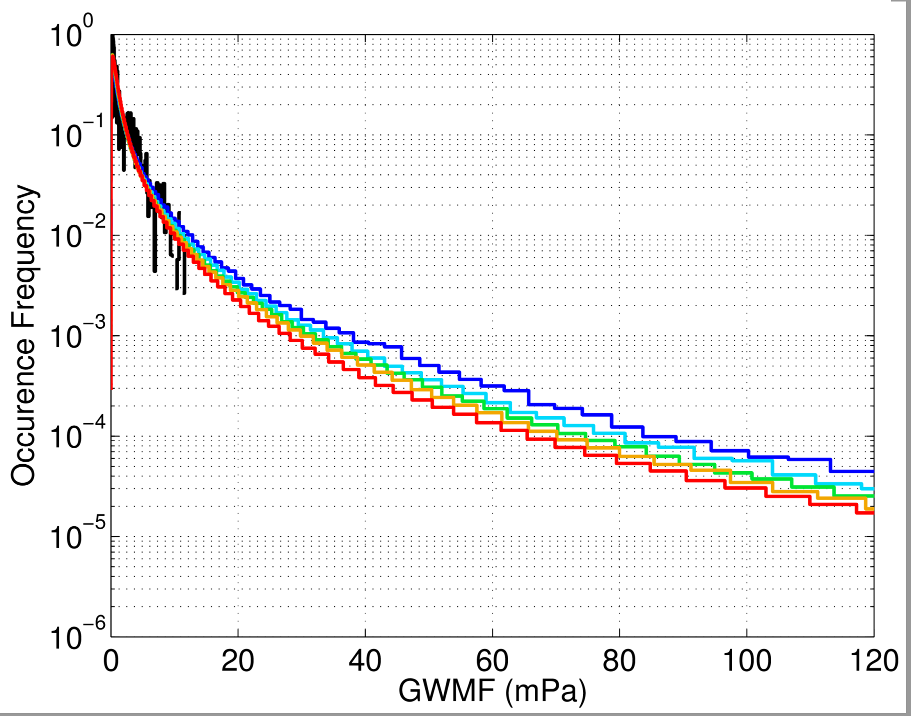




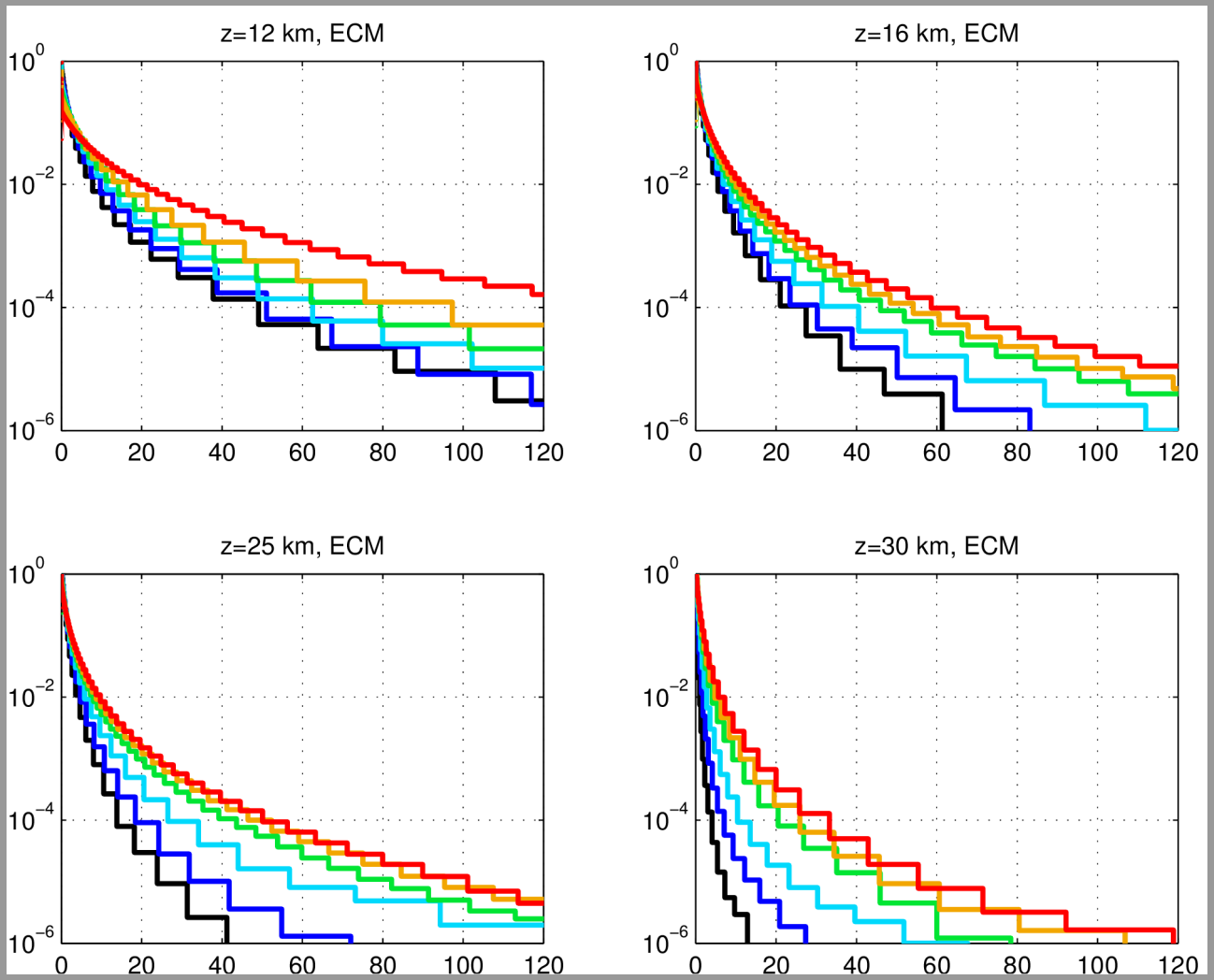
Information from tropospheric indicators of GW sources







PDFs at different heights from ECMWF



Approximating the lognormal tail of the PDF :

Red curve : lognormal distribution with the same median and geometric standard deviation

Black curve : better fit to the tail, using least-squares