Titan zonal wind minimum's turbulence modelling

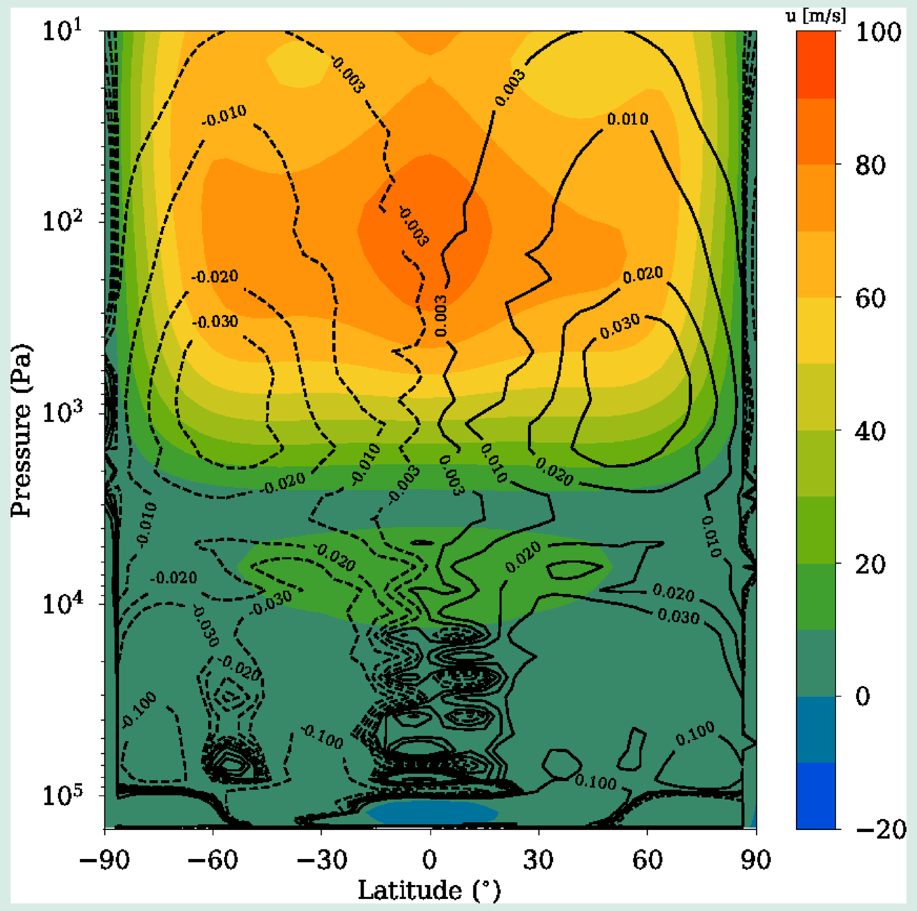
Maxence Lefèvre[1], Jan Vattant D'Ollone[2], Aymeric Spiga[2] and Sébastien Lebonnois[2]

[1] University of Oxford, UK ; [2] Laboratoire de Météorologie Dynamique, SU/IPSL/CNRS, Paris, France

Introduction

The atmosphere of Titan is interesting by many aspects, it has the thickest atmosphere for a moon in the solar system, an atmosphere in superrotation in the stratosphere, an hemispheric asymmetry of temperature and an haze feedback of haze distribution on circulation between many others. There is another feature by which the atmosphere of Titan is unique, a strong decrease of the zonal wind between 60 and 100 km none as the zonal wind collapse [1]. This decrease happens in a transition region between stratospheric and tropospheric meridional cells. Global Circulation Models (GCM) are powerful tools to study atmospheric circulation that are able to reproduce a realistic atmospheric circulation with superrotation [2,3,4] but fail to reproduce a realistic zonal wind collapse with a decrease of only a few meters per second.

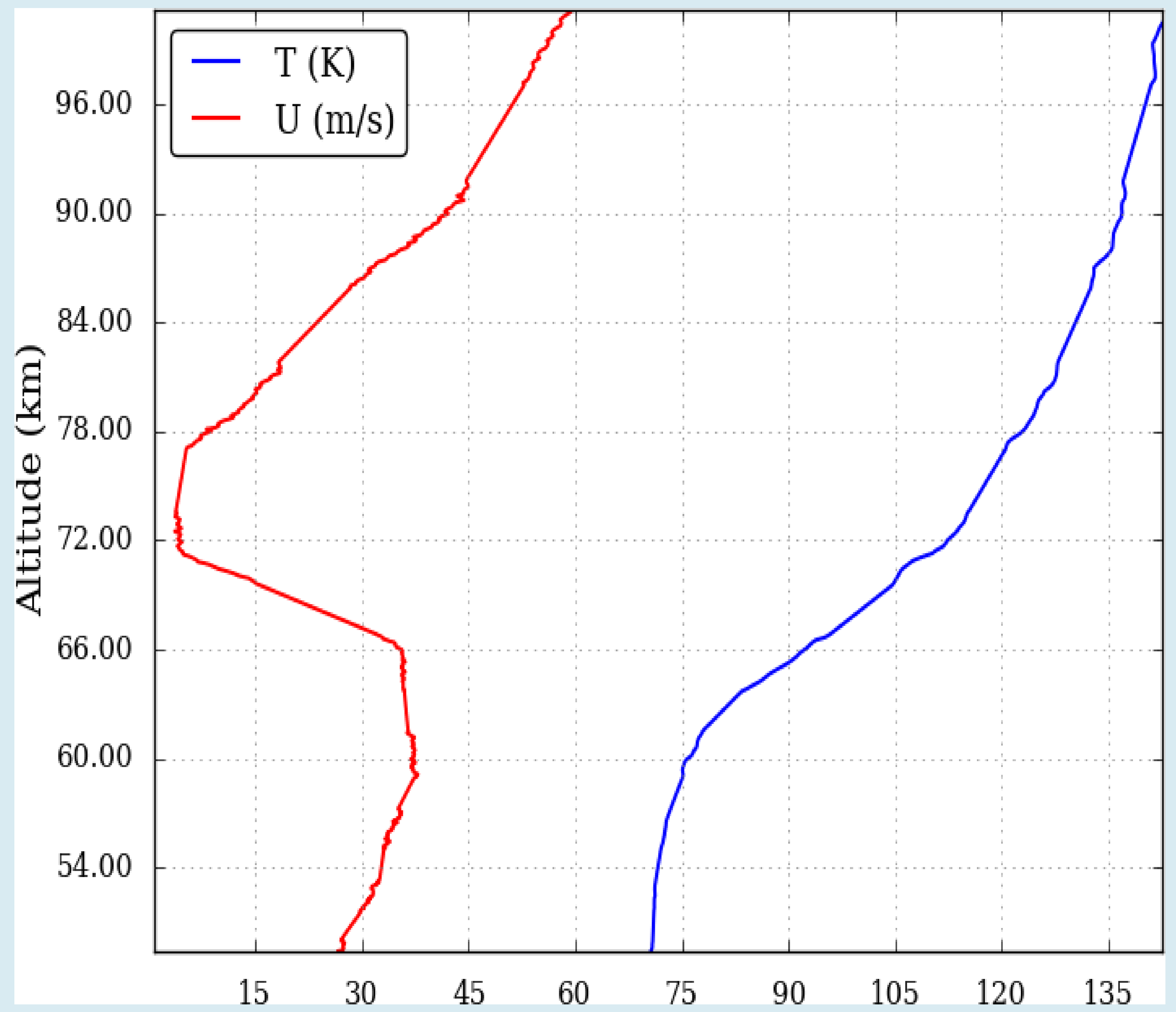
We propose here to study this wind structure using turbulent resolving model.



LMD GCM mean zonal wind (m/s) with stream function as contour (10^9 kg/s)

Model description

To study the turbulence in the zonal wind collapse region we use WRF non-hydrostatic dynamical in Large-Eddy Simulations (LES) [5]. The timescale of the resolved turbulence is significantly smaller than the radiative timescale, comparable to one Titan year at this altitude [6], no radiative processes are taking into account. The model is initialized using pressure, temperature and win vertical profile from Huygens probe shown in Figure 1. The atmospheric constants (gravity, heat capacity ...) are set to Titan values. The horizontal grid width is of 20 m over 2 km and with 300 levels from 60 to 90 km of altitude.



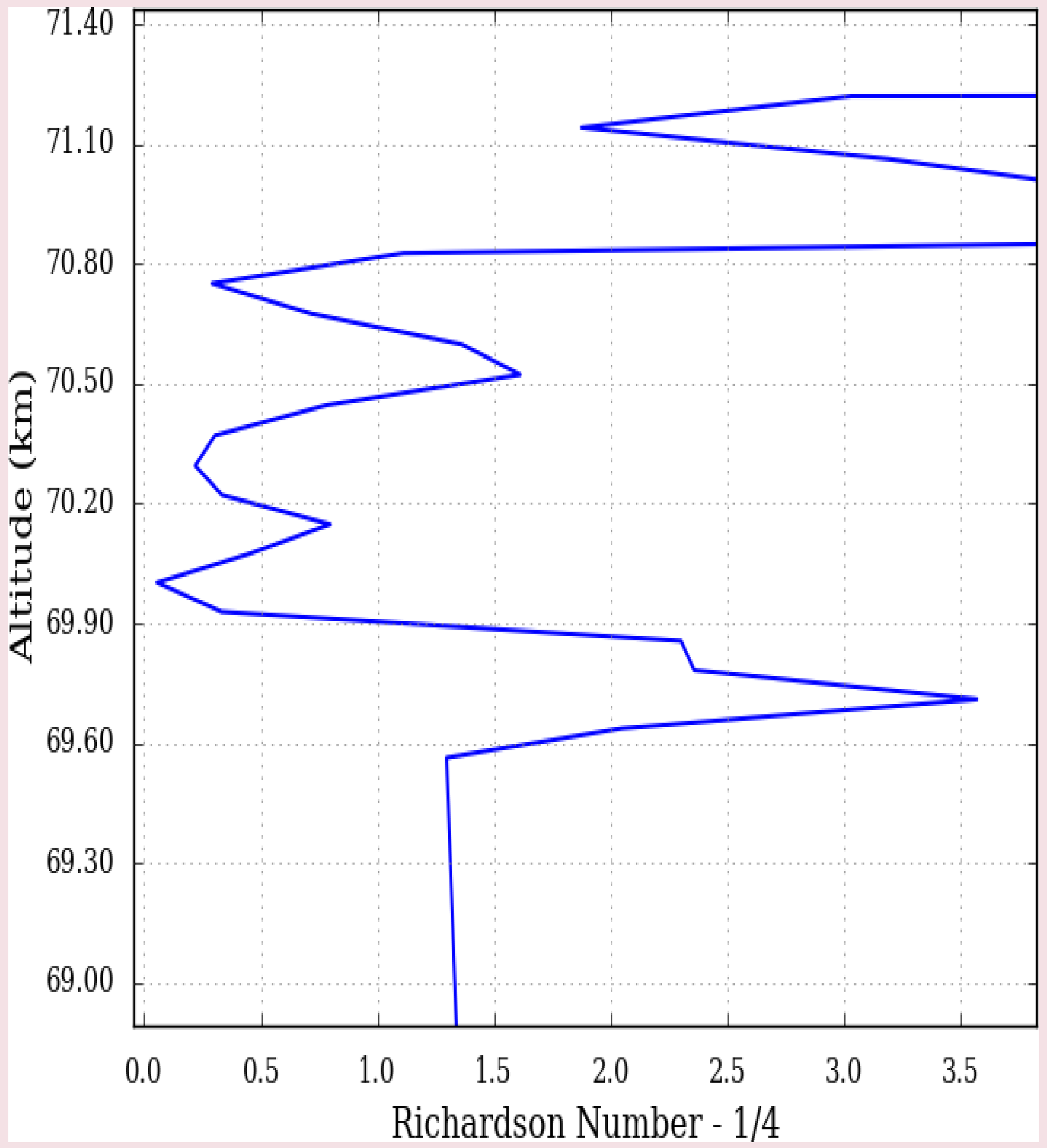
Temperature (K) and zonal wind (m/s) measured by Huygens descent probe

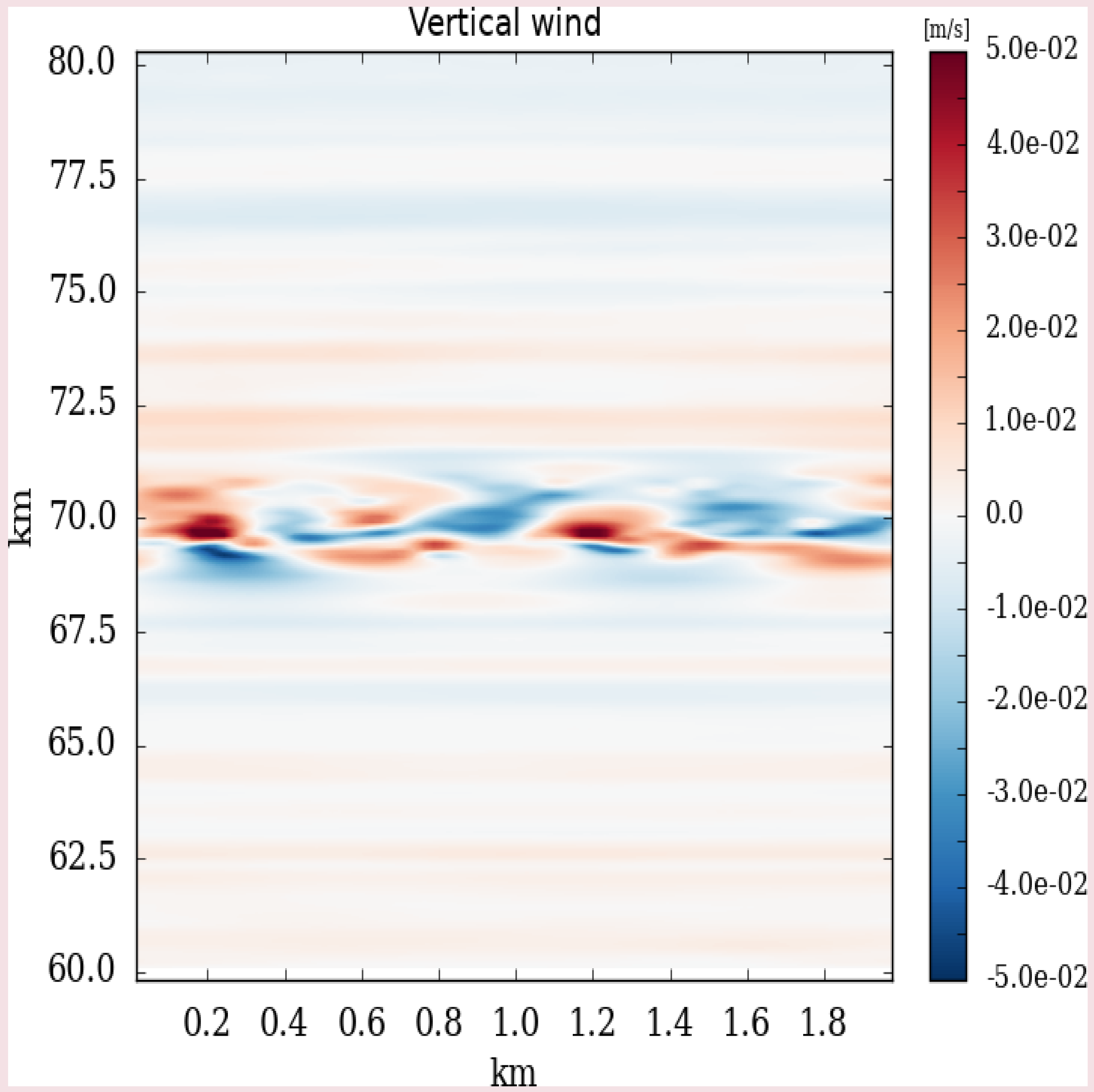
Results

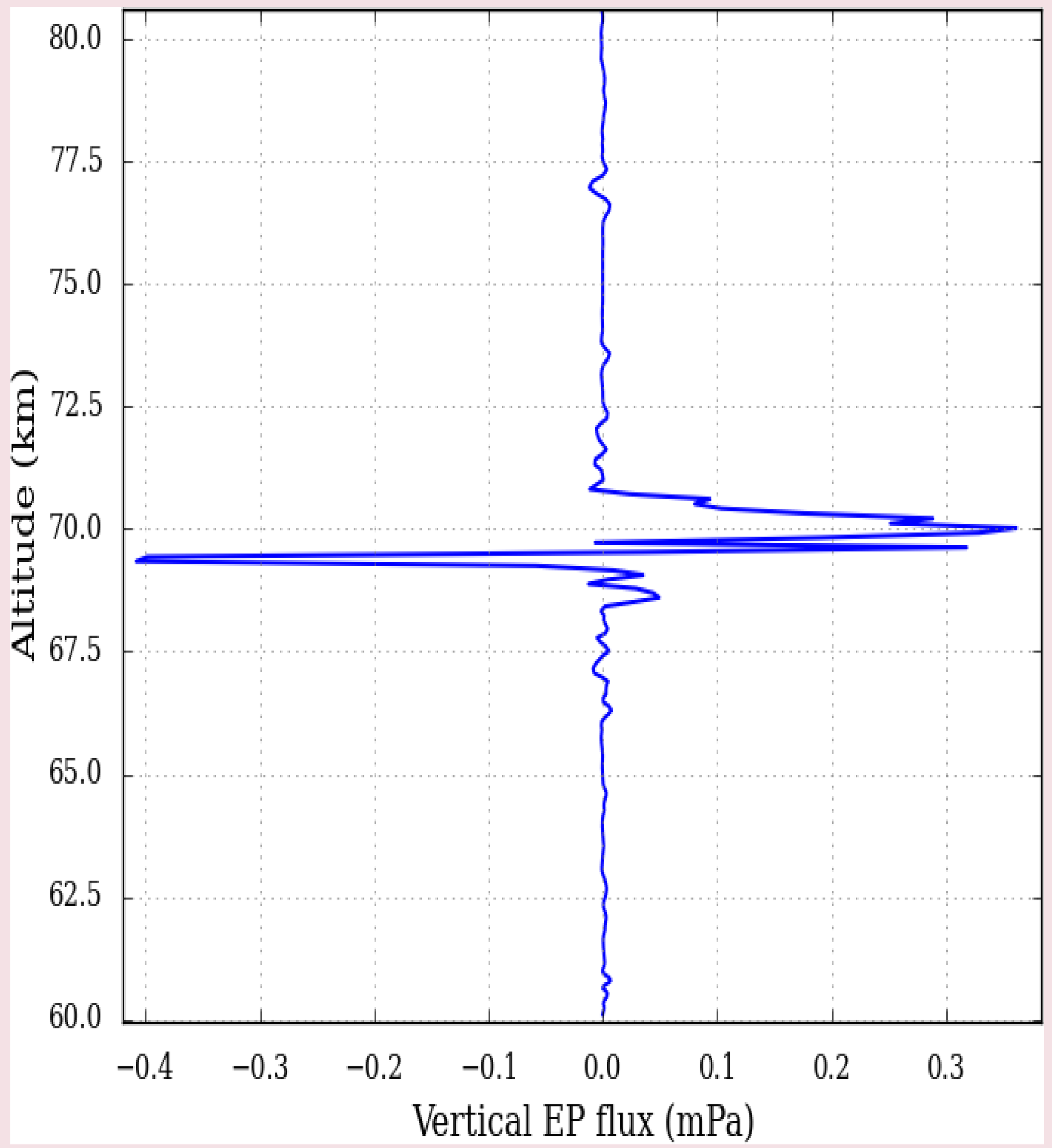
The Richardson number $Ri = (N/U_z)^2$ with N the Brunt-Väisälä frequency and U_z the zonal wind vertical shear, is close to 0.25 around 70 km : the atmosphere is in a shear instability regime.

This regime leads to a generation of waves with a horizontal wavelength of 1 km with an amplitude of $\pm$ 0.05 m/s

The associated vertical EP-flux $\rho \overline{u'w'}$ is shown in the right figure. The resulting acceleration in about $\pm$ 0.5 m/s over 1 Titan day.







References

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Conclusion and perspectives

Shear instability at 70 km $\rightarrow$ wave generation
acceleration : $\pm$ 0.5 m/s over 1 Titan day

To do :
Long time impact on zonal wind
Wave parametrization for GCMs

Author Contact : maxence.lefevre@physics.ox.ac.uk