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# Turbulence modelling in Titan’s zonal wind collapse

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## 1. Context

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 known as the “zonal wind collapse” (Figure 1). The first measurement of this feature performed by ground-based radio-telescopes recording the Doppler Wind Experiment measurements of the carrier frequency during the Huygens descent [1]. The wind measured above 120 km was approximately of 100 m s$^{-1}$. Then, below, the wind decreased to about few meters per seconds around 70 km before increasing again to 40 m s$^{-1}$ at 60 km.

## 2. Our methodology

### 2.1 Principle

Global Circulation Models (GCM) are powerful tools to study atmospheric circulations and have been employed to study the different planets of the solar system as well as Titan [2, 3, 4]. Although the different models are able to reproduce a realistic atmospheric circulation with superrotation, they fail to reproduce the observed zonal wind collapse characterized by a decrease towards only a few meters per second. We propose here to study for the first time this wind structure using turbulence-resolving model [5].

### 2.2 Model description

In order to investigate this peculiar wind feature we use the WRF compressible and non-hydrostatic dynamical core to perform large-eddy simulation (LES) [6]. The timescale of the resolved turbulence is significantly smaller than the radiative timescale, comparable to one Titan year at this altitude [7], so no radiative processes are taken into account. The model is initialized using pressure, temperature and wind vertical profile as measured by the Huygens probe and shown in Figure 1. The atmospheric and planetary constants (gravity, heat capacity ...) within the model are set to Titan values. The horizontal grid spacing is 20 m spread over a 2 km-wide domain and the vertical grid features 300 levels from 60 to 90 km altitudes.

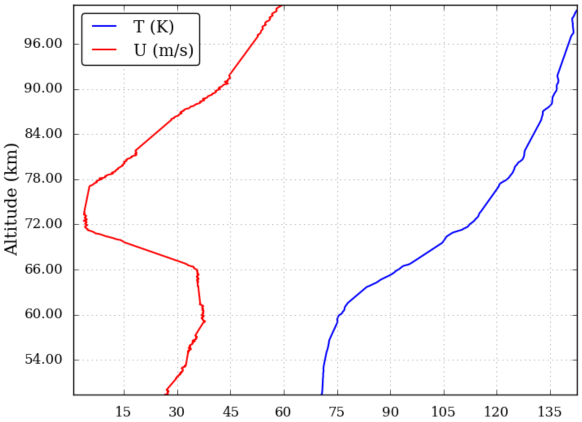

Figure 1: Huygens temperature (K) and zonal wind profile ( m s$^{-1}$) between 50 and 100 km.

## 3. Wave generation

Figure 2 displays the vertical wind (top) the associated vertical Eliassen-Palm flux (bottom) $\rho\overline{u'w'}$ with $\rho$ the density of the atmosphere and $u'$ and $w'$ the mean perturbation to the mean (domain-averaged) value of the zonal wind $u$ and vertical wind $w$. The strong decrease of the zonal wind between 65 and 60 km causes a Kelvin-Helmholtz instability that leads to the generation of gravity waves. These waves propagates both towards the ground and towards the upper atmosphere. The dissipation of the wave engenders a momentum transfer to the flow and impacts the zonal wind.

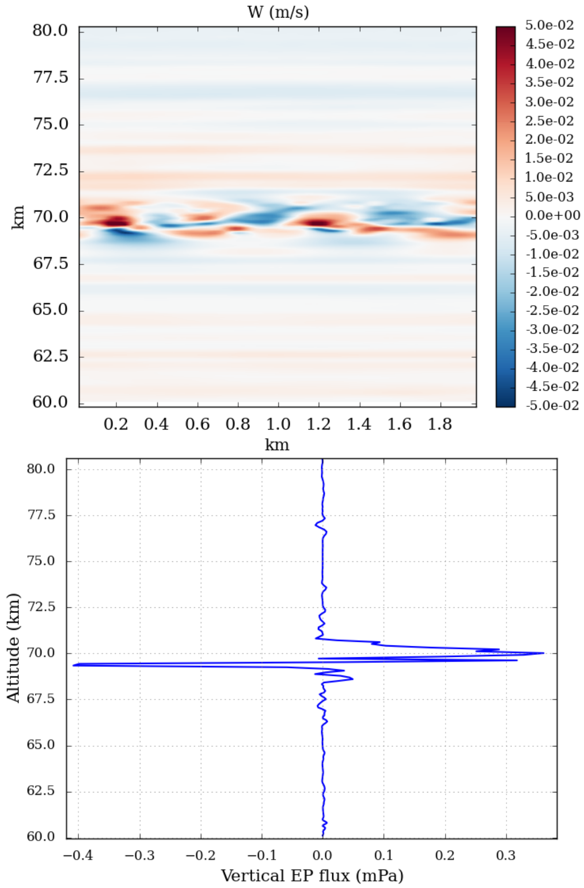

Figure 2: Top : Snapshot of an vertical cross-section of the vertical wind ( m $s^{-1}$) between 60 and 80 km. Bottom : Vertical profile of the vertical Eliassen-Palm momentum flux.

## 4. Ongoing works and perspectives

A better understanding of the small-scale processes shaping this zonal wind minimum, could lead to new constraints for GCM and guidance to design parameterizations of gravity waves emission at those altitudes. If models were to better reproduce this area of Titan's atmosphere, this would certainly have strong impacts on the general circulation since this altitude is a critical transition region between the stratospheric and tropospheric meridional cells. Interaction of this wind minimum with the overall budget of angular momentum is also to be further investigated.

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