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# Progress of gravity waves

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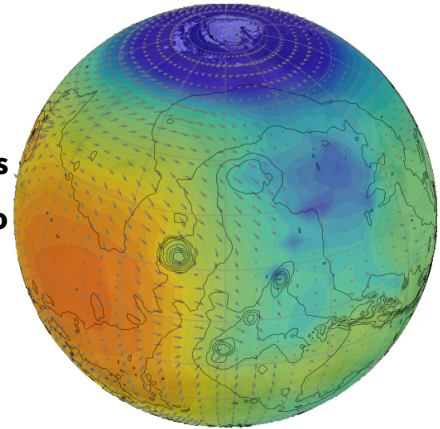
# Context

- **Formalism of inertial gravity waves**
- **Revising the orographic gravity waves**
- **Mixing induced by orographic gravity waves**
- **Implementing non-orographic GWs on Pluto**
- **GWs' impact on the upper atmosphere**



# Sciences:

A generic GW scheme for all planets?

# Inertial non-orographic GWs (almost done):

$$\frac{d^2}{dz^2}\tilde{w} + \left\{ \frac{k^2[N^2(\Omega^2 - 2f^2) + f^2\Omega^2]}{\Omega^2(\Omega^2 - f^2)} - k^2 + \frac{k\Omega^2}{\Omega(\Omega^2 - f^2)}(\bar{u}_{zz} - \frac{\bar{u}_z}{H}) - \frac{1}{4H^2} \right\}\tilde{w} = S_n$$

$$\tilde{w}_j(z_{ll+1}) = \underbrace{\Theta[\Omega(z_{ll+1})\Omega(z_{ll})]}_{\text{CL}} \underbrace{\Theta[\Omega_f^2(z_{ll+1})\Omega_f^2(z_{ll})]}_{\text{CF}} \textbf{MIN}\left\{ \tilde{w}_j(z_{ll}) \sqrt{\frac{m(z_{ll})}{m(z_{ll+1})}} \exp\left( - \underbrace{\frac{\mu^*}{\rho}}_{\text{VD}} \overbrace{\frac{m_r^3}{\Omega}}^{\text{TD}} \delta \right. \right.$$

(1)

If $f = 0$, the wave equation is normalized to,

$$\frac{\partial^2\tilde{w}(z)}{\partial z^2} + \left( \underbrace{\frac{N^2|\vec{k}|^2}{\Omega^2} + \frac{\vec{k}(\vec{u}_{zz} - \vec{u}_z/H)}{\Omega} - \frac{1}{4H^2} - |\vec{k}|^2}_{Q(z)} \right)\tilde{w}(z) = S_n$$

$S_n = 0$, GWs. $S_n \neq 0$, thermal tides, with n=1,2,3...,

## Inertial orographic GWs:

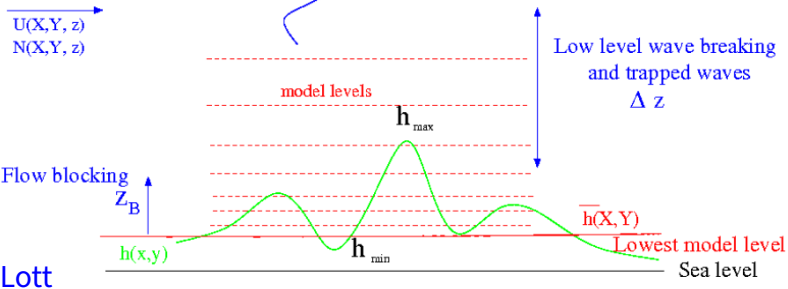
> Formulism would be similar but complicated, and will be available only after the revision of the orographic gravity waves.

# Rivising Orographic GWs in Mars PCM


scheme setting:

No upper level breaking in some cases; Good news is this part of drags are relative smaller; May resulting in bad effect for Venus.

Freely propagating gravity wave drag




Parameters still for Earth?

Lectures from Francois Lott

# Mixing induced orographic GWs

## Variables

Eddy diffusion coefficient $D_{eddy}$ [cm$^2$ s$^{-1}$]

## Ranges

$D_{eddy} \propto \frac{1}{\rho}\nabla\vec{E}$. Thus some simple schemes propose that $D_{eddy} \propto \tau_{drag} e^{-z/H}$.

Formalism derived in minds but is remain not fully understood in some specific points in the thermodynamics.

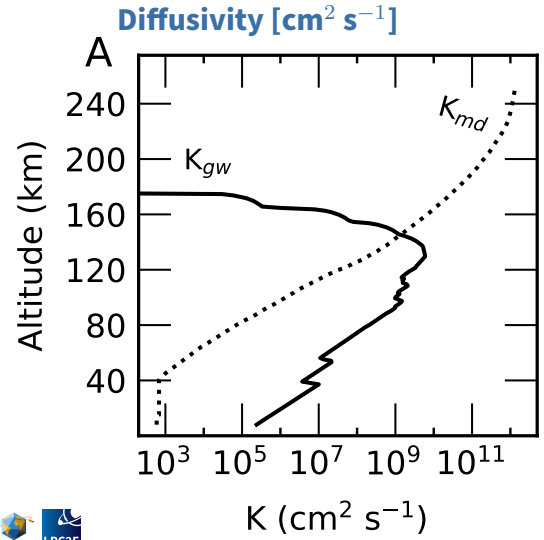
# Implementing non-orographic GWs on Pluto

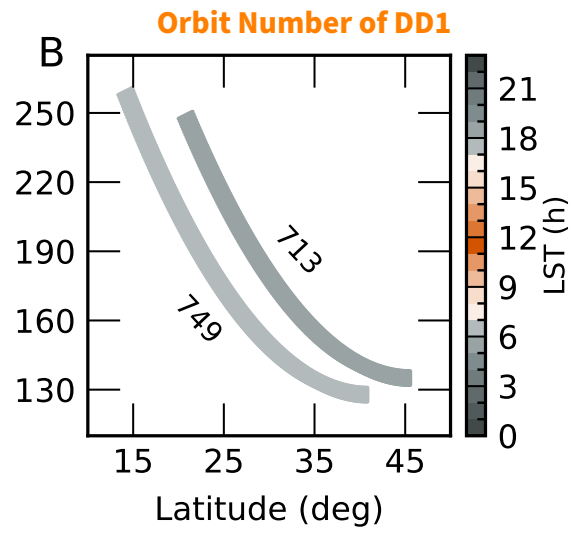
Sources:

EP-flux from weak-convection?

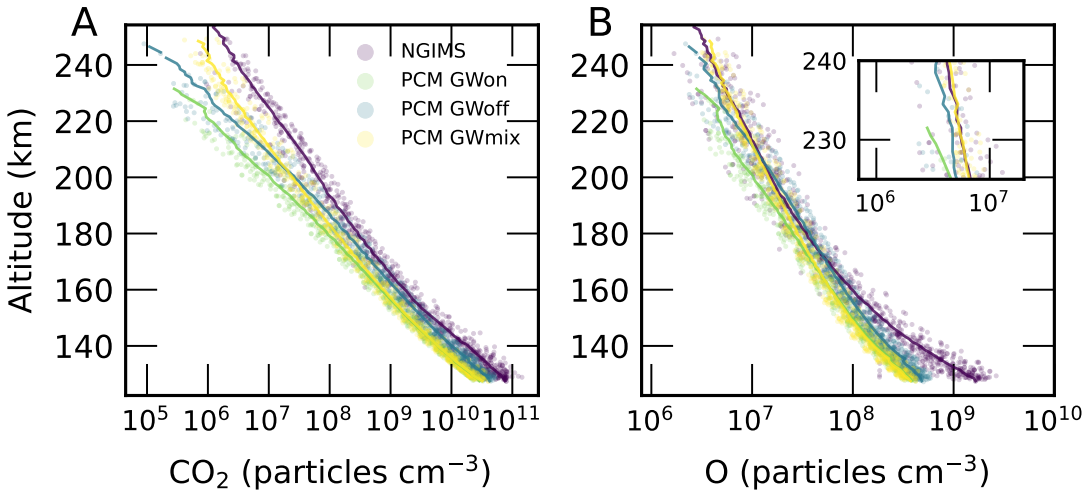
EP-flux from atmospheric relaxing process by N2 sublimation/condensation?

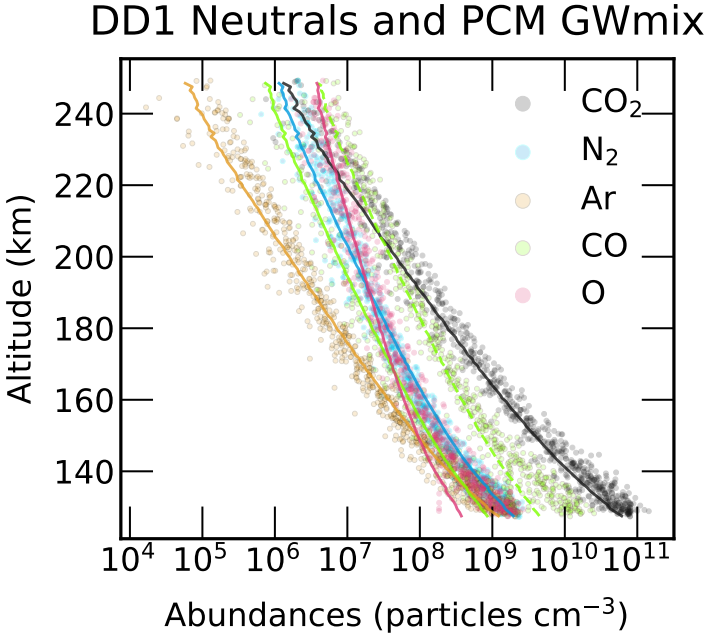
# GWs' impacts on the upper atmosphere

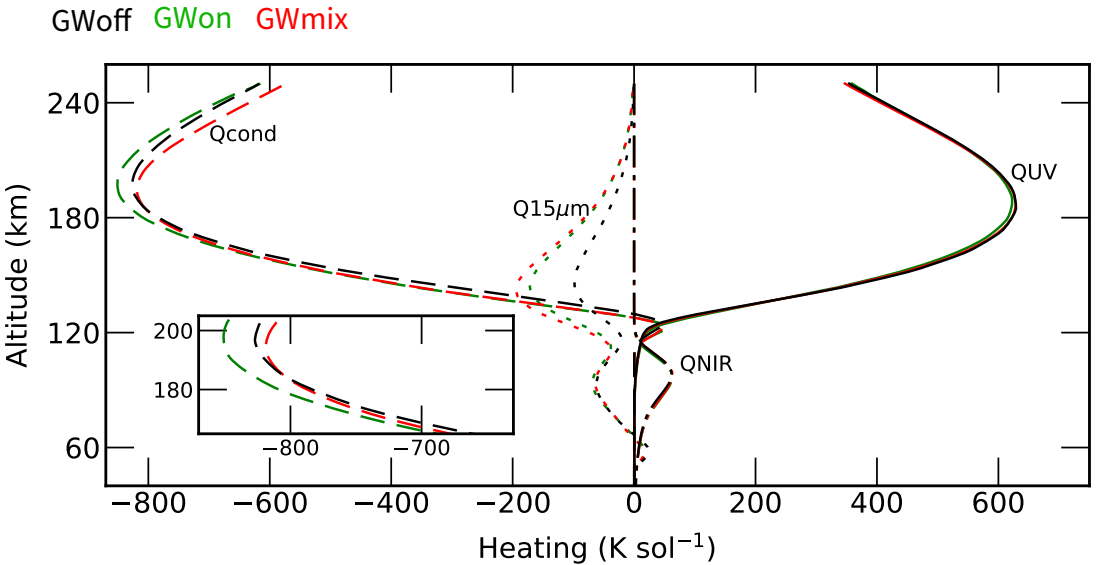


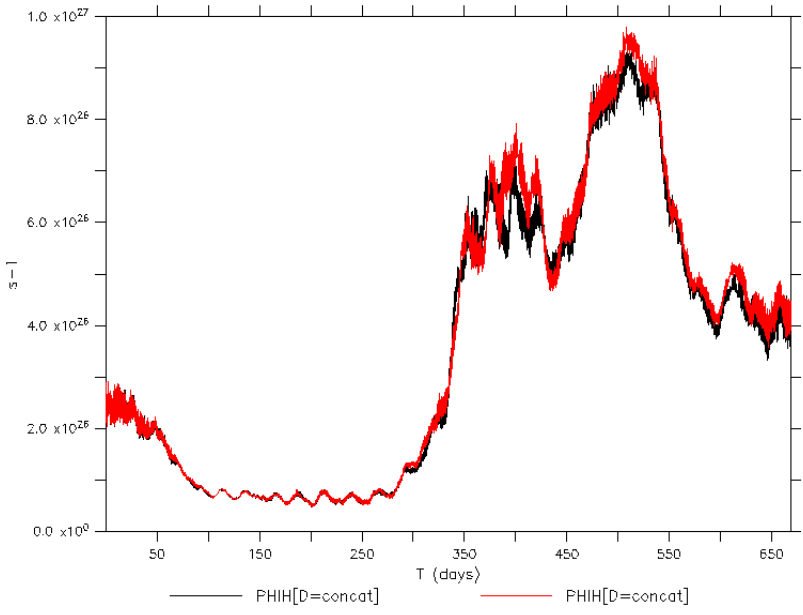
# Effects on CO2 and O



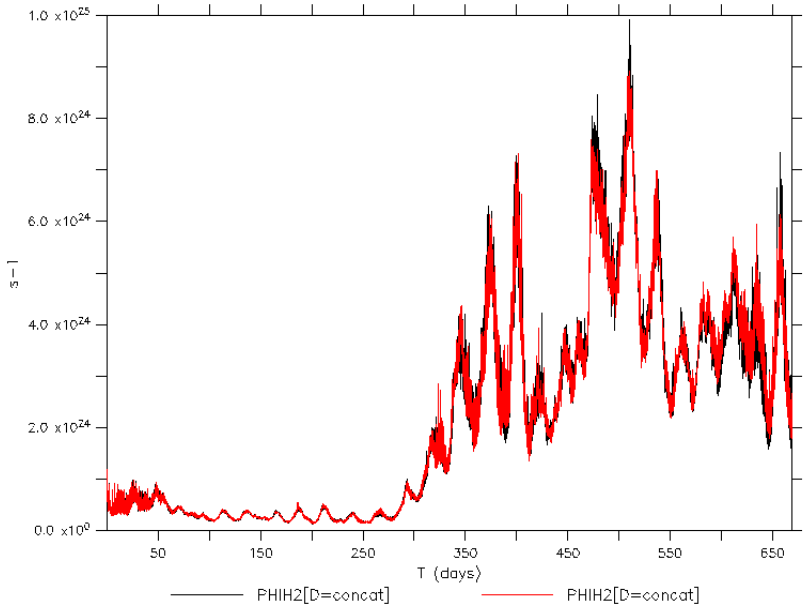

DD1 Neutrals and PCM GWmix
Altitude (km)
240
220
200
180
160
140
$10^4$ $10^5$ $10^6$ $10^7$ $10^8$ $10^9$ $10^{10}$ $10^{11}$
Abundances (particles cm$^{-3}$)
$CO_2$
$N_2$
Ar
CO
O


GWoff
GWon
GWmix
Qcond
Q15$\mu$m
QUV
QNIR
Altitude (km)
240
180
120
60
200
180
−800
−700
−800
−600
−400
−200
0
200
400
600
Heating (K sol$^{-1}$)

GWon GWmix


1.0 x10^27
8.0 x10^26
6.0 x10^26
4.0 x10^26
2.0 x10^26
0.0 x10^0
S-1
50
150
250
350
450
550
650
T (days)
PHIH[D=concat]
PHIH[D=concat]

GWon GWmix


1.0 x10^25
8.0 x10^24
6.0 x10^24
4.0 x10^24
2.0 x10^24
0.0 x10^0
S-1
50
150
250
350
450
550
650
T (days)
PHIH2[D=concat]
PHIH2[D=concat]

Thank you for your time and interest in this topic. Please feel free to ask any questions.
Je vous remercie pour votre temps et votre intérêt. N'hésitez pas à poser vos questions.
承蒙聆听，不胜荣幸，有疑但问.

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