A simplified model to assess wave's impact on homogeneous nucleated ice crystals in tropical cirrus clouds

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Method

– Our model = microphysic 1D + lagrangian trajectories

INPUT – SCENARIO

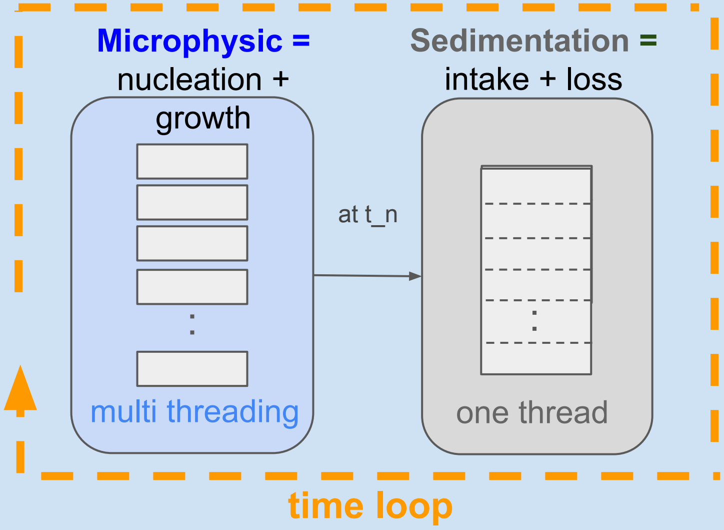
Geometry
- number air parcels
- thickness
- number columns

Dynamics
- mean w
- GW w’

Initial conditions
- rhov = f(RHi)

MODELE

- Homogeneous nucleation
- Aerosols of *** (1 bin of size)
- Sedimentation
- Simplified mixing



OUTPUT

N1 (r)	N2 (r)	N.. (r)	Nbin (r)
M1 (r)	M2 (r)	M.. (r)	Mbin (r)

(Dinh, 2016)

Method – Balloons measurements for GW T° fluctuations

Stratéole-2 :

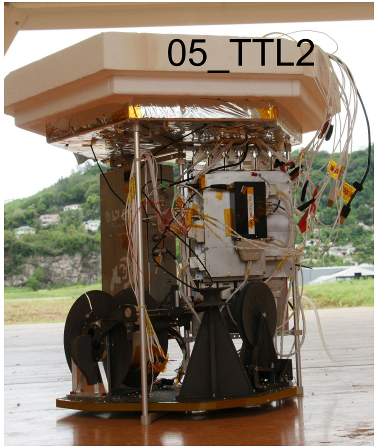
French-US project

50 long duration SPBs in 3 campaigns (2019-2024)

Study climate processes in the tropics, Troposphere /Stratosphere interactions, dynamics , transport and microphysics

+ quasi lagrangian !

Measurement		Instrument type
Pressure, temperature and winds	TTL1	In-situ sensors + GPS receivers
Ozone mixing ratio	TTL1	UV photometer
Water vapor mixing ratio	TTL1	Frost-point hygrometer
Particle size distribution and nature	TTL1	Aerosol counter
Pressure, temperature and winds	TTL2	In-situ sensors + GPS receivers
Water vapor and carbon dioxide mixing ratios	TTL2	IR open-cell spectrometer
Temperature profile down to 2 km below the balloon	TTL2	Fiber optic Raman temperature profiler
Pressure, temperature and winds	TTL3	In-situ sensors + GPS receivers
Particle size distribution	TTL3	Aerosol counter
Profile of temperature, water vapor and aerosol down to 2 km below the balloon	TTL3	Reeled-down temperature sensor, Lyman-α hygrometer and back scatter sonde
Pressure, temperature and winds	STR1	In-situ sensors + GPS receivers
Cirrus cloud	STR1	Backscattering lidar
High-precision position/winds and profile of temperature down to ~5 km altitude	STR1	GPS radio-occultation
Radiative fluxes	STR1	Broadband UV-vis and IR radiometers
Pressure, temperature and winds	STR2	In-situ sensors + GPS receiver



Method – Computing T° fluctuations

$$\delta P = -\rho g \xi_\rho$$

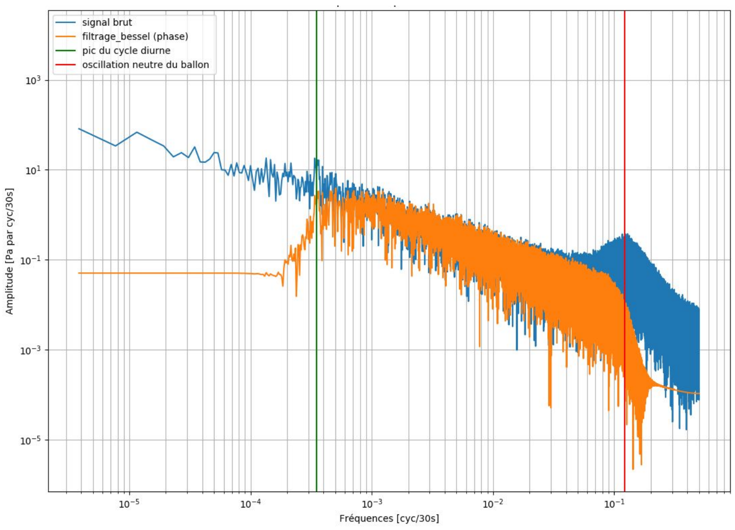
Pressure perturbation linked to balloon vertical displacement perturbation

Balloon **quasi-lagrangian** : from isopycne to isentrope

$$\xi_\rho = \frac{g/cp + \partial\overline{T}/\partial z}{g/R + \partial\overline{T}/\partial z}\xi_\theta$$

$$T' = -\frac{g}{c_p}\xi'_\theta$$

fast temperature fluctuations : **adiabatic** gradient

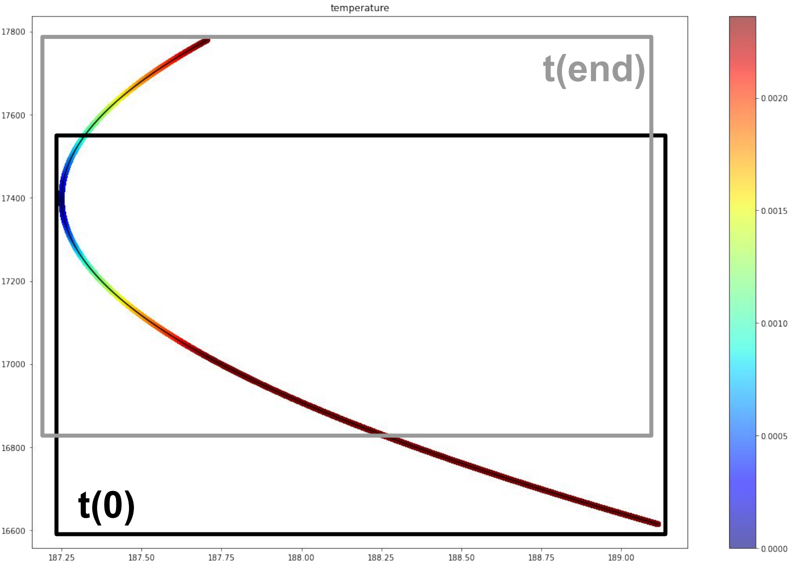


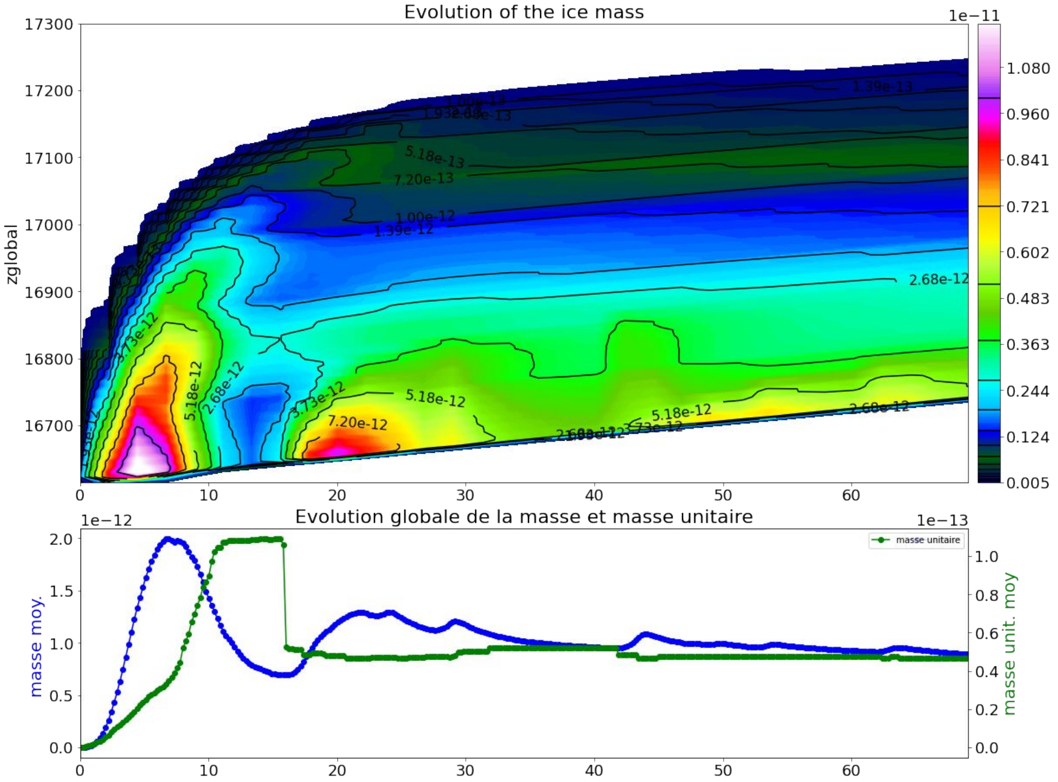
Method – RECAP = our simulations

	NO WAVE	WAVES	
geometry	420, 6 columns 15m thickness	420, 6 columns 15m thickness	
time, ascension	72.2h ~130m	51.5h ~92m	
mean ascent	0.5 mm/s	0.5 mm/s	$\overline{W}$
waves disturbances	0	sigma = 20 m/s	W'

Mean ascent – Evolution of ice in time and altitude

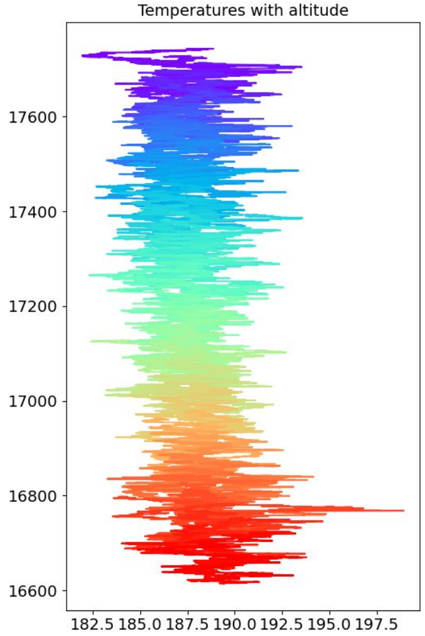
$\overline{w}$ = 0.5 mm/s
n parcels = 420, ncol=6
time simulation =72h

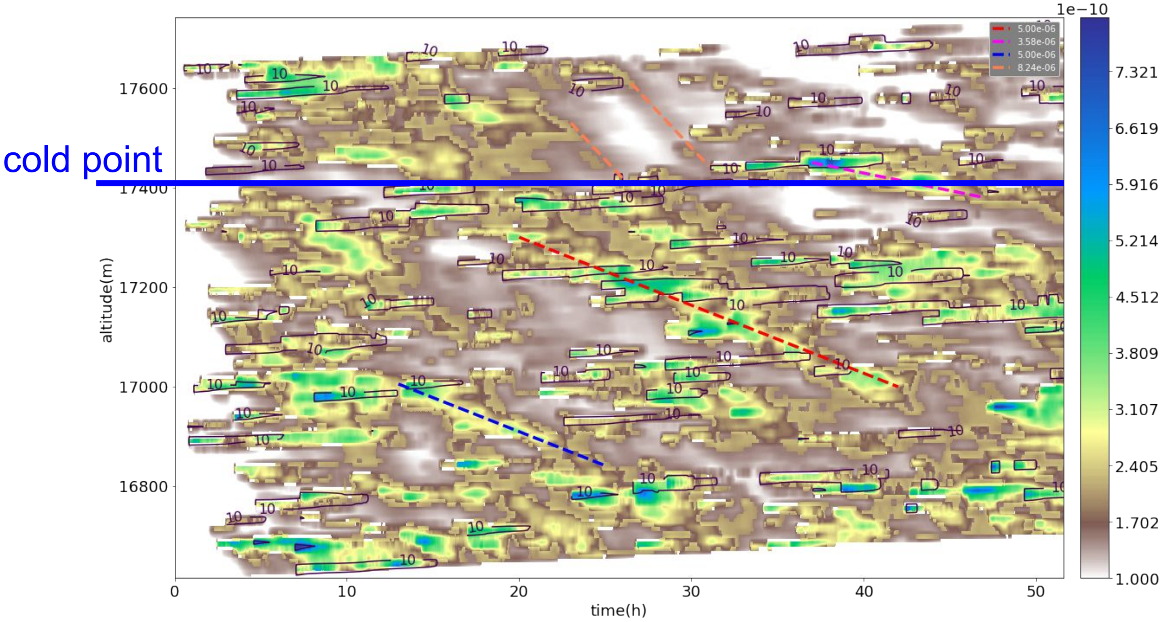




Impact of gravity waves 🧊 – Evolution of ice in time and altitude

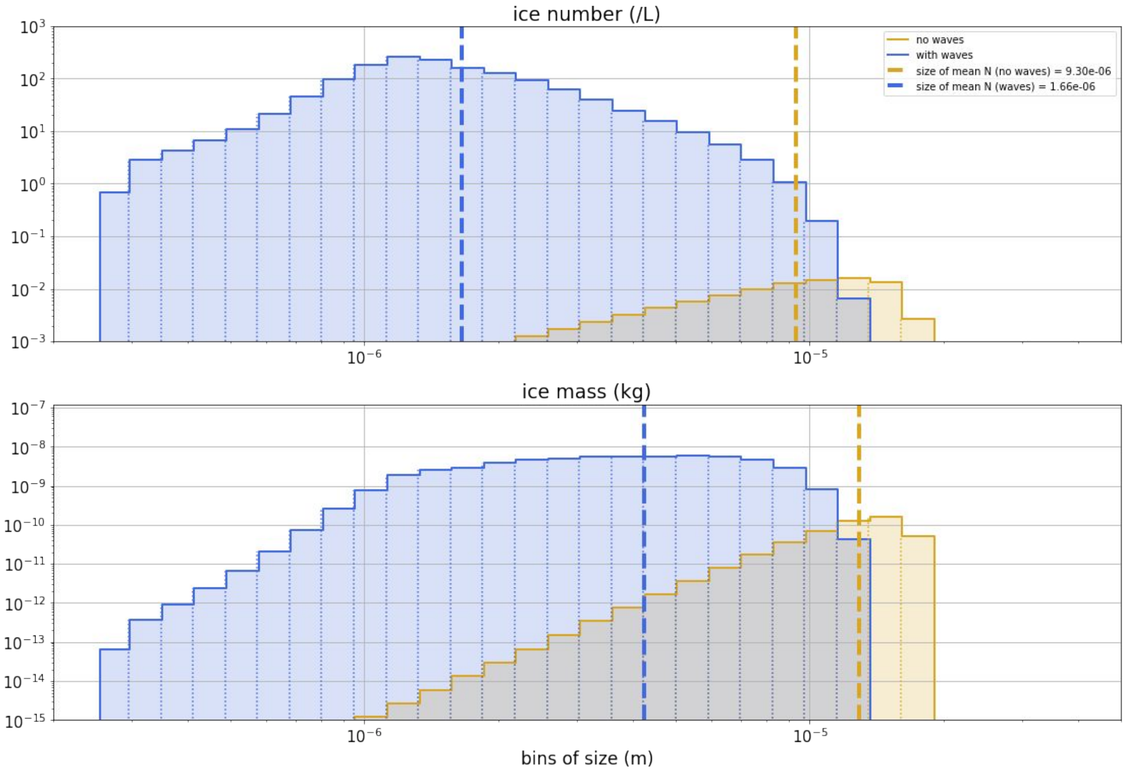
$\overline{w}$ = 0.5 mm/s
n parcels =420, ncol=6
time simulation=52h





Nucleation above cold point
Differential sedimentation broadening cloud vertically

Impact of gravity waves – Ice population



Waves produce larger size distribution of ice crystals and a higher density

But biggest crystals are not appearing anymore

extra slides

Method – Our set-up

Modele

Sedimentation :

For spherical particles, following different regimes depending on Re

Re<1.e-2 Stokes-Cunningham regime

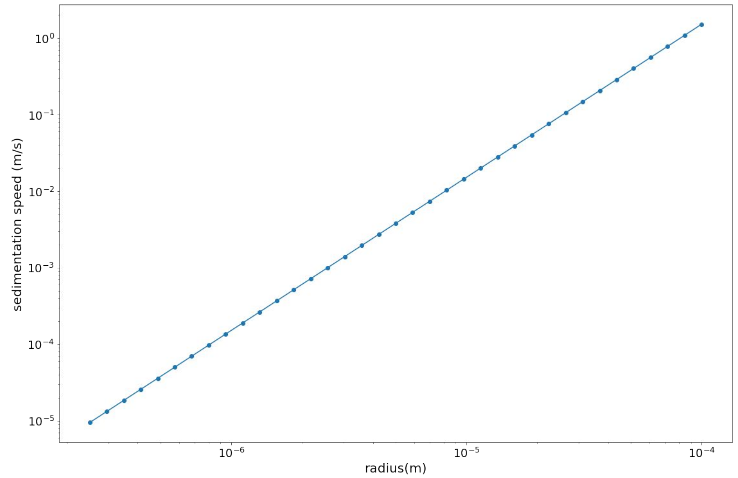
Re> 1.e-2 Hannes and Boehm

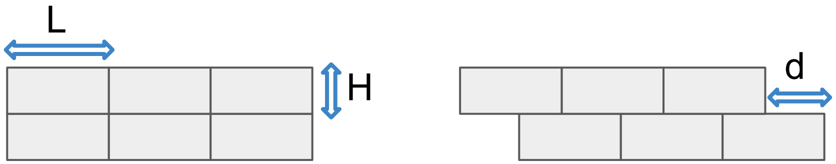
Simplified mixing :

Wind shear (s) of 10 m/s/km

If horizontal displacement (d) > ½ L

→ Random mixing at t = L* (½) * 1/(s*H)





Impact of gravity waves – Ice population