Effects of gravity waves on tropical cirrus clouds

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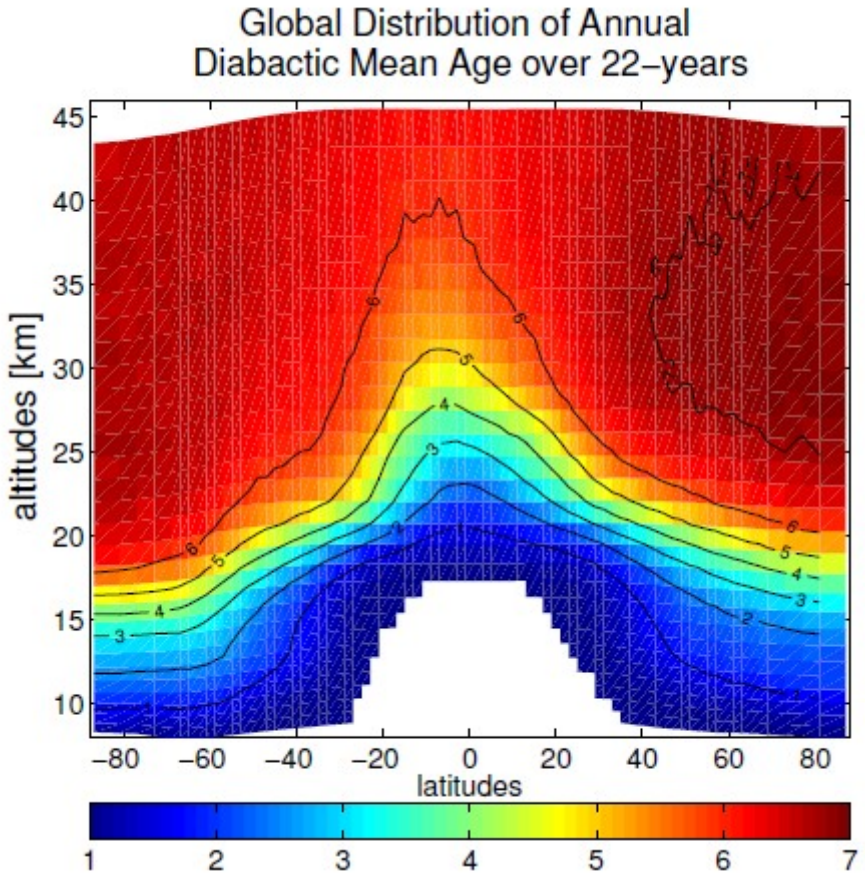
Work carried out with T Dinh, A Podglajen, B Legras and A Hertzog

On our understanding of dehydration at the tropopause

Stratospheric dryness results from the low temperatures at the tropical tropopause

Signature that TTL is the gateway → **Brewer-Dobson circulation**

Much of our understanding comes from **Lagrangian studies**

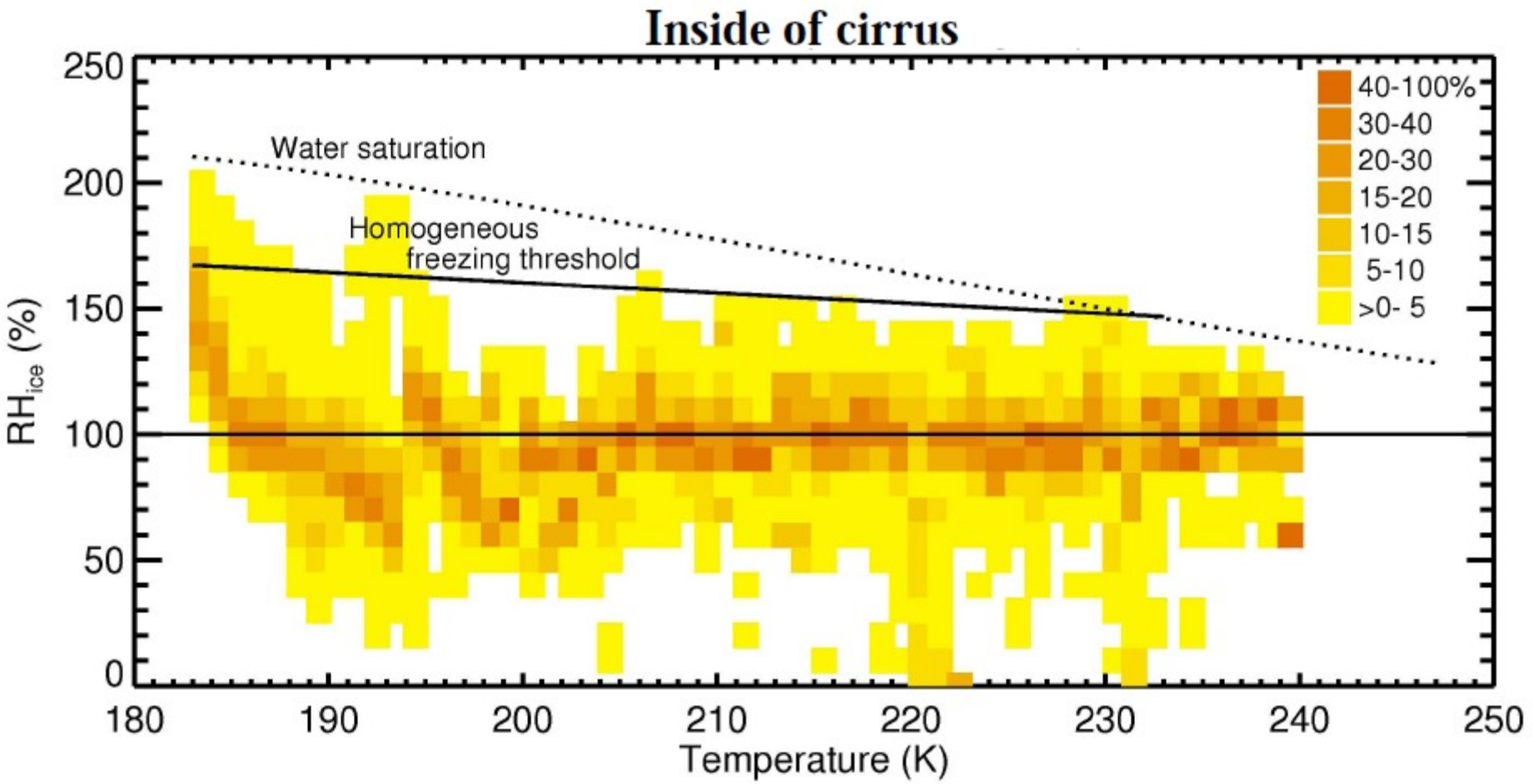


Diallo et al 2013

Tropical cirrus

Large supersaturations
Puzzle of the low ice cristal numbers

- **Homogeneous** of **heterogeneous** nucleation ?



Krämer et al 2009

Expected ice crystal numbers

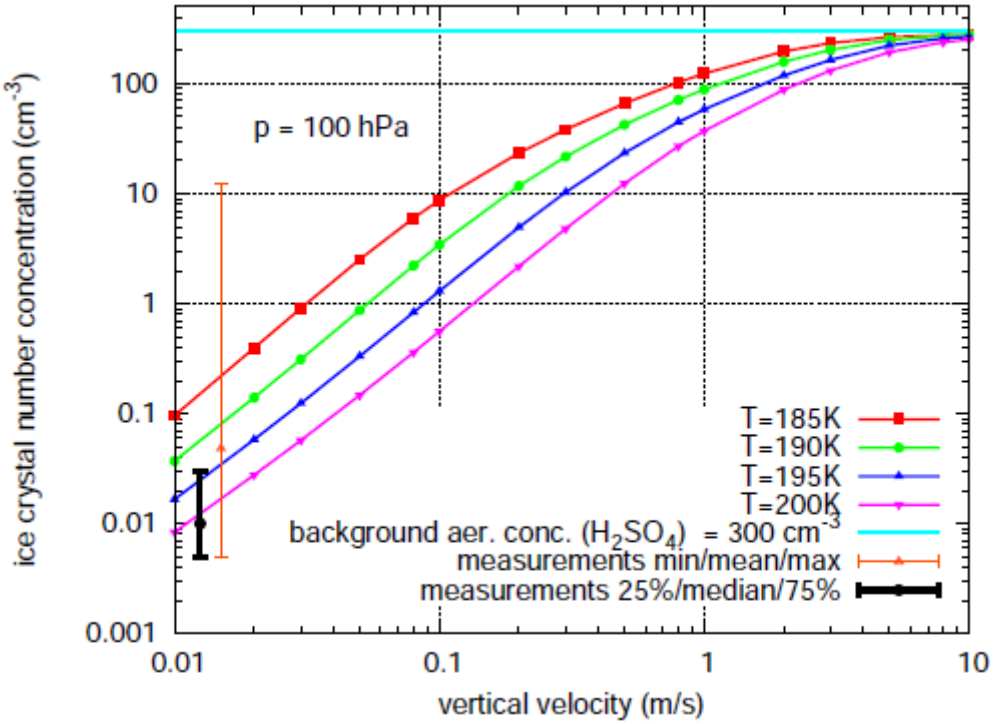
Homogeneous nucleation : fairly well understood

Heterogeneous nucleation : very uncertain and poorly constrained

Koop et al 2000,
Murphy & Koop 2005

Expected ice crystal numbers for **constant upwelling and homogeneous nucleation**

Discrepancy with observations



Spichtinger & Krämer 2013

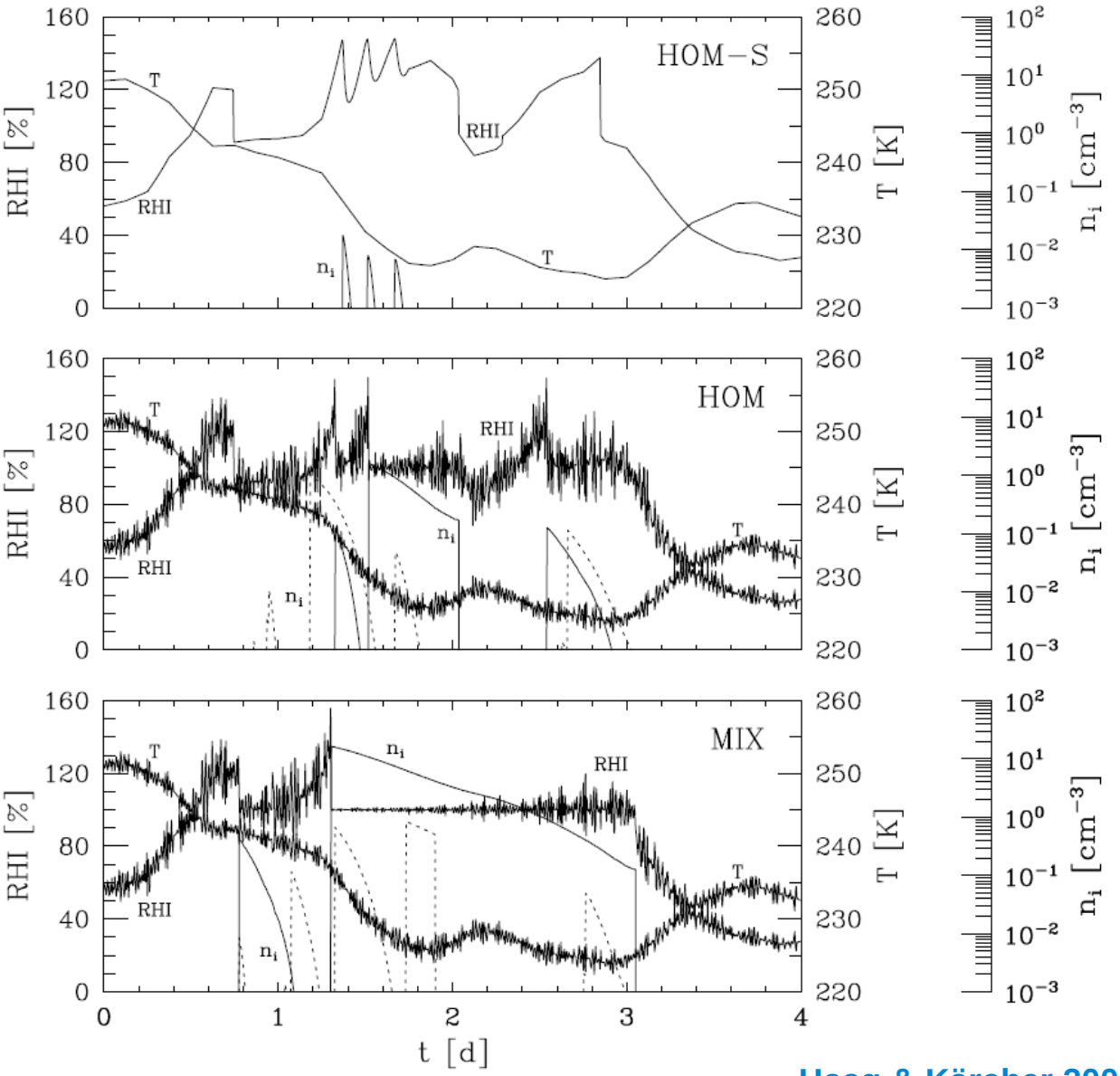
Example of a Lagragnian study at the midlatitudes

Lagrangian studies of cirrus in the midlatitudes

Trajectory using ECMWF temperatures

+ fast fluctuations

+ ice nuclei for heterogeneous nucleation



Haag & Kärcher 2004

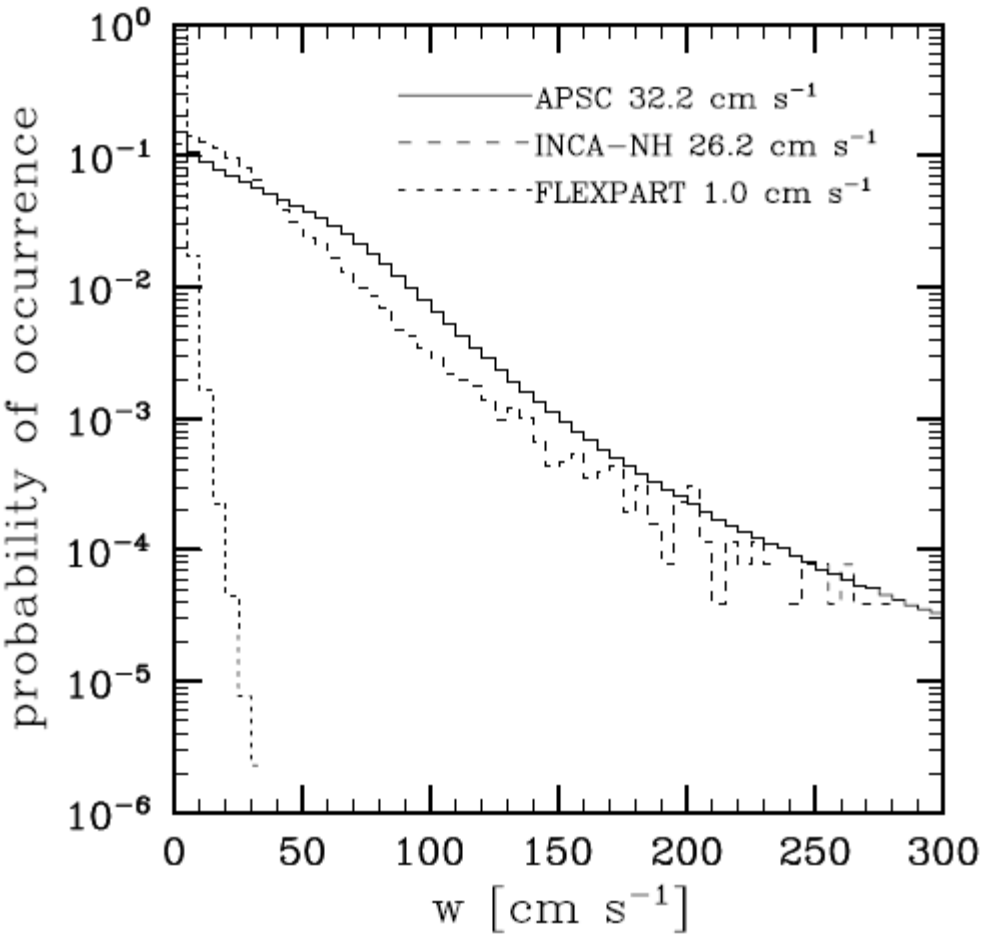
Conclusions of the Haag & Kärcher paper :

- cirrus form in **synoptic cold temperature anomalies**

- characteristics (crystal numbers, thickness...) **dependent on fluctuations and aerosols**

What constraints on the vertical velocity fluxtuations ?

Haag & Kärcher used fluctuations (generated with some randomness) to match PDF from airborne meas.



Observations of vertical velocities

Measurements from research **aircrafts**

Many observational campaigns, but...
uncertainties and difficult to translate into Lagrangian timeseries

⇨ One would wish for measurements from a (quasi-)**Lagrangian** airborne platform, with **high temporal resolution** and **large spatial coverage**...

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Observations of vertical velocities

Measurements from research aircrafts

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Measurements from superpressure balloons

Balloon launched from McMurdo station, Antarctica

Superpressure balloons

- drift on **isopycnic surfaces**,
- **quasi-Lagrangian** behavior,
- direct access to **intrinsic frequencies**,
- measurements (*u, T...*) **every 30'**
- typical **lifetime ~ 2 months**

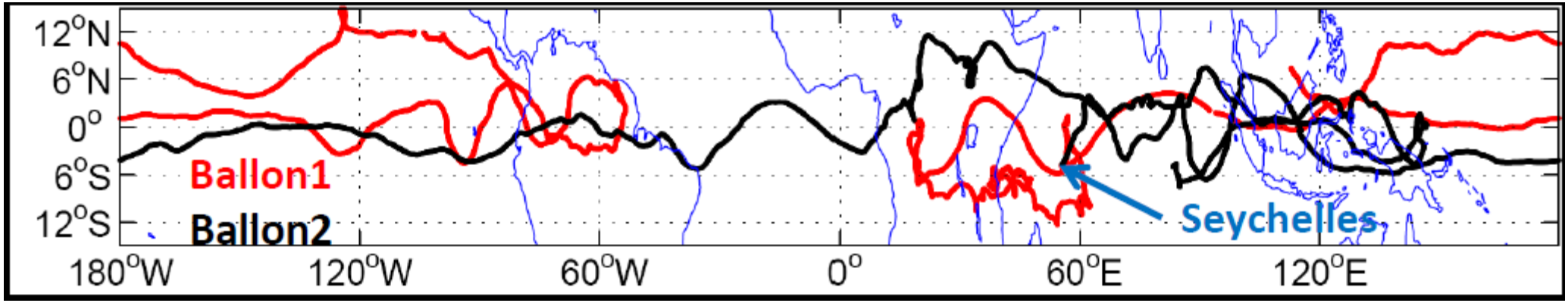
Campaigns around Antarctica :

Vorcore, 2005, 27 balloons
Concordiasi, 2010, 19 balloons

In the Tropics :

PreConcordiasi, 2010 : 2 balloons
Strateole 2 : 2018-2020 ?

Observations of vertical velocities



Pre-Concordiasi campaign, Feb-May 2010

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Investigation of nucleation subject to realistic temperature fluctuations

Collaboration with Tra Dinh

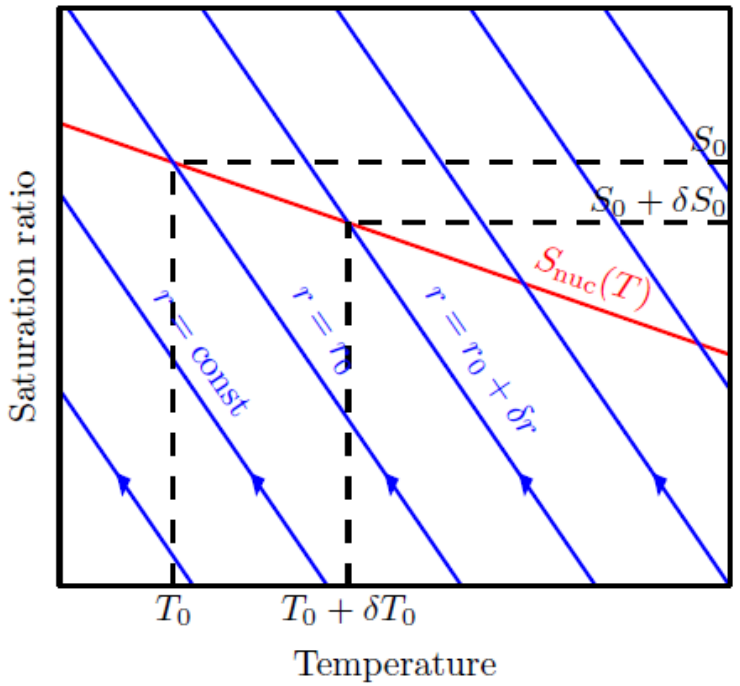
Real timeseries of temperature fluctuations from balloon

Bin microphysical model describing nucleation and growth

Dinh et al, 2012

Analysis of nucleation events and their limiting factors

Evolution of ice crystal numbers after nucleation

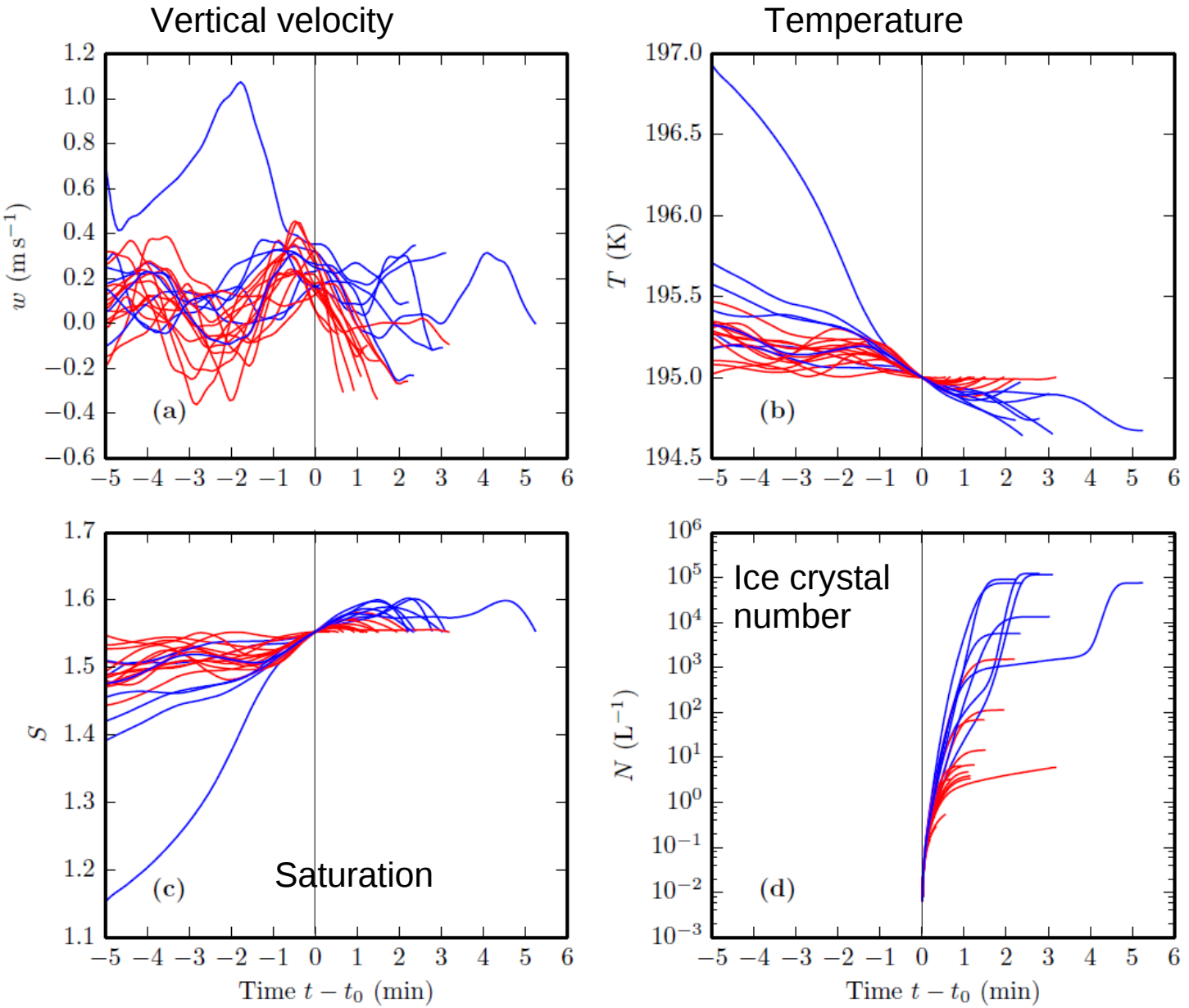


Dinh et al, ACPD 2015

Investigation of nucleation subject to realistic temperature fluctuations

Examples of timeseries

t_0 = nucleation



Dinh et al, ACPD 2015

Investigation of nucleation subject to realistic temperature fluctuations

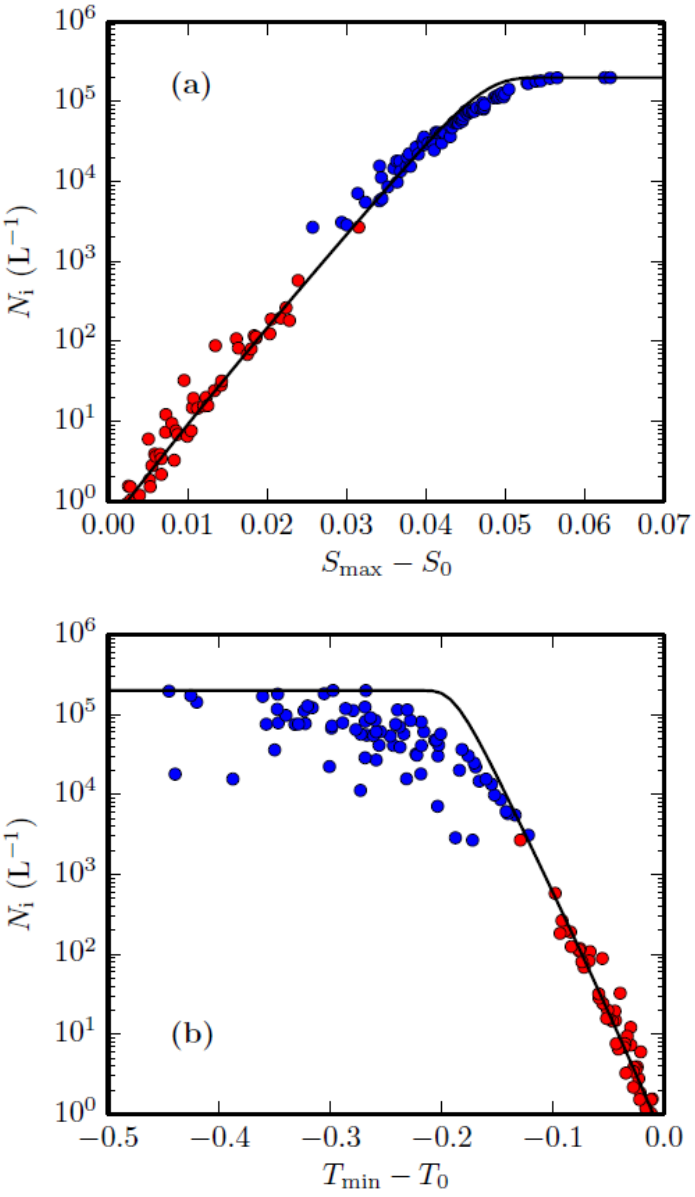
Events sorted between those controlled

by water vapor (ICN limited by depletion of water vapor),

by temperature (ICN limited by temperature evolution)

Results can be summarized by the difference between

maximum saturation and saturation at nucleation



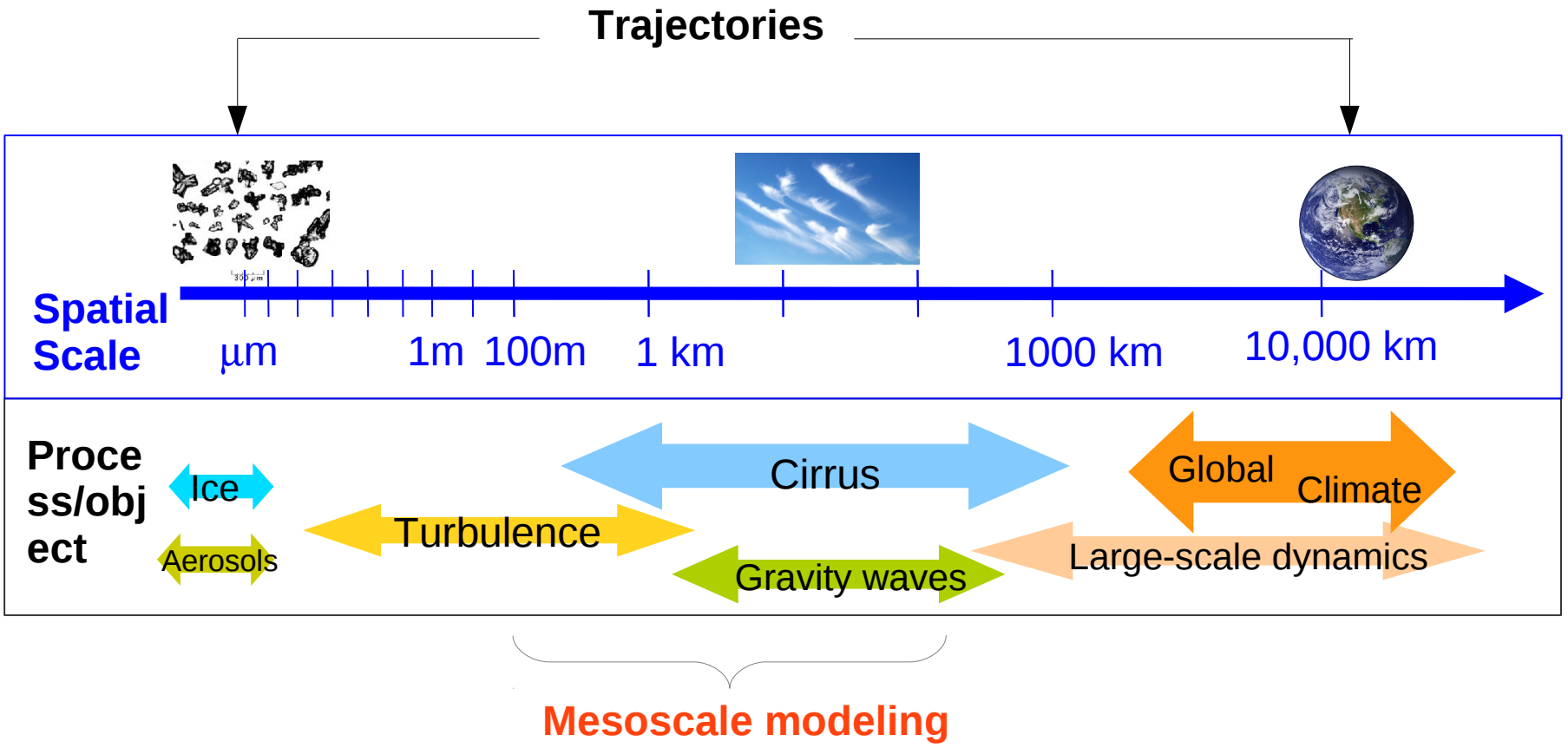
Confirms possibility of **low ice crystal numbers from homogeneous nucleation because of fast T fluctuations**

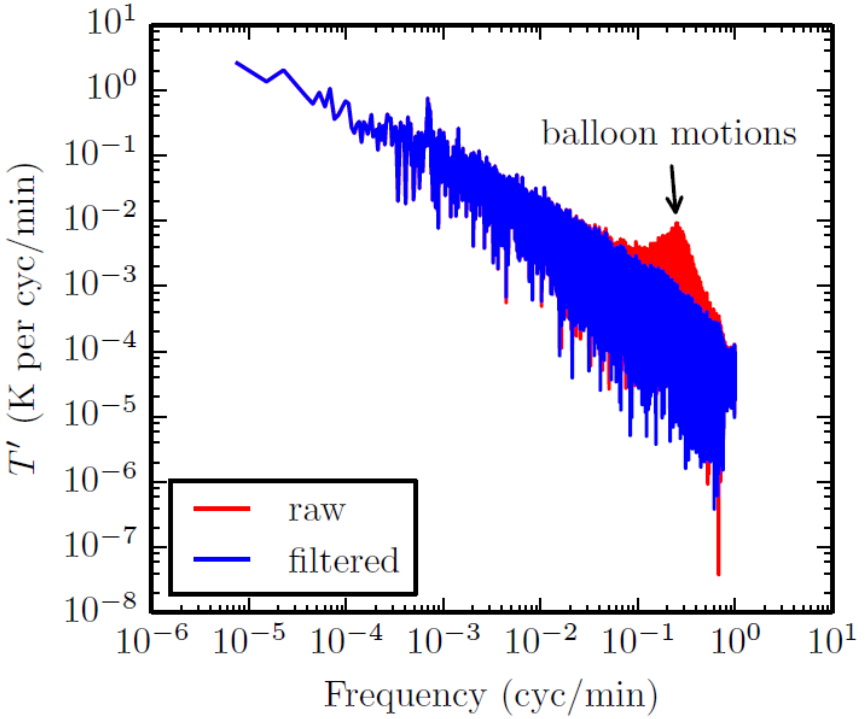
Dinh et al, ACPD 2015

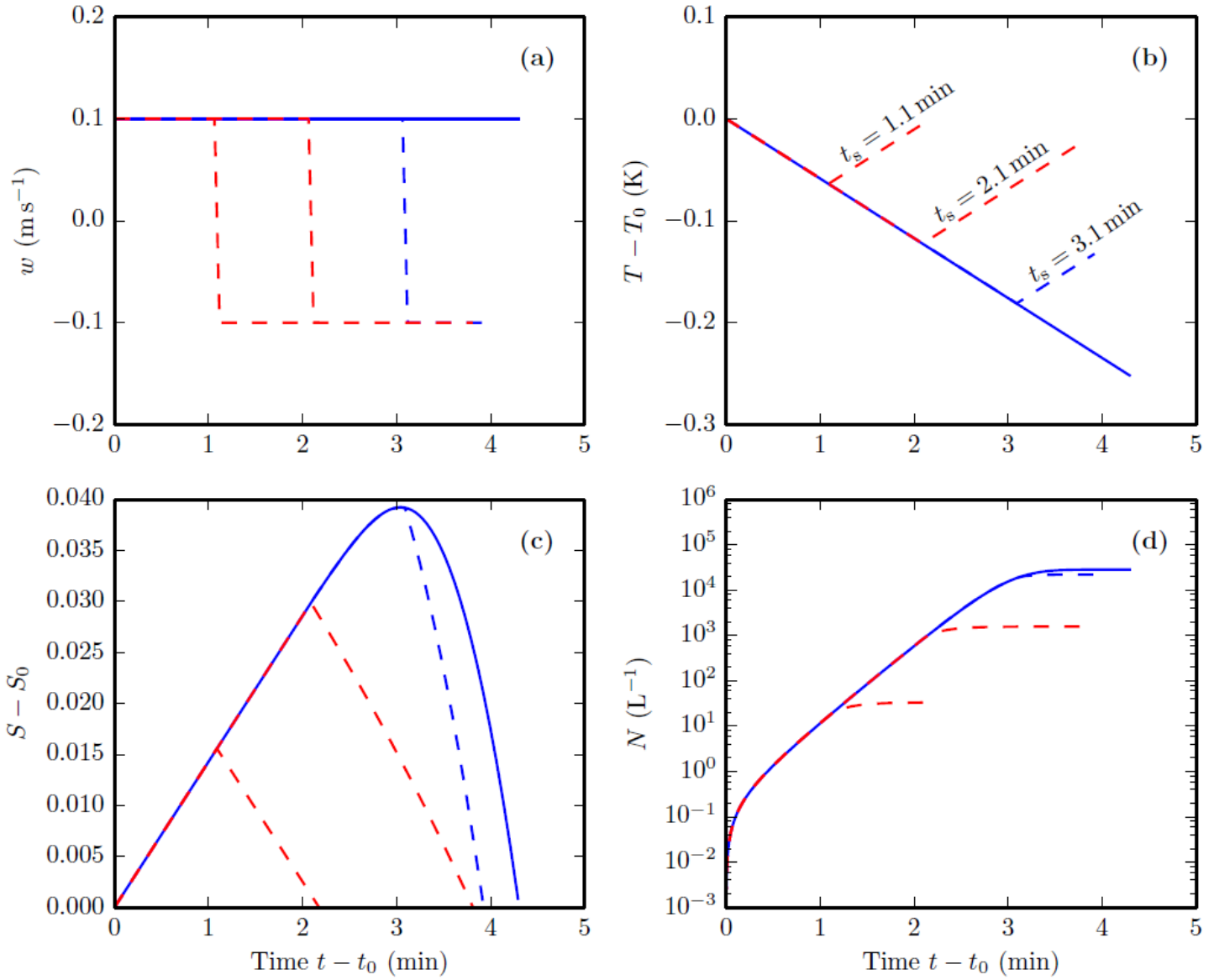
Issues and perspectives

Importance of this effect ?
Resulting implications on
water budget in the TTL ?
cirrus coverage for a given dehydration level ?

Interplay of different mechanisms
(microphysics, aerosols, sedimentation, turbulence, GW...)




10^{1}
10^{0}
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
T' (K per cyc/min)
balloon motions
raw
filtered
10^{-6} 10^{-5} 10^{-4} 10^{-3} 10^{-2} 10^{-1} 10^{0} 10^{1}
Frequency (cyc/min)


(a)
w (m s^{-1})
0.2
0.1
0.0
−0.1
−0.2
0
1
2
3
4
5
(b)
$T - T_0$ (K)
0.1
0.0
−0.1
−0.2
−0.3
$t_s = 1.1$ min
$t_s = 2.1$ min
$t_s = 3.1$ min
(c)
$S - S_0$
0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
0.000
Time $t - t_0$ (min)
(d)
N (L^{-1})
10^6
10^5
10^4
10^3
10^2
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
Time $t - t_0$ (min)