Fine-scale atmospheric dynamics and ice microphysics

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UTCC-PROES meeting- Paris, May 19, 2025

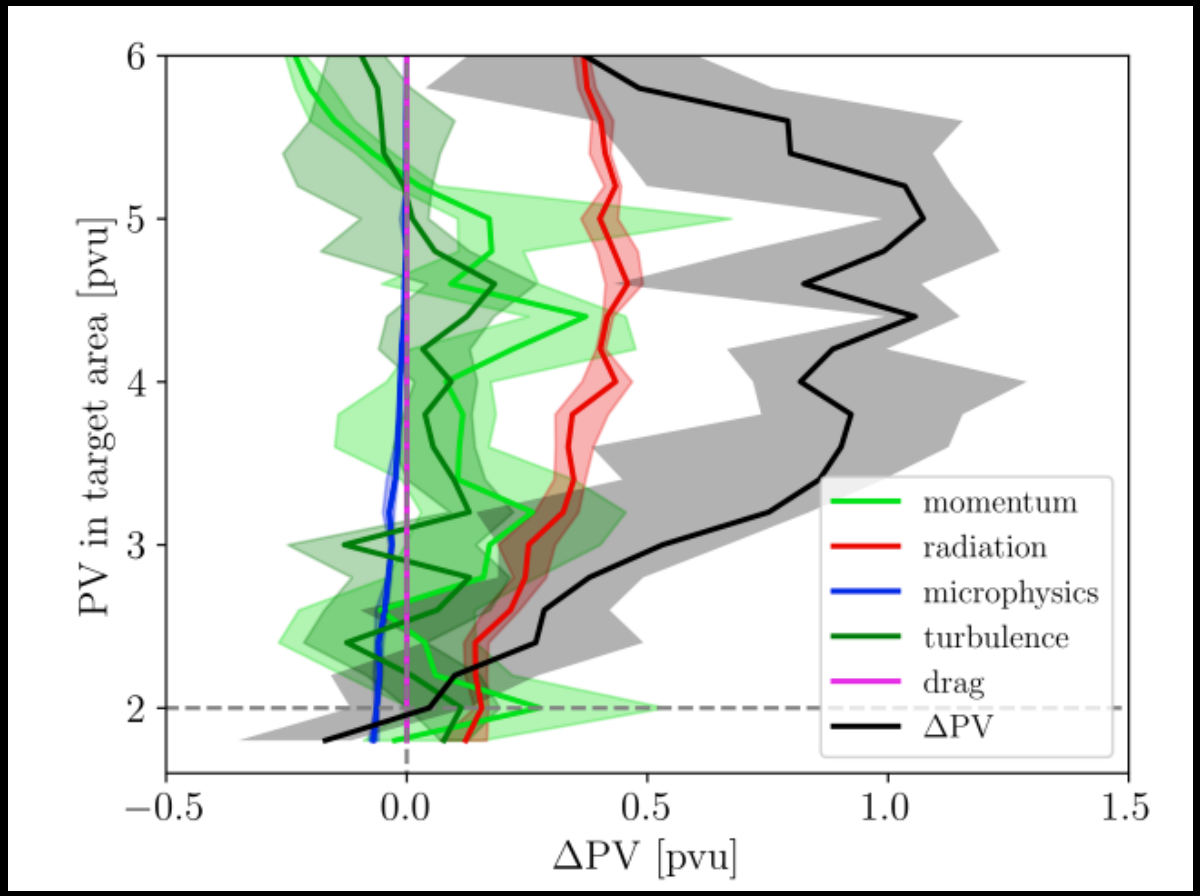
Outline

- Connection with APARC (Atmospheric Processes and their Role in Climate) activities

- Strateole-2 long-duration balloon observations of vertical wind and tropical clouds
- *- Atmospheric dynamics and cirrus in the tropical tropopause layer*

UTCC-PROES/APARC: shared interests

- APARC OCTAV-UTLS (Observed Composition Trends And Variability in the Upper Troposphere and Lower Stratosphere): understanding Cloud Radiative Effect and dynamical impacts



Emig et al., 2025

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- APARC FISAPS Fine Scale Atmospheric Processes and Structures: small-scale turbulence in clear-sky and near clouds; fine-scale mixing

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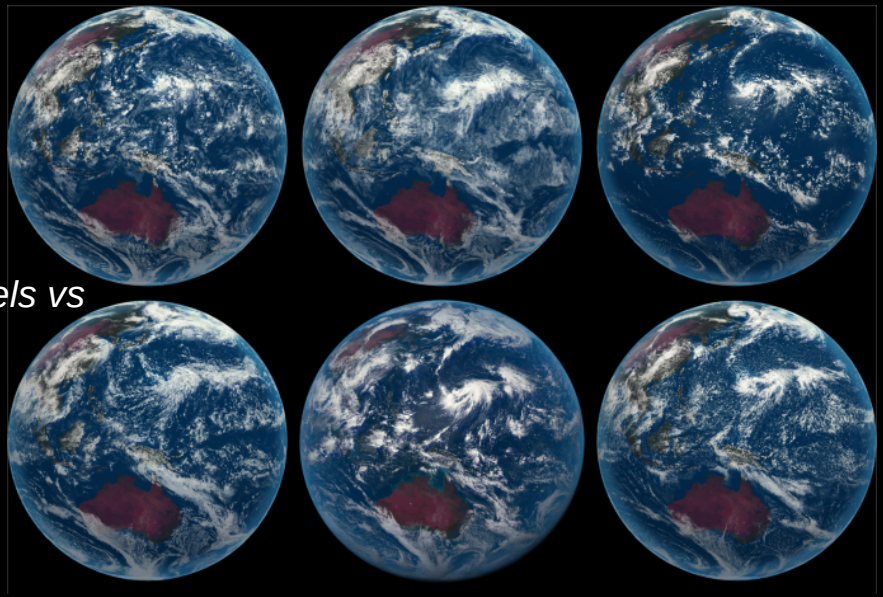
- APARC gravity wave activity:
- - role of convection and convective organization in wave generation
- - its evolution in a changing climate.
- - representation of vertical wind in models

A challenge for atmospheric models: vertical wind

- Over the last decade, advance of global kilometer-resolution models
- Increasing fraction of the vertical wind (w) spectrum is resolved
- ***Is it realistic ??***



DYAMOND models vs HIMAWARI

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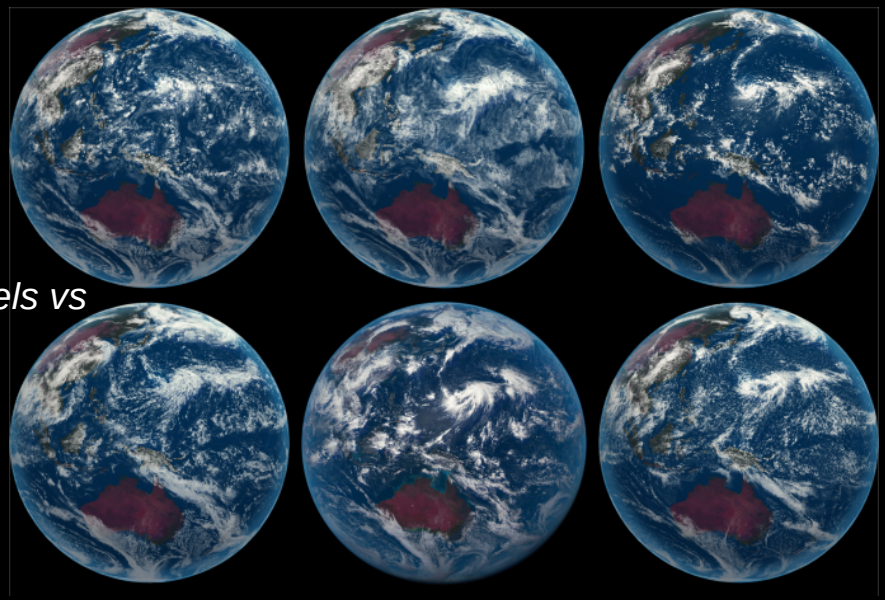
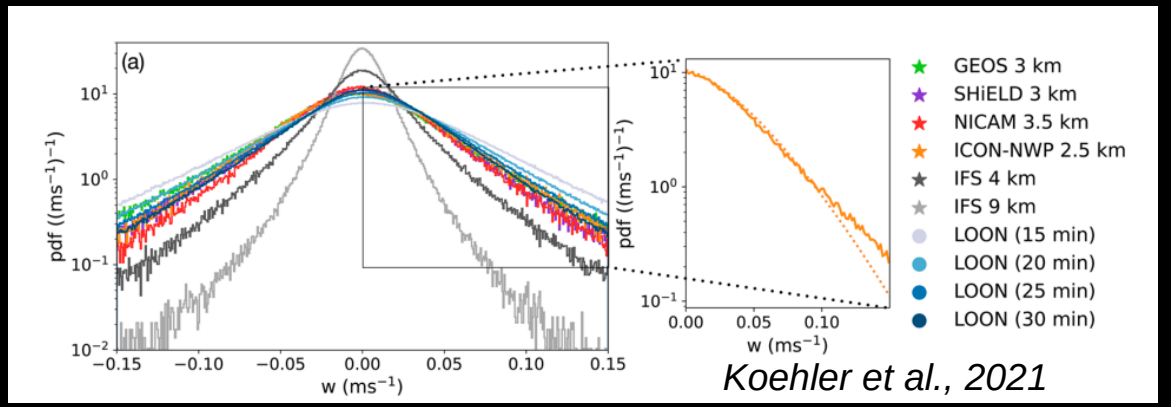


LOON w balloon measurements and DYAMOND models



Koehler et al., 2021

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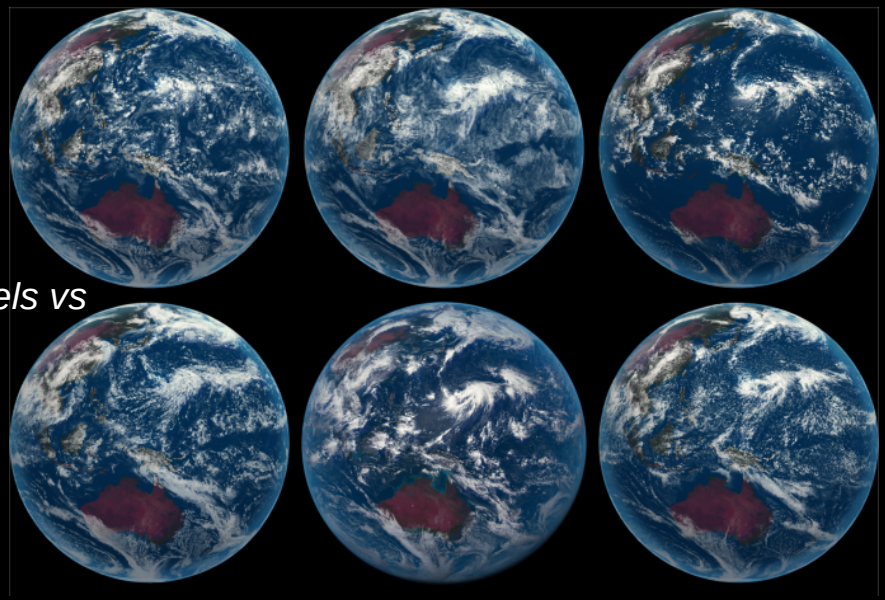
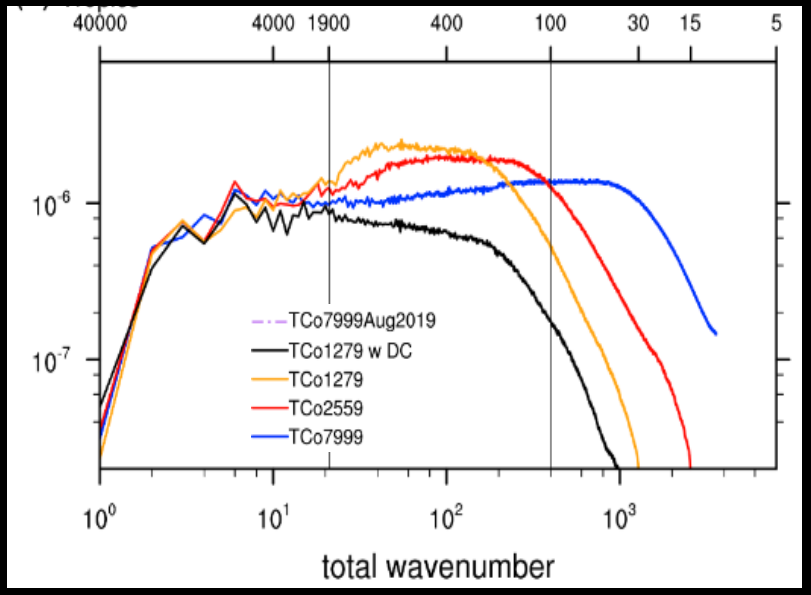


DYAMOND models vs HIMAWARI

W spectrum in the ECMWF model run at various resolutions



Politchouck et al., 2023

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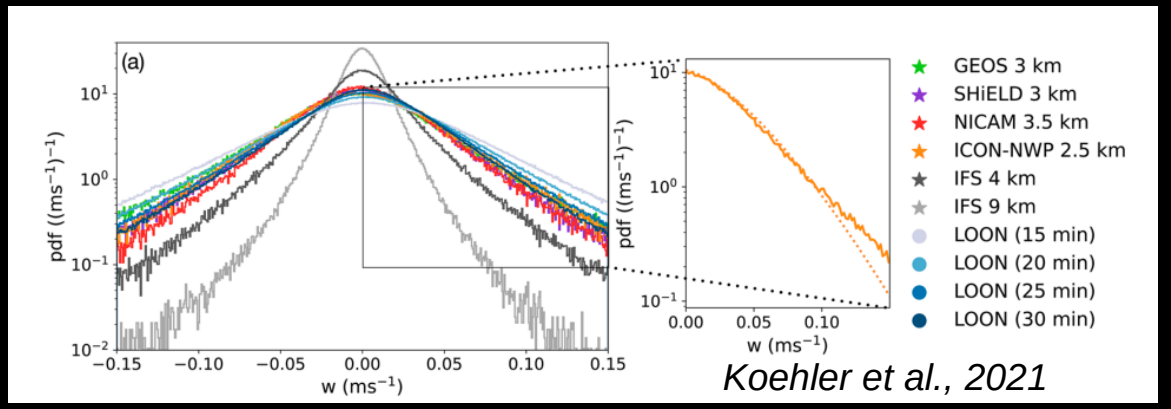

Koehler et al., 2021

A challenge for atmospheric models: vertical wind

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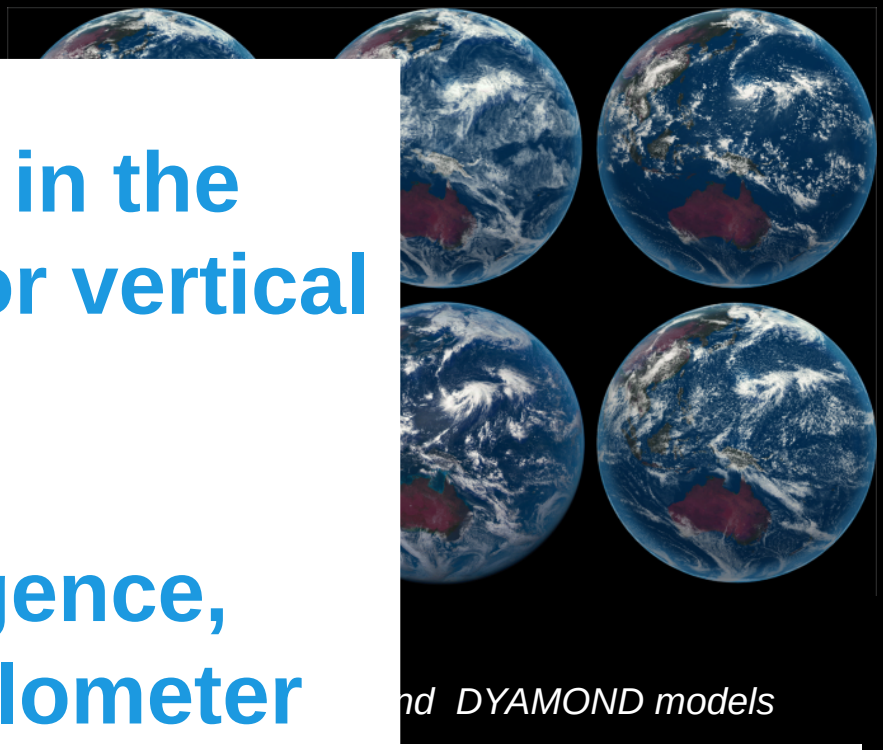
We are still in the grey zone for vertical wind

No convergence, even with kilometer scale models



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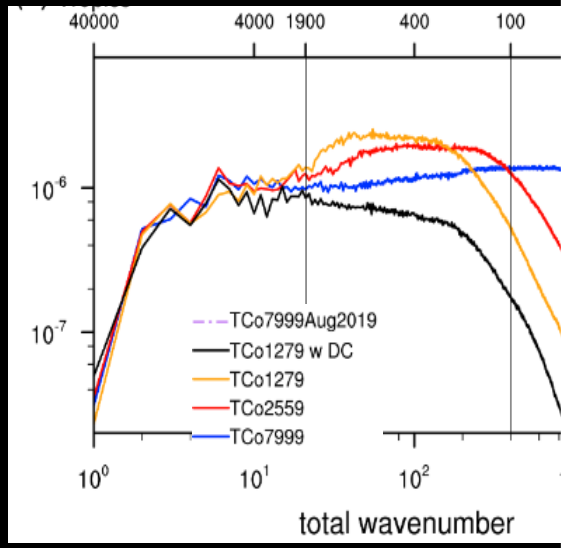
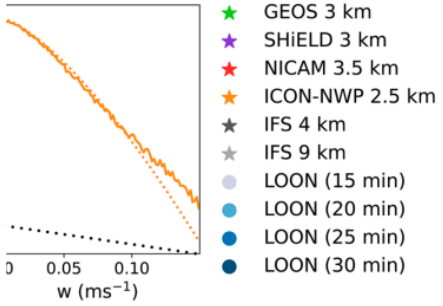
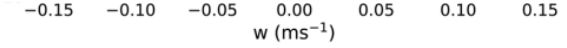
W spectrum in the ECMWF mode



Politchouck et al., 2023





Koehler et al., 2021

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Superpressure balloons: an observational platform for dynamics and clouds

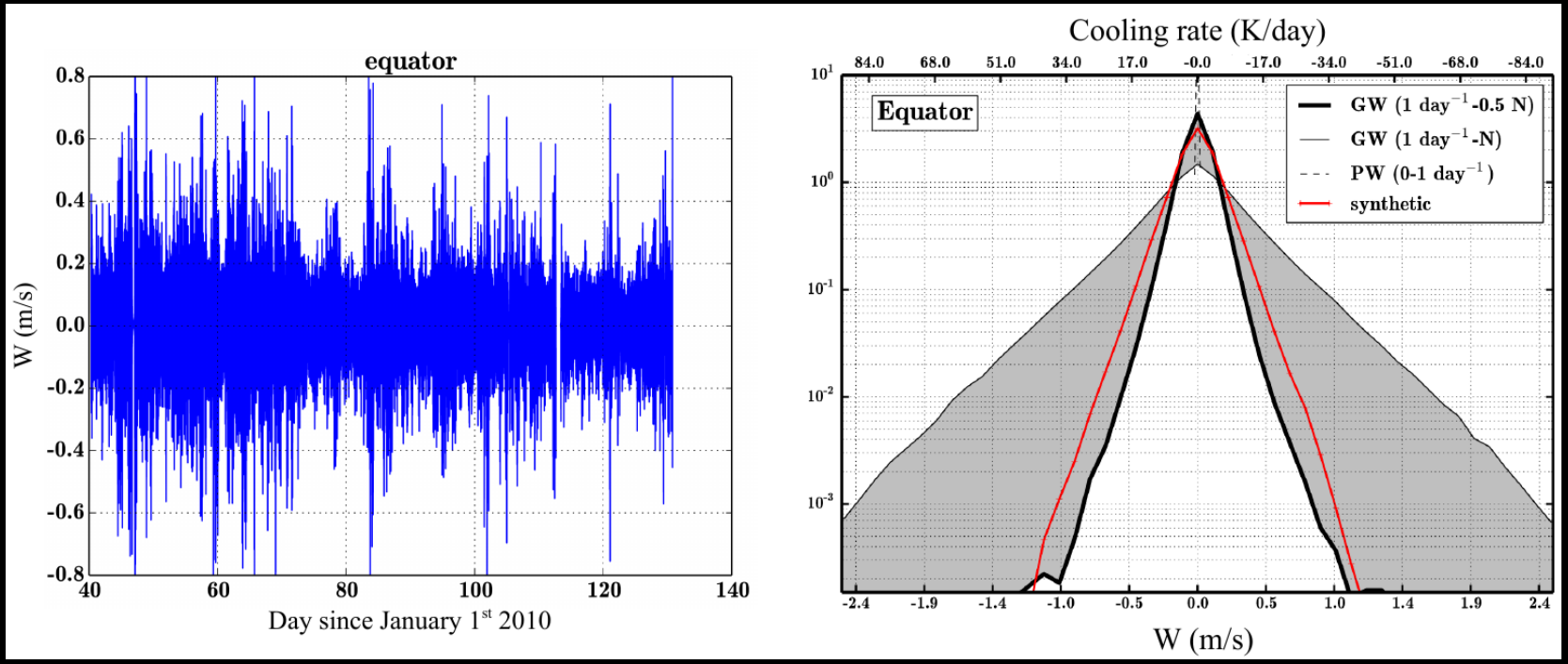
- Drift horizontally following the flow: quasi-Lagrangian behavior, relevant for physical processes
- ~3-month flights at **18-20 km**
- Measurement of **T** and **w** (@ 30 s)
- 4 tropical campaigns since 1998
- Latest vintage = Stratéole 2

Stratéole 2 flight trajectories 2021-2022

Vertical wind

W time serie

W pdf



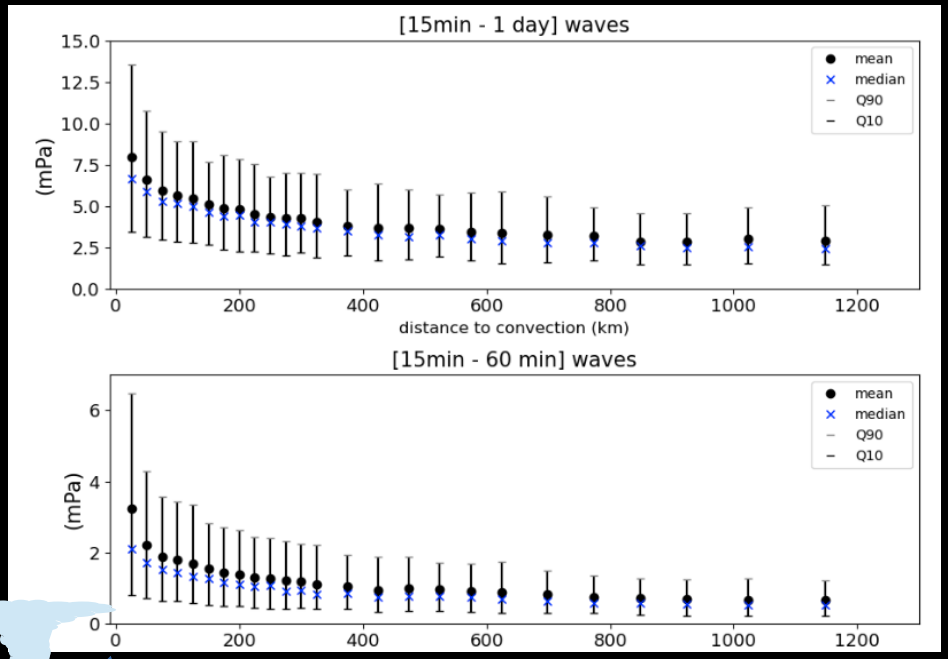
Podglajen et al. , 2016

- Superpressure balloon measurements provide time series of vertical wind (W) fluctuations
- emphasize ubiquitous W variability related to gravity waves
- Intermittent amplitude of the waves. Why ?

Gravity wave relationship with convection

All frequency

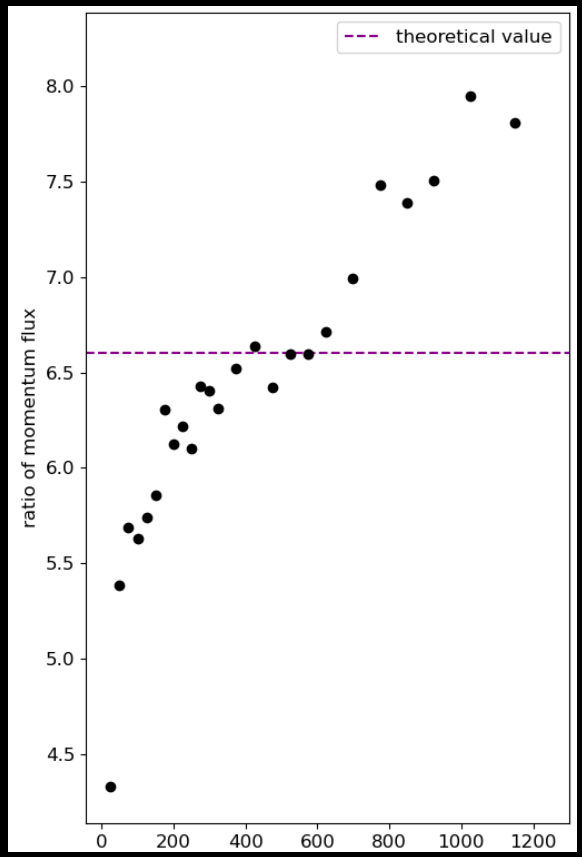
High frequency



Distance to convection

- Wave activity decreases away from convection
- High-frequency wave amplitude decrease faster

Ratio of variances
all-frequencies /High-frequency

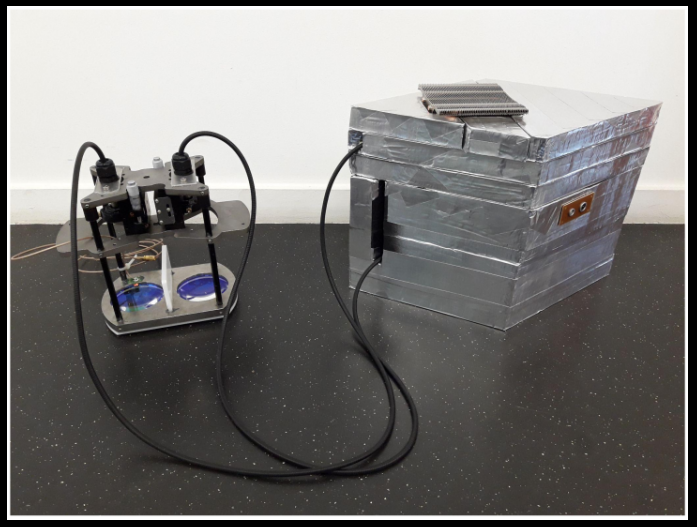


Distance to convection

Corcos et al., JGR, 2021

Clouds from balloons

BeCOOL: The Balloon-borne Cirrus and convective overshOOt Lidar



Light-weight elastic lidar

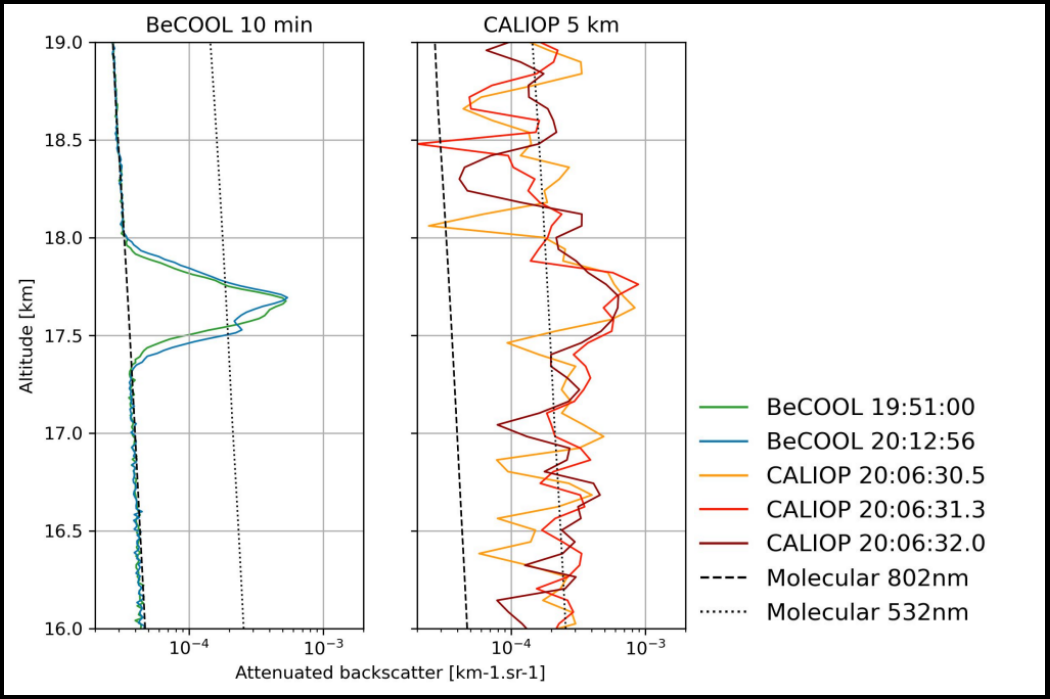
- Single wavelength : 802 nm
- Vertical resolution : 15 m
- Temporal resolution : 1 min
- Flight level : 20 km
- Nighttime observations only

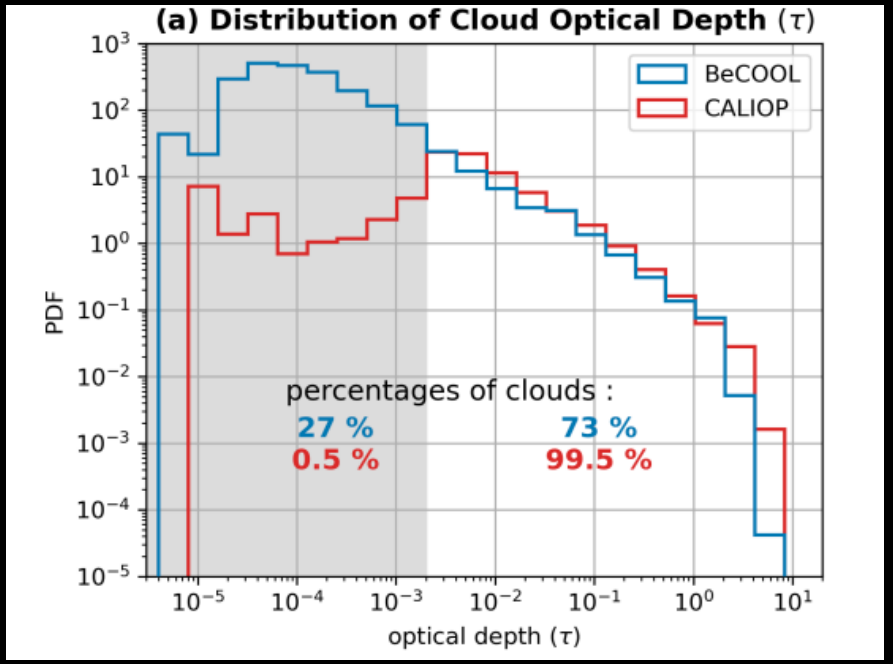
Strateole-2 2021-2022

- 3 BeCOOL flights
- 137 nights of observation

Ravetta et al., in prep

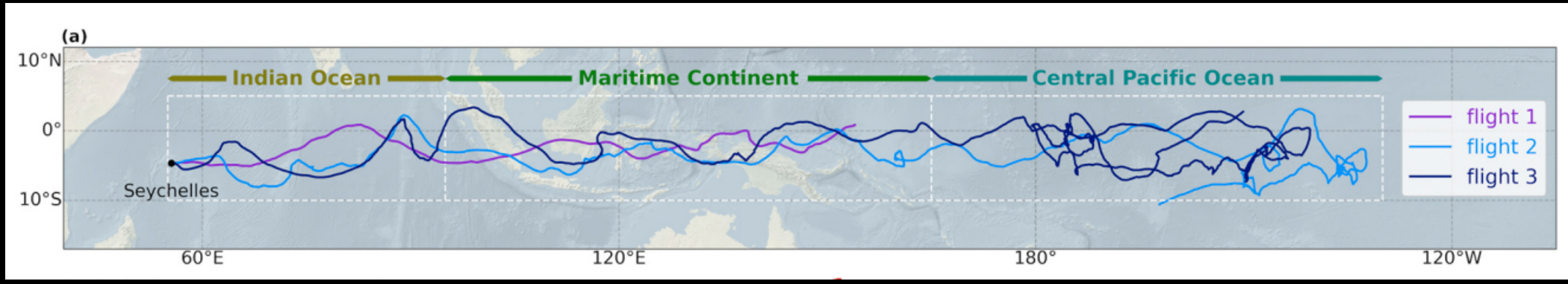
Clouds from balloons

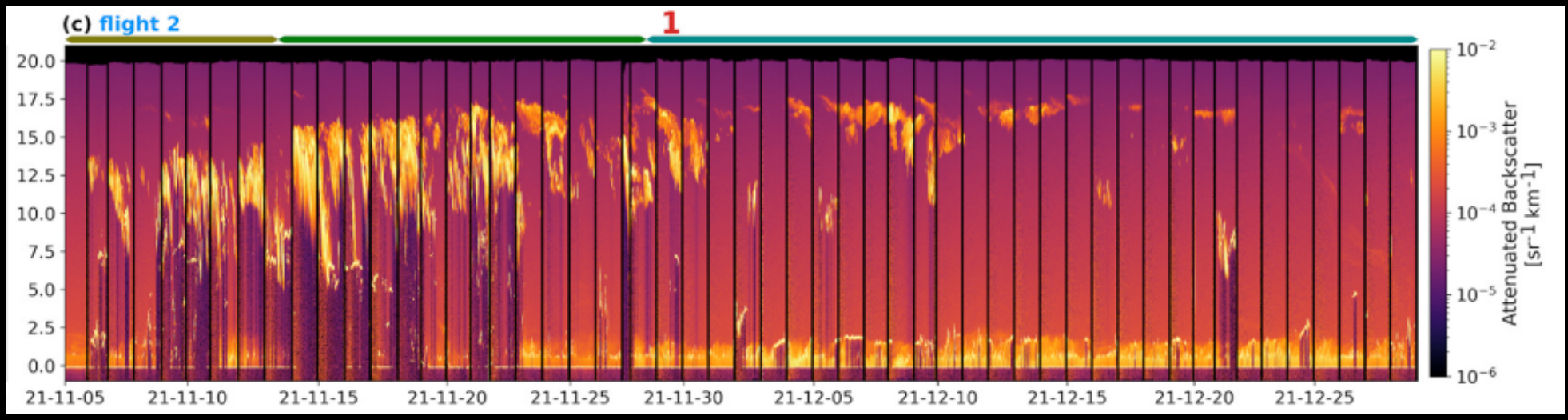




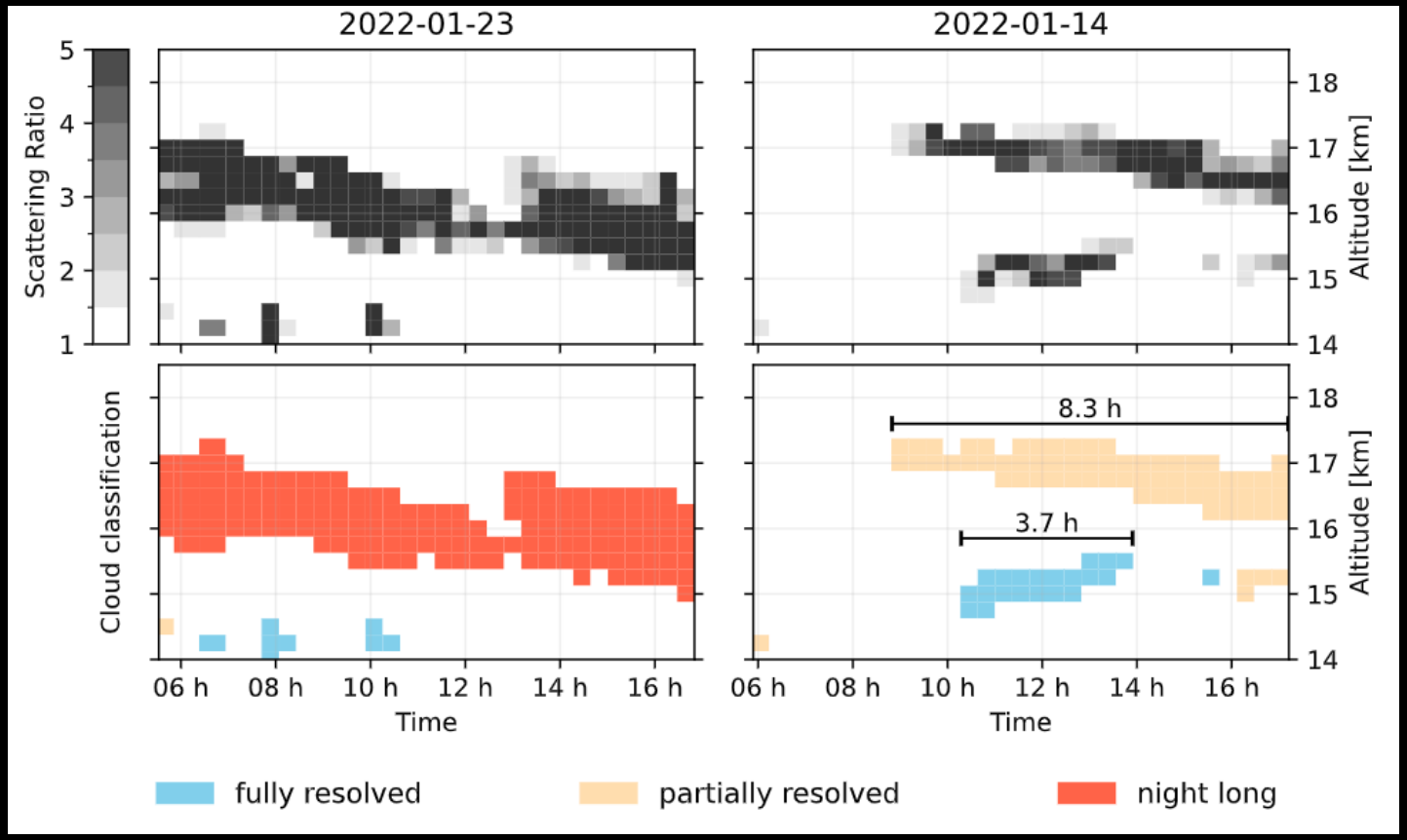
Lesigne et al., 2024

Clouds scenes observed from balloons





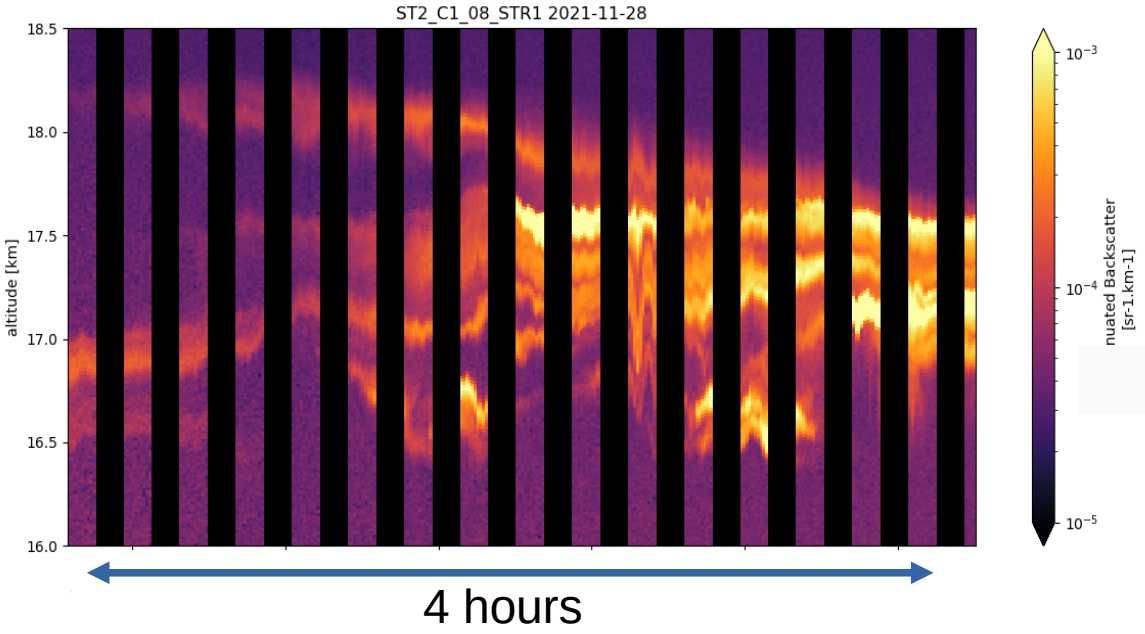
Balloon-borne observations: lifecycle perspective



- Balloons move slowly relative to the cloud field
- Possibility to assess cirrus lifetime (assuming ergodicity, in paritcular no diurnal cycle)
- 90 % of the clouds are shorter than 12 hours, but they represent only 30 % of the coverage
- Application to other type of clouds ?

Lifetime range	$\tau < 1$ h	1 h $< \tau <$ 6 h	6 h $< \tau <$ 12 h	12 h $< \tau$
Percentage of clouds	50 %	32 %	8 %	10 %
Effective Coverage	3 %	15 %	12 %	71 %

Fine-scale microphysics variability revealed by high-resolution BeCOOL data



→ Multi-layered TTL cirrus with thin (<100 m) persistent high-backscatter layer embedded within a lower backscatter cloud

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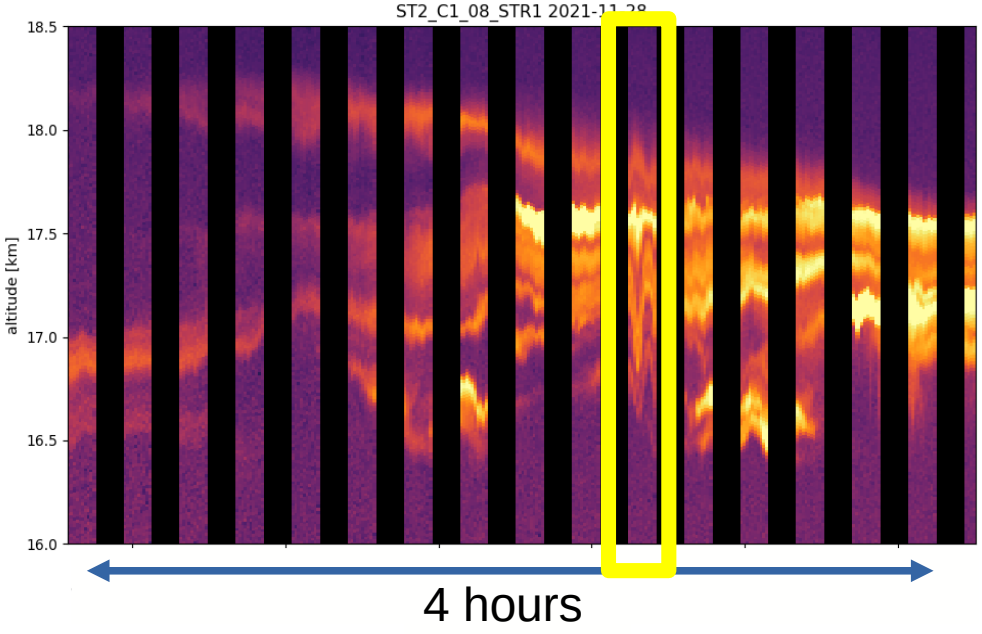

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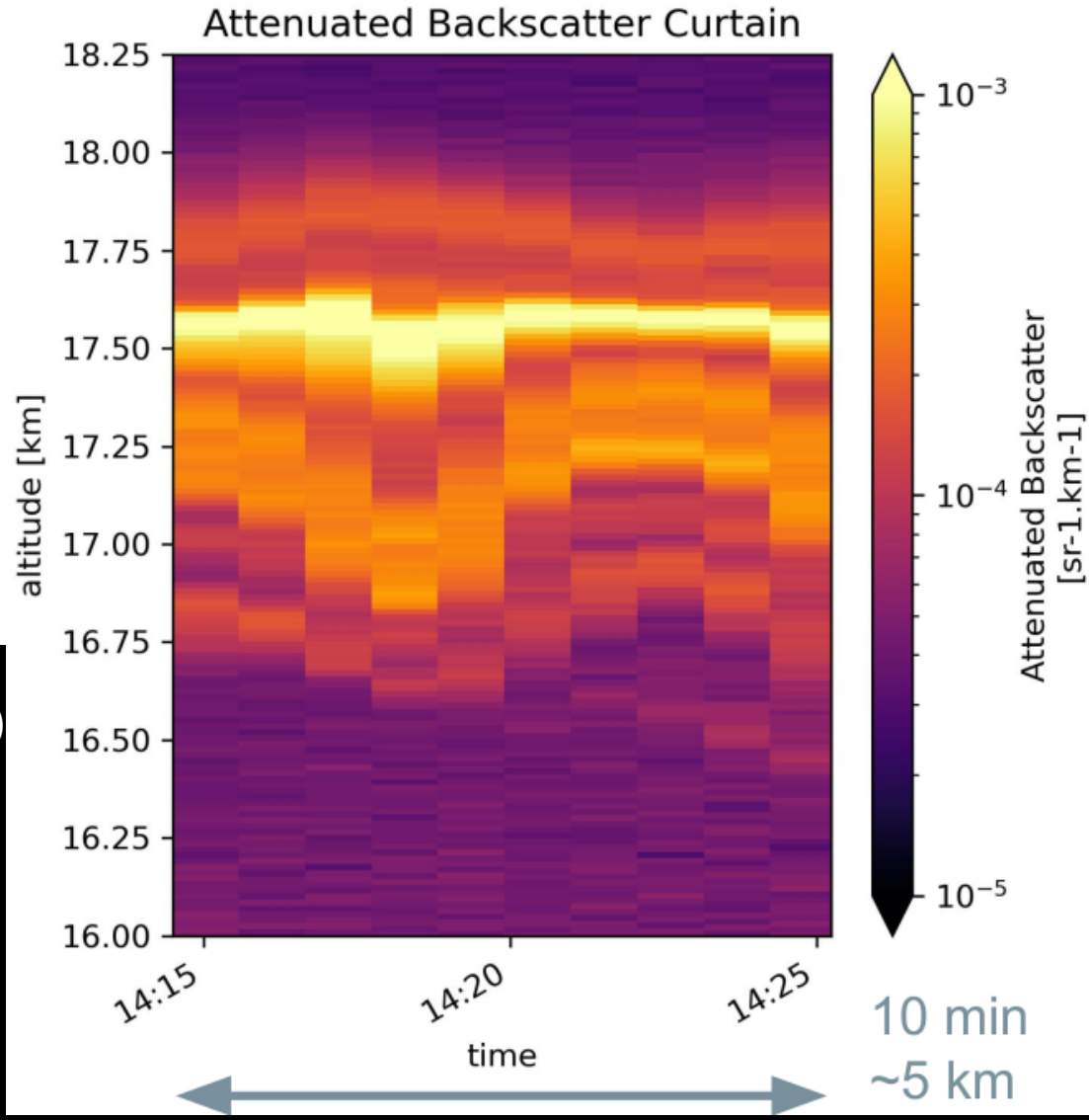

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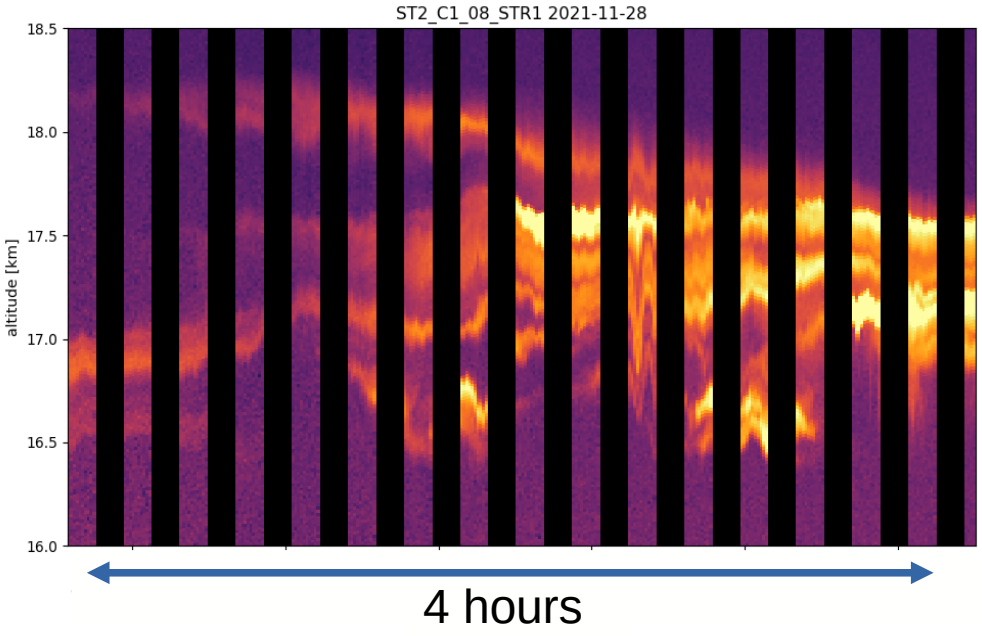

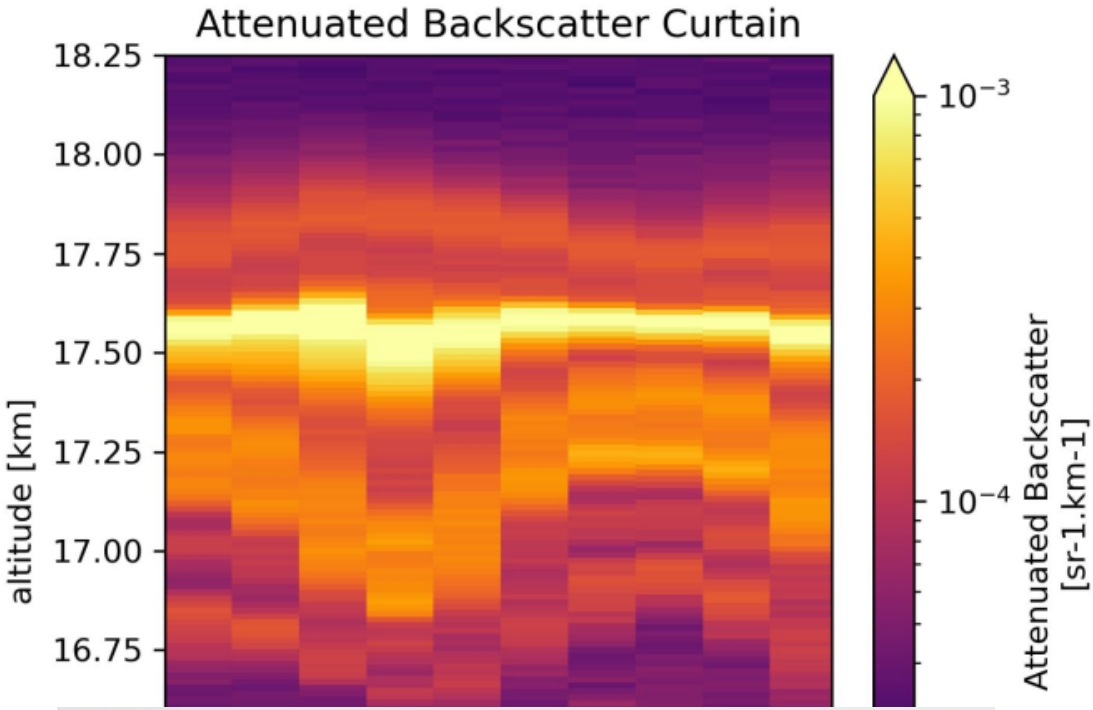

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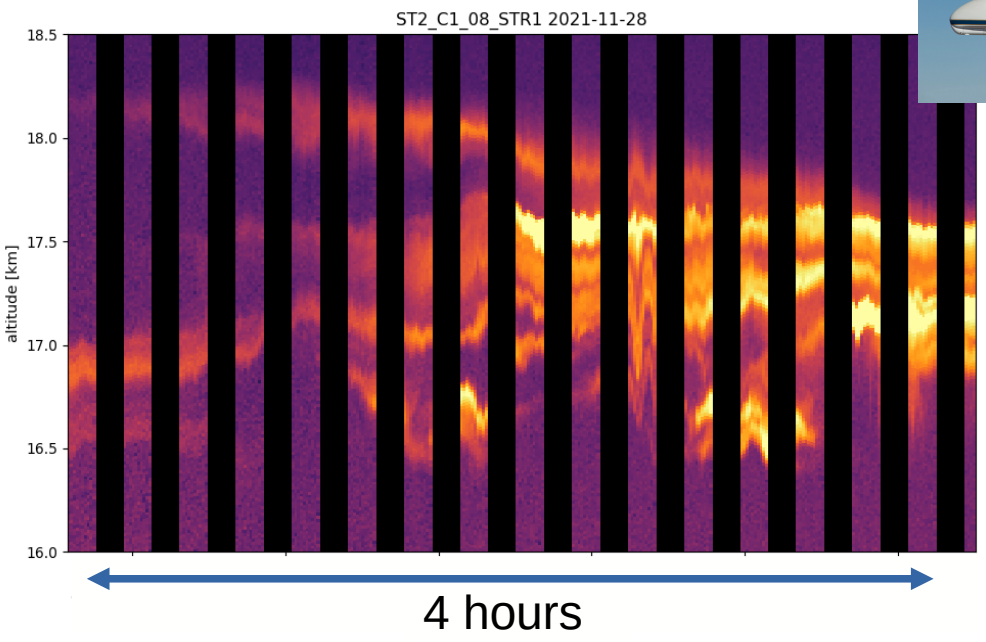
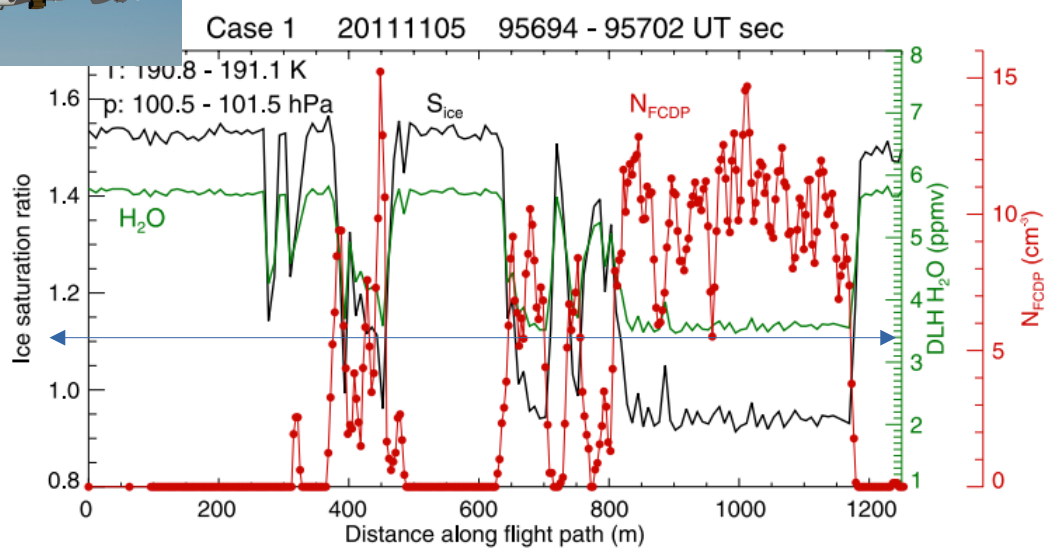


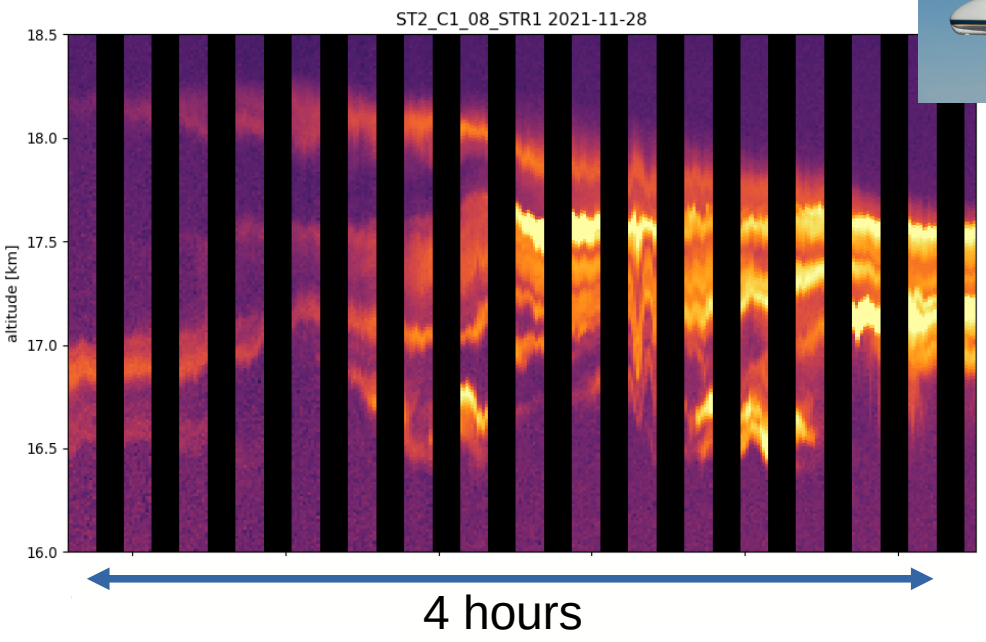


Jensen et al., 2013, 2022

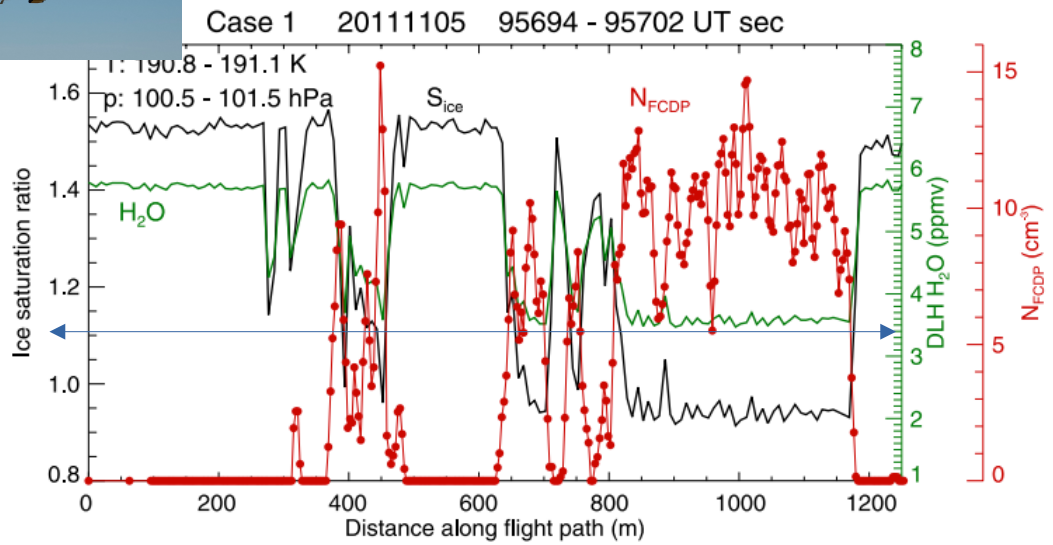
→ Multi-layered TTL cirrus with thin (<100 m) persistent high-backscatter layer embedded within a lower backscatter cloud

→ reminiscent of local spikes in ice crystal number from airborne observation (ATTREX)

Fine-scale microphysics variability revealed by high-resolution BeCOOL data

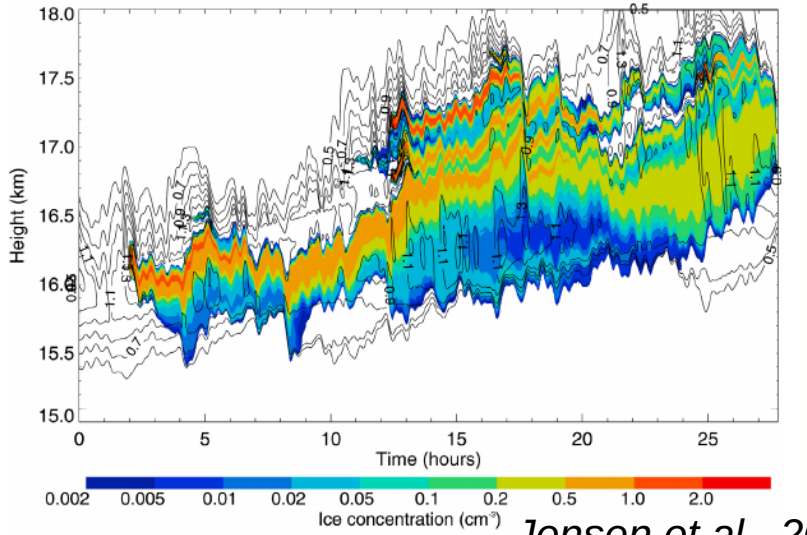


ATTREX airborne data



Jensen et al., 2013, 2022

Cirrus simulations



Jensen et al., 2012

→ Multi-layered TTL cirrus with thin (<100 m) persistent high-backscatter layer embedded within a lower backscatter cloud

→ reminiscent of local spikes in ice crystal number from airborne observation (ATTREX)

→ What resolution is needed to simulate this feature ? Does it matter ?

Summary and outlook

- Need for better observational constraint and modelling efforts on vertical wind

- Balloon-borne observations: - « lifecycle » perspective on clouds
- - high-resolution reveal new features of the cloud field (foliated structures, thin clouds)

- Fine vertical scale structures remain below model resolution: need for dedicated “macrophysics” parameterization in UTLS cirrus for radiation, dynamics and microphysics ?

- *Thank you for your attention*