

# living planet symposium

BONN  
23–27 May  
2022

TAKING THE PULSE  
OF OUR PLANET FROM SPACE



EUMETSAT



ECMWF



## Gravity wave and polar stratospheric cloud observations with ESA's Aeolus satellite

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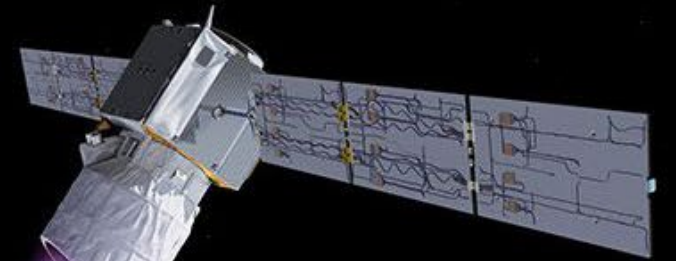
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25 May 2022

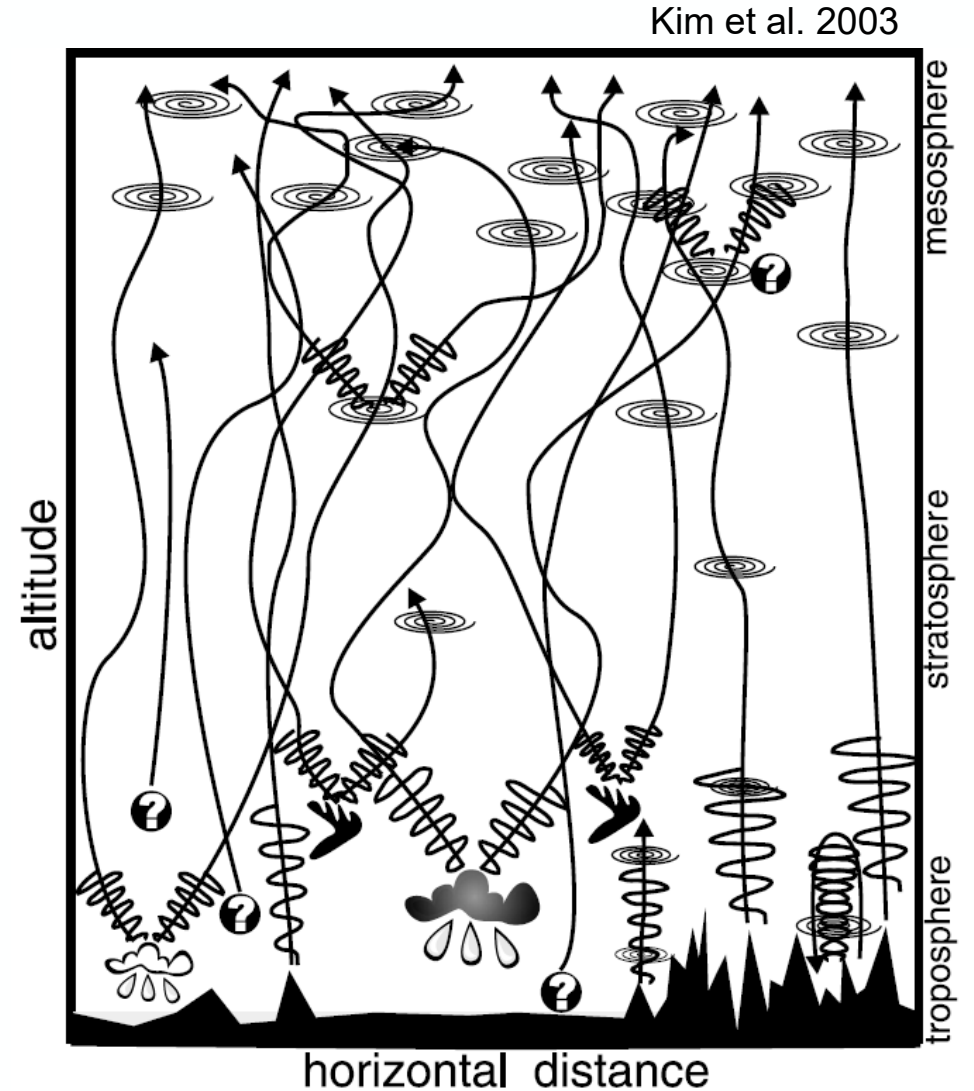


1. Can we observe gravity waves with Aeolus?
2. Can we observe polar stratospheric clouds with Aeolus?
3. What can we learn from Aeolus about gravity wave induced polar stratospheric clouds?



# What are gravity waves (GWs) and why are they important?

- Gravity waves are waves in a fluid medium with gravity as restoring force.
- **Sources of gravity waves** are for example **flow over orography, convection, atmospheric jet streams or fronts**
- **Gravity waves transport energy and momentum** from the troposphere to the stratosphere and mesosphere, where they **drive global circulations**.
- These circulations are linked to surface weather via downward coupling on seasonal to climatological time scales.
- **For an improvement of climate projections a better understanding of these waves** and their interactions with the background flow **is required**.



# What are polar stratospheric clouds (PSCs) and why are they important?

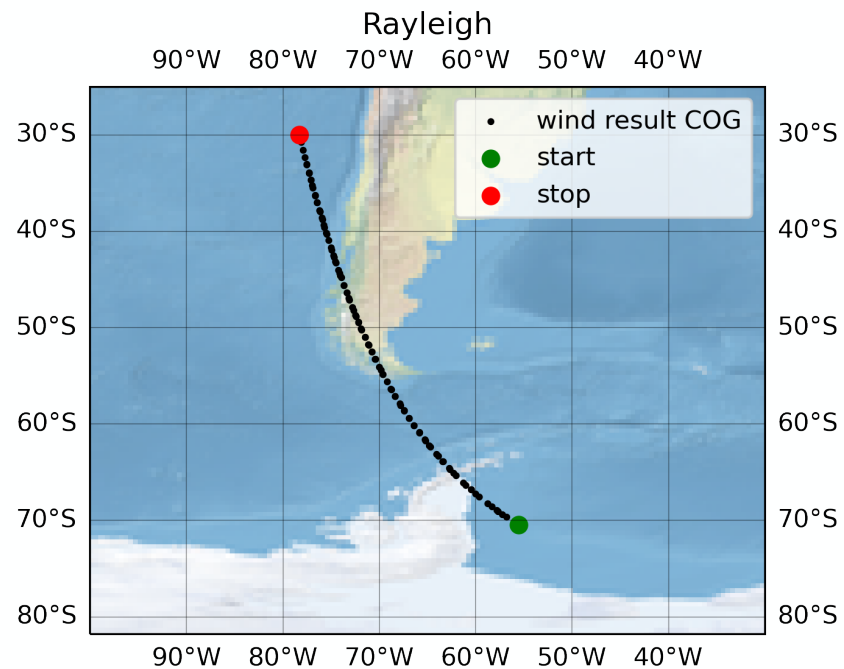
- **PSCs are thin ice clouds** in the polar stratosphere (15-25 km)
- They play a crucial role for **ozone depletion** and form at very **low temperatures** (below  $-78^{\circ}\text{C}$ )
- For details see e.g. PSC review paper by Tritscher et al. (2021), GRL
- At temperatures close to  $-78^{\circ}\text{C}$ , **gravity waves can trigger PSC formation**
- This is **especially important in early winter**
- **Aeolus is the only satellite to directly observe both PSCs** (optical products) and **GWs** (wind product)



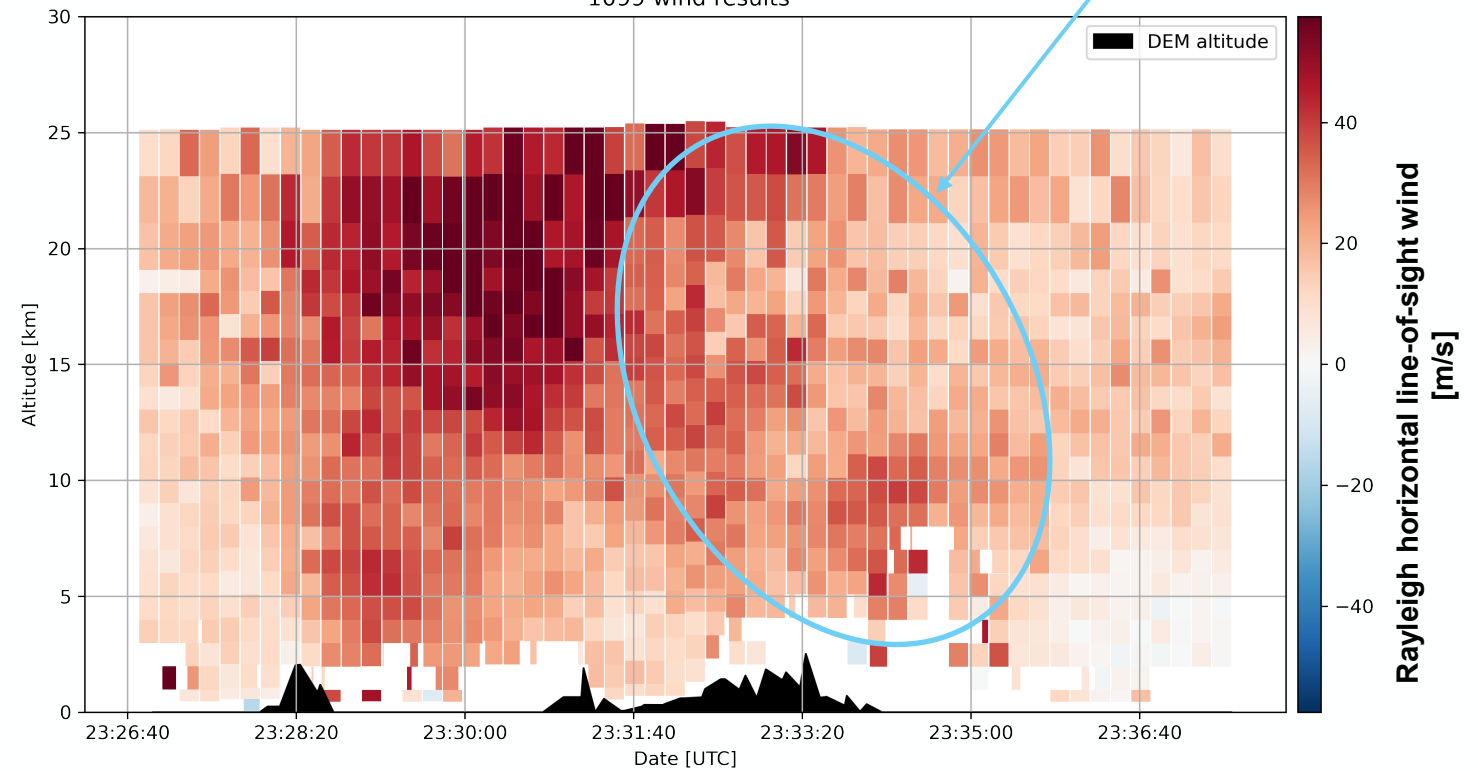
# Can we observe gravity waves with Aeolus?

## A case study above the Andes

Aeolus orbit  
from 2019-09-11T23:26:00Z to 2019-09-11T23:37:00Z



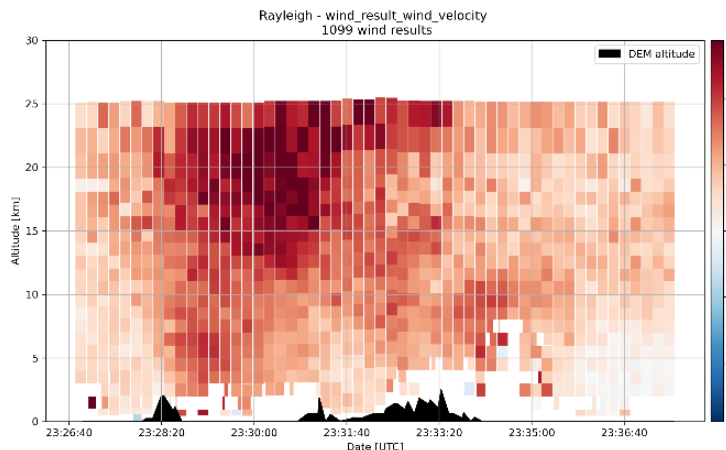
Rayleigh - wind\_result\_wind\_velocity  
1099 wind results



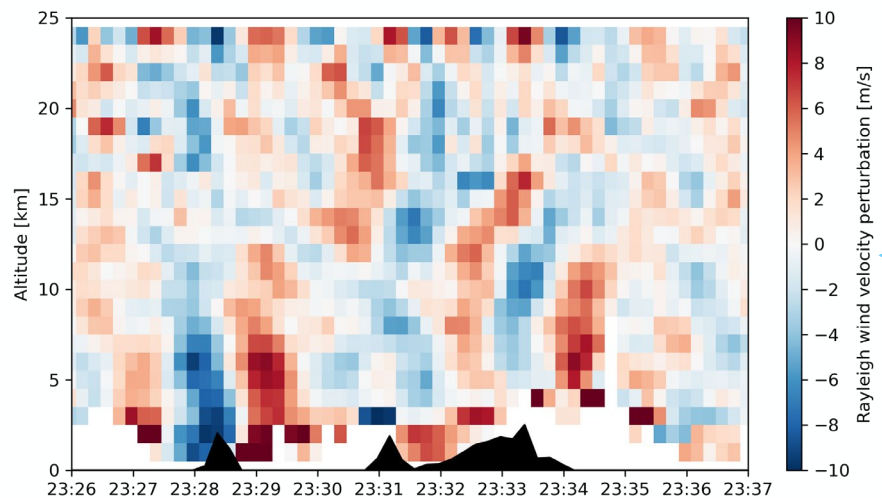
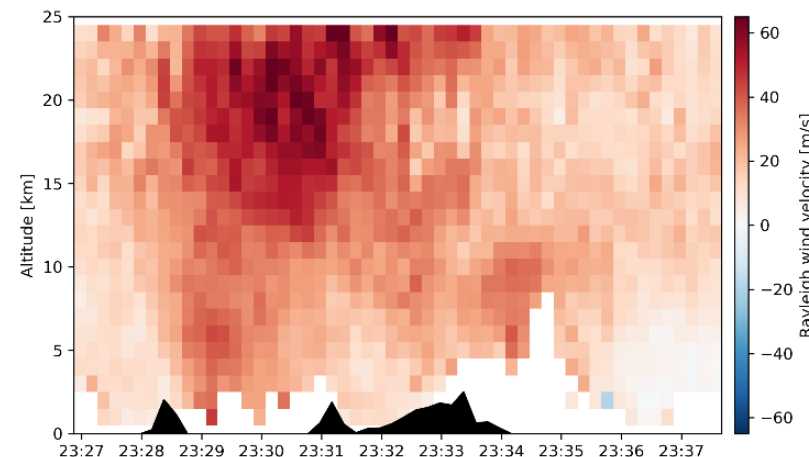
Plots generated with the Aeolus VirES VRE – see Poster by D. Santillan

# Can we observe gravity waves with Aeolus?

## Data treatment



Step 1:  
Interpolation to regular  
profile / altitude grid



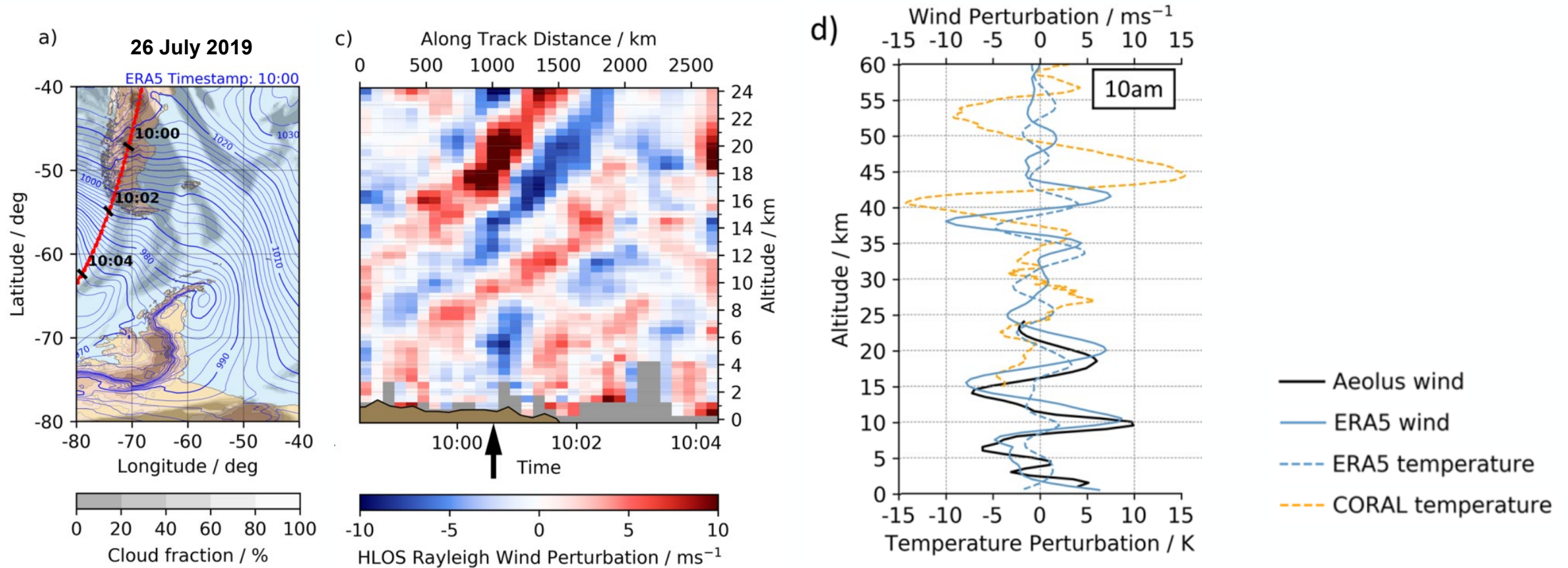
Step 2:  
**Detrending** of data using a 3<sup>rd</sup>  
order Savitzky-Golay filter with a  
horizontal window length of 2000  
km and **denoising** with a Savitzky-  
Golay filter with a horizontal  
window length of 3 profiles.

Data processing and plot generation  
on the Aeolus VirES VRE



# Can we observe gravity waves with Aeolus? ✓

## Good agreement with ERA5 and ground-based observations

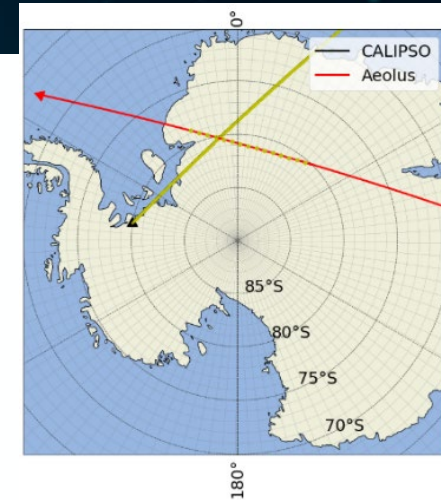




# Can we observe PSCs with Aeolus?

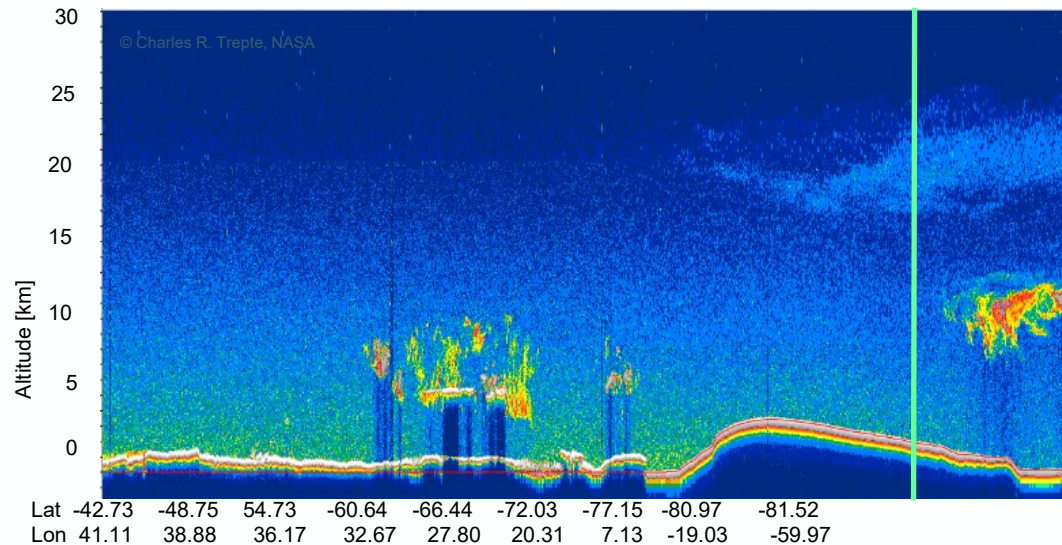
## Good agreement between CALIPSO and Aeolus backscatter products for single cases of PSCs

01 June 2020

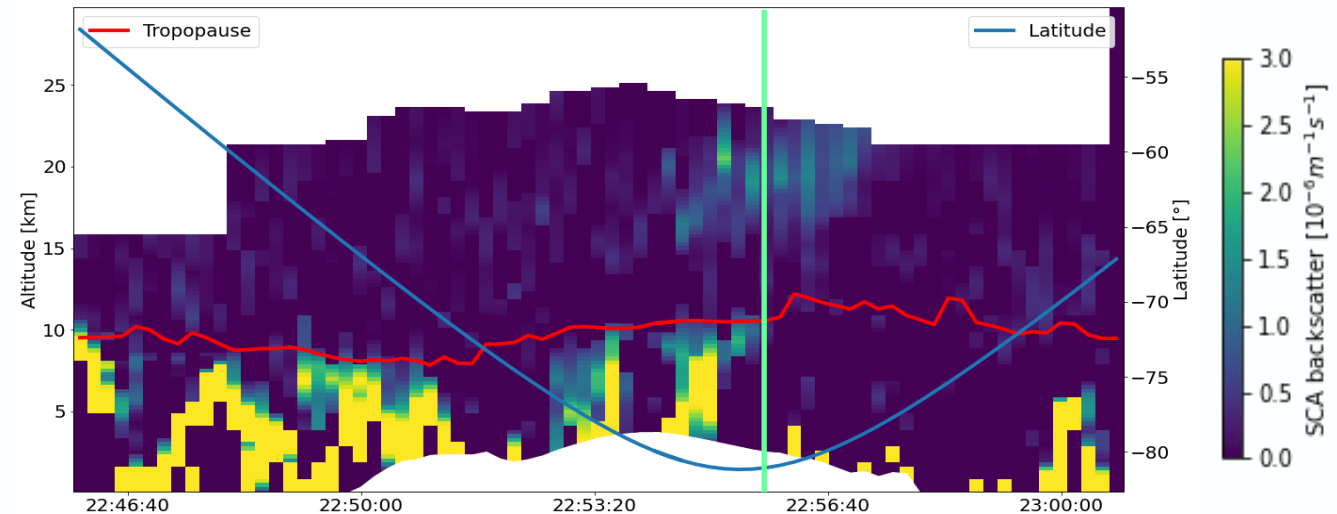


— Approximate crossing location

CALIPSO Total Attenuated Backscatter



Aeolus L2A\_SCA Interpolated Backscatter

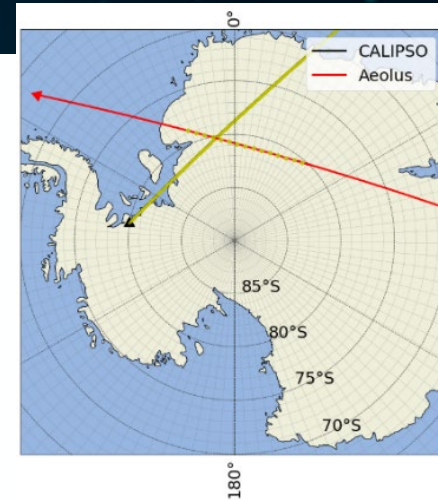


Left figure by Charles R. Trepte, NASA, right Figures by V. Cito Filomarino, DLR

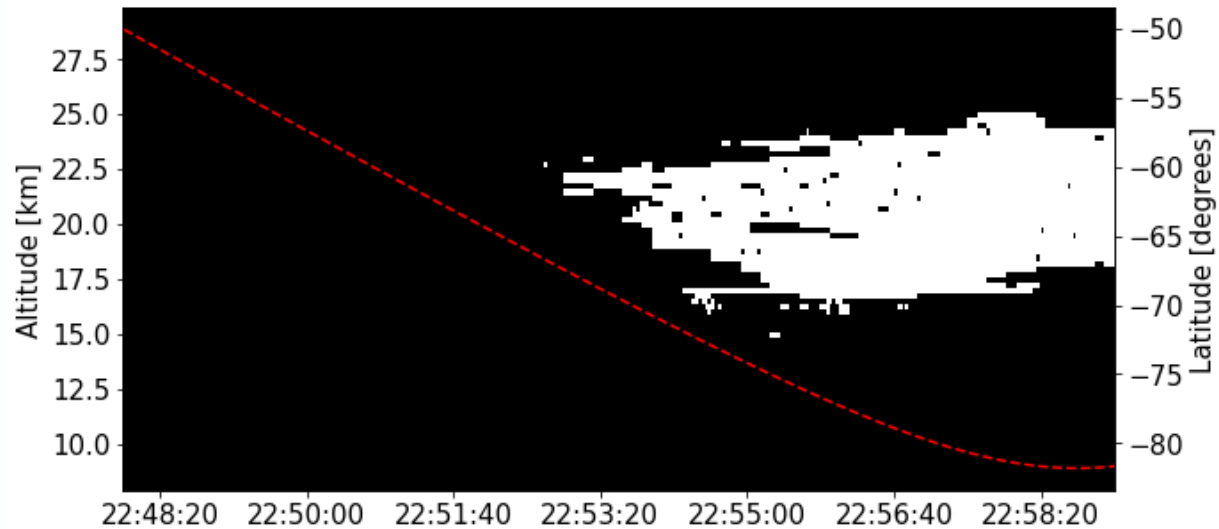
# Can we observe PSCs with Aeolus?

## Can we construct a PSC mask product for Aeolus?

01 June 2020



CALIPSO L2 PSC mask product



Aeolus PSC mask product

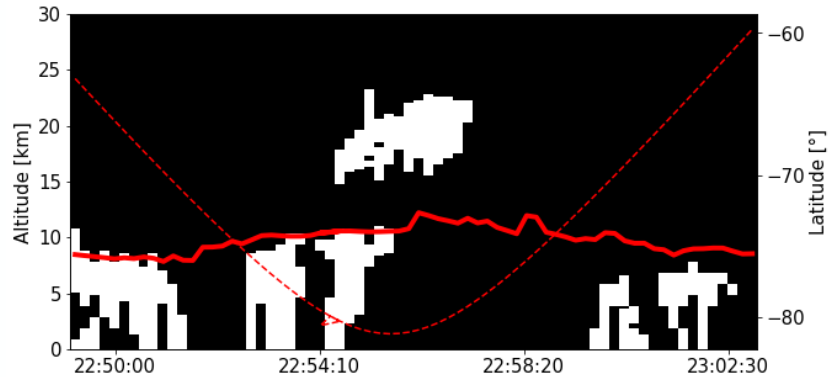


Figures by V. Cito Filomarino, DLR

# Can we observe PSCs with Aeolus?

## How to create a PSC mask for Aeolus?

### 2. Binarize setting a $\beta$ threshold, min number of pixels



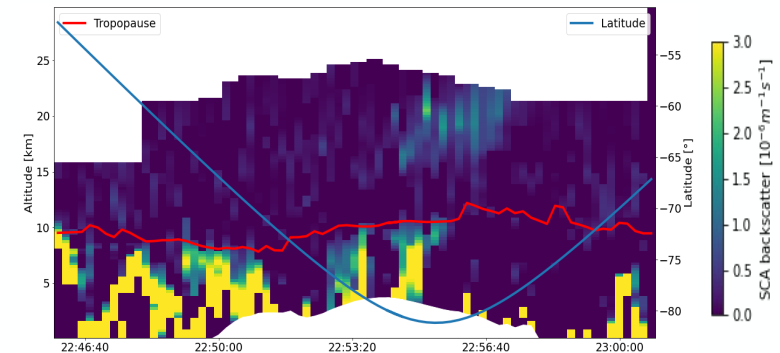
#### Filtering thresholds

BS :  $0.4 [10^{-6} m^{-1} sr^{-1}]$

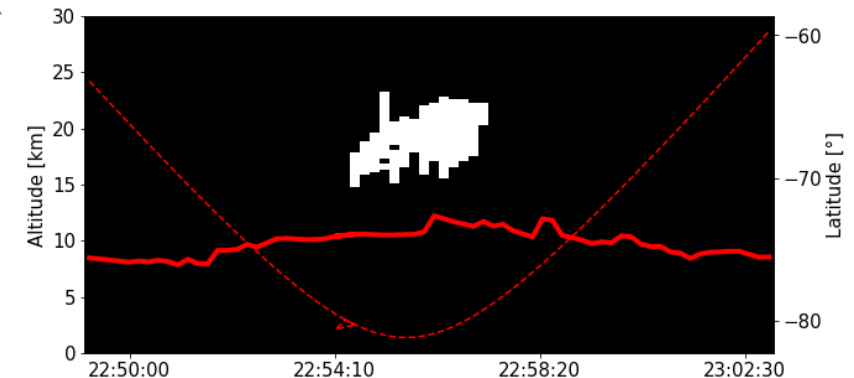
Altitude: AUX\_MET tropopause

Latitude:  $<60 S / >60 N$

### 1. Vertical interpolation to regular grid



### 3. Tropopause Altitude + 2 km as altitude cutoff

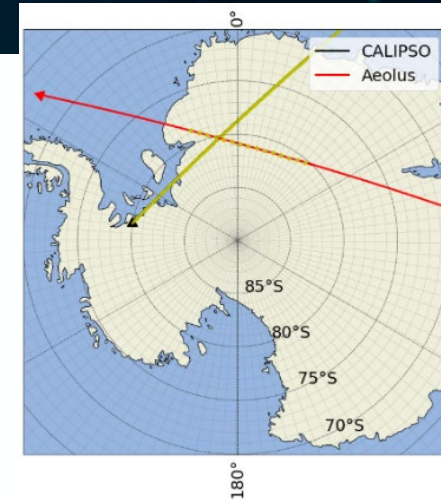


Figures by V. Cito Filomarino, DLR

# Can we observe PSCs with Aeolus?

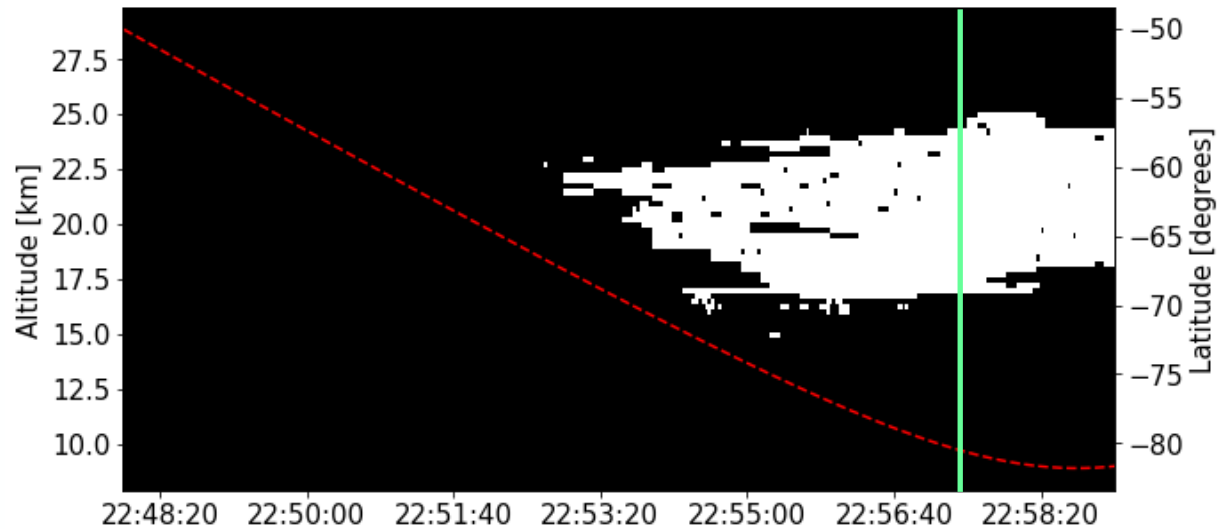
## Can we construct a PSC mask product for Aeolus?

- Prototype yields good results. Further fine tuning necessary. Implementation as operational product planned for Phase F.

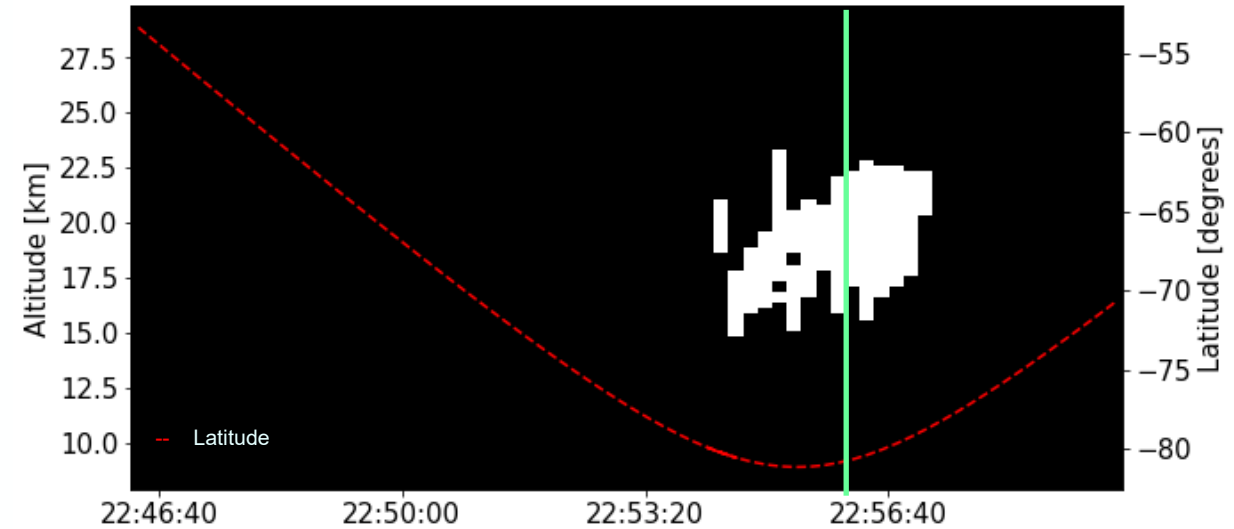


— Approximate crossing location

CALIPSO L2 PSC mask product



Aeolus PSC mask prototype



Figures by V. Cito Filomarino, DLR

# Can we observe PSCs with Aeolus?



## PSC climatology over Antarctica for 2020 (15km altitude)

Figures by V. Cito Filomarino, DLR

Aeolus

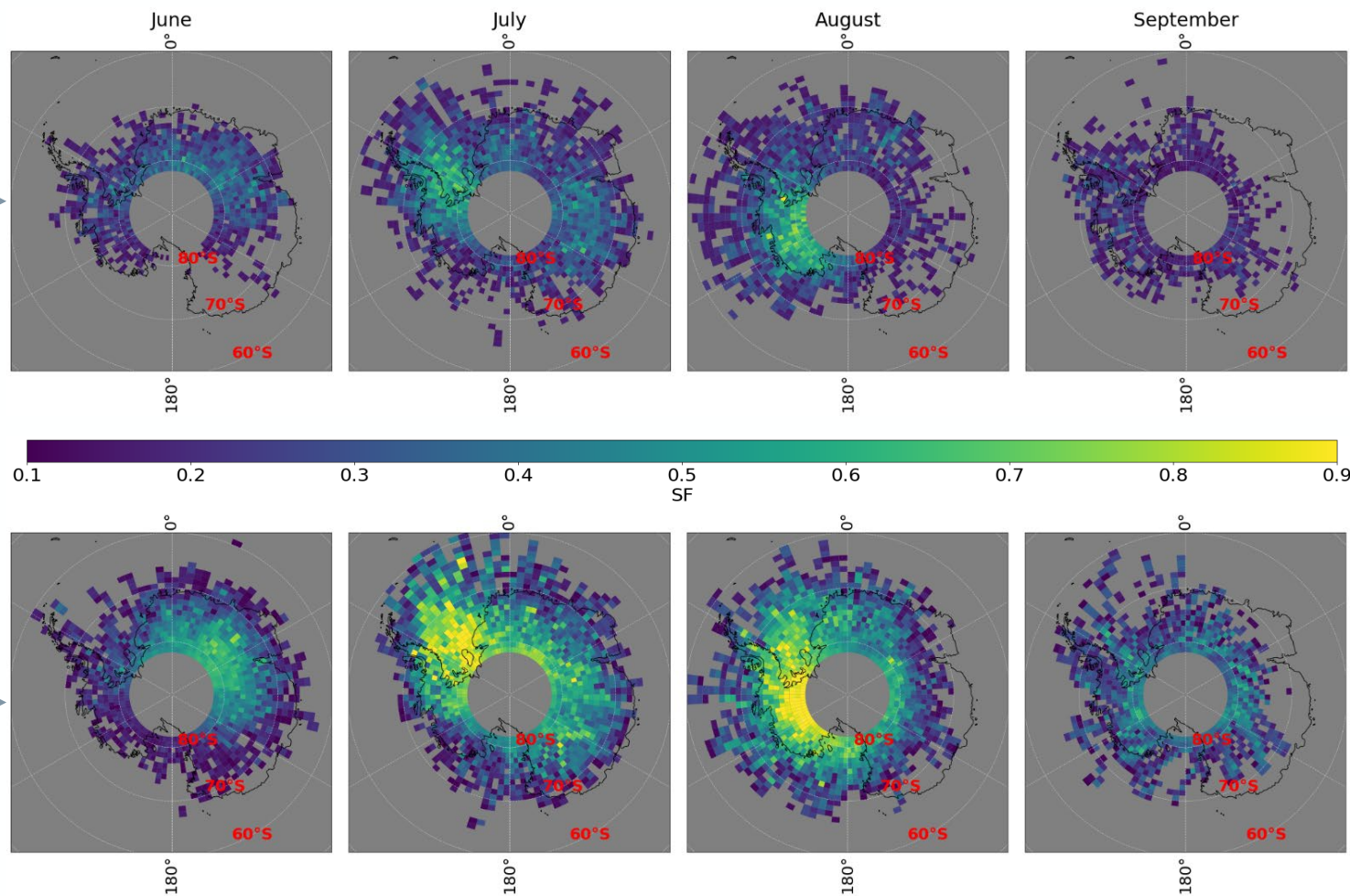
BS Threshold:  
 $0.4 \cdot 10^{-6} m^{-1} sr^{-1}$

$$SF = \frac{N_i}{N_{tot}}$$

SF: Sighting Frequency  
 $N_i$ : PSC in cell  $i$   
 $N_{tot}$ : obs in cell  $i$

CALIPSO

Threshold:  
Scattering ratio or attenuated backscatter above daily median  
plus one median absolute deviation



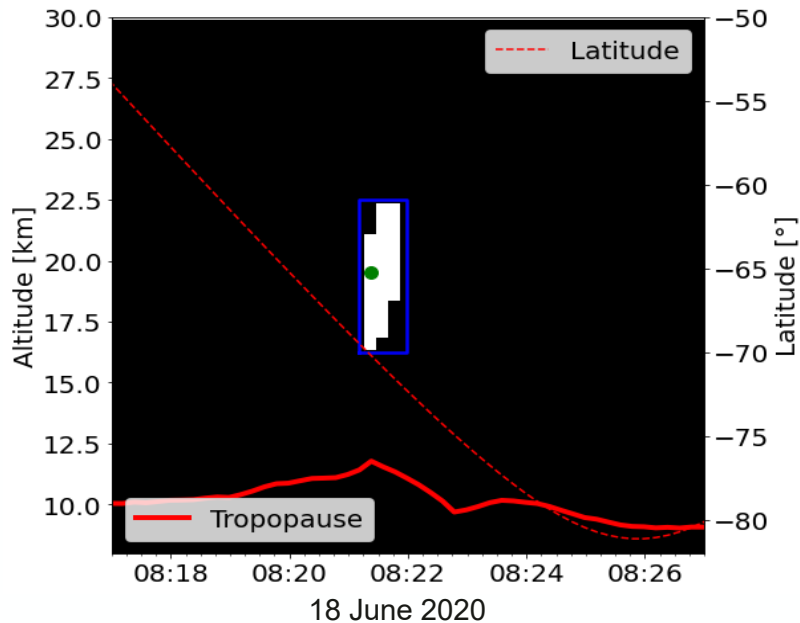
# What can we learn from Aeolus about gravity wave induced polar stratospheric clouds?

## Can we collocate PSCs with GWs using Aeolus observations?



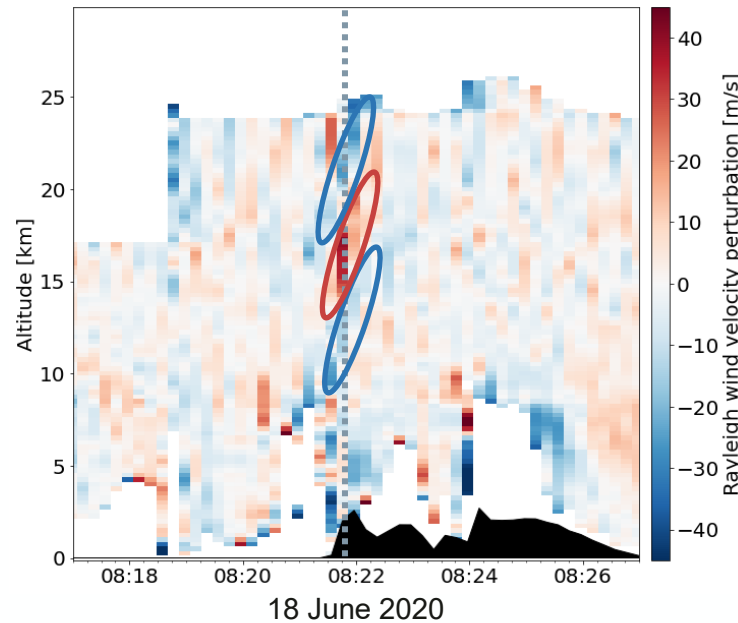
### Aeolus PSC mask prototype

Get PSC time stamp + extent from PSC mask prototype



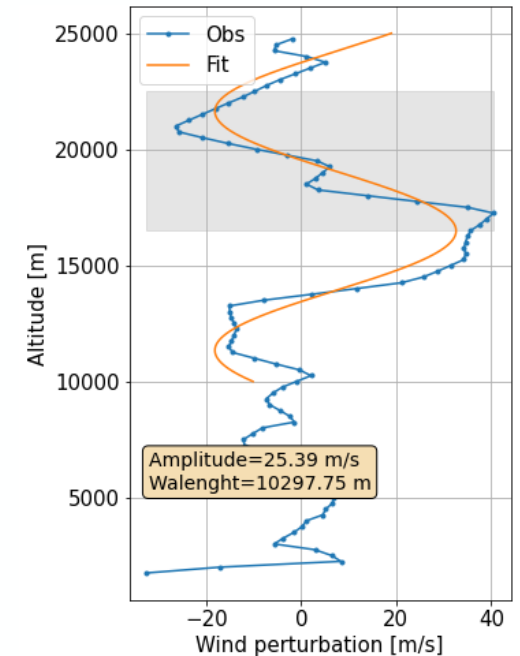
### Aeolus wind product

Horizontal detrending with Savitzki-Golay 3rd order polynomial, window length of 23 bins (~2000 km)



### GW analysis

Perform a sinusoidal fit on single profiles of detrended L2B HLOS data



# Conclusion and Outlook

## Can we observe gravity waves with Aeolus? ✓

- Yes, we even can see details like horizontal refraction of gravity waves.

## Can we observe polar stratospheric clouds with Aeolus? ✓

- PSCs are well detected by Aeolus L2A aerosol product.
- The Aeolus PSC geographical distribution is coherent with the one from CALIPSO.

## What can we learn from Aeolus about gravity wave induced polar stratospheric clouds? ⚒

- PSC events in the Aeolus L2A aerosol product can be collocated with gravity waves using the L2B wind product.

## Next research questions to address 🗣️

- Is gravity wave identification / analysis on a global scale possible with Aeolus data (e.g. climatology)?
- How can we exploit the profile information provided by Aeolus for gravity wave research?
- Can we separate the PSC climatology from Aeolus in wave-induced and non-wave-induced PSCs?



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# What can we learn from Aeolus about gravity wave induced polar stratospheric clouds?

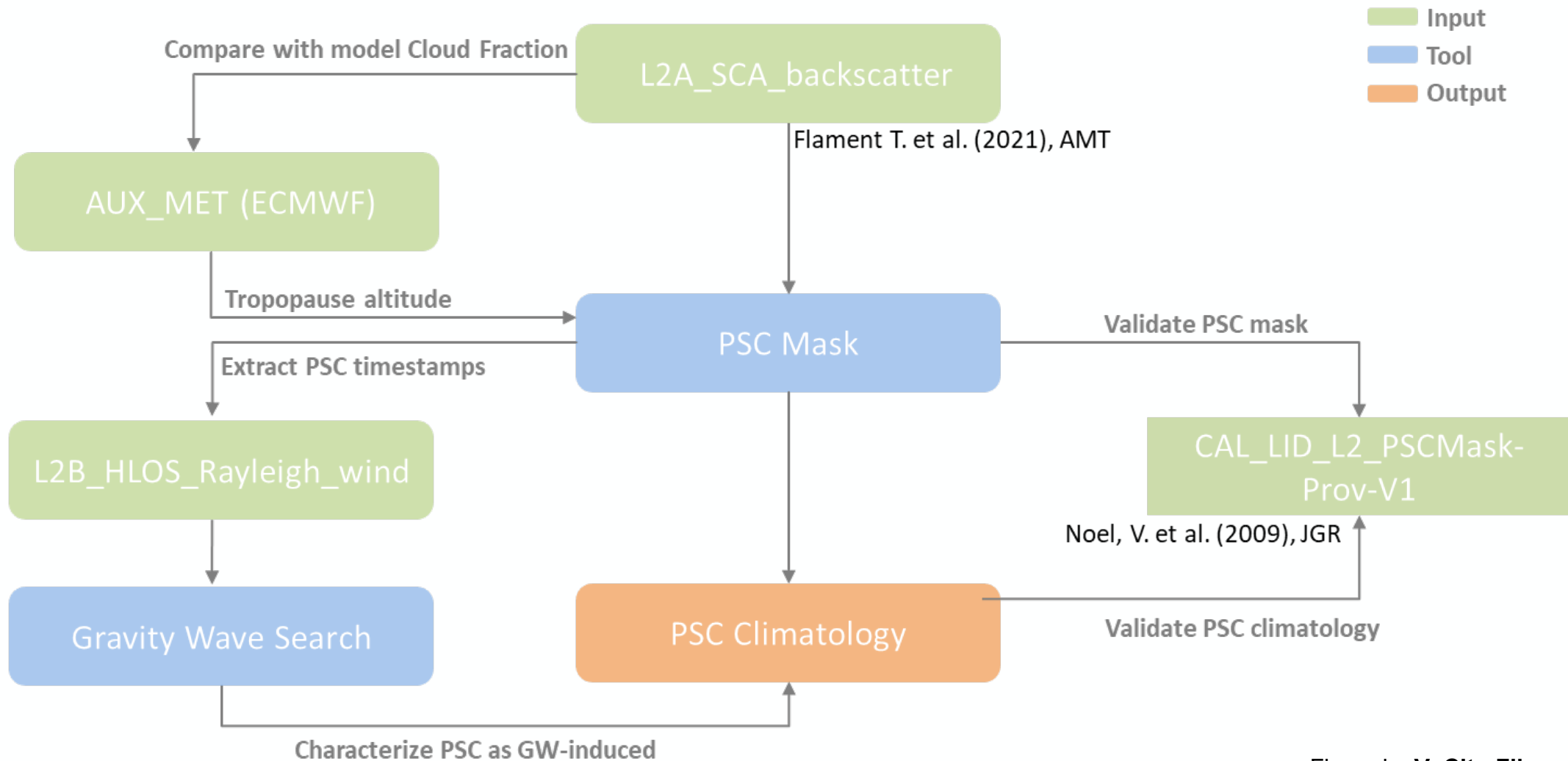


Figure by V. Cito Filomarino