Polar Stratospheric Clouds over Antarctica seen by EarthCARE

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1. Polar Stratospheric Clouds (1)

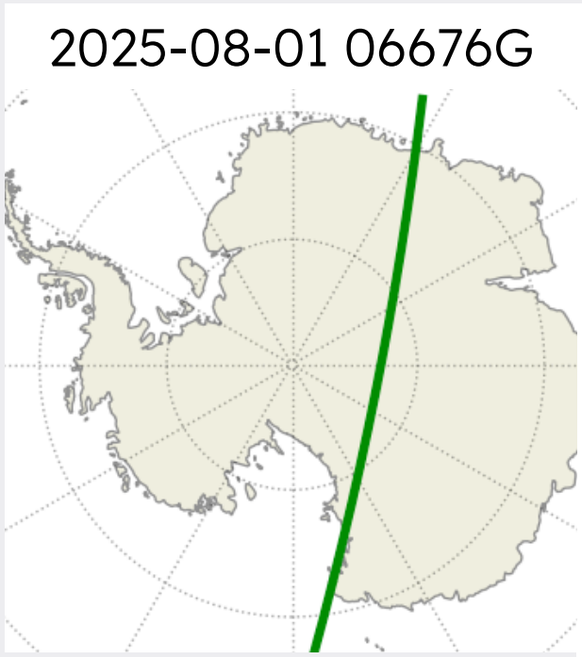
- PSCs appear during the winter polar night (May-Oct over the South pole), when stratospheric temperatures get cold enough for nucleation (T<195K)
- PSC particle types include
    - Sulfate Ternary Solution (**STS**) particles: small, round liquid droplets
    - Nitric Acid Trihydrate (**NAT**) particles: larger, non-spherical crystals
    - **Ice** particles: largest, non-spherical crystals
    - Composition depends on temperature and available species
- PSCs hinder the recovery of the **polar ozone layer**
    - Chemical reactions on the surface of PSC particles facilitate the activation of stable chlorine and bromine reservoirs into reactive radicals
    - Sedimentation of PSC particles into the troposphere leads to removal of HNO_3 and H_2O from the stratosphere, slowing down the return of species to their inactive forms
    - As the stratosphere gets colder due to climate change, PSC cover and influence on ozone could increase

1. Polar Stratospheric Clouds (2)

- CALIPSO (2006-2023) has provided an unprecedented view of PSCs: high resolution mapping, relation with stratospheric aerosols, composition retrieval… for > 15 years
- **Our goal** : To provide a first documentation of PSC presence from ATLID L1-NOM product
- ATLID's first publicly documented PSC season (May-Oct 2025) was in the south hemisphere : here we focus on **Antarctica**

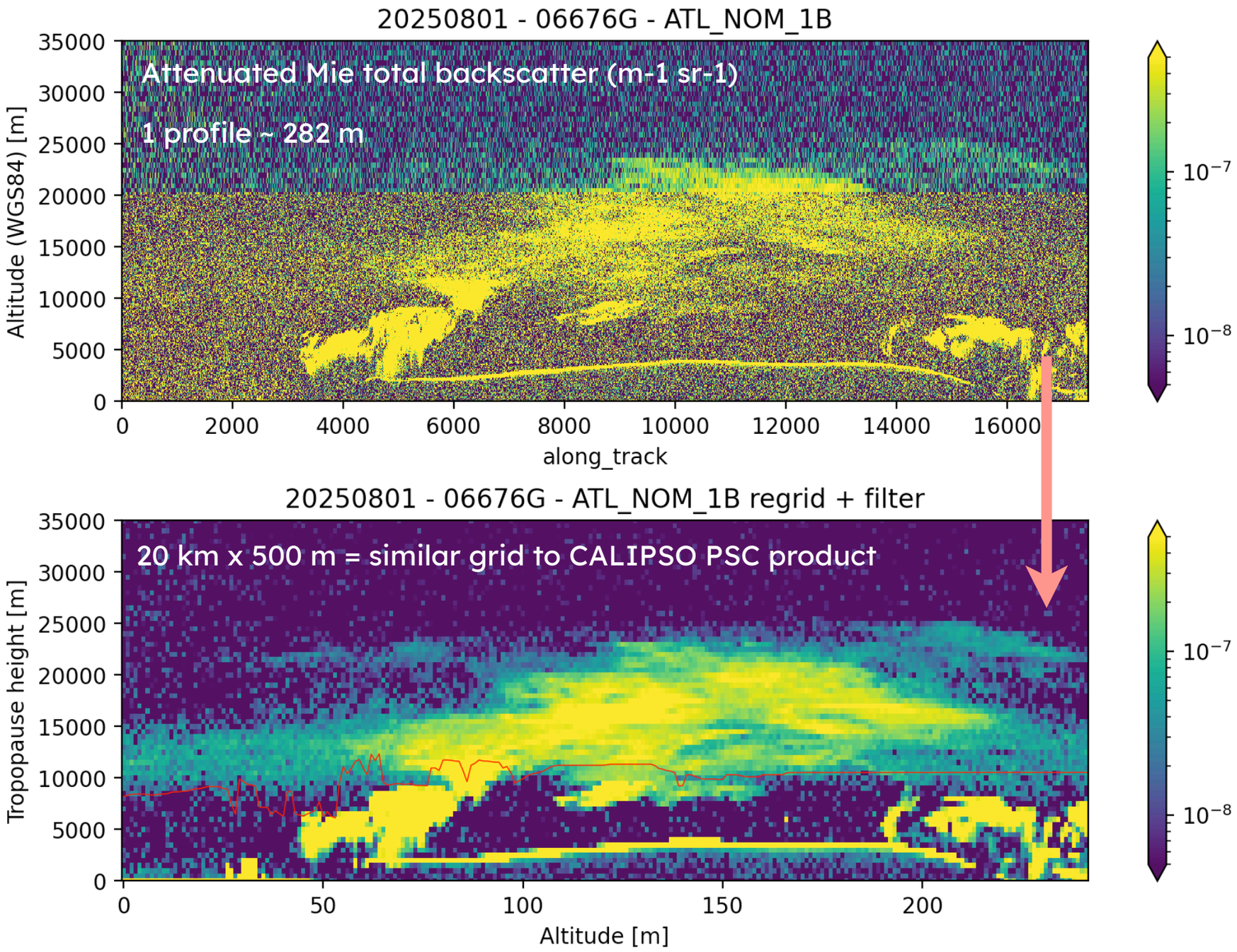
1. Science context (done !)
2. **PSC detection**
3. **PSC distribution**
4. **PSC optical properties**
5. **Comparison with L2**

2. PSC detection from ATLID L1-NOM (1)



STEP 1

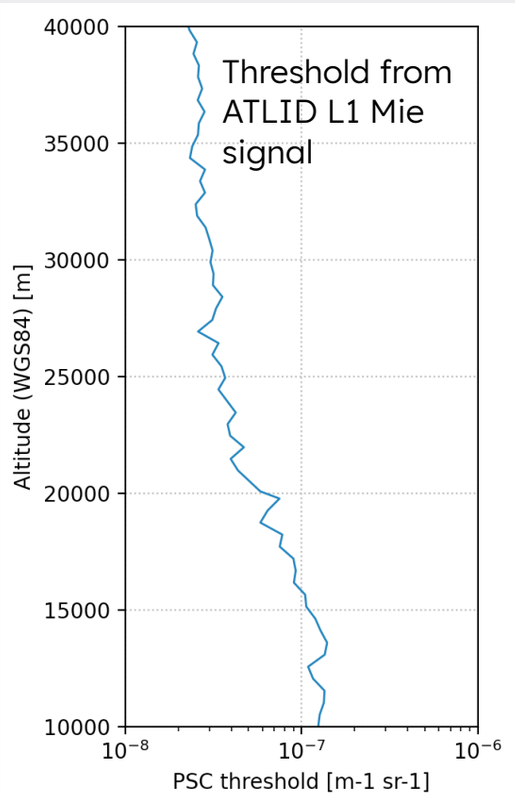
- Vertical regridding of each profile on constant 500m vertical grid
- Horizontal averaging 72 profiles = ~20 km



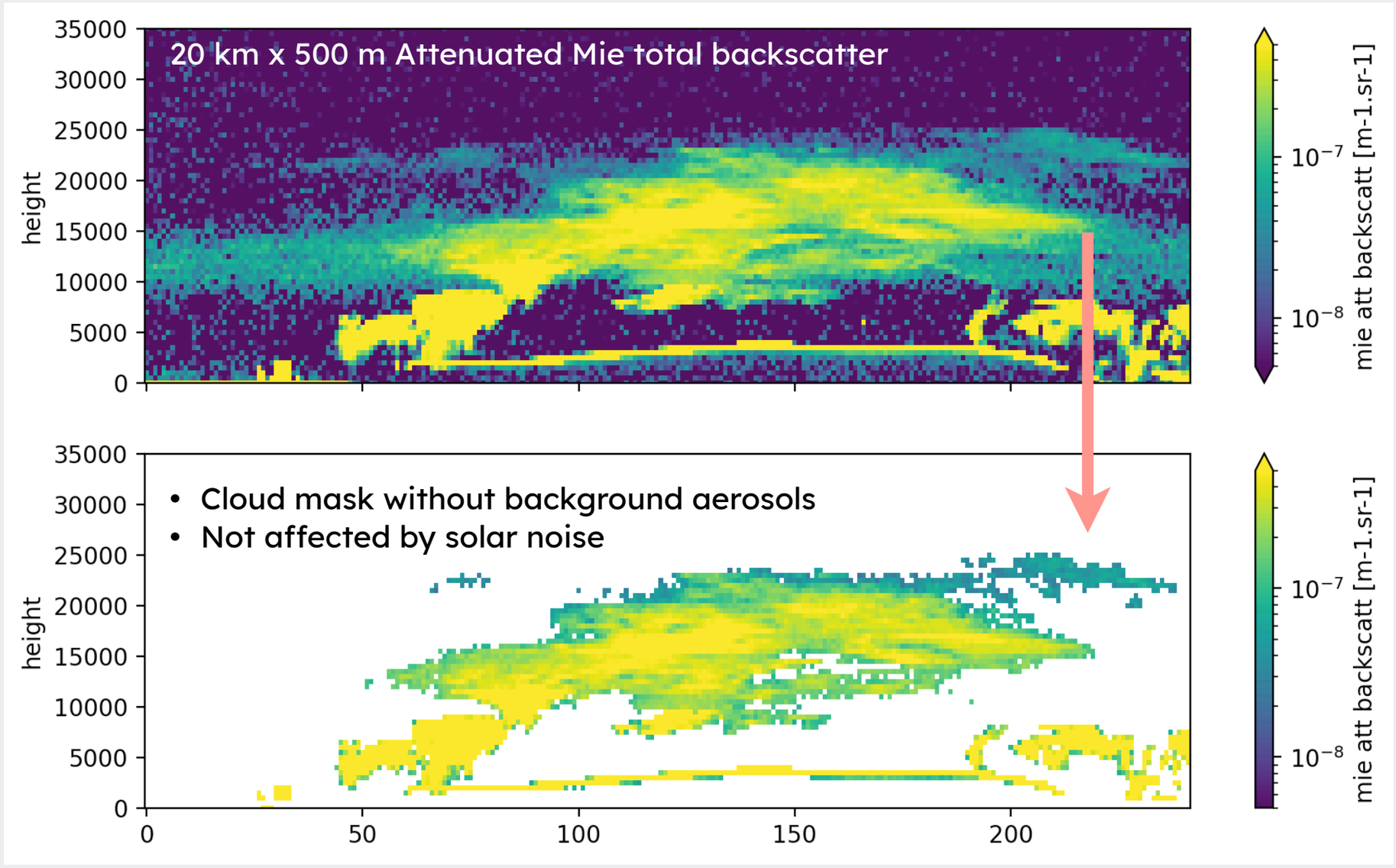
2. PSC detection from ATLID L1-NOM (2)

STEP 2

- Identify points with Mie > threshold defined in clear-sky polar regions



- Apply filter to remove isolated 1x1 points

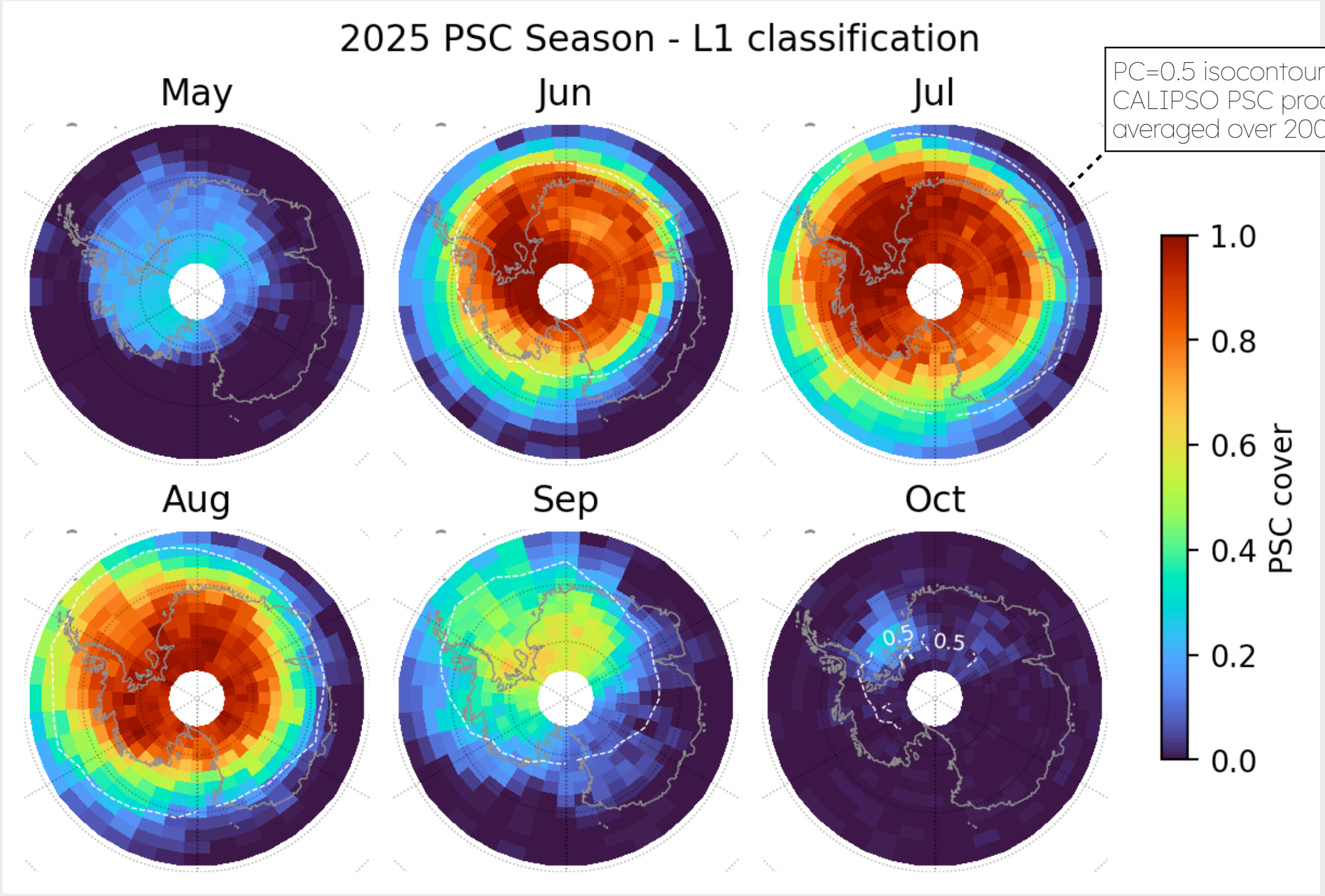


We applied this processing to ATLID L1-NOM BA data (F, G, H) from April to October 2025

It would be great if tropopause height could be included in L1-NOM…

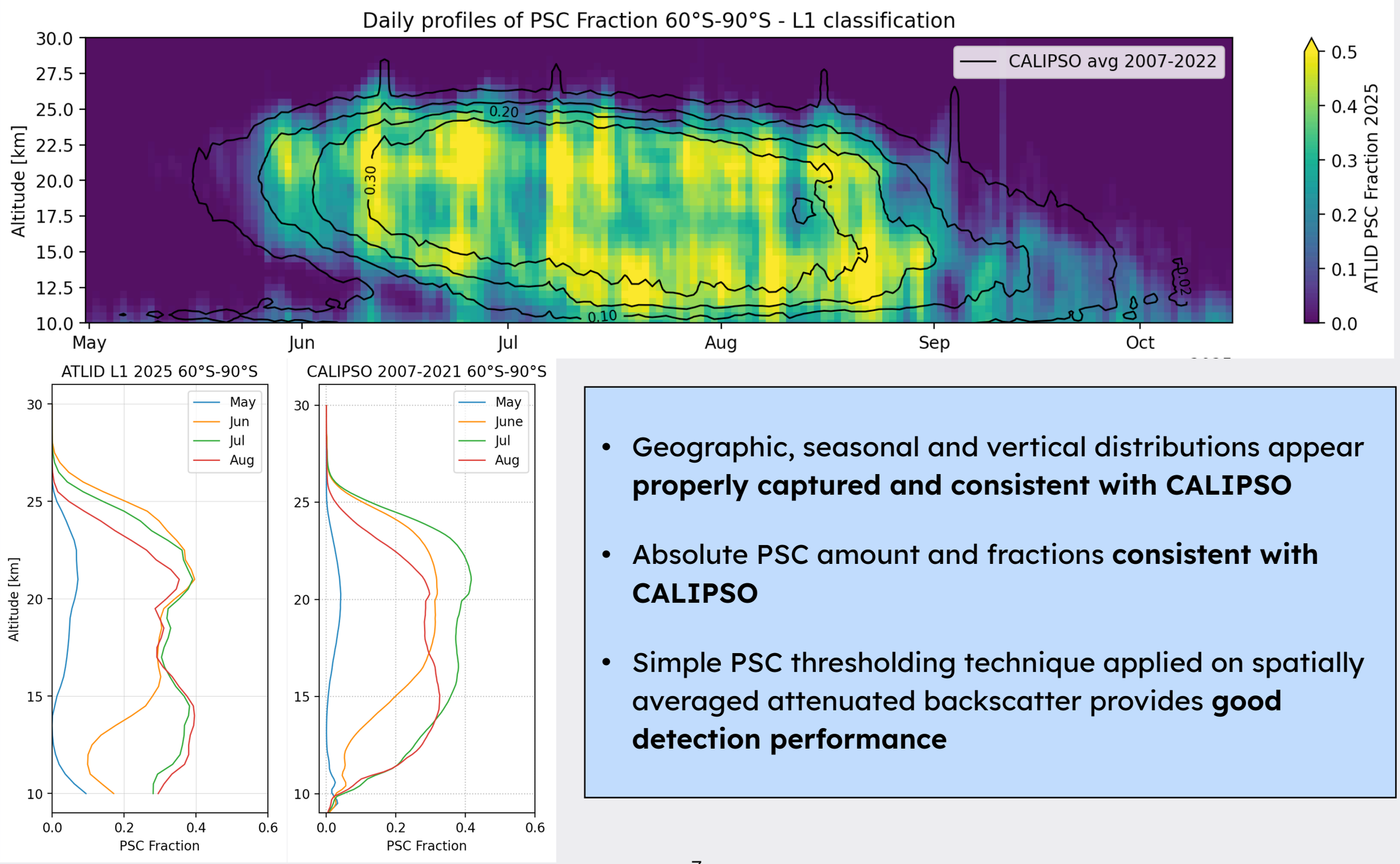
3. PSC distribution - 1 : Geographic

PSC cover = fraction of ATLID profiles in which a cloud is present above 14km ASL



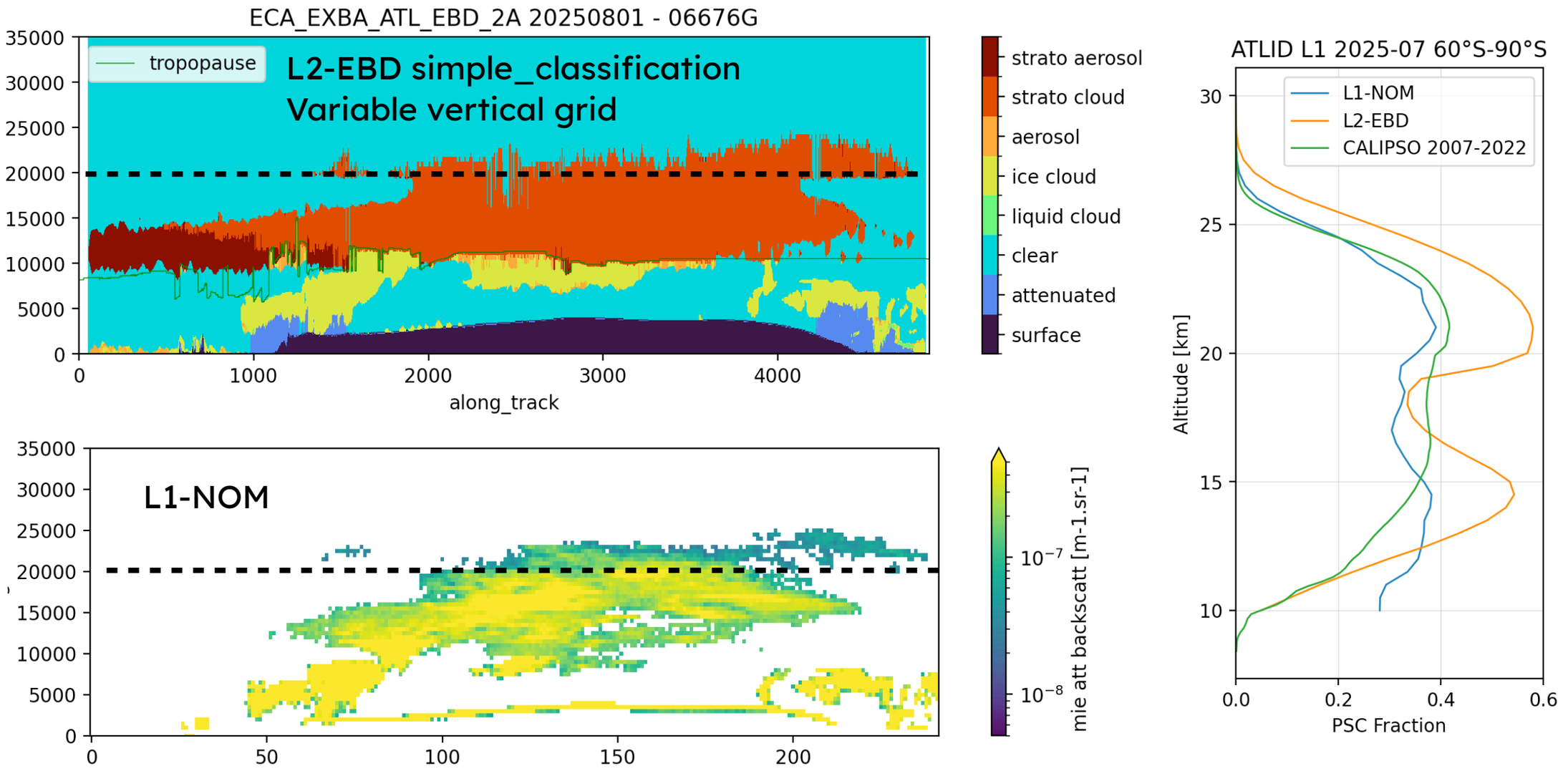
3. PSC distribution - 2 : Vertical and seasonal

PSC fraction = fraction of sampled points in which a cloud is present at a given altitude



- Geographic, seasonal and vertical distributions appear **properly captured and consistent with CALIPSO**
- Absolute PSC amount and fractions **consistent with CALIPSO**
- Simple PSC thresholding technique applied on spatially averaged attenuated backscatter provides **good detection performance**

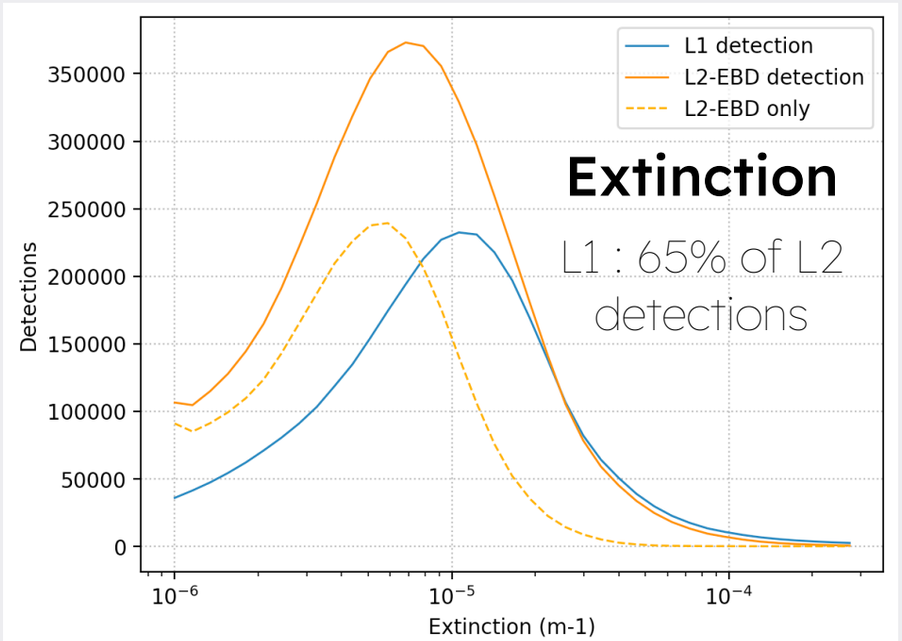
4. PSC optical properties

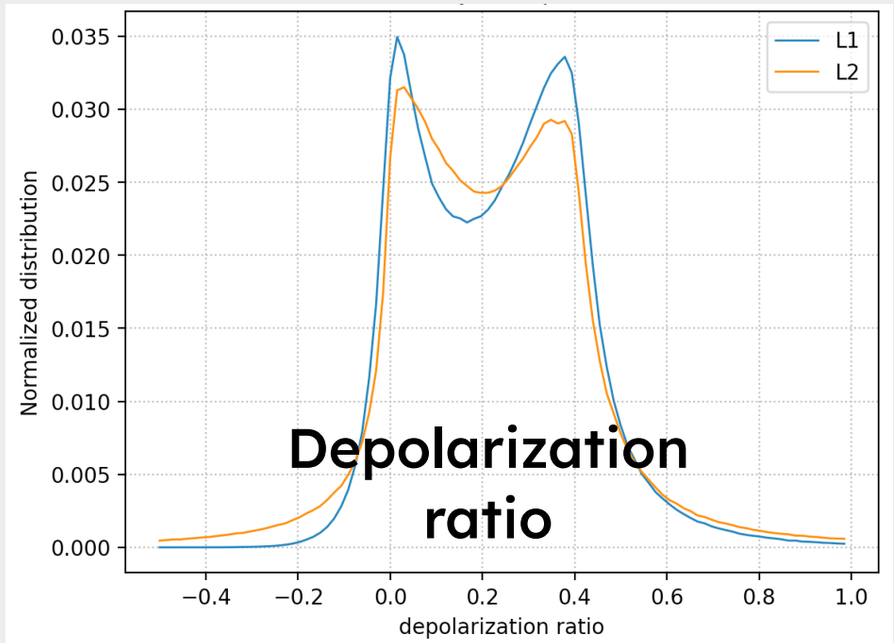


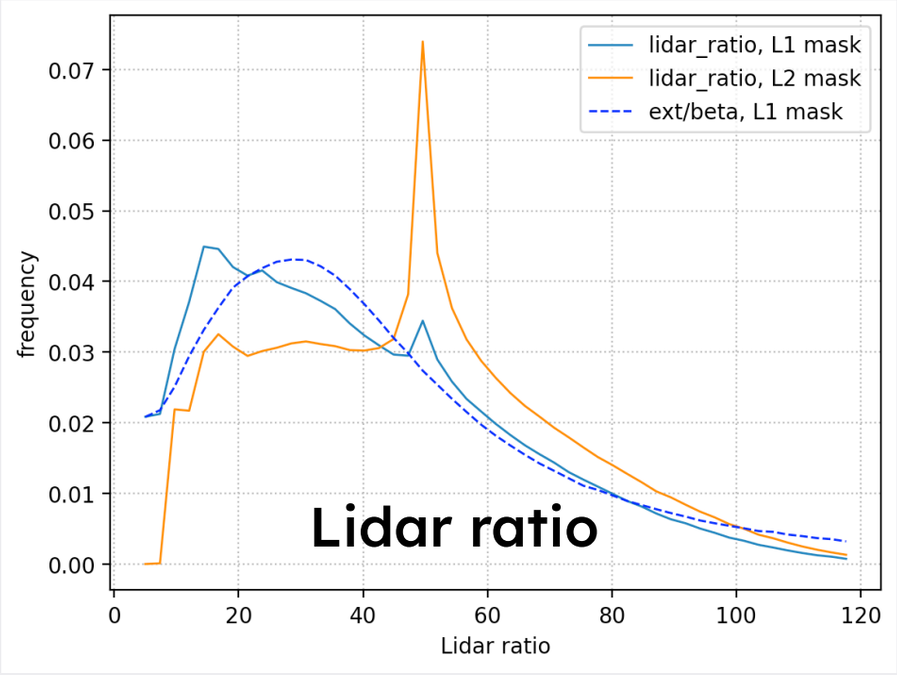
- L2-EBD classification = **larger PSC fraction** (+40%) than L1-NOM and CALIPSO
- Strong drop in detection around 17-19km ASL
- Inconsistencies in L2 PSC mask (vs L1 data) occur near 20 km and the tropopause

4. PSC optical properties

We compare **PSC optical properties** from L2-EBD according to
L1 detection or **L2-EBD detection**



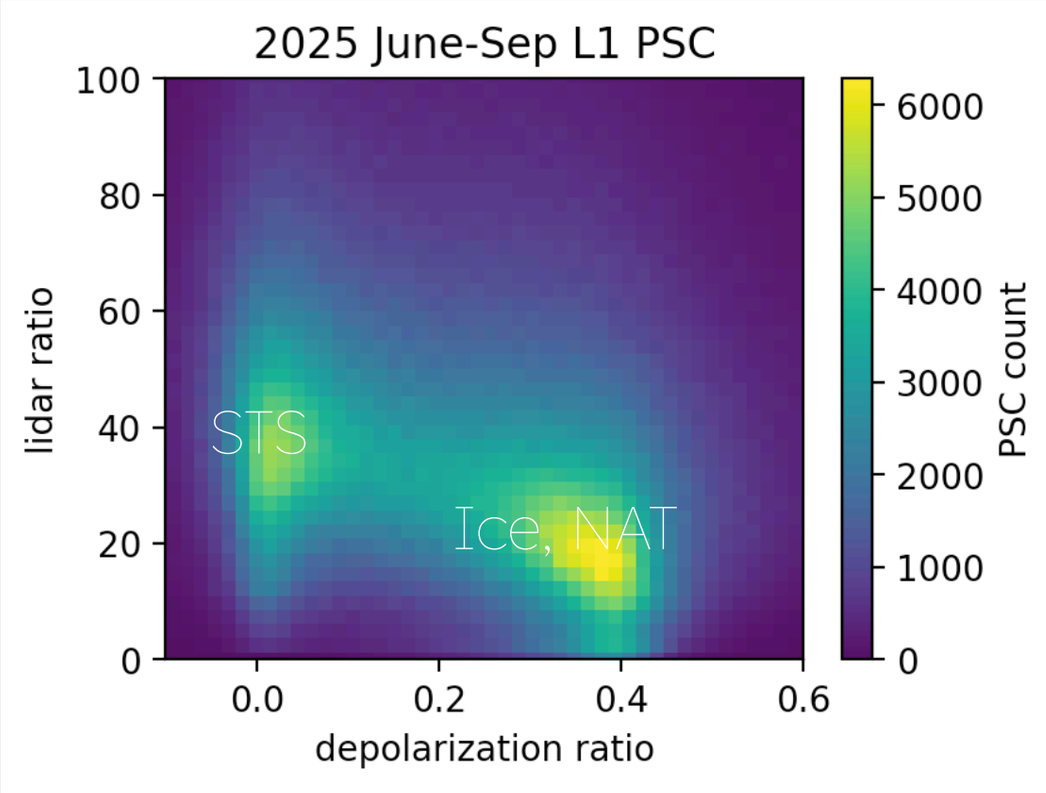


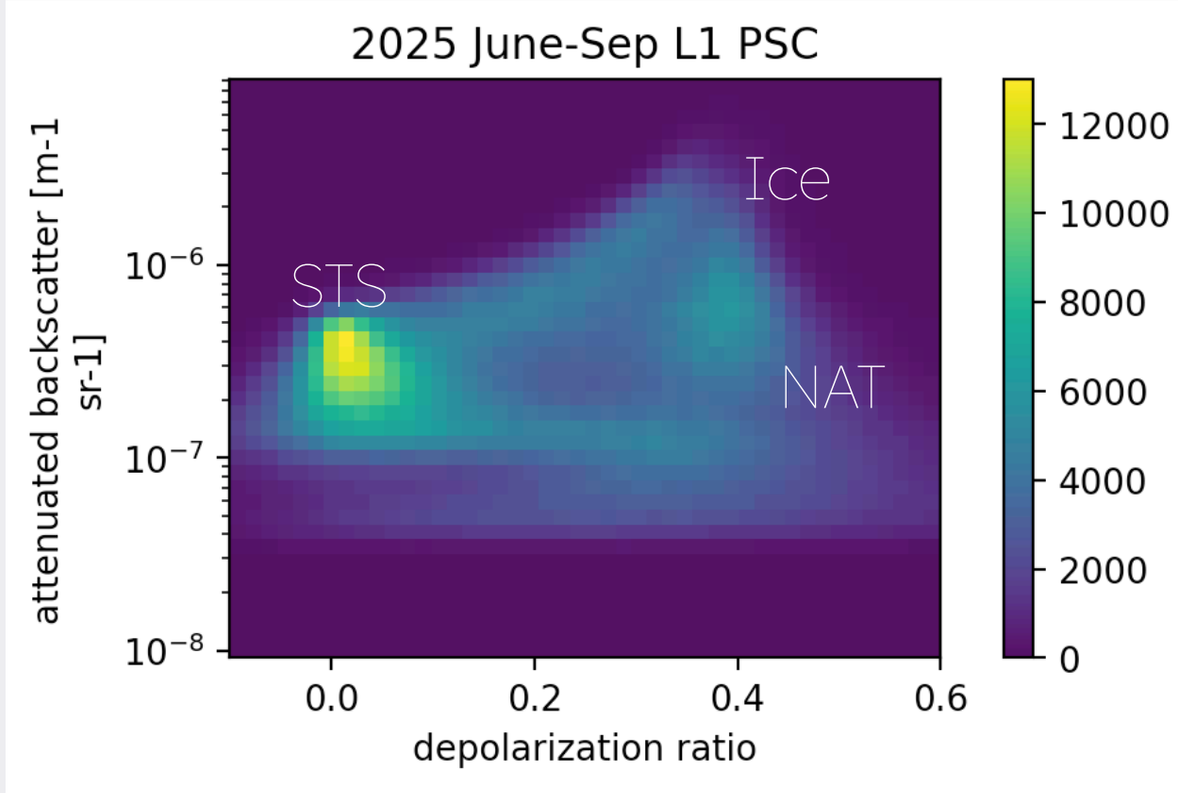


- PSC L1 detections ~65% of L2-EBD detections
- 35% of PSC only in L2-EBD :
  - small extinction : average 6 10^{-6} m^{-1}
  - Lidar ratio peak at 50
- Depolarization ratios ~consistent L1/L2

4. PSC optical properties and composition

Optical properties from **L2-EBD** in PSC according to **L1 detection**





Expected lidar ratios at **532 nm** (Pitts et al., 2018, ACP)

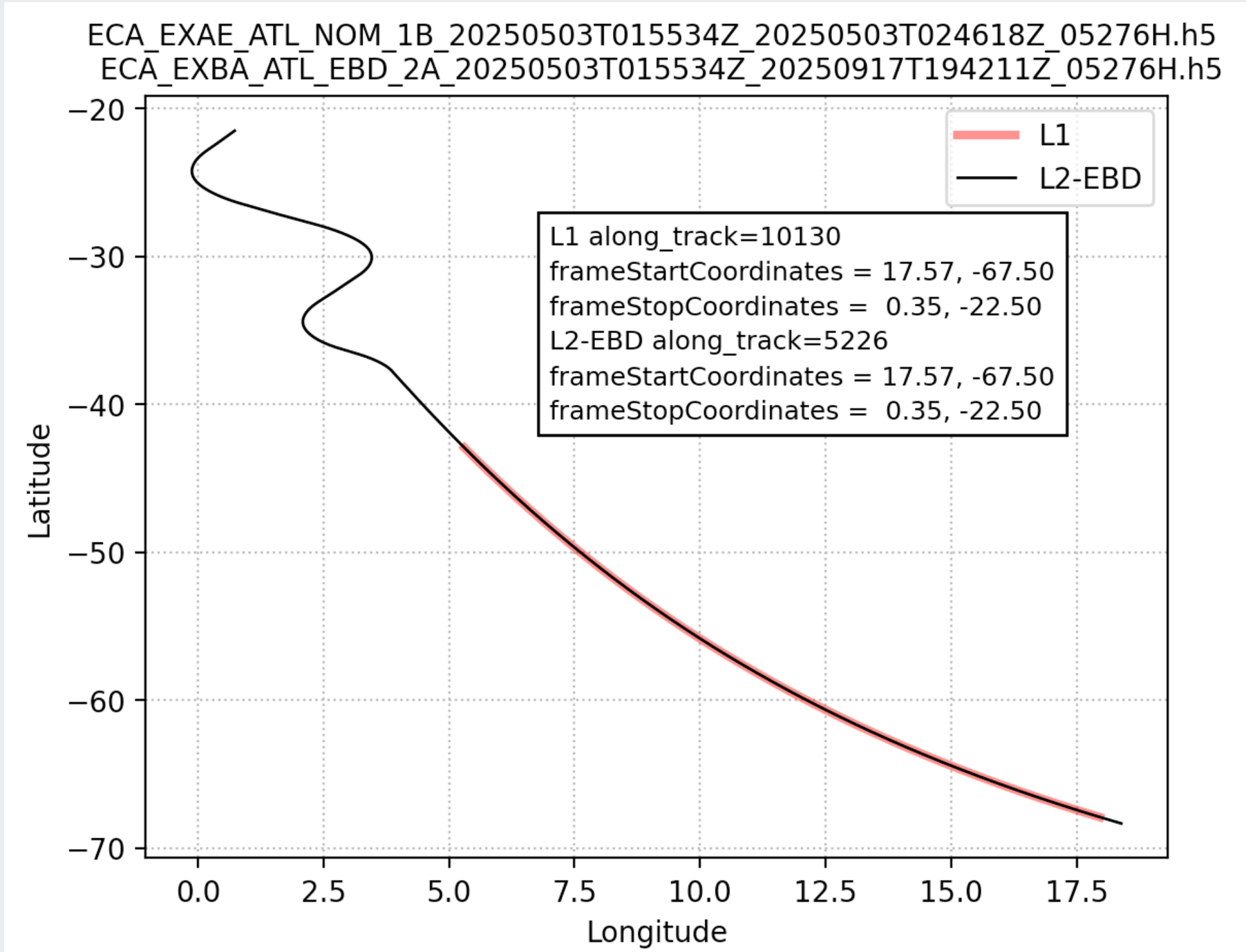
- ~50-80 sr for STS
- ~20-35 sr for mountain-wave PSC with large scattering ratios

- L2-EBD retrievals of depolarization ratio, extinction and lidar ratio in L1-NOM PSC mask provide values in expected ranges
- Distributions of optical properties follow behaviors consistent with known PSC composition

Summary and Conclusions

- PSC mask from L2-EBD finds **substantially more PSCs** than CALIOP and L1-NOM retrievals, except at 17-19km ASL where detections drop
    - Inconsistencies in L2-EBD PSC mask vs L1-NOM could be linked to the impact of **resolution switch**, **unrealistic tropopause** altitudes (e.g. 06196F-H)
    - This mask will eventually enable study of PSCs with extremely low concentrations and their relationships with **pervasive stratospheric aerosols** (cf. next presentation)
- In the meantime, a simple **signal thresholding technique** on **spatially averaged** (20km x 500m) **total attenuated backscatter from L1-NOM p**rovides detection results **consistent with the CALIPSO PSC** product (averaged over 2007-2022) in terms of **geographic, vertical, and temporal distribution**
    - **The threshold could be improved to access PSCs with weaker concentrations, which are currently missed**
    - **Adding this detection technique to L2-EBD optical properties is a powerful combination**
- **L2-EBD optical properties with PSCs confirms ATLID is able to document high-quality, high-resolution depolarization, extinction, and lidar ratios in PSCs**
- **ATLID products provide today the basis for high-quality PSC information** with limited additional analysis

BONUS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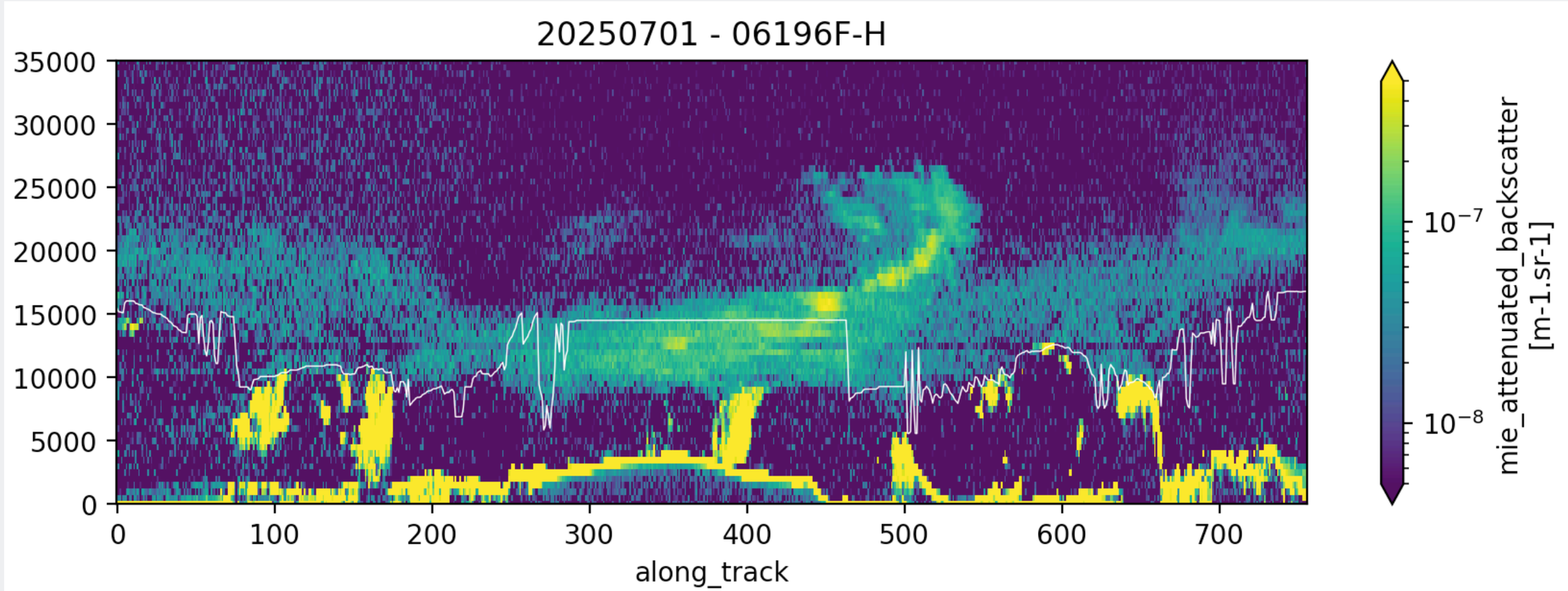
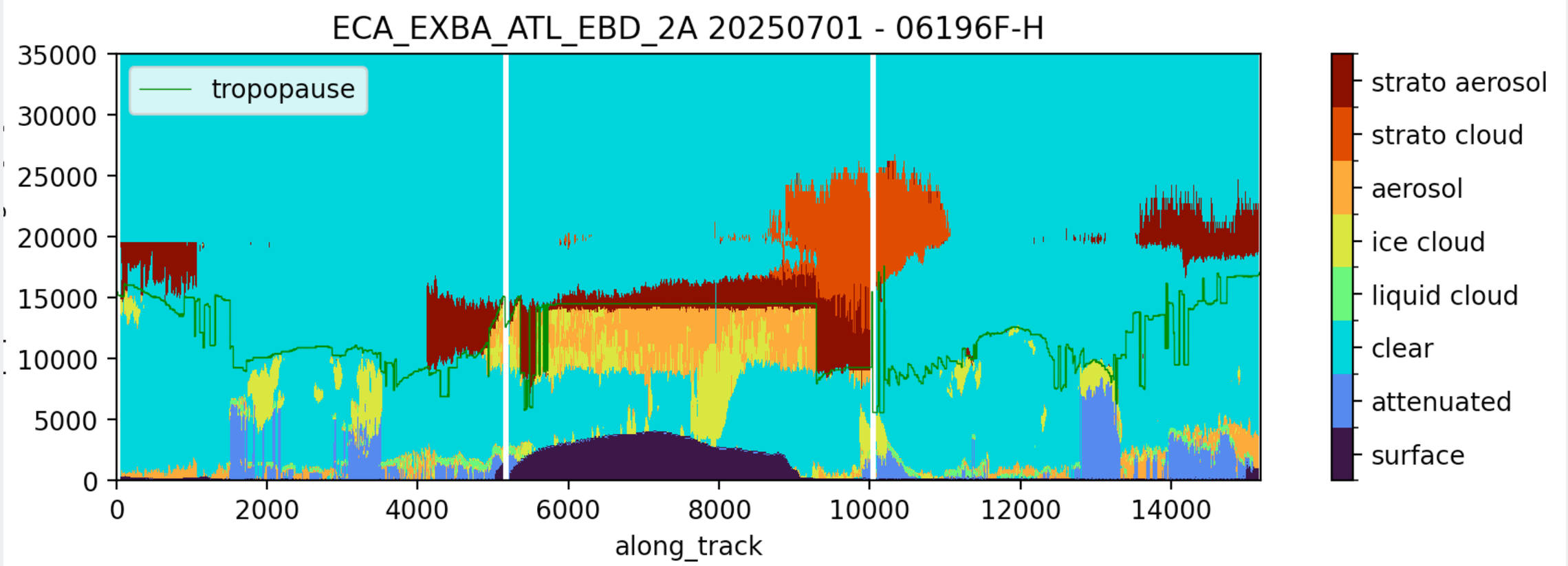
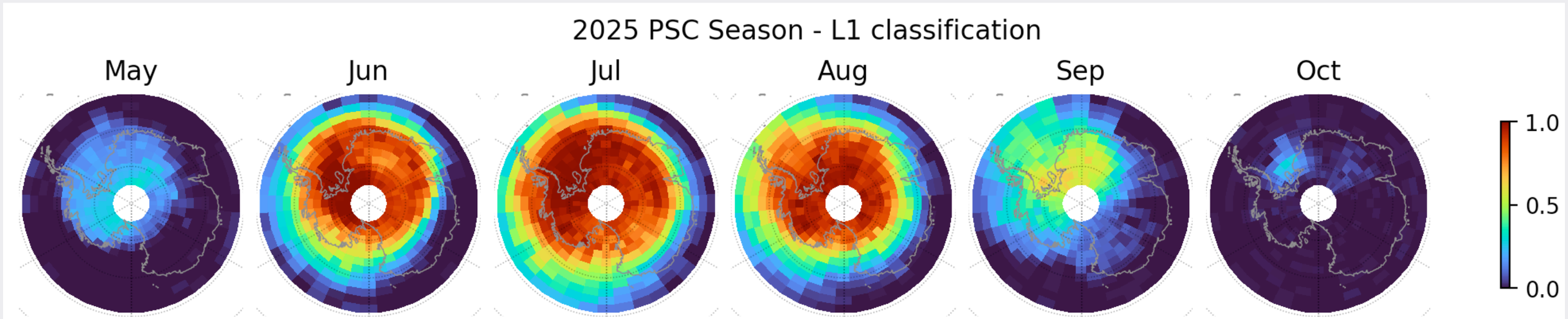
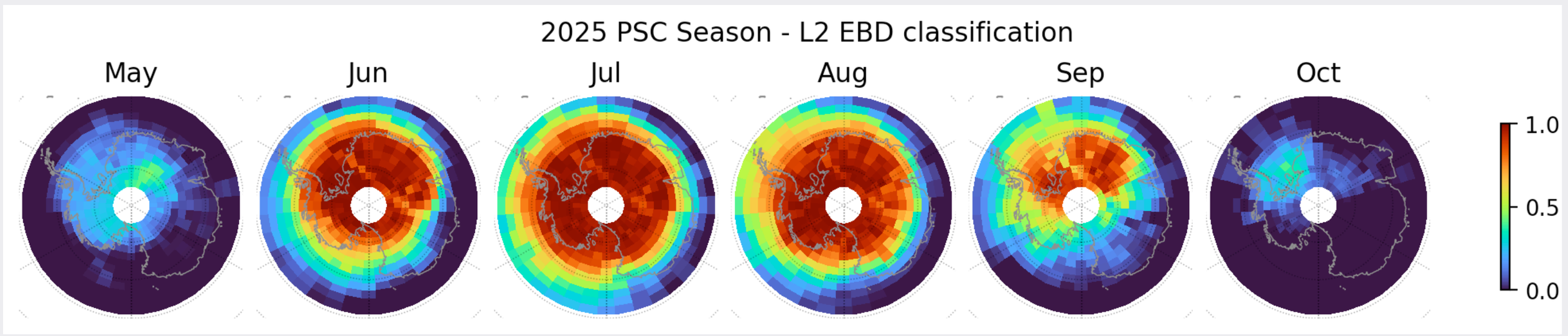
ECA_EXBA_ATL_EBD_2A_20250503T015534Z_20250917T194211Z_05276H.h5
L1
L2-EBD
L1 along_track=10130
frameStartCoordinates = 17.57, -67.50
frameStopCoordinates = 0.35, -22.50
L2-EBD along_track=5226
frameStartCoordinates = 17.57, -67.50
frameStopCoordinates = 0.35, -22.50
Latitude
Longitude
−20
−30
−40
−50
−60
−70
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5

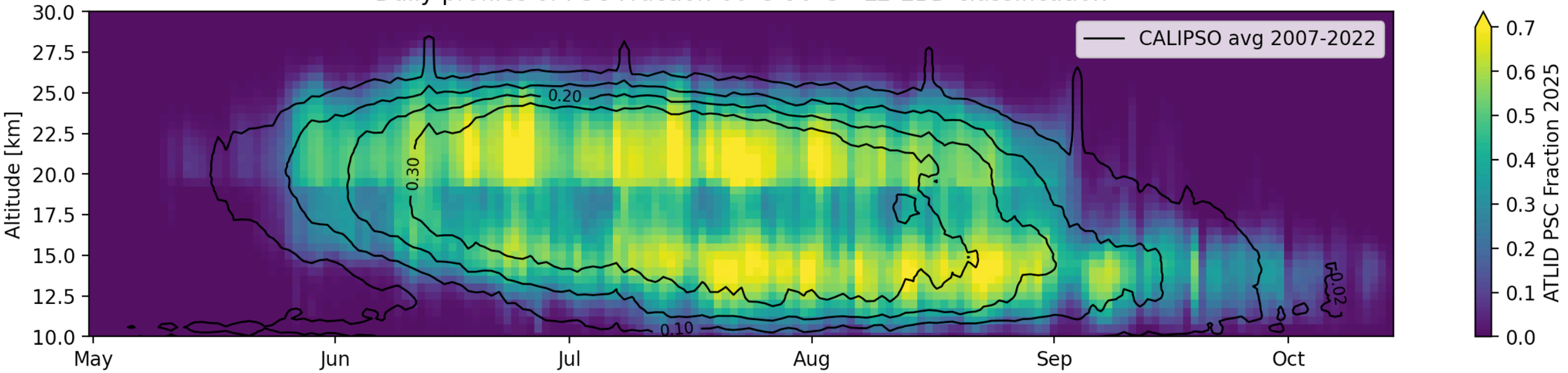

20250701 - 06196F-H
35000
30000
25000
20000
15000
10000
5000
0
0
100
200
300
400
500
600
700
along_track
10^{-7}
10^{-8}
mie_attenuated_backscatter
[m-1.sr-1]


ECA_EXBA_ATL_EBD_2A 20250701 - 06196F-H
tropopause
35000
30000
25000
20000
15000
10000
5000
0
0
2000
4000
6000
8000
10000
12000
14000
along_track
strato aerosol
strato cloud
aerosol
ice cloud
liquid cloud
clear
attenuated
surface

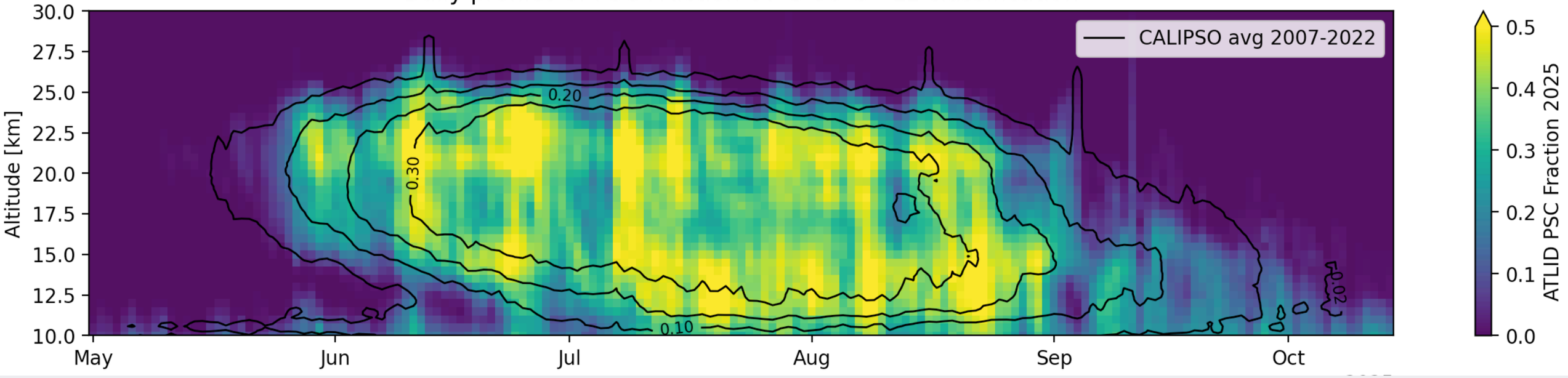

2025 PSC Season - L1 classification
May
Jun
Jul
Aug
Sep
Oct
1.0
0.5
0.0

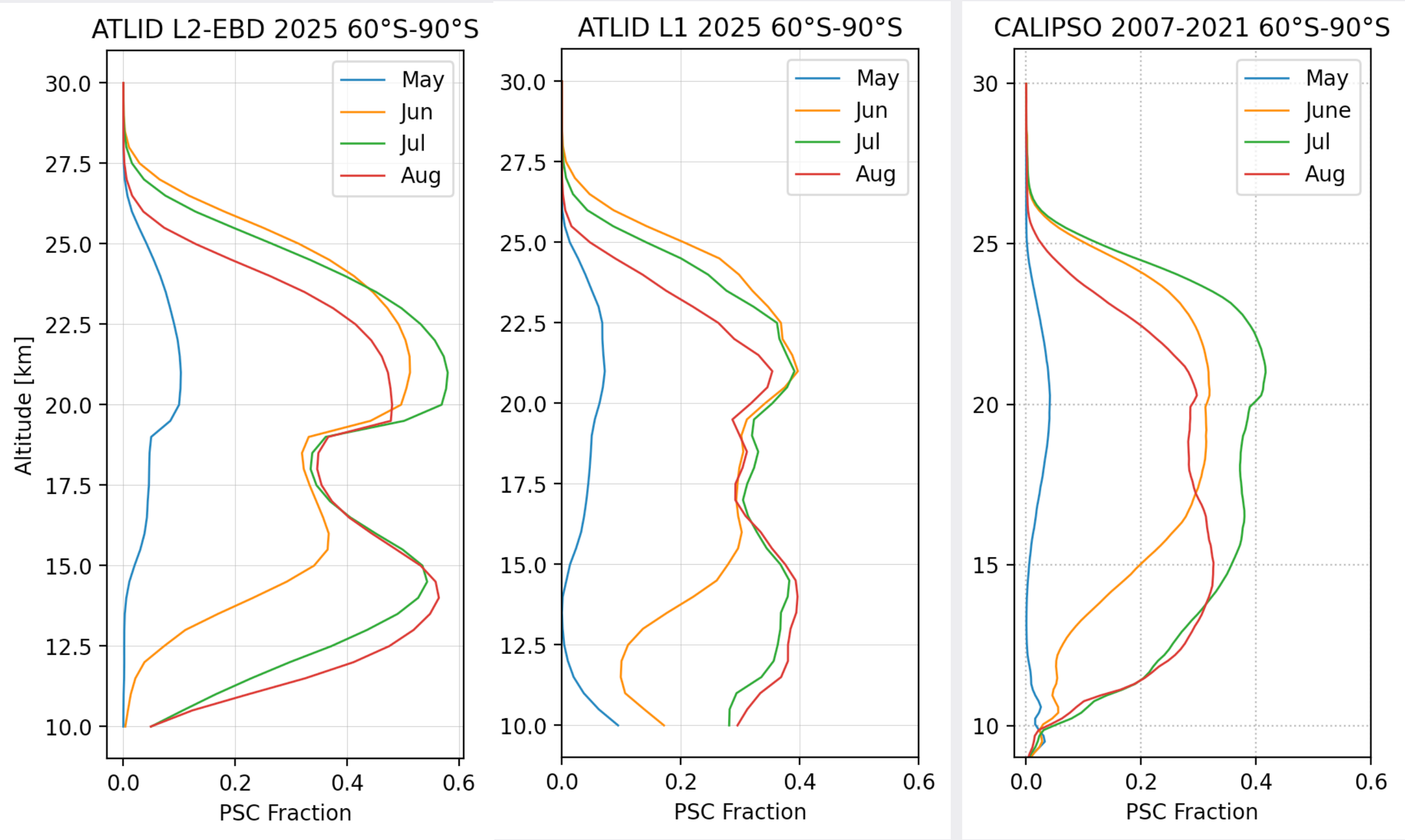

2025 PSC Season - L2 EBD classification
May
Jun
Jul
Aug
Sep
Oct
1.0
0.5
0.0

Daily profiles of PSC Fraction 60°S-90°S - L2-EBD classification



Daily profiles of PSC Fraction 60°S-90°S - L1 classification




ATLID L2-EBD 2025 60°S-90°S
ATLID L1 2025 60°S-90°S
CALIPSO 2007-2021 60°S-90°S
May
Jun
June
Jul
Aug
Altitude [km]
PSC Fraction
30.0
27.5
25.0
22.5
20.0
17.5
15.0
12.5
10.0
30
25
20
15
10
0.0
0.2
0.4
0.6