# Simulation of the ATLID ATB and SR profiles using the COSPv2 lidar aerosol simulator and the E3SMv1 climate model

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***26-05-2022***
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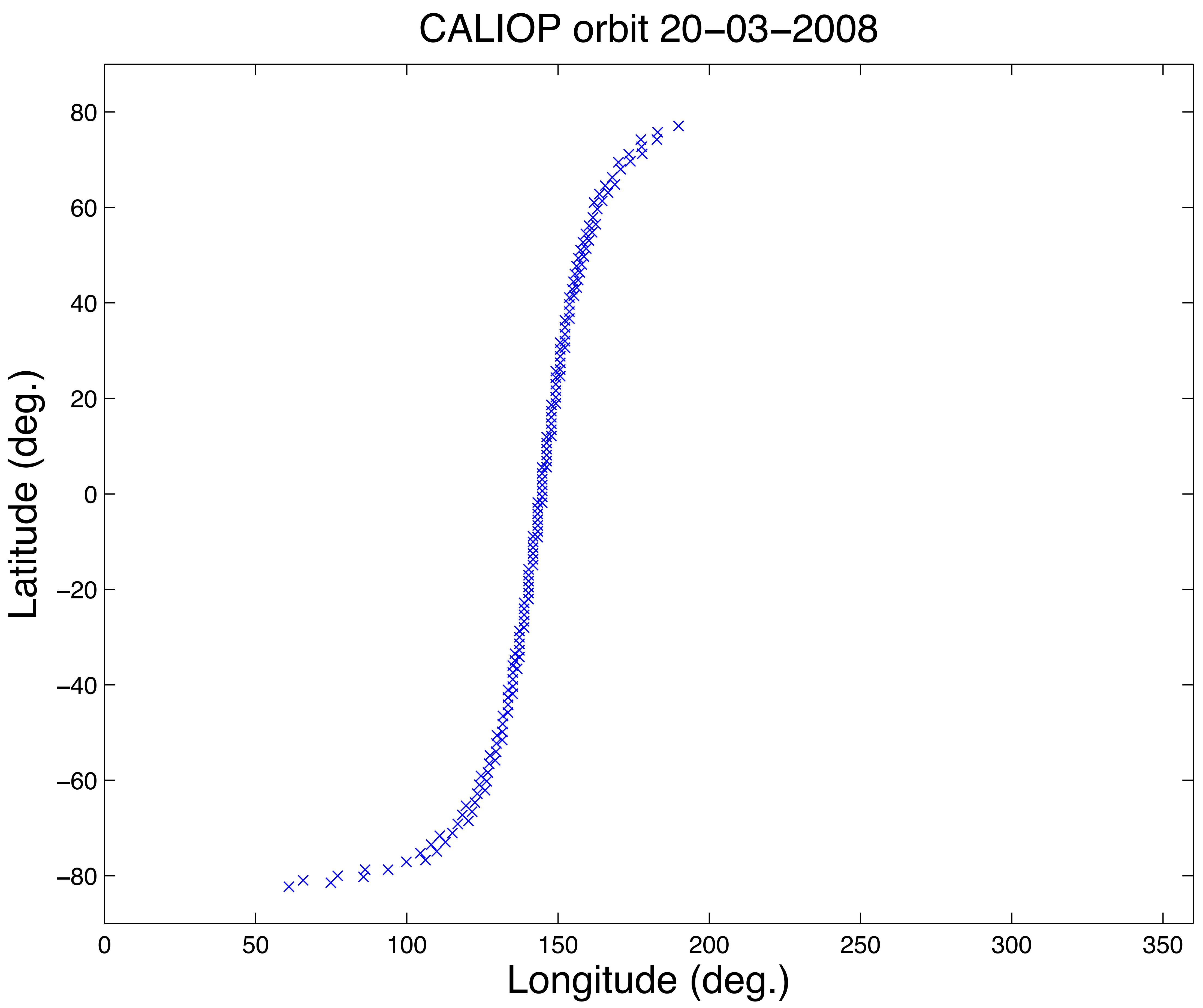
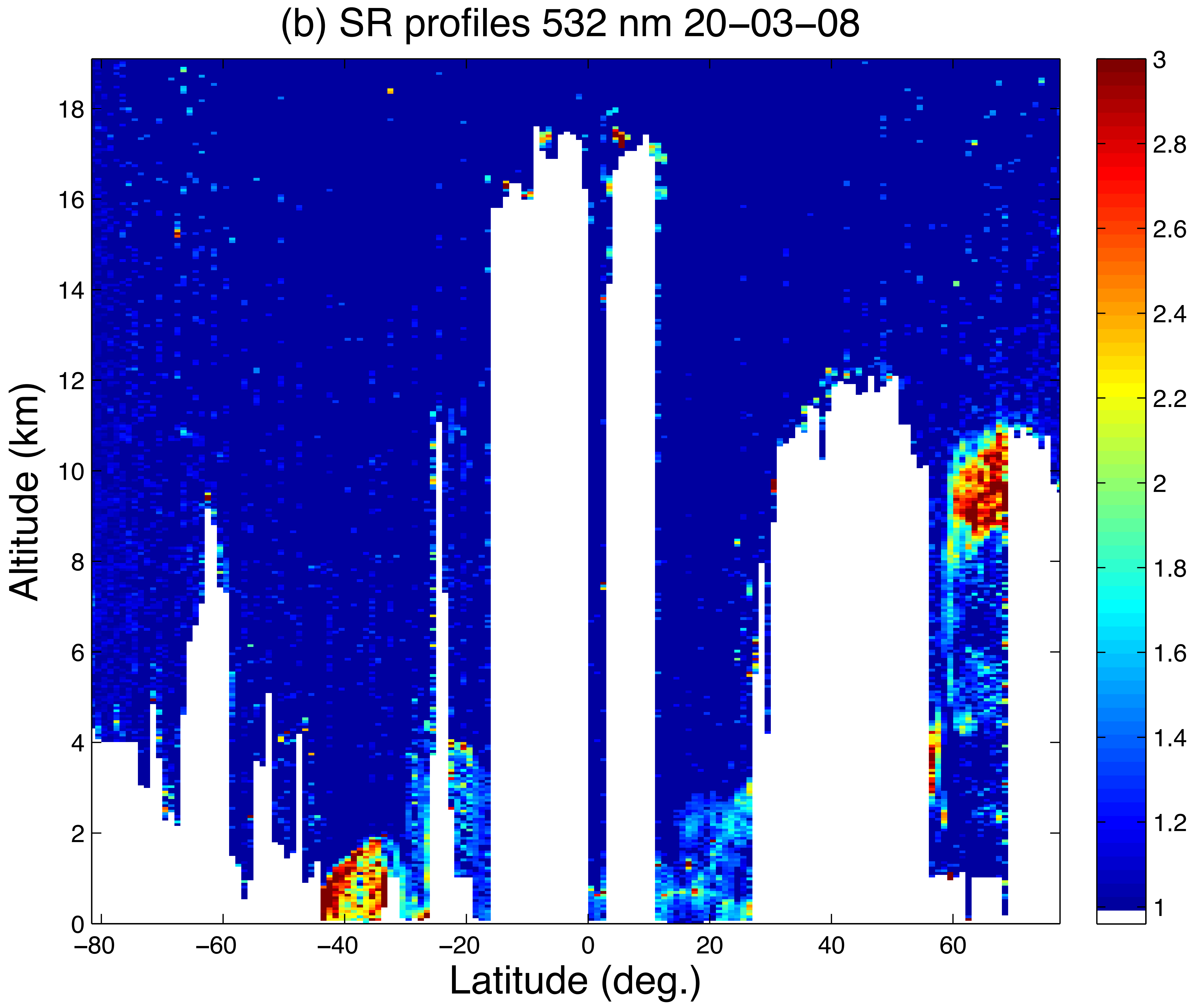
# Outline

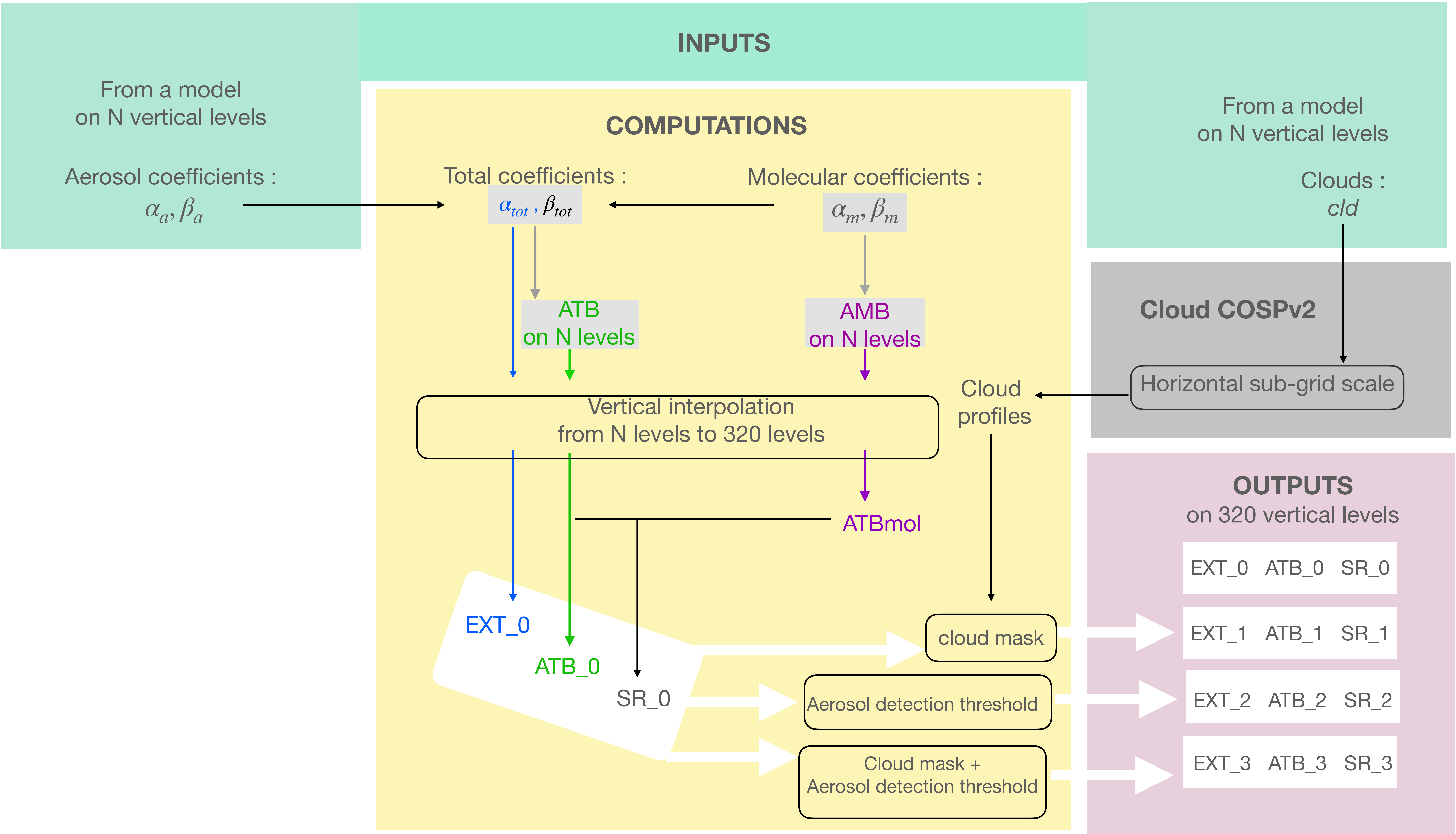
- 1. Principle of the COSPv2 Aerosol simulator : Simulation of a CALIOP orbit
- 2. A 3-month comparison of E3SM outputs and CALIOP data
- 3. Use of the Aerosol simulator for ATLID

# Scattering Ratio profiles along the CALIOP orbit on the 20-03-2008



# Principle of the COSPv2 Aerosol Simulator



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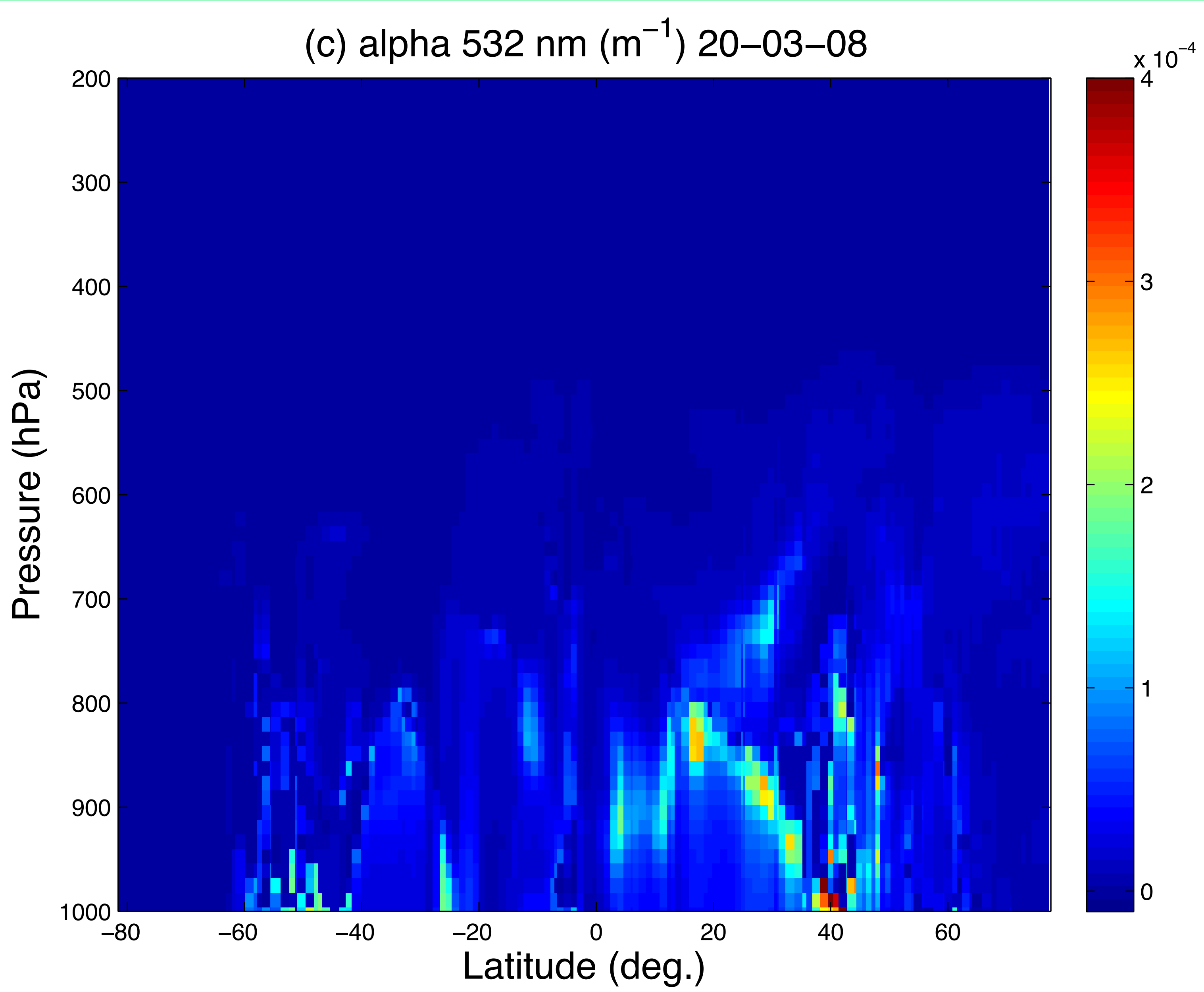
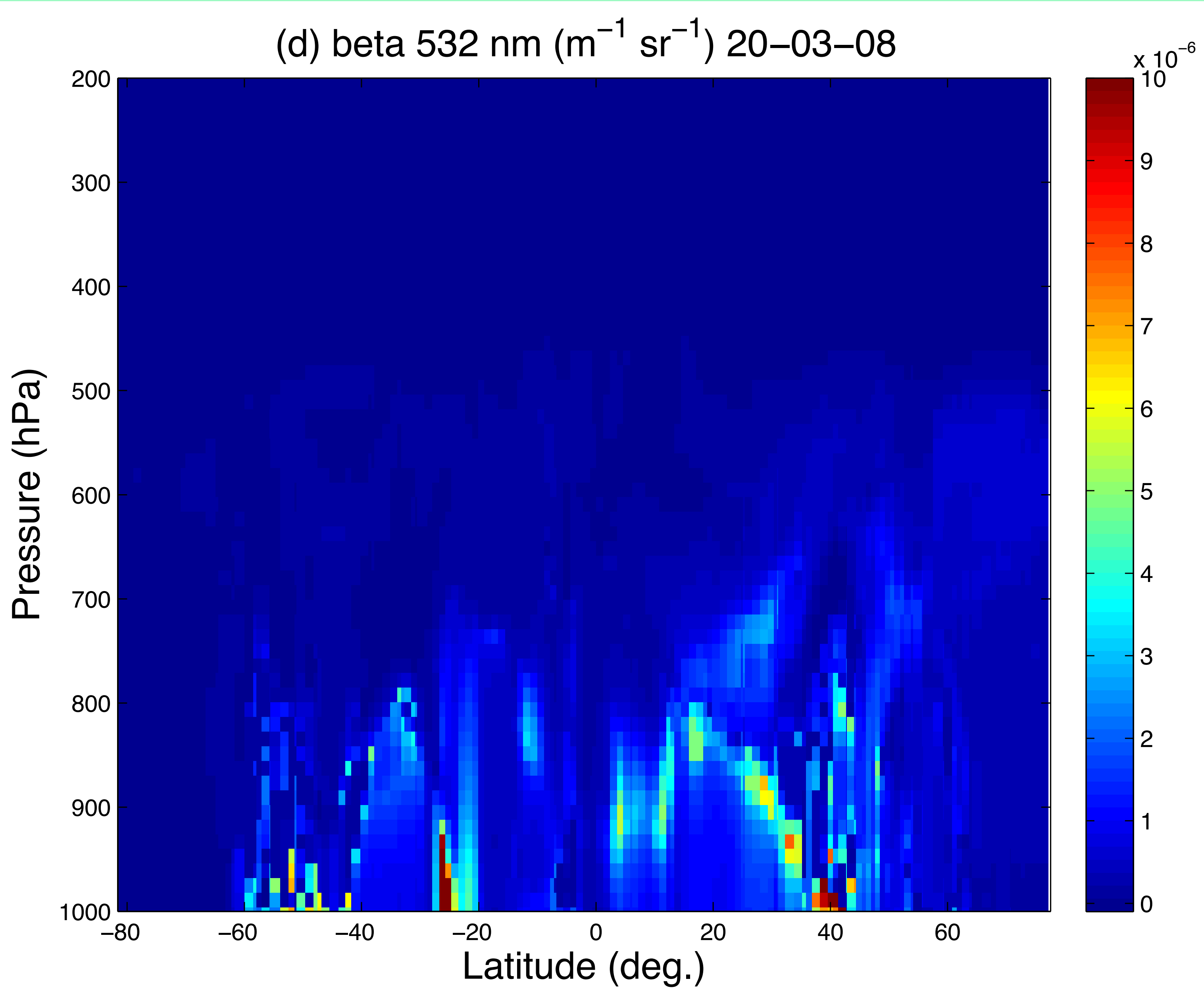
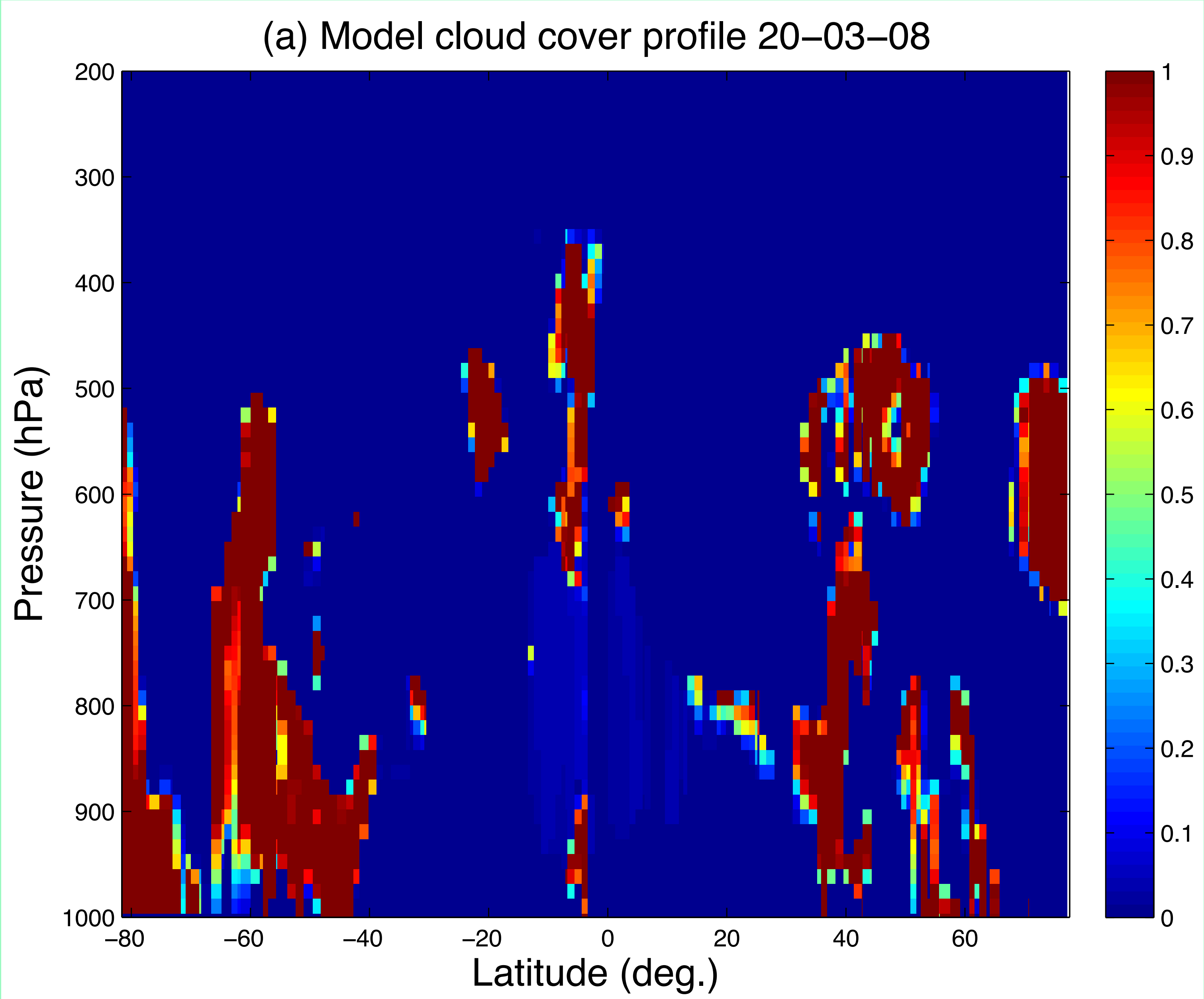


(c) alpha 532 nm (m$^{-1}$) 20–03–08
Pressure (hPa)
Latitude (deg.)
x 10$^{-4}$

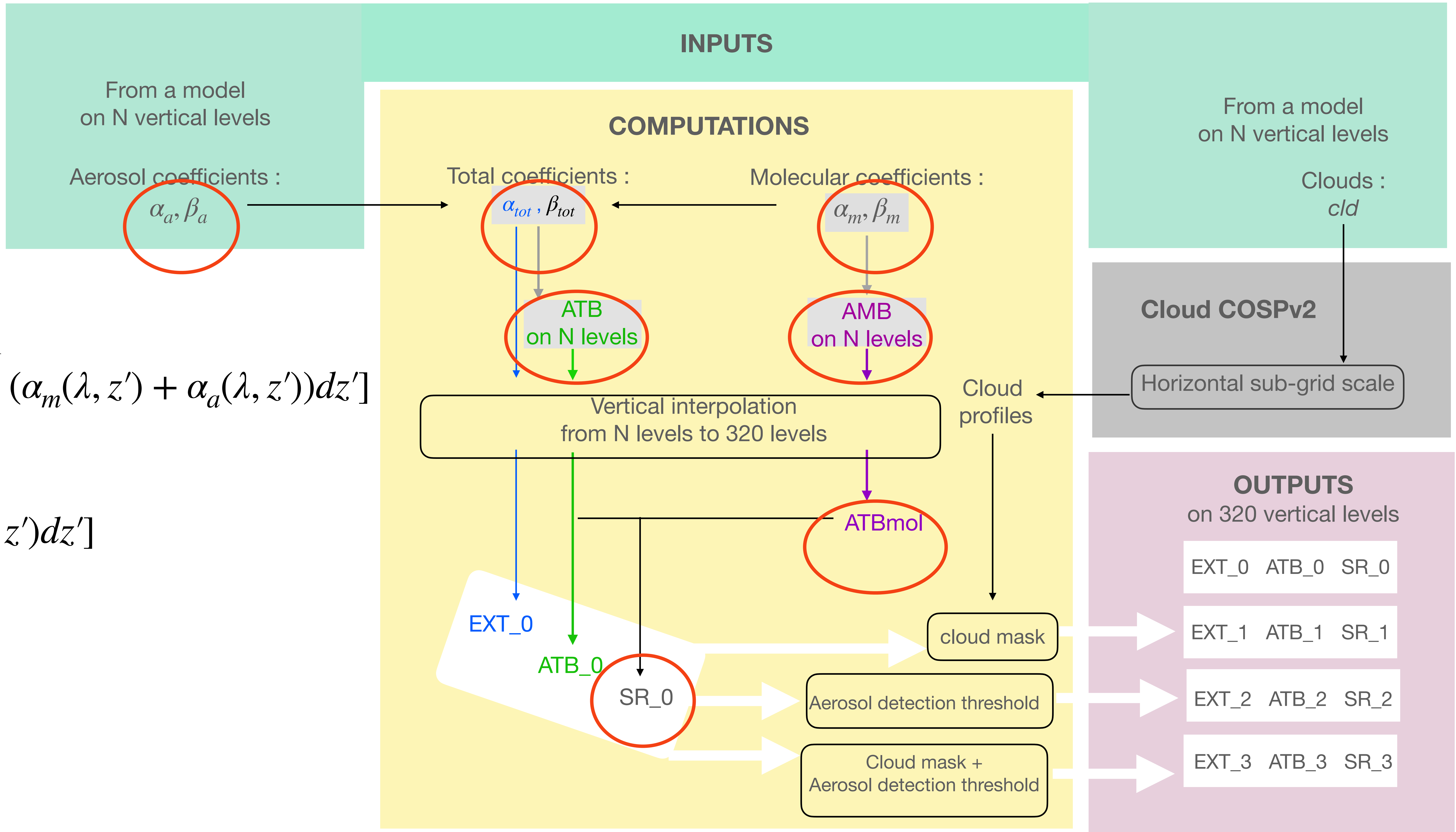
(d) beta 532 nm (m$^{-1}$ sr$^{-1}$) 20–03–08
Pressure (hPa)
Latitude (deg.)
x 10$^{-6}$

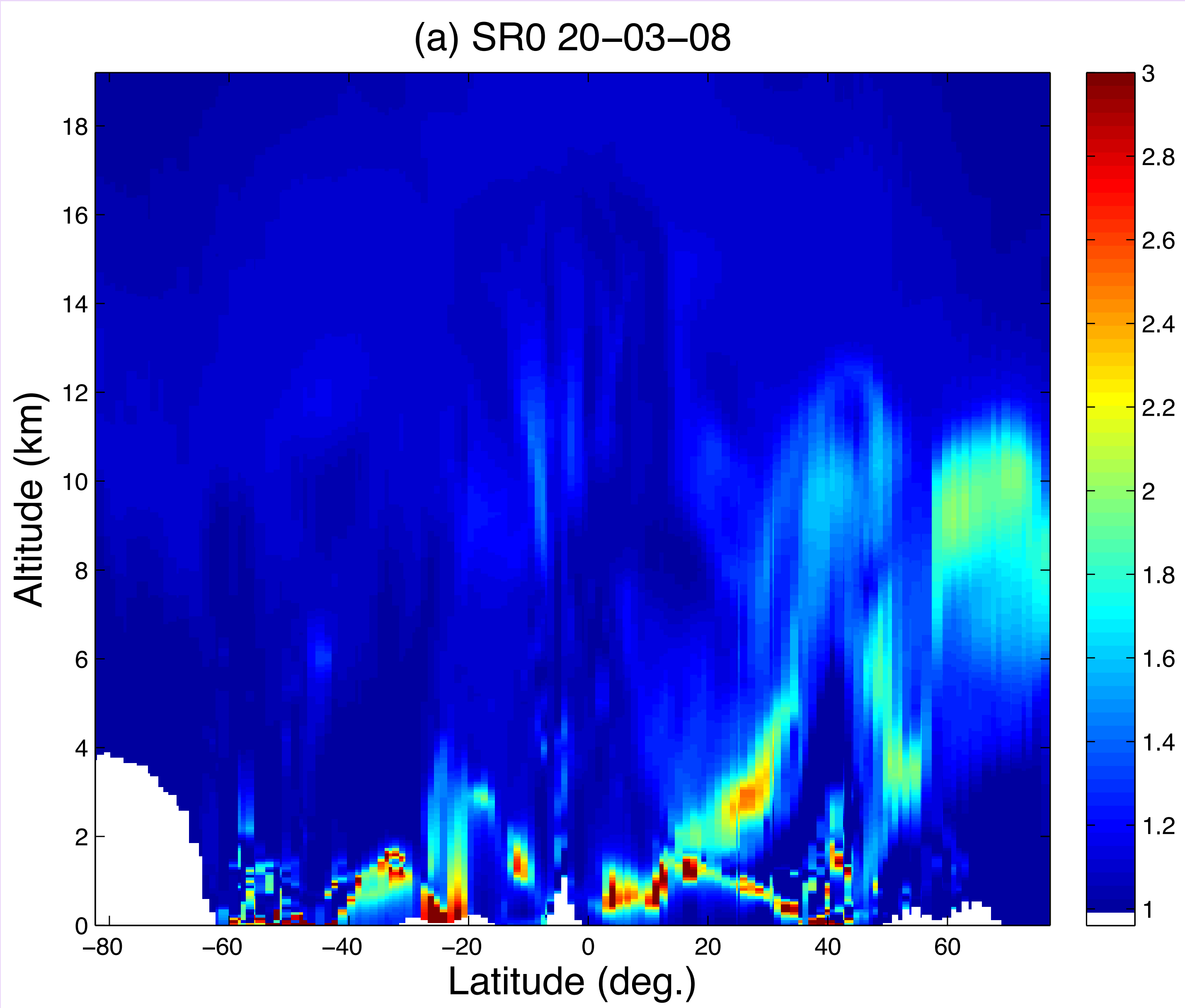
(a) Model cloud cover profile 20–03–08
Pressure (hPa)
Latitude (deg.)

# Computation of the Scattering Ratio (SR0)

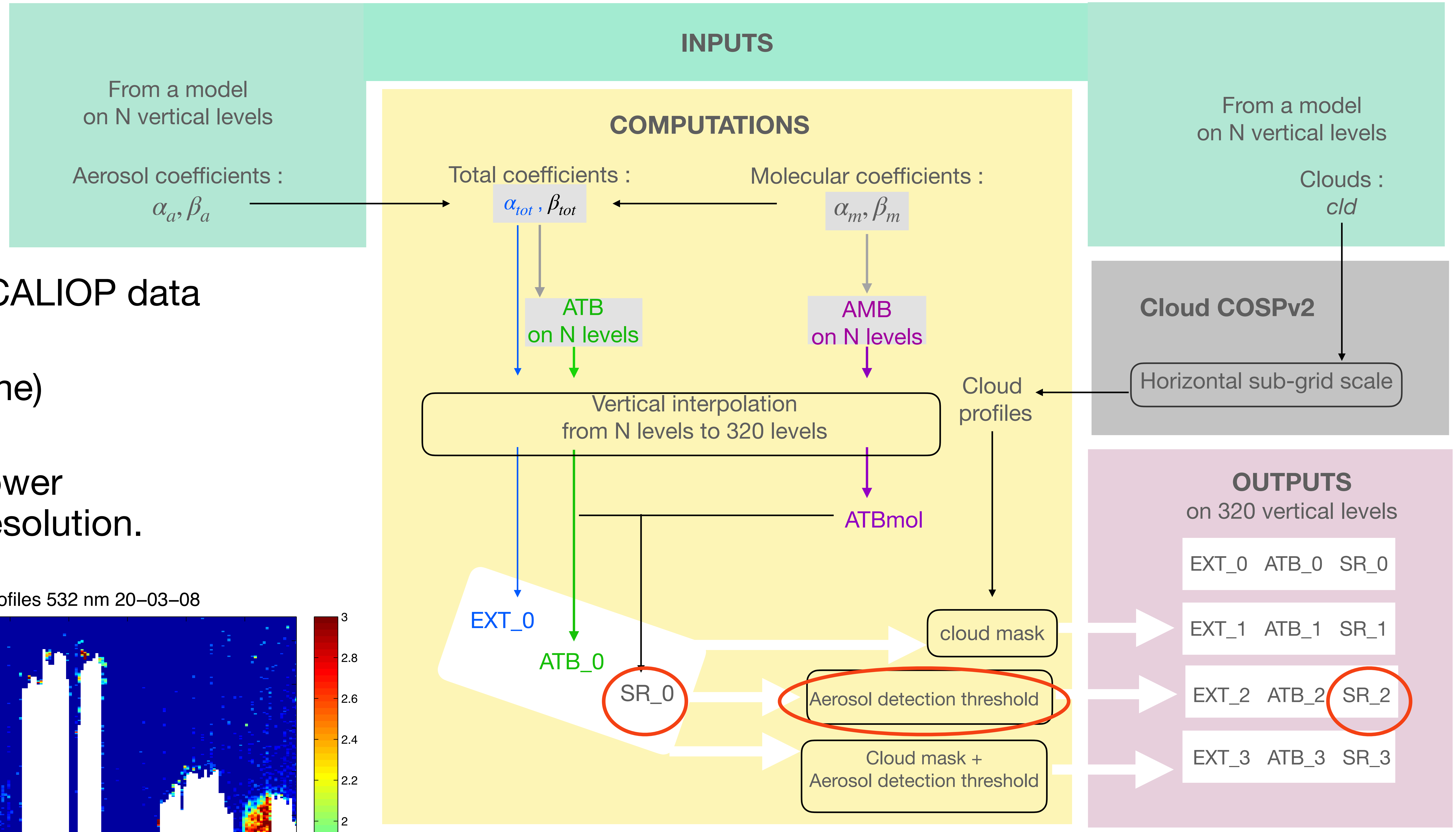
- $$ATB = (\beta_m(\lambda, z) + \beta_a(\lambda, z)) \, . \, exp[-2 \int_z^{TOA} (\alpha_m(\lambda, z') + \alpha_a(\lambda, z'))dz']$$
- $$AMB(\lambda, z) = \beta_m(\lambda, z) \, . \, exp[-2 \int_z^{TOA} \alpha_m(\lambda, z')dz']$$
- $$SR(\lambda, z) = \frac{ATB}{AMB}$$



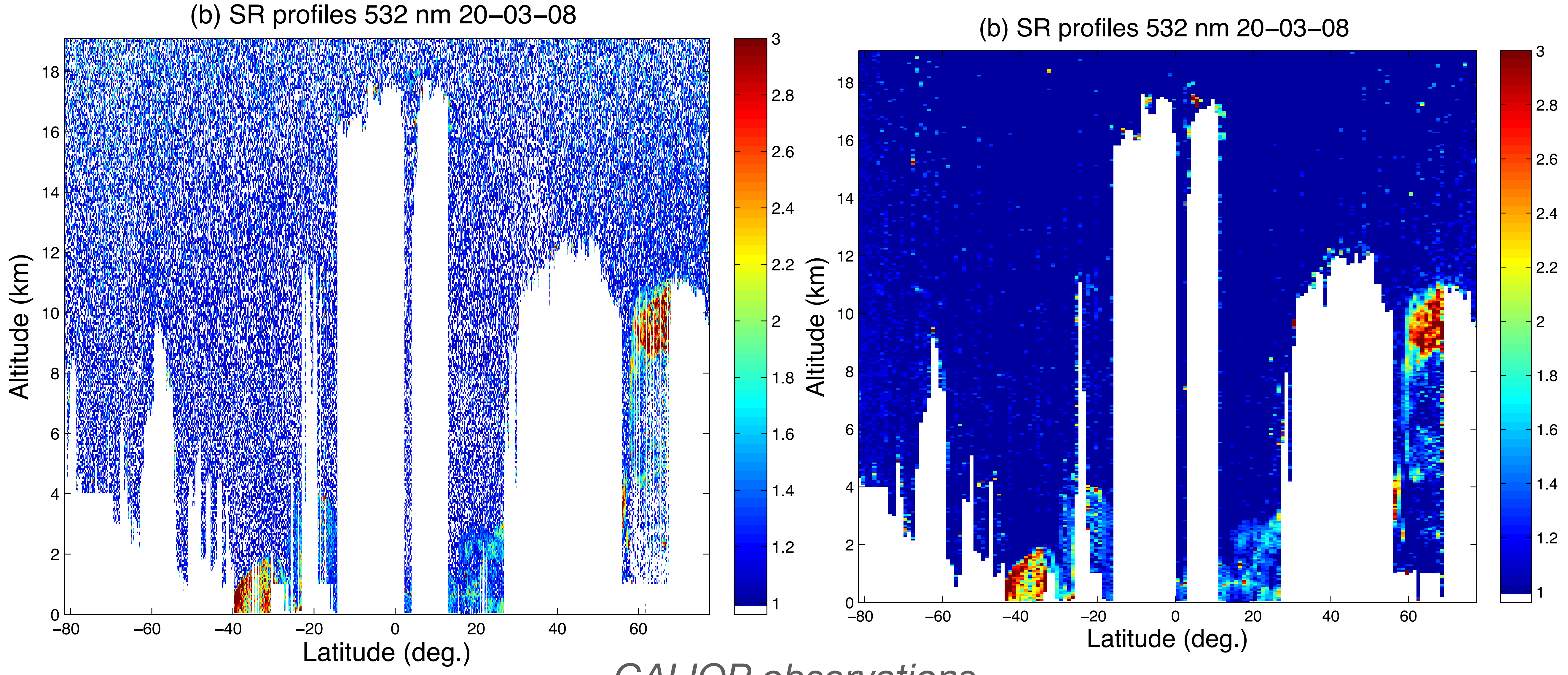
## OUTPUTS


(a) SR0 20−03−08
Altitude (km)
Latitude (deg.)
18
16
14
12
10
8
6
4
2
0
−80
−60
−40
−20
0
20
40
60
3
2.8
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1

# Computation of the Aerosol detection threshold

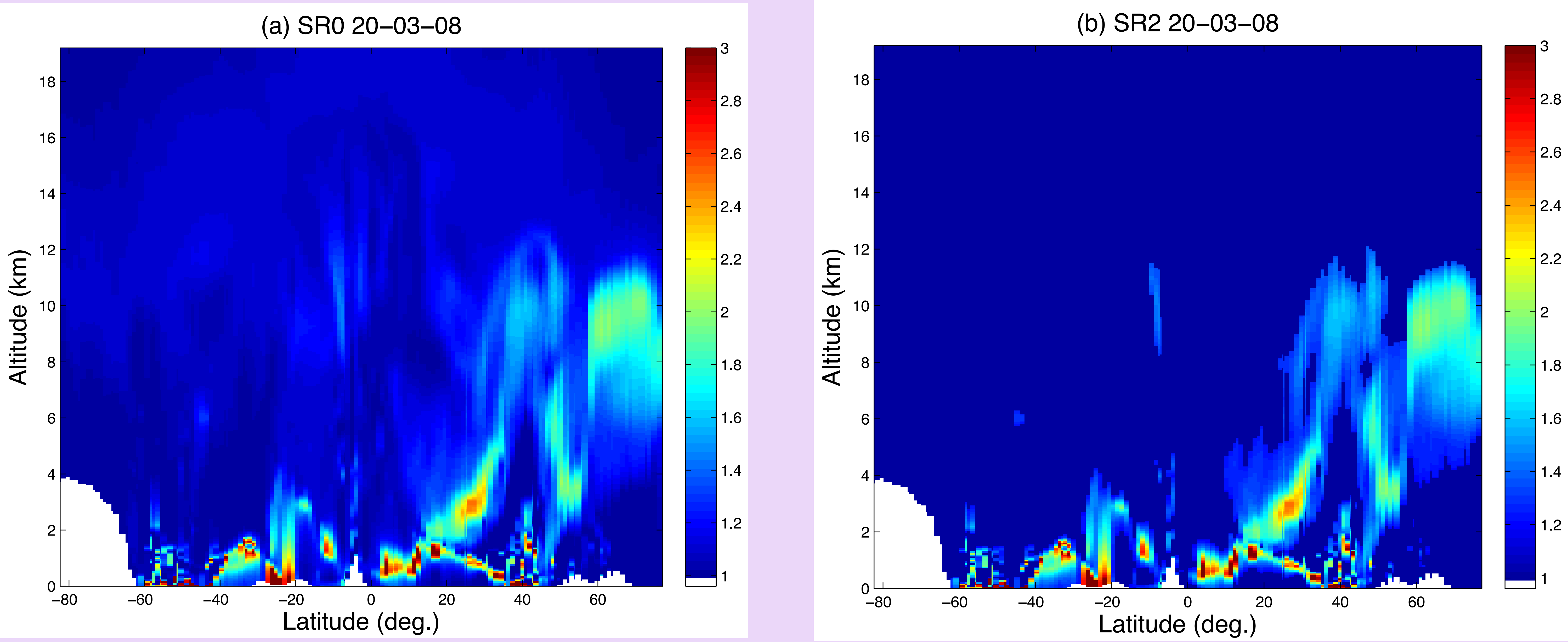



- Threshold determined from the noise in CALIOP data
- Presence of aerosols for SR>1.2 (nighttime)
- Higher threshold required for daytime ; lower threshold required at a coarser vertical resolution.



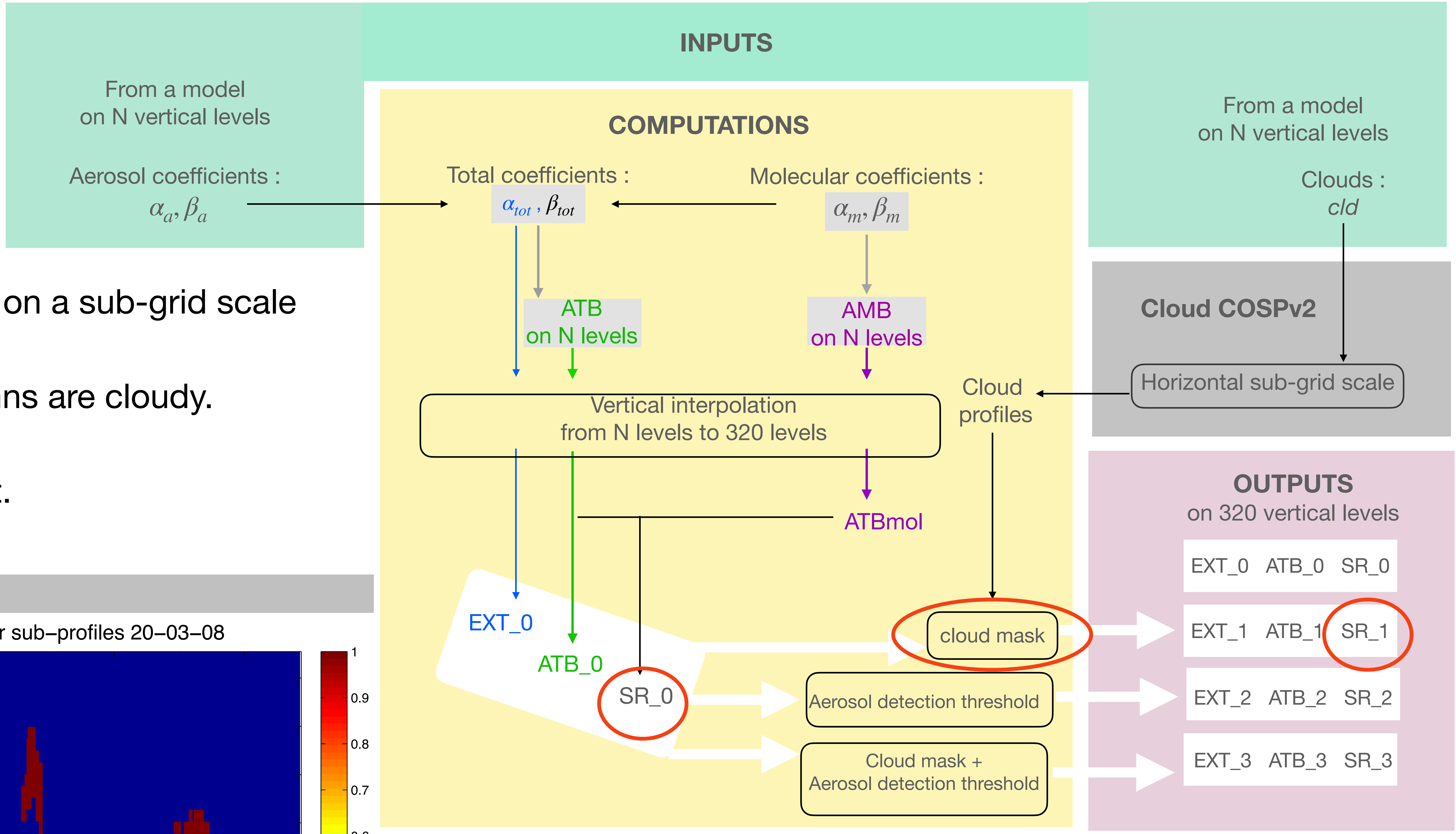

*CALIOP observations*

## OUTPUTS

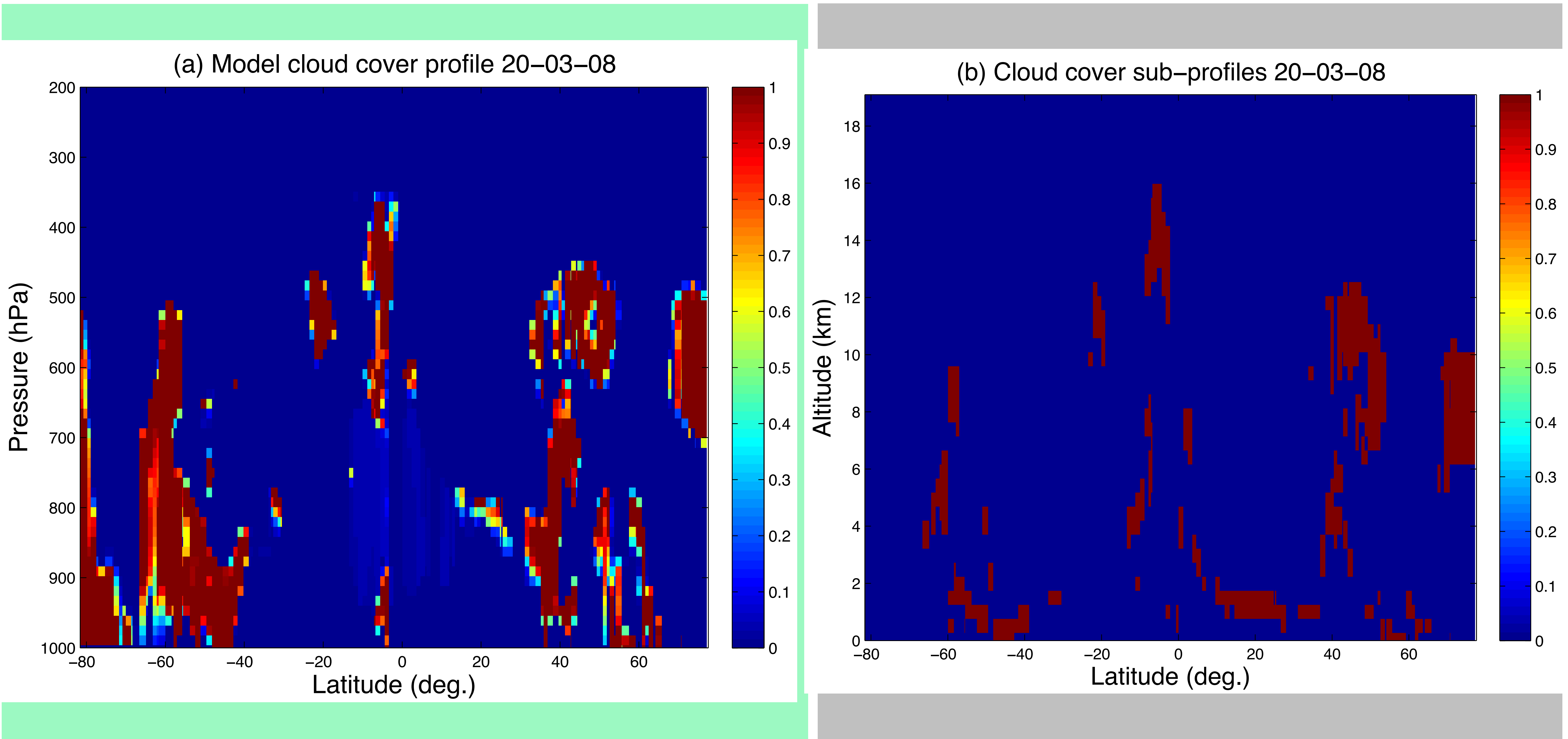


(a) SR0 20–03–08
Altitude (km)
Latitude (deg.)
(b) SR2 20–03–08
Altitude (km)
Latitude (deg.)

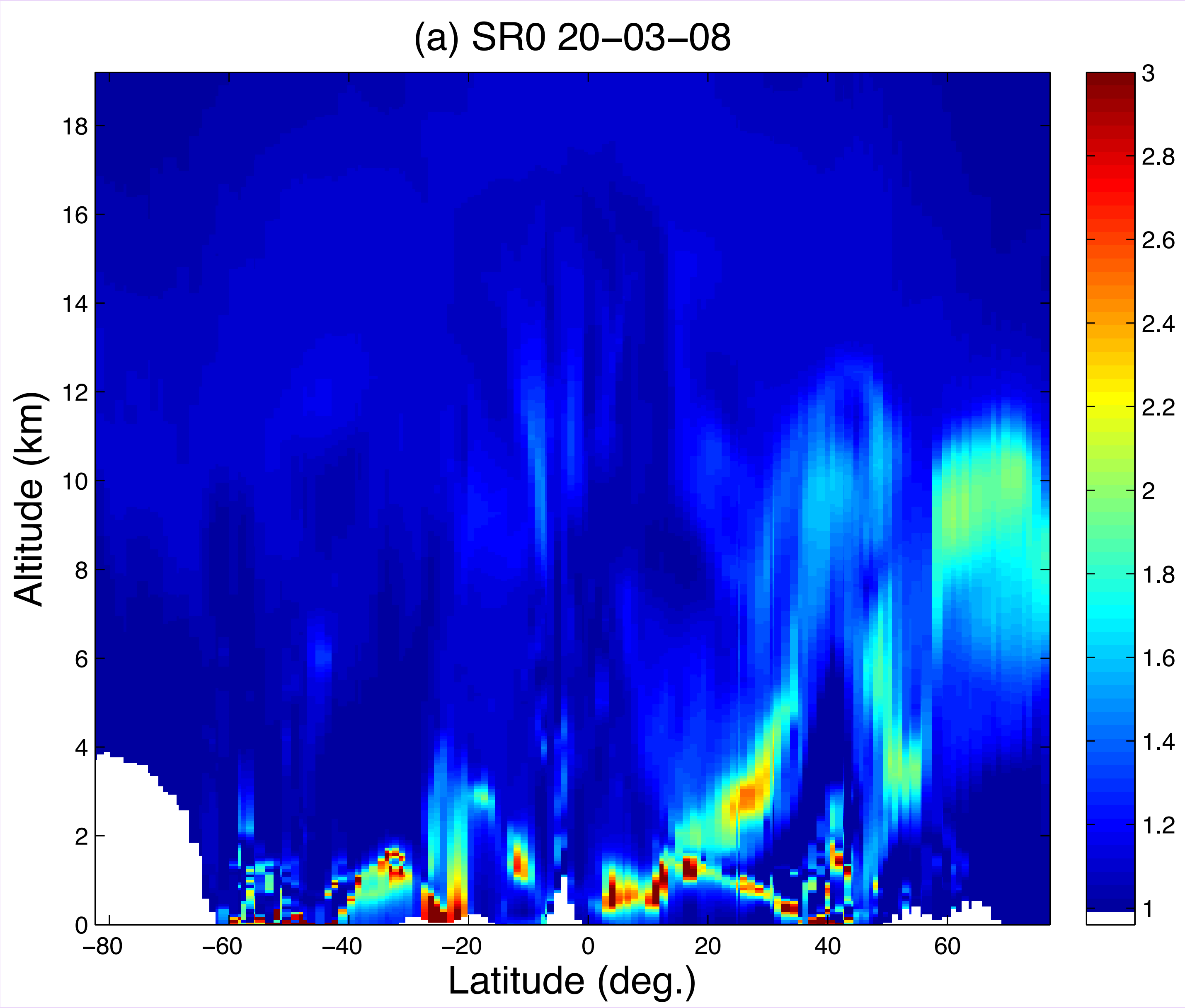
# Computation of the model cloud mask



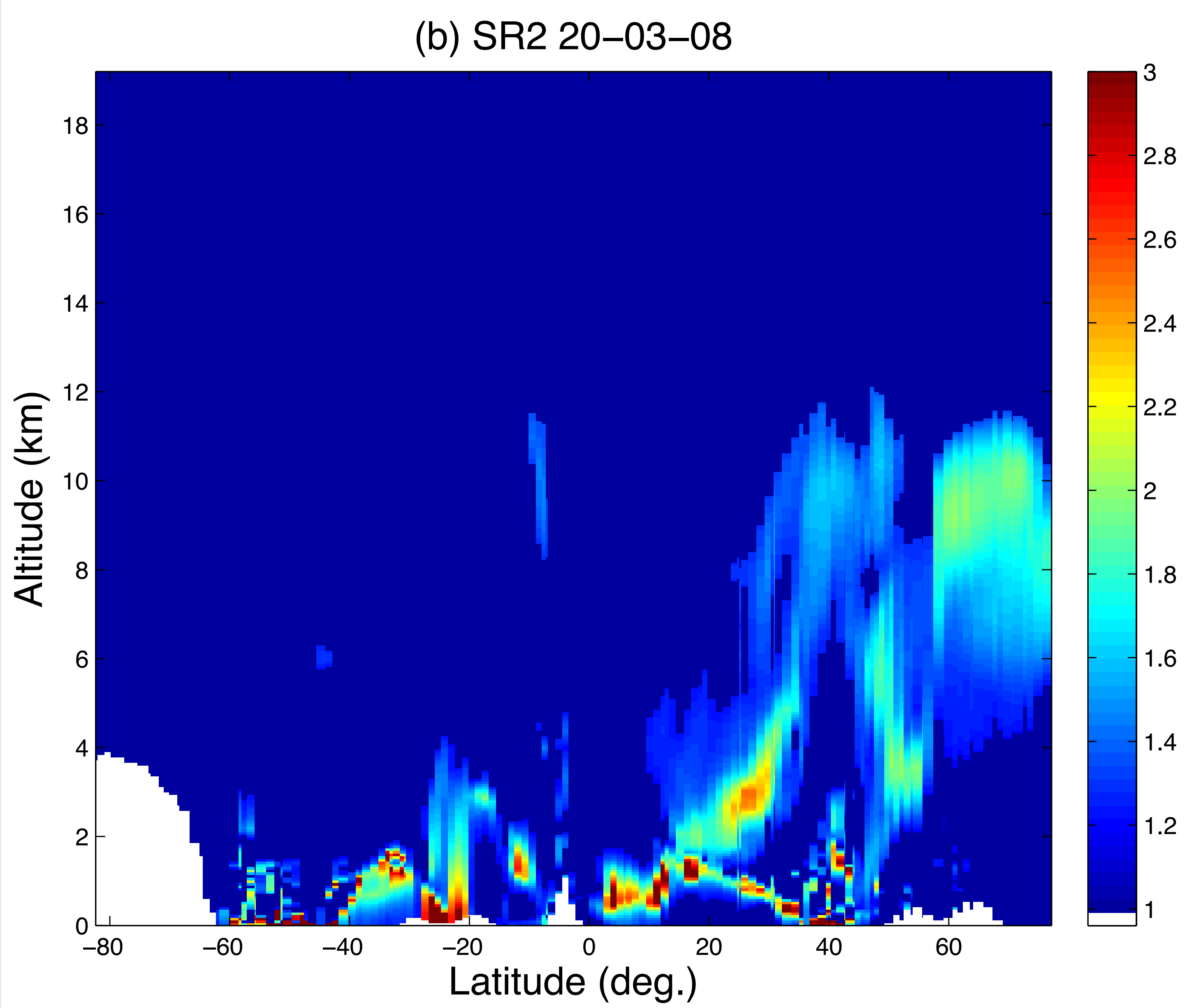

- The Cloud COSPv2 Simulator defines the model clouds on a sub-grid scale
- A model grid cell is considered cloudy if all its subcolumns are cloudy.
- The whole column below a cloudy grid cell is filtered out.



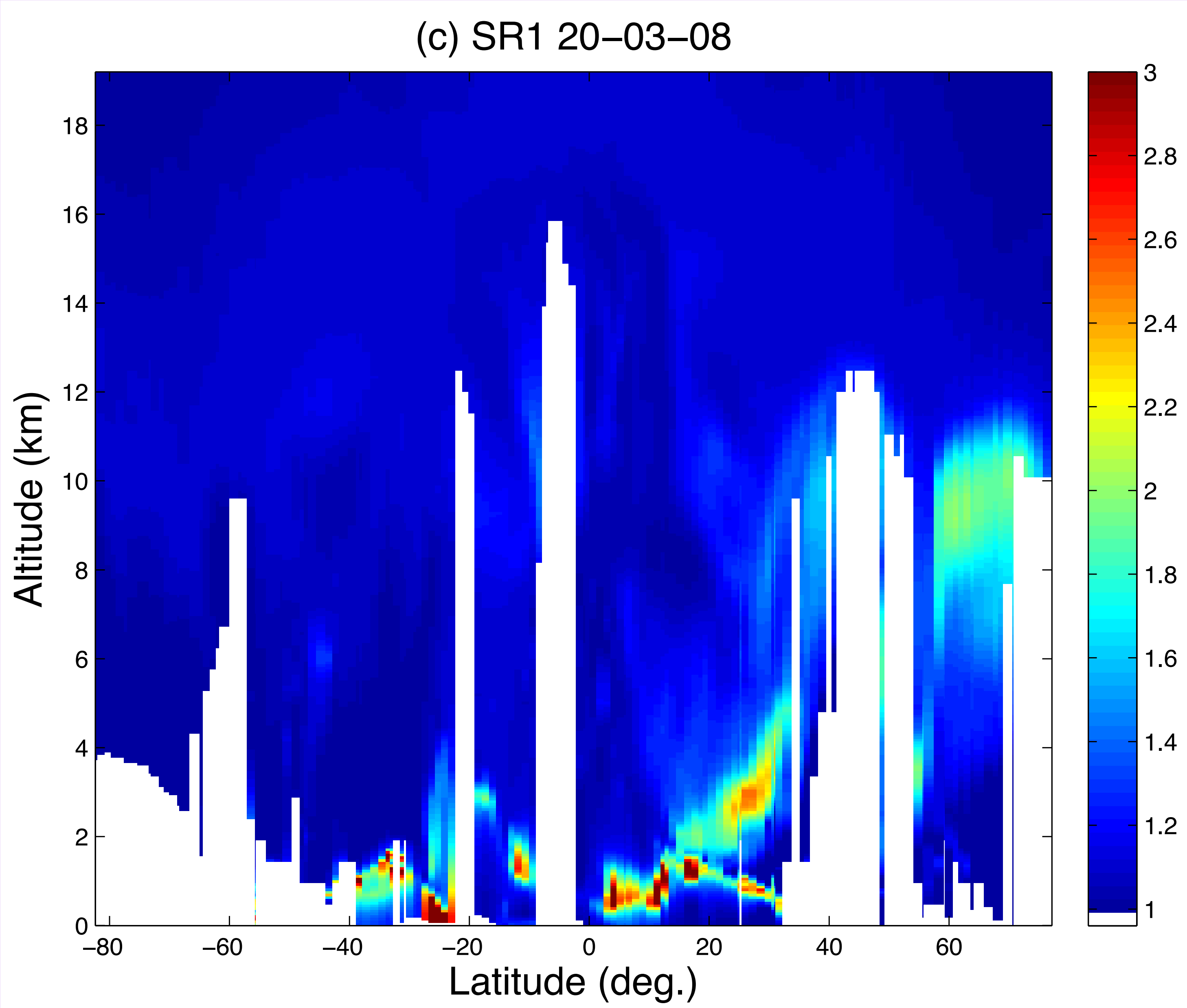
## OUTPUTS



(a) SR0 20−03−08
Altitude (km)
Latitude (deg.)

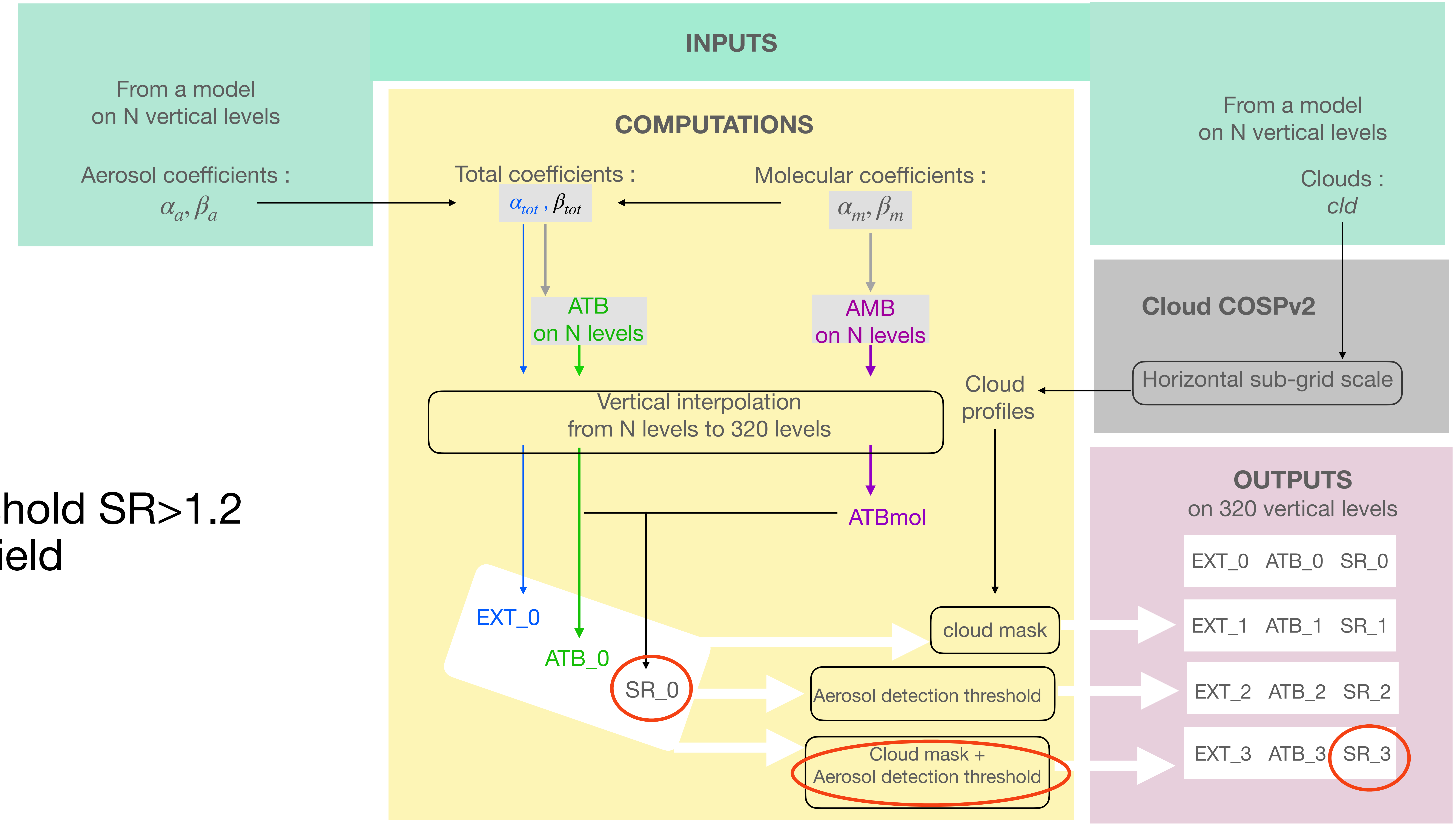
(b) SR2 20−03−08
Altitude (km)
Latitude (deg.)

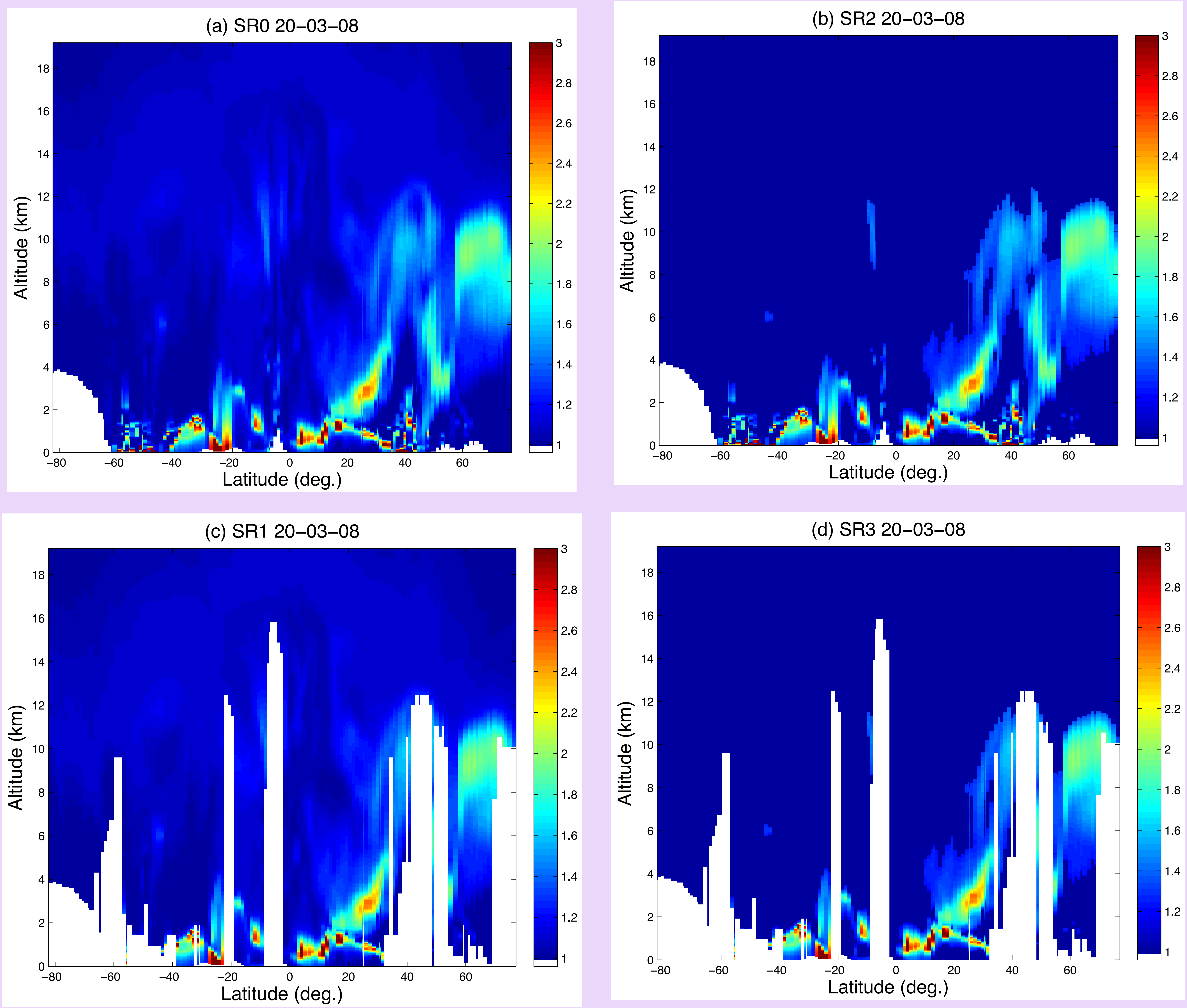
(c) SR1 20−03−08
Altitude (km)
Latitude (deg.)

# Computation of the cloud mask + aerosol detection threshold

- The cloud mask and the threshold SR>1.2 are both applied on the SR0 field

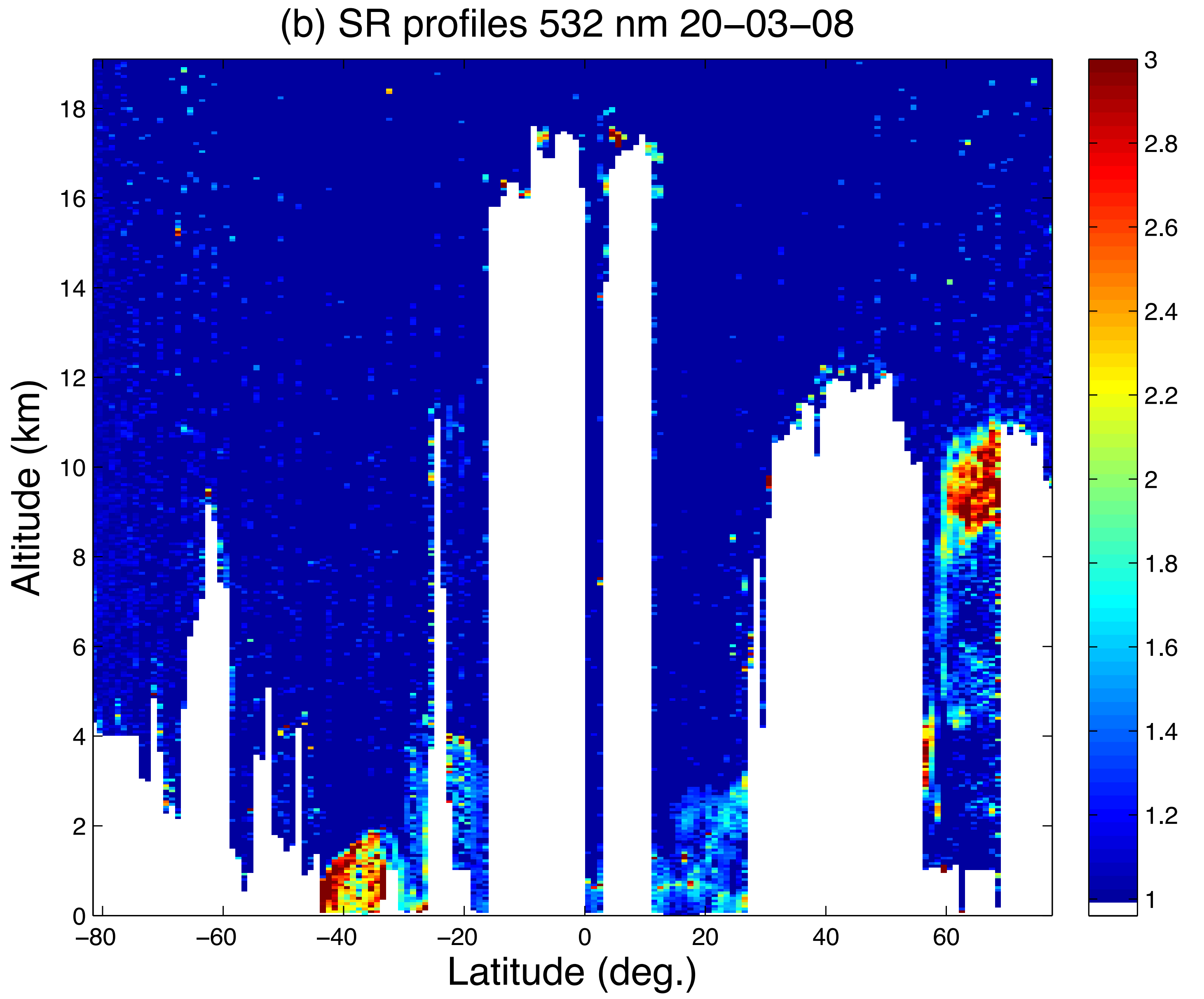


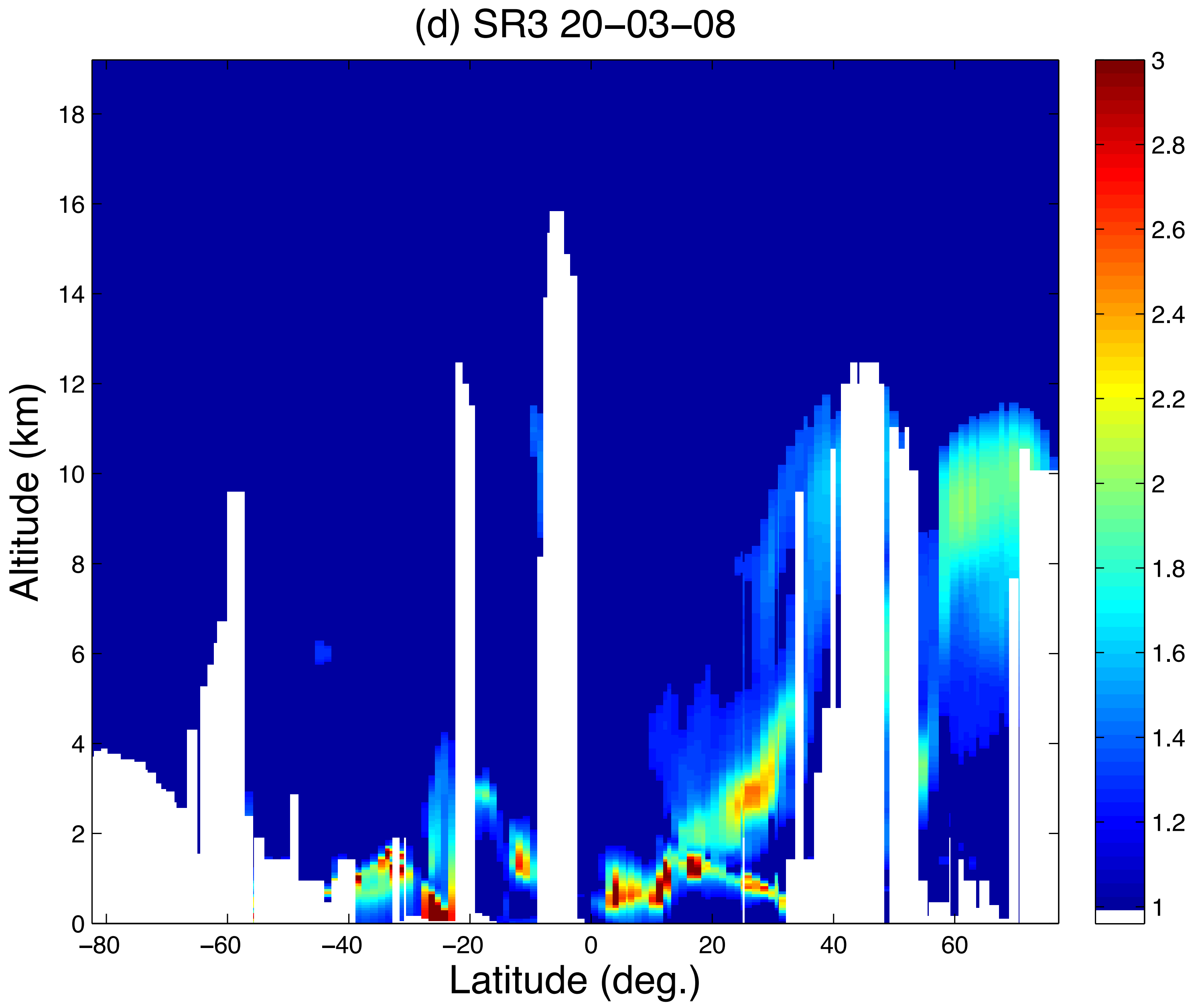
# OUTPUTS

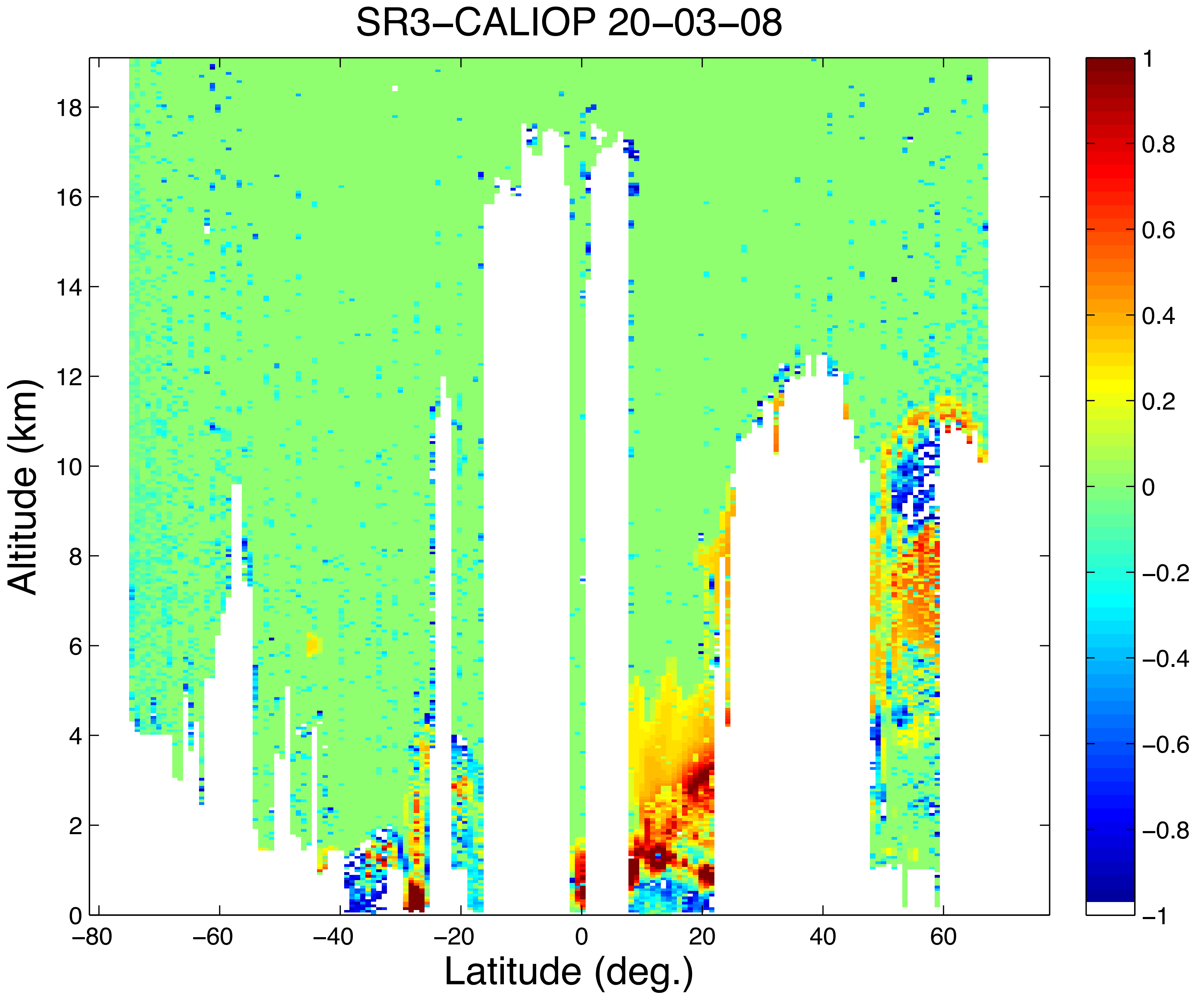


(a) SR0 20−03−08
(b) SR2 20−03−08
(c) SR1 20−03−08
(d) SR3 20−03−08
Altitude (km)
Latitude (deg.)

# E3SM/CALIOP comparison (20-03-2008 orbit)

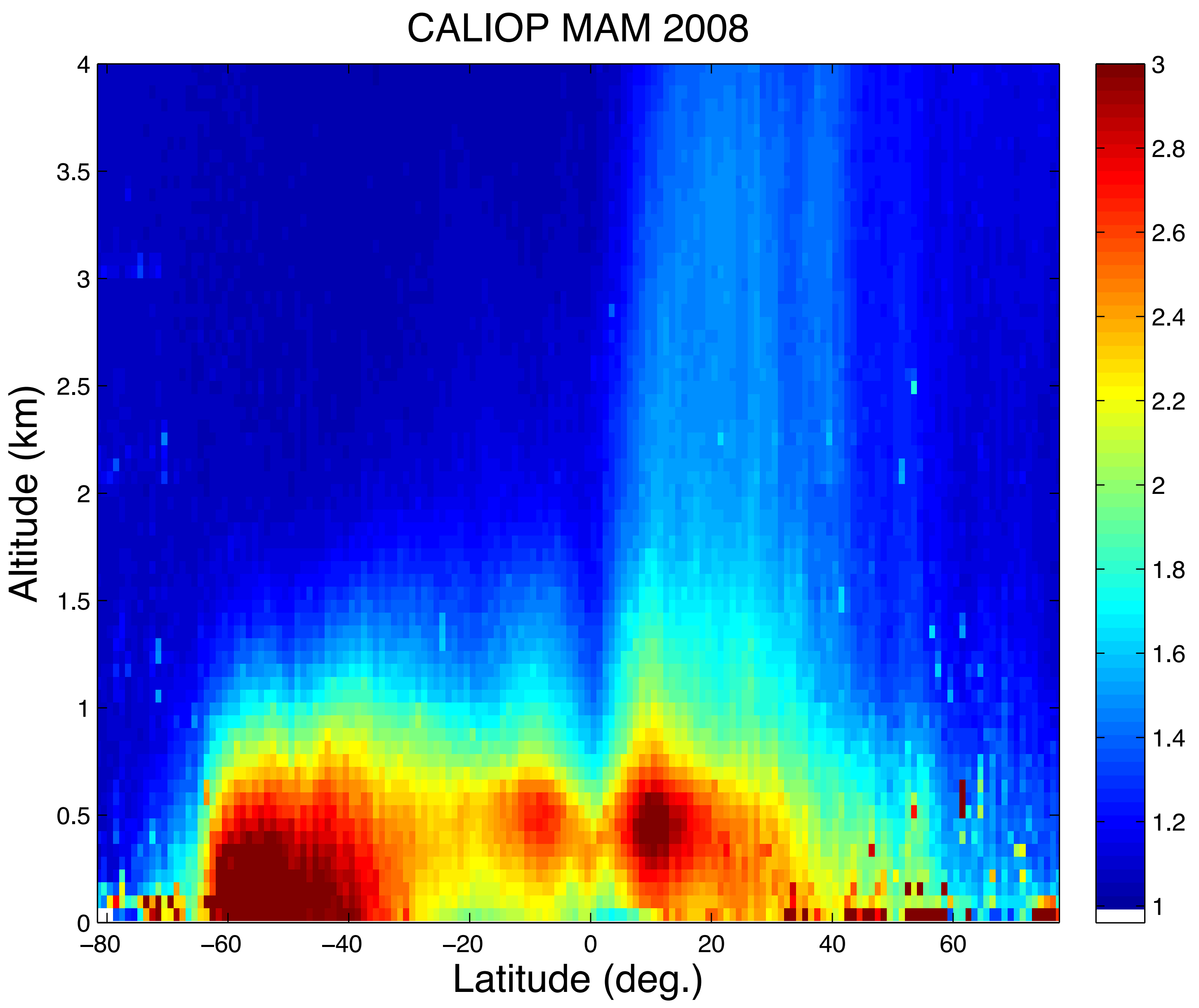


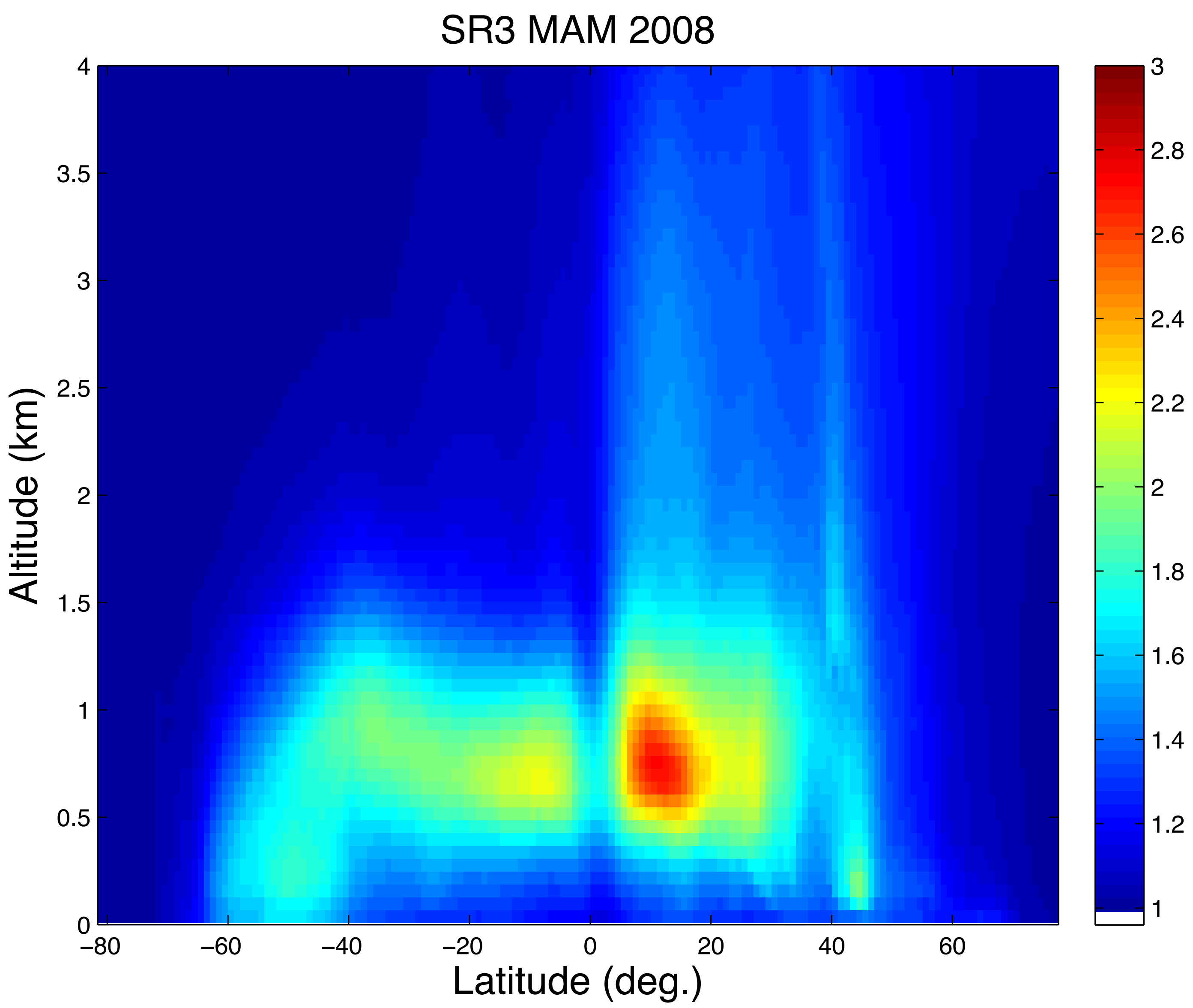



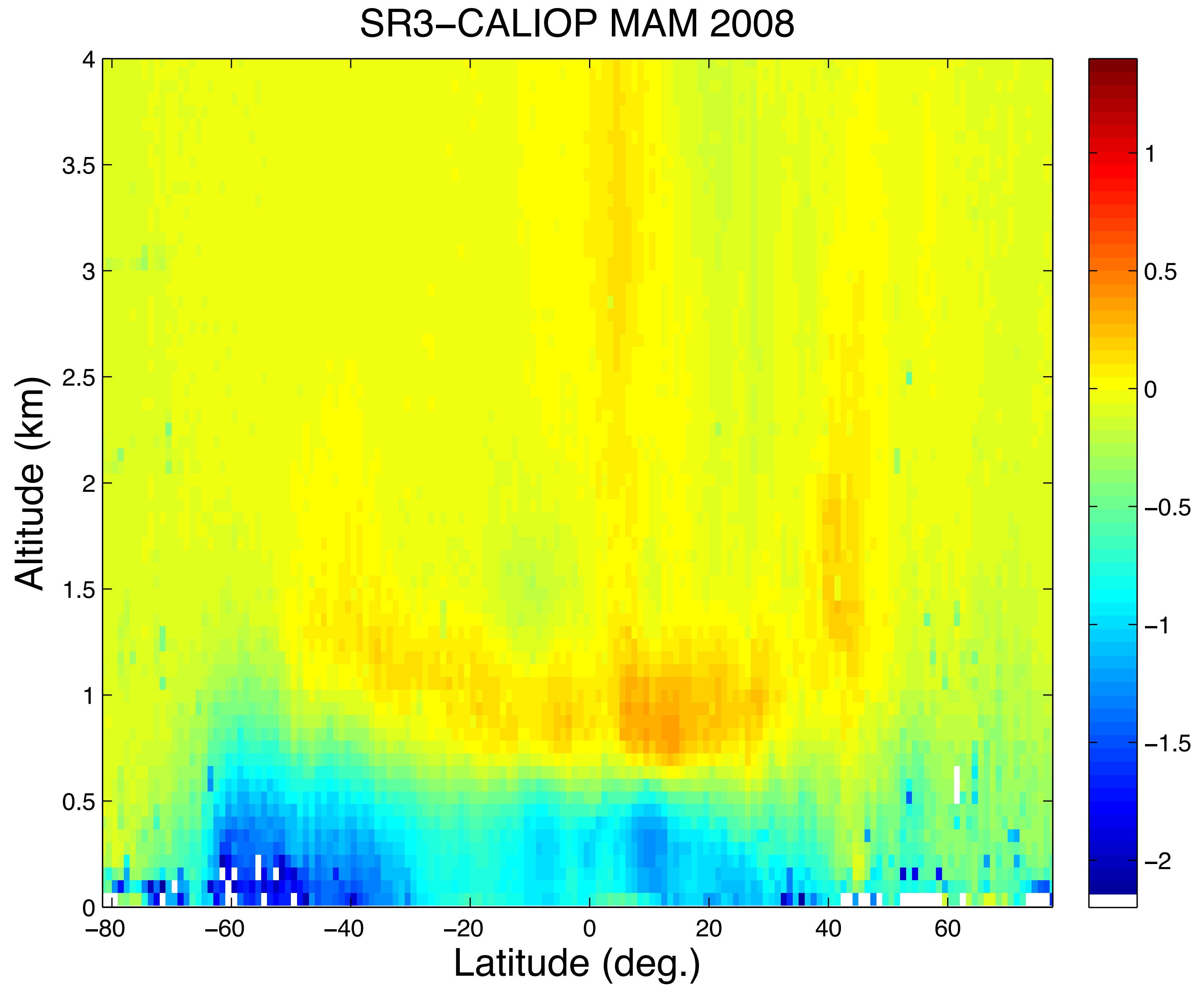




- Simulated and observed clouds are in good agreement in the nudged E3SM simulations.
- Underestimation of aerosol concentrations near the surface
- Overestimation in the aerosol plume north of 20$^{o}$N between 1 and 9 km.

# 3-Month Comparison of E3SM outputs and CALIOP data

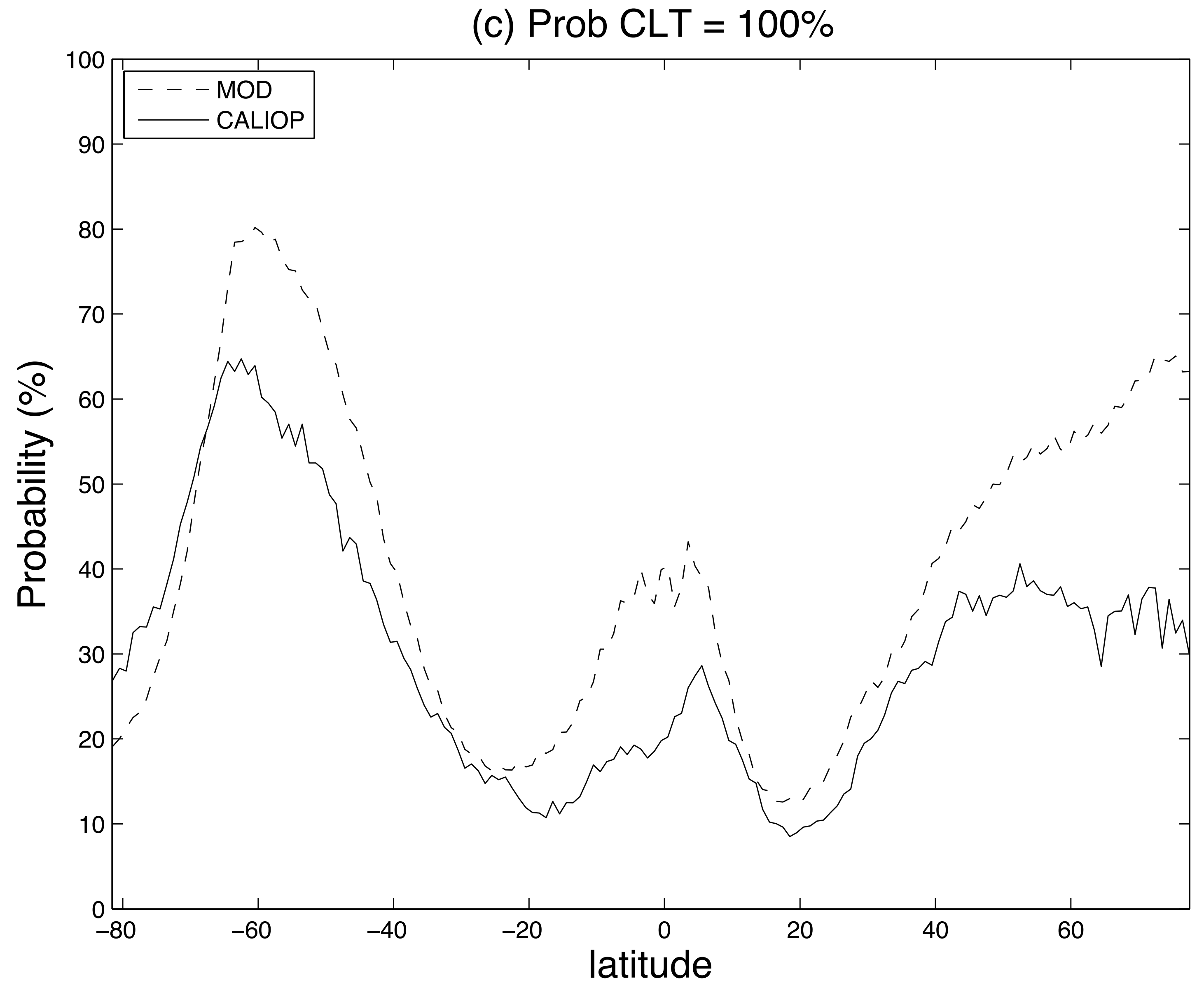


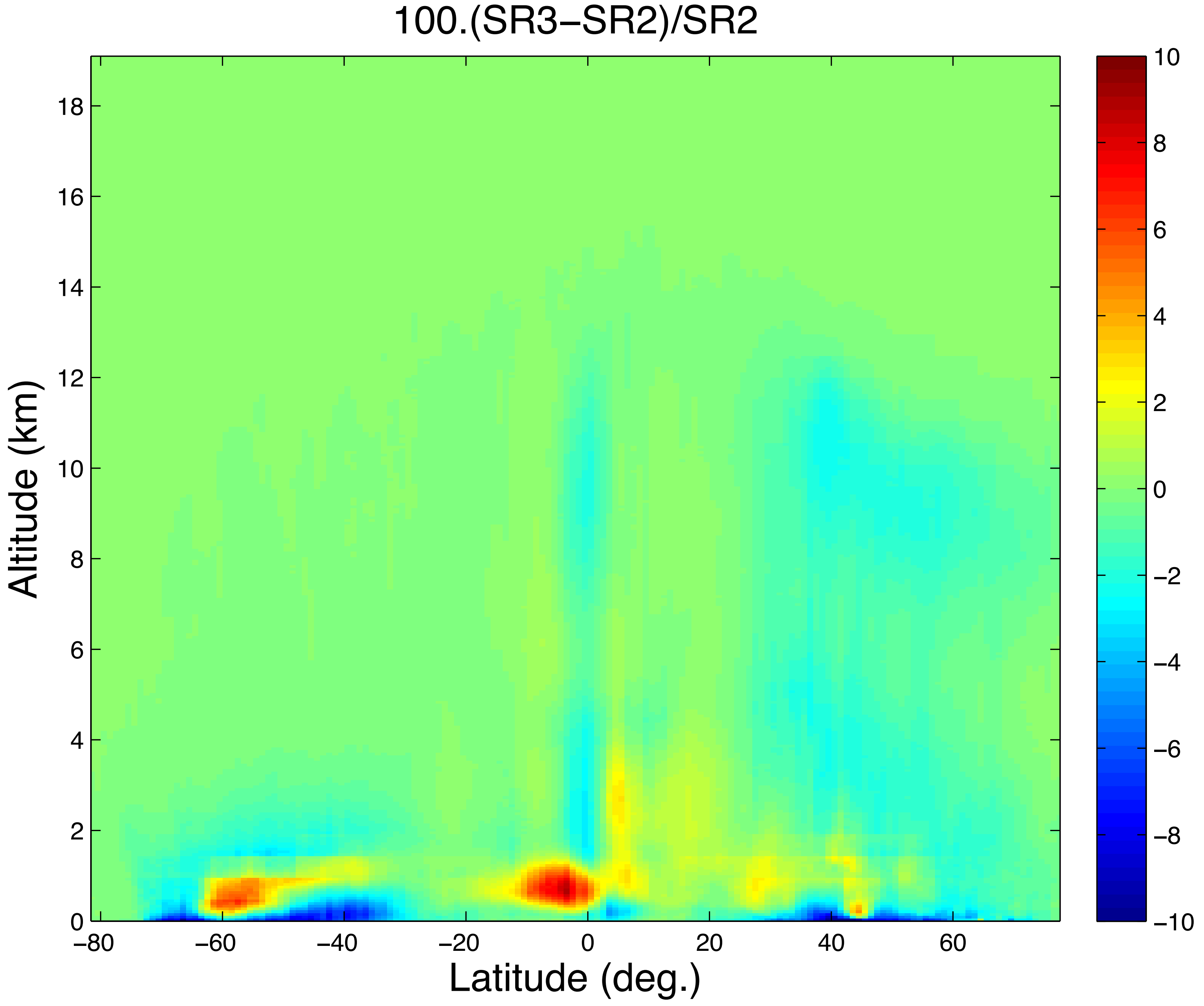




- The maximum at 10°N is well reproduced.
- The maximum over the Southern Ocean does not appear : might be due to inaccurate simulation of sea spray aerosols.
- *Rash et al. (2019)* and *Wang et al. (2020)* also show an aerosol bias over the Southern Ocean.
- Emissions of sea salt and marine organics aerosols depend on the surface wind, that has a bias in the E3SM model.
- New Particle Formation (NPF) might be important in this region, but this process is not well represented in models.
- The SR maxima are underestimated by 1-1.5 below 500-800 m. Slight overestimation from this level up to 1.5-1.8 km.
- The underestimation of SR in the surface layer corresponds to an error of 50% on the AOD.
- Bias in the vertical distribution : too efficient vertical mixing in E3SM?

# Importance of the cloud mask for comparing model and observed aerosols?



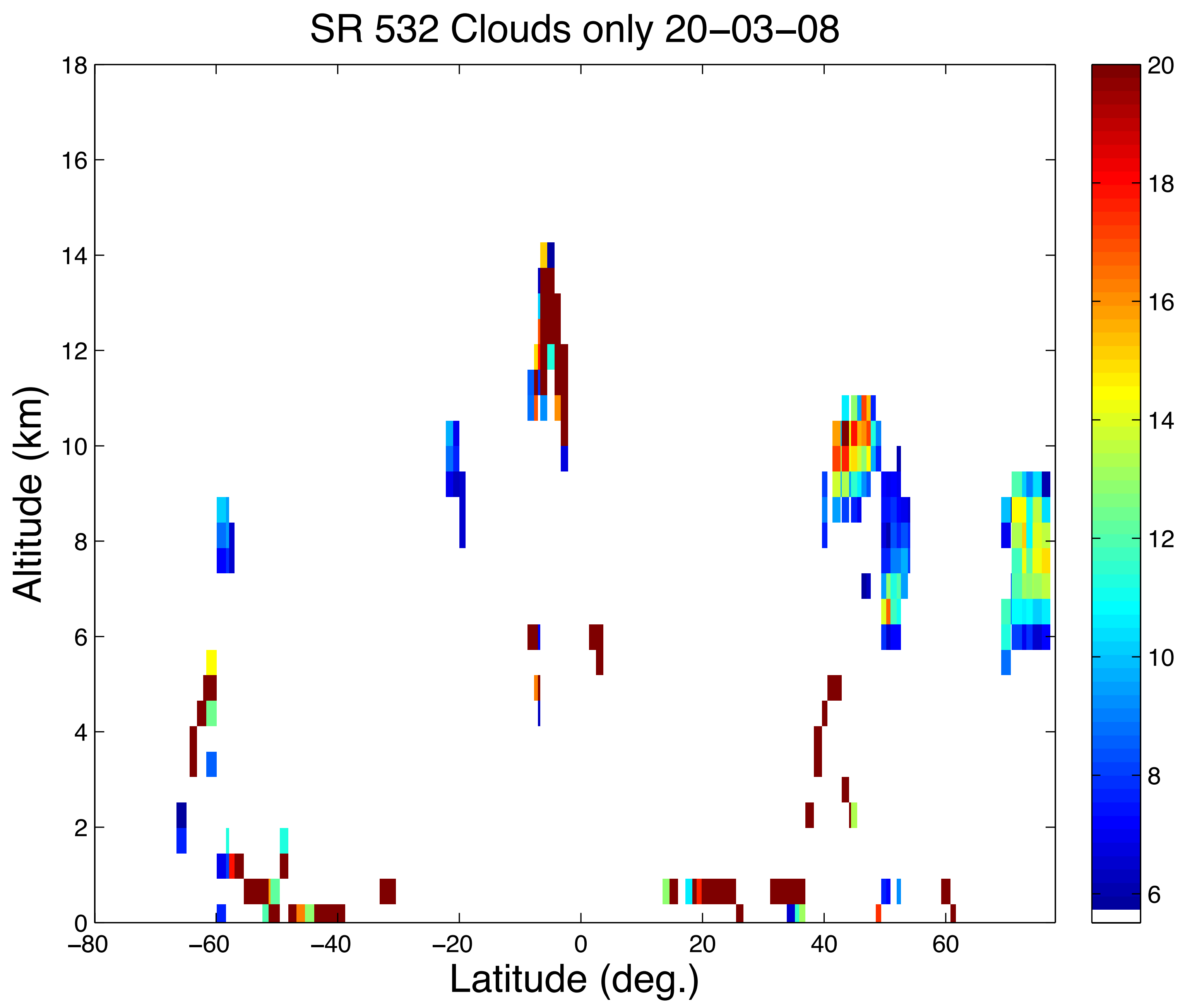



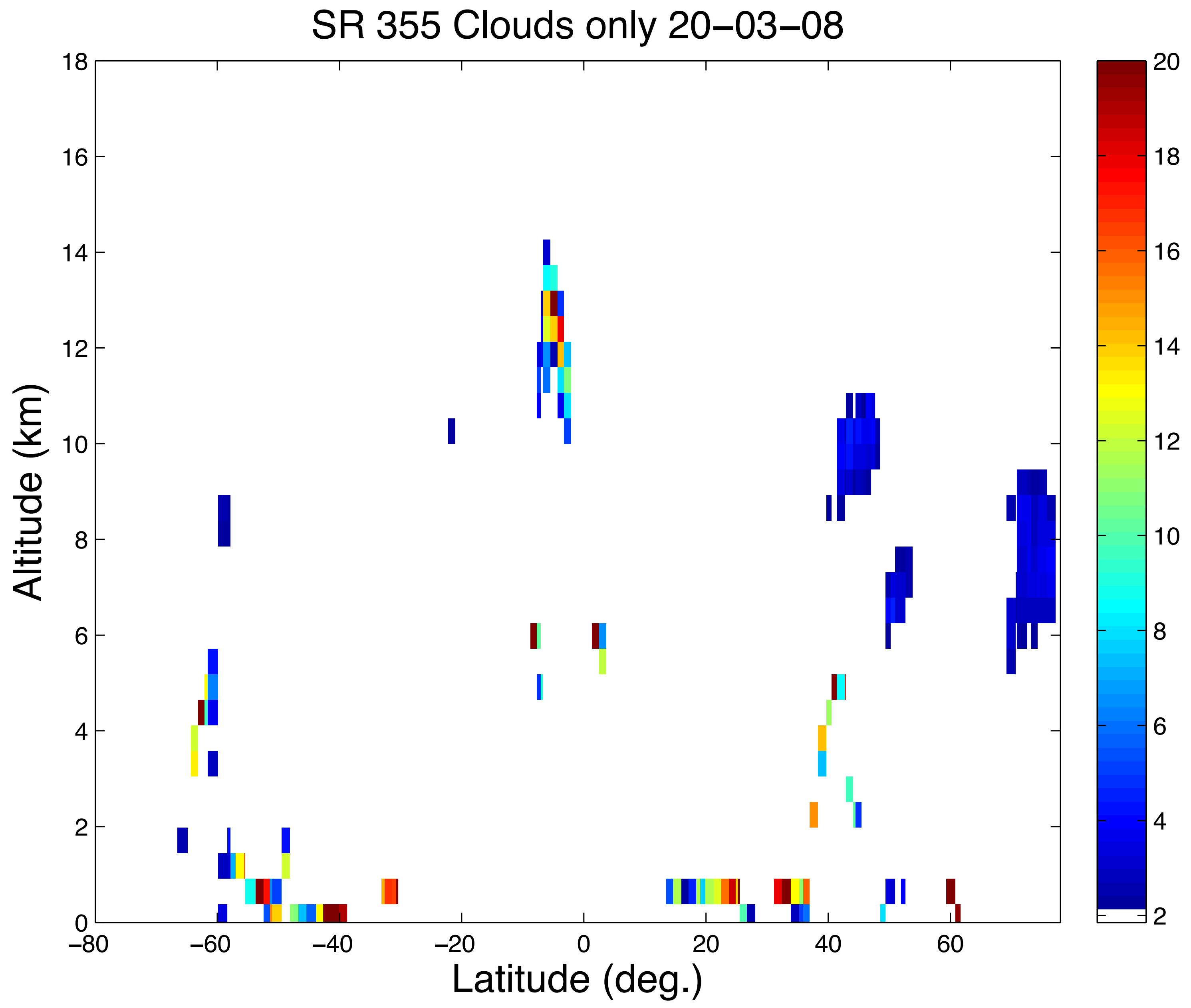

- The 3-month averaged SR2 field corresponds to the aerosol signal for each day (cloudy or not).
- The 3-month averaged SR3 field corresponds to the aerosol signal for clear-sky and partially cloudy days (the 100% cloudy days over 1x1 deg. grid cells are filtered out).
- If there is no 100% cloudy days in observations, no necessity to use the cloud mask (the sampling in model and obs. would be the same).
- However there are 100% cloudy days at some latitudes (Southern Ocean).
- Relative error of about 10% when no cloud mask is used (due to sampling differences).
- Caveat : We use here a model cloud mask, slightly different form the observed cloud mask.

# Differences between ATLID and CALIOP

| | ATLID | CALIOP |
|---|---|---|
| Wavelength | 355 nm | 532/1064 nm |
| Horizontal resolution | 282 m | Below 8.2 km : 330 m<br>Above 8.2 km : 1 km |
| Vertical resolution | 100 m | Below 8.2 km : 30 m<br>Above 8.2 km : 60 m |
| Spectral capability | HSRL | no |
| Retrieved variables | extinction and backscatter profiles | ATB, SR |

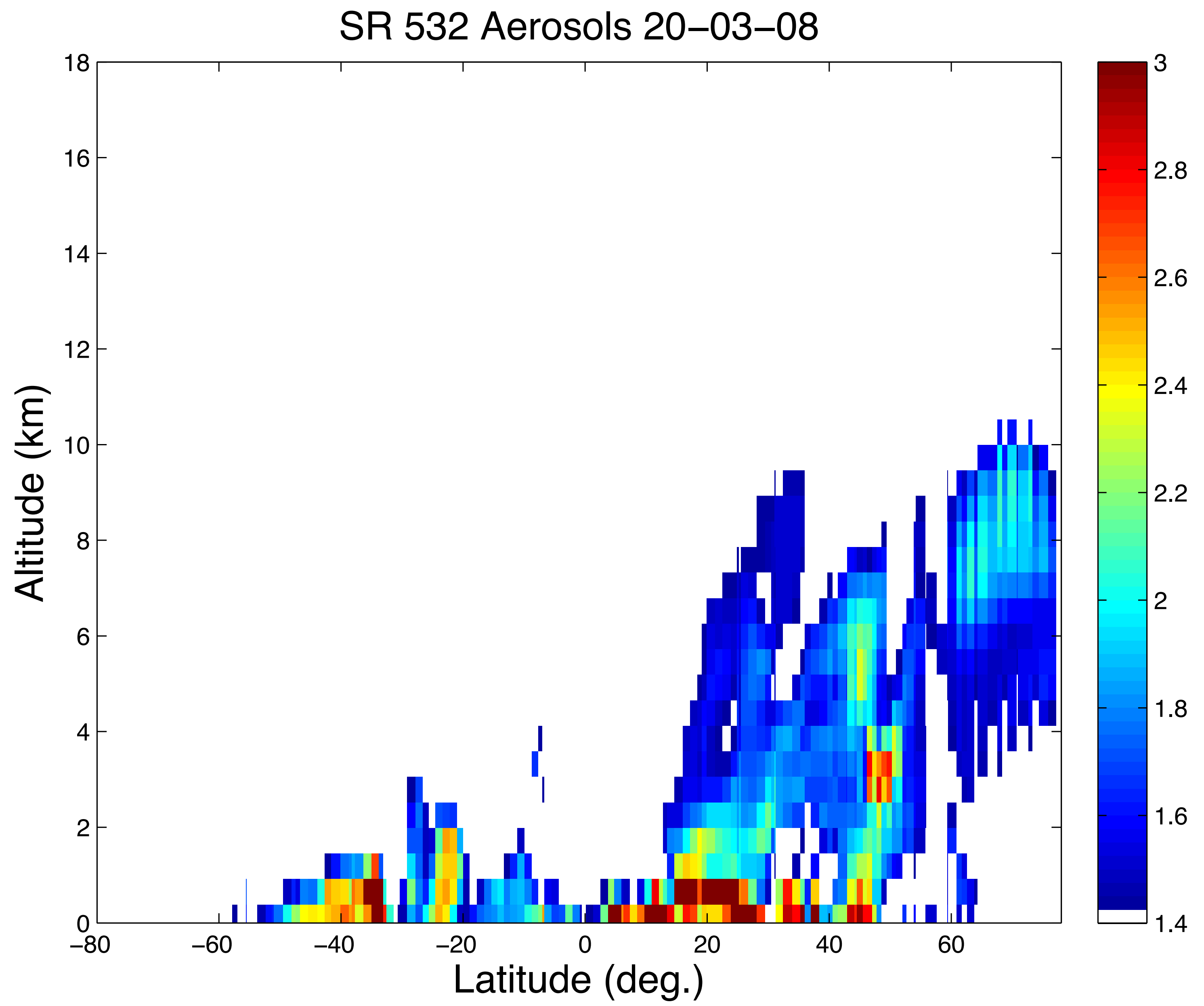
# Constructing a cloud mask with ATLID consistent with the CALIOP cloud mask

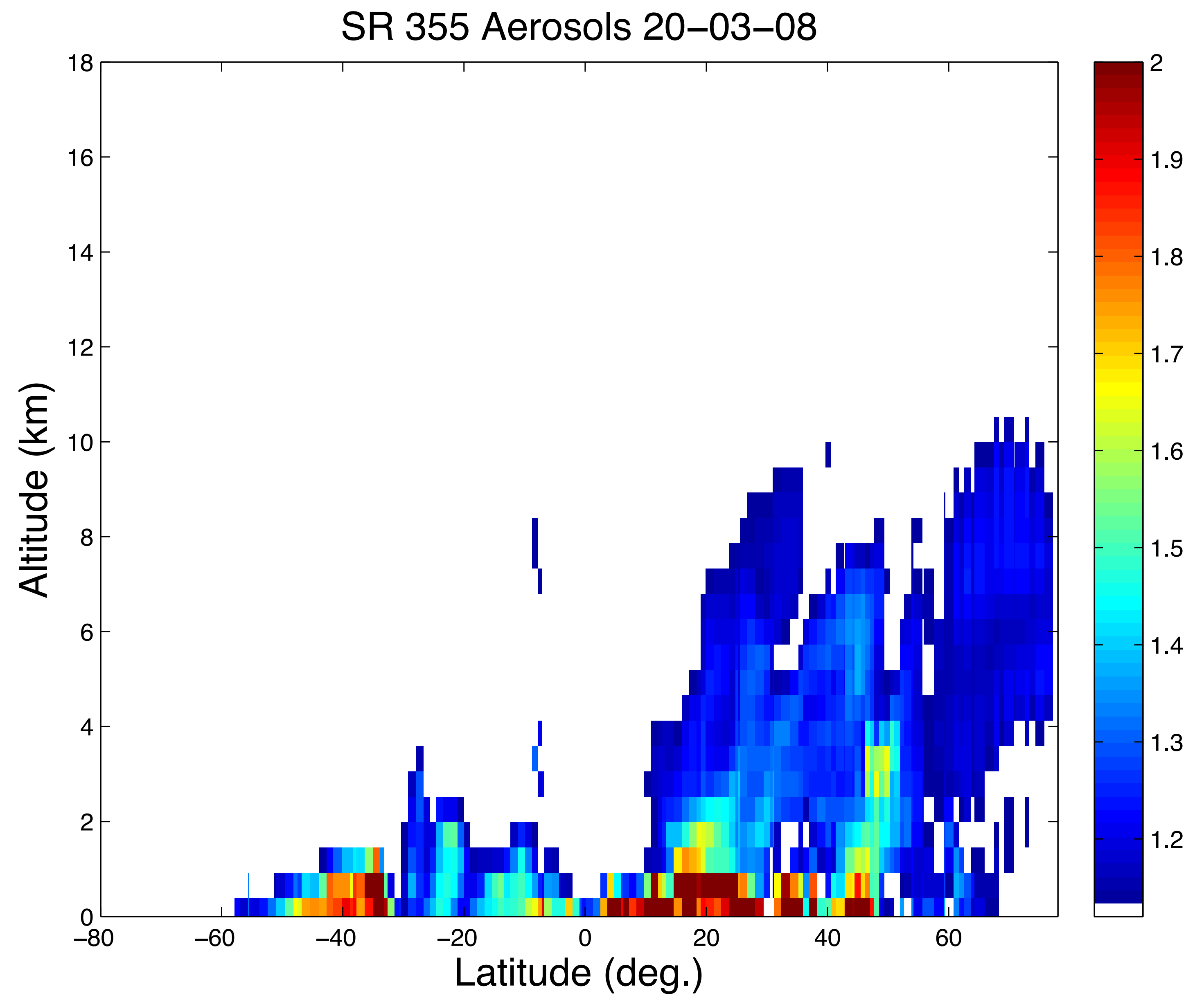



- **ATLID and CALIOP data can be used conjointly for inter annual studies if the SNR is similar in both datasets.**
- *Reverdy et al. 2015* : Hypothesis on the noise standard deviation of ATLID —> threshold of SR>1.84 at 355 nm for cloud detection
- What would be the equivalent for CALIOP? —> SR>5.51 at 532 nm (at the same 480 m vertical resolution)
- **Why a smaller SR threshold at 355 nm than at 532 nm?**
- No molecular absorption at 355 nm and 532 nm (except ozone at 532 nm)
- 5 times stronger molecular (Rayleigh) scattering at 355 nm than at 532 nm
- 5 times more 2-way molecular attenuation at 355 nm than at 532 nm
- Molecular attenuated backscatter ATBmol below 3 km : 2 times larger at 355 nm than at 532 nm
- Contribution of the cloud particles to the ATB : similar at 355 nm and 532 nm
- SR is 5 times lower at 355 nm than 532 nm.
- Thus the SR threshold to detect a cloud is 5 times lower at 355 nm than 532 nm

# Defining an aerosol detectability threshold for ATLID consistent with the CALIOP threshold

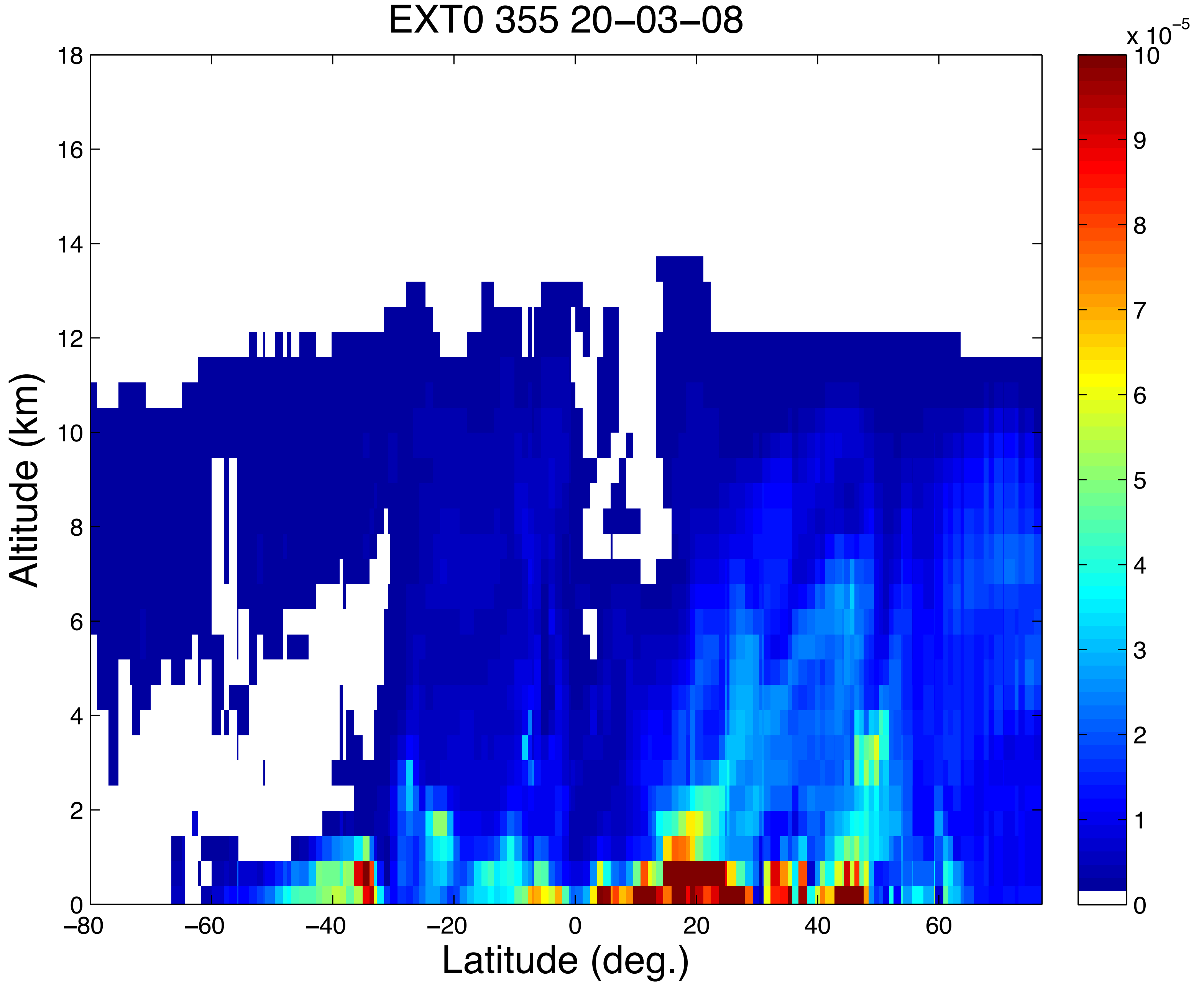


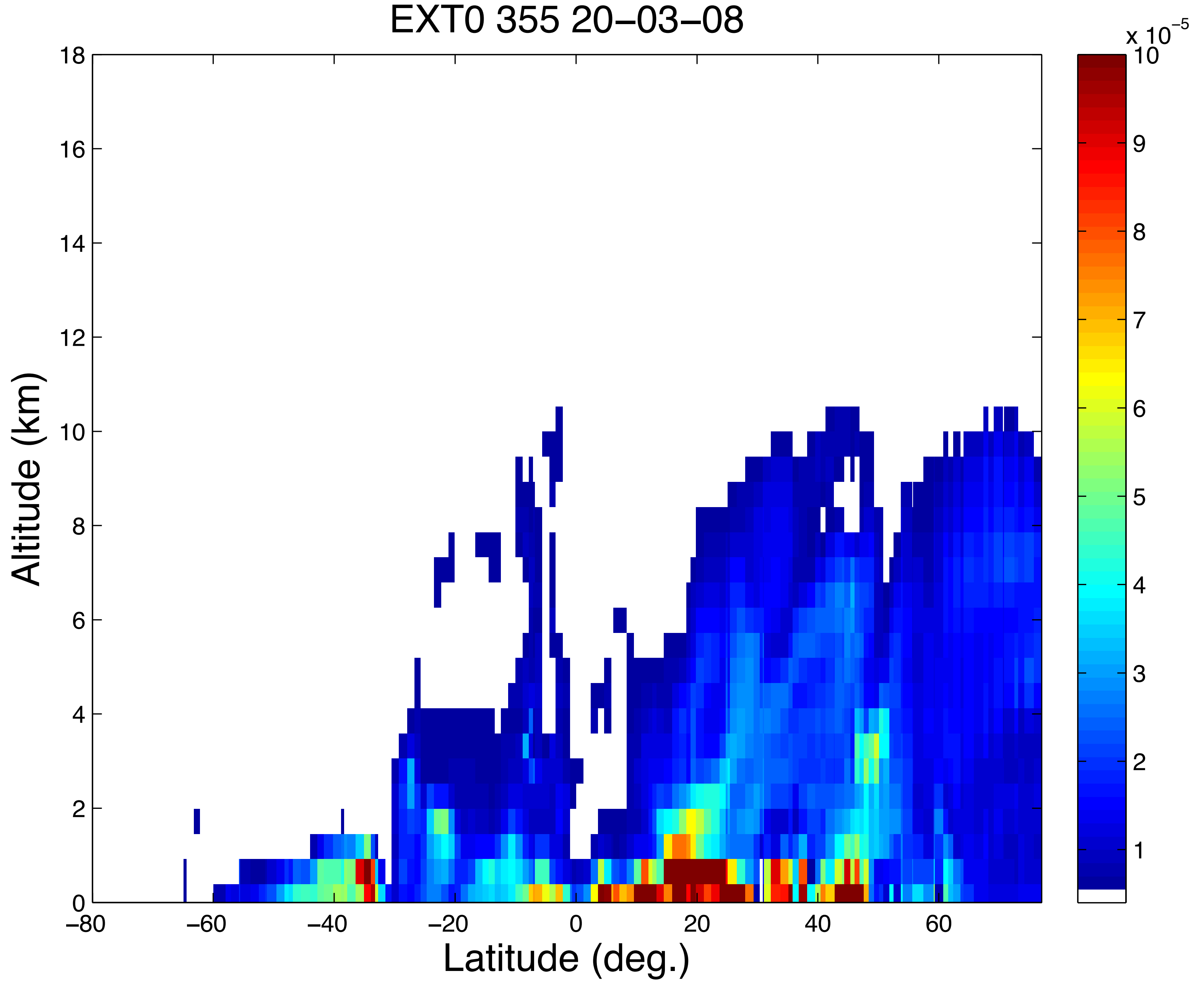

- **We make the assumption that the SNR is the same in both instruments**
- We seek for a SR threshold that allows to detect the same amount of aerosols at 532 nm and 355 nm
- We find SR>1.42 at 532 nm; SR>1.12 at 355 nm (for the same resolution)
- **Why a slightly lower threshold at 355 nm than at 532 nm?**
- Molecular attenuated backscatter ATBmol below 3 km : 2 times larger at 355 nm than at 532 nm
- Contribution of the aerosol particles to the ATB : generally larger at 355 nm than at 532 nm
- Thus the two aerosol SR thresholds are closer to each other than the cloud SR thresholds

## Aerosol extinction profiles with different hypotheses on the detection threshold

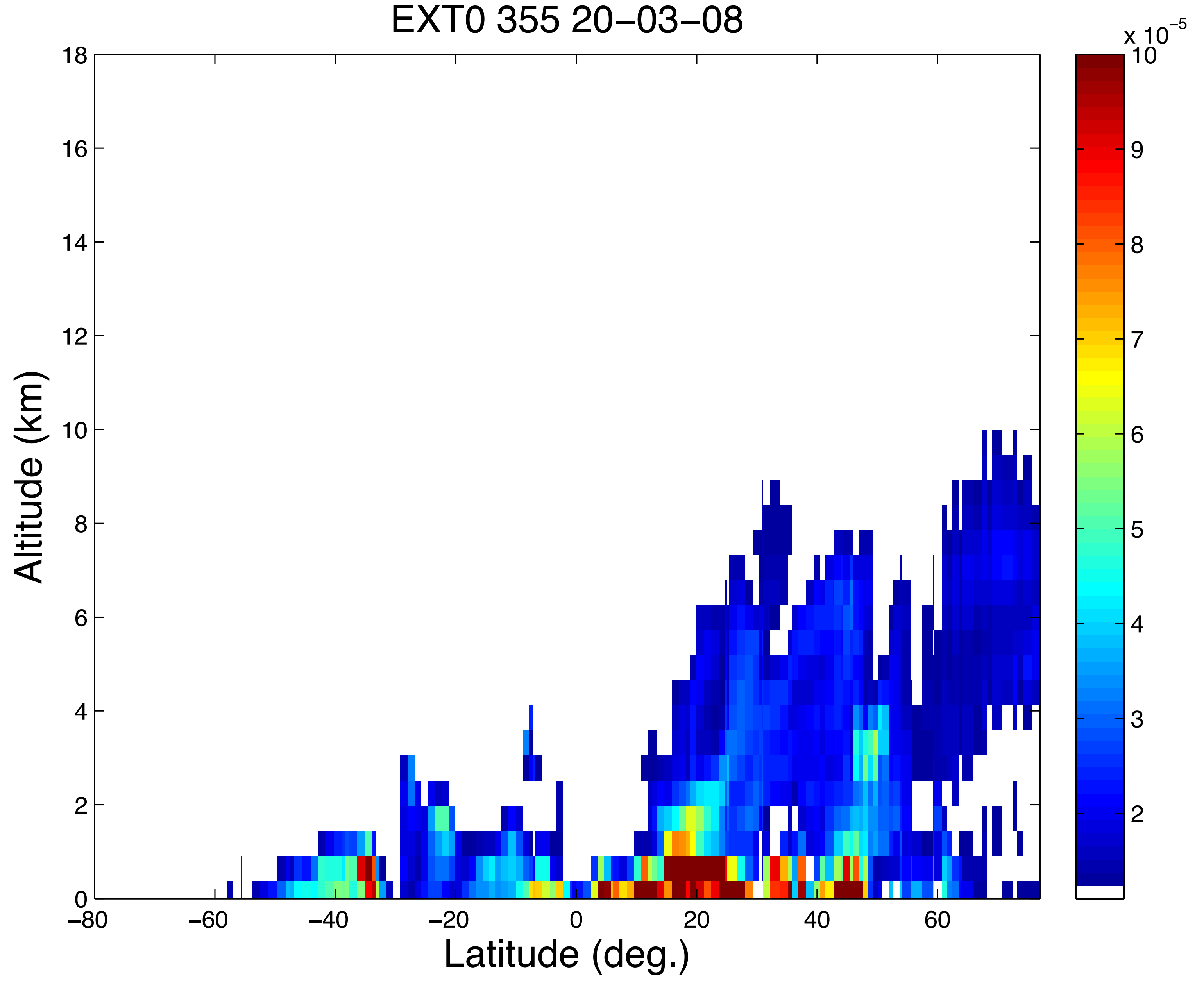
- ATLID is a HSRL : Can retrieve aerosols extinction and backscatter profiles
- What would be the threshold on the aerosol extinction coefficient to retrieve the same amount of aerosol than in CALIOP?
- EXT>1.1e-5 $m^{-1}$ (depends on the resolution)
- Which aerosols could we retrieve if the ATLID SNR was better than for CALIOP?




Perfect instrument :
Aerosol extinction threshold : EXT>0




Intermediate instrument :
Aerosol extinction threshold : EXT> 0.4e-5$m^{-1}$




CALIOP instrument :
Aerosol extinction threshold : EXT> 1.1e-5$m^{-1}$