



*Supplement of*

## **Validation of the Sentinel-5 Precursor TROPOMI cloud data with Cloudnet, Aura OMI O<sub>2</sub>–O<sub>2</sub>, MODIS, and Suomi-NPP VIIRS**

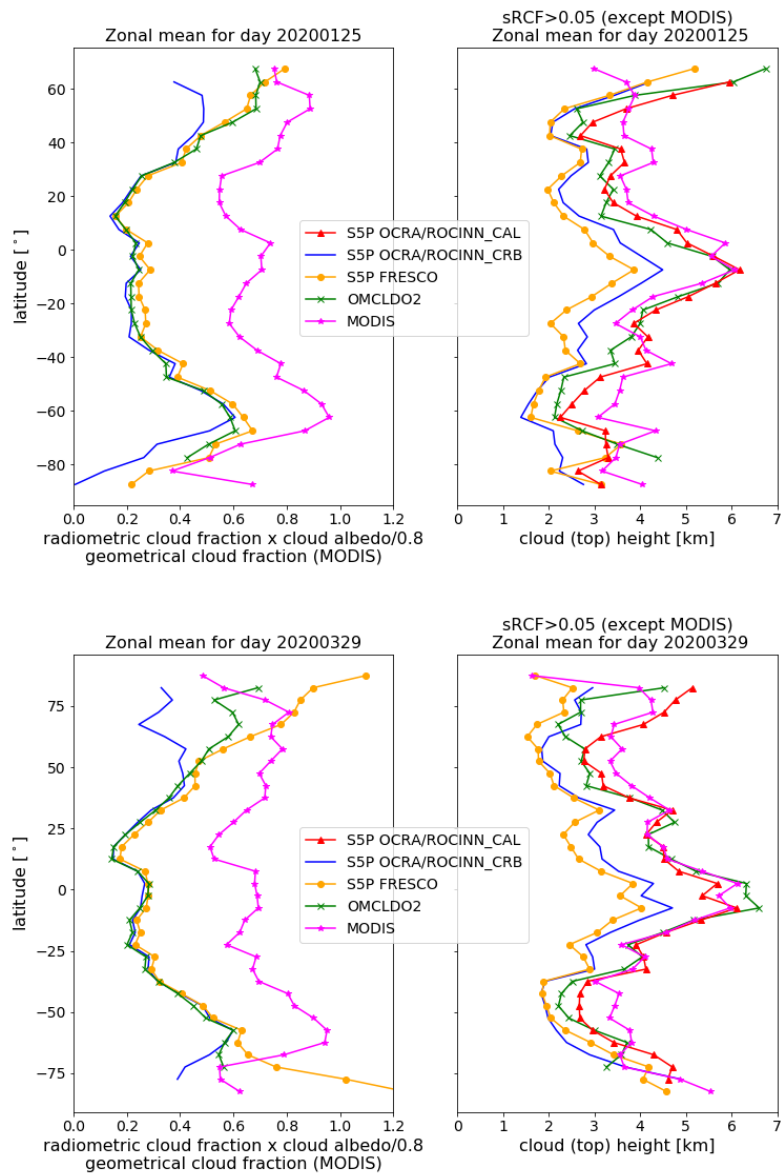
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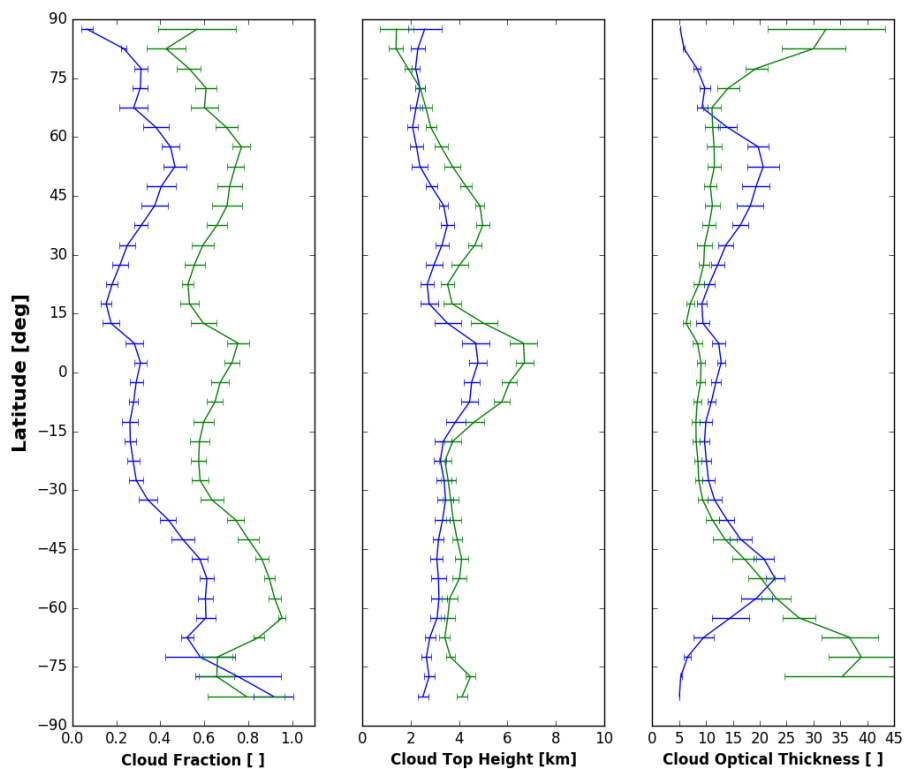
## S1 Comparison of zonal means: supplementary material

This section contains supplementary material for Sect. 4.1.



**Figure S1.** Similar as 4, but for days 2020-01-25 and 2020-03-29.

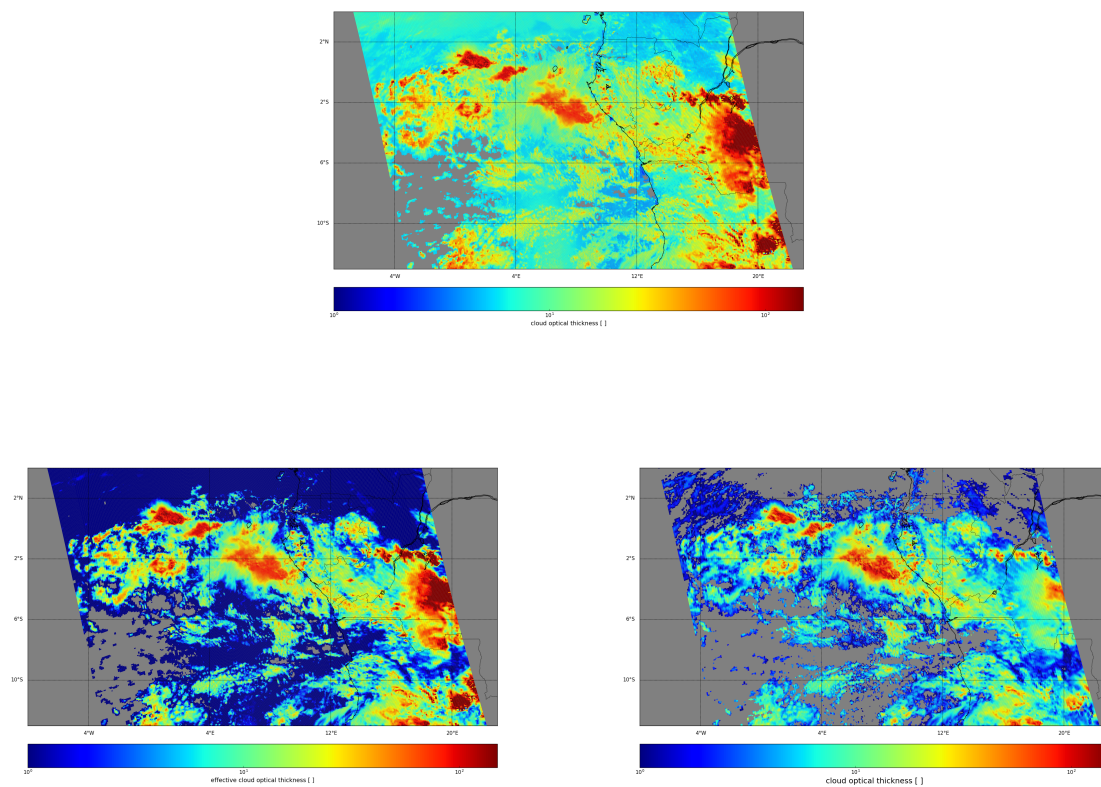
Period: Apr. 2018, Number of days: 30



**Figure S2.** Zonal means for S5P OCRA/ROCINN\_CAL version 1 (blue) and MODIS (green). The comparison refers to data from April 2018 (MODIS cloud fraction is a geometrical cloud fraction whereas the S5P OCRA cloud fraction is a radiometric one).

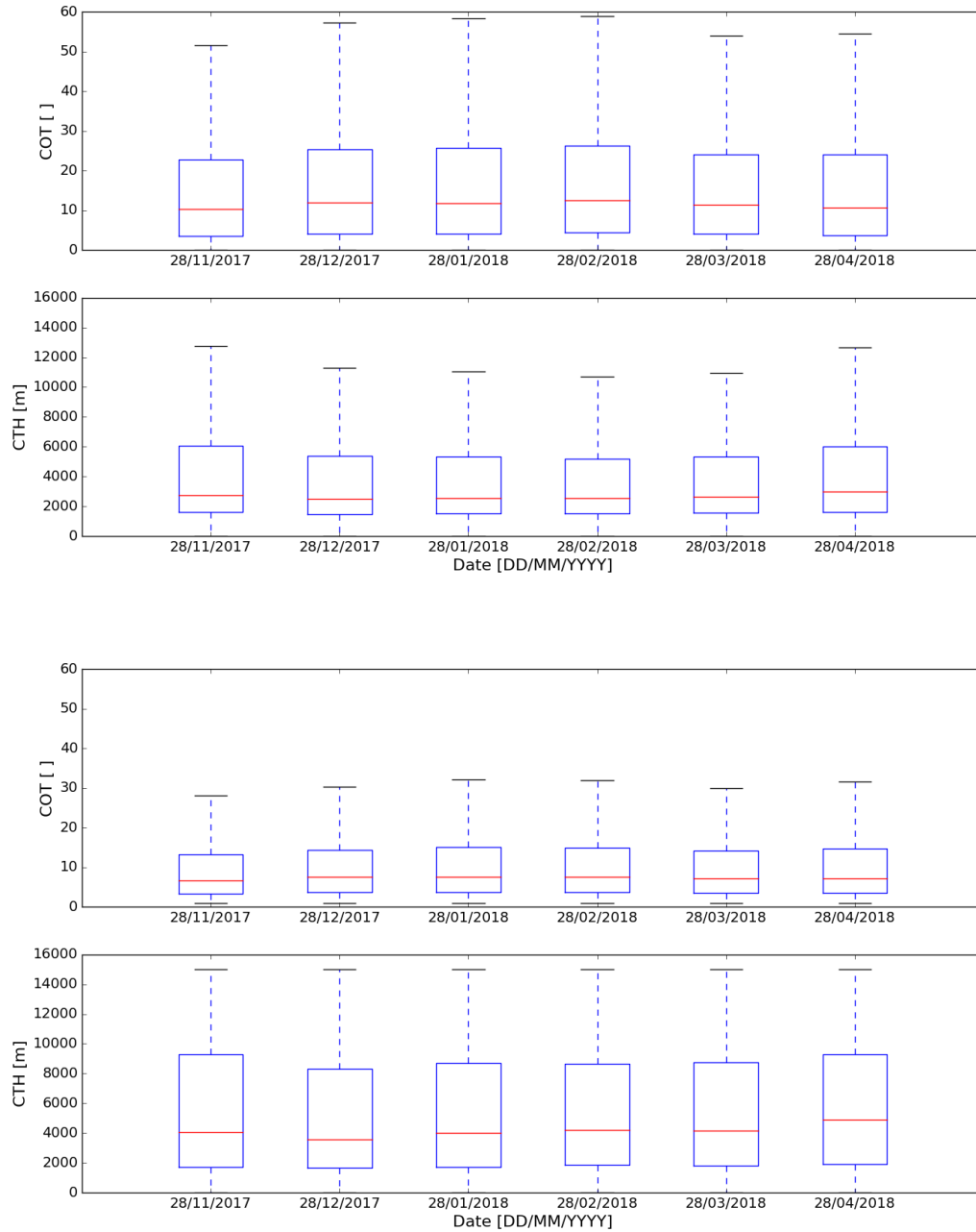
## S2 Comparison between S5P OCRA/ROCINN\_CAL and NPP VIIRS: supplementary material

This section contains extra material for Sect. 4.3.

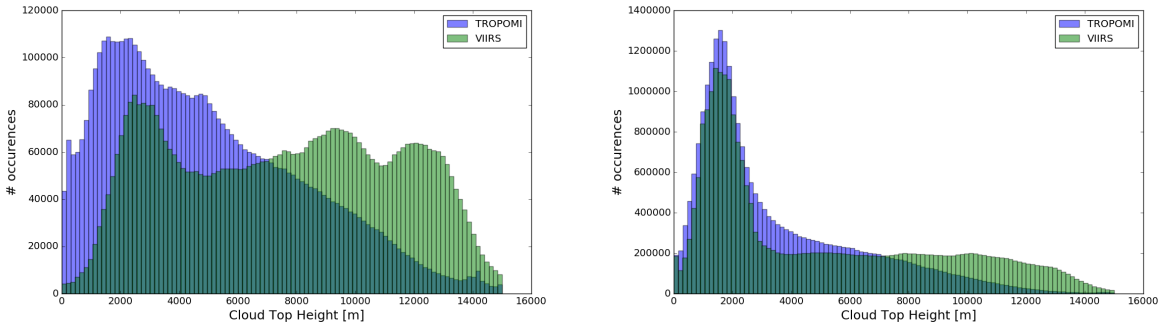


**Figure S3.** Top: S5P OCRA/ROCINN\_CAL version 1 retrieved COT. Bottom left: S5P OCRA/ROCINN\_CAL effective COT (=RCFxCOT). Bottom right: VIIRS COT. A part of orbit 1080 is displayed. Note that TROPOMI's effective COT is more comparable to VIIRS COT than TROPOMI's original COT.

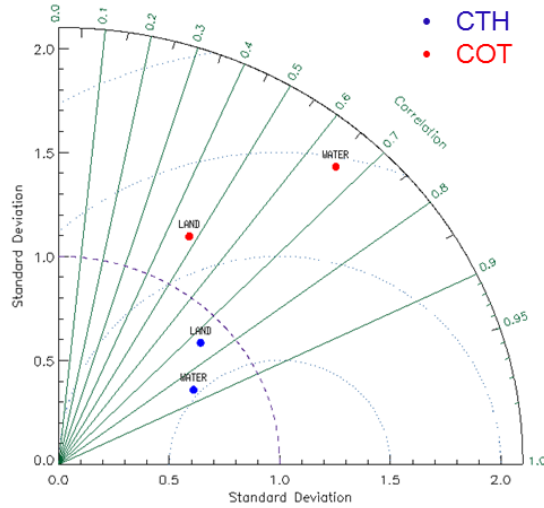




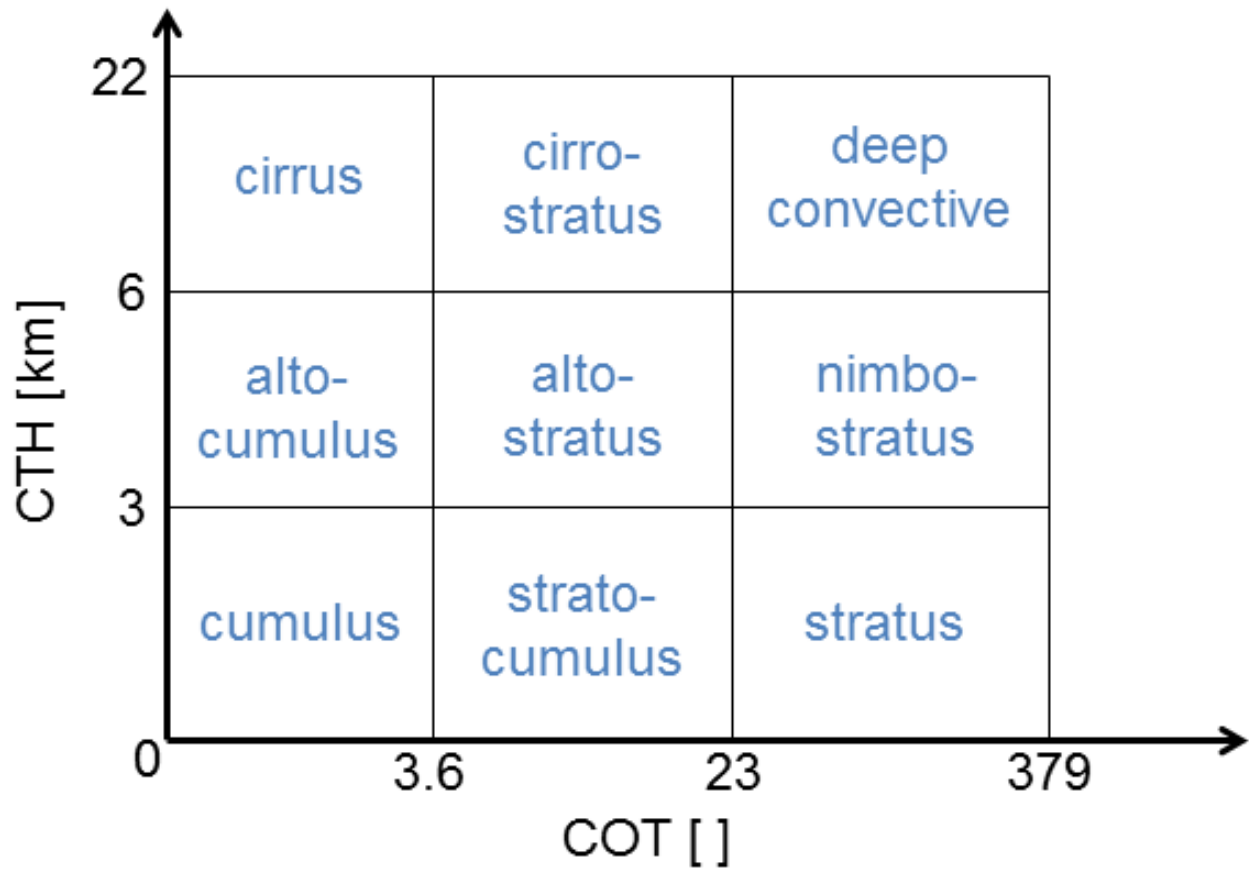
**Figure S4.** Box plots for the COT and CTH of S5P OCRA/ROCINN\_CAL version 1 (top) and re-gridded NASA VIIRS (bottom). The dataset consists of orbits from 6 complete days. Note that for S5P COT the effective COT is shown (=original COT x CRF).



**Figure S5.** Histograms of the CTH for S5P OCRA/ROCINN\_CAL version 1 and VIIRS. (a) Only clouds over land are considered. For S5P OCRA/ROCINN\_CAL mean and standard deviation is  $5.0 \pm 3.3$  km and for VIIRS it is  $7.5 \pm 3.8$  km. (b) Only clouds over water are considered: For S5P OCRA/ROCINN\_CAL mean and standard deviation is  $3.5 \pm 2.8$  km and for VIIRS it is  $4.9 \pm 4.0$  km.



**Figure S6.** Taylor diagram for CTH and COT, of S5P OCRA/ROCINN\_CAL version 1 vs. VIIRS. The complete dataset of 6 days is considered. Note that for TROPOMI COT an effective COT is used (=original COT x CRF).



**Figure S7.** Schematic representation of the ISCCP classification based on CTH and COT ranges.

### S3 Comparison of S5P cloud height with Cloudnet: supplementary material

This section contains extra material for Sect. 4.4.

#### S3.1 Satellite vs Cloudnet comparison pairs, ordered along Cloudnet CTH

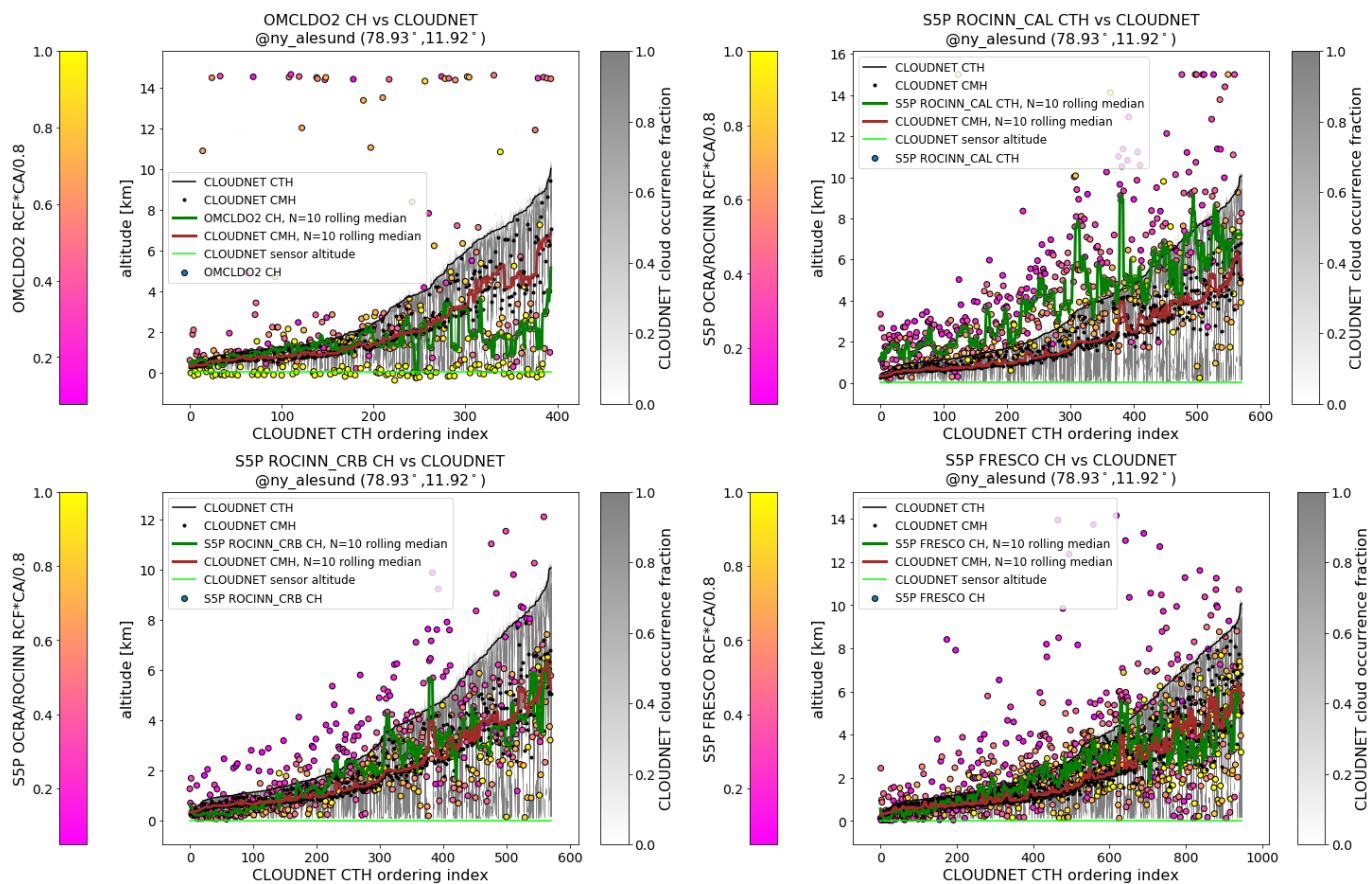
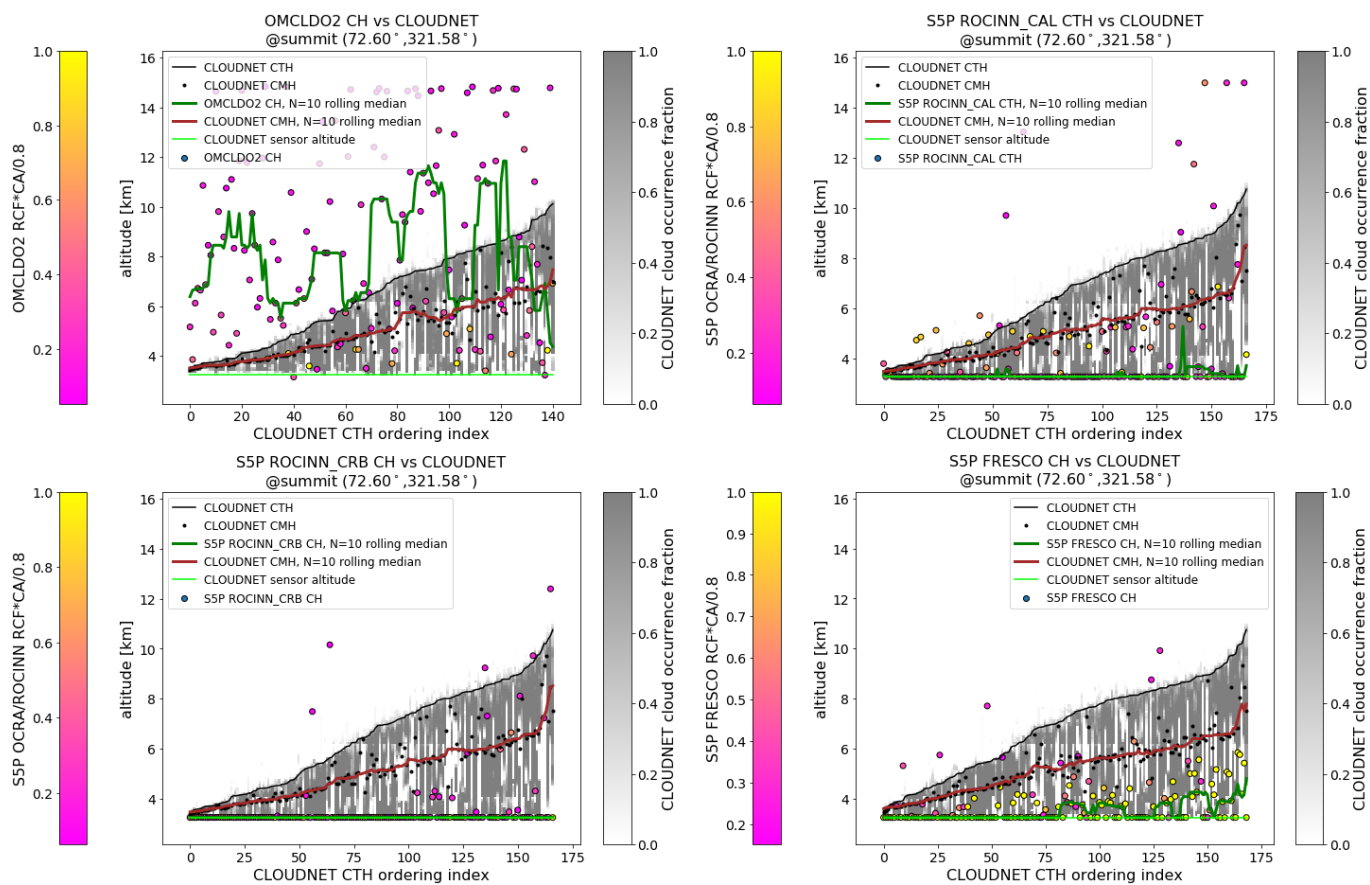
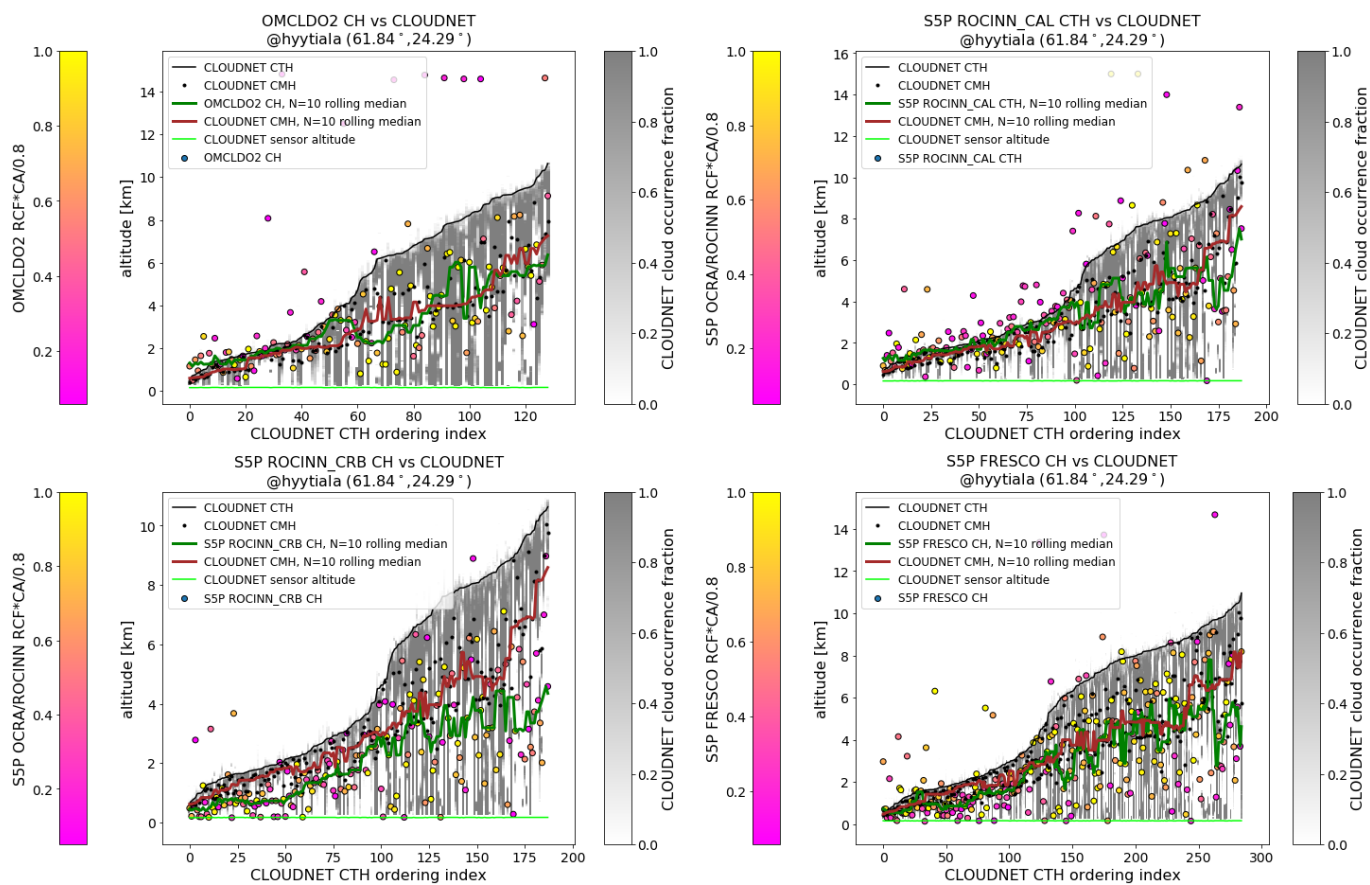


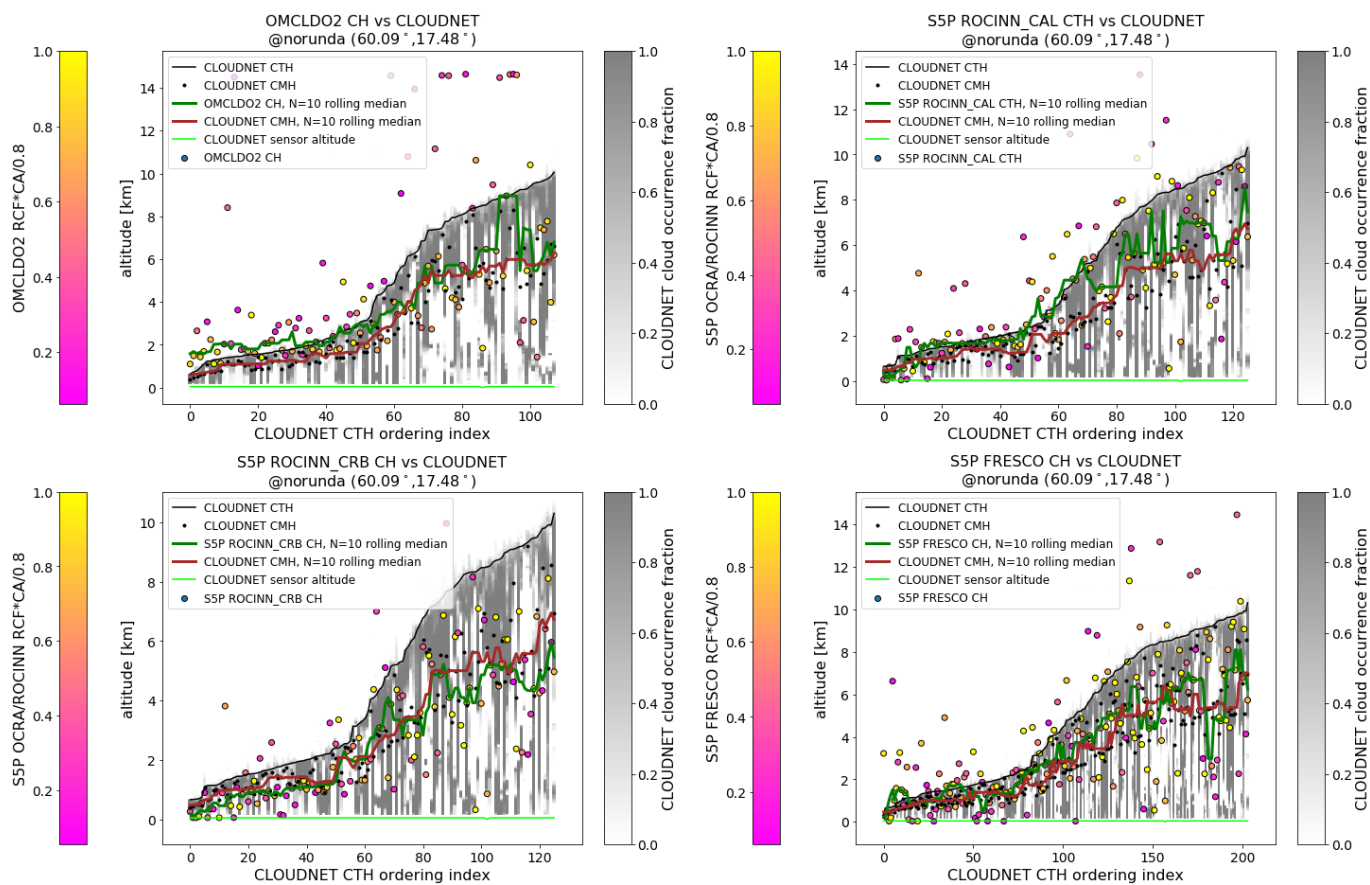
Figure S8. Same as Fig. 8, but for the site Ny-Alesund.



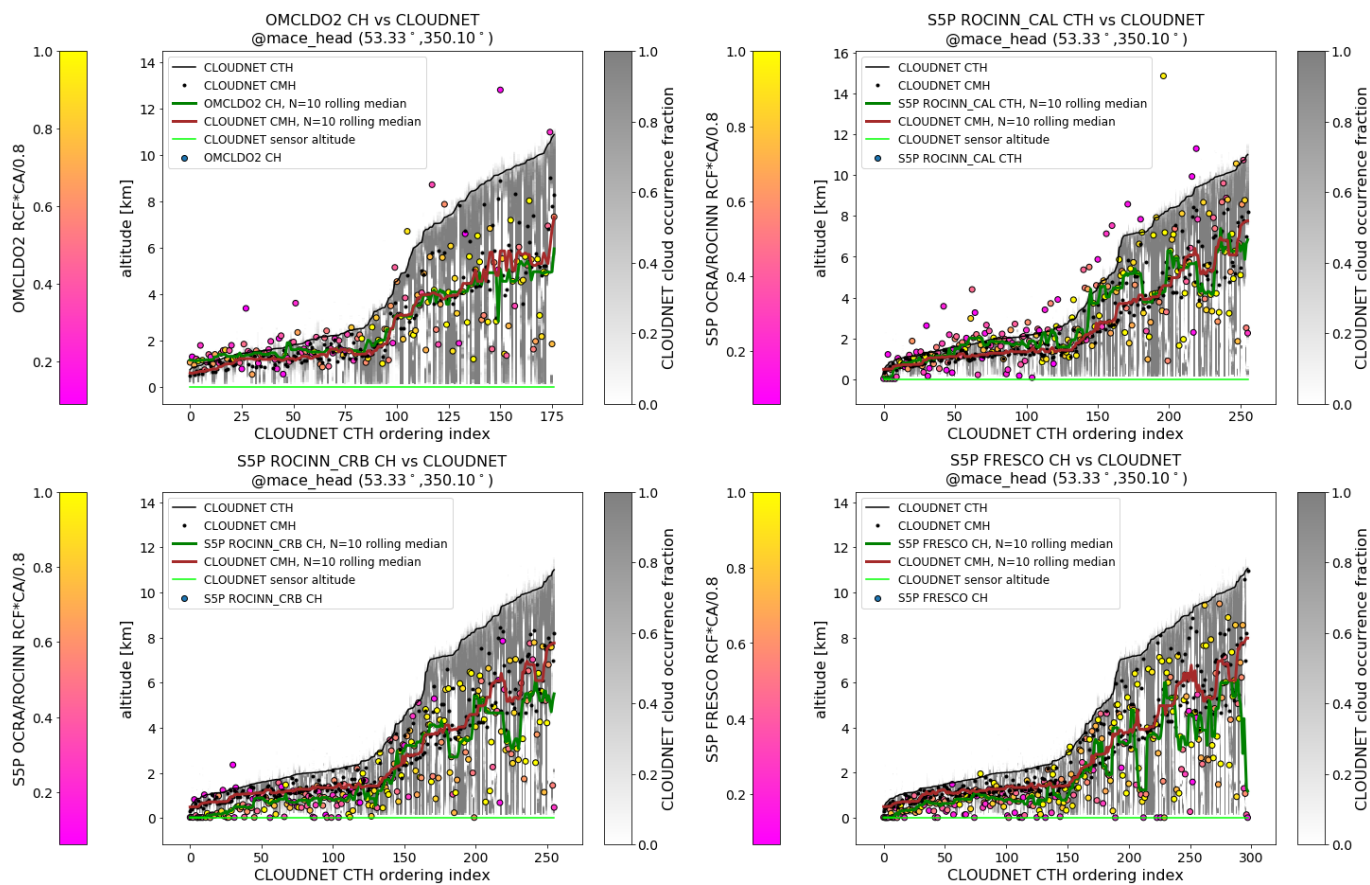
**Figure S9.** Same as Fig. 8, but for the site Summit.



**Figure S10.** Same as Fig. 8, but for the site Hyytiälä.

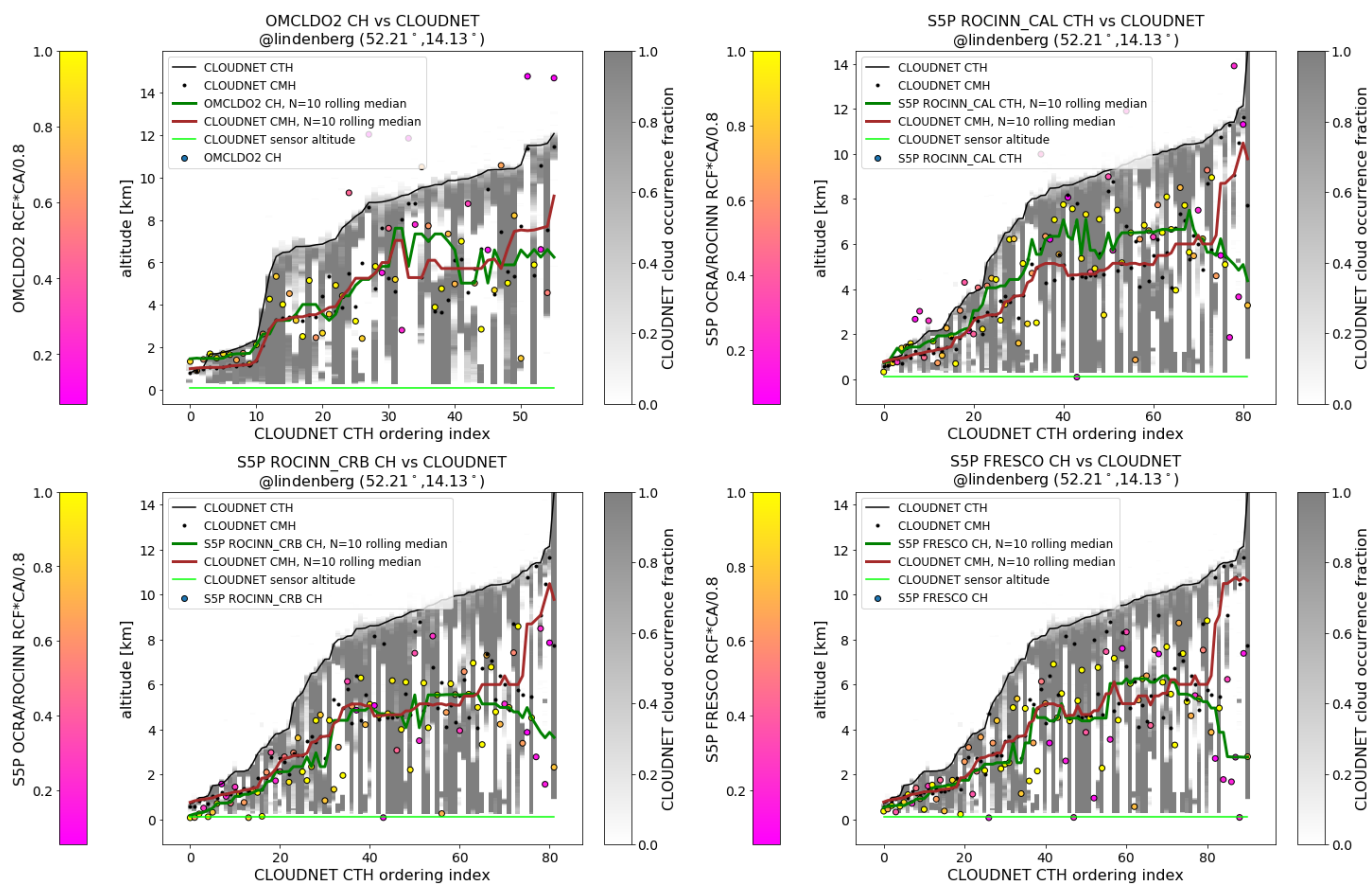


**Figure S11.** Same as Fig. 8, but for the site Norunda.

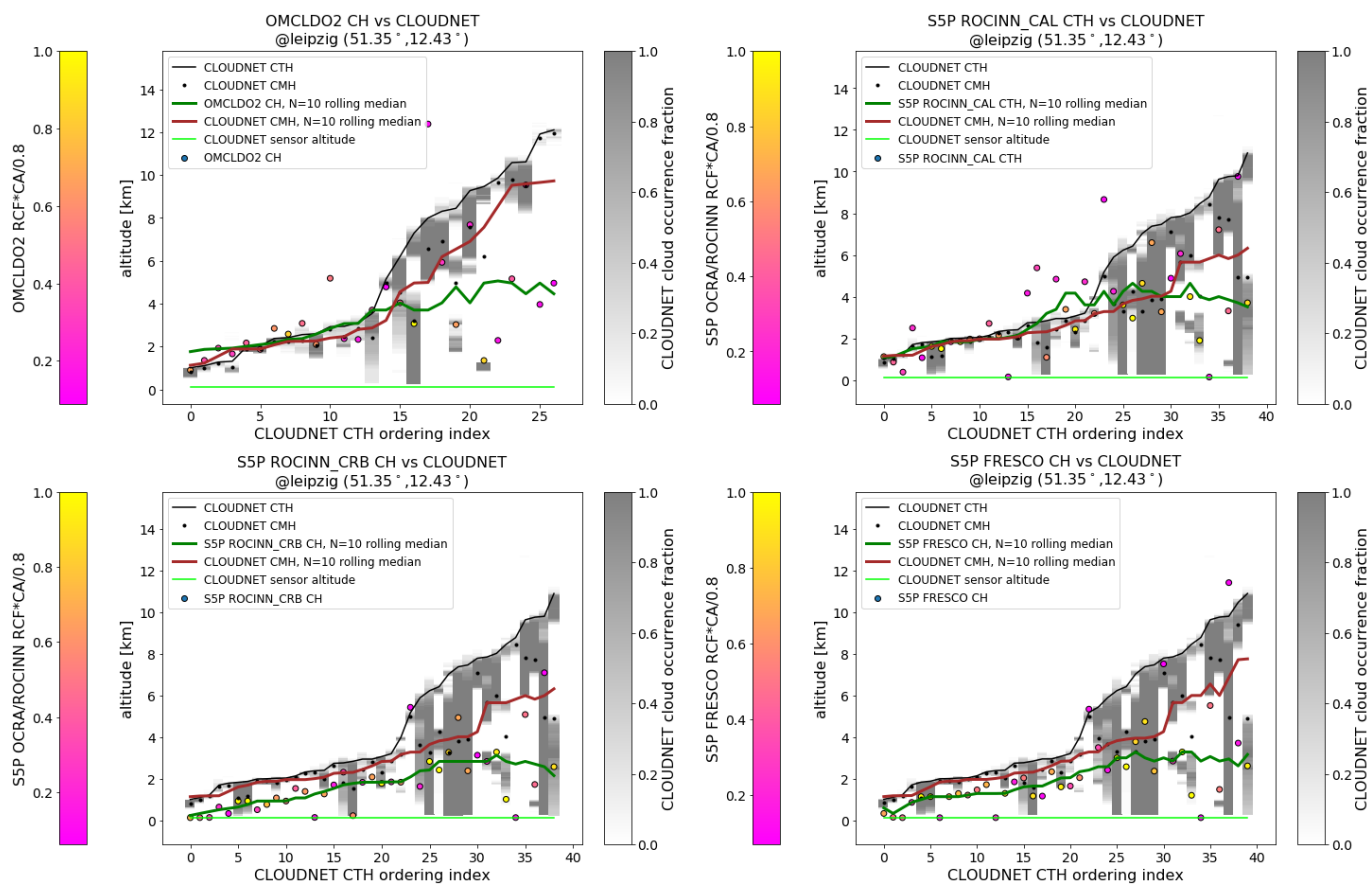


**Figure S12.** Same as Fig. 8, but for the site Mace Head.

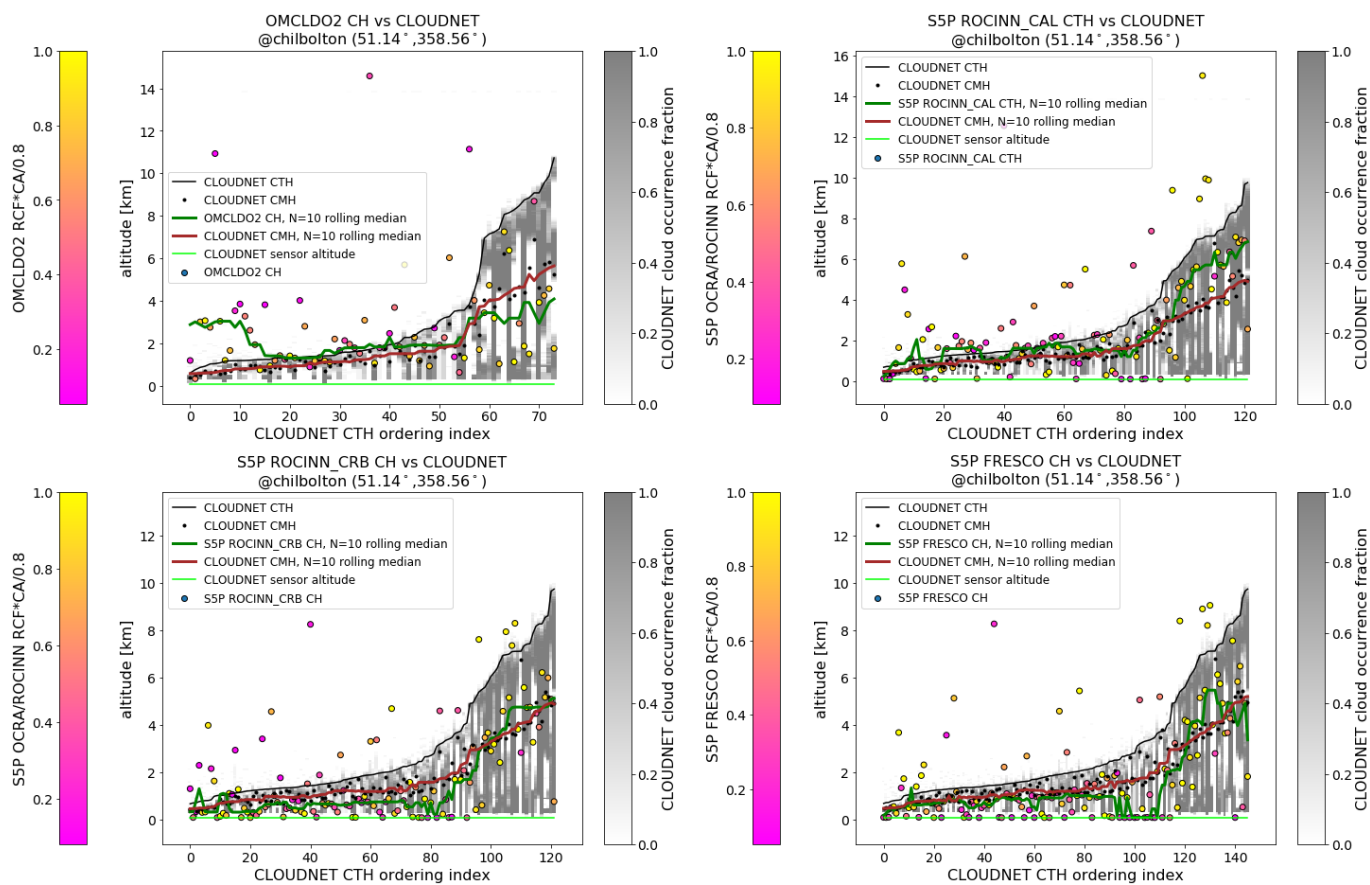




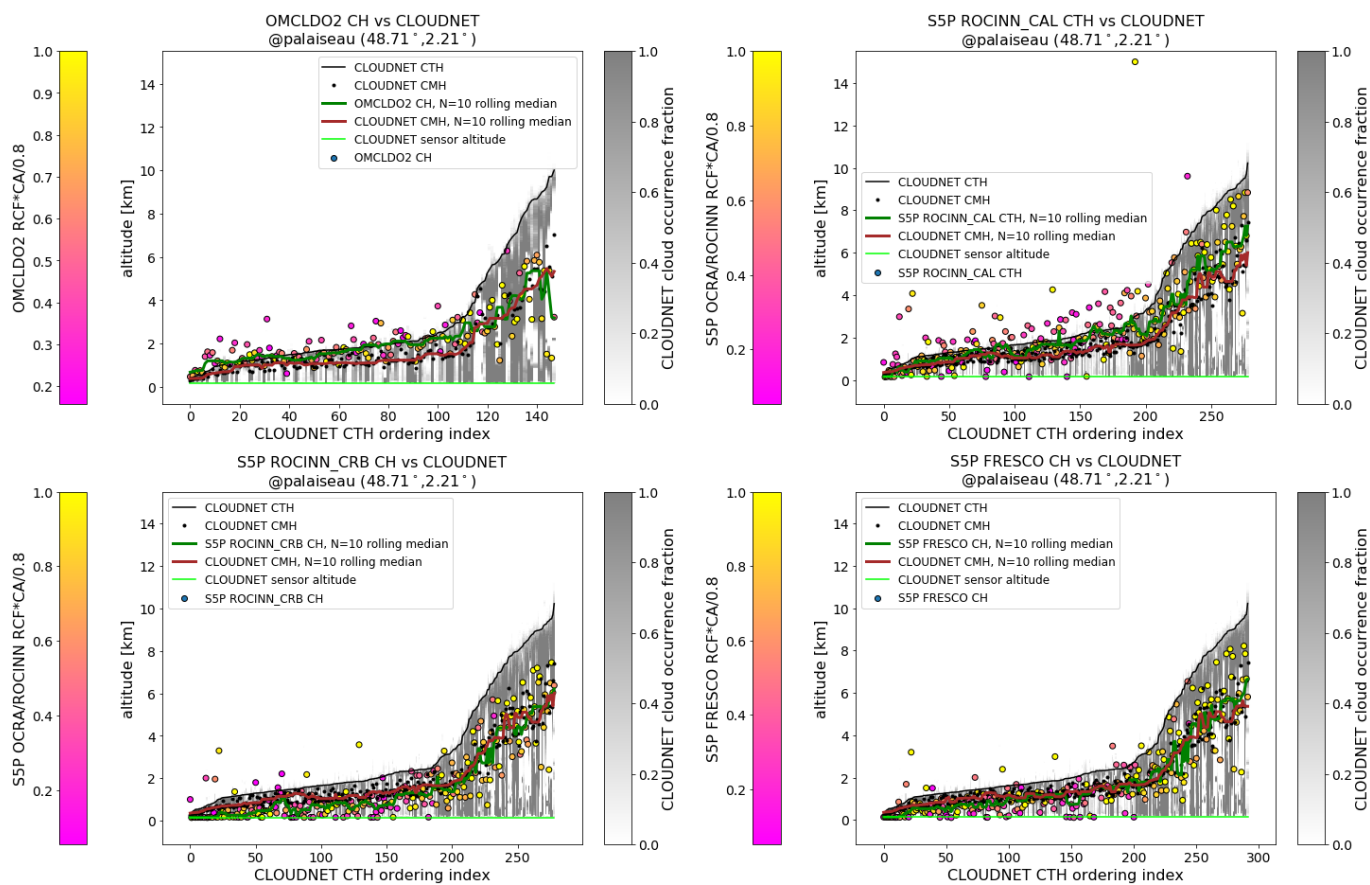
**Figure S13.** Same as Fig. 8, but for the site Lindenbergl.



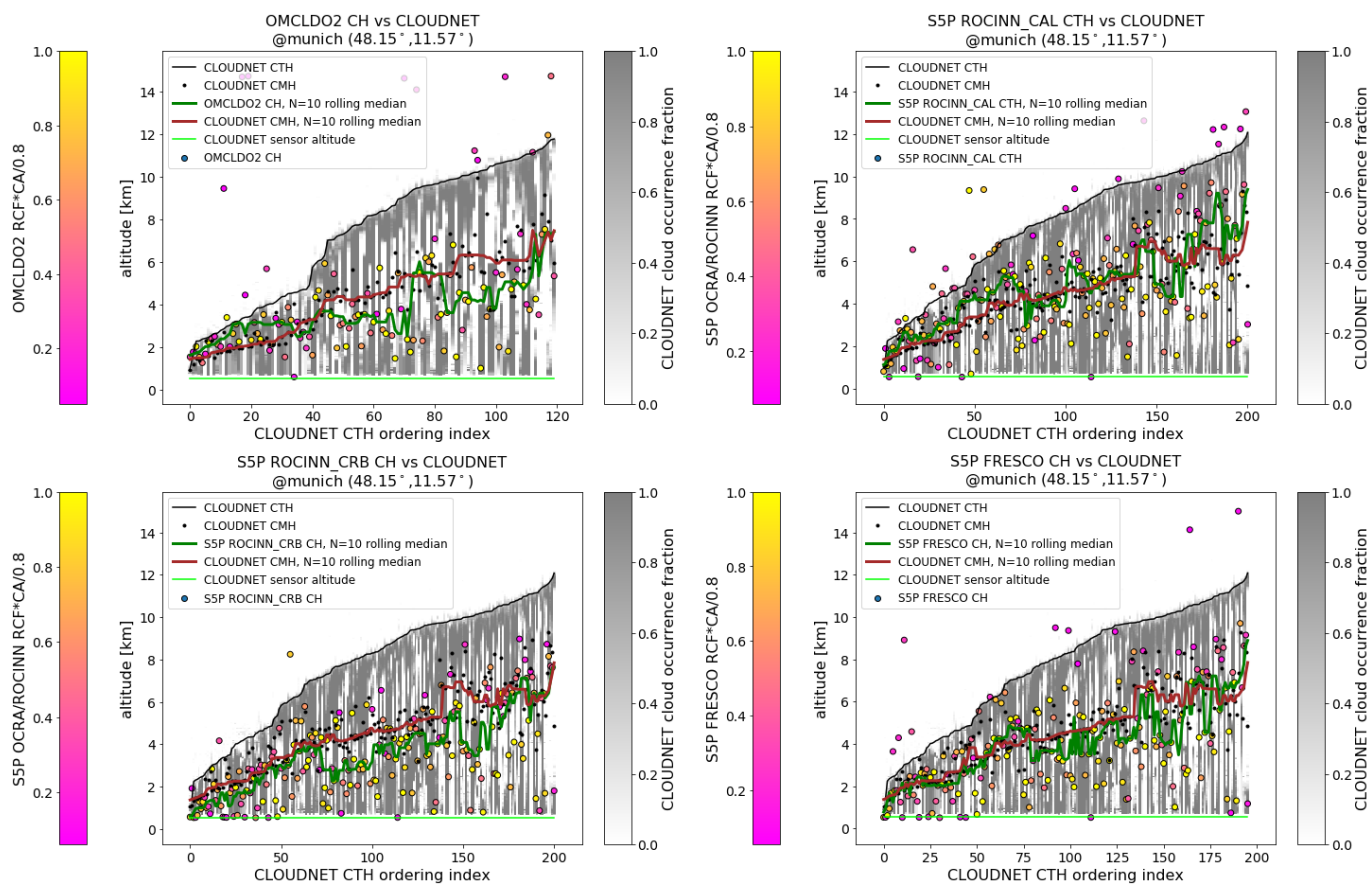
**Figure S14.** Same as Fig. 8, but for the site Leipzig.



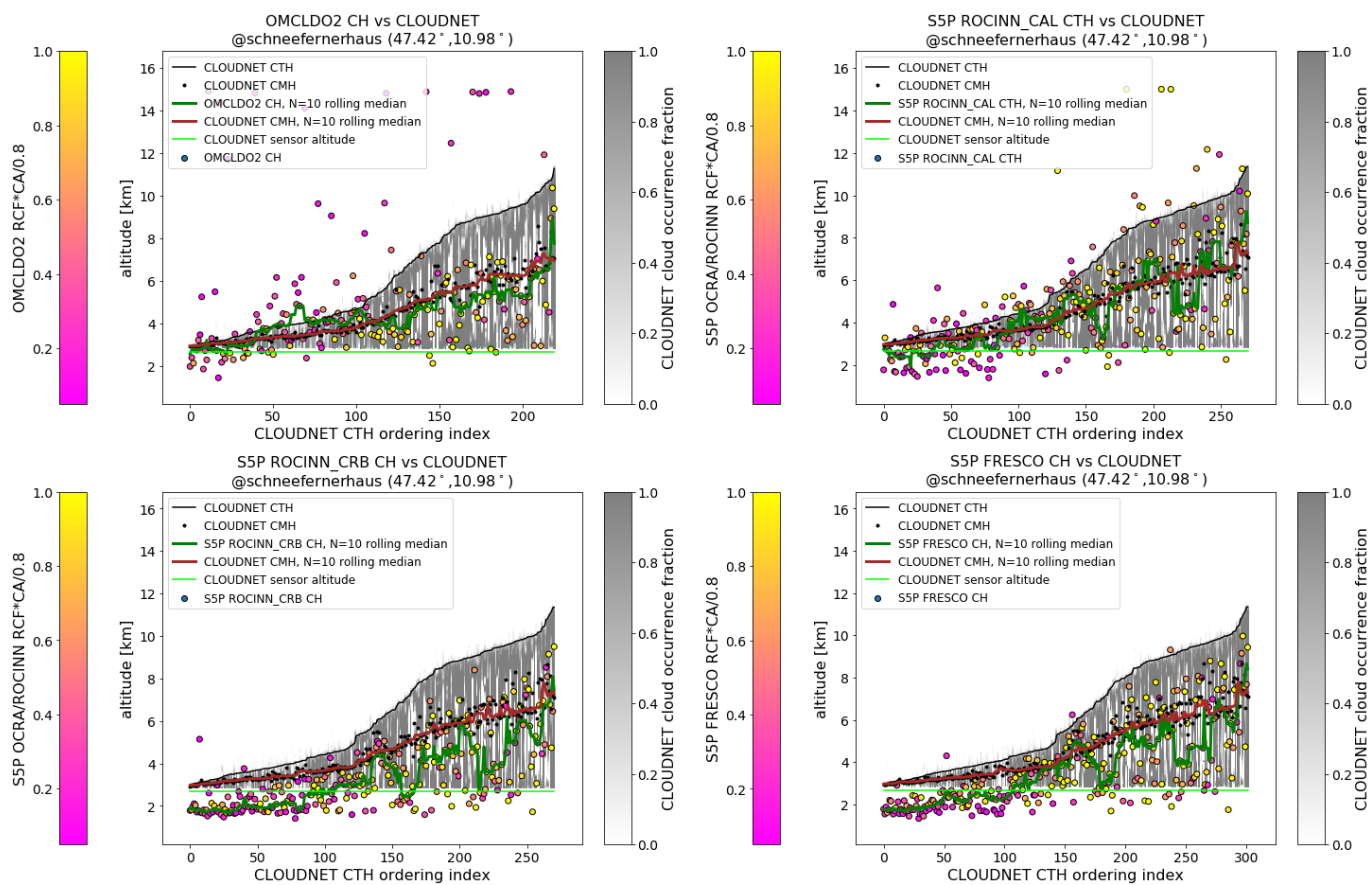
**Figure S15.** Same as Fig. 8, but for the site Chilbolton.



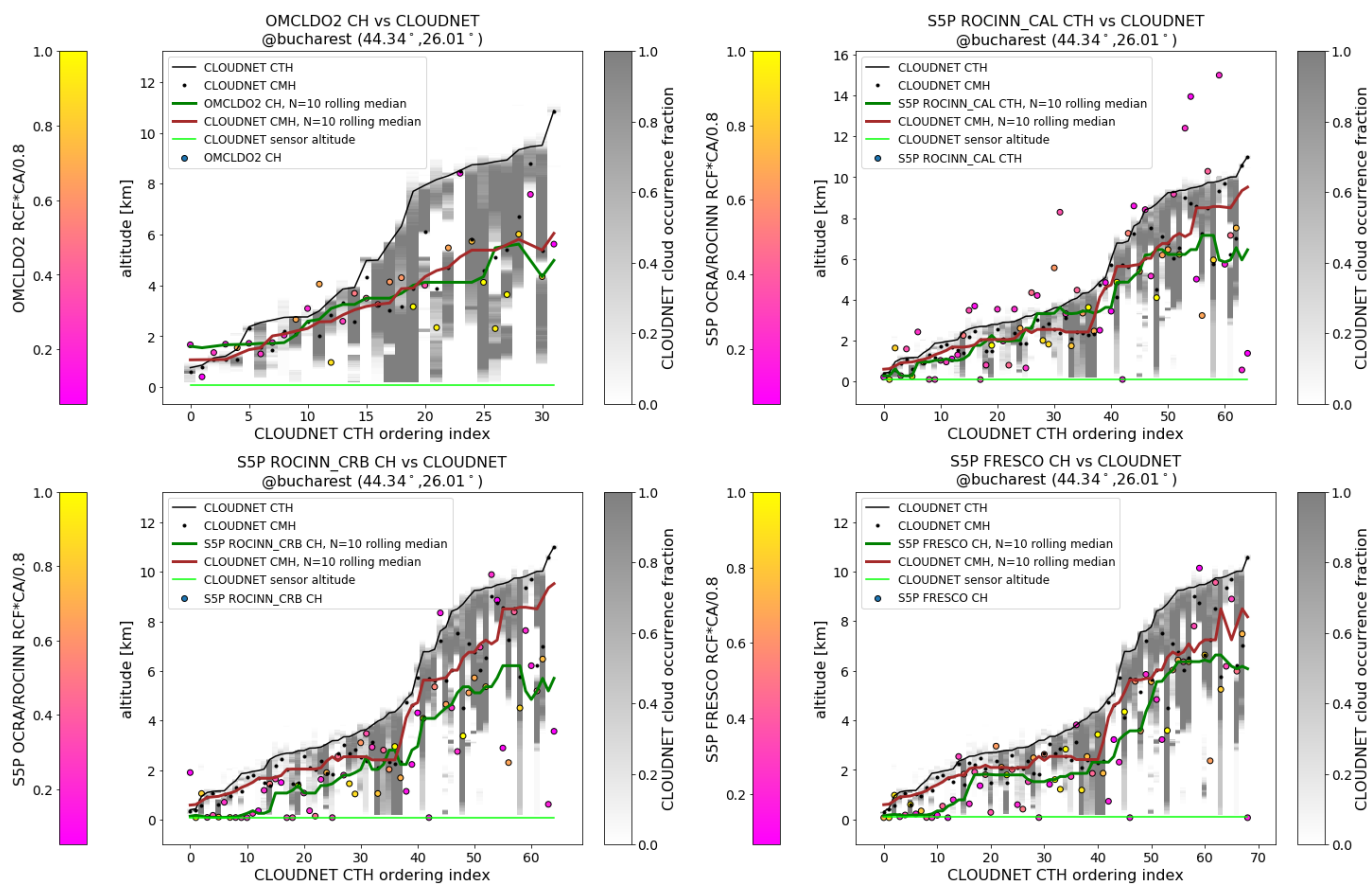
**Figure S16.** Same as Fig. 8, but for the site Palaiseau.



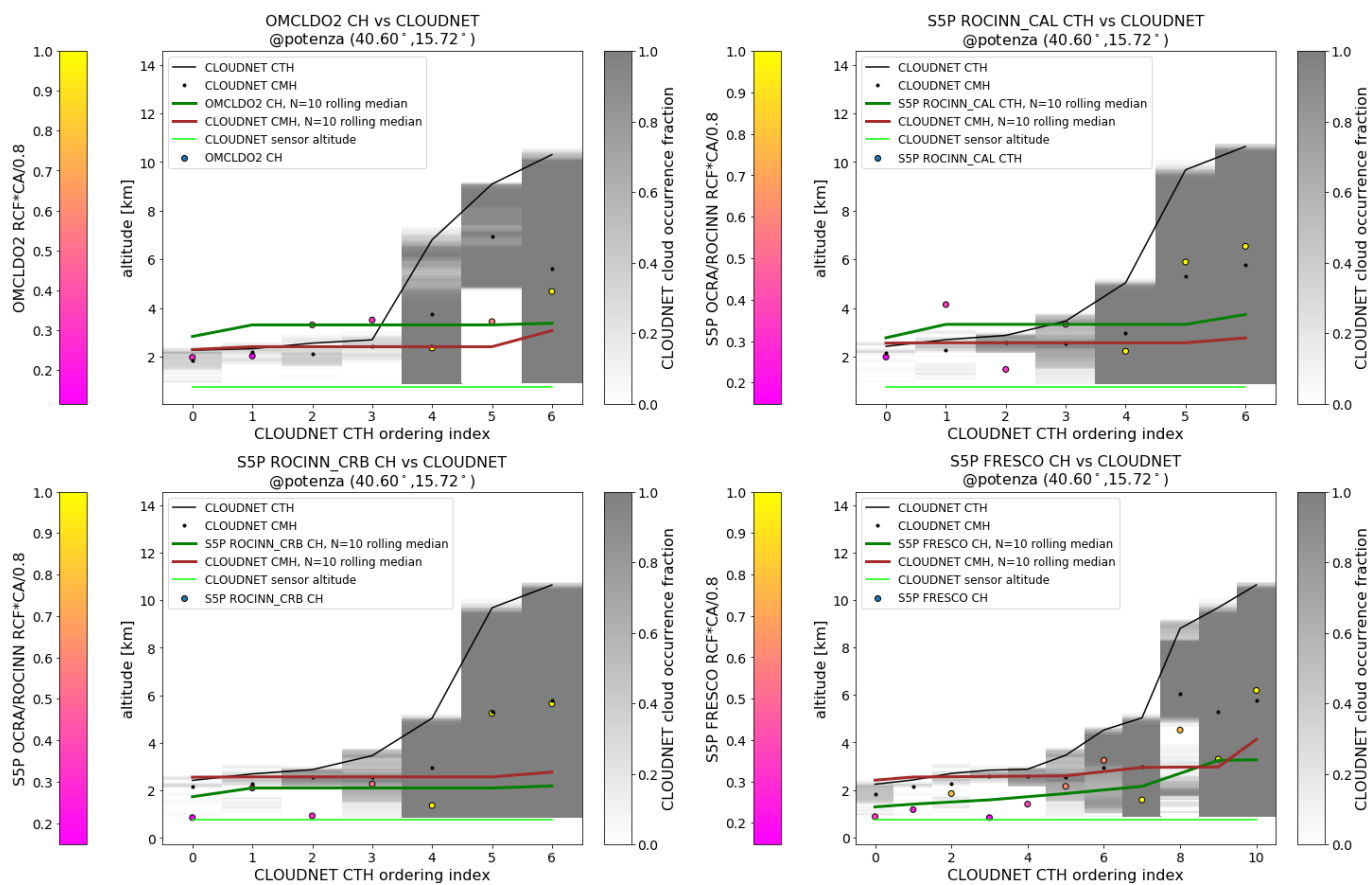
**Figure S17.** Same as Fig. 8, but for the site Munich.



**Figure S18.** Same as Fig. 8, but for the site Schneefernerhaus.

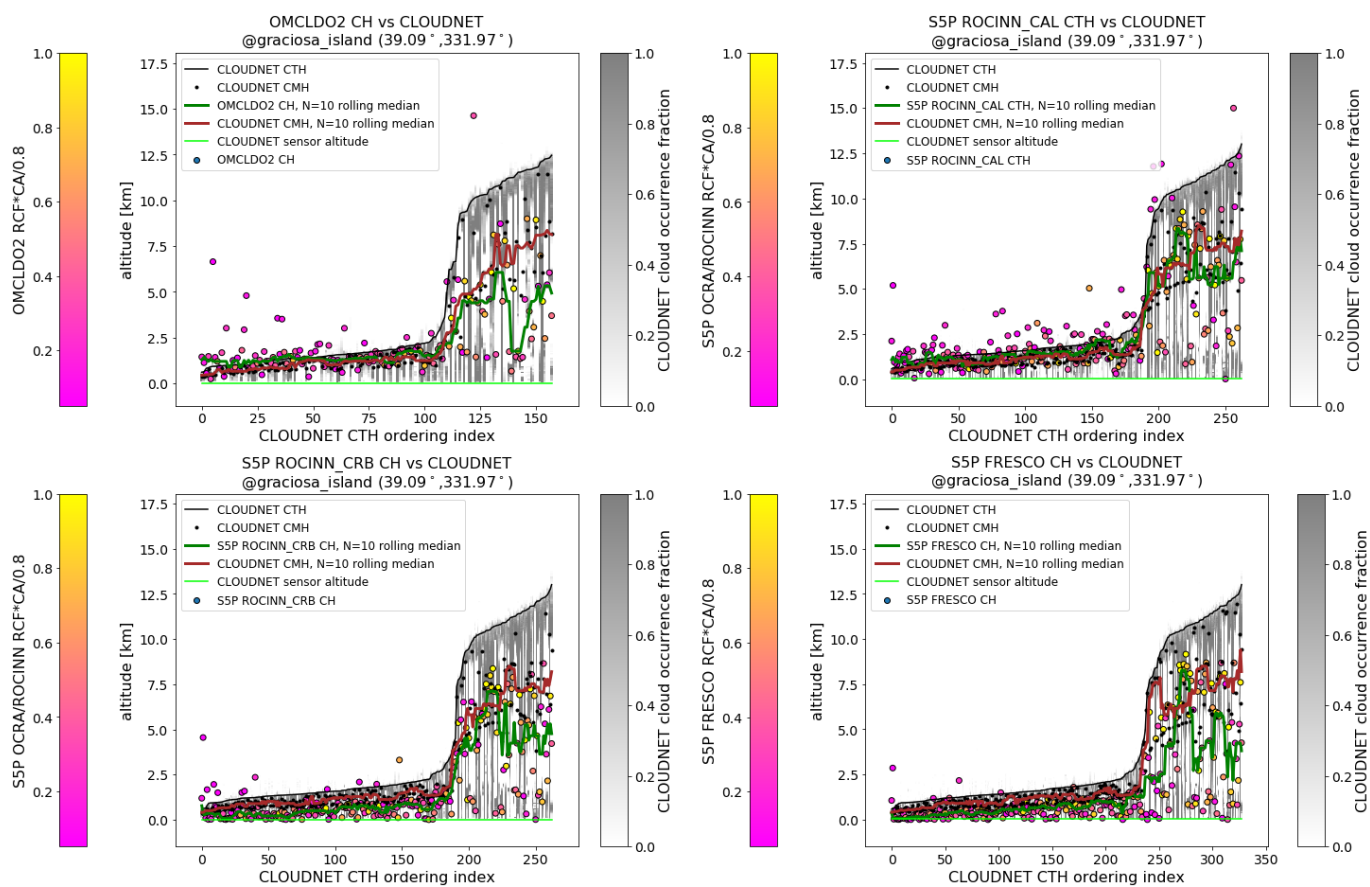


**Figure S19.** Same as Fig. 8, but for the site Bucharest.

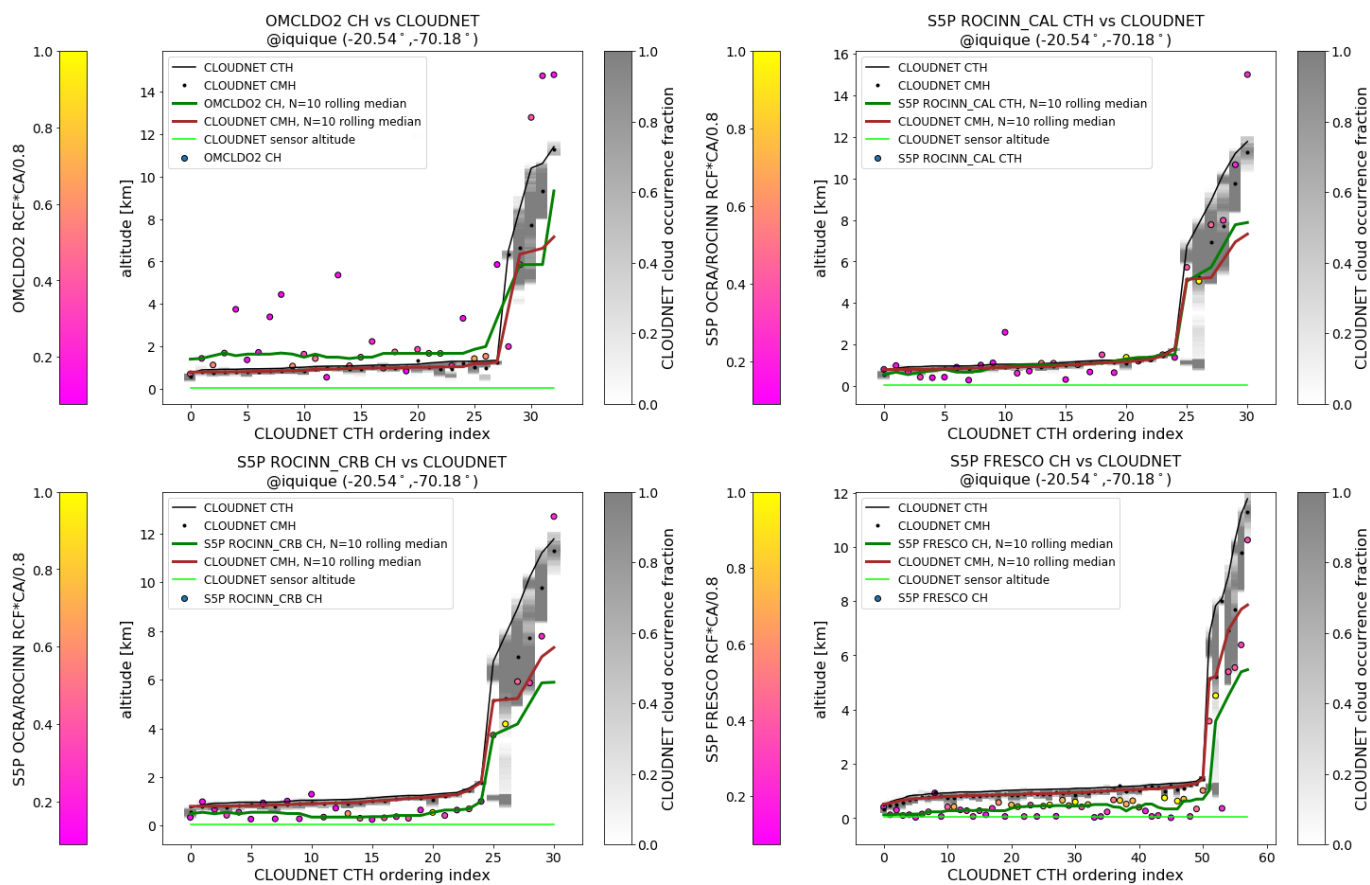


**Figure S20.** Same as Fig. 8, but for the site Potenza.

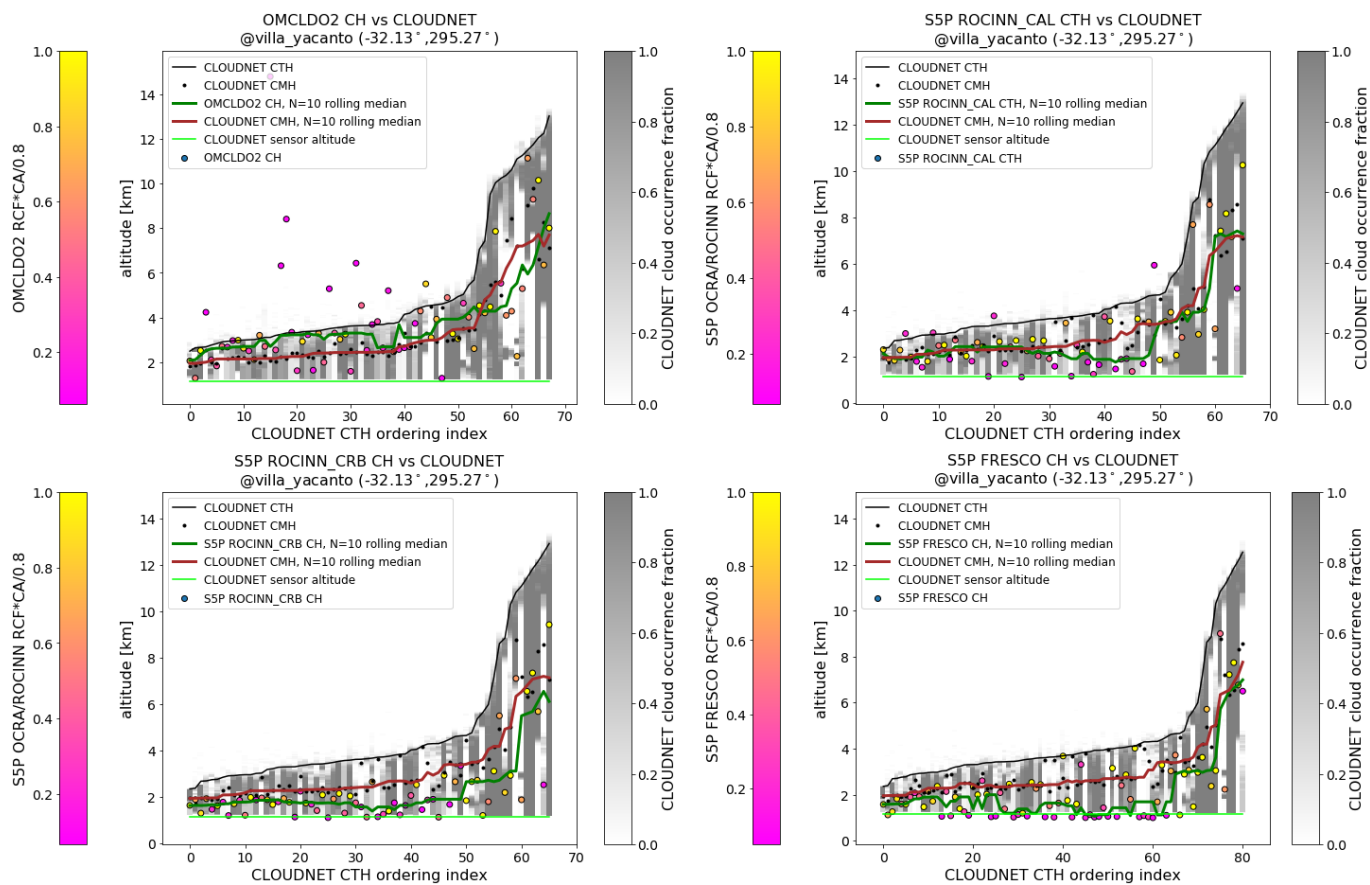




**Figure S21.** Same as Fig. 8, but for the site Graciosa island.



**Figure S22.** Same as Fig. 8, but for the site Iquique.



**Figure S23.** Same as Fig. 8, but for the site Villa Yacanto.

### **S3.2 Satellite vs Cloudnet CTH: normed histograms and distribution estimates**

OMCLDO2 CH vs Cloudnet CTH distribution plots, and S5P OCRA/ROCINN\_CAL CTH vs Cloudnet CTH distribution plots, similar as Fig. 9 for the site Juelich, are presented here. Note that sites with less than 70 co-location pairs, and the site Summit, where satellite cloud height retrievals are problematic, are skipped.

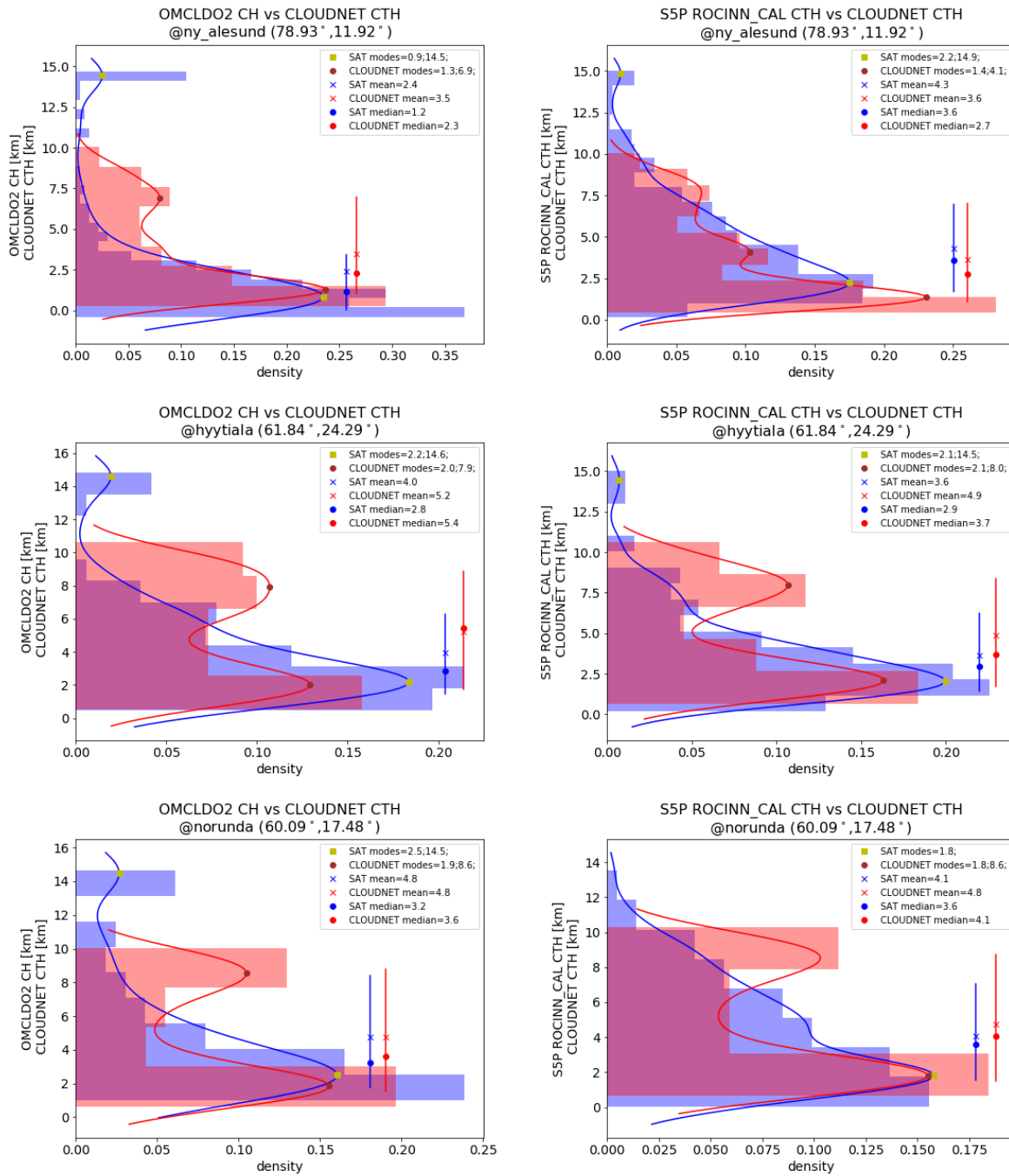


Figure S24. Same as Fig. 9, but for the sites Ny-Alesund, Hyttiala and Norunda.

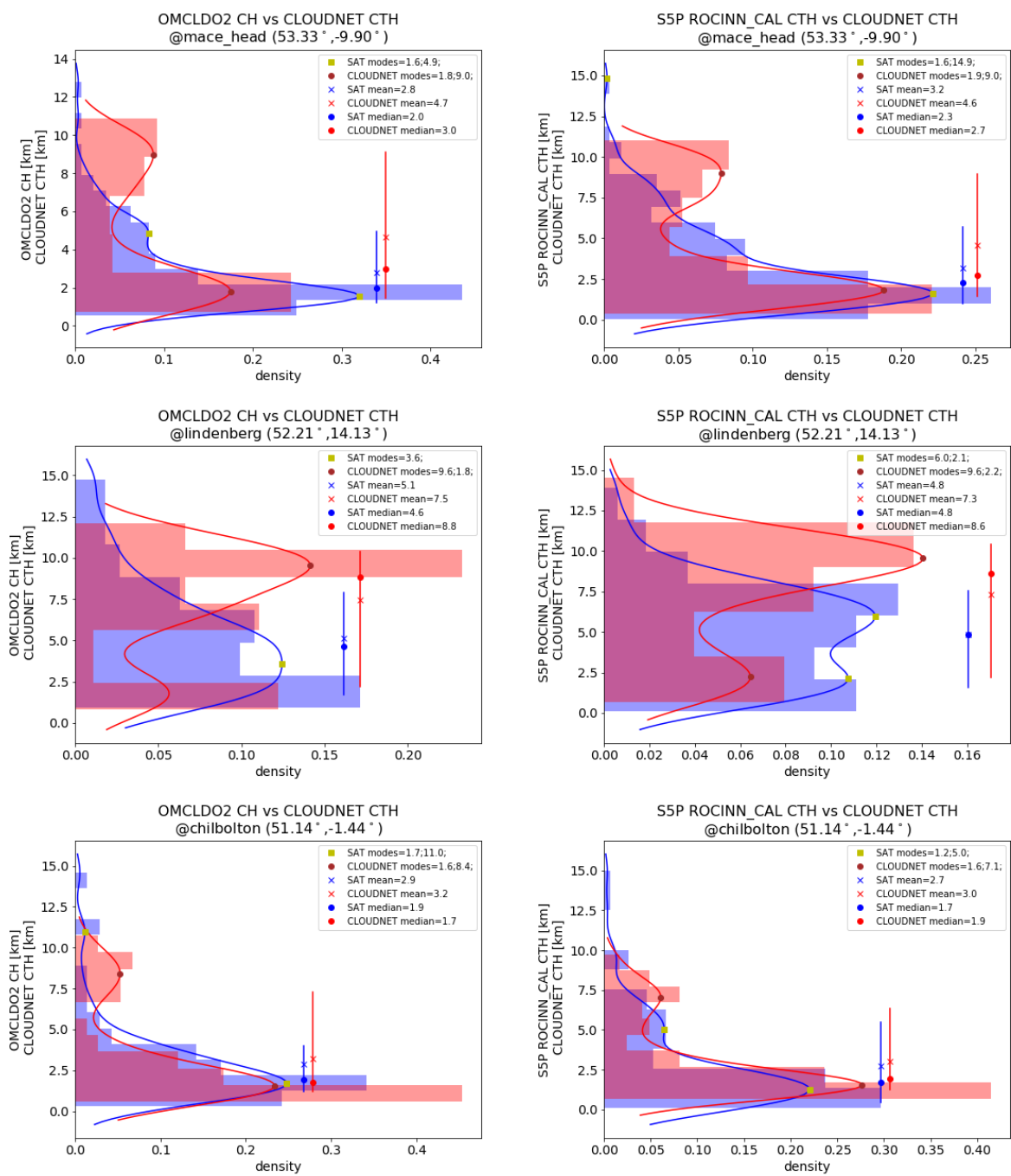


Figure S25. Same as Fig. 9, but for the sites Mace Head, Lindenberg and Chilbolton.

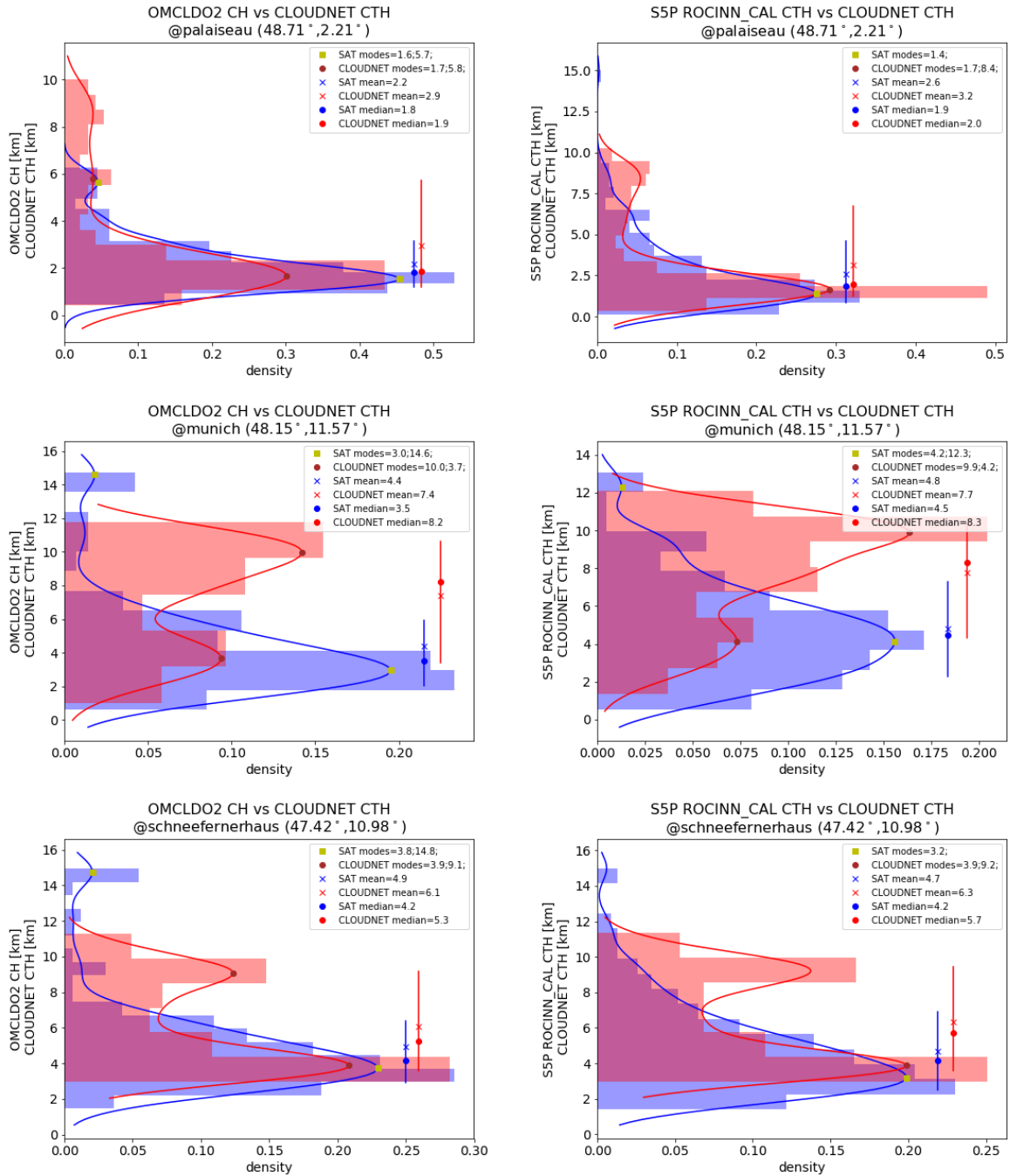
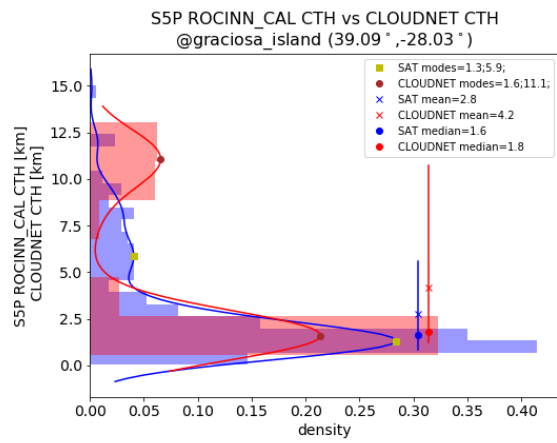
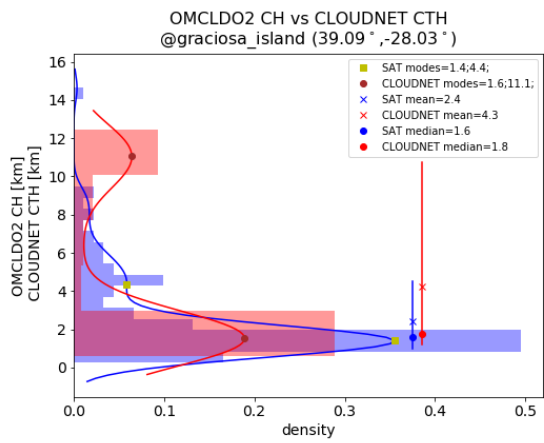


Figure S26. Same as Fig. 9, but for the sites Palaiseau, Munich and Schneefernerhaus.



**Figure S27.** Same as Fig. 9, but for the site Graciosa Island

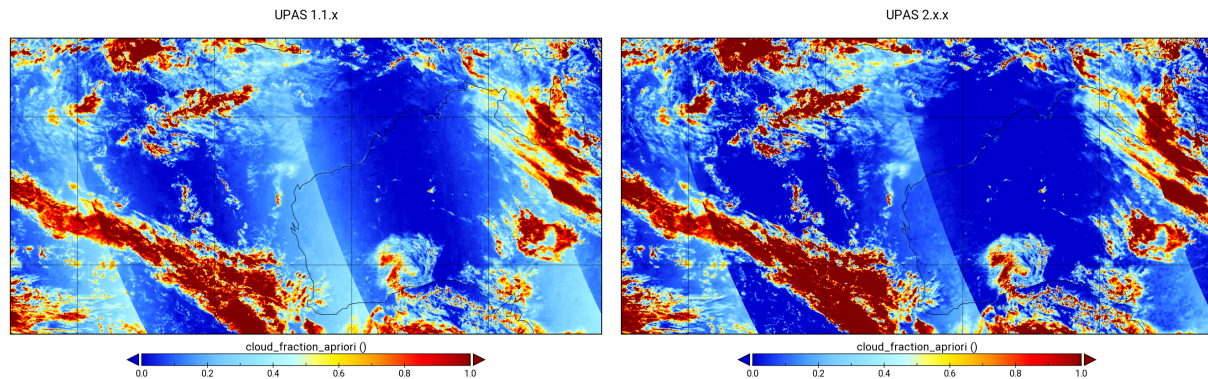


## S4 Impact of processor version upgrades: supplementary material

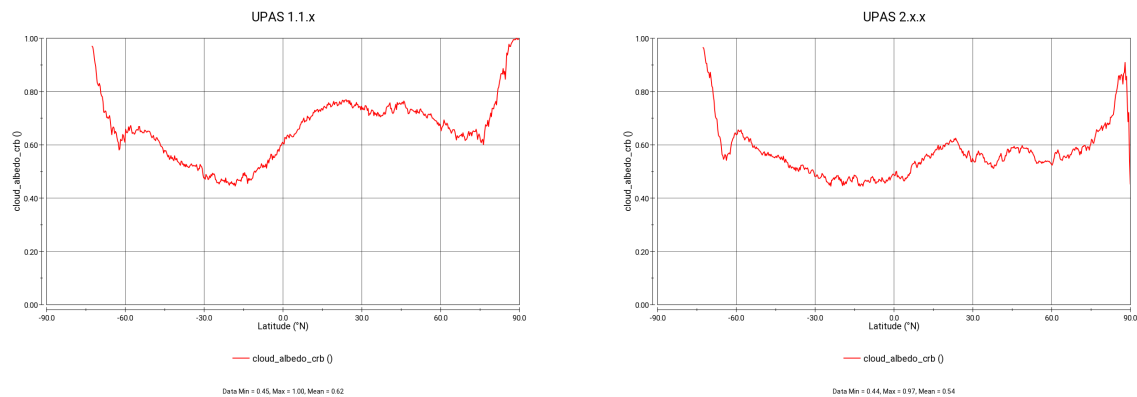
### S4.1 S5P OCRA/ROCINN: version 2 vs version 1

In addition to the material from Sect. 5.1, we here include more examples of artificial geographical patterns for S5P OCRA/ROCINN. Figure S28 presents the enhanced cloud fraction at the east swath edge, and Fig. S29 the North-South gradient in S5P

5 OCRA/ROCINN\_CRB cloud albedo.



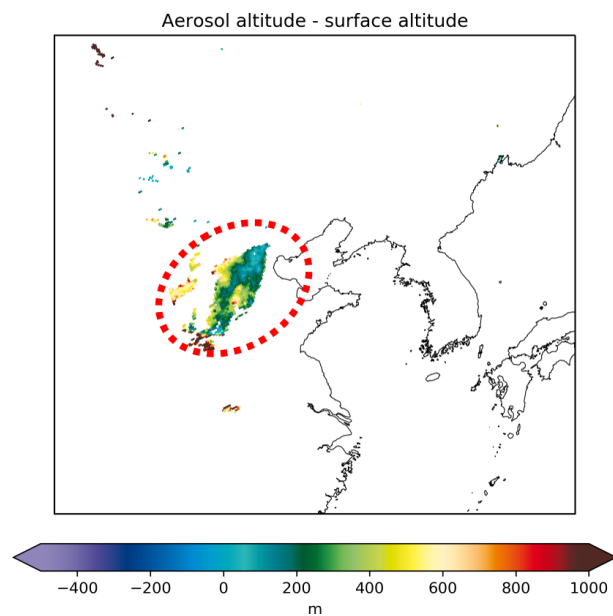
**Figure S28.** S5P OCRA CF of parts of orbits 03614, 03615, 03616 and 03617 on 2018-06-25 for S5P CLOUD OFFL 1.1.5 (left) and S5P CLOUD version 2 (right). Note the sharper contrast in CF at an orbit edge for the released version.



**Figure S29.** S5P ROCINN\_CRB albedo for all orbits within the day 2019-08-08 for CLOUD OFFL 1.1.7 (left) and S5P CLOUD version 2 (right). Note the higher North-South gradient for the released version.

## S4.2 S5P FRESCO version 2 vs version 1

In addition to Sect. 5.2, we include here more material.



**Figure S30.** S5P ALH RPRO 1.3.1 aerosol altitude offset, for the same orbit and place as in Fig. 14: orbit 7062 at 2019-02-23, 1200x1200 km<sup>2</sup> square centered at 38°N, 120°E.