A cloud product for Sentinel-4 to support the Geo-Ring for Air Quality

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1. Sentinel-4

- ❖ Copernicus atmospheric mission
- ❖ objective: **air quality monitoring**
- ❖ **geostationary** orbit
- ❖ **hourly** temporal resolution
- ❖ coverage: Europe and northern Africa
- ❖ spatial resolution: 8 x 8 km2
- ❖ spectral coverage: UV-VIS-NIR
- ❖ spectral resolution: 0.12-0.5 nm
- ❖ Launch: Q2-2025 on MTG-S

- ❖ **Scientific L2 products**:
  - Ozone (total and tropospheric)
  - NO2
  - SO2
  - HCHO
  - CHOCHO
  - **Clouds** and Aerosols
  - Surface properties

Sentinel-4
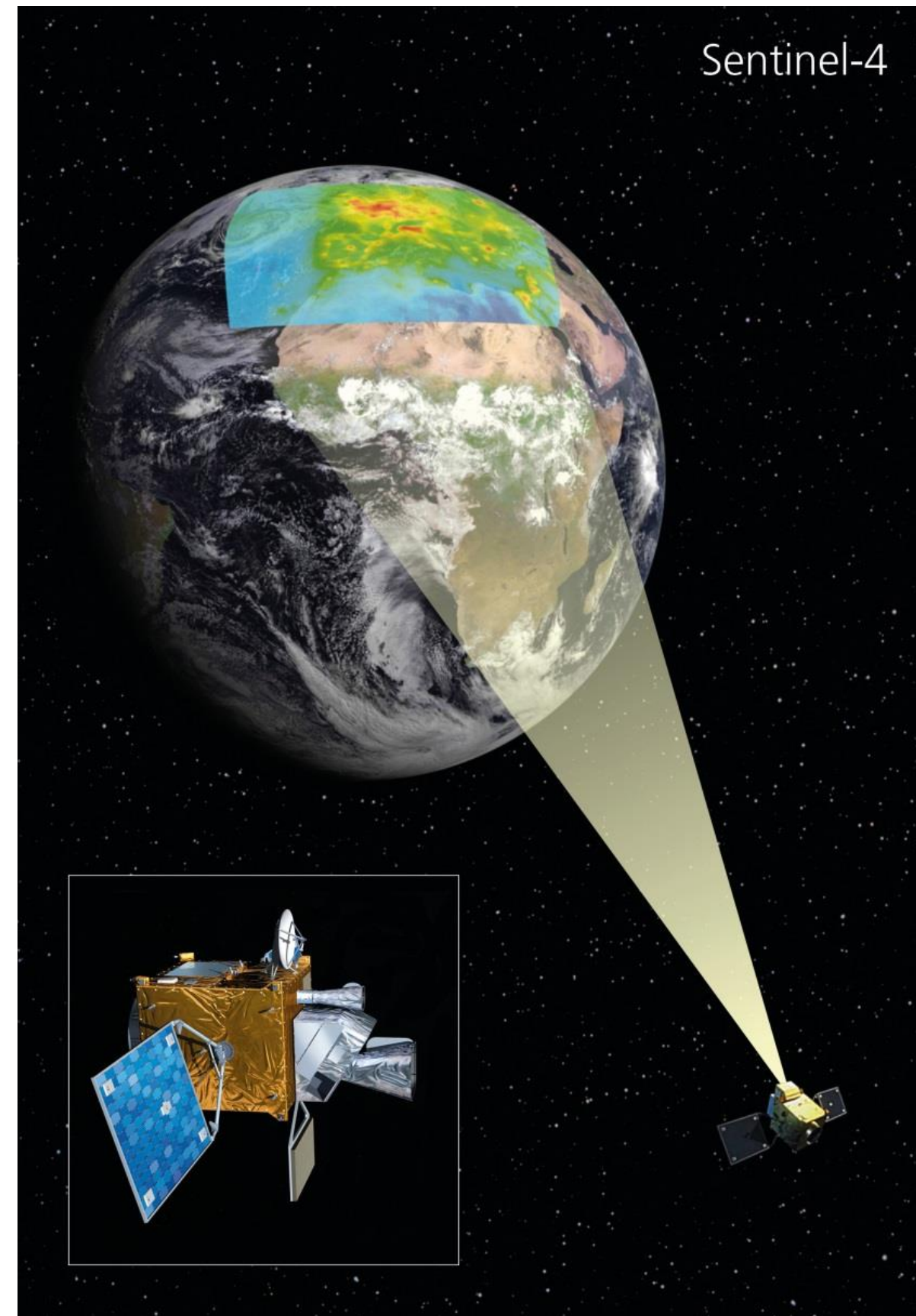
## 2. Cloud Retrieval Algorithms at DLR

- ❖ **OCRA** (Optical Cloud Recognition Algorithm)
  - Color space approach in the UV/VIS
  - Separation into clear-sky background and contribution due to clouds
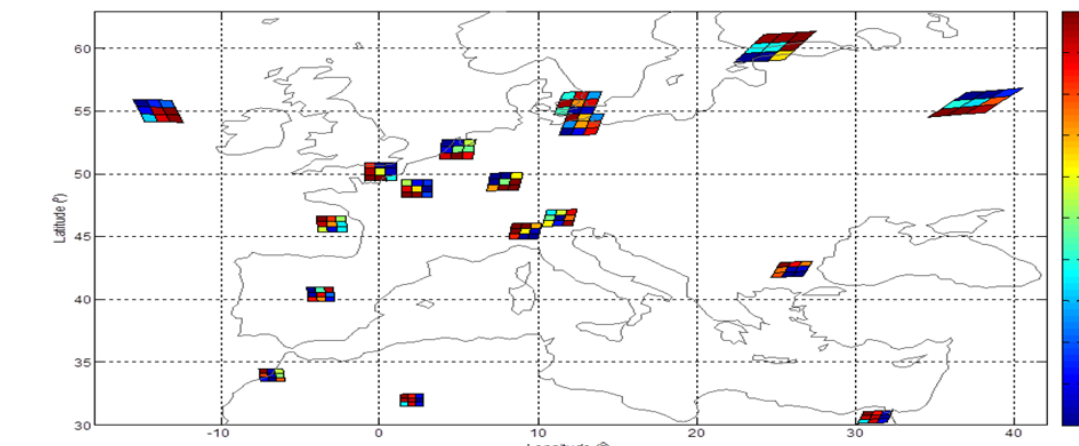 - Retrieval of **radiometric cloud fraction**

CF
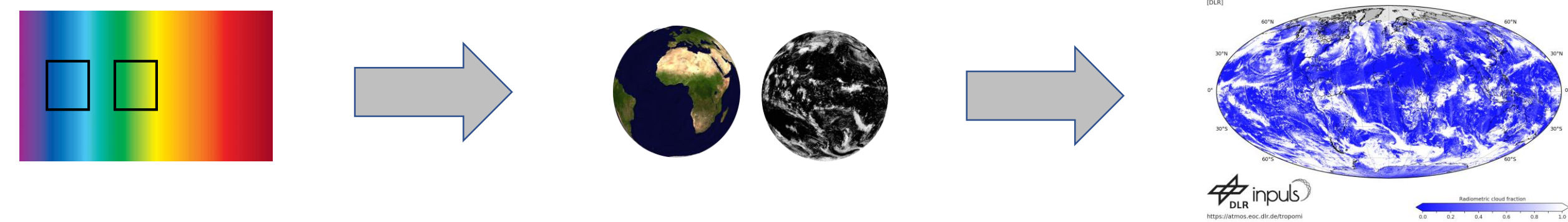
- ❖ **ROCINN** (Retrieval of Cloud Information using Neural Networks)
  - O2 A-band in the NIR, fitting window 758-771nm
  - RTM simulations parameterized with NNs
  - Tikhonov Inversion
  - Two cloud models:
    - Clouds-As-Scattering Layers (CAL)
    - Clouds-As-Refl. Boundaries (CRB)
  - **CAL: cloud top height, cloud opt. thickness**
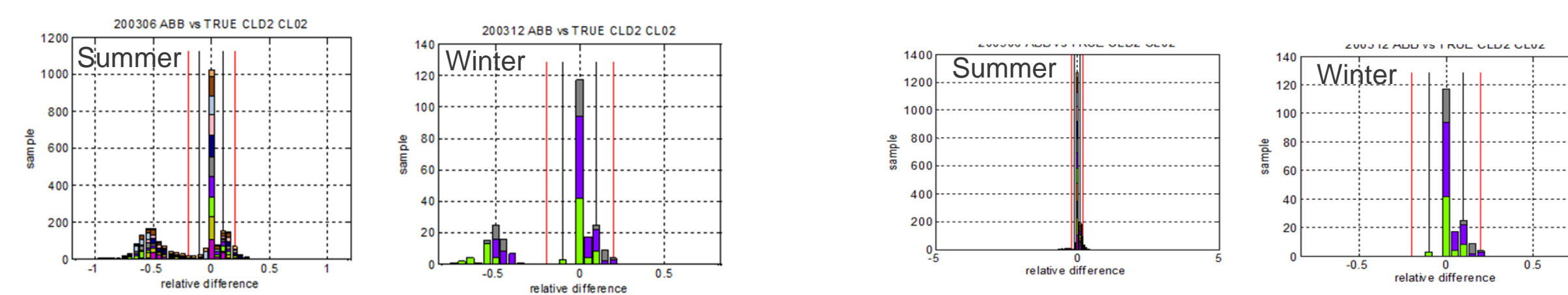 - **CRB: eff. cloud height, cloud albedo**

CTH

COT
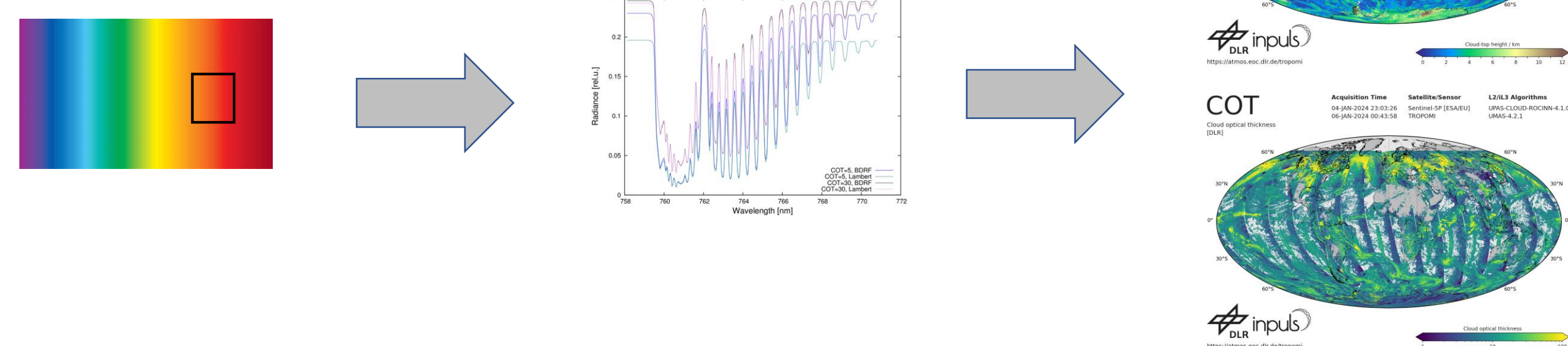
3. Application to synthetic data*

- ❖ Spectral simulations for 17 locations across the Sentinel-4 FOV under varying conditions (cloud coverage, aerosol loads, seasons, hour in day, etc.)
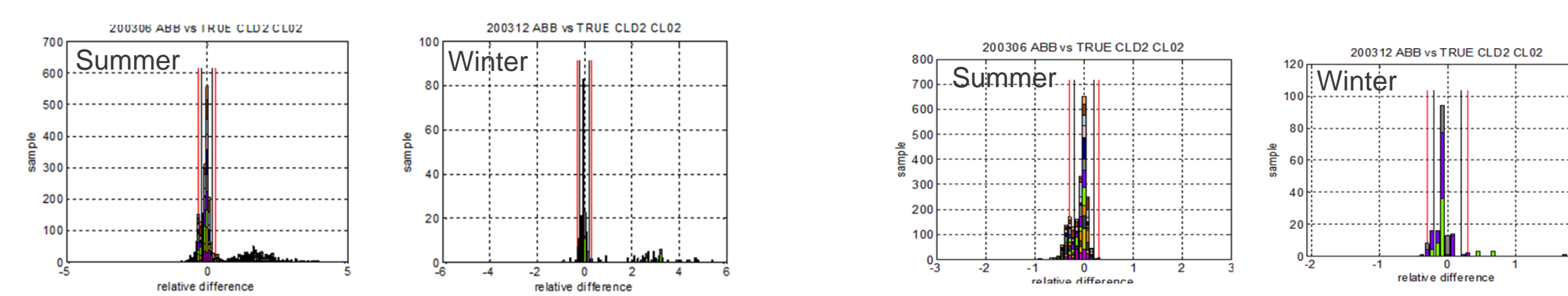
- ❖ **Verification** of the retrieved cloud parameters is done for a sample of
  (i) optically thin and thick clouds (COT=5,20) and
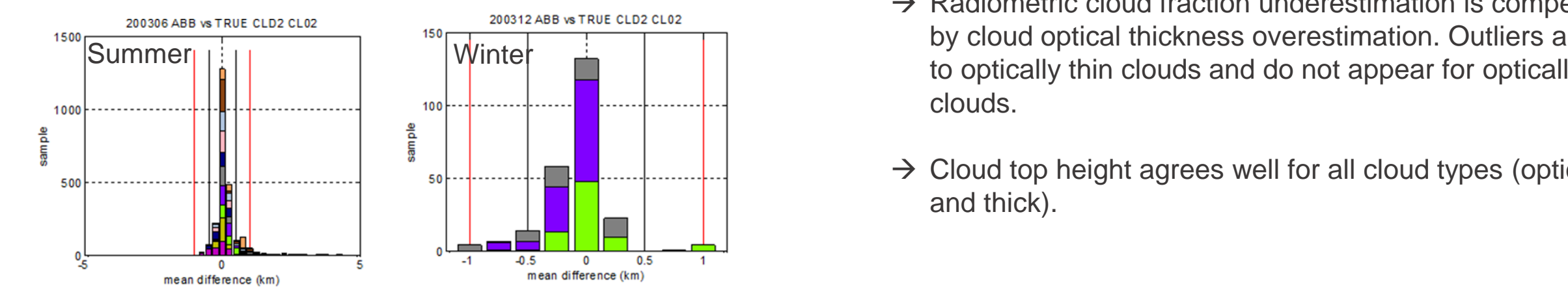 (ii) for optically thick clouds only (COT=20).

(i)   (ii)

- ❖ **radiometric cloud fraction**

Summer | Winter   Summer | Winter

- ❖ **cloud optical thickness**

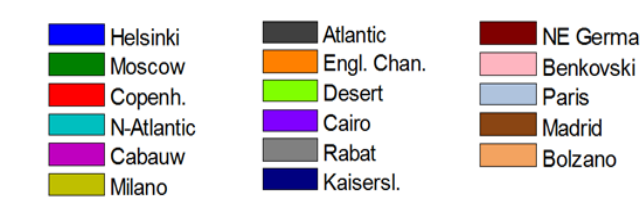Summer | Winter   Summer | Winter

- ❖ **cloud top height**

Summer | Winter

→ Radiometric cloud fraction underestimation is compensated by cloud optical thickness overestimation. Outliers are due to optically thin clouds and do not appear for optically thick clouds.

→ Cloud top height agrees well for all cloud types (optically thin and thick).

*All plots are taken from the S4L2 Geophysical Algorithm Verification Report (GAVR), red and black vertical lines indicate threshold and goal success criteria, respectively. Colors correspond to the individual locations as indicated in the legend on the right.

Helsinki	Atlantic	NE Germany
Moscow	Engl. Chan.	Benkoski
Copenh.	Desert	Paris
N-Atlantic	Cairo	Madrid
Cabauw	Rabat	Bolzano
Milano	Kaiserol.	

4. Geo-Ring for Air Quality

- ❖ Air quality monitoring from **geostationary** orbit for large parts of the northern hemisphere will be achieved by
  - TEMPO (launched April 2023)
  - Sentinel-4 (to be launched Q2/2025)
  - GEMS (launched February 2020)

Image courtesy: CEOS
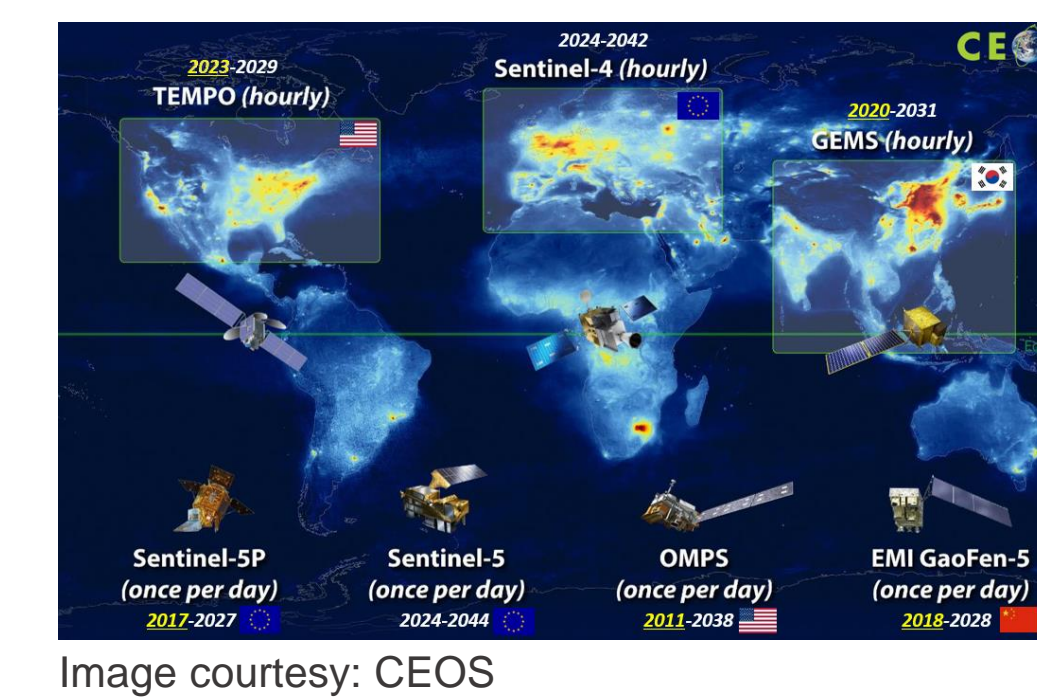
- ❖ The high temporal resolution (but limited geospatial coverage) of the GEO missions provides **great synergetic potential** with the global coverage (but limited temporal resolution) of the LEO missions like e.g Sentinel-5P.

- ❖ For the development of the Sentinel-4 Level 2 processors, the operational GEMS data provide an **ideal testing ground**.

5. Application to GEMS

- ❖ We **apply the S4-L2 Cloud processor to GEMS L1 data** and compare the retrieval results with the operational GEMS L2 Cloud product.

- ❖ The operational GEMS L2 Cloud product is retrieved in the VIS using the O_2-O_2 absorption because GEMS does not cover the NIR. Hence, by applying the S4L2 Cloud processor to GEMS L1 data, we can only retrieve and compare the radiometric cloud fraction.

- ❖ Comparisons for cloud fraction of the S4L2 Cloud OCRA retrieval (left) with the operational GEMS L2 CLD product (right) for 2021-12-02, 3:45UT.
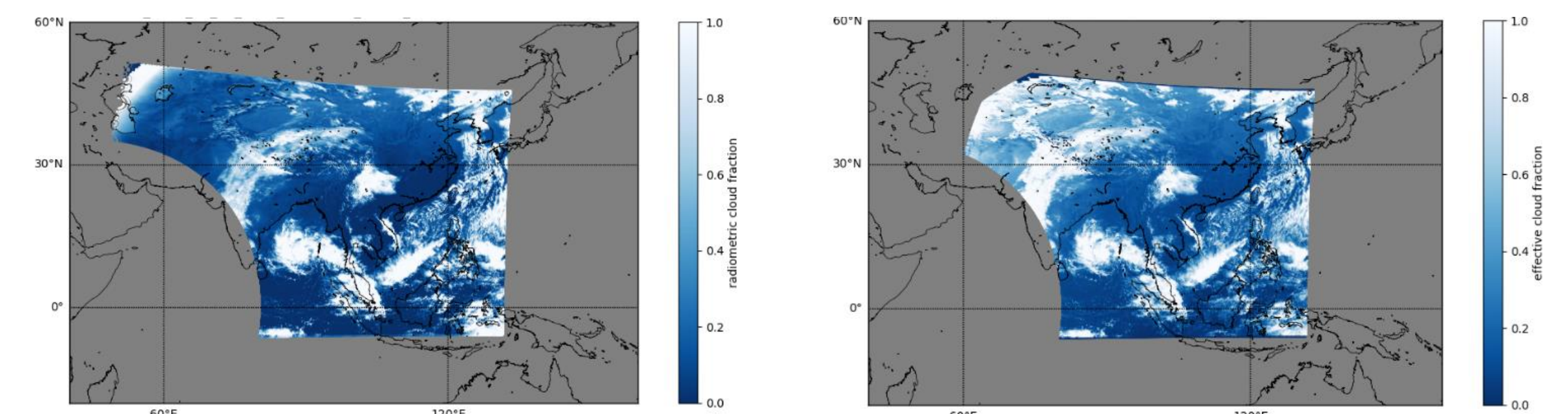
- ❖ Main cloud structures **agree very well**. Differences appear at large viewing angles and for scenes with very low cloud coverage where the impact of the surface becomes more dominant.

- ❖ **Monthly mean data** of cloud fraction agree very well. All examples below are computed for all available hourly scans from June 2021.

- ❖ Difference map (left), zonal- and meridional monthly mean cloud fractions from OCRA (middle) and from the GEMS L2 CLD product (right).
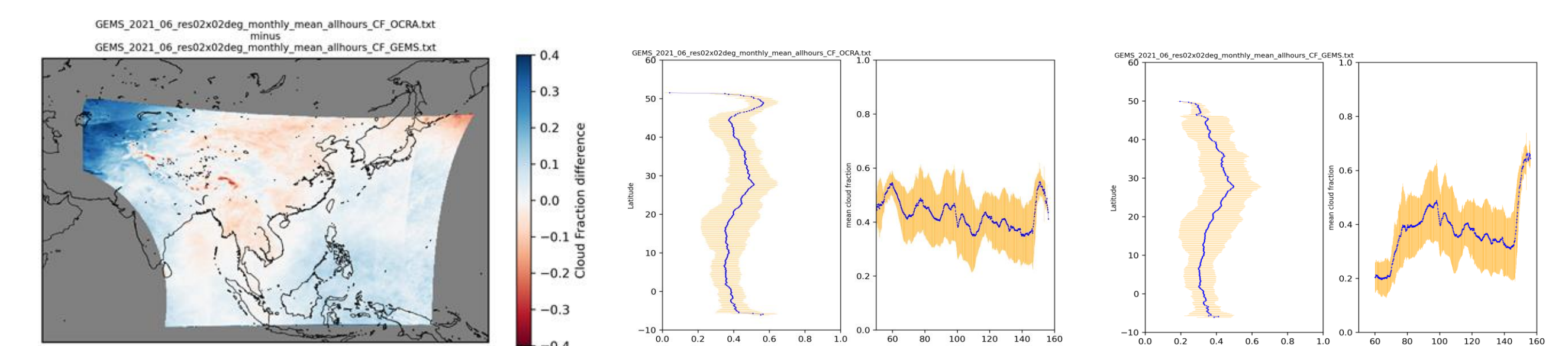
- ❖ Histogram of the differences (left), individual histograms (middle) and 2D scatter density plot (right) of the monthly data. The **monthly mean cloud fraction difference is 0.04**. The GEMS L2 CLD individual histogram peaks at slightly lower values and is more asymmetric than the one from OCRA. The **correlation coefficient is 0.8** and a linear fit suggests a y-intercept close to zero and a slope close to unity (0.9). The outliers in the 2D histogram are due to different behavior of the two cloud retrieval algorithms at extreme viewing geometries, as can also be seen in the difference map.