THE SENTINEL-4/MTG-S OPERATIONAL CLOUD PRODUCT

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German Aerospace Center (DLR)
Earth Observation Center (EOC)
Remote Sensing Technology Institute (IMF)
Atmospheric Processors (ATP)

DLR

Outline

- **Motivation and Sentinel-4 basics**
- **Cloud retrieval algorithms for S4: OCRA & ROCINN**
- **Application to the GEMS instrument**
- **Conclusion / Outlook**

Motivation

- **Sentinel-4 will be dedicated to:**
  - **remote sensing of the atmospheric composition**
  - **air quality monitoring**
- **The retrieval of trace gases and greenhouse gases requires the characterisation of clouds for a given scene measurement**
  - **for Sentinel-4 we provide a L2 cloud product with basic cloud information**
  - **this information can be used as auxiliary input to the trace gas retrievals**

Sentinel-4

Orbit
geostationary

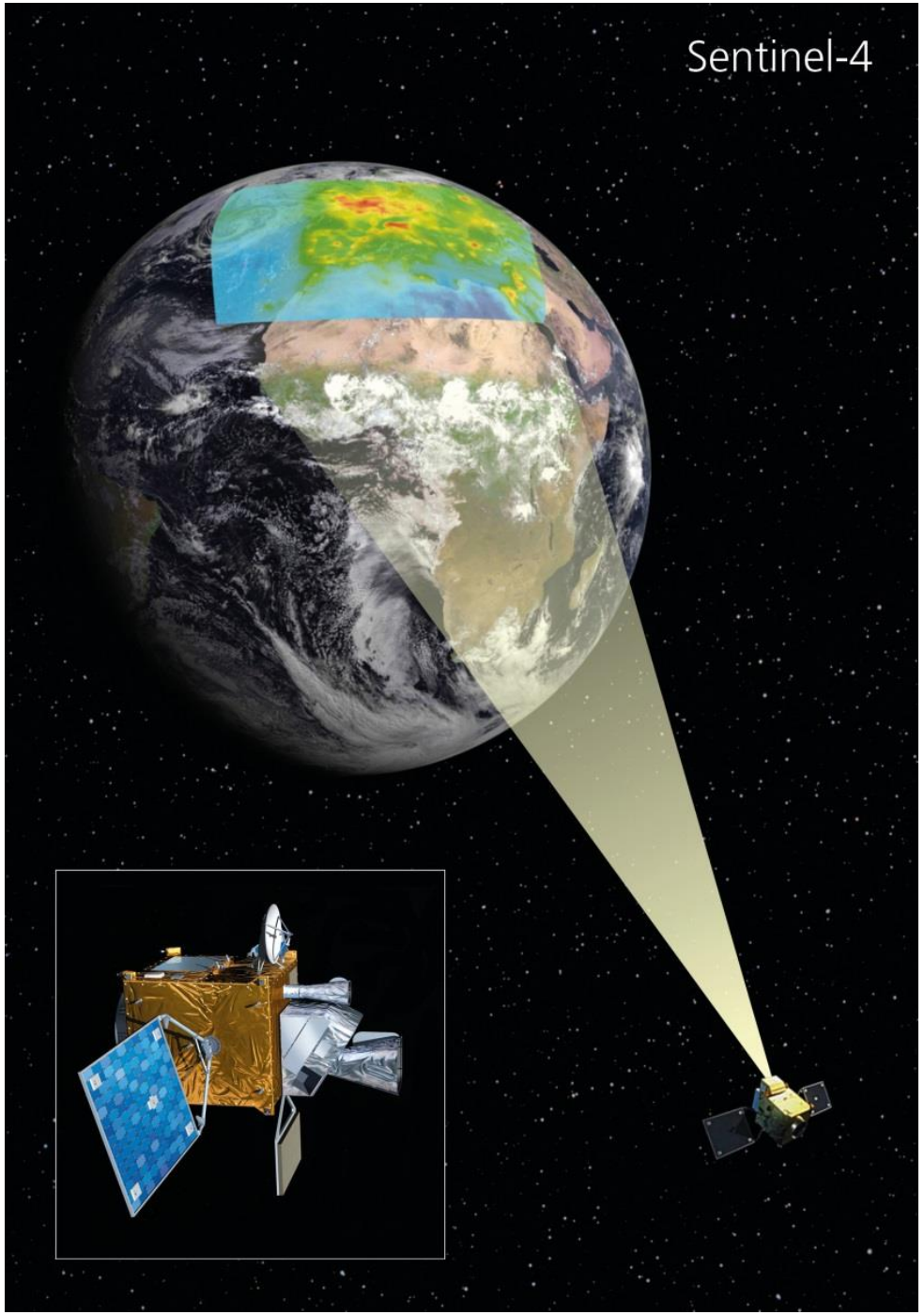
Temporal resolution and coverage
hourly coverage over Europe

Spatial resolution of UVN instrument
8 x 8 km^2

Spectral coverage
UV-VIS-NIR

Spectral resolution in the UVN
0.12-0.5 nm

Launch
Probably Q1/2025



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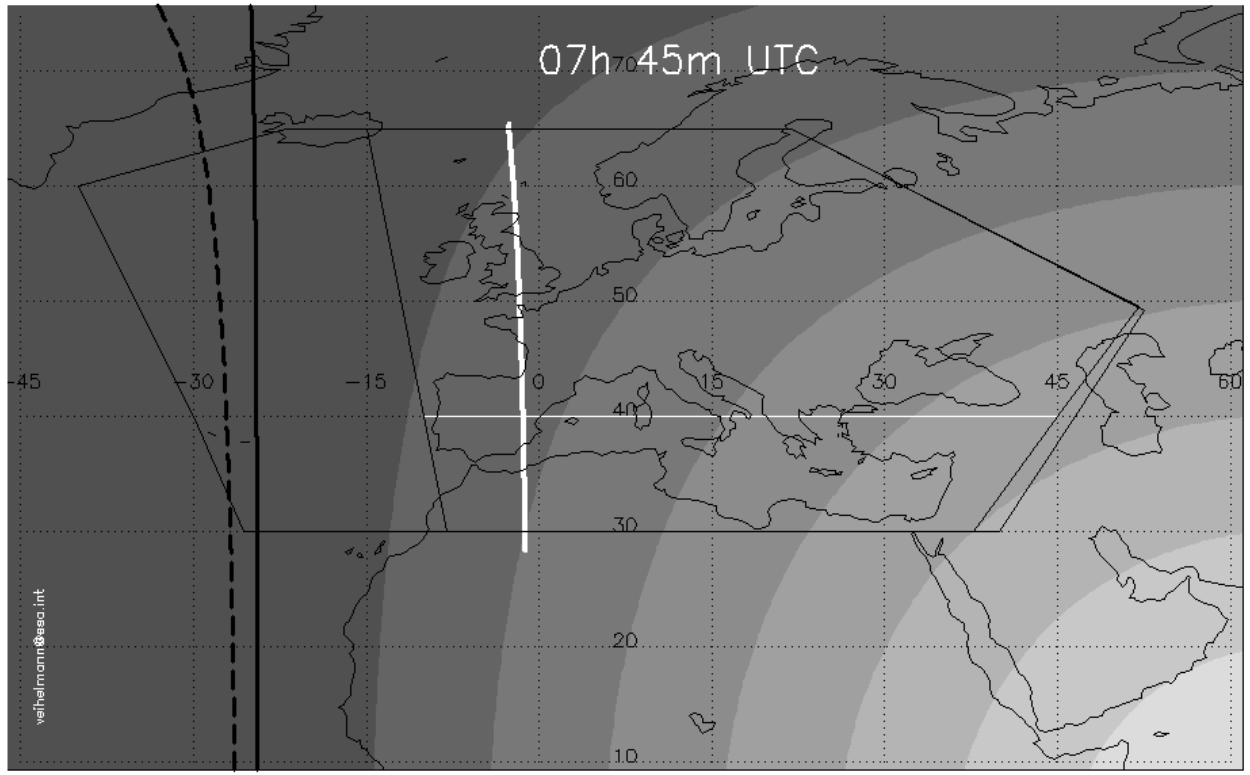

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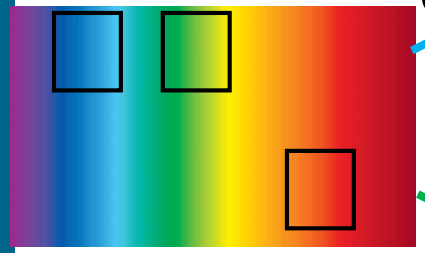
DLR CLOUD RETRIEVAL ALGORITHMS

OCRA & ROCINN – Overview

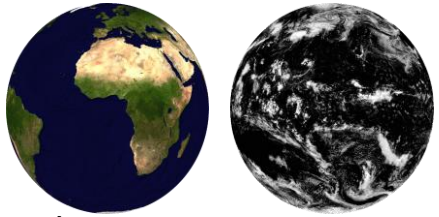
OCRA
Optical Cloud Recognition Algorithm



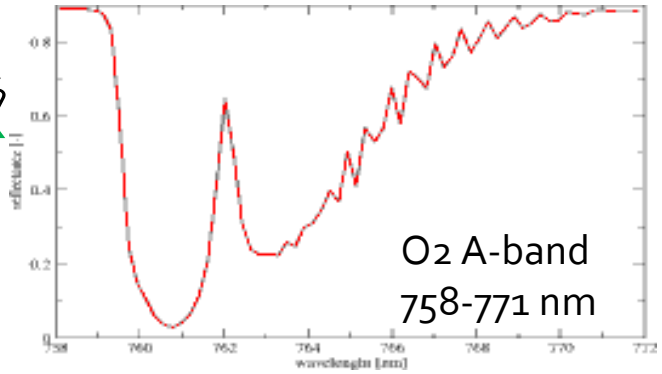
ROCINN
Retrieval of Cloud Information using Neural Networks

color space approach

neural network approach



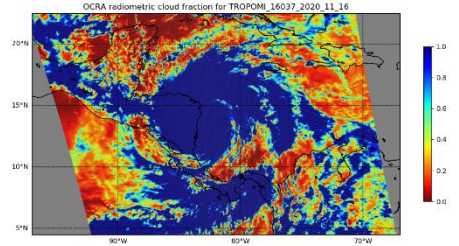
clear-sky composite



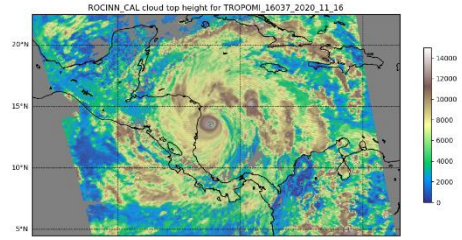
Hurricane Iota
©NASA worldview

CAL
Clouds as layers

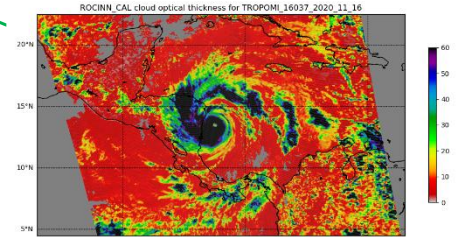
CRB
Clouds as reflecting boundaries



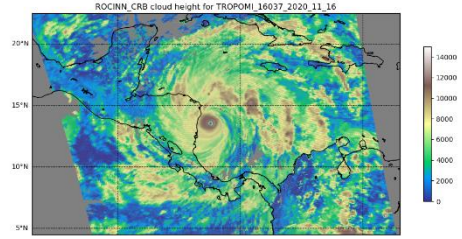
radiometric cloud fraction



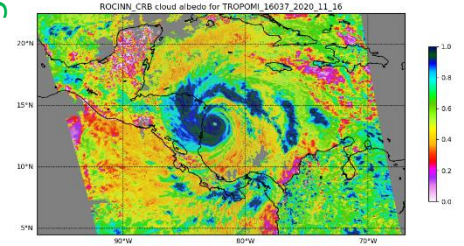
cloud top height



cloud opt. thickness

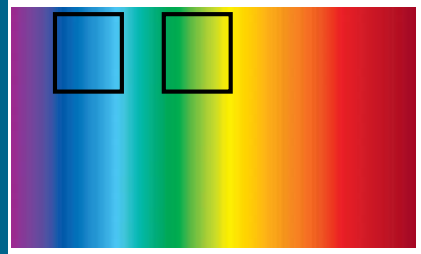


eff. cloud height

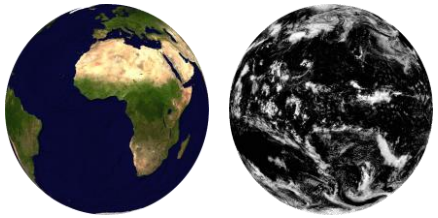


eff. cloud albedo

OCRA – Overview

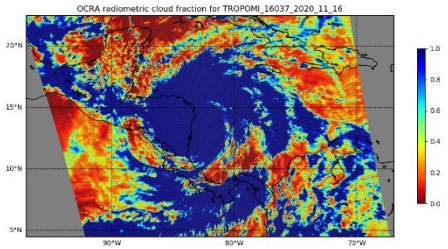


color space approach



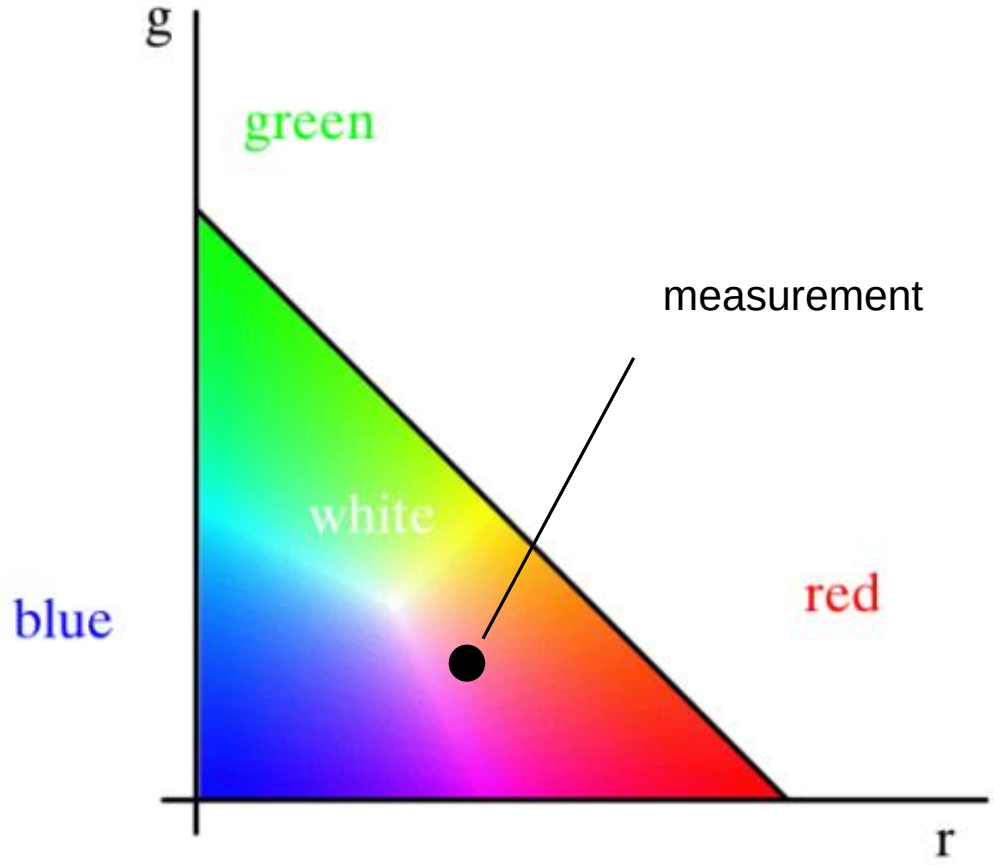
clear-sky composite

radiometric cloud fraction



OCRA
Optical Cloud Recognition Algorithm

- map measured reflectance to color space
- CF=0 from clear-sky composite
- CF=1 from „white point“
- radiometric cloud fraction via scaling of the measurement between the clear-sky and the white point



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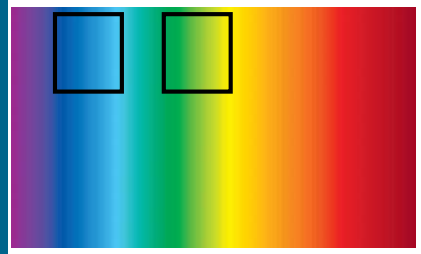

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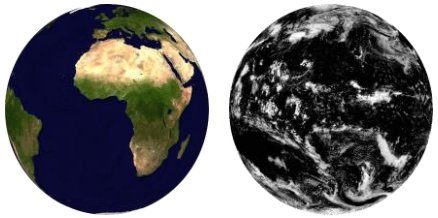

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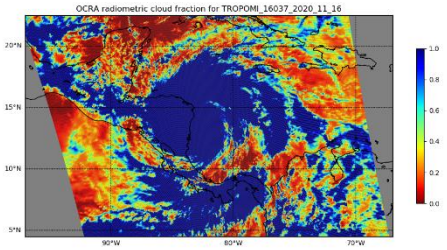

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Orbit
Lagrange Point L1

Temporal resolution and coverage

10-22 full disk images per day

Instrument name

EPIC (Earth Polychromatic Imaging Camera) on NASA DSCOVR platform

Spatial resolution

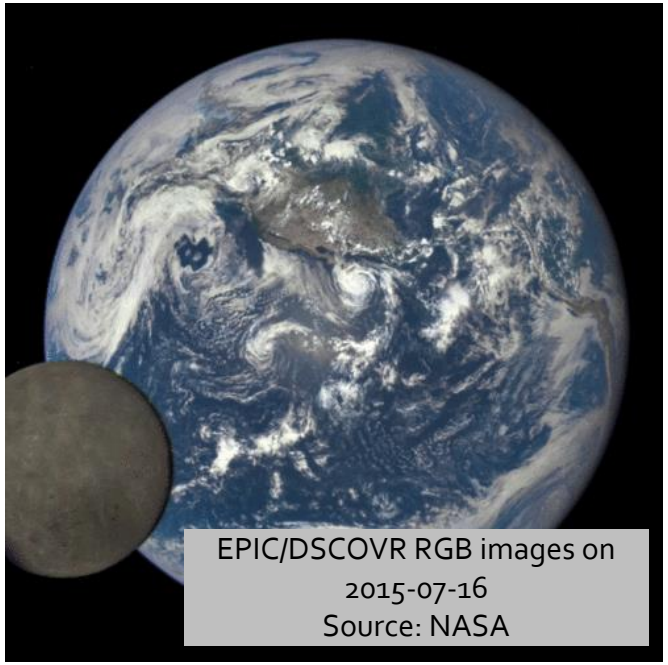
12 km at nadir

Spectral coverage

10 channels across UV-VIS-NIR

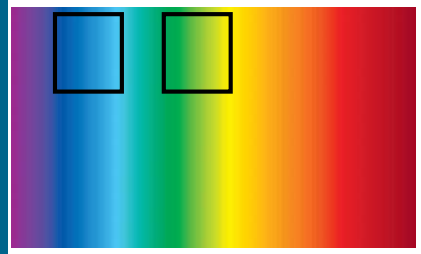
Spectral resolution in the UVN

bandwidth between 1-3 nm



EPIC/DSCOVR RGB images on 2015-07-16
Source: NASA

OCRA – Overview



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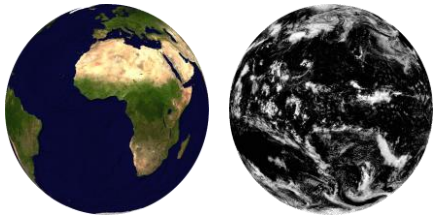

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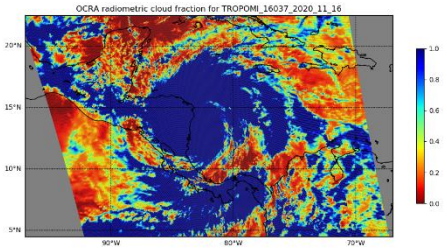

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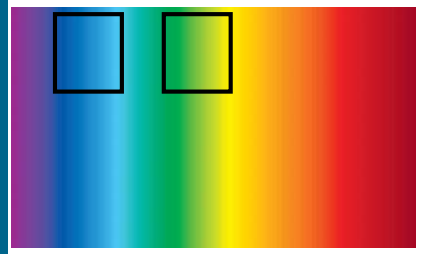
Clear-sky maps for EPIC channels (780, 551, 388) nm
aggregation of daily maps in intervals of +/- 14 days with 0.2 deg resolution

OCRA – Overview



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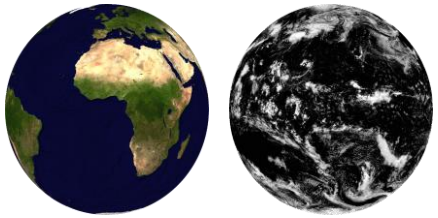

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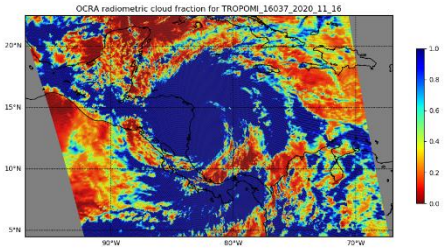

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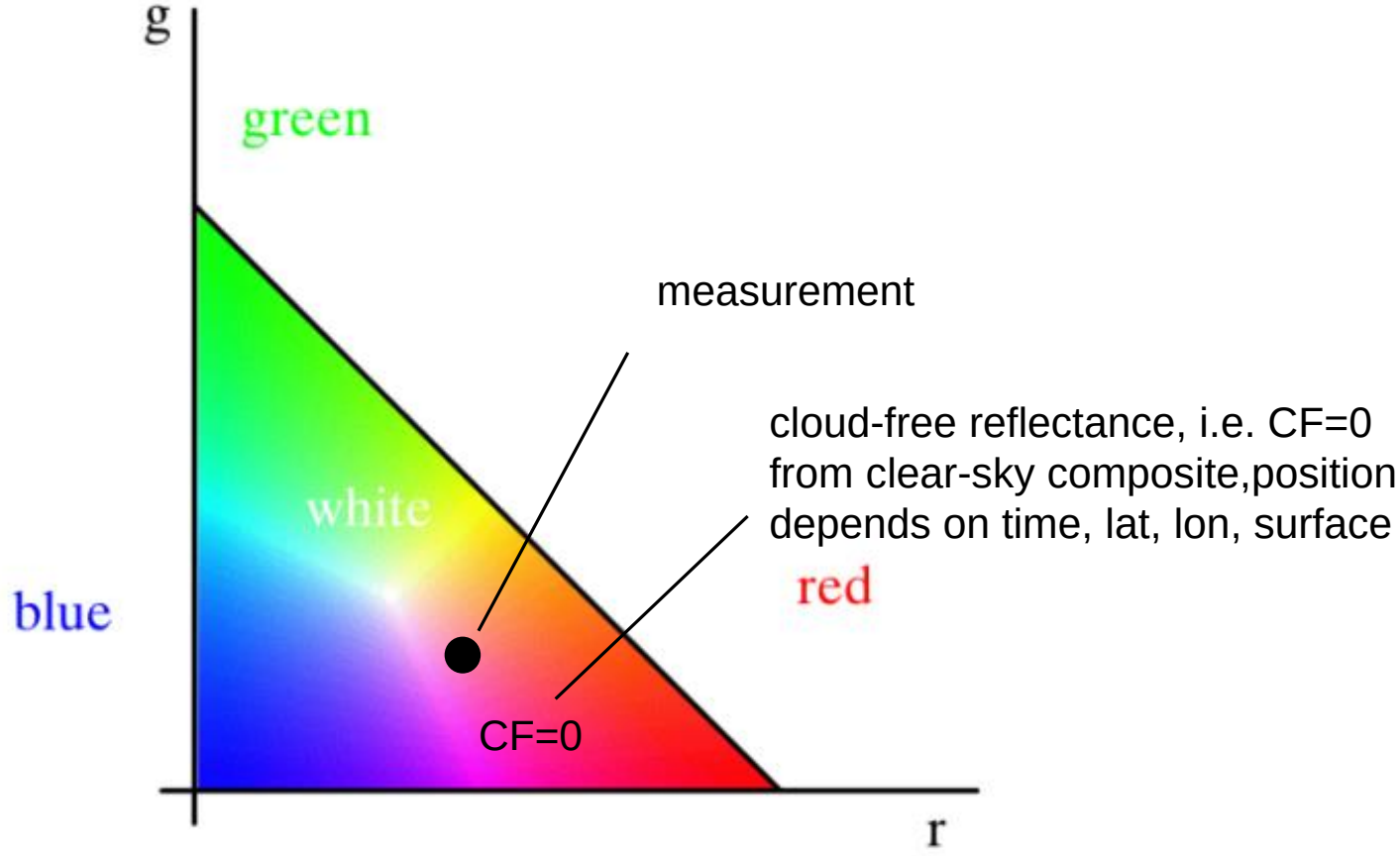

cloud-free reflectance, i.e. CF=0 from clear-sky composite,position depends on time, lat, lon, surface

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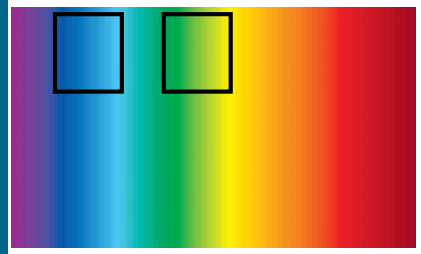

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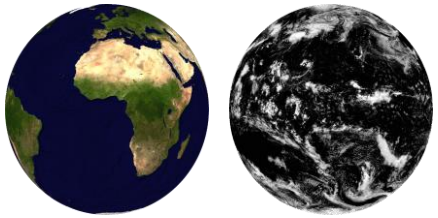

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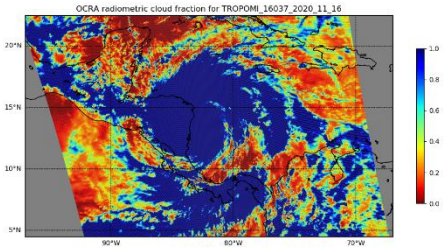

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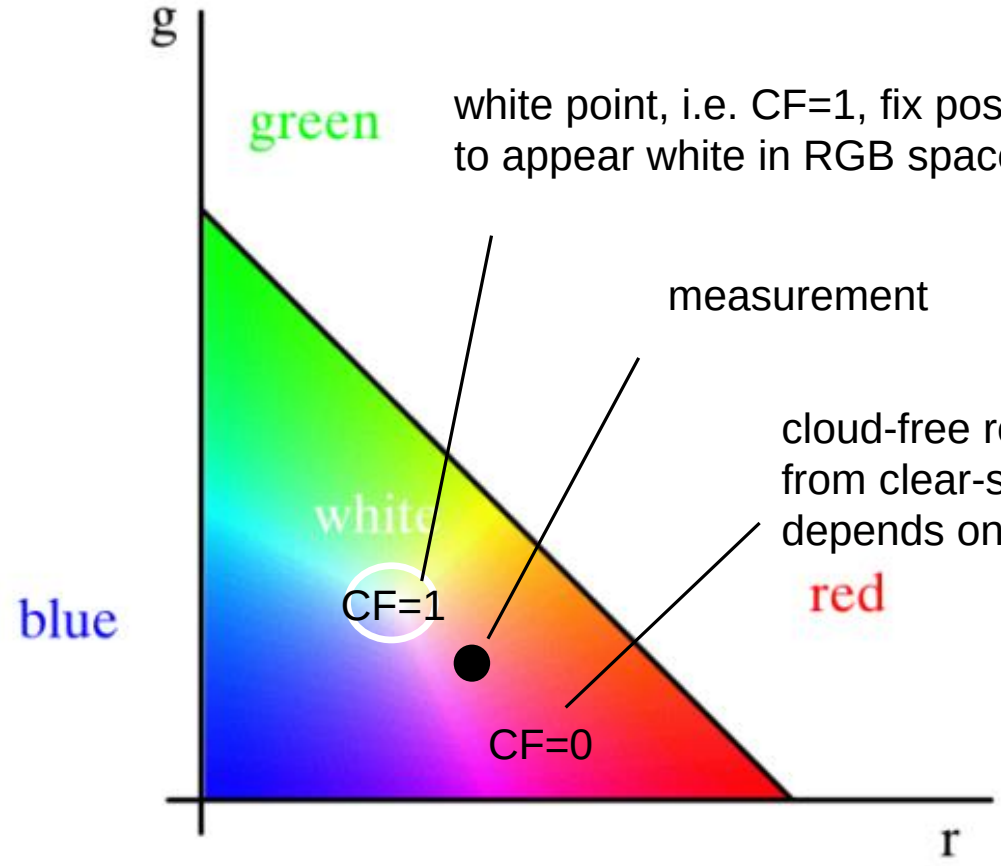

white point, i.e. CF=1, fix position, assume cloud to appear white in RGB space

measurement

cloud-free reflectance, i.e. CF=0 from clear-sky composite,position depends on time, lat, lon, surface

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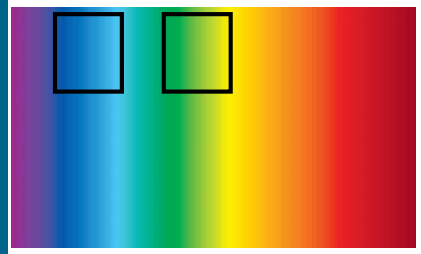

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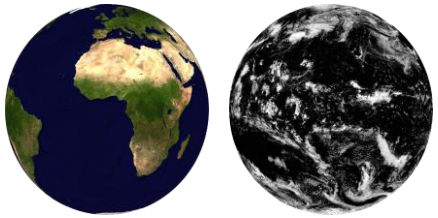
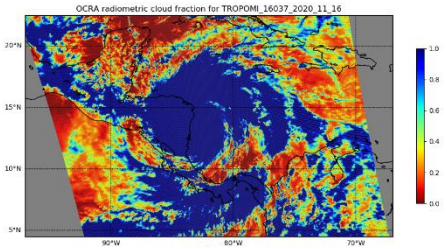


clear-sky composite

radiometric cloud fraction



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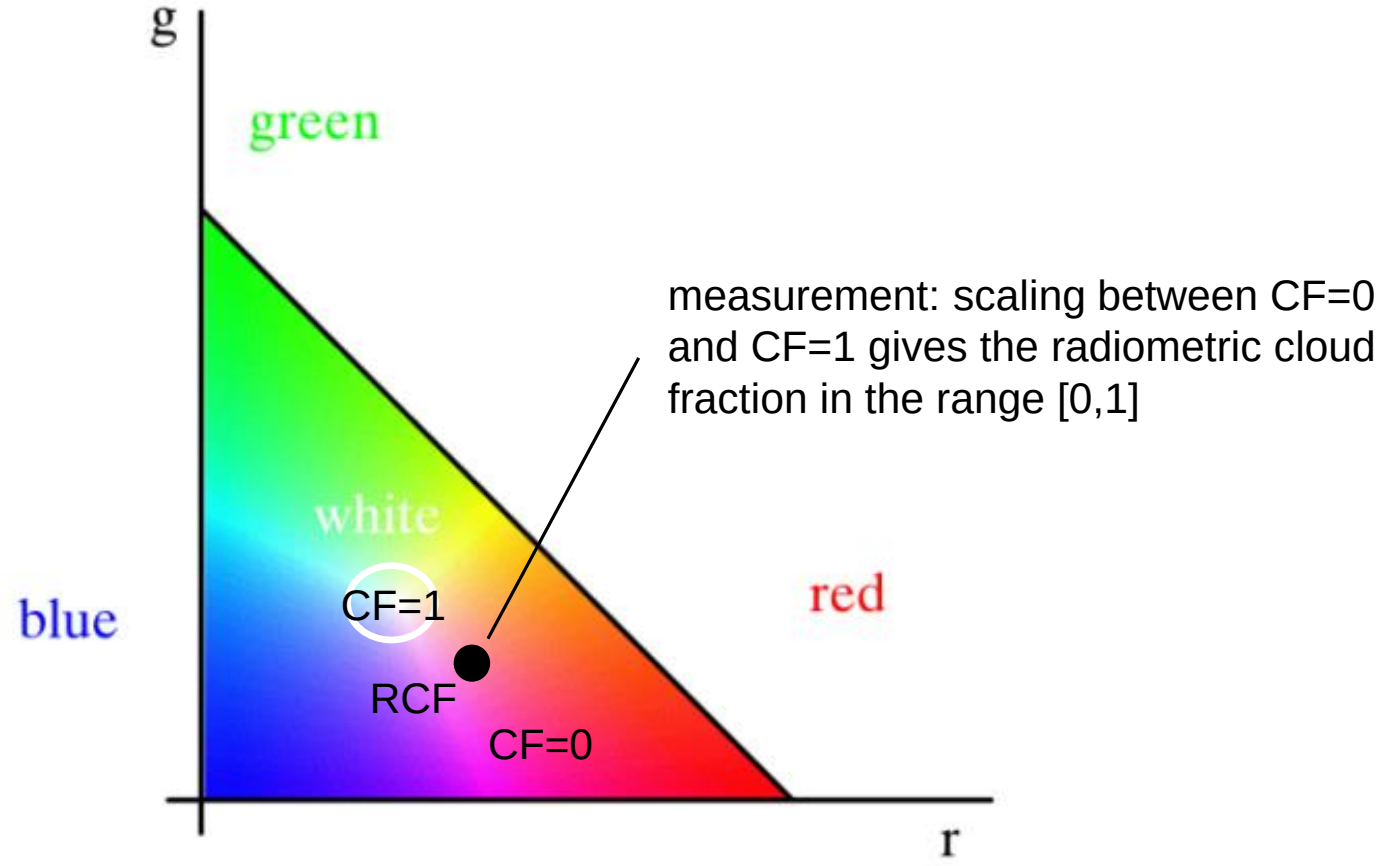
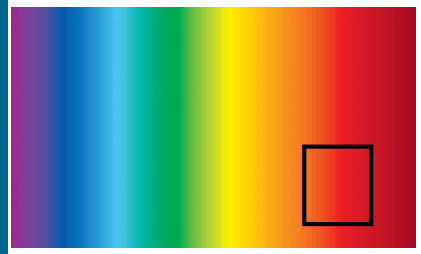
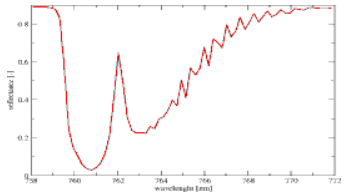


ROCINN – Overview



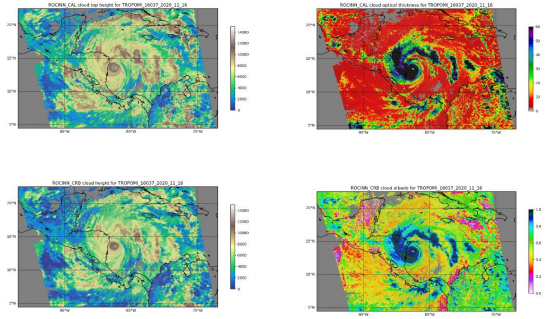
neural network approach



O2 A-band 758-771 nm

CAL

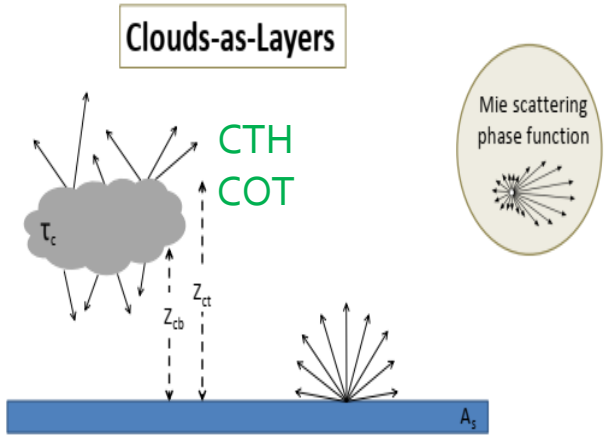
CRB

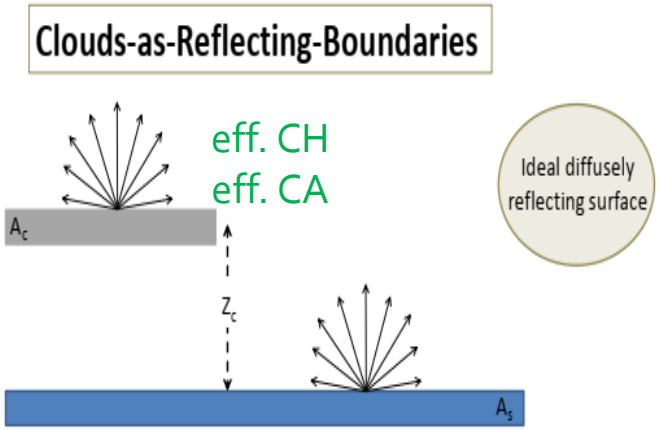


ROCINN

Retrieval of Cloud Information using Neural Networks

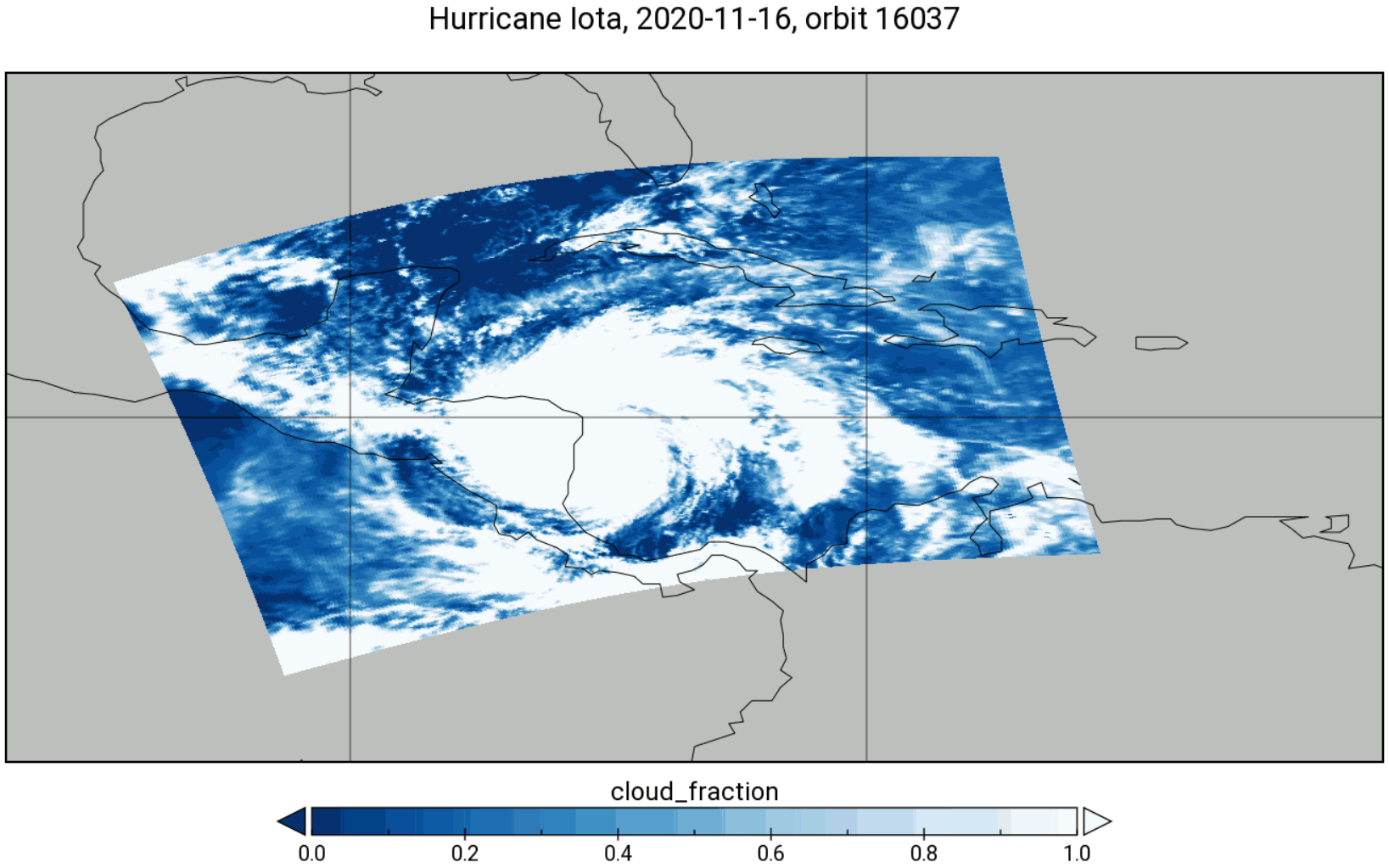
- two cloud models:
  - **CAL**: clouds as layers (Mie-scattering liquid water droplets)
  - **CRB**: clouds as reflecting boundaries (Lambertian reflector)
- in an operational environment, performing on-line RT calculations or applying huge LUTs in the inversion process is either too computationally expensive or too slow
- for near-real-time applications, we use neural networks which were trained with >200.000 samples (simulated O2 A-band spectra with LIDORT radiative transfer code)





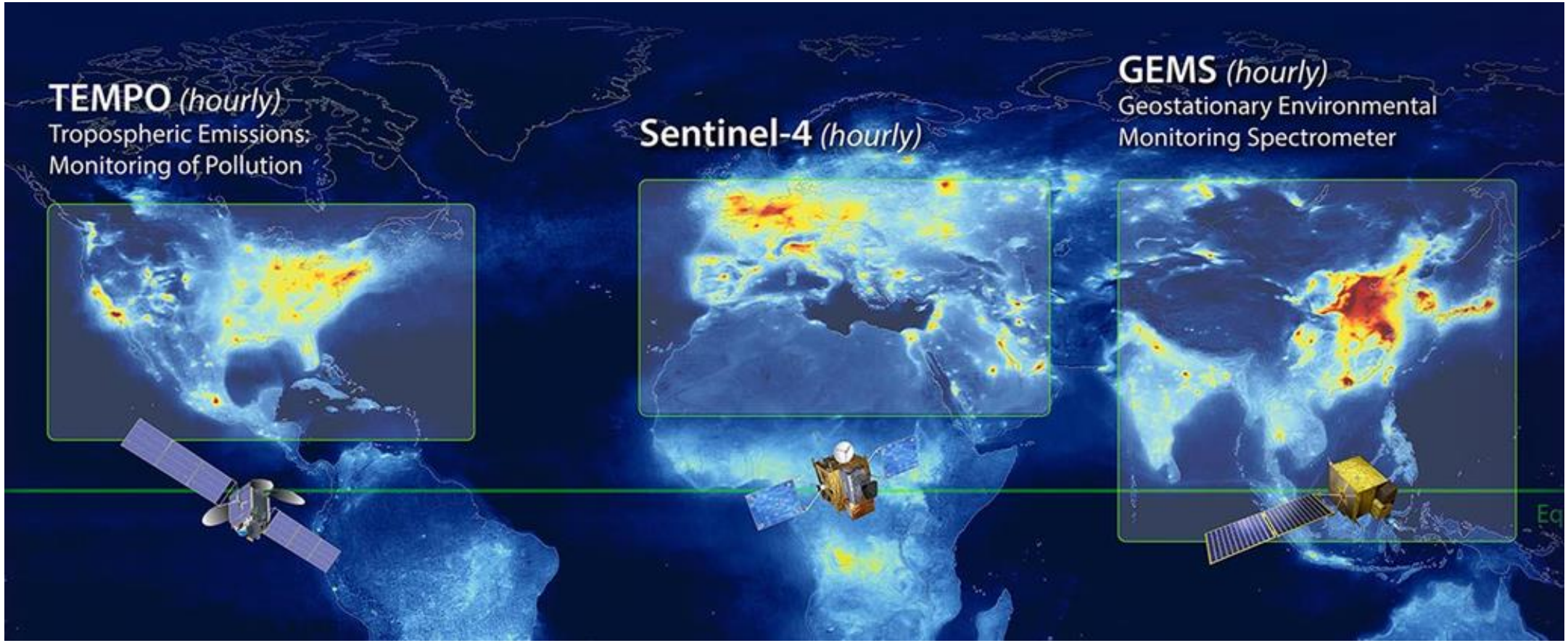
OCRA & ROCINN – Examples: TROPOMI/S5P

Hurricane Iota
©NASA worldview



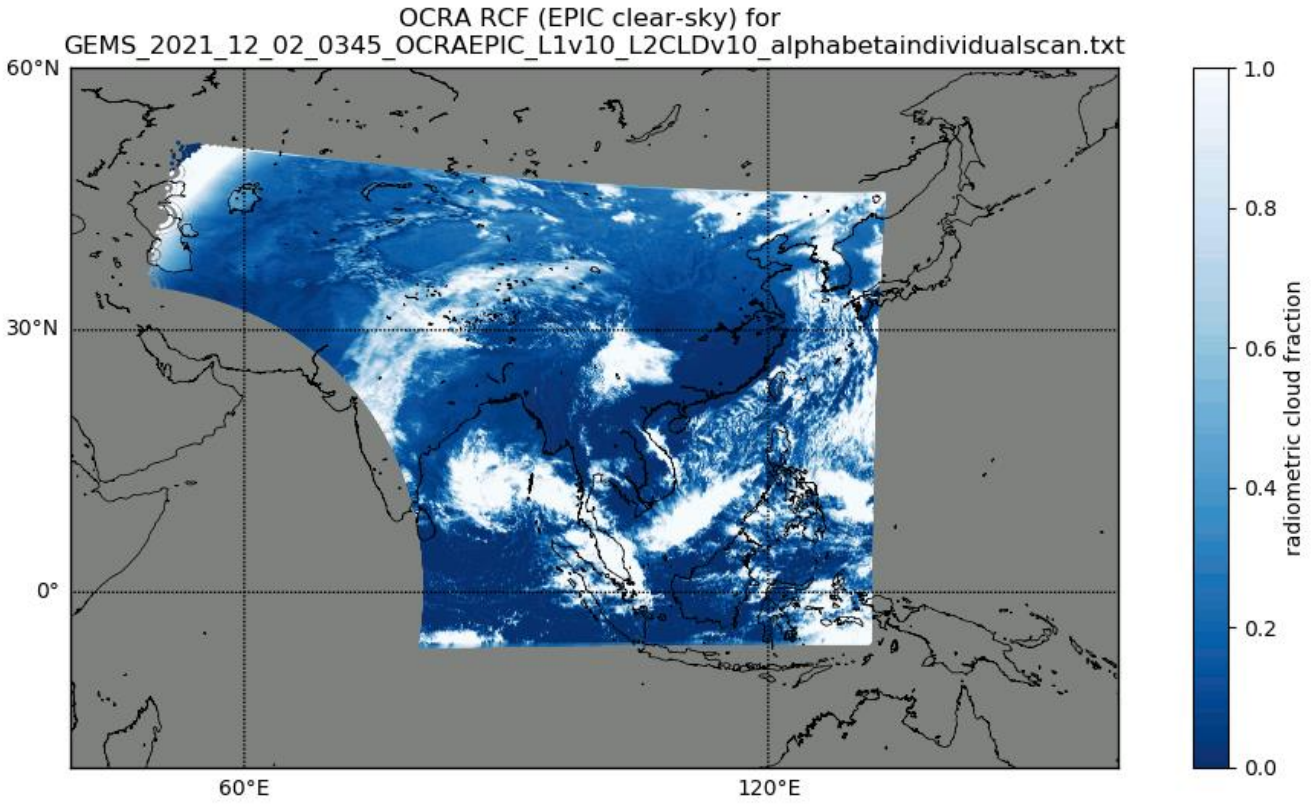
APPLICATION TO GEMS

Application to GEMS



- GEMS/GeoKompsat-2B is a South Korean instrument for air quality over Asia.
- It is part of the geostationary constellation, together with TEMPO (USA) and S4 (Europe)
- Launched in 2018. TEMPO launched on 7 April 2023. Sentinel-4 to launch in Q1/2025.

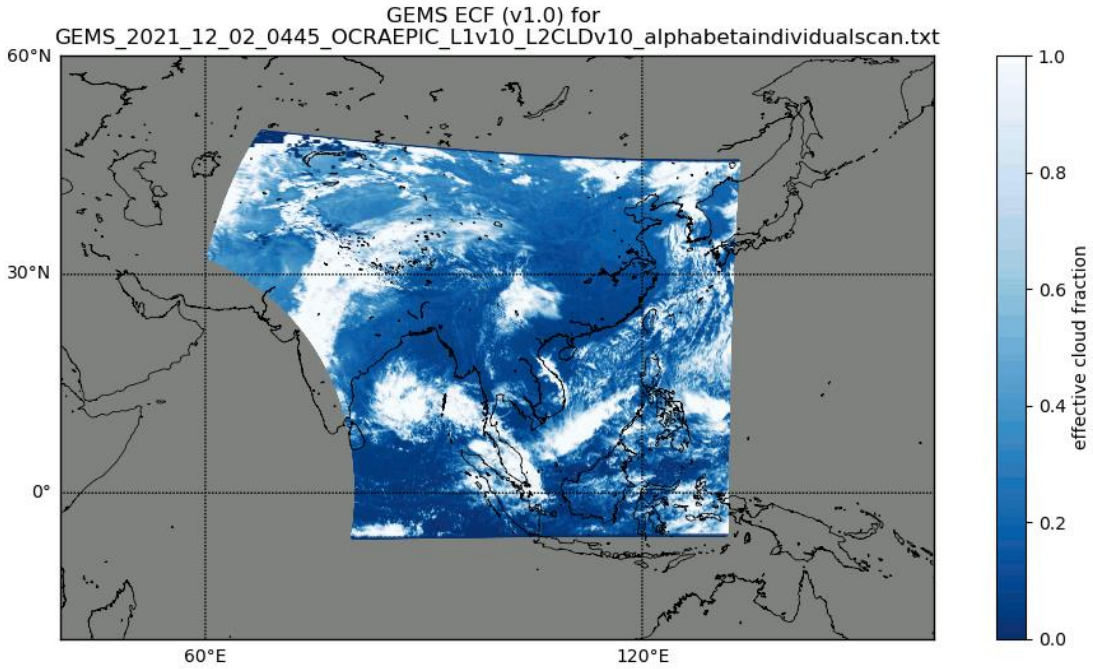
Application to GEMS



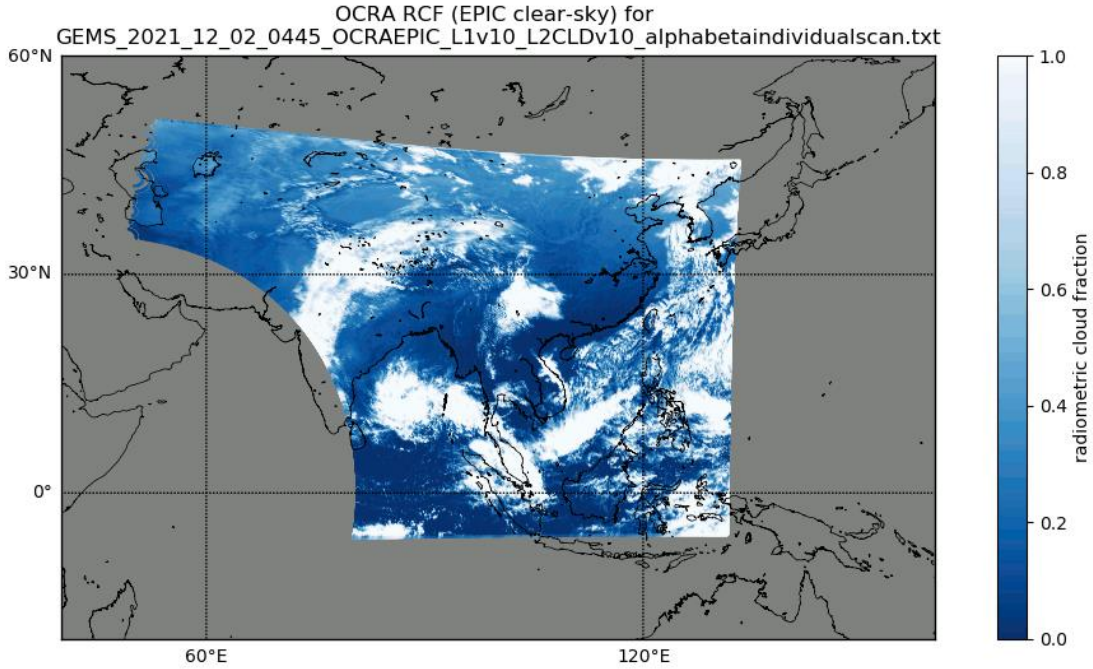
- OCRA applied to GEMS L1 and compared to the operational GEMS L2 Cloud product
- Good agreement of general cloud structures; differences at extreme viewing geometries
- ROCINN cannot be applied because GEMS does not cover the NIR spectral range

Application to GEMS

GEMS L2 Cloud



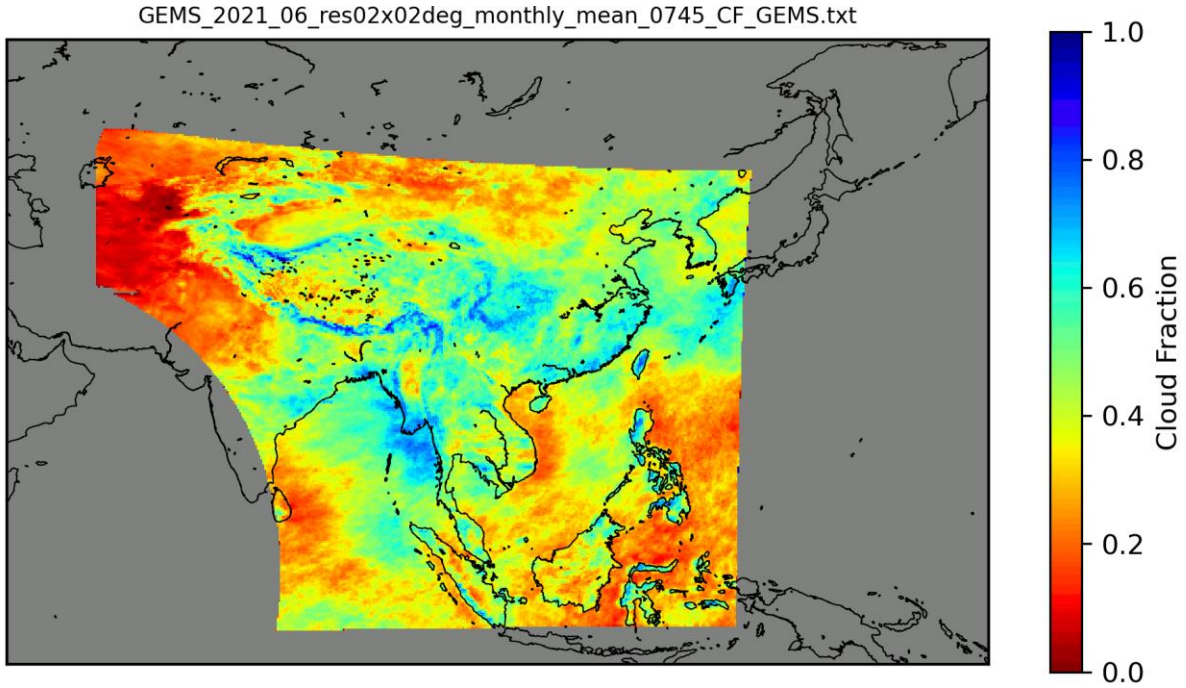
OCRA applied to GEMS L1



- GEMS is an ideal testing ground for our Sentinel-4 processor developments:
  - Inverstigation of diurnal variations
  - Behaviour at extreme viewing geometries
  - Performance testing of the processors when handling real geostationary data

Application to GEMS

GEMS L2 Cloud



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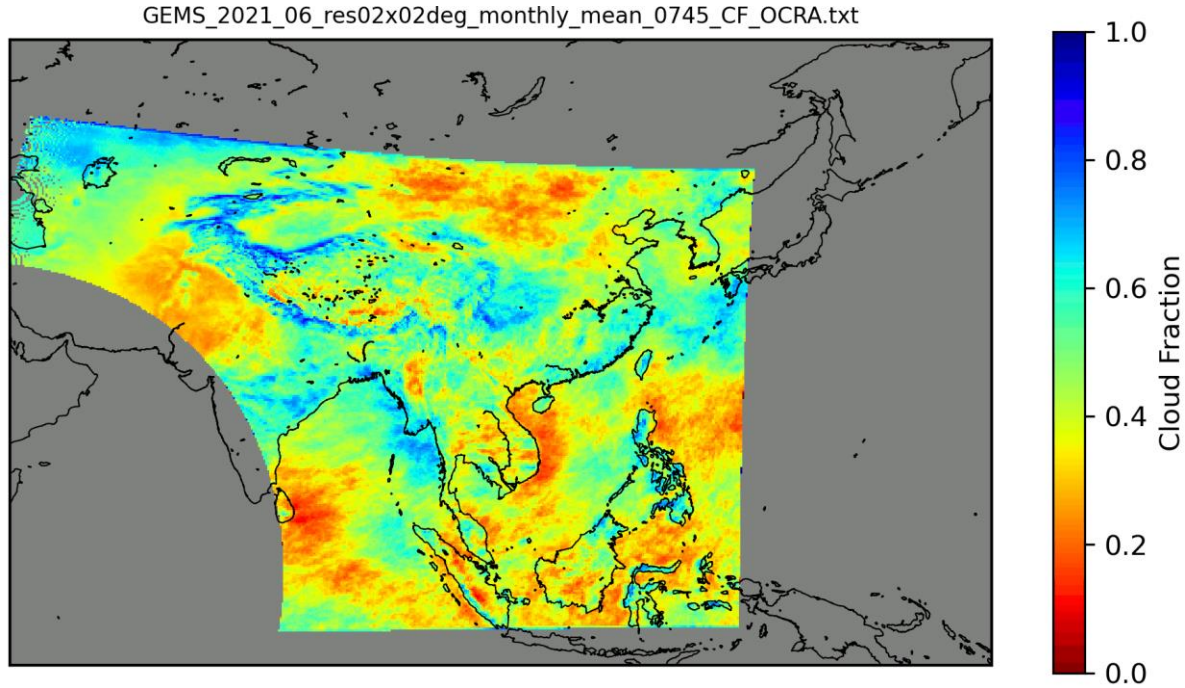
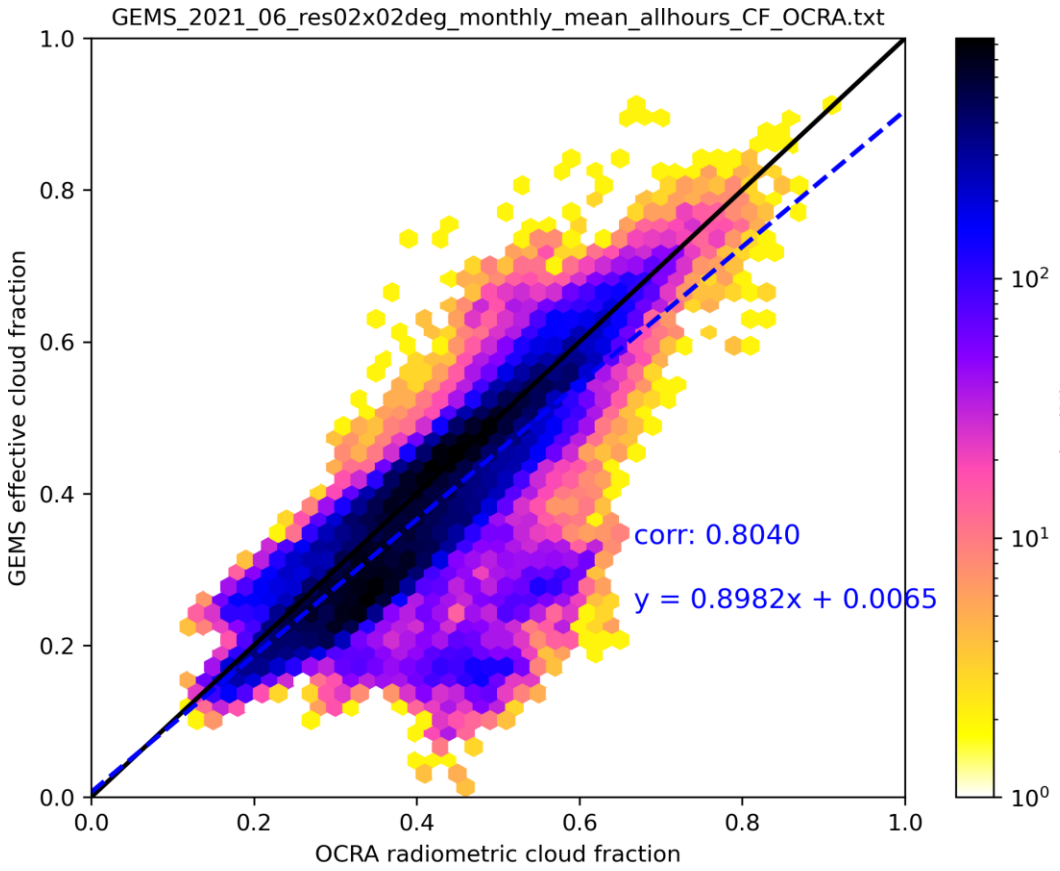
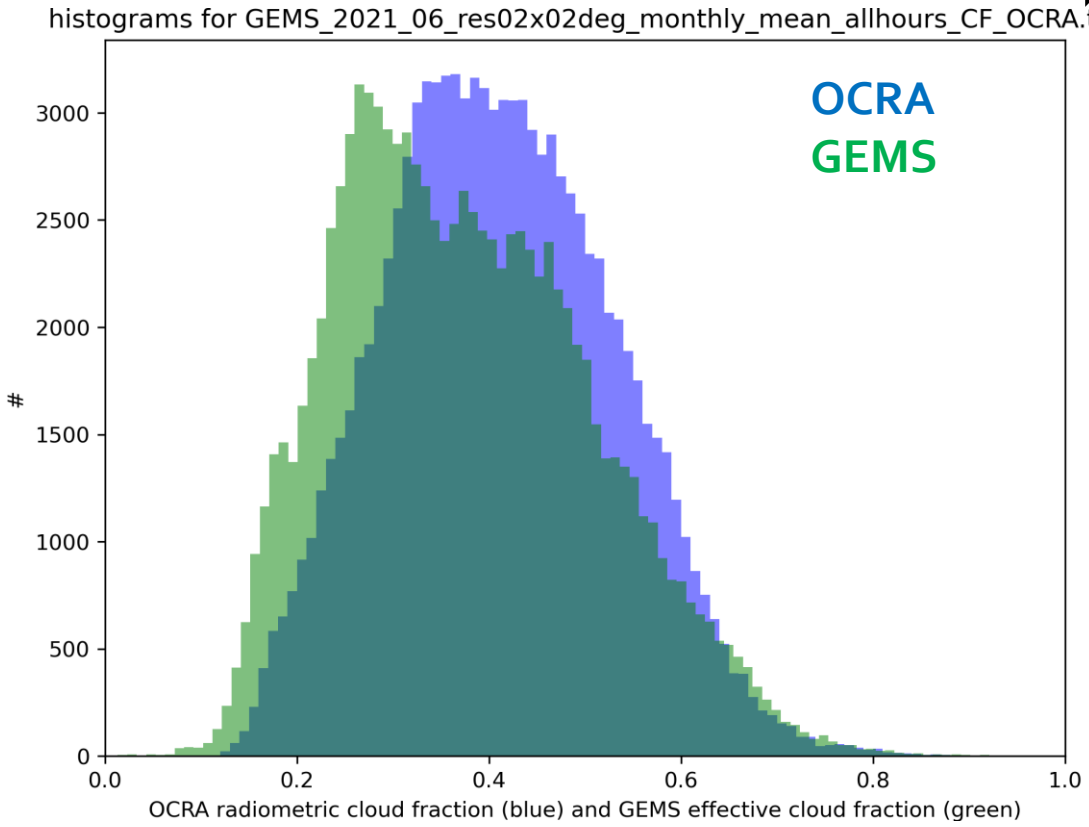


- monthly mean cloud fractions on a regular 0.2° by 0.2° lat/lon grid for each hourly scan
- main structures agree very well

Application to GEMS





- high correlation of 0.80 with slope close to one (0.9) and y-intercept close to zero (0.007)
- histogram shapes agrees well, but peaks are slightly shifted
- “outliers” are coming from regions with extreme solar and/or viewing zenith angles

CONCLUSION AND OUTLOOK

Conclusion and Outlook

Conclusion

- OCRA/ROCINN cloud algorithms have already been successfully implemented for several **LEO** missions in an **operational environment**
- Application of OCRA to the **geostationary** GEMS instrument looks very promising
- OCRA/ROCINN cloud algorithms are ready to be used **operationally for the geostationary Sentinel-4**

Outlook

- Ongoing algorithm developments (**ice cloud** parameterization, …)
- Generation of a consistent OCRA/ROCINN long-term cloud data record **(GOME, SCIAMACHY, GOME-2, S5P, … , S4, S5)**

Thank you for your attention!

Daily quicklook images of trace gases and cloud properties:

- *https://atmos.eoc.dlr.de/calendar*

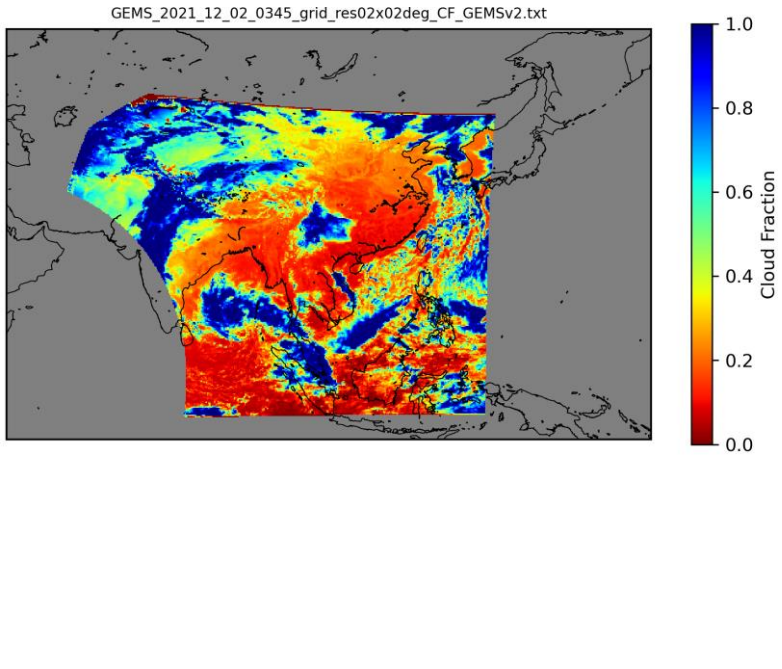
Interested in L3 data? Check the INPULS project:

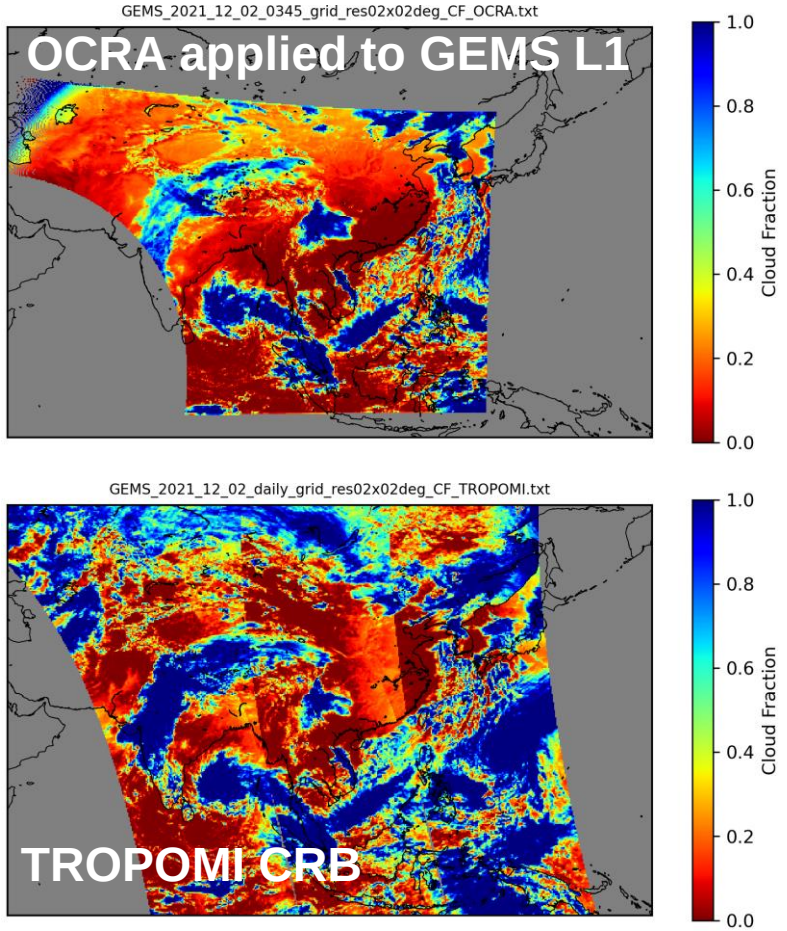
- *https://atmos.eoc.dlr.de/inpuls/*

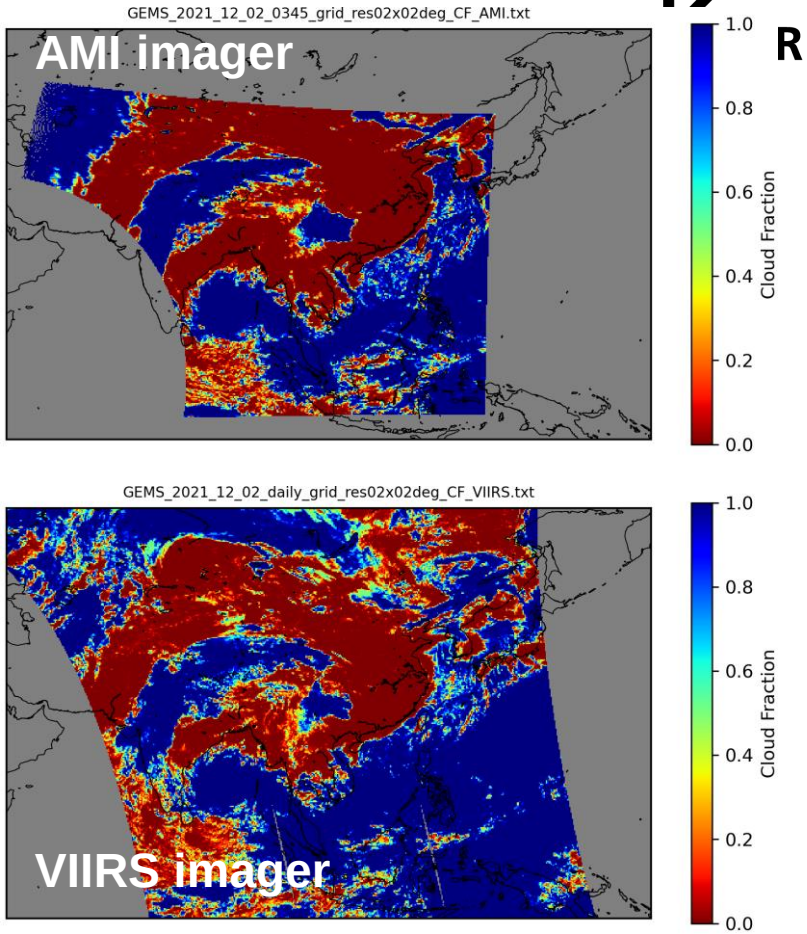
ADDITIONAL SLIDES

Comparison with imagers

GEMS L2



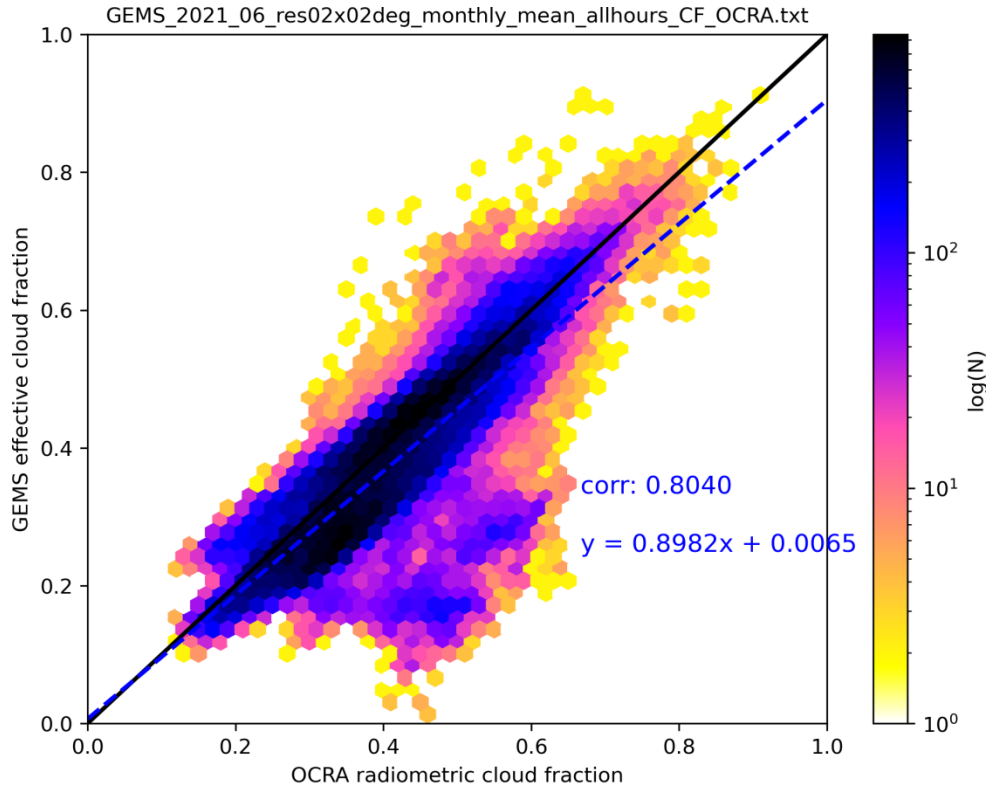




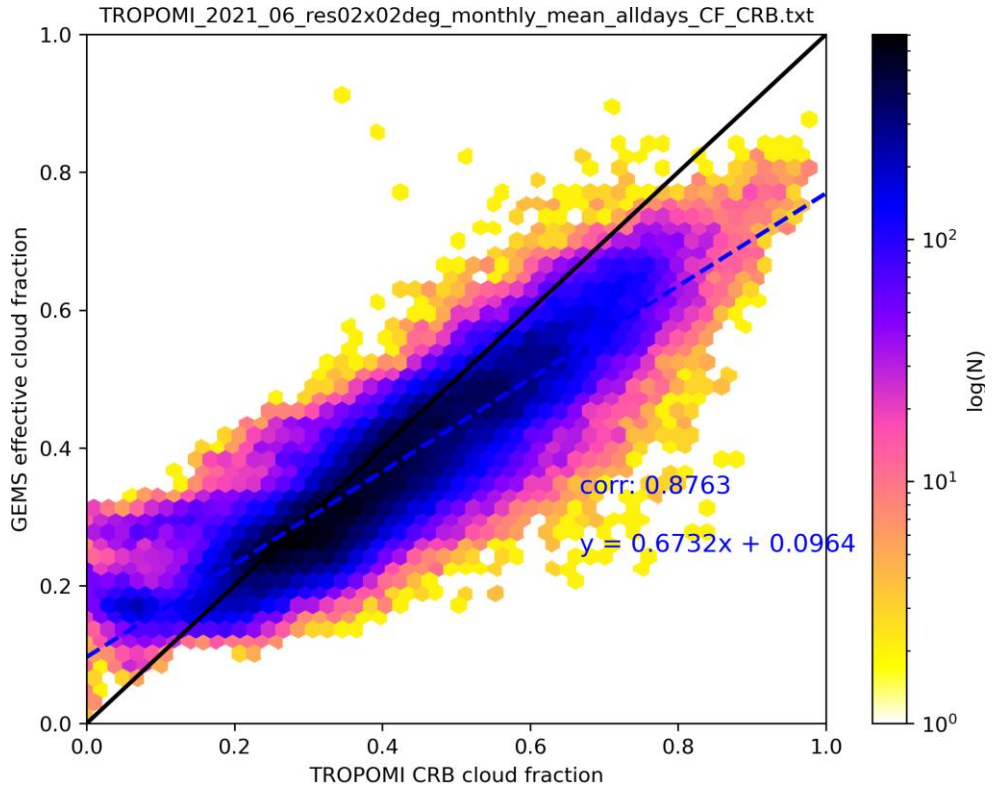
- GEMS L2 effective cloud fraction compares well with radiometric cloud fraction from other UV/VIS sensor s
- Imagers provide geometric cloud fractions and have character of a mask

GEMS L2 Cloud vs OCRA vs TROPOMI CRB

GEMS L2 vs OCRA



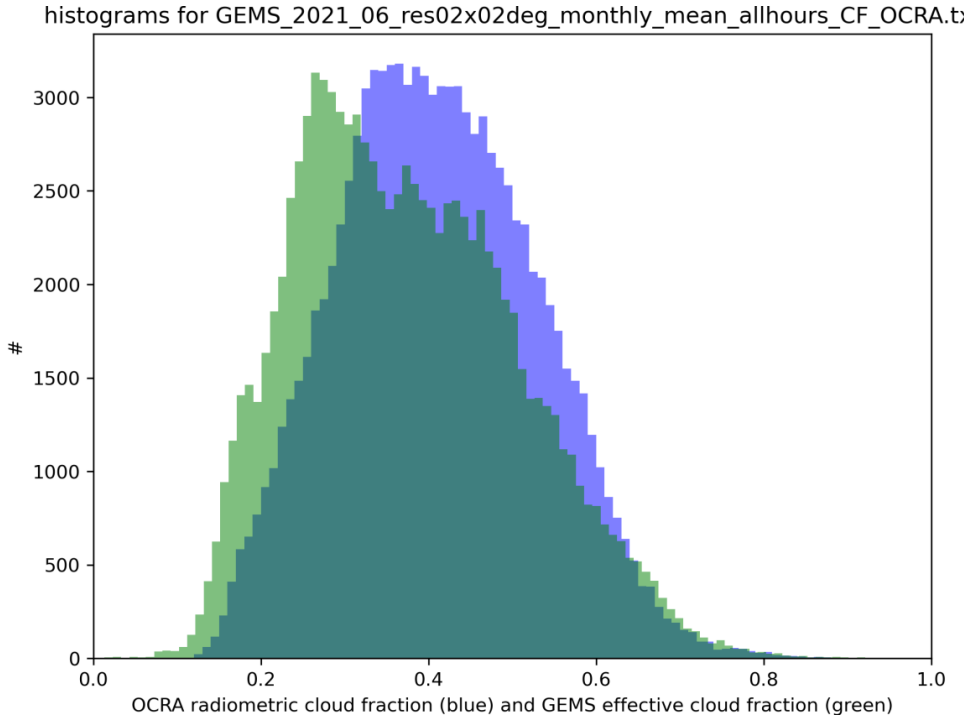
GEMS L2 vs TROPOMI CRB



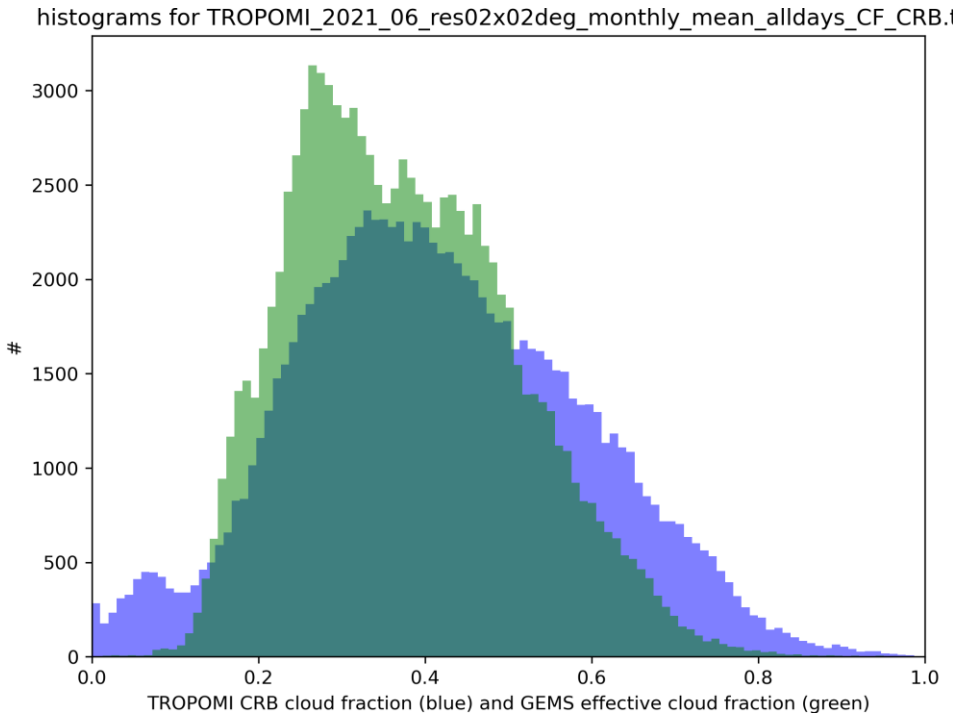
- Correlation of 0.80 for GEMS L2 vs OCRA
- Correlation of 0.88 for GEMS L2 vs TROPOMI CRB
- Outliers in the left plot are due to extreme geometries at the west edge of the scan

GEMS L2 Cloud vs OCRA vs TROPOMI CRB

GEMS L2 vs OCRA



GEMS L2 vs TROPOMI CRB



- GEMS L2 vs OCRA: histogram modes slightly shifted
- GEMS L2 vs TROPOMI CRB: TROPOMI covers slightly broader range