Cloud fraction determination from GOME-2 on MetOp-A/B using the OCRA algorithm

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Introduction

- What is our aim?
  → determine radiometric cloud fraction from GOME-2A/B data (as input for GOME-2 trace gas retrievals in the framework of O3M-SAF)

- How do we want to achieve this?
  → use the information from the Polarization Measurement Devices (PMDs)

- Which tool do we use?
  → Optical Cloud Recognition Algorithm (OCRA), developed for GOME/ERS-2 and used operationally with GOME, SCIAMACHY and GOME-2

- What is the basic idea?
  → distinguish between cloud / no cloud via RGB-color approach

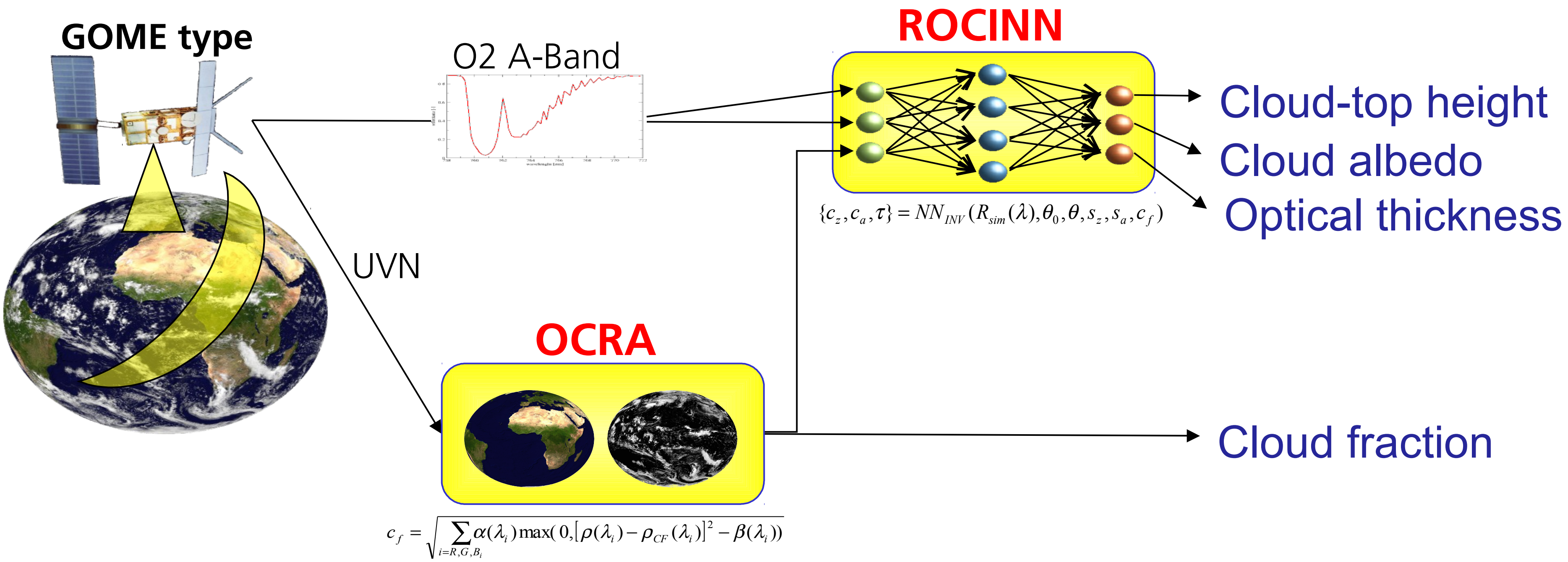
The GOME-2 instrument

- GOME-2 (Global Ozone Monitoring Experiment - 2)
  → GOME-2A on MetOp-A (launched Oct 2006)
  → GOME-2B on MetOp-B (launched Sept 2012)

- nadir-viewing optical spectrometer UV/VIS 240-790nm

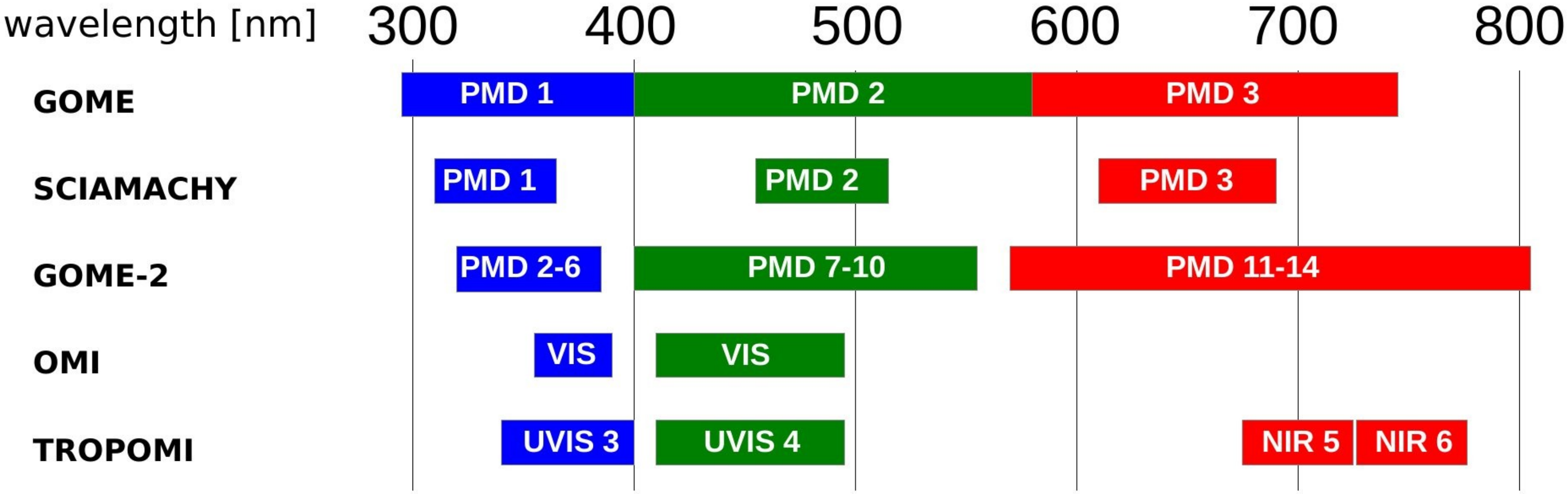
- Polarization Measurement Devices (PMDs)
  → linear polarization (parallel and perpendicular to entrance slit)
  → 15 spectral bands in the region 312-800nm
  → 192 across-track PMD pixel (resolution 10km x 40km)
  → 1920km nominal swath size

Cloud parameter with OCRA & ROCINN



OCRA: **O**ptical **C**loud **R**ecognition **A**lgorithm
ROCINN: **R**etrieval **O**f **C**loud **I**nformation through **N**eural **N**etworks

RGB definitions for OCRA

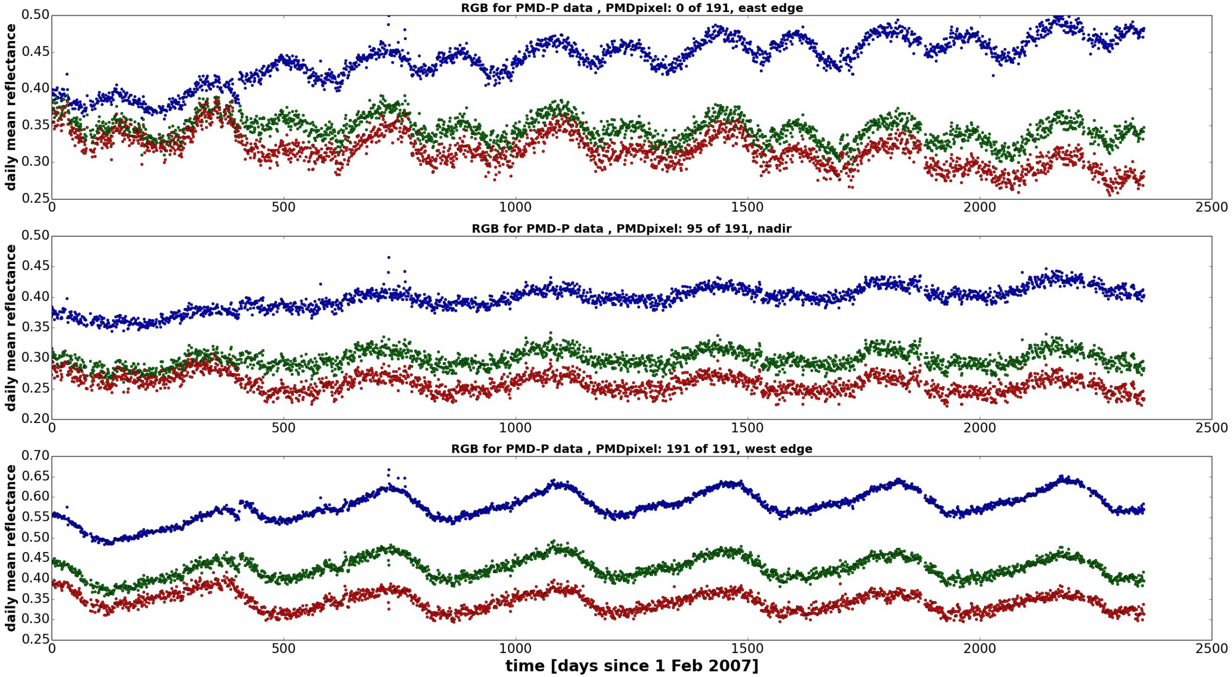


wavelength ranges and bands used by OCRA for different sensors to determine the colors B, G and R

Data input and reduction

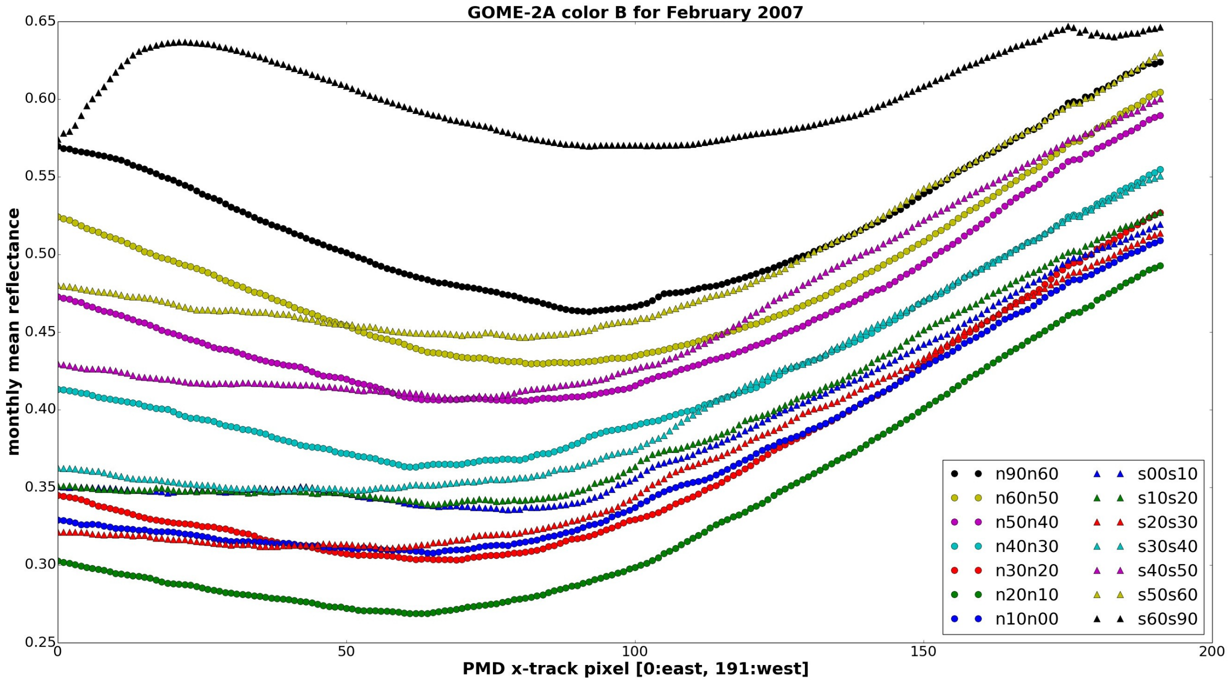
- OCRA for GOME-2 uses the ***PMD data*** with a resolution of 10km x 40km
- mapping of PMD data to RGB-colors
- GOME-2A: data since February 2007
- GOME-2B: data since January 2013
- for the cloud free composites, we use only 1920km swath data from
  → April 2008 until June 2013 (GOME-2A)
- PMD reflectances are corrected for
  → instrumental degradation
  → dependencies on viewing angle and latitude

Data input and reduction



- PMD reflectances are corrected for
  - → instrumental degradation: here G2A, 3rd order polynomial component
  - → dependencies on viewing angle and latitude

Data input and reduction



- PMD reflectances are corrected for
  - → instrumental degradation
  - → dependencies on viewing angle and latitude: 4^{th} order polynomial + linear splines

Method – OCRA

- define grid with resolution of 0.2° x 0.2°

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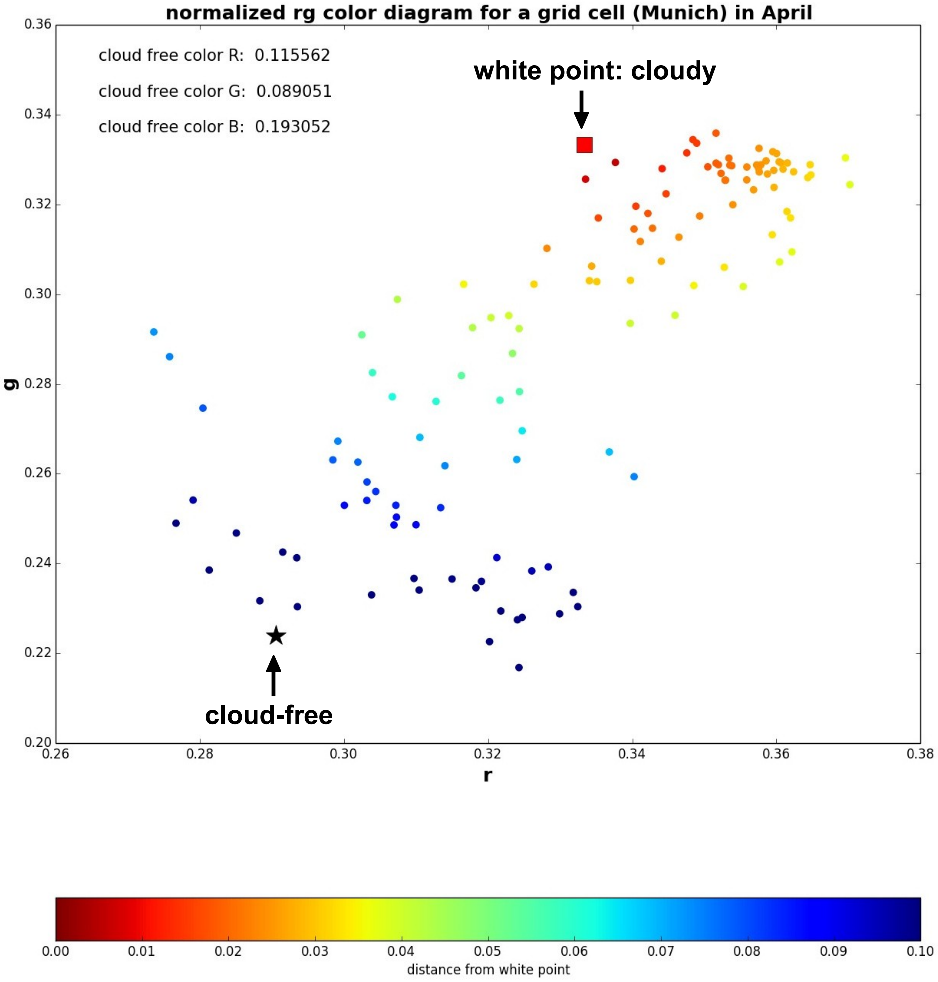
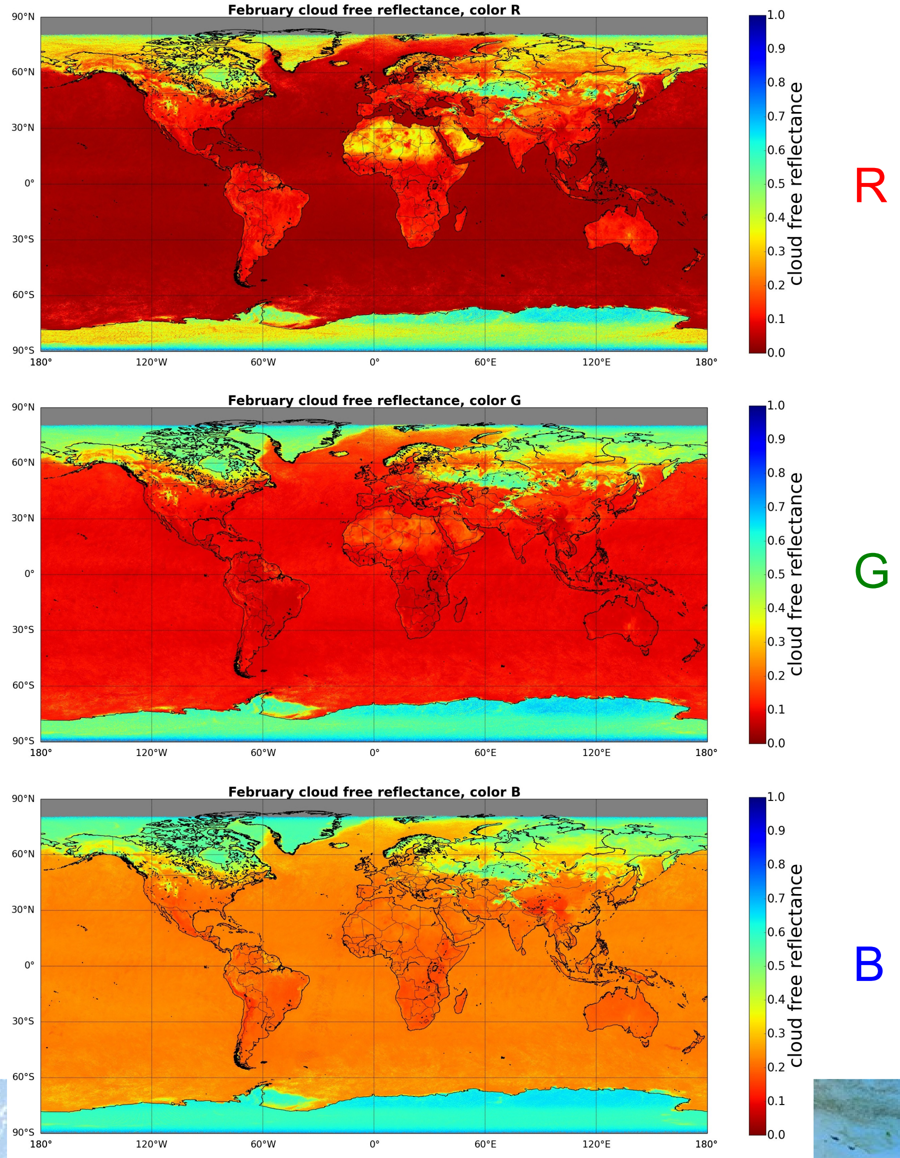
- define grid with resolution of 0.2° x 0.2°
- determine cloud free reflectance for each grid cell



Method – OCRA

- define grid with resolution of 0.2° x 0.2°
- determine cloud free reflectance for each grid cell
- merge all cloud free cells to obtain global cloud free maps for all 12 months and colors R, G and B (and polarizations P, S)



Method – OCRA

- define grid with resolution of 0.2° x 0.2°

- determine cloud free reflectance for each grid cell

- merge all cloud free cells to obtain global cloud free maps for all 12 months and colors R, G and B (and polarizations P, S)

- determine cloud fraction

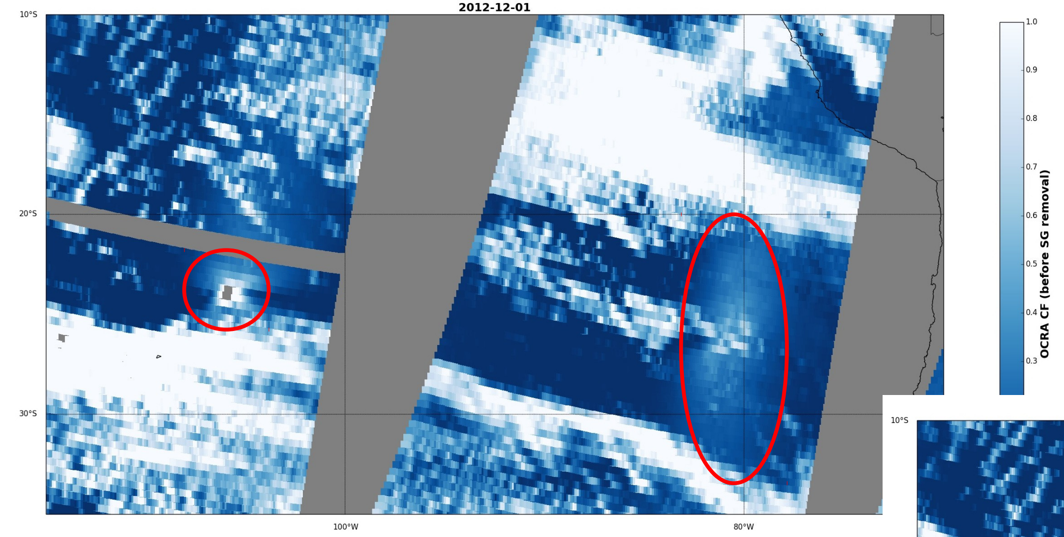
cloud-free reflectances for R,G,B

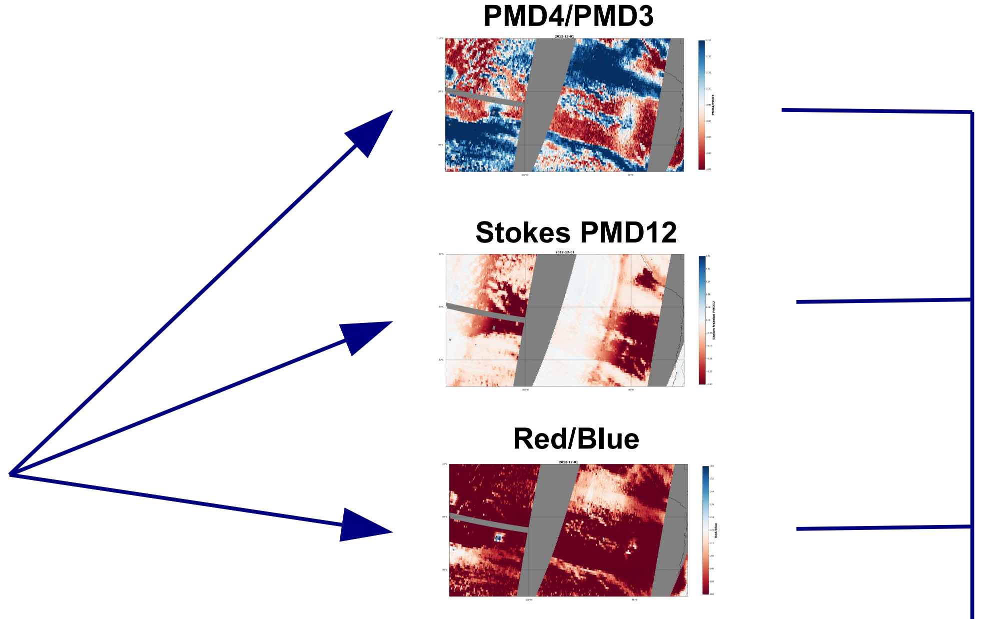
$$c_f = \min\left\{1, \sqrt{\sum_{i=R,G,B} \alpha(\lambda_i)\cdot \max\left\{0, [\rho(\lambda_i) - \rho_{CF}(\lambda_i) - \beta(\lambda_i)]\right\}^2}\right\}$$

reflectances for R,G,B

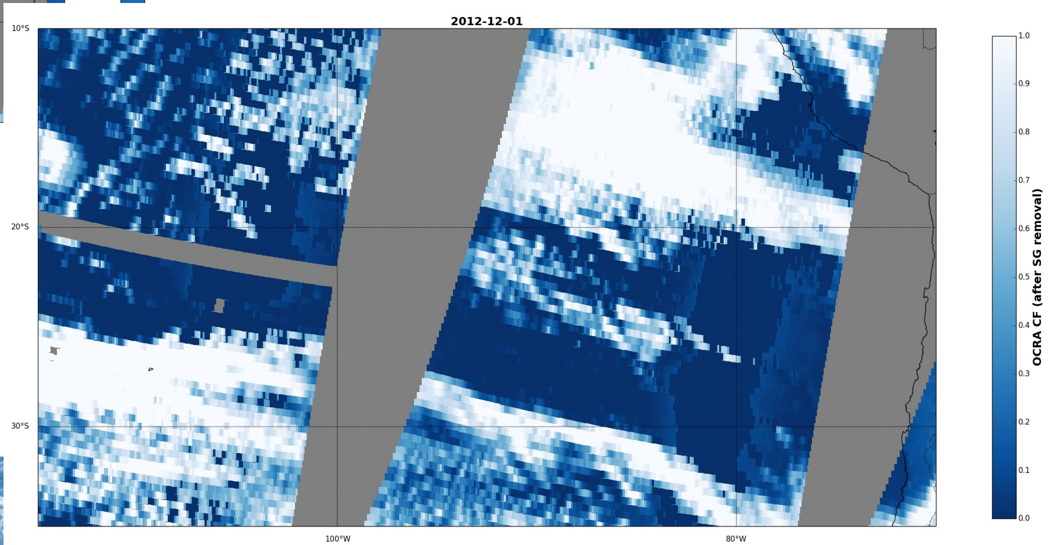
$$\rho = \frac{\pi \cdot I_E}{I_\odot \cdot \cos\vartheta_\odot}$$

Method – OCRA

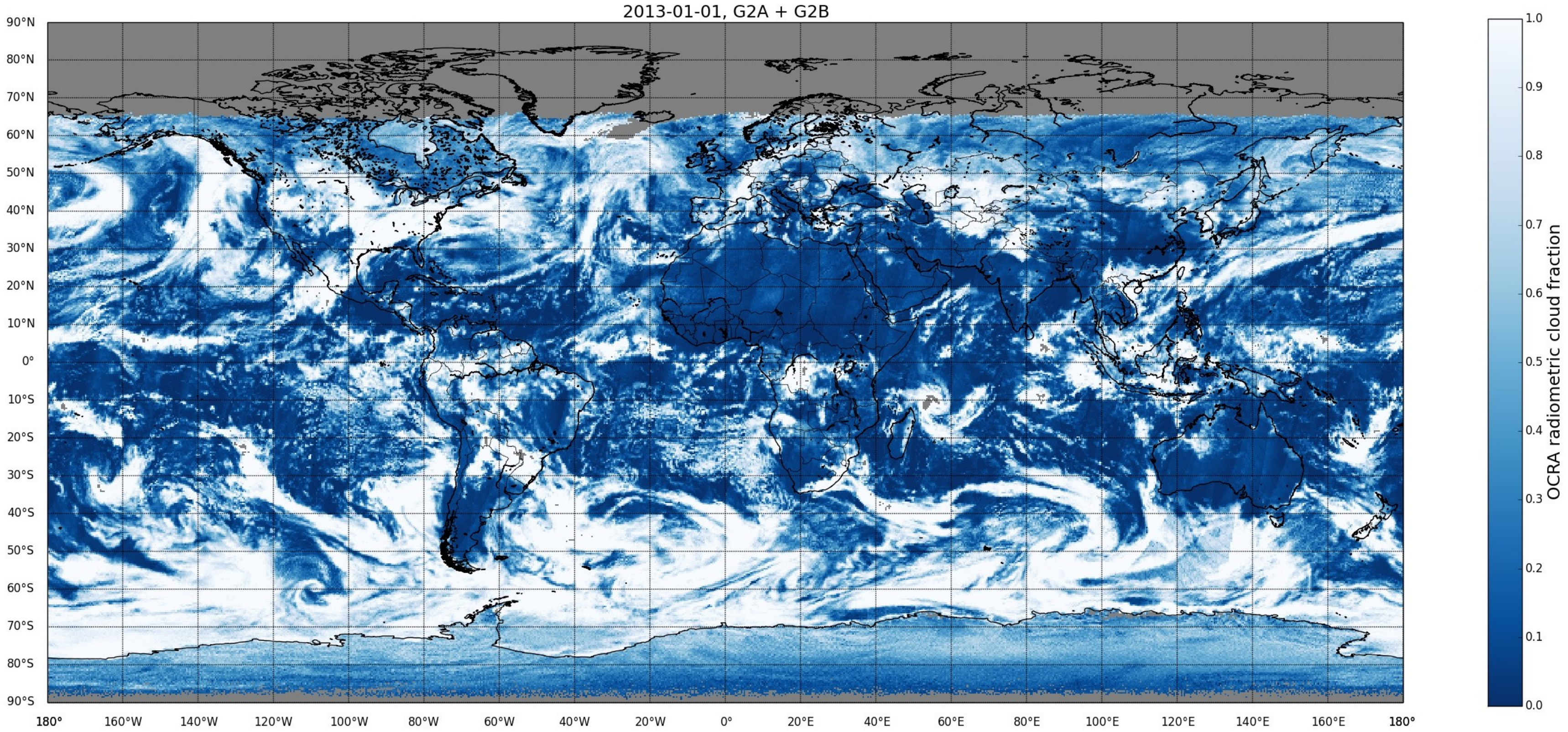




- improved Sun-glint flagging and removal of Loyola et al. (2011)



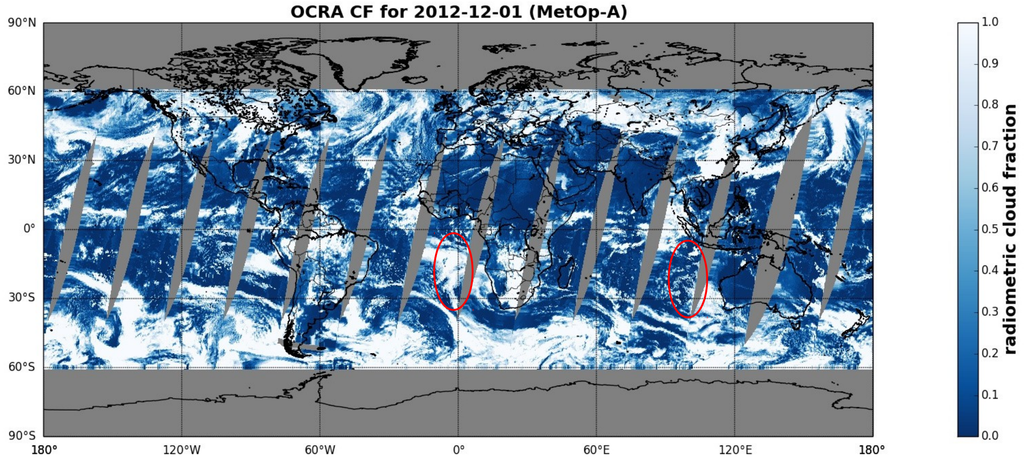
Method – OCRA

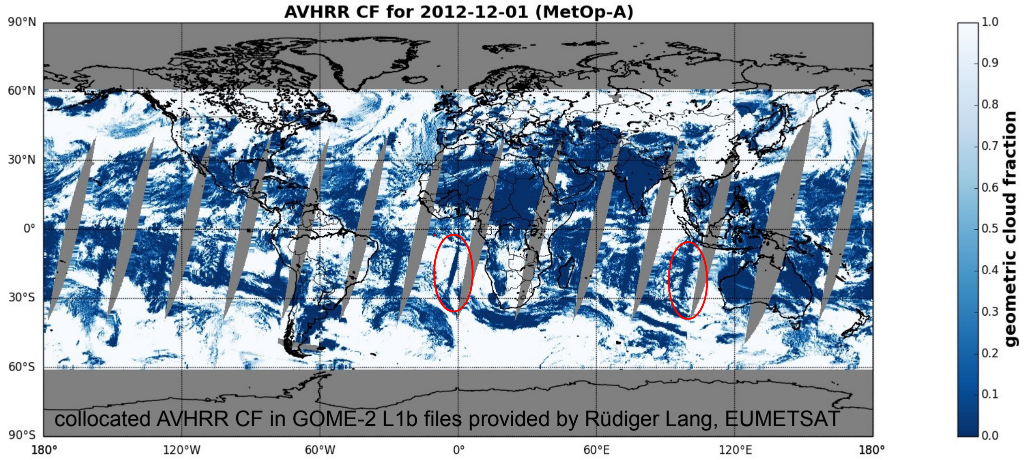


- final product: radiometric cloud fraction (G2A+G2B merged together)

Results – Comparison with AVHRR

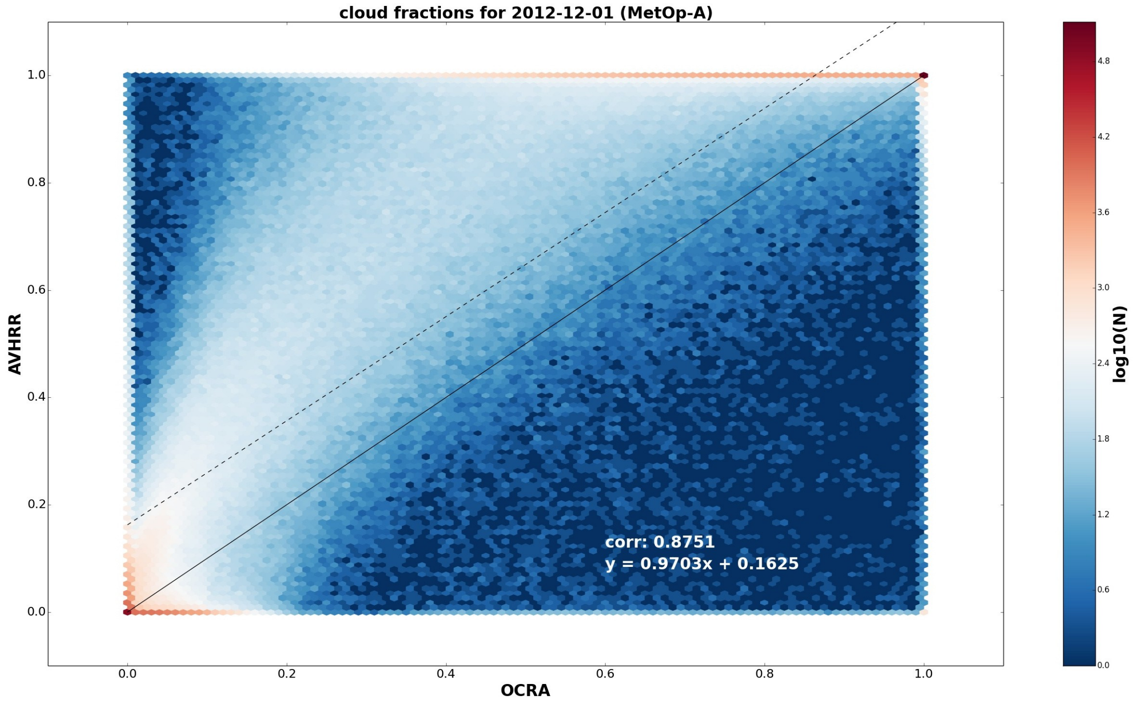
- both products on PMD resolution
- general features agree well





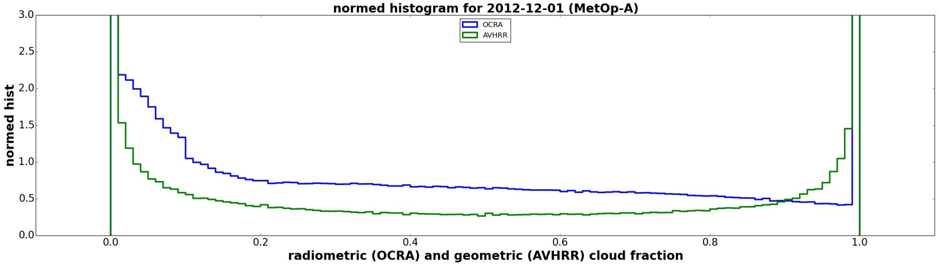
Results – Comparison with AVHRR

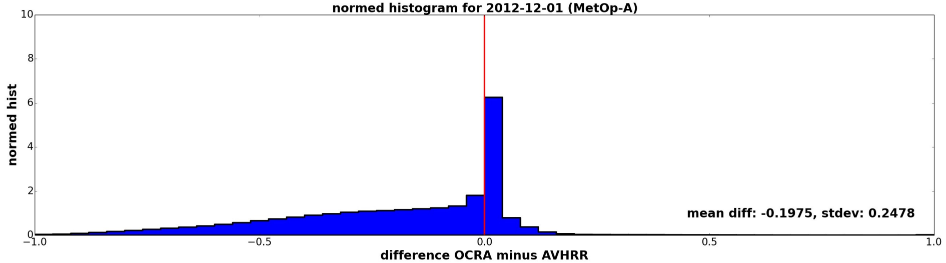
- both products on PMD resolution
- general features agree well
- AVHRR geometrical cloud fractions are as expected systemetically higher than GOME-2 radiometric cloud fractions



Results – Comparison with AVHRR

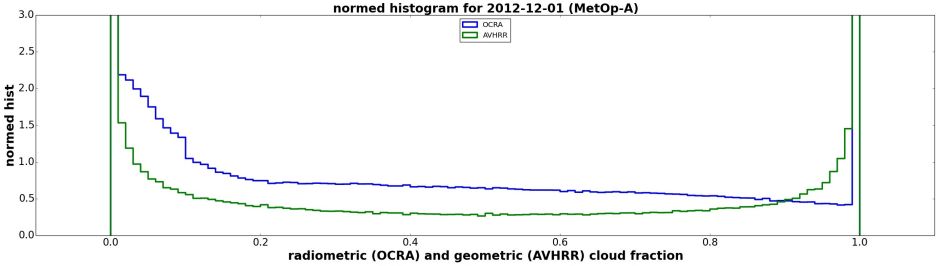
- both products on PMD resolution
- general features agree well
- AVHRR systematically higher
- GOME-2: no IR channels
  → insensitive to clouds with
  low opt. thickness, e.g. cirrus

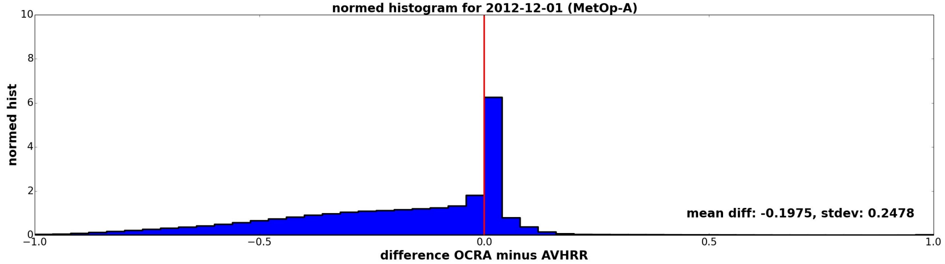


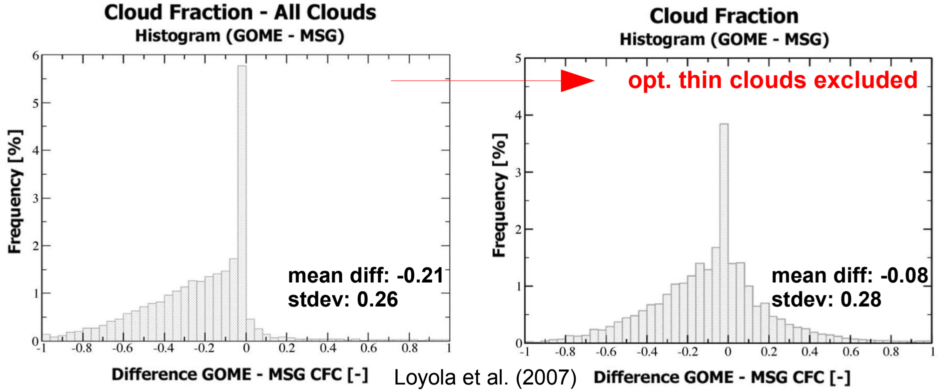


Results – Comparison with AVHRR

- both products on PMD resolution
- general features agree well
- AVHRR systematically higher
- GOME-2: no IR channels → insensitive to clouds with low opt. thickness, e.g. cirrus
- similar to GOME/ERS-2 versus SEVIRI/MSG

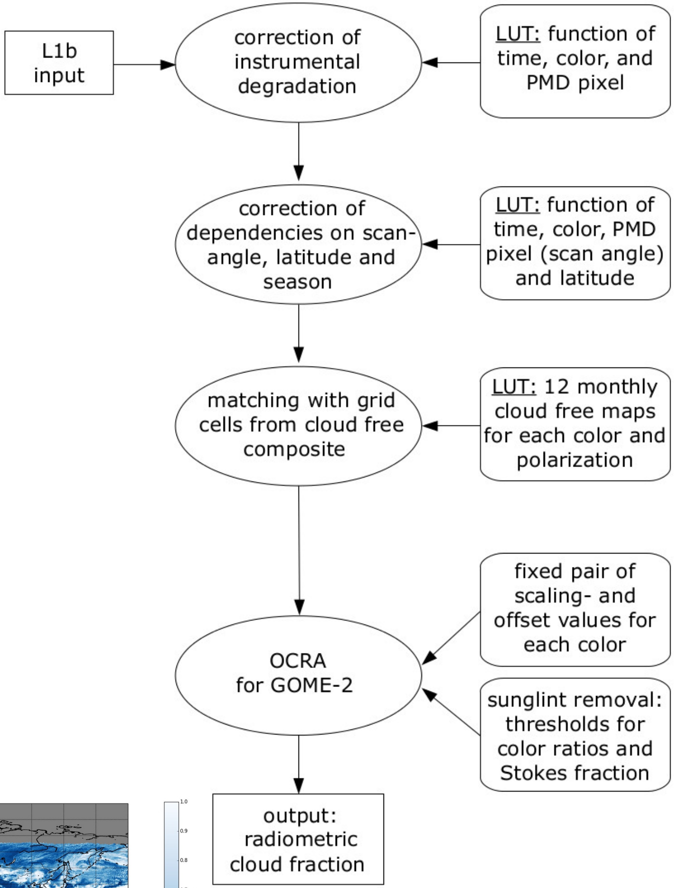




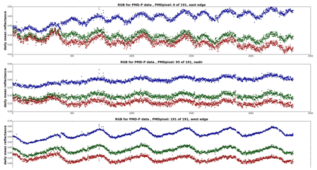


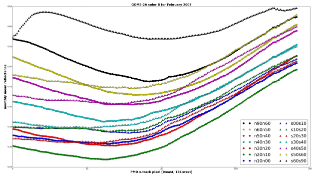
Loyola et al. (2007)

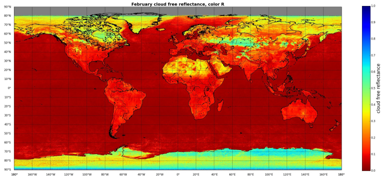
Summary

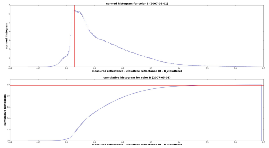


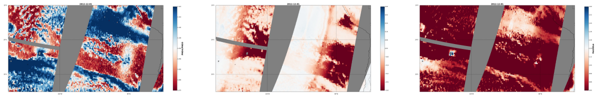
L1b input
correction of instrumental degradation
LUT: function of time, color, and PMD pixel
correction of dependencies on scan-angle, latitude and season
LUT: function of time, color, PMD pixel (scan angle) and latitude
matching with grid cells from cloud free composite
LUT: 12 monthly cloud free maps for each color and polarization
OCRA for GOME-2
fixed pair of scaling- and offset values for each color
sunglint removal: thresholds for color ratios and Stokes fraction
output: radiometric cloud fraction

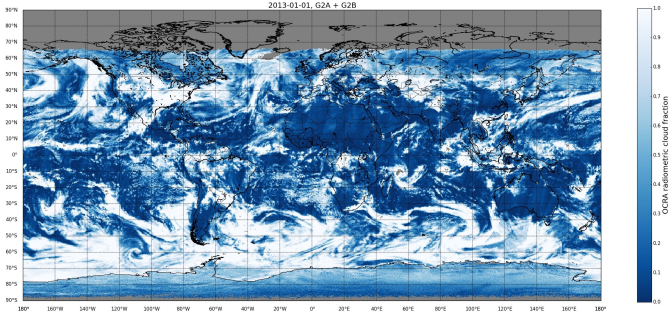












2013-01-01, G2A + G2B
OCRA radiometric cloud fraction

Summary

- OCRA is a fast way to determine radiometric cloud fraction (ca. 20s per GOME-2 orbit)

- OCRA is simple (RGB color approach) and robust

- OCRA concept is transferable to future instruments (e.g. TROPOMI on Sentinel-5p)

- new OCRA features: → PMD corrections for degradation and viewing angle dependencies
  → cloud free composites based on GOME-2 data (2008-2013)
  → improved Sun glint flagging and removal

- GOME-2 vs. AVHRR comparisons consistent with published GOME vs. SEVIRI comparisons

- The updated OCRA algorithm will be used for reprocessing the operational GOME-2 trace gas products from O3M-SAF

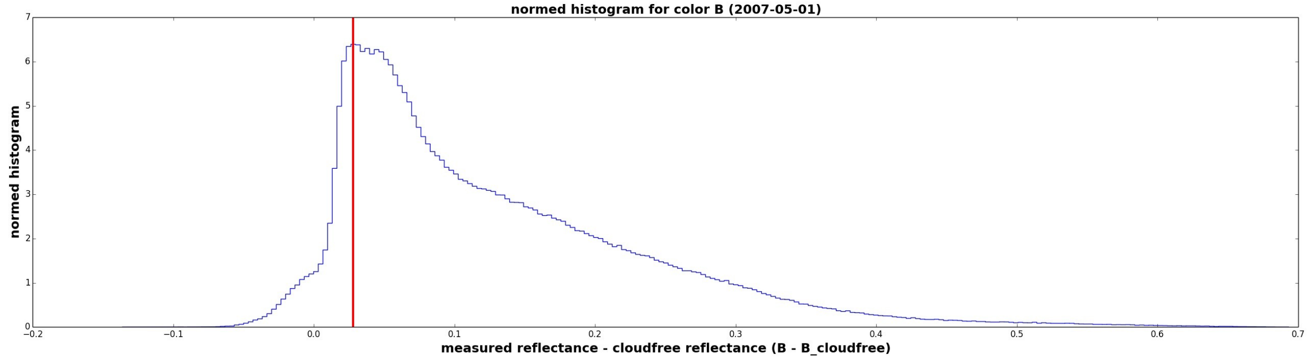
Thank you for your attention!

Additional slide – histogram analysis for scaling factors and offset values

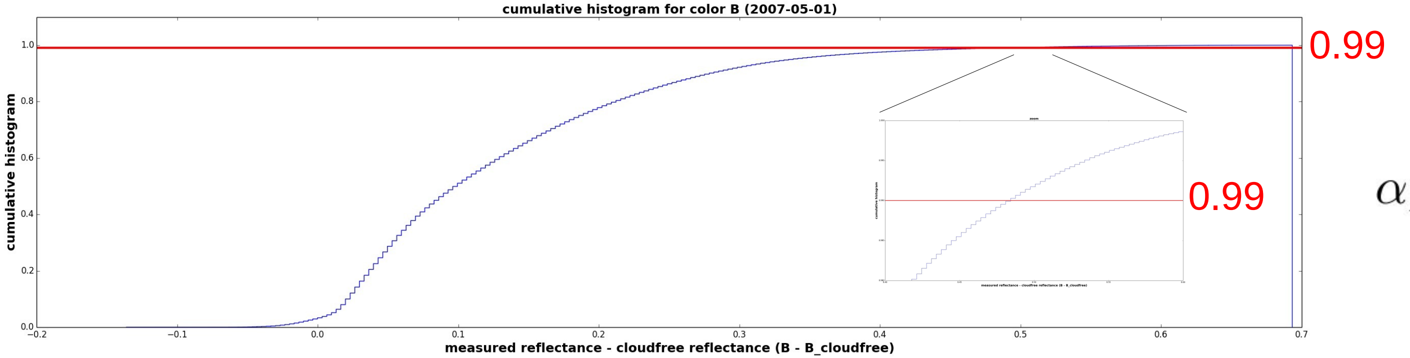
- determine cloud fraction

$$f = \min\left[1, \sqrt{B_{CF} + G_{CF} + R_{CF}}\right]$$

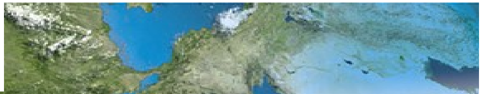
$$B_{CF} = \alpha_B \cdot \max\left[0, (B - B_{free} - \beta_B)\right]^2$$
$$G_{CF} = \alpha_G \cdot \max\left[0, (G - G_{free} - \beta_G)\right]^2$$
$$R_{CF} = \alpha_R \cdot \max\left[0, (R - R_{free} - \beta_R)\right]^2$$



$$\beta_X = (X - X_{free})_{\text{mode}}$$



$$\alpha_X = \frac{1}{(X - X_{free})^2_{0.99}}$$



Additional slide – OCRA

OCRA provides a fast, robust and accurate determination of (radiometric) cloud fraction

reflectance normalization compensates possible instrument / L1 issues

cloud-free composites are produced from data of the same instrument

caution with direct comparison of cloud fractions:
→ dependence on surface albedo, cloud model, wavelength bands, ...
→ distinguish between *effective CF*, *radiometric CF*, *geometrical CF*

caution over snow/ice

transferability to other sensor types: OCRA, which was developed and is used operationally for GOME-type sensors (using the PMD measurements), can also be adapted to OMI-type sensors (using the radiance measurements)

Additional slide – References and Acknowledgements

- Loyola (1998)
A new cloud recognition algorithm for optical sensors

- Loyola et al. (2007)
Cloud properties derived from GOME/ERS-2 backscatter data for trace gas retrieval

- Loyola et al. (2011)
The GOME-2 total column ozone product: Retrieval algorithm and ground-based validation

- Thanks to Rüdiger Lang (EUMETSAT) for providing the pre-operational AVHRR CFs collocated to GOME-2 PMD ground pixels