Cloud fraction determination for OMI using the OCRA algorithm

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DLR

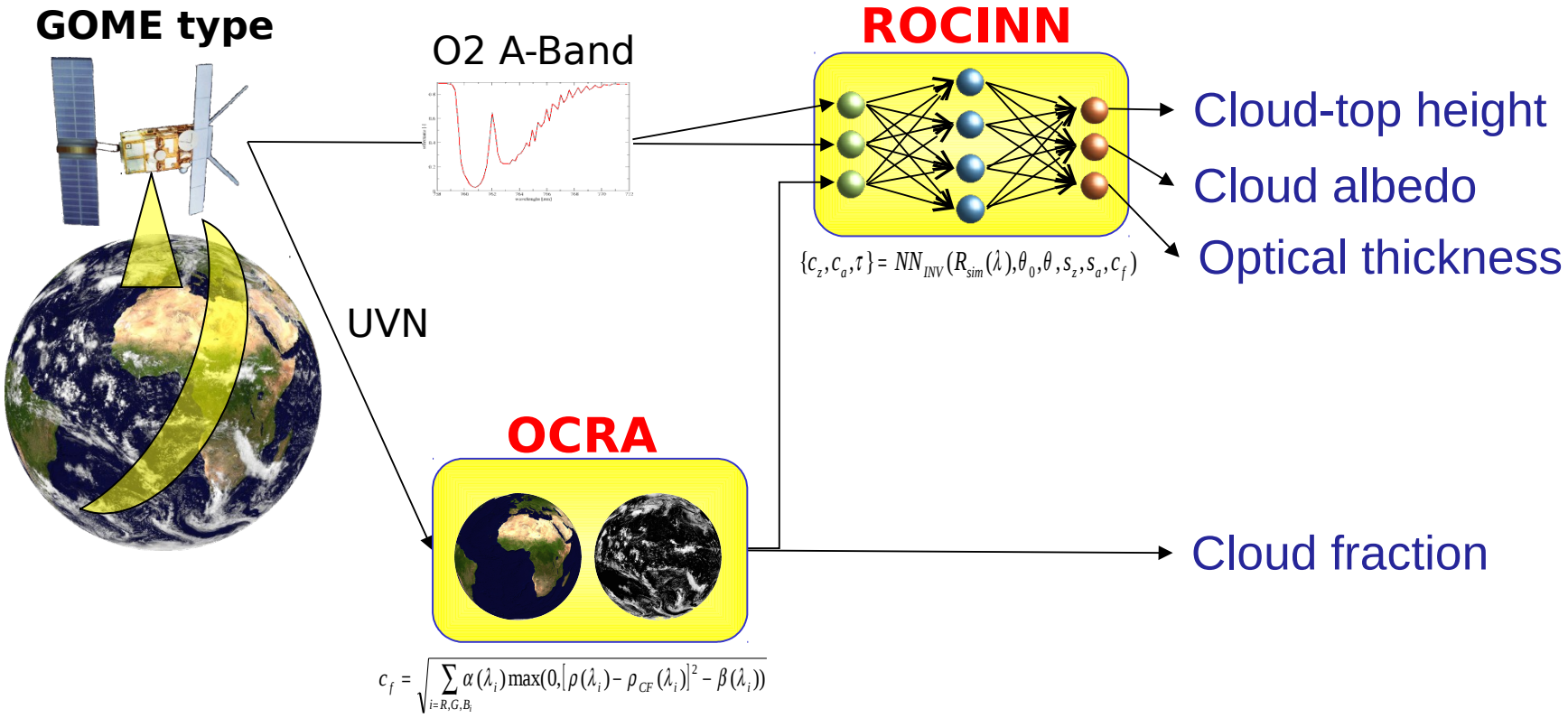
Outline

- Introduction
- OCRA adaption to OMI data
- OCRA comparisons with official OMI cloud products
- Discussion
- Outlook

Introduction – Sentinel 5 Precursor L2 Products

Product Coordinator	Algorithm Prototyping KNMI	Independent Verification IUP	Operational Processor DLR-IMF
O_3 total column	DLR/BIRA	KNMI	DLR
O_3 profile (incl. troposphere)	KNMI	RAL/IUP	KNMI
O_3 tropospheric column	IUP/DLR	KNMI	DLR
NO_2 total & tropospheric	KNMI	IUP/DLR/MPIC	KNMI
SO_2	BIRA	MPIC/DLR	DLR
HCHO	BIRA	IUP	DLR
CO	SRON	IUP	KNMI
CH_4	SRON	IUP	KNMI
Clouds	DLR	KNMI/MPIC/IUP	DLR
Aerosols	KNMI	MPIC/IUP	KNMI
...			

Introduction – 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

Introduction – OCRA adaption to S5P/TROPOMI

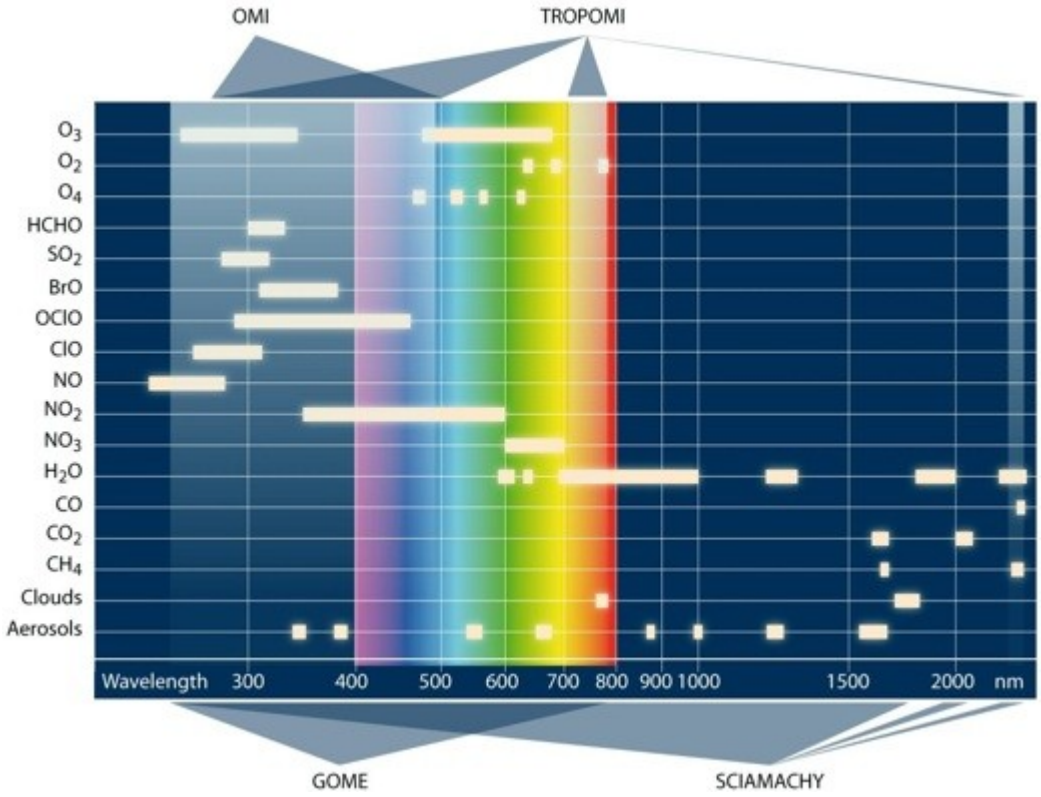


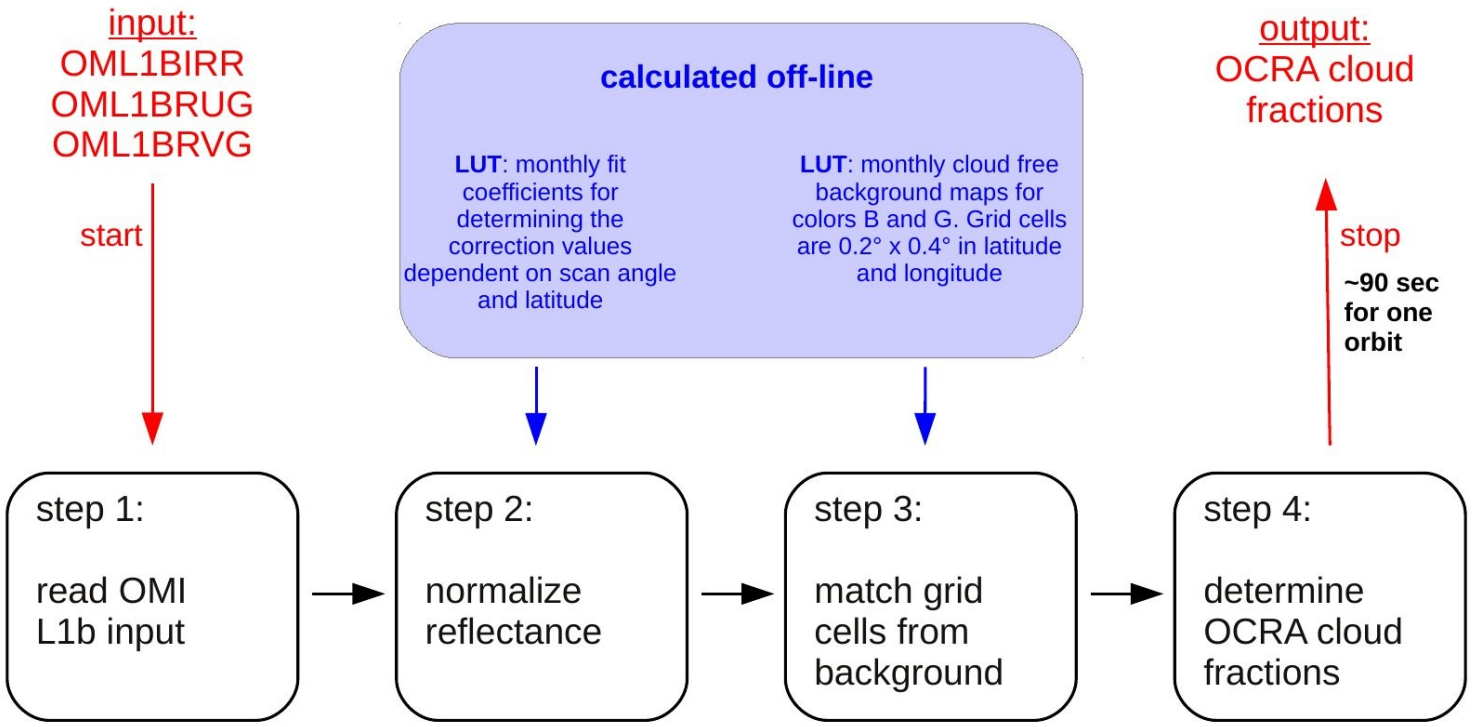
Figure from Veefkind et al. (2012)

OCRA for GOME, SCIAMACHY and GOME-2 uses the ***PMD data*** with a resolution of ~10x40km2

OCRA for OMI uses ***radiance data*** from UV-2 and VIS bands with a resolution of ~13x24km2

OCRA for TROPOMI will use the UVN ***radiance data*** with a resolution of 7x7km2

OCRA – flowchart

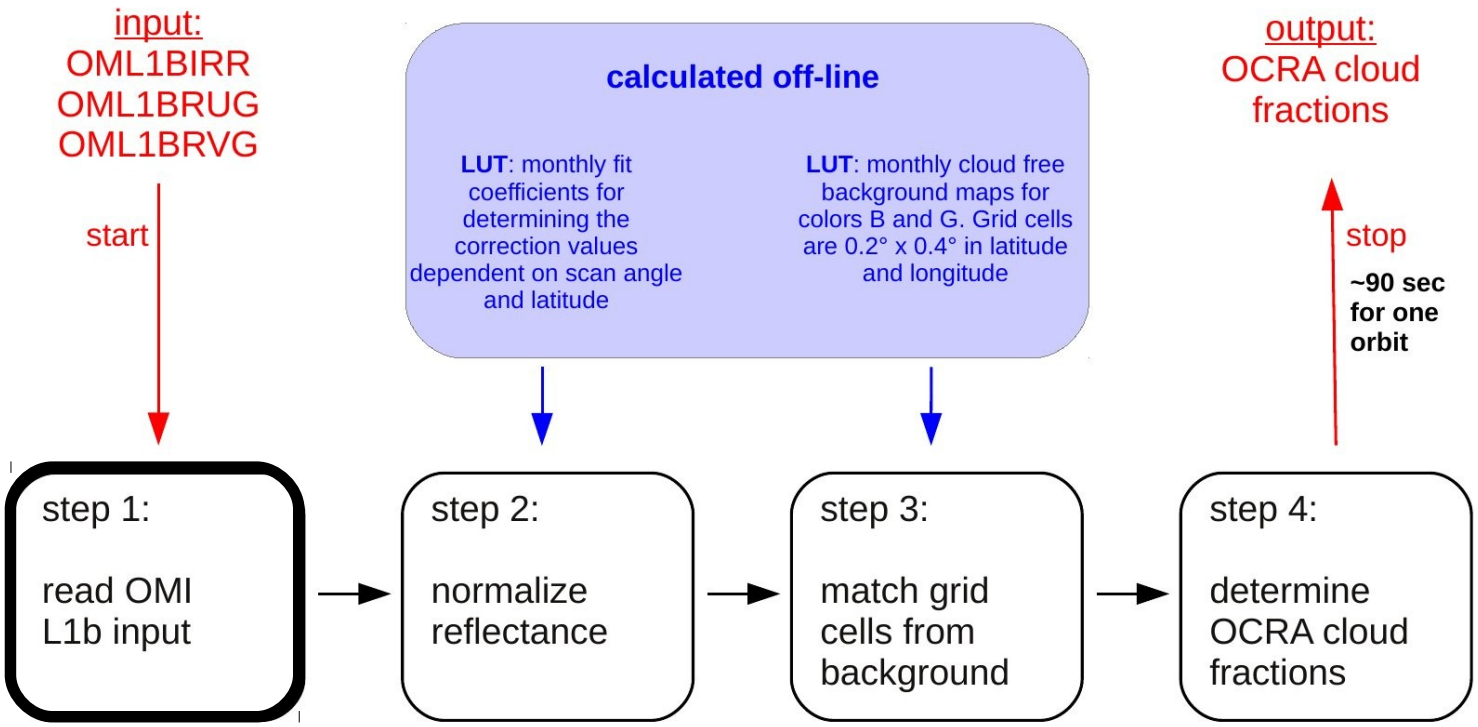


- scan angle dependency calculated for 60 across-track OMI pixel
- latitudinal dependency calculated for eight zonal bands
- fit coefficients for each month of the mission

- the daily cloud-free background of a grid cell is obtained via linear interpolation between the two adjacent monthly maps
- cloud-free background maps for each month of the year

- scaling factors and offset values for OCRA are determined per day and are very stable over long timescales, such that one can use a fixed set

OCRA – flowchart



OCRA – OMI data used

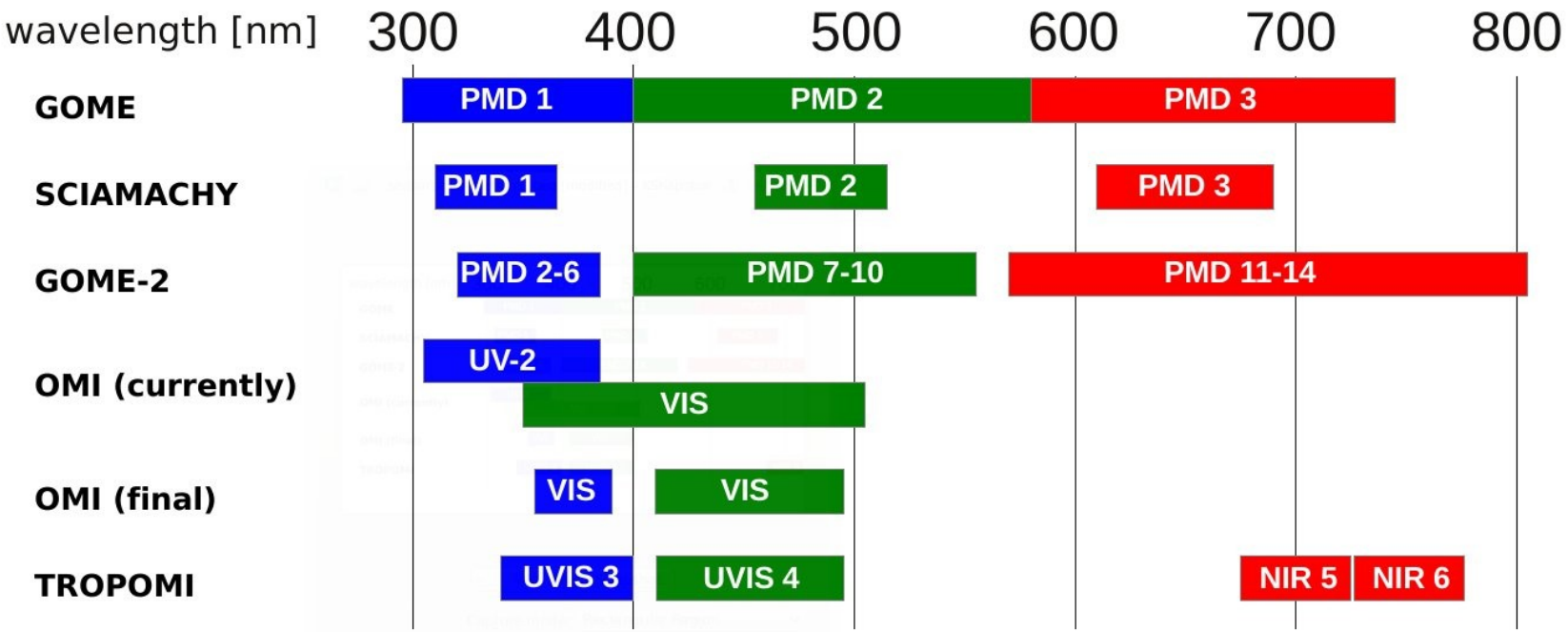
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2004												
2005												
2006												
2007												
2008												

Input data products:
OML1BIRR, OML1BRUG, OML1BRVG (product version 003)

All data considered are NOT affected by OMI row anomaly

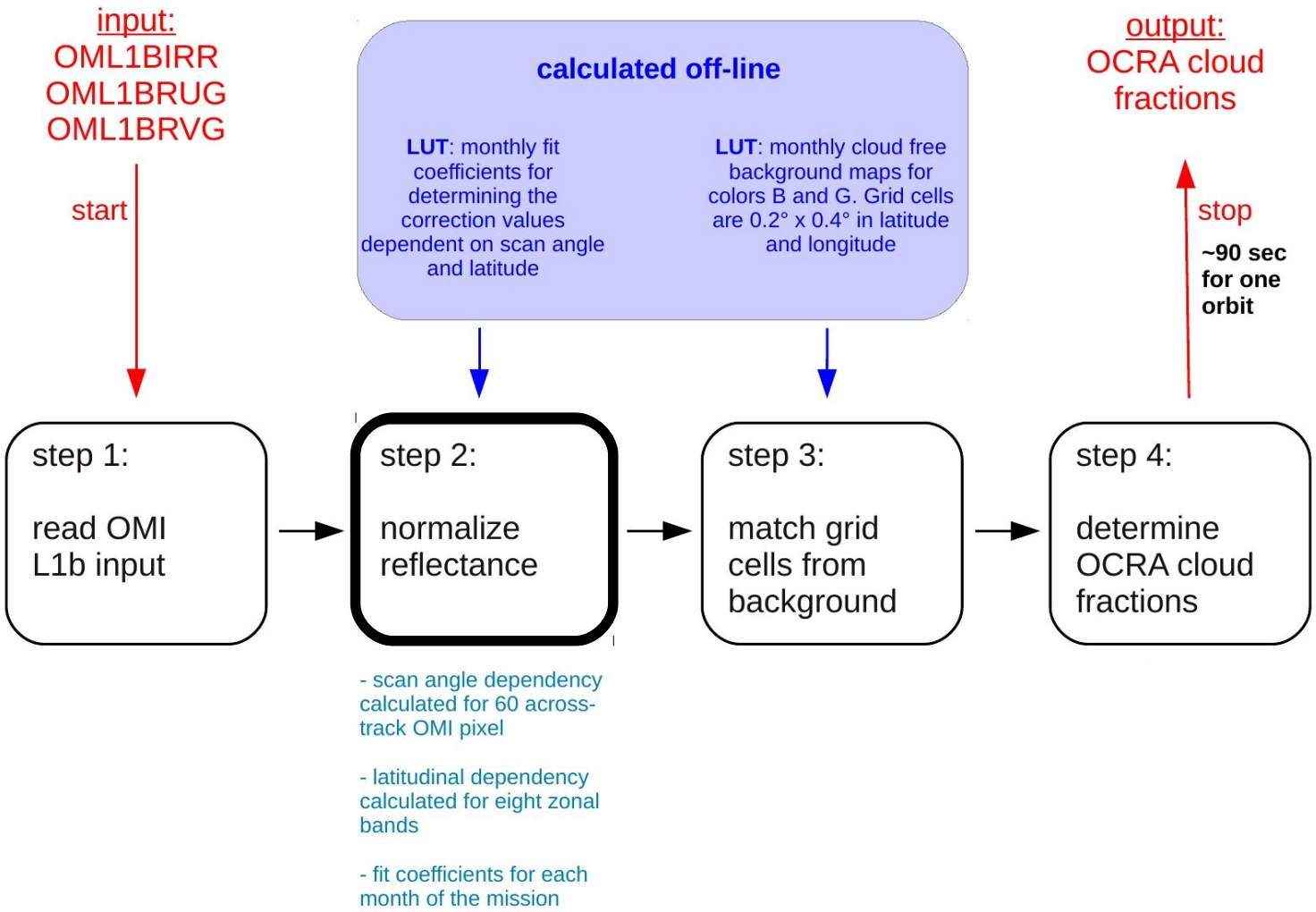
We define the mean of the radiances in the channels of the UV-2 band as color „B“,
and the mean of the radiances in the channels of the VIS band as color „G“

OCRA – mapping reflectance to RGB color space

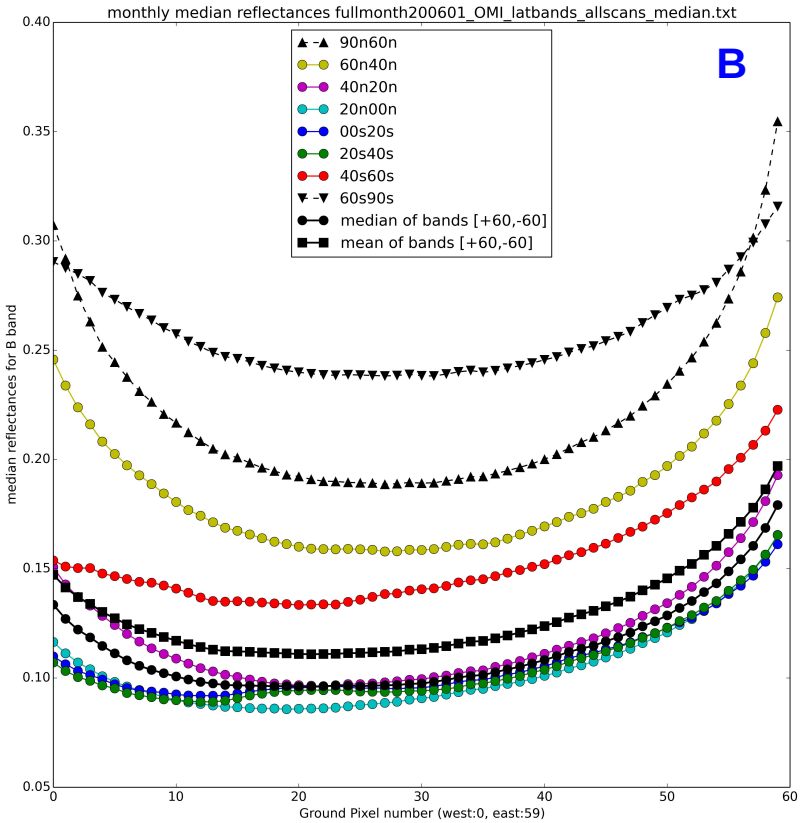


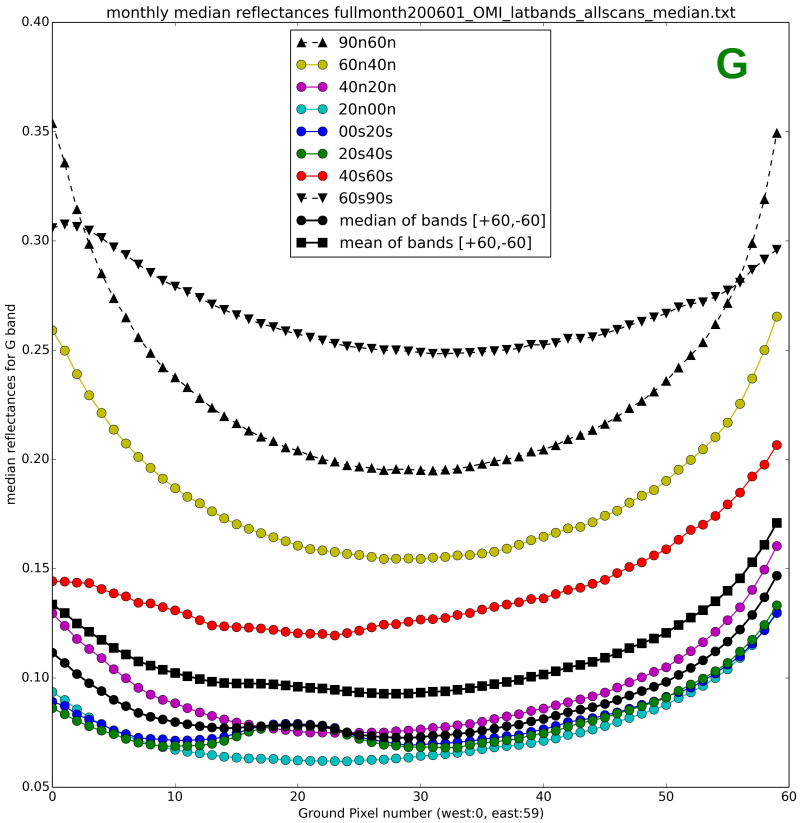
wavelength ranges and bands used by OCRA for different sensors to determine the colors B, G and R

OCRA – flowchart



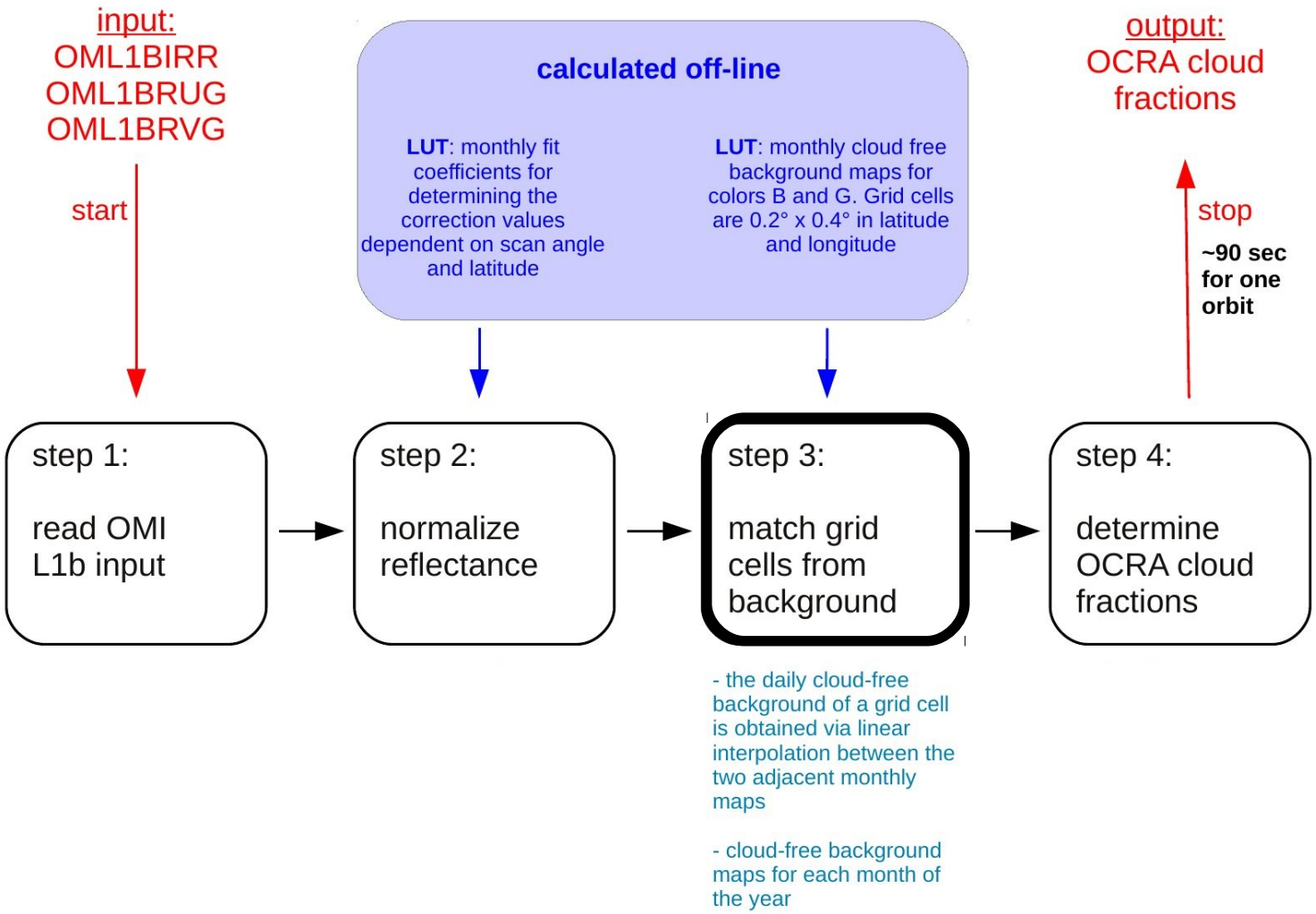
OCRA – normalize reflectance





- monthly median reflectance based on ~650.000 measurements for each of the 60 X-track pixels
- correction values via normalization to pixel #29 (near-nadir) of 4th order polynomial fits
- monthly corrections for each of the 48 months
- „bump“ feature at X-track pixels around #20

OCRA – flowchart



OCRA – cloudfree background

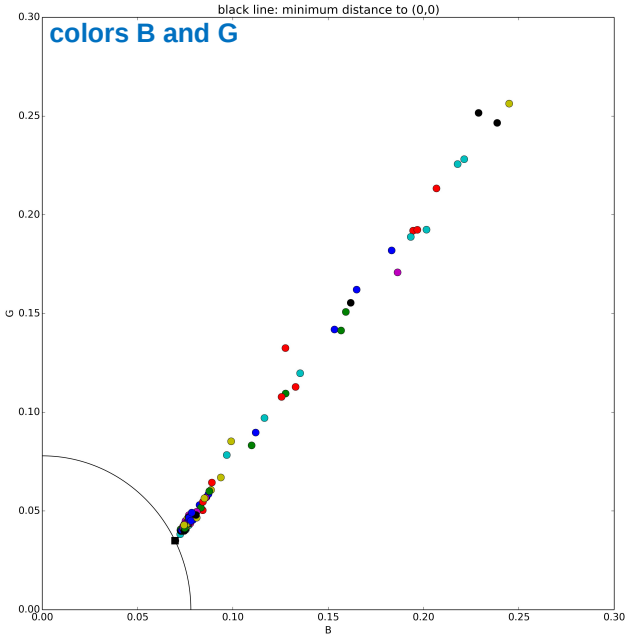
definition of the cloud-free value via BG- or bg- color diagrams:

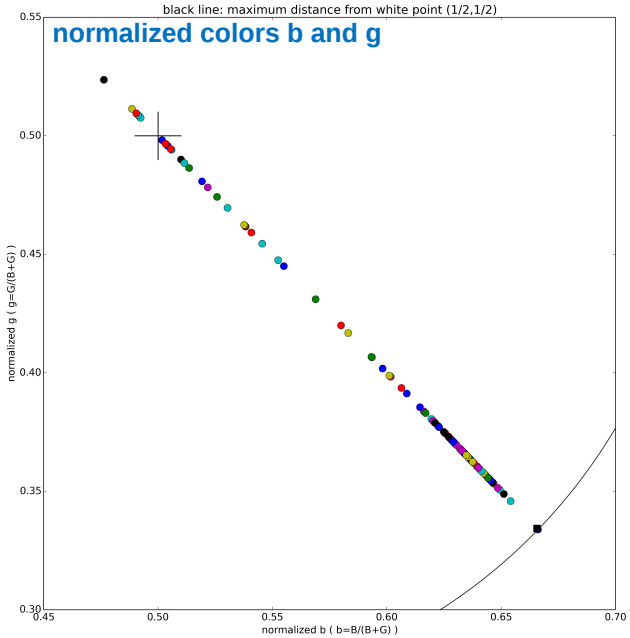
BG-color-diagram: measurement with minimum distance from (0,0)

→ based on assumption that a cloudy scene is brighter

bg-normalized-color-diagram: measurement with maximum distance from (½, ½)

→ same principle as for GOME, GOME-2





colors B and G (left) and normalized colors b and g (right) for one arbitrary grid cell

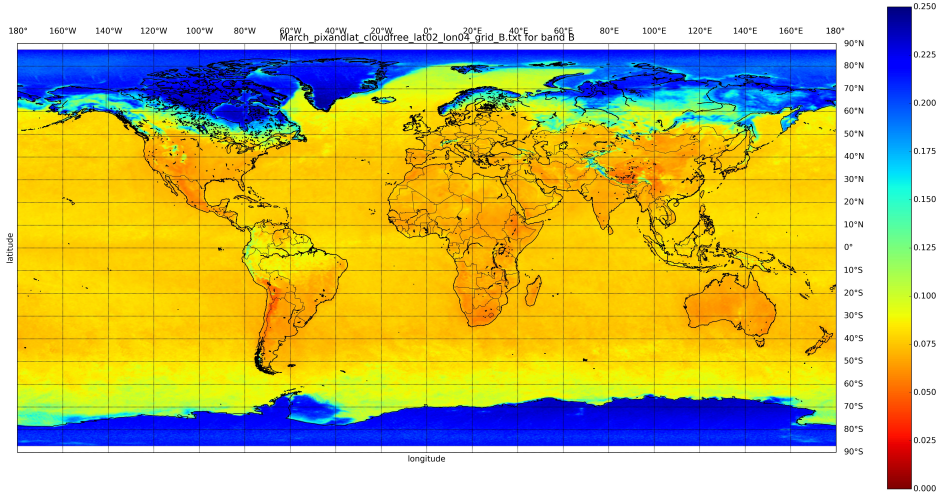
the white point in the bg-diagram is at (½,½)

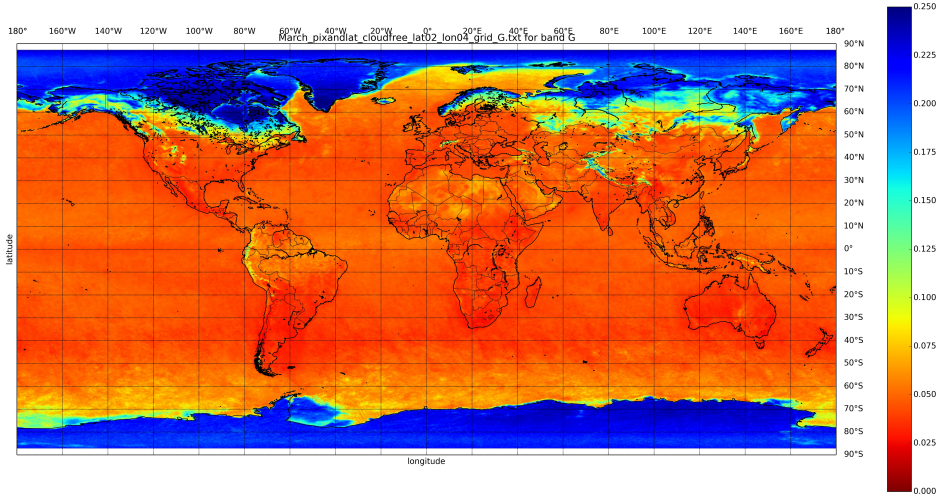
# of measurements per monthly grid cell is around 90-100

in BG, use e.g. 3rd smallest to account for e.g. shadowing or aerosol absorption

another approach: histogram analysis for each grid cell

OCRA – cloudfree background





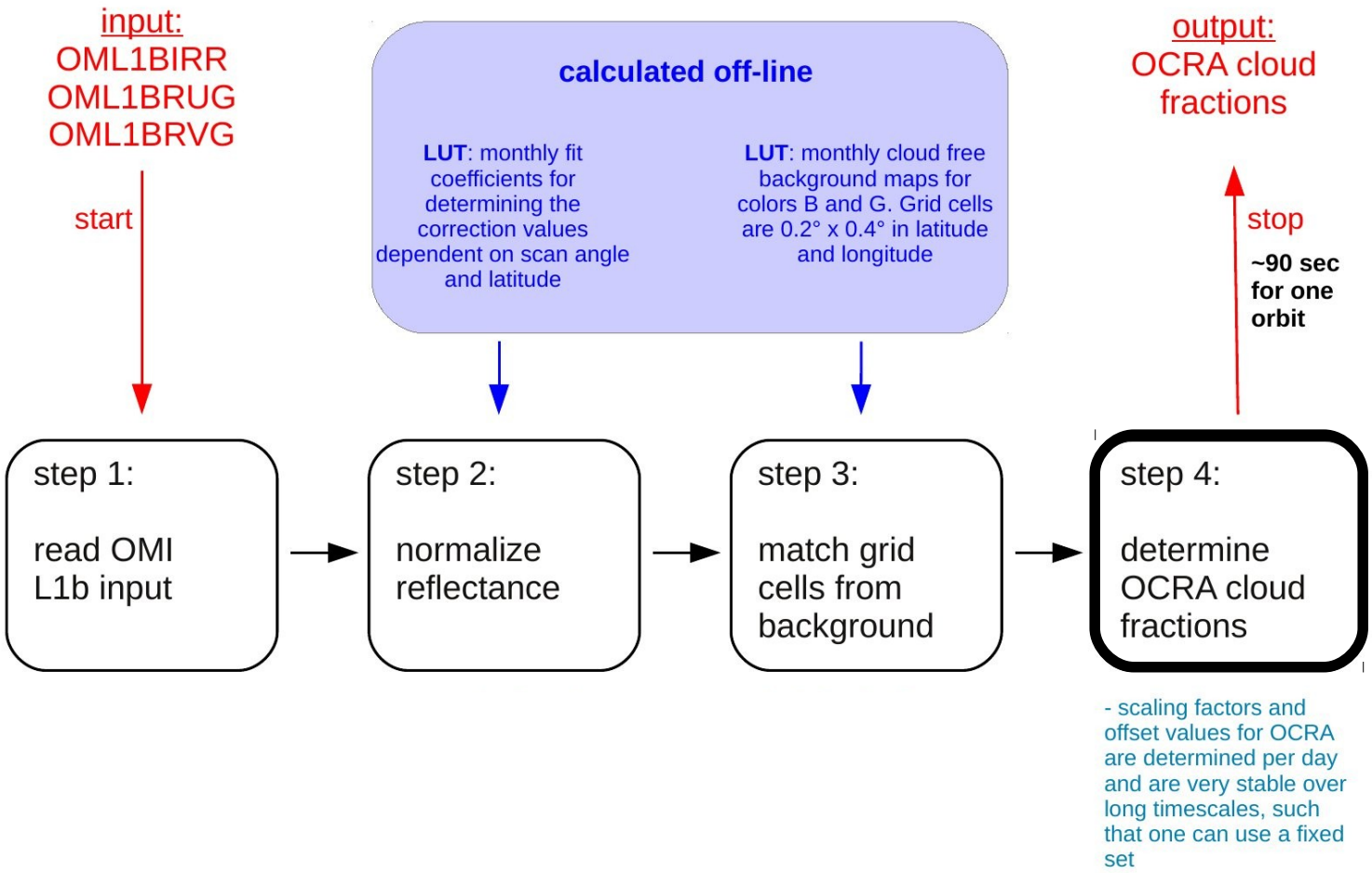
12 monthly background maps for each color B,G

grid resolution:
- **0.2° in latitude**
- **0.4° in longitude**

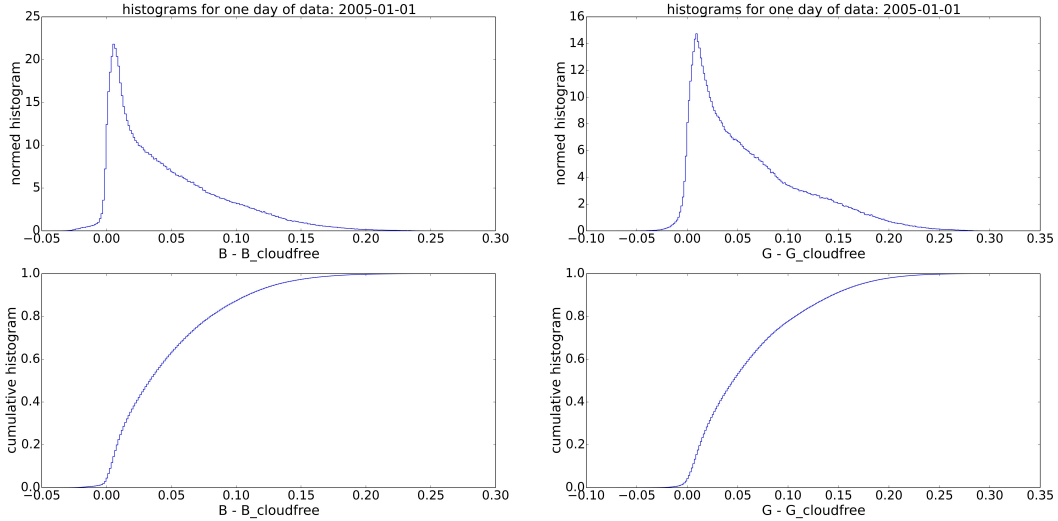
grid cell: ~22x45 km2
OMI at nadir: ~ 13x24 km2
OMI at Pix#8: ~ 17x55 km2

linear interpolation between the monthly cloud-free maps

OCRA – flowchart



OCRA – cloud fraction via histograms



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

$$B_{CF} = \alpha_B \cdot \max\left[0, (B - B_{free} - \beta_B)\right]^2$$

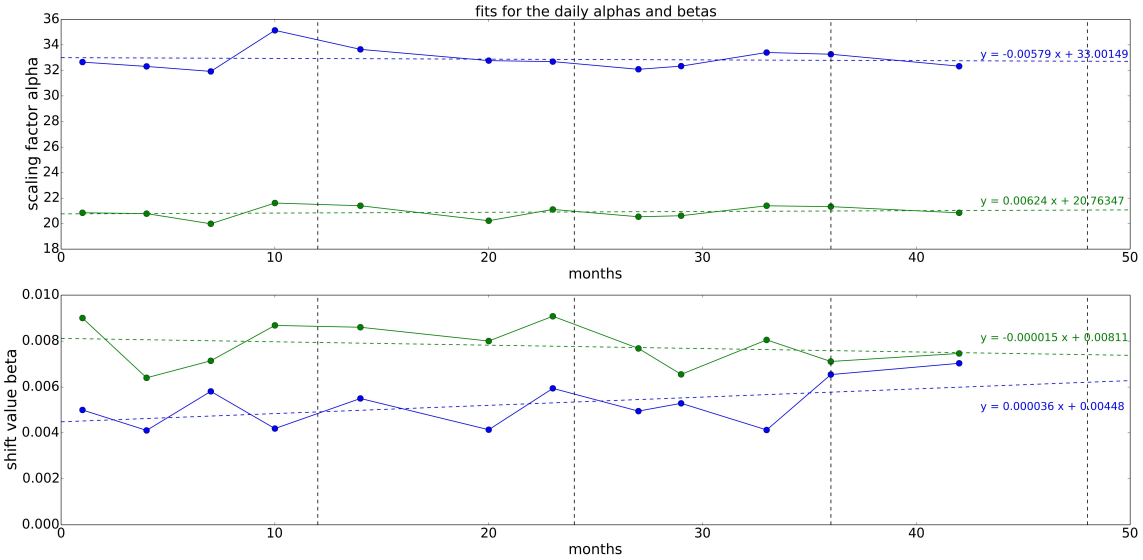
$$G_{CF} = \alpha_G \cdot \max\left[0, (G - G_{free} - \beta_G)\right]^2$$

scaling factor alpha:

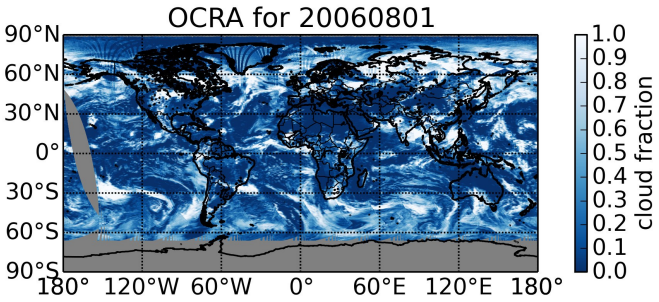
$$\alpha_X = \frac{1}{(X - X_{free})^2_{0.99}}$$

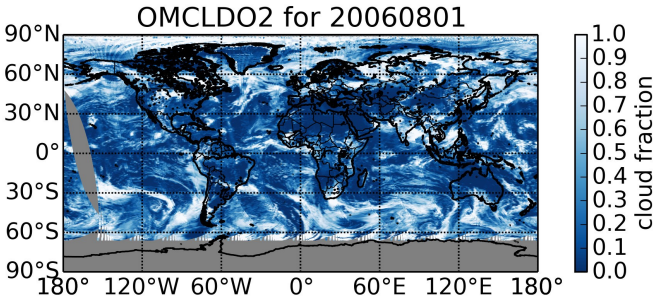
offset value beta:

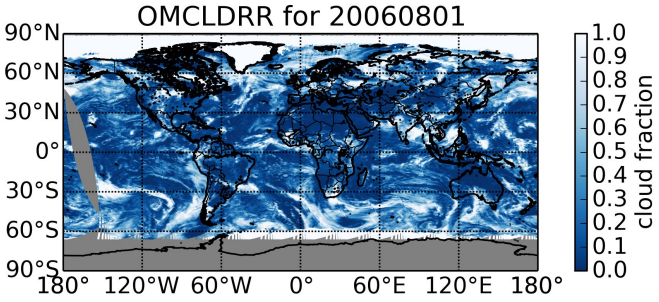
$$\beta_X = (X - X_{free})_{\text{mode}}$$



OCRA – comparison with OMCLDO2 and OMCLDRR



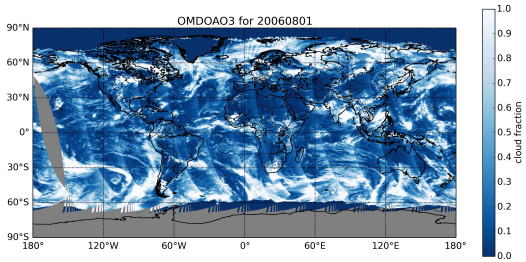


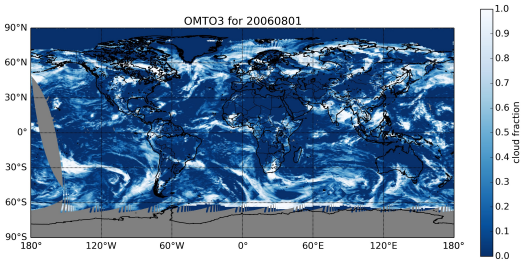


- test results for one day per month, only one example shown here

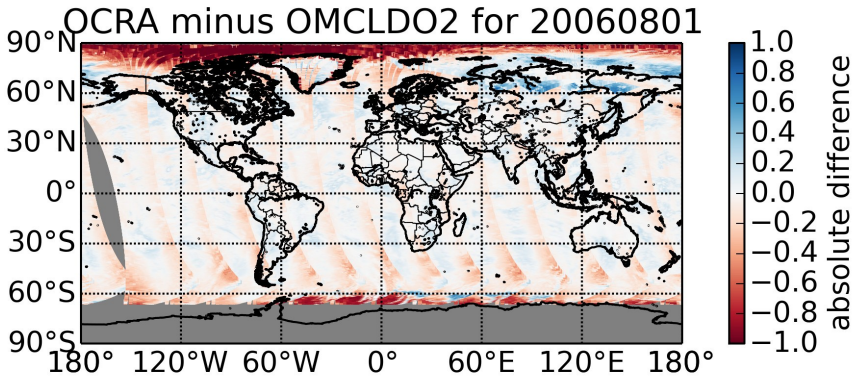
- caution with direct comparison of cloud fractions:
  - → dependence on surface albedo and cloud model
  - → e.g. OMCLDO2: *effective CF*, based on Kleipool surface albedo and fixed CA=0.8
  - → OCRA: *radiometric CF*, which is close to the geometrical CF; no further assumptions on CA

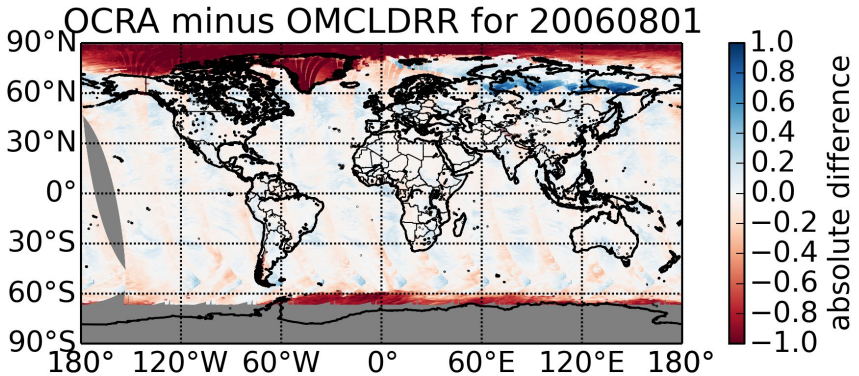
- interpret the following comparisons in the context of systematic trends etc...





OCRA – comparison with OMCLDO2 and OMCLDRR





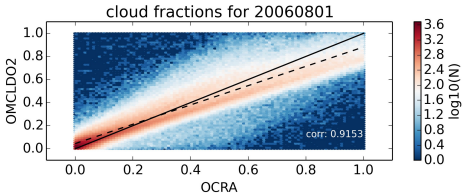
- strong linear correlation between OCRA and OMCLDO2 (corrcoeff 0.915) and OMCLDRR (corrcoeff 0.923)

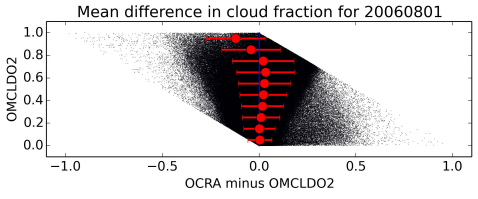
- signatures at swath edges

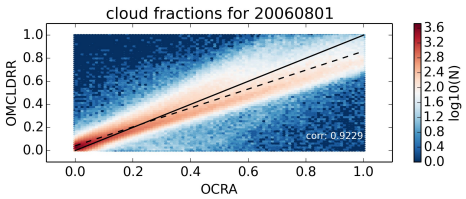
- large differences over snow/ice scenes

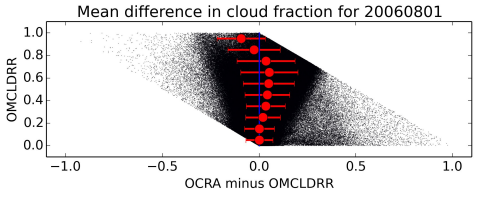
- mean CF differences close to 0, small standard deviations for low CFs, larger for large CFs

- at high CFs > 0.50, OCRA shows larger CFs



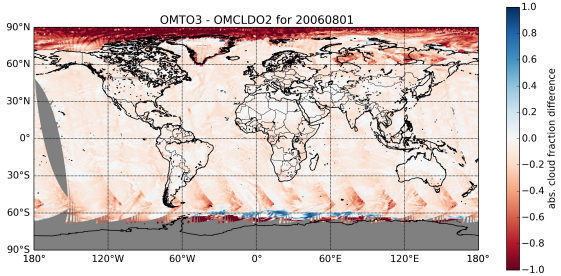


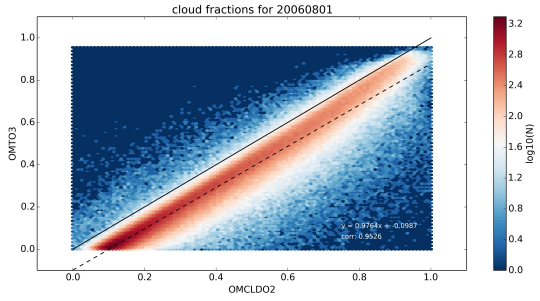


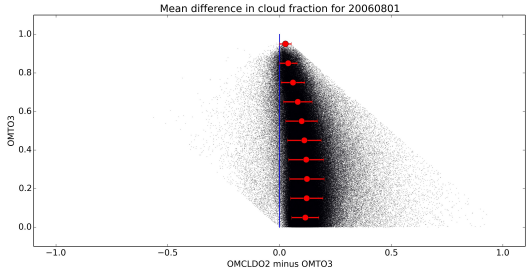


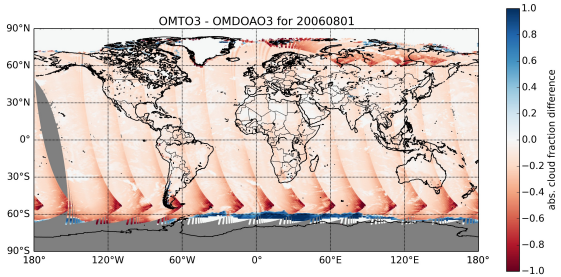
Intercomparison of official products

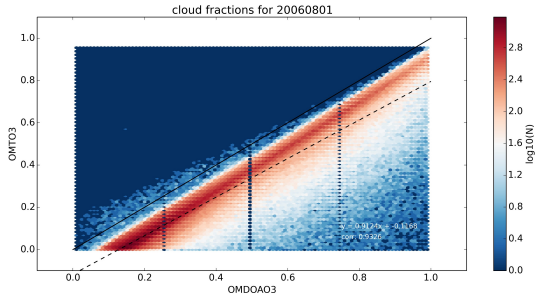
cloud fractions from OMCLDO2, OMCLDRR, OMDOAO3 and OMTO3 are taken from the following fields: „CloudFraction“, „CloudFractionforO3“, „CloudFraction“, „fc“

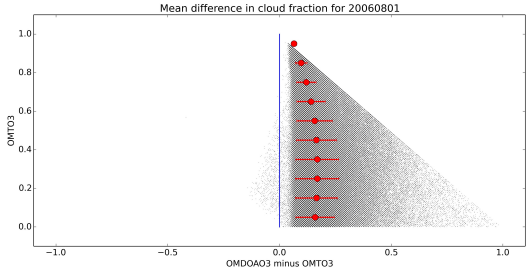


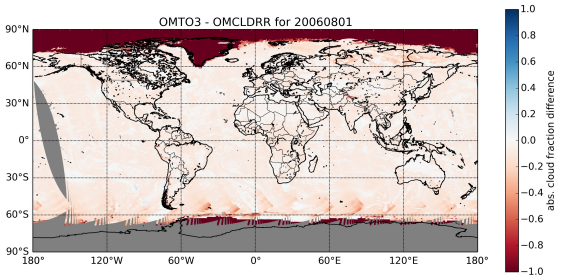


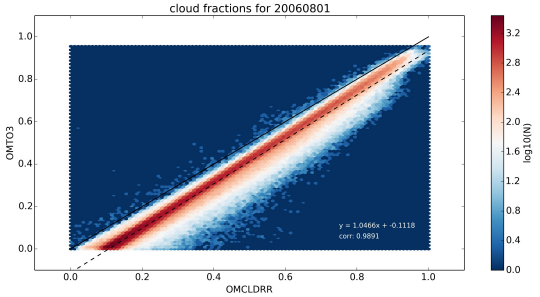


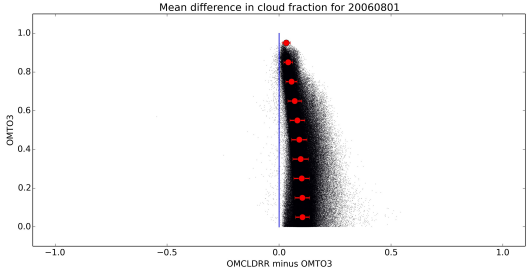




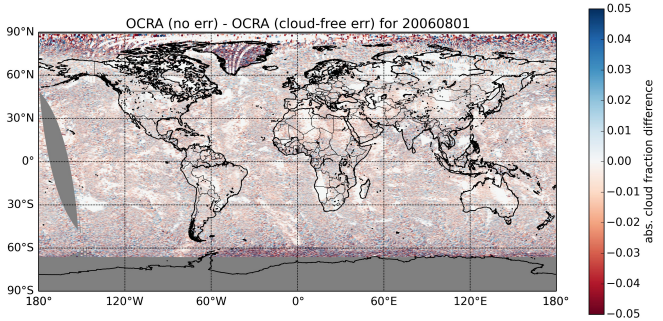


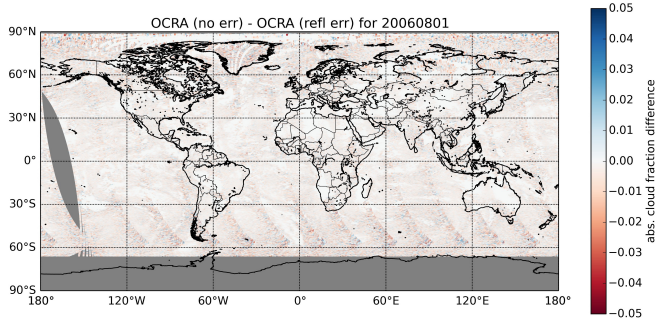


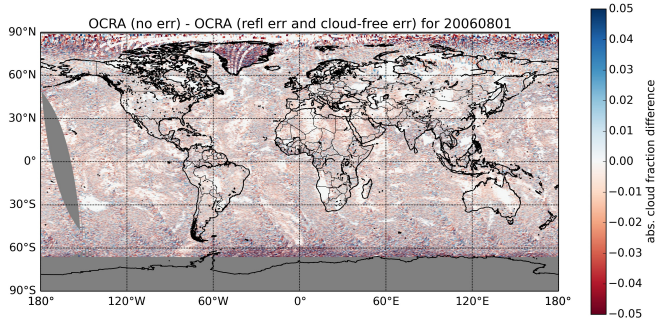




OCRA – sensitivity study

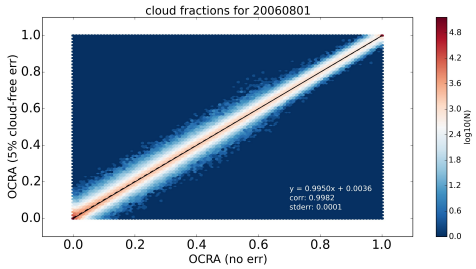


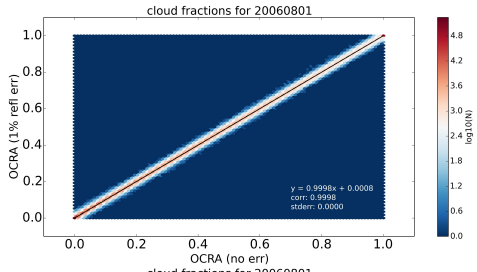


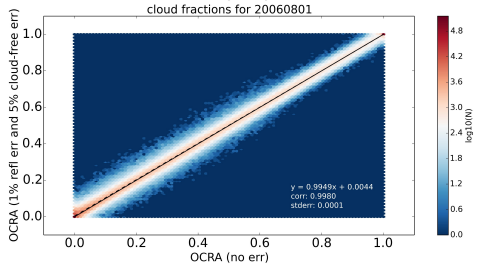


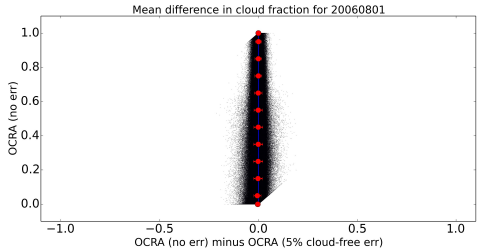
three cases:

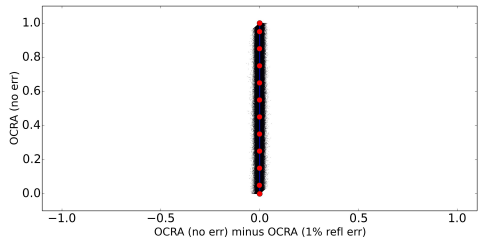
- **add 5% gaussian error on cloud-free background (top)**
- **add 1% gaussian error on reflectance (middle)**
- **add both of the above (bottom)**

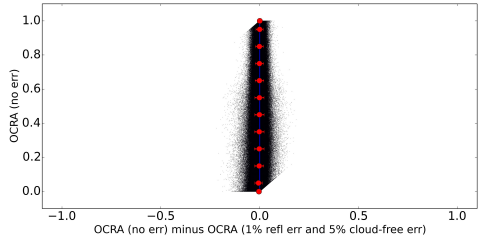












Conclusion

OCRA provides a fast, robust and accurate determination of (radiometric) cloud fraction
→ 1.5 min for one complete OMI orbit (prototype code in Python)

reflectance normalization compensates possible instrument / L1 issues

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

good agreement with official products

caution over snow/ice

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)

Outlook

adjust channel ranges used to determine B and G:

→ use only VIS band due to geolocation mismatch

use finer resolution for latitude dependent reflectance correction

→ e.g. 5° latitude bins instead of 20° latitude bins

TROPOMI: additional color informations for OCRA/ROCINN

→ colors B,G,R for OCRA

→ O2-A band for ROCINN

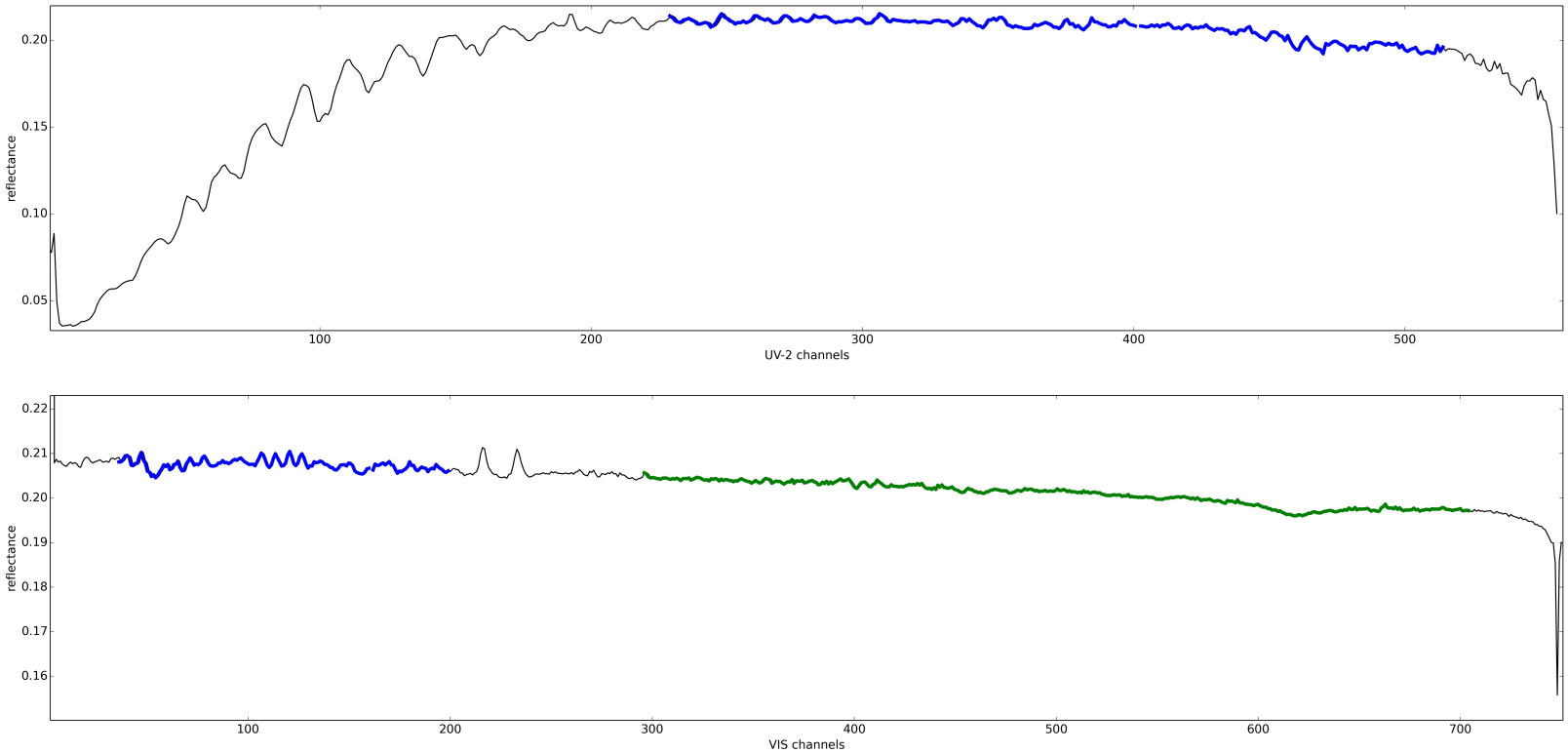
→ *initial*: cloudfree background: B,G from OMI and R from GOME-2

→ *later*: cloudfree background directly based on TROPOMI data

Thank you for your attention!

Additional slides

channel ranges in OMI UV-2 and VIS bands used by OCRA to determine the colors **B** and **G**



reflectance spectra for the arbitrarily chosen Ground Pixel #29 in scan-line 600 on OMI orbit 2472 (2005-01-01)

Sentinel 5 Precursor

- The ESA Sentinel 5 Precursor (S5P) is a Copernicus/GMES mission focussing on global observations of the atmospheric composition for air quality and climate.
- The TROPOspheric Monitoring Instrument (**TROPOMI**) is the payload of the S5P mission and is jointly developed by The Netherlands and ESA.
- The planned launch date for S5P is 2015 with a 7 year design lifetime.

TROPOMI

- UV-VIS-NIR-SWIR nadir view grating spectrometer.
- Spectral range: 270-500, 675-775, 2305-2385 nm
- Spectral Resolution: 0.25-1.1 nm
- Spatial Resolution: 7x7km2
- Global daily coverage at 13:30 LT

CONTRIBUTION TO GMES

- Total column O3, NO2, CO, SO2,CH4, CH2O,H2O,BrO
- Tropospheric column O3, NO2
- O3 profile
- Aerosol index, type, optical depth
- Cloud amount, pressure and optical thickness