New surface albedo databases based on Earth observations by GOME-2 and SCIAMACHY

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Outline

1) Surface albedo type: Lambertian-equivalent reflectivity (LER)
2) Retrieval approach, algorithm steps
3) Some examples of the surface LER databases
4) Validation results (UV-VIS)
5) Qualitative checks (NIR)
6) Summary and conclusions

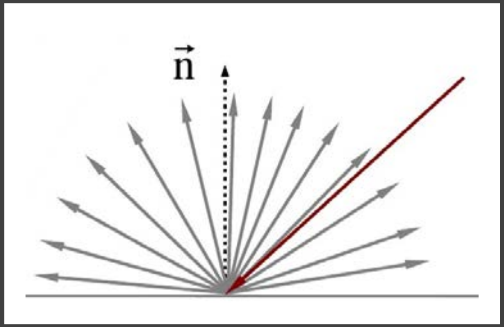
(22 slides)

1.1 – Need for surface albedo databases

Justification: Many retrievals rely on proper surface albedo input:

- ozone (~335 nm)
- NO_2 (~420-450 nm)
- formaldehyde (CH_2O, ~342 nm)
- cloud information (e.g. FRESCO: O_2-A band ~760 nm)

1.2 – Surface albedo type: surface LER



LER = Lambertian-equivalent reflectivity, i.e., diffuse reflection

The surface LER stands for a simplified description of the reflectivity of the surface. In practice, the surface LER may be somewhat off from the actual surface albedo, but the primary goal is to get the TOA radiance right.

2.1 – Retrieval approach

We are only interested in clear-sky scenes. The calculation of the surface LER for such a scene involves removing the (modelled) atmospheric contribution to the TOA reflectance from the measured TOA reflectance.

For clear-sky scenes and Lambertian surface reflection we have:

$$R^{\mathrm{Ray}}(\mu, \mu_0, \phi - \phi_0, A_{\mathrm{s}}) = R^0(\mu, \mu_0, \phi - \phi_0) + \frac{A_{\mathrm{s}}\, T(\mu, \mu_0)}{1 - A_{\mathrm{s}} s^\star}$$

(Chandrasekhar, *Radiative Transfer*, Dover, 1960)

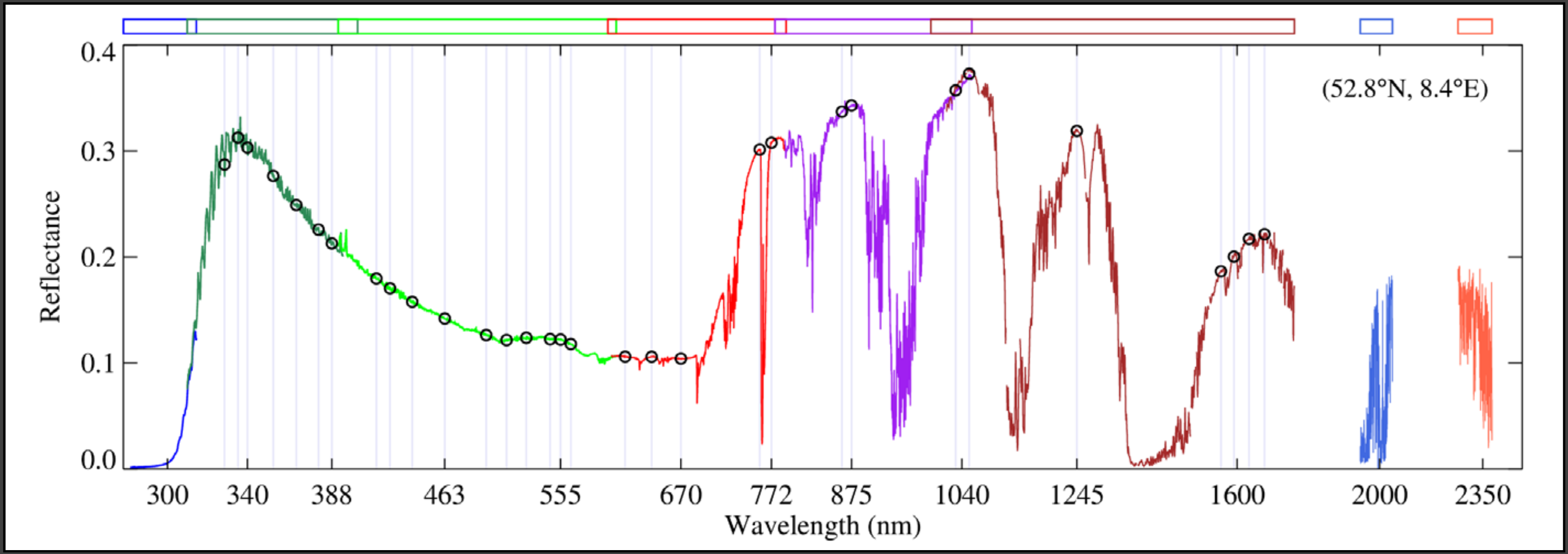
And so,

$$A_{\mathrm{s}} = \frac{R^{\mathrm{m}} - R^0}{T + s^\star (R^{\mathrm{m}} - R^0)}$$

R^0, T, s^* are stored in look-up tables

Only for cloud- and aerosol-free scenes the parameter A_{s} is equal to the surface albedo/LER. In general, A_{s} represents the *scene* albedo/LER.

2.2 – Selection of wavelength bands



The wavelength bands were positioned in the continuum parts of the spectrum, avoiding absorption bands of species other than ozone.

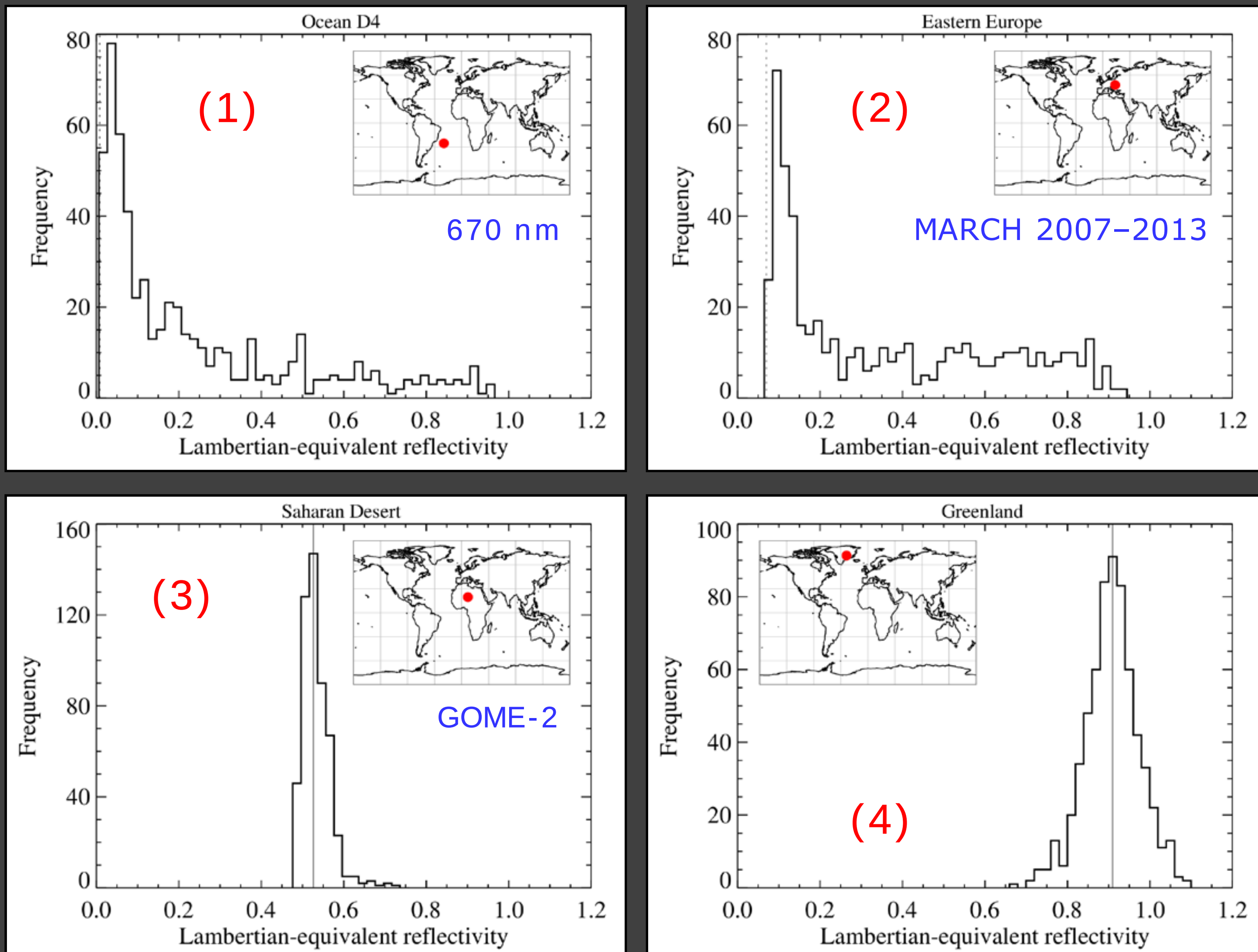
GOME-2: 335–772 nm (spectral channels) ; PMD 3–15 (PMD bands)

SCIAMACHY: 335–1670 nm (spectral channels)

From the 670-nm reflectance, angles, surface height and ozone column the scene LER (at 670 nm) can be calculated and distributed in a 2D grid.

2.3 – Analysing scene LER histograms (“finding clear-sky scenes”)

Which scene LER’s are representative for the surface LER?



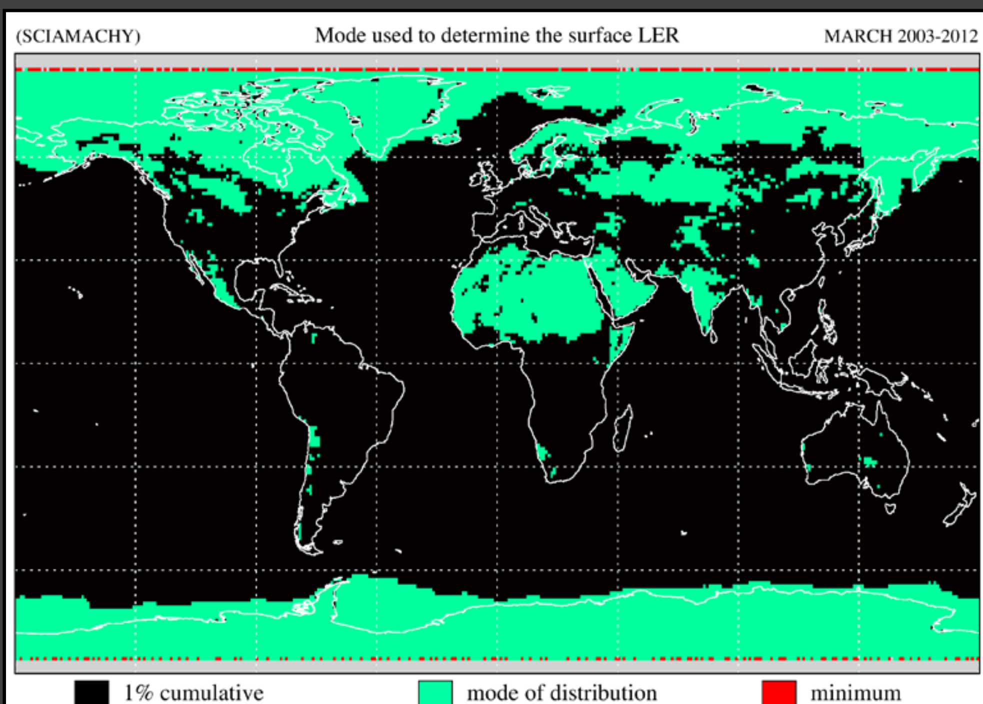
1 + 2:
In these cases the <u>1% cumulative value</u> of the LER distribution is clearly the most representative.

3 + 4:
In these cases it is the <u>mode</u> of the distribution that is the most representative.

2.4 – MIN-LER / MODE-LER:

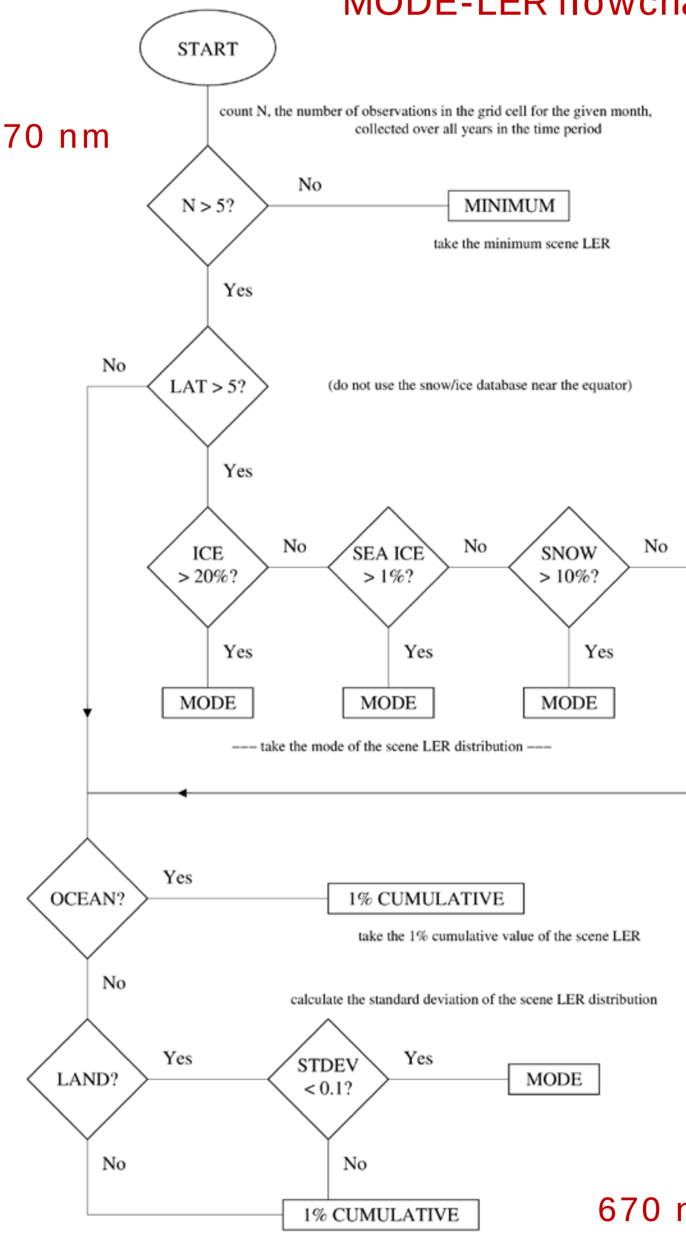
MIN-LER: Always the 1% cumulative value. This is the TOMS and GOME-1 approach.

MODE-LER: For each grid cell we first determine, using the flowchart, whether or not we should use the mode or the 1% cumulative value of the distribution. (OMI)



MODE-LER flowchart

670 nm



670 nm

Kleipool et al. (2008)

2.5 – Other wavelengths

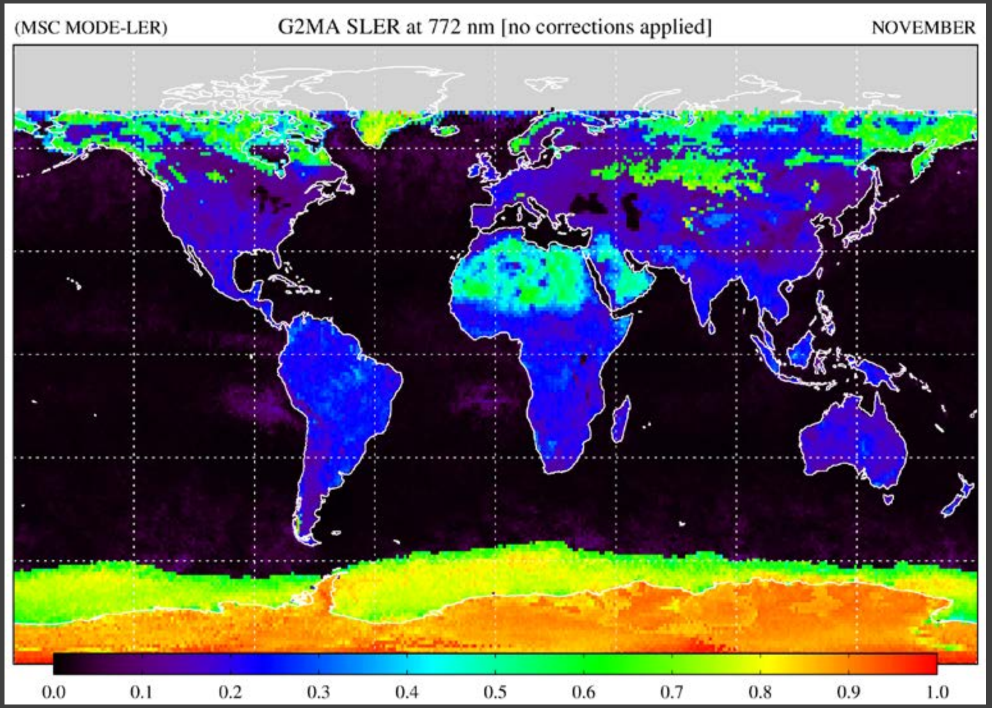
All wavelengths can now be handled.

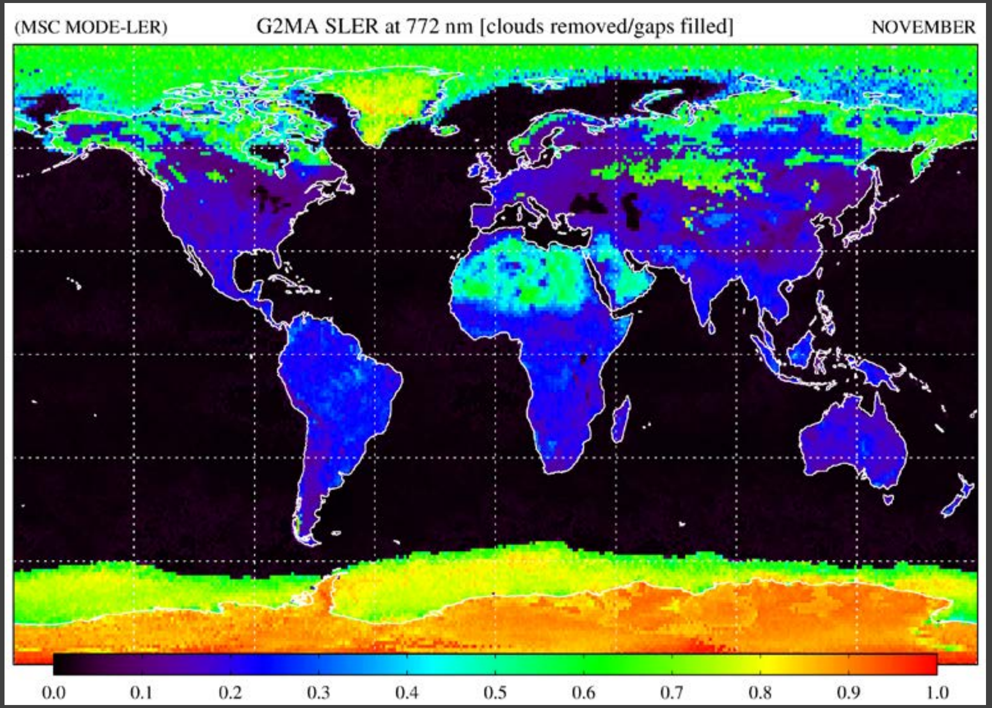
2.6 – Cloud removal

For certain months, certain regions are never observed cloud-free in the entire time range available. This is especially the case over the oceans. These areas are identified and their LER spectra are replaced by the LER spectra of nearby donor cells.

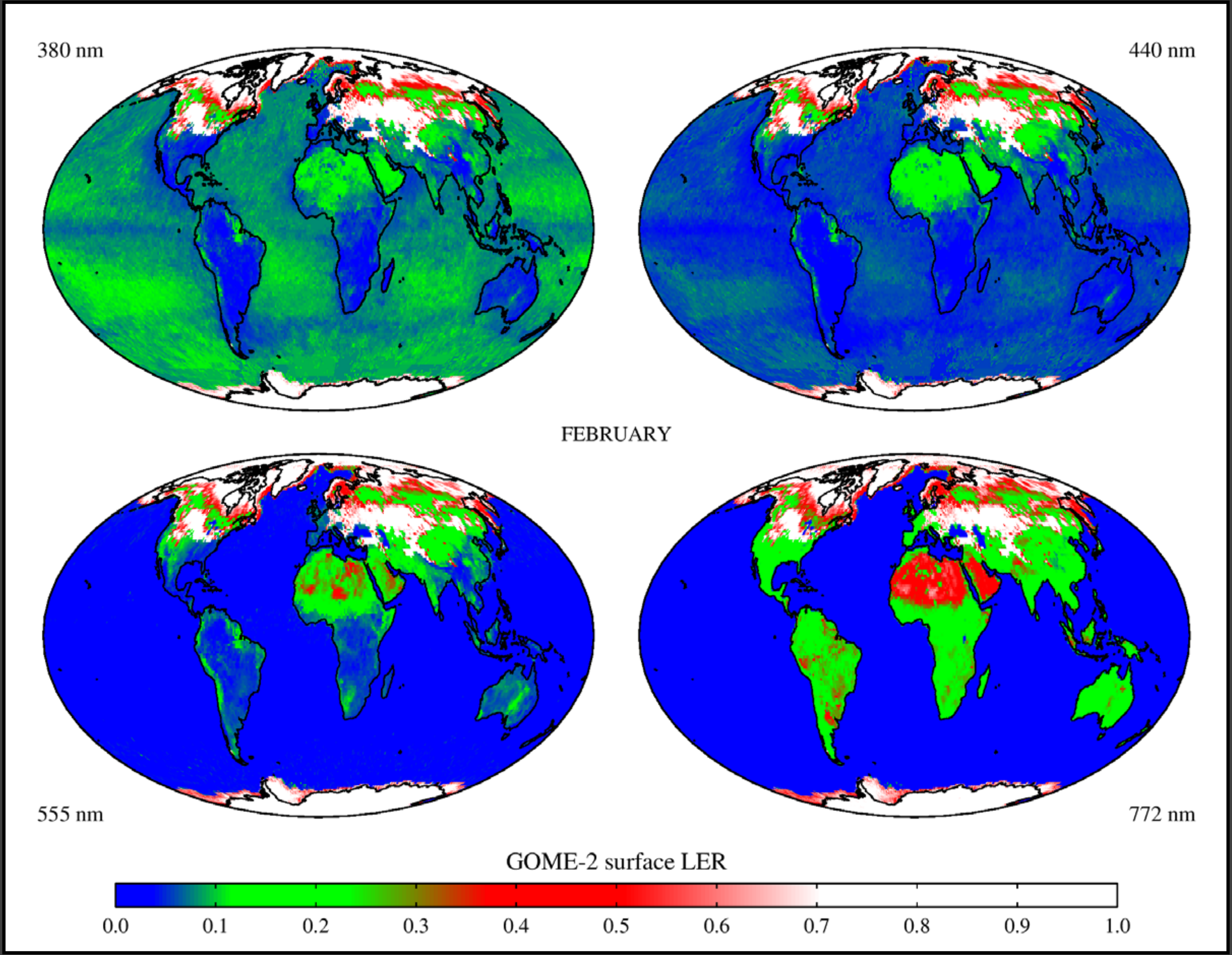
2.7 – Filling gaps

After that, gaps in the polar regions (which are not observed for certain months of the year) are filled using donor cells of the same location but from neighbouring months.



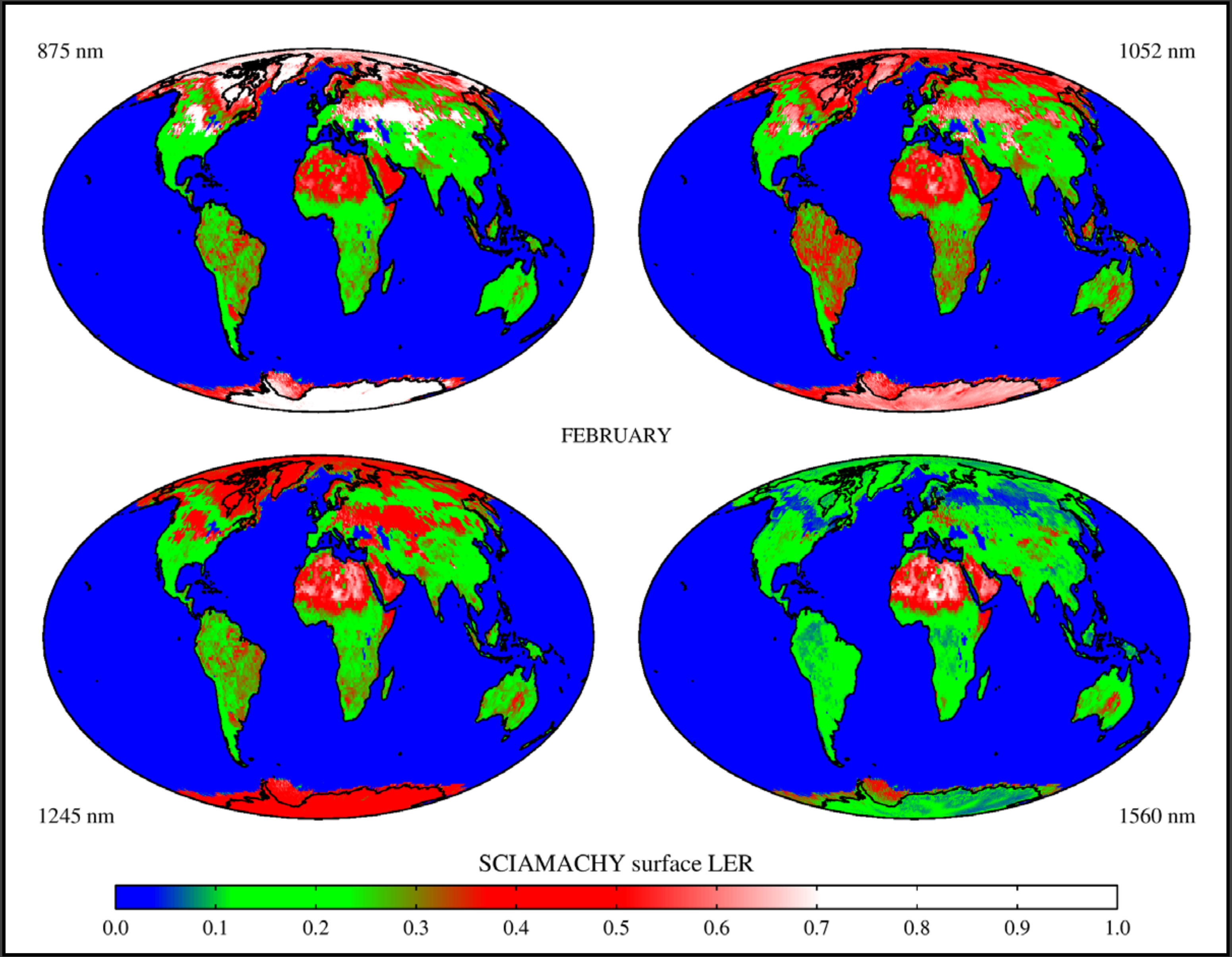


3.1 – Example: GOME-2 surface LER database



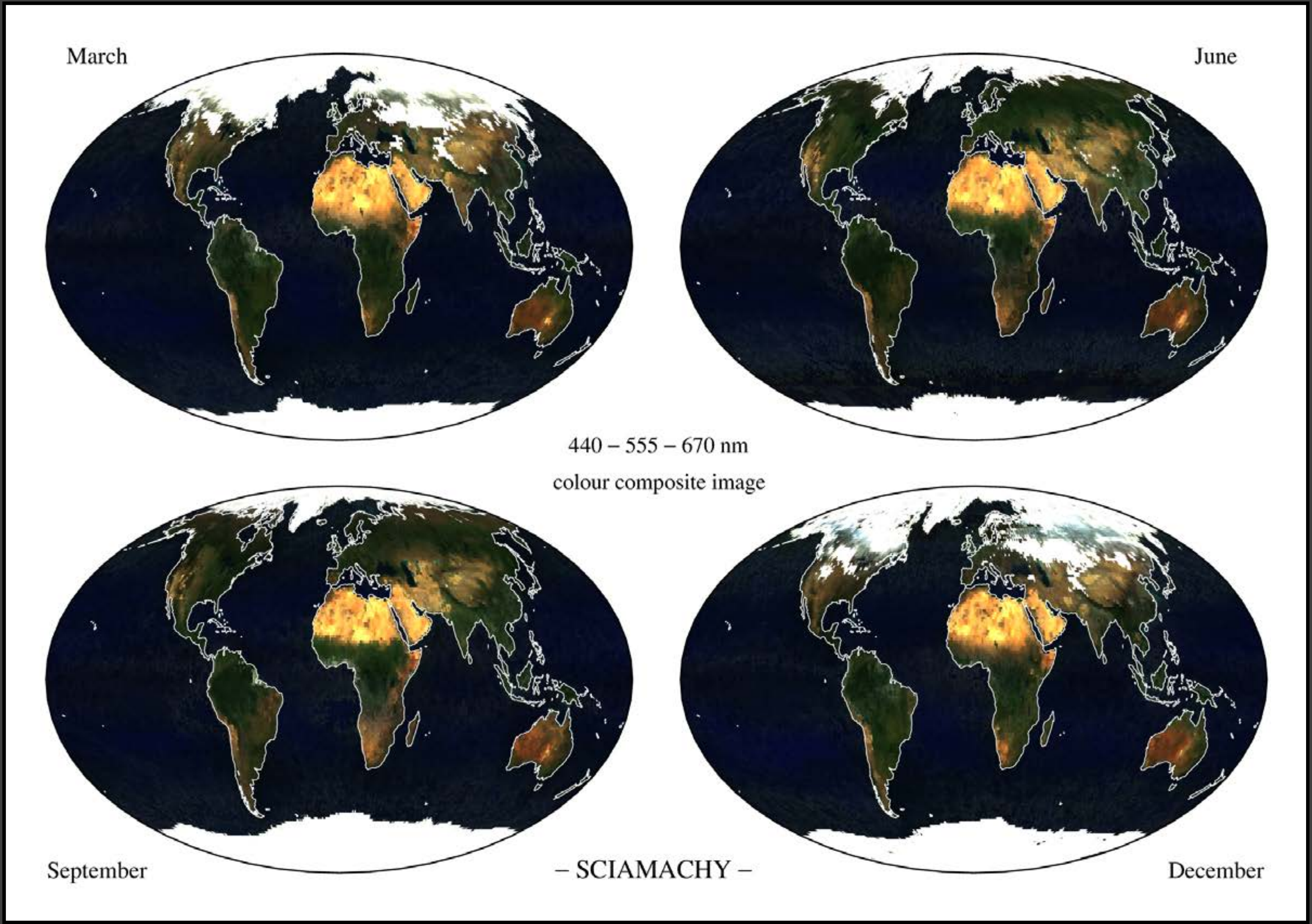
MODE-LER

3.2 – Example: SCIAMACHY surface LER database



MODE-LER

3.3 – Example: SCIAMACHY colour composite image



MODE-LER

Residual cloud contamination is hardly visible, but it does exist for a number of areas.

4.1 – Validation: comparison with other LER databases

There are only a few surface LER databases to compare with:

1) TOMS LER [a]	340–380 nm	1978–1993	(MIN-LER only, outdated)
2) GOME-1 LER [b]	335–772 nm	1995–2000	(MIN-LER only)
3) OMI LER [c]	328–499 nm	2004–2007	(MIN-LER + MODE-LER)

(a) Herman & Celarier, JGR 102, 1997

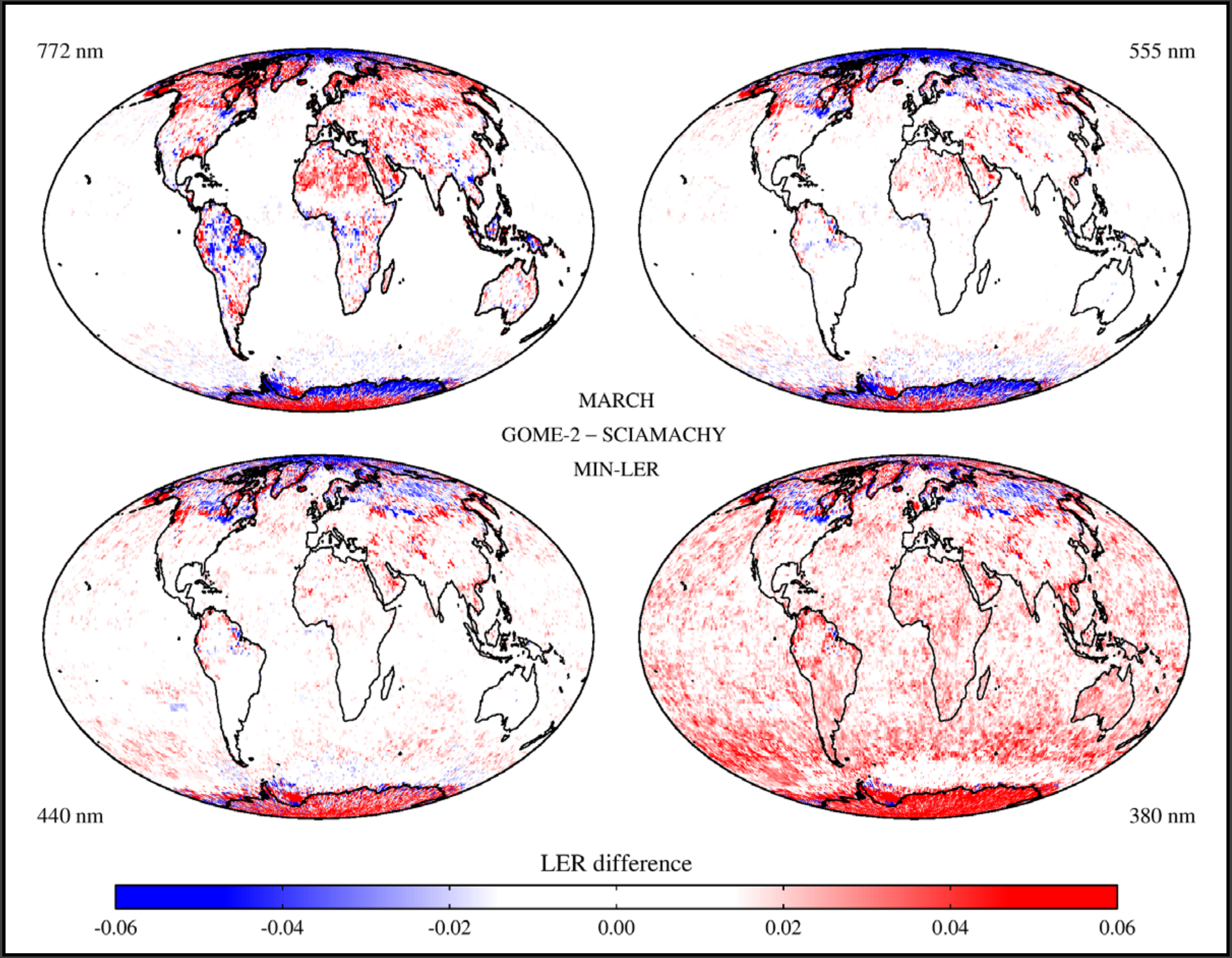
(b) Koelemeijer *et al*., JGR 108, 2003

(c) Kleipool *et al*., JGR 113, 2008

(And of course we can compare GOME-2 and SCIAMACHY surface LER.)

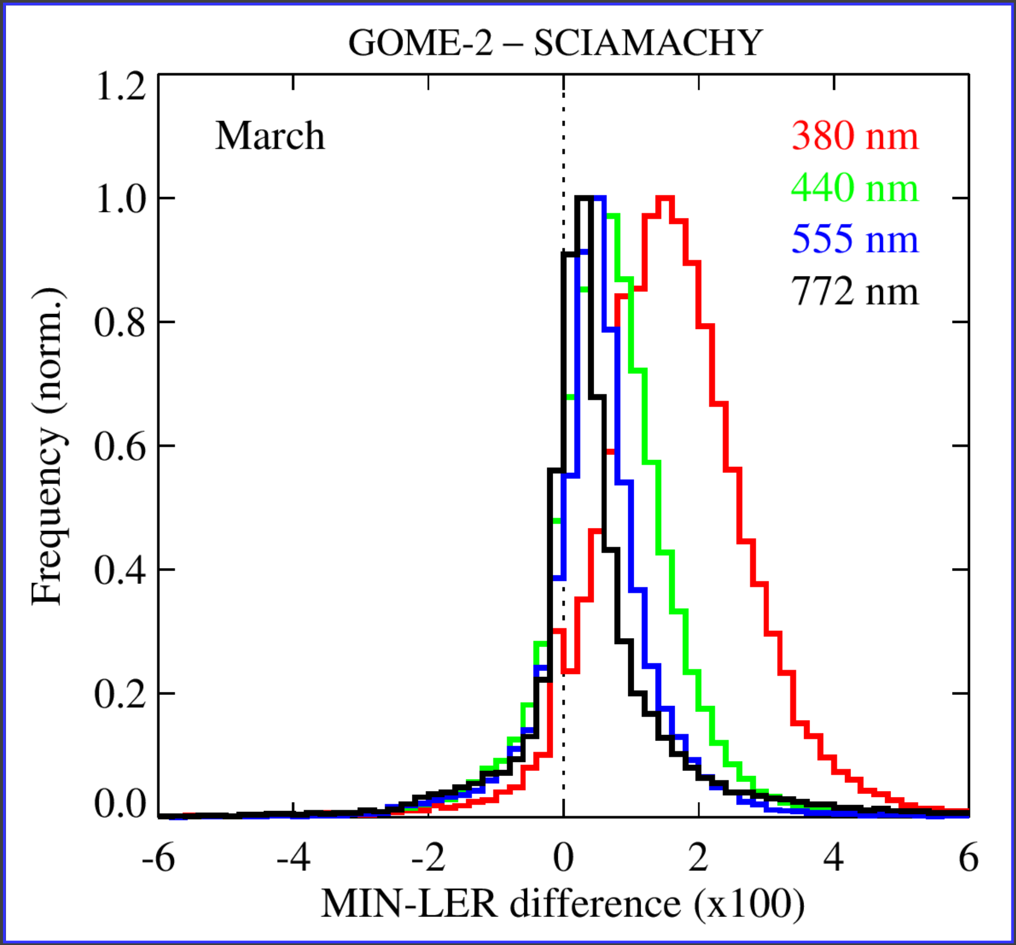
Comparisons with non-LER surface albedo databases such as the MERIS black-sky albedo (BSA) show reasonable agreement, but differences are hard to interpret because LER and BSA are different quantitities.

4.2 – Comparison: GOME-2 versus SCIAMACHY



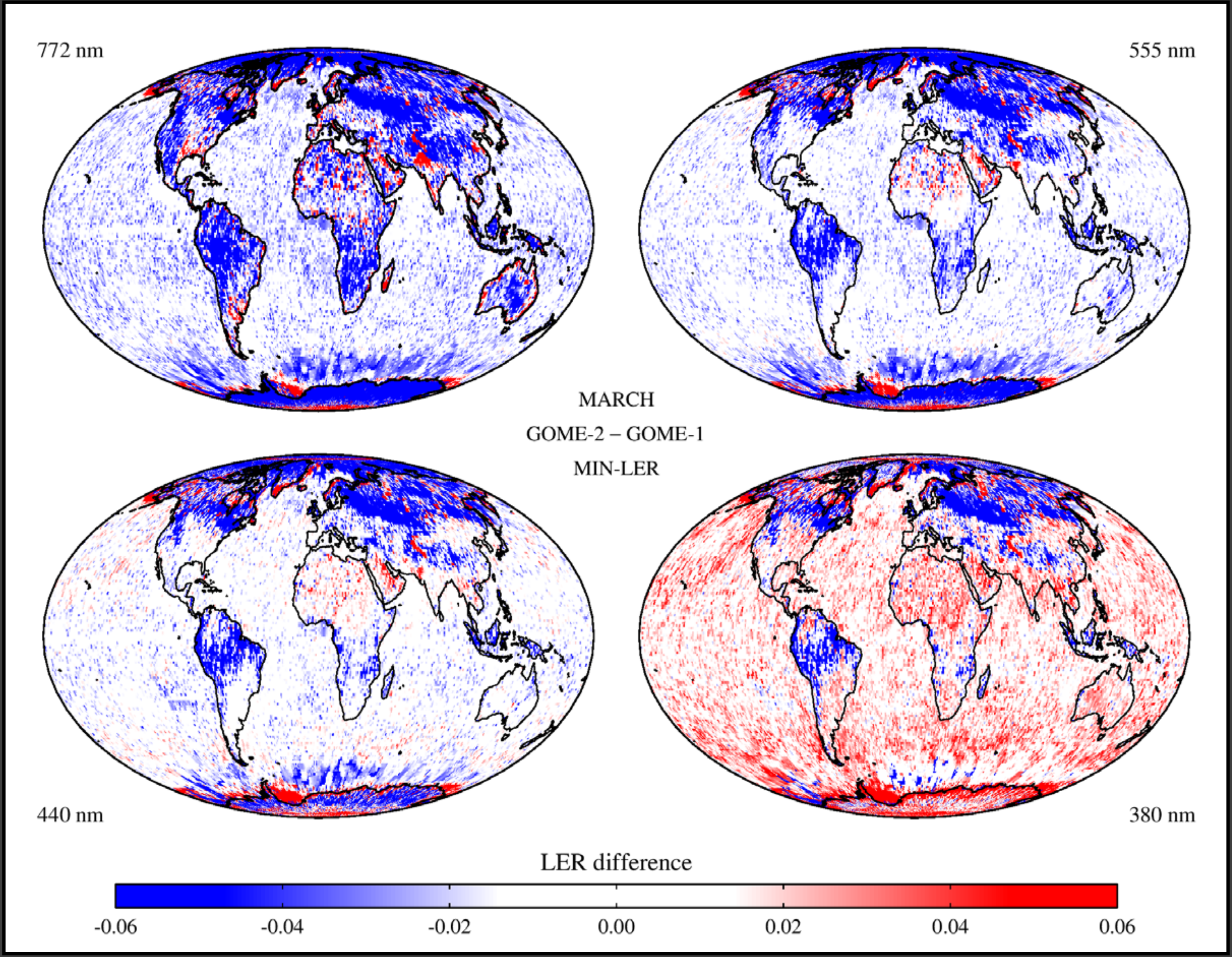
Histograms:

(60°S–60°N)



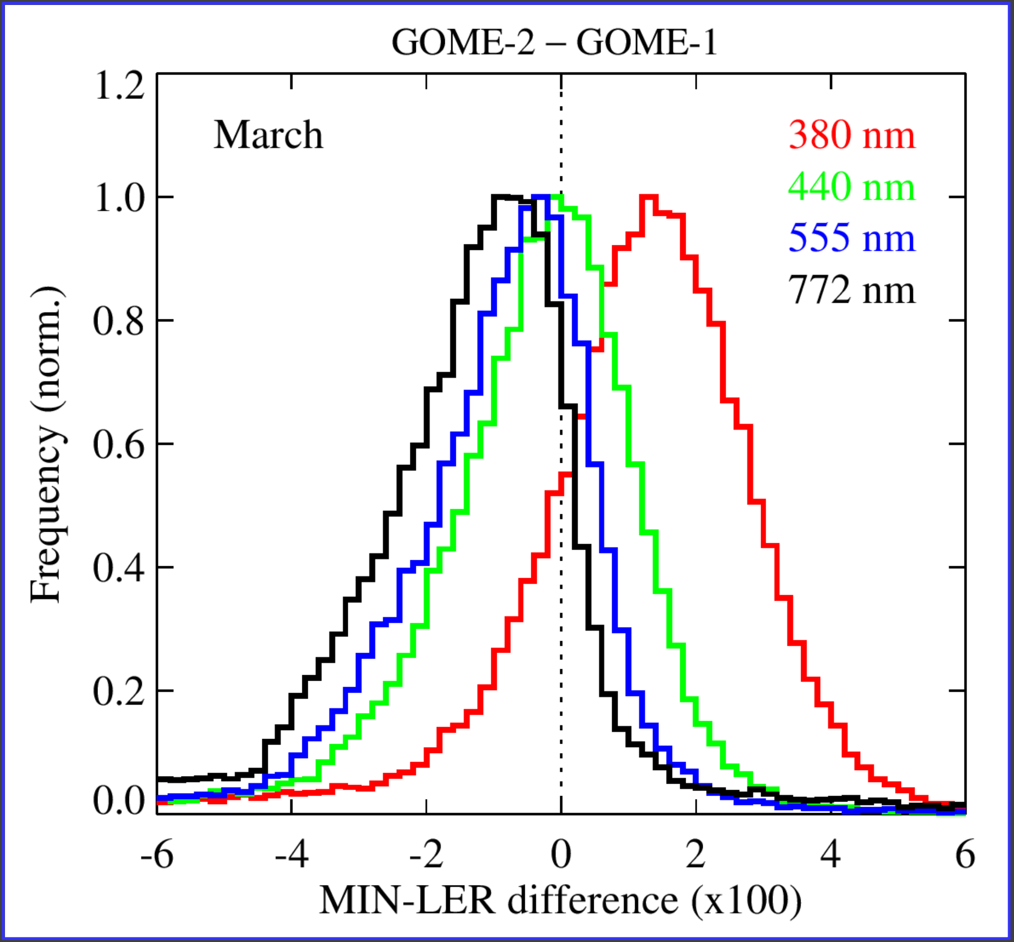
Very good agreement above 400 nm. Below 400 nm the agreement is less good. Calibration issues? A relatively small reflectance error of ~0.01 in one of the instruments would already explain the difference entirely.

4.3 – Comparison: GOME-2 versus GOME-1



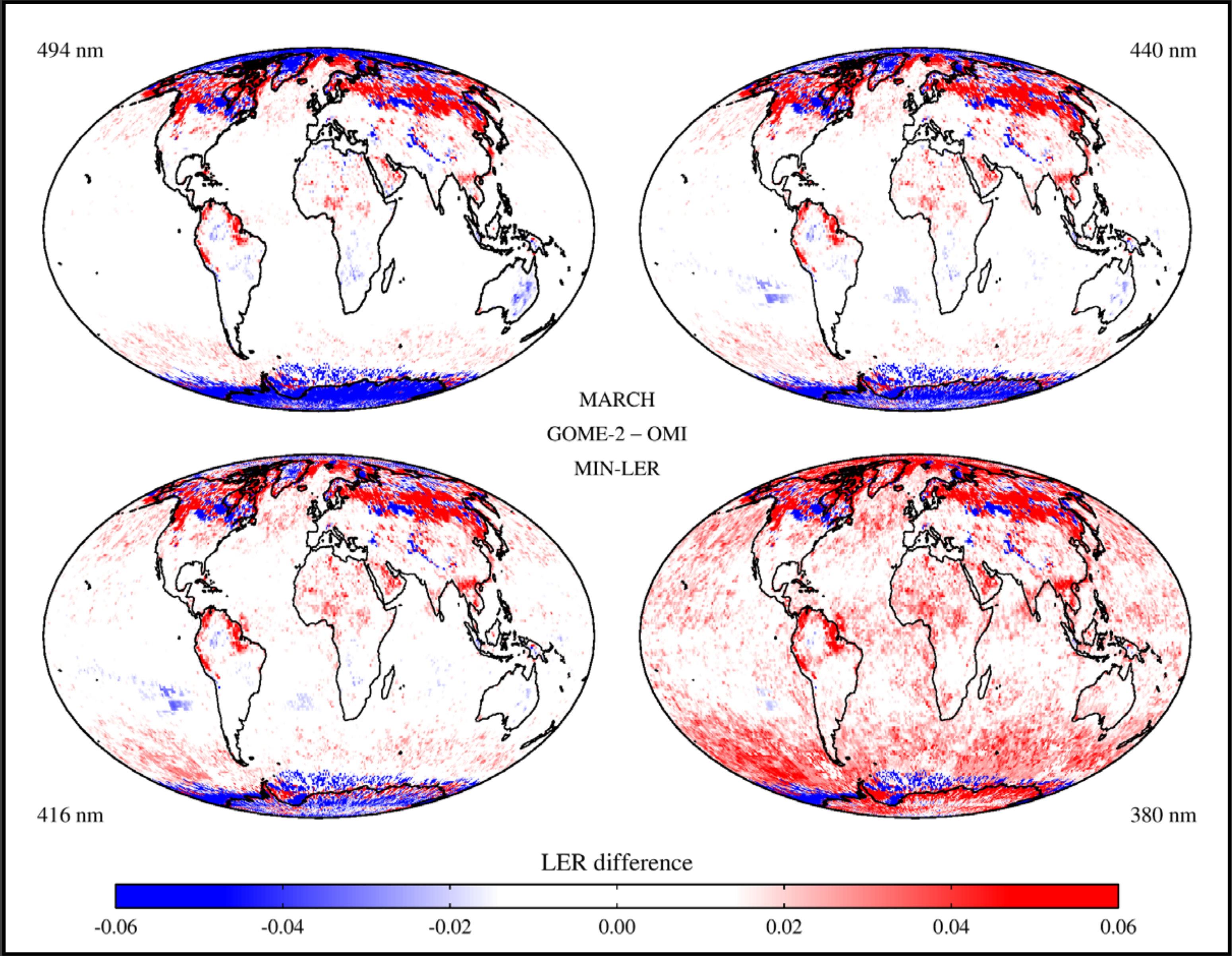
Histograms:

(60°S–60°N)



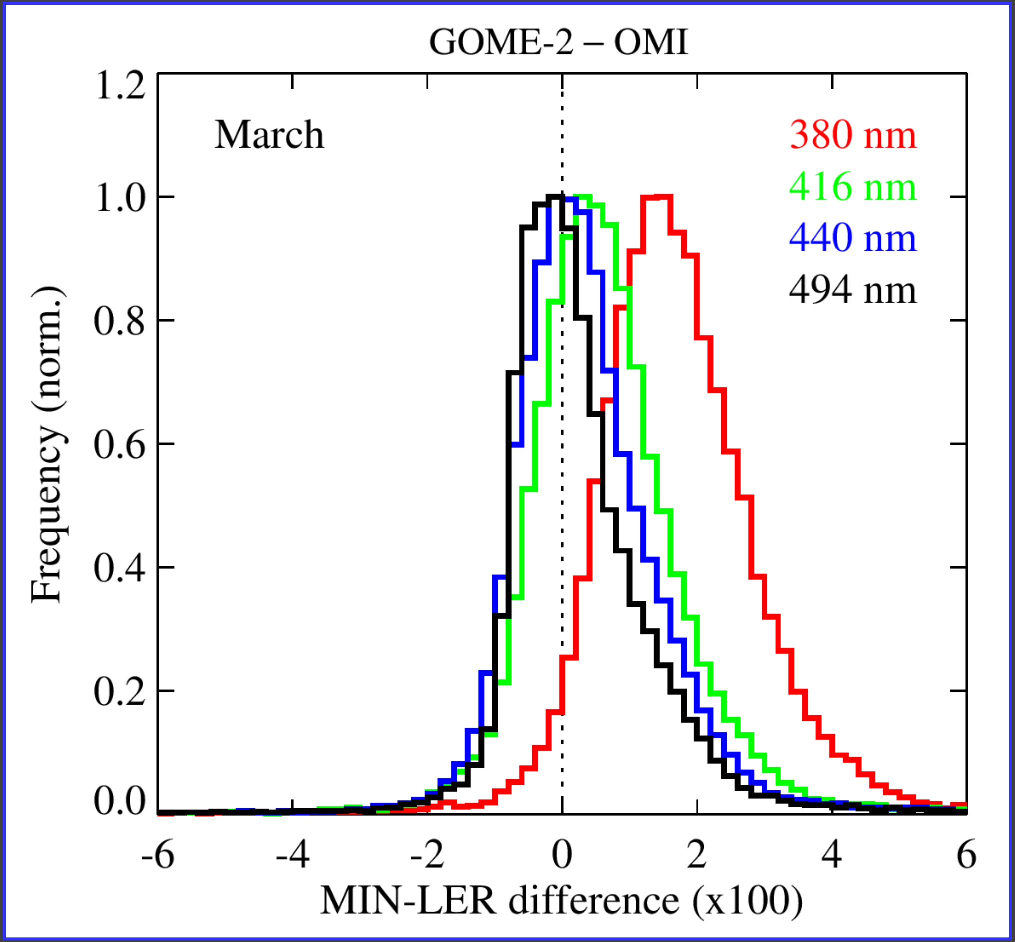
The agreement is reasonable above 400 nm. Below 400 nm again an offset. Wider distributions, most likely due to the smaller spatial resolution and coverage of the GOME-1 instrument. Clear signs of cloud contamination in the GOME-1 LER.

4.4 – Comparison: GOME-2 versus OMI



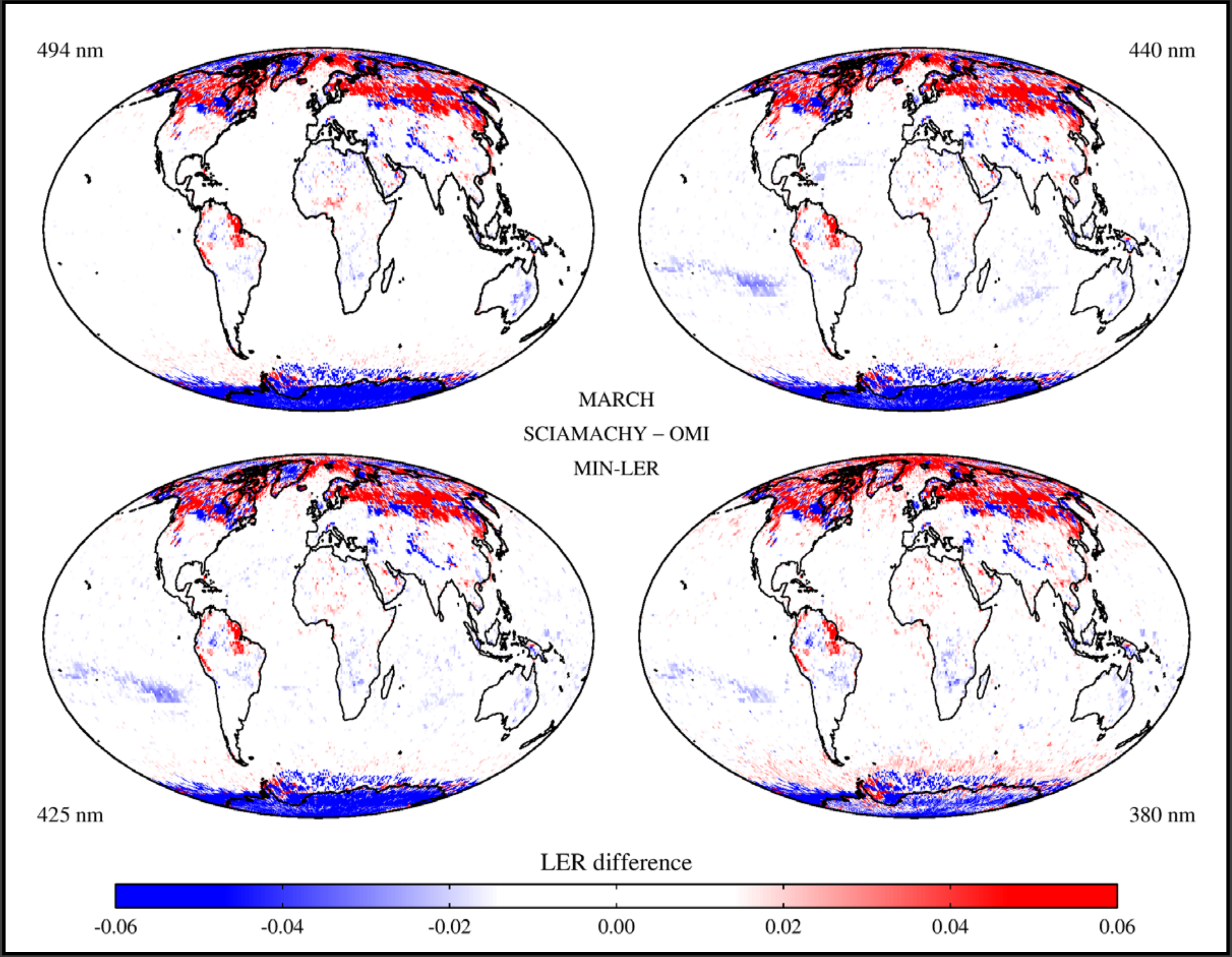
Histograms:

(60°S–60°N)



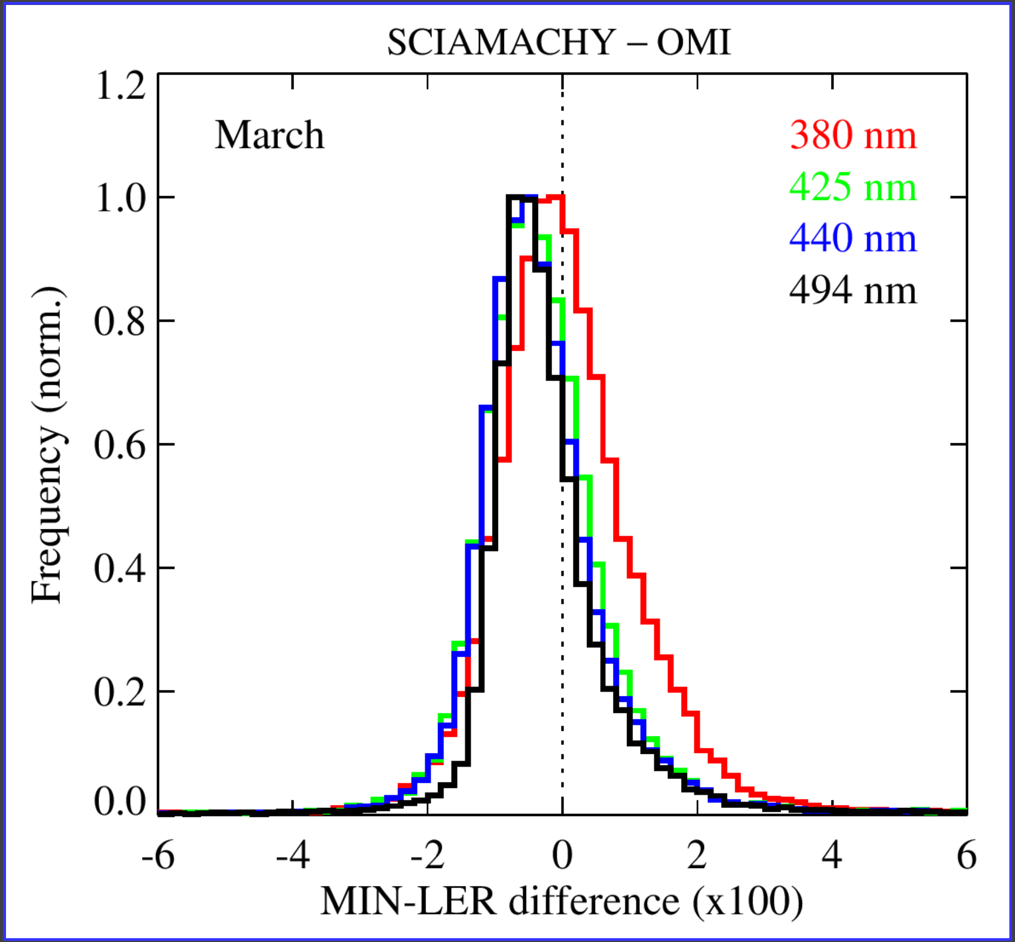
Agreement is very good above 400 nm. Below 400 nm we find, again, an offset.

4.5 – Comparison: SCIAMACHY versus OMI



Histograms:

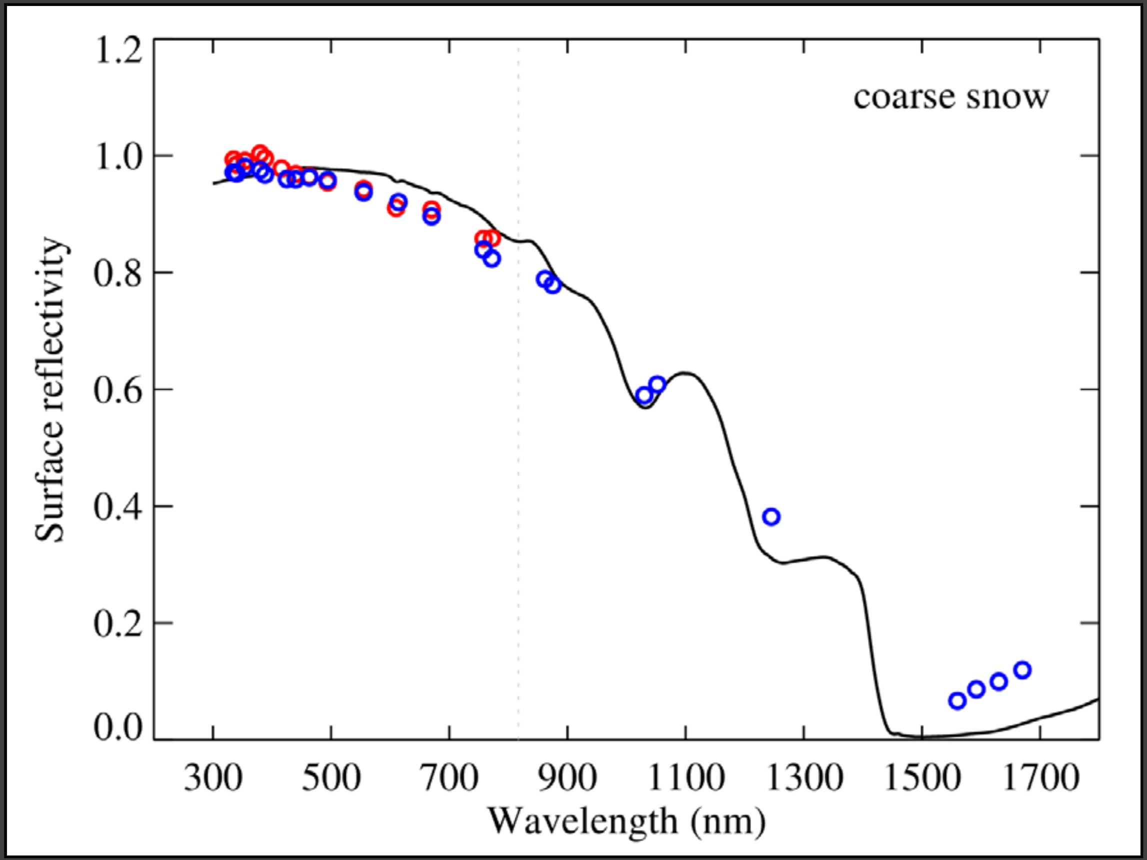
(60°S–60°N)



Very good agreement for all wavelength bands. So, the SCIAMACHY surface LER is ok, but this also means that the GOME-2 surface LER is suffering from the results of a (small) calibration issue of the GOME-2 instrument below 400 nm.

5 – Qualitative checks for the NIR (SCIAMACHY)

Above 800 nm, for SCIAMACHY, there is no surface LER reference available. We use surface reflectivity spectra from the ASTER Spectral Library to perform at least a qualitative comparison.



Coarse snow (modelled)

Particle size: 178 μm effective size

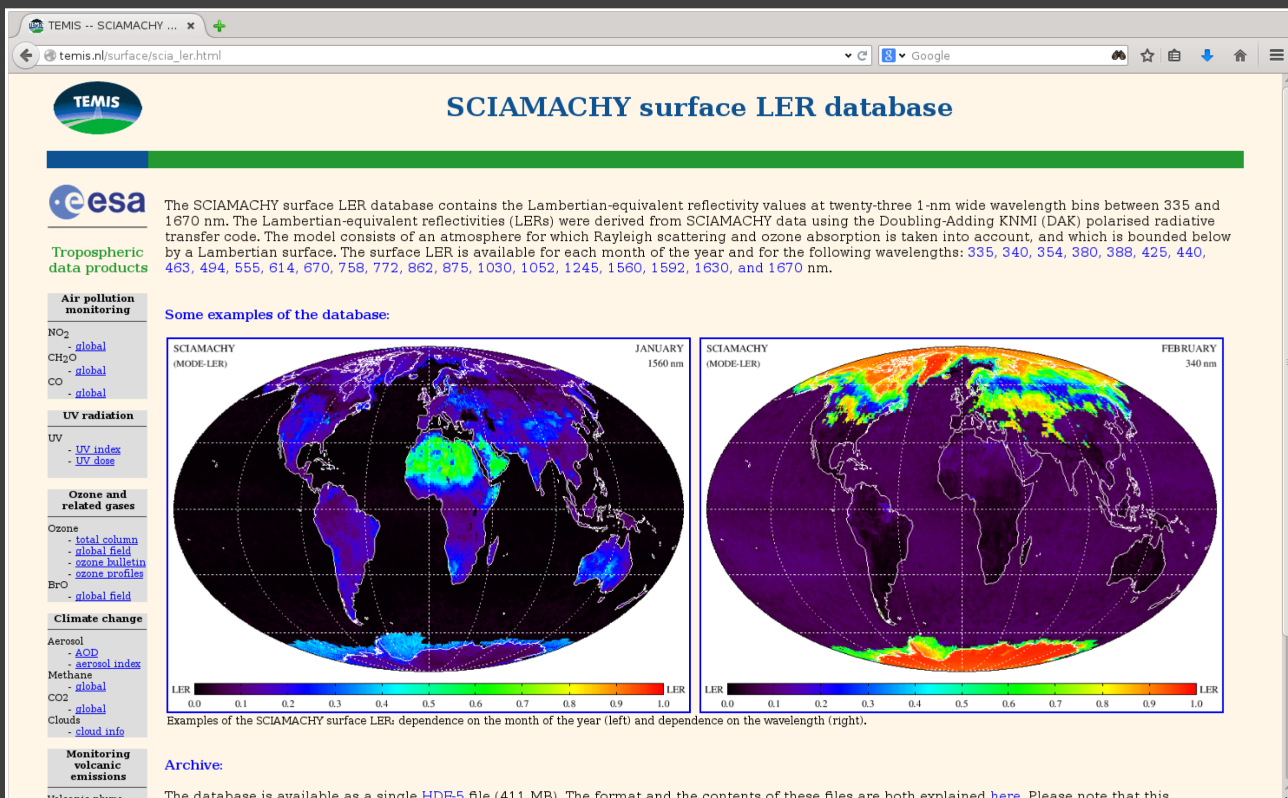
6 – Summary and conclusions

1) Good quality for the new GOME-2 and SCIAMACHY surface LER databases.

2) GOME-2 is showing a small discrepancy below 400 nm.

3) Further improvements: viewing angle dependence of surface LER.

4) Databases are available for download: www.temis.nl/surface/albedo.html



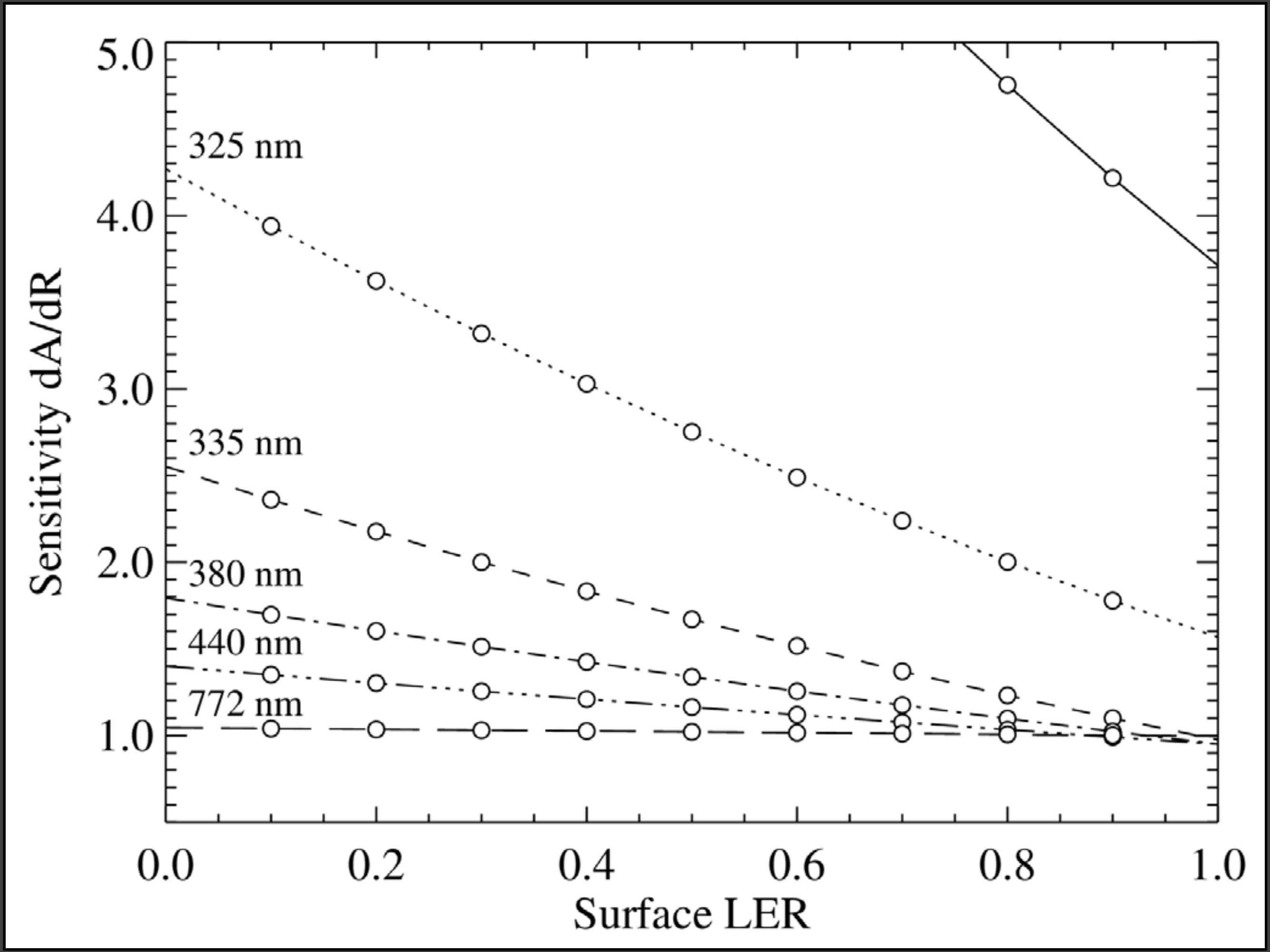
On TEMIS:

- GOME-1 LER
- SCIAMACHY LER
- GOME-2 LER
- OMI LER (link)
- MERIS BSA

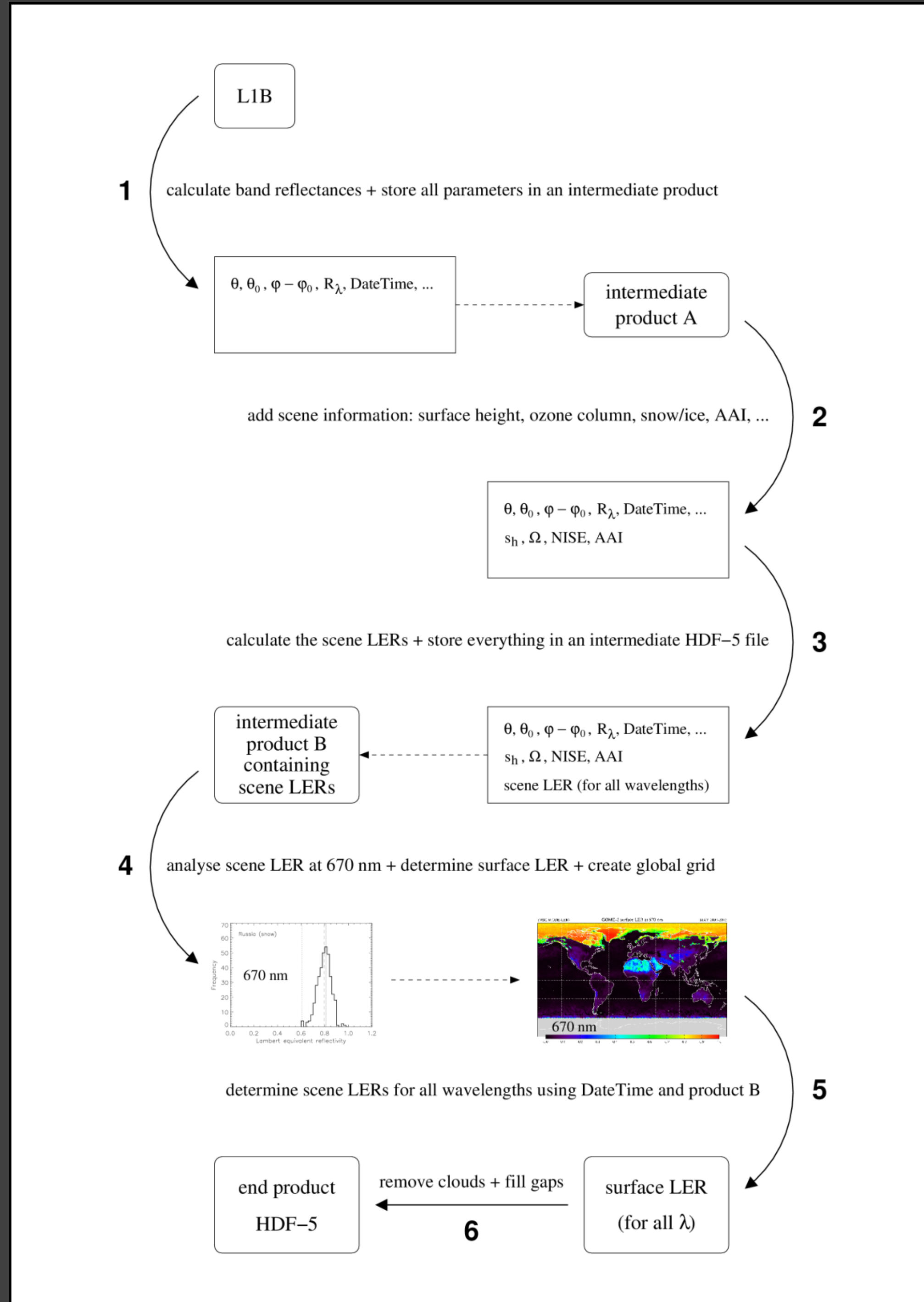
Extra slides

A – Sensitivity of surface LER to errors in the reflectance

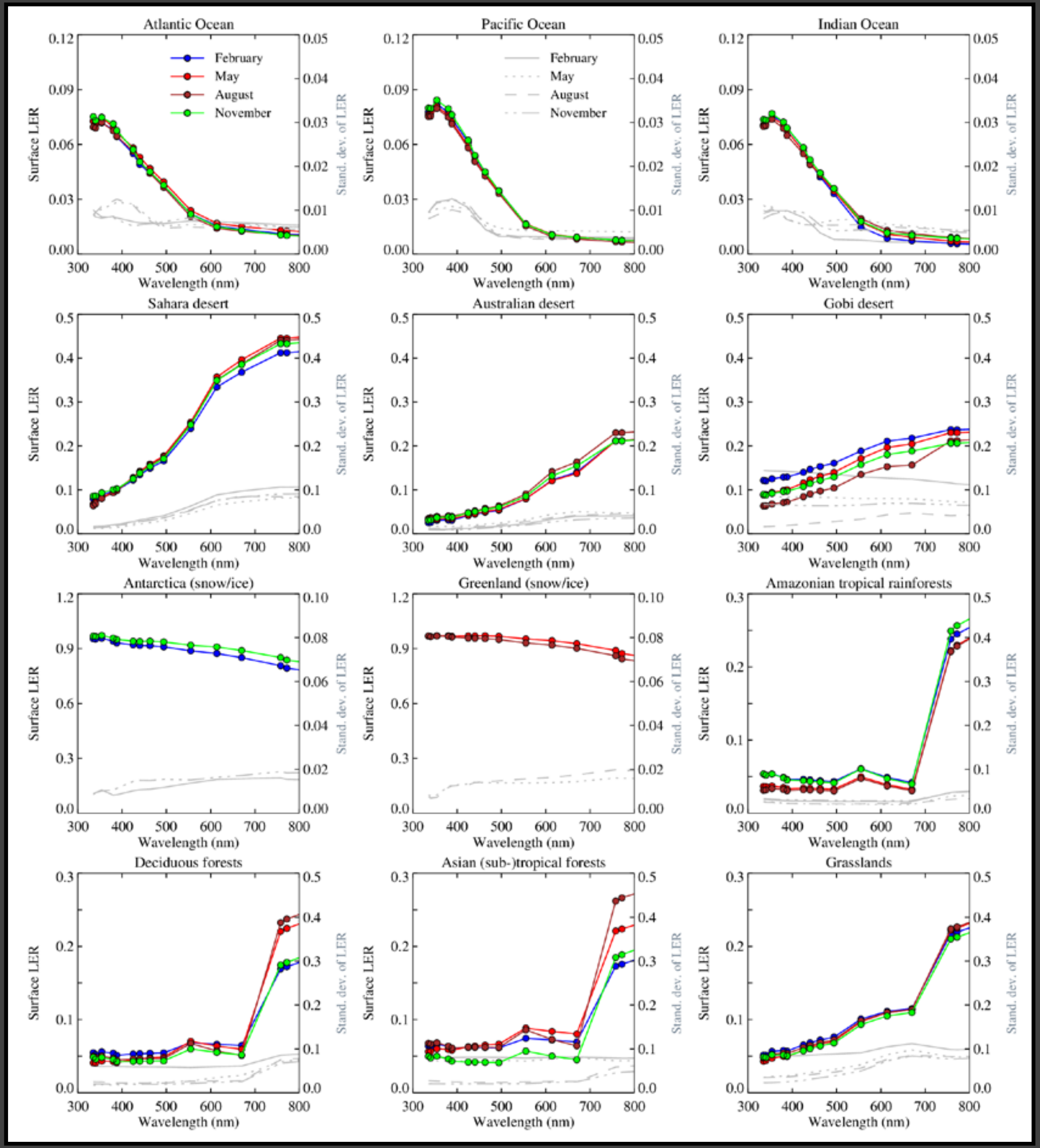
$$A_s = \frac{R^m - R^0}{T + s^\star(R^m - R^0)} \longrightarrow \frac{dA}{dR} = \frac{A^2T}{(R^m - R^0)^2}$$



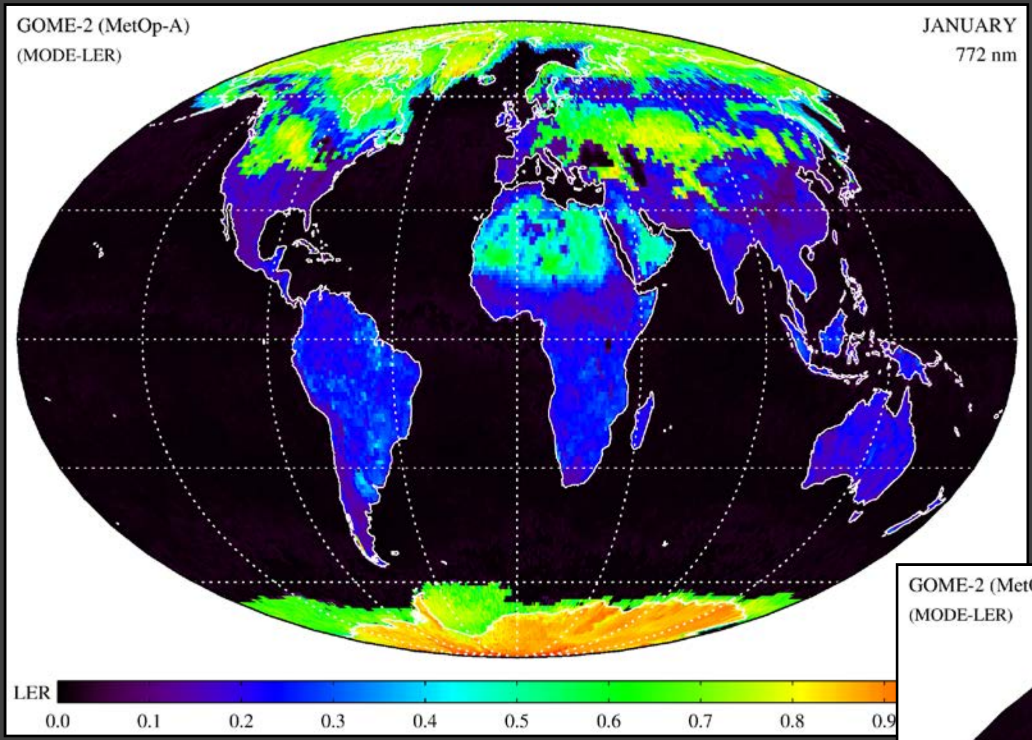
B – Processing scheme



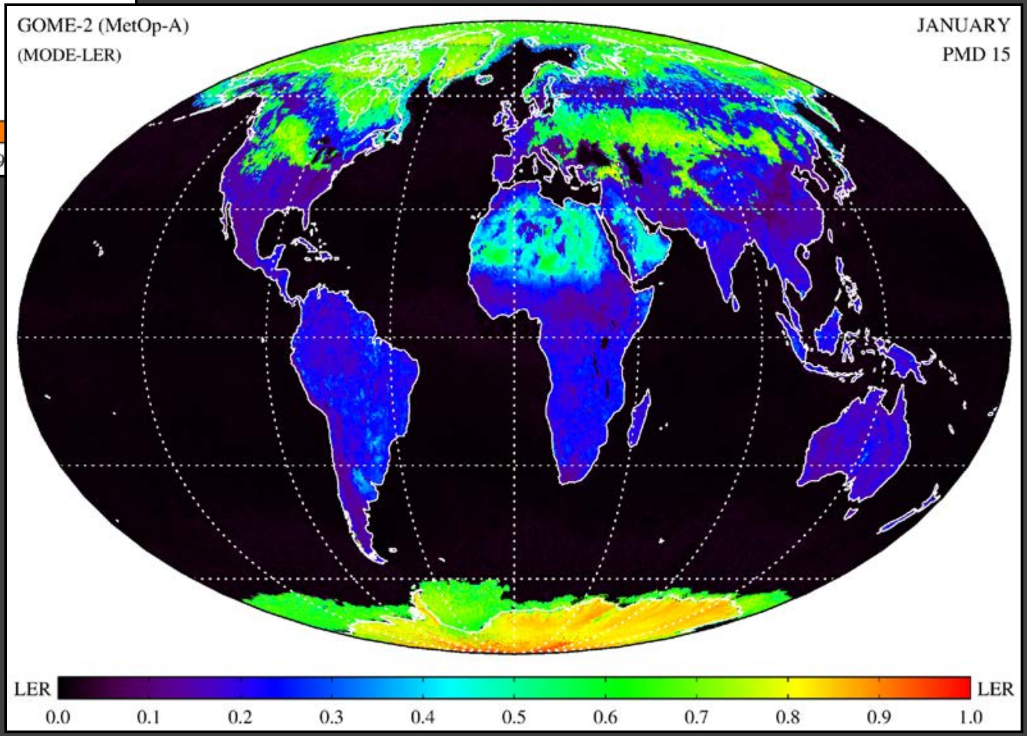
C – Spectral surface albedo



D – GOME-2: Main science channels versus PMD bands



MSC



PMD

E – GOME-2 surface LER at 772 nm