The (level 2) inside story of Sentinel 5 precursor

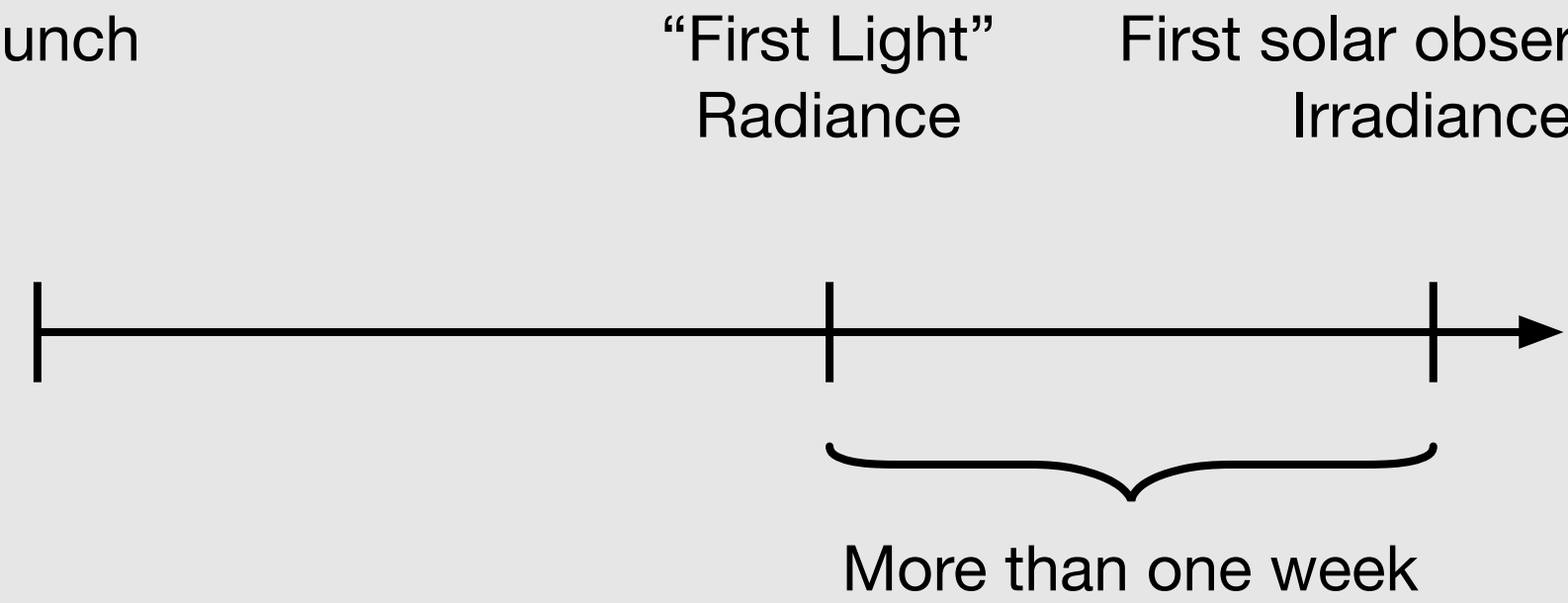
Maarten Sneep, Mark ter Linden, Martien de Haan, Jan de Wit, Pepijn Veefkind, Arnoud Apituley, Jacques Claas, Tobias Borsdorff, Joost aan de Brugh, Haili Hu, Alba Lorente Delgado, Mari Martinez Velarte, Jochen Landgraf, Otto Hasekamp, Andre Butz, Remco Scheepmaker, Sander Houweling, Jos van Geffen, Folkert Boersma, Henk Eskes, Robert van Versendaal, Martin de Graaf, Bram Sanders, Nanda Swadhin, Ping Wang, Piet Stammes, Johan de Haan, Serena di Pede, Deborah Stein Zweers, Gijsbert Tilstra, with support from the L1B and on-ground calibration teams, and input from the international verification team – Andreas Richter *et al*., and further support the PDGS team at DLR, and the UPAS team at DLR, and the team at ESA.

The (level 2) KNMI inside story of Sentinel 5 precursor

Maarten Sneep, Mark ter Linden, Martien de Haan, Jan de Wit, Pepijn Veefkind, Arnoud Apituley, Jacques Claas, Tobias Borsdorff, Joost aan de Brugh, Haili Hu, Alba Lorente Delgado, Mari Martinez Velarte, Jochen Landgraf, Otto Hasekamp, Andre Butz, Remco Scheepmaker, Sander Houweling, Jos van Geffen, Folkert Boersma, Henk Eskes, Robert van Versendaal, Martin de Graaf, Bram Sanders, Nanda Swadhin, Ping Wang, Piet Stammes, Johan de Haan, Serena di Pede, Deborah Stein Zweers, Gijsbert Tilstra, with support from the L1B and on-ground calibration teams, and input from the international verification team – Andreas Richter *et al*., and further support the PDGS team at DLR, and the UPAS team at DLR, and the team at ESA.

Early development of the NL level 2 processors

- First commit on “Tue Jan 22 10:51:27 2013”
  - About 1½ years later than the L1B processor.
  - The L1B time handling code is shared with the L1B processor, and some early experiences were shared, but the rest of the code is developed independently, including the multithreading support.
- At launch version 0.11.7 was active (6734 commits from start).
  - Launch was delayed, and not everyone who had worked on the processor was available to help solve *issues* post launch.
  - Adding people to the team when you need them is far too late, retaining expertise through delays is a challenge.



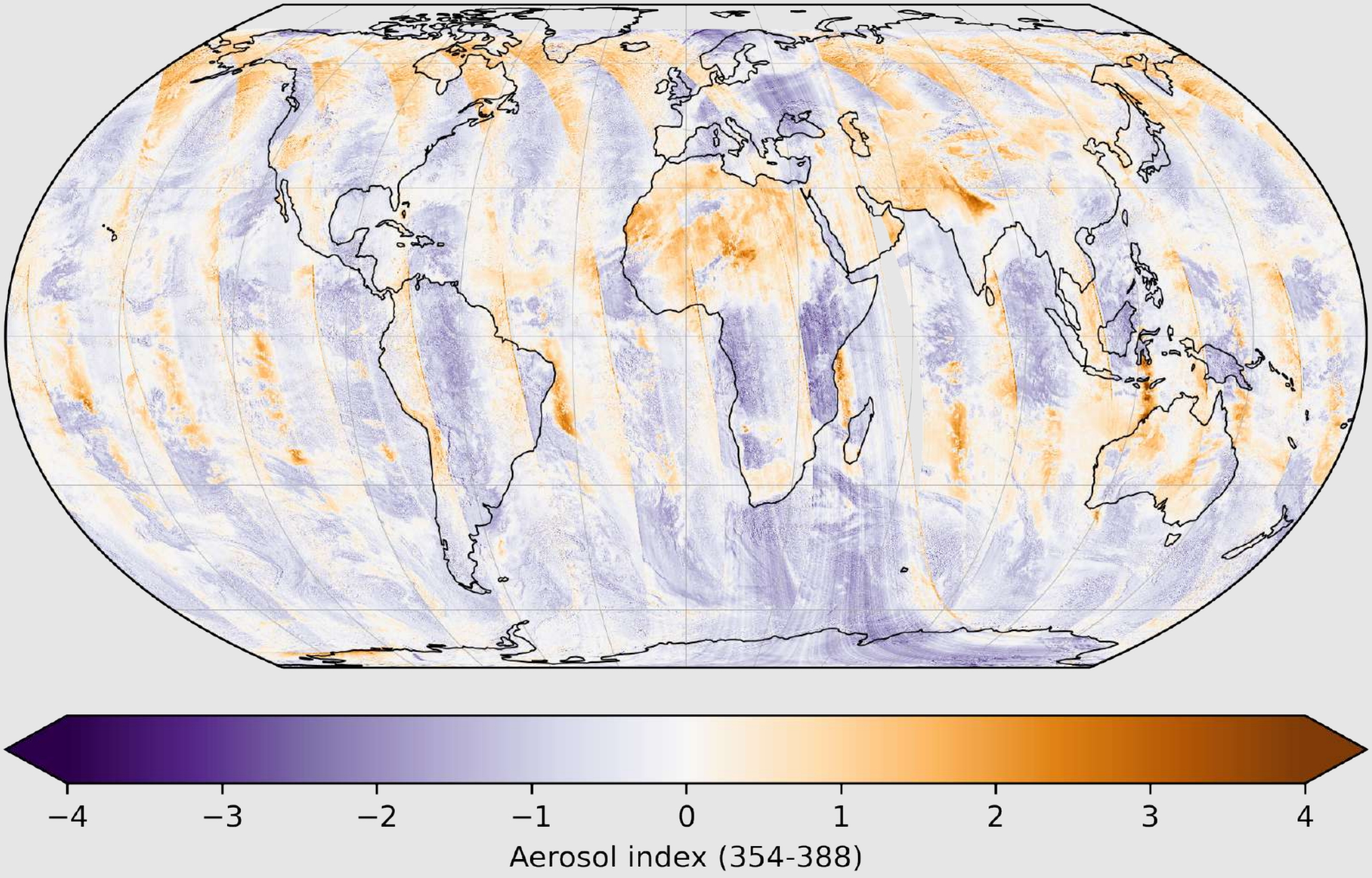
- For Level 1B to Level 2 processing both radiance and irradiance are required.
- More than a week between first radiance and first irradiance
- To keep moving forward, we used a synthetic irradiance file
  - Reference solar spectrum convolved with ISRF sampled at nominal wavelength grid.

First light analysis

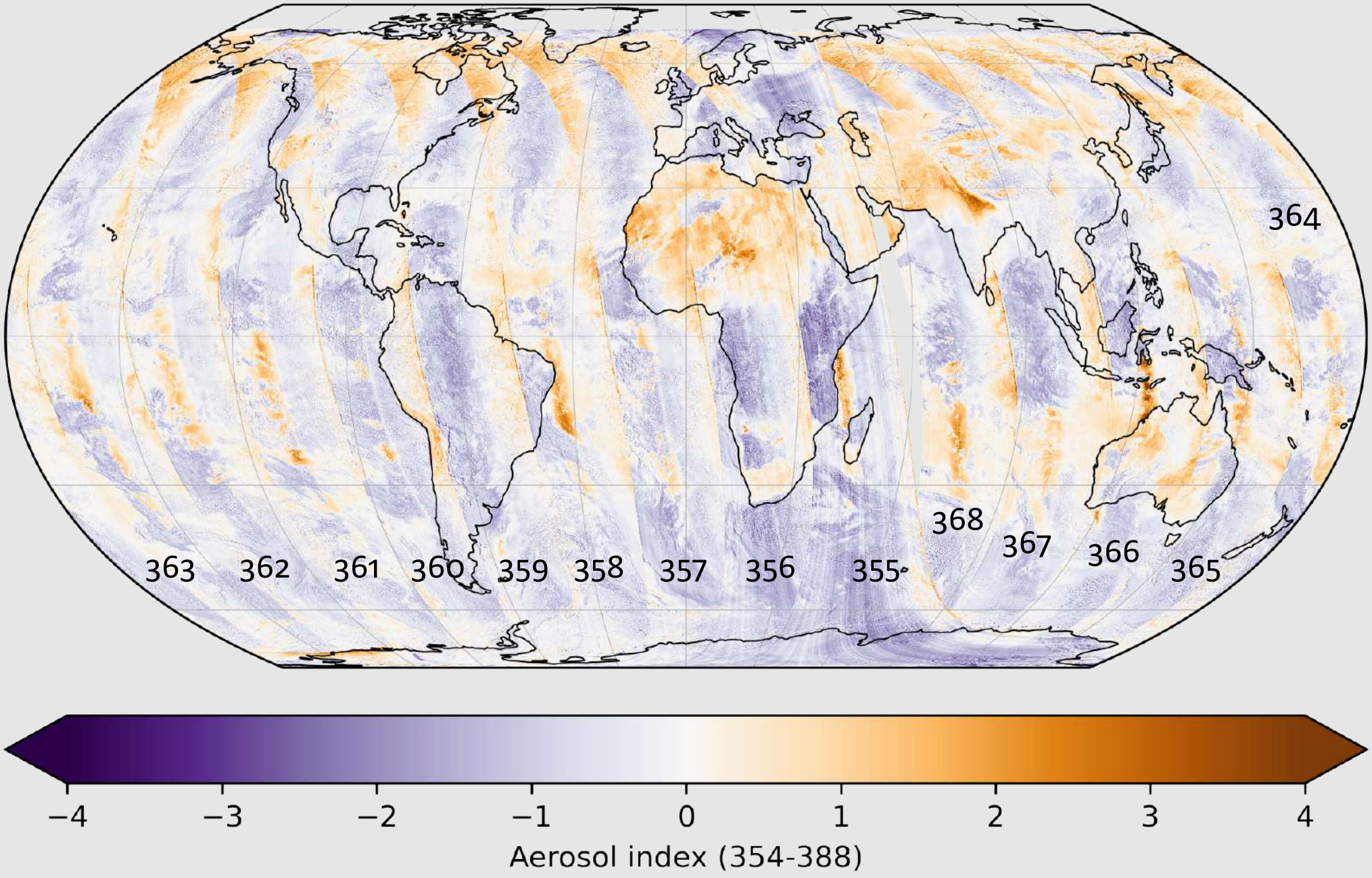
- First results from UV Aerosol Index, FRESCO clouds and NO_2.
  - UV Aerosol Index uses band 3, is very sensitive to calibration.
  - FRESCO cloud uses band 6.
  - NO_2 uses band 4.
- At this moment in the mission the SWIR components are too hot for meaningful results for CO and CH_4 from bands 7 & 8.
- O_3 profile was not tried with the synthetic irradiance (bands 1 & 2).

- I don’t think I’ve seen people bounce up and down the corridor at KNMI in quite the same way as when the first results came in.

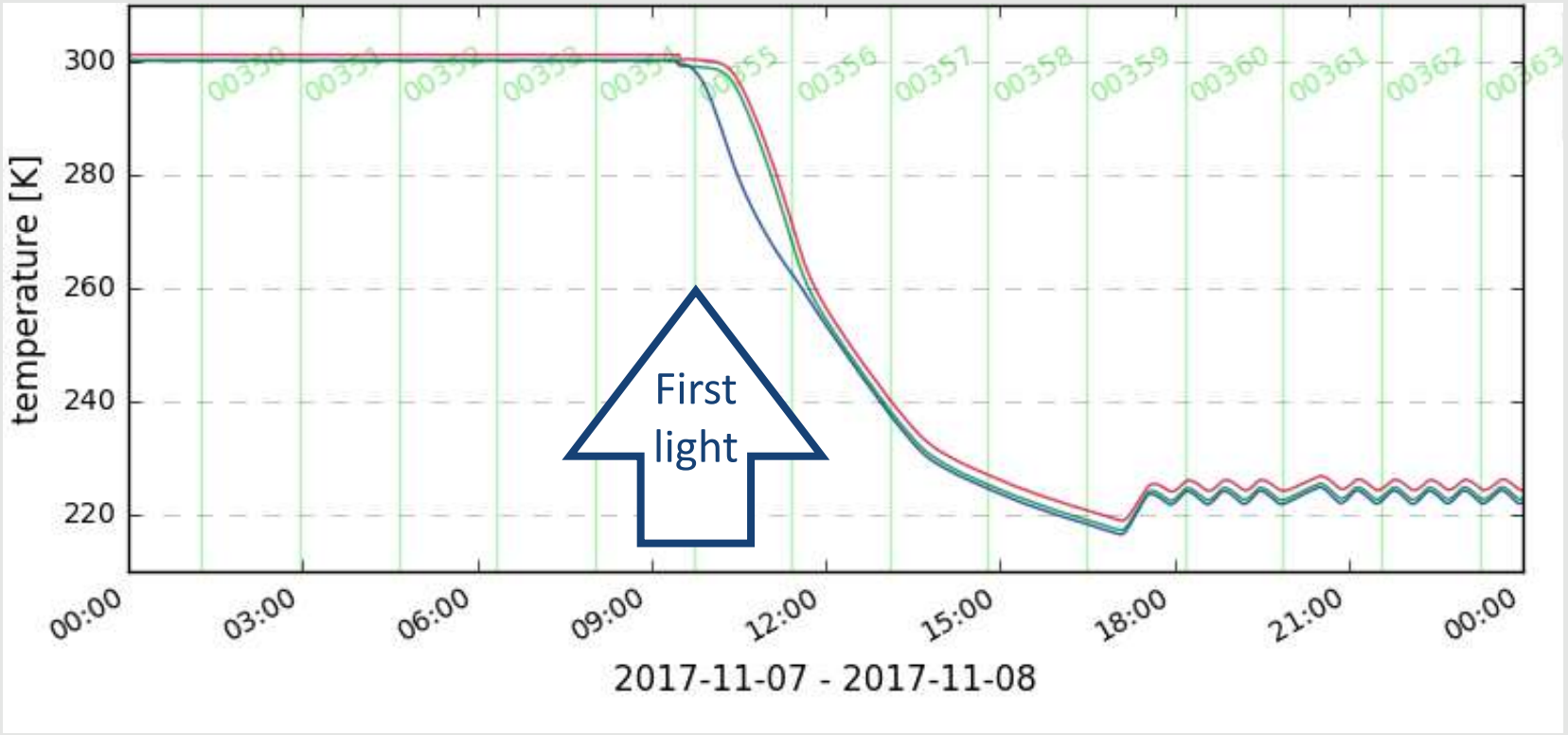
First day, synthetic irradiance, original processor



First day, synthetic irradiance, original processor

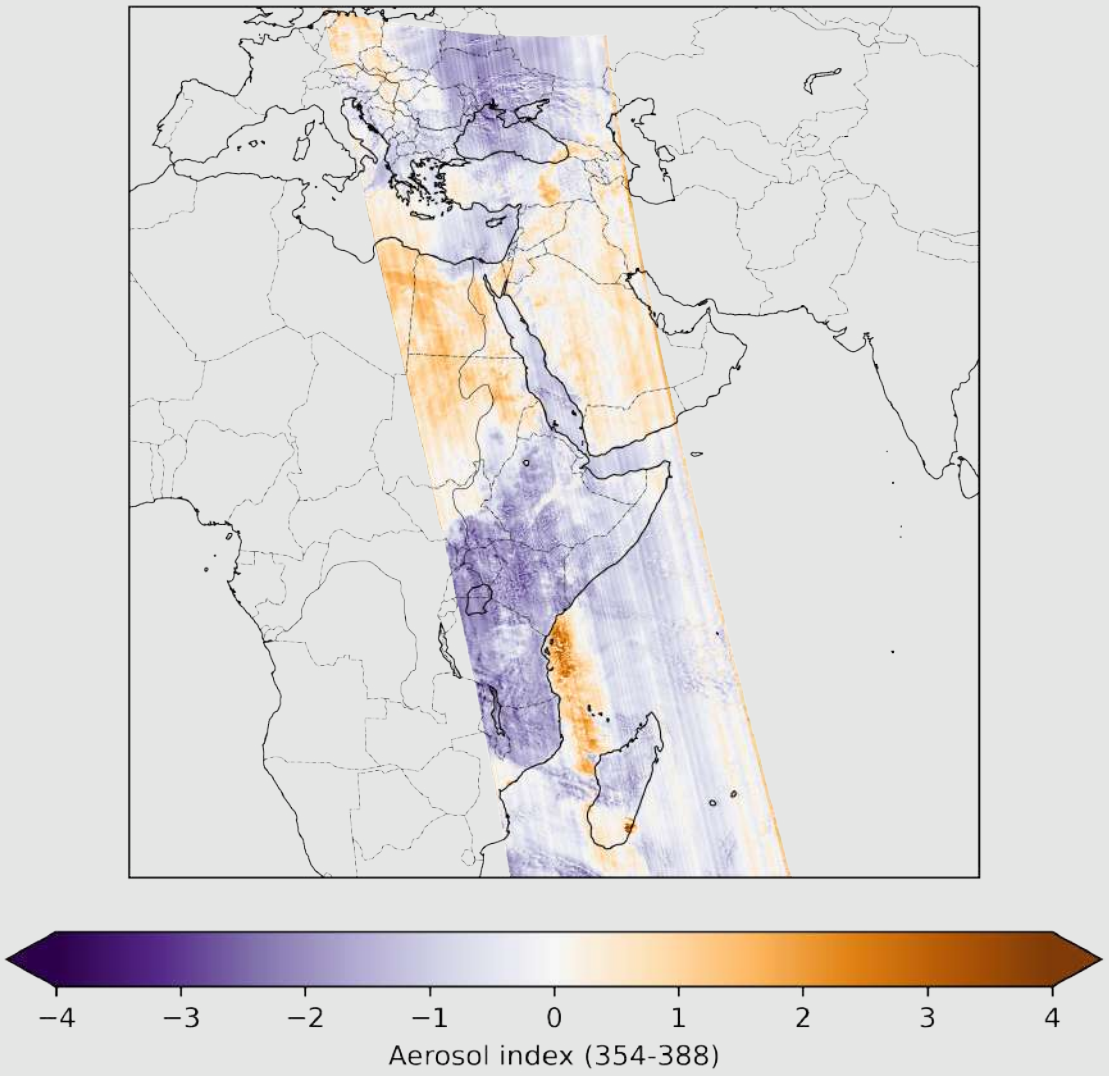


Temperature of the UVN CCD detectors

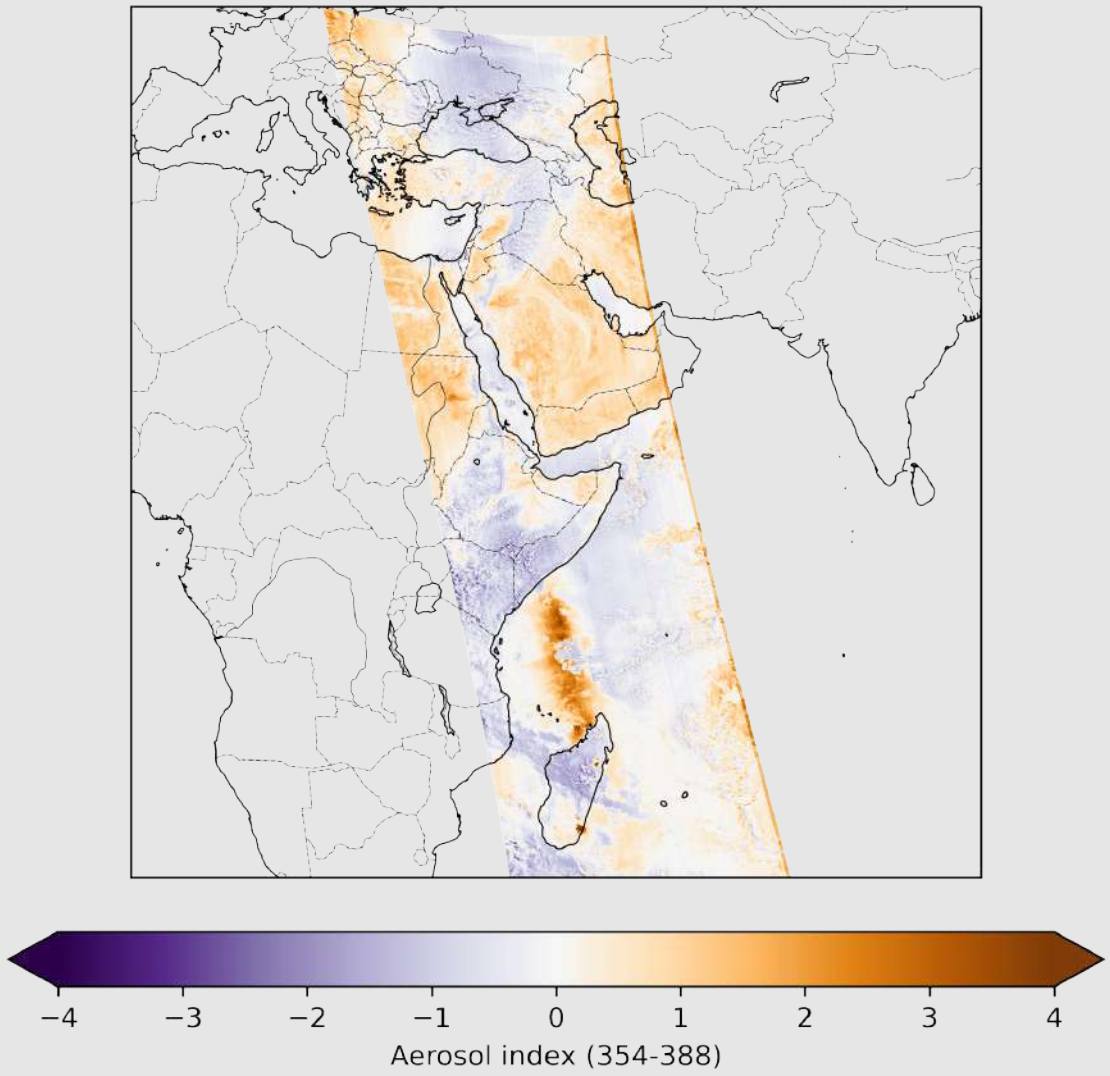


Temperature of the detectors

First light, synthetic irradiance, original processor

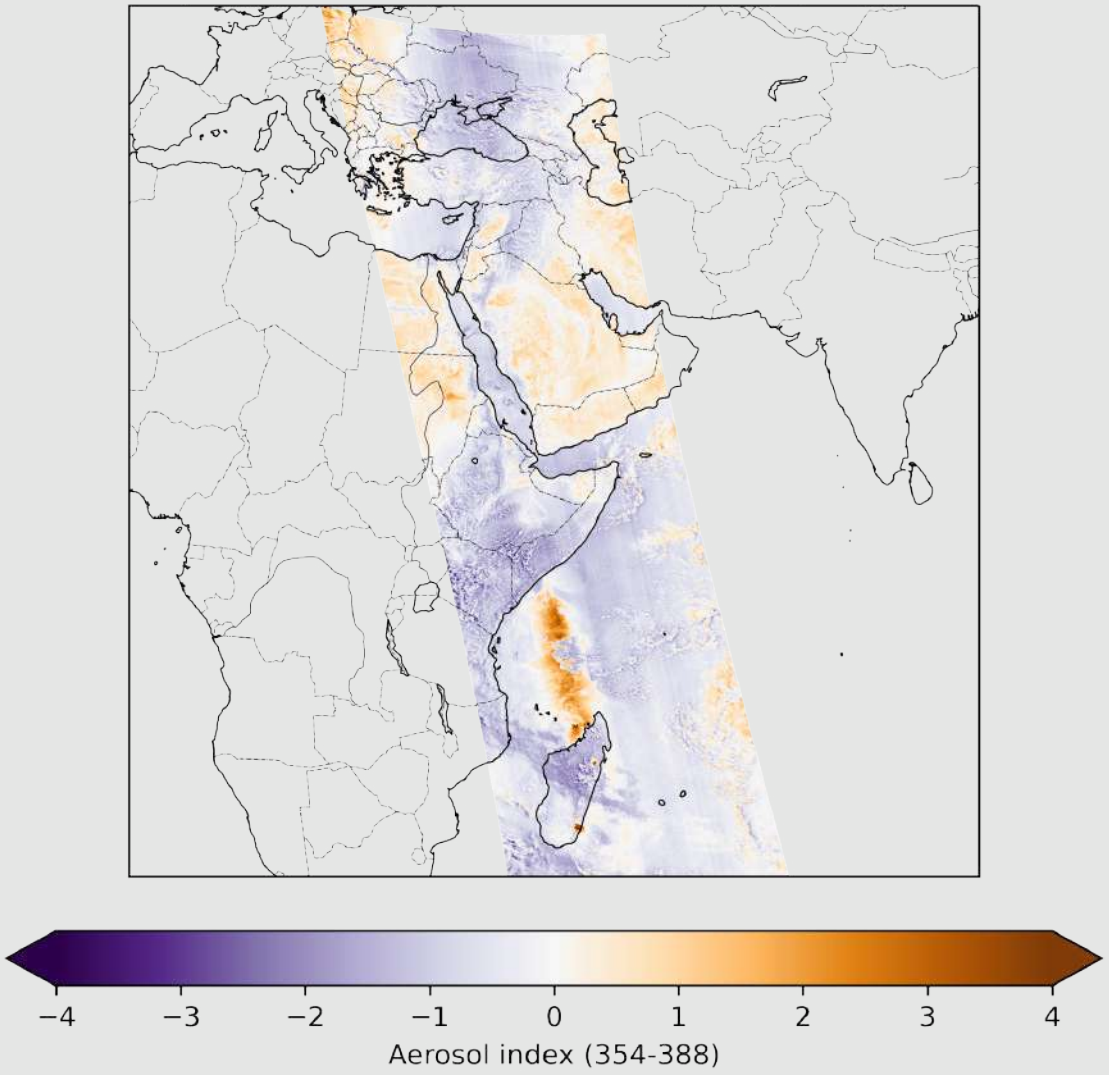


One day later, synthetic irradiance, original processor

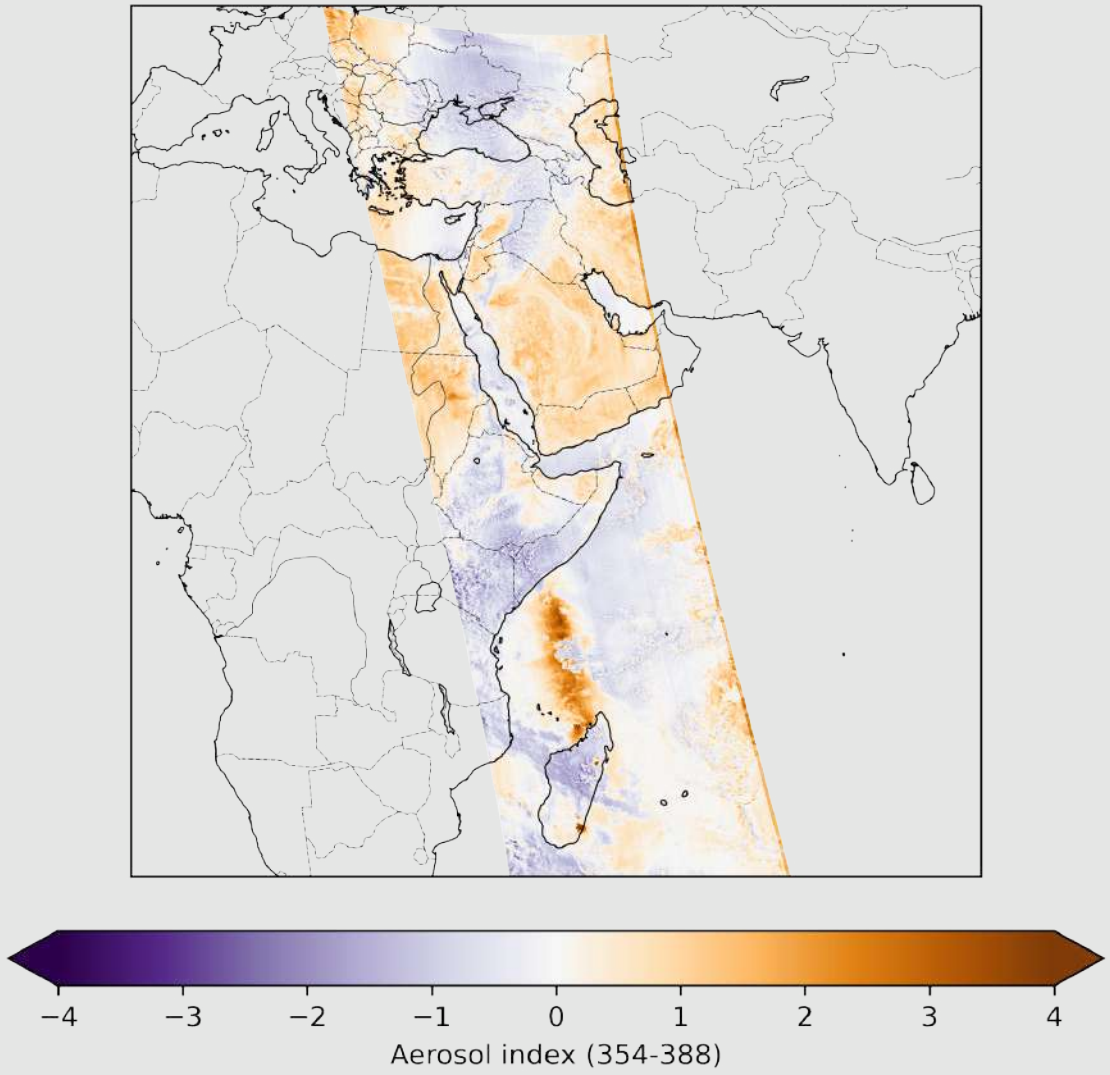


Using observed instead of synthetic irradiance

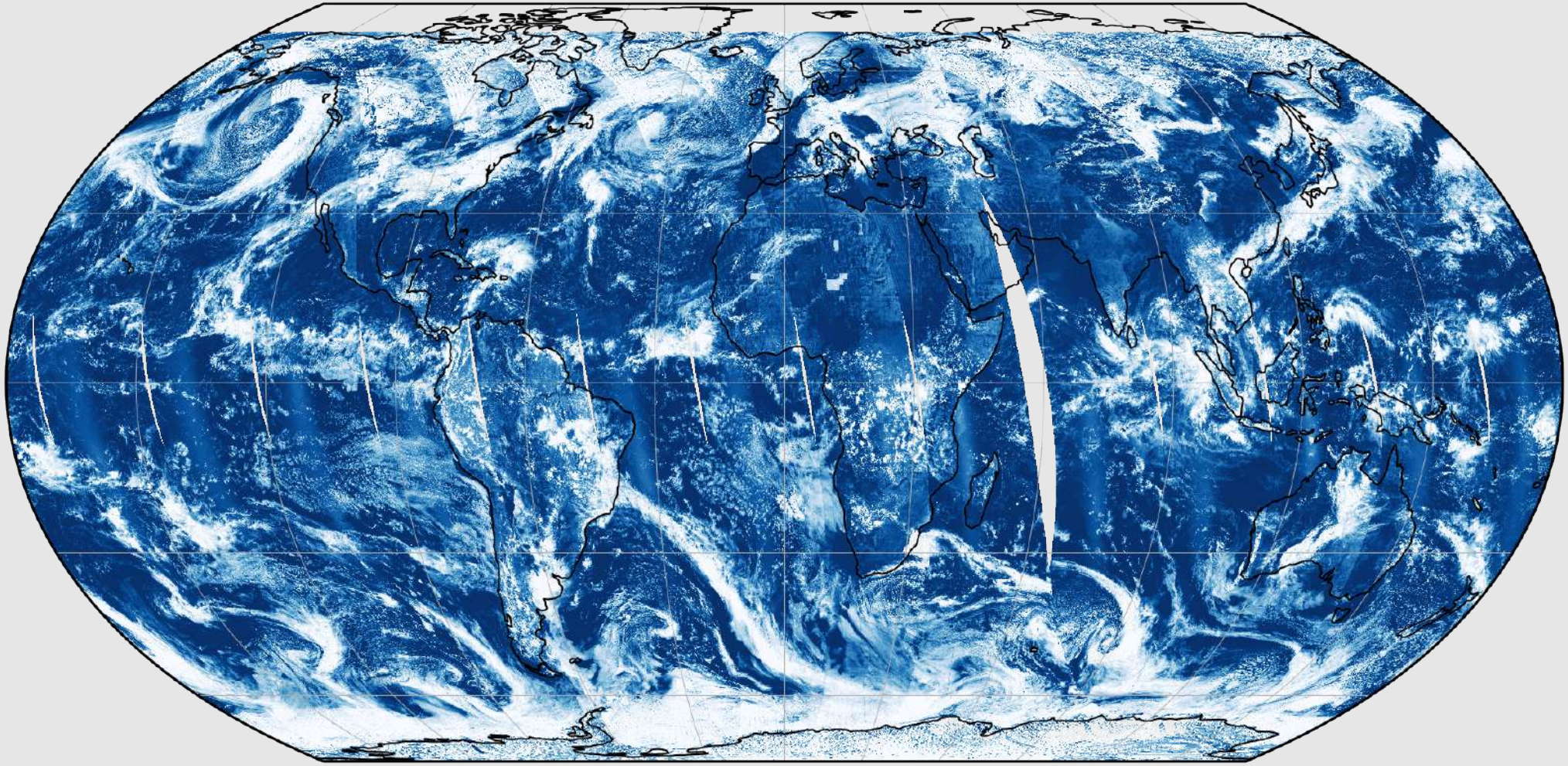
One day later, irradiance from orbit 657, original processor



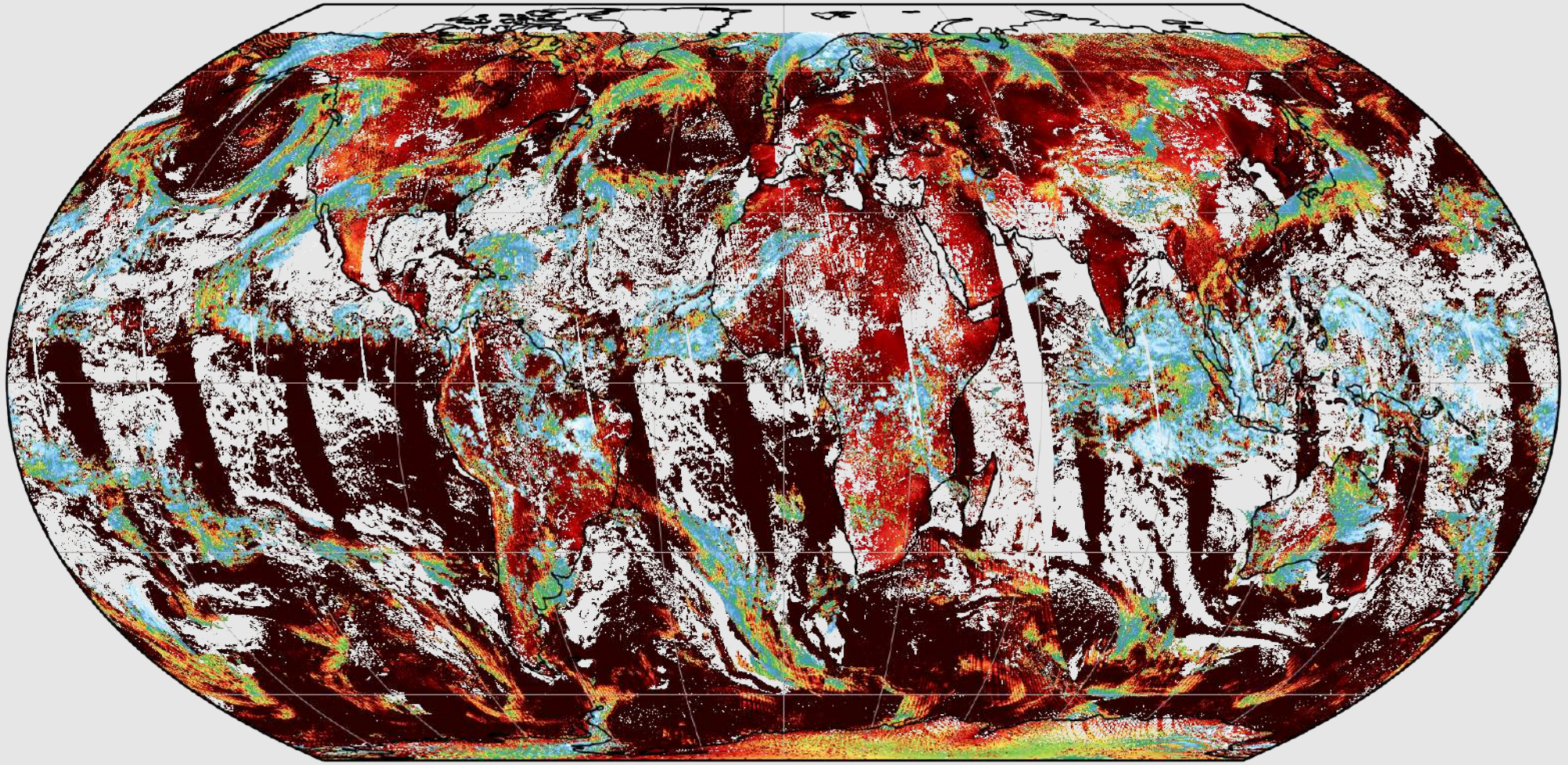
One day later, synthetic irradiance, original processor

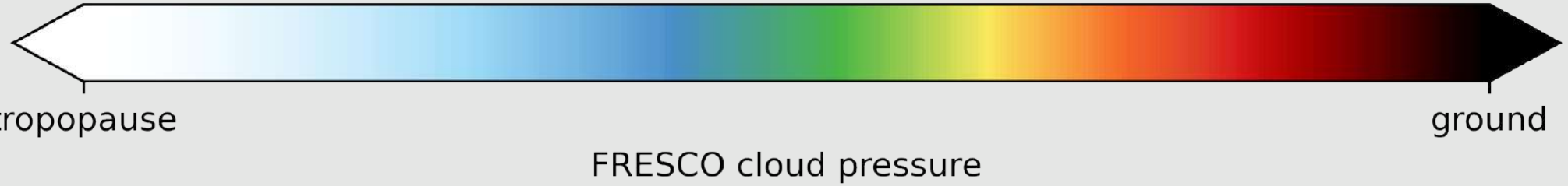


First day, synthetic irradiance, original processor



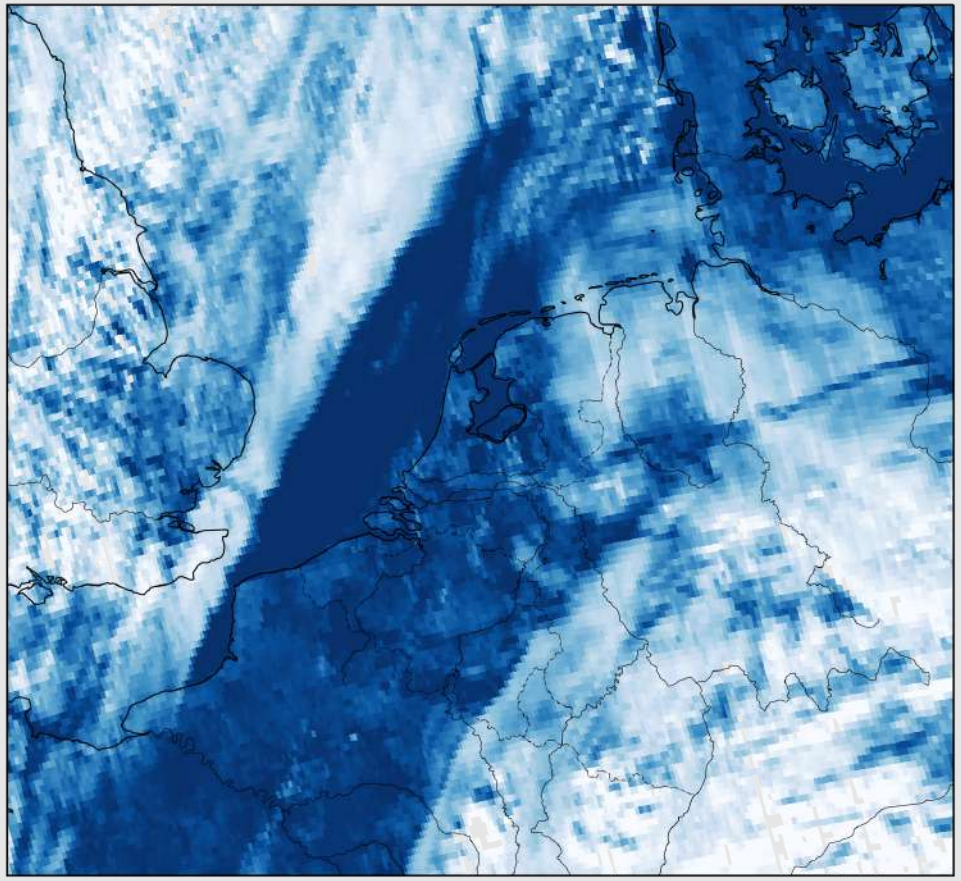
First day, synthetic irradiance, original processor





Cloud parameters detail over the Netherlands

First day, synthetic irradiance, original processor

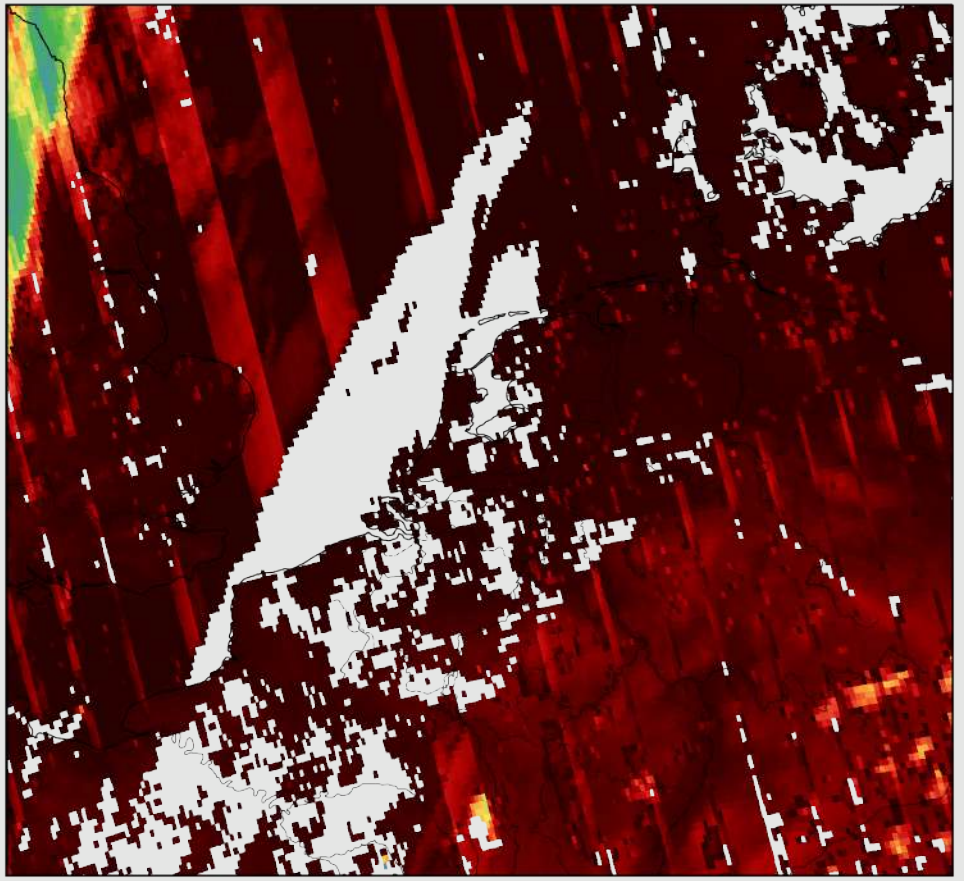


low

high

FRESCO cloud fraction

First day, synthetic irradiance, original processor



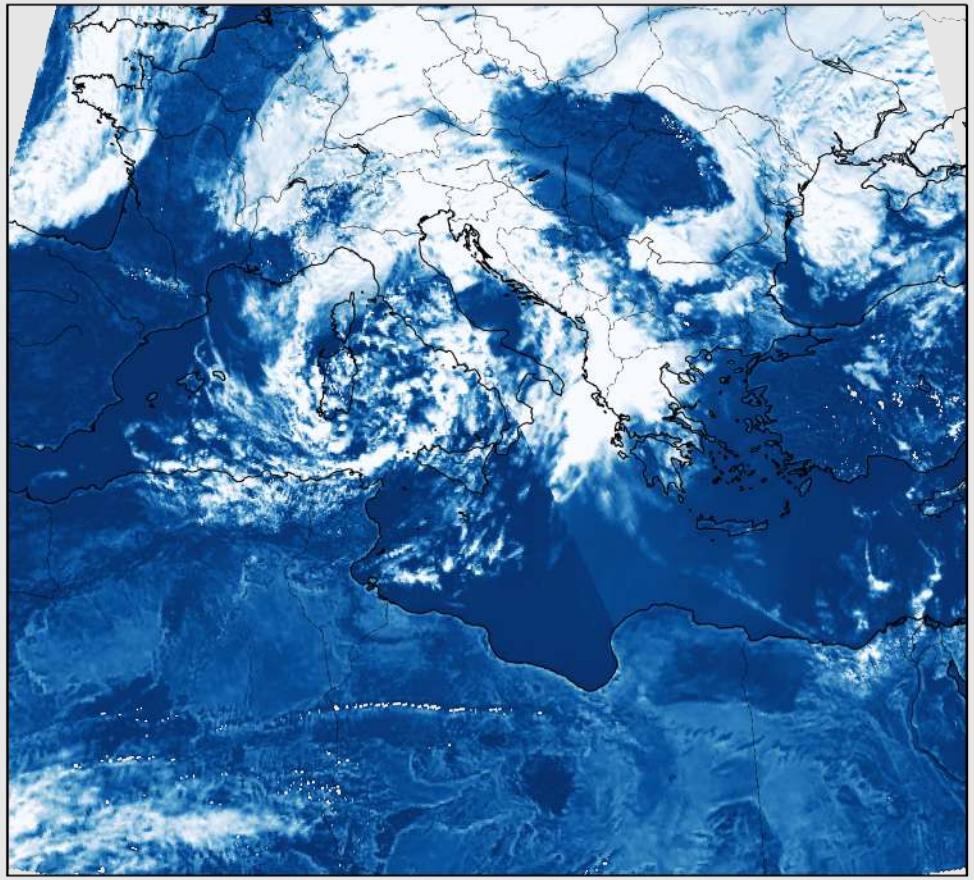
tropopause

ground

FRESCO cloud pressure

Wavelength calibration needs

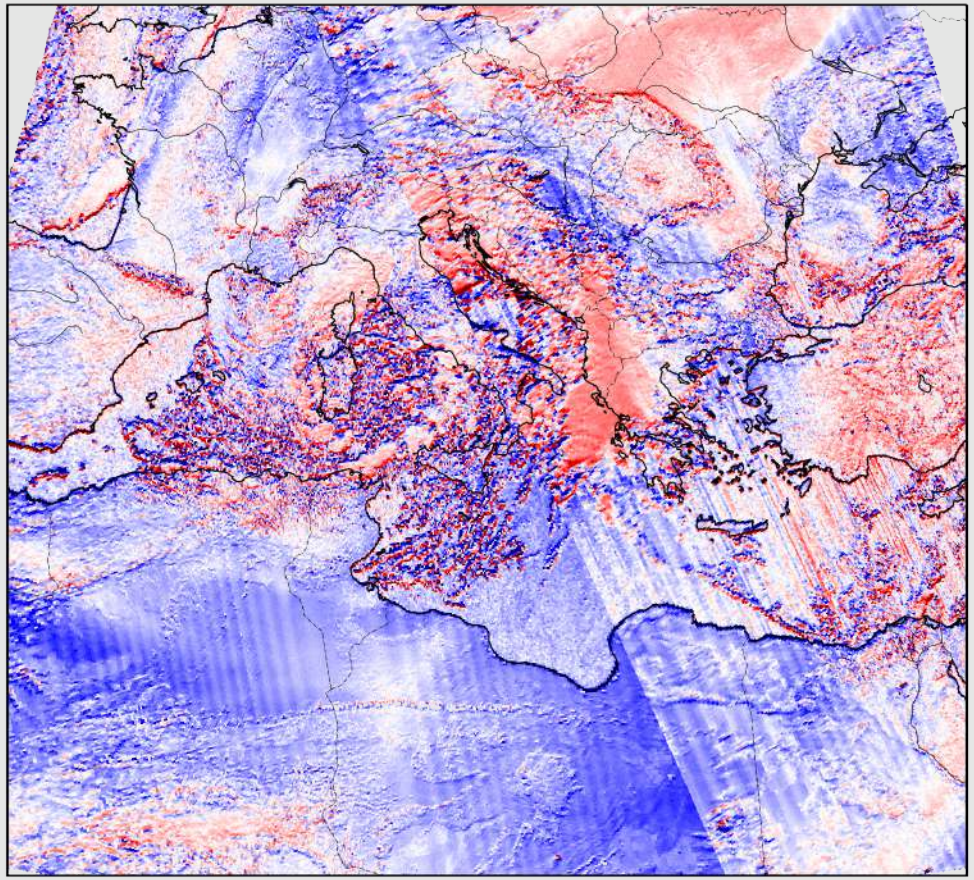
First day, irradiance from orbit 657, current processor



low high

FRESCO cloud fraction

First day, irradiance from orbit 657, current processor

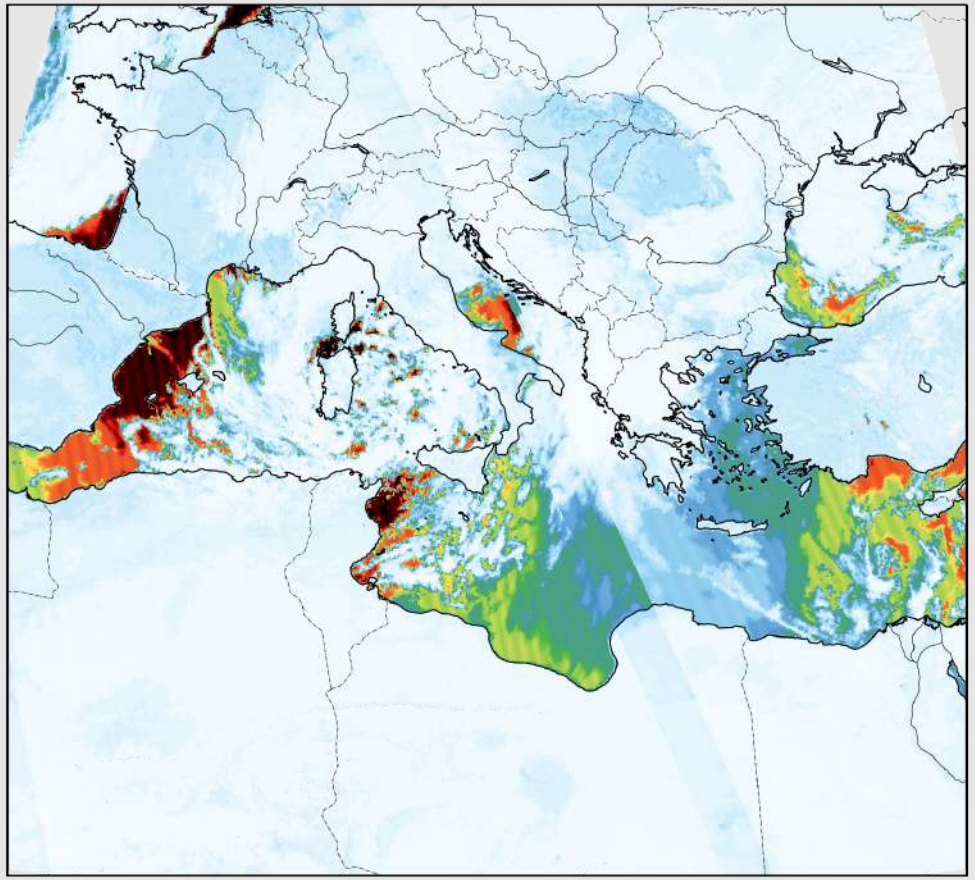


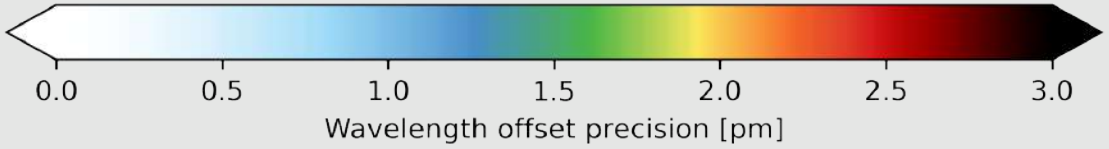
−30 −20 −10 0 10 20 30

Wavelength offset [pm]

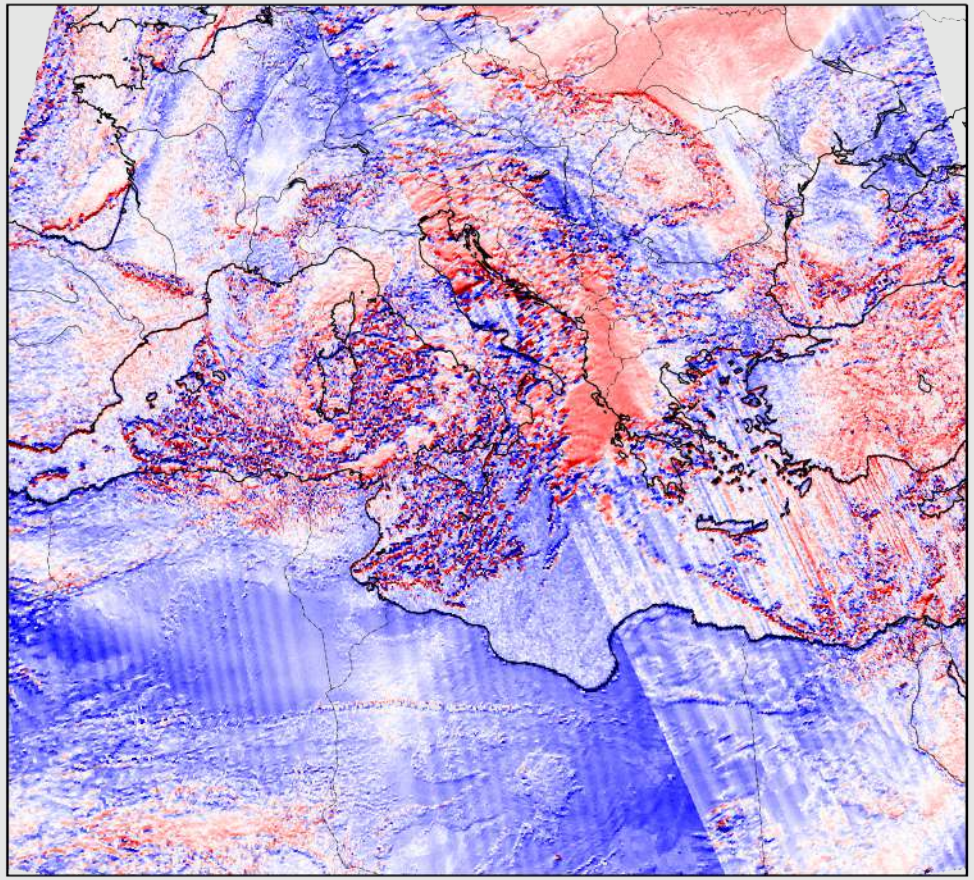
Wavelength calibration needs

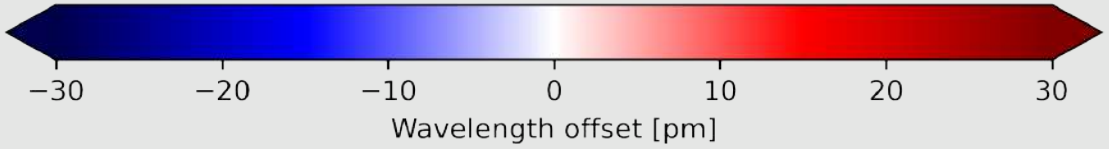
First day, irradiance from orbit 657, current processor





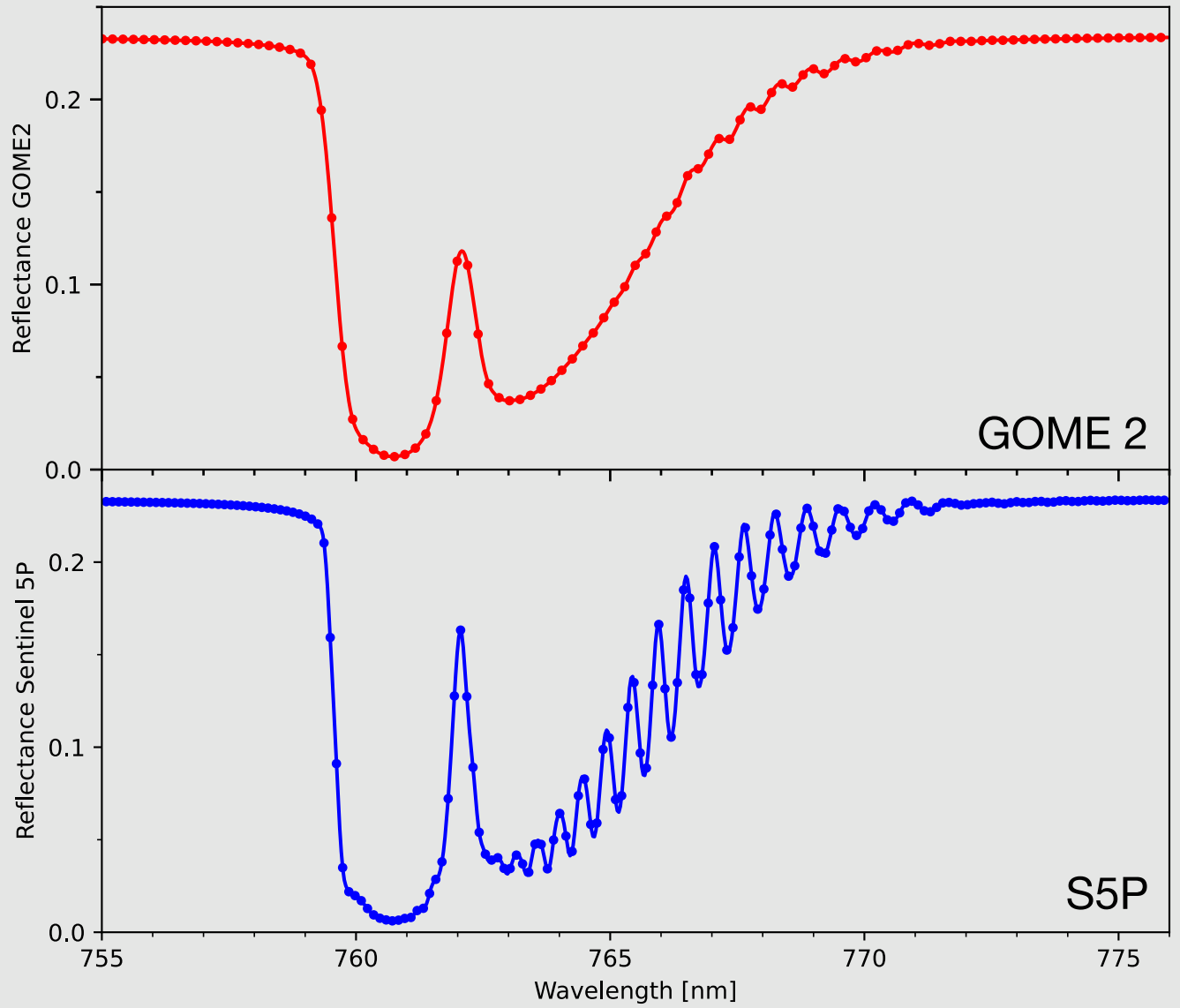
First day, irradiance from orbit 657, current processor





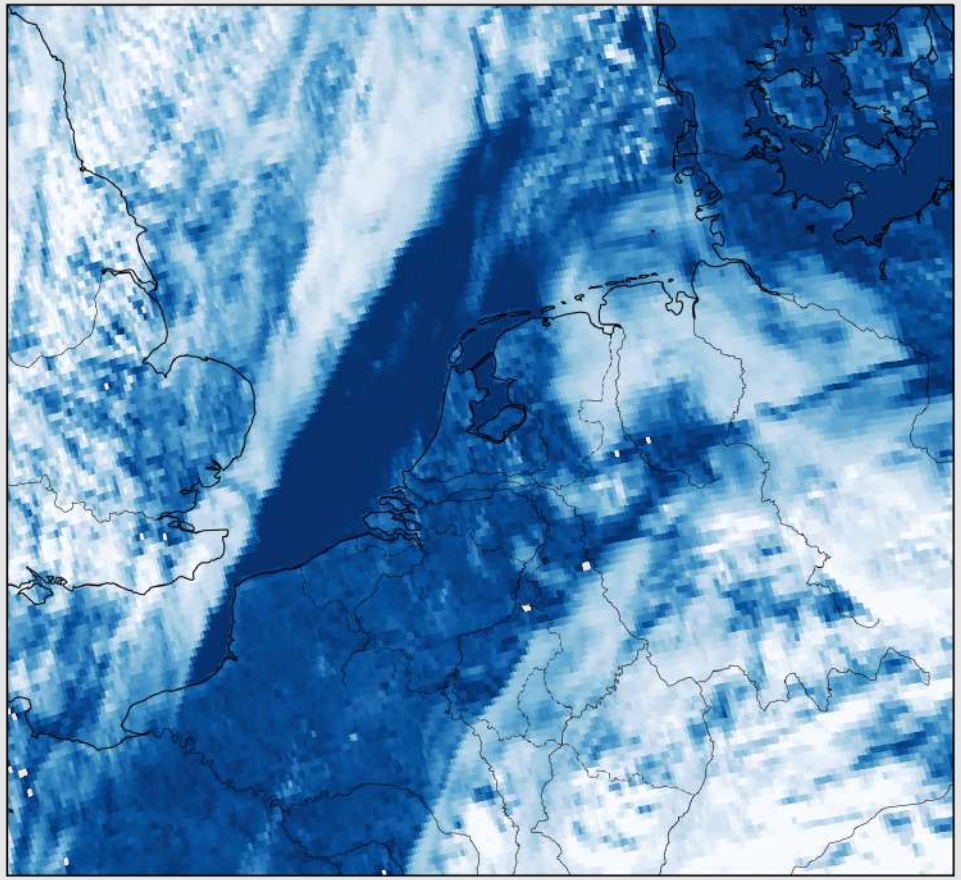
Instrument properties

- Tropomi has a higher spectral resolution than the GOME-2 instrument.
- This leads to finer spectral structures in the O_2 A-band.
- The resulting slopes in the spectrum make any algorithm very sensitive to spectral handling and spectral calibration.
- Changed algorithm to use higher resolution reference LUT, and interpolate the LUT to the radiance spectral grid, rather than interpolating the observation to the LUT.
- Remaining stripes originate from spectral calibration limitations.



Cloud parameters detail over the Netherlands

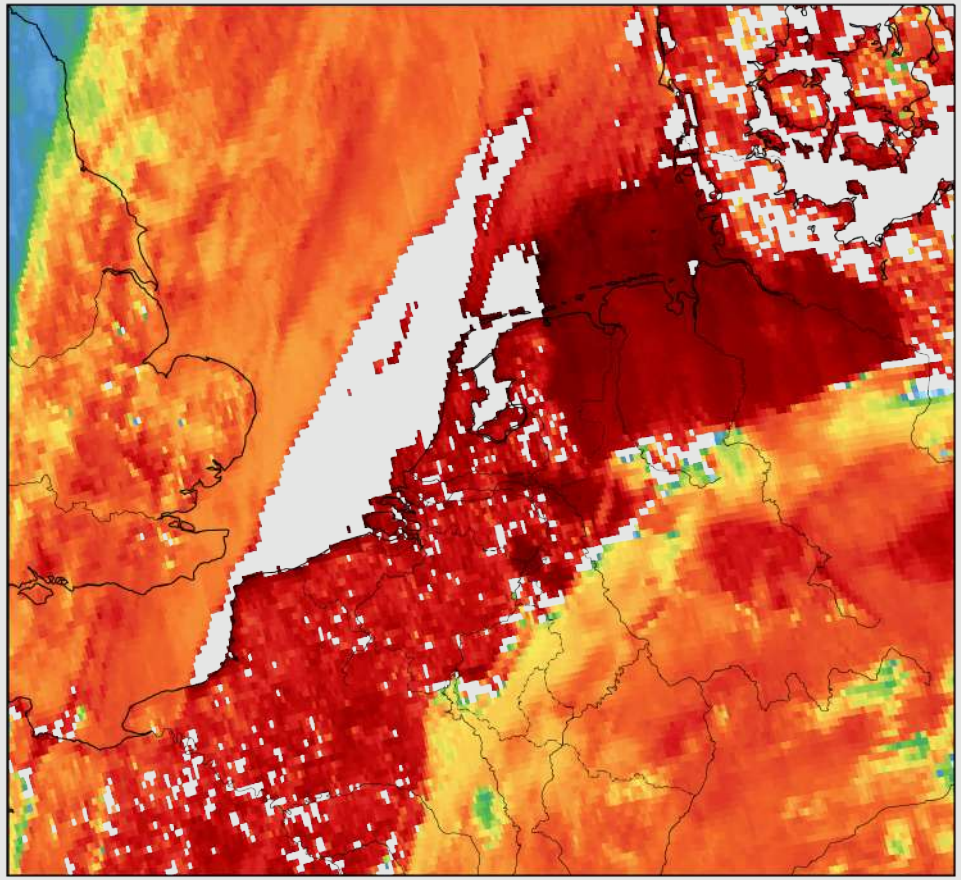
First day, irradiance from orbit 657, current processor



low — high

FRESCO cloud fraction

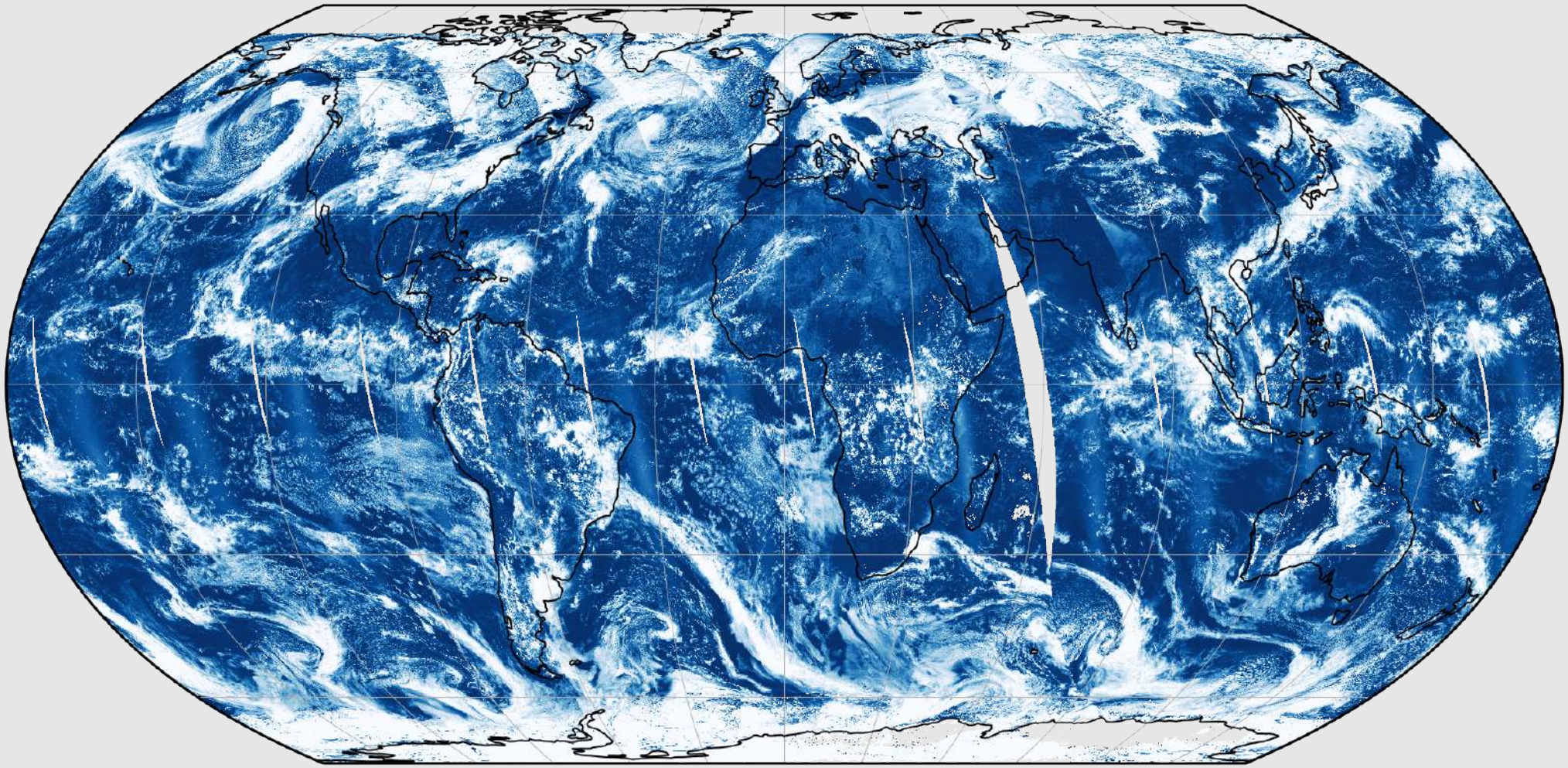
First day, irradiance from orbit 657, current processor



tropopause — ground

FRESCO cloud pressure

First day, irradiance from orbit 657, current processor

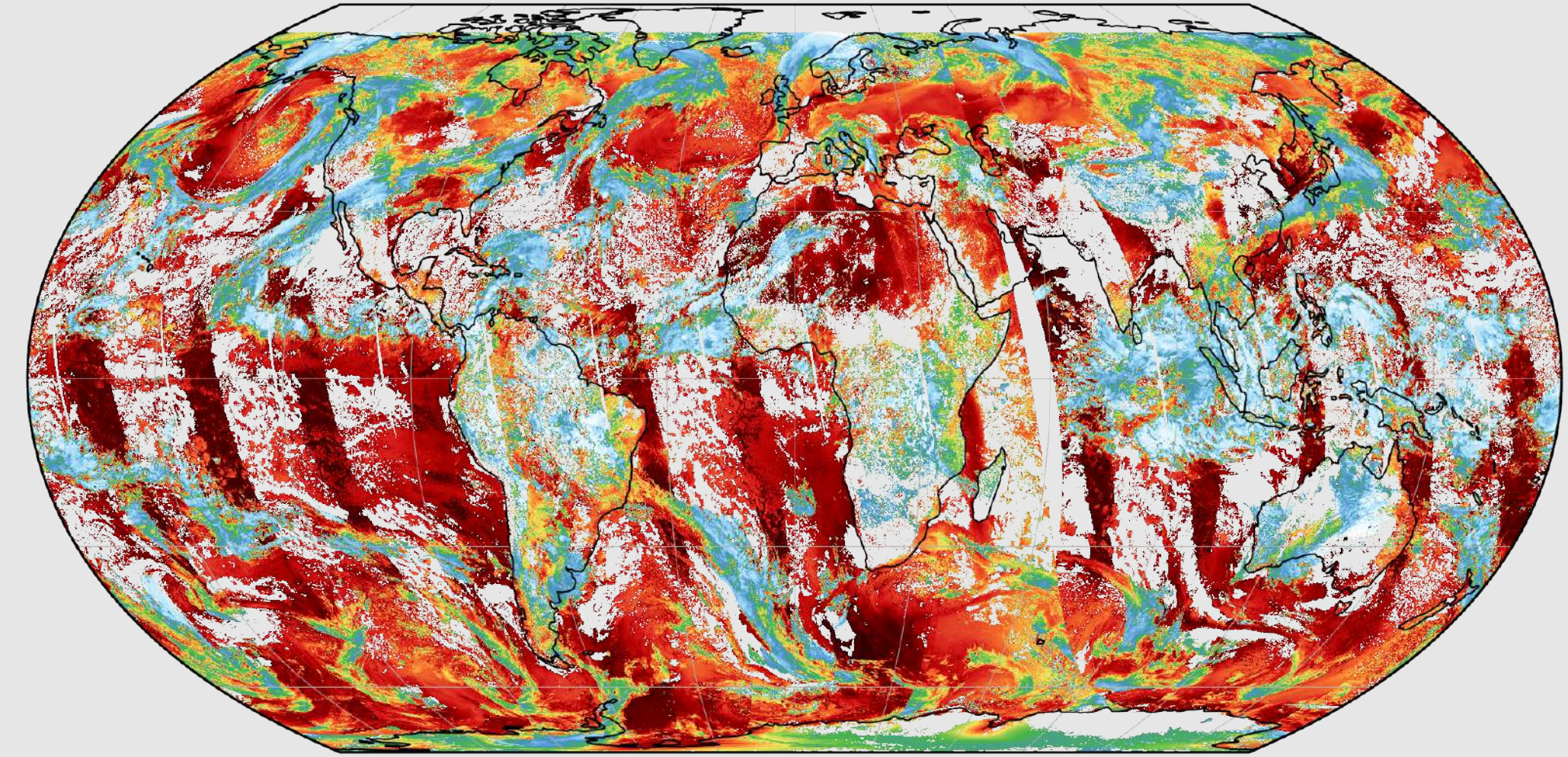


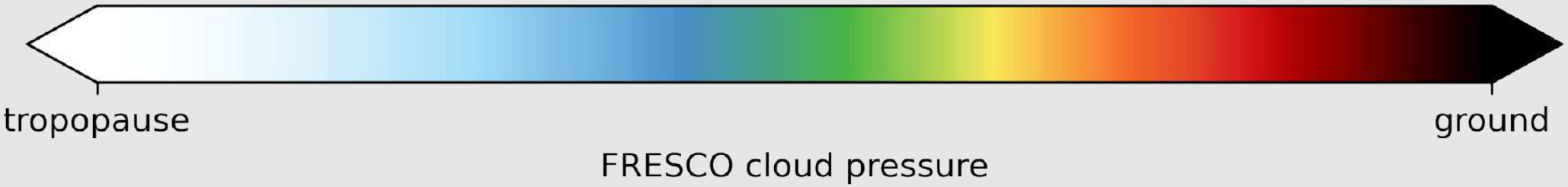
low

high

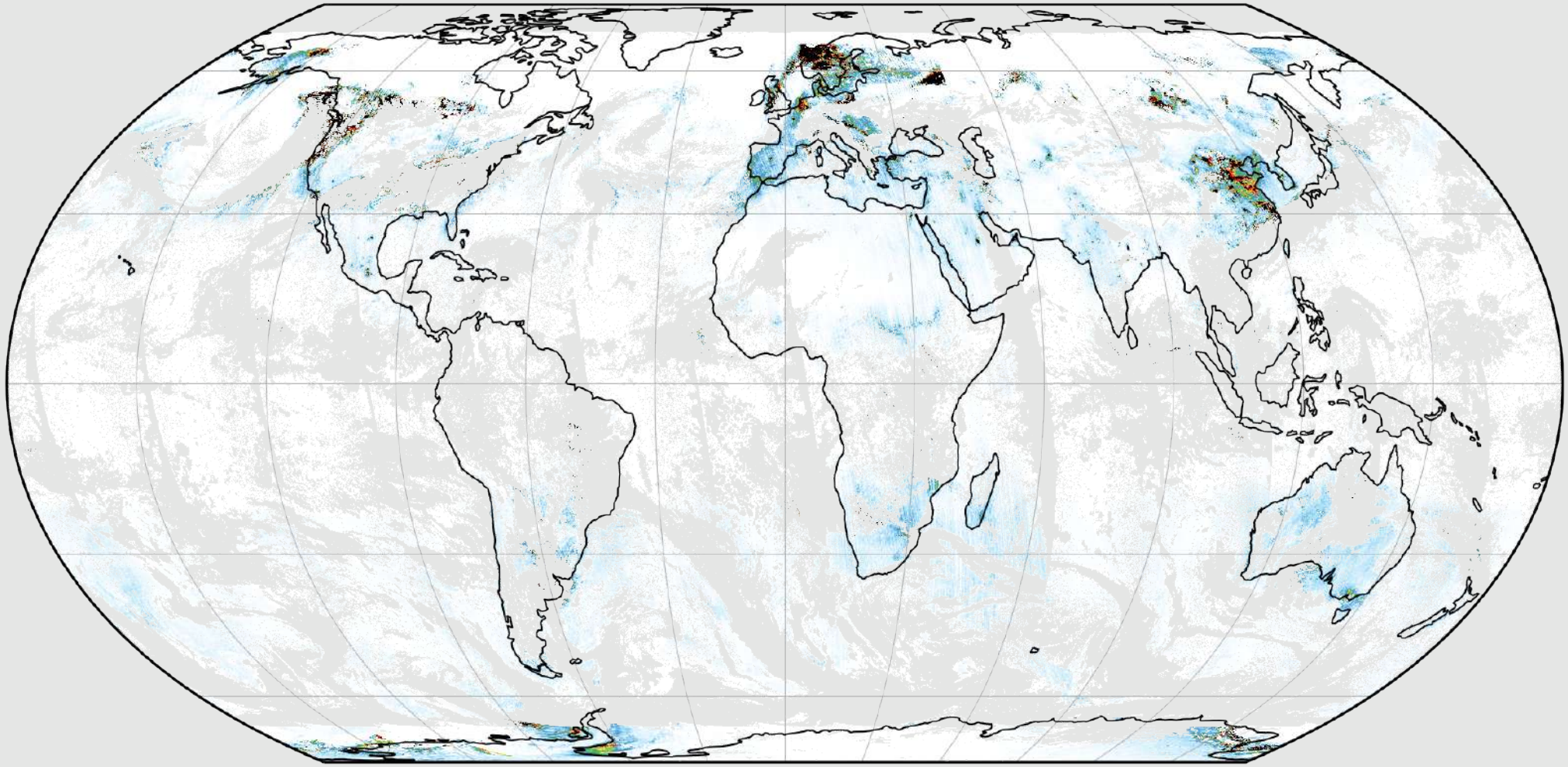
FRESCO cloud fraction

First day, irradiance from orbit 657, current processor





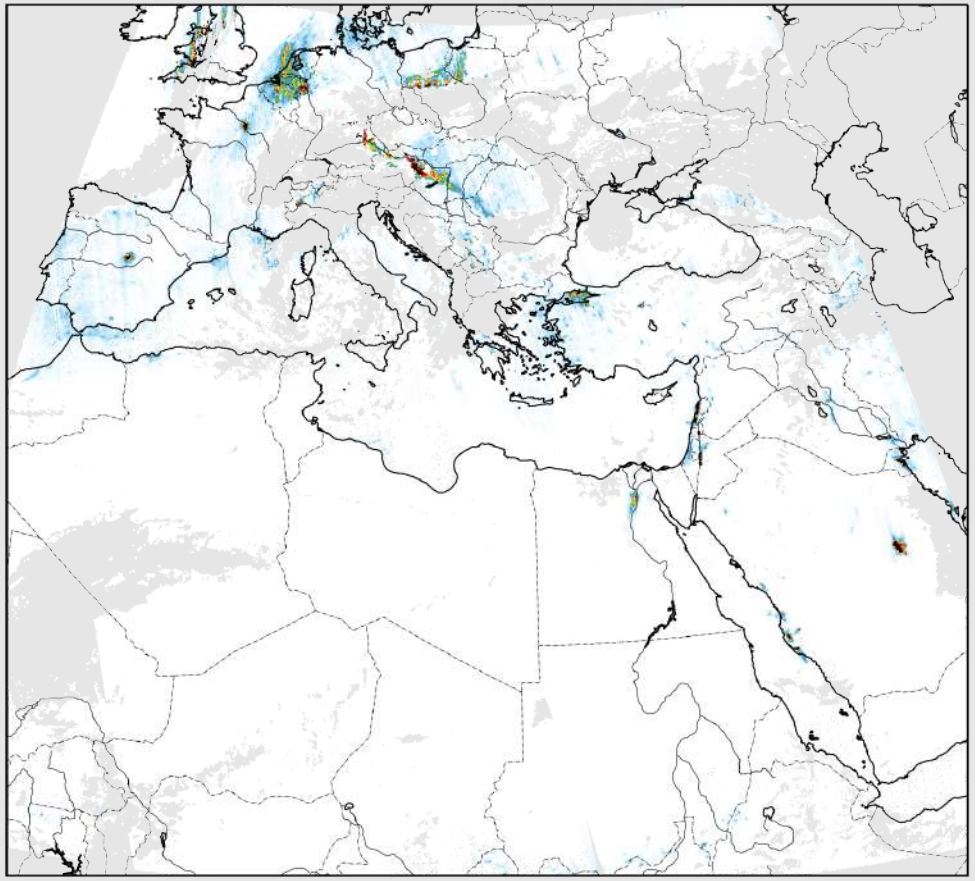
First day, irradiance from orbit 657, original processor

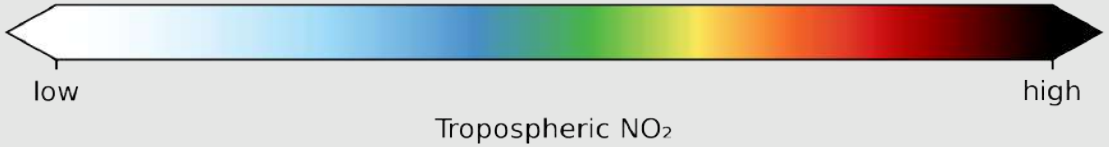


Tropospheric NO_2

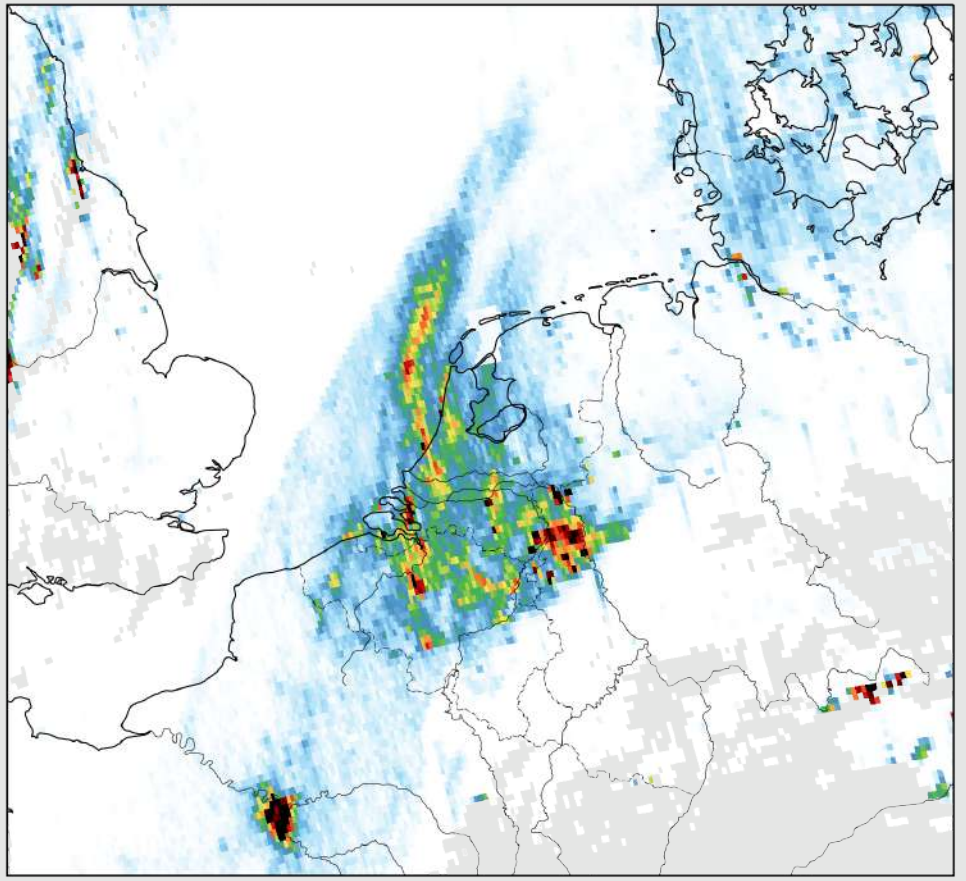
NO_2

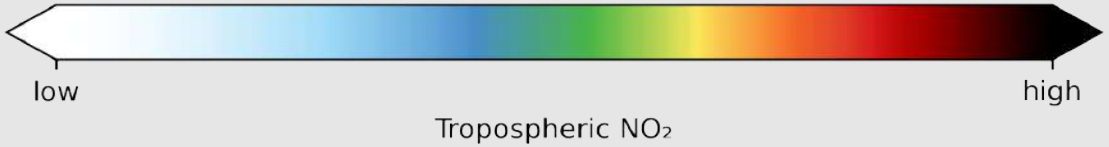
First day, synthetic irradiance, original processor





First day, synthetic irradiance, original processor





Issues fixed during E1

- Exact wavelength selection in UV Aerosol Index.
  - This removed some subtle striping in the product.
- Rewrote FRESCO to better handle the information we have in the spectrum.
  - Use spectrally oversampled LUT.
  - Interpolate LUT to observations.
- Replace OMI NO_2 DOAS fit code with new code to fix various scaling and threading issues.
- Update TM5 model for NO_2 processing.
- Many changes also for the other products.
- Version 1.0.0 tagged in early April, 417 commits beyond the launch version

Lessons Learned

- Launching an instrument is exiting, let’s do more of those.
- Good and open communication between the various teams is essential.
  - L1B ↔ L2, L2 ↔ L2, L2 ↔ PDGS, L1B ↔ PDGS, and all with ESA.
- Flexibility is essential, especially in the early stages after launch.
  - The synthetic irradiance was made on the day of first light.
- Preparing for launch and phase E1 carries a high risk of burn out of team members.
  - This needs attention in the teams, and needs to be taken into account by the management.
  - Add more people earlier in the project and keep them until the really busy times, even with launch delays.

Conclusion

The early results were already promising, and we went from highlight to highlight since then.