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Creating a multi-mission compatible and time-consistent TROPOMI aerosol index data record

13 October 2022 – Taormina, Italy

KNMI Aerosol Retrieval & Data Processing Team

Deborah C. Stein Zweers, Martin de Graaf, Maarten Sneep, Gijsbert Tilstra

with contributions from Mark ter Linden and Piet Stammes

AER_AI: Past, Present, Future

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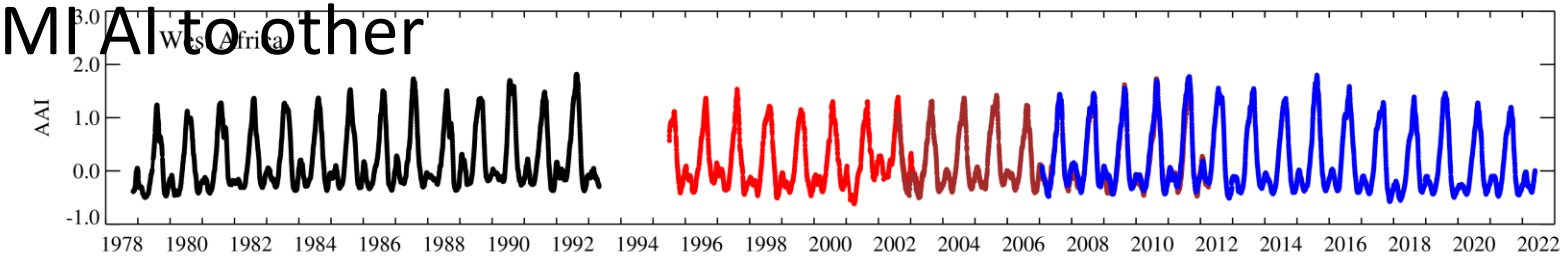
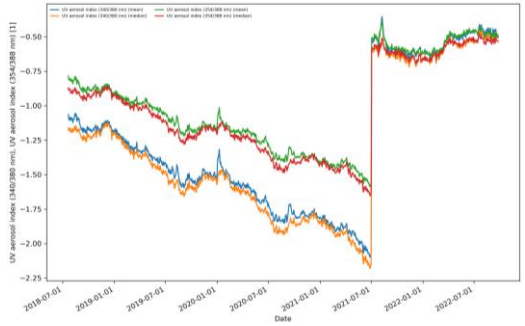
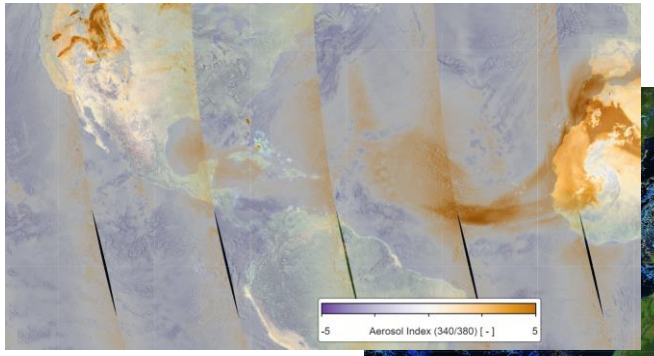
- **Past:** overview of why it is interesting to look back and link TROPOMI AI to other aerosol indices

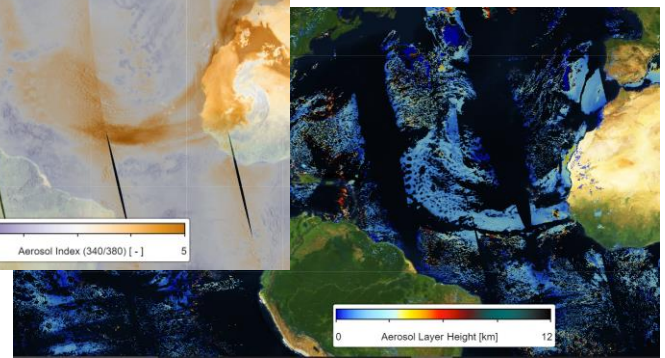


- **Present:** show you new puzzle pieces needed for an OMI + S5P AI record; status summary of TROPOMI AI now



- **Future:** Conclude that TROPOMI is ready for changes in the future with a more integrated aerosol approach & compatibility with future missions





Definition of Aerosol Index

$$\mathrm{AAI} = -100 \cdot \left[\log_{10}\left(\frac{R_{340}}{R_{380}}\right)^{\mathrm{meas}} - \log_{10}\left(\frac{R_{340}}{R_{380}}\right)^{\mathrm{sim}} \right]$$

- Negative difference of measured and modelled reflectance ratios for a λ-pair
- TROPOMI has **three wavelength pairs**: 340/380, 354/388 & ***new 335/367 (for S-5)***
- Uses simulated **Rayleigh atmosphere** and **adjust Lambertian surface albedo** at the reference λ, so that R^{sim}(380 nm) = R^{meas}(380 nm).
- Then the above equation becomes:

$$\mathrm{AAI} = -100\ [\log_{10} R^{\mathrm{meas}}(340) - \log_{10} R^{\mathrm{sim}}\,(340)]$$

- So, since there is UV-absorption by dust, smoke and volcanic aerosol at these λ's

when $R^{sim}\,(340)$ > $R^{meas}\,(340)$: AAI > 0

when $R^{sim}\,(340)$ < $R^{meas}\,(340)$: AAI < 0

Why combine AAI: S5P & OMI

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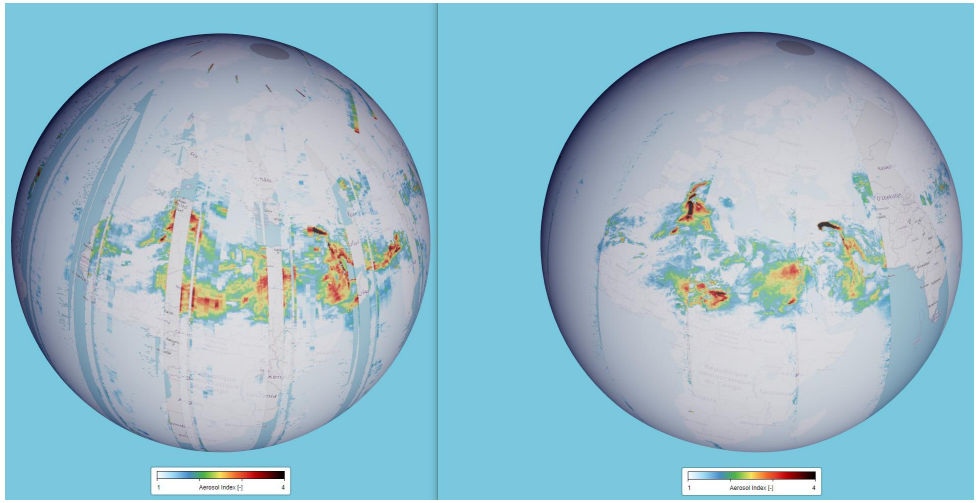
New pieces of the puzzle:

- Prerequisite: S5P RPRO AI data
  - Consistent degradation-corrected time series
  - To be completed before end-2022



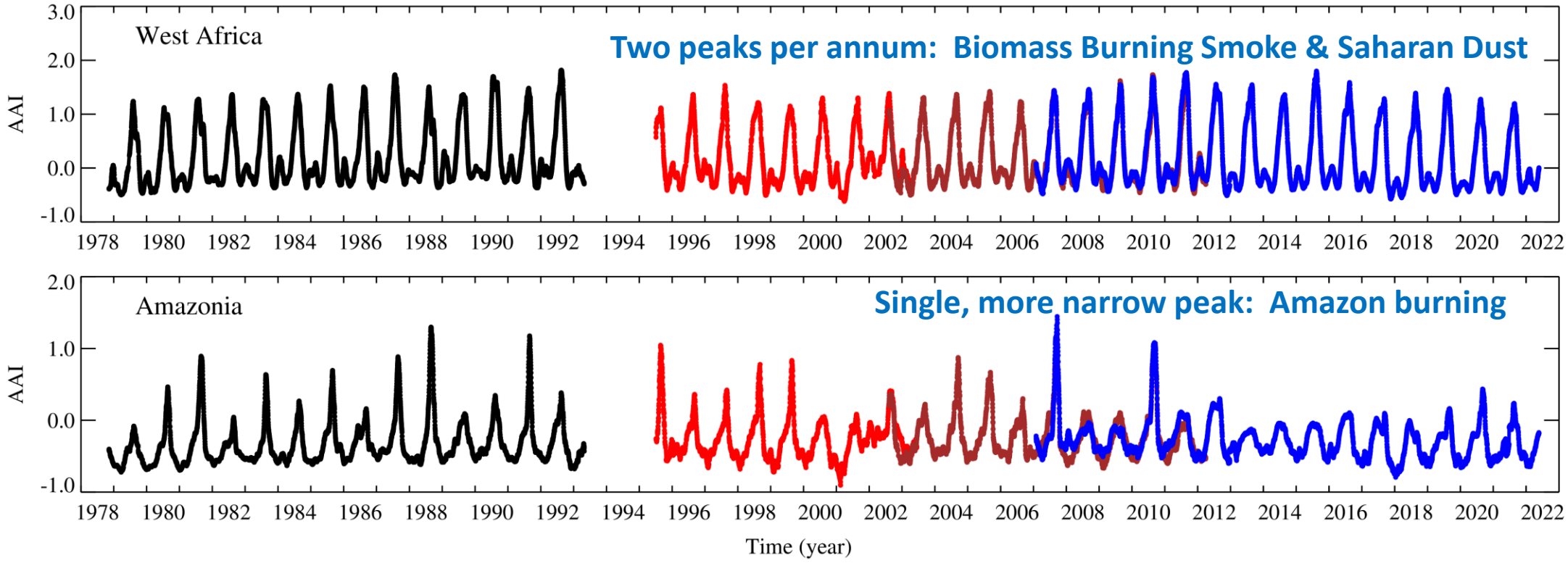
OMI Collection 4, OMAERO (*Dave Haffner's talk at 15:15*)

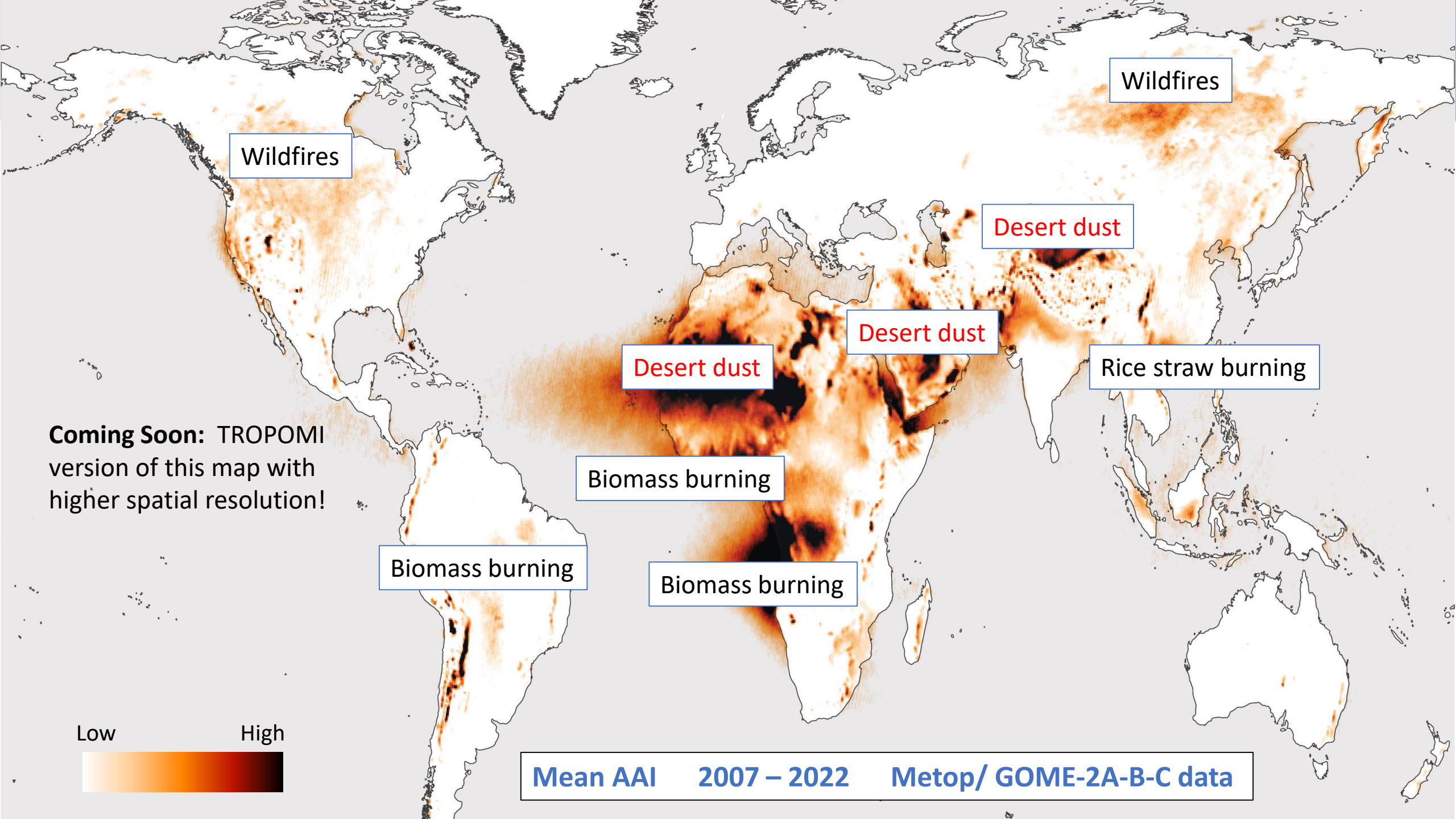
- Nearly same: overpass time, wavelength pair (354/388), algorithm
  - Optimized for compatibility w.r.t. both L1b and L2 (*Kleipool et al. AMT 2022)*
  - A way to check TROPOMI AER_AI better understand what is happening with the new L1bv.2.1 in the aerosol index

Proven concept

Multi-sensor AAI (MS-AAI) dataset 1978 to present

- More than 40 years of data, L3 format, with 1 x 1-deg resolution available at www.temis.nl/airpollution/absaai
- An S5P + OMI series can have higher spatial resolution, easier to zoom in on smaller souce regions




Wildfires
Wildfires
Desert dust
Desert dust
Desert dust
Rice straw burning
Biomass burning
Biomass burning
Biomass burning
Coming Soon: TROPOMI version of this map with higher spatial resolution!
Low
High
Mean AAI 2007 – 2022 Metop/ GOME-2A-B-C data

Using New OMI Collection 4

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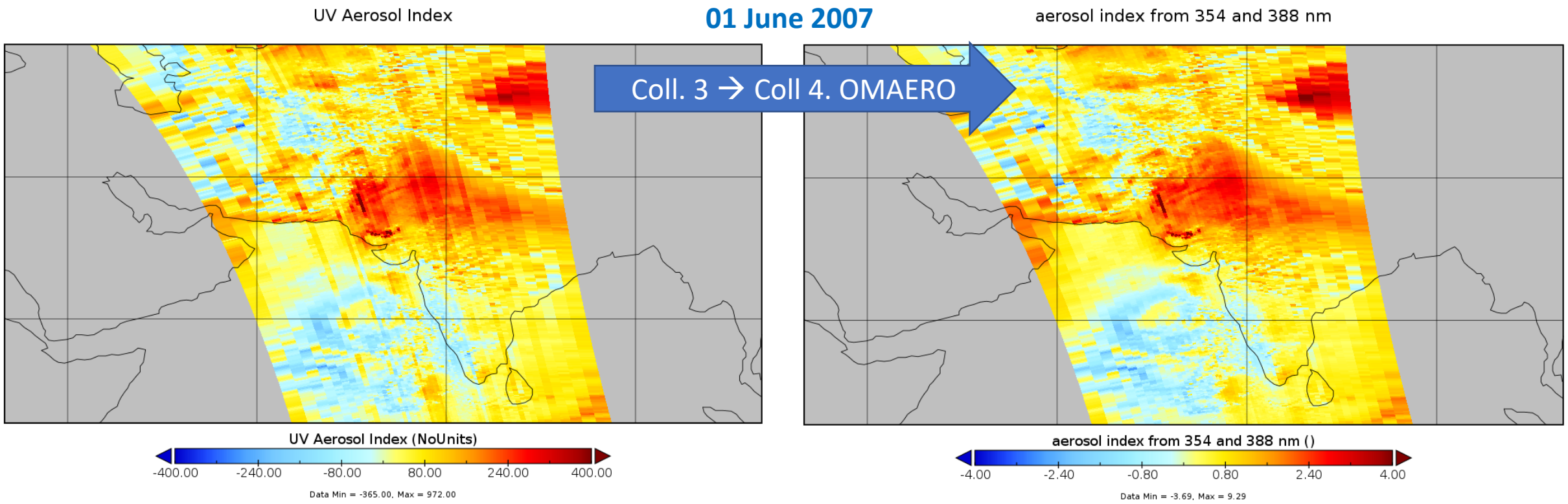
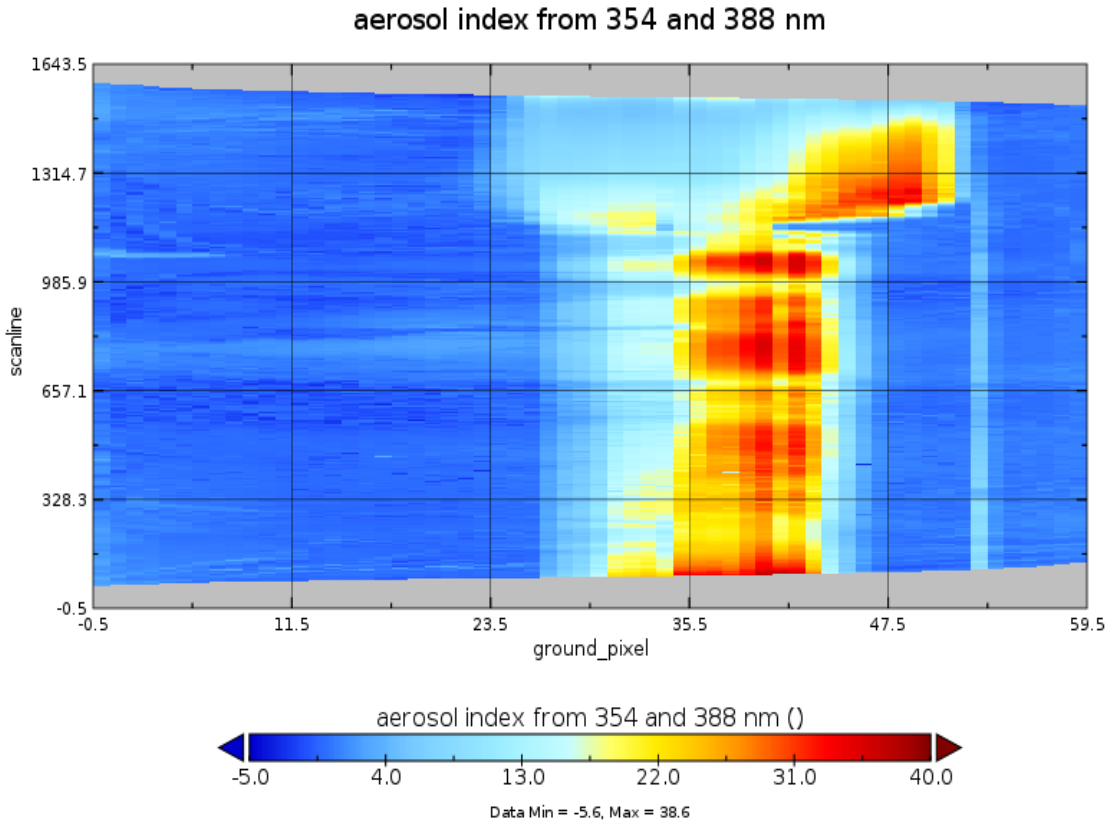
- Highlight of work by KNMI colleague Mark ter Linden based on test data
- Improved, updated row anomaly flagging tailored for AI (July 2021)
- Updated dynamic irradiance input, increases SNR & reduces striping



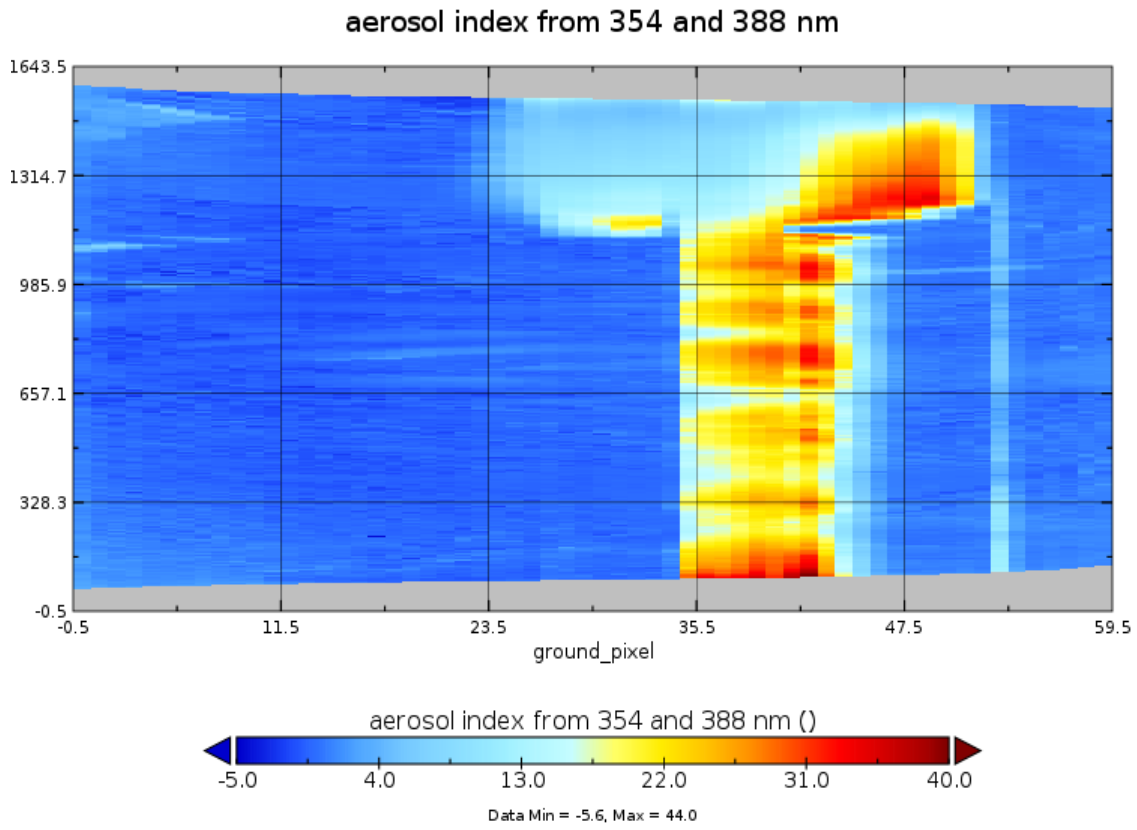
Major row anomaly change

New 'recovered' rows at nadir and near-nadir available in OMAERO Aerosol Index (AI)

08 July 2021



Orbit 90323



Orbit 90324

Aerosol index: OMI & TROPOMI

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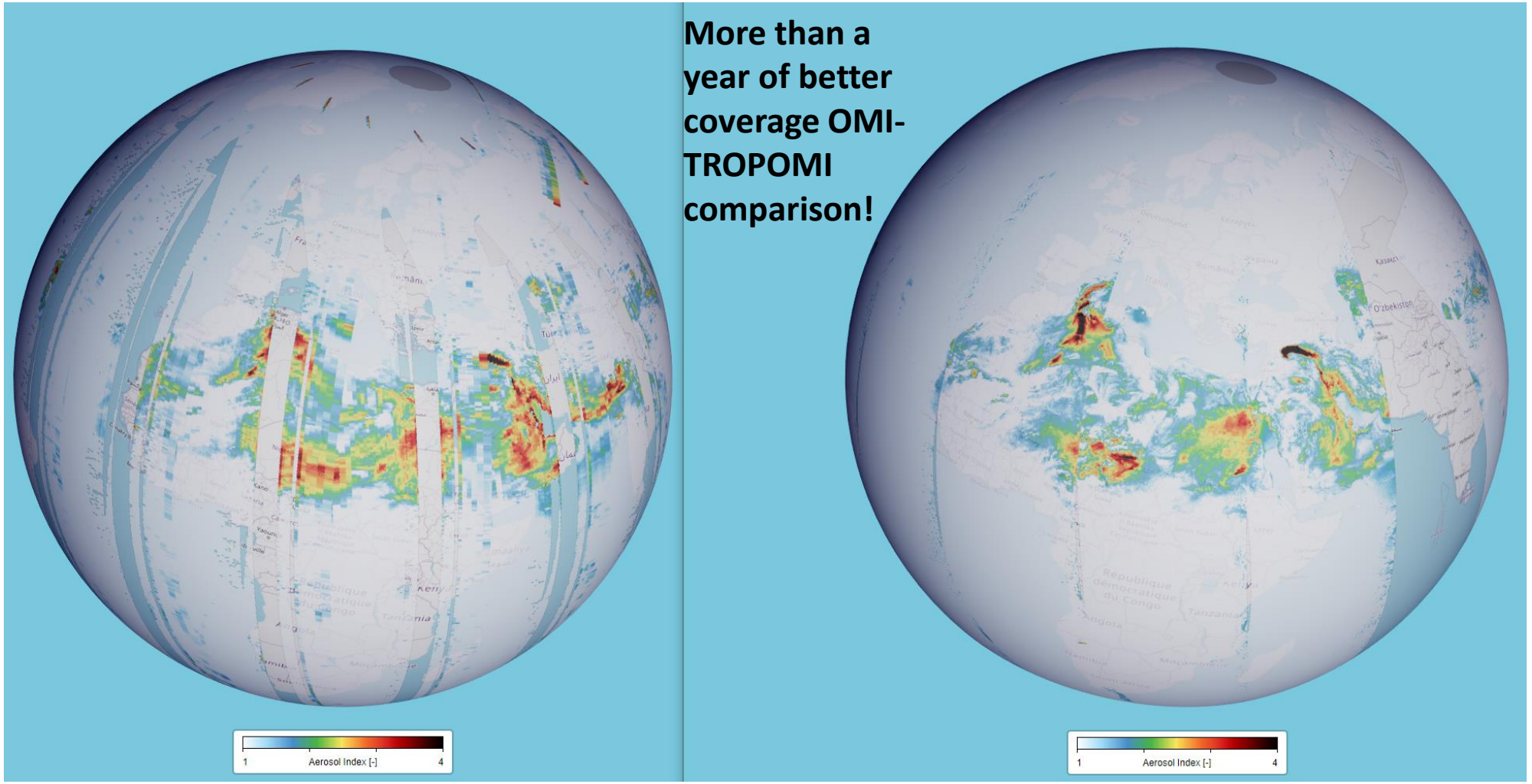
01 June 2022: Comparison between OMI OMAERO collection 4 and TROPOMI



TROPOMI AI record now

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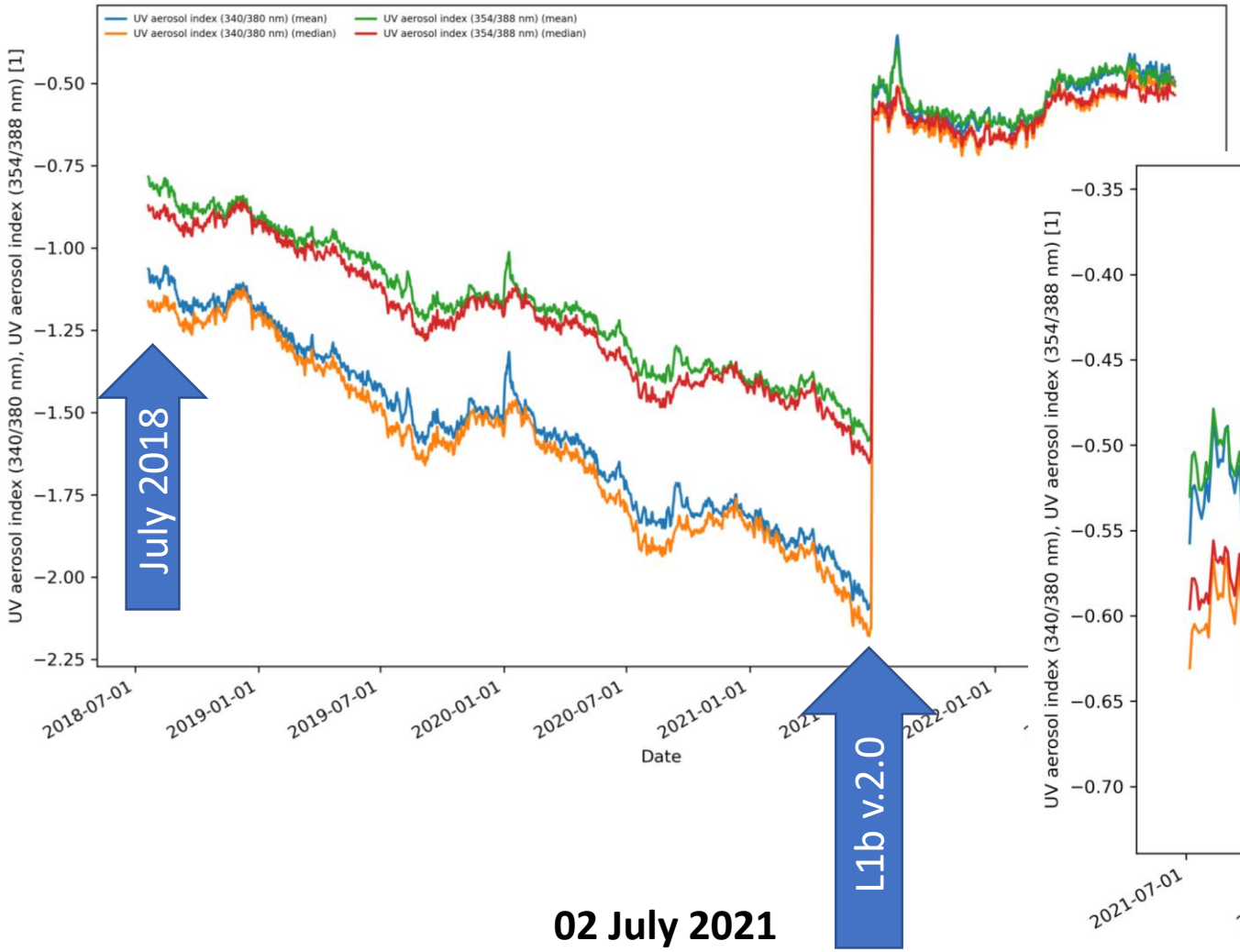
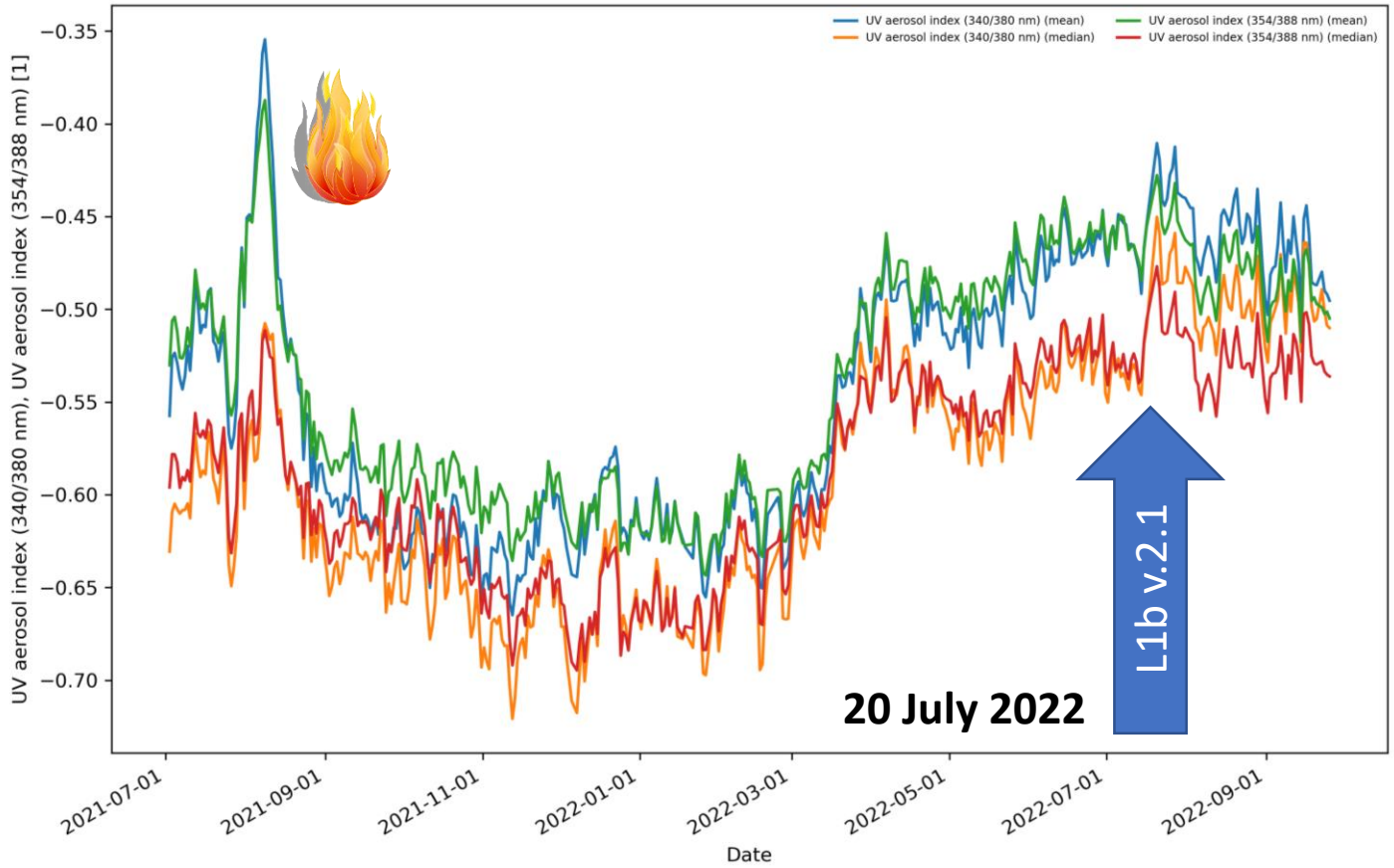
- Dramatic improvement in AER_AI from updated L1b (irrad degradation v.2.0), (irrad+rad degradation corr. v.2.1)
  - Offsets applied, 'overcorrection'





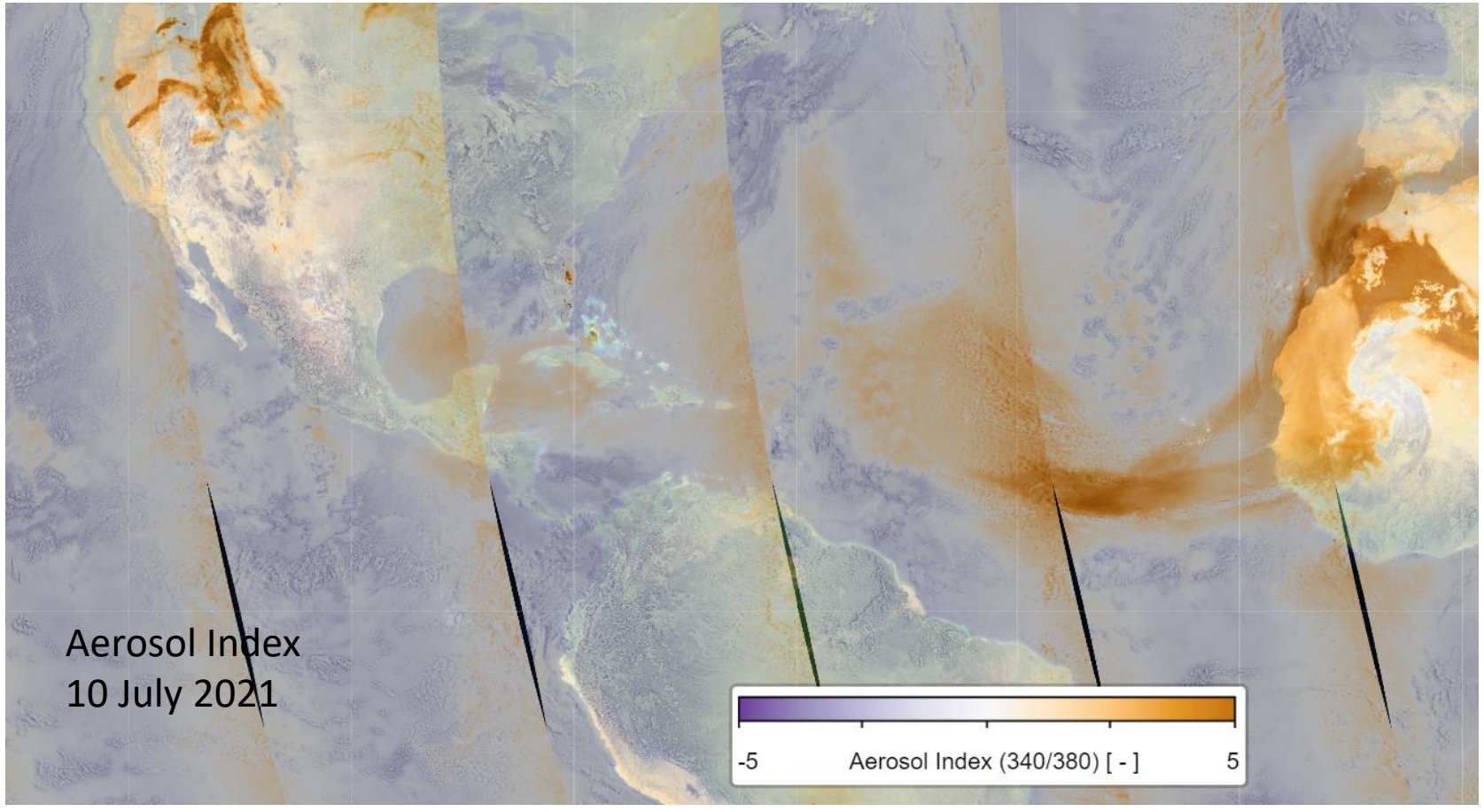
Where are we now with AI?

- Before the end of the year, we'll have a reprocessed aerosol index dataset with consistent L1b
  - **4.5 years of data**: RPRO: May 2018 – July 2022 + OFFL: Aug – Dec 2022
  - Taking degradation in both radiance and irradiance into account

- Our first priority is to understand the degradation-driven negative trend and biases, with the reprocessed dataset we can properly analyze this and better quantify the following:
  - Fully confirm that the degradation-drive downward trend is removed
  - Observed positive bias in S5P AER_AI with newly corrected L1b (v.2.1)
  - Check expected differences per wavelength pair also for new S-5 pair
  - Evaluated Seasonal cycle on global and regional scales

Getting the most out of S5P AER

- **10 July 2021** It is valuable to utilize the information contained TROPOMI AER_LH, since the altitude of the absorbing aerosol layer is such a key determinant of AI value
- Moving toward a more consistent TROPOMI aerosol ‘suite’ (*talk Martin de Graaf, 16:15*)



Getting the most out of S5P AER

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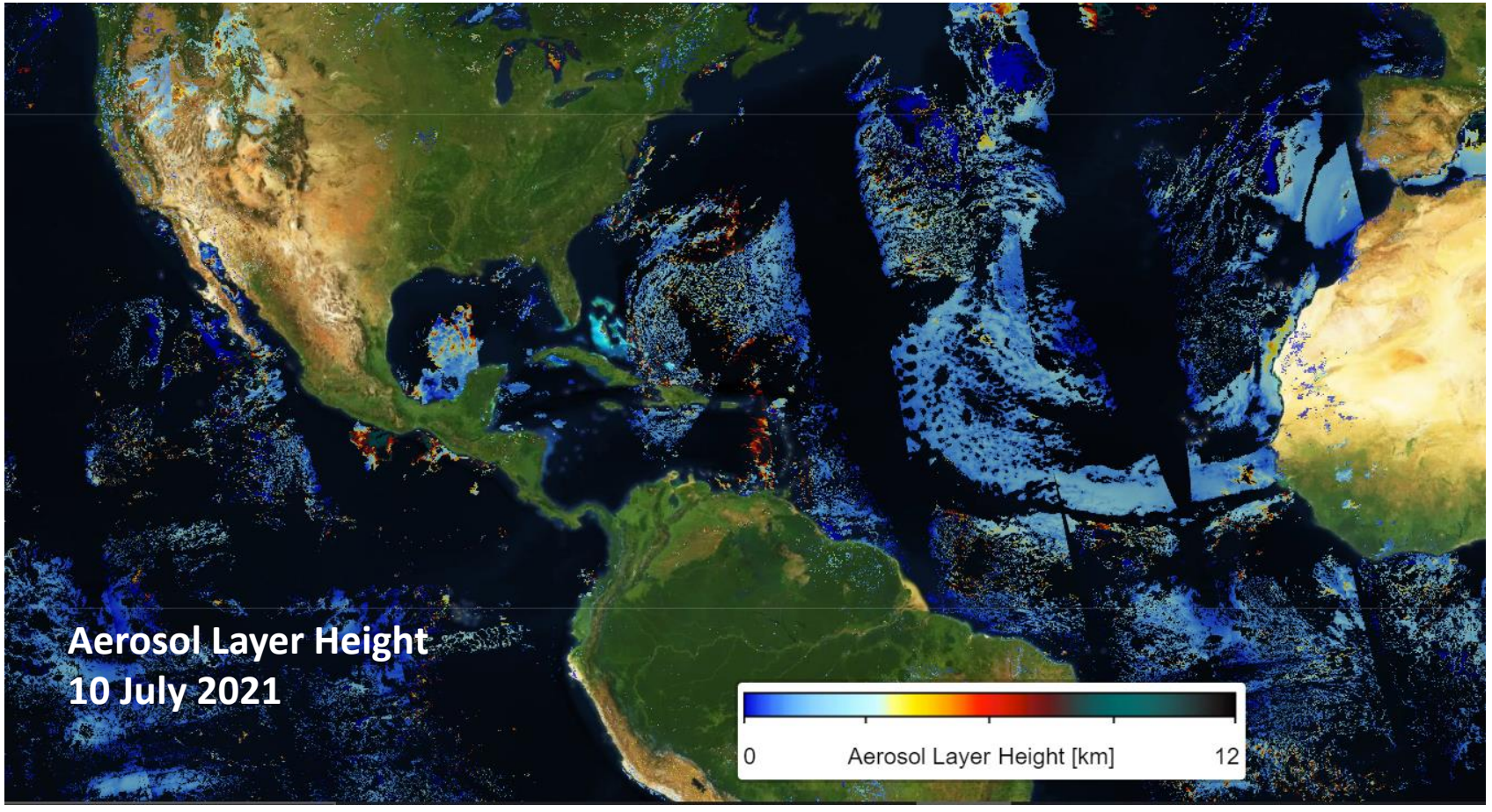

Opportunity to improve AER_AI

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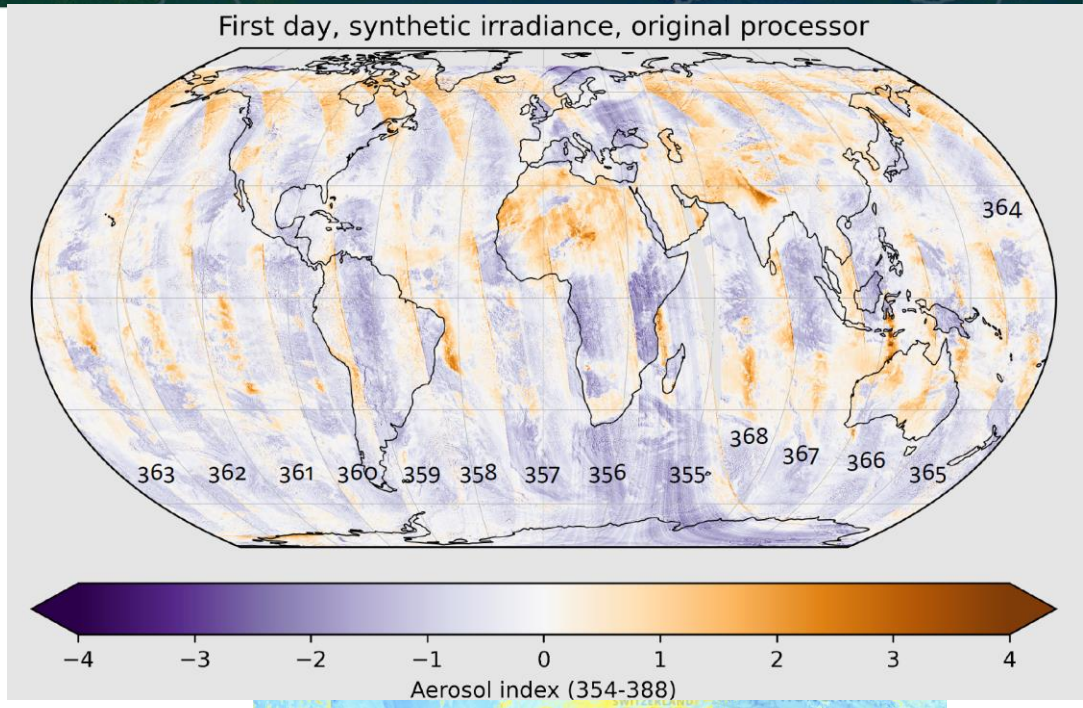
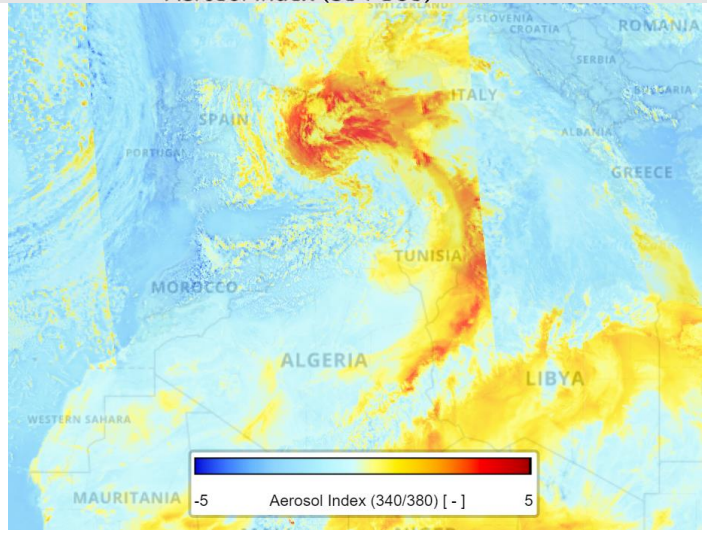
SUMMARY

- Comparison of TROPOMI RPRO AI with OMI Coll. 4 OMAERO AI is an excellent exercise to better understand and check observed effects in AI due to the L1b and increased spatial resolution of TROPOMI
- Use this opportunity to create a consistent TROPOMI AI global time series, map the globally observed emission regions
- Start testing new improvements for TROPOMI AI for non-Lambertian scenarios
- Thanks for your attention, any questions?





Plumes really are filamentary

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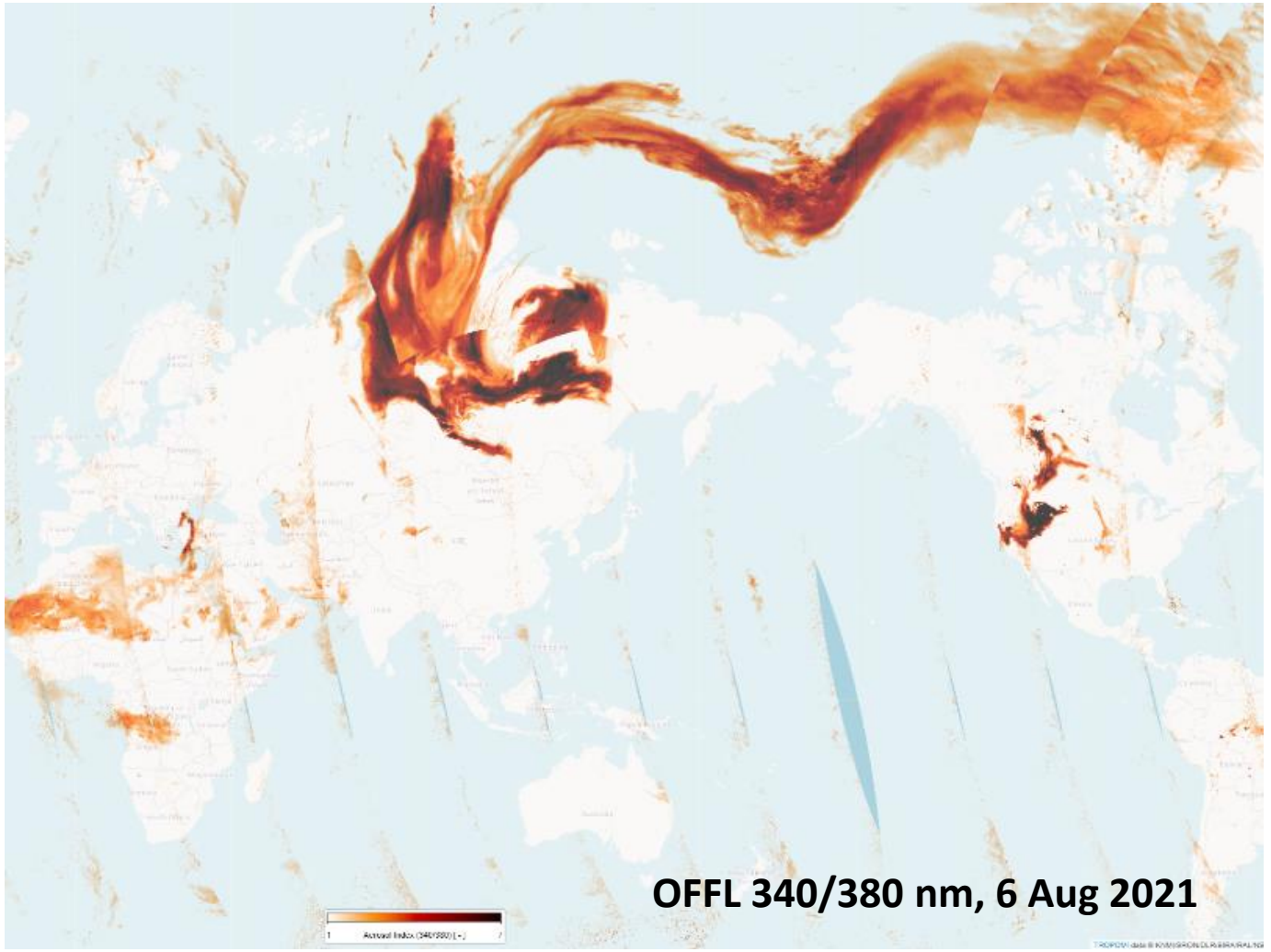
- TROPOMI has given us the opportunity to a new level of fine detail in transported aerosol plumes
- During PhD I created a description & climatology of what I call “Filamentary Aerosol Transport Events”
- At the time (it was based on TOMS & OMI), and a committee member objected to calling the plumes filamentary because didn’t think they were ‘thin’ enough
- I persisted with my title and the high resolution TROPOMI has proved that plumes really can be filamentary!



New case study comparisons

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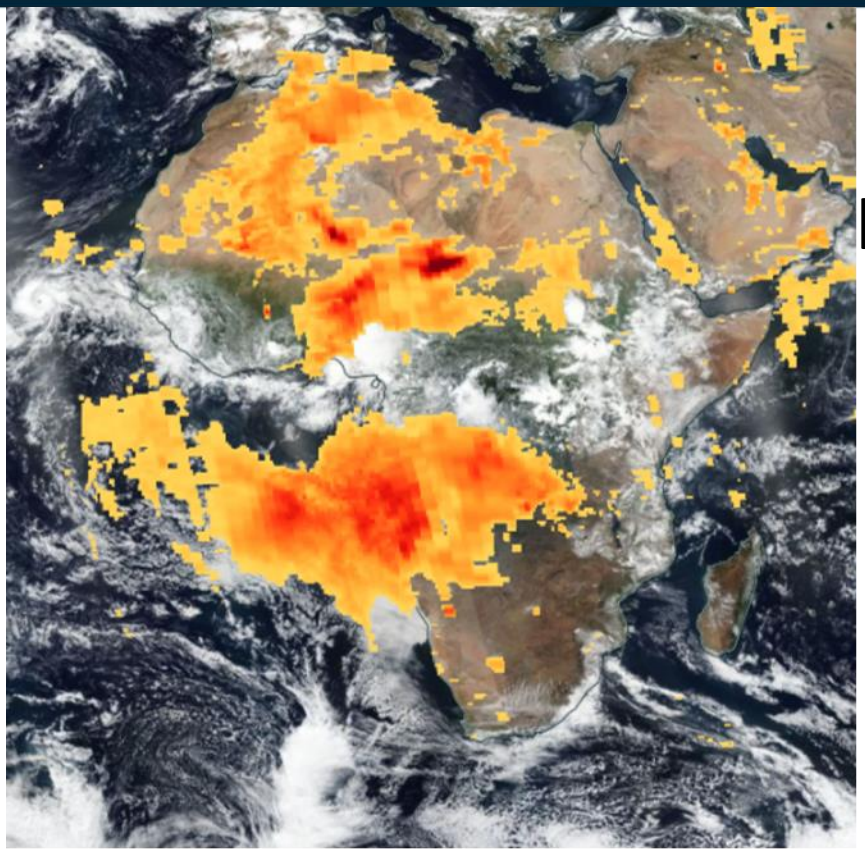
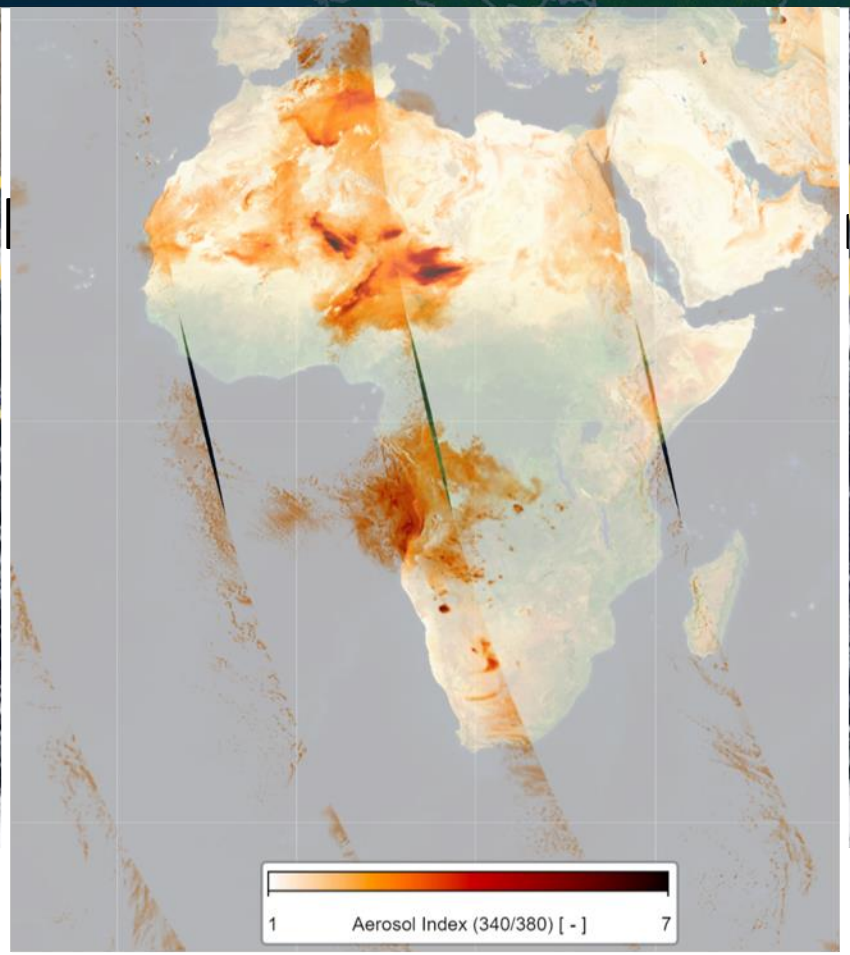
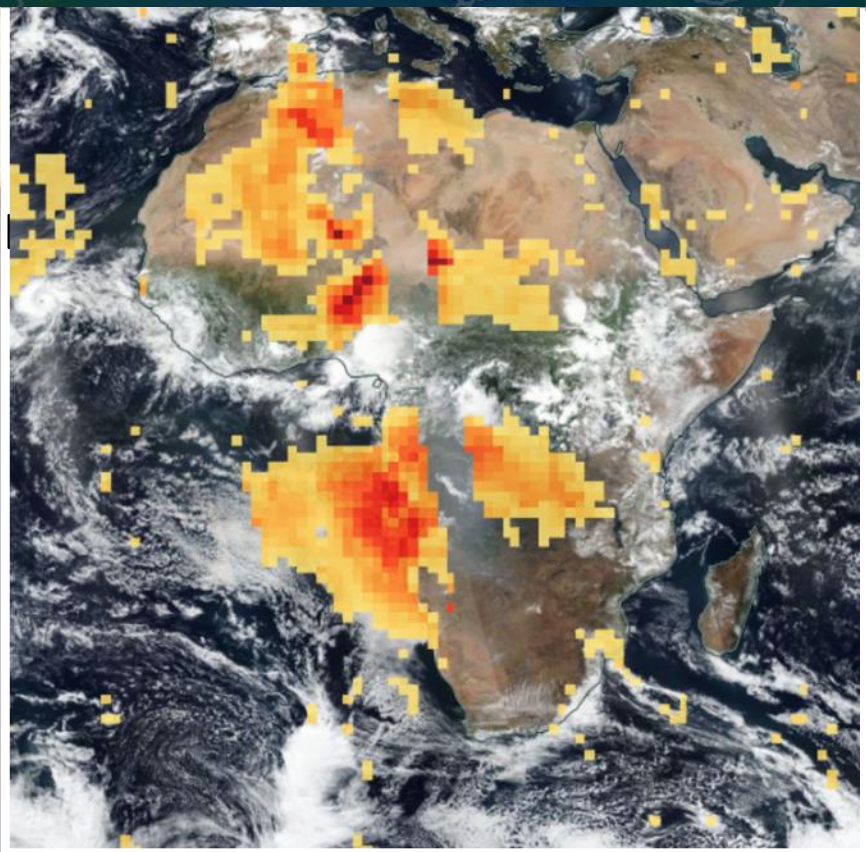






01 Sep 2021
Aerosol Index
OMPS | TROPOMI | OMI

With OMI Coll. 4 we can compare with OMAERO & **OMAERUV**
See Omar Torres talk 16:30

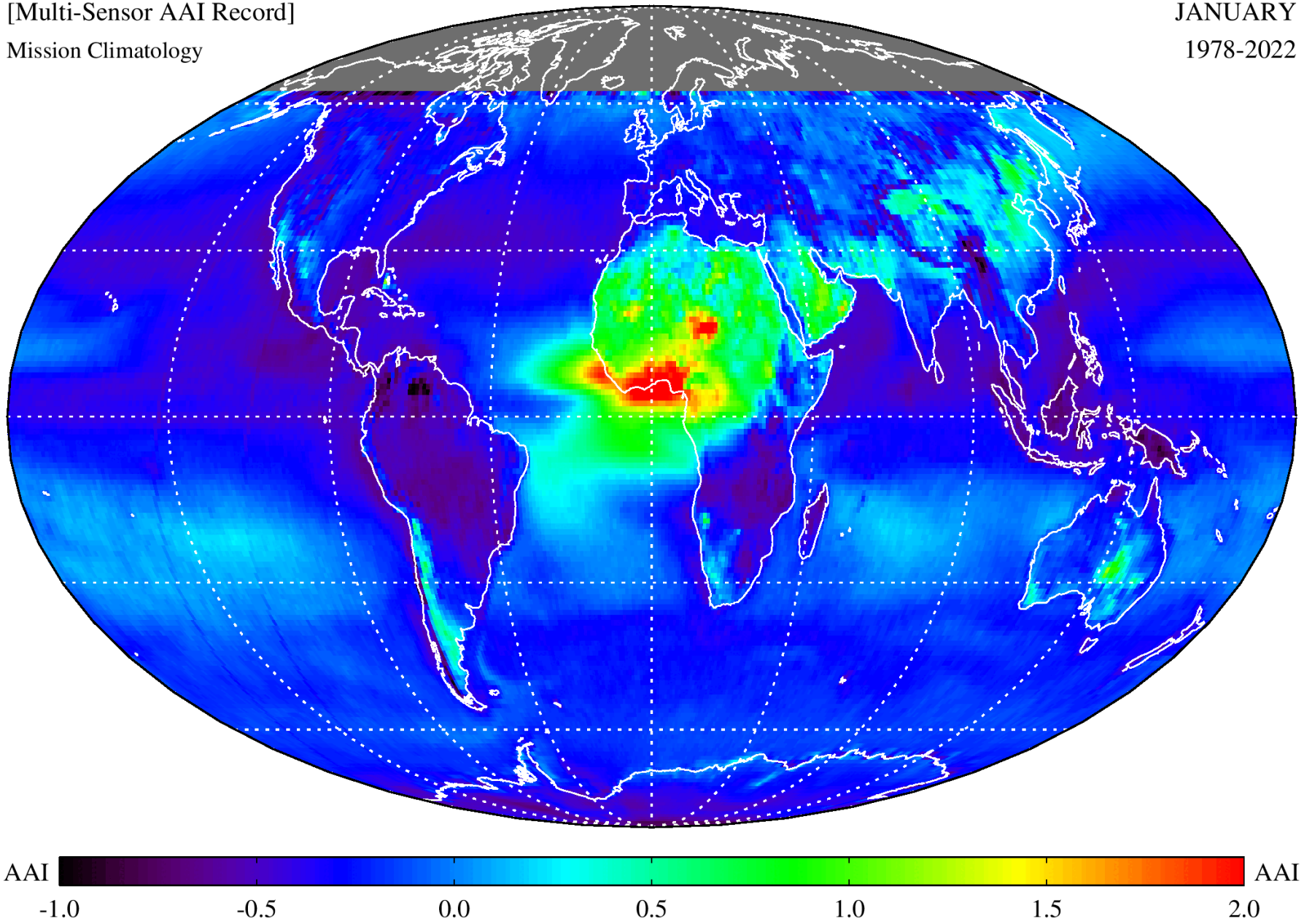
- EXTRA SLIDES

[Multi-Sensor AAI Record]

Mission Climatology

JANUARY

1978-2022



AI, Simple yet Complex

- Robust and relatively simple calculation
- High spatial resolution of TROPOMI reveals much more information about
- There is implicit information built into the AI about aerosol layer height, single scattering albedo (just how absorbing is the aerosol), and optical depth
- Its complexity is largely untapped since ‘as is’ it is useful for flagging aerosol in other data product and because it is powerful for visualizing and tracking potentially dangerous plumes of aerosol from volcanic eruptions, biomass burning and desert dust outbreaks
- By linking AI to other pieces of TROPOMI aerosol information (layer height and AAOT) we can start to answer new questions
  - The ambition for a consistent and value-adding TROPOMI aerosol suite will be given by Martin de Graaf in the next talk

Dependencies of the AAI on aerosol and BRDF parameters

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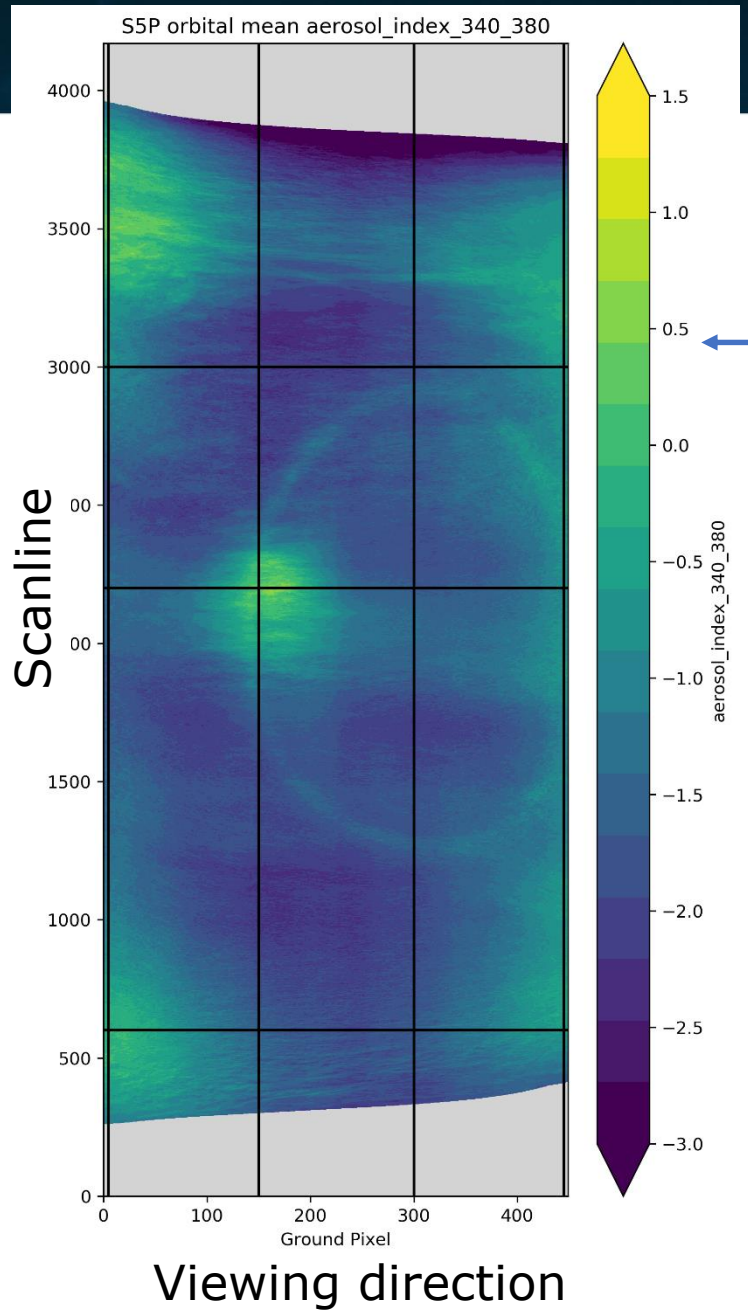
- **Aerosol parameters**:
  - AOT = aerosol optical thickness
  - SSA = single scattering albedo
  - z = Height of the aerosol layer

  $AAI \propto AOT \times (1 - SSA) \times [\, p(0) - p(z) \,]$

- **Cloud and surface reflection**:
  - BRDF – non-Lambertian reflection

Due to TROPOMI's high spatial resolution we can better discriminate the aerosol parameters on one hand, and the cloud and surface parameters on the other hand.

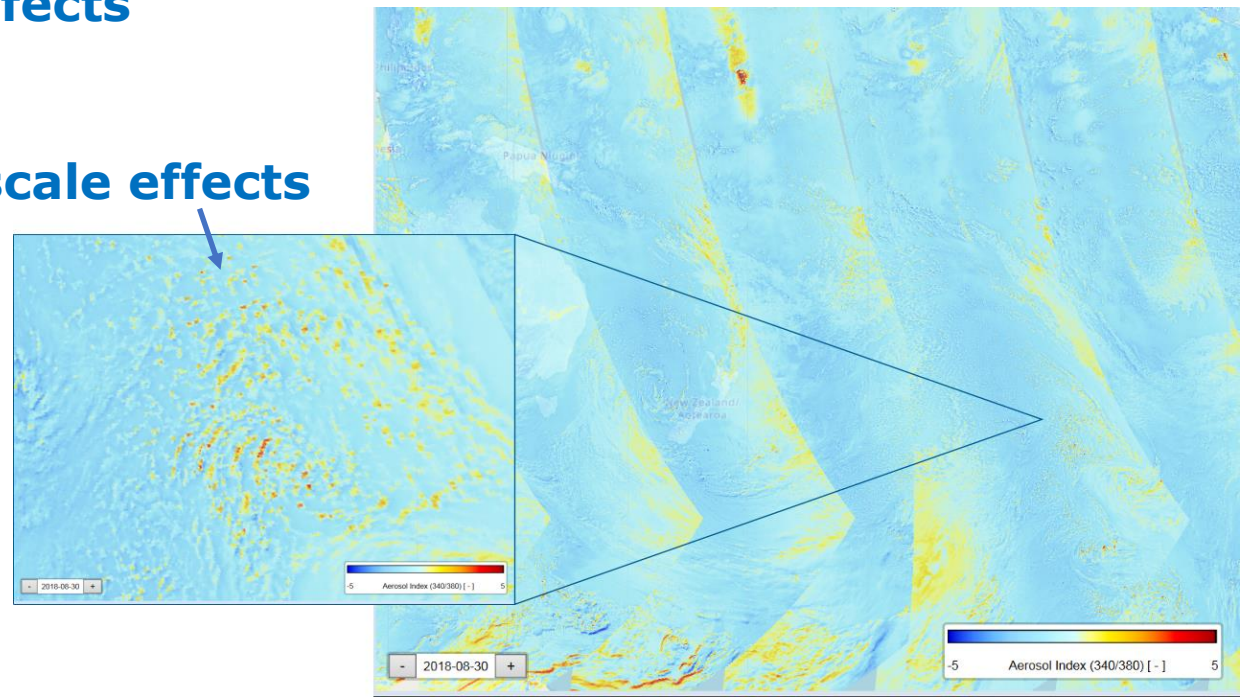
Effect of clouds on AAI in TROPOMI data



Kooreman et al., AMT, 2020

Large scale effects

Small scale effects



Due to high spatial resolution of TROPOMI these effects are well visible, whereas they were not visible in earlier satellite data.

Way Forward & Future Plans

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- Analyze seasonal variability of the RPRO
  - Remove the current applied offset
- Create a (L3) gridded dataset to combine with OMI, this can be done at a higher spatial resolution than MS-AAI
- Describe how well S5P compares with OMI – OMAERO AI
- Compare S5P AER_AI with AER_LH; what kind of relationships, correlations will we find – scatter plot
- To what extent can we utilize NO2 data to verify biomass-burning driven seasonality on a regional scale as in Tilstra et al. 2014

OMI extension: S5P AI comparison

- The effects of the TROPOMI L1b data on the Aerosol Index (AER_AI) are not yet fully understood
  - The TROPOMI AER_AI Reprocessed dataset will be available soon (end-2022)
- The alignment of OMI OMAERO Coll. 4 with the S5P AER_AI provide an ideal opportunity to perform and ‘external’ check
  - Same wavelength pair, nearly same algorithm, similar overpass time, more comparable spatial resolution
- A major change in the row anomaly behavior means that more nadir and near-nadir rows are now good quality and can be used for comparison
- With this change we are presented with an improved opportunity to investigate S5P L1b effects, and to externally check and validate TROPOMI Aerosol Index
- Several years of overlap with the newly available rows would improve the validation effort by fully covering the global seasonal cycle and event-driven variability in the aerosol index (due to biomass burning, desert dust transport)

Row anomaly flagging

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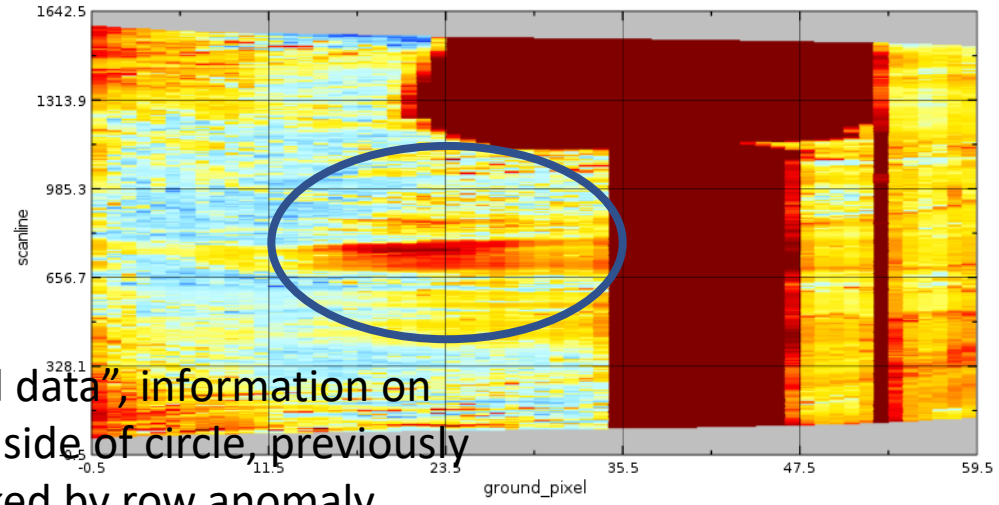
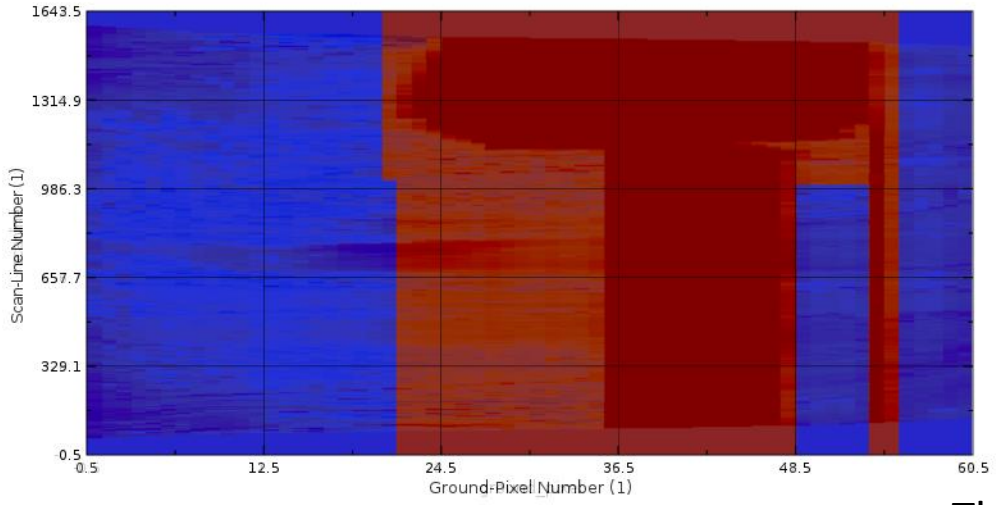
Aerosol Index [-4, 4]



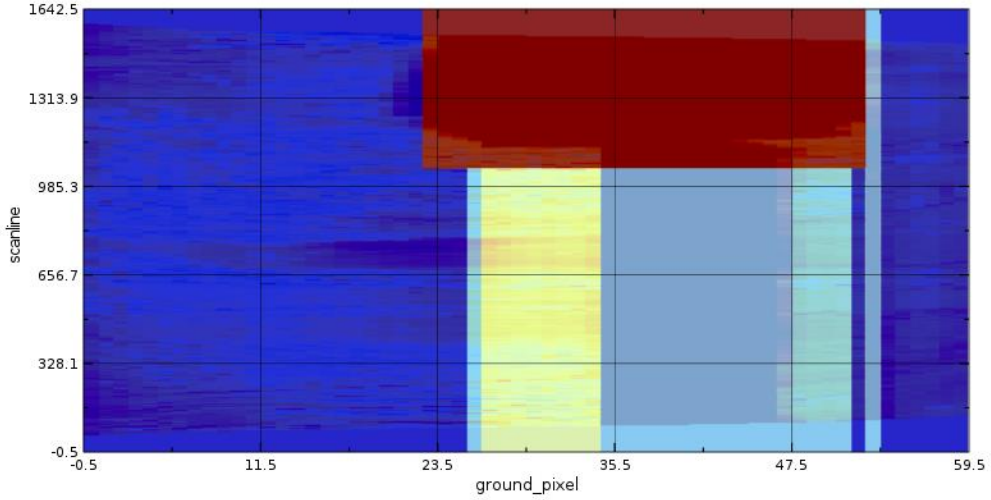
"Real data", information on right side of circle, previously blocked by row anomaly

NASA row anomaly flag

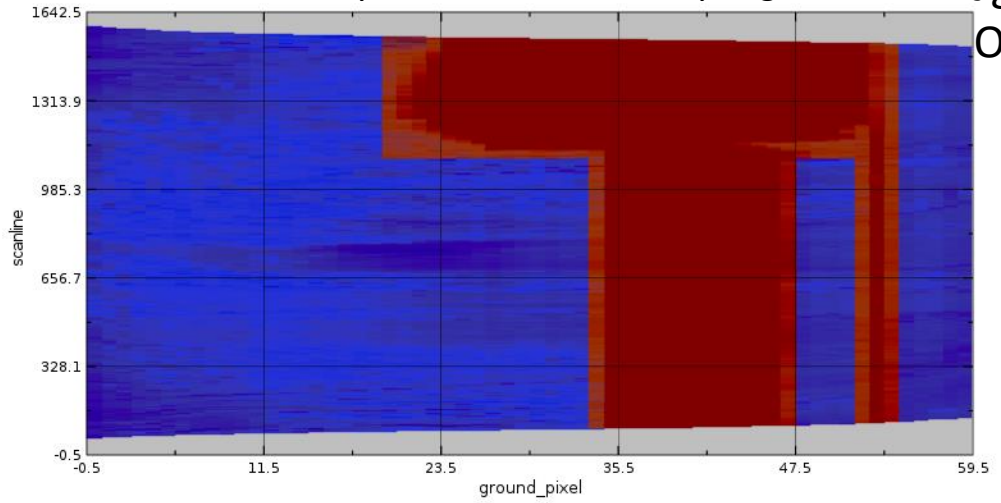


This dynamic flag is used in OMAERO AI Coll. 4

L1b row anomaly flag



Dynamic L2 row anomaly flag



Aerosol index: OMI & TROPOMI

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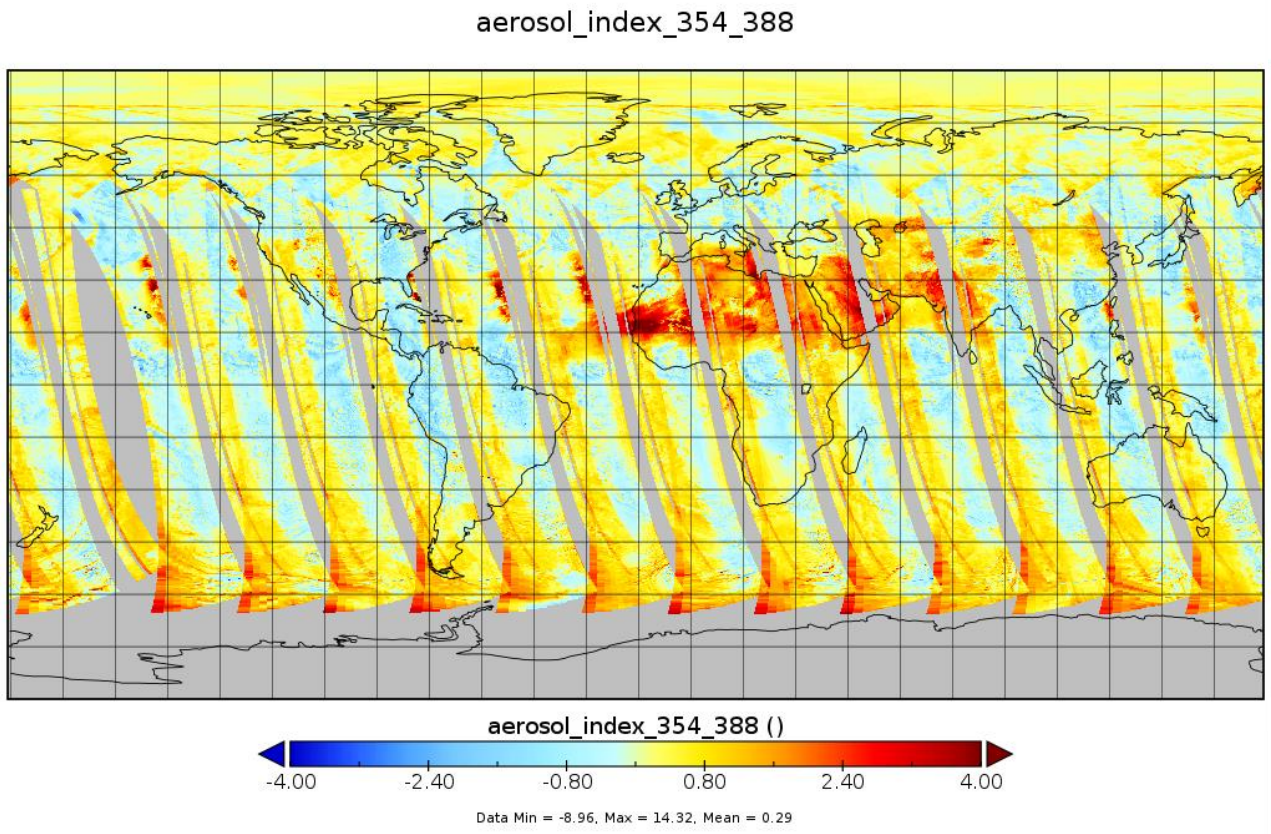

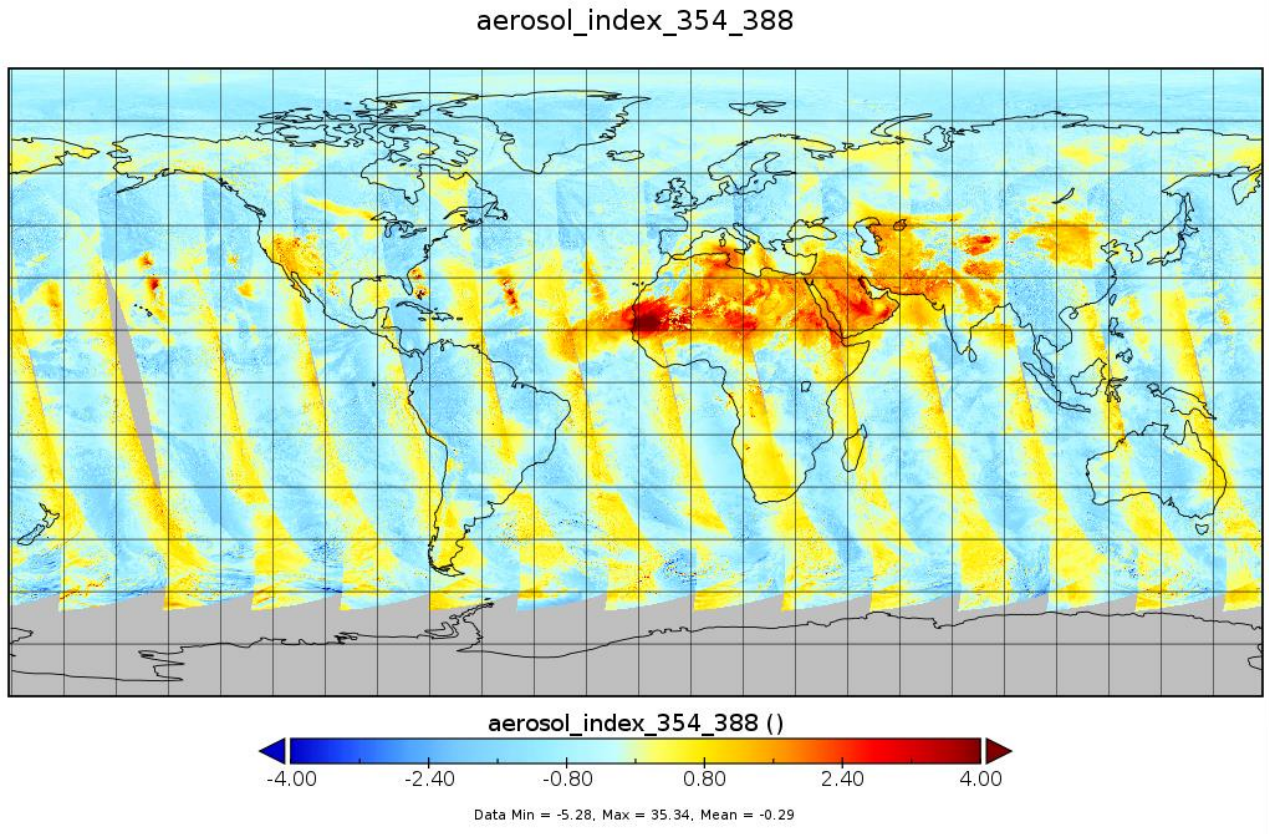

TROPOMI AI is lower than OMI due to negative offset factor applied to TROPOMI in response to apparent 'overcorrection' effects in L1b which warrants further study

Test data set & Planning, Coll. 4

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- 10 full days (146 orbits):
  /net/pc190612/nobackup/users/lindenm/projects/omi/data/col4_test_data_2022-08-29

  2005-06-01, 2007-06-01, 2009-06-01, 2011-06-01, 2015-06-01,
  2019-06-01, 2020-06-01, 2021-06-01, 2021-12-01, 2022-06-01

- September: review of data / processors
- October: final adjustments and deploy to SIPS
- November/December: reprocessing of full mission

Offset details

- Previous operational offset 354/388 = -1.5, changed to -0.85
- Previous operational offset 340/380 = -1.8, changed to -1.05
- Previous operational offset 335/367 = 0.0, changed to -1.1