Optimal A-Train Data Utilization: A Use Case of Aura OMI L2G and MERRA-2 Aerosol Products

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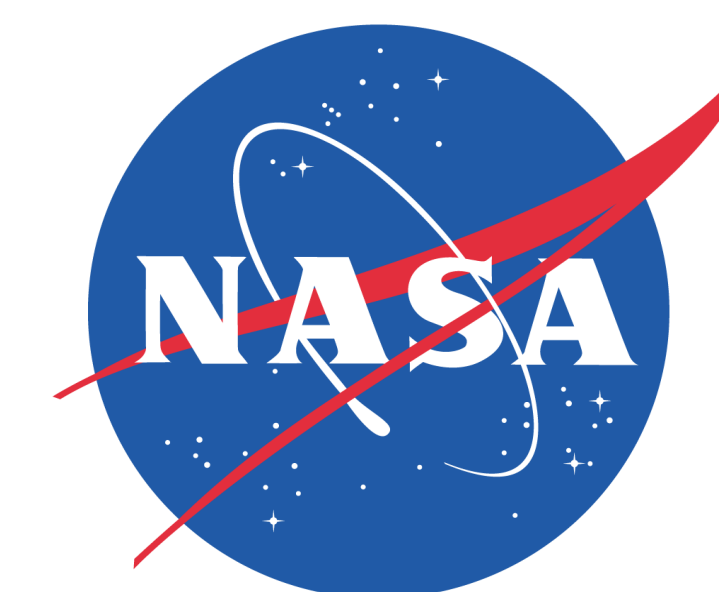
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Introduction

Ozone Monitoring Instrument (OMI) aboard NASA's Aura mission measures ozone column and profile, aerosols, clouds, surface UV irradiance, and the trace gases including NO2, SO2, HCHO, BrO, and OClO using UltraViolet electromagnetic spectrum (280 - 400 nm) with a daily global coverage and a pixel spatial resolution of 13 km × 24 km at nadir, and it's been one of the key instruments to study the Earth's atmospheric composition and chemistry. The second Modern-Era Retrospective analysis for Research and Applications (MERRA-2) is NASA's atmospheric reanalysis using an upgraded version of Goddard Earth Observing System Model, version 5 (GEOS-5) data assimilation system. Compared to its predecessor MERRA, MERRA-2 is enhanced with more aspects of the Earth system among which is aerosol assimilation.

When comparing between satellite pixel measurements and modeled grid data, how to properly handle counterpart pairing is critical considering their spatial and temporal variations. The comparison between satellite and model data by simply using Level 3 (L3) products may result biases due to lack of detailed temporal information. It has been preferred to inter-compare or implement satellite derived physical quantity (i.e., Level 2 (L2) Swath type) directly with/to model measurements with higher temporal and spatial resolution as possible. However, this has posed a challenge in the community to handle. Rather than directly handling the L2 or L3 data, there is a Level 2G (L2G) product conserving L2 pixel scientific data quality but in Grid type with the global coverage. In this presentation, we would like to demonstrate the optimal utilization of OMI L2G daily aerosol products by comparing with MERRA-2 hourly aerosol simulations matched well in both space and time.

Data Investigation

OMI

- OMI flying on NASA's Aura satellite is a collaborative contribution of the Netherland Agency for Aerospace Program and the Finnish Meteorological Institute to observe atmospheric components such as ozone, aerosol, NO2, SO2, HCHO, BrO, OClO, and cloud with a spectrum range of Ultraviolet and visible bands. The push broom telescope of the hyperspectral imaging spectrograph has a 114°field-of-view corresponding to 2600 km on the ground. OMI level-2G (L2G) products contains OMI L2 swath data with all the "good" scenes that are populated the L2G uniformed longitude-latitude grids. The L2G grid size can be either 0.25°×0.25° or 0.125°×0.125°. Currently there are 28 OMI L2G products archived at NASA/GES DISC. Each OMI L2G product defines a "good" scene differently.
- Two aerosol inversion scheme are applied to retrieve OMI aerosol optical thickness/depth (AOT or AOD) and single scattering albedo, producing two L2G products:
  - OMAEROG: The multi-wavelength algorithm uses up to 19 channels from 330nm to 500nm to derive extinction optical thickness.
  - OMAERUVG: The near-UV algorithm uses two UV bands at 342.8nm and 388nm to obtain extinction and absorption AOT.

MERRA-2

- The second Retrospective analysis for Research and Applications (MERRA-2) is NASA's atmospheric reanalysis data assimilation system. MERRA-2 is enhanced with hourly diagnostic aerosol products of different types such as black carbon, organic carbon, dust, sea salt, SO4, and SO2. The grid size is 0.5°×0.625°.

Instrument/Model Specifications for OMI L2G and MERRA-2

Platform/ Sensor or Model	Product	Spatial Resolution	Temporal Resolution	Data Period	Total Column Aerosol Dataset
Aura/OMI	OMAEROG (doi:10.5067/Aura/OMI/DATA3004) (https://uui-test.gesdisc.eosdis.nasa.gov/uui/datasets?page=1&keywords=OMAEROG_V003)	0.25°×0.25°	daily	Oct'04-current	Aerosol Optical Thickness at 342.5nm, 388.0nm, 442.0nm, 463.0nm, and 483.5nm
Aura/OMI	OMAERUVG (doi:10.5067/Aura/OMI/DATA2005) (https://uui-test.gesdisc.eosdis.nasa.gov/uui/datasets?page=1&keywords=OMAERUVG_V003)	0.25°×0.25°	daily	Oct'04-current	Aerosol Optical Thickness at 354nm, 388nm and 500nm; Absorbing Aerosol Optical Thickness at 354nm, 388nm and 500nm
MERRA-2	M2T1NXAER (DOI: 10.5067/KLICLTZ8EM9D) (https://uui-test.gesdisc.eosdis.nasa.gov/uui/datasets?page=1&keywords=m2t1nxaer_v5.12.4)	0.5°×0.625°	hourly	Jan"80-current	Total Column Extinction and Scattering Aerosol Optical Thickness at 550nm; Total Column extinction/scattering aerosol optical thickness and column mass density by different sources such as black carbon, organic carbon, dust, SO4, and Sea Salt

Reference: Torres, O., A. Tanskanen, B. Veihelmann, C. Ahn, R. Braak, P. K. Bhartia, P. Veefkind, and P. Levelt (2007), Aerosols and surface UV products from Ozone Monitoring Instrument observations: An overview, J. Geophys. Res., 112, D24S47, doi:10.1029/2007JD008809.

SCAN ME

How to Use OMI L2G Data?

Advantages of OMI L2G Product
- 24 UTC hours of OMI level-2 data (excluding zoom mode) in one file
- Global coverage
- Grid format
- All data are from "good" scenes.

Disadvantages of OMI L2G Product
- OMI L2G products are not commonly gridded data.
- What is Ncandidate?
  - Core variables of OMI L2G products all have a third dimension of Ncandidate in addition to the dimensions of longitude-grid and latitude-grid, which might cause confusing to some users. Figure 1 show OMTO3G total ozone column amount (DU) of single level candidates versus all-level candidates. Because the candidates in one grid cell of OMI L2G products are sequenced according to their optical paths, choose a single level candidates could not able to represent the true globally spatial distribution of the interest atmospheric composition, thus should not be used to validate modeled parameters.
  - The right figure in figure 1 shows the global map of the total column amount of ozone considering all the candidates with their spatial and temporal signatures collected from OMI L2G data. Each candidate in OMI L2G grid cells are distinguished by specific signatures including line number, orbit number, scene number, geolocation and time stamp. Comparing OMI L2G products with MERRA-2 hourly simulations are
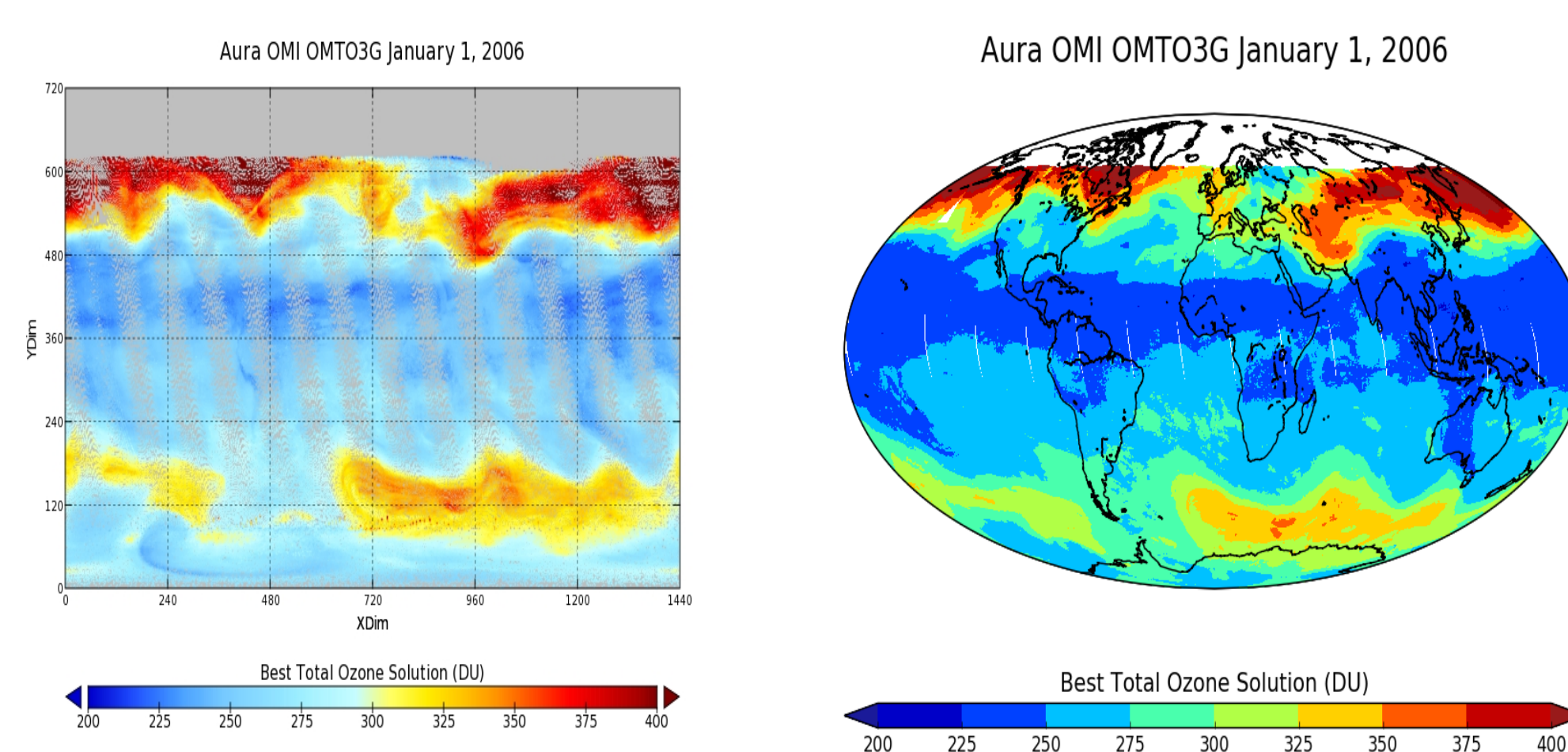

Figure 1: OMI L2G OMTO3G ozone total column amount (DU) on January 1, 2006. The left figure only contains OMI L2 scenes from OMTO3G level 1 candidates that have the shortest optical path among all the candidates in a grid cell. The right figure includes all the candidates from up to 15 levels.

A direct way to compare OMI L2G satellite measurements and MERRA-2 hourly reanalysis simulations

- An algorithm has been developed to create hourly OMI gridded products with all the L2G metadata and OMI L2 spatial and temporal information. See figure 2 for the algorithm flowchart.
- MERRA-2 products are regridded to OMI L2G grids with the GES DISC CDO regridder.
- The accuracy of the algorithm will mainly depend on the regridding techniques, which will be further investigated in the future.
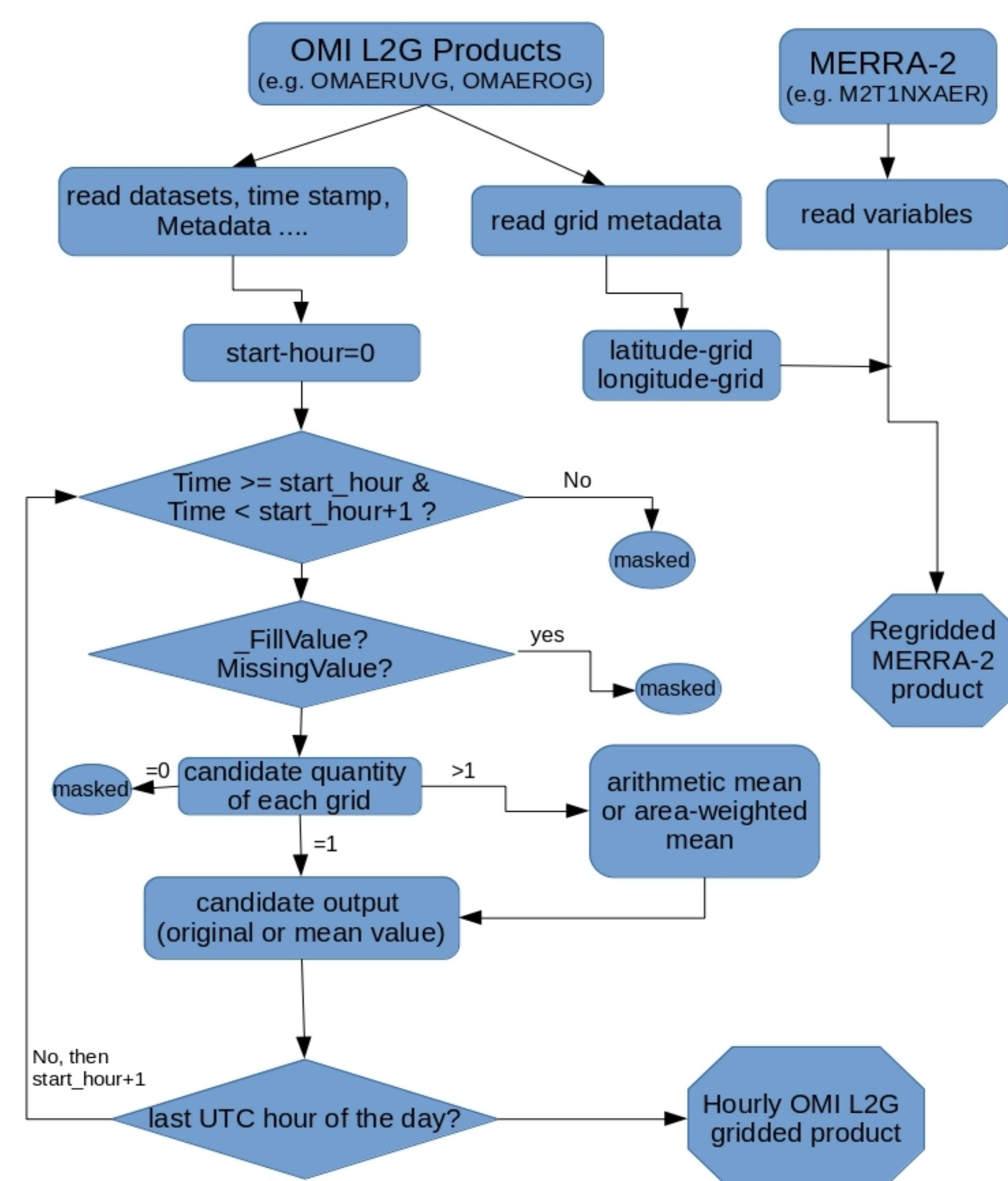- Figure 3 shows an example of the hourly OMAEROG gridded AOT product.

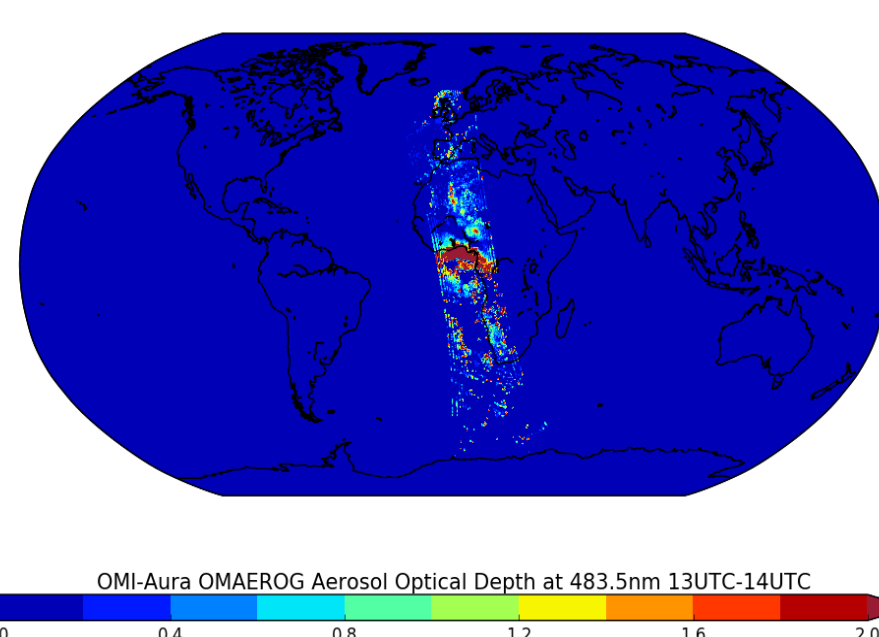*Figure 2: Algorithm flowchart to create Hourly OMI gridded products*

Figure 3: Total Column Aerosol Optical Depth on January 10, 2007 (13UTC-14UTC) from OMI multi-wavelength Aerosol algorithm retrieval

Use Case

- On January 13 of 2007, several significant aerosol episodes were observed by space-based satellite instruments including OMI.
  - Saharan dust blew off the west coast of northern Africa over the Canary Islands.
  - In central Africa, seasonal agricultural burning is common in this time of the year. Smoke spread westward to the Gulf of Guinea.
  - In Victoria, Australia, bushes and vegetation had been burned in Great Dividing Range Mountains since December of 2016 due to extremely dry, windy and hot weather.
  - In south America, north of Concepcion of Chile, a number of agriculture flames caused small smoke plumes. However, the cause of the largest fires near the coast that produced extensive thick smoke plumes could not be identified.
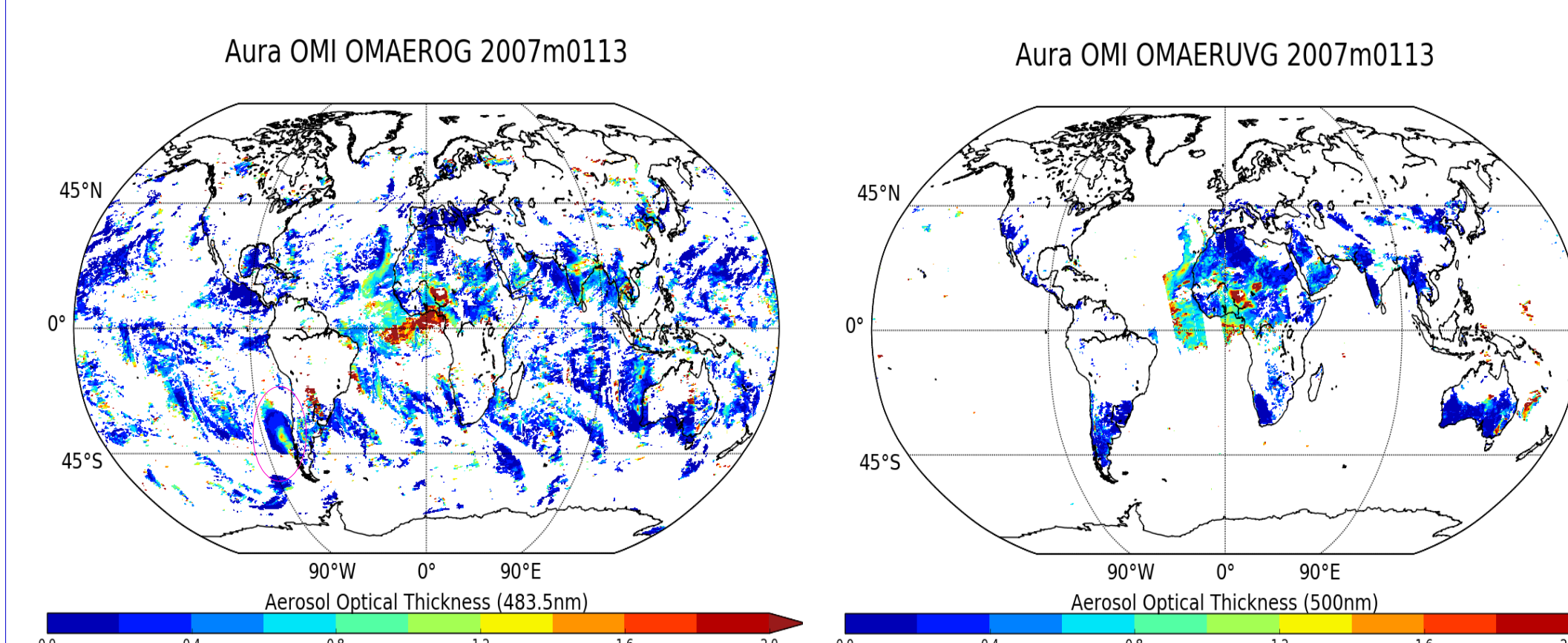

Figure 4: OMI AOT at 483.5nm by multi-wavelength algorithm (left) and AOT at 500nm by the Near-UV retrieval algorithm (right)
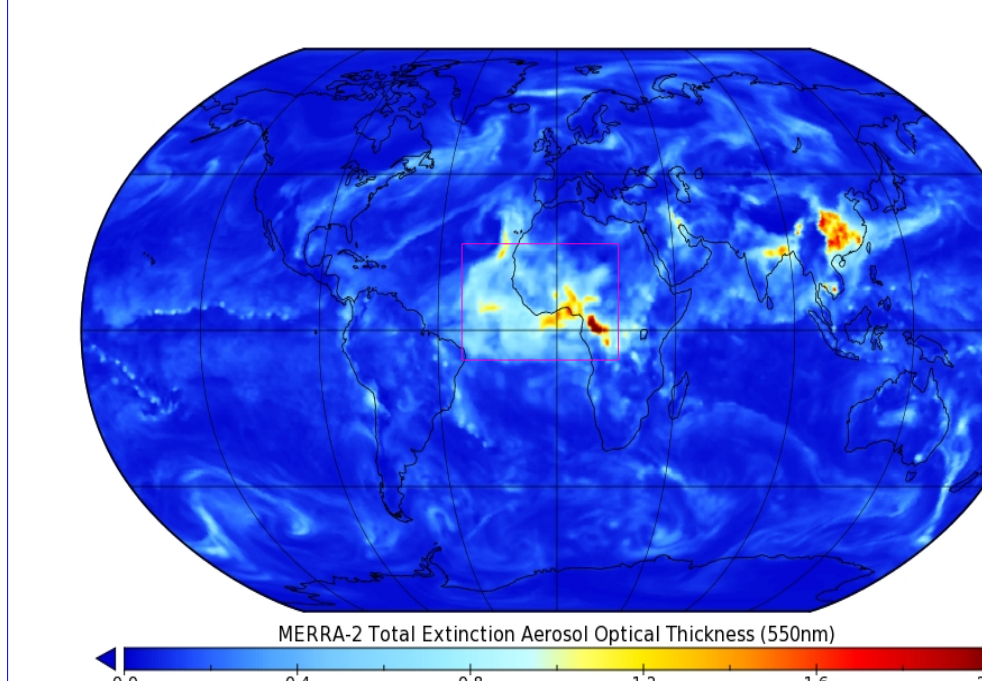

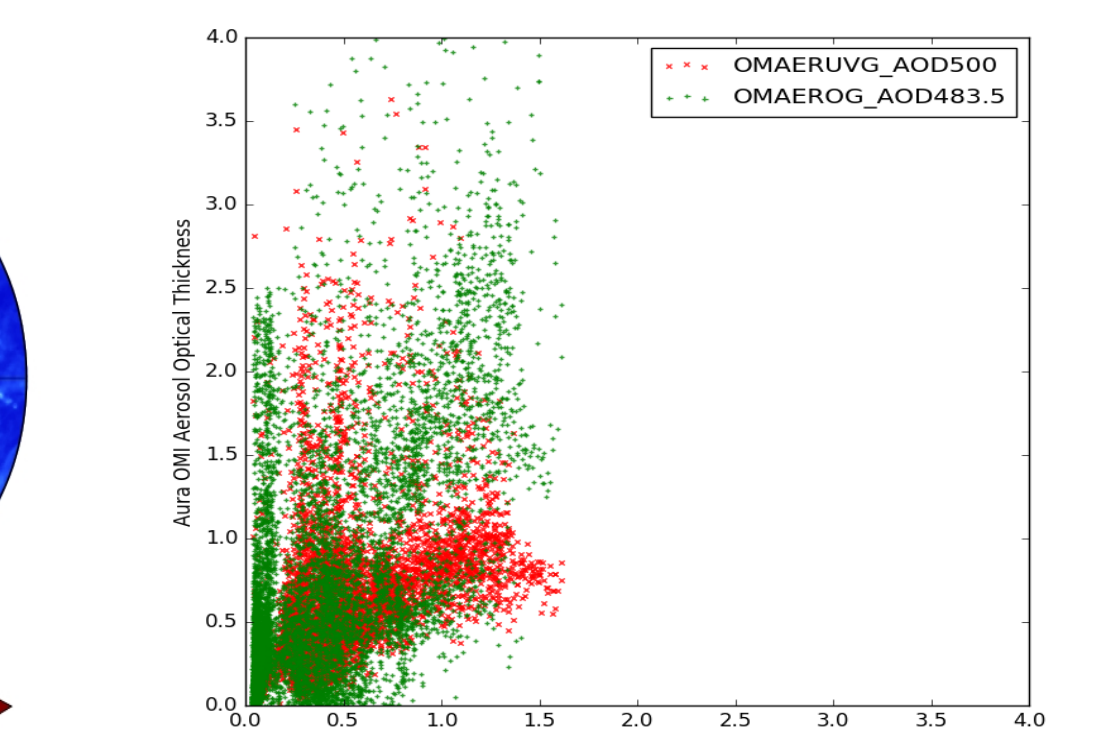*Figure 5: MERRA-2 total extinction AOT at 550nm (13UTC-14UTC) on January 13, 2007.*

Figure 6: Comparison between MERRA-2 total extinction AOT at 550nm and OMAERUVG combined AOT at 500nm as well as OMAEROG AOT at 483.5nm (13UTC-14UTC)
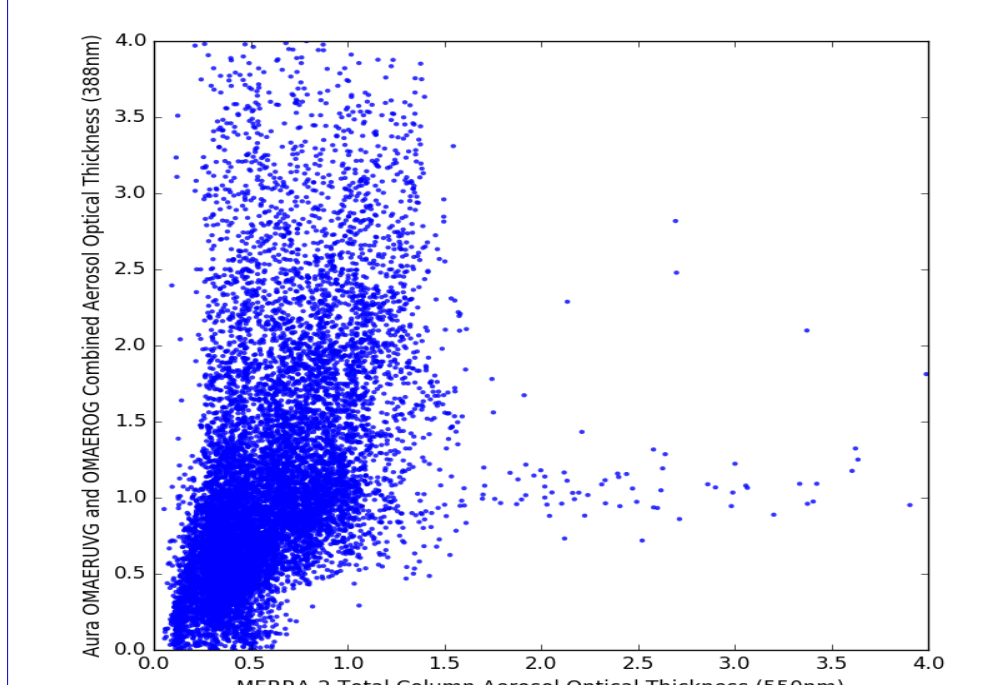

Figure 7: Comparison between MERRA-2 total extinction AOT at 550nm and OMAEROG and OMAERUVG combined AOT at 388nm in the interest region (purple box in figure 5)
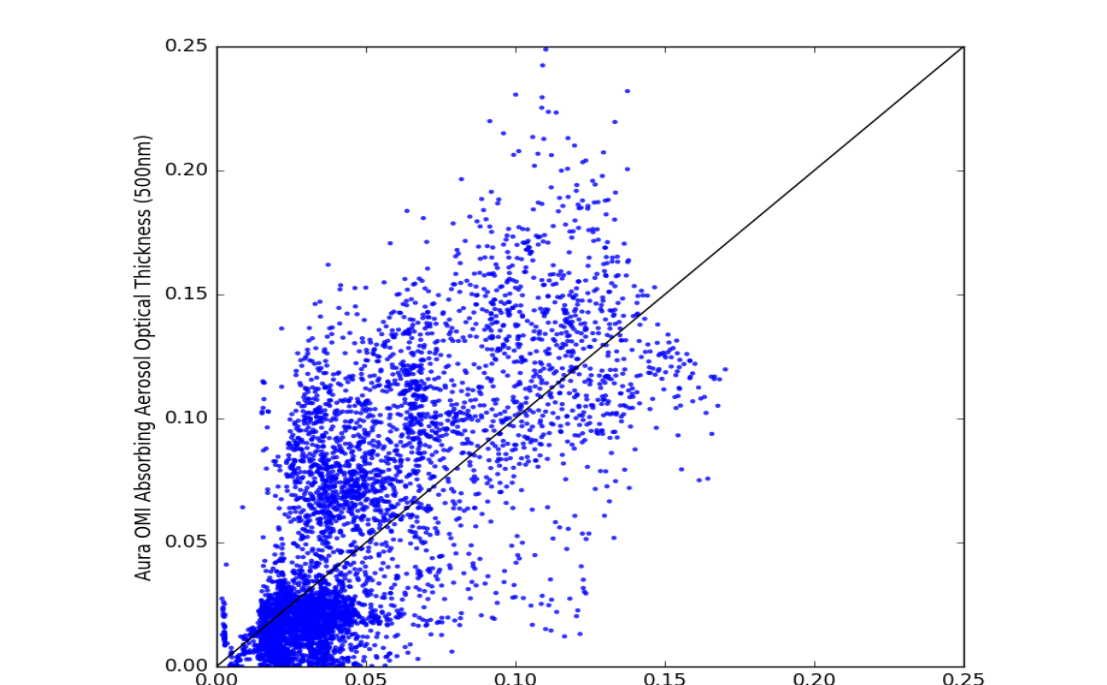

Figure 8: Comparison between MERRA-2 total absorption AOT at 550nm and OMAERUVG Absorbing AOT at 500nm at 13UTC-14UTC

Results:
- Figure 4 demonstrates global distribution of OMI aerosol optical thickness retrieved by the multi-wavelength algorithm (OMAERO) and the near-UV algorithm (OMAERUV). Since the UV-channel only algorithm is more accurate over arid or semi-arid surface environment while the UV-VIS multiple channel algorithm is more applicable over ocean (Torres et. al. 2007), a combined AOD product at 388nm from both algorithms has been created. Figure 5 shows the MERRA-2 AOT simulations at 13UTC-14UTC.
- The smoke plumes over the west coast of Chile are seen from OMAERO retrieval (purple circle in figure 1) but not seen from OMAERUV retrieval. In the meantime, MERRA-2 reanalysis does show comparatively light aerosol plumes.
- Figure 6 illustrates MERRA-2 total extinction AOT reanalysis simulations at 550nm compared to OMI measured AOT retrieved by the Near-UV algorithm (OMAERUVG, red "x") and the Multi-wavelength algorithm (OMAEROG, green "+"). This analysis confirmed the OMAERO multi-wavelength algorithm tends to overestimate the high optical thickness loading, especially over land.
- In figure 7, the 388 nm AOT dataset combined OMAEROG and OMAERUVG products is compared to MERRA-2 total extinction 550nm AOT in the interest region in northern Africa. The large portion of OMAERO overestimated AOTs might come from the big smoke plumes over the Gulf of Guinea.
- Figure 8 shows the absorbing aerosol thickness comparison between MERRA-2 and OMAERUVG near-UV algorithm retrieval.

Summary

In order to optimally utilize Aura OMI daily L2G aerosol products that have a global coverage, an algorithm has been developed to create hourly OMI gridded data products from L2G data. The hourly AOT product will be able to compare to MERRA-2 hourly aerosol simulations directly, thus to emphasize the benefit of L2G products.

The preliminary comparisons to MERRA-2 total extinction and absorption optical thickness are mainly in capability demonstration not in quantity match. However, the results do confirm that OMAERO multi-wavelength algorithm overestimates thick aerosol loading.

With the hourly OMI gridded data product and the GES DISC GIOVANNI service, users are able to visualize parallel comparisons to modeled hourly forecast. Accuracy analysis and more detailed techniques will be investigated in the future.