Planned UV GeoXO ACX Aerosol Algorithm

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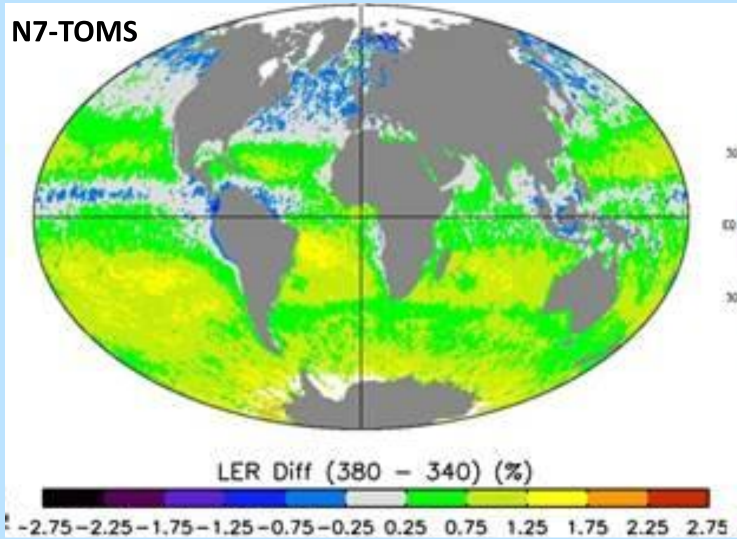
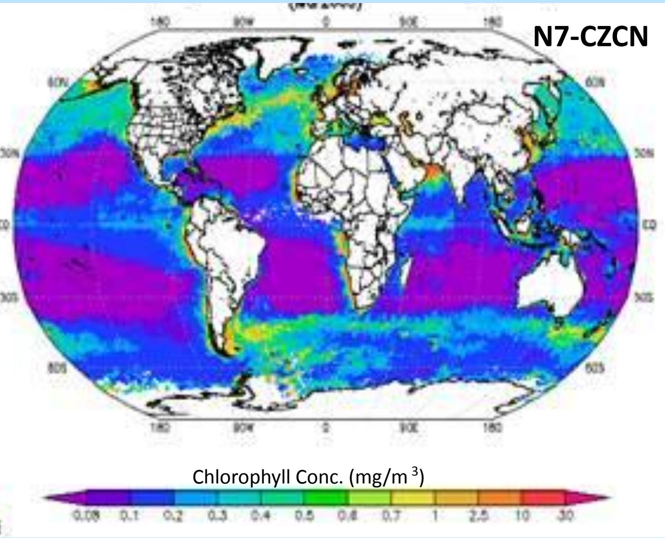
A bit of History: The TOMS Legacy

Nimbus 7 TOMS (Total Ozone Mapping Spectrometer) included 6 wavelengths: 312.5 and 317.5 nm (ozone absorbing) 331.2, 340.0, 360.0, 380.0 nm (reflectivity channels)

In the total ozone algorithm, R (Lambert-equivalent Reflectivity) is calculated at non-absorbing channels

Testing the TOMS algorithm LER λ-dependence assumption: In the mid 90's, R_{380} and R_{340} were independently retrieved and the residual quantity $\Delta R = R_{380} - R_{340}$ was calculated.





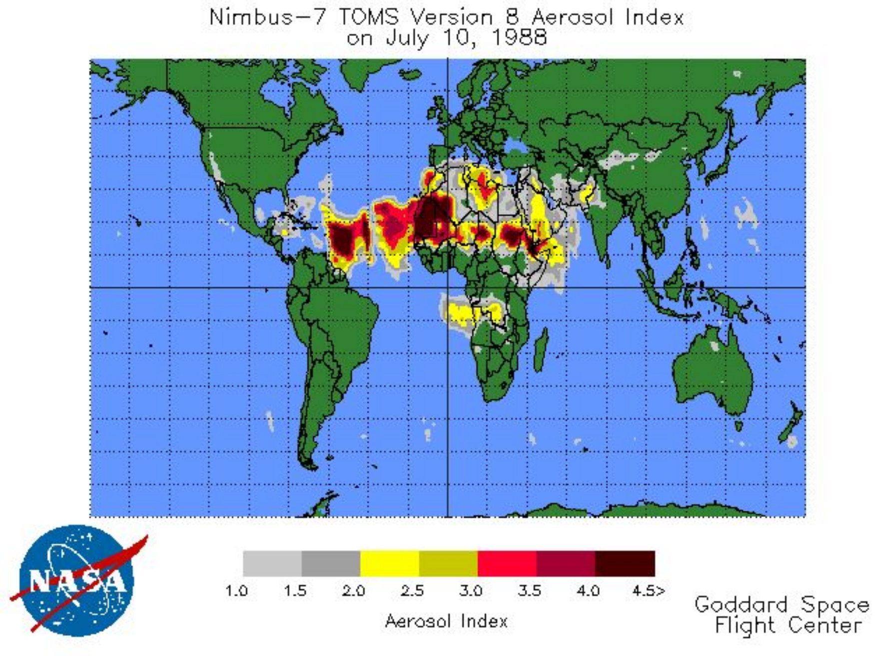
Resulting ΔR values were closely related to specific geophysical atmospheric and surface properties.

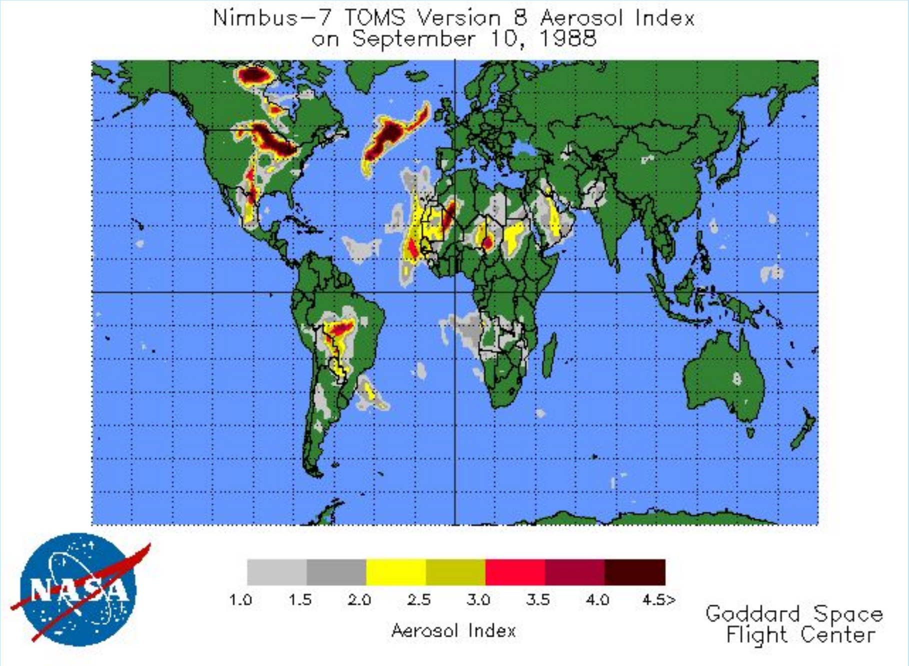
Over the oceans, negative differences were correlated with phytoplankton absorption, whereas positive differences were associated pure sea water absorption.

Over both, land and ocean surfaces, large ΔR values were Associated with the presence of smoke and desert dust aerosol layers.

The UV Aerosol Index (UVAI)

The residual ΔR quantity was later reformulated in terms of radiances as: $-100\left[\log\left(\frac{I_{340}}{I_{380}}\right)_{meas} - \log\left(\frac{I_{340}}{I_{380}}\right)_{calc}\right]$ (Herman et al., 1998), and has since been known as the UV Aerosol Index.





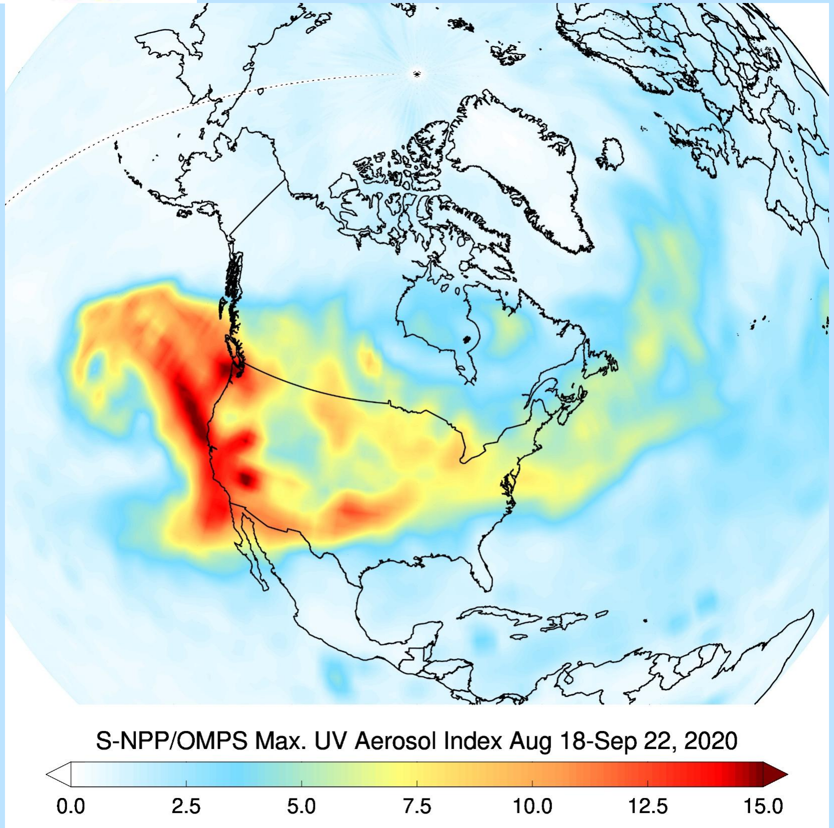
-Near zero for clouds and large particle size non- absorbing aerosols
-Negative for small particle size non-absorbing and low altitude weakly absorbing aerosols
-Positive for uv-absorbing aerosols: mineral dust, smoke, volcanic ash
-Detects absorbing aerosols presence over all terrestrial surfaces (snow/ice) and above clouds.

The aerosol UVAI magnitude depends mainly on

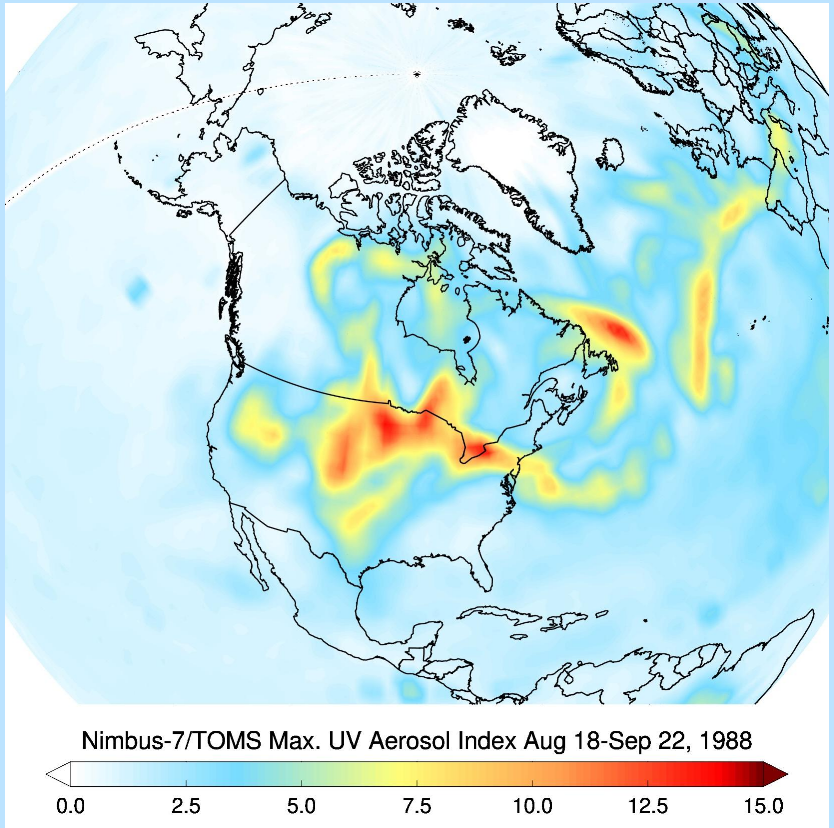
-Aerosol Optical Depth (AOD)
-Single Scattering Albedo (SSA)
-Absorbing aerosol Layer height (ALH)
If one of these parameters is known, the other two can be retrieved.

Mega-Wildfires: A TOMS & OMPS historical context

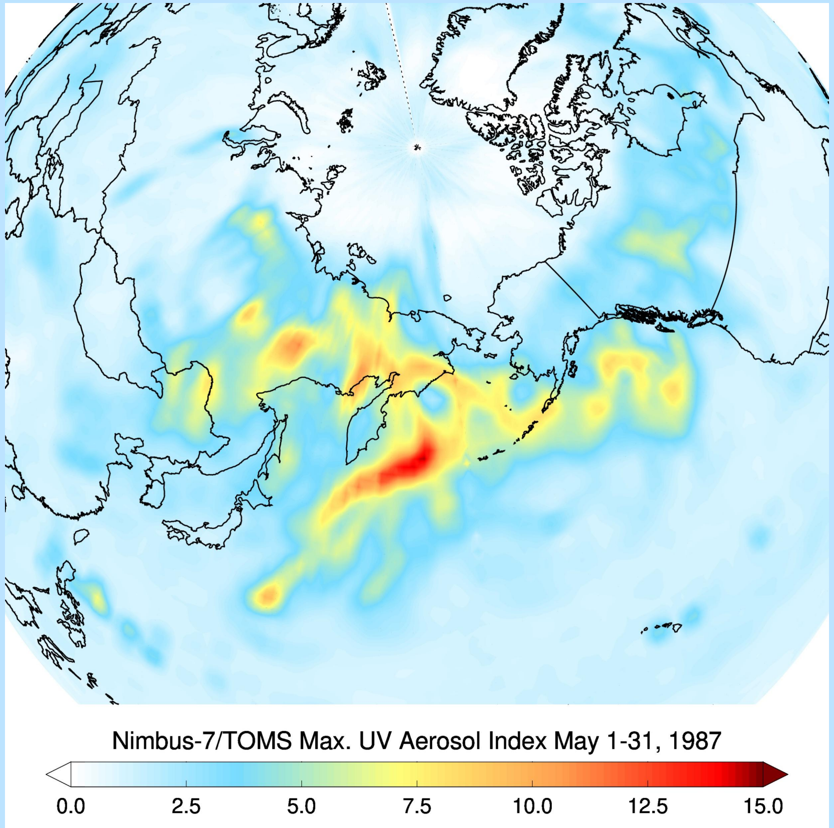
US West Coast Fires, 2020



Yellowstone National Park Fire, 1988



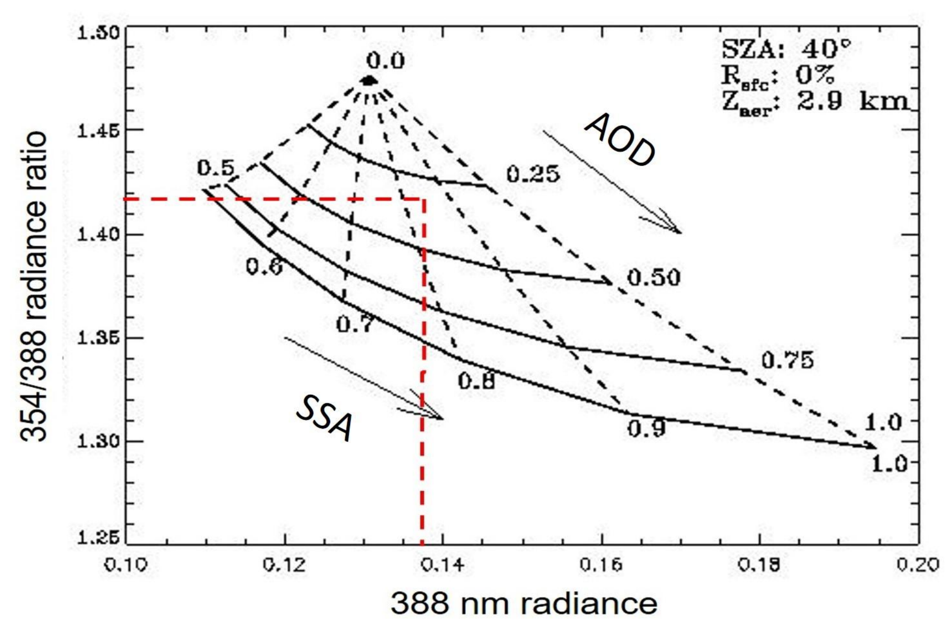
Great China Fire, 1987

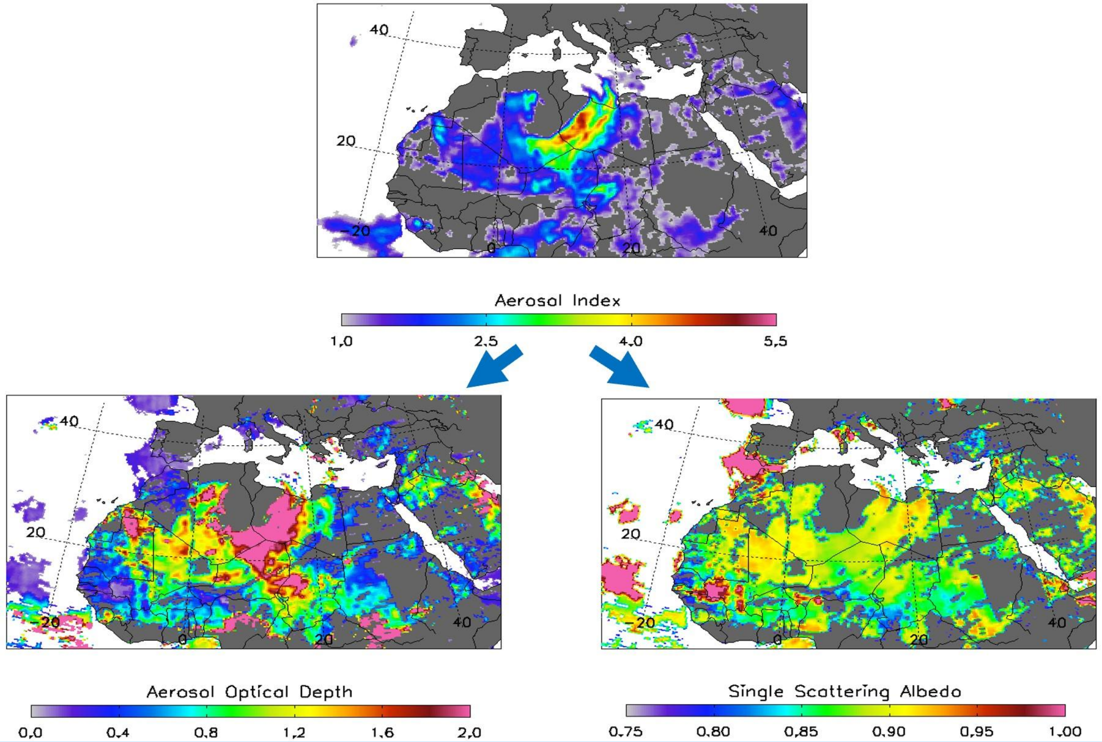


	US West Coast Fire (2020)	Yellowstone Park Fire (1988)	Black Dragon Fire ,5·6大火, (1987)
Dates	July 24 – ongoing	June 14 –Nov. 18, 1988	May 6 – June 2, 1987
Total Fires	100 +	250	----------
Burned area	26,750 km^2	3,213 km^2	73,000 km^2
Cost	>$1.7 billion (2020 USD)	>$120 million (1988 USD)	----------
Casualties	37	2	211

Quantitative Interpretation of the UVAI absorption signal

If ALH is prescribed , AOD and SSA can be retrieved





Aerosol Type	PSD	Particle shape	Real Refractive Index	Identification	Aerosol Profile
Desert Dust	AERONET	Non-spherical	AERONET	High UVAI, Low CO	Single Layer Gaussian, ALH
Carbonaceous	AERONET	Spherical	AERONET	High UVAI, High CO	Single Layer Gaussian, ALH
Sulfate-based	AERONET	Spherical	AERONET	Low UVAI	Exponential

This approach has been applied to observations from several UV-capable sensors yielding a quasi-global multi-decadal AOD/SSA record

The post-TOMS fleet of spaceborne UV-capable sensors

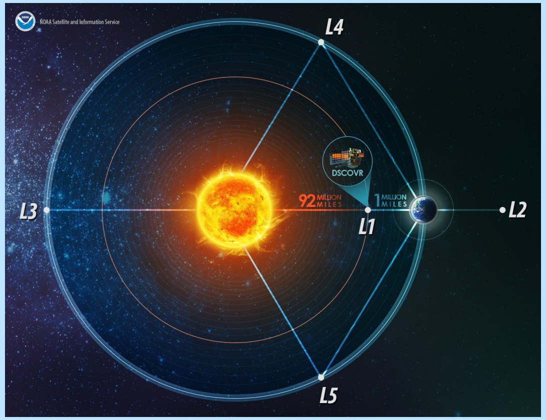
Sensors with combined UV-VIS observing capabilities

Agency	Sensor	Satellite	Spectral range of observations (nm)	Resolution	Period	Orbit
ESA	SCIAMACHY	Envisat	**240-2400 nm** (Hyp.)	32X215 km	2002-2012	LEO
ESA	GOME-2	MetopA	240-790 nm (Hyp.)	80X40 km	2006-Present	LEO
JAXA	CAI	GOSAT-TANSO	**380**,674,870,1600 nm	0.5 km	2009 - ?	LEO
KNMI	OMI	Aura	**270-500 nm** (Hyp.)	13x24 km	2004-Present	LEO
NOAA	OMPS	S-NPP	270 -400 nm (Hyp.)	50 km	2012-Present	LEO
ESA	GOME2	MetopB	240-790 nm (Hyp.)	80X40 km	2012-Present	LEO
NASA	EPIC	DSCOVR	318,**340**, **388**, 443,551,680,688,764,780 nm	~ 18 km	2015-Present	L1
JAXA	SGLI	GCOM-C	**380**-2210 nm (19 channels)	0.25 km	2017-Present	LEO
EU (CAMS/ESA)	TROPOMI	Sentinel 5 Precursor	**270-500**; 675-775 & 2305-2385 (Hyp.)	3.5X5.5 km	2018-Present	LEO
JAXA	TANSO-CAI/2	GOSAT-2	fw: **343**,443,674,1630 and bw: **380**,550,869	0.5 km	2019 - Present	LEO
NIER (Korea)	GEMS	GK-2B	**300-500** nm (Hyp.)	3.5X8 Km	2020-Present	GEO
NOAA	OMPS	JPSS-2	270-400 nm (Hyp.)	50 km	2022-Present	LEO
NASA-SAO	TEMPO	Intelsat-40	**290-490** & 540-740 (Hyp.)	2.1x4.7	2023-Present	GEO
NASA	OCI	PACE	**340-890** nm (2.5nm steps)	1.2 km	2024-Present	LEO
NASA-JPL	MAIA	ASI-PLATINO	**365**-2126 nm (14 channels)	0.2 km (nadir)	2025 (sched.)	LEO
EU (CAMS/ESA)	Sentinel 4	MTG-S	305-400,400-500,750-775 nm		2025 (sched.)	GEO
EU (CAMS/ESA)	Sentinel 5	Met-Op-SG A	270-300; 300-500; 685-773;1590-2385 nm	7km to 50 km	2026 (sched.)	LEO
NOAA	ACX	GeoXO	TBD	TBD	2030?	GEO

Multi-year UV aerosol records

Fourteen sensors with UV-VIS spectral observing capability (most at moderate spatial resolution) have been deployed over the last 20 years. EPIC, TROPOMI, TEMPO, and OCI include O2A and/or B bands, that enable aerosol layer height retrieval capability.

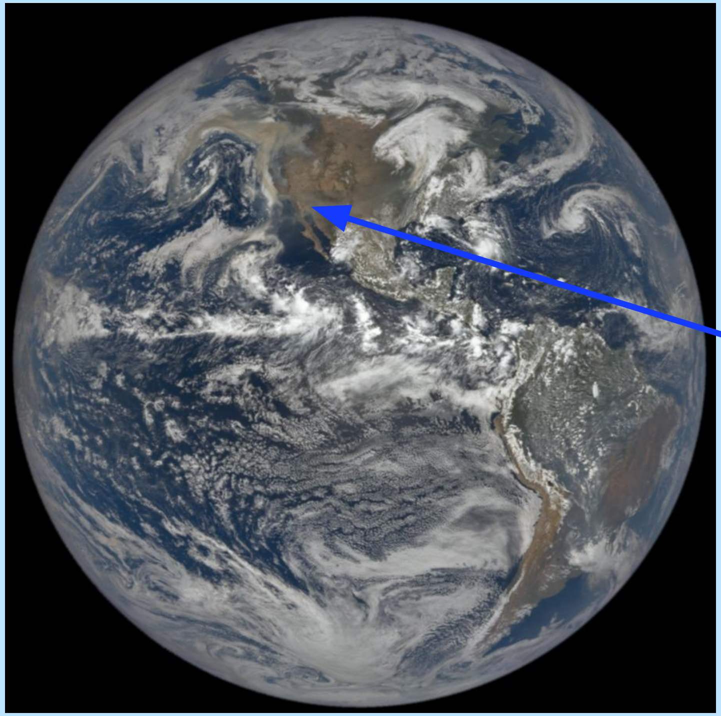
DSCOVR-EPIC: A convenient GeoXO ACX proxy



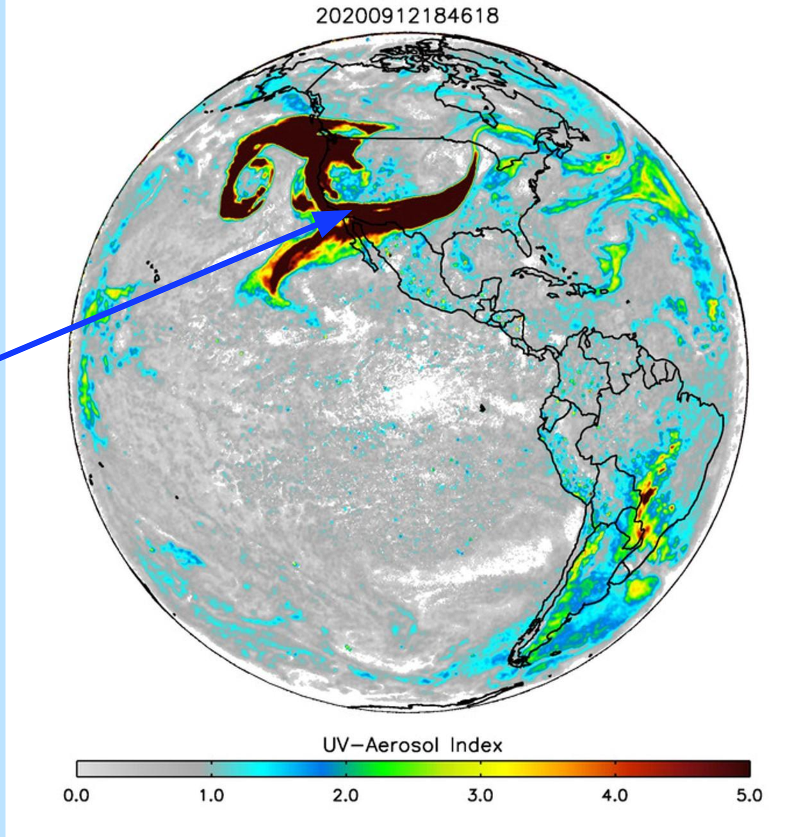
-DSCOVR platform is stationed at the L1 point, 1 million miles away from Earth

-EPIC measures upwelling multi-spectral radiation from the rotating sunlit Earth disk

- EPIC wavelengths: 318,**340**, **388**, 443,551,**680**,**688**,764,780 nm



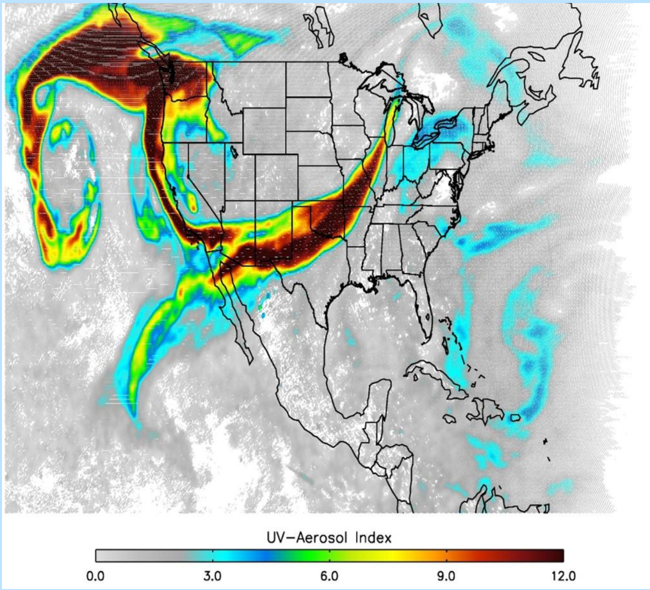
EPIC's view of Earth on September 12, 2020, at 18:46:18

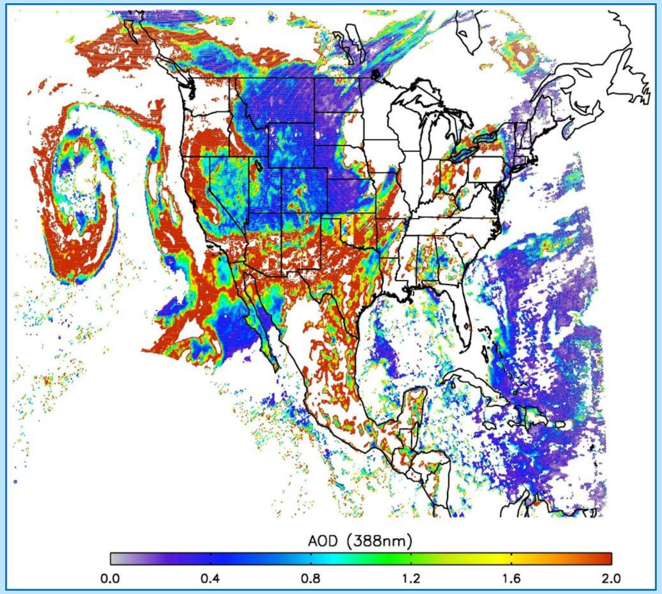


Continental scale smoke plume from 2020 US west coast fires

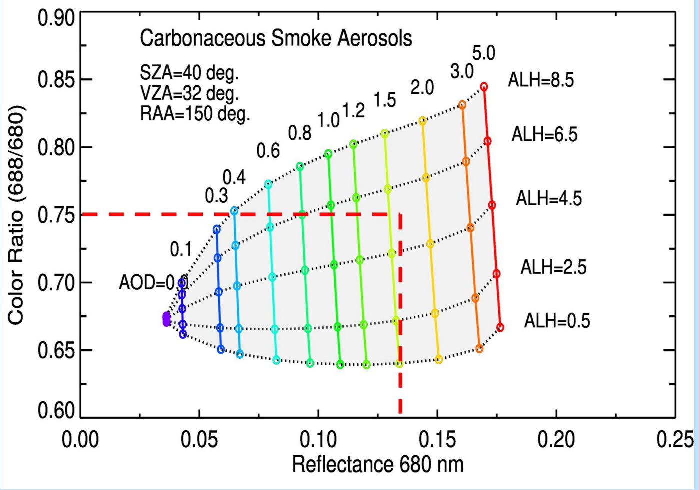
A DSCOVR/EPIC-based GeoXO ACX UV Aerosol Retrieval Algorithm

September 12, 2020

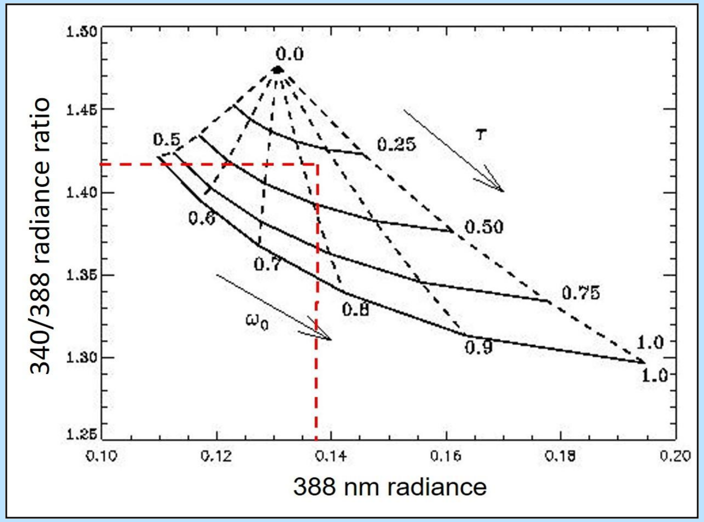




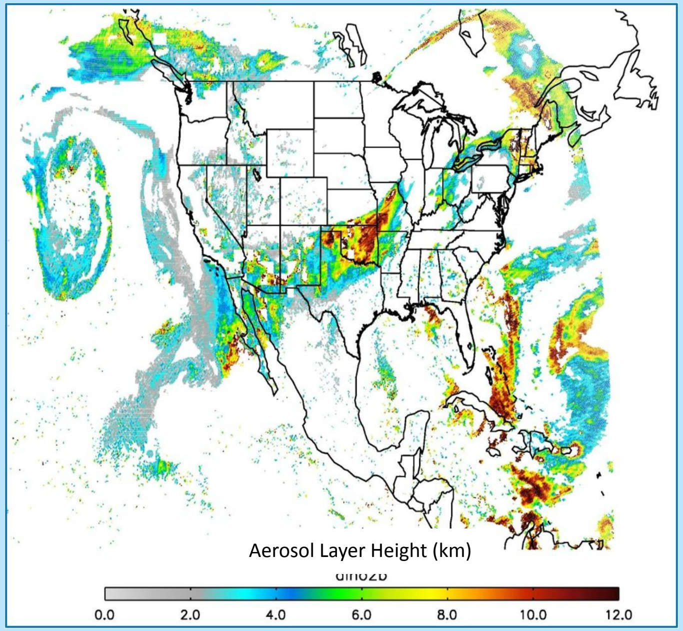
680,688 nm pair is used to simultaneously retrieve ALH nm 680 nm AOD (Xu, et al., 2019)

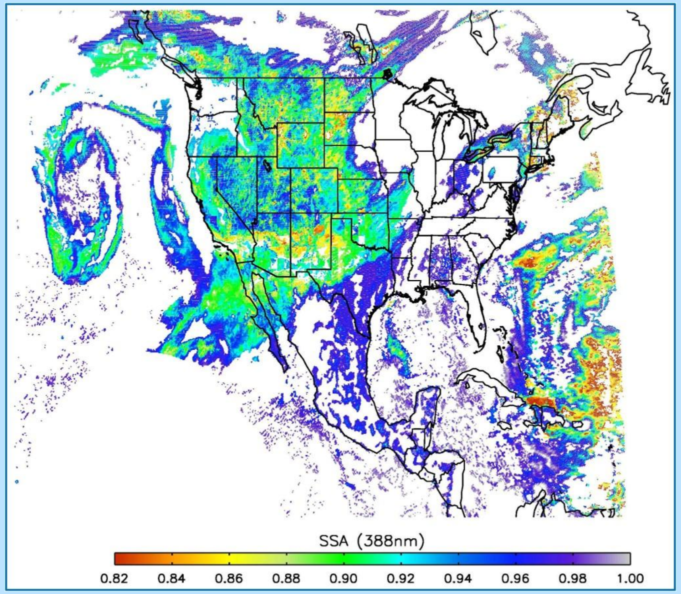


ALH

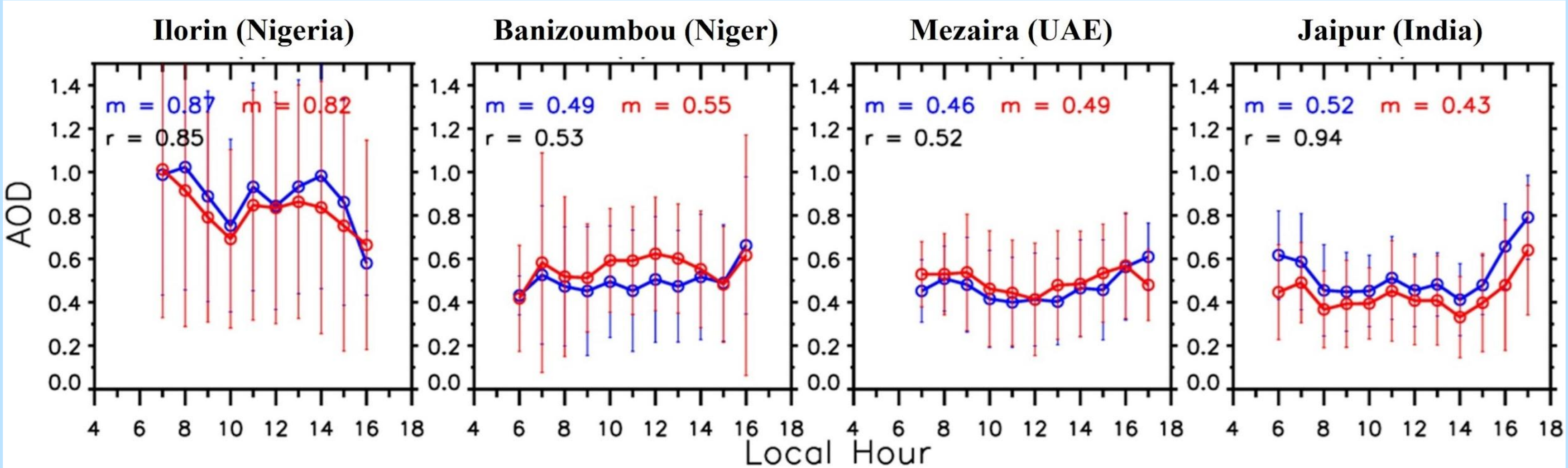


340,388 nm pair is used to simultaneously retrieve 388 nm AOD and SSA



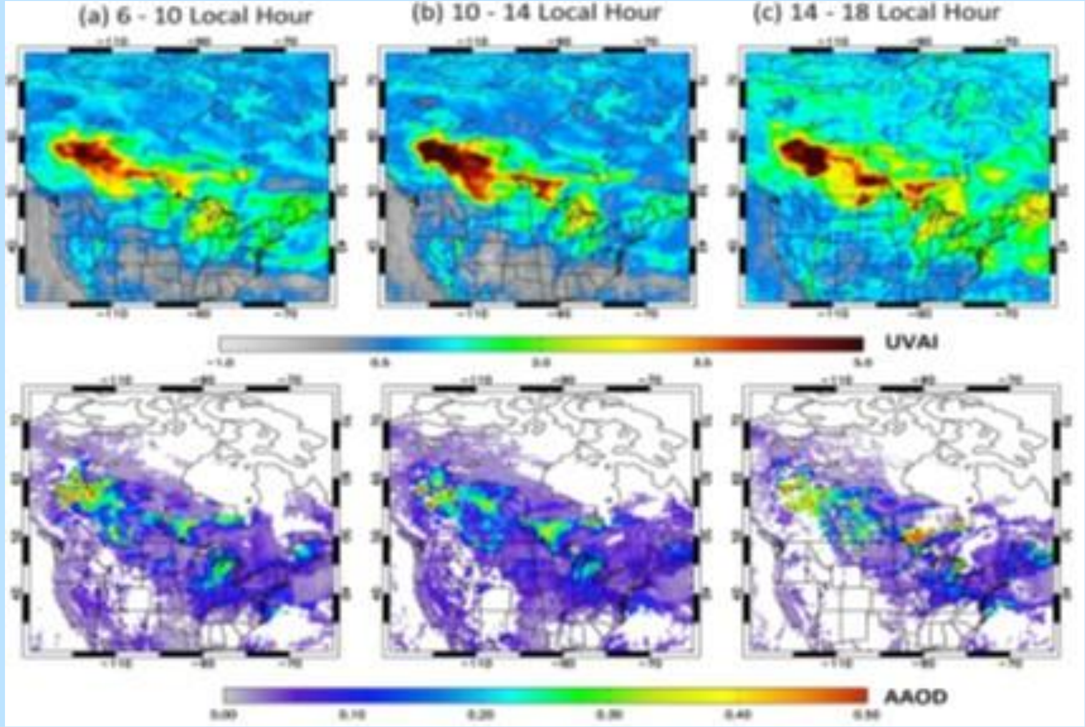


EPIC's view of AOD' s Diurnal Variability

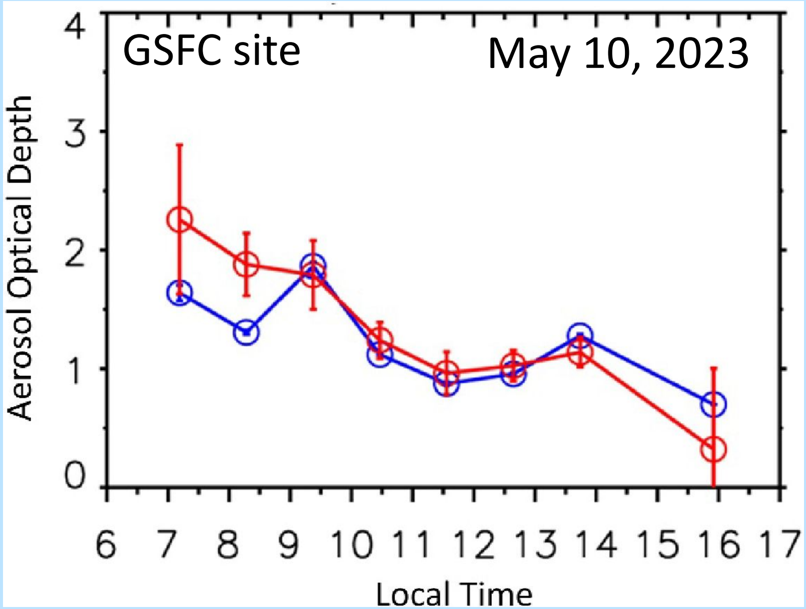


EPIC (388 nm)

AERONET (380 nm)



3-day average (May 18-20) 2023



Torres and Ahn, JGR, 2024

Summary

-The use of satellite UV observations has been established as a reliable method for the characterization of aerosol absorption.

-The spectral coverage of fine spatial resolution satellite-borne instrumentation for aerosol remote sensing developed over the last 15-years, has been expanded to the UV to take advantage of the demonstrated UV retrieval capabilities.

-Observations by the DSCOVR-EPIC sensor can be conveniently used for the development and testing of GeoXO ACX aerosol retrieval algorithms.

-Synergistic combination of the UV Aerosol Algorithm with other GeoXO ACX aerosol products under development will significantly enhance the science of GeoXO ACX aerosol contribution.