Recent Developments in Studying Aerosols using Nadir UV and Limb Scattering Sensors

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A Preliminary Study on the Possibility of Estimating Total Atmospheric Ozone from Satellite Measurements

J. V. DAVE AND CARLTON L. MATEER

National Center for Atmospheric Research, Boulder, Colo.

(Manuscript received 31 October 1966, in revised form 6 March 1967)

Paper Simulates Nadir-UV (0.3-0.4 μ) Radiances (w/o aerosols and clouds) using a Full Vector Code!

Only 4 years later!

Estimation of Total Ozone from Satellite Measurements of Backscattered Ultraviolet Earth Radiance

CARLTON L. MATEER

Canadian Meteorological Service, Toronto

AND DONALD F. HEATH AND ARLIN J. KRUEGER

Goddard Space Flight Center, Greenbelt, Md.

14 April 1971

ABSTRACT

Total ozone is estimated from Nimbus IV satellite measurements of the attenuation of backscattered radiances at wavelengths between 3100 and 3400 Å. A measurement of the backscattered radiance at 3800 Å, outside the O_3 absorption band, is used to determine an equivalent Lambert albedo for the cloud-ground-haze surface viewed by the instrument. The measured relative attenuation at two wavelengths is compared

Lambert-equivalent Reflectivity (LER)

$$I_m = I_0 + \frac{RT}{1 - RS_b}$$

$$R = \frac{(I_m - I_0)}{T + S_b(I - I_0)}$$

Key Assumption: R doesn't vary between 0.3-0.4 micron

Aerosol Effects in the UV

Effect of Aerosols on the Estimation of Total Ozone in an Atmospheric Column from the Measurements of Its Ultraviolet Radiance[1]

J. V. DAVE

IBM Scientific Center, Palo Alto, Calif. 94304

(Manuscript received 17 November 1977, in final form 17 January 1977)

Key Results:

- R doesn't vary with λ for non-absorbing aerosols
- decreases with λ for UV-absorbing aerosols

This paper was largely forgotten for nearly 20 years!

Cloud Effects in the UV

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 109, D01201, doi:10.1029/2003JD003395, 2004

Spectral properties of backscattered UV radiation in cloudy atmospheres

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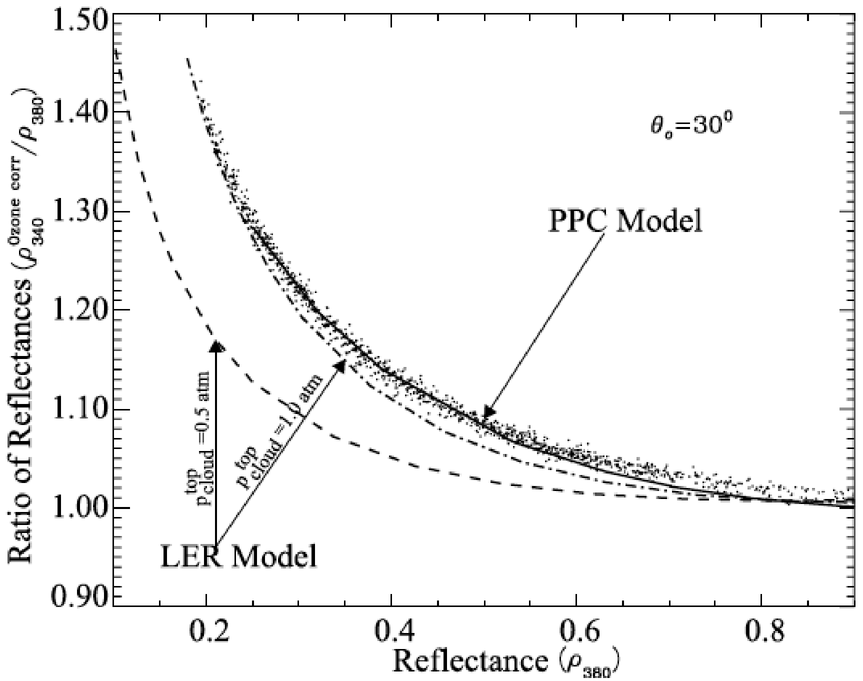
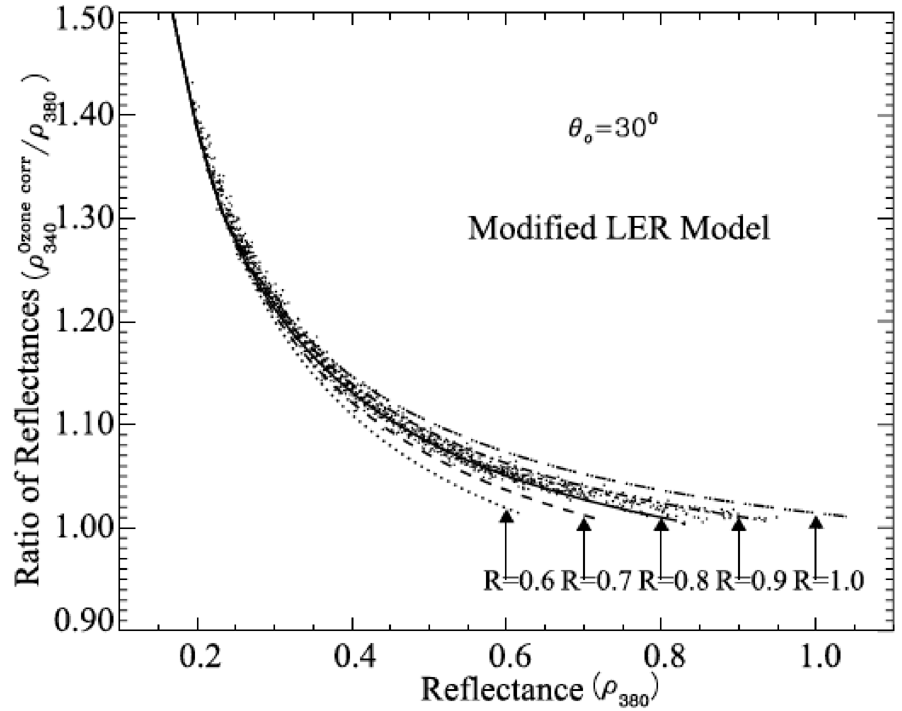
Spectral Dependence TOA Reflectance in the UV



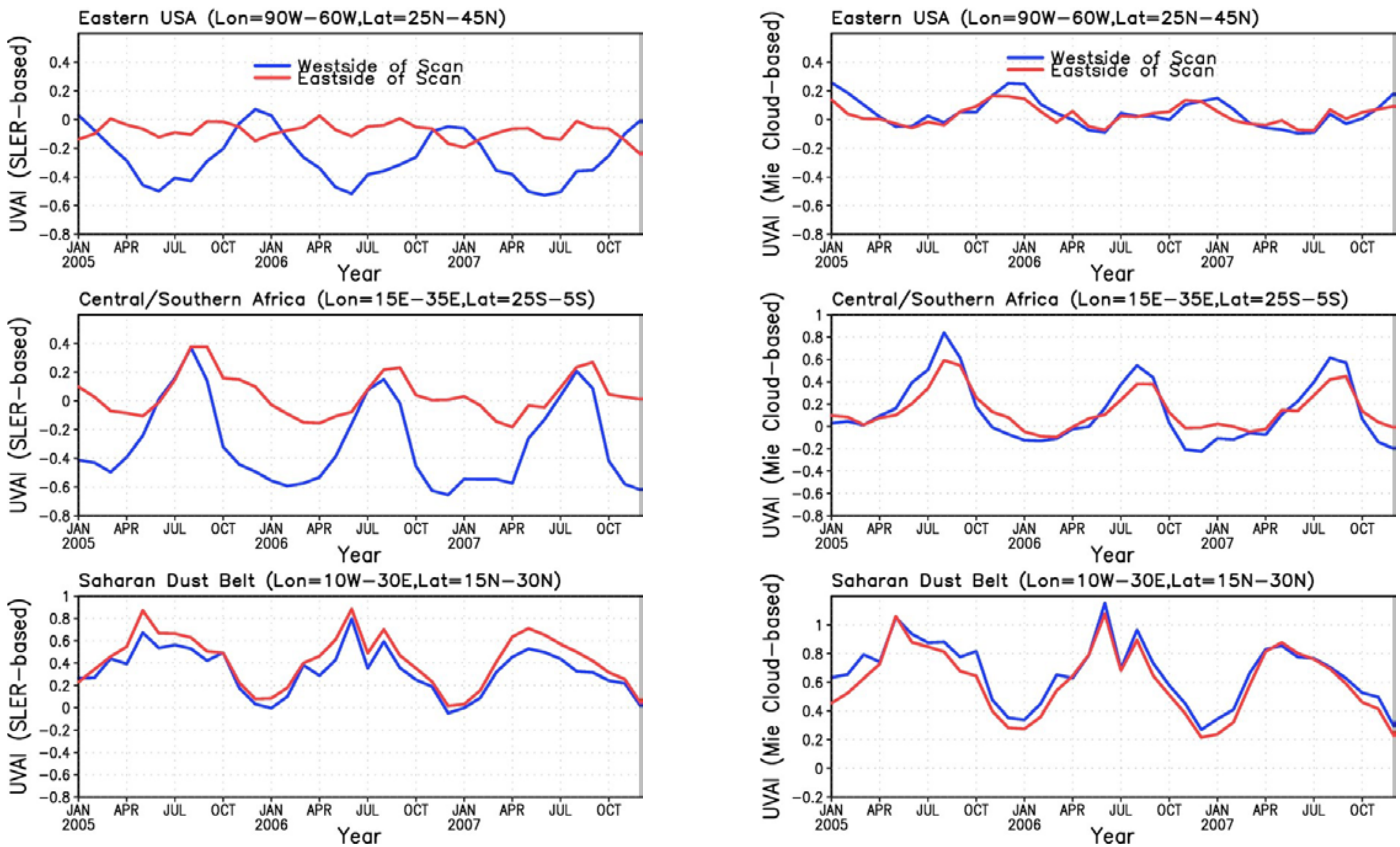


Key Results:
- Clouds appear ”blue” in the UV
- Mateer’s LER model doesn’t explain it adequately
- A modified two layer Lambertian model does better
- The C1 model does even better but only for water clouds

Effect of Cloud Model Assumption on UV Aerosol Index Calculation

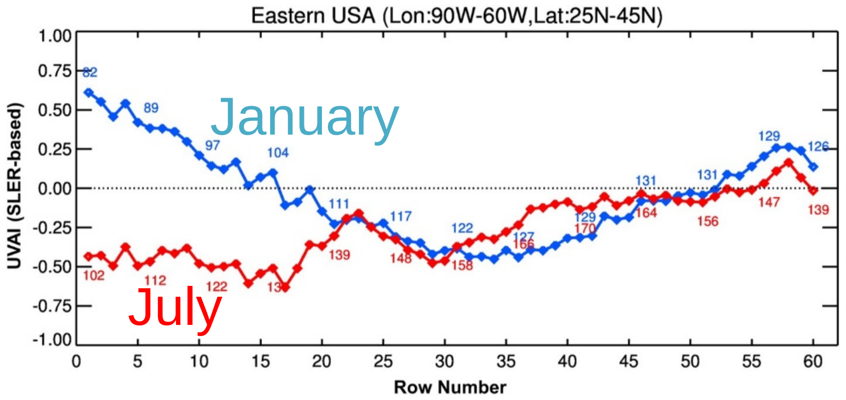
Lambertian Opaque Surface

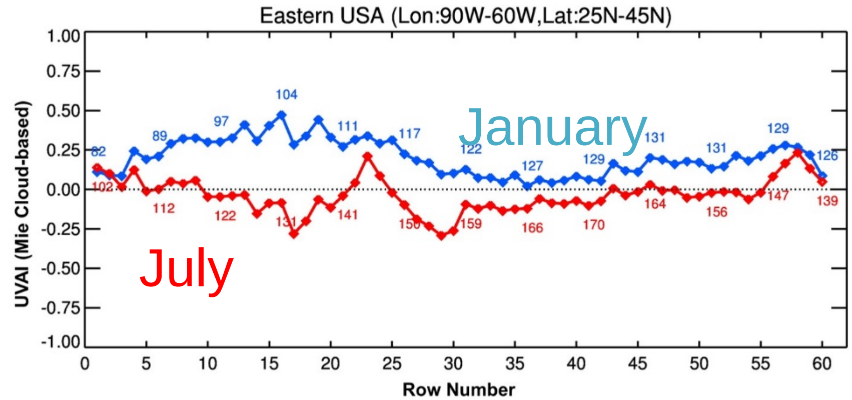
Liquid water droplet polydispersion (C1 cloud model)



Monthly mean UVAI from OMI observations using LER (left) and C1 (right) cloud models

The LER model produces a large scan bias in UVAI.
The scan bias is significantly reduced when the C1 model is used.

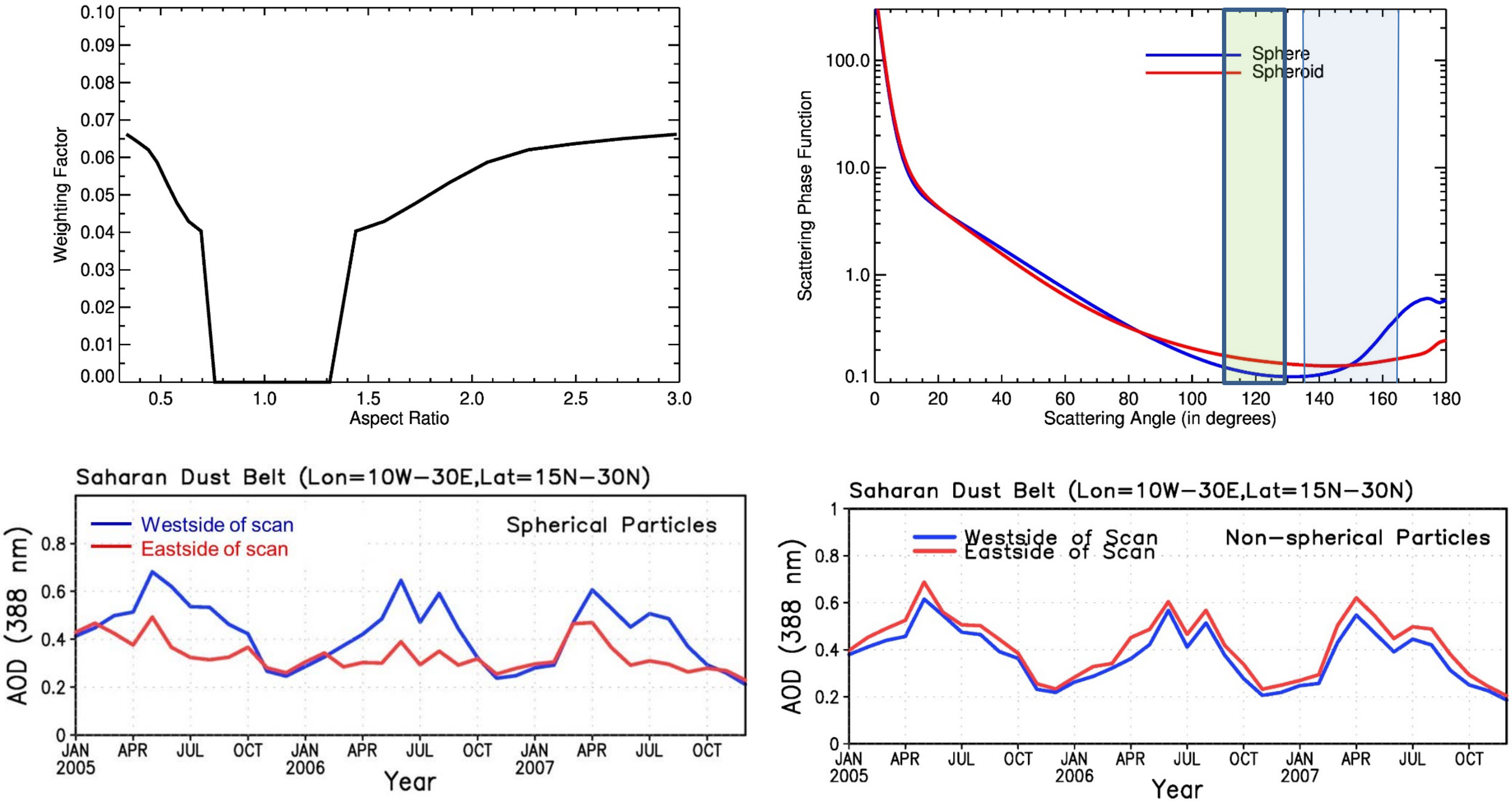




Monthly average values of retrieved LER-based UVAI as a function of viewing position . Results for January and July 2005 are shown.
Numbers indicate the monthly average scattering angle for each row.

Same for C1 model

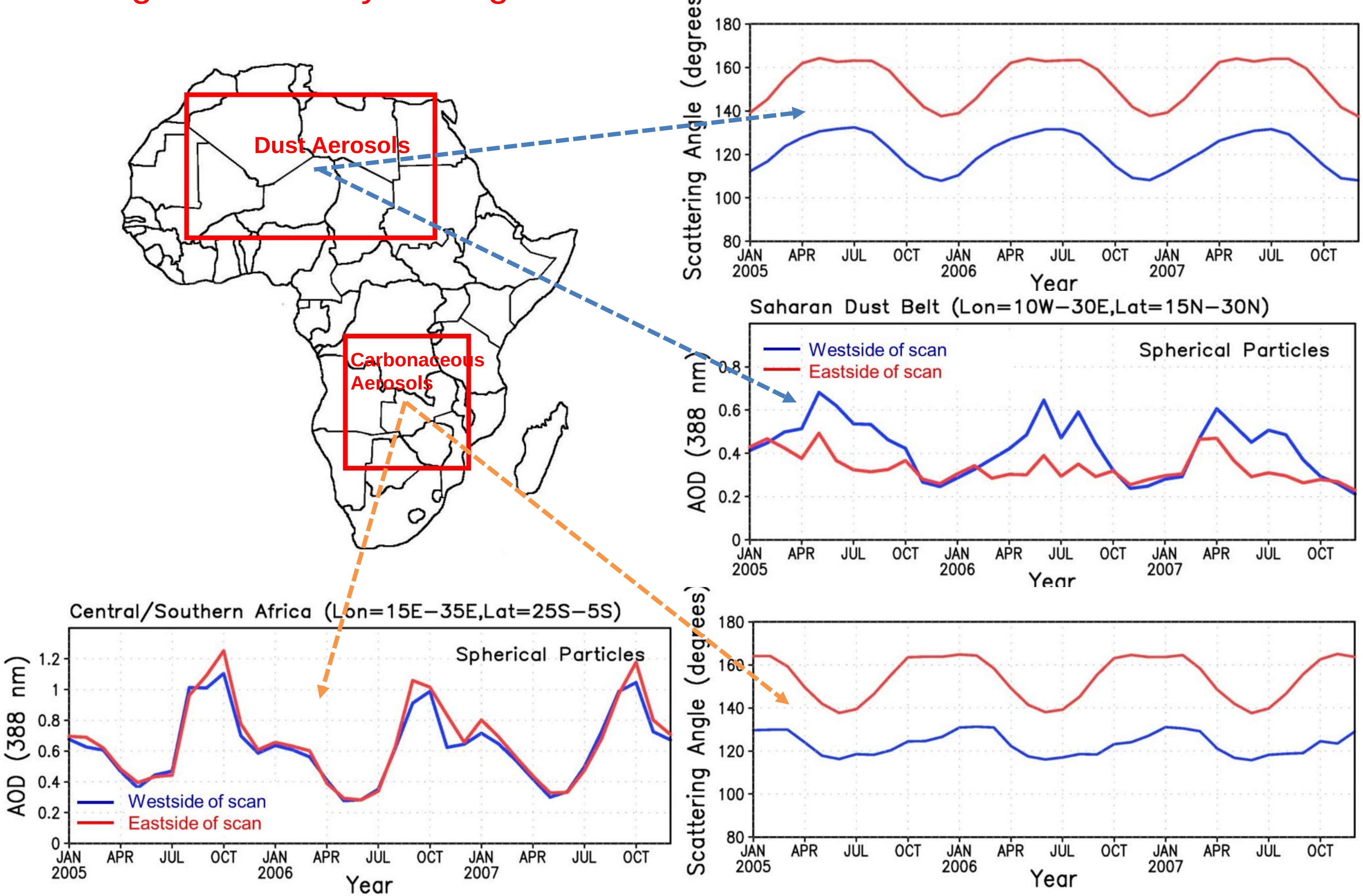
Effect of Non-sphericity of particles



Torres, O., Bhartia, P. K., Jethva, H., and Ahn, C.: Impact of the ozone monitoring instrument row anomaly on the long-term record of aerosol products, Atmos. Meas. Tech., 11, 2701-2715, https://doi.org/10.5194/amt-11-2701-2018, 2018.

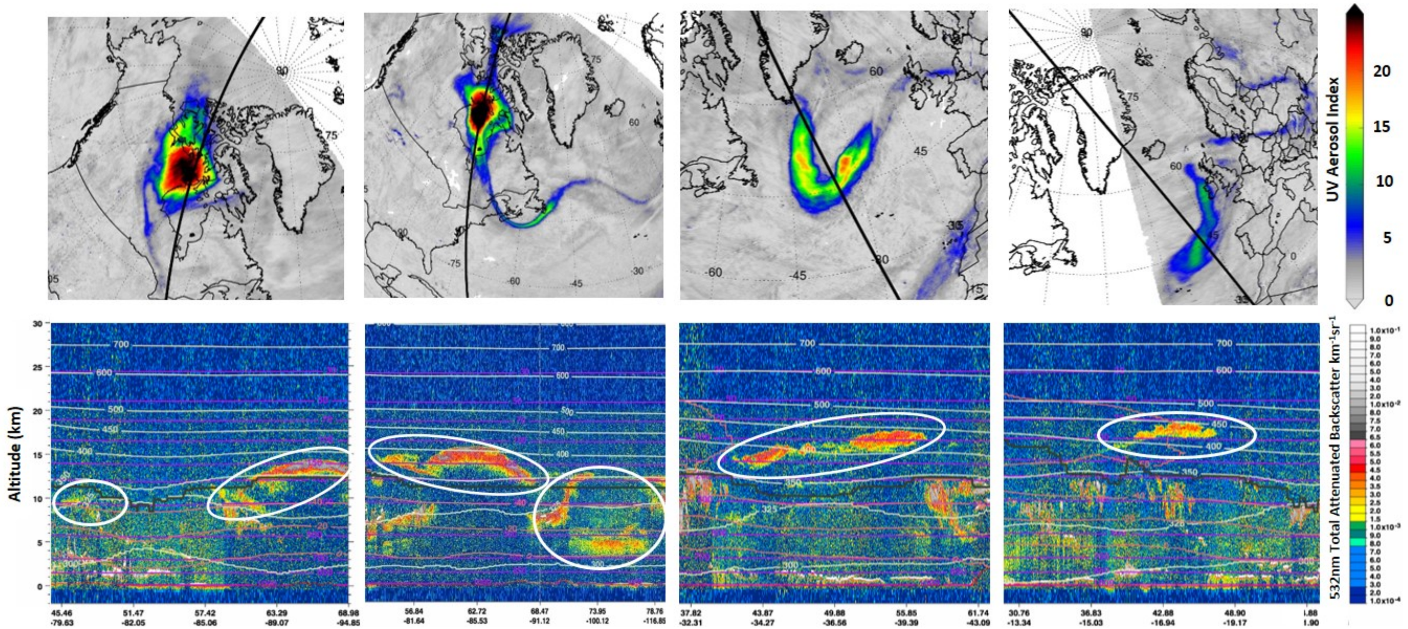
Effect of particle shape assumption in OMI AOD retrievals

Regional monthly average OMI retrieved AOD West and East of Nadir



EPIC-CALIOP Simultaneous Detection of Stratospheric Carbonaceous Aerosols

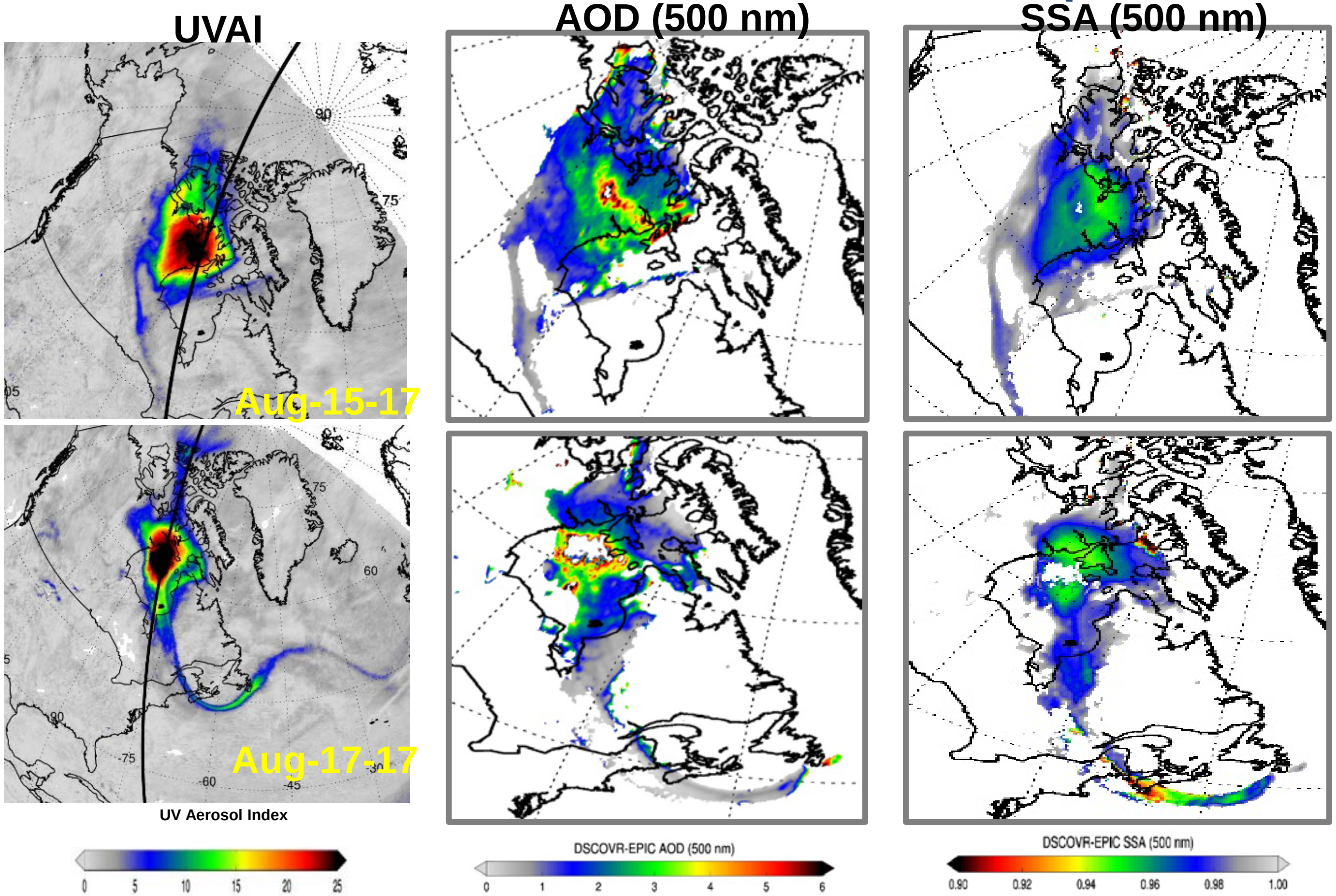
August 15 2017 August 17 2017 August 20 2017 August 23 2017



Record high UVAI values were observed in the aftermath of the aerosol injection. CALIOP observations show that the BC smoke plume reached the stratosphere.

Torres, O., Bhartia, et al., 2018, Stratospheric Injection of Massive Smoke Plume from Canadian Boreal Fires in 2017 as seen by DSCOVR-EPIC, CALIOP and OMPS-LP Observations, to be submitted.

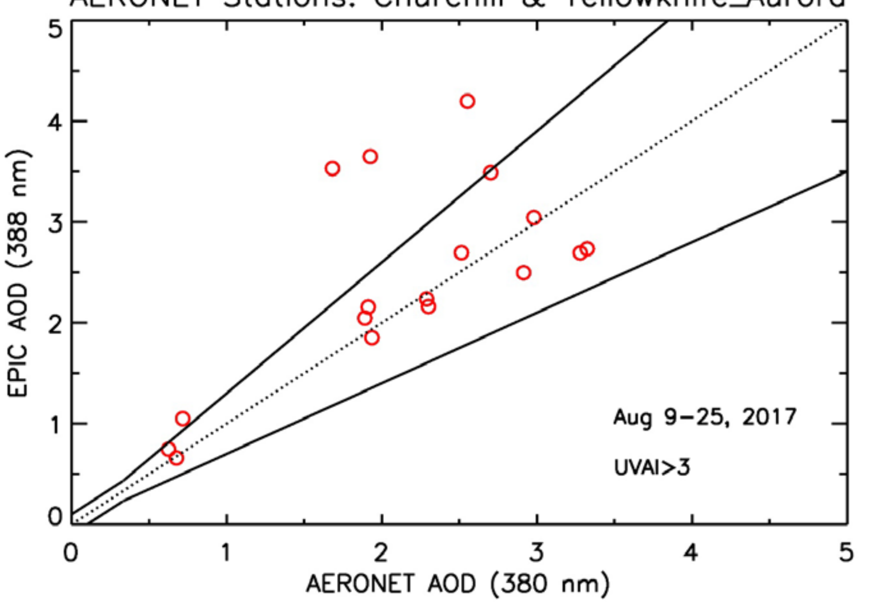
EPIC Retrieval of AOD and SSA of stratospheric aerosols



EPIC retrievals indicate a plume of AOD 4 to 6 and SSA 0.94 to 0.96 (500 nm) was injected in the Stratosphere in mid-August 2017.

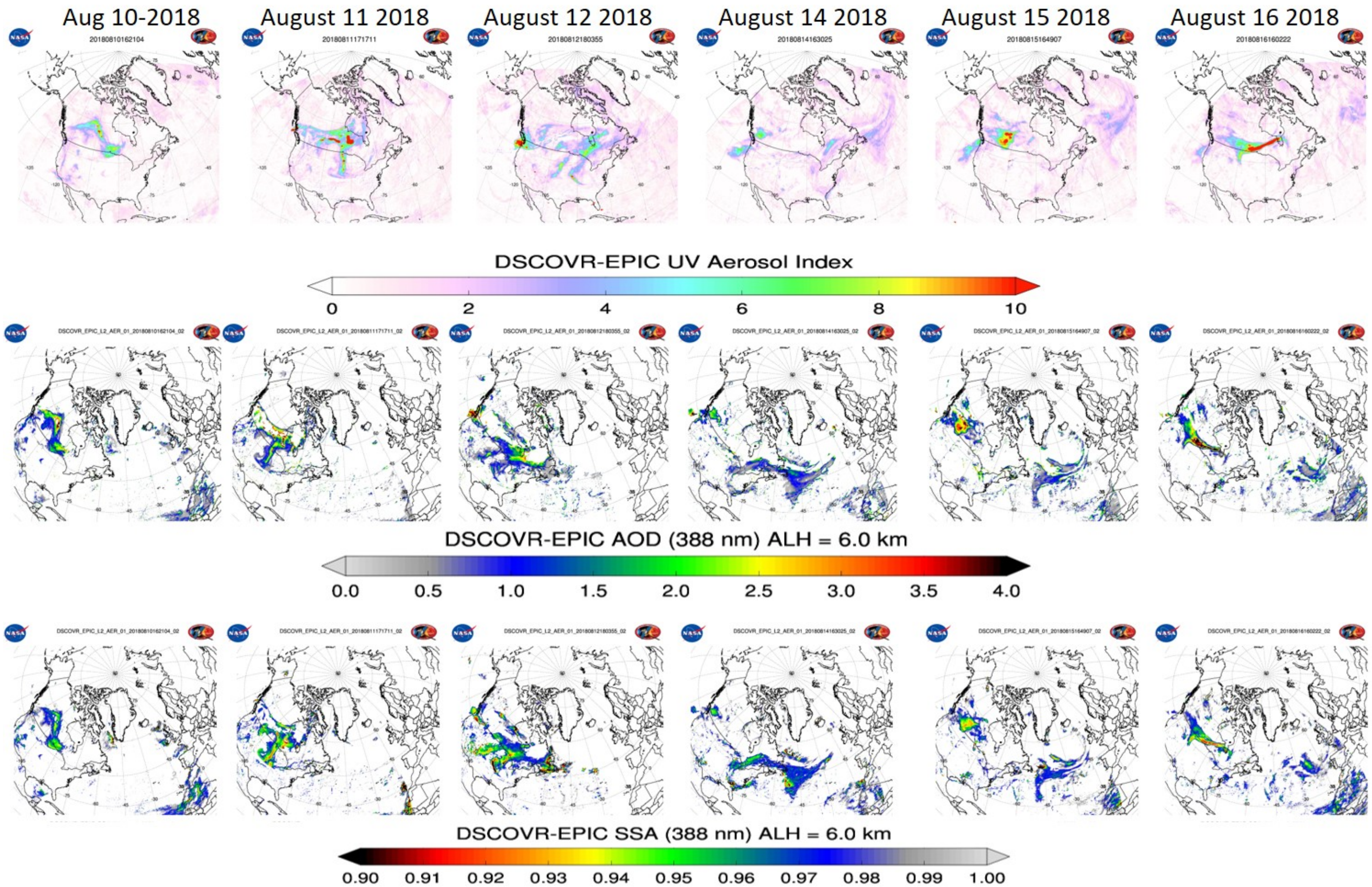
Stratospheric carbonaceous aerosols
EPIC-AERONET AOD Comparison

Spatial domain for averaging EPIC AODs = 0.25 deg.
Temporal domain for averaging AERONET AODs = ± 30 minutes

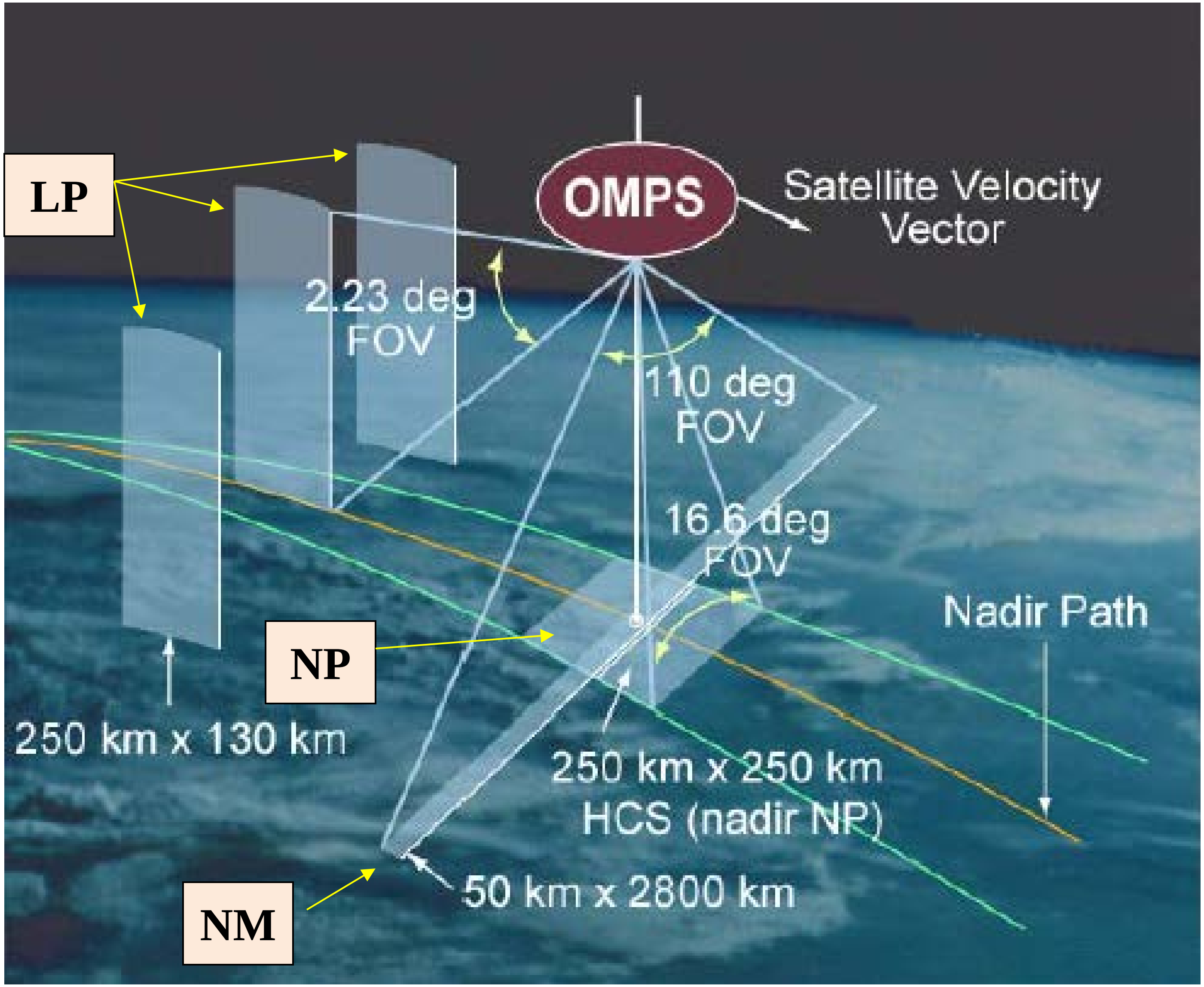


EPIC apparent over-estimates are due to scene heterogeneity

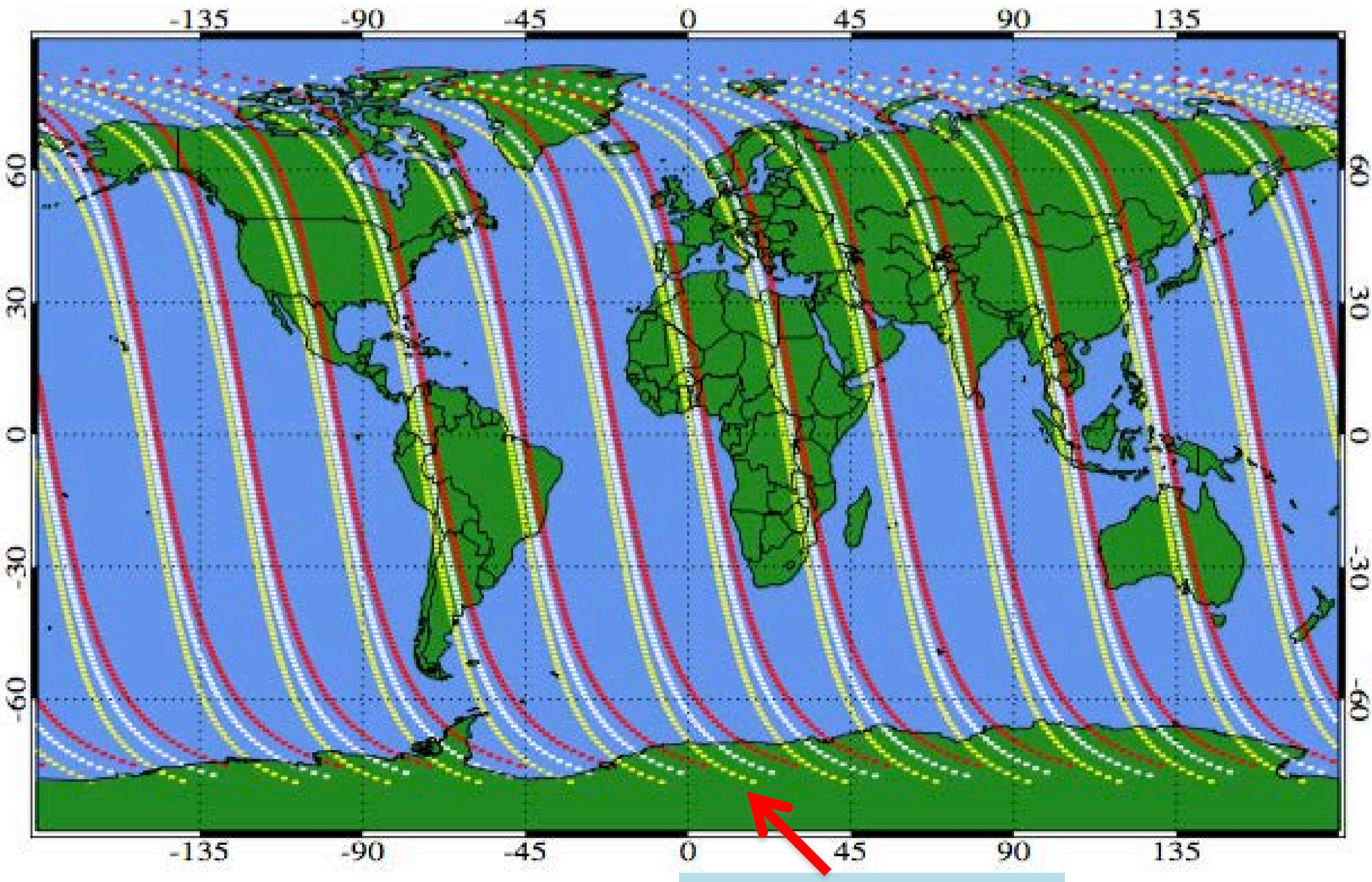
EPIC View of North America's 2018 Boreal Fire Season



Suomi NPP O_3 Monitoring & Profiler Suite (OMPS)



LP Daily Coverage



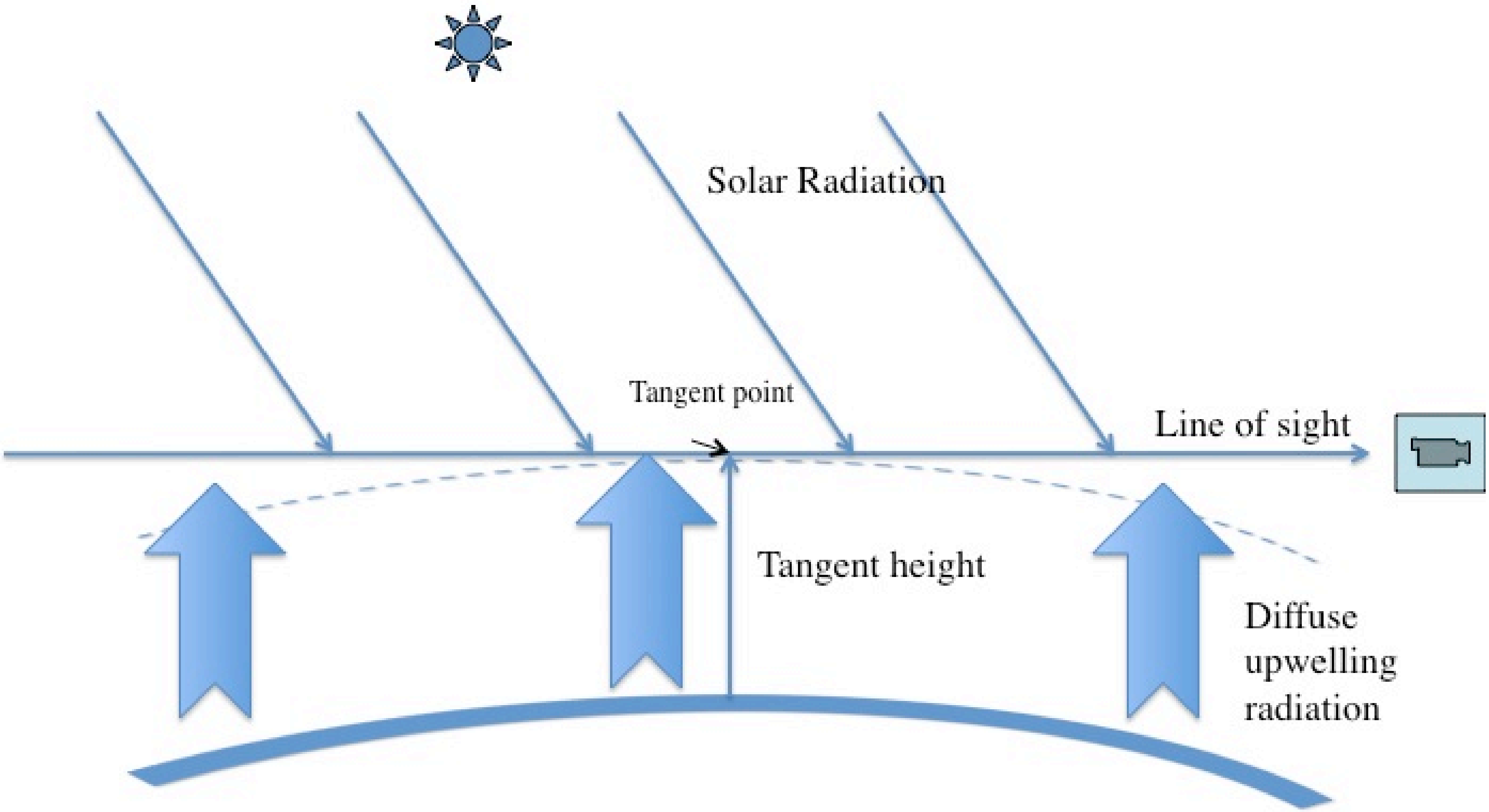
Left slit can go to 85S

Limb Scattering Instruments

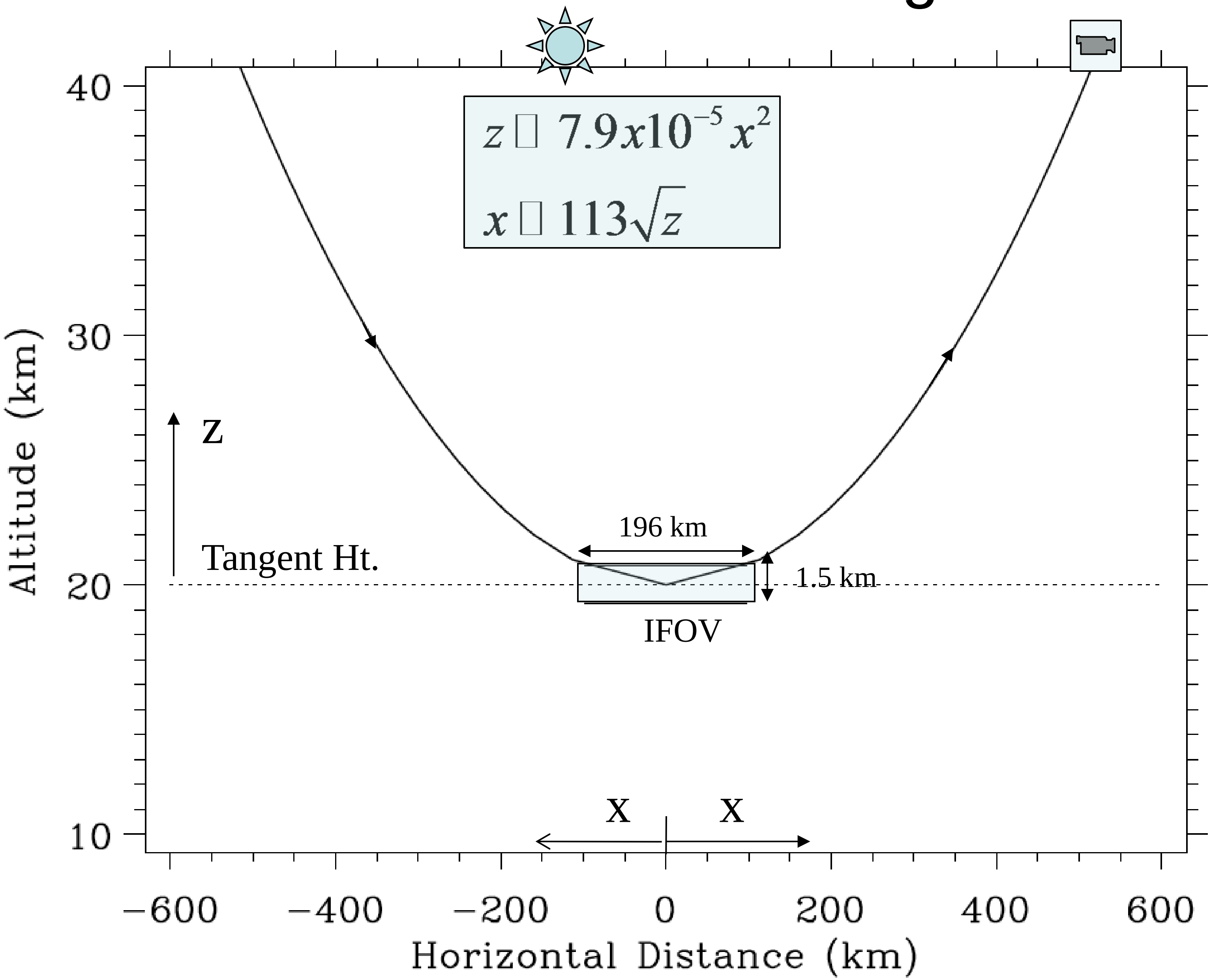
- SME: 1982-1988
- SOLSE/LORE: 1997
- SAGE III: 2002-2005, 2017-
- SCIAMACHY: 2003-2011
- GOMOS:2003-2011
- OSIRIS: 2002-
- OMPS: 2012-

Also flown on MARS missions

Limb Scattering Technique



Altitude vs. Distance Along LOS

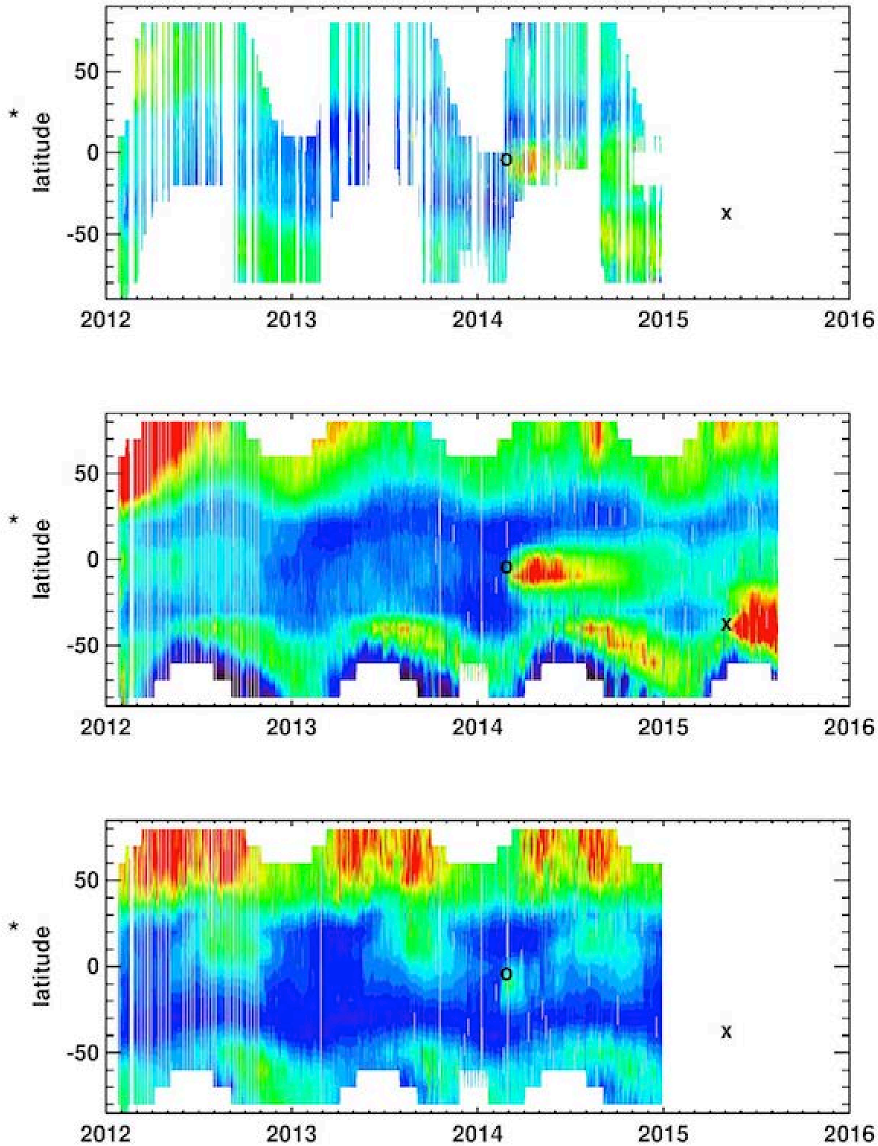


Strat AOD Comparison

OSIRIS
(no data
close to trop)

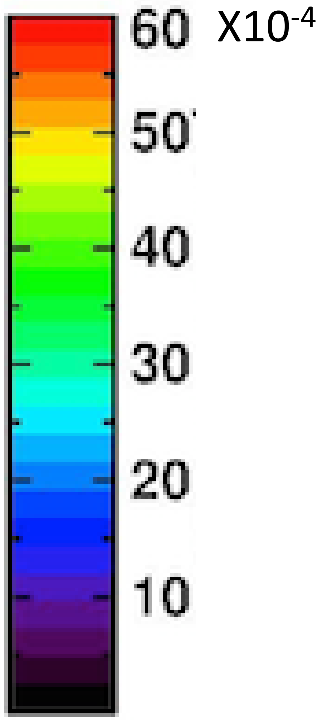
OMPS LP

An Early
Model



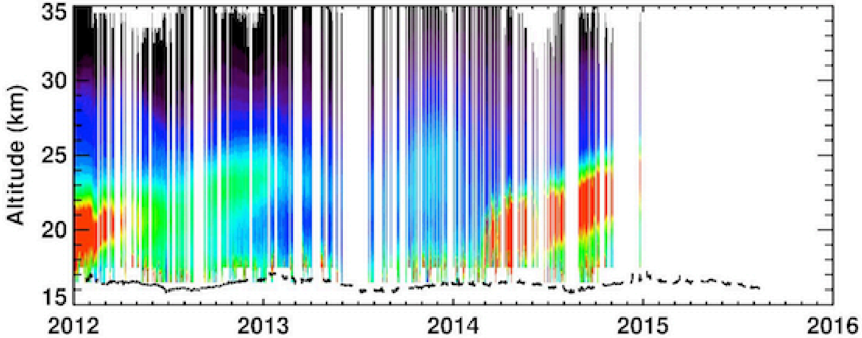
* Nabro o Kelut x Calbuco

AOD @ 750 nm

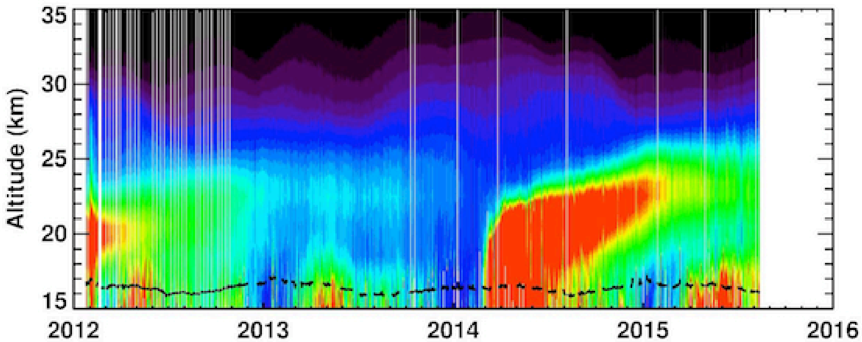


Profile Comparison (0-10N)

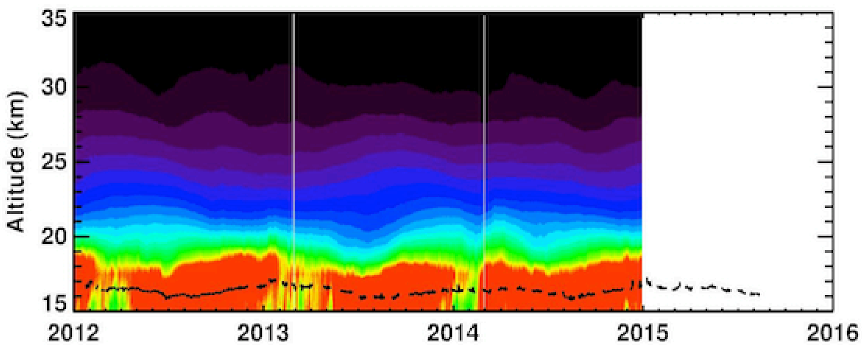
OSIRIS



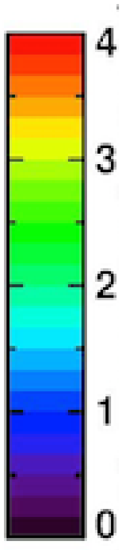
OMPS LP



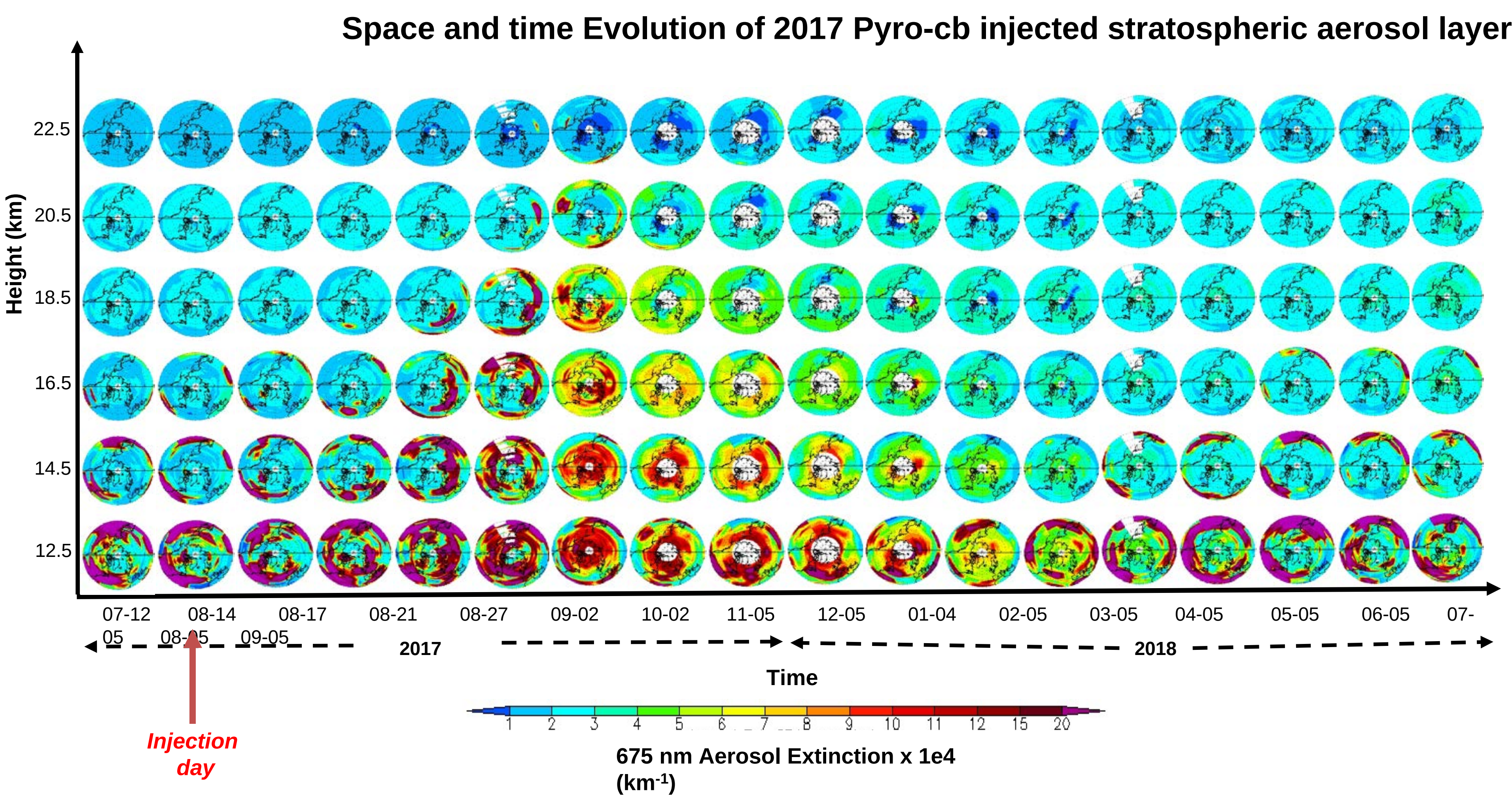
An Early Model



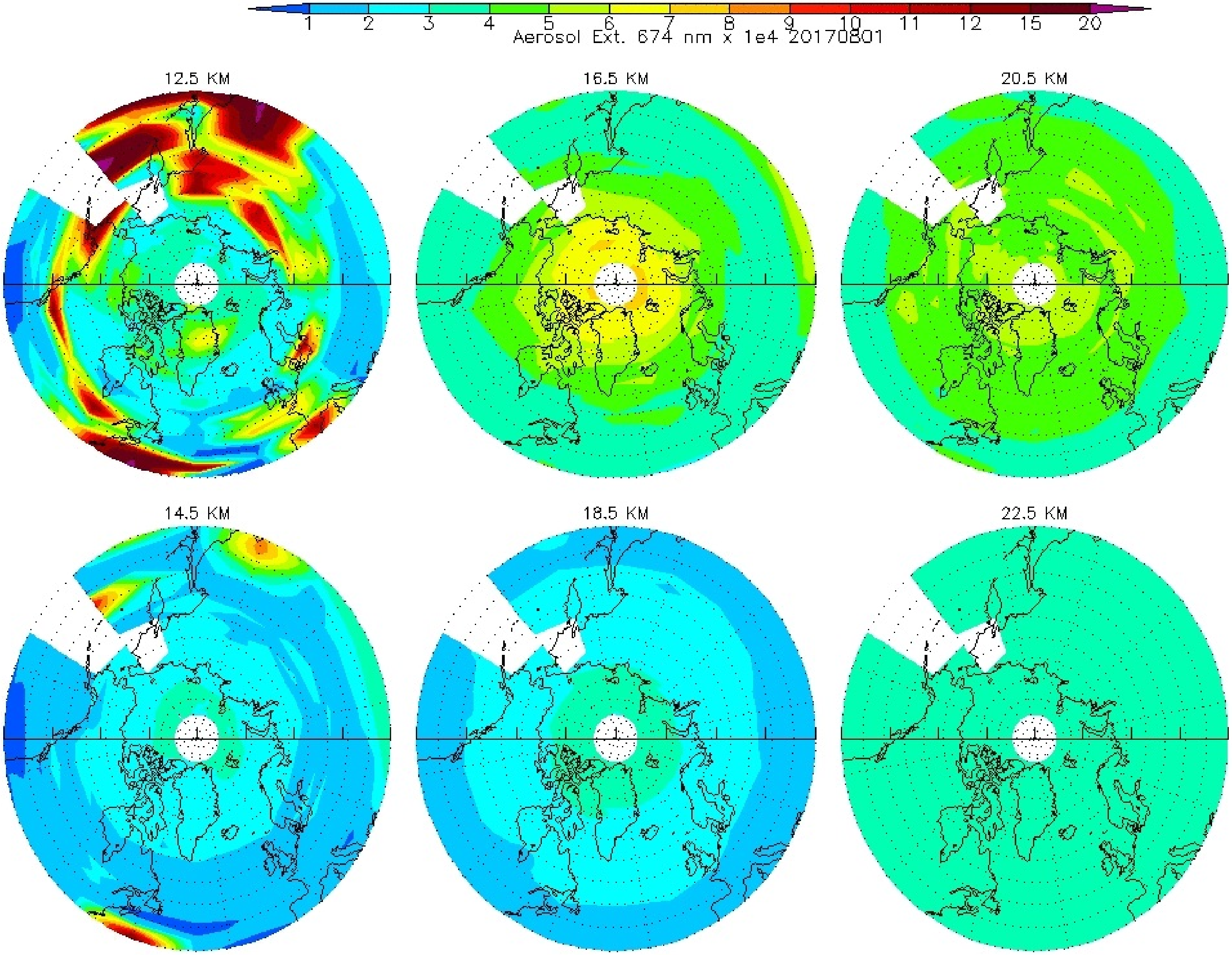
Extinction @ 750 nm



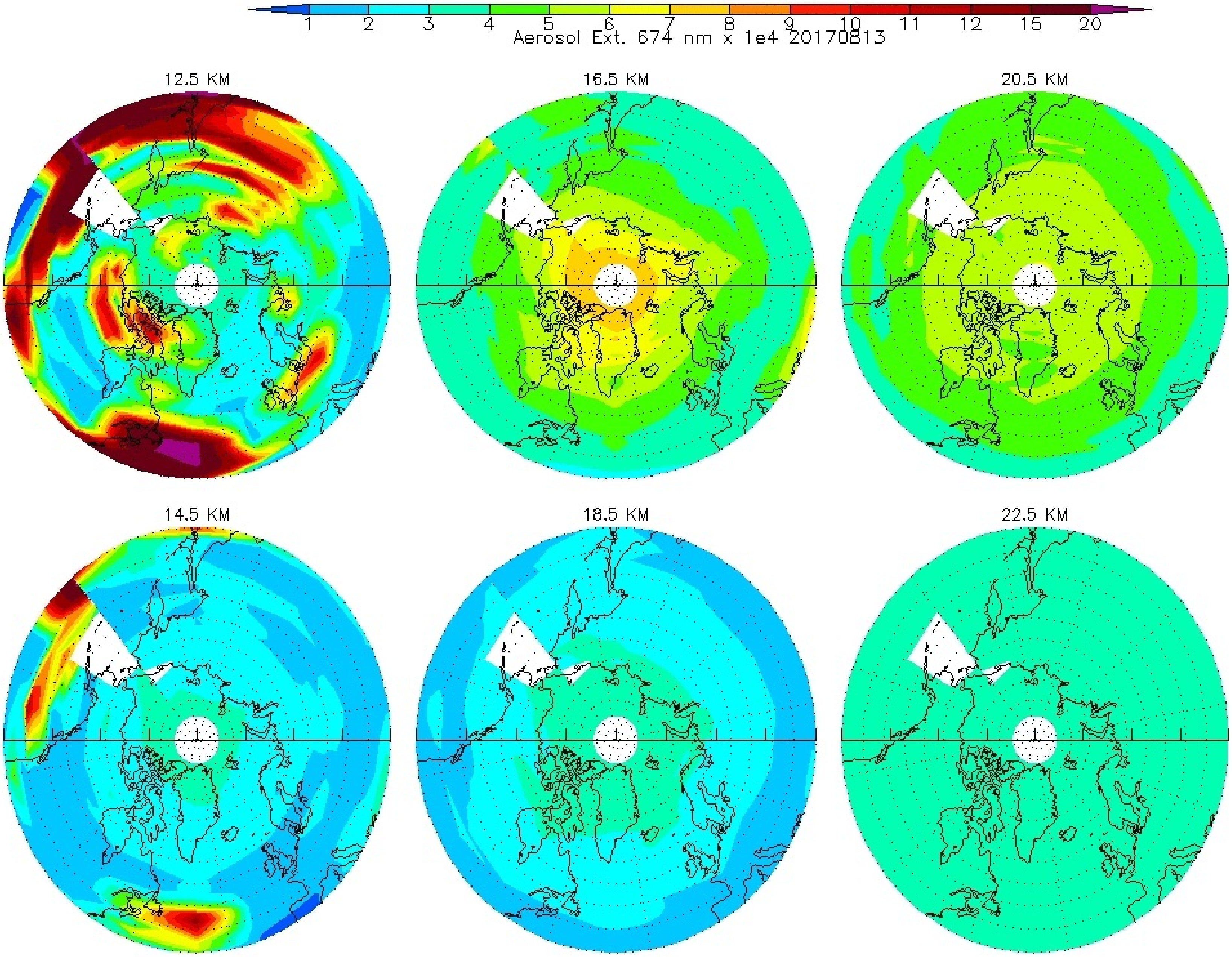
X10^{-4} /km


Space and time Evolution of 2017 Pyro-cb injected stratospheric aerosol layer
Height (km)
22.5
20.5
18.5
16.5
14.5
12.5
07-12
08-14
08-17
08-21
08-27
09-02
10-02
11-05
12-05
01-04
02-05
03-05
04-05
05-05
06-05
07-
05
08-05
09-05
2017
2018
Time
Injection day
1 2 3 4 5 6 7 8 9 10 11 12 15 20
675 nm Aerosol Extinction x 1e4 (km-1)

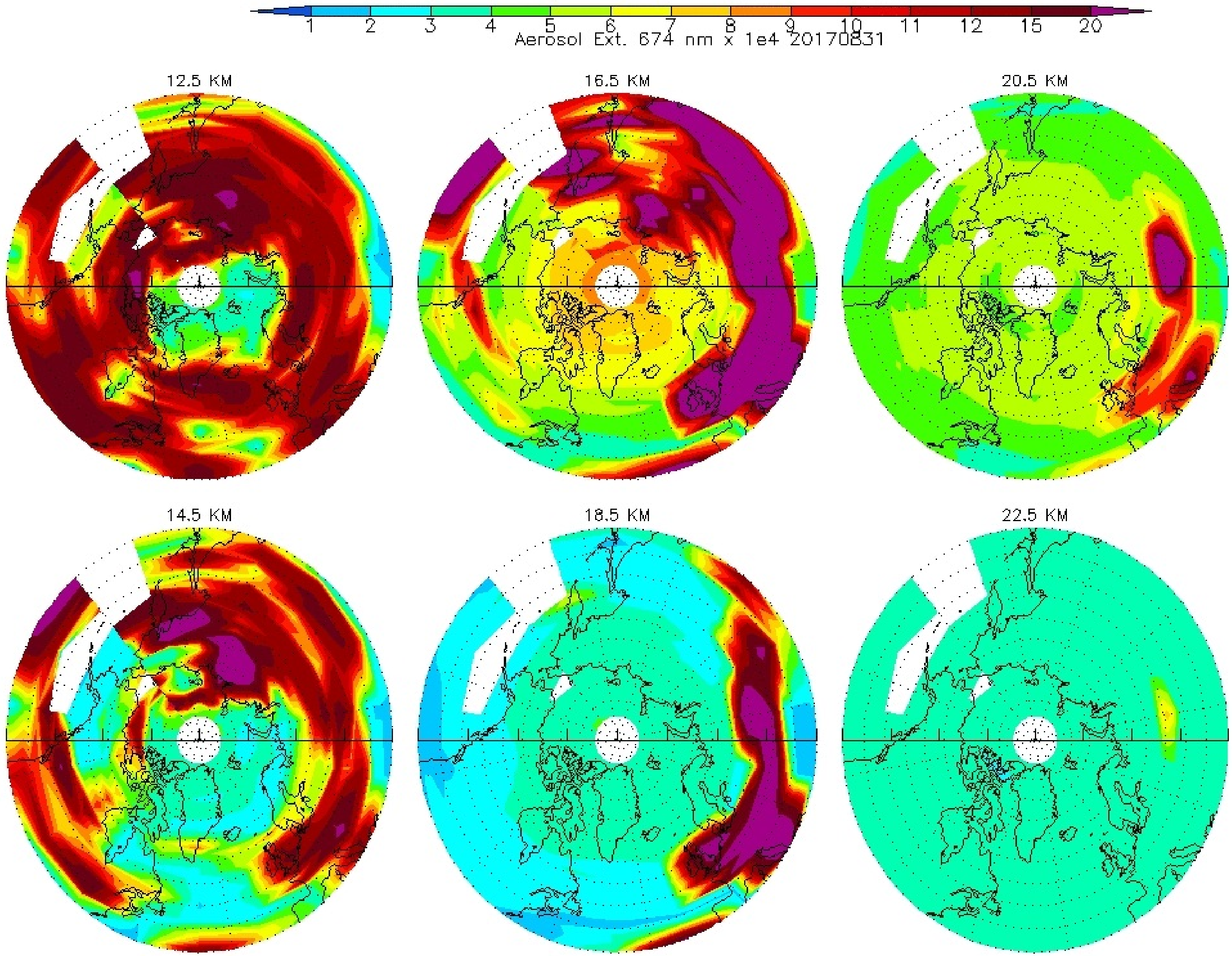
Background Aerosols Aug 1, 2017



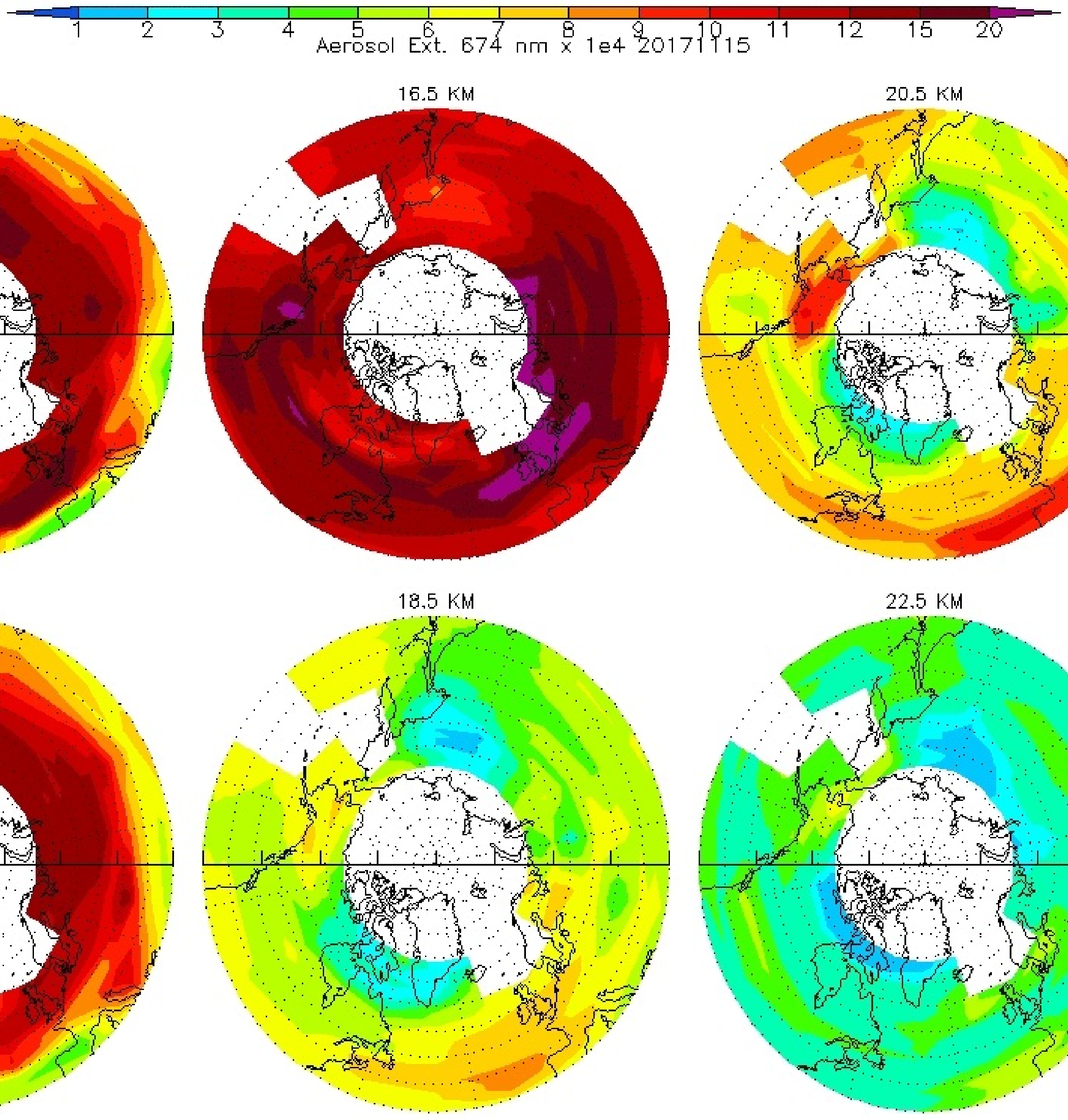
1st PyroCb obs Aug 13, 2017



Lofted to ~22 km   Aug 31, 2017



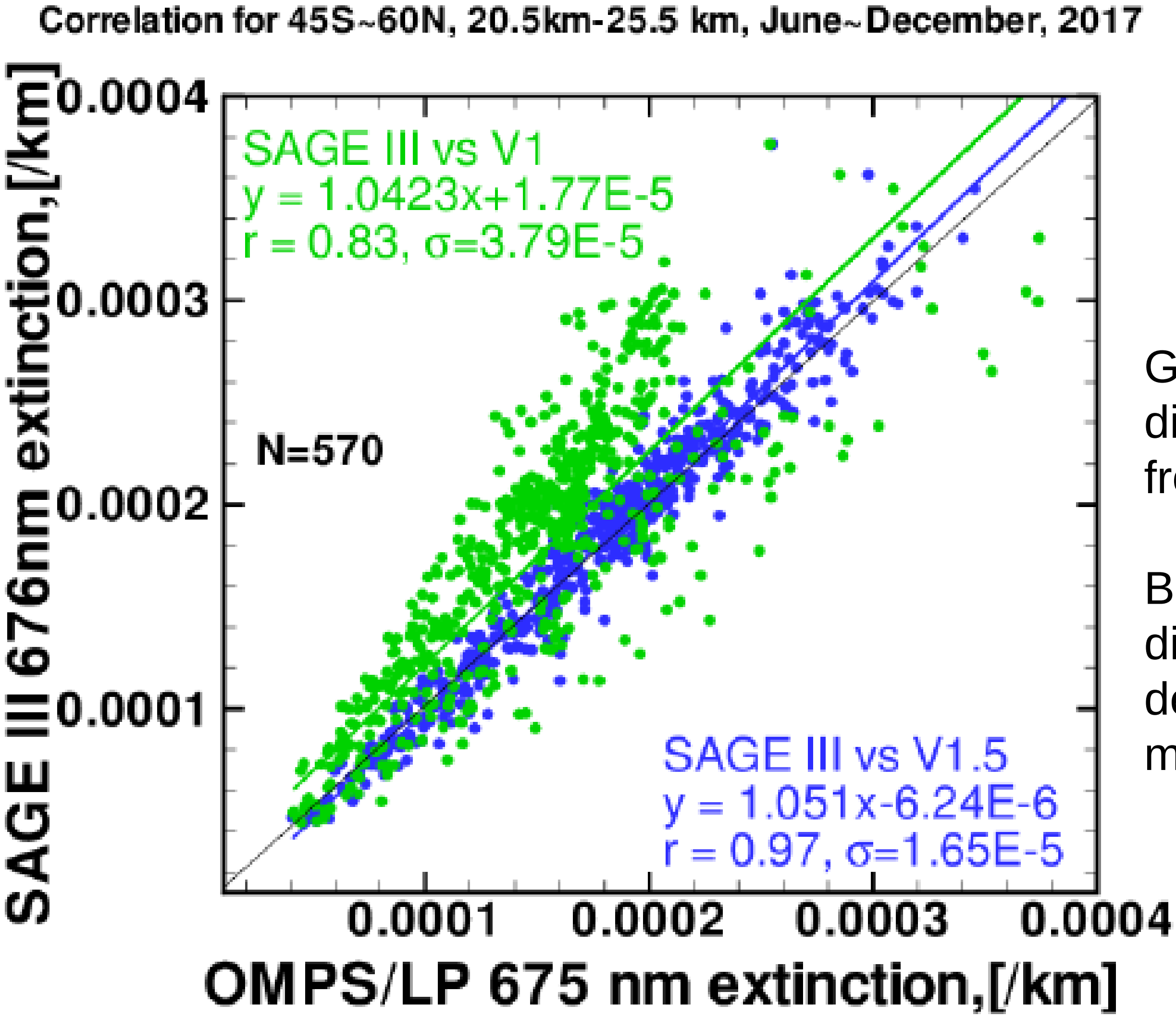
Settled at ~17 km covering the entire NH Nov 15, 2017



Synergy with ISS/SAGE III (Launched Feb 2017)

- SAGE III measures aerosol extinction directly during solar/lunar occultation
  - Comparison with LP can provide phase function information, which can then help tie down aerosol size distribution
- SAGE III can also measure limb scattering between occultations at varying local times
  - LS + occultation can better constrain aerosol size distribution, similar to AERONET DS + Almucantar data.
- High spatial and temporal sampling from LP provides context to interpret SAGE data

Comparison with ISS/SAGE III



Green points: Bimodal LN distribution, parameters from aircraft meas

Blue points: Gamma distribution, parameters derived from CARMA model

Improvement of stratospheric aerosol extinction retrieval from OMPS …….
Chen et al., submitted to AMT., amt-2018-221.

Relevant References

- OMPS Limb Profiler Version 1 Aerosol Extinction Retrieval Algorithm: Theoretical Basis
  - Loughman, Bhartia, Chen, Xu, Nyaku, and Taha.
  - Published in AMT
- Impact of aerosol size distribution on extinction and spectral dependence of radiances measured by the OMPS Limb profiler instrument
  - Chen, Bhartia, Loughman, and Colarco.
  - AMT discussions (under review, publicly available)
- The sensitivity of the stratospheric aerosol phase function to aerosol size distribution models
  - Nyaku, Loughman, Bhartia, Deshler, Chen, and Colarco.
  - Under Revision