

Correcting the record of volcanic stratospheric aerosol impact: Nabro and Sarychev Peak*

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CT3LS Meeting, 20 July 2015

Large Volcanic Aerosol Load in the Stratosphere Linked to Asian Monsoon Transport

Adam E. Bourassa,^{1*} Alan Robock,² William J. Randel,³ Terry Deshler,⁴ Landon A. Rieger,¹ Nicholas D. Lloyd,¹ E. J. (Ted) Llewellyn,¹ Douglas A. Degenstein¹

Nabro volcano, Eritrea
13 June 2011

Saudi
Arabia

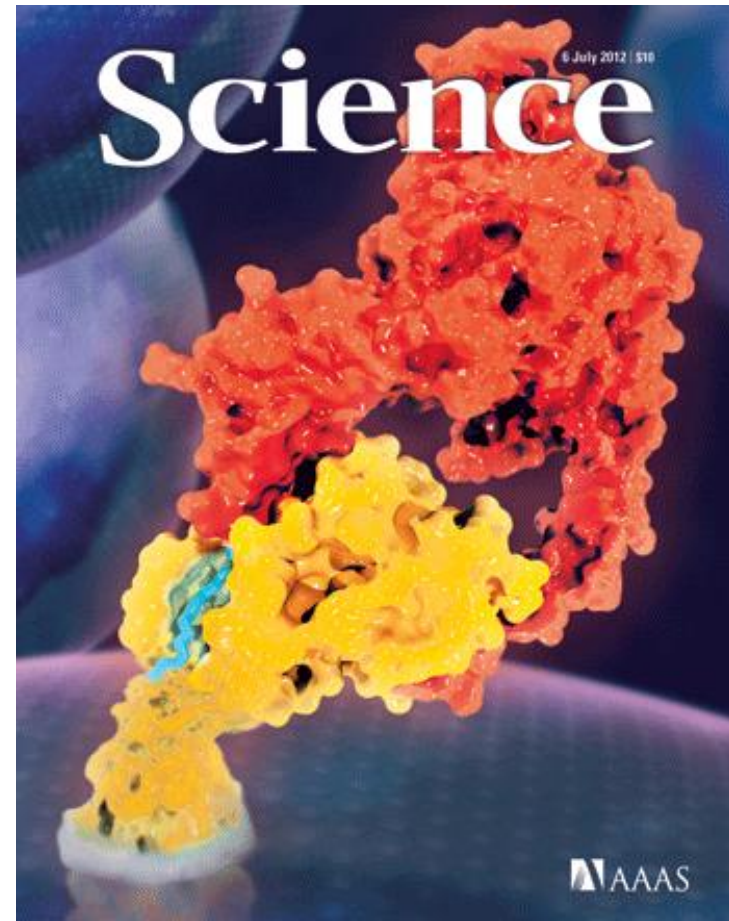
Red
Sea

Yemen

Ethiopia

Image credit: Scott Bachmeier

FY-2E - VISIBLE 0.73 (CHANNEL 01) - 03:31 UTC 13 JUNE 2011 - CIMSS



AAAS

Large Volcanic Aerosol Load in the Stratosphere Linked to Asian Monsoon Transport

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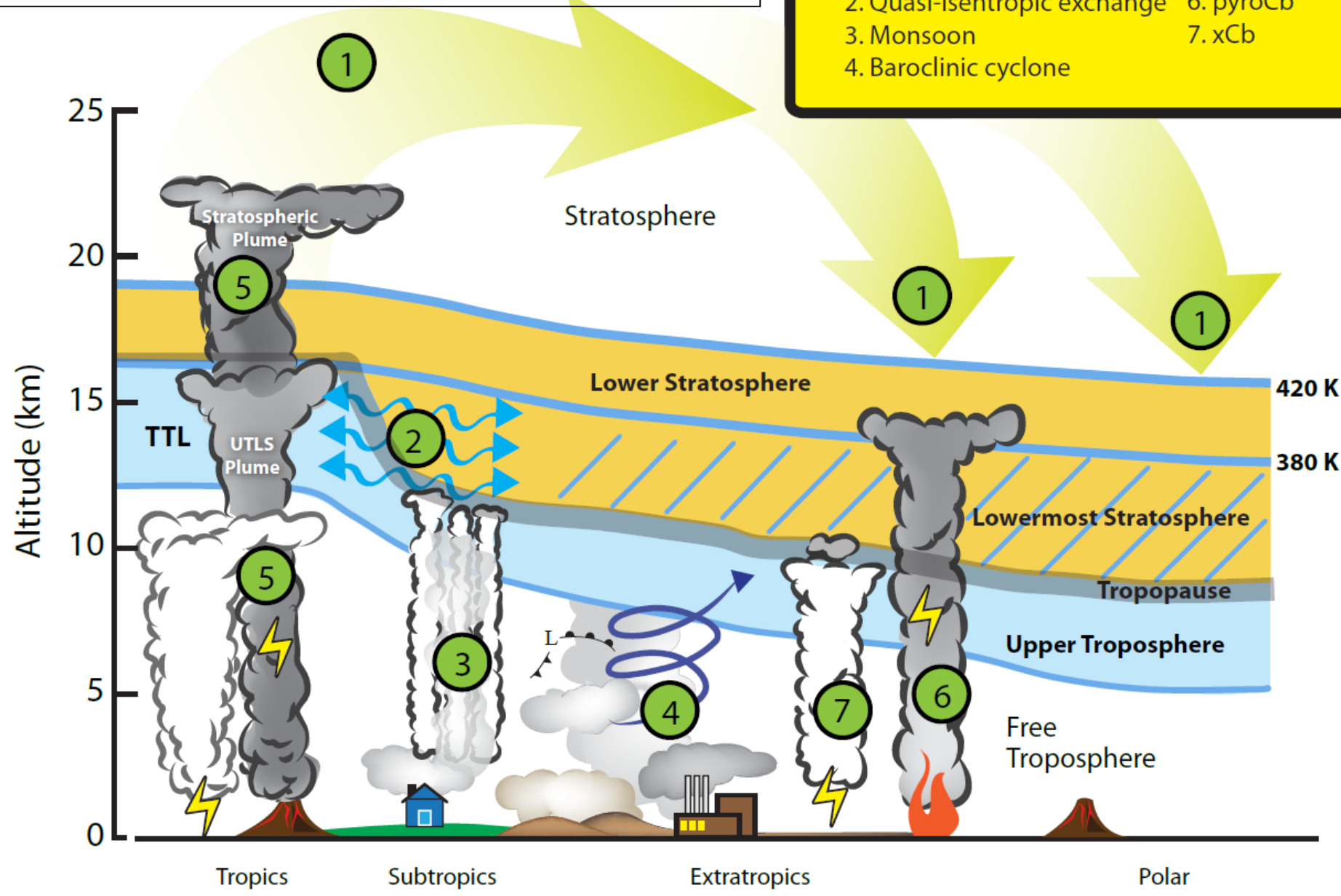
Why does this matter?

What's new here?

Is it correct?

Upper Troposphere & Lower Stratosphere Pathways

- UTLS Pathways**
- | | |
|------------------------------|------------|
| 1. Brewer-Dobson circulation | 5. Volcano |
| 2. Quasi-isentropic exchange | 6. pyroCb |
| 3. Monsoon | 7. xCb |
| 4. Baroclinic cyclone | |



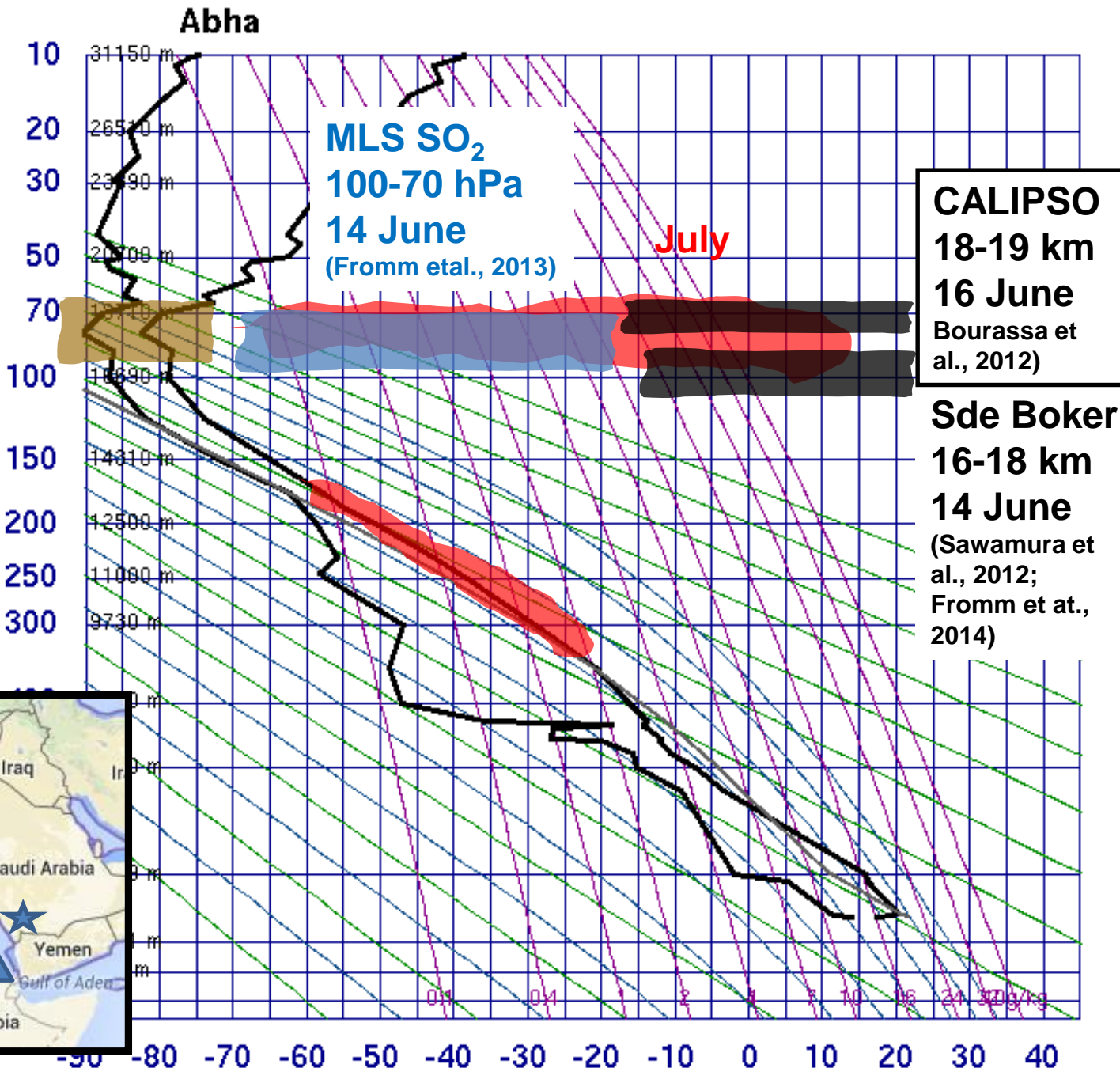
**What's
new
here?**

**Meteosat IR
17-19 km
13 June
(Vernier et al., 2013;
Fromm et al., 2014)**

**VAAC Injection z
9.1-13.7 km
13 June
(Bourassa et al., 2012)**

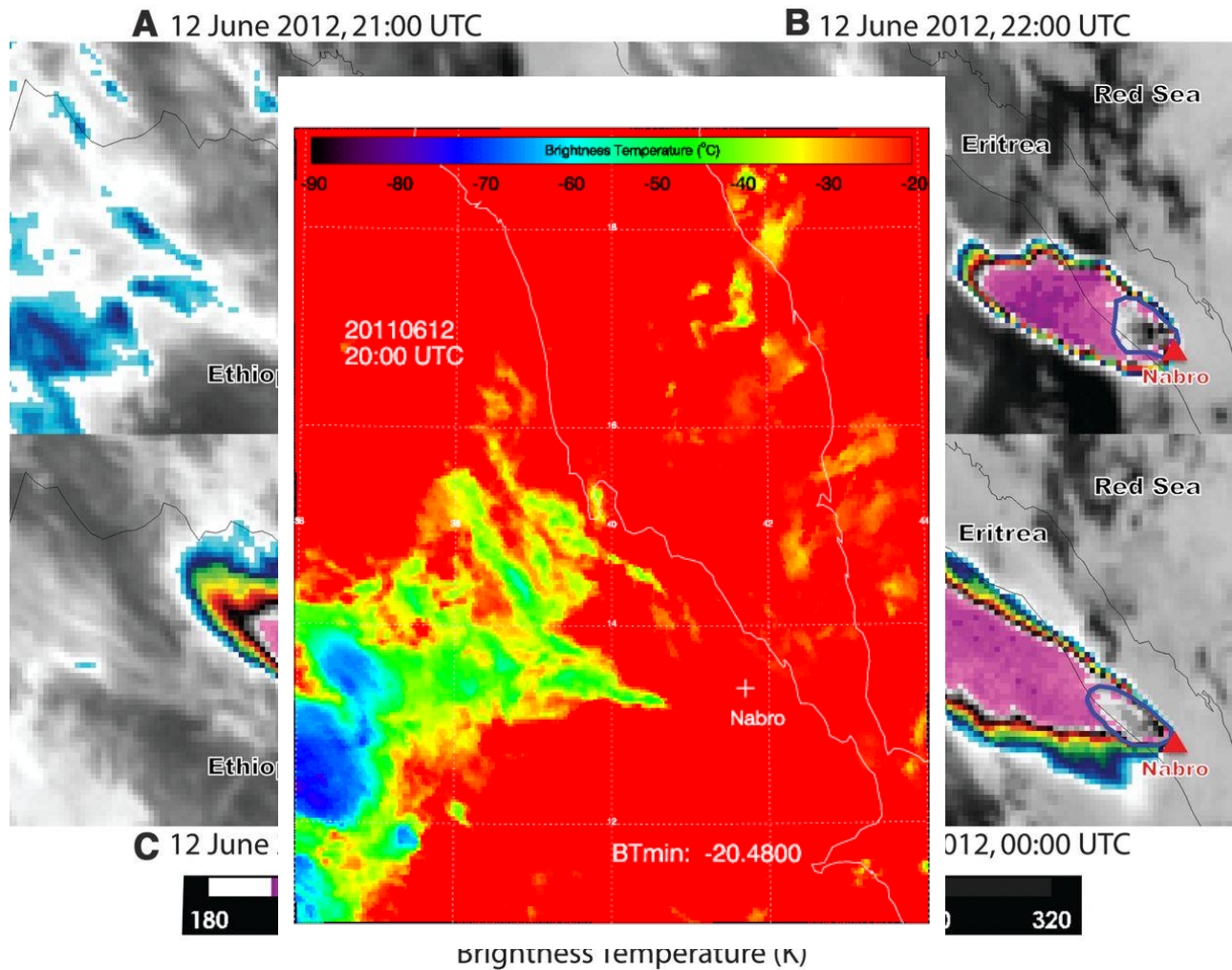


00Z 13 Jun 2011



University of Wyoming

Fig. 3 Snapshots of cloud-top infrared brightness temperature (BT) from SEVIRI/Meteosat-9 on 12 June 2011 at 21:00 (A), 22:00 (B), and 23:00 (C) and 13 June at 00:00 UTC (D) around the Nabro volcano.



J.-P. Vernier et al. Science 2013;339:647



Meteosat thermal IR brightness temperature minimum and altitude inferred using nearest radiosonde profiles.

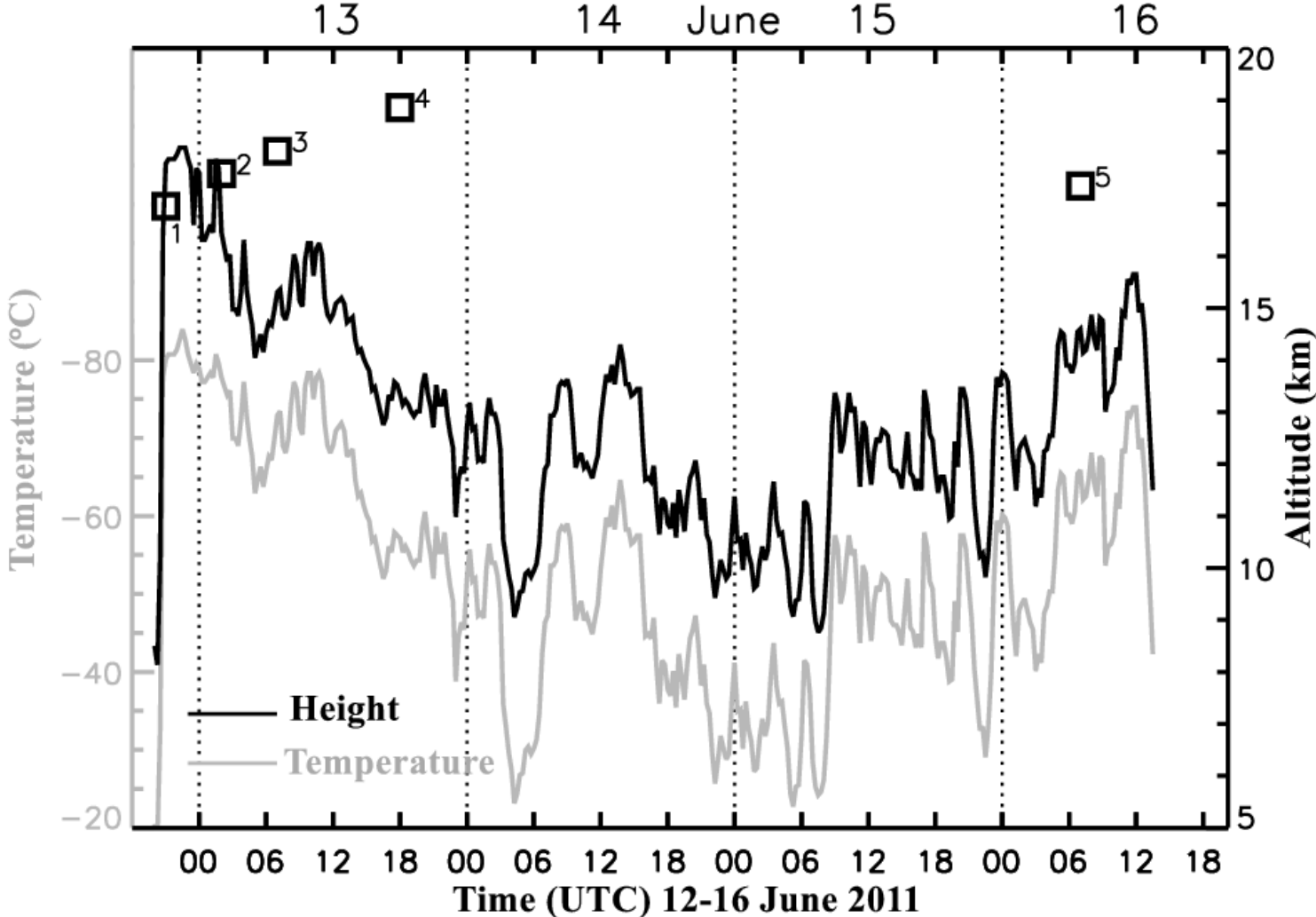
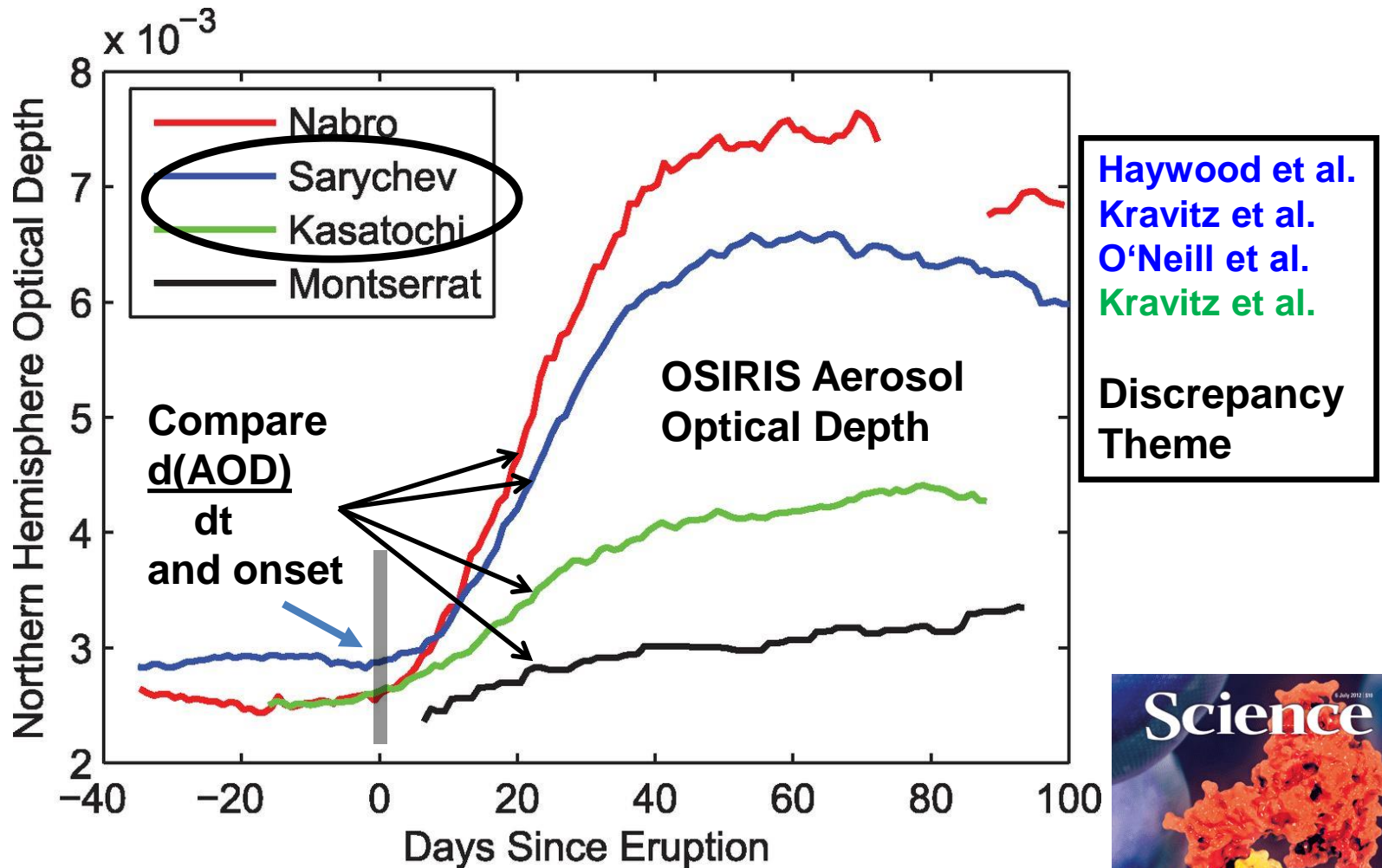
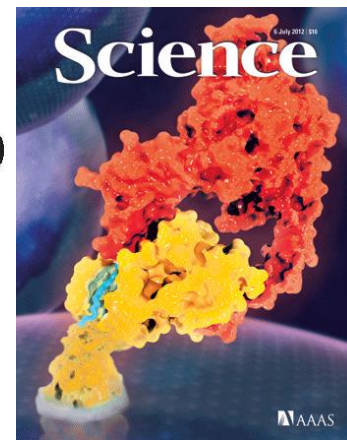


Figure 1, Fromm et al., 2014

Fig. 4 The time series of Northern Hemisphere **stratospheric aerosol optical depth** during days after the volcanic eruptions that caused the four largest stratospheric perturbations as measured by **OSIRIS** since its launch in 2001.

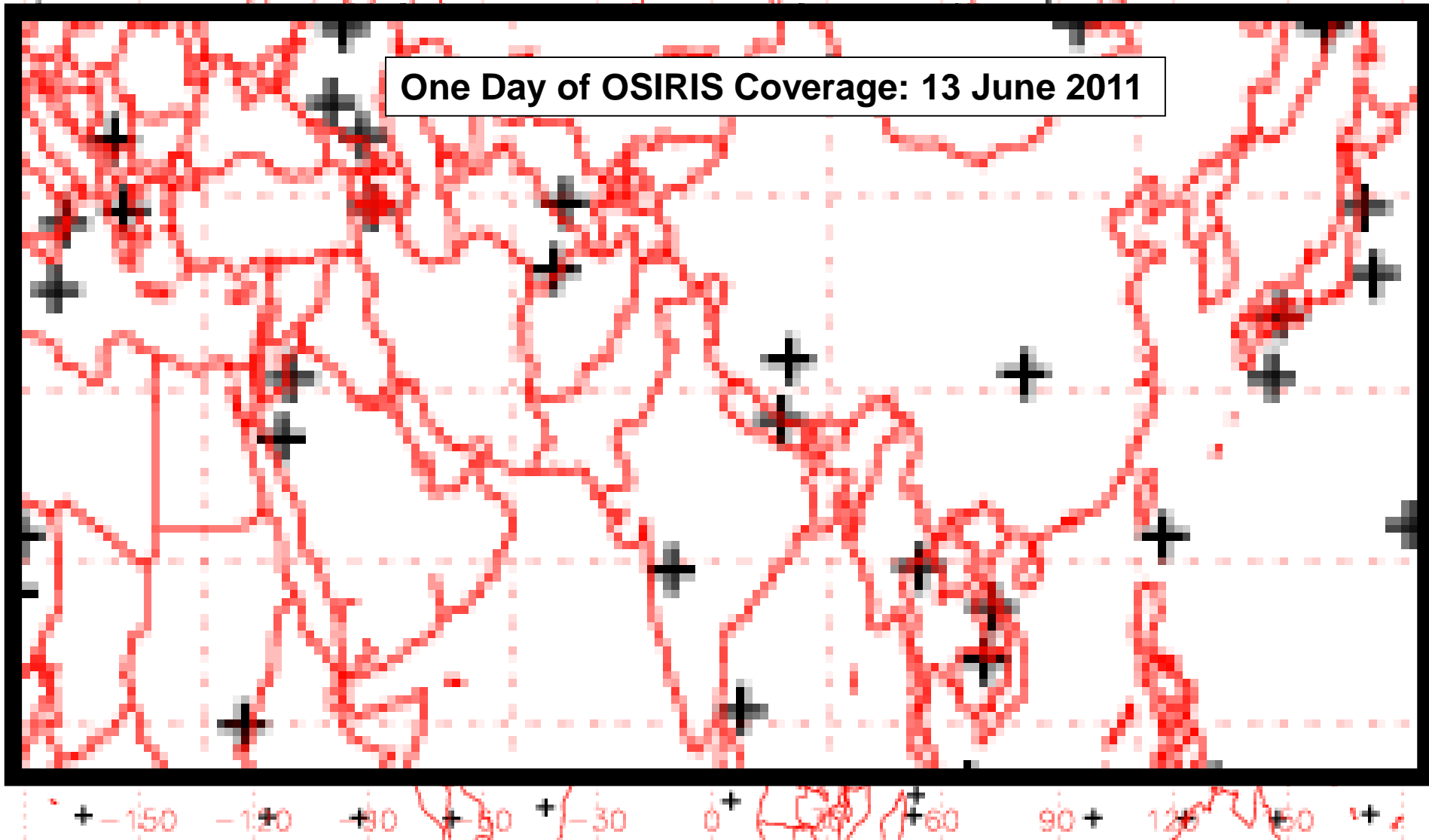


A E Bourassa et al. Science 2012;337:78-81

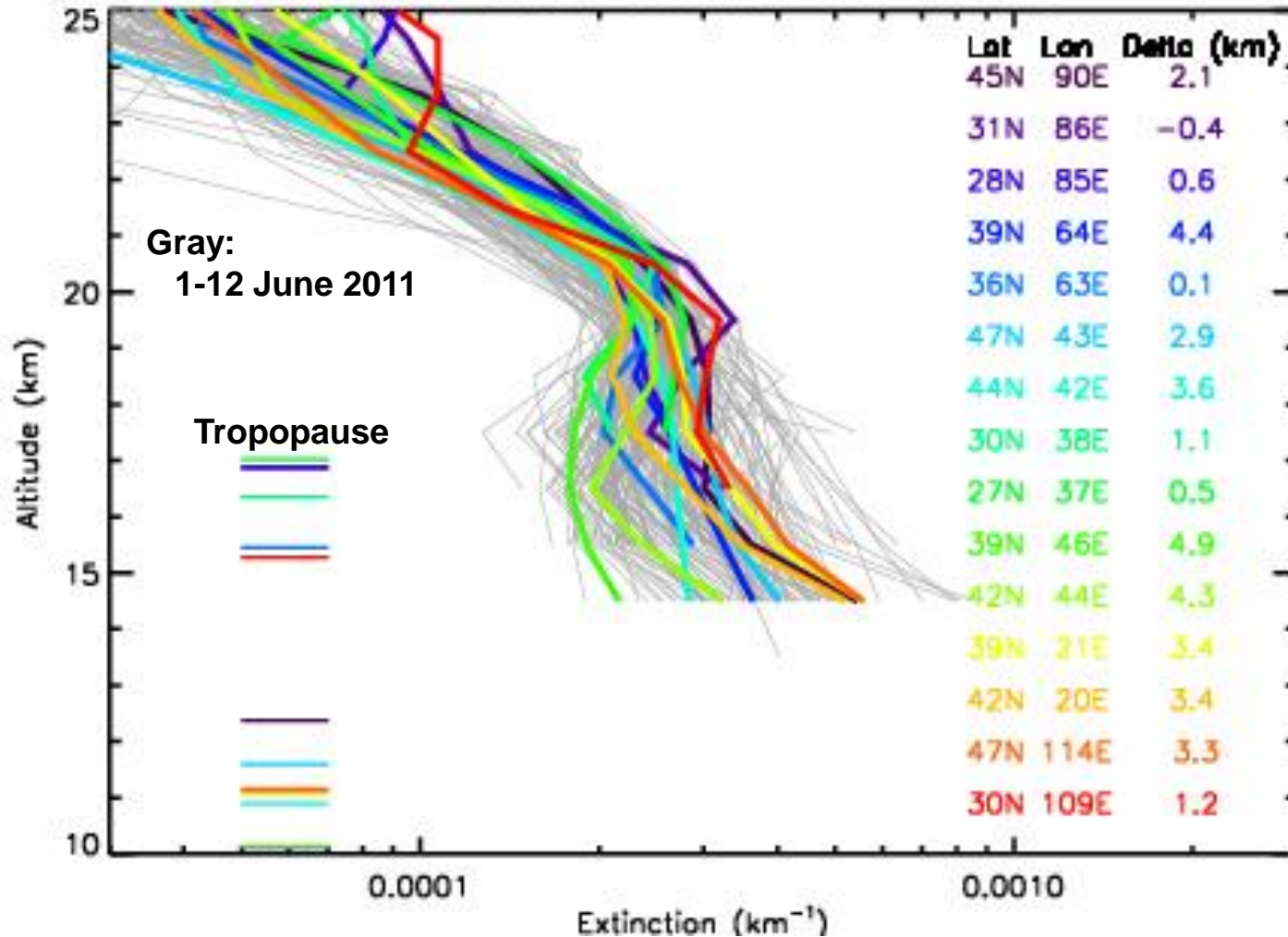


OSIRIS locations inside this Asian Monsoon box.

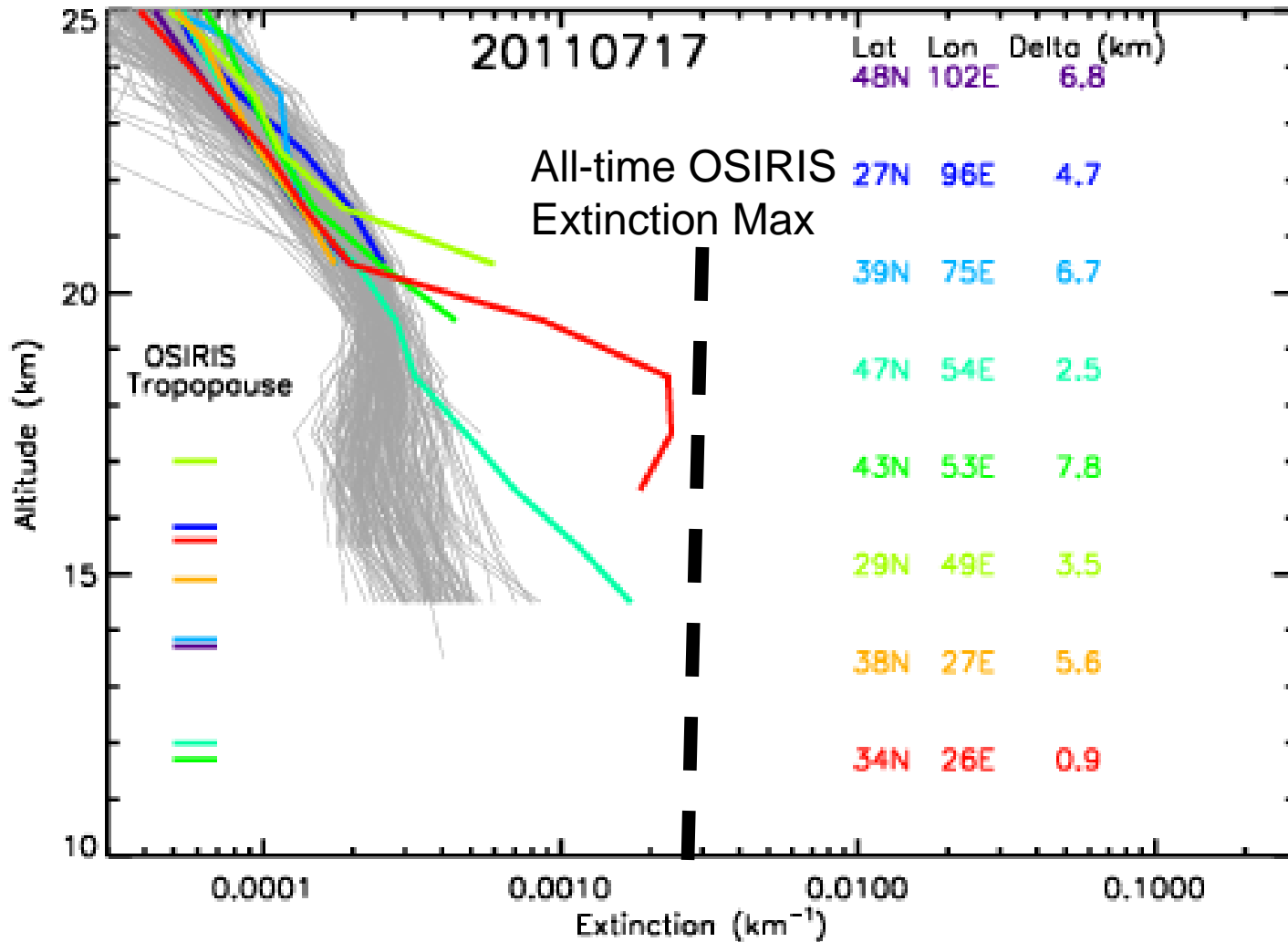
One Day of OSIRIS Coverage: 13 June 2011



OSIRIS Aerosol Extinction Profiles 0613

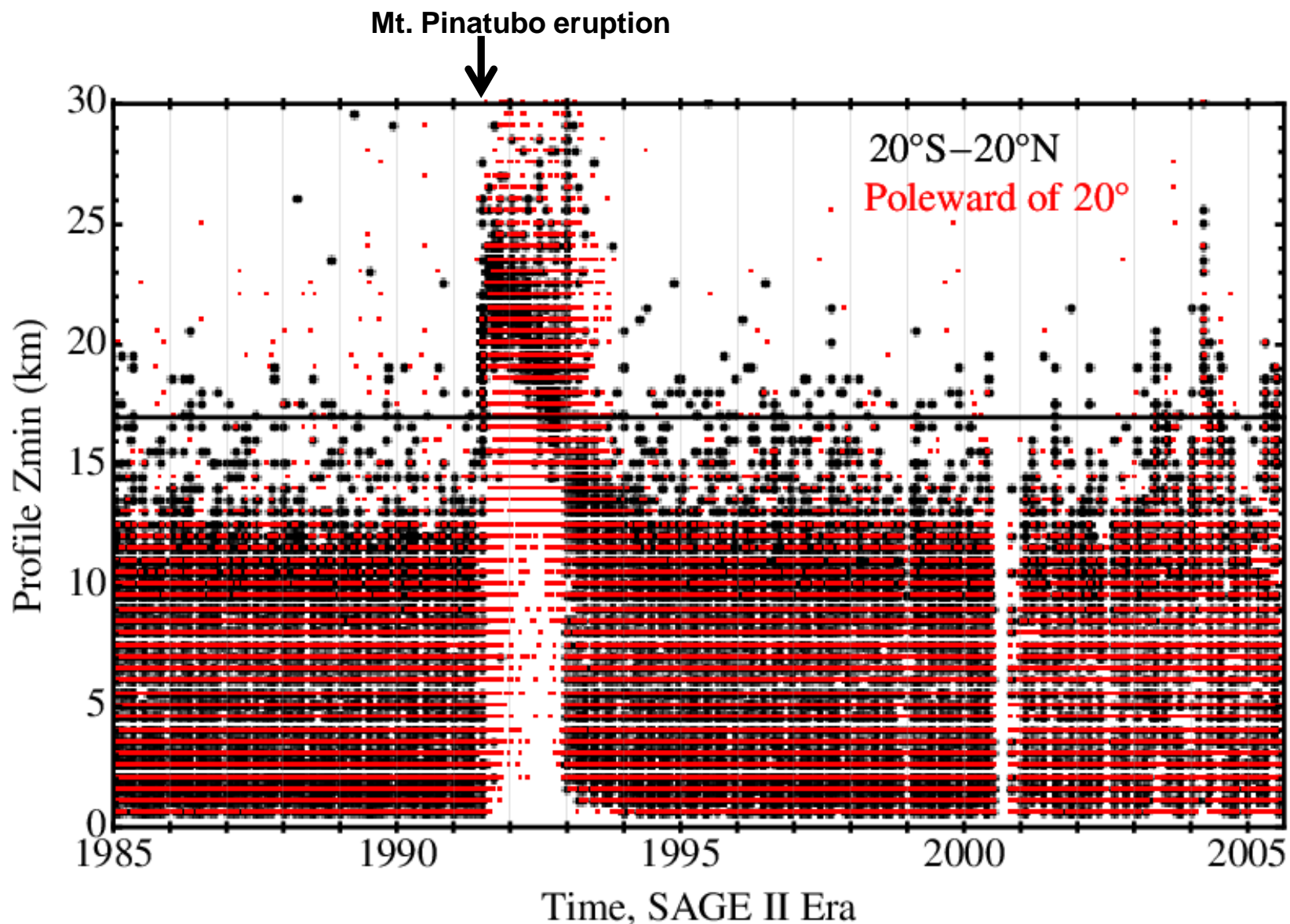


On 13 June, all the aerosol profiles look like pre-Nabro:
i.e. background conditions.



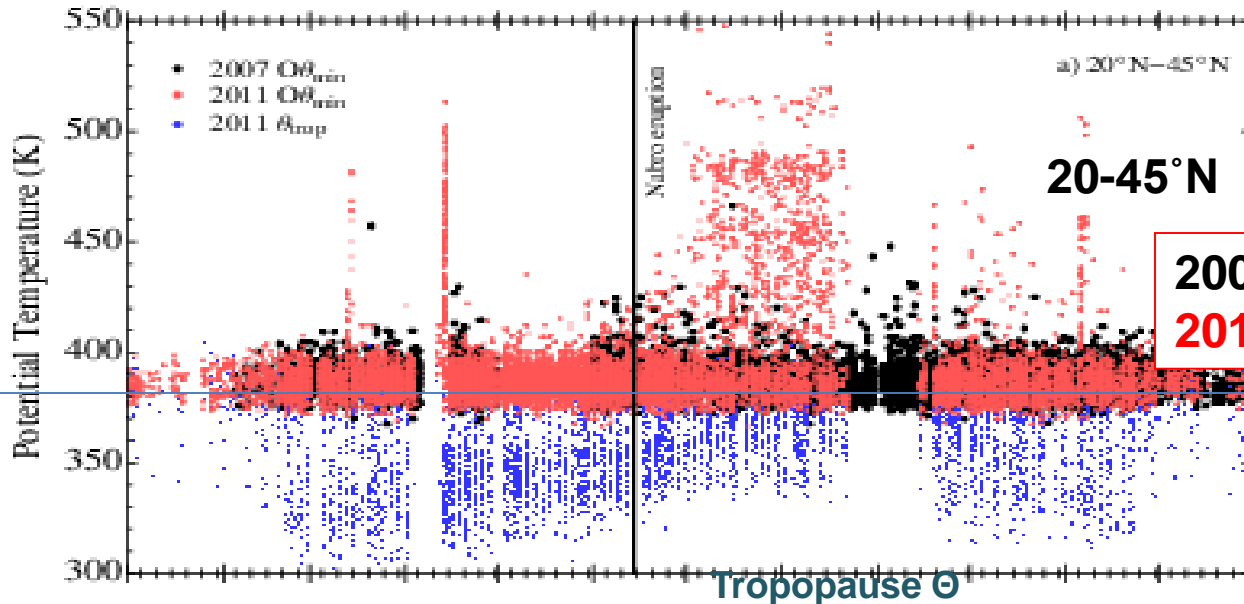
On 17 July, ~5 weeks later. Here is a classic example of an aerosol layer.

SAGE II Profile Zmin Time Series...full mission

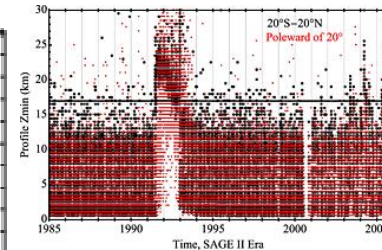
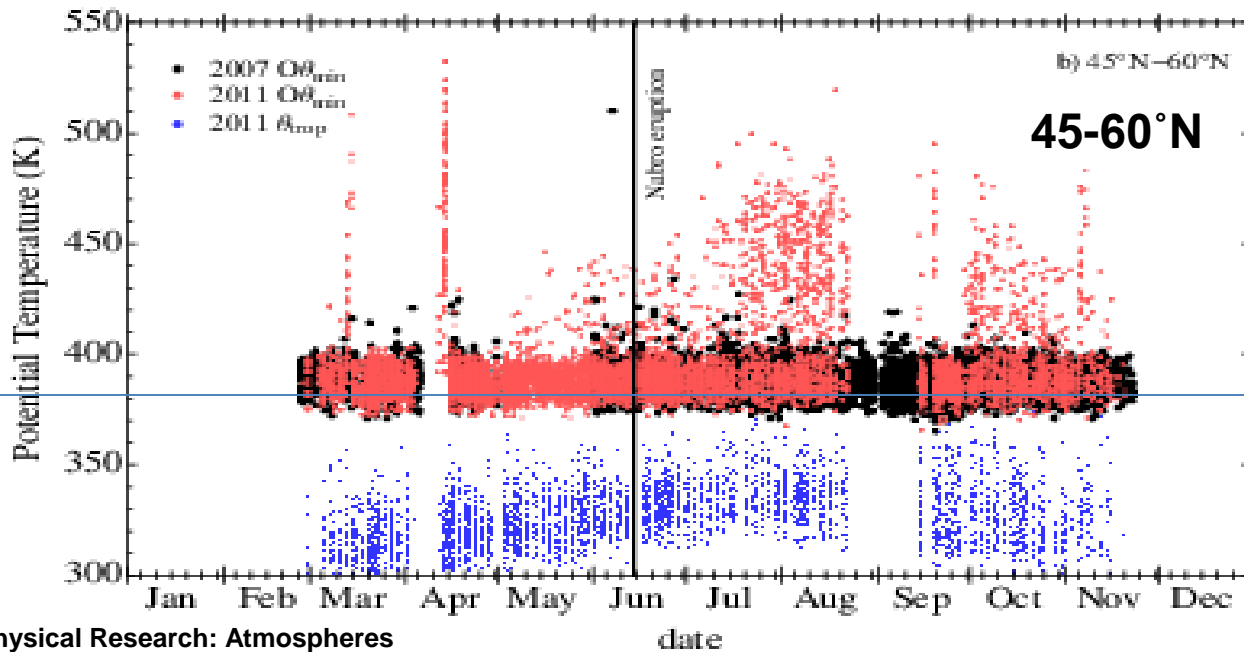


OSIRIS Profile Zmin in terms of Potential Temperature

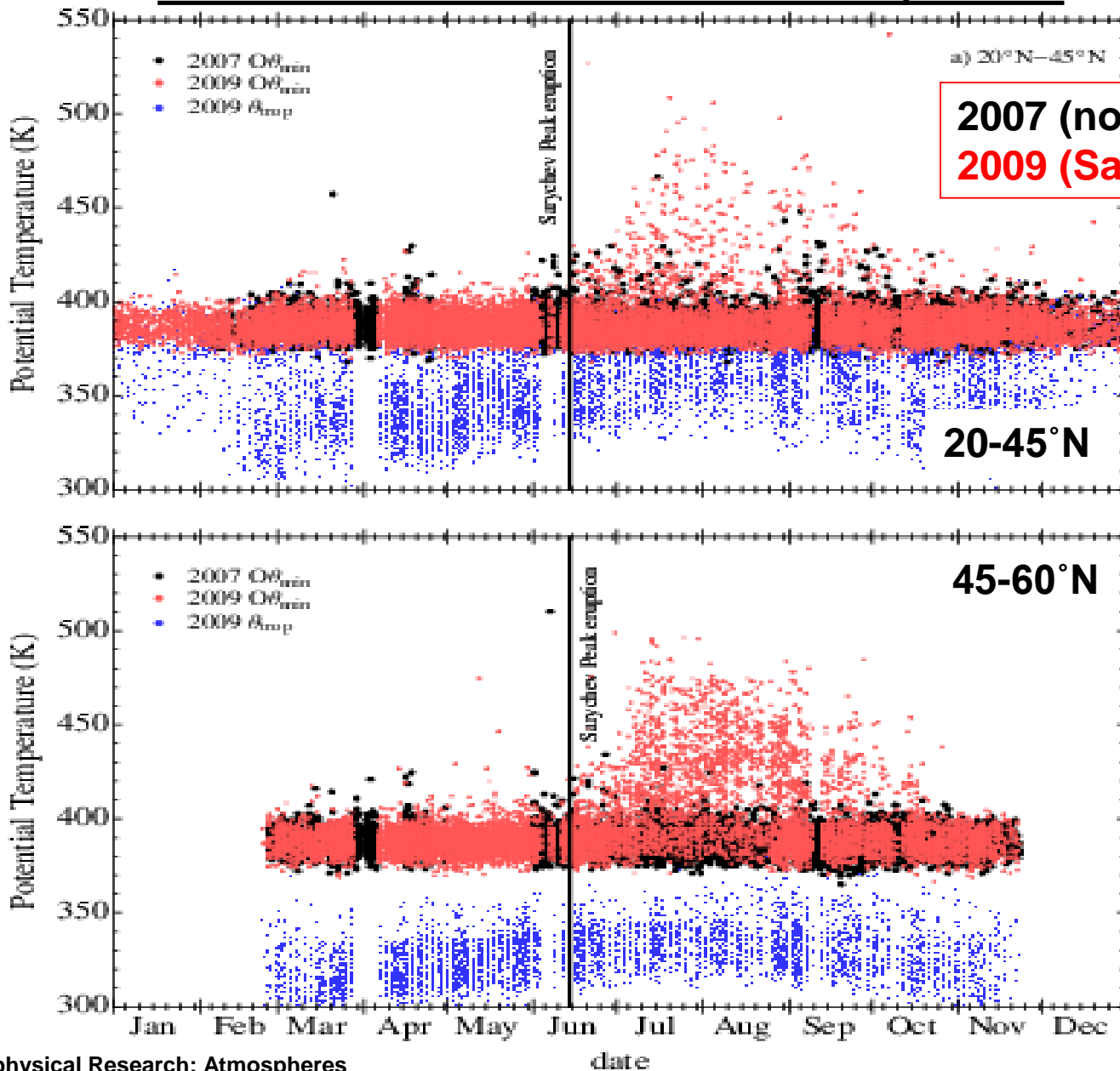
$\Theta = 380$ K
"Overworld"



2007 (no volcano)
2011 (Nabro)



OSIRIS Zmin in terms of Potential Temperature

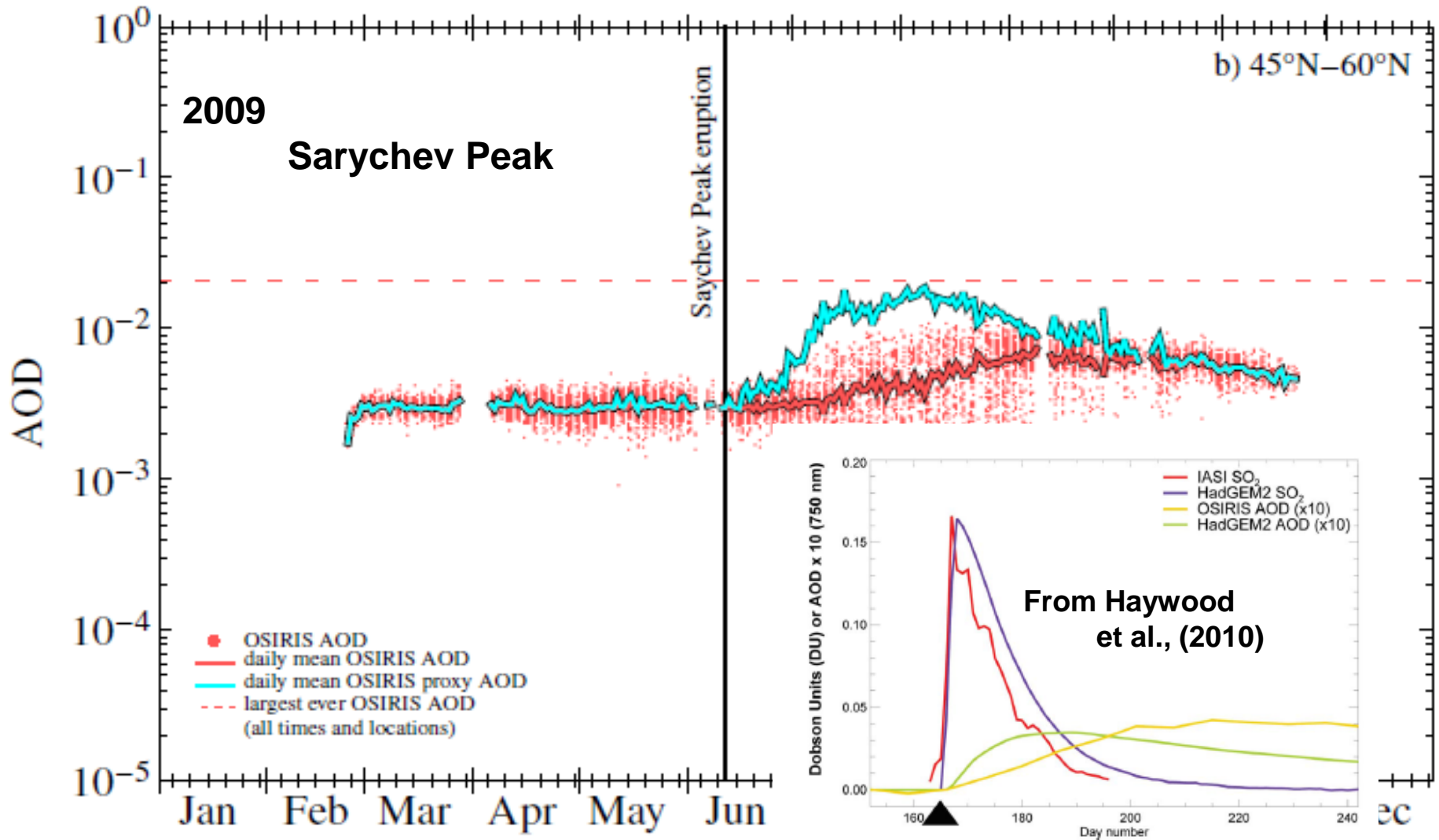


2007 (no volcano)
2009 (Sarychev Peak)

Remedy for the High Zmin:

Proxy AOD supplement

If (High Zmin) then add .02 to AOD



2

Figure 8. The time evolution of SO₂ derived from IASI (red line) and the model (purple line) averaged over the Northern Hemisphere measured in DU. The modeled sulphate AOD is also shown at 750 nm (green line). The OSIRIS AOD is shown by the yellow line. The approximate time period for the Sarychev eruption is shown by the solid black triangle.

**What are the implications for the GISS (Sato) AOD record?
- dominated by OSIRIS since ~2002**

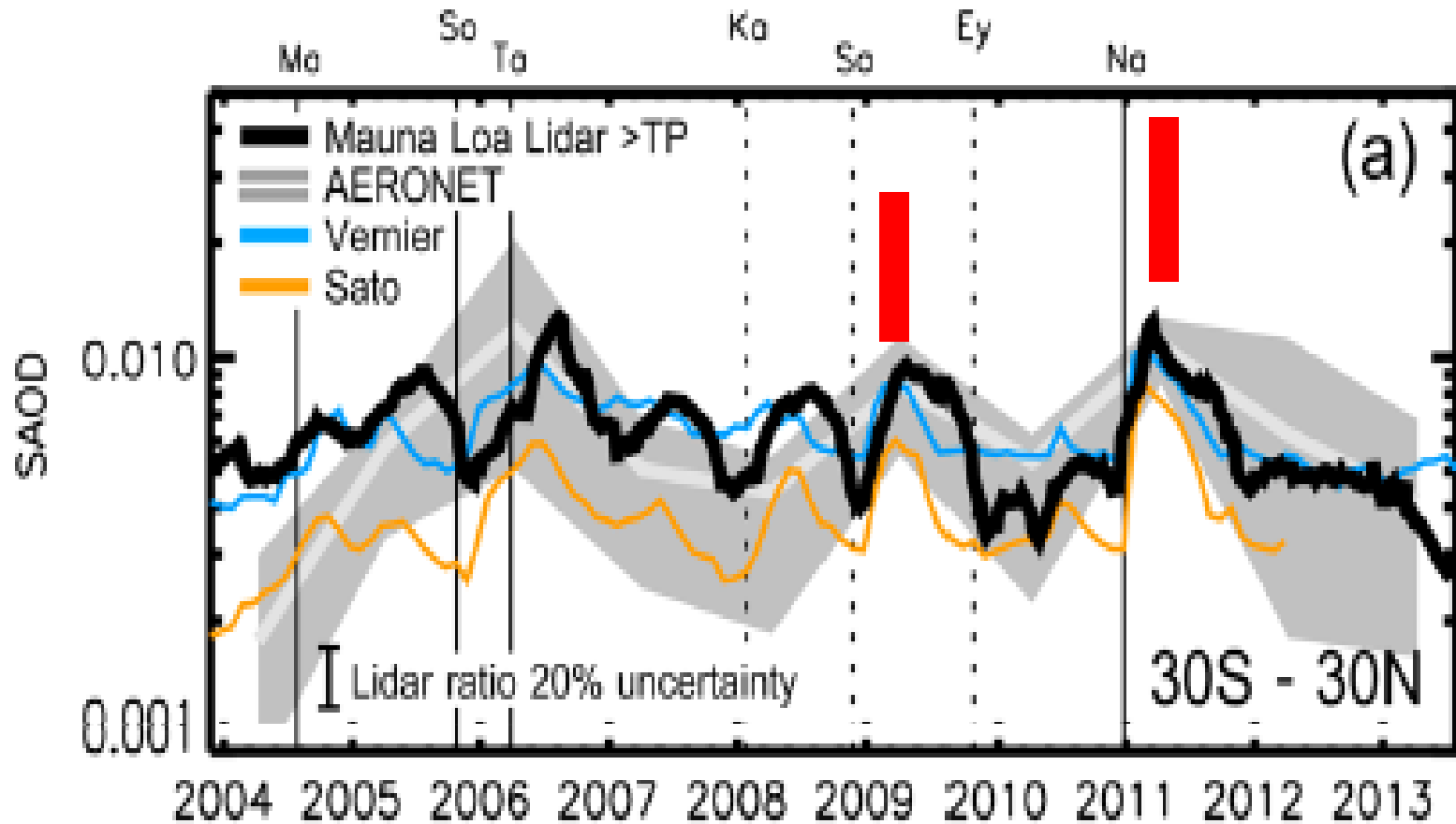


Figure 2. Ridley et al., (GRL, 2014)

Conclusions:

- * Point-source, episodic UTLS pathways are notoriously difficult to characterize
 - fall “between the cracks” w.r.t. space-based remote sensing
 - problem: imputing a geophysical process to an under-sampling issue
- * Nabro’s June 2011 eruption involved “Classic” direct stratospheric injection.
 - * injection altitudes between 16-19 km.
 - * Smithsonian has updated/corrected Nabro injection height.
- * Nabro stratospheric aerosols were in abundance without delay.
- * No evidence for Asian Monsoon role in the stratospheric aerosol injection.
- * OSIRIS stratospheric aerosol data are biased.
 - * systematic under-sampling of the full stratospheric column
 - * additional biasing in presence of plumes with extinction $> 0.0025/\text{km}$
- * A High-Zmin AOD proxy strategically brings OSIRIS into greater agreement with other data.
- * Papers on Kasatochi, Sarychev Peak invoking OSIRIS can be re-assessed.
- * NASA GISS AOD record has substantial contribution since 2002 from OSIRIS.
 - * Caution called for.

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Reining In Global Warming With Volcanic Eruptions?

CP | By The Canadian Press

Posted: 07/05/2012 5:58 pm EDT | Updated: 09/04/2012 5:12 am EDT

Adam Bourassa: "We used to think that a volcano had to have enough energy that it would put its aerosol and gas directly into the stratosphere in order for it to have a climate effect, but what we see now is that it can be a low altitude as long as it's say next to the Asian summer monsoon and then we can get a climate effect."

"This is the first time that we've ever observed volcanic aerosol reaching the stratosphere via some other pathway."

**The "other pathway?"
Monsoon thunderstorm convection**

says small volcanic eruptions could cool the climate.

The team says aerosols — minute droplets of sulphuric acid — from relatively small volcanic bursts can be shot into the high atmosphere by weather systems such as

monsoons.

Adam Bourassa, who is with the university's Institute of Space and Atmospheric Studies, said that until now it was thought that a massive eruption was needed to inject aerosols past the troposphere, the turbulent atmospheric layer closest to the

Four papers on two eruptions, showing discrepancies between OSIRIS aerosol and other observations or model output.

- 1. Kasatochi (Alaska), August 2008**
- 2. Sarychev Peak (Kurile Islands), June 2009**

The discrepancies are:

- 1. Low bias in OSIRIS stratospheric AOD (factors of 2-10)**
- 2. Delayed onset of AOD increase**

What follows: excerpts from one these papers.

Kasatochi: Kravitz et al. (2010)

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, D00L05, doi:10.1029/2009JD013525, 2010

Negligible climatic effects from the 2008 Okmok and Kasatochi volcanic eruptions

Ben Kravitz,¹ Alan Robock,¹ and Adam Bourassa²

[16] The raw optical depths measured by OSIRIS are roughly an order of magnitude smaller than those predicted by the model.

Sarychev Peak: Haywood et al. (2010)

Observations of the eruption of the Sarychev volcano and simulations using the HadGEM2 climate model

James M. Haywood,^{1,2,3} Andy Jones,² Lieven Clarisse,⁴ Adam Bourassa,⁵ John Barnes,⁶
Paul Telford,⁷ Nicolas Bellouin,² Olivier Boucher,² Paul Agnew,⁸ Cathy Clerboux,⁹
Pierre Coheur,⁴ Doug Degenstein,⁵ and Peter Braesicke⁷

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 115, D21212, doi:10.1029/2010JD014447, 2010

Sarychev Peak: Haywood et al. (2010)

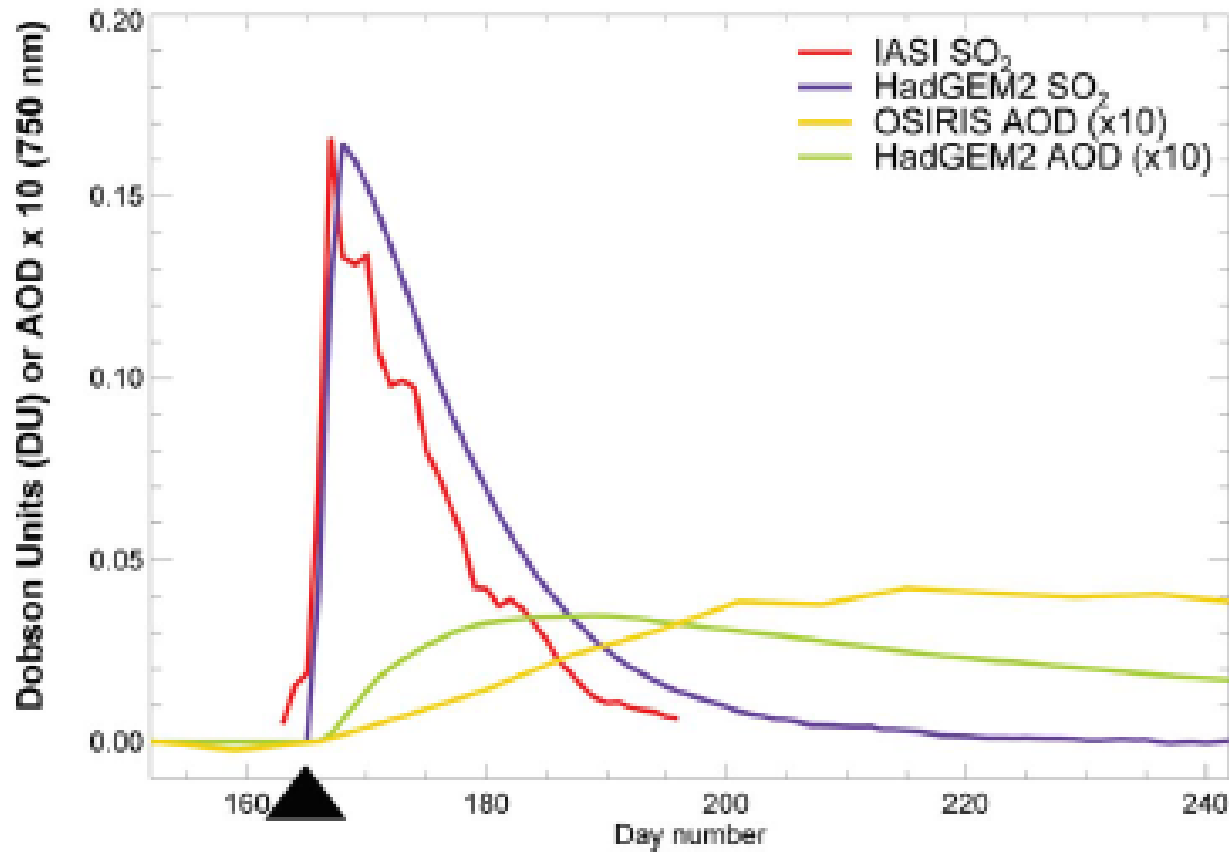


Figure 8. The time evolution of SO₂ derived from IASI (red line) and the model (purple line) averaged over the Northern Hemisphere measured in DU. The modeled sulphate AOD is also shown at 750 nm (green line). The OSIRIS AOD is shown by the yellow line. The approximate time period for the Sarychev eruption is shown by the solid black triangle.

Sarychev Peak: Haywood et al. (2010)

OSIRIS is considered the benchmark.

From Conclusions:

[62] While HadGEM2 may provide reasonable simulations of the transport and oxidation of SO₂ to sulfate aerosol, there are still some particular aspects that require refining, in particular the lack of representation of nucleation means that the transformation of SO₂ to optically active accumulation mode sulfate appears too quick when compared to observations. The observational data from OSIRIS has proved an extremely useful constraint for the model. A strong concern is that since the loss of SAGE III we are extremely reliant on OSIRIS which was launched on the ODIN satellite in 2001 with a lifetime requirement of just 2 years. That high-quality data are still available is extremely fortuitous.

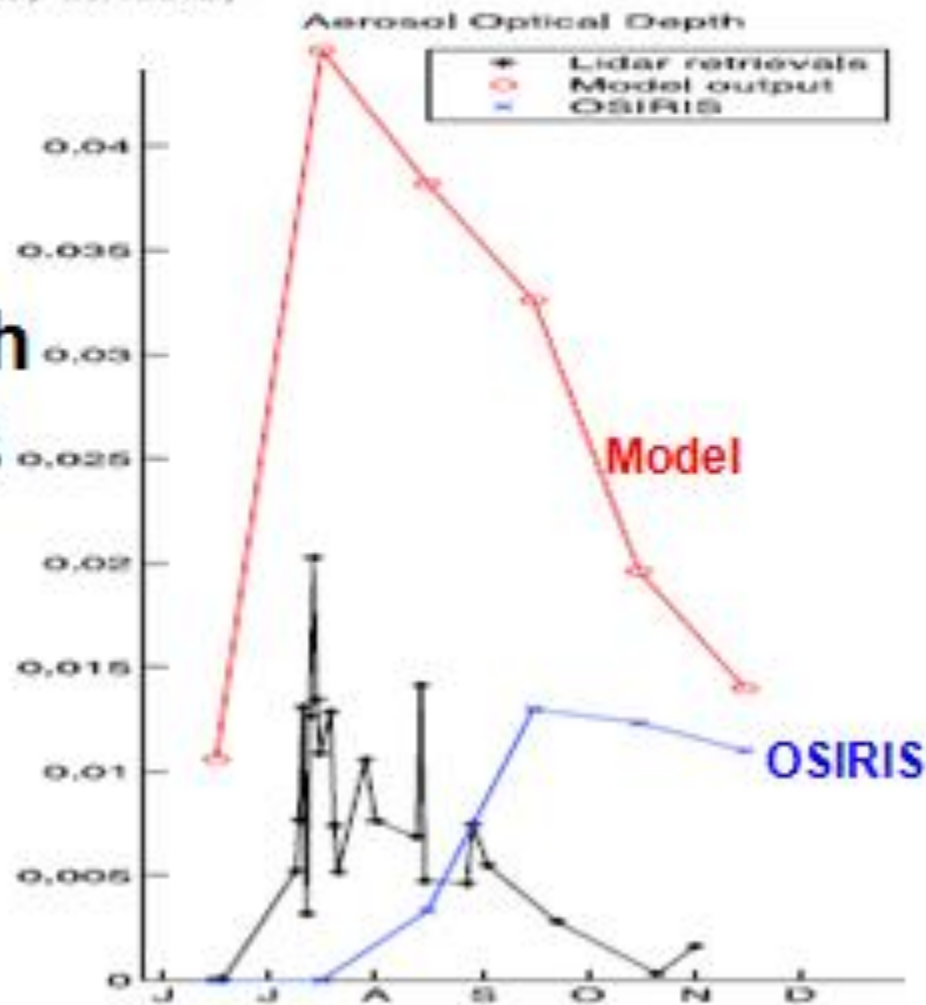
Sarychev Peak: Kravitz et al. (2011)

Simulation and observations of stratospheric aerosols
from the 2009 Sarychev volcanic eruption

Ben Kravitz,^{1,2} Alan Robock,¹ Adam Bourassa,³ Terry Deshler,⁴ Decheng Wu,^{5,6}
Ina Mattis,⁷ Fanny Finger,⁷ Anne Hoffmann,⁸ Christoph Ritter,⁸ Lubna Bitar,^{9,10}
Thomas J. Duck,⁹ and John E. Barnes¹¹

Aerosol Optical Depth - time series

Figure 16. Backscatter and aerosol optical depth from the lidar in Halifax. Backscatter is measured at 532 nm, and the units are the same as in Figure 12. Measurements below 15 km in altitude show strong interference from cirrus clouds and are omitted. Aerosol optical depth was calculated using a lidar ratio of 40 sr. Lidar optical depth values are averaged between 15 and 20 km to avoid interference from cirrus clouds. At right, the red line shows zonally averaged stratospheric aerosol optical depth (750 nm) calculated by the model in the grid latitude band containing the Halifax lidar (44°–48°N), multiplied by 0.8 to reflect an overestimation of SO₂ loading from the eruption and by 1.45 to reflect an overestimation of particle radius (as discussed in section 7). The blue line shows OSIRIS retrievals (750 nm), zonally averaged over the latitude band 40°–45°N, divided by 0.30 to account for differences in wavelength.



Sarychev Peak: Kravitz et al. (2011)

from Conclusions:

[62] We reiterate that OSIRIS is an accurate, indispensable means of obtaining stratospheric aerosol optical depth. Not only is it relatively consistent with lidar retrievals and in situ observations, but its global coverage provides data where the other observation methods discussed previously cannot. OSIRIS is an essential part of a volcanic aerosol observation system that needs a great deal of improvement.

OSIRIS was assumed to be the benchmark (e.g.):

Since the model results show higher optical depths than the OSIRIS retrievals, we suspect the model overestimated the atmospheric loading. For the purposes of calculating discrepancy, we will assume we overestimated the atmospheric loading in our model calculations,

Sarychev Peak: O'Neill et al. (2012)

JOURNAL OF GEOPHYSICAL RESEARCH, VOL. 117, D04203, doi:10.1029/2011JD016838, 2012

Properties of Sarychev sulphate aerosols over the Arctic

N. T. O'Neill,¹ C. Perro,² A. Saha,¹ G. Lesins,² T. J. Duck,² E. W. Eloranta,³
G. J. Nott,² A. Hoffman,⁴ M. L. Karumudi,¹ C. Ritter,⁴ A. Bourassa,⁵
I. Abboud,⁶ S. A. Carn,⁷ and V. Savastiouk⁸

Sarychev Peak: O'Neill et al. (2012)

from Conclusions

[56] The AHSRL values are about a factor of two higher than OSIRIS estimates: we have argued that OSIRIS FOV averaging effects produce low frequency representations of high frequency extinction profiles but that this alone should not produce a reduction in the average amplitude of extinction coefficients and derived SODs. We also showed that the apparent OSIRIS underestimates of Δ SOD are not related to the choice of sulphate model (the choice of big or small $r_{\text{eff},f}$) since OSIRIS Δ SODs at 750 nm remain significantly less than sunphotometer derived Δ SODs at 750 nm.