Absorbing aerosols and their influences on marine boundary layer cloud condensation nuclei

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ASR Fall Meeting – Absorbing Aerosols Session
November 4, 2013

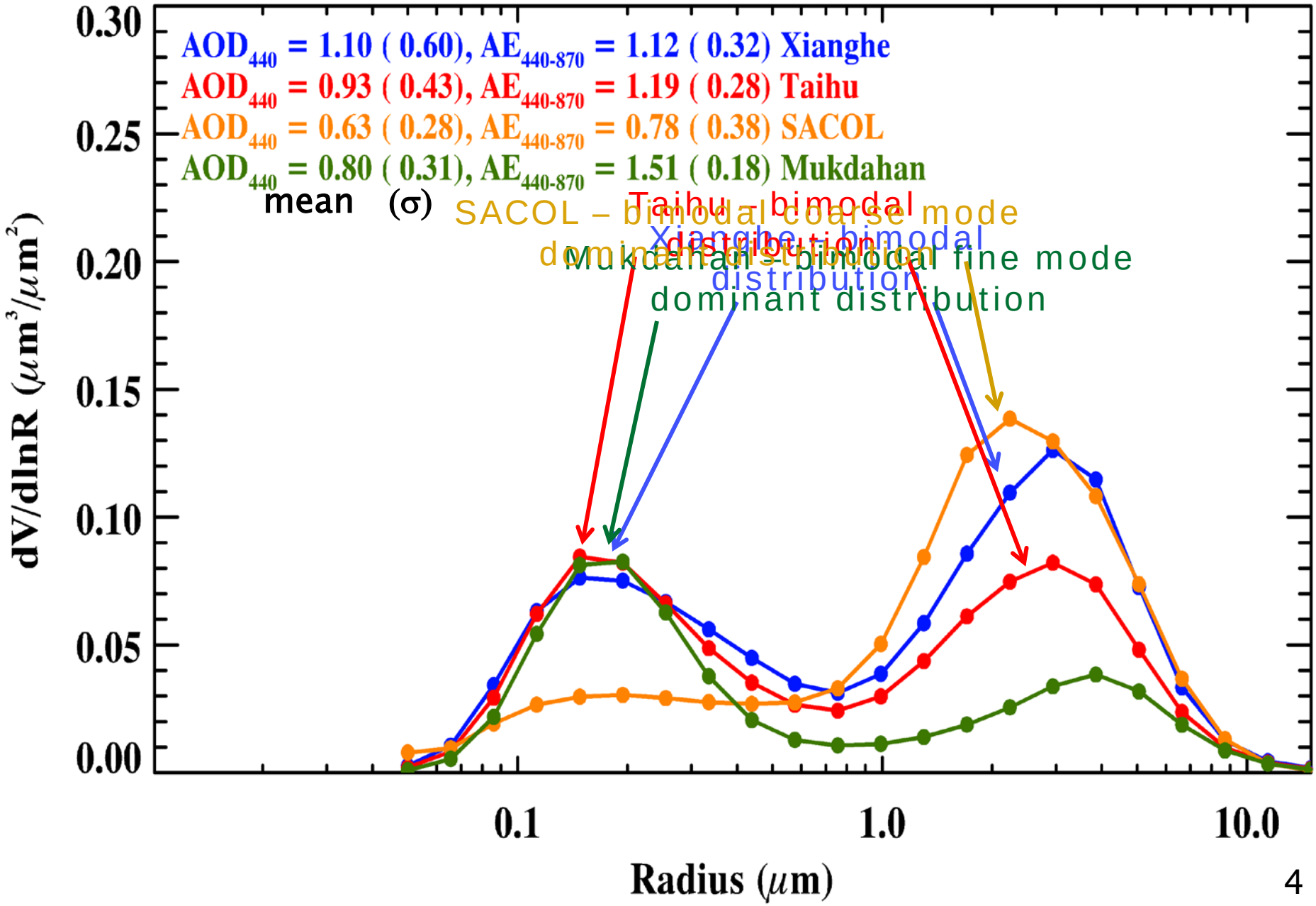
Motivation

- Aerosol physical and chemical properties and their interactions with clouds
  - Complex
  - Present large uncertainties in forcing when estimating climate change
- Investigate two issues involving absorbing aerosols:
  - Various types of and their physico-chemical properties
  - What influences do they have on cloud properties?

Logan et al., 2013a

Courtesy of NASA World Wind Software (http://worldwind.arc.nasa.gov/index.html)

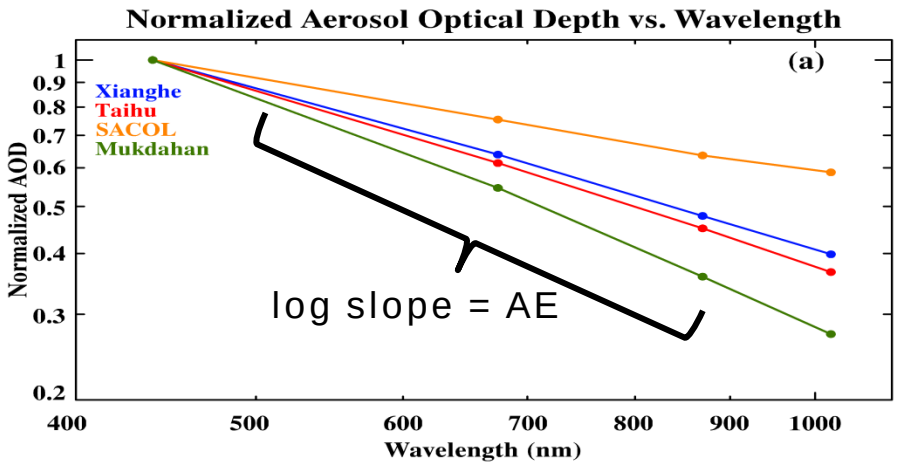
Yearly Retrieved Aerosol Size Distribution

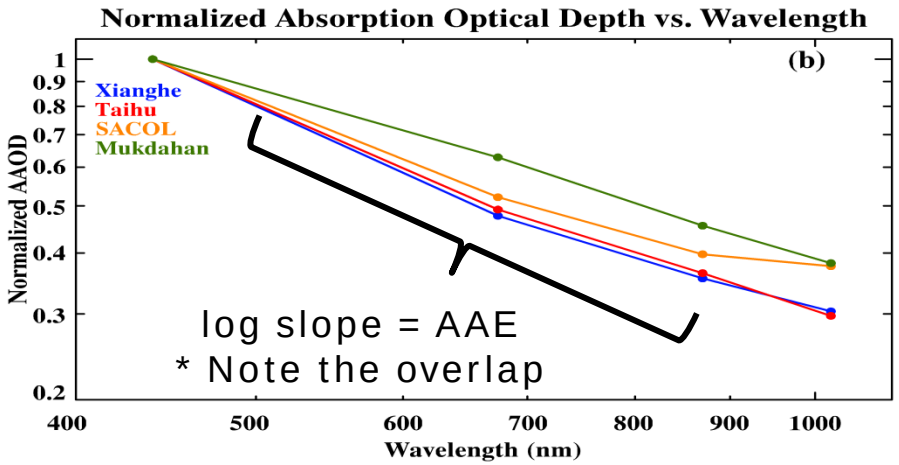


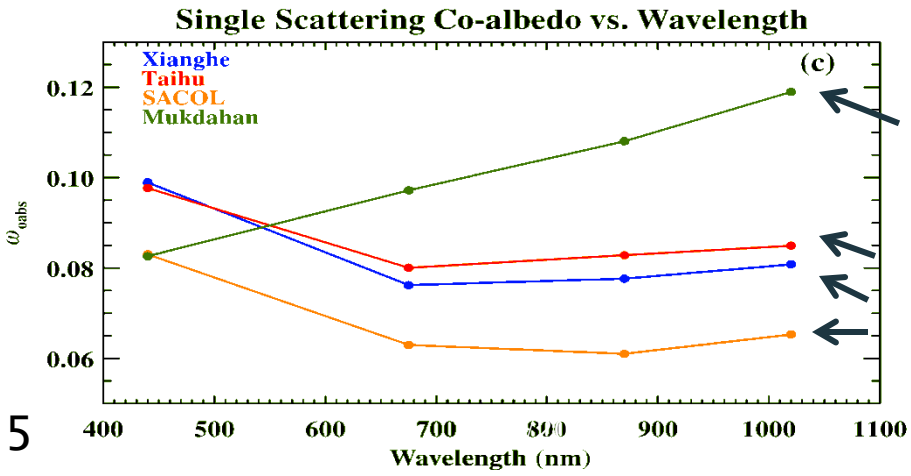
- (a) AOD spectral dependence (AE)
  - SACOL – weakest (coarse mode dominant)
  - Mukdahan – strongest (fine mode dominant)
  - Taihu and Xianghe – intermediate (mixture of fine and coarse modes)

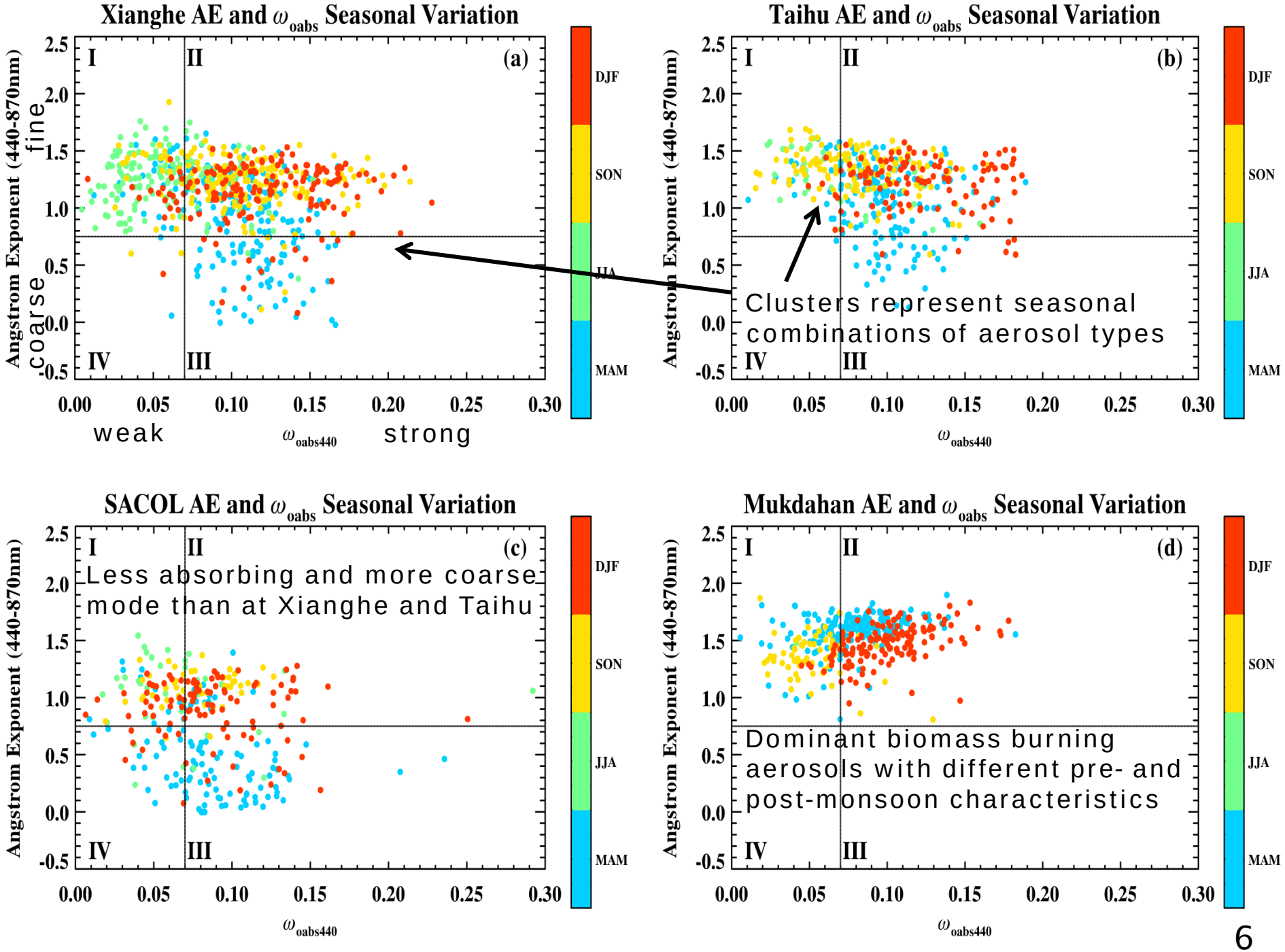
- (b) AAOD spectral dependence (AAE)
  - Mukdahan – nearly linear (BC and weak absorbing OC)
  - Xianghe/Taihu – strongest (BC and strong absorbing OC + mineral dust)
  - SACOL – strong in visible, weak in near IR (mineral dust)

- (c) Ratio of absorptive to extinctive AOD or ω_{oabs}
  - Can better separate aerosol type at the four sites
  - Increasing absorption with wavelength (biomass)
  - Decreasing absorption in near IR with wavelength (mineral dust)
  - Strong absorption in visible, weak in near IR (pollution)

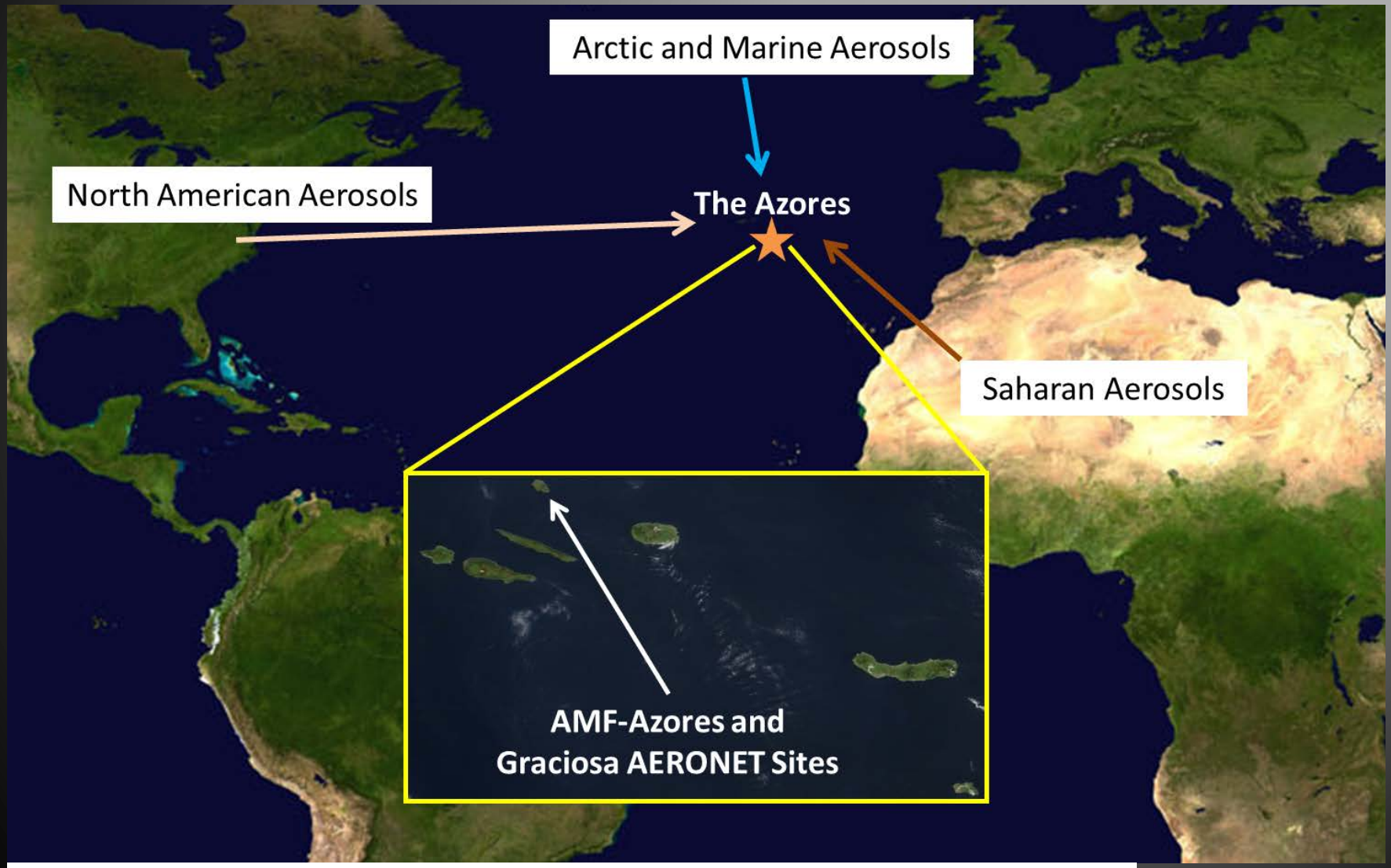




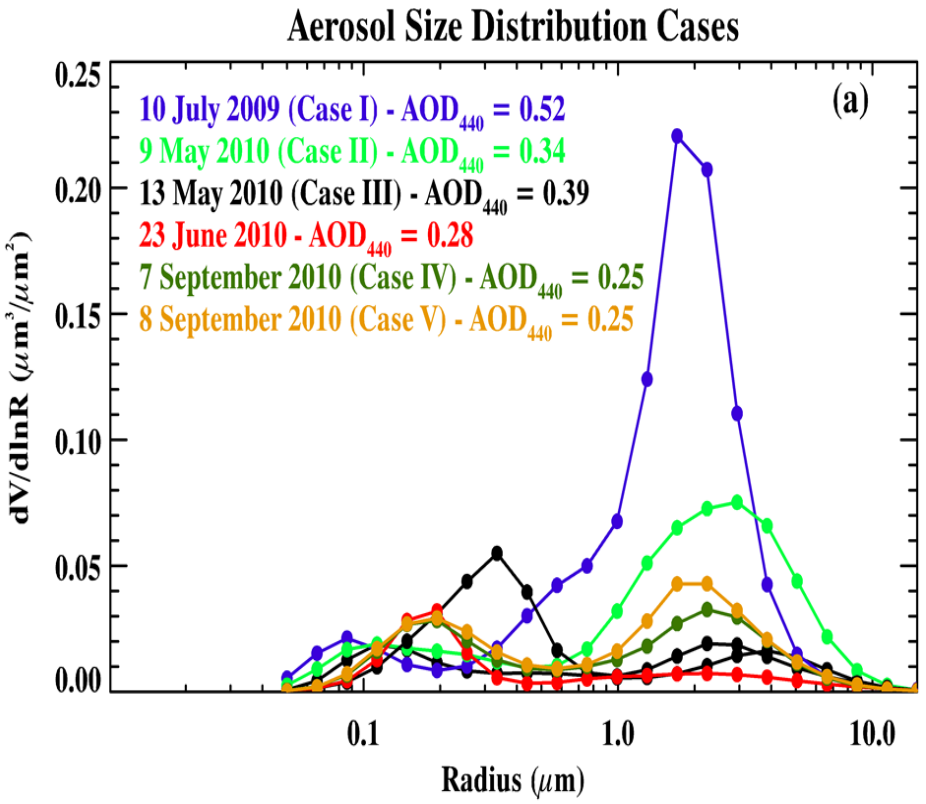


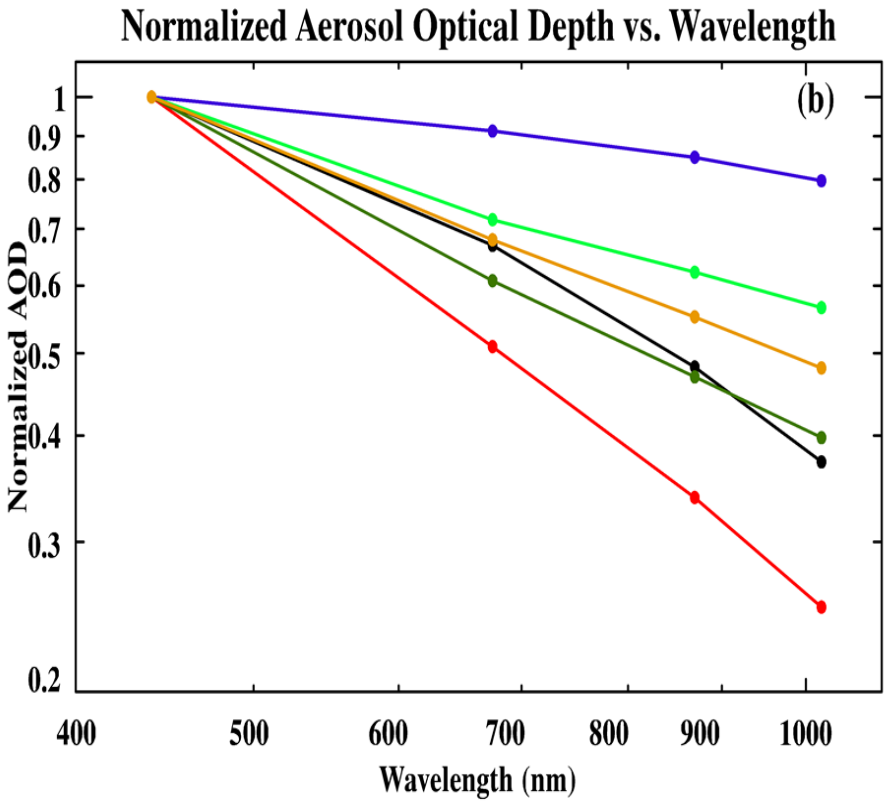

Xianghe AE and ω_{oabs} Seasonal Variation
Taihu AE and ω_{oabs} Seasonal Variation
SACOL AE and ω_{oabs} Seasonal Variation
Mukdahan AE and ω_{oabs} Seasonal Variation
Angstrom Exponent (440-870nm)
fine
coarse
weak
strong
$\omega_{oabs440}$
I
II
III
IV
(a)
(b)
(c)
(d)
DJF
SON
JJA
MAM
Clusters represent seasonal combinations of aerosol types
Less absorbing and more coarse mode than at Xianghe and Taihu
Dominant biomass burning aerosols with different pre- and post-monsoon characteristics

Logan et al., 2013b



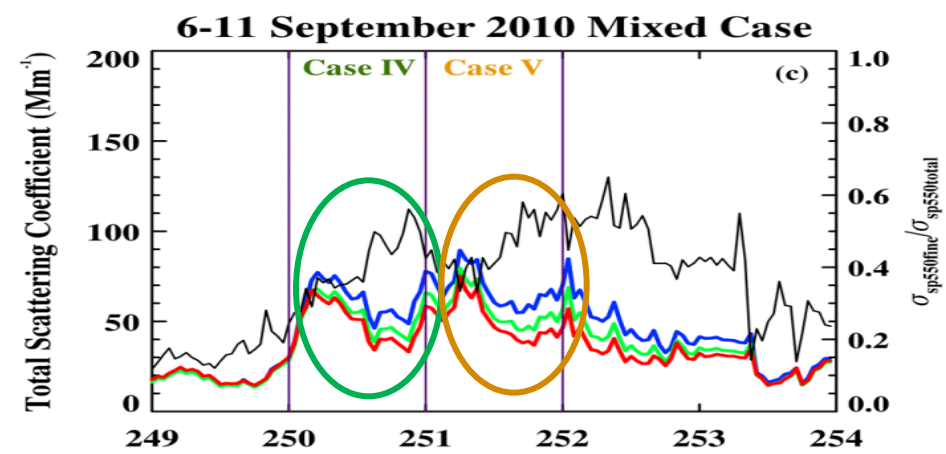
Courtesy of NASA World Wind Software (http://worldwind.arc.nasa.gov/index.html). Inset image provided by NASA EOSDIS Worldview (http://earthdata.nasa.gov/labs/worldview)

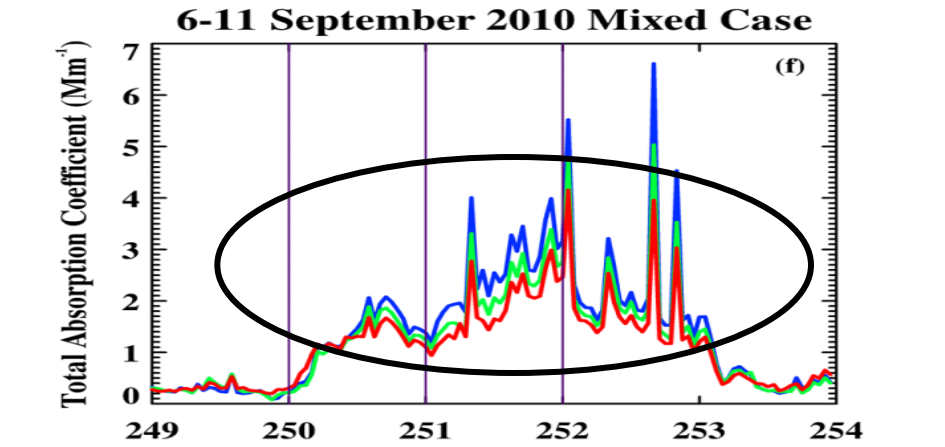


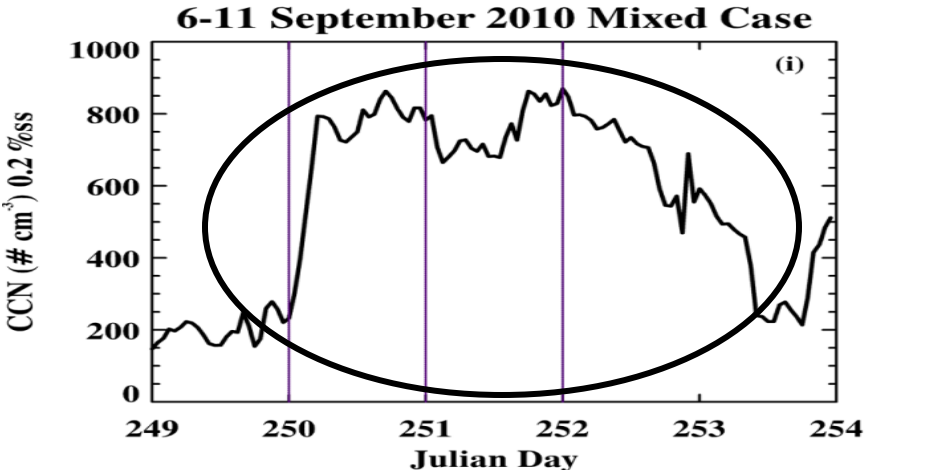


Discussion – Five Selected Cases plus 23 June 2010 case

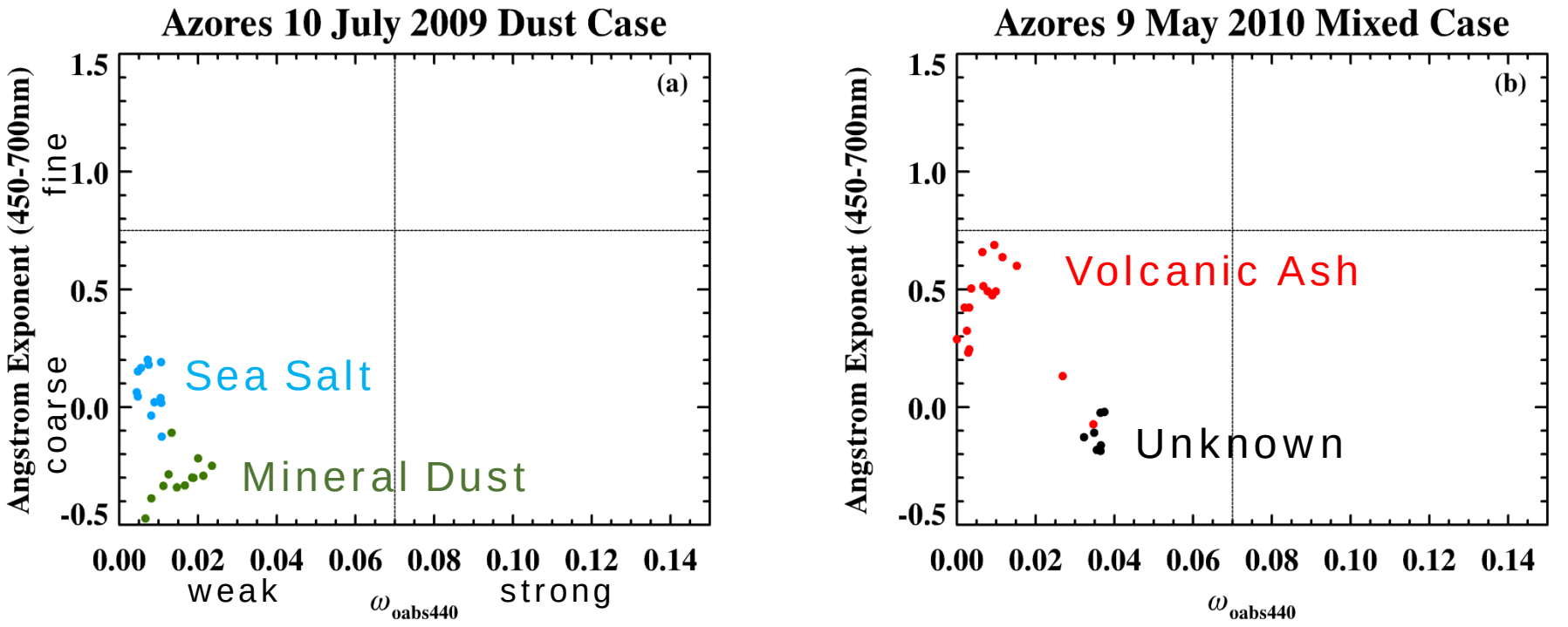
- **Bimodal volume aerosol size distribution shows the dominant aerosol size during each case.**
  - **10 July 2009 and 9 May 2010 – strongest coarse mode dominance.**
  - **13 May 2010 and *23 June 2010 – strongest fine mode dominance. (*No AOS data)**
  - **7 September – 8 September 2010 – contributions from fine and coarse modes.**
- **Spectral dependences illustrate possible mineral dust (weak), pollution type aerosols (moderate), and biomass burning (strong).**



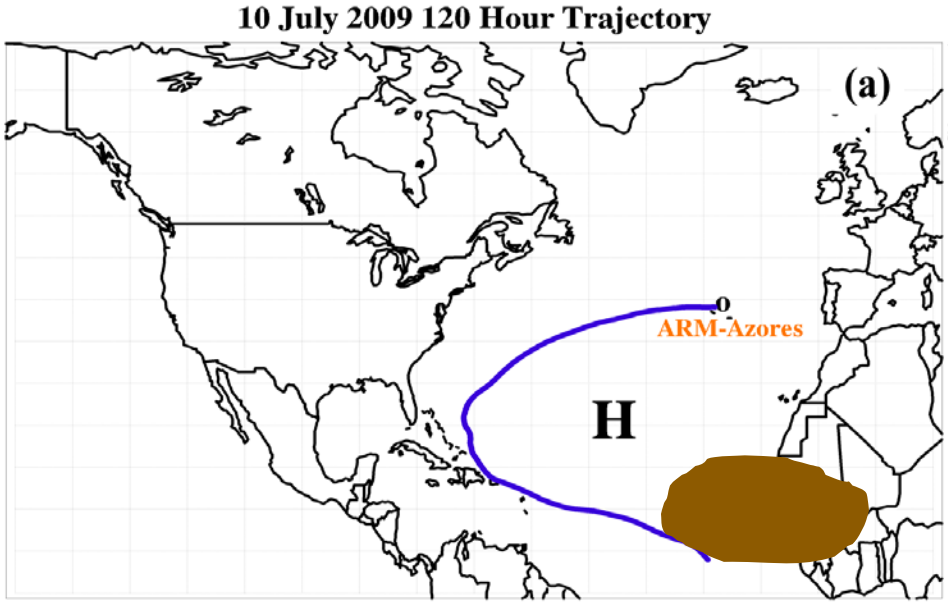


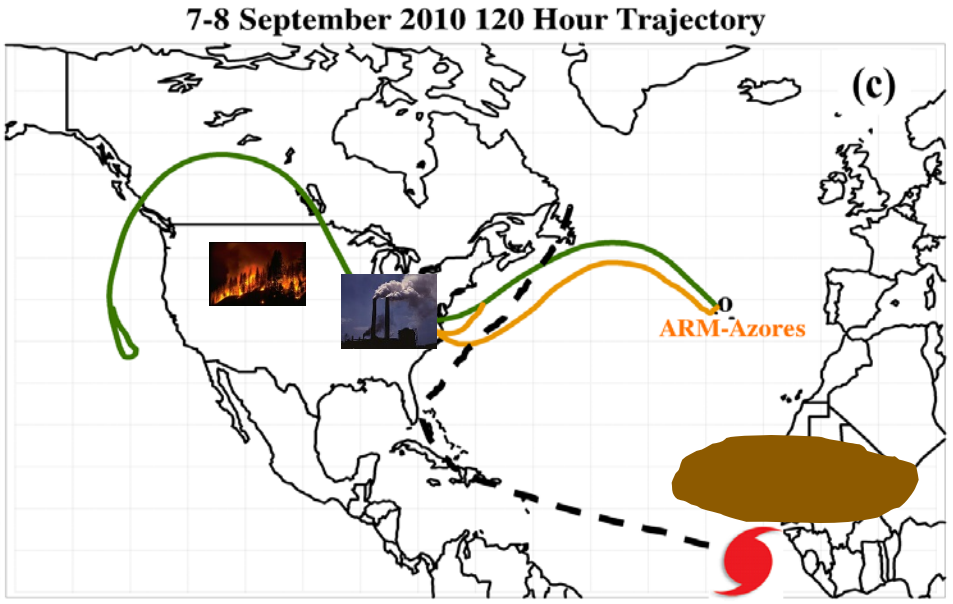


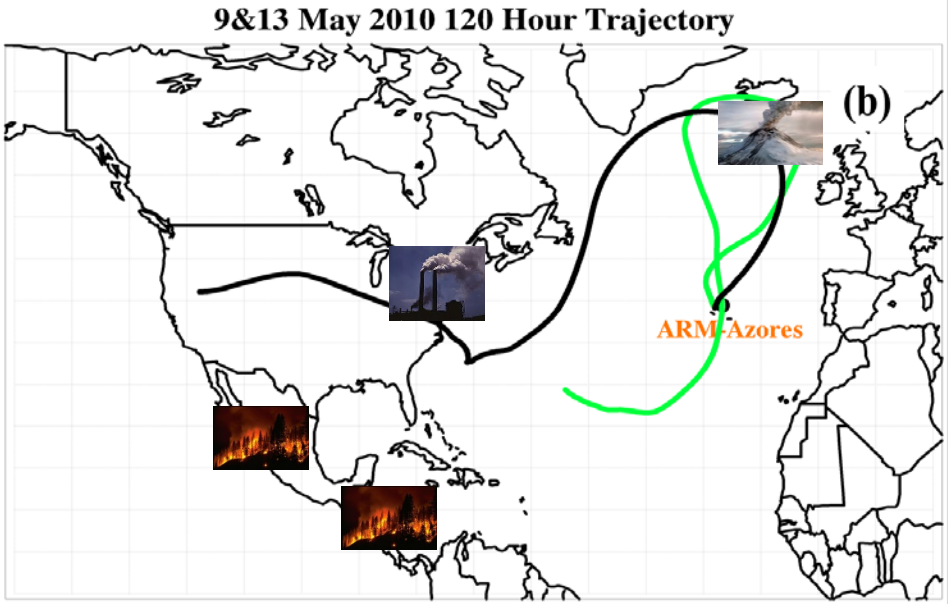
- Cases IV and V aerosols identified as complex mixtures of mineral dust, biomass burning, and pollution
- Moderate σ_{sp} and σ_{ap} spectral dependences, FMF from 40-60%
- Weak correlation between CCN and σ_{sp}
- Weaker correlation with Case V (more mineral dust influence)


Azores 10 July 2009 Dust Case
(a)
Angstrom Exponent (450-700nm)
fine
coarse
Sea Salt
Mineral Dust
weak
strong
$\omega_{oabs440}$
Azores 9 May 2010 Mixed Case
(b)
Volcanic Ash
Unknown
Azores 7 September 2010 Mixed Case
(c)
Pollution
Mineral Dust
Sea Salt
Azores 8 September 2010 Mixed Case
(d)
Pollution
Mineral Dust

HYSPLIT Trajectories







Discussion – Figure 6

- (a) 10 July – Saharan dust transported by a strong Azores High pressure system
- (b) 9 May – Volcanic ash from Iceland advected to the Azores within 72 hours after an eruption
- (b) 13 May – Pollution and biomass burning aerosols from North America
- (c) 7 – 8 September – A combination of North American pollution and Saharan mineral dust from Hurricane Earl

Summary and Future Work

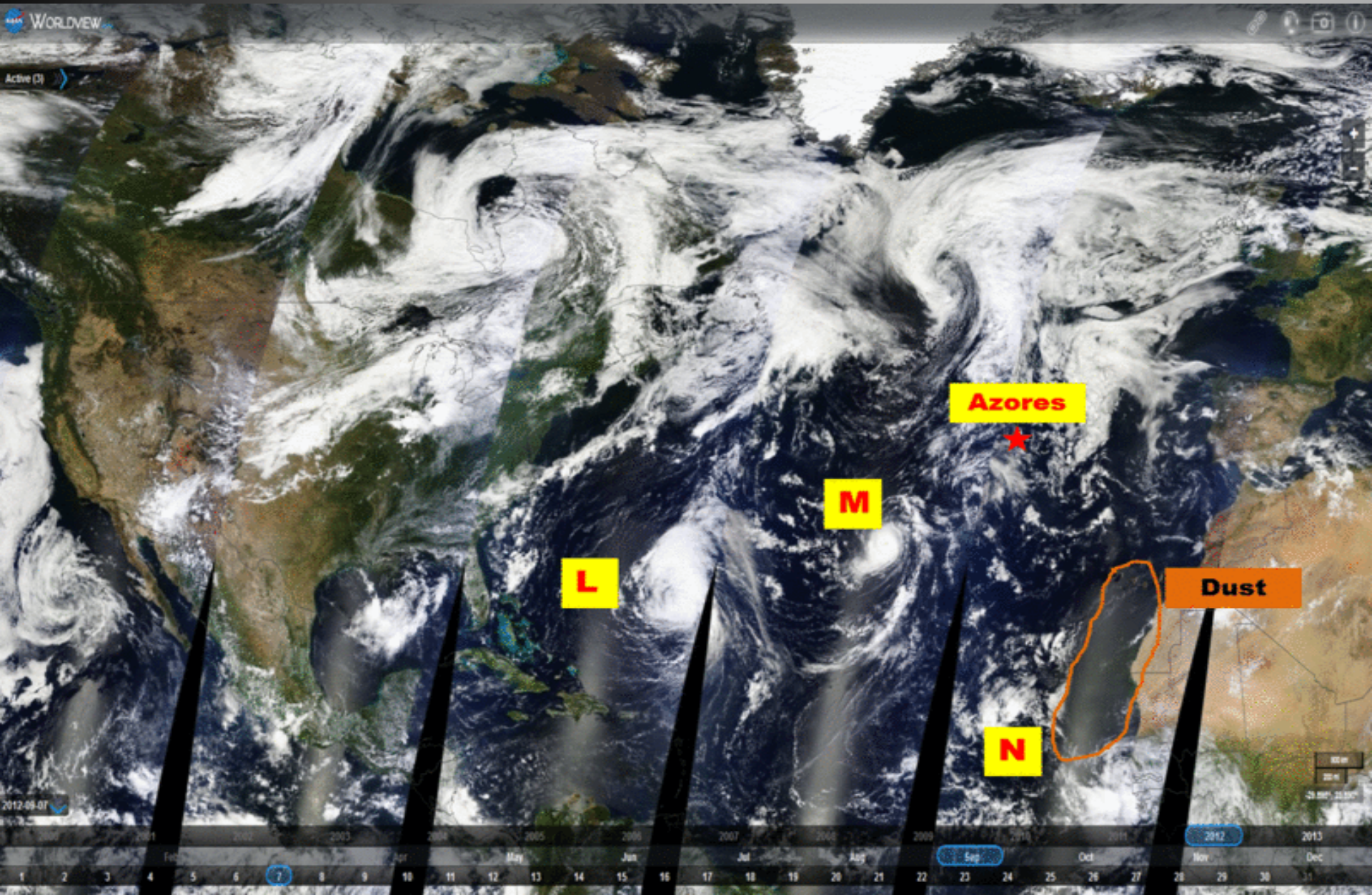
- Several aerosol plumes identified as containing mineral dust, volcanic ash, pollution, and biomass burning by the Logan et al. (2013a) method.
- The CCN number concentration was affected by the presence of these aerosols.
- Changing synoptic meteorological patterns were responsible for the source regions of the aerosols.
- Utilize more cloud microphysical properties in order to determine how different types of aerosols influence cloud development in both marine and continental settings (e.g., new ARM-ENA and ARM-SGP sites).

References

- **Logan, T**., B. Xi, X. Dong, Z. Li, and M. Cribb (2013a), Classification and Investigation of Asian Aerosol Properties, Atmos. Chem. Phys., 13, 2253-2265, www.atmos-chem-phys.net/13/2253/2013/doi:10.5194/acp-13-2253-2013.
- **Logan, T**., B. Xi, X. Dong (2013b), Aerosol Physical and Chemical Properties and Their Relationship with CCN over the ARM-Azores Facility, submitted to Journal of Geophysical Science – Atmospheres.
- Rémillard, J., P. Kollias, E. Luke, and R. Wood (2012), Marine boundary layer cloud observations in the Azores. *J. Climate*, *25*, doi: 10.1175/JCLI-D-11-00610.1, 7381-7398.

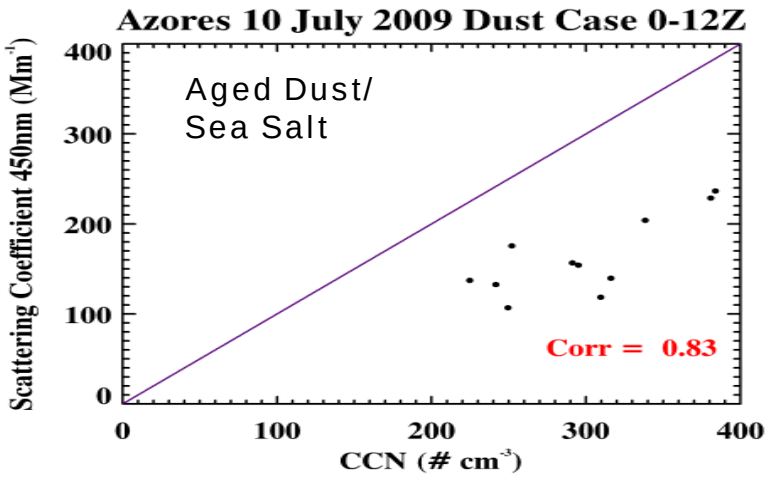
- The authors wish to thank the U.S. Department of Energy ARM Climate Research Facility and staff for maintaining and providing the aerosol and cloud data for the ARM-Azores mobile facility site (www.arm.gov). In addition we thank the Graciosa AERONET P.I. Rick Wagener, Kim Nitschke, and Larry Jones for the retrieved aerosol data.

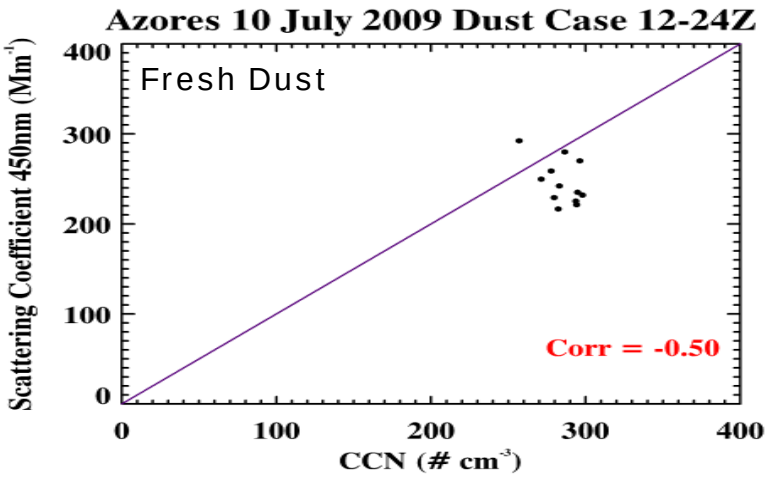
Animation of Hurricane Nadine

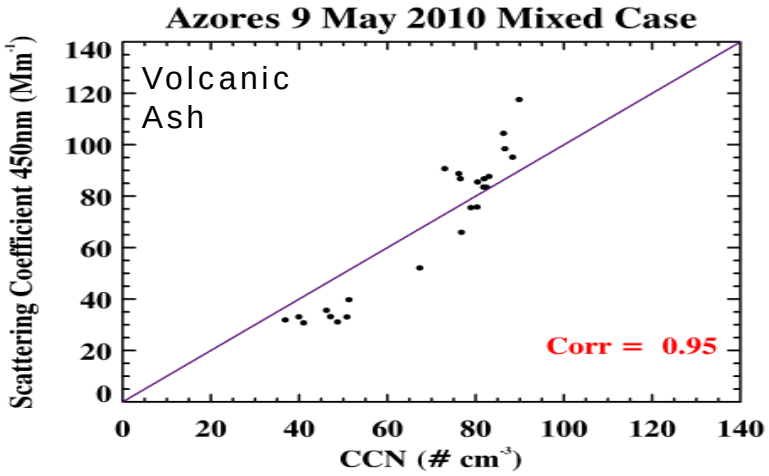


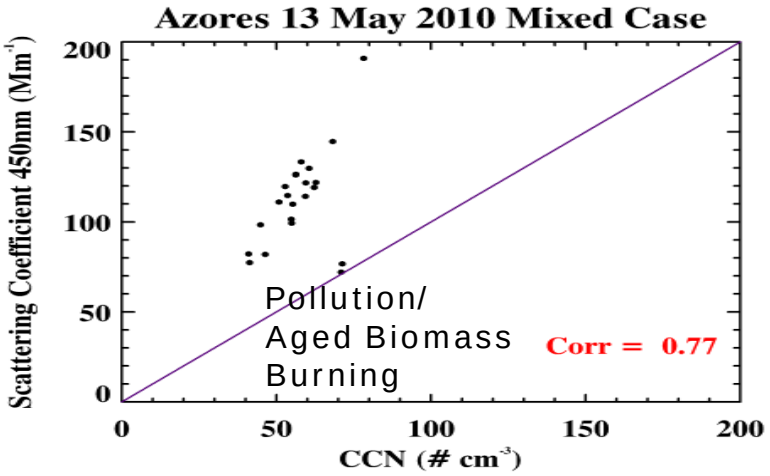
Questions/Comments

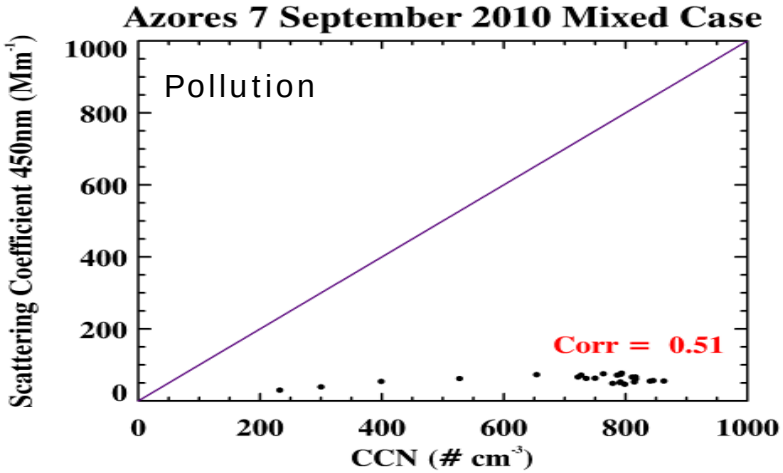
Extra Slides

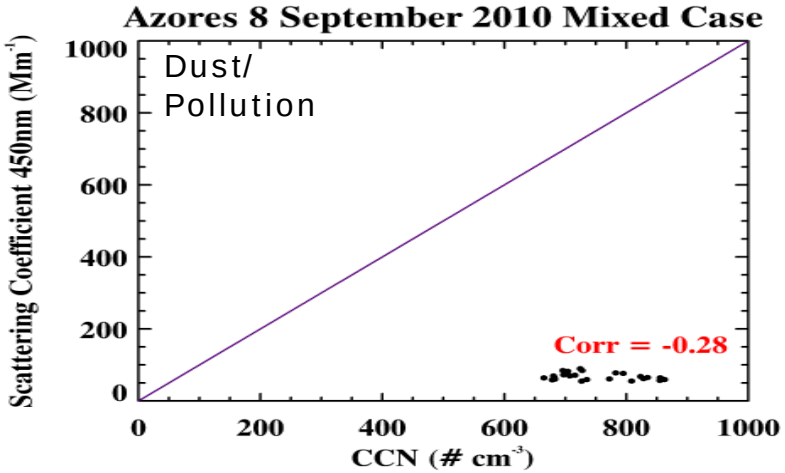

Azores 10 July 2009 Dust Case 0-12Z
Aged Dust/
Sea Salt
Corr = 0.83
Scattering Coefficient 450nm (Mm-1)
CCN (# cm-3)
0
100
200
300
400

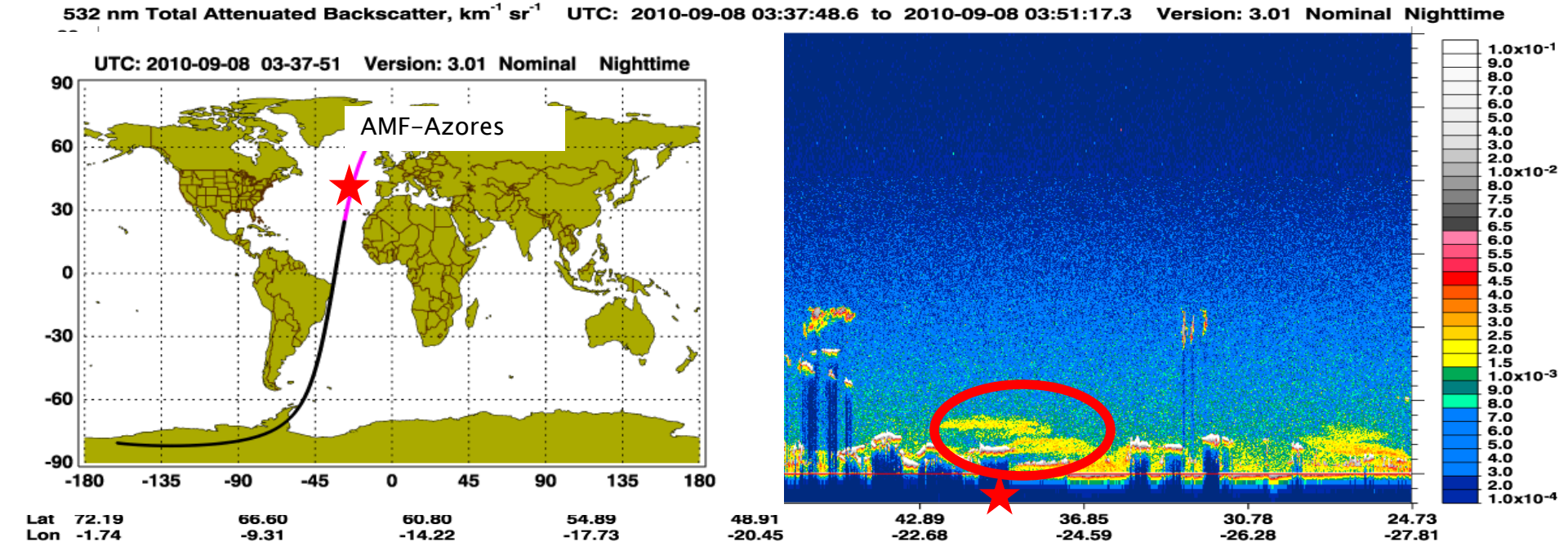

Azores 10 July 2009 Dust Case 12-24Z
Fresh Dust
Corr = -0.50
Scattering Coefficient 450nm (Mm-1)
CCN (# cm-3)
0
100
200
300
400

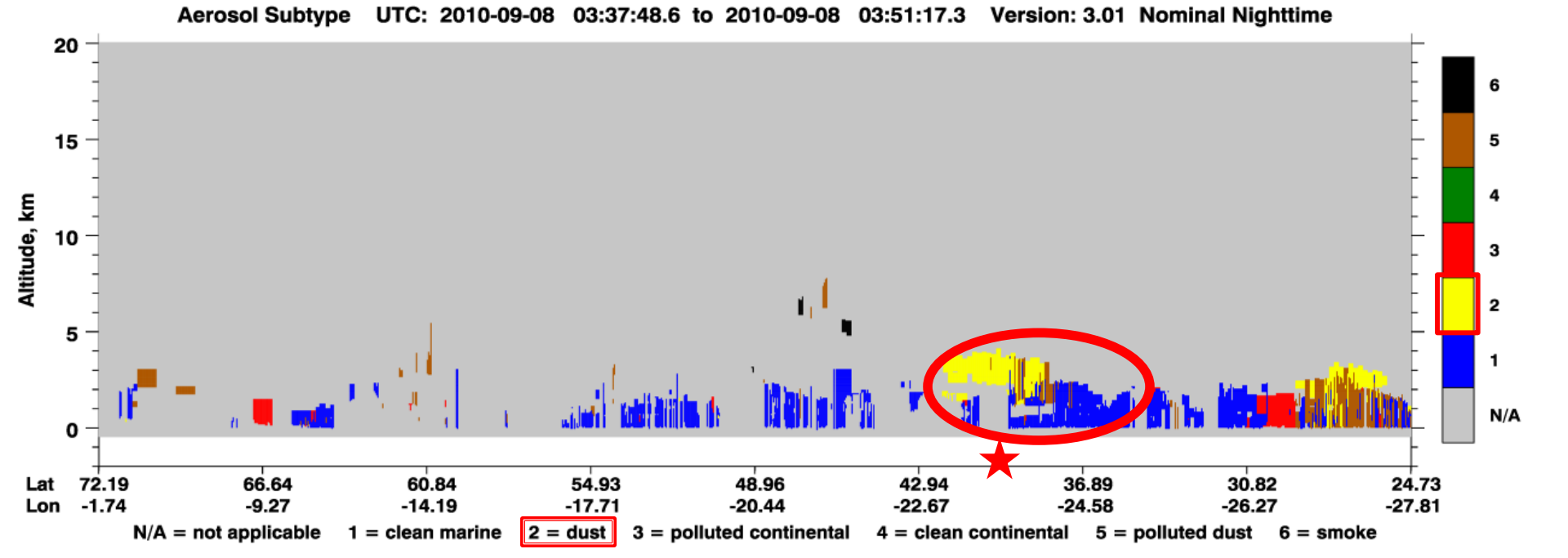

Azores 9 May 2010 Mixed Case
Volcanic
Ash
Corr = 0.95
Scattering Coefficient 450nm (Mm-1)
CCN (# cm-3)
0
20
40
60
80
100
120
140

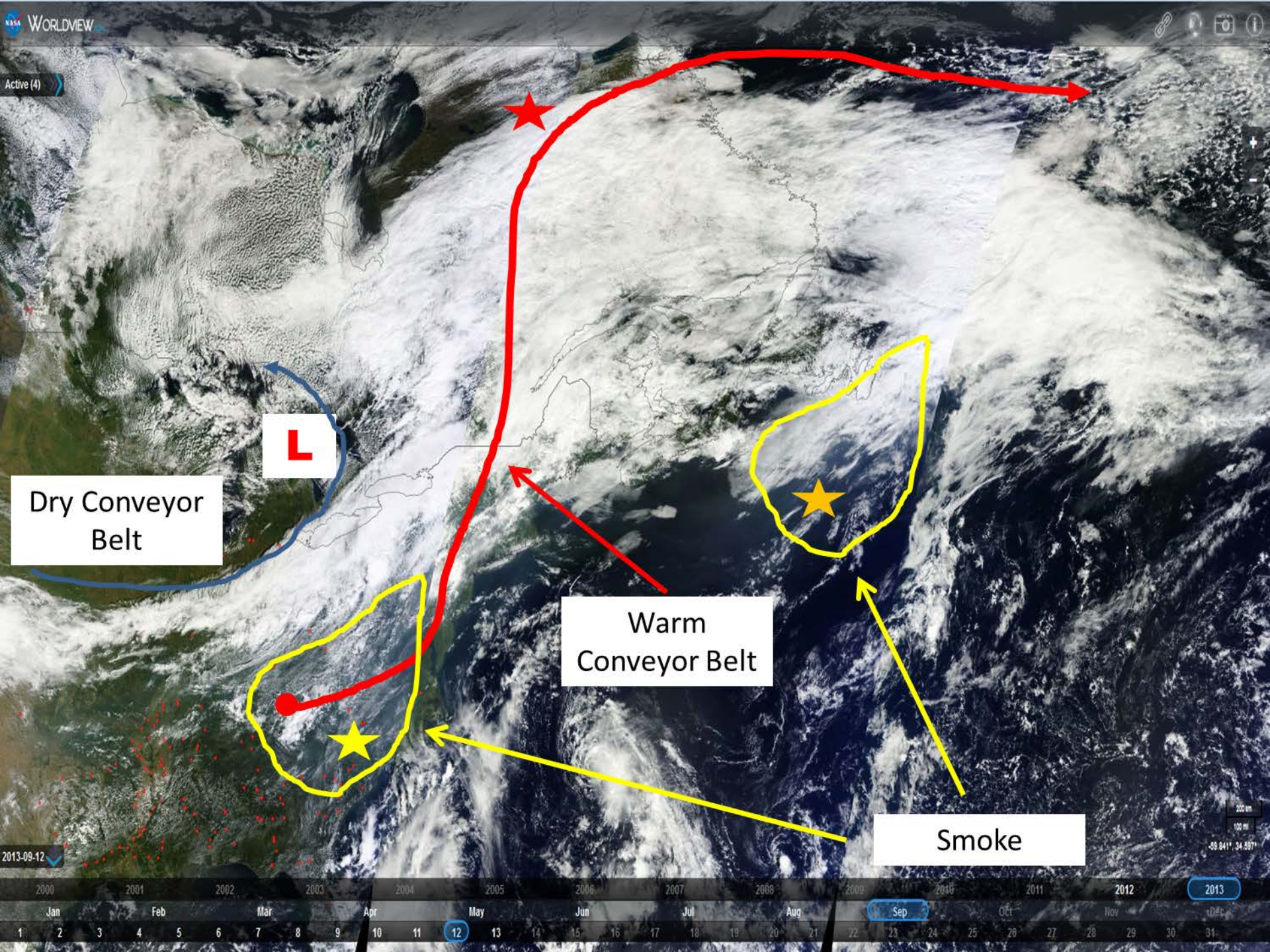

Azores 13 May 2010 Mixed Case
Pollution/
Aged Biomass
Burning
Corr = 0.77
Scattering Coefficient 450nm (Mm-1)
CCN (# cm-3)
0
50
100
150
200

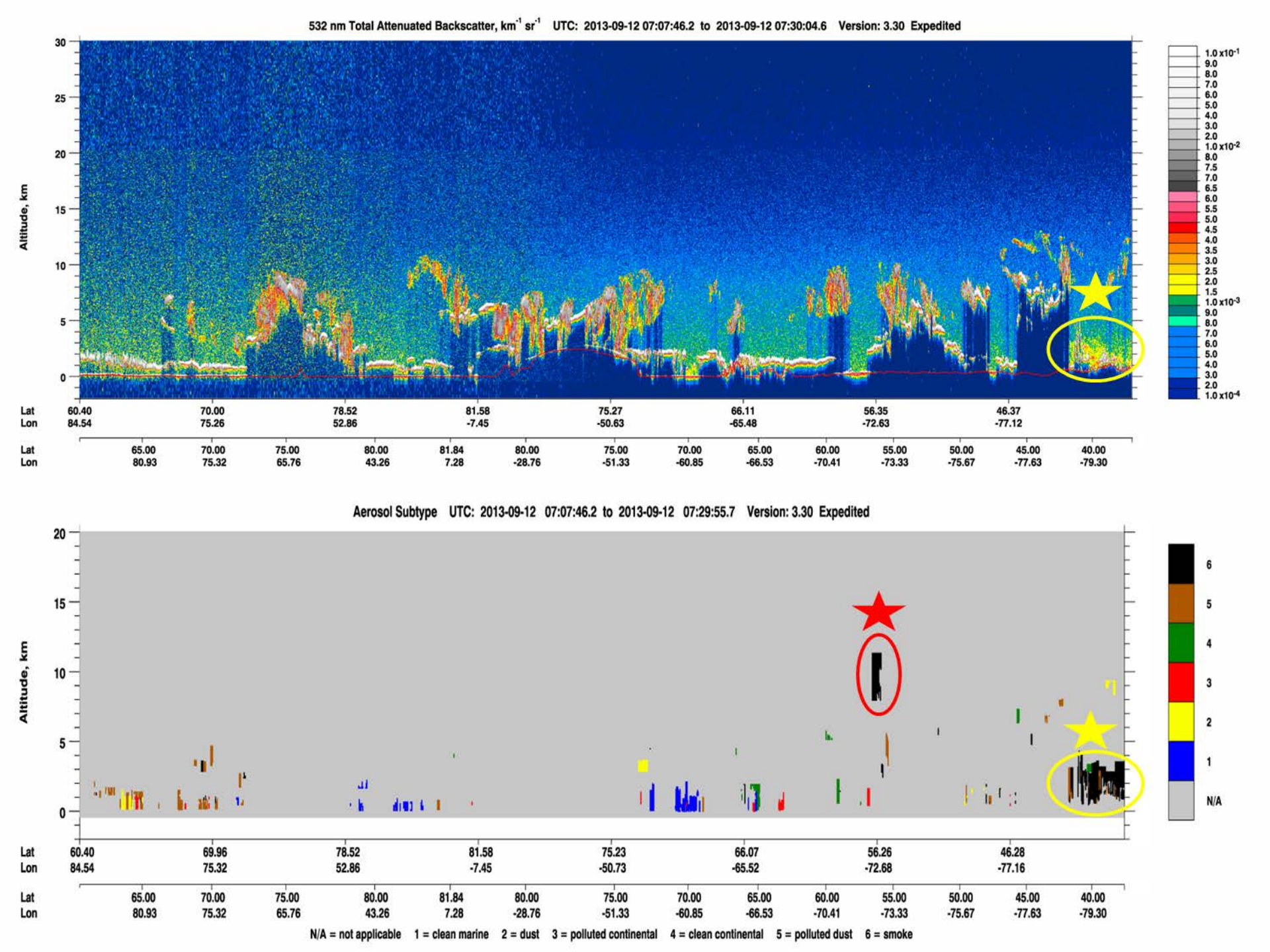

Azores 7 September 2010 Mixed Case
Pollution
Corr = 0.51
Scattering Coefficient 450nm (Mm-1)
CCN (# cm-3)
0
200
400
600
800
1000


Azores 8 September 2010 Mixed Case
Dust/
Pollution
Corr = -0.28
Scattering Coefficient 450nm (Mm-1)
CCN (# cm-3)
0
200
400
600
800
1000


532 nm Total Attenuated Backscatter, km-1 sr-1 UTC: 2010-09-08 03:37:48.6 to 2010-09-08 03:51:17.3 Version: 3.01 Nominal Nighttime
UTC: 2010-09-08 03-37-51 Version: 3.01 Nominal Nighttime
AMF-Azores
90
60
30
0
-30
-60
-90
-180 -135 -90 -45 0 45 90 135 180
1.0x10-1
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0x10-2
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0x10-3
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0x10-4
Lat 72.19 66.60 60.80 54.89 48.91 42.89 36.85 30.78 24.73
Lon -1.74 -9.31 -14.22 -17.73 -20.45 -22.68 -24.59 -26.28 -27.81


Aerosol Subtype UTC: 2010-09-08 03:37:48.6 to 2010-09-08 03:51:17.3 Version: 3.01 Nominal Nighttime
Altitude, km
20
15
10
5
0
6
5
4
3
2
1
N/A
Lat 72.19 66.64 60.84 54.93 48.96 42.94 36.89 30.82 24.73
Lon -1.74 -9.27 -14.19 -17.71 -20.44 -22.67 -24.58 -26.27 -27.81
N/A = not applicable 1 = clean marine 2 = dust 3 = polluted continental 4 = clean continental 5 = polluted dust 6 = smoke


WORLDVIEW
Active (4)
L
Dry Conveyor Belt
Warm Conveyor Belt
Smoke
2013-09-12
2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011 2012 2013
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


532 nm Total Attenuated Backscatter, km-1 sr-1 UTC: 2013-09-12 07:07:46.2 to 2013-09-12 07:30:04.6 Version: 3.30 Expedited
Altitude, km
30
25
20
15
10
5
0
1.0 x10-1
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0 x10-2
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0 x10-3
9.0
8.0
7.0
6.0
5.0
4.0
3.0
2.0
1.0 x10-4
Lat 60.40 70.00 78.52 81.58 75.27 66.11 56.35 46.37
Lon 84.54 75.26 52.86 -7.45 -50.63 -65.48 -72.63 -77.12
Lat 65.00 70.00 75.00 80.00 81.84 80.00 75.00 70.00 65.00 60.00 55.00 50.00 45.00 40.00
Lon 80.93 75.32 65.76 43.26 7.28 -28.76 -51.33 -60.85 -66.53 -70.41 -73.33 -75.67 -77.63 -79.30
Aerosol Subtype UTC: 2013-09-12 07:07:46.2 to 2013-09-12 07:29:55.7 Version: 3.30 Expedited
Altitude, km
20
15
10
5
0
6
5
4
3
2
1
N/A
Lat 60.40 69.96 78.52 81.58 75.23 66.07 56.26 46.28
Lon 84.54 75.32 52.86 -7.45 -50.73 -65.52 -72.68 -77.16
Lat 65.00 70.00 75.00 80.00 81.84 80.00 75.00 70.00 65.00 60.00 55.00 50.00 45.00 40.00
Lon 80.93 75.32 65.76 43.26 7.28 -28.76 -51.33 -60.85 -66.53 -70.41 -73.33 -75.67 -77.63 -79.30
N/A = not applicable 1 = clean marine 2 = dust 3 = polluted continental 4 = clean continental 5 = polluted dust 6 = smoke