Long-Term Variations in Terra/MISR Angular Radiance Differences:

Solar or Aerosol Influences on Polar Cloudiness?

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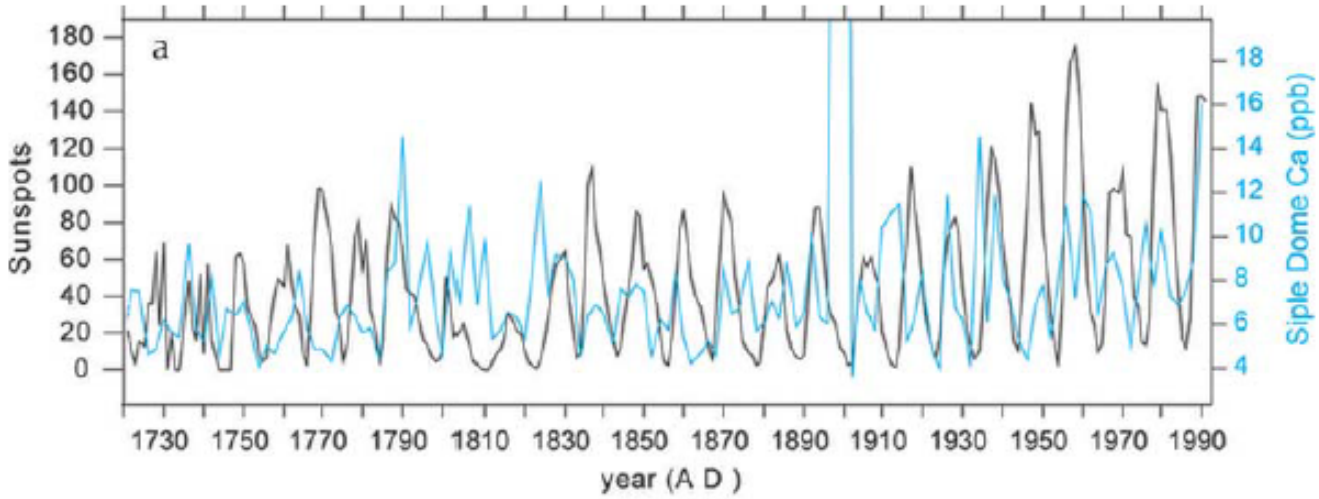
Motivations

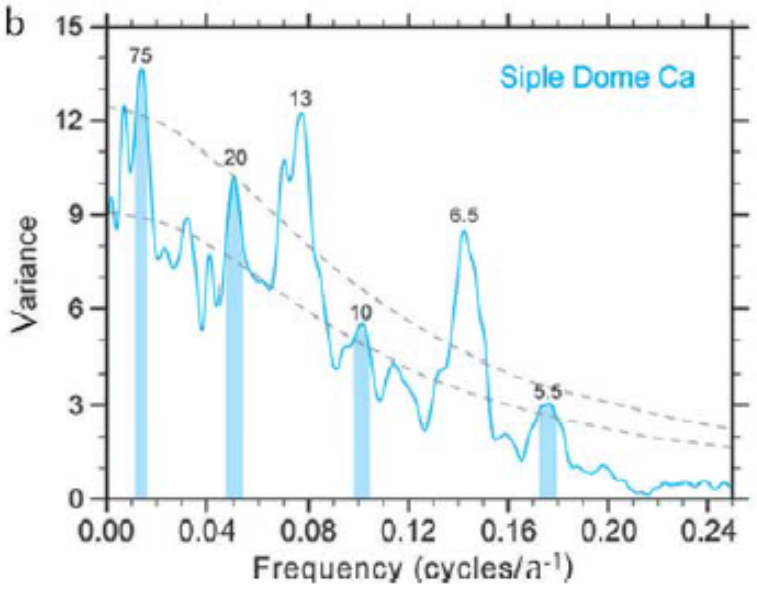
- Polar warming and complex roles of Arctic clouds
- Difficulties and controversy in polar cloud observations
- Intertwined warming/darkening and natural (solar-cycle and volcanic) variabilities and processes

Approach

- Stable sensors from space (e.g., Terra/MISR, Aura/OMI)
- Stereoscopic information



- 600-year South Pole ice core record ^{10}Be and Ca^{2+} since 1720;
- Transport of crustal and marine source Ca^{2+} to Antarctica;
- Ca^{2+} as a proxy of Antarctic circulation



Mayewski et al. (2005)

Lake Victoria, Africa

Alexander et al. (2007)

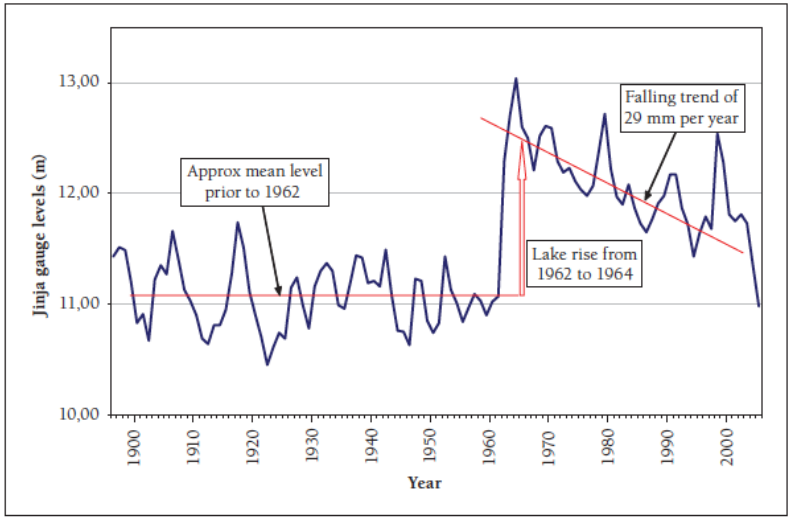


Figure 5a Levels of Lake Victoria from 1896 to 2005

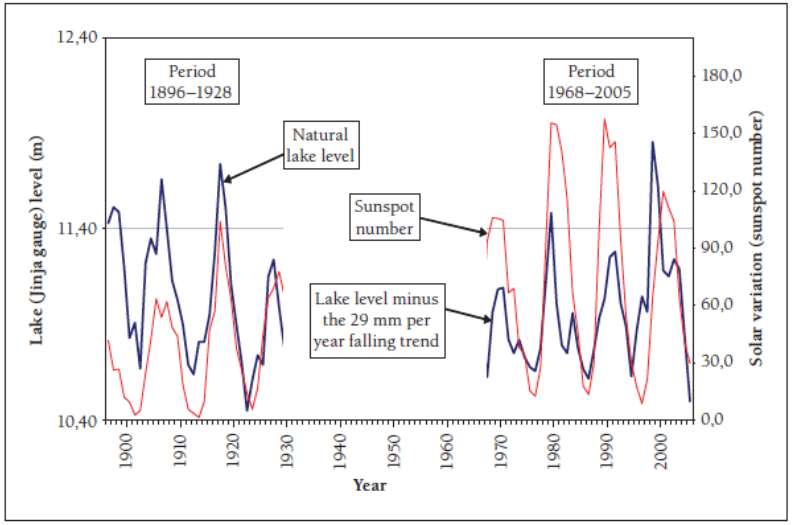
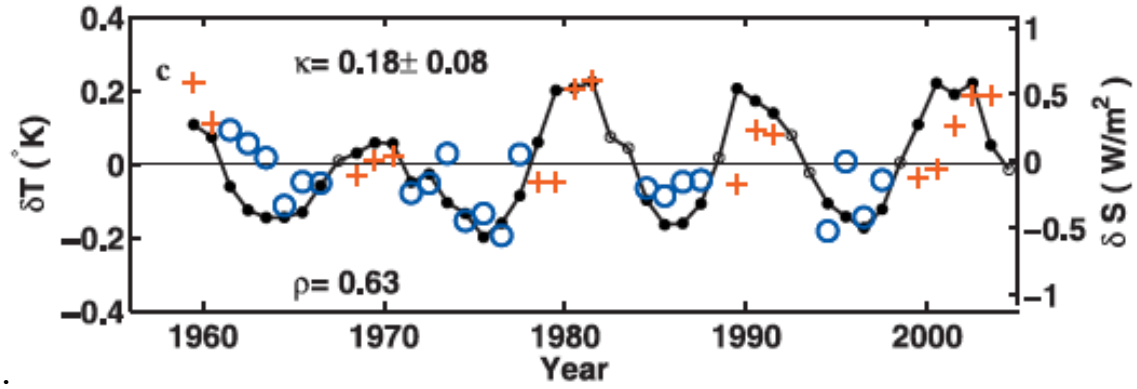
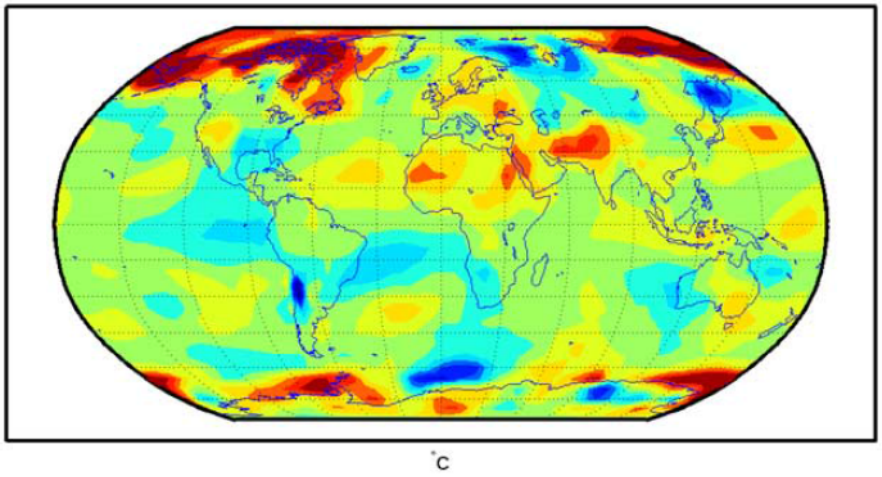


Figure 5b Levels of Lake Victoria from 1896 to 1928 and from 1968 to 2005 compared to solar variation in the form of sunspot number indices, but with the 29 mm per year falling trend in lake level eliminated from the 1968 to 2005 data

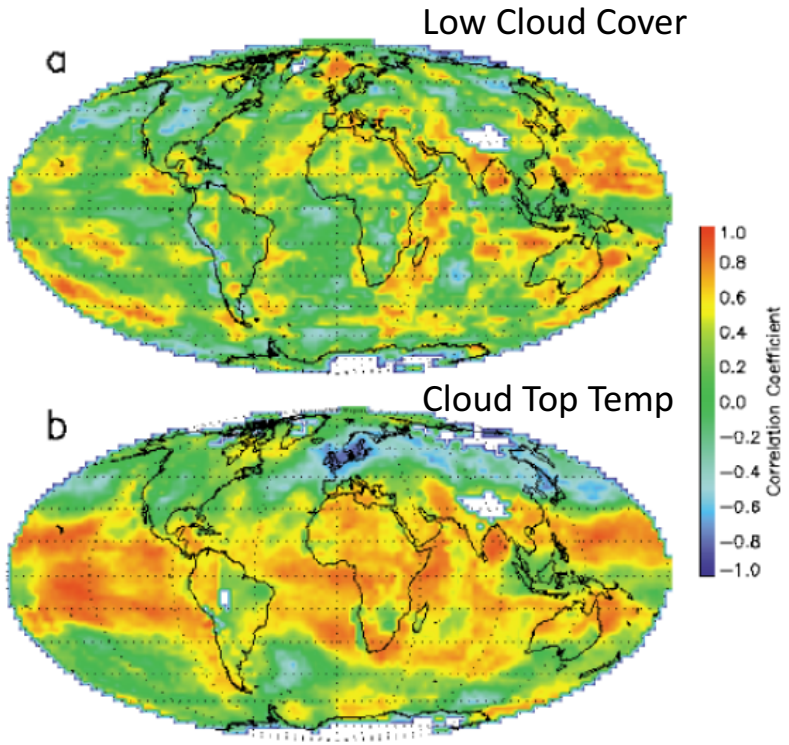


- NCEP temperature reanalysis data (1959–2004)
- ± 0.2 K difference in composite means between solar max and solar min years;
- Statistical significance of globally coherent solar response at the surface

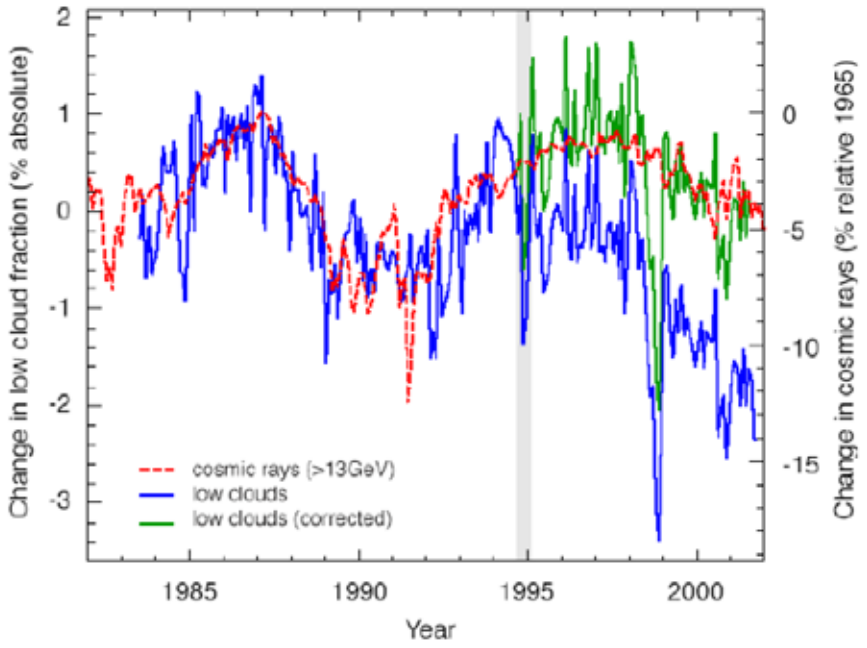


Camp and Tung (2007)

International Satellite Cloud Climate Project (ISCCP) D2 Low Cloud Data

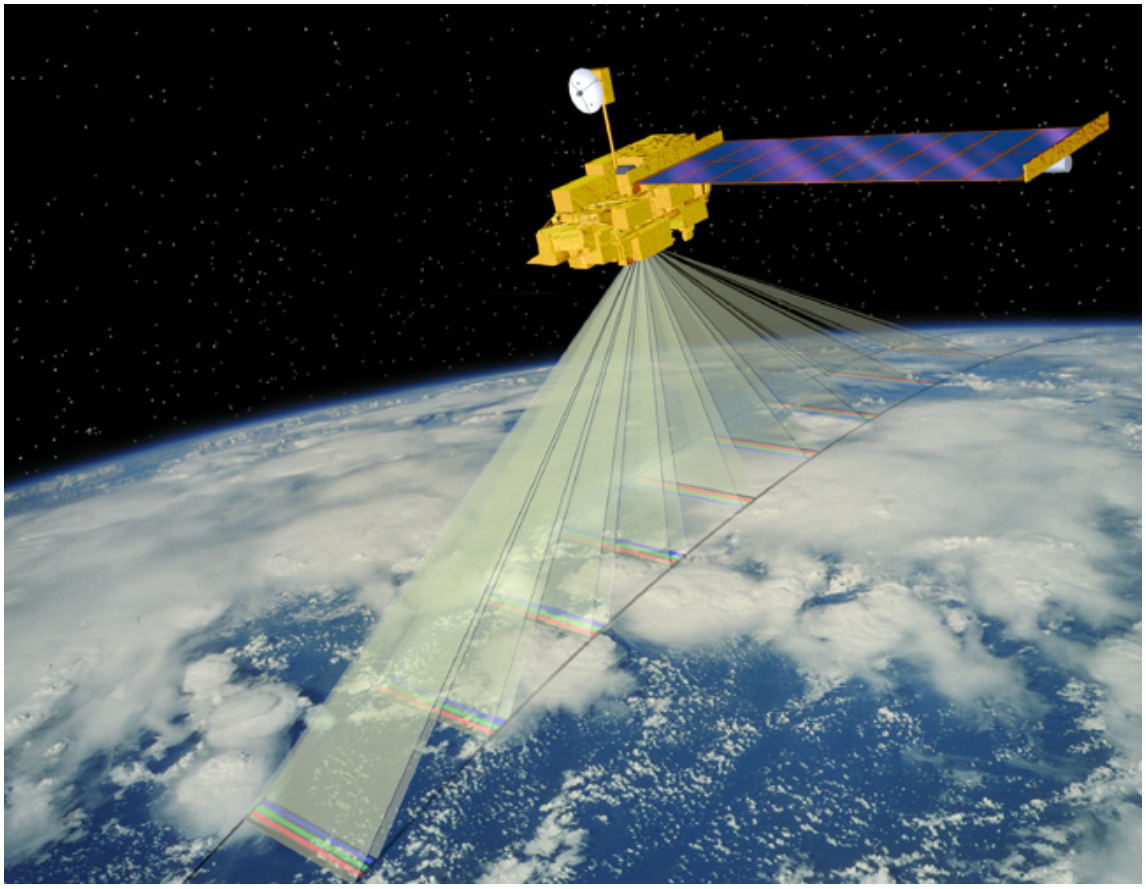


Marsh and Svensmark (2000)



Marsh and Svensmark (2003)

Multi-angle Imaging SpectroRadiometer (MISR)



PI: David Diner (JPL)

9 view angles at Earth surface:
Nadir, ±26º, ±46º,±60º, ±70º

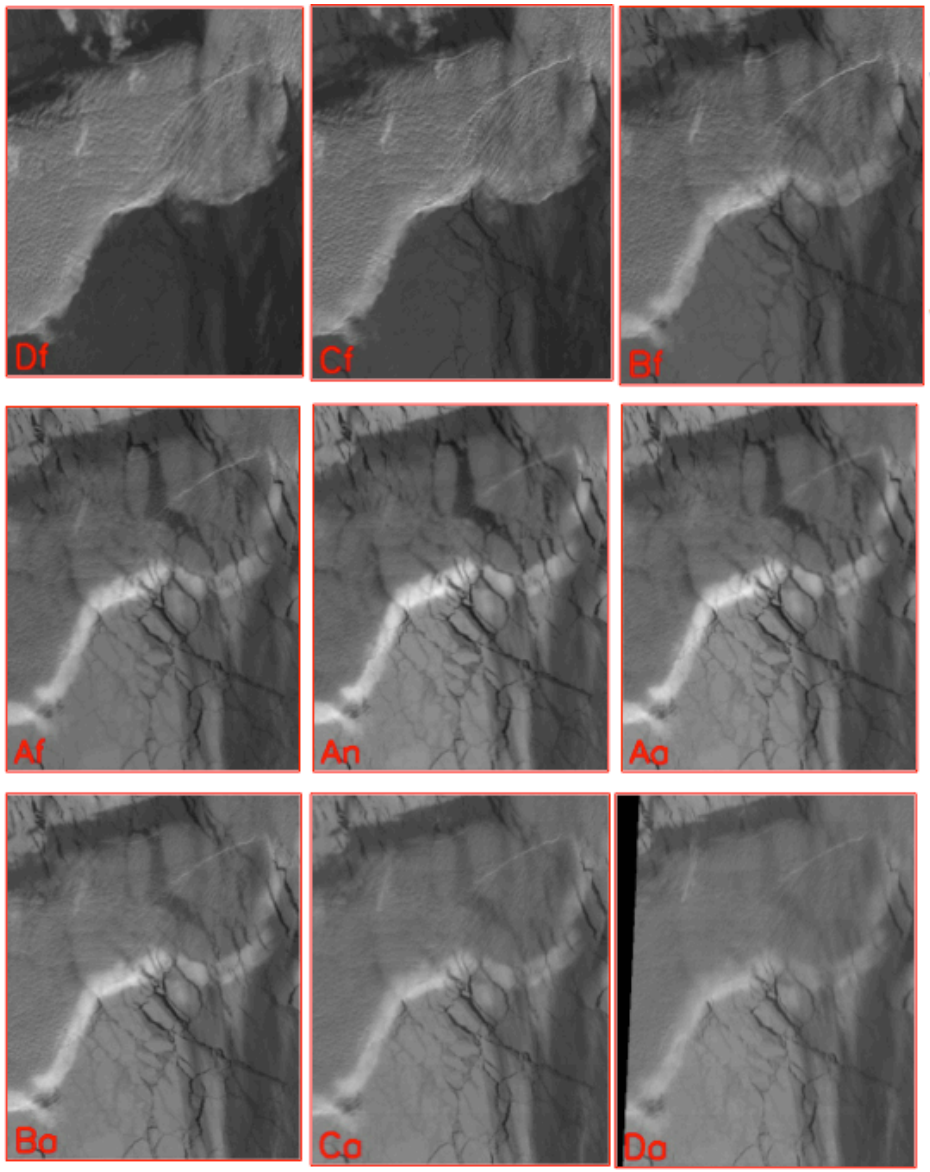
4 bands: 446, 558, 672, 866 nm

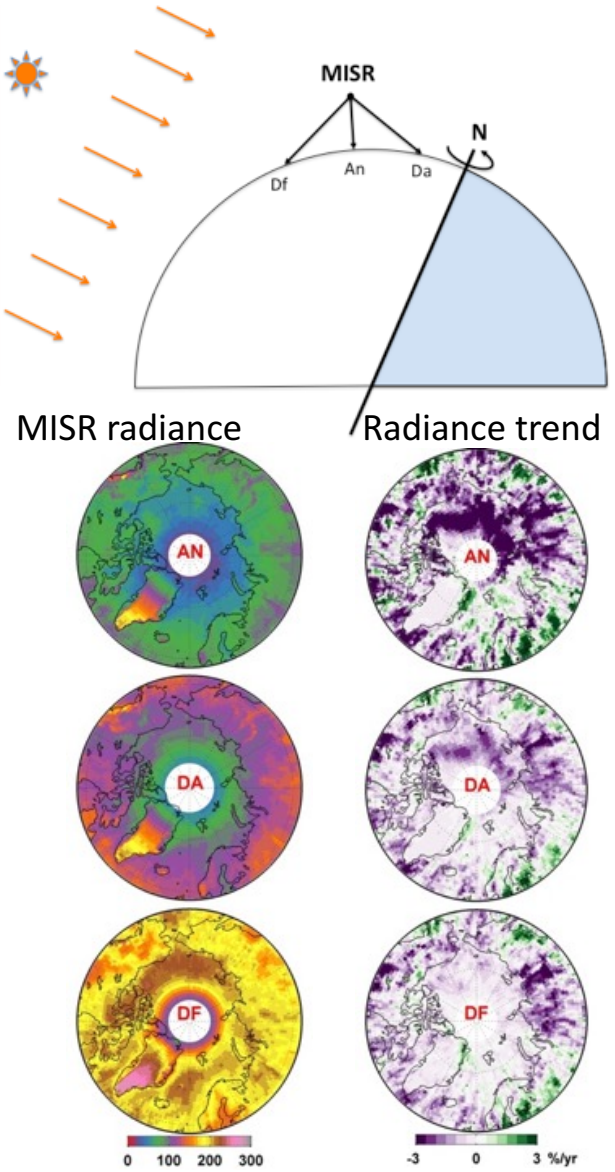
Daytime global coverage

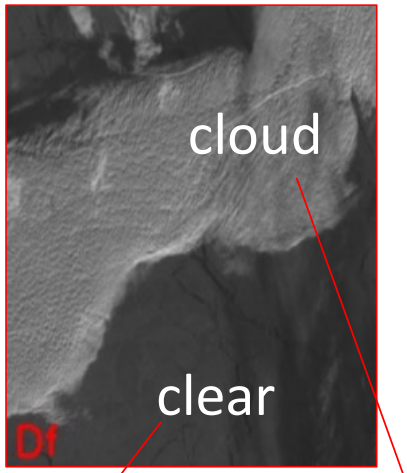
400-km swath

275 m - 1.1 km pixel resolution

Onboard Terra (2000-present)

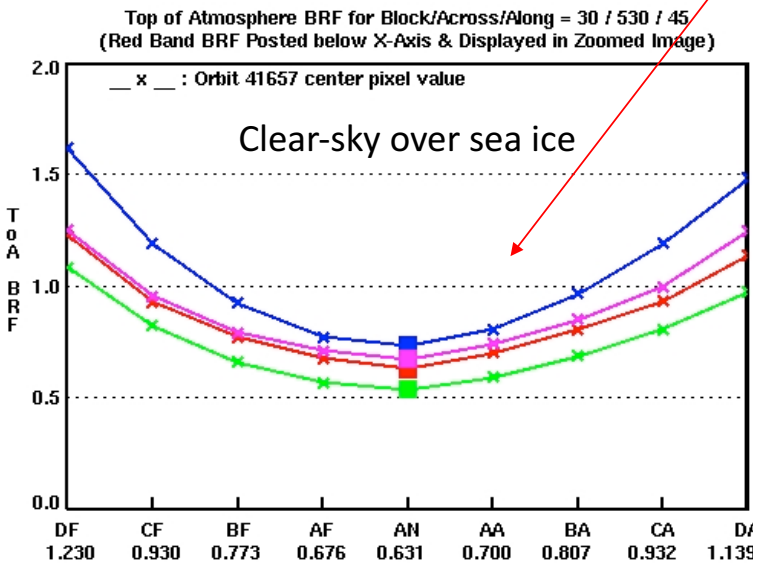

Df
Cf
Bf
Af
An
Aa
Ba
Ca
Da

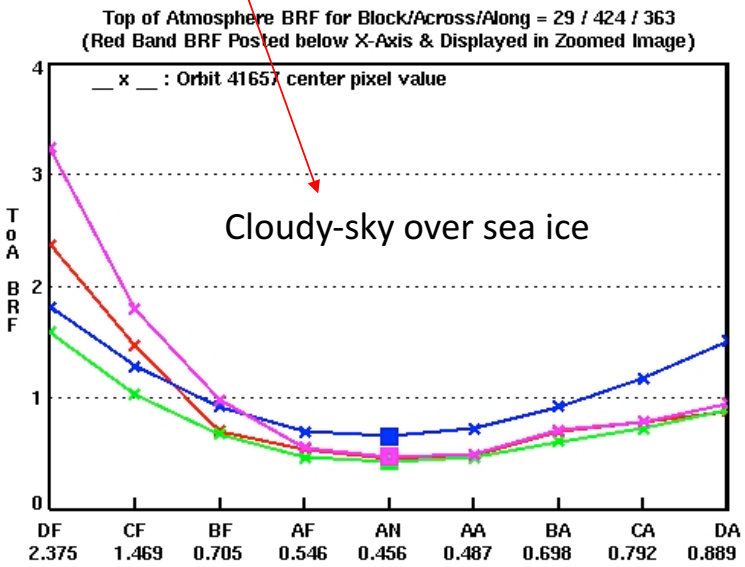

MISR
N
Df
An
Da
MISR radiance
Radiance trend
AN
DA
DF
0
100
200
300
-3
0
3
%/yr



Nearly Lambertian

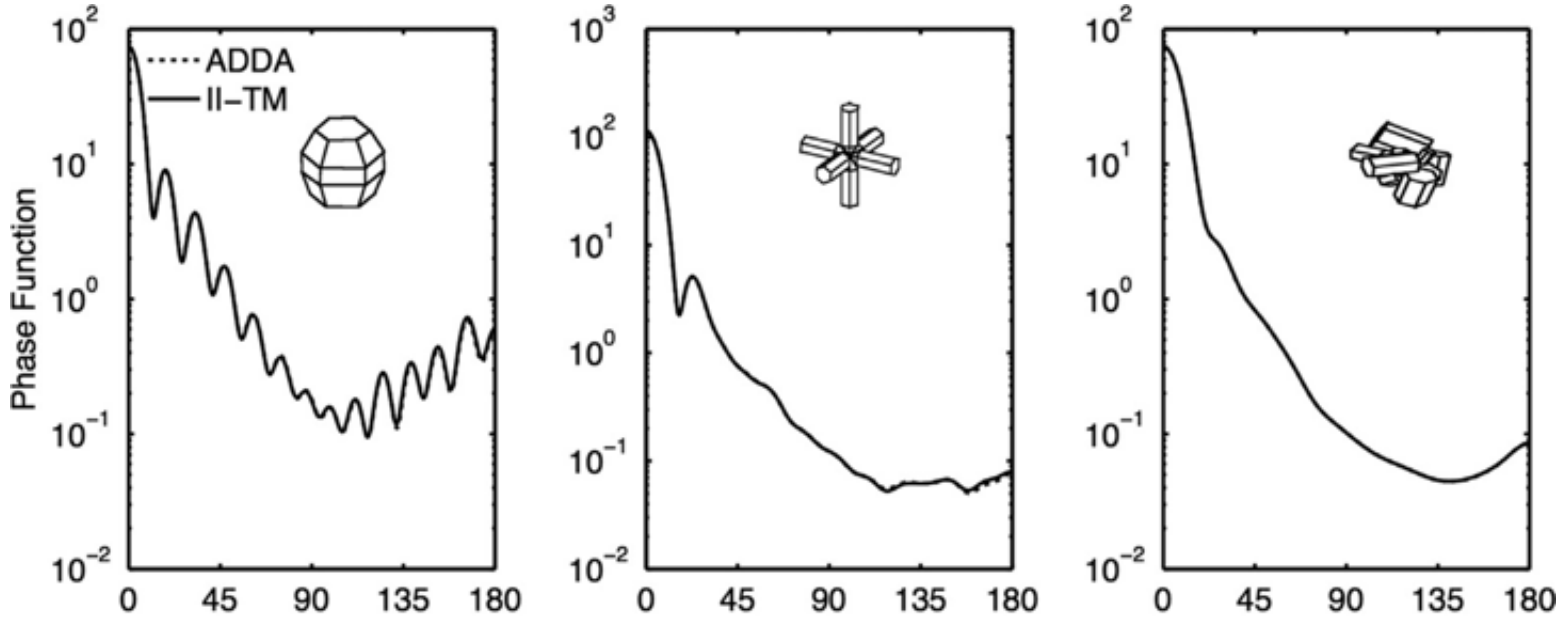
Stronger Forward Scattering

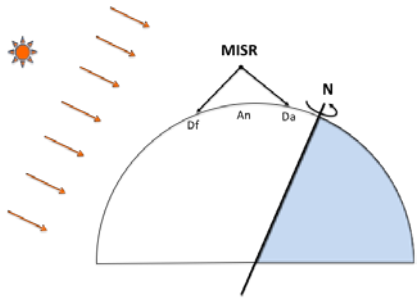


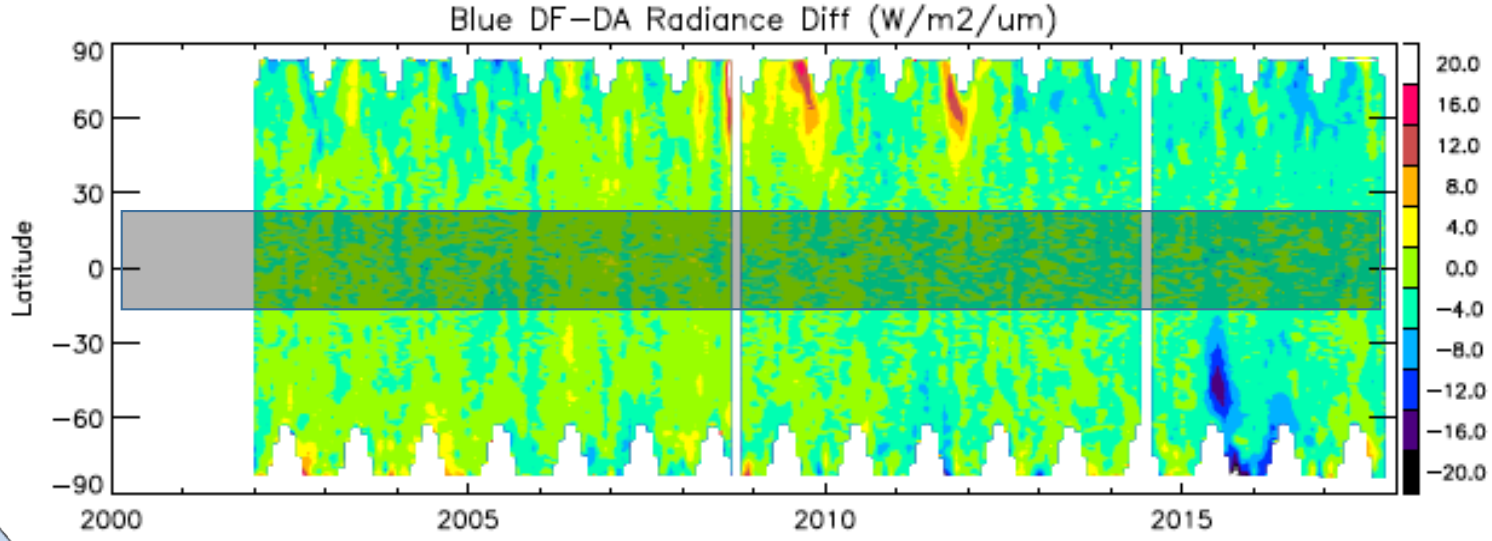


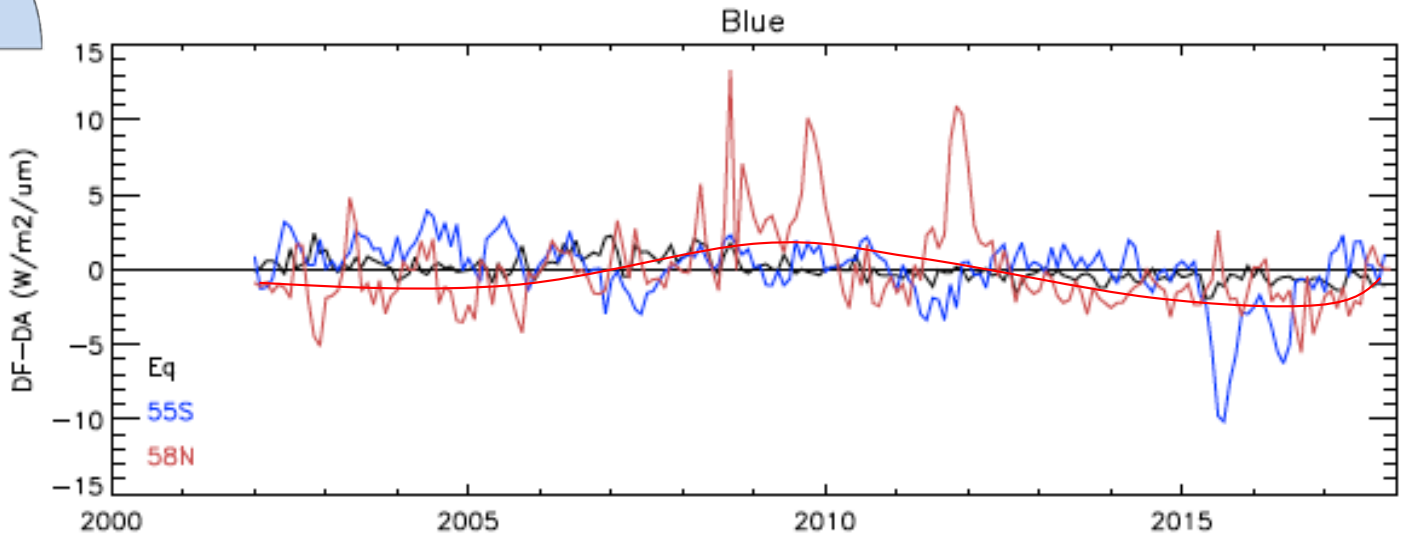
Light Scattering by Ice Crystals

(Liou and Yang, Cambridge University Press, 2016)

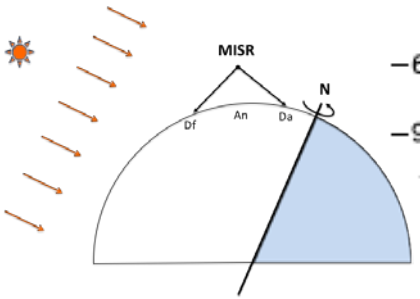


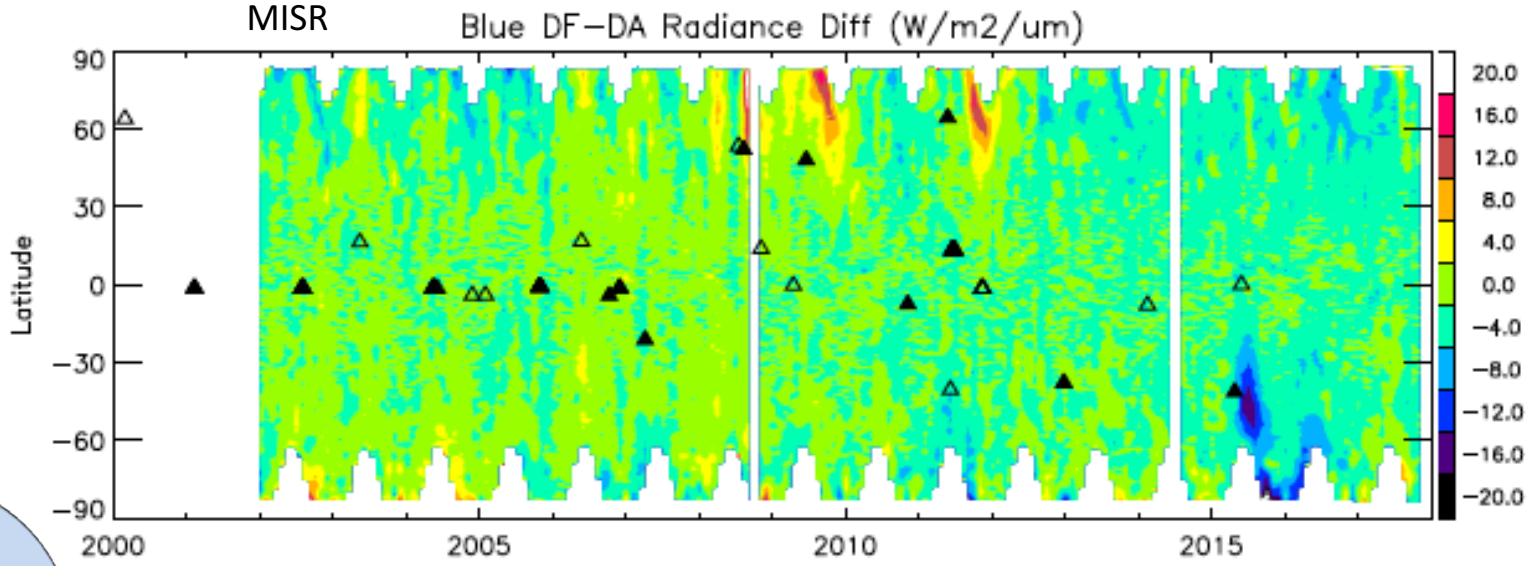

MISR
N
Df
An
Da


Blue DF−DA Radiance Diff (W/m2/um)
Latitude
90
60
30
0
−30
−60
−90
2000
2005
2010
2015
20.0
16.0
12.0
8.0
4.0
0.0
−4.0
−8.0
−12.0
−16.0
−20.0


Blue
DF−DA (W/m2/um)
15
10
5
0
−5
−10
−15
2000
2005
2010
2015
Eq
55S
58N

MISR

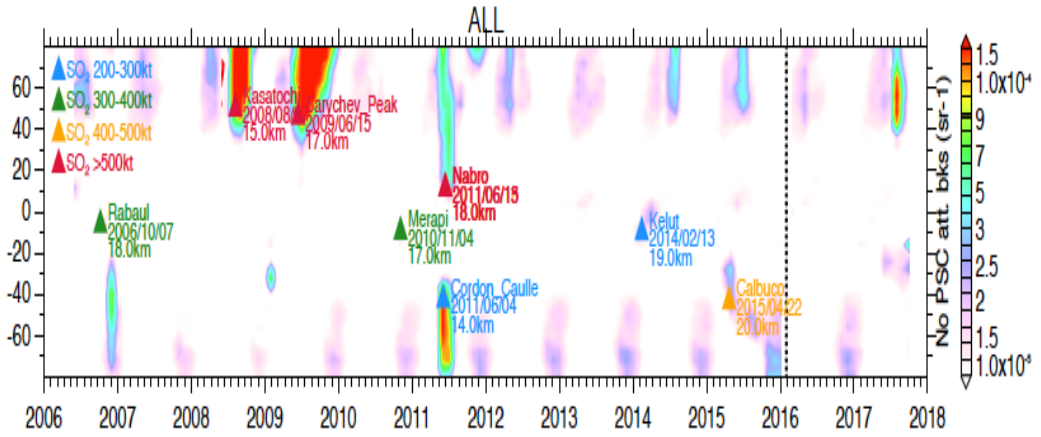




△ SO2 > 100 kt

▲ SO2 > 200 kt

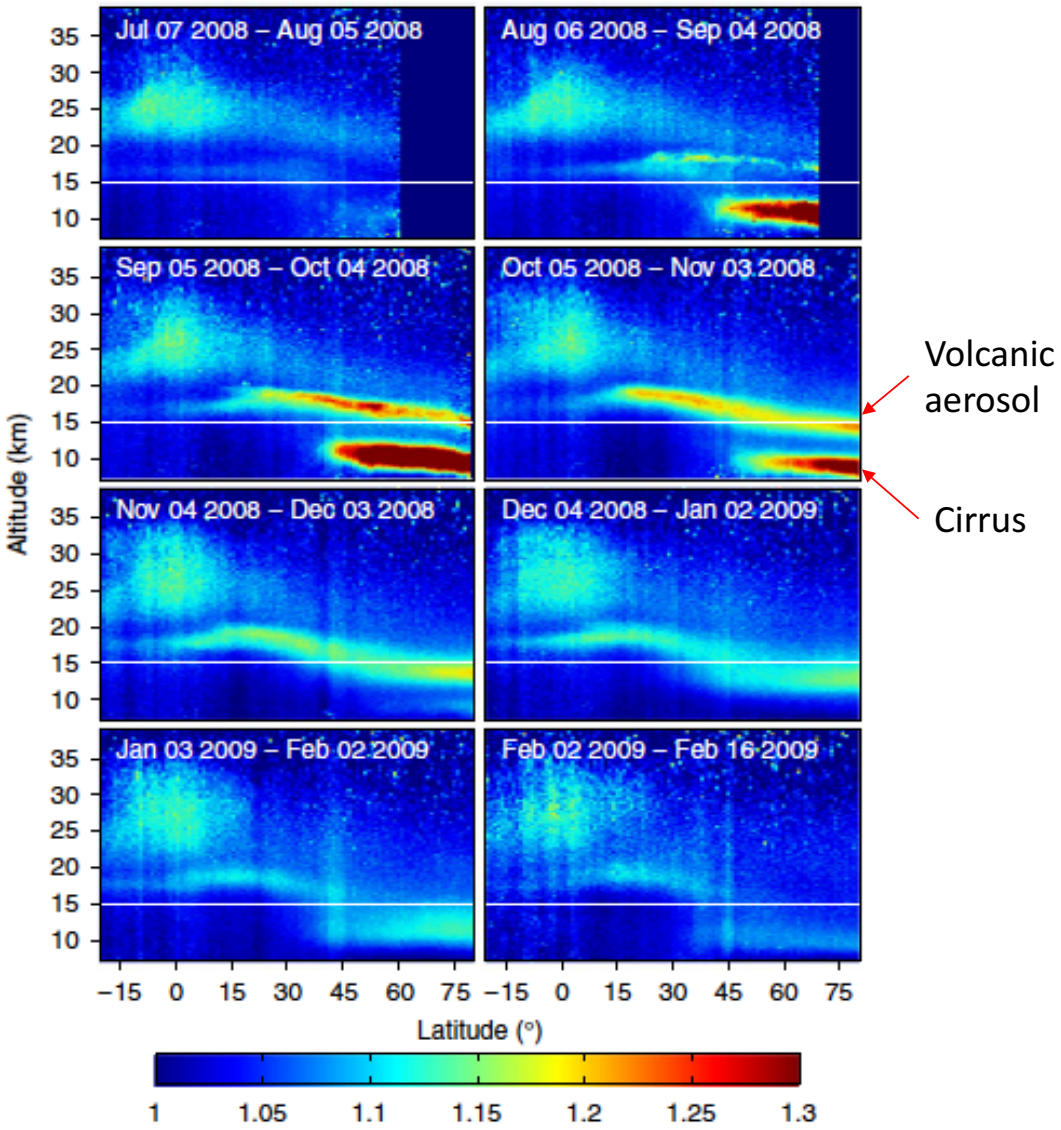
CALIPSO Integrated Backscatter above tropopause

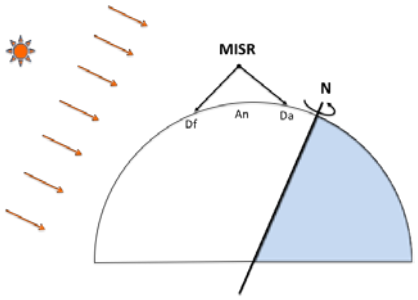


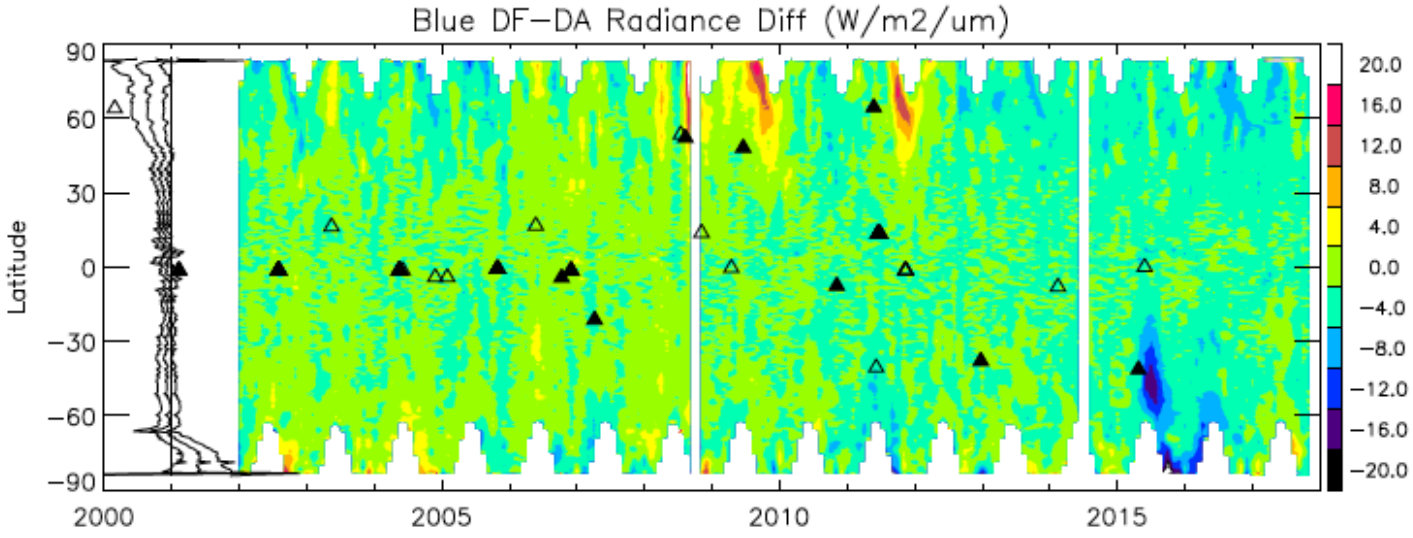
Kasatochi (Aug 7, 2008)

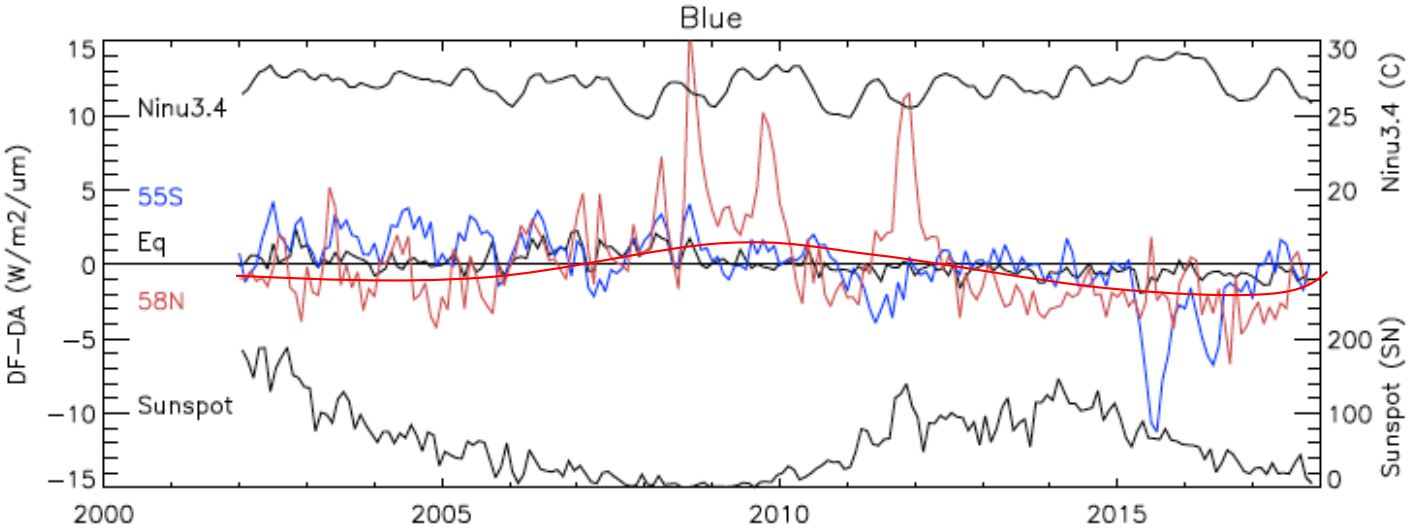
- Volcanism affects polar lower stratosphere frequently.
- Three largest eruptions between 2008-2012, Kasatochi, Sarychev and Nabro, have significant impacts in the NH lower stratosphere; and two in the SH, Merapi and Puyehue-Cordon Caulle.
- Formation of sulfate aerosol from volcanic SO2 takes place in the lower stratosphere.
- Direct volcanically-induced radiative forcing: - 0.15 W/m2

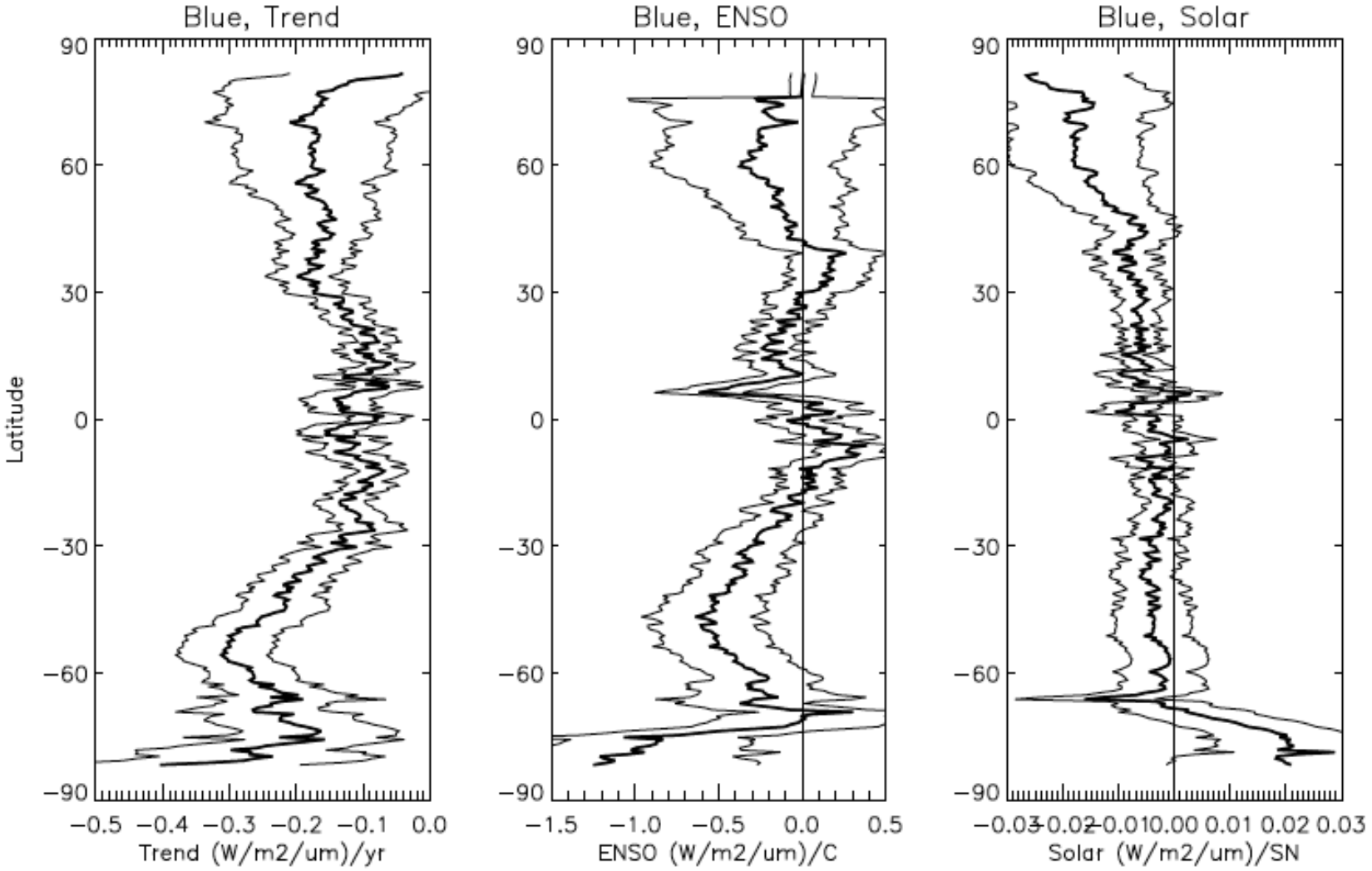
Andersson et al. (Nature Comm, 2015)

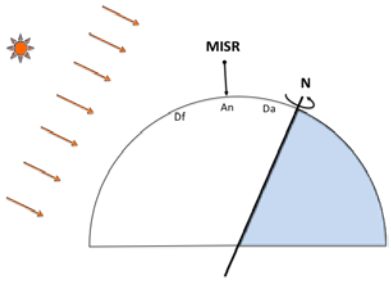


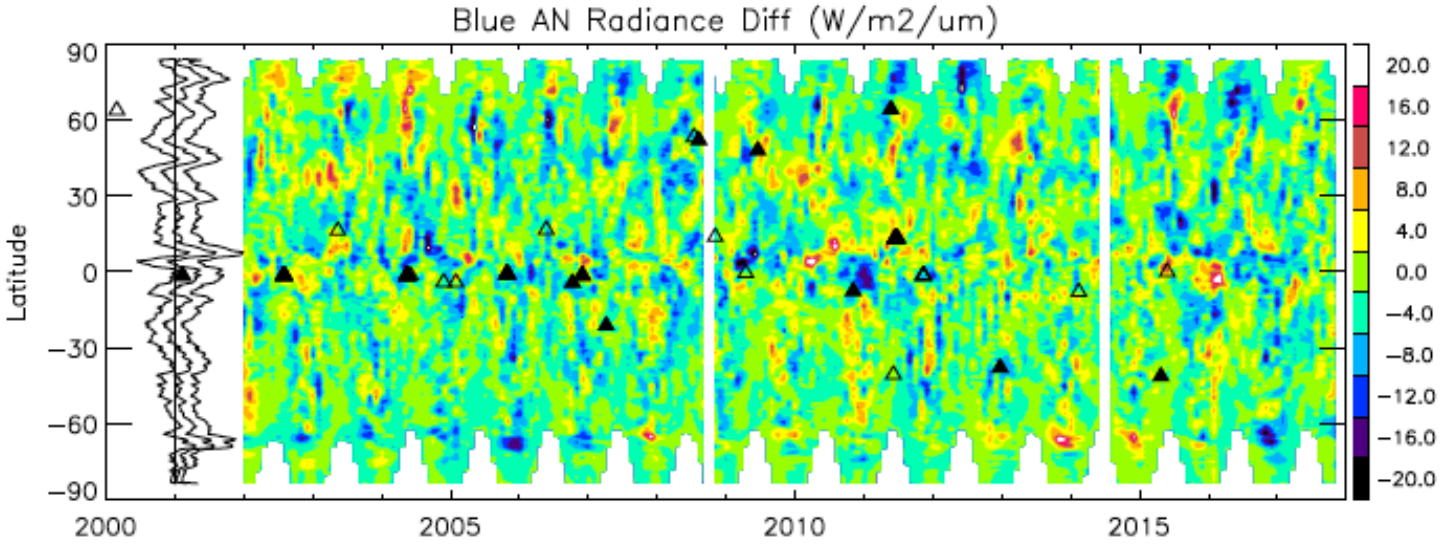

MISR
N
Df
An
Da

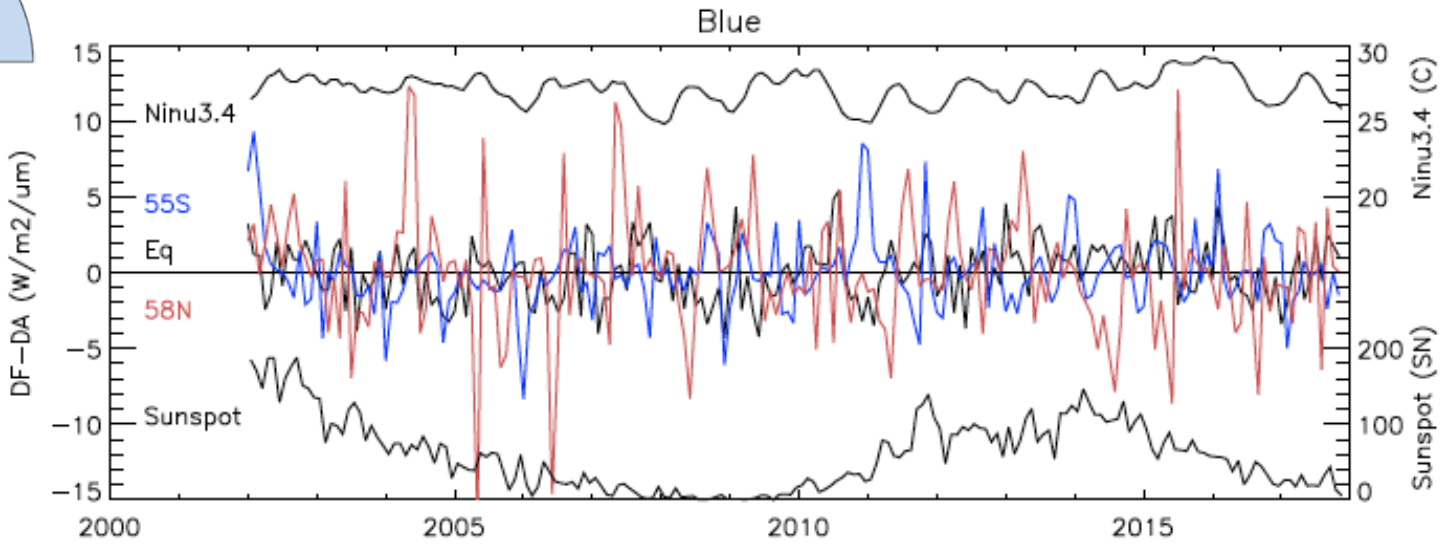

Blue DF−DA Radiance Diff (W/m2/um)
Latitude
90
60
30
0
−30
−60
−90
2000
2005
2010
2015
20.0
16.0
12.0
8.0
4.0
0.0
−4.0
−8.0
−12.0
−16.0
−20.0

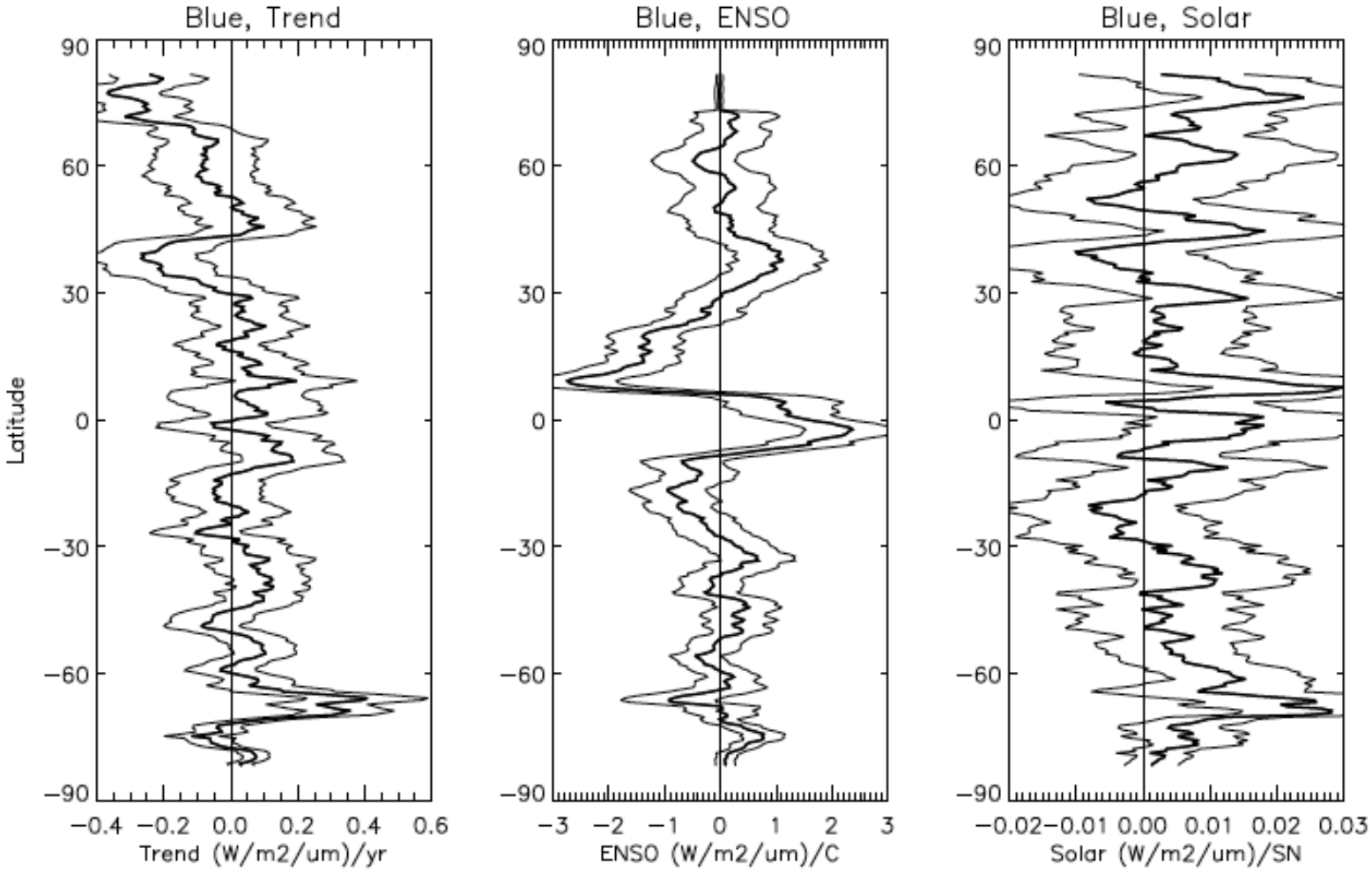

Blue
DF−DA (W/m2/um)
Ninu3.4 (C)
Sunspot (SN)
Ninu3.4
55S
Eq
58N
Sunspot
15
10
5
0
−5
−10
−15
30
25
20
200
100
0
2000
2005
2010
2015


Blue, Trend
Blue, ENSO
Blue, Solar
Latitude
90
60
30
0
−30
−60
−90
−0.5 −0.4 −0.3 −0.2 −0.1 0.0
Trend (W/m2/um)/yr
−1.5 −1.0 −0.5 0.0 0.5
ENSO (W/m2/um)/C
−0.03 −0.02 −0.01 0.00 0.01 0.02 0.03
Solar (W/m2/um)/SN


MISR
N
Df
An
Da


Blue AN Radiance Diff (W/m2/um)
Latitude
90
60
30
0
−30
−60
−90
2000
2005
2010
2015
20.0
16.0
12.0
8.0
4.0
0.0
−4.0
−8.0
−12.0
−16.0
−20.0

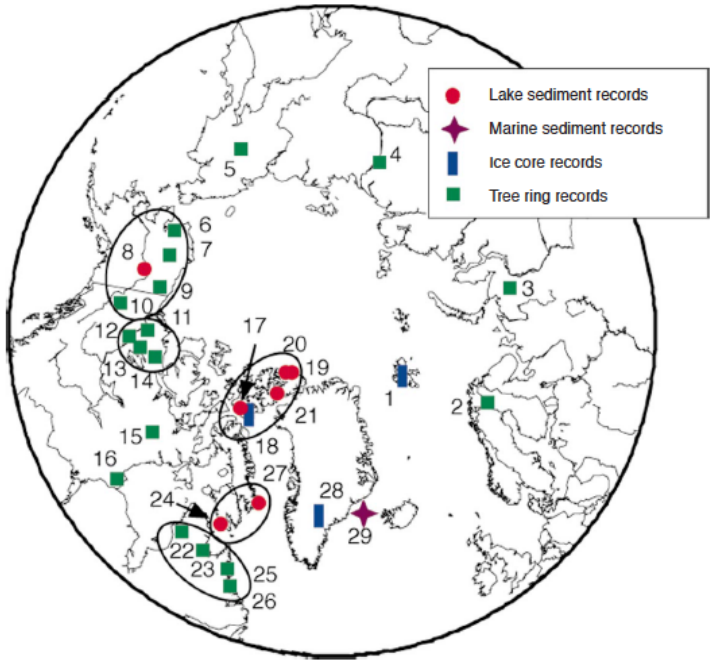

Blue
DF−DA (W/m2/um)
Ninu3.4 (C)
Sunspot (SN)
Ninu3.4
55S
Eq
58N
Sunspot
15
10
5
0
−5
−10
−15
30
25
20
200
100
0
2000
2005
2010
2015


Blue, Trend
Blue, ENSO
Blue, Solar
Latitude
90
60
30
0
−30
−60
−90
−0.4 −0.2 0.0 0.2 0.4 0.6
Trend (W/m2/um)/yr
−3 −2 −1 0 1 2 3
ENSO (W/m2/um)/C
−0.02 −0.01 0.00 0.01 0.02 0.03
Solar (W/m2/um)/SN

Summary

- MISR DF-DA radiance differences are useful for monitoring aerosol/cloud changes at latitudes of 30° poleward.
- Volcanic aerosols may affect cloudiness at mid-to-high latitudes for several months after eruption.
- Solar cycle signals appear to be significant at high latitudes in MISR DF-DA radiance differences.
- MISR/MODIS CFbH (cloud fraction by height), albedo, and single-view radiance products are not sensitive to volcanic aerosols, but strongly correlated with ENSO in the tropics/subtropics.

- 400-year Arctic paleoclimate record of surface temperature;
- Important factors in mid-19th century: increased solar irradiance, decreased volcanic activity, and internal feedback processes.



Overpeck et al. (1997)