A 38 year record of UV cloud albedo from UV sensing instruments: inter-satellite calibration, trends and response in cloudiness during El Nino events

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CGMS International Cloud Working Group
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Introduction Quantifying global cloudiness is critical to understanding Earth's radiation budget and validating climate model feedbacks.

We present a 37-year record of cloudiness from the NOAA /NASA UV (331-380nm) sensing satellite instruments.

The backbone of our record is the suite of **S**olar **B**ackscatter in the **UV** (SBUV) instruments:

Nimbus-7, NOAA-9, 11, 14, 16, 17, 18 and 19. (Nadir only)

When available we include measurements from the Nimbus-7 TOMS, **E**arth **P**robe (EP) TOMS and the **O**zone **M**apper **P**rofiler **S**uite (OMPS-Mapper) (Scanning – off Nadir)

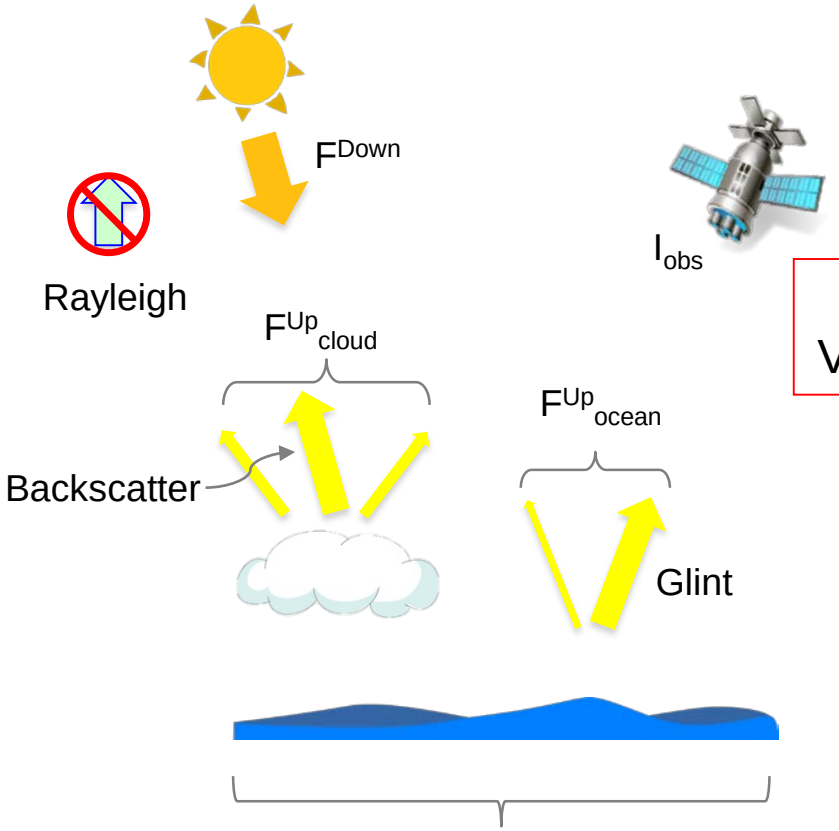
$$\text{Hemispheric Cloud Albedo} = \frac{F^{up}}{F^{Down}} * 100$$

F^{Down} = TOA Downward Flux

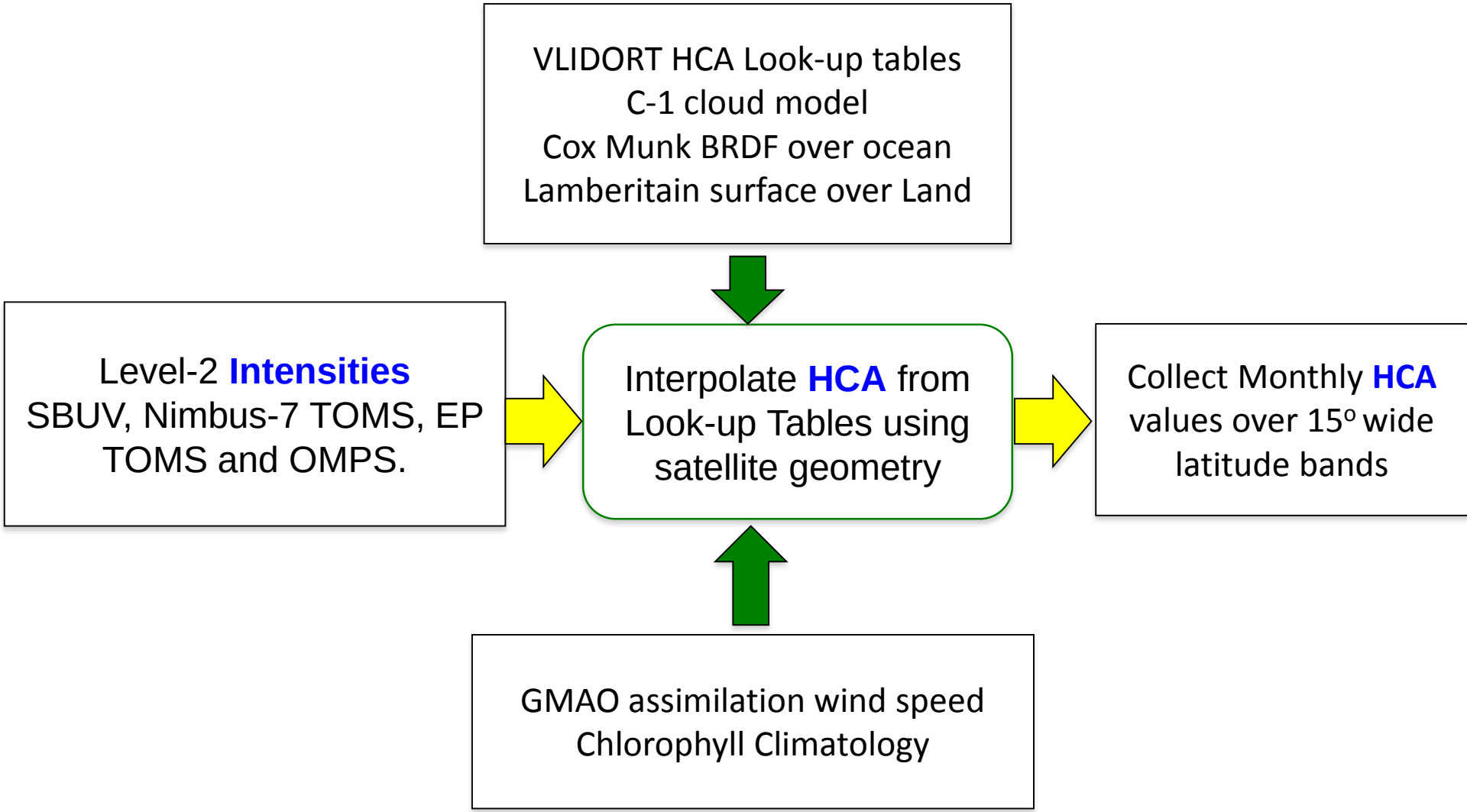
F^{Up}_{cloud} = Hemispherically integrated Upward Flux from clouds

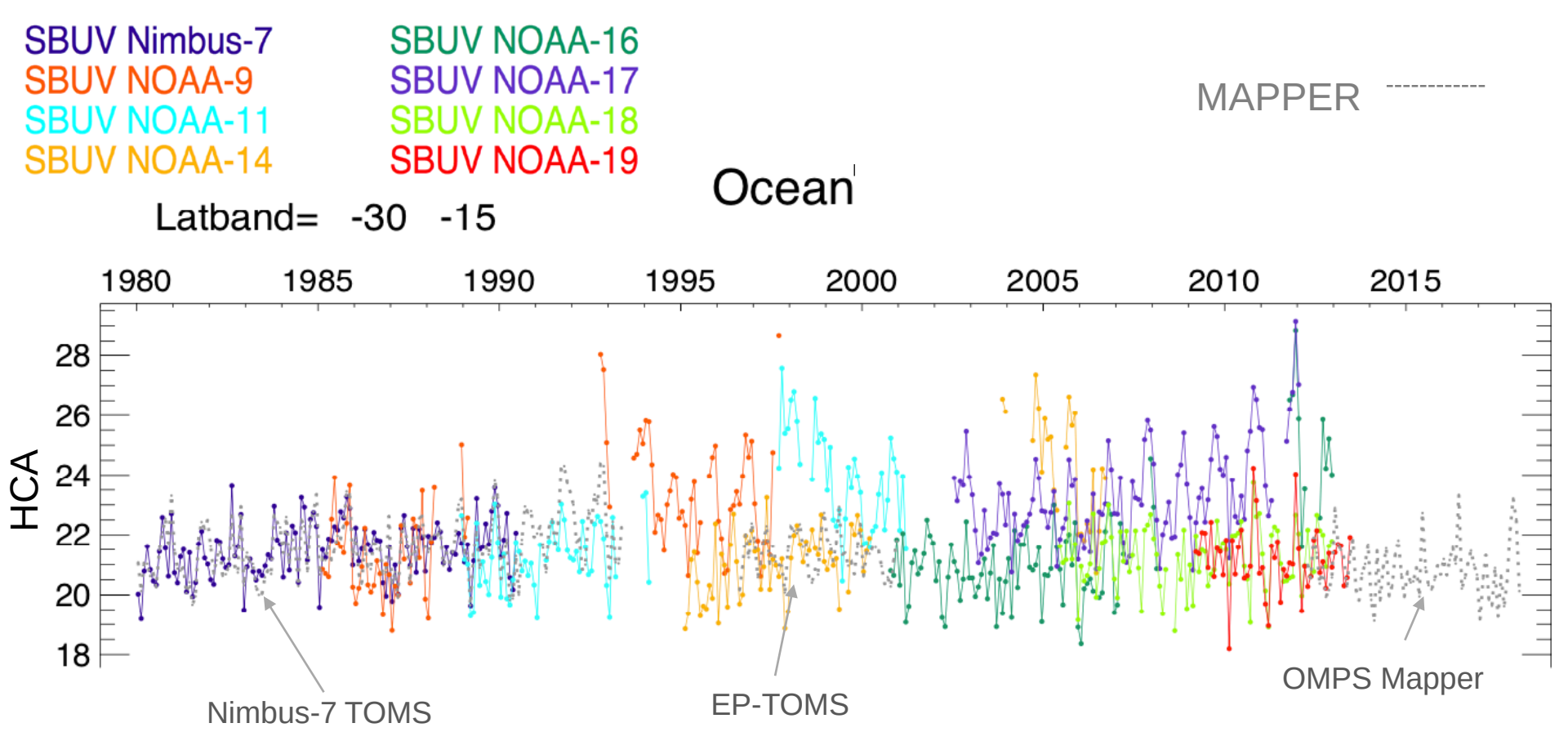
F^{Up}_{ocean} = Hemispherically integrated Upward Flux from ocean surface

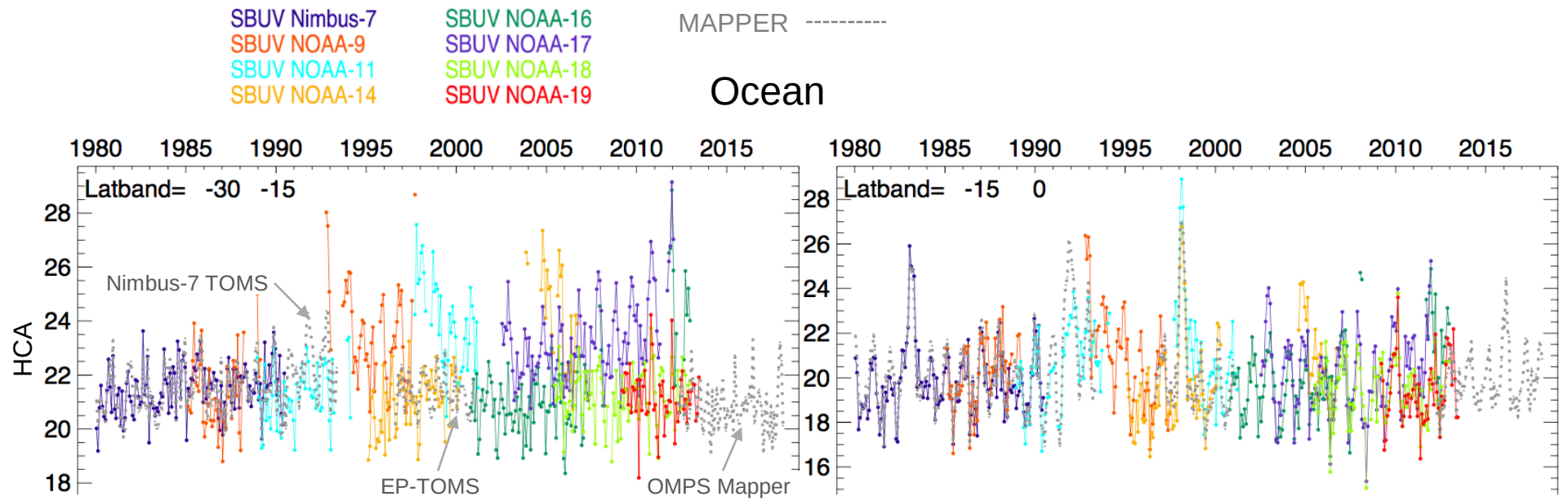
I_{obs} = Intensity observed by satellite instrument

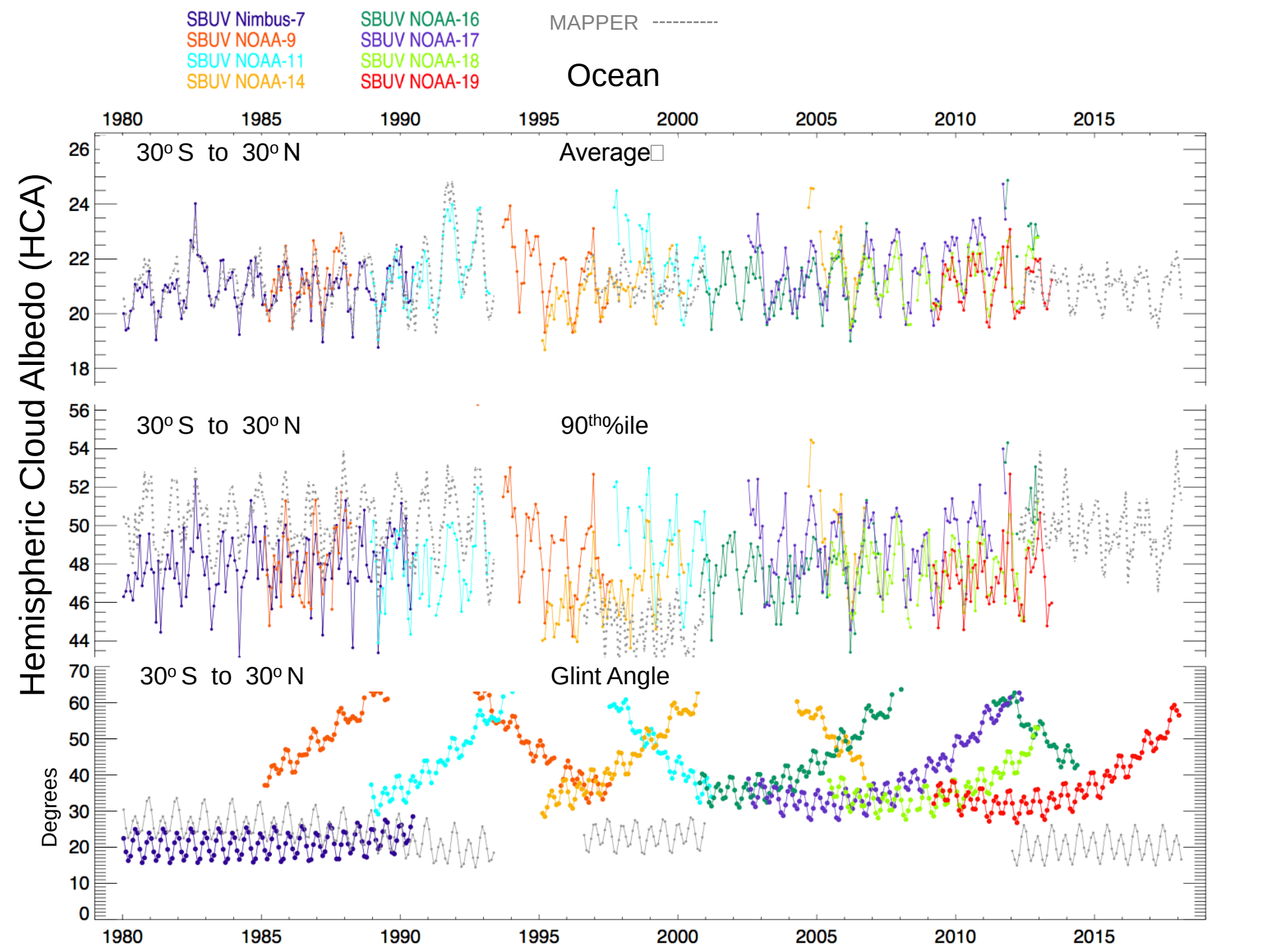


I_{obs} at 340 nm
Very small O_3 absorption

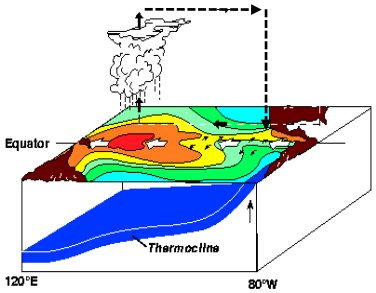

VLIDORT HCA Look-up tables
C-1 cloud model
Cox Munk BRDF over ocean
Lamberitain surface over Land
Level-2 Intensities
SBUV, Nimbus-7 TOMS, EP TOMS and OMPS.
Interpolate HCA from Look-up Tables using satellite geometry
Collect Monthly HCA values over 15° wide latitude bands
GMAO assimilation wind speed
Chlorophyll Climatology


SBUV Nimbus-7
SBUV NOAA-9
SBUV NOAA-11
SBUV NOAA-14
SBUV NOAA-16
SBUV NOAA-17
SBUV NOAA-18
SBUV NOAA-19
MAPPER
Ocean
Latband= -30 -15
1980
1985
1990
1995
2000
2005
2010
2015
HCA
28
26
24
22
20
18
Nimbus-7 TOMS
EP-TOMS
OMPS Mapper

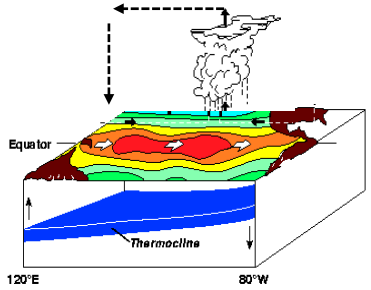

SBUV Nimbus-7
SBUV NOAA-9
SBUV NOAA-11
SBUV NOAA-14
SBUV NOAA-16
SBUV NOAA-17
SBUV NOAA-18
SBUV NOAA-19
MAPPER ----------
Ocean
HCA
Latband= -30 -15
Latband= -15 0
Nimbus-7 TOMS
EP-TOMS
OMPS Mapper
1980
1985
1990
1995
2000
2005
2010
2015
16
18
20
22
24
26
28


SBUV Nimbus-7
SBUV NOAA-9
SBUV NOAA-11
SBUV NOAA-14
SBUV NOAA-16
SBUV NOAA-17
SBUV NOAA-18
SBUV NOAA-19
MAPPER ----------
Ocean
Hemispheric Cloud Albedo (HCA)
30° S to 30° N
Average
90thO%ile
Glint Angle
Degrees
1980
1985
1990
1995
2000
2005
2010
2015

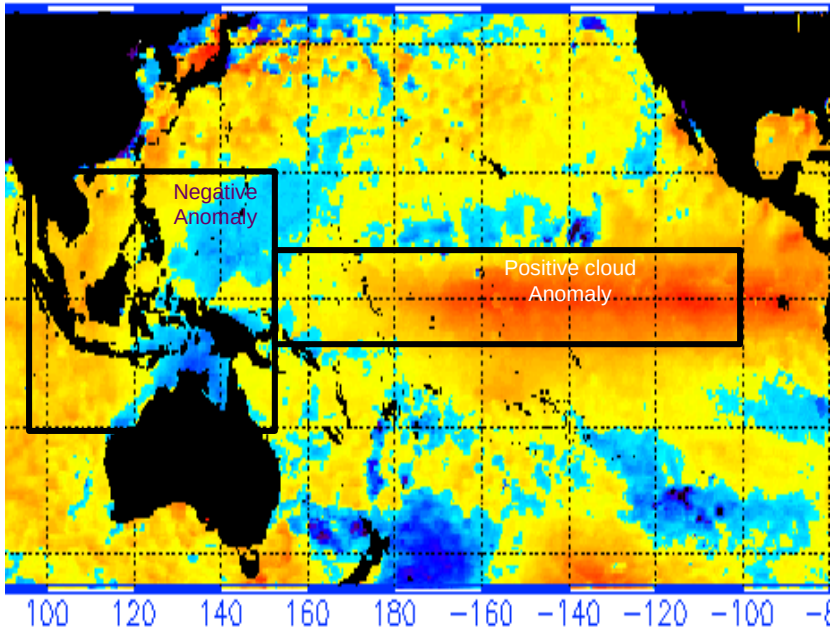
Neutral Conditions

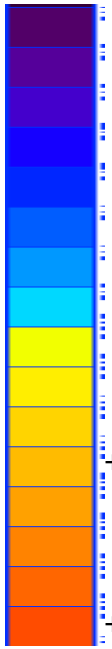


El Nino Conditions

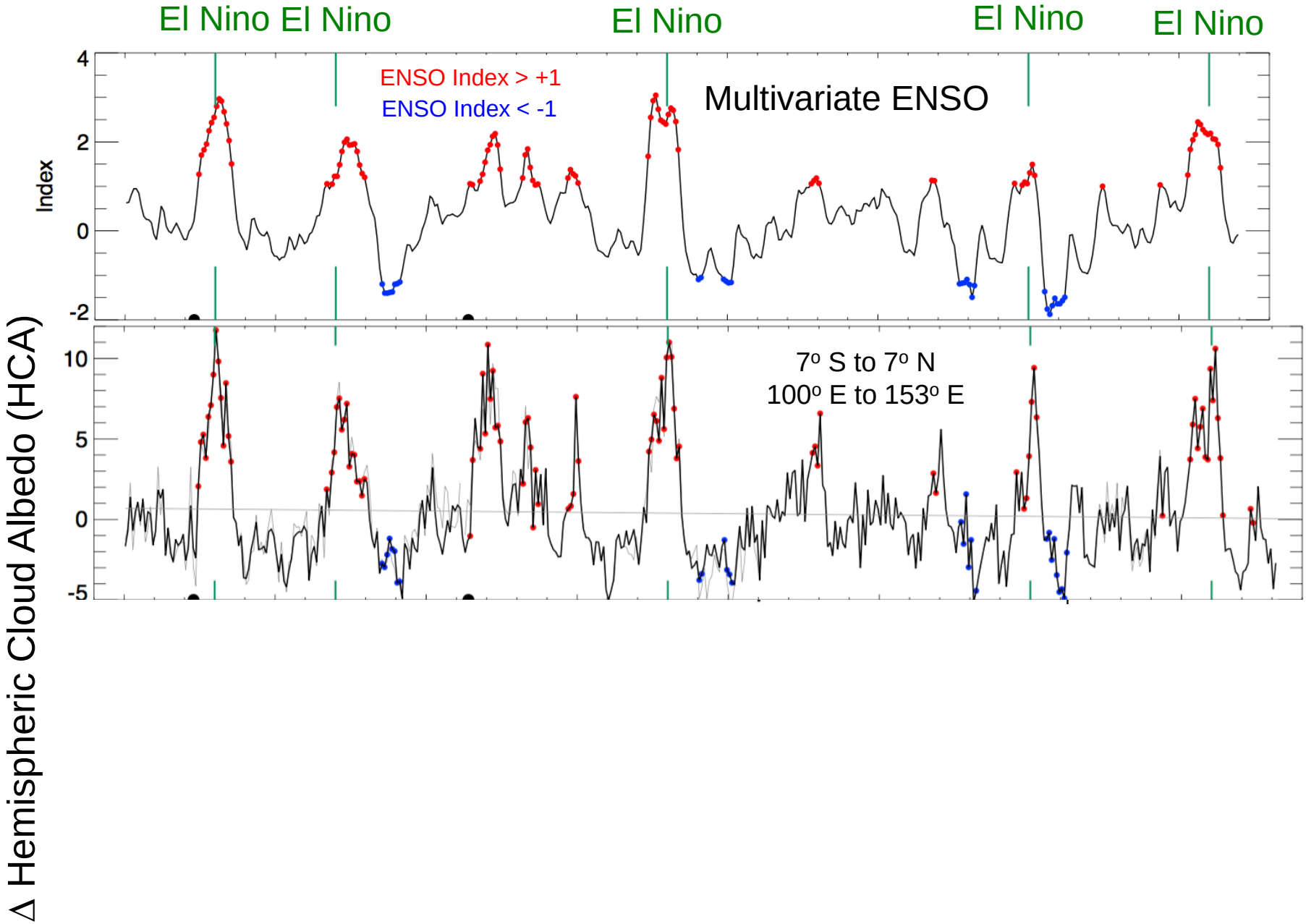


NOAA/NESDIS
SST (C) Anomaly Jan 2016

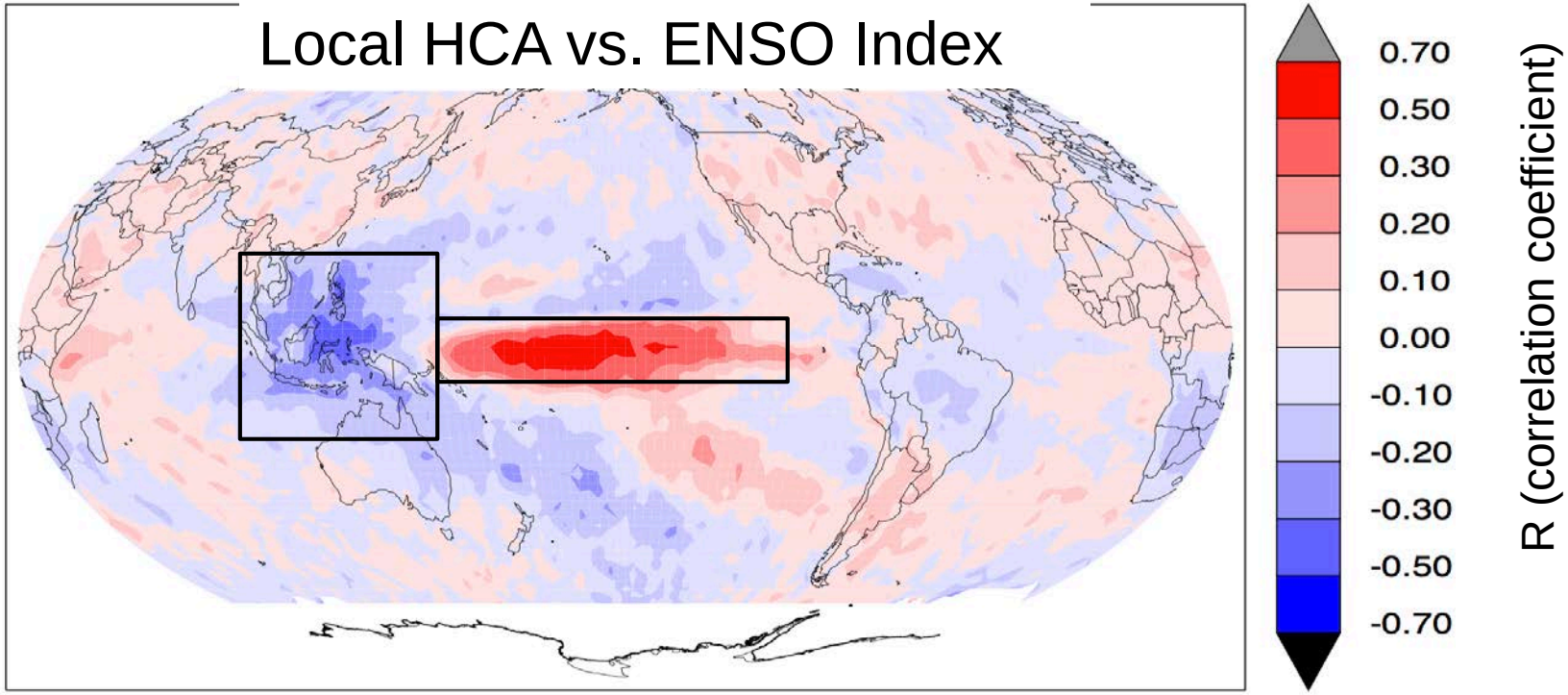




C

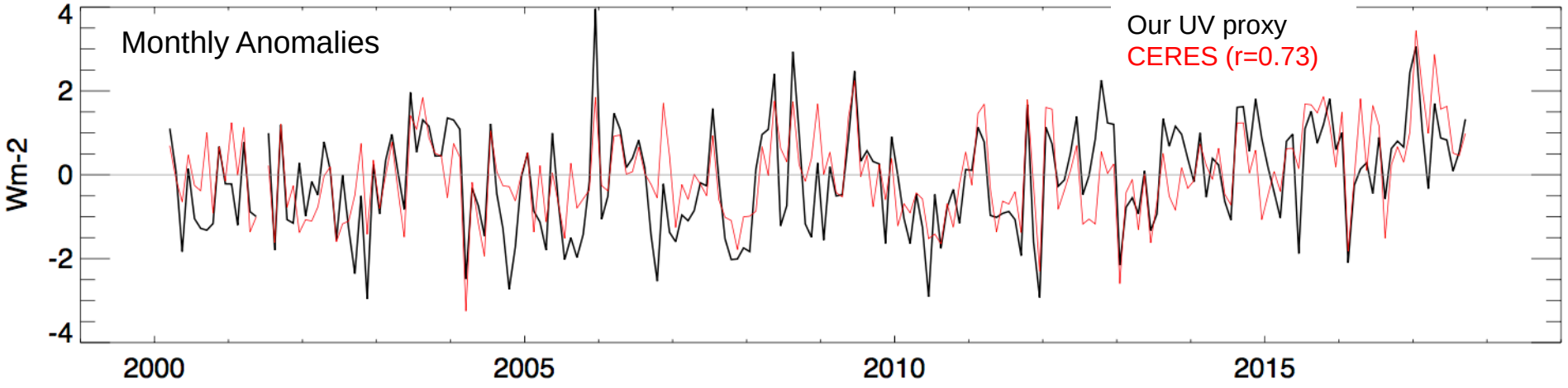

El Nino El Nino
El Nino
El Nino
El Nino
ENSO Index > +1
ENSO Index < -1
Multivariate ENSO
Index
4
2
0
-2
7º S to 7º N
100º E to 153º E
10
5
0
-5
Δ Hemispheric Cloud Albedo (HCA)

Local HCA vs. ENSO Index



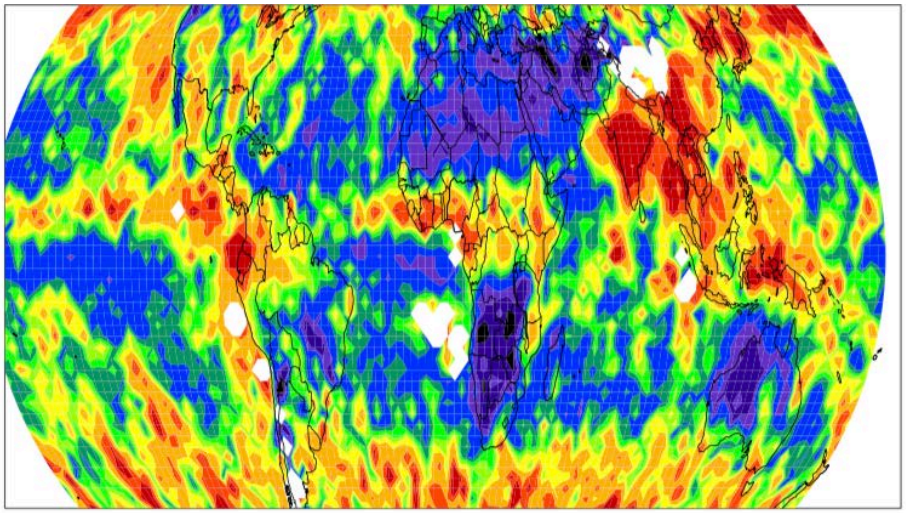
Comparison with CERES SW

SW Cloud albedo forcing Ocean 30ºN – 30ºS

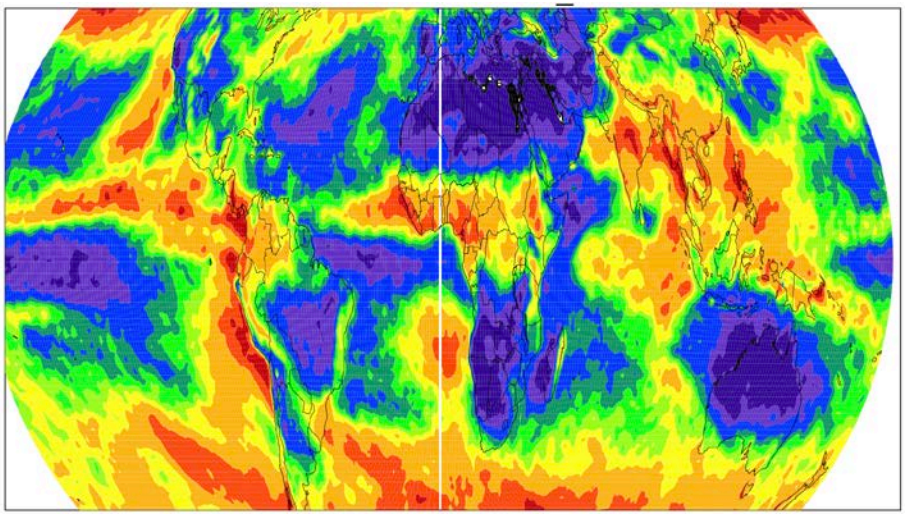


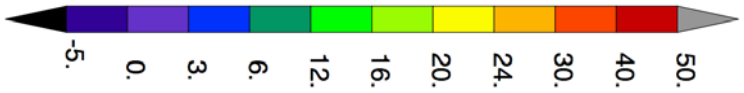
UV Hemispheric Cloud Albedo July 2013

SBUV (150km FOV)



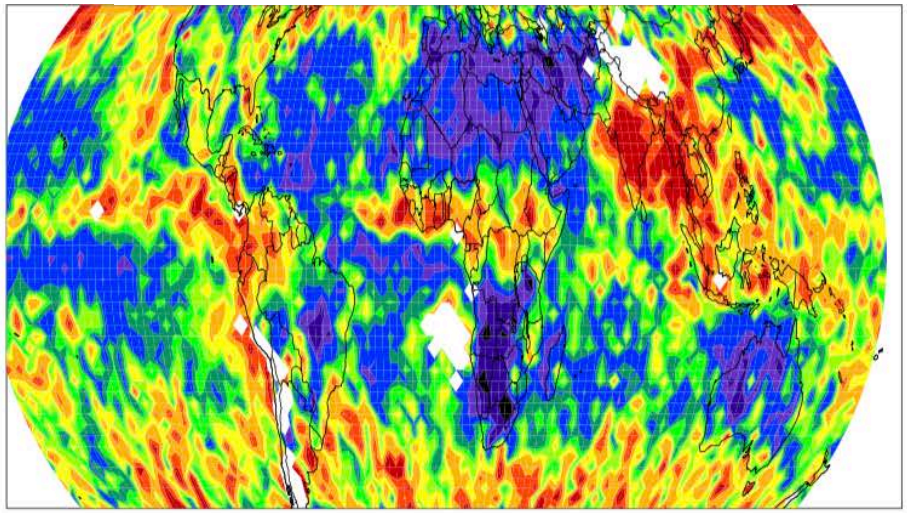
CERES SW cloud forcing (scaled to UV) 2013-07



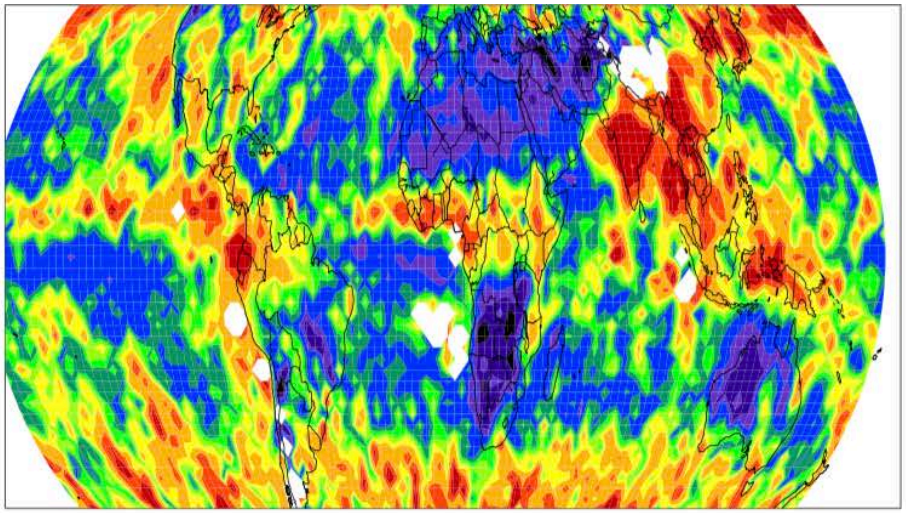


UV Hemispheric Cloud Albedo July 2013

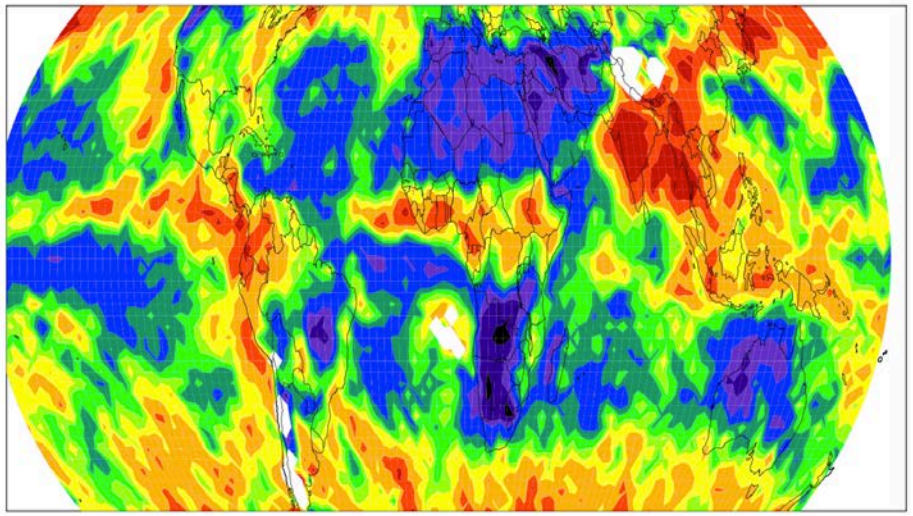
OMPS HCA nadir only



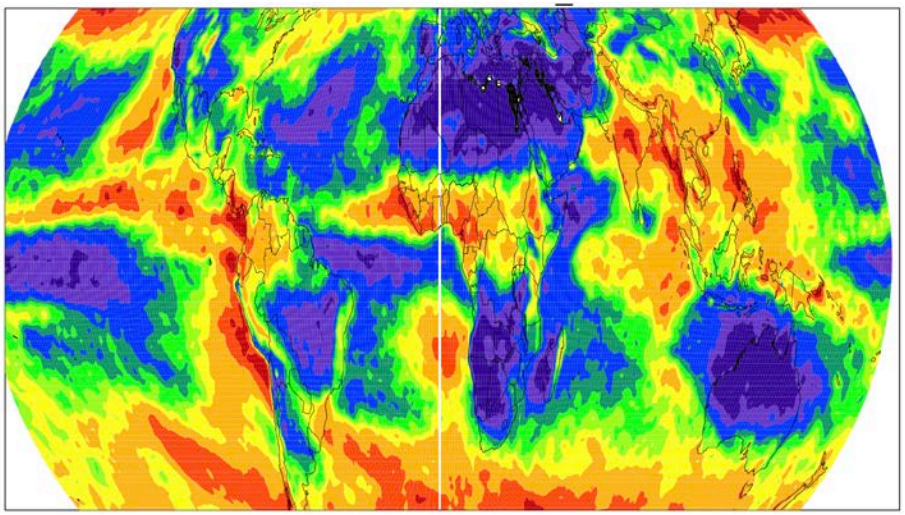
SBUV (150km FOV)

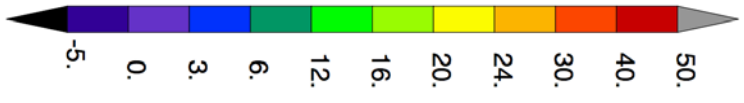


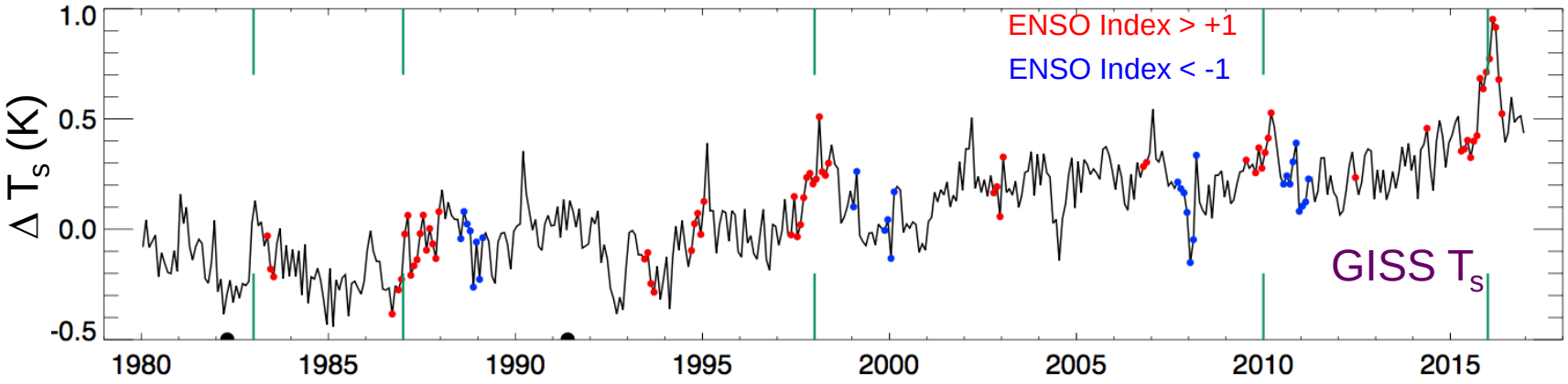
OMPS HCA off-nadir scans



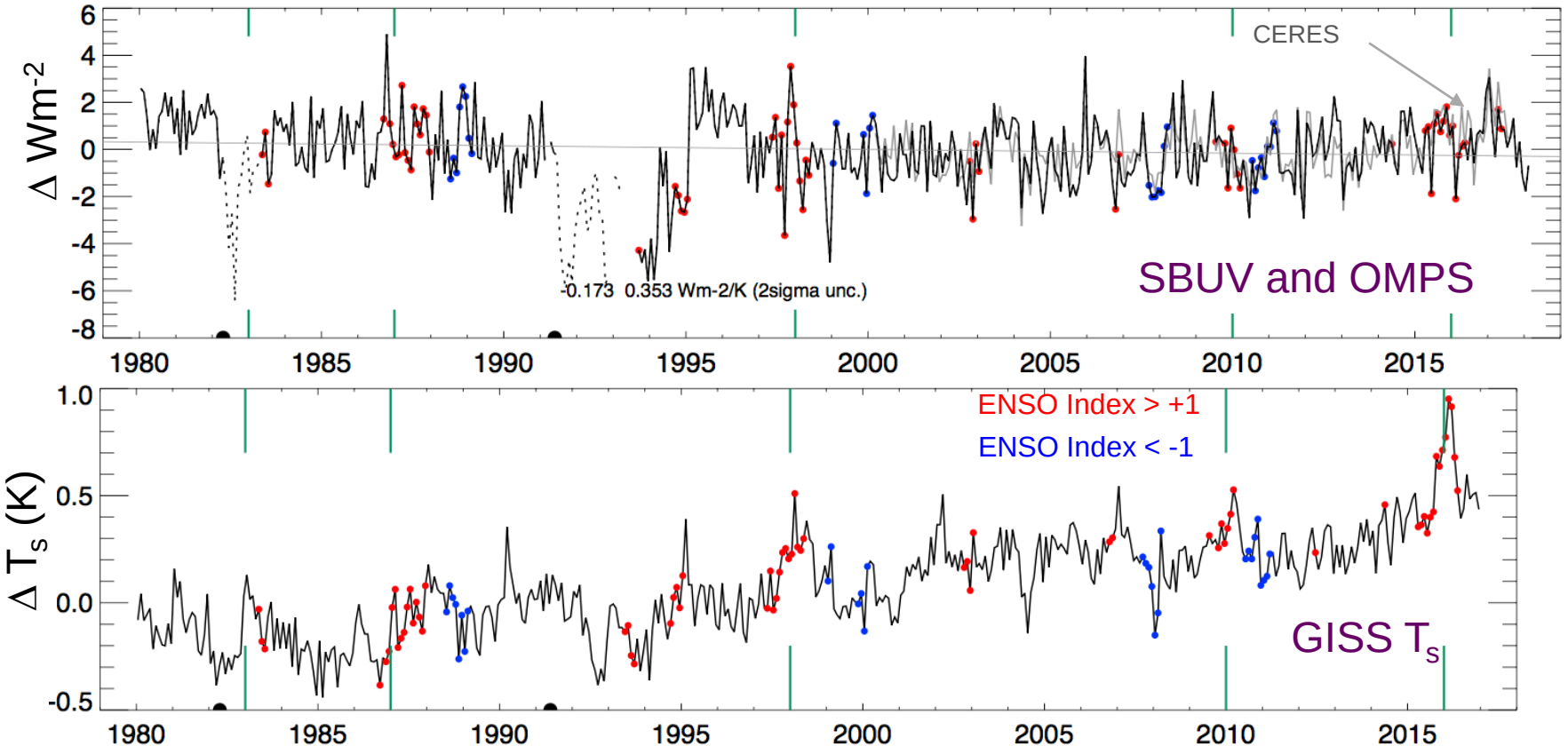
CERES SW cloud forcing (scaled to UV) 2013-07





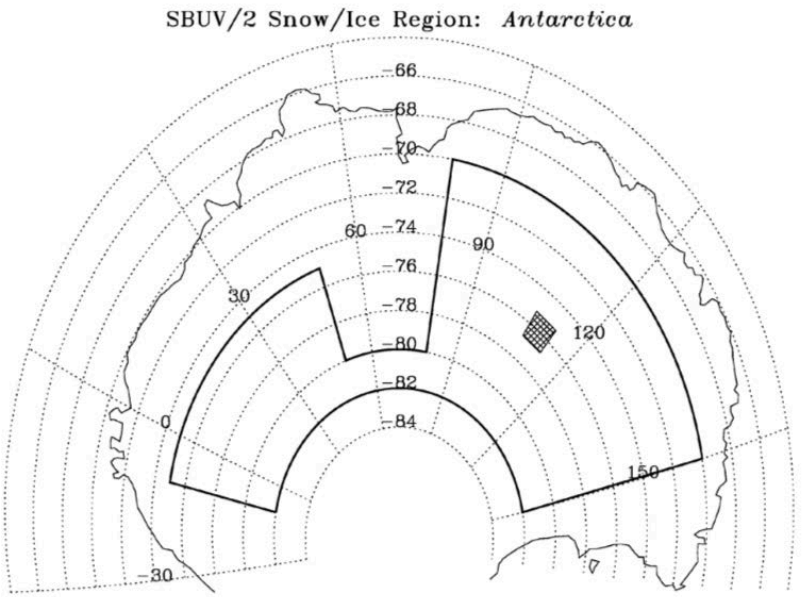

ENSO Index > +1
ENSO Index < -1
GISS T_S
ΔT_S (K)
1.0
0.5
0.0
-0.5
1980
1985
1990
1995
2000
2005
2010
2015

Ocean SW Cloud albedo forcing 30°N – 30°S



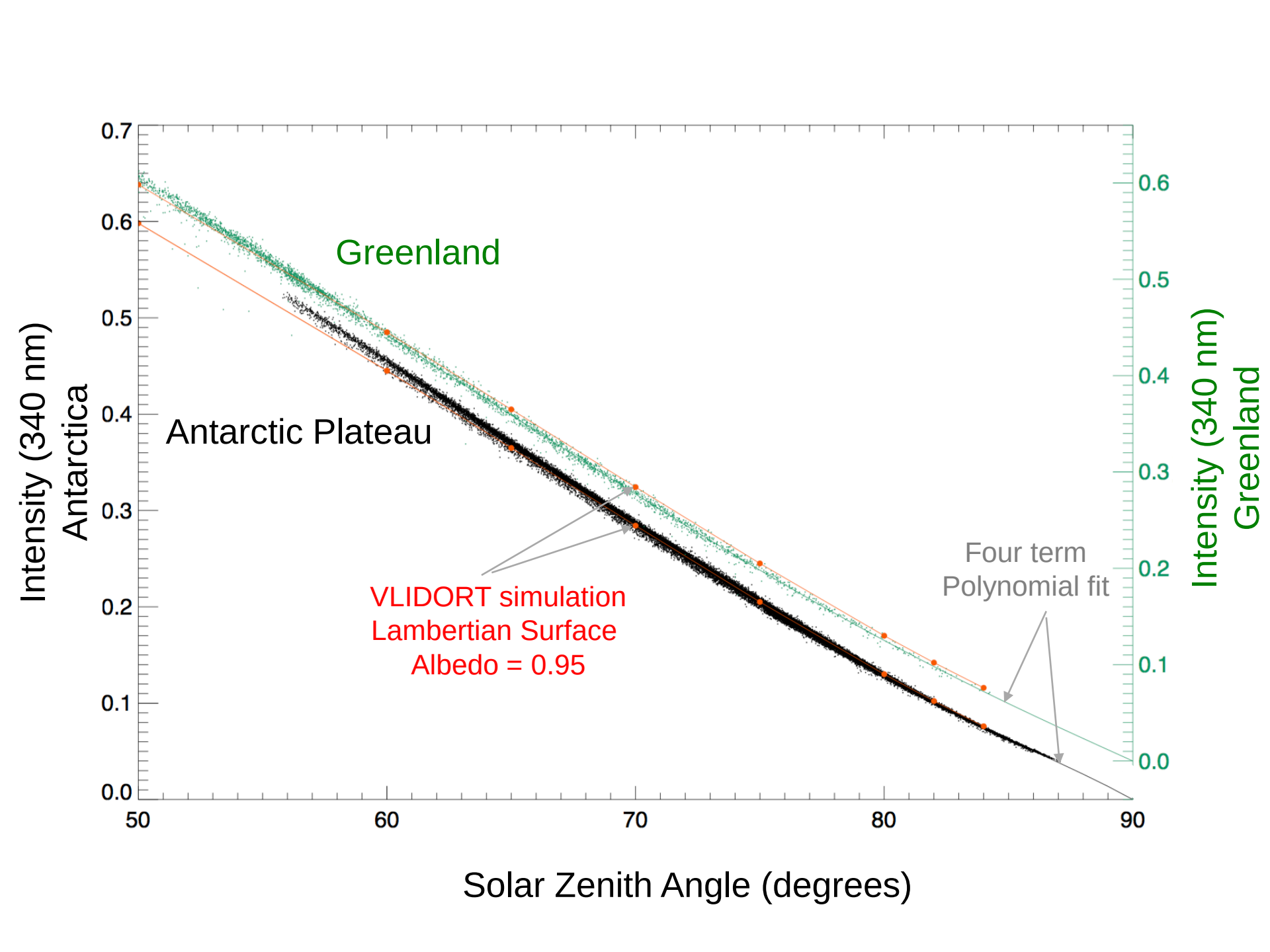
Calibration

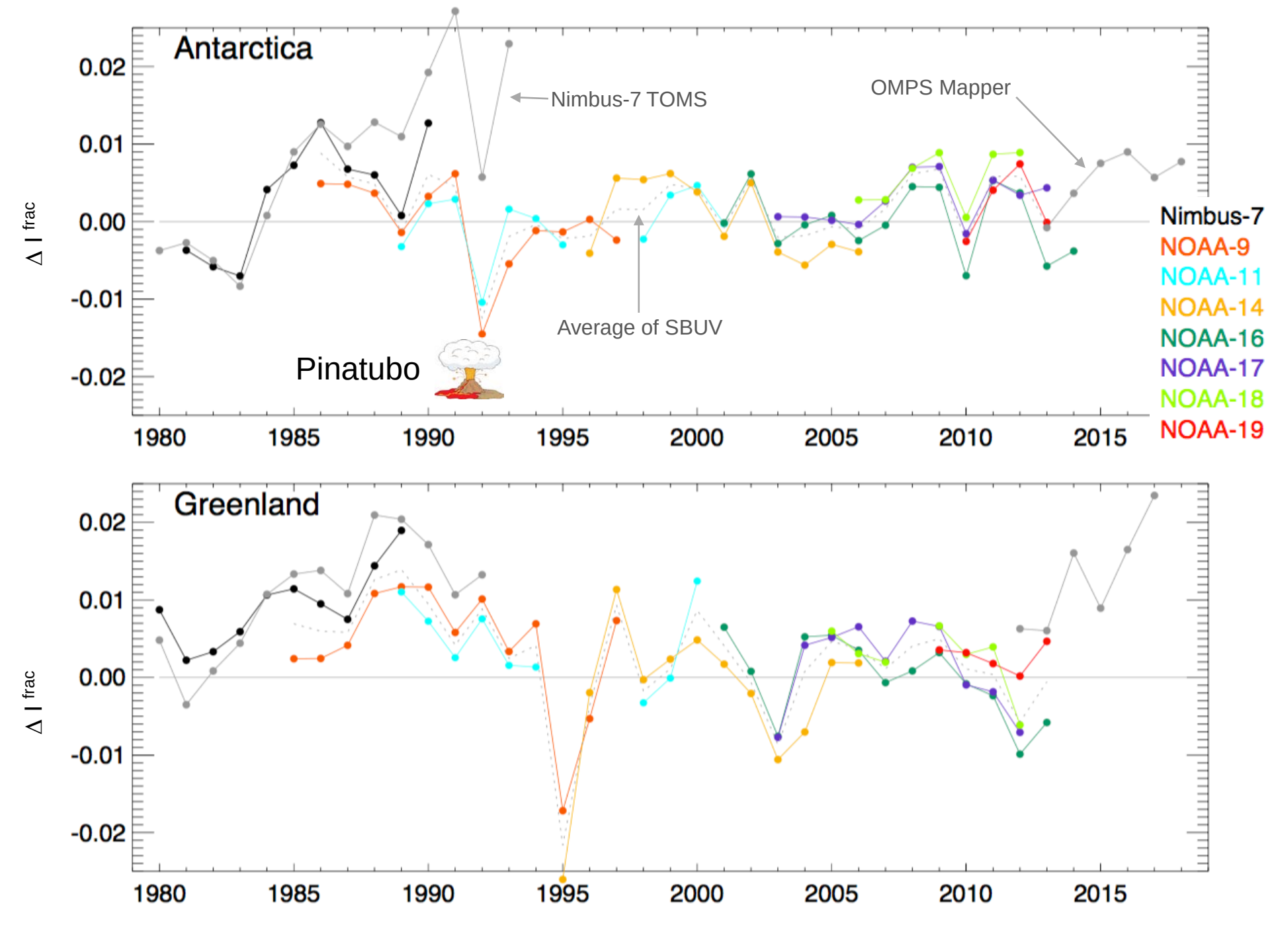
1. East Antarctic Plateau

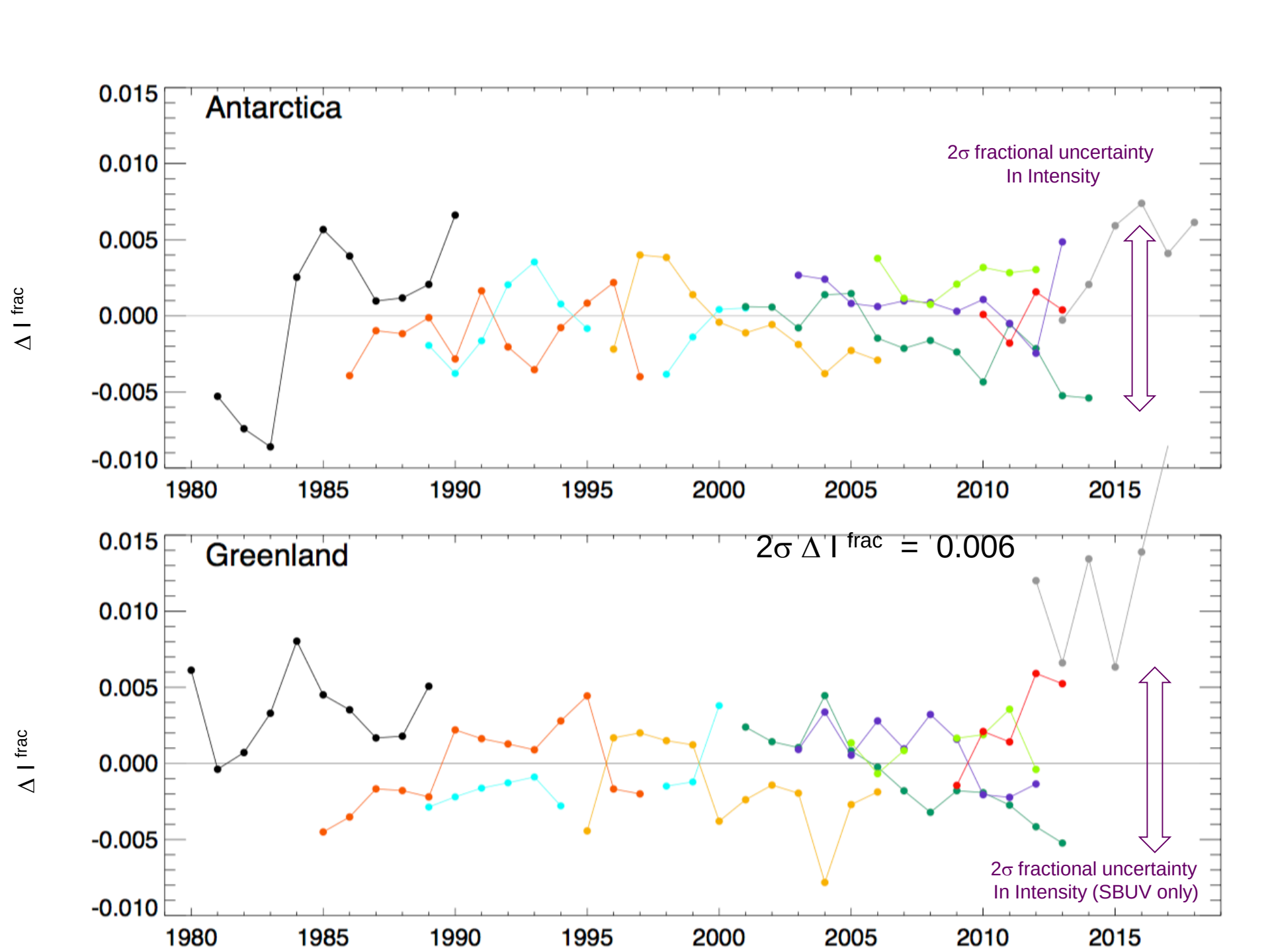


2. Cloud and Aerosol free Ocean scenes

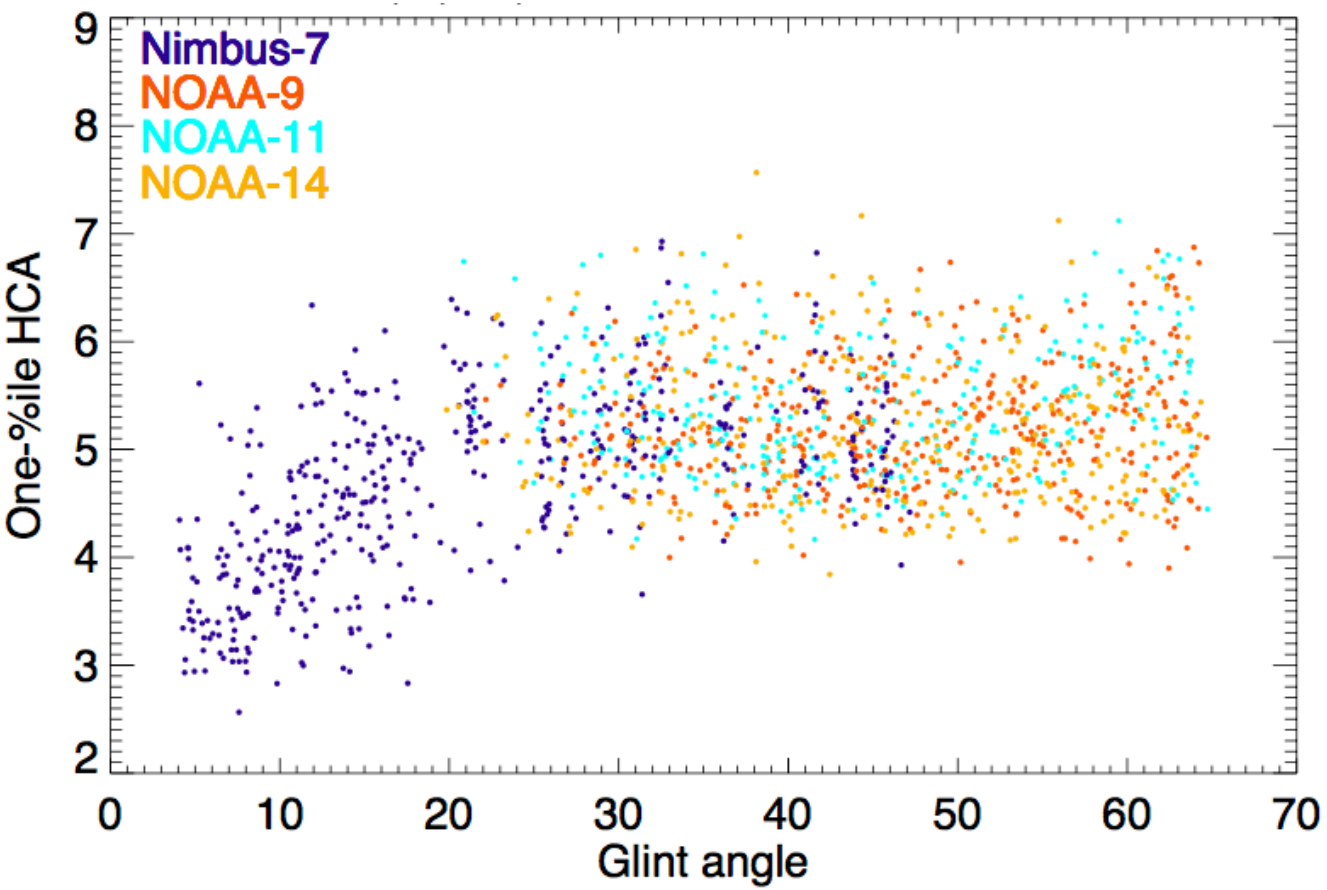
- One percentile values of collection of monthly pixels over 15 degree latitude bands.
- Pacific Ocean only


Greenland
Antarctic Plateau
VLIDORT simulation
Lambertian Surface
Albedo = 0.95
Four term
Polynomial fit
Intensity (340 nm)
Antarctica
Intensity (340 nm)
Greenland
Solar Zenith Angle (degrees)
0.0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
50
60
70
80
90


Antarctica
Nimbus-7 TOMS
OMPS Mapper
Average of SBUV
Pinatubo
Nimbus-7
NOAA-9
NOAA-11
NOAA-14
NOAA-16
NOAA-17
NOAA-18
NOAA-19
Δ I frac
0.02
0.01
0.00
-0.01
-0.02
1980
1985
1990
1995
2000
2005
2010
2015
Greenland
Δ I frac
0.02
0.01
0.00
-0.01
-0.02
1980
1985
1990
1995
2000
2005
2010
2015


Antarctica
2σ fractional uncertainty
In Intensity
Δ I frac
0.015
0.010
0.005
0.000
-0.005
-0.010
1980
1985
1990
1995
2000
2005
2010
2015
Greenland
2σ Δ I frac = 0.006
2σ fractional uncertainty
In Intensity (SBUV only)

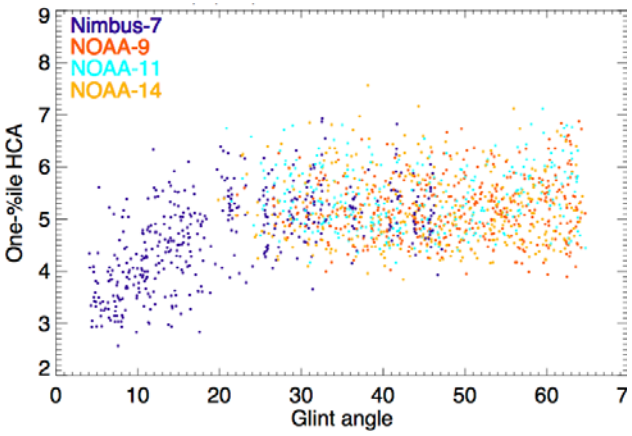
Calibration of early SBUV instruments over Ocean



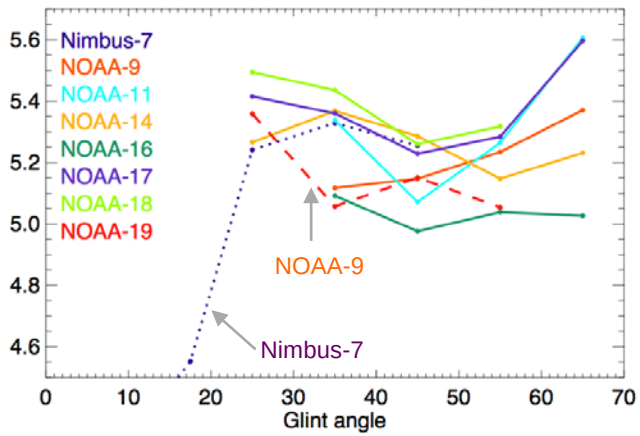
Each point is derived from statistics from one month of observations over 15 latitude band

Calibration of SBUV and Mapper instruments over Ocean

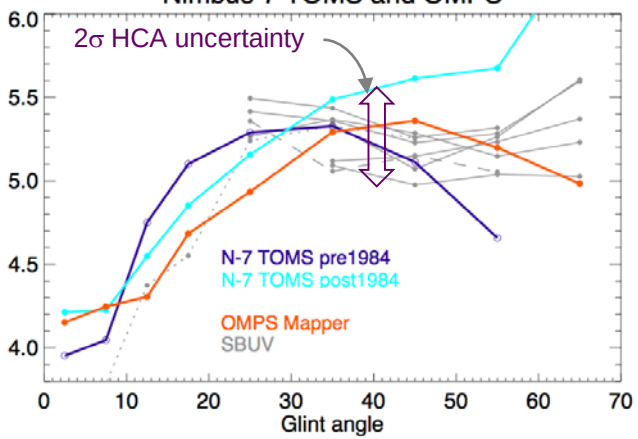
Early SBUV



All SBUV



Nimbus-7 TOMS and OMPS



2σ HCA = 0.54 -> 0.0052 Δ I ^{frac}

Conclusions

The newly-calibrated UV 340nm radiances, produce a long-term UV cloud record since 1980, which allows a study of cloud shortwave radiative responses to ENSO and volcanic forcings. Major events from five ENSO perturbations and two volcanic eruptions are covered by our UV HCA measurements.

Positive ENSO events tend to increase cloudiness in the eastern Pacific but there is an **equally compensating** decrease cloudiness in the western Pacific.

Volcanic eruptions enhance global tropical cloudiness.

The global mean surface temperature has increased by ~0.75 C since 1980. The cloud response over the tropical Pacific at the start of the record (1983 event) is similar to that at the end (2016 event) despite the warmer background state.

Our observed reductions in SW TOA forcings during the early record volcanic events can validate climate model simulations of these volcanic events. Likewise, our observed spatial cloud response to the 5 ENSO events since 1980 can validate ENSO simulations in climate models.

$frac_{cloud}$ = fractional area of cloudy part of FOV

$= (I_{obs} - I_{ocean}) / (I_{COD=10} - I_{ocean})$ Eq.1

$frac_{ocean}$ = fractional area of cloud-free part of FOV

$= 1 - frac_{cloud}$

$F^{Up} = (F^{up}_{cloud} * frac_{cloud} + F^{up}_{ocean} * frac_{ocean})$ Eq. 2