Aerosol Trends and Variability

Patrick Hamill

San Jose State University

Contributors: Phillip B. Russell, Larry Thomason, Mark Hervig, Terry Deshler, Colette Brogniez, Debra Weisenstein, Jill Bauman, Greg Bodeker, Christine David, Rich Bevilaqua, and Juan Carlos Antuna

Aerosol Variability

- **Temporal Variability (Seasonal)**
- **Temporal Variability (Volcanic)**
- **Latitudinal Variability**
- **Longitudinal Variability**
- **Variation with Altitude**

Aerosol Trends

- **Return to Background**
  - **Does background exist?**
  - **Are we at background?**
  - **Is background value changing?**

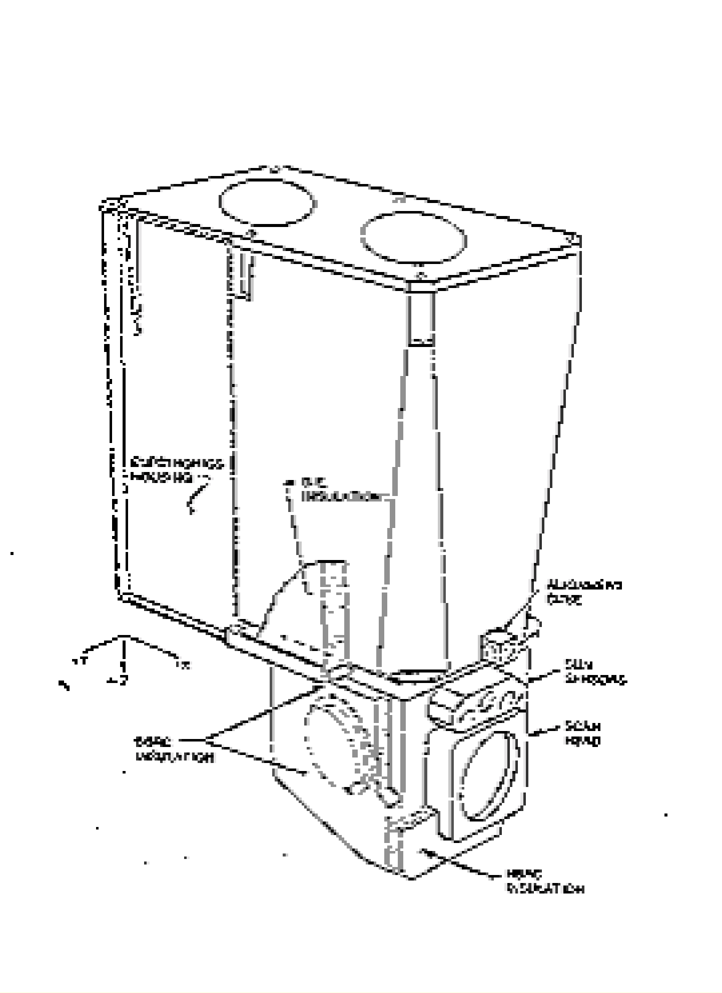
Topics Considered

- Background Information
  - SAM II, SAGE I, SAGE II, SAGE III
  - HALOE
  - POAM
  - ORA
  - Other Instruments (Lidar, Balloons…)
  - Processes affecting the Stratospheric Aerosol
    - » Models
- Variations
- Trends

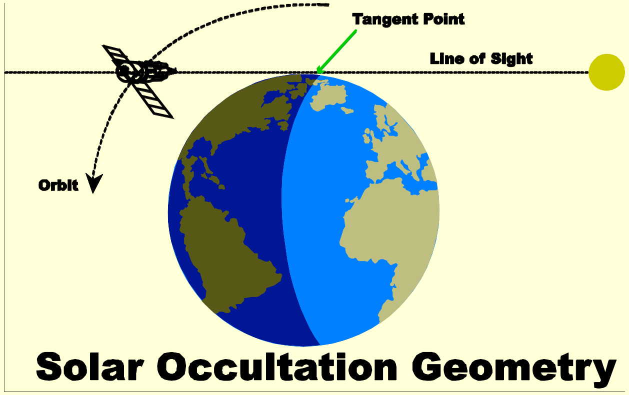
Much of the information being presented here is from the SPARC Stratospheric Aerosol Assessment edited by Larry Thomason and Thomas Peter.

SAM II

The SAM II instrument measured solar intensity at 1 micron. It was the first "SOSST" instrument



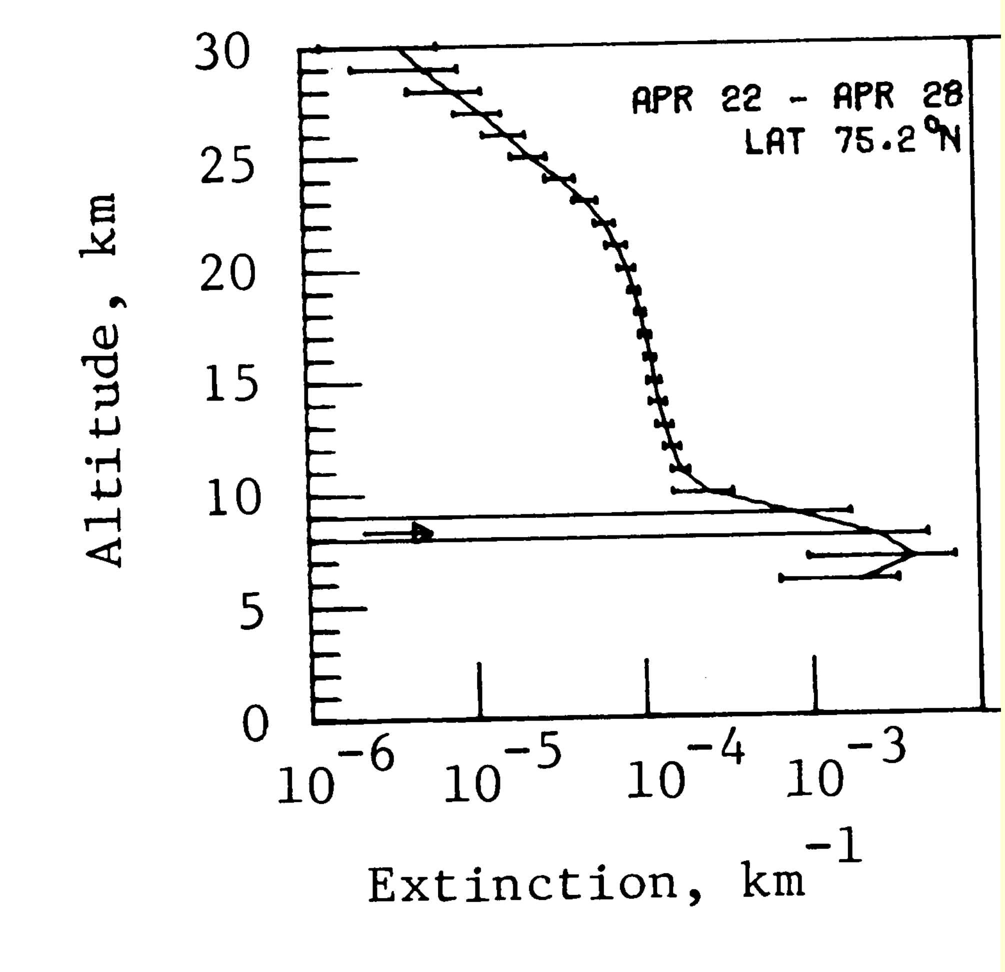
Due to the orbit of the Nimbus 7 satellite, the SAM II instrument primarily made measurements in the 65-80 degree range (north and south).



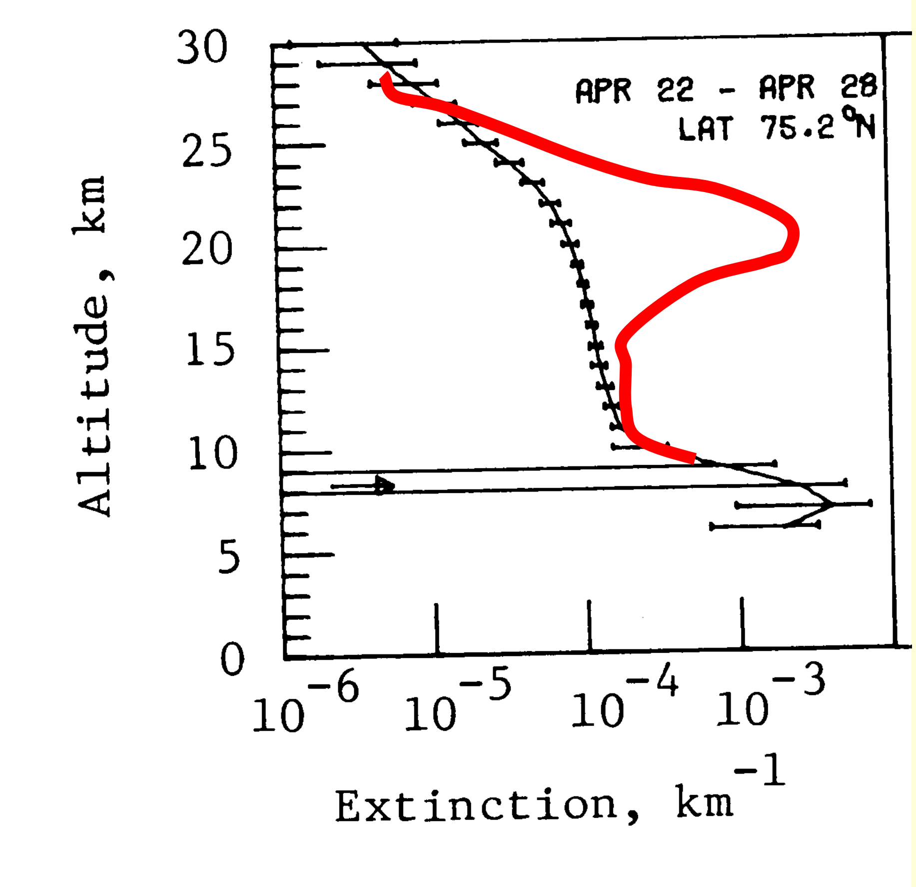
DISCOVERY OF POLAR STRATOSPHERIC CLOUDS

Shortly after launch, SAM II measured a number of profiles with anomalously high extinctions. The high extinction events were named “Polar Stratospheric Clouds” and were eventually recognized as being either crystalline nitric acid hydrates, liquid nitric acid solution droplets or water ice crystals.

Typical SAM II Extinction Profile



Typical PSC Profile



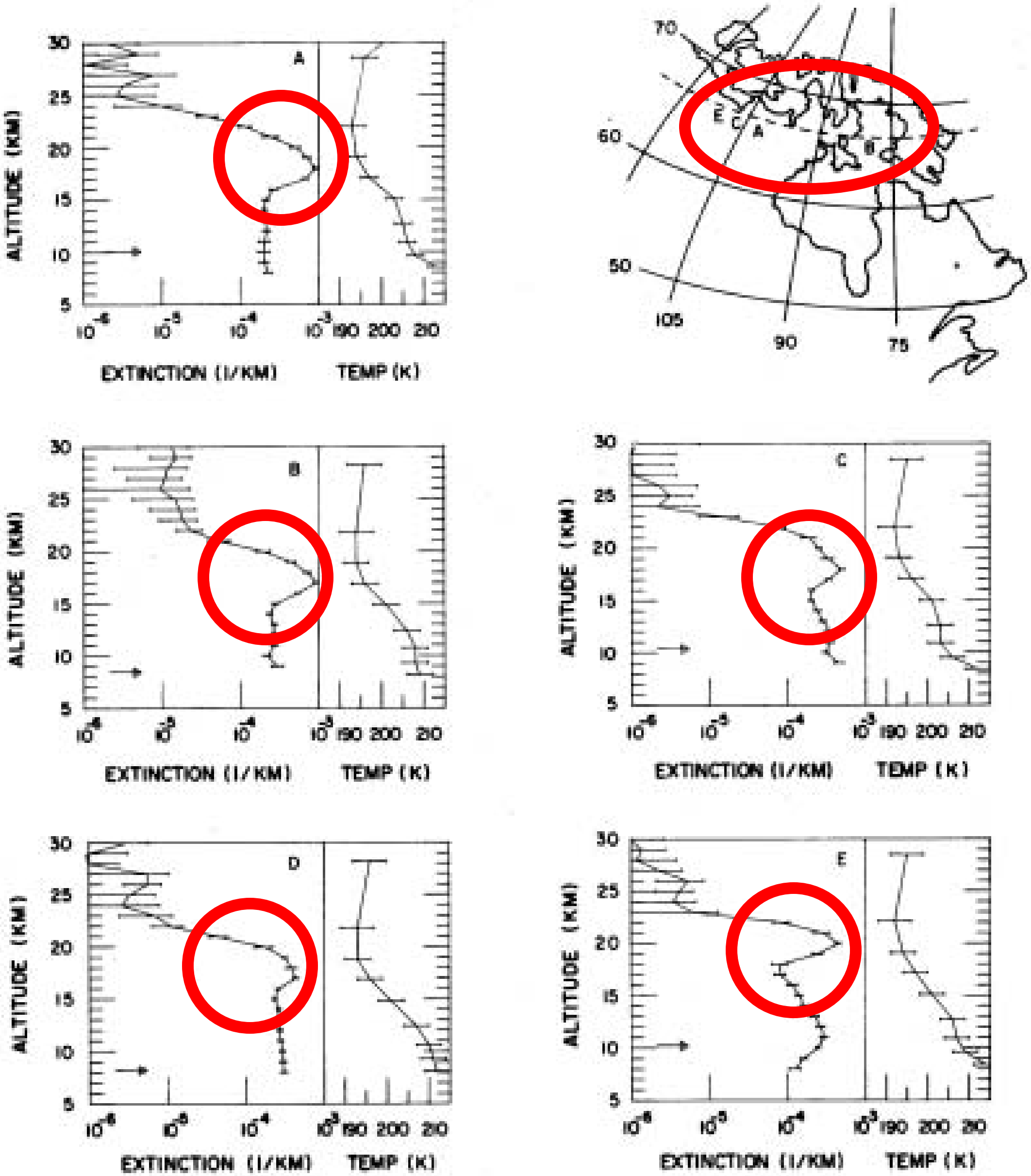


FIG. 3. Extinction and temperature profiles for clouds sighted near Hudson Bay on 11–13 January 1979. The letters on the map indicate the location of the corresponding profiles.

SAM II observations of five PSC's on January 11-13, 1979.

The PSC's were observed over Northern Canada, at the latitude of the Arctic Circle, to the north and north-west of Hudson Bay

A composite picture of the stratospheric optical depth at 1.0 μm as a function of time using data from SAM II, SAGE I and SAGE II

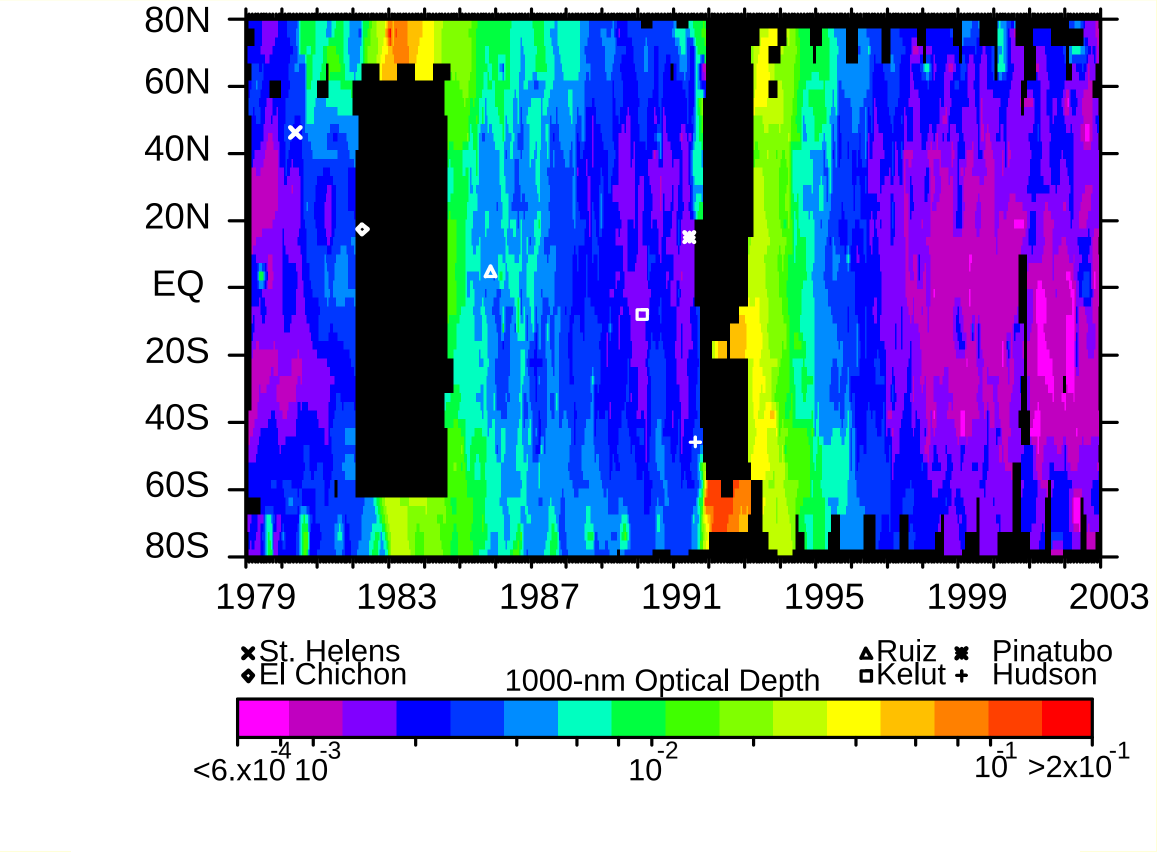


Figure 4.4: SAM II, SAGE, and SAGE II stratospheric aerosol optical depth at 1000 nm from 1979 through 2002. Profiles that do not extend to the tropopause are excluded from the analysis leading to significant regions of missing data following the eruptions of El Chichón and Mt. Pinatubo in 1983 and 1991.

Volcanic eruptions
Mt. St. Helens

Data Gap (Sage I Failure)

Data Gap
Pinatubo Cloud too thick to see through

El Chichon

Pinatubo

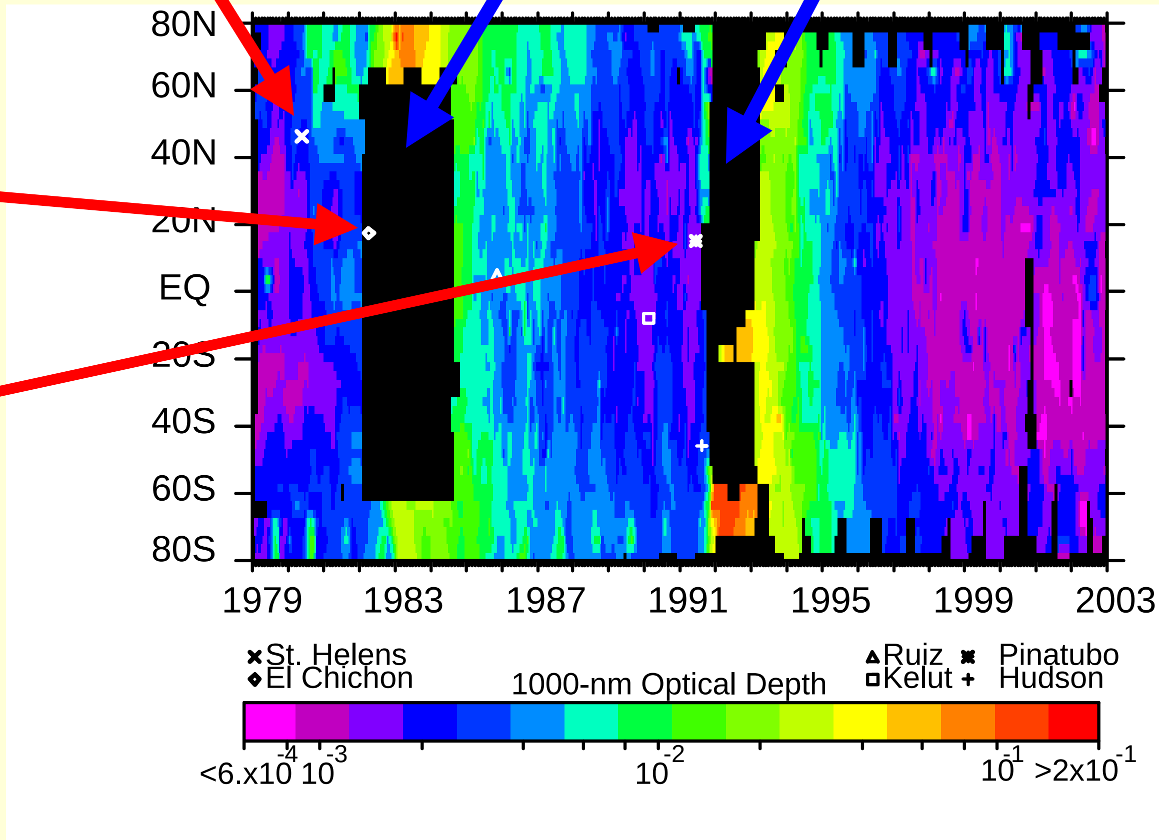


Figure 4.4: SAM II, SAGE, and SAGE II stratospheric aerosol optical depth at 1000 nm from 1979 through 2002. Profiles that do not extend to the tropopause are excluded from the analysis leading to significant regions of missing data following the eruptions of El Chichón and Mt. Pinatubo in 1983 and 1991.

ARE THESE BACKGROUND PERIODS?

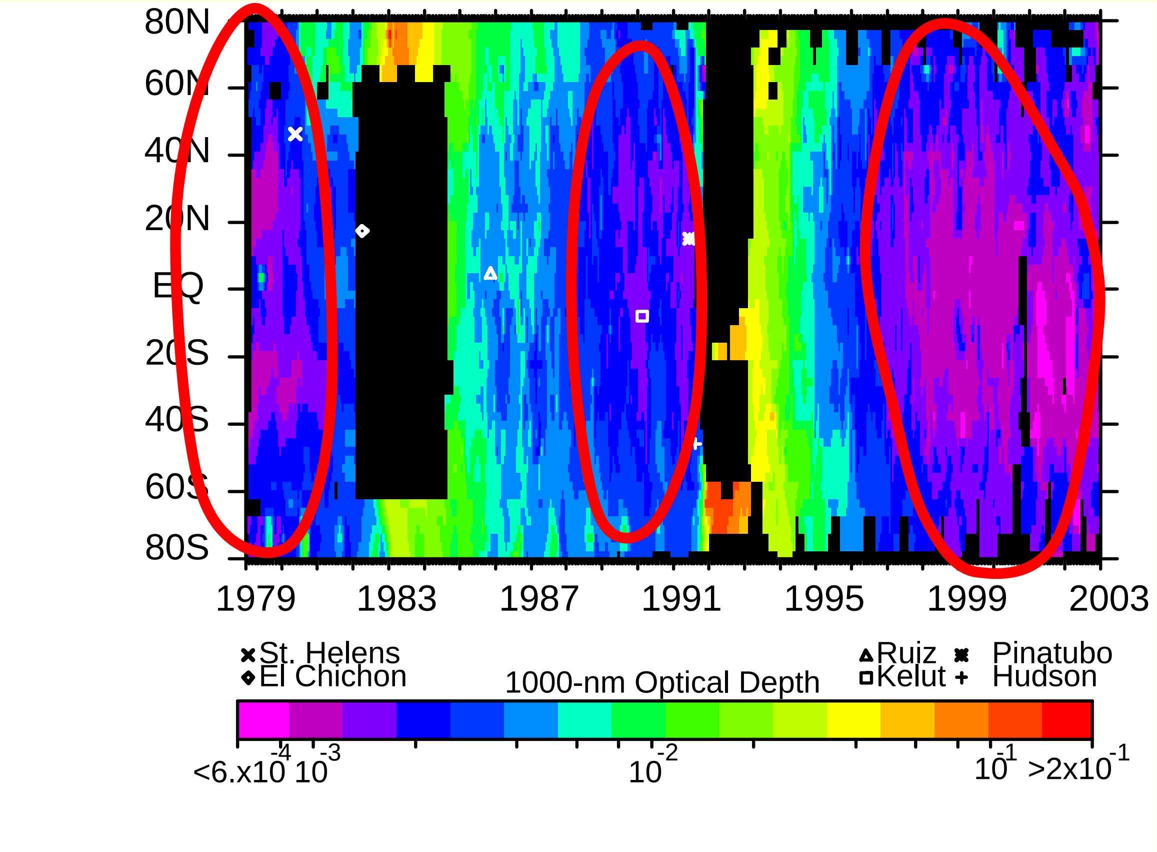
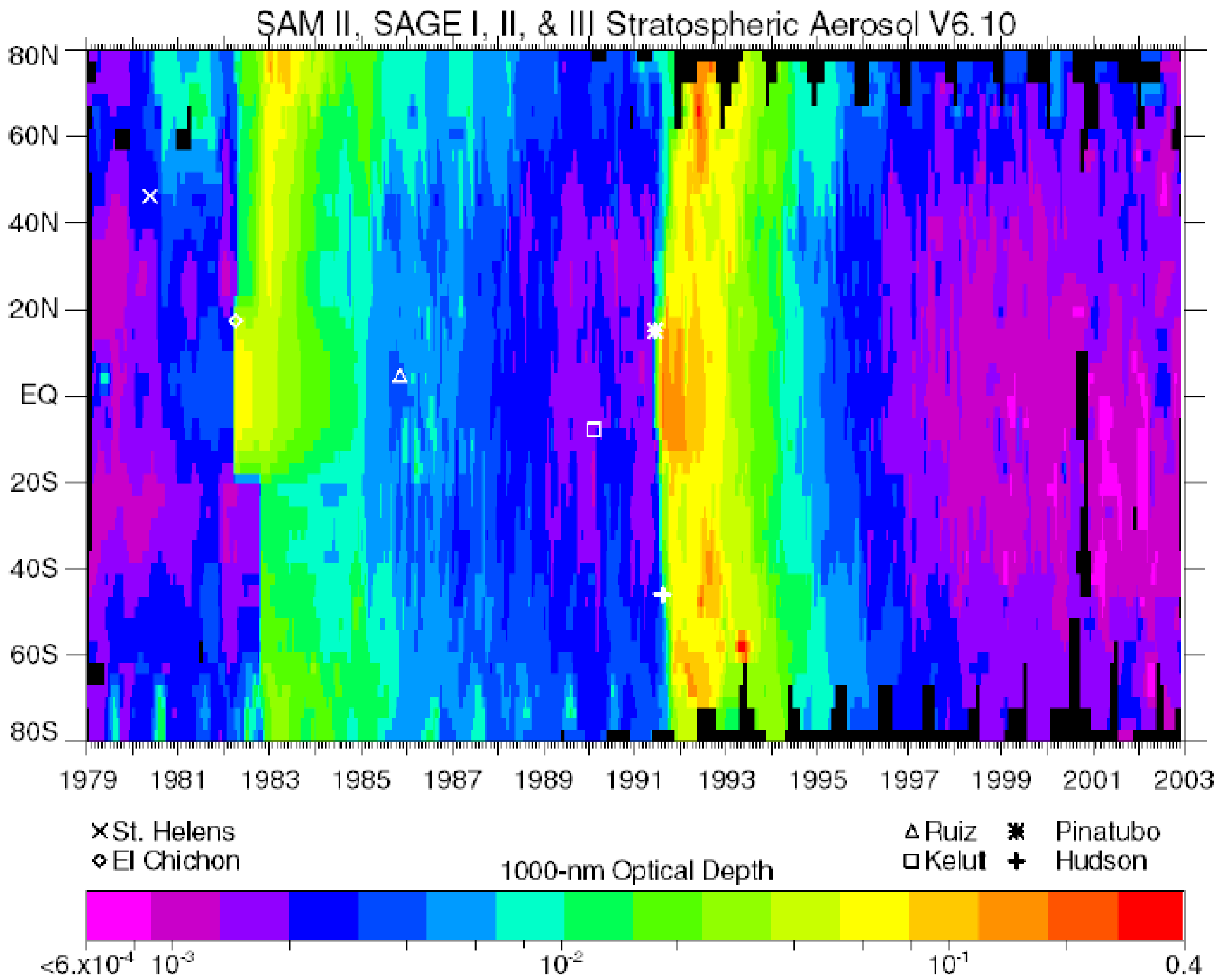


Figure 4.4: SAM II, SAGE, and SAGE II stratospheric aerosol optical depth at 1000 nm from 1979 through 2002. Profiles that do not extend to the tropopause are excluded from the analysis leading to significant regions of missing data following the eruptions of El Chichón and Mt. Pinatubo in 1983 and 1991.

SAGE II data set, “filled” by Larry Thomason



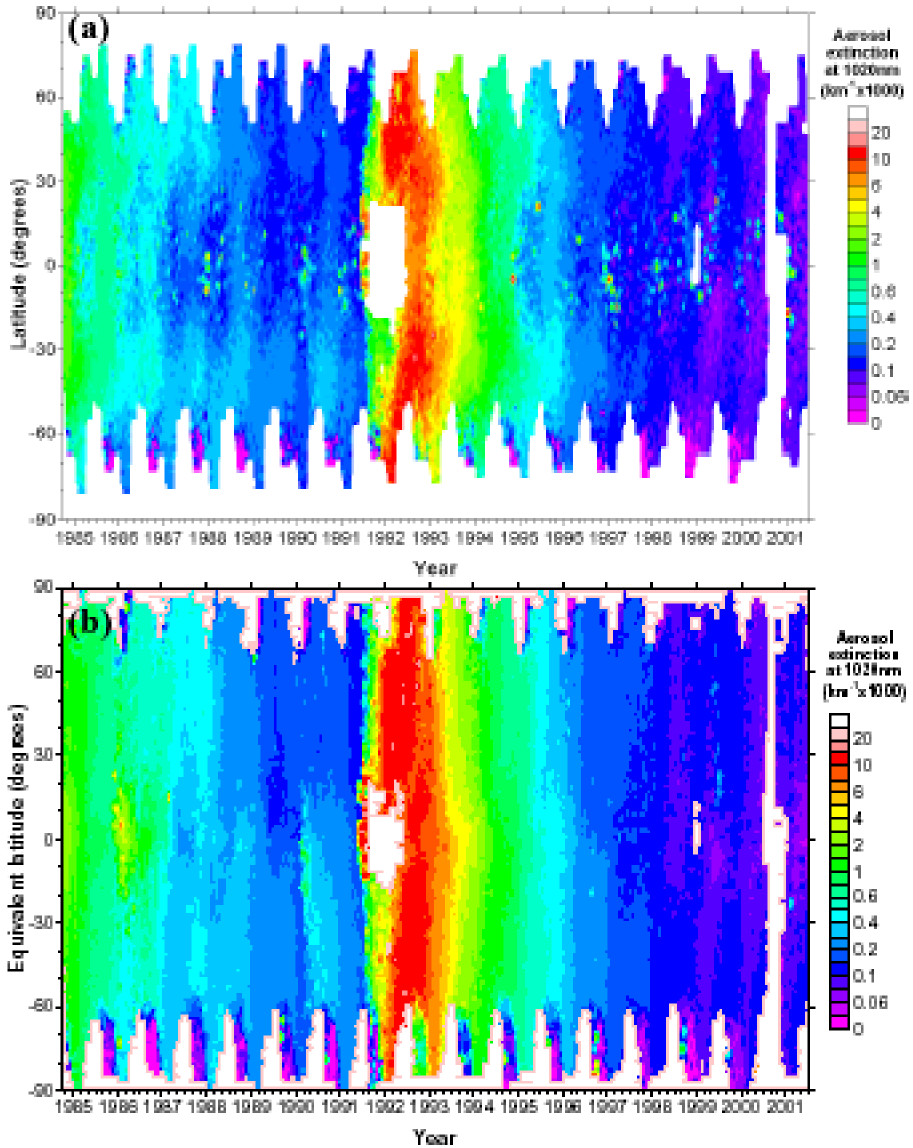


Fig. 4.51: SAGE II aerosol extinction at 1020 nm, (a) at 18 km as function of latitude, (b) at 450 K as function of equivalent latitude.

A different way of looking at SAGE extinctions

SAGE II Extinction at 18 km altitude as a function of latitude and time

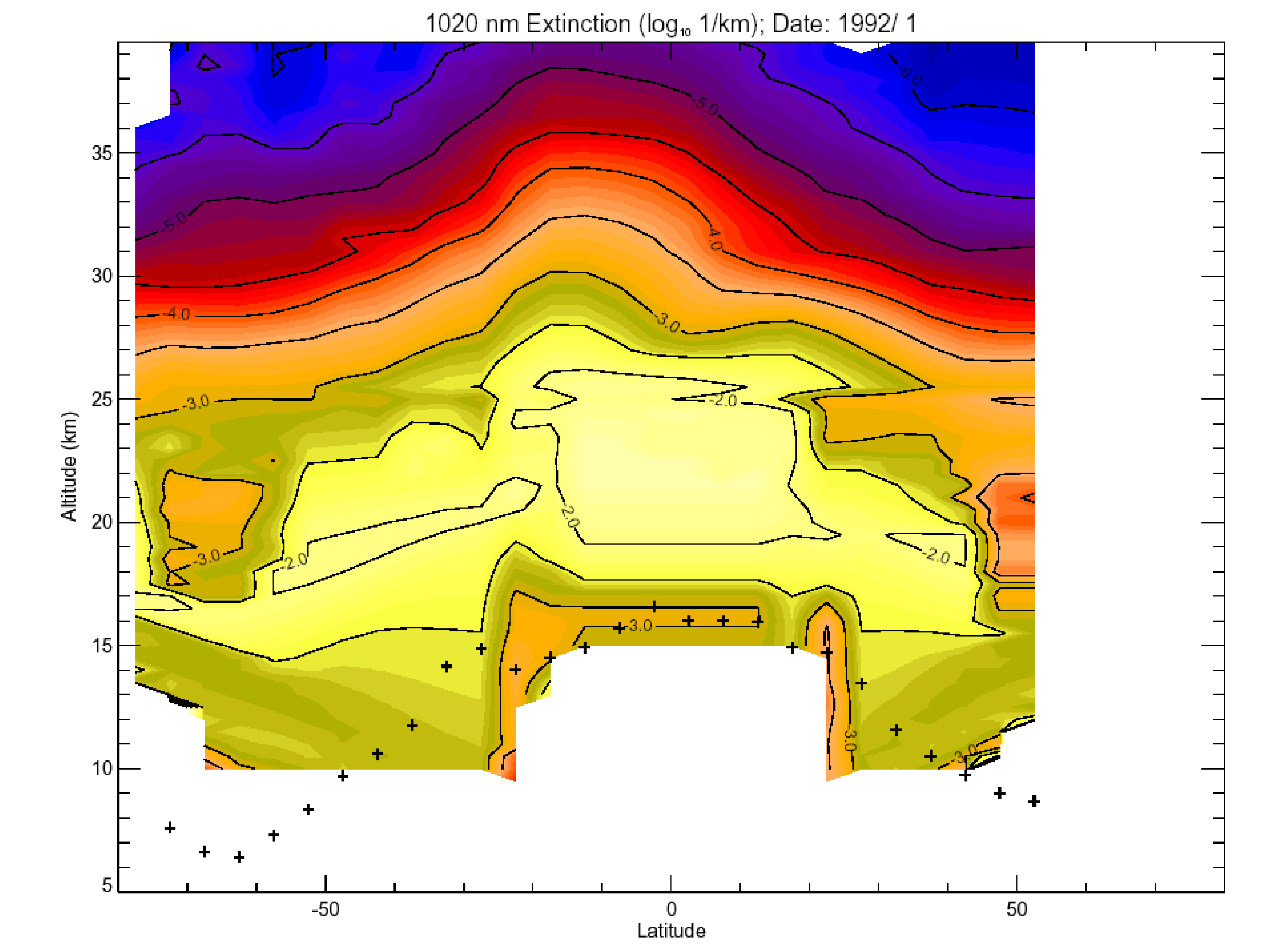
SAGE II Extinction at 450 K potential temperature as a function of equivalent latitude and time

See poster by Greg Bodeker

Can we observe seasonal variations in the SAGE extinction?

A quick look at SAGE extinctions for 1992
(A year after the Pinatubo eruption)

Generated by Larry Thomason



1020 nm Extinction (log_{10} 1/km); Date: 1992/ 1
Altitude (km)
Latitude
35
30
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-6.0
-5.0
-5.0
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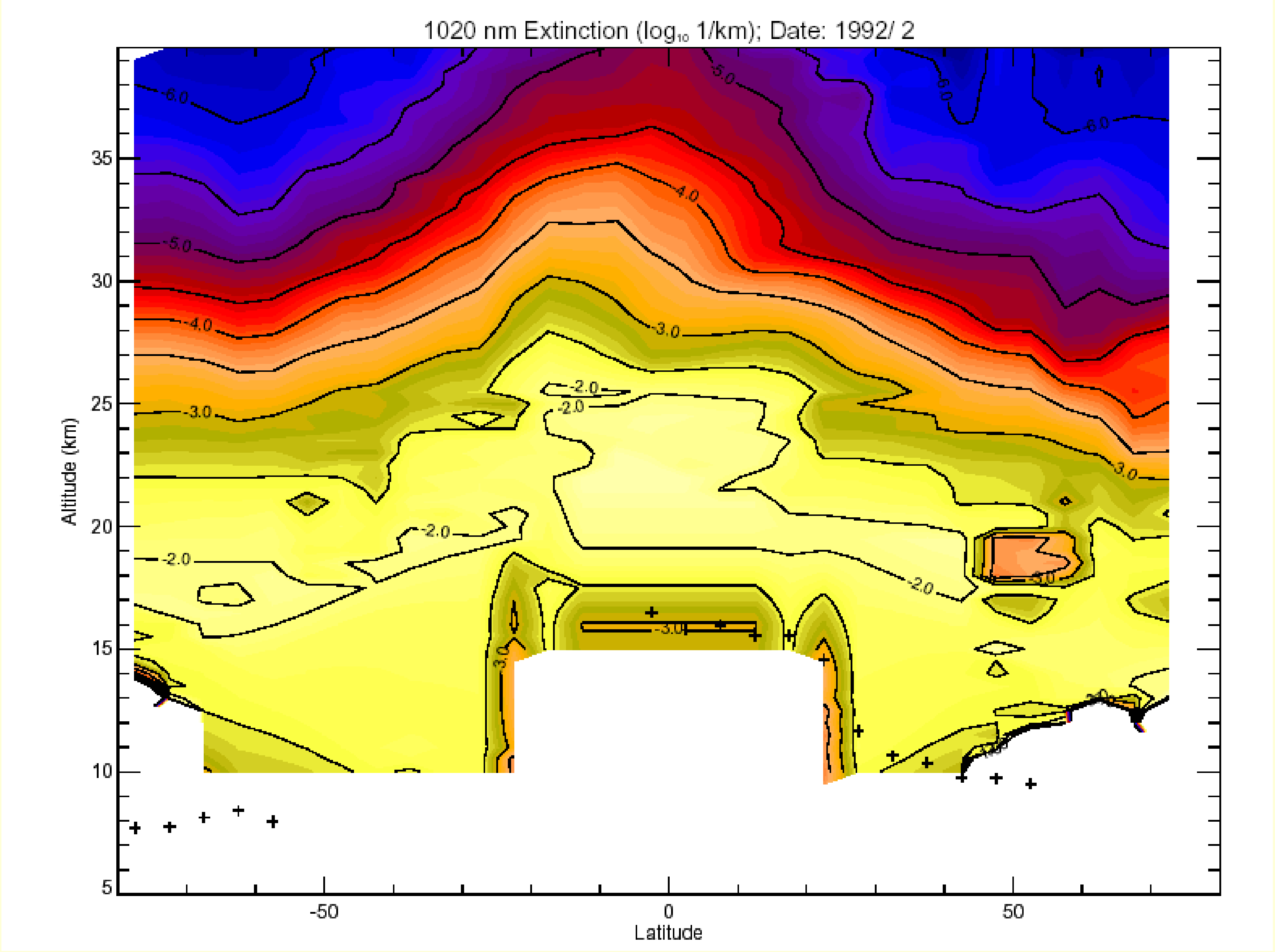

1020 nm Extinction (log_{10} 1/km); Date: 1992/ 2
Altitude (km)
Latitude
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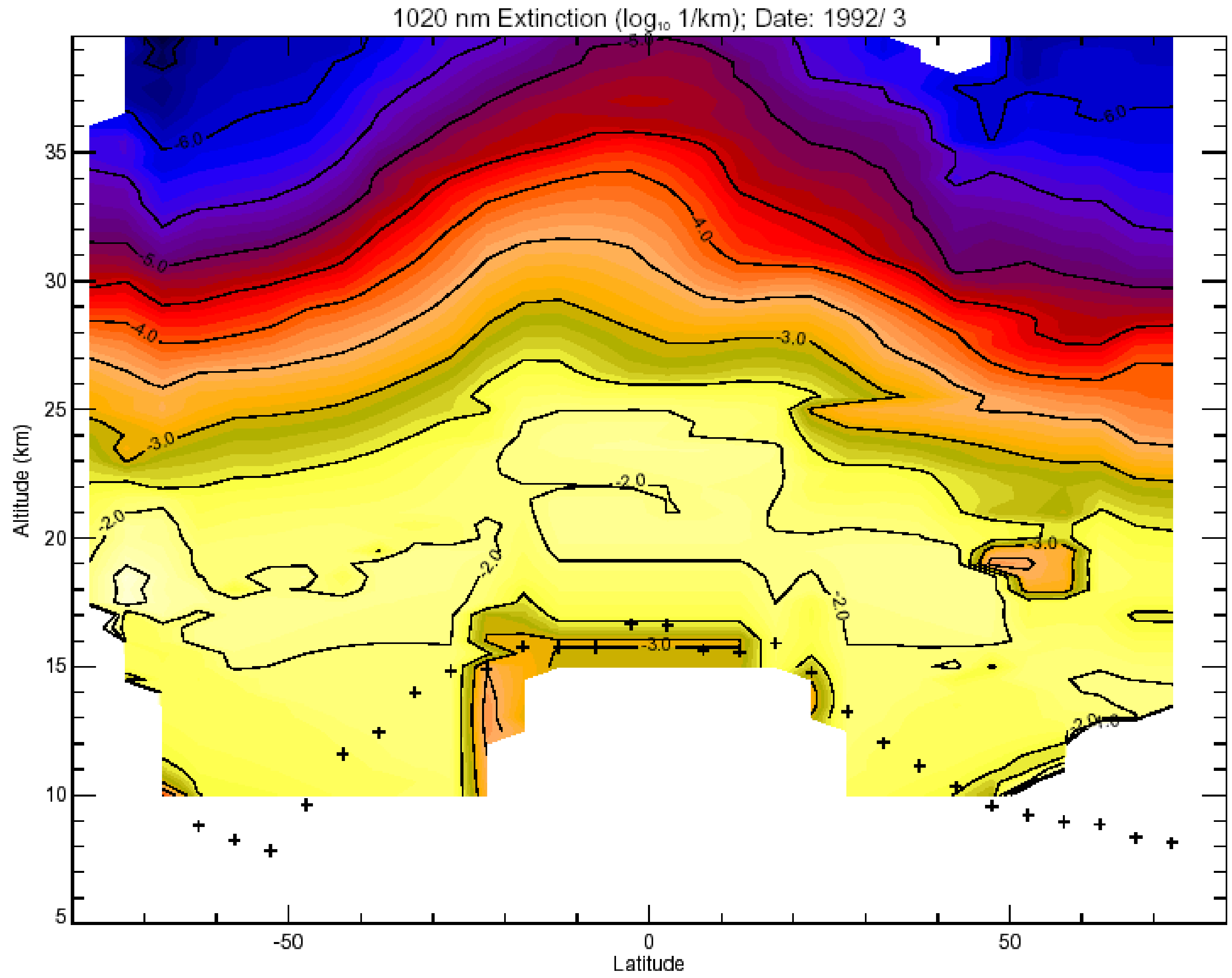
1020 nm Extinction (log10 1/km); Date: 1992/ 3
Altitude (km)
Latitude
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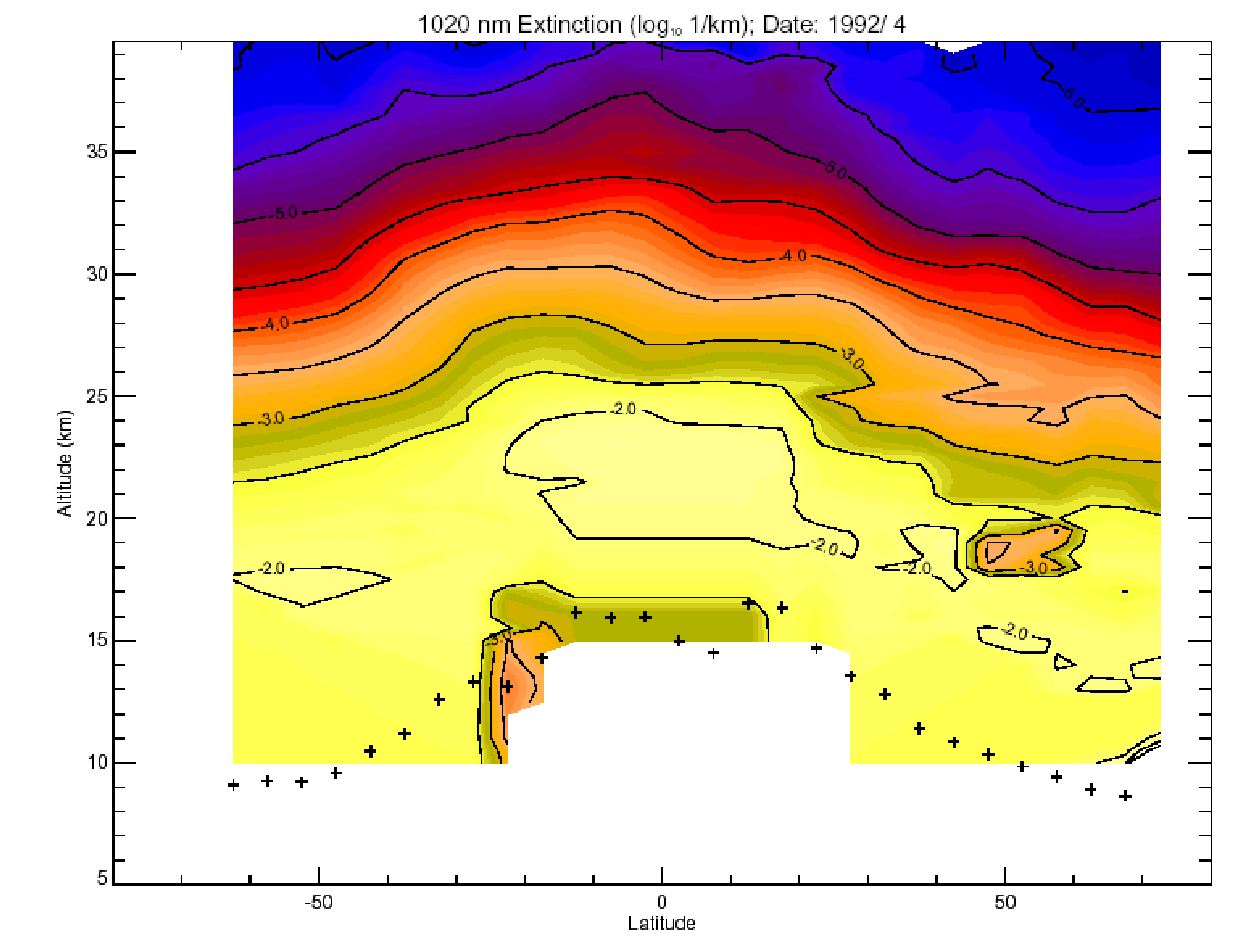

1020 nm Extinction (log10 1/km); Date: 1992/ 4
Altitude (km)
Latitude
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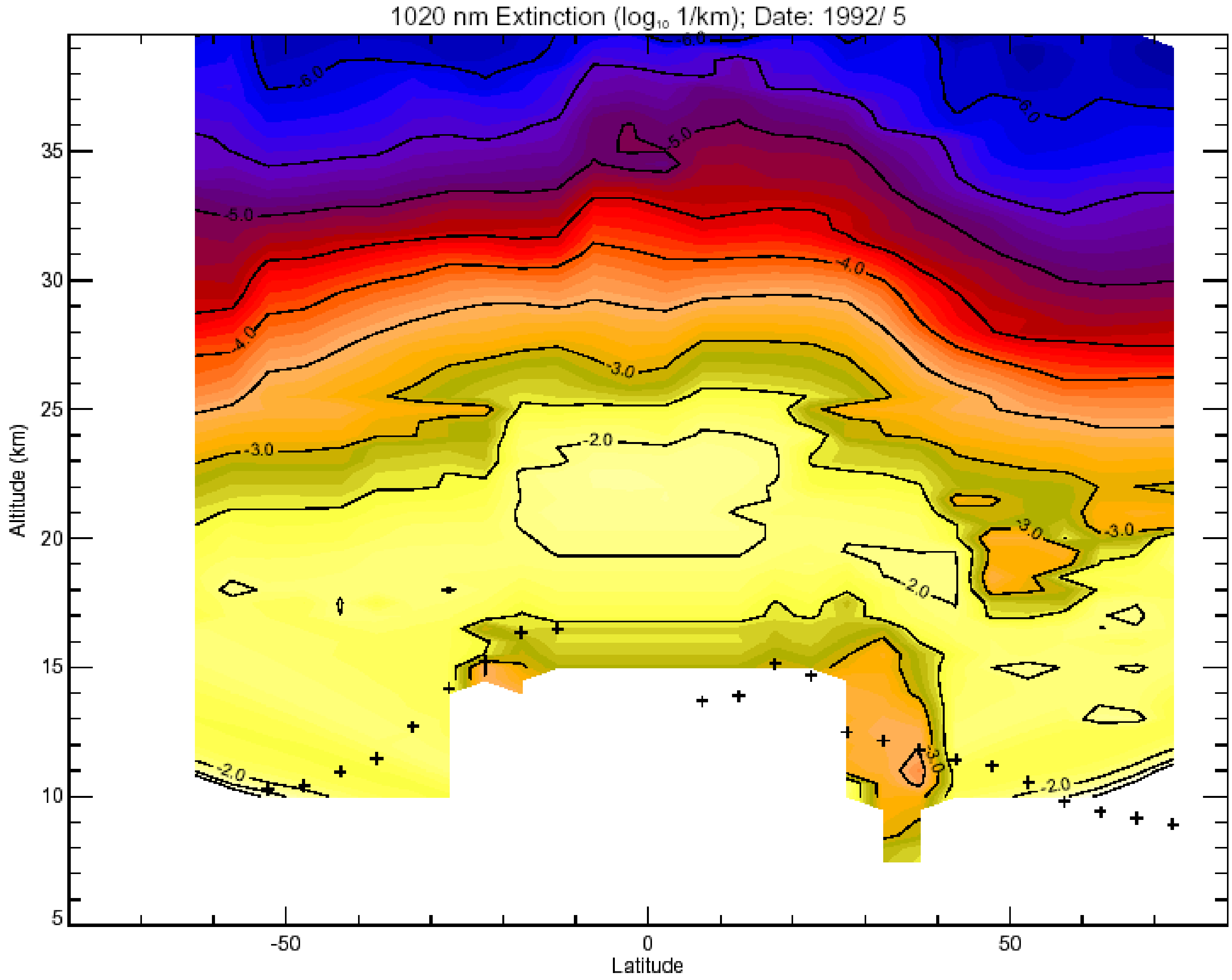
1020 nm Extinction ($\log_{10}$ 1/km); Date: 1992/ 5
Altitude (km)
Latitude
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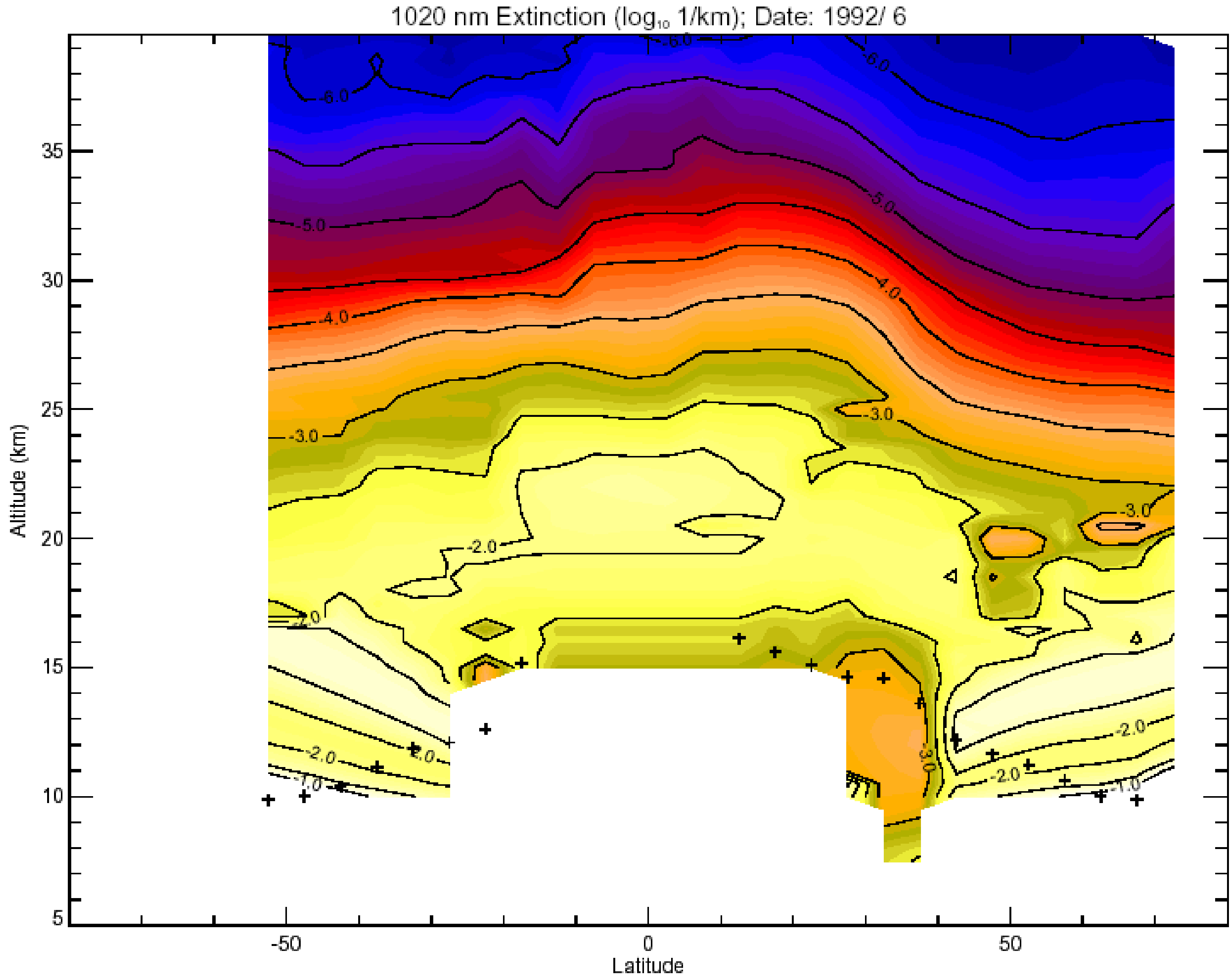

1020 nm Extinction (log10 1/km); Date: 1992/ 6
Altitude (km)
Latitude
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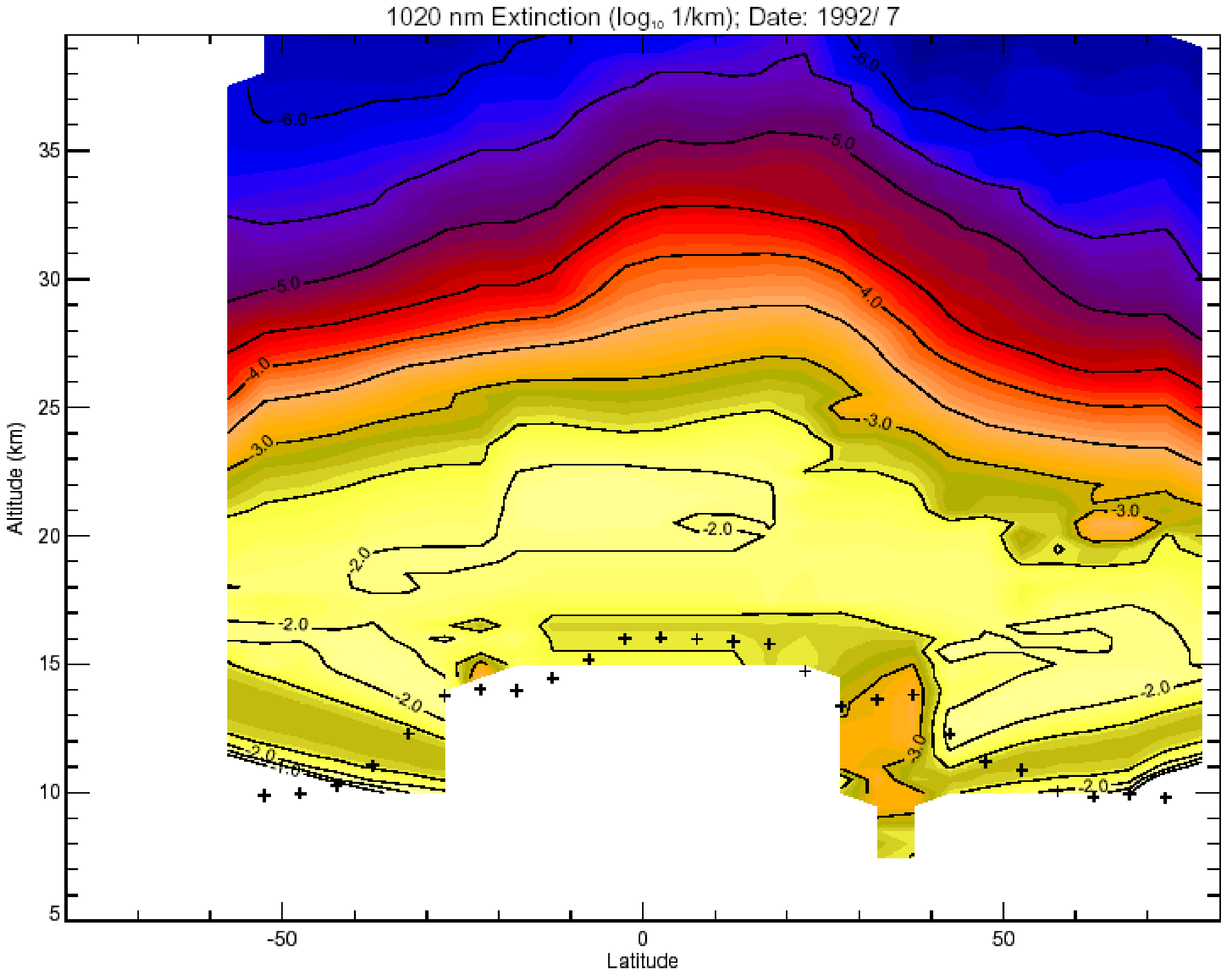

1020 nm Extinction (log10 1/km); Date: 1992/ 7
Altitude (km)
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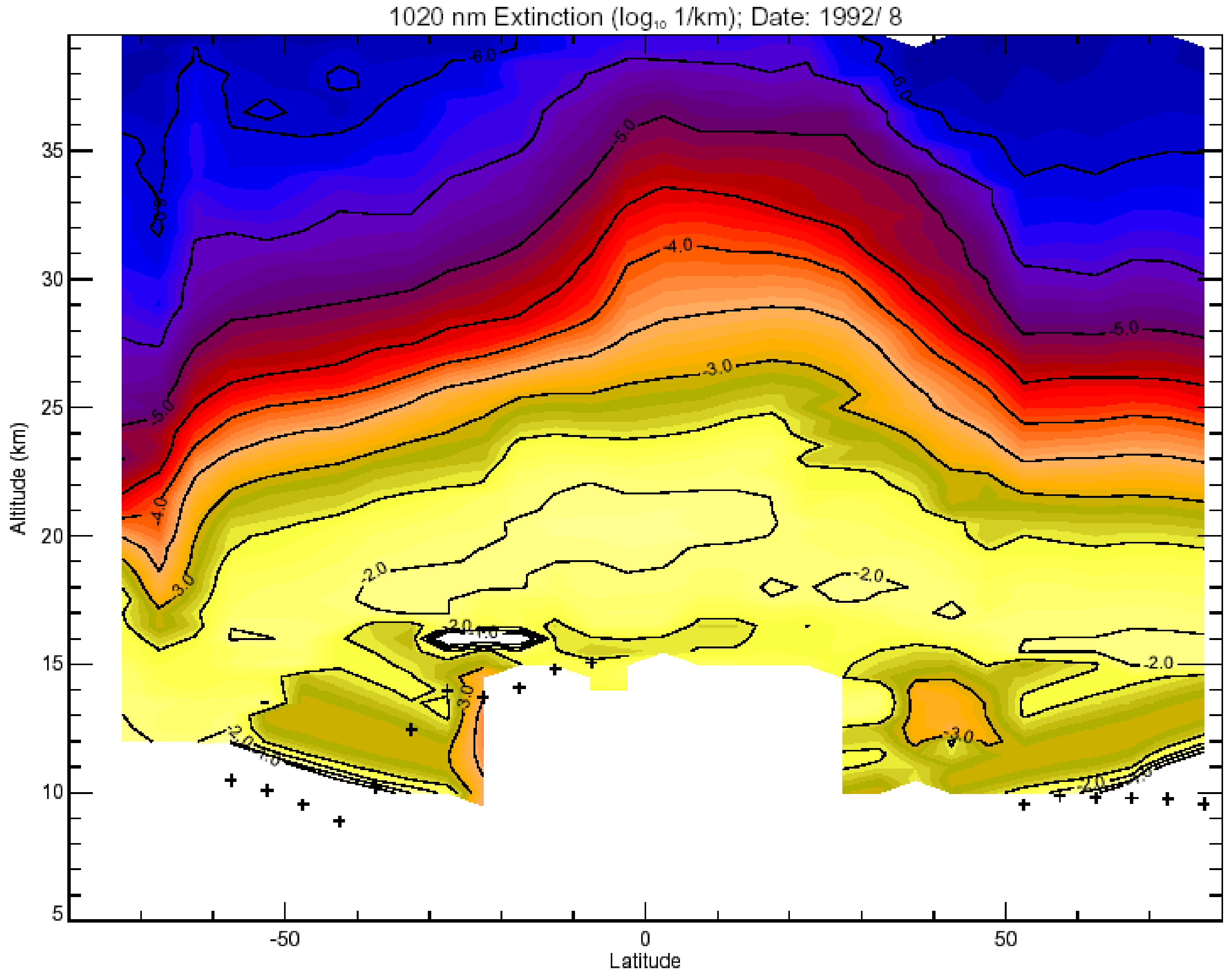
1020 nm Extinction (log_{10} 1/km); Date: 1992/ 8
Altitude (km)
Latitude
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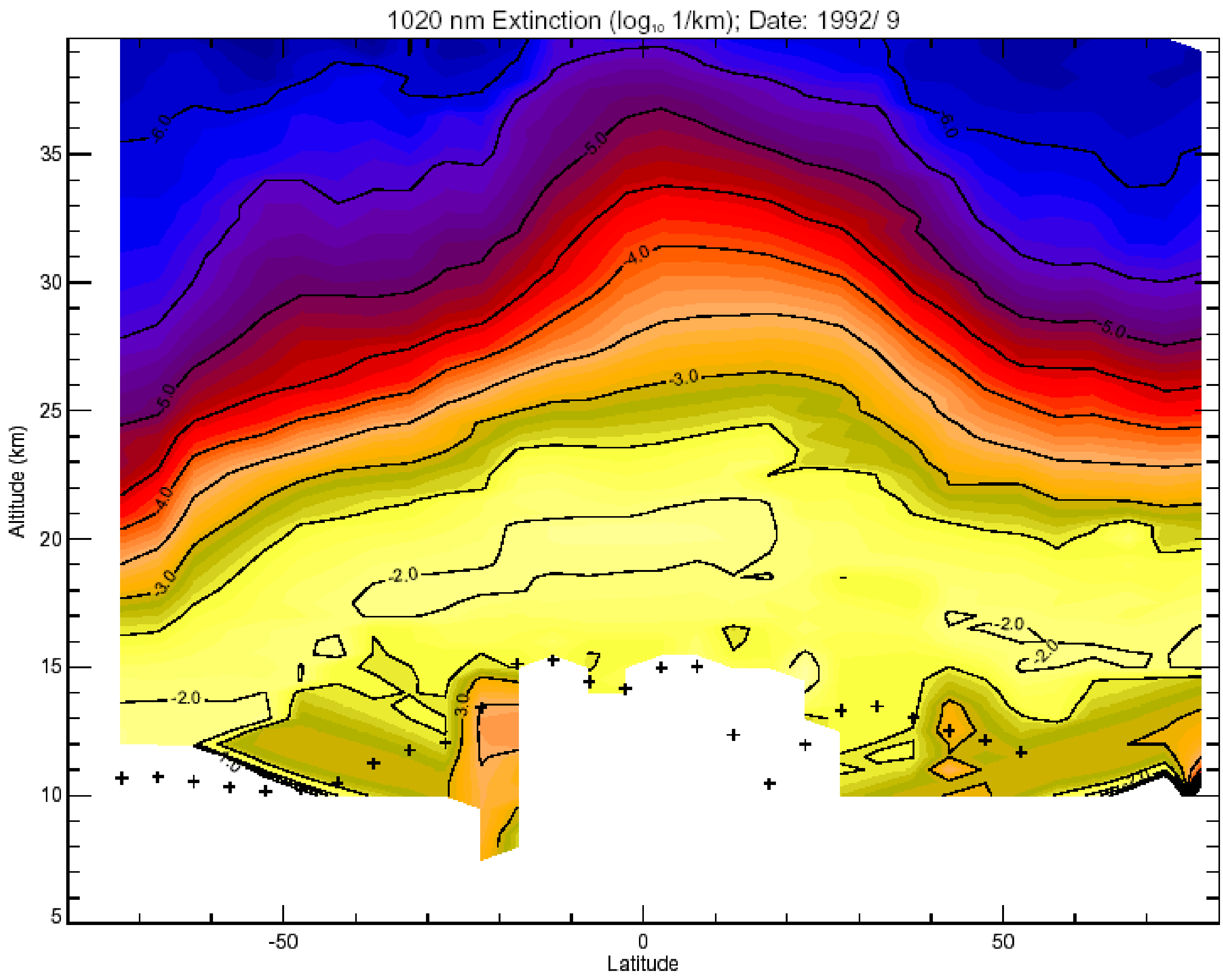
1020 nm Extinction (log10 1/km); Date: 1992/ 9
Altitude (km)
Latitude
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-4.0
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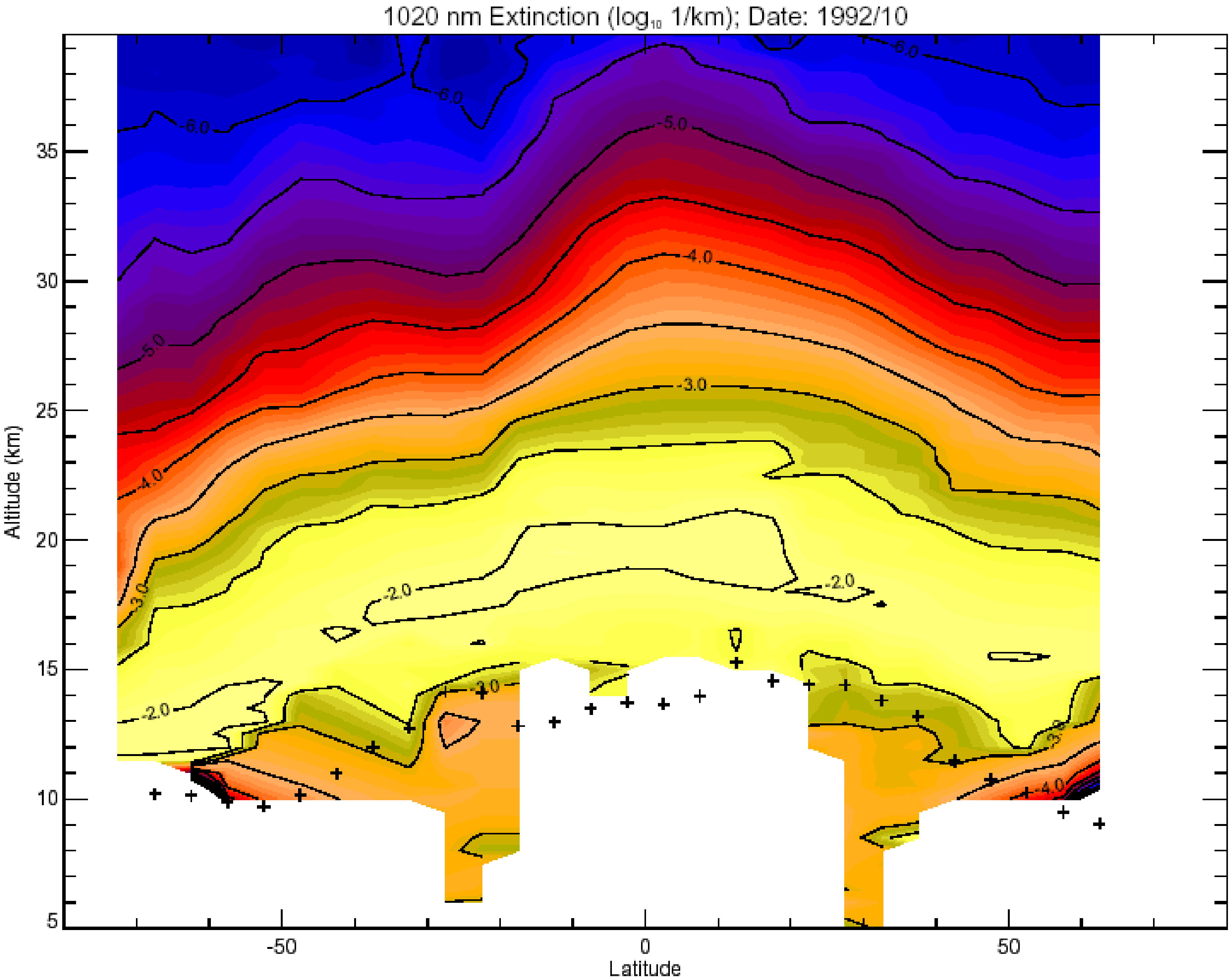

1020 nm Extinction (log10 1/km); Date: 1992/10
Altitude (km)
Latitude
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-6.0
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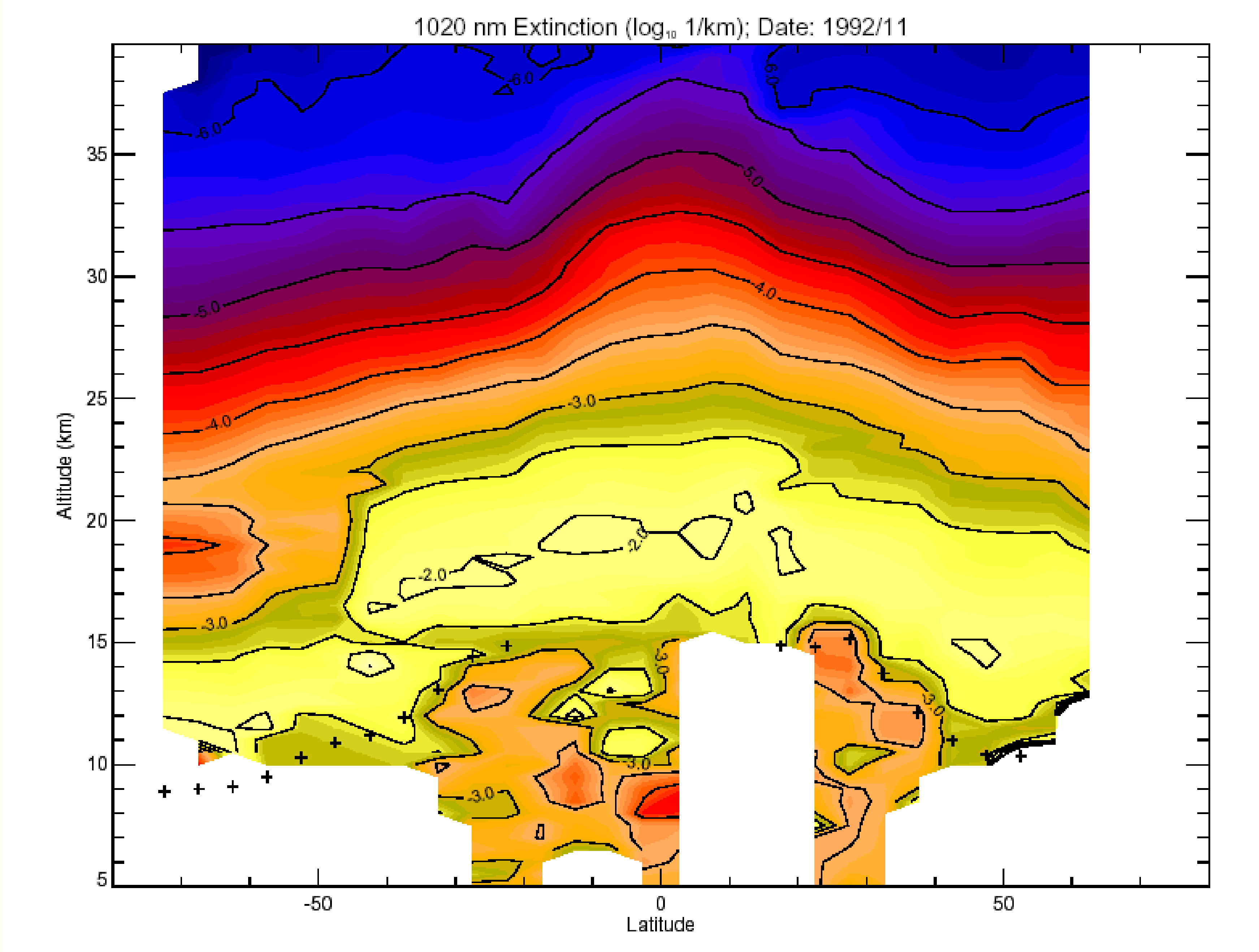
1020 nm Extinction (log_{10} 1/km); Date: 1992/11
Altitude (km)
Latitude
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-4.0
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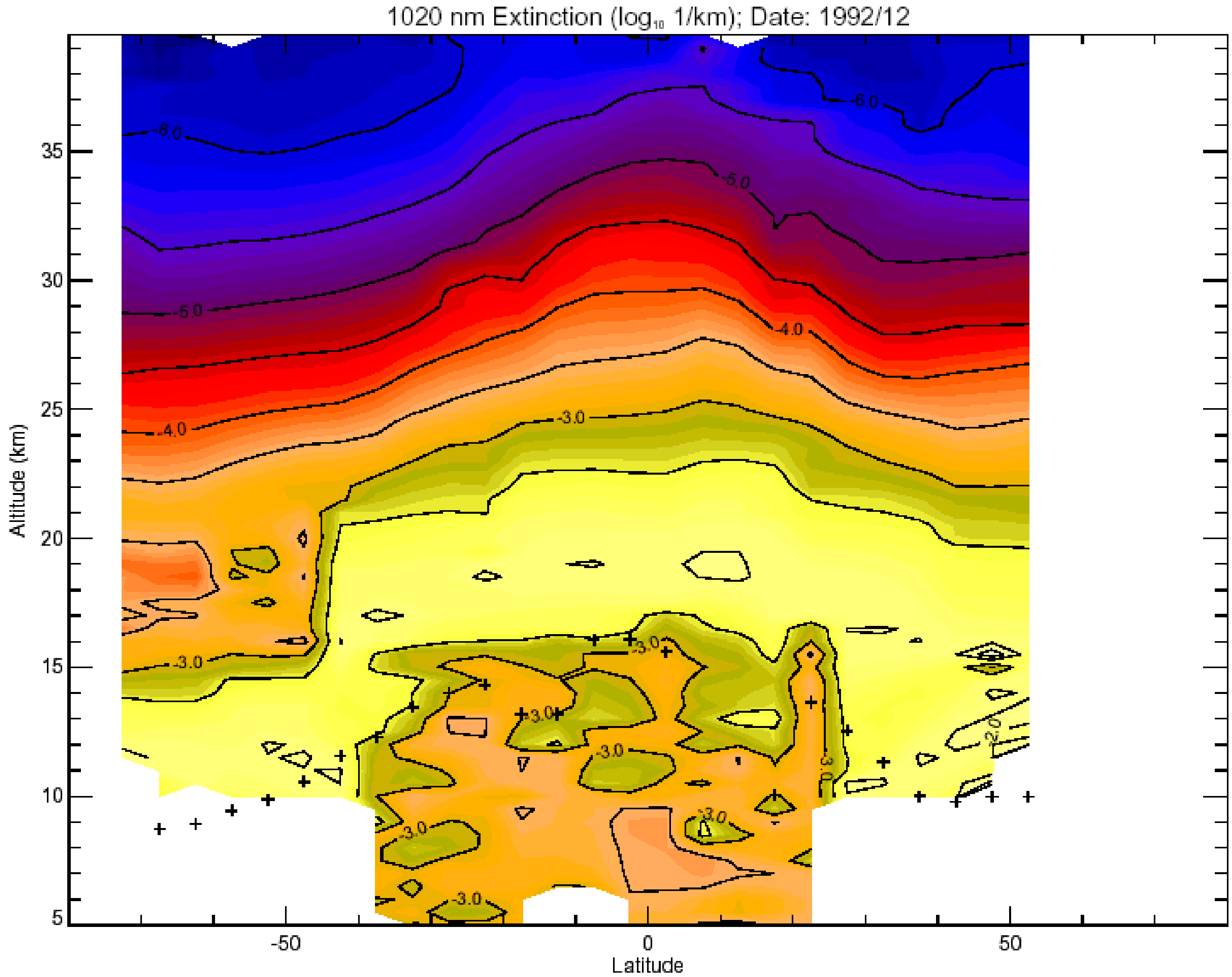

1020 nm Extinction (log_{10} 1/km); Date: 1992/12
Altitude (km)
Latitude
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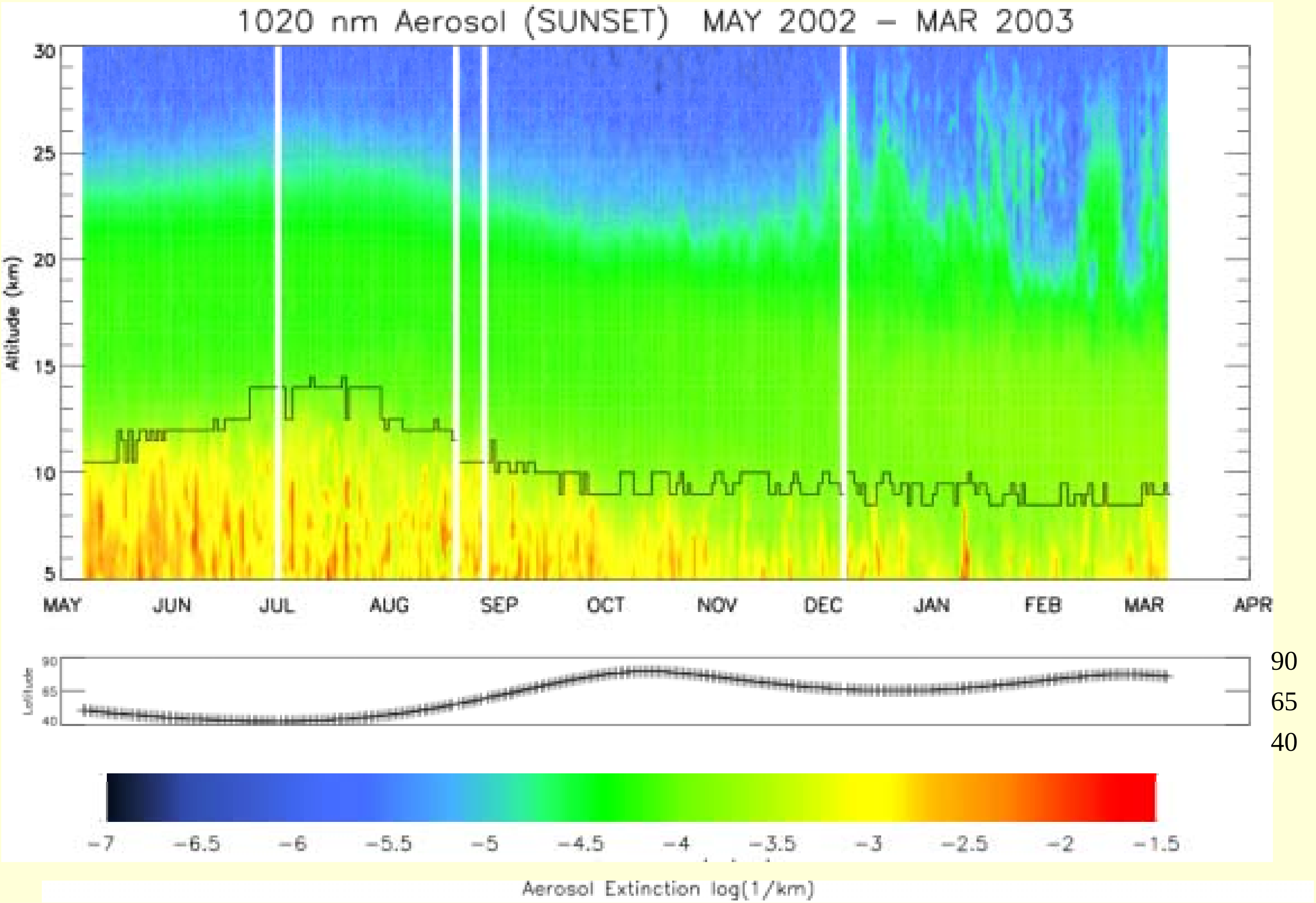
SAGE III Aerosol Extinction in Northern Hemisphere

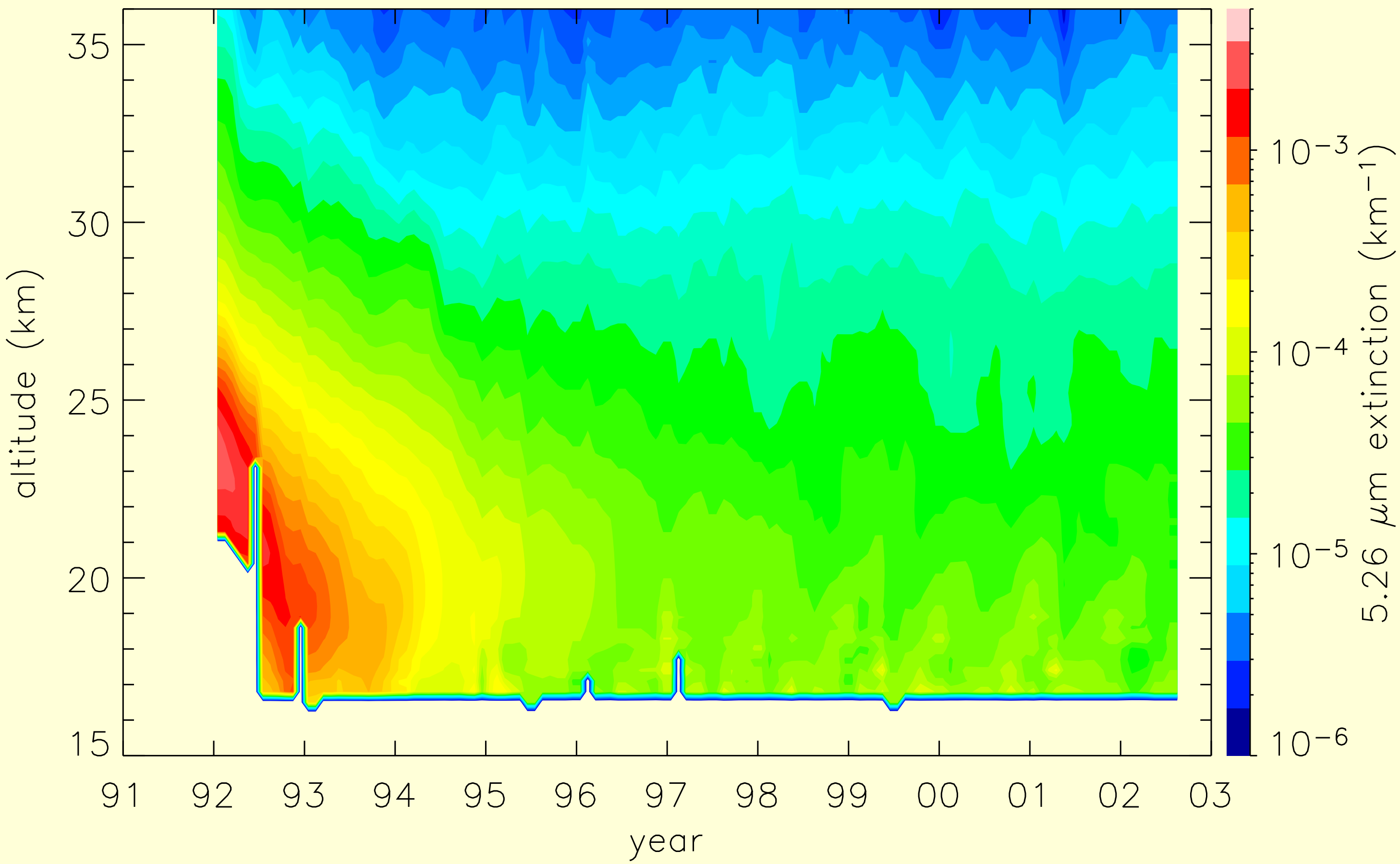


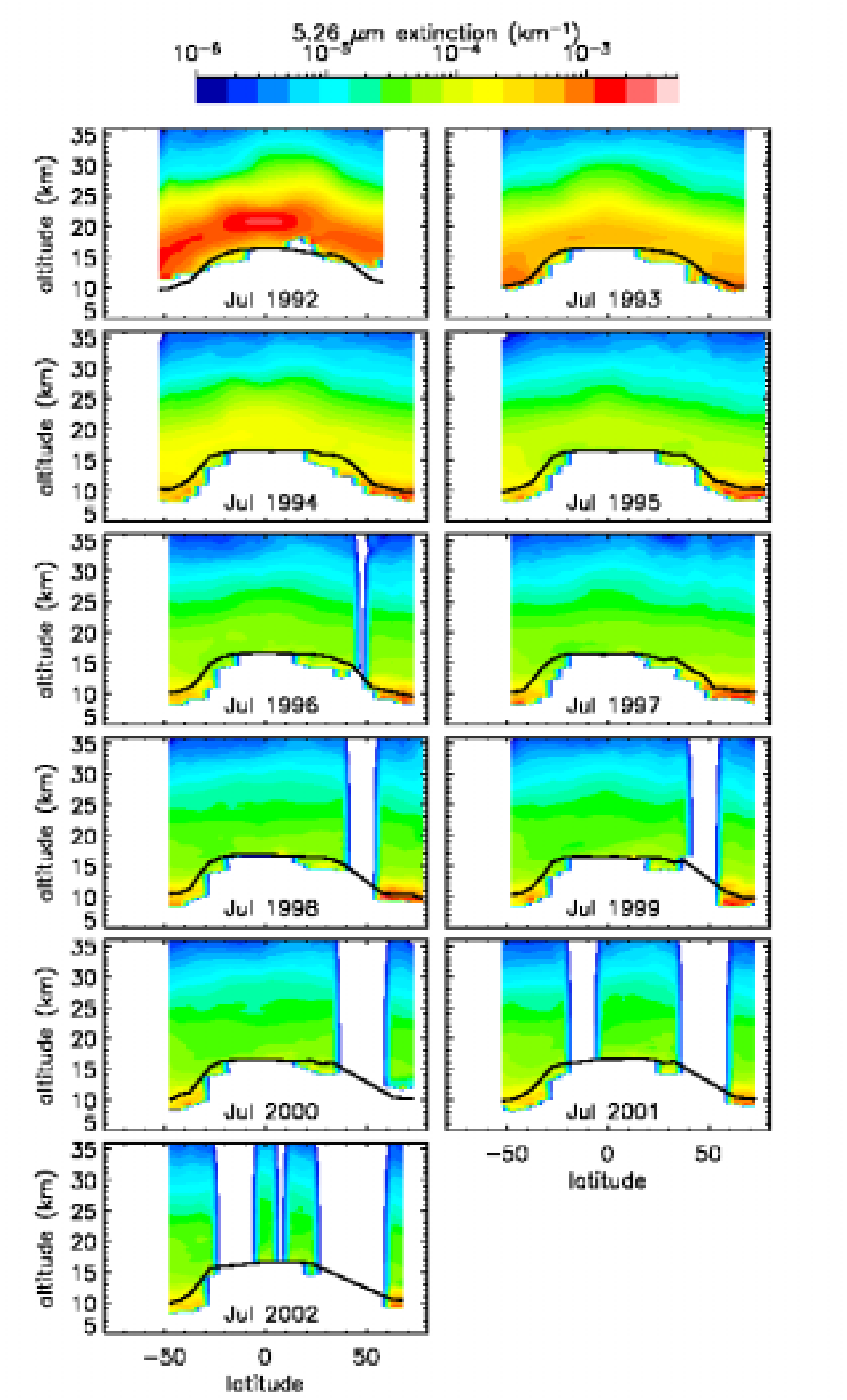
From Bill Chu

Haloe Aerosol

Plots by Mark Hervig

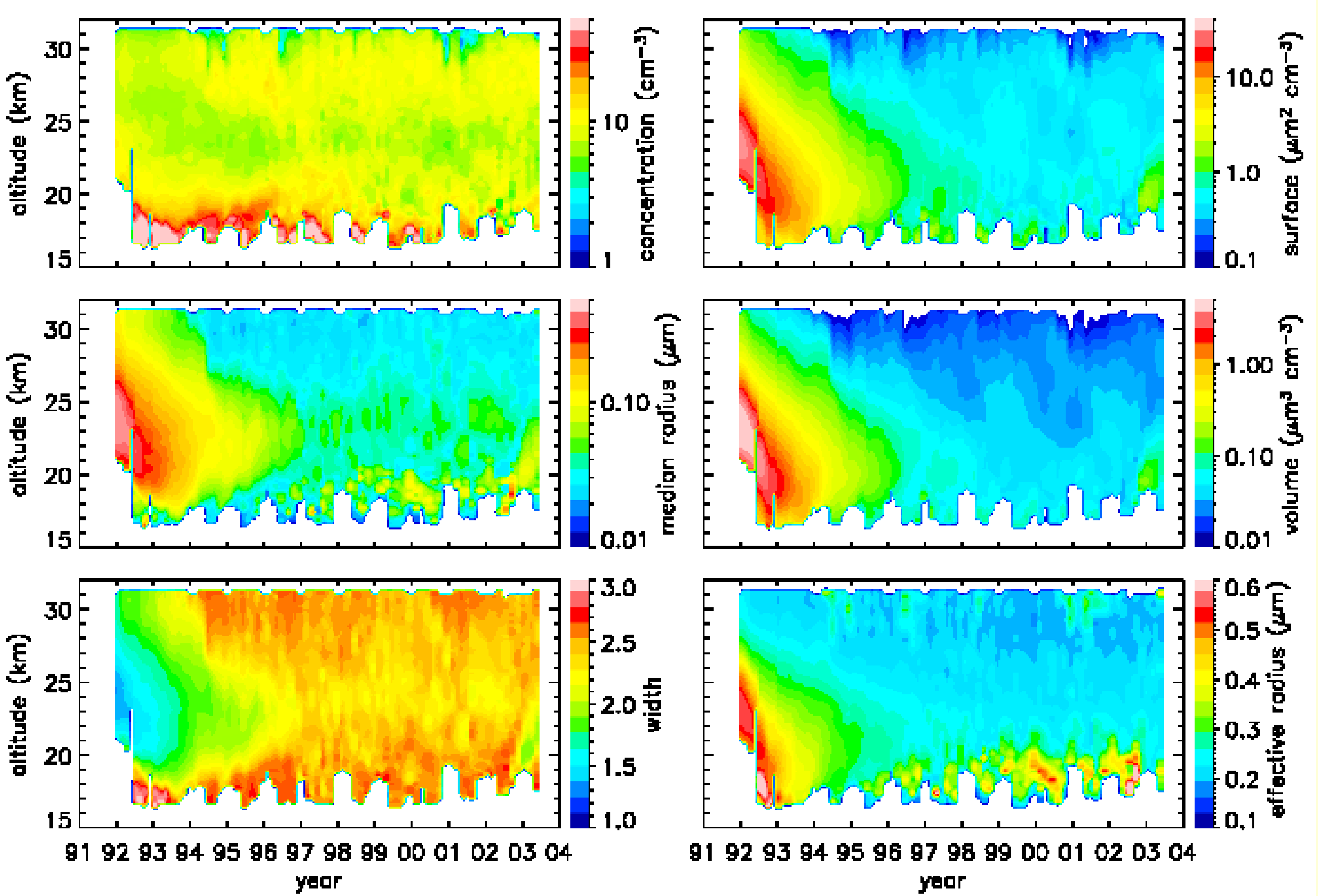
HALOE extinction at 5.26 μm as functions of altitude and time for 5 degree band centered on the equator. Note seasonality.





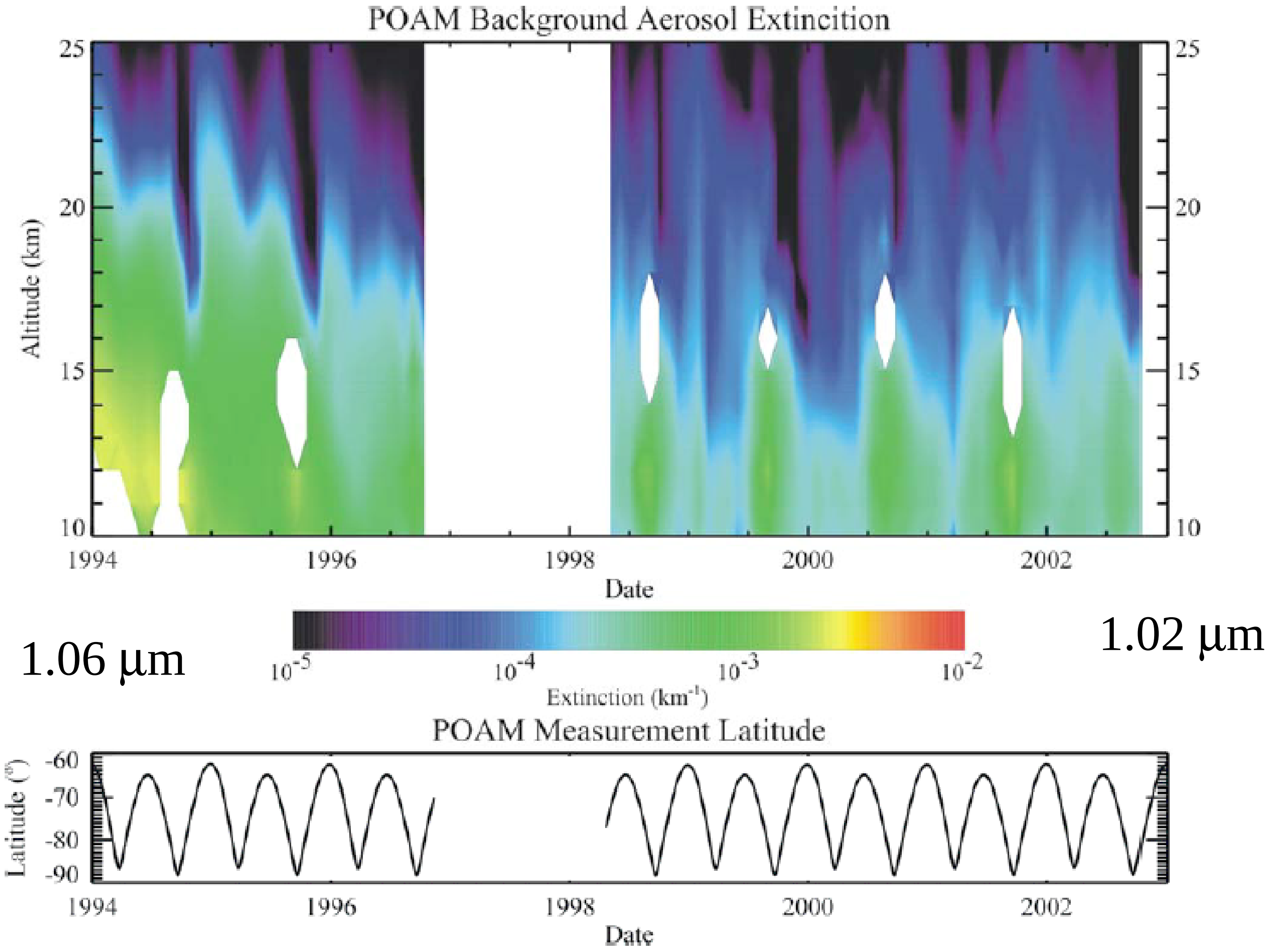
HALOE 5.26 μm extinction as function of altitude and latitude during the month of July for every year from 1992 to 2002 showing the decay of the Pinatubo aereosol.

HALOE derived surface area, volume, and effective radius as functions of altitude and time (1991-2003) at 0-5°N latitude.

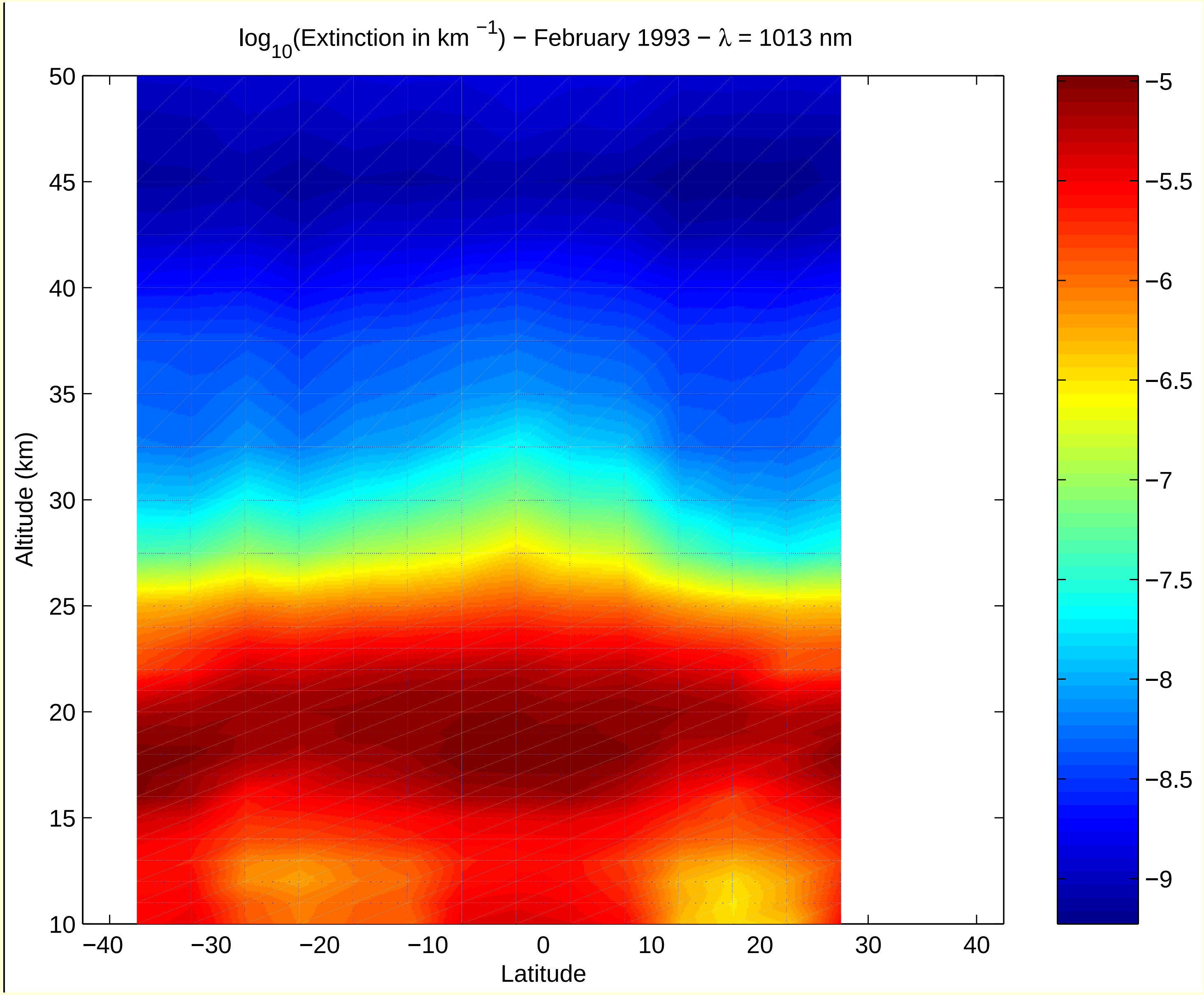


POAM

POAM extinction measurements for the Northern and the Southern hemispheres for the period 1994 to 2003. The data before the gap were obtained by POAM II at 1.06 μm and after the gap by POAM III at 1.02 μm. The graph under the extinction plot shows the latitude at which the data were obtained.



POAM II and III extinction in Southern Hemisphere: PSC’s removed

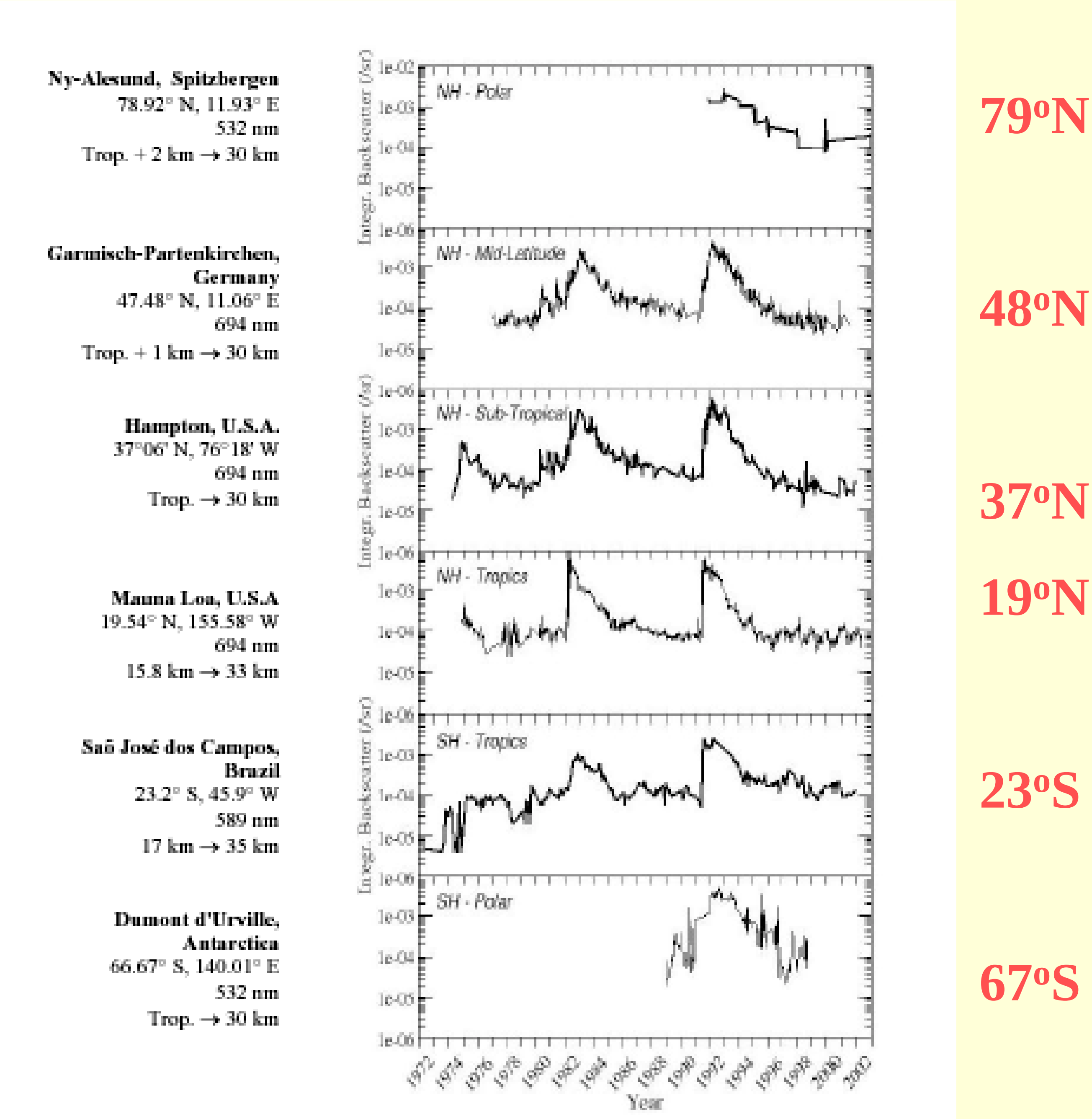


ORA instrument. Extinction at 1.013 μm, February, 1993. Plot by Didier Fussen

Other Instruments and Satellite Validations

LIDAR

Various lidar measurements of the stratospheric aerosol at stations from Arctic to Antarctic.

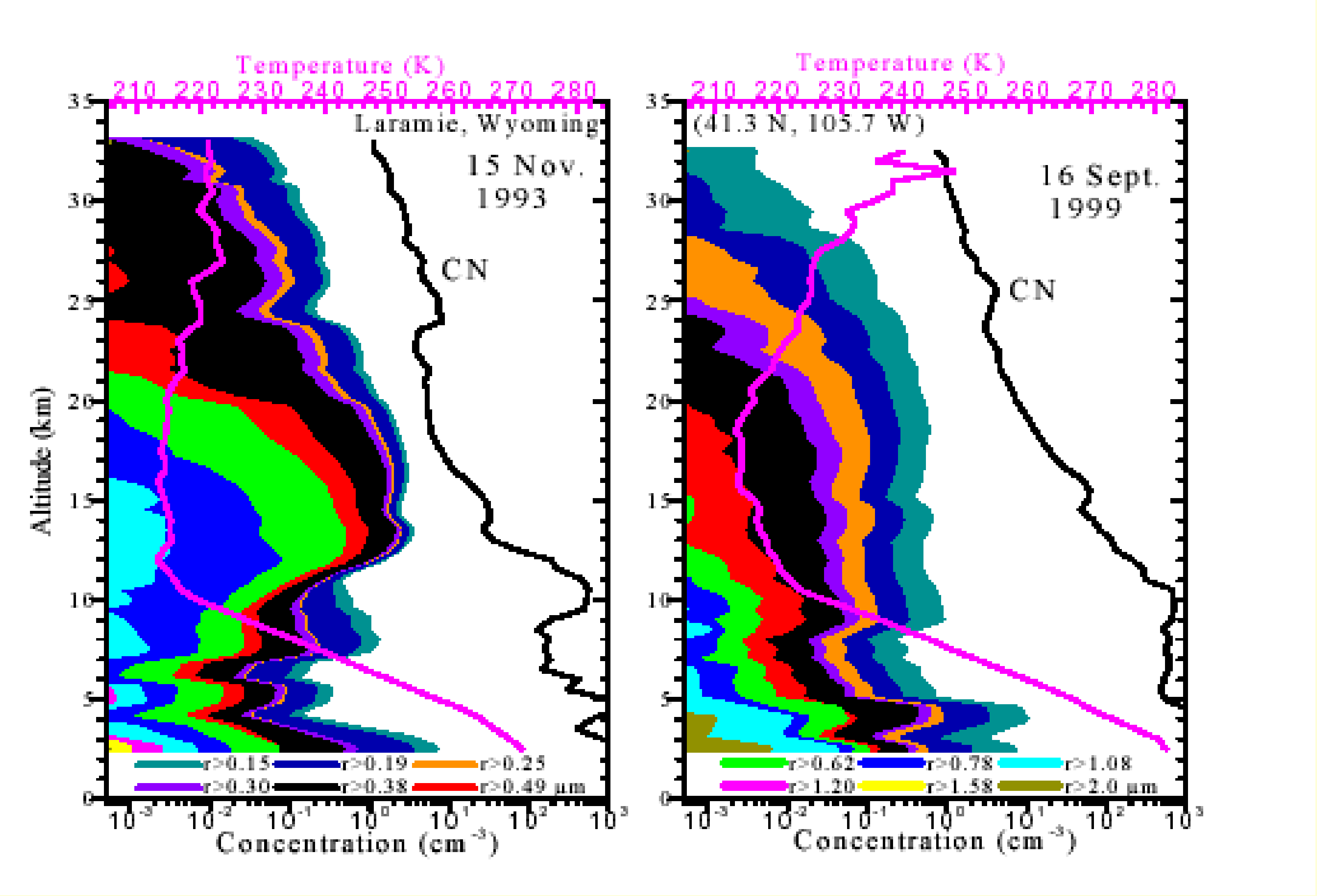


(Compiled by Christine David)

AATS-14

Poster by Phil Russell et al. Compares AATS line of sight transmission with SAGE III measurements.

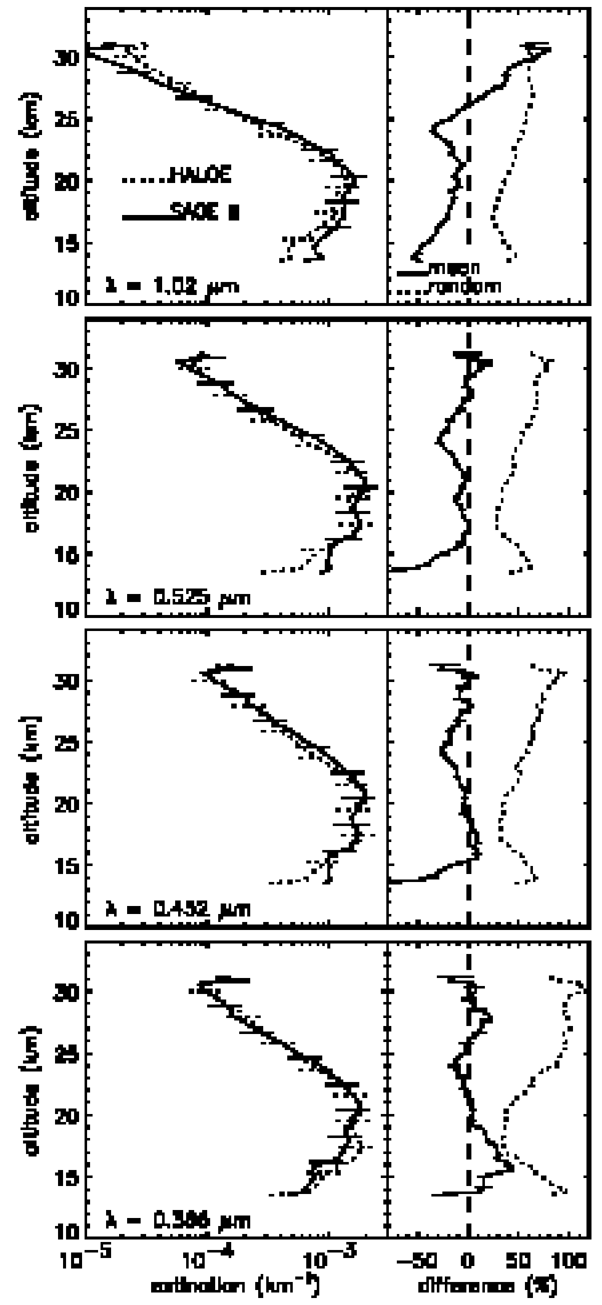
University of Wyoming balloon borne particle counter yields aerosol concentrations in twelve size ranges. Plot by Terry Deshler.



1993

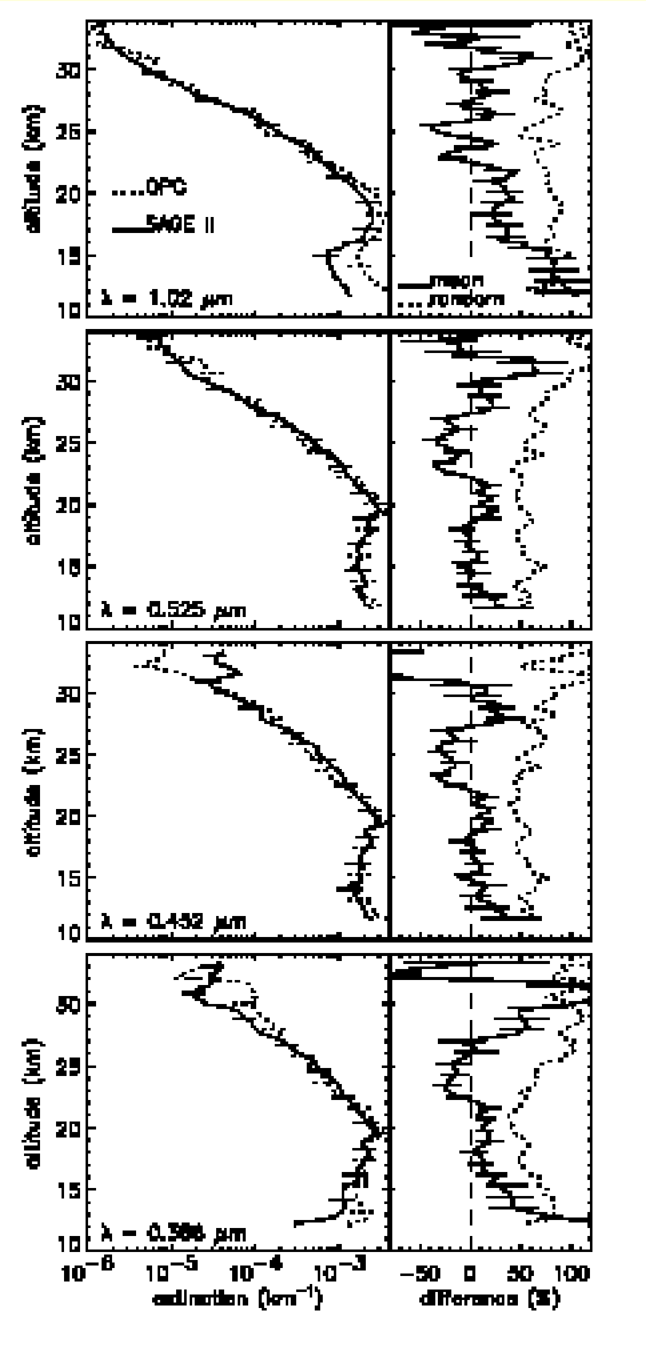
1999

Comparisons



Comparison statistics for 281 coincident HALOE and SAGE II profiles between 38°N and 44°N latitude, from 1991 through 1998. **The average profile separations were 12.1 hours, 0.8° latitude, and 8.0° longitude. Statistics are shown as mean profiles, mean differences (HALOE - SAGE II), and difference standard deviations (random differences). Error bars on the mean profiles indicate the reported measurement uncertainties, and error bars on the mean differences indicate uncertainties in the mean differences (difference standard deviation / *N*1/2).**

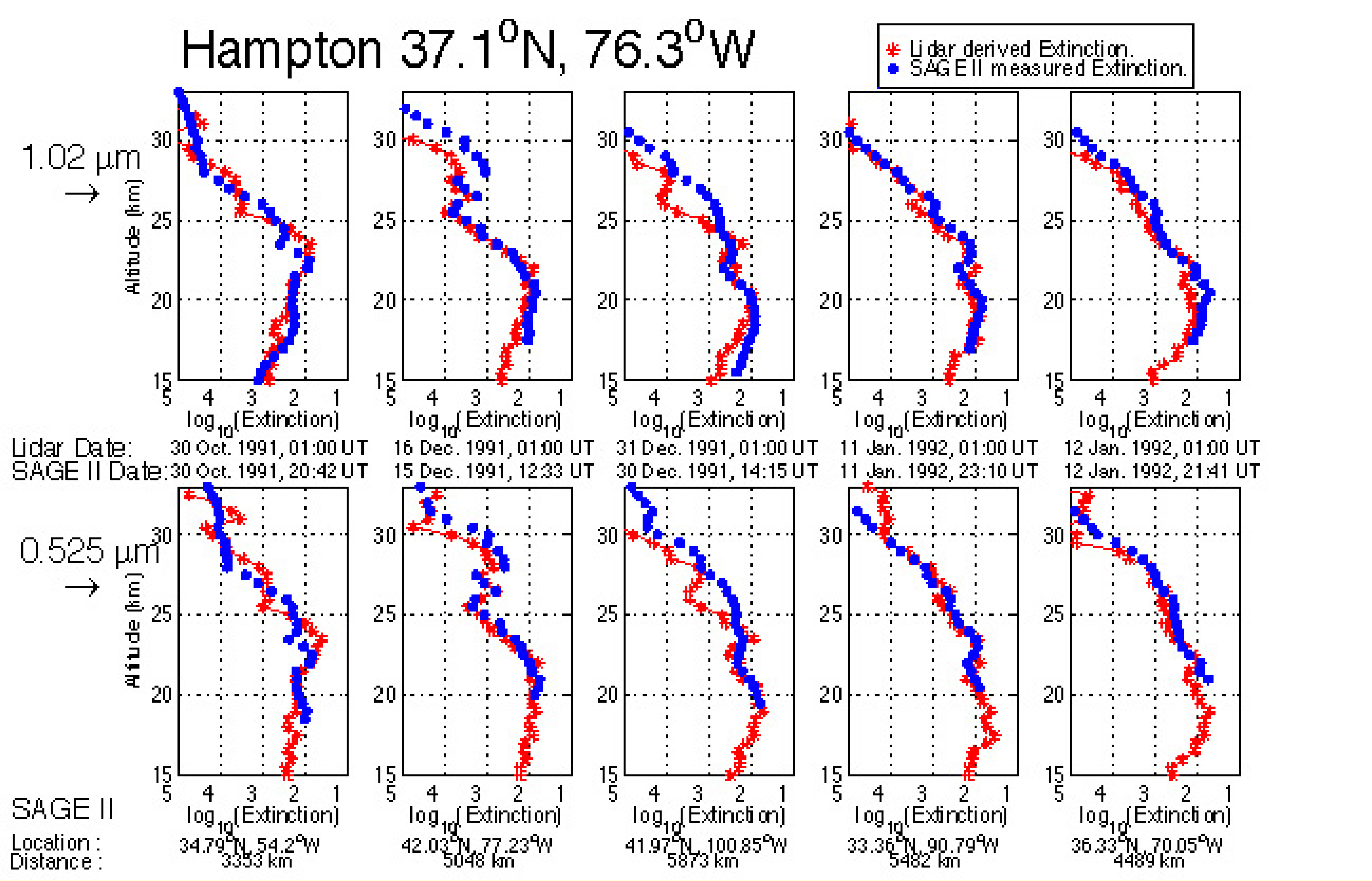
M. Hervig



Comparison statistics for 22 coincident OPC and SAGE II profiles over Laramie, from 1984 through 1999. The average profile separations were 10.7 hours, 0.8° latitude, and 5.8° longitude.

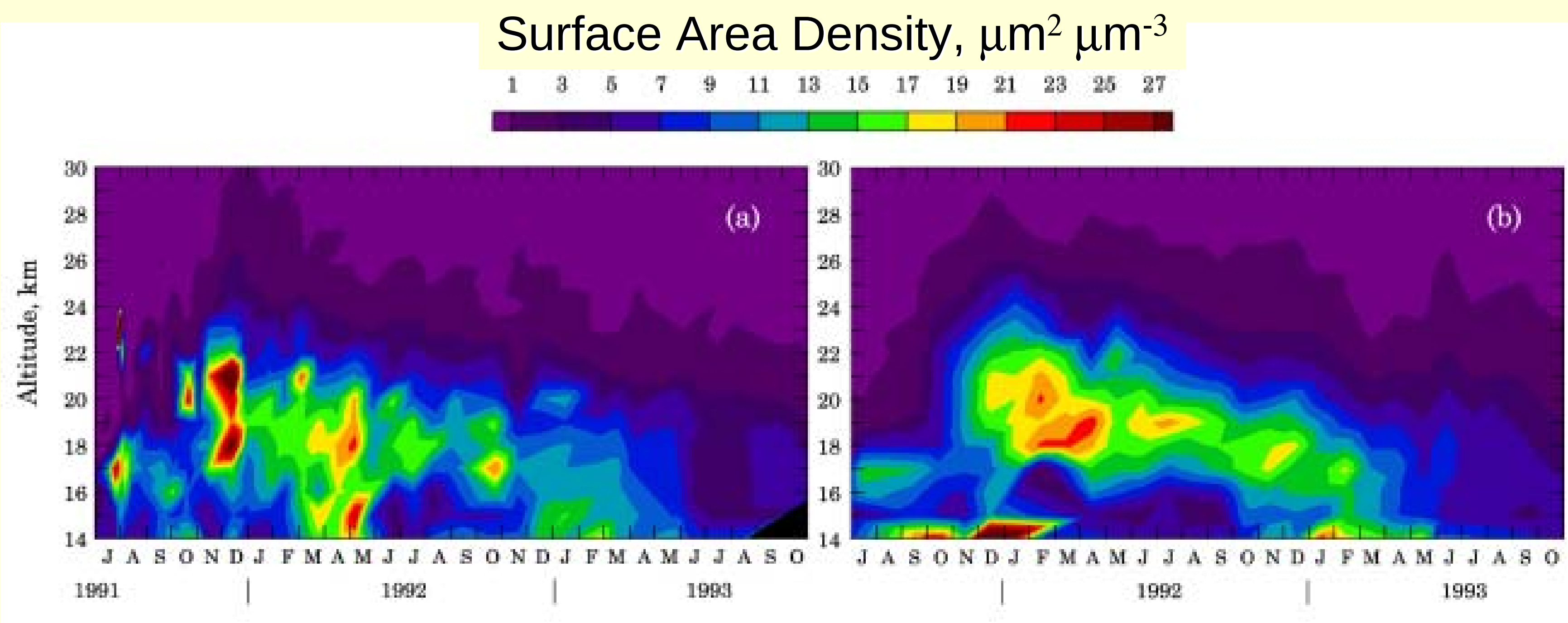
M. Hervig

Hampton Lidar (derived extinction) compared to SAGE II extinctions



Comparisons by Juan Carlos Antuña

Surface area densities obtained from the Wyoming particle counter compared with surface area densities obtained from SAGE II.



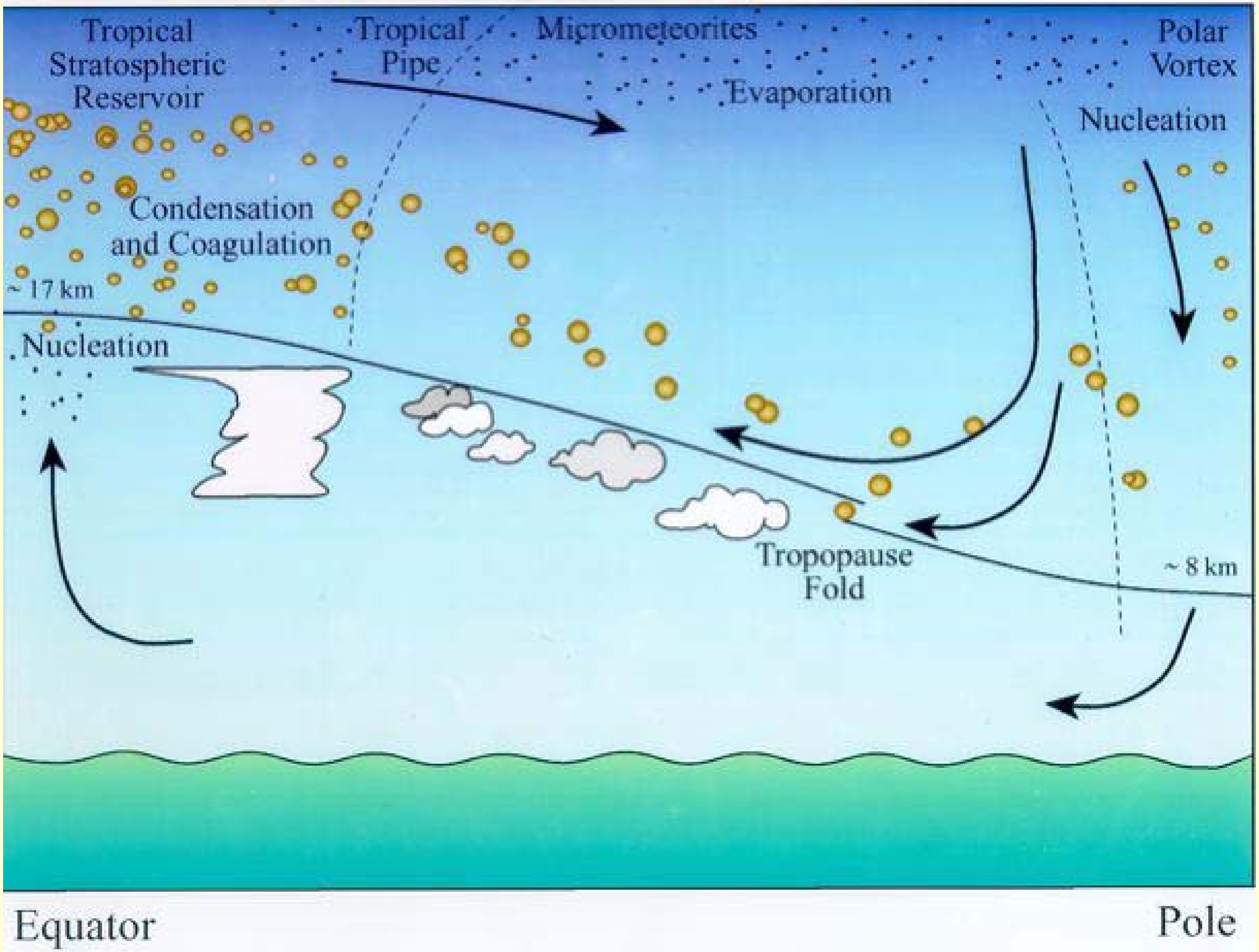
(a) Laramie, Wyoming (41° N), derived by Deshler *et al.* [1993] using lognormal fits to *in situ* size distributions.

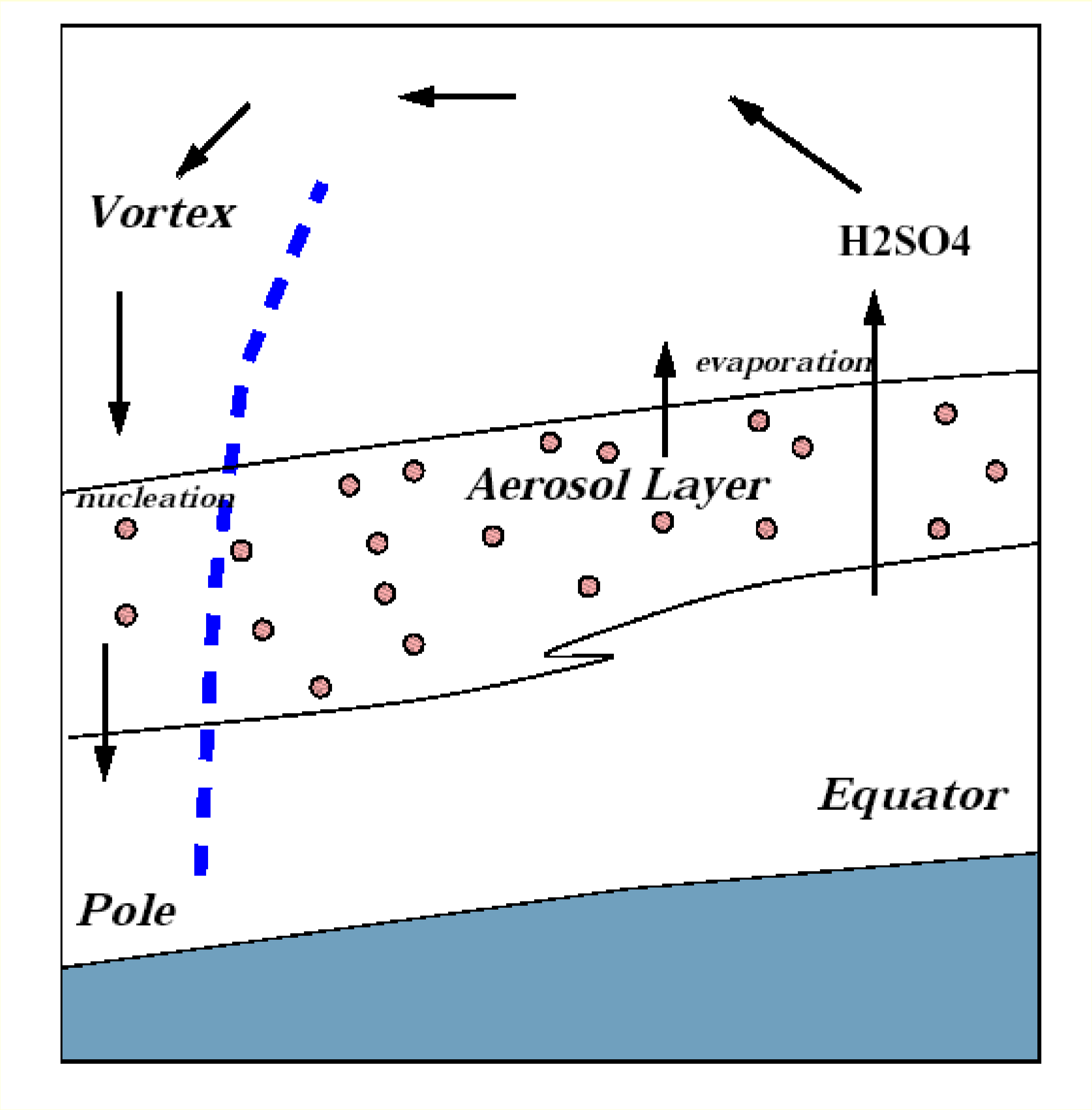
(b) 40° to 45° N, retrieved from SAGE II & CLAES.

[Bauman et al., *JGR* 2003]

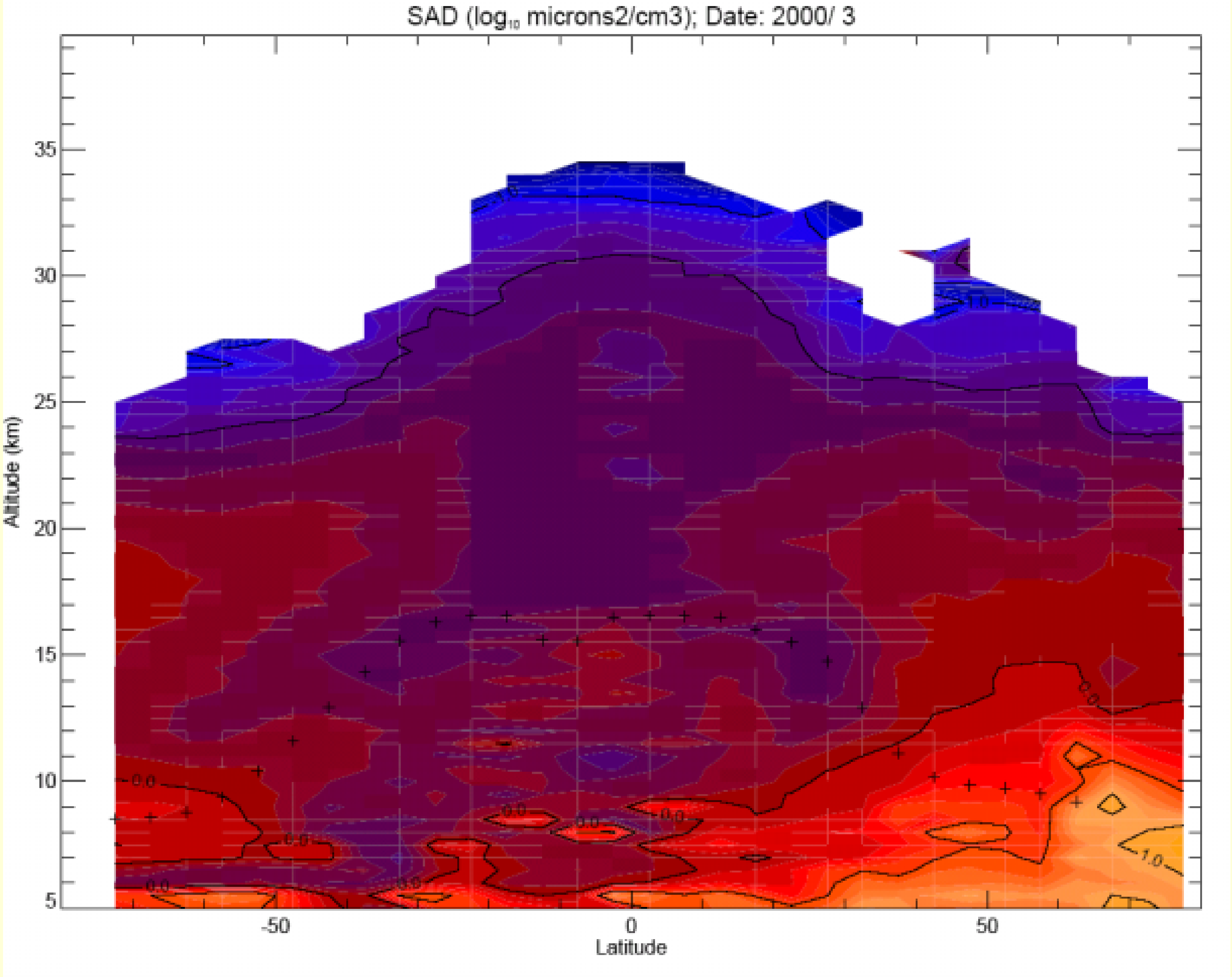
Processes and Models

Life Cycle of Stratospheric Aerosol





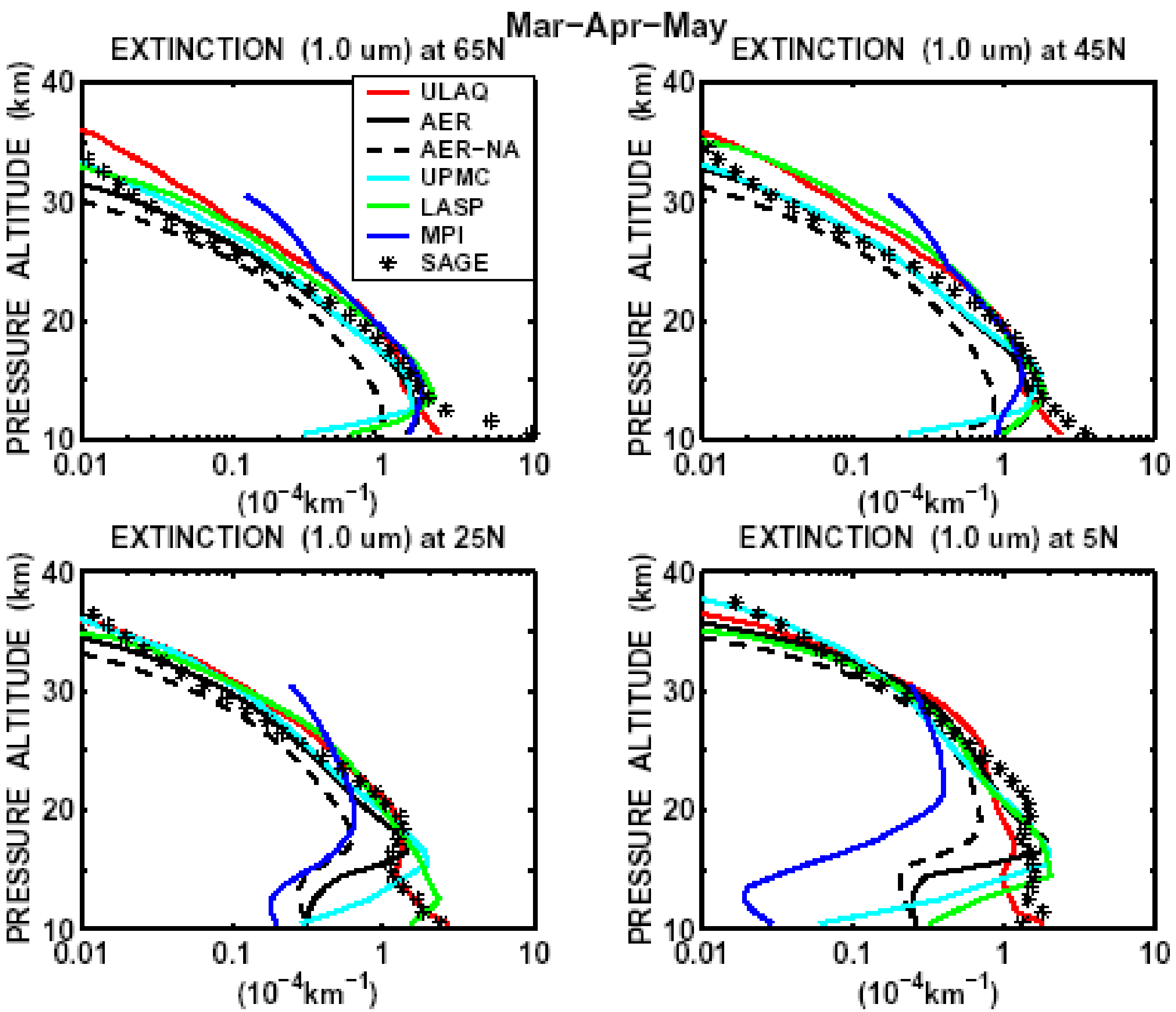
The top of the layer is determined by the temperature at which the sulfuric acid/water solution evaporates. (About 230-235 K)


SAD (log10 microns2/cm3); Date: 2000/ 3
Altitude (km)
Latitude
35
30
25
20
15
10
5
-50
0
50
-1.0
0.0
1.0

Processes

- Nucleation
- Condensation/Evaporation
- Coagulation
- Sedimentation
- Transport

These processes have been incorporated into
1-, 2- and 3-dimensional models



Model results compared with SAGE II 1.02 μm extinction.

L'Aquila

AER

Univ Paris

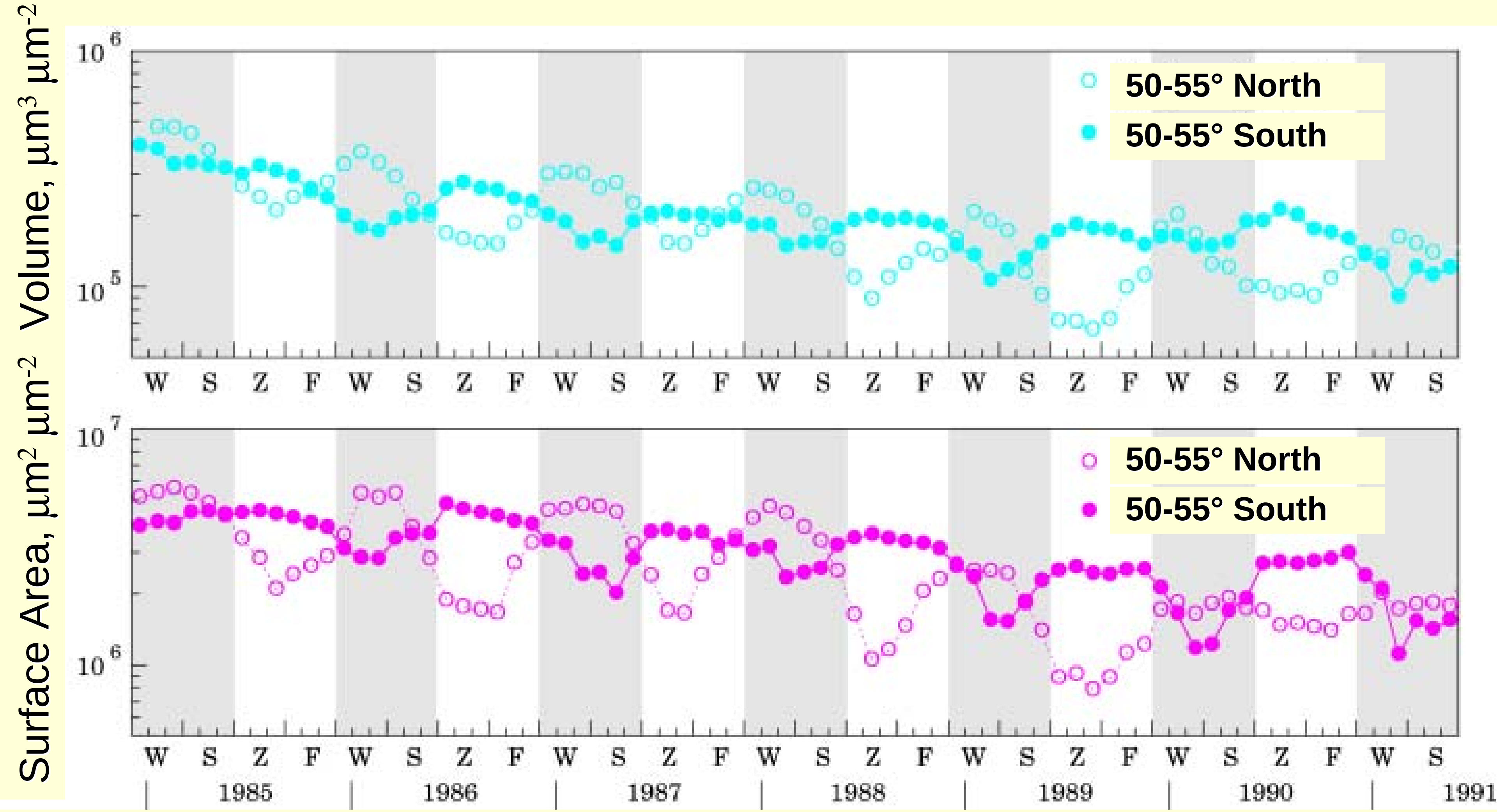
LASP

Hamburg

Compiled by Debra Weisenstein

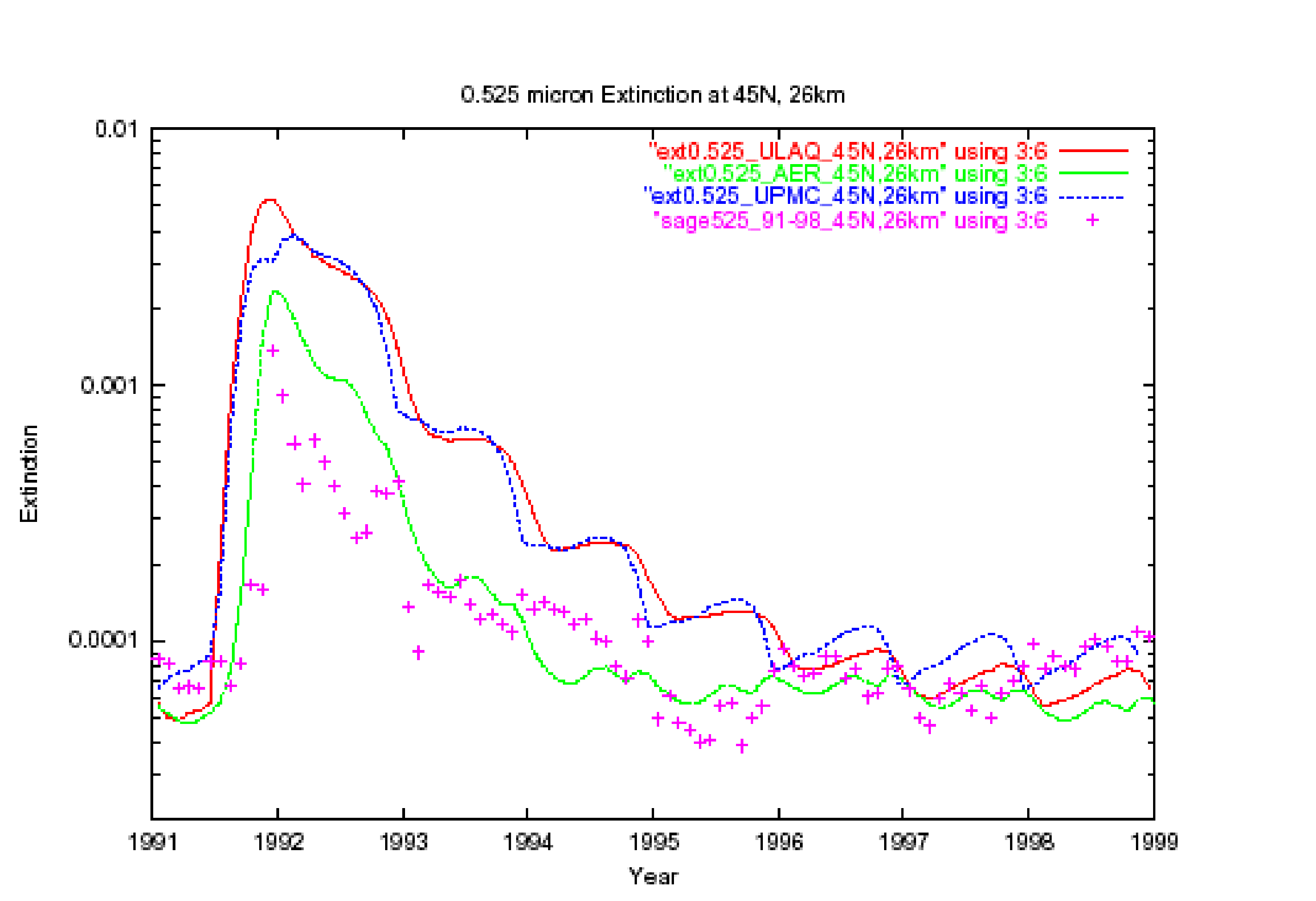
Other models include, for example, the data assimilation model being developed by Giorgi Stenchikov et al. (See his poster for details.)

Seasonal variations in volume and surface area



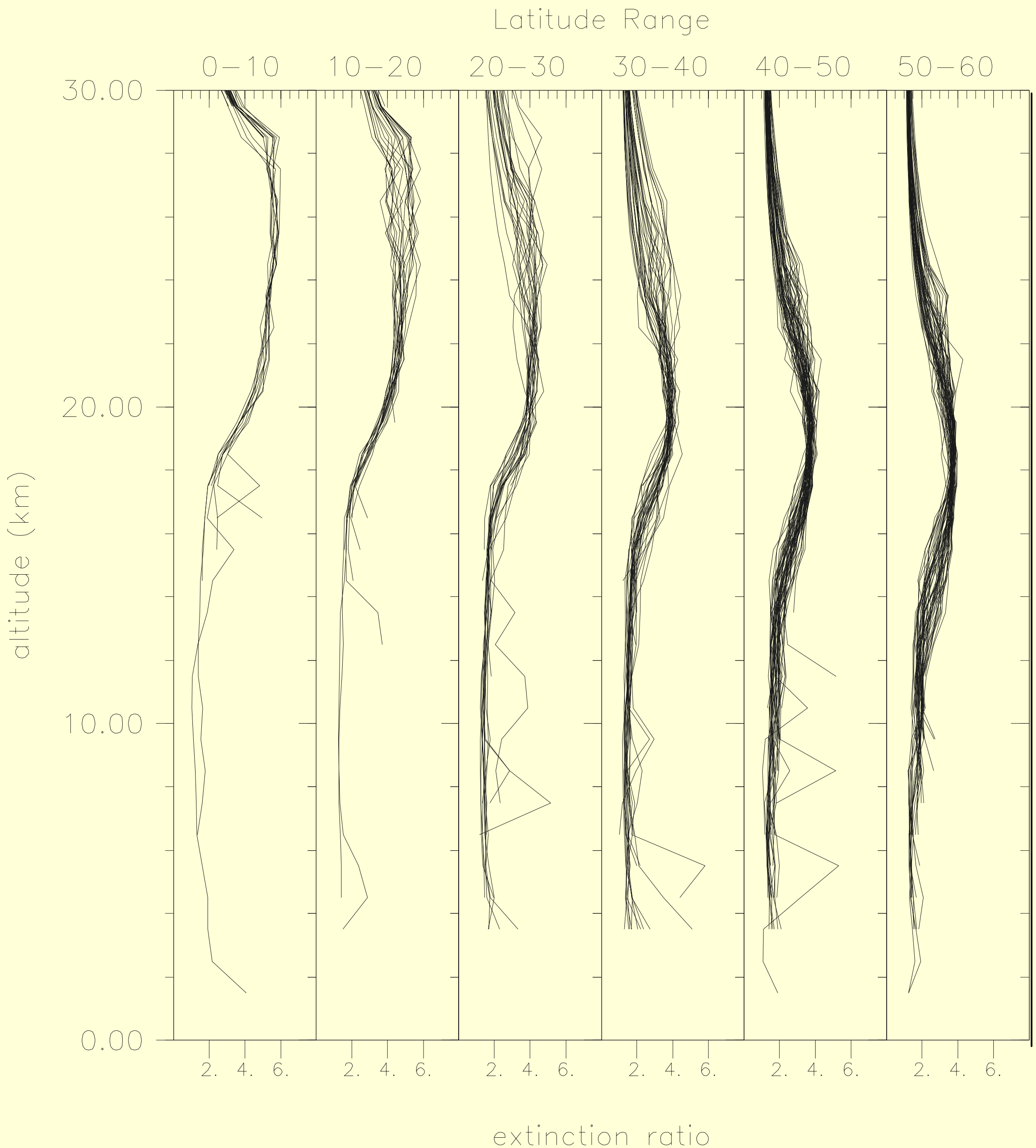
[Bauman et al., *JGR* 2003b]

The variation is also present in the models



See poster by Debra Weisenstein

Latitudinal Variation



Hamill et al (BAMS) 1997

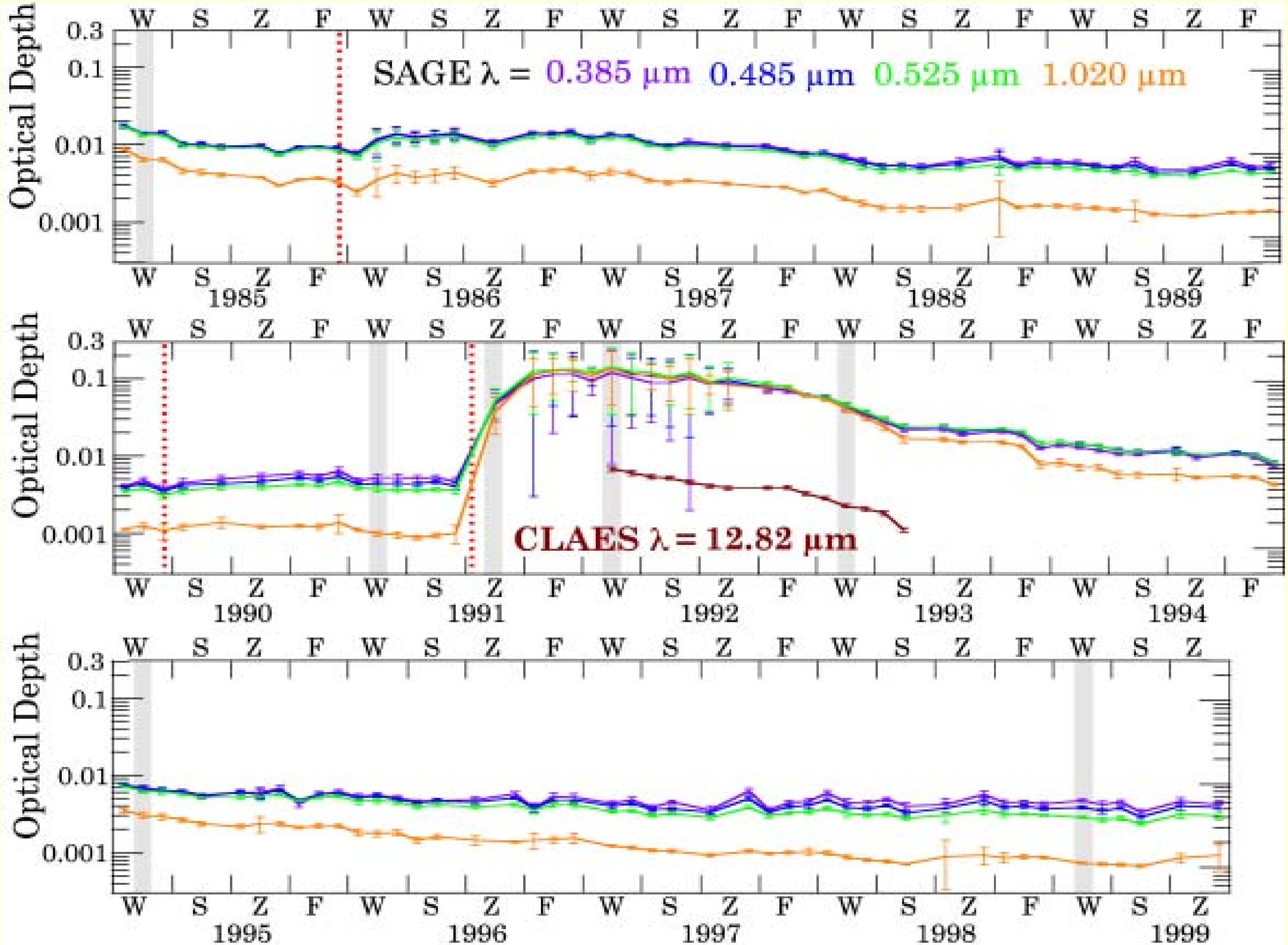
Volcanic eruptions are the most significant factor influencing the stratospheric aerosol

Mt. Pinatubo

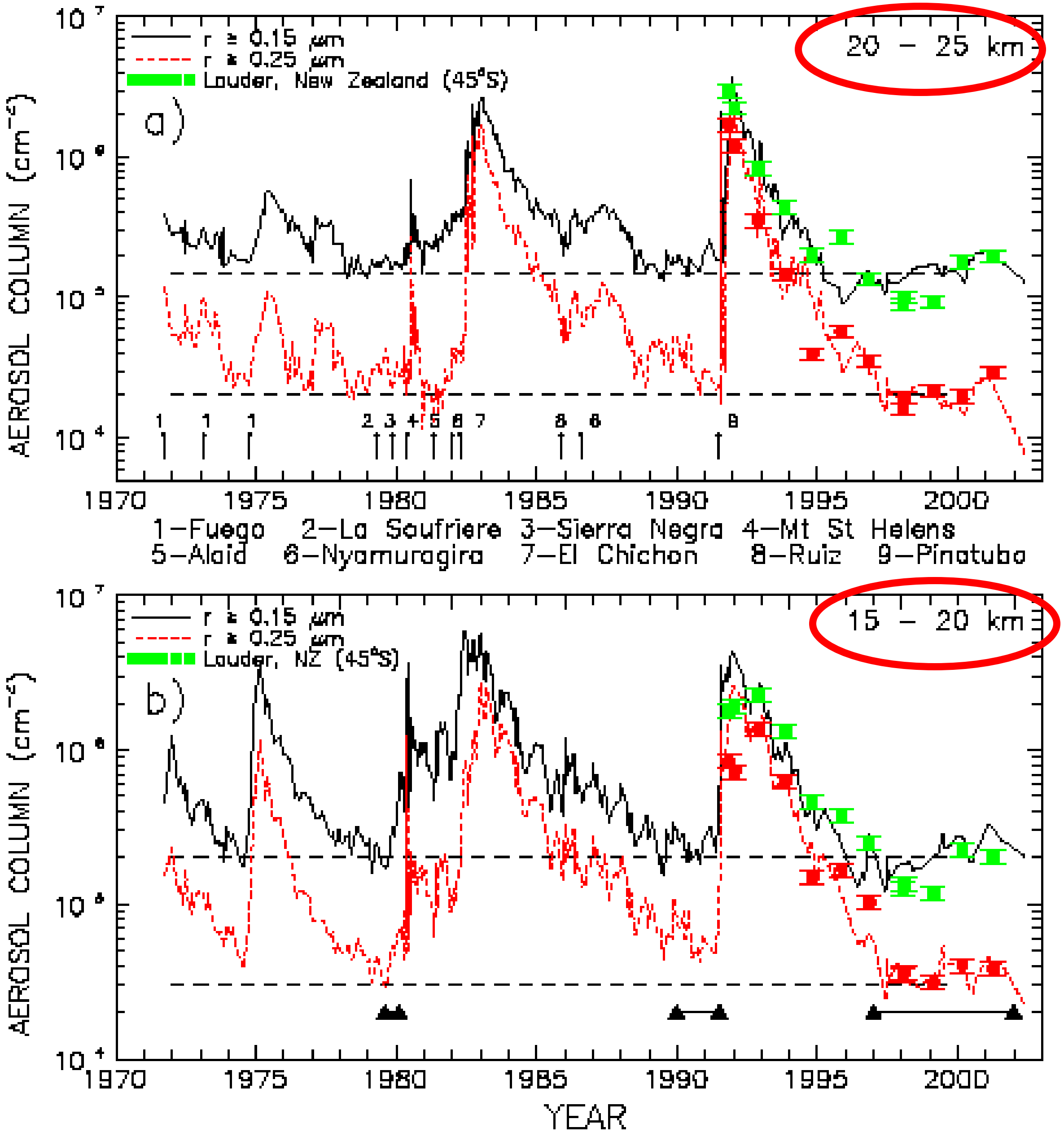
Trends and the “Background” Aerosol Layer

Are we at background? Does a background layer exist?

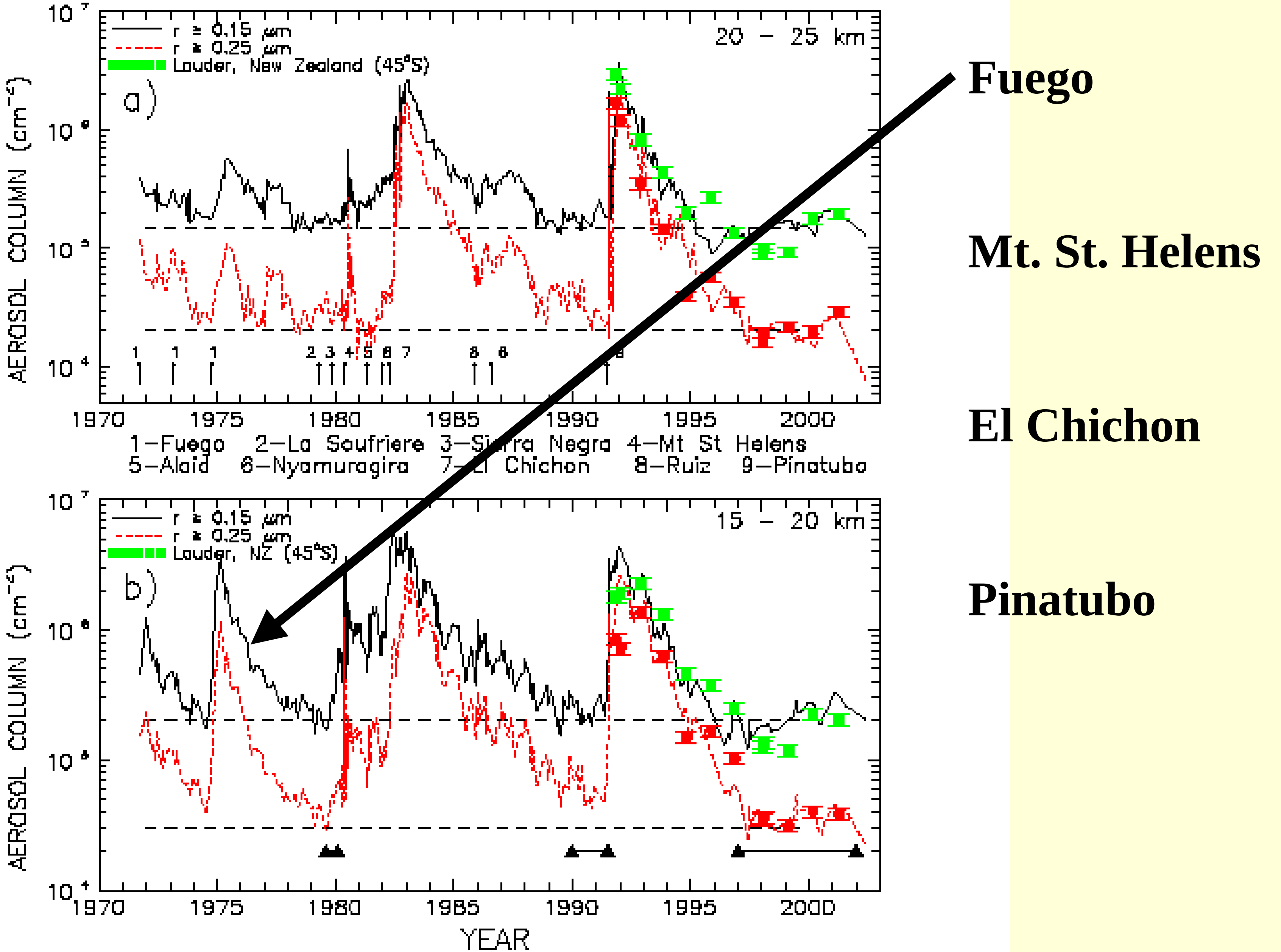
SAGE optical depths at 4 wavelengths 1985-1999 for 15-20°N



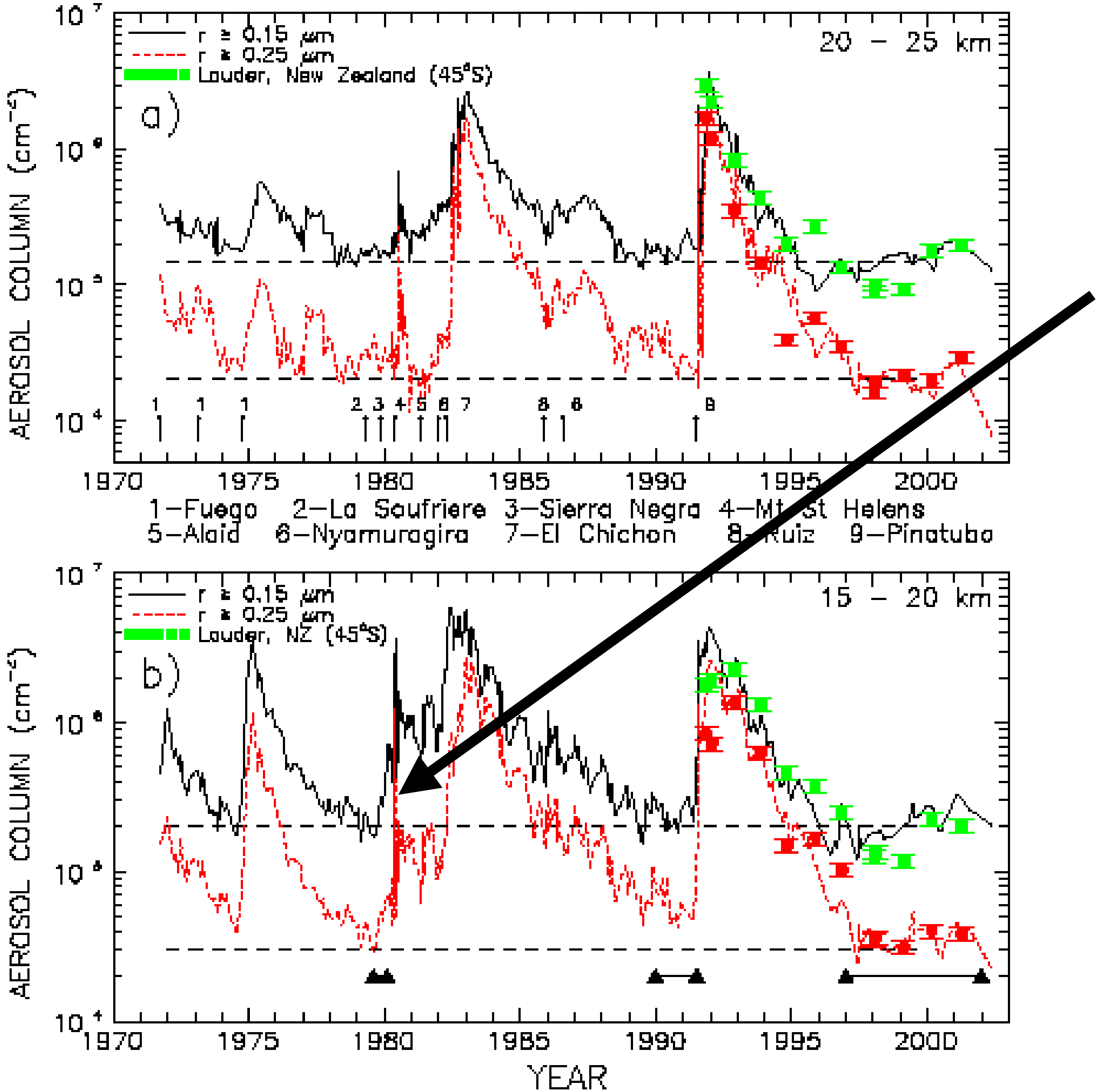
[Bauman et al., *JGR* 2003b]



a)
r ≥ 0.15 µm
r ≥ 0.25 µm
Louder, New Zealand (45°S)
20 – 25 km
AEROSOL COLUMN (cm⁻²)
1 1 1 2 3 4 5 6 7 8 6 9
1970 1975 1980 1985 1990 1995 2000
1–Fuego 2–La Soufriere 3–Sierra Negra 4–Mt St Helens
5–Alaid 6–Nyamuragira 7–El Chichon 8–Ruiz 9–Pinatubo
b)
r ≥ 0.15 µm
r ≥ 0.25 µm
Louder, NZ (45°S)
15 – 20 km
AEROSOL COLUMN (cm⁻²)
YEAR



r ≥ 0.15 μm
r ≥ 0.25 μm
Louder, New Zealand (45°S)
20 – 25 km
a)
AEROSOL COLUMN (cm⁻²)
1970 1975 1980 1985 1990 1995 2000
1–Fuego 2–La Soufriere 3–Sierra Negra 4–Mt St Helens
5–Alaid 6–Nyamuragira 7–El Chichon 8–Ruiz 9–Pinatubo
r ≥ 0.15 μm
r ≥ 0.25 μm
Louder, NZ (45°S)
15 – 20 km
b)
YEAR
Fuego
Mt. St. Helens
El Chichon
Pinatubo

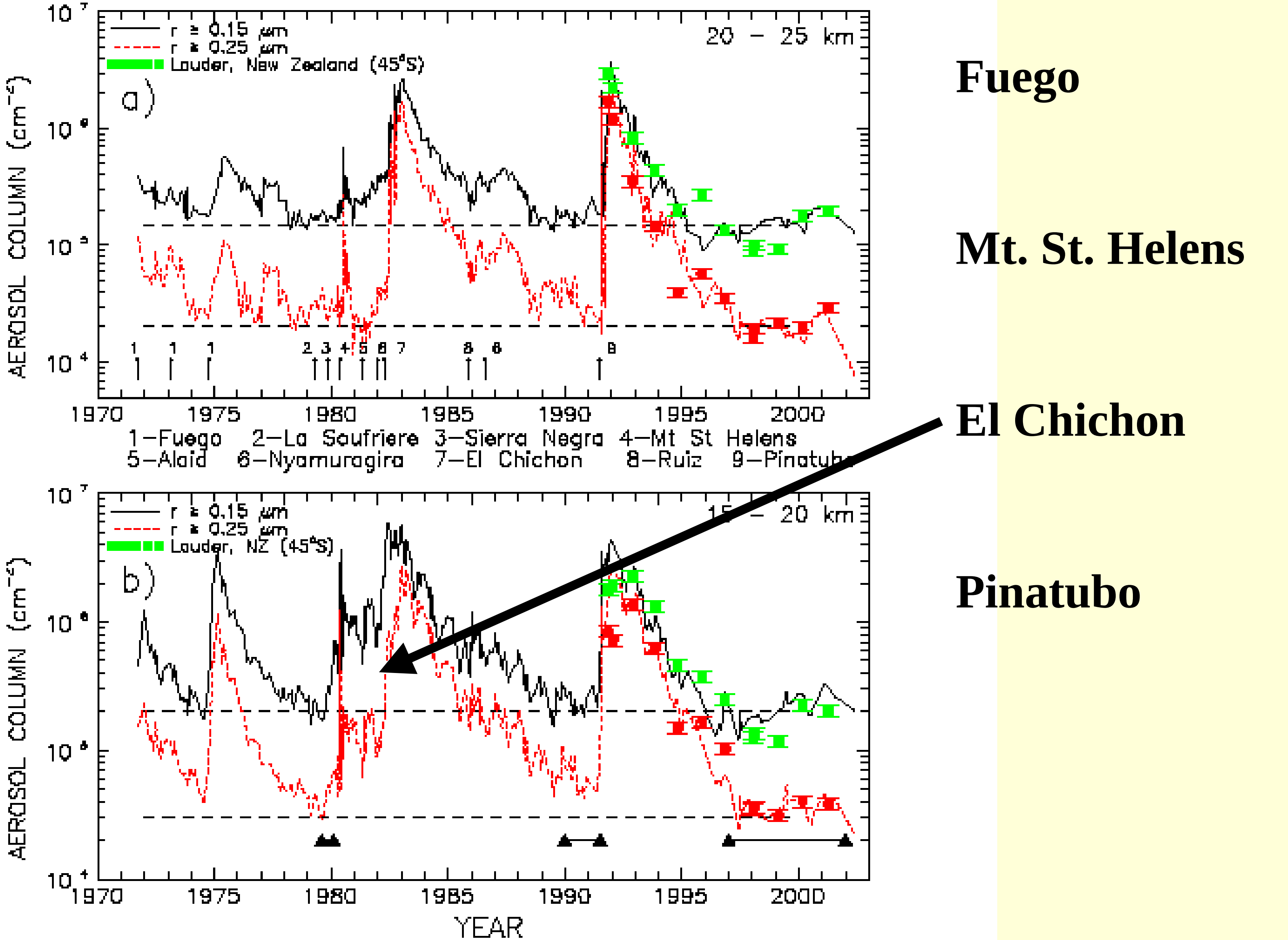


Fuego

Mt. St. Helens

El Chichon

Pinatubo



r ≥ 0.15 μm
r ≥ 0.25 μm
Louder, New Zealand (45°S)
20 – 25 km
a)
AEROSOL COLUMN (cm⁻²)
1 1 1 2 3 4 5 6 7 8 6 9
1–Fuego 2–La Soufriere 3–Sierra Negra 4–Mt St Helens
5–Alaid 6–Nyamuragira 7–El Chichon 8–Ruiz 9–Pinatubo
r ≥ 0.15 μm
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Louder, NZ (45°S)
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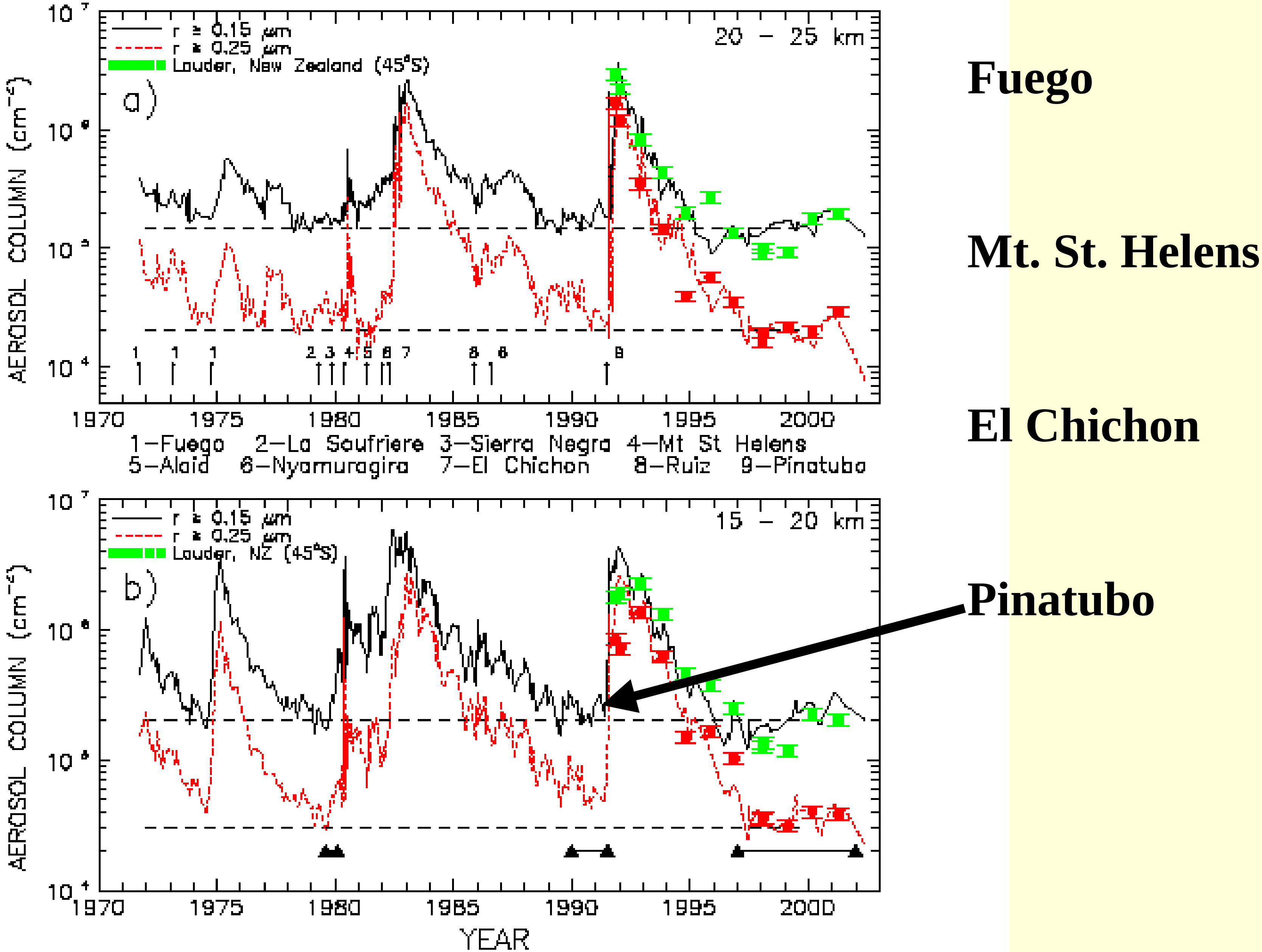
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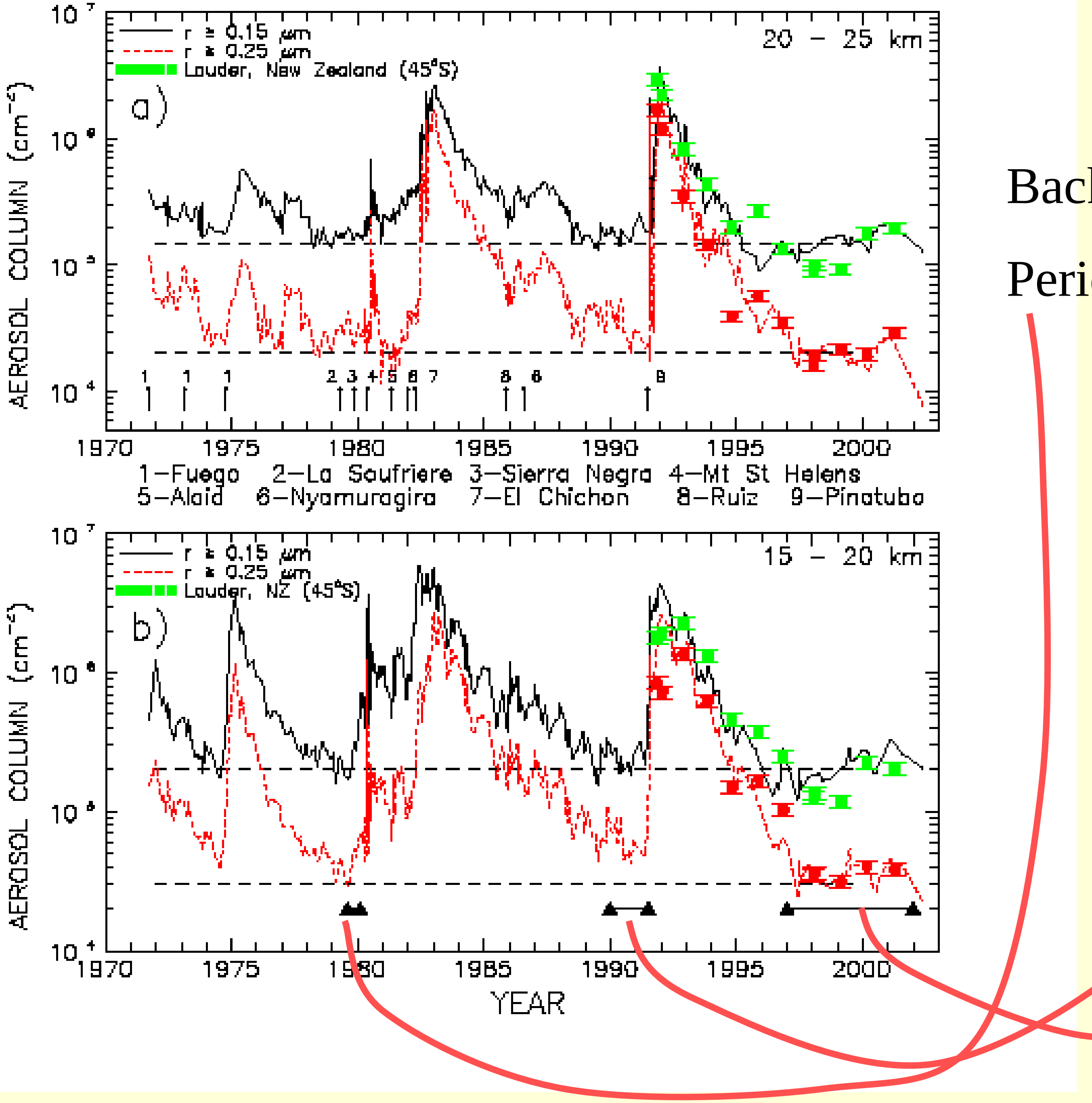


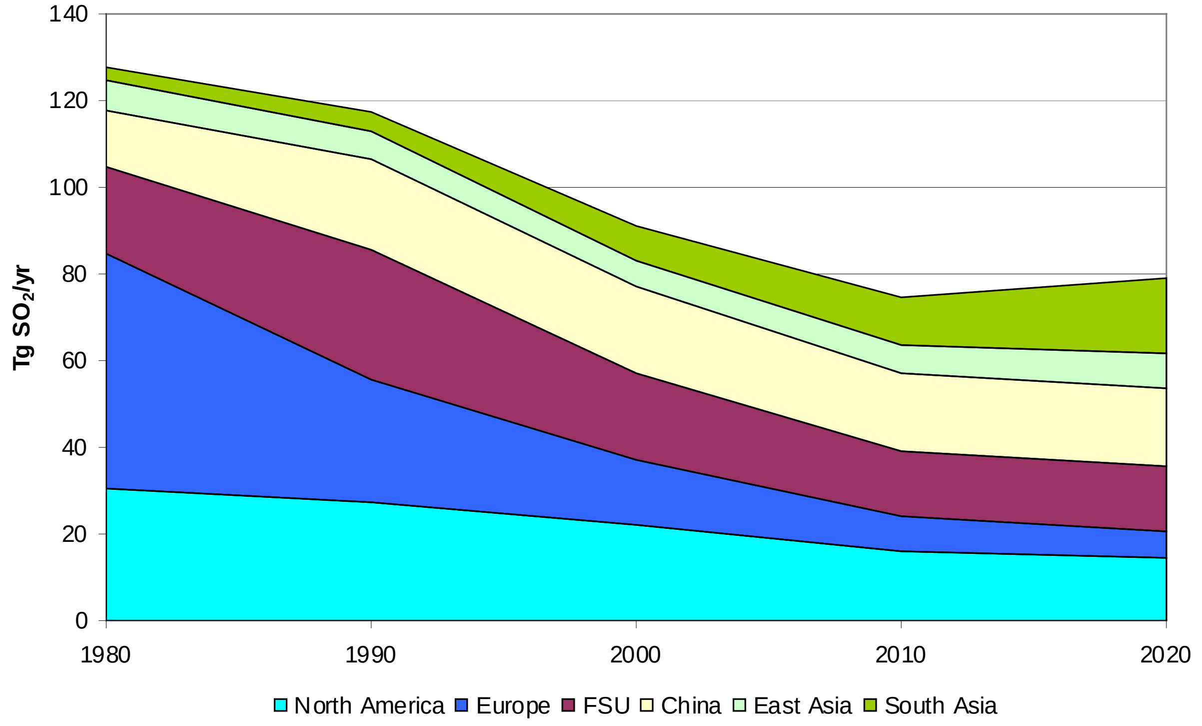
Background

Periods?

Precursor Gases
(Considered in detail in SPARC Report)

If a background layer exists, it is probably maintained by OCS diffusing to the stratosphere. However, SO_2 is the primary sulfur bearing gas in the troposphere, and anthropogenic contributions to SO_2 have been decreasing.

Anthropogenic SO2 emissions in North America and Europe have declined significantly.



Compiled by Hans Bingeman

Trends

- "Background" is difficult to define. Note that balloon data are geographically limited.
- If background was reached three times in the last 30 years, has the background value been changing?
- If the background level has been changing is it due to anthropogenic factors?

Thank you

You can download this presentation from

http://wind.sjsu.edu/sjsu/SOSST