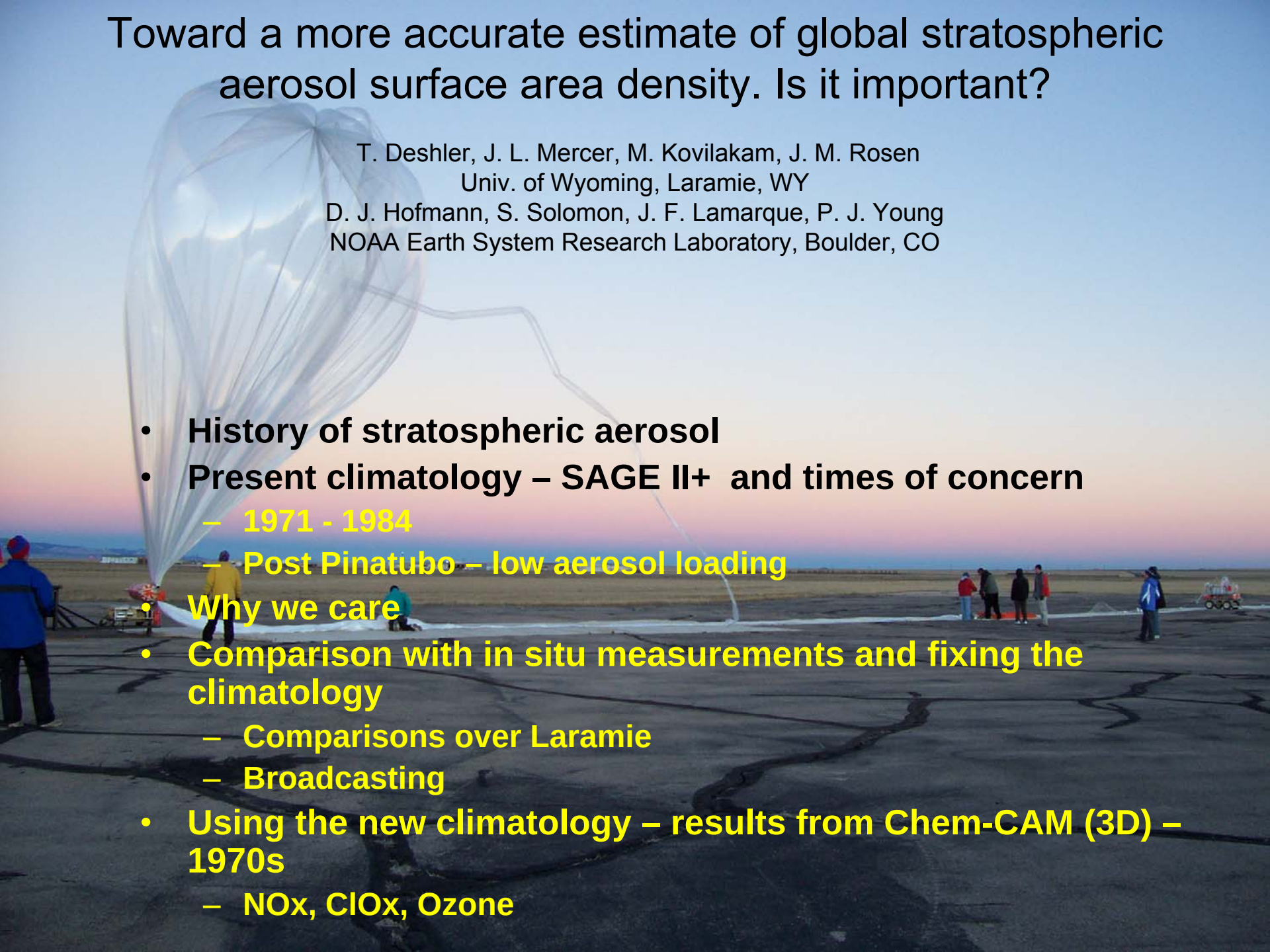
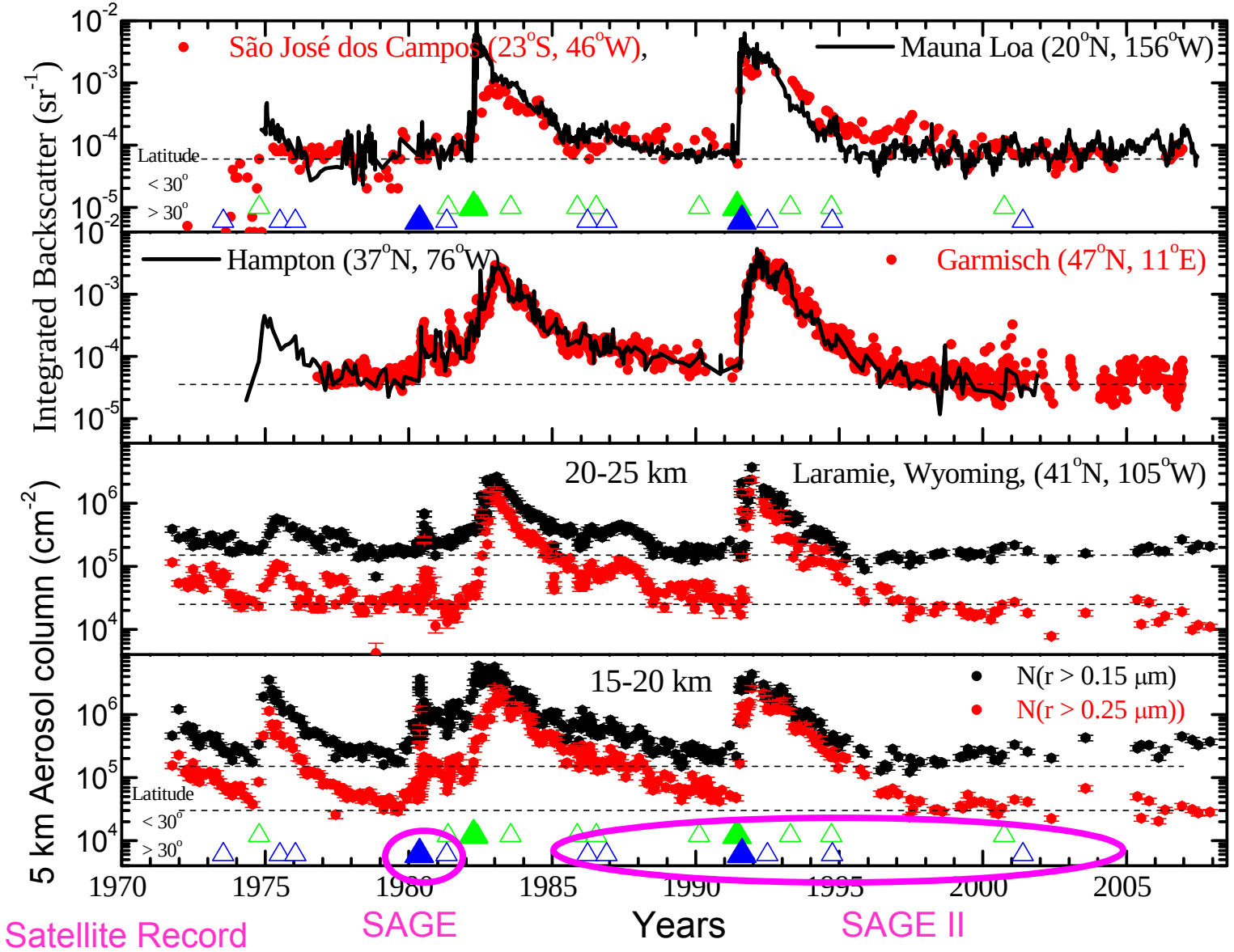
Toward a more accurate estimate of global stratospheric aerosol surface area density. Is it important?

T. Deshler, J. L. Mercer, M. Kovilakam, J. M. Rosen
Univ. of Wyoming, Laramie, WY
D. J. Hofmann, S. Solomon, J. F. Lamarque, P. J. Young
NOAA Earth System Research Laboratory, Boulder, CO



- **History of stratospheric aerosol**
- **Present climatology – SAGE II+ and times of concern**
  - **1971 - 1984**
  - **Post Pinatubo – low aerosol loading**
- **Why we care**
- **Comparison with in situ measurements and fixing the climatology**
  - **Comparisons over Laramie**
  - **Broadcasting**
- **Using the new climatology – results from Chem-CAM (3D) – 1970s**
  - **NOx, ClOx, Ozone**

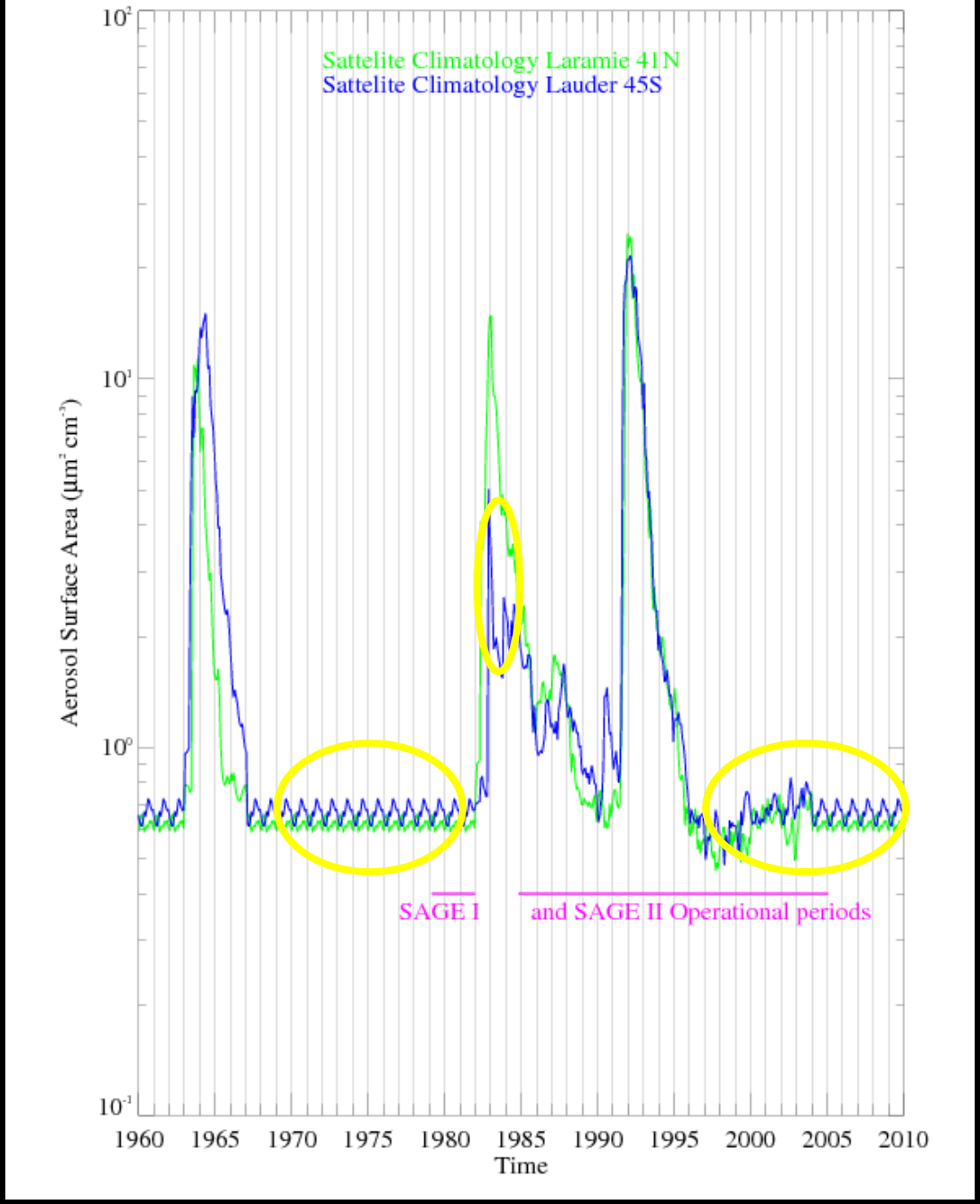


Four Lidar Records

In Situ Record Two altidudes

Deshler, T. (2008), A Review of Global Stratospheric Aerosol: Measurements, Importance, Life Cycle, and Local Stratospheric Aerosol, *Atmos. Res., 90*, 223-232.

Periods of concern



Current Surface area density used in Atmospheric models

Why we care

$N_2O_5 + H_2O_{(aer)} \rightarrow 2HNO_3$

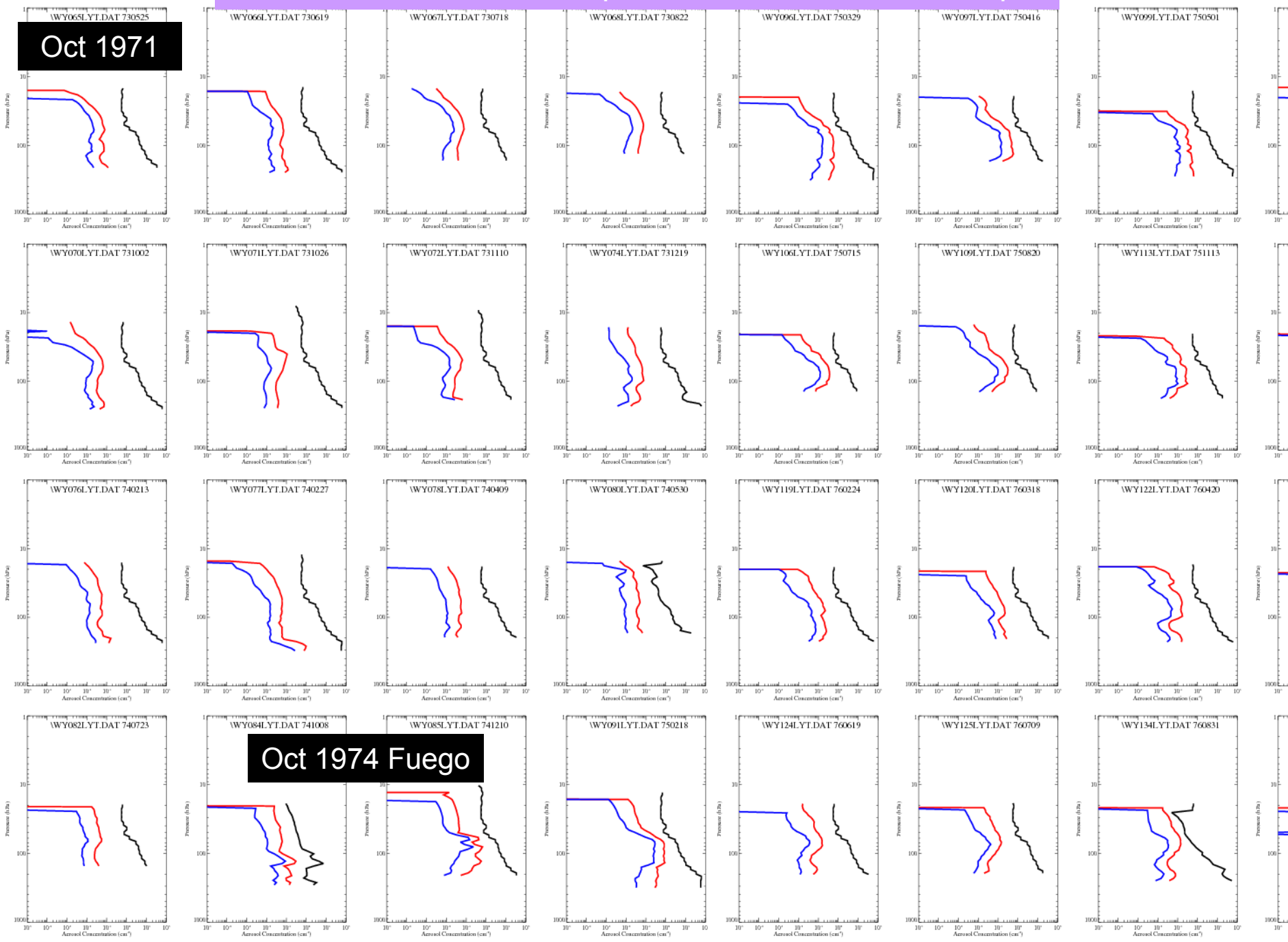
- Results of this conversion
  - Less N_2O_5 for: $N_2O_5 + hv \rightarrow NO_2 + NO_3$
  - Less NO_2 for
    - $NO_2 + ClO + M \rightarrow ClONO_2$
    - $NO_2 + OH + M \rightarrow HNO_3$
  - More ClO for
    - $HO_2 + ClO \rightarrow HOCl + O_2$, $HOCl + hv \rightarrow OH + Cl$
    - $Cl + O_3 \rightarrow ClO + O_2$
  - More OH for
    - $OH + O_3 \rightarrow HO_2 + O_2$
    - $HO_2 + O_3 \rightarrow OH + O_2 + O_2$
- Net result
  - Less ozone from reactions with ClO and OH
  - More ozone from reduction in loss from NOx

Revising the climatology using In Situ Aerosol Profiles

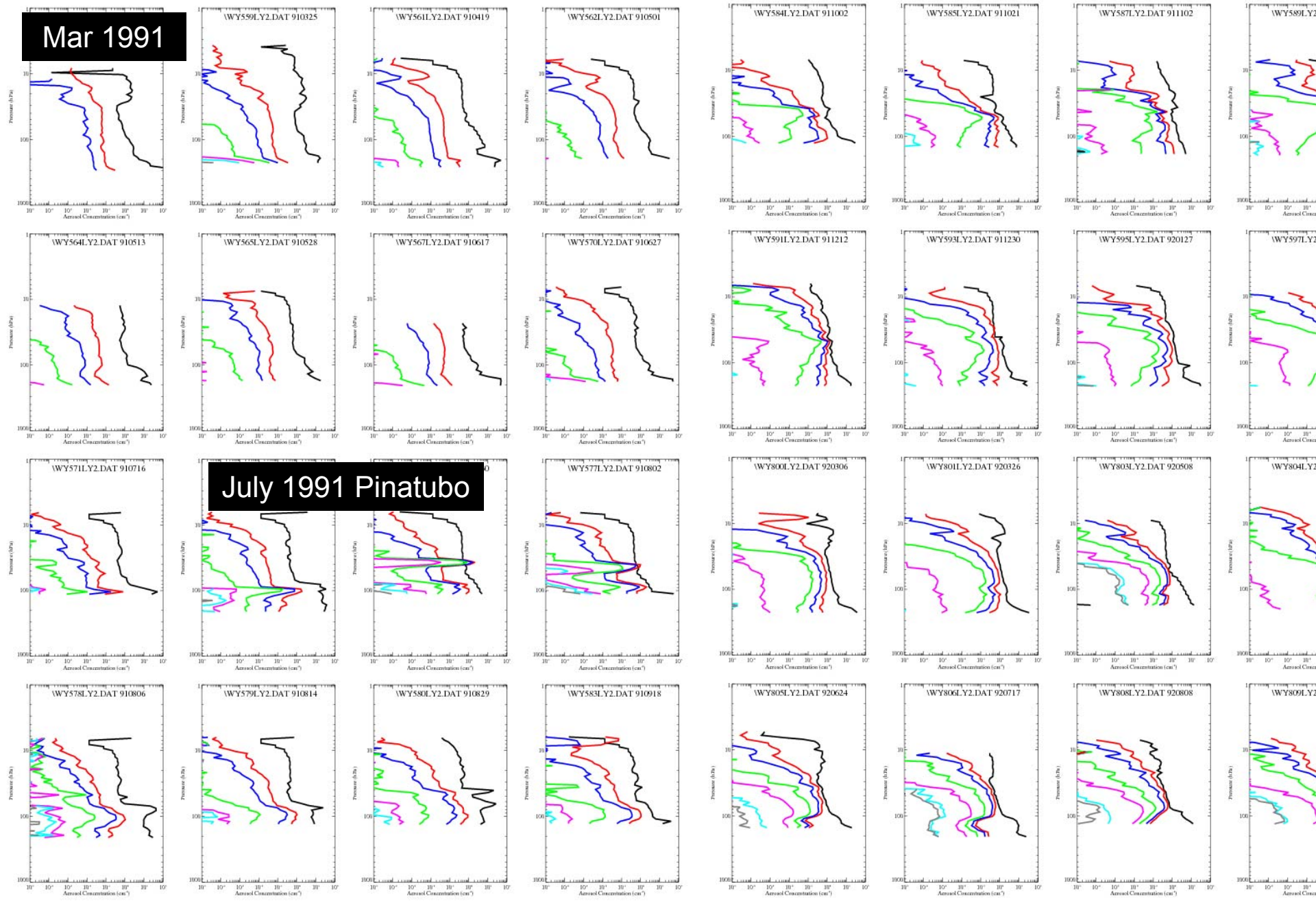
University of Wyoming –
with particular thanks to Jim Rosen and Dave Hofmann

- http://www-das.uwyo.edu/~deshler/
  - US_Laramie_41N_105W (1971 - 2009)
  - AU_Mildura_34S_142W (1972 - 1980)
  - NZ_Lauder_45S_170E (1991 - 2001)
  - Ant_McMurdo_78S_167E (1989 - 2008)
  - SE_Kiruna_68N_21E (1991 - 2004)
  - Miscellaneous
    - Brazil, Niamey, France

Aerosol concentration for particles > 0.01, 0.15, 0.25 µm

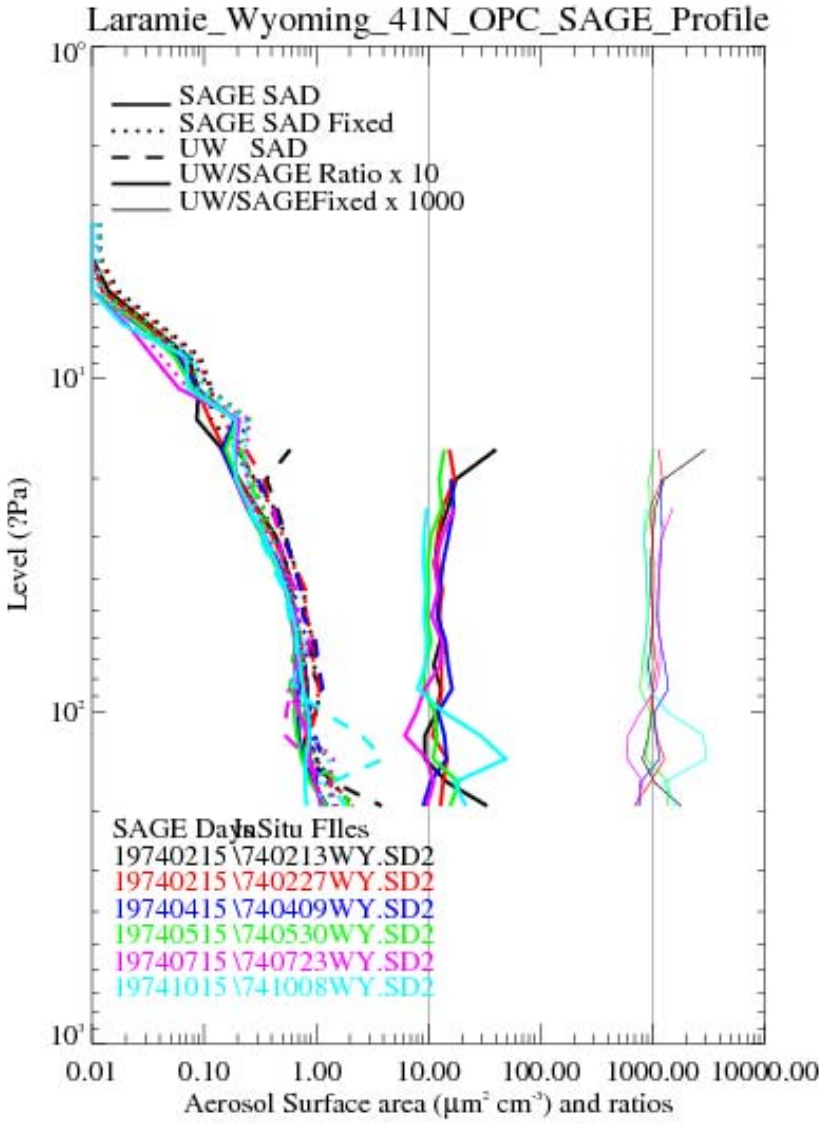


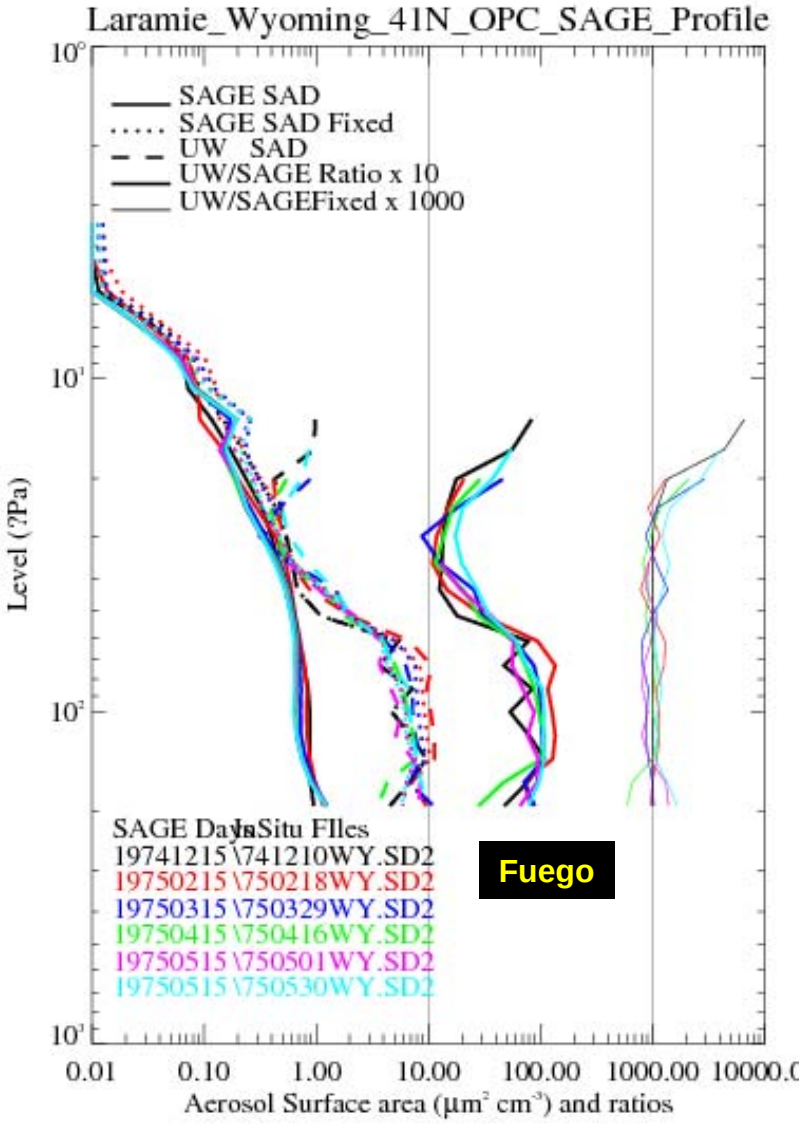
Aerosol concentration for particles > 0.01, 0.15, 0.25, … 2.0/10.0 µm



Fixing the climatology

- Comparisons over Laramie
- Resultant ratios
- Broadcasting
  - Comparison with far flung measurements
    - Mildura Australia (1972-1980)
    - Lauder New Zealand (1991-2001)
  - Led to determining rate of latitudinal spread and weighting functions for dispersal from eruptions


Laramie_Wyoming_41N_OPC_SAGE_Profile
SAGE SAD
SAGE SAD Fixed
UW SAD
UW/SAGE Ratio x 10
UW/SAGEFixed x 1000
SAGE Data In Situ Files
19740215\740213WY.SD2
19740215\740227WY.SD2
19740415\740409WY.SD2
19740515\740530WY.SD2
19740715\740723WY.SD2
19741015\741008WY.SD2
Level (?Pa)
Aerosol Surface area (µm² cm⁻³) and ratios


Laramie_Wyoming_41N_OPC_SAGE_Profile
SAGE SAD
SAGE SAD Fixed
UW SAD
UW/SAGE Ratio x 10
UW/SAGEFixed x 1000
SAGE Data In Situ Files
19741215\741210WY.SD2
19750215\750218WY.SD2
19750315\750329WY.SD2
19750415\750416WY.SD2
19750515\750501WY.SD2
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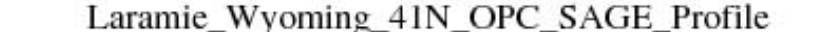
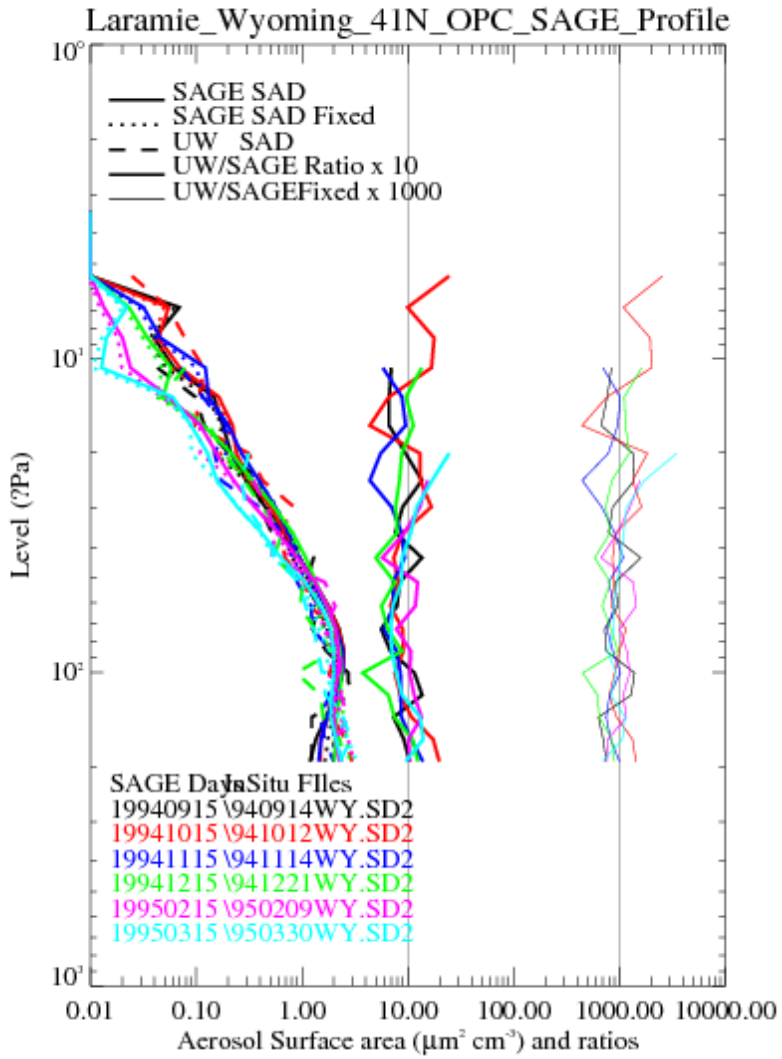
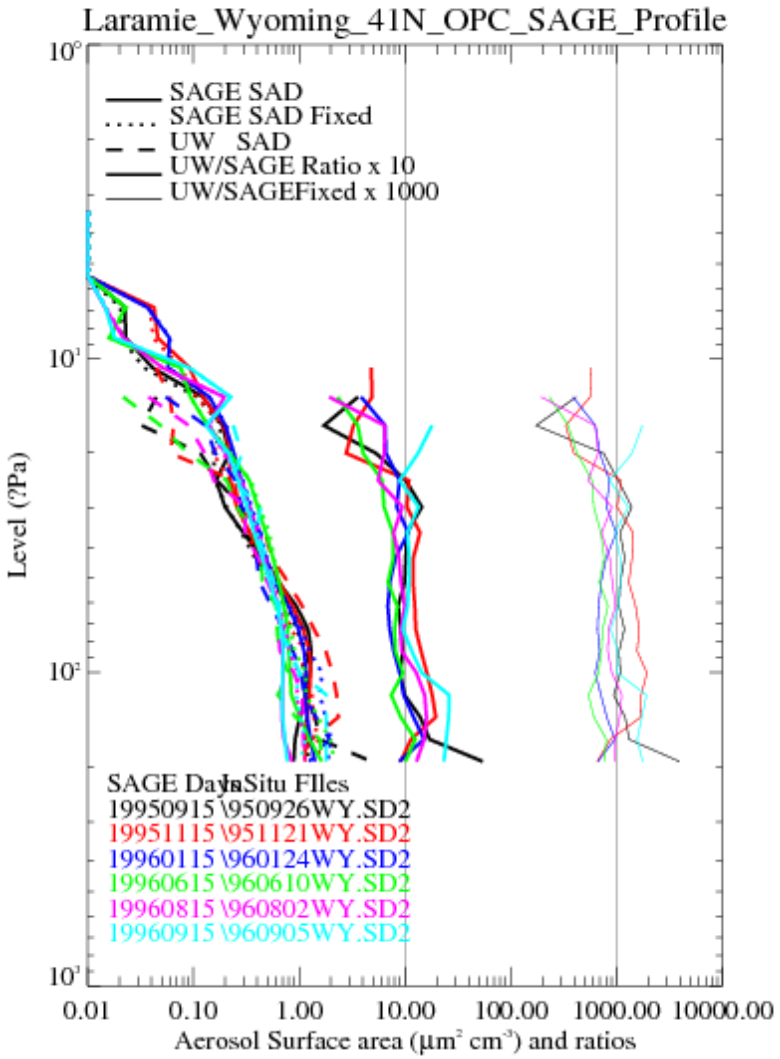
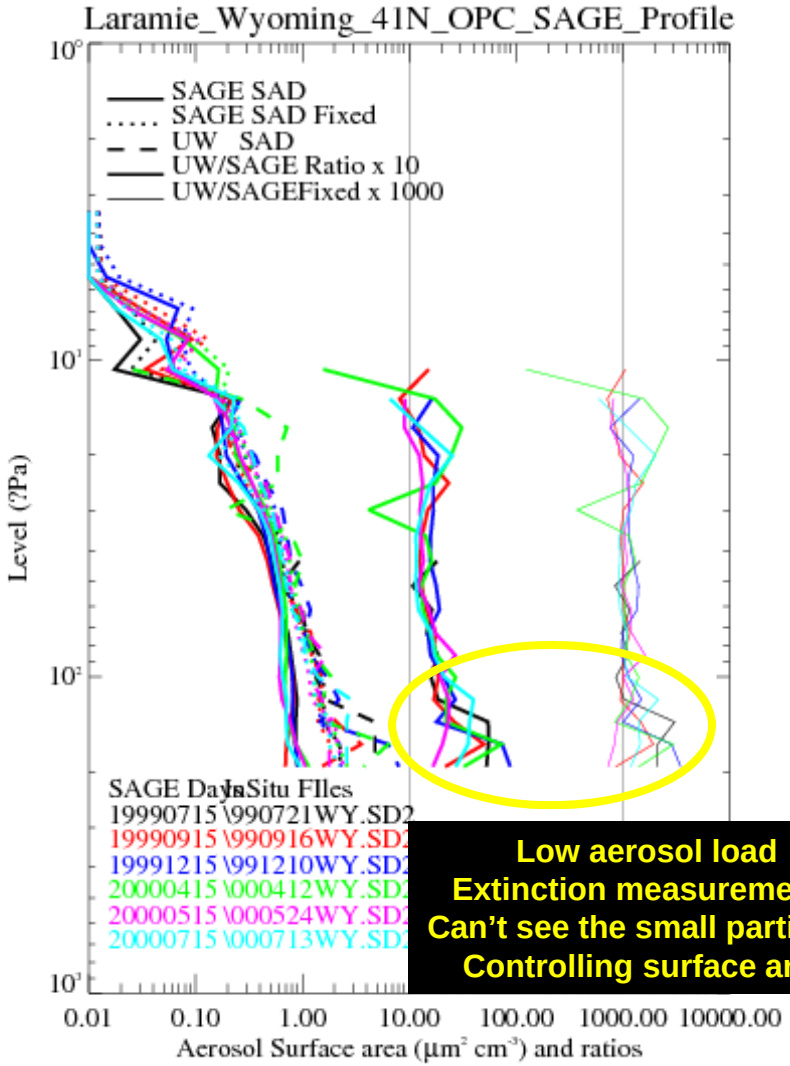
Fuego
Level (?Pa)
Aerosol Surface area (µm² cm⁻³) and ratios

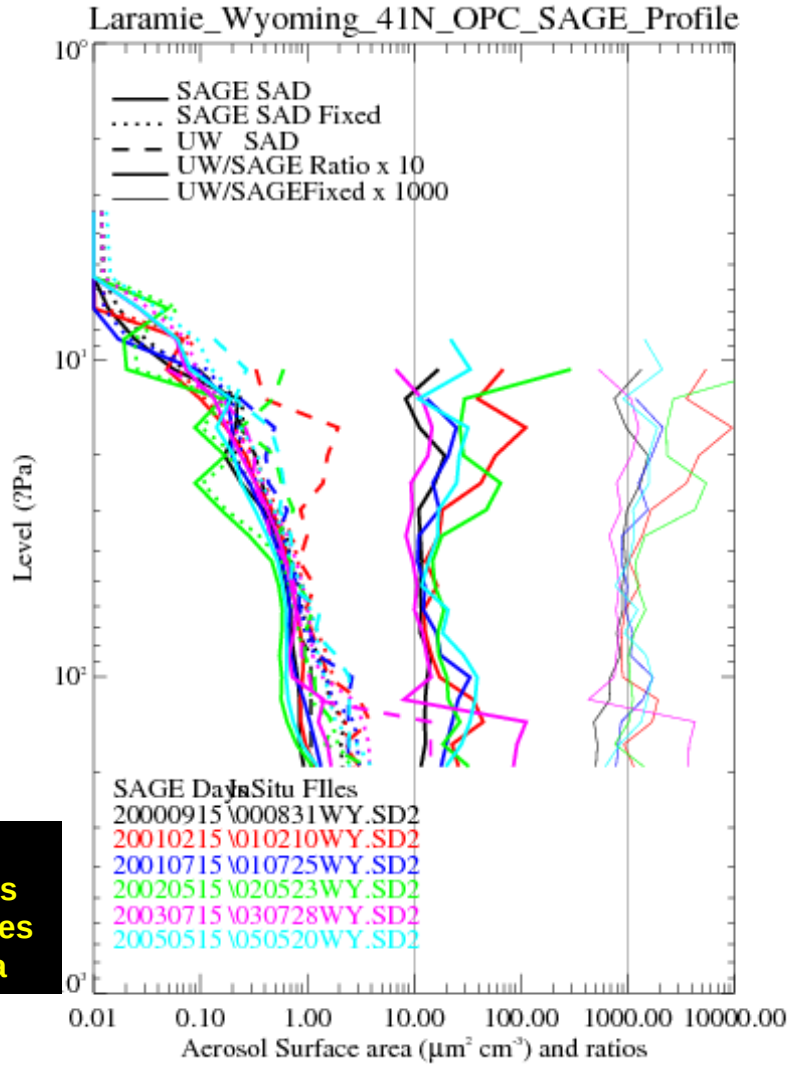

Laramie_Wyoming_41N_OPC_SAGE_Profile

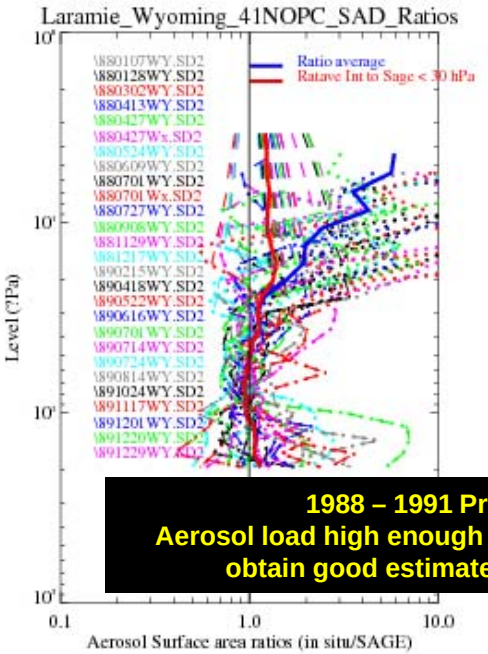

Laramie_Wyoming_41N_OPC_SAGE_Profile

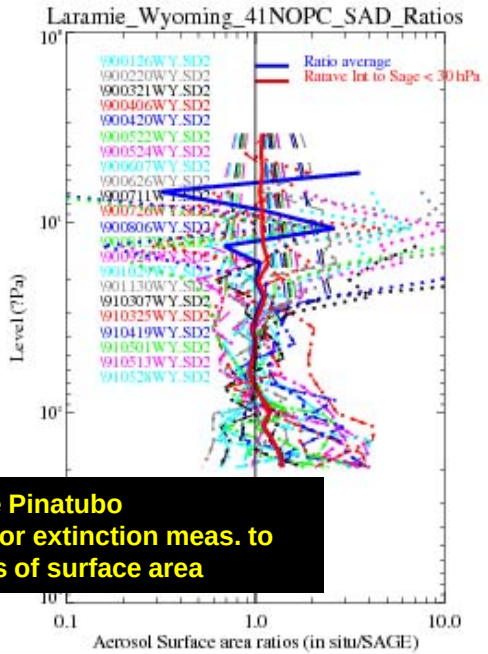

Laramie_Wyoming_41N_OPC_SAGE_Profile
SAGE SAD
SAGE SAD Fixed
UW SAD
UW/SAGE Ratio x 10
UW/SAGEFixed x 1000
SAGE Days In Situ Files
19940915 \940914WY.SD2
19941015 \941012WY.SD2
19941115 \941114WY.SD2
19941215 \941221WY.SD2
19950215 \950209WY.SD2
19950315 \950330WY.SD2
Level (?Pa)
0.01 0.10 1.00 10.00 100.00 1000.00 10000.00
Aerosol Surface area (μm² cm⁻³) and ratios


Laramie_Wyoming_41N_OPC_SAGE_Profile
SAGE SAD
SAGE SAD Fixed
UW SAD
UW/SAGE Ratio x 10
UW/SAGEFixed x 1000
SAGE Days In Situ Files
19950915 \950926WY.SD2
19951115 \951121WY.SD2
19960115 \960124WY.SD2
19960615 \960610WY.SD2
19960815 \960802WY.SD2
19960915 \960905WY.SD2
Level (?Pa)
0.01 0.10 1.00 10.00 100.00 1000.00 10000.00
Aerosol Surface area (μm² cm⁻³) and ratios

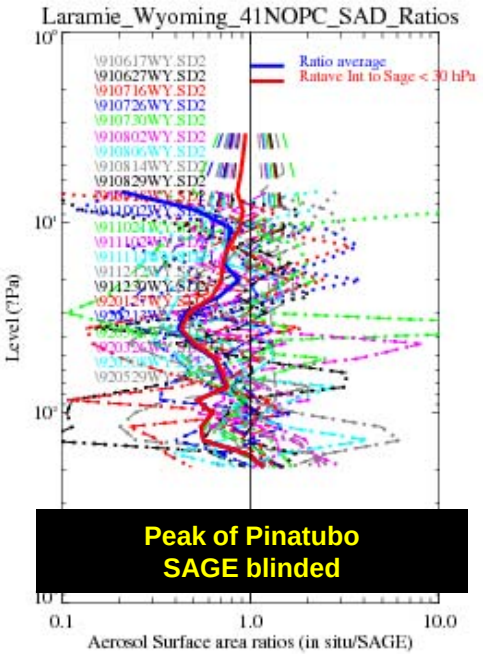

Laramie_Wyoming_41N_OPC_SAGE_Profile
SAGE SAD
SAGE SAD Fixed
UW SAD
UW/SAGE Ratio x 10
UW/SAGEFixed x 1000
Level (?Pa)
SAGE Day InSitu Files
19990715 \990721WY.SD2
19990915 \990916WY.SD2
19991215 \991210WY.SD2
20000415 \000412WY.SD2
20000515 \000524WY.SD2
20000715 \000713WY.SD2
Low aerosol load
Extinction measurements
Can't see the small particles
Controlling surface area
0.01 0.10 1.00 10.00 100.00 1000.00 10000.00
Aerosol Surface area (µm² cm⁻³) and ratios


Laramie_Wyoming_41N_OPC_SAGE_Profile
SAGE SAD
SAGE SAD Fixed
UW SAD
UW/SAGE Ratio x 10
UW/SAGEFixed x 1000
Level (?Pa)
SAGE Day InSitu Files
20000915 \000831WY.SD2
20010215 \010210WY.SD2
20010715 \010725WY.SD2
20020515 \020523WY.SD2
20030715 \030728WY.SD2
20050515 \050520WY.SD2
0.01 0.10 1.00 10.00 100.00 1000.00 10000.00
Aerosol Surface area (µm² cm⁻³) and ratios

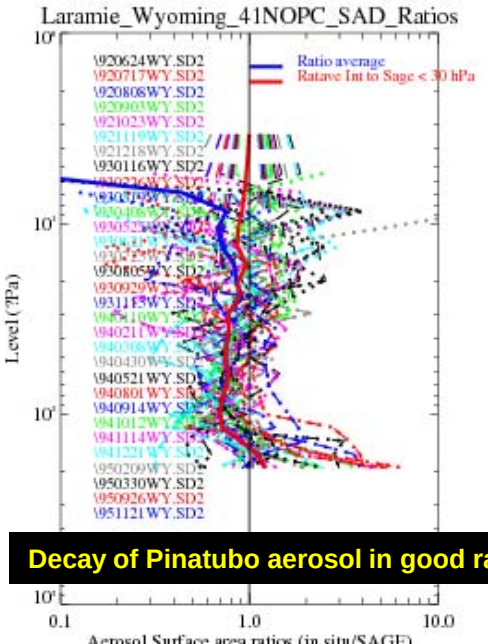


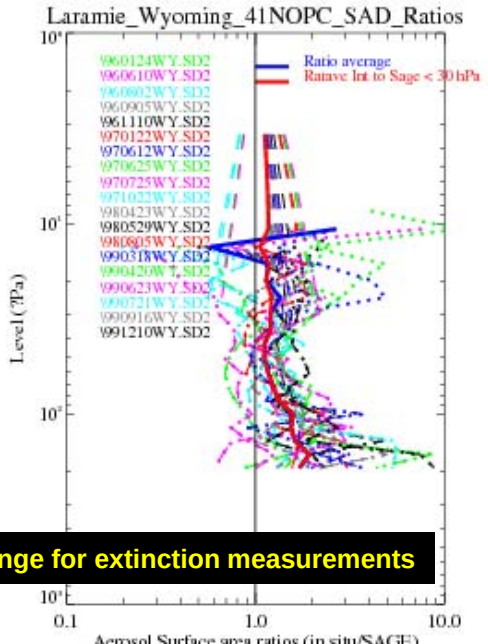


1988 – 1991 Pre Pinatubo
Aerosol load high enough for extinction meas. to obtain good estimates of surface area

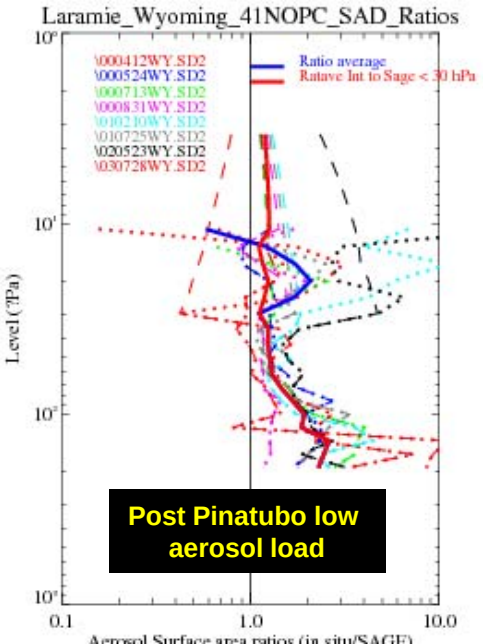


Peak of Pinatubo
SAGE blinded



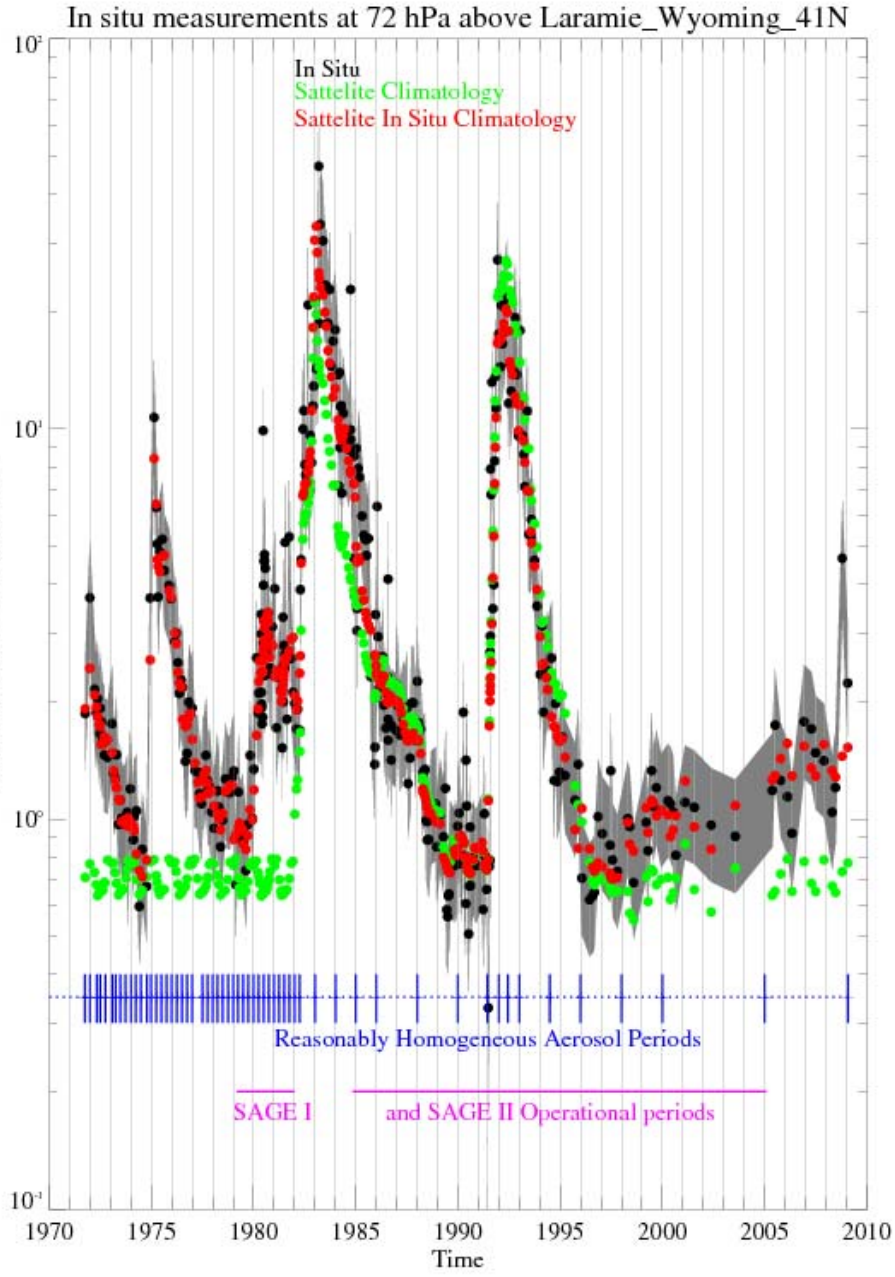


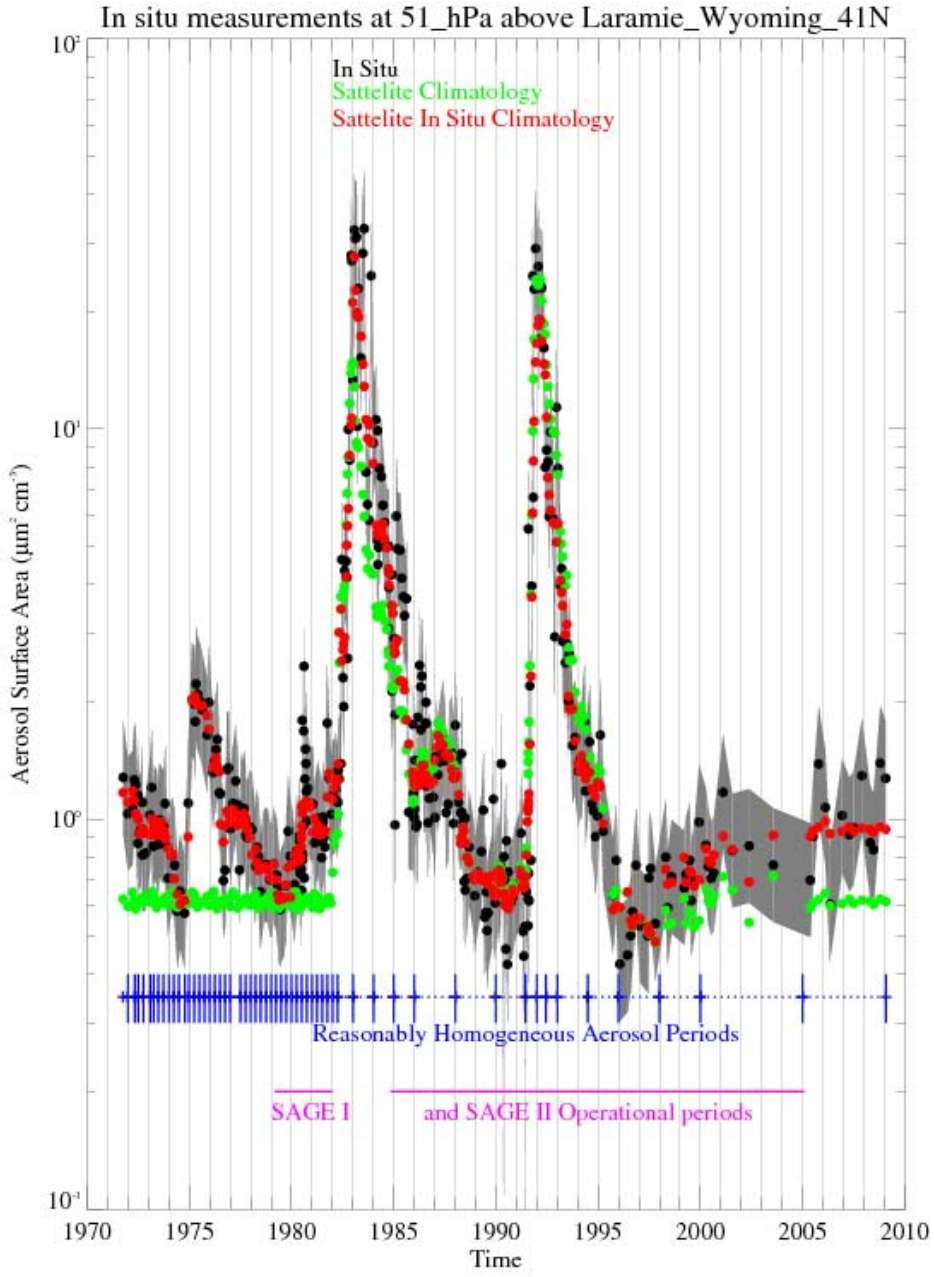
Decay of Pinatubo aerosol in good range for extinction measurements



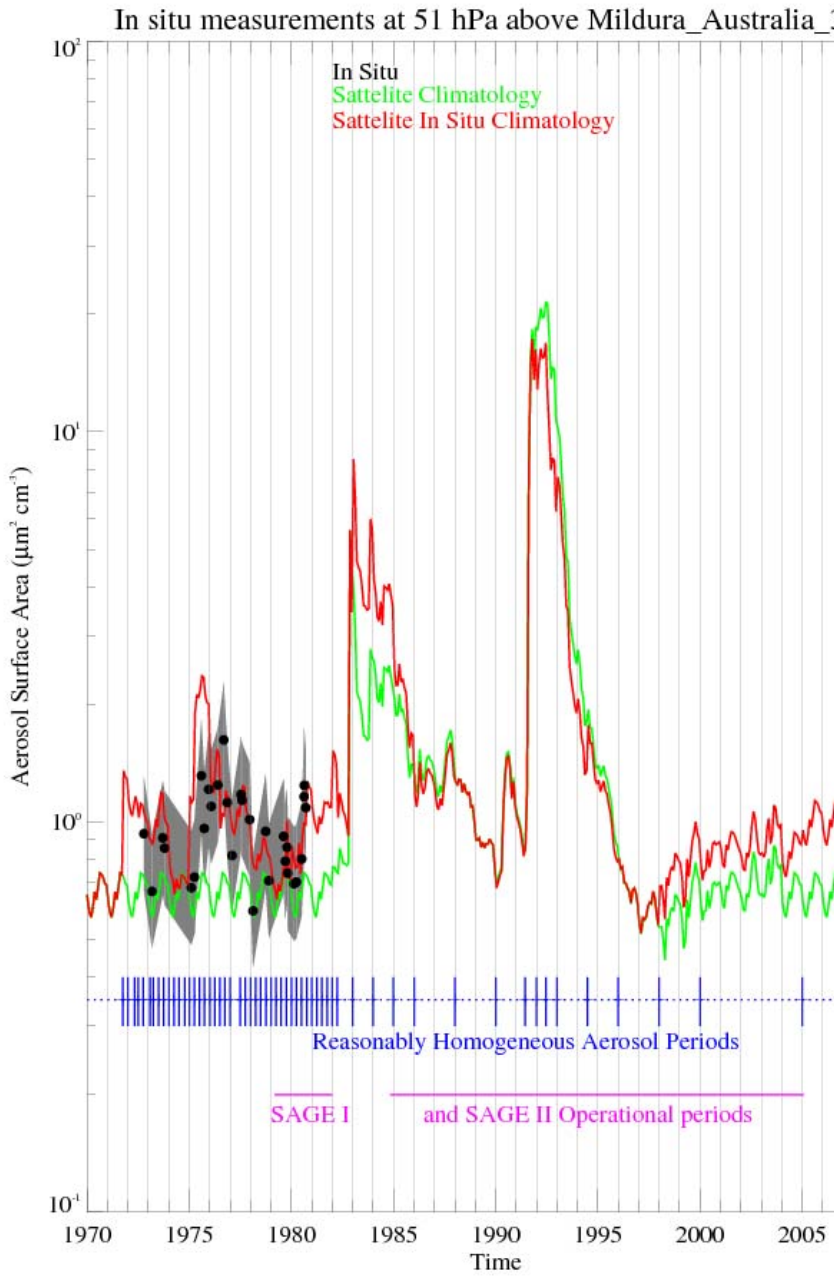
Post Pinatubo low aerosol load

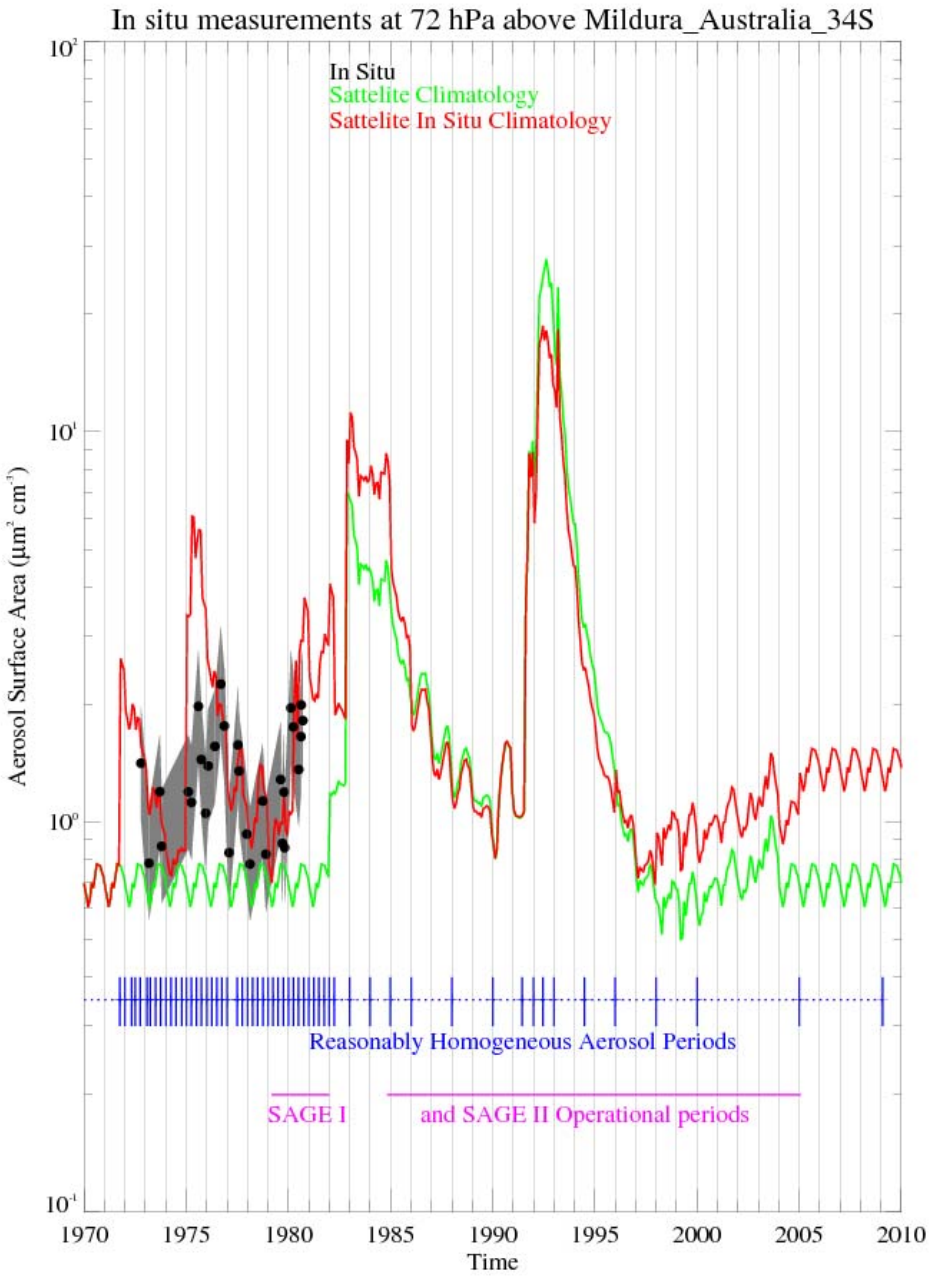
Comparison of revised climatology with measurements





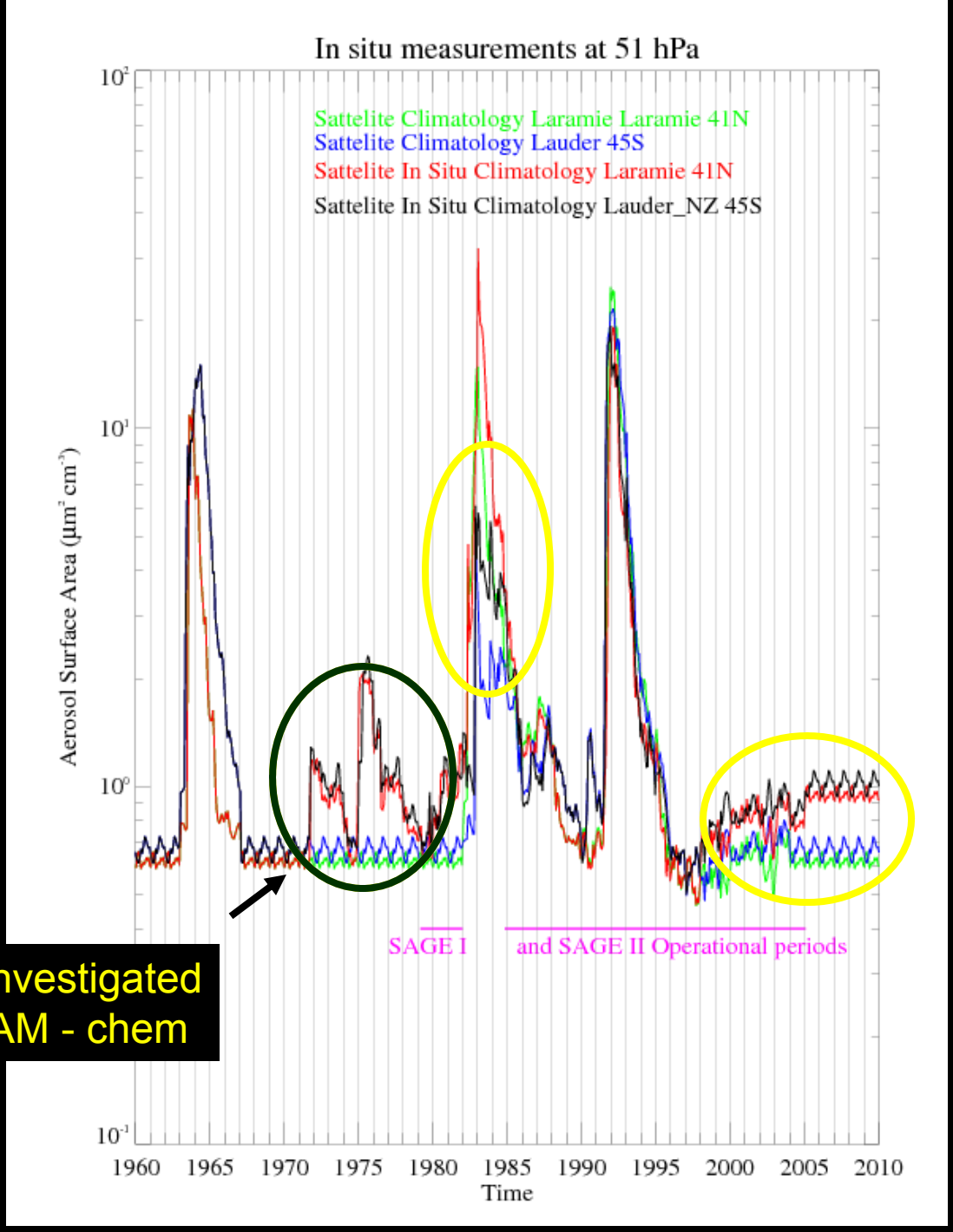
Comparison of revised climatology with measurements

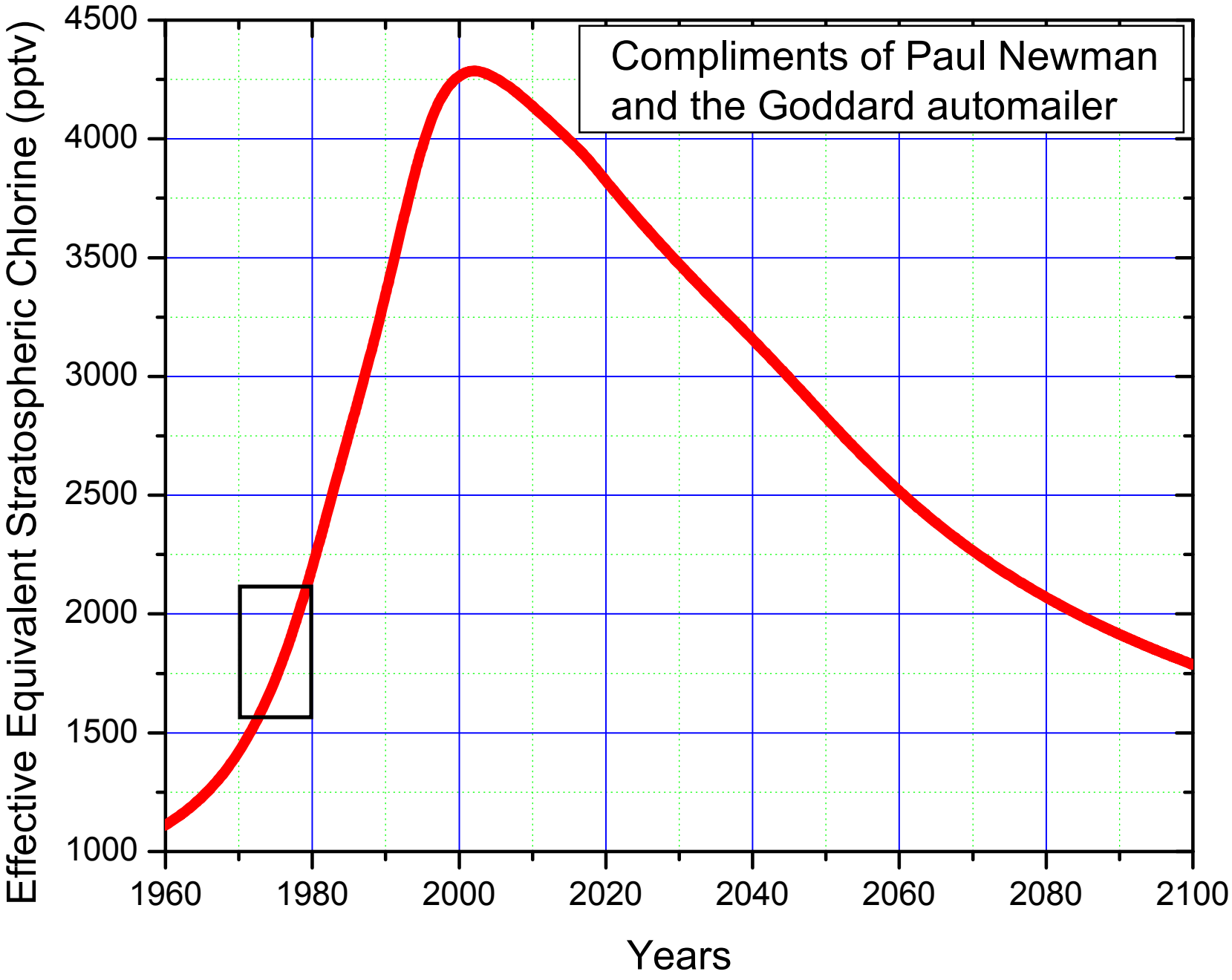




Periods of concern

Period investigated With CAM - chem



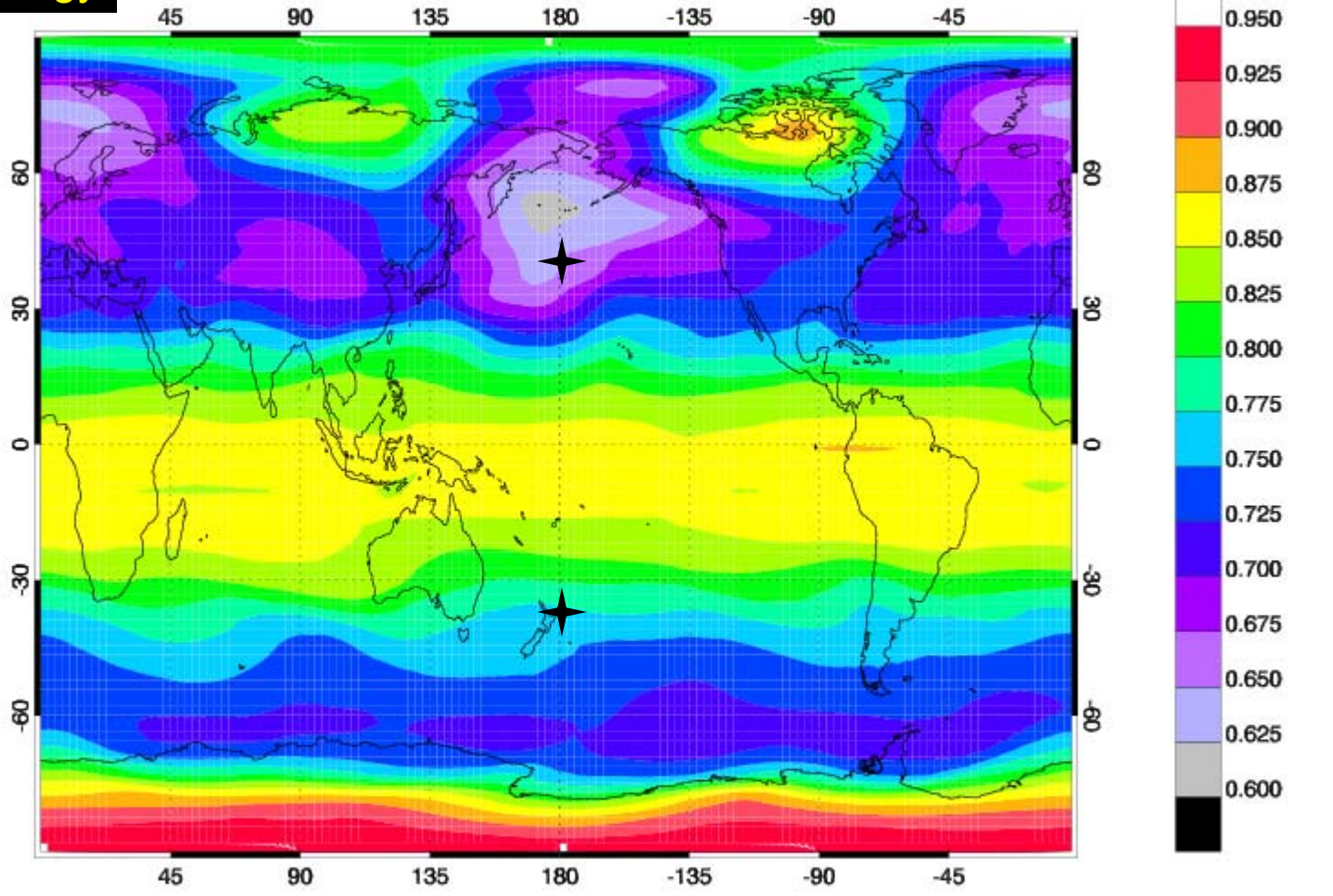

Compliments of Paul Newman
and the Goddard automailer
Effective Equivalent Stratospheric Chlorine (pptv)
4500
4000
3500
3000
2500
2000
1500
1000
1960
1980
2000
2020
2040
2060
2080
2100
Years

NOx
New / Old
Climatology

NOX [mol/mol], 01Mar1975 00:00, ca. 53.114604 hPa

NOX [mol/mol], 01Mar1975 00:00, ca. 53.114604 hPa

Results CAM – chem
run through 1970s



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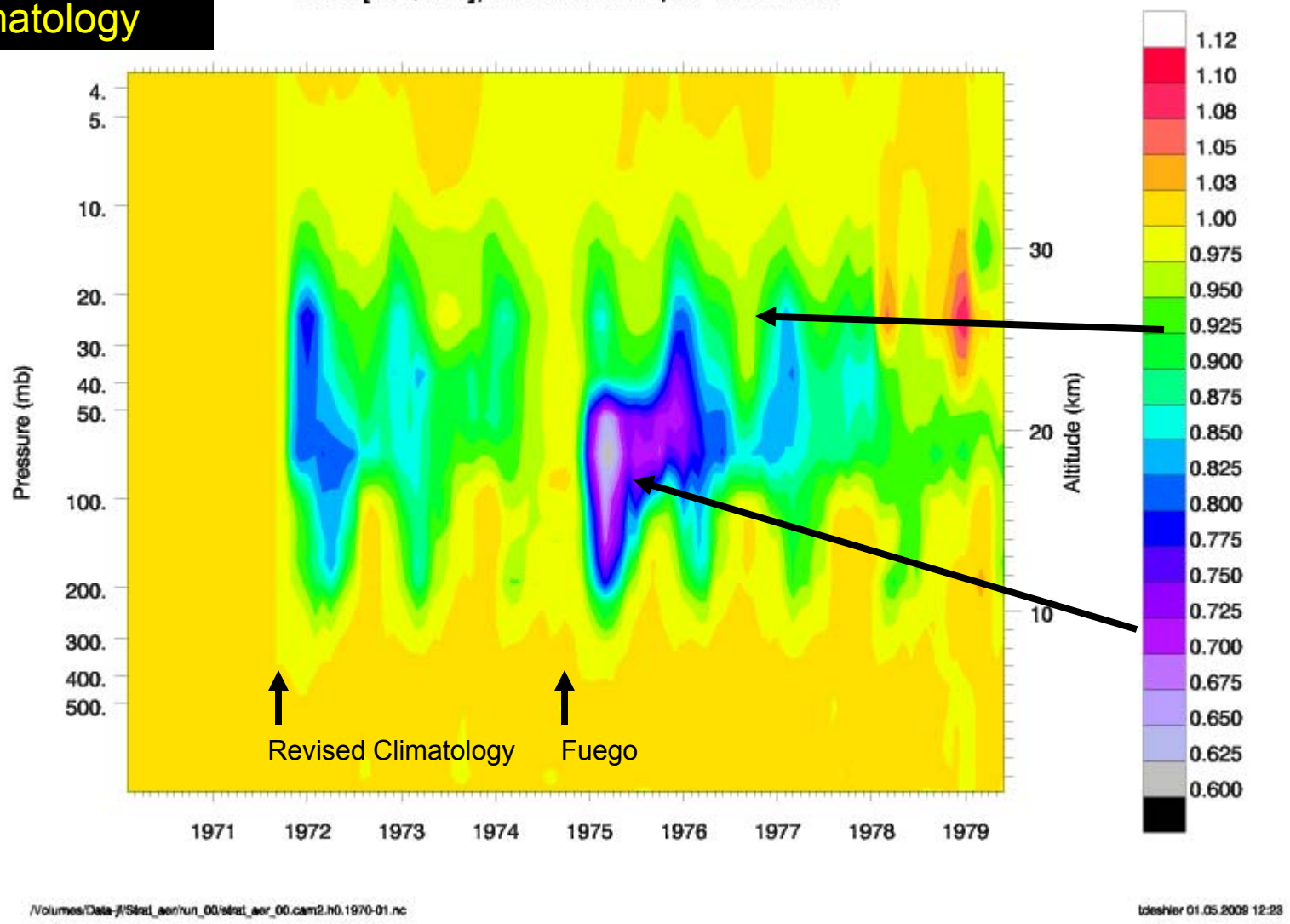
tdeshler 01.05.2009 09:17

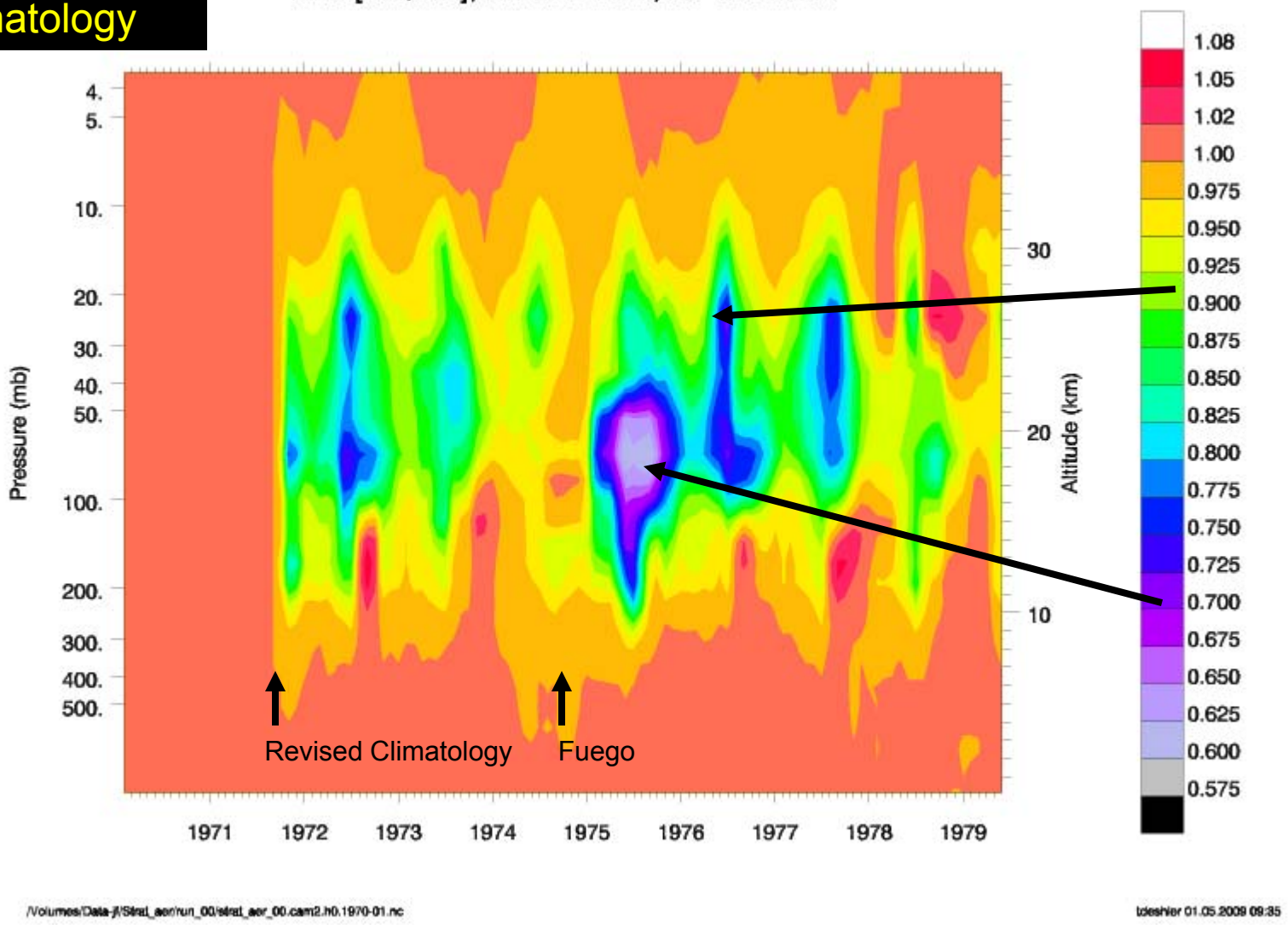
NOx Profiles 40 N
New / Old
Climatology



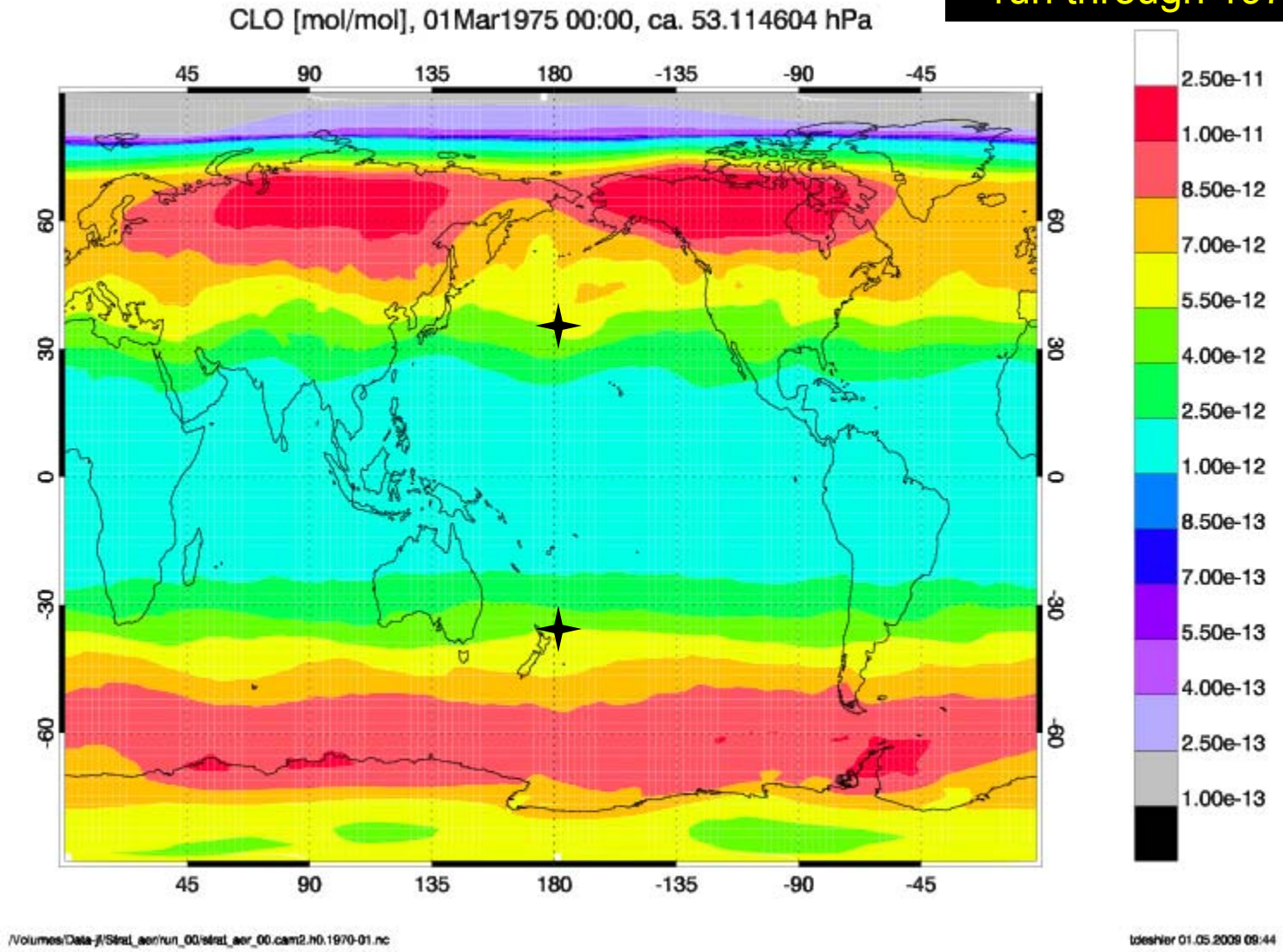
Results CAM – chem
run through 1970s

NOx profiles 40 S
New / Old
Climatology

Results CAM – chem
run through 1970s



Results CAM – chem run through 1970s

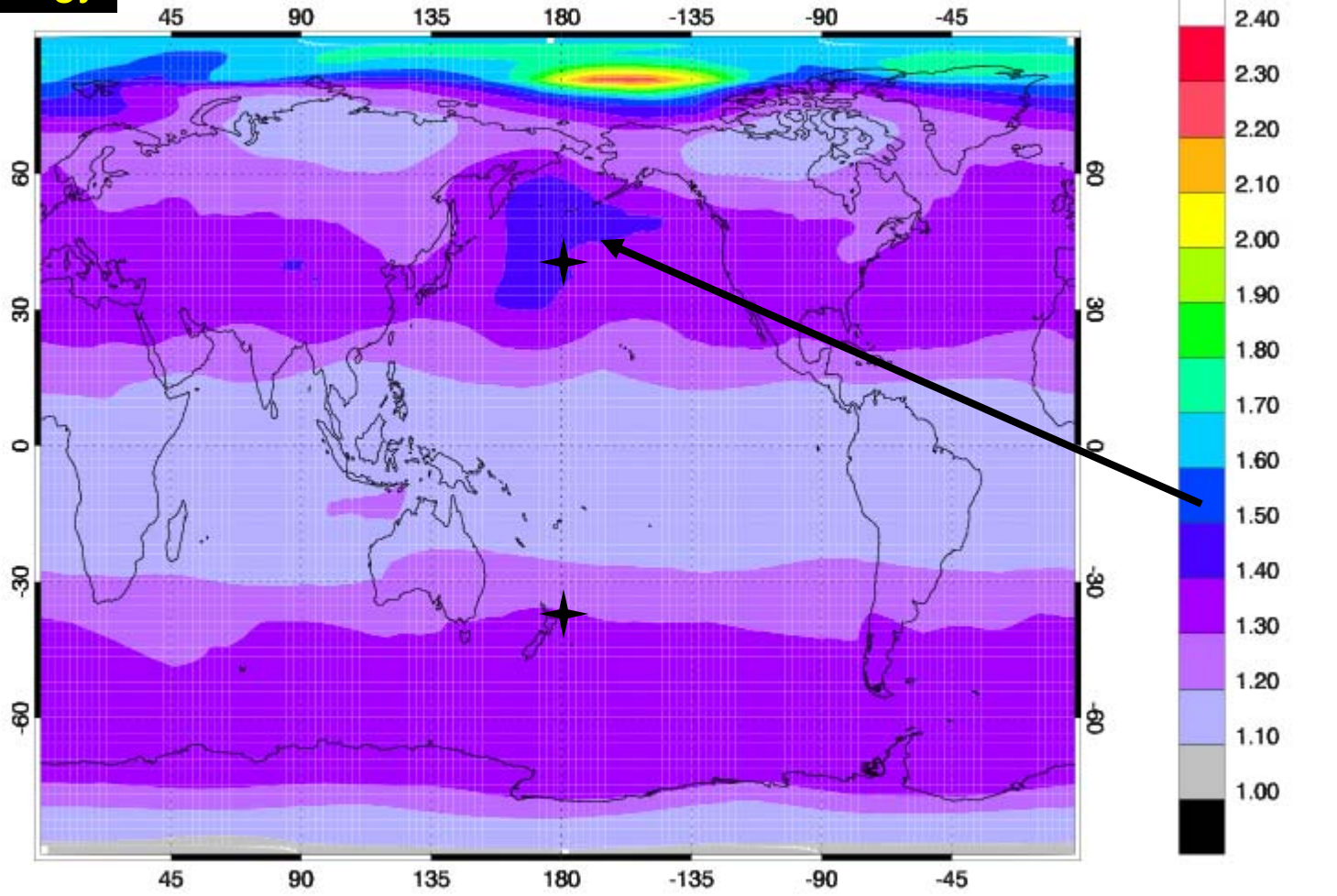


ClO
New / Old
Climatology

CLO [mol/mol], 01Mar1975 00:00, ca. 53.114604 hPa

CLO [mol/mol], 01Mar1975 00:00, ca. 53.114604 hPa

Results CAM – chem
run through 1970s



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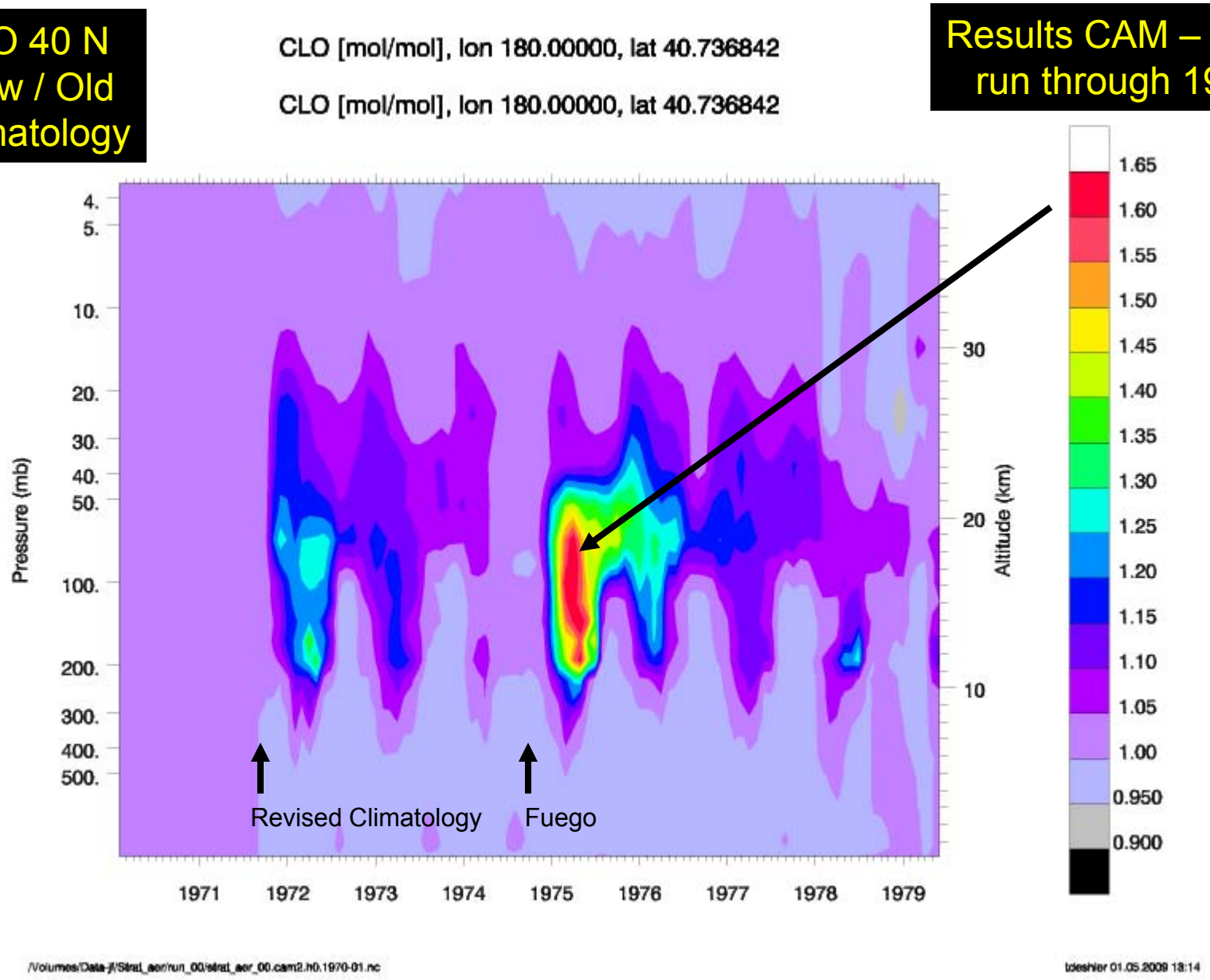
tdeshler 01.05.2009 09:44

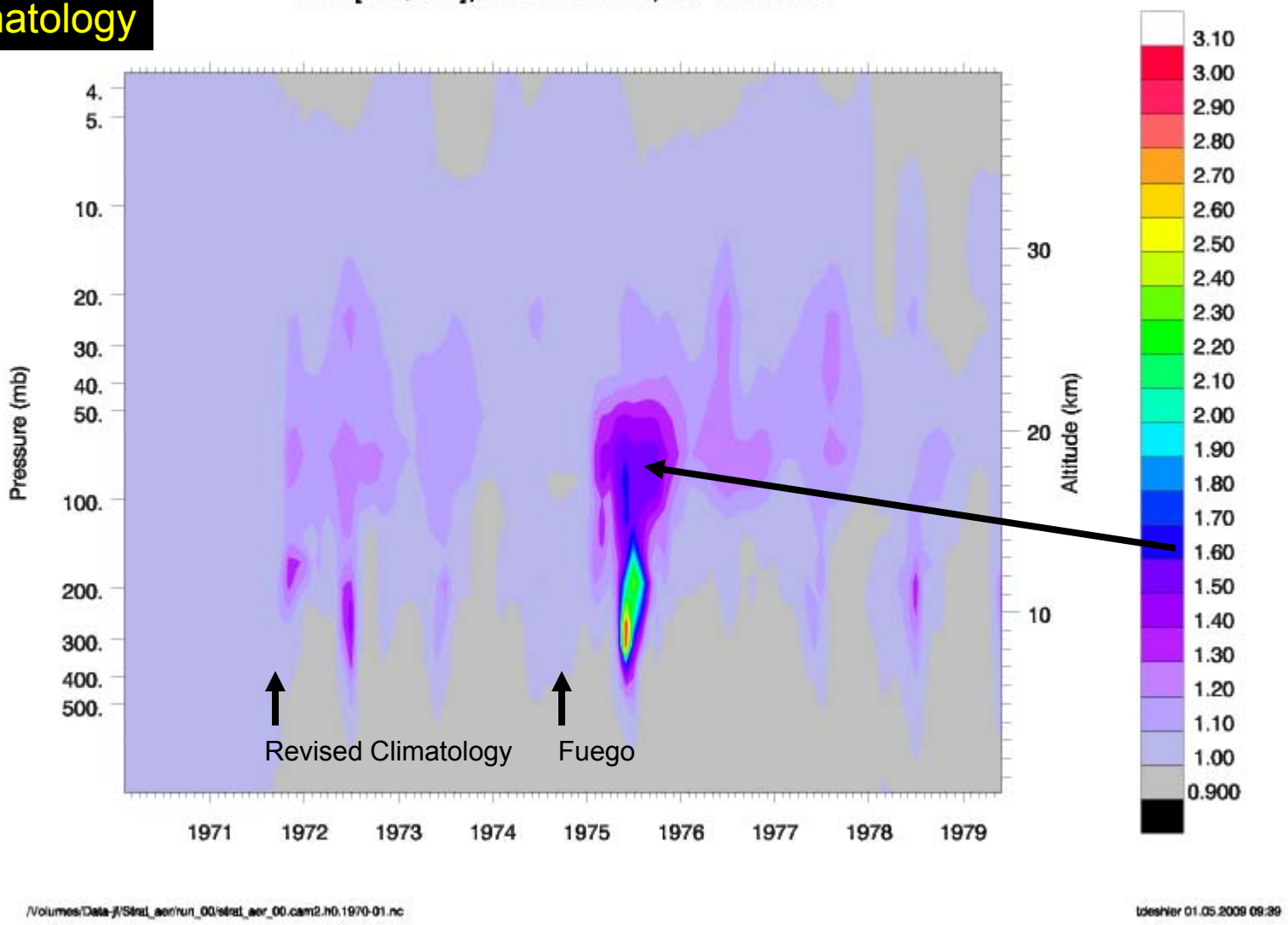
ClO 40 N
New / Old
Climatology



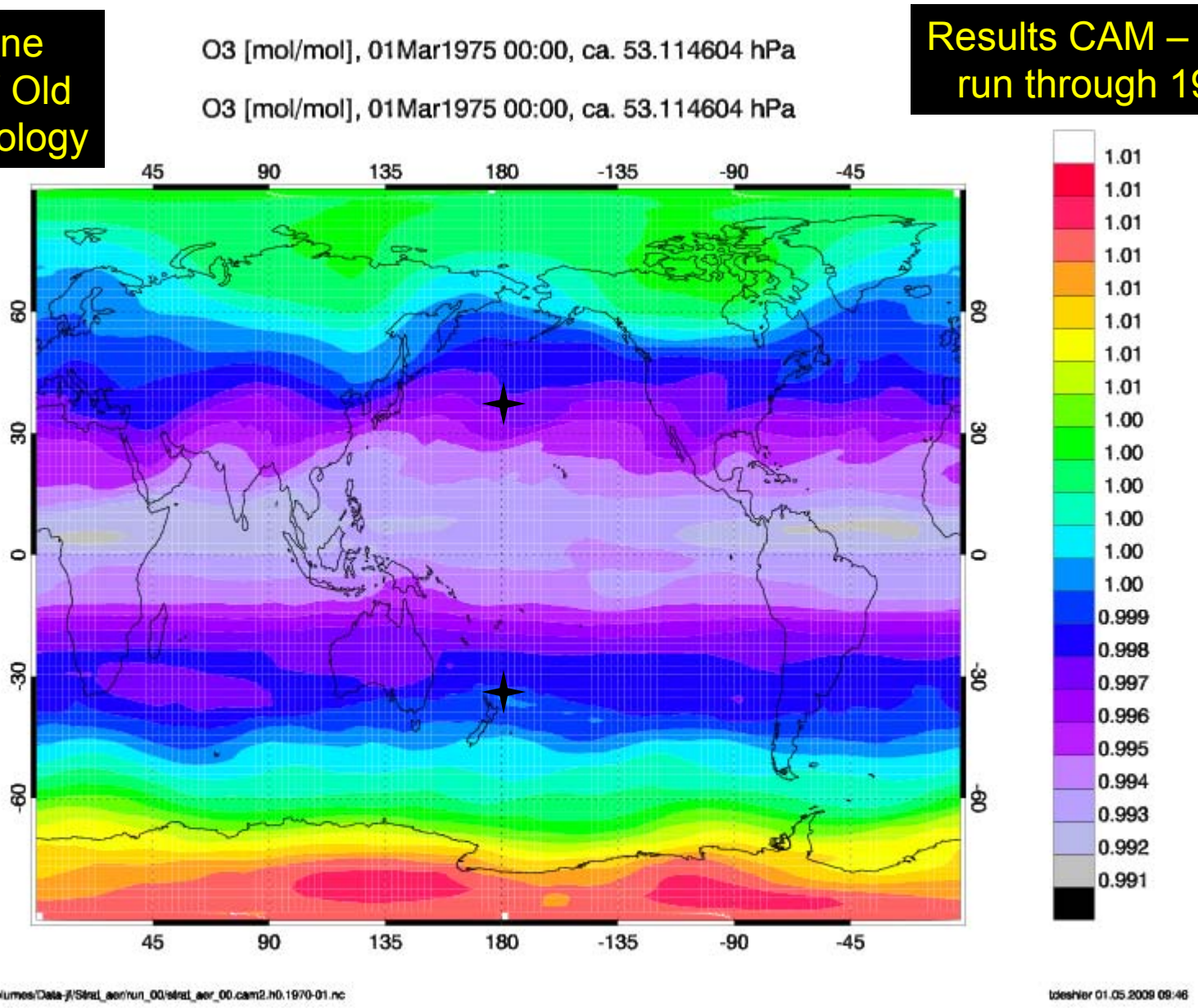
Results CAM – chem
run through 1970s

ClO 40 S New / Old Climatology

Results CAM – chem run through 1970s



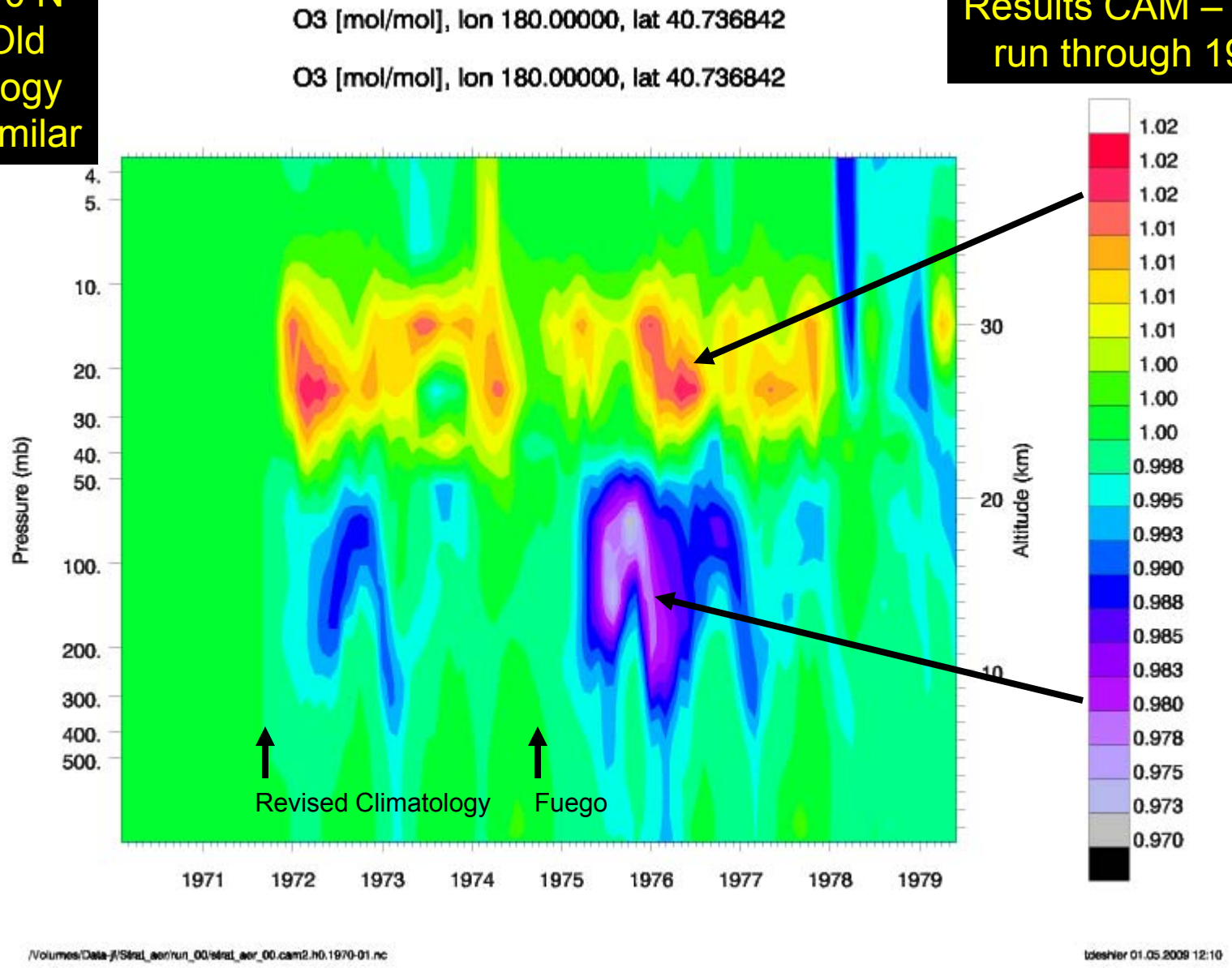
Ozone
New / Old
Climatology



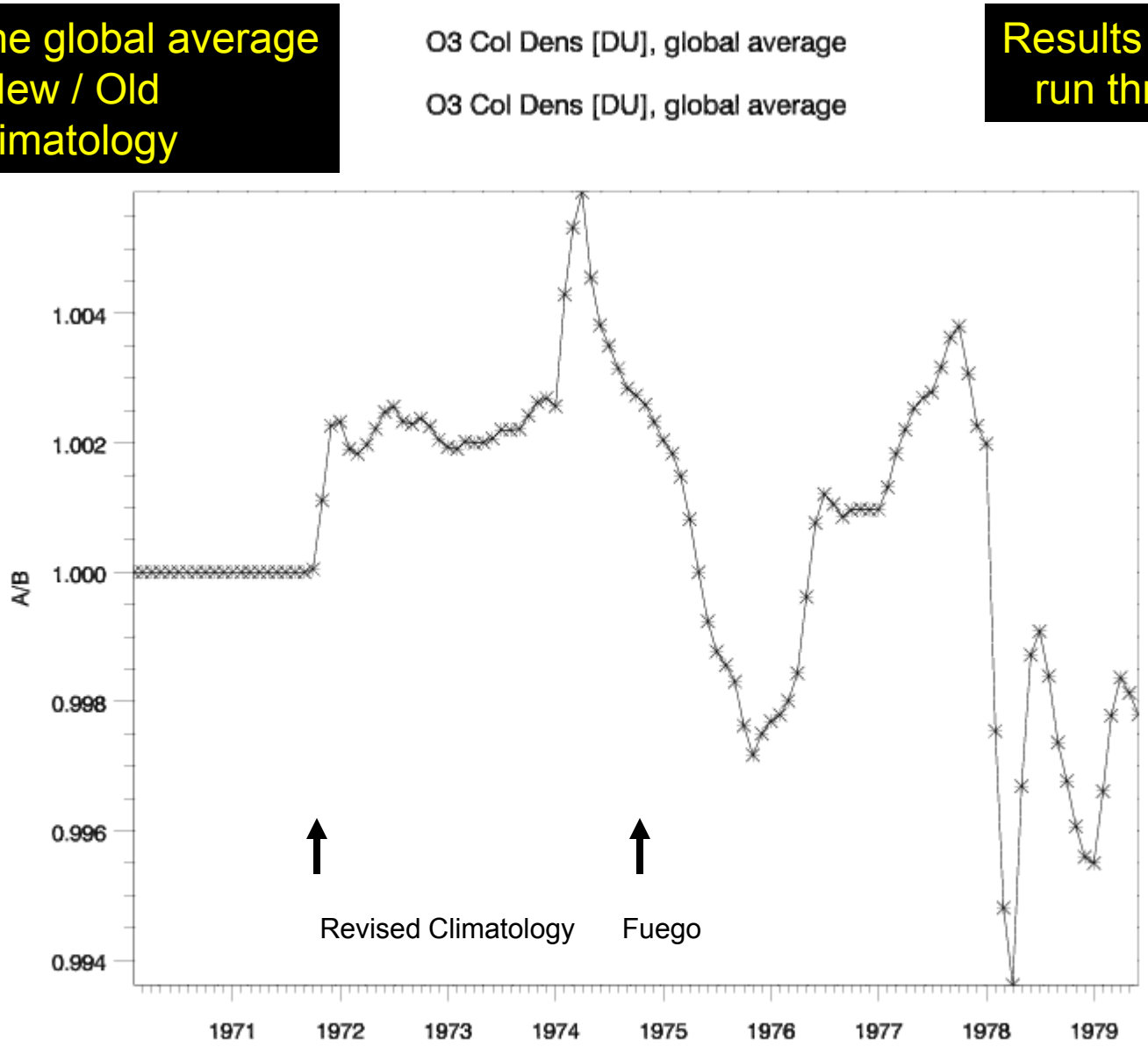
Results CAM – chem
run through 1970s

Ozone 40 N
New / Old
Climatology
40 S is similar

Results CAM – chem run through 1970s



Total ozone global average
New / Old
Climatology



Results CAM – chem
run through 1970s

Summary

- Present aerosol surface area density climatology has some deficiencies, < 1970, 1981-1984, > 2000
- A new climatology corrected with in situ measurements is available along with the in situ measurements used to develop it. See: http://www-das.uwyo.edu/~deshler/
- First results with the new climatology show differences in NOx, ClOx and OH leading to ± 0.5% for global average ozone in the 1970s when stratoshperic chlorine was 1500 – 2000 ppt.
- Future work
  - Fix blanks at pressures > 100 hPa in El Chichon period
  - Smooth climatology at pressures < 20 hPa, where signal is very weak
  - Use the new climatology in model runs, 1980-1985, and 1991-2010
- There are many people and agencies to thank for these results
  - Funding over the last 40 years – NSF, NSF, NSF, NASA, NRL, ...
  - The pioneers Jim Rosen and Dave Hofmann, and their (and my) engineers, technicians, scientists and students necessary to complete the measurements.
  - Susan Solomon for the invitation to a sabbatical and providing the means to get introduced to the world of atmospheric models, and to Jean Francois Lamarque and Paul Young for guiding me into the details