Whole Atmosphere Community Climate Model: Going from v3.1.9 to v3.5.48

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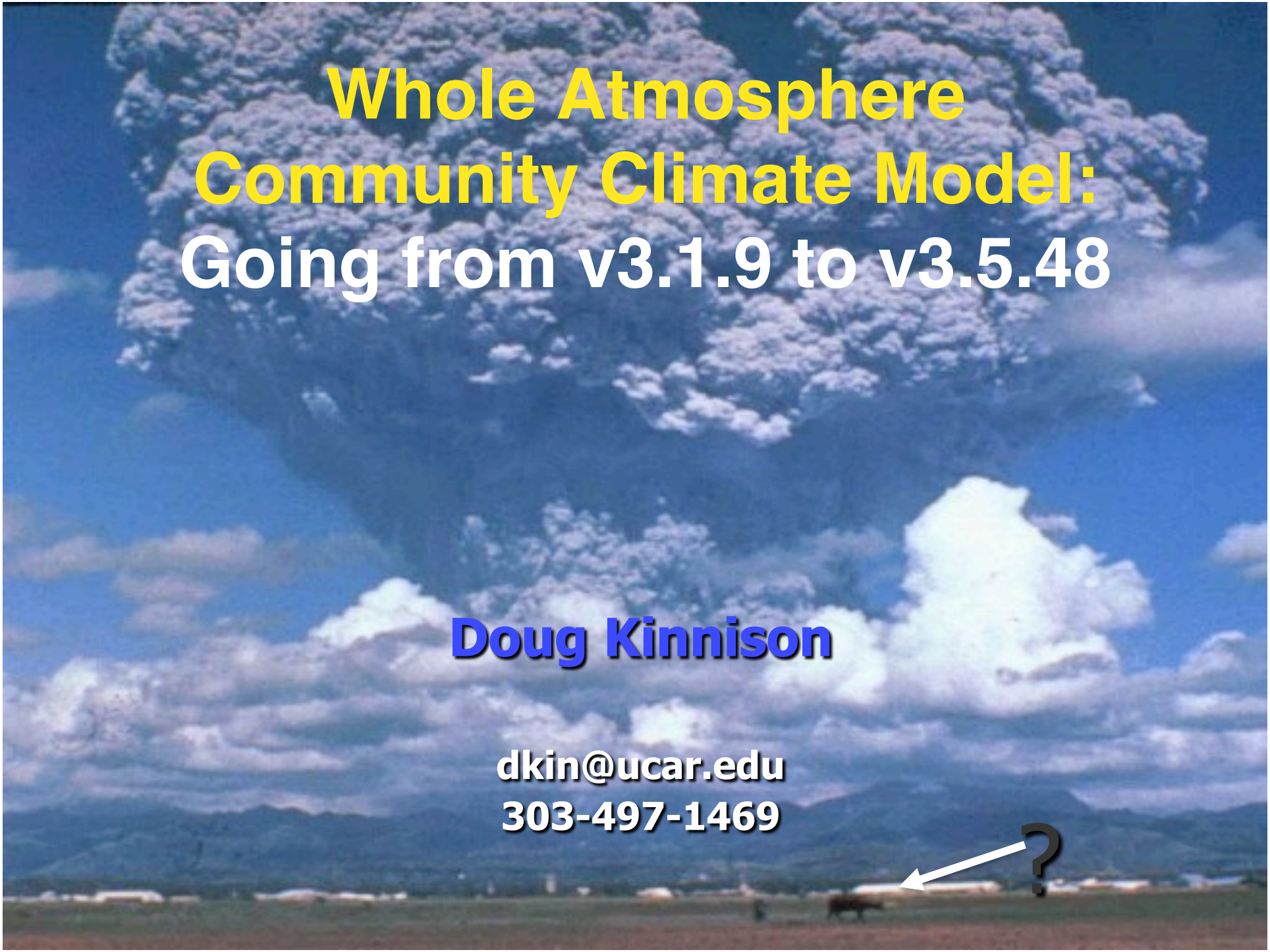
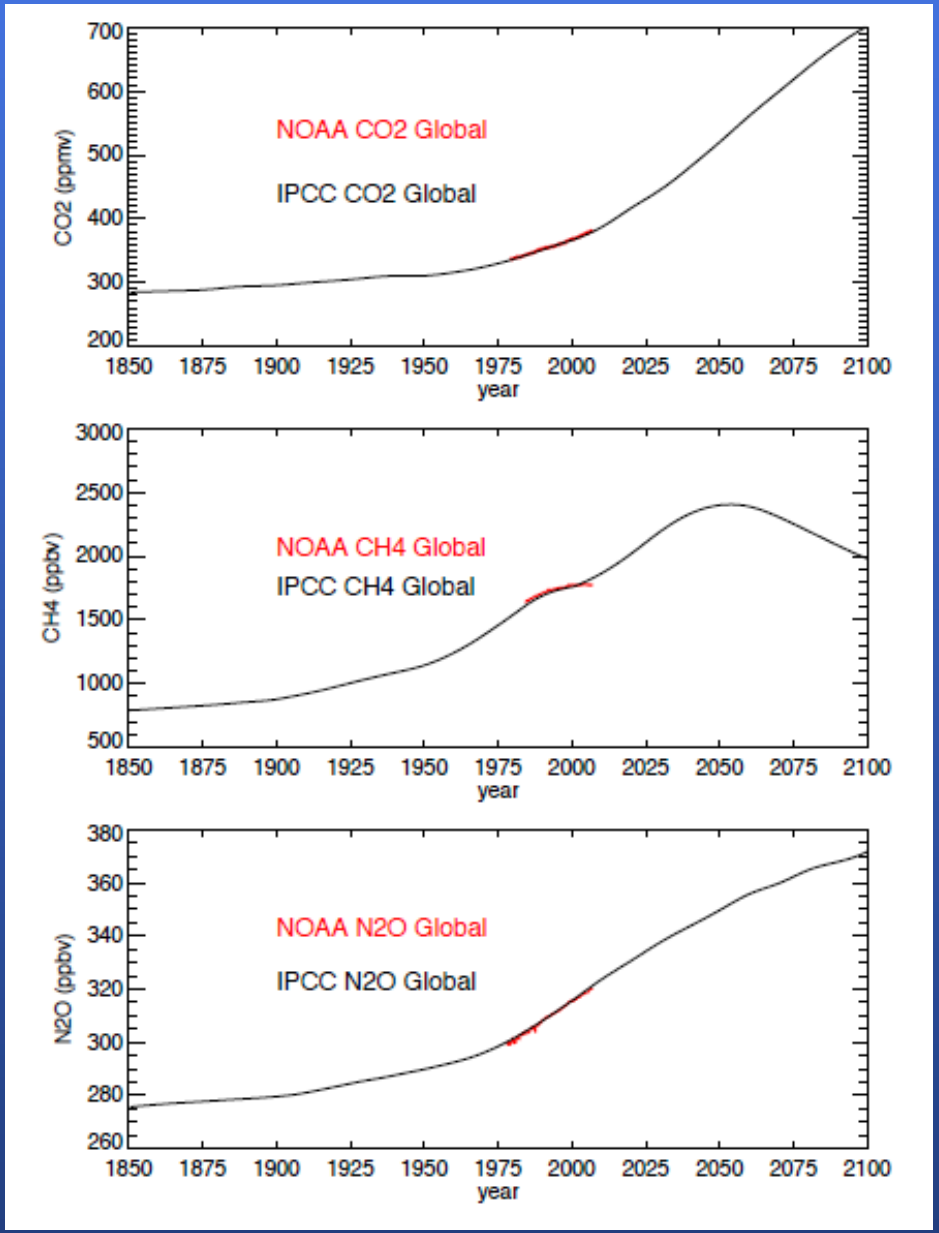


Outline

- Updated GW scheme [Richter / Garcia].
- Parameterization of unresolved mountain drag [Sassi et al.].
- Updated source gas boundary conditions [1850-2100].
- Conservation of CLOY [and BrOY].
- New Sulfate SAD time series [SPARC].
- Volcanic heating module added.
- Update PSCs module [NAT] – less denitrification [more SAD].
- LEAN Extra Terrestrial Fluxes [replaced Woods/Rottman/Neckel]
- QBO inclusion [not used extensively in 319]
- Chemical Mechanism: JPL06 [+photolysis benchmark]
- Specified Dynamics Option Developed [w/GEOS5.1].
- Solar Proton Events [not used extensively in 319].
- Unification of WACCM3 and CAM-CHEM modules [not complete].

Updated source gas boundary conditions [1850-2100]

- CO_2, N_2O, and CH_4 from AR4
  - A1B-medium scn
  - Not what CCSM used in AR4.
  - 1850 – 2100 [ready for WACCM3 / deep ocean sim's]
  - CO_2 and CH_4 have latitudinal and seasonal cycle included.
- New Halocarbon time series [Guss Velders].
  - 1951 - 2100
  - WMO 2006 [chpt8].
  - w/Montreal 2007 HCFC adj.
- New CO, NOx, CH_2O, NMHC Emissions for 1997-2008 [Emmons].
  - Specific for each year.
  - 1999-2007 average
- Coming soon…
  - LBC for VSL Org BrOY and IOY spc.
  - Time series of NMHC's [IPCC AR5]



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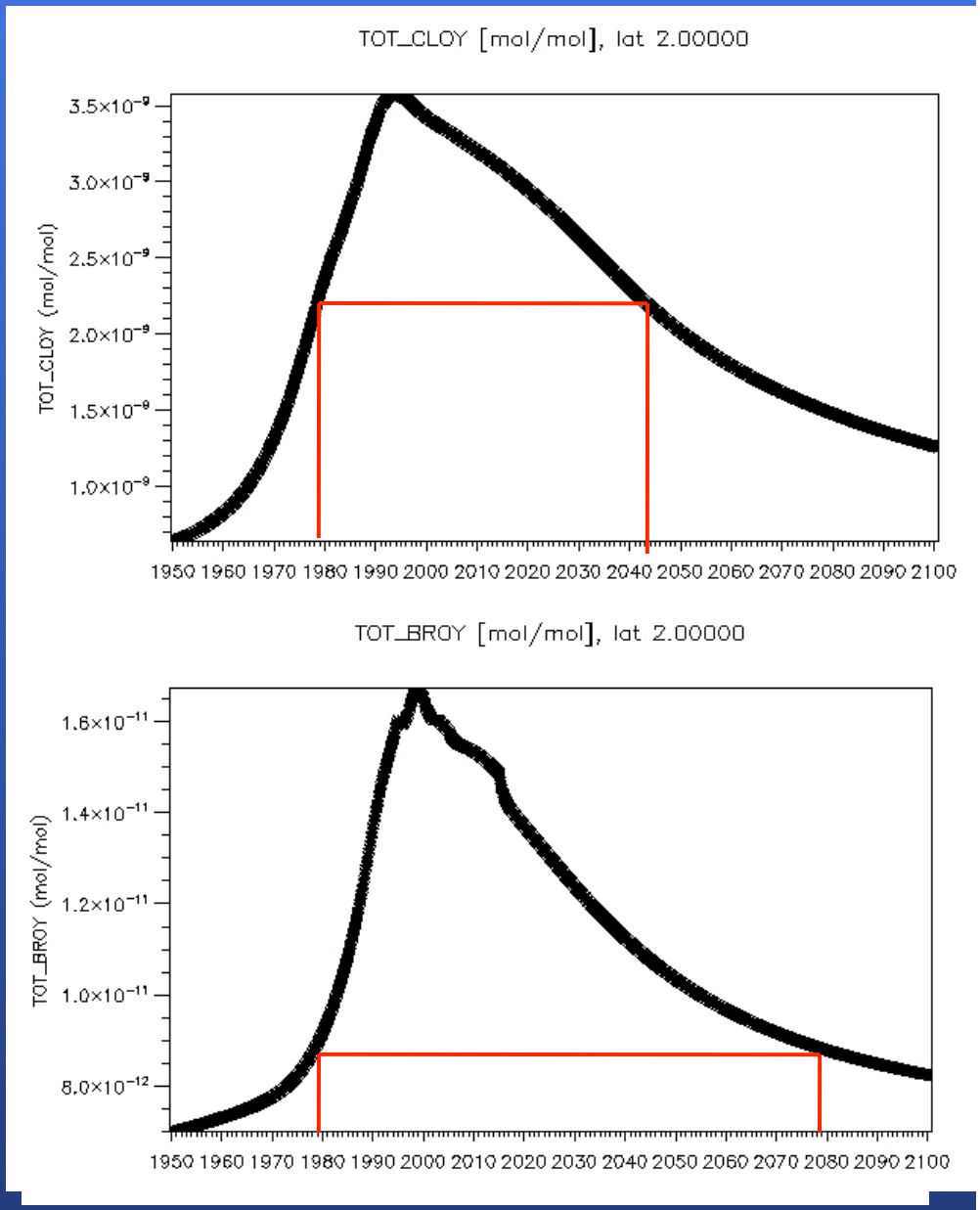
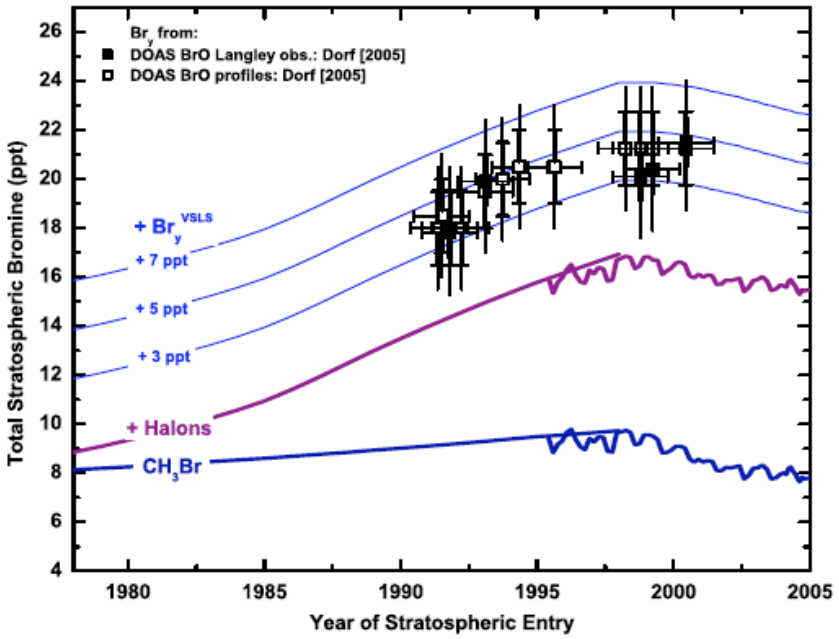
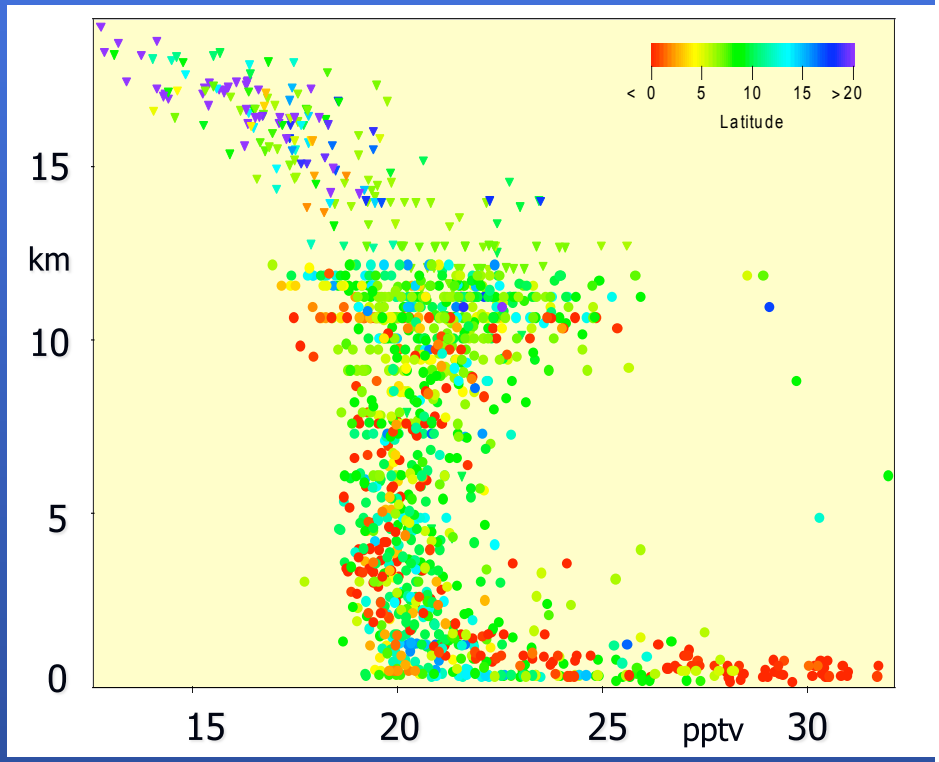


Comparison to WAS (NASA TC4 Campaign)



Taken from Chapter 2, VSLS, WMO, 2006



TC4, Whole Air Sampler, Schauffler, Atlas, et al., AGU, 2007

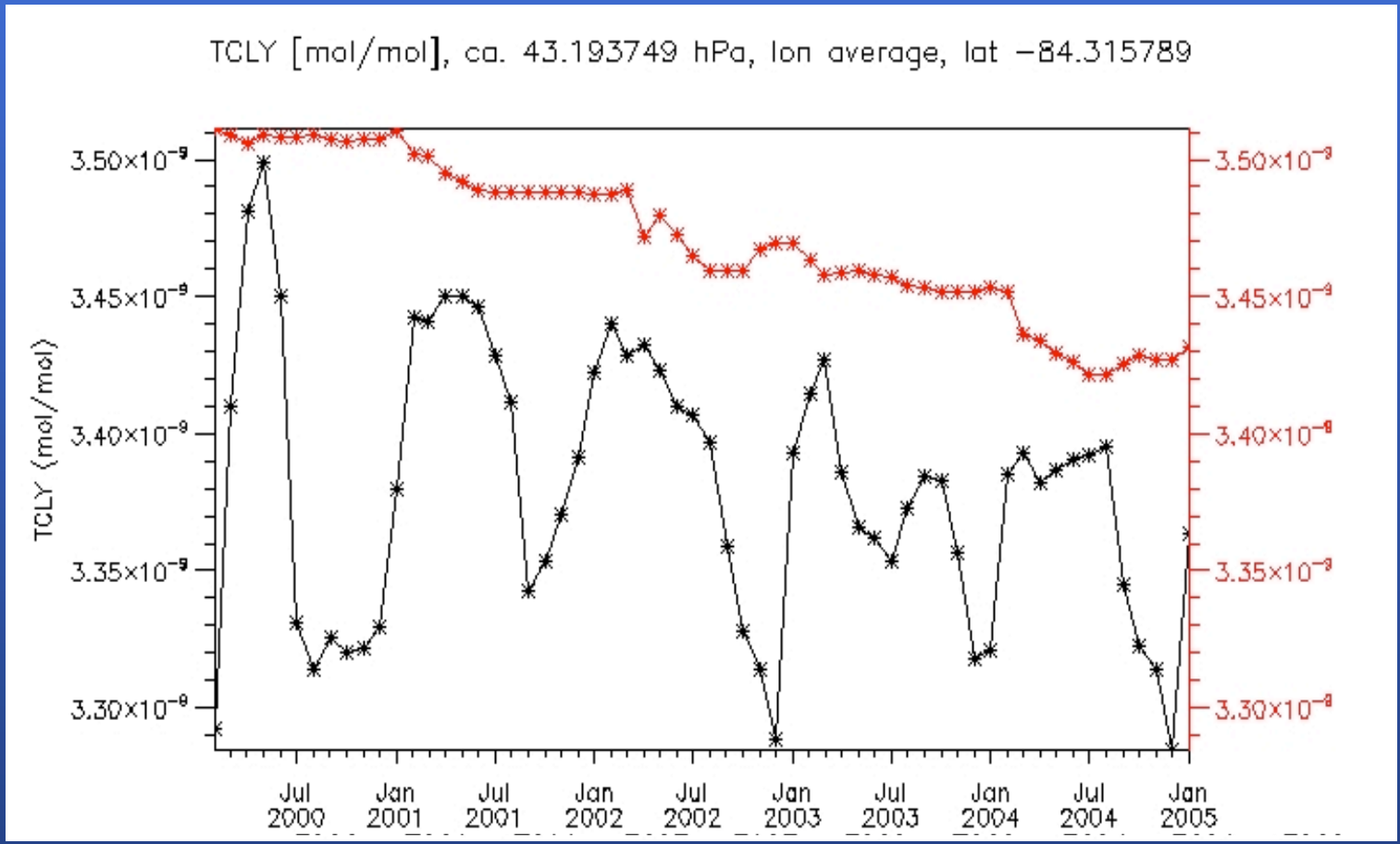
Halogenated Very Short-lived Substances (VSLS) currently being added the WA3 UTLS mechanism

VSL Organic Bromine Species

Source Gas	Formula	Local Lifetime (days)	Main Loss processes	WAS
Bromochloromethane	CH_2BrCl	150	OH	√
Trichloromethane (chloroform)	$CHCl_3$	150	OH	√
Methylene chloride	CH_2Cl_2	140	OH	√
Dibromomethane	CH_2Br_2	120	OH	√
Bromodichloromethane	$CHBrCl_2$	78	OH, hv	√
Dibromochloromethane	$CHBr_2Cl$	69	hv, OH	√
Tribromomethane (bromoform)	$CHBr_3$	26	hv	√

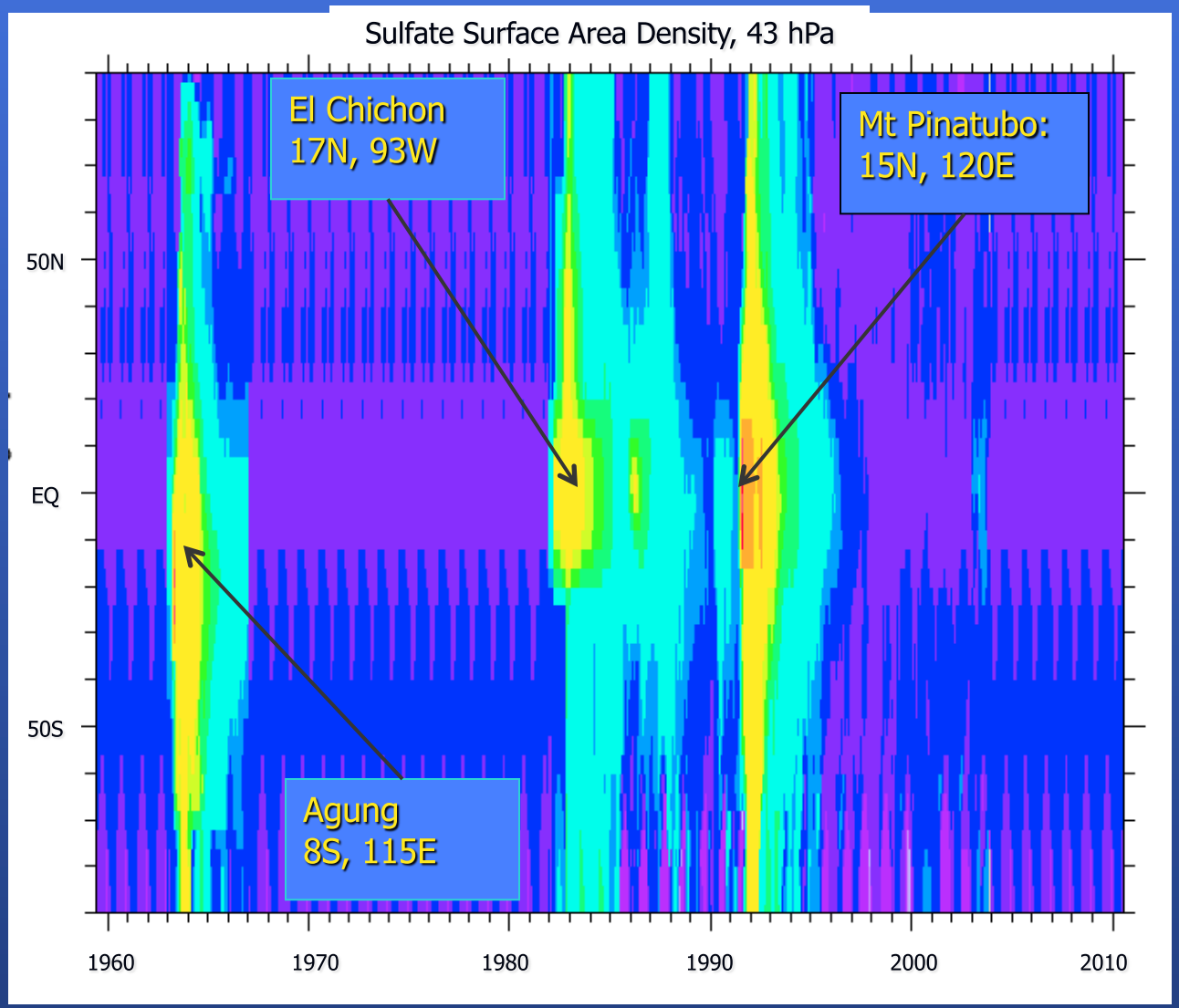
Conservation of CLOY [and BrOY].

- **Conservation of inorganic chlorine: TCLY = org +inorganic**



New Sulfate SAD climatology [SPARC].

SPARC [2006] Time Series – Modified by CCMVal



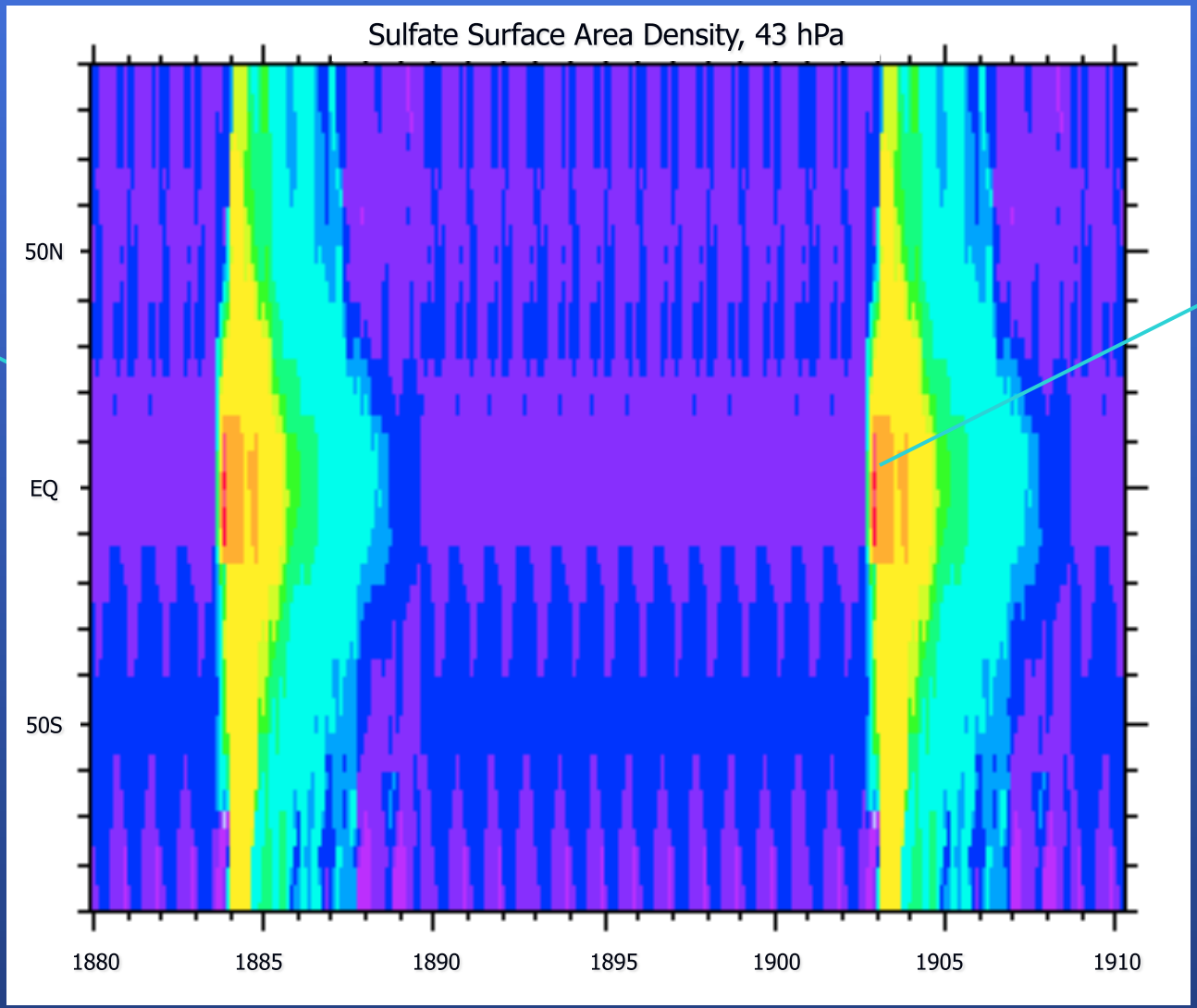
Observations used:
SAGEI, SAGEII, SAM II, and SME instruments.
See Thomason et al., [2007].
Range: 12-40 km and 80S-80N.

Data Gaps:

- **El Chichon period, tropical region <16km. Not filled.**
- **>26km gaps were filled by 0.01 um^2/cm^3**
- **Periods: 1850-1962; 1968-1979, 2005-2100 filled with monthly mean of 1998-2002 values.**
- **Agung (See Dameris, 2005)**

Sulfate SAD before 1962

Used Mt Pinatubo for Krakatau and Santa Maria.

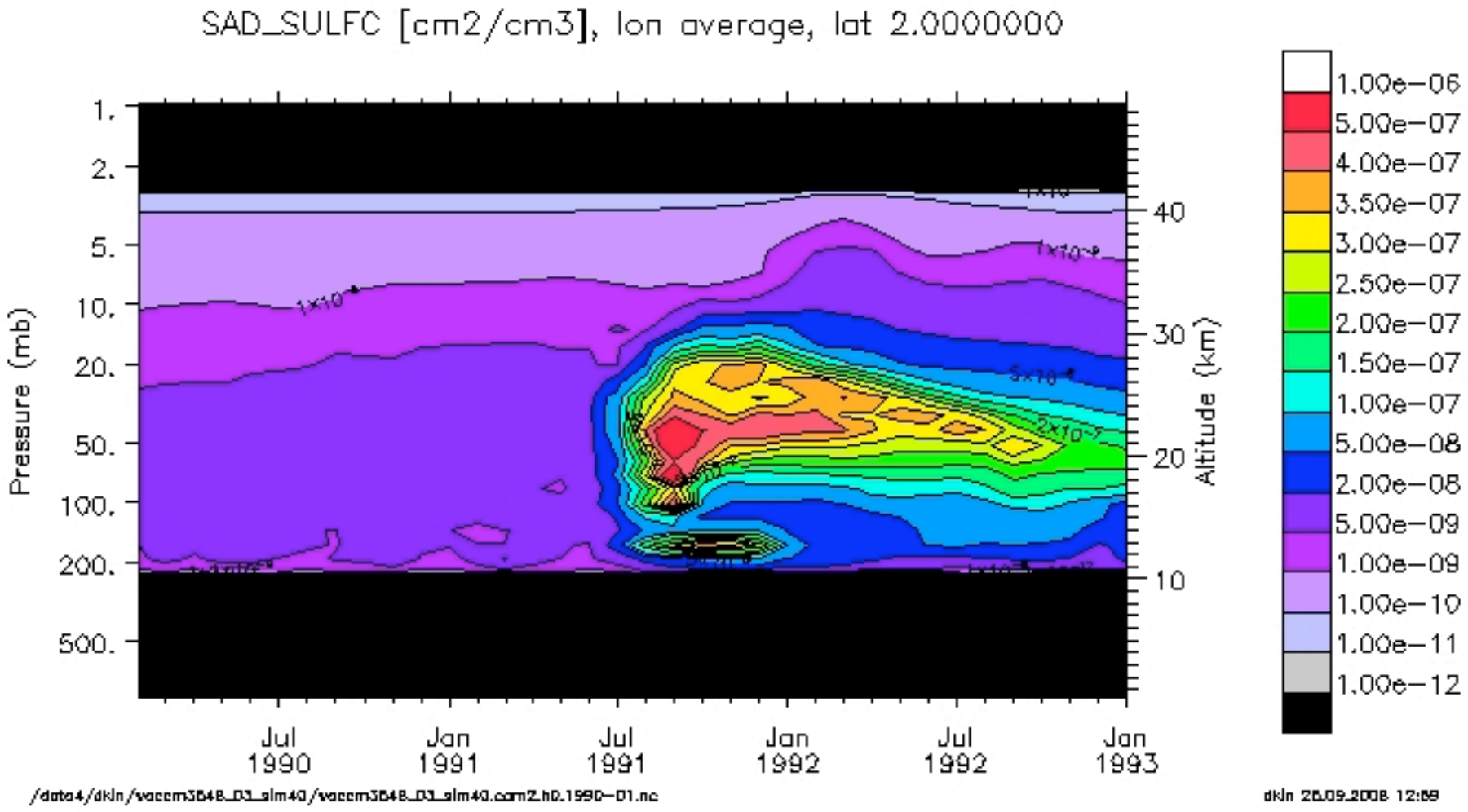


Krakatou: 6S, 105E, 27-28 Aug 1883

Santa Maria: 14N, 91W, 24 Oct. 1902

Mt Pinatubo: 15N, 120E, 15 June 1991

Volcanic Heating Module Added.



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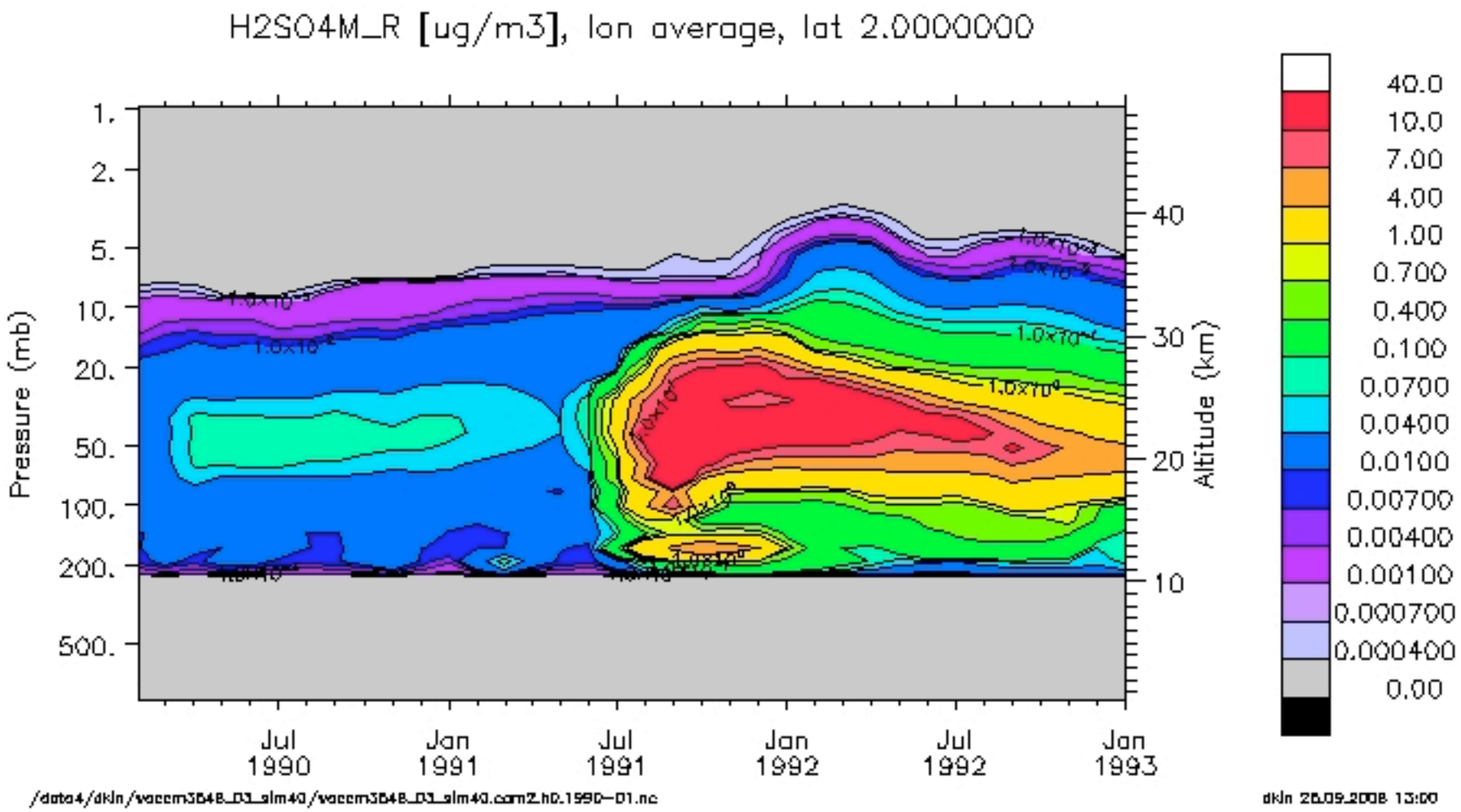

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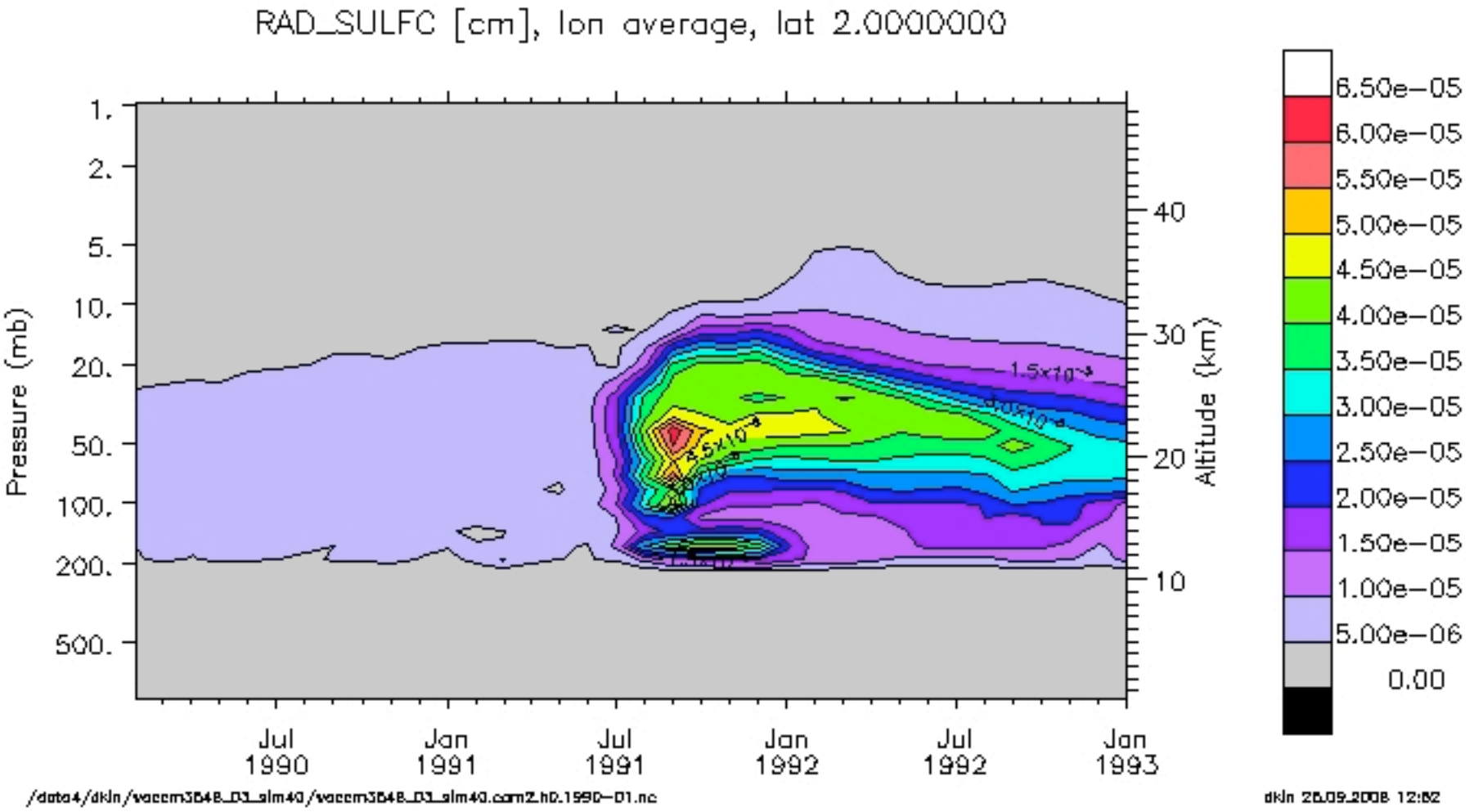

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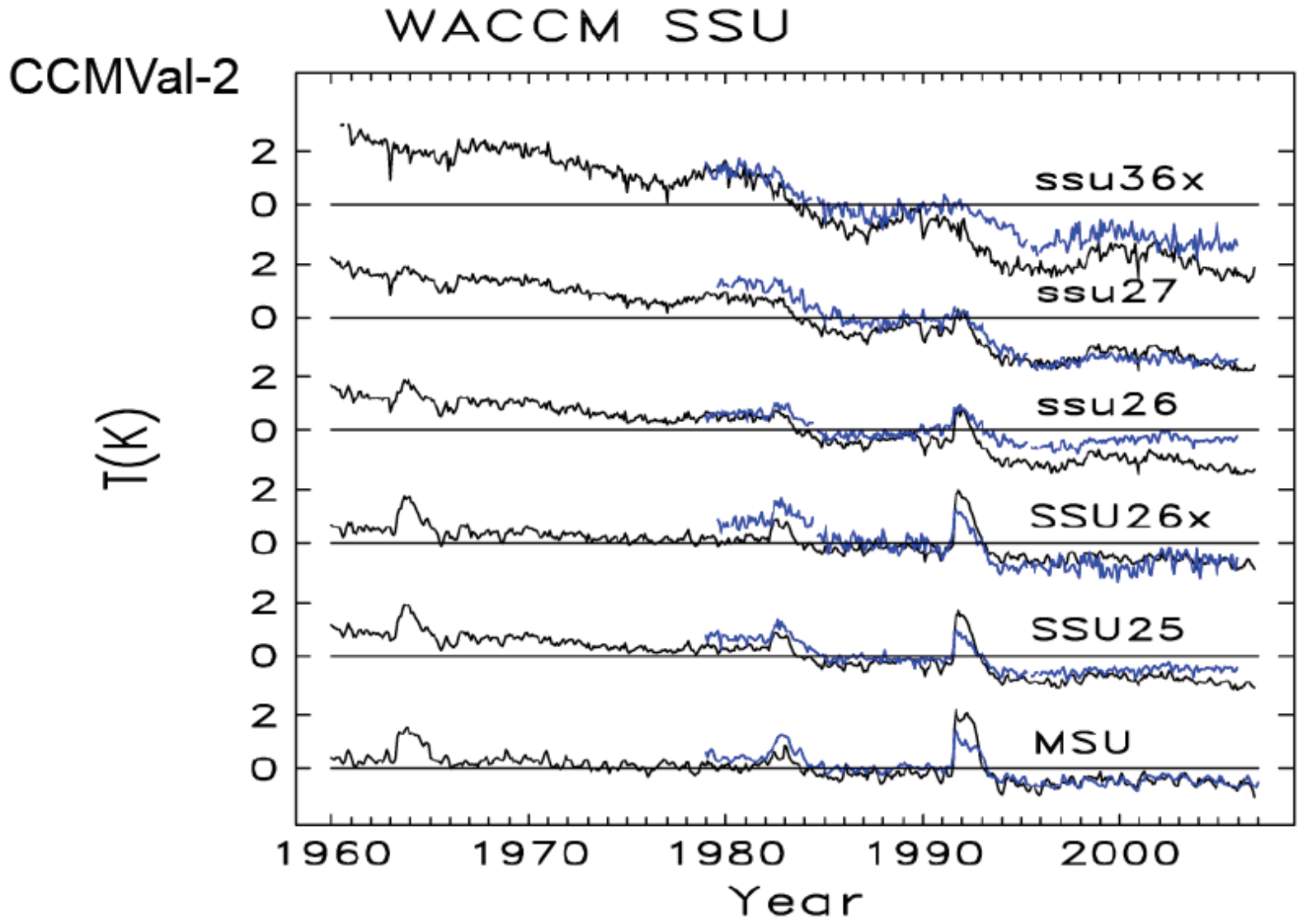
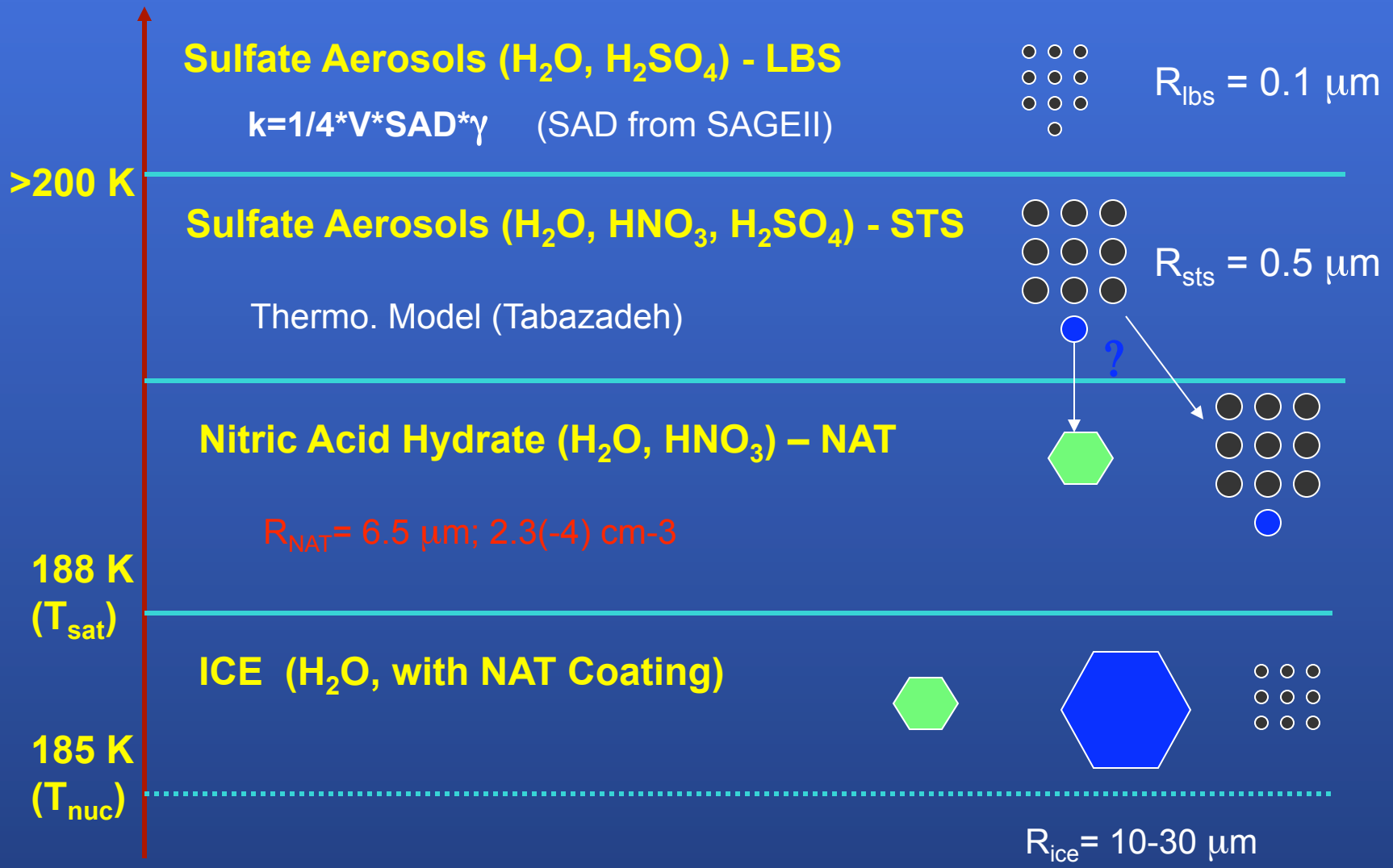


Figure courtesy Bill Randel

New (old) NAT Approach Used



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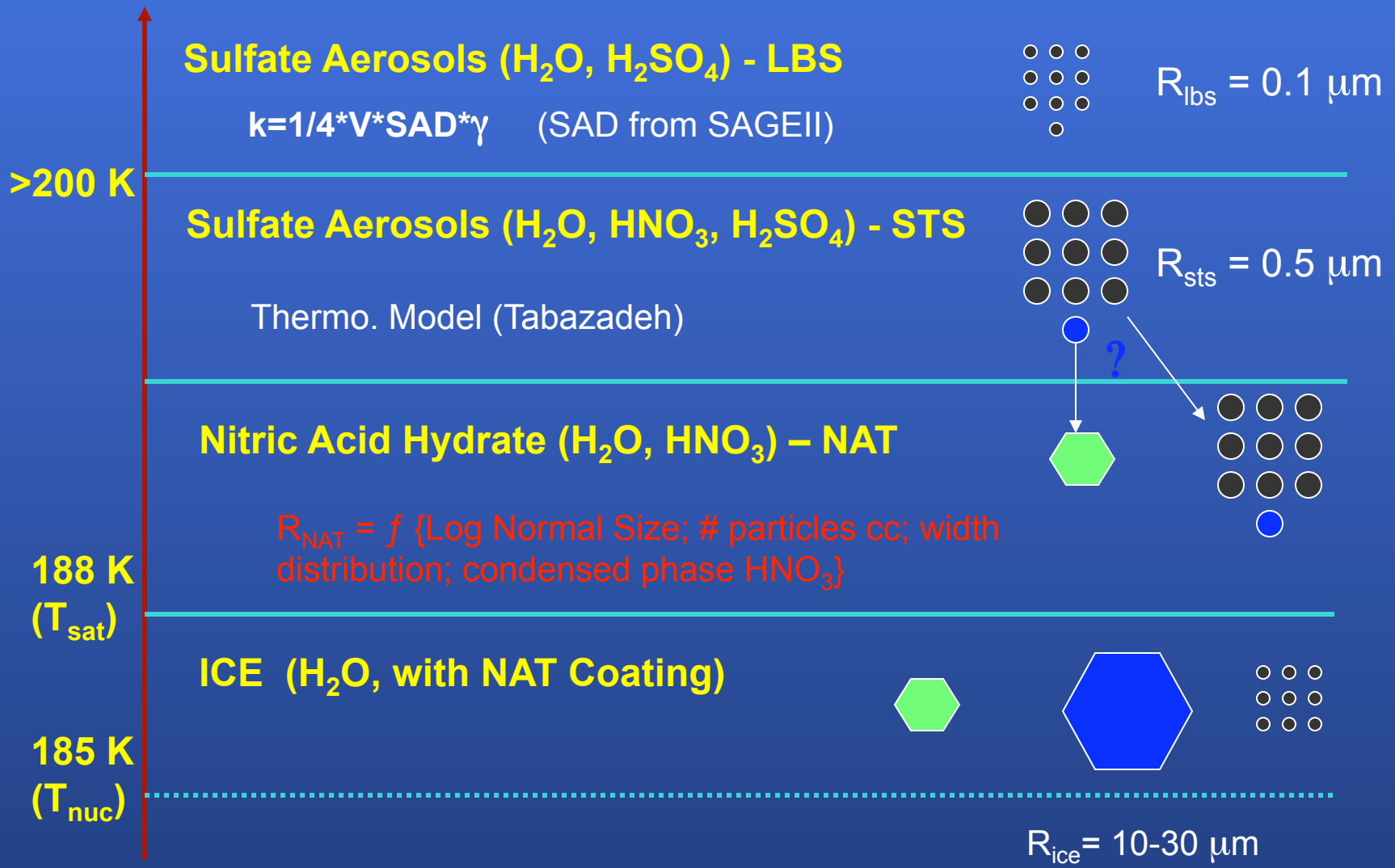

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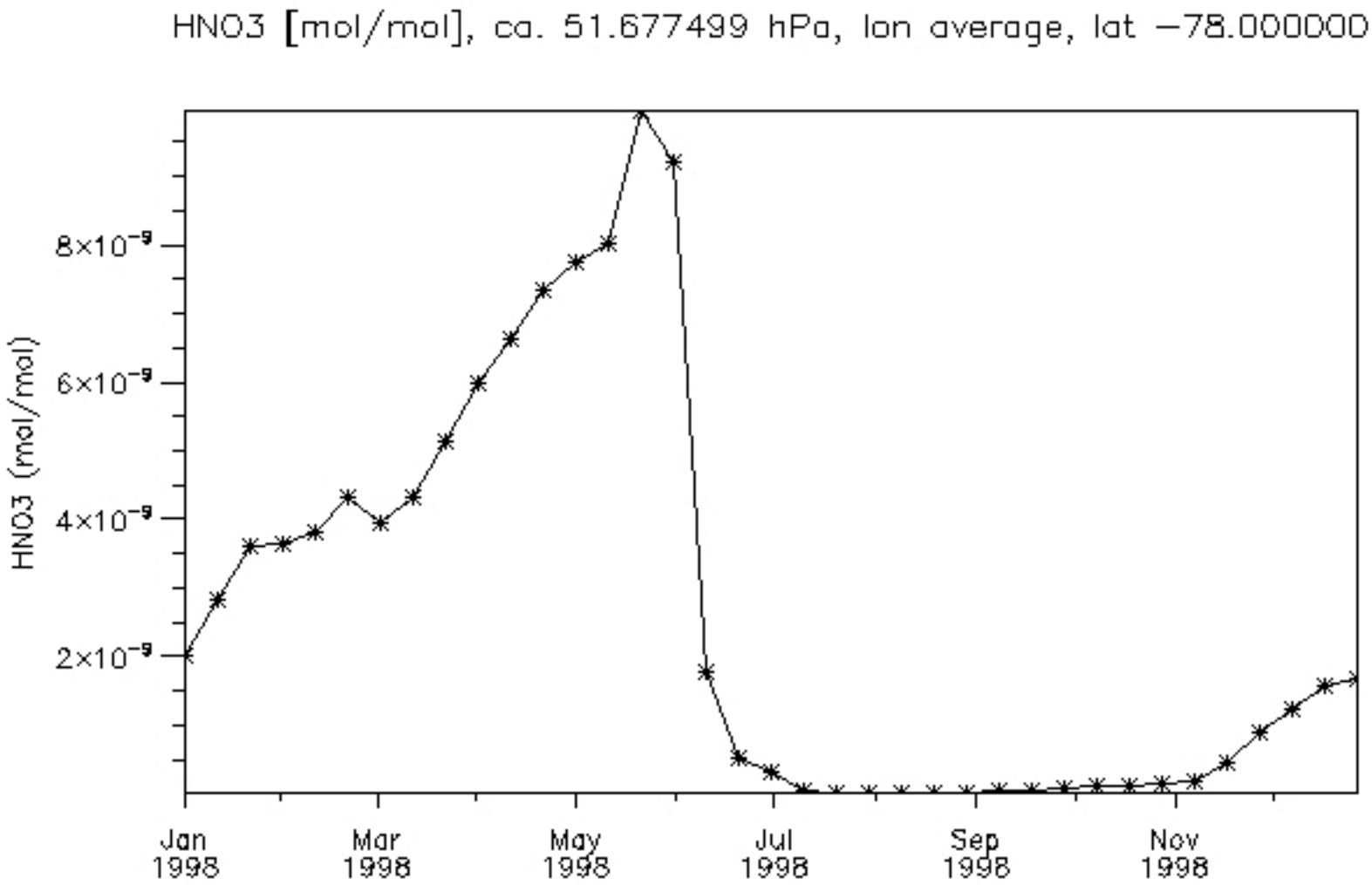

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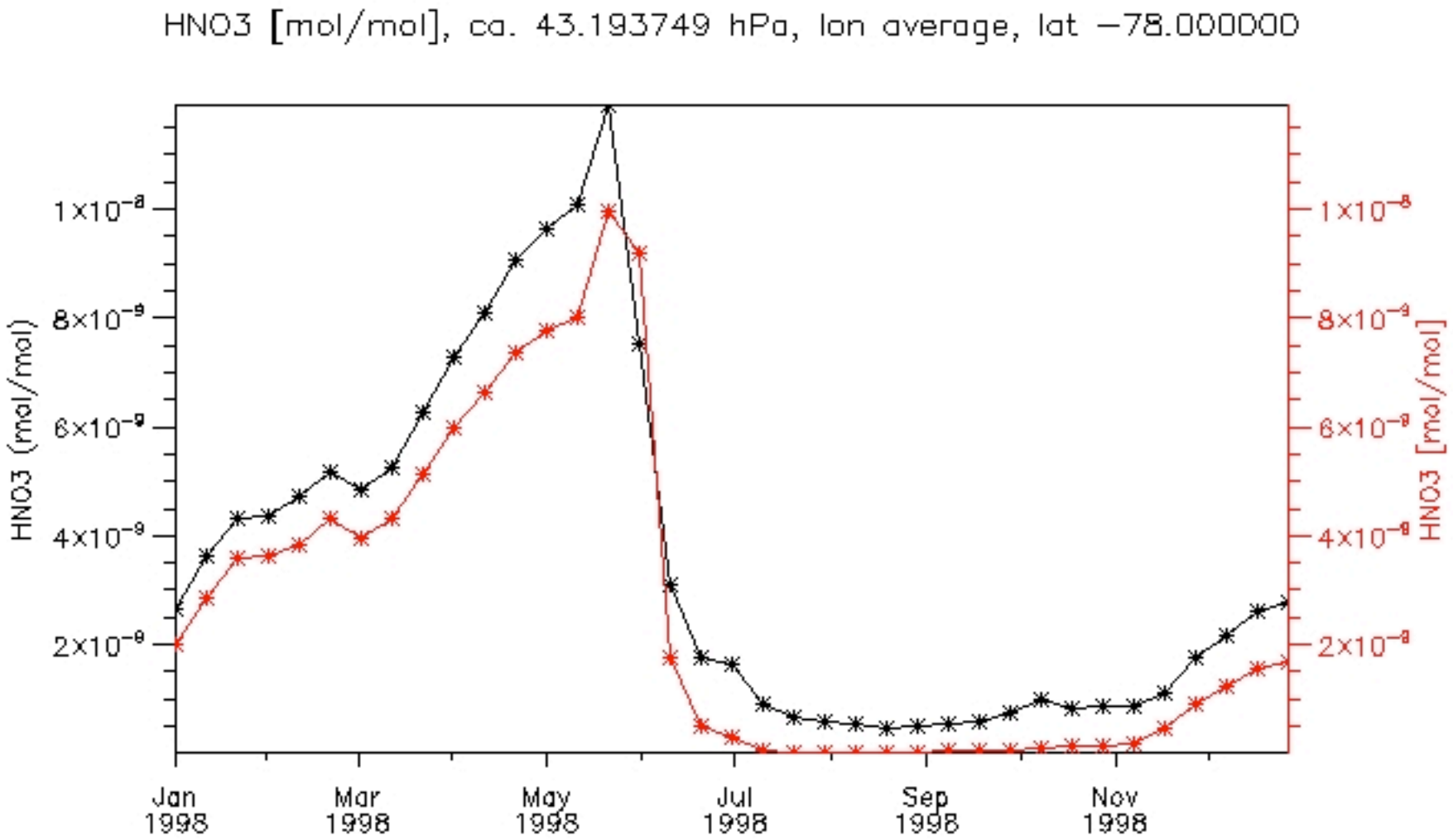

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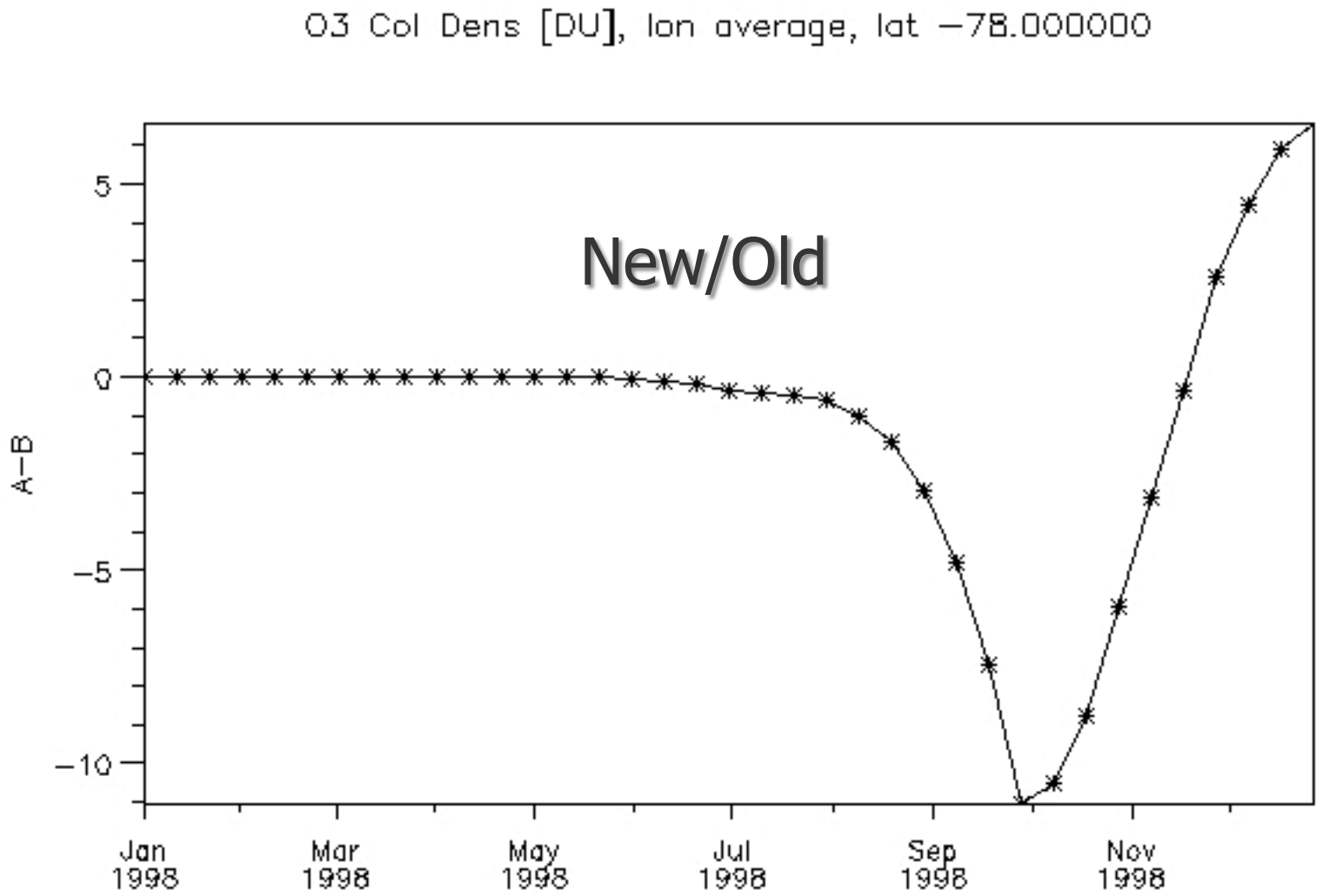
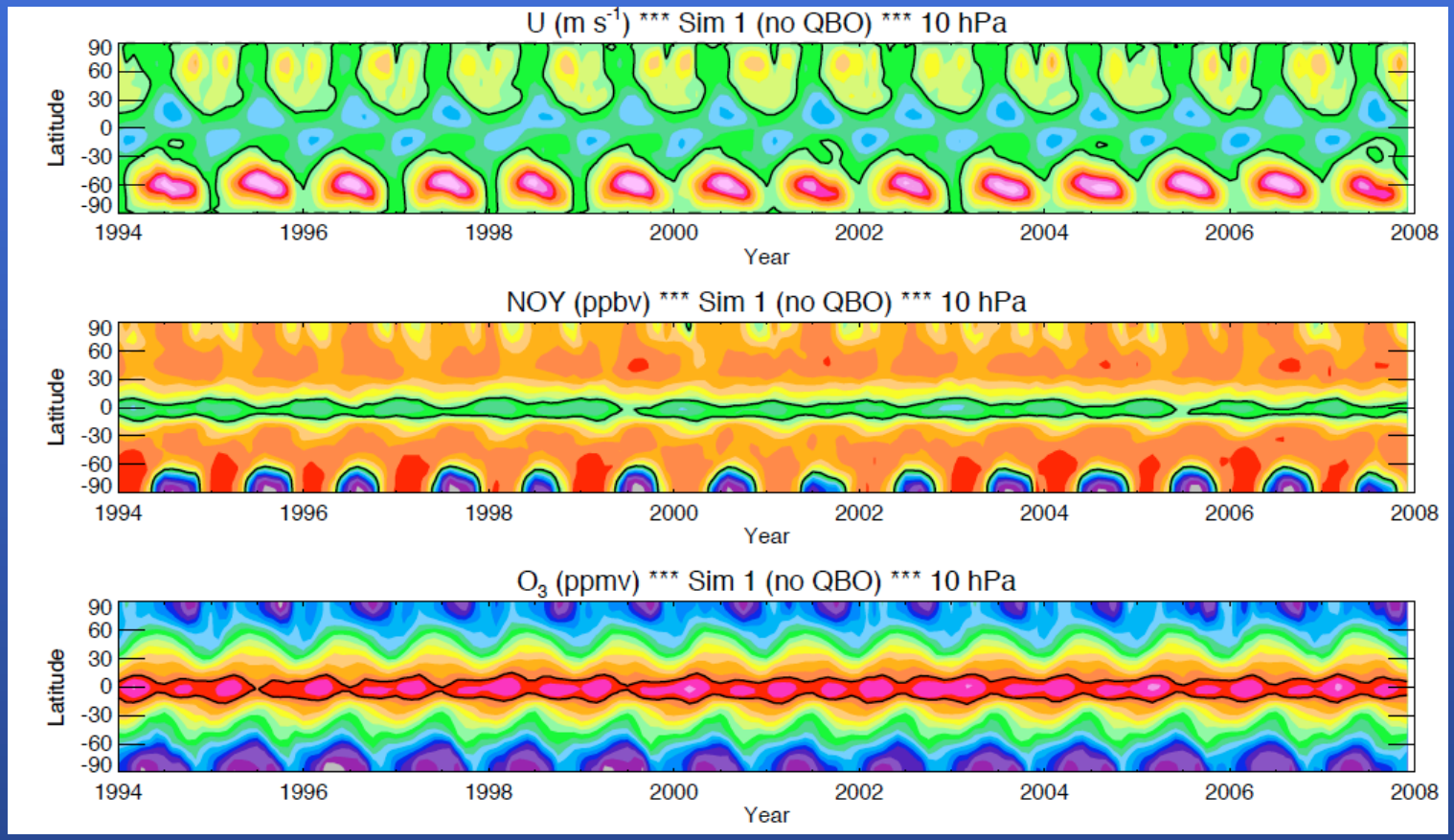


QBO Included in 2009 CCMVal Simulations



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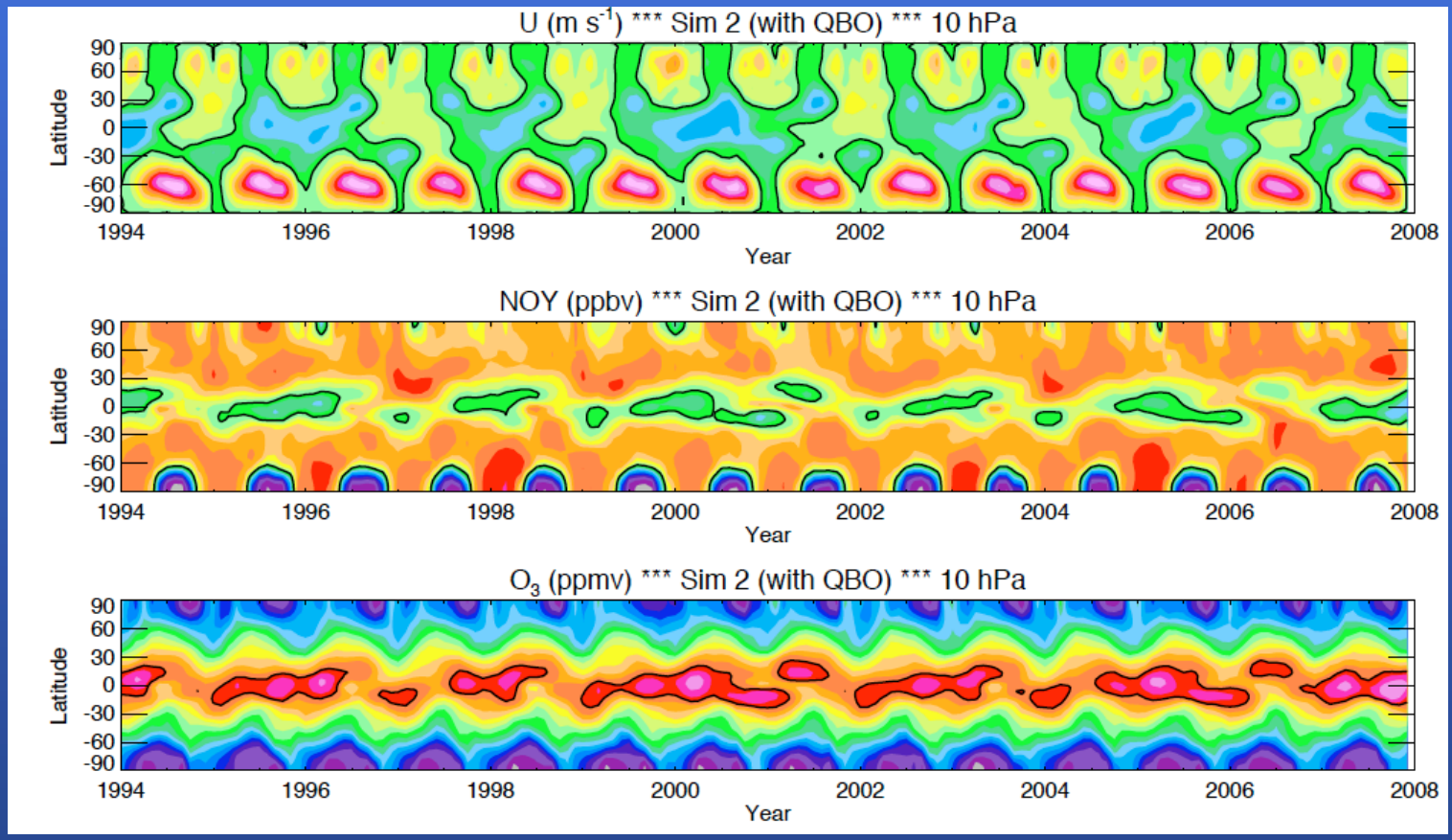


Chemical Mechanism: ~60 species

- **Updated all reactions to JPL06**
  - O + O + M => O_2 + M [Smith and Robertson, 2008]
  - CO + OH => CO_2 + H [more complicated troe like expression]

- **Added:**
  - ClO + hv => Cl + O
  - N + NO_2 => N_2O + O [Marsh recommendation]
  - HBr + O1D => Br + OH
  - HBr + O => Br + OH
  - HOBr + O => OH + BrO
  - $BrONO_2$ + O => BrO + NO_2
  - O1D + CH_3Br => Br
  - O1D + H1211 => Br + Cl
  - O1D + H13O1 => Br

- **Reactions: 159 total;** 128 (gas-phase); 17 (het) ; 14 (ion / e)

- **Photolysis: 73 total;** 48 (120-750 nm); 25 (EUV)

Chemical Mechanism: 125 species

Additional Surface Source Gases (16 additional) …

NHMCs: CH_3OH,
C_2H_6, C_2H_4, C_2H_5OH, CH_3CHO
C_3H_8, C_3H_6, CH_3COCH_3 (Acetone)
C_4H_8 (BIGENE), C_4H_8O (MEK)
C_5H_8 (Isoprene), C_5H_{12} (BIGALK)
C_7H_8 (Toluene)
$C_{10}H_{16}$ (Terpenes)

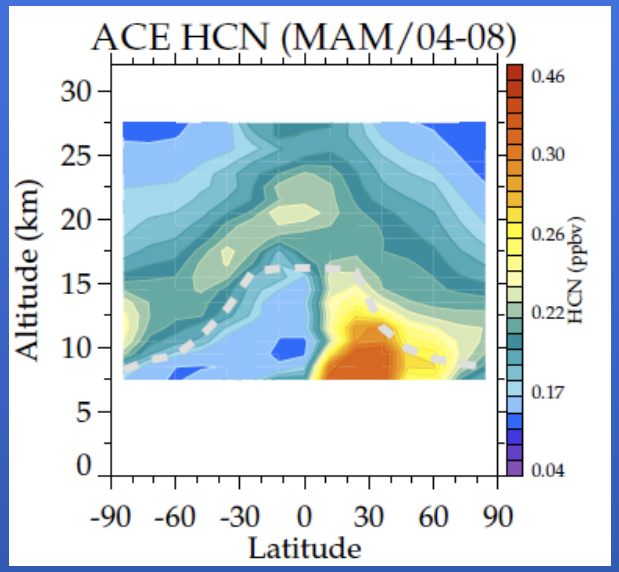
Plus: HCN, CH_3CN

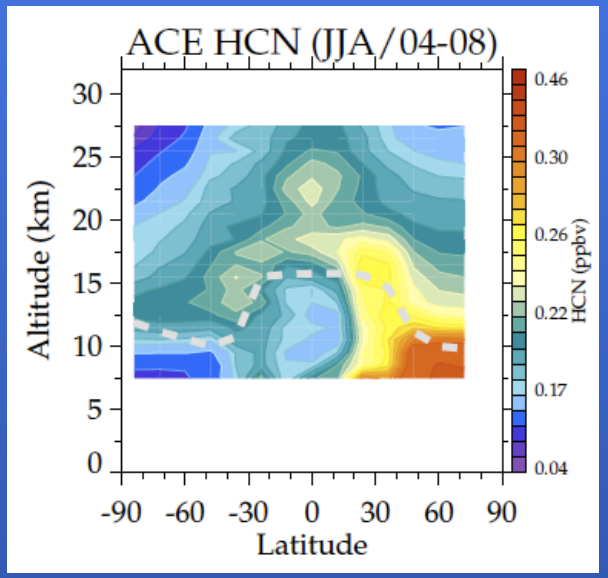
Reactions: **178 total:** 147 (gas-phase); 17 (het); 14 (ions/ electron)

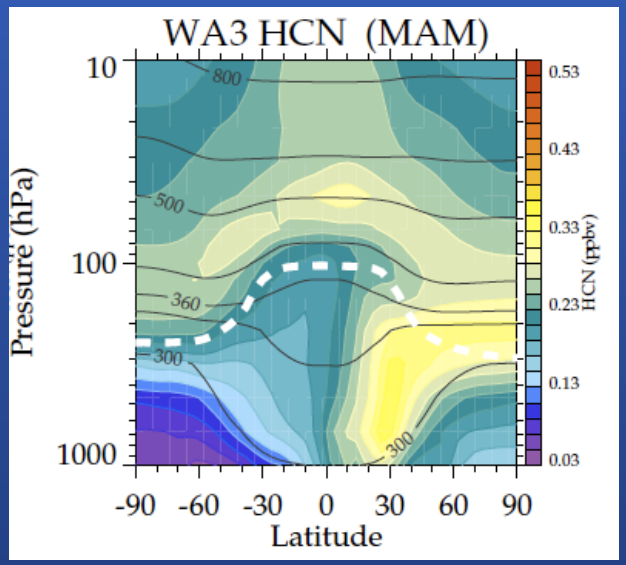
Photolysis: **97 total:** 72 (120-750nm); 25 (EUV)

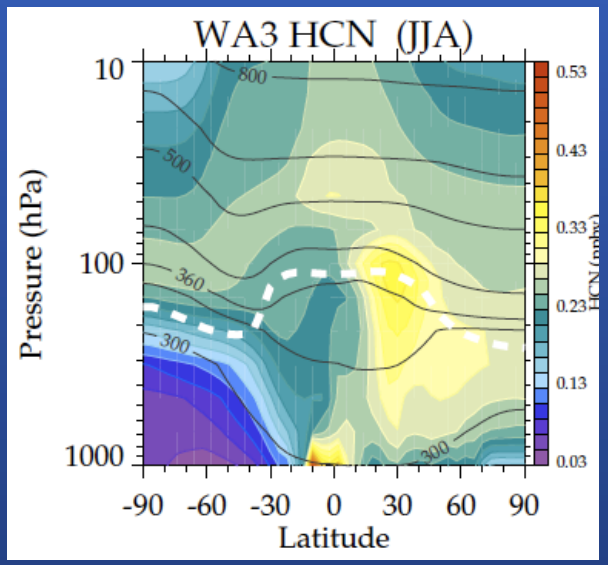
This version has been checked in: /waccm/fvitt/waccm08_cam3_5_48_b1.01

HCN – Fully Interactive WACCM3 vs ACE-FTS









Courtesy of Mijeong Park

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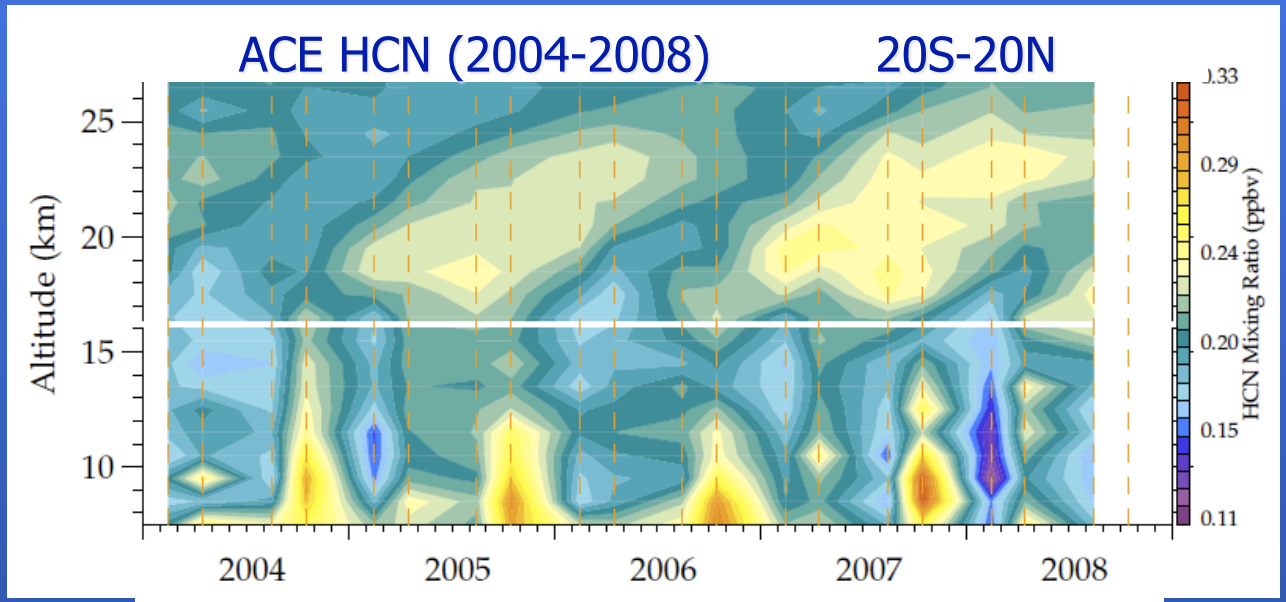
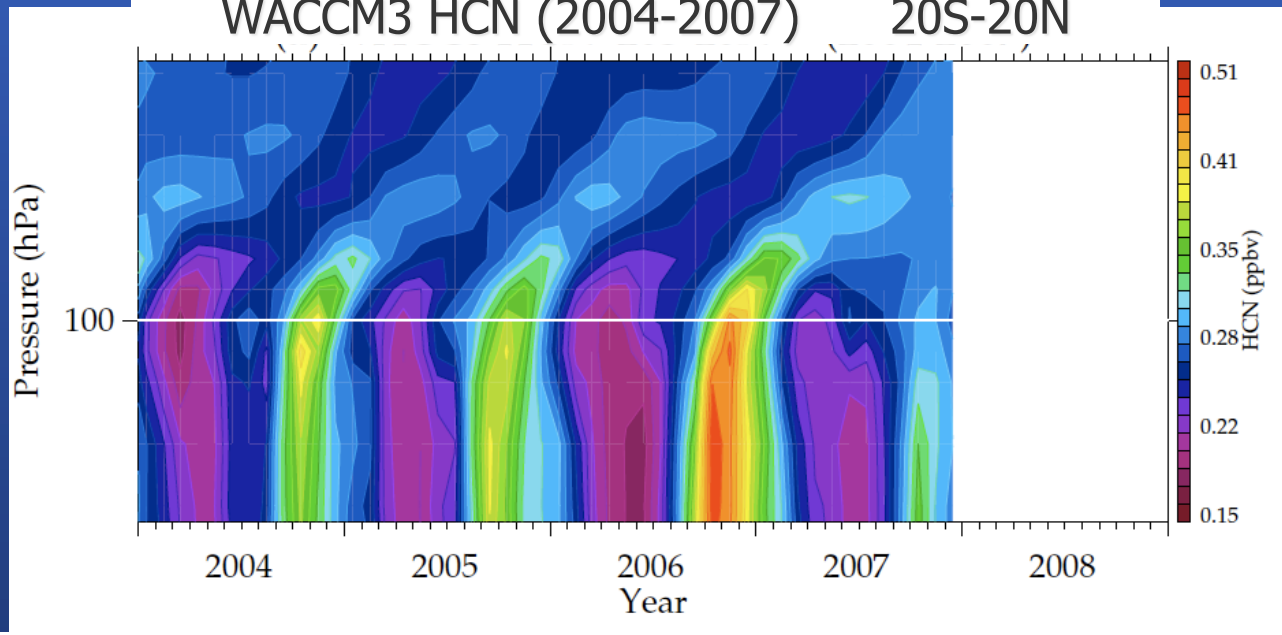


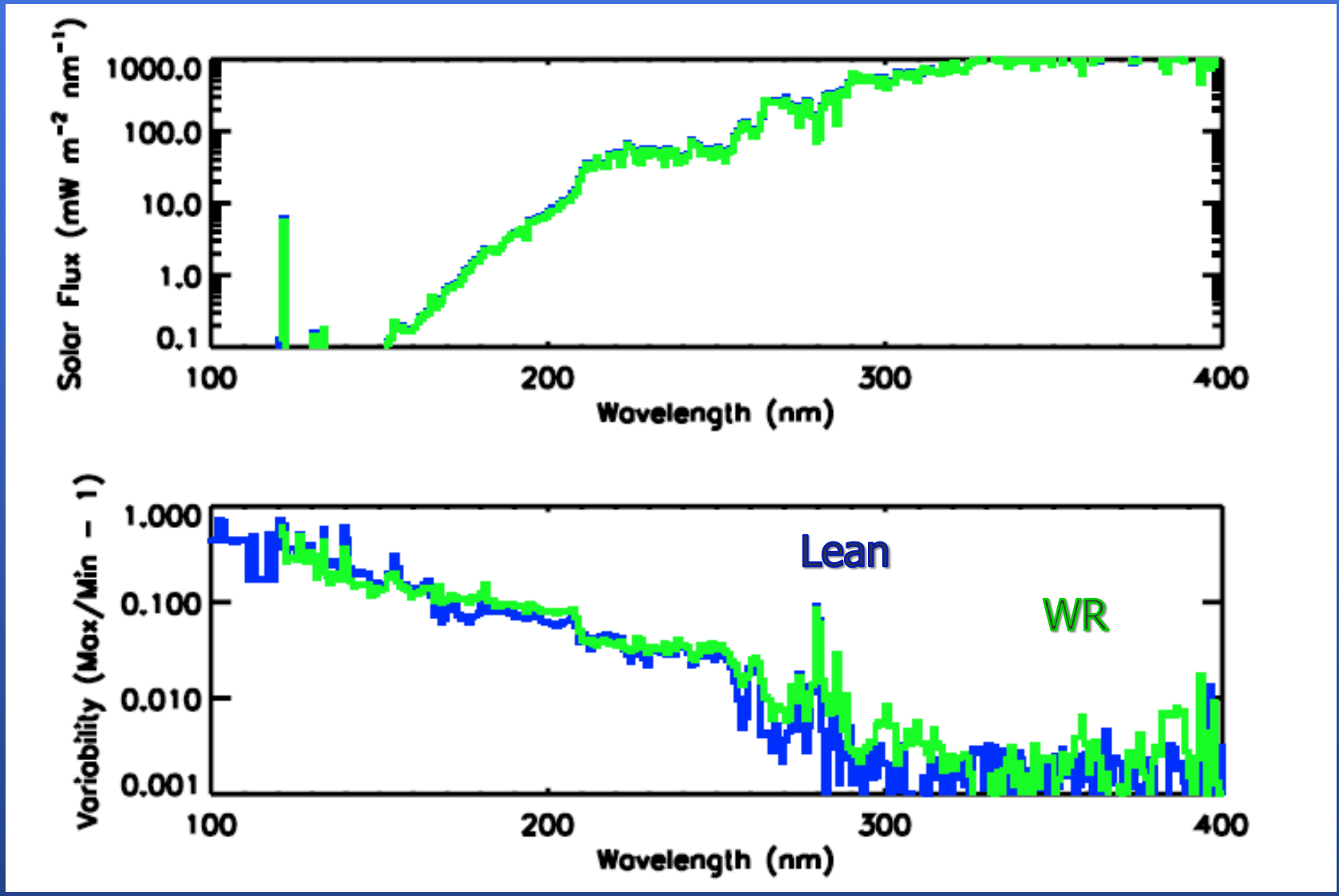


New ETF's

- **Changed to Lean Extraterrestrial Fluxes**
  - Previous: Woods / Rottman [120 – 350 nm]
  - Neckel [>350nm no solar variability]

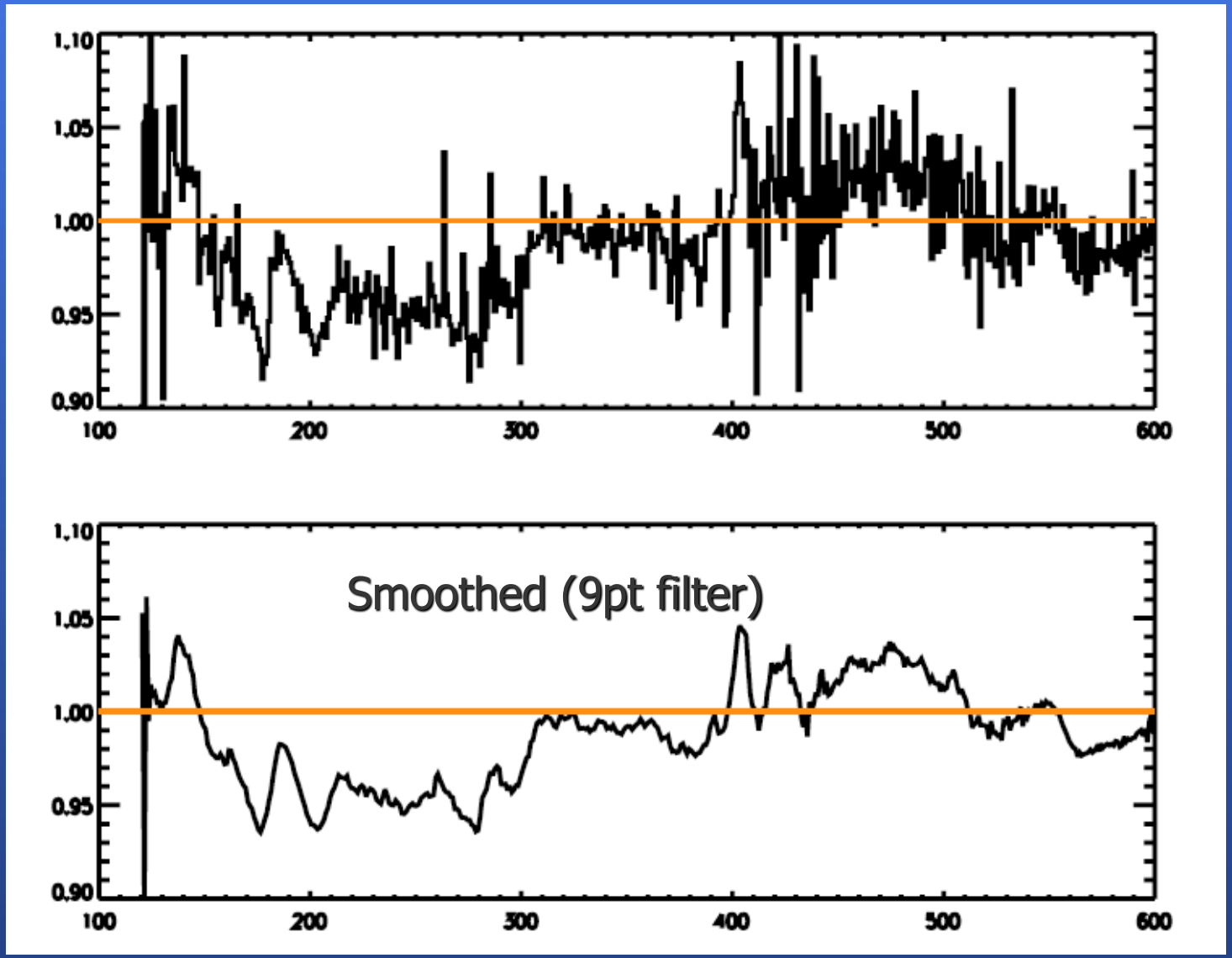
- **Why?**
  - Recommended by CCMVal-2
  - Variability Extends long ward of 350 nm.
  - Have wavelength dependent variability for pre-industrial simulations.

Max to Min variablity: Lean vs WR



Courtesy of Stan Solomon

Ratio at low Solar Activty: Lean / WRN



Courtesy of Stan Solomon

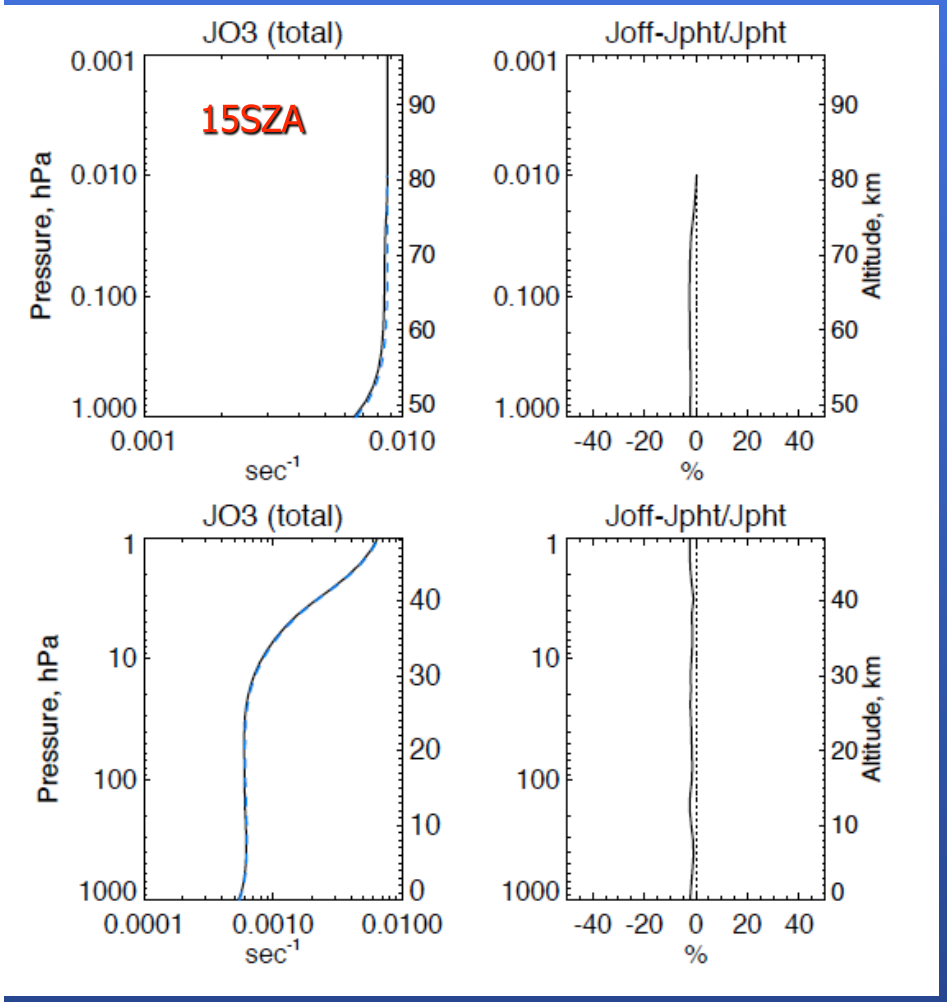
Photolysis

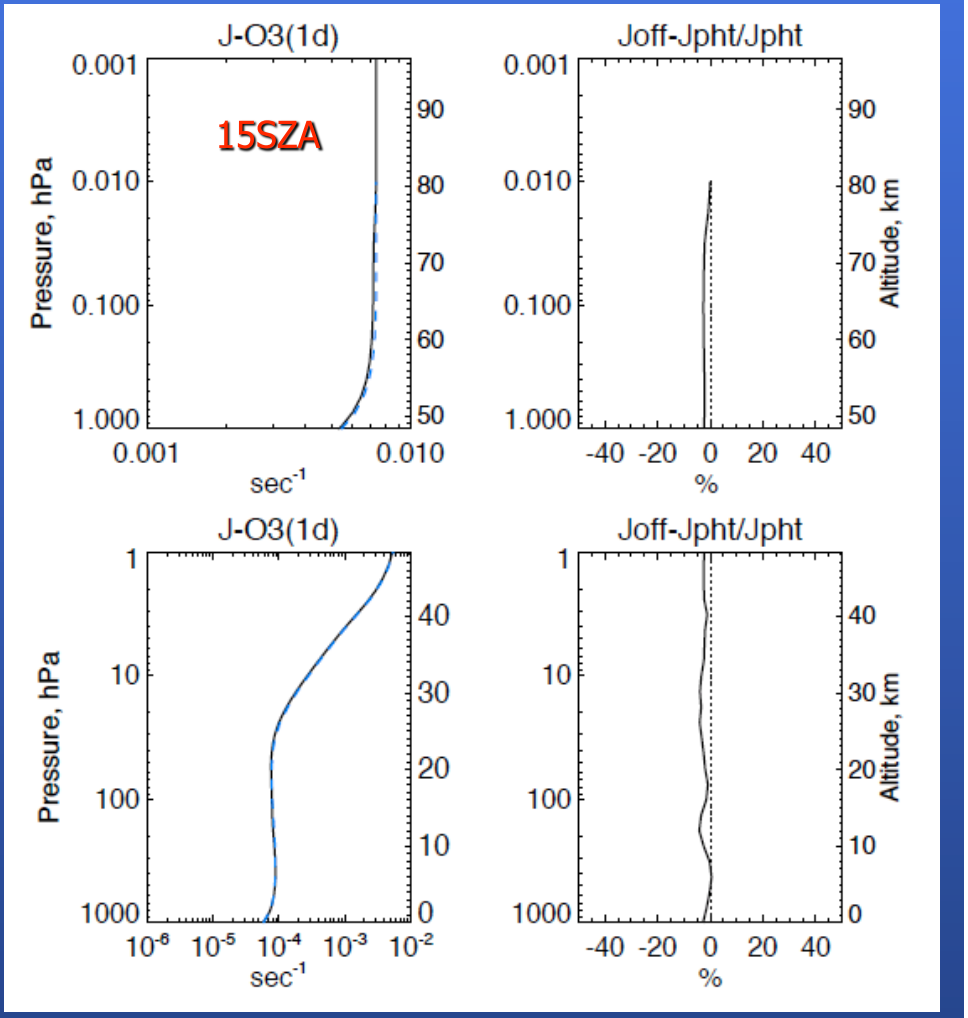
- Updated the preprocessor – tagging each photolysis reaction
  - [jno2] NO2 + hv -> NO + O.
  - The current LUT has >95 J's in the master list [code only reads what it needs].

- Created an "offline" photolysis module that can calculute all J's given ~ 12 constituents [e.g., O_3, T, CLOUD, ASDIR, etc…].

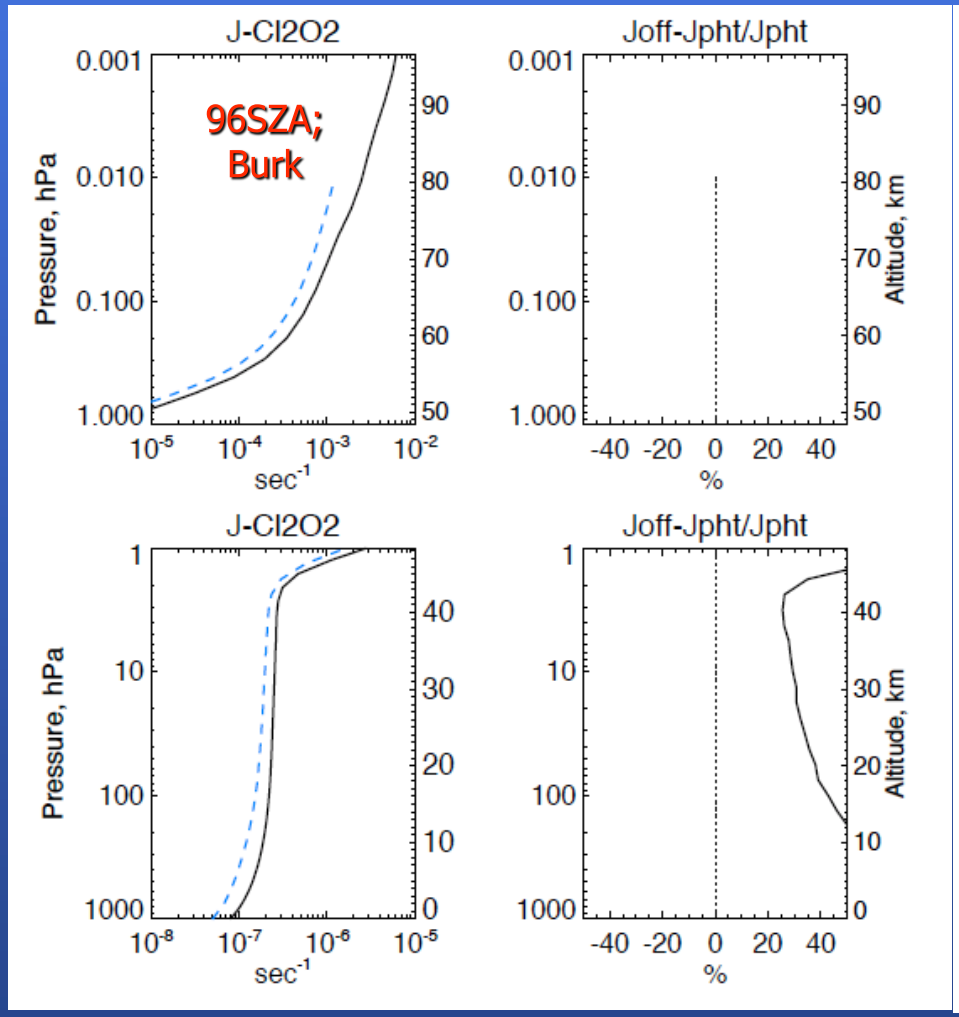
- Ran the "offline" photolysis model for a CCMVal Photocomp.
  - Clear Sky J's at 15°, 84°, 96° SZA
  - 24-hr avg J's at Equinox, 84N.
  - 15° SZA without Rayleigh Scattering

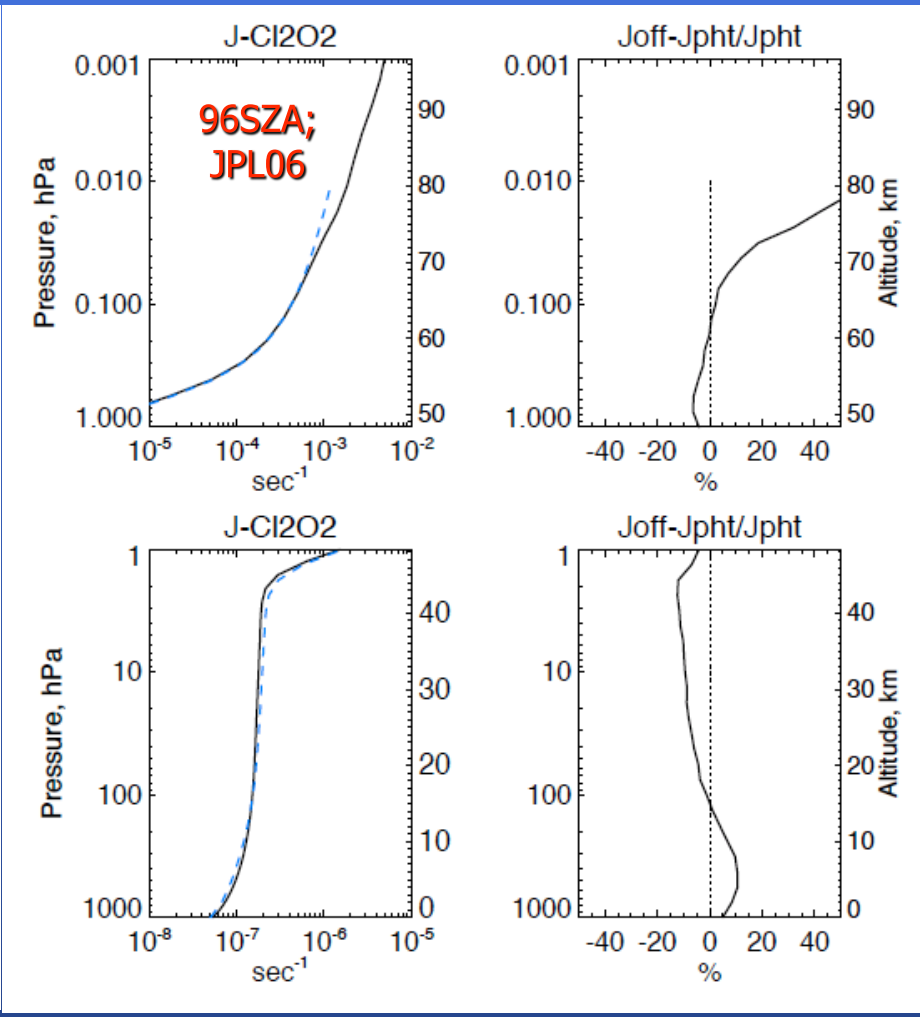
Photolysis


JO3 (total)
15SZA
Pressure, hPa
0.001
0.010
0.100
1.000
90
80
70
60
50
0.001
0.010
sec-1
Joff-Jpht/Jpht
-40 -20 0 20 40
%
Altitude, km
JO3 (total)
1
10
100
1000
40
30
20
10
0
0.0001
0.0010
0.0100
sec-1
Joff-Jpht/Jpht
-40 -20 0 20 40
%
Altitude, km


J-O3(1d)
15SZA
Pressure, hPa
0.001
0.010
0.100
1.000
90
80
70
60
50
0.001
0.010
sec-1
Joff-Jpht/Jpht
-40 -20 0 20 40
%
Altitude, km
J-O3(1d)
1
10
100
1000
40
30
20
10
0
10-6 10-5 10-4 10-3 10-2
sec-1
Joff-Jpht/Jpht
-40 -20 0 20 40
%
Altitude, km

Photolysis


J-Cl2O2
Joff-Jpht/Jpht
96SZA;
Burk
Pressure, hPa
Altitude, km
sec-1
%
0.001
0.010
0.100
1.000
1
10
100
1000
10-5
10-4
10-3
10-2
10-8
10-7
10-6
-40 -20 0 20 40
50
60
70
80
90
0
10
20
30
40


J-Cl2O2
Joff-Jpht/Jpht
96SZA;
JPL06
Pressure, hPa
Altitude, km
sec-1
%
0.001
0.010
0.100
1.000
1
10
100
1000
10-5
10-4
10-3
10-2
10-8
10-7
10-6
-40 -20 0 20 40
50
60
70
80
90
0
10
20
30
40

SD-WACCM3

- **Used extensively in testing updated chemistry module changes.**
- **Support ACD lead Aircraft Campaigns [e.g., STARTO8] and Satellite program [e.g., HIRDLS].**
- **Supports ACD UTLS Science Studies [Randel's group].**
- **Will be made available to the University Community in the next WACCM release.**

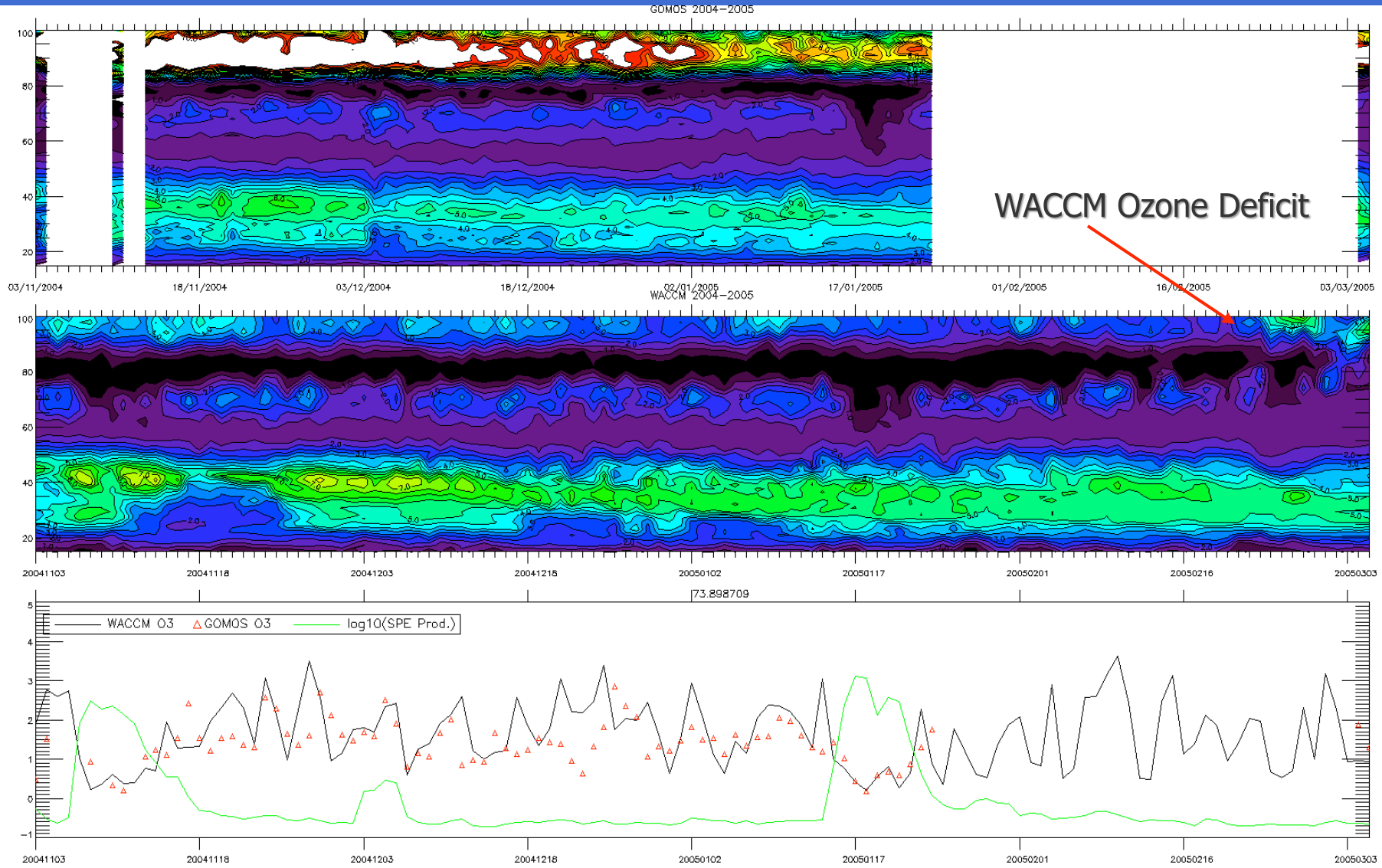
SD-WACCM3

- **Logic existed to nudge CAM3 [WACCM3] met fields with offline met fields every time step** [Hess, Rasch, Vitt].
- **Created a procedure to convert GEOS5.1 met fields from 0.5x0.66 horiz. resolution to 1.9x2.5 (or 4x5).** [Yudin, Kinnison, Tilmes]
- **Transition from nudged met fields to fully interactive dynamics between a specified altitude region was added for WACCM.**
- **Current Studies…**
  - CU/LASP Randall et al. [O_3 loss]
  - Yudin et al. , [Lamina Statistics with HIRDLS]
  - Tilmes et al., [STARTO8 / ARCTAS].
  - Marsh et al., [MLT Ozone / SPE / GOMOS].

SD-WACCM3 *** with SPE's

Comparison with GOMOS data (Viktoria Sofieva)

- GOMOS is stellar occultation and so these are nighttime ozone values.
- Average of data from 70 to 76 N



CAM-CHEM / WACCM3 Merge (>CAM3.6)

Expertise lies in both group for common modules:

- Wet and dry deposition is more advanced in CAM-CHEM
- Emission databases are evaluated in the CAM-CHEM community.
- Lower boundary condition modules are used by both teams.
- Tropospheric mechanisms have been developed and used by the CAM-CHEM team. Stratospheric and MLT mechanism have been developed and used by the WACCM team.
- LUT/parameterization approaches have been developed by the WACCM team and used by CAM-CHEM team.
- Heterogeneous processes on stratospheric aerosols have been developed by the WACCM team and used by CAM-CHEM team.

Maintaining one chemistry pre-processor and common code would increase efficiency for both groups .

Just Remember: Chemistry is Really Important!