New Implementations of Natural Forcing in CCSM4

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With:

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and

Philip Cameron-Smith

Goals Volcanic Aerosol

- Fix broken implementation CAM-RT 3.5+ (Track1)
- Implement Volcanics in RRTMG (Track5)

  science: representation of evolving particle size
  better simulation of large events
  better stratospheric heating
- Merge assumptions CAM / WACCM
  - CAM-climate: Aerosol radiative forcing based on known mass
    - Move from fixed to evolving aerosol size distribution
  - WACCM-chemistry: evolving Surface Area Density (i.e. evolving particles)
    - Radiation from fixed to evolving aerosol (consistent with chemistry
- Fix tropopause “leak”

Status

CCSM4 Track1: Baseline solution

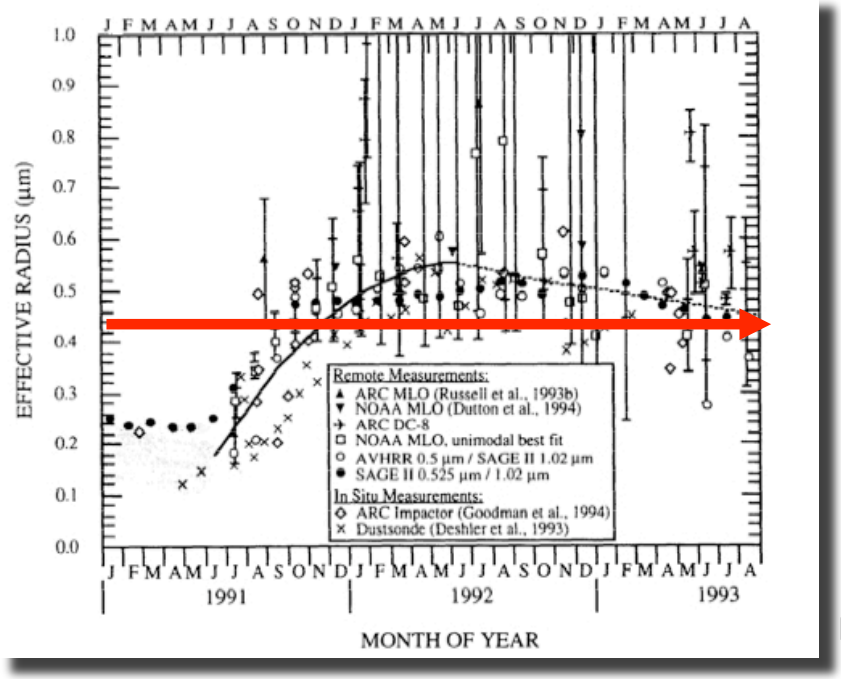
- ✓ Single size distribution radiation (successful for CAM and WACCM)
- ✓ Interface works for CAM and WACCM
- ✓ Tropopause fix in place (lat-function)

CCSM Track5: New Implementation using RRTMG

- ✓ Evolving aerosol effective radius (log-normal size with fixed width)
- ✓ Optics table for evolving size
- ✓ Determine tropopause (instantaneous)

CCSM1-CCSM3 (camRT)

Single size distribution H_2SO_4-H_2O aerosol

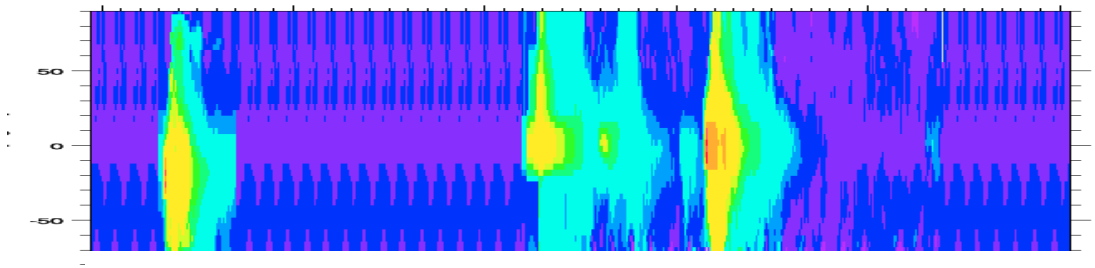


Russell et al. 1996

Too efficient particles in the peak of the volcanic cloud

Additionally: inconsistency between Radiation and Chemistry

Track5 : Evolving Volcanic Aerosol Size



SPARC/CCMVal: SAGE-II Surface Area Density Dataset of H_2SO_4+H_2O

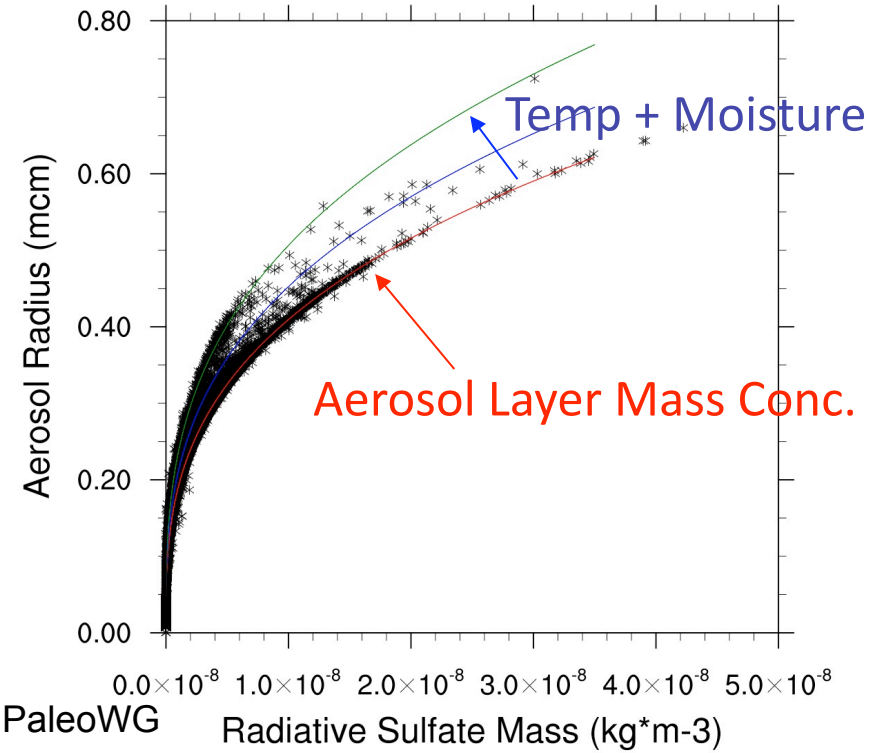
Its own assumptions:

Particle number density = 10 p / cc

Width of the distribution fixed (1.6 micron)

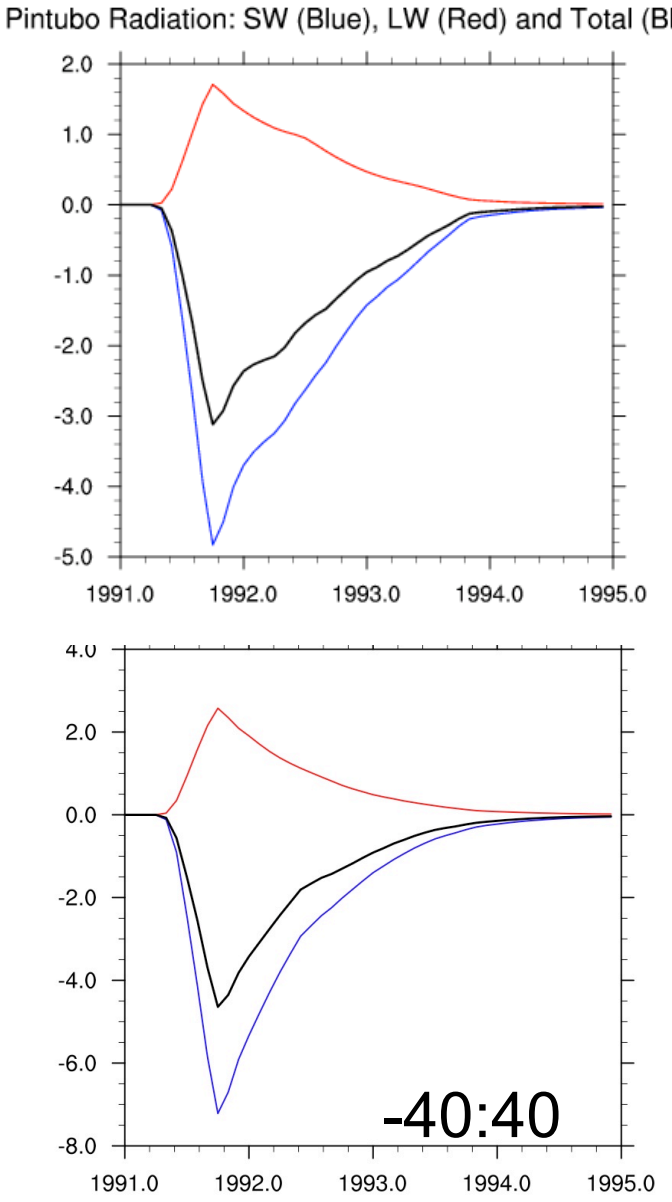
r_{geom}= {(3*Vden) / (4π*Pden)}$^{1/3}$*exp(-3/2*log(σ)^2))

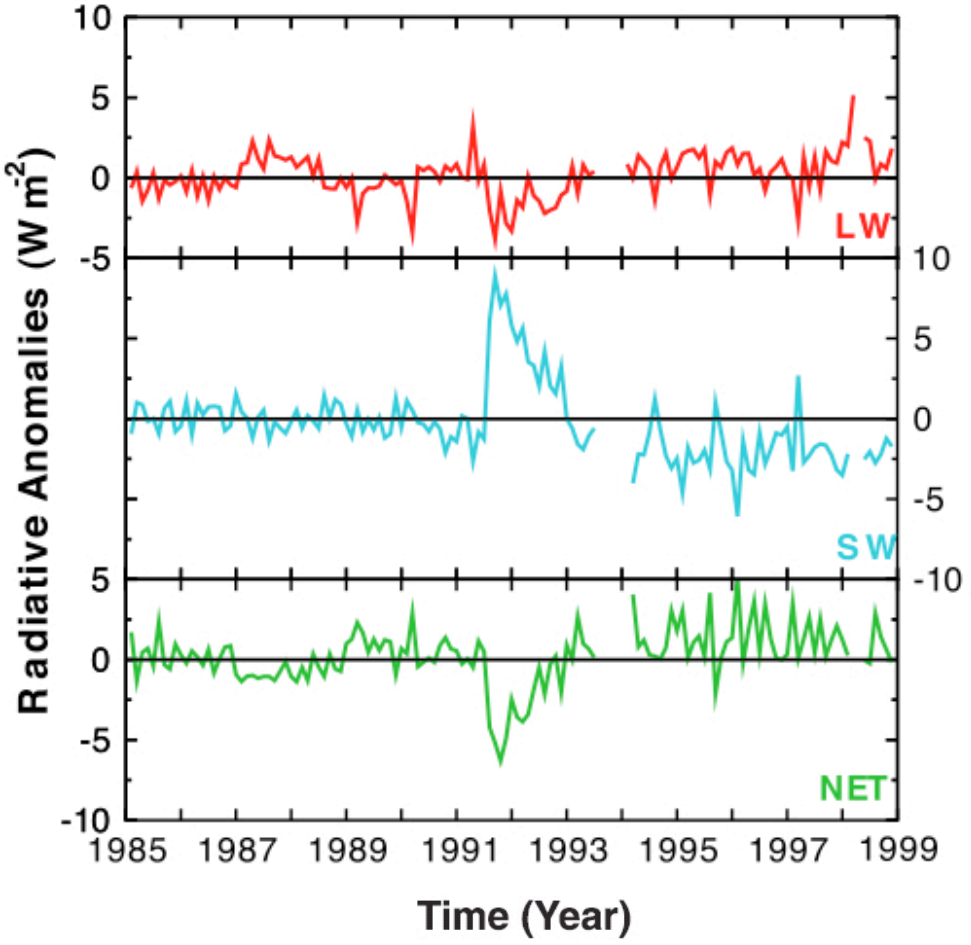
Key: Link through mass concentration, and mass is known past and present



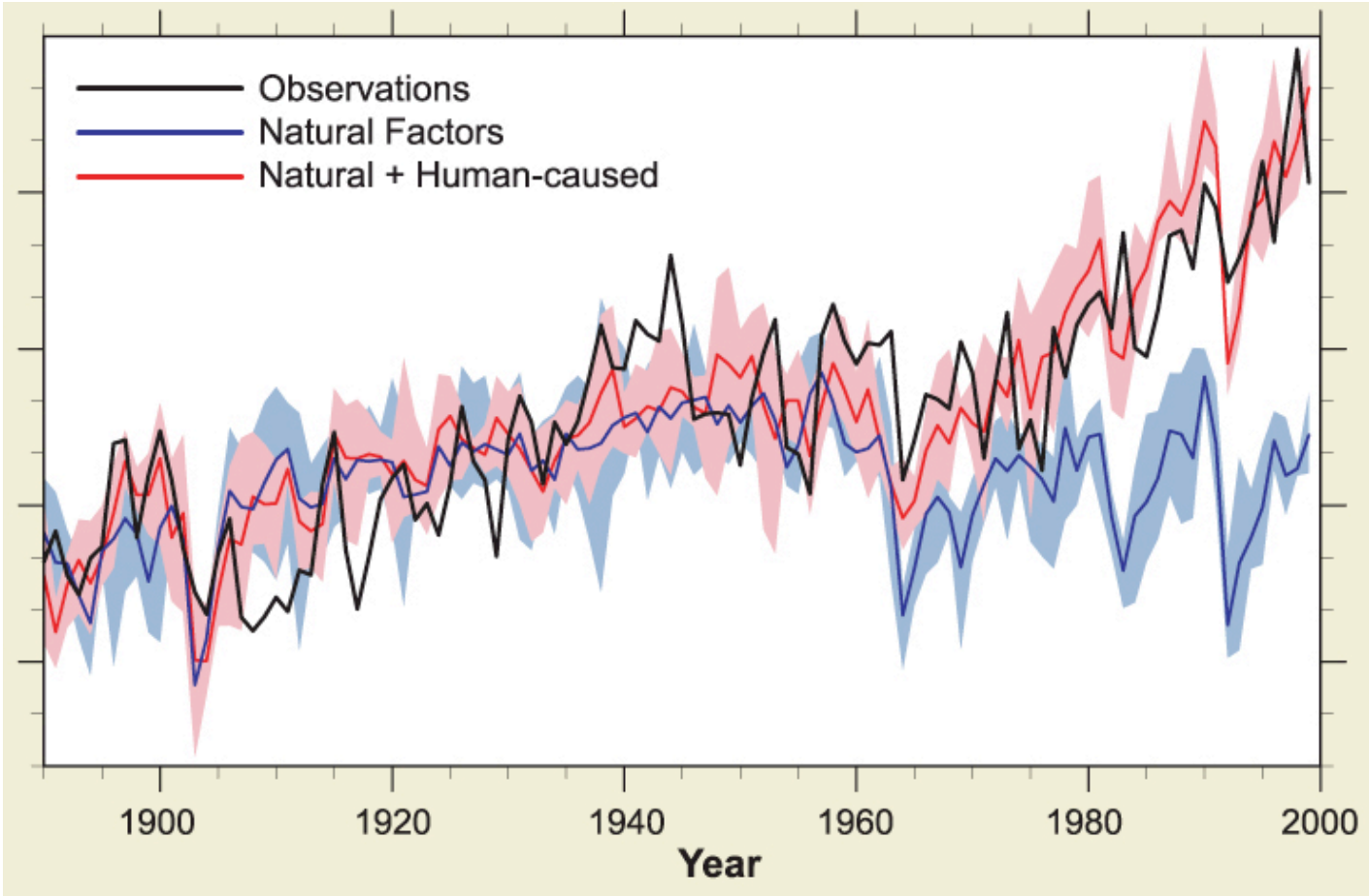
Pinatubo: Radiative Forcing

RRTMG(AMIP) vs ERBS

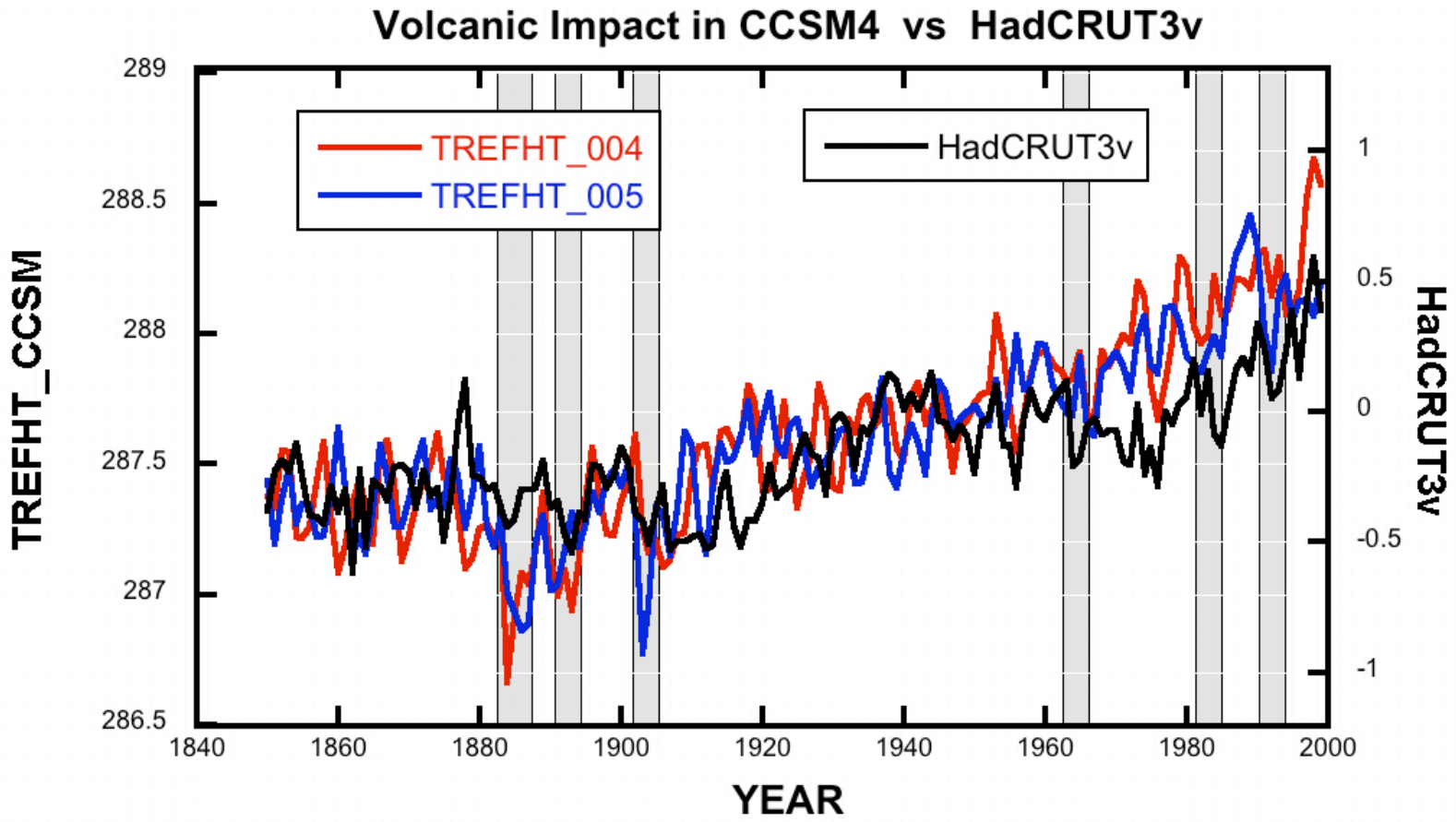




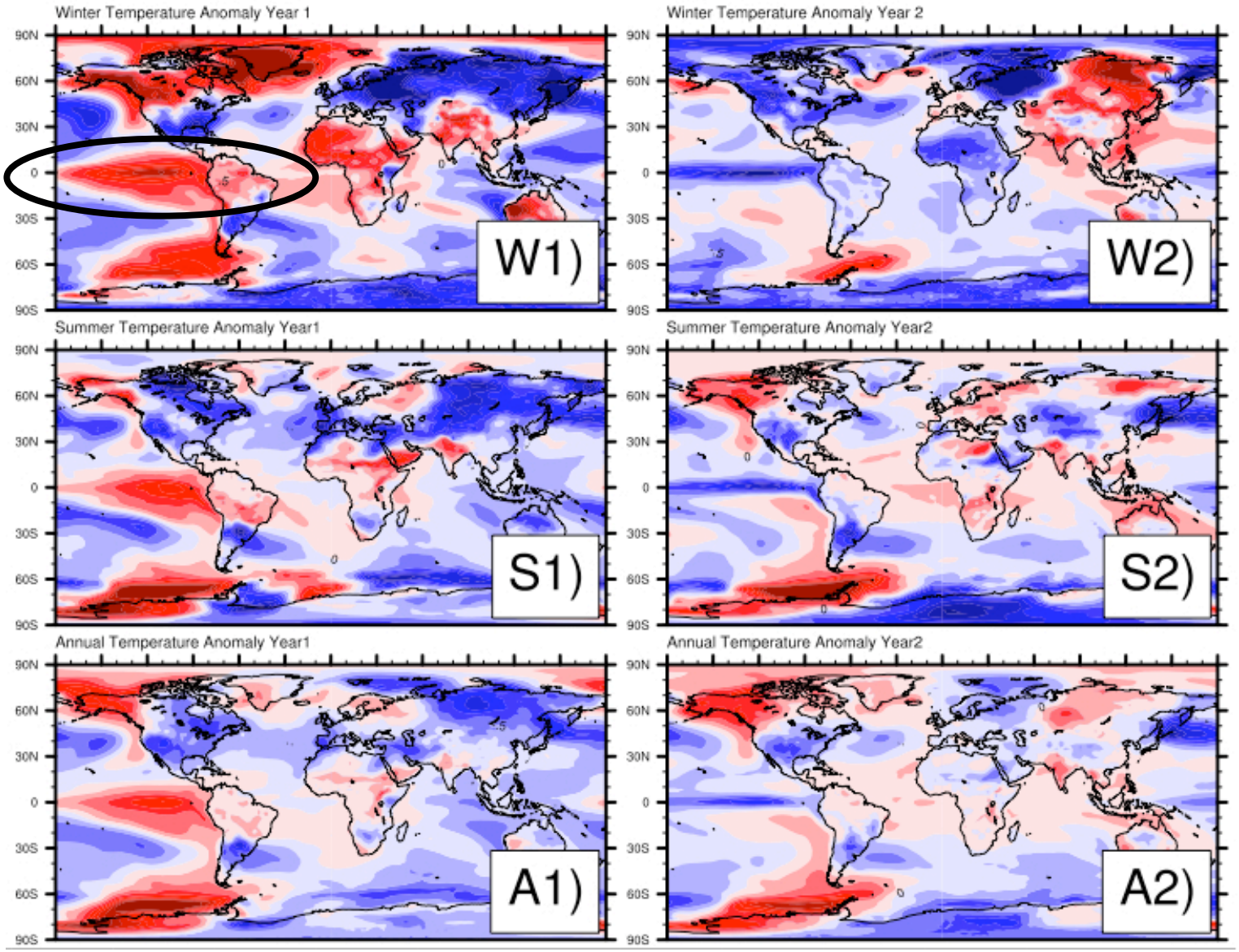
CCSM4 Track1 : Volcanic Response



CCSM4 Track1 : Volcanic Response



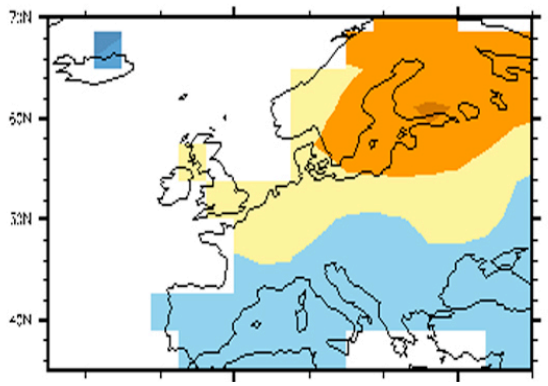
CCSM4 Track1 : Volcanic Response

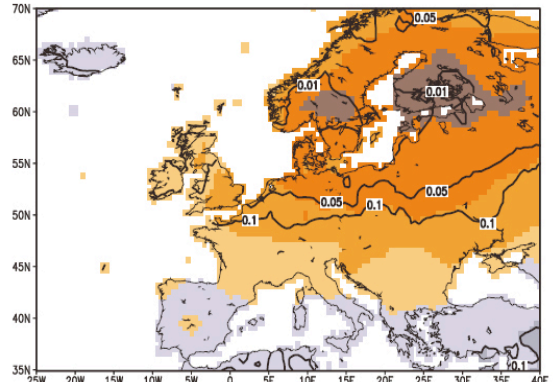


Track1 Volcanic Response Europe:

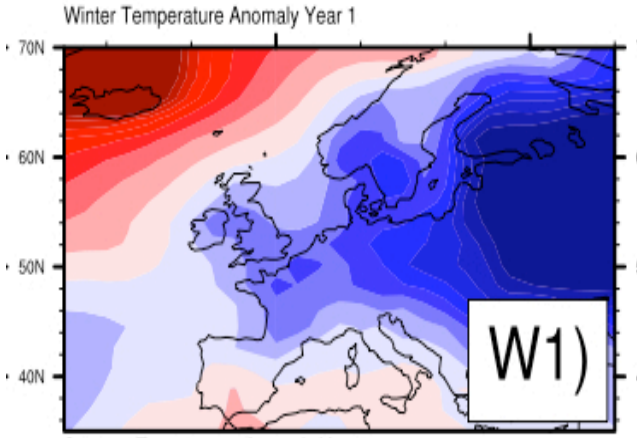
CCSM1 Obs/Recon (Fischer) CCSM4 (Track1)

Winter Tempearture Anomalies Year 1

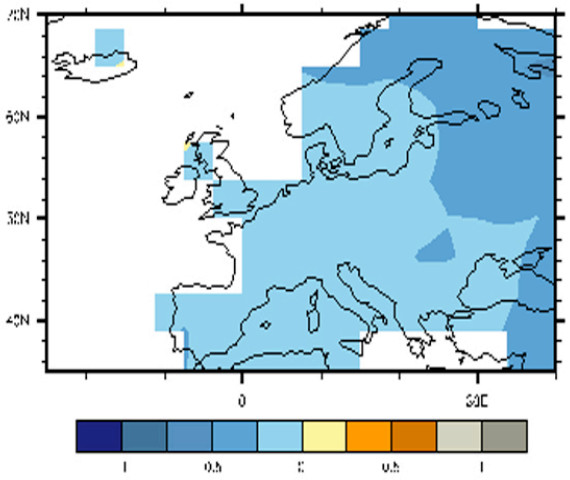


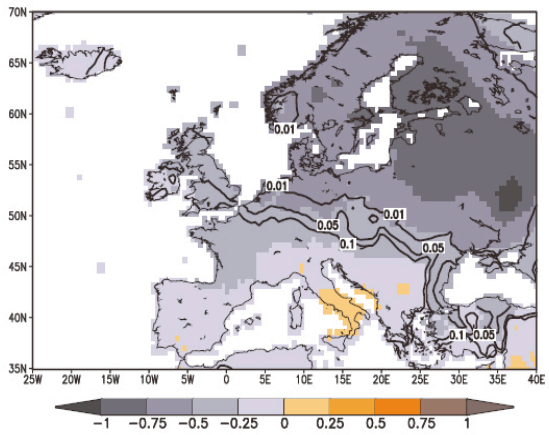


Winter Temperature Anomaly Year 1

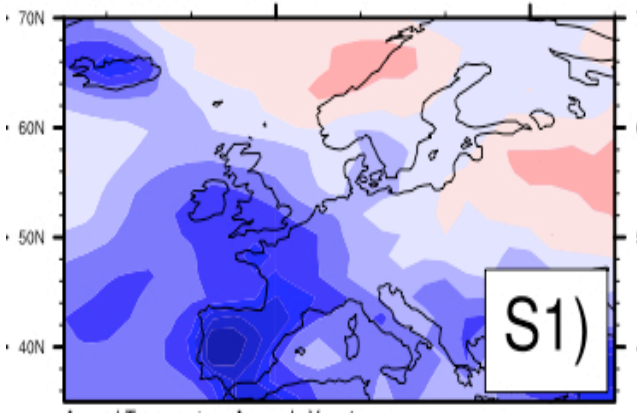


Summer Temperature Anomalies Year 1





Summer Temperature Anomaly Year1



New Solar Module for Climate Studies for CCSM4 and WACCM

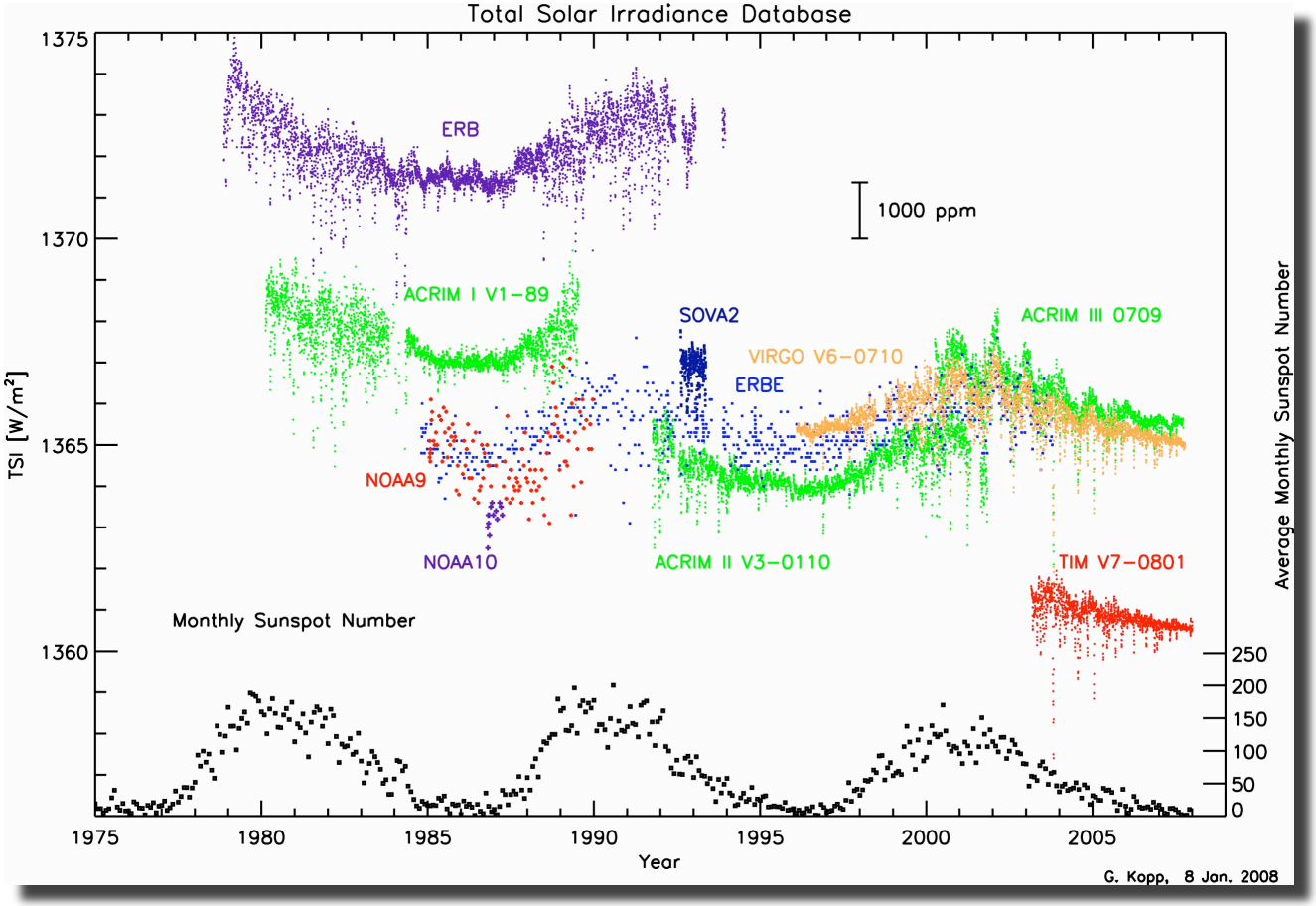
Goals of new implementation:

- Unified and consistent Solar input for CAM and WACCM
- Flexible module to accommodate various solar specifications: path for future replacement of input by physical model of the Sun
- Independence from Radiative Transfer code base
- Realistic solar variability representation through unrestricted spectral and temporal resolution of (CAM4 / WACCM)
- Consistent information for radiative transfer and photolysis (WACCM)
- Improved accuracy in new radiative transfer code of CAM4 (RRTMG)
- Currently available data:
  - Judith Lean TSI for 1610-2008
  - Judith Lean spectral data (1nm resolution) for 1610-2008

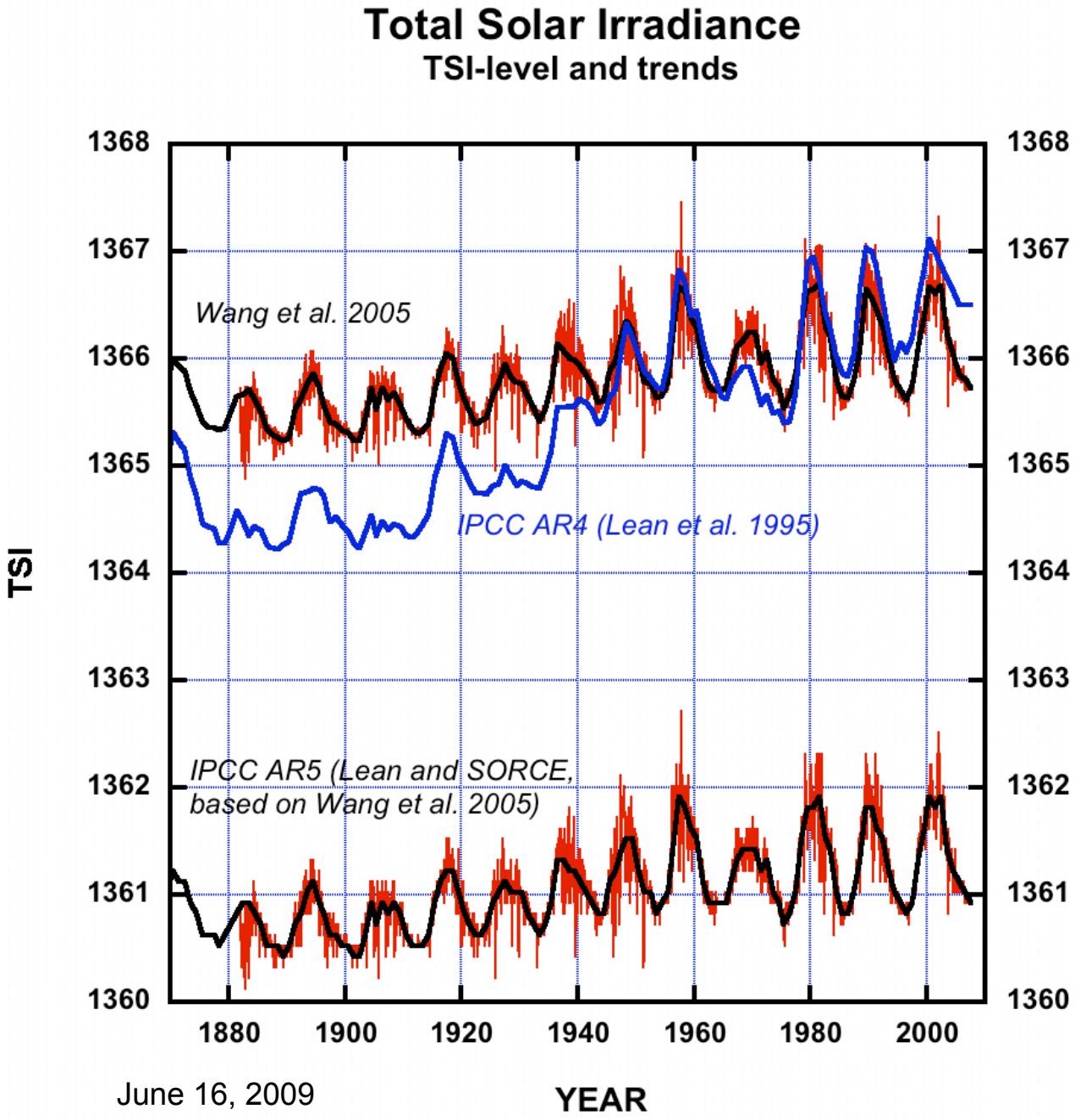
New definitions developed by CCSM and WACCM (alphabetically):
C. Ammann, W. Collins, A. Conley, B. Eaton, J.F Lamarque, D. Marsh, F. Vitt

Observations Total Solar Irradiance

New TSI Level: 1361 Wm^{-2}



Curtsey: G. Kopp, LASP

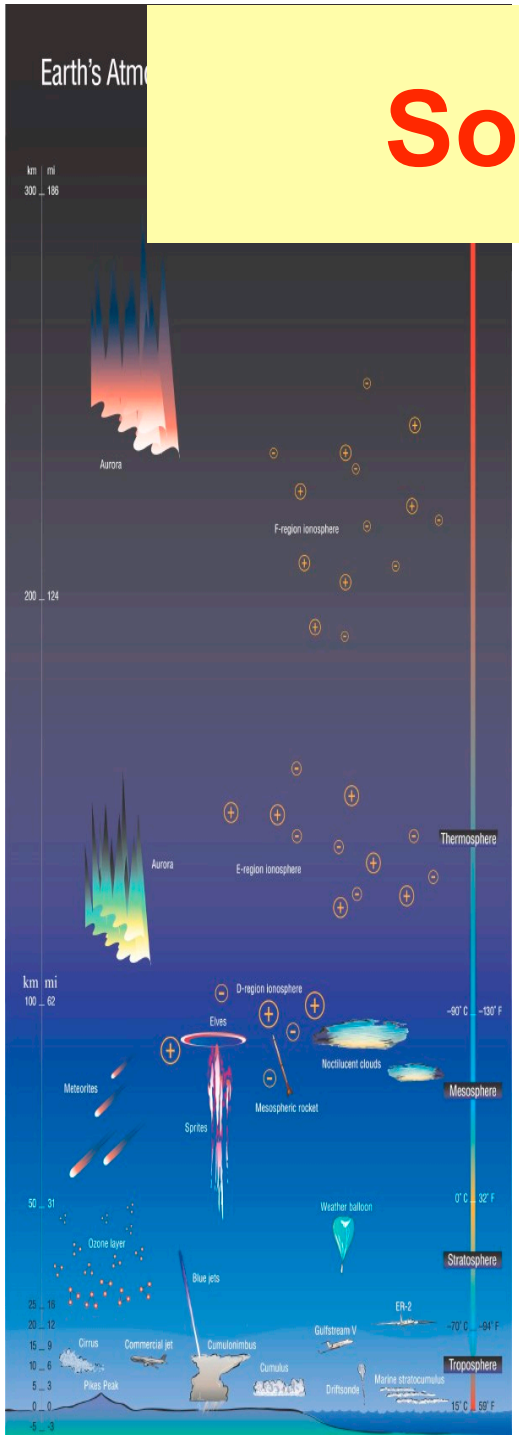


Changes AR5:

(1) Smaller Trend!

(2) New TSI Level

Solar Forcing in CCSM



TSI_only
AR4 (5?)

Spec+TSI
solar input

Spectral TSI + Ozone
solar + feedback

Summary

- **Natural forcing implementations** now consistent for applications with either CAM or WACCM (driven by namelist)

- **Volcanic** forcing implementation ready Track1 and Track5
- New parameterization:
  - ✓ uses layer mass concentration calibrated on SPARC/CCMVal dataset
  - ✓ Needs an evolving (collapsing) profile to keep size large: realistic
  - ✓ Choice of width of distribution new 1.6 micron rather than 1.25
- Other improvement is implementation of predicted tropopause to eliminate heating at cold point
- Climate response:
  - Reasonable forcing
  - New El Nino response to volcanic forcing, but too strong

- **Solar** specification:
  - ✓ Track 1: only TSI (CAM-RT)
  - ✓ Track 5: both TSI and SSI (RRTMG)
- New TSI level implemented in CAM-RT and RRTMG

Model setup / Namelist entries

New Volcanic Namelist: (makes volcanic forcing active if present)

```
&prescribed_volcaero_nl
 prescribed_volcaero_datapath          = '/blhome/ammann/CCSM4'
 prescribed_volcaero_file              = 'CCSM4_volcanic_1990-2000_prototype1.nc'
/
```

Add volcanic sulfuric acid optics to Radiation Constants Namelist:

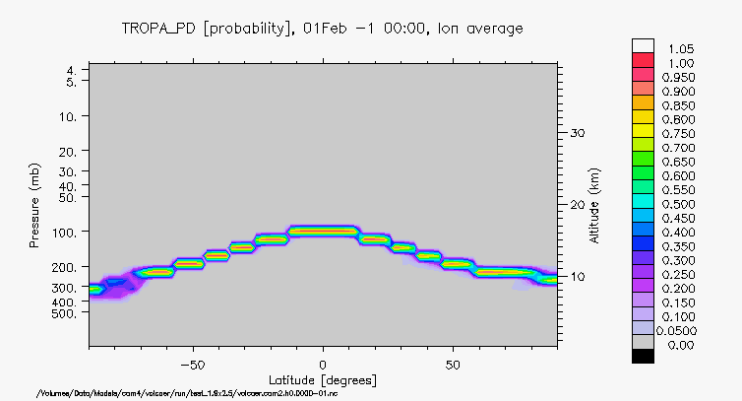
```
&rad_cnst_nl
 rad_climate   =    'P_Q:H2O', 'D_O2:O2', 'D_CO2:CO2', 'D_ozone:O3', 'D_N2O:N2O',
          'D_CH4:CH4', 'D_CFC11:CFC11','D_CFC12:CFC12',
          'D_sulf:/fs/cgd/csm/inputdata/atm/cam/physprops/sulfate_camrt_c080918.nc',
          'D_dust1:/fs/cgd/csm/inputdata/atm/cam/physprops/dust1_camrt_c080918.nc',
            …
       'D_VOLC_MMR:/fs/cgd/csm/inputdata/atm/cam/physprops/sulfuricacid_cam3_c080918.nc'
/
```

New Subroutines:

models/atm/cam/src/chemistry/utils/**prescribed_volcaero.F90**

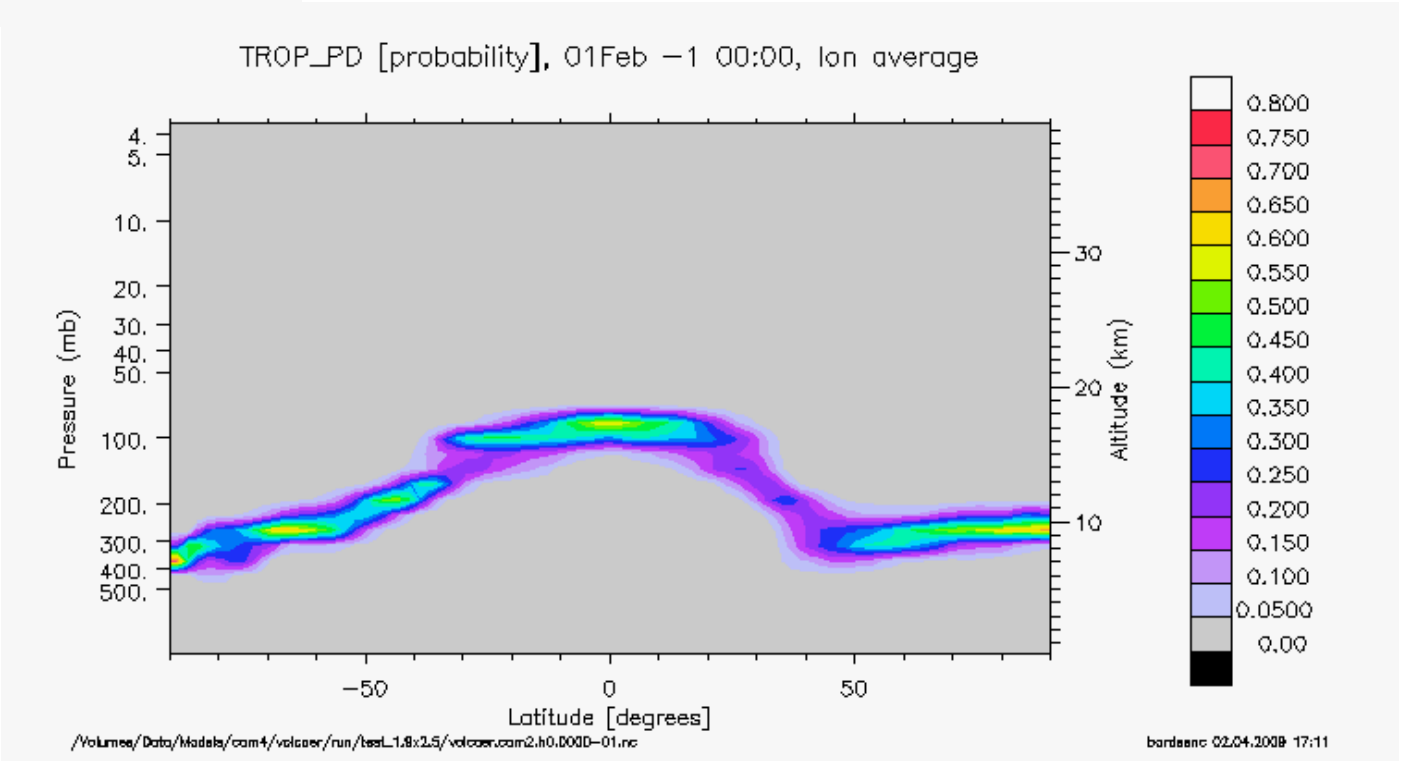
models/atm/cam/src/physics/cam/**tropopause.F90**

Prognostic Tropopause Height



Analytic (lat dependent)

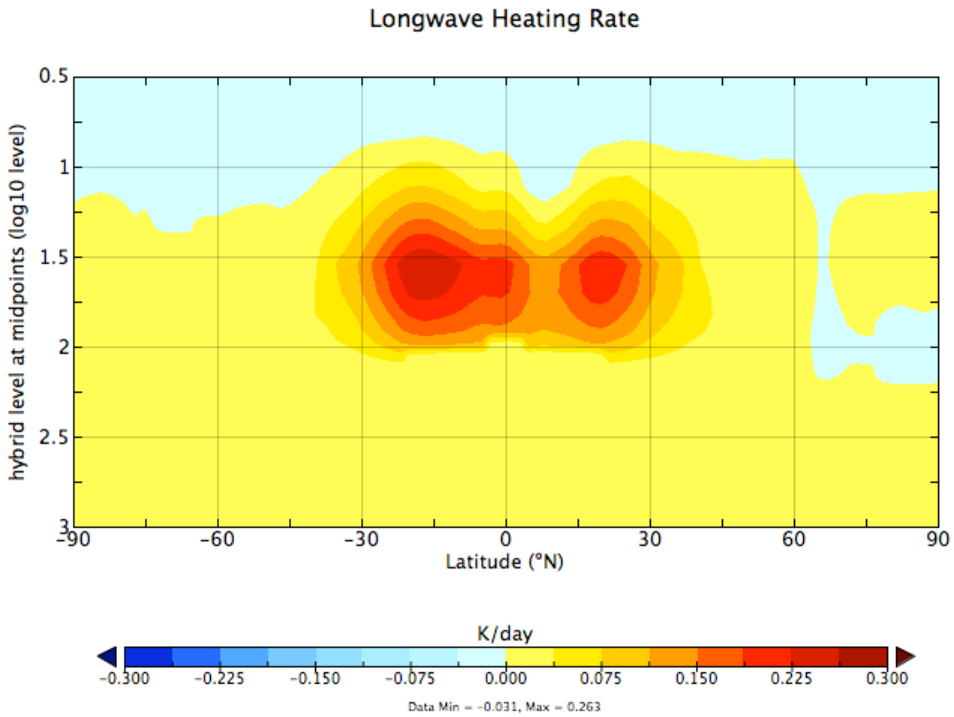
Reichler method (backed by Climatology)

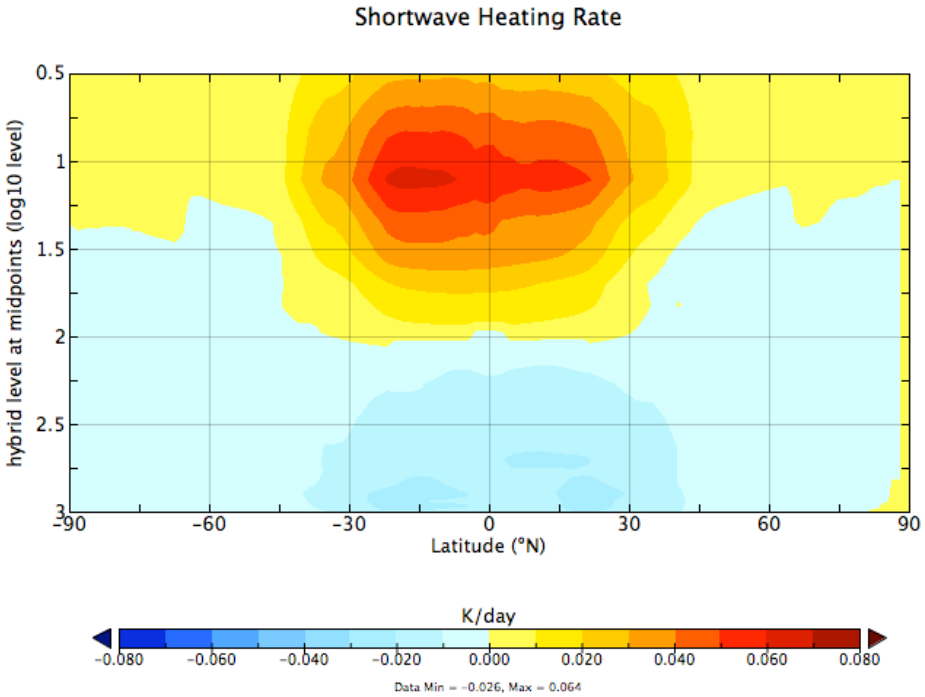


Source: Chuck Bardeen

June 16, 2009

Volcanic Heating Rates (K/day)





Currently LW>>SW heating

- based on wide distribution
- Narrower width will reduce this issue

Global Climate Field Reconstruction