Chemistry-Climate Working Group (Spring 2007)

Chairs: Peter Hess, Michael Prather

Discussion Forum For Science and Development of Two Models

1) CCSM with chemistry

- impacts of chemistry/aerosols on climate in a cost effective way

2) Chemistry Model within the CCSM

- benchmark for simplified versions
- effect of climate on chemistry/air quality
- model-measurement comparison

Meeting Goals

- State of Chemistry in CAM
- Recommendations for CAM4 (CCSM w/ CHEM):
  - Holes (?)
  - Action Items/Priorities (?)
- Next Steps (Chemistry within the CCSM)
  - Action Items/Priorities (?)
  - Where do we go next (?)
    - Combine Stratosphere/Troposphere Model
    - CH4 emissions
    - Wet deposition
    - Dry deposition (make use of CLM and LAI)
    - Effects of Ozone of Vegetation
    - Downscaling (coupling with fine-scale model)
    - Prather fast-j
- Plan for new gaus allocation

Meeting Goals Continued

- Increase Use of Model (Recruitment?)
- Guidelines for Participation in Model Development

Monday February 26
Session 1: State of the Model and Model Development (Damon Room, NCAR Mesa Lab)

8:30 Introduction and Meeting Goals and Discussion (Hess)
9:00 Model status and news (Hess)
9:30 Update on new physics and model developments (Rasch)
9:50 Effect of physics on chemistry (Hess)
10:00 Break
10:20 Progress on aerosol indirect effect in CAM (X. Liu)
10:40 New Stratiform Cloud Microphysics and Cloud Aerosol Interactions in CAM (Gettelman)
11:00 Progress on application of modal aerosol dynamics to CAM (X. Liu)
11:20 Sensitivity of direct effect to aerosol treatment (Hess)
11:40 Update on CAM/CLM Biogenic VOC Emissions and Secondary Organic Aerosols (Heald)

Session 2: Entrepreneurial Research/Science (Main Seminar Room, NCAR Mesa Lab)
12:30 Refreshments (Main Seminar Room)
1:00 New Stratospheric-Tropospheric Chemistry (Lamarque)
1:20 Clouds and photolysis (Neu)
1:40 Developments at UCI (Prather)
2:00 CAM with Chemistry at Lawrence Livermore (Cameron-Smith)
2:20 Changing emissions and climate: CCSP report. (Lamarque)
2:40 Constraining tropospheric CO using ensemble-based data assimilation (Arellano)
3:00 Break
Session 3: Emissions (Main Seminar Room, NCAR Mesa Lab)
3:20 POP ocean emissions (Elliiot)
3:40 Historical emissions (Granier)
4:00 General Discussion

Tuesday February 27

Session 4: Middle Atmosphere Research (Main Seminar Room, NCAR Mesa Lab)

8:30 Climate sensitivity and variability with models extending into the middle atmosphere (Sassi)

8:50 Atmospheric response to solar and geomagnetic forcing (Marsh)

9:10 Impact of climate change on ozone recovery (Kinnison)

9:30 3-D Microphysical Simulations of Meteoric Dust (Bardeen)

9:50 Catastrophic ozone loss following a regional nuclear conflict (Mills)

10:10 Break

Session 5: Discussion (Main Seminar Room, NCAR Mesa Lab)

10:30-12:00

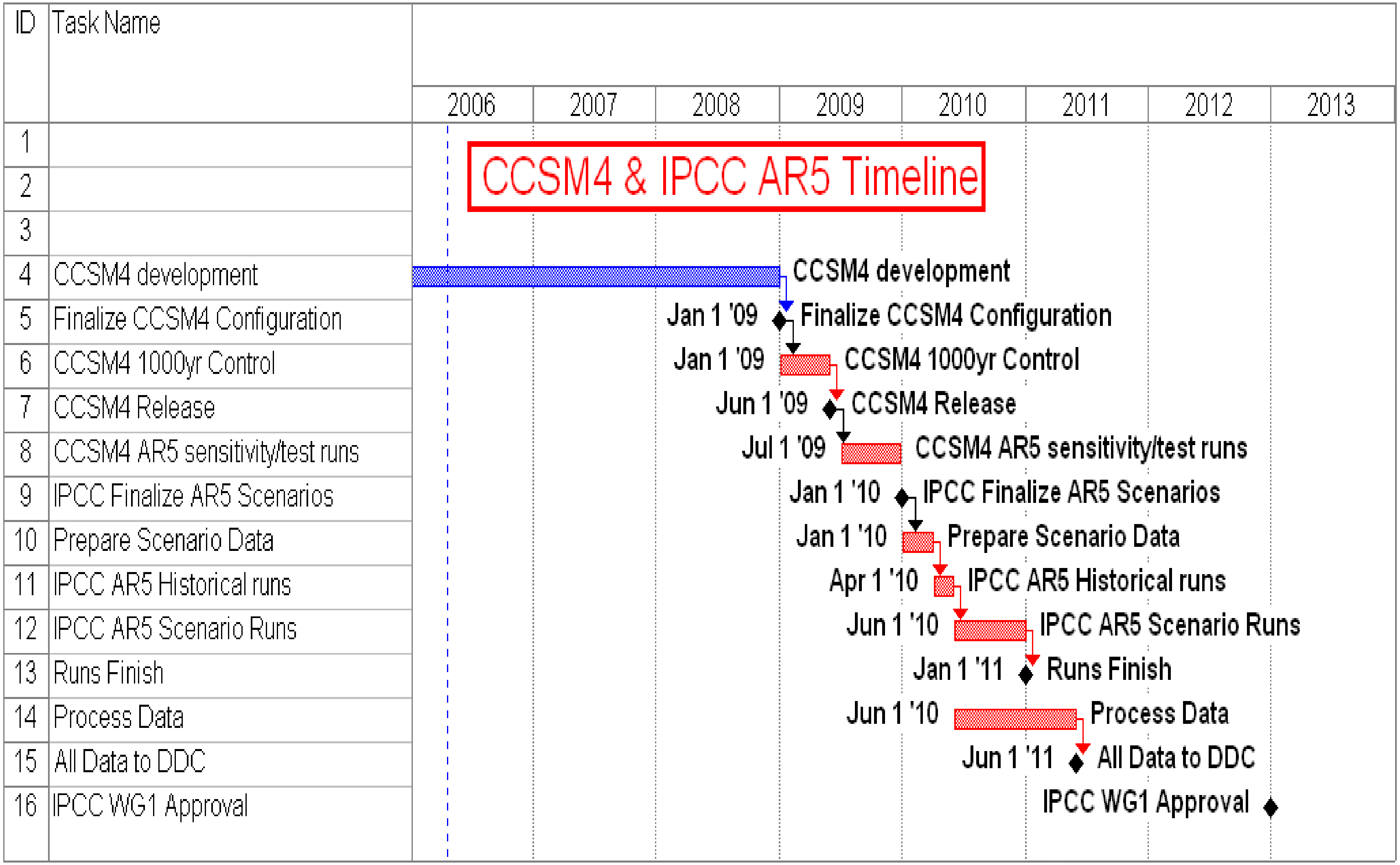
Tuesday afternoon – February 27, 2007 - MAIN SEMINAR ROOM
Joint Session Land, Chemistry, Biogeochemistry Working Groups
1:00 pm Refreshments
Surface hydrology (lakes, wetlands, rivers, irrigation) and methane
1:15 Introduction and opening remarks
1:30 Inez Fung (UC Berkeley)– modeling methane
2:00 Jay Famiglietti (UC Irvine)– river routing
2:20 Gopi Goteti (UC Irvine) - catchment-based modeling
2:30 Reed Maxwell (LLNL) – groundwater and overland flow
2:40 Cindy Nevison (NCAR) - riverine transport of nutrients
2:50 Beth Holland/Julia Lee-Taylor (NCAR) – hydrology and nitrogen diffusivity
3:00 Break – refresh coffee, etc.
3:30 Bill Sacks (U Wisconsin) – impacts of irrigation on climate
3:40 Peter Lawrence (CIRES) - irrigation
3:50 Zong-Liang Yang (U Texas) irrigation
4:00 Discussion
Land use / Land cover
4:40 Johann Feddema (U Kansas)
5:00 Atul Jain (U Illinois) – biogeochemical and economic model drivers
5:10 Discussion (led by Jim Randerson)
END
RECEPTION
Tuesday February 27, 2007
5:30-6:30 (light snacks served) Damon room

CCSM with Chemistry:

- **Stage 1 (end of 2006)**
  - Assemble the latest physical and biogeochemistry components
  - Include a simple form of the indirect effects of aerosols
  - Begin coupled control runs

- **Stage 2: (end of 2007)**
  - **Finalization** of the new physical and biogeochemical components for CCSM 4. (in development branch and *accepted* by SSC)

- **Stage 3 (2008)**
  - Test, finalize, and thoroughly understand the CCSM 4 run in fully coupled mode.



ID
Task Name
2006
2007
2008
2009
2010
2011
2012
2013
CCSM4 & IPCC AR5 Timeline
1
2
3
4 CCSM4 development
5 Finalize CCSM4 Configuration
6 CCSM4 1000yr Control
7 CCSM4 Release
8 CCSM4 AR5 sensitivity/test runs
9 IPCC Finalize AR5 Scenarios
10 Prepare Scenario Data
11 IPCC AR5 Historical runs
12 IPCC AR5 Scenario Runs
13 Runs Finish
14 Process Data
15 All Data to DDC
16 IPCC WG1 Approval
CCSM4 development
Jan 1 '09 Finalize CCSM4 Configuration
Jan 1 '09 CCSM4 1000yr Control
Jun 1 '09 CCSM4 Release
Jul 1 '09 CCSM4 AR5 sensitivity/test runs
Jan 1 '10 IPCC Finalize AR5 Scenarios
Jan 1 '10 Prepare Scenario Data
Apr 1 '10 IPCC AR5 Historical runs
Jun 1 '10 IPCC AR5 Scenario Runs
Jan 1 '11 Runs Finish
Jun 1 '10 Process Data
Jun 1 '11 All Data to DDC
IPCC WG1 Approval

CCSM4 -Configuration to be determined:

- New physics
  - Convection
  - Boundary Layer
- Carbon Cycle
- Indirect Effect
- Chemistry? (CCWG input)
- Aerosols?   (CCWG input)

CCSM4 (Impacts)

Same as above?

CSSM4 – Chemistry (CCWG)

-TBD

1st Spinup To Test CCSM Coupling 1870 - present day

Forcing Agents:

- Solar: time series and spectral changes from J. Lean
- LLGHG: as IPCC #4 reconstruction
- Landuse: Feddema (see Land/BGC meeting)
- Ozone: Lamarque et al, IPCC #4 reconstruction (prescribed)
- Prognostic dust/seasalt?
- Nitrogen deposition from Lamarque et al.
- Other Aerosols To Prescribed from Offline Run
  - No chemistry
  - Oxidants from Lamarque et al.
  - BC, OC anthropogenic: fossil fuel and biofuel 1850-present (T. Bond)
  - Steve Smith, SO2
  - BC/OC from biomass burning
    - Randerson et al.
    - Ramped up from 1/3 present day in tropics - current emissions extra-tropics

Chemistry model in CCSM

- **MOZART4 Incorporated into CCSM**
  - CAM and MOZART routines checked against each other
- **Chemical Mechanism**
  - MZ4 mechanism in place.
  - Simple input of fixed chemical oxidants
  - Query functions so chemical mechanism easy to change.
    - Additions to mechanism for SOA formation (Heald)
- **Dry deposition**
  - Wesley deposition in place (MZ4)
    - Wesley deposition input into CLM
    - Updated scheme using information from CLM (LAI, stomatal resistance)
- **Photolysis**
  - Fast TUV in place
    - Update to Prather Fast-J
    - Use of sophisticated cloud overlap (Neu)
    - Consistency between CAM and CHEM in treatment of aerosols
    - Combined radiation/aerosol calculation

	Fall-Back	1st	2nd	3rd
Chemistry	None	Input Oxidants	Simple	Full
Biogeochem.	Input N	Input N Input O3	Prognostic N and O3	
Stratosphere	NO	YES		
Aerosols	Prescribe	Prog. SS Prog Dust SO4: Input Ox. NH4SO4 ?	Prog. SS Prog. Dust SO4, NH4SO4 w/ Chemistry	Prog. 4/7 mode Internally Mixed
Microphysics	Present w/ Mods	2 moment 4 class		
Emissions	BC, OC Tami Bond, SO2 (Smith, Streets), Oxidants (From POET precursors), BB (Randerson + arbitrary scale)			

Chemistry in CCSM continued

- **Emissions**
  - MEGAN emissions algorithm for isoprene/monoterpene in CLM
    - Update for other biogenic emissions
    - Interactive injection height for biomass burning emissions
  - Lightning based on Price and Rind
    - Update based on work of Barth
- **Washout (gas)**
  - Giorgi and Chameides (both large-scale and convective)
    - Update to more physically based scheme with realistic cloud overlap
    - Include explicit washout within convective scheme
- Washout (aerosol)
  - Updated to Rasch scheme
    - Impact and nucleation scavenging (Ghan, in development)

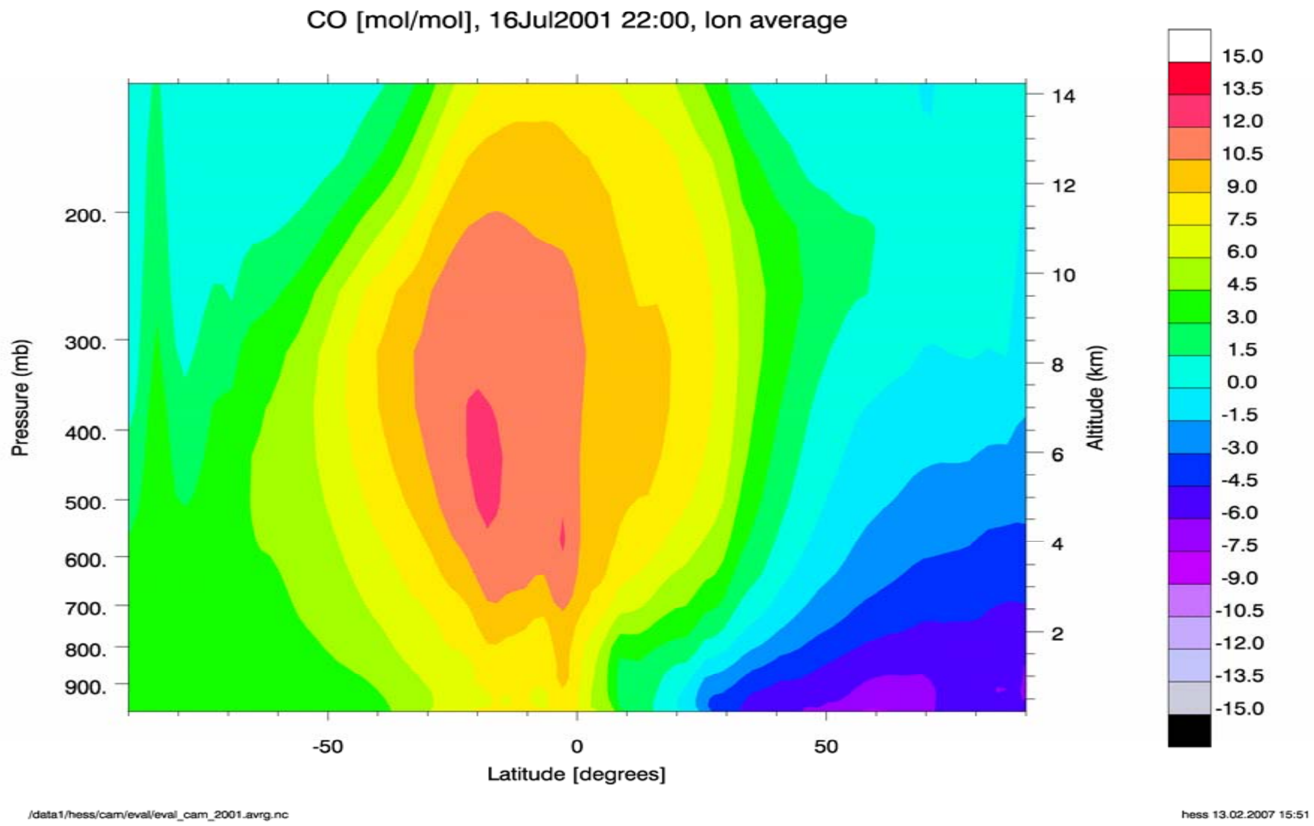
Chemistry model in CCSM continued

- **Aerosols**
  - MOZART4 bulk aerosol scheme w/ NH4NO3
  - Interactive Sea-salt and Dust (Mahowald)
  - Aerosol-Radiation coupling
  - Ability to use sulfate scheme with input oxidants
    - Coupling to cloud microphysics (Gettleman, …)
    - Internally mixed 4 or 7 mode scheme (Ghan, Liu)
    - More sophisticated schemes
- **Upper Boundary Conditions**
  - Stratospheric concentrations specified
  - Synoz
    - Extension of domain to stratosphere/mesosphere

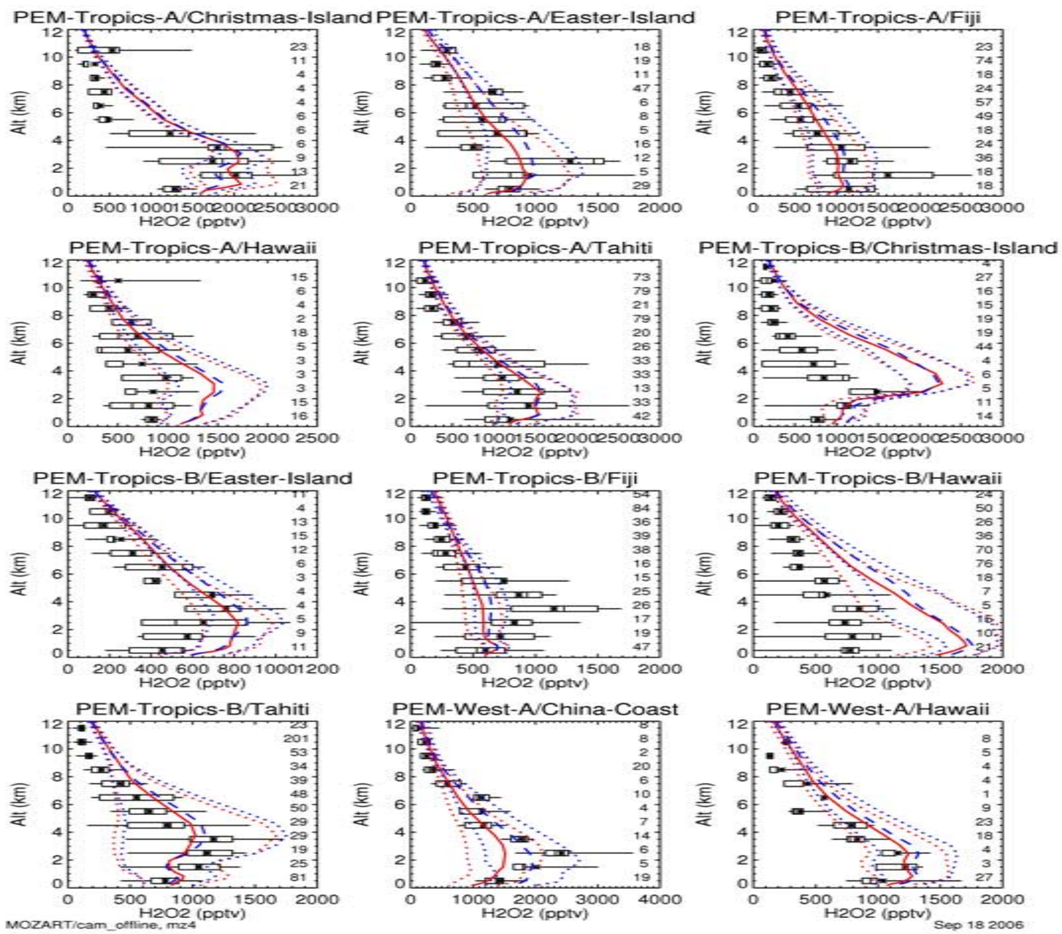
Chemistry model in CCSM continued

- Online/Offline capability
  - Aerosol-Radiation coupling
  - Extension of offline model to WACCM
    - Evolution of lower part of model from analyzed winds
    - Evolution of upper part of model dynamically computed dynamically
- Data assimilation capabilities
  - Ensemble Kalman Filter Meteorological/Chemical data assimilation
- Coupling to CLM/Ocean models
  - Nitrogen coupling to the C cycle
  - Biomass burning algorithm
    - DMS and other ocean emissions
    - CH4 emissions
    - Ozone/Acid rain and the biosphere
- Downscaling and coupling with WRF-chem

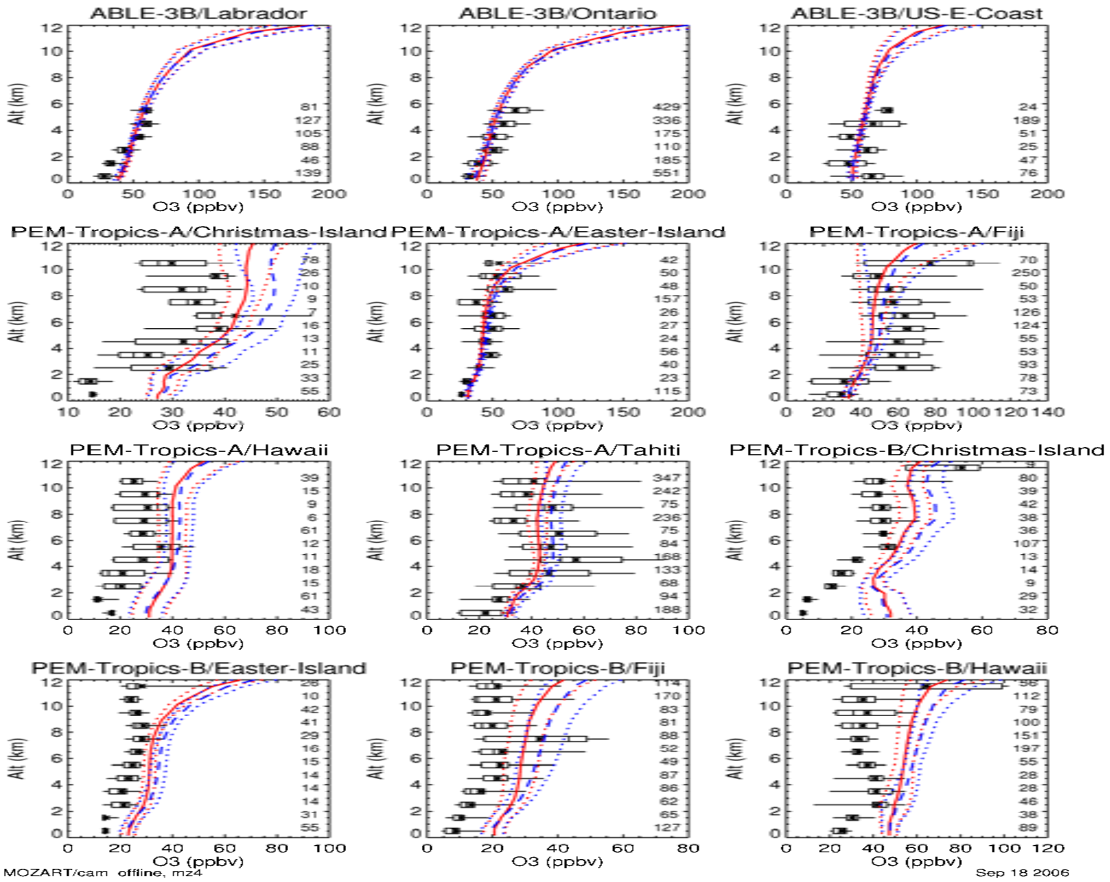
CO: CAM - MOZART



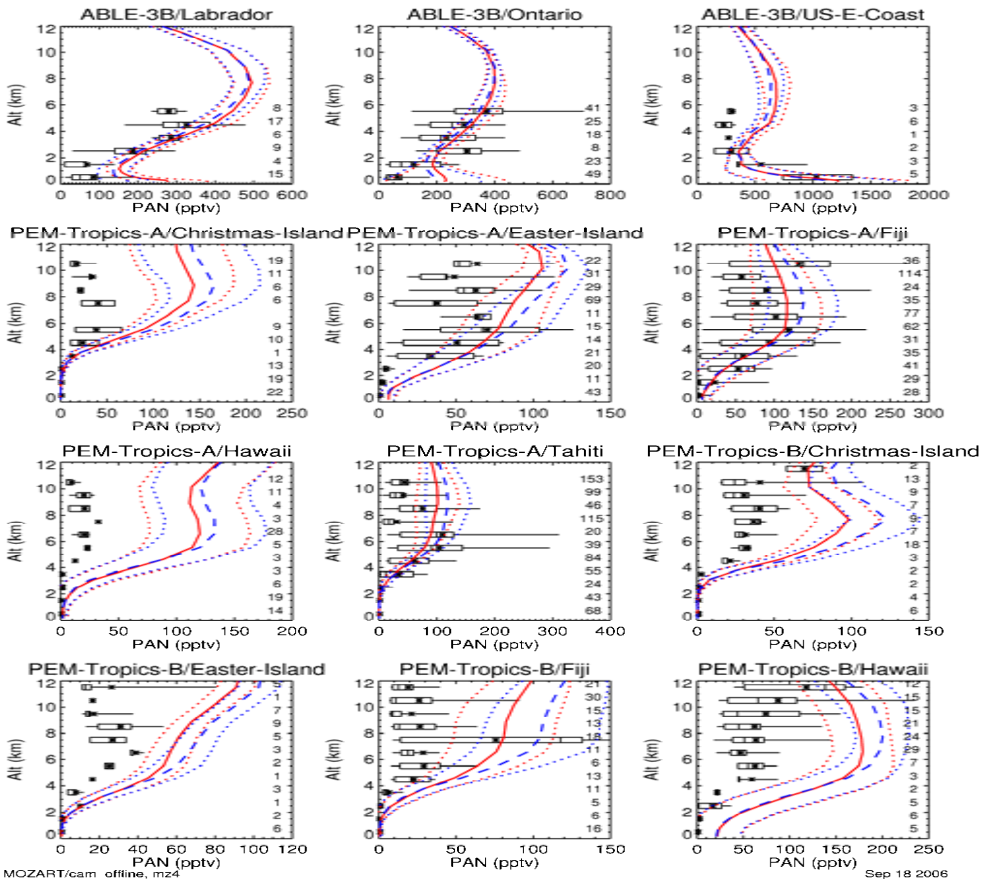
H2O2: CAM (red), MOZART (blue)



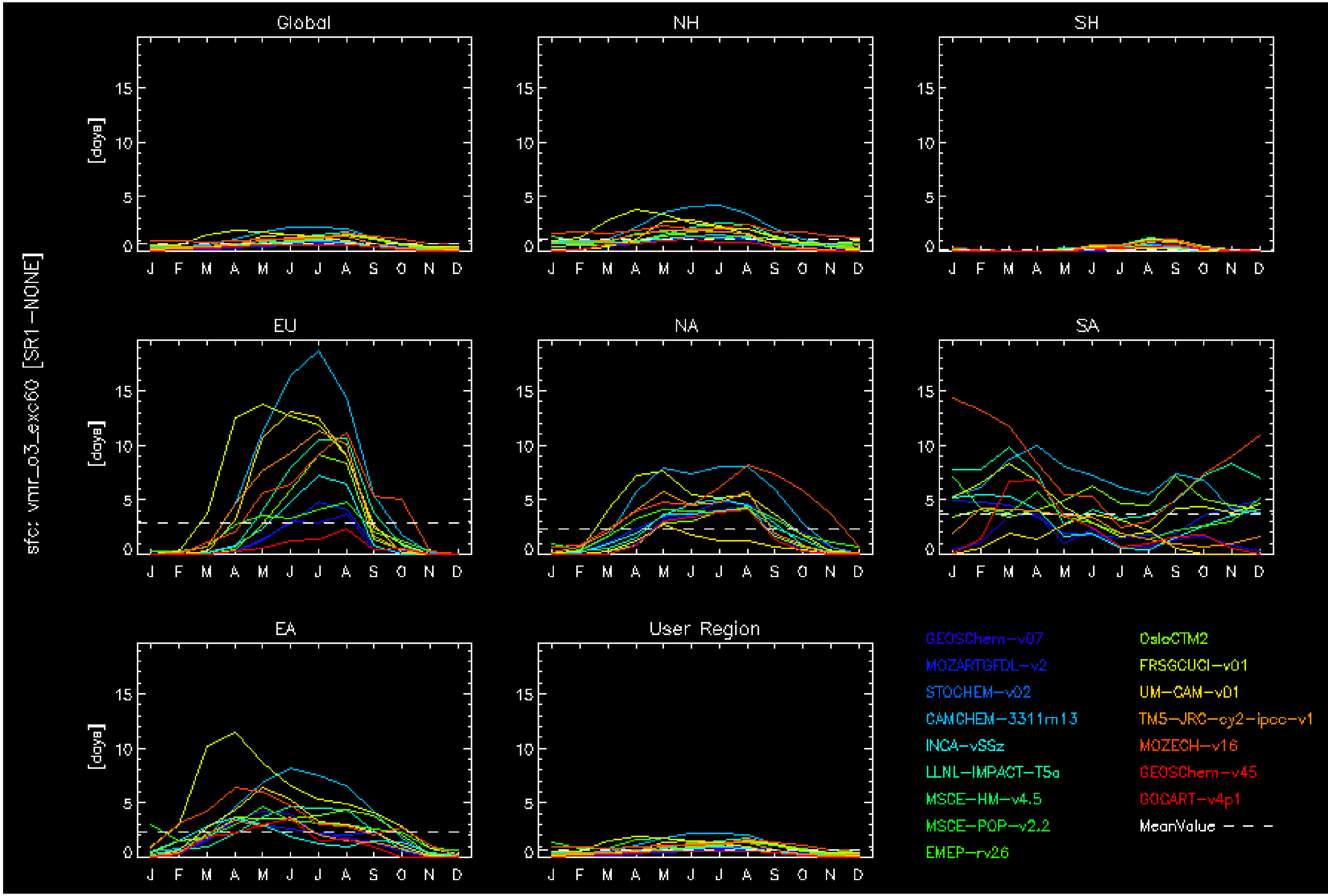
O3: CAM (red), MOZART (blue)



PAN: CAM (red), MOZART (blue)



Task Force on Hemisphere Transport of Pollutants (HTAP)



Courtesy Arlene Fiore

WACCM3 Additions to CAM3

NCAR

Structure and physical processes

- Upper lid extension from 40 km to 150 km
- Standard WACCM3 is consistent with CAM3 resolution in vertical.
- Includes a gravity wave parameterization (heating and transport)
- Includes representations of molecular diffusion of constituents.

Boundary Conditions

- Top of the model boundary conditions (season and phase solar cycle)
  - T, O, O_2, H, N (MSIS); CO, CO_2 (TIME-GCM); NO (SNOE; NOEM)
- Lower boundary Conditions are function time for:
  - CH_4, N_2O, CO_2, H_2, CFC-11, CFC-12, CFC-113, HCFC-22, H-1211, H-1301, CCl_4, MCF, CH_3Cl, CH_3Br.
- Surface emissions of CO and NO.
- Lightning emission of NOx.
- Aircraft emission of CO and NOx.

WACCM3 Additions to CAM3

NCAR

Long and Shortwave heating and cooling

- WACCM3 retains the LW formulation of CAM3. However in the MLT region one needs include NLTE LW cooling for CO_2 (15μm) and NO (5.3μm)
- Heating shortward of 200 nm is obtained from the wave-length dependent photolysis module (specifically for O_2, O_3). - direct heating.
- Include chemical potential heating - recombination and quenching (24 exothermic reactions)
- Heating due to photoionization in the EUV region.
- Effects of moment forcing by ion-drag and Joule heating associated with electric fields (important > 110 nm).
- Heating rates from CAM3 are merged with HR's from WACCM3 at 65 km - Goal is to have both photolysis and heating rates consistent from the UV through the visible.

WACCM3 Additions to CAM3

NCAR

Chemistry and related chemical processes…

- Add additional chemical species (Cly and Bry)
  - 51 Neutral; 5 ions; electrons;
  - 71 photochemical (J's); 149 thermal and heterogeneous reactions
  - Will be enhancing the tropospheric mechanism this year.
- Include a photolysis module (EUV through 750 nm)
  - The influence of the 11-year solar cycle on photolysis and heating rates is parameterized in terms of F10.7.
- Include heterogeneous processes on Sulfate, NAT, Water-Ice Aerosols
  - Time-dependent sulfate aerosol (observations)
  - Polar denitrification on NAT; Dehydration is done by CAM3
- NOx production via particle precipitation in auroral regions.
- Parameterization of NOx and HOx during solar proton events.
- Working on a PMC module (Marsh, Merkel, Gettelman)

Whole Atmosphere Community Climate Model: Specified Met Option

D. Kinnison, P. Hess, F. Vitt, P. Rasch, D. Marsh, R. Garcia, S. Walters, B. Boville

NCAR, CCWG

26 February 2007

National Center for Atmospheric Research

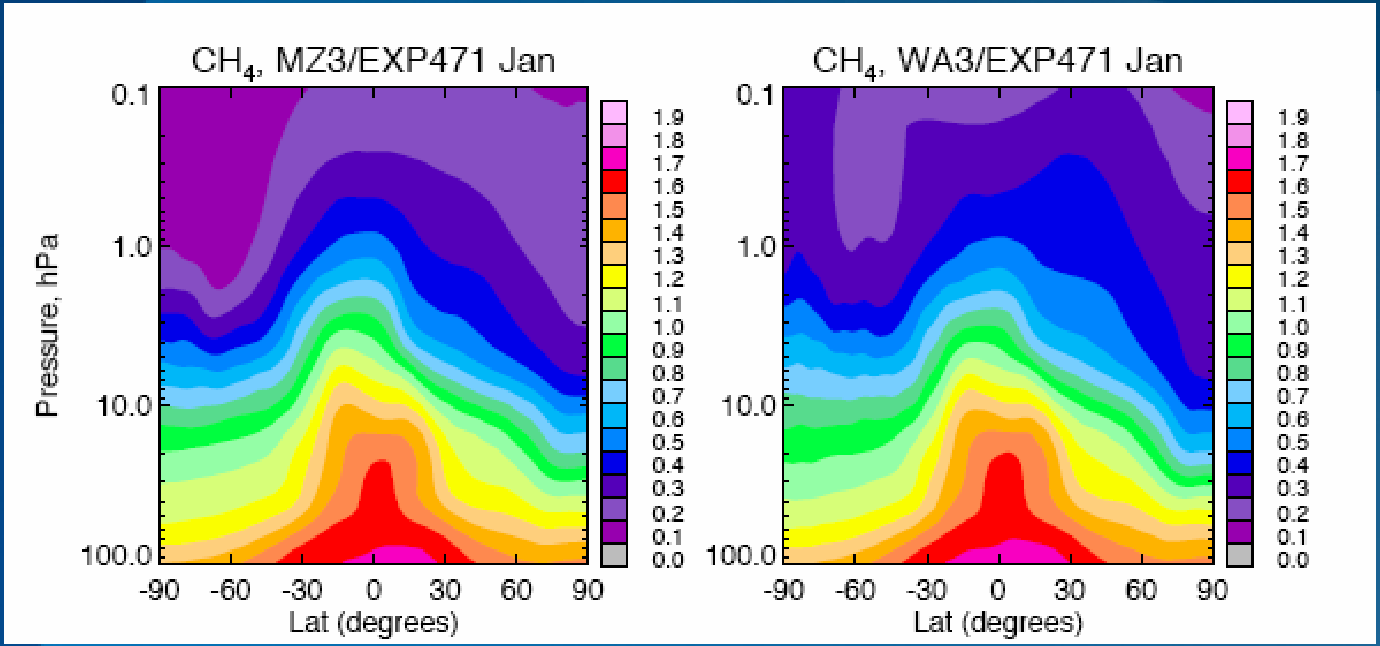
- WACCM3 Driven with ECMWF EXP471
  - New reanalysis product from ECMWF

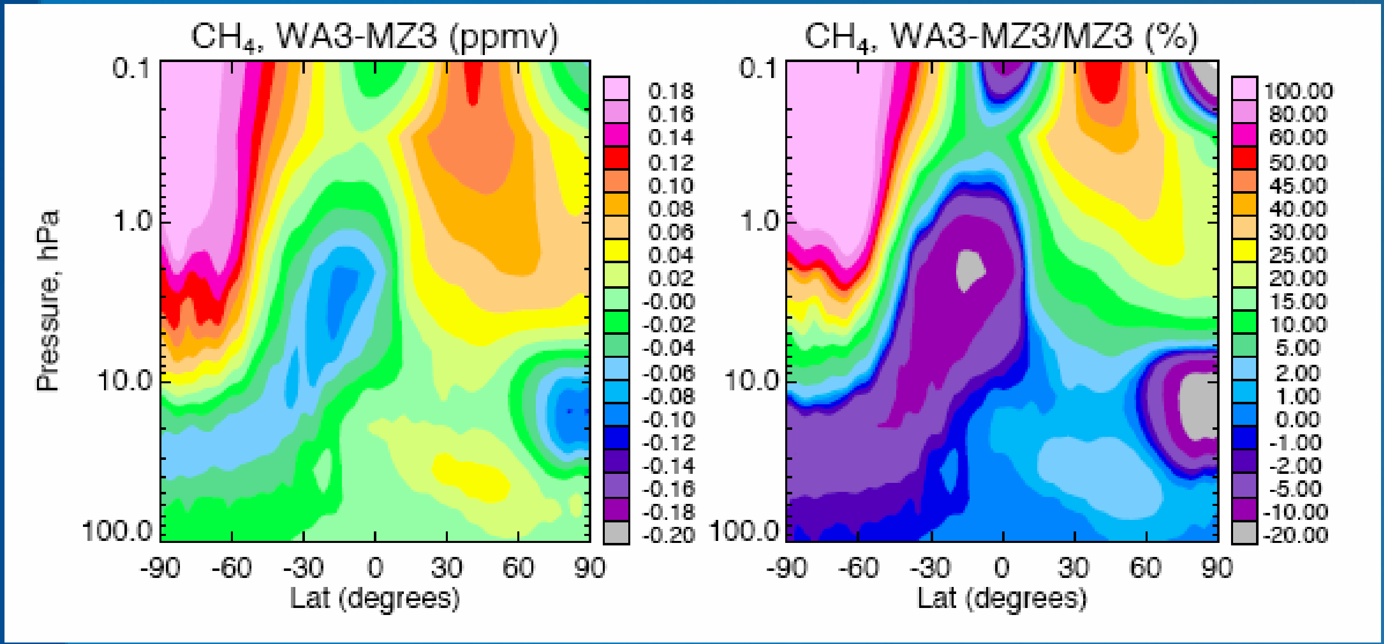
- Simulation
  - Ran two years from a WACCM3 IC
  - 1.9° Horizontal; 0-150 km (66 levels)

- Region constrained by Met Analysis
  - 0-55 km ECMWF EXP471
  - 55-150 km WACCM3 dynamics

- Compare to MZ3/EXP471
  - 1.9° Horizontal; 0-65 km (60 levels)
  - Same IC for both MZ3 and WA3 simulations

- Compare to UARS Climatology





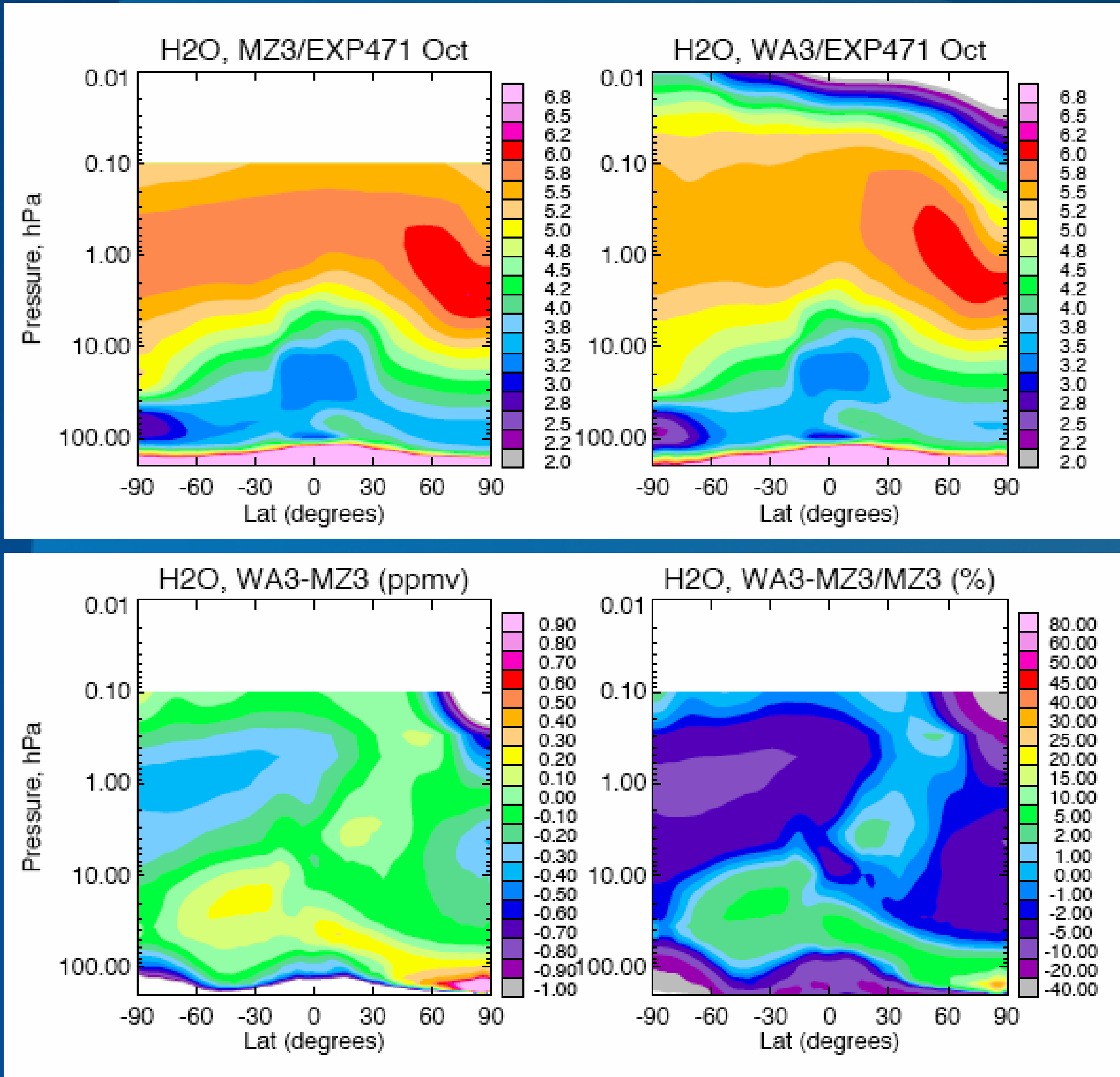
CH_4

MZ3 / EXP471

versus

WA3 / EXP471

Year two.



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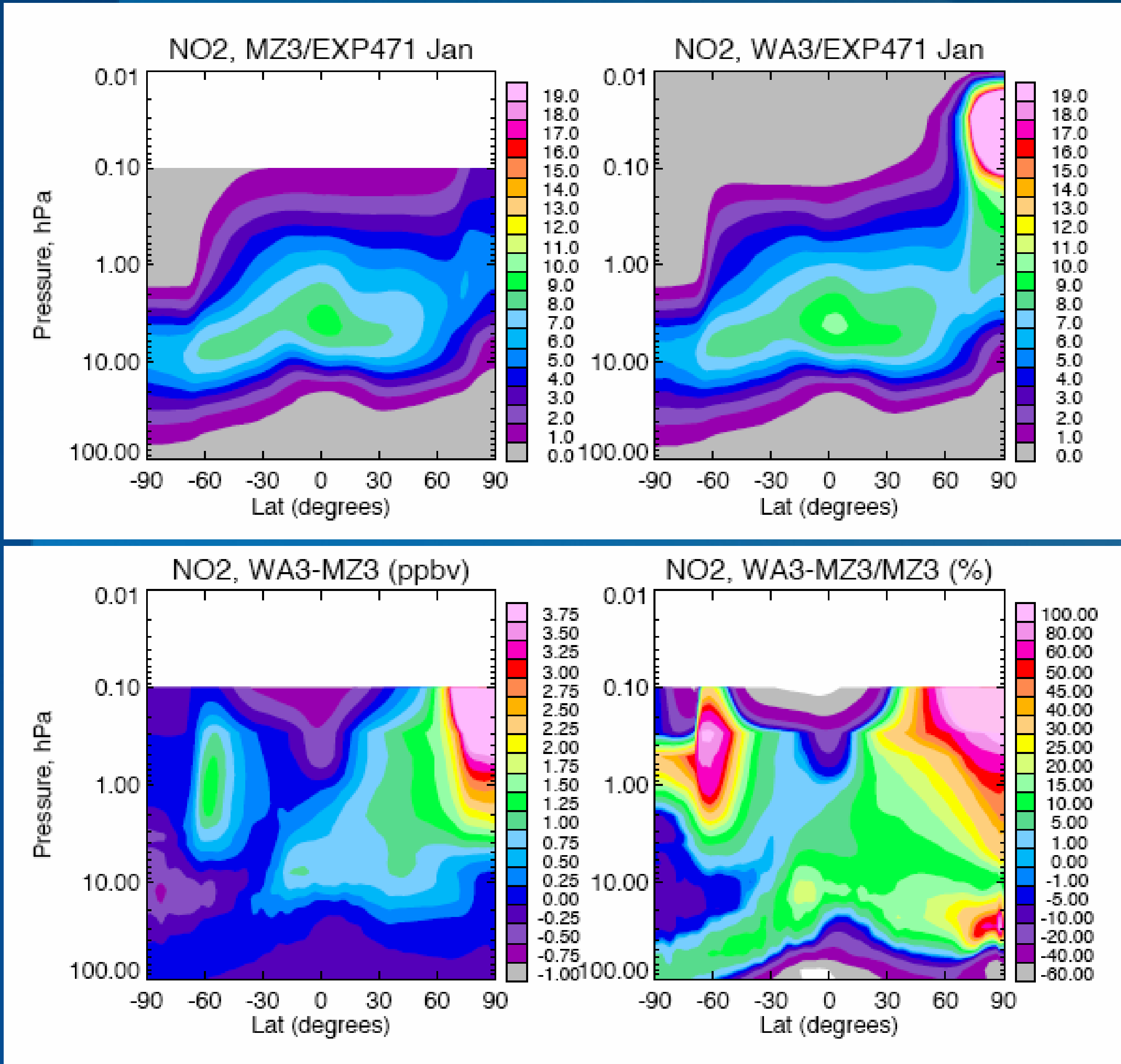
Water Vapor

MZ3 / EXP471

versus

WA3 / EXP471

Year two.



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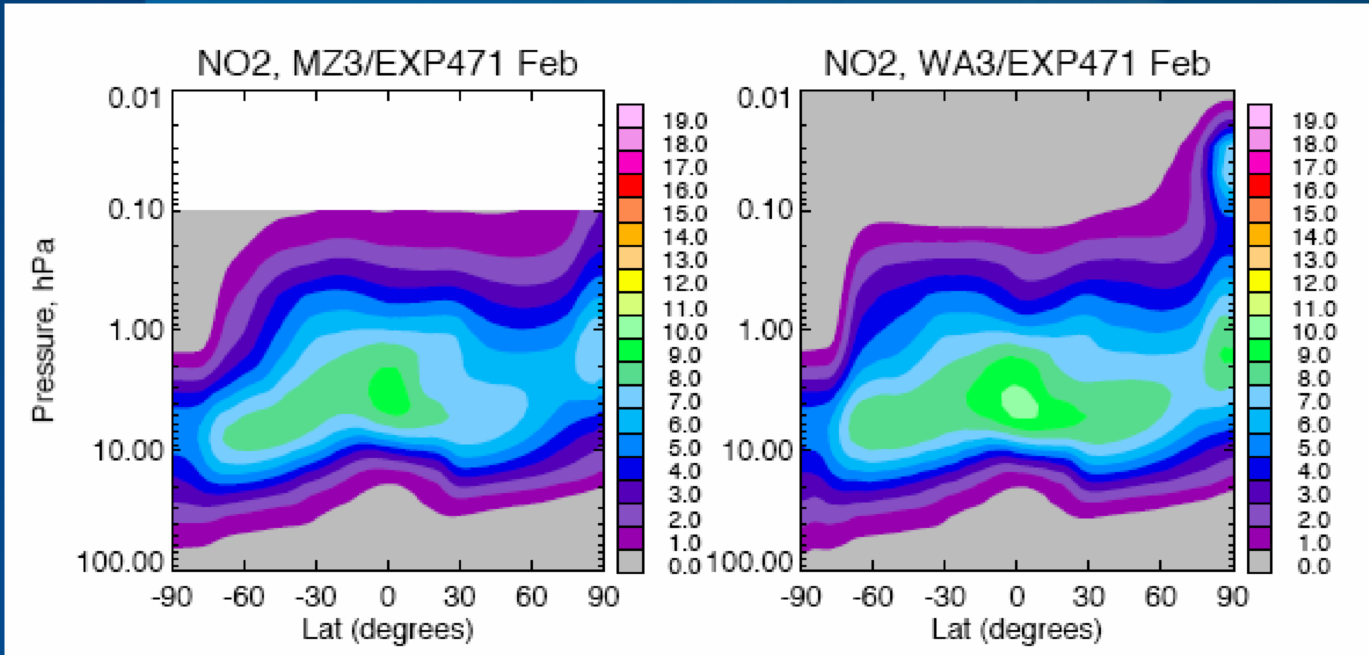
NO_2

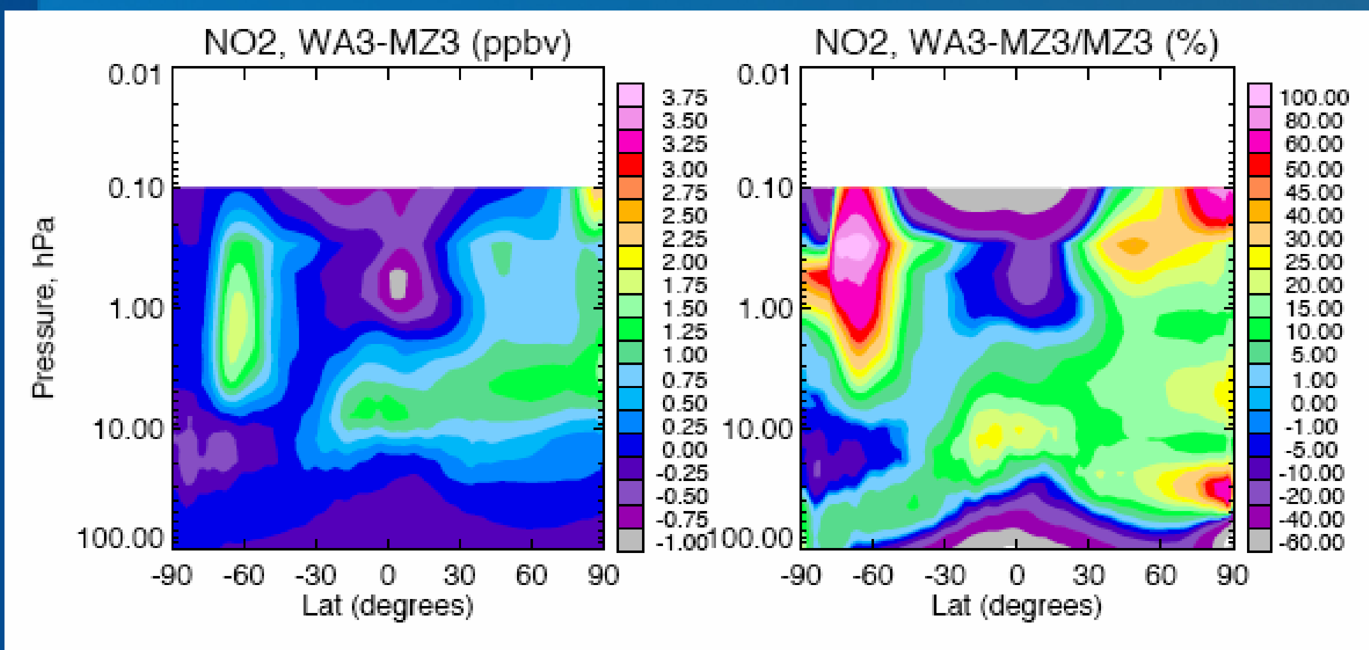
MZ3 / EXP471

versus

WA3 / EXP471

Year two.





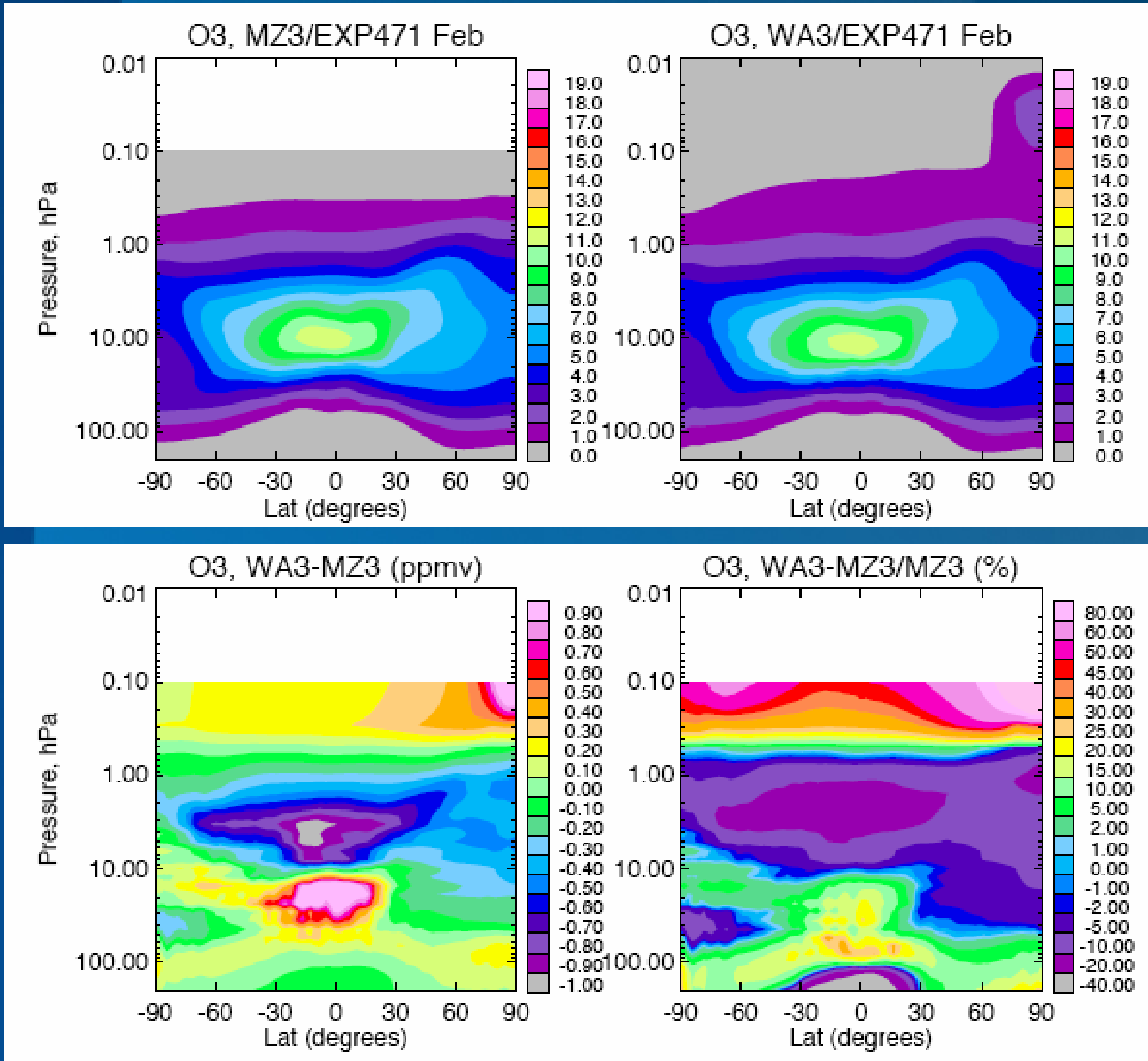
NO_2

MZ3 / EXP471

versus

WA3 / EXP471

Year two.



Ozone

MZ3 / EXP471

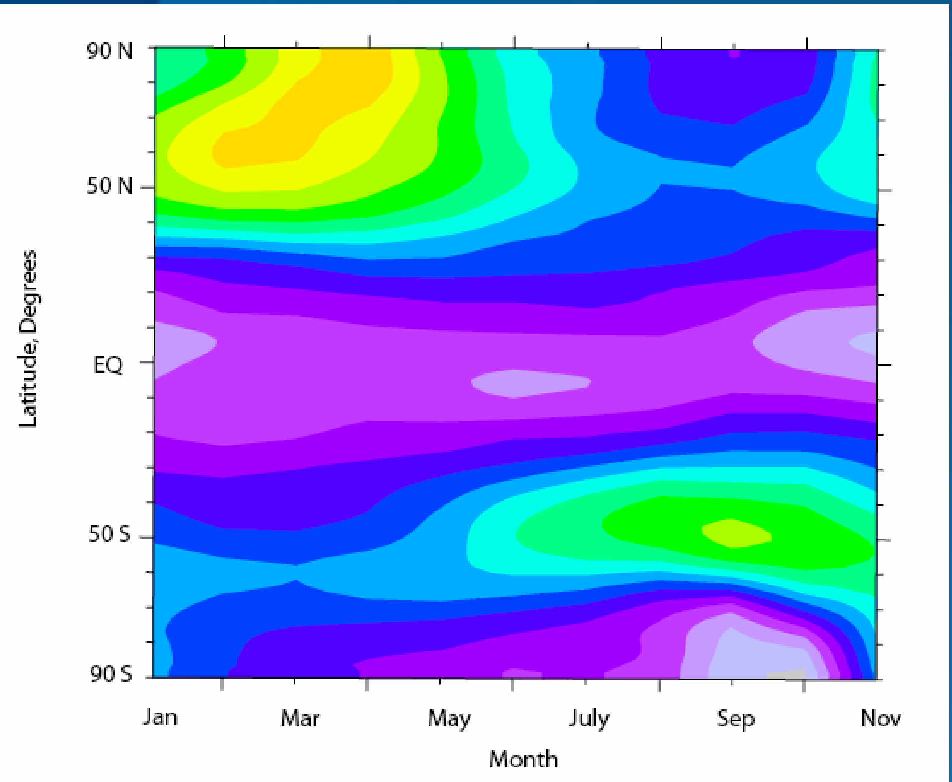
versus

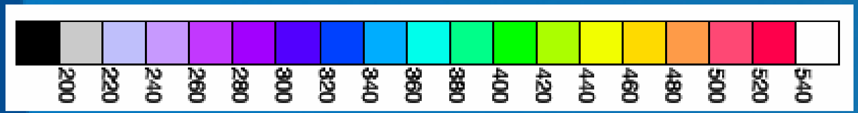
WA3 / EXP471

Year two.

Total Column O_3

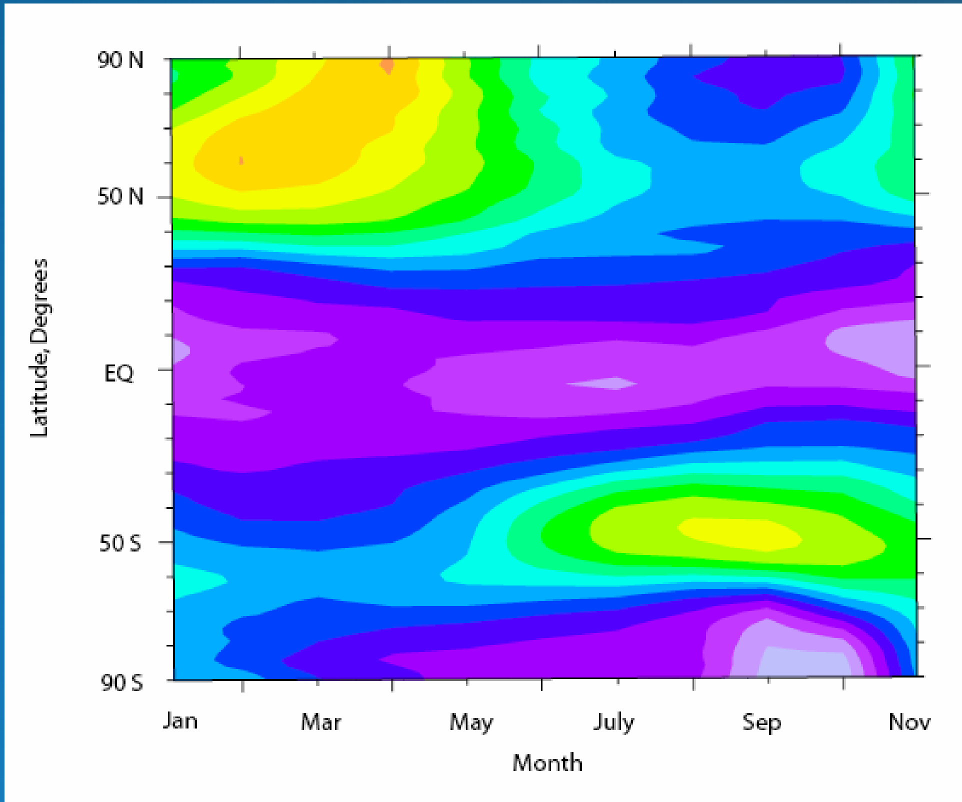
MOZART-3 / EXP471





versus

WACCM3 / EXP471



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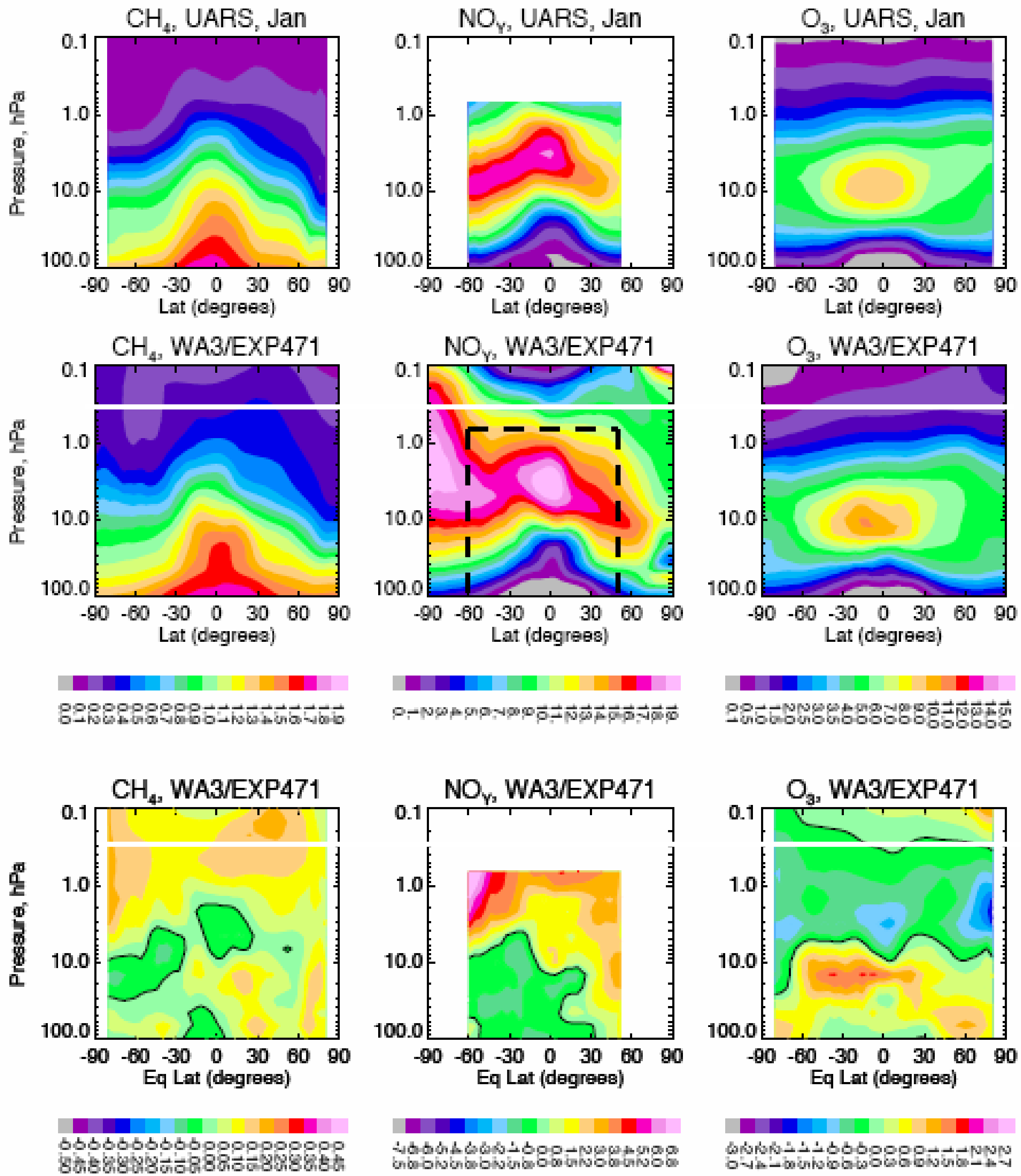
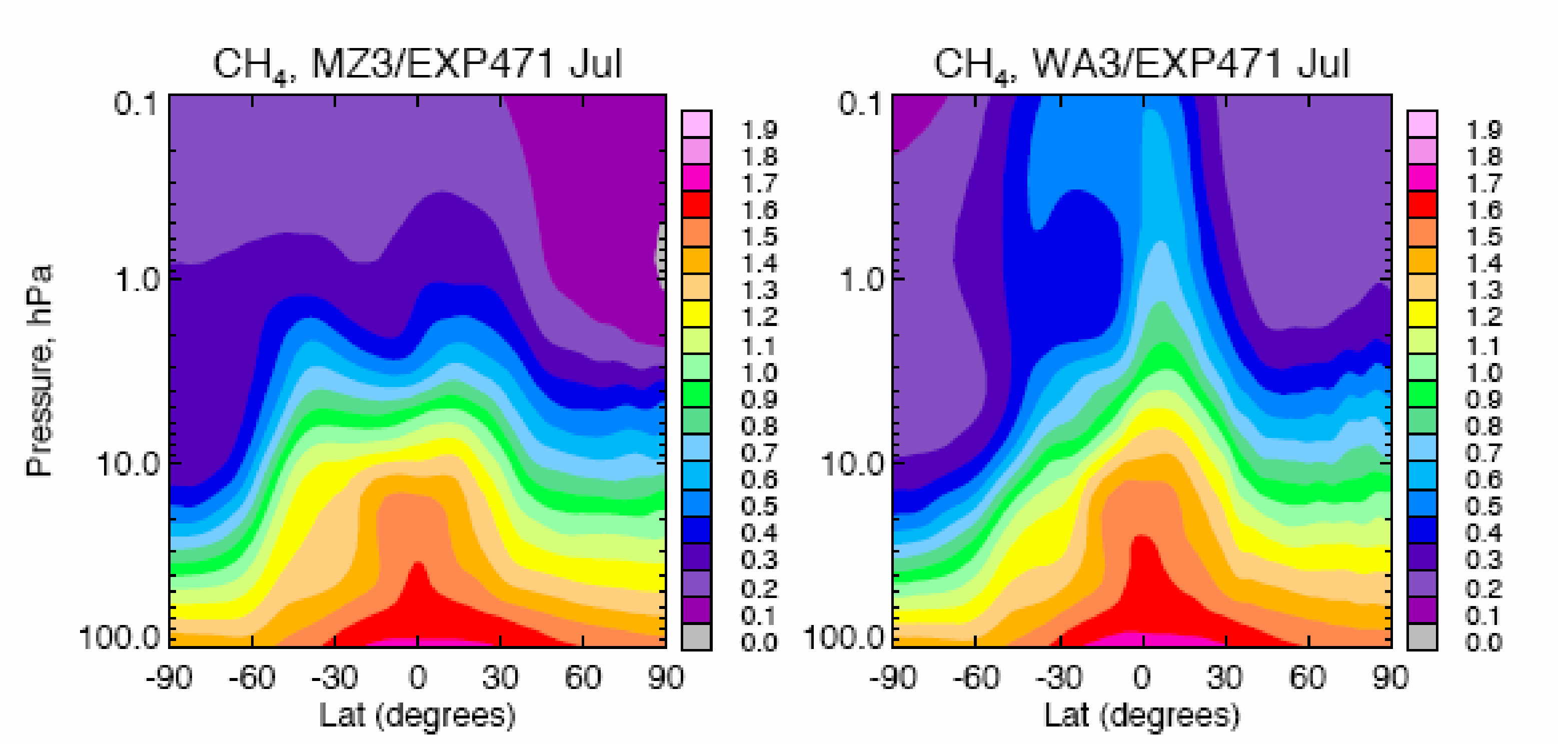
WACCM3 Driven with ECMWF EXP471 - Long-lived Tracers and Ozone



- Comparison to UARS Climatology
- CH_4 for WA3/EXP471 in reasonable agreement
- NO_Y in the Upper Stratosphere is too high - O_3 depleted.
- NO_Y in the lower-mid Stratosphere is too low - O_3 increased
- Self healing also present
- *Use to evaluate the MLT NOx source*

WACCM3 with Specified Met is still in development!

NCAR



The End

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