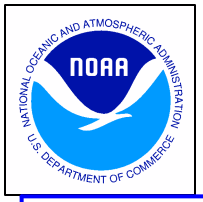
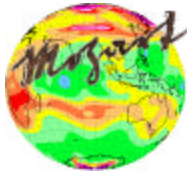




Status of MOZART-2

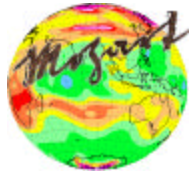
Larry W. Horowitz

GFDL/NOAA

MOZART Workshop

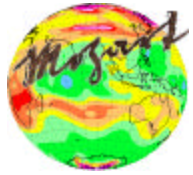
November 29, 2001

MOZART-2 Description



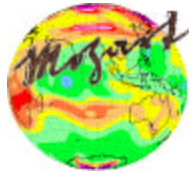
- **Resolution (typical) – 278,528 Grid Cells:**
  - Surface to approximately 40 km altitude – 1-2 km resolution
  - Horizontal Resolution: 2.8° X 2.8 °
- **Dynamical Processes:**
  - **Met. Fields**: Driven by **MACCM3** or Analyzed Fields (e.g., **NCEP**)- winds and temperatures
  - **Advection**: Flux-form semi-Lagrangian advection scheme [*Lin and Rood*, 1996]
  - **Convection**: Rediagnosed by **MATCH** using *Hack* [1994] for mid-level convection and *Zhang and MacFarlane* [1995] scheme for deep convection
  - **Boundary layer exchange**: Parameterization of *Holstag and Boville* [1993]
- **Wet and Dry Deposition:**
  - **Wet deposition**:
    - Represented as a first-order loss process within the chemistry operator, using large scale and convective precipitation rates diagnosed by **MATCH**.
    - Soluble species removed by in-cloud scavenging [*Giorgi and Chamedes*, 1985]
    - Highly soluble species are also removed by below cloud washout [*Brasseur et al*., 1998]
  - **Surface dry deposition**: uses the approach of *Wesely* [1989]

MOZART-2 Description Continued



- **Chemical Constituents and Mechanism:**
  - Approximately 63 Chemical Species:
    - Including O_x, NO_x, HO_x, CH_4, C_2H_6, C_3H_8, C_2H_4, C_3H_6, C_4H_{10}, isoprene, terpenes
    - 133 gas-phase, 2 heterogeneous, and 33 photolytic reactions
- **Source Gas Emissions:**
  - Surface: CO, NO, CH_4, C_2H_6, C_3H_8, C_4H_{10}, C_2H_4, C_3H_6, isoprene, terpenes, CH_3COCH_3, CH_3OH
  - Lightning NO_x: » 4 Tg N yr^{-1} [*Price et al.*, 1997; *Pickering et al.*, 1998]
  - Aircraft: CO, CH_4, NOx (0.44 Tg N yr^{-1}) [NASA, 1995]
- **Stratospheric Constituents Constrained for:**
  - NOx, HNO_3, N_2O_5, CH_4, CO, and N_2O (middle atmosphere model STARS, *Brasseur et al*., 1997),
  - O_3 100 hPa to tropopause [*Logan*, 1999]; above 100 hPa [HALOE data, *Randel et al.,* 1999]
  - 10-day relaxation time constant

MOZART-2 Recent Changes



- Emissions
  - Biomass burning emission ratios [Andreae and Merlet, 2001]
  - Acetone [Jacob et al., 2001]
  - Added methanol (CH_3OH) and ethanol (C_2H_5OH) [Granier]
- Revision to chemical mechanism [Tyndall and Orlando]
- Wet deposition scheme [Giorgi and Chameides, 1985] [Tie]
- Zhang convection bugfix

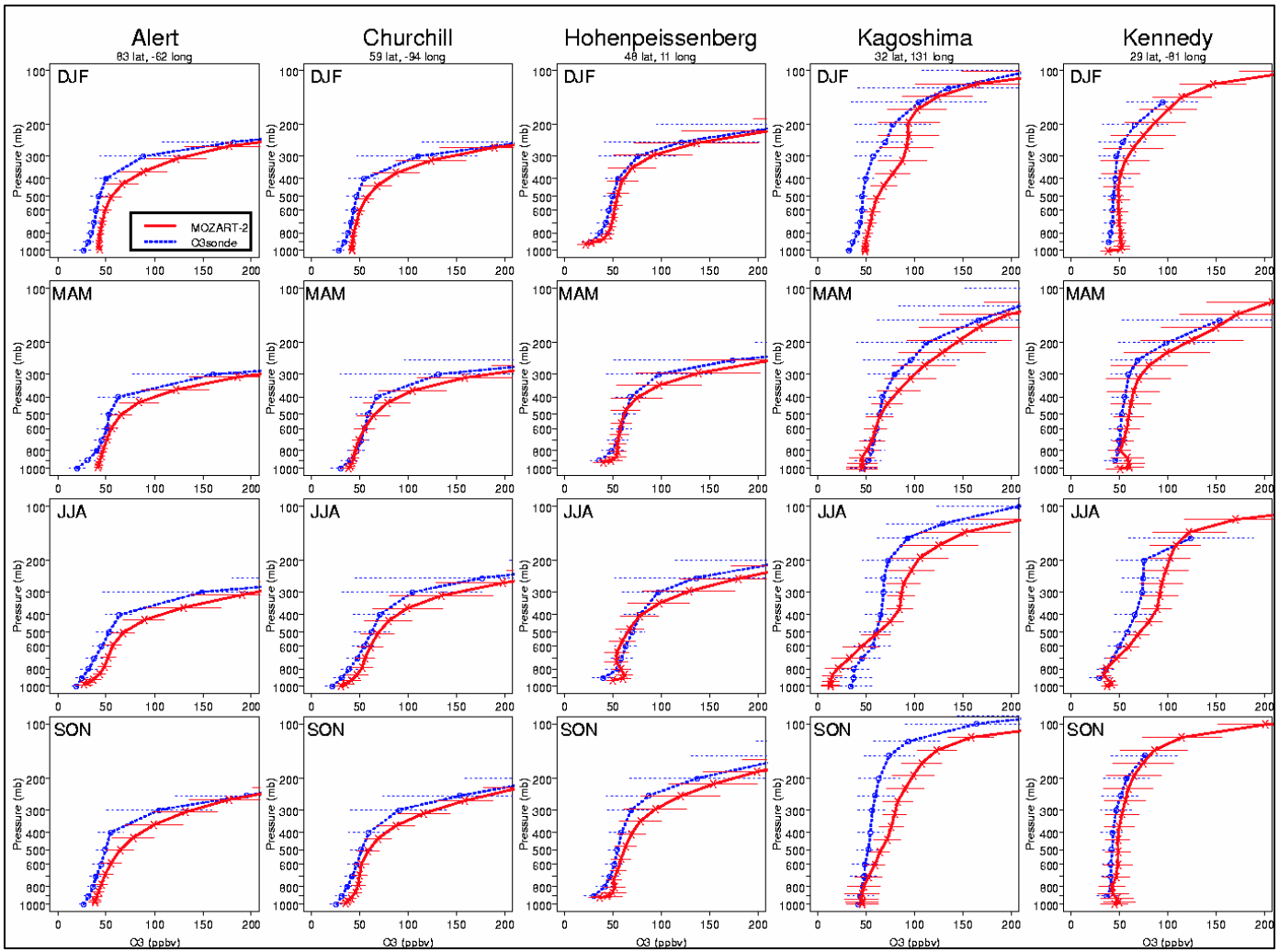
Emissions

Table 4: Surface Emissions in MOZART

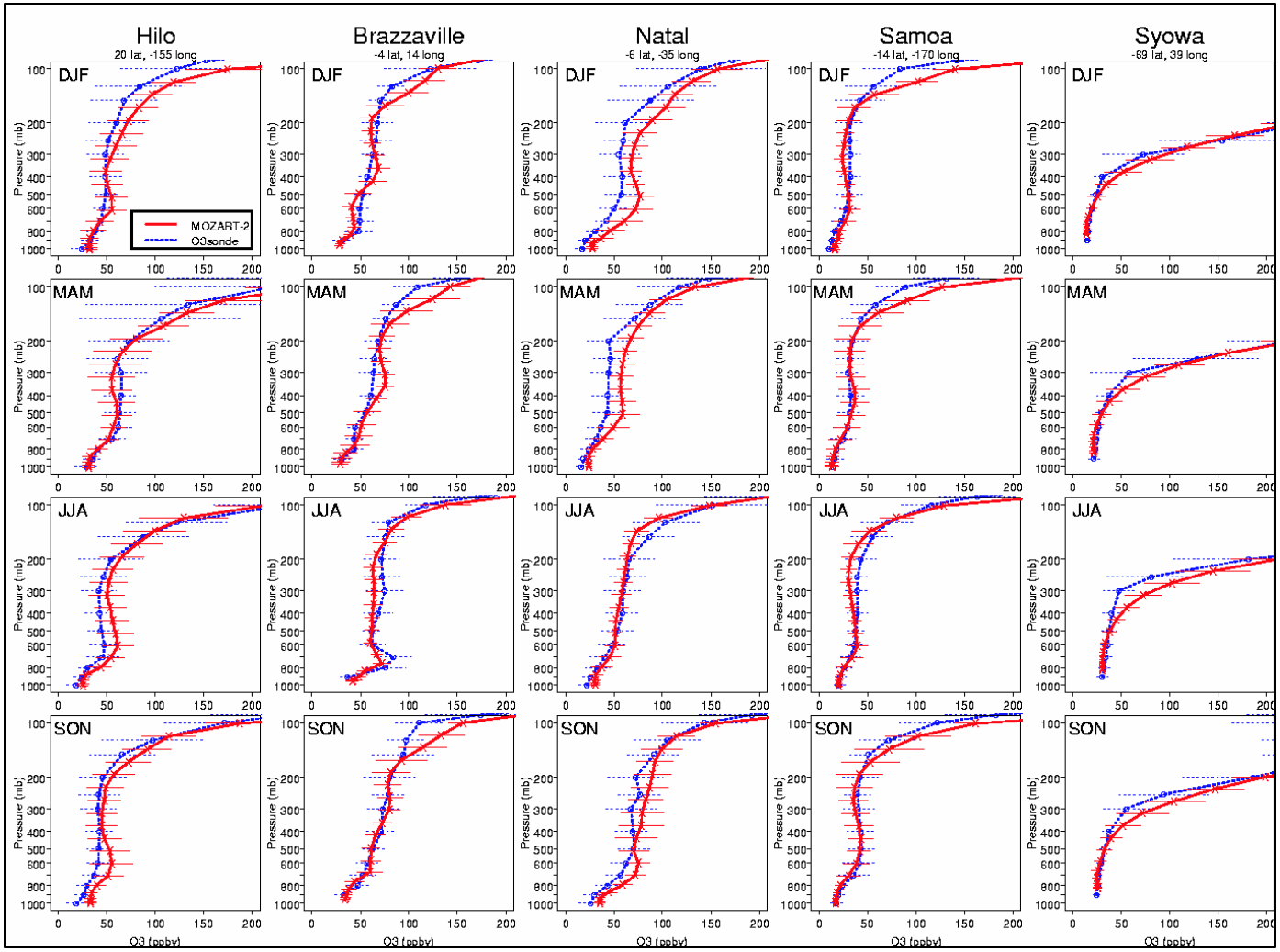
Species	Industry / Fossil fuel	Biofuel combustion	Biomass burning	Biogenic / Soil	Oceans	Total
NO (TgN/y)	23.11	1.25	9.81	6.62	0	40.79
CO (Tg/y)	306.89	170.10	677.98	160.10	10.00	1325.45
C_2H_6 (TgC/y)	3.18	1.43	4.06	0.80	0.08	9.56
C_3H_8 (TgC/y)	5.02	0.47	1.10	1.64	0.11	8.33
C_2H_4 (TgC/y)	2.02	2.88	7.89	4.29	2.07	19.16
C_3H_6 (TgC/y)	0.86	1.43	2.85	0.86	2.52	2.52
C_4H_{10} (TgC/y)	11.08	4.98	7.54	0	6.26	29.88
CH_3COCH_3 (Tg/y)	1.00	0.11	2.51	19.95	13.45	37.02
ISOP (TgC/y)	0	0	0	410.39	0	410.39
$C_{10}H_{16}$ (TgC/y)	0	0	0	129.06	0	129.06
CH_3OH (Tg/y)	0	9.73	15.56	286.73	0	312.02
CH_4 (Tg/y)[a]	94.97	14.01	71.84	145.69	9.98	489.47
N_2O (Tg/y)	5.00	0.16	1.71	20.73	11.31	38.92
H_2 (Tg/y)	14.86	3.37	16.03	3.00	3.00	40.26

a.The emissions for CH_4 also include 59.94 Tg/y from rice cultivation and 93.05 Tg/y from ruminants.

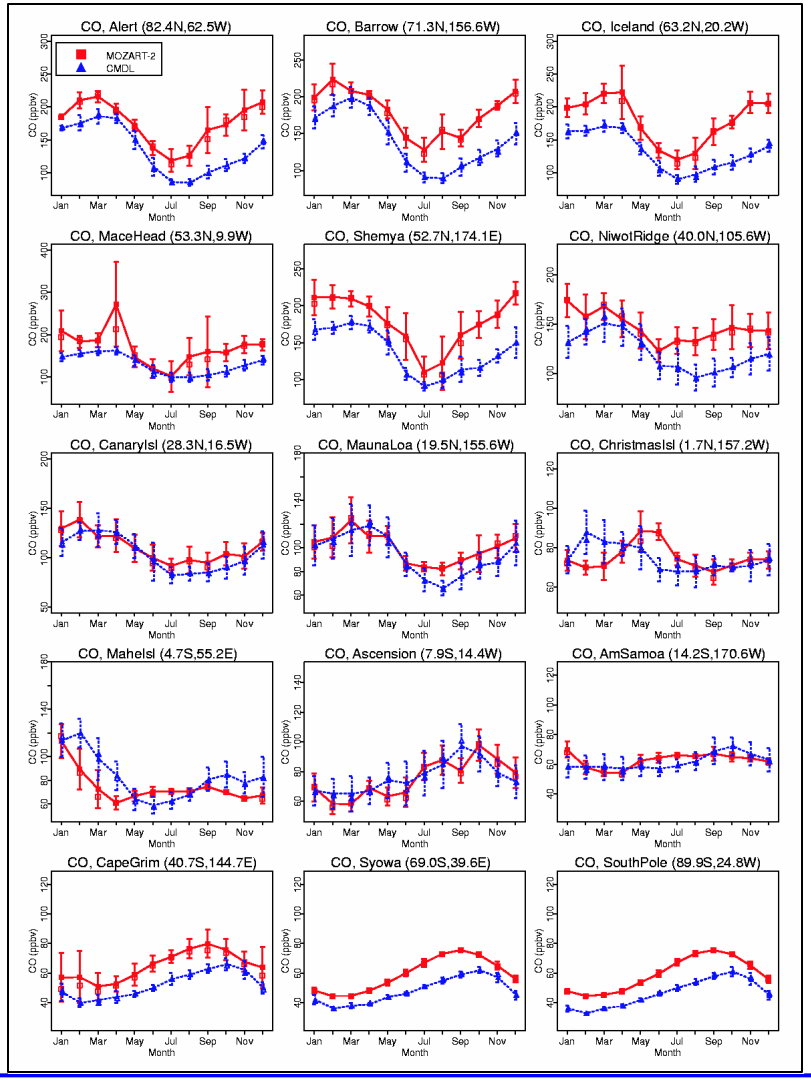
Model Evaluation – Ozonesondes



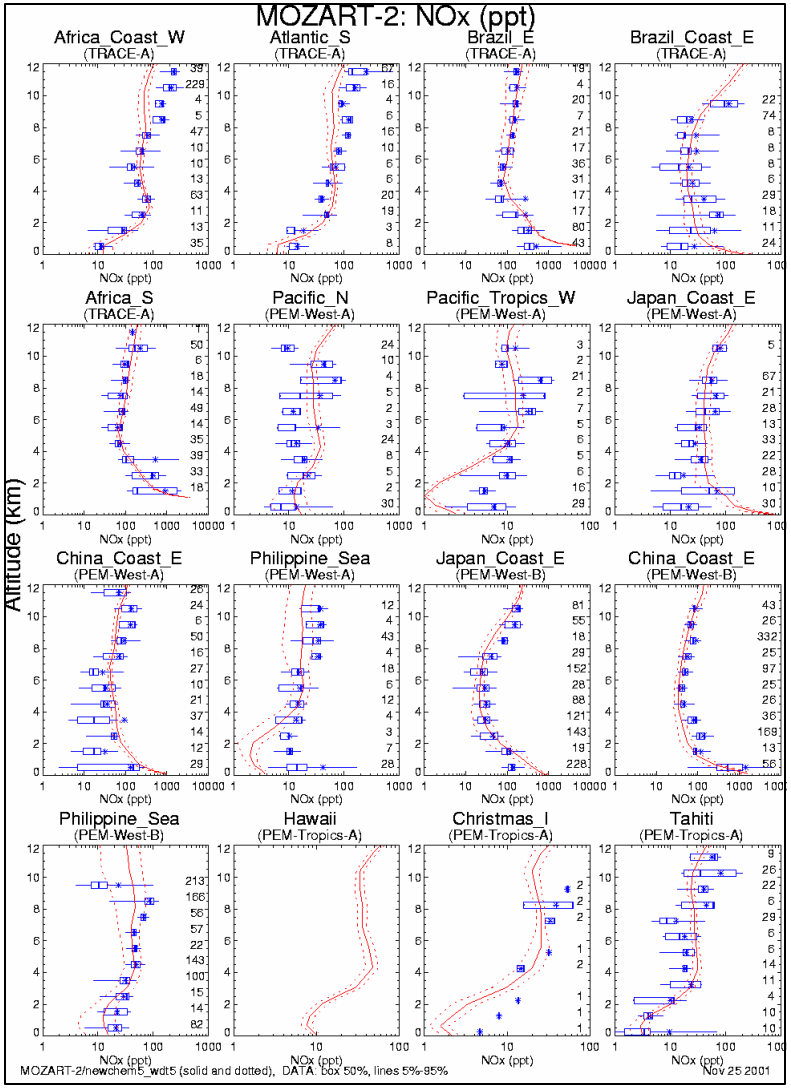
Model Evaluation – Ozonesondes (cont'd)

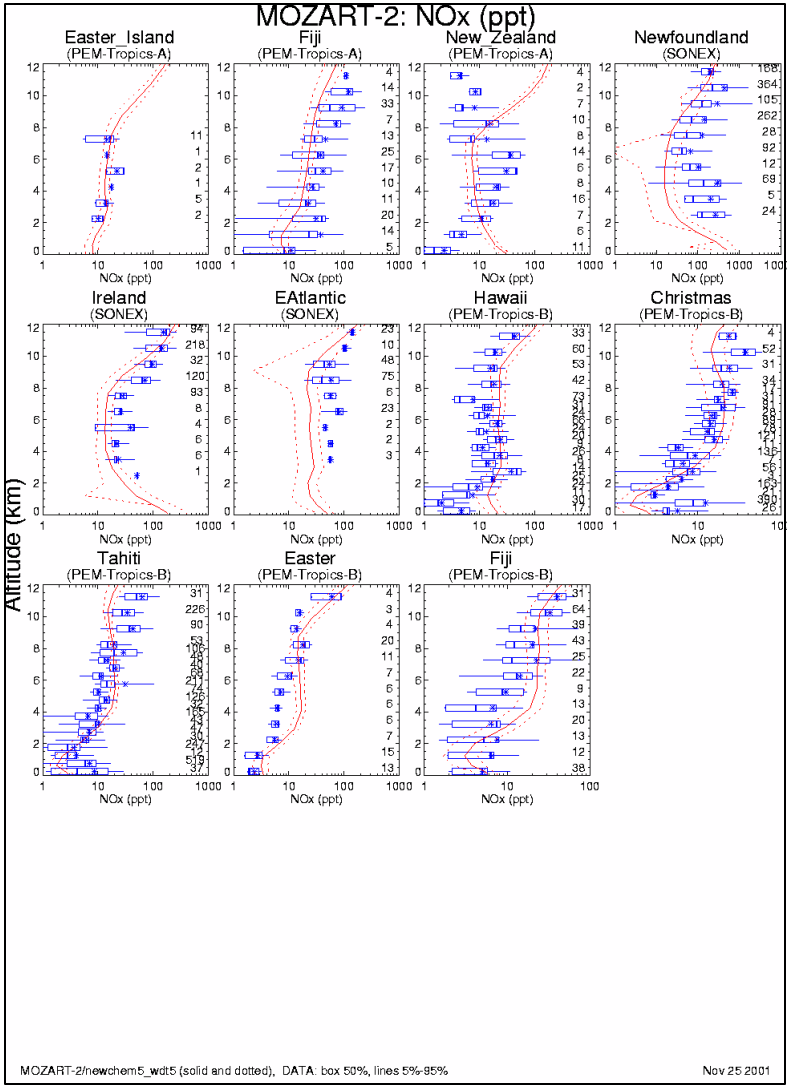


Model Evaluation – CMDL Surface CO

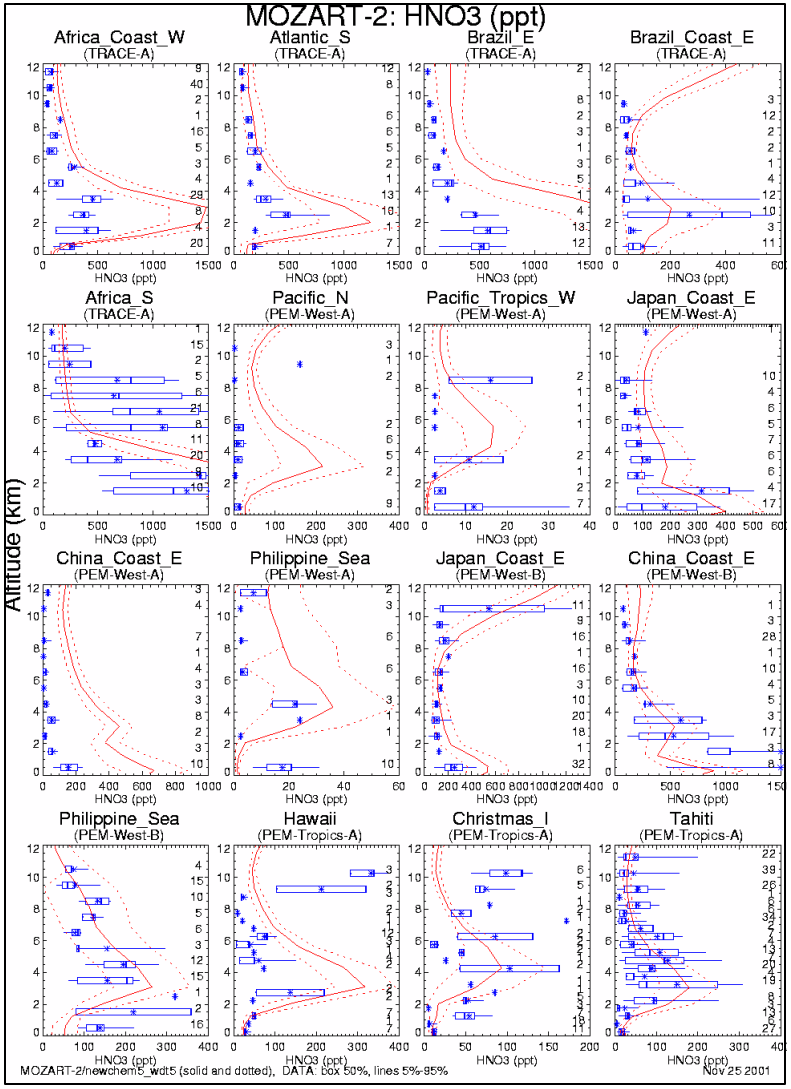


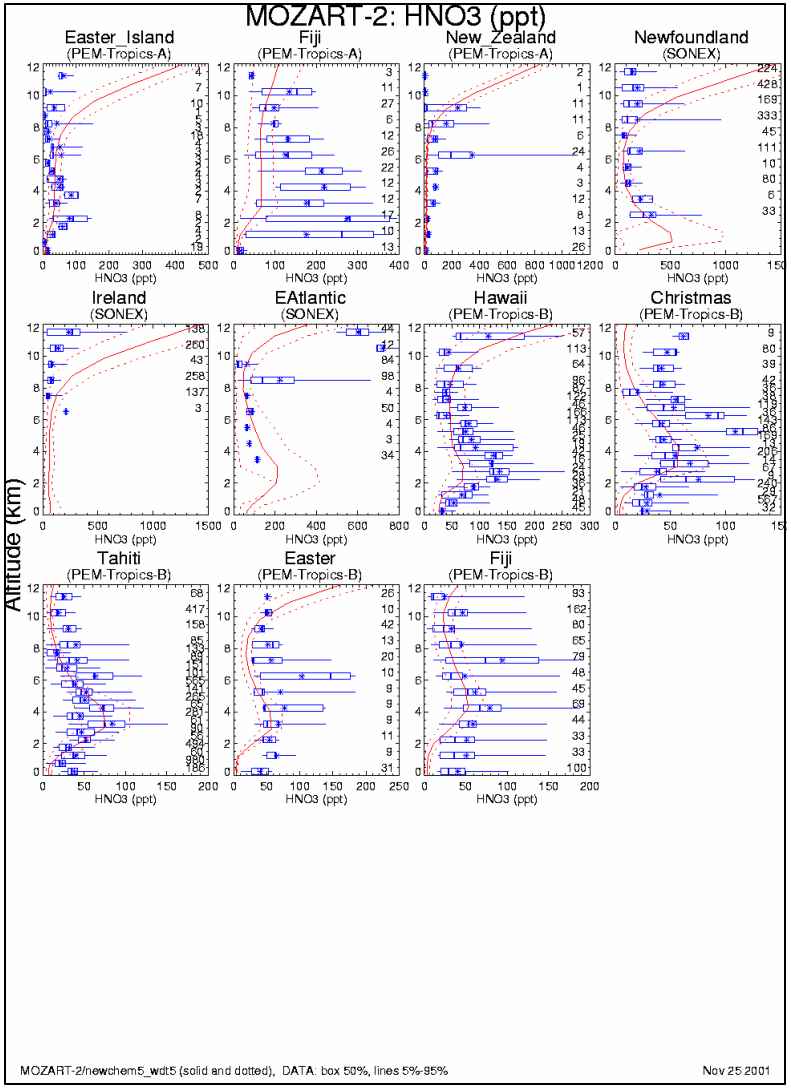
Model Evaluation – Aircraft NO_x



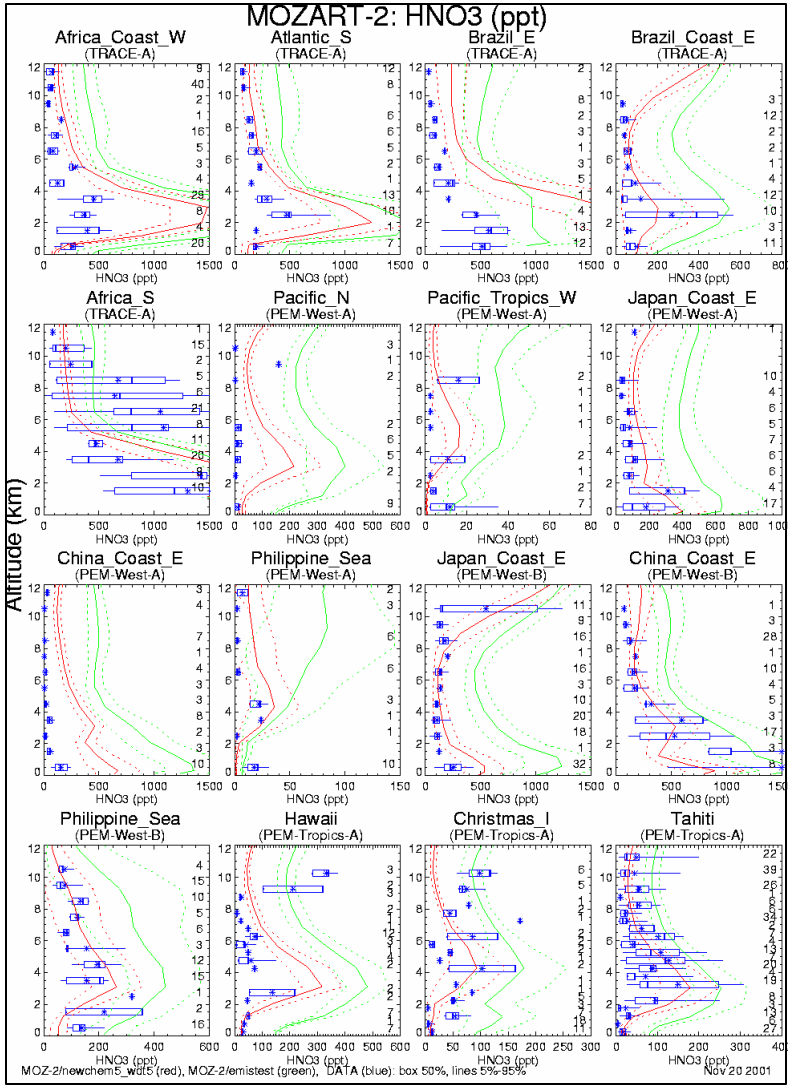


Model Evaluation – Aircraft HNO_3





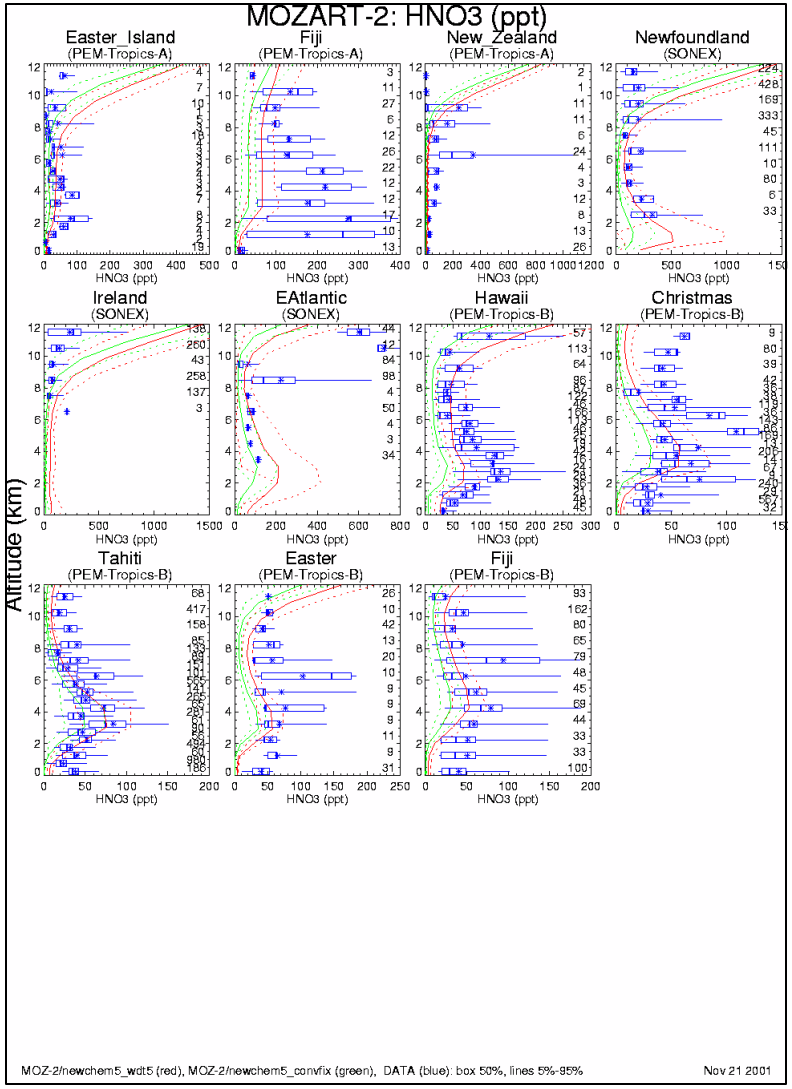
Sensitivity of HNO_3 to Wet Deposition



Red: new wet deposition

Green: "old" wetdep

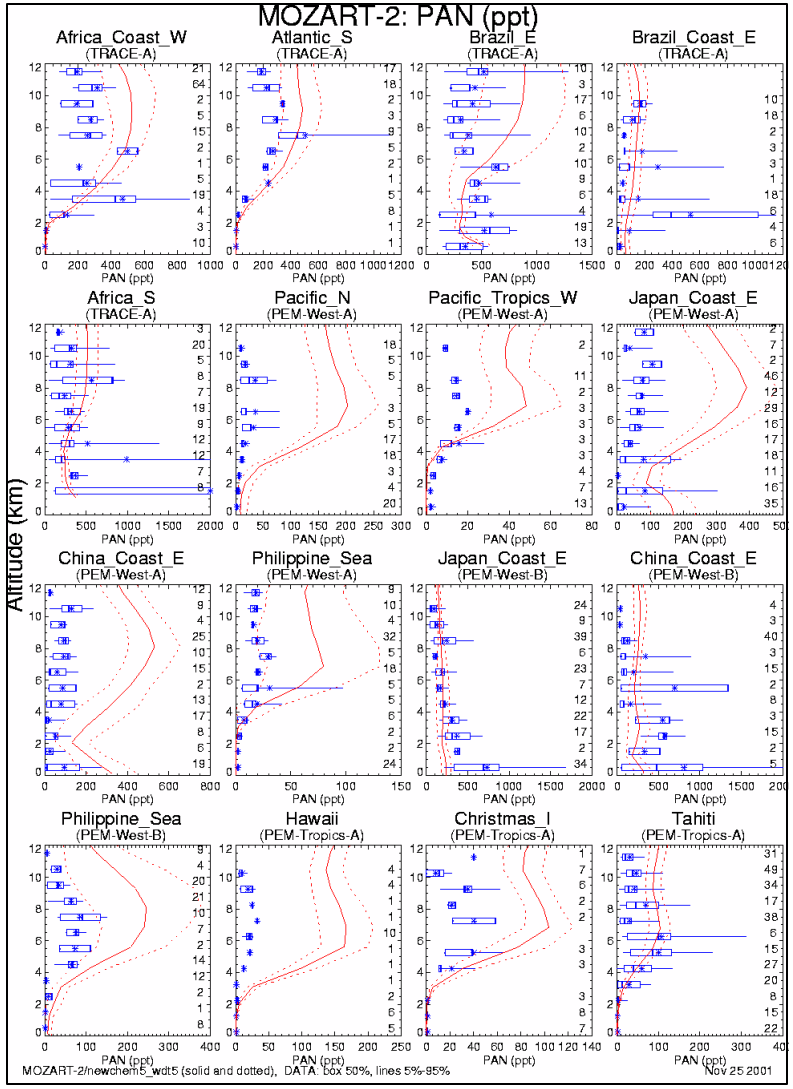
Sensitivity of HNO_3 to Wet Deposition

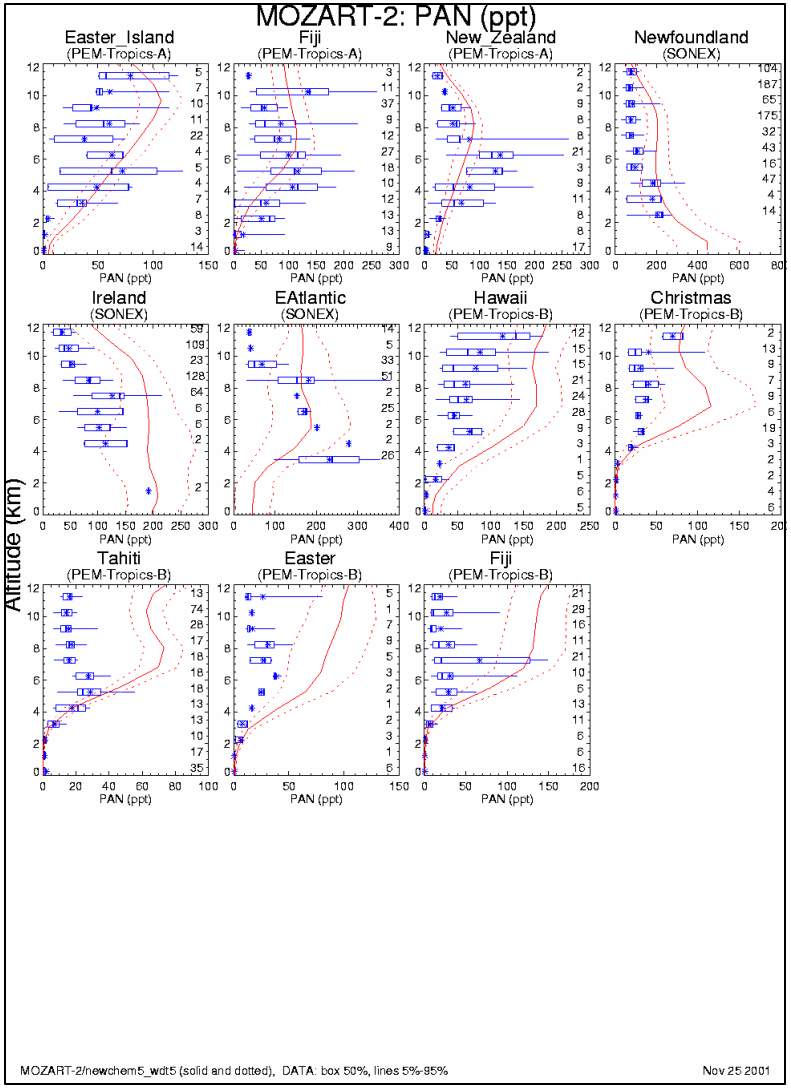


Red: new wet deposition

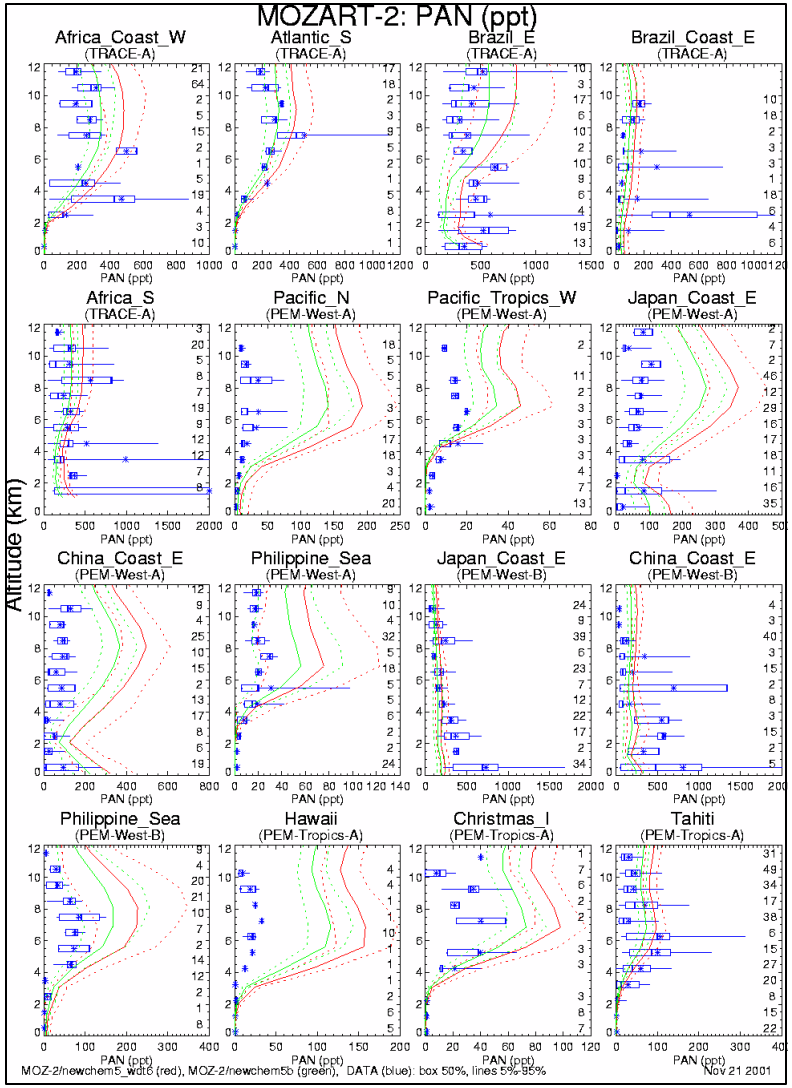
Green: G&C wetdep (Tie)

Model Evaluation – Aircraft PAN





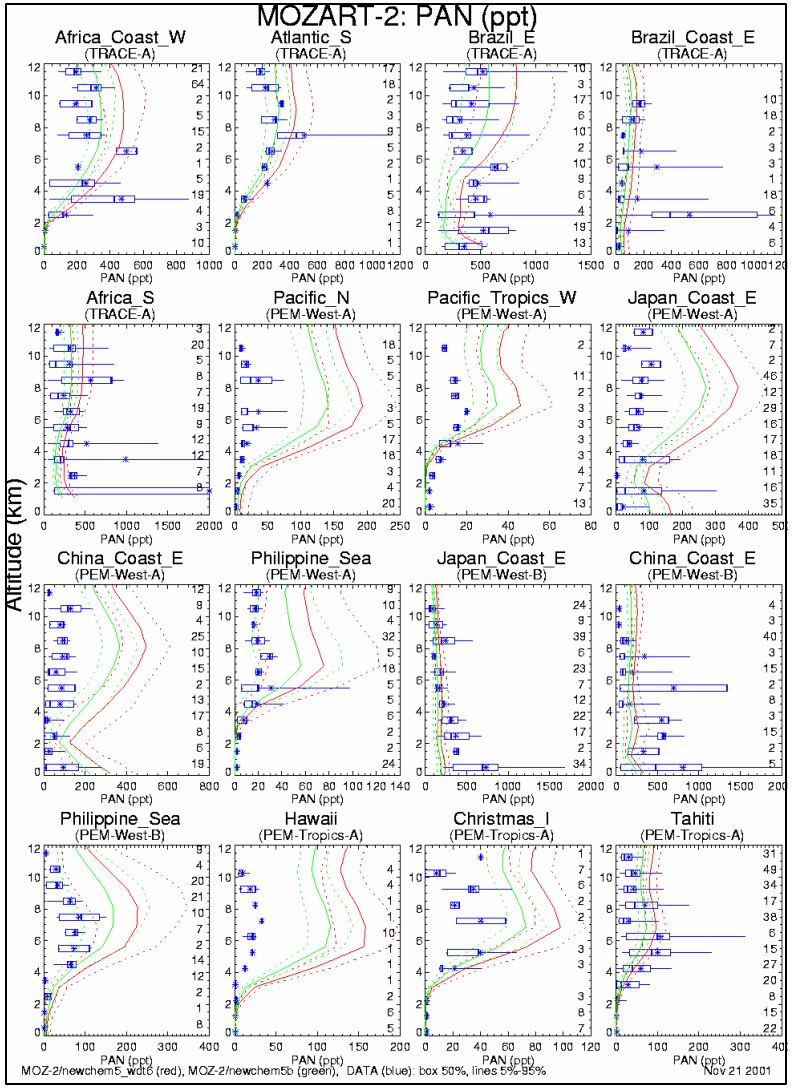
Sensitivity of PAN to Chemical Mechanism



Red: standard run

Green: reduced PAN yields from isoprene

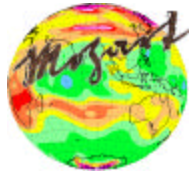
Sensitivity of PAN to Emissions



Red: standard run

Green: 0.5*E(isop,terpenes)

Model Evaluation -- Summary



- O_3, NO_x, HNO_3, NMHCs, peroxides
  - Excellent agreement with observations
- CH_2O and Acetone
  - Good agreement at most locations
- CO, PAN
  - Systematic bias at some locations

Ozone Budget

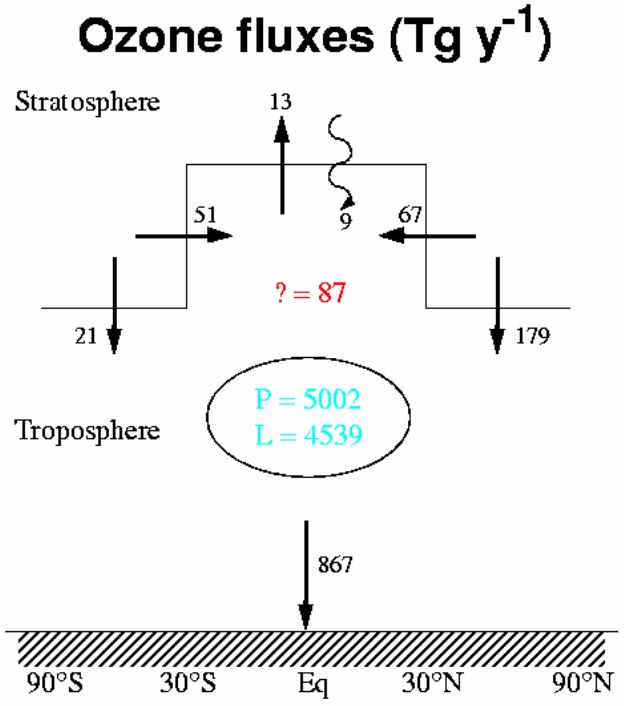


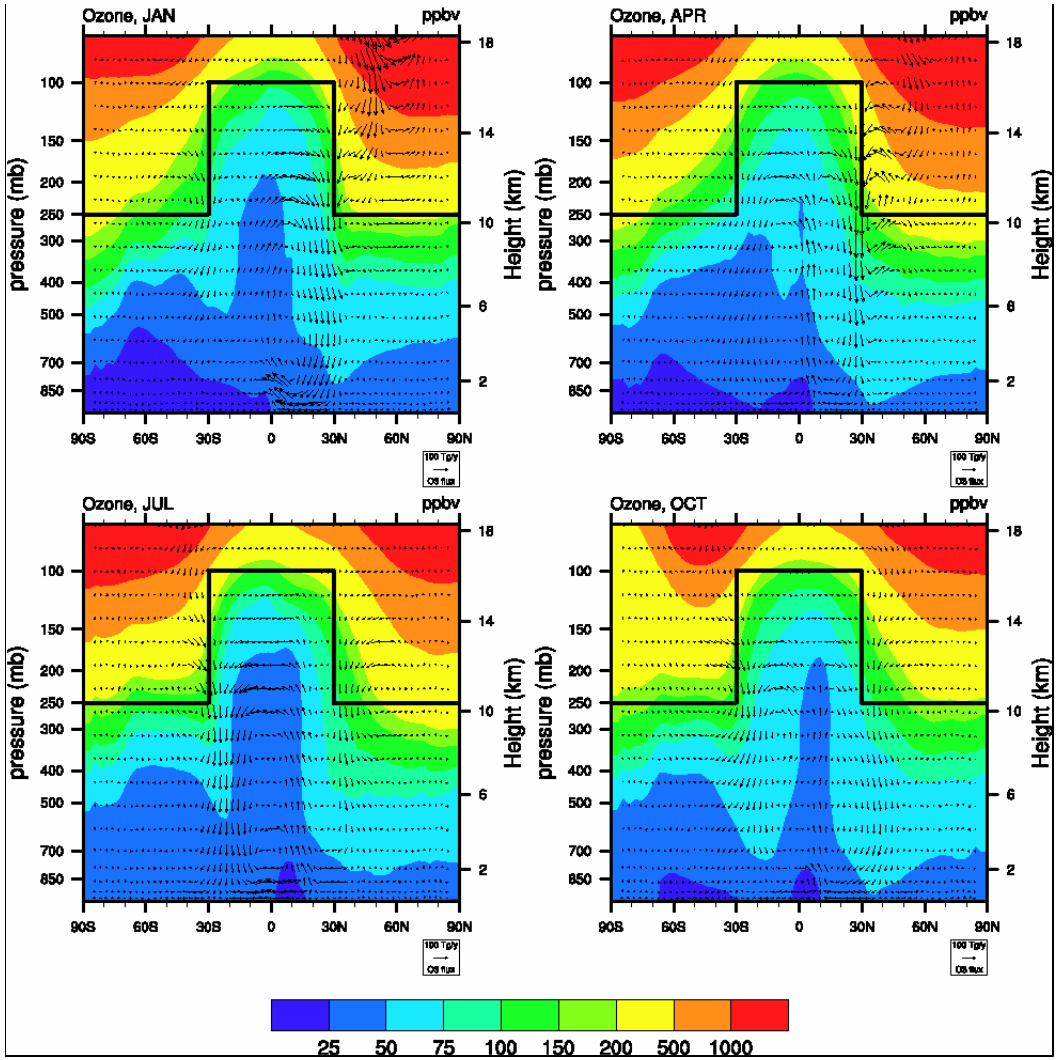
Table 6: Annual Mean Budget of Tropospheric Ozone in MOZART-2

Process	Production (Loss) [Tg O_3 / yr]		
	Global	Northern Hemisphere	Southern Hemisphere
Influx from stratosphere[a]	401[b]	252	149
Photochemical production	5002	3026	1976
Photochemical loss	-4539	-2668	-1871
Dry deposition	-867	-588	-279

For this budget, the tropopause is defined as the hybrid model level interface corresponding to approximately 100 hPa in the tropics (30°S-30°N) and 250hPa in the extratropics.

a. Includes advection, pressure consistency correction, and convection and vertical diffusion.
b. This term consists of advection (305 Tg/y), pressure consistency correction (87 Tg/y), and convection and vertical diffusion (9 Tg/y).

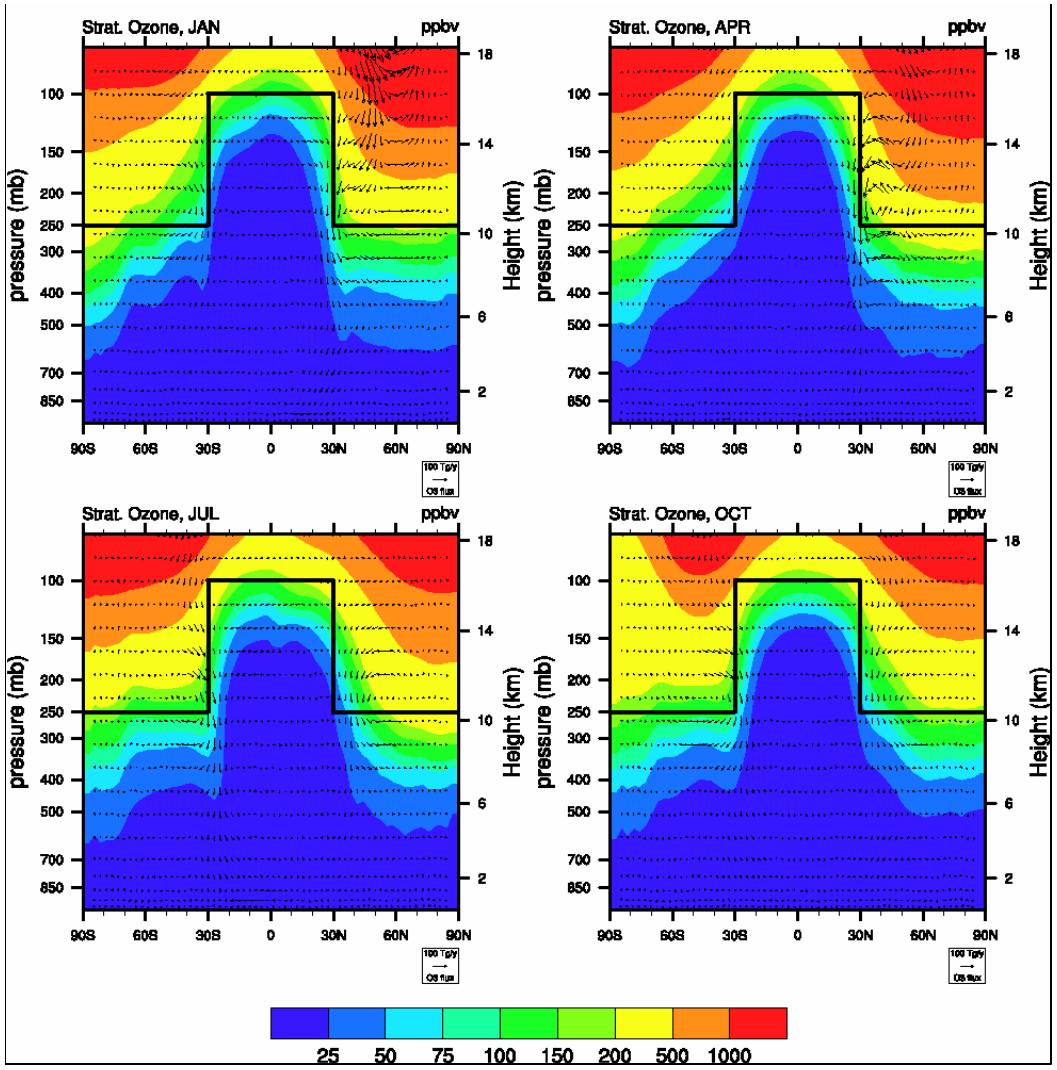
Ozone Fluxes



Colors: $[O_3]$ (ppbv)

Arrows: zonal avg. O_3 fluxes (Tg/y)

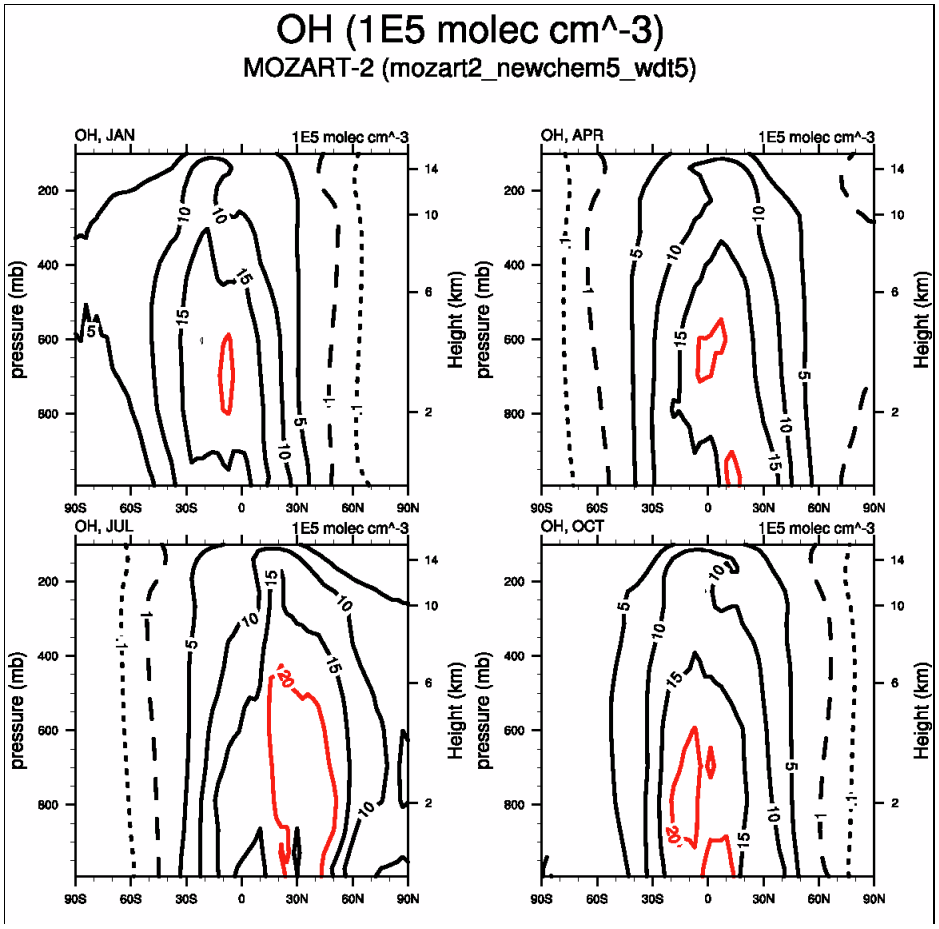
“Stratospheric Ozone” Fluxes

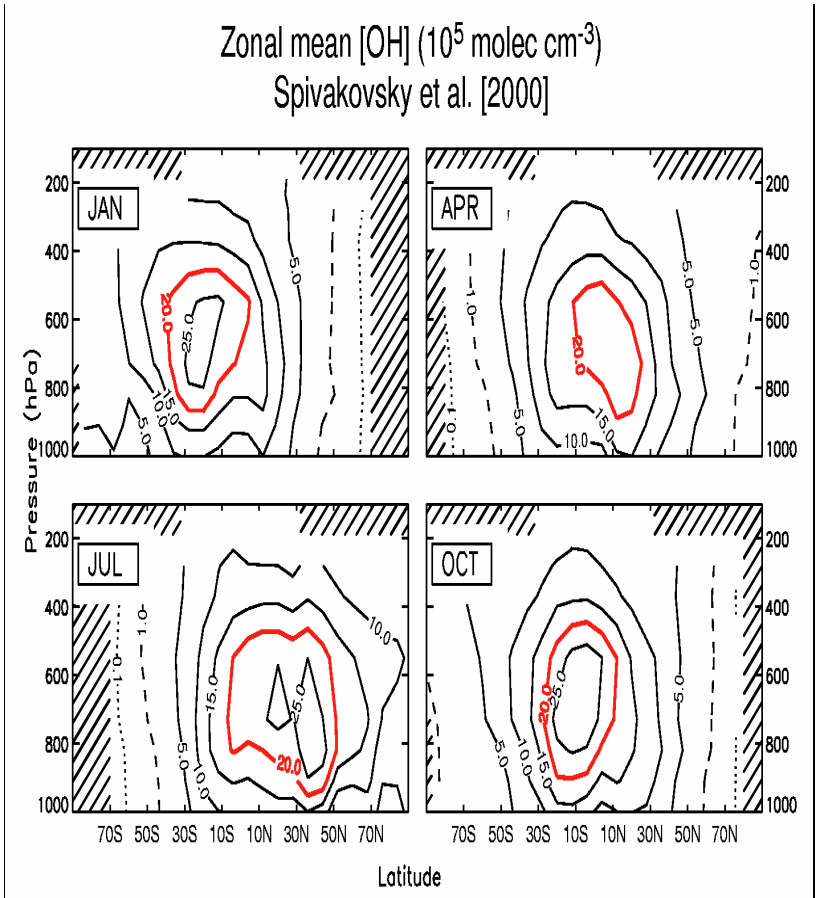


Colors: [O_3S] (ppbv)

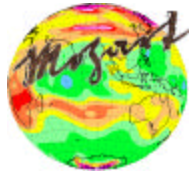
Arrows: zonal avg. O_3S fluxes (Tg/y)

Oxidizing Capacity (OH)





Oxidizing Capacity (cont'd)



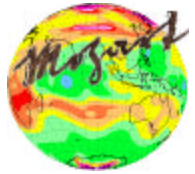
- Methane lifetime (MOZART) = 10.7 years
- IPCC "best guess" = 9.6 years

→ OH may be underestimated by ~10%

NB: Methane lifetimes above are calculated as:

(strat+trop CH_4 burden) / (trop CH_4 loss)

Model Description/Evaluation Paper

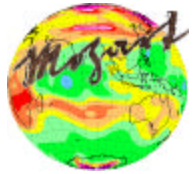


- Horowitz *et al*., A global simulation of tropospheric ozone and related tracers: Description and Evaluation of MOZART, version 2
- Nearly ready for submission to *J. Geophys. Res.*
- Available now at:

  http://www.gfdl.noaa.gov/~lwh/mozart/mozart.html

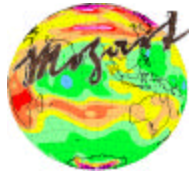
  along with model evaluation plots, etc.

Future plans



- Near-term (for "freeze" of MOZART-2)
  - Photolysis lookup table (LUT)
  - Problems with OH/CO
  - Upper tropospheric PAN
    - NO/NO_2 ratio (?)
    - Convection (?)
  - Lin & Rood mass conservation (LLNL)

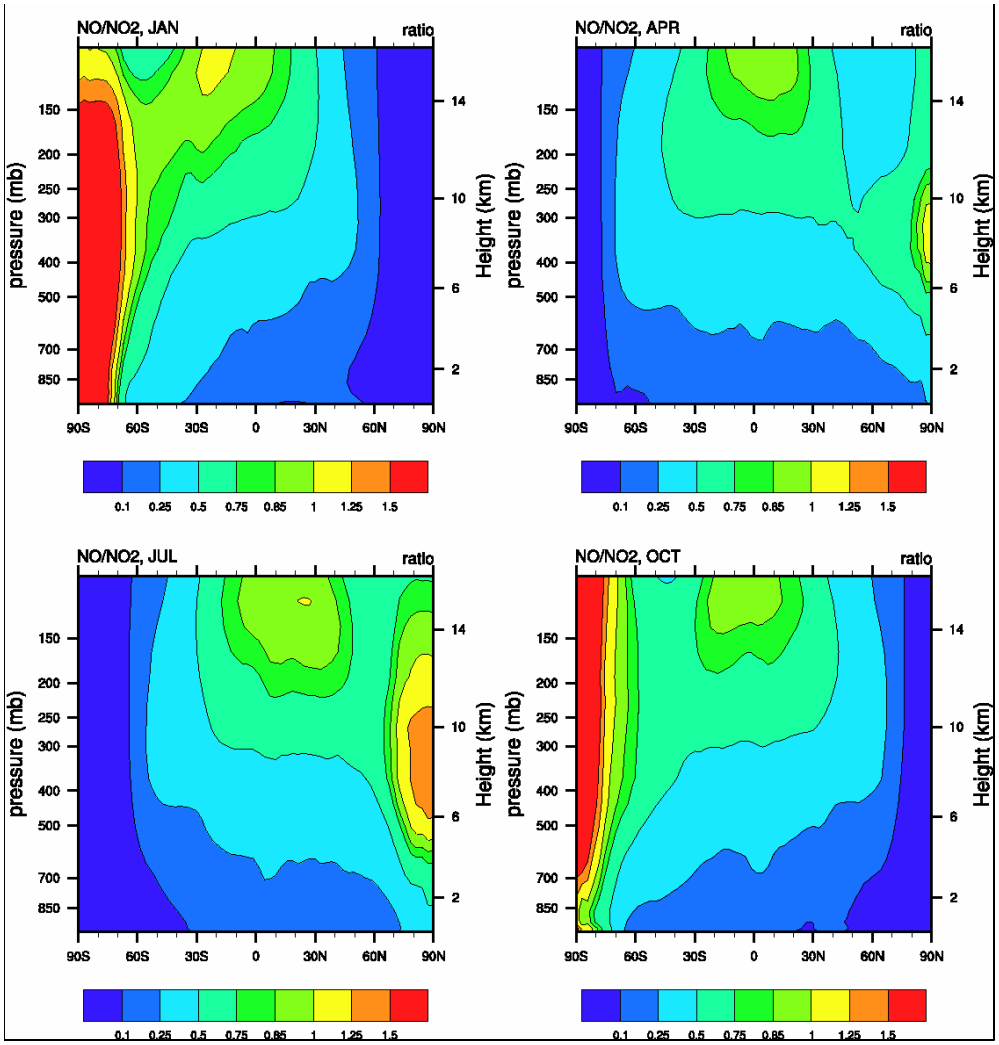
Future plans



- Longer-term
  - Re-examine assimilated wind version of MOZART (NCEP)
  - Aerosols in MOZART-2
  - Coupling to GCMs and CSMs

    (NCAR CCM/CCSM and GFDL FMS AM3)

NO/NO_2 Ratio


NO/NO2, JAN
ratio
NO/NO2, APR
ratio
NO/NO2, JUL
ratio
NO/NO2, OCT
ratio
pressure (mb)
Height (km)
150
200
250
300
400
500
700
850
14
10
6
2
90S
60S
30S
0
30N
60N
90N
0.1
0.25
0.5
0.75
0.85
1
1.25
1.5