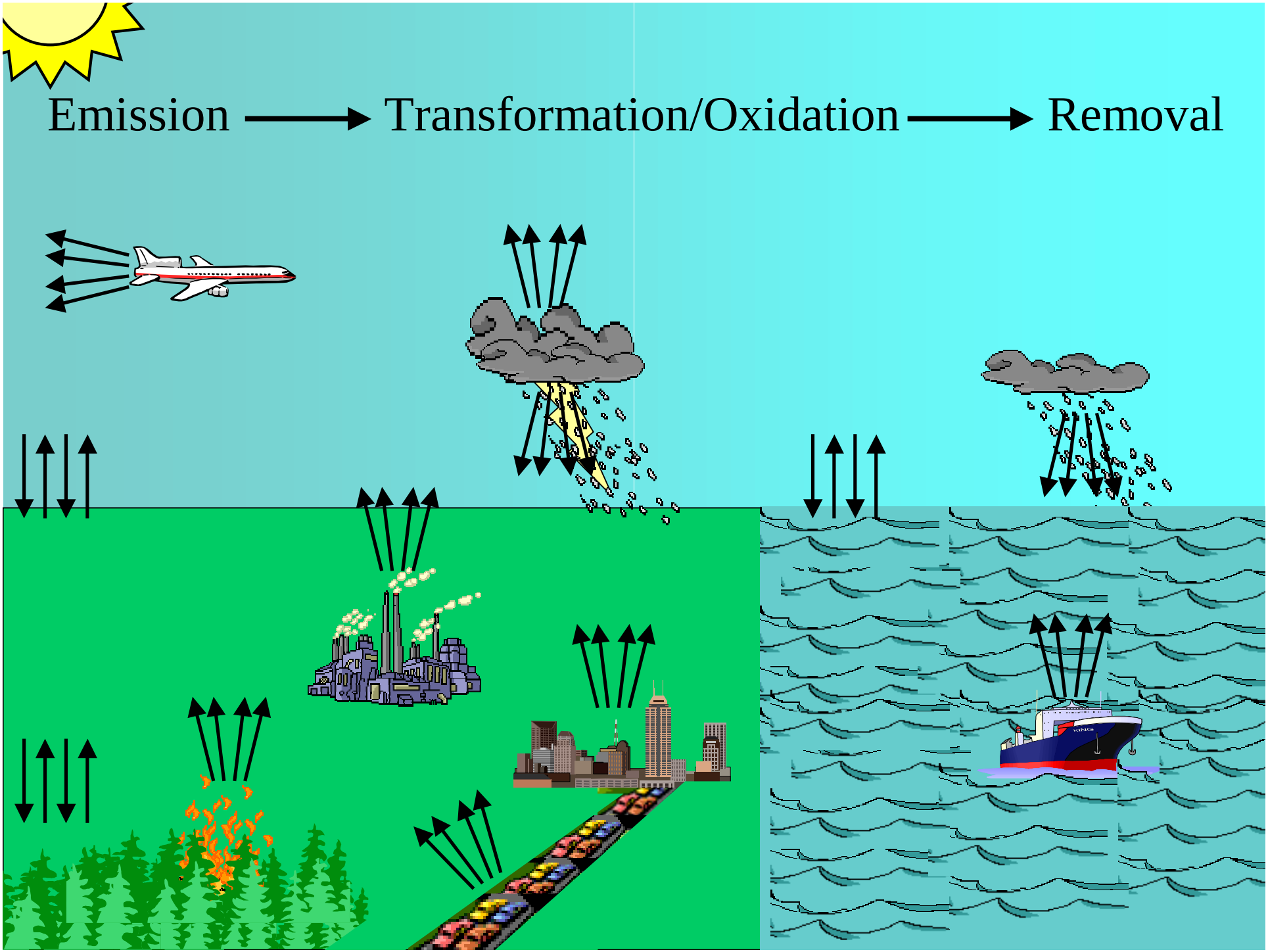
Atmospheric Science Brown Bag Series

Tropospheric Chemistry

Jim Crawford
NASA LaRC


Emission
Transformation/Oxidation
Removal

Why is Ozone Centrally Important to Tropospheric Photochemistry?

Ozone facilitates the removal of pollutants from the atmosphere:

Ozone is a precursor to the OH radical, the primary oxidant for most trace gases, and is an oxidant itself.

Ozone is a toxic pollutant:

High levels of ozone are damaging to lung tissue and can also lead to decreases in agricultural productivity.

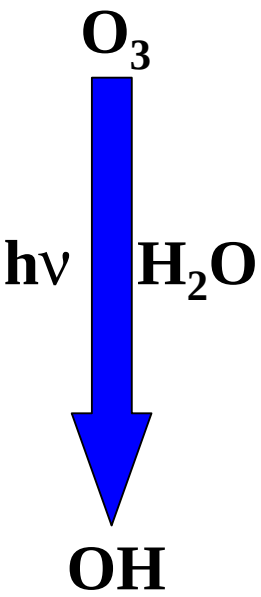
Ozone impacts climate:

Ozone is a greenhouse gas estimated to have a potential climate forcing equal to that of methane.

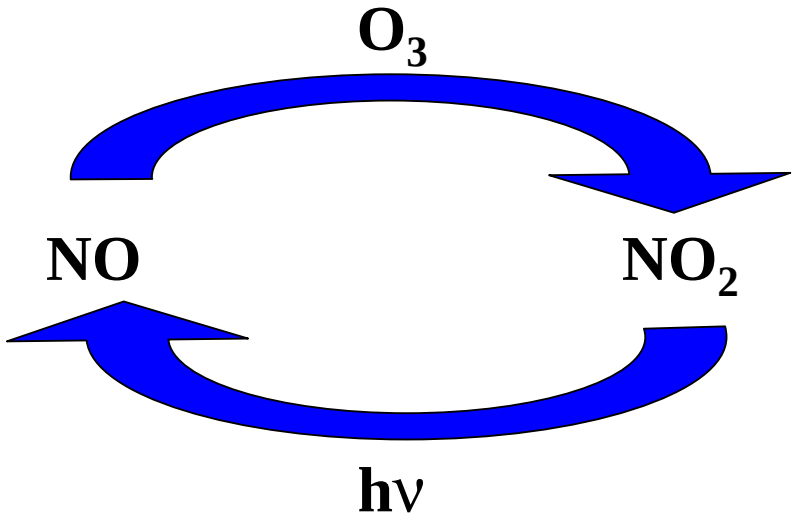
Ozone chemistry leads to the oxidation of several greenhouse gases such as methane and methyl chloroform.

Tropospheric Chemistry
Key Roles for Ozone:

Dominant Source of OH

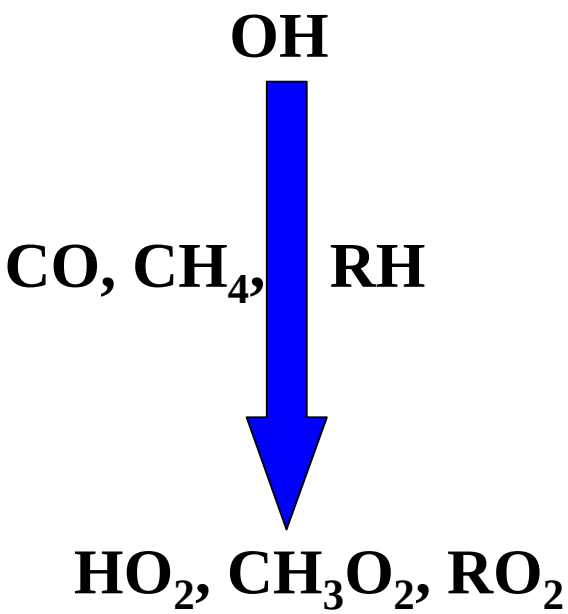


NO_x Partitioning

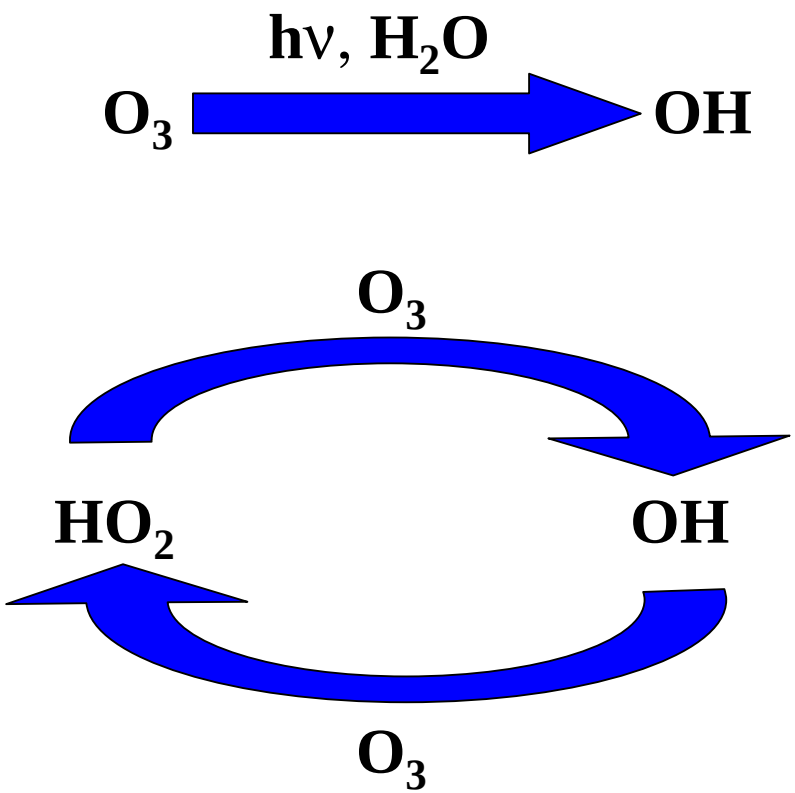


Tropospheric Chemistry
Key Roles for HO_x ($OH+HO_2$):

Oxidation of Pollutants

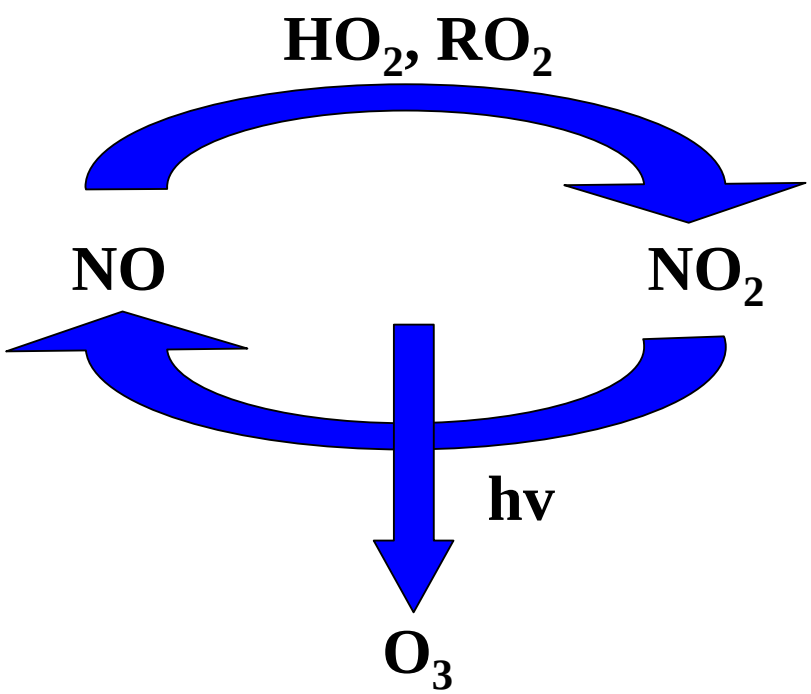


O_3 Destruction

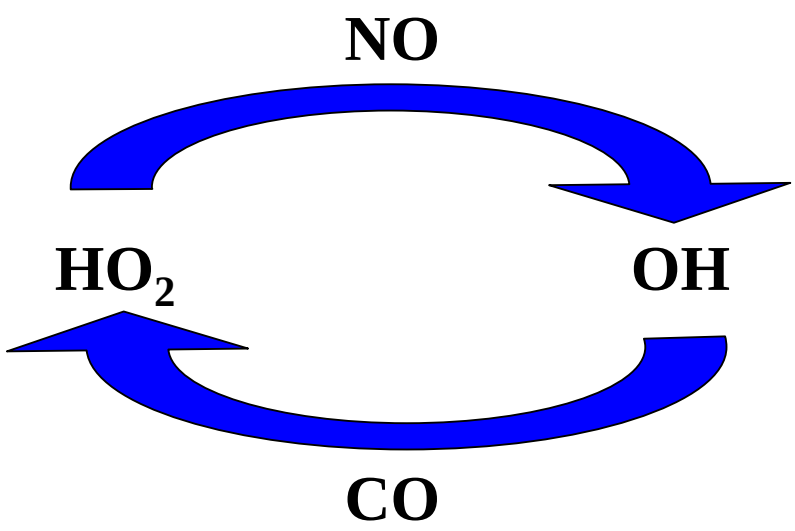


Tropospheric Chemistry
Key Roles for NO_x ($NO+NO_2$):

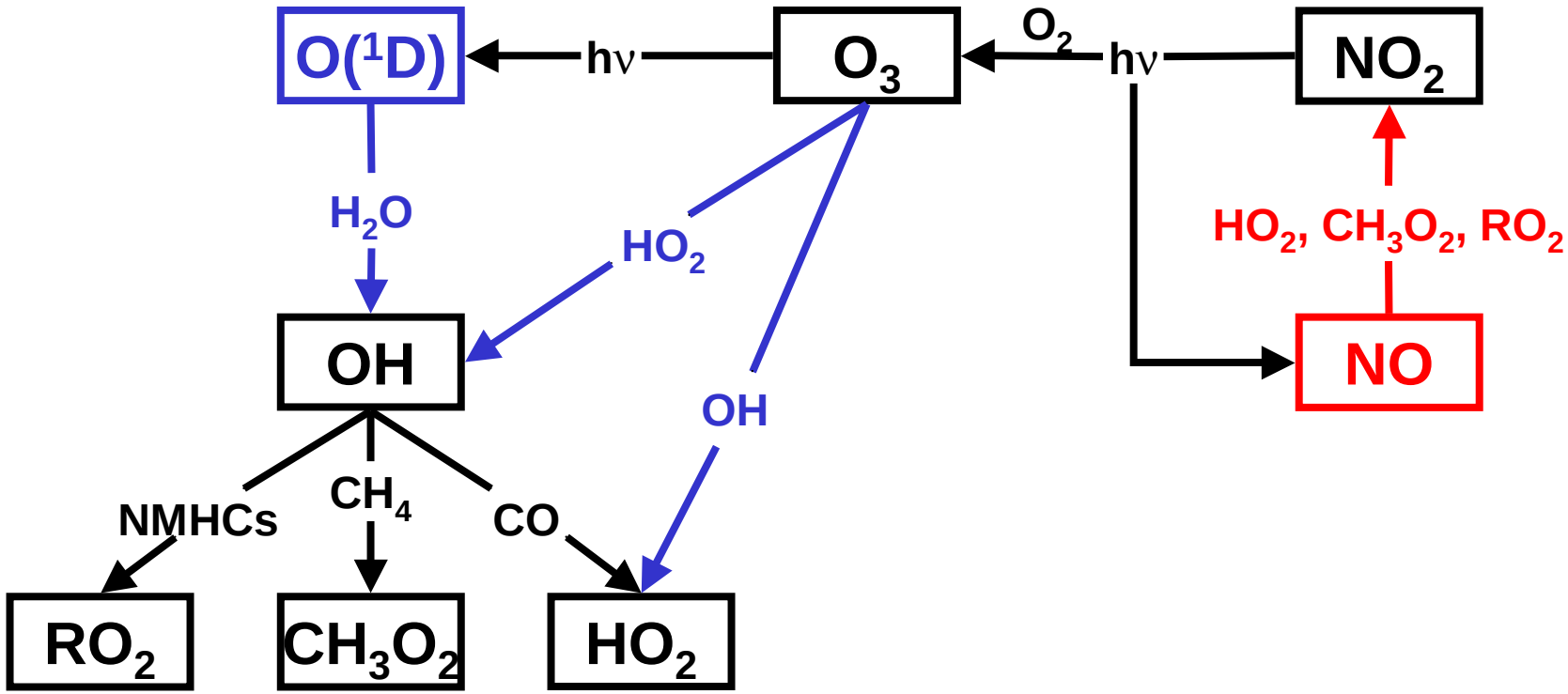
Ozone Production



HO_x Partitioning



Tropospheric Ozone Photochemistry



$$F(O_3) = (k[HO_2] + k[CH_3O_2] + k[RO_2])\,[NO]$$

$$D(O_3) = k[O(^1D)][H_2O] + k[HO_2][O_3] + k[OH][O_3]$$

Net Ozone Tendency = $F(O_3) - D(O_3)$

What Controls Tropospheric Ozone?

Global Ozone Budgets Estimated from 3-D Chemical-Transport Model Calculations: 1995 to Present
(units of Teragrams of O_3 per year)

Authors	Gross Formation	Gross Destruction	Net Chemistry	Strat-Trop Exchange	Dry Deposition
Roelofs and Lelieveld [1995]	3206	-3036	170	575	-740
Muller and Brasseur [1995]	4550	-4000	550	550	-1100
Lawrence [1996]	3580	-3550	30	594	-641
Roelofs et al. [1997]	3415	-3340	75	459	-534
Houweling et al. [1998]	3979	-4065	-86	768	-681
Wang et al. [1998]	4100	-3680	420	400	-820
Hauglustaine et al. [1998]	3018	-2511	507	391	-1237
Lawrence et al. [1999]	2334	-2812	-478	1103	-621
Mickley et al. [1999]	4330	-3960	370	390	-760
Lelieveld and Dentener [2000]	3314	-3174	140	565	-705
Roelofs and Lelieveld [2000]	4375	-4302	73	590	-660

Global Tropospheric Experiment: 1983-present

Airborne study of trace gas distributions and atmospheric chemical processes with a primary focus on tropospheric ozone.

14 aircraft campaigns

Most recent: TRACE-P (Transport and Chemical Evolution - Pacific)

- -2 aircraft, 44 flights
- -Investigative Team representing 4 government facilities, 13 private institutions, and 2 foreign institutions

Tropospheric Ozone Budget

Human Impacts: Industrial Pollution

Atmosphere-Biosphere Exchange: Wetlands

Long-Range Transport: Lightning NO_x

Convective Transport: Marine

Convective Transport: Continental

Marine Sulfur Budget

Human Impacts: Biomass Burning

Fast Photochemistry: NO_2 - NO

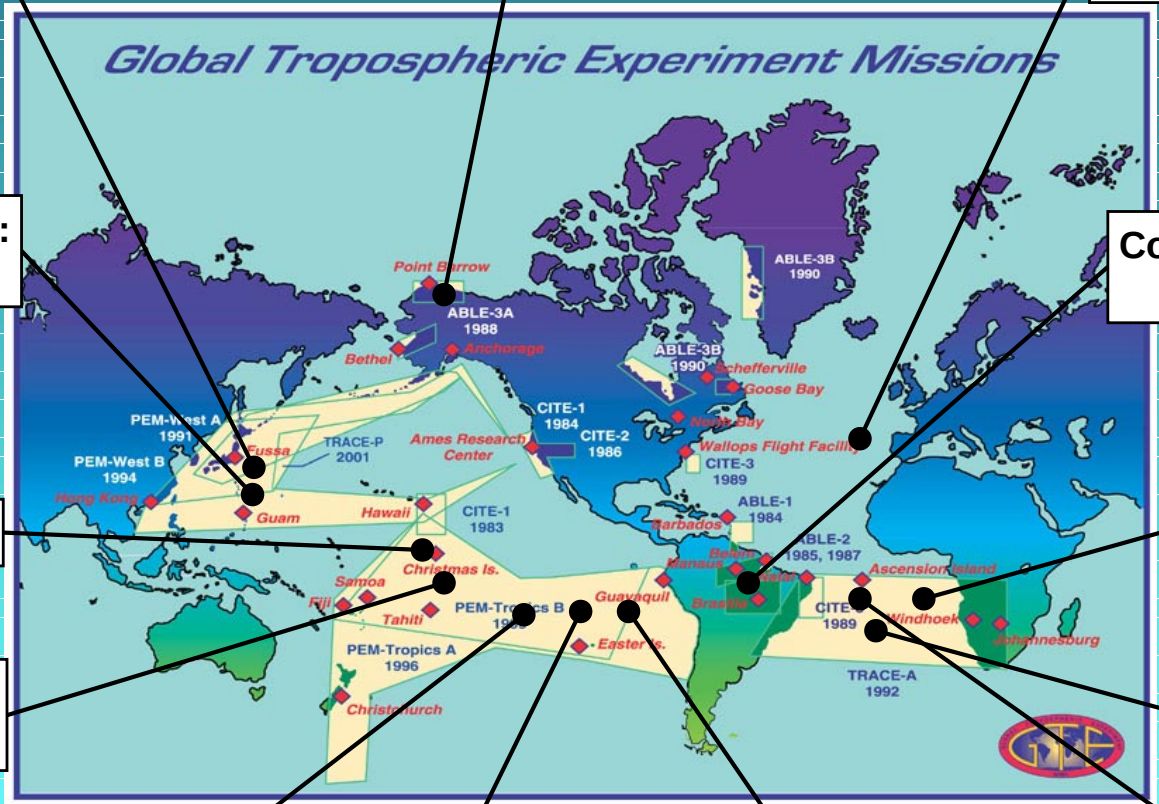
Reactive Nitrogen Budget

Long-Range Transport: Biomass Burning

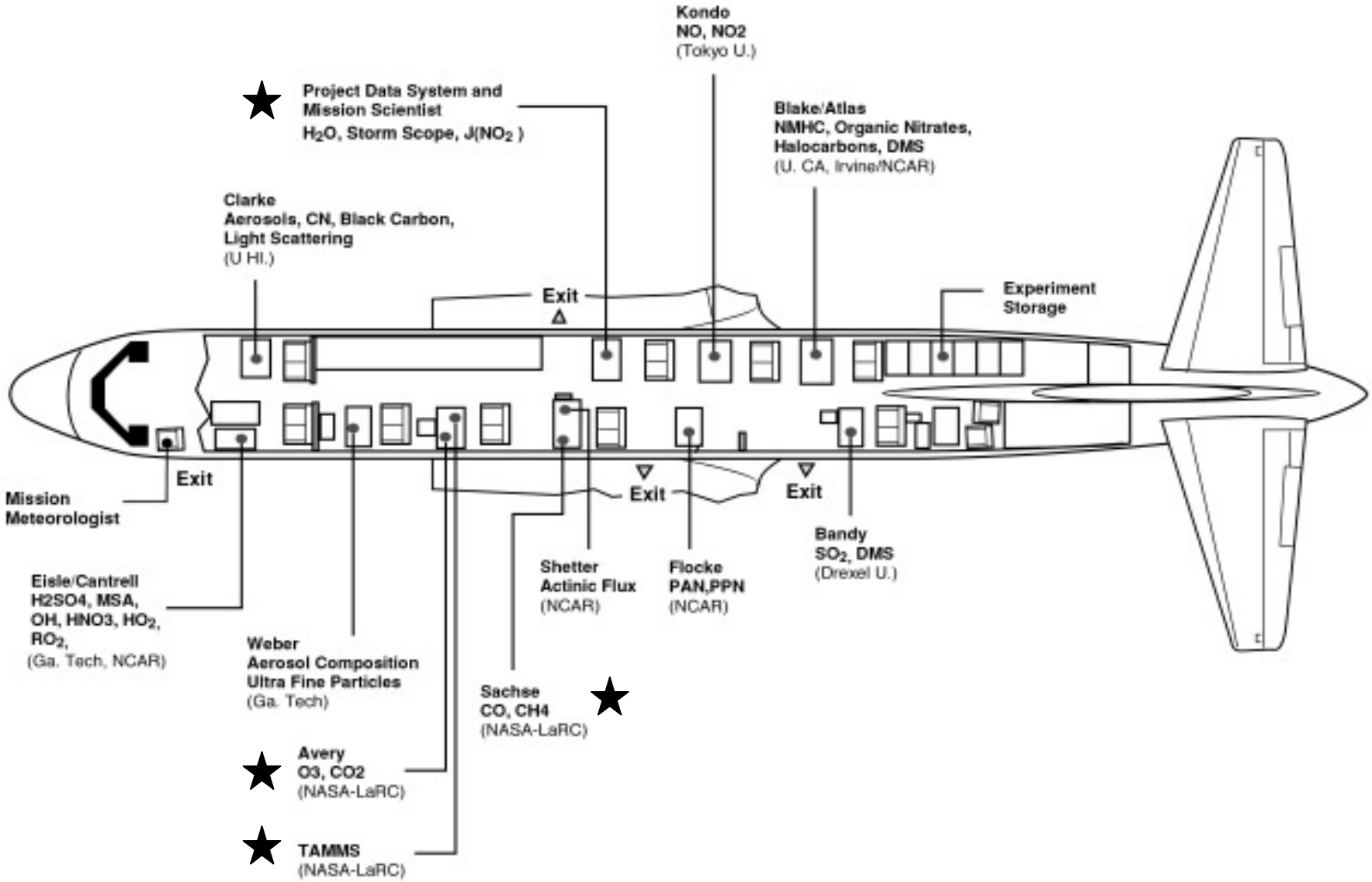
Fast Photochemistry: OH - HO_2

New Particle Formation

Atmosphere-Biosphere Exchange: Rainforest



Trace-P P-3B Mission Payload Floor Plan



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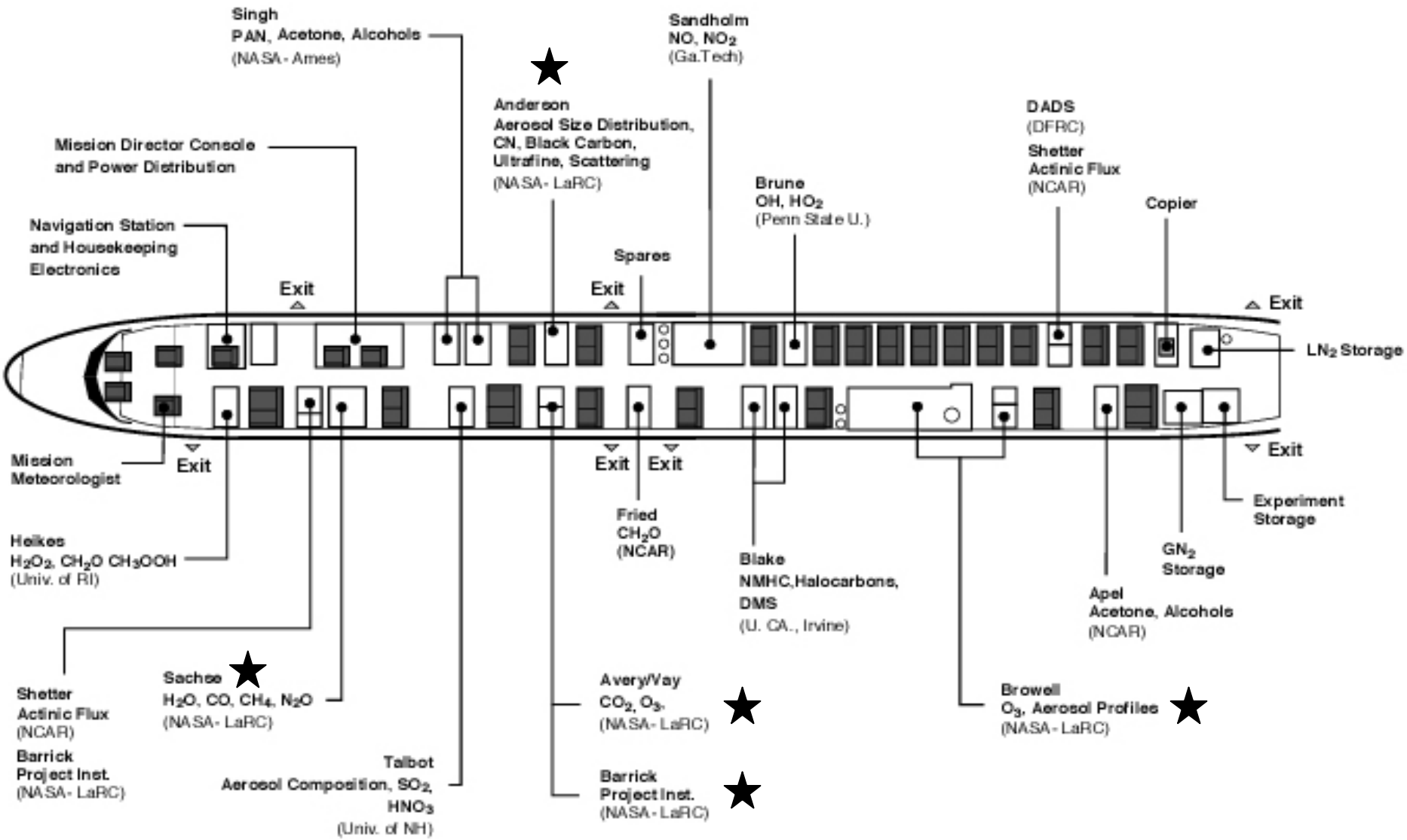
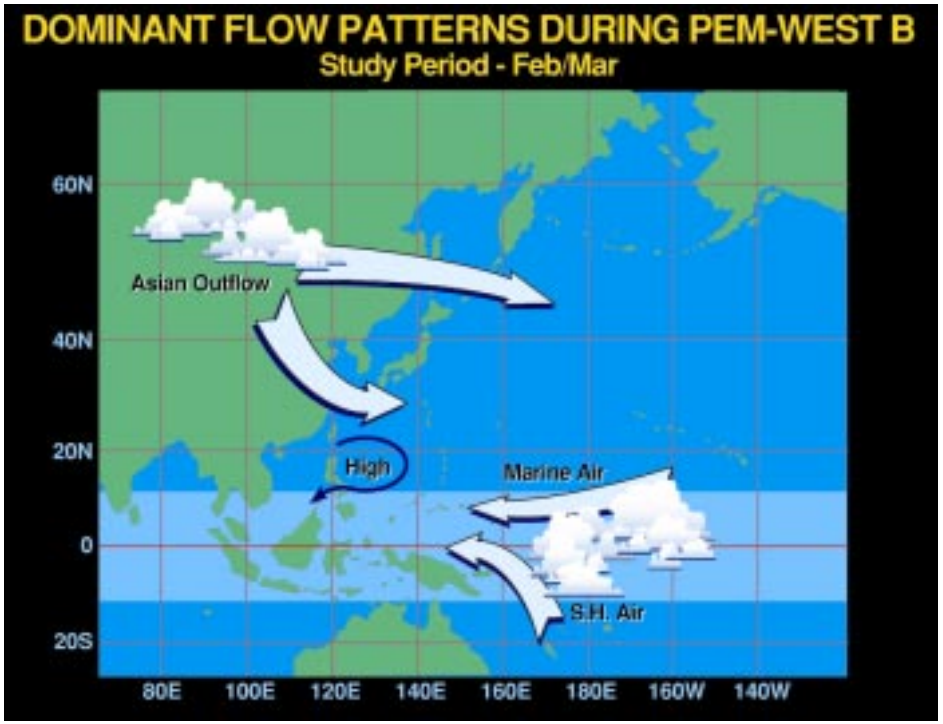
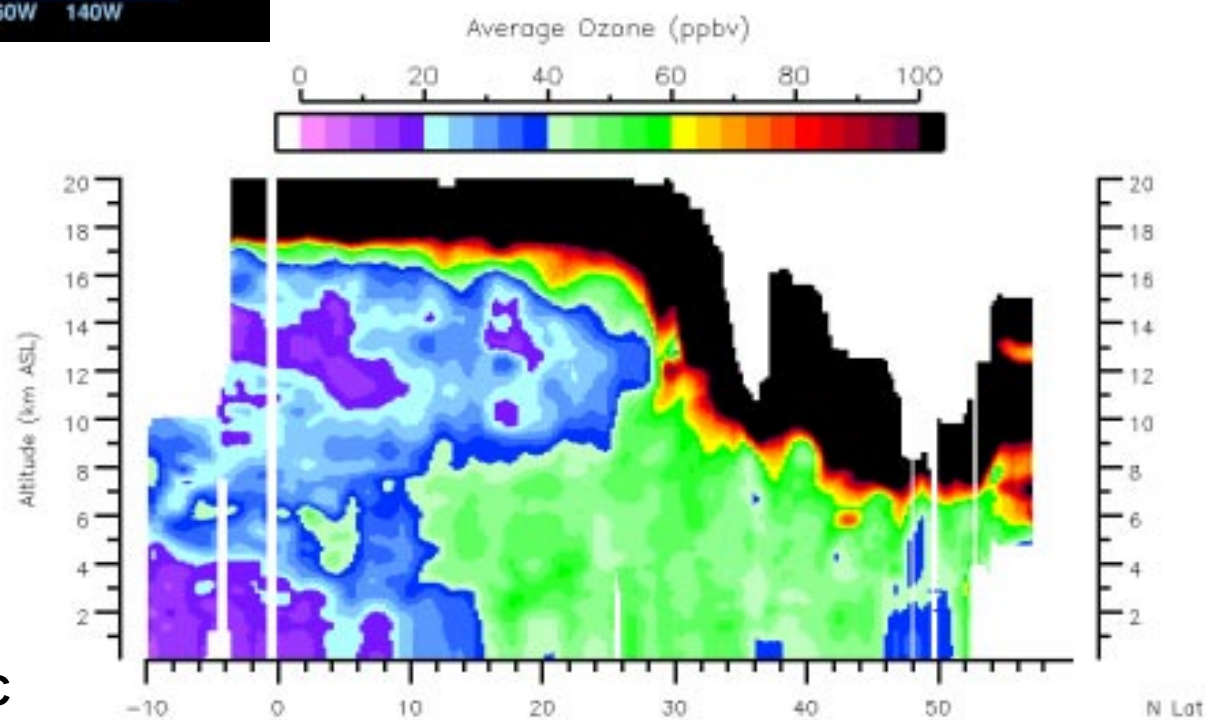
Trace-P DC-8 Mission Payload Floor Plan



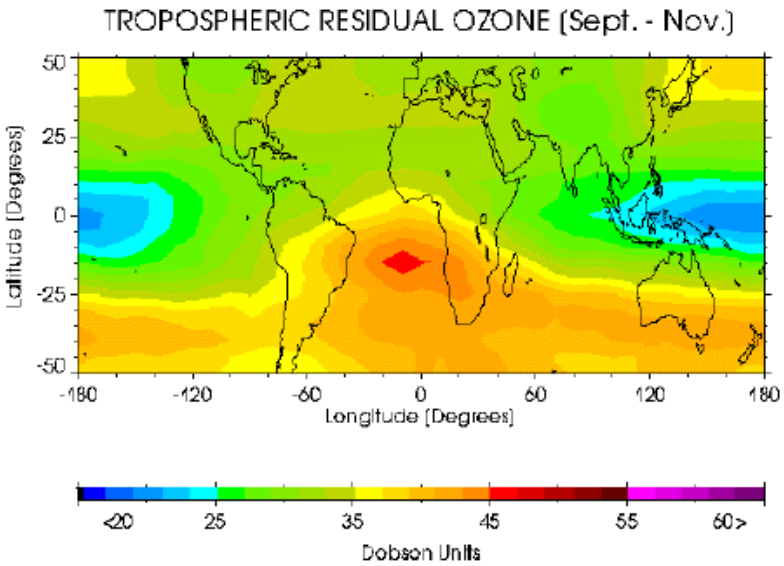


PEM-West B

Latitudinal Ozone Distribution Over Western Pacific

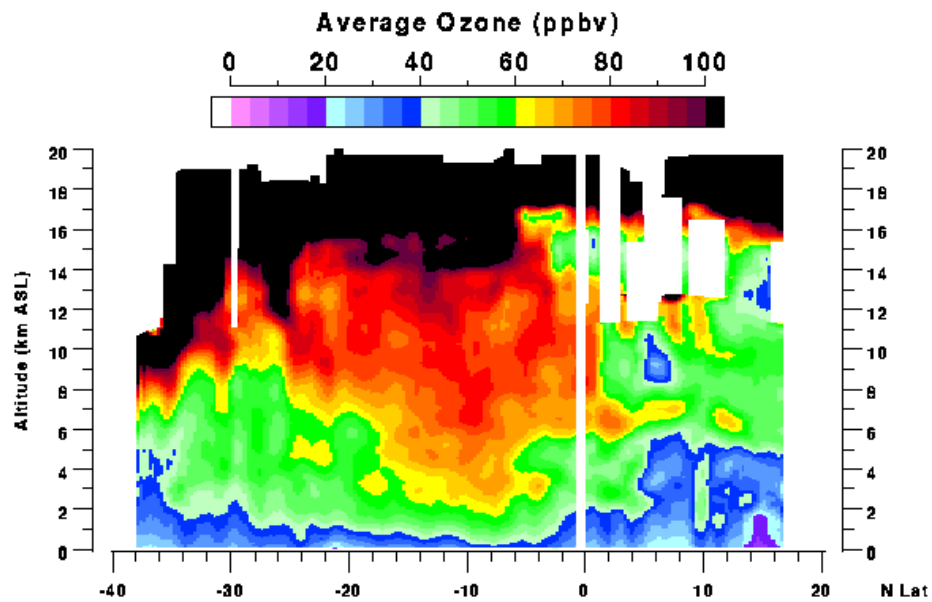


E. V. Browell, NASA LaRC



J. Fishman, NASA LaRC

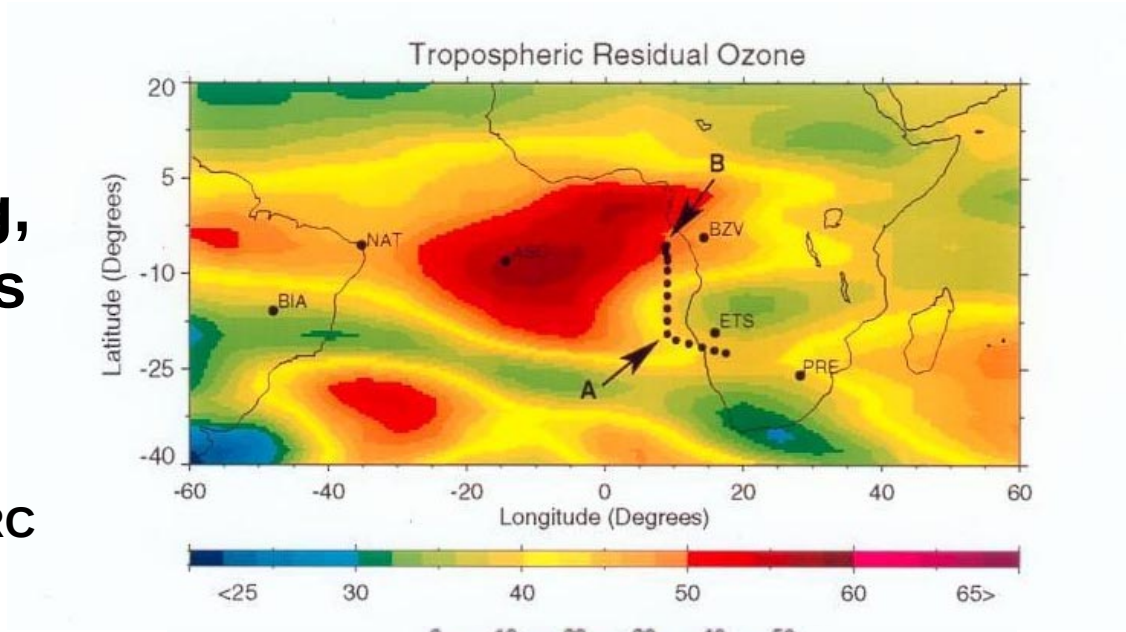
TRACE-A
Latitudinal Ozone Distribution Over the Atlantic Ocean

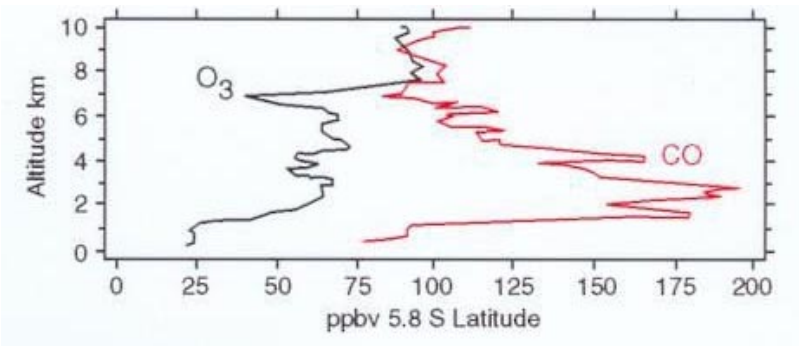


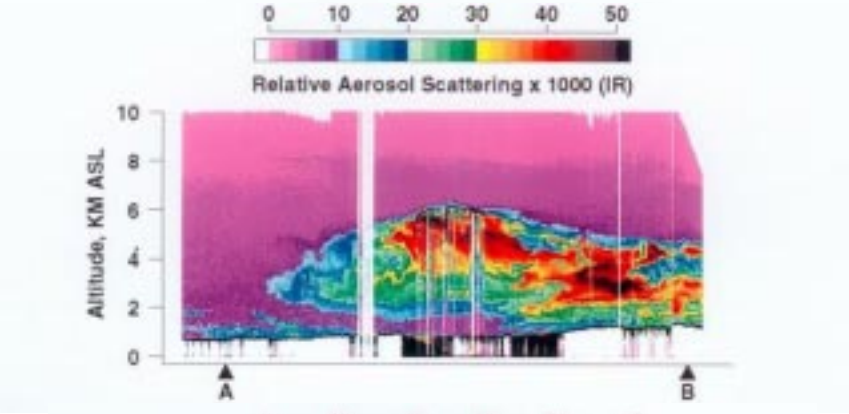
E. V. Browell, NASA LaRC

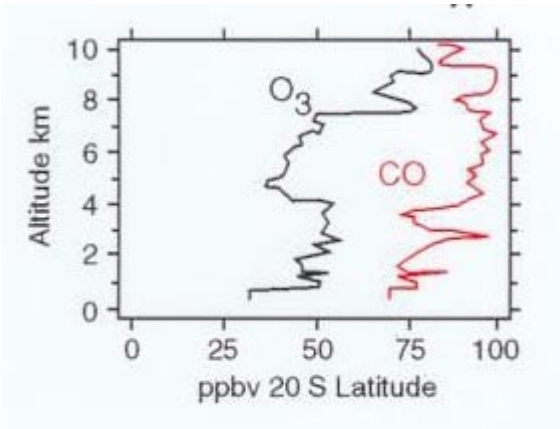
Linking Satellite Data, Airborne Remote Sensing, and In-Situ Measurements during TRACE-A

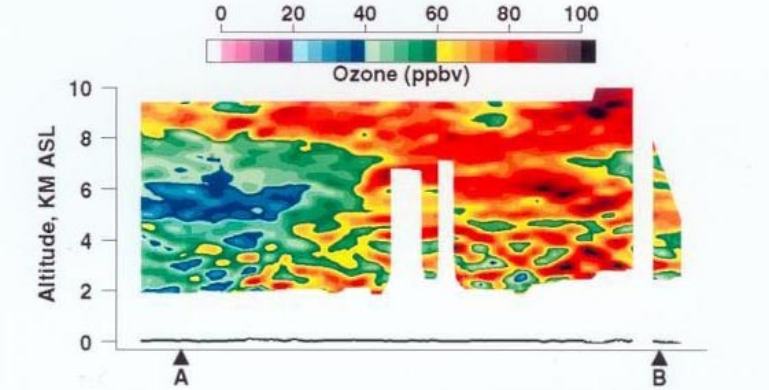
J. Fishman, E. V. Browell,
G. Gregory, and G. Sachse, NASA LaRC



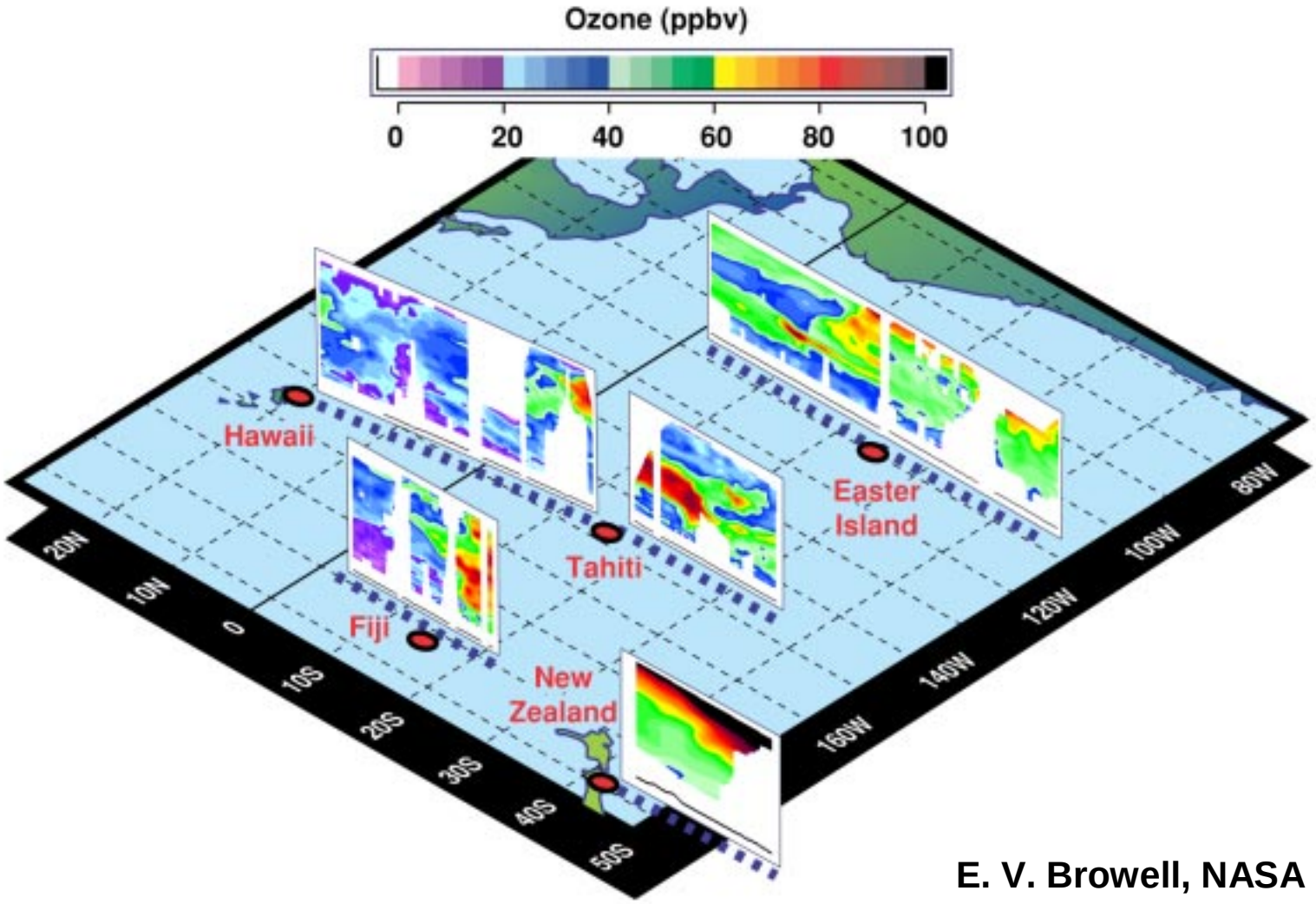






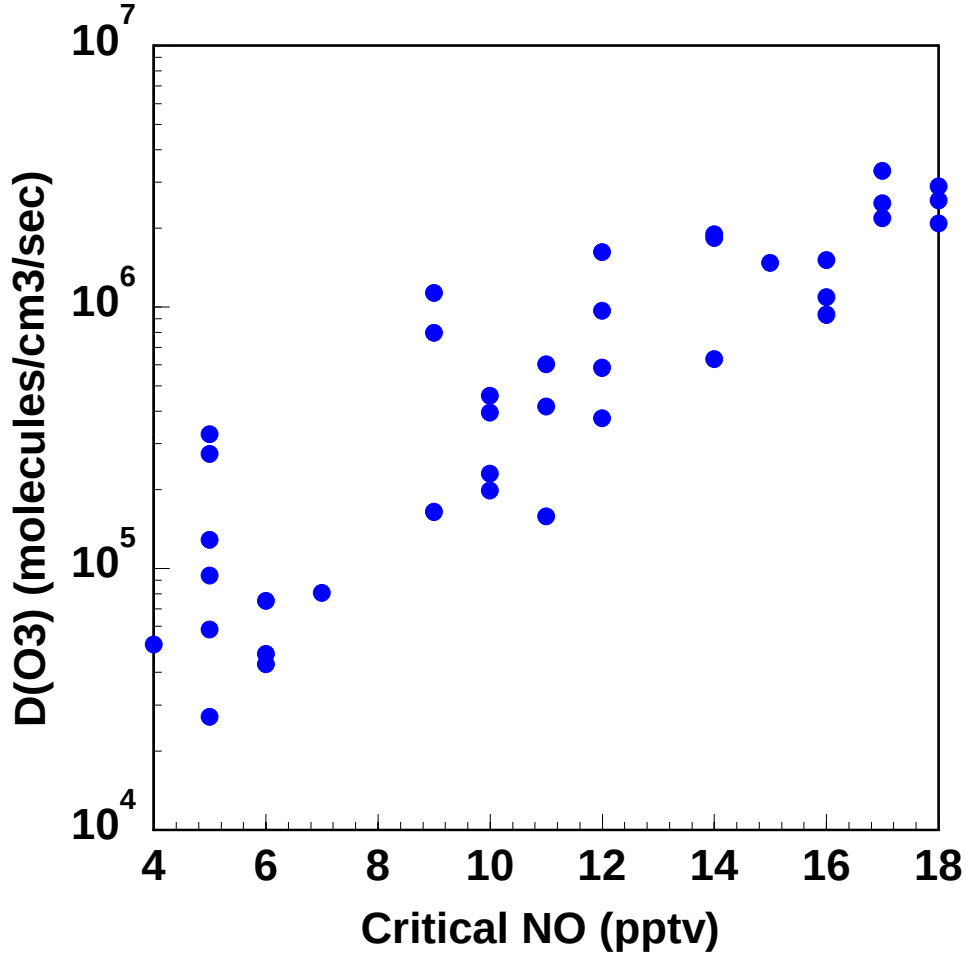


Long-Range Transport of Biomass Burning Emissions During PEM-Tropics B



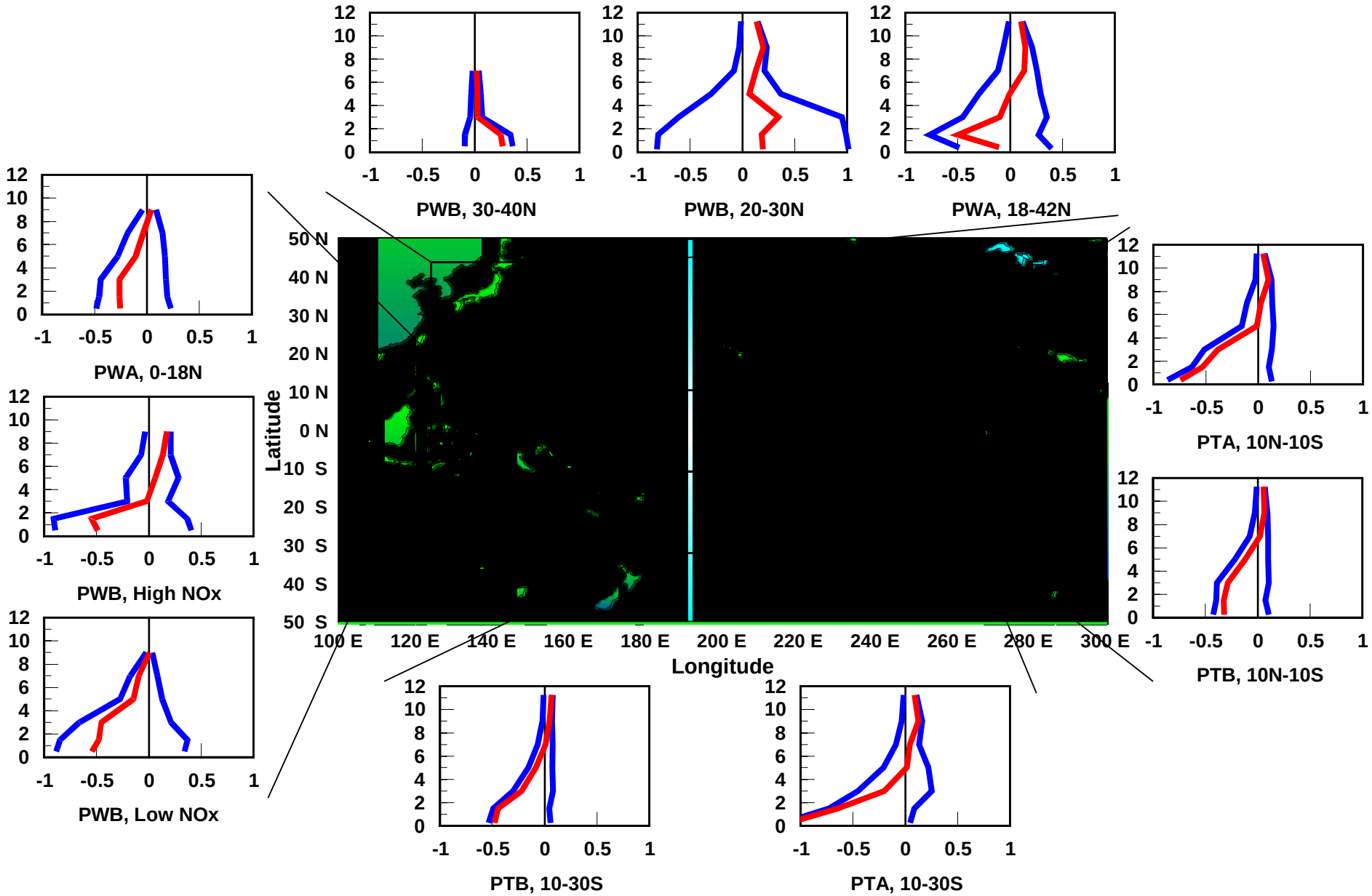
E. V. Browell, NASA LaRC

Critical NO: $F(O_3) = D(O_3)$

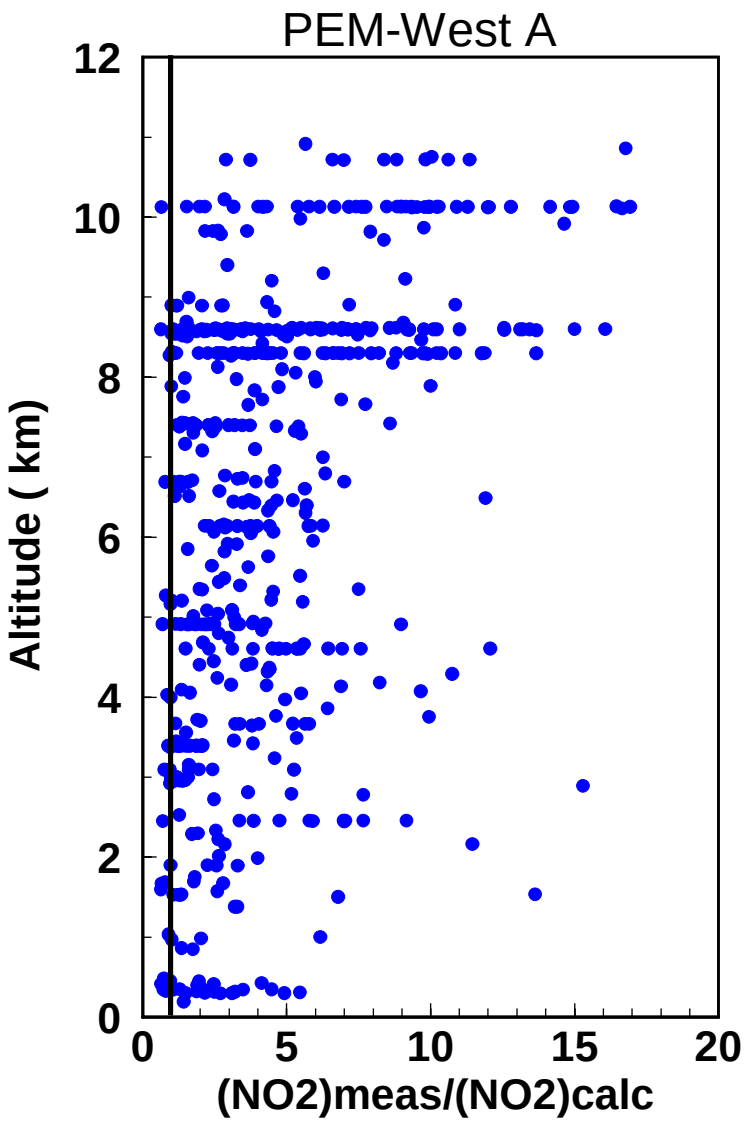


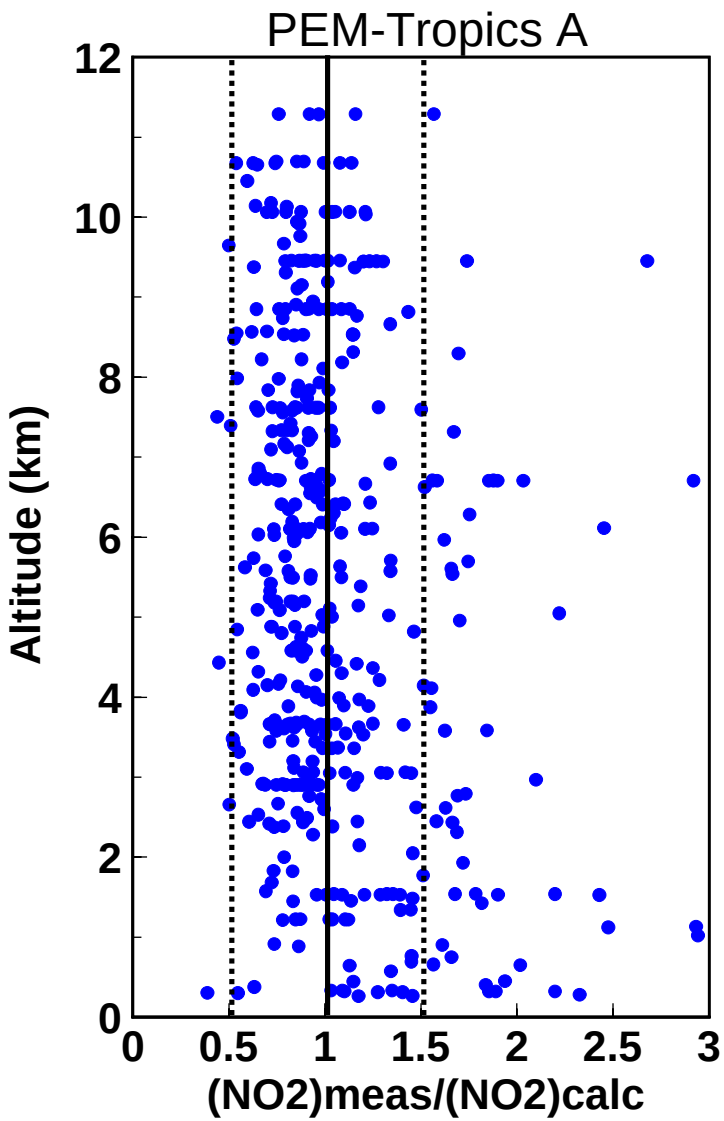
$F(O_3) = f(O_3, H_2O, h\nu, \mathbf{NO})$ $D(O_3) = f(O_3, H_2O, h\nu)$

Theoretical Estimates of Local Ozone Production from the Surface to 12 km Using Detailed Photochemical Box Models.

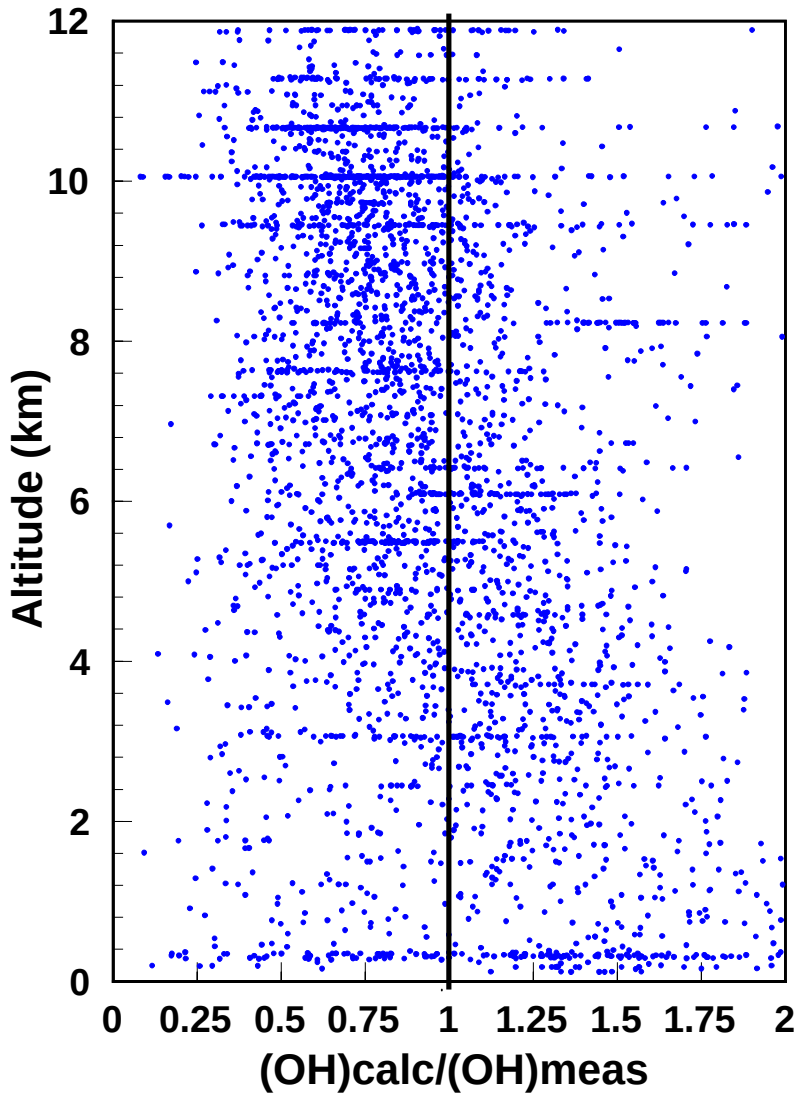


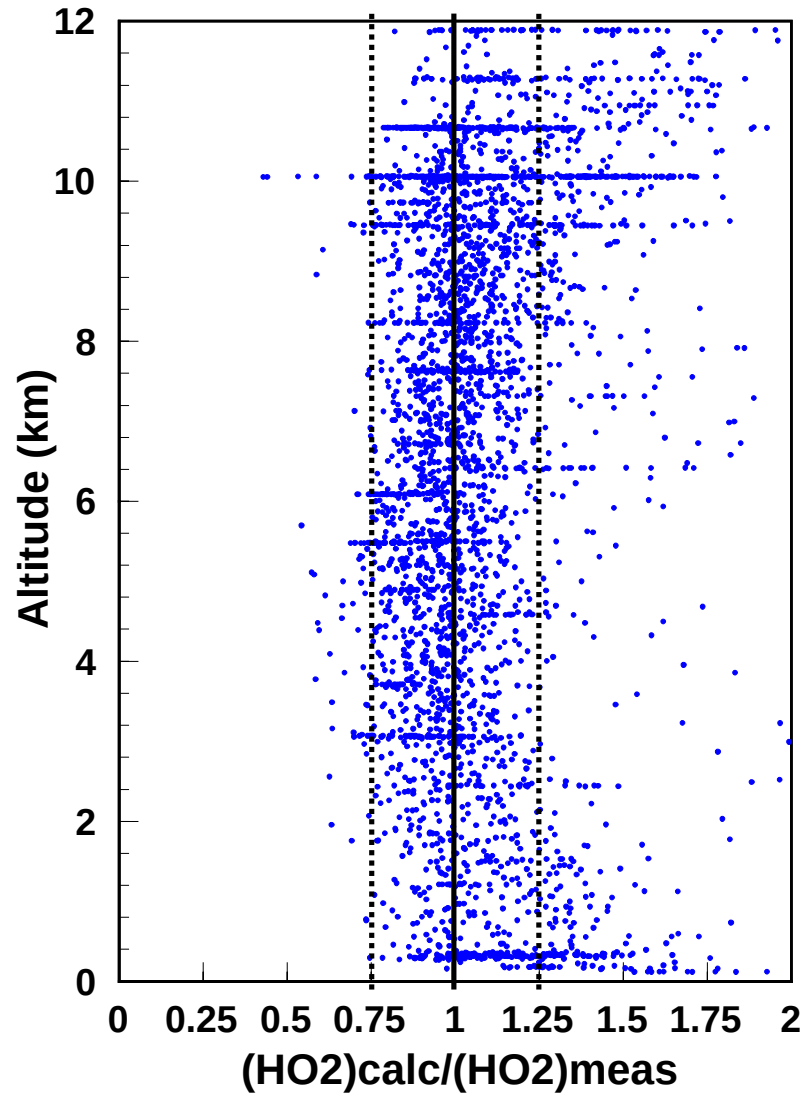
Photochemical Mechanism Testing: NO_2



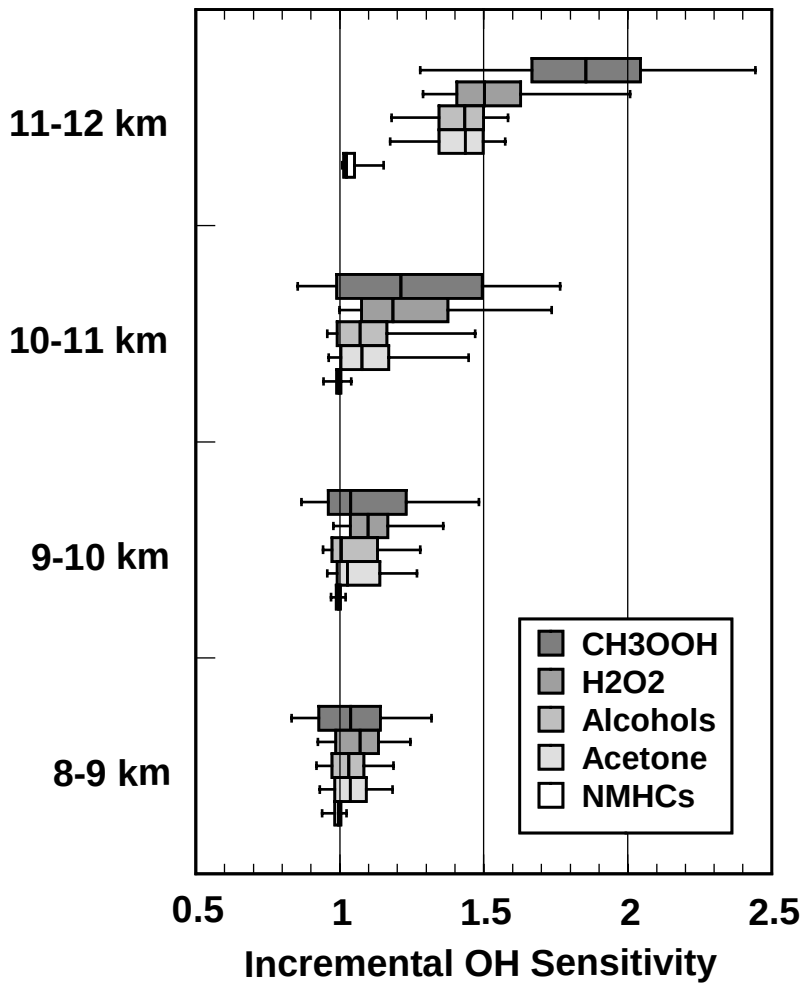


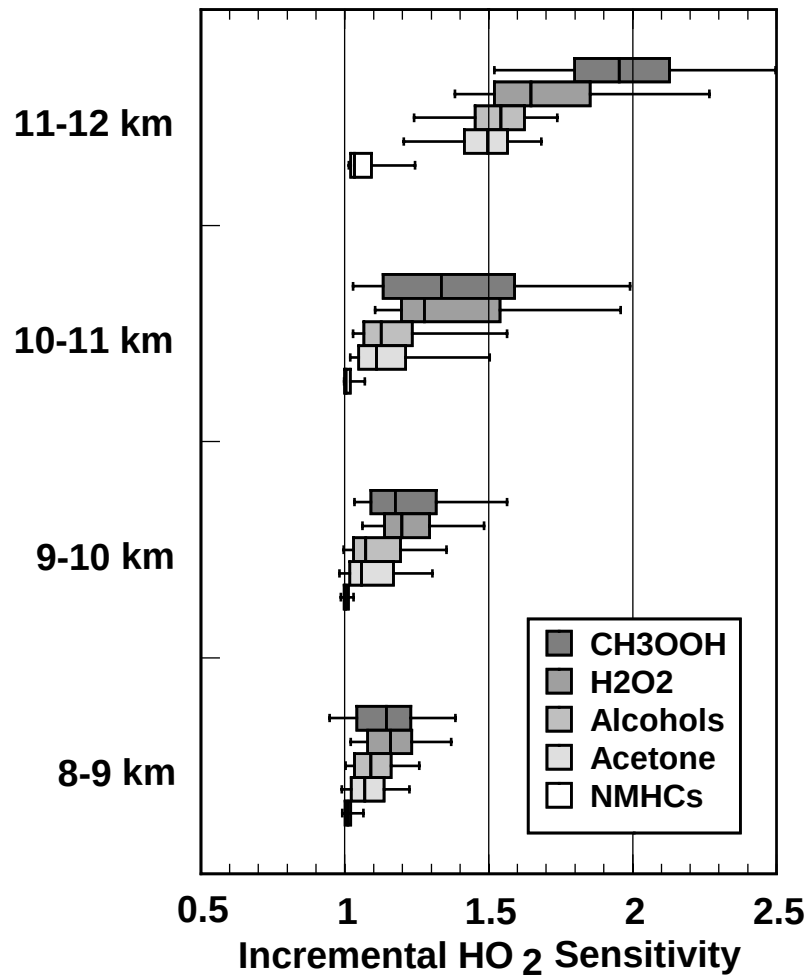
Photochemical Mechanism Testing: OH and HO_2
PEM-Tropics B





Sensitivity of Upper Tropospheric HOx to Additional Model Constraints



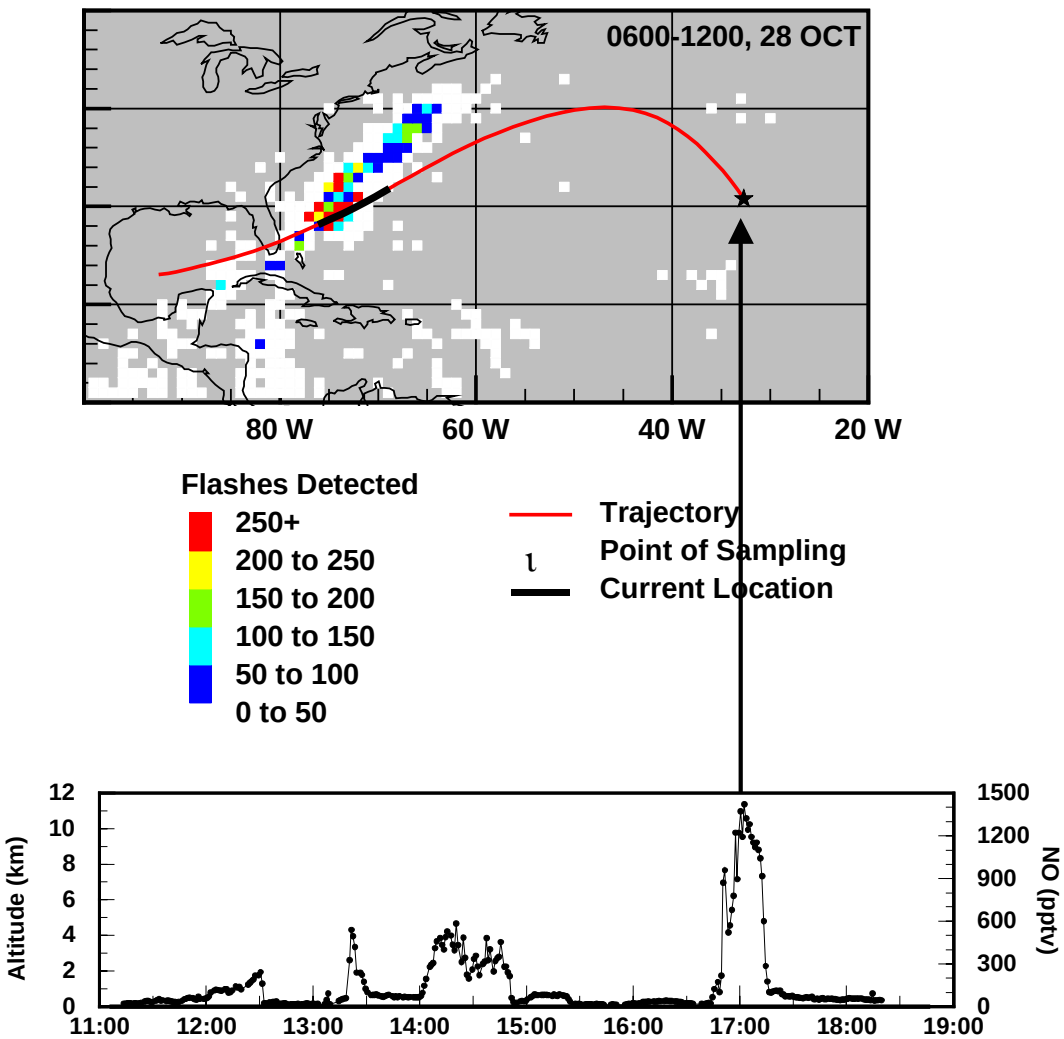
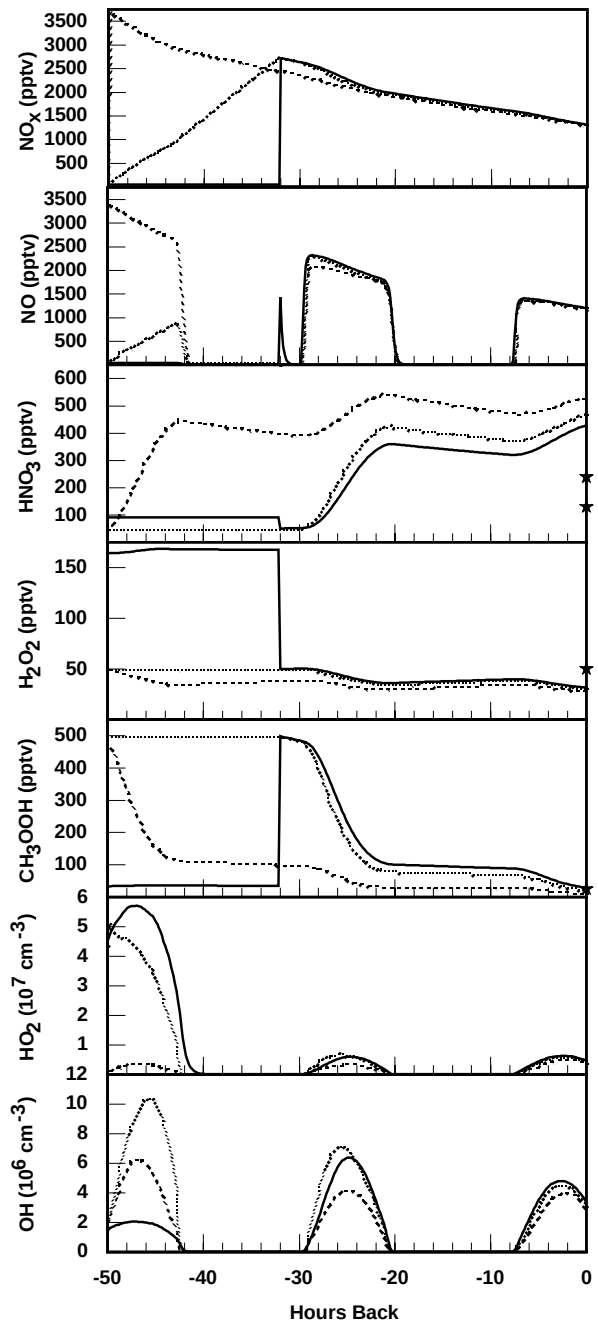


Future Directions for GTE:

Satellite validation

3-D Global and Regional Chemical Forecasting

Satellite Data Assimilation for 3-D Modeling

Detailed Trajectory Modeling

Modeling Chemical Evolution of Lightning NO_x Along a Trajectory