Chemical Weather Forecasts Using the MOZART-2 Global Model in ITCT 2K2

Larry W. Horowitz[1] (lwh@gfdl.noaa.gov), P. Hess[2], and J.-F. Lamarque[2]

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[1]GFDL/NOAA, Princeton, NJ

[2]NCAR/ACD, Boulder, CO

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Abstract

The Model for Ozone and Related Chemical Tracers (MOZART-2) was used as part of the Intercontinental Transport and Chemical Transformation field campaign (ITCT 2K2) conducted in Spring 2002 over the western United States and eastern Pacific. MOZART, a global chemical transport model, was used to forecast future chemical conditions, including the distributions of CO, NO_x, O_3, and other trace species. These forecasts, along with those from several other global and regional models, were used to aid in the flight planning process. Of particular interest were forecasts of the timing and location of long-range pollution transport events from Asia. MOZART was also re-run at higher resolution after the field campaign, using analyzed meteorological input fields and regionally tagged CO tracers, to aid in the interpretation of the observations.

We evaluate the performance of the MOZART-2 forecast and analysis simulations. We present several cases studies comparing the model results with the observations taken aboard the NOAA WP-3D aircraft during the field campaign. The first case study features a long-range transport event observed during the May 5 flight. In this plume, high concentrations of CO and other combustion tracers were observed. Results from MOZART-2 successfully forecast the location and timing of this transport event, but underestimated the concentrations of CO. We present a model analysis of the important source regions for this pollution plume. The second case study focuses on a stratospheric intrusion sampled on the May 10 flight. MOZART-2 successfully simulated the transport of ozone-rich air (O_3 > 100 nmol/mol) down to the mid-troposphere in this event.

MOZART-2 Model Description

[Horowitz et al., 2002]

Resolution
- 1.9^o latitude x 1.9^o longitude (post-mission analysis)
- 2.8^o latitude x 2.8^o longitude (forecast and analysis during mission)
- 42 sigma vertical levels (surface-2 hPa)

Timestep
- 15 minutes for all processes (20 minutes for 2.8^o runs)

Meteorology
- From NCEP Aviation Model (AVN) analysis and forecast, every 3 hours
- Interpolated from T170 horizontal resolution (0.7^o x 0.7^o)

Photochemistry
- 65 chemical species, 135 kinetic + 33 photolysis reactions
- Tagged fossil fuel and biomass burning CO (9 regions)

Surface emissions
- Anthropogenic emissions, EDGAR [Olivier et al., 1996]
- Biomass burning [Hao and Liu, 1994; Mueller, 1992; Granier et al., 1999]
- Biogenic emissions GEIA [Guenther et al., 1995]
- Soil emissions [Yienger and Levy, 1995]
- Oceanic emissions [Brasseur et al., 1998]

Lightning
- NO_x source in convective clouds (3 TgN/y)
- [Price et al., 1997; Pickering et al., 1998]

Advection
- Flux-form semi-Lagrangian scheme [Lin and Rood, 1996]

Convection
- Rediagnosed using Zhang & MacFarlane [1995] and Hack [1994]

Dry deposition
- Velocities calculated using Gao and Wesely [1995], based on
- 10 years of 6-hourly NCEP Reanalysis data

Wet deposition
- Based on Giorgi and Chameides [1985]

Boundary layer diffusion
- Based on Holtslag and Boville [1993]

MOZART-2 Analysis and Forecast

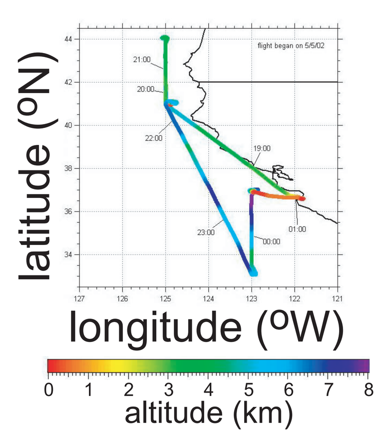
MOZART-2 was run in analysis and forecast mode using meteorological inputs from the NCEP Aviation Model (AVN). Meteorological fields every three hours were produced, using the AVN analysis and 3-hour forecast fields supplied four times daily. The meteorological variables were interpolated horizontally from T170 (0.7^o) resolution to the model resolution, maintaining the vertical resolution of the AVN fields (42 sigma levels).

During the field campaign, a 3-day chemical weather forecast from MOZART-2 was produced daily, using the 12 UTC AVN forecast fields. A near real-time analysis was also produced daily, using AVN analysis fields. These runs, which were performed at NCAR, used a horizontal resolution of 2.8^o. Selected plots of the 6-hourly output from the analysis and forecast runs were generate automatically and placed on a web page. Additional plots could be generated manually from the model output data files.

After the end of the field campaign, MOZART-2 was run at GFDL to produce a higher-resolution (1.9^o) chemical weather analysis for the campaign period, with more frequent output (every 3 hours). These runs also included tagged CO tracers from fossil fuel and biomass burning emissions in 9 geographical regions. The MOZART-2 results shown in this presentation are from the post-mission analysis run.

May 05 Flight
Long-range Transport of Pollution

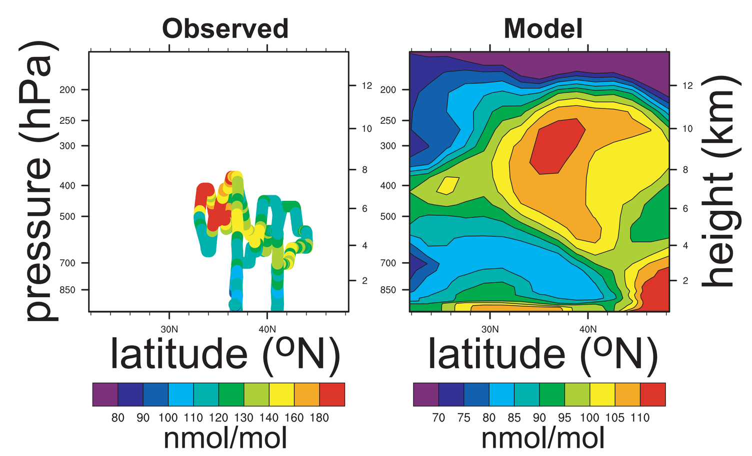
Flight Track



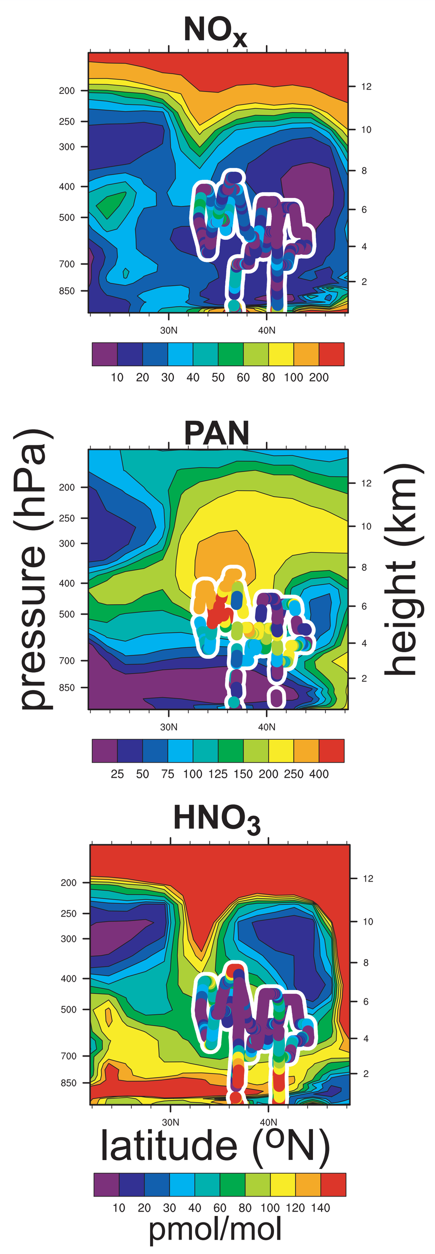
(Left) Flight track for the flight on May 5, 2002. A long-range transport pollution plume was encountered during this flight, most notably near the southern edge of the flight at approximately 6 km altitude.

(Right) Mixing ratios of carbon monoxide (CO) observed and simulated by MOZART. Model results are for 124W at 0 UTC, May 6.

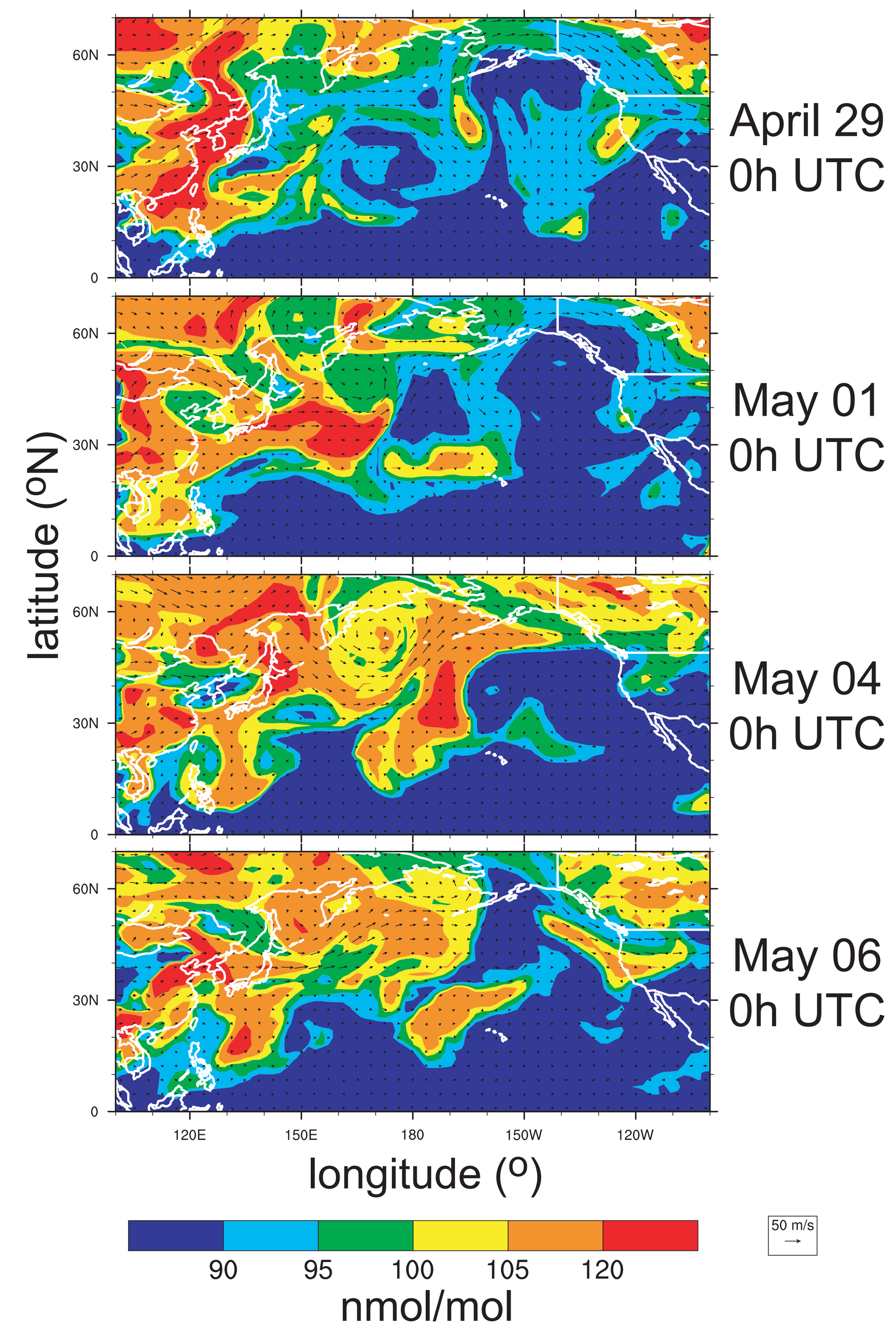
CO (124°W)



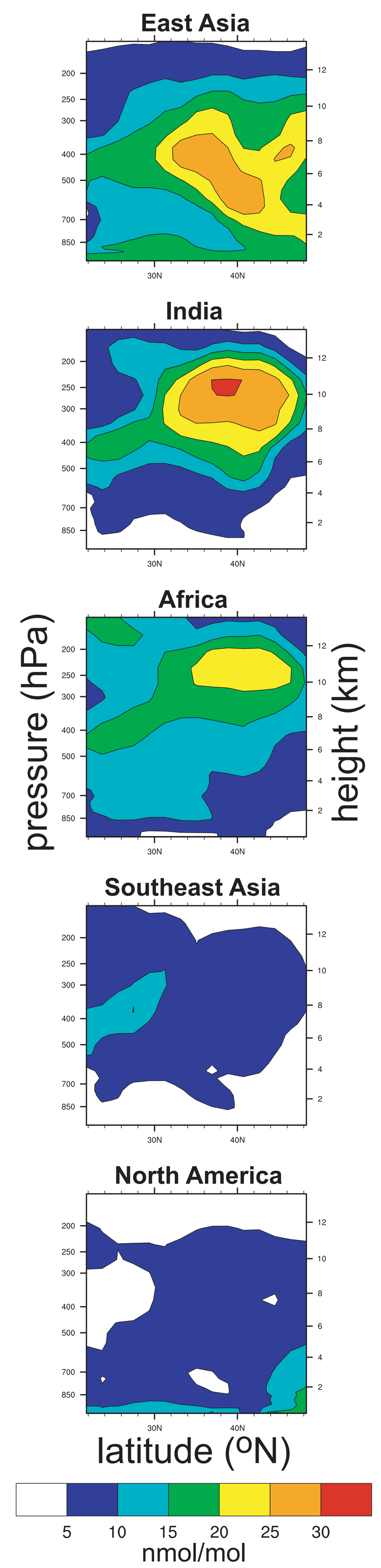
Reactive Nitrogen (NO_y) Species (124°W)



Model CO (500 hPa) Transport History



Model CO (124°W) Tagged by Source Region



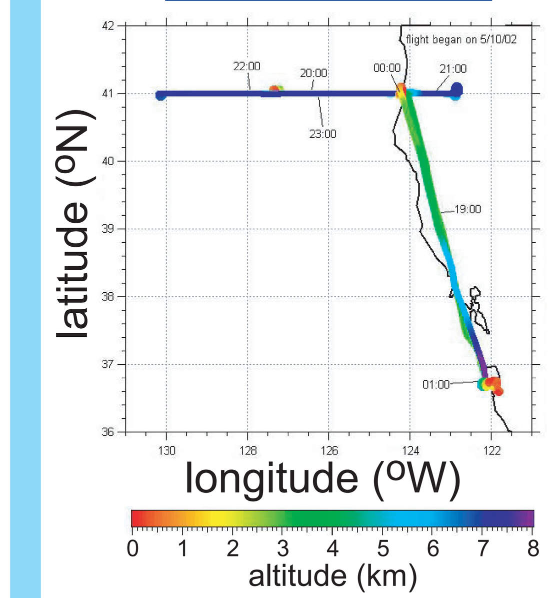
(Left) Mixing ratios of reactive nitrogen species (NO_x, PAN, HNO_3) observed and simulated by MOZART. Model results (shaded contours) are for 124°W at 0 UTC, May 6. Observations are indicated by colored dots.

(Middle) Transport history for pollution plume encountered during May 5 flight. Panels show mixing ratio of CO at model level corresponding approximately to 500 hPa at 0 UTC: 7 days before flight (top), 5 days before flight, 2 days before flight, and during flight (bottom).

(Right) Simulated mixing ratio of CO resulting from emissions from industrial and biomass burning sources in various source regions.

May 10 Flight
Stratospheric Intrusion

Flight Track

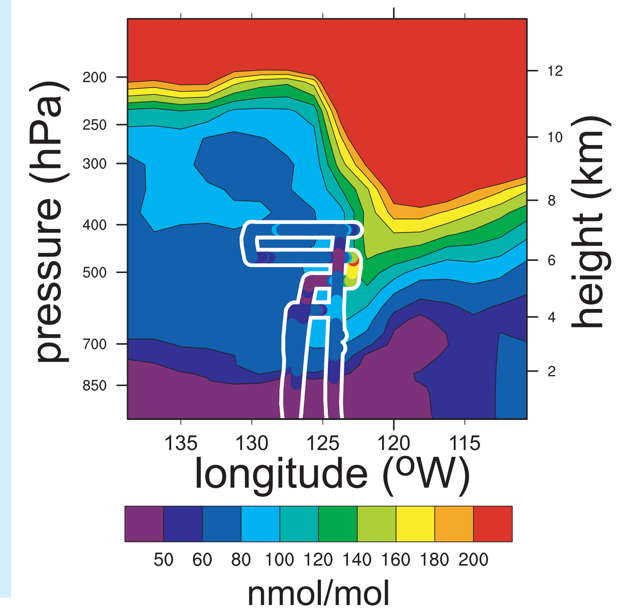


(Left) Flight track for the flight on May 10, 2002. Air with strong stratospheric influence was encountered during this flight, most notably near the northeastern edge of the flight at approximately 6 km.

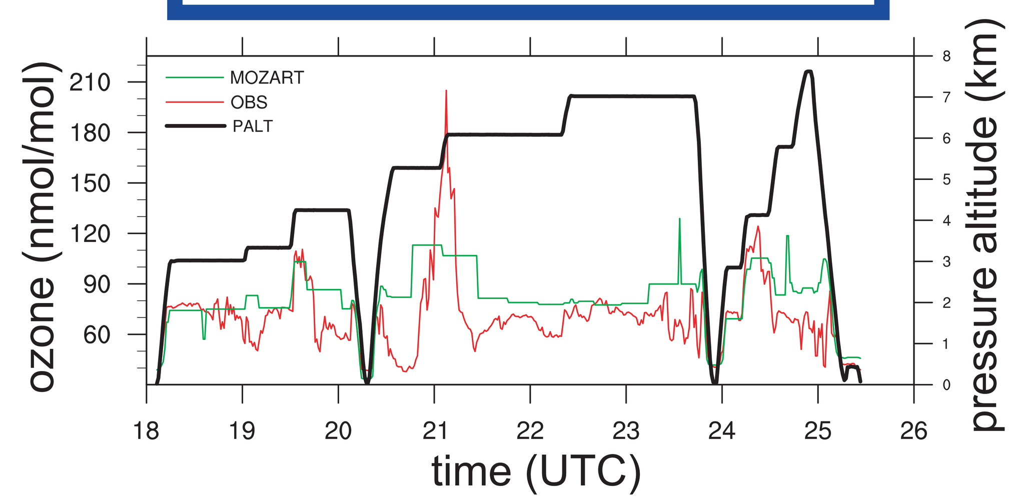
(Right) Mixing ratios of ozone (O_3) observed and simulated by MOZART. Model results (shaded contours) are for 124°W at 21 UTC, May 10. Observations are indicated by colored dots.

(Below) Time series of observed (red) and simulated O_3 (green) along flight track. Pressure altitude is indicated by the black line (right axis). Note the significant enhancement in O_3 at approximately 21 UTC (at 5-6 km) in the observations and the model results, indicating strong stratospheric influence.

Ozone (41°N)



Ozone Along Flight Track



Conclusions

* MOZART-2 chemical weather forecasts provided extremely useful information in guiding day-to-day flight planning during the ITCT 2K2 field campaign
* The model successfully simulated a variety of chemistry and transport conditions observed during ITCT 2K2
* MOZART-2 showed considerable skill in forecasting the location and timing of long-range transport plumes, but tended to underestimate pollutant concentrations within these plumes
* Events of stratospheric influence (indicated by high ozone, low CO, low humidity) extending into the middle to lower troposphere were well simulated by the model
* Comparison of results from various chemical transport models would help improve understanding of factors contributing to model performance

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