GMI and CCM Convective Transport Evaluation

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Objectives

- 1) Evaluate the convective transport of tracers and wet scavenging of soluble species in the GEOS-5 CCM using comparisons between a series of cloud-resolving model simulations for particular observed convective events and simulations conducted with a Single-Column Model version of GEOS-5.
- 2) Perform sensitivity studies in the Single-Column Model to determine optimal improvements in the representation of the convective transport and wet scavenging processes.
- 3) Evaluate convective transport in existing GMI CTM simulations using data from convective field experiments.
- 4) Implement the suggested improved convection and scavenging algorithms in the full GEOS-5 model and run multiple-year simulations with the CCM and off-line GMI CTM.
- 5) Use NASA satellite data to evaluate the global simulations with the improved model.
- 6) Analyze global simulations to determine the net effect of convection on tropospheric ozone under present day conditions and in future climates.

GEOS Parameterized Convection

- **GEOS-4:** Hack shallow convection
  Zhang and McFarlane deep convection
  used for initial “Aura” GMI simulations

- **GEOS-5:** Relaxed Arakawa Schubert (RAS) convection
  GEOS-5.1 – used for GMI offline simulations
  GEOS-5.2 (MERRA) – being used for new GMI runs
  some tuning of RAS done for 5.2
  GEOS-5 (Fortuna) – being used in GEOS-5 CCM
  only significant changes affecting convection were in prognostic cloud scheme: increased re-evaporation of grid-scale and convective precipitation; reformulation of critical relative humidity used to calculate grid-scale condensation/sublimation.

Evaluation Procedures

- **GMI CTM**

  Has been driven by GEOS-5.1 DAS data

  Compare tracer profiles from GMI directly with aircraft data from convective field missions (e.g., TC4, AMMA)

  Perform similar comparison for GMI driven by GEOS-4 DAS

  Compare GEOS-4 and GEOS-5.1 cloud tops, cloud mass fluxes

- **GEOS-5 CCM**

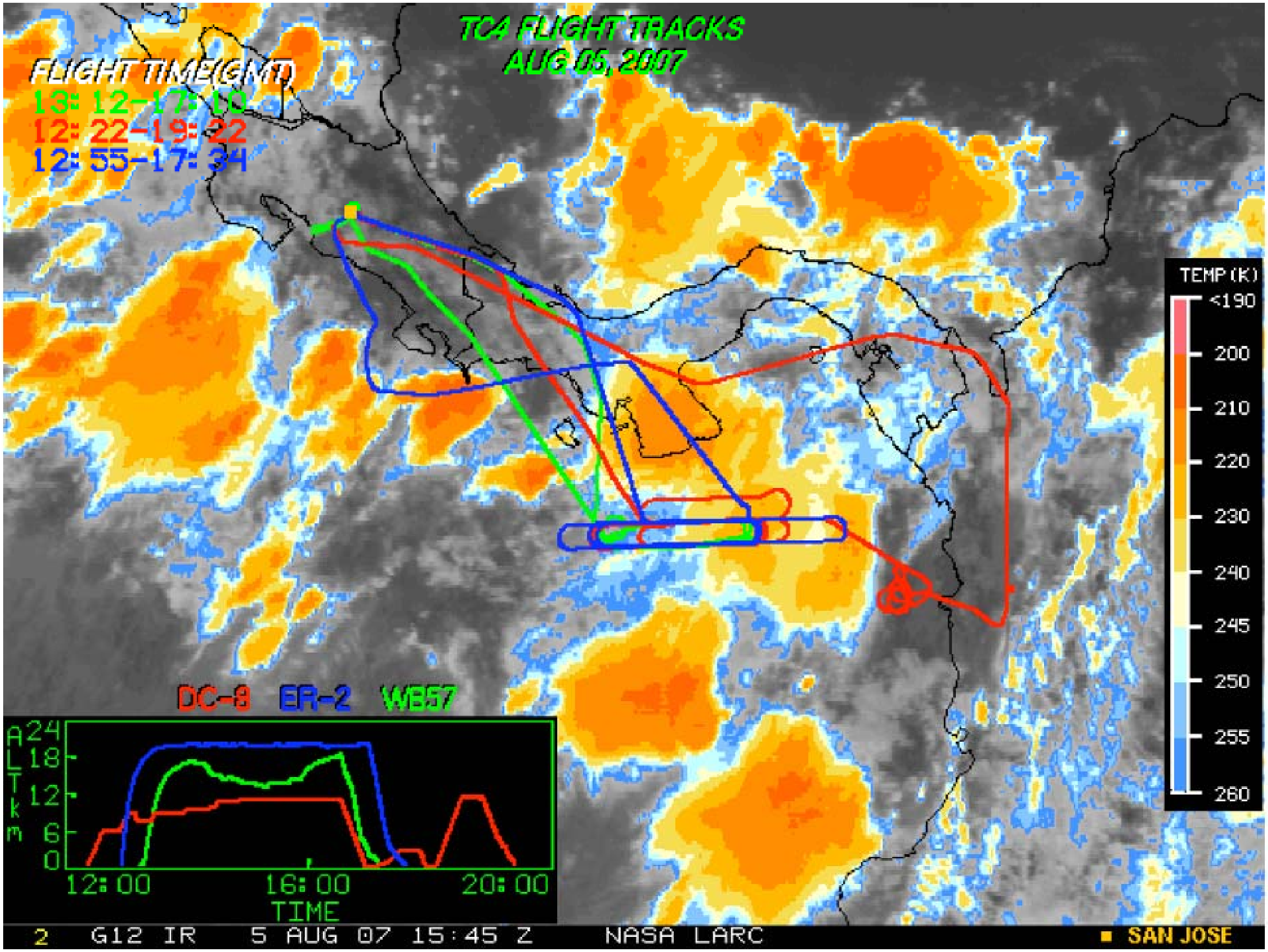
  Select specific events from convective field experiments to simulate tracer transport in detail using a cloud-resolved model (Weather Research and Forecast (WRF) model)

  Simulate tracer transport in same events using Single Column Model (SCM) option of GEOS-5 Fortuna 2.1 (forced by MERRA)

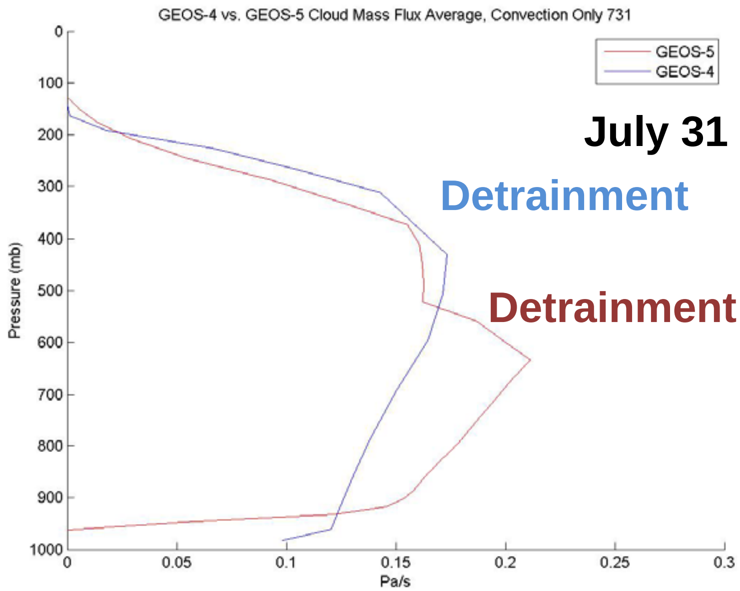
  Evaluate SCM tracer using WRF results

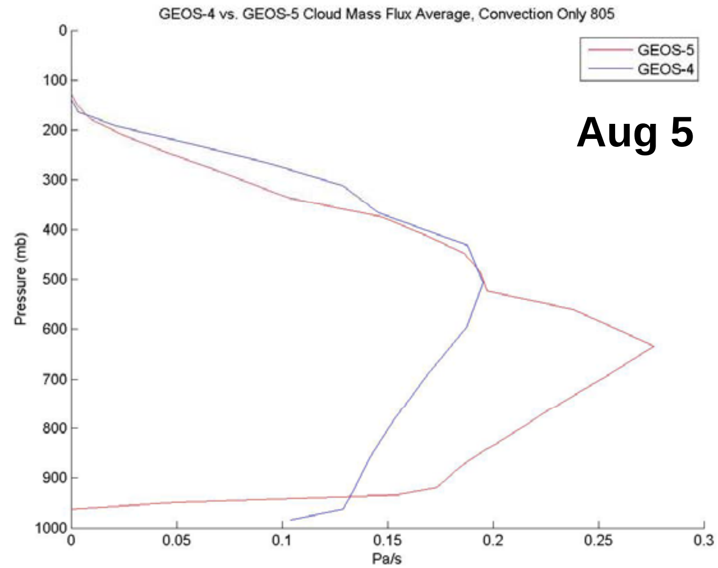
  Adjust RAS parameters to improve agreement

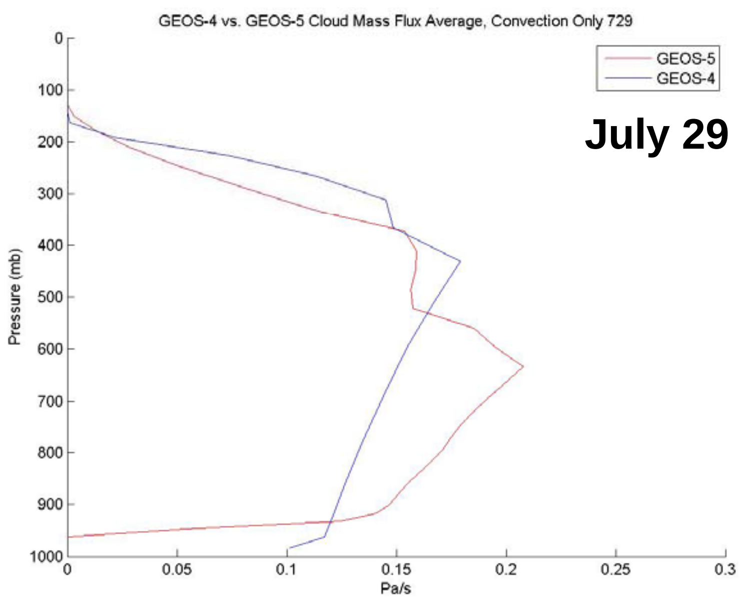
Tropical Composition, Cloud and Climate Coupling (TC4) – July/August 2007

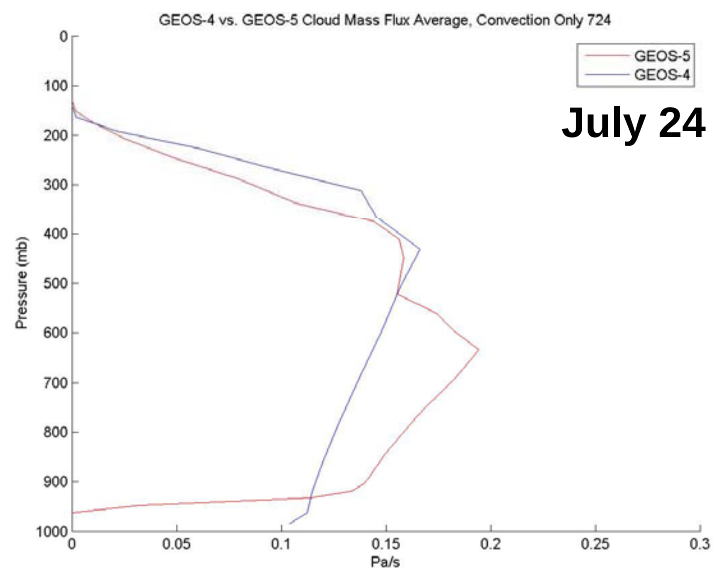


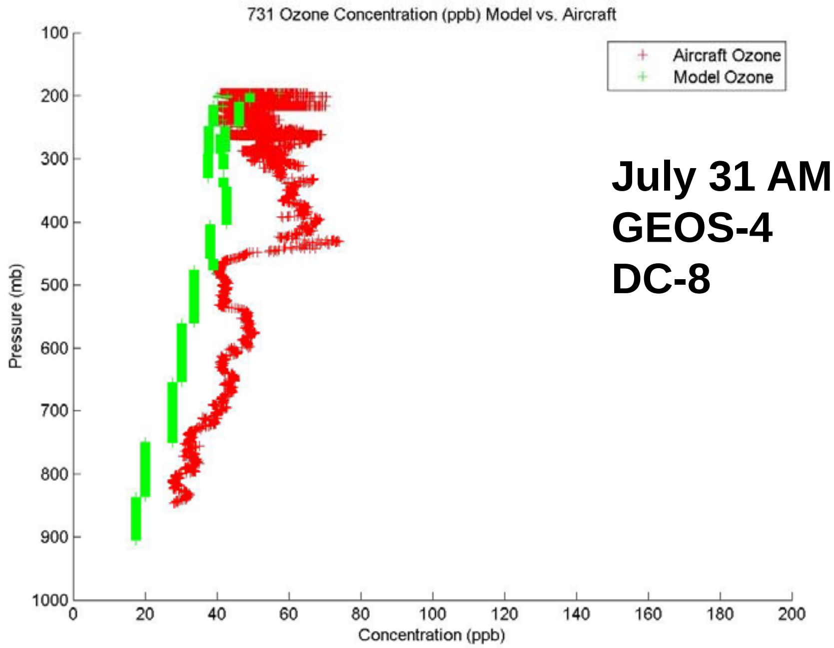
GEOS-4 vs. GEOS-5.1 Upward Cloud Mass Flux Profiles

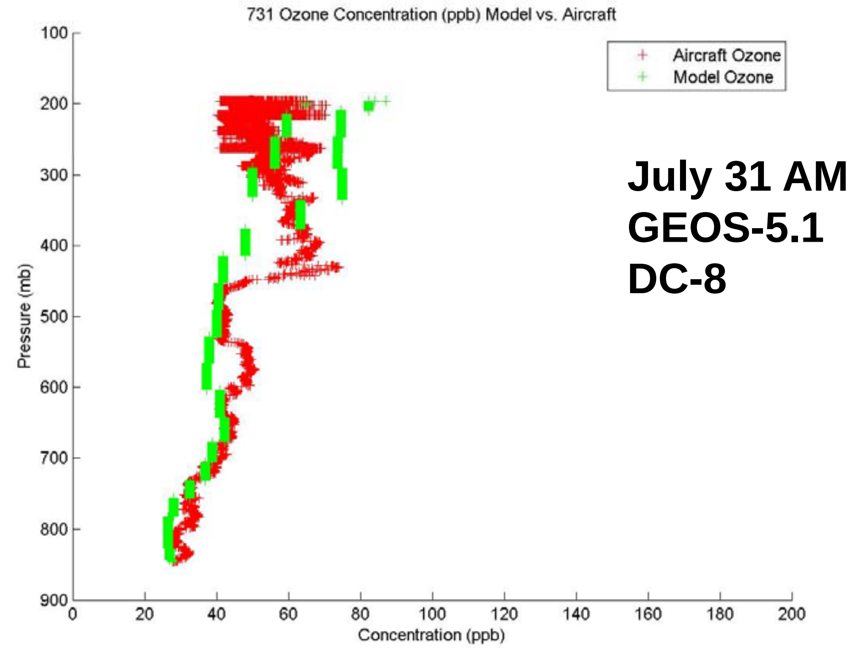


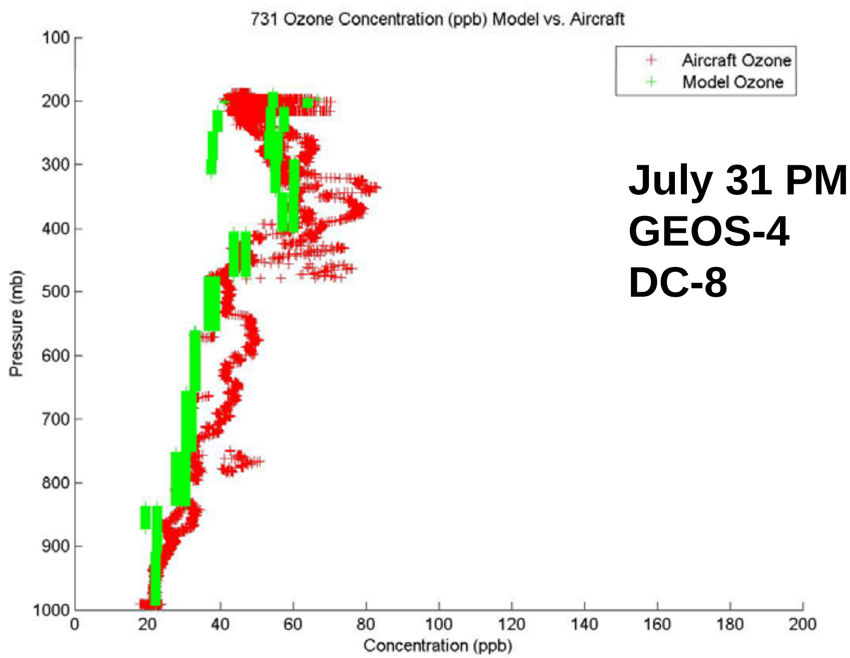


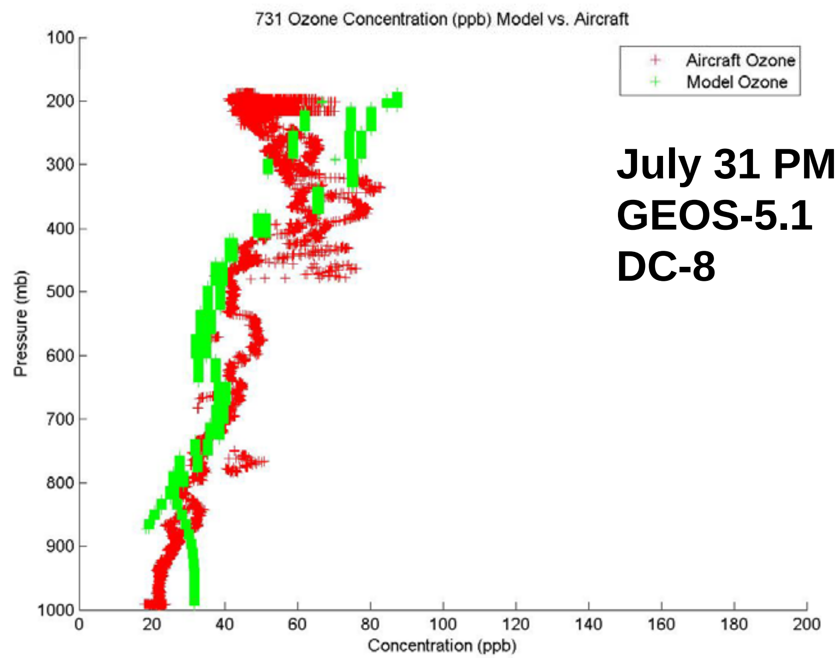


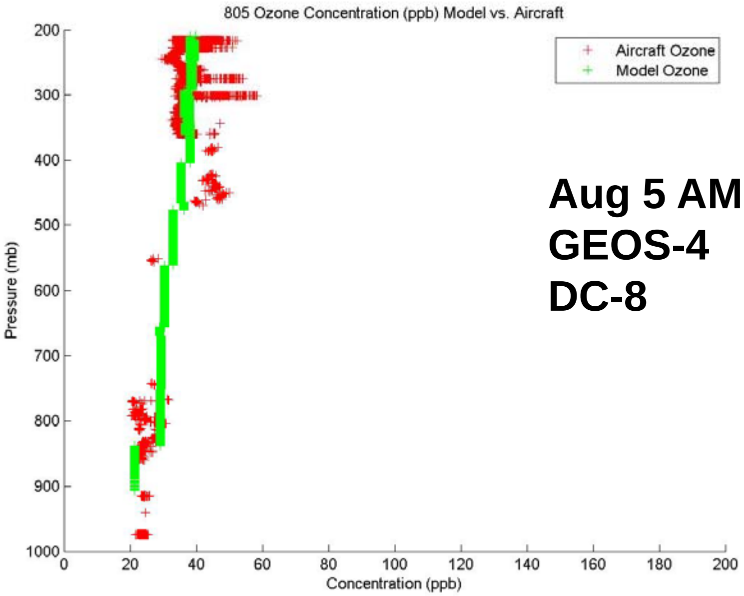



731 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
July 31 AM
GEOS-4
DC-8
Pressure (mb)
Concentration (ppb)

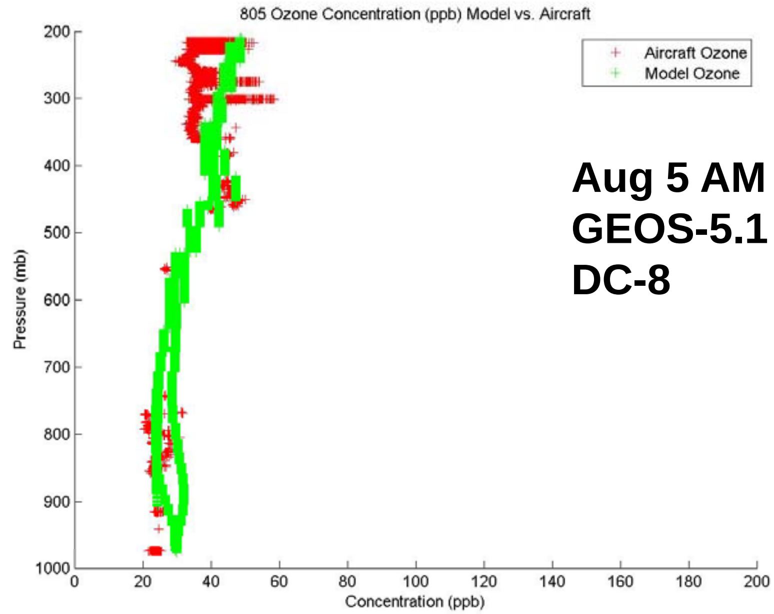

731 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
July 31 AM
GEOS-5.1
DC-8
Pressure (mb)
Concentration (ppb)


731 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
July 31 PM
GEOS-4
DC-8
Pressure (mb)
Concentration (ppb)

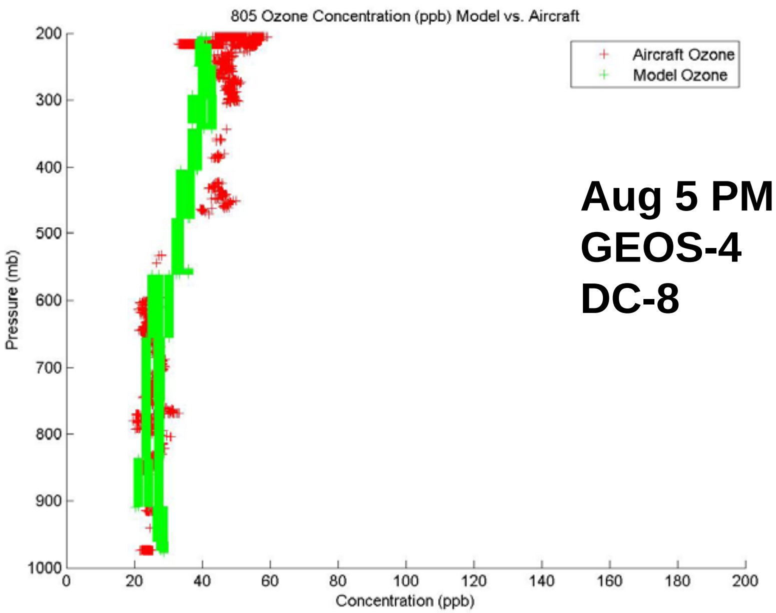

731 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
July 31 PM
GEOS-5.1
DC-8
Pressure (mb)
Concentration (ppb)



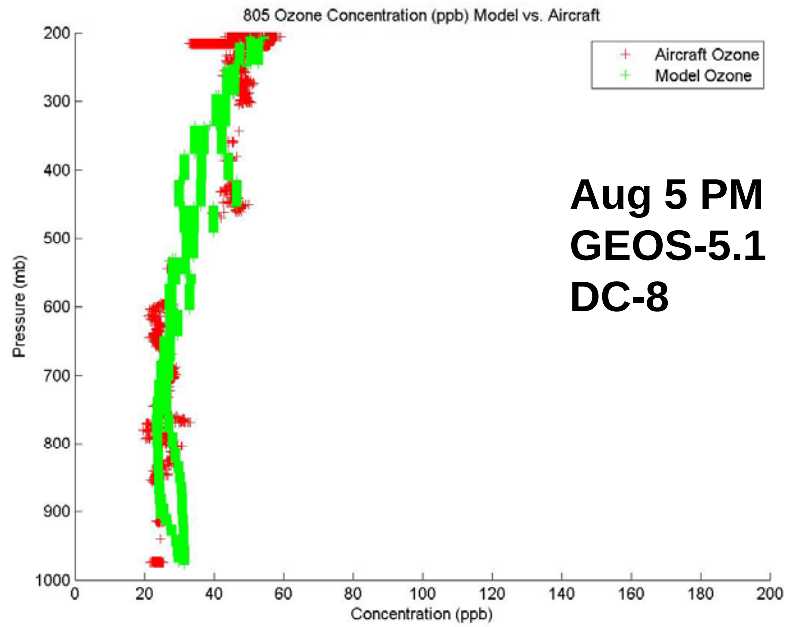
Aug 5 AM
GEOS-4
DC-8



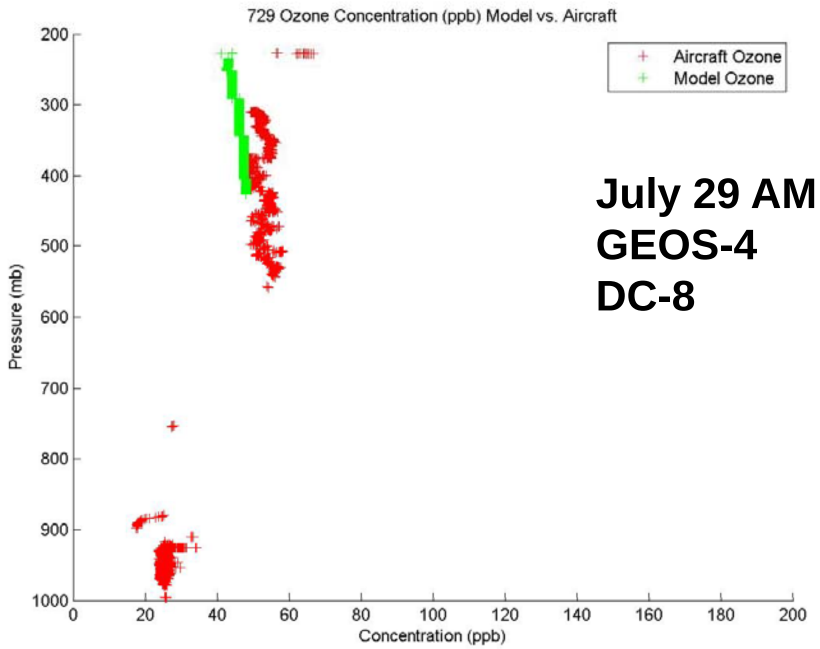
Aug 5 AM
GEOS-5.1
DC-8

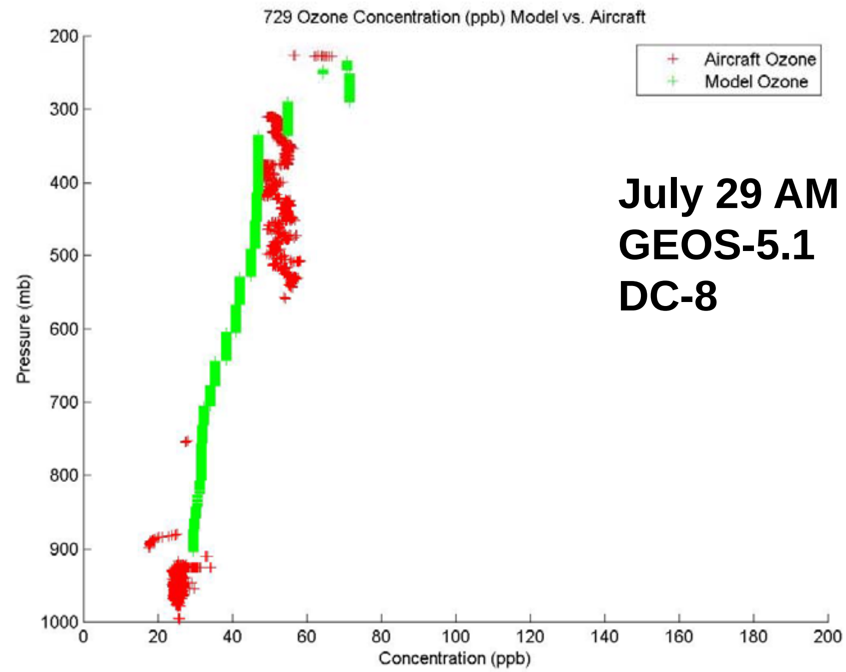


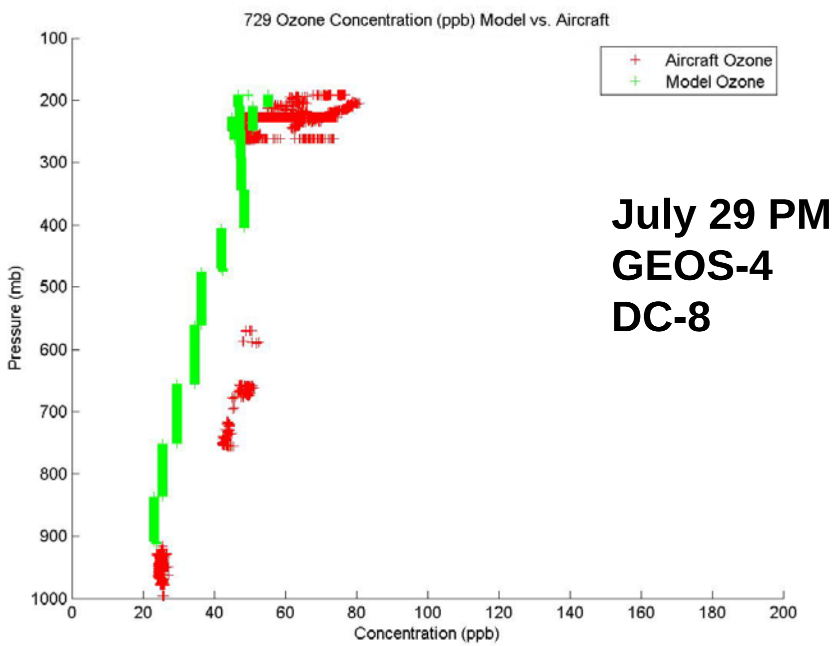
Aug 5 PM
GEOS-4
DC-8

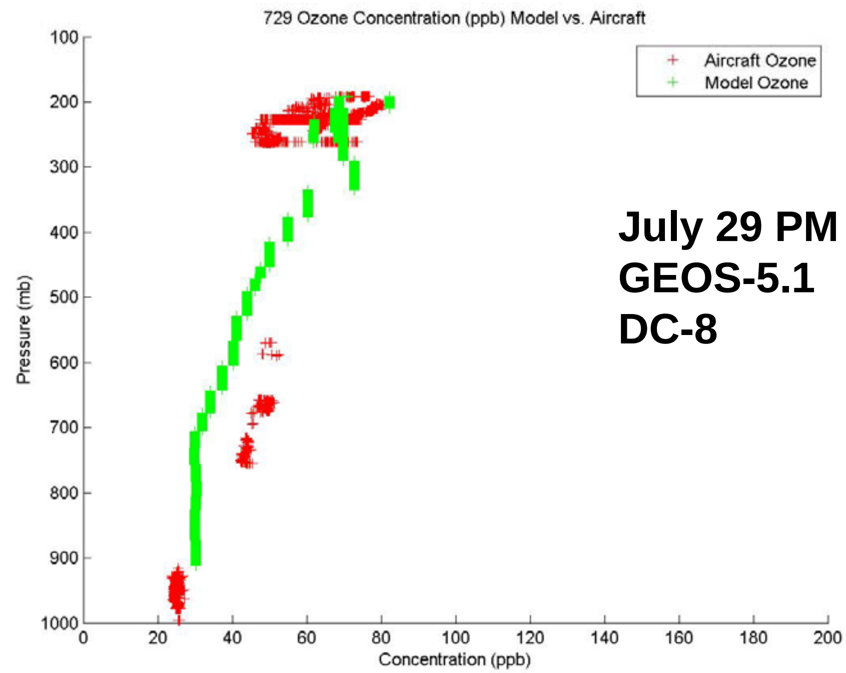


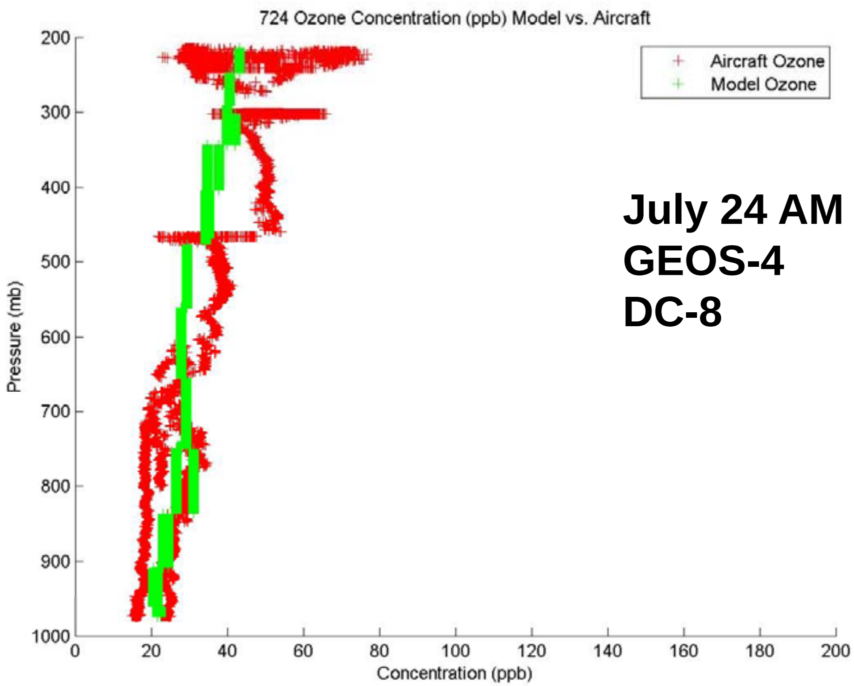
Aug 5 PM
GEOS-5.1
DC-8


729 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
July 29 AM
GEOS-4
DC-8
Pressure (mb)
Concentration (ppb)

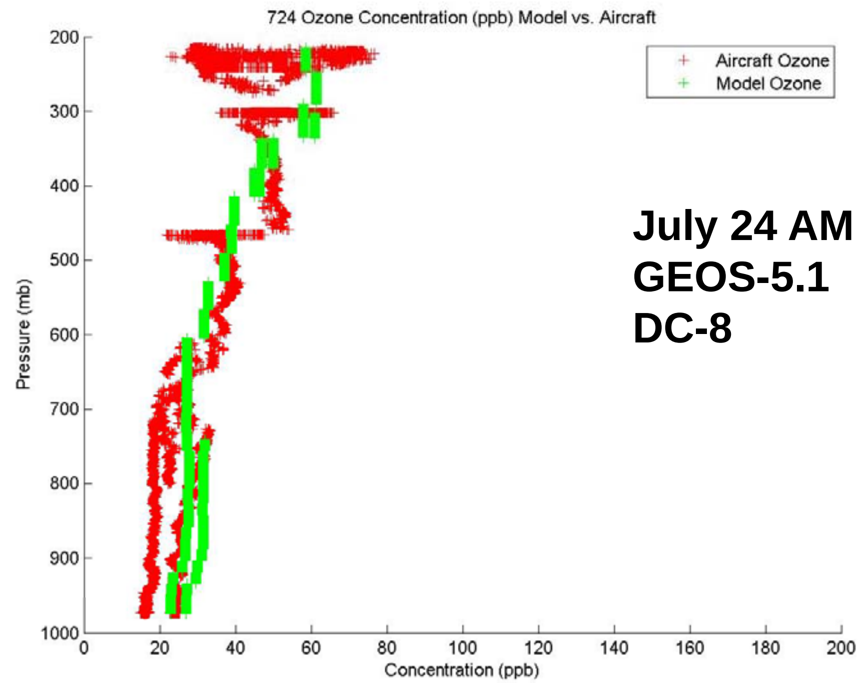

729 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
July 29 AM
GEOS-5.1
DC-8
Pressure (mb)
Concentration (ppb)


729 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
July 29 PM
GEOS-4
DC-8
Pressure (mb)
Concentration (ppb)

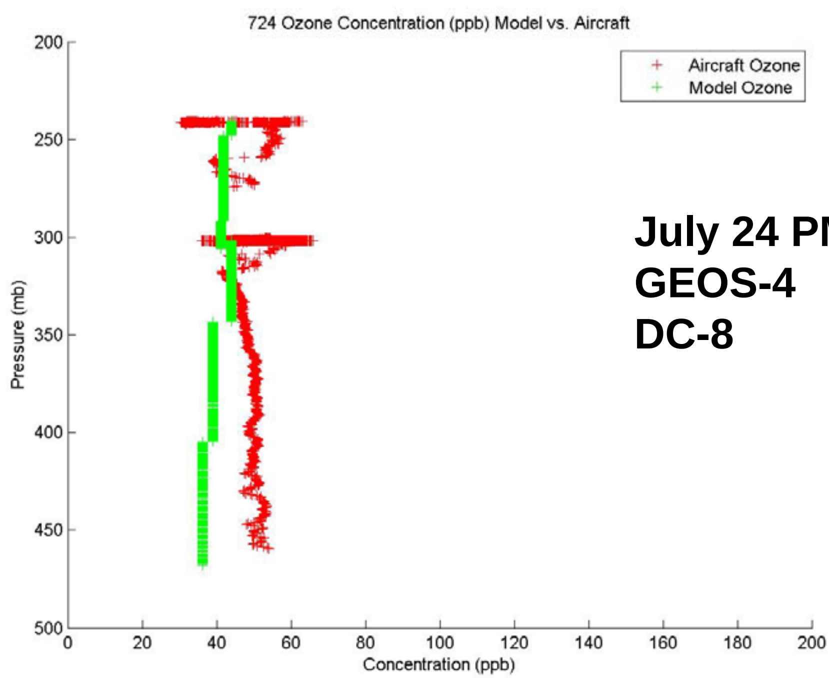

729 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
July 29 PM
GEOS-5.1
DC-8
Pressure (mb)
Concentration (ppb)



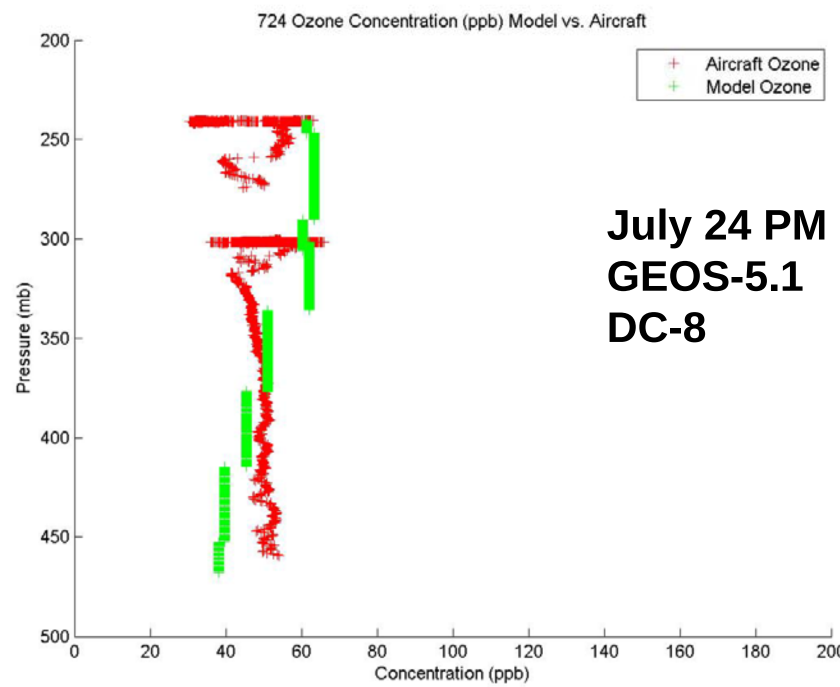
July 24 AM
GEOS-4
DC-8



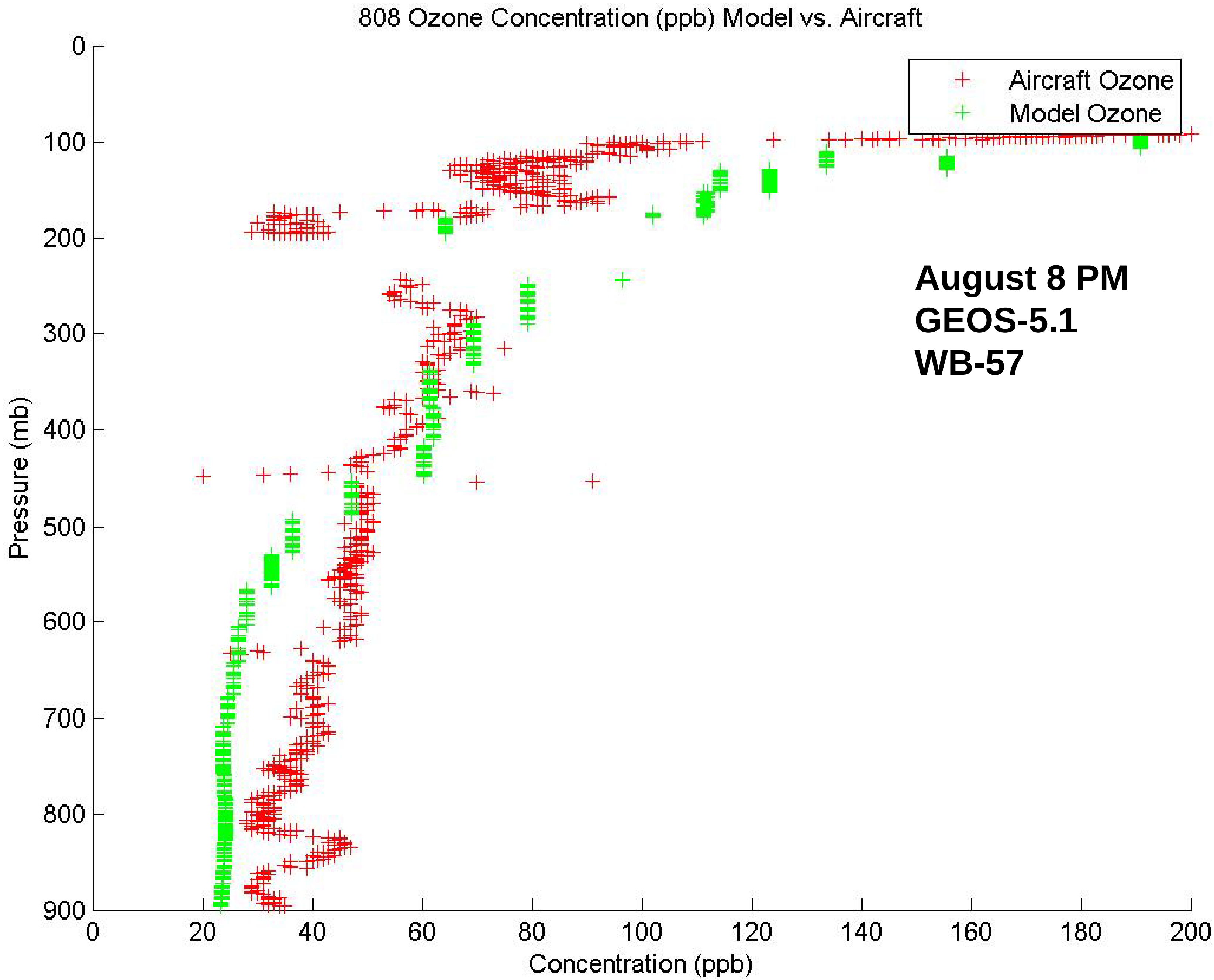
July 24 AM
GEOS-5.1
DC-8



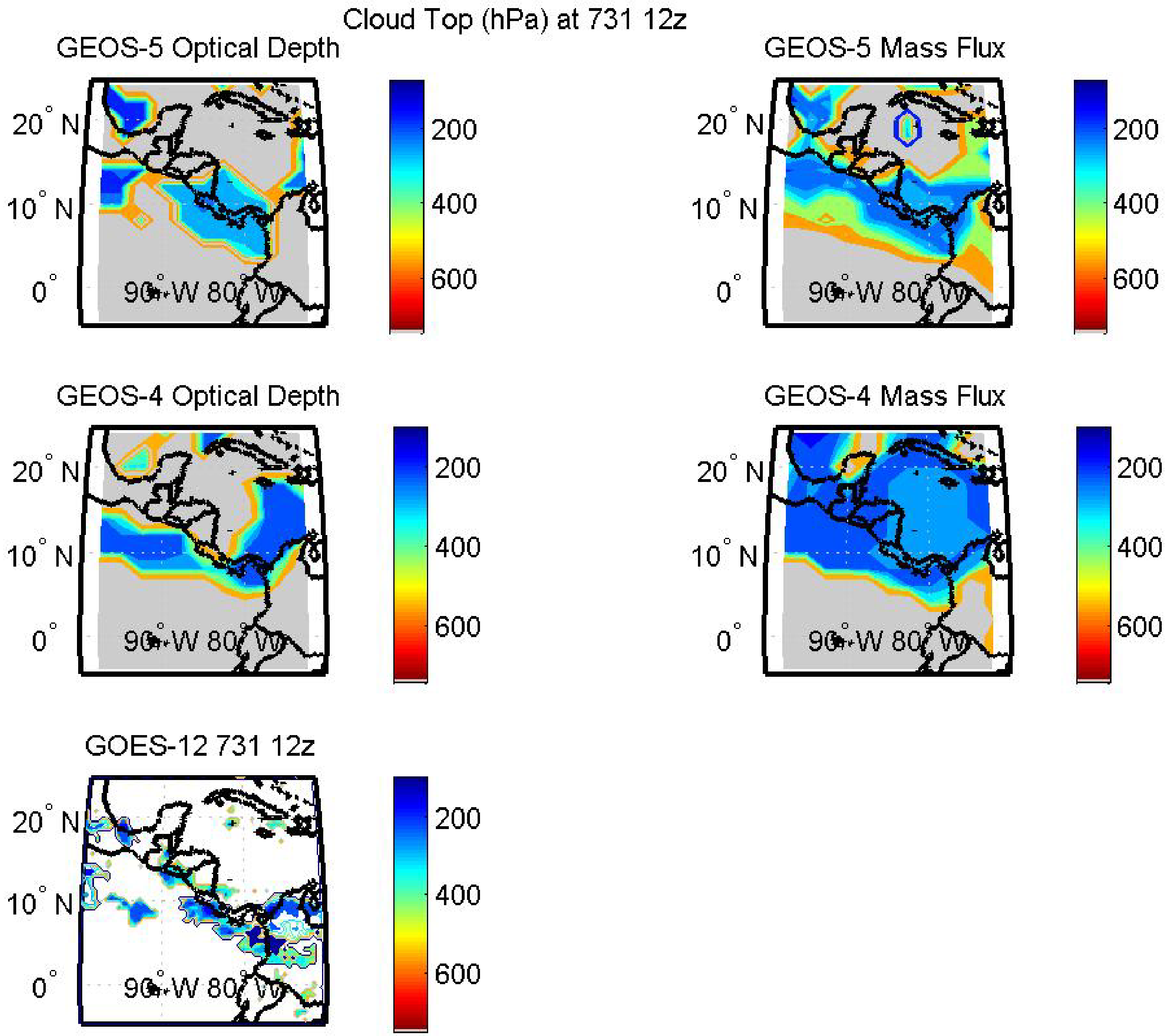
July 24 PM
GEOS-4
DC-8



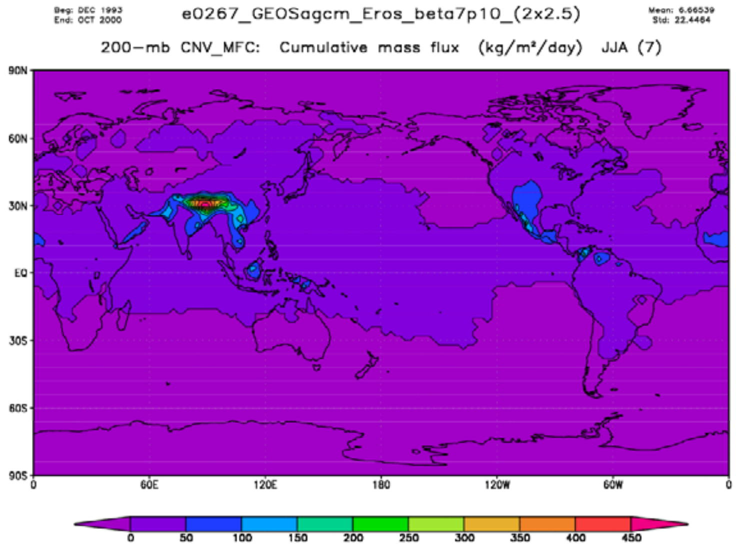
July 24 PM
GEOS-5.1
DC-8



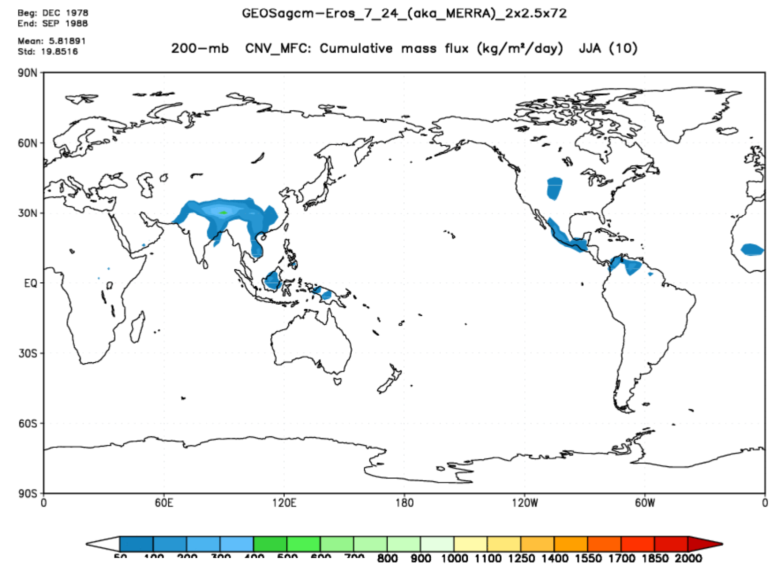
808 Ozone Concentration (ppb) Model vs. Aircraft
Aircraft Ozone
Model Ozone
August 8 PM
GEOS-5.1
WB-57
Pressure (mb)
Concentration (ppb)
0
100
200
300
400
500
600
700
800
900
0
20
40
60
80
100
120
140
160
180
200


Cloud Top (hPa) at 731 12z
GEOS-5 Optical Depth
GEOS-5 Mass Flux
GEOS-4 Optical Depth
GEOS-4 Mass Flux
GOES-12 731 12z
20° N
10° N
0°
90° W 80° W
200
400
600

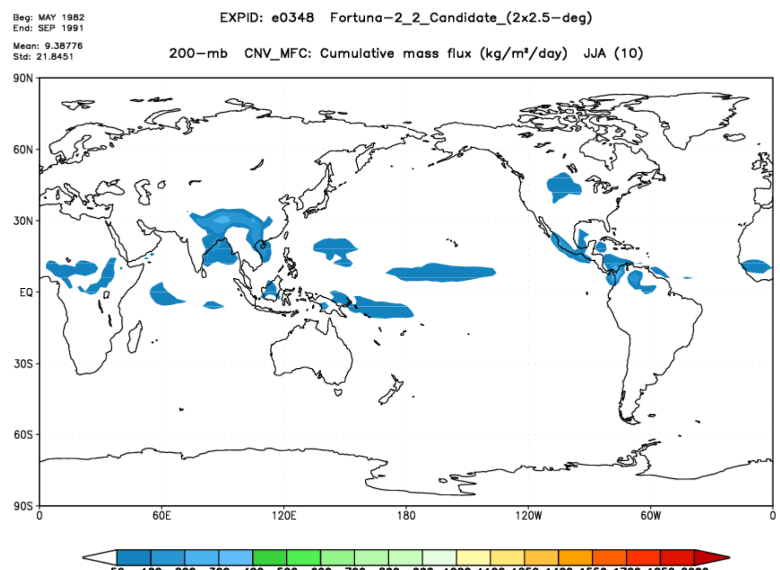
Cloud Mass Flux at 200 hPa



GEOS-5.1

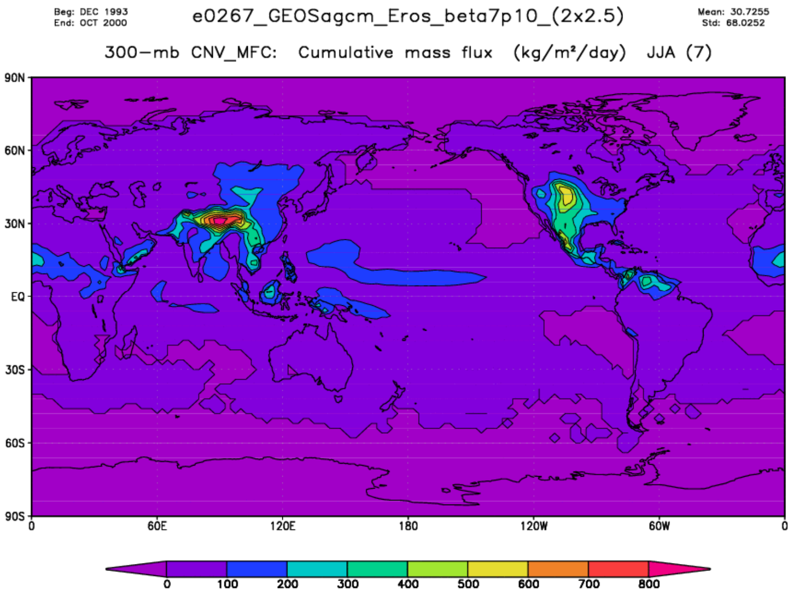


MERRA

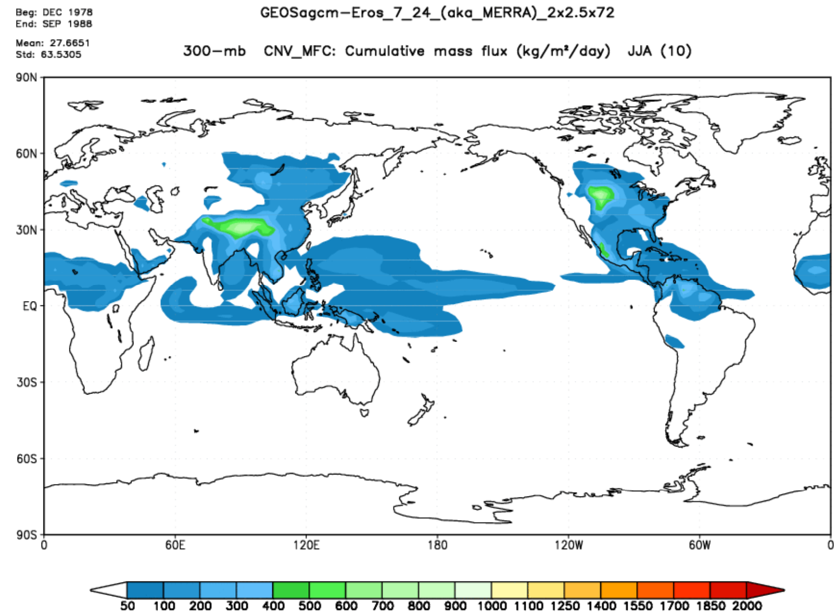


Fortuna 2.2

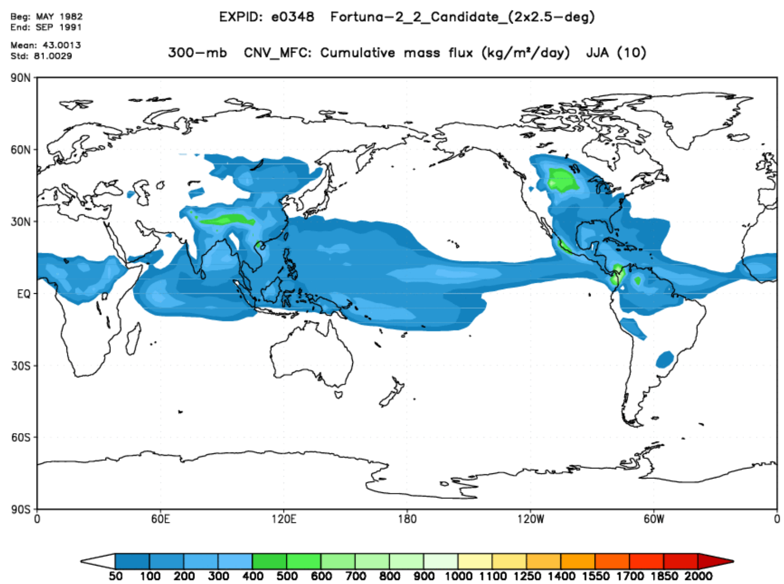
Cloud Mass Flux at 300 hPa



GEOS-5.1

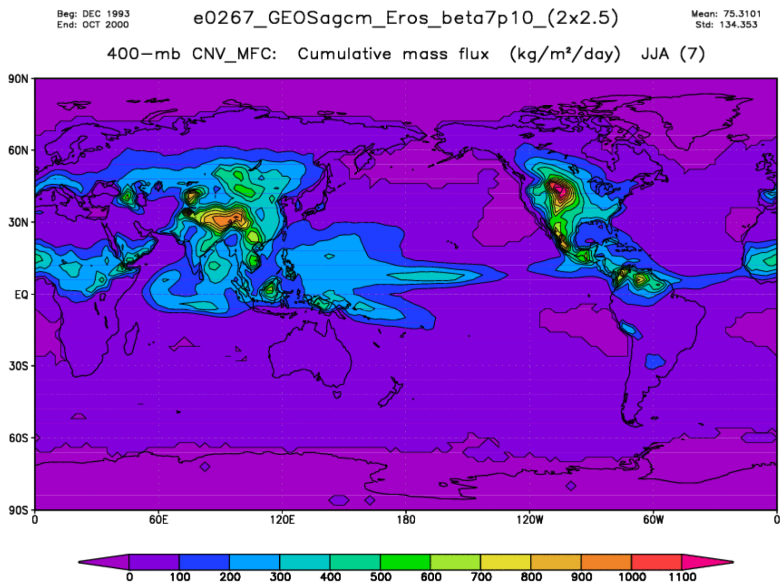


MERRA

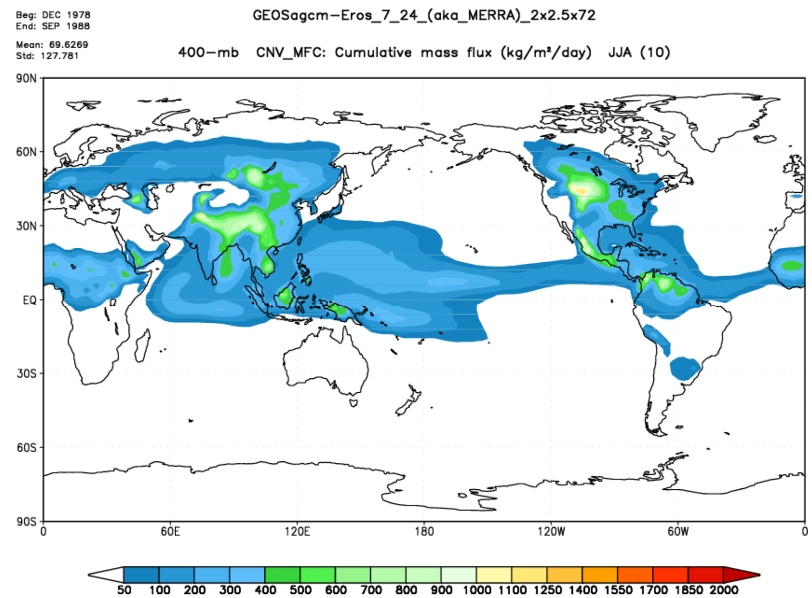


Fortuna 2.1

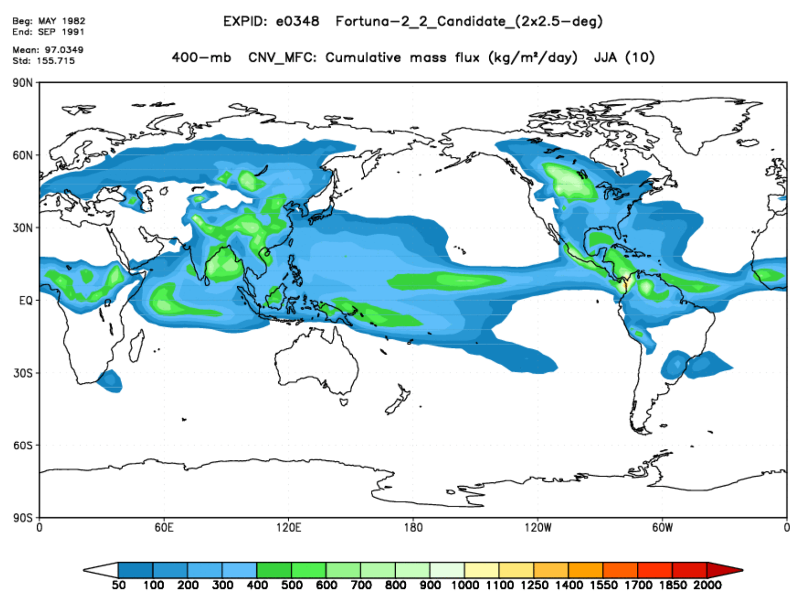
Cloud Mass Flux at 400 hPa



GEOS-5.1

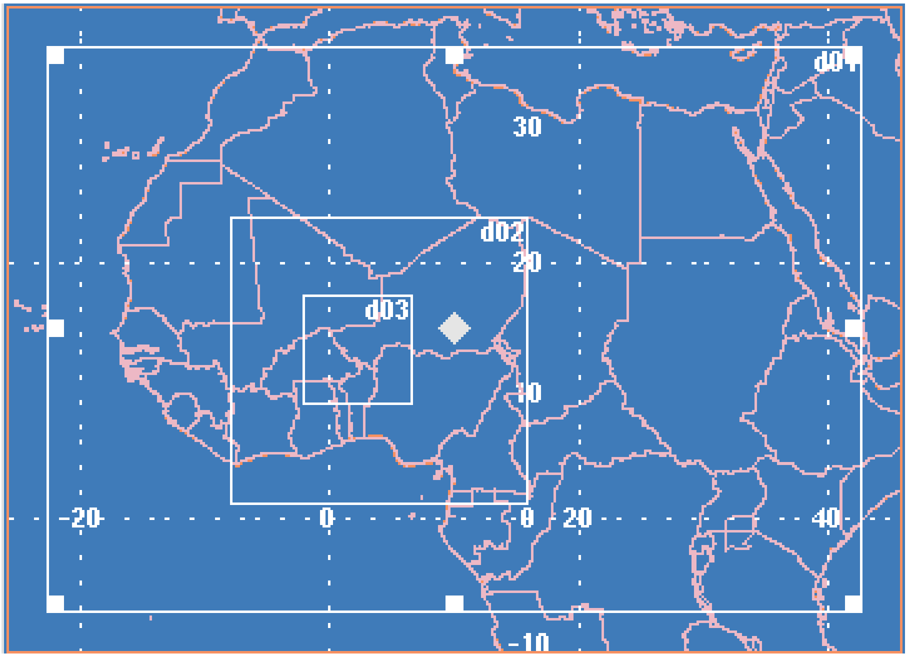


MERRA



Fortuna 2.1

AMMA WRF Simulations



Resolutions: 18, 6 and 2 km

Grid size: 391x271, 424x412, 466x466, and 61 vertical layers

Δt = 18 seconds

Starting time: 00Z 08/06/2006

Initial and Boundary Conditions:

NCEP/GFS, no data assimilation

Physics:

- **Cu parameterization:**

  Kain-Fritsch scheme (for the outer grid only)

- **Cloud microphysics:**

  Goddard microphysics 3ice-Graupel

- **Radiation:**

  New Goddard radiation scheme for both longwave and shortwave

- **PBL parameterization:**

  Mellor-Yamada-Janjic TKE scheme

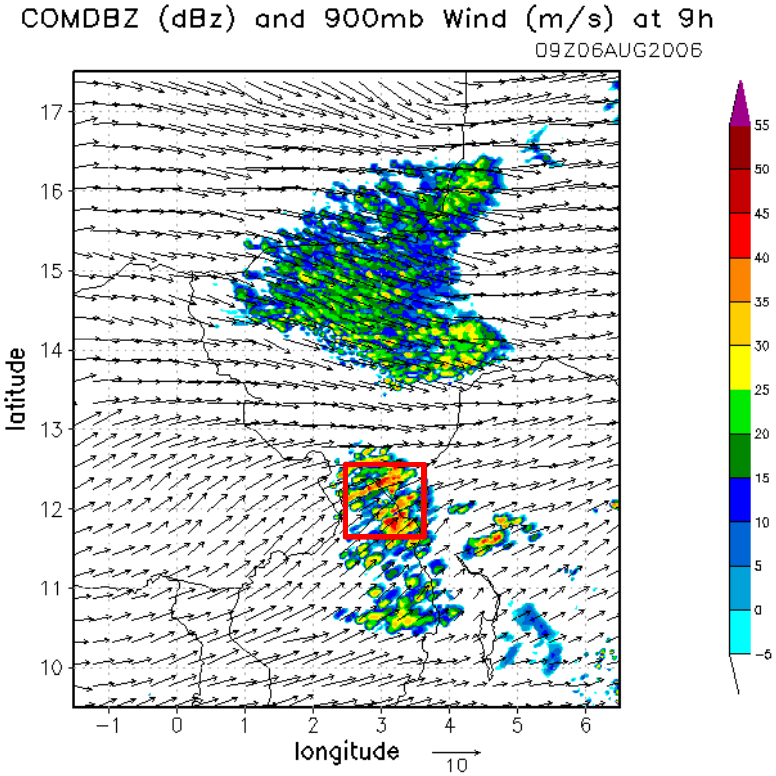
- **Surface Layer:**

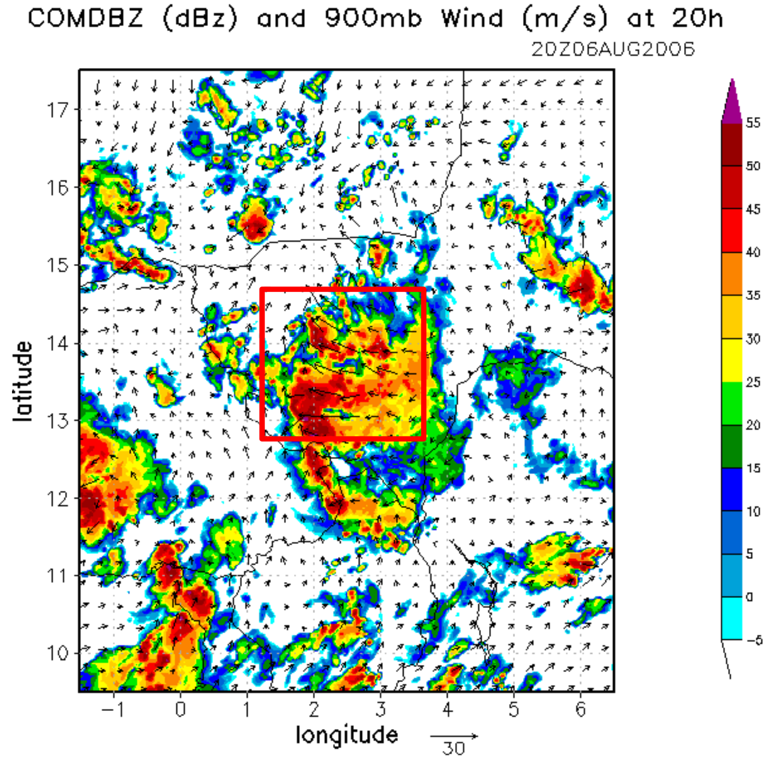
  Monin-Obukhov (Janjic)

- **Land Surface Model:**

  Noah land-surface

WRF-Calculated Radar Reflectivity

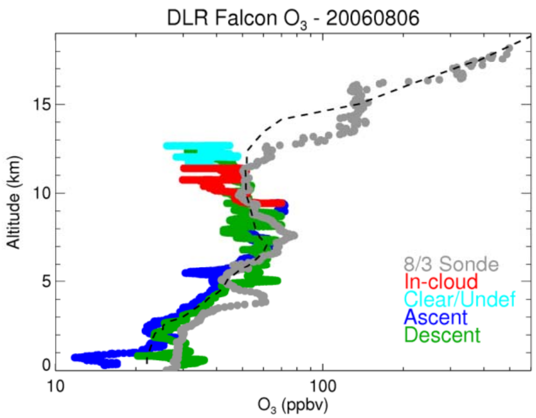


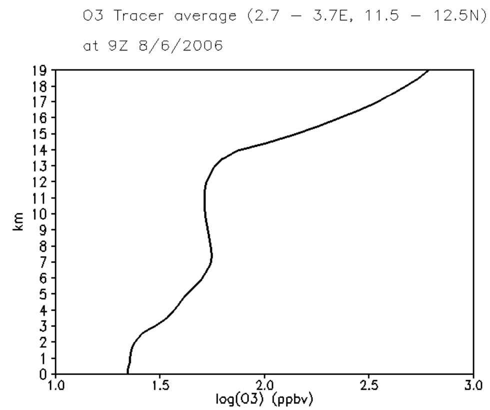


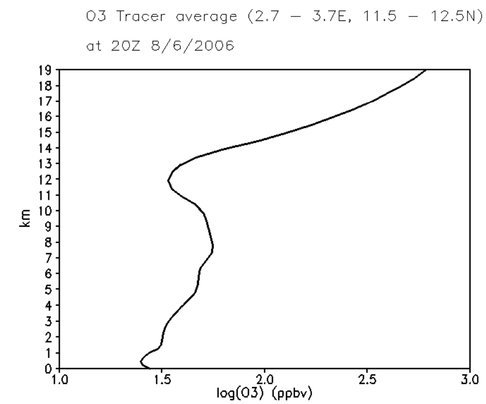
Obs./IC

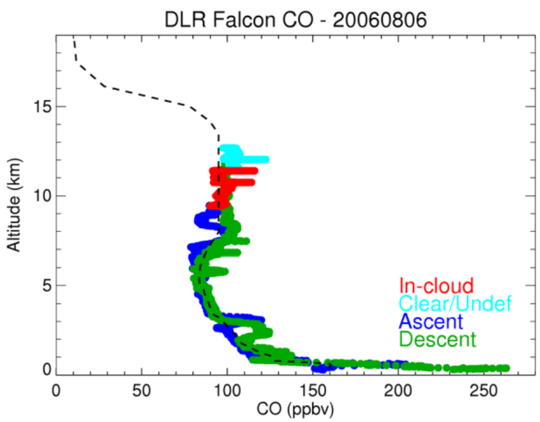
WRF Simulated at 9h

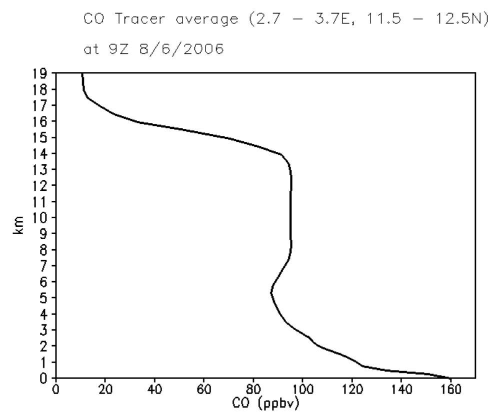
WRF Simulated at 20h

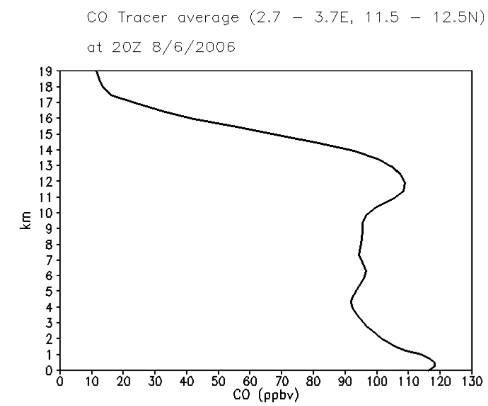


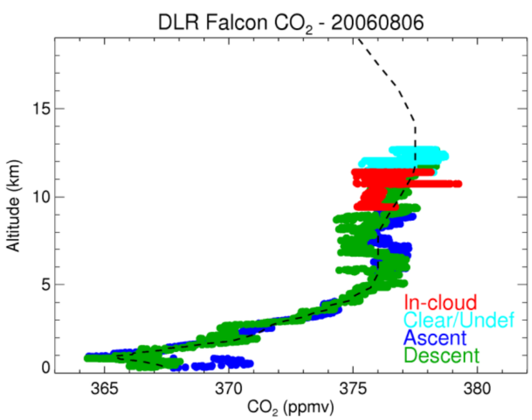


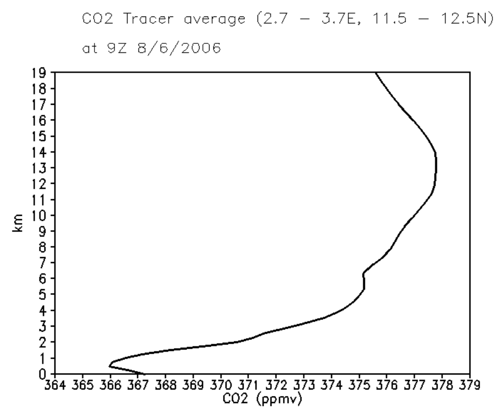


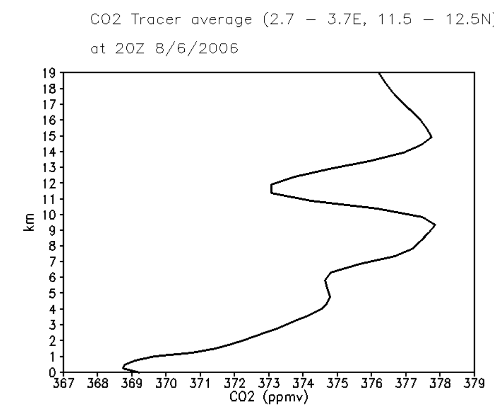


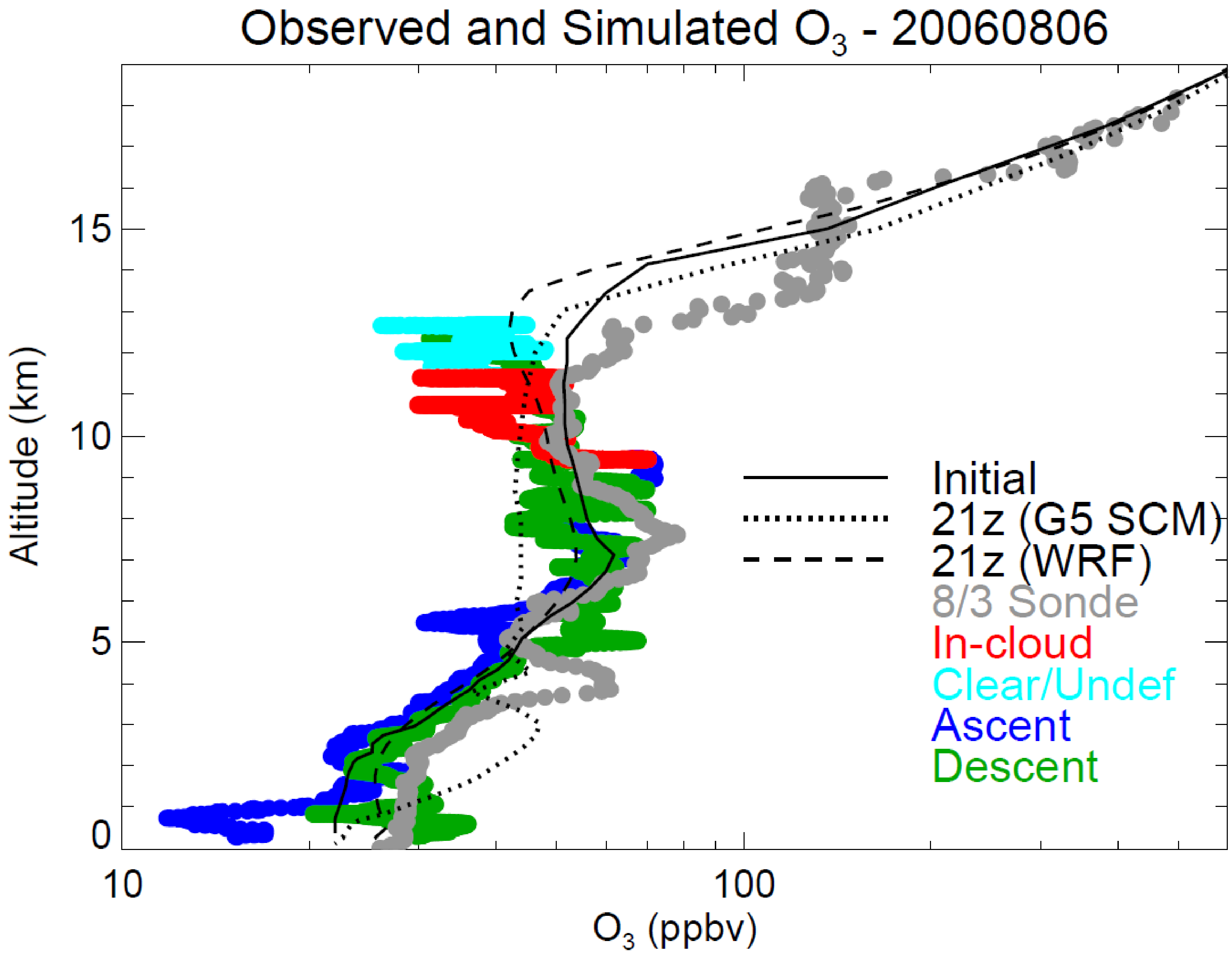




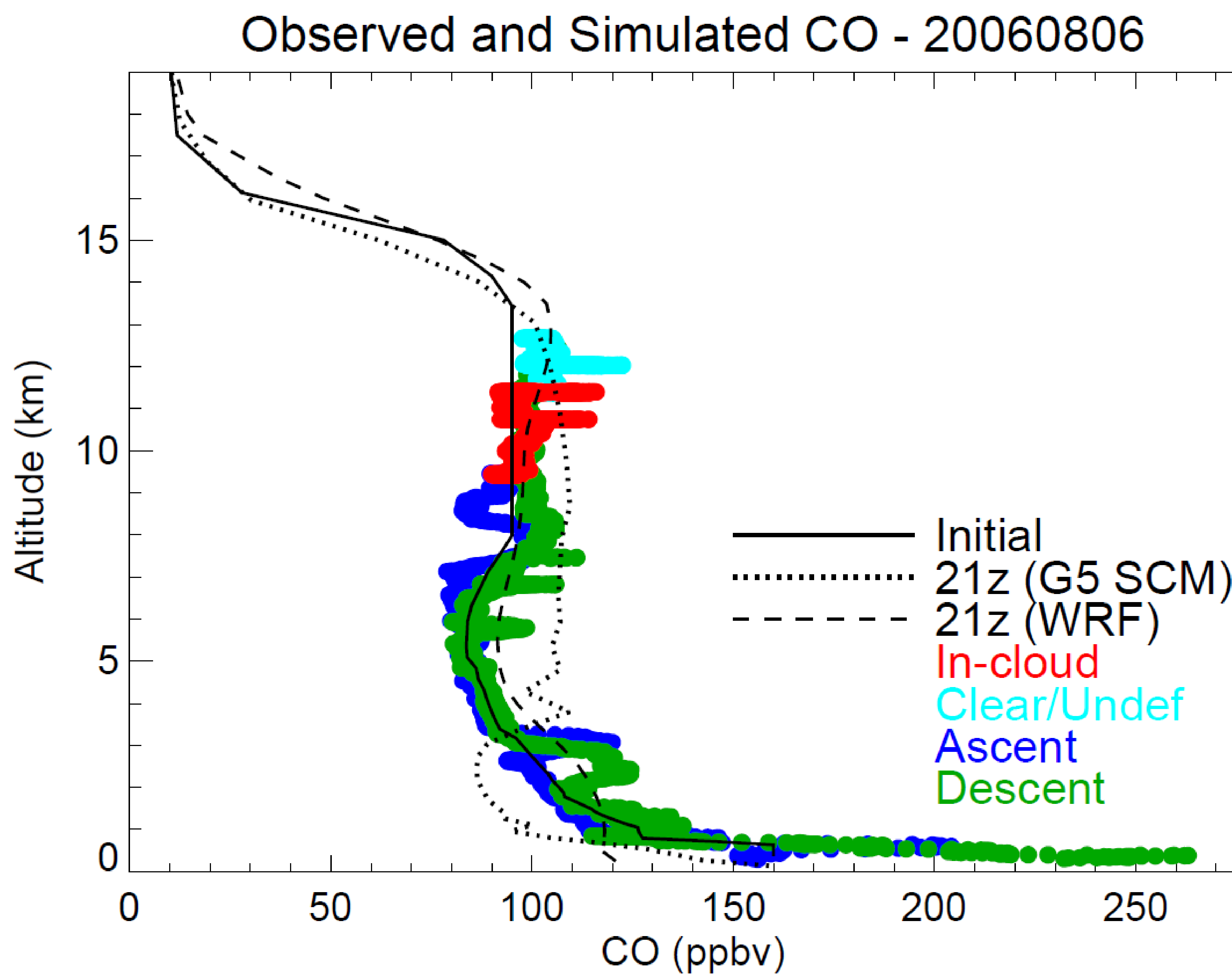


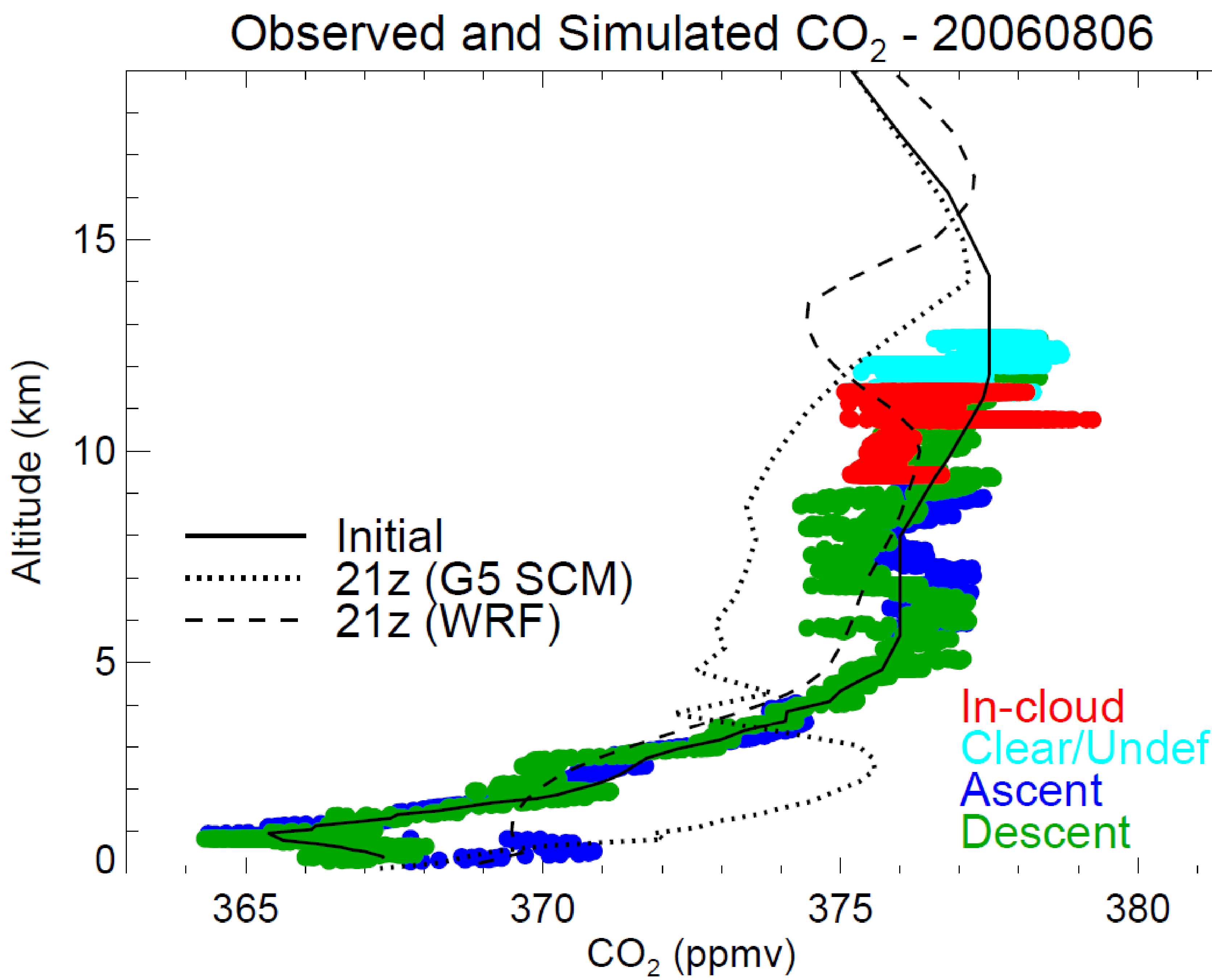






Observed and Simulated O3 - 20060806
Altitude (km)
O3 (ppbv)
0
5
10
15
10
100
Initial
21z (G5 SCM)
21z (WRF)
8/3 Sonde
In-cloud
Clear/Undef
Ascent
Descent


Observed and Simulated CO - 20060806
Altitude (km)
0
5
10
15
0
50
100
150
200
250
CO (ppbv)
Initial
21z (G5 SCM)
21z (WRF)
In-cloud
Clear/Undef
Ascent
Descent



Observed and Simulated CO2 - 20060806
Altitude (km)
CO2 (ppmv)
0
5
10
15
365
370
375
380
Initial
21z (G5 SCM)
21z (WRF)
In-cloud
Clear/Undef
Ascent
Descent

Summary

- Convection in GEOS-5.1 DAS detrained at lower altitudes than in GEOS-4
- Insufficient detrainment of boundary layer tracer in upper troposphere in GMI CTM driven by GEOS-5.1 DAS fields, as demonstrated by comparisons with TC4 O_3 aircraft observations
- GEOS-5.1 convection location better than in GEOS-4 in TC4 region; GEOS-5.1 cloud tops lower than in GEOS-4
- MERRA convective mass fluxes weaker than GEOS-5.1 in upper troposphere. Fortuna 2.2 convective mass fluxes much stronger than MERRA.
- Fortuna 2.1 SCM tracer simulation shows too much detrainment in middle troposphere and insufficient in upper troposphere in comparison with WRF cloud-resolved simulation
- Next step – adjust RAS parameters in SCM to achieve better tracer profile simulation