GEOS-5 and GMI

Steven Pawson, J. Eric Nielsen, Zhengxin Zhu
NASA GSFC – Global Modeling and Assimilation Office
Bryan N. Duncan, Richard S. Stolarski
NASA GSFC – Atmospheric Chemistry and Dynamics Branch

Representing many contributions from GMAO scientists and from the science team of the MAP chemistry-climate modeling project

GMI Meeting, NASA GSFC: May 11-12, 2009

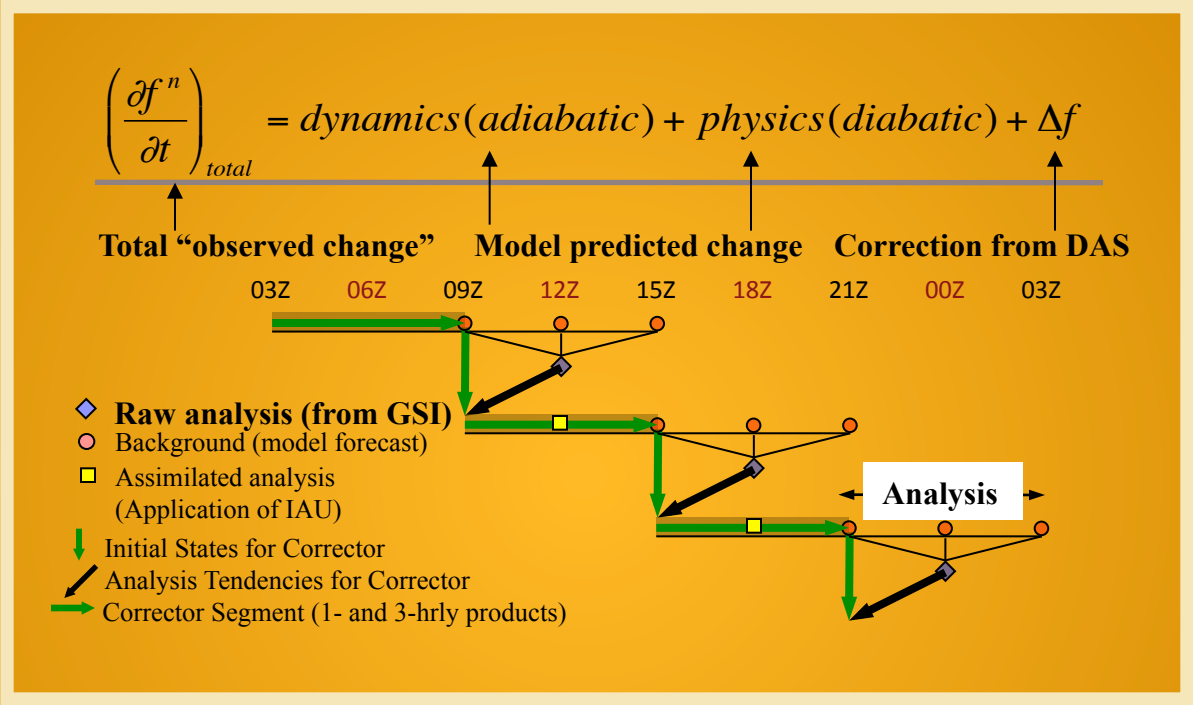
Some of the GEOS-5 systems

AGCM: Atmospheric General Circulation Model, based on Lin-Rood "fv core" and in-house "physics," used to produce meteorological forecasts (e.g., six-hour "backgrounds," five-day weather forecasts, etc.)

ADAS: Atmospheric Data Assimilation System, based on GEOS-5 AGCM and "Gridpoint Statistical Analysis" (GSI) 3D-Var analysis system, used to produce meteorological analyses (p_s, T, u, v, q, O_3) and assimilated products

CCM: Chemistry-Climate Model, based on AGCM and expanded to include a chemistry module – either GSFC "Strat-Chem" or "GMI-COMBO" (also with GOCART aerosols, etc.)

GEOS-5 Analysis and Assimilation



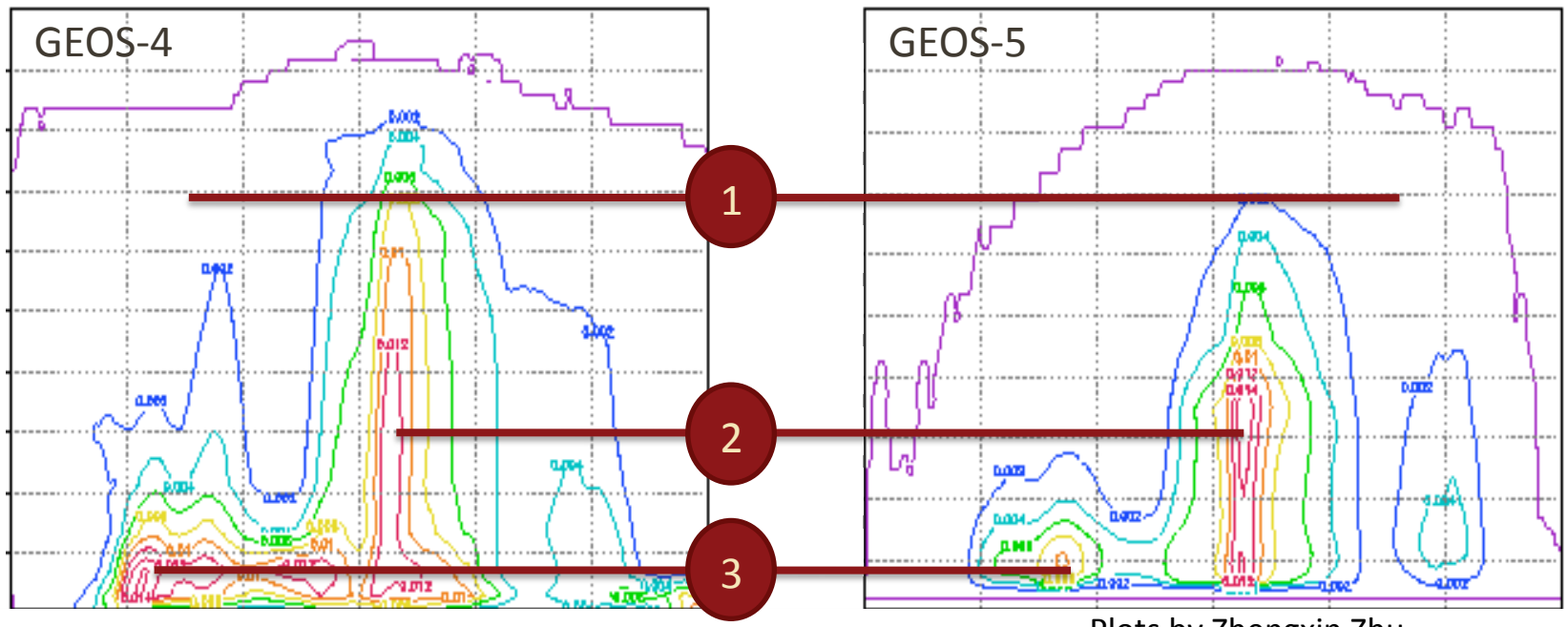
Schematic by Max Suarez

BKG: Backgrounds (six-hour forecasts) produced by running the AGCM from an initialized state

ANA: Analyses produced every six hours using optimal combination of background and observations in GSI – restricted to (p_s, T, u, v, q, O_3)

ASM: Time series of assimilated states using AGCM predictions modified to include an additional "IAU" forcing (Δf) derived from "(ANA-BKG)/(6 hours)" - contain analyzed fields and model-derived quantities – used in CTMs

Cloud Mass Fluxes: GEOS-4 & GEOS-5



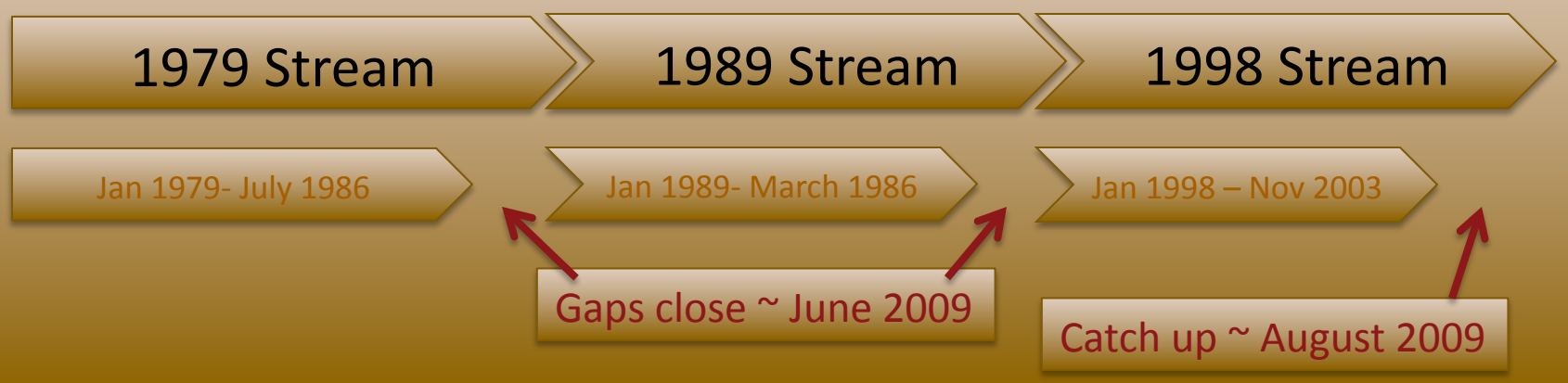
Plots by Zhengxin Zhu

Cloud mass fluxes in July 2005 for GEOS-4 (left) and GEOS-5 (right) show some important differences that will impact chemistry-transport models	
1	Stronger penetration into the tropical upper troposphere in GEOS-4
2	Stronger middle tropospheric convective fluxes in GEOS-5 tropics
3	Stronger shallow convective transport in winter middle latitudes in GEOS-4

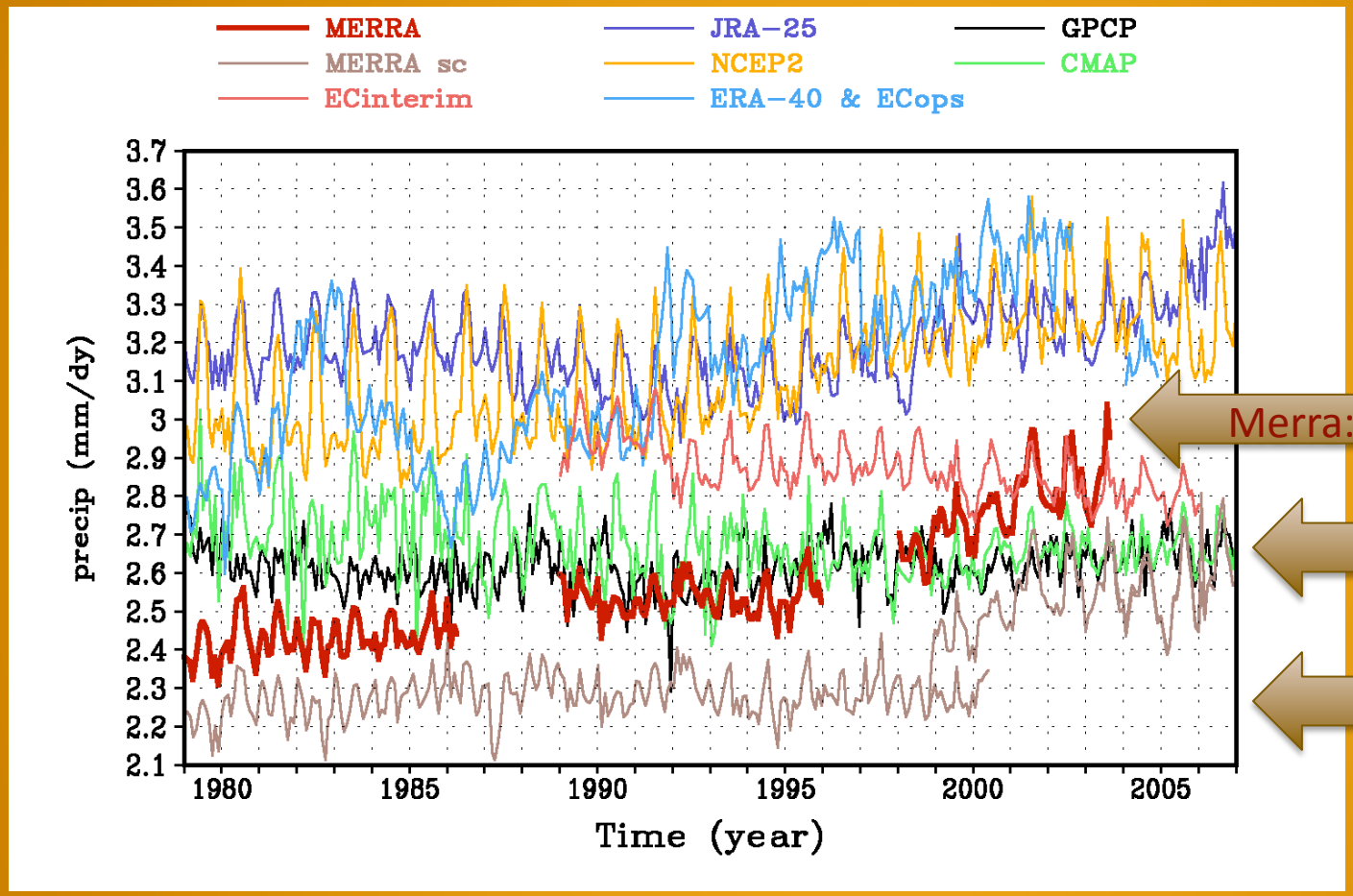
GEOS-5: Systems and Products

System	Products
GEOS-5.0.1	Near-Real Time Processing: 11/04/06 – 10/17/07 Analyses including EOS-Aura Reprocessing: 08/01/2004 – 01/03/2008
GEOS-5.1.0	Near-Real Time Processing: 10/17/2007 – 08/14/2008 Analyses including EOS-Aura Reprocessing: 10/01/2003 – 10/02/2008
GEOS-5.2.0	Near-Real Time Processing: began 08/14/2008 1979-2009 Merra Reanalysis (three streams)

Progress with three streams of Merra (0.5°×0.66°L72)



Long-Term Stability of Merra Products



Plot by
Junye Chen and
Mike Bosilovich

Merra: GEOS-5.2.0 (0.5°)

"Observations"

GEOS-5.2.0 (2°)

Global-mean precipitation is a model-produced quantity from the assimilation.
Merra precipitation is closer to observations than earlier reanalyses were.
Trends may be physical or related to changes in available input data streams.

GEOS-5 Documentation & Data Access

Available online: gmao.gsfc.nasa.gov

- Technical documentation: Rienecker et al. (2008)
- Validation (not yet available): Bosilovich et al. (2009)
- File specs for forward processing
- DIFFERENT file specs for Merra

Merra data are being served – no need for special DAAC access

Merra saves a 3-h averaged data stream at 1°×1.25°L72 for CTMs

tavg3_3d_chm_Fv

ECS short name: AT3FVCHM
ECS long name: MERRA IAU 3d Chem On Layers
Characteristics: Time averaged, 3D model levels, at reduced FV resolution
Dimensions: longitude: 288, latitude: 181, levels: 72 (see Appendix D)
Times : 1:30, 4:30, 7:30, 10:30, 13:30, 16:30, 19:30, 22:30 GMT

Variable Name	Description	Units
DELP	Layer pressure thickness	Pa
T	Air temperature	K
QV	Specific humidity	kg kg^{-1}

Chemistry On-Line in GEOS-5

On-line implementation began with GEOS-4:

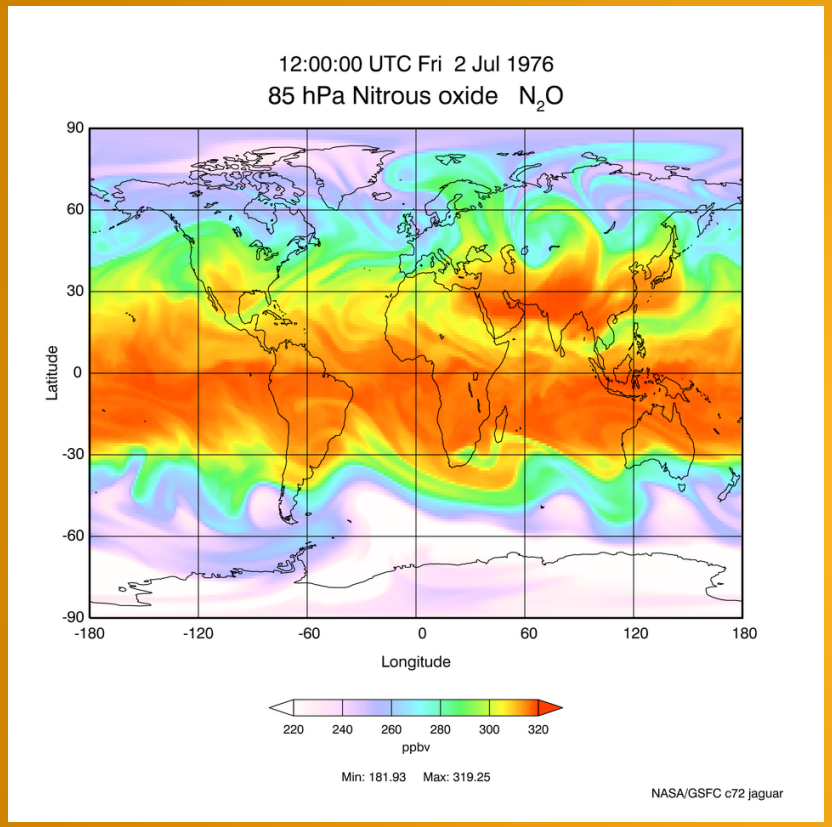
- Linearized (tagged) CO and other gases – Intex-NA support: Harvard University (Jacob) – GMAO (Pawson) collaboration
- Version 1 of GEOS CCM with Stratospheric Chemistry – MAP Project (PI: R. Stolarski)

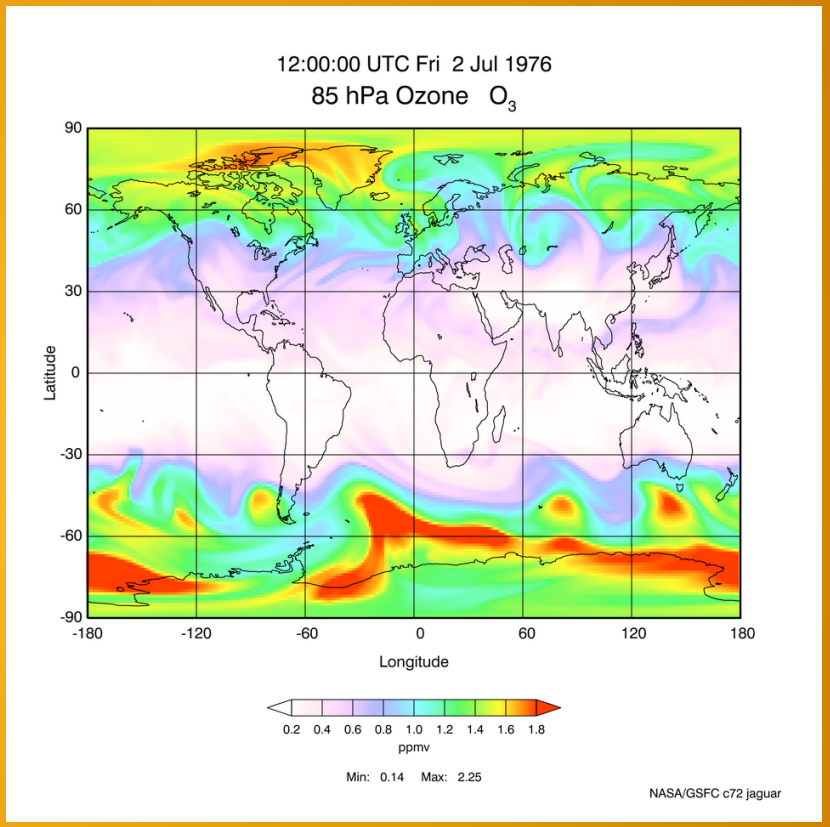
Adopted "Aerochem" framework developed in GMAO (da Silva) and propagated forward to GEOS-5:

- GOCART aerosol modules
- Stratospheric Chemistry: Version 2 of GEOS CCM (CCMVal)
- GMI COMBO Chemistry: Version 3 of GEOS CCM (evaluation)

(Rich Stolarski will discuss the GEOS CCM in detail)

GEOS CCM Version 3

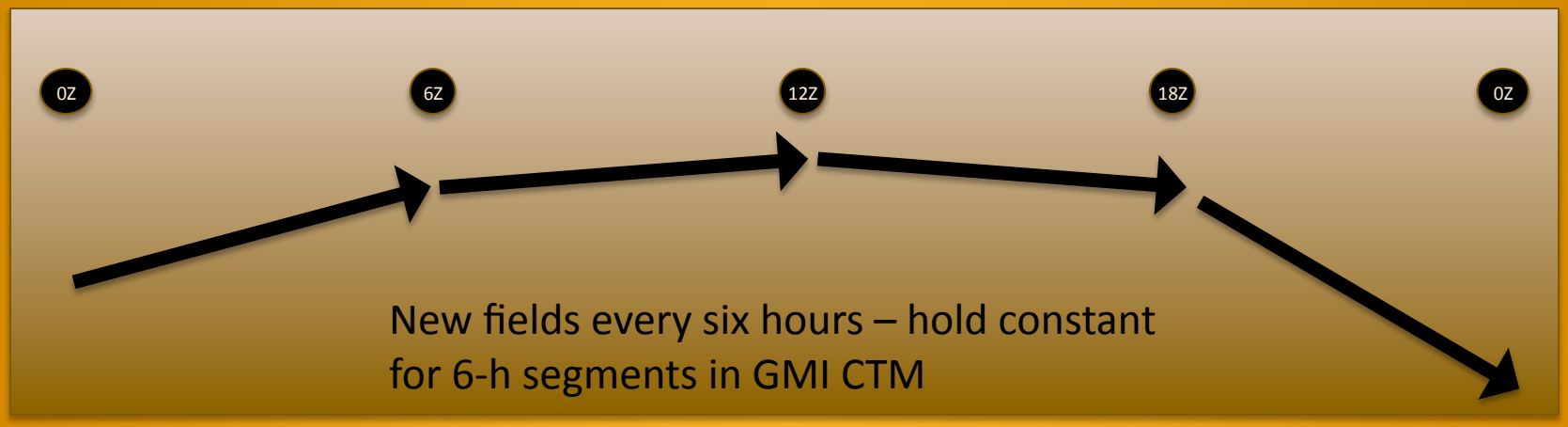


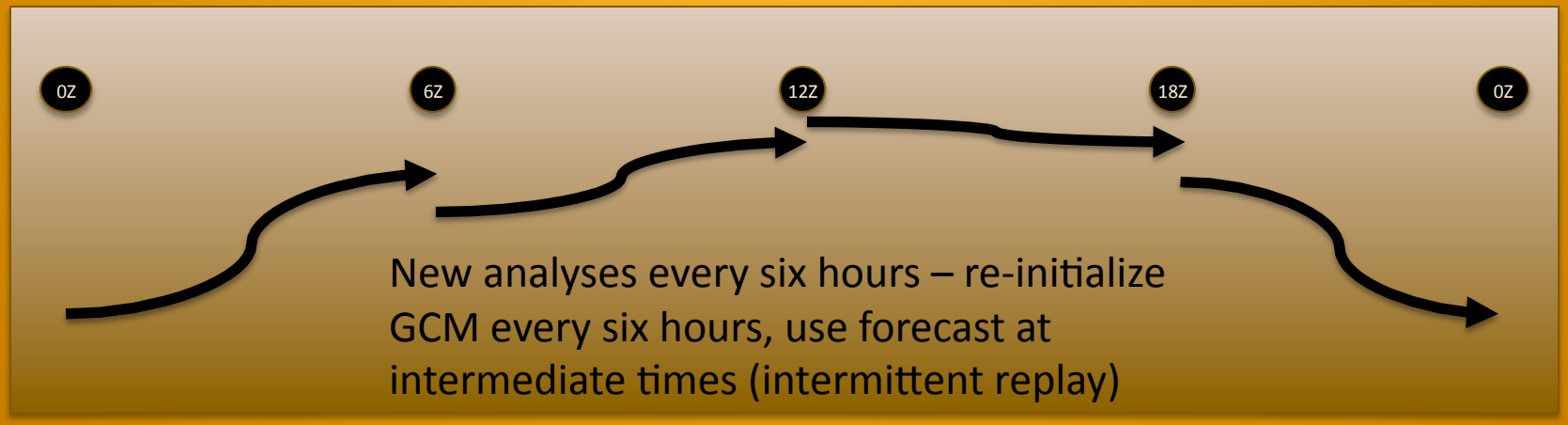


Some results from a 1-degree simulation of the GEOS CCM Version 3 (GEOS-5 with GMI COMBO chemistry) showing the rich structure in N_2O and O_3 fields at 85hPa

Possibility for GMI: “Replay” mode (1)

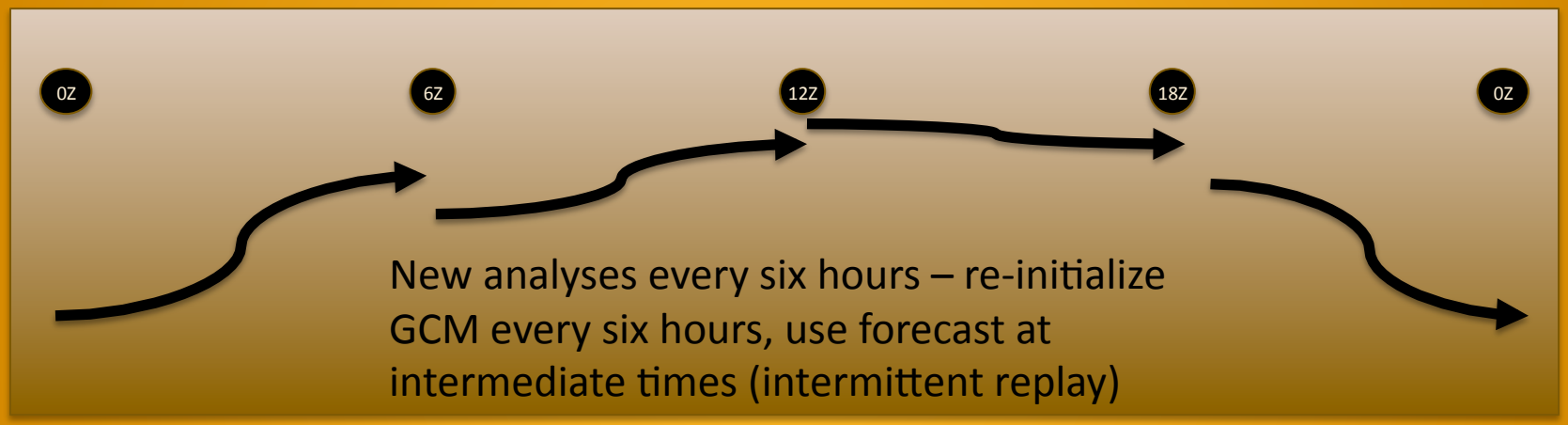
The on-line equivalent of running an off-line CTM
Schematic comparison of CTM with on-line implementation as in MATCH & GEOS-4

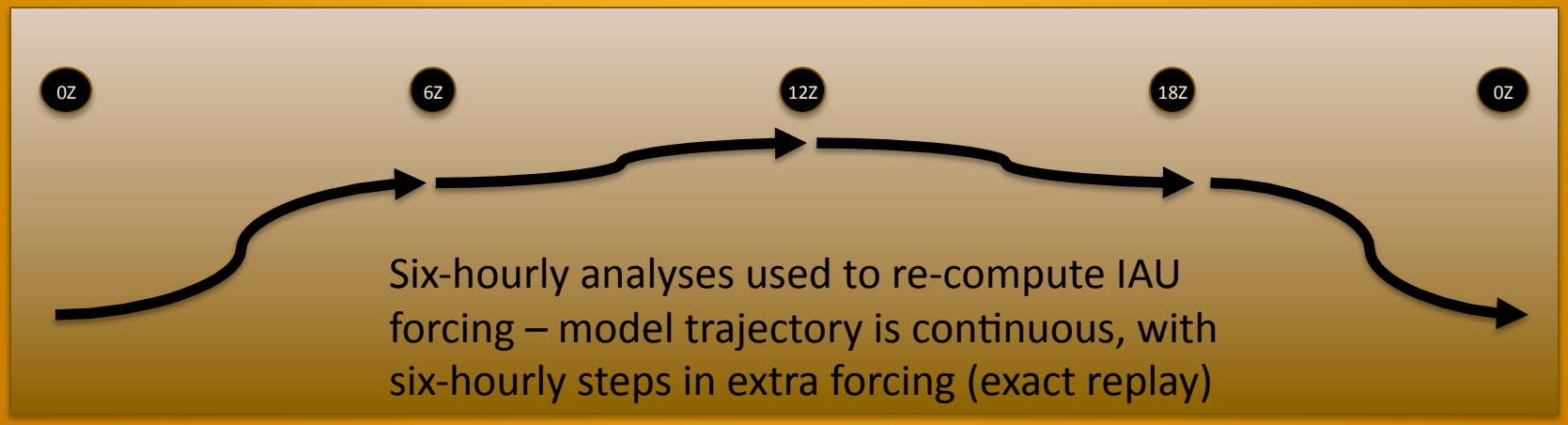




Possibility for GMI: “Replay” mode (2)

Another way of doing replay in GEOS-5
Schematic comparison of “intermittent” and “exact” replay modes





Advantages & Disadvantages

Approach	Positives and Negatives
CTM	+ We know it "works" + Exact reproducibility: large-scale & sub-grid fields always identical - Transport errors because of time resolution of input data - Sensitivity to computational algorithms differing from GCM - Non-unique physical interpretation of (e.g.) cloud mass flux
GCM with Intermittent Replay	+ Resolved fields constrained to be identical every six hours - Resolved & sub-grid fields may differ from run to run + Sub-grid transport resolved at high frequency (30 minutes) - Possibility of superfluous mixing caused by overwriting the winds + Same GCM always has same interpretation of sub-grid quantities
GCM with Exact Replay	- No absolute constraint on resolved fields (tend towards analysis) + Resolved and sub-grid transport resolved at high frequency - Resolved & sub-grid fields may differ from run to run + IAU tendencies reduce superfluous mixing (PV-tracer correlations) + Same GCM always has same interpretation of sub-grid quantities

Which is the least worst approach?

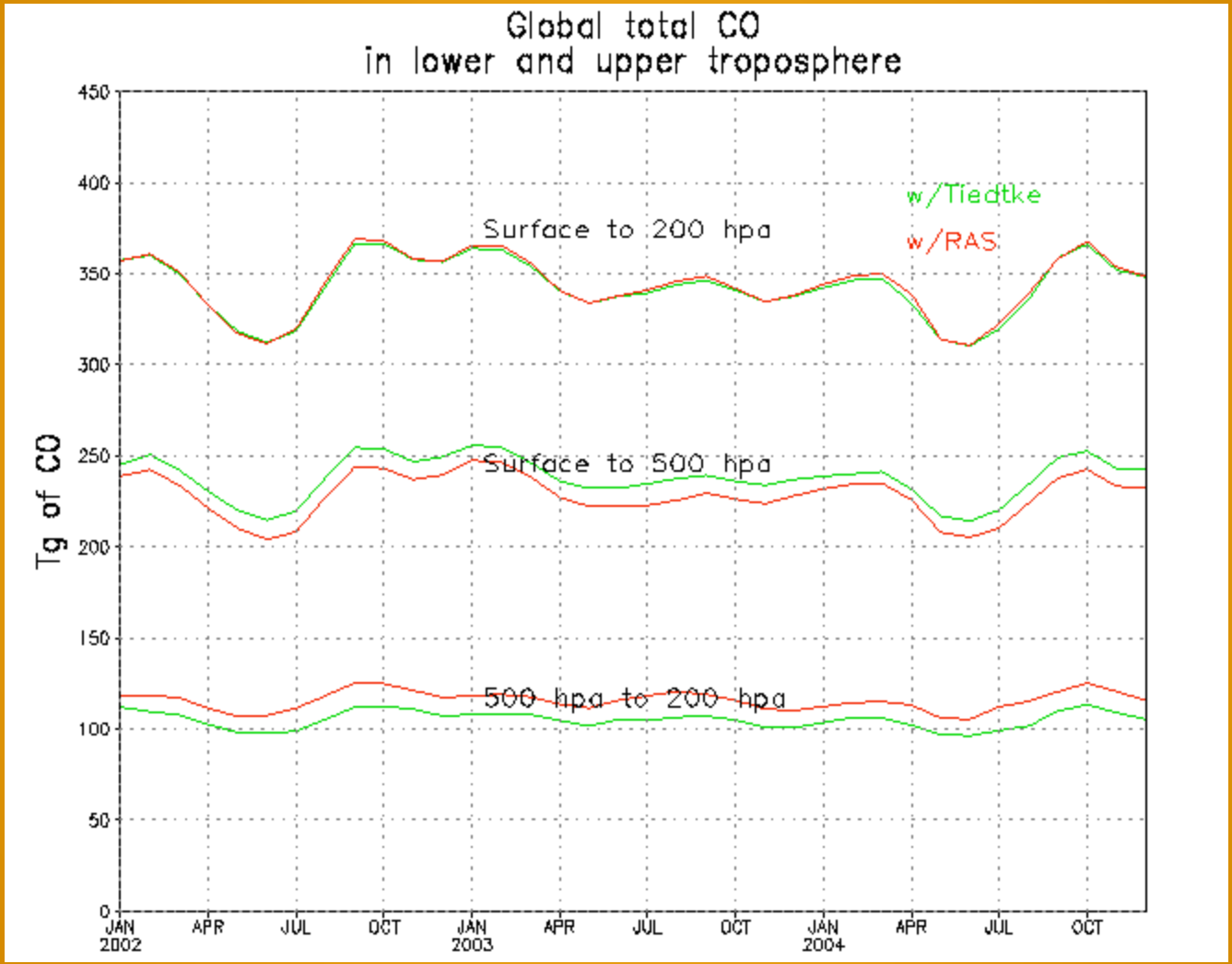
Impact of on-line to off-line transport?

Work in progress:

- Have started to quantify potential impact of changing the way that sub-grid cloud mass fluxes are used in the model
- Still need to look at both the impact of six-hour averaging and use of model (time-dependent) versus fixed winds

- Controlled experiments using GEOS-5 (exact replay) with "full" convective transport for thermodynamic variables but approximate use of mass fluxes for trace gases
- Linearized carbon species and GMI COMBO chemistry

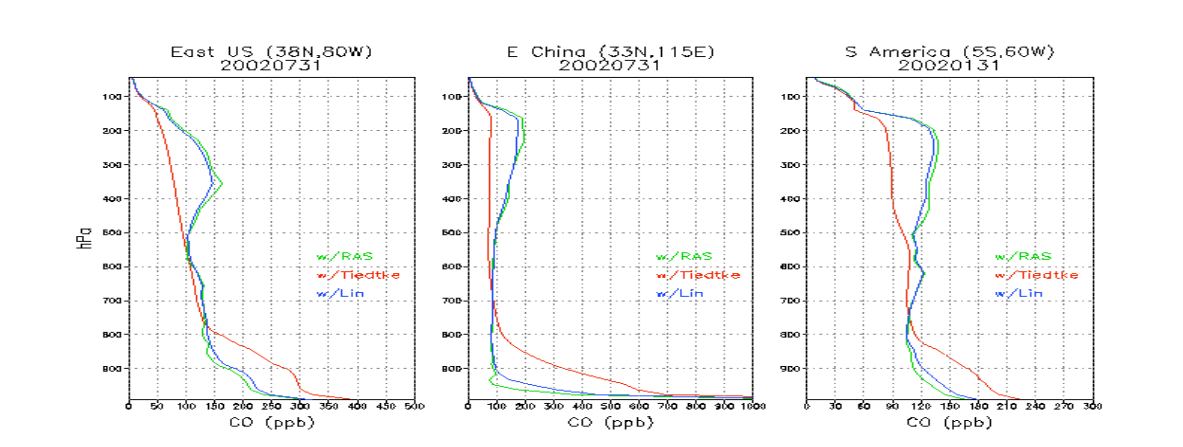
Global CO sensitivity to conv. Transport (1)



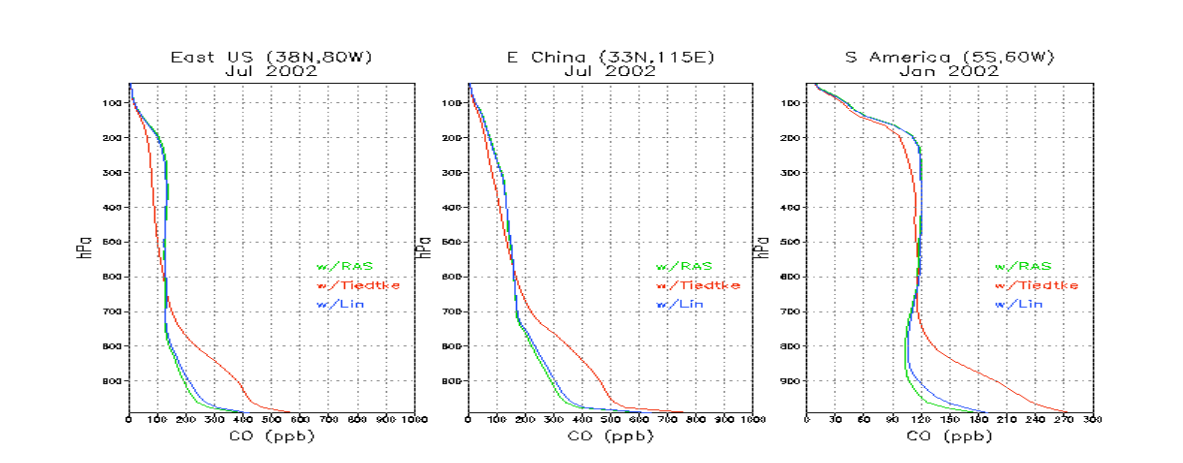
On-line computation in GCM: RAS used to compute meteorological state but in “red” run RAS cloud mass fluxes used with different numerical algorithm for CO transport

Global CO sensitivity to conv. Transport (2)

Instantaneous profiles:

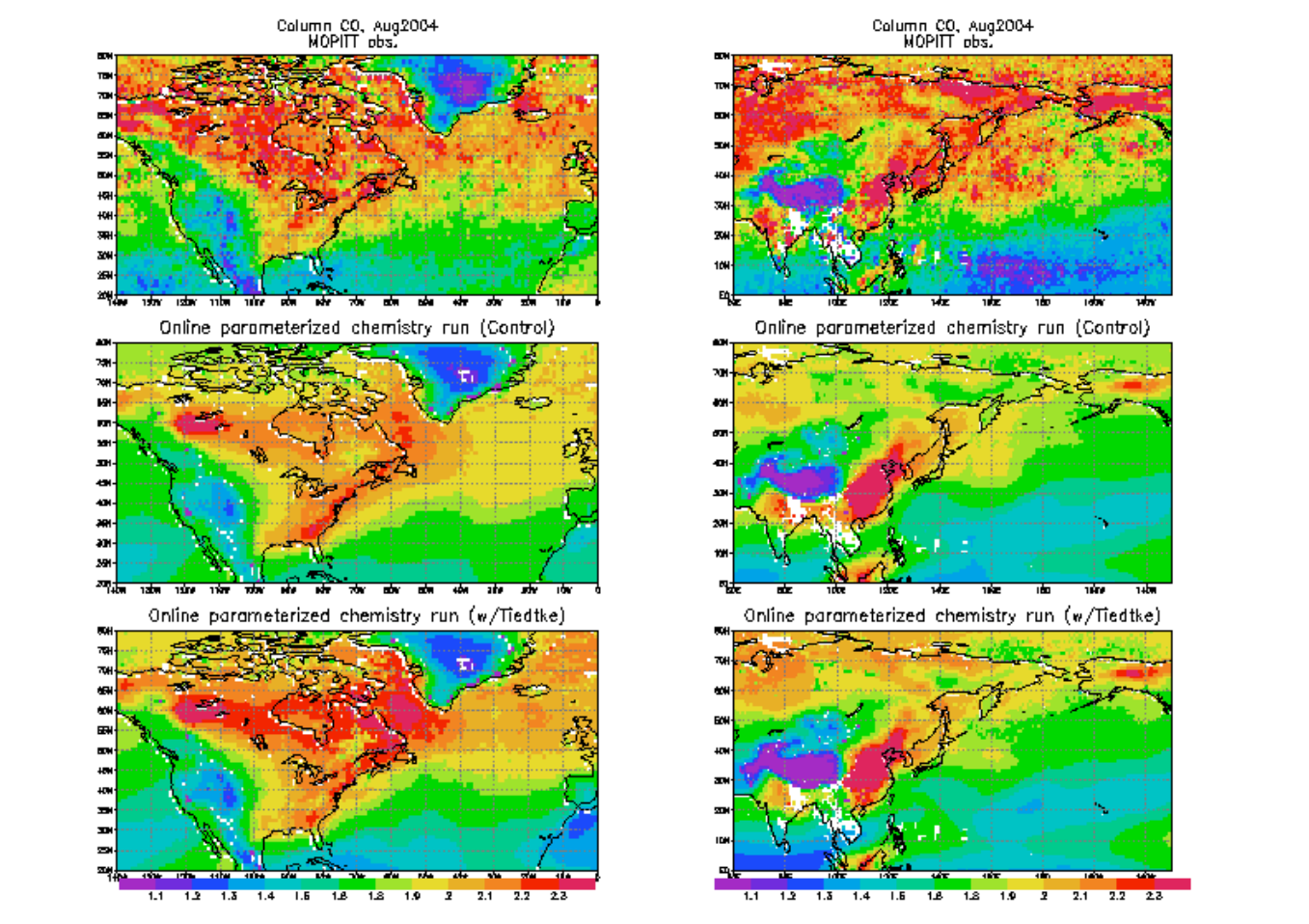


Monthly mean profiles:



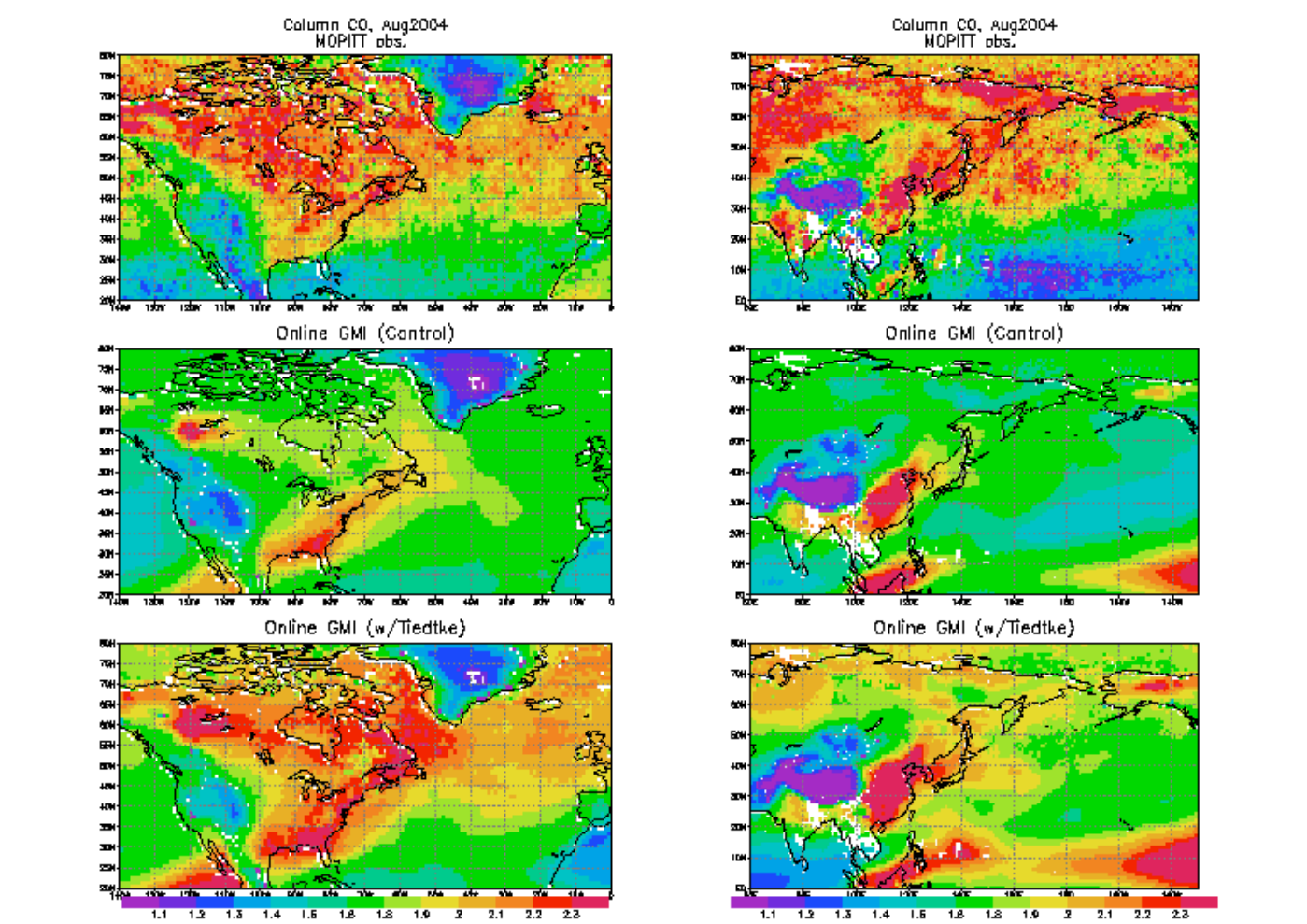
On-line computation in GCM: RAS used to compute meteorological state but in “red” & “blue” runs RAS cloud mass fluxes used with different numerical transport algorithms

Global CO sensitivity to conv. Transport (3)



On-line computation in GCM using linearized chemistry [P & L(OH)]: Comparison of runs with RAS and "Tiedtke" transport against MOPITT column CO. We need to do more validation (e.g., MOZAIC data, field missions, …)

Global CO sensitivity to conv. Transport (4)



On-line computation in GCM using GMI COMBO chemistry: Comparison of runs with RAS and “Tiedtke” transport against MOPITT column CO

Summary

- Need to make the best choices for the problem
- CCM is quite clear – chemistry must be used on line in GCM (radiative coupling, etc.)
- Various approaches to transport using “real” winds – either CTM (off-line) or some form of “replay”
  - Some testing is started (sub-grid transport)
  - Need a concentrated effort to complete a full evaluation
- Needs discussion in GMI context