GFDL AM3 Meteorological Fields with GMI

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Objectives

- To improve our understanding of uncertainties in model predictions due to the use of different input meteorological fields by incorporating output from GFDL AM3 GCM into the GMI modeling framework.

- To assess the AM3 meteorological fields through inter-comparison with those from other major global climate models or data assimilation systems.

- Eventually, to study the effects of climate change on Asian pollution outflow with GMI CTM driven by output from GFDL AM3.

GFDL AM3

- Donner et al., for submission to *J. Climate*, 2010
- The atmospheric component of the GFDL coupled GCM (CM3) for atmosphere, oceans, land, and sea ice.
- Employs a cubed-sphere implementation (Putman and Lin, 2007) of a finite-volume dynamical core (Lin, 2004)
- Coupled to LM3 (a new land model with eco-system dynamics and hydrology)
- Most basic circulation features in AM3 are simulated as realistically, or more so, than in AM2.1.
- Being used for the IPCC 5th Assessment Report (AR5)

GFDL AM3 (cont'd)

- **deep convection**: Donner scheme (Donner, 1993)
- **shallow convection**: Univ of Washington shallow convection scheme (Bretherton et al., 2004)
- **planetary boundary layer**: Louis (1979), Lock et al. (2000)
- **stratiformclouds**: Tiedke(1993)
- **cloud droplet numbers**: prognostic equation (Ming et al., 2007) of Nd
- **chemistry**:
  - Gas phase - MOZART (Horowitz et al, 2003)
  - Aerosols - GOCART (Chin et al., 2000; Ginoux et al. 2001)
  - stratospheric chemistry: Austin & Wilson (2006).
- **radiation**:
  - SW (Freidenreichand Ramaswamy, 1999);
  - LW (Schwarzkopf and Ramaswamy, 1999)
  - on-line gas species and aerosols
  - stochastic overlap of stratiform, shallow and deep conv clouds
- **advection**: C48 20cubed-sphere implementation of the FV dynamical core (Putman and Lin, 07; Lin, 2004)
- **vertical levels**: 48 (additional levels in the stratosphere relative to AM2)

Incorporate AM3 met fields into GMI

- Request a list of meteorological variables required by GMI/GEOS-5 (thanks to Steve Steenrod)
- Identify the corresponding variables in AM3
- Prepare the diagnostic table for the AM3 run
- Integrate AM3 forced with observed sea surface temperatures to generate present-day climate
  - One month - test run
  - One year (2005 for now) – production run
- Re-grid model output from the cubed-sphere grid to regular lat/lon grids.
- Verify the re-griddings
- Next step: to interface AM3 met fields with GMI CTM

AM3 MET FIELDS INTO GMI

- **Total 75 variables**
- **3-hr averaged 3-D variables**
- **3-hr averaged 2-D variables**
- **2-D instantaneous: surface pressure**
- **2-D static: surface height**

About 20GB per month (2x2.5)

AM3 met fields with GMI

in GMI	[Unit]	Definition	in AM3	[Unit]	Definition
3D	**3_hr Ave.**				
T	K	Air Temp	temp	K	air temperature
U	m s-1	Eastward Wind	uwnd	m s-1	zonal wind
V	m s-1	Northward Wind	vwnd	m s-1	meridional wind
KH	m2 s-1	Total Scalar Diffusivity (defined at layer edges)	diff_t	m2 s-1	Vertical diff coeff for heat, moisture, tracers
OPTDEPTH		cloud optical depth (dimensionless)	lsc_cld_amt	%	large-scale cloud amount
			strat_conc_drop	g/m3	In-cloud liq water content of strat clouds
			strat_conc_ice	g/m3	In-cloud ice water content of strat clouds
			meso_cld_amt	%	meso cloud amount
			meso_conc_drop	g/m3	In-cloud liq water content of donner meso clouds
			meso_conc_ice	g/m3	In-cloud ice water content of donner meso clouds
			cell_cld_amt	%	cell cloud amount
			cell_conc_drop	g/m3	In-cloud liquid water content of donner cell clouds
			cell_conc_ice	g/m3	In-cloud ice water content of donner cell clouds
			shallow_cld_amt	%	UW shallow cloud amount
			shallow_conc_drop	g/m3	In-cloud liq water content of uw shallow clouds
			shallow_conc_ice	g/m3	In-cloud ice water content of uw shallow clouds
CMFMC	kg m-2 s-1	Upward Moist Convective Mass Flux	m_cellup	kg m-2 s-1	cell upward mass flux
DTRAIN	kg m-2 s-1	Detrainment Cloud Mass Flux	m_cell_donner	kg m-2 s-1	mass flux detrained from the cells
			mc_donner	kg m-2 s-1	total mass flux from Donner (cell+meso up+meso down)
			mc_donner_up	kg m-2 s-1	total upward mass flux from donner (cell+meso up)
			cmf_uwc	kg m-2 s-1	upward mass flux from shallow convection
			fdr_uwc	Pa-1	total UW shallow conv detrainment rate
CLOUD		3-D Cloud Fraction	tot_cloud_area		Total cloud area – all clouds (0-1)
DORCON	kg m-2 s-1	Precip (rain+snow) Product Rate – Convective	fl_ccrain	kg m-2 s-1	convective rain flux
			fl_ccsnow	kg m-2 s-1	convective snow flux
DQRLSC	kg m-2 s-1	Precip (rain+snow) Product Rate – Large Scale	fl_lsrain	kg m-2 s-1	large scale rain flux
			fl_lssnow	kg m-2 s-1	large scale snow flux
			fl_lsgrpl	kg m-2 s-1	large scale graupel flux
DQVDTMST	kg kg-1 s-1	Water Vapor Tendency from Moist Physics	qdt_conv	kg kg-1 s-1	Specific Humidity tendency from convective cloud
			qdt_ls	kg kg-1 s-1	Specific Humidity tendency from strat cloud
			qdt_phys		all changes to vapor resulting from model physics
DQIDTMST	kg kg-1 s-1	Tendency of ice water due to moist process	ice_wat_phys_moist	kg kg-1 s-1	physics_driver.F90
DQLDTMST	kg kg-1 s-1	Tendency of liquid water due to moist process	liq_wat_phys_moist	kg kg-1 s-1	
QV	kg kg-1	Specific Humidity	sphum	kg kg-1	Specific Humidity
omega	Pa s-1	Vertical pressure velocity	omega	Pa s-1	Vertical pressure velocity
PV	K*m2 kg-1 s-1	3D ertel potential vorticidy	pv	s-1	
QI	kg kg-1	Cloud Ice water mixing ratio	tot_ice_amt	kg kg-1	Cloud Ice water mixing ratio
QL	kg kg-1	Cloud liquid water mixing ratio	tot_liq_amt	kg kg-1	Cloud liquid water mixing ratio
			o3		ozone mixing ratio
2D	**3_hr Ave.**				
T2M	K	Temp Interpolated to 2m above The Displacement Height	t_ref (2m)	K	temperature at ref height
			q_ref (rh_ref)	kg/kg	specific humidity at ref height
TSKIN	K	Skin Temperature	t_surf	K	Skin Temperature

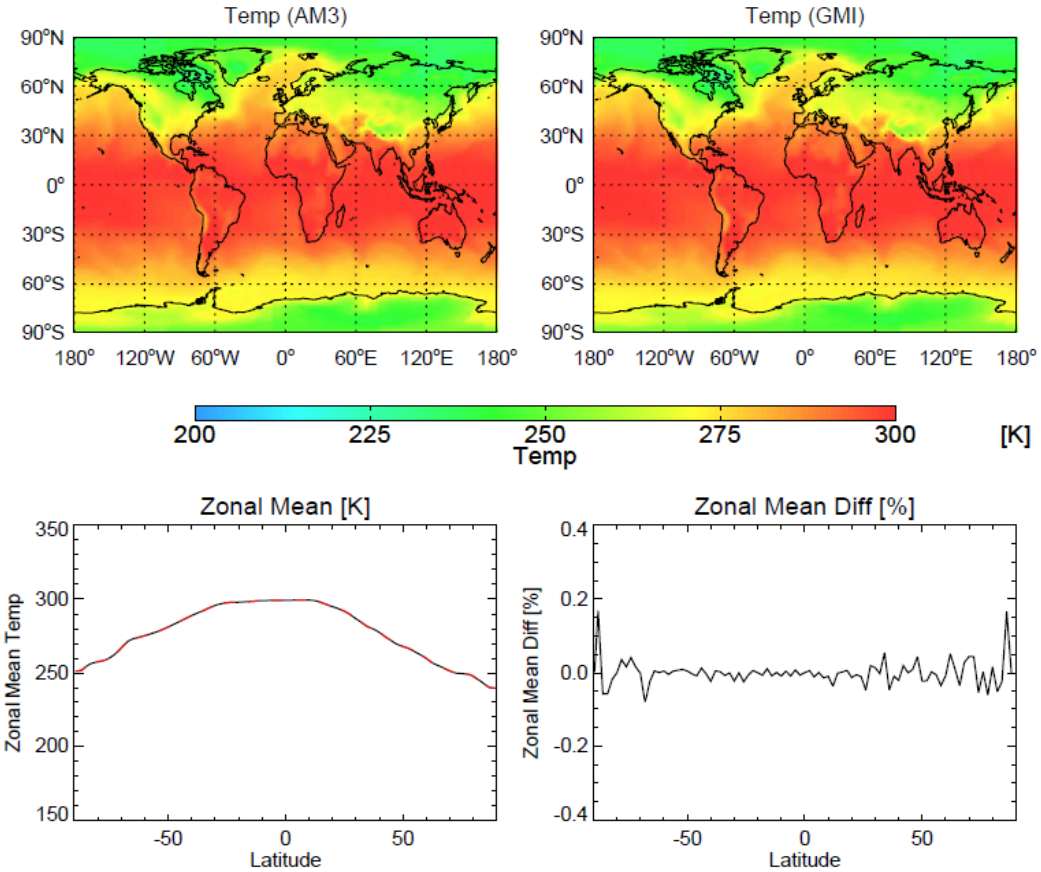
U10M	m s-1	Eastward Wind at 10m above The Displacement Height	u_ref (10m)	m s-1	zonal wind speed at ref height
USTAR	m s-1	Surface Velocity Scale	u_star	m s-1	surface friction velocity
V10M	m s-1	Northward Wind at 10m above The Displacement Height	v_ref (10m)	m s-1	meridional wind speed at ref height
Z0M	m	Roughness Length, Momentum	rough_mom	m	Surface roughness for momentum
SWGNET	W m-2	Net Surface Downward Shortwave Flux	swdn_sfc	W m-2	Short Wave Flux Down at Surface
ALBEDO		surface albedo	alb_sfc		surface albedo
ALBNIRDF		Diffuse Beam NIR Surface Albedo (fraction)	alb_sfc_nir_dif		Diffuse Beam NIR Surface Albedo (fraction)
ALBNIRDR		Direct Beam NIR Surface Albedo (fraction)	alb_sfc_nir_dir		Direct Beam NIR Surface Albedo (fraction)
ALBVISDF		Diffuse Beam VIS Surface Albedo (fraction)	alb_sfc_vis_dif		Diffuse Beam VIS Surface Albedo (fraction)
ALBVISDR		Direct Beam VIS Surface Albedo (fraction)	alb_sfc_vis_dir		Direct Beam VIS Surface Albedo (fraction)
GWETROOT		Root Zone Soil Wetness (fraction)	soil_liq	kg m-3	bulk density of liquid water (monthly)
(monthly)			soil_ice	kg m-3	bulk density of ice water (monthly)
			root_zeta	m	e-folding depth of root biomass (monthly)
			soil_sat		soil porosity (static)
			root_density	kg m-2	total biomass below ground (monthly)
GWETTOP		Top Soil Layer Wetness (fraction)	soil_liq	kg m-3	bulk density of liquid water (1st layer; ~ 2cm) (Daily)
(Daily)			soil_ice	kg m-3	bulk density of ice water (1st layer; ~2cm) (Daily)
		(see above for root_zeta and soil_sat)	root_zeta	m	e-folding depth of root biomass (monthly)
			soil_sat		soil porosity (static)
LWI		Surface Type (0=water, 1=land, 2=ice)	land_mask		fractional amount of land
			ice_mask		fractional amount of sea ice
					water = 1 - (land_mask) – (ice_mask)
PARDF	W m-2	Surface Downward Photosynthetically Active Radiation Diffuse Flux	flux_sw_down_total_dif	W m-2	
PARDR	W m-2	Surface Downward Photosynthetically Active Radiation Bean Flux	flux_sw_down_total_dir	W m-2	
PBLH	m	Planetary Boundary Layer Height	z_pbl	m	vert_turb_driver.F90
PRECANY	kg m-2 s-1	Surface Precipitation Flux from Anvils			meso_precip = tpreal_deep – rcoal_deep
			tprea1_deep	mm day-1	area-weighted total donner precip
			rcoa1_deep	mm day-1	area-weighted convective (cell) precip
PRECCON	kg m-2 s-1	Surface Precipitation Flux from convection	prec_conv	kg m-2 s-1	total precipitation rate from MCA or RAS
PRECLSC	kg m-2 s-1	Surface Precipitation Flux from Large_Scale	prec_ls	kg m-2 s-1	total precipitation rate from LSC or Strat cloud
PRECSNO	kg m-2 s-1	Surface Snowfall Flux	fprec	kg m-2 s-1	frozen precipitation rate (snow)
SNODP	m	Snow Depth	FWSs	kg m-2	snow mass [snow depth = (snow mass)/(snow density)]
					snow density = 300 (kg m-3)
FRLANDICE		Fraction Land Ice	area	m2	
			area_soil	m2	
			area_glac	m2	
			area_lake	m2	
CLDTOT		column cloud fraction	cld_amt_2d		total cloud amount (physical occurrence)
LAI	m2 m-2	leaf area index	lai	m2 m-2	leaf area index
LWTUP	W m-2	Outgoing longwave radiation	olr	W m-2	outgoing longwave radiation
SLP	hPa	Sea level pressure	slp	hPa	sea-level pressure
2D	**3_hr Instantaneous**				
PS	Pa	Surface Pressure	ps	Pa	surface pressure
2D	**static**				
PHIS	m	geopotential height	zsurf	m	surface height

Re-Gridding of AM3 Met Fields

- **AM3**
  - Longitude: [1.25, 3.75, 6.25, ……, 353.75, 356.25, 358.75]
  - Latitude: [-89, -87, -85, ……, 85, 87, 89]
  - Pressure: 48 vertical levels
- **GMI**
  - Longitude: [0, 2.5, 5, ……, 325.5, 355, 357.5]
  - Latitude: -89.5, -88, -86, ……, 86, 88, 89.5]
- A re-gridding scheme developed at GFDL (based on Jones, 1999) was applied to re-grid the output from the cubed-sphere grid (AM3) to 2°×2.5° and 4°×5° latitude/longitude grids as employed by GMI CTM
  - Reference: Jones, P.W., First- and second-order conservative remapping schemes for grids in spherical coordinates, MWR, vol.127, 2204-2210, 1999.

GFDL grid vs. GMI grid: Temp.

- 996 hPa
- 01/15/1980, 12-15hr average

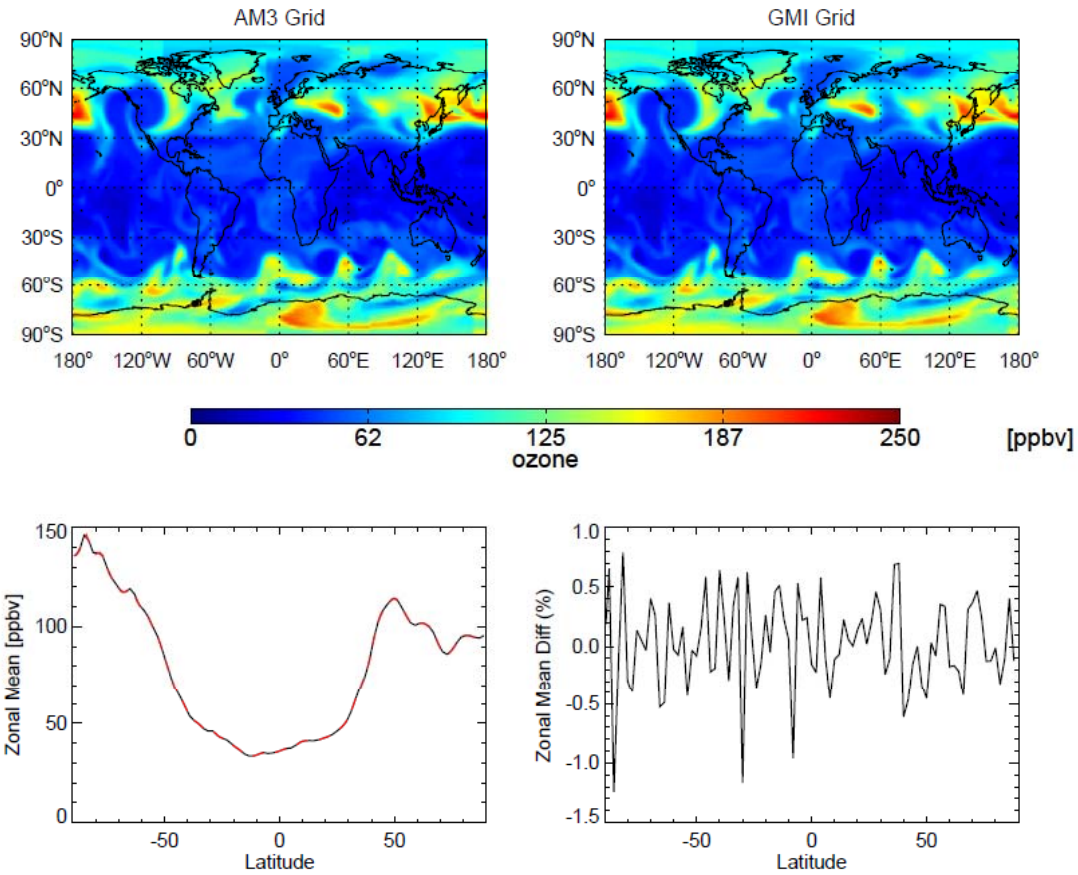


- **AM3 Temp.**
  - Min: 232.869
  - Max: 310.788
  - Median: 280.232
  - Mean: 277.338
- **GMI Temp.**
  - Min: 232.273
  - Max: 311.420
  - Median: 279.850
  - Mean: 276.990

The re-gridded AM3 fields on GMI lat/lon grids were verified against the same fields on GFDL lat/lon grids. (GFDL regularly re-grids AM3 output from cubed-sphere grids to lat/lon grids for analysis.)

GFDL grid vs. GMI grid: Ozone

- 277 hPa
- 01/15/1980, 12-15hr average



- **AM3 Ozone**
  - Min: 17.2397
  - Max: 224.611
  - Median: 65.9896
  - Mean: 78.2020
- **GMI Ozone**
  - Min: 16.0329
  - Max: 233.639
  - Median: 66.8829
  - Mean: 78.6155

GMI/AM3

- **Next step: to interface AM3 met fields with GMI CTM**

- **Need "core" support to interface the re-gridded 2x2.5 and 4x5 AM3 met fields with GMI CTM.**
  - starting model year: 2005
  - Time frame: Oct. – Nov. 2010

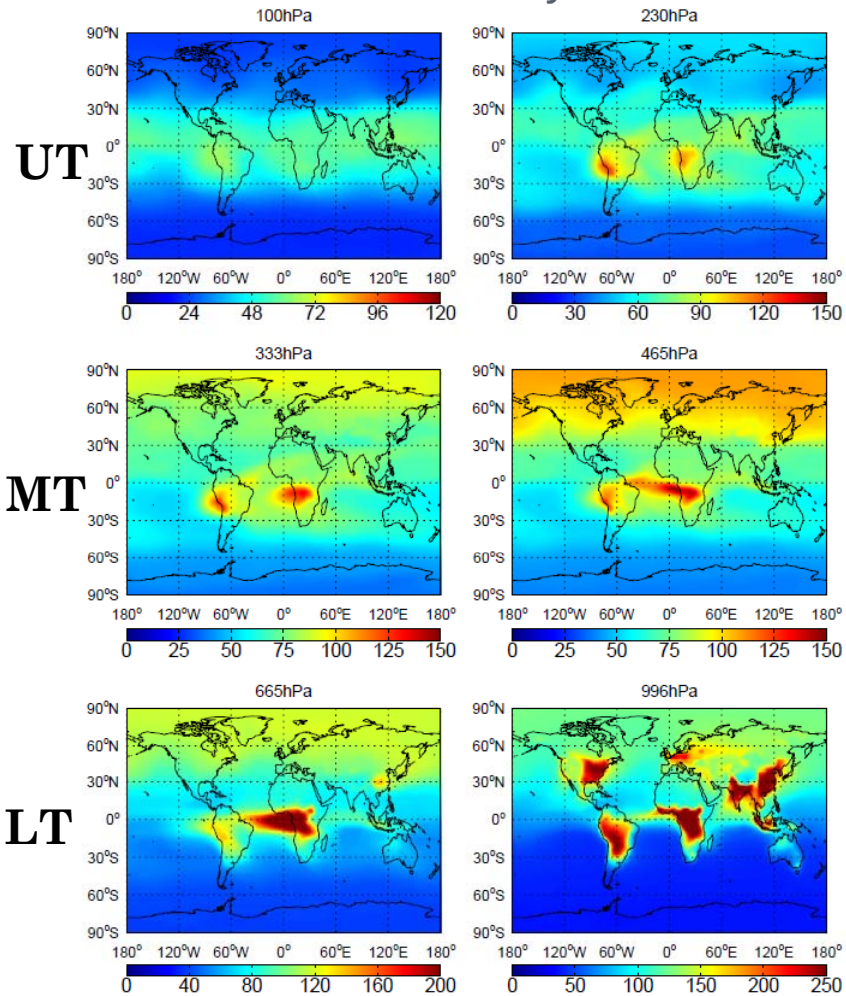
- **Examine the characteristics of transport in AM3 in comparison with other meteorological data sets (e.g., ECMWF, GEOS-5 DAS).**

Evaluation of AM3 O3 & CO with TES observations (ongoing work)

: This will facilitate our future evaluation of GMI/AM3 CTM simulations with TES observations.

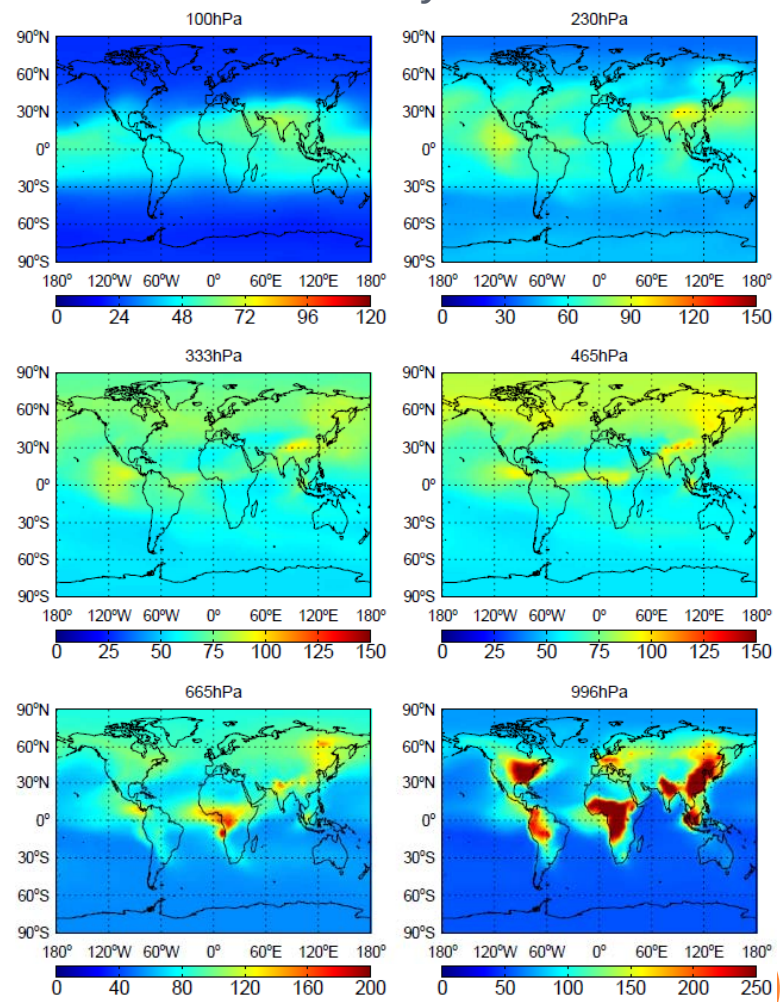
AM3 CO Jan (L) & Jul (R) 1991-2000

January



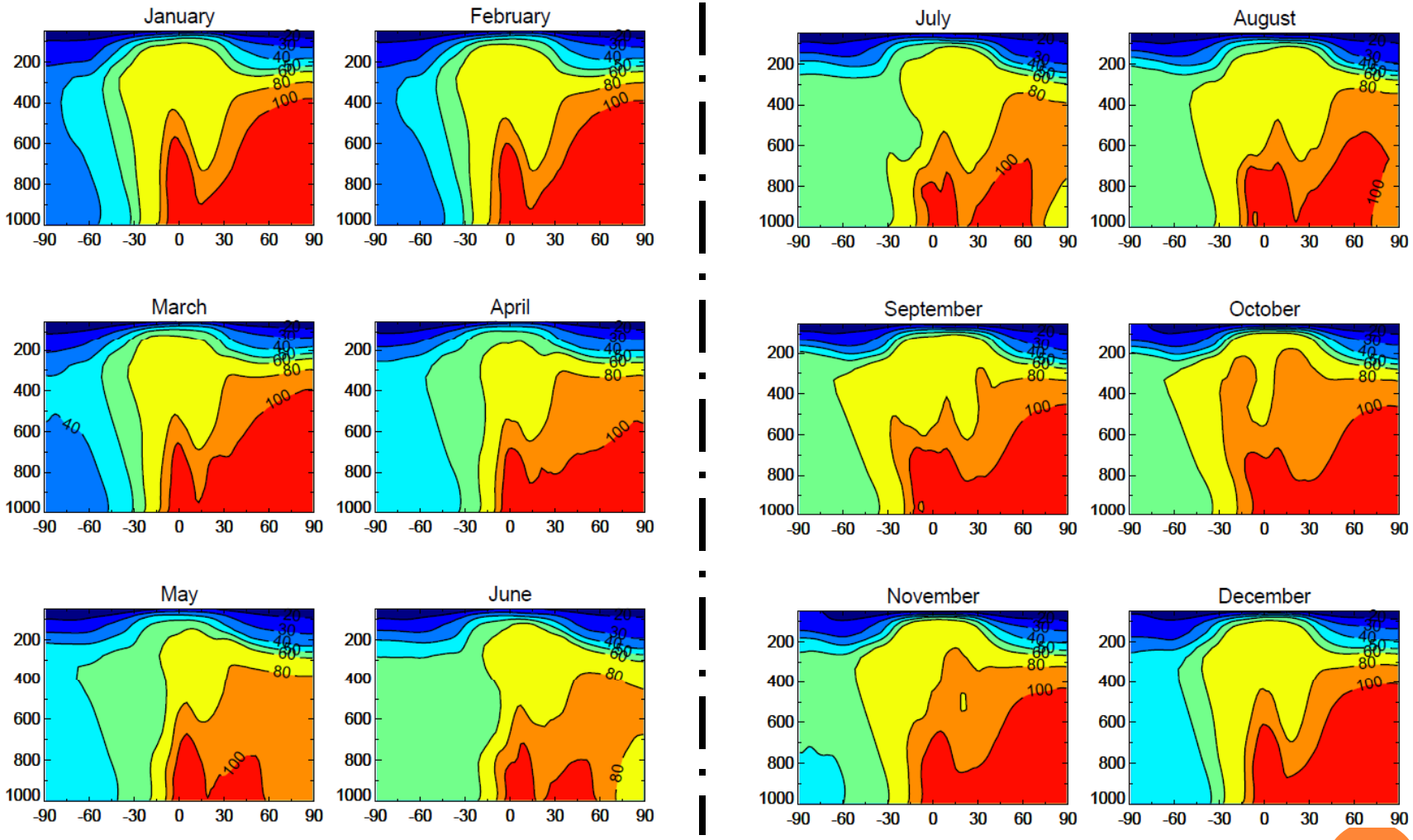
- Biomass burning in North Africa

July



- Enhancement over Tibetan Plateau

AM3 Monthly Zonal Mean [2005]: CO

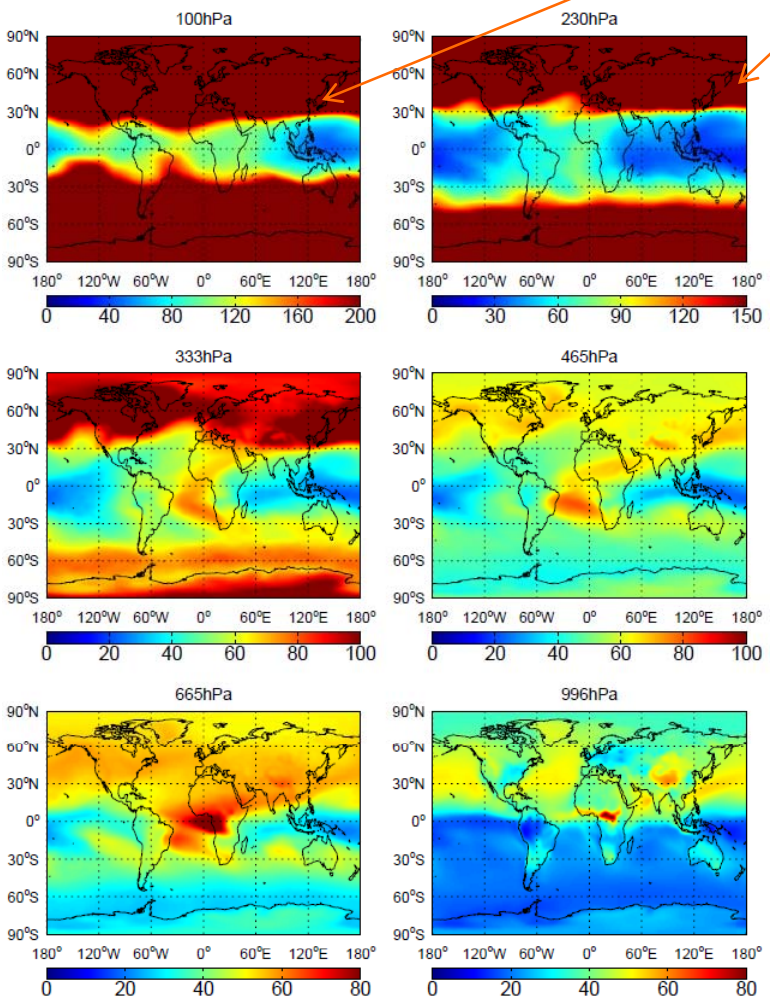


- Tropical convection
- Seasonal variation

AM3 O3 Output: 1991-2000

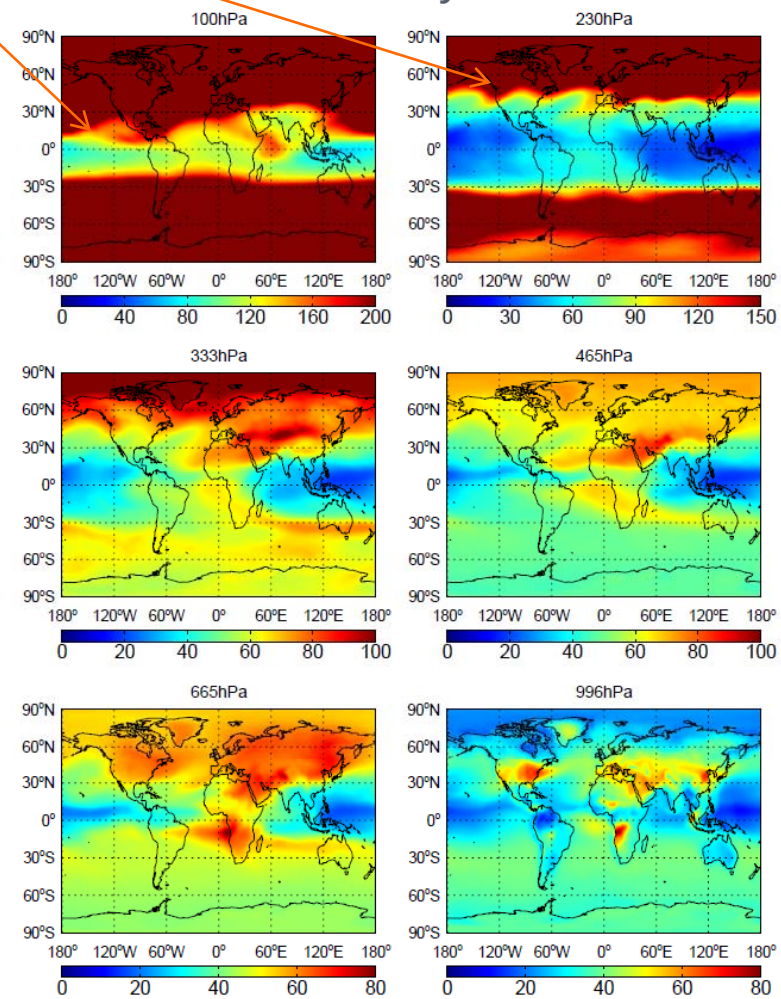
Tropopause

January



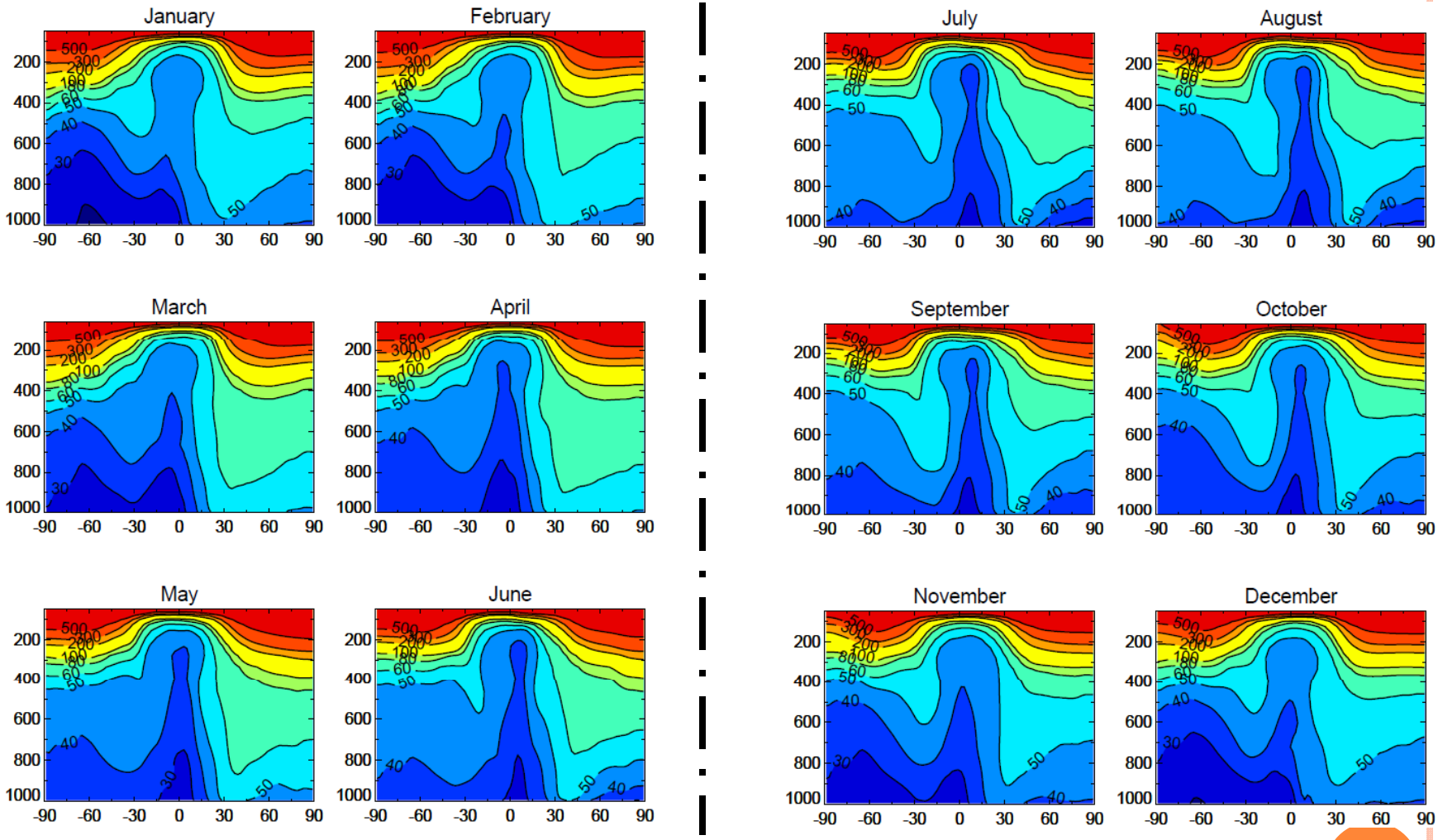
- Enhancement over the tropical Atlantic

July



- Tropospheric O3 maximum over the Middle East [Li et al., 2001]

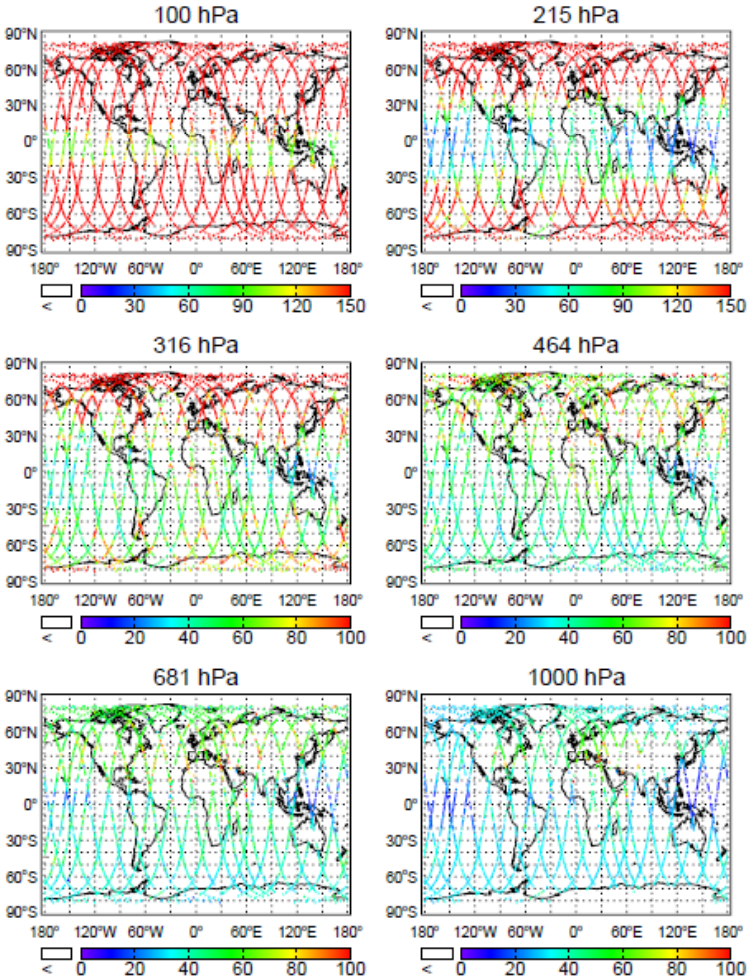
AM3 Monthly Zonal Mean [2005]: O3



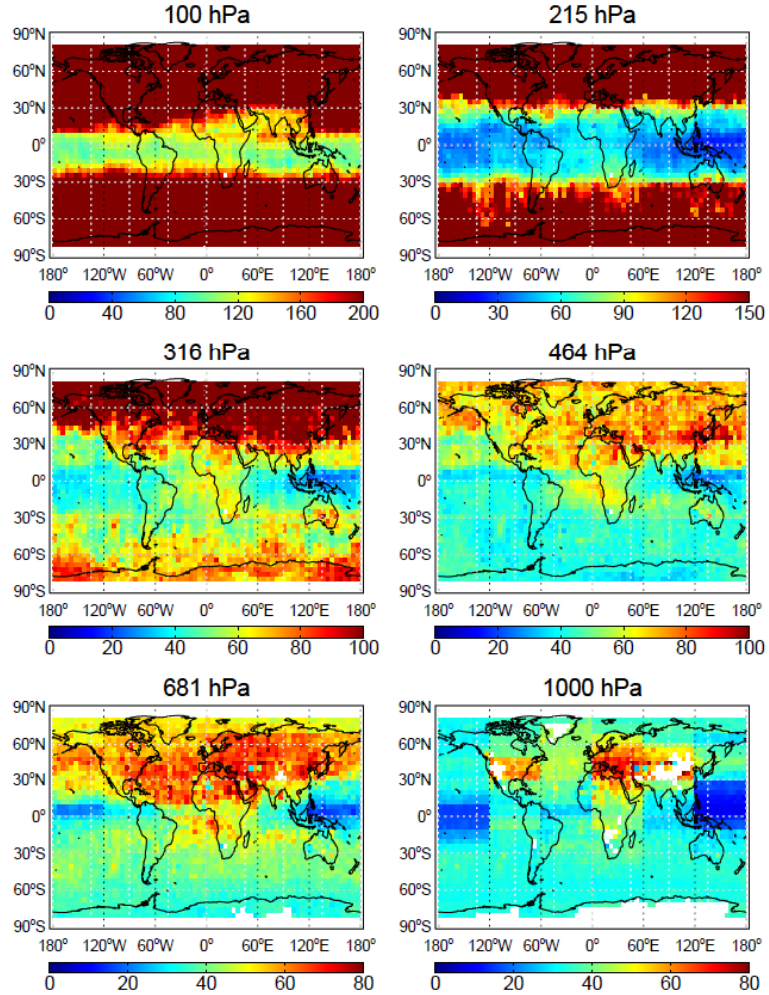
- Tropical convection
- Hemispheric asymmetry: lower in SH & higher in NH
- Maximum tropospheric O3 in spring

TES O3 Level 2 Ver. 4 [F05_07] Data

Daily Orbits on Jun. 22, 2007

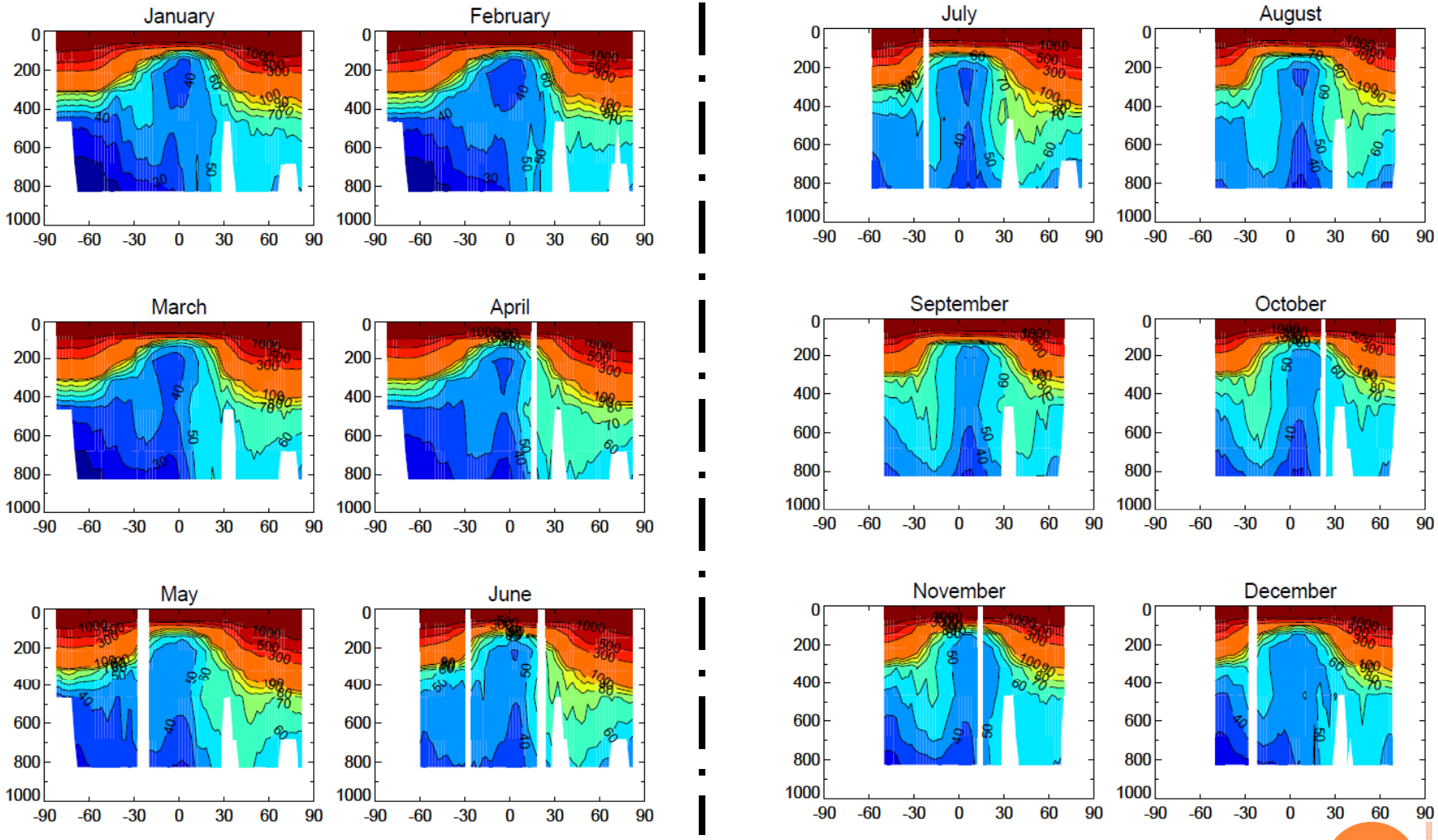


Monthly Mean in Jun. 2007



- O3, water vapor, CO, methane, nitrogen dioxide, and nitric acid for 16 orbits every other day
- Consider master retrieval quality flag, 'C' curve, DOFS for quality check [Worden et al., 2009]
- Monthly mean maps are gridded onto 4º X 5º (or 2º X 2.5º) bins.

TES L3 V1.0 Ozone zonal mean in 2008



- Not calculated if there is even 1 single missing value in the zonal direction
- Tropical convection
- Hemispheric asymmetry - Lower in SH & higher in NH
- Maximum tropospheric O3 in spring

SUMMARY

- **Identified, diagnosed and archived 75 AM3 meteorological variables for use with GMI.**
- **A re-gridding scheme is applied to re-grid the AM3 output from the cubed-sphere grid to regular lat/long grids. The re-gridded output were verified (GFDL lat/long grids vs. GMI lat/long grids; 4x5 vs 2x2.5).**
  - 3-hr averaged 3-D variables
  - 3-hr averaged 2-D variables
  - 2-D instantaneous: surface pressure
  - 2-D static: surface height
- **One year of AM3 output (2x2.5 and 4x5) ready for interfacing with GMI CTM.**
- **Evaluation of AM3 O3 and CO with TES observations is ongoing.**

Future Work

- **Interface AM3 met fields with GMI CTM**
- **Compare radionuclide simulations with GMI/AM3 CTM and AM3**
- **Evaluate GMI/AM3 Combo simulations**
  - Apply TES averaging kernels
  - Calculate TES zonal mean O3 & CO using L2 data
- **Generate AM3 met fields under future climate**
- **Effects of climate change**