Simulations for IPCC and AC&C

Jean-François Lamarque

NOAA (on leave from NCAR)

Purpose of interactive chemistry

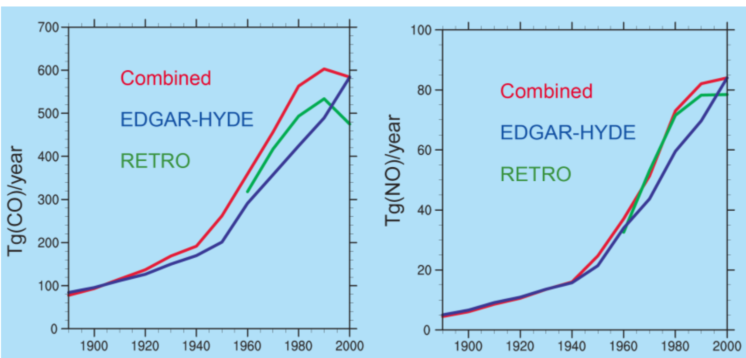
1. Provides consistent distribution of radiatively-active greenhouse gases (troposphere and stratosphere) and aerosols
2. Provides distribution of oxidants for aerosol production, including secondary-organic aerosols*
3. Provides distribution of air quality
4. Provides interaction with biogeochemistry: black carbon deposition, nitrogen deposition, ozone damage

Required data and tools

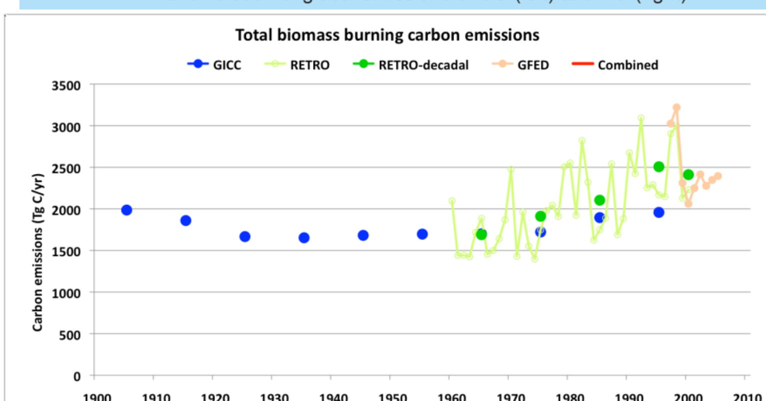
1. Emissions
2. Chemical mechanism
3. Atmosphere model

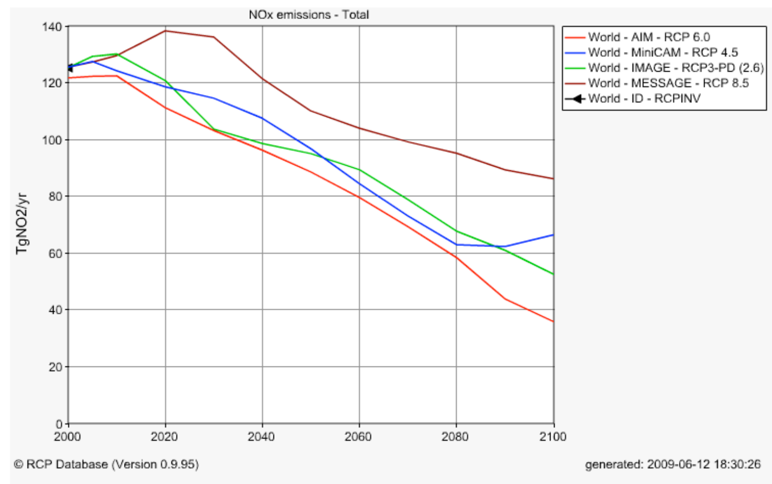
Emissions

Led international effort to provide improved emissions 1850-2300, consistent across 2000 for anthropogenic, biomass burning and natural emissions of ozone precursors and aerosols



Time volution of global emissions of CO (left) and NO (right)

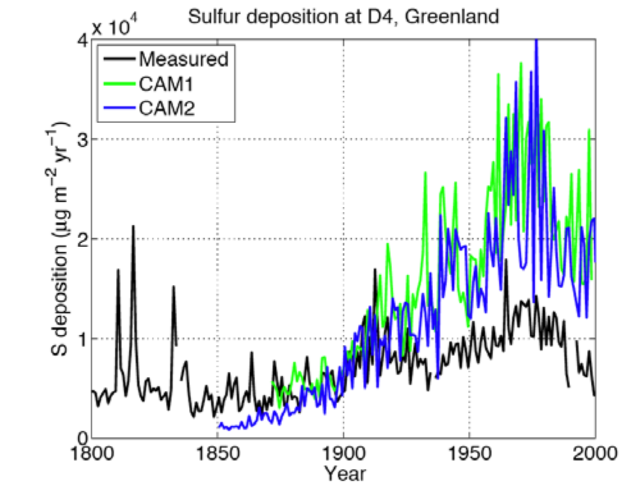


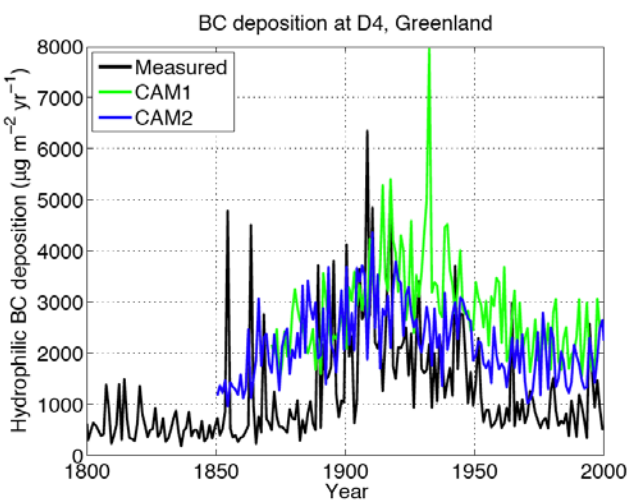


CAM3.5 simulation

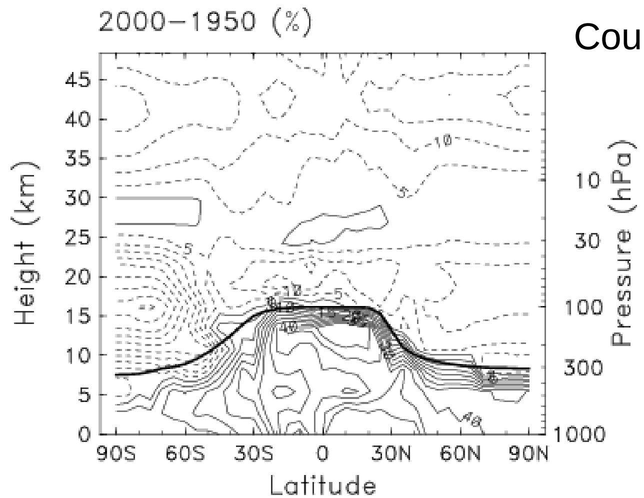
- Continuous simulation 1850-2005 with chemistry (reduced NMHCS + stratospheric + aerosols)
- IPCC emissions
- CCSM-3 SSTs
- 1.9x2.5x26L: approx. 16 years/day

CAM3.5 simulation: results



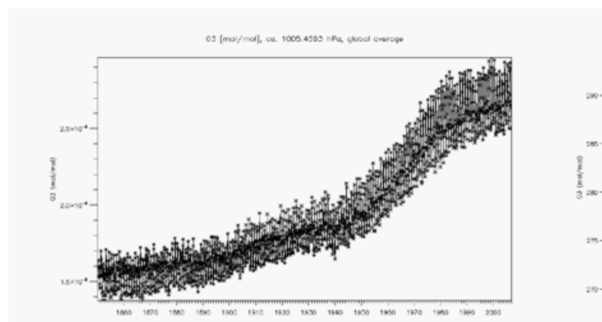


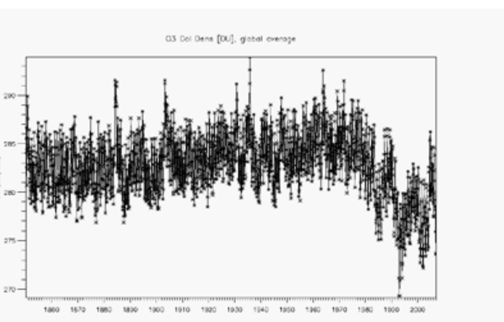
Courtesy of M. Flanner



Courtesy of B. Randel

To be used in CMIP-5 by AOGCMs





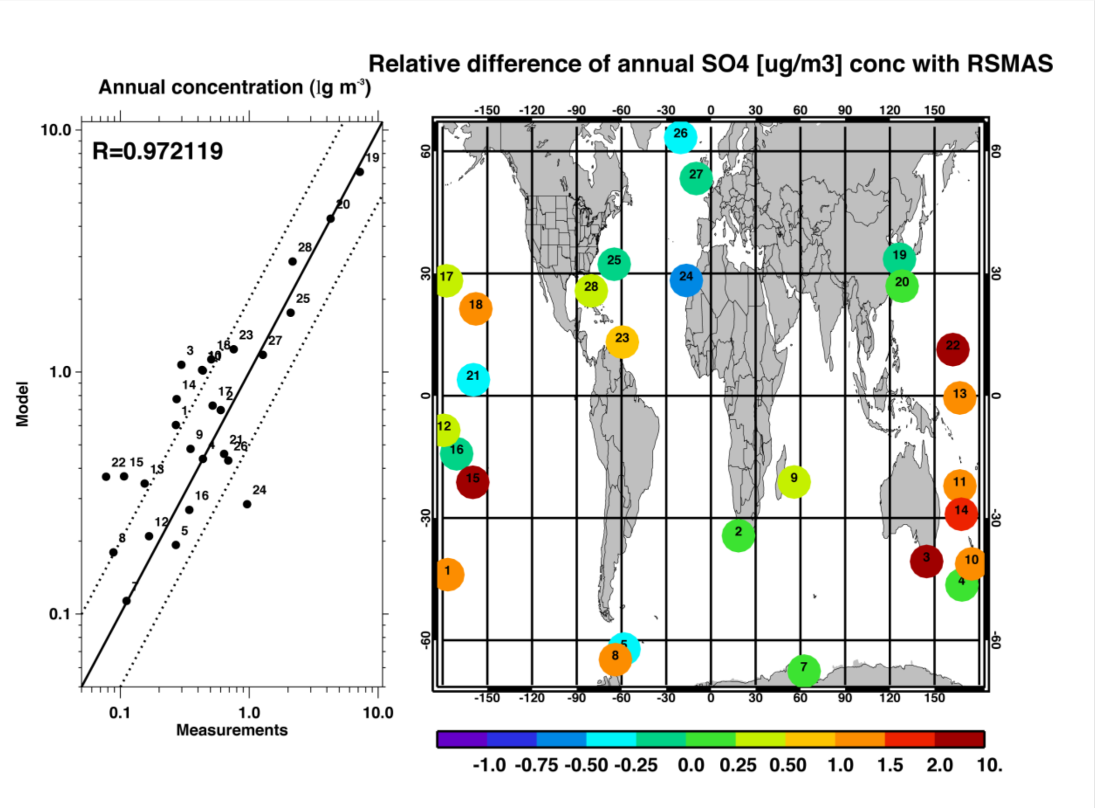
Surface ozone

Total ozone column

Model evaluation: Stratosphere: CCMval-2

Troposphere: ACC-MIP

CAM3.5 simulation: results



CAM3.5 1850-2005

Results are used for

- Nitrogen deposition on land and ocean
- Aerosol deposition on snow and ice
- Ozone distribution: troposphere and stratosphere
- Oxidants distribution
- Methane distribution

Track 1 CCSM

- Superfast chemistry (P. Cameron-Smith, LLNL) + LINOZ (M. Prather, UCI): additional 14 tracers if SO4 (other aerosols read): 20% CAM cost increase
- Methane fixed from previous simulation
- Time-varying ozone
- Performed 10 years for 1850 conditions

RESTOM=0.07 W/m^2

- Need to compare with latest Track1

Planned simulations

CCSM Track1

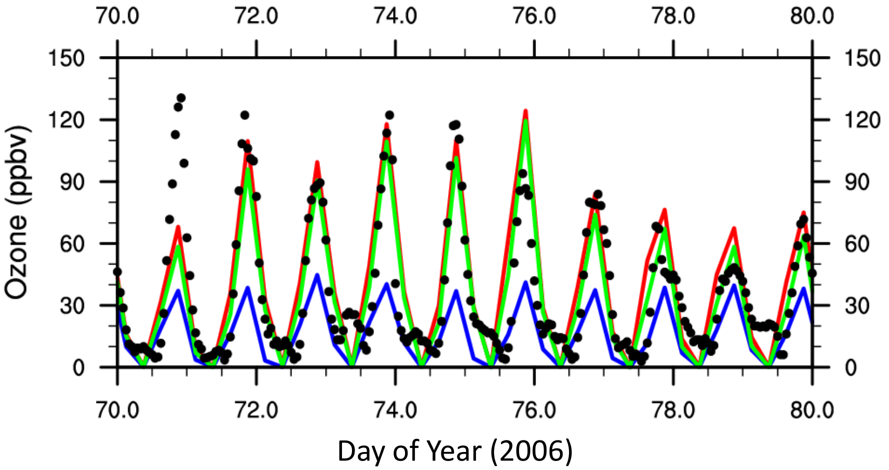
1. 1850-2005: at least 3 (capture ensemble variability)
2. 2005-2100: focus on some scenarios (RCP8.5 and RCP2.6)

CAM3.5

1. 2005-2100: one for each RCP
2. Extension to 2300?

Decadal projections

- Use reduced NMHC mechanism



Red: Full mechanism
Green: Intermediate mechanism
Blue: Fast mechanism
Dots: observations (Mexico City)

- Track1 or Track5?

AC&C #4

- *ACCMIP_1: Timeslice runs complementing CMIP5*
  - Timeslice runs including detailed chemistry diagnostics. Each run 4 years with prescribed SSTs taken from AR5 runs (SSTs should ideally be decadal means around given years), 2-month initialization suggested.
  - 8 historical times (1850, 1890, 1910, 1930, 1950, 1970, 1990, 2000)
  - 5 future times (2010, 2030, 2050, 2070, 2100), each with 2.6 W/m^2 Representative Concentration Pathway (RCP), 4.5 W/m^2 RCP and 8.5 W/m^2 RCP.

AC&C #4

- *ACCMIP_2: Emission sensitivity studies*
  - Run at year 2050 (SSTs from #1), 1 year runs (+2-month initialization), model's own distribution of given emission scaled uniformly:
  - 2.1: +100 Tg isoprene
  - 2.3 +20% biomass burning (all species)
  - 2.4: +50 Tg methane (3 year run in this case, only applicable for models with sources/sinks of methane rather than prescribed)
  - 2.5: +2 Tg N/yr lightning NOx

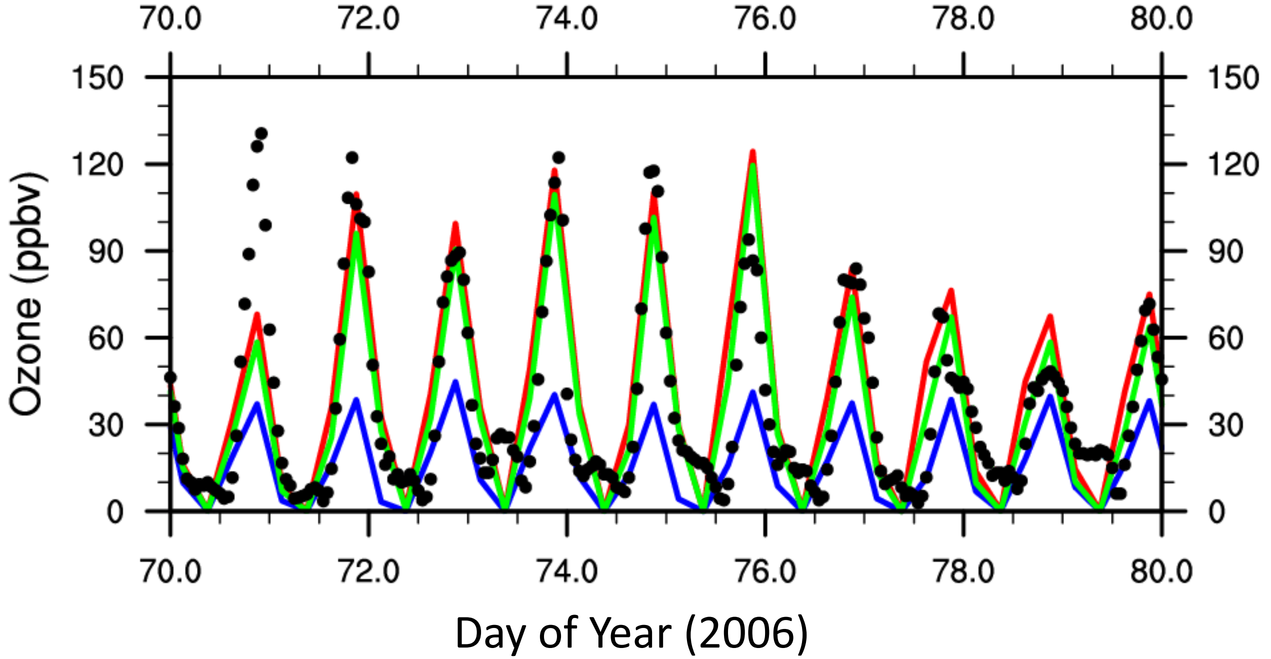
AC&C #4

- *ACCMIP_3: Testing the variation in socio-economic modeling of emissions*
  - This set of runs requests the same 4 year timeslice runs as in ACCMIP_1 for 2050 and 2100 but using emissions for the 2.6 and 4.5 RCPs from the other available Integrated Assessment models (IAMs). Runs without AIE only (as these are not climate runs)
  - [8 runs, 32 model years if 2 additional IAM datasets used]
- *ACCMIP_4: Spread in models using standardized composition*
  - Rerun of 1860, 1930, 1970 and 2000 4 year timeslices with standard 3D constituent fields from ACC Activity 4 Phase 1 climatology. Only applicable to models that did not use climatology in ACCMIP_1 runs. [~17 model years]

AC&C #4

- Meeting in Paris June 20 to discuss/define science questions, diagnostics, lead authors
- Simulations will occur over the next year

Air quality: Comparison with Mexico City surface observations



Red: Full mechanism
Green: Intermediate mechanism
Blue: Fast mechanism
Dots: observations

On most days, full and intermediate capture well the diurnal cycle and amplitude; the fast mechanism is much lower

Recent development: fast chemistry

- Minimal set of chemistry to reproduce mean and response to changes in emissions/climate for
  1. Ozone (methane chemistry and linearized stratospheric chemistry)
  2. Oxidants (for methane lifetime and for aerosol formation)
- Leads to a more consistent picture in main drivers of atmospheric composition and climate
- Additional cost of approx. 40%

  CAM with no chemistry = 6.7 years/day
  super-fast chemistry = 3.5 years/day

- Developed at LLNL by P. Cameron-Smith, M. Prather and collaborators

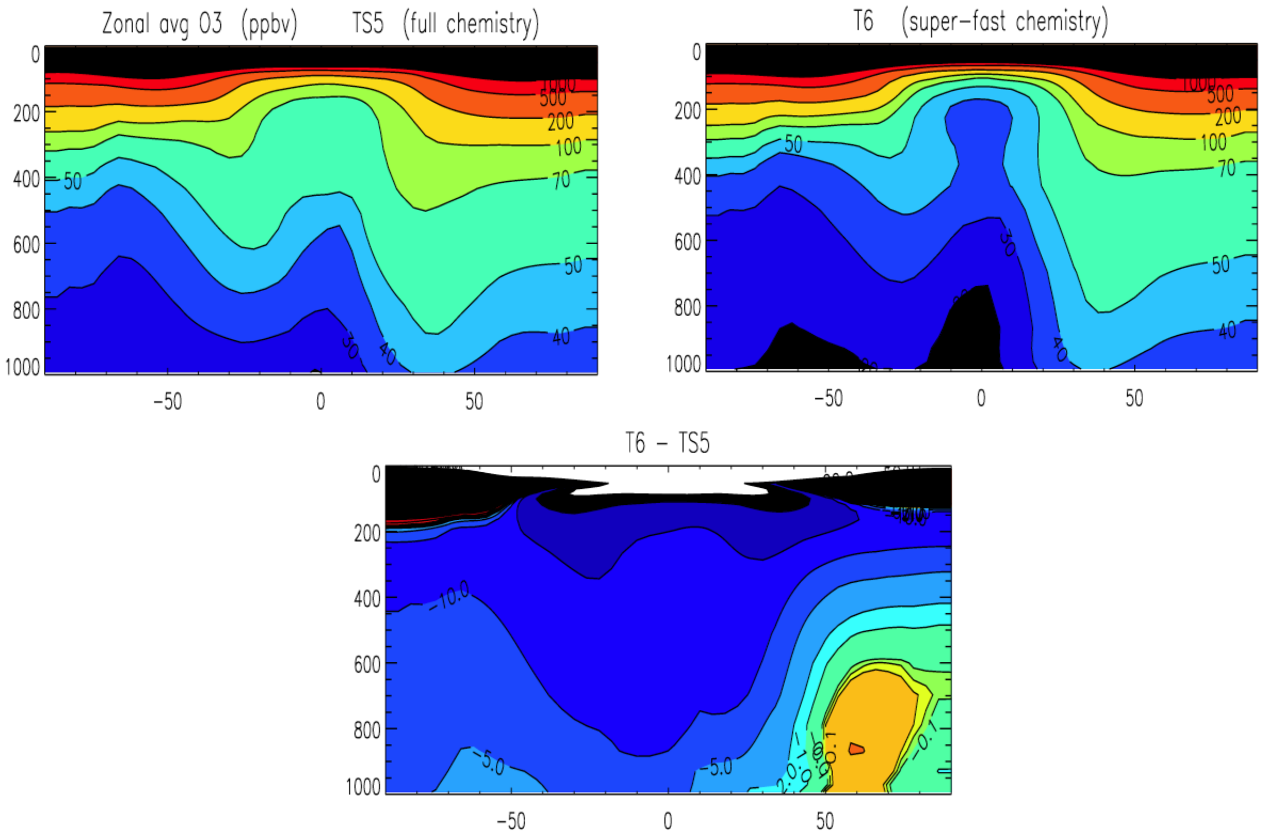
Chemistry benchmarking

Three main chemical mechanisms (list of reactions and rates) are available: full, intermediate and fast. They differ in their decreasing representation of hydrocarbon chemistry and therefore their decreasing computational cost

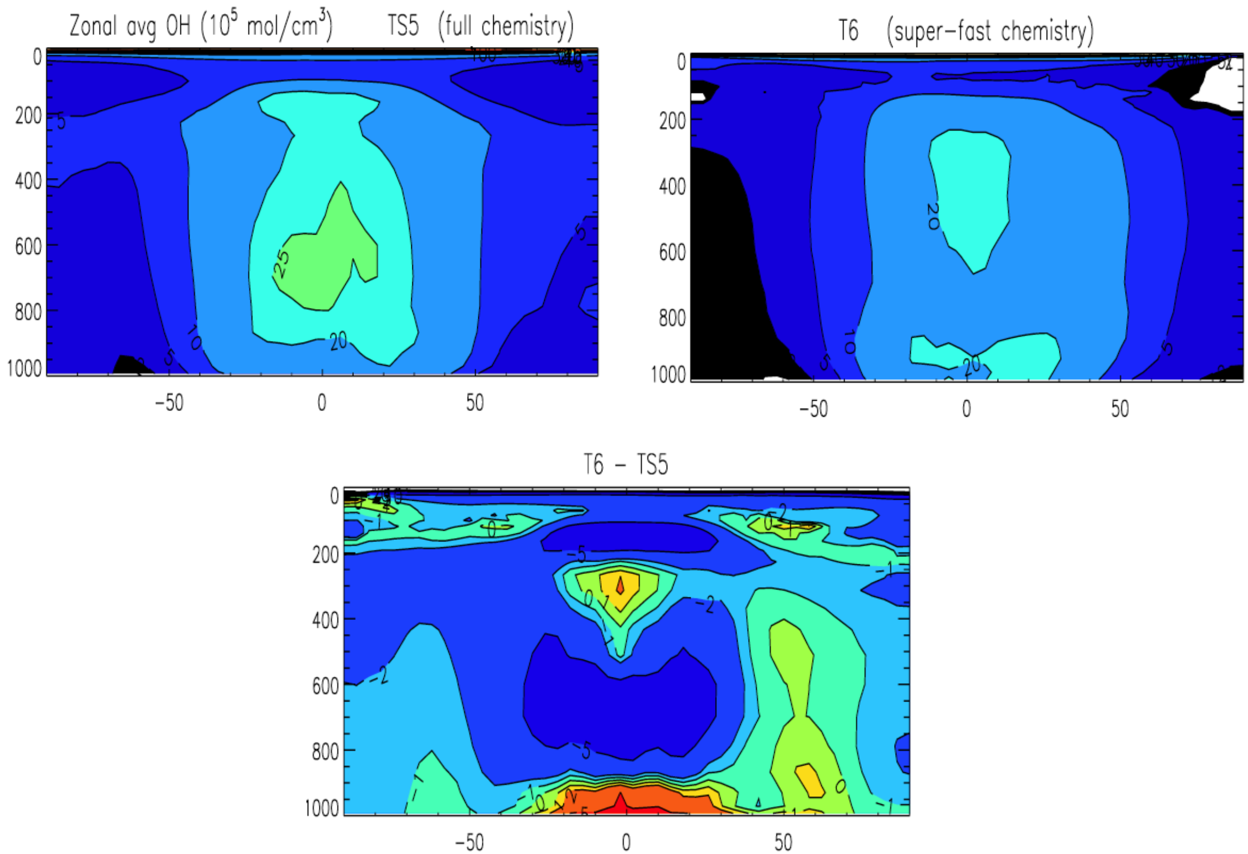
Gas-phase tropospheric chemistry only

- Full mechanism: 79 species
- Intermediate mechanism: 39 species
- Fast mechanism: 13 species

Evaluation of fast chemistry for climate simulations: ozone



Evaluation of fast chemistry for climate simulations: OH



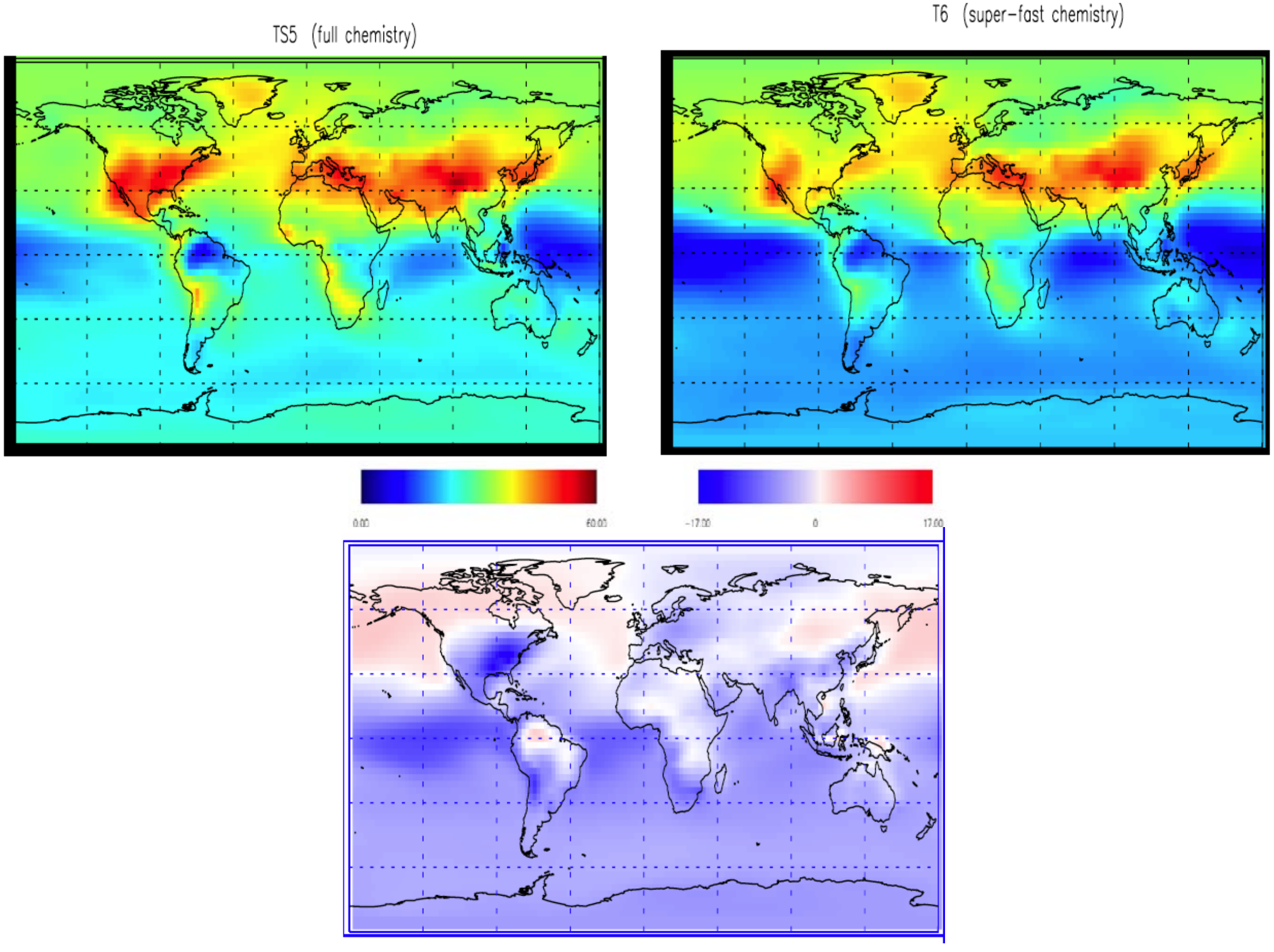
Evaluation of fast chemistry for climate simulations: methane lifetime

	Full (TS5)	**Fast (TS6)**	**Super-fast (T6)**
control	7.03	7.16	8.45
Increase NO_x 10%	6.83 (-0.199 = -2.83%)	6.96 (-0.205 = -2.87%)	8.24 (-0.211 = -2.50%)
Increase CO 10%	7.11 (+0.086 = +1.22%)	7.26 (+0.100 = +1.40%)	8.56 (+0.110 = +1.30%)
Increase CH_4 10%	7.26 (+0.231 = +3.29%)	7.43 (+0.267 = +3.73%)	8.72 (+0.264 = +3.12%)

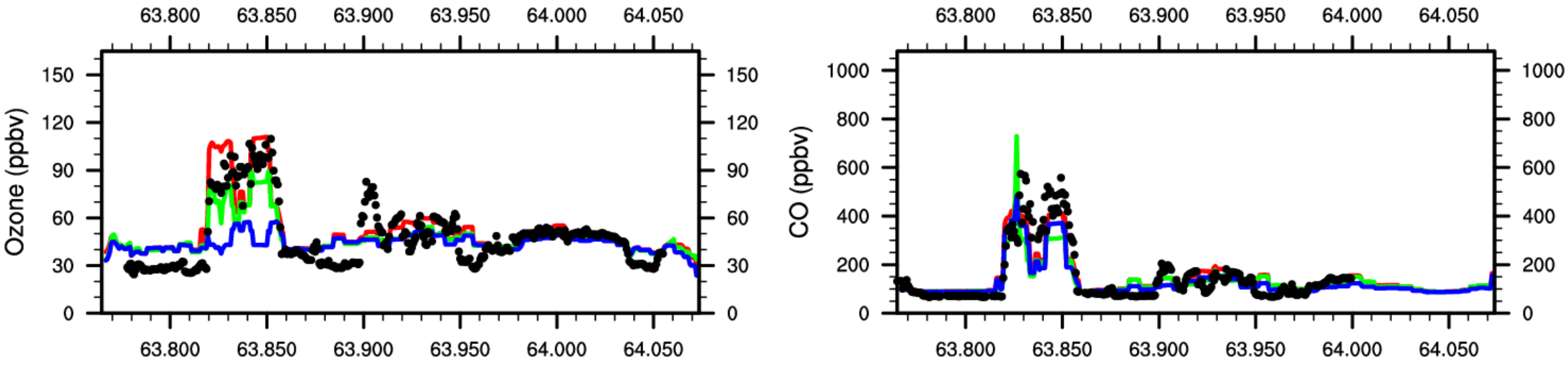
Table 1: methane lifetime in years and, in parentheses, the change in each lifetime due to the change in emission relative to the control in years and percent.

Surface ozone

- Relevance for air quality, role of megacities and impact on vegetation



Air quality: Comparison with aircraft observations



Day of Year (2006)

Red: Full mechanism
Green: Intermediate mechanism
Blue: Fast mechanism
Dots: observations

1. On most days, full and intermediate capture well the background and plume ozone; the fast mechanism captures well the background.
2. CO is well captured by all.

Plans for AR5 (historical and long-term simulations)

- Stratospheric ozone
  1. From reconstruction (SPARC activity)
  2. From offline CAM simulations
  3. From online simulations (fast mechanism)
- Tropospheric ozone
  1. From online simulations (fast mechanism)
  2. From offline CAM simulations
- Other gases (incl. methane)
  1. From online simulations (fast mechanism)
  2. From offline CAM simulations
  3. From observations/IAMs

Plans for AR5 (short-term forecasts)

- Stratospheric ozone
  1. From CCMval (SPARC activity)
  2. From offline CAM simulations
  3. From online simulations (fast mechanism)
- Tropospheric ozone
  1. From online simulations (fast mechanism)
  2. From online simulations (reduced mechanism)
  3. From offline CAM simulations
- Other gases (incl. methane)
  1. From online simulations (fast mechanism)
  2. From online simulations (reduced mechanism)
  3. From offline CAM simulations
  4. From IAMs

Status of model

- All mechanisms are running in CAM
- Need additional development to take into account BVOC emissions in fast mechanism
- Can still improve timings on fast mechanism
- Use of MAM requires rewriting of chemistry on aerosols (few days of work)
- Update CLM to provide latest BVOC emissions and dry deposition
- Transfer of deposition fields to land and sea-ice from CAM

S□chedule

- 2000 and 1850 emissions to be available by mid-December
- All other time periods in early 09
- WGCM schedule to receive offline climatologies of ozone and aerosols
    1. 1850-2000: End of March 2009
    2. 2000-2150: End of June 2009