Fast Chemistry Mechanisms for Climate Applications

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Prepared by LLNL under Contract DE-AC52-07NA27344.

Interactive chemistry brings many benefits to climate simulations.

1. Provides consistent distribution of greenhouse gases (troposphere and stratosphere), including the effects of:
   i. Changes in stratosphere-troposphere exchange (STE),
   ii. Feedback on climate through the GHGs and aerosols.
2. Provides consistent distribution of oxidants for:
   i. Aerosol production, including sulfate & secondary-organic aerosols,
   ii. Lifetimes of many species of interest, including methane.
3. Provides distribution of air quality (background).
4. Provides interaction with biogeochemistry: nitrogen deposition, ozone damage, dimethyl sulfide (CLAW).

Interactive chemistry brings many benefits to climate simulations.

5. Provides statistics from IPCC simulations on:
   i. O_3 columns,
   ii. tropospheric O_3 (radiative forcing),
   iii. tropospheric OH (CH_4 & HCFC lifetimes).
6. Tracers good for diagnosing and validating GCM:
   i. Interhemispheric mixing time,
   ii. Stratospheric lifetime,
   iii. Convective massfluxes.
7. Offline chemical fields take human & computer time too.

Super-fast chemistry is a viable capability for AR5 simulations

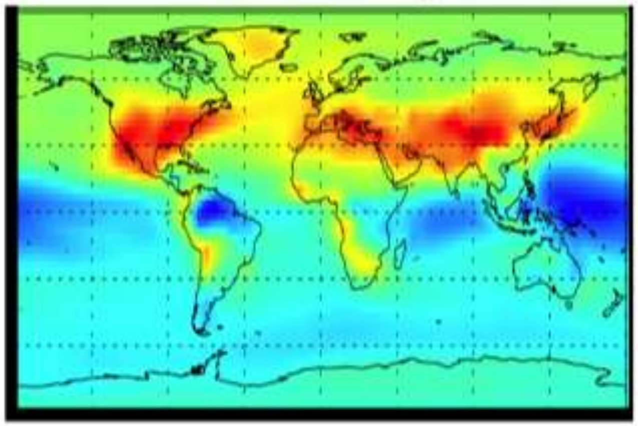
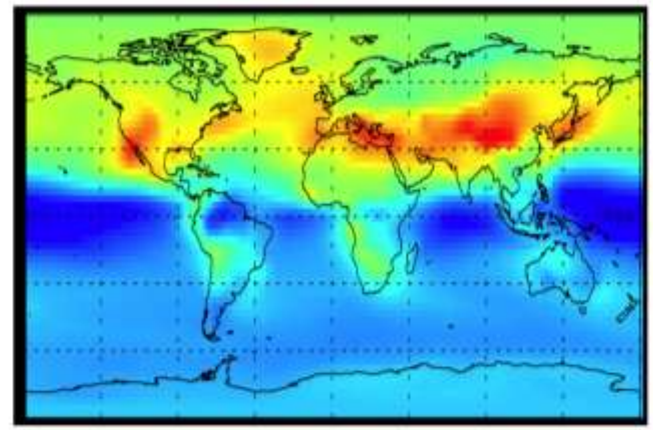
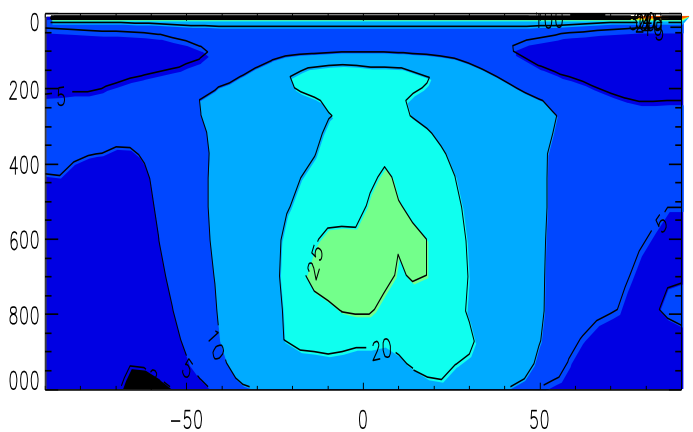
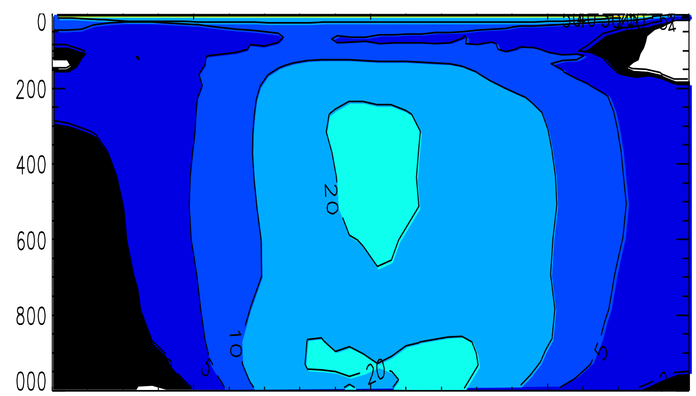
1. Super-fast chemistry increases CAM runtime by 40%.

2. Super-fast chemistry is archived on trunk as a standard chemistry option in CAM 3.6.26.

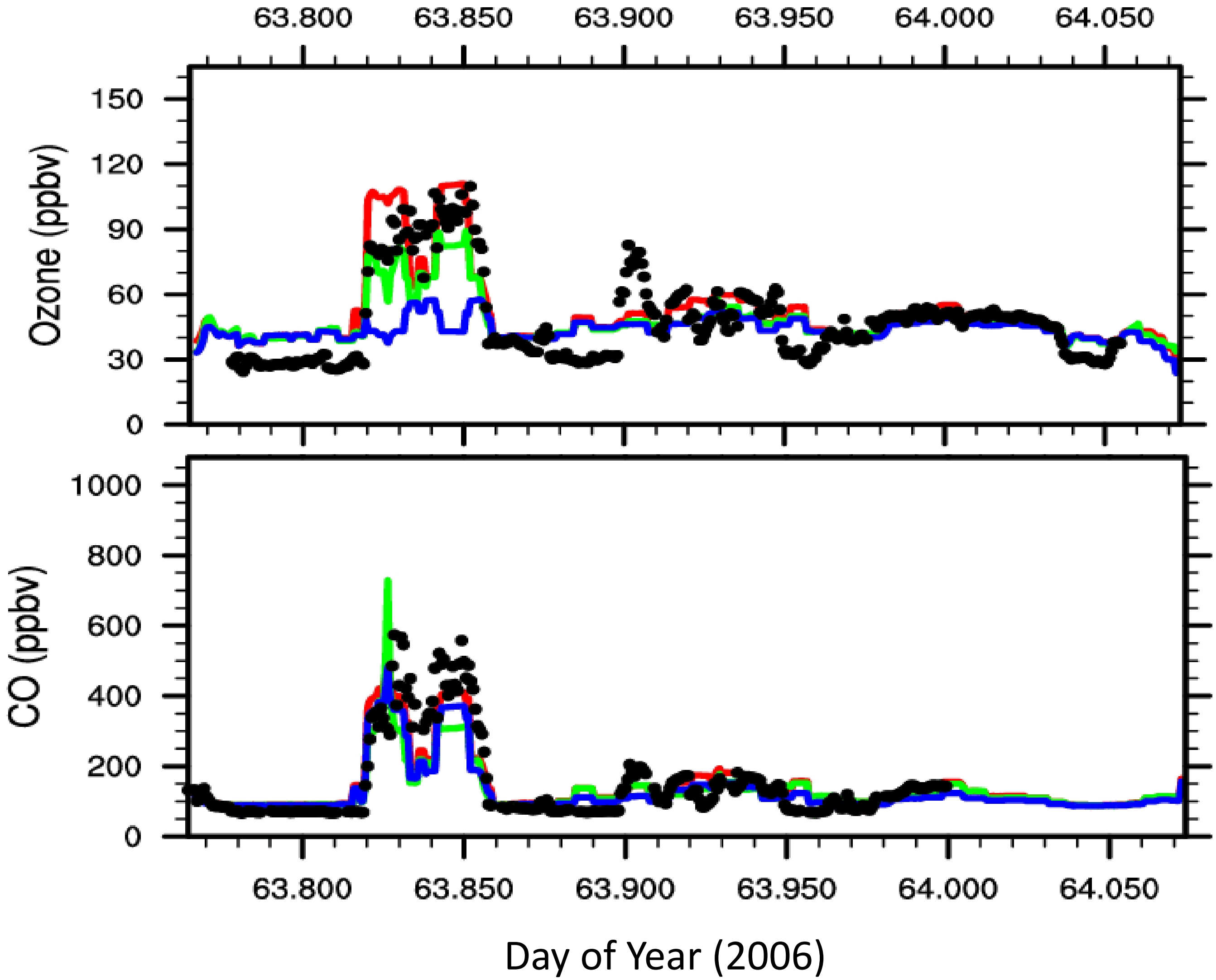
Our fast & super-fast mechanisms increase GCM computational cost by 100% and 40%.

(1) O_3
(2) O
(3) $O(^1D)$
(4) OH
(5) HO_2
(6) H_2O_2
(7) N
(8) N_2O
(9) NO
(10) NO_2
(11) NO_3
(12) N_2O_5
(13) HONO
(14) HNO_3
(15) HO_2NO_2
(16) CO
(17) CH_4
(18) CH_2O
(19) HCOOH
(20) CH_3O_2
(21) CH_3O_3
(22) CH_3OOH
(23) $CH_3O_2NO_2$
(24) DMS
(25) H_2S
(26) MSA
(27) SO_2
(28) SO_4

Super-fast captures 70-80% of O3 & OH large-scale amplitude AND sensitivty.

	Full Chemistry	Super-fast Chemistry
Surface $[O_3]$ ppb		
Zonal mean [OH] 10^5mol/cm^3		

Mexico City aircraft obs. confirm good background, but weak pollution plumes.



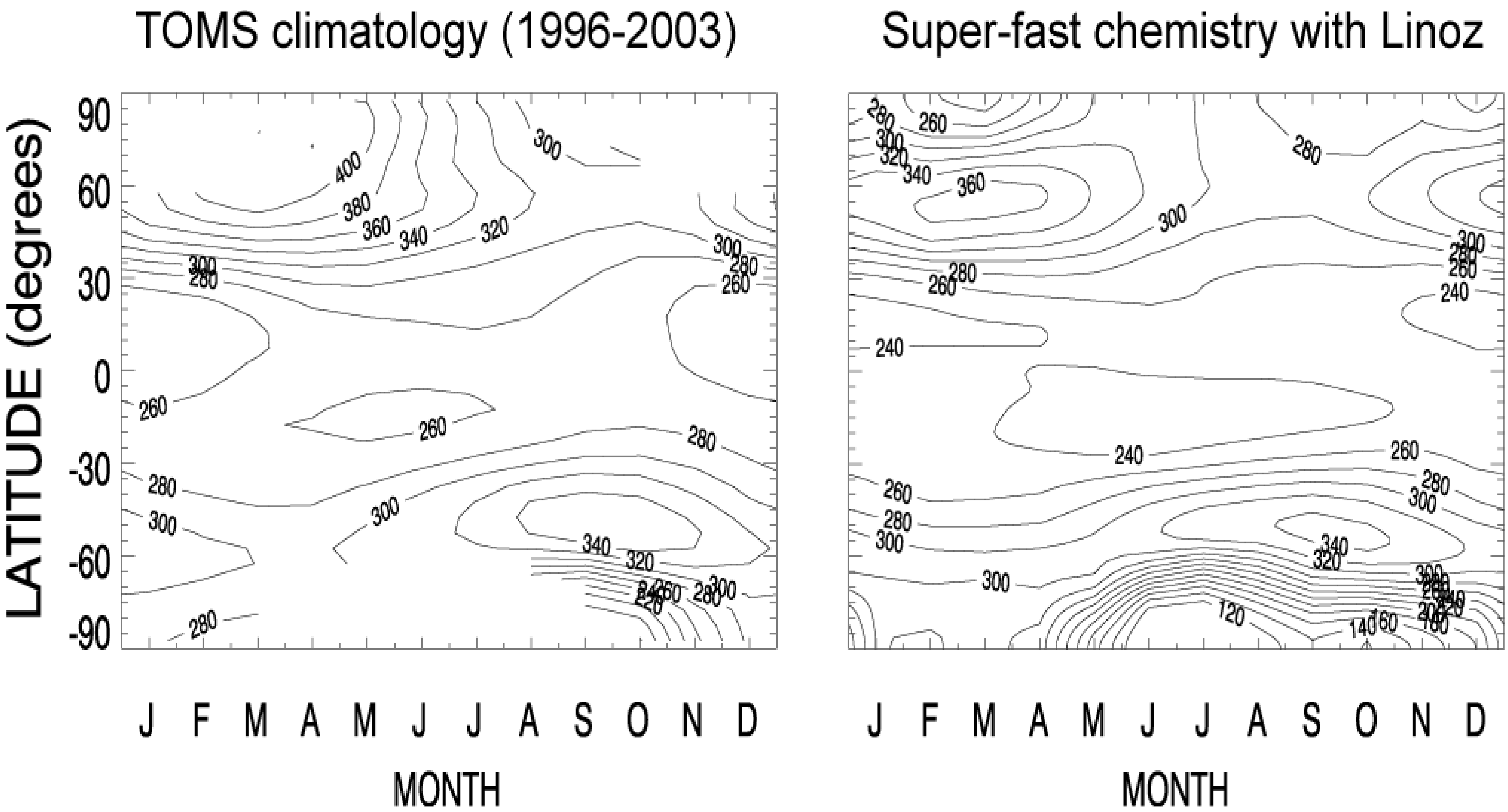
Full mechanism

Intermediate mechanism

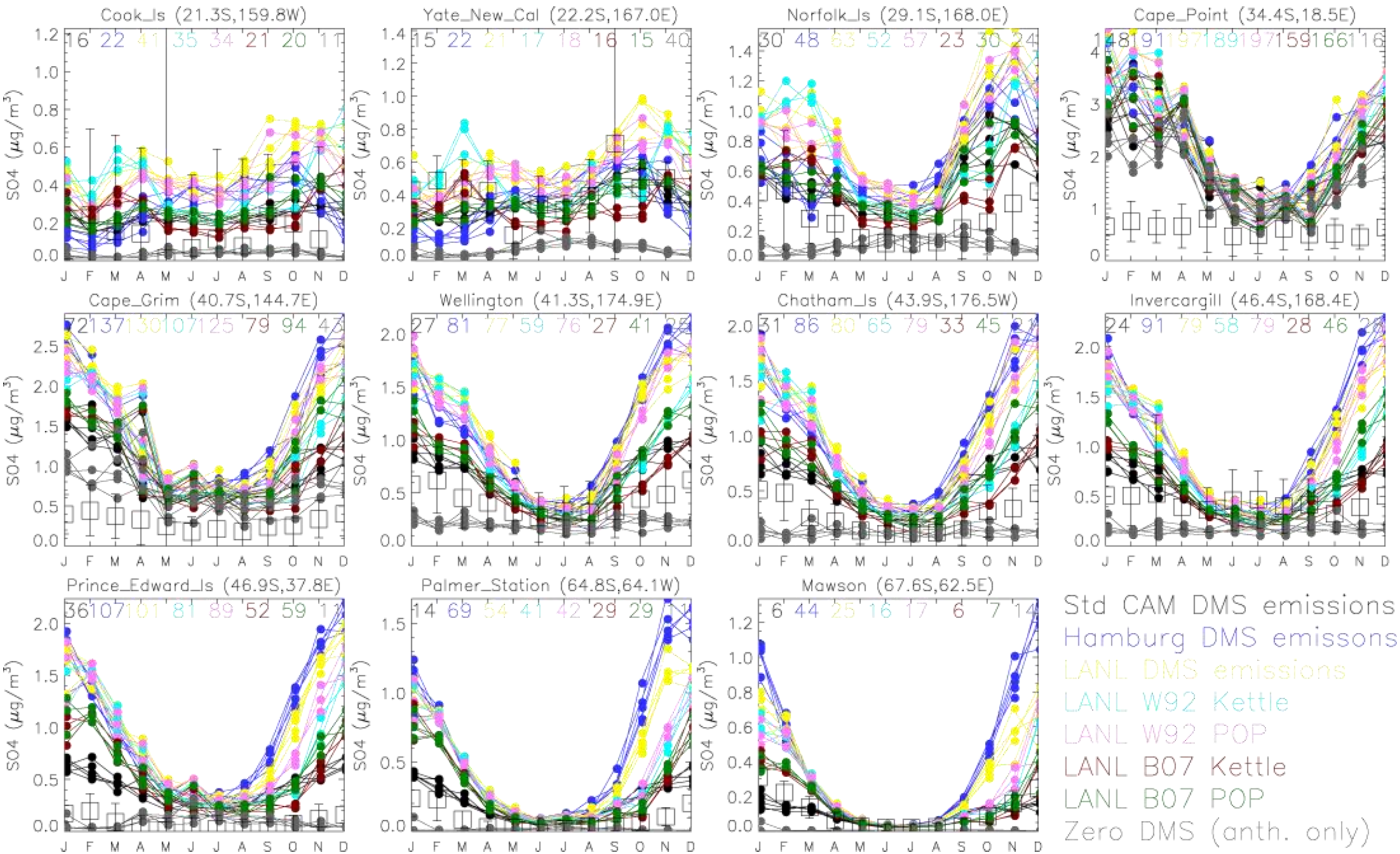
Fast mechanism

Observations

Linoz only needs 1 tracer. Its stratospheric columns compare well with observations.



Sulfate aerosols validate well against surface observations.



Philip Cameron-Smith, LLNL, LLNL-PRES-411135

Fast mechanisms maintain sensitivity of methane lifetime to perturbations.

	Full mechanism	Fast	Super-fast
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%)

Methane lifetime in years. In parentheses, the change in lifetime due to the change in emission relative to the control.

Conclusions

- Our fast mechanisms validate well for present day.
- Chemical *sensitivities* of fast mechanisms compare well to full mechanism.
- Fast mechanisms provide:
  - Consistent greenhouse gas and aerosol fields,
  - Climate feedbacks,
  - Interaction with biogeochemistry,
  - Only background air-quality calculated.
- These mechanisms are fast enough (40% increase in CAM) for inclusion in main IPCC simulations:
  - Provides statistics on chemistry-climate interactions.