Chemistry in CAM-SE

Jean-François Lamarque, A. Conley, P. Lauritzen, and F. Vitt
NCAR, Boulder, CO

Goals of the project

1) Evaluate the performance of the Community Atmosphere Model-Spectral Element (CAM-SE) dynamical core in terms of tracer transport.

2) Implement and apply a specified dynamics (from pre-defined meteorology such as meteorological analyses) capability in CAM-SE without significant additional computational cost.

Motivation:

Enable the simulation of atmospheric chemistry for specific conditions and analysis against field campaigns in CAM-SE.

Approach:

- Study the performance of CAM-SE in idealized flows (as specified and discussed in Lauritzen et al., 2014).
- Compare CAM-SE with CAM-FV and spectral dynamics in the simulation of baroclinic waves (Polvani and Esler, 2007).
- Compare CAM-SE with CAM-FV when forced by the same meteorological fields.

Performance of CAM-SE in idealized flows

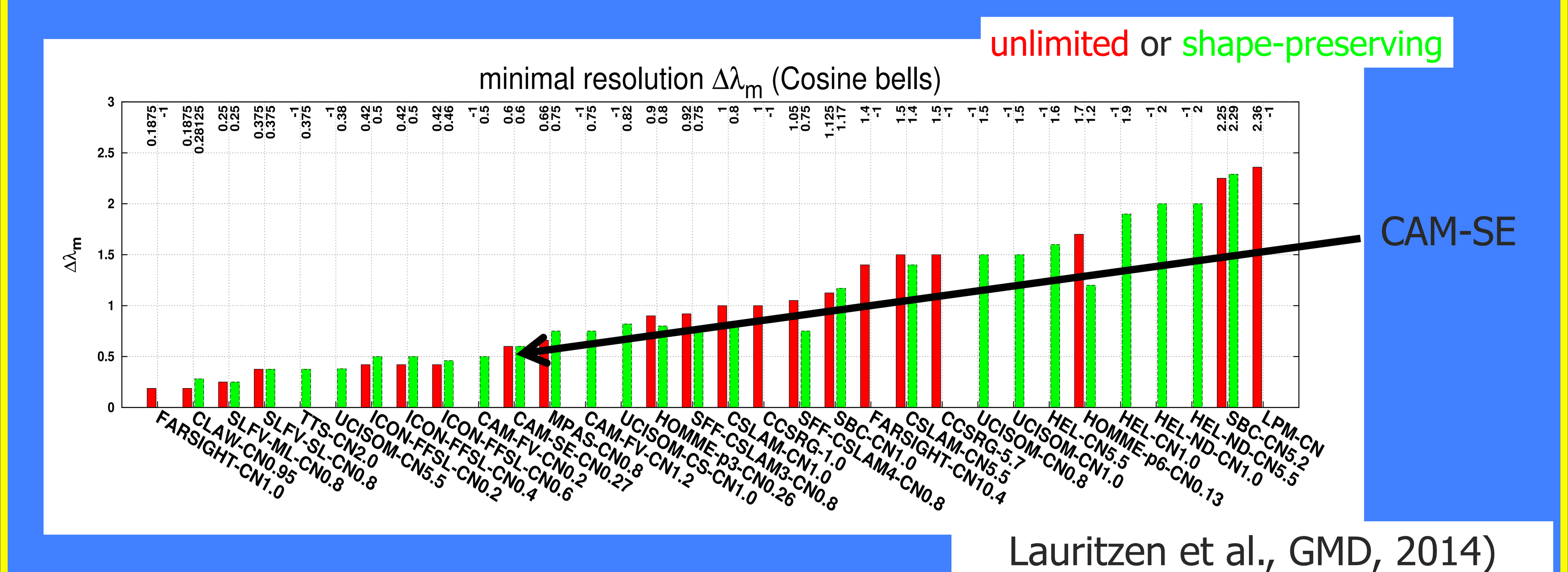

Figure 1. Intercomparison of 19-state-of-the-art advection schemes using an absolute error estimate against the analytical solution of the specified flow and tracer distributions. The larger the value, the better the simulation as the minimal resolution indicates the resolution at which the scheme accurately represents filaments.

References:

Lauritzen, P.H., P.A.Ullrich, C. Jablonowski, P.A. Bosler, D. Calhoun, A.J. Conley, T. Enomoto, L. Dong, S. Dubey, O. Guba, A.B. Hansen, E. Kaas, J. Kent, J.-F. Lamarque, M.J. Prather, D. Reinert, V.V. Shashkin, W.C. Skamarock, B. Sørensen, M.A. Taylor, and M.A. Tolstykh, A standard test case suite for two-dimensional linear transport on the sphere: results from a collection of state-of-the-art schemes. *Geosci. Mod. Dev.*, 7, 105-145, doi:10.5194/gmd-7-105-2014, 2014.

Polvani,L. M.,and J. Esler, Transport and mixing of chemical air masses I idealized baroclinic life cycles,J. Geophys. Res., 112, D23102: doi:10.1029/2007JD008555, 2007.

Acknowledgements

This work was supported by the DOE SciDac grant SC0006747. We would like to acknowledge the help from M. Taylor (SNL) and L. Polvani (Columbia U.). The National Center for Atmospheric Research is sponsored by the National Science Foundation.

Baroclinic wave evolution (no physics)

We have performed the simulation of the evolution of baroclinically unstable initial conditions (LC1 and LC2, following Polvani and Esler, 2007). Using a variety of tracers, the mixing across the tropopause can be quantified. We have implemented and tested for resolutions up to 0.25° or equivalent. We focus on parameter settings (diffusion, substepping and physics timestep) that are from "production" SE configurations.

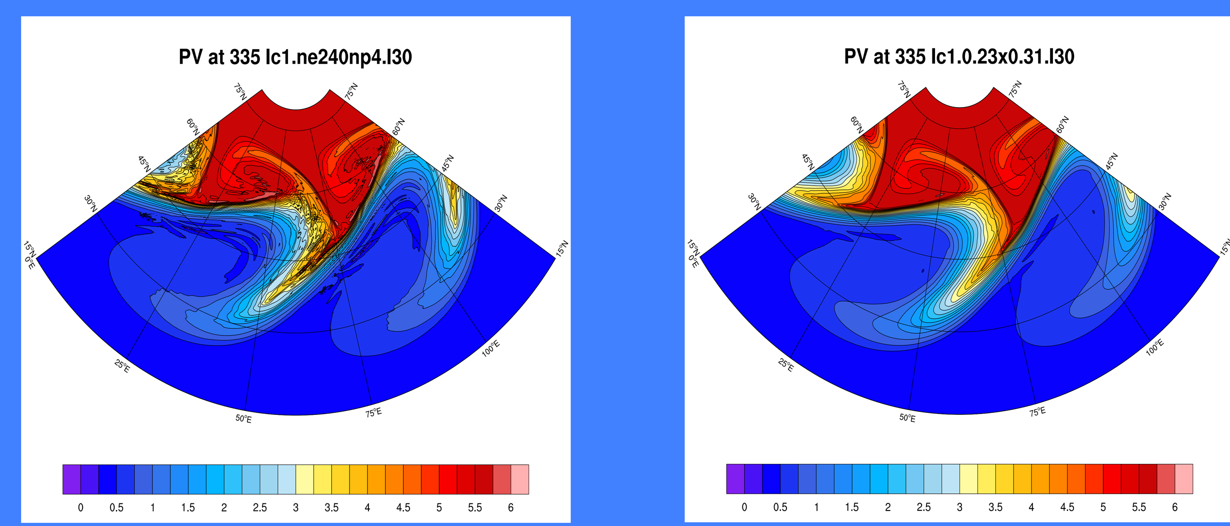

Figure 2. Comparison of the Ertel Potential Vorticity (in PV units) for the LC1 (anticyclonic) case, interpolated to the 335K isentrope. While overall features are very similar, CAM-SE generates small-scale features that are not present in CAM-FV. In addition, there is not a perfect wave 6 symmetry in CAM-SE as opposed to CAM-FV.

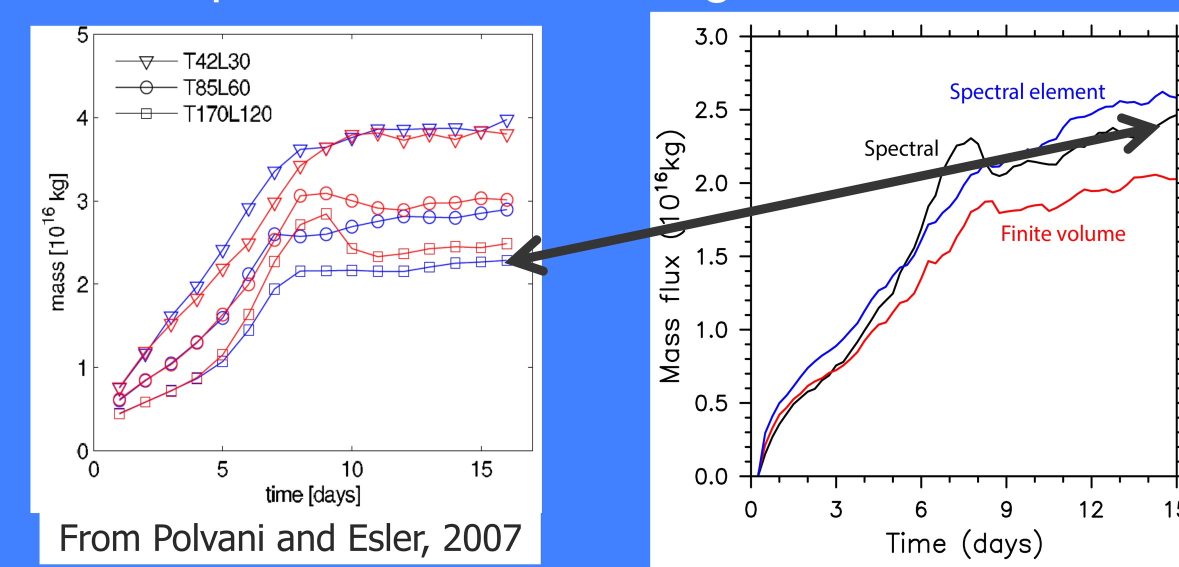

Figure 3. Transport diagnostic of the amount of mass (in 10^{16} kg) transported across the line of maximum PV gradient (similar to the tropopause). The "Spectral" results in our experiments (right panel) are similar to the original results (left panel). CAM-SE indicates a higher amount of transported mass, associated with the small scale structures identified in Figure 2.

Specified dynamics

We have implemented in CAM-SE a method for the specification of dynamics using a forcing term on the momentum and temperature equations $-K(x,y,z)\bullet(X-X_{met})$. From this, the surface pressure is implicitly driven towards the analyzed value through divergence and hydrostatic balance. This is applied to NASA-GEOS5 meteorology, regridded to ne30p4. Linear interpolation in time is used between analysis. No correction for differences in altitude between SE and GEOS5 topography is performed on the GEOS5 meteorology at this point (Figures 4 and 5), but such an approach is being tested (Figure 3).

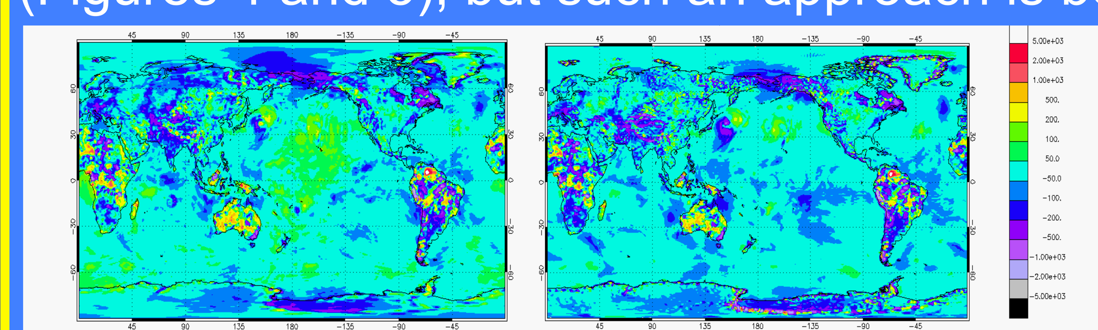

Figure 3. Comparison of the error on surface pressure (in Pa) after 15 days using the forcing approach (left, with altitude correction) and the traditional approach of a 10% overwrite in CAM-FV (right).

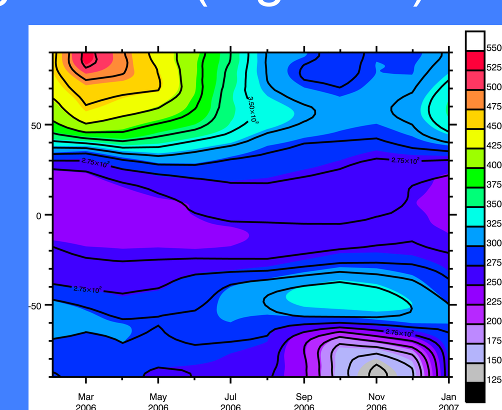

Figure 4. Total ozone column (in Dobson Units) 2006 simulation with CAM-SE (contours) and CAM-FV (lines) .

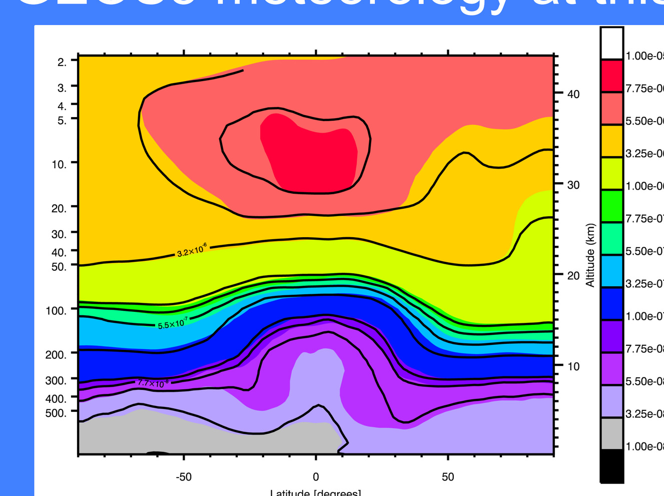

Figure 5. Zonal mean ozone mixing ratio (mol/mol) for Dec.2006 with CAM-SE (contours) and CAM-FV (lines). Notice higher values in tropical UT in CAM-SE.

Conclusions

1)We have successfully implemented and used a suite of idealized flows and baroclinic wave development in CAM-SE. Preliminary analysis from those simulations indicates a performance of CAM-SE similar to CAM-FV, albeit with the presence of small-scale "noise" in the less diffusive CAM-SE.

2)We have implemented and tested in CAM-SE a novel approach to specified dynamics. Preliminary results with full (tropospheric and stratospheric) chemistry indicates no issues and a performance similar to FV.

Note: All tests will be released as part of CESM distribution for testing of additional dynamical cores