Nudging Strategies for CAM
Patrick Callaghan, Julio Bacmeister AMP/CGD/NCAR

Flexible Nudging module for CAM:
- CESM nudging is implemented via a relaxation forcing toward reanalyses values (see below).
- Data is first preprocessed onto the model native grid for the desired dynamical core e.g. SE, FV, EUL. via NCL scripts. (courtesy Jerry Olson AMP)
- Data for YOTC (2 years @ ne120,ne30) and ERA-I (34 years @ ne30) have been processed for use.
- The strength and 3D structure of U, V, T, and Q nudging can be independently specified via namelist parameters.
- The localized 3D structure of the nudging is specified via \( \tanh \) window functions.

Nudging Tendencies:

\[
\dot{\chi}_{ndg} = \frac{\chi_m(t_m) - \chi_{ana}(t_{ana})}{\tau_{ndg}}
\]

\( t_m \) = model update times, \( t_{ana} \) = analysis times,
\( \tau_{ndg} \) = nudging time scale, \( \chi = u, v, T, \) or \( q \)

- Typical implementations update model field every physics time step*, i.e., \( t_m \) is simply “time”.
- Nudging timescale is typically 6 hours.
- Nudging keeps flow close to analysis but tendencies could exert strong damping on integrations
- Infrequent \( t_m \) updates lead to instabilities
- What to do? Explore sensitivities (ne30!!)

\begin{table}[h]
\begin{tabular}{|c|c|c|}
\hline
Experiment & \( t_m \) updates per day & \( \tau_{ndg} \) \\
\hline
CTL & -- & -- \\
N1 & 48 & 6 \\
F1 & 4 & 18 \\
N2 & 48 & 18 \\
\hline
\end{tabular}
\end{table}

*with \( t_m \) updated every 6 hours, i.e., at analysis intervals this becomes forward-in-time analog of incremental analysis update (IAU, Bloom et al., 1996 MWR) used in MERRA reanalysis project.

Fig.1) Monthly mean precipitation fields for ne120 (25km) CAM and TRMM 3B42. Top row shows results for Aug 2009 obtained with full nudging. Bottom row shows results for Aug 2010 from a free-running simulation.

Fig. 2) Precipitation types for experiments shown in Figure 1. Note increased proportion of convective rain in nudged run (top).

Fig.3) Frequency distributions of instantaneous vertical motion accumulated every 6 hours over one month for experiments listed in Table 1 and for YOTC reanalyses interpolated to the SE ne30 grid. Note strong ascent in N1 (Table 1, 2nd row).

Fig.4) Instantaneous zonal wind at 500 hPa: top) from run F1; bottom) from YOTC re-analysis (r>0.96).

Conclusions: Nudging impact on divergent flows can be controlled while maintaining large scale flow close to analysis (only ne30 examined so far)

Availability: Nudging source code is available as a CAM branch and is fully compatible with CESM. Currently processed datasets and preprocessing software are available upon request. E-mail: patc@ucar.edu

• Nudging can keep physics variables, e.g., precipitation (Fig.1), close to observations
  - Pattern correlations of daily precip with TRMM range from 0.4 to 0.7 depending on variables nudged

• Caution: Nudging runs may not preserve some important characteristics of parent model, e.g., convective/large-scale rain ratios (Fig. 2).
  - This could be a problem for some applications
  - Hypothesis: Nudging interferes with divergent flow