Coarse-graining Experiments

From PDEF presentation at 32nd WGNE (Exeter, October 2018)

Model error and stochastic parameterization

- PDEF and WGNE have already helped organize two workshops on systematic and stochastic model error.
- For stochastic error, coarse graining experiments are fundamental for advancing understanding and testing techniques.
- Might NWP centers be persuaded to set-up coarse graining research test-beds for the general research community?
- Action: Advocate experimental design for coarse-graining studies that can be applied in a common framework across different models.

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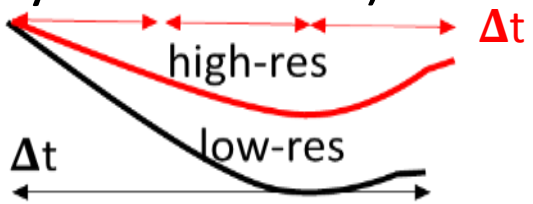
- Straw-man test-bed would contain something like
  1. A *coarse* non-convection resolving model.
  2. High spatio-temporal resolution output from a *fine* convection resolving model temporally and spatially averaged into the discrete deltaT, deltaX, deltaY, deltaZ space-time bins of the coarse resolution model.
  3. Researchers can initialize the coarse resolution model with data from step 2 to test how well their stochastic model accounts for deviations of the coarse resolution model from the coarse-grained fine resolution model.
  4. A web-site set up to describe such research and link published research papers associated with it.

A Community Coarse-graining Project

- One of more high-resolution nature runs (1km?) with explicit convection (should land/sea mask and orography be low res?)



- Targets
  - Study high-res phenomena and statistics
  - Coarse grain and use as initialization for low-res model with parameterizations with the aim to inform parameterization development and uncertainty schemes

- Trajectories will diverge due to

  - Imperfect physics parameterizations
  - Spin-up error (e.g., uninitialized subgrid-state)
  - Differences in lower boundary condition (e.g. different orography)
  - Differences in the attractor of the dycore (unconverged dynamics? Resolution-dependent dissipation?)

  ⇒Might be worth to run only one initialized coarse-grained step

⇒ Input from PDEF/WGNE on utility of such a database?

Coarse-graining Experiments

Issues

- Lack of confidence that the high-res model sufficiently represents nature
  - Even given that the high-res model will not be an imperfect representation of nature, it is still worthwhile to make parameterized low-resolution simulations statistically indistinguishable from high-resolution simulations.
  - A high-res update cycle would remain closer to a nature trajectory than a free simulation.
  - Build infrastructure now to use in the future (as high-res simulations gain fidelity).

- Issue of model drift and initial shock (due to, e.g., different model climate, different representation of orography)
  - Initial tendency method (Klinker and Sardeshmukh, Rodwell and Palmer) relies on forecasts being initialized from a native analysis. However, CAPT community (Phillips et al., Medeiros, Williamson) initialize from model-foreign analysis and compare tendencies to field campaign data
  - Comparison “model-foreign” and “model-intrinsic” tendencies is of interest in itself (model drift is one form of model error that could be addressed by coarse-graining experiments).
  - Focus over ocean to avoid the topography issue?
  - Pseudo-observing update cycle experiment (separate slide).

Coarse-graining Experiments

Use of an update cycle and "pseudo-obs" to get around balance issue

1. Take coarse res model grid box averages (in space and time) of the high res model along a hi-res model trajectory with output times corresponding to the time steps of the coarse res model.

2. Create pseudo observations by letting the obs be equal to the grid box average values computed in step 1.

3. Assimilate the observations from step 2 into a DA cycle using the coarse res model as the first guess and using a DA scheme that preserves an acceptable amount of balance. One could assign larger observation errors over regions where there were discrepancies in topography and land-sea contrast.

4. The output of the "balanced" DA cycle would then be labeled the "coarse grained trajectory corresponding to the high resolution model trajectory"

5. Make the drift correction term in the parameterization scheme depend on geographic location so that it will ultimately correct problems associated with misplaced topography and land-sea contrasts.

Options for Coarse-graining Experimental Frameworks

- **Option 1**
  - Center performs ~ 1km runs for an entire day every 20 days giving, roughly 18 24 hr runs.
  - Center coarse-grains this run (possibly with spherical harmonics) to 10 km horizontal resolution, native vertical resolution and temporal resolution consistent with an advective CFL condition at 10 km, i.e.

$$\Delta T = \Delta X / U \approx 10^4 / 10^2 = 10^2 \text{ s}$$

  - The center only has to save this coarse grained 4D data set – not the high resolution data set.
  - It would be helpful if the center also made available the 2D fields giving the high resolution topography and land-sea mask for their model. At the very least they could provide information like (the fraction of the coarse grained grid box that is land or the mean and variance of the topographical height of the high res model within the 10 km grid box.
  - Researchers download these coarse grained data sets and, possibly, coarse grain it even further to match whatever coarse resolution model they are interested in.

- **Option 2**
  - As in option 1, but center also provides the coarse resolution model for down load and a test case that researchers can experiment with.

Questions

- Any global horizontal field can be approximated with spherical harmonics. Filtering/averaging to differing types of grids is fairly straightforward from the analytical representation of fields given by spherical harmonics. Should each field of the shared data set have a spherical harmonic representation available?

- Is there interest in using such a data set if produced?

- Is there interest in creating the data set?

- Where and how would it be housed and made available?
  - A library of high-res outputs may not be sufficient, need meaningful post-processing approach

- What would a pilot study look like?
  - Would a single column model be a good first tool? (ala Christensen and Berner?)

- What other avenues are available for collaboration on representing/accounting for model uncertainties/model errors?