HIWPP Task 3.1.1
Perturbation of land and sea surface state within ensembles
Tom Hamill, Jun 10, 2016

The milestone of "test(ing) methods for perturbing land surface and sea-surface state within ensemble system" is intended to serve the larger goal of improving the spread of near-surface forecasts in the GEFS. Too often, root-mean-squared errors are larger than spread, indicating either (a) systematic errors in the prediction system, or (b) methodological problems in the ensemble system causing too little spread.

Our earliest work in HIWPP (with funding also provided by NWS Sandy Supplemental, and more recently NGGPS) focused on (b), increasing spread. Gary Bates tested two general methods for increasing the spread over the oceans, the first being an inclusion of skin-layer SST dynamics that permitted diurnal cycles of SST, the second being perturbations to initial SSTs. For the first of these, called "NSST", the hope was that allowing the interacting skin-layer dynamics with different winds, temperatures, and solar radiation from different members, would result in some increase in spread of SSTs and therefore of 2-meter temperatures and convective precipitation. Though Gary found some increase in spread, it was quite small. When perturbation magnitudes which represent the reasonable uncertainty in SST measurements are applied, the increase in ensemble spread is larger than produced by the NSST method, although the increase is still modest.

In discussions with EMC about these, there was agreement that the effects were small. There was also some concern that there was related work going on by Malaquias Pena for perturbing SSTs, and we made an interim decision that for this aspect of the project (introducing SST variability), Malaquias would take the lead hereafter, leveraging our work. However, Malaquias has since gone to work on other projects, and if any SST perturbations are to make it into GEFS v12 operations, it will likely be through ESRL proposed system changes. We will return to discuss next steps at the end of the discussion of this milestone.

Regarding the work on land-surface variability, Maria Gehne joined our staff for this aspect of the project, and working with Gary, she developed physically based perturbations for many parameters in the land-surface model, parameters that are treated as constants currently but which in fact are not known precisely. The underlying methodology was to first determine what was a realistic perturbation magnitude for the parameters, which included roughness lengths for momentum, heat/momentum roughness length ratio, soil hydraulic conductivity, leaf area index, and surface albedo, with those magnitudes based largely on a literature review. These magnitudes were then used in conjunction with a random pattern generator (borrowed from the SPPT software being developed for perturbing atmospheric parameterization tendencies) to generate fields of perturbations to parameters. Generally, the introduction of perturbations to these parameters was found to have a small, positive impact on 2-meter temperature spread and precipitation spread, though the effect was much smaller than the spread impacts caused by stochastic physics changes, discussed elsewhere. Pending agreement with NCEP/EMC, we expect these initial parameter perturbations to be part of GEFS v12.

A last component of the work to increase spread has been to explore the possibility of perturbing soil moisture initial states consistent with their analysis uncertainty to introduce

spread. Maria Gehne has been leading work to determine what are potentially realistic magnitudes for perturbing the soil moistures by cycling a land-data assimilation system using different precipitation forcings from different precipitation analysis products. This work is in progress, but initial results suggest that these different precipitation forcings may not introduce a lot of spread to the soil moisture. We will face a decision in the next month or so as to whether this line of inquiry can be brought to a successful conclusion and incorporated into GEFS v12. There is much work to be done; once the general magnitude of soil moisture uncertainty is realistically estimated, we'd need to develop a perturbation methodology, test the perturbation methodology in the GEFS system, determine if it has a significant impact on its own, and determine if it works realistically in conjunction with all the other improvements expected for the GEFSv12 system. We need to wrap up all of this by the end of the summer.

As mentioned in the first paragraph above, another way of addressing spread vs. error inconsistencies is to potentially lower the error. For the land surface, improving the initial estimate of soil moisture and temperature may be one way of reducing systematic error. In the current GEFS, there is no soil moisture initialization; the background forecasts are used to initialize the model state. Anna Shlyaeva has some preliminary results that show that 2-meter temperature biases can be markedly improved by initializing a forecast with the GLDAS, the (offline) Global Land Data Assimilation System soil state estimate.

Though we seek more clarification from NCEP/EMC on the exact timeline and exact information needed, roughly what will be needed to nail down the GEFS v12 configuration by early next year (necessary for the production of reanalyses and reforecasts) will be to propose a suite of improvements to the GEFS system, to demonstrate their collective effects, and to provide high-quality code and documentation. It's quite likely that we will propose a suite of improvements consisting of SST initial perturbations, surface parameter perturbations, and improvement of the mean soil-state initialization via GLDAS. It's possible but not as likely (due to the compressed timeline) that we may also include a method for perturbing initial soil moisture states. We expect the collective description of these will eventually be published in a journal article, but our priority right now is getting all the components tested, documented, and ready for handoff to NCEP.