Uncertainty in the Coupled System

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Introduction

Uncertainty in a coupled forecast system arises from unresolved processes in each of the components (atmosphere, ocean, land, ice, etc.) as well as the interfaces between the components.

In the process of developing stochastic schemes in the different components, physical consistencies across the interfaces between the different components must be considered. This physical consistency should conserve mass and energy within each component and through the coupling between components.

Current NOAA Operational Configuration

The current operational medium range ensemble run at NOAA/NCEP only consists of an atmosphere and land model. There are two stochastic schemes to account for model uncertainty:
Stochastic Kinetic Energy Backscatter (**SKEB**, Berner et al. 2009) and
Stochastically Perturbed Physics Tendencies (**SPPT**, Palmer et. al 2009)

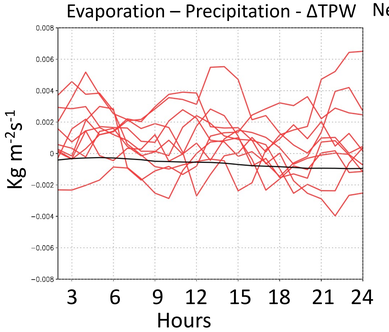
Details of operational SPPT scheme

Departing from Palmer et al. 2009, we made the following changes for physical and computational stability reasons

- Only perturb the cloudy contribution to radiation tendencies
- Perturb the precipitation generated each time-step along with the physics tendencies
- Allow the perturbation to go further into the PBL
- Limit the range of perturbations to be between 0 and 2. This prevents the sign of the physics tendencies from being flipped.
- Taper the perturbations near the surface. Layer 2 has ½ the perturbation of the free atmosphere, and layer 1 has no perturbations.
- Additional tapering of perturbation in regions of blocked flow based on the dividing streamline.

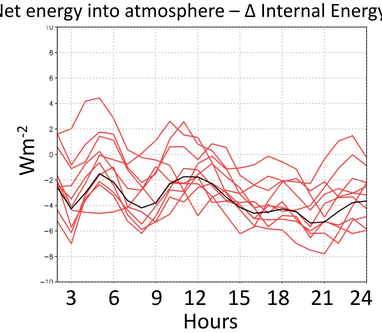
Moisture Conservation

Evaporation – Precipitation - ΔTPW



Energy Conservation

Net energy into atmosphere – Δ Internal Energy



Coupled model with no stochastic physics
Ensemble members with same initial condition but different random patterns

The coupled system

- The ocean is no longer a lower boundary condition that can absorb imbalances in surface energy exchange.
- Target forecast leads are much longer (weeks to months), so the potential for any bias associated with stochastic physics will have more time to amplify.
- Perturbations should be physically consistent across the interface between the component models

Modifications to SPPT for a coupled model

Limitations of operational SPPT

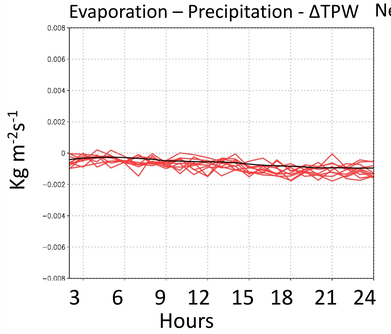
- The current method only perturbs radiative heating tendences, the radiation going into the surface is not perturbed
- The fluxes from the surface enter the atmosphere through the PBL scheme, whose tendences are perturbed, but the fluxes are not

Updates to SPPT

- Remove radiative heating perturbations, and replace with cloud fraction perturbations that the radiation sees.
- Replace PBL tendency perturbations with physically consistent perturbations
  - TKE production and dissipation perturbations in the PBL scheme
- Extend the physics tendency perturbations to all microphysics species, not just specific humidity
- Remove tapering of the perturbations near the surface and below the dividing streamline.

Moisture Conservation

Evaporation – Precipitation - ΔTPW



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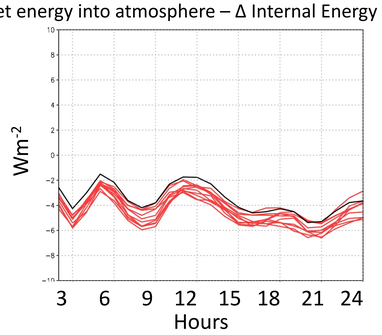


Moisture and Energy conservations is closer to control. Some of the residual may arise from budgets being computed on 32-bit output, whereas the model runs at 64-bit.

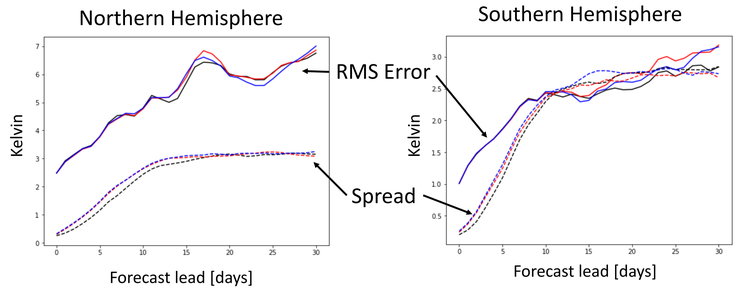
Subseasonal Hindcasts

Experiment design:

10-member retrospective forecasts.
8 initializations (Jan, Apr, Jul, and Oct. 1 of 2012 and 2013)
Initial condition perturbations in the atmosphere and ocean.
35-day fully coupled model forecasts at 1-degree.

Control: No stochastic physics
OPNL: Current operational stochastic physics suite (SPPT and SKEB)
EXPT: modifications of SPPT and inclusion of PBL TKE dissipation perturbations

2m Temperature RMS Error/ Ensemble spread



Both stochastic experiments result in only a modest increase in ensemble spread.

Conclusions

- The current operational SPPT scheme does not conservate moisture or energy in the atmosphere.
- Removing radiative heating perturbations and replacing PBL tendency perturbations with TKE production/dissipation perturbations brings the moisture and energy conservation closer to the non-stochastic version of the model.
- These modifications to SPPT improve the numerical stability
- Neutral impact on spread/error relationship in 35-day forecasts.