A CPT for Improving Turbulence and Cloud Processes in the NCEP Global Models

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The proposed project is a CPT for improving cloud and cloud-radiative processes by testing and evaluating the impact of improved process models when embedded in the GFS and CFS global models. It is relevant to the MAPP Program's competition for Research to Advance Climate and Earth System Models. The focus of our proposed CPT is to install and test state-of-the-art parameterizations for turbulence and clouds, convection, and radiation in the GFS and CFS. The proposed project will help to achieve the first of the NOAA Next-Generation Strategic Plan climate objectives, an improved scientific understanding of the changing climate system and its impacts, by improving two core capabilities: understanding and modeling, and as a consequence, predictions and projections.

Clouds and precipitation occur on a wide range of scales, ranging from hundreds of kilometers to hundreds of meters. All global models have to parameterize the effects of turbulence and convection and the associated cloud processes that occur on scales near or below the horizontal grid spacing. As model resolutions increase, the elements of cloud systems such as mesoscale convective systems will increasingly be resolved. However, shallow cumulus clouds will not be resolved in global climate simulations in the foreseeable future. Shallow cumuli are upward, cloudy extensions of the boundary-layer turbulence.

The shallow cumulus regime covers about half the Earth's surface, and is very important in the global climate system. It strongly affects the planetary albedo and produces a significant amount of precipitation. The diurnal cycle of precipitation over land, which climate models have trouble simulating realistically, is a dramatic example of an interaction between the turbulent boundary layer, shallow cumulus convection, and deep cumulus convection. Turbulence and cloud processes are also thought to control the radiatively important transition between stratocumulus convection and shallow cumulus convection.

For these reasons, and many others, the interactions between turbulence and clouds are of key importance for the climate system. Unfortunately, cloud parameterizations and turbulence parameterizations have historically been developed independently. We propose to alleviate the resulting problems by implementing a PDF-based subgrid-scale turbulence and cloudiness scheme in the GFS and CFS that would replace the boundary layer turbulence scheme, the shallow convection scheme, and the cloud fraction schemes. Conventional parameterizations of deep convection were developed for use in models with horizontal grid spacings of hundreds of kilometers.

Today, global forecast models use grid spacings of a few tens of kilometers, and in the next few years some global forecasts will be run with grid spacings of less than ten kilometers. Conventional parameterizations of deep convection cannot be justified for use in such high-resolution models. The Unified Parameterization proposed by Arakawa et al. (2011) is designed to allow a model to simulate individual clouds when and where the grid spacing is sufficiently fine, while acting as a conventional parameterization of deep convection when and where the grid spacing is coarse. Between these two limiting cases, the Unified Parameterization scales continuously. We propose to test the Unified Parameterization in the GFS and CFS.

We also propose to improve the representation of the interactions of clouds and radiation in GFS/CFS by taking advantage of the additional information provided by the PDF-based SGS cloud scheme.