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Coupled Global-Regional Data Assimilation Using Joint States

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LONG-TERM GOALS

The main goal of this research project is to develop a data assimilation system to obtain a global atmospheric analysis for the U. S. Navy Global Environmental Model (NAVGEM) model, as well as a set of limited area atmospheric analyses for multiple local domains for the Coupled Ocean/Atmosphere Mesoscale Prediction System (COAMPS) model by a single data assimilation process. We will achieve this goal by developing a novel data assimilation system based on analyzing the joint states of the global and the limited area models.

OBJECTIVES

The Fleet Numerical Meteorology and Oceanography Center (FNMOC) prepares both global and limited area weather analyses and forecasts. In fact, FNMOC prepares limited area model products for more regions (more than 60) than any other center in the world (Figure 1). In the current implementation of the model suite, the global model is started from analyses prepared by the Naval Research Laboratory Atmospheric Variational Data Assimilation--Accelerated Presenter (NAVDAS-AR) data assimilation system, which is based on a 4D-VAR data assimilation scheme, while the regional model is started from analyses provided by the Naval Research Laboratory Atmospheric Variational Data Assimilation (NAVDAS) system for the atmosphere and the Navy Coupled Ocean Data Assimilation (NCODA) for the ocean. Both NAVDAS and NCODA are 3D-VAR schemes. In this configuration, deterministic model information is propagated from the global model to the regional analysis through the lateral boundary conditions. Building on the results of our earlier research, we are developing a data assimilation algorithm, in which information flows in both directions between the global and the limited area data assimilation systems. We expect both the global and the limited area analyses to benefit from the coupled approach. In particular, we expect that in the coupled data assimilation system, the global analyses will benefit from the availability of the high-resolution limited area model information in regions where the presence of small scale atmospheric flow features (e.g., in a tropical cyclone or over complex terrain) severely restrict the representativeness of the observations at the scales resolved by the global model.

In addition, we hope that in the process of developing and testing the data assimilation system, we will gain new knowledge about the mechanisms by which mesoscale processes influence synoptic and

global scale predictability. Such new knowledge will help make strategic decisions about the development of the analysis and forecast systems of the future.

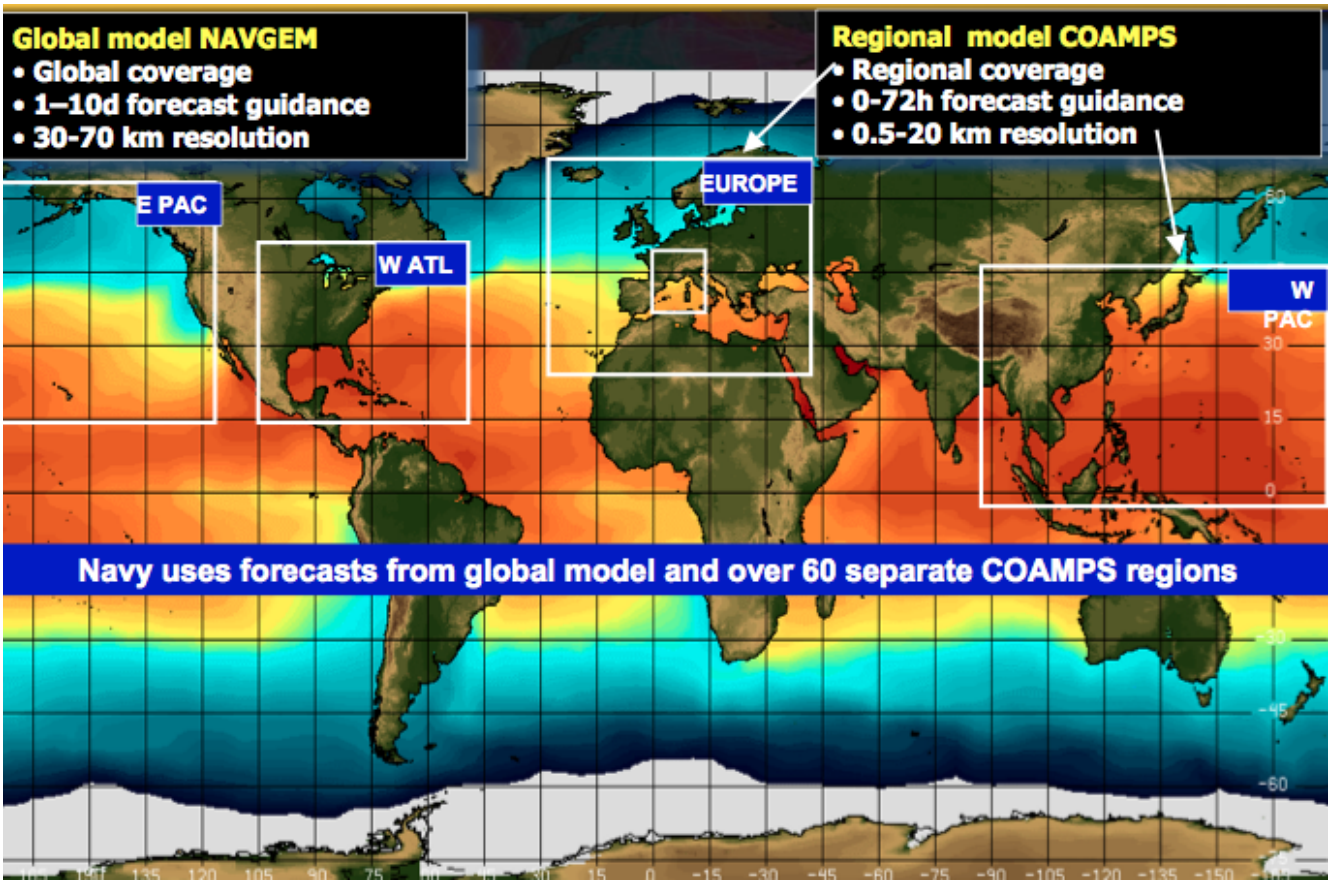

Figure 1. Illustration of the suite of atmospheric model forecast products of the Navy.

APPROACH

Our approach takes advantage of the results of our earlier theoretical and modeling efforts on coupling the global and the limited area data assimilation processes (Merkova et al. 2011; Holt 2011; Holt et al. 2013; Yoon et al. 2012) and the advances made by Dr. Craig Bishop and his NRL Monterey-based research group by incorporating ensemble-based flow-dependent information into NAVDAS. Dr. Bishop and his group have developed an ensemble-based, highly portable version of NAVDAS for NAVGEM and COAMPS. We work in close collaboration with Dr. Bishop's group. The relevance of our research is expected to highly benefit from using a state-of-the-art operational system that includes capabilities to assimilate satellite radiance observations and to perform normal mode initialization. In addition, using the NRL system is expected to greatly accelerate the transfer of the research results to NRL, Monterey, and eventually to FNMOC.

WORK COMPLETED

This year we finally managed to gain access to the model and data assimilation codes from the Naval Research Laboratory, Monterey, CA. Our efforts in FY14 were focused on

- finalizing the theoretical and numerical experiental results that we reported last year for publication, and
- implementing, in close collaboration with Dr. Bishop's group, our newly developed techniques on the NAVGEM and COAMPS model, and the NAVDAS data assimilation system.

Our research has resulted in a total of five journal articles, which have either already been published (Yoon et al. 2012; Roh et al. 2013), or submitted to a leading journals of the atmospheric sciences (Holt et al. 2014; Kretschmer et al. 2014; Roh et al. 2014). Results were also published in a Ph.D. thesis (Holt 2014) and in the recently published book Szunyogh (2014).

RESULTS

We decided to implement the composite state method (Kretschmer et al. 2014) rather than our original joint state method (Yoon et al. 2012) on the original Navy models. The motivation for this decision was twofold:

- the results of the experiments with the idealized models of the atmosphere revealed that the implementation of the method of Yoon et al. (2012) became problematic in situations where the forecast domains of the limited area models overlapped, while the composite state method was able to properly handle those situations;
- the code implementation of the composite state method on the complex operation models in the framework of NAVDAS is much more stratightforward.

The key capability required for the implementation of the composite state method is the availability of techniques (codes) that can be used to compute a local linear combination of the state vectors of the models whose forecast domain includes the given location. Additional capabilities are required to interpolate the resulting blended state vector to the native grid of NAVDAS and COAMPS. Developing such a capability for the combination of NAVGEM and COAMPS model states is a challenging task, because in addition to having different resolutions, the two models also use different vertical coordinates and different horizontal discretization strategies.

We carried out a large number of calculations with NAVDAS model fields to investigate the advantages and disadvantages of the different potential blending strategies. The primary focus of our efforts was on finding the optimal choice of the vertical coordinate for the computation of the blended fields. The results suggests that using the vertical coordinate of NAVDAS for blending results in more realistic vertical profiles of the atmospheric fields than doing blending on pressure or height surfaces.

The codes for the horizontal interpolation between the NAVDAS and COAMPS grids have been developed. The next step of our investigation will be the examination of the three dimensional model fields obtained by blending. We will start the data assimilation experiements once we are satisfied with the NAVDAS and COAMPS representation of the blended model fields.

IMPACT/APPLICATIONS

Our results with the idealized models suggest that using multiple limited area regions in the data assimilation process, which are available at no extra cost in the FNMOC forecast suite, can lead to improvements in both the limited area and the global analysess. We are in the process of developing a prototype system, which is based on NAVGEM, COAMPS and NAVDAS, to investigate whether those potential improvements can be realized in a realistic setting. We expect to have at least some preliminary data assimilation results by the end of the next fiscal year.

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