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Theme 5: Ocean Prediction Systems and Services

Session 4: Global and Regional Prediction Systems II

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The CMCC Global Ocean Forecast System at eddying resolution

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An operational system to forecast the state of the global ocean has been developed and implemented at CMCC over the last 5 years, and runs daily since July 2017. The system, known as GLOB16, consists of a global ocean/sea ice configurations at 1/16 horizontal resolution of (7km at the equator and 3km at high latitudes) with 98 unevenly-spaced vertical levels, that makes it one of the few mesoscale-resolving global operational systems in the world. GOFS16 is based on the NEMO ocean/sea ice modelling framework, an open source community model that the CMCC is both user and developer of. The global NEMO configuration is coupled to a three-dimensional variational data assimilation method to provide daily initialization fields. The system assimilates salinity and temperature profiles, sea surface temperature, along track sea surface height, and sea-ice concentration on a daily basis. The forecast system is forced with 3-hourly momentum, radiation, precipitation fluxes from the operational Global Forecast System (GFS) fields, and it runs operationally once a day to produce a 7-day forecast of the three-dimensional temperature, salinity, velocity fields, and sea-ice properties. An overview of the system is presented together with an extensive assessment of its predictive skills.

This forecast system is also used for several downstream applications, namely regional and coastal downscaling in several regions of the world ocean. Downscaling is realized with a new tool, the Structured and Unstructured Relocatable ocean model for Forecasting (SURF) based on NEMO, reaching resolutions of 1/64 and nested within the global operational model. SURF produces forecasts every day with best initial and boundary conditions from GOFS16. An overview of the system is presented.

Keywords: Systems - Implementation of Ocean Prediction Systems, Models - Ocean model configurations, Models - Downscaling, DA - Data assimilation applications,

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Multi-resolution modeling and data assimilation applied to the Indian Ocean

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Ocean forecasting systems such as the ones being developed the Indian National Center for Ocean Information Services have diverse applications, ranging from climate studies to operational support for the offshore industry. Such modeling and forecasting systems are required to produce consistent estimates of the ocean state across a range of scales, so that the system outputs are relevant to a diverse set of applications. At INCOIS, we have been exploring the use of multi-resolution modeling, and scale-recursive estimation techniques. In particular, we have developed a multi-resolution system, exploring different model configurations that include a global model at 1/4 degree and an Indian Ocean basin domain model at 1/16 degree resolution. The novel approach taken here is to identify these models as multi-level tree structures, where each level represents a certain scale (resolution) and are linked to each other in the tree, essentially providing a connection between processes represented at different scales. These estimates at each level are then linked to each other along the nodes of the tree with an up sweep and a down sweep steps using appropriate prolongation and restriction operators. Starting from the lowest node, restricted estimates computed at lower levels are used as priors for the next coarser level and then up on reaching the top the estimates are propagated back down the tree in a smoothing downward pass using prolongation operators. Standard Kalman analysis algorithm is used for obtaining estimates at any given level.We have implemented such a multi-resolution system with the HYCOM numerical code and a data assimilation system based on Optimum Statistical Interpolation using the Tendral Statistical Interpolation System. The models assimilate ARGO profiles, surface temperature (SST) and sea level anomalies derived from satellites. Here, we present details of hindcast experiments using the system. Results show that that the system provides consistent estimates of ocean state across states both at the surface and at depth, and as expected is able to improve the representation of the mean circulation at multiple scales by reducing errors through out the water column. The system has been implemented operationally at INCOIS and regular nowcast and forecasts from this system have been available for 2018 onwards. Overall the system outputs are comparable to estimates from observations and similar systems running at other forecasting centers around the world.

Keywords: Models - Downscaling, Applications - Ocean products for scientific, economic and societal use, DA - Data assimilation applications, DA - Smoother/smoothing in data assimilation, Systems - Prediction system performance & evaluation

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The global operational oceanography forecasting system and services in China

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The Chinese Global operational Oceanography Forecasting System (CGOFS-v1.0), including 6 global or regional subsystems in Global Ocean, Indian Ocean, Northwest Pacific (NWP), Yellow Sea and East China Sea (YES), South China Sea (SCS) and polar regions, had been developed and operated by NMEFC of China since 2013. The efforts on the improvements and upgrade to all the subsystems have been kept doing in the following years. Firstly, the new generation state-of-the-art Global Ocean subsystem has been developed and operated based on NEMO model. The tripolar grids is used in horizontal with the resolution is 1/12, the partial-z coordinate is employed in vertical with 75 layers. It is constructed with tree system architecture, including data collection, hierarchical data assimilation, numerical forecasting, and quasi online product produce 4 subsystems in total. It has assimilated multi-source (satellite and Argo profile) observed data by employing the Parallel Data Assimilation Framework (PDAF) assimilation technologies. It can provide 120 hourly ocean forecasting products of the global ocean, such as ocean currents, seawater temperature, and salinity. At the same time, the other ones, such as NWP, YES, and SCS, regional subsystems have been updated for the model version, system settings, and some parameterizations, too.

The numerical polar atmosphere and sea ice forecasting system has been initially established. With the advanced data assimilation module based on Ensemble Kalman Filter, the Arctic Sea Ice-Ocean Prediction System (ArcIOPS) was established. In the future, the high-resolution numerical forecasting system in polar region will be developed and parameterizations of key physical processes in coupled models will be improved. Sea ice-ocean-atmosphere coupled numerical models for the Arctic will be scheduled.

The forecasting products from the CGOFS have been used to provide many kinds of service, including the routine marine environmental and hazards forecasting, decision-making support, submersible Jiaolong exploration, Xuelong icebreaker trapped event, exploitation of Flammable ice in the South China Sea, and the Maritime Silk Road, etc. Numerical forecasting services of sea ice, meteorology and ocean wave are provided to Chinese Arctic and Antarctic scientific expeditions since 2010, as well as Chinese Arctic commercial navigations since 2013.

Keywords: Systems - Ocean Prediction Systems types (forecasting, analysis, scales, assessment, regions, ecosystem, ice, wave, etc.), Applications - Ocean products for scientific, economic and societal use, Models - Downscaling, Systems - Service providers, Systems - Ocean product distribution/dissemination and accessibility

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Development of a coupled coastal circulation and inland hydrology modeling framework based on ESMF/NUOPC infrastructure

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To enable flexible model coupling for compound inland and coastal hydrodynamic operational forecasts and applications, a coupling system based on ESMF/NUOPC technology under a common modeling framework called the NOAA Environmental Modeling System (NEMS) is being developed. The system provides dynamic interaction between the wave, ocean circulation, hydrology/inland flooding modeling components. The data communication between components occurs interactively by sending spatiotemporal water level and current fields from the ocean circulation component to the wave component, and in turn sends radiation stress gradients from the wave component to the ocean circulation component. The ocean circulation component also provides water level and current velocities to the hydrology/inland flooding component and receives river discharge and lateral fluxes as the upstream inflow boundary. NOAA is currently implementing this coupled system approach by employing WAVEWATCH III (WW3), ADCIRC and National Water Model (NWM) models as the wave, storm-surge and hydrology/in-land flooding model components. The system is forced by high-resolution wind and pressure fields derived from the Hurricane Weather Research and Forecasting Model (HWRF). The WW3-ADCIRC sub-system has been validated successfully for numerous major recent storm events (e.g. Ike and Sandy) for the U.S. Atlantic coast. As a next step, the ADCIRC-NWM sub-system will be evaluated for Hurricane Isabel, Irene and Sandy for the Delaware Bay region before the fully coupled system (ADCIRC-WW3-NWM) is validated for the U.S. Atlantic coast. Following validation of this system, this coupled system approach will be modified to include NOS three-dimensional ocean circulation operational forecasting systems (e.g. FVCOM and ROMS) as the ocean circulation component. The ESMF/NUOPC flexible coupling infrastructure and softwares developed as a part of this effort are open source and would be available to community upon request.

Keywords: Models - Future trends in ocean modelling, Models - Coupled modelling, Systems - Earth-system models, Systems - Coupled systems, Applications - Ocean products for scientific, economic and societal use

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Upgrading NCEP's operational ocean monitoring system with Hybrid-GODAS

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The Global Ocean Data Assimilation System (GODAS) was implemented at NCEP in 2003 and has since served as the real-time ocean monitoring system used at the Climate Prediction Center, as well as the ocean component of the data assimilation used to initialize the Climate Forecast System version 2 (CFSv2) for subseasonal to seasonal prediction. In recent years the international Ocean Reanalysis Intercomparison Project (ORA-IP) has helped identify deficiencies in GODAS when compared with other operational ocean reanalysis products, leading to an urgent need to upgrade the 15 year old GODAS to Hybrid-GODAS.

A key feature of the Hybrid-GODAS is the replacement of the univariate 3DVar data assimilation with a state-of-the-art ensemble based EnKF/3DVar. This ensemble-based system provides a multivariate analysis update, resulting in improved ocean analyses that are in better dynamical balance, and allows for straightforward assimilation of various observation data sets. In contrast to GODAS that assimilates in situ temperature profiles and synthetic salinity profiles that are calculated with the climatological T/S relationship, Hybrid-GODAS assimilates in situ temperature and salinity profiles, along-track L2P AVHRR SST, and L2P altimetry absolute dynamic topography. The model has been upgraded from the 1 degree ocean-only MOM3 to the latest eddy permitting 1/4 degree ocean and sea ice MOM6/SIS2 with 2m vertical resolution near the surface. The upgrade, without a relaxation to an analyzed SST product, allows the model SST to interact with surface fluxes through the bulk formula and atmospheric reanalysis variables that are bias-corrected CFSR plus perturbations from the 20CRv2c ensembles.

Early results show that the Hybrid-GODAS SST analysis is superior to the daily OISST and weekly OISST that are currently being used by CPCs ocean monitoring and seasonal forecast. The Hybrid-GODAS also provides much-improved 3D ocean temperature/salinity and ocean current structure comparing favorably with the OSCAR surface current analyses and TAO ADCP currents. The proposed upgrades will produce an ocean reanalysis from 1979 to present, and also contribute to ocean initialization of the newly developed coupled FV3GFS-MOM6-CICE5 model for subseasonal-to-seasonal prediction at NCEP.

Keywords: DA - Hybrid data assimilation, Systems - General ocean monitoring (including those based on ocean DA and prediction systems), Systems - Ocean reanalysis, DA - Ensemble data assimilation, DA - Variational data assimilation

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