Theme 5: Ocean Prediction Systems and Services
Session 1: Ocean reanalysis and applications

The Copernicus Marine Service Global Reanalysis Ensemble Product GREP: deriving robustness estimates for ocean variability over the altimetry era

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Several high resolution - 1/4 horizontal grid - ocean reanalyses based on the NEMO ocean model and constrained by altimetry, SST observations and in situ T and S profiles, were produced with different tunings, and were evaluated jointly using common validation guidelines (Masina et al, 2015, DOI: 10.1007/s00382-015-2728-5). The Copernicus Marine Environment Monitoring Service CMEMS http://marine.copernicus.eu - delivers a multi-reanalyses ensemble product based on GLORYS2V4 from Mercator Ocean (Fr), ORAS5 from ECMWF, FOAM/GloSea from Met Office (UK), and C-GLORS from CMCC (It). The four time series of global ocean monthly estimates were post-processed to create the Global Reanalysis Ensemble Product GREP, covering the altimetry ERA -1993-2017-. The ensemble mean and standard deviation of the ensemble, as well as the four individual members for the period 1993-2017, are available from CMEMS catalogue and the time series are extended by one year each year.

In the framework of the CMEMS Ocean State Report #2 (2018, DOI: 10.1080/1755876X.2018.1489208), we have explored, following Xue et al (2017, DOI: 10.1007/s00382-017-3535-y), the possibility to use the spread in between individual members in order to highlight robust ocean variability signals. For a subsample of indicators, regional reanalyses or gridded observed products from CMEMS were also used to enlarge the ensemble. Indicators and associated uncertainty estimates of heat content, surface currents, heat and mass transports, and western boundary currents will be shown in this presentation.

Keywords: Systems - General ocean monitoring (including those based on ocean DA and prediction systems), Systems - Multi-model ensemble systems, Systems - Ocean reanalysis, Systems - Prediction system validation/ intercomparisons, Applications - Ocean products for scientific, economic and societal use

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The Copernicus Marine Environment Monitoring Service global ocean 1/12° physical reanalysis GLORYS12V1: description and quality assessment

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Over the past years, Mercator Ocean has been regularly upgrading its global ocean physical reanalysis through improvements in the ocean model, assimilation scheme and assimilated data sets. RD activities have been conducted at Mercator Ocean International (MOI) to propose, in the framework of Copernicus Marine Environment Monitoring Service (CMEMS), a global eddy-resolving physical reanalysis GLORYS12V1, covering the altimetry era (1993-2016) and based on the current real-time global forecasting CMEMS system (1/12 horizontal resolution and 50 vertical levels).

The model component is the NEMO platform driven at the surface by ECMWF ERA-Interim reanalysis. Observations are assimilated by means of a reduced-order Kalman filter. Along track altimeter data (Sea Level Anomaly SLA), satellite Sea Surface Temperature (SST), Sea Ice Concentration and in situ temperature and salinity (T/S) vertical profiles are jointly assimilated. Moreover, a 3D-VAR scheme provides a correction for the slowly-evolving large-scale biases in temperature and salinity.

Compared to previous MOI reanalysis, except the horizontal resolution, GLORYS12V1 reanalysis benefits from the following main updates: global steric effect added to the model sea level, new seasonal observation error for assimilation of in situ T/S vertical profiles, adaptive tuning of observational SLA and SST errors, additional Quality Control on the assimilated T/S vertical profiles based on dynamical height criteria, assimilation in the deep ocean (below 2000m) of climatological T/S vertical profiles using a non-Gaussian error at depth.

This presentation will provide an overall assessment of this first global 1/12 ocean reanalysis highlighting the level of performance and the reliability of this new eddy-resolving physical reanalysis. The results of the latter will also be compared with those of reanalysis at resolution. A particular focus will be made on the meso-scale activity and the energy levels.

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

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Comparison of Three Global Ocean Reanalyses, NRL Global Ocean Forecast System (GOFS), Mercator GLobal Ocean ReanalYSis (GLORYS) and U. Maryland Simple Ocean Data Assimilation (SODA)

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The Oceanography Division of the Naval Research Laboratory recently completed a 23-year (1993-2015) coupled ocean-sea ice reanalysis forced by NCEP CFS reanalysis fluxes. The reanalysis uses the Global Ocean Forecast System (GOFS) framework of the HYbrid Coordinate Ocean Model (HYCOM) and the Los Alamos Community Ice CodE (CICE) and the Navy Coupled Ocean Data Assimilation 3D Var system (NCODA). The ocean model has 41 layers and an equatorial resolution of 0.08 (8.8 km) on a tri-polar grid with the sea ice model on the same grid that reduces to ~3.5 km at the North Pole. Sea surface temperature (SST), sea surface height (SSH) and temperature-salinity profile data are assimilated every day. The SSH anomalies are converted into synthetic profiles of temperature and salinity prior to assimilation. Geostrophically balanced analysis increments are inserted over a 6-hour insertion window. Sea-ice concentration analysis increments are inserted directly into the sea ice model every day. For comparison, two other reanalysis are compared, Mercator Ocean GLobal Ocean ReanalYSis (GLORYS) using the 1/12 eddy-resolving model, and Simple Ocean Data Assimilation (SODA v 3.3.1) using a eddy-permitting model.

Following the lead of the Ocean Reanalysis Intercomparison Project (ORA-IP), the monthly mean upper ocean heat and salt content from the surface to 300 m, 700m and 1500 m, the mixed layer depth, the depth of the 20C isotherm and the steric sea surface height for the GOFS, GLORYS and SODA 3.3.1 have been compared on a global uniform 0.5 grid. The differences between the three ocean reanalyses in heat and salt content increase with increasing integration depth. Globally, GOFS trends to be colder than SODA at all depths and similar to GLORYS. Warming trends are observed at all depths over the 23 year period. The correlation of the upper ocean heat content is significant above 700 m. Prior to 2004, differences in the data assimilated lead to larger biases. The GOFS reanalysis assimilates SSH as profile data. GLORYS uses internal correlations of SSH anomalies with temperature and salinity for data assimilation. SODA doesnt assimilate SSH. Large differences are found in the Western Boundary Currents, Southern Ocean and equatorial regions. In the Indian Ocean, the Equatorial Counter Current extends to far to the east and the subsurface flow in the thermocline is too weak in GOFS. The 20C isotherm is shallower in SODA compared to GOFS and GLORYS, but the monthly anomalies in the depth are highly correlated.

Keywords: Systems - Ocean reanalysis, Systems - Prediction system validation/ intercomparisons, Systems - Prediction system performance & evaluation, Systems - General ocean monitoring (including those based on ocean DA and prediction systems), Systems - Implementation of Ocean Prediction Systems

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An LETKF-based ocean reanalysis for the Asia-Oceania region using Himawari-8 SSTs and SMOS/SMAP SSS

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With the global spread of the Argo floats and development of high-resolution ocean models, global ocean reanalysis datasets have been released. Regional ocean reanalysis datasets also have been established around the North Pacific. In most datasets, the coverage area is limited to regions north of 10N. We suggest that reanalysis datasets for tropical-subtropical oceans are yet to be constructed for coastal environmental monitoring and typhoon researches around the Asia-Oceania region.

Since July 2015, a geostationary satellite Himawari-8 has been measuring sea surface temperatures (SSTs) with a high spatiotemporal resolution (horizontal/temporal resolution of 2 km/10 min.) in the western Pacific region using an infrared sensor. Because of the high temporal resolution, daily composite map shows that the coverage area of Himawari-8 SSTs exceeds that of an orbital satellite GCOM-W with a microwave sensor. The infrared sensor enables us to capture fine nearshore SST structure, such as localized cool SSTs induced by Ekman upwelling along the Vietnam coast during the southwesterly summer monsoon.

We have established a one-way nest ocean assimilation system based on LETKF (Local Ensemble Transform Kalman Filter; Hunt et al. 2007) with 20 ensemble members at 1-day interval. The southeast Asia coastal region [98115E, 022N] has been modeled at a spatial resolution of 1/36 and 47 layers with an intent to be applied for fishery and marine environmental monitoring, while the large-scale western Pacific region [95E165W, 50S50N] has been constructed at a spatial resolution of 1/12 and 47 layers to make a contribution to tropical cyclone studies. In addition to Himawari-8 SSTs, sea surface salinity (SSS) derived from SMOS and SMAP satellites as well as sea surface height and temperature/salinity derived from GTSPP and AQC Argo dataset have been assimilated. To improve the reproducibility of the salinity field, freshwater fluxes (the sum of evaporation, precipitation, and river discharge) also have been incorporated to this system. We will introduce the transport of the low salinity water formed by the river discharge in the southeast Asia system and the SST cooling with the passage of the tropical cyclone in the western Pacific system.

Keywords: DA - Ensemble data assimilation, Observations - Satellite ocean observing systems, Systems - Integration of coastal systems in large-scale systems,

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Investigating atmospheric blocking and linkages between Arctic sea-ice condition and SST

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The anomalies of the tropical, subtropical, and polar circulation over the underlying surface conditions could be responsible for the weather condition. In this study, we have assessed the forecast skill of extremes predicted by the global seasonal forecast system, GloSea5 with respect to the atmospheric blocking index based on geopotential height at 500 hPa. Atmospheric blocking events can explain local extremes as a part of the global climate variability. However, despite their relevance, many current coupled earth system models still struggle to represent the observed blocking statistics. The GloSea5 prediction operated by Korea Meteorological Administration is analysed the atmospheric blocking associated with atmospheric circulation, Arctic sea ice condition and sea surface temperature, and is compared to ERA-Interim which agree on Northern Hemisphere blocking characteristics. Results show that blocking events are detected on a central blocking latitude. However, the strength of blocking events tends to be underestimated relative to ERA-Interim over the Atlantic and Eurasia. Results also indicate slightly larger biases relative to ERA-Interim and the signal is weak. Overall, the GloSea5 can capture blocking frequency well despite biases in representing the mean state of geopotential height.

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Skill Assessment of Ocean Products around the Korean Peninsula for the Korea Operational Oceanographic System (KOOS)

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An Operational ocean forecast system should include information about its forecasting performance to enable end-users to exploit the products. An appropriate assessment method is also required to identify its strengths and weakness for the improvement of the system. In addition, it is necessary to consider the observation system and marine climatology of the area forecasted by the system. In this study, we developed a skill assessment system for a regional ocean prediction system based on the Korea Operational Oceanographic System (KOOS) in South Korea. The KOOS provides 72-h prediction data daily such as wind, water elevation, current, wave, water temperature, and salinity generated by the following meteorological and hydrodynamic numerical models: Weather Research and Forecasting model (WRF), Regional Ocean Modeling System (ROMS), Modular Ocean Model 5 (MOM5), Wave Watch 3 (WW3), and MOHID. We used approximately 200 real-time moored buoys and stations and 25 section tracking data around Korean Peninsula from Korea national agencies. We evaluated skill metrics with these data using not only common and widely used statistics such as mean, bias, root-mean-squared error and correlation, but also complex correlation for vector components and normalized statistics such as skill score to consider regional climatology. For detailed descriptions around the Korean Peninsula, we defined different areas such as the Yellow Sea, Korean Strait, East/Japan Sea according to their bathymetry, tidal range and specific ocean dynamics. Lastly, we developed a scoring method to help the public understand the data which was normalized from 0 to 100 with regard to error, local climatology and target criteria.

Keywords: Systems - Prediction system performance & evaluation, Systems - Prediction system validation/ intercomparisons, Systems - Ocean Prediction Systems types (forecasting, analysis, scales, assessment, regions, ecosystem, ice, wave, etc.), Models - Model assessments and verification, Systems - Visualisation

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Towards an operational Maritime Continent forecast system

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The maritime continent refers to the tropical region between the Indian and Pacific Oceans characterised by an archipelago of thousands of islands of various sizes and terrains and forms many straits and passageways for the ocean. This region is at the confluence of two large basin scale circulation cells referred to as the El Nino/Southern Oscillation and the Indian Ocean Dipole. The western Pacific accumulates heat forming the western warm pool some of which is transported through this region to the Indian Ocean via the so-called Indonesian throughflow. In addition to these large scale processes a feature of this region are large convective storms, that can occur daily, that form over the land surface drawing on the surrounding warm-moist air masses. The ocean in this region also exhibits large diurnal warming of the near-surface and a complex tide circulation generating internal tides. In addition to having a significant influence of global and regional climate this region has an important influence on the global economy and trade.

A one-year pilot project was undertaken to explore the feasibility of forecasting the atmospheric, oceanic and wave conditions in this region. A common region defined by 114.3E to 142.5E and 17.75S to 7.85N was resolved by all component models at a uniform 1/50 resolution. The atmospheric model was based on the Unified Model v10.6 with a full Euler (non-hydrostatic) formulation, 80 model levels and an explicit treatment of convection. The ocean model was based on the Regional Ocean Modeling System (ROMS) with 30 vertical levels and SRTM30+ bathymetry. The wave model used WaveWatch III with an unstructured grid and boundary conditions from AUSWAVE.

 The three models were assessed for a parallel forecast period of one month, March 2018. This period included two tropical cyclones, TC Kelvin (4-9 March) and TC Marcus (14-24 March). The atmospheric model demonstrated an improved representation of tropical convection but a reduction in general precipitation. The wave model demonstrated improvements associated with resolved narrow passages and islands. A reduction in errors for extreme wave heights was obtained relative to altimetry observations. The ocean model was compared with 16 tide gauges showing correlations better than 0.94 for all gauges except those along the boundary in Torres Strait and one in the Gulf of Carpentaria. Mean absolute differences of 0.67 degrees and 0.141 PSU for temperature and salinity respectively were obtained from ~8000 profiles.

The results obtained were based on downscaled models without data assimilation. The performance was determined to be sufficient to advance to a full development stage. An overview of this project will be presented as well as progress toward coupled modelling and ocean data assimilation.

Keywords: Systems - Earth-system models, Systems - Prediction system performance & evaluation, Models - Coupled modelling, Models - Ocean model boundary conditions and forcings,

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