Abstracts

for

Sub-session 3.3

Validation of Ocean Forecasting Systems: Addressing User Needs for Accurate Information

Session conveners:

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Session 3

Key Scientific & Technological Advances – Scientific capabilities & data requirements and user applications

Session 3.1: Validation of Ocean Forecasting Systems: Addressing User Needs for Accurate Information

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Evaluation of the ECMWF ORAS4 ocean reanalysis system

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Abstract

A new operational ocean reanalysis system (ORAS4) has been implemented at ECMWF. It spans the period 1958 to the present. ORAS4 has been evaluated using different metrics, including comparison with observed ocean currents, RAPID-derived transports, sea-level gauges, and GRACE-derived bottom pressure. Compared to a control ocean model simulation, ORAS4 improves the fit to observations, the interannual variability, and seasonal forecast skill. Some problems have been identified, such as the underestimation of meridional overturning at 26°N, the magnitude of which is shown to be sensitive to the treatment of the coastal observations.

ORAS4 shows a clear and robust shallowing trend of the Pacific Equatorial thermocline. It also shows a clear and robust nonlinear trend in the 0–700 m ocean heat content, consistent with other observational estimates. Some aspects of these climate signals are sensitive to the choice of sea-surface temperature product and the specification of the observation-error variances. The global sea-level trend is consistent with the altimeter estimate, but the partition into volume and mass variations is more debatable, as inferred by discrepancies in the trend between ORAS4- and GRACE-derived bottom pressure. These directions are written in the format required for the abstract of the paper for the GODAE OceanView Symposium of November 2013. We advise you to download these directions as a word-document and use it as the template for your abstract because it contains all necessary formats and styles.

ID: 3.3.2

Validation of Navy Ocean Forecasting Systems in Trident Warrior 13

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Abstract

Operational oceanography is often faced with the question of which system is best suited for a particular application. In many cases, different systems may be more appropriate for different. We examine such issues in the context of Trident Warrior ’13, a Navy exercise conducted off of the Virginia/Maryland coast in July 2013. A variety of models and assimilation strategies are employed to produce various candidate simulations of the ocean environment. These in turn are evaluated relative to a variety of confirming observations, including satellite altimetry, sea surface temperatures, glider measurements, AXBT surveys, and shipboard hydrographic observations. The models offer alternate assimilation approaches with differing emphases as applied in a domain spanning shallow regimes with significant freshwater estuarine exchange, a broad shelf, slope, and open ocean regions with a strong western boundary current. Performance of the model alternatives in these regimes offers insight for operational recommendations in future operational applications.

ID: 3.3.3

Developing Key performance indicators for global operational ocean models around Sothern Africa

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Abstract

The Agulhas Current plays an important role in both regional and global climate. Through Agulhas leakage warm and saline Indian Ocean water is transported into the Atlantic Ocean. The flux of Indian Ocean water into the Atlantic is vital for maintaining the global overturning circulation. Recently, significant effort has been placed on providing accurate reanalysis products combining global ocean models and data assimilation techniques. In order to advance our understanding of the regional ocean dynamics and their importance in the global system, these reanalysis products need to be properly evaluated for the Agulhas region, which is known to be difficult to simulate accurately. Presently, there are no regionally specific methods to assess and quantify the performance of these systems. The aim of this study is to objectively evaluate global operational systems such as the reanalysis provided by MyOcean, Bluelink, and the HYCOM consortium. Through this assessment, validation indices will be developed, which may then be applied to other ocean simulations of the region. Here we use the Mercator GLORYS2V1 reanalysis product and generally validate it for the region using independent observations. Following this validation, the transports in the greater Agulhas Region are assessed at 32°S (ACE) and in the Mozambique Channel (LOCO) and compared against historical data using the physical analysis of ocean data (PAGO) to consistently extract section data. Initial results show an average transport of 58.54Sv and 23.91Sv across 32°S and the Mozambique Channel in the reanalysis product respectively.

ID: 3.3.4

GODAE OceanView Class-4 Inter-comparison efforts at the Australian Bureau of Meteorology

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Abstract

A routine inter-comparison of the class-4 metrics is proposed by the Inter-comparison and Validation Task Team (IV-TT), with the aim to provide useful information on the forecast performance of the operational systems. Started in late 2011, lead by the UK Met Office, the project routinely produces a set of standard commonly agreed forecast products in observational space by each of the participating centres. Currently the Australian Bureau of Meteorology (BoM), UK Met Office and National Centers for Environmental Prediction (NCEP) produce class-4 files for SST, SLA and Profiles in near real time. At BoM the project has been performed operationally since February 2013 at the National Meteorological and Oceanographic Centre. This paper details results on the performance of the forecasting systems in the Australian region for 2013.

ID: 3.3.5

GLOBAL EDDY-PERMITTING OCEAN REANALYSES and SIMULATIONS of the PERIOD 1992 to PRESENT

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Abstract

The GLORYS (Global Ocean reanalysis and Simulation) Project is motivated by the need of a realistic description of the ocean state and variability over the recent decades, at the global scale, and at the scale of the ocean basins and regional seas (https://reanalyses.org/ocean/overview-current-reanalyses). The French research community (CNRS), the operational ocean forecasting center MERCATOR-Ocean (http://www.mercator-

ocean.fr) and the CORIOLIS data center (http://www.coriolis.eu.org/), have gathered their skills and expertise in physical oceanography, ocean modeling and data assimilation, to carry out global ocean reanalyses at eddy scale resolution for the period 1992 to present. This reanalysis effort is part of the project MyOcean granted by the European Commission within the GMES Program (7th Framework Program, http://www.myocean.eu/).

This paper will present the GLORYS reanalysis system relies on the ORCA025 global model configuration developed by the DRAKKAR consortium (http://www.drakkar-ocean.eu/), on the basis of the NEMO3 ocean/sea-ice general circulation model (http://www.nemo-ocean.eu/). ORCA025 uses a horizontal grid resolution of 1/4° and 75 vertical levels, which permits the growth of mesoscale eddies. The data assimilation scheme developed for the operational forecasting systems of Mercator Océan is used in this reanalysis system. It is based on a reduced order Kalman filter (SEEK formulation) and an incremental analysis update, in conjunction with a bias correction scheme for temperature and salinity. AVHRR Sea Surface Temperature, along track Sea Level Anomalies and in situ Temperature and Salinity profile data are assimilated for the ocean component. In parallel, Sea Ice Concentration data (CERSAT, http://cersat.ifremer.fr/) are assimilated to constrain the LIM sea ice model. At the surface, the GLORYS reanalyses are forced with atmospheric surface variables from ERA-INTERIM atmospheric reanalysis (http://www.ecmwf.int/research/era/do/get/era-interim) at high frequency (3 hours). In parallel, a control experiment with no observation assimilated is integrated, to estimate the benefit of data assimilation.

The paper will present assessments and measures of the quality of GLORYS products obtained from a validation protocol based on recommended GODAE (https://www.godae-oceanview.org/) and CLIVAR-GSOP reanalysis diagnostics, and from a comparison with the control simulation. The scientific value of the GLORYS reanalysis products will be illustrated with results from independent scientific studies obtained in a wide range of areas such as climate, seaice, mesoscale processes, mixed layer processes, etc.

ID: 3.3.6

CLIVAR-GSOP/GODAE ocean synthesis intercomparison of sea level variability

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Abstract

In the framework of the GSOP/GOV intercomparison project, the sea level from 20 reanalysis and observed products on a monthly basis is analysed over the 1993-2010 period. Mean sea level values, global and basin scale averages are compared over time. Global trends and interannual changes are discussed, with regards to observed satellite altimetry reference, and a selection of tide gauges time series. Seasonal cycles are assessed similarly.

Results are discussed considering the specific aspect of each reanalysis: models and resolution, forcing functions, assimilation techniques and assimilated data. An ensemble approach is also carried out: different ensemble computation methods are tested, with regards to their spreading, and satellite altimetry.

An expected outcome of the GSOP/GOV project is the implementation of ocean climate monitoring in operational oceanography centres, and the definition of relevant ocean indicators. Several sea levels indicators are proposed and discussed.

ID: 3.3.7

CLIVAR-GSOP/GODAE ocean synthesis intercomparison of depth of the 20°C isotherm (D20) variability

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Abstract

In the framework of the GSOP/GOV intercomparison project, the D20 from 20 reanalysis and observed products on a monthly basis is analysed over the 1993-2010 period, focusing on the tropical band.
The D20 is used as a proxy for the depth of the tropical thermocline. An analysis of the mean values, and the variability from seasonal to interannual time scales is performed over the different reanalysis estimates. Values are also compared to ARMOR3D and EN3 observed products.

Results are discussed considering the specific aspect of each reanalysis: models and resolution, forcing functions, assimilation techniques and assimilated data. An ensemble approach is also carried out: different ensemble computation methods are tested, with regards to their spreading, departures from ARMOR3D and EN3 observed products.

An expected outcome of the GSOP/GOV project is the implementation of ocean climate monitoring in operational oceanography centres, and the definition of relevant ocean indicators. For instance, the tropical Pacific D20 witnesses the ENSO variability. Several other indicators based on D20 are proposed and discussed for monitoring tropical ocean variability.

ID: 3.3.8

General Validation Framework for the Baltic Sea

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Abstract

The MyOcean Baltic Monitoring and Forecasting Centre (BalticMFC) is providing forecast and re-analysis products for the physical as well as biogeochemical parameters in the Baltic Sea. In order to assure constant quality control of the Baltic MFC products a comprehensive validation framework was built and is routinely applied to the products (Fig. 1). The quality information is routinely fed back to the production centres and is published as part of the product information in the MyOcean user portal (www.myocean.eu).

Initially based on the GODAE metrics classes a set of regionally optimized metrics was defined within the validation framework. The range of validation parameters covers sea level, ice thickness and concentration, temperature, salinity, transports and biogeochemical parameters like chlorophyl-a, oxygen, nitrate and phosphate. Observational data is gathered from MyOcean products and BOOS ftp for sea level and HELCOM BMP for profile data for temperature, salinity and biochemical parameters. AATSR L3 SST, Mersea/Météo-France L3 supercollated SST product is used for SST validation. Ice maps are used to validate ice thickness and concentration.

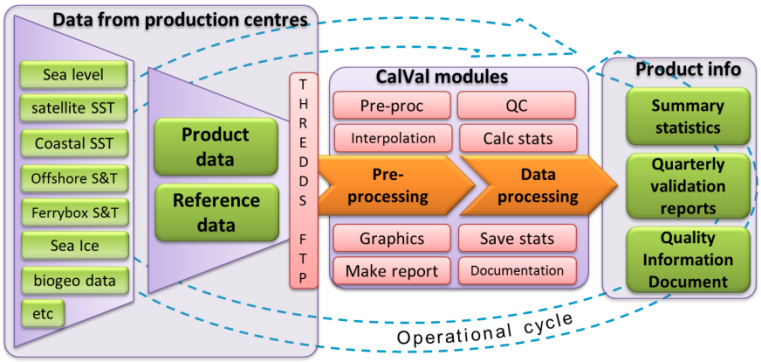

Fig. 1. The structure of validation framework for the Baltic Sea

Motivated by the different types of observations the validation framework gives statistical measures for model performance against time series and satellite born data. Validation is based on time series for sea level and coastal SST. Vertical profiles are used for temperature, salinity and biogeochemical variables. Ferrybox data are available in near-real-time for SST and SSS. From satellite born data the validation is done for SST, Chl-a and sea ice. In future versions it is planned to include also the altimetry data into the validation routines.

The validation framework is designed to evaluate both hindcast as well as forecast products. In hindcast mode only the best available model results are handled while in forecast mode the statistics are calculated for several forecast lead times. Although the framework was designed under the MyOcean umbrella, initially validating only the models operated within the MyOcean project it is now generalised in a way so that it can handle different models. The work towards involving other operational models from the Baltic Sea area, for example the models developed and operated under the HIROMB programme, into the validation routines for comparative purposes is ongoing.

ID: 3.3.9

CLIVAR-GSOP/GODAE ocean synthesis intercomparison of historical heat content variability and change

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Abstract

We present an intercomparison of historical ocean heat content (OHC) simulations from a number of international ocean synthesis efforts, as part of a joint initiative between the CLIVAR Global Synthesis and Observations Panel (GSOP) and the Global Ocean Data Assimilation Experiment (GODAE). The results presented here form part of a larger intercomparison project that includes other climate and forecast relevant metrics, such as mixed-layer depth, steric height, sea level, surface fluxes, horizontal transports, sea ice and ocean salinity.

Adopting a similar approach to previous studies, we compare spatial maps of the ensemble average to the ensemble spread as a means to assess what variables and regions are well constrained among the analyses. The length of simulation varies for each synthesis product, according to forcing set and data assimilation methods (e.g. use of satellite altimetry), with the longest simulations starting around 1950. For the common of period 1993-2009 we compare: (i) the time-mean OHC; (ii) the amplitude of the seasonal cycle of OHC; (iii) the inter-annual variability in OHC; over a number of depth intervals.

Time series of global OHC show best agreement for the upper few hundred metres, with substantial divergence among syntheses as for the deeper layers. The largest divergence occurs during the 1990s and appears to result from model “spin-up” with some synthesis products showing unphysical rates of ocean heat uptake. The recently reported increased rate of deep ocean heat uptake over the last decade for the ORAS4 product is qualitatively supported by our ensemble. Finally, we present simulated patterns of deep ocean heat uptake over the period 2000-2009 and discuss the implications for monitoring Earth's energy budget.

ID: 3.3.10

Multi-model Intercomparison with class4 metric

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Abstract

Mercator Océan, the French ocean forecast service provider, develops and operates ocean analysis and forecasting systems based on state-of-the-art Ocean General Circulation Models assimilating observations of the Global Ocean Observing System. The mandate of Mercator Ocean in the European/GMES (Global Monitoring for Environment and Security) context is to cover the global ocean at eddy resolving resolution.

Mercator Océan runs several global (1/4° and 1/12°) and regional (1/12° and 1/36°) ocean forecasting systems. In the context of the Inter-comparison and Validation Task Team (IVTT) the Mercator validation team has developed intercomparison tools that are regularly used to intercompare the various Mercator configurations. In the large number of metrics defined in IVTT we focus our study on class4 metric to look at the accuracy and forecast capabilities of the different GODAE systems.

The intercomparison is based on the methodology developed in the Mercator Quarterly Validation report (Quovadis available at http://www.mercator-ocean/fr/fre/science/qualification). This report, partially built with diagnostics coming from class4 metric, aims to measure and keep track of the performance of the global monitoring and forecasting system (MFC) in order to identify possible improvements. We compare, for the year 2013, the performance of the different GODAE systems with the following observations: insitu and salinity profiles, along tracks altimetric data from Jason1, Jason2 and Cryosat, and SST data from in situ surface drifters.

Physical diagnostics, such as water masses T/S diagrams, and skill scores are also performed with respect to these three kinds of observations.

ID: 3.3.11

Class 4 global forecasting centre intercomparison

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Abstract

The Intercomparison and Validation Task Team (IV-TT) is initiating a routine inter-comparison of the forecast accuracy of GODAE OceanView systems. The intercomparison is based on GODAE class 4 metrics, which consist of model counterparts in observation space. Participating forecast centres are supplying model counterparts to a common set of observations, delivered within a few days of the operational forecast to enable near real time forecast accuracy monitoring. The observation data sets are: surface in-situ SST drifters supplied by USGODAE, ARGO Temperature and Salinity profiles supplied by MyOcean and Altimeter satellite data (Jason-1/2, Envisat & Cryosat). At the time of writing, participating operational oceanography forecast systems include FOAM from the UK Met Office, RTOFS-HYCOM from NOAA/NCEP, USA, OMAPS from BlueLink, Australia, ATLe0.25-HYCOM from REMO, Brazil and PSY3V3R1 from Mercator-Ocean, France. We will present results from an investigation of summary statistics and accuracy metrics both globally and in regions of interest, which reveals interesting features of each operational forecast system.

ID: 3.3.12

An Assessment of Upper Ocean Salinity Reanalyses from CLIVAR GSOP/GODAE Systems

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Abstract

Since both sea temperature and salinity play very important roles for seawater density and thus oceanic circulation, assimilating in-situ salinity profiles can provide more accurate oceanic initial conditions for ocean and seasonal forecast systems. In this study, upper ocean (0-300 meters) salinity reanalyses from some ocean assimilation systems of the CLIVAR GSOP/GODAE project are assessed for the period 1993-2010.

It is found that the discrepancies of the upper ocean salinity reanalyses from the 8 systems of the GSOP/GODAE relative to their ensemble mean (ENSM8S) in the ARGO period (2002-2010) are significantly smaller than that in the period prior to the ARGO. Therefore, the ARGO data plays a crucial role on the improvement of the salinity reanalyses. Besides the in-situ salinity profiles, the dynamics of the ocean models and assimilation techniques have also very important impacts on the performance of the salinity reanalyses.

The salinity reanalyses from 8 systems of the GSOP/GODAE are more consistent in the tropical oceans than in the high latitude Oceans, in particular the Southern Ocean. In addition, the salinity reanalyses in the tropical Pacific Ocean from the 8 systems shows significantly better performance relative to the ENSM8S than that in the tropical Indian Ocean. This indicates that the abundant temperature observation in the tropical Pacific Ocean, e.g. from the TOGA-TAO array, can be very helpful to improve the salinity reanalyses there.

ID: 3.3.13

Evaluating oil-spill dispersion forecasting in the Northern Aegean Sea

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Abstract

In the framework of a series of research projects, a 48-hours oil spill dispersion forecasting system was developed, implemented and tested in the Northern Aegean Sea, aiming at oil spill dispersion management in an area of heavy maritime activity. The system is based on atmospheric, wave and ocean circulation models coupled with the operational systems ALERMO (nested in the MyOcean forecasting system) and SKIRON of the University of Athens and oil-spill dispersion models. The various components of the system were successfully developed, improved through sensitivity tests and coupled to form an operational oil spill dispersion forecasting system, available at an interactive web-site (http://diavlos.oc.phys.uoa.gr), in order to be used by interested authorities. The system was also tested against field observations, in a series of experiments (an example is provided in Figure 1), using drifting floats and special oil-spill drifting instruments that monitor the trajectories and spreading of oil spills. Overall, the system provides satisfactory results and in most cases the forecasting error is quite small, allowing the operational use of the system. Analysis of the results under different conditions and in areas of different dynamic regimes provides information on the forecasting skill of such systems and suggestions for further development.

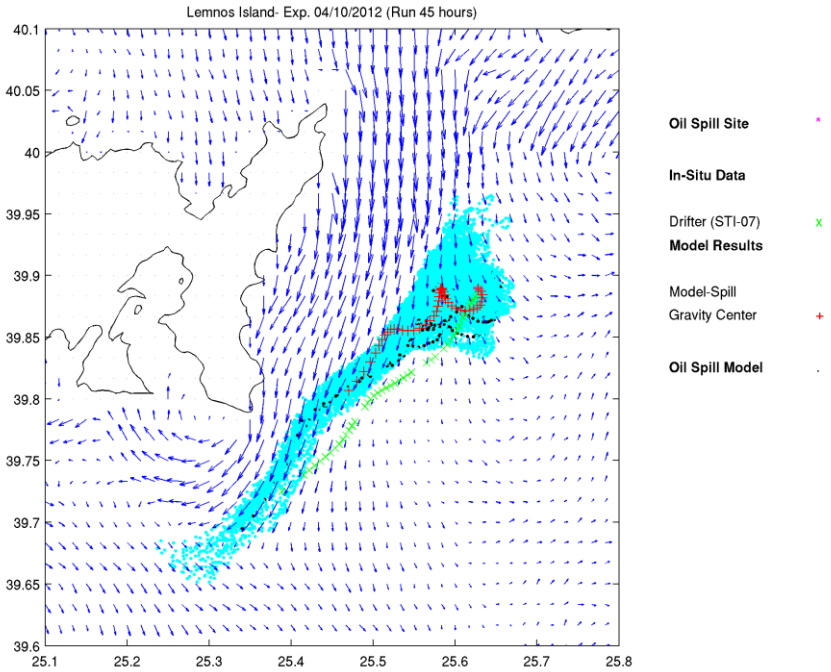

Figure 1:. Example of forecast validation with surface drifters

GLOBAL OCEAN NOWCAST/FORECAST SST'S FROM MULTI-MODEL ENSEMBLES

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Abstract

Multiple global SST nowcasts/forecasts are now available from various ocean operational systems (OOS). It can also be safely assumed that these systems have complementary predictive skills. There is also now well-documented literature that shows combining multiple forecasts using simple combinations can help substantially increase accuracy (or reduce error) of such forecasts (Clemen, 1989, Galmarini et al., 2004).

Daily global nowcast SST fields from five different OOS (HYCOM, FOAM, CFS, RTOFS and MERCATOR) are used for investigation of ensemble techniques. The employed techniques include weighted means, clustering algorithms (Hartigan, 1975; Arthur and Vassilivitski, 2006) and operational consensus forecasts (Woodcock & Engel, 2005). Preliminary results are presented and discussed along with their limitations. Other alternatives to building ensembles including forecasts from prior run cycles of the same OOS will also be considered.

ID: 3.3.15

An Inter-Comparison of Steric Sea Level from Ocean Reanalyses and Objective Analyses

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Abstract

During one of the last CLIVAR/GSOP and GODAE meetings, it was established a joint initiative among ocean synthesis producing centers in order to extensively compare some climate key parameters. CMCC is leading the inter-comparison of the steric sea level (SSL), with the scientific objectives of i) quantify the global SSL, its uncertainty and the reanalyses skill with respect to independent estimates; ii) assess the regional SSL change and the agreement between the ocean reanalyses; iii) quantify the relative contributions of the thermal and haline components and iv) quantify the relative contributions of different vertical regions. We present here the first results from the inter-comparison study, which involved 20

products, of which 16 ocean reanalyses and 4 observation-only products, thus representing a major effort in evaluating the SSL provided by state-of-the-art ocean reanalyses.

The comparison strategy consists of a validation period (2005-2009) and an extended inter-comparison period (1993-2009), the former covering the gravimetry era, while the latter the altimetry era. Within the validation period, the ocean synthesis products are compared with the independent SSL estimation given by monthly means of altimetric sea-level anomaly minus gravimetric ocean bottom mass anomaly, the latter from the ensemble of the GRACE RL05 solutions.

For the validation period, it turned out that the Global SSL (GSSL) fluctuations are quite well reproduced by the reanalyses, its ensemble mean leading to an anomaly correlation of 0.82 with the independent satellite estimates; the seasonality of the GSSL is generally well reproduced while linear trends exhibit large uncertainty and variability among the reanalyses and are generally under-estimated w.r.t. the altimetry minus gravimetry dataset. Interestingly, the ensemble of the ocean reanalyses is more skillful than the ensemble of objective analyses (i.e. observation-only products), especially in areas with a poor observing network and/or impact of deep and bottom waters (e.g. ACC, Bering Sea). The ensemble strategy itself proves a robust tool for further diagnostics, provided that the ensemble mean exhibits higher correlation than any individual product.

For the extended inter-comparison period, GSSL trends from the ensemble mean (1.1 +/- 0.1 mm/yr) are found in agreement with all recent estimates. We generally found poor agreement on the globally averaged halosteric component of the steric signal between the ocean products, and, consequently, no consensus on the relative contributions of the thermal and haline components of the GSSL: the halosteric contribution to the GSSL trend is generally found statistically non-significant with respect to its ensemble spread, while its contribution to the GSSL variability (explained variance) ranges from 5 to 40 %, the Southern Ocean being however the basin more impacted. Finally, we show the assessment of the contribution of the “unobserved ocean” (that we consider below 700 m for the 1993-2009 period), which accounts, on the average, for the 22 to 38% of the inter-annual signal variability in the case of the reanalyses ensemble, with peaks in the Indian and Southern Oceans (27 to 47% and 38 to 42%, respectively).

ID: 3.3.16

Ocean Mixed Layer Depth Intercomparison among syntheses

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Abstract

Recent improvement in modeling and assimilation techniques and increase of observations offer a better description of global ocean processes. Now, evaluation of global ocean syntheses is needed in the context of observation-based estimates. CLIVAR GSOP (Global

Synthesis and Observations Panel) is making an effort of evaluating the ocean syntheses/reanalyses in terms of several metrics. As one of the most important metrics for the dynamical process of climate variation, ocean surface mixed layer depth fields from syntheses/reanalyses are compared in this study.

The submitted syntheses/reanalyses to this intercomparison are as follows: EN3 (UKMO) and ARMOR3D (CLS) are syntheses without model; G2V1 (Mercator), C-GLORS (CLS), UR025.4 (U. Reading), GloSea5 (UKMO), ORAS4 (ECMWF), GECCO2 (U. Hamburg), GEOS5 (GMAO), ECCO-NRT, ECCOv4 (JPL), ECDA3 (GFDL), RIGC-ODA, K7-CDA (JAMSTEC), MOVE-G2, MOVE-CORE, MOVE-C (MRI) are reanalyses with various ocean/coupled models, resolutions, forcings, and assimilation methods. Mixed layer depth (MLD) and isothermal layer depth (ILD) defined here as the depth where the density is larger than the 10-meter value by 0.03 or 0.125$\sigma\theta$ and where the temperature is smaller than the 10-meter value by 0.2 or 0.5˚C, respectively, are estimated from the monthly-mean tempereture and salinity (TS) fields. In addition, open MLD/ILD datasets, MILA-GPV (Hosoda et al., 2010) and de Boyer Montegut (2004) derived from individual observed TS profiles and MLD/ILD estimated from WOA09 climatology are also investigated.

The observational MLDs/ILDs are underestimated by using monthly-mean and gridded TS instead of individual profiles, consistent with de Boyer Montegut (2004), but the use of the larger criteria (0.125$\sigma\theta$ or 0.5˚C) reduces the biases to less than 20%. The ensemble mean of reanalyses can be considered “observational“ if the model biases are cancelled out. It is revealed that the ensemble mean of MLDs/ILDs from monthly-mean TS of reanalyses exhibits much smaller biases than those of synseses without model, except for the region where common biases are known in the coarse-resolution models (e.g., the Kuroshio Extension region). The interannual variability is more represented in EN3 and ARMOR3D than MILA-GPV derived from only ARGO float data due to their spatio-temporal coverage. In addition, ensemble mean of the reanalyses represents it in a similar level to EN3 and ARMOR3D.

ID: 3.3.17

CLIVAR-GSOP/GODAE Ocean Synthesis Inter-Comparison of Global Air-Sea Fluxes Obtained Through Ocean Data Assimilation

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Abstract

The GODAE and CLIVAR-GSOP ocean synthesis program has been accessing the degree of consistency between global air-sea flux data sets obtained from ocean or coupled reanalyses. So far, we have analysed the homogeneity and closure of the reanalysis-based flux products, and compared them with model independent products using different data sources and methodologies. Most reanalyses show a positive imbalance in global surface heating with a twelve-member ensemble mean of 5 Wm^{-2} over the period 1993 - 2009, decreasing steadily after 2004 when more ocean observations are available. This is far

smaller than the 20 - 25 Wm^{-2} global heat flux imbalance in Objectively Analysed (OA) flux products based on ship or/and satellite observations, and the about 15 Wm^{-2} seen in coupled reanalyses. A comparison of the spatial flux maps reveals that the main discrepancies between products are located across the tropical Pacific, the WBCs and in the Southern Ocean. Meridional heat transports implied to balance the 17-year mean surface heat fluxes show a large range of estimates among products, which is due to a combination of flux/model biases and ocean heat storage. The ensemble average surface flux still implies 3 PW of tropical heating transported to the north, mostly in the Atlantic, which is almost 2 times greater than estimates from ocean observations; however when the surface fluxes are adjusted by data assimilation implied transports are within the uncertainty of direct estimates of ocean heat transport.

Regional comparisons of individual flux components representing radiative and turbulent transfers are now underway and reveal that mean values of net fluxes from ocean reanalyses are generally low compared to observation-based fluxes (consistent with the known positive global bias in OA flux data), although variability on seasonal to interannual timescales is generally in good agreement. Ongoing work is now looking at validation of ocean/coupled reanalysis-based fluxes against in situ flux measurements at a number of buoy sites (Papa, KEO, CLIMODE, WHOTS, NTAS, PIRATA, and STRATUS), which provide an independent check that is not reliably gained from any other source.

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CLIVAR-GSOP/GODAE Ocean Synthesis Inter-Comparison of the 26^{o}N AMOC and Other Transports

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Abstract

The GODAE and CLIVAR-GSOP ocean synthesis program has been comparing the Atlantic Meridional Overturning Circulation (AMOC) from a number of ocean synthesis products of different resolution. The Atlantic 26^{o}N section has been compared in detail with the RAPID array monitoring since 2004, including breaking the AMOC down into different components, as well as looking at the associated heat and freshwater/salt transports. None of these products assimilates transport information or the RAPID array data itself, so this is an independent comparison. Seasonal and interannual variability are compared and ensemble products are also produced and assessed. We have also begun work to extend the comparisons to other sections which, while not monitored observationally, have previously published “mean” transport estimates. We will look to summarise what we can learn from these comparisons of very different models and comment on the importance of evaluating these model transports.

ID: 3.3.19

Evaluation of the ECMWF Ensemble of Ocean Reanalyses using Assimilation Diagnostics

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Abstract

A new operational global ocean reanalysis system (ORAS4) has been implemented at ECMWF, spanning 1958 to present. ORAS4 consists of five ensemble members: one unperturbed member and four additional members obtained by randomly perturbing the surface wind-stress forcing, the initial conditions at the start of the reanalysis period, and the observation rejection criterion. The ensembles have been used to provide information about the uncertainty in the reanalysis but have not been used interactively to specify the background-error (bge) covariance matrix. ORAS4 has been evaluated using various metrics, including comparisons with non-assimilated observations, impact on seasonal forecast skill, and robustness of prominent climate signals. Observation-space assimilation diagnostics provide an additional metric. This presentation describes results from a statistical analysis of the innovations and analysis residuals in ORAS4. The objectives of this work are to assess: 1) the quality of the model fit to the assimilated observations; 2) the statistical consistency of the bge and observation-error (obe) covariance specifications; and 3) the adequacy of the ensemble spread.

Results show that the fit to temperature and salinity data in the forecast cycle of the reanalysis is systematically improved with ORAS4 compared to a control experiment defined as an ensemble of forced simulations with no data assimilation. The specified bge variances are reasonably consistent with the diagnosed bge variances, especially for temperature, and notably are able to capture seasonal variations by using a flow-dependent parameterization in terms of the background state. The parameterized bge variances are independent of the observing network, however, and this limitation manifests itself as an increasing discrepancy between specified and diagnosed bge variances with time. The specified obe variances are generally much larger than the diagnosed obe variances for all data types (temperature and salinity profiles, as well as altimeter data), which can be mainly attributed to the deliberate inflation of the specified obe variances near continental boundaries to account for representativeness error. As expected, comparisons with ORAS4 and the control illustrate that data assimilation has a significant damping effect on the ensemble spread, particularly in the last half of the reanalysis period. Compared to the diagnosed bge standard deviations, the ensemble spread in ORAS4 is too small suggesting that variance inflation and/or improvements in the ensemble generation strategy will be necessary in order to use the ensemble perturbations effectively for defining flow-dependent bge covariances in the variational assimilation system.

ID: 3.3.20

A Comparative Analysis of Upper Ocean Heat Content Variability from an Ensemble of Operational Ocean Reanalyses

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Ocean heat content (HC) is one of the key indicators of climate variability and also provides ocean memory critical for seasonal and decadal predictions. The availability of multiple operational ocean analyses (ORA) now routinely produced around the world is an opportunity for estimation of uncertainties in HC analysis and development of ensemble based *operational* HC climate indices. In this context, the spread across the ORAs is used to quantify uncertainties in HC analysis and the ensemble mean of ORAs to identify, and to monitor, climate signals. Towards this goal, we analyzed ten ORAs, two objective analyses based on in situ data only and eight model analyses based on ocean data assimilation systems. The mean, annual cycle, interannual variability and long-term trend of HC in the upper 300m (HC300) from 1980 to 2009 are compared.

The spread across HC300 analyses generally decreased with time and reached a minimum in the early 2000s when the Argo data became available. There was a good correspondence between the increase of data counts and reduction of the spread. The agreement of HC300 anomalies among different ORAs, measured by the signal to noise ratio (S/N), is generally high in the tropical Pacific, tropical Indian Ocean, North Pacific and North Atlantic, but low in the tropical Atlantic and extratropical southern oceans where observations are very sparse. A set of climate indices were derived as HC300 anomalies averaged over the areas where the co-variability between SST and HC300 represents the major climate modes such as ENSO, Indian Ocean Dipole, Atlantic Nino, Pacific Decadal Oscillation, and Atlantic Multidecadal Oscillation.

ID: 3.3.21

Gulf of Mexico Pilot Prediction Project: Evaluation of 60-day Ensemble Forecasts of the Loop Current System

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Abstract

The Gulf of Mexico Pilot Prediction Project (GOMEX-PPP) is investigating the performance of ocean forecast systems for long-range (2 to 3 month) forecasts of Loop Current behavior and eddy shedding. Such long-range forecasts are sought to support activities in offshore regions of the Gulf which are impacted by strong currents associated with the Loop Current and its eddies, and to provide boundary conditions for coastal ocean models operating in the Gulf. During Phase I of the project a suite of six systems provided real-time 3 mo. forecasts at bi-weekly intervals for the 2011-2012 time period. Results indicated a correlation between model forecast skill and multi-model ensemble spread. During Phase II of the project an ensemble forecast system is being developed at the Naval Research Laboratory (NRL) which provides 2 mo. forecasts at weekly intervals.

The skill of NRL ensemble forecast system is presently being evaluated via comparison against altimeter-derived sea-surface height and other data. New products and skill metrics are being developed to communicate forecasts and their uncertainties to potential users. The project seeks to demonstrate a level of useful skill in the current development phase, and is a prototype for long-range operational ocean forecasting systems of the future.
