Joint DA & OSEval-TT Meeting

The Joint Workshop of the GOV

Data Assimilation and Observing System Evaluation Task Team

CMRE, La Spezia, Italy

11-13 October 2017

Report

Prepared by

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DA-TT & OSEval-TT meeting participants, CMRE, La Spezia, Italy in October 2017

Many thanks to CMRE and ONRG for their sponsorship and outstanding organization

Presentations referred to in this report are available from the GODAE OceanView website at https://www.godae-oceanview.org/outreach/meetings-workshops/task-team-meetings/joint-da-meap-tt-workshop/presentations/

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1. Workshop introduction

1.1 Motivation for a Joint Task Team Workshop

The Data Assimilation Task Team (DA-TT) was created to foster the development and evaluation of data assimilation systems relevant to GOV to support the coordination of the fundamental and challenging issues in the ocean forecasting process, of which data assimilation is a significant part.

The main goal of the Observing System Evaluation Task Team (OSEval-TT) under GODAE OceanView is the provision of ongoing demonstrations of the impacts of observations on global and regional ocean forecast and analysis systems.

The focus of this joint workshop was to review new methods and impacts of ocean data assimilation in its own right as well as in the context of observing system experiments which are relevant for GOV and the wider ocean community.

Further joint GOV TT meetings are anticipated, particular in conjunction with DA-TT.

1.2 Workshop objectives and format

The workshop was a 3-day event and focused on the current state-of-the-art in data assimilation and observing system evaluations. Particular focus was given to the overlap of both disciplines. The workshop included a series of discussions about progress made within the task teams (DA-TT and OSEval-TT) and options for future collaborations.

Before this workshop, the co-chairs of OSEval-TT are took over from Peter Oke and Gilles Larnicol to Elisabeth Remy and Yosuke Fujii. This workshop provided an essential opportunity to discuss modification of the strategy on the TT activities under the leadership of the new co-chairs.

This event brought together over 35 scientists and experts. Joint plenary sessions were used to discuss common issues of both TTs, while parallel sessions allowed each TT to address their own specific questions.

The workshop was organized as a combination of oral presentations, posters and discussions. Presentations were allocated as 15 min talks + 5 min Q&A. Poster presentations were displayed throughout the workshop. The workshop sessions were organized as shown in table 1:

	Descriptions
DA	Recent developments in global and regional ocean data assimilation systems
DA	Error covariance modelling
DA	Hybrid variational / ensemble data assimilation
OSEval	Requests and requirements of assessing present and future observation networks

OSEval	Method development: network design
Joint	Recent studies of observation impacts, sensitivity, and assessment of observation networks
Joint	Assimilation of new/novel observation types
Joint	Impact of physical data assimilation on unassimilated variables/ processes, e.g. vertical velocities, vertical mixing

***Table 1**: Abstracts (oral/poster) were invited to cover the above categories*

The workshop organisation was kindly supported by session chairs and rapporteurs, taking notes, coordinating the timing of presentations and the subsequent questions and answer sessions.

1.3 Host, attendance and contributions

The workshop was held at CMRE, La Spezia, Italy from the 11-13 October 2017, with DA-TT and OSEval-TT members-only meetings on the last day. CMRE provided very nice facilities for this international workshop allowing participants to discuss and exchange experiences in a friendly and functional environment next to the beautiful town of La Spezia and the Mediterranean Sea.

The provision of breaks and lunches as well as the workshop reception was kindly organised and sponsored by CMRE and ONRG. The workshop was well attended with over 35 registered participants, representing many countries, organisations and projects involved in data assimilation and observing system evaluations at regional and global level.

The 36 participants from 10 countries submitted 39 abstracts.

2. Science sessions

The workshop was organised by science sessions (*table 1*) in plenary. All sessions included presentations followed by discussions aimed at identifying the main areas of interest and options for collaboration and common activities.

2.1 Recent developments in global and regional ocean data assimilation systems

Chaired by Alexander Kurapov and YoungHo Kim, and Andy Moore and Anna Teruzzi

No	Title	Presenter	Affiliation
2.1.1	Three-dimensional Variational Ocean data assimilation using NCODA	Shastri Paturi	NOAA
2.1.2	Recent developments in global ocean data assimilation using NEMOVAR at the Met Office	Matt Martin	Met Office
2.1.3	The Global Ocean Forecasting System in the NMEFC and its Intercomparison with the GODAE OceanView IV-TT Class 4 metrics	Liying Wan	NMEFC
2.1.4	Comparing variational methods aware of model error evolution for long-term ocean applications with OceanVar	Andrea Storto	CMCC
2.1.5	Recent advances in the Mercator-Ocean reanalysis system: Application to an Arctic configuration	Charles-Emmanuel Testut	Mercator Ocean
2.1.6	The US West Coast Ocean Forecast System: skill assessment and data assimilation	Alexander Kurapov	Oregon State University
2.1.7	Development of the KIOST regional ocean prediction system : OPEM (Ocean Predictability Experiment for Marine environment)	YoungHo Kim	KIOST
2.1.8	Profile, altimeter and SST data assimilation in An operational shelf-seas model - Met Office FOAM-Shelf version 9	Rob King	Met Office
2.1.9	Data Assimilation of Argo profiles in Northwest Pacific Model	Yun Li	NMEFC
2.1.10	Modeling the circulation in the Kattegat and Skagerrak	Kai Håkon Christensen	Met.no

2.1.1 Presentation abstracts

Three-dimensional Variational Ocean data assimilation using NCODA

Shastri Paturi[1*], Zulema Garraffo[1], Jim Cummings[2], Ilya Rivin[1], Avichal Mehra[3], Hae-Cheol Kim[1], Arun Chawla[3]

[1]IMSG at NOAA/NWS/NCEP/EMC
[2] IMSG/SAIC at NOAA/NWS/NCEP/EMC
[3]NOAA/NWS/NCEP/EMC

Models and observations alone provide imperfect representations of the ocean state, but together they can offer improved estimates. Variational and sequential methods are among the most widely used in regional and global ocean systems.
A three-dimensional variational (3D VAR) data assimilation system, part of the Navy Coupled Ocean Data Assimilation (NCODA) system developed at Navy Research Laboratory (NRL), is used for assimilating Sea Surface Temperature (SST), Sea Surface Height (SSH) and other ocean data observations. The NCODA 3D VAR produces simultaneous analyses of temperature, salinity, and vector velocity.
The Hybrid Coordinate Ocean Model (HYCOM) was cycled with NCODA using a sequential incremental update cycle for the global ocean at 1/12^o grid resolution for February-March 2017 period. The performance of the assimilation was assessed by comparison with independent observations and with a free-run of HYCOM for the same time-period..
The NCODA 3D VAR system is currently in the testing phase with the likely intent of making it operational.

Recent developments in global ocean data assimilation using NEMOVAR at the Met Office

Matthew Martin, Robert King, Daniel Lea, Martin Price, Jonah Robert-Jones, Jennifer Waters, James While

Met Office, Exeter, United Kingdom

The Met Office runs a number of ocean analysis and forecasting systems that include data assimilation. These include the global Forecasting Ocean Assimilating Model (FOAM) system for short range ocean forecasts which is currently run at ¼ degree resolution. A new short-range global coupled forecasting system has also been implemented in the operational suite which is initialized using a weakly coupled DA (WCDA) approach in which the ocean component uses the same set-up as FOAM (but with a different time window). The ocean data assimilation system used in FOAM and the WCDA system is NEMOVAR which is developed jointly with CERFACS, ECMWF and INRIA. We run it in 3DVAR-FGAT mode assimilating sea surface temperature data from in situ and satellite platforms, sea level anomaly data from satellite altimeters, in situ temperature and salinity profile data, and satellite sea-ice concentration data.
A new version of the global FOAM system (v14) is currently being developed. This includes an update to the ocean model to NEMO version 3.6, including the use of a non-linear free-surface; an update to the sea-ice model CICE to include multi-layer thermodynamics; and improvements to the data assimilation. DA developments include an improved scheme for satellite SST bias correction; implementation of the Incremental Pressure Correction (IPC) scheme to improve assimilation at the equator; and improved estimates of the seasonally varying background error covariances. An overview of these developments will be presented.

Other on-going research in global ocean DA will also be presented. This includes developments in order to assimilate satellite salinity data from SMOS, Aquarius and SMAP; testing of the use of large-scale error covariance models based on 3D multivariate EOFs; implementation of data assimilation in a 1/12 degree global configuration; and preliminary work on generating ensembles for use in representing background error covariances.

The Global Ocean Forecasting System in the NMEFC and its Intercomparison with the GODAE OceanView IV-TT Class 4 metrics

Liying Wan, Yu Zhang, Huier Mo, Yinghao Qin
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The High Resolution Global Ocean Forecasting System in the National Marine Environmental Forecasting Center is introduced, including its development and improvement. This operational ocean forecasting system consists four parts, those are data collect system, data assimilation system, forecasting system and products release system. Besides the standard products, the conventional static visualization products and animation products are also provided. Based on the standard metrics recommended by the GODAE OceanView Intercomparison and Validation Task Team (IV-TT), the accuracy and performance of this system is evaluated. The analysis indicates that this operational ocean forecasting system with higher resolution improves the eddy simulation and forecasting skill at the global scale, especially in the western boundary current region. The strength and path of the Kuroshio in the NEMO system also shows better performance than that in the MOM4 system (old global operational forecasting system in NMEFC).

Comparing variational methods aware of model error evolution for long-term ocean applications with OceanVar

Andrea Storto

CMCC

Traditional formulations of three-dimensional variational (3DVAR) data assimilation scheme for oceanographic applications neglect the temporal evolution of model errors within and across assimilation temporal windows. Such a simplification appears limiting for long-term applications (e.g. reanalyses), or low-resolution configurations with long assimilation time windows. This work compares possible extensions of 3DVAR aiming at relaxing these assumptions. General formulations are proposed and implemented in order to extend the OceanVar data assimilation system into a simplified hybrid 4DVAR scheme. These two extensions (hybrid formulation of B and low-order 4DVAR) are compared to the standard 3DVAR scheme in terms of both accuracy gain and computational time increase, in order to draw sensible conclusions for practical applications.

Recent advances in the Mercator-Ocean reanalysis system:

Application to an Arctic configuration

Testut Charles-Emmanuel[1], Bricaud Clement[1], Chanut Jerome[1],
Garric Gilles[1], Ruggiero Giovanni [1] and Smith Greg[2]

[1]*Mercator-Océan, Toulouse, France*
[2]*Meteorological Research Division, EC, Dorval, Canada*

In the framework of the Copernicus EU (FP7 and Horizon 2020) funded projects , Mercator Ocean, the French operational oceanography centre, is in charge of the development and of the production of real time analysis and forecasts and reanalysis for the global ocean at the resolution of 1/12°. The operational systems are all based on the ocean (NEMO3.6) and sea ice model (LIM3) and the multivariate data assimilation system SAM2 (Système d'Assimilation Mercator V2). The assimilation method is a reduced order Kalman filter based on SEEK formulation with bias correction scheme for temperature and salinity and an Incremental Analysis Update.
The strong need of a realistic description of the mean state and variability of the rapid changing Arctic Ocean and its adjacent seas over the last decades motivated the use of the Canadian Arctic Ocean and Nordic seas configuration (CREG). This dedicated configuration at 1/4° developed by the Canadian research teams has been coupled to the multivariate data assimilation system SAM2. The objectives of this pan-Arctic platform is both to improve the sea ice assimilation method used in the Mercator Ocean and Canadian analysis and forecasting systems and to produce reanalysis over recent periods at lower numerical cost in order to prepare global higher resolution reanalysis at 1/12° . After a description of this Arctic reanalysis system, we present results on the abilities of this configuration to reproduce sea ice extent and volume interannual variability without assimilation and, secondly, the impact of assimilating sea ice data on the sea ice cover with hindcasts experiments.

Key words: data assimilation, reanalysis, sea ice model, sea ice concentration

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The US West Coast Ocean Forecast System: skill assessment and data assimilation

A. Kurapov

Oregon State University

The US West Coast Ocean Forecast System (WCOFS) has been under development at the Coast Survey Development Lab and the Joint Center for Satellite Data Assimilation, National Oceanic and Atmospheric Administration (CSDL and JCSDA, NOAA). The WCOFS dynamics are based on the Regional Ocean Modeling System (ROMS). The horizontal model resolution is close to 2 km. The model skill was assessed for a 6-year simulation without assimilation using observations of coastal sea level at tide gauges, surface velocities from a network of high-frequency (HF) radars, satellite SST, Argo temperature (T) and salinity (S) profiles, moored T and S time series, and glider T and S sections. In particular, we find that inclusion of evaporation and precipitation (E-P) has helped reduce positive salinity bias in the top 100 m over the shelf off Oregon, compared to the case without E-P. The WCOFS model with E-P, run without assimilation, has a smaller bias than the data assimilative 1/12th degree resolution global Navy HYCOM system that shows strong

negative subsurface model salinity bias over the Oregon shelf and slope. Data assimilation tests have been run using the ROMS 4DVAR component, assimilating JPSS VIIRS SST, alongtrack altimetry, and hourly HF radar surface velocity data. Our initial tests have demonstrated that assimilation of SSH and SST impacts surface transports (e.g., in the Santa Barbara Channel case study). Assimilation of HF radar data improves 3-day forecasts of the daily-averaged surface currents. Suggested discussion points include the initial condition error covariance appropriate for the coastal ocean, compatibility of the altimetry data and model SSH, poorly predictable high frequency surface currents due to the internal tide, etc.

Development of the KIOST regional ocean prediction system: OPEM (Ocean Predictability Experiment for Marine environment)

Young Ho Kim[1], Hyun Keun Jin[1], Gyun Do Pak[1]

KIOST (Korea Institute of Ocean Science and Technology)

The KIOST (Korea Institute of Ocean Science and Technology) has developed the regional ocean prediction system over the Northwestern Pacific called OPEM (Ocean Predictability Experiment for Marine environment). The base model is the GFDL MOM5 (Modular Ocean Model Version 5). The horizontal domain of the KIOST-OPEM is ranging from 98 to 170°E and from 5 to 65°N including the Northwestern Pacific and Korean marginal seas with 1/24° grid size both latitudinal and longitudinal. The vertical grid has 51 layers with varying grid size from 10 m at the surface to 367 m near the bottom. The KIOST-OPEM is forced by daily open boundary conditions from the Operational Mercator global ocean analysis and forecast data (Ferry et al, 2007) and meteorological surface forcing taken from the global weather model of the Korea Meteorological Agency. Also, climatological river discharges of 40 rivers taken from RivDIS have been injected into the ocean grid.

The Data Assimilation System of the KIOST (DASK; Kim et al., 2015) has been developed based on the Ensemble Optimal Interpolation (EnOI). The initial data of the KIOST-OPEM is generated by the DASK assimilating the satellite-borne Sea Surface Temperature (NCDC OISST) and hydrographic profiles taken from various sources. Since 1st of March, 2017, the KIOST-OPEM has been operated to forecast 10-days ocean circulation over the domain every Wednesday.

Various analyses have been performed to evaluate its prediction skill. Observed hydrographic profiles, SST as well as observed oceanic current, volume transports through the straits have been compared to the forecasted ones. We have also analyzed the impacts of Korean marginal seas on the circulation in the open ocean including the Northwestern Pacific through the observation sensitivity experiment.

Profile, altimeter and SST data assimilation in an operational shelf-seas model - Met Office FOAM-Shelf version 9

Robert R. King, James While, Matthew J. Martin, Daniel J. Lea, Benedicte Lemieux-Dudon, Jennifer Waters, Enda O'Dea

Met Office

The Forecasting Ocean Assimilation Model (FOAM) is the short-range operational ocean prediction system at the Met Office. Although many data-types are assimilated into deep ocean configurations of FOAM, until recently only SST observations were assimilated in operational shelf-seas configurations. This has been due to a number of issues including the complex vertical co-ordinate systems employed in coastal models, the mismatch between the cadence of observations and actual shelf dynamics, and the availability of operational altimeter products for the region of interest which retain the atmospheric and tidal signals generally removed for assimilation in global models.
Here we present our recent developments to the data assimilation component of FOAM-Shelf v9, our new operational forecasting system for the North-West European Shelf (AMM7). I will describe the implementation of assimilation of altimeter observations and in situ temperature/salinity profiles in addition to SST observations. This has resulted in a >25% reduction in the RMSE of the sub-surface T/S innovations, allowing us to correct known model biases and significantly improve the forecast initialisation. I will describe some of the remaining issues and look ahead to the assimilation developments planned for implementation of the 1.5km resolution AMM15.

Data Assimilation of Argo profiles in Northwest Pacific Model

Yun Li

National Marine Environmental Forecasting Center, China

Based on a novel estimation of background error covariances for assimilating Argo profiles, an oceanographic three-dimensional variational (3DVAR) data assimilation scheme was developed for the Northwest Pacific Ocean Model (NwPM), for potential use in operational predictions and maritime safety applications. Temperature and salinity data extracted from Argo profiles from January to December 2010were assimilated into the Northwest Pacific Model. The results show that the average daily temperature (salinity) Root Mean Square Error (RMSE) decreased from 0.99 °C (0.10 psu) to 0.62 °C (0.07 psu) in assimilation experiments throughout the Northwest Pacific, with represents a 37.2% (27.6%) reduction in the error. The temperature (salinity) RMSE decreased by ~0.60 °C (~0.05psu) for the upper 900m (1000 m). Sea level, temperature and salinity were in better agreement with in-situ and satellite datasets after data assimilation than before. In addition, aone-month experiment with daily analysis cycles and five-day forecasts explored the performance of the system in an operational configuration. The results highlighted the positive impact of the 3DVAR initialization at all forecast ranges compared to the non-assimilative experiment. Therefore, the 3DVAR scheme proposed here, coupled to ROMS, shows a good predictive performance and can be used as an assimilation scheme for operational forecasting.

Modeling the circulation in the Kattegat and Skagerrak

K.H. Christensen[1,2], A.K. Sperrevik[1] and G. Broström [1,3]

[1]*Norwegian Meteorological Institute, Oslo, Norway*
[2] *University of Oslo, Oslo, Norway*

[3] *University of Gothenburg, Gothenburg, Sweden*

The Kattegat and Skagerrak are two adjacent small ocean basins that form a transition zone between the Baltic Sea and the North Sea. Some of the most densely populated areas in Norway, Sweden and Denmark border the Kattegat and Skagerrak, and the ship traffic in the region is heavy. Outstanding environmental challenges include marine debris from local and remote sources that tend to accumulate along the Swedish coast, oil spills following groundings or ship collisions, and leaks from chemical munitions that were dumped in the ocean after WW2. Three different water masses meet in the Kattegat and Skagerrak: saline Atlantic water, brackish Baltic water, and North Sea water that is influenced by major rivers further south. The overall circulation is cyclonic with strong coastal currents, but the general patterns are often disrupted due to episodic wind events. We present result from a high resolution (1 km horizontal, 50 layers) reanalysis in which satellite SST, in-situ hydrography and HF radar currents were assimilated, commenting on the challenges associated with the open boundaries, the impact of the observations, and the model's ability to reproduce a realistic freshwater distribution.

2.2 Error covariance modelling

Chaired by Matt Martin and Hernan Arango

No	Title	Presenter	Affiliation
2.2.1	Assimilation using large scale EOF error covariances	Daniel Lea	Met Office

2.2.1 Presentation abstracts

Assimilation using large scale EOF error covariances

Daniel Lea and Matthew Martin

Met Office

In ocean data assimilation systems, generally isotropic and relatively small length scale error covariance structures are used. Due to the historically inhomogeneous distribution of ocean observations, these covariances lead to large areas of the ocean not being corrected. We describe an enhancement to a variational data assimilation system (NEMOVAR) to use Empirical Orthogonal Function (EOF) error covariances. We assess the system by assimilating subsampled modern day observations to emulate historical data distributions. The EOF DA method is shown to work efficiently in a 1/4 degree global configuration and does a good job of filling in the large data gaps.

The system can run in hybrid mode where the EOF error covariances are used in combination with standard climatological error covariances. Results show that this can give results better than either EOF or climatological error covariances alone.

2.2.2 Presentation summaries

The only talk in this session was from Daniel Lea (Met Office) who described progress in using large scale Empirical Orthogonal Function (EOF)-based error covariances in the NEMOVAR data assimilation scheme. The idea is to try to make better use of sparse observations by improving error covariance structures. This is done with NEMOVAR which is a 3DVar scheme where the existing, standard background error covariances are represented by multi length-scale Gaussian functions. The EOF-based approach was used to produce an objective analysis for each month of a year. Results were assessed by sub-sampling modern day observation coverage to represent 1953 and then comparing to the withheld data. The hybrid EOF/standard error covariances were better than either standard only or EOF only. Recent results in a cycling reanalysis framework were also positive. The minimisation needed many more iterations with the hybrid DA (120 vs 40) than the standard approach. Results seem to give similar innovation statistics to standard DA but might be promising to fill in gaps in historical analyses.

2.3 Hybrid variational/ensemble data assimilation

Chaired by Matt Martin and Hernan Arango, and by Dan Lea and Andrea Storto

No	Title	Presenter	Affiliation
2.3.1	A model for generating atmosphere forcing perturbations	Isabelle Mirouze	CMCC
2.3.2	A comparison of 4D-Var and an Ensemble Adjustment Kalman Filter applied to the California Current system	Andy Moore	USCS
2.3.3	On-going, real-time hybrid variational data assimilation at the CMRE	Paulo Oddo	CMRE
2.3.4	Ensemble-variational assimilation with NEMOVAR. Part 1: formulation, algorithms and illustrative examples	Anthony Weaver	CERFACS
2.3.5	Ensemble-variational assimilation with NEMOVAR. Part 2: experiments with the ECMWF system	Hao Zuo	ECMWF
2.3.6	Ensemble-variational data assimilation in the coastal ocean circulation model off Oregon-Washington (at the US West Coast)	Ivo Pasmans	Oregon State University

2.3.1 Presentation abstracts

A model for generating atmosphere forcing perturbations

Isabelle Mirouze and Andrea Storto

CMCC foundation, Bologna, Italy

Running an ensemble of reanalyses has several advantages despite its cost. For example, it allows the data assimilation scheme to account for an evolving background error covariance matrix. Ensembles of reanalyses are designed by generating perturbations for the observations, for some equations within the ocean model, and for the atmosphere forcing. A common way to generate the latter is to use the differences between two sets of atmosphere forcing. Although widely used, this method has some caveats. For example, the perturbations include in general a seasonal bias that might affect the reanalysis or the forecast. Moreover, the spatial structure of the generated error is not necessarily preserved.
To compensate these caveats, we have designed a statistical model for generating random perturbations for the atmosphere forcing. The training data used to construct this model is a ten-year set of differences between ERA-INTERIM (from ECMWF) and MERRA (from NASA) atmosphere forcing. The short wave radiation is considered as an independent variable and is generated through a normal distribution with a varying standard deviation depending on the time of the year and the location. The other variables, i.e. the long wav radiation, the zonal and meridional components of wind, the air temperature, the relative humidity, the precipitations and the snow, are constructed through relationships with each other and with the independent variable, in order to introduce some balance between the perturbations. A random component from a normal distribution is also added with a varying standard deviation depending on the time of the year and the location.
The distribution of the modelled perturbations has been compared to the distribution of a test set of differences between ERA-INTERIM and MERRA atmosphere forcing. The results of a Kolmogorov-Smirnov test show a good fit of the modelled perturbations in general, except for the precipitations and snow, for which more complex modelling might be required. An ensemble framework has been set up in order to compare the impact on the ensemble spread of these modelled perturbations to perturbations defined by differences between two sets of atmosphere forcing. Results from this comparison will be shown.

A comparison of 4D-Var and an Ensemble Adjustment Kalman Filter applied to the California Current system

Andrew Moore[1], Hernan Arango[2] and Christopher Edwards[1]

[1] *Department of Ocean Sciences, University of California Santa Cruz, USA*
[2] *Department of Marine and Coastal Sciences, Rutgers University, USA*

In addition to 4D-Var, the community version of ROMS now supports a Ensemble Kalman filter via an interface to the Data Assimilation Research Testbed (DART) developed at NCAR. The performance of ROMS configured for the California Current system using 4D-Var and an Ensemble Adjustment Kalman Filter (EAKF) will be presented. Results from identical twin

and real data experiments will be presented. This work represents a stepping stone to the development of a hybrid 4D-Var data assimilation system for ROMS.

On-going, real-time hybrid variational data assimilation at the CMRE

P. Oddo[*], S. Falchetti[*], and the EKOE[+] Team

[*]NATO-STO Centre for Maritime Research and Experimentation (CMRE), La Spezia, Italy.
[+]Environmental Knowledge and Operational Effectiveness.

Started on 14 Sep 2017 the "LOng term Gliders Mission for Environmental Characterisation" (LOGMEC-17) is a multi-scale, multi-platform sea trial aimed to improve current Marine Rapid Environmental Characterisation capabilities at CMRE. The investigated area is the Ligurian Sea. Two deep gliders rated to a maximum depth of 1000m operate continuously and, when possible, glider tracks are synchronised with the contemporaneous footprints of the satellite altimeters. Complementary oceanographic data are collected at different scales with various oceanographic instruments: shipborne CTD; undulating towed vehicle; ADCP; oceanographic moorings and surface drifters. Additional information is retrieved in real time mostly accounting for remote sensing data. LOGMEC17 will end on 14 Nov 2017. Gliders, satellite and CTD data are assimilated into a modelling suite to provide daily 7 days forecast. The limited area numerical ocean model in use is based on ROMS; it has a horizontal resolution of about 1.6 km while 32 sigma levels define the vertical space. The data are assimilated by mean of a hybrid variational method on a daily basis. The Background Error Covariance matrix is defined as a linear combination of a static-homogeneous-large scale and a space-time variable components (climatological and hybrid parts respectively). The climatological component is computed using 25 years re-analysis provided by CMEMS services for the Mediterranean Sea. The hybrid part is computed daily using the statistics of a medium-size (44) ensemble run. The 44 ensemble members have been generated combing different initial, lateral and surface boundary conditions. Four different large scale ocean state estimates (produced by the Hybrid Coordinate Ocean Model, the CMEMS global analysis and forecast product at 1/12° and at 1/4° horizontal resolution and the CMEMS Mediterranean Forecasting System respectively) are used to initialize and force at the lateral open boundary the ensemble members, while 11 atmospheric ensemble members extracted from the NCEP operational global ensemble provide the atmospheric parameters used in bulk formula providing interactively surface fluxes. Real-time operational results are presented and discussed.

Ensemble-variational assimilation with NEMOVAR
Part 1: formulation, algorithms and illustrative examples

Anthony Weaver[1], Marcin Chrust[2], Benjamin Ménétrier[3], Andrea Piacentini[1]

[1]CERFACS, Toulouse, France
[2]ECMWF, Reading, UK
[3]Meteo France, Toulouse, France

This is the first of a two-part presentation describing work by the NEMOVAR consortium (CERFACS, ECMWF Met Office, INRIA) to develop an ensemble-variational data assimilation (DA) system for the NEMO model. The first presentation will describe the basic design of the system and the different methods that have been developed for using ensemble information in defining a flow-dependent background error covariance matrix (**B**). The second presentation (Chrust *et. al*) will describe recent experiments using the ensemble DA system for global ocean analysis at ECMWF.
The NEMOVAR **B** operator is based on a general hybrid formulation. It consists of a weighted linear combination of 1) a modeled component (**B**mod), 2) a "large-scale" EOF component (**B**EOF), and 3) a localized sample covariance matrix of ensemble perturbations (**B**ens). **B**mod is itself formulated as a linear combination of covariance models in order to account for multiple correlation length scales. This talk will focus on the components **B**mod and **B**ens where ensemble information is used. The components of **B**mod are constructed using a standard decomposition involving a balance operator, standard deviation matrix and correlation operator. Ensemble perturbations are used to define the standard deviations and the diffusion tensor of the diffusion operator used to represent correlation functions. Filtering of the ensemble-estimated parameters is crucial since the small ensemble sizes used in practice lead to large sampling error. An objective algorithm has been implemented for this purpose and will be described. **B**ens also exploits the matrix decomposition used for **B**mod but instead defines the correlation matrix form the sample correlation of ensemble perturbations. Localization of this matrix is necessary to remove spurious correlations at long distances associated with sampling error. This is achieved using a Schur product with a specified localization matrix. An objective method is used to determine the localization scales and the relative weights between **B**mod and **B**ens. Different formulations of the localization matrix have been implemented and will be discussed.

Ensemble-variational assimilation with NEMOVAR
Part 2: experiments with the ECMWF system

Marcin Chrust[1], Anthony Weaver[2] and Hao Zuo[1]

[1] ECMWF, Reading, UK
[2] CERFACS, Toulouse, France

This is the second of a two-part presentation describing work by the NEMOVAR consortium (CERFACS, ECMWF, Met Office, INRIA) to develop ensemble-variational data assimilation system for the NEMO model.
This presentation will describe implementation of ensemble-variational data assimilation at ECMWF ocean system for the NEMO model. We will summarize the recent results obtained for the global ORCA 1o degree and ¼ o degree configurations when the flow dependency is introduced to the background error covariance through combining the parametrized and filtered ensemble based background error variances. The Desrozier diagnostics of the temperature background error standard deviations show good agreement with the specified values in the tropical regions, while the eddy active regions in extra-tropical regions are not captured by the latter. The ensemble spread of the temperature is present in these regions, but it remains largely under-dispersive in the tropics. The same diagnostics were calculated for the salinity background

error standard deviations revealing that the specified values are overestimated in our system. The ensemble spread of the salinity is more consistent geographically with the diagnosed values, but remains generally smaller. The ensemble spread of both the temperature and salinity collapses in the deep ocean. The hybrid background error variances are demonstrated to be beneficial for the analysis quality, but choosing the optimal hybridization weights and inflation factors remains challenging.

Ensemble-variational data assimilation in the coastal ocean circulation model off Oregon Washington (at the US West Coast)

Ivo Pasmans, Alexander Kurapov

Oregon State University, USA

4DVAR implementations for ocean forecasting traditionally proceed in a series of relatively short time windows and assume that the covariance of background errors in the initial conditions is static in time. Rapidly changing background conditions in the coastal ocean can challenge this assumption. For example, ocean shelf dynamics along the Oregon (OR) and Washington (WA) coasts in the US Pacific region are influenced in summer by the wind-driven upwelling and fresh water discharge from the Columbia River. The hydrographic conditions and the shape and location of the river plume change on 2-10 day time scales in conjunction with the winds. To capture this variability in the background error covariance, we have implemented ensemble-variational (E4DVAR) data assimilation in the OR-WA coastal ocean forecast system. In this system the initial conditions at the beginning of each 3-day window are corrected by combining the previous 3-day model forecast from a 2-km ROMS (Regional Ocean Modeling System) model with observations of GOES sea-surface temperatures, high-frequency radar surface current observations and satellite altimetry using 4DVAR. For the tangent linear and adjoint parts of the 4DVAR algorithm the system uses codes developed in-house. The background error covariance is estimated from a 50-member ensemble. The members of this ensemble are generated by running the system using different wind fields and perturbed observations. A newly developed localization method deploys a Monte Carlo approximation to rapidly estimate the background error covariance from a large ensemble of localized ensemble members. We have also used a parallel Arnoldi method to speed-up minimization of the cost-function. Results show that the new system provides better forecasts for the subsurface temperature and a more accurate representation of the temperature-salinity relationship. However, maintaining the fresh water content in the plume can be challenging. Near the Columbia River plume, the ensemble salinity variance and hence temperature-salinity covariance are large and the sea surface salinity (SSS) increment can be overly sensitive to errors in the sea-surface temperature. As a solution, the attempt has been made to constrain the averaged SSS in the area of the plume, assimilated as additional data.

2.3.2 Presentation summaries

Isabelle Mirouze (CMCC) presented work to improve the generation of atmospheric forcing perturbations to improve the ocean ensemble in the C-GLORS reanalysis system. The old scheme used ERA-Interim/NCEP-R2 differences on a 2 degree grid to generate the forcing perturbations.

The new scheme uses differences between ERA-Interim and the MERRA reanalysis on a 0.75 degree grid using daily fields. De-biasing the fields is important – this was done using a high-pass filter. Time-series were then modelled by a normal distribution with the standard deviation varying during the year. The short-wave radiation is treated as the independent variable and a regression model is used to model the long-wave radiation, winds, T2m, Q2m, precipitation and snow. The resulting model was tested by generating 3 years of perturbations for 2001 to 2003 and comparing the distribution with the training data. Most variables agreed well with the training data except for precipitation and snow (probably because they are not well-represented by a Gaussian). Experiments were carried out using the perturbed fluxes using the new and old methods (and with no perturbations). The new forcing perturbations increase the spread in temperature in the top 100m, with SST being much more spread especially in the summer and the yearly mean SST increments seem to be smaller than the control.

Andrew Moore (UCSC) presented a comparison of 4D-Var and an Ensemble Adjustment Kalman Filter (EAKF) applied to the California Current system. The EAKF is taken from the DART software with Gaspari-Cohn localisation, adaptive inflation and a First-Guess-at-Appropriate-Time (FGAT) approach. 50 ensemble members were used. The 4DVar was set up to use 2 outer loops, 7 inner loops, with 1, 2, 4 and 8 day time windows tested. This uses about the same CPU as the ensemble. The model is ROMS at 10km resolution and 42 sigma levels. Identical twin and real observation experiments were carried out with SST, gridded SSH, T/S profiles assimilated for the period 4-18th April 2003. In the idealised experiments, the EAKF performed best with 1-day time window while the 4DVar worked best with an 8-day time window. The EAKF seemed to perform worse for salinity than no DA. 4DVar worked better than the EAKF particularly at depth for both T and S. Rank histograms showed the initial ensemble didn't have enough spread for SST and SSH and this improved towards the end of the experiment. 8 day forecasts from each analysis showed that the 4DVar had lower RMS errors for all variables than the EAKF. This was also true in the experiments with real observations. The next step is to develop a hybrid DA scheme for ROMS.

Paul Oddo (CMRE) presented results from on-going, real-time hybrid variational data assimilation at the CMRE. The aim is to improve the assimilation using a limited area model where there are dense observations in a scheme which is not too computationally heavy. The experiment was making use of real-time data from the LOGMEC17 experiment (Long-term glider missions for Environmental Characterisation 2017). Observations included altimeter data, ADCPs, 2 gliders, 2 moorings, 3 ships, LIDAR, 16 drifters, CTD and ScanFish. The 3DVar scheme is based on OceanVar which uses EOFs in the vertical. The hybrid aspects of the DA are in the generation of the vertical EOFs which are from a combination of climatological and ensemble estimates. The model is ROMS at 1.6km resolution with 32 levels, 60 ensemble members with perturbed forcing (from NCEP) and boundary conditions (from MFS, Mercator and Met Office). Every day a 3-day analysis cycle is run with daily time-windows, and a 7-day forecast. There was an issue (probably with the MFS boundaries) a couple of weeks into the experiment so only 40 members continued after that. The error correlations from the ensemble had a lot of daily variability and were sometimes quite different to the climatological ones. The plan is to include drifters and ADCP into the assimilation chain and to do a nested higher resolution model to assimilate the ScanFish data.

Three talks were presented in the second part of session 2.3, all of them focusing on challenges and preliminary results on the estimation and use of hybrid ensemble-variational covariances, either in global or regional data assimilation systems.

Anthony Weaver presented the hybrid ensemble-variational formulation recently included in NEMOVAR, with the long-term goal of implementing a low-resolution ensemble for feeding high-

resolution deterministic analyses with flow-dependent background errors, and with re-centering of the ensemble. NEMOVAR implements a combination of different B matrices: two (or more) for multi-scale data assimilation (i.e. multiple horizontal correlation length-scales), one localized flow-dependent component, and one in EOF space (later detailed by D. Lea). Optimal spatial filtering of ensemble derived variances is performed according to Menetrier et al. (2015). However, Anthony showed how noisy can be the ensemble-derived correlation length scale, further to the high costs for on-line computation of the normalization factors of the horizontal operator.

Hao Zuo presented the ECMWF activities about ocean reanalysis activities (ORAS4, ORAS5 and ORAS6). ORAS6 is planned to bear information from ensemble data assimilation through inclusion flow-dependent covariances component. Perturbation is performed through perturbation of the observations representation error (e.g. perturbing horizontal and vertical location of observation in order to conserve the balance and stratification of the original profiles). The comparison between static and flow-dependent covariances suggests the need to inflate ensemble-derived covariances. Preliminary tests about hybrid B provide contrasting results (e.g. benefits in the North Atlantic, detrimental effect in the Tropics). It is likely that the under dispersive ensemble prevents significant and unambiguous improvements, and lead to deterioration for SSH

Ivo Pasmans presented on Hybrid ensemble-variational data assimilation which is performed within a coastal ocean circulation model. Static covariances lead reanalyses to span unrealistic T/S diagrams: this motivates the adoption of hybrid covariances, though running Ens4DVAR experiments. A lot of care was devoted to the optimal perturbation of the atmospheric forcing, on top of the random perturbation of observations. In particular, physically-based large-scale perturbations from ASCAT-derived EOFs were combined with random small-scale wind perturbations. The consequent use of hybrid covariances recovers the problems in the T/S diagrams. Improvements were also found in the verification against glider data.

2.4 Requests and requirements of assessing present and future observation networks

Chaired by Elisabeth Remy and Hao Zuo

No	Title	Presenter	Affiliation
2.4.1	Impact of wide-swath altimetry missions to ocean analysis and forecasting system in the Iberian-Biscay-Ireland (IBI) region	Antonio Bonaduce	Mercator Ocean
2.4.2	Current Status of Tropical Pacific Observing System 2020 project and the Request to the Ocean Data Assimilation Community	Yosuke Fujii	MRI-JMA
2.4.3	Coordinated observing system experiments to assess the impact of satellite sea surface to assess the impact of satellite sea surface	Elisabeth Remy	Mercator Ocean

2.4.4	Significant contribution of operational oceanography for an Integrated and More Sustainable Atlantic (AtlantOS) Ocean Observing	Florent Gasparin	Mercator Ocean

2.4.1 Presentation abstracts

Impact of wide-swath altimetry missions to ocean analysis and forecasting system in the Iberian-Biscay-Ireland (IBI) region

A. Bonaduce[1], M. Benkiran[1], E. Remy[1], P.Y. Le Traon[1], G. Garric[1]

[1]Mercator-Ocean, Toulouse, France

The impact of forthcoming wide-swath altimetry missions to the ocean analysis and forecasting system, based on NEMO (Nucleus for European Modelling of the Ocean) and implemented in the Iberian-Biscay-Ireland (IBI) region, was investigated by means of OSSEs (Observing System Simulation Experiments) performed during the period from January to December 2009. An eddy resolving OGCM (Ocean General Circulation Model) configuration, with horizontal resolution of 1/36° (~3 km), was adopted to obtain the "truth" run representing the "real" state of the ocean in an OSSE approach and which was used to simulate the satellite altimetry observations. The synthetic observations obtained were assimilated into a different eddy resolving OGCM, implemented in the IBI region with an horizontal resolution of 1/12° (~7 km), and the OSSEs performances were evaluated by comparing the results of each experiment with the "truth" data. OSSEs were carried out using different observing system configurations, considering both conventional altimeters (Jason2, Cryosat2 and Sentinel3) and a constellation of wide-swath altimeters, and investigating the sensitivity of the system to the instrumental error of wide-swath altimetry data. We found that wide-swath altimetry data significantly contribute to correctly represent "real" SSH (sea-surface height) dynamics in the IBI region and a reduction of the error up to the order of ~30 % in the analysis and ~20 % in the forecast is observed, with respect to the experiment which considers only conventional altimeters. Significant impacts were also observed on the capability of the system to resolve the mesoscale variability in the ocean, once wideswath data were considered in the analysis.

Current Status of Tropical Pacific Observing System 2020 project and the Request to the Ocean Data Assimilation Community

Yosuke Fujii[1], Arun Kumar[2]

[1]Meteorologicl Research Institute
[2]Natinal Center of Environmental Prediction

The deterioration of the tropical moored buoy array in the Pacific in 2012-2014 revealed a significant risk to ENSO predictions and associated services which essentially rely on ocean data assimilation techniques. Tropical Pacific Observing System 2020 project (TPOS2020) was initiated to mitigate this risk as well as to accelerate advances in the understanding and prediction of

tropical Pacific variability. TPOS2020 issued the first report (http://tpos2020.org/first-report/) in December 2016. In the report, the project recommended to retain all existing and historical near-equatorial moorings at 2ºS, 0º, 2ºN, and to extend some meridional mooring lines to cross the ITCZ and SPCZ regimes but to reduce priority for other meridional mooring lines. Doubling of Argo profiles in the 10ºS-10ºN band was also recommend in order to compensate the reduction of tropical moorings.

TPOS2020 would like the ocean data assimilation community to assess the effectiveness of the recommended backbone design through a coordinated program. Use of a combination of Observing System Experiments (OSEs), Observing System Simulation Experiments (OSSEs), and possibly alternative techniques such as Degree of Freedom System and Forecast System Observation Impact are proposed for the assessments. The project also recommended to build up an effort to monitor the influence of observation data from ocean observing systems routinely in near-real time. For this purpose, regular sharing and comparison of ocean data assimilation products, including ocean fields, forcing data, analysis increments and fits to observations was proposed. The model and data assimilation task team of TPOS2020 is now seeking the way to realize these recommendations. The GODAE Ocean View community, particularly the observation system evaluation task team, is strongly expected to contribute to these efforts through collaboration with TPOS2020.

Coordinated observing system experiments to assess the impact of satellite sea surface salinity data

Matthew Martin[1], Robert King[1], **Elisabeth Remy[3]**, Benoit Tranchant[2], Kirsten Wilmer-Becker[1]

[1] Met Office, Exeter, United Kingdom
[2] CLS, Toulouse, France
[3] Mercator Ocean, Toulouse, France

An ESA project (SMOS-Nino15) was set up in October 2016 aimed at assessing the impact of satellite sea surface salinity (SSS) data assimilation on analyses/forecasts of the 2015/16 El Nino event. To improve the uptake and use of SSS data for ocean forecasting this project is designing and performing Observing System Experiments (OSEs) of SSS using ocean modelling and assimilation systems. The systems used in the project are the Met Office FOAM and Mercator Ocean systems. Work is going on to develop assimilation of SSS data in these systems, with particular attention on observation bias correction. Coordinated experiments are planned so that assessments of the impact of the satellite SSS data can be made from more than one system. It is planned to write an Observing System Impact statement as a contribution to the GOV OSEVal-TT based on the outcomes. The project will be described and the latest results shown.

Significant contribution of operational oceanography for an Integrated and More Sustainable Atlantic Ocean Observing (AtlantOS)

Florent Gasparin, Elisabeth Remy, Mathieu Hamon, Pierre-Yves Le Traon

Mercator-Ocean, Ramonville, France

During the last two decades, the development of observing system practices and new technologies, associated with operational oceanography advances, have revolutionized oceanography. The AtlantOS H2020 project was set up to deliver an advance framework for the development of an integrated Atlantic Ocean Observing System. It aims at achieving a transition from a loosely coordinated set of existing ocean observing activities, towards a sustainable and fit-for-purpose integrated ocean observing system for the Atlantic Ocean. In that context, European forecasting centers are performing numerical experiments, called "Observing System Simulated Experiments", to provide quantitative assessment of current and future ocean observing systems on global monitoring and forecasting systems. Mercator-ocean plays a key role in this multi-approaches exercise (i) by providing ocean state estimations from the high resolution operational system at 1/12°, which is considered as representing the true ocean ("Nature Run") in all joint experiments (pseudo observations, including future extensions, will be extracted from this Nature Run and then assimilated to estimate their potential impact in an operational system), (ii) by performing several numerical experiments for current and future ocean *in situ* networks (e.g., Argo, drifters), and (iii) by assessing impacts based on usual statistics, but also focused on particular phenomena. The present work exploits the capabilities of operational systems to improve the description of the physical state of the global ocean, and provides comprehensive information for the development of an integrated Atlantic Ocean Observing System.

2.4.2 Presentation summaries

Antonio Bonaduce from Mercator Ocean discussed the Impact of wide-swath altimetry missions to ocean analysis and forecasting system in the Iberian-Biscay-Ireland (IBI) region. Satellite altimeter data is the key to resolve the meso-scale eddies in the ocean. A series of OSSEs have been carried out when assimilating simulated wide-swath observation from a nature run. Results suggest that adding wide-swath altimeter data in addition to the conventional nadir altimeter data can improve coherence for both SSH and ocean surface current. It also improves the currents at 100m by reduce error variance up to 45% when adding 2 wide swath data. In addition, it is demonstrated that wide swath data significantly contribute to reduce the errors in the ocean forecasts (20%- 30%).

Yosuke Fujii from MRI-JMA discussed Tropical Pacific Observing System (TPOS) 2020 project and the connection to ocean data assimilation community. He highlighted the TAO array crisis in 2012-2014 and explained the TPOS project with some details. Inter-comparison shows that lack of TPOS results in very different ocean states between different ORAs products (JMA, ECMWF, NCEP …). Yosuke also suggested that TPOS2020 would benefit from strong connection with GOV community, by doing inter-comparison and assessment of proposed TPOS array in the different systems (model, DA method, initial conditions, obs data set..).

Elisabeth Remy from Mercator Ocean showed results from investigating the impact of assimilating satellite Sea Surface Salinity (SSS) data on the 2015/2016 El-Nino event. SSS data from ESA SMOS mission was tested with both UKMO and Mercator Ocean operational ocean forecasting system using OSEs. Assimilation of SMOS data reduced the SSS RMSE and subsurface fit-to-obs errors. It also leads to less increment in SLA and dynamic height. In short SMOS SSS show positive impact on forecasting system if bias correction is carefully applied.

Florent Gasparin from Mercator Ocean discussed significant contribution of operational oceanography for an integrated and more sustainable Atlantic Ocean Observing (AtlantOS), using OSSEs based on multi-models/multi-system approaches. Synthetic observations as produced from a nature run were assimilated in a series of OSSEs at CLS, CMCC, UKMO and Mercator Ocean using different systems. Results suggest that global in-situ observations are critical for ocean monitoring and forecasting system and futures in-situ observations will fulfil the vision of comprehensive global ocean observation through the scale-matching improvement of in-situ and remote observations. However, results can be very model-dependent, multi-model approach is required for robustness of results.

2.5 Recent studies of observation impacts, sensitivity, and assessments of observation networks

Chaired by Yosuke Fujii and Anthony Weaver

No	Title	Presenter	Affiliation
2.5.1	4D-Var Observation Impacts and Sensitivities in the Mid-Atlantic Bight	Hernan Arango	Rutgers University
2.5.2	Quantitative Impact Assessment of Ocean Observations on Tropical Cyclone Prediction and Ocean Monitoring: Results from a New, Rigorously-Validated OSE-OSSE System	George Halliwell	NOAA
2.5.3	Influence of the Deep NINJA float data on a deep ocean state estimation	Shuhei Masuda	JAMSTEC
2.5.4	Reduced-rank array modes of the California Current ocean observing system	Andy Moore	UCSC
2.5.5	Impact of using an improved Mean Dynamic Topography on the Mercator-Ocean analysis and forecasts	Marie-Helene Rio	CLS
2.5.6	Use of in-situ observations in ECMWF's Ocean (Re)analysis system	Hao Zuo	ECMWF

2.5.1 Presentation abstracts

4D-Var Observation Impacts and Sensitivities in the Mid-Atlantic Bight

Hernan G. Arango[1], Andrew Moore[2], John Wilkin[1], and Julia Levin[1]

[1]DMCS, Rutgers University, New Brunswick, NJ, USA
[2]University of California Santa Cruz, Santa Cruz, CA, USA

The observations impacts and sensitivities of the observing system from 4D-Var circulation estimates in the Mid-Atlantic Bight and Gulf of Maine have been computed for the period 2014-2015. Two observation impact/sensitivity metrics across the 200m-isobath in the target site next to the Ocean Observatories Initiative (OOI) Pioneer Coastal Array have been considered: cross-shelf heat transport and cross-shelf volume transport. The observation impacts on the across-shelf heat transport show that the SSH observations (Jason-2, AltiKa, Cryosat) on and off the continental shelf and Gulf of Maine are important and contribute around 5-30 W per datum. The SST observations' impacts (AVHRR, GOES, AMSR2) along the shelf-break down stream of the target site contribute around 5-25 W per datum. However, *in situ* temperature and salinity observations (Buoys, Argo, XBT, Drifters, Gliders) in the vicinity of the target site exert considerable influence on the cross-shelf heat transport (~1000 W per datum). The same is true for remote *in situ* observations. The observation sensitivities computed for the adjoint of the 4D-Var analysis $(4D\text{-}Var)^T$ show that the cross-shelf volume transport is most sensitive to changes of the HF Radar observations between Cape Cod and Chesapeake Bay. This metric can be used to estimate the change in the analyzed cross-shelf transport if individual HF radar observations were unavailable or not assimilated. It also can be used to determine antennae redundancy, to estimate the impact from equipment failures (e.g. due to storm damage), or to aid the design of more optimal sampling.

Quantitative Impact Assessment of Ocean Observations on Tropical Cyclone Prediction and Ocean Monitoring: Results from a New, Rigorously-Validated OSE-OSSE System

G. R. Halliwell, Jr.[1], M. Mehari[1,2], V. H. Kourafalou[3], R. Atlas[4], H. Kang[3], M. Le Hénaff[1,2], Y.S. Androulidakis[3]

[1]NOAA/AOML/PhOD, Miami, Florida, USA
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[3]RSMAS, University of Miami, Miami, Florida, USA
[4]NOAA/AOML, Miami Florida, USA

The ocean OSSE system developed by the Joint Ocean Modelling and OSSE Center (OMOC) of NOAA/AOML, CIMAS, and RSMAS, University of Miami is designed and rigorously validated to ensure that credible observing system impact assessments are obtained. The system was initially used to perform OSEs and OSSEs in the Gulf of Mexico. It has since been extended to a North Atlantic domain, and is presently being expanded to the global ocean. Example results are presented to illustrate system capabilities. An OSE was performed in the North Atlantic domain to document the impact of ocean observations on Hurricane Gonzalo (2014) intensity forecasts in the North Atlantic. When a coupled ocean-atmosphere prediction system was initialized by ocean analyses from an unconstrained simulation, the predicted storm was too weak. When initialized by an analysis that assimilated all available ocean observations, the predicted intensity error was substantially corrected. Assimilation of observations corrected the upper-ocean heat content ahead of the storm, enabling the coupled model to more-accurately predict the heat flux from ocean to atmosphere that fuels the storm. OSSEs were also performed for Hurricane Gonzalo to quantitatively assess the positive impact of conducting rapid-response airborne ocean profile surveys ahead of storms. These OSSE assessments are based on error reduction in ocean analyses used for initialization in comparison to the truth as represented by the Nature Run. Collectively, the OSE-OSSE results demonstrate that ocean observations will play an important future role toward improving intensity forecasts of tropical cyclones throughout the world. The initial effort

toward expanding the system to the global ocean involves performing OSEs to quantitatively assess the impact of observing systems on the ability to monitor important indices of seasonal to interannual ocean variability using global ocean analysis systems. Evaluation is based on error reduction with respect to long-term observations of ocean variability indices such as the Atlantic Meridional Overturning Circulation transport and associated meridional heat flux. Initial global experiments are now underway. The design of, and preliminary results from, these global OSEs will be summarized at the meeting.

Influence of the Deep NINJA float data on a deep ocean state estimation

Shuhei Masuda, Satoshi Osafune, Tadashi Hemmi, Nozomi Sugiura and Toshimasa Doi

Research and Development Center for Global Change,
Japan Agency for Marine-Earth Science and Technology

The importance of deep ocean observations has now been recognized in conjunction with the revealed deep ocean changes like a global bottom-water warming. Within this background, Argo-type floats are proposed for a sustainable global deep ocean monitoring. At present, a small number of deep floats have been deployed in the world. Here we show a new approach to utilize on-going float data to improve a deep ocean state estimation. The influence of this new observation is examined by a twin experiment on the basis of 4D-VAR adjoint ocean data synthesis system.

Reduced-Rank Array Modes of the California Current Ocean Observing System

Andrew Moore[1], Hernan Arango[2] and Christopher Edwards[1]

[1] Department of Ocean Sciences, University of California Santa Cruz, USA
[2] Department of Marine and Coastal Sciences, Rutgers University, USA

A reduced-rank formulation of the array modes of an observing system is presented that spans the sub-space explored by a 4D-Var data assimilation system. Like the array modes, the reduced-rank array modes depend only on the observation locations and are independent of the measurement values. The array modes are closely related to the degrees of freedom of the observing system, and provide a quantitative measure of the degree to which the observations span the model control space, thus providing information about the efficacy of the observing system. They also yield a useful stopping criteria for the iterative 4D-Var procedure. These ideas are explored using a 31 year sequence of historical 4D-Var analyses of the California Current system using ROMS.

Impact of using an improved Mean Dynamic Topography on the Mercator-Ocean analysis and forecasts

M-H Rio[1], M. Hamon[2], E. Remy[2], G. Dibarboure[3], N. Picot[3]

[1]CLS
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[3]CNES

The Mean Dynamic Topography (MDT) is a key reference surface for the optimal assimilation of altimeter Sea Level Anomalies (SLA) into ocean models. In the recent years, thanks to the GOCE mission, whose measurements have allowed to derive the Earth marine geoid at 100km resolution with unprecedented accuracy (centimetre level), and to the availability of long-term in-situ measurements of the ocean surface velocities and dynamic heights, new Mean Dynamic Topographies based on observations only have been calculated. A review of the presently available observation-based MDTs is done. Then we present the results of a study run at Mercator-Ocean to investigate the impact of using accurate observed MDT solutions on the model analysis and forecasts. Two experiments with SLA assimilation and two different MDT solutions have been compared. It is shown that the MDT changes have impact not only on the sea surface height estimations but also on the 3D temperature and salinity fields. Also, the use of an improved MDT leads to a better forecasting skill of the system.

Use of in-situ observations in ECMWF's Ocean (Re)analysis system

H. Zuo, M. A. Balmaseda, C. Robert

ECMWF, UK

Temperature and salinity observations from Argo profiling buoys and other in-situ types are actively assimilated in the ECMWF's Ocean ReAnalysis System (ORAS), for the purpose of studying of climate signals and providing ocean and sea ice initial conditions for the ECMWF's Coupled Forecasting System. It is demonstrated (Zuo et al., 2015) that the changing Ocean Observing System, e.g. introducing Argo, can has a significant impact on the reconstruction of historical ocean states. e.g. ocean heat content, using ORAS. It also affects climate signals derived from ocean reanalysis products. Observation System Experiments have been carried out at ECMWF in order to assess temporal and spatial coverage of different ocean observation types and its impact on reconstruction of historical climate changes using ECMWF's ORAS, and in predicting extended-range weather forecasts using ECMWF's seasonal forecasting system. Assimilation of Argo profiles with subsurface information provides vital constrains in ocean states, and has a strong impact on the Atlantic Meridional Overturning Circulation (AMOC).

2.5.2 Presentation summaries

Hernan Arango from Rutgers University presented sensitivity of the cross-shelf volume transport to assimilated observation data in the ROMS 4DVAR system applied to the region including Mid-Atlantic Bight and the Gulf of Maine. Hernan indicated that SSH observations on and off Gulf of Maine are important and contribute around 15-30^{o}W, that SST observations impacts along the shelf-break down stream of the target site but in situ temperature and salinity observations in the vicinity of the target site exert considerable influence on the cross heat transport, and that

the cross shelf volume transport is most sensitive to changes of the HF Radar observations between Cape Cod and Chesapeake Bay. Hernan highlighted that observation sensitivity is useful for monitoring of the influence of each observing datum/platform in the analysis and forecasts. Hernan also introduced ERDDAP, the web visualization tool of model fields and assimilated observation data in NOAA.

George Halliwell from NOAA introduced the new ocean OSE-OSSE system developed by the Joint AOML/CIMAS/RSMAS Ocean Modelling and OSSE Center (OMOC). George demonstrated that assimilating satellite altimetry, Argo floats, and SST data in the ocean data assimilation system reduced errors on the Tropical Cyclone Heat Potential (THCP) and improve intensity forecasts for Hurricane Gonzalo. George showed the result of OSSE which indicated that additional airborne observations (AXBT and AXCTD) improve temperature, SSH and THCP fields. George also introduced Initial development of a global OSE-OSSE system to assess the impacts of global ocean observing systems on the capacity to monitor indicators of climate variability using ocean analysis-forecast system.

Shuhei Masuda from JAMSTEC introduced a research on use of special profiling floats, DeepNINJA which are capable to observe temperature and salinity at the level of 4000 dbar in maximum. JAMSTEC has deployed DeepNINJA in the western North Pacific and the Southern Ocean. They tried assimilating the DeepNINJA data in their 4DVAR ocean state estimation system, ESTOC. They correct the bias of DeepNINJA data by using EN4 climatology as a pre-process before data assimilation. Shuhei indicated assimilating the data made some difference in the estimated ocean fields by ESTOC.

Andy Moore from UCSC discussed utility of reduced rank array modes (RAMs) which can be calculated by search direction and gradient vectors generated in a minimization process by conjugate gradient method. The RAMS identify the sub-space informed by the observations during 4DVAR. Andy indicated that use of high-order array modes whose eigen values are smaller than 1/100 of the largest eigen value causes overfitting to the observations in 4DVAR analysis. Andy also indicated that the array modes must effectively explain the dominant EOF modes of the background error covariance matrix in order to reduce errors in the background fields in 4DVAR analysis.

Marie-Helene Rio from CLS introduced a synthetic method of generating the Mean Dynamic Topography (MDT) field. In the method, small-scale features of the MDT are estimated by combining altimetric anomalies and in-situ data, and large-to-medium-scale features of a geoid model estimated from satellite gravity measurements are merged to them. Marie-Helene then showed the result of OSEs that demonstrated impacts of updating the MDT data from CNES-CLS09, which is based on the GRACE geoid, to CNES-CLS13, which is based on the GOCE geoid and updated in-situ dataset, in the ocean forecasting system of Mercator-Ocean. She highlighted that using better MDT improved not only sea surface height but also the 3D thermohaline structure, and improvement of forecast skill was also confirmed. They are currently working on an improved version of the MDT that will be available in mid 2018.

Hao Zuo from ECMWF introduced the new ocean reanalysis dataset in ECMWF, ORAS5. ORAS5 is generated by the current operational ocean analysis system, OCEAN5, which adopts 3DVAR-FGAT and has 0.25^{o} resolution. A bias correction scheme is also applied in the system and corrects spurious climate signals introduced by changing global ocean observing systems, especially with the introduction of Argo floats. Results of OSEs showed that near coast observations and observations placed in strategically important areas (e.g. Barents Sea) can have

a large impact on the ocean analysis state and that Argo plays an important role on reproducing reliable signals by correcting model errors in reanalysis.

2.6 Method development: network design

Chaired by Paolo Oddo and Andy Moore

No	Title	Presenter	Affiliation
2.6.1	Stochastic Coastal/Regional Uncertainty Modelling and Array Design: insights from ensemble sensitivity/consistency experiments	Pierre De Mey	LEGOS
2.6.2	Recent Development of Ocean Data Assimilation Systems and Recent Observing System Evaluation Studies in JMA/MRI	Yosuke Fujii	MRI-JMA

2.6.1 Presentation abstracts

Stochastic Coastal/Regional Uncertainty Modelling and Array Design: insights from ensemble sensitivity/consistency experiments

Vassilios Vervatis[1], Pierre De Mey[2], Marios Kailas[1], Nadia Ayoub[2], Guillaume Charria and Sarantis Sofianos[1]

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[2] *Laboratoire d'Etudes en Géophysique et Océanographie Spatiales, CNRS, France*

Ocean model uncertainties arise on a range of spatiotemporal scales from the formulation of forecast models themselves and erroneous surface-lateral boundary forcings. In the past two decades, successful applications of advanced ocean data assimilation methods have led to an increased interest in their estimation.

This study is based on (1) a Copernicus marine research project entitled Stochastic Coastal/Regional Uncertainty Modelling (SCRUM), led by the University of Athens and LEGOS/CNRS research teams, and (2) on previous work on Array Modes and stochastic array design in the LEGOS team.

The SCRUM project is meant to contribute to the evolution of advanced data assimilation and ensemble forecasting operational capabilities to better serve coastal downscaling, aiming at: a) the improvement and validation of Ensemble-based error estimates in coastal regions, b) ensemble assimilation methods involving physical-biogeochemical variables.

Our stochastic implementation is based on autoregressive processes for ocean and ecosystem model uncertainties, performing ensembles in a high-resolution Bay of Biscay configuration. Two

methodologies, i.e. rank histograms and array modes, are introduced to validate the consistency of model errors with respect to CMEMS data and arrays.

The underlying theory as well as recent examples in the framework of regional/coastal ocean circulation will be presented.

Recent Development of Ocean Data Assimilation Systems and Recent Observing System Evaluation Studies in JMA/MRI

Yosuke Fujii, Norihisa Usui, Nariaki Hirose, Takahiro Toyoda, Hiroyuki Tsujino

Meteorological Research Institute/ Japan Meteorological Agency

JMA/MRI is now developing eddy-permitting (resolution: 0.25º) global ocean and 2 km-mesh near-Japan ocean data assimilation systems using a 4 dimensional variational (4DVAR) method and a simplified inner loop-outer loop approach. We use a global ocean 4DVAR system with a resolution of 1º × 0.5º (zonal × meridional) and a North Pacific Ocean 4DVAR system with a resolution of 0.1º around Japan in order to correct the outer models which have higher resolutions through an approach similar to Incremental Analysis Updates. We have confirmed that this method successfully constrain the 2 km-mesh model and contributes to improve representation of sea level variation at the costal positions of tide gages.

Recent observing system evaluation studies are also introduced in this presentation. We have demonstrated positive impacts of using sea level data from multiple satellites in a western North Pacific Ocean 4DVAR System. We also evaluated whether current density of Argo floats is enough for reproducing mesoscale eddy activities using the horizontal correlation scales of sea level variation calculated from historical satellite altimetry data. We are also developing a method to evaluate an analysis error covariance matrix using ensemble 4DVAR calculation using vectors of search directions and gradients of the cost function generated in a quasi-Newton minimizing scheme.

2.7 Assimilation of new/ novel observations types

Chaired by Paolo Oddo and Andy Moore

No	Title	Presenter	Affiliation
2.7.1	A multi-data variational assimilation scheme of BGC-Argo and satellite data into the CMEMS Mediterranean biogeochemical model	Anna Teruzzi	OGS

2.7.1 Presentation abstracts

A multi-data variational assimilation scheme of BGC-Argo and satellite data into the CMEMS

Mediterranean biogeochemical model

Teruzzi A.[1], Cossarini G.[1], Mariotti L.[1], Salon S.[1], D'Ortenzio F.[2], Mignot A.[2]

[1] *Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS), Trieste, Italy*
[2] *Laboratoire d'Océanographie de Villefranche-sur-Mer (LOV), Villefranche-sur-Mer, France*

The Mediterranean Sea is a very promising site to develop and test a multi-data biogeochemical assimilation scheme, since the BGC-Argo network is one of the densest of the global ocean and a consolidate data assimilation framework (3DVARBIO) of satellite remote chlorophyll observations already exists within the OGSTM-BFM biogeochemical model.

The 3DVARBIO assimilation scheme has been upgraded to use BGC-Argo float chlorophyll data by introducing updated versions of vertical-varying non-homogeneous horizontal covariance operator, EOFs decomposition of the vertical covariance operator and observation error parameterizations.

However, when dealing with assimilation of multi-data sources, several issues have to be considered: the data consistency, the integration of the different spatial scales of the observation errors, and the optimization of the frequency of the assimilation-forecast cycles with respect to the time and space coverage of the data.

In our work, preliminary results of the application of different strategies will be shown: a priori data consistency versus data hierarchy procedures, use of different horizontal covariance length scales for each data type, use of tuning procedures for the observation errors, multiple times versus synoptic assimilation cycles.

The sensitivity of the multi-data assimilation to the different factors provides insights to the effectiveness of the assimilation in terms of persistency, extension and intensity of the chlorophyll field modifications, and of impacts to other biogeochemical not-assimilated variables and to modeled ecosystem processes (such us deep chlorophyll maximum location, surface phytoplankton blooms during winter mixing, and primary production estimates).

2.8 Impact of physical data assimilation on unassimilated variables /processes, e.g. vertical velocities, vertical mixing

Chaired by Paolo Oddo and Andy Moore

No	Title	Presenter	Affiliation
2.8.1	Vertical velocities within eddies (movie download, large file)	Peter Oke (recorded)	CSIRO

2.8.1 Presentation abstracts

Vertical velocities within eddies

Gabi Pilo, Tatiana Rykova, Peter Oke

CSIRO

Vertical motions within eddies play an important role in the exchange of properties and energy between the upper ocean and the ocean interior. Here, we analyse the submesoscale circulation within eddies, and identify alternating upward and downward cells in anticyclonic eddies in the East Australian Current region using a global eddy resolving model. For some cases, the cells explain over 50% of the variance of vertical velocity within these eddies. We show that the upward and downward cells vary together with eddy distortion – the change in eddy shape. In anticyclonic eddies in the Southern Hemisphere, an inward distortion is associated with upward velocities and an outward distortion is associated with downward velocities. Through analysis of the latest Bluelink Reanalysis, we investigate how data assimilation impacts the submesoscale circulation within eddies.

2.9 Data Assimilation Task Team meeting

A DA-TT meeting was held after the main plenary sessions (in parallel to the OSEVal-TT meeting). Various issues were discussed by the DA-TT members:

- In terms of the joint workshop, the members were happy with the meeting. They emphasised the need to keep the meeting atmosphere relaxed and fluid to allow people plenty of time for discussion, and to keep a reasonable amount of time for presentations. They also wanted to encourage speakers at future workshops to feel able to discuss issues and problems, not just the positive results.
- There was a discussion about the DA-TT work plan items and how to get more input from the members. It was decided to write up the current status of the idealised observations intercomparison project as a way of taking stock and seeing whether further inputs are necessary.
- The membership of the DA-TT was reviewed. It was decided to contact inactive members to see whether they felt able to contribute in the future, and if not they would be removed from the list of members.
- The next DA-TT meeting was also discussed, including the possibility of holding it in conjunction with the COSS-TT. This was agreed to be a good idea, if a suitable common date could be found which was not too close to the GOV Symposium.

2.10 Observing System Evaluation Task Team meeting

A OSEval-TT meeting was held after the main plenary sessions (in parallel to the DA-TT meeting). Discussions in the meeting were mainly focused on what should be done within the OSEval-TT on short term basis and to define the way we could work.

- In order to be able to efficiently exchange information and work together, we will deal with updating the member list and setting up the mailing list.
- Participants of the meeting agreed that sharing information on the ongoing OSEval related activities in each centers will already be valuable to enhance discussions on outcomes and difficulties. Therefore, we agreed to update the webpages of the TT (https://www.godae-oceanview.org/science/task-teams/observing-system-evaluation-tt-oseval-tt/), including bibliography, and to create additional ones if necessary. We also agreed to strengthen communication among TT members via internet (e.g., mailing list, wiki, SNS).
- Yosuke Fujii, one of the co-chair of the TT, proposed a common action to support the TPOS2020 project (http://tpos2020.org/) by writing OIS for the tropical moorings. (Example of OIS can be seen at https://www.godae.org/~godae-data/GOVST-IV/presentations/TT-day/2.OSE-E1AD2d01.pdf.) OIS can also be produced by each groups when performing OSEval experiments for other networks. OIS "format" can be revised/discussed.
- The context of performing OSEval can differ between the GODAE centers. The primary purpose for most of the groups is to improve the DA system.
- Mercator Ocean and UK MetOffice are currently involved in supported projects based on Observing System Evaluation (e.g, AtlantOS, SMOS-Nino2015). These projects are considered to be a part of the OSEval TT activity. It is favourable to make it possible that international TT members can contribute the activity.
- There is a common interest in not only being aware of the different ongoing studies but also sharing tools and data sets. This includes "up to date" data sets (like SMOS,…), but also simulated observations and the associated Nature Run. The TT may need to find a "place" to share large data sets.
- The assimilation of satellite SSS and large swath altimeter data (SWOT) are one of the common interests through the different groups.
- TT meetings on annual basis could be difficult to follow. The GOV final symposium was planned to be held in November 2018 (This symposium is currently moved to May 2019.) The proposition was to organize the next TT meeting in spring 2019. This has to be discussed further (The date should be changed to later due to the change of the date of GOV final symposium). Also, having a joint meeting is favourable.

3. Conclusion

The joint workshop of the GOV Data Assimilation Task Team (DA-TT) and the Observing System Evaluation Task Team (OSEval-TT) has given the participating experts a unique opportunity to exchange, interact and share expertise on the closely related fields of DA and OSEs. The result is a strengthening of the relationship between the TTs, an increased interest in pursuing common activities and the development of strategies to engage and support international research projects, e.g. AtlantOS, TPOS2020, etc. The value of the GOV TTs is reflected in their international representation and inclusive approach to research collaborations, based on practical activities. This workshop also provided the opportunity to discuss the strategy of managing OSEval-TT under the new leadership, which will contribute to set up TT activities effective to strengthen the linkage between ocean forecasting centers and observing agencies.

GOV, through its science team (GOVST), is providing leadership in consolidating and improving R&D for global & regional ocean analysis and forecasting systems and specifically fosters the development of new ocean monitoring, modelling and data assimilation systems. It promotes access to data and information products and strongly emphasizes the demonstration of the value of the ocean observing system. The GOV strategic plan provides an overview of the current and future plans and defines the focus of the GOV task teams, i.e. data assimilation, observing system evaluations, coastal ocean forecasting, coupled predictions, model intercomparisons and marine ecosystem analysis and prediction. This strategy has allowed GOV to be proactive in consolidating and refreshing TT plans and to engage in structured and well-defined activities.

This workshop was sponsored by the CMRE and ONRG.

Appendices

Appendix A: Workshop agenda

Day 1 - Wednesday, 11th October 2017

08:30 – 09:00	**Registration**	

Introductory Session

09:00 – 09:15	Welcome	**Paolo Oddo**
09:15 – 09:25	Overview of GODAE OceanView	**Kirsten Wilmer-Becker**
09:25 – 09:40	Current Status and Overview of Data Assimilation Task Team	**Andy Moore/ Matt Martin**
09:40 – 09:55	Current Status and Overview of OSEval Task Team	**Elisabeth Remy/Yosuke Fujii**
09:55 – 10:10	Workshop aims and objectives	**DA- and OSEval-TT co-chairs**

Session 1: *Recent developments in global and regional ocean data assimilation system (DA)*

Session chairs: **Alex Kurapov and YoungHo Kim**

10:10 – 10:30	Three-dimensional Variational Ocean data assimilation using NCODA	**Shastri Paturi, NOAA**
10:30 – 11:00	**Coffee Break**	
11:00 – 11:20	Recent developments in global ocean data assimilation using NEMOVAR at the Met Office	**Matt Martin, Met Office**
11:20 – 11:40	The Global Ocean Forecasting System in the NMEFC and its Intercomparison with the GODAE OceanView IV-TT Class 4 metrics	**Liying Wan, NMEFC**
11:40 – 12:00	Comparing variational methods aware of model error evolution for long-term ocean applications with OceanVar	**Andrea Storto, CMCC**
12:00 – 12:20	Recent advances in the Mercator-Ocean reanalysis system: Application to an Arctic configuration	**Charles-Emmanuel Testut, Mercator Ocean**
12:20 – 13:00	**Discussion**	
13:00 – 14:00	**Lunch Break**	

Session 1: *Recent developments in global and regional ocean data assimilation system cntd. (DA)*

Session chairs: **Andy Moore and Anna Teruzzi**

14:00 – 14:20	The US West Coast Ocean Forecast System: skill assessment and data assimilation	**Alexander Kurapov, Oregon State University**
14:20 – 14:40	Development of the KIOST regional ocean prediction system : OPEM (Ocean Predictability Experiment for Marine environment)	**YoungHo Kim, KIOST**
14:40 – 15:00	Profile, altimeter and SST data assimilation in An operational shelf-seas model - Met Office FOAM-Shelf version 9	**Rob King, Met Office**
15:00 – 15:20	Data Assimilation of Argo profiles in Northwest Pacific Model	**Yun Li, NMEFC**
15:20 – 15:50	**Coffee Break**	
15:50 – 16:10	Modeling the circulation in the Kattegat and Skagerrak	**Kai Håkon Christensen, Met.no**

Session 2: *Error covariance modelling (DA)*

Session chairs: **Matt Martin and Hernan Arango**

16:10 – 16:30	Assimilation using large scale EOF error covariances	**Daniel Lea, Met Office**
16:30 – 17:00	**Discussion**	

17:00 End of day 1

Day 2 - Thursday, 12th October 2017

Please note later start at 9:30

Session 3: *Hybrid variational/ensemble data assimilation (DA)*

Session chairs: **Matt Martin and Hernan Arango**

09:30 – 09:50	A model for generating atmosphere forcing perturbations	**Isabelle Mirouze, CMCC**
09:50 – 10:10	A comparison of 4D-Var and an Ensemble Adjustment Kalman Filter applied to the California Current system	**Andy Moore, UCSC**
10:10 – 10:30	On-going, real-time hybrid variational data assimilation at the CMRE	**Paulo Oddo, CMRE**
10:30 – 11:00	**Coffee**	

Session 3: *Hybrid variational/ensemble data assimilation (DA) contd.*

Session chairs: **Dan Lea and Andrea Storto**

11:00 – 11:20	Ensemble-variational assimilation with NEMOVAR. **Part 1:** formulation, algorithms and illustrative examples	**Anthony Weaver, CERFACS**
11:20 – 11:40	Ensemble-variational assimilation with NEMOVAR. **Part 2:** experiments with the ECMWF system	**Hao Zuo, ECMWF**
11:40 – 12:00	Ensemble-variational data assimilation in the coastal ocean circulation model off Oregon-Washington (at the US West Coast)	**Ivo Pasmans, Oregon State University**

Session 5: *Requests and requirements of assessing present and future observation networks (OSEval)*

Session chairs: **Elisabeth Remy and Hao Zuo**

12:00 – 12:20	Impact of wide-swath altimetry missions to ocean analysis and forecasting system in the Iberian-Biscay-Ireland (IBI) region	**Antonio Bonaduce, Mercator Ocean**
12:20 – 12:50	**Discussion**	
12:50 – 13:00	**Group Photo**	
13:00 – 14:00	**Lunch Break**	
14:00 – 14:20	Current Status of Tropical Pacific Observing	**Yosuke Fujii, MRI-JMA**

	System 2020 project and the Request to the Ocean Data Assimilation Community	
14:20 – 14:40	Coordinated observing system experiments to assess the impact of satellite sea surface salinity data	**Elisabeth Remy, Mercator Ocean**
14:40 – 15:00	Significant contribution of operational oceanography for an Integrated and More Sustainable Atlantic Ocean Observing (AtlantOS)	**Florent Gasparin, Mercator Ocean**
15:00 – 15:30	**Coffee Break**	

Session 6: *Recent studies of observation impacts, sensitivity, and assessments of observation networks (Joint)*

Session chairs: **Yosuke Fujii and Anthony Weaver**

15:30 – 15:50	4D-Var Observation Impacts and Sensitivities in the Mid-Atlantic Bight	**Hernan Arango, Rutgers University**
15:50 – 16:10	Quantitative Impact Assessment of Ocean Observations on Tropical Cyclone Prediction and Ocean Monitoring: Results from a New, Rigorously-Validated OSE-OSSE System	**George Halliwell, NOAA**
16:10 – 16:30	Influence of the Deep NINJA float data on a deep ocean state estimation	**Shuhei Masuda, JAMSTEC**
16:30 – 16:50	Reduced-rank array modes of the California Current ocean observing system	**Andy Moore, UCSC**
16:50 – 17:10	**Discussion**	

17:10 End of day 2

Day 3 - Friday, 13th October 2017

Session 6: *Recent studies of observation impacts, sensitivity, and assessments of observation networks – cntd (Joint)*

Session chairs: **Yosuke Fujii and Anthony Weaver**

09:30 – 09:50	Impact of using an improved Mean Dynamic Topography on the Mercator-Ocean analysis and forecasts	**Marie-Helene Rio, CLS**
09:50 – 10:10	Use of in-situ observations in ECMWF's Ocean (Re)analysis system	**Hao Zuo, ECMWF**
10:10 – 10:40	**Coffee**	

Session 7: *Method development: network design (OSEval)*

Session chair: **Paolo Oddo and Andy Moore**

10:40 – 11:00	Stochastic Coastal/Regional Uncertainty Modelling and Array Design: insights from ensemble sensitivity/consistency experiments	**Pierre De Mey, LEGOS**
11:00 – 11:20	Recent Development of Ocean Data Assimilation Systems and Recent Observing System Evaluation Studies in JMA/MRI	**Yosuke Fujii, MRI-JMA**

Session 8: *Assimilation of new/novel observation types (Joint)*

Session chair: **Paolo Oddo and Andy Moore**

11:20 – 11:40	A multi-data variational assimilation scheme of BGC-Argo and satellite data into the CMEMS Mediterranean biogeochemical model	**Anna Teruzzi, OGS**

Session 9: *Impact of physical data assimilation on unassimilated variables /processes, e.g. vertical velocities, vertical mixing (Joint)*

Session chair: **Paolo Oddo and Andy Moore**

11:40 – 12:00	Vertical velocities within eddies	**Peter Oke, CSIRO (recorded)**
12:00 – 12:30	**Discussion**	

GOV-session/TT-meeting: *Preparing for the next GOV symposium/review and review of OSEval-TT and DA-TT work plans (Joint)*

Session chairs: **Matt Martin, Andy Moore, Elisabeth Remy and Yosuke Fujii**

The format of both the DA- and OSEval task team meetings is still to be confirmed. We might run these as separate meetings (break-outs) or in plenary.

12:30 – 12:45	**Wrap up & discussion**
12:45 – 13:00	**Introduction to TT meeting(s)**
13:00 – 14:00	**Lunch Break**
14:00 – 15:00	**TT Discussion**
15:00 – 15:30	**Coffee Break**

15:30 Close of meeting

Appendix B: Participants list

No	First name	Surname	Affiliation	Country
1	Hernan G.	Arango	Rutgers University	USA
2	Rossella	Arcucci	University of Naples Federico II	Italy
3	Joao Marcos	Azevedo Correia de Souza	CICESE	Mexico
4	Antonio	Bonaduce	Mercator-Ocean	France
5	Carlo	Brandini	CNR IBIMET	Italy
6	Kai Hakon	Christensen	Norwegian Meteorological Institute	Norway
7	Marcin	Chrust	ECMWF	UK
8	Pierre	De Mey	LEGOS/CNRS	France
9	Maria	Fattorini	CNR Ibimet	Italy
10	Yosuke	Fujii	JMA/MRI	Japan
11	Florent	Gasparin	Mercator Ocean	France
12	George	Halliwell	NOAA/AOML/PhOD	USA
13	Hyunkeun	Jin	KIOST	South Korea
14	YoungHo	Kim	KIOST	South Korea
15	Robert	King	Met Office	UK
16	Alexander	Kurapov	CEOAS, Oregon State University	USA
17	Dan	Lea	Met Office	UK
18	Yun	Li	NMEFC	China
19	Matthew	Martin	Met Office	UK
20	Shuhei	Masuda	JAMSTEC	Japan
21	Isabelle	Mirouze	CMCC foundation	Italy
22	Andrew	Moore	University of California Santa Cruz	USA
23	Paolo	Oddo	CMRE	Italy
24	Gyundo	Pak	KIOST	South Korea
25	Ivo	Pasmans	Oregon State University	United States
26	Shastri	Paturi	IMSG at NOAA/NWS/NCEP/EMC	USA
27	Elisabeth	Remy	Mercator Ocean	France
28	Marie-Helene	Rio	CLS	France
29	Andrea	Storto	CMCC	Italy
30	Anna	Teruzzi	OGS	Italy
31	Charles-Emmanuel	Testut	Mercator Ocean	France
32	Arthur	Vidard	Inria	France
33	Liying	Wan	NMEFC	China
34	Anthony	Weaver	CERFACS	France
35	Kirsten	Wilmer-Becker	Met Office	UK
36	Hao	Zuo	ECMWF	UK

Appendix C: Presentations

Introduction

No	Title	Presenter	Affiliation
1.1	GOVST Overview	Kirsten Wilmer-Becker	Met Office
1.2	Current Status and Overview of DA Task Team	Andy Moore Matt Martin	UCSC / Met Office
1.3	Current Status and Overview of OSEval TT	Elisabeth Remy Yosuke Fujii	Mercator Ocean/ MRI-JMA

Recent developments in global and regional ocean data assimilation system

No	Title	Presenter	Affiliation
2.1	Three-dimensional Variational Ocean data assimilation using NCODA	Shastri Paturi	NOAA
2.2	Recent developments in global ocean data assimilation using NEMOVAR at the Met Office	Matt Martin	Met Office
2.3	The Global Ocean Forecasting System in the NMEFC and its Intercomparison with the GODAE OceanView IV-TT Class 4 metrics	Liying Wan	NMEFC
2.4	Comparing variational methods aware of model error evolution for long-term ocean applications with OceanVar	Andrea Storto	CMCC
2.5	Recent advances in the Mercator-Ocean reanalysis system: Application to an Arctic configuration	Charles-Emmanuel Testut	Mercator Ocean
2.6	The US West Coast Ocean Forecast System: skill assessment and data assimilation	Alexander Kurapov	Oregon State University
2.7	Development of the KIOST regional ocean prediction system : OPEM (Ocean Predictability Experiment for Marine environment)	YoungHo Kim	KIOST
2.8	Profile, altimeter and SST data assimilation in An operational shelf-seas model - Met Office FOAM-Shelf version 9	Rob King	Met Office
2.9	Data Assimilation of Argo profiles in Northwest Pacific Model	Yun Li	NMEFC
2.10	Modeling the circulation in the Kattegat and Skagerrak	Kai Håkon Christensen	Met.no

Error covariance modelling

No	Title	Presenter	Affiliation
3.1	Assimilation using large scale EOF error covariances	Daniel Lea	Met Office

Hybrid variational/ensemble data assimilation

No	Title	Presenter	Affiliation
4.1	A model for generating atmosphere forcing perturbations	Isabelle Mirouze	CMCC
4.2	A comparison of 4D-Var and an Ensemble Adjustment Kalman Filter applied to the California Current system	Andy Moore	USCS
4.3	On-going, real-time hybrid variational data assimilation at the CMRE	Paulo Oddo	CMRE
4.4	Ensemble-variational assimilation with NEMOVAR. Part 1: formulation, algorithms and illustrative examples	Anthony Weaver	CERFACS
4.5	Ensemble-variational assimilation with NEMOVAR. Part 2: experiments with the ECMWF system	Hao Zuo	ECMWF
4.6	Ensemble-variational data assimilation in the coastal ocean circulation model off Oregon-Washington (at the US West Coast)	Ivo Pasmans	Oregon State University

Requests and requirements of assessing present and future observation networks

No	Title	Presenter	Affiliation
5.1	Impact of wide-swath altimetry missions to ocean analysis and forecasting system in the Iberian-Biscay-Ireland (IBI) region	Antonio Bonaduce	Mercator Ocean
5.2	Current Status of Tropical Pacific Observing System 2020 project and the Request to the Ocean Data Assimilation Community	Yosuke Fujii	MRI-JMA
5.3	Coordinated observing system experiments to assess the impact of satellite sea surface to assess the impact of satellite sea surface	Elisabeth Remy	Mercator Ocean
5.4	Significant contribution of operational oceanography for an Integrated and More Sustainable Atlantic (AtlantOS) Ocean Observing	Florent Gasparin	Mercator Ocean

Recent studies of observation impacts, sensitivity, and assessments of observation networks (Joint)

No	Title	Presenter	Affiliation
6.1	4D-Var Observation Impacts and Sensitivities in the Mid-Atlantic Bight	Hernan Arango	Rutgers University
6.2	Quantitative Impact Assessment of Ocean Observations on Tropical Cyclone Prediction and Ocean Monitoring: Results from a New, Rigorously-Validated OSE-OSSE System	George Halliwell	NOAA
6.3	Influence of the Deep NINJA float data on a deep ocean state estimation	Shuhei Masuda	JAMSTEC
6.4	Reduced-rank array modes of the California Current ocean observing system	Andy Moore	UCSC
6.5	Impact of using an improved Mean Dynamic Topography on the Mercator-Ocean analysis and forecasts	Marie-Helene Rio	CLS
6.6	Use of in-situ observations in ECMWF's Ocean (Re)analysis system	Hao Zuo	ECMWF

Method development: network design (OSEval)

No	Title	Presenter	Affiliation
7.1	Stochastic Coastal/Regional Uncertainty Modelling and Array Design: insights from ensemble sensitivity/consistency experiments	Pierre De Mey	LEGOS
7.2	Recent Development of Ocean Data Assimilation Systems and Recent Observing System Evaluation Studies in JMA/MRI	Yosuke Fujii	MRI-JMA

Assimilation of new/ novel observations types (Joint)

No	Title	Presenter	Affiliation
8.1	A multi-data variational assimilation scheme of BGC-Argo and satellite data into the CMEMS Mediterranean biogeochemical model	Anna Teruzzi	OGS

Impact of physical data assimilation on unassimilated variables /processes, e.g. vertical velocities, vertical mixing (Joint)

No	Title	Presenter	Affiliation
9.1	Vertical velocities within eddies (movie download, large file)	Peter Oke (recorded)	CSIRO

Posters

No	Title	Presenter	Affiliation
P.1	Development of a Gulf of Mexico reanalysis – the road towards a Mexican ocean operational forecast system	Joao Marcos Azevedo Correia de Souza	CICESE
P.2	Why gliders appreciate good company: glider assimilation in a 4DVAR system with and without surface observations	Ivo Pasmans	Oregon State University
P.3	Constraining the global ocean heat content through the use of CERES derived TOA Energy Imbalance estimates	Andrea Storto	CMCC