GODAE OceanView – CLIVAR-GSOP Workshop

on

Observing system evaluations and Intercomparison

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Executive summary

One of the goals of the workshop was to demonstrate the value of observations to ocean forecast and analysis systems. Many studies were presented that demonstrate the value of the global ocean observing system (GOOS) for seasonal ocean-atmosphere forecasting and short-range ocean forecasting (see section 3.4). Details are described in the workshop report. In several presentations, the value of Argo data was highlighted, as was the value of altimetry, SST, XBT, and moored buoys. At the end of the workshop, it was agreed that the ocean forecasting and reanalysis community need a common framework for reporting results to the observational community and agencies that are responsible for maintaining the GOOS. Although, the specific details of how this should be done were not specified, several members of GODAE OceanView and CLIVAR-GSOP teams were left with actions to carry this forward (see Appendix C).

Several GODAE OceanView, CLIVAR-GSOP, and coastal groups have developed capabilities that permit the routine monitoring of the impact of ocean observations on their systems (see section 3.2). These include a range of methods, most of which are derived from data assimilation theory. The success of the near-real-time observing system experiments (NRT OSEs), proposed in the GODAE OceanView science plan, was demonstrated by the results presented by D. Lea from the UK Met Office. The UK Met Office was the only operational centre to participate in this activity. At the conclusion of the workshop, several other operational centres stated their intention to participate in the NRT OSE activity (see section 3.2). However, it was noted that these activities require significant computational resources and human effort.

The value of international inter-comparison activities was highlighted by the great success of the CLIVAR-GSOP community – showing inter-comparisons of nine different seasonal forecast systems, and highlighting common problems with all systems. These inter-comparisons help the research community to clarify the common-problems in the systems, which gives them greater focus towards a solution. The GODAE OceanView initiative to perform routine class 4 metrics inter-comparisons was discussed and a way forward agreed.

It was generally agreed that the GODAE OceanView community should work towards the generation of a multi-model ensemble. This would provide the user community with forecasts as well as an indication of uncertainty. It would also enable the data producers to identify areas of significant differences between the systems and thereby facilitate their improvement.

In summary, the main outcomes of the meeting are:

- Further clarification of a way forward with near-real time OSEs and a demonstration of their usefulness
- Agreement on a way forward for developing Observing Impact Statements
- Further clarification of the class 4 inter-comparison project, and a feasible way forward
- Agreement to produce a multi-model ensemble from GOV systems
- Agreement to produce and inter-compare various climate metrics from GOV and GSOP systems
- Agreement to extend the existing Quality Control inter-comparison exercise in GOV to include extra information, and to include outputs from GSOP systems

1. Introduction

This workshop was jointly organised by two GODAE OceanView Task Teams (www.godae-oceanview.org/science/task-teams/) – the Observing System Evaluation Task Team (OSEval-TT) and the Inter-comparison and Validation Task Team (IV-TT); and the Climate Variability Global Synthesis and Observations Panel (CLIVAR-GSOP; www.clivar.org/organization/gsop/gsop.php), aiming at providing a forum for researchers in data assimilation and ocean forecasting to engage with each other and exchange ideas.

Specific **goals** of the workshop were to:

- Demonstrate the value of in situ and satellite observations to short-term, seasonal, and decadal forecast systems;
- Move towards routine monitoring of the global ocean observing system (explore possibilities for "*Observation Impact Statements*");
- Review inter-comparison of class 4 metrics from operational short-range forecast systems and seasonal prediction systems; and
- Linking inter-comparison and observing system evaluation monitoring activities within GODAE OceanView to those of CLIVAR.

The expected **outcomes** included establishing the status of ocean data assimilation systems, the status of efforts in observing system evaluation and inter-comparison experiments in view of updating OSEval- and IV-TTs work plans (www.godae-oceanview.org/science/work-plan/) as well as learning of such efforts in the wider ocean community. The organization of a joint workshop allowed representatives from different groups to evenly contribute to the workshop outcome, improving the collaborations between GODAE OceanView and CLIVAR communities. It also allowed discussions on the engagement between the ocean forecasting community and the observational community.

The meeting **organisers** shared responsibility in capturing relevant outcomes:

Observing System Evaluation - Peter Oke

Inter-comparisons and validation - Matt Martin

CLIVAR GSOP - Magdalena Balmaseda

Community engagement - Gary Brassington

General discussion and Report Coordinator/Editor - Kirsten Wilmer-Becker

2. Observing System requirements (panel discussion)

Drafted by Peter Oke

On the first day of the workshop a short panel discussion was conducted. The panel members were G. Brassington (BoM; JCOMM ET-OOFS Chair), K. Haines (Univ. Reading; CLIVAR GSOP Co-Chair); E. Harrison (NOAA; former OOPC Chair), and E. Lindstrom (NASA; OOPC Chair, GODAE OceanView Patrons Co-chair); A. Schiller (CSIRO; GODAE OceanView Co-Chair) had intended to participate, but was unable to attend the workshop. The panel members were asked to present their view on what they considered to be the most important questions faced by the observational community; and what scientific questions do they think the ocean/coupled prediction and state estimation communities should help address.

2.1. Future observation types

It was agreed by all panel members that there is an ongoing challenge for the observational community to maintain all components of the Global Ocean Observing System (GOOS). It was noted that prior to OceanObs09 the level of deployed observations stalled at about 60% of the coverage proposed in 2000. The proposed coverage was based on requirements for monitoring the state of the climate. Most of the GOOS is designed to monitor the physical state of the ocean and climate. It was suggested that we may need to broaden the scope of the observing system to better include observations that are more relevant to other aspects of the ocean, such as ocean acidification. Such a system would include more observations of biological variables in the ocean. It was noted that the climate community tapped into the international, collective desire to document the climate system through the climate convention. We need to do the same for the biological community, e.g. to address issues like ocean acidification. There was some speculation that in the future, perhaps the Argo project may adopt a new mission of monitoring biological properties, and not just the physical properties. There was also some speculation that in the future, the priorities of decision makers may shift from climate monitoring, to climate forecasting. It was suggested that an important future activity in ocean forecasting might involve adaptive sampling – where targeted observations (e.g., gliders) are made with the purpose of reducing uncertainty in short-range or seasonal forecast systems. The message to the ocean forecasting and reanalysis community is that we need to be ready for these possible shifts in priorities and focus.

2.2. Observing system maintenance

Two different perspectives were presented on how we should provide motivation for the maintenance and enhancement of the GOOS. The first perspective relates to applications – we should identify the priorities and applications that are important to the funders and relevant for society, and demonstrate how observations benefit those applications. It was noted that priorities are different in different countries. We need to understand the priorities of policy makers in our own country and the priorities of policy makers in those countries that fund the observation platforms. The second perspective relates to the science – we should pursue the most interesting and cutting-edge science we can identify, and demonstrate how observations facilitate this research. At the end of the discussion, it was agreed that we should be motivated by both the science and applications.

2.3. Climate vs. short-range observations

There was recognition that the short-range ocean forecasting community routinely assimilate observations that are primarily maintained for monitoring the state of the climate (e.g., Argo data, altimeter data). The short-range ocean forecasting community have demonstrated that a good level of forecast skill can be achieved using those observations. However, it was noted that the observational requirements of the operational short-range forecasting community may be different if the skill of those systems is to improve further. There was recognition that the requirements of the short-range ocean forecasting and the climate community are likely to be different – and that we need to learn how to deal with these differences.

2.4. Assessment and reporting

Panel members encouraged the modelling and data assimilation community to "be positive" and "less negative" when they are assessing the observing system. To this end, we should avoid making blanket statements about components of the observing system. It is clear that data assimilating models do not make optimal use of observations, and so a demonstration that a particular observation does not have a significant impact on an assimilating model is not a demonstration that the observation is not useful – rather it is a demonstration that the use of the observation needs to be improved.

It was noted that perhaps we, the ocean forecasting and reanalysis community, need a common framework for reporting results to the observational community and agencies that are responsible for maintaining the GOOS. This is one of the objectives of the present workshop – to develop a framework for "Observation Impact Statements".

We need to continue to publish results that relate to observing system evaluation and to maintain a list of published material that can be referred to by the broad oceanography community. In these studies, we need to present our findings with the appropriate caveats. For example, many model- and assimilation-based studies include assumptions about prior errors, observation errors, and even about the dynamics that are implicit to the model, given its parameterisations and resolution. We can only evaluate the impact of observations on our particular system. We need to be clear about these limitations when publishing results so that the implications of our results are not misunderstood.

Several specific science questions were raised by the panel, including:

- How common are significant events of remotely forced along-shore propagation?
- How common are heat content anomalies related to the generation of tropical cyclones or hurricanes?
- Can we identify lead or lag relationships between climate variability – looking at heat content for example? What time-scales are associated with the lead/lag time of ocean variability?
- Can we move our analyses away from broad brush – to phenomenological assessments?
- Is it feasible to address what observations are necessary to help us understand the rate of ice sheet melting around Antarctica and Greenland?

3. Summary of outcomes relating to Observing System Evaluations

Drafted by Peter Oke

One of the goals of the workshop was to determine the status of observing system evaluation activities within the GODAE OceanView, CLIVAR, and coastal ocean forecasting communities. Another goal of the workshop was to provide a demonstration of the value of in-situ and satellite observations on short-range, seasonal, and decadal forecast systems. A summary of presentations and discussion that meet these goals follows.

3.1 Community Activities

Several community activities were described during the workshop that are either directly relevant for, or related to, OSEval activities, including:

- A call for action from OceanObs09 was to form a task team to put together a "Framework for Ocean Observing" (www.oceanobs09.net/wg/), as discussed above in HERE
- One of the outcomes from OceanObs09 was the establishment of a task team (www.oceanobs09.net/wg/), chaired by E. Lindstrom (NOAA) and J. Gunn (AAD), that was asked to outline a framework for ocean observing. The Framework is meant to help guide the many different global and regional organizations with a stake in an ocean observing system to work together in a voluntary collaborative way for mutual gain. It introduces the concept of Essential Ocean Variables (EOV), and of assessment and development of readiness for sustained observations; and promotes collaboration in developing requirements, observing networks, and data and information streams. This common language is meant to guide participating organizations and programmes in finding and defining their niche and contribution in this larger Framework.
- NOAA/IOOS formed a HF radar data impact working group (www.ioos.gov/program/projects.html; Jim Cummings is a member)
- OOPC state of the ocean climate website (stateoftheocean.osmc.noaa.gov/) may be a suitable place to deliver information to the broader community

3.2 Existing Capabilities for Routine Monitoring of Data Impacts

Following the GODAE Workshop on Observing System Evaluation June 2009 (www.godae.org/OSSE-OSE-Second-workshop.html), it was agreed that all GODAE partners should work towards the development of capabilities to routinely monitor the impact of components of the GOOS on operational forecasts and reanalyses. Several techniques for routine monitoring were discussed at that workshop. Since that meeting, several groups have established capabilities to routinely evaluate the impact of observations on forecast and analysis systems. Details follow:

- The TOPAZ group, at NERSC, have developed the capabilities to routinely compute degrees of Freedom of signal (DFS; Cardinali et al. 2009[1]) and spread (or variance) reduction factors (SRFs; Sakov et al. 2011, submitted) that quantify the impact of assimilated observations on each analysis. This capability has been applied to a multi-year reanalysis.
- The FOAM group, at the UK Met Office, has established the capability to perform and evaluate Near-Real-Time (NRT) Observing System Evaluation Experiments (OSEs). This capability has been deployed for the period February-June 2011 to evaluate the impact of

different components of the Global Ocean Observing System (GOOS) on operational short-range ocean forecasts.

- JMA/MRI has developed a capability to perform forecasts sensitivities to assess the impact of all assimilated observations on seasonal forecasts.
- ECMWF is conducting delayed OSEs to assess the impact of different observing systems in their latest ocean reanalysis (ORAS4) and seasonal forecasting system (S4).
- The ROMS community has established a capability for routinely computing DFS and forecast sensitivities that assess the impact of assimilated observations on analyses and forecasts respectively. These capabilities have been applied to a forecast/hindcast system configured for the Californian Current System.
- The CLS group has established a capability for computing DFS for altimeter data (DUACS/AVISO-MyOcean/SLTAC center) to quantify the impact of each observation analysed to produce Aviso maps (Dibarboure et al. Marine Geodesy Jason 2 special issue[3]). This approach will be implemented in NRT to provide key performance indicators.
- NRL is developing a capability to assess the impact of all assimilated observations using analysis sensitivities metrics derived from an adjoint-based system.
- Bluelink is developing a capability to routinely estimate analysis errors for reanalyses and operational short-range ocean forecasts.

A new initiative introduced in the GODAE OceanView Observing System Evaluation Task Team (OSEval-TT) work plan is to perform coordinated NRT OSEs. These involve the systematic with-holding of a single observation type each month, according to a pre-specified schedule. Leading up to this workshop, only the UK Met Office performed NRT OSEs according to the work plan. At the workshop, several forecast groups indicated that they intend to begin performing NRT OSEs in the future. Details follow:

- UK Met Office: intend to continue to perform NRT OSEs;
- Mercator Ocean: intend to perform NRT OSEs (for one forecast cycle each month), beginning some time in the second half of 2011;
- Bureau of Meteorology: intend to perform NRT OSEs, beginning some time in the second half of 2011;
- JMA/MRI: JMA/MRI does not have the super-computing resources (following recent natural disasters in Japan) to perform NRT OSEs;
- NRL: regularly perform specialised OSEs to address specific “events” (e.g., Deepwater Horizon Oil Spill). NRL does not have the human resources to analyse NRT OSEs. But if the required metrics were clearer and toolboxes available, NRL could consider performing NRT OSEs.
- MFS (Mediterranean): may be able to perform NRT OSEs beginning 2012.
- REMO (Brazil): are not ready to perform NRT OSEs;
- NMEFC (China): intend to perform NRT OSEs, beginning in 2012;
- UCSC ROMS: may be able to perform NRT OSEs, beginning some time in 2012;
- OSU ROMS: regularly perform delayed-mode OSEs, but are not resourced to perform NRT OSEs;

- C-NOOFS (Canada): may begin performing NRT OSEs, beginning some time in 2012;
- INDOFOS (India): are not ready to perform NRT OSEs; and
- TOPAZ: probably cannot afford to perform NRT OSEs.

Several action items relating to NRT OSEs resulted from the OSEval breakout session *(see Actions in Appendix C.)*

3.3 Provision of Observation Impact Statements (OISs)

It was suggested that OISs provided by GODAE OceanView groups should be called a "GODAE OceanView Observation Impact Reports (GODAE OceanView -OIRs)", "GODAE OceanView Papers", or similar.

Options – GODAE OceanView-OIRs could be:

1) a summary of the results from NRT OSEs from multiple systems;
2) a comprehensive evaluation of each observation platform based on various experiments (e.g., OSEs, DFS, etc Impact study, rather than impact statement) based on multiple systems at multiple centers and publish the impacts for each platform once (until the impact of those observations change significantly due to significant changes in models, methods, observation accuracy); or
3) a compilation of additional (new) NRT metrics for quantifying the impact of observations. Such a metric(s) would need to be developed.

The proposition at the beginning of the workshop was option 3, with details to be worked through during and after the workshop. After discussion in the breakout session, the consensus proposal was to begin by pursuing GODAE OceanView-OIRs (or OISs) according to option 1 – and send feedback to the GODAE OceanView patrons group that if funding for a postdoctoral researcher was available (e.g., at UK Met Office), we could expand this scope to include community activities associated with the inter-comparison of class 4 metrics.

Additional comments regarding OISs:

- Requirements of GODAE OceanView papers:
    - Must be simple and short;
    - Reports could start by simply documenting what observations are used; and
    - Reports should be peer-reviewed.

- Further discussion is required to determine:
    - Should we compute impact on "analysis", "forecast", or "dynamics"?
    - Who are the OISs prepared for – who is the target "audience"?
    - What are the impacts of observations on analyses or forecasts of "Essential Ocean Variables"?
    - Coordinate evaluating activities with "special events" (intense observation campaigns).

- Observation types to be included:
    - Conventional observations;
    - Scatterometer data;

    - Ocean colour.

- What is a suitable metric?
    - A metric that quantifies the impact on a forecast is preferable;
    - We can most easily compute metrics that quantify the impact on an analysis;
    - Often the neglect of data at one instance is much less than the accumulated impact over time.

Several action items relating to provision of OISs resulted from the OSEval breakout session *(see Actions in Appendix C.)*

3.4 Impacts of observations types on forecast and reanalysis systems

Several studies presented at the workshop (please see *also Appendix 4: Presentation notes*) demonstrate the value of one or more observation type. Some key results from these studies that were presented at the workshop are described below.

Throughout the workshop, limitations of all methods used for evaluating the "value of observations" using models and data assimilation or analysis systems were discussed. In all cases, the impact of an observation on an assimilating model, or an analysis system, depends on limitations and assumptions that are associated with the model (e.g., represented dynamics, topography, forcing, parameterisations, numerical methods, model bias) and the analysis or data assimilation system (e.g., estimates of observation and prior errors, and their covariance; initialisation schemes). It is therefore important to recognise that the demonstrated impact of an observation on any system is relevant for that system only. We expect that the true value of an observation will always be under-estimated by an analysis- or model-based study. This should be taken into consideration, when interpreting the results that follow.

Through a comprehensive series of inter-comparison of nine ~30-year climate-scale ocean (and some coupled) reanalyses Xue demonstrated a step-change improvement in the agreement between different reanalysis systems, indicating that these systems are better constrained by assimilation following 1993, when the TAO array was completed. Similarly, Xue showed that performance of most systems steadily improves in the Tropical Pacific, the Tropical Indian, and the Southern Ocean after 1997, as the number of Argo array floats increased. Most reanalysis systems show a step-change in their agreement with each other in the equatorial Atlantic Ocean after 2005. Despite this improvement, all systems seem to struggle to realistically represent the variability in the tropical Atlantic Ocean, with little agreement between reanalysis systems there.

[*Oral presentation:* Xue, Y., Comparative Analysis of Upper Ocean Heat Content Variability from Ensemble Operational Ocean Analyses]

Through a series of Observing System Experiments (OSEs), where different observation types were systematically with-held from the JMA/MRI seasonal prediction system, Fujii demonstrated that Argo improves the skill of SST forecasts in the NINO3.4 region over 1-7 months and 8-13 months by 9% and 25% respectively (Fujii et al. 2011)[5]. Similarly, Fujii demonstrated that the assimilation of observations from the TAO/TRITON array improved the forecasts of the NINO3.4 SST over 1-7 months and 8-13 months by 6% and 9% respectively. Fujii further shows the improvements of atmospheric fields by assimilating Argo or TAO/TRITON array. Specifically, Argo returned the most significant improvements to 8-13 month forecasts of SST, sea-level pressure (SLP), and atmospheric temperature (between 850-200 hPa) in the tropical Pacific.

In the discussion that followed Fujii's presentation, Fujii reported that the decadal community is also active in the evaluation of the observing system. Fujii reported work by Dunstone and Smith (2010)[4], where the initialization of the ocean contributed to the skill on tropical Atlantic precipitation, wind shear (proxy for tropical cyclones) and MOC, at lead times of 2-6 years ahead.

Haines reported work of using OSSEs to assess which areas of the ocean influence the prediction most. Haines reported work by Johnson et al on the decadal prediction of the heat content in the subpolar gyre and its relation with the Atlantic MOC. In particular they investigate the roles of the density signal versus the wind driven circulation.

[*Oral presentation:* Fujii, Y., Ocean Observing System Evaluation for Seasonal/Decadal Prediction]

Lea presented results from a series of Near-Real-Time (NRT) Observing System Experiments (OSEs) using FOAM, the operational short-range ocean forecast system developed and run at the UK Met Office. Lea systematically with-held XBT, TAO, Argo, SST, Jason-2, and all altimeter data for a month during the first half of 2011. Results from these OSEs showed that with-holding XBT data resulted in changes in 7-day forecasts by over 1°C 100-m depth temperature in the vicinity of the XBT observations. With-holding observations from the TAO/TRITON array degraded FOAM forecasts over 2°C in the tropical Pacific Ocean, particularly around the depth of the thermocline. With-holding Jason-2 observations significantly degraded forecasts of sea-level anomaly (SLA) by over 20 cm in western boundary currents (WBCs), WBC extensions (WBCext), and along the path of the Antarctic Circumpolar Current (ACC). Similarly, the neglect of all altimeter data degraded forecasts of SLA in WBCs, WBCext, and the ACC by over 50 cm in many cases. The neglect of altimeter data degraded forecasts in the tropical oceans by 5-10 cm in many regions. Although the OSE with-holding SST data were incomplete at the time of the workshop, preliminary results demonstrated a degradation of forecast SST by over 1°C in some locations.

[*Oral presentation*: Lea, D., FOAM observing system evaluation (OSE) experiments in near-real time]

The new seasonal forecast system, developed at the ECMWF (ORAS4), uses Argo observations to perform an offline bias correction for their ocean reanalysis. This application of Argo observations significantly improves the performance of the reanalysis system. Balmaseda presented a series of OSEs using ORAS4. These OSEs demonstrated only a moderate impact of altimeter observations on their system; however it was shown that the neglect of moorings increases the RMSE by about 5% for many variables. Without data assimilation, the model undergoes a significant drift. With data assimilation, this drift is eliminated, and the long-term trends of the reanalysis closely match the observed trend derived from model-independent estimates. The neglect of Argo data modifies the simulated trends in ocean heat content.

[*Oral presentation*: Balmaseda, M., The New ORA-S4 ECMWF ocean reanalysis]

Through a data assimilation model of the Californian Current system, Moore demonstrated that although in-situ observations only comprise about 10% of the assimilated observations, they exert considerable impact of the assimilated coastal circulation. However, the forecast skill of the system is largely attributable to the assimilation of satellite observations.

[*Oral presentation*: Moore, A., Assessing the Information Content and Impact of Observations on Ocean Circulation Estimates using 4D-Var]

Through analyses of various assimilation metrics Sakov showed that all observation types (altimeter, Argo, SST, satellite-based ice concentration, and ice drift) have a significant impact on a 6-year ocean-sea ice reanalysis using the new TOPAZ system (TOPAZ4). Notably, altimeter and SST data have the most significant impact on the ocean circulation near boundary currents and in regions of significant mesoscale variability. Observations of ice concentration had the greatest impact at the sea ice edge.

[*Oral presentation* (given by P. Oke): Sakov, P., Metrics for quantifying observation impact in data assimilation: application to the TOPAZ pilot reanalysis]

Guinehut demonstrated the impact of Argo observations on an observation-based, statistical analysis system. The analysis system involves two steps. The first involves a projection of altimeter and SST data to sub-surface temperature and salinity. The second involves an adjustment to the estimated sub-surface temperature and salinity using Argo data. It was demonstrated that the adjustment using Argo data is most significant in the tropical Indian Ocean and in the South Atlantic Ocean. This implies that Argo data provides different/complimentary information to satellite observations in those regions.

[*Oral presentation*: Guinehut, S., Combination of in-situ and satellite observations to monitor the Global Ocean State]

Through an analysis of the footprint of oceanic variables at different locations around Australia, Oke showed that the existing 9-mooring national reference stations provide remarkably good coverage of the interannual (>14-month) variability around Australia; and that the recently-enhanced network of Australian moorings (now including 29-moorings) provides significantly improved coverage of intraseasonal (<60-day) variability of the Australian shelf circulation.

[*Oral presentation*: Oke, P., Design and Assessment of the Australian Integrated Marine Observing System]

Evaluation of the Mercator Ocean system demonstrates that the new 1/12° system performs very well, and that the eddy kinetic energy (EKE) of the simulated fields often exceeds the EKE of the observations. This implies that either the assimilation system needs to be improved to make better use of the available observations, that the observations are not sufficient to constrain the 1/12° model, or that the Aviso maps need to be refined to better represent finer-scale variability.

[*Oral presentation*: Hernandez, F., The new 1/12° global forecasting system at Mercator in the framework of MyOcean] *(80MB to download)*

The impact of using different mean dynamic topography (MDT) estimates for the assimilation of SLA on an intermediate-coarse (0.5-2°) resolution reanalysis was shown by Storto to be as much as 20%. Moreover, Storto showed results from a series of OSEs, demonstrating that SLA, CTD and XBT data had the most significant impact on upper ocean temperature (0-100 m depth) on 1-15-day forecasts, while Argo data had the most significant impact on temperature between 100-300 m depth. By contrast Argo and SLA impacted salinity over the top 100 m, while SLA impacted salinity between 100-300 m depth.

[*Oral presentation*: Storto, A., The CMCC experience in the context of Global Ocean reanalyses]

Through an evaluation of the new Canadian global coupled (ocean, atmosphere, sea ice; CONCEPTS) forecast system, Smith demonstrated that the sea surface salinity (SSS) is poorly constrained by the current GOOS. This implies either, that the existing observations do not adequately constrain the ocean salinity, the freshwater fluxes are degrading the forecasts, or the assimilation of observations is not making sufficient use of the available observations.

[*Oral presentation*: Smith, G., Evaluation of CONCEPTS Ice-Ocean Forecasting Systems]

Through a series of assimilating-model runs using a ¼° and a 1° model, it was shown that the assimilation of RAPID data (in situ moorings) has a significant (positive) impact on the meridional overturning circulation and consequently on the ocean and atmosphere heat budget.

[Poster presentation (presented by K. Haines): Stephanov, V., The impact of EN3 and RAPID data assimilation on the change of heat balance in the Atlantic]

3.5 Design of future observing systems

Several studies address different aspects of the design of future observing systems (please see *also Appendix 4: Presentation notes*). Some key results of these studies are summarized below.

Through a series of OSSEs, Zuo showed that the performance of a coupled seasonal prediction system can be significantly improved by performing coupled data assimilation. It was demonstrated that the improved skill of the intermediate coupled model is because of the relatively high correlations between surface winds and ocean velocities.

[*Poster presentation*: Zuo, H., Assimilation impacts on Arctic Ocean circulation, heat and freshwater budgets]

Through a series of OSSEs, Juza demonstrated that the addition of Argo floats in shallow waters could significantly decrease errors in estimates of the ocean heat content. Specifically, errors of OHC on seasonal and interannual time-scales could be decreased by as much as 20% and 10% respectively if Argo floats, or a similar platform were to be deployed in shallow waters.

[*Poster presentation*: Juza, M., Contribution of regions not sampled by the Argo array to the variability of the global ocean heat content]

Larnicol provided a series of Observing System Simulation Experiments (OSSEs) to assess the relative value of different satellite altimeter constellations. Different options were considered; include 3 nadir, 1 SWOT, 2 SWOT, 1 SWOT + 11 nadir. This study shows that SWOT mission needs to be completed by additional constellation of nadir altimeter. In parallel, Lyapunov exponent and mean distance error diagnostics have been tested to provide quantitative information of the performance of the different missions.

[*Oral presentation*: Larnicol, G., New diagnostics to assess the impact of satellite constellation for (sub)mesocale applications]

Preliminary results were shown on the attempt to assimilate the future on a regional model situated in south California Bay. Ubelmann demonstrated that the assimilation of data from a wide-swath alitimter (SWOT) could reduce errors in SSH by as much as 60% and could reduce errors of sub-surface temperature and velocities by as much as 40%. Further work will be performed by taking into account a better description of the measurements errors. *Poster currently not available*

3.6 New methods for evaluating observing systems

Some studies use some un/less conventional metrics to evaluate the performance of analysis systems of models. These include:

- Bred vectors (O'Kane):
- Lyaponov exponents (Larnicol)

- Degrees of Freedom of Signal (Moore, Sakov, Storto)
- Spread reduction Factors (Sakov)
- Observation footprints (Oke)

Lyapunov exponents software will be available in the coming weeks/months and will be available for the GODAE members. *(Please contact CLS/G. Larnicol).*

Bred vectors identify growing modes that may represent suitable locations for adaptively deploying additional observations (e.g., gliders) to better constrain forecast systems for developing instabilities.

[*Oral presentation*: O'Kane, T., Predicting the East Australian Current]

3.7 Other Comments

- No impact studies have been presented related to Surface salinity (SMOS, AQUARIUS) and GOCE mission (MDT) and Argo Bio. Why not?
- Discussed but not presented: Need to have Cryosat-2 ocean data (feedback from Larnicol (MyOcean presentation to the Cryosat-2 workshop). Do we plan to provide recommendations?

4. Summary of outcomes relating to Intercomparison and validation

Drafted by Matt Martin

4.1 Introduction

The goals of the workshop related to inter-comparison and validation were to review the inter-comparison of class 4 metrics from operational short-range forecast systems and to link the inter-comparison and monitoring activities within GODAE OceanView to those of CLIVAR GSOP. The outcomes of the workshop with respect to these objectives are summarised below.

On the first day of the workshop some introductory talks were given which put the work of GODAE OceanView and CLIVAR-GSOP into a more general context. An example of this is the Integrated Framework for Sustained Ocean Observations (IFSOO; www.oceanobs09.net/wg/) which was set-up following the OceanObs09 conference. Integrated climate data centres and operational ocean forecasting centres produce synthesis products which provide a mechanism for getting the information from observations to the users. In order for the users (and the observation community) to make best use of this information we need to understand the "readiness for use" of these synthesis products. Inter-comparison and validation work is crucial to understand the level of readiness for the various systems.

There is also a need to define synthesis metrics, based on the EOVs, and to define who they are for and how to promote them. The main type of metrics and their relevance for GSOP (and partly for GODAE OceanView) are:

1. Technical metrics (assimilation statistics, common to GSOP/GODAE OceanView);
2. Prediction applications (skill metrics, common to GSOP/GODAE OceanView) for coupled predictions (seasonal/decadal), ocean skill and atmospheric skill;.
3. Real-time monitoring applications: climate mode phases (PDO, ENSO, NAO, …), transport indices (e.g. AMOC); and
4. Climate quality reconstructions: for detection/attribution (heat content, water mass properties), integrated quantities which can't be measure directly by observations and to establish natural variability baselines.

The technical (assimilation statistics) metrics can be used to measure the readiness of the systems for assessing the other types of metrics (and other metrics more relevant to the GODAE OceanView systems). There is interest in agreeing common methods and goals between GODAE OceanView, GSOP and OOPC.

Other points related to inter-comparison and validation arising from the panel discussion on the first day include:

- The impact of the global ocean on coastal waters is crucial for national funders;
- There is need to persuade national funders of the importance of the GOOS as they are ultimately the ones which fund it;
- We need to assess the maturity of the operational ocean forecasting systems (OOFS) to judge whether the results of OSEs are robust;
- We need a standard framework for communicating results;

- Good communication between OOPC and the GODAE OceanView/CLIVAR-GSOP community is needed in order for the OOPC to feel able to request information about observational impacts;
- Assessment of specific phenomena would have more impact with funders than global statistics; and
- The use of relative errors (with respect to the anomalies to be estimated), is more useful than absolute errors.

4.2 Validation and assessment techniques

A number of presentations describing validation and assessment activities were presented. (*see Appendix 4: Presentation notes*). An overview of the types of assessments commonly used and some less widely used diagnostics are presented below. Various issues related to these validation studies are outlined.

Commonly used assessment techniques from the various GODAE OceanView and coastal groups include:

- Observation-minus-background (OmB) statistics including root-mean-square-error (RMSE), anomaly correlation coefficient (ACC) and bias. These are usually calculated for sea surface temperature (SST), sea level anomaly (SLA), temperature (T) and salinity (S) profiles.
- Time-average increments are used for assessing model biases;
- Skill of forecasts compared with observations and analyses are widely used;
- Taylor diagrams were used to present results;
- Comparisons to climatology for different variables;
- Assessment of the separation of the western boundary currents; and
- Variability of SSH from the model compared to altimeter data variability.

Some assessment methods commonly used by the CLIVAR-GSOP community that could be calculated from GODAE OceanView systems include:

- Comparing Atlantic meridional overturning circulation (AMOC) from the models to RAPID data;
- Heat transport diagnostics;
- Sea-ice assessments;
- Comparisons of the depth of the 20°C isotherm; and
- Upper ocean heat content for various depth ranges.

Less commonly used or new assessment techniques (for ocean forecasting systems) include:

- Assessment of tides in a global system using tide gauges as reference;
- Altimetry-based analysis of the internal tide (sampling the model in the same way as the data);

- Comparisons with HF radar data as an independent reference (especially useful when the available velocity data is assimilated);
- Forecast skill assessments in ensemble forecasting systems, e.g. by comparing spread in the ensemble with the RMSE of the mean;
- Calculating EOFs of assimilation increments to ascribe various dynamical processes to the model errors;
- Using Lyapunov exponents to show the scales which are reconstructed by the analysis;
- Statistical verification of the location of features (e.g. eddies);
- Verification of Arctic Ocean circulation and investigation of Arctic heat budget;
- Assessment of volume-integrated heat content in a particular 3D box and calculation of various contributing terms (advective and surface fluxes, data assimilation impact);
- Diagnosing the meridional heat transport (MHT) using meridional volume transport (MVT) estimates of the AMOC;
- Validation of geostrophic currents at 1000m depth using the ANDRO data-base (based on Argo trajectories);
- Comparison of currents with ADCP data from ships and from moored buoys;
- Verification of sea-ice against NOAA IMS analyses (ice or no-ice) to produce a contingency table analysis; and
- Comparison of modeled ice thickness with IceSat thickness data.

A number of other issues coming out of the presentations (some of which were summarized in the presentation by Balmaseda) include:

- Assimilation metrics (fit to observations, error growth, consistency of B and R) are insufficient for an overall assessment;
- Spatial/temporal consistency compared to current moorings, OSCAR currents, transports are useful but there are limited independent data;
- Calculating skill of forecasts is expensive and model error complicates this method particularly for longer range forecasts;
- It was suggested to produce normalised RMSE (normalized by the RMSE of a reference run, or by the natural variability in a particular region);
- There is a need to be careful about what is used as a validation data-set when using analyses for validation – can significantly affect results, particularly for salinity;
- Coupled model biases are a problem for assessing impact of observations on seasonal forecasts. Impact on seasonal forecasting is very important as it is a very influential product of observational data;
- Cryosat ocean data has been requested from ESA which will provide a useful assessment/assimilation data-set; and
- Marine mammal data off the California coast is not available in EN3 (or on GTS). Dan Costa provided it to the ROMS group at UCSC which was used for validation.

4.3 Inter-comparisons

Summary of inter-comparison aspects of the presentations

Hernandez presented an overview of the IV-TT work plan which includes:

- Inter-comparisons, both of class 4 metrics and of climate indices
- Investigation of new validation methodologies
- The possibility of producing multi-model ensembles
- Links with OSE-TT and ETOOFS

Various national work plans in GODAE OceanView include an interest in the inter-comparisons which are planned. A forecast assessment inter-comparison has been proposed with a detailed proposal document available. This type of class 4 validation is carried out at various centres, and an example from the Mercator system was shown. There are clear links with the OSE-TT and a potential link with seasonal forecasting groups through calculation of climate indices.

Xue presented a detailed comparison of upper ocean heat content (over the top 300m, HC300) from various ocean reanalyses. The questions addressed by the study included:

- How well is the mean HC300 analysed?
- What are the impacts of changes in the observing system?
- How well do the reanalyses capture inter-annual and multi-decadal variability?
- What climate indices should be monitored?
- What is the role of HC300 in predictability of ENSO, PDO, NAO, …?

Within the European MyOcean project there will be an inter-comparison of various global reanalyses (Mercator/Drakkar, UReading, CMCC).

The new PEODAS system was inter-compared with other centres and compared to EN3. This included comparisons of NINO3 and IOD forecast skill of SST anomaly correlations, heat content and salt content forecast skill in the Tropics, T and S forecast skill at 3-months lead time as a function of depth along the equator.

*Summary of the inter-comparison and validation **breakout sessions***

GODAE OceanView group

There is a need to re-iterate the objectives of inter-comparisons. For example, it is important to understand the reasons why the models differ and to develop a list of mechanisms for improving the models and data assimilation schemes. There is a particular interest in bias as well as RMSE and ACC in order to try to diagnose and then decrease the systematic model errors.

The status of the previously proposed **class 4 inter-comparison** in the various operational ocean forecasting centres is:

- NRL are producing class 4 files and are happy to convert to the common format.
- Bluelink are producing class 4 files but maybe not for the same data, and are happy to convert them to the common format.
- Mercator are producing class 4 files and are happy to produce these in the common format.

- REMO would like to contribute but are not ready now.
- INDOFOS would like to contribute but are not ready now.
- CONCEPTS are ready to contribute.
- NCEP would like to contribute once their new system is operational.
- UK Met Office has recently begun producing the class 4 files and have developed some code for producing these in a common format.

The need to provide files with common information was emphasised. It was therefore suggested that UK Met Office produce the class 4 files 7-days behind real-time and send them to the US GODAE server. The other groups will retrieve those files and produce the same information at the same locations/times. The class 4 generation code should be put on the GODAE OceanView web-site so that it can be used to produce files in the common format. It was suggested to also include a variable in the netCDF files describing whether a particular observation had been assimilated by each system.

Communication of progress with the class 4 inter-comparison should be improved to keep things moving forward. The class 4 inter-comparison proposal document should be re-circulated and an up-to-date version should be kept on the GODAE OceanView web-site. It was suggested to produce a twiki page to share information.

Extensions to the class 4 inter-comparison project were proposed:

- CONCEPTS (and probably TOPAZ) are interested in assessments in the Arctic region.
- Should biological variables be included in the analysis? Start with a small sub-set of physical variables, and once it is working think about adding extra variables.
- It was suggested to include observation and background error covariance information at observation locations. These could be added as extra fields in the netCDF files if desired.
- It was recommended to show RMSE plots as percentage of the natural variability in order to be able to compare different regions/depths consistently.
- Code to calculate statistics from the class 4 files should be shared and developed communally.

A proposal was made to begin generation of a GODAE OceanView **multi-model ensemble**. There was a general consensus that this should be done. Practical aspects were discussed including:

- It was agreed to provide information on native grid (because we are considering only surface variables this is feasible in terms of amount of data).
- It was agreed to provide analyses and daily mean forecasts out to 6-days of SST, SSS, SSH, surface u and v, and sea-ice concentration and thickness.
- When producing an ensemble we discussed whether the common grid should be at the highest or lowest resolution? It was agreed that the highest resolution grid would be most appropriate in most cases.
- There are issues with interpolation on the fly for some of the model grids used. It was noted that if files are CF compliant then they should contain all the information required to perform the interpolation.

- Groups interested in ensembles in particular areas could develop a regional version of the ensemble in that region, e.g. Gulf of Mexico, EAC.
- The ensemble mean/median should be compared with each forecast product to diagnose where they differ significantly.

The production of **climate indices** from GODAE OceanView systems was discussed. Mercator are involved in the GSOP inter-comparisons and plan to produce various climate indices from their 1/4°- and 1/12°-resolution model, which has proved useful. For a number of the GODAE OceanView systems, the priorities are the class 4 and ensemble inter-comparison projects discussed above. However, it was agreed that we should produce the surface climate indices as part of the multi-model ensemble as a minimum (and interested groups could provide other information if desired).

CLIVAR/GSOP group

Which indices should be assessed for climate monitoring? "State of the ocean" website on OOPC webpage - sub-surface monitoring is largely absent from that website so there should be an agreement to provide information in a NRT fashion. But which metrics?

- Ocean heat content in upper 300m calculated regionally and as maps on monthly time-scales.
- Meridional transports, e.g. AMOC at 26°N. Volume and heat transports.
- Comparisons of analysis of sea level with tide gauges.
- Indices of SSS and upper ocean salinity.
- Surface fluxes?

How and who should do this? Each centre will take on consolidating in gathering the data for one variable:

- BMRC might gather and examine upper ocean salinity from multiple centres.
- NCEP will do upper ocean heat content.
- Mercator could do the tide gauges.
- UReading: collect AMOC and heat transport at 26N on monthly time-scale.

OOPC will try to get the resources if the metrics are sent to them. Each collection centre will write a page on the specific requirements for gathering the data, probably using monthly data feeds.

Timescales are that things should be on-line by May 2012 ready for reanalysis conference and CLIVAR SSG meeting.

5. Summary of outcomes relating to CLIVAR/GSOP

Drafted by Magdalena Alonso Balmaseda

5.1 GODAE OceanView and CLIVAR Intersections

Ocean reanalyses and seamless prediction systems are common ground between the GODAE OceanView and CLIVAR community. The predecessor of GODAE OceanView, GODAE, was concerned with high-resolution, short to medium-range ocean forecasting systems, while CLIVAR was concerned with the role of the ocean in seasonal prediction and climate. GODAE OceanView has continued the GODAE activities and extended to cover ocean reanalyses and seasonal forecasting (which are also CLIVAR interests). Similarly, there is a move within the climate community to adopt higher resolution ocean models, with resolution comparable to some of those in GODAE OceanView. In both CLIVAR and GODAE OceanView communities there is a strong drive towards coupled ocean-atmosphere forecasting systems for the medium range, intraseasonal and seasonal time scales, which fits the paradigm of seamless prediction systems. Therefore, the two communities should share resources such as:

- Development of Data Assimilation (DA) methods;
- Ocean Model development;
- Observational data sets (compilation and quality control);
- Validation Data Sets; and
- Surface Fluxes

There is also room for coordinating activities in the fields of:

- Observing System Evaluation;
- Metrics for validation of (re-)analysis systems;
- Inter-comparison (and ensembles) of reanalysis products; and
- Data repositories

One of the aims of this workshop was to bring the GODAE OceanView and CLIVAR communities together to discuss several of these common areas. Specific issues addressed during the workshop were:

- Development of DA systems;
- Evaluation of the Observing System: existing efforts, methods, metrics, and consolidation; and
- Ocean Re-Analyses: status, evaluation, exploitation

The discussions focused on how to consolidate community efforts on observing system evaluation and provision of useful ocean reanalysis products. The role of the OOPC (Ocean Observation Panel for Climate http://ioc-goos-oopc.org/) as a framework for effective communication between observation providers and users (both CLIVAR and GODAE OceanView community) was also discussed.

The area of ocean-atmosphere coupled forecasting was outside the scope of this workshop, although some references were made to existing efforts. Other topics that appeared briefly in presentations, but were not discussed in the working groups, related to the design/impact of new observing systems and OSSEs. What follows is a summary of the discussions from the working groups on Observing System Evaluation and Ocean Reanalyses

5.2 Discussion on Observing System Evaluation

5.2.1 Inventory of Methodologies

The following methodologies are currently used for the evaluation of the ocean observing system:

- Routine monitoring of observation impact in observation space. This involves diagnostics based on quantities such as FG – O. A good metric that summarizes results and is illustrative enough is needed (to be defined). These diagnostics will tend to underestimate impact of the observing system, since they effect of past observations in the FG is not considered. Results are dependent on the forecasting/analysis system.

- Routine Near-Real Time OSEs: where a parallel analysis system is run in real time withholding different observing systems. For instance, at the UK Met Office FOAM system, a different observing system is withheld every month (see Dan Lea's presentation). These experiments are expensive, and not applicable to seasonal forecasting or ocean re-analysis. Results are dependent on the forecasting/analysis system.

- Delayed mode OSEs, performed for relevant observing systems. They tend to be performed whenever the forecasting/analysis system is changed. They are relatively expensive and not reactive enough. In systems with bias correction, where observations have been used to estimate the bias term, the impact of the observing system may be underestimated. Delayed OSEs are still considered an interesting tool, since they allow a more in-depth analysis of results. Results are dependent on the forecasting/analysis system.

- Automated Routine Diagnostics (such as observation information, observation impact on analysis, observation impact on forecast). These are really desirable, but they are not implemented in all the forecasting/analysis systems. These diagnostics are not applicable to measure impact on seasonal forecasts. Results are dependent on the forecasting/analysis system.

- OSSEs: useful to investigate potential impact and design of new observing systems. They tend to be overoptimistic since it is difficult to represent errors in the model, observation, and data assimilation system, which are often ignored in the OSSEs.

- Observation Footprint (see Peter Oke's presentation): Model and data assimilation independent diagnostics, which can be done by other communities (not only the DA community). They need a large number of observations for a sufficiently long time-period. Independent of forecasting/analysis system.

5.2.2 Diagnostics: How to measure impact?

The impact of the observing system on skill of relevant variables is the ultimate metric, but quite stringent, because forecasting systems are not discerning enough, and long records are needed to establish statistical significance. Some specific high-impact, but infrequent events can be overlooked.

A hierarchy of diagnostics can be established according on whether it is

a) a single case versus multiple cases with statistical significance attached,

b) just a descriptive impact versus providing scientific insight on the reasons and potential consequences,
c) impact on the behaviour only or it is possible to judge the impact on the skill.

An impact that presents statistically significant improvement of the skill with scientific explanation of reasons & potential would be ideal. But if this is not possible, rather than saying this observation does not have any significant impact, it will be better to concentrate on a single case with good scientific justification. In any case, careful interpretation and formulation of results is needed, since the statements can be easily misunderstood.

5.2.3 Community activity for consolidation of observing system evaluation

There is an ongoing activity under GODAE OceanView consisting on the exchange and comparison on quality control (QC) decisions. Different ocean forecasting systems send their QC decisions to the US-GODAE server hosted by NRL on a routine basis. It is recommended that the operational ocean reanalysis join this effort. It is also recommended that the files should include information about the first guess (FG), and possibly the analysis (AN), so information about the FG-O, AN-O can be gathered in the same common repository. The University of Reading can start diagnostics and visualization projects shortly if the data is in a central repository.

Specific actions for the formulation of format, contents and diagnostics have been identified.

It is also recommended to keep a good up-to-date bibliography on Observing System Evaluation in the GODAE OceanView/GSOP web pages. This can be very useful to the observational agencies when needed.

The possibility of issuing Observation Impact Statements (OIS) was discussed. But overall it was considered premature. As mentioned before, the statements can be easily misinterpreted. They also depend very much on the area of benefit.

It was recommended to engage the modelling community, since the observations are not only used for data assimilation but also for model development.

The need for quick and thorough reaction to observing system issues was raised, i.e. the possibility of addressing specific questions posed by the observational agencies at critical times. For instance, can we provide any guidance to the question whether some of the TAO array can be thinned out, and if so, which moorings are less needed?

5.3 Discussion on Exploitation of Ocean Reanalysis products

There is a clear need to exploit the value of the ensemble or reanalysis products, especially those brought up to Near Real Time. It will enhance the visibility of the ocean reanalysis activities, and it will provide some tools for monitoring of the ocean variability at interannual and decadal time scales, as well as a measure of the uncertainty in the estimations.

A viable proposal was put forward based on the criteria of minimum effort rather than a comprehensive solution. The implementation can be improved as time progresses. The participants can change as considered convenient. The idea is to gather ocean re-analyses products in real time aiming at producing a multi re-analyses monitoring system of the ocean variability. This monitoring can have different degrees of public visibility and scientific detail. The most elaborate products will be time-series indices, such as heat content in the upper ocean for different areas, and will be hosted in the OOPC web page. (http://stateoftheocean.osmc.noaa.gov/). This page currently displays SST indices, and observation-only index. It is desirable to enhance it with information about the ocean subsurface from ocean reanalyses. The following procedure is proposed:

1. *Producing centers* to provide routinely relevant information (gridded fields of specific variables) at regular intervals (likely monthly or 3-monthly). The data volumes will be quite limited, and not considered a problem, since in most cases will be monthly values of 2D fields.
2. *Processing centers*, responsible for the processing of a given variable, should gather the information from the different producing centers, process the ensemble of reanalyses and assess its value. If considered that the product is mature enough, produce relevant indices to be displayed at the:
3. *Host website,* which should have high public visibility, and would display selected relevant indices from the ensemble of ocean re-analyses.

Producing centers identified so far are: JMA, NASA-GMAO, NCEP, ECMWF, CMCC, BMRC, Mercator Ocean, CLS, UK Met Office.

Processing centers which have volunteered so far are:

- NCEP for upper ocean (300m) heat content.
- BMRC for salinity
- University of Reading for Atlantic MOC
- Environment Canada for Sea-Ice
- LEGI (Grenoble) for heat fluxes.
- Mercator for sea level?
- CMCC for steric height.

OOPC will act as host center, since it seems to have enough visibility.

The variable which is more mature for public display is ocean heat content, after the work done at NCEP by Yan Xue. The target is to have a live automatic monitoring system in place for one or two variables by mid 2012. A document with timelines and requirements will be circulated.

5.3.1 Metrics

There was little time to discuss metrics in detail. In the past years there has been a proliferation on definition of metrics for different purposes. Sometimes the purpose is not made explicit, which leads to confusion. A very useful metric for a certain purpose (e.g. NINO3.4 SST to validate a coupled forecast) is often not very meaningful for the validation of an ocean reanalysis (since SST are usually well constrained in these products by the input data). There is also the need to distinguish between observable metrics and non observable diagnostics.

Regarding an ocean reanalysis, one could distinguish between two types of metrics:

- Metrics for evaluation of any standard data assimilation system: Background minus Observations (Bm), Analysis minus Observations (AmO), consistency between (a-priori) prescribed background and observation error covariance and (a-posteriori) innovation statistics, number of degrees of freedom, and so on.

- Metrics to evaluate the temporal and spatial consistency of a re-anlaysis product. For this purpose, long time series, preferable of independent data are needed. For instance, the ACDP currents form the moorings, which are usually not assimilated, are very useful to evaluate the quality of the ocean reanalysis. Surface currents which blend altimeter with drifters, even if not completely independent, provide a good data set for spatial and temporal correlation. Sea level from selected tide gauges, properly treated (tide removed, selected according to representativeness of large scale circulation), as those used for the reconstruction of global sea level change, could be useful, but not generally available. Transport measurements are very useful, and can help to improve the assimilation methods. For instance the RAPID derived transports in the Atlantic at 26N.

Some recommended metrics have already been identified in previous community documents: GSOP, GODAE, WGOMD… The inventory is probably too broad, and not targeted enough. Some revision may be needed. But this is a "life" field, which is evolving rapidly. There has been a lot of progress in the last few years. Individual groups pay more attention to the validation of their reanalysis, since a good validation is essential to gain credibility.

6. Summary of discussion on "Community engagement"

Drafted by Kirsten Wilmer-Becker, Gary Brassington

Initial discussion topics

- What is an Observation Impact Statement (OIS)?
  What information should be included?
  How frequently should they be published?
- What common ground do GODAE OceanView and CLIVAR have?
  How can GODAE OceanView and CLIVAR communities help/learn from/work with each other?

6.1. Observation Impact statements (OIS)

The purpose of Observations Impact Statements, or OISs, is to routinely document the impacts of the ocean observing system components on the ocean short, medium and long term forecasts including climate predictions. Adopting the production of regular OISs would not only provide information about the observation system, but would also allow assessing the usefulness and readiness of model/data assimilation systems.

The specification and definition of OIS requires stakeholder involvement (e.g. observation agencies, including both the in-situ and satellite communities) and should not be confused with judgement of observation quality (avoid the negative). Rather, OISs should describe factual differences between the model outputs and observations in observation space. OISs should not be confused with impact studies, which are often commissioned by space agencies, for example, to assess a specific observational infrastructure with regard to specific system limitations, for example.

It was highlighted that it will need time and effort to mature the development of OIS. As described in section 3.3, a number of steps were suggested to move the progress forward for OISs including:

- a summary of the results from NRT OSEs from multiple systems;
- a comprehensive evaluation of each observation platform based on various experiments (e.g., OSEs, DFS, etc Impact study, rather than impact statement);
- a compilation of additional (new) NRT metrics for quantifying the impact of observations.

- Initial options towards the specification of OISs include:
    - Assessment of usefulness of OISs among model/forecast community;
    - Assessment of what model/observations are used/not used by the community (GODAE OceanView/CLIVAR groups);
    - Assessment of impact through case studies (not routinely) – maybe review paper(s) on relevant published impact studies;
    - Run a pure one-off experiment; and
    - Proposal to write a GODAE OceanView report (peer reviewed) on this subject.

- Further steps could include:
    - Define/agree metrics to be used;
    - Use case studies to develop an OIS template;
    - Provide an OIS for special events (e.g. intense observations campaigns); and

- Start reporting on NRT metrics routinely.

6.2. Implications for engagement with stake-holder and policy makers

The challenge to providing useful information (such as OIS) to stake holders requires understanding of the decision processes at policy makers' level and the need for positive and clear messages. Impact studies have substantial limitations, are method-specific and may include numerous assumptions, which make them hard to interpret. OSEs and OSSEs are expensive and difficult to perform due to a limited funding.

It is important to further develop methodologies, but also to critically review all studies/methods for their limitations and to take responsibility of messages/recommendations (e.g., reviews, consolidated statements, etc.) coming from the GODAE OceanView/CLIVAR modelling community.

6.3. Common ground – international communities

Building a stronger relationship between GODAE OceanView and CLIVAR was encouraged, but needs clarification of common points and sharing of methodologies. This workshop allowed the exploration of common questions relating to impacts, but has also shown sufficient differences, providing a good basis for future discussions.

Common ground for GODAE OceanView and CLIVAR could include **intercomparisons** of model forecast system reanalyses. This would help assess system limitations and readiness, as well as assess uncertainties (engagement with modellers to address uncertainty issues). To be prepared to run efficient intercomparisons it was suggested to be more careful on the set-up, to use best practice and to develop a list of principles or guidelines on how to run such experiments. The principles should include improved communication on what is used and more sharing of data online for better understanding of each others systems. OIS could be used as a basis for setting up intercomparisons. With regard to metrics, it was stated that they should be designed to include spread to give information about (their) uncertainty. This could provide a valuable measurement.

GODAE OceanView and CLIVAR are also closing up due to increased resolution used in climate models (eddy resolving) allowing comparisons of transport, model stream function, etc. There is also value in comparing behaviour and differences of a lower to high-resolution models when taken down to lower resolution.

In the long term, engagement with other communities will help to provide higher level of international recognition for observing system requirements. Biogeochemical communities (e.g. IMBER – which are of economical interest) should be targeted for this purpose. The GODAE OceanView Task Team for Ecosystem Modelling and Predictions (MEP-TT) is already considering such involvement. Similarly collaborations with the coastal community (e.g. PICO) should be sought and the GODAE OceanView Coastal and Shelf Seas Task Team (COSS-TT) could provide the link. Joint workshops would be a good way to open discussions with other communities.

It was advised for GODAE OceanView and CLIVAR to review the Essential Ocean Variables (EOV) [see IFSOO proposal for "Framework for Ocean Observing"] for use in operational oceanography, driving their requirements within the observing community. For example engagement with the Glider community may be an opportunity to foster a group representing short to medium range predictions.

It could be beneficial to consider formalising representation of GODAE OceanView with the OSTST, GHRSST, Argo science team and other observing system groups in coordination with JCOMM.

However, there are limitations for responding to requirements related to costs. Enhancement of the observation system, in particular Argo, depends on additional investment, which might be difficult to gather

It was agreed to continue fostering national coordination of stake holders' requirements of ocean forecasting. Although this is a challenge, it could link national efforts into international commons to support the GOOS.

6.4. GODAE OceanView/ET-OOFS

Due to the need of using observational requirements for operational oceanography in a variety of international processes, it is important to provide more robust estimates from impact studies and the GODAE OceanView Task Teams are well placed within this structure. The TTs are encouraged to continue to develop an infrastructure for routine monitoring and intercomparisons and to seek consensus on metrics and reporting. Sharing and publishing the results in collaboration with JCOMM ET-OOFS will provide ways to facilitate web-reporting and implementation into the operational centre guidance.

Appendix

Appendix A: Agenda

2011 GODAE OceanView Technical Workshop on Observing System Evaluation and Inter-comparison

When: 13-17 June 2011

Where: Santa Cruz, CA, USA

Duration: 5-days

Organisers: Oke (co-chair of OSEval-TT, CSIRO), Martin (co-chair of IV-TT, UK Met Office), Balmaseda (CLIVAR-GSOP, ECMWF), Cummings (NRL), Andrew Moore (UCSC, local Organiser), Kirsten Wilmer-Becker (UK Met Office)

Purpose

The purpose of this workshop is to provide a forum for the exchange of ideas on ocean data assimilation and ocean forecasting. The workshop is intended to be a mix of oral presentations, open discussion, and poster presentations. Oral (and poster) presentations will be invited on:

- data assimilation methods;
- observing system evaluation activities (OSEs, OSSEs, etc);
- routine monitoring/validation of ocean analysis and forecast systems;
- inter-comparisons (of short-range and seasonal forecast systems); and
- validation (of forecasts and hindcasts).

Applications of interest include short-range forecasting (GODAE OceanView), seasonal to decadal forecasting (CLIVAR), and reanalyses (GODAE OceanView and CLIVAR GSOP); global and regional applications; in operational and research environments.

Some specific goals of the workshop include:

- demonstration of the value of in situ and satellite observations on short-term, seasonal and decadal forecast systems;
- review and inter-comparison of class 4 metrics from operational short-range forecast systems; and
- linking inter-comparison and monitoring activities within GODAE OceanView to those of CLIVAR.

Expected outcomes of the workshop:

- status report on ocean data assimilation systems
- status reports on OSE and Intercomparison experiments
- updated workplans for OSE and IV Task Teams in GOV
- improved collaborations between GOV and CLIVAR

Day 1 (13 June 2011)

* invited speakers

Introductions (Convener: Peter Oke)		
0900-0920	Peter Oke	Purpose of meeting / meeting forum/ etc
0920-0940	Peter Oke	GODAE OceanView, OSEval-TT and IV-TT
0940-1000	Keith Haines	CLIVAR GSOP
Recent advances in forecasting systems (Convener: Peter Oke)		
1000-1030	Jim Cummings*	Status of Global HYCOM/NCODA Analysis Forecast System
1030-1100	Bernard Barnier*	GLORYS – the French reanalysis effort
1100-1115	***Break***	
1115-1145	Magdalena Balmaseda*	The New ORA-S4 ECMWF ocean reanalysis
1145-1230	Eric Lindstrom, Ed Harrison, Keith Haines, Gary Brassington	→ What the ocean community really needs → What groups make decisions about the GOOS? → How are decisions to change components of the GOOS made? → How can we engage with those groups to help them make informed decisions? → How can the ocean forecasting community best convey relevant findings that have implications for the GOOS to the broader community? → Open Q&A
1230-1400	***Lunch (Put posters up)***	
Posters (Convener: Andy Moore)		
1400-1430	Poster summaries (about 5 min each)	
	Melanie Juza	Contribution of regions not sampled by the Argo array to the variability of the global ocean heat content
	Clement Ubelmann	OSSEs to evaluate the impact of the future SWOT assimilated data in a regional coastal model
	Avichal Mehra	A Real-time Operational Global Ocean Forecast System
	Keith Haines (for Hao Zuo)	Assimilation impacts on Arctic Ocean circulation, heat and freshwater budgets
	Keith Haines (for Vladimir Stepanov)	The impact of EN3 and RAPID data assimilation on the change of heat balance in the Atlantic
	Jiang Zhu	Coupled assimilation of both atmospheric and oceanic observations for ENSO prediction using an intermediate coupled model
Data assimilation methods (Convener: Andy Moore)		
1430-1500	Craig Bishop*	Accounting for ensemble variance inaccuracy with Hybrid Ensemble 4D-VAR
1500-1530	Anthony Weaver*	Using ensembles in variational assimilation
1530-1545	***Break***	

1545-1600	Fabrice Hernandez	The new 1/12° global forecasting system at Mercator in the framework of MyOcean
1600-1615	Terry O'Kane	Predicting the East Australian Current
1615-1630	Isabelle Mirouze	Representation of correlation functions using one-dimensional implicit diffusion
1630-1645	Oscar Alves	Towards coupled data assimilation in an intraseasonal-seasonal ensemble forecast system
1645-1700	Balu Nadiga	Model Bias Correction in Ensemble Ocean Data Assimilation
1700-1730	*Discussion of presentations*	
1730	***Close day 1***	

Day 2 (Tuesday 14 June 2011)

OSEs and OSSEs (Convener: Matt Martin)		
0900-0920	Gilles Larnicol	GOV OSEval Work Plan (OSEs/OSSEs)
0920-0950	Yosuke Fujii*	Ocean Observing System Evaluation for Seasonal/Decadal Prediction
0950-1020	Andy Moore*	Assessing the Information Content and Impact of Observations on Ocean Circulation Estimates using 4D-Var
1020-1045	***Break***	
1045-1100	Peter Oke (for Pavel Sakov)	Metrics for quantifying observation impact in data assimilation: application to the TOPAZ pilot reanalysis
1100-1115	Gilles Larnicol	New diagnostics to assess the impact of satellite constellation for (sub)mesocale applications
1115-1130	Daniel Lea	FOAM observing system evaluation (OSE) experiments in near-real time
1130-1145	*Discussion of presentations*	
1145-1200	Oscar Alves	Salinity initialization and seasonal prediction
1200-1215	Chris Edwards	The UCSC California Current System Data Assimilative Ocean Modeling System
1215-1230	Peter Oke	Design and Assessment of the Australian Integrated Marine Observing System
1230-1240	*Instructions for OSEval breakout session (Peter Oke)*	
1240-1400	***Lunch***	
OSEval – Breakout session • Routine OSEs – assess status and how to improve them; • Techniques for OSE/OSSEs; Is the methodology sound? • Community nature run for OSSEs; • Quantifying the impact of assimilation "bad data"? How do we document bad data (black lists, reports to data providers)?		

• What should be the null hypothesis? Observations are useful unless demonstrated otherwise – or – observations are not useful unless demonstrated? • How to measure impact? Skill scores only, or process studies? Assessing impact of new and future observing systems (planned experiments); • How can the scientific/operational community reach the “policy makers”? What is the role of GOV? ETOOFS? Etc. • Recent literature review (given by nominated participant); Other	
1400-1530	GOV group (Discussion leaders: Peter Oke & Gilles Larnicol)
1400-1530	CLIVAR group (Discussion leaders: Magdalena Balmaseda & Oscar Alves)
1530-1600	***Break***
1600-1700	Plenary Breakout Summaries and Discussion (30 minutes each)
1700	***Close day 2***

Day 3 (Wednesday 15 June 2011)

Inter-comparisons and Validation (IV) (Convener: Magdalena Balmaseda)		
0900-0920	Fabrice Hernandez	GOV IV Work Plan
0920-0950	Yan Xue*	Comparative Analysis of Upper Ocean Heat Content Variability from Ensemble Operational Ocean Analyses
0950-1020	Alexandre Kurapov*	The data assimilation component of the real-time coastal ocean circulation forecast system off Oregon
1020-1045	***Break***	
1045-1100	Tong Lee	Inferring meridional heat transport through meridional volume transport of the AMOC
1100-1115	Clemente Tanajura	A Sensitivity Study of Short-Range Forecasts over the Atlantic METAREA V with HYCOM and the Cooper and Haines Scheme Using Different Sea Surface Heights
1115-1130	Mario Adani	Quality Assessment of a 1985–2007 Mediterranean Sea Reanalysis
1130-1145	Stephanie Guinehut	Combination of in-situ and satellite observations to monitor the Global Ocean State
1145-1200	Gary Brassington	OceanMAPS version 2 – what did we get from this upgrade?
1200-1230	*Discussion of morning presentations*	
1230	***Lunch***	
1330	***Close of day 3***	
Afternoon outing (Golf, Whale Watching, Aquarium, …)		

Day 4 (Thursday 16 June 2011)

<table>
<tr><td colspan="3">Inter-comparisons and validation (IV) (Convener: Jim Cummings)</td></tr>
<tr><td>0900-0915</td><td>Andrea Storto</td><td>The CMCC experience in the context of Global Ocean reanalyses</td></tr>
<tr><td>0915-0930</td><td>Oscar Alves</td><td>An ensemble ocean data assimilation system for seasonal prediction and its comparison with other state-of-the-art ocean reanalyses</td></tr>
<tr><td>0930-0945</td><td>Balakrishnan Nair</td><td>Real-time and delayed mode validation for Indian Ocean Forecasting System (INDOFOS)</td></tr>
<tr><td>0945-1000</td><td>Gregory Smith</td><td>Evaluation of CONCEPTS Ice-Ocean Forecasting Systems</td></tr>
<tr><td>1000-1015</td><td>Santha Akella</td><td>The GMAO Ocean Retrospective Analysis</td></tr>
<tr><td>1015-1030</td><td colspan="2">Discussion of morning presentations</td></tr>
<tr><td>1030-1040</td><td colspan="2">Instructions for IV Breakout session (Matt Martin)</td></tr>
<tr><td>1040-1100</td><td colspan="2">Break</td></tr>
<tr><td colspan="3">Intercomparison and validation – Breakout session
• Validation techniques;
• Links between global and regional forecast systems;
• What is the impact of nesting – what is the relative skill of regional and global models?
• Routine inter-comparisons of forecast metrics and climate indices;
• Monitoring climate; what indices should be used (heat content, thermocline depth, 26D isotherm depth for hurricanes/TCs). How many indices can we digest?
• Should an ensemble approach be used?
• Who is reporting climate indices? How are they reporting? Multi-center indices are likely to have more impact – who will coordinate, disseminate etc.
• Recent literature review (given by nominated participant);
• Other…</td></tr>
<tr><td>1100-1230</td><td colspan="2">GOV group (Discussion leaders: Matt Martin & Fabrice Hernandez)</td></tr>
<tr><td>1100-1230</td><td colspan="2">CLIVAR group (Discussion leaders: Tong Lee & Keith Haines)</td></tr>
<tr><td>1230-1400</td><td colspan="2">Lunch</td></tr>
<tr><td colspan="3">Community Engagement (Convener: Gary Brassington)</td></tr>
<tr><td>1400-1500</td><td colspan="2">Plenary Breakout Summaries and Discussion (30 minutes each)</td></tr>
<tr><td colspan="3">Discussion starters</td></tr>
<tr><td>1500-1510</td><td>Peter Oke</td><td>Observation Impact Statements</td></tr>
<tr><td>1510-1520</td><td>Keith Haines and/or Andreas Schiller</td><td>GODAE OceanView and CLIVAR working together</td></tr>
<tr><td>1520 - 1550</td><td>Eric Lindstrom</td><td>Framework for Ocean Observing</td></tr>
<tr><td>1550-1600</td><td colspan="2">Instructions for Community Engagement Breakout session (Gary Brassington)</td></tr>
<tr><td>1500-1630</td><td colspan="2">Break</td></tr>
<tr><td colspan="3">Community Engagement – Breakout session
• What is an Observation Impact Statement? What information should be included? How frequently should they be published?
• What common ground do GOV and CLIVAR have? How can GOV and CLIVAR communities</td></tr>
</table>

	help/learn from/work with each other?
1630-1730	Group A: Mixed GOV/CLIVAR group (Discussion leaders: Gary Brassington & Ed Harrison)
1630-1730	Group B: Mixed GOV/CLIVAR group (Discussion leaders: Hans Bonekamp & Eric Lindstrom)
1730	***Close day 4***
19:00	***Dinner – Ideal Bar & Grill, 106 Beach Street, Santa Cruz***

Day 5 (Friday 17 June 2011)

Summary Session (Convener: Peter Oke)		
0900-1000	Plenary Breakout Summaries and Discussion (30 minutes each)	
1000-1030	Gary Brassington	Implications for engagement with stake-holders and policy makers
1030-1100	***Break***	
1100-1130	Peter Oke	GOV OSEval outcomes
1130-1200	Matt Martin	GOV IV outcomes
1200-1230	Magdalena Balmaseda	CLIVAR GSOP outcomes
1230-1300	Kirsten Wilmer-Becker	Meeting Report summary and adoption
1300	***Meeting closed***	

Appendix B: Participants list

First name	Surname	Affiliation
Mario	Adani	INGV
Santha	Akella	NASA/GSFC/GMAO
Oscar	Alves	CAWCR/Bureau of Meteorology
Magdalena	Balmaseda	ECMWF
Bernard	Barnier	LEGI-CNRS Grenoble
Eric	Baylor	NOAA/NESDIS/STAR
Craig	Bishop	NRL
Hans	Bonekamp	EUMETSAT
Gary	Brassington	Bureau of Meteorology
Jim	Cummings	NRL
Chris	Edwards	UCSC, USA
Jerome	Fiechter	UCSC, USA
Yosuke	Fujii	MRI
Stephanie	Guinehut	CLS
Gigab	Ha	Kesti, South Korea
Keith	Haines	Reading University, UK
Ed	Harrison	NOAA/PMEL
Fabrice	Hernandez	IRD/Mercator Ocean
Pat	Hogan	NRL
Melanie	Juza	CNES-INSU
Jason	Joh	Kesti, South Korea
Alexandre	Kurapov	Oregon State University
Gilles	Larnicol	CLS
Daniel	Lea	Met Office
Tong	Lee	JPL/NASA, USA
Eric	Lindstrom	NASA, USA
Matt	Martin	Met Office
Avichal	Mehra	NCEP/NWS
Isabelle	Mirouze	CERFACS
Andrew	Moore	UCSC, USA
Balu	Nadiga	Los Alamos National Lab (LANL)
Balakrishnan	Nair	INCOIS, India
Terence	O'Kane	CSIRO, Australia
Peter	Oke	CSIRO, Australia
Andreas	Schiller	CSIRO, Australia
Gregory	Smith	Environment Canada
Kevin	Smith	UCSC, USA
Polly	Smith	UCSC, USA
Hajoon	Song	UCSC, USA
Andrea	Storto	CMCC. Italy

Clemente	Tanajura	UFBA
Clement	Ubelmann	CALTECH/JPL
Anthony	Weaver	CERFACS, France
Kirsten	Wilmer-Becker	Met Office
Yan	Xue	Climate Prediction Center/NCEP
Jiang	Zhu	IAP/CAS, China

Appendix C: Actions

1. Near-real time OSEs

Action 1.1: Oke and Martin in collaboration with the GODAE OceanView IV-TT to agree on what fields should be stored for each NRT OSE.

Action 1.2: All NRT OSE participants to be led by Lea: Reach agreement on how NRT OSEs should be evaluated. It was noted that traditional methods for evaluation a system's performance, e.g. global averaged root-mean-squared errors are often too imprecise to identify the true regional impacts of with-holding different data types – particularly those data types that are relatively few in number (e.g., XBT data)

Action 1.3 Wilmer-Becker to implement OSEval-TT website information on GODAE OceanView website (OSEva-TT pages).

Action 1.4 Brassington to investigate/suggest **a** common toolbox which could be used for evaluating NRT OSEs, as it would be beneficial and would better utilised our limited resources.

Action 1.5 Brassington to contact e.g. JCOMM/OPA (or other data providers) to investigate what format would be needed to report bad data.

Action 1.6 Larnicol to suggest a new schedule for NRT OSEs , which should be established soon. The new schedule will repeat on a 7-8 month cycle to avoid performing equivalent NRT OSEs at the same time each year (should NRT OSE activities continue for several years).

Action 1.7 All workshop participants to report to Oke and Larnicol when what type of "nature runs" are planned.

Action 1.8 Oke to organise an email list of participating groups/contacts so that we can communicate details of the NRT OSE plans to participants; including modifications to the schedule that may arise in response to observing system events (e.g., when a new data stream, like CRYOSAT, become available).

Action 1.9 Oke and Larnicol to define how the information coming from routine monitoring should be synthesised to be provided as Observation Impact Statements (OISs).

Action 1.10 All participating groups (as listed below) to consider contributing/taking part in future NRT OSEs:

- UK Met office: intend to continue to perform NRT OSEs;
- Mercator Ocean: intend to perform NRT OSEs (for one forecast cycle each month), beginning some time in the second half of 2011;
- Bureau of Meteorology: intend to perform NRT OSEs, beginning some time in the second half of 2011;
- MFS (Mediterranean): may be able to perform NRT OSEs beginning 2012.
- NMEFC (China): intend to perform NRT OSEs, beginning in 2012;

- UCSC ROMS: may be able to start performing NRT OSEs, some time in 2012;
- OSU ROMS: regularly perform delayed-mode OSEs, but are not resourced to perform NRT OSEs;
- C-NOOFS (Canada): may begin performing NRT OSEs, beginning some time in 2012;

2. Provision of Observation Impact Statements (OISs) actions

Action 2.1 Martin and Oke to develop a proposal for OIS for GODAE OceanView Patrons group.

Action 2.2 Oke and Larnicol to evaluate the feasibility of compiling a series of review articles to describe the impact of different observation platforms on GODAE OceanView analysis and forecast systems (see option 2, "Observation Impact Statements (6.1)".

Action 2.3 Oke and Larnicol to propose a process to deliver the GODAE OceanView -OISs to the observation agencies (e.g., collect reports from forecast/analysis centres, or compile reports based on results obtained from forecast/analysis centres; and delivery reports to GODAE OceanView co-chairs and GODAE OceanView patrons for peer review).

Action 2.4 Schiller and Dombrowsky to consider whether GODAE OceanView has a sufficient presence at OOPC, Argo Science Team; OSTST, DBCP, and GHRSST meetings.

3. Intercomparison and validation TT

Action 3.1 Martin and Hernandez to update the class 4 inter-comparison proposal document

Action 3.2 Martin to distribute code to produce class 4 files and to calculate statistics from them

Action 3.3 All GODAE OceanView system representatives to begin sending class 4 files to the US GODAE server routinely.

Action 3.4 Martin and Hernandez to produce a document describing the proposed multi-model ensemble system.

Action 3.5 Martin, Hernandez and system representatives to work out the data size requirements for the Class 4 files and multi-model ensemble fields and send information to Jim Cummings

Action 3.6 Martin, Hernandez and Wilmer-Becker to produce a twiki page to share information on the class 4 and ensemble work.

Action 3.7 Martin, Hernandez and system representatives to investigate how GODAE OceanView systems can contribute to the climate indices initiative of GSOP *– please also see action 4.7*

Action 3.8 Martin and Hernandez together with Balmaseda to think about how the GSOP systems can be included within the inter-comparison of assimilation statistics and QC.

Action 3.9 Martin and Hernandez to update the IV-TT work plan to reflect the new initiatives on the multi-model ensemble and production of climate indices

Action 3.10 Martin to discuss including the plan for GODAE OceanView/CLIVAR community to work towards multi-model ensemble to be added to the GEO sub-task on “promoting the use of ensemble forecasting outside the weather forecasting community”.

4. ***GSOP/CLIVAR***

Action 4.1 Martin, Hernandez, Cummings and Balmaseda to agree on contents and format for the QC and FG/AN –OBs (FB) and to invite reanalysis groups to send data to the GODAE US repository.

Action 4.2 All to send relevant data to the GODAE US repository

Action 4.3 Haines to continue diagnostics on QC decisions

Action 4.4 Haines to start diagnostics on FG-Obs

Action 4.5 Wilmer-Becker, Caltabiano and all to build/keep a good up to date bibliography on Observing System Evaluation on GODAE OceanView/GSOP websites.

Action 4.6 Xue (HC), Alves (salinity), Haines (MOC), Barnier (surface fluxes), Smith, G, (Sea-Ice) to draft document on data requests from reanalysis groups for Routine monitoring

Action 4.7 Harrison, Xue and Haines to agree on minimum set of indices to display in OOPC web-pages *– please also see Action 3.7*

Action 4.8 All Producing/Production Centres to send data to the processing centers (please see further details in chapter *5.4 Discussion on Exploitation of Ocean Reanalysis products* (28/29)

Action 4.9 Larnicol to contact Sea Level community to recommend a good quality subset of tide gauges for reanalyses validation (AVISO SL very valuable but short)

Appendix D: Presentations notes (in order of agenda)

Day 1 – Introduction and advances in ocean forecasting systems

Peter Oke (on behalf of **Andreas Schiller**) provided an overview of previous inter-comparison work within GODAE. He emphasised the need to produce information in such a way to make it easy for non-specialists to understand.

Keith Haines described the Integrated Framework for Sustained Ocean Observations (IFSOO). Integrated Climate Data Centres produce synthesis products which provide a mechanism for getting the information from observations to the users. In order for the users (and observation community) to make best use of this information we need to understand the "readiness for use" of these synthesis products. There is also a need to define synthesis metrics, based on the Essential Ocean Variables (EOV), and to decide who they are for and how to promote them. Formats of synthesis products should be based on CMIP5.

The main type of metrics and their relevancy for GODAE OceanView and GSOP are:

1. Technical metrics (assimilation stats, common GSOP/GODAE OceanView)
2. Prediction applications (skill metrics, common GSOP/GODAE OceanView) for coupled predictions (seasonal/decadal), ocean skill and atmospheric skill.
3. Real-time monitoring applications: climate mode phases (PDO, ENSO, NAO, …), transport indices (AMOC).
4. Climate quality reconstructions: for detection/attribution (heat content, water mass properties), integrated quantities which can't be measured directly by observations, establish natural variability baselines.

The technical (assimilation stats) metrics can be used to measure the readiness of the systems for assessing the other types of metrics. Various examples of these assessment metrics were given from a GSOP perspective.

There is interest in agreeing common methods and goals between GODAE OceanView, GSOP and OOPC.

Pat Hogan and Jim Cummings assessed and inter-compared various aspects of the 1/12° and 1/25° HYCOM/NCODA systems:

- Tides using the tide gauges as reference.
- Altimetry-based analysis of the internal tide (sampling the model in the same way as the data).
- Inter-compared the two resolutions without data assimilation and looked at the separation of the western boundary currents which are better in the 1/25° model and variability of SSH better.

They plan to run 4 experiments inter-comparing different aspects of the data assimilation scheme: MVOI vs. 3DVar, impact of ISOP (improved synthetic ocean profiles) and CICE (ice model), all at 1/12° resolution. For this inter-comparison they are assimilating velocity data (drifters, gliders, Argo trajectories are assimilated), so using HF radar data which as an independent reference. They are investigating assimilation of radiances directly which implies that assessment of SSTs may be more difficult.

They perform real-time verification using class 4 metrics for Argo, SST, SSH which can be made available in GODAE OceanView inter-comparison.

Bernard Barnier showed various assessments of the GLORYS reanalysis including:

- Convection in Labrador Sea: MLD with and without data assimilation (model has a too deep ML and DA shallows it)
- EOFs of the temperature increments in order to determine model error. He ascribed particular patterns to dynamical phenomena (Irminger Eddies, convective eddies, boundary currents).
- Trends and variability of the heat content.
- Compared AMOC to RAPID data (more variability in model than the RAPID data).
- Heat transport diagnostics.
- Sea-ice assessment in the Arctic, focusing on 2007 sea-ice minimum.
- RMSE and bias of (o-b) for SSH and T, S profiles.
- Various GODAE metrics including differences to climatology (class 1), trends in SST, heat content and SL, compared to RAPID AMOC data.

He mentioned that within MyOcean there will be an inter-comparison of various global reanalyses (Mercator/Drakkar, UoR, CMCC).

He noted that it was the first time using GODAE metrics and found them very useful.

Magdalena Balmaseda assessed the new ECMWF ocean reanalysis system and described the pros and cons of various ways of assessment:

- Assimilation metrics (fit to observations, error growth, consistency of B and R) are insufficient for an overall assessment
- Spatial/temporal consistency compared to current moorings, OSCAR currents, transports are useful but there are limited independent data.
- Skill of seasonal forecasts is expensive and model error complicates this method

The methods used for assessment of OSE runs were:

- RMS of (o-b) for T+S and T+S+Alti runs.
- Correlations with altimeter data
- Skill of seasonal forecasts of SST (ACC vs f/c time)
- Depth of 20° isotherm
- Regional (o-b) stats using the GSOP regions.
- Normalised temperature profile RMSE (normalized by the RMSE of the reference run) to produce relative RMSE at different depths.
- Upper ocean heat content for various depth ranges.
- Impact of assimilation on the representation of the AMOC
- Hovmuller diagrams of AMOC at various depths which shows the deep MOC (at 3000m) has a decadal signal

The **panel discussion (see also 2. Observing system requirements)** made various important points related to inter-comparison and validation:

- The impact of global ocean on coastal waters is crucial for national funders.
- We need to assess the maturity of the OOFS to judge whether the results of OSEs are robust.
- We need to expand the disciplines to get this improved, i.e. short-range forecasting, biological applications.

- IFSOO has defined some EOVs which are related to the ECVs (following the model of GCOS)
- We need to advocate the usefulness of synthesis products
- We need a standard framework for communicating results
- Good communication between OOPC and the GODAE OceanView/GSOP community needed in order for the OOPC to request information.
- Specific phenomena would have more impact with funders than global statistics.
- Need to persuade national funders of importance of GOOS as they are ultimately the ones which fund it.
- The use of relative errors (with respect to the anomalies to be estimated), is more useful than absolute errors.

The **posters** included various inter-comparison and verification aspects:

- Melanie Juza: Heat content variability from Argo sampling was compared to global ocean estimates from a model.
- Clement Ubelmann: Assessed potential impact of SWOT data including the mesoscale and sub-mesoscale.
- Avichal Mehra: Gulf Stream location verification of 1/12 HYCOM and statistical verification of location of features (e.g. eddies).
- Keith Haines/Hao Zuo: Verification of Arctic Ocean circulation in NEMO reanalysis. Additional Arctic data collected. Investigated heat budget verification.
- Keith Haines/Vladimir Stepanov: North Atlantic comparison using RAPID AMOC data.

Craig Bishop discussed a new analytic model of the distribution of true error variances given an imperfect ensemble variance. In this model, hybrid error covariance models that linearly combine ensemble and static variances are more accurate than either the ensemble variance or the static variance. He then showed how the new theory could be used to regionally tune weights for a Hybrid 4D-VAR data assimilation scheme.

Fabrice Hernandez assessed the Mercator ocean ¼° and 1/12° systems, including calculating (o-b) stats (RMSE and bias)**.** Mercator plan to contribute to the NRT and delayed-mode inter-comparison projects.

Balu Nadiga investigated forecast skill in an ensemble system, partly by comparing spread in the ensemble with the RMSEs of the mean.

Day 2 – Continued advances in ocean forecasting systems and data assimilation

Gilles Larnicol said that Cryosat ocean data has been requested from ESA which will provide a useful assessment/assimilation data-set.

Yosuke Fujii presented results of assessing various coupled seasonal and decadal prediction OSE experiments. He measured impacts as a ratio of the reduction in RMSE for different variables. Coupled model biases are a problem for assessing impact of observations on seasonal forecasts. Impact on seasonal forecasting is very important as it is a very influential product of observational data.

Andy Moore presented results from assimilation runs in 10km and 30km ROMS using 4DVar with a 7-day assimilation cycle. Marine mammal data off California coast is not available in EN3 (or on GTS). Dan Costa provided it to them. Presented methods for observation impact studies. Assessed the impact of the data on transport along a particular section.

Peter Oke/Pavel Sakov presented a reanalysis from the TOPAZ system (particularly interested in Arctic Ocean and sea-ice). Ensemble spread plus the assumed observation error should equal the RMSE of the innovations.

Gilles Larnicol investigated the impact of SWOT and other satellite altimeters on objective analysis system using OSSE set-up. Assessed the reconstruction error as % of signal variance. Looked at Lyapunov exponents to show the scales which are reconstructed by the objective analysis.

Daniel Lea assessed some NRT OSEs with FOAM using (o-b) RMS and bias, and looking at the impact of the observations on the model fields.

Oscar Alves investigated the impact of Argo salinity data on PEODAS. He looked at how T and S perturbations evolve in the forecast on the equator. T errors generate Kelvin waves and dissipate. S errors result in a local S and T error.

Chris Edwards presented the ROMS system and showed that high resolution forcing has large impact for regional modeling studies. He investigated errors of 2-week forecasts for SST, salinity profiles by comparing to the observations.

Peter Oke investigated data impacts using an analysis based only on data. He assessed the ability of the observations to reconstruct intraseasonal (<60 days) and interannual (>14 months) timescales for coastal observations. This was done by computing spatial correlations for observations of SST and SSH.

<u>**Day 3-Intercomparisons**</u>

Fabrice Hernandez presented an overview of the IV-TT work plan which includes:

- Inter-comparisons, both of class 4 metrics and of climate indices
- New validation methodologies
- The possibility of producing multi-model ensembles
- Links with OSE-TT and ETOOFS

Various national work plans include an interest in the inter-comparisons which are planned. A forecast assessment inter-comparison has been proposed with a detailed proposal document available. This type of class 4 validation is carried out at various centres, and an example from the Mercator system was shown. There are clear links with the OSE-TT and a potential link with seasonal forecasting groups through calculation of climate indices.

Yan Xue presented a detailed comparison of upper ocean heat content (over the top 300m, called HC300) variability from different operational ocean analyses. The questions addressed by the study included:

- How well is the mean HC300 analysed?
- What are the impacts of changes in the observing system?
- How well do the reanalyses capture inter-annual and multi-decadal variability?
- What climate indices should be monitored?

- What is the role of HC300 on predictability of ENSO, PDO, NAO, …?

Mean heat content from each of the systems was compared to the EN3 objective analysis. The spread of the ensemble of reanalyses was largest in the Southern Ocean and Western boundary currents. RMS differences from EN3 were calculated in different basins as time-series for all analyses. During the Argo period the various analyses are closer to each other in the Trop. Pacific, Indian Ocean and Southern Ocean.

Hovmoller plots of HC300 in various regions were generated. The results in the equatorial Pacific highlighted the impact of the TAO array (shown as a decrease in the spread of the analyses). The Argo impact could be seen in the equatorial Indian Ocean and the equatorial Atlantic.

Anomaly correlations with EN3 as global maps were plotted which showed low correlations in Southern Ocean and western boundary currents and a large spread in the Equatorial Atlantic.

Anomaly correlations with OI SST in the equatorial regions showed larger correlations in E. Pacific (El Nino), the Indian Ocean Dipole and Atlantic Nino. Subtropical N. Atlantic has high correlations between SST and HC300 perhaps due to hurricanes.

Average correlations between SST and HC300 in Nino boxes were calculated with correlations of about 0.8. Correlations of ~0.4-0.6 were observed in the Western Pacific and Eastern Atlantic, and were lower in the S.E. Indian Ocean.

Anomaly indices were calculated for ENSO, IOD (Indian Ocean Dipole) and Atlantic Nino. The various systems agree well in the Tropical Pacific regions with more spread in the IOD regions. Atlantic Nino spread is even larger (signal to noise ratio of 1.3) and has higher frequency signals. A warming trend in the last ten years in the Atlantic Nino region was evident.

The linear trend of HC300 anomaly from 1993-2009 from the mean of the analyses was calculated.

Lagged correlations between HC300 and SST are strongest in the NINO3.4 region. They were also significant in the Atlantic Nino and IOD regions. There was generally good agreement north of 30S except some regions with the Atlantic having large differences between the analyses.

A question was raised whether it is a good idea to use the EN3 objective analysis as a reference for these inter-comparisons.

Alex Kurapov described the Oregon coastal forecast system which is based on ROMS with 4DVar used to assimilate HF radar, SLA, SST. The validation methods used included:

- Data denial experiments (OSEs)
- Interpretation of dynamical structures
- Data assimilation information, e.g. looking at the increments.

Various runs (free run, SSH assimilated, SSH and SST assimilated) were compared to satellite SST data and RMSE and correlations were calculated.

Less data at below the surface is available in coastal regions. Results were compared to some CTD data.

The impact of assimilation on volume-integrated heat content was assessed in a particular 3D box and various contributing terms (advective, fluxes, data assimilation impact) compared. Data assimilation corrections are of the same order of magnitude as the other terms in the heat balance equation.

Tony Lee presented the use of a method to assess meridional heat transport (MHT) using meridional volume transport (MVT) estimates of the AMOC from various ECCO (ECCO-JPL, ECCO2 and GECCO) reanalyses and observations such as RAPID/MOCHA.

MHT is a more climate-relevant quantity than MVT. MVT and MHT have high correlation so using a linear regression and assessing ECCO-JPL, ECCO2 and GECCO reanalysis products.

The anomaly of MVT from RAPID has a strong relationship with models except for particular issues with the data (due to missing cable measurements).

Correlations of MVT to MHT agree between RAPID and ECCO models.

Regressions of MVT and MHT were calculated for different time-scales (monthly and 2-yearly). A different relationship exists at the two time-scales because the longer time-scales remove the impact from the Ekman component on the vertical T gradients.

The latitudinal variation of MVT/MHT correlations and regressions were used to determine where an array should be placed to best determine the MHT. 26N is a good location but more information might be extracted if placed at 15N. For the South Atlantic it would be good to do measure the MVT at 35S.

Might not be a good method for capturing the decadal variations like this so good to measure temperature as well as MVT, e.g. Argo.

B. Barnier suggests using isopycnals rather than depth analysis.

Clemente Tanajura presented an overview of the REMO system which uses HYCOM in the Atlantic region and a Cooper and Haines scheme to assimilate SSH fields. The ¼ Atlantic model and 1/12° Brazilian region model have been set up using HYCOM and higher coastal models using ROMS. He would like to develop routines to validate the models and forecasts to compare with the other GODAE OceanView systems.

He compared results from a 60-day period to Argo data using 24-hour forecasts.

Taylor diagrams were used in different depth ranges for Argo comparisons (0-2000m, 0-100m, 125-800m). Comparisons with PIRATA data were performed for different forecast lengths out to 7 days.

Mario Adani presented an assessment of two Mediterranean Sea reanalyses (with different data assimilation schemes) from 1985-2007. Various diagnostics were investigated including Mediterranean volume temperature, and contributions from advection/diffusion, solar radiation and relaxation to SST terms. RMS and mean (o-b) statistics were calculated and displayed as depth/time plots for T and S profiles in particular regions. SLA statistics were also calculated. The mean circulation at 15m and 200-300m was assessed.

Stephanie Guinehut described a method for estimating 3D T/S/u/v from only observations and statistical methods (called ARMOR3D), which is complementary to DA/model techniques. This uses T/S profiles, drifters, SST, SSH data from 1993-2009 to calculate weekly 3D fields. T variability from 2004-2008 was compared as global zonal averages from various reanalyses (ARMOR, SCRIPPS and SODA and with a synthetic estimate from altimetry only). All T estimates agreed quite well while S variability is quite different between the estimates. Geostrophic currents were validated at 1000m using the ANDRO database based on Argo trajectories. The meridional component was plotted as an example on a Taylor diagram.

Currents were also compared with ADCP data from a cruise off Cape of Good Hope for a one month period. They were also compared to RAPID current-meter data at 25.5N, 76.5W.

The AMOC at 25N was calculated and compared to Bryden estimates, and at 26.5N compared to RAPID MOC.

The outputs would be useful for inter-comparison exercises as a model-independent estimate.

Gary Brassington presented results of an assessment of the new version of the Bluelink operational system. Various changes have been made including:

- Latest version of MOM
- Similar resolution as previous model. Slightly different vertical grid.
- A new bathymetry.
- More members in ensemble used in BODAS.
- New initialization (adaptive nonlinear initialization).
- Forcing based on UM
- Using NAVOCEANO SSTs.

Time mean SLA increments showed large biases in the Southern Ocean in both new and old systems. New fluxes may be causing some biases in the Southern Ocean.

Results were assessed using (o-b) and (o-a) RMSE. New system is improved in both RMS and bias compared to SLA data.

Forecasts were compared to data and statistics were plotted as a function of lead time (for RMSE and ACC). Similar diagnostics for SST were also presented including a comparison with persistence.

Day 4- OSEs and OSSEs

Andrea Storto presented an assessment of a reanalysis performed at CMCC. Verification against TAO and RAMA profiles. Impact of various observation types calculated by comparing diagnosed forecast error covariance matrices so that they could be looked at in full model space. They were computed as forecast errors over various lead-times out to 15-days for Argo, Buoys, SLA, SST, CTDs, XBTs. Also as a function of depth in different regions. Also assessed salinity stats in the same way. Compared to observed SSTs as well. Looked at RMSD for CTD obs at 200m for impact of SLA data on their new reanalysis.

Oscar Alves presented an assessment of the new PEODAS system including forecast skill assessment and comparison with other centres. Compared to EN3. Looked at NINO3 and IOD forecast skill of SST anomaly correlations out to 6 months. Assessed heat content and salt content forecast skill in the Tropics out to 9 months. Then assessed T and S forecast skill at 3-months lead time as a function of depth along the equator, and investigated various analyses for doing the validation (new, old analyses and observations) which had a large impact. Noted the need to be careful about what is used as a validation data-set when using analyses for validation. Inter-compared heat content down to 300m with ECMWF as correlations with EN3. Also looked at correlations of surface currents with the OSCAR analysis. Showed Hofvmuller plots of heat content and surface salinity along the equator to show El Nino, and compared PEODAS with ECMWF and NCEP which were generally similar for temperature but more differences for salinity. Also did this in the IOD region with similar results.

Balakrishnan Nair presented an overview of the Indian Ocean forecasting system INDOFOS. Using ROMS for global, regional and coastal forecasting. Have very large numbers of users (over 100,000 per year). Validation of coastal significant wave height against buoy data, and mean wave direction and period. Also validated wave height against Aviso altimeter data. They perform real-time validation of wave heights. Plotted Taylor diagrams of wave heights compared to buoys.

Intercompared wind speeds with ECMWF and validated against surface ships, for analyses and forecasts. For ROMS, they assessed SST forecasts compared to buoys, also the depth of the 20°C isotherm, mixed layer depth. Validated against Argo and GHRSST products.

Gregory Smith presented an evaluation of the CONCEPTS ice-ocean forecasting systems (regional and global). Looked at a coupled regional system which showed significant improvement in temperature forecasts – air/sea-ice coupling very important to get correct fluxes. For ocean forecasts they have global ¼° and regional 1/12° systems. Looked at comparison with AVHRR SST observations for a one-year period: global plots of mean and standard deviations at different lead times. Noticed a warm bias in the equatorial Pacific and a cold bias in the polar regions (south and north) which is due to the RTG analysis which is assimilated. Changed this to assimilate the CMC analysis which significantly improved the comparison to AVHRR SST data. Produce a sea-ice analysis using SSM/I, AMSRE, ice charts, RadaraSAT data. Verified this against NOAA IMS analyses (ice or no-ice) and produced a contingency table analysis. This showed large differences in the open water areas, but not so much where ice already existed. They did an inter-comparison with the Mercator analyses for surface properties: SSH differences were small but SST differences were as expected, but the SSS had very large differences (mainly due to different fluxes and multi-variate error covariances) which implies the Argo S data can't constrain SSS. Evaluated long-range (30-day) forecasts of ice by comparing to Radarsat data (mean and standard deviation). Small-scale details, e.g. ice leads, which are in the Radarsat data are not in exactly the correct place in the model – this increases the large stdv. For regional system (CNOOFS) they compared bottom temperatures with data, and with the global model. They are producing a high resolution regional system over the Arctic region. They are interested in improving diagnostics for the marginal ice zone.

Santha Akella presented an assessment of the GMAO retrospective analysis which is a coupled ocean-sea-ice-atmosphere model, with an EnOI assimilation method. Sea-ice concentration assimilation is used to update the T and S fields in the mixed layer. Assessed the sub-surface reanalysis by comparing analysis and forecasts to Argo, CTD and XBTs separately as a function of depth, for T and S. Compared equatorial Pacific currents with ADCP measurements on TAO moorings. Assessed monthly mean sea-ice concentration with the NSIDC analysis. Ice thickness was compared to Icesat thickness data for annual means during 2004-2008. Looked at heat content (upper 300m) compared to EN3 (both corrected for XBTs and uncorrected). Heat content anomalies as a time-series in Nino boxes also assessed. Compared to sea level from tide gauges.

Keith Haines showed an inter-comparison of the QC decisions made by the operational centres for Argo data. (BMRC, FNMOC, MEDS, UKMO)

Framework for Ocean Observing

Eric Lindstrom presented the plans for setting up the IOC Framework for Ocean Observing, initiated following OceanObs 09, by making better progress in fully implementing and sustaining the observing system (physical, bio, biogeochem) through commitment of all nations/communities driven by scientific and societal needs. Using "Essential Ocean Variables (EOV)" was promoted as a common language that would add another level to communication specifying requirement (and achievements) with observing agencies, governments or end users. The current observing system is mainly built on the back of the research communities, but operational and research requirements should not be separated. The framework needs to be build around a sustainable system, covering all needs. Assessment of "readiness" [applying to all - requirements, observations and products] is based on feasibility and impact and integrates the R&D activity into the framework.

Appendix E: Presentations

* Invited speakers

Introduction presentations

Topic	Presenter	Download
Purpose of meeting / meeting forum etc.	Peter Oke, CSIRO	ppt (0.5 MB)
GODAE OceanView, OSEval-TT and IV-TT (Andreas Schiller)	Peter Oke, CSIRO	ppt (10 MB)
CLIVAR GSOP	Keith Haines, University of Reading, ESSC	pdf (2 MB)

Recent advances in forecasting systems

Presentation title	Presenter	Download
NCODA Variational Ocean Data Assimilation System	Jim Cummings*, NRL	ppt (13.5 MB)
U.S. Navy Global Ocean Prediction Update	Pat Hogan, NRL	ppt (9 MB)
GLORYS - The French reanalysis effort	Bernard Barnier*, LEGI-CNRS	ppt (24 MB)
The NEW ORA-S4 ECMWF ocean reanalysis	Magdalena Balmaseda*, ECMWF	ppt (4.5 MB)
Contribution of regions not sampled by the Argo array to the variability of the global ocean heat content	Melanie Juza, CNES-INSU (poster presentation)	pdf (0.2 MB)
OSSEs to evaluate the impact of the future SWOT assimilated data in a regional coastal model	Clement Ubelmann, CALTEC/JPL (poster presentation)	PDF
A Real-time Operational Global Ocean Forecast System	Avichal Mehra, NCEP/NWS (poster presentation)	ppt (2.5 MB)
Assimilation impacts on Arctic Ocean circulation, heat and freshwater budgets	Hao Zuo, University of Reading, ESSC (poster presentation)	pdf (3.2 MB)
The impact of EN3 and RAPID data assimilation on the change of heat balance in the Atlantic	Vladimir Stepanov, University of Reading, ESSC (poster presentation)	pdf (0.2 MB)
Coupled assimilation of both atmospheric and oceanic observations for ENSO prediction using an intermediate coupled model	Jiang Zhu, IAP/CAS (poster presentation)	gif (0.2 MB)

Data assimilation methods

Presentation title	Presenter	Download
Accounting for ensemble variance inaccuracy with Hybrid Ensemble 4D-VAR	Craig Bishop*, NRL	ppt (7.5 MB)
Using ensembles in variational assimilation	Anthony Weaver*, CERFACS	pdf (0.5 MB)

The new 1/12° global forecasting system at Mercator in the framework of MyOcean	Fabrice Hernandez, Mercator Ocean	ppt (80 MB)
Predicting the East Australian Current	Terry O'Kane,CSIRO	pdf (5.5 MB)
Representation of correlation function using one-dimensional implicit diffusion	Isabelle Mirouze, CERFACS	pdf (1.5 MB)
Towards coupled data assimilation in an intra-seasonal ensemble forecast system	Oscar Alves, CAWCR	ppt (3 MB)
Model Bias Correction in Ensemble Ocean Data Assimilation	Balu Nadiga, Los Alamos National Laboratoy	pdf (7.5 MB)

OSEs and OSSEs

Presentation title	Presenter	Download
GODAE OV OSEval Work Plan (OSEs/OSSEs)	Gilles Larnicol, CLS	ppt (0.5 MB)
Ocean Observing System Evaluation for Seasonal/Decadal prediction	Yosuke Fujii*, MRI/JMA	ppt (10 MB)
Assessing the Information Content and Impact of Observations on Ocean Circulation Estimates using 4D-VAR	Andy Moore*, UCSC	ppt (3 MB)
Metrics for quantifying onservation impact in data assimilation: application to the TOPAZ pilot reanalysis	Peter Oke (for Pavel Sakov), CSIRO	ppt (4 MB)
New diagnostics to assess the impact of satellite constellation for (sub)meso-scale applications	Gilles Larnicol, CLS	ppt (3.5 MB)
FOAM observing system evaluation (OSE) experiments in near-real time	Daniel Lea, Met Office	ppt (17 MB)
Salinity initialisation and seasonal prediction	Oscar Alves, CSIRO	ppt (2 MB)
The UCSC California Current System Data Assimilative Ocean Modeling System	Chris Edwards, UCSC	pdf (2 MB)
Design and Assessment of the Australian Integrated Marine Observing System	Peter Oke, CSIRO	ppt (4 MB)

OSE/OSSE Breakout Summaries

Topic	Presenter	Download
GODAE OceanView aspects	Peter Oke, CSIRO (oral presenation)	ppt (0.2 MB)
CLIVAR aspects	Magdalena Balmaseda, ECMWF (oral presenation)	ppt (0.1 MB)

Inter-Comparisons and validation (IV)

Presentation title	Presenter	Download
GODAE OV IV Work Plan	Fabrice Hernandez , Mercator Ocean	ppt (0.3 MB)
Comparative Analysis of Upper Heat Content Variability	Yan Xue*, NOAA	ppt (4 MB)

from Ensemble Operational Ocean Analyses		
The data assimilation component of the real-time coastal ocean circulation forecast system off Oregon	Alexandre Kurapov* , USU/COAS	ppt (17 MB)
Inferring meridional heat transport through meridional volume transport of the AMOC	Tong Lee, JPL/NASA	ppt (1 MB)
A Sensitivity Study of short-range Forecasts over the Atlantic METAREA V with HYCOM and the Cooper Haines Scheme using different sea surface heights	Clemente Tanajura, UFBA	ppt (2 MB)
Quality Assessment of a 1985 - 2007 Mediterranean Sea Reanalysis	Mario Adani, INGV	ppt (9 MB)
Combination of in-situ and satellite observations to monitor the Global Ocean State	Stephanie Guinehut, CLS	ppt (11 MB)
OceanMAPS version 2 - what did we get from the upgrade?	Gary Brassington, BoM	ppt (35 MB)
The CMCC experience in the context of Global Ocean reanalyses	Andrea Storto, CMCC	ppt (3 MB)
An ensemble ocean data assimilation system for seasonal prediction and its comparison with other state-of-the-art ocean reanalysis (PEODAS)	Oscar Alves, CAWCR	ppt (8 MB)
Real-time and delayed mode validation for the Indian Ocean Forecasting System (INDOFOS)	Balakrishnan Nair, INCOIS	pdf (4 MB)
Evaluation of CONCEPTS Ice-Ocean Forecasting System	Gregory Smith, Environment Canada	ppt (8 MB)
The GMAO Ocean Retrospective Analysis	Santha Akella, NASA/GSFC/GMAO	pdf (6.5 MB)

Intercomparison and validation (IV) Breakout Summaries

Topic	Presenter	Download
GODAE OceanView aspects	Matt Martin, Met Office	ppt (0.3 MB)

Community Engagement

Observation Impact Statements	Peter Oke, CSIRO	ppt (0.2 MB)
GODAE OceanView and CLIVAR working together (Metrics)	Keith Haines, University of Reading, ESSC	ppt (0.8 MB)
Framework for Ocean Observing	Eric Lindstrom, NASA	pdf (8 MB)

Community engagement Breakout Summaries

Topic	Presenter	Download
Group A	Gary Brassington (Peter Oke), BoM (CSIRO)	pdf
Group B	Hans Bonekamp, EUMETSAT	ppt (0.2 MB)

Appendix F: References

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Appendix G: Acronyms

AN	Analysis
ACC	Antarctic Circumpolar Current
ACC	Anomaly correlation coefficient
ADCP	Acoustic Doppler Current Profiler
AMOC	Atlantic meridional overturning circulation
AN-O	Analysis minus observations
AVHRR	Advanced Very High Resolution Radiometer
BAMS	Bulletin of the American Meteorological Society
BMRC	Bureau of Meteorology Research Centre
BoM	Bureau of Meteorology
CICE	Los Alamos sea ice model
CLIVAR	Climate Variability and Predictability
CLS	Collecte Localisation Satellites
CMCC	Centro Euro-Mediterraneo per i Cambiamenti Climatici
C-NOOFS	Canadian-Newfoundland operational ocean forecasting system
CONCEPTS	Canadian Operational Network of Coupled Environmental Prediction Systems
COSS-TT	Coastal Ocean and Shels Seas Task Team
COSS-TT	Coastal and Shelf Seas Task Team
CTD	Conductivity, Temperature and Density
DA	Data assimilation
DFS	Degrees of freedom of signal
DUACS	Data Unification and Altimeter Combination System
EAC	East Australian Current
ECMWF	European Centre for Medium Range Weather Forecasting
EKE	Eddy kinetic energy
EnOI	Ensemble Optimal Interpolation
ENSO	El Niño/La Niña-Southern Oscillation
EOV	Essential Ocean Variables
ESA	European Space Agency
ETKF	Ensemble Transform Kalman Filter
ET-OOFS	Expert Team for Operational Ocean Forecasting Systems
ET-OOFS	Expert Team for Operational Ocean Forecasting Systems
EVP sea-ice	Elastic-viscous-plastic sea-ice
FG	First guess
FG-O	First guess minus observations
FNMOC	The Fleet Numerical Meteorology and Oceanography Center
FOAM	Forecast Ocean Atmosphere Model
GEOS DAS	Goddard Earth Observing System Data Assimilation System
GEWEX	Global Energy and Water Cycle Experiment
GFDL	Geophysical Fluid Dynamics Laboratory
GHRSST	Global High Resolution Sea Surface Temperature
GMAO	NASA Goddard Global Modeling and Assimilation Office

GOCE	Global Ocean Circulation Explorer
GODAE	Global Ocean Data Assimilation Experiment
GOOS	Global Ocean Observing System
GSOP	Global Synthesis and Observations Panel
GTS	Global Telecommunication System
HYCOM	Hybrid Coordinate Ocean Model
IFSOO	Integrated Framework for Sustained Ocean Observations
IMBER	Integrated Marine Biogeochemistry and Ecosystem Research
INDOFOS	Indian Ocean Forecast System
IOD	Indian Ocean Dipole
IOOS	Integrated Ocean Observing System
ISOP	Improved synthetic ocean profiles
IV-TT	Intercomparison and Validation Task Team
JCOMM	WMO-IOC Joint Technical Commission for Oceanography and Marine Meteorology
JMA	Japan Meteorological Agency
LEGI	Laboratoire des Ecoulements Géophysiques et Industriels (
MDT	Mean dynamic topography
MEP-TT	Marine Ecosystem and Prediction Task Team
MEP-TT	Ecosystem Modelling and Predictions Task Team
MERRA	Modern Era Retrospective-Analysis for Research and Applications
MFS	Mediterranean Forecasting System
MHT	Meridional heat transport
MLD	Mean level density
MOM	GFDL Modular Ocean Model
MRI	Meteorological Research Institute
MVOI	Multi-Variable Optimal Interpolation
MVT	Meridional volume transport
NAO	North Atlantic Oscillation
NASA	National Aeronautics and Space Administration
NCEP	National Centers for Environmental Prediction
NEMO	Nucleus for European Modeling of the Ocean
NERSC	Nansen Environmental and Remote Sensing Center, Norway
netCDF	Network Common Data From
NMEFC	National Marine Environmental Forecasting Center, China
NOAA	National Oceanic and Atmospheric Administration
NOAA IMS	NOAA Internet Map Server
NRL	Naval Research Laboratory
NRT	Near real time
NSIDC	National Snow and Ice Data Center
NWP	Numerical Weather Prediction
O-B	Observation minus background
OI	Optimal Interpolation
OIS	Observation Impact Statement
OLR	Outgoing Longwave Radiation
ONR	Ocean Naval Laboratory

OOFS	Operational ocean forecasting system
OOPC	Ocean Observation Panel for Climate
OSCAR	Ocean Surface Current Analysis - Real time
OSE	Observing System Experiments
OSEval-TT	Observing System Evaluation Task Team
OSSE	Observing Simulation System Experiments
OSTST	Ocean Surface Topography Science Team
OSU	Oregon State University
PDO	Pacific Decadal Oscillation
PEODAS	POAMA Ensemble Ocean Data Assimilation System
POP	Parallel Ocean Program
RAMA	Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction
REMO	Oceanographic Modelling and Research Network, Brazil
RMS	Root mean square
RMSD	Root-mean-square deviation
RMSE	Root-mean-square-error
ROMS	Relocatable Ocean Model System
SLA	Sea level anomaly
SLP	Sea level pressure
SLTAC	Sea Level Thematic Assembly Centre
SMOS	Soil Moisture and Ocean Salinity (ESA mission)
SRF	Spread reduction factor
SSH	Sea surface height
SSS	Sea surface salinity
SST	Sea surface temperature
SWOT	Surface Water and Ocean Topography (NASA mission)
TAO	Tropical Atmosphere Ocean
TC	Tropical cyclones
TOPAZ	Towards an Operational Prediction system for the North Atlantic European coastal Zones
TT	Task Team
UCSC	University of California, Santa Cruz
WBC	Western boundary currents
WBCext	Western boundary currents extensions
WGOMD	CLIVAR Working Group for Ocean Model Development
XBT	Expendable Bathythermograph