BLUElink> Development of Operational Oceanography and Servicing in Australia

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The Bureau of Meteorology is scheduled in 2007 to expand its oceanographic services for the Australian community to include operational mesoscale ocean forecasts. The past decade has seen the rapid development of a near real-time global ocean observing system which includes both in-situ and satellite instrumentation. The spatial coverage and frequency of observations has provided the capacity for developing ocean prediction systems. Operational oceanography is a significant investment both in terms of human and computational resources, which is being actively pursued in public centres throughout the world. BLUElink is a joint initiative of the Bureau of Meteorology, Commonwealth Scientific and Industrial Research Organisation and the Royal Australian Navy to develop this capability for Australia's regional and territorial waters. Numerical ocean prediction is a computationally intensive task with the prototype system requiring resources comparable with numerical weather prediction and similarly takes full advantage of the very latest in high performance computing. In addition, the volume of observational, model and analysis data has demanded a comprehensive data management system. Effective information technology solutions are essential for managing, maintaining and servicing this new capacity to fulfil the needs of the Australian community.

Keywords: BLUElink, operational oceanography, high-performance computing, data management system

ACM Classification: J2; I.6; H.3; G.4

1. INTRODUCTION

Operational oceanography is a relatively new capability, which is following on from the on-going and successful implementation of the Global Ocean Observing System (GOOS). Operational oceanography, in this context, refers to the hindcast, nowcast and forecast of three-dimensional ocean state (temperature, salinity and pressure) and currents for short-range timescales out to one month. Although the driving force for much of the observing system is for modelling and monitoring the climate system, the same instrumentation can support short-range ocean forecasting A pilot project called the Global Ocean Data Assimilation Experiment (GODAE; Smith and Lefebvre, 1997) has set out a vision for supporting the development of data assimilation of GOOS into state of the art models of the global ocean circulation in near real-time (NRT). GODAE

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promotes the sharing of data, standardising metrics for model intercomparisons and supporting common infrastructure, formats and protocols for data servicing. Several GODAE server nodes in both the USA (Naval Meteorology and Oceanography Command, 2005) and Europe (MERSEA/GMES, 2005) now provide public domain access to NRT satellite and profile observational data. GOOS and GODAE have introduced a rapid increase in observational, analysis and model data volumes. The changes in the ocean observing system now require sophisticated software tools and extensive computational architecture to manage and analyse the raw data and to facilitate their assimilation into numerical models. Examples of the infrastructure being implemented include two open-source software: Open-source Project for a Network Data Access Protocol (OPeNDAP; Sgouros, 2004) and the Live Access Server, (LAS; Callahan, 2005), a configurable web server designed to provide flexible access to geo-referenced scientific data.

The speed of change presents a challenge to the broader research community with only relatively few universities having access to the level of infrastructure required. Recently, within the climate research community, the Australian Research Council has supported a capacity building proposal, called the Australian Earth System Science Network, (Pitman, 2004). This initiative aims to improve the interface between the Australian agencies and the university climate research community. APAC has also supported Earth Systems Science capacity building applications including OPeNDAP servers (Canberra, BMRC, Hobart) and the installation of HPC and bandwidth through AARNet and the APAC national facility. Similar to activities in the climate sciences, operational oceanography will also need a vigorous participation from the university community. Improving and extending the access to operational oceanographic products by the research community is also essential and in Australia's long-term interests. This paper outlines the scale of the operational oceanographic problem and the developments for a local capacity through BLUElink.

2. OCEANOGRAPHIC DATA

Australian ocean data holdings are serviced by several national agencies including: the Bureau of Meteorology (Bureau), CSIRO Marine and Atmospheric Research (CMAR), National Ocean Office, National Tidal Facility and the Royal Australian Navy (RAN). Since 1998, the Bureau and CMAR created the Joint Australian Facility for Ocean Observing Systems (JAFOOS) (Cowen, 2005), which provides access to operational forecast products and observational data.

Observational oceanography has seen a rapid expansion in earth observing instrumentation over the past two decades driven by the need to observe the climate system and respond to climate change science. The International Ocean Commission has implemented GOOS permanently. NASA, under this umbrella, has supported large satellite programs such as the Earth Observing System, (McClung, 2005). Some of the oceanographic variables being routinely observed together with the instrumented satellites and launch dates are outlined in Table 1.

In addition to satellite oceanography several in-situ observational programs have been undertaken including: SOOP (Ship of opportunity program) that deploy XBT (expendable Bathy-Thermograph), TAO (Tropical Atmosphere Ocean) that maintains a network of moorings in the tropical Pacific and Argo a program to deploy autonomous vertical profiling drifters. A significant number of these instruments contribute to the NRT ocean observing system, which is routinely distributed by the World Meteorological Organisation's Global Telecommunications System (GTS) as well as internet servers. Extensive processing, including quality control both in NRT and a higher quality manual QC in delayed mode, is performed on each data type. The data is used for a variety of purposes including data assimilation for ocean forecasting, model validation, data analyses and the development of climatological data sets.

Variables	Instruments	Launch
Sea Surface Temperature	AVHRR, AATSR, AMSR-E	…,2000,2002 2001 2001
Sea surface height	Geosat Follow-On (GFO) Jason-1, ENVISAT	1998 2001 2002
Sea state	ENVISAT	2002
Sea Surface Salinity	Aquarius	2002
Wind stress	QuikSCAT	1999

Table 1: Earth observing satellites currently measuring ocean related variables that contribute to the near-real time global ocean observing system

High resolution, accurate bathymetry is essential for many oceanographic applications including ocean circulation, coastal and littoral zone circulation, shallow water waves, tides, storm-surges and tsunamis. Several agencies maintain survey data and produce analysed gridded products. Geoscience Australia, produce a 1km resolution bathymetry dataset for the Australian region. Global datasets are also available at a variety of resolutions from the US Navy. Ocean circulation modelling also requires surface fluxes of momentum, heat and fresh water from an atmospheric model. Atmospheric forcing is available from Numerical Weather Prediction (NWP) systems normally run twice daily by Meteorological Centres such as the Bureau, European Centre for Medium-range Weather Forecasting (ECMWF) and National Centers for Environmental Prediction (NCEP) or as atmospheric reanalyses such NCEP reanalysis (Kanamitsu *et al*, 2002) and ERA40 (Kallberg *et al*, 2004). The Bureau currently runs two main NWP systems operationally. These are the Global Assimilation and Prediction System (GASP; Seaman *et al*, 1995) and the Limited Area Prediction System (Puri *et al*, 1998) for the Australian region.

The Bureau supports, in partnership, a number of ocean models based around the Modular Ocean Model Version 4, (MOM4; Griffies *et al*, 2003). These include the Australian Climate Ocean Model (AusCOM), Ocean Forecast Australia Model (OFAM) and a Regional coupled model. These models provide predictions of three-dimensional current vectors, temperature, salinity and sea-level. Model fields are output as snapshots or time-averages. The convention for storing array-oriented scientific data in the oceanographic community is Network Common Data Form (NetCDF), a machine independent self-describing format that was developed by Unidata (Unidata, 2005).

3. OPERATIONAL OCEAN PREDICTION SYSTEM FOR AUSTRALIA

BLUElink is an Australian government initiative between the Bureau of Meteorology, CSIRO and RAN with the goal to develop the Ocean Model Analysis and Prediction System (OceanMAPS; Brassington *et al*, 2006) for operational implementation through the operational branch of the Bureau. The system will draw together the Ocean Forecast Australia Model (OFAM), the BLUElink Ocean Data Assimilation System (BODAS; Oke *et al*, 2005), a data management system and enhanced surface winds from NWP and high resolution SST products. The system components have been optimised to run on the NEC SX6 machine at the Bureau/CSIRO High Performance

Computing and Communications Centre. BLUElink also includes the development of a Relocatable Ocean Atmosphere Model (ROAM) for operational applications by RAN. ROAM will use forecasts from OceanMAPS as initial and boundary conditions. Only OceanMAPS, which the Bureau is scheduled to run operationally and issue forecasts to the public, is described below.

3.1 Ocean Model Development

Ocean circulation can be represented using a mathematical model that solves the appropriate non-linear equations of motion for the ocean on a rotating sphere. The numerical software for these equations is referred to as an Ocean General Circulation Model (OGCM). Ocean model development in Australia has never achieved the critical mass required to develop a comprehensive software package. The Australian scientific community has instead adopted the strategy of actively adapting and extending open-source software. There are several open-source models developed largely in the United States that are made available to the broader community for non-commercial use. In general, these codes are written in Fortran 90 standard or higher with extensive use of libraries for I/O handling. A long and on-going relationship has been established with GFDL to adapt MOM software for Australian climate research applications. This model and associated expertise in the Australian scientific community is being exploited as the basis for the OFAM.

High performance computing in the United States has moved almost exclusively toward scalable parallel designs employing large numbers of commodity scalar processors. As a result the associated software development coming from the US is optimised for that architecture. This presents issues for performance of the software on alternative architectures such as the parallel vector NEC SX6 at the HPCCC. CSIRO researchers thus found it necessary to invest some time O(1 month) in optimising the MOM4 software for the NEC SX6 with excellent results. This additional development requires an on-going relationship for support and maintenance for the implementation of MOM4 upgrades and for modifications necessitated by the compiler and computing environment.

The OFAM grid has been designed as a global model, to avoid complexities associated with open boundary conditions. In the Australian region (90E-180E, 75S-16N) the horizontal resolution is 10km, which resolves mesoscale ocean variability. In order to minimise the costs of the model, the grid employs lower resolutions outside the Australian region as shown in Figure 1, where the

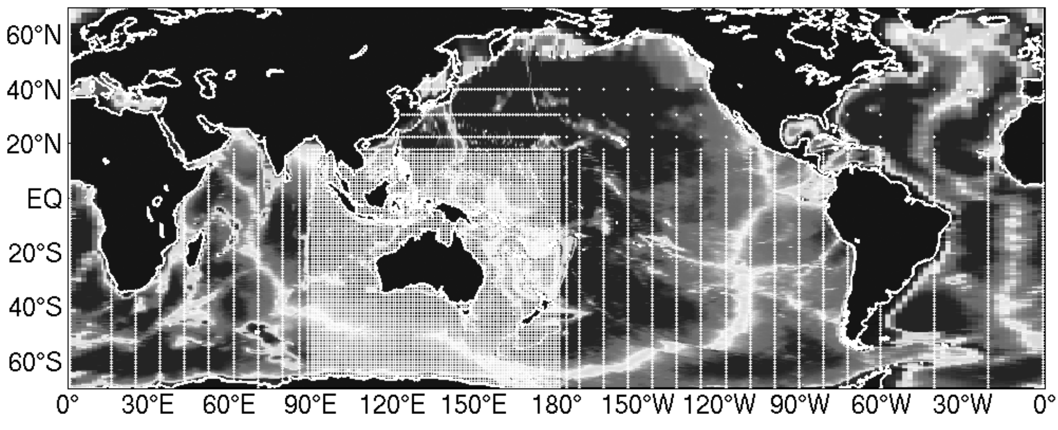

Figure 1: Ocean Forecast Australia Model horizontal grid. Water cells are coloured according the depth of bathymetry, every 10th grid point is shown as a white dot.

	Spinup I	Spinup II
Nodes	3	6
Cpu's (total)	21	42
Memory(total)	~86GBytes	~114GBytes
Cputime/model day	20 minutes	11.5 minutes
Sustained flops (total)	20.3 Gflops	31.8 Gflops

Table 2: Performance of OFAM (MOM4) on the NEC SX6

Input files	Size
Grid specification	~400 MBytes
Restart	~5 GBytes
NWP surface fluxes	~150 MBytes
SST analysis	23 MBytes

Table 3: Input files required for the Ocean Forecast Australia Model

white dots represent every 10th grid point. The vertical grid is comprised of 47 levels, with the top 20 levels at a resolution of 10m. Each three-dimensional variable has dimension 1191×968×47 and a single snapshot is approximately 250Mbytes. The snapshot of all the prognostic variables of the model is 0.9 Gbytes.

The OFAM's performance on the NEC SX6 has been measured during two ocean model only integrations (so called "spinup" using ERA40. The first integration was performed using MOM4p0b, which included the leap-frog time integration scheme and neutral physics using a baroclinic timestep of 300s. This was performed on 21 processors across 3 nodes sustaining 10.8 Gflops. The second integration was performed using MOM4p0d, which included a new time integration scheme and with neutral physics switched to false using a baroclinic timestep of 600s. This was performed on 42 processors across 6 nodes sustaining 31.8 Gflops demonstrating some problems in scalability of the MOM software. The usage values are summarised in Table 2. MOM4p0d has since been benchmarked on a number of systems revealing that the core code scales on all platforms including the NEC-SX6 while the I/O performance does not scale on any system. OFAM's I/O requirements are outlined in Table 3 and include a complete ocean state specification either as initial conditions or a restart, O(5) Gbytes.

3.2 Data Assimilation

The ocean model is initialised by BODAS (Oke *et al*, 2005). This data assimilation system adjusts a nowcast of the ocean state towards the true ocean state based on a sparse set of observations. The system essentially produces a weighted least squares adjustment of the background ocean state to ocean observations. Determining the appropriate weights combined with the constraints of computational cost lead to a wide variety of implementations. BODAS is a new software package development based on a multi-variate, ensemble-based optimal interpolation scheme (e.g., Oke *et al*, 2006). The key feature of BODAS is that the background error covariances are defined from an ensemble of seasonal anomalies derived from a nine year spinup integration of the ocean model

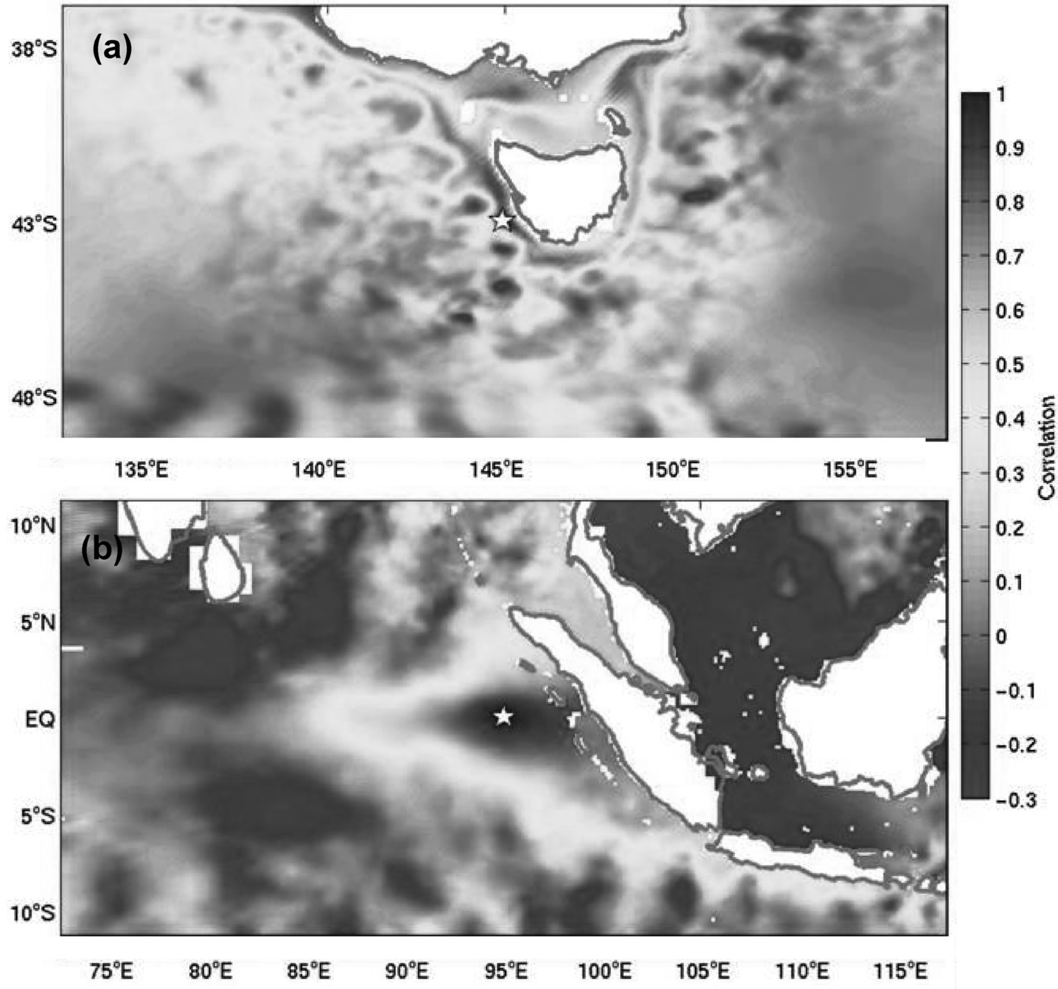

Figure 2: Horizontal spatial correlations of sea surface height anomalies based on an ensemble of modelled states (a) Tasmania, (b) Indonesia (adapted from Oke *et al*, 2005)

without data assimilation. An example of the spatial structure of the ensemble covariances is shown in Figure 2 for two locations indicated by a star with the immediate surroundings off the coast of (a) Tasmania and (b) Indonesia. These covariances have clear physical interpretations to the known dynamics of the region, (a) coastal currents off Tasmania and (b) the equatorial waveguide off Indonesia.

The computational requirements of the present configuration of BODAS include a full background state obtained from the restart file of OFAM, a 72 member ensemble of model states, an 11 day window of observations including sea surface height anomalies from JASON-1, ENVISAT, GFO and Topex-Poseidon and profile observations from XBT, CTD and Argo. The analysis has been parallelised, by domain decomposition with a modest memory overhead of a halo region for each domain. A recent implementation conducted an analysis over 40 processors, each a single processor job using a total of 260Gbytes of memory. Present optimisation has achieved a completion time of

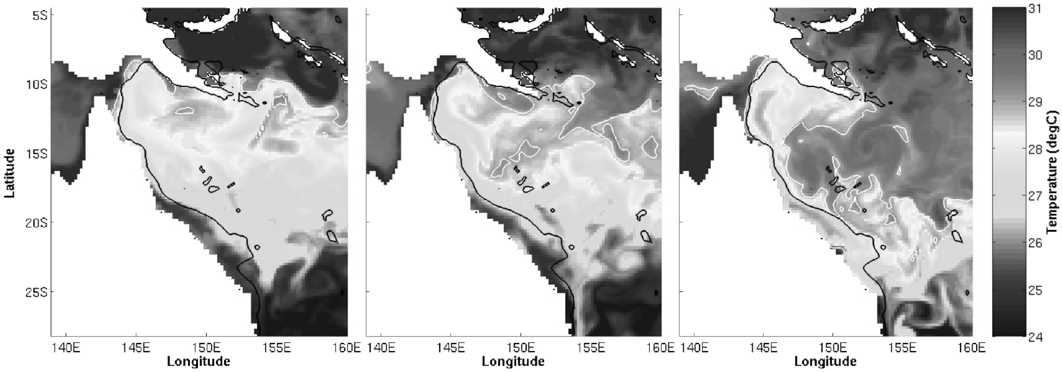

Figure 3: BRAN surface temperature (10m) in the Coral Sea for the 6th January, 2000, 2001 and 2002. The 29 degree isotherm is represented by the white contour. The 200m isobath is represented by the black contour.

20 minutes wall-clock. Load imbalances can arise through inhomogeneous distribution of observations and inhomogeneous domain sizes due to the structure of the OFAM grid.

3.3 Ocean Reanalysis

OFAM and BODAS have been applied to construct an ocean reanalysis for the period 1992-2004. The BLUElink ReANalysis (BRAN) uses delayed mode observations including along track sea-level anomalies from altimetry (ERS, GFO, Jason, ENVISAT), coastal tide gauges, temperature and salinity profiles (WOCE, TAO, Argo, XBT) and analysed atmospheric forcing, ERA40 (Kallberg *et al*, 2004). Assimilation is performed every three model days. BRAN is the first eddy-resolving ocean analysis for the Australian and South-east Asian region and preliminary analysis shows qualitative agreement between modelled surface currents and observed surface drifters which are independent of BRAN (Oke *et al*, 2005). An example of the analysed flow for sea surface temperature is shown in Figure 3 for the Coral Sea. The three figures illustrate the variability on interannual timescales for 1 January, 2000, 2001 and 2002. The extensive warm intrusion shown in 2002 corresponds to a year of wide spread coral bleaching in the Great Barrier Reef.

BODAS was parallelised into 40 zonal sections each with a halo region in the meridional direction to eliminate communications. These were then submitted as 40 single processor jobs with usage values outlined in Table 4. The input files required to complete an ocean state analysis is outlined in Table 5. BODAS uses a stationary set of model error covariance statistics, which is based on a 72 member ensemble of model anomalies, O(15) Gbytes.

3.4 Operational Environment

The Bureau's operations branch has the central responsibility for issuing meteorological analyses and predictions and distributing this information to the community through a network of regional

Cpu's	40
Memory (total)	80GBytes
Cputime/analysis	20 minutes

Table 4: Performance of BODAS on the NEC SX6

Input files	Size
Background field	~5 GBytes
Grid specifcation	~400 Mbytes
Ensemble Anomalies	~15 GBytes
OFAM statistics	~1 GByte
Observations	~50 MBytes

Table 5: Input files required to complete a BODAS analysis for OFAM

forecast centres. In addition to meteorological forecasts, the Bureau also produces a range of other services in climate, hydrology and oceanography. Oceanographic services at present cover a modest range of operational products including, tides, sea surface and subsurface temperature analyses and wave forecasts. The implementation of a high-resolution three-dimensional ocean state analysis and forecast system represents a major upgrade in computational resource requirements and servicing requirements. The proposed operational configuration is shown schematically in Figure 4.

The backbone of the computational infrastructure to support the operations branch is the NEC SX6 managed through the HPCCC. The SX6 is accessed through an NQS based queue system that provides pre-emptive priority service to operational jobs while still providing services for research

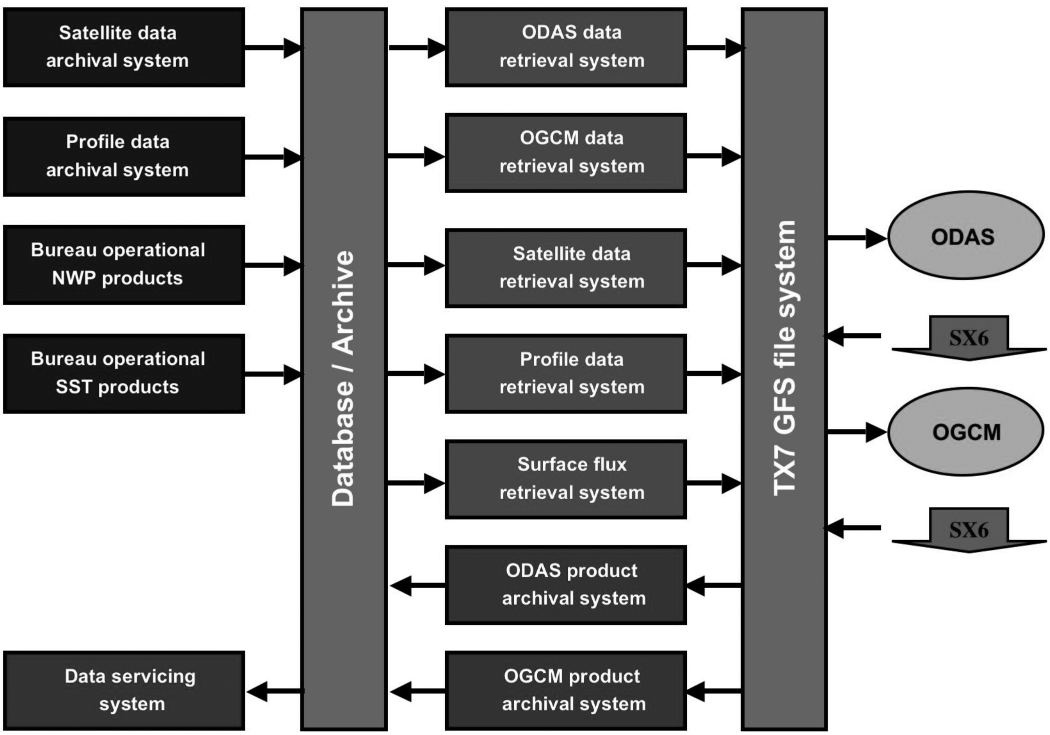

Figure 4: Operational system configuration for the Australian global ocean forecast system

and development tasks performed by other sections of the Bureau and CSIRO. The SX6 is front-ended by dual NEC TX7 servers, each having 16 CPU and 16GB of memory. The TX7s provide global file system services for the SX6 nodes, and also scalar services for tasks associated with file transfers and data handling. Compilation of code for the SX6 is normally performed on central servers of different architectures by way of cross compilers that have been specifically written for the SX6 and job scripts are submitted from central servers for execution in various single node and multi-node job queues. Access to this common high performance computing facility has been critical to the success of the BLUElink project to date. The SX6 includes high bandwidth, large scale storage and large shared memory per node that enable all of the data required for OceanMAPS to be stored for online operations. This structure minimises the interaction of the operational models with archive devices to post processing storage.

The schedule for OceanMAPS shown schematically in Figure 5, is dependent on three inputs that are handled by the data management system, (a) NRT observations, (b) NWP surface fluxes and (c) Sea surface temperature analyses. The system includes an analysis and forecast cycle that depends on the data management system for handling the distribution and servicing of products.

The Bureau maintains communications with a variety of networks including GTS, Internet, Grangenet, AARNet2 (proposed to move to AARNet3) to support NRT observation retrievals and data distribution. The majority of ocean profile observations are obtained from the GTS. Satellite observations such as sea surface height anomalies from JASON-1 are available between 5-7hrs behind real-time either on GODAE servers in a pull mode or for operational centres such as the

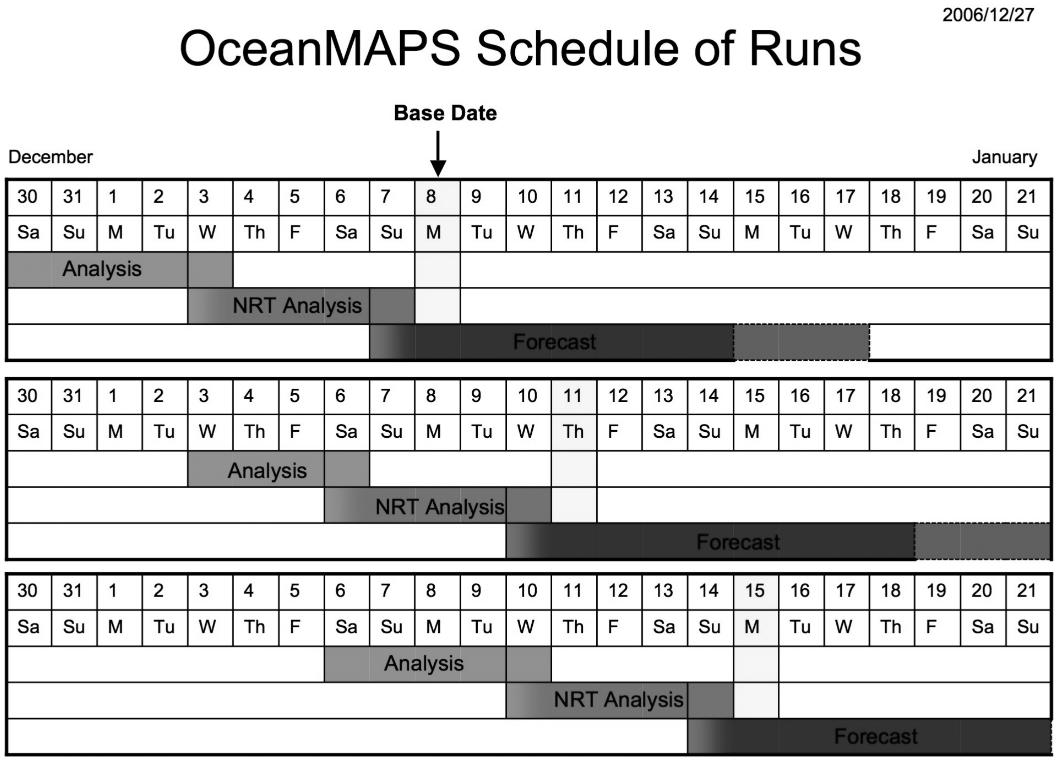

Figure 5: OceanMAPS schedule integrated with GASP

Bureau in a push mode. Recent observations are collected into over-written files in local memory and later archived.

Operational systems are designed to perform robustly to a regular schedule. The operational ocean prediction system has been implemented to produce forecasts out to seven days, twice per week. The schedule includes: an analysis cycle for high-quality analyses, a nrt analysis cycle for forecast initial conditions using near real-time observations and a forecast cycle. Both the analysis and forecast cycles depend on the availability of NWP fluxes and SST analyses. Both of these are operational products that have unique schedules. GASP is integrated twice daily at 6UTC and 18UTC. Operational high resolution SST analyses are generated daily for the local region and weekly for the global domain. The OceanMAPS schedule must fit within the schedule of these other systems. The analysis cycle shown in Figure 5 is constrained by the time scale of one complete altimeter orbit (~three days behind real time) and is repeated daily using three day old analysed NWP fluxes. The NRT cycle at present does not include an assimilation due to the low returns currently being obtained from Jason1.

The Bureau has recently implemented the Meteorological Archival and Retrieval System (MARS) to serve as the primary meteorological database. This system was developed by ECMWF and was designed for storage of NWP output. The system supports two file formats Gridded Binary (GRIB) and Binary Universal Form for the Representation of meteorological data (BUFR) which

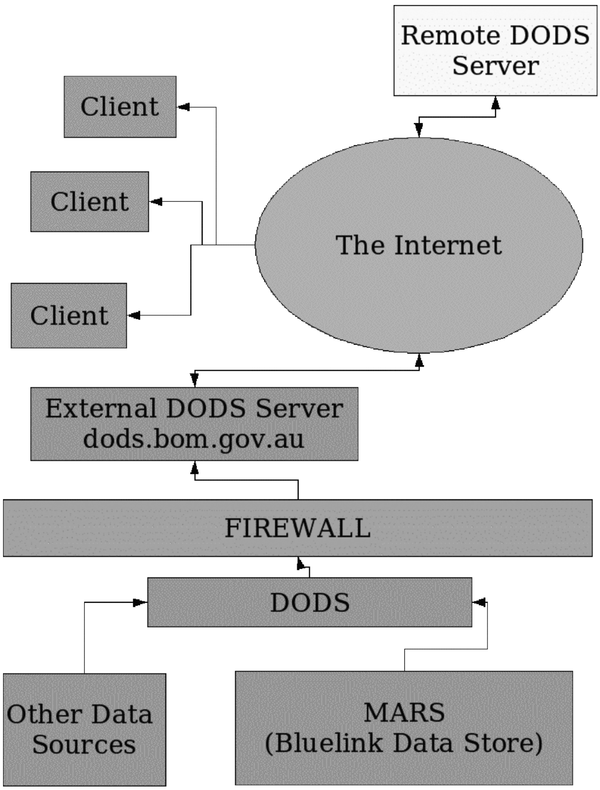

Figure 6: Distributed Ocean Data System (DODS) sources allowing data exchange from multiple independent sources. DODS was the forerunner to the more generic OPeNDAP.

are specific formats developed by ECMWF for the meteorological community that provide good compression. However, neither of these two formats are widely used or supported within the ocean community at other centres or by software developers. The Bureau has supports code to convert between file formats such as NetCDF and GRIB and BUFR.

Data management and exchange in the BLUElink project involves several emerging standards. This has involved significant development of new systems, including the integration of the back-end database with available OPeNDAP servers as shown in Figure 6. The push to standardisation is often hard to justify in the course of a single project, and can seem like more risk than reward. The advantage of enabling these standards, however, rather than relying on technologies such as FTP, is that it enables data sharing in a highly automated fashion. Just as XML and machine-independent data standards are becoming increasingly popular in business, so scientific standards will become increasingly popular in institutions. OPeNDAP, an openly-published data exchange specification, allows tighter integration between heterogeneous applications, ultimately reducing the effort of end users and application developers in accepting new data sources. Putting in the additional effort to use open technologies will encourage faster take-up across the community, allowing smaller projects to achieve high-level goals faster. OPeNDAP has the advantage of being highly scalable. Its ability to sub-select data on the server side allows data providers to reduce bandwidth by sending only the data which is requested by the client. Highly flexible, OPeNDAP servers can be used to both aggregate external data sources into a single format, easing the task of integrating new data into existing applications, or as a universal publishing mechanism. The ability to abstract away the problem of data exchange is a powerful enabler of new technologies.

4. CONCLUSION

The objective of BLUElink was to produce the first operational forecasts of mesoscale ocean circulation for the Australian region. At the time of publication BLUElink has seen the first routine forecasts being delivered in January 2007. The system is transitioning from research to full operational implementation and thorough evaluation. The scale of the problem being undertaken is at the high-end of high performance computing and data management and will continue to pose interesting challenges to the Bureau. The development of this system has been constrained in its design to deliver the capability within the project period. There are numerous areas that have been identified for further development which will be funded through a three year follow-on project. The volume of information contained in the system is of a scale that ensures full use must be made of the wider research community. Connectivity and cost-effective distribution of data to this community is a critical activity.

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BIOGRAPHICAL NOTES

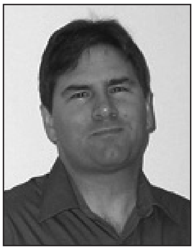
Gary Brassington

Dr Gary Brassington is a BSc(hons) and PhD graduate from the University of New South Wales with his doctorate titled "Accurate methods for a free-surface, nonhydrostatic ocean model" under the supervision of Professor Lance Leslie and Dr Brian Sanderson. Gary was a postdoctoral research fellow at both the School of Civil and Environmental Engineering, James Cook University, Townsville, Queensland and the College of Oceanic and Atmospheric Science, Oregon State University, USA.

Gary is currently a Senior Professional Officer at the Bureau of Meterology Research Centre within the Ocean and Marine Forecasting Group. He is science leader for the ocean analysis and prediction program which includes the BLUElink> project.

Gary leads the Ocean Model Analysis and Prediction System (OceanMAPS) implementation team that has developed and implemented the ocean prediction system under the BLUElink> project. He also leads ocean model development at the BMRC, which includes the Ocean Forecast Australia Model (OFAM), Australian Climate Ocean Model (AusCOM) and the Coupled Limited Area Model (CLAM).

Dr Francis (Tim) Pugh II graduated in 1987 with a BSc in aeronautical engineering with Cal Poly State University , USA. Tim has worked as a professional scientific programmer for over 20 years with Jenike & Johanson engineering consultants and the College of Oceanic and Atmospheric Sciences, Oregon State University. He has extensive experience in scientific programming and optimization for high performance computing environments particularly with community ocean codes. His current position since 2005 is as a Senior Information Technology Officer at the Bureau of Meteorology Research Centre where he is contributing to the BLUElink project and implementation of the operational ocean prediction system.



Tim Pugh

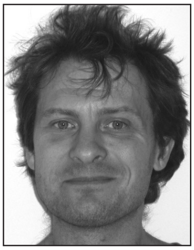
Claire Spillman is a BE (Environmental)(Hons)/BSc (Chemistry) graduate from the University of Western Australia (UWA). Claire has recently submitted her PhD thesis entitled "A Modelling Assessment of Hydrodynamics and Biogeochemistry of the Northern Adriatic Sea, and Effects on Clam Dynamics in Barbamarco Lagoon, Italy" to UWA for examination, under the supervision of Professor Jorg Imberger, Professor David Hamilton and Dr Jose Romero.

Claire is currently employed at the Bureau of Meteorology Research Centre in the Ocean and Marine Forecasting Group. Claire is involved in observations management and quality control for OceanMAPS under the BLUElink> project, the scientific quality control of XBT data collected by the Bureau and the prediction of coral bleaching in the Great Barrier Reef using the seasonal forecast system POAMA.

Claire Spillman

Dr Eric Schulz graduated with a BSc (Hons) in oceanography and meteorology from Flinders University of South Australia. After working at the Commonwealth Scientific and Industrial Research Organization, Division of Oceanography for a year, he commenced a PhD at the University of New South Wales. His doctorate, titled "Air-Sea Flux Parameterisations in a Shallow Tropical Sea" was awarded in 2002, and was supervised by Dr Brian Sanderson and Professor Michael Banner.

After holding brief research assistant appointments at the University of New South Wales and then the Australian Defence Force Academy, he undertook a postdoctoral fellowship at the Centre for the Study of Earth and Planets Environments, CNRS, France.



Eric Schulz

Eric took up his current position at the Bureau of Meteorology Research Centre, Ocean and Marine Forecasting Group in 2004. His duties focus on marine meteorology, and supporting operational oceanography by gaining a better understanding of air-sea interactions.

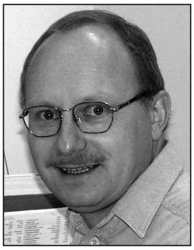
Dr Helen Beggs received her BSc (Hons) in Physics at the University of Melbourne in 1984. She then undertook an MSc project titled "Study of Traveling Ionospheric Disturbances over Macquarie Island using an Oblique cw HF Sounder" in the Department of Theoretical and Space Physics at La Trobe University, which was awarded in 1989. Helen wintered twice at Australian Antarctic Stations as an Atmospheric and Space Physicist employed by the Australian Antarctic Division.

She was conferred her PhD in 1996, titled "air-Sea Exchange of CO^2

Helen Beggs

over the Antarctic Seasonal Ice Zone" from the Institute of Antarctic and Southern Ocean Studies at the University of Tasmania.

Helen was employed in the Data Centre at the Commonwealth Scientific and Industrial Research Organization, Division of Oceanography for a number of years, before moving across to systems analysis in private industry. She took up her current position at the Bureau of Meteorology Research Centre, Ocean and Marine Forecasting Group in late 2003. Her research is concerned with satellite sea surface temperature observations and the development of new products and analyses to support operational oceanography and international research efforts.



Andreas Schiller

Dr Andreas Schiller has extensive experience in large-scale ocean physics and modelling, ranging from climate research to "ocean weather" forecasting. Until recently Dr Schiller led the CSIRO component of a world-class project to implement the first operational "ocean weather" forecasting system in the southern hemisphere (BLUElink project). The project combines state-of-the-art ocean observing systems (satellite altimetry, satellite SST, autonomous ARGO floats) with the latest modelling and data assimilation technology to estimate the three-dimensional ocean circulation around Australia. The BLUElink project is one of the key projects of the National Wealth from Oceans Flagship Program. Products from the project will support a wide range of marine industries and sectors such as the offshore oil and gas industry, commercial and recreational fishing, coastal zone management, search and rescue, and defence.

Peter Oke

Dr Peter Oke is a senior research scientist at CSIRO's division of marine and atmospheric research. Dr Oke obtained a BSc (Hons) and PhD from the School of Mathematics at the University of New South Wales. He has been a research fellow at the College of Oceanic and Atmospheric Science, Oregon State University, USA, and at the School of Mathematics at the University of New South Wales. Dr Oke is a key scientist in the BLUElink project, under which he has led the development of the data assimilation and ocean reanalysis components. He enjoys swimming and filling in irrelevant paperwork.