

1. Title: Ocean-shelf exchange with an emphasis on the roles of waves, tides, eddies and cross-shelf flows on carbon exchange

2. Summary (200 words):

Improved understanding of exchanges between continental shelf seas and the deep ocean are required for models for studying climate, the carbon cycle, sedimentation and marine ecosystem function. For example, it has been proposed that the continental shelf pump acts as a mechanism to transport carbon (as either dissolved or particulate material) from coastal waters to the interior of the adjacent deep ocean and therefore acts as a sink for atmospheric CO₂. In this proposal, we aim to investigate ocean-shelf exchange on Australian continental shelves which encompass tropical, sub-tropical and temperate regions, with an emphasis on the role of waves, tides, eddies on carbon exchange. Using IMOS data streams and application of coupled physical-biogeochemical models, forced by global models such as Bluelink, we will define the carbon fluxes on the Australian shelves and compare them to global estimates. A highly qualified and experienced research team, which includes Australian and international partners, with a proven record of high quality outputs have been assembled to undertake this study.

3. Principal Co-Investigators (At least from 2 Institutes-JCU, UWA, UTas):

Prof C Pattiaratchi (UWA)
Dr Roger Proctor (UTas)
Dr Peter Ridd (JCU)

4. Outline of the project, including Workshops (6 pages maximum):

The ocean currently absorbs 2 ± 0.4 billion tonnes of carbon per year, approximately one third of anthropogenic carbon emissions. The rate of absorption of carbon dioxide depends on both physical and biological processes. Globally, continental shelf regions occupy < 10 % of the global ocean surface area but the coastal ocean plays a disproportionately important role in the overall ocean carbon cycle: such as up to 30% of the oceanic primary production; 80% of the organic matter burial; 90% of the sedimentary mineralization; and, 50% of the deposition of calcium carbonate. Tsunogai *et al.* (1999) proposed that the continental shelf pump acts as a mechanism to transport carbon (as either dissolved or particulate material) from surface waters to the interior of the adjacent deep ocean. Using data from the East China Sea, these investigators estimated an air-to-sea flux of $\sim 1 \text{ Gt C y}^{-1}$ over the world's shelf area, which is $\sim 50\%$ of the global estimate for ocean uptake; the continental shelf pump may therefore play an important role in the ocean's carbon cycle.

The edge of the continental shelf represents a major boundary within the ocean system, and exchange of water and material over this boundary has a considerable impact on the shelf seas as well as impacting the global ocean. The shelf break is a region of steep and changing slopes, strong currents, upwelling, internal tides, continental shelf waves and significant vertical motion. In Australia, the major boundary currents such as the East Australian and the Leeuwin Currents flow parallel to this boundary. Improved understanding of the exchanges between the continental shelf seas and the deep ocean are useful for more realistic models for studying climate, the carbon cycle, sedimentation and marine ecosystems. Increased detail in the improved models often leads to prediction of features that have not yet been observed. Location of continental shelf carbon export to the deep sea can also be areas of both high benthic and pelagic diversity and abundance. Exchange of water between the oceans and the shelf seas affect:

- the export of carbon and contaminants to the deep seas;
- nutrient exchanges across the shelf break which fuel much of the productivity of shelf seas overall, and the high productivity and associated fisheries around the shelf edge;
- the regional climate via heat exchange; and
- large scale oceanographic processes via the exchange of freshwater.

Climate change has the potential to significantly impact all of these processes. In this proposal we address the ocean-shelf exchange on Australian continental shelves with an emphasis on the roles of waves, tides, eddies and cross-shelf flows on water and carbon exchange.

The main aims of this project are to:

- Collate relevant field data obtained from Australian continental shelves/break, the majority of which are being collected as part of the Integrated Marine Observing System (IMOS);
- Define major processes influencing shelf-ocean exchanges along different sections of the Australian mainland
- Undertake numerical modelling (2D or 3D) using cross-shelf coupled physical-biogeochemical models of key shelf regions around Australia
- Define the carbon fluxes on the Australian shelves and compare them to global estimates
- Investigate correlations with benthic and pelagic diversity and abundance

Australian coastal oceanography

The continental shelves surround almost all of the Earth's land masses. On average, shelf seas are hundreds of meters deep, compared to the average depth of the ocean of nearly four kilometres. Australia boasts the world's largest continuous continental shelf in terms of surface area: 12% ($2.5 \times 10^6 \text{ km}^2$) of the global system (Yool and Fasham, 2001) with the shelf wider in the north (> 200 km), extending to the New Guinea islands, and narrower in the south (< 10 km; Figure 1). Extreme climate conditions (intense rainfall, large waves, storm surges) from tropical cyclones impact northern Australia, whilst swell generated in the Southern Ocean and severe storms impact the southern Australian coastline which is also characterised by lower tidal ranges.



Figure 1 – Australian continental shelf including proposed locations (white lines) for the application of numerical models. Majority of the sites correspond to current deployments of IMOS infrastructure.

The Australian region is bordered by the Indian, Pacific and Southern Oceans and is characterised by boundary currents: the west and east coasts are bounded by major warm, nutrient-poor, poleward-flowing currents whilst the southern coast is bounded by zonal currents (Figure 2), which exert considerable influence on marine flora and fauna. Along the east coast, the East Australian Current (EAC) originates in the Coral Sea, where the northern arm of the South Pacific anti-cyclonic gyre, the South Equatorial Current, flows west and approaches the Australian coast between 14°-20°S. Here it bifurcates, with a smaller northward flow and a larger southward flow that forms the EAC. As the EAC flows south, it accelerates along the coastal boundary, and then separates into north eastward (Subtropical Counter Current), eastward (Tasman Front) and residual southward (EAC Extension) components at around 31°S. The EAC is dominated by large mesoscale cyclonic (clockwise) and anti-cyclonic eddies. Eddies generally originate immediately south of the Great Barrier Reef and eddy activity increases as the current moves south. Eddies spawned by the EAC continue southward into the Tasman Sea, bringing episodic incursions of warm water to temperate eastern Australia and Tasmanian waters (Ridgway and Godfrey 1997). The EAC is strongest and penetrates furthest south during summer and is weakest in winter.

Along the west coast the Leeuwin Current (LC) flows southward and is much weaker than the EAC, with mean flow about 20% of the strength of the EAC. The LC originates from both the Indian Ocean in the west and the Pacific Ocean in the east (via the Indonesian Throughflow). The LC rounds Cape Leeuwin in the south and continues eastward into the Great Australian Bight where it becomes the South Australia Current that finally flows into the Zeehan Current, which can reach Tasmania during the winter (Ridgway and Condie 2004). The strength of the LC varies seasonally, being greatest in the autumn and winter when southerly winds are weakest. The LC is influenced by El Niño, with the current weakening under El Niño and strengthening under La Niña conditions (Feng et al., 2003).



Figure 2 – Major boundary currents around Australia.

In terms of cross-shelf flows, the arid Australian climate with high evaporation rates and winter cooling is conducive to the formation of dense shelf water, where the density of inner shelf waters is affected by a decrease in temperature (through cooling) and/or an increase in salinity (through evaporation).. This water is transported as a bottom gravity current (termed dense shelf water cascade, DSWC) near the sea bed, where it flows across the continental shelf and onwards into the deeper ocean and thus can play a major role in shelf-ocean exchange. The sinking of this

denser water is an irreversible process, and forms a major sink for carbon. Formation and propagation of this buoyancy driven current, known as dense shelf water cascade (DSWC; Canals et al., 2009; Shearman and Brink, 2010), have been documented in over 60 locations globally (Ivanov et al., 2004). The DSWC provides an effective mechanism for the exchange of water, heat, salt, phytoplankton, nutrients and pollutants between shallow coastal regions and the deep ocean (Whitehead, 1987), as well as an understanding of the impacts of climate change being transferred to the deep ocean (Canals et al., 2009) and the supply of organic matter to deep-sea ecosystems (Canals et al., 2006). In Australia DSWC has been documented in shelf regions such as in the Great Australian Bight (Petruševics et al., 2009), offshore Sydney (Symonds and Gardiner-Garden, 1994) and the northwest Australian Shelf (Shearman and Brink, 2010), and from inverse estuarine systems such as Spencer Gulf (Bowers and Lennon, 1987), Shark Bay (Pattiaratchi and Woo, 2009) and Hervey Bay (Ribbe, 2006). Prior to IMOS, these shelf-based DSWC studies have been limited to data collected during a single season (e.g. a single cruise) and therefore the seasonal variation of DSWC due to changing atmospheric conditions have not been addressed. The significance of such research is highlighted by Canals et al. (2009): *'As cascades often occur simultaneously with spring phytoplankton blooms..., there is no doubt that their role as a natural mechanism for carbon sequestration from the shallow ocean layers will demand the attention of the scientific community in the coming years.'* Off Western Australia, WAIMOS ocean glider data (Pattiaratchi et al. 2011) has demonstrated that DSWCs are a regular occurrence particularly during autumn and winter months (and also coincide with the shelf-scale phytoplankton bloom that occurs during this time of year; Lourey et al. 2006).

IMOS datasets and integration into coastal numerical modelling

In many global models (e.g. Bluelink, Hycom), the continental shelf region is poorly resolved with only a few grid points. Field measurements are difficult at the edge of the shelf due to the narrowness of the currents and steep slopes. However, new technologies are now enabling measurements in such challenging environments. The establishment of the Integrated Ocean Observing System (IMOS) has provided an unprecedented data set from the Australian region. For example, the use of autonomous underwater vehicles (AUV's) provides high resolution benthic habitat mapping to define the structure of the sea bed to estimate benthic production. An extensive mooring network with bio-optical sensors and acoustic Doppler current profilers allow measurements throughout the water column allowing us to estimate fluxes. Towed samplers (e.g. continuous plankton recorder; CPR) and ocean gliders are now providing observations, continuous in time and space, in shelf areas increasing the ability to observe these regions continuously. At the same time, fine-scale (1 km or less) coastal models with multiple depth layers can be used to model the movement of water, chemical species and sediments on the shelf, and are being connected to biogeochemical models of the local ecosystem. Meshing these models into larger-scale deep ocean models offers the chance to resolve some of the unknowns on the shelf-ocean exchange – **this is the main aim of the project**: A coupled physical-biological-chemical model will be used to simulate carbon biogeochemistry on the continental shelves of the Australian mainland, with the aim of predicting the carbon fluxes in the different regions covering tropical, sub-tropical and temperate regions (Figure 1).

Significance

The fate of anthropogenic CO₂ is an open question with a missing CO₂ term. Past global ocean and atmosphere carbon cycle studies do not consider the coastal oceans. With ~75% of the global human population expected to live within the coastal zone by 2025, the effects of human activities will be dramatic in ocean margins and are likely to greatly alter the dynamics of carbon cycling. Currently, >80% of Australians live within 50 km of the coast and will increase into the future. This project will assess the role of ocean margins in transport of CO₂ between the atmosphere and different ocean regions (shelf/deep). Most previous conclusions on the role of

coastal oceans are based on studies from mid- and high latitude ocean margins. Exchange between the deep ocean and the shelf can occur through a variety of mechanisms at time scales from days to years and space scales from kilometres to ocean basins. There is a need to characterize the relative importance of these mechanisms by region. This work will be the first project to cover a whole continent encompassing tropical, sub-tropical and temperate systems.

IMOS infrastructure is based on the provision of physical and biogeochemical data streams. There is a strong need to integrate with a modelling component to get best benefit from IMOS data sets. This project will be a first step in filling this void. The team includes the majority of the node and deputy node leaders of the IMOS coastal nodes (Roughan, Doblin, Thompson, Middleton, Leterme, Pattiaratchi) and leaders of two key IMOS facilities (Pattiaratchi, ocean gliders and Proctor, eMII) there will be a very strong synergy with the IMOS activity and this project. The research team includes scientists from all the Australian coastal states and from the two Commonwealth research agencies: CSIRO and AIMS.

The projects also fit with current global studies. A recent SCOR working group 129 on shelf ocean exchanges identified the following as future research priorities: (a) continued development of nested regional models that couple physical and biogeochemical processes; (b) development of data assimilation tools that allow biogeochemical models to take advantage of emerging ocean observations; and, (c) OGCM model development using adaptive unstructured grids to deliver the detail needed for cross shelf break and along shelf break flows and fluxes. Some of these topics, in particular (a) and (b) form a major component of this study. Similarly, the Natural Environmental Research Council (NERC) in the UK is embarking on an observational and modelling study of Ocean Shelf-Edge Exchange around UK waters and Prof Sharples who is a member of the study team has a major role in this project. In the Indian Ocean, the SIBER (Sustained Indian Ocean Biogeochemical and Ecological Research) project is concentrating on the biogeochemical fluxes in the Indian Ocean region. The scientific leaders of SIBER Profs Rayleigh Hood and Jerry Wiggert are members of the task team.

The *broader impacts* of the proposed research include its enhancement of **our understanding and ability to predict the fate of anthropogenic CO₂ in the atmosphere, an issue of great societal concern, and thus with high potential for publication in A* journals.**

Work plan:

We propose to conduct 4 workshops, with the first and the fourth including our international collaborators.

- Workshop 1 (within 1-3 months of project initialisation): Define the study, identify data sources (collator), develop numerical modelling approach – identify regions to model. Develop detailed work plan. Identify subgroups to undertake reviews of data, knowledge and concepts.
- Workshop 2 (after ~12 months of project initialisation): Review work undertaken and progress, Discuss outcomes from preliminary analysis of data; update on modelling (smaller number of people).
- Workshop 3 (after ~15 months of project initialisation): Review work undertaken and progress, Finalise data analysis – discuss outputs in terms of papers; update on modelling (smaller number of people).

- Workshop 4 (after ~20 months of project initialisation): Final workshop; Synthesis of data analysis and model results for each region; drafts of papers. Identify and develop proposals for continuing collaborative research.

The following two major tasks comprise the overall study:

- (1) Collation of the relevant physical and biogeochemical data from the different regions (Figure 1). This data will be used for identification of processes as well as for model validation. Majority of the study regions (Figure 1) are coincident with the location of IMOS infrastructure. The data collation thus will be facilitated by accessing the IMOS eMII and the AODN data portals (Dr Roger Proctor, who is the eMII facility leader and Director of the AODN Development Office is one of the Principal Investigators). The study team, includes majority of the individuals in Australia, who are responsible for the collection and analysis of this data (both physical and biogeochemical) and is therefore very familiar with the required data sets.
- (2) A coupled physical-biological-chemical model will be used to simulate carbon biogeochemistry on the continental shelves of Australia, with the aim of predicting the carbon fluxes in the different regions covering tropical, sub-tropical and temperate regions (Figure 1). The most appropriate modelling approach: either a fully 3-dimensional (e.g. McDonald et al., 2009) or a 2D dimensional slice model (e.g. Proctor et al., 2003), and the actual model will be discussed and adopted during the first workshop. The model will use global models such as Bluelink to provide the necessary boundary conditions for physical forcing. The study team has experience with the type of models required with many currently working and publishing in this area. The research associate appointed as part of this proposal will spend majority of the time adapting the model selected to different regions across Australia (Figure 1). Priorities for model application will be developed during Workshop 1.

5. Proposed Participants (National and International):

National

Prof C Pattiaratchi (UWA)
Dr Roger Proctor (UTas)
Dr Peter Ridd (JCU)
Prof Gary Kendrick (UWA)
Prof Malcolm McCulloch (UWA)
Dr Christine Hanson (UWA)
Dr Peter Thompson (CSIRO)
Dr Richard Brinkman (AIMS)
Dr Moninya Roughan (UNSW)
Dr Martina Doblin (UTS)
Dr Mark Baird (UTS)
Dr John Middleton (SARDI/Flinders)
Dr Sophie Leterme (Flinders)
Dr Nick D'Adamo (IOC)

International

Prof Jonathan Sharpley (Proudman Oceanographic Laboratory, UK)

Prof Jerry Wiggert (University of Southern Mississippi, USA)

Prof Raleigh Hood (University of Maryland, USA)

Prof Hans Burchard (Baltic Sea Research Institute, Germany)

6. Short biographical paragraph for each Participant

Charitha Pattiaratchi

Prof. Charitha Pattiaratchi is Winthrop Professor of Coastal Oceanography and Head of the School of Environmental Systems Engineering at The University of Western Australia. He is also the Leader of the Australian National Facility for Ocean Gliders (ANFOG) and the node leader for West Australian Integrated Marine Observing System (WAIMOS). He has supervised over 35 PhD students and 105 honours students and has published over 300 articles/reports on coastal oceanography, which include over 100 in peer-reviewed international journals. He has received more than \$ 25 million in research funding. Prof. Pattiaratchi's research interests are in coastal oceanography and encompass physical processes and their influence on geological, climate and biological processes in the continental shelf region, the nearshore (beach) zone and estuaries based on field experiments and numerical modelling. He has played an active role in examining climate change effects in coastal regions of Western Australia and particularly in terms ocean currents, wind and wave climate, sea level variability, coastal flooding and beach stability.

Roger Proctor

Roger Proctor is the Director of the eMarine Information Infrastructure Facility of the Integrated Marine Observing System and the Director of the Australian Ocean Data Network Development Office, both based in the University of Tasmania, Hobart. He has a PhD in Applied Oceanography (numerical modelling) from the University of Liverpool (1981). Prior to his appointment in IMOS he was Research Program Leader for Modelling and Observation Systems for Shelf Seas at the Proudman Oceanographic Laboratory (now National Oceanography Centre) in the UK where he established the Irish Sea Observatory and the coupled physical-biogeochemical modelling system POLCOMS (POL Coastal Ocean Modelling System) incorporating 3-dimensional baroclinic hydrodynamics, wind waves, biogeochemical processes and sea ice. Research interests include shelf seas oceanography, interactions between physical and biological processes, data assimilation, tracer studies, global palaeotidal modelling, tide & storm surge modelling, and recently data management and research. He has authored more than 200 articles including over 75 peer-reviewed publications.

Peter Ridd

Before receiving his PhD in Physics (Electromagnetics) from JCU, Peter Ridd worked at the Australian Institute of Marine Science from '84-88 as an experimental scientist working on the oceanography of the North Australian region. He joined the staff at James Cook University in 1988. His research interests are in mangrove swamp hydrodynamics, sediment transport, instrument design, electromagnetic ground conductivity sensors, coastal oceanography, coral reef sediment dynamics, the health of the Great Barrier Reef, geological climate records, ocean energy sources. He has published extensively in the general area of environmental Physics.

Gary Kendrick

Gary Kendrick research focuses on the interrelationship between abiotic and biotic processes in the marine environment, and their impact on the patterns of biodiversity and distribution and abundance of communities and populations of organisms. Kendrick has focused this research on two model systems: species-rich marine algal assemblages, and species-poor seagrass landscapes. In the species-poor subtidal seagrass systems he has studied the dynamics of seagrass landscapes and modelled emergent landscape-scale phenomena related to the clonal growth of seagrasses at

the shoot scale. There is a strong spatial base for this research agenda with innovations in research into seagrass spatial ecology and marine landscape ecology. The mapping and modelling of seagrasses has been a productive avenue for the study of the evolution of seagrass landscapes. The major limitation of interpreting landscape pattern is the poor understanding of clonal and population genetic diversity in seagrass landscapes. His long-term research goal is to move from marine ecological studies that describe the distribution of marine organisms to a predictive framework for understanding the spatial linkages between marine species distributions, their genetics, biology and the physical environment. To successfully address this research interest Kendrick has built an interdisciplinary research team, and has obtained large national competitive research grants (CRC, NHT 2, ARC Discovery, ARC Linkage). The Marine Ecology research group at Plant Biology, University of Western Australia under Kendrick's supervision has over the last 8 years developed an internationally recognised profile in benthic marine ecology research and a capacity for mapping benthic habitats using a combination of hydroacoustic and video methodologies. Since 2009, Gary has been the acting Director of the UWA Oceans Institute. He has published 105 refereed articles, conference proceedings and book chapters.

Malcolm McCulloch FAA FRS

Malcolm McCulloch was appointed as a Western Australian Premier's Fellow in mid 2009 and holds a Professorship in the School of Earth and Environment at The University of Western Australia. He has been responsible for establishing a new node for the ARC Centre of Excellence for Coral Reef Studies at The University of Western Australia, and heads the Centre's research Program 1: *Evolutionary and Environmental Change*. He is also establishing a new state-of-the-art mass spectrometry and geochemistry facility that will enable new innovative techniques to be applied to the environmental sciences. His research interests focus on the modern part of the geological record using isotopic and trace element geochemical methods to determine how climate and anthropogenic processes have influenced both past and present marine environments with particular emphasis on coral reefs. Malcolm received his PhD from the prestigious Californian Institute of Technology (Caltech), and in his early career was a leader in crustal and mantle evolution, and cosmochemistry. Malcolm is an *ISI Highly Cited Researcher* and has published over 250 scientific papers in leading international journals including 23 in *Science* and *Nature*. He has received a number of prestigious awards including Fellowships of the American Geophysical Union (2002), the Australian Academy of Science (2004), the Geological Society of Australia (2007), the Geochemical Society (2008) and was recently elected to The Royal Society (2010). He also holds an Honorary Doctorate from Curtin University (2007) and was awarded the Jaeger Medal for career excellence in the earth sciences by the Australian Academy of Sciences (2009).

Christine Hanson

Christine Hanson (PhD, UWA, 2004) is a biological oceanographer based at the Australian National Facility for Ocean Gliders (ANFOG). She has expertise in bio-physical oceanography and phytoplankton ecology, and has published on phytoplankton productivity dynamics within the Leeuwin Current system, including quantifying the ecological importance of seasonal, sporadic upwelling in WA coastal waters and the significance of deep chlorophyll/ phytoplankton layers to regional production dynamics. Christine is a member of the WAIMOS Scientific Reference Committee, and is Co-Convenor of the IMOS National Working Group on Bio-optical Instrumentation and Observing.

Peter Thompson

Peter Thompson (BSc, University of British Columbia, 1977. MMST, University of Toronto, 1983. PhD, University of British Columbia, 1991) is a phytoplankton ecologist with interest in understanding how, where, when and why phytoplankton blooms occur. Phytoplankton are the

major vector transferring carbon from the atmosphere to long term sequestration in the sediments. These processes are the main focus for the small team Peter leads at CSIRO Marine and Atmospheric Research. Peter is Leader for the Tasmanian Node of IMOS and a member of the SCOR working group #137 on phytoplankton time series. He was lead author on the analysis of long term time series of oceanographic data from Australia's coastal stations (published 2009) and lead author on the comparison of phytoplankton ecology on the east versus west coast, a study that investigated how the differences in oceanographic conditions shaped the differences in community composition and seasonal bloom dynamics (2011). Peter has worked extensively on the links between physics, phytoplankton and zooplankton, studying trophic transfer efficiency. He has published ~ 70 papers in the international literature and is an Associate Editor for Journal of Phycology.

Richard Brinkman

Richard Brinkman is a Senior Research Scientist at the Australian Institute of Marine Science (www.aims.gov.au), where he leads and implements research projects within the broad topics of coastal oceanography and physical-biological interactions on continental shelves. Richard currently undertakes research on shelf dynamics, coupling of shelf and ocean circulation, sediment dynamics on tropical coasts, wave propagation over coral reefs and physical-biological interactions at regional and local scales, using a mix of field observations and numerical modelling.

Moninya Roughan

Dr Moninya Roughan is a physical oceanographer with expertise in regional ocean circulation, and continental shelf processes. She is actively involved in NSW-IMOS, being part of its leadership team since its inception in 2006. She also leads the physical oceanography program and the moorings team (> \$1 Mill p.a.). She leads an active research group at UNSW in regional ocean dynamics using a combination of observations and modelling techniques. Working closely with national and international modelling experts Roughan and her team have developed a high resolution regional model for the shelf waters along the coast of NSW. This expertise will be highly valuable to this project.

Martina Doblin

BSc (Hons), Monash University, 1993. PhD, University of Tasmania, 1998. Postdoc, Old Dominion University, 1998-2000. Self-supporting Research Assistant Professor, Old Dominion University, 2000-2004. Senior Research Fellow, University of Technology, Sydney, 2005 – present. Recognised nationally and internationally for her work on biogeochemical cycling in marine and estuarine foodwebs, as well as plankton ecology, she was awarded the U.S. Department of Commerce Gold Medal in 2008 together with colleagues for her work on species introductions to the Great Lakes. Martina has published more than 40 peer-reviewed papers including book chapters, and has received > \$3.8 million in research funds. Her current research examines responses of lower trophic levels to physical forcing, bio-optical measurements in coastal systems to improve satellite remote sensing products as well as impacts of climate change on biodiversity and functioning of marine systems. She is currently the co-leader for the NSW node of IMOS.

John Middleton

A/Professor John Middleton leads the Oceanography Program at SARDI Aquatic Sciences. He has published over 50 papers and reports and is an executive member of the International Association for the Physical Sciences of the Oceans. John also leads the \$6M Southern Australian Integrated Marine Observing System (SAIMOS) as well as the SAIMOS mooring facility. The Oceanography Program is continuing to develop a hydro/biogeochemical modelling facility for

the region that is being used to study both the physical and planktonic systems of the region. Funding for non-SAIMOS projects includes \$1.2M for the FRDC Carrying capacity of Aquaculture in Spencer Gulf project as well as over \$600K for commercial marine monitoring projects.

Sophie Leterme

BSc (Hons), Universite des Sciences & Technologies de Lille (Lille I, France), 2002. MSc, Universite Pierre & Marie Curie (Paris VI, France), 2003. PhD, University of Plymouth (UoP, UK), 2006. Postdoc, Flinders University, 2006-2008. Lecturer and Node sub-leader of SAIMOS (South Australian Marine Observing System), 2008-present. Since 2006, she focused her research on an innovative project combining chemistry, molecular techniques and marine biology, investigating the impact of salinity on phytoplankton dynamics and diatoms frustules morphology, in particular the size of their nano-pores. She also co-developed the biological component of the SAIMOS program that aims to monitor the physical processes on the South Australian continental shelf and associated spatio-temporal dynamic of the planktonic community. Her work and collaborations have been published in 16 papers. In collaboration with PEARSON she developed customised editions of textbooks for the topic she lectures at Flinders University, the latest titled 'BIOL2701 Experimental Design and Statistics for Biology'.

Mark Baird

Mark Baird is biological oceanographer in the Climate Change Cluster at the University of Technology Sydney. He uses both observations and numerical models to explain how the circulation of the ocean affects marine life. Baird has been on 7 research cruises and 9 autonomous glider deployments. He develops coupled physical-biological ocean models, and uses them to test ideas of how physical and biological processes interact. These studies have resulted in 28 peer-review journal articles. Baird has also supervised 6 PhD students.

Nick D'Adamo

Dr Nick D'Adamo is a physical oceanographer in the UNESCO Intergovernmental Oceanographic Commission, Perth Regional Programme Office. He has a B.Eng Civil, MSc (Research) and PhD in physical oceanography, with the research history involving estuarine and coastal/shelf physical oceanography and related biological behaviour. He is a member of the Australian IMOS National Advisory Board. Dr D'Adamo facilitates and coordinates marine scientific alliances for programs and projects in the deep ocean and coastal waters around Australia, focusing on the Indian Ocean, South East Asian and SW Pacific regions. Understanding cross-shelf processes that bring water and contained substances towards, along and away from the coastal zone are important drivers in the programs that Dr D'Adamo is associated with and his past experience and publication history relates directly to the oceanography and associated biological relationships that characterise the coastal zone, with specific reference to existing and prospective marine protected areas in tropical and temperate ecosystems of the Western Australian marine region.

Prof Jonathan Sharples

Prof. Jonathan Sharples is since 2010 a Professor in Oceanography, a post jointly supported by the University and the National Oceanography Centre. He graduated with a BSc in Physics with Astrophysics (Univ. Birmingham) in 1987, and carried out an MSc and PhD in Physical Oceanography at the University of Wales, (1987-1992). He has worked as a PDRA at the University of Wales Bangor (1992-1993), a scientist at New Zealand's National Institute of Water and Atmospheric Research (1993-1996), and research fellow, lecturer then senior lecturer at the University of Southampton (1996-2003), and a senior scientist at the Proudman Oceanographic Laboratory (2003-2009). His research (47 papers since 1991) is on shelf and shelf

edge oceanography, linking physical processes to ecosystems, using seagoing process studies and numerical models. He has led 3 research cruises aboard NERC vessels to the shelf edge of the Celtic Sea, has supervised 5 PhD students to completion, and is currently a supervisor or joint supervisor for 5 students. He has carried out research into internal tides and their impacts on shelf edge ecosystem structures off NE New Zealand and off the Celtic Sea. He currently leads the National Oceanography Centre's research programme in Shelf Sea Processes, with a budget of £1.8M per year, and is a co-PI on a NERC responsive mode project on turbulent mixing and nutrient fluxes at the shelf sea thermocline (NE/F002432/1 A thermocline nutrient pump (joint with Rippeth, University of Bangor)).

Prof Jerry Wiggert

Professor at the Department of Marine Science, University of Southern Mississippi, USA. He received his Ph.D. from University of Southern California (1995); E.A.E. Aerospace Engineering, University of Southern California (1991); M.S. Aerospace Engineering, University of Southern California (1986). His research interests are: oceanic biogeochemical and ecological responses to physical variability over the full range of spatio-temporal scales; determination of the impact of aeolian nutrient deposition on spatio-temporal variability of marine primary production, export fluxes and carbon cycling; Effect of riverine freshwater fluxes and associated particulate and dissolved materials on the physical and biogeochemical processes of adjacent coastal waters; and, biological and chemical response of the ocean to extreme, episodic forcing. He has published widely, including editing 2 books, on biogeochemical processes in the Indian Ocean. He is a member of International scientific committee of SIBER (Sustained Indian Ocean Biogeochemical and Ecological Research).

Prof Rayleigh Hood

Professor at University of *Maryland* Center for Environmental Science (UMCES). Studied at University of California, San Diego - Scripps Institution of Oceanography (1990, PhD) and University of Washington (1983, BS). Research interests are in phytoplankton production and light response; analytical and numerical modeling of primary production and pelagic ecosystems; bio-optical oceanography; phytoplankton physiology; carbon dioxide flux at the air/sea interface. He is the program leader for SIBER (Sustained Indian Ocean Biogeochemical and Ecological Research), an international program currently under planning in the Indian Ocean region.

Prof Hans Burchard

Prof. Dr. Hans Burchard (HB) received his M.Sc. in Applied Mathematics in 1992 from the University of Hamburg, Germany. In 1995, he received his Ph.D. at the Institut für Meereskunde of the University of Hamburg. After a one-year stay at the International Centre for Computational Hydrodynamics (ICCH) in Hørsholm, Denmark, he was employed from 1996 - 1998 at the Joint Research Centre (JRC) in Ispra, Italy. From 1999-2001, he worked at the Institut für Meereskunde of the University of Hamburg. Since 2002, he is Professor at the Baltic Sea Research Institute Warnemünde. His main research activities are numerical modelling of marine turbulent flow as well as coastal ocean process studies. He is developer of the Public Domain water column model GOTM and the three-dimensional circulation model GETM.

7. 2011-2012 Detailed Budget and justification

Item	Year 1 (2011)	Year 2 (2012)
Research Associate (Level B) including on-costs	\$ 104,445	\$ 107,578
Computer support for RA (multi-core 64 bit)	\$ 4,400	
Workshop 1	\$ 22,000	
Workshop 2	\$ 12,000	
Workshop 3		\$ 12,000
Workshop 4		\$ 22,000
Local (within Australia) travel	\$ 4,000	\$ 2,100
Conference Travel	\$ 3,000	\$ 3,500
Publication costs		\$ 2500
TOTAL	\$149,845	\$149,678
		\$299,523

Budget justification

Personnel

The only personnel costs will be for a full-time post-doc as a level B appointment.

Computer Support

UWA has access to high performance computers with establishment of the Pawsey Centre. However, a high end desk top for the Research Associate is required.

Travel and accommodation

Funds under this category is divided into 3 categories: (1) costs for hosting the workshops – we have planned 4 workshops with the initial and final including international collaborators whilst the other two will be limited to Australian participants; (2) Australian travel by the PI's and/or research associates to visit collaborators at JCU and UTas and perhaps other Centres; (3) We expect that the research associate will participate in 2 international conferences one each in each year. Presentation of the results of the study is a key element in the communication plan of the project. We have budgeted \$1,000 per domestic participant per workshop and \$4,000 per international participant per workshop.

Publication costs

In general A* journals (ARC ERA rank) in Oceanography and Biogeochemistry: Journal of Physical Oceanography, Geophysical Research (Oceans), Geophysical Research Letters, Nature Geoscience, etc incur page charges and additional amounts for colour figures. We anticipate publications in the second year of the project and have allocated ~\$2,500.

8. *Expected Outcomes*

This project has assembled a world class team with expertise in physical oceanography and biogeochemistry and also in field data techniques/analysis and numerical modelling. The team has a proven record (total of over 200 papers over the past 5 years) of publishing in high quality journals (e.g. *Science*, *Nature* and ARC ERA A*&A) and the subject matter to be covered in this study is highly amenable to continuing these high quality publications.

The project will also lead to a number of PhD and Honours projects. The subject matter is highly topical with complementary studies being undertaken in the UK and the US. However, this is the first time that a study covering a whole continent has been undertaken which also encompasses different climatic environments: tropical, sub-tropical and temperate. The study results could be a topic for a series of papers for a special issue of a leading journal focussing on the regional differences of the continental shelf pump across Australia. It will also establish a strong basis for continuing the collaborative work into the future through ARC and other research funding opportunities.

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