GAIC-2015

Program and Abstracts

A view of the Aran Islands (*Oileáin Áran*) in Galway Bay.

GAIC-2015

"Sustained ocean observing for the next decade"
A combined GO-SHIP/Argo/ IOCCP conference on physical and biogeochemical measurements of the water column

14-18th September 2015, Galway, Ireland

The USB memory keys in your registration bag are supplied by the JCOMMOPS Office in Brest. These contain the complete volume (in a pdf file) including all abstracts with hyperlinking connecting the program to the abstracts and vice versa. The key should also contain (this document was being written before the plan for the keys was complete) maps and information about the programs supported by our colleagues at JCOMMOPS. We thank everyone at JCOMMOPS for their continued and invaluable support of the observing programs.

EuroArgo is a key sponsor of the GAIC-2015 meeting. It is because of EuroArgo sponsorship that the Argo Director can attend this meeting. We thank the EuroArgo consortium for its generous support and encourage attendees to visit their display booth.

Welcome from the Conference Conveners

The conveners have great pleasure in welcoming you to a science meeting where we bring together participants in GO-SHIP, Argo and IOCCP, with the particular purpose of reviewing and stimulating further research that exploits the synergies among the sponsoring programs. The paragraphs below highlight some science themes that span the programs, and some questions that might be addressed during the conference.

Ultimately the scope and content of the conference is determined by the abstracts submitted. The three sponsoring programs for this conference promote and coordinate sustained observations of the water column to reveal the changing physics, chemistry and biology of the ocean. Argo began with a focus on physical properties of the upper 2000 metres of the ocean. GO-SHIP covers the full water column, with repeat physical and biogeochemical measurements from research ships. The focus of IOCCP is on coordination of ocean carbon and marine biogeochemistry observations, including data from research ships and other platforms. Each program has established maturity in its own field. Studies combining data from these programs are addressing new research questions and adding value to the individual programs. New technology means there is growing overlap in the research questions that each program can now address. It also presents challenges for how to implement and utilise new technology.

Questions about the climate of the global earth system present new challenges. Ocean observations must be used to provide ever better descriptions of variability and trends, leading to greater understanding of anthropogenic change. The ocean integrates changes in forcing on large space and time scales. This conference will bring together these programs that make sustained observations of the water column on global scales, showcasing the individual programs as well as the synergies among them. An additional focus of the conference will be the future opportunities presented by these programs: in particular the technological development of Argo into the realms of Deep and Bio-Argo. Deep and Bio Argo measurements will supplement GO-SHIP and IOCCP observations in new ways. In turn, these new measurements will depend on ship-borne programs for calibration and data quality assurance of the new float data. Oceanographers are entering a new and exciting phase of ocean exploration. It is timely to bring together scientists from the communities that will enact the next phase of the revolution.

Science Program Committee

Brian King	b.king@noc.ac.uk
Elaine McDonagh	elm@noc.ac.uk
Richard Feely	Richard.A.Feely@noaa.gov
Howard Freeland	argodirector@outlook.com
Nicolas Gruber	nicolas.gruber@env.ethz.ch
Gregory Johnson	gregory.c.johnson@noaa.gov
Megan Scanderbeg	mscanderbeg@ucsd.edu
Toste Tanhua	ttanhua@geomar.de
Maciej Telszewski	m.telszewski@ioccp.org
Rik Wanninkhof	rik.wanninkhof@noaa.gov

Local Arrangements Committee

Fiona Grant	Fiona.Grant@Marine.ie
Mick Gilooly	Mick.Gillooly@Marine.ie
Deirdre Fitzhenry	Deirdre.Fitzhenry@Marine.ie
Brian Ward	bward@nuigalway.ie
Evin McGovern	Evin.McGovern@Marine.ie

Welcome from Dr. Peter Heffernan, the Chief Executive of the Marine Institute, Galway.

I have great pleasure in welcoming each of you to the GAIC 2015 Conference in Galway. It is an exciting time for an ocean observing community with programmes and projects launched recently aimed at the development of sustained and integrated ocean observing systems, which will stimulate further research in the field of oceanography.

Ireland, taking its seabed area into account, is one of the largest EU states, with rights over one of the largest sea to land ratios (over 10:1) of any EU state. Our ocean is recognised as a national asset and the Government has implemented an Integrated Marine Plan, called Harnessing Our Ocean Wealth. Harnessing Our Ocean Wealth sets out the Irish Government's vision, high-level goals, and key actions to put in place the appropriate policy, governance and business climate to enable our marine potential to be realised.

Galway, located on the fringes of Europe and facing the Atlantic Ocean, was previously the setting for important gatherings of the ocean observing scientific communities and governing authorities. In 2013, the Galway Statement on Atlantic Ocean Cooperation was signed by representatives of the European Union, the United States and Canada who agreed to join forces on Atlantic Ocean Research. The goal is to better understand the Atlantic Ocean and promote the sustainable management of its resources. The work will also study the interplay of the Atlantic Ocean with the Arctic Ocean, particularly in relation to climate change.

The Marine Institute has been an active member in initiatives aimed at the development and implementation of strategies targeting sustained and integrated ocean observations, including Euro-Argo. Since the signing of the 'Galway Statement' we have engaged in several relevant Horizon 2020 projects that make the vision put forward in the Statement a reality. These projects include 'The Atlantic Ocean Research Alliance Coordination and Support Action' (AORAC-SA) and 'Optimizing and Enhancing the Integrated Atlantic Ocean Observing System' (AtlantOS), amongst others.

I would like to thank each of you for attending the GAIC 2015 Conference and for bringing your expertise to this gathering. Throughout this conference, I ask you to stay engaged and to help us shape the future of sustained ocean observing. I wish you all a fruitful event and a memorable time in Galway.

Dr. Peter Heffernan MRIA
Chief Executive
Marine Institute

The Marine Institute, Galway

Exhibitors at GAIC-2015

The following companies and organisations have rented display space. Please visit their displays during the meeting, we depend on them to make our programs work.

Swale Technologies has been supplying a range of quality instrumentation and equipment for over 25 years and has represented Teledyne Webb Research for much of this time. Customers include researchers and operators in environmental, engineering, defence, dredging, oil & gas, renewable energy and survey sectors. In addition to the APEX floats, widely used in the Argo programme, our product portfolio includes:

- Acoustic modems, hydrophones, pingers, releases and ADCP current profilers & wave sensors.
- Pop-up buoys, current meters and wave and tide recorders, CTDs and single & multi-parameter data loggers. Glass sphere floats and instrument housings.
- Winches, rosettes & Niskin bottles for water sampling. ROVs & towed vehicles.
- Plankton nets and oil-spill sampling kits. As well as our own custom built battery packs.

Sea-Bird Scientific, a global provider of oceanographic and water quality sensors and platforms, is headquartered in Bellevue, WA. Over 40+ years, Sea-Bird Scientific has developed award-winning technologies to solve the most difficult problems in natural water. Its CTDs are the centerpiece of most oceanographic moorings, AUVs and profiling systems. The global Argo Array, with unprecedented accuracy and stability in temperature and salinity, has enabled scientists to detect ocean climate trends not previously possible. Sea-Bird Scientific combines the capabilities of Sea-Bird Electronics, WET Labs, and Satlantic to provide best-of-class sensors and systems for oceanographic research and environmental water quality monitoring of physical and biogeochemical properties. Today Sea-Bird Scientific employs over 200 people in the USA, Canada, and Europe in the development, manufacture, calibration, sales, and support of our products.

The Marine Institute is the State agency responsible for marine research, technology development and innovation in Ireland. It carries out environmental, fisheries, and aquaculture surveys and monitoring programmes to meet Ireland's national and international legal requirements. It provides scientific and technical advice to Government to help inform policy and to support the sustainable development of Ireland's marine resource. It aims to safeguard Ireland's unique marine heritage through research and environmental monitoring. Its research, strategic funding programmes, and national marine research platforms support the development of Ireland's maritime economy.

The Tsurumi-Seiki, Co. LTD (TSK) is a leading oceanographic equipment manufacturer based in Yokohama, Japan. Founded in 1928, TSK products include a wide range of instrumentation designed specifically to support the study of the water environment, including the 4,000m Deep NINJA Argo-style float. They include expendable probes and probe autolaunchers, water quality monitors, laboratory salinometers, wave meters, CTDs, and mechanical oceanographic equipment.

Established in 1982, RS Aqua are a UK based team of marine scientists, engineers and instrument technicians who work with clients in the marine scientific industry to design and deliver marine measurement solutions. Over the years the company has developed longstanding relationships with an elite group of high-specification manufacturers and service providers, and is able to offer intelligent solutions across a range of oceanographic, environmental and ecological survey requirements. This instrumentation and survey design expertise is complimented by a properly resourced technical support team and they offer a variety of certified maintenance and calibration services from their base in Hampshire.

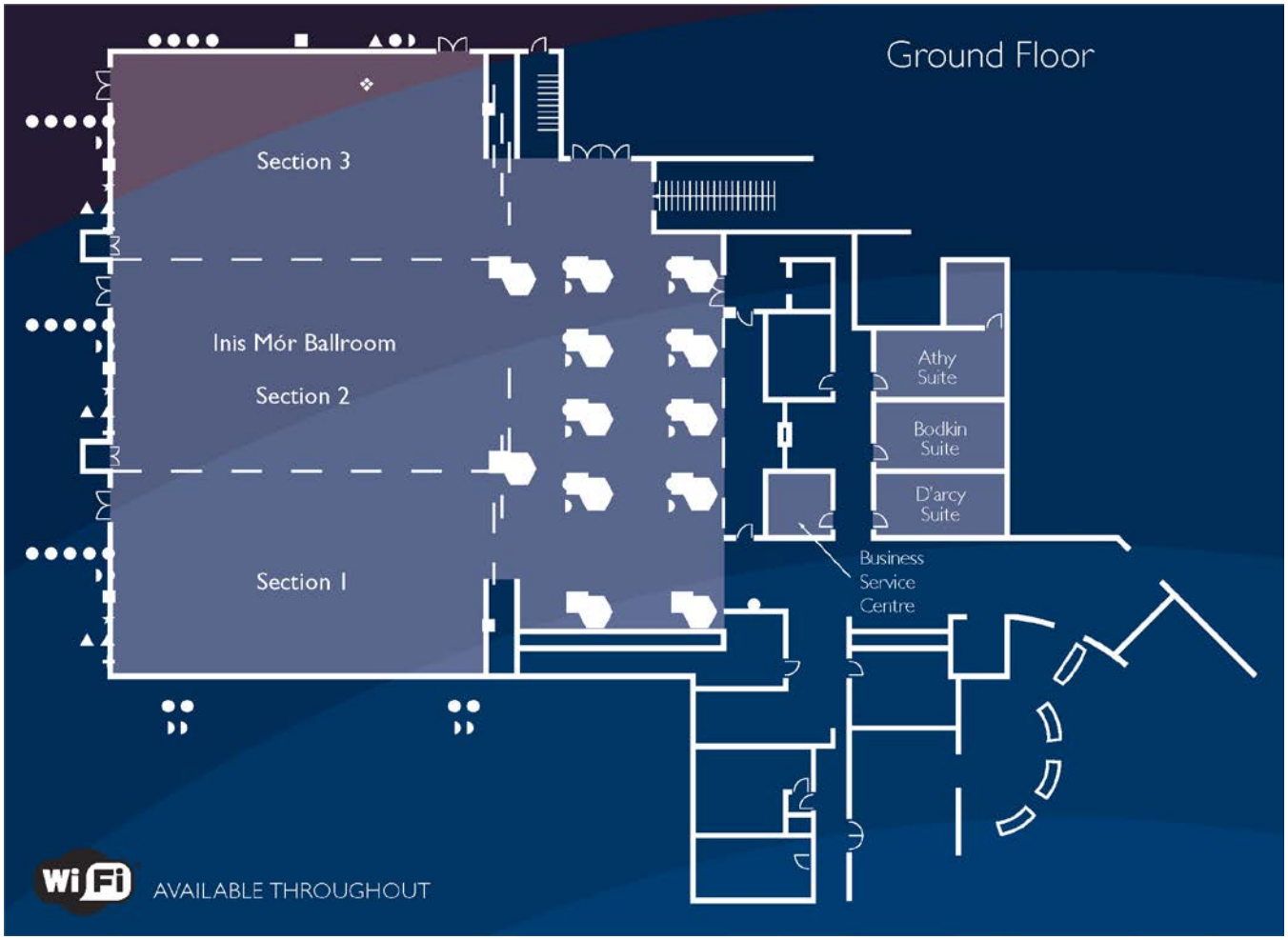
RBR creates instruments to measure the blue planet. From the ocean abyss to the polar ice cap, their sensors track water parameters – temperature, depth, salinity, dissolved gases, pH, and many others. With design and manufacturing centrally located in Ottawa, their team works in a fast paced, dynamic atmosphere to serve customers from all corners of the globe.

The Euro-Argo research infrastructure organizes and federates European contribution to Argo (http://www.euro-argo.eu); it is part of the European roadmap on large research infrastructures. Euro-Argo engaged in a preparatory phase 2008 to 2011, funded through the EU 7th Framework Research Program, whose main outcome was to agree on the legal and governance framework (Euro-Argo ERIC) under which to establish the research infrastructure. Ministries from 9 European countries (Finland, France, Germany, Italy, Netherlands, Greece, UK, Norway, Poland) have agreed to form this new legal European entity to organize a long-term European contribution to Argo. It was set up by a Commission Implementing Decision of May 5, 2014. The Euro-Argo Research Infrastructure (RI) is a distributed facility centralised in France (Ifremer, Brest) which is owned and controlled by the Euro-Argo ERIC and distributed national facilities. The distributed national facilities operate with direct national resources. As part of the Euro-Argo research infrastructure, they agree to a multi-annual commitment of resources (in particular, floats to be deployed and for the data system), and to coordinate their activities through the Euro-Argo ERIC. The priorities are first to maintain and consolidate the global array and regional coverage for European seas by increasing European contribution from 150-200 floats to 250 floats/year and consolidating the data processing system. Secondly the Euro-Argo ERIC will prepare the evolution of Argo to address new scientific and operational challenges and in particular engage in the new phases of Argo (biogeochemistry, deep ocean, Arctic).

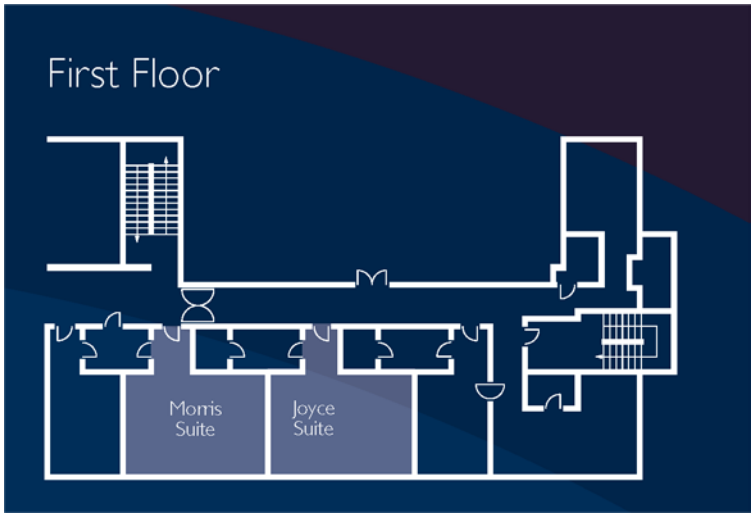
nke Instrumentation designs, manufactures and sells instruments and systems for the measurement and the monitoring of oceans and fresh waters. nke's fields of application: are ocean, deep sea, coastal, rivers and lakes. Our range of products includes: data loggers, autonomous buoys, deep floats, sediment sensors, profilers.

nke Instrumentation is involved in several research projects, both nationally and internationally, and works in partnership with scientific institutions such as Ifremer and CNRS. The french company has launched its Brazilian subsidiary in July 2013 : nke Instrumentaçao, located in Rio de Janeiro (Serviços e Equipamentos Ambientais e Oceanogràficos). nke Instrumentation has extensive experience in the design and the manufacturing equipment useful for oceanographers studies of the evolution of oceans and climate.

Talks, open discussions and Thursday's Banquet will take place in the Inis Mór Ballroom on the ground floor.



The breakout room "D'arcy Suite" on the ground floor is available for use; also the Morris and Joyce Suites on the First Floor are available for use.



Program Overview

Date	Time	Event
Monday 14th Sept.	16:00	The registration desk opens
	18:00	The Teledyne Marine Systems icebreaker/cocktail party
Tuesday 15th Sept.	08:30	Welcome
	08:50	Session 1A - Talks presenting an overview of the problems being addressed at GAIC
	10:00	Refreshment break
	10:30	Session 1B - Talks presenting an overview of the problems being addressed at GAIC
	11:30	Poster/exhibition session
	12:30	Catered lunch
	13:30	Session 1C focussing on papers concerning the Indo-Pacific Region
	15:20	Refreshment break
	15:50	Session 1D continues a focus on papers concerning the Indo-Pacific Region
Wednesday 16th Sept.	08:50	Session 2A and Poster Session largely concerning the Southern Ocean Please note that the start time is later than other days.
	10:00	Refreshment break
	10:30	Discussion period #1
	11:30	Poster/exhibition session
	12:30	Catered lunch
	13:30	Session 2C largely concerning the Southern Ocean
	15:20	Refreshment break
	15:50	Session 2D – Papers concerning the Atlantic Ocean and its marginal seas
	19:30	Public lecture at NUI Galway
Thursday 17th Sept.	08:30	Session 3A largely concerning the Atlantic Ocean and its marginal seas.
	10:00	Refreshment break
	10:30	Session 3B largely concerning the Atlantic Ocean and its marginal seas.
	11:50	Poster/exhibition session
	12:30	Catered lunch
	13:30	Session 3C largely concerning the Atlantic Ocean and its marginal seas.
	14:40	Refreshment break
	15:10	Session 3D largely concerning the Atlantic Ocean and its marginal seas.
	16:10	Discussion period #2
	19:00	The conference banquet
Friday 18th Sept.	08:30	Session 4A largely concerning technical issues.
	10:00	Refreshment break
	10:30	Session 4B largely concerning technical issues.
	12:30	Catered lunch
	13:30	Session 4C largely concerning technical issues.
	14:40	Refreshment break
	15:10	Session 4D largely concerning technical issues.
	16:10	Discussion period #3
	17:10	Closing messages and farewell

Monday 14th September, 2015

The registration desk opens at 16:00 and there will be an icebreaker/cocktail party starting at 18:00, both in the Raddison Blu Hotel. The ice breaker party is sponsored by Teledyne Marine Systems. The meeting organisers thank them for their support and encourage attendees to visit the display of their agent, Swale Technologies.

Posters can be displayed any time after the registration desk opens. Posters can remain displayed until the end of the afternoon break on Thursday 17th and then taken down. The space will be needed that evening.

The individual talks are identified by a code 1 = Tues., 2 = Wed. etc, A is the first session in the morning, B after coffee etc, the final digit lists the sequence in the session. The talk identifier, e.g. 1A3 below, is a hyperlink in the electronic version of the program and abstracts. Click on the identifier to go to the abstract. Click on the identifier again beside the abstract to return to the program.

Tuesday 15th September, 2015

08:30-08:50 Welcome from the Organisers, the Chairs of the GO-SHIP, Argo and IOCCP programs, the Mayor of Galway and Dr. Peter Heffernan, the Chief Executive of the Marine Institute, Galway.

Session 1A - Talks presenting an overview of the problems being addressed at GAIC-2015
Chair: Brian KING

08:50-09:20 1A1 **Changes in ocean heat, carbon content, and ventilation: Review of the first decade of global repeat hydrography (GO-SHIP).**
Lynne D. TALLEY and many coauthors

09:20-09:40 1A2 **Deep Argo Workshop Report**
Nathalie ZILBERMAN, Guillaume MAZE, Dean ROEMMICH, Susan WIJFFELS, Steve RISER and Breck OWENS

09:40-10:00 1A3 **Informing Deep Argo array design using repeat hydrographic section data**
Gregory C. JOHNSON, John M. LYMAN and Sarah G. PURKEY

10:00-10:30 **Refreshment break**

Session 1B - Talks presenting an overview of the problems being addressed at GAIC-2015
Chair: Bernadette SLOYAN

10:30-10:50 1B1 **Informing a strategy for Deep Argo temperature observations**
Freya GARRY, Chris ROBERTS, Elaine McDONAGH, Brian KING, Adam BLAKER and Eleanor FRAJKA-WILLIAMS

10:50-11:10 1B2 **Global temperature trends from Argo and Hydrography data**
Damien DESBRUYERES, Elaine McDONAGH and Brian KING

11:10-11:30 1B3 **Euro-Argo : a new European Research Infrastructure for climate change research and operational oceanography**
Sylvie POULIQUEN, Pierre-Yves LE TRAON and Euro-Argo Partners

11:30-12:30 **An extended break (see next page)**

Tuesday 15th September, 2015 (continued)

11:30-12:30 **An extended break to view posters and visit the exhibits. The following poster presenters are asked to attend their posters during this break.**

1P1 **The Blob - A Pacific warm event 2013 to 2015.**
Howard J. FREELAND

1P2 **Formation mechanism of barrier layer in the subtropical Pacific**
Shota KATSURA, Eitarou OKA and Kanako SATO

1P3 **Mesoscale variability of deep currents south of the Kuroshio Extension**
Masatoshi MIYAMOTO, Eitarou OKA, Daigo YANAGIMOTO, Shinzou FUJIO, Masao KUROGI, Hiroyasu HASUMI

1P4 **SIO's Oceanographic Data Facility serves the GO-SHIP and Argo communities**
Daniel SCHULLER, Lynne TALLEY, Hannah ZANOWSKI, Robert KEY, Ken JOHNSON and Emmanuel BOSS

1P5 **Operational data delivery powered by Web and Geospatial standards**
Justin BUCK and Adam LEADBETTER

1P6 **Long-term variations of water property in the major three water masses along the JMA 137°E repeat hydrographic section**
Toshiya NAKANO, Tomoyuki KITAMURA, Kiyoshi MURAKAMI, Yusuke TAKATANI, Masao ISHII and Masafumi KAMACHI

1P7 **From Antarctica to Alaska:**
Ten Thousand Miles of Properties and Decadal Changes along 150°W
Alison MACDONALD, Sabine MECKING, Brendan CARTER, Jessica CROSS,

1P8 **Building Europe's Ocean Observing System (EOOS)**
Glenn NOLAN, Erik BUCH, Patrick GORRINGE, Niall McDONOUGH and Kate LARKIN

1P10 **JCOMMOPS: Delivering integrated information for the benefit of GO-SHIP and Argo**
Mathieu BELBEOCH, Champika GALLAGE, Martin KRAMP, Anthonin LIZE

1P11 **GO-SHIP: Building a global time-series of a suite of ocean properties.**
Steve DIGGS, Bernadette SLOYAN, Rik WANNINKHOF and Martin KRAMP

12:30-13:30 **Lunch Break**

Tuesday 15th September, 2015 (continued)

Session 1C focussing on papers concerning the Indo-Pacific Region
Chair: Lynne D. TALLEY

13:30-14:00 1C1 **Slowing of the deep meridional overturning circulation in the North Pacific**
Hiroshi UCHIDA, Shinya KOUKETSU, Masahide WAKITA, Takeshi KAWANO, James H. SWIFT and Masao FUKASAWA

14:00-14:20 1C2 **Subtropical thermocline variability: Changes in oxygen at 30°N and 32°S in the Indo-Pacific Basins**
Sabine MECKING, Lynne D. TALLEY, Alison M. McDONALD and Gregory C. JOHNSON

14:20-14:40 1C3 **Cross-mean flow spreading of North Pacific Central Mode Water: Property transport by mesoscale eddies**
Toshio SUGA , Kazunori NAKASHIMA and Yuta MURAI

14:40-15:00 1C4 **Decadal changes along 47°N based on hydrographic observations**
Shinya KOUKETSU, Satoshi OSAFUNE, Hiroshi UCHIDA, Yuichiro KUMAMOTO and Akihiko MURATA

15:00-15:20 1C5 **Trends of oxygen decrease and carbon increase in the western North Pacific as revealed at high-frequency repeat sections**
Masao ISHII

15:20-15:50 **Refreshment break**

Session 1D continues a focus on papers concerning the Indo-Pacific Region
Chair: Pierre-Marie POULAIN

15:50-16:10 1D1 **Recent freshening of the East Australian Current and its eddies**
Tatiana RYKOVA and Peter OKE

16:10-16:30 1D2 **Estimating the velocity and transport of the East Australian Current using Argo, XBT, and Altimetry**
Nathalie ZILBERMAN, Dean ROEMMICH and Sarah GILLE

16:30-16:50 1D3 **Decadal variability of Subtropical Mode Water subduction and its impact on biogeochemistry**
Eitarou OKA, Bo QIU, Masao ISHII, Toshiya NAKANO, and Toshio SUGA

16:50-17:10 1D4 **Eddy transport at 1000 m depth estimated by Argo floats**
Katsuro KATSUMATA

17:10-17:30 1D5 **Methane distributions and sea-to-air fluxes in the South China Sea and the West Philippines Sea**
Hsiao-Chun TSENG, Chen-Tung Arthur CHEN, Alberto V. BORGES, and T. Angel DELVALLS

Wednesday 16th September, 2015

Session 2A and Poster Session largely concerning the Southern Ocean
Chair: Toshio SUGA

08:50-09:20 2A1 **Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM): Linking GO-SHIP and biogeochemical Argo observations**
Jorge SARMIENTO, Kenneth JOHNSON, Lynne TALLEY, Stephen RISER, Joellen RUSSELL and Emmanuel BOSS

09:20-09:40 2A2 **Deep temperature variability on line SR1b in Drake Passage**
Yvonne FIRING, Elaine McDONAGH, Brian KING and Damien DESBRUYERES

09:40-10:00 2A4 **Thermohaline variability of the Atlantic sector of the Southern Ocean from 1992-2012 using an Argo-including altimetry-based GEM**
Katherine HUTCHINSON, Sebastiaan SWART, Andrew MEIJERS, Isabelle ANSORGE and Sabrina SPEICH

10:00-10:30 **Refreshment Break**

10:30-11:30 **Discussion Period:** Gregory Johnson, Nathalie Zilberman, Toshio Suga, and Virginie Thierry will lead a discussion on requirements for exploring the global deep ocean, including synergies among Deep Argo, GO-SHIP, and other observations. Scientific motivations for deep ocean measurements include assessing changes in heat content and salinity, variations in water-mass formation and circulation, and their relations to air-sea and cryosphere-sea fluxes. We invite additions to and refinement of these topics and discussion of the measurements, accuracies, and technologies required.

11:30-12:30 **An extended break to view posters and visit the exhibits. The following poster presenters are asked to attend their posters during this break.**

2P1 **The SAPIGH service for HPLC phytoplankton pigment analysis and database maintenance**
Joséphine RAS, Hervé CLAUSTRE, Mustapha OUHSSAIN, Céline DIMIER, Julia UITZ, and Catherine SCHMECHTIG

2P2 **How do I cite Argo data in my publication?**
Justin BUCK, Thierry CARVAL, Kenneth CASEY, Frederick MERCEUR and Megan SCANDERBEG

2P3 **Annual wintertime inorganic carbon chemistry along a transect across the Rockall Trough**
Triona McGRATH, Evin McGOVERN and Rachel R. CAVE

2P4 **Seasonal and Inter-annual changes of Antarctic Bottom Water off the Adelie Coast observed by Deep NINJA**
Taiyo KOBAYASHI

2P5 **Uncertainties in detecting decadal changes in total inorganic carbon from the GO-SHIP decadal surveys.**
Rik WANNINKHOF

Wednesday 16th September, 2015 (continued)

An extended break to view posters and visit the exhibits. The following poster presenters are asked to attend their posters during this break.

2P6 **Trends in nutrients at a repeat section from 1996 to 2011 through the Weddell Sea**
Mario HOPPEMA, Steven VAN HEUVEN and Karel BAKKER

2P7 **Biogeochemical variations at the Porcupine Abyssal Plain Sustained Observatory (PAP-SO) in the northeast Atlantic Ocean**
Susan HARTMAN, Richard LAMPITT and Ute SCHUSTER

2P8 **The 'Global Coast': Filling the gaps where the ocean is not deep**
Holger BRIX

2P9 **Considerations on the collection of data from Bio-Argo floats across sampling scales.**
Ian D. WALSH, Dan QUITTMAN, David J. MURPHY and Thomas O. MITCHELL

12:30-13:30 **Lunch Break**

Session 2C largely concerning the Southern Ocean
Chair: Rik WANNINKHOF

13:30-14:00 2C1 **The ACC Subantarctic and Polar fronts, and Southern Ocean heat and freshwater content variability: a view from Argo**
Donata GIGLIO and Gregory C. JOHNSON

14:00-14:20 2C2 **Seasonal trends in pH and aragonite saturation state in the Pacific sector of the Southern Ocean based on the SOCCOM Argo float**
Richard A. FEELY, Lauren JURANEK, Nancy L. WILLIAMS, Ken JOHNSON and Joellen RUSSELL

14:20-14:40 2C3 **The seasonal cycle of carbon in the Southern Ocean determined from autonomous profiling floats**
Alison GRAY, Ken JOHNSON, Jorge SARMIENTO, Brendan CARTER, Lynne TALLEY and Stephen C. RISER

14:40-15:00 2C4 **Long-term CO_2 monitoring in the Southern Indian Ocean**
Claire LO MONACO, Nicolas METZL, Renaud GOMEZ, Claude MIGNON, Catherine PIERRE and Virginie RACAPE

15:00-15:20 2C5 **Status, achievements and outlook for under-ice Argo in the Southern Ocean**
Esmee VAN WIJK, Susan WIJFFELS and Stephen RINTOUL

15:20-15:50 **Refreshment Break**

Wednesday 16th September, 2015 (continued)

Session 2D – Papers concerning the Atlantic Ocean and its marginal seas
Chair: Kumiko AZETSU-SCOTT

15:50-16:10 2D1 **Estimation of the ventilation in the Bay of Biscay in 2009-2012 using oxygen profiles from Argo data**
Marta ÁLVAREZ, Manuel RUIZ-VILLARREAL, César GONZÁLEZ-POLA and Alicia LAVÍN

16:10-16:30 2D2 **Shelf-Sea Biogeochemistry – what goes on upon the N.W. European Shelf?**
Caroline KIVIMAE, Susan HARTMAN, Naomi GREENWOOD, Evin McGOVERN, Brian STEWARD and Pamela WALSHAM

16:30-16:50 2D3 **Phytoplankton bloom in the NW Mediterranean: impacts of a deep convection event revealed by Bio-Argo, Bio-Gliders and Ship data**
Nicolas MAYOT and Fabrizio D'ORTENZIO

16:50-17:10 2D4 **Seasonal variability of nutrient concentrations in the Mediterranean Sea: Contribution of Bio-Argo floats**
Orens DE FOMMERVAULT, Fabrizio D'ORTENZIO and Christophe MIGON

17:10-17:30 2D5 **Argo observations in the Mediterranean and Black Sea: status and future prospective**
Pierre-Marie POULAIN, Giulio NOTASTEFANO and Fabrizio D'ORTENZIO

19:30-21:30 Wednesday evening:

2E1 Public Lecture: Ocean Acidification: A Global Problem with Local Impacts

Richard A. FEELY

The Public Lecture will start at 19:30 at the National University of Ireland, Galway. It is aimed at the general public; however, conference attendees are invited and welcome to attend. A reception will take place immediately following the Public Lecture. The Public Lecture and reception are both sponsored by the President's Office, NUI Galway. The conference organising committees thank Dr. James Browne for his support.

Thursday 17th September, 2015

Session 3A largely concerning the Atlantic Ocean and its marginal seas.
Chair: Blair GREENAN

08:30-09:00 3A1 **Atlantic BiogeoChemical (ABC) Fluxes: adding carbon and nutrients to the RAPID array, a contribution to NERC's RAPID-AMOC programme.**
Elaine McDONAGH and many co-authors (please see the abstract)

09:00-09:20 3A2 **Temporal variability of North Atlantic carbon fluxes and their sensitivity to the meridional overturning circulation**
Peter BROWN, Elaine McDONAGH, Richard SANDERS, Brian KING, David SMEED, Andrew WATSON, Ute SCHUSTER, Molly BARINGER, Rik WANNINKHOF, Chris MEINEN, Bill JOHNS and Stuart CUNNINGHAM

09:20-09:40 3A3 **SAMOC: An international effort to monitor the meridional overturning circulation in the South Atlantic**
Edmo CAMPOS, Silvia GARZOLI, Christopher MEINEN, Alberto PIOLA. Michael ROBERTS and Sabrina SPEICH

09:40-10:00 3A4 **Observations of subpolar North Atlantic variability and overturning circulation from the Extended Ellett Line**
N. Penny HOLLIDAY , Stuart A. CUNNINGHAM, Stefan F. GARY, Clare JOHNSON and Matthew P. HUMPHREYS

10:00-10:30 **Refreshment Break**

Session 3B largely concerning the Atlantic Ocean and its marginal seas.
Chair: Fiona GRANT

10:30-10:50 3B1 **Regional variability of freshwater in the North Atlantic in the RAPID/Argo era**
Brian KING, Elaine L. MCDONAGH, Damien DESBRUYERES and N. Penny HOLLIDAY

10:50-11:10 3B2 **Watermass transformation in the Lofoten Basin of the Nordic Seas**
Clark RICHARDS and Fiamma STRANEO

11:10-11:30 3B3 **Nutrient fluxes in the eastern subpolar North Atlantic**
Clare JOHNSON, Stuart CUNNINGHAM, Penny HOLIDAY and Stefan GARY

11:30-11:50 3B4 **Long-term change in carbon chemistry in the Labrador Sea**
Kumiko AZETSU-SCOTT and the Atlantic Zone Offshore Monitoring Program Team

11:50-12:30 **A break to view posters and visit the exhibits.**

Thursday 17th September, 2015 (continued)

11:50-12:30 **A break to view posters and visit the exhibits. The following poster presenters are asked to attend their posters during this break.**

3P1 **Interannual variability of subduction rate estimated using Argo and its implication for anthropogenic carbon uptake by the ocean**
Katsuya TOYAMA, Toshio SUGA, Keith B. RODGERS, Aiko IWASAKI and Bruno BLANKE

3P2 **CTD profiles for global ocean forecasting: a system for real-time data delivery from UK research vessels**
Fiona CARSE, Tim SMYTH, Simon GOOD, Jonathan TURTON and Malcolm HEARN

3P3 **Instrumented seals help us to observe the ocean**
Fabien ROQUET, Christophe GUINET, Baptiste PICARD and Gilles REVERDIN

3P4 **Deep Black sea circulation described by Argo profiling floats**
Milena MILANOVA and Elisaveta PENEVA

3P5 **Deep-Arvor float (4000m) : first results and future plans**
Virginie THIERRY, Herlé MERCIER, Guillaume MAZE, Serge LE RESTE, Vincent DUTREUIL and Xavier ANDRÉ

3P6 **Small scale processes in the ocean surface boundary layer**
Brian WARD, Graig SUTHERLAND, Kieran WALESBY, Anneke ten DOESCHATE and Leonie ESTERS

3P7 **Use of GO-SHIP data, Hycom and SOSE output, and Argo data to inform deployments of SOCCOM biogeochemical profiling floats**
Lynne TALLEY, and numerous co-authors (please see abstract)

3P8 **Observing Mixed layer depth in density, temperature and absolute salinity measurements in the Northwestern Mediterranean: A combined laboratory and NOSS profiling floats observations**
Damien MALARDE, Arnaud DAVID, Marc LE MENN, Patrice BRAULT & Serge LE RESTE

12:30-13:30 **Lunch Break**

Session 3C largely concerning the Atlantic Ocean and its marginal seas.
Chair: Elaine McDONAGH

13:30-14:00 3C1 **Decadal trends of upper-ocean water masses in the Northeast Atlantic**
Birgit KLEIN ,Dagmar KIEKE, Monika RHEIN, Holger KLEIN and Claudia DENKER

14:00-14:20 3C2 **Assessing Variability in the Gulf Stream Northern Recirculation Gyre using Argo**
Blair GREENAN, Denis GILBERT, Dave HEBERT and Ingrid PETERSON

14:20-14:40 3C3 **Dynamic Response of the North Atlantic Circulation to Rapid Ocean Heat Content Changes between 1990 and 2014**
Stuart CUNNINGHAM and Clare JOHNSON

14:40-15:10 **Refreshment Break**

Thursday 17th September, 2015 (continued)

Session 3D largely concerning the Atlantic Ocean and its marginal seas.
Chair: Richard FEELY

15:10-15:30 3D1 **Estimates of the seasonal variability of volume, heat, and freshwater fluxes in the eastern subpolar North Atlantic**
Stefan GARY, Stuart CUNNINGHAM, Clare JOHNSON, Penny HOLLIDAY and Loic HOUPERT

15:30-15:50 3D2 **Acidification in Atlantic Repeat Sections**
Aida F. RIOS, Maribel I. GARCÍA-IBÁÑEZ, Noelia M. FAJAR, Elisa F. GUALLART and Fiz F. PÉREZ

15:50-16:10 3D3 **Trends and recent shifts in the hydrography of the temperate north-east Atlantic. Insights from repeated sections around Spain**
Cesar GONZALEZ-POLA, Pedro VELEZ-BELCHI, Ricardo F. SANCHEZ, Raquel SOMAVILLA, Alicia LAVIN and Alonso HERNANDEZ-GUERRA

16:10-17:10 **Discussion Period**: A panel will lead meeting attendees in a discussion on improving observations of biogeochemical processes and looking for synergies among all three of the programs highlighted at GAIC-2015. For instance, what measurements and accuracies do we need to improve our understanding of the seasonal cycle of upper ocean biogeochemistry around the globe? Similarly what measurements and accuracies are required to understand longer-term changes? Questions to consider include how existing sensors can be improved and what obstacles exist to their increased use? Obstacles might include power demand, accuracy or stability, attendant requirements for calibration and post-processing, cost etc. Do we have the sensors we need to measure the scientifically interesting water properties? If not are there developments on the horizon that might be valuable?

19:00 onwards: **The Conference banquet** will take place in the Inis Mór Ballroom at the Raddison Blu Hotel. A cash bar will be open before 19:00.

Friday 18th September, 2015

Session 4A largely concerning technical issues.
Chair: Ken JOHNSON

08:30-09:00 4A1 **GO-SHIP: a review and looking forward to the next decade**
Bernadette SLOYAN and Rik WANNINKHOF

09:00-09:20 4A2 **Bio-Argo and Ocean Colour: latest achievements**
Hervé CLAUSTRE

09:20-09:40 4A3 **Mixing and internal wave observations from EM-APEX floats in the Southern Ocean**
Amelie MEYER, Bernadette SLOYAN, Helen PHILLIPS, Kurt POLZIN and Nathan BINDOFF

09:40-10:00 4A4 **Guidance for glider deployments in an energetic western boundary current**
Peter OKE, Tatiana RYKOVA, Bernadette SLOYAN and Susan WIJFFELS

10:00-10:30 **Refreshment Break**

Session 4B largely concerning technical issues.
Chair: Albert FISCHER

10:30-10:50 4B1 **Towards comparability of global oceanic nutrient data**
Malcolm WOODWARD and Michio AOYAMA

10:50-11:10 4B2 **Integration of bio-optical profiling floats within an Indian Ocean biogeochemical observing system**
Nick HARDMAN-MOUNTFORD, Jim GREENWOOD, Francois DUFOIS, Dirk SLAWINSKI, Muthalagu RAVICHANDRAN and Tom TRULL

11:10-11:30 4B3 **The future of O_2 optode measurements - Lessons learned from a decade of autonomous observations**
Henry C. BITTIG, Arne KÖRTZINGER and Hervé CLAUSTRE

11:30-11:50 4B4 **Continued development of an ocean pH sensor for profiling floats**
Dave MURPHY, Jim HOCHSTEIN and Ken JOHNSON

11:50-12:10 4B5 **Evaluation of the performance of optical oxygen sensors in profiling the deep ocean**
David MURPHY, Carol JANZEN and Nordeen LARSON

12:10-12:30 4B6 **What are optimum observational networks to identify changes in the marine carbon cycle?**
Ute SCHUSTER and the Global Marine Carbon Community

12:30-13:30 **Lunch Break**

Friday 18th September, 2015 (continued)

Sessions 4C largely concerning technical issues.
Chair: Birgit KLEIN

13:30-14:00 4C1 **Assessing the impact of observations on ocean forecasts and reanalyses**
Peter OKE and Gilles LARNICOL

14:00-14:20 4C2 **Assessing climate model simulations of the Southern Ocean with standardized, observationally-based metrics**
Joellen RUSSELL and Igor KAMENKOVICH

14:20-14:40 4C3 **Seasonal and interannual changes of sea surface temperature affected by subsurface oceanic variability during early summer**
Shigeki HOSODA, Masami NONAKA, Tomohiko TOMITA, Bunmei TAGUCHI, Hiroyuki TOMITA and Yoshikazu SASAI

14:40-15:10 **Refreshment Break**

Sessions 4D largely concerning technical issues.
Chair: Brian KING

15:10-15:30 4D1 **French contribution to Bio-Argo float deployment as part of GO-SHIP and other cruises: implementation of good practices**
Catherine SCHMECHTIG

15:30-15:50 4D2 **Integrating Data and Information across Observing Systems**
Kevin O'BRIEN, Bob SIMONS, Ansley MANKE, Eugene BURGER and Roy MENDELSSOHN

15:50-16:10 4D3 **Biogeochemical Cycling of Trace Elements in the Ocean: Current and future opportunities linking GEOTRACES to Argo and GO-SHIP**
Peter CROOT, Greg CUTTER, Maeve LOHAN and Past and Present members of the GEOTRACES S&IC

16:10-17:10 **Discussion Period:** Using historical observations and models to plan for the future: priorities, limitations, and how to have real impact.

Peter Oke, Hervé Claustre, Freya Garry, Katsuro Katsumata, Alison Macdonald and Joellen Russell will lead meeting attendees in a discussion to address questions relating to the integration of physical and biogeochemical observations through various means. The panel will present their views on how physical and biogeochemical observations could be united in traditional hind-casts using ocean models, data-assimilating models, and databases. The panel will also seek to identify the key physical and biogeochemical questions that have been identified at GAIC2015 and will discuss how these questions could be addressed through observing system design and assessment studies. This will include a discussion of the limitations of such studies. The panel will attempt to conclude by summarizing how they think the ocean modelling, forecasting, and state-estimation communities could contribute to the design and maintenance of the global ocean observing system to have real impact.

17:10-17:15 **Thanks to all and close of the GAIC-2015 event.**

1A1 Changes in ocean heat, carbon content, and ventilation: Review of the first decade of global repeat hydrography (GO-SHIP)

L. D. TALLEY[1], R. A. FEELY[2], B. M. SLOYAN[3], R. WANNINKHOF[4], M. O. BARINGER[4], J. L. BULLISTER[2], C. A. CARLSON[5], S. C. DONEY[6], R. A. FINE[7], E. FIRING[8], N. GRUBER[9], D. A. HANSELL[7], M. ISHII[10], G. C. JOHNSON[2], K. KATSUMATA[11], R. M. KEY[12], M. KRAMP[13], C. LANGDON[7], A. MACDONALD[6], J.T. MATHIS[2], E. McDONAGH[14], S. MECKING[15], F. J. MILLERO[7], C. W. MORDY[2], C. L. SABINE[2], W. M. SMETHIE[16], J. H. SWIFT[1], T. TANHUA[17], A. M. THURNHERR[16], M. J. WARNER[15] and J.-Z. ZHANG[4]

[1] Scripps Institution of Oceanography, La Jolla, CA
[2] NOAA/PMEL, Seattle, WA
[3] CSIRO, Hobart, Tasmania, Australia
[4] NOAA/AOML, Miami, FL
[5] University of California, Santa Barbara, CA
[6] Woods Hole Oceanog. Inst., Woods Hole, MA
[7] RSMAS, Univ. of Miami, Miami, FL
[8] University of Hawai'i Manoa, Honolulu, HI
[9] ETH, Zurich, Switzerland
[10] MRI-JMA, Japan
[11] JAMSTEC, Japan
[12] Princeton University, Princeton, NJ
[13] JCOMMOPS, IFREMER, Brest, France
[14] NOC, Southampton, UK
[15] University of Washington, Seattle, WA
[16] LDEO, Columbia University, Palisades, NY
[17] GEOMAR, Germany
Email: ltalley@ucsd.edu

Abstract: The ocean, which is an integral and important part of Earth's climate system, is changing. Systematic, decadally repeated, full-depth, highly accurate, basin-scale ocean observations of physical and biogeochemical properties allow quantification of ocean heat and carbon uptake; variations in freshwater, oxygen, nutrients, and acidity; and analyses of ocean circulation and mixing. These observations, from the Global Ocean Ship-based hydrographic Investigations Program (GO-SHIP), have been key for the following climate-related results:

• The abyssal ocean is warming, taking up around a quarter of the excess heat in the entire Earth system over recent decades.
• Abyssal waters originating in the Pacific and Indian sectors of the Southern Ocean have been freshening and becoming lighter.
• Ocean ventilation and circulation are variable and changing over timescales from several years to decades. Changes are related to wind forcing and stratification changes.
• Vertical diffusivity has a maximum in the bottom 1500 m of the ocean as well as in the near-surface ocean, influencing the upwelling of the ocean's overturning circulation.
• Anthropogenic carbon uptake has been mapped and the oceans currently sequester about 25 % of the anthropogenic carbon released to the atmosphere.
• The oceans are acidifying.
• Oxygen concentrations are declining in the thermocline, and tropical oxygen minimum zones are expanding.

1A2 Deep Argo Workshop Report

Nathalie ZILBERMAN[1], Guillaume MAZE[2], Dean ROEMMICH[1], Susan WIJFFELS[3], Steve RISER[5] and Breck OWENS[6]
[1] Scripps Institution of Oceanography, La Jolla, CA, USA
[2] IFREMER, Brest, France
[3] CSIRO, Hobart, Tas., Australia
[4] University of Washington, Seattle, WA, USA
[5] Woods Hole Oceanographic Institution, MA, USA
Email: nzilberman@ucsd.edu

Abstract: Deep-ocean (> 2000 m) hydrographic observations are limited to sparse ship-board hydrographic sections repeated every decade and short-lived moored arrays of confined spatial coverage. Upper-ocean (< 2000 m) sampling, largely carried out by the conventional Argo array, has much higher resolution in space and time. The need for more intensive sampling in the deep ocean has been widely recognized by the scientific community. The development of deep profiling Argo floats, a new generation of autonomous instruments capable of diving and recording temperature and salinity down to 4000 to 6000 m depth, is underway. A Deep Argo Workshop was organized to initiate science and implementation planning for a global Deep Argo array, to satisfy broad-scale requirements for measurement of temperature, salinity, and ocean circulation and for combination with other observing system technologies that will complement the float array's large-scale attributes.

The main objectives of the Workshop were:
1. Articulate key scientific issues for Deep Argo: (i) closing the heat, freshwater, and sea level budgets, (ii) characterizing decadal variability in deep ocean water masses, (iii) estimating the mean and decadal variability in deep ocean. circulation including meridional overturning circulations.
2. Determine sampling requirements to achieve Deep Argo objectives.
3. Refine plans for the deployments of Deep Argo pilot arrays.
4. Promote international collaboration within the Deep Argo community.
Early results of deep float deployments and research plans for Deep Argo regional pilot arrays were presented.

1A3 Informing Deep Argo array design using repeat hydrographic section data

Gregory C. JOHNSON[1], John M. LYMAN[2] and Sarah G. PURKEY[3]
[1] NOAA/Pacific Marine Environmental Laboratory, Seattle, Washington, USA
[2] Joint Institute for Marine and Atmospheric Research, University of Hawaii, Honolulu, Hawaii, USA
[3] Lamont-Doherty Earth Observatory, Columbia University, Palisades, New York, USA
Email: gregory.c.johnson@noaa.gov

Abstract: We use data from global repeat hydrographic sections (WOCE and GO-SHIP) to inform the design of a future Deep Argo array by assessing temperature trends, variance, and spatial de-correlation scales in the deep (> 2000 m) and abyssal (> 4000 m) ocean. Abyssal warming trends from 1992–2005 are ~5 mºC decade^{-1} in the global mean and deep trends ~30 mºC decade^{-1} in the Southern Ocean, with spatial decorrelation scales of ~160 km. These trends result in a global integrated decadal trend estimate of 50 TW for the rate of deep-ocean warming. Here we estimate temperature variance using 500-km high-passed WOCE and GO-SHIP hydrographic section data averaged in 5º x 5º bins to assess noise levels. We cast our findings in terms of local and global decadal trends detectable above one standard error for a straw plan of a 5º x 5º Deep Argo array with monthly cycling. Such an array would be capable of resolving, on average, local trends of < 1 mºC decade^{-1} in the abyssal Pacific and < 20 mºC decade^{-1} in the deep Antarctic Circumpolar Current. Thus, this array would be capable of detecting anticipated decadal signals at 5º x 5º resolution, in contrast with the much larger spatial averages required when analyzing repeat hydrographic sections. This Deep Argo array would also resolve global decadal deep ocean warming trends with an estimated uncertainty of ±3 TW, compared with ±17 TW for repeat hydrographic data.

1B1 Informing a strategy for Deep Argo temperature observations

Freya GARRY[1], Chris ROBERTS[2], Elaine McDONAGH[1], Brian KING[1], Adam BLAKER[1]
and Eleanor FRAJKA-WILLIAMS[3]
[1] National Oceanography Centre Southampton
[2] Met Office Hadley Centre, Exeter, UK
[3] Ocean and Earth Science, University of Southampton
Email: freya.garry@noc.soton.ac.uk

Abstract: The ocean has the largest available capacity for heat uptake in the Earth's climate system. However, sparse and infrequent measurements of ocean temperatures below 2000 m limit our ability to observe deep ocean heat content changes and therefore close the global heat budget or improve projection capability for future climate change and sea level rise.

We present results from state of the art climate model experiments that inform the optimal design of a deep ocean observing system of automated floats that repeatedly sample to at least 4000m and transmit data via satellite (a deep water extension of the current Argo array). Using long control simulations and forced experiments, we consider to what depths and in which regions we need observations to effectively capture internal variability of temperature in the oceans and emergent signals of climate change.

Our results highlight the continuing importance of the Argo array (to 2000 m) for measuring ocean heat content. In forced scenarios we find additional deep ocean sampling below 2000 m is essential in most ocean basins to accurately estimate total ocean heat content changes, but monitoring in the Atlantic and Southern Ocean is most critical.

Analysis of model output indicates that deep ocean sampling below 2000 m is much more important in some areas than others. For example, we highlight the particular importance of monitoring temperature changes in the Southern Ocean to at least 4000 m to gain accurate estimates of global ocean heat content change and the thermosteric component of sea level rise.

1B2 Global temperature trends from Argo and Hydrography data

Damien DESBRUYERES, Elaine McDONAGH and Brian KING

National Oceanography Centre, UK

Email: dades@noc.ac.uk

Abstract: Using a combination of Argo data and repeat ship-board hydrography, we compute a full-depth estimate of oceanic heat uptake of 0.43 ± 0.12 W m^{-2} during the period 2006-2013. The contribution of the deep and abyssal layers (2000-6000m) reaches about 15% but important uncertainty may reside, notably due to relatively poor sampling in the Southern and Indian Ocean. Upper ocean heat uptake (0-2000m) has a strong signature in the Southern Hemisphere subtropical regions, and is shown here to primarily reflects dynamically-induced temperature changes (wind-driven heave). In other regions (e.g. the North Atlantic), the dynamically-driven temperature change is found to "hide" significant intrinsic changes in water mass properties.

1B3 Euro-Argo : a new European Research Infrastructure for climate change research and operational oceanography

Sylvie POULIQUEN[1], Pierre-Yves Le Traon[2] and Euro-Argo Partners[3]
[1] ERIC-Euro-Argo
[2] IFREMER
[3] http://www.euro-argo.eu/
Email: euroargo@ifremer.fr

Abstract: In May 2014, the Euro-Argo research infrastructure became a new European legal entity (Euro-Argo ERIC). The objective is to organize a long term European contribution to the international Argo array of profiling floats. Argo is now the most important global in-situ observing system required to observe and understand the role of the ocean on the earth climate. Euro-Argo is also an essential component of the in-situ infrastructure required for the Copernicus Marine Core Service. Euro-Argo will thus develop European contribution to the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS). We will provide an overview of the development of Euro-Argo over the past years, detail the now agreed Euro-Argo long term organization, and provide some highlights on the work-plan for the years to come and the Argo extensions for the next decade especially to abyssal oceans and biogeochemical measurements. We will also illustrate some key achievements on the use of Argo in Europe both for operational oceanography, ocean and climate change research.

1P1 The Blob - A Pacific warm event 2013 to 2015.

Howard J. FREELAND
Institute of Ocean Sciences, Sidney, BC, Canada
Email: Howard.Freeland@dfo-mpo.gc.ca

Abstract: In late 2013 a large climate anomaly developed in the NE Pacific Ocean. This talk will show the evolution of this anomaly over the following 18 months. The data sources used to describe the evolution of the anomaly are the Reynolds monthly SST anomalies, temperature and salinity data from Argo floats and multi-disciplinary data from Line-P surveys (also known as WHP line PR-16). These data sources have different strengths and together allow a description of the evolution of the anomaly that is not available to any single source. It will be shown that non-overlapping data sources show deviations in monthly temperatures and salinity up to 4.3 standard deviations from climatology. The anomalies changed the vertical structure of the water column in most of the Gulf of Alaska with profound impacts on the biota.

1P2 Formation mechanism of barrier layer in the subtropical Pacific

Shota KATSURA[1], Eitarou OKA[1] and Kanako SATO[2]
[1] Atmosphere and Ocean Research Institute, The University of Tokyo
[2] Japan Agency for Marine-Earth Science and Technology
Email: katsura@aori.u-tokyo.ac.jp

Abstract: Seasonal and interannual variations of barrier layer (BL) and its formation mechanism in the subtropical North and South Pacific were investigated by using raw and gridded Argo profiling float data and various surface flux data in 2003−12 and hydrographic section data from the WOCE Hydrographic Programme. BLs detected by raw Argo profiles, which existed within the sea surface salinity (SSS) front located on the equator side of SSS maxima, were thickest and most frequent in winter and had small temporal and spatial scales, indicating their

transient nature. Surface and subsurface processes for the BL formation suggested by previous studies were evaluated. Poleward Ekman advection of fresher water was dominant as the surface freshening, but cannot explain the observed seasonal variations of BL. Subsurface equatorward intrusion of high-salinity tropical water was too deep to produce salinity stratification within isothermal layers. These results strongly suggest that BLs in the subtropical Pacific are formed mainly through tilting of the SSS front due to the poleward Ekman flow near the sea surface and the equatorward geostrophic flow in the subsurface. This idea is supported by dominant contribution of the meridional SSS gradient to the meridional sea surface density gradient within the SSS front and the correspondence between the seasonal variations of BL and isothermal layer depth. On interannual time scale, the winter BL thickness in the North and South Pacific was related to the Pacific Decadal Oscillation and the El Niño-Southern Oscillation, respectively, through the intensity of trade winds controlling isothermal layer depth.

1P3 Mesoscale variability of deep currents south of the Kuroshio Extension

Masatoshi MIYAMOTO, Eitarou OKA, Daigo YANAGIMOTO, Shinzou FUJIO,
Masao KUROGI, Hiroyasu HASUMI
Email: masatoshi@aori.u-tokyo.ac.jp

Abstract: To clarify structure, origin and propagation of mesoscale variability with timescales of 20–150 days in the deep ocean, we are conducting high-resolution mooring observations at St. B (30°N, 147°E) since May 2014. We deployed nine moorings in a 3×3 diamond shape, whose zonal and meridional widths are both 100 km. As a preliminary analysis for this observation, we analyzed past mooring observations obtained around St. B during 1978–1985. At two mooring sites that were zonally 100 km apart, power spectral density at 5000-m depth had a peak at 45-70 days. Based on the phase lag at a 47-day period at which coherence between the two sites was highest, the zonal wavelength and westward phase speed were estimated to be 250 km and 6.1 cm s-1, respectively. This wavelength possibly satisfied the dispersion relation for topographic barotropic Rossby waves.

We also analyzed a 10-year output of an eddy-resolving ocean general circulation model. At 5000-m depth, power spectral density at the dominant period of 54-day had a maximum in the region of 30–32°N, 146–148°E. Furthermore, 45–60 day band-pass filtered variability component propagated westward with a phase speed about 6 cm s-1 and a wavelength about 250 km and was intensified in this region. Based on distributions of energy flux and coherence, the energy needed for this intensification was considered to originate from the Kuroshio Extension.

1P4 SIO's Oceanographic Data Facility serves the GO-SHIP and Argo communities

Daniel SCHULLER[1], Lynne TALLEY[1], Hannah ZANOWSKI[2], Robert KEY[2], Ken JOHNSON[3] and Emmanuel BOSS[4].
[1] Scripps Institution of Oceanography, La Jolla, CA, USA
[2] Princeton University, Princeton, NJ, USA
[3] Monterey Bay Aquarium Research Institute, Monterey, CA, USA
[4] University of Maine
Email: dschuller@ucsd.edu

The Oceanographic Data Facility (ODF) at the Scripps Institution of Oceanography (SIO) provides high-quality hydrographic technical services. ODF has participated in numerous large-scale, worldwide oceanographic expeditions including Geochemical Ocean Sections Study (GEOSECS), World Ocean Circulation Experiment (WOCE), Joint Global Ocean Flux Study (JGOFS), Climate Variability and Predictability (CLIVAR), Ship-based Hydrographic Investigations Program (GO-SHIP), and Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM) programs. The advice and support ODF provides these programs enables them to obtain the high quality reference data that is required for the science objectives of the programs to be met.

The ODF chemistry laboratory has been producing world-class reference data for over 40 years. Analyses include dissolved inorganic nutrients, dissolved oxygen, and salinity; both at sea in near real-time and ashore. The ODF chemistry laboratory is involved in the development of reference materials for nutrients in seawater along with their implementation in global time series expeditions. ODF is a full member of the international Scientific Committee on Oceanic Research (SCOR) working group 147- Towards comparability of global oceanic nutrient data (COMPONUT).

ODF participated in the 2014-2015 Polarstern ANT 30.2 cruise. Twelve SOCCOM Argo-equivalent floats were deployed from Polarstern between Capetown, South Africa, and Antarctica. ODF provided shipboard nutrient data to calibrate nitrate sensors aboard the floats. ODF was also in charge of collecting, preserving, and shipping a large suite of samples back to the USA for calibration of the associated biogeochemical sensors aboard the floats.

1P5 Operational data delivery powered by Web and Geospatial standards

Justin BUCK[1] and Adam LEADBETTER[2]
[1] BODC, Liverpool, UK
[2] Marine Institute, Galway, Ireland
Email: juck@bodc.ac.uk

Abstract: As novel sensor types and new platforms are being deployed to monitor the global oceans, the volumes of scientific and environmental data collected in the marine context are rapidly growing. In order to use these data in both the traditional operational modes and in innovative "Big Data" applications the data must be easily understood by software agents. One approach to achieving this is through the application to the data of both World Wide Web and Open Geospatial Consortium standards: namely Linked Data[1] and Sensor Web Enablement[2] (SWE). Through involvement in a number of European Commission funded projects (NETMAR; SenseOCEAN; Ocean Data Interoperability Platform - ODIP; and AtlantOS) the British Oceanographic Data Centre is combining its existing data archiving architecture with SWE components (such as Sensor Observation Services) and a Linked Data interface. The Marine Institute is following a similar approach to SenseOCEAN with its streaming data platform prototype: using Big Data software and cutting edge streaming applications and then releasing the data with standards integrated as the final step.

Similarly, the Marine Institute are working with the INSIGHT Centre for Data Analytics on building a prototype of Linked Data observations from its weather buoy network. In addition to bringing the data new audiences through interconnections to other Linked Data providers such as broadcast media, the application of standards such as these also makes the automated global sharing of ocean data a possibility.

References:

1. World Wide Web Consortium. (2013). Linked Data. Available: http://www.w3.org/standards/semanticweb/data.

2. Open Geospatial Consortium. (2014). Sensor Web Enablement (SWE). Available: http://www.opengeospatial.org/ogc/markets-technologies/swe

1P6 Long-term variations of water property in the major three water masses along the JMA 137°E repeat hydrographic section

Toshiya NAKANO[1], Tomoyuki KITAMURA[1], Kiyoshi MURAKAMI[1], Yusuke TAKATANI[1], Masao ISHII[2] and Masafumi KAMACHI[2]
[1] Japan Meteorological Agency
[2] Meteorological Research Institute
Email: nakano_t@met.kishou.go.jp

Abstract: Temporal variations of water property in the major three water masses, North Pacific Subtropical Mode Water (STMW), North pacific Tropical Water (NPTW) and North Pacific Intermediate Water (NPIW), in the North Pacific subtropical gyre are investigated using a half-century-long repeat hydrographic and hydrochemical dataset along the 137°E meridian conducted by the Japan Meteorological Agency. The observations at the 137°E section started in 1967 for winter season and in 1972 for summer season. The 137°E section extends from the south of Japan (34°N) across the subtropical gyre to the tropics at 3°N off New Guinea. The 137°E section is categorized into the GO-SHIP high-frequency repeat section. To understand the changes in ocean circulation, oceanic structure and air-sea interactions that are related to climate change in the North Pacific, these repeat surveys have been playing important roles. The major three water masses had significant decadal-scale (about 10 years) variations. These temporal variations associated with the variability of wind stress field in the central North Pacific accompanied by the two types of Aleutian Low (AL) changes: a change in the magnitude of AL and meridional movement of AL. Furthermore, the variation in the distribution of the STMW and NPTW related with the large eddy activity in the Subtropical Countercurrent and subtropical fronts regions between 15°N and 25°N.

1P7 From Antarctica to Alaska:
Ten Thousand Miles of Properties and Decadal Changes along 150°W

Alison MACDONALD Sabine MECKING, Brendan CARTER, Jessica CROSS,
Samantha SIEDLECKI and Lynne D. Talley
[1] Woods Hole Oceanographic Institution
[2] Applied Physics Laboratory, University of Washington
[3] Joint Institute for the Study of the Atmosphere and Ocean, University of Washington
[4] Pacific Marine Environmental Laboratory
[5] Scripps Institution of Oceanography
Email: amacdonald@whoi.edu

Abstract: In the boreal spring of 2014, the crew and science party aboard the Nathaniel B. Palmer occupied the WOCE/CLIVAR repeat line along 150°W known as P16S carrying out 90 full hydrographic casts from 67°S to 15°S. In 2015, NOAA ship Ronald Brown, on leg1 of P16N, picked up the 150°W occupation near Tahiti with 100+ stations between 15°S and 20°N. This section was followed immediately by leg 2, which continued northward onto the Alaskan Shelf. For portions of P16S this was the fourth repeat since 1991, while to the north some sections of line have been occupied 7 times since 1980. Here, we present the highlights of the preliminary results from these cruises describing properties and property changes seen over the last two and half decades. In collaboration with most of P16 science groups who carried out the work both at sea and in the lab, we report on results from the temperature, salinity, oxygen, nutrients, large particle abundance, direct velocity and direct mixing observations, as well as the SOCCOM floats deployed in the Southern Ocean. Further, we will direct attention to the results of the dissolved inorganic carbon, pH, and alkalinity observations that will be presented elsewhere at the meeting.

1P8 Building Europe's Ocean Observing System (EOOS)

Glenn NOLAN[1], Erik BUCH[1], Patrick GORRINGE[1], Niall McDONOUGH[2] and Kate LARKIN[2]
1: EuroGOOS AISBL.
2: European Marine Board
Email: Glenn.Nolan@marine.ie

Abstract: Under the Blue Growth policy, Europe plans to double the contribution that marine and maritime industries make to economic growth. In order to underpin Blue Growth and economic development in key marine sectors several European entities have proposed the development of a European Ocean Observing System. There are many ocean observation and marine data initiatives in Europe at present including the activities of Regional Operational Oceanographic Systems (known as a ROOS under the EuroGOOS umbrella), the Copernicus Marine Service and the European Marine Observations and Data Network (EMODNET). EU member states make a significant contribution to the observing system by deploying an array of platforms in their respective territorial waters and by channelling data from these platforms through National Oceanographic Data Centres to the wider European and global data centres. Significant value-added research and development is made through the EC funding programmes including Interreg and Horizon 2020. Projects such as AtlantOS and JERICO aim to consolidate ocean observing efforts in the open-ocean and coastal seas respectively.

The European Ocean Observing System (EOOS) will require strong collaboration with wider initiatives including GO-SHIP, Euro-Argo, GOOS, and EMSO among others. In this paper we present the emerging vision for EOOS with a view to widening the partnership required to deliver EOOS.

1P10 JCOMMOPS: Delivering integrated information for the benefit of GO-SHIP and Argo

Mathieu BELBEOCH, Champika GALLAGE, Martin KRAMP, Anthonin LIZE
JCOMMOPS, Brest, France
Email: support@jcommops.org

Abstract: JCOMMOPS is the operational centre of the IOC-UNESCO and its WMO partner, providing day to day support to the main in-situ elements of the Global Ocean Observing System, on a wide range of domains covering the implementation, instrumentation, data management, operations and intergovernmental issues, through a team of international technical coordinators.

Observing systems under its mandate include subsurface profiling floats, surface drifters, moorings, arctic buoys, tsunameters, deep ocean time series reference stations, ship based observations from merchant vessels, and sustained hydrographic sections.

Established initially in Toulouse in 2001, JCOMMOPS was relocated in Brest in March 2015 with increased means, thanks to a strong support of local ocean professionals and elected officials.

With a strong link to national observation programme actors, JCOMMOPS is serving the regular needs of platform operators, programme managers, data systems, research and operational communities, funding agencies, Member States, parent international organizations, and education and outreach initiatives.

It aims to optimize the status of these global observing networks, to provide the transparency on their implementation, democratize the data access and develop synergies between the systems.

JCOMMOPS is entering a new decade of integrated services through a solidified infrastructure, partnerships with information technology or marine and sailing companies, and will continue escorting observing systems to the sustained mode.

JCOMMOPS will in particular address the synergetic aspects between Argo and GOSHIP with regard to reference data, performance indicators, monitoring tools and cruise planning.

1P11 GO-SHIP: Building a global time-series of a suite of ocean properties.

Steve DIGGS[1], Bernadette SLOYAN[2], Rik WANNINKHOF[3] and Martin KRAMP[4]
[1] Scripps Institution of Oceanography, USA
[2] CSIRO Marine and Atmospheric Research, Australia
[3] NOAA Atlantic Oceanographic and Meteorological Laboratory, USA
[4] JCOMMOPS, Brest, France
Email: sdiggs@ucsd.edu

Hydrographic Program in the 1990s and continuing with CLIVAR and other programs, the international oceanographic community has been completing hydrographic surveys of the global ocean approximately decadally. Ship-based hydrography remains the only method for obtaining the highest-quality, multi-parameter, complete water column measurements, complementing and serving as a reference for other measurements. This time-series of ocean properties derived from the global survey continues to provide significant insight into the importance of the ocean in climate and climate variability. The success of the program relies on expert field work carried out by teams devoted to meeting the highest standards, data and program management to provide rapid availability of carefully-vetted, ready-to-use data to the international community, and long-term national science funding support in participating nations. International GO-SHIP (the Global Ocean Ship-Based Hydrographic Investigations Program) now provides overall management by bringing together users and collectors of hydrographic data to globally coordinate this network of sustained hydrographic sections as part of the global ocean/climate observing system. The CLIVAR and Carbon Hydrographic Data Office (CCHDO) serves as the GO-SHIP data assembly and distribution center.
Website: http://www.go-ship.org

1C1 Slowing of the deep meridional overturning circulation in the North Pacific

Hiroshi UCHIDA[1], Shinya KOUKETSU[1], Masahide WAKITA[1], Takeshi KAWANO[1], James H. SWIFT[2] and Masao FUKASAWA[1]
[1] Japan Agency for Marine-Earth Science and Technology
[2] Scripps Institution of Oceanography
Email: huchida@jamstec.go.jp

Abstract: Long-term changes of properties (temperature, dissolved oxygen and salinity) and volume transport of the bottom water in the North Pacific were examined based on ship-based high-quality hydrography data repeatedly obtained along zonal WOCE Hydrographic Programme (WHP) lines at 47˚N (P01 in 1985, 1999, 2007 and 2014), 30˚N (P02 in 1994, 2004 and 2013), and 25˚N (P03 in 1985 and 2006). Averages for depths below 4000 dbar were calculated for temperature, dissolved oxygen and salinity for each cruise. Significant trends were detected for temperature (1.5±0.09 mK per decade) and dissolved oxygen (−0.99±0.12 μmol/kg per decade), although salinity trend was not significant (0.08±0.34 mg/kg per decade). Half of the hypoxia (−0.54 μmol/kg per decade) could be described by the isotherm heave associated with the bottom water warming which is well examined by the previous studies. The rest of the hypoxia (−0.45 μmol/kg per decade) might be caused by remineralization due to increasing residence time (oxygen utilization rate for the bottom water can be estimated from dissolved oxygen and radiocarbon data to be −1.22 μmol/kg per decade). In fact, a reduction of volume transport for depths below 4000 dbar estimated from geostrophic velocities (northward is positive) relative to 4000 dbar for P02 and P03 lines were observed (−0.41±0.06 Sv per decade) suggesting that the deep meridional overturning circulation in the North Pacific is slowing.

1C2 Subtropical thermocline variability:
Changes in oxygen at 30°N and 32°S in the Indo-Pacific Basins

Sabine MECKING[1], Lynne D. TALLEY[2], Alison M. McDONALD[3] and Gregory C. JOHNSON[4]
[1] APL, University of Washington
[2] Scripps Institution of Oceanography, UCSD
[3] Woods Hole Oceanographic Institution
[4] NOAA, PMEL
Email: smecking@apl.washington.edu

Abstract: As part of the U.S. CLIVAR Repeat Hydrography Program, zonal sections across the centers of the subtropical gyres in the Indo-Pacific Basins were most recently occupied in 2009 (South Indian Ocean, 32°S), 2009/10 (South Pacific Ocean, 32°S), and 2013 (North Pacific Ocean, 30°N). Dissolved oxygen differences along these sections provide information on how ocean ventilation is changing on decadal time scales. The reversal in the 1987-2002 South Indian Ocean thermocline oxygen trend (an increase), as determined from the 2002-2009 32°S section comparison, has been reported on previously (Kobayashi et al., 2012; Mecking et al., 2012; Feely et al., 2014). Recent trends in the South Pacific Ocean are less clear, but they also hint at an overall decrease in oxygen and reduction in ventilation over a similar time frame (2003-2009/10), likely due to changes in the Southern Hemisphere forcing. In the North Pacific, we find that oxygen also decreased in the lower part of the ventilated thermocline from 2004-2013, continuing a trend observed in the 1994-2004 30°N section comparison here. We present these results in the context of forcing indices, namely the Southern Annular Mode (South Indian and South Pacific Oceans) and the Pacific Decadal Oscillation (North Pacific Ocean), as well as earlier observations and changes of other properties such as salinity and nutrients.

1C3 Cross-mean flow spreading of North Pacific Central Mode Water:
Property transport by mesoscale eddies

Toshio SUGA[1] , Kazunori NAKASHIMA[2] and Yuta MURAI[2]
[1] Tohoku University / JAMSTEC
[2] Tohoku University

Abstract: North Pacific Central Mode Water (CMW) is formed in the deep wintertime mixed layer near the northern edge of the subtropical gyre and subducted into the permanent pycnocline. While its spreading from the formation region had been considered to be generally in line with the mean gyre circulation, systematic deviation of the CMW distribution from the mean circulation pathway was suggested by recent analysis based on pre-Argo climatological data and synoptic hydrographic section data. We examine the relation between locations of low potential vorticity signature of CMW from individual Argo profile data and the mean geostrophic streamlines in detail.

It is demonstrated that CMW spreads southeastward in the northern part of the gyre and southwestward in the eastern part of the gyre across the geostrophic streamlines. With the aid of eddy-resolving ocean general circulation model simulation and satellite sea surface height data, we argue that the cross-mean flow spreading of CMW is due to southward/westward movement of mesoscale eddies trapping CMW. It is suggested that mesoscale eddies have significant effect on property distribution in the permanent pycnocline.

1C4 Decadal changes along 47°N based on hydrographic observations

Shinya KOUKETSU, Satoshi OSAFUNE, Hiroshi UCHIDA, Yuichiro KUMAMOTO
and Akihiko MURATA
JAMSTEC, Yokohama, Japan
Email: skouketsu@jamstec.go.jp

Abstract: The hydrographic observation along 47°N (WHP P1) was carried out by JAMSTEC in 2014. The section has been occupied four times since WOCE (1985, 1999, 2007, and 2014). The water property (temperature, salinity, and oxygen) changes in the subsurface layers between 2007 and 2014 were opposite pattern to the ones between 1999 and 2007. Furthermore, the temperature (salinity) changes between 2007 and 2014 were similar to those in the monthly objective mapping data based on Argo floats. Using the monthly data based on Argo floats, we traced the decadal changes in temperature (salinity) revealed by hydrographic sections on isopycnal surfaces and try to infer the decadal changes in oxygen (total carbon, and nutrients) after 2007.

1C5 Trends of oxygen decrease and carbon increase in the western North Pacific as revealed at high-frequency repeat sections

Masao ISHII
Meteorological Research Institute, JMA, Tokyo, Japan
Email: mishii@mri-jma.go.jp

Abstract: Japan Meteorological Agency has been conducting GO-SHIP category 2 high frequency surveys at sections P09 (137°E, 3°N-34°N) and P13 (165°E, 8°S-50°N) as subsets of category 1 decadal surveys at the same sections. These annual or sub-annual observations provide unique quasi time series data sets for the most GO-SHIP level 1 physical and biogeochemical properties including DIC and oxygen, and revealed the trends of oxygen decrease (e.g., -0.45 μmol/kg/yr on potential density of 25.3 in the NPSTMW and -0.44 μmol/kg/yr in the NPIW at 165°E) due to warming and the ocean circulation change and DIC increase associated with oxygen decrease as well as anthropogenic CO_2 invasion (e.g., +0.92 mol/m^2/yr at 30°N at 137°E) for the past decades. In addition, measurements with O_2 sensor on CTD in these surveys, being calibrated with data from Winkler titration of discrete water samples, facilitated to observe the developments of subsurface oxygen maximum in summer over the wide expanse of the subtropics that is ascribed to the net community production being likely associated with the enigmatic seasonal variation in the salinity-normalized DIC that reaches to more than 30 μmol/kg in amplitude under nitrate-depletion in the surface. These data from high-frequency repeat section as well as the GO-SHIP reference sections will provide benchmarks for calibration/validation of the data of physical/biogeochemical parameters from autonomous platforms such as Bio-Argo, and help to understand the variability in the upper ocean biogeochemistry in additional temporal and spatial scales.

1D1 Recent freshening of the East Australian Current and its eddies

Tatiana RYKOVA and Peter OKE
Commonwealth Scientific and Industrial Research Organisation (CSIRO)
Email: tatiana.rykova@csiro.au

Abstract: The East Australian Current (EAC) has a relatively weak mean flow and an energetic eddy field that dominates the circulation. The properties of the mean flow have been studied in detail, but the changes in the eddy field have received little attention. We analyse Argo temperature and salinity profiles for 2005-2012 to construct a picture of the time-mean and time-varying properties of EAC eddies. We find that both cyclonic and anticyclonic eddies are freshening at a rate of 0.12-0.18 psu/decade, with no significant temperature change. Analysis of expendable bathythermograph data also shows no significant warming at 30°S. Consistent with observations, fields from an eddy-resolving ocean model show similar freshening with no temperature trend, indicating that observed changes are significant in the context of the variability over the last 20 years. We attribute the freshening of the EAC and its eddies to increased precipitation over the Southern Great Barrier Reef.

1D2 Estimating the velocity and transport of the East Australian Current using Argo, XBT, and Altimetry

Nathalie ZILBERMAN, Dean ROEMMICH and Sarah GILLE
Scripps Institution of Oceanography
Email: nzilberman@ucsd.edu

Abstract: Western Boundary Currents (WBCs) play an essential role in the meridional distribution of heat, mass, and freshwater of the global ocean and constitute the primary pathway for basin-scale heat exchange between the tropics and the mid-latitudes. Because of the narrowness and strong mesoscale variability of WBCs, estimation of WBC velocity and transport places heavy demands on any potential sampling scheme. One strategy for studying WBCs is to combine multiple complementary data sources. High-resolution bathythermograph (HRX) profiles to 800-m have been collected along transects crossing the East Australian Current (EAC) system at 3-month nominal sampling intervals since 1991. EAC transects, with spatial sampling as fine as 10-15 km, are obtained off Brisbane (27°S) and Sydney (34°S), and crossing the related East Auckland Current north of Auckland. Here, HRX profiles collected since 2004 off Brisbane are merged with Argo float profiles and 1000 m trajectory-based velocities to expand HRX shear estimates to 2000-m and to estimate absolute geostrophic velocity and transport. A method for combining altimetric data with HRX and Argo profiles to mitigate temporal aliasing by the HRX transects and to reduce sampling errors in the HRX/Argo datasets is described. The HRX/Argo/altimetry-based estimate of the time-mean poleward alongshore transport of the EAC off Brisbane is 18.3 Sv, with a width of about 180 km, and of which 3.7 Sv recirculates equatorward on a similar spatial scale farther offshore. Geostrophic transport anomalies in the EAC at 27°S show variability of ± 1.3 Sv at interannual times scales related to ENSO. The present calculation is a case study that will be extended to other subtropical WBCs.

1D3 Decadal variability of Subtropical Mode Water subduction and its impact on biogeochemistry

Eitarou OKA[1], Bo QIU[2], Masao ISHII[3,4], Toshiya NAKANO[4,3], and Toshio SUGA[5,6]
[1]Atmosphere and Ocean Research Institute, The University of Tokyo
[2]Department of Oceanography, University of Hawaii at Manoa
[3]Oceanography and Geochemistry Research Department, Meteorological Research Institute
[4]Global Environment and Marine Department, Japan Meteorological Agency
[5]Department of Geophysics, Graduate School of Science, Tohoku University
[6]Research and Development Center for Global Change, Japan Agency for Marine-Earth Science and Technology
Email : eoka@aori.u-tokyo.ac.jp

Abstract: Temperature and salinity data from Argo profiling floats during 2005−2014 were analyzed to examine the decadal variability of the North Pacific Subtropical Mode Water (STMW) in relation to that of the Kuroshio Extension (KE) system. The formation volume of STMW in the southern recirculation gyre of KE in the cooling season was larger during the stable KE period after 2010 than the unstable KE period of 2006−2009 by 50%. As a result, the volume and spatial extent of STMW increased (decreased) in the formation region during the stable (unstable) KE period, as well as in the southern, downstream region with a time lag of 1−2 years. The decadal expansion and contraction of STMW were also detected by shipboard observations conducted routinely in the most downstream region near the western boundary, in terms of not only physical but also biogeochemical parameters. After 2010, enhanced subduction of STMW consistently increased dissolved oxygen, pH, and aragonite saturation state and decreased potential vorticity, apparent oxygen utilization, nitrate, and dissolved inorganic carbon, among which changes of dissolved inorganic carbon, pH, and aragonite saturation state were against their long-term trends. These results indicate a new mechanism consisting of westward sea surface height anomaly propagation, the KE state transition, and the STMW formation and subduction, by which the climate variability affects physical and biogeochemical structures in the ocean's interior and potentially impacts the surface ocean acidification trend and biological production.

1D4 Eddy transport at 1000 m depth estimated by Argo floats

Katsuro KATSUMATA
JAMSTEC, Yokohama, Japan
Email: k.katsumata@jamstec.go.jp

Abstract: With recent accumulation of Argo data, it is now feasible to estimate eddy statistics at the parking depth of 1000 m. After 2005, for example, if one defines the mean field as spatial average within a 300 km radius circle and temporal average over a year, most of grid points have more than 50 samples, often over 100, to yield significant eddy statistics.

Here, we estimate horizontal eddy transport at the parking depth described by the temporal-residual-mean theory of McDougall and McIntosh (2001). Velocity is estimated as displacement between two consecutive surfacing locations divided by the temporal interval, while two consecutive temperature-salinity profiles are used to estimate the layer thickness and heaving. The result shows large eddy transport in the western boundary currents and around large topographical features, particularly in the Southern Ocean.

1D5 Methane distributions and sea-to-air fluxes in the South China Sea and the West Philippines Sea

Hsiao-Chun TSENG[1,2], Chen-Tung Arthur CHEN[2*], Alberto V. BORGES[3], and T. Angel DELVALLS[1]
[1] UNESCO UNITWIN/WiCop. Physical Chemistry Department. Faculty of Marine and Environmental Sciences. Polígono río San Pedro s/n, University of Cadiz, 11519, Puerto Real, Cadiz, Spain
[2] Department of Oceanography, National Sun Yat-sen University, Kaohsiung 804, Taiwan
[3] Université de Liège, Unité d'Océanographie Chimique, Institut de Physique (B5), B-4000, Belgium
Email: h.c.jean.tseng@gmail.com

Abstract: We collected 700 water samples in the South China Sea (SCS) and 300 water samples in the West Philippines Sea (WPS), in order to determine methane (CH_4) distributions from surface to depths of 4250 m and sea-to-air fluxes during summer. The surface CH_4 concentrations were above atmospheric equilibrium, both in the SCS and the WPS, with an average concentration of 4.5±3.6 and 3.0±1.2 nM, respectively. The SCS emits 29.75×10^6 mol d^{-1} CH_4 to the atmosphere and exports 1.88×10^6 mol d^{-1} CH_4 to the WPS during summer (wet season). That is, the SCS exports CH_4 to the atmosphere and the WPS, and the sea-to-air flux is larger than the horizontal flux.

Both the concentrations of CH_4 and chlorophyll *a* were higher in the 200 m surface layer of the WPS, however, not correlated. CH_4 concentrations generally decrease with depth below the euphotic zone but remain constant below 1,000 m, both in the SCS and the WPS. Some high CH_4 values were observed at mid-depths in the SCS, and were most likely attributed to the anoxic generation of CH_4 or the release of CH_4 from sediments, gas hydrates or gas seepage.

2A1 Southern Ocean Carbon and Climate Observations and Modeling (SOCCOM): Linking GO-SHIP and biogeochemical Argo observations

Jorge SARMIENTO[1], Kenneth JOHNSON[2], Lynne TALLEY[3], Stephen RISER[4], Joellen RUSSELL[5] and Emmanuel BOSS[6]
[1] Princeton University, Princeton, NJ, USA
[2] Monterey Bay Aquarium Res., Monterey, CA, USA
[3] Scripps Inst. of Oceanography, La Jolla, CA, USA
[4] University of Washington, Seattle, WA, USA
[5] University of Arizona
[6] University of Maine
Email: Johnson@mbari.org

Abstract: The SOCCOM (Southern Ocean Carbon and Climate Observations and Modeling) project is a six year effort that plans to deploy about 40 biogeochemical profiling floats per year (~200 total) in the Southern Ocean. The program is led by Princeton University (http://soccom.princeton.edu). It includes an integrated biogeochemical state estimate model and close interaction with GFDL climate models. SOCCOM floats are equipped with Deep-Sea DuraFET pH sensors, ISUS nitrate sensors, Aanderaa oxygen sensors, and WetLabs fluorescence and backscatter sensors. Deployments of SOCCOM profiling floats are closely linked to the GO-SHIP hydrography program to ensure sensor calibration and to extend the GO-SHIP observations from decadal snapshots to full annual observations of carbon cycling. An array of biogeochemical floats was deployed from the ice edge near 66°S to 40°S along 150°W during the US GO-SHIP P16S cruise in March/May 2014. The float sensors have provided what is the first in situ view of the annual carbon cycle in the upper 1500 m of the Southern Ocean. The floats have observed deep winter mixing (to near 400 m), the spring bloom, and summer seasons in the open waters of the Southern Ocean. A second set of floats was deployed along the Good Hope Line from the R/V Polarstern (ANT-XXX/2, Olaf Boebel, Chief Scientist) in December 2014/January 2015. These floats will provide a contrasting view of carbon cycling in the Atlantic sector, relative to the P16S floats in the Pacific sector.

2A2 Deep temperature variability on line SR1b in Drake Passage

Yvonne FIRING, Elaine McDONAGH, Brian KING and Damien DESBRUYERES
National Oceanography Centre, UK
Email: yvonne.firing@noc.ac.uk

Abstract: Complete hydrographic sections of Drake Passage have been made on GO-SHIP designated line SR1b in 20 of the austral summers from 1993/1994 to 2014/2015. Temperature deeper than 2000 m shows strong year-to-year variability but no significant trend over two decades. This variability is dominated by heave associated with the movements of the Antarctic Circumpolar Current (ACC) fronts and is strongly correlated with a proxy for front position and strength derived from baroclinic geostrophic transport from the hydrographic sections. We investigate related proxies derived from satellite and upper ocean Argo data in order to predict deep temperature variability between SR1b occupations.

2A4 Thermohaline variability of the Atlantic sector of the Southern Ocean from 1992-2012 using an Argo-including altimetry-based GEM

Katherine HUTCHINSON[1], Sebastiaan SWART[2], Andrew MEIJERS[3], Isabelle ANSORGE[4] and Sabrina SPEICH[5]
[1] University of Cape Town and South African Environmental Observations Network
[2] CSIR - Southern Ocean Carbon & Climate Observatory
[3] British Antarctic Survey
[4] University of Cape Town
[5] Laboratoire de Météorologie Dynamique (LMD)
Email: kath.hutchinson@gmail.com

Abstract: The South Atlantic sector of the Southern Ocean plays a critical role in global ocean circulation; however water mass variability in this region is poorly understood. By taking advantage of repeat hydrographic CTD sections along the GoodHope line, the large number of Argo floats deployed in the area, and the satellite altimetry data, an Altimetry Gravest Empirical Mode (AGEM) is developed for the ACC south of Africa. The AGEM has improved precision to comparable proxies and offers an ideal technique to investigate the thermohaline variability of the upper 2000dbar of the water column over the past two decades. To assess and attribute changes in water masses, we separate the diabatic and adiabatic components of the reconstructed trends. Integrated over the whole top 2000dbar of the ACC south of Africa, results show adiabatic changes of 0.016 ± 0.010°C yr^{-1} and $3.86x10^{-4} \pm 1.30x10^{-4}$ yr^{-1}, and diabatic trends of $8.29x10^{-4} \pm 9.20x10^{-3}$ °C yr^{-1} and $-5.72x10^{-4} \pm 1.0x10^{-3}$ yr^{-1} for temperature and salinity respectively. By combining the original AGEM fields with the diabatic differences, a new AGEM (AD-AGEM) is created rendering mean property changes of 0.012 ± 0.011°C.yr^{-1} and $-5.47x10^{-4} \pm 1.60x10^{-3}yr^{-1}$. The study focuses on the temporal evolution of the Antarctic Intermediate Water (AAIW), finding mean trends of -0.015 ± 0.096°C yr^{-1} and -2.8 $x10^{-3} \pm 1.33$ $x10^{-2}yr^{-1}$ for the layer within the Subantarctic zone, and 0.029±0.12°C.yr^{-1} and $7.17x10^{-4} \pm 5.90x10^{-3}$ yr^{-1} for the Polar Frontal Zone. The results expose the uniqueness of the ACC south of Africa in its response to climate change.

2P1 The SAPIGH service for HPLC phytoplankton pigment analysis and database maintenance

Joséphine RAS[1,2], Hervé CLAUSTRE[1,2], Mustapha OUHSSAIN[1,2], Céline DIMIER[1,2], Julia UITZ[1,2], Catherine SCHMECHTIG[3,4].
[1] CNRS, UMR 7093, LOV, Observatoire Océanologique de Villefranche, Villefranche-sur-Mer, France
[2] Sorbonne Universités, UPMC Université Paris 6, UMR 7093, LOV, Observatoire Océanologique de Villefranche, Villefranche-sur-Mer, France.
[3] Sorbonne Universités, UPMC Univ Paris 06, UMS 3455, OSU Ecce-Terra, 4 place Jussieu 75252 Paris cedex 05, France
[4] CNRS, UMS 3455, OSU Ecce-Terra, 4 place Jussieu 75252 Paris cedex 05, France
Email : jras@obs-vlfr.fr

Abstract: SAPIGH is a French analytical service based at the "Laboratoire d'Océanographie de Villefranche" (LOV), and dedicated to High Performance Liquid Chromatography (HPLC) measurements of phytoplankton pigment concentrations. Over 2000 samples from various types of marine environments are analysed each year, covering a wide range of trophic conditions (from hyper-oligotrophic subtropical gyres to eutrophic upwelling and bloom conditions) and locations (from polar to tropical regions).

To maintain high quality standards, SAPIGH conducts research and development activities focused on various methodological aspects. We therefore regularly participate in international intercomparison exercises that bring together a global network of experts on HPLC phytoplankton pigments (e.g. since 2000, seven SeaHARRE experiments coordinated by NASA; reports at http://oceancolor.gsfc.nasa.gov/DOCS/). These experiments encourage step by step improvements on quality control procedures. Pigment analysis training courses are also proposed for technical staff and students.

An extensive global pigment database comprising vertical profiles of phytoplankton pigment concentrations has been created at the LOV since 1990, with samples collected from numerous surveys worldwide. SAPIGH contributed to 22% of the MAREDAT pigment database published in 2013 (http://doi.pangaea.de/10.1594/PANGAEA.808535). The SAPIGH database is regularly updated (over 6500 extra data points available since the MAREDAT publication). Furthermore, simultaneous deployment of Bio-Argo Floats (measuring chlorophyll a fluorescence) and vertical pigment sampling have recently been coordinated in the North Atlantic, Mediterranean Sea and Southern Ocean.

Systematic HPLC pigment measurements could be envisaged for GO-SHIP in particular for sections where Bio-Argo float sensors will be deployed. Members of SAPIGH are available to discuss the conditions of this contribution.

2P2 How do I cite Argo data in my publication?

Justin BUCK[1], Thierry CARVAL[2], Kenneth CASEY[3], Frederick MERCEUR[2] and Megan SCANDERBEG[4]
[1] BODC, Liverpool, England
[2] IFREMER, Brest, France
[3] NODC, Silver Springs, MD, USA
[4] Scripps Institution of Oceanography, La Jolla, CA, USA
Email: juck@bodc.ac.uk

Abstract: The Argo dataset is considered to be "dynamic" because it grows and evolves with time as it is appended to and quality control is updated. When data are cited or referenced in scientific literature this needs to be unambiguous to ensure the scientific reproducibility of results. Assignment of Digital Object Identifiers (DOIs) has been an active area of work for the last three years and it is now possible to cite Argo data in such a manner via "data snapshots" hosted by IFREMER where each snapshot has its own DOI assigned. Work is on-going with a method to simplify citation under development that should reduce the number of DOIs. The current status and future developments in the context of other international efforts to cite dynamic data series are presented.

2P3 Annual wintertime inorganic carbon chemistry along a transect across the Rockall Trough

Triona McGRATH[1], Evin McGOVERN[2] and Rachel R. CAVE[1]
[1] National University of Ireland, Galway
[2] Marine Institute, Ireland
Email: triona_mcgrath@hotmail.com

Abstract: Monitoring ocean carbonate parameters is necessary to determine the rate of ocean acidification in different oceanic regions and to understand potential impacts on marine ecosystems. Wintertime total alkalinity (TA) and dissolved inorganic carbon (DIC) were sampled annually across the Rockall Trough, a deep sea channel in the eastern North Atlantic, between 2009 and 2013. The results have been compared WOCE data in the region from the 1990s to assess the temporal evolution of anthropogenic carbon over two decades. There was a significant increase in DIC-abio (DIC corrected for biological activity) of 23±4μmol kg^{-1} in subsurface waters between 1991 and 2013, equivalent to a decrease of 0.050±0.003 pH units (or -0.002 units per year). There was also a significant decrease in the saturation state of aragonite (ArΩ) and calcite (CaΩ) in subsurface waters over the 22 years, which may have implications for calcifying organisms in the region.

Labrador Sea Water (LSW), a relatively young water mass in the Rockall Trough, occupies much of the water column between 1500-2000m. There was a significant increase in both DIC and DIC-abio of 16±4μmol kg^{-1} in LSW between 1991 and 2013, which has acidified by 0.055±0.002 pH units over the same period. The rate of acidification in LSW was twice as fast over the last 5 years (2009-2013) than it was in the 1990s. There has been a reduction in saturation of calcium carbonate minerals in LSW, with ArΩ close to undersaturation (1.07) in 2013.

2P4 Seasonal and Inter-annual changes of Antarctic Bottom Water off the Adelie Coast observed by Deep NINJA

Taiyo KOBAYASHI
JAMSTEC
Email: taiyok@jamstec.go.jp

Abstract: Since December 2012 four Deep NINJA floats have observed Antarctic Bottom Water (AABW) off the Adelie Coast, Antarctica, to clarify its seasonal and inter-annual changes. Until now, they transferred 59 profiles up to the depth of 4000 dbar for the period of 20 months (December 2012 to August 2014), including the profiles under sea ice in Austral winter. AABW showed the seasonal variation that it was freshened in the early winter (April to June). In 2014, the freshening began at the isotherm of -0.2°C first in April and then was followed at the colder isotherms. The freshening at the coldest layer (-0.4°C) there occurred suddenly in June. Whereas in 2013, the seasonal variation of AABW was unclear: the weak freshening seemed to begin at the isotherm of -0.2°C in May, but there were no such variations at the colder isotherms. In the Antarctic Ocean, winter sea ice began to extend earlier and spread more broadly in the 2014 than in 2013. Thus, a part of the inter-annual difference could be explained by the difference of winter cooling there.

2P5 Uncertainties in detecting decadal changes in total inorganic carbon from the GO-SHIP decadal surveys.

Rik WANNINKHOF
NOAA/AOML, Miami FL
Email: Rik.wanninkhof@noaa.gov

Abstract: One of the major goals of the Global Ocean Ship-based Hydrographic Surveys, GO-SHIP is to determine changes in water column inorganic carbon content and associated biogeochemical parameters. Quantifying these changes is challenging because of small magnitude and relative sparse sampling, interpolation errors, and poorly quantified uncertainty in the measurements. Here we use data from two GO-SHIP lines in the North Atlantic, A16˚N and a16˚S occupied in 2003/2005 and 2013/2014 to assess the different sources of uncertainty in total dissolved inorganic carbon DIC and discrete partial pressure of CO_2 measured at 20˚C, pCO_2.

This analysis provides a single transect assessment of measurements by a single group that is compared with the global uncertainty comparison and adjustments of biogeochemical parameters during GLODAP-I (Key *et al*. 2004) and GLODAP-II (in preparation). The analytical uncertainty for the cruises is assessed from propagating the stated error in measurement of the calculated quantities of individual components of the inorganic carbon system and comparing them to the measured values. This is possible as for these cruises all four carbon system parameters were determined, the so-called over-determination of the inorganic carbon system After quality control of the data the uncertainty is close to the instrumental uncertainty with greatest uncertainty in deep waters because of its smaller buffer capacity. Under-sampling error along the lines is estimated by a multi-linear fit of the DIC and $pCO_2(20)$ data to the 1-m averaged temperature, salinity of O_2 data from the CTD/O sensor. Initial analyses indicate no significant systematic differences between the sparsely sampled DIC and pCO_2 , and higher resolution synthetic parameters, suggesting that sampling density is adequate, even for $pCO_2(20)$ that was sampled at low resolution of the cruises.

Changes in DIC content between the 2003/2005 and 2013/2014 cruises are largely in the upper water column and attributed invasion of anthropogenic CO_2 but the patchiness also suggests large natural changes. The observed decadal changes are well above the experimental error. Biases between measurements remain a challenge and are often dealt with through normalization to deep waters. In regions of Deep water formation such as in the North Atlantic where changes can propagate to the deep this is not always possible.

2P6 Trends in nutrients at a repeat section from 1996 to 2011 through the Weddell Sea

Mario HOPPEMA[1], Steven VAN HEUVEN[2] and Karel BAKKER[2]
[1] Alfred Wegener Institute Helmholtz Centre for Polar and Marine Research, Bremerhaven
[2] Netherlands Institute for Sea Research, Texel
Email: Mario.Hoppema@awi.de

Abstract: Phosphate, nitrate and silicate data spanning 1996 to 2011 are presented for a repeat section crossing the Weddell Sea. Data have been standardized against the same reference material in all those years, yielding an outstanding internal consistency which enables detection of minor changes. The generic structure of the Weddell Gyre and its hydrographic features are visible in the nutrient distributions. The variability is largest in the Circumpolar Deep Water (CDW) layer at 200-1500 m and clearly less in other water masses. The distribution of silicate appears to be powerful for describing water mass processes in the bottom layer. The distribution of nitrite is described in detail for the first time. Opposed to common knowledge, a considerable part of the abyssal Weddell Sea had significant nitrite concentrations, hinting at active biological activity at these depths. Trends in nutrients all over the water column were investigated by applying linear regression on gridded data. We infer significant trends of increasing nutrients mainly in the surface layer, but also some in the CDW layer. An increasing rate of upwelling of nutrient-rich subsurface water over those 15 years is a likely reason for the considerable increase of nutrient concentrations in the surface layer. In the bottom water, silicate exhibits an increasing trend, which is probably caused by a changing composition of the bottom water.

2P7 Biogeochemical variations at the Porcupine Abyssal Plain Sustained Observatory (PAP-SO) in the northeast Atlantic Ocean

Susan HARTMAN[1], Richard LAMPITT[1] and Ute SCHUSTER[2]
[1] NOC, Southampton, UK
[2] University of Exeter
Email: suh@noc.ac.uk

Abstract: We examine high-resolution autonomous measurements of carbon dioxide partial pressure $p(CO_2)$ taken in situ at the Porcupine Abyssal Plain sustained observatory (PAP-SO) in the northeast Atlantic (49°N, 16.5°W; water depth of 4850 m) for the period 2010 to 2012. Measurements of $p(CO_2)$ made at 30 m depth on a sensor frame are compared with other autonomous biogeochemical measurements at that depth (including chlorophyll a-fluorescence and nitrate concentration data) to analyse weekly to seasonal controls on $p(CO_2)$ flux in the inter-gyre region of the North Atlantic.

Comparisons are also made with in situ regional time-series data from a ship of opportunity and mixed layer depth (MLD) measurements from profiling Argo floats. There is a persistent under saturation of CO_2 in surface waters throughout the year which gives rise to a perennial CO_2 sink. Comparison with an earlier dataset collected at the site (2003 to 2005) confirms seasonal and inter-annual changes in surface seawater chemistry. There is year-to-year variability in the timing of deep winter mixing and the intensity of the spring bloom.

2P8 The 'Global Coast': Filling the gaps where the ocean is not deep

Holger BRIX
Institute of Coastal Research, Helmholtz-Zentrum Geesthacht, Germany
Email: holger.brix@hzg.de

Abstract: Many global problems such as climate change, sea level rise, or ocean acidification influence in particular the ecosystems and communities along the coasts. Coastal regions on the other hand provide the 'boundary conditions' for the deep ocean. While programs like Deep-Argo venture toward the abyss shallow regions like shelves and regional seas require other means of monitoring. Traditionally, coastal research concentrated on local or regional approaches and problems. Methods and techniques developed there can, however, be relevant in a wider context. The research focus area Global Coast at the Institute of Coastal Research, Helmholtz-Zentrum Geesthacht in Germany investigates the relevance of coastal waters for global processes, as for example carbon exchange processes with the open ocean or oceanic energy budgets.

The two-pronged approach concentrates on the investigation of specific coastal region that are potentially representative for larger stretches of coast lines or shallow seas and their relevance for key global processes and mechanisms by combining observations and models. In cooperation with local partners, measurement and analysis strategies are designed that involve development and deployment of mobile measurement stations such as profiling buoys, gliders, radar etc. for campaigns worldwide as well as hydrographic and biogeochemical numerical modeling efforts using models of varying complexity (e.g., grid spacing and forms, processes, etc.). These efforts are geared towards closing our gaps in understanding the contribution of the multifaceted coasts of the world to globally relevant research questions.

2P9 Considerations on the collection of data from Bio-Argo floats across sampling scales.

Ian D. WALSH, Dan QUITTMAN, David J. MURPHY and Thomas O. MITCHELL
Sea-Bird Scientific
Email: ian@wetlabs.com

Abstract: The flexibility of the current generation of float sensor packages is an opportunity to craft mission specific sampling schemes that balance the collection of data for specific sampling goals with the practicalities of float operation.

Autonomous floats operate within constraints of battery life and data transfer rates. For simplicity of data transfer and handling, most float data sets are transmitted after binning on pressure. Within a given pressure bin different instruments will be sampling within a particular defined sequence. A sampling sequence should be balanced towards minimizing energy consumption while maximizing data accuracy of each instrument. As the number of sensors increases and the breadth of mission parameters expands it becomes more difficult to optimize data sequencing and reporting.

We consider methods to reduce the size of the problem by setting rules for sequence development and test those rules relative to field data. We examine a set of data from a float that was equipped with internal memory that captured the full set of sample data taken during the profiling mission.

Comparing the 'raw' data and the transmitted data we examine the variance around the transmitted data and discuss the impact of data sequencing on the data. We further consider the impact and benefit of collecting data during the park phase of missions.

2C1 The ACC Subantarctic and Polar fronts, and Southern Ocean heat and freshwater content variability: a view from Argo

Donata GIGLIO and Gregory C. JOHNSON
University of Washington
First author Email address: dgiglio@uw.edu

Abstract: Argo profiling floats initiated a revolution in observational physical oceanography by providing numerous, high-quality, global, year-round *in situ* (0-2000 db) temperature and salinity observations. Here, we use Argo's unprecedented sampling of the Southern Ocean during 2006–2013 to describe the position of the Antarctic Circumpolar Current's Subantarctic and Polar fronts, comparing and contrasting two different methods for locating fronts using the same data set. The first method locates three fronts along dynamic height contours that each correspond to a local maximum in vertically integrated shear. The second approach locates the fronts using specific features in the potential temperature or salinity fields, following Orsi *et al*. (1995). Results from our analysis of Argo data are compared to those from Orsi *et al*. (1995) and other more recent studies. Argo spatial resolution is not adequate to resolve annual and interannual movements of the fronts on a circumpolar scale, since they are on the order of 1º latitude (Kim and Orsi, 2014), smaller than the resolution of the gridded product we use in our analysis. Still, Argo's four-dimensional coverage of the Southern Ocean equatorward of 60ºS can be used to quantify heat and freshwater content there with respect to the time-mean front locations. Here, we describe changes in heat and freshwater content in the Southern Ocean and in regions between fronts during 2006–2013, considering both pressure and potential density ranges (i.e. different water masses) and in relation to wind forcing (i.e., Ekman upwelling and downwelling).

2C2 Seasonal trends in pH and aragonite saturation state in the Pacific sector of the Southern Ocean based on the SOCCOM Argo float

Richard A. FEELY[1], Lauren JURANEK[2], Nancy L. WILLIAMS[2], Ken JOHNSON[3]
and Joellen RUSSELL[4]
[1] Pacific Marine Environmental Laboratory/NOAA
[2] Oregon State University
[3] Monterey Bay Research Aquarium Institute
[4] University of Arizona
Email: Richard.A.Feely@noaa.gov

Abstract: The Southern Ocean accounts for as much as 50% of the annual uptake of anthropogenic carbon dioxide from the atmosphere and, as such, the region is highly vulnerable to acidification over the coming decades. Examining the magnitude and spatial changes of pH and aragonite saturation state is critical for understanding the Southern Ocean's response to continued increases of this greenhouse gas. Here we demonstrate the ability to obtain accurate estimates of pH and aragonite saturation state (Ωarag) from the SOCCOM Argo profiling floats equipped oxygen and pH sensors in the Southern Ocean. Using the recent GO-SHIP hydrographic S4P, P15S and P16S cruise data we developed empirical algorithms to predict pH and Ωarag using observations of temperature, salinity, dissolved O_2, density, and pressure. We obtained R2 values of 0.984 (pH) and 0.993 (Ωarag) and RMS errors of 0.007 (pH), 0.052 (Ωarag), for data between 100–1500 m. We applied the algorithms to the Argo profiling float data to produce 13-month time-series of estimated pH and Ωarag in the upper water column of the Southern Ocean south of 40°S.

Comparison to independent pH data collected on the floats indicated that the algorithm-based estimates are robust to within ± 0.03 for pH. The results show strong seasonal trends with both pH and Ωarag reaching their maximum values in the austral summer and fall. The seasonal changes can be as high as 0.05 for pH and 0.1 for Ωarag.

2C3 The seasonal cycle of carbon in the Southern Ocean determined from autonomous profiling floats

Alison GRAY[1], Ken JOHNSON[2], Jorge SARMIENTO[1], Brendan CARTER[3], Lynne Talley and Stephen C. RISER
[1] Princeton University
[2] Monterey Bay Aquarium Research Institute
[3] Pacific Marine Environmental Laboratory, Seattle
Email: argray@princeton.edu

Abstract: The Southern Ocean is thought to play an important role in the ocean-atmosphere exchange of carbon dioxide and the uptake of anthropogenic carbon dioxide. However, the total number of observations of the carbonate system in this region is small and heavily biased towards the summer. Here we present a full year of biogeochemical measurements, including pH, oxygen, and nitrate, collected by 11 autonomous profiling floats deployed in the Pacific sector of the Southern Ocean in April 2014. These floats sampled a variety of oceanographic regimes ranging from the seasonally ice-covered zone to the subtropical gyre. Using an algorithm trained with bottle measurements from GLODAP, alkalinity is estimated from salinity, temperature, oxygen, and nitrate and then used together with the measured pH to calculate total carbon dioxide and pCO_2 in the upper 1500 m. The seasonal cycle in the biogeochemical quantities is examined, and the factors governing pCO_2 in the surface waters are analyzed. Comparing the different regimes sampled by the floats demonstrates the complex and variable nature of the carbon cycle in the Southern Ocean.

2C4 Long-term CO_2 monitoring in the Southern Indian Ocean

Claire LO MONACO, Nicolas METZL, Renaud GOMEZ, Claude MIGNON, Catherine PIERRE and Virginie RACAPE
Sorbonne Universités (UPMC)-CNRS-IRD-MNHN, LOCEAN/IPSL Laboratory
Email: claire.lomonaco@locean-ipsl.upmc.fr

Abstract: Underway and water column CO_2 observations have been collected in the South-West Indian Ocean (20°S-60°S) onboard R/V Marion Dufresne since the mid-eighties, with yearly cruises since 1998 in the frame of the OISO monitoring project (Ocean Indien Service d'Observations), complementing the global ocean network. In all sectors we observed a positive trend in surface fCO_2, roughly following the increase in the atmosphere. In the Sub-Antarctic zone, a major sink for atmospheric CO_2, we observed a gradual increase in total CO2 (TCO2) and a decrease in its isotopic composition (13C) mostly driven by the large accumulation of anthropogenic CO_2. This led to a decrease in pH by approximately 0.02/decade, a signal that propagates in the ocean interior with the spreading of Sub-Antarctic mode waters. At higher latitudes, we observed a rapid increase in surface fCO_2 over the period 1991-2009, likely caused by intensification and poleward shift of the westerly winds that could have enhanced the upwelling of CO_2-rich subsurface waters. However, we observed a relatively slow increase in TCO_2 in Antarctic surface waters and a decrease in surface alkalinity, also resulting in a decrease in pH by approximately 0.02/decade. It is crucial to maintain these observations in the future in order to better understand the evolution of both air-sea CO_2 fluxes (global carbon budget) and on-going changes in carbonate chemistry (ocean acidification) in response to both anthropogenic emissions and climate variability and change.

2C5 Status, achievements and outlook for under-ice Argo in the Southern Ocean

Esmee VAN WIJK, Susan WIJFFELS and Stephen RINTOUL
CSIRO, Hobart, Tasmania
Email: Esmee.vanWijk@csiro.au

Abstract: The original design of the Argo program specified a nominal density of one float every 3 x 3 degrees between 60°N and 60°S, excluding the marginal seas and high latitudes. However, key science questions relevant to climate and sea level rise require broad-scale observations of the global oceans that extend into the seasonally ice-covered seas. Historically, measurements from shipboard hydrography are sparse in the high latitudes, particularly during the winter months. Ice-capable floats have provided year-round sampling of the seasonally-ice covered Southern Ocean since the mid 2000's and are the only feasible broad-scale observational platform that will enable us to fill in this 'blind spot' in our global ocean observing system. We review the status of the Southern Ocean Argo array south of 40°S and in particular under-ice Argo floats south of 60°S (distribution and number of profiles, float lifetimes, reliability and loss rates). We highlight new science from under-ice float data, including estimates of sea ice production, seasonal salinification, mixed layer development, circulation, and heat and salt budgets. Floats parked on the sea-floor between profiles have provided year-round sampling of the circulation and water properties on the continental shelf, including onshore flow of Circumpolar Deep Water and export of Ice Shelf Water from ice shelf cavities. Deployments of ice-capable floats have proven the feasibility of under-ice observing and provide guidance for the design of a sustained under-ice observing system.

2D1 Estimation of the ventilation in the Bay of Biscay in 2009-2012 using oxygen profiles from Argo data

Marta ÁLVAREZ, Manuel RUIZ-VILLARREAL, César GONZÁLEZ-POLA
and Alicia LAVÍN
Instituto Español de Oceanografía
Email: marta.alvarez@co.ieo.es

Abstract: Three Argo floats equipped with SBE43 oxygen sensors were deployed in the center of the Bay of Biscay in September 2010 during the RADPROF cruise. Winkler oxygen measurements were also taken for calibration. A few weeks later two sensors failed. We present the remaining Argo oxygen data from September 2010 to August 2012 covering from center of the Bay of Biscay to 15ºW in the North-East Atlantic. We caught two episodes of winter convection where the upper 400 meter were homogenized in temperature and salinity and took a deep breath in oxygen. A winter shallow oxygen maximum was developed. We will try to elucidate the mechanisms behind its formation. Sea surface layer altimetry data will be used to study the trajectory of the floats in relation with surface currents. The seasonal variability in the Mediterranean and Labrador Sea Water layers will be studied focusing in the dissolved oxygen variability.

2D2 Shelf-Sea Biogeochemistry – what goes on upon the N.W. European Shelf?

Caroline KIVIMAE[1], Susan HARTMAN[1], Naomi GREENWOOD[2], Evin McGOVERN[3], Brian STEWARD[4] and Pamela WALSHAM[5]
[1] National Oceanography Centre
[2] CEFAS, UK
[3] Marine Institute, Ireland
[4] AFBI, UK
[5] Marine Scotland Science
Email: anck@noc.ac.uk

Abstract: On the global scale more primary production and air-sea exchange of carbon dioxide takes place on the shelf seas than indicated by their area. The shelf seas are also of large societal importance. The Shelf Sea Biogeochemistry programme (SSB) is a large UK project that aims to reduce th uncertainty in the understanding of carbon and nutrient cycling within the shelf seas, focusing on the North-west European shelf.

As part of the SSB we have undertaken shelf-wide sampling of DIC/TA, nutrients and DOM, aiming to quantify the fluxes of carbon into and out of the shelf. Samples have been collected for about a year on the SSB cruises and by our partners at AFBI, CEFAS, MI and MSS. Combining surface samples with surveys along the shelf break will allow us to reach the aim of the programme. We will present the ongoing activities and the first results.

2D3 Phytoplankton bloom in the NW Mediterranean: impacts of a deep convection event revealed by Bio-Argo, Bio-Gliders and Ship data

Nicolas MAYOT and Fabrizio D'ORTENZIO
Laboratoire d'Océanographie de Villefranche (LOV, FRANCE)
Email: mayot@obs-vlfr.fr

Abstract: The North Western Mediterranean Sea (NWM) combines, in a relatively small area, recurrent intense open-ocean deep convection events and significant phytoplankton spring blooms (in terms of spatial extent and of observed chlorophyll-a concentrations). However, the importance of the deep convection in structuration of spring blooms is still debated. To answer to the still open questions, an intense scientific effort coupling ship observations and autonomous platforms has been carried out in the NWM during the winter-to-spring transition 2012-2013 (DEWEX program).

During this program, six campaigns of ship observations (from September 2012 to September 2013) were supplemented by physical Argo (10 floats), Bio-Argo (5 floats) and Bio-Gliders (6 gliders). The sampling strategy was elaborated to help reconstruct of the seasonal cycle of different physical and biogeochemical properties across the water column. The calibration of biogeochemical sensors of autonomous platforms was performed after co-localization with ship profiles (in terms of time and space). The *in situ* data (Argo/Bio-Argo, Bio-Gliders and Ship observations) were then merged and analyzed in a bioregional framework (determined using ocean color images).

The analysis of this unique dataset reveals that the open-ocean deep convection event in 2013 was followed by an unusually strong phytoplankton spring bloom. This may be explained by a change in the stoichiometry of the nutrients available for phytoplankton growth in the euphotic zone. Moreover, the physical mixing appears to have significantly enhanced the export of organic carbon at depth before the spring stratification.

2D4 Seasonal variability of nutrient concentrations in the Mediterranean Sea: Contribution of Bio-Argo floats

Orens DE FOMMERVAULT, Fabrizio D'ORTENZIO and Christophe MIGON
LOV-UPMC-ACRI
Email: orens@obs-vlfr.fr

Abstract: The characterization of the open ocean nutrient distribution is central to understand the marine life. Despite this, available nutrient in situ data are often too rare. The recent development of UV optical sensors to evaluate the concentration of nitrate (NO_3) without water samples, and the further integration of these sensors on profiling floats, open a real new frontier in biogeochemical studies. As part of the French NAOS (Novel Argo Oceanic observing System) program, a first basin scale network of NO_3 profiling floats was deployed in the Mediterranean Sea. Six Bio-Argo, also equipped with NO_3 sensors, were deployed over the period 2012-2013, conducting to the retrieval of more than 500 NO3 profiles over the whole basin.

The Mediterranean Sea has been selected to drive this pilot experience as it is characterized by the coexistence of contrasted trophic regimes, distributed along a northwest-southeast gradient of oligotrophy. It is mainly characterized by tropical like regime, although some spots marked by a temperate-like regime (i.e. with large spring bloom) exist. The obtained data set provides an unprecedented description of the annual nutrient cycle in the Mediterranean Sea, which is here presented and discussed. Results are also compared with climatological patterns, achieved from available *in situ* observations, and the added value of the Bio-Argo network is analyzed. The specific conditions of the Mediterranean Sea (i.e. very low nutrient concentrations, high temperature and salinity) required improved data processing, calibration, and quality control. Existing protocols were then specifically adapted to the basin conditions.

2D5 Argo observations in the Mediterranean and Black Sea: status and future prospective

Pierre-Marie POULAIN[1], Giulio NOTASTEFANO[1] and Fabrizio D'ORTENZIO[2]
[1] OGS
[2] LOV
Email: ppoulain@inogs.it

Abstract: Since the turn of the Century, in concert with the development of the international Argo program, a limited number of Argo floats have been deployed in the Mediterranean and Black Seas as part of European and national programs. Over the last few years several countries have started to contribute substantially to the Argo fleet in these marginal seas, triggered by the creation of Euro-Argo, an European research infrastructure aimed to consolidate the European contribution to Argo. As a result, the Argo fleet has increased to reach a total of about 70 operating floats in early 2015. As part of Euro-Argo, an international coordination has been set up with the goal to sustain and optimize the Argo sampling in the Mediterranean and Black seas. Efforts are particularly focused on capacity building and outreach in North African and Middle East countries in order to sample efficiently the southern and eastern areas of the Mediterranean, for example, and to help with regional legal issues and with possible float recoveries on their coasts. The Mediterranean and Black seas are also pilot areas for the so-called Bio-Argo program. Indeed, since a few years ago, French, Italian and European projects have included the operations Argo floats with biogeochemical sensors. This talk presents the current status of the Argo program in the Mediterranean and Black seas, and considerations for future plans in terms of deployment and sampling strategies, including the implementation of deep Argo floats to monitor water masses near the bottom of the main sub-basins.

3A1 Atlantic BiogeoChemical (ABC) Fluxes: adding carbon and nutrients to the RAPID array, a contribution to NERC's RAPID-AMOC programme.

E. McDONAGH[1], R. SANDERS[1], P. BROWN[1], B. KING[1], D. RAYNER[1], A. YOOL[1], S. HARTMAN[1], S. TORRES-VALDES[1], V. BYFIELD[1], D. SMEED[1], M. MOORE[2], N. BATES[2], A. WATSON[3], P. HALLORAN[3], U. SCHUSTER[3], M.-J. MESSIAS[3], T. SMYTH[4], S CIAVATTA[4], G DALL'OLMO[4], Rosa BARCIELA[5], Molly BARINGER[6], Chris MEINEN[6], Shenfu DONG[7], Dennis HANSELL[8], Becky GARLEY[9] and Steven EMERSON[10]

[1] National Oceanography Centre, UK
[2] University of Southampton, UK
[3] University of Exeter, UK
[4] Plymouth Marine Laboratory, UK
[5] UK Met Office, UK
[6] NOAA/AOML, USA
[7] NOAA/AOML and Univ. of Miami, USA
[8] University of Miami, USA
[9] BIOS
[10] University of Washington, USA

Email: e.mcdonagh@noc.ac.uk

Abstract: ABC fluxes is a six-year project running from October 2014 to September 2020 funded by NERC's RAPID-AMOC programme. In addition to data from the RAPID array this project uses GO-SHIP repeat hydrography data, Argo data and moored sensors and samplers for carbon system parameters. Here we present an overview of the project.

The North Atlantic Ocean plays a pivotal role in the global carbon cycle, by storing anthropogenically mobilised carbon and by supporting the downward flux of organic matter. Our understanding of how lateral oceanic fluxes in the subtropics contribute to these processes is largely based on hydrographic sections occupied every 5 years at 24.5°N, a sampling programme that is inadequate to resolve and understand the role these transfers play in regulating these processes. Detailed time series of physical fluxes at 26.5°N from the RAPID array suggest that variability in these transfers will be occurring on a range of timescales, which, once measured, will likely modify our understanding of the role the North Atlantic subtropical gyre plays in the global carbon cycle.

ABC fluxes is addressing these issues by deploying new instruments on the RAPID array at 26.5°N, making biogeochemical measurements on the bi-monthly NOAA cruises in Florida Straits and deploying oxygen-enabled Argo floats. ABC fluxes has purchased pCO2 sensors and Remote Access (RAS) samplers that will be deployed on a mooring in the array in October 2015. ABC fluxes will sample its first of 22 Florida Straits cruises in May 2015. The first 12 moored oxygen sensors (sampling the western boundary) will be recovered in October 2015 and 24 new sensors deployed at that time to make observations in the western boundary, Mid-Atlantic ridge and eastern boundary. In December 2015 we will deploy 16 oxygen-enabled Argo floats from the GO-SHIP repeat hydrographic section at 24.5°N.

ABC fluxes will calculate time series of nutrient and carbon, including anthropogenic carbon, fluxes across 26.5°N. We adopt an hierarchical approach, successively using existing observations, then new oxygen observations and ultimately direct observations of the carbon and nutrient fields to identify the added value each successive stage of ABC observations provides. We interpret our direct flux calculations as contributions to the North Atlantic budget in conjunction with other observations and models to assess how oceanic fluxes control the strength and variability of the role the North Atlantic plays in the global carbon cycle. In another abstract at this meeting Brown presents ABC fluxes calculations of Anthropogenic carbon fluxes using existing observations.

3A2 Temporal variability of North Atlantic carbon fluxes and their sensitivity to the meridional overturning circulation

Peter BROWN[1], Elaine McDONAGH[1], Richard SANDERS[1], Brian KING[1], David SMEED[1], Andrew WATSON[2], Ute SCHUSTER[2], Molly BARINGER[3], Rik WANNINKHOF[3], Chris MEINEN[3], Bill JOHNS[4], Stuart CUNNINGHAM[5]
[1] National Oceanography Centre, Southampton
[2] University of Exeter
[3] NOAA, AOML
[4] University of Miami
[5] SAMS
Email: peter.brown@noc.ac.uk

Abstract: The North Atlantic plays a critical role in the global carbon cycle both as a region of substantial air-sea carbon dioxide uptake and as a location for the transfer of CO_2 to depth on climatically-important timescales. However, while surface flux variability is relatively well constrained, our understanding of the changing deep carbon distribution is restricted to sub-decadal repeat hydrographic sections, and for anthropogenic carbon (C_{anth}), integrated multi-decadal basin-scale estimates.

Here, we present the first observation-derived high-resolution estimate of short-term meridional carbon transport variability and long-term trends across the subtropical North Atlantic. Historical hydrographic data-based estimates of C_{anth} are used to generate predictive regressions that, combined with RAPID mooring and Argo float-derived transport estimates, create a 10-day frequency interior ocean carbon flux time-series for 2004-2012.

The mean net C_{anth} transport across this timeframe is found to be relatively independent of calculation method and robust at 0.22 PgC yr^{-1} northwards, with poleward advection of high C_{anth} shallow waters outweighing the predominantly southwards transports of low concentrations at depth. Substantial seasonal, sub-annual and interannual transport variability is observed that is highly sensitive to the strength of the overturning circulation. While the recently identified multi-year decrease in MOC strength similarly impacts C_{anth} transports, its full effect is masked by the northwards transport of increasing surface C_{anth} levels. A comparison with historical estimates of the regional carbon sink reveals an intrinsic relationship between air-sea uptake, ocean transport and heat fluxes, which will become more important as the ocean responds to a changing global climate.

3A3 SAMOC: An international effort to monitor the meridional overturning circulation in the South Atlantic

Edmo CAMPOS[1], Silvia GARZOLI[2], Christopher MEINEN[3], Alberto PIOLA[4]. Michael ROBERTS[5] and Sabrina SPEICH[6]
[1] Oceanographic Institute of the University of Sao Paulo, Brazil
[2] NOAA/AOML and CIMAS/University of Miami, U.S.A.
[3] NOAA/AOML, U.S.A.
[4] Servicio de Hidrografia Naval and University of Buenos Aires, Argentina
[5] Oceans and Coasts Research / South Africa
[6] École Normale Supérieure, Departement de Geosciences, France
Contact Email: edmo@usp.br

Abstract: An observing system to monitor the meridional overturning circulation in the South Atlantic is being implemented based on a strong international effort. This South Atlantic Meridional Overturning Circulation initiative (SAMOC) includes observations in the South Atlantic as well as in the Southern Ocean passages that connect to the other basins. In particular, a major component is moored arrays and hydrographic surveys on a transatlantic section along 34.5°S. International CLIVAR has endorsed the SAMOC initiative. The 34.5°S zonal section, which is near to the A10 GO-SHIP line, is referred as the SAMOC Basin-Wide Array (SAMBA). This presentation will highlight recent updates to the MOC observing system programs in the South Atlantic, with

focus on the Argentina-Brazil-US effort in the western end of SAMBA. This includes an array of bottom mounted pressure-equipped inverted echo sounders (PIES) and current-and-pressure-equipped inverted-echo sounders (CPIES), from the continental slope (~ 52°W) slope out to 44°W. It also includes a pair of instruments mounted on sea floor near the shelf-break: an Acoustic-Doppler Current Profiler (ADCP) and a bottom-pressure gauge. Since 2009, ten hydrographic cruises have been conducted in the region for sampling water mass properties and to retrieve data from the PIES and CPIES. As of April 2015, the next cruises are scheduled for early July and late 2015.

3A4 Observations of subpolar North Atlantic variability and overturning circulation from the Extended Ellett Line

N. Penny HOLLIDAY[1] , Stuart A. CUNNINGHAM[2], Stefan F. GARY[2], Clare JOHNSON[2] and Matthew P. HUMPHREYS[3]
[1] NOC, UK
[2] SAMS
[3] University of Southampton
Email: penny.holliday@noc.ac.uk

Abstract: Since 1996 the GO-SHIP section known as the "Extended Ellett Line" has been measuring the properties (temperature, salinity, carbon) and overturning circulation between Iceland and Scotland. The section monitors the upper limb of the AMOC in the subpolar North Atlantic (SPNA): the northward flow of warm water into the Nordic Seas and Arctic, and eastern subpolar mode waters that travel cyclonically around the subpolar gyre to the Labrador Sea. Four decades of high quality ship-based measurements in the easternmost basin of the SPNA, the Rockall Trough, enhanced by data in the wider Iceland Basin, reveal long term salinity and carbon variability that represents conditions across the SPNA and Nordic Seas. We will describe the observed variability in properties and discuss the uncertainties associated with the measurements. We compute the mean and variance of the overturning circulation at the section and consider the implications for present and future observing networks including OSNAP.

3B1 Regional variability of freshwater in the North Atlantic in the RAPID/Argo era

Brian KING, Elaine L. MCDONAGH, Damien DESBRUYERES and N. Penny HOLLIDAY
National Oceanography Centre, Southampton, UK
Email: b.king@noc.ac.uk

Abstract: The most striking interannual variability in the strength of the Atlantic Meridional Overturning Circulation since moored measurements began in 2004, was a reduction for a period of 18 to 24 months in 2009/10. This event, as measured by the 26.5°N array, reduced the amount of heat and salt transported northwards by the AMOC, and was associated with a deficit of heat and salt in the region of the subtropical Atlantic north of the monitoring array. Our analysis of Argo data in the region north of 26.5°N showed that the heat deficit recovered more quickly than the salt deficit. We have constructed time series of heat and freshwater flux across 26.5°N, which are a synthesis of Argo measurements and the basin endpoint measurements made by the 26.5°N moorings. By combining the spatial inventories determined from Argo data only, with the horizontal fluxes due to the AMOC, we identify the AMOC contribution to the freshwater budget north of 26.5°N, and its persistence in time and spatial signature. We will show the vertical and horizontal distribution of changes in inventory, and the impact of air-sea exchange on the separate evolution of temperature and salinity. Finally, we will show the extent to which the subtropical and subpolar variability in freshwater are either correlated to each other or to variability in the AMOC measured at 26.5°N.

3B2 Watermass transformation in the Lofoten Basin of the Nordic Seas

Clark RICHARDS[1] and Fiamma STRANEO[2]
[1] RBR Ltd, Woods Hole Oceanographic Institution
[2] Woods Hole Oceanographic Institution
Email: clark.richards@rbr-global.com

Abstract: Recent work to understand the Meridional Overturning Circulation has focused on the role of water mass transformation in high latitude marginal seas. Despite increased understanding, observations of the relevant processes are sparse, and there remain many questions to be answered. In the Nordic Seas, the Lofoten Basin has been increasingly recognized as a region of significant water mass transformation, owing to the large wintertime surface buoyancy loss. Climatologically, the Lofoten Basin accounts for approximately 1/3rd of the total surface buoyancy loss over the Nordic Seas despite only covering about 1/5th of the total area (Richards and Straneo, 2015). Here we compare two years of high temporal resolution mooring data with Argo profiles from within the basin, to highlight the spatial and temporal variability of basin water properties (including: mixed layer depths, upper ocean heat content, and springtime restratification), and extrapolate the results of the mooring observations over longer periods.

3B3 Nutrient fluxes in the eastern subpolar North Atlantic

Clare JOHNSON[1], Stuart CUNNINGHAM[1], Penny HOLIDAY[2] and Stefan GARY[1]
[1] SAMS
[2] NOC
Email: cljo@sams.ac.uk

Abstract: The GO-SHIP Extended Ellett Line, stretching from Iceland to Scotland, crosses the important eastern portion of the subpolar North Atlantic. In this area the upper limb of the Atlantic Meridional Overturning Circulation flows northwards into the Nordic Seas. Whilst the importance of this pathway for heat and salt fluxes is well established, the chemical fluxes are less well known. We combine both physical and chemical hydrographic data over an 18 year period to investigate the northward nutrient flux. As the Extended Ellett Line also captures the return deep flow through the Faroe Bank Channel, southward nutrient fluxes within this overflow water will also be discussed.

3B4 Long-term change in carbon chemistry in the Labrador Sea

Kumiko AZETSU-SCOTT and the Atlantic Zone Offshore Monitoring Program Team
Ocean and Ecosystem Sciences Section, Department of Fisheries and Oceans, Canada,
Bedford Institute of Oceanography
Email: Kumiko.Azetsu-Scott@dfo-mpo.gc.ca

Abstract: The Labrador Sea is one of two sites in the North Atlantic that produce intermediate and deep water by winter convection which extends from 500m to over 2000m depth depending on atmospheric conditions and stratification in the water column. This convection produces Labrador Sea Water (LSW), a well-ventilated and relatively homogeneous water mass. LSW is characterized by low salinity and temperature, and provides an important vehicle for the transport of atmospheric gases, including carbon dioxide, feeding the intermediate depths of the North Atlantic. The North East Atlantic Deep Water (NEADW) and Denmark Strait Overflow Water (DSOW) that were formed in the Nordic seas flow into the region under the LSW. Consequently, all of the water masses in the Labrador Sea are relatively young (<20 years) and inventories of anthropogenic gases are high.

A time series study from 1996 to 2014 shows the steady increase of dissolved inorganic carbon (DIC) concentrations in all water masses in the Labrador Sea. In the newly ventilated LSW, the DIC concentration increased by 0.87 μmol/kg^3/year and pHtotal decreased by 0.003/year. The total alkalinity was correlated negatively with salinity during 1993 to 2002, and became positively correlated with salinity after 2003, which implies a large shift in freshwater sources influencing the newly ventilated LSW.

3P1 Interannual variability of subduction rate estimated using Argo and its implication for anthropogenic carbon uptake by the ocean

Katsuya TOYAMA[1], Toshio SUGA[2], Keith B. RODGERS[3], Aiko IWASAKI[4]
and Bruno BLANKE[5]
1 Meteorological Research Institute, Japan
2 Tohoku University/JAMSTEC
3 Princeton University
4 Tohoku University
5 Laboratoire de Physique des Oceans
Email: ktoyama@mri-jma.go.jp

Abstract: What are the large-scale controls on the uptake of anthropogenic carbon (Cant) by the ocean? It has long been known that the principal impedance to uptake is exchange across the base of the mixed layer (MLbase) associated with subduction. The new era of multiple-platform observing systems that include Argo provide a means to evaluate the critical processes, with the aid of modeling tools. Analysis of Argo products suggest that the subduction rate in the subtropical North Pacific shows significant year-to-year variability ranging from 25 to 50 Sv during 2005-2012, which is well correlated with the Pacific Decadal Oscillation. An ocean biogeochemical model output is used to estimate anthropogenic carbon (Cant) transport across the MLbase under WOCE-era climatological conditions. Globally integrated Cant transports are estimated to be approximately 5.0 PgC/yr downward via subduction and 4.6 PgC/yr upward via obduction, with net transport of 0.4 PgC/yr downward. The spatial distribution of the Cant subduction is quite similar to that of physical subduction, underscoring the importance of ocean dynamics in transferring Cant between surface and interior oceans. The net downward transport is an order of magnitude less than surface carbon flux of 2.0 PgC/yr during the WOCE-era, implying an important role of diffusion transporting Cant downward. The large spatio-temporal variability of the physical subduction rate found through analysis of Argo products suggest that the Cant transport across the MLbase will also have large variability, which consequently have large impact on carbon cycle and ocean biogeochemistry both on global and local scales.

3P2 CTD profiles for global ocean forecasting: a system for real-time data delivery from UK research vessels

Fiona CARSE[1], Tim SMYTH[2], Simon GOOD[1], Jonathan TURTON[1] and Malcolm HEARN[3]
[1] UK Met. Office
[2] Plymouth Marine Laboratory
[3] British Oceanographic Data Centre
Contact Email: fiona.carse@metoffice.gov.uk

Abstract: We describe a new system to obtain real-time temperature, salinity and pressure profiles from the RRS James Clark Ross. The aim is to increase the amount of full depth profiles available for assimilation into the Met Office's operational ocean forecasting system FOAM (Forecasting Ocean Assimilation Model), which requires data to arrive no more than 48 hours after the measurement time. Despite being un-calibrated, ship's CTD profiles have a data quality similar to or better than real-time Argo profiles and can be an extremely valuable source of sub-surface observations, often sampling in regions where there are few other observations.

Until recently, the process for this was semi-manual and difficult to sustain, however the new system is fully automated. With this new system, it is possible to have data available for assimilation into the models within two to three hours of the CTD arriving on deck. With the agreement of cruise PIs, the sub-sampled data will also be distributed on the WMO's Global Telecommunication Service for use by other National Meteorological Services.

In the near future, we aim to install the system on other UK research vessels and encourage other countries to develop similar systems for real-time delivery of ship's CTD data.

3P3 Instrumented seals help us to observe the ocean

Fabien ROQUET[1], Christophe GUINET[2], Baptiste PICARD[2] and Gilles REVERDIN[3]
[1] Stockholm University
[2] CEBC/CNRS, Chize
[3] LOCEAN, Sorbonne University, Paris

Abstract: Since 2004, several hundreds of diving marine animals, mainly Antarctic and Arctic seals, were fitted with a new generation of Argos-CTD tags developed by the Sea Mammal Research Unit of the University of St. Andrews in Scotland. These tags can be used to investigate simultaneously the at-sea ecology (displacement behavior dives, fishing success ...) of these animals while collecting valuable oceanographic data. Some of these species are able to travel thousands of kilometres, continuously diving to great depths (590 ± 200 m, with maxima around 2000m). Through the years, these animals have become an essential source of temperature and salinity profiles, especially for the polar oceans, complementing efficiently the Argo array. Over 300,000 oceanographic profiles (i.e. representing 1/3 of the total number of Argo profiles) collected by marine biologists from fifteen different countries grouped together are now freely available to the international community as part of the MEOP-CTD database. These profiles were individually checked, edited, corrected and validated, and they have a typical accuracy of 0.02°C in temperature and 0.05 PSU in salinity. In this presentation, we will introduce the MEOP-CTD database and we will show how these data are reshaping the polar oceanographic research through a number of selected oceanographic studies.

3P4 Deep Black sea circulation described by Argo profiling floats

Milena MILANOVA and Elisaveta PENEVA
Sofia University "St. Kliment Ohridski", Bulgaria
Email: mimilanova@phys.uni-sofia.bg

Abstract: The Black Sea Argo program has been initiated in 2002 and since then 27 Argo floats have been deployed generating ~ 3400 profiles of the termochaline properties of the sea in the 2000 m water column. The high temporal resolution of the data (float cycling period of 5 days generally) allows to use their deep displacement as an indicator of the deep sea currents at their parking depth (varying from 200m to 1000m). At the moment (April 2015) 12 Argo floats are operating in the Black Sea measuring the physical properties of the water. Furthermore, 5 floats are equipped to measure also the dissolved oxygen and the sea water optical properties. In this study an investigation of the deep circulation derived from the recent Argo floats trajectories is performed and the results are compared to the surface circulation obtained from altimeter data. The source of the near-real time altimeter data is AVISO regional product for the Black Sea SSALTO/DUAC, which is a compilation of several altimeter missions (Topex/Poseidon, ERS 1 and 2, Jason-1 and 2, Envisat, Cryosat-2). This product gives the sea level anomalies and calculated geostrophic currents anomalies for the 22 year period October 1993 to April 2015 with spatial resolution of 1/8ºx1/8º degrees and temporal resolution of 1 day. The circulation is analyzed separately for the different time scales: seasonally and annually.

3P5 Deep-Arvor float (4000m) : first results and future plans

Virginie THIERRY[1], Herlé MERCIER[1], Guillaume MAZE[1], Serge LE RESTE[2], Vincent DUTREUIL[2] and Xavier ANDRÉ[2]
[1] IFREMER/LPO
[2] IFREMER

Abstract: The Deep-Arvor float is an Argo float designed to achieve more than 150 profiles at 4000m depth. It is equipped with a SBE41CP CTD. Oxygen measurements are in option (4330 optode). Two 3500 dbar models were deployed in 2012 and 2013. Two 4000 m (4120 db) industrials prototypes were deployed in 2014. We expect to deploy twelve 4000 m floats in 2015 and 2016. Results at sea of the first 4 Deep-Arvor are presented. Future plans regarding the deployment of a Deep-Argo pilot array in the Atlantic are presented as well as the plan to valorize this dataset in combination with GO-SHIP data.

3P6 Small scale processes in the ocean surface boundary layer

Brian WARD[1], Graig SUTHERLAND[2], Kieran WALESBY[1], Anneke ten DOESCHATE[1] and Leonie ESTERS[1]
[1] NUI, Galway
[2] University of Oslo
Email: bward@nuigalway.ie

This presentation responds to the GAIC science issue: What new research questions can be addressed with emerging new technologies?

The research question relates to the role of small-scale turbulent processes on air-sea exchange and surface ocean dynamics. According to the Surface Ocean Lower Atmosphere Study (SOLAS), the scales of interacting phenomena become progressively smaller as the air-sea interface is approached, and there is a greater interdependence of different processes with increasing nonlinear interaction.

The new technology we present is the Air-Sea Interaction Profiler. ASIP is an autonomous, vertically profiling, microstructure instrument designed to ascend through the water column, so as to provide undisturbed measurements. It is equipped with high-resolution sensors for the measurement of temperature, salinity, light, and turbulence.

We present results on two ocean surface processes: (i) the diurnal cycle of turbulence, where the data shows an enhancement of the dissipation rate of turbulent kinetic energy in the upper 0.5 m under conditions of diurnal warming (ii) stratification arising from rainfall over the ocean, which can penetrate to different depths depending on the surface forcing conditions, and which exhibits a more complicated relationship between rainfall rate and the resulting salinity gradients.

These observations could not have been made with Argo, due to its relatively coarse resolution (1 m), and due to the fact that it has a minimum depth of 1 m. In comparison, ASIP provides sub-centimetre resolution from below the mixed layer to the air-sea interface.

3P7 Use of GO-SHIP data, Hycom and SOSE output, and Argo data to inform deployments of SOCCOM biogeochemical profiling floats

Lynne TALLEY[1] ,Jinbo WANG[1], Matthew MAZLOFF[1], Igor KAMENKOVICH[2], Stephen RISER[3], and Jorge SARMIENTO[4]
[1] Scripps Institution of Oceanography, UCSD
[2] RSMAS, University of Miami
[3] University of Washington
[4] Princeton University
Email: ltalley@ucsd.edu

Abstract: Biogeochemical floats are being deployed in the Southern Ocean south of 30°S as part of the U.S. SOCCOM project, with the standard T/S measurements a contribution to the Argo program. The floats carry oxygen, nitrate, pH, fluorescence and backscatter sensors. Because the complete array will consist of no more than 200 floats deployed from research ships of opportunity with ship tracks dictated by other programs, care is taken prior to deployment to maximize the probability that the floats sample varied oceanographic regimes, and that all important regimes present along a deployment track are seeded with at least one float. Thus far most floats have been deployed along GO-SHIP sections, and such GO-SHIP deployments will constitute more than half the deployments over the next 5 years. For deployments thus far along P16S, A12, and south of Tasmania, prior GO-

SHIP property sections (theta, salinity, oxygen, nutrients, alkalinity, DIC) have been used to locate water mass regimes that are targeted for deployments.

Simulations of Argo floats in the Southern Ocean State Estimate (SOSE) and data-assimilating HYCOM model and previous Argo trajectories were used to predict ensemble float trajectories, and have functioned well to delineate latitudes of reversal from westward to eastward flow. Trajectories and water mass regimes from floats after deployment have generally agreed well with those projected prior to deployment. The exercise of examining this suite of information prior to the cruises has provided valuable regional information for interpreting the actual float profiles and trajectories.

3P8 **Observing Mixed layer depth in density, temperature and absolute salinity measurements in the Northwestern Mediterranean: A combined laboratory and NOSS profiling floats observations**

Damien MALARDE[1], Arnaud DAVID[1], Marc LE MENN[2], Patrice BRAULT[1] and Serge LE RESTE[3]
[1] nke instrumentation
[2] SHOM
[3] IFREMER, RDT/I2M
Email: dmalarde@nke.fr

In recent years the introduction in 2010 of the Thermodynamic Equation of Seawater TEOS-10 has represented an important milestone towards the implementation of a global thermodynamic ocean model by introducing the concept of absolute salinity in the calculation of seawater density. The traceability of its measurement to the SI has become crucial and the development of absolute salinity measurement methods and tools are essential.

Two profiling floats, in addition to the standard temperature and salinity sensors, were equipped with in situ density and absolute salinity measurement NOSS sensors and deployed in the northwestern Mediterranean (43°25.2773N, 7°52.963E for profiling float I and 43°25.2460N 7°52.868E for profiling float II) during spring 2015. Time series of temperature, refractive index, absolute salinity and in situ density measurement were also collected, though at higher vertical resolution (about 2 m in the 0-2000m layer), analyzed to characterize the mixed layer depth and evaluate the potential anomalies of composition in the area. A specific calibration of the NOSS sensor was developed, which accounted for the pressure and the temperature influence. Laboratory performances are compliant with the target in terms of accuracy. A post calibration check at the end of the mission was performed to determine if the sensor drifted out of calibration or due to the growth of biofouling on optical windows. Seawater samples from CTD probe were extracted to evaluate physicochemical measurements at float locations at the beginning of deployment and during the recovery of floats. Float data were thus compared with reference density and salinity data observations.

This study will present NOSS sensor as one of the first underwater sensors for in situ refractive index measurement in the past years, opening up the scope of possibilities of direct access to density parameter. The NOSS floats provided relevant observations on the physicochemical functioning of the Mediterranean Sea by exploiting the potentiality of the coupled NOSS sensor and CTD observations. The challenge remains to perform a cruise in open-ocean waters over a much longer period in waters closed to the reference composition of seawater as the North Atlantic Ocean.

3C1 Decadal trends of upper-ocean water masses in the Northeast Atlantic

Birgit KLEIN[1] ,Dagmar KIEKE[2], Monika RHEIN[2], Holger KLEIN and Claudia DENKER[1]
[1] Bundesamt fuer Seeschifffahrt und Hydrographie
[2] University of Bremen
Email: birgit.klein@bsh.de

Abstract: We examine decadal water mass variability in the Northeast Atlantic in two 2x2° boxes in the Rockall Trough and the Iceland Basin based on Argo data for the period 2000-2015. The two sampling areas have been selected because they are in the pathway of two main branches of North Atlantic Current (NAC) towards the Nordic Seas and Arctic Ocean. For the Rockall Trough the time series derived from Argo profiles has been combined with the long-term hydrographic observations carried out along the Extended Ellet Line to provide a long-term perspective for the decadal time series available from Argo. Water mass variability is studied for four layers: Subpolar Mode Water (SPMW), Intermediate Water (IW) and upper and deep Labrador Sea Water (uLSW and dLSW). It has been well documented in literature that salinities and temperature in the upper Northeast Atlantic increased since the mid-1990s. The Argo time series demonstrate that until about 2010 SPMW and IW temperatures and salinities remained at high levels in both basins, but are showing decreasing values since then. Labrador Sea Water shows opposing trends in uLSW and dLSW at both locations. The dLSW shows the expected clear increase in temperature and salinity as a result of respective changes in the formation area in the Labrador Sea. The trends in uLSW are less clear because of high inter-annual variability but show decreasing temperatures and salinities.

3C2 Assessing Variability in the Gulf Stream Northern Recirculation Gyre using Argo

Blair GREENAN[1], Denis GILBERT[2], Dave HEBERT[1] and Ingrid PETERSON[1]
[1] Bedford Institute of Oceanography
[2] Institut Maurice Lamontagne

Abstract: We utilize Argo temperature, salinity, and oxygen data to assess water mass variability in the Gulf Stream Northern Recirculation Gyre (Hogg et al. 1986), an area often referred to as the Slope Water (Gatien 1976). This region is between Cape Hatteras and the Tail of the Grand Bank, with the meandering Gulf Stream to the south and the continental shelf break to the north. A series of deep channels allow water mass exchanges between the Slope Water and the Gulf of Maine, the deep basins of the Scotian Shelf, and the Gulf of St. Lawrence. Therefore, temperature, salinity, and oxygen observations from the Slope Water provide much-needed information on deep-ocean conditions and also on the role of open-ocean forcing as a driver of climate variability on the continental shelf and adjacent shelf seas in the Northwest Atlantic (Petrie and Drinkwater 1993, Gilbert et al. 2005).

3C3 Dynamic Response of the North Atlantic Circulation to Rapid Ocean Heat Content Changes between 1990 and 2014

Stuart CUNNINGHAM and Clare JOHNSON

The Scottish Association for Marine Science
Email: Stuart.Cunningham@sams.ac.uk

Abstract: Ocean heat content (OHC) in the subpolar region of the North Atlantic varies on interannual to decadal timescales and with spatial variations between its sub-basins as large as the temporal variability. We show how variability in OHC dynamically drives changes in current speeds and locations, quantifying changes to the horizontal and overturning circulations and heat flux. We focus on GO-SHIP reference sections AR07W/E across

the Labrador Sea and from Greenland to Scotland. OHC increases in the subpolar Atlantic from 1990 to 2014, decreasing the strength of the boundary currents and limiting the extent of the subpolar gyre in the Labrador and Irminger Basins. In the eastern subpolar gyre there is much less net change in OHC from 1990 to 2014, but the path of the North Atlantic Current through the Iceland Basin is altered and the European Slope Current strength is diminished. The overturning in the Labrador Sea is enhanced by 1.5 Sv at 600 m depth, and from Greenland to Scotland the anomaly is 1.5 Sv southward at a depth of 1000 m. There is no change in net heat flux into the Labrador Sea but the meridional heat flux between Scotland and Greenland is smaller by 0.025 PW –10% reduction from 1990. These estimates of the multi-decadal change are discussed in the context of seasonal variations. We use satellite altimeter and scatterometer data to examine surface circulation and forcing and HydroBase3 & EN4 quality controlled in situ temperature and salinities to quantify changes in the subsurface circulation.

3D1 Estimates of the seasonal variability of volume, heat, and freshwater fluxes in the eastern subpolar North Atlantic

Stefan GARY[1], Stuart CUNNINGHAM[1], Clare JOHNSON[1], Penny HOLLIDAY[2]
and Loic HOUPERT[1]
[1] Scottish Association for Marine Science
[2] National Oceanography Centre
Email: stefan.gary@sams.ac.uk

Abstract: Recently, glider missions have supplemented the long-established ship-based observations along the Extended Ellett Line (EEL) hydrographic section between Scotland and Iceland. The EEL hydrographic section is situated to capture a large fraction of the volume, heat, and freshwater fluxes associated with the upper limb of the AMOC. Due to the weather, ship-based observations have primarily been in the summer and gliders present a renewed opportunity to investigate the seasonal variability of volume, heat, and freshwater fluxes in the upper layer of the AMOC in the eastern subpolar North Atlantic. First, we describe the quality control of glider data relative to ship-based observations and the merging of glider observations into a database of ship-based observations. Then, we present our estimates for the seasonal variability of volume, heat, and freshwater transports in the eastern subpolar North Atlantic. Finally, we interpret these fluxes in light of the larger scale circulation.

3D2 Acidification in Atlantic Repeat Sections

Aida F. RIOS, Maribel I. GARCÍA-IBÁÑEZ, Noelia M. FAJAR, Elisa F. GUALLART
and Fiz F. PÉREZ
CSIC, Instituto de Investigaciones Marinas
Email: aida@iim.csic.es

Abstract: Trends in ocean acidification in the Atlantic Ocean are shown throughout the last decades using pH data obtained during repeat sections in the North Atlantic from Iberian-Peninsula to Greenland (A25), in the Subtropical Atlantic along 24.5ºN (A05), in the Equatorial Atlantic along 8ºN (A06) and along the Atlantic from 50ºS to 33ºN (A17). In the North Atlantic highest acidification rates were associated with surface waters and with Labrador Sea Water (LSW). The deep convection activity in the North Atlantic Subpolar Gyre injects surface waters loaded with anthropogenic CO_2 into lower layers, provoking a remarkable acidification rate for the LSW in the Iceland Basin. In the Subtropical Atlantic (24.5ºN), the deconvolution of pH changes into anthropogenic and non-anthropogenic components reveals that natural variability, mostly due to a decrease in O_2, explains the vertical distribution of larger pH decreases, within the permanent thermocline. The anthropogenic component explains significant acidification deeper than 1000 m in the western basin, within the Deep Western Boundary

Current. In the Equatorial Atlantic (8ºN), highest acidification rates were observed in Central Waters. In the SubAntarctic Mode Water, acidification rates were slightly lower and decreasing eastward. Conversely, acidification rates in the Antarctic Intermediate Water were decreasing westward. Using the IPSL model, the decadal acidification along the Atlantic was examined and put into long-term perspective. Observations and model results confirm that pH changes are dominated by the anthropogenic component in surface waters. In contrast, anthropogenic and natural components are of the same order of magnitude in mode and intermediate waters.

3D3 Trends and recent shifts in the hydrography of the temperate north-east Atlantic. Insights from repeated sections around Spain

Cesar GONZALEZ-POLA[1], Pedro VELEZ-BELCHI[1], Ricardo F. SANCHEZ[1], Raquel SOMAVILLA[1], Alicia LAVIN[1] and Alonso HERNANDEZ-GUERRA[2]
[1] Spanish Institute of Oceanography
[2] Universidad de Las Palmas de Gran Canaria
Email: cesar.pola@gi.ieo.es

Abstract: Routinely sampling of hydrography around Spanish waters started in the late 80`s as part of multidisciplinary ocean monitoring programs by the Spanish Institute of Oceanography. Deep ocean coverage was progressively being added during the 90`s and early 00`s. Present monitoring programs include (1) monthly sampling of water column down to 1000 m depth in a fixed station in southeastern Biscay since 1994, (2) mostly semi-annual (at least annual) full-depth sampling of southern Biscay and Western Iberian Margin basins since 2003, as 100-250 nautical miles (nm) sections, (3) 2-3 per year grid-based cruises in the Gulf of Cadiz since 1996 and (4) semi-annual (though with some gaps) sampling of the Canary basin since 1997 as a zonal 600 nm section or a box surrounding the Canaries.

The record accounts for the high frequency variability of water masses in the deep basins of the Atlantic Iberia and the Canaries for one to two decades. Upper permanent thermocline (modal waters) warmed considerably in Biscay and Western Iberia, up to 0.5ºC in 20 years at mid-depths (c.a. 500 m), showing a quick shift towards a much warmer/saltier type in 2005. The Canary basin also shows comparable warming of upper permanent thermocline, though exclusively by heave of isopycnals. Lower thermocline waters (Mediterranean, Antarctic Intermediate and Labrador) are subjected to strong interannual variability apparently linked to large-scale atmospheric patterns.

Seasonality of the Mediterranean vein spreading has also being described west of Iberia. No relevant changes have been found in deep waters (below 2000) in any basin. Continuous review of monitoring strategies currently focuses on optimizing the synergy with the Argo record.

4A1 GO-SHIP: a review and looking forward to the next decade

Bernadette SLOYAN[1] and Rik WANNINKHOF[2]
[1] CSIRO, Ocean and Atmosphere Flagship
[2] NOAA
Email: Bernadette.Sloyan@csiro.au

Abstract: Global hydrographic surveys have been carried out approximately every decade since the 1960s through various research programs such as IIOE, GEOSECS, WOCE/JGOFS, and CLIVAR. In 2009 the Global Ocean Ship-based Hydrographic Program (GO-SHIP) was established as part of the Global Ocean Observing System to provide international coordination and scientific oversight of the decadal global ocean survey.

We will provide an overview of present GO-SHIP network of sustained hydrographic sections and future directions of the program.

4A2 Bio-Argo and Ocean Colour: latest achievements

Hervé CLAUSTRE
CNRS, France
Email: claustre@obs-vlfr.fr

Abstract: Following International Ocean Color Coordinating group (IOCCG) recommendations, a number of Bio-Argo floats equipped with bio-optical sensors are currently monitoring diverse oceanic regions. These floats measure properties that can be either derived from satellite Ocean Colour Radiometry (OCR) or acquired through ship-based sampling [e.g. chlorophyll a concentration (Chla; mg m^{-3}), particulate backscattering coefficient (bbp, m^{-1}), coloured detrital matter (CDOM; m^{-1}) and diffuse attenuation coefficient (Kd, m^{-1})]. New synergetic approaches using these in situ and remote acquisitions can now be developed. Three undergoing developments will be exemplified here. The first application, a matchup analysis, allows the comparison of the OCR-derived quantities (e.g. Chla, Kd, bbp) with their Bio-Argo counterparts in the surface ocean. Such application allows cross-validation of both OCR and Bio-Argo datasets and will lead to the development of appropriate quality-control procedures. Furthermore, potential "regional" bio-optical anomalies can be highlighted using the abundant Bio-Argo data acquisitions. The second application deals with the fusion of in situ and remote properties (e.g. Chla, bbp) aiming at their 3D reconstruction. In particular, a recently developed method uses the full Argo TS (not only Bio-Argo) dataset to better constrain the propagation of the surface Chla and bbp satellite signals over the vertical dimension. Finally, with the intensive data acquisition expected in the future thanks to autonomous platforms, methods are required to make certain key datasets (Chla) interoperable over a wide range of acquisition periods. Such a method and its application to generate a reference dataset of ~ 49,000 Chla vertical profiles will be presented.

4A3 Mixing and internal wave observations from EM-APEX floats in the Southern Ocean

Amelie MEYER[1], Bernadette SLOYAN[2], Helen PHILLIPS[1], Kurt POLZIN[3], Nathan BINDOFF[1]
[1] CSIRO, Ocean and Atmosphere Flagship, University of Tasmania
[2] CSIRO, Ocean and Atmosphere Flagship
[3] Woods Hole Oceanographic Institution
Email: amelie.meyer@npolar.no

Abstract: Understanding the dynamics that maintain the deep ocean stratification structure is of fundamental importance to understanding large-scale ocean circulation. Dissipating internal waves are the main source of mixing in the stratified ocean. Here we explore the nature of mixing and its sources north of the Kerguelen Plateau, a large topographic feature in the Southern Ocean. Based on novel observations, we present the distribution and intensity of mixing, and the internal wave field properties.

The data consist of 914 temperature, salinity, pressure and horizontal velocity profiles from Electromagnetic Autonomous Profiling Explorer (EM-APEX) floats deployed NE of the Kerguelen Plateau in 2008. We estimate diapycnal mixing in the upper 1600 m of the water column applying a shear-strain fine-scale parameterization.

The observational results provide the first clear connection between the distribution and intensity of mixing, and the associated internal wave field properties. Mixing intensities show strong spatial and temporal variability. Topographic roughness at the seafloor, mean current speed and wind speed are identified as important factors in determining local dynamical mixing regimes. In particular, identified fronts of the Antarctic Circumpolar Current are associated with the most intense mixing and internal wave activity of the region. We identify 46 internal waves with characteristics that support the findings from the mixing analysis. We show evidence that local generation of internal waves can set the large-scale stratification of the Southern Ocean. This analysis demonstrates the value of the floats to better understand upper ocean dynamics and processes driving the internal wave and mixing field.

4A4 Guidance for glider deployments in an energetic western boundary current

Peter OKE, Tatiana RYKOVA, Bernadette SLOYAN and Susan WIJFFELS
CSIRO Australia
Email: peter.oke@csiro.au

Abstract: Western boundary currents (WBCs) are important for the transport of heat, salt, and other properties from low to high latitudes. Monitoring WBC variability is challenging. Short temporal and spatial length-scales mean that relatively high spatial and temporal sampling is needed to properly monitor the variability of WBCs. In this study, we analyse fields from an eddy-resolving ocean model to investigate different sampling strategies of gliders. Piloting slow-moving gliders (~0.25 m/s) in a region of strong currents (0.5-1 m/s) is challenging. Here, we explore different sampling strategies using 2-3 gliders for monitoring the variability of the East Australian Current (EAC) at its choke point (around 26oS). We assess the feasibility of maintaining gliders on the preferred path, and offer recommendations on required sampling frequency and effective glider flight-paths.

4B1 Towards comparability of global oceanic nutrient data

Malcolm WOODWARD[1] and Michio AOYAMA[2]
[1] Plymouth Marine Laboratory, Plymouth, UK
[2] RGCG-JAMSTEC/IER-Fukushima University, Fukushima, Japan
Email: emsw@pml.ac.uk

Abstract: To better manage the global impacts of human activities on the world's oceans, it is necessary to have accurate observations of changes in carbon and dissolved nutrients in both upper and deep ocean waters. By establishing mechanisms for comparability of nutrient analyses, we will be able to detect changes in nutrient levels due to human impact and shifting physical processes. Such changes could, either alter the supply of nutrients to the upper ocean directly or be from changes to ocean circulation. A recent Framework of Ocean Observing statement introduced the concept of Essential Ocean Variables (EOVs), and the assessment and development of readiness for sustained observations, with the aim of promoting collaboration in developing requirements, observing networks, and data information streams. Nutrients are identified as one of these EOVs. In 2014, two certified reference materials (CRMs) became available for measurements of nutrients in seawater. A SCOR working group, 147, has recently been funded to work towards improving comparability of global nutrient analysis through international intercomparability exercises (in conjunction with IOCCP), education and advice, plus leading an update of the GO_SHIP nutrient manual during the coming years. The primary goal is that for nutrient data collected anywhere by one individual laboratory, and data collected over long time periods by one or more laboratories, will be consistent and traceable with certified comparability. For future generations it is unacceptable to produce historical data sets without the absolute consistency necessary to assess spatial and temporal trends.

4B2 Integration of bio-optical profiling floats within an Indian Ocean biogeochemical observing system

Nick HARDMAN-MOUNTFORD[1], Jim GREENWOOD[1], Francois DUFOIS[1],
Dirk SLAWINSKI[1], Muthalagu RAVICHANDRAN[2] and Tom TRULL[1]
[1] CSIRO, Australia
[2] INCOIS, India

Abstract: The integration of robotic profiling floats with next-generation optical sensors (bio-profilers) is enabling measurement of optical proxies for several biogeochemical variables in remote areas of the ocean that were previously inaccessible to observation, except through occasional snapshots from ship-based expeditions. While Earth observation satellites can measure optical proxies of several of these quantities (chlorophyll, CDOM, light scattering), their field of view is restricted to the surface layer (first optical depth) of the ocean. Simultaneous

measurement from bio-profilers and satellites provides the potential to derive a dynamic 3D view of biogeochemical dynamics at the basin and global scale. Understanding the capabilities and stability of these sensors for prolonged deployments, development of standardised quality control (QC) procedures and investigation of optimised deployment configurations are all key challenges for including bio-profilers in basin-scale ocean observing systems. Here we describe results that address these challenges from a joint project between Australia's Commonwealth Scientific and Industrial Research Organisation (CSIRO), the Indian National Institute of Oceanography (CSIR-NIO), the Indian National Centre for Ocean Information Services (INCOIS) and the Indian Ocean regional program office of the Intergovernmental Oceanographic Commission (IOC). We address QC issues, comparisons with ocean colour remote sensing and considerations for capturing high-frequency and mesoscale variability in observing system design.

4B3 The future of O_2 optode measurements - Lessons learned from a decade of autonomous observations

Henry C. BITTIG[1], Arne KÖRTZINGER[2] and Hervé CLAUSTRE[1]
[1] Laboratoire d'Océanographie de Villefranche (LOV), Villefranche-sur-Mer, France
and Helmholtz-Centre for Ocean Research Kiel (GEOMAR), Kiel, Germany
[2] Helmholtz-Centre for Ocean Research Kiel (GEOMAR), Kiel, Germany
Email: hbittig@geomar.de

Abstract: The introduction of optical O_2 sensors (optodes) in oceanography about a decade ago revolutionized autonomous O_2 observation due to the optodes' low energy consumption, small size, robustness, and stability. Accordingly, the quantity of O_2 observations rose quickly. However, their quality often had issues and remained behind initial expectations, especially in profiling applications. Nonetheless, autonomous O_2 observations advanced and the evolution is traced from (I) the first use of an Argo-O_2 float to monitor the deep ventilation of the Labrador Sea via (II) its application as a tool to expand the spatial and temporal coverage around time series sites or ship campaigns to (III) today's capabilities to remotely quantify productivity in the open ocean.

Based on extensive laboratory characterization and field deployments, we want to glance over the state of our current understanding of oxygen optodes regarding time response, pressure effect, accuracy, and stability as well as to raise awareness for potential pitfalls for deployments of this technology. While there are solutions to most technical aspects, calibration stability proved to be a persistent issue. *In situ* validation/calibration thus becomes a crucial part to ensure high quality data. New quality control measures are under development and latest recommendations from SCOR WG 142 are reviewed briefly.

4B4 Continued development of an ocean pH sensor for profiling floats

Dave MURPHY[1], Jim HOCHSTEIN[1] and Ken JOHNSON[2]
[1] Sea-Bird Scientific
[2] Monterey Bay Aquarium Research Institute
Email: jhochstein@seabird.com

Abstract: FET-based pH sensors rated to 2000m depth for multi-year missions have been deployed aboard profiling floats since 2012. This approach, created by Monterey Bay Aquarium Research Institute (MBARI), Scripps Institution of Oceanography (SIO), and Honeywell is now being developed as a commercially produced sensor. We will discuss the history of the FET-based measurement approach for natural waters and provide an overview of current deployments. We will present the status of the transition of the technology to Sea-Bird Scientific, the related validation activities, the development of the commercial production processes, and possible follow-on applications of the FET technology.

4B5 Evaluation of the performance of optical oxygen sensors in profiling the deep ocean

David MURPHY, Carol JANZEN and Nordeen LARSON
Sea-Bird Scientific
Email: dmurphy@seabird.com

Abstract: We examine the performance of optical oxygen sensors in the deep ocean by comparing sensors deployed on Deep Argo prototype CTDs mounted to a full resolution shipboard CTD system equipped with SBE 43 electrode oxygen sensors and Winkler titrations of discrete samples. The effects of pressure and time response on oxygen measurement accuracy in the deep ocean are characterized. We also consider the effects of data binning on measurement accuracy by comparing a Deep Argo CTD modified to sample continuously at 4Hz with one using the standard Argo CTD sample protocol of a 1Hz sample rate and data binning.

4B6 What are optimum observational networks to identify changes in the marine carbon cycle?

Ute SCHUSTER and the Global Marine Carbon Community
University of Exeter, UK
Email: U.Schuster@exeter.ac.uk

Abstract: The marine carbon cycle shows variabilities that range from seasonal to multi-decadal time scales, from local to global spatial scales, and from the surface to the deep ocean. Natural variability as well as anthropogenically induced changes require not only observations of marine carbon parameters, but additionally of the biogeochemical-physical drivers of any observed change, at different spatial scales and for different locations in the world oceans.

This complexity means that studying the changing marine carbon cycle requires observational networks that comprise multi-platform and multi-sensor/instrumentation components.

Existing observational networks include those of research vessels, commercial vessels, and Argo floats, whilst other drifting floats, mooring, and gliders are also being deployed. Analytical and sensing technology includes numerous ship-based instrumentation as well as submerged sensors, with great advances are being made in developing and improving the instrumentation and sensors. Global initiatives and programs have developed over the last two decades or so, aimed at coordinating these networks. However, in order to ensure sustainable and efficient observations in the future, the improved synergy between networks is required, as well as the identification of the nature of optimum integrated observational networks.

In this presentation, the activities and research aimed at identifying optimum observational networks are reviewed, the progress been made is highlighted, and further future challenges are outlined.

4C1 Assessing the impact of observations on ocean forecasts and reanalyses

Peter OKE[1] and Gilles LARNICOL[2]
[1] CSIRO, Australia
[2] CLS, France
Email: peter.oke@csiro.au

Abstract: Under GODAE OceanView the operational ocean modelling community has developed a suite of global ocean forecast, reanalysis and analysis systems. Each system has a critical dependence on ocean observations – routinely assimilating observations of *in situ* temperature and salinity, and satellite sea-level anomaly and sea surface temperature. Under GODAE OceanView (GOV), the Observing System Evaluation Task Team (https://www.godae-oceanview.org/science/task-teams/observing-system-evaluation-tt-oseval-tt/) regularly coordinates analyses from the GOV community to demonstration the value and impact of ocean observations on different global and regional data-assimilating forecast and reanalysis systems. Highlights of the latest suite of demonstrations will be presented here. Results show that Argo data are critically important – the most critical for seasonal prediction, and as critical as satellite altimetry for eddy-resolving applications. Most systems show that TAO data are as important as Argo in the tropical Pacific, and that XBT data have an impact that is comparable to other data types in the vicinity of XBT transects. It is clear that no currently available data type is redundant. On the contrary, the components of the global ocean observing system complement each other remarkably well, providing sufficient information to monitor and forecast the global ocean.

4C2 Assessing climate model simulations of the Southern Ocean with standardized, observationally-based metrics

Joellen RUSSELL[1] and Igor KAMENKOVICH[2]
[1] University of Arizona
[2] RSMAS/University of Miami
Contact Email: jrussell@email.arizona.edu

Abstract: Understanding the physical and biogeochemical processes that determine the Southern Ocean's mean state, variability, and response to external forcing is critical to our understanding of the climate system as a whole, and for reducing uncertainties in climate projections. Global climate model simulations, however, differ greatly in the Southern Ocean. We will make the case for the importance of standardized, observationally-based metrics, especially for those processes with large inter-model differences. Much work and discussion has gone into what are the "most useful" metrics for assessing a model simulation of the Southern Ocean. We will present a series of metrics that, while not exhaustive, provide a solid overview of the strengths or weaknesses of a climate model simulation. These metrics include those related to: the atmosphere – zonal wind stress and cloud cover; ice – seasonal extent and volume; air/sea fluxes – fresh water, heat and carbon; and ocean – transports like the ACC, sea surface height, stratification, mixed layer depths, carbon and nutrient profiles, and inverse estimates of flow across 30°S.

4C3 Seasonal and interannual changes of sea surface temperature affected by subsurface oceanic variability during early summer

Shigeki HOSODA[1], Masami NONAKA[1], Tomohiko TOMITA[2], Bunmei TAGUCHI[1], Hiroyuki TOMITA[3] and Yoshikazu SASAI[1]
[1] JAMSTEC, Japan
[2] Kunamoto University
[3] Nagoya University
Email: hosodas@jamstec.go.jp

Abstract: We clarified that subsurface ocean plays important role to seasonal and inter-annual changes of sea surface temperature (SST) even during warming season using Argo. Previously, many studies had considered that SST changes passively against downward net heat flux (Qnet) and there may be little effect from subsurface ocean during the warming season. Here we show two important results.

(1) Effect of Qnet penetrates below shallow mixed layer (SML) during the warming season and then SST warms more moderately. By introducing the concept of heat penetration depth (HPD), defined as the depth to which Qnet distinctly penetrates below SML, we successfully characterized the heat capacity in terms of the heat content above the HPD with a simple, one-dimensional vertical model. The downward heat penetration into the layer below the shallow seasonal thermocline is widely found throughout the North Pacific (NP), and two-thirds of Qnet penetrates below SML.
(2) Vertical structures of interannual temperature variability in early summer are investigated, showing that temperature anomalies in the western NP (not central and eastern NP) extends below SML.

An eddy-resolving OGCM suggest that the temperature variability is associated with changes in the oceanic frontal structures that extend below SML such as the northern branch of Kuroshio Extension, indicating that it is caused not by atmospheric thermal forcing but by oceanic structure changes. Those results suggest that the oceanic subsurface layer strongly affects to the seasonal/interannual changes in SST and plays a crucial role in climate variations even during the warming season.

4D1 French contribution to Bio-Argo float deployment as part of GO-SHIP and other cruises: implementation of good practices

Catherine SCHMECHTIG
CNRS, France
Email: catherine.schmechtig@obs-vlfr.fr

Abstract: Thanks to sensor miniaturization, key biogeochemical and bio-optical quantities can now be acquired by Bio-Argo floats. To date, this concerns nitrate concentrations, dissolved oxygen concentrations, chlorophyll-a concentrations, downwelling irradiance, particle backscattering, coloured dissolved organic matter concentrations and attenuation coefficients. Before reaching the ambitious target of a global Bio-Argo program, best practices (cross-calibration, deployment..) nevertheless still need to be developed and tested. By taking advantage of hydrographic measurements collected as part of GO-SHIP, IMBER or SOLAS relevant cruises in various open ocean areas, we have benefited from the availability of discrete biogeochemical and bio-optical measurements to support Bio-Argo deployments, in particular as part of the French LEFE-CYBER data service (http://www.obs-vlfr.fr/proof/). Eight Bio-Argo floats have been deployed in the sub-tropical gyres of North and South Atlantic (AMT 22; 2012), two along the OVIDE (A25) section in the North Atlantic (GEOVIDE, 2014), seven along the AR07W (2013) in the Labrador Sea, six in the Indian sector of the Austral Ocean (OISO 24; 2015) and four in the sub-tropical South Pacific (OUTPACE; 2015). Pooling Bio-Argo and hydrographic stations provides us with reference profile values in contrasted areas for chlorophyll-a, nitrate and dissolved oxygen concentrations. Additionally, floats have often been deployed as a group at the same place and time (up to seven) so as to evaluate sensor inter-variability (especially for bio-optical ones) and to complete the sensor performance tests initially carried out in the laboratory. The latest feedback from these tests and comparisons will be presented.

4D2 Integrating Data and Information across Observing Systems

Kevin O'BRIEN[1], Bob SIMONS[2], Ansley MANKE[3], Eugene BURGER[3], Roy MENDELSSOHN[4]
[1] University of Washington/JISAO
[2] NOAA/SWFC
[3] NOAA/PMEL
[4] NOAA/SWFC
Email: Kevin.M.OBrien@noaa.gov

Abstract: The term *Integrated data management* is best understood by contrasting it with today's norms for ocean data management. Today each platform assembly center typically provides its own web site at which users (humans, but not machines) can select data of interest. Data can then be downloaded in the file format(s) favored by that network. A user desiring data from more than one network must learn to navigate independently designed web sites and deal potentially with different format types. With the emerging open data access paradigm of today, users would prefer to use their own tools to access data, and not have to fuss with format differences and user registrations. General users are also most often interested in observing-system based parameters as a whole (i.e., temperature), rather than analyzing data on a network by network basis.

This presentation will discuss the work done through the Observing System Monitoring Center to integrate information and data across observing system networks leveraging current standards and conventions. Utilizing a software tool called ERDDAP, we are able to provide standards-based, interoperable access to observation collections that span these various networks. We will discuss and demonstrate the pilot project that supports this integrated view of ocean data in support of the Tropical Pacific Observing System (TPOS) 2020 effort.

4D3 Biogeochemical Cycling of Trace Elements in the Ocean: Current and future opportunities linking GEOTRACES to Argo and GO-SHIP

Peter CROOT[1], Greg CUTTER[2], Maeve LOHAN[3] and Past and Present members of the GEOTRACES S&IC
[1] National University of Ireland, Galway
[2] Old Dominion University
[3] University of Plymouth

Abstract: The international GEOTRACES (www.geotraces.org) program is focused on identifying the processes, and quantifying the fluxes, that control the distributions of key trace elements and isotopes (TEIs) in the ocean, and to establishing the sensitivity of these distributions to changing environmental conditions. The successful launch in 2014 of the GEOTRACES intermediate data product (IDP) (http://www.geotraces.org/dp/idp2014) was the first release of the global dataset for TEIs and provides a valuable resource for ocean researchers. In the absence of open ocean CRMs for seawater, quality control for the IDP2014 was achieved through community analysis of consensus samples (e.g. SAFe and GEOTRACES) by the GEOTRACES research community with oversight by the GEOTRACES Standards and Intercalibration Committee (S&IC). This presentation will provide an overview of the approaches used currently by the GEOTRACES S&IC in examining data quality and the potential for greater overlap with other programs such as GO-SHIP, IOCCP and Argo in the future for examining the role of TEIs in ocean biogeochemistry and climate.

2E1 Public Lecture: Ocean Acidification: A Global Problem with Local Impacts

Richard A. FEELY
Pacific Marine Environmental Laboratory/NOAA, Seattle, WA, U.S.A.
Email: Richard.A.Feely@noaa.gov

Abstract: Carbon dioxide (CO_2) is one of the most important "green-house" gases in the atmosphere affecting the radiative heat balance of the earth. As a direct result of the industrial and agricultural activities of humans over the past two centuries, atmospheric CO_2 concentrations have increased by about 120 parts per million. The atmospheric concentration of CO_2 is now higher than experienced on Earth for at least the last 800,000 years, and is expected to continue to rise, leading to significant temperature increases in the atmosphere and oceans by the end of this century. The global oceans are the largest natural long-term reservoir for this excess heat and CO_2, absorbing approximately 85% of the heat and nearly 30% of the anthropogenic carbon released into the atmosphere since the start of the industrial era. Recent studies have demonstrated that the increased concentrations of CO_2 in the oceans can cause significant changes in marine organisms due to ocean acidification. Some marine organisms are already affected by this anthropogenic stress. Dr. Feely will discuss the present and future implications of increased CO_2 levels on the health of our ocean ecosystems and related ocean-based economies.