Argo Science Workshop 3
Abstracts Volume

第三届国际 **Argo** 科学研讨会
论文摘要汇编

Hangzhou, China, March 25–27, 2009
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The Third Argo Science Workshop:
The Future of Argo

March 25-27, 2009
Hangzhou, People's Republic of China

Hangzhou, March 2009

Welcome to the Third Argo Science Workshop:
the Future of Argo

A decade has passed since a prospectus for a project to be called Argo was circulated and was affirmed at the OceanObs '99 Conference held in Villefranche Sur Mer, France. In the past ten years, the global Argo array grew out of nothing and reached its initial target of operating 3000 robotic profiling floats in the global ocean in late 2007. Now we can count almost 3300 active floats, which revolutionize the collection of critical information from the upper layers of the global ocean. By systematically measuring temperature and salinity to a depth of 2000m, Argo has improved estimates and forecasts of regional to global climate change and is playing a key role in improving seasonal climate forecasts and giving new insights into meteorological and oceanographic events.

The Third Argo Science Workshop (ASW-3), co-sponsored by the International Argo Steering Team and the North Pacific Marine Science Organization (PICES) and hosted by the Second Institute of Oceanography, State Oceanic Administration (SOA) of PR China and the State Key Laboratory of Satellite Ocean Environment Dynamics, will be a great gathering of the Argo community to summarize the achievements of the Argo Program and to shape its future.

We would like to thank the Ministry of Science and Technology of PR China and SOA as well as its subordinate the Second Institute of Oceanography for providing financial support for the workshop, and PICES for assembling and supplying the volume of abstracts.

Special thanks should be given to the national Argo programs, their funding agencies and scientists for enabling us to reach this important milestone in the development of Argo.

We wish you a pleasant stay in Hangzhou and a fruitful and rewarding time at the workshop.

Xu Jianping
Professor, Chief Scientist of China Argo

We acknowledge the support of our sponsors

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North Pacific Marine Science Organization (PICES)

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Industrial Exhibitors

ROCKLAND Scientific International Inc., Victoria, BC, Canada
www.rocklandscientific.com
Rockland Scientific specializes in instrumentation systems for the measurement of microstructure and turbulent mixing. Our instruments can be used as vertical profilers, towed systems, or modules that are deployed on ocean gliders, ARGO floats, or AUVs. All our instrument systems are known for their extremely high accuracy, low noise levels and high depth rating (down to 6000 m).

JFE-ALEC, Kobe, Japan
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JFE-Alec is the leading manufacturer of oceanographic equipment in Japan. Established in 1973, the company enjoys a large customer base all over the world.

TELEDYNE Webb Research, Falmouth, MA, USA
www.webbresearch.com
Based on a long record of innovative success in ocean engineering, Webb Research personnel work cooperatively with clients to solve oceanographic problems and bring reliable data home to their laboratories. The 5000th Webb APEX float shipped in early 2008.

SEA Corp., Chiba, Japan
www.seanet.co.jp

OPTIMARE Sensorsysteme AG, Bremerhaven, Germany
www.optimare.de
OPTIMARE develops and sells sensors, remote sensing systems and data acquisition/network solutions for environmental monitoring and marine and polar research. As platforms, the company serves aircraft and ships as well as land- and underwater-operated systems like the NEMO float.

AANDERAA Data Instruments, Bergen, Norway,
www.aanderaa.com/
AADI has made reliable and technically advanced oceanographic instruments since 1966. Commercially available oxygen optodes were introduced in 2002. The long-term stability and reliability of these sensors have revolutionized oxygen measurements. We hope to continue to serve and collaborate with the float and glider communities towards a better understanding of oxygen dynamics and other parameters in the marine environment.
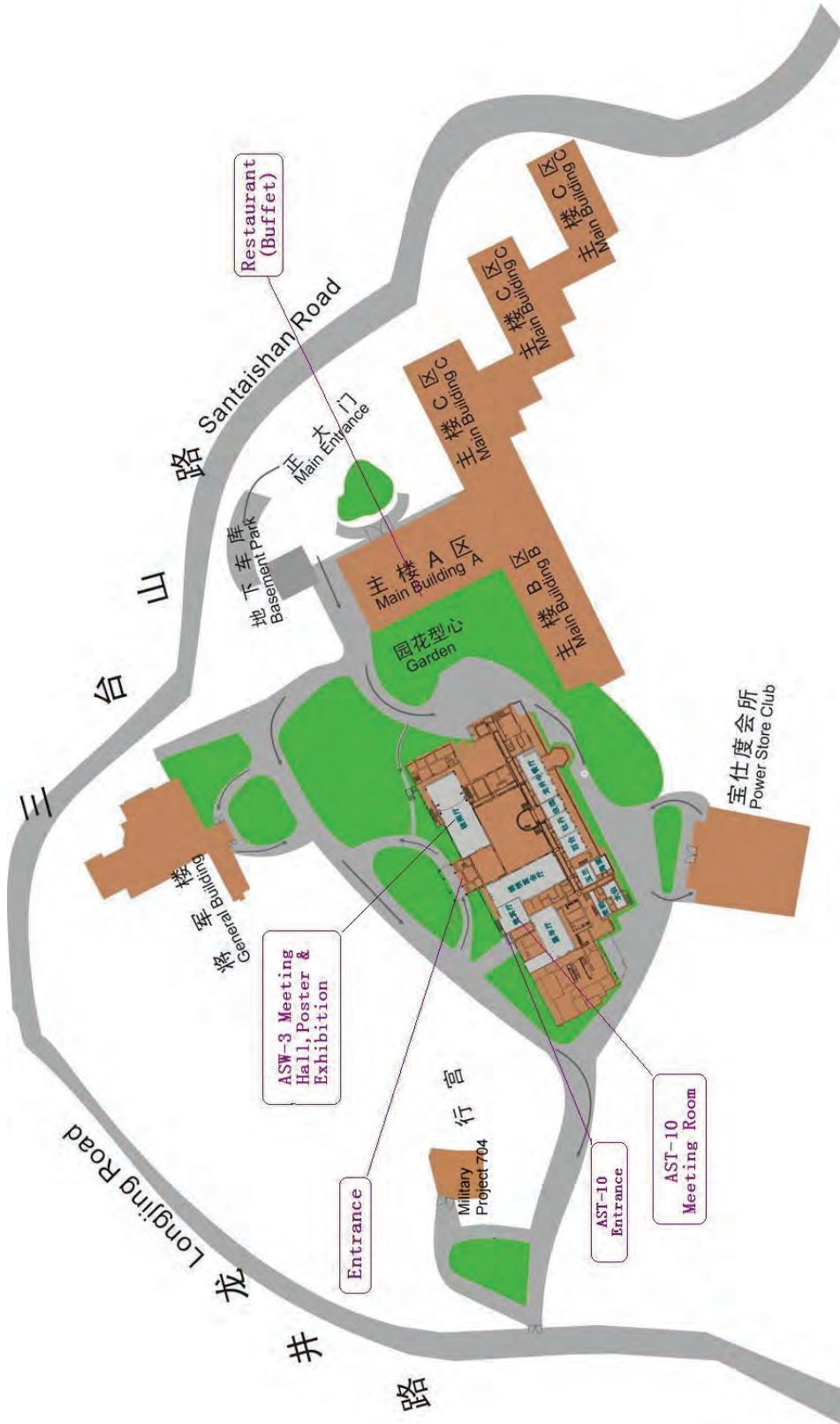
NKE Instrumentation, Hennebont, France. http://www.nke.fr
NKE Instrumentation manufactures PROVOR and ARVOR subsurface floats for Argo and scientific projects. We also manufacture a wide range of oceanographic instrumentation: including sensors, data loggers, drifting and moored buoys with telemetry.

Yichang Institute of Testing Technology, Yichang, Hubei, China. Email: xucssc@tom.com The Yichang Institute is a major institute in China for ship science and technology and ocean engineering. Its main products include environmental buoys, submersible buoys, underwater multi-purpose platforms, underwater float depth setting, ocean intelligent towing, light underwater robots, and measurement of weak magnetism and applications.

Workshop Venue

三台山路 Santaishan Road

龙井路 Longjing Road

三台山

Restaurant (Buffet)

正大门 Main Entrance

地下车库 Basement Park

主楼 A 区 Main Building A

主楼 B 区 Main Building B

园花型心 Garden

主楼 C 区 Main Building C

主楼 C 区 Main Building C

主楼 C 区 Main Building C

将楼 General Building

宝仕度会所 Power Store Club

行宫 Military Project 704

ASW-3 Meeting Hall, Poster & Exhibition

Entrance

AST-10 Entrance

AST-10 Meeting Room

General Program

March 25, Wednesday		March 26, Thursday		March 27, Friday	
Opening Session		Theme 3		Theme 4 (day 2 cont.)	
08:30	Opening Session starts	08:30	Theme 3 starts	8:30	Theme 4 continues
10:00	Coffee Break with Poster Viewing	10:00	Coffee Break with long Poster Viewing	10:20	Coffee Break with Poster Viewing
Theme 1					
10:40	Theme 1 starts	11:00	Theme 3 continues	11:00	Theme 4 continues
12:00	Lunch	12:00	Lunch	12:00	Lunch
Theme 2		Theme 4 (day 1)		Theme 5	
13:30	Theme 2 starts	14:00	Theme 4 starts	13:30	Theme 5 starts
15:00	Coffee Break with Poster Viewing	15:40	Coffee Break with Poster Viewing	15:00	Coffee Break with Poster Viewing
15:30	Theme 2 continues	16:00	Theme 4 continues	16:00	Theme 5 continues
17:30		17:30		17:20	
18:30	Welcome Dinner	Evening	Buffet event with Posters and Industrial Exhibits		Final Comments and farewell

Posters can be put up on Tuesday Evening, March 24

Theme 1:   Heat and salt budgets on global to regional scales
Theme 2:   Estimation of circulation fields on global to regional scales
Theme 3:   The role of Argo in constraining Ocean Data Assimilation fields
Theme 4:   Seasonal to inter-annual variability as seen by Argo
Theme 5:   New technology

Table of Contents

Abstracts for oral presentations are sorted first by session and then by presentation time. Abstracts for posters are sorted by paper ID number. Presenter name is in bold-face type and underlined. The Author Index lists all authors and co-authors in alphabetical order and includes their page numbers. Abstracts in this collection have been subjected to a very light editing process that leaves them essentially in the condition they were received.

March 25, Wednesday

Opening Session

Chairman: Dake Chen

08:30   Brief comments from program chairs and LAC, and opening ceremonies

09:00   Dean **Roemmich** and John Gilson (Invited)
                     The Future of Argo: An Introduction

09:30   Sylvie **Pouliquen** and Mark Ignaszewski (Invited)
                     Argo Data Management

10:00   *Coffee break and poster viewing*

Theme 1: Heat and salt budgets on global to regional scales

10:40   W. Timothy **Liu** and Xiaosu Xie
                     Time-varying Ocean Heat Storage

11:00   Howard J. **Freeland** and Denis Gilbert
                     Separating the Steric and Eustatic Contributions to Global Sea-Level Rise

11:20   Sindu R. **Parampil**, G. Anitha, M. Ravichandran and D. Sengupta
                     Intraseasonal Response of Near-Surface North Indian Ocean to Heat and Freshwater Forcing

11:40   Paul J. **Durack** and Susan E. Wijffels (presented by Esmee M. van Wijk)
                     50 Year Salinity Trends for the Global and Regional Oceans from Argo and Historical Data

12:00   *Lunch*

Theme 2: Estimation of circulation fields on global to regional scales

Chairman: Dean Roemmich

13:30   Virginie **Thierry**, Eric de Boisséson and Herlé Mercier (Invited)
                     Water Mass and Circulation Variability in the North-Atlantic

14:00   Alison L. Rogers and Stephen C. **Riser**
                     Observations of Large-scale Upper Ocean Volume Transport in the Pacific

14:20   Yaochu **Yuan**, Guanghong Liao, Chenghao Yang and Zeng-hong Liu
                     Variability of the Currents in the Luzon Strait during October Cruise of 2008 Obtained from Observations and a Diagnostic Calculation of the Circulation

14:40   Baogang **Jin**, Guihua Wang, Ren Zhang and Huizan Wang
                     Studies on the Interaction between the Kuroshio and Mesoscale Eddies East to Luzon Strait

15:00   *Coffee break and poster viewing*

15:30	Jiping **Xie** and Jiang Zhu A Dataset of Global Ocean Surface Currents for 1999-2007 Derived from Argo Float Trajectories: Comparison with Surface Drifter and TAO measurements
15:50	Alonso **Hernández-Guerra**, Terrence M. Joyce, Eugenio Fraile-Nuez and Pedro Vélez-Belchí Using Argo Data to Investigate the Meridional Overturning Circulation in the North Atlantic
16:10	H. **Abe** and K. Hanawa Mean Sea Surface Height in the World Ocean using Argo Floats and Altimetry
16:30	Moon-Sik **Suk**, Sung Won Shin and Youn Ha Ahn Temporal and Spatial Scales of Deep Eddies Observed from Argo Floats Near Ulleung Basin in the East Sea
16:50	Guided discussion. Each day Stan Wilson and Kimio Hanawa will lead us through a discussion about what we have learned today that affects the future of Argo. Please come prepared to participate.
18:30	Welcome dinner for the participants of the workshop

March 26, Thursday

Theme 3: The role of Argo in constraining Ocean Data Assimilation field

Chairman: Toshio Suga

08:30	P.-Y. Le **Traon** and GODAE OceanView Science Team (Invited) The Role of Argo for Global Ocean Analysis and Forecasting
09:00	Ziwang Deng, Youmin **Tang** and GuiHua Wang Impacts of Argo Observations on the Pacific Ocean Data Assimilation
09:20	Hiroshi **Yoshinari**, Akira Okuno, Takashi Setou, Daisuke Ambe, Yasumasa Miyazawa and FRA-JCOPE Group Impact Evaluation of Argo and Sea Surface Altimeter Data for the Reproducibility of FRA-JCOPE: An Ocean Prediction System for the Seas around Japan
09:40	Xunqiang **Yin**, Fangli Qiao, Yongzeng Yang and Changshui Xia Ensemble Adjustment Kalman Filter Study for Argo Data
10:00	*Coffee break and long poster viewing*
11:00	Fabrice **Hernandez**, Eric Dombrowsky, Marie Drévillon, Nicolas Ferry, Eric Greiner, Jean-Michel Lellouche and Charles-Emmanuel Testut Benefit of Argo Data for the Global Mercator Operational Ocean Forecasting System
11:20	Denis **Gilbert** Adequacy of the Argo Array for Monitoring Water Mass Changes in the Gulf Stream Northern Recirculation Gyre
11:40	Kazuhiko **Hayashi**, Shiro Ishizaki, Yosuke Fujii, Yoshiaki Kanno and Yasushi Takatsuki Impact of Argo Temperature and Salinity Measurements in the New JMA Ocean Analysis System
12:00	G. **Larnicol**, S. Guinehut, M.H. Rio, A.-L. Dhomps and G. Nicolas Monitoring the Ocean State from the Observations
12:20	*Lunch*

Theme 4: Seasonal to inter-annual variability as seen by Argo

Chairman: Stephen Riser

14:00   Dake **Chen**, Qiaoyan Wu and Yuhua Pei (Invited)
        Upper Ocean Response to Tropical Cyclones Observed by Argo: Recent Progress and Future Needs

14:30   Liang **Sun**, Yuan-Jian Yang and Yun-Fei Fu
        Impacts of Typhoons on Kuroshio Large Meander: Observational Evidence

14:50   P. **Vélez-Belchi**, A. Hernández-Guerra and E. Fraile-Nuez
        Changes of the Temperature Tendencies in the Upper Levels of the Subtropical North Atlantic Ocean

15:10   Toshio **Suga**, Chiho Sukigara, Toshiro Saino, Katsuya Toyama, Daigo Yanagimoto, Kimio Hanawa and Nobuyuki Shikama[2]
        Subsurface Primary Production in the Western Subtropical North Pacific as Evidence of Large Diapycnal Diffusivity Associated with the Subtropical Mode Water

15:40   *Coffee break and poster viewing*

16:00   Xianyao **Chen**, Qin Wang and Xiuhong Wang
        Decadal Changes of Antarctic Intermediate Water in the South Pacific

16:20   Eitarou **Oka**
        Seasonal and Interannual Variation of North Pacific Subtropical Mode Water in 2003−2006

16:40   Igor **Yashayaev** and Michael Dunphy
        Seasonal Cycle, Interannual Variability and Associated Heat and Freshwater Content Changes in the Subpolar North Atlantic Inferred from Argo, Hydrographic and Moored Measurements

17:00   Guided Discussion - Stan Wilson and Kimio Hanawa

Evening   Poster Session and Industrial Exhibits (combined with buffet)

        This will give participants an extended opportunity to examine all posters and exhibits. The buffet has been paid for by the following exhibitors, please visit them.

The Yichang Institute of Testing Technology
Yichang, Hubei, China. Email: xucssc@tom.com

March 27

Theme 4 (continued): Seasonal to inter-annual variability as seen by Argo

Chairman: Muthalagu Ravichandran

08:30   Matthew **Martin**, R. Barciela, E. Blockley, R. Furner, C. Guiavarc'h, A. Hines, D. Lea, R. Mahdon, M. McCulloch, D. Storkey, D. Smith and D. Peterson (Invited)
Use of Argo Data in Ocean Forecasting Systems at the UK Met Office

09:00   C. **Gnanaseelan** and J.S. Chowdary
Interannual Variability in the Tropical Indian Ocean Subsurface Temperature from Argo Observations and its Climatic Impacts

09:20   V.S.N. **Murty**, Bulusu Subrahmanyam, T.V.S. Uday Bhaskar and M. Ravichandran
Seasonal and Interannual Variability of Sea Surface Salinity during 2002-06 from Argo Profiles in the Tropical Indian Ocean

09:40   Michel **Ollitrault** and Jean-Philippe Rannou
The Mean-depth Circulation of the Atlantic with Argo Float Displacements from the ANDRO Atlas (AOML and Coriolis Data only)

10:00   Huizan **Wang**, Guihua Wang, Ren Zhang and Baogang Jin
Sea Surface Temperature Characteristics of the Western Pacific Warm Pool

10:20   *Coffee break and poster viewing*

11:00   Clement de **Boyer Montégut**, J. Mignot, M. Tomczak, F. Durand, R. Bourdallé-Badie and B. Blanke
On the Permeability of Barrier Layers Observed by Argo Floats

11:20   Li **Ren** and Stephen C. Riser
Decadal Time-scale Salinity Changes in the Subtropical Thermocline in the North Pacific Ocean Observed from Argo Floats

11:40   Qinyu **Liu**, Lixiao Xu, Wei Wang and Haibo Hu
Subtropical Subsurface High Salinity Water in the North Pacific

12:00   *Lunch*

Theme 5: New Technology

Chairman: Howard Freeland

13:30	Stephen C. **Riser** (Invited) Future Technological Advances and Challenges for Argo
14:00	Bill **Woodward**, Christian Ortega and Michel Guigue ARGOS-3 for the Argo Program
14:20	Hervé **Claustre**, Fabrizio d'Ortenzio and Odile Fanton d'Andon Observations by Bio-optical Floats Deployed in Various Oceanic Waters: Potential Synergies with Information Derived from Satellite Ocean Colour Sensors
14:40	Yoshitake **Nakagawa**, Toshio Suga, Chiho Sukigara, Kimio Hanawa, Taiyo Kobayashi and Nobuyuki Shikama Sea-to-air Oxygen Flux Associated with the Destruction of the Shallow Oxygen Maximum
15:00	*Coffee break and long poster inspection*
16:00	Annie Wong and Stephen C. **Riser** Observations of Water Masses and Circulation Under Antarctic Ice from Argo Floats Deployed in the Seasonal Ice Zone
16:20	Jia-Xun **Li**, Ren Zhang, Gui-Hua Wang and Hui-Zan Wang A Study on the Division of the Stratification of Seawater and Simulation of Underwater Acoustic Field in Pacific Ocean Using Argo Profiling Floats
16:40	Guided discussion - Stan Wilson and Kimio Hanawa
17:20	Final comments and farewell
Evening	A room will be available for a small group meeting to discuss the main items learned that will form input to the draft paper for OceanObs-2009

POSTERS

Th3-P17   Sheng-Long **Yang**, Su-Fang Zhou, Yu-Mei Wu and Xue-Seng Cui
The Relationship between Jack Mackerel Fishing Grounds and Subsurface Temperature and Surface Salinity Outside Chile, Based on Argo Data

Th3-P18   Zhongjie **He**, Guijun Han, Jirui Ma, Wei Li and Xuefeng Zhang
Study of Mesoscale Eddies in the Subtropical Ocean of the Northwest-Pacific Using Reanalysis Method

Th3-P19   Wei **Li**, Jirui Ma, Guijun Han, Xuefeng Zhang and Zhongjie He
Numerical Study of the Kuroshio Front to the East of Taiwan

Th3-P20   Megan C. **Scanderbeg**, Dean Roemmich and John Gilson
Are Argo Data Useful for SST Analyses?

Th3-P21   Lorna M. **McLean** and Brian A. King
Determining Ocean Correlation Scales using Argo Float Data

Th3-P22   Xinrong **Wu**
The Ideal Experiments of Sequential Filter and Variational Analysis Coupled Data Assimilation

Th4-P23   Simon Good, Matt **Martin**, Matt Palmer, Nick Rayner, Rob Smith, Nick Dunstone, Peter Stott and Richard Wood
How Has Argo Helped Us Understand the Climate of Our Oceans?

Th4-P24   Kanako **Sato** and Toshio Suga
Structure and Modification of the South Pacific Eastern Subtropical Mode Water

Th4-P25   Qilong **Zhang**, Hui Zhou and Hongwei Liu
Interannual Variability in the Mindanao Eddy and its Impact on Thermohaline Structure Pattern

Th4-P26   Aijun **Pan**, Wenju Cai, Dean Roemmich, Tim Cowan and Xiaogang Guo
Is ENSO Responsible for the Recent Indian Ocean Dipole Events?

Th4-P27   Shigeki **Hosoda**, Toshio Suga, Nobuyuki Shikama and Keisuke Mizuno
Recent Global Changes in Surface Layer Salinity Based on Argo Floats

Th4-P28   Katsuya **Toyama** and Toshio Suga
Vertical Structures of the North Pacific Mode Waters

Th4-P29   Toshio Suga, Kanako **Sato**, Shigeki Hosoda, Hiromichi Ueno, Nobuyuki Shikama, Taiyo Kobayashi, Naoto Iwasaka, Eitaro Oka and Masami Nonaka
A Revisit of the Reason Why the Properties of the Central Mode Water in the North Pacific Changed Associated with Regime Shifts

Th4-P30   Di-Sheng **Wu**, Jian-Ping Xu, Shui-Hua Zhou, Wen-Jing Zhang, Sheng-Bin Yu, Juan Wen and Juan Zhang
The Indo-Pacific Ocean Warm Pool and the South China Sea Summer Monsoon Onset

Th4-P31   Di-Sheng **Wu**, Jian-Ping Xu, Shui-Hua Zhou and Zhang Juan
The Air-Sea Interface Heat Exchange of the Typhoon

Th4-P32   Shigeki **Hosoda**, Nobuyuki Shikama, Toshio Suga and Keisuke Mizuno
Global Decorrelation Radii Maps of Temperature and Salinity Variability Based on Argo Float Data

Th4-P33   Sally **Close**, Alberto Naveira Garabato, Elaine McDonagh, Lars Böhme, Brian King, Mike Fedak and Martin Biuw
Southern Ocean Variability from Seal-mounted Sensors and Argo Floats

Th4-P34   Taiyo **Kobayashi**, Keisuke Mizuno and Toshio Suga
Seasonal to Decadal Variations of Upper Layer Waters in the South Indian Ocean Along 32°S

Th4-P35   J. Alexander **Brearley**, Elaine L. McDonagh, Brian A. King and Harry L. Bryden
Interannual Variability of the Atlantic Interior Geostrophic Transport at 36ºN

Th4-P36   Xiang-Zhou **Song**, Xiao-Pei Lin, Myrtle-Rose Padmore, Pei-Nan Zheng and Hui Qian
The Space Structure and Annual Variation of Northwestern Pacific Subtropical Mode Water by Argo Float Data

Th4-P37   K.V.S.R. **Prasad**, P. Sreenivas, Ch. Venkata Ramu and K.V.K.R.K. Patnaik
Observations of Temperature Inversions in the North Indian Ocean using Argo Data

Th4-P38   Guihua **Wang** Dongxiao Wang and Tianjun Zhou
Upper Layer Circulation at the Luzon Strait

Th4-P39   Shusaku **Sugimoto** and Kimio Hanawa
North-south Shift of Northern Boundary of the North Pacific Intermediate Water on 26.8 $\sigma\theta$ Surface and its Relation to the Atmospheric Variation

Th4-P40   Xidong **Wang** and Wei Li
Northwest Pacific Barrier Layer from Argo

Th4-P41   Zuojun **Yu** and Jonathan M. Lilly
Near-surface Salinity Structure Revealed by Different Gridded Products

Th4-P42   Lixiao **Xu** and Qinyu Liu
Subduction and Transportation of Low Potential Vorticity Water in the Subtropical North Pacific

Th5-P43   Taiyo **Kobayashi**, Brian A. King and Nobuyuki Shikama
An Estimation of the Average Lifetime of the Latest Model of APEX Floats

Th5-P44   David **Lindo**, Jose Ramón Bergueiro and François Merlin
Geographical Boundaries for the Free Use of Dispersants – Improving Physical Process Modelling by Global Observation Strategies

Th5-P45   Taiyo **Kobayashi**, Tomoaki Nakamura and Naoko Ogita
Quality Control of Argo Surface Trajectory Data Considering Position Errors Fixed by ARGOS System

Th5-P46   Yoshitake **Nakagawa**, Toshio Suga, Chiho Sukigara, Kimio Hanawa, Taiyo Kobayashi and Nobuyuki Shikama
Primary Production and Respiration Estimated from Dissolved Oxygen

Th5-P47   Igor **Yashayaev** and Michael Dunphy
An Interactive Tool for Real-Time Monitoring and Exploration of Ocean Basins (ArgoBrowser)

Abstracts

March 25, Wednesday

Opening Session

25 March, 9:00-9:30, Invited (Open-IT1)

The Future of Argo: An Introduction

Dean **Roemmich** and John Gilson

Scripps Institution of Oceanography, University of California, San Diego, 9500 Gilman Drive, La Jolla, CA, 92093-0230, USA
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The topic of Argo's future is introduced by considering Argo's present status and the 5 years of global Argo implementation, 2004 – 2008. Using 450,000 Argo profiles, we constructed an upper-ocean climatology and monthly anomaly fields for the 60-month global Argo era. A basic description of the modern upper ocean based entirely on Argo data is presented here. Objectives are to:

- evaluate the adequacy of present Argo sampling of large-scale ocean variability,
- provide a baseline for comparison with past datasets and ongoing Argo data, and
- examine the consistency of the Argo dataset with related ocean observations.

The Argo mean is compared to the World Ocean Atlas, highlighting the middle and high latitudes of the southern hemisphere as a region of strong multi-decadal warming and freshening. Moreover, that region is one where Argo data have contributed an enormous increment to historical sampling, and where error analyses indicate that additional Argo floats are most needed for documenting large-scale variability. Globally, the Argo-era ocean is warmer than the historical climatology at nearly all depths, and increasingly so toward the sea surface; it is saltier overall in the surface layer and fresher at intermediate levels. Annual cycles in temperature and salinity are compared, again to WOA01, and to the NOC air-sea flux climatology, the NOAA OI SST product, and AVISO satellite altimetric height. These products are consistent with Argo data on hemispheric and global scales, but show regional differences that may point either to systematic errors or to physical processes that need further investigation. The present work is an initial step toward integrating Argo and other climate-relevant global ocean datasets. A general conclusion is that much remains to be done to increase Argo's effectiveness for its original objectives. Highest priority must be given to improved sampling in the southern hemisphere and to identification and correction of systematic errors for critical global change research applications.

A PC-based data viewer has been developed for easy display of horizontal maps, vertical sections, time-series plots, and line drawings from gridded Argo data. An installation file is available, including the global Argo gridded dataset described above, at: ftp://kakapo.ucsd.edu/pub/argo/Pacific_Marine_Atlas

25 March, 9:30-10:00, Invited (Open-IT2)

Argo Data Management

Sylvie **Pouliquen**[1] and Mark Ignaszewski[2]

[1] Ifremer, BP70 20280, Plouzané, France. E-mail: sylvie.pouliquen@ifremer.fr
[2] FNMOC, Monterey, USA

The challenges of the Argo data system are to serve both the operational and climate communities with data processed the same way in a distributed organization implementing a free open data policy.

It's composed of ten data centers that processed the float data, two GDACS (Global Data Centers) in USA and France that provide access to the best official version of the Argo data, delayed mode operators who process data in delayed mode and finally the regional centers which check the consistency of the dataset at basin scale level and generate products. In order to serve all the users two data streams have been implemented:

- The first one, in real time, aims at detecting and flagging the suspicious or bad data, within 24 hours from acquisition, using the same automatic procedures.

- The second one, in delayed mode, aims at detecting and proposing a correction for sensor offset or linear drift using the same statistical method that compares Argo data to recent CTD data.

The Argo data management system is still under development. The first focus has been on the real-time stream and more than 95% of the profiles are distributed on the GTS and GDACs with 24 hours. Bad data are flagged and a grey list is provided to identify suspicious floats. The second step has been the delayed mode processing. It has been requested that operators adopt the method developed by Wong & Owens which is found to be efficient in all oceans and trains the delayed mode operators to reduce the effects of subjective analysis. Presently 60% of the floats have been processed. In 2007, the data team started to work on velocity data and there is still some reprocessing to clean up the trajectory files and to record the missing technical information and metadata necessary to derive accurate velocity fields. Finally, tools are under development to check the consistency of the Argo data in near real time to detect outliers that have passed through the automatic tests or delayed mode QC. This implies comparison with other data such as recent climatology or altimetry. Some of these tools will be turned to operational in 2009.

The Argo data management system has proven its efficiency and reliability over the past 10 years and this architecture has been taken as an example for the GOSUD and OceanSITES observing systems. Its distributed architecture allows sharing the work load among the different institutes without degradation of the quality because monitoring of the implementation of the agreed procedures is performed. Also the Argo Information center, managed at JCOMMOPS, ensures a monitoring of both the implementation of the observing system and its data management activities. Its implementation, step by step, has allowed a constant amelioration of the data.

Changes in format and distribution means are not often done within Argo as this needs a lot of coordination in all centers at once and also communication with users to reduce the impact of the changes. Nonetheless changes exist and are necessary when major steps are taken within Argo (*i.e.* when Delayed mode processing started, now for trajectory work, *etc.*). When the Argo data management structure and format was designed , no "on the shelves" standards were available. In the past ten years, progress has been made in terms of vocabulary, conventions (CF) and interoperability (OGC standards, OPeNDAP/THREDDS …) that have induced changes in the context where Argo operates. We foresee some changes in the Argo data management to be more interoperable with other observing systems within JCOMMOPS and to benefit from enhanced tools developed above these standards.

Opening Session Posters

Open-P1

The Preliminary Study of Two Delayed-mode Quality Control Methods on Argo Profiling Floats

Ting **Tu**

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The Argo profiling floats which provide temperature and salinity data in the upper ocean are a credible basic database for many oceanic and meteorological researches. The effective appliance of them must be built upon the reliable quality control of the original data. In the present study, two delayed-mode quality control methods are introduced and evaluated in several aspects, by employing the data set from IFREMER data center in France. Several floats which are located in the Northwest Pacific are selected. The results show that the advantages and disadvantages of the two methods, both theoretically and practically. Choosing the right historical dataset, sliding window and mapping scale as well as the development of the calibration method could improve the precision of salinity correction.

Open-P2

Large Eddy Simulation of the Dynamical Mixing in the Upper Ocean

Zhanhong **Wan**[1], Dake Chen[1,2] and Yang Zhang[1]

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[2]   The State Key Lab of Satellite Ocean Environment Dynamics, Hangzhou, 310012, PR China

It is of great interest to understand and simulate the turbulent mixing processes in the upper ocean because of their important roles in ocean dynamics. The turbulence production in the surface layer depends on surface fluxes of buoyancy and momentum, and also on surface waves. The wind-driven shear flow and the Stokes drift of surface waves can generate large-scale eddies. Craik and Leibovich established the fundamental governing equations that include the effects of the wind stress and wave forcing. Surface wave breaking causes strong turbulence dissipation by generating large amounts of small-scale turbulence. Buoyancy forcing may also play an important role in turbulent mixing, as thermal convection may occur when the ocean heat loss through longwave radiation or evaporative cooling surpasses the heat gain through shortwave radiation. In this paper, based on the Navier-Stokes equation, a large eddy simulation model is developed to investigate the turbulent mixing in the upper ocean. We extend the work of Craik and Leibovich by considering the effects of wave breaking and buoyancy forcing. The model is forced by heat fluxes at the ocean surface and by a random forcing term representing wave breaking. High resolution simulations are carried out with or without each contribution, in order to clarify their respective roles in the ocean upper mixed layer. The results of our models are compared to and verified by Argo float observations.

Open-P3

The Joint Effect of Breaking Waves and Tides in Modeling the Summer Structure of Temperature of the Yellow Sea

Xuefeng **Zhang**

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The summer structure of temperature of the Yellow sea, such as the upper mixing layer and the tidal front, can hardly be well simulated by the Mellor-Yamada (1982, hereafter M-Y) turbulence closure model because of its underestimation of turbulent kinetic energy without considering the effect of waves and tides. In the study, as the ingredient of breaking waves and tides is considered in the POM model whose turbulence closure scheme is M-Y, the temperature structure can be well simulated with their common effects. The turbulence mixing is enhanced greatly due to the joint effect of breaking waves and tides. A well-mixed temperature surface layer and tidal front can be well reproduced by using wave breaking parameterization and tidal boundary condition in a thee-dimensional simulation with POM.

Open-P4

Status of the *in situ* Global Ocean Observing System

Candyce **Clark**

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An *in situ* global ocean observing system for the physical climate system was conceived largely at the Ocean Observations conference in St. Raphaël in September 1999. It was recognized that society did not have adequate information about the state of the world ocean or its regional variations to address a range of important societal needs, and the subsequent work by the marine carbon community and others in the ocean science and operational communities led to an agreed international plan that was described in the GCOS Implementation Plan (GCOS-92, 2004). We here describe the efforts that have been made to reach these goals. Thanks to these efforts, most of the ice free ocean above 2000m is now being observed systematically for the first time, and a global repeat hydrographic survey and selected transport measurements supplement these networks.

The system is both integrated and composite. It depends upon satellite and *in situ* networks with observations of the same variable from different sensors. In this way optimum use is made of all available platforms and sensors to maximize coverage and attain maximum accuracy. Wherever feasible observations are transmitted in real time or near-real time because of the desirability to use every observation for as many purposes as possible, from short term ocean forecasting to estimation of century-long trends. Because our historical knowledge of oceanic variability is limited, we are learning about the sampling requirements and needed accuracies as the system is implemented and exploited, and the system will evolve as technology and knowledge improve.

Key *in situ* networks are world-ocean coverage with surface drifting buoy and profiling float (Argo) arrays; basin-spanning repeat lines of XBTs and hydrographic/carbon/tracer observations; a handful of fully time-resolving moored reference sites, a global tropical mooring array; coastal tide gauges that are geo-centric referenced; selected transport observations at key locations; and the highest quality observations of surface and near-surface variables from commercial and research ships. The progress in implementation of these arrays is described and the role of the WMO-IOC Joint Commission on Oceanography and Marine Meteorology (JCOMM) in these networks is described.

Theme 1: Heat and salt budgets on global to regional scales

25 March, 10:40-11:00 (Th1-T1)

Time-varying Ocean Heat Storage

W. Timothy **Liu** and Xiaosu Xie

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Ocean temperature and heat storage have been derived from profilers and buoys for decades and the climatology over the global ocean is available. However, even with the deployment of Argo global array of free-drifting profiling floats, the spatial and temporal resolution and coverage are not sufficient to understand many ocean processes and observations from the vantage of space are needed. The sea level change measured by space-borne radar altimeter is the sum of the steric change and bottom pressure (mass change). Ocean heat storage could be derived from the steric changes. By removing the mass change measured by Gravity Recovery and Climate Experiment (GRACE) from the sea levels measured by radar altimeter, we should be able to retrieve the steric change and heat storage. In practice, unknown bias and trend exist between the heat storage derived from JASON-GRACE data and from *in situ* measurement. A statistical model has been built to derive heat storage from the space based data; the model is trained and validated with Argo data. Application of the time-varying ocean heat storage with ocean surface heat flux to derive meridional heat transport in the Atlantic is being explored.

25 March, 11:00-11:20 (Th1-T2)

Separating the Steric and Eustatic Contributions to Global Sea-Level Rise

Howard J. **Freeland**[1] and Denis Gilbert[2]

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It is well known from observations by the altimetric satellites (predominantly Topex-Poseidon and Jason-1) that global sea-level is rising. What is less well known is exactly how the observed sea-level rise is partitioned between a steric contribution (sea-level rises because of changes in ambient temperature and salinity) and a eustatic contribution (the addition of new water mass to the oceans). Strictly, such a separation is not possible because of the nonlinearity in the equation of state for seawater, but in practice the nonlinearities are sufficiently small to allow this separation as a very good first approximation.

A careful comparison of the WOCE one-time survey with recent observations by the Argo array indicate a steric component to sea-level rise of 1.8 ± 0.7 mm/year between the early 1990s and the present time. The altimetric satellite time series indicates a total sea level rise rate of 3.2 ± 0.4 mm/year over this period. The difference is 1.4 ± 0.8 mm/year which, if supplied entirely by melting ice on land, translates into a melt rate of 515 ± 300 km^3/year.

25 March, 11:20-11:40 (Th1-T3)

Intraseasonal Response of Near-Surface North Indian Ocean to Heat and Freshwater Forcing

Sindu R. **Parampil**[1], G. Anitha[2], M. Ravichandran[2] and D. Sengupta[1]

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Previous work using *in situ* surface observations and satellite data suggest that intraseasonal oscillations (ISO) of Bay of Bengal SST are mainly forced by changes in surface heat flux associated with the monsoon active-break cycle. Here we study intraseasonal variability of near-surface temperature and freshwater content (SST and FW) in the Bay of Bengal and Arabian Sea using Argo floats. We selected three floats lying between 10-20°N latitude in each basin, in the period 2003 to 2007, which give temperature and salinity profiles from 5m depth every five days. This is the first study of ISO of freshwater in the north Indian Ocean, and the first study of ISO using subsurface data.

We ask whether ISO of near-surface (upper 15m) temperature and freshwater content is mainly a response to surface heat and freshwater fluxes, and whether processes internal to the ocean (advection/mixing) are important. Net surface heat flux (Qnet) and freshwater flux (precipitation minus evaporation; P-E), are based on estimates from daily satellite data, sampled along the float trajectory. Penetrative solar radiation below 15m depth (Qpen) is estimated from satellite estimates of surface insolation and chlorophyll. We define the "effective" heat flux as the heat absorbed in the upper 15 m, Qeff = Qnet-Qpen.

During the summer monsoon season (June-September), the rate of intraseasonal (10-90 day period) warming/cooling of SST is by and large forced by ISO of Qeff. The amplitude and phase of d(SST)/dt matches reasonably well with Qeff; correlations are high (0.6-0.8) in both basins, and the ratio of forcing and response amplitudes is close to one. However, this is not true during other seasons. For instance, winter (November-January) correlations are less than 0.3, and the intraseasonal variability of d(SST)/dt is much larger than that of Qeff, suggesting the dominance of advection /mixing in the heat balance. Note that we have no estimates of horizontal or vertical advection, or of mixing, from the observations.

The Argo observations show large amplitude ISO of near-surface freshwater content in all seasons. One of the Bay of Bengal floats was located in a region of intense rainfall in the summer of 2006 – the seasonal increase of FW at this time does appear to be a direct response to rain. However, the intraseasonal variability of FW is not a response to local freshwater flux, even during the monsoon season. The rate of change of freshwater d(FW)/dt, both in the Bay of Bengal and Arabian Sea, are nearly uncorrelated with P-E in all seasons. Occasionally, intense monsoon rainfall leads to local freshening, but such events are rare. The amplitude of FW ISO can be as large as 1.5 m late in the monsoon season, while that of P-E reaches 0.4 m during July/August. The upper ocean is stably stratified by salt at these times, so the effects of vertical mixing or entrainment are likely to be small. The largest intraseasonal freshening (salting) events appear to be due to lateral advection, suggesting that spatial gradients of salinity are large.

Intraseasonal variability of SST is mainly forced by local heat fluxes during the summer monsoon, whereas internal ocean processes appear to be important in winter and spring. Intraseasonal variability of near-surface freshwater is not a response to surface freshwater flux, but appears to be dominated by advection from Bay of Bengal rivers and remote rainfall, in all seasons. Our analysis suggests that near-surface river and rain water moves to remote regions of the north Indian Ocean in eddies or ribbons.

50 Year Salinity Trends for the Global and Regional Oceans from Argo and Historical Data

Paul J. **Durack**[1] and Susan E. Wijffels[1] (presented by Esmee M. van Wijk[2])

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[2]   Antarctic Climate and Ecosystems Co-operative Research Centre & Centre for Australian Weather and Climate Research, A partnership of CSIRO and the Bureau of Meteorology, GPO Box 1538, Hobart, Tasmania 7001, Australia. E-mail: Esmee.Vanwijk@csiro.au

We combine historical ocean observations with the new Argo global data set to estimate changes in the ocean salinity fields to 2000m depth over the last 50 years.

Robust and significant salinity changes are found in all ocean basins. Surface salinity changes and contrasts strongly resemble the mean salinity field and the mean ocean-atmosphere surface freshwater flux field. Subduction and circulation by the mean flow of surface salinity and temperature anomalies appear to account for many regional features of salinity changes on isopycnals.

Water masses formed under regions of excess evaporation over precipitation have become saltier and those formed under regions of excess precipitation have become fresher. This implies that, to first order, salinity changes are due to a strengthening of the global hydrological cycle. As a result, inter-basin contrasts have been enhanced as well as contrasts between existing water masses.

Freshening of North Pacific Central Water is seen to penetrate the South Indian Ocean via the Indonesian Throughflow.

In several regions salinity changes on pressure levels are driven by isopycnal deepening, a feature of a warming ocean, such as the increase in salinity in the Atlantic subtropics. Warming as well as freshening has markedly increased the near surface stratification under the tropical warm pools.

Theme 1 Posters

Th1-P5

Analysis of the Annual Cycle of the Oceanic Heat Budget of the Mixed Layer in the Atlantic Using Different Surface Flux Products

Claudia **Schmid**

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A better understanding of the mixed layer heat budget in the tropical Atlantic is important for climate research and prediction. Of particular interest are regions where the heat balance is not dominated by the surface heat fluxes. Such regions include, for example, the equatorial cold tongue and the coastal upwelling regions off Africa. The approach is based on the analysis of a wide range of in situ and satellite observations covering the years 1992-2008. Hydrographic profiles are used to derive a time series of the monthly heat storage rate. The oceanic heat transports are derived from drifter observations in conjunction with geostrophic velocities from altimetric fields and Ekman currents from scatterometer winds. Various surface flux products (ERA15, ERA40, NCEP1, NCEP2 and OAFlux) are used to derive the heat budget in selected regions of the North and South Atlantic. The focus is on the monthly climatology of these quantities. It is found that the current data set does not allow the closure of the heat budget in some regions, for example the eastern tropical North Atlantic (around 15W, 10N). This is the case even so: (1) the errors of the heat storage rate are quite large due to significant interannual variability and varying data coverage, and (2) large differences between the surface flux products exist. The reason for this is likely to be due to the uncertainties in the horizontal transport of heat and the entrainment. In other areas, for example the tropical South Atlantic (around 20W, 15S) and the tropical North Atlantic (around 50W, 20N), the heat budget can be closed within the errors of the components. Typically, the horizontal transport of heat plays a much smaller role in these regions.

Th1-P6

Variability of Temperature and Salinity around 30°S in the South Atlantic Revealed by Argo Data

Gerard **McCarthy**, Elaine McDonagh and Brian A. King

National Oceanography Centre, Southampton, UK. E-mail: gdm2v07@noc.soton.ac.uk

The South Atlantic plays a key role in the global thermohaline circulation. It is the only ocean in the world which transports heat equatorwards. In this way it contributes information to the North Atlantic from the rest of the world's oceans by closing the upper branch of the global overturning cell.

Two hydrographic sections from the South Atlantic at 30ºS are compared. Salinification between the years 1993 and 2003 is observed in the eastern basin with a maximum of 0.07 psu near 13°C – a temperature which is associated with the Mode Water of the southwest Indian Ocean. We also observe salinification at the salinity minimum associated with Antarctic Intermediate Water in the eastern basin however, a freshening of the same water mass is noted in the western basin.

Argo data are used to investigate the temporal and spatial extent of these changes in salinity. Argo data has previously been used in the Indian Ocean to ascertain the spatial extent of changes revealed by hydrographic sections (King and McDonagh (2005)). Here Argo data since 2003 are optimally interpolated onto the cruise stations to investigate the temporal extent of the changes noted in the cruise comparison. The ability of Argo data to reveal changes in ocean properties in the absence of hydrographic sections is one of the major advantages of the Argo programme.

Th1-P7

Upper Ocean Variability in the Bay of Bengal during the Tropical Cyclone 'Nargis' from Argo Data

K. **Maneesha**[1], V.S.N. Murty[1], M.J. McPhaden[2], T. Lee[3] and M. Ravichandran[4]

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The tropical cyclone Nargis developed over the Bay of Bengal during 24 April – 2 May 2008 and was the worst disaster to affect the Indian Ocean region in recent years with a huge loss of life and economy. It was estimated that the destruction included over 130,000 dead and missing and billions of dollars in economic losses. It made land fall in Myanmar on 2 May 2008 with winds equivalent to a category 3-4 hurricane. The international oceanographic community has been involved over the past several years in developing an observing system in the Indian Ocean for climate research and forecasting. Elements of this Indian Ocean Observing System (IndOOS) captured the development of cyclone Nargis as it grew in strength and migrated eastward across the Bay of Bengal in late April 2008. A sub-program of IndOOS consists of the newly established in situ measurement platforms, including Argo and the Research Moored Array for African-Asian-Australian Monsoon Analysis and Prediction (RAMA). In this study, we focus on the upper ocean variability during the Nargis cyclone period using Argo floats measured time-series of temperature and salinity profiles. Using the Argo profiles and considering the nature of salinity stratification in the Bay of Bengal, we computed the mixed layer depth (MLD) based on density criterion ($0.2 \ kg/m^3$). The heat content in different layers (0-30 m, 0-50 m, 0-100 m) and the cyclone heat potential (CHP, relative to 26°C isotherm) are estimated using the Argo data from 7 Argo floats located on either side of the cyclone track.

The differences in ocean parameters before Nargis and after Nargis over 10 day interval in Sea Surface Temperature (SST), Sea Surface Salinity (SSS), MLD, heat content and CHP are computed. The Nargis cyclone intensified on 27-28 April in the west-central Bay of Bengal and weakened slowly towards eastern Bay of Bengal. It is interesting to note higher SST drop of ~2°C on the right of the cyclone track in the central Bay. Together with the rightward bias in upper layer cooling, freshening at sea surface is noticed. Freshening may partly be due to intense precipitation during cyclone or to advection of low salinity waters into the cyclone area. Associated with the surface cooling, there is a corresponding increase in MLD on the right side of the cyclone track. The rate change of CHP is negative and high on the right side of the track indicating the intense loss of heat from the upper ocean. This heat loss is largely occurred through the sea surface enhancing the latent heat flux (LHF) and partly by advective processes. The upper ocean heat loss to the overlying atmosphere through enhanced LHF contributed to the strengthening of Nargis. The RAMA buoy data and the derived heat fluxes from the central Bay of Bengal supports this view. The upper ocean variability during another cyclone 'Sidr' will also be discussed using Argo data.

Th1-P8

On the Use of Satellite Altimeter Data in Argo Quality Control

S. **Guinehut**[1], C. Coatanoan[2], A.-L. Dhomps[1], P.-Y. Le Traon[2] and G. Larnicol[1]

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[2]   IFREMER, Technopole de Brest-Iroise, Plouzane, France

A new method has been developed to check the quality of each Argo profiling floats time series. It compares collocated Sea Level Anomalies (SLA) from altimeter measurements and Dynamic Height Anomalies (DHA) calculated from the Argo temperature (T) and salinity (S) profiles. By exploiting the correlation that exists between the two data sets along with mean representative statistical differences between the two, the altimeter measurements are used to extract random or systematic errors in the Argo float time series. Different kinds of anomalies (sensor drift, bias, spikes, *etc.*) have been identified on some real-time but also delayed-mode Argo floats.

An example of SLA/DHA time series is given in the diagram for float number 1900249. It shows clearly a positive drift of the DHA time series regarding the SLA time series as the float is traveling from East to West in the Tropical Atlantic Ocean. It seems that one of the float sensors presents a malfunction and it has to be carefully checked by the PI.

The possible impact of these remaining anomalies in the real-time and delayed-mode Argo data set on heat and salt budgets will also be illustrated.
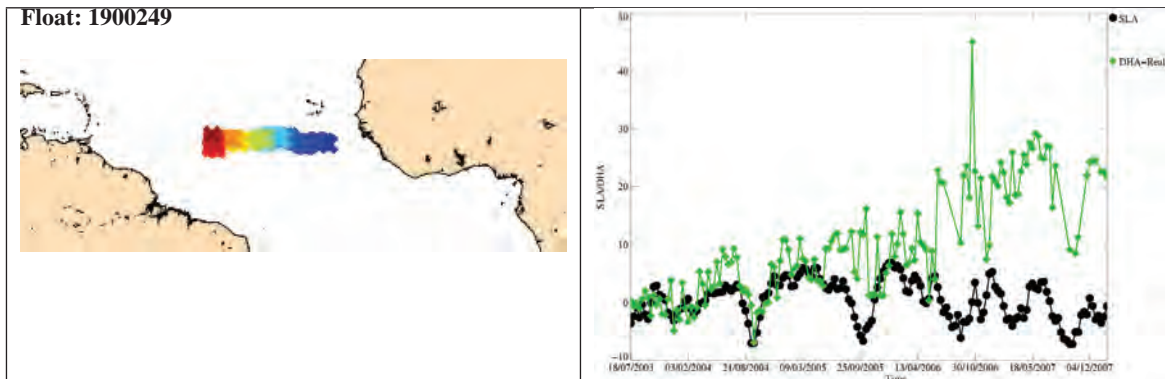
SLA and DHA time series for float number 1900249 (in cm). The geographical position of the float is also indicated, the cross at the RHS corresponding to the deployment position and the cross at the LHS to its last reported position.

Th1-P9

Global Hydrographic Variability Patterns During 2003-2007

K. von Schuckmann[1], F. **Gaillard**[1] and P.-Y. Le Traon[2]

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Monthly global temperature and salinity fields from 0 to 2000m depth based on Argo measurements are used to analyze large-scale variability patterns on annual to interannual time scales during the years 2003-2007. Previous estimates of global hydrographic fluctuations have been derived using different data sets, partly based on scarce sampling. The substantial advantage of this study includes a detailed summary of global variability patterns based on a single and more uniform data base. The dominant signal of upper ocean variability is the annual cycle which plays an important role in the tropical and sub-polar parts of the global ocean. Seasonal temperature changes peak at mid-latitude from 0 to 300 m depth and amplitudes are subsurface intensified in the tropical basin. Seasonal, interannual and long term fluctuations are more pronounced in the Northern hemisphere compared to the southern ocean. Moreover, features in the northern hemisphere are associated with strong interannual fluctuations. In the southern ocean interannual changes are dominant but also distinct freshening and warming occurs between 40-60°S from the surface to 1000m depth. Other areas of surface freshening include the upper 200 m of the tropical basin. Patterns of increased salinity are confined to the upper 500 m depth of the southern subtropics and northern mid latitudes. Heat contents and steric height changes are associated with a positive trend during the 5 years of measurements. Changes of freshwater content are dominated by interannual variability. Steric height deduced from *in situ* measurements are in reasonable agreement with satellite derived quantities.

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Theme 2: Estimation of circulation fields on global to regional scales

Chairman: Dean Roemmich

25 March, 13:30-14:00, Invited (Th2-IT)

Water Mass and Circulation Variability in the North-Atlantic

Virginie **Thierry**, Eric de Boisséson and Herlé Mercier

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The North Atlantic subpolar gyre is a key region for European climate. The northward heat transport associated with the northward advection of warm subtropical waters by the North Atlantic Current constitutes the upper limb of the meridional overturning circulation (MOC). Due to the winter heat release from the ocean to the atmosphere, which contributes to temperate Western European winters, the subtropical waters are progressively cooled and transformed into subpolar mode waters and eventually reach deep convection areas (Labrador and Greenland seas) where the North Atlantic Deep Waters (NADW) are formed. NADW are then exported southward as part of the lower limb of the MOC.

Documenting and understanding the variability in strength and structure of the MOC is of primary importance as, in response to global warming, most climate models predict a decline of the MOC. This can have dramatic effect on the global climate system. Using Argo data with tools of various complexities, we show that the Argo array provides a unique dataset to follow and help understand the dynamics of the different components of the MOC system.

Individual profiles are used to follow the variability of the mode and deep water properties, as well as the location and occurrence of deep convection in the North-Atlantic. Comparing Argo data with model outputs, we confirm the robustness of Argo-based seasonal heat budgets in the mixed layer and we show that the mode water properties variability is linked to change in the mean advection pattern while on seasonal time scale the local air-sea forcing is the dominant term. Finally, the assimilation of Argo profiles collected in the North Atlantic in a low resolution general circulation model (GCM) using the adjoint method leads to vast improvements in the model circulation, including the sea surface height, the meridional heat transport and the deep circulation (below 2000m depth).

All of those studies require data of high-quality but the detection of sensor drift is difficult as the North-Atlantic ocean has a very complex topography and the deep water mass properties are highly variable. We thus provide a brief overview of the quality control of the Argo data in the North-Atlantic and on the expected measurement uncertainties in that area.

25 March, 14:00-14:20 (Th2-T1)

Observations of Large-scale Upper Ocean Volume Transport in the Pacific

Alison L. Rogers and Stephen C. **Riser**

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Historical estimates of the large-scale volume transport in the upper ocean have been based on a limited number of hydrographic transects. The multitude of velocity observations and profiles of temperature and salinity that have been recorded by the Argo array provide a data set that is vastly improved in spatial and temporal resolution. Using these data we examine the large-scale circulation in the Pacific Ocean during the period 2005–2007. From the drift of the floats we compute the absolute geostrophic velocity at the parking depth (1000 db). We then objectively analyze these data to determine the large-scale geostrophic streamfunction at that depth, for both the North and South Pacific. Combining this estimate with the measured temperature and salinity profiles allows us to determine the absolute

geostrophic streamfunction throughout the upper 2000 db on annual and inter-annual timescales. In order to examine the contribution of wind forcing to the observed transport, we compare the total computed meridional transport with that expected from the curl of the wind stress, according to the canonical Sverdrup relation.

25 March, 14:20-14:40 (Th2-T2)

Variability of the Currents in the Luzon Strait during October Cruise of 2008 Obtained from Observations and a Diagnostic Calculation of the Circulation

Yaochu **Yuan**, Guanghong Liao, Chenghao Yang and Zeng-hong Liu

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Five Argo floats 2901169, 290170, 2901171, 2901172 and 2901167 were deployed at (20°N, 120°45′ E), (20°N, 121°13′ E), (20°N, 122°20′ E), (20°N, 122°40′ E) and (20°N, 123°0′ E) respectively during October 2008, (see the diagram). On the basis of current measurements and hydrographic data from the Argo floats and CTD and wind data obtained in the Luzon Strait during October cruise of 2008, a three-dimensional diagnostic model of ocean circulation with a modified inverse method (MIM) is used to study the circulation in the investigated area. The observed and computed results both show that there is a branch of the Kuroshio in the areas above 400 m, and it intrudes northwestward in the region southwest of Taiwan.
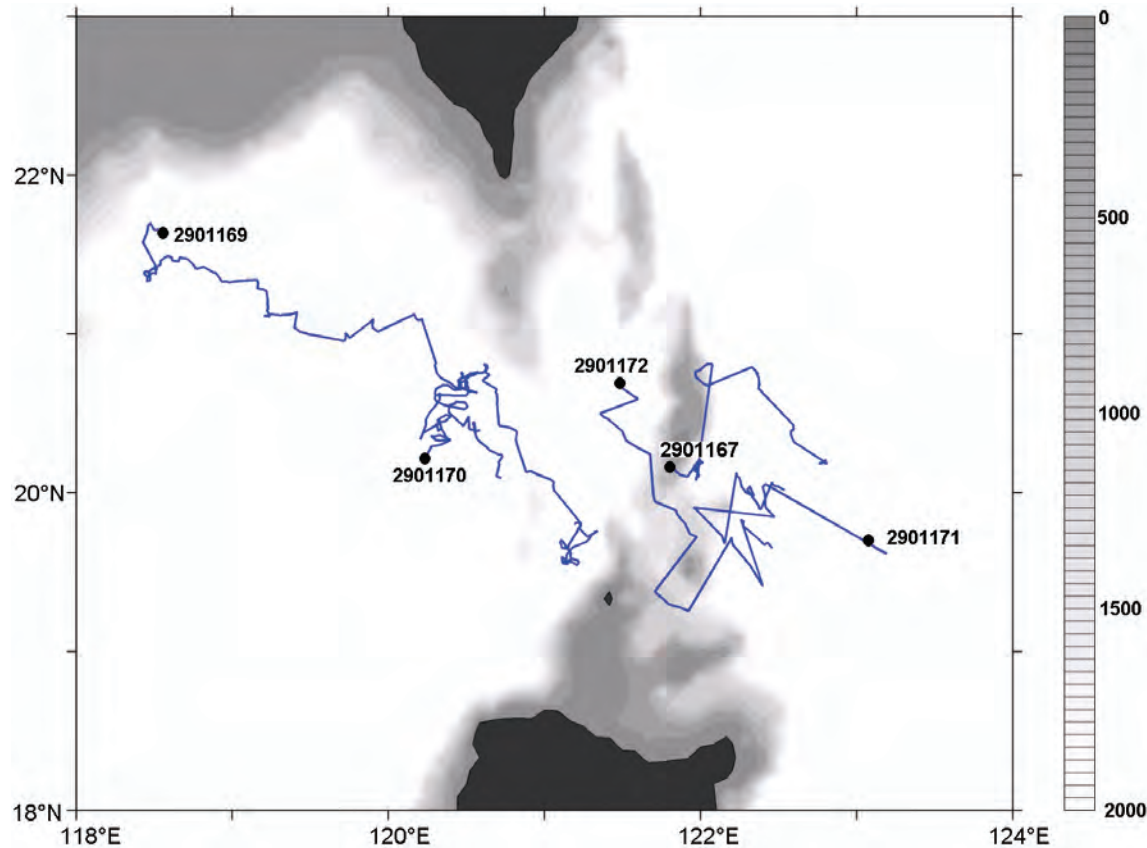
Trajectories of five Argo floats in the Luzon Strait

25 March, 14:40-15:00 (Th2-T3)

Studies on the Interaction between the Kuroshio and Mesoscale Eddies East to Luzon Strait*

Baogang **Jin**[1,2], Guihua Wang[2], Ren Zhang[1] and Huizan Wang[1,2]

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[2]   State Key Laboratory of Satellite Ocean Environment Dynamics, Second Institute of Oceanography, State Oceanic Administration, Hangzhou 310012, PR China

The Kuroshio, the poleward western boundary current of the subtropical North Pacific Ocean, has a large variability east to Luzon Strait, however, whether the Kuroshio is influenced by westward propagating eddies is still not clear. The satellite altimeter data and the Argo data are used to analyze the features of mesoscale eddies between 15°N~25°N and 120°E~130°E with a time range of 15 years(1993~2007). The interaction between the Kuroshio and mesoscale eddies is also studied with these datasets.

The main results are as follows: (1) There are seasonal or periodic variations for the eddies' number, radius, propagation speed and strength. (2) As the cyclonic and anticyclonic eddies approach the Kuroshio, the Kuroshio takes them away at different speeds. (3) The higher the latitude of a mesoscale eddy, the stronger it is, and the lower propagation speed it has. The strength and the propagation speed are negatively correlated. (4) The propagation speed, strength and the life history of eddies are affected by the Kuroshio strength and the gap between Luzon and Taiwan Islands. These results preliminarily reveal some characters of mesoscale eddies east to Luzon Strait. They also indicate the interaction between mesoscale eddies and Kuroshio, however, the dynamics need further study.

25 March, 15:30-15:50 (Th2-T4)

A Dataset of Global Ocean Surface Currents for 1999-2007 Derived from Argo Float Trajectories: Comparison with Surface Drifter and TAO measurements

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A dataset of surface current vectors with error estimate from 1999 to 2007 is derived from the Argo float surface trajectories over the global ocean. The errors of the estimated surface currents are about 4.7 cm s^{-1} that is equivalent to the accuracy of the currents from the surface drifters. Geographically the Argo derived surface currents can fill many gaps left by the Global Drifter Program due to the larger number of floats and provide a complementary in situ observational system to monitor global ocean surface currents. The surface currents from the Argo floats are compared with the surface drifter derived currents and the TAO measurements and show good agreement both on the current amplitude and on the direction of surface currents. Results indicate the feasibility to obtain ocean surface currents from the Argo array and to combine the surface currents from Argo and the ocean surface drifters for in situ mapping of the global surface currents. We also made the dataset available to users of interest for many types of applications.

25 March, 15:50-16:10 (Th2-T5)

Using Argo Data to Investigate the Meridional Overturning Circulation in the North Atlantic

Alonso **Hernández-Guerra**[1], Terrence M. Joyce[2], Eugenio Fraile-Nuez[3] and Pedro Vélez-Belchí[3]

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Using a variety of oceanographic data, including direct volume transports in the Florida Strait, and Argo float profiles and drift velocities at 24 and 36N in the North Atlantic, inverse calculations are presented in which the net meridional transport, down to a depth of approximately 1600 m, is estimated at both latitudes for a five year period 2003-2007. The upper ocean is divided into 7 layers using neutral density, and mass conservation constraints have been applied to a closed box bounded by these latitudes, including the Florida Strait. Ekman layer transports have been included in the top-most layer, and the inverse calculation has solved for changes from the initial reference velocities, Ekman and Florida Strait transports, given a priori estimates on the accuracy of each of these quantities. Solutions with and without transformations due to Mediterranean Water (MW) formation are made. Our results indicate that 1) time-averaged transport estimates derived from Argo have significant less eddy noise than individual hydrographic sections, 2) Argo drift velocities provide significant information to the inverse solution for the ocean interior, and 3) comparison of the total integrated interior mass transports in the thermocline waters for the period 2003-2007 with the previous estimates based on trans-ocean hydrographic sections shows that the Meridional Overturning Circulation has not significantly changed since 1957.

25 March, 16:10-16:30 (Th2-T6)

Mean Sea Surface Height in the World Ocean using Argo Floats and Altimetry

H. **Abe** and Kimio Hanawa

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Since satellite altimetry provides only anomalies of sea surface height (SSH) from mean SSH field temporally averaged for 1993-1999, it is needed to estimate mean SSH field in order to obtain 'absolute' SSH field from some reference level, such as 2000db. In the present study, we newly developed the procedure to obtain mean SSH field using the Argo float data and satellite altimetry data. By subtracting satellite SSH anomalies from the SSH estimated using temperature and salinity profile, we can obtain mean SSH. Since we cannot expect exact coincidence in place and time between satellite altimetry and Argo float observations, we first estimate the statistics of temporal and spatial behaviour of SSH variation using satellite altimetry and determine the match-up condition between satellite altimetry and Argo observation. The match-up conditions are different in latitude and longitude. It was found that, although the obtained mean SSH field is similar to that obtained using climatological temperature and salinity profiles such as WOA05 as a gross, there are significant differences especially in the regions of the western boundary currents and the Antarctic Circumpolar Current.
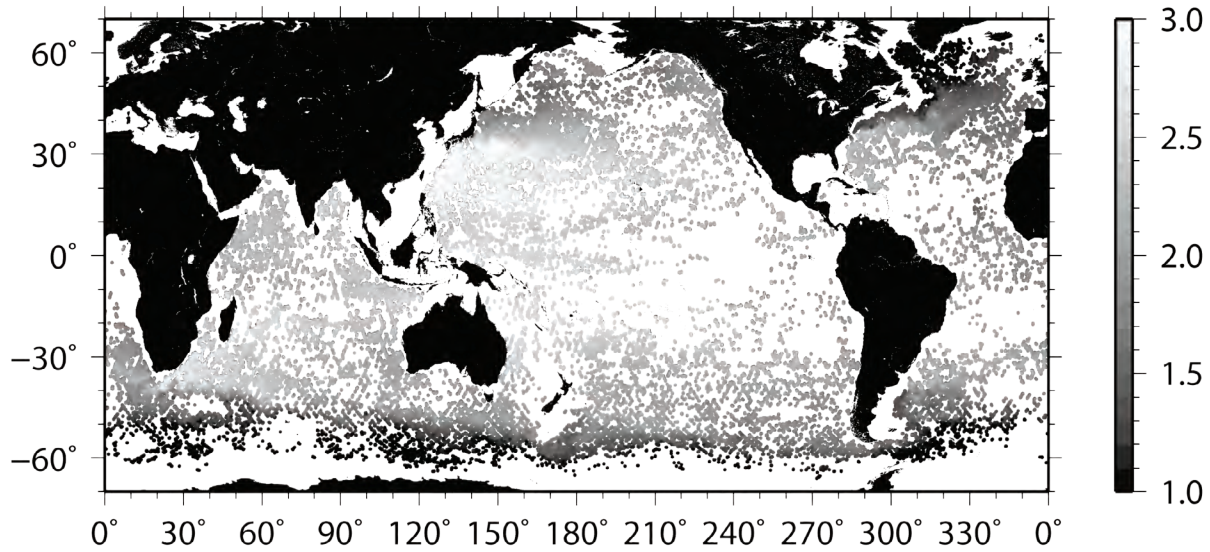
Estimated MSSH at altimetric points.

25 March, 16:30-16:50 (Th2-T7)

Temporal and Spatial Scales of Deep Eddies Observed from Argo Floats Near Ulleung Basin in the East Sea

Moon-Sik **Suk**, Sung Won Shin and Youn Ha Ahn

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Trajectories of Argo floats in the East Sea show remarkably rich features with the existence of the subpolar front situated in the middle of the Sea, around which eddies are generated. An elliptical shape is easily recognized in the trajectories. Satellite images of SST and SSH show surface oceanic features such as meso-scale eddies, fronts. However, the vertical extent of these features is hardly studied by using satellite images only. Deep *in situ* observations are essential to study the vertical extent of these features. The Argo array of profiling floats provides the deep *in situ* observations. The present study aims to examine numerous cases of elliptical shape and their horizontal and vertical extent in time and space. There are over 50 cases showing partial elliptical shape.

Theme 2 Posters

Th2-P10

Anticyclonic Eddies in the Alaskan Stream

Hiromichi **Ueno**[1], Howard J. Freeland[2], W.R. Crawford[2], H. Onishi[3], E. Oka[1,4], Kanako Sato[1] and Toshio Suga[1,5]

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Anticyclonic eddies propagating southwestward in the Alaskan Stream (AS) were investigated through analysis of altimetry data from satellite observations during 1992–2006 and hydrographic data from profiling float observations during 2001–2006. Fifteen long-lived eddies were identified and categorized based on the area of first appearance. Three eddies were present at the beginning of the satellite observations; another three formed in the eastern Gulf of Alaska off Sitka; four were first detected at the head of the Gulf of Alaska near Yakutat. The other five eddies formed along the AS between 157º–169ºW, and were named AS eddies. While the eddies formed in the Gulf of Alaska mainly decayed before exiting the Gulf of Alaska, AS eddies mostly crossed the 180º meridian and reached the western subarctic gyre. Four of five AS eddies formed under negative or weakly positive wind stress curl, which possibly caused AS separation from the coast. Comparison of eddy propagation speeds in the AS with bottom slope showed that eddies propagated faster over steeper slopes, although eddy speeds were slower than those predicted by the topographic planetary wave dispersion relation. An AS eddy was observed by profiling floats in the western subarctic gyre after it detached from the AS. Intermediate-layer water near the eddy center had low potential vorticity compared with the surrounding water, suggesting that AS eddies provided the western subarctic gyre with water just south of the Aleutian Islands.

Th2-P11

Partition Between Barotropic and First Baroclinic Modes Inferred from Altimetric Surface Velocities and Argo Float Mid-depth Displacements

C. **Cabanes**[1,2], T. Huck[1], A. Colin de Verdière[1] and M. Ollitrault[1]

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Recent observations suggest that a strong correlation exists between mid-depth velocity anomalies deduced from Argo float displacements and surface geostrophic velocity anomalies from altimetry at middle and high latitudes. In this paper we first investigate in which range of wavelengths or periods the surface velocity anomalies correlate best with the velocity anomalies at 1000 m depth. It is found that in regions of high eddy kinetic energy, the correlation is mainly related to large eddies with 300-400 km wavelength. In regions of lower eddy kinetic energy such as the southeast Pacific, the correlation is rather due to smaller structures with 200-300 km wavelength and period longer than 8 months. Then we assess how the two vertical modes (barotropic and first baroclinic) would partition to best explain the collocated observed anomalies of the surface (derived from satellite altimetry) and intermediate-depth (derived from trajectories of floats). The first baroclinic mode dominates in the sub-tropics while the barotropic mode is more important poleward (becoming dominant south of 40 S).

Th2-P12

«Virtual Argo Floats Deployment Experiment»: Estimation of Velocity Errors at Parking Depth for Argo Floats Using an Ocean General Circulation Model

Hiroshi **Yoshinari**[1], Yoshio Masuda[2] and Yoshikazu Sasai[3]

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We estimated the errors of velocity for Argo float at parking depth by executing "Virtual Argo Floats Deployment Experiment": Deploying virtual Argo floats in the ocean general circulation model.

The velocities at float parking depth and at the sea surface are calculated with fixed sea surface position of floats (*e.g.*, YoMaHa series of velocity dataset assessed from trajectories of Argo floats: http://apdrc.soest.hawaii.edu/ projects/yomaha/). Calculating the velocity at parking depth, two principal types of error occurs as follows; 1) Due to specifications of position fixing system, we rarely obtain the exact positions where surfacing first occurs and descent begins, causing error of velocity at float parking depth by the sea surface drift. 2) Vertical current shear causes the error because of the slow ascent/descent speed of the floats (about 10 cm/s).

We calculated the 2 kinds of velocities; velocity at parking depth and at the sea surface by deploying 'virtual' Argo floats in the ocean general circulation model: OIFES (Ocean-sea-Ice model For the Earth Simulator) to estimate both 'presumed' velocity errors described above.

OIFES is the extended version of OFES (Ocean general circulation model For the Earth Simulator [Masumoto *et al.*, 2004]), including sea-ice model. After spinning up for fifty years, climatological seasonal integration was executed, and daily mean values (including velocities) were used for this experiment.

Specifications of virtual floats were as follows; duration of one cycle: 10 days (240 hours), parking depth: 1000 m, the deepest depth: 2000 m, ascent/descent speed: 10 cm/s, duration of the sea surface drift: about 10 hours. As a first step, virtual floats were deployed in the North Pacific.

Preliminary results suggest that comparatively large errors were detected in the western boundary current region where strong baclinicity exists, implying the validness of the simple error estimation method which YoMaHa series adopted; calculating the error from the velocity at parking depth and at the sea surface.

Th2-P13

Sampling Uncertainties in a Global Mapping of Argo Drift Data at the Parking Level

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In addition to the well-known hydrography data, Argo floats provide material for estimating velocities at the parking level through the positions fixed by satellites at the surface. A compilation of these drift data is YoMaHa'07 (Lebedev *et al.*, 2007). The dataset contains the drift velocity data at the parking level from August 1997 to May 2007, as estimated by dividing the displacement by the time from the last fix before submerging to the first fix after surfacing. Here a global mapping of the drift data is attempted to estimate a mean flow field over the decade at 1000 dbar. After removing outliers and the data with possible grounding, the mapping procedure by Davis (2005, *J. Phys. Oceanogr.*) is applied globally on a 1 degree by 1 degree grid, with the constraint of no flow through the horizontal boundaries. The errors in the resultant map comes from the observation errors and the sampling errors. Although the observation errors

include various errors in the original drift dataset (error in the satellite fixing, error due to advection during ascent and descent, error due to the near-surface advection before the first fix and after the last fix) they are assumed constant (0.5 cm/s). The sampling errors include the array bias (Davis, 1991, *Deep-Sea Res. I.*) and error due to subgrid diffusion by eddies. For about 260000 drift data included in YoMaHa'07, the array bias is found comparable to the estimated mean field in many regions, including the mid-latitude Pacific, equatorial oceans, in addition to the near coastal regions where the bias is inevitable. The objective mapping yields uncertainty of the similar or larger magnitude to the mean flow, which is particularly large in the Southern Ocean, where the variability is large but the data are relatively sparse. These two sampling errors are expected to decrease as more data are accumulated.

Th2-P14

Spreading and Properties of the Antarctic Intermediate Water in the Atlantic Derived from Argo and Other Observations

Claudia **Schmid** and Silvia L. Garzoli

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The Antarctic Intermediate Water (AAIW) is part of the upper branch of the Meridional Overturning Circulation in the Atlantic Ocean. The general pathway to the north starts with the subtropical gyre in the South Atlantic. In the southern branch of the gyre water of Pacific origin is subducted to form the fresher variety of this water mass. It also mixes with older AAIW that has recirculated around the subtropical gyre. In the eastern Atlantic (mainly in the Cape Basin) this blend of AAIW mixes with more salty AAIW from the Indian Ocean. In the northern branch of the subtropical gyre the AAIW reaches the western boundary near the Rio Grande Rise where it splits into northward and southward branch. The northward branch eventually crosses the equator, but it also feeds into the complex system of zonal currents of the tropical Atlantic. This pattern was derived from observations widely scattered in space and time. Now a more precise picture can be derived thanks to the much larger data density achieved largely with profiling floats. A combination of hydrographic, Lagrangian and quasi-Lagrangian data are used to increase the understanding of the spreading of the AAIW in the Atlantic Ocean. The hydrographic data are used to follow the salinity minimum and to study the change of the temperature-salinity relationship, especially in the regions where the different blends of AAIW mix. The quasi-Lagrangian and Lagrangian observations from profiling and other floats are used to derive the flow field and estimate transports. The shear of the geostrophic velocity is used to asses the uncertainty of these transports. Signs for seasonal variability are assessed in selected regions based on observations and model results.

Th2- P15

Formation and Circulation of South Pacific Waters as Seen by Argo

Tangdong **Qu**

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Using available high-resolution CTD observations, complemented by a large number of recently available Argo float profiles, this study provides a brief description of the formation and circulation of South Pacific waters. Based on a new, reliable climatological dataset on mixed layer properties, an annual subduction rate of about 50 Sv (1 Sv=10^6 m^3 s^{-1}) is obtained. Two peaks stand out in this subduction rate sorted by winter mixed layer density. One corresponds to the formation of Eastern Subtropical Mode Water and the other to the formation of Sub-Antarctic Mode and Antarctic Intermediate Water. After being subducted into the thermocline, these waters circulate about the subtropical gyre and make their ways to the equator. Both interior and western boundary pathways are revealed, but the latter becomes increasingly important with depth. We hope that this study will initiate a more complete understanding of how the shallow subtropical cells relate to thermocline waters originating in the South Pacific and how variations in these waters contribute to climate variability.

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March 26, Thursday

Theme 3: The role of Argo in constraining Ocean Data Assimilation field

Chairman: Toshio Suga

26 March, 8:30-9:00, Invited (Th3-IT)

The Role of Argo for Global Ocean Analysis and Forecasting

P.-Y. Le **Traon**[1] and GODAE OceanView Science Team

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Over the past 10 years, GODAE has had a major impact on the development of global operational oceanography capability. Global modeling and data assimilation systems have been progressively developed, implemented and inter-compared. Argo data together with other in-situ and remote sensing data are now routinely assimilated in global ocean models to provide an integrated description of the ocean state. There has been increased attention to development of products and services and the demonstration of their utility for applications. GODAE main achievements will be briefly reviewed here and an outline of GODAE OceanView, the new sustained phase of GODAE, will be given. The presentation will then be focused on global ocean observing system issues and on links between GODAE/GODAE OceanView and Argo. We will first review the present use (validation, assimilation) and impact of Argo data in GODAE systems. Data assimilation issues will also be discussed. While there have been major progresses in the way Argo data are assimilated in ocean models, improvements are still needed for an effective use of Argo data in high resolution models. We will also summarize the main requirements and recommendations from GODAE as far as the Argo data system is concerned (*e.g.* real-time and delayed mode data streams, quality control issues, requirements for new products such as climatologies, gridded fields, deep current atlases). Some preliminary GODAE views on the required evolution of Argo mission will also be given. While the first priority should be to sustain the core mission (*i.e.* global T&S – 0-2000m – 3°x3° - 10 days), several evolutions should be considered (*e.g.* different space and time sampling depending on geographical areas, deeper measurements, under ice measurements, near surface measurements, marginal seas, new sensors such as O_2 and Chl-*a*). These recommendations should be based on an improved understanding of the impact and utility of Argo data for data assimilation systems and their applications.

26 March, 9:00-9:20 (Th3-T1)

Impacts of Argo Observations on the Pacific Ocean Data Assimilation

Ziwang Deng[1], Youmin **Tang**[1] and Guihua Wang[2]

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An assimilation system has been developed for Argo and XBT observations using local Ensemble Kalman filter (LEnKF), where the temperature and salinity were assumed to be uncorrelated in the prediction covariance matrix. With this assimilation system, Argo temperature-salinity (T-S) profiles from the surface to the depth of 1800 metres were assimilated into an oceanic general circulation models for the Pacific Ocean (120E-70W, 60S-60N), accompanying with the assimilation of XBT observations, for the period from 2005-2007. The preliminary results show that Argo T-S profiles significantly improved the simulation of temperature and salinity, especially for the southern Pacific Ocean. More sensitivity experiments are being performed to further investigate the impact of Argo observations on the assimilation. A better assimilation scheme considering T-S coherence is also under the way.

26 March, 9:20-9:40 (Th3-T2)

Impact Evaluation of Argo and Sea Surface Altimeter Data for the Reproducibility of FRA-JCOPE: An Ocean Prediction System for the Seas around Japan

Hiroshi **Yoshinari**[1], Akira Okuno[1], Takashi Setou[1], Daisuke Ambe[1], Yasumasa Miyazawa[2] and FRA-JCOPE Group[1,3,4]

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We investigated the impact of Argo and satellite altimeter (sea surface height) data assimilation for reproducibility of FRA-JCOPE, an ocean prediction system for the seas around Japan, by checking water mass vertical structure and sea surface velocity, respectively.

 In case of water mass vertical structure, we found obvious (statistically significant) difference between the Argo data assimilated reproductions; 'Argo assimilated', and the no Argo data assimilated reproductions; 'Argo non-assimilated' in the Subtropical Region, indicating that 'Argo assimilated' was more realistic. We also found slight differences (statistically insignificant) between the altimeter data assimilated and non-assimilated reproductions. 'Altimeter non-assimilated' was a little more realistic, implying that altimeter data assimilation system of FRA-JCOPE might not perform well.

For sea surface velocity, we found that altimeter data contributed to high reproducibility of the Kuroshio path in Kuroshio Region. In Kuroshio Extension Region, 'Argo assimilated' was more realistic than 'Argo non-assimilated', indicating that Argo data assimilation also plays important role to reproduce the path of the Kuroshio Extension. Furthermore, 'altimeter non-assimilated' was more unrealistic, indicating that assimilating altimeter data is also important to reproduce the sea surface velocity of the Kuroshio Extension.

These consequences described above suggest that both Argo and satellite altimeter data are essential to reproduce the ocean conditions around Japan as assimilated data to FRA-JCOPE system.

26 March, 9:40-10:00 (Th3-T3)

Ensemble Adjustment Kalman Filter Study for Argo Data

Xunqiang **Yin**[1,2], Fangli Qiao[1,2], Yongzeng Yang[1,2] and Changshui Xia[1,2]

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An ensemble adjustment Kalman filter system is developed to assimilate Argo profiles into the North-West Pacific MASNUM wave-circulation coupled model, which is based on the Princeton Ocean Model (POM). This model was recoded in FORTRAN-90 style, and some new data types were defined to improve the efficiency of system designing and execution. This system is arranged for parallel computing by using UNIX shell scripts; it is easier for single model running separately with the required information exchanged through input/output files.

Some tests are carried out to check the performance of the system: one for checking the ensemble spread and the other one for the performance of assimilation of the Argo data in 2005. The first experiment shows that the assimilation system performs well. The comparison with the Satellite derived sea surface temperature (SST) shows that modeled SST errors are reduced after assimilation; at the same time, the spatial correlation between the simulated SST anomalies and the satellite data is improved because of Argo assimilation. Furthermore, the temporal evolution/trend of SST becomes much better than those results without data assimilation. The comparison against GTSPP profiles shows that the improvement is not only in the upper layers of ocean, but also in the deeper layers. All these results suggest that this system is potentially capable of reconstructing oceanic data sets which are of high quality, and temporally and spatially continuous.

26 March, 11:00-11:20 (Th3-T4)

Benefit of Argo Data for the Global Mercator Operational Ocean Forecasting System

Fabrice **Hernandez**[1], Eric Dombrowsky[1], Marie Drévillon[1], Nicolas Ferry[1], Eric Greiner[2], Jean-Michel Lellouche[1] and Charles-Emmanuel Testut[1]

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Argo data are used weekly to constrain daily hindcast/nowcast of the Mercator forecasting system. Argo data are assimilated through the SAM filter, that allows first to reduce misfits of temperature and salinity on the top 2000-m, but also constrain the density field and the associated geostrophic flow. By the way, forecasting skill up to 14 days ahead are drastically improved at high latitudes, and wherever XBT lines and permanent moorings are lacking. However, it appears that few Argo data are provided at the very ocean surface. Thus, surface temperature corrections mostly rely on satellite SST, and there is a lack for correcting surface salinity fields, known to be impacted by errors on fresh water fluxes from NWP. It is important to mention that efforts made by the Argo community to provide data in near-real time (delay less than 1-5 days) also participate to the positive impact on Argo data to routine and operational forecasting.

In delayed time, ocean reanalysis are performed at Mercator. The benefit of Argo data is clearly evident on reanalysis estimates of the water masses after 2002. However, the reanalysis requires well calibrated data of temperature and salinity data that will not affect detection of long-term changes of ocean parameters (water masses, sea level, *etc.*).

In both operational and delayed time, Argo data are also used for validation of operational products and characterisation of forecasting system errors. An assessment methodology has been both implemented in the European MERSEA and international GODAE projects.

A global coupled biogeochemical/physical forecasting system is currently implemented at Mercator. Both for the assimilation or the assessment strategies, there is a clear need for biogeochemical observations provided in near real time. Argo profilers equipped with oxygen/carbon sensors will provide a very useful complementary set of observation for ocean operational products.

26 March, 11:20-11:40 (Th3-T5)

Adequacy of the Argo Array for Monitoring Water Mass Changes in the Gulf Stream Northern Recirculation Gyre

Denis **Gilbert**

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The northern recirculation gyre of the Gulf Stream, also known as the Slope Water region, is under the influence of cold, fresh, well oxygenated waters from the Labrador Current and warm, salty, less oxygenated waters from the Gulf Stream. I will present temperature, salinity and oxygen statistics at fixed depths and on isopycnal surfaces for this region (35°N to 48°N, 45°W to 75°W) calculated exclusively from data collected by PALACE and Argo floats between 1998 and 2009. In addition, I will present maps of winter mixed layer depth for this region, and I will examine the adequacy of the 300 km x 300 km Argo array for ocean climate monitoring in this region and for resolving the tongue of relatively cold, fresh and well oxygenated waters from the Labrador Current between the Tail of the Grand Banks of Newfoundland and the mouth of the Laurentian Channel. I will also try to determine whether the present spatial coverage of the Argo array is sufficient to reliably track interannual changes in the proportions of Labrador Current Water (LCW) and North Atlantic Central Water (NACW) in the Slope Water region. Finally I will present maps of dynamic height, calculated from a reference depth of 1000 m to the surface, indicating the mean path of the Gulf Stream.

Impact of Argo Temperature and Salinity Measurements in the New JMA Ocean Analysis System

Kazuhiko **Hayashi**[1], Shiro Ishizaki[1], Yosuke Fujii[2], Yoshiaki Kanno[1] and Yasushi Takatsuki[1]

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[2]   Meteorological Research Institute/JMA

Japan Meteorological Agency (JMA) started operational use of new ocean analysis system for the global ocean (MOVE-G) and for the western North Pacific (MOVE-WNP) in early 2008. In these systems, we use an ocean data assimilation system (MOVE/MRI.COM), developed by MRI and JMA. These systems improved the representation of ocean state, and provide good initial conditions to forecasting models. In order to investigate an impact of Argo temperature and salinity data on MOVE/MRI.COM, we conducted several assimilation experiments using MOVE-G and MOVE-WNP, respectively.

MOVE/MRI.COM consists of an ocean general circulation model (MRI Community Ocean Model (MRI.COM)) and a data assimilation system (Multivariate Ocean Variational Estimation (MOVE) System). The analysis scheme adopted in the MOVE system is a multivariate three-dimensional variational (3DVAR) analysis scheme with vertical coupled temperature-salinity Empirical Orthogonal Function (EOF) modal decomposition. The MOVE system assimilates *in situ* temperature and salinity profiles, and Sea Surface Height anomaly (SSHA) from satellite altimeter into the dynamical model. Incremental Analysis Updates (IAU) is adopted as the assimilation method.

In MOVE-G, the ocean model covers global ocean from 75°S to 75°N and its horizontal resolution is 1°. As for MOVE-WNP, the model domain spans from 117°E to 160°W zonally and from 15°N to 65°N meridionally, and the horizontal resolution is variable: it is 1/10° around Japan. In the operational system (both MOVE-G and MOVE-WNP), the ocean model is driven by wind stress and heat flux calculated with the JMA's operational Climate Data Assimilation System (JCDAS). For operational analysis, gridded sea surface temperature analysis data (COBE-SST for MOVE-G, and MGDSST for MOVE-WNP) is used as observation data as well as in situ temperature and salinity data (including Argo data).

We conducted two types of analysis runs using two datasets. In the first run, we used all *in situ* data which contain Argo measurement (ALL). The other run uses in situ data except Argo observation (NOARGO). These analysis runs were carried out using each of MOVE-G and MOVE-WNP. Provided the initial conditions from the result of these analysis experiments, we also made forecasting experiments using an atmosphere-ocean coupled model for the global ocean (MOVE-G) and a regional ocean model for the western North Pacific (MOVE-WNP).

In the global ocean experiment (using MOVE-G), Argo data have an impact in reproducing the temperature and salinity field around the equator, resulting in the improvement of El Niño prediction. On the other hand, a structure of the stratification in the subtropical region is modified in the regional analysis (using MOVE-WNP) with Argo data. The detailed results of these experiments will be shown and discussed.

26 March, 12:00-12:20 (Th3-T7)

Monitoring the Ocean State from the Observations

G. **Larnicol**, S. Guinehut, M.H. Rio, A.-L. Dhomps and G. Nicolas

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Producing comprehensive information about the ocean has become a top priority to monitor and predict the ocean and climate changes. Complementary to the modelling/assimilation approach, an observed based approach based on the combination all the observations provided by the Global Ocean Observing System (altimetry, sea surface temperature, temperature and salinity profiles, drifters, *etc.*) is proposed here. It consists to produce Global Observed Ocean Products (GooP) corresponding to 3D fields of temperature, salinity and velocity from the surface down to 1500m.

The study aims to demonstrate the impact of the Argo observing system and its complementary with other observing system such as altimetry for the monitoring the ocean variability.

In practice, three kinds of products are generated. First, accurate but sparse *in situ* T/S profiles data are merged with high resolution altimeter and SST data in order to reconstruct global instantaneous thermohaline fields from the surface down to 1500 m depth. Second, global instantaneous surface currents are derived from a combination of altimeter geostrophic currents, Ekman currents derived from wind-fields and *in situ* surface currents derived from drifting buoys. Thirdly, the combination of the two later products allows us to the retrieve the 3D velocity field.

A Global Observed Ocean Products re-analysis that covers the recent period (1993 to 2007) will be produced and assessed. Interannual variability of the whole ocean will be characterised in term of variation of heat content, transport, weakening or acceleration of the main features of the general circulation. Comparison with existing model re-analysis will be also presented.

Theme 3 Posters

Th3-P16

JMA's New Operational Ocean Analysis System for Monitoring the Western North Pacific

Kazuhiko **Hayashi**[1], Shiro Ishizaki[1], Norihisa Usui[2], Hiroyuki Tsujino[2], Yoshiaki Kanno[1] and Yasushi Takatsuki[1]

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An ocean data assimilation system, MOVE/MRI.COM-WNP, has been operated in Japan Meteorological Agency (JMA) from March, 2008. The purposes of the system are: understanding ocean variability in the western North Pacific as a local response to a global climate change using assimilated four-dimensional data sets, nowcasting and forecasting of ocean states, and a contribution to the GODAE project. MOVE/MRI.COM-WNP is an operational system which provides near-real time information about ocean states, and follows an original concept of GODAE, Argo and GHRSST.

MOVE/MRI.COM-WNP is one of the varieties of the MOVE/MRI.COM (MOVE : MRI Multivariate Ocean Variational Estimation). MOVE/MRI.COM system is composed of OGCM and a variational analysis scheme which synthesizes the observed information (*i.e.*, temperature, salinity and sea surface height) together with the OGCM. The domain of the ocean model of MOVE/MRI.COM-WNP extends from 15°N to 65°N, and 117°E to 160°W, with a grid spacing of $1/10° \times 1/10°$ around Japan. The OGCM used in the system is the MRI community ocean model (MRI. COM). The analysis scheme adopted in the MOVE/MRI.COM system is a multivariate 3DVAR analysis scheme with vertical coupled T–S EOF modal decomposition of a background error covariance matrix. The amplitudes of the coupled EOF modes are employed as control variables and the analyzed temperature and salinity fields are represented by a linear combination of the EOF modes in the scheme. The model temperature and salinity fields are corrected by the analysis result through the incremental analysis updates (IAU) technique.

Observing systems assimilated are temperature, salinity and along-track SSH observations. The temperature and salinity observations that contain ship hydrography, XBT, drifting buoy, Argo float are collected mainly through GTS network. The SSH data is the near-real time along-track data of Jason-1 and ENVISAT obtained from AVISO. JMA Real time global merged SST analysis, MGDSST (*i.e.*, Japan GHRSST), based on ship and satellite data is also adopted.

The assimilation run is implemented every five days, and the forecasting period of prediction is one month. The ocean model is driven by wind stress and heat flux calculated with the JMA's Climate Data Assimilation System (JCDAS) in assimilation run and forced by the result of the climate forecasting model in forecasting run.

MOVE/MRI.COM-WNP successfully reproduces the current field in the seas around Japan such as the Kuroshio, Oyashio and Tsushima Current, and it provides better SST prediction compared to the previous system. In this presentation, an outline of the MOVE/MRI.COM-WNP system and some results using the system will be shown.

Th3-P17

The Relationship between Jack Mackerel Fishing Grounds and Subsurface Temperature and Surface Salinity Outside Chile, Based on Argo Data

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Based on jack mackerel trawl data outside Chile of the Shanghai pelagic fishery company and Argo profile data from April to August of 2007, the CPUE of jack mackerel distribution maps whose format is 0.5°latitude by 0.5°longitude and temperature and salinity distribution maps of 50m and 75m layers in each month were drawn by Arcview software. The results show that the highest catch appeared in June, the highest CPUE in July. The most optimum SST is 12~12.5° and 11.5~12.5° in the 50m and 75m layers respectively; The 50m and 75m layers have same most optimum salinity is 33.9~33.95‰. The above result is authentic since it has been tested by K-S test.

Th3-P18

Study of Mesoscale Eddies in the Subtropical Ocean of the Northwest-Pacific Using Reanalysis Method

Zhongjie **He**, Guijun Han, Jirui Ma, Wei Li and Xuefeng Zhang

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Meso-scale eddies in the region of Subtropical Countercurrent (STCC) in the Northwest-Pacific are active and they are important ocean processes in such area. To study these eddies' three-dimensional structures, an ocean reanalysis system is constructed, which is based on the sigma-coordinate Princeton Ocean Model (POMs), and three-dimensional variational (3DVAR) ocean data assimilation. Using such reanalysis system, ten years of altimeter data, sea surface temperature data, Argo data and other temperature and salinity profile data are reprocessed. Based on the reanalysis data set, the eddies' characteristics, especially their three dimensional structures, are discussed.

Th3-P19

Numerical Study of the Kuroshio Front to the East of Taiwan

Wei **Li**[1,2], Jirui Ma[2], Guijun Han[2], Xuefeng Zhang[2] and Zhongjie He[1,2]

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In this paper, based on the stronger judgment criterion for oceanic thermal front, the thermal front information is extracted from the temperature profile observations in the study area. By using the hydrographical atlas and referring to related literatures, the temperature distribution trend of different levels is also analyzed. The results show that the surface thermal front to the east of Taiwan is not obvious, while there is an all-year strong Kuroshio thermal front under the surface. The sea surface height (SSH), 3-dimensional (3D) temperature, salinity and current in that area are numerically simulated. The result is consistent in the tendency with that from observations and atlas. There is more obvious Kuroshio thermal front from subsurface to 350m to the east of Taiwan; with depth increasing, both intensity and width of this thermal front has the tendency of decrease following increase; and the position of such thermal front tends to be eastward with the depth's increasing; such front is characterized by seasonal changes that the strongest strength and width are in summer and the weakest in winter.

The oceanic thermal front information is extracted from the satellite remote sensing sea surface temperature (SST) data of China Seas. It is found that the surface thermal front is not obvious if the strong criterion is adopted. In order to study the 3D multi-scale temperature variation rule of the Kuroshio front under the surface to the east of Taiwan and discuss the mechanism of frontogenesis, the SSH, 3D temperature, salinity and current are numerically reanalyzed in this frontal zone by assimilating satellite SSHa (sea surface height anomaly), SST, and all available temperature and salinity profile, including Argo profiles. The paralleled hybrid coordinates POMgcs is applied in this reanalysis. A new full-space multi-scale data assimilation method applicable to the analysis of the ocean front is developed.

Based on the reanalysis results above, by using the same stronger judgment criterion for oceanic front, the oceanic thermal front information is extracted. The climatology statistic results of the Kuroshio thermal front to the east of Taiwan are basically consistent with the above simulated results. From the maximum entropy spectral analysis, this thermal front not only has the significant annual cycle, but also has the significant multi-scale variation cycle, like 2.1a, 195d, 124d, 90d and 59d.By using the reanalysis results and the extracted thermal front information, the frontogenesis mechanisms of the Kuroshio thermal front to the east of Taiwan is studied. It is found through the diagnostic analysis that the contribution of the upwelling to this thermal front is three times than that of the Kuroshio warm advection, that is to say, the upwelling is the main mechanism for the frontogenesis and maintenance of this thermal front.

Th3-P20

Are Argo Data Useful for SST Analyses?

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The shallowest Argo temperature and salinity values are typically collected at about 5 m, deeper than the ~1 m measurements used to calibrate satellite data for bulk sea surface temperature (SST) analyses. Understanding the relationship between near-surface Argo data, bulk SST measurements, and SST analyses is important for improving the design of global ocean observations and for synthesizing the sub-surface and surface datasets in a range of applications.

For the period from 2004 to mid-2008, about 27,000 Argo profiles were found to have a nearby surface drifter temperature measurement from the Global Drifter Program. The Argo/drifter measurement pairs were further divided according to their space/time separation, time of day, wind speed, and geographic location. For the full collection, there was no statistically significant difference between Argo and drifter temperatures. The standard deviation of Argo/drifter temperature difference increased from about 0.4-degrees C at separations less than 10 km to 0.9-degrees C at 50 km. Closer examination showed the drifter measurements to be significantly warmer than Argo in a subset of daytime low-wind pairs of measurements. It is thought that Argo can provide useful estimates of bulk SST (and SSS) under moderate and stronger winds. Indeed a comparison of gridded near-surface Argo temperature with the NOAA Optimal Interpolation SST product (Reynolds *et al.*, 2002, which does not use Argo data) shows striking similarities in tropical Pacific temperature anomaly patterns. This illustrates the effectiveness of Argo's spatial sampling as well as the agreement between near-surface Argo and SST datasets.

Th3-P21

Determining Ocean Correlation Scales using Argo Float Data

Lorna M. **McLean** and Brian A. King

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The scales over which ocean properties vary play an important part in the assimilation of ocean data. In this study Argo data have been used to develop a method of estimating the correlation scales of salinity on a potential temperature surface. The correlation scales of salinity anomalies relative to a reference field from WOA05 have been examined. For the development of the method, test regions in the Pacific and Atlantic Oceans were chosen and scales estimated on the 6° theta surface (approximately 500 m in depth).

For data pairs in a region, the difference in salinity anomaly is found. 8 years of Argo data are used but pairs are only included when the observations fall within a 9-day window. The salinity differences are divided into 50 km bins according to the distance between the data points. The median salinity difference is then calculated for each bin. A curve is fitted to the data varying exponentially from the near field to a far field limit based on a function devised by Boehme and Send [2005, Deep Sea Research II, 52, 651-664]. By varying the scale parameter in the equation and finding the best fit to the data the correlation scale is found.

This method is used to examine variability of correlation scales with region and on varying potential temperature and depth levels. The variation of zonal scales with latitude is examined over the Pacific basin. Initial results show the zonal scales varying from 200 km at 50°S to 400 km between 30°S and 30°N. The zonal scale in high northern latitudes is found to be unexpectedly large with a value of 600 km.

Th3-P22

The Ideal Experiments of Sequential Filter and Variational Analysis Coupled Data Assimilation

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Develop a new data assimilation method: Sequential Filter and Variational Coupled data assimilation. Apply the Sequential Filter property of Ensemble Kalman Filter to the Background term of Three-Dimensional Variational data assimilation, using background field to adjust analysis field sequentially. Under Lorenz63 model and Global Barotropic Spectral model, ideal experiments show that this method is better than Ensemble Adjustment Kalman Filter and Three-Dimensional data assimilation respectively.

Theme 4: Seasonal to inter-annual variability as seen by Argo

Chairman: Stephen Riser

26 March, 14:00-14:30, Invited (Th4-IT1)

Upper Ocean Response to Tropical Cyclones Observed by Argo: Recent Progress and Future Needs

Dake **Chen**[1,2], Qiaoyan Wu[1] and Yuhua Pei[1]

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Although the main focus of Argo by design is not on transient and synoptic phenomena, the past decade has seen increasingly significant contribution of Argo data to our understanding of oceanic response to tropical cyclones (TCs) on regional as well as global scales. Argo profiling floats are advantageous for such research because they have no problem operating under the harsh conditions brought about by TCs, they as a network can track the footprints of TCs in the ocean, and they measure both temperature and salinity, thus providing a complete picture of upper ocean thermohaline structure and its variability in response to TCs. In this presentation we review some recent progress in the application of Argo data to this important research area and point out the needs for further improvement. Based on statistical analysis as well as case studies, we quantify the changes of the surface mixed layer depth, temperature and salinity caused by TCs, for different ocean basins, latitudes, forcing strengths and initial conditions. The results are compared to previous theoretical, modeling and observational work, and the reasons for agreements and differences are discussed. We also emphasize that one must exercise caution when interpreting Argo data in the context of TC impact, because the background variability, especially those due to the diurnal cycle and meso-scale eddies, can be as large as the changes induced by TCs. Finally, based on data analysis and theoretical argument, we make some tentative suggestions on the optimal temporal and spatial resolutions of Argo network to study upper ocean response to TCs, and to provide oceanic initial conditions for operational TC forecasting. This last point is of great interest because the development and intensification of TCs depend not only on the sea surface temperature but also on the entire upper ocean column. The lack of in-situ, real-time oceanic observations is a major limitation on the accuracy of present TC prediction, and the global Argo network has the potential to fill this gap.

26 March, 14:30-14:50 (Th4-T1)

Impacts of Typhoons on Kuroshio Large Meander: Observational Evidence

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When the Kuroshio flows in Shikoku Basin, the sea south of Japan, it occupies one of three different paths: the nearshore non-large-meander path, the offshore non-large-meander path and the large-meander path. The shift from one path to another would significantly cause oceanic changes and corresponding climatic changes due to the strong eddy-current interactions and air-sea interactions at the sea surface along the Kuroshio path. Besides, the variations of both shape and position of the current also have large influences on fisheries, ship navigation, marine resource, *etc.*

The formation of the Kuroshio large meander in summer 2004 was investigated by using the cruise data, Argo profiles data, and satellite remote sensing data. We firstly confirmed the former conclusion that cyclonic eddy contributes to the

large meander. Moreover, using the observation data, it was found that the cyclonic eddy accompanied with typhoons is the major factor of the Kuroshio large meander formation in summer 2004. From 29 July to 4 August, the typhoons stirred the ocean and upwelled the deep sea water, which enhanced the existed cyclonic eddy. The enhanced cyclonic eddy pushed the Kuroshio path to the south, and immediately made a right shift of the Kuroshio path with more that 100 km. This large meander of the Kuroshio path continued for about 1 year.

The impact of typhoons on the initial small meander will also be discussed. We found that the unexpected typhoons in June 2004 adversely affected the model skill, and also contributed to the initial meander at Tokara Strait. In this case, the pre-existing eddy was indispensable, as the most vigorous air-sea interaction due to typhoons always occurs near these eddies.

The results show an alternative meander mechanism of Kuroshio path via typhoon-eddy-Kuroshio interactions. As only the oceanic processes (inflow velocity, mesoscale eddies and local topography) were proposed to be the triggers of Kuroshio meander, it is argued that typhoons accompanied with cyclonic eddies, might also be crucial in the Kuroshio path meander. It implies that to accurately predict the Kuroshio path, the large synoptic processes, especially the typhoons, should be taken into account. This will likely provide a more comprehensive understanding of the dynamics of western boundary flows like the Kuroshio and the Gulf Stream.

26 March, 14:50-15:10 (Th4-T2)

Changes of the Temperature Tendencies in the Upper Levels of the Subtropical North Atlantic Ocean

Pedro **Vélez-Belchí**[1], Alonso Hernández-Guerra[2] and Eugenio Fraile-Nuez[1]

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The Atlantic Meridional Overturning Circulation contributes to moderate the climate in Europe through the northward transport of 25% of the global heat flux, reaching its maximum of 1.5 PW at around 24.5ºN. Consequently, the transatlantic oceanographic sections at this latitude, since the first occupation during the International Geophysical Year in 1957, have become a benchmark to monitor long-term changes in temperatures in the Atlantic, in order to understand the nature and causes of climate change. In this study, Argo data are used to investigate the time variation of temperature at 24.5ºN. The Argo global ocean observing system has evolved to the point that the goal of 3000 autonomous floats, providing temperature and salinity profiles from the surface to 2000 dbar at regular 10 day intervals, has just been achieved. Data from this network has been used to build up a synthetic section at 24.5ºN, with a sampling equivalent time equal to 2005. Data from two independent data-sets, the Argo synthetic section and the five oceanographic cruises carried out at 24.5ºN are used to quantify the temperature and salinity variation at this latitude. Results show, for the first time, that there has been a significant cooling (-0.13ºC) in the upper ocean (600-1800 dbar range) during the last seven years (1998-2005), contrary to the continuous warming (0.27ºC) observed in the previous forty years (1957-1998). This cooling significantly decreases the maximum upper-ocean warming found in 1998 to only 0.14ºC for the period 1957-2005, slightly higher than half of that found during the 1957-1998 period. Salinity shows a similar change in tendency to that found in temperature, with freshening since 1998. These results, together with oscillations in mode-water properties, sensitive indicators of ocean climate change, found in the Indian Ocean, and the reverse in the tendency of the deep waters of the Mediterranean Sea, a proxy for climate change, demonstrate that there are still important unknown mechanisms of ocean variability that complicate the understanding of ocean climate change.

26 March, 15:10-15:40 (Th4-T3)

Subsurface Primary Production in the Western Subtropical North Pacific as Evidence of Large Diapycnal Diffusivity Associated with the Subtropical Mode Water

Toshio **Suga**[1,2], Chiho Sukigara[1], Toshiro Saino[2], Katsuya Toyama[1], Daigo Yanagimoto[3], Kimio Hanawa[1] and Nobuyuki Shikama[2]

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Based on the extensive profiling float observation carried out as part of the Kuroshio Extension System Study (KESS), Qiu *et al.* (2006) reported large vertical eddy diffusivity (2-5 x10^{-4} m^2s^{-1}) near the upper boundary of Subtropical Mode Water (STMW). This large diffusivity possibly has an impact on subsurface redistribution of heat, nutrients and dissolved gas components, *etc.*, in the subtropical ocean. On the other hand, recent measurement of the turbulent kinetic energy dissipation rate by Mori *et al.* (2008) indicates much smaller vertical eddy diffusivity (10^{-7} -10^{-5} m^2s^{-1} over the whole depth range of STMW). However, a direct comparison between the estimate by Qiu *et al.* and that by Mori *et al.* is possibly inappropriate because the former is based on the PV change over a couple of months and the latter on instantaneous turbulent measurements.

We carried out physical and biogeochemical observation to examine the vertical diffusivity near the top of STMW using a profiling float. The profiling float, which was equipped with a fluorometer and a dissolved oxygen sensor along with temperature and salinity sensors, was deployed in the STMW formation region and acquired quasi-Lagrangian, 5-day-interval time-series records from March to July in 2006. The time-series distribution of chl.a showed a sustained and sizable deep chlorophyll maximum just above the upper boundary of the STMW throughout early summer. Vertically integrated chlorophyll in this period consistently ranged from 15-30 mgm^{-2}, indicating sustained primary production and a continuous supply of nutrients ranging from 10-30 mgNm^{-2}day^{-1}. The time-series data indicate no appreciable sporadic events to supply nutrients and instead support, along with vertical profiles of nitrate obtained by ship-board measurements near the float, the large vertical diffusivity reported by Qiu *et al.* Since our estimation of vertical diffusivity is based on temporal evolution of primary production over several weeks, it is fairly consistent with their estimation.

26 March, 16:00-16:20 (Th4-T4)

Decadal Changes of Antarctic Intermediate Water in the South Pacific

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Salinity observations at the depth obtained by the Argo floats in the South Pacific reveals that the Antarctic Intermediate Water (AAIW), which is characterized by the minimum salinity at 800-1500 m depth, has become fresher since the 1990s. Compared with the hydrographic data in the South Pacific since the 1970s, this freshening trend is similar to that from the 1970s to 1980s, but reverses the salinity trend from the 1980s to 1990s. Furthermore, the depth of the AAIW, *i.e.* the depth where the minimum salinity is found below the thermocline, shows similar properties. The fresher AAIW is located shallower, at the depth of about 600-800 m during the 1980s and 2000s, and the saltier AAIW located deeper at the depth of about 900-1100 m during the 1970s and 1990s. This demonstrates the substantial decadal variability of the AAIW in the South Pacific. The dynamics of these decadal variations is related to the precipitation and the upper ocean T-S variability in the South Pacific and Antarctic Circumpolar Circulation.

26 March, 16:20-16:40 (Th4-T5)

Seasonal and Interannual Variation of North Pacific Subtropical Mode Water in 2003−2006

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Temperature and salinity data from 2003 through 2006 from Argo profiling floats have been analyzed to examine the formation and circulation of the North Pacific Subtropical Mode Water (STMW) and the interannual variation of its properties over the entire distribution region. STMW is formed in late winter in the zonally-elongated recirculation gyre south of the Kuroshio and its extension, which extends north of ~28ºN, from 135ºE to near the date line. The recirculation gyre consists of several anticyclonic circulations, in each of which thick STMW with a characteristic temperature is formed. After spring, the thick STMW tends to be continually trapped in the respective circulations, remaining in the formation region. From this stagnant pool of thick STMW, some portion seeps little by little into the southern region, where southwestward subsurface currents advect relatively thin STMW as far as 20ºN to the south and just east of Taiwan to the west. The STMW formed in the recirculation gyre becomes colder, less saline, and denser to the east, with an abrupt change of properties across 140ºE and a gradual change east of 140ºE. The STMW formed east of 140ºE exhibits coherent interannual variations, increasing its temperature by ~1ºC from 2003 through 2006 and also increasing its salinity by ~0.05 from 2003 through 2005. These property changes are clearly detected in the southern region as far downstream as just east of Taiwan, with reasonable time lags.

26 March, 16:40-17:00 (Th4-T6)

Seasonal Cycle, Interannual Variability and Associated Heat and Freshwater Content Changes in the Subpolar North Atlantic Inferred from Argo, Hydrographic and Moored Measurements

Igor **Yashayaev**[1] and Michael Dunphy[2]

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Argo floats provide real-time monitoring of temperature and salinity in the upper 2000 m layer of critical basins of the world ocean. In the northern North Atlantic, and particularly in the Labrador Sea, the continuous Argo observations resolve seasonal cycles of key parameters, reveal major water-mass developments, portray gain, loss and redistribution of heat and freshwater, and just nicely complement the annual snapshots from repeat hydrographic surveys.

Regional time series of vertical temperature and salinity structure based on the Argo and moored measurements are extremely useful for analysis of convective overturning varying in strength and duration from year to year, and identification of pathways and arrival times of newly-formed waters.

The Argo observations also help to track continuity of ocean climate signal and its possible disruptions. One of such disruptions was recently observed in the Labrador Sea. An oceanographic survey and Argo float profiles have revealed that convective overturning extended to a depth of about 1600 m during the winter of 2008, producing a large "year class" of Labrador Sea Water and disrupting a steady warming of the intermediate-depth waters since 1994.

Annual cycles of regional heat and freshwater content derived from Argo data have are consistent with annual curves of cumulative heat transfer through the sea surface. The Argo-based estimates combined with the net surface fluxes provide a means for inferring horizontal advection of heat and freshwater in the ocean.

27 March, Friday

Theme 4: Seasonal to inter-annual variability as seen by Argo (Continued)

Chairman: Muthalagu Ravichandran

27 March, 8:30-9:00, Invited (Th4-IT2)

Use of Argo Data in Ocean Forecasting Systems at the UK Met Office

Matthew **Martin**, R. Barciela, E. Blockley, R. Furner, C. Guiavarc'h, A. Hines, D. Lea, R. Mahdon, M. McCulloch, D. Storkey, D. Smith and D. Peterson

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Forecasting Ocean Assimilation Model (FOAM) system produces daily operational analyses and forecasts of deep ocean and sea-ice parameters. A major upgrade to the system has recently been developed which includes changes to both the model and data assimilation components. The model has been changed to use the Nucleus for European Modelling of the Ocean (NEMO) system in a 1/4 degree resolution global configuration, with nested 1/12 degree resolution regional configurations in the North Atlantic, Mediterranean and Indian Ocean. The FOAM data assimilation scheme, based on an Optimal Interpolation method, has been made to work with this new model and some improvements to the scheme have been included which enable better use to be made of the data. These include a more accurate calculation of the model equivalent of the observations (using a first-guess-at-appropriate-time scheme) and improved specification of the background and observation error covariances. Validation of the new FOAM-NEMO system has been performed using a number of metrics including comparisons with observations prior to assimilation, with independent data and with results from other GODAE forecasting systems. Routine monitoring of the performance of the new system is also carried out. A description of the new system will be presented, together with an overview of the validation and monitoring.

The UK Met Office runs two other ocean forecasting systems which make predictions on longer time-scales. The GloSea system is a coupled ocean-atmosphere forecasting system which makes predictions on seasonal time-scales using a similar data assimilation scheme to the FOAM system; and the DePreSys system makes coupled climate predictions on decadal time-scales. A brief overview of the use of Argo data in these systems will be given, with some results from studies into the impact of the data on their predictions.

27 March, 9:00-9:20 (Th4-T7)

Interannual Variability in the Tropical Indian Ocean Subsurface Temperature from Argo Observations and its Climatic Impacts

C. **Gnanaseelan**[1] and J.S. Chowdary[2]

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The optimally interpolated temperature profiles from Argo and Expendable Bathy Thermographs and a data assimilative ocean model simulations are used to understand the subsurface temperature variability in the tropical Indian Ocean from 2000 to 2007 with special emphasis on the Indian Ocean Dipole (IOD) events and basin scale winter warming events. The study highlights the importance of Argo observations in mapping the vertical structure of the tropical Indian Ocean. Questions such as what is the vertical extent of the temperature anomalies associated

with IOD forcing and the vertical extent of basin scale warming associated with the El Nino forcing are answered in this paper. The anomalous deepening of the Seychelles thermocline ridge is observed from October 2006 to April 2007. This deepening of the thermocline and subsequent warming in the western equatorial Indian Ocean are due to downwelling Rossby waves from the east and local Ekman pumping. Subsurface temperature anomalies over 4oC are observed in the eastern and western basin and these anomalies penetrated beyond 250m depth. Consistent basin scale winter warming (surface) is observed in the entire tropical Indian Ocean during 2006-2007 and 2002-2003. The basin scale subsurface winter warming is found up to 100m and is restricted only to the western basin during winter 2006-2007. Whereas, the subsurface anomalies during 2002-2003 were limited to surface only. This study provides the observed three dimensional view of the entire tropical Indian Ocean basin. Similar to the up-eastward propagation of warming associated with El Nino in the Pacific, Argo profiles revealed a pronounced up-westward propagation of subsurface warming in the southern tropical Indian Ocean associated with Rossby waves traveling on the sloping thermocline. With the thermocline deepening by 80 m, a thick barrier layer forms and propagates with the Rossby wave, potentially contributing to the mixed layer warming. The mixed layer warming associated with these events contributes to anomalous monsoon circulations over India and maintains active convection and a cyclonic circulation in surface wind over the southwest tropical Indian Ocean.

27 March, 9:20-9:40 (Th4-T8)

Seasonal and Interannual Variability of Sea Surface Salinity during 2002-06 from Argo Profiles in the Tropical Indian Ocean

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The seasonal and interannual variability of Sea Surface Temperature (SST) in the tropical Indian Ocean are well documented from in situ observations, satellite measurements, model simulations *etc.* At interannual time scales the variability in SST in the Equatorial Indian Ocean (EIO) is interesting with observed anomalous intense cooling off the Java/Sumatra coast in the eastern EIO and warming in the western/central EIO during boreal winter, a phenomenon widely known as the positive Indian Ocean Dipole Zonal Mode (IODZM) event. During the positive (negative) IODZM event, the eastern EIO exhibits anomalous cooling (warming) with negative (positive) SST anomalies. However, studies on the seasonal variability of salinity are limited to the climatological data sets only, whereas the studies on the interannual variability of salinity are in progress with the launch of Argo program in the tropical Indian Ocean. In this presentation, we present the analysis of Argo data from the EIO, southeastern Arabian Sea and Bay of Bengal during 2002-2006 and discuss the seasonal and interannual variability in selected 5 x 5 degree grid boxes. The boxes are the EIO: 5°S-5°N, 90°-95°E, Southeastern Arabian Sea (SEAS: 5°-9°N, 72°-76°E) and western Bay of Bengal (BoB: 12°-15°N, 80°-85°E). The observational period covered one strong negative IODZM event in 2005 and positive IODZM events in 2002, 2003 and 2006. The interannual variation in sea surface salinity (SSS) is obtained as the SSS anomaly (SSSA) from the 5 year seasonal mean SSS. The Argo profiles in each box captured the impact of these IODZM events with a larger impact in the EIO box showing salting (positive SSSA, +0.9 PSU, Practical Salinity Unit) during negative IODZM (November 2005) and freshening (negative SSSA,   -0.6 PSU) during positive IODZM (November 2006). The impact is similar, with reduced magnitudes, in the SEAS box and opposite in the BoB box. We will also discuss the Hybrid Coordinate Ocean Model (HYCOM) simulations and Ocean General Circulation Model (OGCM) simulations and satellite altimetry observations for the same period to understand the dynamics behind the interannual variability in sea surface salinity. This study reveals that the anomalous surface circulation during IODZM events and the westward propagation of annual Rossby waves are responsible for the observed interannual variability of SSSA in the boxes.

27 March, 9:40-10:00 (Th4-T9)

The Mean-depth Circulation of the Atlantic with Argo Float Displacements from the ANDRO Atlas (AOML and Coriolis Data only)

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Argo float displacements from AOML and Coriolis DACs were carefully scrutinised and corrected for errors in the drifting depths. Grounded cycles were excluded as well as erroneous ARGOS surface fixes. An atlas of subsurface displacements with the same format as YoMaHa'07 has been generated, named ANDRO for the name of an old celtic dance of Brittany. Almost 15% of ANDRO parking depths differ from the YoMaHa'07 corresponding ones.

10-day deep float velocities were box-averaged over a 1 by 1 grid, within layers (200 dbar thick) centred near 400, 1000, 1500 and 1900 dbar. Alternating zonal currents are clearly revealed between 20S and 20N. The bathymetry exerts a strong control in mid latitude and polar regions.

A few regions are still lacking data, even for the best sampled level (1000 dbar), in particular the shadow zones near Africa near 10S and 10N.

A comparison is done between the absolute mean flow field at intermediate depths (700 to 900 dbar) obtained from acoustic floats and ALACE floats over the past decade and the mean flow field (900 to 1100 dbar) from Argo over the present decade.

Besides AOML and Coriolis data (65% of world data), we are presently working to include JMA data (15% of world data) into the ANDRO atlas. It is also scheduled to treat along the same lines the rest of data (from BODC, MEDS, CSIRO, KMA, KORDI and CSIO DACs) before the end of 2009.

A second version of ANDRO is under development. It will contain deep displacements estimated from extrapolated surface positions at plunging and surfacing times.

27 March, 10:00-10:20 (Th4-T10)

Sea Surface Temperature Characteristics of the Western Pacific Warm Pool*

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We have examined historical distributions of sea surface temperature (SST) observations in a data set consisting of a combination of the Argo data and World Ocean Database 2005(WOD05) data in the western Pacific warm pool. The number of SST samples taken per year in the western Pacific warm pool rose exponentially during the main period from 1900 to 1990, and then decreased slightly after the early 1990s. The number of samples rose greatly since the Argo observations network, in particular from 2000. We found most frequency histograms to be non-Gaussian and left-skewed for the SST with three-degree grids in the western Pacific warm pool. The main departure from Gaussian distribution is caused by the negative skewness due to anomalous low-temperature measurements, which is also verified by examining statistics of mean-median SST difference. The non-Gaussian nature of the SST distributions in the western Pacific warm pool is a significant phenomenon. The studies show the Argo is useful to determine the characters of SST in the western Pacific warm pool.

27 March, 11:00-11:20 (Th4-T11)

On the Permeability of Barrier Layers Observed by Argo Floats

Clement de **Boyer Montégut**[1], J. Mignot[2], M. Tomczak[3], F. Durand[4], R. Bourdallé-Badie[5] and B. Blanke[6]

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A Barrier Layer (BL) exists in ocean regions where the temperature immediately below the surface mixed layer is either the same or slightly higher than the temperature in the mixed layer itself. It received its name (Godfrey and Lindstrom, 1989) from its property of inhibiting turbulent and entrainment heat exchange between the atmosphere and the subsurface ocean. During a recent oceanographic campaign in the central equatorial Pacific Ocean, it became evident that stations with BL alternated with stations where a BL was not found. The observed BL patchiness has the potential to modify the importance of the BL on air/sea heat exchange, since the BL can only effectively obstruct the heat transfer if it is continuous over a sufficiently large area. If the BL is dotted with "holes" its role as an inhibitor of heat transfer can be greatly reduced.

To investigate this further, we decided to repeat the analysis of de Boyer Montégut *et al.* (2007) with a slightly amended methodology. This new approach became reliable especially thanks to the great amount of Argo profiles available since then. For this revisited global ocean climatology of BL thickness, we propose a modified computation method in order to take into account the observed permeability of BLs. We name permeability the fact that BLs can, in some areas, be very patchy relatively to the space and time scales we consider here (2 degrees, 1 month). Differences between the two approaches are weak for robust BLs that are formed by large-scale processes. The analysis of de Boyer Montégut *et al.* (2007) however largely underestimates the thickness of BLs formed by mesoscale mechanisms (in south Arabian Sea and under the ITCZ in particular) and patchy BLs detected in the mid latitudes. In those regions, dedicated observations and/or an increase in Argo floats could give more insights in the space and time scales of BLs. A special focus on the BL of the south Arabian Sea has been done. Using both Argo data and an ocean model, we show that the mechanism at play for this BL formation indeed is strongly linked to mesoscale processes. Complete characterization of regional BL dynamics therefore requires the description of BL robustness through the determination of both BL thickness and BL permeability.

27 March, 11:20-11:40 (Th4-T12)

Decadal Time-scale Salinity Changes in the Subtropical Thermocline in the North Pacific Ocean Observed from Argo Floats

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Argo float data from the period 2003-2006 in the North Pacific Ocean is used to detect decadal-scale salinity changes in the North Pacific Ocean. The data show that significant salinity changes have occurred in the North Pacific thermocline relative to data collected during the WOCE hydrographic program 10-20 years earlier. Such a salinity decrease on both isopyncals and isobars implies a freshening scenario in the surface source region of this water mass. Data from the frequently-repeated meridional section P16 can be used to show the evolution of these changes. The spatial distribution of salinity difference on the $\sigma\theta = 25.5$ surface is examined through comparison of Argo data and most of the North Pacific WOCE sections (1985-1994), historical data during 1970s-1990s, the Hydrobase climatology. All these comparisons indicate a large-scale, basinwide decrease in subsurface salinity between the last decades of the 20th century and the Argo time period. This signal is maximum in the northeast area and spreads southward and westward, generally following geostrophic streamlines. The near-surface salinity also freshened over this time period and is consistent with the repeat meridional section analysis.

Subtropical Subsurface High Salinity Water in the North Pacific

Qinyu **Liu**, Lixiao Xu, Wei Wang and Haibo Hu

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Based on the analysis of observation data by Argo floats during 2004-2008, some features of the Subtropical Subsurface High Salinity Water (SSHSW) in the North Pacific have been confirmed: there are two kinds of SSHSW, one is water with high salinity (>34.8) in the upper mixed layer and below the mixed layer, other is water with low salinity (<34.8) in the upper mixed layer and high salinity (>34.8) below the mixed layer. Both SSHSW appears on the seasonal pycnocline between $23.2\sigma\theta$ and $25.2\sigma\theta$. The second kind of SSHSW is located west or south of the North Pacific Subtropical Gyre and between 100-300m; on the isopycnal surface of $24.0\sigma\theta$, after the surface high salinity water is subducted and the SSHSW forms in the area (20-30°N, 160°E -145°W), the SSHSW is transported southwestwards by the North Equatorial Current (NEC) and arrives at east of the Philippine Island. On the isopycnal surface of $25.2\sigma\theta$, the SSHSW forms at two places in the 25-30°N zonal band in late winter, one is the east area (160°W -145°W) and other is the west area (160°E-170°E), and the SSHSW is transported to east of Taiwan and Ryukyu Islands. Most of the SSHSW in the North Pacific cannot be transported to the Equatorial Pacific directly, but there is the possibility that a few of the SSHSW in the North Pacific can be transported to the Equatorial Pacific by the western boundary current in low latitudes.

Theme 4 Posters

Th4-P23

How Has Argo Helped Us Understand the Climate of Our Oceans?

Simon Good, Matthew **Martin**, Matt Palmer, Nick Rayner, Rob Smith, Nick Dunstone, Peter Stott and Richard Wood

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This presentation will outline some of the many ways in which Argo data have helped us to understand the climate of our oceans. We focus on the uses these data have been put to by researchers at the Met Office Hadley Centre.

We discuss recent work comparing estimates of ocean warming from observations and climate models and detection and attribution studies of ocean temperature and ocean salinity, *inter alia*.

We show the importance of Argo for successful decadal predictions, using results from the Met Office Hadley Centre Decadal Prediction System.

We present results from an investigation of deep water formation in the western basin of the Mediterranean Sea using Argo data.

We provide a first assessment of how newly available near-surface SST data from Argo floats compares to those from other platform types such as Voluntary Observing Ships, drifting buoys and moored buoys.

Th4-P24

Structure and Modification of the South Pacific Eastern Subtropical Mode Water

Kanako **Sato**[1] and Toshio Suga[1,2]

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Using all available temperature and salinity profiles obtained by Argo floats from July 2004 to June 2007, this study investigated the structure and modification of the South Pacific Eastern Subtropical Mode Water (SPESTMW). Based on the observed characteristics of the vertical minima of potential vorticity over the subtropical South Pacific, SPESTMW is defined as water with potential vorticity magnitude less than $2.5 \times 10\text{-}10$ $m^{-1} \cdot s^{-1}$ and thickness exceeding 40 m. It is found between 35°-5°S and 160°-70°W and has a temperature of 13°-26°C, salinity greater than 34.0, and density of 24.5-25.8 $kg \cdot m^{-3}$ at its core.

This study confirmed that vertical changes in temperature and salinity tend to compensate for each other in terms of density changes, resulting in favorable salt fingering conditions, as previously reported. By analyzing many profiles of Argo data in spring immediately after the SPESTMW formation period, its temperature and salinity are vertically uniform in the formation region, but large vertical gradients of temperature and salinity are found downstream from that region, even in the SPESTMW core. Consequently, the low potential vorticity signature of SPESTMW spread much wider than its signature as a thermostad. The Argo data also captured the seasonal change of the vertical gradients of temperature and salinity at the SPESTMW core; these gradients increased as the seasons progressed, even in the formation region. Therefore, SPESTMW is truly vertically uniform water (*i.e.*, thermostad, halostad, and pycnostad simultaneously) only immediately after the formation period. Afterwards, it is only pycnostad. This seasonal evolution is related to temperature and salinity diffusion due to salt fingering in a manner similar to the rapid modification of interannual anomalies as shown by Johnson (2006). Temperature and salinity near the SPESTMW core and lower region decreased soon after its formation.

Th4-P25

Interannual Variability in the Mindanao Eddy and its Impact on Thermohaline Structure Pattern

Qilong **Zhang**, Hui Zhou and Hongwei Liu

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The Mindanao Eddy (ME) is a conspicuous cyclonic eddy between Mindanao Island and New Guinea Island. Therefore, it has been investigated widely since 1937. Owing to the lack of the long-term observed data, however, the ME interannual variability and its impact on thermohaline structure are very unclear so far. Hence, we adopted the Argo data, the temperature and salinity data observed on Section 137°E and the SODA data to investigate the ME vertical structure, interannual variability and variability causes and its impact on thermohaline structure to further understand the thermohaline structure pattern variability of the northwestern Pacific Ocean.

The analyses showed that the ME is a permanent meso-scale eddy and it can range vertically from around 500m depth to about 50m depth. In addition to its strong seasonal variability, the ME displays a remarkable interannual variability associated with ENSO. It strengthens and expands eastward during El Niño while it weakens and retreats westward during La Niña. The correlation analyses suggest that the ME interannual variability may result from the North Equatorial Counter Current, the North Equatorial Current, the Mindanao Current and the Indonesian Throughflow. Further analysis reveals that the ME variability affects greatly the thermohaline structure pattern in the local upper ocean. When the eddy is very strong, the cold and low salinity water inside the eddy moves violently upward from deeper layers, the thermocline depth evidently shallows, the subsurface high salinity water reduces largely and the upper mixed layer becomes very thin; and vice versa.

Th4-P26

Is ENSO Responsible for the Recent Indian Ocean Dipole Events?

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During 2006-2008, the Indian Ocean (IO) experienced a rare realization of three consecutive positive IO Dipoles (pIODs), including an unusual occurrence with a La Niña in 2007. Common to all three pIODs is an early excitation of equatorial easterly anomalies. Argo profiles reveal that for the 2008 and 2006 pIODs the wind anomalies are generated by the following process: upwelling Rossby waves propagating into the thermocline dome and their subsequent reflection as equatorial upwelling Kelvin waves enhance the seasonal upwelling, changing sea surface temperature (SST) gradients. For the 2007 pIOD, coastal upwelling Kelvin waves off the Sumatra-Java coast associated with the 2006 pIOD/El Niño, radiate into the IO as upwelling Rossby waves. They curve sharply equatorward to arrive at the central equatorial IO, inducing easterly anomalies, upwelling Kelvin waves, and the unusual pIOD. Our results suggest that real-time Argo observations, when assimilated into predictive systems, will enhance IOD forecasting skills.

Th4-P27

Recent Global Changes in Surface Layer Salinity Based on Argo Floats

Shigeki **Hosoda**[1], Toshio Suga[1,2], Nobuyuki Shikama[1] and Keisuke Mizuno[1]

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We investigated surface layer salinity distributions and characteristics of those spatial and temporal variations in the global ice-free ocean. Surface layer salinity is one of the most important measures indicating the condition of an ocean. However, due to a lack of temporally and spatially homogeneous salinity data, previous observational studies did not detail global changes in surface layer salinity. Since the start of the Argo Project in 2000, the development of the Argo float is increasing and the Argo float array has allowed us to document changes in global salinity. In the climatology calculated using historical data in 1970-1989, the surface layer salinity is generally lower in the subpolar and tropical regions and higher in the subtropics. We compared the annual averaged surface layer salinity distribution in 2003-2007 with the climatology and found a general enhancement of lower and higher surface layer salinity, except in the North Atlantic Ocean. Since direct estimation of evaporation and precipitation (E-P flux) by observations is difficult at the sea surface, estimating the E-P flux from oceanic salinity is an effective alternative. We estimated the changes of basin-scale E-P flux associated with the enhancement of the global hydrological cycle from the surface layer salinity in 2006. The result shows that the strength of the global hydrological cycle is enhanced by a few percent compared to that 25 years ago. Our result shows that surface layer salinity change is a useful proxy to detect long-time climate change or trend, such as global warming.

Th4-P28

Vertical Structures of the North Pacific Mode Waters

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Vertical structures of mode waters in the North Pacific are investigated using the Argo data from 2001 until 2007. As parameters of vertical structures, the vertical gradient of water properties and the Turner angle are used. Four mode waters in the North Pacific, Subtropical Mode Water (STMW), Eastern STMW (ESTMW), Central Mode Water (CMW) and Transition Region Mode Water (TRMW) are defined as thick (> 100 dbar) low potential vorticity $(PV < 2.0 \times 10^{-10} \ m^{-1} \ s^{-1})$ waters with specific water properties within specific areas.

The temperature gradient and density gradient of SMTW is a linear relationship and the salinity gradient of STMW is very small. The density gradient of STMW is mostly determined by the temperature gradient. On the other hand, the gradient of salinity and that of temperature of CMW, ESTMW and TRMW are relatively large and take various values in wide ranges. It is suggested that these three mode waters have density compensating stratification of temperature and salinity.

In the low-PV portion of STMW, the Turner angle is less than 60º and vertically homogeneous. Tu in the low-PV portion of CMW is mostly homogeneous with 60 – 70º. Tu of ESTMW and TRMW, on the other hand, have different structures in the upper and lower side of the low-PV portion. In the lower side of ESTMW and in the upper side of TRMW, Tu is larger than 70º on average, indicating active salt finger type convection. In the upper side of ESTMW and in the lower of TRMW, Tu is less than 70º, suggesting relatively stable stratification.

Salt finger type convection possibly modifies temperature and salinity of ESTMW and TRMW from the lower and upper side of those, respectively. T/S modification by double diffusive convection appears relatively small in the case of STMW and CMW.

Th4- P29

A Revisit of the Reason Why the Properties of the Central Mode Water in the North Pacific Changed Associated with Regime Shifts

Toshio Suga[1,2], Kanako **Sato**[1], Shigeki Hosoda[1], Hiromichi Ueno[1], Nobuyuki Shikama[1], Taiyo Kobayashi[1], Naoto Iwasaka[1,3], Eitaro Oka[1,4] and Masami Nonaka[5]

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The Central Mode Water (CMW) is known as a water mass in the lower part of the ventilated pycnocline in the North Pacific subtropical gyre. It was reported that CMW got warmer, saltier and lighter remarkably just after the regime shift at the end of 1980s (Suga *et al.*, 2003). This change was considered to result from the decrease of heat and freshwater losses at the sea surface in the CMW formation region accompanied by weaker westerly wind. However, it was recently found using atmospheric reanalysis data that the change of these factors was not large enough to explain the change of CMW properties. Rather, a high-resolution OGCM indicated that the increase of the sea surface temperature and salinity in the CMW formation region might be due to northward movement of the Kuroshio Extension and acceleration of the upstream Kuroshio Extension jet. Therefore, we hypothesize that the dynamical change of the Kuroshio Extension affects a northward supply of high temperature and salinity water to the northern margin of the subtropical gyre and makes the CMW properties change.

To inspect this hypothesis, we analyzed Argo data from 2000. The Kuroshio Extension moved southward rapidly at the beginning of 2006, although the shift was small compared to that at the end of 1980s. Associated with this shift, sea surface temperature and salinity in the area north of the Kuroshio Extension decreased from January to March in 2006. Temperature and salinity at the core of CMW observed from May to September in 2006 also decreased compared to those in 2005 by 1°C and 0.1, respectively. Although heat and freshwater losses in the CMW formation region increased in winter of 2006, the change of these factors was not large enough to explain that of CMW properties. Thus, the change of CMW properties in 2006 supports our hypothesis.

Th4-P30

The Indo-Pacific Ocean Warm Pool and the South China Sea Summer Monsoon Onset

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In order to explore the impacts of Indo-Pacific Ocean subsurface water temperature on the monsoon over the South China Sea, measurements such as Argo profiles are used to analyze the impacts of Subsurface Ocean Temperature Anomaly (SOTA) in the Indo-Pacific Ocean Warm Pool on the South China Sea Summer Monsoon. The results show that earlier (or later) onset of the South China Sea Summer Monsoon is the main phenomenon in year when SOTA of the Indo-Pacific Ocean Warm Pool is warmer (or colder) in January. The mechanisms are as follows. If in January SOTA of the Indo-Pacific Ocean Warm Pool is warmer, the Walker Circulations may be enhanced. In May the Western Pacific Subtropical High is weaker, its central position shifts northwards and eastwards, and a cyclonic anomaly circulation appears in the lower troposphere over the South China Sea and Western Pacific Ocean, which is helpful for the strengthening of west to southwest lair stream in the lower atmosphere and induces the earlier onset of South China Sea Summer Monsoon. On the contrary, if in January SOTA of the Indo-Pacific Ocean Warm Pool is colder, Walker Circulations may be weakened and Walker Circulation may also move eastwards. Then in May the Western Pacific Subtropical High is stronger, its central position shifts southwards and westwards, and an anticyclonic anomaly circulation appears in the lower troposphere over the South China Sea and Western Pacific Ocean, which is detrimental

for the strengthening of west to southwest air streams in the lower atmosphere and induces the later onset of South China Sea Summer Monsoon. The conclusion of this work is: onset of the South China Sea Summer Monsoon comes earlier (or later) in year when SOTA of the Indo-Pacific Ocean Warm Pool is warmer (or colder) in January.

Th4-P31

The Air-Sea Interface Heat Exchange of the Typhoon

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In order to explore the interaction between typhoons and the ocean, the heat exchanges at the air-sea interface of seven typhoons in 1986 are calculated using observational data in this paper. It shows that the air-sea interface heat exchange of the typhoon is very strong. The main contribution to the heat is from latent heat fluxes (Qk). In the circumfluence of the typhoon, both of the water temperature and the air temperature dropped. The air temperature dropped more obviously. In summer, sensible heat fluxes are negative in the circumfluence of the typhoon, and the net long wave radiation appears to be very weak. But in spring and autumn, the sensible heat fluxes and the net long wave radiation in the circumfluence of the typhoon become stronger. In the circumfluence of the typhoon, absorbing short wave radiation by the sea surface becomes weaker. And the effect from relative humidity on the air-sea interface heat exchange is obvious. Conclusion: the main trend is the typhoon responding to the ocean.

T4-P32

Global Decorrelation Radii Maps of Temperature and Salinity Variability Based on Argo Float Data

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We calculated spatial and temporal decorrelation radii of temperature and salinity variability on the basis of Argo float data. The data is accumulated for about ten years, which enables us to obtain some statistical parameters in the upper layer temperature and salinity of the world ocean, such as decorrelation radii. The decorrelation radii are important (1) to estimate appropriate temperature and salinity fields using optimal interpolation methods and (2) to understand ocean variability. However, the decorrelation radii of temperature below the thermocline and of salinity were not offered yet due to a lack of historical data. Because the quality of Argo data is uniform, the quality of the radii is expected to be better than that obtained using the other data. Since the time series of the data is still too short to describe inter-annual or decadal variability and the temporal resolution is 10 days, we focused on the intra-annual or seasonal variability. For describing such time scales, we prepared spatial and temporal averaged data in 3x3 grids each 10 days. The distributions of spatial and temporal decorrelation radii are different in temperature and salinity, especially in the surface layer and below the thermocline. The temporal decorrelation radii of temperature are 60 days in most regions and the seasonal cycle is dominant. On the contrary, those of salinity are smaller than temperature and the variability is not periodical. The spatial and temporal decorrelation radii in the horizontal distribution are smaller in mid-latitude than in the other region. This may be associated with mesoscale eddies. They also change with the vertical gradient of temperature and salinity. These results indicate that such statistical parameters should be defined as horizontal, vertical and temporal functions in temperature and salinity fields.

Th4-P33

Southern Ocean Variability from Seal-mounted Sensors and Argo Floats

Sally **Close**[1], Alberto Naveira Garabato[1], Elaine McDonagh[1], Lars Böhme[2], Brian A. King[1], Mike Fedak[2] and Martin Biuw[3]

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Between 2004-5, as part of the Southern Elephant seals as Oceanographic Samplers (SEaOS) project, Conductivity Temperature Depth Satellite Relay Data Loggers (CTD-SRDL) were deployed on Southern Elephant seals in the Southern Ocean. Data obtained during the SEaOS project will be used alongside Argo data (covering the period 2002 onwards) and available historic hydrographic ship-based data (1969 onwards) to investigate interannual and seasonal variability in temperature and salinity around the Drake Passage area, with particular focus here being placed on the Bellingshausen Sea and West Antarctic Peninsula region. The Bellingshausen Sea in particular has traditionally been extremely undersampled. However, over the past decade or so, more data have become available in this area, with the Palmer LTER programme (covering 1992-2005), SEaOS and Argo providing complementary information to the, typically summer-biased, hydrographic cruise data. All available data for the region will be combined with the aims of obtaining a more comprehensive understanding of the hydrography of the area and how this compares to existing descriptions. Where the data are sufficiently dense, variability of salinity and temperature will be investigated.

Th4-P34

Seasonal to Decadal Variations of Upper Layer Waters in the South Indian Ocean Along 32°S

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In the subtropics of the South Indian Ocean, water-masses of Subantarctic Mode Water (SAMW) and Antarctic Intermediate Water (AAIW) are widely distributed. Their properties are determined by long-term sea surface heat/ freshwater fluxes: changes of the properties are suitable to investigate the long-term changes of the fluxes. Along the section of 32°S, four trans-Indian observations are carried out (in 1936, 1965, 1987, and 2002; partly done in 1995 additionally) and decadal changes of the upper waters there have been studied. Meanwhile, climate model results suggest the surface and intermediate waters become less saline with progress of global warming, which is partially inconsistent with the observations. It is also pointed out that SAMW in the models shows large variations with shorter time scales and that the trans-Indian observations seem too infrequent to resolve the actual features of variations there. It also becomes more important to identify "variations" and "trends" of the oceanic changes in the observations, especially for analysis on global warming. Here, we try to reconstruct a time-series (1950-present) of water properties at 32°S from historical observations and recent Argo data with an Optimal Interpolation (OI) method and to examine seasonal to decadal variations of SAMW and AAIW.

The Argo data provide us with a remarkable result that seasonal variations are detectable even at great depth. The variations, however, are due to perturbations in the depths of isopycnal surfaces there and their influences on the water properties seems limited to the layers above the core of SAMW (about 26.8σθ). The features also provide a basis on which we can discuss inter-annual (decadal) variations of SAMW/AAIW properties estimated from historical data regardless of seasonal variations.

On the isopycnals above 26.7σθ, more saline waters are distributed around 1960 throughout the section. They are replaced with less saline thermocline waters in the later half of the 1980s after 5-10 year oscillations with the amplitude exceeding 0.1 of salinity. Then the low salinity retreats and more saline SAMW occupies again after 2000. The salinity on 26.9σθ decreases about 0.1 from 1960s to 2000s, but it seems difficult to identify long term trends of SAMW water properties due to large variations. It is worth describing that SAMW is much thicker around 1965 and then thins to show the minimum around 1980. After that SAMW becomes as thick as it was, but the core density seems to

become less dense. On the other hand, AAIW becomes less saline gradually with a smaller peak in 1980 in the whole section. The salinity change of AAIW during 40 years (from 1960s to 2000s) is about 0.04 on 27.3σθ. These features of SAMW seem consistent with recent studies with numerical models, which demonstrated that the properties of both water-masses may change toward lower salinity with very large variations in time due to natural variations and global warming effects.

Th4-P35

Interannual Variability of the Atlantic Interior Geostrophic Transport at 36ºN

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The flow in the top 1000 m of the subtropical North Atlantic is dominated by a gyre circulation, comprising a poleward directed boundary current (the Gulf Stream) and a southward interior return flow between ~70ºW and the eastern boundary. Three repeat sections at 36ºN have quantified this interior geostrophic transport (~50 Sv), but the magnitude and zonal structure of its interannual variability is not well understood. In this study, temperature and salinity profiles from Argo floats are used to construct time series of the variability in the interior geostrophic transport. Results suggest that variability at the western end (5.5 Sv) is around three times greater than that at the eastern end (1.6 Sv), but no long-term trend is detectable between 2001 and 2007 in either region. Work has also focused on determining the role of the wind stress in controlling this variability through an analysis of the monthly Sverdrup transports estimated from NOC, QuickSCAT and NCAR/NCEP data. Whilst no direct correlation between Sverdrup transport and interior flow at 36ºN has been found, results from the OCCAM model suggest that the interior transport variability is controlled in large part by baroclinic Rossby waves which transmit changes in density generated close to the eastern boundary westward across the basin. We are currently attempting to synthesise Argo temperature and salinity measurements with data collected from the Line W array between Cape Cod and Bermuda to provide a time series of full basin-width estimates of transport in the upper 2000 m between 2004 and 2008.

Th4-P36

The Space Structure and Annual Variation of Northwestern Pacific Subtropical Mode Water by Argo Float Data

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Based on the Argo float data from January 2004 to October 2007 we analyze the space structure and temporal variation of the North Pacific Subtropical Mode Water (NPSTMW). The 4 year averaged temperature and salinity in March shows that the space range of NPSTMW in the study area (30°~35°N 140°~155°E) is from 30°N to 34.5°N, 140°E to 151.5°E and shallower than 350m. We also describe the seasonal variation of NPSTMW by the monthly averaged temperature and salinity. At the same time, we put forward a new method to define the NPSTMW through the salinity. Combined with the altimetry data, we analyze the effect of eddies on the NPSTMW. Our results show that eddies only have a temporary effect on the NPSTMW and the water property will recover to the normal state after the eddies move away. Finally, the 4 year observations demonstrate that the NPSTMW is relative stable and changing very little during the observation time.

The presentation will include the above paper and another paper about Proper Water in the Yamato Basin of Japan Sea also by Argo Float Data which has already been published. During the presentation some advise on the Argo float will be brought forth based on the experience on R/V Dong Fang Hong 2 in the 863 program of 'Quality Control and Open Sea Standardization Experiment' summer cruise in July 2007 and August 2008.

Th4-P37

Observations of Temperature Inversions in the North Indian Ocean using Argo Data

K.V.S.R. **Prasad**, P. Sreenivas, Ch. Venkata Ramu and K.V.K.R.K. Patnaik

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Studies on thermal inversions play an important role in understanding ocean dynamics and the response of ocean to the changing radiative and atmospheric forcing. The inversions show remarkable variability in temporal and spatial scales both in magnitude and structure. Oceanic thermal inversions over the North Indian Ocean were computed for the six successive years 2003 – 2008 using Argo float data. The large availability of Argo floats for the above period resulted in better detection of temperature inversions over the North Indian Ocean for every season within a year.

The observed results are compared with inversions obtained from World Ocean Atlas (WOA) data. It is found that inversions in this region are a consistent feature. The temperature inversions occur in the coastal waters of the western and northern bay during the winter season. Inter annual variability of the inversion is significantly high and it is caused by inter annual variability of fresh water flux and surface cooling in the Northern Bay. The temperature inversions in the Arabian Sea start appearing in November, peak in mid January and disappear in late April. Surface and deeper inversions are consistent over the Bay of Bengal and the Arabian Sea respectively.

As a whole the North Indian Ocean experiences relatively fewer inversions during the pre – monsoon season. Past studies on thermal inversions over the North Indian Ocean are of short duration and limited opportunistic spatial extent. With the advent of Argo it is possible to get continuous data on global spatial extent. In this paper we are making an attempt to examine the consistency of Argo in studying the intra as well as inter-annual variability of inversions over the North Indian Ocean during 2004 -2008.

Th4-P38

Upper Layer Circulation at the Luzon Strait*

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Several observations including Argos satellite-tracked drifters, Argo profilers and altimetry satellite data were analyzed to understand the upper layer circulation at Luzon strait. The different roles of the wind and the Kuroshio on the Luzon upper layer circulation have been revealed with a reduced gravity model.

The observations show that the Kuroshio has a relatively stable pattern and may enter into the South China Sea, at least in winter. Several Argo profilers deployed at the Luzon strait by our laboratory also indicate the water exchanges between the Pacific and the South China Sea.

The circulation at Luzon strait is mainly controlled by the Kuroshio and the monsoon wind, which have different roles: the Kuroshio could induce a cyclonic gyre in the west of Luzon strait in either summer or winter. The cyclonic gyre will be stronger and extend more westward as the Kuroshio becomes stronger. The monsoon wind could drive a cyclonic gyre in the Luzon strait in summer, while an anticyclonic gyre is produced in the west of Luzon strait in winter.

North-south Shift of Northern Boundary of the North Pacific Intermediate Water on 26.8 σθ Surface and its Relation to the Atmospheric Variation

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We investigate temporal changes of the distribution of the North Pacific Intermediate Water (NPIW) characterized by a salinity minimum in the layer from 300 to 700 m depth, using vertically-spatially gridded temperature and salinity datasets produced using Argo float profiles. The NPIW is defined as water mass with salinity S < 34.2. Variation of the NPIW distribution, the westernmost location of which is situated around Japan, has an interannual timescale. In order to reveal temporal and spatial behaviors of NPIW distribution, we newly prepared a gridded dataset of salinity on the surface of $\sigma\theta = 26.8$ kg m^{-3} regarded as a core layer of NPIW and thickness of NPIW, by adopting an Optimum Interpolation (OI) method using Argo float profiles. Although the NPIW has almost the same thickness during our analysis period (2003 to 2007), the location of the northern boundary of NPIW on the surface of $\sigma\theta = 26.8$ kg m^{-3} clearly shows the interannual variation. This north-south shift of northern boundary well synchronizes with the NPIW variation in size. In the northern boundary region, the oceanic Rossby wave propagation, which might be excited by the wind in the central North Pacific, is observed using the AVISO altimetry dataset. It is found that the north-south shift of the northern boundary due to the baroclinic Rossby wave propagation is the dominant factor in determining variation of the NPIW distribution.

Northwest Pacific Barrier Layer from Argo

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As the Argo project develops, Argo will provide 100,000 T-S profiles per year from about 3000 floats distributed over the global ocean at 3-degree spacing. Those Argo data can provide us with important information about the ocean mixed layer which plays an important role as an interface between the atmosphere and the ocean interior. Especially, because Argo can provide both temperature and salinity data, we can use these data to study the barrier layer, which is a layer between the bottom mixed layer depth (MLD) and the isotherm layer depth (ILD). In this study we estimate the barrier thickness using Argo data, and compare it with other barrier layer products. Then we analyze seasonal variability characteristics of the barrier layer.

Near-surface Salinity Structure Revealed by Different Gridded Products

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There are a growing number of Argo-based, gridded salinity products at various constant depths. Each of the products is produced by a unique mapping technique, and some of them blend Argo data with measurements obtained via other means. In addition, there exist several ocean reanalysis products. Our goals are 1) to compare these gridded products and see how well they converge and in which regions, 2) to examine near-surface salinity structure that may suggest significant vertical variability in the upper 50-100 m, and 3) to find out how well ocean reanalysis products represent the existing observations. This study will help us to identify regions where the Aquarius/SAC-D may encounter problems in terms of calibration/validation when mapping global sea-surface salinity and to distinguish actual oceanic structures from mapping artifacts.

Th4-P42

Subduction and Transportation of Low Potential Vorticity Water in the Subtropical North Pacific

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Based on the analysis of the observation data by Argo floats during 2004-2008, the Subduction and transportation of the low potential vorticity (PV) water in the Subtropical North Pacific is analyzed. It is confirmed that the low PV water subducted in the 30°-35°N, 150°-170°E area with potential vorticity of $25.2\sigma\theta$-$25.8\sigma\theta$ was transported southwest to the east of Taiwan Island in the subsurface pathway. It is found that the Subtropical Subsurface High Salinity Water in North Pacific is exactly the "top sheet" of the low PV water in the Subtropical North Pacific. According to the distribution of the low PV water on the 9 sections located on the both sides of the Ryukyu Islands, it is also found that the low PV water exists in both the Kuroshio in the East China Sea (KECS) and the western boundary current in the east of the Ryukyu Islands. The low PV water transportation along the west boundary current plays important roles in the climate change in North Pacific.

Theme 5: New Technology

Chairman: Howard Freeland

27 March, 13:30-14:00, Invited (Th5-IT1)

Future Technological Advances and Challenges for Argo

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Profiling float technology has evolved from the early days of the World Ocean Circulation Experiment to the floats presently used in Argo, characterized by relatively accurate, long-lived CTD units, extended lifetimes, faster communications, and options for many different types of missions. In looking to the future of Argo, there are several lines of development that would seem to be crucial to advancing our knowledge of the global circulation. Argo can be made more cost-effective if the lifetime of floats can be increased even further. Yet to accomplish this feat will require more than additional battery capacity in the floats. The efficiency of the buoyancy engine in the floats must somehow be increased, which will require new float designs and prototypes. Faster communications would allow the floats to collect and transmit more data than is presently possible; floats using the Iridium system have already been deployed by several groups, and the wider adoption of this technology could lead to important new insights and capabilities on Argo floats. Presently, floats are limited to 2000 m missions, and removing this limit and allowing profiling into the abyssal ocean would provide important new observations in regions of the ocean where deep water renewal is active. Such deep profiling comes with the potential downside of decreased float lifetime and increased cost, but carrying out such work in at least a few places in the world ocean would seem to be a worthy goal of Argo. Now that the basic buoyancy engine and CTD on Argo floats have been proven, there are many discussions about adding new sensors and capabilities to floats. While most of these suggestions have merit, the Argo community must continue to stress the major goals of Argo, including global coverage and multi-year float lifetimes, before adding major new specifications to the float missions that could potentially distract from the main goals of the program.

27 March, 14:00-14:20 (Th5-T1)

ARGOS-3 for the Argo Program

Bill **Woodward**[1], Christian Ortega[2] and Michel Guigue[2]

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There are currently more than 3,000 profiling floats in operation that are relaying ocean and meteorological data via Argos-2, the second generation of the Argos system. The third generation Argos-3, has been operational on one satellite since August 2007. The Argos constellation will be enhanced with the launch in February 2009 and July 2010 of the next satellites carrying Argos-3. The increased capabilities of Argos-3 can significantly improve the performance of existing Argos equipped floats. Argos-3 floats are expected to have much shorter surface times, higher resolution profiles and significantly less energy consumption resulting in increased lifetimes.

The Argo Program can benefit significantly from these improvements and CLS has implemented an Evaluation Project to test and evaluate the Argos-3 capabilities for the float community.

With support from CLS, all manufacturers are being encouraged to integrate the new Argos-3 PMT into their products. Drifting buoy manufacturers are now performing the necessary engineering work. For profiling floats, CLS is cooperating with manufacturers/users interested in i) developing a prototype Argos-3 float, ii) testing it, and iii) applying modifications if needed, then iv) producing some pre-production floats. Those pre-production floats would

be available for evaluation by interested members of the community. Feedback from manufacturers as well as users will be collected at the end of the Project to improve the service and define the specifications for the future satellite generations.

An Argo Evaluation Project is believed to be the best way to independently and objectively evaluate Argos-3 for use by the global float community. Consequently, CLS has proposed an Argos -3 Evaluation Project to the Argo Steering Team. The Project has the goal to: i) identify users interested in deploying the pre-production floats to evaluate Argos-3, ii) defining the evaluation criteria, methods and procedures, iii) coordinating and harmonizing the desired multiple evaluations, and iv) providing a community-wide forum to present and disseminate the evaluation results and conclusions. CLS is prepared to participate with the Argo community in an Argos-3 evaluation project by fostering PMT integration into float products and making them available for evaluation, and by providing guidelines and assistance to help the float community make the best of Argos-3.

27 March, 14:20-14:40 (Th5-T2)

Observations by Bio-optical Floats Deployed in Various Oceanic Waters: Potential Synergies with Information Derived from Satellite Ocean Colour Sensors

Hervé **Claustre**[1], Fabrizio d'Ortenzio[1] and Odile Fanton d'Andon[2]

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Profiling floats now represent a mature technology. Their large potential for research in physical oceanography (dramatic increase in observation density) is clearly asserted in the context of global ocean observation programs like Argo. In parallel with the emergence of these technologies, the field of miniature, low power bio-optical and biogeochemical sensors is rapidly evolving. We have thus developed bio-optical floats by implementing a complete optical package on PROVOR floats equipped with Iridium transmission. Eight of these floats, the so-called PROVBIOB, have been deployed to date in various oceanic provinces [North Pacific Gyre (2); South Pacific Gyre (2); North Atlantic (2); Mediterranean Sea (2)]. An additional deployment of 7 floats is planned for 2009. We will present the first analysis of the measurements obtained by these floats, including an assessment of their complementarity with ocean colour satellite remote sensing. Indeed, thanks to recent algorithmic improvements, new optical products (*e.g.* backscattering coefficient, absorption by coloured dissolved material) are at present routinely retrieved from remotely sensed ocean colour. The optical package on the floats allows the same measurement to be performed, thus providing the vertical extension that is missed by the satellite. In the future, an intensification of in situ observations by bio-optical profiling floats would permit the elaboration of unique bio-optical 3D/4D climatologies, linking surface (remotely detected) properties to their vertical distribution (measured by autonomous platforms), from which new research topics could be developed. This synergetic approach between both measurements (space and *in situ*) would be essential in the context of studies addressing global change impact on biogeochemical cycles and ecosystems. In this context, the objectives and first recommendations of the IOCCG (International Ocean Colour Coordinating Group) BIO-Argo working group will be also briefly presented.

27 March, 14:40-15:00 (Th5-T3)

Sea-to-air Oxygen Flux Associated with the Destruction of the Shallow Oxygen Maximum

Yoshitake **Nakagawa**[1], Toshio Suga[1,2], Chiho Sukigara[1], Kimio Hanawa[1], Taiyo Kobayashi[2] and Nobuyuki Shikama[2]

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The concentration of oceanic dissolved oxygen (DO) and its temporal and spatial distribution depend on physical, chemical and biological processes and vary associated with changes in those processes. Therefore, it is important and useful to analyze the variability of DO for understanding of ocean circulation, biogeochemical fluxes and their variability. Shulenberger and Reid (1981) proposed that biologically produced oxygen is trapped and accumulates

under strong vertical stratification of the seasonal pycnocline as a possible production process of the shallow oxygen maximum (SOM). From considerations of productivity, they also mentioned that the destruction of the SOM may result not from respiration but from autumn mixing, which vertically homogenize density and permit out gassing. Riser and Johnson (2008) quantitatively described seasonal variations of DO using vertically and temporally high-resolution data obtained by profiling floats and confirmed these production and destruction processes of the SOM suggested by Shulenberger and Reid (1981). Tohoku University and JAMSTEC have deployed 16 Argo floats with DO sensors in the mid-latitude North Pacific (Kobayashi *et al.*, 2006). These floats provide DO profile data with considerable temporal and spatial coverage. We present production and destruction processes of the SOM in more detail with these data. Then we examine whether or not sea-to-air oxygen flux at the sea surface associated with the SOM destruction is detected or not even during the period when the ocean is able to absorb oxygen, *i.e.*, mixed layer depth and oxygen solubility increase due to autumn cooling. For comparison, we also calculate sea-to-air oxygen flux due to summer heating.

27 March, 16:00-16:20 (Th5-T4)

Observations of Water Masses and Circulation Under Antarctic Ice from Argo Floats Deployed in the Seasonal Ice Zone

Annie Wong and Stephen C. **Riser**

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Nearly 75 Argo floats have been deployed by the University of Washington in the seasonal ice zone around the Antarctic continent in the past 2 years. Over 90% of these have survived through two winters and the resulting profiles of temperature, salinity, and dissolved oxygen from under the wintertime ice are providing new insights into mixing and circulation in the vicinity of the ice. The profiles show weakened variability in properties under the ice in wintertime and a resurgence of weekly timescale variability in the spring when the ice melts. Some of this variability can be seen at depths of up to several hundred meters. The spring thaw is nearly always accompanied by an observed decrease in the near-surface salinity, consistent with a fresh water cap at the sea surface derived from melting ice. Additionally, there is nearly always an increase in near-surface dissolved oxygen during the spring thaw, due to both gas transfer from the atmosphere and increased biological production when the ice melts. In order to collect these observations, extensive software modifications to the floats were necessary, and all of the floats in the ice zone used the Iridium system for communications.

27 March, 16:20-16:40 (Th5-T5)

A Study on the Division of the Stratification of Seawater and Simulation of Underwater Acoustic Field in Pacific Ocean Using Argo Profiling Floats

Jia-Xun **Li**[1,2], Ren Zhang[1,2], Guihua Wang[2] and Huizan Wang[1,2]

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The stratification of seawater in Pacific Ocean was studied using the temperature and salinity data obtained by Argo profiling floats. Results show the stratification in this area consists of five types: uniform, shallow-layer apex, mixed apex, deep-layer apex, multilayer apex, further, the causes of formation and the distribution characteristics of these types were analyzed briefly. Then five cases of these types were chosen to calculate the vertical modes of Rossby internal wave in a quasi-geostrophic ocean. The results show that the vertical mode shape is distorted because of the non-homogeneity of the seawater density and the existence of the pycnocline and pycnocline corresponds to the extremum in amplitude. Based on the relationship between the complex internal wave displacements and sound speed fluctuations, the sound speed fluctuations were computed under different kinds of stratification conditions. The results show that the fluctuations obey the law of stationary wave, and the fluctuations in the pycnocline are greater than under the pycnocline. Finally, the sound speed fluctuations added to the sound speed background field obtained by Argo data

were used in the MMPE underwater acoustic propagation model to process the simulation of the acoustic field caused by the internal waves. There is no doubt that these results have a significant practical value for underwater acoustic field analysis and sonar application.

Theme 5 Posters

Th5-P43

An Estimation of the Average Lifetime of the Latest Model of APEX Floats

Taiyo **Kobayashi**[1], Brian A. King[2] and Nobuyuki Shikama[1]

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Estimating the average lifetime of floats is very important for Argo, because its total cost largely depends on float lifetime. APEX floats are most widely deployed in Argo, we estimate the lifetime of its latest model powered by alkaline batteries. The expected lifetime is estimated with a statistical method that allows for floats that are still active and that failed due to a known and now fixed hardware fault that should not recur in the latest model. The expected lifetime of the latest APEX model is 134.6 cycles based on the APEX fleet of JAMSTEC (Japan Agency for Marine-Earth Science and Technology) (n = 571, as of 7 May 2008). Thus, the annual deployment of 813 APEX floats is needed to maintain the Argo network of 3000 floats. Floats with different hardware configurations or different mission programs are expected to have a longer lifetime.

Th5-P44

Geographical Boundaries for the Free Use of Dispersants – Improving Physical Process Modelling by Global Observation Strategies

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When an accidental oil spill occurs, several response options are possible. These possibilities are usually studied though two different approaches; to recover the hydrocarbon or to leave the oil in the environment. This second approach includes the spreading of dispersants and the natural elimination of the pollutant. The appropriate use of one or other option should minimize the impact of environmental pollution.

Before deciding on which response strategy to choose, it is often timely to see whether the response will mitigate the pollution and improve the situation or whether it is better to leave well alone and refrain from responding. This approach is called NEBA (Net Environmental Benefit Analysis). The impact of the dispersed oil has to be less than that of non dispersed oil. Dispersed oil is more dangerous for the aquatic fauna and flora (corals, fish farm water intakes and industrial water intakes) than oil floating on the water surface. Defining areas where it is possible to disperse

is tantamount to doing a «net environmental benefit analysis» or an «ecological advantage analysis» of dispersant spraying for set scenarios. However, contradictory opinions exist regarding dispersant use, their effect on oil and their environmental impact. Thus, only certain countries have a clearly defined policy regarding the use of dispersants

The use of dispersants should be applied rapidly. If the oil weathers, the treatment is less effective. Based on the above considerations and from practical experience, it is evident that response actions using dispersants should be initiated as soon as possible, and every effort should be made to apply the dispersants before significant oil weathering has occurred to improve the probability of success. It should be noted that increased viscosity and water content in an emulsion also affect the ability to treat spilled oil by other response methods.

This study aims to serve as a model to follow when establishing the boundaries for the use of dispersants in order to allow the response authorities to define which dispersion should be take immediately after the incident. To this end, the conclusions of this paper will be based on the comparison between the results of the simulation model AREAS, the simulation model DISPERSANTES and the boundaries for the free use of dispersants established by the French research centre CEDRE.

There have been some attempts to incorporate surface flow measurements into real-time oil transport models. However, these require pre-installation of data acquisition (*e.g.*, high frequency radar) and transmission systems are currently applicable only to horizontal surface current and diffusion with relatively coarse grid resolution—not for the three-dimensional distributions needed for the three-dimensional modeling. The growing availability of ocean observing systems and global observation strategies (ARGO) in coastal waters will likely improve the availability of real-time data useful for improved modeling of physical processes.

Th5-P45

Quality Control of Argo Surface Trajectory Data Considering Position Errors Fixed by ARGOS System

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To estimate global surface and subsurface velocities is another goal of the array of numerous profiling floats, Argo. Here, we introduce an automatic quality control (QC) method of Argo float positions to save the trouble of discarding "suspicious" positions when trajectory data are used. This method has been suggested to Argo as one of candidates for the standard QC method. We expect that it will work as a preliminary QC of Argo trajectory data and will be succeeded by a more sophisticated inter- and extrapolating scheme (*i.e.*, "delayed-mode QC") to estimate actual float movements and locations where a float arrives at and departs from sea surface.

The method identifies suspicious position data based on the float's speed estimated from the surface trajectory as follows. Considering a segment composed by two temporal-continuous positions, one position, at least, is identified suspicious if float speed on the segment is estimated at 3 m/sec or faster. The suspicious position is determined by the relation among the segment and the temporally back/forth positions of the float trajectory. In case that the distance between the positions is less than the error range determined by Argos position errors of them, both positions are considered to be acceptable. The method gives us fairly reasonable QC results which are comparable with those by visual inspection of experts, and several percents of position data are identified "bad" in average. An execution program and detail documents about it has been prepared from PARC-JAMSTEC web-site so as that this method will be tried widely.

PARC-JAMSTEC: http://www.jamstec.go.jp/ARGORC/location_top.html

Th5-P46

Primary Production and Respiration Estimated from Dissolved Oxygen

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The concentration of oceanic dissolved oxygen (DO) and its temporal and spatial distribution depend on physical, chemical and biological processes and vary associated with changes in those processes. Therefore, it is important and useful to analyze the variability of DO for understanding of ocean circulation, biogeochemical fluxes and their variability. Shulenberger and Reid (1981) proposed that biologically produced oxygen is trapped and accumulates under strong vertical stratification of the seasonal pycnocline as a possible production process of the shallow oxygen maximum (SOM). Therefore, the increase of DO within the SOM layer is due to biological oxygen production. Riser and Johnson (2008) calculated net community production (NCP) from the increase rate of DO in the SOM layer. They also pointed out that NCP value is almost zero near the bottom of euphotic zone. Tohoku University and JAMSTEC have deployed 16 Argo floats with DO sensor in the mid-latitude North Pacific (Kobayashi *et al.*, 2006). These floats provide DO profile data with considerable temporal and spatial coverage. We calculate NCP at a given depth in each sampling date. From the temporal integration of NCP values at each depth, we describe vertical distribution of NCP. To sum up NCP above the depth of most developed mixed layer in winter, the region where carbon is produced/decomposed are identified. Below the base of euphotic zone, negative values of NCP correspond to respiration. Assuming that the respiratory oxygen utilization within the euphotic zone is similar to that below the base of euphotic zone, gross primary production is estimated. Finally we discuss the effect of surface layer structure on these biogeochemical processes.

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An Interactive Tool for Real-Time Monitoring and Exploration of Ocean Basins (ArgoBrowser)

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The Argo data Browser (ArgoBrowser) is a multipurpose MATLAB-based application for quality control, analysis and visualization of oceanographic data from various platforms, including profiling floats, ships and moorings. ArgoBrowser includes download manager, database builder, data post-processor, profile browser, vertical section, map and time series tools.

The download manager can be configured to perform routine (automated) visits to the World Data Centres as well as other off-site data collections and transfers newly found data to the ArgoBrowser server.

The database builder reads, filters and indexes all available measurements as a result creating internal homogeneous data structure for quick, easy and reliable manipulation with acquired data.

The data post-processor is a multifunctional tool for quality control, editing (both manual and automated), calibration and cross-comparison of Argo and other data. For example, salinities from an individual Argo float can be validated/calibrated using nearby shipboard and/or Argo measurements.

The vertical section tool operates with three types of coordinates connecting a certain data point with an arbitrarily chosen spatial line (position of the point on the line and the distance to the line). The first set of coordinates is defined by using the shortest horizontal distance or direct projection method, the second set is based on following bathymetric contours from the measurement location to the section line, and the third most effective type of section-based coordinates is defined through a weighted combination of the direct and bathymetry-flowing coordinates.

The time series tool creates time series of seawater properties, estimates seasonal cycle, removes data outliers, and depicts short and long term variability at various locations and depths.

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