Argo Australia – 2012 Activities

Report to the Argo Steering Team

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The Australian Centre for Atmosphere, Weather and Climate Research: a joint partnership between the Australian Bureau of Meteorology and CSIRO

1. Status of implementation

Floats deployed and their performance

Australia currently has 378 active floats distributed across the Indian and South Pacific Oceans (Figure 1)

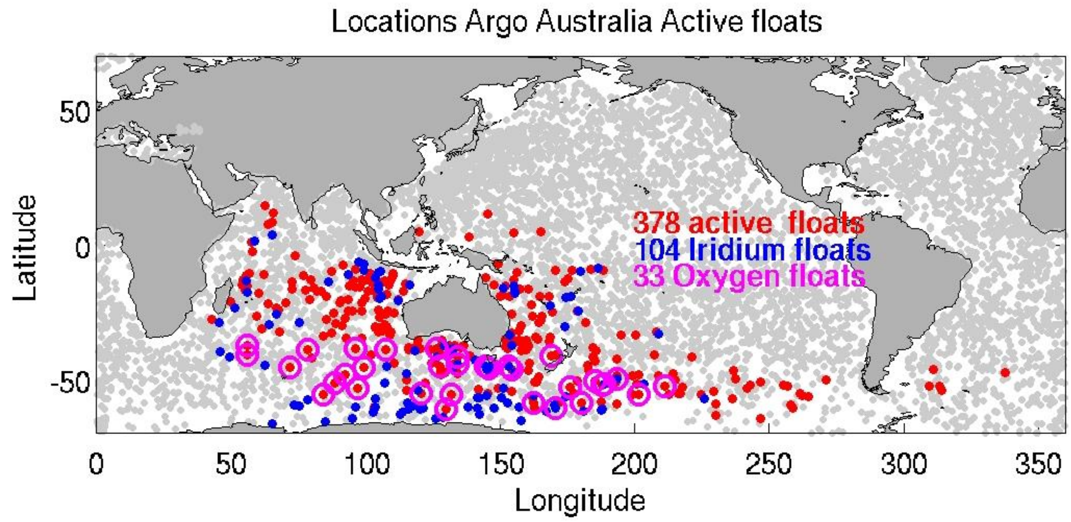
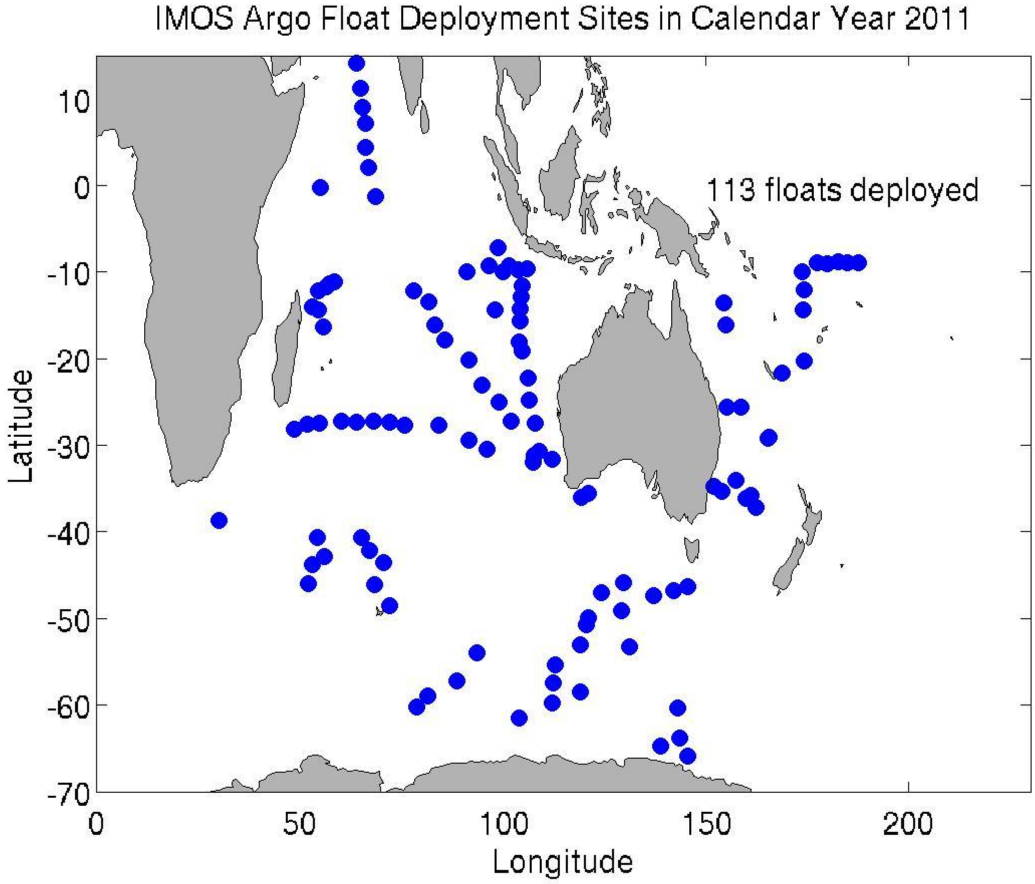


Figure 1. Locations of active Argo Australia floats (colours) as of February 2012 with active international floats in gray. Australian floats using Iridium Communications are in blue and those equipped with oxygen sensors are circled in magenta.

In the calendar year 2011, the program deployed 113 floats most of which were in the Indian Ocean where the program worked hard to target the thinning array in the region affected by piracy (using US and Australian Navy ships) and the mid and eastern basin, extensively employing the Schooner Lady Amber.   The Lady Amber has now deployed 55 floats for Argo Australia. After her long Indian Ocean deployment voyage the crew also worked with the IOC office in Perth and CSIRO communications in a media story on ocean observing which gained considerable coverage and involved Ministers from the Western Australian government. She will be returning to the Indian Ocean and deploy another 9 floats for our program in 2012. To date all the floats deployed are Teledyne Webb APEX floats.



Technical problems encountered and solved

Our use of Iridium communications continues to ramp up as we plan on all new acquisitions to use this system. Problems encountered in the second half of 2010 with our Iridium fleet have largely been solved. These included unpredictably high call costs caused by multiple signal dropouts and large file sizes (primarily caused by poor buoyancy or failed air bladders, solved by changing suppliers and reducing file size) and the need to build more redundancy into the data stream (we are solving this by moving to RUDICS). We now feel that using Iridium is extremely good value and past reliability issues are hopefully behind us. Using Iridium in the floats being piloted in the sea-ice zone in particular looks very promising, with winter profiles taken and stored over many months below the ice returned to us in spring. One drawback of Iridium is the initial hardware setup of linux servers, backup servers and dialup modems, including on-going maintenance, this also applies to RUDICS. One of the main advantages of iridium is two-way communications which enables floats to have missions changed on demand, the other advantage is the amount of data which can be uplinked - currently all of our iridium floats uplink 2-dbar vertical resolution data from 2000dbars to near surface, including vast amounts of technical and diagnostic data. Typical cost per profile with dialup is just over $4.00AU and with RUDICS the estimated cost will be approximately$12.00AU – this will vary between providers.

<u>Float Failure Mode Analysis</u>

As of the 24th of Feb 2012, the Australian Argo program had deployed 515 floats. From the total number of floats deployed; 106 are dead. Of the remaining 409 operational floats, 389 are returning good data, a further 20 are producing suspect or bad data and are under review including 4 floats that are confirmed as suffering from the Druck microleak issue. Of the dead floats, only 10% ceased to operate due to normal end of life when they ran down their battery packs. A further 21% died due to unknown reasons. The remainder of floats ceased to operate prematurely mainly due to environmental reasons such as grounding (18%) and loss or damage under sea ice (5.6%). Other contributing factors are summarized below

This year we retrieved a float from the Solomon Islands with funding from Teledyne Webb Research. This float was leaking and it was deemed useful to get it back to assess the source of the leak. The float was returned to Teledyne Webb for analysis and this confirmed that indeed the antenna was leaking through the internal potting compound which had failed to adhere to the internal surface of the aluminium antenna tubing. Antenna construction has since been improved and the problem resolved. . The float has now been re-calibrated and reconditioned and is on its way back for redeployment.

We have another series of floats which are not strictly Argo mission because they carry FLBB sensors. These floats have an inordinate number of failure modes, distributed over 7 of the 8 floats of this type we have deployed. At least 3 are leaking, one has apparently lost its FLBB sensor, one died on deployment, one disappeared after only 108 profiles (rapid profiling so less than a year in the water), some are returning spiky salinities, and some have lost contact with their oxygen sensors. Finally, one is exhibiting signs of a Druck microleak despite carrying a screened pressure sensor. We are in discussions with the manufacturer about these and have returned the 3 remaining in the lab to Webb for analysis. The percentage of high leaks in this batch indicates possibly another mode of ingress, and not the antenna.

Float failure mode for dead floats	**Number of floats** (106)	**% of dead floats**
Unknown	23	21.5
Grounded	19	17.8
End of life	11	10.3
Firmware issues	5	5.6
Lost under ice	6	5.6
Turned on too early – went too deep	3	2.8
CTD failure/damage	3	2.8
Premature Battery Failure	10	9.3
Communications failure	1	0.9
Leak	10	9.3
Deployed in plastic bag	1	0.9
Druck snowflake	1	0.9
Air Solenoid failure	3	2.8
Died on Deployment	9	8.4
Faulty Hydraulic pump	1	0.9

Float failure mode for floats with	**Number of**	**% of suspect**

suspect or bad data	**floats** (35)	**floats**
Unknown/Other	5	14.3
Grounded and contaminated CTD	12	34.3
Gradual leaks	3	8.6
Druck microleak	4	11.4
Suspect conductivity cell	3	8.6
Faulty Air Solenoid or Pump	1	2.9
Buoyancy problems	4	11.4
Unreliable Iridium	1	2.9
Unreliable GPS	1	2.9
Ice damage	1	2.9

Summary of Technical Issues

Faulty Solenoids

We have been having problems with the solenoid valve on the air pumps not working properly so that the valve does not shut off and does not maintain air pressure in the bladder. The problem can be identified in the lab when the bladder pressure equals the vacuum pressure. A couple of floats (2-3) have been identified with this problem in the lab during pre-deployment testing. The problem cannot be easily identified once floats are in the field as it is not possible to determine the difference between a failed air pump and a failed air pump switch. In either case, if the air bladder does not inflate, iridium floats are unable to communicate with the iridium network and thus appear to have failed without cause. Argos based floats are able to partially transmit and thus able to be diagnosed.

The failure rate for solenoids from the Italian supplier went up drastically after they changed their manufacturing process to eliminate oil on the switch (previously Webb had been cleaning this off themselves). The manufacturing process has now been changed but at least 54 of our floats are potentially affected. Solenoids will be replaced where possible, depending on the amount of replacement solenoids available from the manufacturer. Priority for replacement will be given to Iridium floats and those deployed in the tropics. Note that 30 solenoid valves were replaced by our technicians (from a suspect batch of serial numbers) in our lab, with the replacement solenoids and shipping costs provided by Webb.

Miscellaneous Float and other Technical Problems:

- Two floats had faulty CPUs, the boards were returned to Webb. This seems to be a relatively rare problem.
- One oxygen calibrated float had a corroded seal; the source of corrosion was unclear.
- One float delivered with the wrong model GPS hardware that was not compatible with the version of firmware and did not work at all. This was picked up in the lab before deployment and was replaced.
- Two Iridium floats have had GPS problems – they had low signal strength and the GPS units were replaced in the lab.
- One float had a weak Iridium signal caused by an unreliable low frequency band transmitter not communicating with the CPU and resulting in poor uplink.
- Poor Iridium communications – we reduced the log file size from 60K to 5K which has helped make the communications more reliable but sometimes results in not all the diagnostics we need being transmitted if the message file doesn’t arrive.

- We have also had problems with inadequate fluorometer calibrations on the Fluorometer Backscattering Meter (FLBB) sensors. Testing in the lab when the floats arrived showed the sensors were not calibrated properly. We found differences between the data readings from the sensor and those transmitted through the float. Also, there was a significant warming up period required before the readings stabilised. The problem sensors were sent back to Webb for recalibration and in some cases were sent back a second time.
- Three floats were received with incorrect CPU IDs programmed into the floats, these were detected in the lab and re-programmed here.
- Webb final test software: the final test software implemented in LabView which is provided by Webb to enable the end-user to test the floats upon arrival. Unfortunately this software needed to be modified before it would work.

Status of contributions to Argo data management

Collaboration with Argo India: The program has continued to work with the Indian Argo program in the continuing bedding down of their use of the Australian realtime data processing software (http://www.marine.csiro.au/~gronell/ArgoRT/). They have now begun encoding TESAC messages so that GTS insertion by the Indian Meteorological Service can begin. At this point, the software is operational.

Collaboration with KORDI: We are working with KORDI on installing Australia RT software. While still not operational due to the quality of their raw data and the complexities of processing so many float types, much progress has been made.

1. Pressure Biases in the Global Argo data set: An analysis and correction of pressure drift errors in the global data set as available at the end of 2008 is now published (Barker P. M., J. R. Dunn, C. M. Domingues and S. Wijffels, 2011: Pressure Sensor Drifts in Argo and Their Impacts . *J. Atm. Ocean Tech*, **28**, *1036-1049*. DOI: 10.1175/2011JTECHO831.)

Jeff Dunn has applied the methods described in the above paper in building software that checks pressure corrections carried out by DACs and also compliance with ADMT recommendations around the treatment of Truncating Negative Drifting Pressure (TNDP) floats. This audit can be carried out 3-6 monthly, and its latest results will be reported on at AST-12. The latest audit can be accessed at

http://www.cmar.csiro.au/argo/dmqc/audits_2012_03_04/summary.html

Technical Naming Table: Ann Thresher has been working with the DACs to build and maintain a fixed table of technical parameter names for use in Argo data files. A common approach to naming these parameters is vital if these files are to be machine parseable. Previously each DAC had an almost non-overlapping set of names for parameters.

Status of delayed mode quality control process

Detailed descriptions of the quality control process, including the data and plots for each float are available at the following CSIRO website:
http://www.cmar.csiro.au/argo/dmqc/index.html

In addition, to aid those working with trajectory data or for those who are interested in float data formats, electronic copies of the CSIRO APEX float manuals are now available online:
http://www.cmar.csiro.au/argo/dmqc/html/Australian_float_manuals.html

Australian DM Statistics (as at07/03/2012)	
D files submitted to GDAC	31632
Total R files	22864
R files eligible for DMQC	7073
Total eligible files for DMQC	38705
Total files at GDAC	54496

Table 1. Delayed Mode processing statistics for the Australian array.

The Australian Argo array continues to grow rapidly with a 36% increase in the total number of profiles delivered to the GDAC in the past year. A total of 516 floats have been deployed to date since the beginning of the Argo program and 378 floats are still operational. As at 07/03/2012, 82% of eligible profiles (those that are greater than 6 months old) have been processed through delayed mode quality control.

The DMQC processing software suite is now complete and includes new scripts that allow floats to be processed in 'maintenance' mode, i.e. when a float is revisited, new profiles are added whilst earlier QC for old profiles is retained. The next 12 months will focus on the incorporation of new float types, data formats and metadata variables, multi-profile files, trajectory files, oxygen data and delivery of Argo products.

A total of 364 floats have been assessed through the DMQC process for drift of the salinity sensor. Of these, 7 floats (2 %) returned no data from deployment and 8 floats (2 %) returned bad data for the entire record due to pressure sensor issues or other hardware problems. Of the remaining 349 assessable floats, 315 (90%) show no salinity drift for the life of the float. A further 34 or 10% of floats show a positive salinity drift.. A small number of floats (8 instruments or 2 %) are affected by a fresh offset or biofouling. Of the floats that are either salt or fresh offset, most were corrected using the OW salinity drift correction. 15 floats (4 %) suffered from TBTO fouling at the start of the record, generally only the first or second profiles but in some cases up to 7 profiles.

2. Present level of and future prospects for national funding for Argo

Argo Australia has been part of Australian Government initiative: an Australian Integrated Marine Observing System (IMOS; www.imos.org.au) for research infrastructure funded under the and now the Education Infrastructure Fund (EIF). EIF funding for Argo Australia is now secured through June 2013. The Australian government is proposing a renewed National Collaborative Research Infrastructure Initiative (NCRIS) and IMOS will be a proposed element of this program. Argo Australia also get direct funding from CSIRO and the Australian Climate Change Science Program, the Bureau of Meteorology and also logistical assistance from the Royal Australian Navy.

Through IMOS, and if levels of support from our partners remains steady, Argo Australia will sustain deployments of 50-60 floats per year. Due to longer float life times, this may maintain an array of around 350 active floats.

3. Summary of deployment plans (level of commitment, areas of float deployment)

We have just over 50 floats the lab for deployment in 2012/13, most in the Indian and Southern Oceans, and some in the Pacific Ocean (Figure 2). Lady Amber was very successful as a deployment platform last year and we intend to use her for a further 3 floats this year; she will also deploy the 6 floats that were missed from her original plans because of the risk of cyclones when she was in the region between Australia and Indonesia.

In the Pacific, floats will be deployed from both ships of opportunity but also the RV *Kaharoa,* in partnership with US Argo and New Zealand's NIWA.

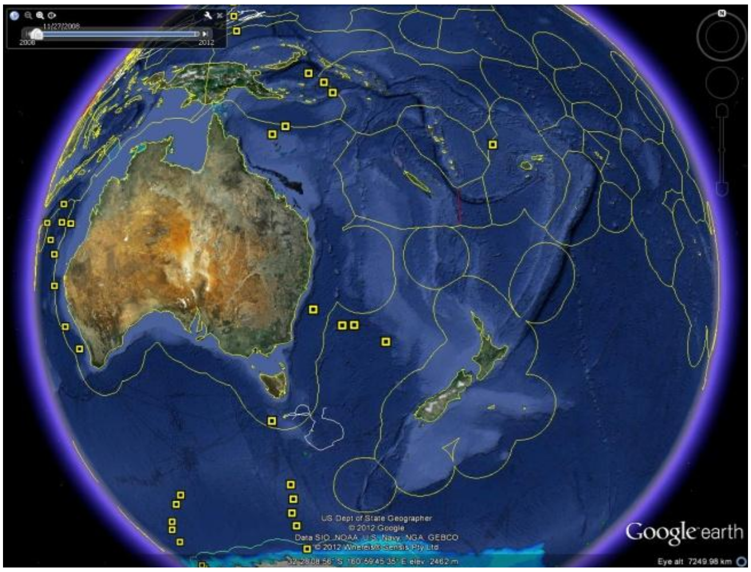


Figure 2. Locations of planned float deployments over the next year – Yellow squares are proposed deployment positions.

4. Summary of national research and operational uses of Argo data as well as contributions to Argo Regional Centres.

- Argo data are routinely used in the operational upper ocean analyses Australian Bureau of Meteorology (http://www.bom.gov.au/bmrc/ocean/results/climocan.htm).
- The dynamical seasonal forecasting system POAMA heavily uses Argo data for forecast initialization, including assimilating salinity which great improves the analysis – Oscar Alves, Australian Bureau of Meteorology
- CSIRO Marine and Atmospheric Research, in collaboration with the Bureau of Meteorology Research Center, has developed an ocean model/data assimilation system for ocean forecasting and hindcasting. Argo data is the largest *in situ* data source for this

system. Ocean forecasts and reanalysis products are now routinely published and are available via the Bureau of Meteorology website .

- Many students in the CSIRO/University of Tasmania graduate program and University of New South Wales are utilizing Argo data in their thesis studies.
- We are developing techniques to produce an Argo-gridded steric height data set (Dunn, Monselan, Wijffels,Church)

Argo Australia's web site is: http://imos.org.au/argo.html

Real Time data documentation : http://www.marine.csiro.au/~gronell/ArgoRT/

Delayed Mode data documentation: http://www.cmar.csiro.au/argo/dmqc/index.html

5. Issues to be raised with the Argo Steering Team

Pressure Bias Corrections: The national DACs have made tremendous progress in removing the pressure errors in float data, improving their technical files and their identification and treatment of TNDP floats. Many were also very helpful in improving the pressure bias auditing system. We urge them to complete this task as soon as possible so that Argo may be confidently be used to track the evolution of the global ocean heat content.

6. CTD Data Delivered to CCHDO

The historical archive of RV Franklin and RV Southern Surveyor data from the 1980's through to 2009 was sent to CCHDO. Some of this data was already in the CCHDO archive but new data (mostly coastal Australian) was included.

Data from the recently completed I9 (Antarctica to Western Australia) repeat hydrographic line will also be sent to CCHDO soon.

7. Argo Publications by Australian Authors 2011

Johnson, G, Wijffels, S 2011, Ocean density change contributions to sea level rise, Oceanography, vol. 24, no. 2, pp. 112-121, doi:10.5670/oceanog.2011.31

O'Kane, TJ, Oke, PR, Sandery, PA 2011, Predicting the East Australian Current, Ocean Modelling, vol. 38, pp. 251-266

Oke, PR, Greenslade, DJM 2011, The cold-core eddy and strong upwelling off the coast of New South Wales in early 2007, Deep Sea Research Part II, vol. 58, no. 5, pp. 574-591, doi:10.1016/j.dsr2.2010.06.006

Sallee, J-B, Rintoul, S 2011, Parameterization of eddy-induced subduction in the Southern Ocean surface layer, Ocean Modelling, vol. 39, pp. 146-153

Barker, PM, Dunn, Jr, Wijffels, S, Domingues, CM 2011, Pressure sensor drifts in Argo and their impacts, Journal of Atmospheric and Oceanic Technology, vol. 28, no. 8, pp. 1036-1049, doi:10.1175/2011JTECHO831.1

Herraiz-Borreguero, L, Rintoul, S 2011, Regional circulation and its impact on upper ocean variability south of Tasmania (Australia), Deep Sea Research Part II, vol. 58, no. 21-22, pp. 2071-2081, doi:10.1016/jdsr2.2011.05.022

Holbrook, N, Goodwin, ID, McGregor, S, Molina, E, Power, SB 2011, ENSO to multi-decadal time scale changes in East Australian Current transports and Fort Denison sea level: Oceanic Rossby waves as the connecting mechanism, Deep Sea Research Part II, vol. 58, no. 5, pp. 547-558, doi:10.1016/j.dsr2.2010.06.007

Liu, Q, Feng, M, Wang, D 2011, ENSO-induced interannual variability in the southeastern South China Sea, Journal of Oceanography, vol. 67, no. 1, pp. 127-133, doi:10.1007/5/0872-011-0002-y

Herraiz-Borreguero, L, Rintoul, S 2011, Subantarctic Mode Water: distribution and circulation, Ocean Dynamics, vol. 61, no. 1, pp. 103-126, doi:10.1007/5/0236-010-0352-9

Yin, Y, Alves, O, Oke, PR 2011, An ensemble ocean data assimilation system for seasonal prediction, Monthly Weather Review, doi:10.1175/2010MWR3419.0

Meijers, AJS, Bindoff, N, Rintoul, S 2011, Estimating the 4-dimensional structure of the Southern Ocean using satellite altimetry, Journal of Atmospheric and Oceanic Technology, vol. 28, pp. 548-568, doi:10.1175/2010JTECHO790.1

Williams, A, Althaus, F, Clark, M, Gowlett-Holmes, K 2011, Composition and distribution of deep-sea benthic invertebrate megafauna on the Lord Howe Rise and Norfolk Ridge, southwest Pacific Ocean, Deep Sea Research Part II, vol. 58, no. 7-8, pp. 948-958, doi:10.1016/j.dsr2.2010.10.050

Hill, K, Rintoul, S, Ridgway, K, Oke, PR 2011, Decadal changes in the South Pacific western boundary current system revealed in observations and reanalysis state estimates, Journal of Geophysical Research - Oceans, vol. 116, doi:10.1029/2009JC005926

Sandery, PA, Brassington, GB 2011, Adaptive nonlinear dynamical initialization, Journal of Geophysical Research - Oceans, vol. 116, doi:10.1029/2010JC006260

Schiller, A 2011, Ocean circulation on the North Australian Shelf , Continental Shelf Research, vol. 31, no. 10, pp. 1087-1095, doi:10.1016/j.csr.2011.03.013

Feng, M, Caputi, N, Penn, J, Slawinski, D, de Lestang, S, Pearce, A 2011, Ocean circulation, Stokes drift and connectivity of western rock lobster population, Canadian Journal of Fisheries and Aquatic Sciences, vol. 68, pp. 1182-1196

Book Chapters

Rintoul, S, Turner, J, et, al. 2010, The Instrumental Period, in J Turner, RA Bindschadler, P Convey, G Di Prisco, E Fahrbach, J Gutt, DA Hodgson, PA Mayewski, CP Summerhayes (eds.), Antarctic Climate Change and the Environment, SCAR, Cambridge, pp.183-298

Rintoul, S 2011, The Southern Ocean in the Earth System, in PA Berkman, MA Lang, DWH Walton, OR Young (eds.), Science Diplomacy: Antarctica, Science and the Governance of International Spaces, Smithsonian Institution Scholarly Press, Washington DC, pp.175-187

Brassington, GB 2011, System design for operational ocean forecasting, in A Schiller, GB Brassington (eds.), Operational Oceanography in the 21st Century, Springer, Amsterdam, pp.441-486

Alves, O, Hudson, M, Balmaseda, MA, Shi, L 2011, Seasonal and Decadal Predicition, in A Schiller, GB Brassington (eds.), Operational Oceanography in the 21st Century, Springer, Amsterdam, pp.513-542

Woodham, RH 2011, Defence applications of operational oceanography: an Australian perspective, in GB Brassington, A Schiller (eds.), Operational Oceanography in the 21st Century, Springer, Amsterdam, pp.659-679

Oke, PR, O'Kane, TJ 2011, Observing system design and assessment, in A Schiller, GB Brassington (eds.), Operational Oceanography in the 21st Century, Springer, Amsterdam, pp.123-151

Church, JA, White, N, Domingues, CM, Barker, PM, Wijffels, S, Dunn, Jr, Drillet, Y 2011, Box 1.3: Ocean warming and sea-level rise , in K Richardson, W Steffen, D Liverman (eds.), Climate change: Global risks, challenges and decisions, Cambridge University Press, Cambridge, pp.14-17

In Press

Meijers, AJS, Bindoff, N, Rintoul, S 2010, Combining a Southern Ocean gravest empirical mode with satellite altimetry, Journal of Atmospheric and Oceanic Technology

Martin, MJ, et, al. 2011, Group for High Resoultion SST (GHRSST) Analysis Fields intercomparisons: Part 1. A GHRSST Multi-Product Ensemble (GMPE), Deep Sea Research Part II

2012

Baird, M. E. and K. R. Ridgway (2012), The southward transport of sub-mesoscale lenses of Bass Strait Water in the centre of anti-cyclonic mesoscale eddies, *Geophys. Res. Lett.*, 39, L02603, doi:10.1029/2011GL050643.