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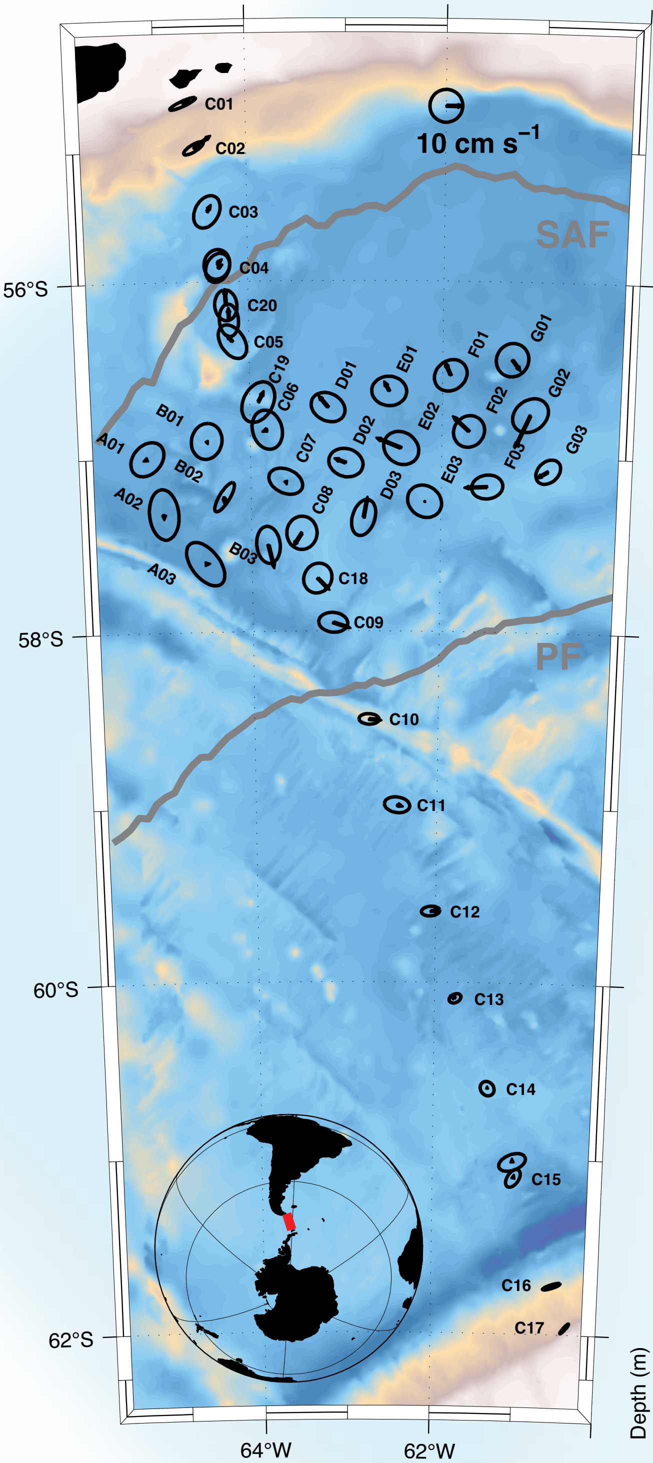
cDrake: Dynamics and Transport of the Antarctic Circumpolar Current in Drake Passage

BY TERESA K. CHERESKIN, KATHLEEN A. DONOHUE, AND D. RANDOLPH WATTS



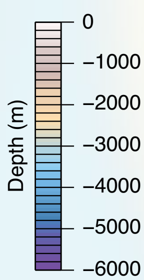


Figure 1. Record-length mean velocities and standard deviation ellipses (most records are four years long) of currents measured 50 m above the bottom at 41 CPIES sites during cDrake. Gray curves indicate the mean locations of the Subantarctic Front (SAF) and Polar Front (PF). Color fill indicates depth in m. *Updated from Chereskin et al. (2009)*

The Southern Ocean is especially sensitive to climate change, responding to winds that have increased over the past 30 years (Thompson and Solomon, 2002) and warming at about one degree per century in the core of the Antarctic Circumpolar Current (ACC; Gille, 2002). Drake Passage is a major control point of the ACC. It is a region of high mesoscale variability and complex topography. Eddies are thought to be essential for transferring momentum from the circumpolar winds that drive the ACC down to the seafloor where topographic form stresses regulate its transport. The cDrake experiment was designed to address fundamental dynamics not yet understood regarding wind forcing, eddy-mean momentum, and heat exchange, as well as form-drag interaction with bathymetry (Chereskin et al., 2009; http://cDrake.org).

The recently completed cDrake field program resolves the seasonal to interannual variability of the ACC transport and dynamics over a four-year period using 41 bottom-moored Current and Pressure-recording Inverted Echo Sounders (CPIESs). The cDrake array (Figure 1) is composed of a transport line spanning the entire passage and a local dynamics array (LDA) situated where surface variability is at a local maximum. Sites were instrumented from November to December 2007 during the International Polar Year and recovered in late 2011. During five annual cruises on RVIB *Nathaniel B. Palmer*, daily-averaged data were collected by acoustic telemetry to the ship in order to leave instruments undisturbed on the seafloor. Additionally, a total of 287 full depth conductivity-temperature-depth/lowered acoustic Doppler current profiler (CTD/LADCP) casts were made, and the complex topography of seamounts and ridges in the 24,000 km^2 LDA was mapped with the Simrad multibeam system.

A CPIES is composed of three measurements: ocean currents from an Aanderaa Doppler current sensor tethered 50 m above the seafloor, bottom pressure, and tau, the round trip acoustic travel time to the sea surface and back. Taus are used to estimate full-water-column profiles of temperature, salinity, and density based on an empirical look-up table (the gravest empirical mode or GEM) derived from the regional hydrography (Watts et al., 2001). Through geostrophy, density profiles at laterally paired CPIES sites yield vertical profiles of baroclinic velocity. The near-bottom current and bottom pressure measurements provide the barotropic reference velocity to render the velocity profiles absolute.

The LDA was designed to quantify eddy exchanges with the mean current and density structure. Four-year records from currents measured at 50 m above bottom reveal

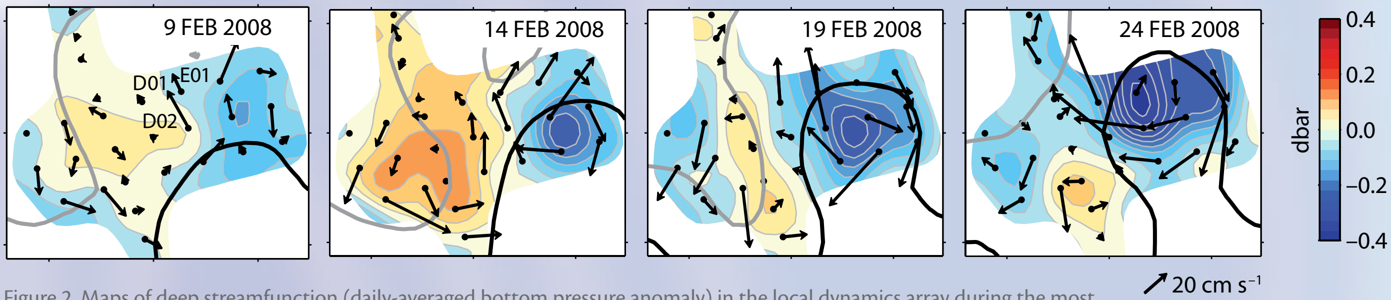


Figure 2. Maps of deep streamfunction (daily-averaged bottom pressure anomaly) in the local dynamics array during the most energetic cyclogenesis event in 2008 are shown at five-day intervals (Chereskin et al., 2009). Daily-averaged current vectors are shown at CPIES sites. Thick gray and black curves indicate the respective paths of the surface Subantarctic and Polar Fronts.

extremely large bottom velocities in northern Drake Passage, where means exceeded 10 cm s^{-1} at nine sites in the LDA and mean directions were not, in general, aligned with the surface fronts (Figure 1). Deep transient eddies were observed to form within the LDA when the upper ACC meandered, consistent with deep cyclogenesis (Chereskin et al., 2009). For example, during the most energetic 2008 cyclogenesis event, a steep crest in a meander of the Subantarctic Front of the ACC moved into the LDA on February 9 while a deep anticyclone formed, reaching its peak pressure anomaly of 0.28 dbar on February 14 (Figure 2). Meanwhile, a trough in the meandering Polar Front rapidly steepened and advanced northeastward in the LDA from February 9–24, coincident with the spinup of a deep cyclone that reached a peak pressure anomaly of −0.4 dbar on February 24. The associated peak bottom currents exceeded 70 cm s^{-1} (Figure 2). The cDrake four-year record will be used to test hypotheses regarding the processes that govern the dynamics of the time-varying ACC.

The transport line was designed to determine seasonal to interannual varying total ACC transport, its vertical structure partitioned between barotropic and baroclinic components, and its lateral structure partitioned among the multiple jets occurring within the ACC. Some of the earliest work in Drake Passage suggested that variability in transport was mainly barotropic and could therefore be monitored using across-passage pressure differences (for a recent review, see Meredith et al., 2011). cDrake observations indicate that barotropic transport is sensitive to both the northern and the southern endpoint locations. A suite of reasonable endpoint choices yields barotropic transport variability with standard deviations near 10 Sv. In all cases, large transport fluctuations, as high as 30 Sv, occur over timescales of weeks to days. A multiple-site average reduces local small-scale eddy variability at both the southern and northern endpoints and best describes barotropic transport variation in Drake Passage.

A high priority is placed on sustained observations in Drake Passage because of its role in the global-scale ocean circulation (Rintoul et al., 2010). The cDrake observations will be used to design an optimal array for future monitoring efforts. Assimilation of cDrake observations in the Southern Ocean State Estimate (Mazloff, et al., 2010) will improve the representation of the Southern Ocean in numerical models and will provide a framework for the synthesis of cDrake observations with those from other experiments during the International Polar Year time frame.

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AUTHORS

Teresa K. Chereskin *(tchereskin@ucsd.edu) is Research Oceanographer, Scripps Institution of Oceanography, University of California, San Diego, CA, USA.*
Kathleen A. Donohue *is Associate Professor, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI, USA.*
D. Randolph Watts *is Professor, Graduate School of Oceanography, University of Rhode Island, Narragansett, RI, USA.*

REFERENCES

Chereskin, T.K., K.A. Donohue, D.R. Watts, K.L. Tracey, Y.L. Firing, and A.L. Cutting. 2009. Strong bottom currents and cyclogenesis in Drake Passage. *Geophysical Research Letters* 36, L23602, http://dx.doi.org/10.1029/2009GL040940.

Gille, S.T. 2002. Warming of the Southern Ocean since the 1950s. *Science* 295:1,275–1,277, http://dx.doi.org/10.1126/science.1065863.

Mazloff, M.R., P. Heimbach, and C. Wunsch. 2010. An eddy permitting Southern Ocean state estimate. *Journal of Physical Oceanography* 40:880–899, http://dx.doi.org/10.1175/2009JPO4236.1.

Meredith, M.P., P.L. Woodworth, T.K. Chereskin, D.P. Marshall, L.C. Allison, G.R. Bigg, K.A. Donohue, K.J. Heywood, C.W. Hughes, A. Hibbert, and others. 2011. Sustained monitoring of the Southern Ocean at Drake Passage: Past achievements and future priorities. *Reviews of Geophysics* 49, RG4005, http://dx.doi.org/10.1029/2010RG000348.

Thompson, D.W.J., and S. Solomon. 2002. Interpretation of recent Southern Hemisphere climate change. *Science* 296:895–899, http://dx.doi.org/10.1126/science.1069270.

Rintoul, S.R., K. Speer, M. Sparrow, M. Meredith, E. Hofmann, E. Fahrbach, C. Summerhayes, A. Worby, M. England, R. Bellerby, and others. 2010. Southern Ocean Observing System (SOOS): Rationale and strategy for sustained observations of the Southern Ocean. In *Proceedings of OceanObs '09: Sustained Ocean Observations and Information for Society (Vol. 2), Venice, Italy, September 21–25, 2009*. J. Hall, D.E. Harrison, and D. Stammer, eds. European Space Agency Publication WPP-306, http://dx.doi.org/10.5270/OceanObs09.cwp.74.

Watts, D.R., C. Sun, and S. Rintoul. 2001. A two-dimensional gravest empirical mode determined from hydrographic observations in the Subantarctic Front. *Journal of Physical Oceanography* 31:2,186–2,209, http://dx.doi.org/10.1175/1520-0485(2001)031<2186:ATDGEM>2.0.CO;2.