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Bibliography

- Aagaard, K. and Carmack, E. C. (1989). The role of sea ice and other fresh water in the Arctic circulation. *Journal of Geophysical Research*, 94(1):414–485. doi:10.1029/JC094iC10p14485.
- Aagaard, K., Coachman, L., and Carmack, E. (1981). On the halocline of the Arctic Ocean. *Deep Sea Research Part A. Oceanographic Research Papers*, 28(6):529–545. doi:10.1016/0198-0149(81)90115-1.
- Abe-Ouchi, A., Saito, F., Kawamura, K., Raymo, M. E., Okuno, J., Takahashi, K., and Blatter, H. (2013). Insolation-driven 100,000-year glacial cycles and hysteresis of ice-sheet volume. *Nature*, 500(7461):190–193. doi:10.1038/nature12374.
- Abernathy, R. P., Cerovecki, I., Holland, P. R., Newsom, E., Mazloff, M., and Talley, L. D. (2016). Water-mass transformation by sea ice in the upper branch of the Southern Ocean overturning. *Nature Geoscience*, 9:596–601. doi:10.1038/ngeo2749.
- Abram, N. J., McGregor, H. V., Tierney, J. E., Evans, M. N., McKay, N. P., Kaufman, D. S., Thirumalai, K., Martrat, B., Goosse, H., Phipps, S. J., Steig, E. J., Kilbourne, K. H., Saenger, C. P., Zinke, J., Leduc, G., Addison, J. A., Mortyn, P. G., Seidenkrantz, M.-S., Sicre, M.-A., Selvaraj, K., Filipsson, H. L., Neukom, R., Gergis, J., Curran, M. A. J., and von Gunten, L. (2016). Early onset of industrial-era warming across the oceans and continents. *Nature*, 536(7617):411–418. doi:10.1038/nature19082.
- Abram, N. J., Mulvaney, R., Vimeux, F., Phipps, S. J., Turner, J., and England, M. H. (2014). Evolution of the Southern Annular Mode during the past millennium. *Nature Climate Change*, 4:564–569. doi:10.1038/nclimate2235.
- Adkins, J. F., McIntyre, K., and Schrag, D. P. (2002). The Salinity, Temperature, and $\delta^{18}\text{O}$ of the Glacial Deep Ocean. *Science*, 298(5599):1769–1773. doi:10.1126/science.1076252.
- Aguilar, E., Auer, I., Brunet, M., Peterson, T. C., and Wieringa, J. (2003). Guidelines on climate metadata and homogenization. Technical report, World Meteorological Organization.
- Anderson, R. F., Ali, S., Bradtmiller, L. I., Nielsen, S. H. H., Fleisher, M. Q., Anderson, B. E., and Burckle, L. H. (2009). Wind-driven upwelling in the Southern Ocean and the deglacial rise in atmospheric CO_2 . *Science*, 323(5920):1443–1448. doi:10.1126/science.1167441.
- Andersson, A., Fennig, K., Klepp, C., Bakan, S., Graßl, H., and Schulz, J. (2010). The Hamburg Ocean Atmosphere Parameters and Fluxes from Satellite Data HOAPS-3. *Earth System Science Data*, 2(2):215–234. doi:10.5194/essd-2-215-2010.
- Andrews, T., Gregory, J. M., Webb, M. J., Andrews, T., Gregory, J. M., and Webb, M. J. (2015). The Dependence of Radiative Forcing and Feedback on Evolving Patterns of Surface Temperature Change in Climate Models. *Journal of Climate*, 28(4):1630–1648. doi:10.1175/JCLI-D-14-00545.1.

- Arakawa, A. and Lamb, V. R. (1977). *General Circulation Models of the Atmosphere*, volume 17 of *Methods in Computational Physics: Advances in Research and Applications*. Elsevier. doi:10.1016/B978-0-12-460817-7.50009-4.
- Arblaster, J. M. and Meehl, G. A. (2006). Contributions of external forcings to Southern Annular Mode trends. *Journal of Climate*, 19(12):2896–2905. doi:10.1175/JCLI3774.1.
- Archer, D., Winguth, A., Lea, D., and Mahowald, N. (2000). What caused the glacial/interglacial atmospheric pCO₂ cycles? *Reviews of Geophysics*, 38(2):159–189. doi:10.1029/1999RG000066.
- Armour, K. C., Marshall, J., Scott, J. R., Donohoe, A., and Newsom, E. R. (2016). Southern Ocean warming delayed by circumpolar upwelling and equatorward transport. *Nature Geoscience*, 9(7):549–554. doi:10.1038/ngeo2731.
- Assmann, K. M. and Timmermann, R. (2005). Variability of dense water formation in the Ross Sea. *Ocean Dynamics*, 55(2):68–87. doi:10.1007/s10236-004-0106-7.
- Ballantyne, A. P., Alden, C. B., Miller, J. B., Tans, P. P., and White, J. W. C. (2012). Increase in observed net carbon dioxide uptake by land and oceans during the past 50 years. *Nature*, 488(7409):70–72. doi:10.1038/nature11299.
- Barnier, B., Marchesiello, P., De Miranda, A. P., Molines, J. M., and Coulibaly, M. (1998). A sigma-coordinate primitive equation model for studying the circulation in the South Atlantic. Part I: Model configuration with error estimates. *Deep-Sea Research Part I: Oceanographic Research Papers*, 45(4-5):543–572. doi:10.1016/S0967-0637(97)00086-1.
- Barth, A., Canter, M., van Schaeystroeck, B., Vannitsem, S., Massonnet, F., Zunz, V., Mathiot, P., Alvera-Azcárate, A., and Beckers, J. M. (2015). Assimilation of sea surface temperature, sea ice concentration and sea ice drift in a model of the Southern Ocean. *Ocean Modelling*, 93:22–39. doi:10.1016/j.ocemod.2015.07.011.
- Barthélemy, A., Fichefet, T., Goosse, H., and Madec, G. (2015). Modeling the interplay between sea ice formation and the oceanic mixed layer: Limitations of simple brine rejection parameterizations. *Ocean Modelling*, 86:141–152. doi:10.1016/j.ocemod.2014.12.009.
- Beckmann, A. and Goosse, H. (2003). A parameterization of ice shelf–ocean interaction for climate models. *Ocean Modelling*, 5(2):157–170. doi:10.1016/S1463-5003(02)00019-7.
- Beckmann, A., Hellmer, H. H., and Timmermann, R. (1999). A numerical model of the Weddell Sea: Large-scale circulation and water mass distribution. *Journal of Geophysical Research*, 104(C10):23375–23391. doi:10.1029/1999JC900194.
- Benz, V., Esper, O., Gersonde, R., Lamy, F., and Tiedemann, R. (2016). Last Glacial Maximum sea surface temperature and sea-ice extent in the Pacific sector of the Southern Ocean. *Quaternary Science Reviews*, 146:216–237. doi:10.1016/j.quascirev.2016.06.006.
- Berger, A., Tricot, C., Gallee, H., and Loutre, M. F. (1993). Water Vapour, CO₂ and Insolation over the Last Glacial-Interglacial Cycles. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 341(1297):253–261. doi:10.1098/rstb.1993.0110.
- Bernardello, R., Marinov, I., Palter, J. B., Galbraith, E. D., and Sarmiento, J. L. (2014a). Impact of Weddell Sea deep convection on natural and anthropogenic carbon in a climate model. *Geophysical Research Letters*, 41(20):7262–7269. doi:10.1002/2014GL061313.

- Bernardello, R., Marinov, I., Palter, J. B., Sarmiento, J. L., Galbraith, E. D., and Slater, R. D. (2014b). Response of the ocean natural carbon storage to projected twenty-first-century climate change. *Journal of Climate*, 27(5):2033–2053. doi:10.1175/JCLI-D-13-00343.1.
- Bintanja, R., van Oldenborgh, G. J., Drijfhout, S. S., Wouters, B., and Katsman, C. A. (2013). Important role for ocean warming and increased ice-shelf melt in Antarctic sea-ice expansion. *Nature Geoscience*, 6(5):376–379. doi:10.1038/ngeo1767.
- Bitz, C. M., Gent, P. R., Woodgate, R. A., Holland, M. M., and Lindsay, R. (2006). The influence of sea ice on ocean heat uptake in response to increasing CO₂. *Journal of Climate*, 19(11):2437–2450. doi:10.1175/JCLI3756.1.
- Bitz, C. M. and Polvani, L. M. (2012). Antarctic climate response to stratospheric ozone depletion in a fine resolution ocean climate model. *Geophysical Research Letters*, 39(20):L20705. doi:10.1029/2012GL053393.
- Blumberg, A. F. and Mellor, G. L. (1987). A description of a three-dimensional coastal ocean circulation model. In *Three-dimensional coastal ocean models (ed N.S. Heaps)*, volume 4, pages 1–16. American Geophysical Union. doi:10.1029/CO004p0001.
- Boé, J., Hall, A., and Qu, X. (2009). Deep ocean heat uptake as a major source of spread in transient climate change simulations. *Geophysical Research Letters*, 36(22):L22701. doi:10.1029/2009GL040845.
- Böning, C. W., Dispert, A., Visbeck, M., Rintoul, S. R., and Schwarzkopf, F. U. (2008). The response of the Antarctic Circumpolar Current to recent climate change. *Nature Geoscience*, 1(12):864–869. doi:10.1038/ngeo362.
- Bopp, L., Lévy, M., Resplandy, L., and Sallée, J.-B. (2015). Pathways of anthropogenic carbon subduction in the global ocean. *Geophysical Research Letters*, 42(15):6416–6423. doi:10.1002/2015GL065073.
- Bourassa, M. A., Gille, S. T., Bitz, C., Carlson, D., Cerovecki, I., Clayson, C. A., Cronin, M. F., Drennan, W. M., Fairall, C. W., Hoffman, R. N., Magnusdottir, G., Pinker, R. T., Renfrew, I. A., Serreze, M., Speer, K., Talley, L. D., and Wick, G. A. (2013). High-latitude ocean and sea ice surface fluxes: Challenges for climate research. *Bulletin of the American Meteorological Society*, 94(3):403–423. doi:10.1175/BAMS-D-11-00244.1.
- Bouttes, N., Paillard, D., and Roche, D. M. (2010). Impact of brine-induced stratification on the glacial carbon cycle. *Climate of the Past*, 6(5):575–589. doi:10.5194/cp-6-575-2010.
- Bouttes, N., Paillard, D., Roche, D. M., Waelbroeck, C., Kageyama, M., Laurantou, A., Michel, E., and Bopp, L. (2012). Impact of oceanic processes on the carbon cycle during the last termination. *Climate of the Past*, 8(1):149–170. doi:10.5194/cp-8-149-2012.
- Boyer, T. P., Antonov, J. I., Baranova, O. K., Coleman, C., Garcia, H. E., Grodsky, A., Johnson, D. R., Locarnini, R. A., Mishonov, A. V., O'Brien, T. D., Paver, C. R., Reagan, J. R., Seidov, D., Smolyar, I. V., and Zweng, M. M. (2013). World Ocean Database 2013, p. 209, Silver Spring. NOAA Atlas NESDIS 72, S. Levitus, Ed., A. Mishonov, Technical Ed. doi:10.7289/V5NZ85MT.
- Bracegirdle, T. J. (2013). Climatology and recent increase of westerly winds over the Amundsen Sea derived from six reanalyses. *International Journal of Climatology*, 33(4):843–851. doi:10.1002/joc.3473.

- Bracegirdle, T. J. and Marshall, G. J. (2012). The reliability of Antarctic tropospheric pressure and temperature in the latest global reanalyses. *Journal of Climate*, 25(20):7138–7146. doi:10.1175/JCLI-D-11-00685.1.
- Bracegirdle, T. J., Shuckburgh, E., Sallée, J.-B., Wang, Z., Meijers, A. J. S., Bruneau, N., Phillips, T., and Wilcox, L. J. (2013). Assessment of surface winds over the Atlantic, Indian, and Pacific Ocean sectors of the Southern Ocean in CMIP5 models: Historical bias, forcing response, and state dependence. *Journal of Geophysical Research Atmospheres*, 118(2):547–562. doi:10.1002/jgrd.50153.
- Brannigan, L., Lenn, Y.-D., Rippeth, T. P., McDonagh, E., Chereskin, T. K., and Sprintall, J. (2013). Shear at the Base of the Oceanic Mixed Layer Generated by Wind Shear Alignment. *Journal of Physical Oceanography*, 43(8):1798–1810. doi:10.1175/JPO-D-12-0104.1.
- Broecker, W. S. (1987). The biggest chill. *Natural History*, 96(10):74.
- Broecker, W. S. (1991). The Great Ocean Conveyor. *Oceanography*, 4(2):79–89. doi:10.5670/oceanog.1991.07.
- Broecker, W. S. (1997). Thermohaline Circulation, the Achilles Heel of Our Climate System: Will Man-Made CO₂ Upset the Current Balance? *Science*, 278(5343):1582–1588. doi:10.1126/science.278.5343.1582.
- Broecker, W. S. and Peng, T.-H. (1982). *Tracers in the sea*. Lamont-Doherty Geological Observatory, Columbia University, New York.
- Bromwich, D. H., Nicolas, J. P., and Monaghan, A. J. (2011). An Assessment of Precipitation Changes over Antarctica and the Southern Ocean since 1989 in Contemporary Global Reanalyses. *Journal of Climate*, 24(16):4189–4209. doi:10.1175/2011JCLI4074.1.
- Budgell, W. P. (2005). Numerical simulation of ice-ocean variability in the Barents Sea region. *Ocean Dynamics*, 55(3-4):370–387. doi:10.1007/s10236-005-0008-3.
- Butterworth, B. J. and Miller, S. D. (2016). Air-sea exchange of carbon dioxide in the Southern Ocean and Antarctic marginal ice zone. *Geophysical Research Letters*, 43(13):7223–7230. doi:10.1002/2016GL069581.
- Byrne, D., Papritz, L., Frenger, I., Münnich, M., and Gruber, N. (2014). Atmospheric Response to Mesoscale Sea Surface Temperature Anomalies: Assessment of Mechanisms and Coupling Strength in a High-Resolution Coupled Model over the South Atlantic. *Journal of the Atmospheric Sciences*, 72(5):1872–1890. doi:10.1175/JAS-D-14-0195.1.
- Cai, W., Cowan, T., Godfrey, S., Wijffels, S., Cai, W., Cowan, T., Godfrey, S., and Wijffels, S. (2010). Simulations of Processes Associated with the Fast Warming Rate of the Southern Midlatitude Ocean. *Journal of Climate*, 23(1):197–206. doi:10.1175/2009JCLI3081.1.
- Caldeira, K. and Duffy, P. B. (2000). The role of the southern ocean in uptake and storage of anthropogenic carbon dioxide. *Science*, 287(5453):620–622. doi:10.1126/science.287.5453.620.
- Cao, M. and Woodward, F. I. (1998). Dynamic responses of terrestrial ecosystem carbon cycling to global climate change. *Nature*, 393(6682):249–252. doi:10.1038/30460.
- Carril, A. F. and Navarra, A. (2001). Low-frequency variability of the Antarctic Circumpolar Wave. *Geophysical Research Letters*, 28(24):4623–4626. doi:10.1029/2001GL013804.

- Carton, J. A. and Giese, B. S. (2008). A Reanalysis of Ocean Climate Using Simple Ocean Data Assimilation (SODA). *Monthly Weather Review*, 136(8):2999–3017. doi:10.1175/2007MWR1978.1.
- Cavalieri, D. J. and Parkinson, C. L. (2008). Antarctic sea ice variability and trends, 1979–2006. *Journal of Geophysical Research*, 113(C7):C07004. doi:10.1029/2007JC004564.
- CDO (2015). Climate Data Operators (version 1.6.8). Available at: <http://www.mpimet.mpg.de/cdo>.
- Cerovečki, I. and Mazloff, M. R. (2016). The Spatiotemporal Structure of Diabatic Processes Governing the Evolution of Subantarctic Mode Water in the Southern Ocean. *Journal of Physical Oceanography*, 46(2):683–710. doi:10.1175/JPO-D-14-0243.1.
- Cerovečki, I., Talley, L. D., and Mazloff, M. R. (2011). A Comparison of Southern Ocean Air-Sea Buoyancy Flux from an Ocean State Estimate with Five Other Products. *Journal of Climate*, 24(24):6283–6306. doi:10.1175/2011JCLI3858.1.
- Chassignet, E. P., Arango, H., Dietrich, D., Ezer, T., Ghil, M., Haidvogel, D. B., Ma, C. C., Mehra, A., Paiva, A. M., and Sirkes, Z. (2000). DAMEE-NAB: The base experiments. *Dynamics of Atmospheres and Oceans*, 32(3-4):155–183. doi:10.1016/S0377-0265(00)00046-4.
- Chassignet, E. P., Smith, L. T., Halliwell, G. R., and Bleck, R. (2003). North Atlantic Simulations with the Hybrid Coordinate Ocean Model (HYCOM): Impact of the Vertical Coordinate Choice, Reference Pressure, and Thermobaricity. *Journal of Physical Oceanography*, 33(1981):2504–2526. doi:10.1175/1520-0485(2003)033<2504:NASWTH>2.0.CO;2.
- Chassignet, E. P., Xu, X., and Danabasoglu, G. (2014). Overflow parameterisations in climate models. *CLIVAR Exchanges*, 65(19/2):34–37.
- Chelton, D. B., DeSzoeke, R. A., Schlax, M. G., El Naggar, K., Siwertz, N., Chelton, D. B., DeSzoeke, R. A., Schlax, M. G., Naggar, K. E., and Siwertz, N. (1998). Geographical Variability of the First Baroclinic Rossby Radius of Deformation. *Journal of Physical Oceanography*, 28(3):433–460. doi:10.1175/1520-0485(1998)028<0433:GVOTFB>2.0.CO;2.
- Cheng, L., Trenberth, K. E., Palmer, M. D., Zhu, J., and Abraham, J. P. (2016). Observed and simulated full-depth ocean heat-content changes for 1970–2005. *Ocean Science*, 12(4):925–935. doi:10.5194/os-12-925-2016.
- Cionni, I., Eyring, V., Lamarque, J. F., Randel, W. J., Stevenson, D. S., Wu, F., Bodeker, G. E., Shepherd, T. G., Shindell, D. T., and Waugh, D. W. (2011). Ozone database in support of CMIP5 simulations: Results and corresponding radiative forcing. *Atmospheric Chemistry and Physics*, 11(21):11267–11292. doi:10.5194/acp-11-11267-2011.
- Clark, P. U., Pisias, N. G., Stocker, T. F., and Weaver, A. J. (2002). The role of the thermohaline circulation in abrupt climate change. *Nature*, 415(6874):863–869. doi:10.1038/415863a.
- Comiso, J. C. (1986). Characteristics of Arctic winter sea ice from satellite multi-spectral microwave observations. *Journal of Geophysical Research*, 91(C1):975–994. doi:10.1029/JC091iC01p00975.
- Comiso, J. C., Cavalieri, D. J., Parkinson, C. L., and Gloersen, P. (1997). Passive microwave algorithms for sea ice concentration: A comparison of two techniques. *Remote Sensing of Environment*, 60(3):357–384. doi:10.1016/S0034-4257(96)00220-9.

- Comiso, J. C., Kwok, R., Martin, S., and Gordon, A. L. (2011). Variability and trends in sea ice extent and ice production in the Ross Sea. *Journal of Geophysical Research*, 116(4):C04021. doi:10.1029/2010JC006391.
- Comiso, J. C. and Nishio, F. (2008). Trends in the sea ice cover using enhanced and compatible AMSR-E, SSM/I, and SMMR data. *Journal of Geophysical Research*, 113(C2):C02S07. doi:10.1029/2007JC004257.
- Cook, A. J., Holland, P. R., Meredith, M. P., Murray, T., Luckman, A., and Vaughan, D. G. (2016). Ocean forcing of glacier retreat in the western Antarctic Peninsula. *Science*, 353(6296):1261–1273. doi:10.1126/science.aae0017.
- Cox, P. M., Betts, R. A., Jones, C. D., Spall, S. A., and Totterdell, I. J. (2000). Acceleration of global warming due to carbon-cycle feedbacks in a coupled climate model. *Nature*, 408(6809):184–187. doi:10.1038/35041539.
- Cummins, P. F., Masson, D., and Saenko, O. A. (2016). Vertical heat flux in the ocean: Estimates from observations and from a coupled general circulation model. *Journal of Geophysical Research: Oceans*, 121(6):3790–3802. doi:10.1002/2016JC011647.
- Cunningham, S. A., Alderson, S. G., King, B. A., and Brandon, M. A. (2003). Transport and variability of the Antarctic Circumpolar Current in Drake Passage. *Journal of Geophysical Research*, 108(C5):8084. doi:10.1029/2001JC001147.
- Cunningham, S. A., Kanzow, T., Rayner, D., Baringer, M. O., Johns, W. E., Marotzke, J., Longworth, H. R., Grant, E. M., Hirschi, J. J.-M., Beal, L. M., Meinen, C. S., and Bryden, H. L. (2007). Temporal variability of the Atlantic meridional overturning circulation at 26.5 degrees N. *Science*, 317(5840):935–938. doi:10.1126/science.1141304.
- Curry, J. A., Schramm, J. L., and Ebert, E. E. (1995). Sea ice-albedo climate feedback mechanism. *Journal of Climate*, 8(2):240–247. doi:10.1175/1520-0442(1995)008<0240:SIACFM>2.0.CO;2.
- Curry, W. B. and Oppo, D. W. (2005). Glacial water mass geometry and the distribution of $\delta^{13}\text{C}$ of $\sum\text{CO}_2$ in the western Atlantic Ocean. *Paleoceanography*, 20(1):1–12. doi:10.1029/2004PA001021.
- Cushman-Roisin, B. and Beckers, J.-M. (2011). *Introduction to Geophysical Fluid Dynamics - Physical and Numerical Aspects*, volume 101 of *International Geophysics Series*. Elsevier Academic Press, Burlington, San Diego, London, 2 edition.
- Danabasoglu, G., Large, W. G., Tribbia, J. J., Gent, P. R., Briegleb, B. P., and McWilliams, J. C. (2006). Diurnal coupling in the tropical oceans of CCSM3. *Journal of Climate*, 19(11):2347–2365. doi:10.1175/JCLI3739.1.
- de Boer, A., Sigman, D. M., Toggweiler, J. R., and Russell, J. L. (2007). Effect of global ocean temperature change on deep ocean ventilation. *Paleoceanography*, 22(PA2210):15. doi:10.1029/2005PA001242.
- de Boyer Montégut, C., Madec, G., Fischer, A. S., Lazar, A., and Iudicone, D. (2004). Mixed layer depth over the global ocean: An examination of profile data and a profile-based climatology. *Journal of Geophysical Research*, 109(12):1–20. doi:10.1029/2004JC002378.

- de Lavergne, C., Palter, J. B., Galbraith, E. D., Bernardello, R., and Marinov, I. (2014). Cessation of deep convection in the open Southern Ocean under anthropogenic climate change. *Nature Climate Change*, 4(4):278–282. doi:10.1038/nclimate2132.
- Deacon, G. E. R. (1937). The hydrology of the Southern Ocean, In *Discovery reports*, pages 1–124. Cambridge University Press.
- DeConto, R. M. and Pollard, D. (2016). Contribution of Antarctica to past and future sea-level rise. *Nature*, 531(7596):591–597. doi:10.1038/nature17145.
- Dee, D. P., Uppala, S. M., Simmons, A. J., Berrisford, P., Poli, P., Kobayashi, S., Andrae, U., Balmaseda, M. A., Balsamo, G., Bauer, P., Bechtold, P., Beljaars, A. C. M., van de Berg, L., Bidlot, J., Bormann, N., Delsol, C., Dragani, R., Fuentes, M., Geer, A. J., Haimberger, L., Healy, S. B., Hersbach, H., Hólm, E. V., Isaksen, L., Kållberg, P., Köhler, M., Matricardi, M., McNally, A. P., Monge-Sanz, B. M., Morcrette, J. J., Park, B. K., Peubey, C., de Rosnay, P., Tavolato, C., Thépaut, J. N., and Vitart, F. (2011). The ERA-Interim reanalysis: configuration and performance of the data assimilation system. *Quarterly Journal of the Royal Meteorological Society*, 137(656):553–597. doi:10.1002/qj.828.
- Delworth, T., Manabe, S., and Stouffer, R. J. (1993). Interdecadal Variations of the Thermohaline Circulation in a Coupled Ocean-Atmosphere Model. *Journal of Climate*, 6(11):1993–2011. doi:10.1175/1520-0442(1993)006<1993:IVOTTC>2.0.CO;2.
- Depoorter, M. A., Bamber, J. L., Griggs, J. A., Lenaerts, J. T. M., Ligtenberg, S. R. M., van den Broeke, M. R., and Moholdt, G. (2013). Calving fluxes and basal melt rates of Antarctic ice shelves. *Nature*, 502(7469):89–92. doi:10.1038/nature12567.
- DeVries, T. and Primeau, F. (2011). Dynamically and observationally constrained estimates of water-mass distributions and ages in the global ocean. *Journal of Physical Oceanography*, 41(12):2381–2401. doi:10.1175/JPO-D-10-05011.1.
- Ding, Q., Steig, E. J., Battisti, D. S., and Kuttel, M. (2011). Winter warming in West Antarctica caused by central tropical Pacific warming. *Nature Geoscience*, 4(6):398–403. doi:10.1038/ngeo1129.
- Ding, Q., Steig, E. J., Battisti, D. S., and Wallace, J. M. (2012). Influence of the Tropics on the Southern Annular Mode. *Journal of Climate*, 25(18):6330–6348. doi:10.1175/JCLI-D-11-00523.1.
- Dinniman, M. S., Klinck, J. M., and Hofmann, E. E. (2012). Sensitivity of Circumpolar Deep Water Transport and Ice Shelf Basal Melt along the West Antarctic Peninsula to Changes in the Winds. *Journal of Climate*, 25(14):4799–4816. doi:10.1175/JCLI-D-11-00307.1.
- Dinniman, M. S., Klinck, J. M., and Smith, W. O. (2003). Cross-shelf exchange in a model of the Ross Sea circulation and biogeochemistry. *Deep Sea Research Part II: Topical Studies in Oceanography*, 50(22-26):3103–3120. doi:10.1016/j.dsr2.2003.07.011.
- Dinniman, M. S., Klinck, J. M., and Smith, W. O. (2011). A model study of Circumpolar Deep Water on the West Antarctic Peninsula and Ross Sea continental shelves. *Deep Sea Research Part II: Topical Studies in Oceanography*, 58(13-16):1508–1523. doi:10.1016/j.dsr2.2010.11.013.

- Dinniman, M. S., Klinck, J. M., and Smith, W. O. J. (2007). Influence of sea ice cover and icebergs on circulation and water mass formation in a numerical circulation model of the Ross Sea, Antarctica. *Journal of Geophysical Research*, 112(C11):C11013. doi:10.1029/2006JC004036.
- Doney, S. C. and Hecht, M. W. (2002). Antarctic Bottom Water formation and deep-water Chlorofluorocarbon distributions in a global ocean climate model. *Journal of Physical Oceanography*, 32(6):1642–1666. doi:10.1175/1520-0485(2002)032<1642:ABWFAD>2.0.CO;2.
- Doney, S. C., Lindsay, K., Caldeira, K., Campin, J.-M., Drange, H., Dutay, J.-C., Follows, M., Gao, Y., Gnanadesikan, A., Gruber, N., Ishida, A., Joos, F., Madec, G., Maier-Reimer, E., Marshall, J. C., Matear, R. J., Monfray, P., Mouchet, A., Najjar, R., Orr, J. C., Plattner, G.-K., Sarmiento, J., Schlitzer, R., Slater, R., Totterdell, I. J., Weirig, M.-F., Yamanaka, Y., and Yool, A. (2004). Evaluating global ocean carbon models: The importance of realistic physics. *Global Biogeochemical Cycles*, 18(3):GB3017. doi:10.1029/2003GB002150.
- Dong, J., Speer, K., and Jullion, L. (2016). The Antarctic Slope Current near 30°E. *Journal of Geophysical Research: Oceans*, 121(2):1051–1062. doi:10.1002/2015JC011099.
- Döös, K. and Webb, D. J. (1994). The Deacon Cell and the Other Meridional Cells of the Southern Ocean. *Journal of Physical Oceanography*, 24(2):429–442. doi:10.1175/1520-0485(1994)024<0429:TDCATO>2.0.CO;2.
- Downes, S. M., Bindoff, N. L., and Rintoul, S. R. (2010). Changes in the subduction of Southern Ocean water masses at the end of the twenty-first century in eight IPCC models. *Journal of Climate*, 23(24):6526–6541. doi:10.1175/2010JCLI3620.1.
- Downes, S. M., Farneti, R., Uotila, P., Griffies, S. M., Marsland, S. J., Bailey, D., Behrens, E., Bentsen, M., Bi, D., Biastoch, A., Böning, C., Bozec, A., Canuto, V. M., Chassignet, E., Danabasoglu, G., Danilov, S., Diansky, N., Drange, H., Fogli, P. G., Gusev, A., Howard, A., Ilicak, M., Jung, T., Kelley, M., Large, W. G., Leboissetier, A., Long, M., Lu, J., Masina, S., Mishra, A., Navarra, A., George Nurser, A. J., Patara, L., Samuels, B. L., Sidorenko, D., Spence, P., Tsujino, H., Wang, Q., and Yeager, S. G. (2015). An assessment of Southern Ocean water masses and sea ice during 1988-2007 in a suite of interannual CORE-II simulations. *Ocean Modelling*, 94:67–94. doi:10.1016/j.ocemod.2015.07.022.
- Downes, S. M., Gnanadesikan, A., Griffies, S. M., and Sarmiento, J. L. (2011). Water Mass Exchange in the Southern Ocean in Coupled Climate Models. *Journal of Physical Oceanography*, 41(2001):1756–1771. doi:10.1175/2011JPO4586.1.
- Downes, S. M. and Hogg, A. M. C. C. (2013). Southern Ocean circulation and eddy compensation in CMIP5 models. *Journal of Climate*, 26(18):7198–7220. doi:10.1175/JCLI-D-12-00504.1.
- Drucker, R., Martin, S., and Kwok, R. (2011). Sea ice production and export from coastal polynyas in the Weddell and Ross Seas. *Geophysical Research Letters*, 38(17):L17502. doi:10.1029/2011GL048668.
- Duffy, P. B. and Caldeira, K. (1997). Sensitivity of simulated salinity in a three-dimensional ocean model to upper ocean transport of salt from sea-ice formation. *Geophysical Research Letters*, 24(11):1323–1326. doi:10.1029/97GL01294.
- Duffy, P. B., Eby, M., and Weaver, A. J. (1999). Effects of sinking of salt rejected during formation of sea ice on results of an ocean-atmosphere-sea ice climate model. *Geophysical Research Letters*, 26(12):1739–1742. doi:10.1029/1999GL900286.

- Dufour, C. O., Griffies, S. M., de Souza, G. F., Frenger, I., Morrison, A. K., Palter, J. B., Sarmiento, J. L., Galbraith, E. D., Dunne, J. P., Anderson, W. G., and Slater, R. D. (2015). Role of Mesoscale Eddies in Cross-Frontal Transport of Heat and Biogeochemical Tracers in the Southern Ocean. *Journal of Physical Oceanography*, 45(12):3057–3081. doi:10.1175/JPO-D-14-0240.1.
- Dufour, C. O., Sommer, J. L., Gehlen, M., Orr, J. C., Molines, J.-M., Simeon, J., and Barnier, B. (2013). Eddy compensation and controls of the enhanced sea-to-air CO₂ flux during positive phases of the Southern Annular Mode. *Global Biogeochemical Cycles*, 27(3):950–961. doi:10.1002/gbc.20090.
- Dukowicz, J. K. (2001). Reduction of Density and Pressure Gradient Errors in Ocean Simulations. *Journal of Physical Oceanography*, 31(7):1915–1921. doi:10.1175/1520-0485(2001)031<1915:RODAPG>2.0.CO;2.
- Dunn, J. and Ridgway, K. (2002). Mapping ocean properties in regions of complex topography. *Deep Sea Research Part I: Oceanographic Research Papers*, 49(3):591–604. doi:10.1016/S0967-0637(01)00069-3.
- Durack, P. J., Gleckler, P. J., Landerer, F. W., and Taylor, K. E. (2014). Quantifying underestimates of long-term upper-ocean warming. *Nature Climate Change*, 4(11):999–1005. doi:10.1038/nclimate2389.
- Durack, P. J. and Wijffels, S. E. (2010). Fifty-year trends in global ocean salinities and their relationship to broad-scale warming. *Journal of Climate*, 23(16):4342–4362. doi:10.1175/2010JCLI3377.1.
- Durack, P. J., Wijffels, S. E., and Matear, R. J. (2012). Ocean salinities reveal strong global water cycle intensification during 1950 to 2000. *Science*, 336(6080):455–458. doi:10.1126/science.1212222.
- Dussin, R., Barnier, B., Brodeau, L., and Molines, J. M. (2016). The making of the DRAKKAR FORCING SET DFS5. Technical report, LGGE, Grenoble, France.
- Eberenz, S. (2015). Effect of sea ice freshwater flux on Southern Ocean mixed layer processes. *Master's Thesis: ETH Zürich*, p. 64.
- ECMWF (2007). Part IV: Physical Processes. In *IFS Documentation CY31R1*, p. 155. ECMWF.
- Eisenman, I., Meier, W. N., and Norris, J. R. (2014). A spurious jump in the satellite record: has Antarctic sea ice expansion been overestimated? *The Cryosphere*, 8(4):1289–1296. doi:10.5194/tc-8-1289-2014.
- Emery, W. J., Fowler, C. W., and Maslanik, J. A. (1995). Satellite remote sensing of ice motion. In Ikeda, M. and Dobson, F. W., editors, *Oceanographic applications of remote sensing*, Oceanographic Applications of Remote Sensing, chapter 23, pages 367–379. CRC Press.
- Emery, W. J., Fowler, C. W., and Maslanik, J. A. (1997). Satellite-derived maps of Arctic and Antarctic sea ice motion: 1988 to 1994. *Geophysical Research Letters*, 24(8):897–900. doi:10.1029/97GL00755.
- England, M. H. (1992). On the Formation of Antarctic Intermediate and Bottom Water in Ocean General Circulation Models. *Journal of Physical Oceanography*, 22(8):918–926. doi:10.1175/1520-0485(1992)022<0918:OTFOAI>2.0.CO;2.

- England, M. H., Godfrey, J. S., Hirst, A. C., and Tomczak, M. (1993). The mechanism for Antarctic Intermediate Water renewal in a world ocean model. *Journal of Physical Oceanography*, 23(7):1553–1560. doi:10.1175/1520-0485(1993)023<1553:TMFAIW>2.0.CO;2.
- EPICA community members, Augustin, L., Barbante, C., Barnes, P. R. F., Marc Barnola, J., Bigler, M., Castellano, E., Cattani, O., Chappellaz, J., Dahl-Jensen, D., Delmonte, B., Dreyfus, G., Durand, G., Falourd, S., Fischer, H., Flückiger, J., Hansson, M. E., Huybrechts, P., Jugie, G., Johnsen, S. J., Jouzel, J., Kaufmann, P., Kipfstuhl, J., Lambert, F., Lipenkov, V. Y., Littot, G. C., Longinelli, A., Lorrain, R., Maggi, V., Masson-Delmotte, V., Miller, H., Mulvaney, R., Oerlemans, J., Oerter, H., Orombelli, G., Parrenin, F., Peel, D. A., Petit, J.-R., Raynaud, D., Ritz, C., Ruth, U., Schwander, J., Siegenthaler, U., Souchez, R., Stauffer, B., Peder Steffensen, J., Stenni, B., Stocker, T. F., Tabacco, I. E., Udisti, R., van de Wal, R. S. W., van den Broeke, M., Weiss, J., Wilhelms, F., Winther, J.-G., Wolff, E. W., and Zucchelli, M. (2004). Eight glacial cycles from an Antarctic ice core. *Nature*, 429(6992):623–628. doi:10.1038/nature02599.
- Eveleth, R., Cassar, N., Sherrell, R., Ducklow, H., Meredith, M., Venables, H., Lin, Y., and Li, Z. (2017). Ice melt influence on summertime net community production along the Western Antarctic Peninsula. *Deep Sea Research Part II: Topical Studies in Oceanography*, 139:89–102. doi:10.1016/j.dsr2.2016.07.016.
- Fahrbach, E., Augstein, E., and Olbers, D. (1994). Impact of shelf and sea ice on water mass modifications and large-scale oceanic circulation in the Weddell Sea. In *Antarctic Science*, pages 167–187. Springer Berlin Heidelberg, Berlin, Heidelberg. doi:10.1007/978-3-642-78711-9_12.
- Fahrbach, E., Rohardt, G., and Krause, G. (1992). The Antarctic coastal current in the southeastern Weddell Sea. *Polar Biology*, 12(2):171–182. doi:10.1007/BF00238257.
- Fan, T., Deser, C., and Schneider, D. P. (2014). Recent Antarctic sea ice trends in the context of Southern Ocean surface climate variations since 1950. *Geophysical Research Letters*, 41(7):2419–2426. doi:10.1002/2014GL059239.
- Farneti, R., Delworth, T. L., Rosati, A. J., Griffies, S. M., and Zeng, F. (2010). The Role of Mesoscale Eddies in the Rectification of the Southern Ocean Response to Climate Change. *Journal of Physical Oceanography*, 40(7):1539–1557. doi:10.1175/2010JPO4353.1.
- Farneti, R., Downes, S. M., Griffies, S. M., Marsland, S. J., Behrens, E., Bentsen, M., Bi, D., Biastoch, A., Böning, C., Bozec, A., Canuto, V. M., Chassignet, E., Danabasoglu, G., Danilov, S., Diansky, N., Drange, H., Fogli, P. G., Gusev, A., Hallberg, R. W., Howard, A., Ilicak, M., Jung, T., Kelley, M., Large, W. G., Leboissetier, A., Long, M., Lu, J., Masina, S., Mishra, A., Navarra, A., George Nurser, A. J., Patara, L., Samuels, B. L., Sidorenko, D., Tsujino, H., Uotila, P., Wang, Q., and Yeager, S. G. (2015). An assessment of Antarctic Circumpolar Current and Southern Ocean meridional overturning circulation during 1958–2007 in a suite of interannual CORE-II simulations. *Ocean Modelling*, 93:84–120. doi:10.1016/j.ocemod.2015.07.009.
- Farneti, R. and Gent, P. R. (2011). The effects of the eddy-induced advection coefficient in a coarse-resolution coupled climate model. *Ocean Modelling*, 39(1-2):135–145. doi:10.1016/j.ocemod.2011.02.005.
- Fay, A. R., McKinley, G. A., and Lovenduski, N. S. (2014). Southern Ocean carbon trends: Sensitivity to methods. *Geophysical Research Letters*, 41(19):6833–6840. doi:10.1002/2014GL061324.

- Ferrari, R., Jansen, M. F., Adkins, J. F., Burke, A., Stewart, A. L., and Thompson, A. F. (2014). Antarctic sea ice control on ocean circulation in present and glacial climates. *Proceedings of the National Academy of Sciences*, 111(24):8753–8758. doi:10.1073/pnas.1323922111.
- Ferrari, R. and Wunsch, C. (2009). Ocean Circulation Kinetic Energy: Reservoirs, Sources, and Sinks. *Annual Review of Fluid Mechanics*, 41(1):253–282. doi:10.1146/annurev.fluid.40.111406.102139.
- Ferreira, D., Marshall, J., Bitz, C. M., Solomon, S., and Plumb, A. (2015). Antarctic ocean and sea ice response to ozone depletion: A two-time-scale problem. *Journal of Climate*, 28(3):1206–1226. doi:10.1175/JCLI-D-14-00313.1.
- Fischer, H., Schmitt, J., Lüthi, D., Stocker, T. F., Tschumi, T., Parekh, P., Joos, F., Köhler, P., Völker, C., Gersonde, R., Barbante, C., Le Floch, M., Raynaud, D., and Wolff, E. (2010). The role of Southern Ocean processes in orbital and millennial CO₂ variations - A synthesis. *Quaternary Science Reviews*, 29(1-2):193–205. doi:10.1016/j.quascirev.2009.06.007.
- Flather, R. A. (1976). A tidal model of the northwest European continental shelf. *Memoires de la Societe Royale des Sciences de Liege*, 6(10):141–164.
- Fogt, R. L., Jones, J. M., and Renwick, J. (2012). Seasonal zonal asymmetries in the Southern Annular Mode and their impact on regional temperature anomalies. *Journal of Climate*, 25(18):6253–6270. doi:10.1175/JCLI-D-11-00474.1.
- Fogwill, C. J., Phipps, S. J., Turney, C. S. M., and Golledge, N. R. (2015). Sensitivity of the Southern Ocean to enhanced regional Antarctic ice sheet meltwater input. *Earth's Future*, 3(10):317–329. doi:10.1002/2015EF000306.
- Forryan, A., Naveira Garabato, A. C., Polzin, K. L., and Waterman, S. (2015). Rapid injection of near-inertial shear into the stratified upper ocean at an Antarctic Circumpolar Current front. *Geophysical Research Letters*, 42(9):3431–3441. doi:10.1002/2015GL063494.
- Fowler, C., Emery, W. J., and Tschudi, M. A. (2013a). Polar Pathfinder daily 25 km EASE-Grid sea ice motion vectors, version 2, 1979–2011, Boulder, Colorado USA. National Snow and Ice Data Center, distributed in netCDF format by the Integrated Climate Data Center University of Hamburg. Digital media.
- Fowler, C., Emery, W. J., and Tschudi, M. A. (2013b). Polar Pathfinder daily 25 km EASE-Grid sea ice motion vectors, version 2, 1980–2009, Boulder, Colorado USA. National Snow and Ice Data Center, distributed in netCDF format by the Integrated Climate Data Center University of Hamburg. Digital media.
- Francois, R., Altabet, M. A., Yu, E.-F., Sigman, D. M., Bacon, M. P., Frank, M., Bohrmann, G., Bareille, G., and Labeyrie, L. D. (1997). Contribution of Southern Ocean surface-water stratification to low atmospheric CO₂ concentrations during the last glacial period. *Nature*, 389(6654):929–935. doi:10.1038/40073.
- Freeman, N. M., Lovenduski, N. S., and Gent, P. R. (2016). Temporal variability in the Antarctic Polar Front (2002–2014). *Journal of Geophysical Research: Oceans*, 121. doi:10.1002/2016JC012145.
- Frenger, I., Gruber, N., Knutti, R., and Münnich, M. (2013). Imprint of Southern Ocean eddies on winds, clouds and rainfall. *Nature Geoscience*, 6(8):608–612. doi:10.1038/ngeo1863.

- Frenger, I., Münnich, M., Gruber, N., and Knutti, R. (2015). Southern Ocean eddy phenomenology. *Journal of Geophysical Research*, 120(11):7413–7449. doi:10.1002/2015JC011047.
- Friedlingstein, P., Bopp, L., Ciais, P., Dufresne, J.-L., Fairhead, L., LeTreut, H., Monfray, P., and Orr, J. (2001). Positive feedback between future climate change and the carbon cycle. *Geophysical Research Letters*, 28(8):1543–1546. doi:10.1029/2000GL012015.
- Friedlingstein, P., Cox, P., Betts, R., Bopp, L., von Bloh, W., Brovkin, V., Cadule, P., Doney, S., Eby, M., Fung, I., Bala, G., John, J., Jones, C., Joos, F., Kato, T., Kawamiya, M., Knorr, W., Lindsay, K., Matthews, H. D., Raddatz, T., Rayner, P., Reick, C., Roeckner, E., Schnitzler, K.-G., Schnur, R., Strassmann, K., Weaver, A. J., Yoshikawa, C., and Zeng, N. (2006). Climate–carbon cycle feedback analysis: Results from the C4MIP model intercomparison. *Journal of Climate*, 19(14):3337–3353. doi:10.1175/JCLI3800.1.
- Frischknecht, M., Münnich, M., and Gruber, N. (2015). Remote versus local influence of ENSO on the California Current System. *Journal of Geophysical Research*, 120(2):1353–1374. doi:10.1002/2014JC010531.
- Frölicher, T. L., Sarmiento, J. L., Paynter, D. J., Dunne, J. P., Krasting, J. P., and Winton, M. (2015). Dominance of the Southern Ocean in anthropogenic carbon and heat uptake in CMIP5 models. *Journal of Climate*, 28(2):862–886. doi:10.1175/JCLI-D-14-00117.1.
- Frölicher, T. L., Winton, M., and Sarmiento, J. L. (2014). Continued global warming after CO₂ emissions stoppage. *Nature Climate Change*, 4(1):40–44. doi:10.1038/nclimate2060.
- Fyfe, J. C. and Saenko, O. A. (2006). Simulated changes in the extratropical Southern Hemisphere winds and currents. *Geophys. Res. Lett.*, 33(6):L06701.
- Fyfe, J. C., Saenko, O. A., Zickfeld, K., Eby, M., and Weaver, A. J. (2007). The role of poleward-intensifying winds on Southern Ocean warming. *Journal of Climate*, 20(21):5391–5400. doi:10.1175/2007JCLI1764.1.
- Ganachaud, A. and Wunsch, C. (2000). Improved estimates of global ocean circulation, heat transport and mixing from hydrographic data. *Nature*, 408(6811):453–457. doi:10.1038/35044048.
- Ganopolski, A. and Rahmstorf, S. (2001). Rapid changes of glacial climate simulated in a coupled climate model. *Nature*, 409(6817):153–158.
- Garcia, H. E., Locarnini, R. A., Boyer, T. P., Antonov, J. I., Baranova, O. K., Zweng, M. M., Reagan, J. R., and Johnson, D. R. (2014a). World Ocean Atlas 2013, Volume 3: Dissolved Oxygen, Apparent Oxygen Utilization, and Oxygen Saturation, p. 27. NOAA Atlas NESDIS 75.
- Garcia, H. E., Locarnini, R. A., Boyer, T. P., Antonov, J. I., Baranova, O. K., Zweng, M. M., Reagan, J. R., and Johnson, D. R. (2014b). World Ocean Atlas 2013, Volume 4: Dissolved Inorganic Nutrients (phosphate, nitrate, silicate), p. 25. NOAA Atlas NESDIS 76.
- Gargett, A. E. (1991). Physical processes and the maintenance of nutrient-rich euphotic zones. *Limnology and Oceanography*, 36(8):1527–1545. doi:10.4319/lo.1991.36.8.1527.
- Gent, P. R., Craig, A. P., Bitz, C. M., and Weatherly, J. W. (2002). Parameterization improvements in an eddy-permitting ocean model for climate. *Journal of Climate*, 15(12):1447–1459. doi:10.1175/1520-0442(2002)015<1447:PIIAEP>2.0.CO;2.

- Gent, P. R. and McWilliams, J. C. (1990). Isopycnal Mixing in Ocean Circulation Models. *Journal of Physical Oceanography*, 20(1):150–155. doi:10.1175/1520-0485(1990)020<0150:IMIOCM>2.0.CO;2.
- Gent, P. R., Willebrand, J., McDougall, T. J., and McWilliams, J. C. (1995). Parameterizing Eddy-Induced Tracer Transports in Ocean Circulation Models. *Journal of Physical Oceanography*, 25(4):463–474. doi:10.1175/1520-0485(1995)025<0463:PEITTI>2.0.CO;2.
- Gersonde, R., Crosta, X., Abelmann, A., and Armand, L. (2005). Sea-surface temperature and sea ice distribution of the Southern Ocean at the EPILOG Last Glacial Maximum - A circum-Antarctic view based on siliceous microfossil records. *Quaternary Science Reviews*, 24(7-9):869–896. doi:10.1016/j.quascirev.2004.07.015.
- Giese, B. S., Seidel, H. F., Compo, G. P., and Sardeshmukh, P. D. (2016). An ensemble of ocean reanalyses for 1815-2013 with sparse observational input. *Journal of Geophysical Research: Oceans*, 121(9):6891–6910. doi:10.1002/2016JC012079.
- Gildor, H. and Tziperman, E. (2000). Sea ice as the glacial cycles' climate switch: role of seasonal and orbital forcing. *Paleoceanography*, 15(6):605–615. doi:10.1029/1999PA000461.
- Gille, S. T. (2002). Warming of the Southern Ocean since the 1950s. *Science*, 295(5558):1275–1277. doi:10.1126/science.1065863.
- Gille, S. T. (2008). Decadal-scale temperature trends in the Southern Hemisphere ocean. *Journal of Climate*, 21(18):4749–4765. doi:10.1175/2008JCLI2131.1.
- Giorgetta, M. A., Jungclaus, J. H., Reick, C. H., Legutke, S., Bader, J., Böttinger, M., Brovkin, V., Crueger, T., Esch, M., Fieg, K., Glushak, K., Gayler, V., Haak, H., Hollweg, H.-D., Ilyina, T., Kinne, S., Kornbluh, L., Matei, D., Mauritsen, T., Mikolajewicz, U., Mueller, W., Notz, D., Pithan, F., Raddatz, T., Rast, S., Redler, R., Roeckner, E., Schmidt, H., Schnur, R., Segschneider, J., Six, K. D., Stockhause, M., Timmreck, C., Wegner, J., Widmann, H., Wieners, K.-H., Claussen, M., Marotzke, J., and Stevens, B. (2013). Climate and carbon cycle changes from 1850 to 2100 in MPI-ESM simulations for the Coupled Model Intercomparison Project phase 5. *Journal of Advances in Modeling Earth Systems*, 5(3):572–597. doi:10.1002/jame.20038.
- Giorgetta et al. (2012a). CMIP5 Simulations of the Max Planck Institute for Meteorology (MPI-M) Based on the MPI-ESM-LR Model: The Historical Experiment, Served by ESGF, World Data Cent. for Clim. doi:10.1594/WDCC/CMIP5.MXELhi.
- Giorgetta et al. (2012b). CMIP5 Simulations of the Max Planck Institute for Meteorology (MPI-M) Based on the MPI-ESM-LR Model: The piControl Experiment, Served by ESGF, World Data Cent. for Clim. doi:10.1594/WDCC/CMIP5.MXELpc.
- Giorgetta et al. (2012c). CMIP5 Simulations of the Max Planck Institute for Meteorology (MPI-M) Based on the MPI-ESM-LR Model: The RCP45 Experiment, Served by ESGF, World Data Cent. for Clim. doi:10.1594/WDCC/CMIP5.MXELr4.
- Gladstone, R. M., Bigg, G. R., and Nicholls, K. W. (2001). Iceberg trajectory modeling and meltwater injection in the Southern Ocean. *Journal of Geophysical Research: Oceans*, 106(C9):19903–19915. doi:10.1029/2000JC000347.
- Gleckler, P. J., Durack, P. J., Stouffer, R. J., Johnson, G. C., and Forest, C. E. (2016). Industrial-era global ocean heat uptake doubles in recent decades. *Nature Climate Change*, 6(4):394–398. doi:10.1038/nclimate2915.

- Gnanadesikan, A. (1999). A Simple Predictive Model for the Structure of the Oceanic Pycnocline. *Science*, 283(5410):2077–2079. doi:10.1126/science.283.5410.2077.
- Goldberg, D. N., Little, C. M., Sergienko, O. V., Gnanadesikan, A., Hallberg, R., and Oppenheimer, M. (2012). Investigation of land ice-ocean interaction with a fully coupled ice-ocean model: 1. Model description and behavior. *Journal of Geophysical Research: Earth Surface*, 117(F2):F02037. doi:10.1029/2011JF002246.
- Golledge, N. R., Kowalewski, D. E., Naish, T. R., Levy, R. H., Fogwill, C. J., and Gasson, E. G. W. (2015). The multi-millennial Antarctic commitment to future sea-level rise. *Nature*, 526(7573):421–425. doi:10.1038/nature15706.
- Good, S. A., Martin, M. J., and Rayner, N. A. (2013). EN4: Quality controlled ocean temperature and salinity profiles and monthly objective analyses with uncertainty estimates. *Journal of Geophysical Research: Oceans*, 118(12):6704–6716. doi:10.1002/2013JC009067.
- Goosse, H., Deleersnijder, E., Fichefet, T., and England, M. H. (1999). Sensitivity of a global coupled ocean-sea ice model to the parameterization of vertical mixing. *J. Geophys. Res.*, 104(C6):13681–13695. doi:10.1029/1999JC900099.
- Goosse, H. and Fichefet, T. (1999). Importance of ice-ocean interactions for the global ocean circulation: A model study. *J. Geophys. Res.*, 104(C10):23337–23355.
- Goosse, H. and Zunz, V. (2014). Decadal trends in the Antarctic sea ice extent ultimately controlled by ice-ocean feedback. *The Cryosphere*, 8(2):453–470. doi:10.5194/tc-8-453-2014.
- Gordon, A. L. (1986a). Interocean exchange of thermocline water. *J. Geophys. Res.*, 91(C4):5037–5046. doi:10.1029/JC091iC04p05037.
- Gordon, A. L. (1986b). Is there a global scale ocean circulation? *Eos, Transactions American Geophysical Union*, 67(9):109. doi:10.1029/EO067i009p00109.
- Gordon, A. L. (1991). Two Stable Modes of Southern Ocean Winter Stratification. In Chu, P. C. and Gascard, J. C., editors, *Elsevier Oceanography Series*, volume 57 of *Elsevier Oceanography Series*, pages 17–35. Elsevier. doi:10.1016/S0422-9894(08)70058-8.
- Gordon, A. L. (2012). Circumpolar View of the Southern Ocean from 1962 to 1992. *Oceanography*, 25(3):18–23. doi:10.5670/oceanog.2012.69.
- Gordon, A. L. (2014). Southern Ocean polynya. *Nature Climate Change*, 4(April):249–250. doi:10.1038/nclimate2179.
- Gordon, A. L. (2016). The marine hydrological cycle: the ocean's floods and droughts. *Geophysical Research Letters*, 43:7649–7652. doi:10.1002/2016GL070279.
- Gordon, A. L. and Huber, B. A. (1984). Thermohaline stratification below the Southern Ocean sea ice. *Journal of Geophysical Research*, 89(C1):641–648. doi:10.1029/JC089iC01p00641.
- Gordon, A. L. and Huber, B. A. (1990). Southern ocean winter mixed layer. *Journal of Geophysical Research*, 95(C7):11655. doi:10.1029/JC095iC07p11655.
- Gordon, A. L., Huber, B. A., and Busecke, J. (2015). Bottom water export from the western Ross Sea, 2007 through 2010. *Geophysical Research Letters*, 42(13):5387–5394. doi:10.1002/2015GL064457.

- Gordon, A. L. and Taylor, H. W. (1975). Seasonal Change of Antarctic Sea Ice Cover. *Science*, 187(4174):346–347.
- GRDC (2014). Annual freshwater inputs to the oceans—5 latitudinal bands (1971-2000). Global Freshwater Fluxes into the World Oceans., Koblenz, Germany. Global Runoff Data Centre, Federal Institute of Hydrology (BfG).
- Griffies, S. M., Böning, C., Bryan, F. O., Chassignet, E. P., Gerdes, R., Hasumi, H., Hirst, A., Treguier, A.-M., and Webb, D. (2000a). Developments in ocean climate modelling. *Journal of Computational Physics*, 2(3-4):123–192. doi:10.1016/S1463-5003(00)00014-7.
- Griffies, S. M., Pacanowski, R. C., and Hallberg, R. W. (2000b). Spurious Diapycnal Mixing Associated with Advection in a z-Coordinate Ocean Model. *Monthly Weather Review*, 128(3):538–564. doi:10.1175/1520-0493(2000)128<0538:SDMAWA>2.0.CO;2.
- Gruber, N. (2011). Warming up, turning sour, losing breath: ocean biogeochemistry under global change. *Philosophical Transactions of the Royal Society A*, 369(1943):1980–1996. doi:10.1098/rsta.2011.0003.
- Gruber, N., Frenzel, H., Doney, S. C., Marchesiello, P., McWilliams, J. C., Moisan, J. R., Oram, J. J., Plattner, G. K., and Stolzenbach, K. D. (2006). Eddy-resolving simulation of plankton ecosystem dynamics in the California Current System. *Deep-Sea Research Part I: Oceanographic Research Papers*, 53(9):1483–1516. doi:10.1016/j.dsr.2006.06.005.
- Gruber, N., Friedlingstein, P., Field, C. B., Valentini, R., Heimann, M., Richey, J. E., Lankao, P. R., Schulze, E.-D., and Chen, C.-T. A. (2004). The vulnerability of the carbon cycle in the 21st century: An assessment of carbon-climate-human interactions. In Field, C. B. and Raupach, M. R., editors, *The Global Carbon Cycle: Integrating Humans, Climate, and the Natural World*, volume 62, chapter 3, pages 45–76. Island Press, Washington, D. C.
- Gruber, N., Gloor, M., Mikaloff Fletcher, S. E., Doney, S. C., Dutkiewicz, S., Follows, M. J., Gerber, M., Jacobson, A. R., Joos, F., Lindsay, K., Menemenlis, D., Mouchet, A., Müller, S. A., Sarmiento, J. L., and Takahashi, T. (2009). Oceanic sources, sinks, and transport of atmospheric CO₂. *Global Biogeochemical Cycles*, 23(1):GB1005. doi:10.1029/2008GB003349.
- Gruber, N., Lachkar, Z., Frenzel, H., Marchesiello, P., Münnich, M., McWilliams, J. C., Nagai, T., and Plattner, G.-K. (2011). Eddy-induced reduction of biological production in eastern boundary upwelling systems. *Nature Geoscience*, 4(October):1–6. doi:doi:10.1038/ngeo1273.
- Gruber, N. and Sarmiento, J. L. (2002). Large-scale biogeochemical/physical interactions in elemental cycles. In Robinson, A. R., McCarthy, J. J., and Rothschild, B. J., editors, *The Sea: Biological-Physical Interactions in the Oceans*, pages 337–399. John Wiley and Sons, Ltd., New York.
- Haidvogel, D. B., Arango, H., Budgell, W. P., Cornuelle, B. D., Curchitser, E., Di Lorenzo, E., Fennel, K., Geyer, W. R., Hermann, A. J., Lanerolle, L., Levin, J., McWilliams, J. C., Miller, A. J., Moore, A. M., Powell, T. M., Shchepetkin, A. F., Sherwood, C. R., Signell, R. P., Warner, J. C., and Wilkin, J. (2008). Ocean forecasting in terrain-following coordinates: Formulation and skill assessment of the Regional Ocean Modeling System. *Journal of Computational Physics*, 227(7):3595–3624. doi:10.1016/j.jcp.2007.06.016.

- Haidvogel, D. B., Arango, H. G., Hedstrom, K., Beckmann, A., Malanotte-Rizzoli, P., and Shchepetkin, A. F. (2000). Model evaluation experiments in the North Atlantic Basin: Simulations in nonlinear terrain-following coordinates. *Dynamics of Atmospheres and Oceans*, 32(3-4):239–281. doi:10.1016/S0377-0265(00)00049-X.
- Haidvogel, D. B. and Beckmann, a. (1999). *Numerical Ocean Circulation Modeling*, volume 2 of *Environmental Science and Management*. Imperial College Press. doi:10.2277/0521781825.
- Haidvogel, D. B., Wilkin, J. L., and Young, R. (1991). A semi-spectral primitive equation ocean circulation model using vertical sigma and orthogonal curvilinear horizontal coordinates. *Journal of Computational Physics*, 94(1):151–185. doi:10.1016/0021-9991(91)90141-7.
- Häkkinen, S. and Mellor, G. L. (1992). Modeling the seasonal variability of a coupled Arctic ice-ocean system. *Journal of Geophysical Research*, 97(C12):20285. doi:10.1029/92JC02037.
- Hallberg, R. (2013). Using a resolution function to regulate parameterizations of oceanic mesoscale eddy effects. *Ocean Modelling*, 72:92–103. doi:10.1016/j.ocemod.2013.08.007.
- Hallberg, R. and Gnanadesikan, A. (2001). An Exploration of the Role of Transient Eddies in Determining the Transport of a Zonally Reentrant Current. *Journal of Physical Oceanography*, 31(2000):3312–3330. doi:10.1175/1520-0485(2001)031<3312:AEOTRO>2.0.CO;2.
- Hallberg, R. and Gnanadesikan, A. (2006). The Role of Eddies in Determining the Structure and Response of the Wind-Driven Southern Hemisphere Overturning: Results from the Modeling Eddies in the Southern Ocean (MESO) Project. *Journal of Physical Oceanography*, 36(12):2232–2252. doi:10.1175/JPO2980.1.
- Hansen, J., Ruedy, R., Sato, M., and Lo, K. (2010). Global surface temperature change. *Reviews of Geophysics*, 48(4):RG4004. doi:10.1029/2010RG000345.
- Harms, S., Fahrbach, E., and Strass, V. H. (2001). Sea ice transports in the Weddell Sea. *Journal of Geophysical Research*, 106(C5):9057–9073. doi:10.1029/1999JC000027.
- Hartin, C. A., Fine, R. A., Sloyan, B. M., Talley, L. D., Chereskin, T. K., and Happell, J. (2011). Formation rates of Subantarctic mode water and Antarctic intermediate water within the South Pacific. *Deep-Sea Research Part I*, 58(5):524–534. doi:10.1016/j.dsr.2011.02.010.
- Hasselmann, K. (1991). Ocean circulation and climate change. *Tellus B*, 43(4):82–103. doi:10.1034/j.1600-0889.1991.t01-2-00008.x.
- Hauck, J., Völker, C., Wang, T., Hoppema, M., Losch, M., and Wolf-Gladrow, D. A. (2013). Seasonally different carbon flux changes in the Southern Ocean in response to the Southern Annular Mode. *Global Biogeochemical Cycles*, 27(4):1236–1245. doi:10.1002/2013GB004600.
- Haug, G. H., Sigman, D. M., Tiedemann, R., Pedersen, T. F., and Sarntheink, M. (1999). Onset of permanent stratification in the subarctic Pacific Ocean. *Nature*, 401(6755):21–24. doi:10.1038/44550.
- Haumann, F. A. (2011). Dynamical interaction between atmosphere and sea ice in Antarctica. *Master's Thesis: Utrecht University*, p. 131.
- Haumann, F. A., Gruber, N., Münnich, M., Frenger, I., and Kern, S. (2016a). Antarctic sea-ice freshwater fluxes associated with freezing, transport, and melting, Zurich, Switzerland. ETH Zurich. doi:10.16904/8.

- Haumann, F. A., Gruber, N., Münnich, M., Frenger, I., and Kern, S. (2016b). Sea-ice transport driving Southern Ocean salinity and its recent trends. *Nature*, 537(7618):89–92. doi:10.1038/nature19101.
- Haumann, F. A., Münnich, M., Gruber, N., and Eberenz, S. (2017). Recent changes of Southern Ocean waters induced by sea-ice freshwater fluxes. *Journal of Climate*, In prep.
- Haumann, F. A., Notz, D., and Schmidt, H. (2014). Anthropogenic influence on recent circulation-driven Antarctic sea ice changes. *Geophysical Research Letters*, 41(23):8429–8437. doi:10.1002/2014GL061659.
- Hays, J. D., Imbrie, J., and Shackleton, N. J. (1976). Variations in the Earth's Orbit: Pacemaker of the Ice Ages. *Science*, 194(4270):1121–1132. doi:10.1126/science.194.4270.1121.
- Heil, P., Fowler, C. W., Maslanik, J. A., Emery, W. J., and Allison, I. (2001). A comparison of East Antarctic sea-ice motion derived using drifting buoys and remote sensing. *Annals of Glaciology*, 33(1):139–144. doi:10.3189/172756401781818374.
- Heinze, C., Maier-Reimer, E., and Winn, K. (1991). Glacial pCO₂ Reduction by the World Ocean: Experiments With the Hamburg Carbon Cycle Model. *Paleoceanography*, 6(4):395–430. doi:10.1029/91PA00489.
- Hellmer, H. H. (2004). Impact of Antarctic ice shelf basal melting on sea ice and deep ocean properties. *Geophysical Research Letters*, 31(10):L10307. doi:10.1029/2004GL019506.
- Hellmer, H. H., Huhn, O., Gomis, D., and Timmermann, R. (2011). On the freshening of the northwestern Weddell Sea continental shelf. *Ocean Science*, 7(3):305–316. doi:10.5194/os-7-305-2011.
- Hellmer, H. H., Kauker, F., Timmermann, R., Determann, J., and Rae, J. (2012). Twenty-first-century warming of a large Antarctic ice-shelf cavity by a redirected coastal current. *Nature*, 485(7397):225–228. doi:10.1038/nature11064.
- Helm, K. P., Bindoff, N. L., and Church, J. A. (2010). Changes in the global hydrological-cycle inferred from ocean salinity. *Geophysical Research Letters*, 37(18):L18701. doi:10.1029/2010GL044222.
- Helm, K. P., Bindoff, N. L., and Church, J. A. (2011). Observed decreases in oxygen content of the global ocean. *Geophysical Research Letters*, 38(23):L23602. doi:10.1029/2011GL049513.
- Henning, C. C. and Vallis, G. K. (2005). The Effects of Mesoscale Eddies on the Stratification and Transport of an Ocean with a Circumpolar Channel. *Journal of Physical Oceanography*, 35(5):880–896. doi:10.1175/JPO2727.1.
- Heuzé, C., Heywood, K. J., Stevens, D. P., and Ridley, J. K. (2013). Southern Ocean bottom water characteristics in CMIP5 models. *Geophysical Research Letters*, 40(7):1409–1414. doi:10.1002/grl.50287.
- Heuzé, C., Heywood, K. J., Stevens, D. P., and Ridley, J. K. (2015). Changes in global ocean bottom properties and volume transports in CMIP5 models under climate change scenarios. *Journal of Climate*, 28(8):2917–2944. doi:10.1175/JCLI-D-14-00381.1.
- Hewitt, A. J., Booth, B. B. B., Jones, C. D., Robertson, E. S., Wiltshire, A. J., Sansom, P. G., Stephenson, D. B., and Yip, S. (2016). Sources of uncertainty in future projections of the carbon cycle. *Journal of Climate*, 29:7203–7213. doi:10.1175/JCLI-D-16-0161.1.

- Hobbs, W. R., Massom, R., Stammerjohn, S., Reid, P., Williams, G., and Meier, W. (2016). A review of recent changes in Southern Ocean sea ice, their drivers and forcings. *Global and Planetary Change*, 143:228–250. doi:10.1016/j.gloplacha.2016.06.008.
- Hogg, A. M. (2010). An Antarctic Circumpolar Current driven by surface buoyancy forcing. *Geophysical Research Letters*, 37(23):L23601. doi:10.1029/2010GL044777.
- Hogg, A. M., Meredith, M. P., Chambers, D. P., Abrahamsen, E. P., Hughes, C. W., and Morrison, A. K. (2015). Recent trends in the Southern Ocean eddy field. *Journal of Geophysical Research C: Oceans*, 120(1):257–267. doi:10.1002/2014JC010470.
- Holland, D. M. and Jenkins, A. (1999). Modeling Thermodynamic Ice-Ocean Interactions at the Base of an Ice Shelf. *Journal of Physical Oceanography*, 29(8):1787–1800. doi:10.1175/1520-0485(1999)029<1787:MTIOIA>2.0.CO;2.
- Holland, P. R. (2014). The seasonality of Antarctic sea ice trends. *Geophysical Research Letters*, 41(12):4230–4237. doi:10.1002/2014GL060172.
- Holland, P. R. and Kwok, R. (2012). Wind-driven trends in Antarctic sea-ice drift. *Nature Geoscience*, 5(12):872–875. doi:10.1038/ngeo1627.
- Hoppema, M. (2004). Weddell Sea turned from source to sink for atmospheric CO₂ between pre-industrial time and present. *Global and Planetary Change*, 40(3):219–231. doi:10.1016/j.gloplacha.2003.08.001.
- Hosking, J. S., Orr, A., Marshall, G. J., Turner, J., and Phillips, T. (2013). The Influence of the Amundsen-Bellinghousen Seas Low on the Climate of West Antarctica and Its Representation in Coupled Climate Model Simulations. *Journal of Climate*, 26(17):6633–6648. doi:10.1175/JCLI-D-12-00813.1.
- Huang, C. J., Qiao, F., Shu, Q., and Song, Z. (2012). Evaluating austral summer mixed-layer response to surface wave-induced mixing in the Southern Ocean. *Journal of Geophysical Research: Oceans*, 117(C11):C00J18. doi:10.1029/2012JC007892.
- Hunke, E. C. (2001). Viscous–Plastic Sea Ice Dynamics with the EVP Model: Linearization Issues. *Journal of Computational Physics*, 170(1):18–38. doi:10.1006/jcph.2001.6710.
- Hunke, E. C. and Dukowicz, J. K. (1997). An Elastic–Viscous–Plastic Model for Sea Ice Dynamics. *Journal of Physical Oceanography*, 27:1849–1867. doi:10.1175/1520-0485(1997)027<1849:AEVPMF>2.0.CO;2.
- Huybers, P. and Wunsch, C. (2005). Obliquity pacing of the late Pleistocene glacial terminations. *Nature*, 434(7032):491–494. doi:10.1038/nature03401.
- Ilicak, M., Adcroft, A. J., Griffies, S. M., and Hallberg, R. W. (2012). Spurious di-anneutral mixing and the role of momentum closure. *Ocean Modelling*, 45-46:37–58. doi:10.1016/j.ocemod.2011.10.003.
- Ilyina, T. and Friedlingstein, P. (2016). WCRP Grand Challenge: Carbon feedbacks in the climate system. Technical report, World Climate Research Programme.
- Imbrie, J., Berger, A., Boyle, E. A., Clemens, S. C., Duffy, A., Howard, W. R., Kukla, G., Kutzbach, J., Martinson, D. G., McIntyre, A., Mix, A. C., Molfino, B., Morley, J. J., Peterson, L. C., Pisias, N. G., Prell, W. L., Raymo, M. E., Shackleton, N. J., and Toggweiler, J. R.

- (1993). On the structure and origin of major glaciation cycles 2. The 100,000-year cycle. *Paleoceanography*, 8(6):699–735. doi:10.1029/93PA02751.
- Imbrie, J. and Imbrie, J. Z. (1980). Modeling the climatic response to orbital variations. *Science*, 207(4434):943–953. doi:10.1126/science.207.4434.943.
- Ingleby, B. and Huddleston, M. (2007). Quality control of ocean temperature and salinity profiles: Historical and real-time data. *Journal of Marine Systems*, 65(1-4):158–175. doi:10.1016/j.jmarsys.2005.11.019.
- IOC, SCOR, and IAPSO (2010). The international thermodynamic equation of seawater - 2010: Calculation and use of thermodynamic properties. Technical report, Intergovernmental Oceanographic Commission, Manuals and Guides No. 56, UNESCO.
- IPCC (2013). *Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley (eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
- Ito, T. and Marshall, J. (2008). Control of Lower-Limb Overturning Circulation in the Southern Ocean by Diapycnal Mixing and Mesoscale Eddy Transfer. *Journal of Physical Oceanography*, 38(12):2832–2845. doi:10.1175/2008JPO3878.1.
- Iudicone, D., Madec, G., Blanke, B., and Speich, S. (2008). The Role of Southern Ocean Surface Forcings and Mixing in the Global Conveyor. *Journal of Physical Oceanography*, 38(7):1377. doi:10.1175/2008JPO3519.1.
- Iudicone, D., Rodgers, K. B., Schopp, R., and Madec, G. (2007). An exchange window for the injection of Antarctic Intermediate Water into the South Pacific. *Journal of Physical Oceanography*, 37(1):31–49. doi:10.1175/JPO2985.1.
- Iudicone, D., Rodgers, K. B., Stendardo, I., Aumont, O., Madec, G., Bopp, L., Mangoni, O., and Ribera D'Alcala', M. (2011). Water masses as a unifying framework for understanding the Southern Ocean Carbon Cycle. *Biogeosciences*, 8(5):1031–1052. doi:10.5194/bg-8-1031-2011.
- Jaccard, S. L., Hayes, C. T., Martínez-García, A., Hodell, D. A., Anderson, R. F., Sigman, D. M., and Haug, G. H. (2013). Two modes of change in Southern Ocean productivity over the past million years. *Science*, 339(6126):1419–23. doi:10.1126/science.1227545.
- Jackett, D. R. and McDougall, T. J. (1995). Minimal Adjustment of Hydrographic Profiles to Achieve Static Stability. *Journal of Atmospheric and Oceanic Technology*, 12(2):381–389. doi:10.1175/1520-0426(1995)012<0381:MAOHPT>2.0.CO;2.
- Jacobs, S. S. (1991). On the nature and significance of the Antarctic Slope Front. *Marine Chemistry*, 35(1-4):9–24. doi:10.1016/S0304-4203(09)90005-6.
- Jacobs, S. S. (2004). Bottom water production and its links with the thermohaline circulation. *Antarctic Science*, 16(4):427–437. doi:10.1017/S095410200400224X.
- Jacobs, S. S., Fairbanks, R. G., and Horibe, Y. (1985). Origin and evolution of water masses near the Antarctic continental margin: Evidence from $H_2^{18}O/H_2^{16}O$ ratios in seawater. In Jacobs, S., editor, *Oceanology of the Antarctic Continental Shelf*, volume 43 of *Antarctic Research Series*, pages 59–85. American Geophysical Union, Washington, D. C. doi:10.1029/AR043.

- Jacobs, S. S. and Giulivi, C. F. (2010). Large multidecadal salinity trends near the Pacific-Antarctic continental margin. *Journal of Climate*, 23(17):4508–4524. doi:10.1175/2010JCLI3284.1.
- Jacobs, S. S., Giulivi, C. F., and Mele, P. A. (2002). Freshening of the Ross Sea during the late 20th century. *Science*, 297(5580):386–389. doi:10.1126/science.1069574.
- Jacobs, S. S., Jenkins, A., Hellmer, H. H., Giulivi, C. F., Nitsche, F., Huber, B., and Guerrero, R. (2012). The Amundsen Sea and the Antarctic Ice Sheet. *Oceanography*, 25(3):154–163. doi:10.5670/oceanog.2012.90.
- Jin, X., Gruber, N., Frenzel, H., Doney, S. C., and McWilliams, J. C. (2008). The impact on atmospheric CO₂ of iron fertilization induced changes in the ocean's biological pump. *Biogeosciences*, 5(2):385–406. doi:10.5194/bg-5-385-2008.
- Jones, J. M., Gille, S. T., Goosse, H., Abram, N. J., Canziani, P. O., Charman, D. J., Clem, K. R., Crosta, X., de Lavergne, C., Eisenman, I., England, M. H., Fogt, R. L., Frankcombe, L. M., Marshall, G. J., Masson-Delmotte, V., Morrison, A. K., Orsi, A. J., Raphael, M. N., Renwick, J. A., Schneider, D. P., Simpkins, G. R., Steig, E. J., Stenni, B., Swingedouw, D., and Vance, T. R. (2016). Assessing recent trends in high-latitude Southern Hemisphere surface climate. *Nature Climate Change*, 6(10):917–926. doi:10.1038/nclimate3103.
- Joos, F., Plattner, G.-K., Stocker, T. F., Marchal, O., and Schmittner, A. (1999). Global warming and marine carbon cycle feedbacks on future atmospheric CO₂. *Science*, 284(5413):464–467. doi:10.1126/science.284.5413.464.
- Jouzel, J., Masson-Delmotte, V., Cattani, O., Dreyfus, G., Falourd, S., Hoffmann, G., Minster, B., Nouet, J., Barnola, J. M., Chappellaz, J., Fischer, H., Gallet, J. C., Johnsen, S., Leuenberger, M., Loulergue, L., Luethi, D., Oerter, H., Parrenin, F., Raisbeck, G., Raynaud, D., Schilt, A., Schwander, J., Selmo, E., Souchez, R., Spahni, R., Stauffer, B., Steffensen, J. P., Stenni, B., Stocker, T. F., Tison, J. L., Werner, M., and Wolff, E. W. (2007). Orbital and millennial Antarctic climate variability over the past 800,000 years. *Science*, 317(5839):793–796. doi:10.1126/science.1141038.
- Jullion, L., Naveira Garabato, A. C., Meredith, M. P., Holland, P. R., Courtois, P., and King, B. A. (2013). Decadal Freshening of the Antarctic Bottom Water Exported from the Weddell Sea. *Journal of Climate*, 26(20):8111–8125. doi:10.1175/JCLI-D-12-00765.1.
- Jungclaus, J. H., Fischer, N., Haak, H., Lohmann, K., Marotzke, J., Matei, D., Mikolajewicz, U., Notz, D., and Von Storch, J. S. (2013). Characteristics of the ocean simulations in the Max Planck Institute Ocean Model (MPIOM) the ocean component of the MPI-Earth system model. *Journal of Advances in Modeling Earth Systems*, 5(2):422–446. doi:10.1002/jame.20023.
- Kanarska, Y., Shchepetkin, A., and McWilliams, J. C. (2007). Algorithm for non-hydrostatic dynamics in the Regional Oceanic Modeling System. *Ocean Modelling*, 18(3-4):143–174. doi:10.1016/j.ocemod.2007.04.001.
- Karsten, R. H., Marshall, J., Karsten, R. H., and Marshall, J. (2002). Constructing the Residual Circulation of the ACC from Observations. *Journal of Physical Oceanography*, 32(12):3315–3327. doi:10.1175/1520-0485(2002)032<3315:CTRCOT>2.0.CO;2.
- Kern, S., Ozsoy-Çiçek, B., and Worby, A. (2016). Antarctic sea-ice thickness retrieval from ICESat: Inter-comparison of different approaches. *Remote Sensing*, 8(7):538. doi:10.3390/rs8070538.

- Kern, S. and Spreen, G. (2015). Uncertainties in Antarctic sea-ice thickness retrieval from ICESat. *Annals of Glaciology*, 56(69):107–119. doi:10.3189/2015AoG69A736.
- Kessler, A. and Tjiputra, J. (2016). The Southern Ocean as a constraint to reduce uncertainty in future ocean carbon sinks. *Earth System Dynamics*, 7(2):295–312. doi:10.5194/esd-7-295-2016.
- Key, R. M., Kozyr, A., Sabine, C. L., Lee, K., Wanninkhof, R., Bullister, J. L., Feely, R. A., Millero, F. J., Mordy, C., and Peng, T.-H. (2004). A global ocean carbon climatology: Results from Global Data Analysis Project (GLODAP). *Global Biogeochemical Cycles*, 18(4):GB4031. doi:10.1029/2004GB002247.
- Khatiwala, S., Primeau, F., and Hall, T. (2009). Reconstruction of the history of anthropogenic CO₂ concentrations in the ocean. *Nature*, 462(7271):346–349. doi:10.1038/nature08526.
- Khatiwala, S., Tanhua, T., Mikaloff Fletcher, S., Gerber, M., Doney, S. C., Graven, H. D., Gruber, N., McKinley, G. A., Murata, A., Ríos, A. F., and Sabine, C. L. (2013). Global ocean storage of anthropogenic carbon. *Biogeosciences*, 10(4):2169–2191. doi:10.5194/bg-10-2169-2013.
- Killworth, P. D., Webb, D. J., Stainforth, D., and Paterson, S. M. (1991). The Development of a Free-Surface Bryan-Cox-Semtner Ocean Model. *Journal of Physical Oceanography*, 21(9):1333–1348. doi:10.1175/1520-0485(1991)021<1333:TDOAFS>2.0.CO;2.
- Kimura, N. (2004). Sea ice motion in response to surface wind and ocean current in the Southern Ocean. *Journal of the Meteorological Society of Japan*, 82(4):1223–1231. doi:10.2151/jmsj.2004.1223.
- Kirkman, C. H. and Bitz, C. M. (2011). The effect of the sea ice freshwater flux on Southern Ocean temperatures in CCSM3: deep-ocean warming and delayed surface warming. *Journal of Climate*, 24(9):2224–2237. doi:10.1175/2010JCLI3625.1.
- Kjellsson, J., Holland, P. R., Marshall, G. J., Mathiot, P., Aksenov, Y., Coward, A. C., Bacon, S., Megann, A. P., and Ridley, J. (2015). Model sensitivity of the Weddell and Ross seas, Antarctica, to vertical mixing and freshwater forcing. *Ocean Modelling*, 94:141–152. doi:10.1016/j.ocemod.2015.08.003.
- Knox, F. and McElroy, M. B. (1984). Changes in Atmospheric CO₂: Influence of the Marine Biota at High Latitude. *Journal of Geophysical Research*, 89(D3):4629–4637. doi:10.1029/JD089iD03p04629.
- Knutti, R. and Sedláček, J. (2013). Robustness and uncertainties in the new CMIP5 climate model projections. *Nature Climate Change*, 3:369–373. doi:10.1038/nclimate1716.
- Koenig, Z., Provost, C., Ferrari, R., Sennéchaël, N., and Rio, M.-H. (2014). Volume transport of the Antarctic Circumpolar Current: Production and validation of a 20 year long time series obtained from in situ and satellite observations. *Journal of Geophysical Research*, 119(8):5407–5433. doi:10.1002/2014jc009966.
- Köhler, P., Bintanja, R., Joos, F., Knutti, R., Lohmann, G., and Masson-Delmotte, V. (2010). What caused Earth's temperature variations during the last 800,000 years? Data-based evidence on radiative forcing and constraints on climate sensitivity. *Quaternary Science Reviews*, 29(1):129–145. doi:10.1016/j.quascirev.2009.09.026.

- Komuro, Y. and Hasumi, H. (2003). Effects of surface freshwater flux induced by sea ice transport on the global thermohaline circulation. *Journal of Geophysical Research*, 108(C2):3047. doi:10.1029/2002JC001476.
- Kostov, Y., Marshall, J., Hausmann, U., Armour, K. C., Ferreira, D., and Holland, M. M. (2016). Fast and slow responses of Southern Ocean sea surface temperature to SAM in coupled climate models. *Climate Dynamics*, pages 1–15. doi:10.1007/s00382-016-3162-z.
- Kottmeier, C., Olf, J., Frieden, W., and Roth, R. (1992). Wind forcing and ice motion in the Weddell Sea region. *Journal of Geophysical Research*, 97(D18):20373–20383. doi:10.1029/92JD02171.
- Kottmeier, C. and Sellmann, L. (1996). Atmospheric and oceanic forcing of Weddell Sea ice motion. *Journal of Geophysical Research: Oceans*, 101(C9):20809–20824. doi:10.1029/96JC01293.
- Kurtz, N. T. and Markus, T. (2012). Satellite observations of Antarctic sea ice thickness and volume. *Journal of Geophysical Research: Oceans*, 117(C8):C08025. doi:10.1029/2012JC008141.
- Kusahara, K. and Hasumi, H. (2014). Pathways of basal meltwater from Antarctic ice shelves: A model study. *Journal of Geophysical Research: Oceans*, 119(9):5690–5704. doi:10.1002/2014JC009915.
- Kwok, R. (2005). Ross sea ice motion, area flux, and deformation. *Journal of Climate*, 18(18):3759–3776. doi:10.1175/JCLI3507.1.
- Kwok, R. and Maksym, T. (2014). Snow depth of the Weddell and Bellingshausen sea ice covers from IceBridge surveys in 2010 and 2011: An examination. *Journal of Geophysical Research: Oceans*, 119(7):4141–4167. doi:10.1002/2014JC009943.
- Kwok, R., Schweiger, A., Rothrock, D. A., Pang, S., and Kottmeier, C. (1998). Sea ice motion from satellite passive microwave imagery assessed with ERS SAR and buoy motions. *Journal of Geophysical Research*, 103(C4):8191–8214. doi:10.1029/97JC03334.
- Kwon, E. Y. (2013). Temporal variability of transformation, formation, and subduction rates of upper Southern Ocean waters. *Journal of Geophysical Research: Oceans*, 118(11):6285–6302. doi:10.1002/2013JC008823.
- Kwon, E. Y., Primeau, F., and Sarmiento, J. L. (2009). The impact of remineralization depth on the air-sea carbon balance. *Nature Geoscience*, 2(9):630–635. doi:10.1038/ngeo612.
- Lachkar, Z. and Gruber, N. (2011). What controls biological production in coastal upwelling systems? Insights from a comparative modeling study. *Biogeosciences*, 8(10):2961–2976. doi:10.5194/bg-8-2961-2011.
- Lachkar, Z. and Gruber, N. (2013). Response of biological production and air-sea CO₂ fluxes to upwelling intensification in the California and Canary Current Systems. *Journal of Marine Systems*, 109-110(0):149–160. doi:10.1016/j.jmarsys.2012.04.003.
- Lachlan-Cope, T. A., Connolley, W. M., and Turner, J. (2001). The Role of the Non-Axisymmetric Antarctic Orography in forcing the Observed Pattern of Variability of the Antarctic Climate. *Geophysical Research Letters*, 28(21):4111–4114. doi:10.1029/2001GL013465.

- Landschützer, P., Gruber, N., and Bakker, D. C. E. (2015a). A 30 years observation-based global monthly gridded sea surface pCO₂ product from 1982 through 2011, Oak Ridge, Tennessee. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy. doi:10.3334/CDIAC/OTG.SPCO2_1982_2011_ETH_SOM-FFN.
- Landschützer, P., Gruber, N., Bakker, D. C. E., and Schuster, U. (2014a). An observation-based global monthly gridded sea surface pCO₂ product from 1998 through 2011 and its monthly climatology. Carbon Dioxide Information Analysis Center, Oak Ridge National Laboratory, US Department of Energy, Oak Ridge, Tennessee. doi:10.3334/CDIAC/OTG.SPCO2_1998_2011_ETH_SOM-FFN.
- Landschützer, P., Gruber, N., Bakker, D. C. E., and Schuster, U. (2014b). Recent variability of the global ocean carbon sink. *Global Biogeochemical Cycles*, 28(9):927–949. doi:10.1002/2014GB004853.
- Landschützer, P., Gruber, N., Haumann, F. A., Rödenbeck, C., Bakker, D. C. E., van Heuven, S., Hoppema, M., Metzl, N., Sweeney, C., and Takahashi, T. (2015b). The reinvigoration of the Southern Ocean carbon sink. *Science*, 349(6253):1221–1224. doi:10.1126/science.aab2620.
- Large, W. G., McWilliams, J. C., and Doney, S. C. (1994). Oceanic vertical mixing: A review and a model with a nonlocal boundary layer parameterization. *Reviews of Geophysics*, 32(4):363. doi:10.1029/94RG01872.
- Latif, M., Martin, T., Park, W., Latif, M., Martin, T., and Park, W. (2013). Southern Ocean Sector Centennial Climate Variability and Recent Decadal Trends. *Journal of Climate*, 26(19):7767–7782. doi:10.1175/JCLI-D-12-00281.1.
- Le Quéré, C., Andrew, R. M., Canadell, J. G., Sitch, S., Korsbakken, J. I., Peters, G. P., Manning, A. C., Boden, T. A., Tans, P. P., Houghton, R. A., Keeling, R. F., Alin, S., Andrews, O. D., Anthoni, P., Barbero, L., Bopp, L., Chevallier, F., Chini, L. P., Ciais, P., Currie, K., Delire, C., Doney, S. C., Friedlingstein, P., Gkritzalis, T., Harris, I., Hauck, J., Haverd, V., Hoppema, M., Klein Goldewijk, K., Jain, A. K., Kato, E., Körtzinger, A., Landschützer, P., Lefèvre, N., Lenton, A., Lienert, S., Lombardozzi, D., Melton, J. R., Metzl, N., Millero, F., Monteiro, P. M. S., Munro, D. R., Nabel, J. E. M. S., Nakaoka, S.-i., O'Brien, K., Olsen, A., Omar, A. M., Ono, T., Pierrot, D., Poulter, B., Rödenbeck, C., Salisbury, J., Schuster, U., Schwinger, J., Séférian, R., Skjelvan, I., Stocker, B. D., Sutton, A. J., Takahashi, T., Tian, H., Tilbrook, B., van der Laan-Luijkx, I. T., van der Werf, G. R., Viovy, N., Walker, A. P., Wiltshire, A. J., and Zaehle, S. (2016). Global Carbon Budget 2016. *Earth System Science Data Discussions*. doi:10.5194/essd-2016-51.
- Le Quéré, C., Moriarty, R., Andrew, R. M., Canadell, J. G., Sitch, S., Korsbakken, J. I., Friedlingstein, P., Peters, G. P., Andres, R. J., Boden, T. A., Houghton, R. A., House, J. I., Keeling, R. F., Tans, P., Arneeth, A., Bakker, D. C. E., Barbero, L., Bopp, L., Chang, J., Chevallier, F., Chini, L. P., Ciais, P., Fader, M., Feely, R. A., Gkritzalis, T., Harris, I., Hauck, J., Ilyina, T., Jain, A. K., Kato, E., Kitidis, V., Klein Goldewijk, K., Koven, C., Landschützer, P., Lauvset, S. K., Lefèvre, N., Lenton, A., Lima, I. D., Metzl, N., Millero, F., Munro, D. R., Murata, A., Nabel, J. E. M. S., Nakaoka, S., Nojiri, Y., O'Brien, K., Olsen, A., Ono, T., Pérez, F. F., Pfeil, B., Pierrot, D., Poulter, B., Rehder, G., Rödenbeck, C., Saito, S., Schuster, U., Schwinger, J., Séférian, R., Steinhoff, T., Stocker, B. D., Sutton, A. J., Takahashi, T., Tilbrook, B., van der Laan-Luijkx, I. T., van der Werf, G. R., van Heuven, S., Vandemark, D., Viovy, N., Wiltshire, A., Zaehle, S., and Zeng, N. (2015). Global Carbon Budget 2015. *Earth System Science Data*, 7(2):349–396. doi:10.5194/essd-7-349-2015.

- Le Quéré, C., Raupach, M. R., Canadell, J. G., and Al., G. M. (2009). Trends in the sources and sinks of carbon dioxide. *Nature Geoscience*, 2(12):831–836. doi:10.1038/ngeo689.
- Le Quéré, C., Rödenbeck, C., Buitenhuis, E. T., Conway, T. J., Langenfelds, R., Gomez, A., Labuschagne, C., Ramonet, M., Nakazawa, T., Metzl, N., Gillett, N. P., and Heimann, M. (2007). Saturation of the Southern Ocean CO₂ Sink Due to Recent Climate Change. *Science*, 316(5832):1735–1738. doi:10.1126/science.1136188.
- Lecomte, O., Goosse, H., Fichefet, T., Holland, P., Uotila, P., Zunz, V., and Kimura, N. (2016). Impact of surface wind biases on the Antarctic sea ice concentration budget in climate models. *Ocean Modelling*, 105:60–70. doi:10.1016/j.ocemod.2016.08.001.
- Lee, K., Tong, L. T., Millero, F. J., Sabine, C. L., Dickson, A. G., Goyet, C., Park, G.-H., Wanninkhof, R., Feely, R. A., and Key, R. M. (2006). Global relationships of total alkalinity with salinity and temperature in surface waters of the world's oceans. *Geophysical Research Letters*, 33(19):L19605. doi:10.1029/2006GL027207.
- Lee, S. and Feldstein, S. B. (2013). Detecting ozone- and greenhouse gas-driven wind trends with observational data. *Science*, 339(6119):563–567. doi:10.1126/science.1225154.
- Lemarié, F., Debreu, L., Shchepetkin, A. F., and McWilliams, J. C. (2012a). On the stability and accuracy of the harmonic and biharmonic isoneutral mixing operators in ocean models. *Ocean Modelling*, 52-53:9–35. doi:10.1016/j.ocemod.2012.04.007.
- Lemarié, F., Kurian, J., Shchepetkin, A. F., Jeroen Molemaker, M., Colas, F., and McWilliams, J. C. (2012b). Are there inescapable issues prohibiting the use of terrain-following coordinates in climate models? *Ocean Modelling*, 42:57–79. doi:10.1016/j.ocemod.2011.11.007.
- Lemke, P. (1987). A coupled one-dimensional sea ice-ocean model. *Journal of Geophysical Research*, 92(C12):13164. doi:10.1029/JC092iC12p13164.
- Lenaerts, J. T. M., Vizcaino, M., Fyke, J., van Kampenhout, L., and van den Broeke, M. R. (2016). Present-day and future Antarctic ice sheet climate and surface mass balance in the Community Earth System Model. *Climate Dynamics*, 47(5-6):1367–1381. doi:10.1007/s00382-015-2907-4.
- Lenton, A., Codron, F., Bopp, L., Metzl, N., Cadule, P., Tagliabue, A., and Le Sommer, J. (2009). Stratospheric ozone depletion reduces ocean carbon uptake and enhances ocean acidification. *Geophysical Research Letters*, 36(12):L12606. doi:10.1029/2009GL038227.
- Lenton, A., Tilbrook, B., Law, R. M., Bakker, D., Doney, S. C., Gruber, N., Ishii, M., Hoppema, M., Lovenduski, N. S., Matear, R. J., McNeil, B. I., Metzl, N., Mikaloff Fletcher, S. E., Monteiro, P. M. S., Rödenbeck, C., Sweeney, C., and Takahashi, T. (2013). Sea-air CO₂ fluxes in the Southern Ocean for the period 1990–2009. *Biogeosciences*, 10(6):4037–4054. doi:10.5194/bg-10-4037-2013.
- Leonard, K. C., Massom, R., Reid, P., Schlosser, E., Meredith, M. P., Tsukernik, M., Gorodetskaya, I., and Stammerjohn, S. (2016). Quantifying precipitation and its contribution to surface freshening in the Southern Ocean. ACE Project Proposal.
- Leppäranta, M. (2011). *The Drift of Sea Ice*. Springer Berlin Heidelberg, Berlin, Heidelberg. doi:10.1007/978-3-642-04683-4.

- Levitus, S., Antonov, J. I., Boyer, T. P., Baranova, O. K., Garcia, H. E., Locarnini, R. A., Mishonov, A. V., Reagan, J. R., Seidov, D., Yarosh, E. S., and Zweng, M. M. (2012). World ocean heat content and thermosteric sea level change (0-2000 m), 1955-2010. *Geophysical Research Letters*, 39(10):L10603. doi:10.1029/2012GL051106.
- Levitus, S., Antonov, J. I., Wang, J., Delworth, T. L., Dixon, K. W., and Broccoli, A. J. (2001). Anthropogenic warming of Earth's climate system. *Science*, 292(5515):267–270. doi:10.1126/science.1058154.
- Li, Q., Webb, A., Fox-Kemper, B., Craig, A., Danabasoglu, G., Large, W. G., and Vertenstein, M. (2016). Langmuir mixing effects on global climate: WAVEWATCH III in CESM. *Ocean Modelling*, 103:145–160. doi:10.1016/j.ocemod.2015.07.020.
- Li, X., Holland, D. M., Gerber, E. P., and Yoo, C. (2014). Impacts of the north and tropical Atlantic Ocean on the Antarctic Peninsula and sea ice. *Nature*, 505(7484):538–542. doi:10.1038/nature12945.
- Liu, J. and Curry, J. A. (2010). Accelerated warming of the Southern Ocean and its impacts on the hydrological cycle and sea ice. *Proceedings of the National Academy of Sciences of the United States of America*, 107(34):14987–92. doi:10.1073/pnas.1003336107.
- Locarnini, R. A., Mishonov, A. V., Antonov, J. I., Boyer, T. P., Garcia, H. E., Baranova, O. K., Zweng, M. M., Paver, C. R., Reagan, J. R., Johnson, D. R., Hamilton, M., and Seidov, D. (2013). World Ocean Atlas 2013, Volume 1: Temperature, p. 40. NOAA Atlas NESDIS 73.
- Lorenz, C. and Kunstmann, H. (2012). The hydrological cycle in three state-of-the-art reanalyses: Intercomparison and performance analysis. *Journal of Hydrometeorology*, 13(5):1397–1420. doi:10.1175/JHM-D-11-088.1.
- Lovenduski, N. S., Gruber, N., and Doney, S. C. (2008). Toward a mechanistic understanding of the decadal trends in the Southern Ocean carbon sink. *Global Biogeochem. Cycles*, 22(3):GB3016. doi:10.1029/2007GB003139.
- Lovenduski, N. S., Gruber, N., Doney, S. C., and Lima, I. D. (2007). Enhanced CO₂ outgassing in the Southern Ocean from a positive phase of the Southern Annular Mode. *Global Biogeochemical Cycles*, 21(2):GB2026. doi:10.1029/2006GB002900.
- Lovenduski, N. S. and Ito, T. (2009). The Future evolution of the Southern Ocean CO₂ sink. *Journal of Marine Research*, 67(5):597–617. doi:10.1357/002224009791218832.
- Lu, P., Li, Z., and Han, H. (2016). Introduction of parameterized sea ice drag coefficients into ice free-drift modeling. *Acta Oceanologica Sinica*, 35(1):53–59. doi:10.1007/s13131-016-0796-y.
- Lumpkin, R. and Speer, K. (2007). Global Ocean Meridional Overturning. *Journal of Physical Oceanography*, 37(10):2550–2562. doi:10.1175/JPO3130.1.
- Lüthi, D., Le Floch, M., Bereiter, B., Blunier, T., Barnola, J.-M., Siegenthaler, U., Raynaud, D., Jouzel, J., Fischer, H., Kawamura, K., and Stocker, T. F. (2008). High-resolution carbon dioxide concentration record 650,000-800,000 years before present. *Nature*, 453(7193):379–382. doi:10.1038/nature06949.
- Lynch-Stieglitz, J., Adkins, J. F., Curry, W. B., Dokken, T., Hall, I. R., Herguera, J. C., Hirschi, J. J.-M., Ivanova, E. V., Kissel, C., Marchal, O., Marchitto, T. M., McCave, I. N., McManus,

- J. F., Mulitza, S., Ninnemann, U., Peeters, F., Yu, E.-F., and Zahn, R. (2007). Atlantic meridional overturning circulation during the Last Glacial Maximum. *Science*, 316(5821):66–69. doi:10.1126/science.1137127.
- MacDonald, A. M. and Wunsch, C. (1996). An estimate of global ocean circulation and heat fluxes. *Nature*, 382(6590):436–439. doi:10.1038/382436a0.
- Mahlstein, I., Gent, P. R., and Solomon, S. (2013). Historical Antarctic mean sea ice area, sea ice trends, and winds in CMIP5 simulations. *Journal of Geophysical Research Atmospheres*, 118(11):5105–5110. doi:10.1002/jgrd.50443.
- Mahowald, N. M., Engelstaedter, S., Luo, C., Sealy, A., Artaxo, P., Benitez-Nelson, C., Bonnet, S., Chen, Y., Chuang, P. Y., Cohen, D. D., Dulac, F., Herut, B., Johansen, A. M., Kubilay, N., Losno, R., Maenhaut, W., Paytan, A., Prospero, J. M., Shank, L. M., and Siefert, R. L. (2009). Atmospheric Iron Deposition: Global Distribution, Variability, and Human Perturbations. *Annual Review of Marine Science*, 1(1):245–278. doi:10.1146/annurev.marine.010908.163727.
- Majkut, J. D., Carter, B. R., Frölicher, T. L., Dufour, C. O., Rodgers, K. B., and Sarmiento, J. L. (2014). An observing system simulation for Southern Ocean carbon dioxide uptake. *Philosophical Transactions of the Royal Society A*, 372(2019):20130046. doi:10.1098/rsta.2013.0046.
- Maksym, T. (2016). Climate science: Southern Ocean freshened by sea ice. *Nature*, 537(7618):40–41. doi:10.1038/537040a.
- Maksym, T. and Markus, T. (2008). Antarctic sea ice thickness and snow-to-ice conversion from atmospheric reanalysis and passive microwave snow depth. *Journal of Geophysical Research*, 113(2):C02S12. doi:10.1029/2006JC004085.
- Manabe, S. and Stouffer, R. J. (1993). Century-scale effects of increased atmospheric CO₂ on the ocean-atmosphere system. *Nature*, 364(6434):215–218. doi:10.1038/364215a0.
- Marchesiello, P., Debreu, L., and Couvelard, X. (2009). Spurious diapycnal mixing in terrain-following coordinate models: The problem and a solution. *Ocean Modelling*, 26(3-4):156–169. doi:10.1016/j.ocemod.2008.09.004.
- Marchesiello, P., McWilliams, J. C., and Shchepetkin, A. (2001). Open boundary conditions for long-term integration of regional oceanic models. *Ocean Modelling*, 3(1-2):1–20. doi:10.1016/S1463-5003(00)00013-5.
- Marchesiello, P., McWilliams, J. C., and Shchepetkin, A. F. (2003). Equilibrium Structure and Dynamics of the California Current System. *Journal of Physical Oceanography*, 33(4):753–783. doi:10.1175/1520-0485(2003)33<753:ESADOT>2.0.CO;2.
- Marinov, I., Gnanadesikan, A., Toggweiler, J. R., and Sarmiento, J. L. (2006). The Southern Ocean biogeochemical divide. *Nature*, 441(7096):964–967. doi:10.1038/nature04883.
- Markus, T. (1999). Results from an ECMWF-SSM/I forced mixed layer model of the Southern Ocean. *Journal of Geophysical Research*, 104(C7):15603. doi:10.1029/1999JC900080.
- Marmorino, G. O. and Caldwell, D. R. (1976). Heat and salt transport through a diffusive thermohaline interface. *Deep Sea Research and Oceanographic Abstracts*, 23(1):59–67. doi:10.1016/0011-7471(76)90808-1.

- Marsh, R., Ivchenko, V. O., Skliris, N., Alderson, S., Bigg, G. R., Madec, G., Blaker, A. T., Aksenov, Y., Sinha, B., Coward, A. C., Le Sommer, J., Merino, N., and Zalesny, V. B. (2015). NEMOICB (v1.0): interactive icebergs in the NEMO ocean model globally configured at eddy-permitting resolution. *Geoscientific Model Development*, 8(5):1547–1562. doi:10.5194/gmd-8-1547-2015.
- Marshall, G. J. (2003). Trends in the Southern Annular Mode from observations and reanalyses. *Journal of Climate*, 16(24):4134–4143. doi:10.1175/1520-0442(2003)016<4134:TITSAM>2.0.CO;2.
- Marshall, J. and Radko, T. (2003). Residual-Mean Solutions for the Antarctic Circumpolar Current and Its Associated Overturning Circulation. *Journal of Physical Oceanography*, 33(11):2341–2354. doi:10.1175/1520-0485(2003)033<2341:RSFTAC>2.0.CO;2.
- Marshall, J. and Schott, F. (1999). Open-ocean convection: Observations, theory, and models. *Reviews of Geophysics*, 37(1):1–64. doi:10.1029/98RG02739.
- Marshall, J. and Speer, K. (2012). Closure of the meridional overturning circulation through Southern Ocean upwelling. *Nature Geoscience*, 5(3):171–180. doi:10.1038/ngeo1391.
- Marsland, S. J. and Wolff, J. O. (2001). On the sensitivity of Southern Ocean sea ice to the surface freshwater flux: A model study. *Journal of Geophysical Research*, 106(C2):2723–2741.
- Martin, S., Drucker, R. S., and Kwok, R. (2007). The areas and ice production of the western and central Ross Sea polynyas, 1992–2002, and their relation to the B-15 and C-19 iceberg events of 2000 and 2002. *Journal of Marine Systems*, 68(1-2):201–214. doi:10.1016/j.jmarsys.2006.11.008.
- Martin, T. and Adcroft, A. (2010). Parameterizing the fresh-water flux from land ice to ocean with interactive icebergs in a coupled climate model. *Ocean Modelling*, 34(3-4):111–124. doi:10.1016/j.ocemod.2010.05.001.
- Martin, T., Park, W., and Latif, M. (2013). Multi-centennial variability controlled by Southern Ocean convection in the Kiel Climate Model. *Climate Dynamics*, 40(7-8):2005–2022. doi:10.1007/s00382-012-1586-7.
- Martinson, D. G. (1990). Evolution of the Southern Ocean winter mixed layer and sea ice: Open ocean deepwater formation and ventilation. *Journal of Geophysical Research Oceans*, 95(C7):11641–11654. doi:10.1029/JC095iC07p11641.
- Martinson, D. G. (1991). Open Ocean Convection in the Southern Ocean. In Chu, P. C. and Gascard, J. C., editors, *Elsevier Oceanography Series*, volume 57, pages 37–52. Elsevier. doi:10.1016/S0422-9894(08)70059-X.
- Martinson, D. G., Killworth, P. D., and Gordon, A. L. (1981). A Convective Model for the Weddell Polynya. *Journal of Physical Oceanography*, 11(4):466–488. doi:10.1175/1520-0485(1981)011<0466:ACMFTW>2.0.CO;2.
- Martinson, D. G. and McKee, D. C. (2012). Transport of warm Upper Circumpolar Deep Water onto the western Antarctic Peninsula continental shelf. *Ocean Science*, 8(4):433–442. doi:10.5194/os-8-433-2012.
- Maslanik, J., Fowler, C., Key, J., Scambos, T., Hutchinson, T., and Emery, W. (1997). AVHRR-based Polar Pathfinder products for modeling applications. *Annals of Glaciology*, 25:388–392.

- Massom, R. A., Eicken, H., Haas, C., Jeffries, M. O., Drinkwater, M. R., Sturm, M., Worby, A. P., Wu, X., Lytle, V. I., Ushio, S., Morris, K., Reid, P. A., Warren, S. G., and Allison, I. (2001). Snow on Antarctic sea ice. *Reviews of Geophysics*, 39(3):413–445. doi:10.1029/2000RG000085.
- Massonnet, F., Mathiot, P., Fichet, T., Goosse, H., König Beatty, C., Vancoppenolle, M., and Lavergne, T. (2013). A model reconstruction of the Antarctic sea ice thickness and volume changes over 1980-2008 using data assimilation. *Ocean Modelling*, 64:67–75. doi:10.1016/j.ocemod.2013.01.003.
- Matear, R. J. and Lenton, A. (2008). Impact of Historical Climate Change on the Southern Ocean Carbon Cycle. *Journal of Climate*, 21(22):5820–5834. doi:10.1175/2008jcli2194.1.
- Mathiot, P., Barnier, B., Gallée, H., Molines, J. M., Sommer, J. L., Juza, M., and Penduff, T. (2010). Introducing katabatic winds in global ERA40 fields to simulate their impacts on the Southern Ocean and sea-ice. *Ocean Modelling*, 35(3):146–160. doi:10.1016/j.ocemod.2010.07.001.
- Mathiot, P., Jourdain, N. C., Barnier, B., Gallée, H., Molines, J. M., Le Sommer, J., and Penduff, T. (2012). Sensitivity of coastal polynyas and high-salinity shelf water production in the Ross Sea, Antarctica, to the atmospheric forcing. *Ocean Dynamics*, 62(5):701–723. doi:10.1007/s10236-012-0531-y.
- Maykut, G. A. and Untersteiner, N. (1971). Some results from a time-dependent thermodynamic model of sea ice. *Journal of Geophysical Research*, 76(6):1550–1575. doi:10.1029/JC076i006p01550.
- Mazloff, M. R., Heimbach, P., and Wunsch, C. (2010). An Eddy-Permitting Southern Ocean State Estimate. *Journal of Physical Oceanography*, 40(5):880–899. doi:10.1175/2009JPO4236.1.
- McDougall, T. J. (1987). Thermobaricity, cabbeling, and water-mass conversion. *Journal of Geophysical Research*, 92(C5):5448. doi:10.1029/JC092iC05p05448.
- McPhee, M. (2008). *Air-ice-ocean interaction: Turbulent ocean boundary layer exchange processes*. Springer, New York, Dordrecht, Heidelberg, London. doi:10.1007/978-0-387-78335-2.
- McPhee, M. G. (1992). Turbulent heat flux in the upper ocean under sea ice. *Journal of Geophysical Research*, 97(C4):5365. doi:10.1029/92JC00239.
- McPhee, M. G. (2003). Is thermobaricity a major factor in Southern Ocean ventilation? *Antarctic Science*, 15(1):153–160. doi:10.1017/S0954102003001159.
- McWilliams, J. C., Huckle, E., and Shchepetkin, A. F. (2009). Buoyancy Effects in a Stratified Ekman Layer. *Journal of Physical Oceanography*, 39(10):2581–2599. doi:10.1175/2009JPO4130.1.
- Meehl, G. A., Arblaster, J. M., Bitz, C. M., Chung, C. T. Y., and Teng, H. (2016). Antarctic sea-ice expansion between 2000 and 2014 driven by tropical Pacific decadal climate variability. *Nature Geoscience*, 9(8):590–595. doi:10.1038/ngeo2751.
- Meier, W., Fetterer, F., Savoie, M., Mallory, S., Duerr, R., and Stroeve, J. (2013a). NOAA/NSIDC Climate Data Record of passive microwave sea ice concentration, version 2, 1979–2011, In *Boulder, Colorado USA: National Snow and Ice Data Center*, Boulder, Colorado USA. doi:10.7265/N55M63M1.

- Meier, W., Fetterer, F., Savoie, M., Mallory, S., Duerr, R., and Stroeve, J. (2013b). NOAA/NSIDC Climate Data Record of passive microwave sea ice concentration, version 2, 1980–2009, In *Boulder, Colorado USA: National Snow and Ice Data Center*, Boulder, Colorado USA. doi:10.7265/N55M63M1.
- Meijers, A. J. S., Bindoff, N. L., and Rintoul, S. R. (2011). Frontal movements and property fluxes: Contributions to heat and freshwater trends in the Southern Ocean. *Journal of Geophysical Research*, 116(8):C08024. doi:10.1029/2010JC006832.
- Meijers, A. J. S., Bindoff, N. L., and Roberts, J. L. (2007). On the Total, Mean, and Eddy Heat and Freshwater Transports in the Southern Hemisphere of a $1/8^\circ \times 1/8^\circ$ Global Ocean Model. *Journal of Physical Oceanography*, 37(2):277–295. doi:10.1175/JPO3012.1.
- Meijers, A. J. S., Shuckburgh, E., Bruneau, N., Sallée, J.-B., Bracegirdle, T. J., and Wang, Z. (2012). Representation of the Antarctic Circumpolar Current in the CMIP5 climate models and future changes under warming scenarios. *Journal of Geophysical Research: Oceans*, 117(12):C12008. doi:10.1029/2012JC008412.
- Mellor, G. L. and Kantha, L. (1989). An ice-ocean coupled model. *Journal of Geophysical Research*, 94(C8):10937. doi:10.1029/JC094iC08p10937.
- Meredith, M. P., Gordon, A. L., Naveira Garabato, A. C., Abrahamsen, E. P., Huber, B. A., Jullion, L., and Venables, H. J. (2011a). Synchronous intensification and warming of Antarctic Bottom Water outflow from the Weddell Gyre. *Geophysical Research Letters*, 38(3):L03603. doi:10.1029/2010GL046265.
- Meredith, M. P. and Hogg, A. M. (2006). Circumpolar response of Southern Ocean eddy activity to a change in the Southern Annular Mode. *Geophysical Research Letters*, 33(16):L16608. doi:10.1029/2006GL026499.
- Meredith, M. P., Naveira Garabato, A. C., Hogg, A. M., and Farneti, R. (2012). Sensitivity of the overturning circulation in the Southern Ocean to decadal changes in wind forcing. *Journal of Climate*, 25(1):99–110. doi:10.1175/2011JCLI4204.1.
- Meredith, M. P., Venables, H. J., Clarke, A., Ducklow, H. W., Erickson, M., Leng, M. J., Lenaerts, J. T. M., and Van Den Broeke, M. R. (2013). The freshwater system west of the Antarctic Peninsula: Spatial and temporal changes. *Journal of Climate*, 26(5):1669–1684. doi:10.1175/JCLID-12-00246.1.
- Meredith, M. P., Wallace, M. I., Stammerjohn, S. E., Renfrew, I. A., Clarke, A., Venables, H. J., Shoosmith, D. R., Souster, T., and Leng, M. J. (2010). Changes in the freshwater composition of the upper ocean west of the Antarctic Peninsula during the first decade of the 21st century. *Progress in Oceanography*, 87(1-4):127–143. doi:10.1016/j.pocean.2010.09.019.
- Meredith, M. P., Woodworth, P. L., Chereskin, T. K., Marshall, D. P., Allison, L. C., Bigg, G. R., Donohue, K., Heywood, K. J., Hughes, C. W., Hibbert, A., Hogg, A. M., Johnson, H. L., Jullion, L., King, B. A., Leach, H., Lenn, Y.-D., Morales Maqueda, M. A., Munday, D. R., Naveira Garabato, A. C., Provost, C., Sallée, J.-B., and Sprintall, J. (2011b). Sustained monitoring of the Southern Ocean at Drake Passage: past achievements and future priorities. *Reviews of Geophysics*, 49(4):RG4005. doi:10.1029/2010RG000348.
- Meredith, M. P., Woodworth, P. L., Hughes, C. W., and Stepanov, V. (2004). Changes in the ocean transport through Drake Passage during the 1980s and 1990s, forced by changes in the Southern Annular Mode. *Geophysical Research Letters*, 31(21):L21305. doi:10.1029/2004GL021169.

- Merino, I., Le Sommer, J., Durand, G. G., Jourdain, N. C., Madec, G., Mathiot, P., and Tournadre, J. (2016). Antarctic icebergs melt over the Southern Ocean: Climatology and impact on sea ice. *Ocean Modelling*, 104:99–110. doi:10.1016/j.ocemod.2016.05.001.
- Merrifield, S. T., Laurent, L. S., Owens, B., Thurnherr, A. M., and Toole, J. M. (2016). Enhanced Diapycnal Diffusivity in Intrusive Regions of the Drake Passage. *Journal of Physical Oceanography*, 46(4):1309–1321. doi:10.1175/JPO-D-15-0068.1.
- Meyer, A., Sloyan, B. M., Polzin, K. L., Phillips, H. E., and Bindoff, N. L. (2015). Mixing Variability in the Southern Ocean. *Journal of Physical Oceanography*, 45(4):966–987. doi:10.1175/JPO-D-14-0110.1.
- Middleton, J. H. and Foster, T. D. (1980). Fine structure measurements in a temperature-compensated halocline. *Journal of Geophysical Research*, 85(C2):1107. doi:10.1029/JC085iC02p01107.
- Mikaloff Fletcher, S. E., Gruber, N., Jacobson, A. R., Doney, S. C., Dutkiewicz, S., Gerber, M., Follows, M., Joos, F., Lindsay, K., Menemenlis, D., Mouchet, A., Müller, S. A., and Sarmiento, J. L. (2006). Inverse estimates of anthropogenic CO₂ uptake, transport, and storage by the ocean. *Global Biogeochemical Cycles*, 20(2):GB2002. doi:10.1029/2005GB002530.
- Mikaloff Fletcher, S. E., Gruber, N., Jacobson, A. R., Gloor, M., Doney, S. C., Dutkiewicz, S., Gerber, M., Follows, M. J., Joos, F., Lindsay, K., Menemenlis, D., Mouchet, A., Müller, S. A., and Sarmiento, J. L. (2007). Inverse estimates of the oceanic sources and sinks of natural CO₂ and the implied oceanic carbon transport. *Global Biogeochemical Cycles*, 21(1):GB1010. doi:10.1029/2006GB002751.
- Moore, J., Doney, S. C., Glover, D. M., and Fung, I. Y. (2001a). Iron cycling and nutrient-limitation patterns in surface waters of the World Ocean. *Deep Sea Research Part II: Topical Studies in Oceanography*, 49(1-3):463–507. doi:10.1016/S0967-0645(01)00109-6.
- Moore, J., Doney, S. C., Kleypas, J. A., Glover, D. M., and Fung, I. Y. (2001b). An intermediate complexity marine ecosystem model for the global domain. *Deep Sea Research Part II: Topical Studies in Oceanography*, 49(1-3):403–462. doi:10.1016/S0967-0645(01)00108-4.
- Moore, J. K., Doney, S. C., and Lindsay, K. (2004). Upper ocean ecosystem dynamics and iron cycling in a global three-dimensional model. *Global Biogeochemical Cycles*, 18(4):1–21. doi:10.1029/2004GB002220.
- Moore, J. K., Lindsay, K., Doney, S. C., Long, M. C., and Misumi, K. (2013). Marine Ecosystem Dynamics and Biogeochemical Cycling in the Community Earth System Model [CESM1(BGC)]: Comparison of the 1990s with the 2090s under the RCP4.5 and RCP8.5 Scenarios. *Journal of Climate*, 26(23):9291–9312. doi:10.1175/JCLI-D-12-00566.1.
- Morel, A. and Berthon, J.-F. (1989). Surface pigments, algal biomass profiles, and potential production of the euphotic layer: Relationships reinvestigated in view of remote-sensing applications. *Limnology and Oceanography*, 34(8):1545–1562. doi:10.4319/lo.1989.34.8.1545.
- Morrison, A. K., Frölicher, T. L., and Sarmiento, J. L. (2015). Upwelling in the Southern Ocean. *Physics Today*, 68(1):27–32. doi:10.1063/PT.3.2654.
- Morrison, A. K., Griffies, S. M., Winton, M., Anderson, W. G., and Sarmiento, J. L. (2016). Mechanisms of Southern Ocean heat uptake and transport in a global eddying climate model. *Journal of Climate*, 29:2059–2075. doi:10.1175/JCLI-D-15-0579.1.

- Morrison, A. K. and Hogg, A. M. (2013). On the Relationship between Southern Ocean Overturning and ACC Transport. *Journal of Physical Oceanography*, 43(1):140–148. doi:10.1175/JPO-D-12-057.1.
- Morrison, A. K., Hogg, A. M., and Ward, M. L. (2011). Sensitivity of the Southern Ocean overturning circulation to surface buoyancy forcing. *Geophysical Research Letters*, 38(14):L14602. doi:10.1029/2011GL048031.
- Muench, R. D., Fernando, H. J. S., and Stegen, G. R. (1990). Temperature and Salinity Staircases in the Northwestern Weddell Sea. *Journal of Physical Oceanography*, 20(2):295–306. doi:10.1175/1520-0485(1990)020<0295:TASSIT>2.0.CO;2.
- Munk, W. and Wunsch, C. (1998). Abyssal recipes II: Energetics of tidal and wind mixing. *Deep-Sea Research Part I: Oceanographic Research Papers*, 45(12):1977–2010. doi:10.1016/S0967-0637(98)00070-3.
- Munk, W. H. (1966). Abyssal recipes. *Deep Sea Research and Oceanographic Abstracts*, 13(4):707–730. doi:10.1016/0011-7471(66)90602-4.
- Munro, D. R., Lovenduski, N. S., Takahashi, T., Stephens, B. B., Newberger, T., and Sweeney, C. (2015). Recent evidence for a strengthening CO₂ sink in the Southern Ocean from carbonate system measurements in the Drake Passage (2002–2015). *Geophysical Research Letters*, 42(18):7623–7630. doi:10.1002/2015GL065194.
- Nakayama, Y., Timmermann, R., Rodehacke, C. B., Schröder, M., and Hellmer, H. H. (2014). Modeling the spreading of glacial meltwater from the Amundsen and Bellingshausen Seas. *Geophysical Research Letters*, 41(22):7942–7949. doi:10.1002/2014GL061600.
- NASA Aquarius Project (2015). Aquarius Official Release Level 3 Sea Surface Salinity Standard Mapped Image Monthly Data V4.0. PO.DAAC, CA, USA. doi:10.5067/AQR40-3SMCS.
- Naveira Garabato, A. C., Jullion, L., Stevens, D. P., Heywood, K. J., and King, B. A. (2009). Variability of Subantarctic Mode Water and Antarctic Intermediate Water in the Drake Passage during the Late-Twentieth and Early-Twenty-First Centuries. *Journal of Climate*, 22(13):3661–3688. doi:10.1175/2009JCLI2621.1.
- Naveira Garabato, A. C., Williams, A. P., and Bacon, S. (2014). The three-dimensional overturning circulation of the Southern Ocean during the WOCE era. *Progress in Oceanography*, 120:41–78. doi:10.1016/j.pocean.2013.07.018.
- Neff, W., Perlwitz, J., and Hoerling, M. (2008). Observational evidence for asymmetric changes in tropospheric heights over Antarctica on decadal time scales. *Geophysical Research Letters*, 35(18):L18703. doi:10.1029/2008GL035074.
- Nevison, C. D., Manizza, M., Keeling, R. F., Stephens, B. B., Bent, J. D., Dunne, J., Ilyina, T., Long, M., Resplandy, L., Tjiputra, J., and Yukimoto, S. (2016). Evaluating CMIP5 ocean biogeochemistry and Southern Ocean carbon uptake using atmospheric potential oxygen: Present-day performance and future projection. *Geophysical Research Letters*, 43(5):2077–2085. doi:10.1002/2015GL067584.
- Nguyen, A. T., Menemenlis, D., and Kwok, R. (2009). Improved modeling of the Arctic halocline with a subgrid-scale brine rejection parameterization. *Journal of Geophysical Research: Oceans*, 114(11):C11014. doi:10.1029/2008JC005121.

- Nicholson, S.-A., Lévy, M., Llort, J., Swart, S., and Monteiro, P. M. S. (2016). Investigation into the impact of storms on sustaining summer primary productivity in the Sub-Antarctic Ocean. *Geophysical Research Letters*. doi:10.1002/2016GL069973.
- Nicolas, J. P. and Bromwich, D. H. (2011). Precipitation Changes in High Southern Latitudes from Global Reanalyses: A Cautionary Tale. *Surveys in Geophysics*, 32(4-5):475–494. doi:10.1007/s10712-011-9114-6.
- Niiler, P. P. and Kraus, E. B. (1977). One-dimensional models of the upper ocean. In Kraus, E. B., editor, *Modeling and Prediction of the Upper Layers of the Ocean*, pages 143–172. Pergamon, New York.
- Nikurashin, M., Vallis, G. K., and Adcroft, A. (2012). Routes to energy dissipation for geostrophic flows in the Southern Ocean. *Nature Geoscience*, 6(1):48–51. doi:10.1038/ngeo1657.
- Notz, D., Haumann, F. A., Haak, H., Jungclaus, J. H., and Marotzke, J. (2013). Arctic sea-ice evolution as modeled by Max Planck Institute for Meteorology's Earth system model. *Journal of Advances in Modeling Earth Systems*, 5(2):173–194. doi:10.1002/jame.20016.
- Oerlemans, J. (1980). Model experiments on the 100,000-yr glacial cycle. *Nature*, 287(5781):430–432. doi:10.1038/287430a0.
- Ogura, T. (2004). Effects of sea ice dynamics on the Antarctic sea ice distribution in a coupled ocean atmosphere model. *Journal of Geophysical Research*, 109(C4):C04025. doi:10.1029/2003JC002022.
- Ohshima, K. I., Fukamachi, Y., Williams, G. D., Nihashi, S., Roquet, F., Kitade, Y., Tamura, T., Hirano, D., Herraiz-Borreguero, L., Field, I., Hindell, M., Aoki, S., and Wakatsuchi, M. (2013). Antarctic Bottom Water production by intense sea-ice formation in the Cape Darnley polynya. *Nature Geoscience*, 6(3):235–240. doi:10.1038/ngeo1738.
- Ohshima, K. I., Nakanowatari, T., Riser, S., Volkov, Y., and Wakatsuchi, M. (2014). Freshening and dense shelf water reduction in the Okhotsk Sea linked with sea ice decline. *Progress in Oceanography*, 126:71–79. doi:10.1016/j.pocean.2014.04.020.
- Oke, P. R. and England, M. H. (2004). Oceanic response to changes in the latitude of the Southern Hemisphere subpolar westerly winds. *Journal of Climate*, 17(5):1040–1054. doi:10.1175/1520-0442(2004)017<1040:ORTCIT>2.0.CO;2.
- Olason, E. and Notz, D. (2014). Drivers of variability in Arctic sea-ice drift speed. *Journal of Geophysical Research*, 119(9):5755–5775. doi:10.1002/2014JC009897.
- Olbers, D., Borowski, D., Völker, C., and Wölff, J.-O. (2004). The dynamical balance, transport and circulation of the Antarctic Circumpolar Current. *Antarctic Science*, 16(4):439–470. doi:10.1017/S0954102004002251.
- Omstedt, A., Nyberg, L., and Leppäranta, M. (1996). On the ice-ocean response to wind forcing. *Tellus A*, 48(4):593–606. doi:10.1034/j.1600-0870.1996.t01-3-00008.x.
- Orlanski, I. (1976). A simple boundary condition for unbounded hyperbolic flows. *Journal of Computational Physics*, 21(3):251–269. doi:10.1016/0021-9991(76)90023-1.

- Orr, J. C., Maier-Reimer, E., Mikolajewicz, U., Monfray, P., Sarmiento, J. L., Toggweiler, J. R., Taylor, N. K., Palmer, J., Gruber, N., Sabine, C. L., Le Quéré, C., Key, R. M., and Boutin, J. (2001). Estimates of anthropogenic carbon uptake from four three-dimensional global ocean models. *Global Biogeochemical Cycles*, 15(1):43–60. doi:10.1029/2000GB001273.
- Orsi, A. H., Johnson, G. C., and Bullister, J. L. (1999). Circulation, mixing, and production of Antarctic Bottom Water. *Progress in Oceanography*, 43(1):55–109.
- Orsi, A. H., Smethie, W. M., and Bullister, J. L. (2002). On the total input of Antarctic waters to the deep ocean: A preliminary estimate from chlorofluorocarbon measurements. *Journal of Geophysical Research*, 107(C8):3122. doi:10.1029/2001JC000976.
- Orsi, A. H., Whitworth, T., and Nowlin, W. D. (1995). On the meridional extent and fronts of the Antarctic Circumpolar Current. *Deep-Sea Research Part I*, 42(5):641–673. doi:10.1016/0967-0637(95)00021-W.
- Oschlies, A., Dietze, H., and Köhler, P. (2003). Salt-finger driven enhancement of upper ocean nutrient supply. *Geophysical Research Letters*, 30(23):2204. doi:10.1029/2003GL018552.
- Otto-Bliesner, B. L., Hewitt, C. D., Marchitto, T. M., Brady, E., Abe-Ouchi, A., Crucifix, M., Murakami, S., and Weber, S. L. (2007). Last Glacial Maximum ocean thermohaline circulation: PMIP2 model intercomparisons and data constraints. *Geophysical Research Letters*, 34(12):L12706. doi:10.1029/2007GL029475.
- Paolo, F. S., Fricker, H. A., and Padman, L. (2015). Volume loss from Antarctic ice shelves is accelerating. *Science*, 348(6232):327–331. doi:10.1126/science.aaa0940.
- Papritz, L., Pfahl, S., Rudeva, I., Simmonds, I., Sodemann, H., and Wernli, H. (2014). The role of extratropical cyclones and fronts for Southern Ocean freshwater fluxes. *Journal of Climate*, 27(16):6205–6224. doi:10.1175/JCLI-D-13-00409.1.
- Papritz, L., Pfahl, S., Sodemann, H., and Wernli, H. (2015). A climatology of cold air outbreaks and their impact on air-sea heat fluxes in the high-latitude South Pacific. *Journal of Climate*, 28(1):342–364. doi:10.1175/JCLI-D-14-00482.1.
- Park, W. and Latif, M. (2008). Multidecadal and multicentennial variability of the meridional overturning circulation. *Geophysical Research Letters*, 35(22):L22703. doi:10.1029/2008GL035779.
- Parrenin, F., Masson-Delmotte, V., Köhler, P., Raynaud, D., Paillard, D., Schwander, J., Barbante, C., Landais, A., Wegner, A., and Jouzel, J. (2013). Synchronous change of atmospheric CO₂ and Antarctic temperature during the last deglacial warming. *Science*, 339(6123):1060–1063. doi:10.1126/science.1226368.
- Patara, L., Böning, C. W., and Biastoch, A. (2016). Variability and trends in Southern Ocean eddy activity in 1/12 ocean model simulations. *Geophysical Research Letters*, 43(9):4517–4523. doi:10.1002/2016GL069026.
- Pauling, A. G., Bitz, C. M., Smith, I. J., and Langhorne, P. J. (2016). The Response of the Southern Ocean and Antarctic Sea Ice to Freshwater from Ice Shelves in an Earth System Model. *Journal of Climate*, 29(5):1655–1672. doi:10.1175/JCLI-D-15-0501.1.

- Peña-Molino, B., McCartney, M. S., and Rintoul, S. R. (2016). Direct observations of the Antarctic Slope Current transport at 113°E. *Journal of Geophysical Research: Oceans*. doi:10.1002/2015JC011594.
- Pérez, F. F., Mercier, H., Vázquez-Rodríguez, M., Lherminier, P., Velo, A., Pardo, P. C., Rosón, G., and Ríos, A. F. (2013). Atlantic Ocean CO₂ uptake reduced by weakening of the meridional overturning circulation. *Nature Geoscience*, 6(2):146–152. doi:10.1038/ngeo1680.
- Peterson, T. C., Easterling, D. R., Karl, T. R., Groisman, P., Nicholls, N., Plummer, N., Torok, S., Auer, I., Boehm, R., Gullett, D., Vincent, L., Heino, R., Tuomenvirta, H., Mestre, O., Szentimrey, T., Salinger, J., Førland, E. J., Hanssen-Bauer, I., Alexandersson, H., Jones, P., and Parker, D. (1998). Homogeneity adjustments of in situ atmospheric climate data: a review. *International Journal of Climatology*, 18(13):1493–1517. doi:10.1002/(SICI)1097-0088(19981115)18:13<1493::AID-JOC329>3.0.CO;2-T.
- Petit, J. R., Jouzel, J., Raynaud, D., Barkov, N. I., Barnola, J.-M., Basile, I., Bender, M., Chappellaz, J., Davis, M., Delaygue, G., Delmotte, M., Kotlyakov, V. M., Legrand, M., Lipenkov, V. Y., Lorius, C., Pépin, L., Ritz, C., Saltzman, E., and Stievenard, M. (1999). Climate and atmospheric history of the past 420,000 years from the Vostok ice core, Antarctica. *Nature*, 399(6735):429–436. doi:10.1038/20859.
- Petrelli, P., Bindoff, N. L., and Bergamasco, A. (2008). The sea ice dynamics of Terra Nova Bay and Ross Ice Shelf Polynyas during a spring and winter simulation. *Journal of Geophysical Research*, 113(C9):C09003. doi:10.1029/2006JC004048.
- Pierrehumbert, R. T. (2011). Infrared radiation and planetary temperature. *Physics Today*, 64(1):33. doi:10.1063/1.3541943.
- Poisson, A. and Chen, C.-T. A. (1987). Why is there little anthropogenic CO₂ in the Antarctic bottom water? *Deep Sea Research Part A. Oceanographic Research Papers*, 34(7):1255–1275. doi:10.1016/0198-0149(87)90075-6.
- Pollard, D. and Thompson, S. L. (1994). Sea-ice dynamics and CO₂ sensitivity in a global climate model. *Atmosphere-Ocean*, 32(2):449–467. doi:10.1080/07055900.1994.9649506.
- Polvani, L. M. and Smith, K. L. (2013). Can natural variability explain observed Antarctic sea ice trends? New modeling evidence from CMIP5. *Geophysical Research Letters*, 40(12):3195–3199. doi:10.1002/grl.50578.
- Primeau, F. (2005). Characterizing Transport between the Surface Mixed Layer and the Ocean Interior with a Forward and Adjoint Global Ocean Transport Model. *Journal of Physical Oceanography*, 35(4):545–564. doi:10.1175/JPO2699.1.
- Pritchard, H. D., Ligtenberg, S. R. M., Fricker, H. A., Vaughan, D. G., van den Broeke, M. R., and Padman, L. (2012). Antarctic ice-sheet loss driven by basal melting of ice shelves. *Nature*, 484(7395):502–505. doi:10.1038/nature10968.
- Purkey, S. G. and Johnson, G. C. (2013). Antarctic Bottom Water warming and freshening: contributions to sea level rise, ocean freshwater budgets, and global heat gain. *Journal of Climate*, 26(16):6105–6122. doi:10.1175/JCLI-D-12-00834.1.
- Qiao, F. and Huang, C. J. (2012). Comparison between vertical shear mixing and surface wave-induced mixing in the extratropical ocean. *Journal of Geophysical Research: Oceans*, 117(C11):C00J16. doi:10.1029/2012JC007930.

- Rahmstorf, S. (2002). Ocean circulation and climate during the past 120,000 years. *Nature*, 419(6903):207–214. doi:10.1038/nature01090.
- Rahmstorf, S., Box, J. E., Feulner, G., Mann, M. E., Robinson, A., Rutherford, S., and Schaf-fernicht, E. J. (2015). Exceptional twentieth-century slowdown in Atlantic Ocean overturning circulation. *Nature Climate Change*, 5(5):475–480. doi:10.1038/nclimate2554.
- Randerson, J. T., Lindsay, K., Munoz, E., Fu, W., Moore, J. K., Hoffman, F. M., Mahowald, N. M., and Doney, S. C. (2015). Multicentury changes in ocean and land contributions to the climate-carbon feedback. *Global Biogeochemical Cycles*, 29(6):744–759. doi:10.1002/2014GB005079.
- Raphael, M. N., Marshall, G. J., Turner, J., Fogt, R. L., Schneider, D., Dixon, D. A., Hosking, J. S., Jones, J. M., and Hobbs, W. R. (2016). The Amundsen Sea Low: Variability, Change, and Impact on Antarctic Climate. *Bulletin of the American Meteorological Society*, 97(1):111–121. doi:10.1175/BAMS-D-14-00018.1.
- Raymond, W. H. and Kuo, H. L. (1984). A radiation boundary condition for multi-dimensional flows. *Quarterly Journal of the Royal Meteorological Society*, 110(464):535–551. doi:10.1002/qj.49711046414.
- Ren, L., Speer, K., and Chassignet, E. P. (2011). The mixed layer salinity budget and sea ice in the Southern Ocean. *Journal of Geophysical Research: Oceans*, 116(8):C08031. doi:10.1029/2010JC006634.
- Reynolds, R. W., Smith, T. M., Liu, C., Chelton, D. B., Casey, K. S., and Schlax, M. G. (2007). Daily high-resolution-blended analyses for sea surface temperature. *Journal of Climate*, 20(22):5473–5496. doi:10.1175/2007JCLI1824.1.
- Ridderinkhof, H., van der Werf, P. M., Ullgren, J. E., van Aken, H. M., van Leeuwen, P. J., and de Ruijter, W. P. M. (2010). Seasonal and interannual variability in the Mozambique Channel from moored current observations. *Journal of Geophysical Research*, 115(C6):C06010. doi:10.1029/2009JC005619.
- Ridgway, K. R., Dunn, J. R., and Wilkin, J. L. (2002). Ocean Interpolation by Four-Dimensional Weighted Least Squares Application to the Waters around Australasia. *Journal of Atmospheric and Oceanic Technology*, 19(9):1357–1375. doi:10.1175/1520-0426(2002)019<1357:OIBFDW>2.0.CO;2.
- Rignot, E., Bamber, J. L., van den Broeke, M. R., Davis, C., Li, Y., van de Berg, W. J., and Van Meijgaard, E. (2008). Recent Antarctic ice mass loss from radar interferometry and regional climate modelling. *Nature Geoscience*, 1(2):106–110. doi:10.1038/ngeo102.
- Rignot, E., Jacobs, S., Mouginot, J., and Scheuchl, B. (2013). Ice-shelf melting around Antarctica. *Science*, 341(6143):266–70. doi:10.1126/science.1235798.
- Rintoul, S. R. and England, M. H. (2002). Ekman Transport Dominates Local Air–Sea Fluxes in Driving Variability of Subantarctic Mode Water. *Journal of Physical Oceanography*, 32(5):1308–1321. doi:10.1175/1520-0485(2002)032<1308:ETDLAS>2.0.CO;2.
- Rintoul, S. R. and Naveira Garabato, A. C. (2013). Dynamics of the Southern Ocean Circulation. In *Ocean Circulation and Climate - A 21st Century Perspective*, volume 103 of *International Geophysics*, pages 471–492. Elsevier. doi:10.1016/B978-0-12-391851-2.00018-0.

- Riser, S. C., Freeland, H. J., Roemmich, D., Wijffels, S., Troisi, A., Belbéoch, M., Gilbert, D., Xu, J., Pouliquen, S., Thresher, A., Le Traon, P.-Y., Maze, G., Klein, B., Ravichandran, M., Grant, F., Poulain, P.-M., Suga, T., Lim, B., Sterl, A., Sutton, P., Mork, K.-A., Vélez-Belchí, P. J., Ansorge, I., King, B., Turton, J., Baringer, M., and Jayne, S. R. (2016). Fifteen years of ocean observations with the global Argo array. *Nature Climate Change*, 6(2):145–153. doi:10.1038/nclimate2872.
- Ritz, C., Edwards, T. L., Durand, G., Payne, A. J., Peyaud, V., and Hindmarsh, R. C. A. (2015). Potential sea-level rise from Antarctic ice-sheet instability constrained by observations. *Nature*, 528(7580):115–118. doi:10.1038/nature16147.
- Roberts, M. and Marshall, D. (1998). Do We Require Adiabatic Dissipation Schemes in Eddy-Resolving Ocean Models? *Journal of Physical Oceanography*, 28(10):2050–2063. doi:10.1175/1520-0485(1998)028<2050:DWRADS>2.0.CO;2.
- Roche, D. M., Crosta, X., and Renssen, H. (2012). Evaluating Southern Ocean sea-ice for the Last Glacial Maximum and pre-industrial climates: PMIP-2 models and data evidence. *Quaternary Science Reviews*, 56:99–106. doi:10.1016/j.quascirev.2012.09.020.
- Rodehacke, C. B., Hellmer, H. H., Beckmann, A., and Roether, W. (2007). Formation and spreading of Antarctic deep and bottom waters inferred from a chlorofluorocarbon (CFC) simulation. *Journal of Geophysical Research: Oceans*, 112(9):C09001. doi:10.1029/2006JC003884.
- Roemmich, D., Church, J., Gilson, J., Monselesan, D., Sutton, P., and Wijffels, S. (2015). Unabated planetary warming and its ocean structure since 2006. *Nature Climate Change*, 5(February):2–7. doi:10.1038/nclimate2513.
- Roemmich, D., Gould, W. J., and Gilson, J. (2012). 135 years of global ocean warming between the Challenger expedition and the Argo Programme. *Nature Climate Change*, 2(6):425–428. doi:10.1038/nclimate1461.
- Rojas, M. (2013). Sensitivity of Southern Hemisphere circulation to LGM and 4x CO₂ climates. *Geophysical Research Letters*, 40(5):965–970. doi:10.1002/grl.50195.
- Russell, J. L., Dixon, K. W., Gnanadesikan, A., Stouffer, R. J., and Toggweiler, J. R. (2006). The Southern hemisphere westerlies in a warming world: Propping open the door to the deep ocean. *Journal of Climate*, 19(24):6382–6390. doi:10.1175/JCLI3984.1.
- Rye, C. D., Naveira Garabato, A. C., Holland, P. R., Meredith, M. P., Nurser, A. J. G., Hughes, C. W., Coward, A. C., and Webb, D. J. (2014). Rapid sea-level rise along the Antarctic margins in response to increased glacial discharge. *Nature Geoscience*, 7(August):2–5. doi:10.1038/ngeo2230.
- Sabine, C. L., Feely, R. A., Gruber, N., Key, R. M., Lee, K., Bullister, J. L., Wanninkhof, R., Wong, C. S. S., Wallace, D. W. R., Tilbrook, B., Millero, F. J., Peng, T.-H., Kozyr, A., Ono, T., and Rios, A. F. (2004). The Oceanic Sink for Anthropogenic CO₂. *Science*, 305(5682):367–371. doi:10.1126/science.1097403.
- Saenko, O. A., Fyfe, J. C., and England, M. H. (2005). On the response of the oceanic wind-driven circulation to atmospheric CO₂ increase. *Climate Dynamics*, 25(4):415–426. doi:10.1007/s00382-005-0032-5.

- Saenko, O. A., Schmittner, A., and Weaver, A. J. (2002). On the role of wind-driven sea ice motion on ocean ventilation. *Journal of Physical Oceanography*, 32(12):3376–3395. doi:10.1175/1520-0485(2002)032<3376:OTROWD>2.0.CO;2.
- Saenko, O. A. and Weaver, A. J. (2001). Importance of wind-driven sea ice motion for the formation of Antarctic Intermediate Water in a global climate model. *Geophysical Research Letters*, 28(21):4147–4150. doi:10.1029/2001GL013632.
- Saenko, O. A., Weaver, A. J., and England, M. H. (2003). A Region of Enhanced Northward Antarctic Intermediate Water Transport in a Coupled Climate Model. *Journal of Physical Oceanography*, 33(7):1528–1535. doi:10.1175/1520-0485(2003)033<1528:AROENA>2.0.CO;2.
- Sallée, J.-B., Shuckburgh, E., Bruneau, N., Meijers, A. J. S., Bracegirdle, T. J., and Wang, Z. (2013a). Assessment of Southern Ocean mixed-layer depths in CMIP5 models: Historical bias and forcing response. *Journal of Geophysical Research: Oceans*, 118(4):1845–1862. doi:10.1002/jgrc.20157.
- Sallée, J.-B., Shuckburgh, E., Bruneau, N., Meijers, A. J. S., Bracegirdle, T. J., Wang, Z., and Roy, T. (2013b). Assessment of Southern Ocean water mass circulation and characteristics in CMIP5 models: Historical bias and forcing response. *Journal of Geophysical Research: Oceans*, 118(4):1830–1844. doi:10.1002/jgrc.20135.
- Sallée, J.-B., Speer, K., Rintoul, S. R., and Wijffels, S. E. (2010a). Southern Ocean Thermocline Ventilation. *Journal of Physical Oceanography*, 40(3):509–529. doi:10.1175/2009JPO4291.1.
- Sallée, J. B., Speer, K. G., and Rintoul, S. R. (2010b). Zonally asymmetric response of the Southern Ocean mixed-layer depth to the Southern Annular Mode. *Nature Geoscience*, 3(4):273–279.
- Sallée, J.-B., Speer, K. G., and Rintoul, S. R. (2011). Mean-flow and topographic control on surface eddy-mixing in the Southern Ocean. *Journal of Marine Research*, 69(4-6):753–777. doi:10.1357/002224011799849408.
- Saltzman, B., Hansen, A. R., and Maasch, K. A. (1984). The Late Quaternary Glaciations as the Response of a Three-Component Feedback System to Earth-Orbital Forcing. *Journal of the Atmospheric Sciences*, 41(23):3380–3389. doi:10.1175/1520-0469(1984)041<3380:TLQGAT>2.0.CO;2.
- Santer, B. D., Wehner, M. F., Wigley, T. M. L., Sausen, R., Meehl, G. A., Taylor, K. E., Ammann, C., Arblaster, J., Washington, W. M., Boyle, J. S., and Brüggemann, W. (2003). Contributions of Anthropogenic and Natural Forcing to Recent Tropopause Height Changes. *Science*, 301(5632):479–483. doi:10.1126/science.1084123.
- Santer, B. D., Wigley, T. M. L., Boyle, J. S., Gaffen, D. J., Hnilo, J. J., Nychka, D., Parker, D. E., and Taylor, K. E. (2000). Statistical significance of trends and trend differences in layer-average atmospheric temperature time series. *Journal of Geophysical Research*, 105(D6):7337–7356. doi:10.1029/1999JD901105.
- Santoso, A. and England, M. H. (2004). Antarctic Intermediate Water Circulation and Variability in a Coupled Climate Model. *Journal of Physical Oceanography*, 34(10):2160–2179. doi:10.1175/1520-0485(2004)034<2160:AIWCAV>2.0.CO;2.

- Sanz Rodrigo, J., Buchlin, J. M., van Beeck, J., Lenaerts, J. T. M., and van den Broeke, M. R. (2013). Evaluation of the antarctic surface wind climate from ERA reanalyses and RACMO2/ANT simulations based on automatic weather stations. *Climate Dynamics*, 40(1-2):353–376. doi:10.1007/s00382-012-1396-y.
- Sarmiento, J. L. and Gruber, N. (2006). *Ocean Biogeochemical Dynamics*. Princeton University Press, Princeton, NJ.
- Sarmiento, J. L., Gruber, N., Brzezinski, M. A., and Dunne, J. P. (2004). High-latitude controls of thermocline nutrients and low latitude biological productivity. *Nature*, 427(6969):56–60. doi:10.1038/nature10605.
- Sarmiento, J. L., Hughes, T. M. C., Stouffer, R. J., and Manabe, S. (1998). Simulated response of the ocean carbon cycle to anthropogenic climate warming. *Nature*, 393(6682):245–249. doi:10.1038/30455.
- Sarmiento, J. L. and Le Quéré, C. (1996). Oceanic Carbon Dioxide Uptake in a Model of Century-Scale Global Warming. *Science*, 274(5291):1346–1350. doi:10.1126/science.274.5291.1346.
- Sarmiento, J. L., Le Quéré, C., and Pacala, S. W. (1995). Limiting future atmospheric carbon dioxide. *Global Biogeochemical Cycles*, 9(1):121–137. doi:10.1029/94GB01779.
- Sarmiento, J. L., Orr, J. C., and Siegenthaler, U. (1992). A perturbation simulation of CO₂ uptake in an ocean general circulation model. *Journal of Geophysical Research*, 97(C3):3621. doi:10.1029/91JC02849.
- Sarmiento, J. L. and Toggweiler, J. R. (1984). A new model for the role of the oceans in determining atmospheric PCO₂. *Nature*, 308(5960):621–624. doi:10.1038/308621a0.
- Sarmiento, J. L. and Toggweiler, J. R. (1986). A Preliminary Model of the Role of Upper Ocean Chemical Dynamics in Determining Oceanic Oxygen and Atmospheric Carbon Dioxide Levels. In Burton, J. D., Brewer, P. G., and Chesselet, R., editors, *Dynamic Processes in the Chemistry of the Upper Ocean*, chapter 18, pages 233–240. Springer US, Boston, MA. doi:10.1007/978-1-4684-5215-0_18.
- Sarmiento, J. L., Toggweiler, J. R., Najjar, R., Webb, D. J., Jenkins, W. J., Wunsch, C., Elderfield, H., Whitfield, M., and Minster, J.-F. (1988). Ocean Carbon-Cycle Dynamics and Atmospheric pCO₂ [and Discussion]. *Philosophical Transactions of the Royal Society A*, 325(1583):3–21. doi:10.1098/rsta.1988.0039.
- Schaffer, J., Timmermann, R., Arndt, J. E., Kristensen, S. S., Mayer, C., Morlighem, M., and Steinhage, D. (2016). A global, high-resolution data set of ice sheet topography, cavity geometry, and ocean bathymetry. *Earth System Science Data*, 8:543–557. doi:10.5194/essd-8-543-2016.
- Schmidt, G. A., Bigg, G. R., and Rohling, E. J. (1999). Global Seawater Oxygen-18 Database - v1.21. NASA GISS.
- Schmidt, H., Rast, S., Bunzel, F., Esch, M., Giorgetta, M., Kinne, S., Krismer, T., Stenchikov, G., Timmreck, C., Tomassini, L., and Walz, M. (2013). Response of the middle atmosphere to anthropogenic and natural forcings in the CMIP5 simulations with the Max Planck Institute Earth system model. *Journal of Advances in Modeling Earth Systems*, 5(1):98–116. doi:10.1002/jame.20014.

- Schmidtko, S., Heywood, K. J., Thompson, A. F., and Aoki, S. (2014). Multidecadal warming of Antarctic waters. *Science*, 346(6214):1227–1231. doi:10.1126/science.1256117.
- Schmidtko, S. and Johnson, G. C. (2012). Multidecadal warming and shoaling of Antarctic Intermediate Water. *Journal of Climate*, 25(1):207–221. doi:10.1175/JCLI-D-11-00021.1.
- Schmidtko, S., Johnson, G. C., and Lyman, J. M. (2013). MIMOC: A global monthly isopycnal upper-ocean climatology with mixed layers. *Journal of Geophysical Research: Oceans*, 118(4):1658–1672. doi:10.1002/jgrc.20122.
- Schmitz, W. J. (1995). On the interbasin-scale thermohaline circulation. *Reviews of Geophysics*, 33(2):151. doi:10.1029/95RG00879.
- Schmitz, W. J. (1996). On the World Ocean Circulation: Volume I. Some global features / North Atlantic circulation. Technical report, Woods Hole Oceanographic Institution, Woods Hole, MA.
- Schneider, D. P., Deser, C., and Okumura, Y. (2012a). An assessment and interpretation of the observed warming of West Antarctica in the austral spring. *Climate Dynamics*, 38(1-2):323–347. doi:10.1007/s00382-010-0985-x.
- Schneider, D. P., Okumura, Y., and Deser, C. (2012b). Observed Antarctic Interannual Climate Variability and Tropical Linkages. *J. Climate*, 25(12):4048–4066. doi:10.1175/JCLI-D-11-00273.1.
- Schodlok, M. P., Hellmer, H. H., and Beckmann, A. (2002). On the transport, variability and origin of dense water masses crossing the South Scotia Ridge. *Deep-Sea Research Part II: Topical Studies in Oceanography*, 49(21):4807–4825. doi:10.1016/S0967-0645(02)00160-1.
- Schröder, M. and Fahrbach, E. (1999). On the structure and the transport of the eastern Weddell Gyre. *Deep Sea Research Part II: Topical Studies in Oceanography*, 46(1-2):501–527. doi:10.1016/S0967-0645(98)00112-X.
- Schwegmann, S., Haas, C., Fowler, C., and Gerdes, R. (2011). A comparison of satellite-derived sea-ice motion with drifting-buoy data in the Weddell Sea, Antarctica. *Annals of Glaciology*, 52(57):103–110. doi:10.3189/172756411795931813.
- Schwegmann, S., Rinne, E., Ricker, R., Hendricks, S., and Helm, V. (2016). About the consistency between Envisat and CryoSat-2 radar freeboard retrieval over Antarctic sea ice. *The Cryosphere*, 10(4):1415–1425. doi:10.5194/tc-10-1415-2016.
- SeaWiFS Project, . (2003). SeaWiFS Global Monthly Mapped 9 km Chlorophyll a. Ver. 1., CA, USA. PO.DAAC.
- Sen Gupta, A., Santoso, A., Taschetto, A. S., Ummenhofer, C. C., Trevena, J., and England, M. H. (2009). Projected Changes to the Southern Hemisphere Ocean and Sea Ice in the IPCC AR4 Climate Models. *J. Climate*, 22(11):3047–3078. doi:10.1175/2008JCLI2827.1.
- Seviour, W. J. M., Gnanadesikan, A., and Waugh, D. W. (2016). The Transient Response of the Southern Ocean to Stratospheric Ozone Depletion. *Journal of Climate*. doi:10.1175/JCLI-D-16-0198.1.
- Shackleton, N. J. (2000). The 100,000-year ice-age cycle identified and found to lag temperature, carbon dioxide, and orbital eccentricity. *Science*, 289(5486):1897–1902. doi:10.1126/science.289.5486.1897.

- Shakun, J. D., Clark, P. U., He, F., Marcott, S. A., Mix, A. C., Liu, Z., Otto-Bliesner, B., Schmitner, A., and Bard, E. (2012). Global warming preceded by increasing carbon dioxide concentrations during the last deglaciation. *Nature*, 484(7392):49–54. doi:10.1038/nature10915.
- Shchepetkin, A. F. (2005). If-less KPP. *ROMS/TOMS Workshop: Adjoint Modeling and Applications*.
- Shchepetkin, A. F. (2015). An adaptive, Courant-number-dependent implicit scheme for vertical advection in oceanic modeling. *Ocean Modelling*, 91:38–69. doi:10.1016/j.ocemod.2015.03.006.
- Shchepetkin, A. F. and McWilliams, J. C. (1998). Quasi-Monotone Advection Schemes Based on Explicit Locally Adaptive Dissipation. *Monthly Weather Review*, 126(6):1541–1580. doi:10.1175/1520-0493(1998)126<1541:QMASBO>2.0.CO;2.
- Shchepetkin, A. F. and McWilliams, J. C. (2003). A method for computing horizontal pressure-gradient force in an oceanic model with a nonaligned vertical coordinate. *Journal of Geophysical Research*, 108(C3):3090. doi:10.1029/2001JC001047.
- Shchepetkin, A. F. and McWilliams, J. C. (2005). The regional oceanic modeling system (ROMS): A split-explicit, free-surface, topography-following-coordinate oceanic model. *Ocean Modelling*, 9(4):347–404. doi:10.1016/j.ocemod.2004.08.002.
- Shchepetkin, A. F. and McWilliams, J. C. (2009a). Computational Kernel Algorithms for Fine-Scale, Multiprocess, Longtime Oceanic Simulations. *Handbook of Numerical Analysis*, 14:121–183. doi:10.1016/S1570-8659(08)01202-0.
- Shchepetkin, A. F. and McWilliams, J. C. (2009b). Correction and commentary for "Ocean forecasting in terrain-following coordinates: Formulation and skill assessment of the regional ocean modeling system" by Haidvogel et al., *J. Comp. Phys.* 227, pp. 3595–3624. *Journal of Computational Physics*, 228(24):8985–9000. doi:10.1016/j.jcp.2009.09.002.
- Shchepetkin, A. F. and McWilliams, J. C. (2011). Accurate Boussinesq oceanic modeling with a practical, "Stiffened" Equation of State. *Ocean Modelling*, 38(1-2):41–70. doi:10.1016/j.ocemod.2011.01.010.
- Shepherd, A., Ivins, E. R., A, G., Barletta, V. R., Bentley, M. J., Bettadpur, S., Briggs, K. H., Bromwich, D. H., Forsberg, R., Galin, N., Horwath, M., Jacobs, S., Joughin, I., King, M. A., Lenaerts, J. T. M., Li, J., Ligtenberg, S. R. M., Luckman, A., Luthcke, S. B., McMillan, M., Meister, R., Milne, G., Mouginot, J., Muir, A., Nicolas, J. P., Paden, J., Payne, A. J., Pritchard, H., Rignot, E., Rott, H., Sorensen, L. S., Scambos, T. A., Scheuchl, B., Schrama, E. J. O., Smith, B., Sundal, A. V., van Angelen, J. H., van de Berg, W. J., van den Broeke, M. R., Vaughan, D. G., Velicogna, I., Wahr, J., Whitehouse, P. L., Wingham, D. J., Yi, D., Young, D., and Zwally, H. J. (2012). A Reconciled Estimate of Ice-Sheet Mass Balance. *Science*, 338(6111):1183–1189. doi:10.1126/science.1228102.
- Siegenthaler, U. and Wenk, T. (1984). Rapid atmospheric CO₂ variations and ocean circulation. *Nature*, 308(5960):624–626. doi:10.1038/308624a0.
- Sigman, D. M. and Boyle, E. A. (2000). Glacial/interglacial variations in atmospheric carbon dioxide. *Nature*, 407(6806):859–869. doi:10.1038/35038000.
- Sigman, D. M., Hain, M. P., and Haug, G. H. (2010). The polar ocean and glacial cycles in atmospheric CO₂ concentration. *Nature*, 466(7302):47–55. doi:10.1038/nature09149.

- Sigman, D. M., Jaccard, S. L., and Haug, G. H. (2004). Polar ocean stratification in a cold climate. *Nature*, 428(6978):59–63. doi:10.1038/nature02378.1.
- Sigmond, M. and Fyfe, J. C. (2014). The Antarctic Sea Ice Response to the Ozone Hole in Climate Models. *Journal of Climate*, 27(3):1336–1342. doi:10.1175/JCLI-D-13-00590.1.
- Sigmond, M., Reader, M. C., Fyfe, J. C., and Gillett, N. P. (2011). Drivers of past and future Southern Ocean change: Stratospheric ozone versus greenhouse gas impacts. *Geophysical Research Letters*, 38(12):L12601. doi:10.1029/2011GL047120.
- Silva, T. A. M., Bigg, G. R., and Nicholls, K. W. (2006). Contribution of giant icebergs to the Southern Ocean freshwater flux. *Journal of Geophysical Research: Oceans*, 111(3):C03004. doi:10.1029/2004JC002843.
- Simpkins, G. R., Ciasto, L. M., Thompson, D. W. J., and England, M. H. (2012). Seasonal relationships between large-scale climate variability and antarctic sea ice concentration. *Journal of Climate*, 25(16):5451–5469. doi:10.1175/JCLI-D-11-00367.1.
- Simpkins, G. R., McGregor, S., Taschetto, A. S., Ciasto, L. M., and England, M. H. (2014). Tropical Connections to Climatic Change in the Extratropical Southern Hemisphere: The Role of Atlantic SST Trends. *Journal of Climate*, 27(13):4923–4936. doi:10.1175/JCLI-D-13-00615.1.
- Skinner, L. C., Fallon, S., Waelbroeck, C., Michel, E., and Barker, S. (2010). Ventilation of the deep Southern Ocean and deglacial CO₂ rise. *Science*, 328(5982):1147–1151. doi:10.1126/science.1183627.
- Sloyan, B. M. and Rintoul, S. R. (2001a). Circulation, renewal, and modification of Antarctic Mode and Intermediate Water. *Journal of Physical Oceanography*, 31(4):1005–1030. doi:10.1175/1520-0485(2001)031<1005:CRAMOA>2.0.CO;2.
- Sloyan, B. M. and Rintoul, S. R. (2001b). The Southern Ocean Limb of the Global Deep Overturning Circulation. *Journal of Physical Oceanography*, 31(1):143–173. doi:10.1175/1520-0485(2001)031<0143:TSOLOT>2.0.CO;2.
- Smith, K. L. and Polvani, L. M. (2016). Spatial patterns of recent Antarctic surface temperature trends and the importance of natural variability: lessons from multiple reconstructions and the CMIP5 models. *Climate Dynamics*, 48(7-8):2653–2670. doi:10.1007/s00382-016-3230-4.
- Smith, R. D. and Gent, P. R. (2004). Anisotropic Gent-McWilliams parameterization for ocean models. *Journal of Physical Oceanography*, 34(11):2541–2564. doi:10.1175/JPO2613.1.
- Snow, K., Hogg, A. M., Downes, S. M., Sloyan, B. M., Bates, M. L., and Griffies, S. M. (2015). Sensitivity of abyssal water masses to overflow parameterisations. *Ocean Modelling*, 89:84–103. doi:10.1016/j.ocemod.2015.03.004.
- Snow, K., Sloyan, B. M., Rintoul, S. R., Hogg, A. M., and Downes, S. M. (2016). Controls on circulation, cross-shelf exchange, and dense water formation in an Antarctic polynya. *Geophysical Research Letters*, 43(13):7089–7096. doi:10.1002/2016GL069479.
- Sokolov, S. and Rintoul, S. R. (2009a). Circumpolar structure and distribution of the Antarctic Circumpolar Current fronts: 1. Mean circumpolar paths. *Journal of Geophysical Research*, 114(11):C11018. doi:10.1029/2008JC005108.

- Sokolov, S. and Rintoul, S. R. (2009b). Circumpolar structure and distribution of the Antarctic Circumpolar Current fronts: 2. Variability and relationship to sea surface height. *Journal of Geophysical Research*, 114(11):C11019. doi:10.1029/2008JC005248.
- Son, S.-W., Gerber, E. P., Perlwitz, J., Polvani, L. M., Gillett, N. P., Seo, K.-H., Eyring, V., Shepherd, T. G., Waugh, D., Akiyoshi, H., Austin, J., Baumgaertner, A., Bekki, S., Braesicke, P., Brühl, C., Butchart, N., Chipperfield, M. P., Cugnet, D., Dameris, M., Dhomse, S., Frith, S., Garny, H., Garcia, R., Hardiman, S. C., Jöckel, P., Lamarque, J. F., Mancini, E., Marchand, M., Michou, M., Nakamura, T., Morgenstern, O., Pitari, G., Plummer, D. A., Pyle, J., Rozanov, E., Scinocca, J. F., Shibata, K., Smale, D., Teyssède, H., Tian, W., and Yamashita, Y. (2010). Impact of stratospheric ozone on Southern Hemisphere circulation change: A multimodel assessment. *Journal of Geophysical Research*, 115(D3):D00M07. doi:10.1029/2010JD014271.
- Son, S.-W., Polvani, L. M., Waugh, D. W., Akiyoshi, H., Garcia, R., Kinnison, D., Pawson, S., Rozanov, E., Shepherd, T. G., and Shibata, K. (2008). The impact of stratospheric ozone recovery on the Southern Hemisphere westerly jet. *Science*, 320(5882):1486–1489. doi:10.1126/science.1155939.
- Song, Y. and Haidvogel, D. (1994). A Semi-implicit Ocean Circulation Model Using a Generalized Topography-Following Coordinate System. *Journal of Computational Physics*, 115(1):228–244. doi:10.1006/jcph.1994.1189.
- Speer, K., Lovenduski, N., England, M., Thompson, D. J., and Beswick, C. (2012). Developing a vision for climate variability research in the Southern Ocean-Ice-Atmosphere system, In *CLIVAR Exchanges*, 17(58), pages 43–45.
- Speer, K., Rintoul, S. R., and Sloyan, B. (2000). The Diabatic Deacon Cell. *Journal of Physical Oceanography*, 30(12):3212–3222. doi:10.1175/1520-0485(2000)030<3212:TDDC>2.0.CO;2.
- Spence, P., Griffies, S. M., England, M. H., Hogg, A. M., Saenko, O. A., and Jourdain, N. C. (2014). Rapid subsurface warming and circulation changes of Antarctic coastal waters by poleward shifting winds. *Geophysical Research Letters*, 41(13):4601–4610. doi:10.1002/2014GL060613.
- Stammer, D., Ueyoshi, K., Köhl, A., Large, W. G., Josey, S. A., and Wunsch, C. (2004). Estimating air-sea fluxes of heat, freshwater, and momentum through global ocean data assimilation. *Journal of Geophysical Research*, 109(C5):C05023. doi:10.1029/2003JC002082.
- Stammer, D., Wunsch, C., Giering, R., Eckert, C., Heimbach, P., Marotzke, J., Adcroft, A., Hill, C. N., and Marshall, J. (2003). Volume, heat, and freshwater transports of the global ocean circulation 1993-2000, estimated from a general circulation model constrained by World Ocean Circulation Experiment (WOCE) data. *Journal of Geophysical Research*, 108(C1):3007. doi:10.1029/2001JC001115.
- Stammerjohn, S., Massom, R., Rind, D., and Martinson, D. (2012). Regions of rapid sea ice change: An inter-hemispheric seasonal comparison. *Geophysical Research Letters*, 39(6):L06501. doi:10.1029/2012GL050874.
- Stammerjohn, S. E., Martinson, D. G., Smith, R. C., Yuan, X., and Rind, D. (2008). Trends in Antarctic annual sea ice retreat and advance and their relation to El Niño-Southern Oscillation and Southern Annular Mode variability. *Journal of Geophysical Research*, 113:C03S90. doi:10.1029/2007JC004269.

- Steele, M., Mellor, G. L., and McPhee, M. G. (1989). Role of the Molecular Sublayer in the Melting or Freezing of Sea Ice. *Journal of Physical Oceanography*, 19(1):139–147. doi:10.1175/1520-0485(1989)019<0139:ROTMSI>2.0.CO;2.
- Stevens, B., Giorgetta, M., Esch, M., Mauritsen, T., Crueger, T., Rast, S., Salzmann, M., Schmidt, H., Bader, J., Block, K., Brokopf, R., Fast, I., Kinne, S., Kornblueh, L., Lohmann, U., Pincus, R., Reichler, T., and Roeckner, E. (2013). Atmospheric component of the MPI-M Earth System Model: ECHAM6. *Journal of Advances in Modeling Earth Systems*, 5(2):146–172. doi:10.1002/jame.20015.
- Stewart, A. L. and Thompson, A. F. (2013). Connecting Antarctic Cross-Slope Exchange with Southern Ocean Overturning. *Journal of Physical Oceanography*, 43(7):1453–1471. doi:10.1175/JPO-D-12-0205.1.
- Stewart, K. D., Haine, T. W. N., Stewart, K. D., and Haine, T. W. N. (2016). Thermobaricity in the Transition Zones between Alpha and Beta Oceans. *Journal of Physical Oceanography*, 46(6):1805–1821. doi:10.1175/JPO-D-16-0017.1.
- Stocker, B. D., Roth, R., Joos, F., Spahni, R., Steinacher, M., Zaehle, S., Bouwman, L., Xu-Ri, and Prentice, I. C. (2013). Multiple greenhouse-gas feedbacks from the land biosphere under future climate change scenarios. *Nature Climate Change*, 3(7):666–672. doi:10.1038/nclimate1864.
- Stocker, T. F. (2015). The silent services of the world ocean. *Science*, 350(6262):764–766. doi:10.1126/science.aac8720.
- Stocker, T. F. and Schmittner, A. (1997). Influence of CO₂ emission rates on the stability of the thermohaline circulation. *Nature*, 388(6645):862–865. doi:10.1038/42224.
- Stössel, A., Notz, D., Haumann, F. A., Haak, H., Jungclaus, J., and Mikolajewicz, U. (2015). Controlling high-latitude Southern Ocean convection in climate models. *Ocean Modelling*, 86:58–75. doi:10.1016/j.ocemod.2014.11.008.
- Stössel, A., Yang, K., and Kim, S.-J. (2002). On the Role of Sea Ice and Convection in a Global Ocean Model. *Journal of Physical Oceanography*, 32(4):1194–1208. doi:10.1175/1520-0485(2002)032<1194:OTROSI>2.0.CO;2.
- Stössel, A., Zhang, Z., and Vihma, T. (2011). The effect of alternative real-time wind forcing on Southern Ocean sea ice simulations. *Journal of Geophysical Research: Oceans*, 116(11):C11021. doi:10.1029/2011JC007328.
- Stull, R. B. (1988). *An Introduction to Boundary Layer Meteorology*, volume 13 of *Atmospheric Sciences Library*. Kluwer Academic Publishers, Dordrecht, Boston, London. doi:10.1007/978-94-009-3027-8.
- Suess, E. (1980). Particulate organic carbon flux in the oceans surface productivity and oxygen utilization. *Nature*, 288(5788):260–263. doi:10.1038/288260a0.
- Sumata, H., Lavergne, T., Girard-Arduin, F., Kimura, N., Tschudi, M. A., Kauker, F., Karcher, M., and Gerdes, R. (2014). An intercomparison of Arctic ice drift products to deduce uncertainty estimates. *Journal of Geophysical Research: Oceans*, 119(8):4887–4921. doi:10.1002/2013JC009724.

- Sun, S., Eisenman, I., and Stewart, A. L. (2016). The influence of Southern Ocean surface buoyancy forcing on glacial-interglacial changes in the global deep ocean stratification. *Geophysical Research Letters*, 43(15):8124–8132. doi:10.1002/2016GL070058.
- Sutterley, T. C., Velicogna, I., Rignot, E., Mouginot, J., Flament, T., van den Broeke, M. R., van Wessem, J. M., and Reijmer, C. H. (2014). Mass loss of the Amundsen Sea Embayment of West Antarctica from four independent techniques. *Geophysical Research Letters*, 41(23):8421–8428. doi:10.1002/2014GL061940.
- Sverdrup, H. U. (1933). On vertical circulation in the ocean due to the action of the wind with application to conditions within the Antarctic Circumpolar Current, In *Discovery reports*, pages 139–170. Cambridge University Press.
- Swart, N. C. and Fyfe, J. C. (2012). Observed and simulated changes in the Southern Hemisphere surface westerly wind-stress. *Geophysical Research Letters*, 39(16):L16711. doi:10.1029/2012GL052810.
- Tagliabue, A. and Arrigo, K. R. (2016). Decadal trends in air-sea CO₂ exchange in the Ross Sea (Antarctica). *Geophysical Research Letters*, 43(10):5271–5278. doi:10.1002/2016GL069071.
- Takahashi, T., Sutherland, S. C., Sweeney, C., Poisson, A., Metzl, N., Tilbrook, B., Bates, N., Wanninkhof, R., Feely, R. A., Sabine, C., Olafsson, J., and Nojiri, Y. (2002). Global sea-air CO₂ flux based on climatological surface ocean pCO₂, and seasonal biological and temperature effects. *Deep Sea Research Part II: Topical Studies in Oceanography*, 49(9):1601–1622. doi:10.1016/S0967-0645(02)00003-6.
- Takahashi, T., Sutherland, S. C., Wanninkhof, R., Sweeney, C., Feely, R. A., Chipman, D. W., Hales, B., Friederich, G., Chavez, F., Sabine, C., Watson, A., Bakker, D. C. E., Schuster, U., Metzl, N., Yoshikawa-Inoue, H., Ishii, M., Midorikawa, T., Nojiri, Y., Körtzinger, A., Steinhoff, T., Hoppema, M., Olafsson, J., Arnarson, T. S., Tilbrook, B., Johannessen, T., Olsen, A., Bellerby, R., Wong, C. S., Delille, B., Bates, N. R., and de Baar, H. J. W. (2009). Climatological mean and decadal change in surface ocean pCO₂, and net sea-air CO₂ flux over the global oceans. *Deep Sea Research Part II: Topical Studies in Oceanography*, 56(8-10):554–577. doi:10.1016/j.dsr2.2008.12.009.
- Talley, L. D. (1996). Antarctic Intermediate Water in the South Atlantic. In Wefer, G., Berger, W., Siedler, G., and Webb, D., editors, *The South Atlantic: present and past circulation*, pages 219–238. Springer, Berlin, Heidelberg. doi:10.1007/978-3-642-80353-6_11.
- Talley, L. D. (2003). Shallow, Intermediate, and Deep Overturning Components of the Global Heat Budget. *Journal of Physical Oceanography*, 33(3):530–560. doi:10.1175/1520-0485(2003)033<0530:SIADOC>2.0.CO;2.
- Talley, L. D. (2008). Freshwater transport estimates and the global overturning circulation: Shallow, deep and throughflow components. *Progress in Oceanography*, 78(4):257–303. doi:10.1016/j.pocean.2008.05.001.
- Talley, L. D. (2013). Closure of the global overturning circulation through the Indian, Pacific, and Southern Oceans: Schematics and transports. *Oceanography*, 26(1):80–97. doi:10.5670/oceanog.2013.07.
- Tamura, T., Ohshima, K. I., and Nihashi, S. (2008). Mapping of sea ice production for Antarctic coastal polynyas. *Geophysical Research Letters*, 35(7):L07606. doi:10.1029/2007GL032903.

- Tamura, T., Ohshima, K. I., Nihashi, S., and Hasumi, H. (2011). Estimation of surface heat/salt fluxes associated with sea ice growth/melt in the Southern Ocean. *SOLA*, 7:17–20. doi:10.2151/sola.2011-005.
- Thomas, E. R. and Abram, N. J. (2016). Ice core reconstruction of sea ice change in the Amundsen-Ross Seas since 1702 A.D. *Geophysical Research Letters*, 43(10):5309–5317. doi:10.1002/2016GL068130.
- Thompson, A. F., Heywood, K. J., Schmidtko, S., and Stewart, A. L. (2014). Eddy transport as a key component of the Antarctic overturning circulation. *Nature Geoscience*, 7(12):879–884. doi:10.1038/ngeo2289.
- Thompson, D. W. J., Solomon, S., Kushner, P. J., England, M. H., Grise, K. M., and Karoly, D. J. (2011). Signatures of the Antarctic ozone hole in Southern Hemisphere surface climate change. *Nature Geoscience*, 4(11):741–749. doi:10.1038/ngeo1296.
- Thorndike, A. S. and Colony, R. (1982). Sea ice motion in response to geostrophic winds. *Journal of Geophysical Research*, 87(C8):5845–5852. doi:10.1029/JC087iC08p05845.
- Tietäväinen, H. and Vihma, T. (2008). Atmospheric moisture budget over Antarctica and the Southern Ocean based on the ERA-40 reanalysis. *International Journal of Climatology*, 28(15):1977–1995. doi:10.1002/joc.1684.
- Timco, G. W. and Frederking, R. M. W. (1996). A review of sea ice density. *Cold Regions Science and Technology*, 24(1):1–6. doi:10.1016/0165-232X(95)00007-X.
- Timmermann, R. and Beckmann, A. (2004). Parameterization of vertical mixing in the Weddell Sea. *Ocean Modelling*, 6(1):83–100. doi:10.1016/S1463-5003(02)00061-6.
- Timmermann, R., Beckmann, A., and Hellmer, H. H. (2001). The role of sea ice in the fresh-water budget of the Weddell Sea, Antarctica. *Annals of Glaciology*, 33(1):419–424. doi:10.3189/172756401781818121.
- Timmermann, R., Beckmann, A., and Hellmer, H. H. (2002). Simulations of ice-ocean dynamics in the Weddell Sea 1. Model configuration and validation. *Journal of Geophysical Research*, 107(C3):3024. doi:10.1029/2000JC000741.
- Timmermann, R. and Hellmer, H. H. (2013). Southern Ocean warming and increased ice shelf basal melting in the twenty-first and twenty-second centuries based on coupled ice-ocean finite-element modelling. *Ocean Dynamics*, 63(9-10):1011–1026. doi:10.1007/s10236-013-0642-0.
- Timmermann, R., Le Brocq, A., Deen, T., Domack, E., Dutrieux, P., Galton-Fenzi, B., Hellmer, H., Humbert, A., Jansen, D., Jenkins, A., Lambrecht, A., Makinson, K., Niederjasper, F., Nitsche, F., Nøst, O. A., Smedsrud, L. H., and Smith, W. H. F. (2010). A consistent data set of Antarctic ice sheet topography, cavity geometry, and global bathymetry. *Earth System Science Data*, 2(2):261–273. doi:10.5194/essd-2-261-2010.
- Timmermann, R., Wang, Q., and Hellmer, H. H. (2012). Ice-shelf basal melting in a global finite-element sea-ice/ice-shelf/ocean model. *Annals of Glaciology*, 53(60):303–314. doi:10.3189/2012AoG60A156.
- Toggweiler, J. and Samuels, B. (1995). Effect of drake passage on the global thermohaline circulation. *Deep Sea Research Part I: Oceanographic Research Papers*, 42(4):477–500. doi:10.1016/0967-0637(95)00012-U.

- Toggweiler, J. R. (1999). Variation of atmospheric CO₂ by ventilation of the ocean's deepest water. *Paleoceanography*, 14(5):571. doi:10.1029/1999PA900033.
- Toggweiler, J. R. and Russell, J. (2008). Ocean circulation in a warming climate. *Nature*, 451(7176):286–288. doi:10.1038/nature06590.
- Toggweiler, J. R., Russell, J. L., and Carson, S. R. (2006). Midlatitude westerlies, atmospheric CO₂, and climate change during the ice ages. *Paleoceanography*, 21(2):PA2005. doi:10.1029/2005PA001154.
- Toggweiler, J. R. and Samuels, B. (1993). Is the Magnitude of the Deep Outflow from the Atlantic Ocean Actually Governed by Southern Hemisphere Winds? In *The Global Carbon Cycle*, pages 303–331. Springer Berlin Heidelberg, Berlin, Heidelberg. doi:10.1007/978-3-642-84608-3_13.
- Tournadre, J., Bouhier, N., Girard-Ardhuin, F., and Rémy, F. (2016). Antarctic icebergs distributions 1992-2014. *Journal of Geophysical Research: Oceans*, 121:327–349. doi:10.1002/2015JC011178.
- Treguier, A. M., Le Sommer, J., Molines, J. M., and de Cuevas, B. (2010). Response of the Southern Ocean to the Southern Annular Mode: Interannual Variability and Multidecadal Trend. *Journal of Physical Oceanography*, 40(7):1659–1668. doi:10.1175/2010JPO4364.1.
- Trenberth, K. E., Caron, J. M., Trenberth, K. E., and Caron, J. M. (2001). Estimates of Meridional Atmosphere and Ocean Heat Transports. *Journal of Climate*, 14(16):3433–3443. doi:10.1175/1520-0442(2001)014<3433:EOMAAO>2.0.CO;2.
- Trenberth, K. E., Fasullo, J. T., and Mackaro, J. (2011). Atmospheric moisture transports from ocean to land and global energy flows in reanalyses. *Journal of Climate*, 24(18):4907–4924. doi:10.1175/2011JCLI4171.1.
- Turi, G., Lachkar, Z., and Gruber, N. (2014). Spatiotemporal variability and drivers of pCO₂ and air-sea CO₂ fluxes in the California Current System: An eddy-resolving modeling study. *Biogeosciences*, 11(3):671–690. doi:10.5194/bg-11-671-2014.
- Turi, G., Lachkar, Z., Gruber, N., and Münnich, M. (2016). Climatic modulation of recent trends in ocean acidification in the California Current System. *Environmental Research Letters*, 11(1):014007. doi:10.1088/1748-9326/11/1/014007.
- Turner, J., Bracegirdle, T. J., Phillips, T., Marshall, G. J., Hosking, J. S., and Scott Hosking, J. (2013). An Initial Assessment of Antarctic Sea Ice Extent in the CMIP5 Models. *Journal of Climate*, 26(5):1473–1484. doi:10.1175/JCLI-D-12-00068.1.
- Turner, J., Comiso, J. C., Marshall, G. J., Lachlan-Cope, T. A., Bracegirdle, T., Maksym, T., Meredith, M. P., Wang, Z., and Orr, A. (2009). Non-annular atmospheric circulation change induced by stratospheric ozone depletion and its role in the recent increase of Antarctic sea ice extent. *Geophysical Research Letters*, 36(8):L08502. doi:10.1029/2009GL037524.
- Turner, J., Lu, H., White, I., King, J. C., Phillips, T., Hosking, J. S., Bracegirdle, T. J., Marshall, G. J., Mulvaney, R., and Deb, P. (2016). Absence of 21st century warming on Antarctic Peninsula consistent with natural variability. *Nature*, 535(7612):411–415. doi:10.1038/nature18645.
- Turner, J. S. (1973). *Buoyancy Effects in Fluids*. Cambridge University Press, Cambridge. doi:10.1017/CBO9780511608827.

- Uotila, P., Holland, P. R., Vihma, T., Marsland, S. J., and Kimura, N. (2014). Is realistic Antarctic sea-ice extent in climate models the result of excessive ice drift? *Ocean Modelling*, 79:33–42. doi:10.1016/j.ocemod.2014.04.004.
- Urakawa, L. S. and Hasumi, H. (2012). Eddy-Resolving Model Estimate of the Cabbeling Effect on the Water Mass Transformation in the Southern Ocean. *Journal of Physical Oceanography*, 42(8):1288–1302. doi:10.1175/JPO-D-11-0173.1.
- van Loon, H. and Jenne, R. L. (1972). The zonal harmonic standing waves in the southern hemisphere. *Journal of Geophysical Research*, 77(6):992–1003. doi:10.1029/JC077i006p00992.
- Vancoppenolle, M., Fichefet, T., and Goosse, H. (2009). Simulating the mass balance and salinity of Arctic and Antarctic sea ice. 2. Importance of sea ice salinity variations. *Ocean Modelling*, 27(1-2):54–69. doi:10.1016/j.ocemod.2008.11.003.
- Viglione, G. A. and Thompson, A. F. (2016). Lagrangian pathways of upwelling in the Southern Ocean. *Journal of Geophysical Research*. doi:10.1002/2016JC011773.
- Wang, S. and Moore, J. K. (2012). Variability of primary production and air–sea CO₂ flux in the Southern Ocean. *Global Biogeochemical Cycles*, 26(1):GB1008. doi:10.1029/2010GB003981.
- Wanninkhof, R. and McGillis, W. R. (1999). A cubic relationship between air-sea CO₂ exchange and wind speed. *Geophysical Research Letters*, 26(13):1889–1892. doi:10.1029/1999GL900363.
- Watson, A. J., Ledwell, J. R., Messias, M.-J., King, B. a., Mackay, N., Meredith, M. P., Mills, B., and Naveira Garabato, A. C. (2013). Rapid cross-density ocean mixing at mid-depths in the Drake Passage measured by tracer release. *Nature*, 501(7467):408–411. doi:10.1038/nature12432.
- Watson, A. J. and Naveira Garabato, A. C. (2006). The role of Southern Ocean mixing and upwelling in glacial-interglacial atmospheric CO₂ change. *Tellus, Series B: Chemical and Physical Meteorology*, 58(1):73–87. doi:10.1111/j.1600-0889.2005.00167.x.
- Watson, A. J., Vallis, G. K., and Nikurashin, M. (2015). Southern Ocean buoyancy forcing of ocean ventilation and glacial atmospheric CO₂. *Nature Geoscience*, 8(11):861–864. doi:10.1038/ngeo2538.
- Waugh, D. W. (2014). Changes in the ventilation of the southern oceans. *Philosophical transactions. Series A*, 372(2019):20130269. doi:10.1098/rsta.2013.0269.
- Waugh, D. W., Primeau, F., DeVries, T., and Holzer, M. (2013). Recent Changes in the Ventilation of the Southern Oceans. *Science*, 339(6119):568–570. doi:10.1126/science.1225411.
- Weaver, A. J., Sarachik, E. S., and Marotze, J. (1991). Freshwater flux forcing of decadal and interdecadal oceanic variability. *Nature*, 353(6347):836–838. doi:10.1038/353836a0.
- Wentz, F. J. (1991). User's manual: SSM/I antenna temperature tapes (revision 1), report number 120191. Technical report, Remote Sensing Systems, Santa Rosa, CA, USA.
- Wijffels, S. (2001). Freshwater Transport and Climate. In Steele, J. H., editor, *Encyclopedia of Ocean Sciences*, pages 1104–1111. Academic Press, Oxford. doi:10.1006/rwos.2001.0265.

- Willebrand, J., Barnier, B., Böning, C., Dieterich, C., Killworth, P. D., Le Provost, C., Jia, Y., Molines, J. M., and New, A. L. (2001). Circulation characteristics in three eddy-permitting models of the North Atlantic. *Progress in Oceanography*, 48(2-3):123–161. doi:10.1016/S0079-6611(01)00003-9.
- Williams, G., Maksym, T., Wilkinson, J., Kunz, C., Murphy, C., Kimball, P., and Singh, H. (2015). Thick and deformed Antarctic sea ice mapped with autonomous underwater vehicles. *Nature Geoscience*, 8(1):61–67. doi:10.1038/ngeo2299.
- Williams, G. D., Aoki, S., Jacobs, S. S., Rintoul, S. R., Tamura, T., and Bindoff, N. L. (2010). Antarctic Bottom Water from the Adélie and George V Land coast, East Antarctica (140–149°E). *Journal of Geophysical Research*, 115(C4):C04027. doi:10.1029/2009JC005812.
- Williams, G. D., Herraiz-Borreguero, L., Roquet, F., Tamura, T., Ohshima, K. I., Fukamachi, Y., Fraser, A. D., Gao, L., Chen, H., McMahon, C. R., Harcourt, R., and Hindell, M. (2016). The suppression of Antarctic bottom water formation by melting ice shelves in Prydz Bay. *Nature Communications*, 7:12577. doi:10.1038/ncomms12577.
- Wolff, E. W., Fischer, H., Fundel, F., Ruth, U., Twarloh, B., and Littot, G. C. (2006). Southern Ocean sea-ice extent, productivity and iron flux over the past eight glacial cycles. *Nature*, 449(October):6271. doi:10.1038/nature06271.
- Wong, A. P. S., Bindoff, N. L., and Church, J. A. (1999). Large-scale freshening of intermediate waters in the Pacific and Indian oceans. *Nature*, 400(6743):440–443. doi:10.1038/22733.
- Worby, A. P., Geiger, C. A., Paget, M. J., van Woert, M. L., Ackley, S. F., and DeLiberty, T. L. (2008). Thickness distribution of Antarctic sea ice. *Journal of Geophysical Research*, 113(C5):C05S92. doi:10.1029/2007JC004254.
- Wunsch, C. and Ferrari, R. (2004). Vertical mixing, energy, and the general circulation of the oceans. *Annual Review of Fluid Mechanics*, 36(1):281–314. doi:10.1146/annurev.fluid.36.050802.122121.
- Wunsch, C. and Stammer, D. (1998). Satellite altimetry, the marine geoid, and the oceanic general circulation. *Annual Review of Earth and Planetary Sciences*, 26(1):219–253. doi:10.1146/annurev.earth.26.1.219.
- Xiao, W., Esper, O., and Gersonde, R. (2016). Last Glacial - Holocene climate variability in the Atlantic sector of the Southern Ocean. *Quaternary Science Reviews*, 135:115–137. doi:10.1016/j.quascirev.2016.01.023.
- Yang, S. and Gruber, N. (2016). The anthropogenic perturbation of the marine nitrogen cycle by atmospheric deposition: Nitrogen cycle feedbacks and the ¹⁵N Haber-Bosch effect. *Global Biogeochemical Cycles*, 30:1418–1440. doi:10.1002/2016GB005421.
- Yang, S., Gruber, N., Long, M. C., and Vogt, M. (2017). ENSO driven variability of denitrification and suboxia in the Eastern Pacific Ocean. *In preparation*.
- Yeo, S.-R. and Kim, K.-Y. (2015). Decadal changes in the Southern Hemisphere sea surface temperature in association with El Niño Southern Oscillation and Southern Annular Mode. *Climate Dynamics*, 45(11-12):3227–3242. doi:10.1007/s00382-015-2535-z.

- Yi, D., Zwally, H. J., and Robbins, J. W. (2011). ICESat observations of seasonal and inter-annual variations of sea-ice freeboard and estimated thickness in the Weddell Sea, Antarctica (2003-2009), In *Annals of Glaciology*, 52(57), pages 43–51. International Glaciological Society. doi:10.3189/172756411795931480.
- Yuan, X. and Martinson, D. G. (2001). The Antarctic dipole and its predictability. *Geophysical Research Letters*, 28(18):3609–3612. doi:10.1029/2001GL012969.
- Yuan, X. and Yonekura, E. (2011). Decadal variability in the Southern Hemisphere. *Journal of Geophysical Research*, 116(D19):D19115. doi:10.1029/2011JD015673.
- Zachos, J., Pagani, M., Sloan, L., Thomas, E., and Billups, K. (2001). Trends, rhythms, and aberrations in global climate 65 Ma to present. *Science*, 292(5517):686–693. doi:10.1126/science.1059412.
- Zeebe, R. E., Ridgwell, A., and Zachos, J. C. (2016). Anthropogenic carbon release rate unprecedented during the past 66 million years. *Nature Geoscience*, 9(4):325–329. doi:10.1038/ngeo2681.
- Zeng, N., Mariotti, A., and Wetzel, P. (2005). Terrestrial mechanisms of interannual CO₂ variability. *Global Biogeochemical Cycles*, 19(1):GB1016. doi:10.1029/2004GB002273.
- Zhai, X., Greatbatch, R. J., and Zhao, J. (2005). Enhanced vertical propagation of storm-induced near-inertial energy in an eddying ocean channel model. *Geophysical Research Letters*, 32(18):L18602. doi:10.1029/2005GL023643.
- Zhang, J. (2007). Increasing Antarctic sea ice under warming atmospheric and oceanic conditions. *Journal of Climate*, 20(11):2515–2529. doi:10.1175/JCLI4136.1.
- Zhang, J. (2014). Modeling the impact of wind intensification on Antarctic sea ice volume. *Journal of Climate*, 27(1):202–214. doi:10.1175/JCLI-D-12-00139.1.
- Zhang, J., Schmitt, R. W., and Huang, R. X. (1998). Sensitivity of the GFDL Modular Ocean Model to Parameterization of Double-Diffusive Processes. *Journal of Physical Oceanography*, 28(4):589–605. doi:10.1175/1520-0485(1998)028<0589:SOTGMO>2.0.CO;2.
- Zhang, Z., Vihma, T., Stössel, A., and Uotila, P. (2015). The role of wind forcing from operational analyses for the model representation of Antarctic coastal sea ice. *Ocean Modelling*, 94:95–111. doi:10.1016/j.ocemod.2015.07.019.
- Zika, J. D., England, M. H., Sijp, W. P., Zika, J. D., England, M. H., and Sijp, W. P. (2012). The Ocean Circulation in Thermohaline Coordinates. *Journal of Physical Oceanography*, 42(5):708–724. doi:10.1175/JPO-D-11-0139.1.
- Zunz, V., Goosse, H., and Massonnet, F. (2013). How does internal variability influence the ability of CMIP5 models to reproduce the recent trend in Southern Ocean sea ice extent? *The Cryosphere*, 7(2):451–468. doi:10.5194/tc-7-451-2013.
- Zwally, H. J., Comiso, J. C., and Gordon, A. L. (1985). Antarctic offshore leads and polynyas and oceanographic effects. In Jacobs, S. S., editor, *Oceanology of the Antarctic Continental Shelf*, pages 203–226. American Geophysical Union, Washington, D. C. doi:10.1029/AR043p0203.
- Zweng, M. M., Reagan, J. R., Antonov, J. I., Locarnini, R. A., Mishonov, A. V., Boyer, T. P., Garcia, H. E., Baranova, O. K., Johnson, D. R., Seidov, D., and Biddle, M. M. (2013). World Ocean Atlas 2013, Volume 2: Salinity, p. 39. NOAA Atlas NESDIS 74.

Acknowledgements

Throughout the process of exploring the Southern Ocean from my desk and writing this dissertation, I realized that among the many ingredients that a Ph. D. project requires, a supportive and inspiring working environment and persistence are probably the most important ones. However, the latter can only be obtained by having people around you that provide you with motivation, skills, and recognition. Therefore, I am hugely grateful to Environmental Physics group at ETH Zürich, my friends and my family for providing me with these ingredients; without receiving their tremendous support I could have never achieved my goals.

I am grateful to Niki for letting me be part of a fantastic and inspirational research environment, for giving me guidance and support when I needed it, and for providing me freedom to pursue my ideas. Thank you for teaching me valuable skills that are not only important for my future research career, but also for life in general. Your openness to a wide field of research and search for unexpected results widened my horizon and at the same time sharpened my own research interests.

Matt, I would like to thank you for being a great adviser, for always keeping your door open for everyone to come in and ask you questions, and for the countless hours of great discussions on modeling, statistics, and oceanography during which I learned a lot. I also thank you for your support, for motivating me, and for cheering me up when things were not working as expected.

Thank you Gerald and Mike for being part of my examination committee, for your support, for reading this thesis, and for providing valuable ideas and thoughts.

I would like to thank C2SM for making this research project possible as part of the *CHIRP2* project, entitled “*Modeling the water cycle in a changing climate - a multiscale interaction challenge*”.

I thank the many people in our research team for great scientific discussions, but also for the fun and support throughout the years. Simon, a special thank you goes to you for being such a great Ph. D. companion and for the countless discussions about science and life. I would like to thank Thomas and Ivy for discussing all the challenges that one faces when doing Southern Ocean research and sharing their thoughts. I am grateful to Peter for a fantastic collaboration and great discussions on Southern Ocean carbon sink. I am thankful to Bianca for all her fantastic support in administrative issues and always taking such great care of us all. I would like to thank David, Giuliana, Martin, Ana, Elisa, Cara, and Damian for their great help in working with ROMS. A special thank you goes to Samuel for his great support in analyzing the model output and identifying issues in the model during his M.Sc. thesis.

Many people outside our research group greatly contributed to this work. I would like to thank Alexander (Sasha) Shchepetkin for sharing his recent model developments with us and helping

us to solve existing issues in the model. I would like to thank Julien Le Sommer, Paul Holland, and Judith Hauck for inviting me to their institutes and for sharing their thoughts and ideas. These visits and discussions have greatly improved my research and helped me to understand my results and resolve issues. I would also like to thank Mike Dinniman for sharing his experience in modeling the Southern Ocean with ROMS. I thank Julienne Stroeve and the National Academies of Science as well as Stefan Kern and the International Space Science Institute for inviting me to two great and inspiring workshops on Antarctic sea ice. I especially thank Stefan for his valuable input regarding uncertainties in observational sea-ice data.

I am thankful to Dirk Notz, Michiel van den Broeke, Jan Lenaerts, Jan van Angelen, Thomas Röckmann, and Anneke Batenburg for providing me with initial skills and ideas that led to the success of this Ph. D. project.

I have had many great scientific discussions throughout this Ph. D. project that helped me to shape my research. I especially would like to thank François Massonnet, Achim Stössel, Daniel Sigman, Jorge Sarmiento, Lynne Talley, Kay Ohshima, Ted Maksym, Clara Deser, Nicole Lovenduski, Marika Holland, David Schneider, Raffaele Bernadello, Ivana Cerovečki, Corinne Le Quéré, Samuel Jaccard, Adam Hasenfratz, Heini Wernli, Lukas Papritz, Nacho Merino, Gildas Main-sant, and Hugues Goosse for discussions, ideas, and asking the right questions.

I am hugely grateful to my family Carmen, Jürgen, Kai, Simon, and Fabian for their loving and caring support, providing me with motivation, and teaching me persistence and curiosity. Thank you for filling my breaks from science with uncountable great times, laughs, and memories.

I am endlessly thankful to Heike for her loving and caring mental and emotional support throughout the years, for giving me confidence, perspective, and for always understanding me and believing in me. Thank you for improving my writing and for cross-reading this thesis. And more importantly, I am grateful to you for being part of this entire journey through my Ph. D. project, for providing me with countless wonderful thoughts, and teaching me how to pursue balance and happiness. Thank you.

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Awards

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Peer-reviewed publications

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Landschützer, P., N. Gruber, **F. A. Haumann**, C. Rödenbeck, D. C. E. Bakker, S. van Heuven, M. Hoppema, N. Metzl, C. Sweeney, T. Takahashi, B. Tilbrook, and R. Wanninkhof (2015): The reinvigoration of the Southern Ocean carbon sink. *Science*, 349 (6253), 1221–1224. doi:10.1126/science.aab2620.

Stössel, A., D. Notz, **F. A. Haumann**, H. Haak, J. Jungclaus, and U. Mikolajewicz (2015): Controlling High-Latitude Southern Ocean Convection in Climate Models. *Ocean Modelling*, 86, 58–75. doi:10.1016/j.ocemod.2014.11.008.

Haumann, F. A., D. Notz, and H. Schmidt (2014): Anthropogenic influence on recent circulation-driven Antarctic sea-ice changes. *Geophysical Research Letters*, 41 (23), 8429–8437. doi:10.1002/2014GL061659.

Haumann, F. A., A. M. Batenburg, G. Pieterse, C. Gerbig, M. C. Krol, and T. Röckmann (2013): Emission ratio and isotopic signatures of molecular hydrogen emissions from tropical biomass burning. *Atmospheric Chemistry and Physics*, 13 (18), 9401–9413. doi:10.5194/acp-13-9401-2013.

Notz, D., **F. A. Haumann**, H. Haak, J. Jungclauss, and J. Marotzke (2013): Arctic sea-ice evolution as modeled by Max Planck Institute for Meteorology's Earth system model. *Journal of Advances in Modeling Earth Systems*, 5 (2), 173–194. doi:10.1002/jame.20016.

Tomassini, L., S. Hagemann, C. Moseley, **A. Haumann**, R. Podzun, and D. Jacob (2011): Extremes and predictability in the European pre-industrial climate of a regional climate model. *Climate Dynamics*, 36 (11), 2371–2397. doi:10.1007/s00382-010-0814-2.

Thesis

Haumann, F. A. (2011): Dynamical Interaction between Atmosphere and Sea Ice in Antarctica. Master's thesis. Utrecht University. Available online: <http://dspace.library.uu.nl/handle/1874/285256>.

Other publications

Haumann, F. A., N. Gruber, M. Münnich, I. Frenger, and S. Kern (2016): Antarctic sea-ice freshwater fluxes associated with freezing, transport, and melting. ETH Zurich. doi:10.16904/8.

Gruber, N., D. Clement, T. Frölicher, **A. Haumann**, and P. Landschützer (2015): The Global Ocean Carbon Sink: Recent Trends and Variability. *Nova Acta Leopoldina*, 121 (408), 85–88.

Conference and workshop presentations

Haumann, F. A., N. Gruber, M. Münnich, S. Eberenz, C. Nissen, and P. Landschützer (2016): Strengthening of the Southern Ocean Carbon Sink through Recent Changes in Freshwater Forcing. 2016 Ocean Sciences Meeting, New Orleans, USA.

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Haumann, F. A., S. Eberenz, M. Münnich, and N. Gruber (2015): Cryospheric influence on recent Southern Ocean stratification changes. 8th IBP PhD Congress, Switzerland.

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Haumann, F. A., D. Notz, and H. Schmidt (2014): Circulation-driven response of Antarctic sea ice to external anthropogenic forcings: Why do models and observations disagree? IGS 2014 Sea-Ice Symposium, C3 Convention Centre, Hobart, Australia.

Haumann, F. A., I. Frenger, M. Münnich, and N. Gruber (2013): Sea ice freshwater fluxes: An underestimated driver of the Southern Ocean water cycle and its recent changes. The Royal Society meeting on New models and observations of the Southern Ocean, its role in global climate and the carbon cycle, Chicheley Hall, Buckinghamshire, United Kingdom.

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Haumann, F. A., M. Münnich, I. Frenger, and N. Gruber (2013): On the role of sea ice for Southern Ocean stratification. EGU General Assembly, Vienna, Austria.

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