

Carl Wunsch - Curriculum Vitae

April 21, 2018

Date of Birth: May 5, 1941 **Place of Birth:** Brooklyn, New York

Education: Massachusetts Institute of Technology S.B. in Mathematics, June 1962. Ph.D. in Geophysics, September 1966 (PhD adviser, Henry Stommel)

Positions Held:

Lecturer in Oceanography, M.I.T., 1966-1967

Assistant Professor of Oceanography, M.I.T., 1967-1970

Associate Professor of Oceanography, M.I.T., 1970-1975

Professor of Physical Oceanography, M.I.T., 1975-1976

Cecil and Ida Green Professor of Physical Oceanography, M.I.T. 1976-2012. Emeritus, 2013+

Head, Department of Earth and Planetary Sciences, M.I.T., 1977-1981

Secretary of the Navy Research Professor, MIT, 1985-1989

Visiting Professor: Harvard University, 1980, and Visitor, 2007-2012; University of Washington, 1980

Senior Visiting Fellow, Department of Applied Mathematics and Theoretical Physics, University of Cambridge 1969, 1974-1975, 1981-1982. Life Member, Clare Hall

Senior Visiting Scientist, Geophysical Fluid Dynamics Laboratory, Princeton University, 1993-94

Visiting Scientist, Groupe de Recherche de Géodesie Spatiale-CNES/CNRS, Toulouse, France, 1994

Distinguished Visiting Scientist, Jet Propulsion Laboratory, 1994-2011

Moore Distinguished Scholar, California Institute of Technology, 2000

Visiting Professor, University College London and Visiting Scientist, Southampton Oceanography Centre, 2001

George Eastman Visiting Professor, Dept. of Atmospheres, Oceans and Planetary Physics, and Fellow, Balliol College, Oxford University, 2011-2012

Visiting Professor of Physical Oceanography and Climate, Harvard University, 2013+

Honors: Sigma Xi; James B. Macelwane Award, American Geophysical Union, 1971; Fellow, American Geophysical Union, 1971; Founders' Prize, Texas Instruments Foundation, 1975; Member, National Academy of Sciences, 1978; Fellow, American Academy of Arts and Sciences, 1979; Fulbright Scholar, 1981-1982; John Simon Guggenheim Foundation Fellow, 1981-82; A. G. Huntsman Prize, Bedford Institute of Oceanography and Government of Nova Scotia, 1988; Maurice Ewing Medal, American Geophysical Union and U.S. Navy, 1990; Fellow, American Meteorological Society, 1991; Public Service Medal, National Aeronautics and Space Administration, 1993; Henry Stommel Research Prize, American Meteorological Society, 2000; Foreign Member, Royal Society of London, 2002; Member, American Philosophical Society, 2003; Fellow, American Association for the Advancement of Science, 2004; Bowie Medal, American Geophysical Union, 2006; Prince Albert 1^{er} Medal, 2007; Honorary Fellow, Royal Meteorological Society, 2012; Walter Munk Medal, The Oceanography Society and US Navy, 2015.

Professional Groups: American Geophysical Union; American Meteorological Society; The Oceanography Society; Society for Industrial and Applied Mathematics; European Geosciences Union; Royal Meteorological Society.

Selected, Past Miscellaneous Outside Service: Space Science Board - NRC/National Academy of Sciences (NAS). Committee on Earth Sciences -NRC/NAS. Chairman, Ocean Studies Board - NRC/NAS. Chairman, Science Working Group for Altimetry (TOPEX) - NASA. Member, Editorial Board, The MIT Press. Member, JASON. Co-editor, Monographs on Applied Mechanics and Applied Mathematics, Cambridge Un. Press. Chairman and Co-chairman, International Steering Group for World Ocean Circulation Experiment (WOCE), and Co-chairman, US Steering Committee for WOCE; Report Review Committee, NAS/NRC.

Author or co-author of about 300 scientific papers and five books

PhD Students, Completed Degrees:

- Christopher Welch, *On the calculation of windstress curl over open ocean areas from synoptic meteorological data with application to time dependent ocean circulation*, 1969 (co-supervised with N. Fofonoff).
- David Cacchione, *Experimental study of internal gravity waves over a slope*, 1970 (co-supervised with J. Southard).
- Nelson Hogg, *The influence of topography on steady currents and internal waves*, 1971.
- Ross Hendry, *The generation, energetics and propagation of internal tides in the western North Atlantic Ocean*, 1975.
- James Richman, *Kinematics and energetics of the mesoscale mid-ocean circulation: MODE*, 1976.
- Charles Eriksen, *Measurements and models of fine-structure, internal gravity waves and wave breaking in the deep ocean*, 1976.
- Dean Roemmich, *The application of inverse methods to problems in ocean circulation*, 1979.
- Lee-lueng Fu, *Observations and models of inertial waves in the deep ocean*, 1980.
- Douglas Luther, *Observations of long period waves in the tropical oceans and atmosphere*, 1980.
- Bruce Cornuelle, *Inverse methods and results from the 1981 ocean acoustic tomography experiment*, 1983.
- Victor Zlotnicki, *The oceanographic and geoidal components of seafloor topography*, 1983.
- Eli Tziperman, *Mixing and general circulation dynamics: theory and observations*, 1987.
- Steven Rintoul, *The transport of mass, heat and nutrients in the Atlantic Ocean determined by inverse methods*, 1988.
- Ichiro Fukumori, *Efficient representation of the hydrographic structure of the North Atlantic Ocean and aspects of the circulation from objective methods*, 1989.
- Pascal Legrand, *What do paleo-geochemical tracers tell us about the deep ocean circulation during the last ice age?*, 1994.
- Alison M. Macdonald, *Oceanic fluxes of mass, heat and freshwater: a global estimate and perspective*, 1995.
- Michael Chechelnitsky, *Adaptive error estimation in linearized ocean general circulation models*, 1999.
- Alexandre Ganachaud, *Large Scale Ocean Circulation and Fluxes of Freshwater, Heat, Nutrients and Oxygen*, 1999.
- Xiaoyun Zang, *Spectral Description of Low Frequency Oceanic Variability*, 2000.
- Xingwen Li, *Constraining the North Atlantic Circulation with Transient Tracer Observations*, 2002.
- Geoffrey Gebbie, *An Eddy-Resolving State Estimate of the Subduction Experiment*, 2004.
- Peter Huybers, *The Origins of Ice Ages: Insolation Forcing, Age Models, and Nonlinear Climate Change*, 2004.
- Matthew Mazloff, *The Southern Ocean Meridional Overturning Circulation as Diagnosed from an Eddy Permitting State Estimate*, 2008.
- Ian Fenty, *State Estimation of the Labrador Sea with a Coupled Sea Ice-Ocean Adjoint Model*, 2010.
- Holly Dail, *Atlantic Ocean Circulation at the Last Glacial Maximum: Inferences from Data and Models*, 2012.

Cimarron Wortham IV, *A Multi-Dimensional Spectral Description of Oceanic Variability with Applications*, 2012.

Ru Chen, *Energy Pathways and Structures of Oceanic Eddies from the ECCO2 State Estimate and Simplified Models*, 2012 (with Glenn Flierl).

Alex Kalmikov, *Uncertainty Quantification in Ocean State Estimation*, 2012 (with Patrick Heimbach).

Daniel Amrhein, *Inferring Ocean Circulation during the Last Glacial Maximum and Last Deglaciation Using Data and Models*, 2016.

Masters Students, Completed Degrees: Stephen Miller, Ronald Regal, Stephen Riser, William Dewar, Fran Hotchkiss, Rui Ponte, Joyce Federiuk, Kris Holderied, Jeffrey Campbell, Xiaoming Zhang, Alison MacDonald, Xiaoyun Zang, Guienaelle Jeunhomme, Sarah Samuel, Peter Huybers, Zan Stine, Matt Mazloff, Elise Olson, Shaoyu Yuan, Antoine Cogeze (Paris), Charlotte Siberlin, Daniel Amrhein

Post-Docs: Richard Scarlet, Fred Newman, Peter Baines, Jack Calman, Lee Gordon, D. Edmund Harrison, J.-F. Minster, C.-K. Tai, Fabienne Gaillard, Herlé Mercier, Jens Schröter, Laurent Mémer, Mitsuhiro Kawase, Reiner Schlitzer, Yehuda Agnon, Phillipe Gaspar, Norman Barth, Nathan Bindoff, Françoise Martel, Jerome Benveniste, Jochem Marotzke, Ric Williams, Daniel Jamous, Detlef Stammer, Dimitris Menemenlis, Kirill Pankratov, Rowan Hughes, Jeremy Harris, Ralf Giering, Nadia Ayoub, Christian Eckert, Patrick Heimbach, Francis Condi, Samar Khatiwala, Jeffrey Scott, Martin Losch, Benjamin Martinez-Lopez, Gaël Forget, Johanna Baehr, Martin Scharffenberg, Fabien Roquet, Xinfeng Liang, Maike Sonnewald (with P. Heimbach)

Publications: Carl Wunsch

- (1) Wunsch, C., The multiple spectral factorization procedure of Wiener and Masani, *IEEE Trans. Inform. Th.*, 11, 175-182, 1965.
- (2) Wunsch, C., The long-period tides, *Revs. Geophys.*, 5, 447-476, 1967.
- (3) Wunsch, C., On the propagation of internal waves up a slope, *Deep-Sea Res.*, 15, 251-258, 1969.
- (4) Wunsch, C., Progressive internal waves on slopes, *J. Fluid Mech.*, 35, 131-145, 1969.
- (5) Wunsch, C., D. Hansen and B. Zetler, Fluctuations of the Florida Current inferred from sealevel records, *Deep-Sea Res.*, 16 (Supplement. Fuglister Volume), 447-460, 1969.
- (6) Martin, S., W. F. Simmons and C. Wunsch, Resonant internal wave interactions, *Nature*, 224, 1014-1016, 1969.
- (7) Wunsch, C., On oceanic boundary mixing, *Deep-sea Res.*, 17, 293-301, 1970.
- (8) Wunsch, C. and J. Dahlen, Preliminary results of internal wave measurements in the main thermocline at Bermuda, *J. Geophys. Res.*, 75, 5889-5908, 1970.
- (9) Wunsch, C., Note on some Reynolds stress effects of internal waves on slopes, *Deep-Sea Res.*, 18, 583-592, 1971.
- (10) Wunsch, C., Internal waves - Quadrennial review of XVth General Assembly IUGG, Moscow, *EOS, Trans. Am. Geophys. Union*, 52, 233-235, 1971.
- (11) Wunsch, C., Bermuda sea level in relation to tides, weather, and baroclinic fluctuations, *Revs. Geophys.*, 10, 1-49, 1972.
- (12) Martin, S., W. F. Simmons and C. Wunsch, The excitation of resonant triads by single internal waves, *J. Fluid Mech.*, 53, 17-44, 1972.
- (13) Wunsch, C., Temperature microstructure on the Bermuda slope, with application to the mean flow, *Tellus*, 24, 350-367, 1972.
- (14) Wunsch, C., The spectrum from two years to two minutes of temperature fluctuations in the main thermocline at Bermuda, *Deep-Sea Res.*, 19, 577-593, 1972.
- (15) Wunsch, C. and R. Hendry, Array measurements of the bottom boundary layer and internal wave field on the continental slope, *Geophys. Fl. Dyn.*, 4, 101-145, 1972.
- (16) Miller, S. P. and C. Wunsch, The pole tide, *Nature Physical Science*, 246, No.155, 98-102, 1973.
- (17) Regal, R. and C. Wunsch, M2 tidal currents in the western North Atlantic, *Deep-Sea Res.*, 20, 493-502, 1973.
- (18) Hendry, R. and C. Wunsch, High Reynolds number flow past an equatorial island, *J. Fluid Mech.*, 58, 97-114, 1973.
- (19) Wunsch, C., On the mean drift in large lakes, *Limnol. and Oceanog.*, 18, 793-795, 1973.
- (20) Wunsch, C. and J. Dahlen, A moored temperature and pressure recorder, *Deep-Sea Res.*, 21, 145-154, 1974.
- (21) Taft, B., B. Hickey, C. Wunsch and D. J. Baker, Jr, Equatorial undercurrent and deeper flows in the Central Pacific, *Deep-Sea Res.*, 21, 403-430, 1974.
- (22) Cacchione, D. A. and C. Wunsch, Experimental study of internal waves on a slope, *J. Fluid Mech.*, 66, 223-239, 1974.
- (23) Gould, W. J., W. J. Schmitz, Jr. and C. Wunsch, Preliminary field results for a mid-ocean dynamics experiment (MODE-0), *Deep-Sea Res.*, 21, 911-932, 1974.

- (24) Wunsch, C., Dynamics of the pole tide and the damping of the Chandler wobble, *Geophys. J. Roy. Astron. Soc.*, 39, 539-550 (Errata, *Geophys. J. Roy. Astron. Soc.*, 44, 539, 1975), 1974.
- (25) Wunsch, C., Simple models of the deformation of an earth with a fluid core, I, *Geophys. J. Roy. Astron. Soc.*, 39, 539-550, 1974.
- (26) Wunsch, C., Deep ocean internal waves: what do we really know?, *J. Geophys. Res.*, 80, 339-343, 1975.
- (27) Wunsch, C., Internal tides in the ocean, *Revs. Geophys. and Space Phys.*, 13, 167-182, 1975.
- (28) Luther, D. S. and C. Wunsch, Tidal charts of the Central Pacific, *J. Phys. Oc.*, 5, 222-230, 1975.
- (29) Wunsch, C., Simple models of the deformation of an earth with a fluid core, II: Dissipation and magnetohydrodynamic effects, *Geophys. J. Roy. Astron. Soc.*, 41, 165-184, 1975.
- (30) Wunsch, C. and A. E. Gill, Observations of equatorially trapped waves in Pacific sea level variations, *Deep-Sea Res.*, 23, 371-390, 1976.
- (31) Wunsch, C., Geographical variability of the internal wave field: a search for sources and sinks, *J. Phys. Oc.*, 6, 471-485, 1976.
- (32) Richman, J., C. Wunsch and N. Hogg, Space and time scales of meso-scale motion in the western North Atlantic, *Revs. Geophys. and Space Phys.*, 15, 385-420, 1977.
- (33) Wunsch, C., Determining the general circulation of the oceans: A preliminary discussion, *Science*, 196, 871-875, 1977.
- (34) Wunsch, C. and M. Wimbush, Simultaneous pressure, velocity and temperature measurements in the Florida Straits, *J. Mar. Res.*, 35, 75-104, 1977.
- (35) Wunsch, C., Response of an equatorial ocean to a periodic monsoon, *J. Phys. Oc.*, 7, 497-511, 1977.
- (36) McCammon, C. and C. Wunsch, Tidal charts of the Indian Ocean north of 15°S, *J. Geophys. Res.*, 82, 5993-5998, 1977.
- (37) Wunsch, C., The North Atlantic general circulation west of 50°W determined by inverse methods, *Revs. Geophys. and Space Phys.*, 16, 583-620, 1978.
- (38) Moore, D., P. Hisard, J. McCreary, J. Merle, J. O'Brien, J. Picaut, J.-M. Verstraete and C. Wunsch, Equatorial adjustment in the Eastern Atlantic, *Geophys. Res. Letters*, 5, 637-640, 1978.
- (39) MODE Group, The, Mid-Ocean Dynamics Experiment, *Deep-Sea Res.*, 25, 859-910, 1978.
- (40) Munk, W. and C. Wunsch, Ocean acoustic tomography: A scheme for large scale monitoring, *Deep-Sea Res.*, 26A, 439-464, 1979.
- (41) Wunsch, C. and S. Webb, Climatology of deep ocean internal waves, *J. Phys. Oc.*, 9, 235-243, 1979.
- (42) Wunsch, C., Properties for inverse analysis of sound propagation in simple oceanic waveguides, *J. Mar. Res.*, 38, 413-433, 1980.
- (43) Wunsch, C. and E. M. Gaposchkin, On using satellite altimetry to determine the general circulation of the oceans with application to geoid improvement, *Revs. Geophys and Space Phys.*, 18, 725-745, 1980.
- (44) Wunsch, C., Meridional heat flux of the North Atlantic Ocean, *Proc. Nat. Acad. Scis.*, USA, 77, 5043-5047, 1980.

- (45) Wunsch, C., An interim relative sea surface for the North Atlantic Ocean, *Mar. Geod.* 5, 103-119, 1981.
- (47) Wunsch, C., Low frequency variability of the sea, in *Evolution of Physical Oceanography: Scientific Surveys in Honor of Henry Stommel*, 342-374, B. A. Warren and C. Wunsch, eds., The MIT Press, Cambridge, 1981.
- (48) Fu, L.-l., T. Keffer, P. Niiler and C. Wunsch, Observations of mesoscale variability in the western North Atlantic: A comparative study, *J. Mar. Res.*, 40, 809-848, 1982.
- (49) Munk, W. and C. Wunsch, Observing the ocean in the 1990s, *Phil. Trans. Roy. Soc. A*, 307, 439-464, 1982.
- (50) Roemmich, D. and C. Wunsch, On combining satellite altimetry with hydrographic data, *J. Mar. Res.*, 33 (*Worthington Volume supplement*), 605-619, 1982.
- (51) Wunsch, C. and B. Grant, Towards the general circulation of the North Atlantic Ocean, *Prog. in Oceanog.*, 11, 1-59, 1982.
- (52) Wunsch, C. and J.-F. Minster, Methods for box models and ocean circulation tracers: Mathematical programming and non-linear inverse theory, *J. Geophys. Res.*, 87, 5647-5662, 1982.
- (53) Zlotnicki, V., B. Parsons and C. Wunsch, The inverse problem of constructing a gravimetric geoid, *J. Geophys. Res.*, 87, 1835-1848, 1982.
- (54) Hotchkiss, F. S. and C. Wunsch, Internal waves in Hudson Canyon with possible geological implications, *Deep-Sea Res.*, 29, 415-442, 1982.
- (55) Ocean Tomography Group, The, A demonstration of ocean acoustic tomography, *Nature*, 299, 121-125, 1982.
- (56) Munk, W. and C. Wunsch, Up/down resolution in ocean acoustic tomography, *Deep-Sea Res.*, 29, 1415-1436, 1982.
- (57) Munk, W. and C. Wunsch, Ocean acoustic tomography: rays and modes, *Revs. Geophys. and Space Phys.*, 21, 777-793, 1983.
- (58) Tai, C.-K. and C. Wunsch, Absolute measurement by satellite altimetry of dynamic topography of the Pacific Ocean, *Nature*, 301, 408-410, 1983.
- (59) Wunsch, C., D.-X. Hu, and B. Grant, Mass, heat, salt and nutrient fluxes in the South Pacific Ocean, *J. Phys. Oc.*, 13, 725-753, 1983.
- (60) Wunsch, C., Western North Atlantic interior, in *Eddies in Marine Science*, 46-65, A. R. Robinson, ed., Springer-Verlag, 1983.
- (61) Roemmich, D. and C. Wunsch, Apparent change in the climatic state of the deep North Atlantic Ocean, *Nature*, 307, 447-450, 1984.
- (62) Tai, C.-K. and C. Wunsch, An estimate of global absolute dynamic topography, *J. Phys. Oc.*, 14, 457-463, 1984.
- (63) Wunsch, C. and V. Zlotnicki, The accuracy of altimetric surfaces, *Geophys. J. Roy. Astron. Soc.*, 78, 795-808, 1984.
- (64) Wunsch, C., The ocean circulation in climate, *The Global Climate*, 189-203, J. T. Houghton, ed., Cambridge University Press, Cambridge, 1984.
- (65) Wunsch, C., An eclectic Atlantic Ocean circulation model. Part I: The meridional flux of heat, *J. Phys. Oc.*, 14, 1712-1733, 1984.
- (66) Wunsch, C., An estimate of the upwelling rate in the equatorial Atlantic based on the distribution of bomb radiocarbon and quasigeostrophic dynamics, *J. Geophys. Res.*, 89, 7971-7978, 1984.

- (67) Luyten, J., H. Stommel, and C. Wunsch, A diagnostic study of the North Atlantic subpolar gyre, *J. Phys. Oc.*, 15, 1344-1348, 1985.
- (68) Munk, W. and C. Wunsch, Biases and caustics in long-range acoustic tomography, *Deep-Sea Res.*, 32, 1317-1346, 1985.
- (69) Roemmich, D. and C. Wunsch, Two transatlantic sections: Meridional circulation and heat flux in the subtropical North Atlantic Ocean, *Deep-Sea Res.* 32, 619-664, 1985.
- (70) Wunsch, C. and D. Roemmich, Is the North Atlantic in Sverdrup balance?, *J. Phys. Oc.*, 15, 1876-1880, 1985.
- (71) Wunsch, C., Can a tracer field be inverted for velocity?, *J. Phys. Oc.*, 11, 1521-1531, 1985.
- (72) Cornuelle, B., C. Wunsch, D. Behringer, T. Birdsall, M. Brown, R. Heinmiller, R. Knox, K. Metzger, W. Munk, J. Spiesberger, R. Spindel, D. Webb, and P. Worcester, Tomographic maps of the ocean mesoscale, part 1, Pure acoustics, *J. Phys. Oc.*, 15, 133-152, 1985.
- (73) Joyce, T. M., C. Wunsch, S. D. Pierce, Synoptic Gulf Stream velocity profiles through simultaneous inversion of hydrographic and acoustic doppler data, *J. Geophys. Res.*, 91, 7573-7585, 1986.
- (74) Schröter, J. and C. Wunsch, Solution of non-linear finite difference ocean models by optimization methods with sensitivity and observational strategy analysis, *J. Phys. Oc.*, 16, 1855-1874, 1986.
- (75) Wunsch, C., Dynamics of the North Sea pole tide revisited, *Geophys. J. Roy. Astron. Soc.*, 87, 869-884, 1986.
- (76) Wunsch, C., Calibrating an altimeter: how many tide gauges is enough?, *J. Atm. and Oceanic Tech.*, 3, 746-754, 1986.
- (77) Wunsch, C., Reply to Veronis, *J. Phys. Oc.*, 16, 1731-1732, 1986.
- (78) Wunsch, C., Using transient tracers: The regularization problem, *Tellus*, 39B, 477-492, 1987.
- (79) Munk, W. and C. Wunsch, Bias in acoustic travel time through an ocean with adiabatic range-dependence, *Geophys. and Astrophys. Fl. Dyn.*, 39, 1-24, 1987.
- (80) Schröter, J. and C. Wunsch, Reply to P. C. McIntosh, *J. Phys. Oc.*, 17, 841-842, 1987.
- (81) Wunsch, C., Acoustic tomography by Hamiltonian methods including the adiabatic approximation, *Revs. Geophys.*, 25, 41-53, 1987.
- (82) Wunsch, C., Transient tracers as a problem in control theory, *J. Geophys. Res.* 93, 8099-8110, 1988.
- (83) Wunsch, C., Eclectic modelling of the North Atlantic. II. Transient tracers and the ventilation of the eastern basin thermocline, *Phil. Trans. Roy. Soc.*, A, 201-236, 1988.
- (84) Barth, N. and C. Wunsch, Oceanographic experiment design by simulated annealing, *J. Phys. Oc.*, 20, 1249-1263, 1989.
- (85) Gaspar, P. and C. Wunsch, Estimates from altimeter data of barotropic Rossby waves in the northwestern Atlantic Ocean, *J. Phys. Oc.*, 19, 1821-1844, 1989.
- (86) Wunsch, C., Sampling characteristics of satellite orbits, *J. Atmo. and Oceanic Tech.*, 6, 891-907, 1989.
- (87) Wunsch, C., Tracer inverse problems, in *Oceanic Circulation Models: Combining Data and Dynamics*, 1-77, D. L. T. Anderson and J. Willebrand, eds., Kluwer, Dordrecht, 1989.
- (88) Mémery, L. and C. Wunsch, Constraining the North Atlantic circulation with tritium data, *J. Geophys. Res.*, 95, 5229-5256, 1990.

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- (90) Wunsch, C., Using data with models; Ill-posed problems, in, *Oceanographic and Geophysical Tomography*, 205-248, Y. Desaubies, A. Tarantola, and J. Zinn-Justin, eds., North-Holland, Amsterdam, 1990.
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- (92) Fukumori, I., F. Martel and C. Wunsch, The hydrography of the North Atlantic in the early 1980's. An atlas, *Prog. in Oceanog.*, 27, 1-110 1991.
- (93) Fukumori, I. and C. Wunsch, Efficient representation of the North Atlantic hydrographic and chemical distributions, *Prog. in Oceanog.*, 27, 111-195, 1991.
- (94) Wunsch, C., Global-scale sea surface variability from combined altimetric and tide gauge measurements, *J. Geophys. Res.*, 96, 15,003-15,082, 1991.
- (95) Wunsch, C., Large-scale response of the ocean to atmospheric forcing at low frequencies, *J. Geophys. Res.*, 15,083-15,092, 1991.
- (96) Bindoff, N. and C. Wunsch, Comparison of synoptic and climatologically mapped sections in the South Pacific Ocean, *J. of Climate*, 5, 631-645 1992.
- (97) Wunsch, C., Decade-to-century changes in the ocean circulation, *Oceanography*, 5 (2) 99-106, 1992.
- (98) Martel, F. and C. Wunsch, The North Atlantic circulation in the early 1980s - an estimate from inversion of a finite difference model, *J. Phys. Oc.*, 23, 898-924, 1993.
- (99) Fukumori, I., J. Benveniste, C. Wunsch and D. B. Haidvogel, Assimilation of sea surface topography into an ocean circulation model using a steady state smoother, *J. Phys. Oc.*, 23, 1831-1855, 1993.
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