

Mission & partners overview Project start: 2004

Main partners:

- MIT (PI: Wunsch, Co-PI: Heimbach)
- AER (Co-PI: Ponte)
- JPL (Co-PI: Fukumori)
- GFDL (Co-I: Rosati)
- Formerly (ECCO): Stammer (SIO/UCSD, now ZMAW/U.Hamburg)
- Strong links to NASA-MAP: ECCO2 (Co-PI: Menemenlis, JPL)



Ocean State Estimation - combining the knowledge reservoirs Observations - theory (model) - uncertainties



Combined use of very diverse/disparate types of observations Sum = [100(obs) + 800(forcing)] million individual elements

observation	instrument	product	area	period	dī	#
Mean dynamic topography (MDT)	GRACE GGM02 GRACE SM004-GRACE3	U-Texas (B. Tapley) CLS/GFZ (A.M. Rio)	global global	time-mean	time-mean	3.2E4
Sea level anomaly (SLA)	• T/P, Jason • ERS, ENVISAT • GFO	PO.DAAC AVISO NOAA, USN	66°N/S 82°N/S 65°N/S	1992 - 2006 1992 - 2006 2001 - 2004	daily daily daily	1.7E7 1.2E7 6.6E6
SST	 blended, AVHRR (O/I) TRMM/TMI AMSR-E (MODIS/Aqua) 	Reynolds & Smith (1999) NASA, NOAA NASA, NOAA	Global 40°N/S	1992 - 2006 1998 - 2003 2001 - 2006	monthly monthly monthly	6.5E6 2.9E6
SSS	In-situ, ships	ECOP (France)	Pacific	1992 - 1999	monthly	2.4E4
In-situ T, S	 Argo, P-Alace XBT CTD SEaOS TOGA/TAO, Pirata 	Ifremer, S. Behringer (NCEP) Various SMRU & BAS (UK) PMEL/NOAA	"global" "gobal" sections SO Trop. Pac.	2003 - 2006 1992 - 2006 1992 - 2006 1992 - 2006	daily daily daily daily daily	2.1E7 1.0E7 2.0E6 5.2E5 3.3E6
Mooring velocities	TOGA/TAO, PirataRAPID	PMEL/NOAA SOC (UK)	Trop. Pac. N. Atl.	1992 - 2006 3/2004 - 5/2005	daily daily	2 x 1.1E6
Climatological T,S	• WOA01 (upper 300 m) • WOCE	Conkright et al., 2002 Gouretski & Koltermann, 2004	"global" "global"	1950 - 2000 1950 - 2002	time-mean time-mean	2 x 8.1E6
Wind stress	QuickScat	NOAA, NASA	global	1999 - 2004	2-day	2 x 4.7E6
Tide gauge SSH	Tide gauges	NBDC/NOAA	sparse	1992 - 2006	monthly	5.5E4
Flux constraints	NCEP/NCAR variances	Kalnay et al., 1997	global	1992 - 2006	2-day	4 x 2.0E8
Balance constraints			global	1992 - 2006	time-mean	2 × 3 6E5
bathymetry		Smith & Sandwell, ETOPO5	global	-	-	EUGU

Some milestones - not unlike the work load of a NWP center MIT/AER/JPL

Synthesis of all available, disparate observations, sustained production & provision of state estimates, dynamical consistency, i.e. closed property budgets, and a focus on climate, i.e. (multi-)decadal time scales

- independent quality control and provision of error estimates for *all* data
- ongoing open-source forward and adjoint model development important for production, analysis, observation design, sensitivities, ...
- wide use of results and tools by diverse community of researchers, e.g.,
 - geodesy
 - ocean biogeochemistry & ecology
 - regional & coastal oceanography
 - CLIVAR projects, e.g., CLIMODE, DIMES, GSOP, OceanObs'09, ...
- open-source automatic differentiation tool development (OpenAD)
- various products:
 - MIT/AER: quasi-global decadal v2/3 (fully global v4 under way)
 - OCCA atlas covering Argo-rich period (2005-2007)
 - SOSE: eddy-permitting Southern Ocean State Estimate
 - JPL: near real-time quasi-global solutions & ECCO2 cubed-sphere
- shift of effort from R&D (MIT/AER) to sustained production & product improvement (JPL with MIT/AER)

Some users and applications

1.	MIT Darwin Project (Follows et al., Science, 2007; Dutkiewicz et al., GBC, 2009)
	 marine ecosystem modeling; ocean biogeochemical cycle
2.	CLIMODE: CLIvar MOe Water Dynamic Experiment (Marshall et al., BAMS, 2009)
	- Investigation of sub-tropical 18° mode water formation dynamics (Maze et al. 2009)
3	CODAF: Central California ODAF (C. Edwards IJCSC: Veneziani et al. JGP 2009a/b)
0.	Study of the Monterov Bay & Contral Colifornia coast circulation
4	- Study of the Monteley bay & Central California Coast Circulation
4.	2006/07)
5.	LDEO/Columbia U.: Long-term biogeochemical tracer calculations (Khatiwala, GBC, 2007)
6.	GOCE: Mean Dynamic Topography uncertainties (Fossepoel, JGR, 2008; IMAU, Utrecht)
	 Uncertainty estimate in preparation of the GOCE satellite mission
7.	GFZ Potsdam: Ocean circulation magnetic field signals (Manoj et al., EPS, 2006)
8.	U. Toronto: "Liming" the ocean inceases CO_2 absorption (<i>Harvey, JGR, 2008</i>)
	- Uses upwelling velocities to investigate pCO_2 increases in response to $CaCO_3$
9.	MISU, Sweden: Thermodynamic analysis of ocean circulation (J. Nycander et al.)
	 Streamfunction-based calculations of MOC energetics
10.	IERS/SBO: Ocean mass changes and Earth rotation (R. Gross et al., JPL)
11.	Global gravitational model development for GRACE (N. Pavlis, SGT)
12.	Transient amplification, predictability, and SVD's (Zanna et al, JPO, 2010; Harvard)
13.	Atlantic MOC sensitivities for US AMOC (Czeschel, Marshall, Johnson, Oxford)
14.	Irminger Sea assimilation for ASOF (Haine et al., JHU)
15.	CLIVAR/GSOP & OceanObs'09 (see various plenary & community white papers)
16.	ANL/U.Chicago: Open-source automatic differentiation tool (OpenAD)

17. Many more ...











Serving satellite oceanography: De-aliasing of altimetric (T/P) and gravity (GRACE) signals



experiment from SOSE

80°

(Abernathey et al., JPO, 2010)





Outlook

- ECCO remains primarily directed at qunatitative, mechanistic understanding of climate variability from ocean state that is consistent with synthesis of all observations and known physics, as a necessary prerequisite for prediction
- Rigorous state estimation using most of the available observations is possible and scientifically useful. Some studies includes:
 - Decadal variability in poleward heat and mass transports
 - Regional patterns of sea-level & heat budget changes
- Serving various communities, e.g., NASA, CLIVAR (GSOP, CLIMODE, DIMES, ...), coastal, microbial oceanography, geodesy, correction of satellite signals, ...
- Adjoint and estimation system should be used for formal observing system design
- ECCO now going fully global as coupled ocean/sea-ice system, with increased focus on high latitudes (see also NASA-MAP project ECCO2)
- The need to
 - improve prior, and to provide posterior uncertainty estimates
 - couple to the atmosphere (and cryosphere) as a way to overcome major shortcoming of re-analyses for climate purposes



