INTEGRATED BOUNDARY CURRENT OBSERVATIONS IN THE GLOBAL CLIMATE SYSTEM

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Project Summary

The current national and international ocean observing system for climate consists of several components, none of which are designed for capturing intense, concentrated, or deep circulation systems. Therefore, additional approaches and infrastructure are needed for observing western and eastern boundary currents, throughflows/overflows, and deep circulation regimes.

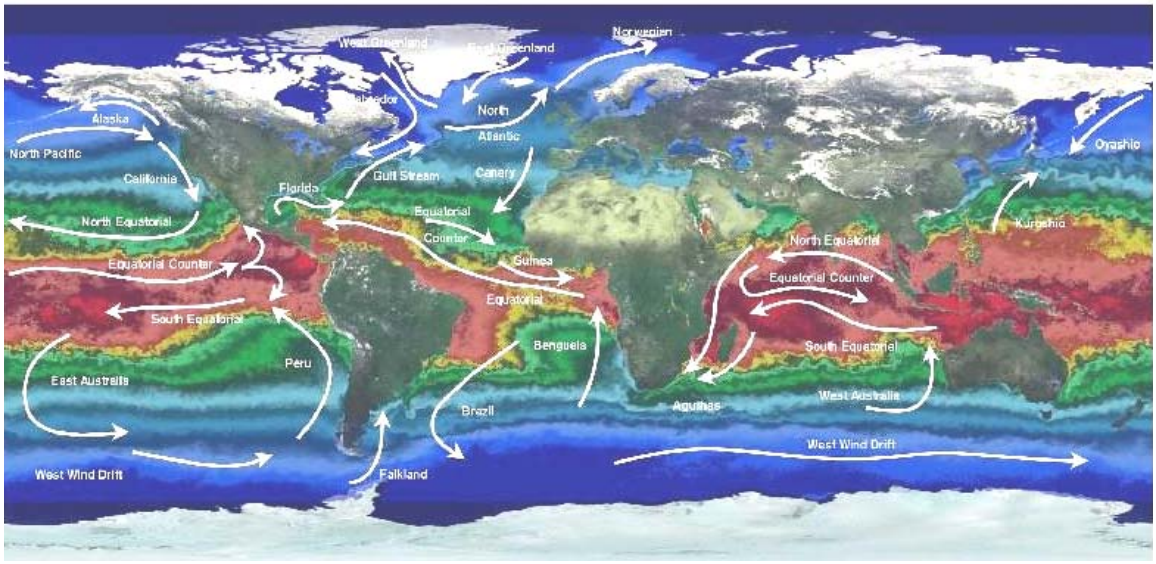
We propose to develop, demonstrate, and implement a system that can fully monitor the intensity (mass and heat transports) of most boundary currents in a sustained and routine mode, delivering indicators about the state of those regimes in near-realtime. To this end we will merge several technologies and techniques that have been used by the P.I.'s in the past, and that were partly developed in prior CORC phases. These include

- *end-point moorings* (with CTD sensors throughout the water column and bottom pressure sensors) at the ends of a section to determine the dynamic height difference, and thus geostrophic transports, as a time series.
- *underwater gliders* to estimate the heat transport through a section, by providing the horizontal (and vertical) distribution of heat content and its correlation with the flow.
- *inverted echosounders plus bottom pressure (PIES)* distributed along the section to be monitored. These will yield 2 vertical integrals (e.g. dynamic height and heat content) at each location, providing the depth (and time) coverage along the section that the gliders can not.
- *data telemetry* for the PIES and (subsurface) moorings using acoustic modems between these and the gliders. In very high (surface intensified) current regions, the gliders may need to remain submerged on one of the round-trip crossings each time. In this case, a navigation capability will be needed in the gliders to pass within close enough proximity of the PIES and moorings.
- *data assimilation* for determining heat and flow distributions, and thus the full mass and heat transports, that are consistent with all the data types collected, with satellite altimetry, with the forcing fields (wind) and with up/downstream and offshore information.

The pilot and testbed application will be carried out in the California Current which has large climate and socio-economic relevance and does not have a routine monitoring system. Operation along CalCOFI line 90 in southern California assures synergy with other programs, and coincides approximately with the high resolution XBT line PX31 which will contribute comparison data and connect sampling to the basin interior. In addition automated surface drifter releases will quantify the eddy variability and the Ekman flow in the boundary current region.

Later in the project, implementation of the system in the climatically highly relevant western boundary current of the low-latitude western Pacific is planned (which feeds the Equatorial Undercurrent through the Solomon Sea).

FY 2006 Activities



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A: Glider Operations in Integrated Boundary Current Observations Pilot
(Russ E. Davis and Daniel L. Rudnick)

There are two components to our project on using underwater gliders to monitor climatically significant variability of boundary currents to augment the global Argo array. In the longer running component, we are using Spray gliders to observe, first, the structure and magnitude of the flows from the tropical South Pacific to the equatorial zone and, eventually, temporal variability of this transport. A component that began this grant year is expanding the capability of the Spray glider so that, in strong boundary currents where surface piercing moorings are not feasible, the glider can acoustically gather data from submerged instrumentation and carry it to the surface for satellite communication.

In the current reporting period, we have (1) completed another crossing of the South Pacific's Equatorial Current (SEC) between Guadalcanal and New Caledonia, (2) prepared and shipped a second Spray for exploration of the SEC as it enters to Solomon Sea on its way to the equator, and (3) made substantial progress modifying Spray for its acoustic transponder capability.

Our second sampling of the SEC between Guadalcanal and New Caledonia, completed in collaboration with William Kessler (PMEL) and Lionel Gourdeau (IRD, Noumea), was less successful than the first crossing, which was reported in "Zonal jets entering the Coral Sea" by Gourdeau, L., W.S. Kessler, R.E. Davis, J. Sherman, C. Maes and E. Kestenare, submitted to *Journal of Physical Oceanography*. About halfway across the transit, while operating well below the surface, Spray 01 was hit/bitten hard enough by something that its attitude was upset and it could not subsequently maintain its cruising speed; on recovery, part of the tail was

missing. Further into the mission, the CTD salinity underwent a sudden step change of O(0.1) the cause of which we cannot diagnose until the vehicle returns to SIO. Attack by predators and measurement errors caused by bio-fouling are intrinsic problems with autonomous sampling and, although rare, this cruise shows they are a real operational factor.

A second Spray is in transit to Noumea for deployment this September near the south-east corner of the New Guinea land mass where it will begin to transit east to Guadalcanal and then possibly to New Caledonia. This will first of all give direct observations of the SEC as it turns north, both in the New Guinea Coastal Undercurrent, where strong currents have been documented, and in other interior-ocean pathways to the equator. The strength of these flows is a concern for future operations as is the remoteness of the sites for shore support.

CORC contributions to monitoring climate variability in the California Current were development of a 750 kHz acoustic Doppler current profiler (ADCP) for the Spray glider and the implementation of continuous sampling along CalCOFI Line 90 since 19 October 2006. This is the section where the pilot boundary current array will be deployed. The objectives of this effort are (1) to begin monitoring conditions on the line that our prototype boundary current monitoring system will be tested on in order to extend the temporal context, (2) to gather scales (energy, temporal and spatial) of variability on this line to use in optimizing control of gliders when they are interrogating bottom instruments, and (3) to gain operational experience steering Spray to a fixed point as will be necessary to get within acoustic range of transponding instruments. These gliders support a CTD for temperature and salinity observations, a chlorophyll-a fluorometer as a qualitative measure of phytoplankton abundance, and a 750 kHz acoustic Doppler current profiler to measure velocity shear and acoustic backscatter, which serves as rough index of zooplankton abundance and the presence of schools of small fish. This instrument suite was developed under previous CORC funding and seems well suited for characterizing the coupled physical and biological responses to climate variability.

For the new integrated system using gliders together with PIES and moorings, we have purchased one acoustic modem and transducer that will be used on Spray to interrogate submerged instruments. A way has been devised to install a transponder in Spray by lengthening it by only about 5 cm, and construction of the larger hull has begun. A way to physically incorporate the electronics for the modem into Spray has also been designed. Work has further begun for structuring the software expansion that will be needed. We look to having a prototype ready for testing this summer.

B: Moorings and PIES in the Integrated Boundary Current Observations Pilot
(U.Send)

An acoustic modem system has been selected for use on the moorings, on the inverted echosounders/pressure sensors (PIES) and in Spray gliders in their role of interrogating subsurface instruments in the pilot boundary current array. Two such modem systems have been purchased for this task (plus one in the glider task). Engineering bench tests with the modems have been completed to check their functionality, power consumption, and performance.

Designs for the modem integration (hardware and software) with the PIES and the moorings are completed. Modifications for the PIES have been agreed on and implemented with the manufacturer, and two such PIES ready for external modem interfacing have been purchased and received. The mechanical design for adding the modem to the PIES on their bottom tripod is completed and will be tested soon.

For the mooring work, a new controller is nearing completion which will allow collection of data from moored instruments (inductively from microcats, and via serial line from ADCPs), and which will pre-process the data, and pass them to the acoustic modem. Some mooring sensors have been acquired already, and more mooring hardware is now being purchased to prepare the first test moorings off San Diego. We plan a trial deployment of a PIES with the acoustic modem on the seafloor soon, which can be used to test the telemetry from small boats and later with a prototype glider.

C: XBT data in support of the California Current observing system
(D.Roemmich)

We are organizing CalCOFI and XBT datasets to address questions about interannual variability in the transport of the California Current. First, we have updated, to the present, estimates of geostrophic velocity and transport for CalCOFI lines 80 and 90. Similarly, we have calculated geostrophic velocity for the XBT lines out of Los Angeles and San Francisco. Scientific questions are: (i) do we see the same interannual variability in CalCOFI Line 90 and the Fiji-Los Angeles XBT line, (ii) where is the offshore edge of the California Current in the Fiji-Los Angeles XBT line, (iii) is the interannual transport variability in the California Current at the two XBT lines correlated?

For the research-quality deep XBT probes (LMP-5 T1) development work at Sippican is proceeding slowly. Sippican carried out an unsuccessful test at Bermuda a few months ago. We're hoping for a new batch of probes for evaluation in the next few months.

D: Synthesis of transports through the southern CCS
(Peter Niiler, Yoo Yin Kim, Luca Centurioni)

The combined data sets on circulation of the CCS are being analyzed for the purpose of computing both the time mean and the deviations from that mean. In the period of February-April, 2007 we have organized the historical drifter and altimeter data sets from 1985-2006 and computed from these the 15m geostrophic velocity distribution in the 1982-2007 CALCOFI survey area (Figure 1). In the present funding period, we will combine these observations with the ADCP data sets acquired from the CALCOFI surveys since 1993 by Dr. T. Chereskin at SIO, as well as the CALCOFI hydrographic data to compute the mass transports of the upper layers through the CORC observation regions. Of interest is both the time mean and time variability of the geostrophic (that contains no divergence) and the ageostrophic (that contains the divergence and upwelling) horizontal circulation patterns.

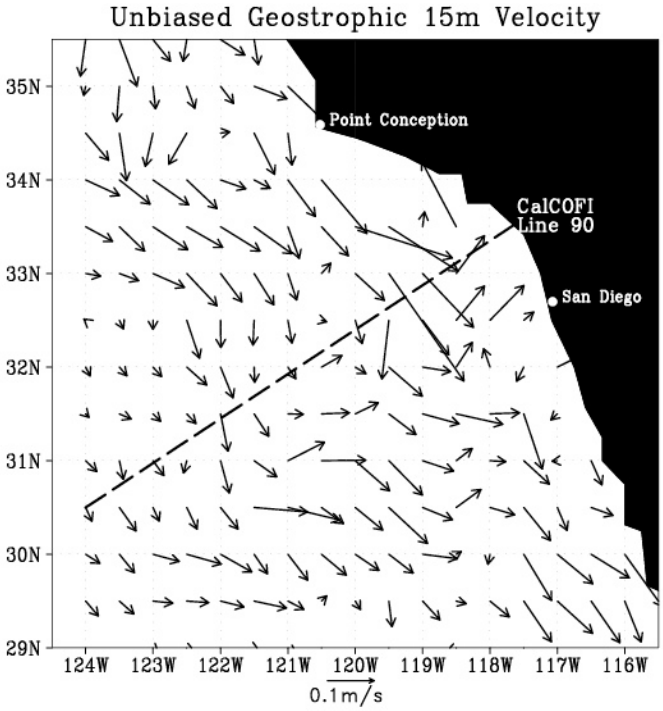

Fig.1: *Unbiased 1992-2002 geostrophic 15m velocity in the CCS off southern California (from Centurioni, L. , J.C. Ohlmann and P.P. Niiler: Permanent meanders in the California Current System, submitted to J. Phys. Oceanogr., February, 2007). Along CalCOFI line 90, the section to be sampled by CORC, the CCS is concentrated in two branches.*

E: Modelling and assimilation of future CORC data in the California Current
(B. Cornuelle)

A second paper on the modeling and assimilation in the tropical pacific from the previous CORC project has been accepted (J. Atm. Ocean. Tech.), and we are working on two others, one on TIWs and one on the completed assimilation for the year 2000.

For the modeling work, an MITgcm model grid has been made for the CCS region from north of San Francisco to south of San Diego, at 1/6 degree resolution. A few months of test assimilation runs have been performed using altimeter SSH and satellite SST only. The assimilation seems to work as expected so far, but a lot of work is needed to evaluate the choices of parameters (viscosity, diffusivity, Kpp, etc.) and to assemble the datasets.

We are continuing to work on the California Current assimilation, although we have not yet incorporated the in situ observations. We are presently updgrading to the newer version of the ECCO code (which is the assimilation package including the MITgcm), so we are in a debugging process, since many features have changed. We are planning to do hindcast experiments from CalCOFI observations to evaluate the model skill. To that end, we have begun to look at assembling forcing fields and observations.

Summary
At present, the project is proceeding as planned. For the coming months first in-water tests are expected with the acoustic hardware near San Diego. First trials with a glider are anticipated for the summer. If everything is successful, we will be ready for first combined mooring, PIES, and glider deployments after the summer.