High Resolution XBT Transects: Progress Report

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Project Summary

The High Resolution Expendable Bathythermograph (HR-XBT) network was initiated in 1986 along a commercial shipping route between New Zealand, Fiji, and Hawaii. It was subsequently expanded during the 1990's to include basin-spanning temperature transects in all of the oceans. Major partners in the HR-XBT network include Scripps (Pacific and Indian Ocean), NOAA/AOML (Atlantic), and CSIRO (SW Pacific, Indian). Typically, each transect is repeated on a quarterly basis to resolve variability in temperature, geostrophic circulation and transport on annual and longer periods. A technician is on board in order to carry out sampling, with XBT probe spacing at 50 km or less in the ocean interior and as fine as 10-15 km in boundary currents. The ship rider also provides technical support for ancillary programs including improved marine meteorological sensors (IMET), Argo float deployments

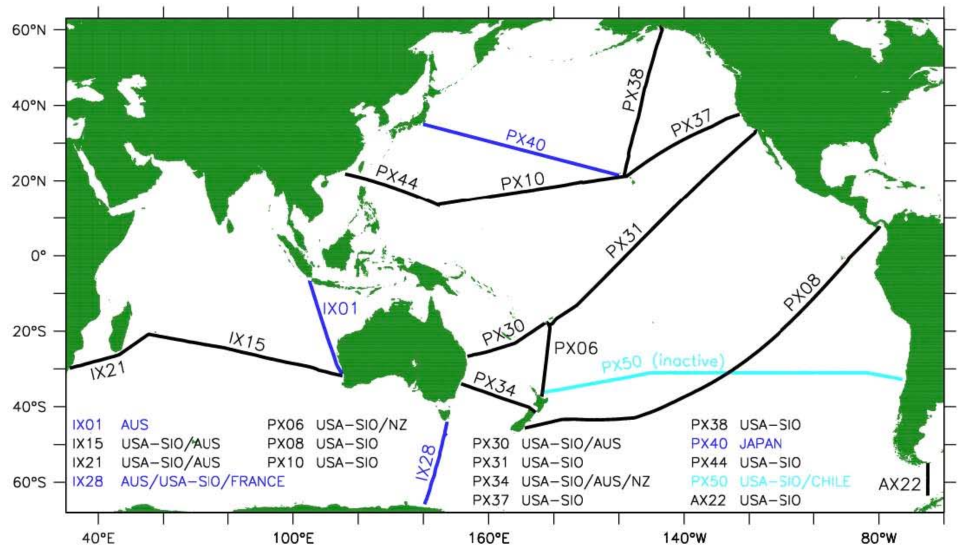

Fig 1: The HRX Network in the Pacific and Indian Ocean. International partnerships are indicated in the notes on the bottom of the figure.

and surface drifter deployments. Fig 1 shows the present transects sampled by the Scripps HR-XBT program and its partners in the Indian and Pacific Oceans. A typical temperature section is shown in Fig 2.

Scientific Objectives-

A primary scientific goal of the HR-XBT network is to determine whether interannual variability in the transport of heat by ocean currents is a major contributor to the heat budget of the ocean and hence to air-sea interactions and feedbacks in the climate system. Specific scientific objectives of the HR-XBT program are to:

- Measure the seasonal and interannual fluctuations in the transport of mass, heat, and freshwater across transects which define large enclosed ocean areas.
- Determine the long-term mean, annual cycle and interannual fluctuations of temperature, geostrophic velocity and large-scale ocean circulation in the top 800 m of the ocean.
- Obtain long time-series of temperature profiles at precisely repeating locations in order to unambiguously separate temporal from spatial variability.
- Determine the space-time statistics of variability of the temperature and geostrophic shear fields.
- Provide appropriate *in situ* data (together with Argo profiling floats, tropical moorings, air-sea flux measurements, sea level etc.) for testing ocean and ocean-atmosphere models.
- Determine the synergy between HR-XBT transects, satellite altimetry, Argo, and models of the general circulation. What are the minimal sampling requirements for *in situ* data?
- Identify permanent boundary currents and fronts, describe their persistence and recurrence and their relation to large-scale transports.
- Estimate the significance of baroclinic eddy heat fluxes.

In the context of NOAA's *Program Plan for Building a Sustained Ocean Observing System for Climate*, the HR-XBT Network is a part of the Ship-of-Opportunity Networks. It directly addresses objective 3 of the Plan: *Document the ocean's storage and global transport of heat and fresh water.*

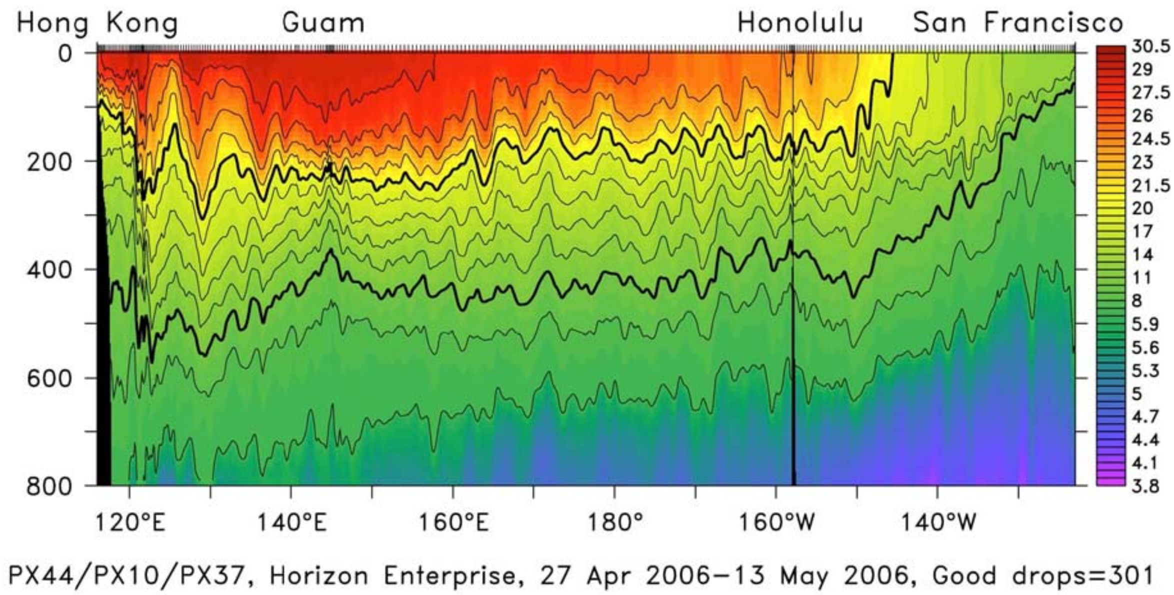

Fig 2. Example of a single temperature transect using 301 XBT profiles along PX37/10/44.

The configuration of the HR-XBT Network is in accordance with the recommendations of the Upper Ocean Thermal Review (Melbourne, 1999, see http://www.brest.ird.fr/soopip/).The Scripps HR-XBT network is managed for compatibility with the NOAA/SEAS system, and all XBT casts are transmitted (Global Telecommunications System) in near real-time for operational users as well as sent to NODC for archiving. The HRX Network is managed in accordance with the Global Climate Observing System (GCOS) Ten Climate Monitoring Principles.

FY2006 Accomplishments: October 2005 – September 2006.

Observations

HRX transects were collected by ship riders along the routes illustrated in Fig 1, and as described in the previous section, in the following months:

PX37/10/44 (North Pacific -San Francisco to Hawaii to Guam to Hong Kong) 4 transects: November 2005, February 2006, April 2006, August 6

PX38 (North Pacific – Hawaii to Alaska) 2 transects: January 2006, August 2006

PX08 (South Pacific – New Zealand to Panama) 4 transects: December 2005, February 2006, April 2006, July 2006 +2 transects along PX50 New Zealand to Chile: October 2005, August 2006

PX06/31 (Central Pacific – New Zealand to Fiji to Los Angeles) 5 transects – October 2005, January 2006, April 2006, July 2006, September 2006

PX30 (South Pacific – Brisbane to Fiji, collaborative with Australia) 4 transects – November 2005, March 2006, June 2006, September 2006

IX21 (South Indian – Durban to Mauritius) 3 transects – March 2006, July 2006, September 2006

IX15 (South Indian – Mauritius to Bass Strait) 4 transects – October 2005, January 2006, April 2006, July 2006

Data return rate is close to the planned four occupations per year for all lines, except for the short PX38 line due to lack of shipping. The number of transects in any 12-month period may vary from 3 to 5 depending on ship schedules. Sampling issues and our strategy for dealing with them are explained in the logistics section below.

In addition, logistical assistance and/or some XBT probes are provided collaboratively for:

PX34 (South Pacific – Wellington to Sydney)
IX28 (Southern Ocean – Hobart to Antarctica)
AX22 (Southern Ocean -Drake Passage, including 2 ship rider cruises)

Logistics

The commercial shipping industry has undergone enormous change since the beginnings of the HR-XBT network 20 years ago. With respect to HR-XBT sampling, there are two main changes. First, consolidation in the industry has resulted in the elimination of many shipping routes and an increasing reliance on feeder vessels. Second, ships remain on a given line for a much shorter period of time, necessitating frequent recruitment/changeover to new vessels. Specific impacts on HRX sampling include:

1. Elimination of the preferred South Pacific route (PX50) in 2003. The best alternate is PX08, with occasional PX50 transits by research vessels.

2. Occasional disappearance of IX15/21, including in early 2005. We have re-initiated sampling in September 2005 using two vessels (including a feeder vessel on IX21), and have enlisted collaborative support from the University of Capetown. This line appears stable for the time, but is logistically difficult due to its remote location.
3. Serious reduction in tanker traffic along PX38. All of these logistical issues result in increasing demands on the HR-XBT program's operations manager and the staff of trained ship riders, for recruitment and setup of new vessels. The transient nature of remote commercial shipping routes will continue. Our strategy is to continue sampling at our full capacity, but to shift to alternate routes with high scientific value in case shipping is unavailable along primary routes.

Development –

Two substantial development tasks took place in the present year.

First, the conversion of the SIO Automatic XBT Launcher System from Sippican MK12 data acquisition card to the new Windows-based MK21 was successfully completed. New software was developed and tested, and is fully compatible with NOAA/SEAS XBT data acquisition. This work was done collaboratively with NOAA/AOML. Replacement of shipboard computers and acquisition of MK21 is ongoing. The new systems are being used along all routes.

A new electronic temperature profiler from Sippican (LMP5-T1), providing research quality data to 2000 m from a 20 knot ship, is being tested and evaluated. Such a profiler is badly needed, especially for profiling in the western boundary currents. Test drops with LMP5-T1 probes have been carried out and are being evaluated.

Analysis and research highlights -

HR-XBT data are being incorporated in regional, basin-wide, and global analyses.

- Interannual circulation variability in the Northeast Pacific was described by Douglass *et al* (2006a) using XBT data from PX37 and PX38 together with a data assimilation model. Principal variability during the decade of observations was an increase in the eastward transport of the North Pacific Current in 1998, with a resultant increase in the subtropical gyre recirculation in the eastern Pacific.
- The time mean and interannual variability in heat and freshwater transport is investigated in Douglass *et al.* (2006b). The heat and freshwater budgets for the North Pacific north of PX37/10/44 are closed using HRX data and results from the ECCO data assimilation model.

- At the WCRP Workshop on Understanding Sea Level Rise and Variability, Roemmich *et al* (2006) reviewed the present state of knowledge on ocean heat content and steric sea level rise. This review focused on the past 50 years, the past 13 years, and the improved capabilities of the present ocean observing system.

Refereed publications –

Bowen M. M., P. J. H. Sutton, D. Roemmich, 2006. Wind-driven and steric fluctuations of sea surface height in the southwest Pacific, *Geophys. Res. Lett., 33,* L14617, doi:10.1029/2006GL026160.

Ueno, H., E. Oka, T. Suga, H. Onishi and D. Roemmich, 2006. Formation and variation of temperature inversions in the eastern subarctic North Pacific. Submitted to *Geophys. Res Lett.*

Douglass, E., D. Roemmich, and D. Stammer, 2006. Interannual variability in northeast Pacific circulation, J. Geophys. Res., 111, C04001, doi:10.1029/2005JC003015.

Douglass, E., D. Roemmich, and D. Stammer, 2006. The mean and Interannual variability of heat and freshwater transport in the North Pacific Ocean. In preparation.

Roemmich, D. and 15 co-authors. Global warming and sea level rise. WCRP Workshop on Understanding Sea Level Rise and Variability, Paris, June 6-9, 2006.

Community service –

D. Roemmich is active in design, coordination, and implementation of global ocean observations. He serves as co-chairman of international CLIVAR's Global Synthesis and Observations Panel, and as co-chairman of the Argo Science/Steering Team. He is also a member of the Steering Team for Pacific Islands -Global Ocean Observing System (PI-GOOS) and for the SEREAD education initiative, which develops teaching units and educational materials relevant to climate and ocean observations for primary and secondary curricula in South Pacific island nations.