SIO High Resolution XBT Transects

Dean Roemmich, Bruce Cornuelle, Janet Sprintall and Glenn Pezzoli
Scripps Institution of Oceanography
University of California San Diego, La Jolla CA

1. 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 (VOS-IMET), Argo float and surface drifter deployments, underway thermosalinograph, and water sampling. Figure 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 Figure 2.

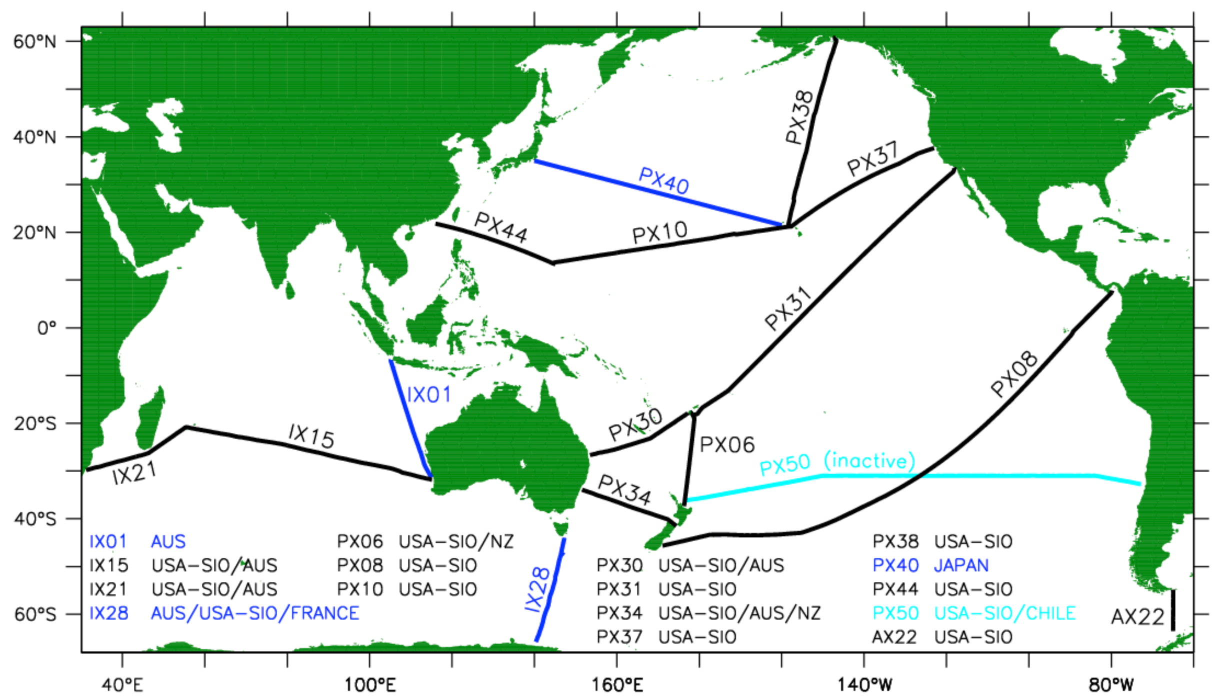

Figure 1. The HRX Network in the Pacific and Indian Ocean. International partnerships are indicated in the notes on the bottom of the figure.

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.*

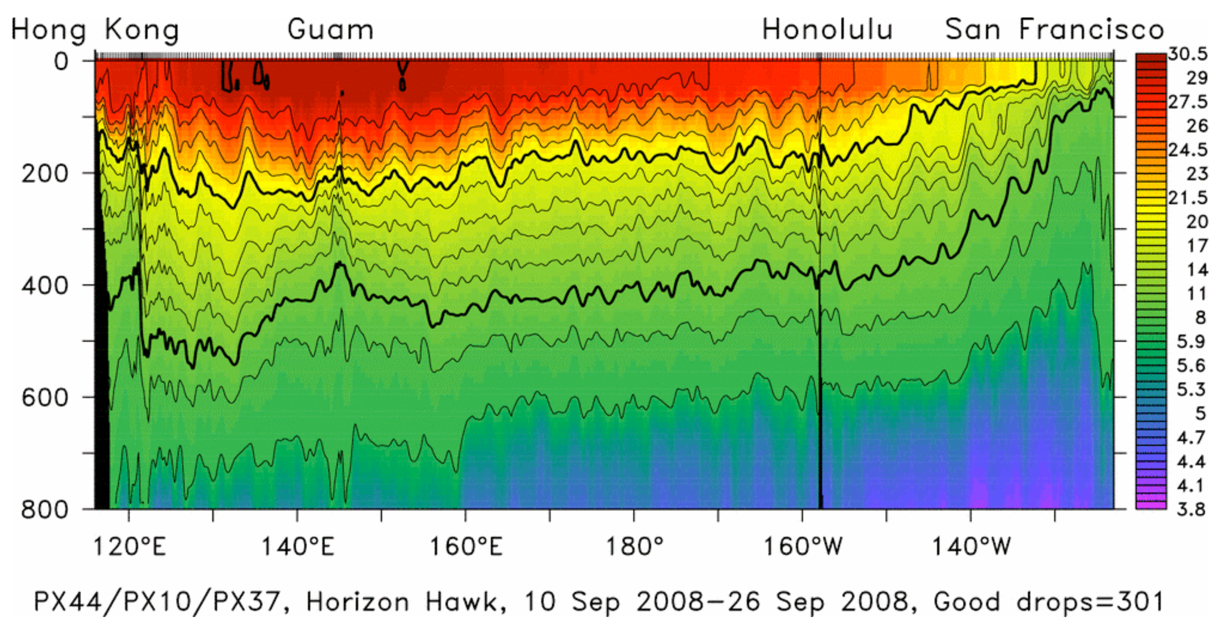

Figure 2. Example of a recent temperature transect with 301 XBT profiles along PX37/10/44.

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.

2. ACCOMPLISHMENTS

2.1. Observations

HRX transects were collected by ship riders along the routes illustrated in Figure 1, and as described in the previous section, in the following months, including yearly sums for total XBT drops and good (or partially good) XBT drops:

PX37/10/44 (North Pacific - San Francisco to Hawaii to Guam to Hong Kong)
4 transects: Oct 2007, Feb 2008, May 2008, July 2008 (1221 good/1243 total drops)

PX38 (North Pacific – Hawaii to Alaska)
4 transects: Dec 2007, Feb 2008, April 2008, August 2008 (354 good/356 total drops)

PX08 (South Pacific – New Zealand to Panama)
3 transects: Oct 2007, Feb 2008, August 2008 (701 good/708 total drops)
+ 2 transects on PX50 NZ to Chile Dec 2007, March 2008 (499 good/502 total drops)

PX06/31 (Central Pacific – New Zealand to Fiji to California)
4 transects: Nov 2007, Feb 2008, May 2008, August 2008 (1076 good/1151 total drops)

PX30 (South Pacific – Brisbane to Fiji, collaborative with Australia)
4 transects: Nov 2007, Feb 2008, May 2008, August 2008 (450 good/480 total drops)

IX21/6 (South Indian – Durban to Mauritius to Strait of Malacca)
4 transects: Oct 2007, Feb 2008, May 2008, June 2008 (826 good/835 total drops)

IX15/31 (South Indian – Mauritius to Fremantle to Bass Strait)
4 transects: Oct 2007, Jan 2008, April 2008, July 2008 (865 good/882 total drops)

The sampling objectives, which are 4 transects per year, have been met on all lines. The probe total for all lines is 5992 good/6157 total (97% yield). The preferred South Pacific line is PX50 (New Zealand to Chile). Due to a lack of shipping, this is done as PX08 (New Zealand to Panama), with occasional research vessel transits on PX50. The South Indian line, IX21/15 (Durban to Mauritius to Fremantle) is done using two ships, and with a ship-rider already on board we've sampled IX-6, Mauritius-Strait of Malacca, as well.

In addition, logistical assistance and/or some XBT probes are provided collaboratively (480 probes per year are as part of our collaboration with CSIRO) for:

PX34 (South Pacific – Wellington to Sydney)
IX28 (Southern Ocean – Hobart to Antarctica)
AX22 (Southern Ocean - Drake Passage, occasionally providing a ship rider)

2.2. 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. We re-initiated sampling in September 2005 using two vessels (including a feeder vessel on IX21), and enlisted collaborative support from the University of Capetown. This line appears stable for the time, though is going to Bass Strait rather than Fremantle. It is logistically very 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.

2.3. Development and technical issues

The most substantial XBT technical issue of the past year has been the identification of a (warm) temperature bias due to variations over time of XBT fall-rate. Work is ongoing to estimate the time history of fall-rate corrections and to apply this correction to historical data:

Wijffels, S. and 7 co-authors: Changing eXpendable Bathythermograph Fall-rates and their Impact on Estimates of Thermosteric Sea Level Rise, Journal of Climate, in press.

Our role in this work is through providing datasets, suggestions, and ancillary calculations.

The SIO Automatic XBT launcher system and its software are fully integrated with the NOAA/SEAS XBT data acquisition system. This allows HRX data to be transmitted in near real-time, and permits SIO HRX hardware to be used for broadscale XBT sampling.

2.4. Analysis and research highlights

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

- HRX line PX37/10/44, San Francisco-to-Hong Kong (Figures 1 et 2), has proven especially valuable, with 17 years of data comprising 66 transects along the repeating route, and the dataset having been used in many publications.
- E. M. Douglass completed her PhD thesis in which HRX data were analyzed in combination with other datasets and results from the ECCO Ocean Data Assimilation

model (Douglass, 2007, Douglass et. al., 2008a, 2008b). North Pacific HRX transects, especially PX37/10/44, were a key dataset in this work.

- D. Roemmich, J. Gilson and L. Lehmann are analyzing HRX data from the eastern North Pacific together with Argo and CalCOFI data to study the offshore extent of the California Current and the current's variability in relation to the North Pacific circulation.
- X. Zhang, B. Cornuelle, and D. Roemmich are using HRX and Argo datasets in a tropical Pacific regional version of the ECCO ocean data assimilation model to study recent ENSO variability.
- J. Gilson is pursuing accuracy and consistency issues for both HRX and Argo datasets (e.g. Willis et al., 2008). This is a community-wide effort, whose objectives are to identify and remove systematic errors in the global datasets to enable the XBT and Argo records to be combined with one another as well as with other historical and ongoing data collections.

2.5. Refereed publications

Uehara, H., S. Kizu, K. Hanawa, Y. Yoshikawa, and D. Roemmich, 2008. Estimation of heat and freshwater transports in the North Pacific using high-resolution expendable bathythermograph data. *Journal of Geophysical Research, 113,* C02014, doi:10.1029/2007JC004165.

Douglass, E. M., D. Roemmich, and D. Stammer, 2008a. Data-sensitivity of the ECCO state estimate in a regional setting. Submitted to the *Journal of Atmospheric and Oceanic Technology.*

Douglass, E.M., D. Roemmich and D. Stammer, 2008b. Interannual variability in North Pacific heat and freshwater budgets. Submitted to Deep-Sea Research.

Willis, J., J. Lyman, G. Johnson, and J. Gilson, 2008. In situ data biases and recent ocean heat content variability. Journal of Atmospheric and Oceanic Technology, in press.

2.6. PhD Thesis

Douglass, E.M., 2007. *Interannual Variability in North Pacific Ocean Circulation and Heat Transport: Results from Data Analysis and Ocean Data Assimilation Modeling.* PhD Thesis, Scripps Institution of Oceanography, University of California San Diego.

2.7. ***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.