Ocean circulation and the mass and heat budgets of large ocean regions: The synergies of High Resolution XBT transects, Argo, and satellite altimetry

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The High Resolution XBT (HRX) Network was initiated in 1986 with a quarterly transect between New Zealand and Fiji, and expanded toward today's global coverage during the 1990s. The HRX Network consists of repeating boundary-to-boundary transects, resolving eddies and boundary currents for estimation of geostrophic velocity and transport across routes enclosing large ocean regions. The early limitations of HRX sampling – the 800 m depth of XBTs, lack of salinity and absolute geostrophic velocity data, and poor estimates of ocean heat storage and air-sea fluxes - are all mitigated in the modern era thanks to Argo, satellite altimetry, and other ocean observations. The high value of the HRX Network in today's integrated ocean observing system is illustrated here in two parts.

First, a survey of the World Ocean's boundary current systems, as seen in HRX data, demonstrates the global scope of the network. All five of the subtropical western boundary currents (WBCs) are sampled, including multiple crossings of the Kuroshio and the Gulf Stream. Eastern boundary currents, low latitude WBCs, and the Antarctic Circumpolar Current are all observed systematically. The large volume of Argo data can provide either an absolute 800 m reference velocity, or a deeper relative (to 2000 m) estimate, for geostrophic velocity and transport in the boundary current systems. In combination, HRX, Argo, and altimetry provide the resolution needed for estimation of the time-varying currents and their upper-ocean transport.

Second, progress is illustrated in closing mass and heat budgets using the HRX transect spanning the North Pacific from San Francisco to Honolulu to Guam to Hong Kong (PX37/10/44). This route, sampled quarterly since 1993 (75 cruises), has been used in earlier studies of the Kuroshio system, the California Current, the mass and heat budget of the North Pacific, and the transport properties of mesoscale eddies.. During the Argo era (29 cruises), the time-mean mass budget for the region north of this transect closes: geostrophic transport out of the region and Ekman transport into it are each about 13.7 Sv ± 1.5. The corresponding heat flux convergence is 0.75 pW ± 0.1. The heat transport is consistent with earlier ocean-based estimates, but is larger than estimates based on air-sea fluxes. During the Argo era, substantial time variability is also seen in the mass and heat budgets. The temporal variations of heat and freshwater transport, storage, and air-sea flux are described together with the spatial pattern of low frequency storage. The heat transport and storage terms, with interannual fluctuations of tenths of a pW, are both known with small fractional errors; at present the larger errors in air-sea heat fluxes suggest that component is best estimated on large spatial scales as a residual.