Argo and Jason in the South Pacific: Interannual-to-decadal variability in water mass properties and circulation.

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Introduction:

The Argo project has nearly 1500 active profiling floats (FIG 1), provided by 18 nations, spanning the globe in the ice-free oceans. The present number is about 50% of the completion target for Argo, and is increasing by about 50 floats per month. Every month these instruments provide over 4000 high quality temperature and salinity profiles, plus reference velocities at 1000 m – data that are strongly complementary to satellite altimetric height. Argo data are freely available (http://www.argo.net) for all operational and research applications. One of the major foci of Argo deployments in 2004 is the South Pacific, the largest and most remote of the oceans, and arguably the least sampled. Following recent US/New Zealand joint deployment of 144 floats, there are now over 320 active Argo instruments in the South Pacific from the equator to the Southern Ocean. These are the focus of the present study.

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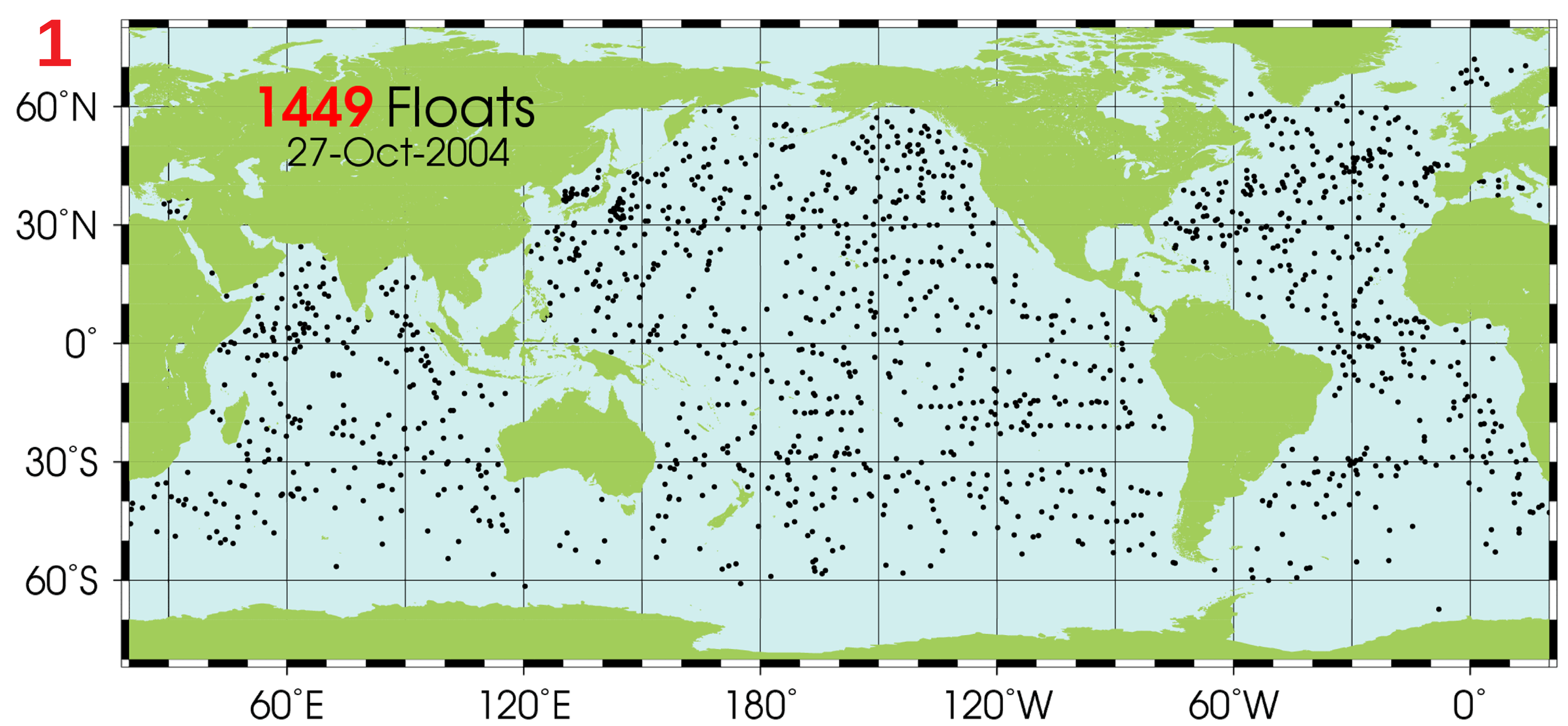

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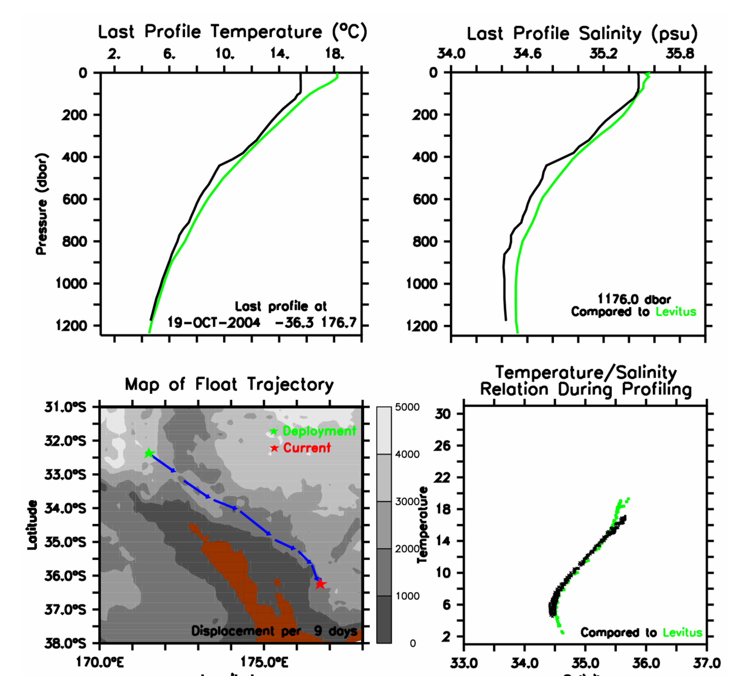

Argo floats provide T and S profiles and 1000 m reference velocity every 10 days. This float is following the East Auckland Current.

Ocean circulation: 10-year spin-up of the deep subtropical gyre seen by Argo and altimetry:

The 2004 Argo dataset reveals a spin-up of the South Pacific subtropical gyre relative to WOCE transects a decade earlier. This dynamical signal is seen in anomalies of dynamic height of 2-3 dyn cm at 1000 db/2000 db (FIG 3), increasing to about 10 dyn cm at the sea surface (FIG 4, upper). A similar 10+ cm anomaly is seen in altimetric sea surface height (FIG 4, middle). Interestingly the sea surface anomaly is mainly an expression of steric variability well below the surface layer, amounting to spin-up of the deeper portions of the gyre by about 15%. The maximum sea surface anomaly is found at 40°S, near the center of the deep subtropical gyre. The corresponding anomaly in water column heat content may account for the finding of Willis *et al* (2004) that the maximum in zonally averaged global heat content increase during the last decade was 4 W/m² at 40°S. Global ocean warming of 0.9 W/m² over the past 10 years (Willis *et al*, 2004) is redistributed by time-varying ocean circulation to produce regional patterns of variability. Consistent with the observed spin-up of the gyre, wind stress curl in the South Pacific was greater during the decade 1994/2003 than during the previous 10-year period (FIG 4, lower) according to NCEP reanalysis.

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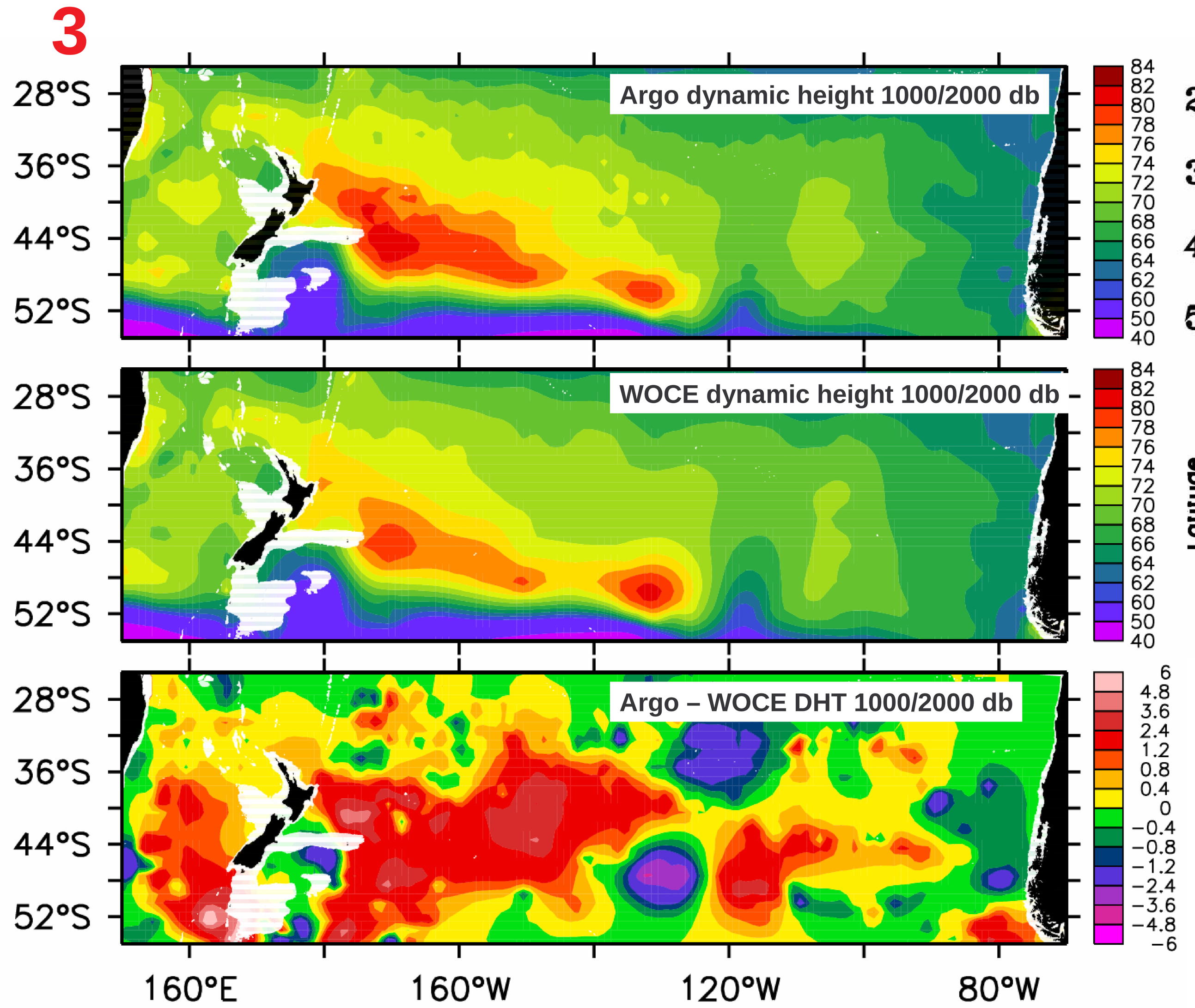

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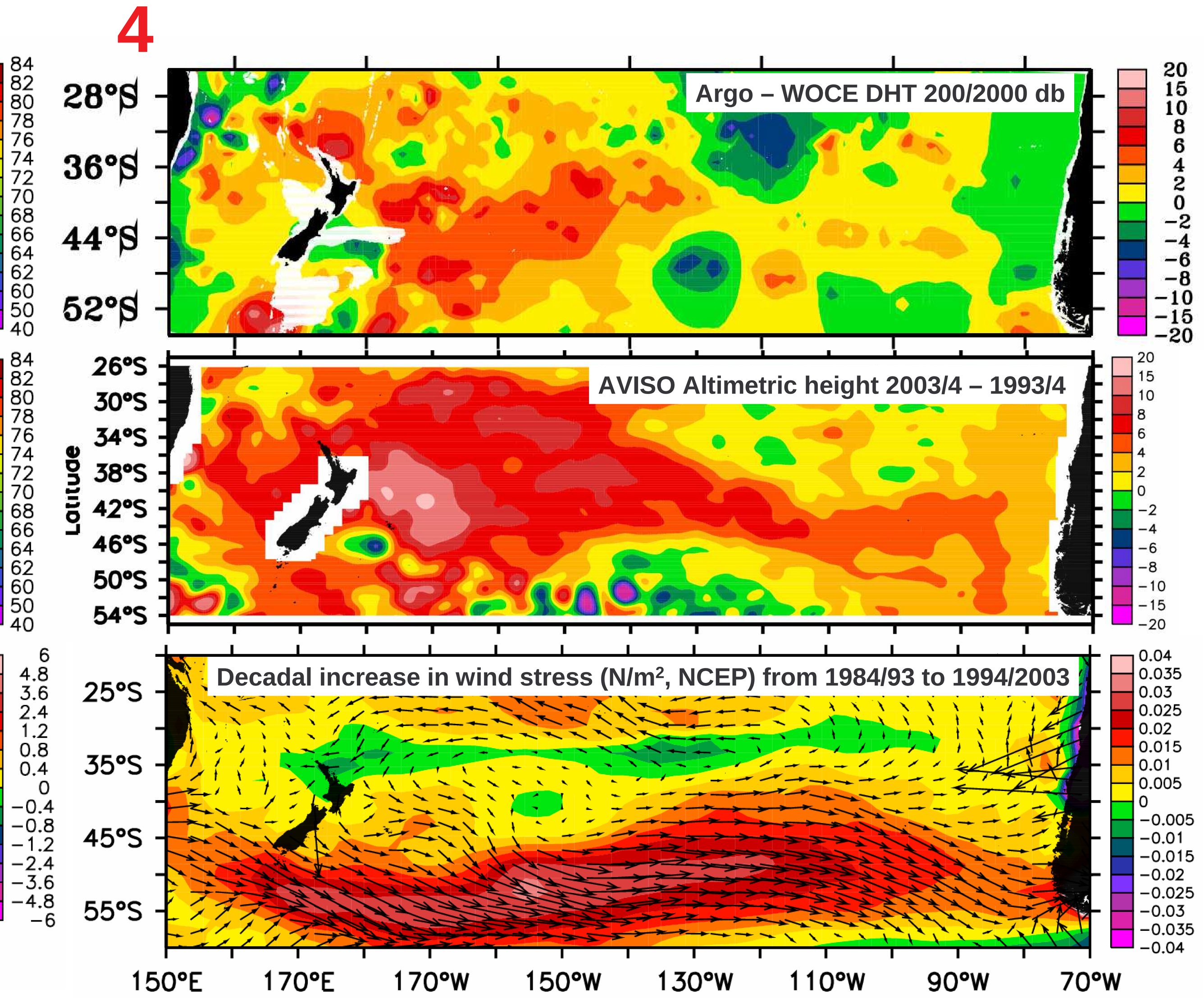

Freshening of intermediate waters:

A freshening of intermediate layers in the southern hemisphere was described by Wong *et al* (1999) based on comparison of WOCE data to earlier (sparse) transects. The Argo dataset provides much better spatial definition of the freshening signal, and also confirms that it continues in the post-WOCE era. At middle latitudes, fresh anomalies of about .03 psu, relative to the WOCE 1991-1994 data, span the South Pacific basin at densities of 26.8 to 27.0 (FIG 5). Shallower waters show stronger, patchier anomalies (FIG 6). A number of questions are addressed by the Argo dataset with respect to the salinity signal, including long term P-E variability, northward transport of salinity anomaly, and the anomaly's effect on sea surface height.

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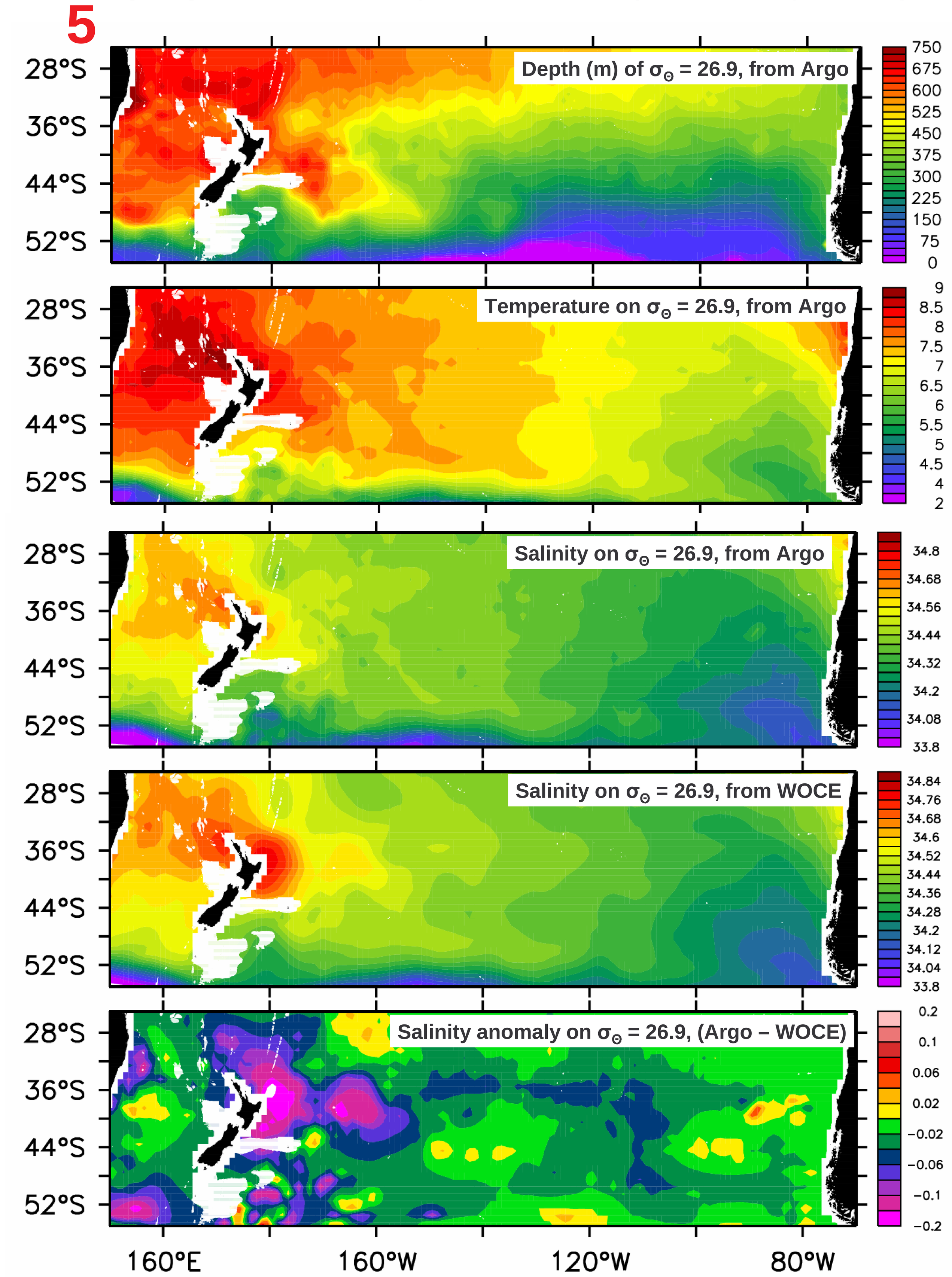
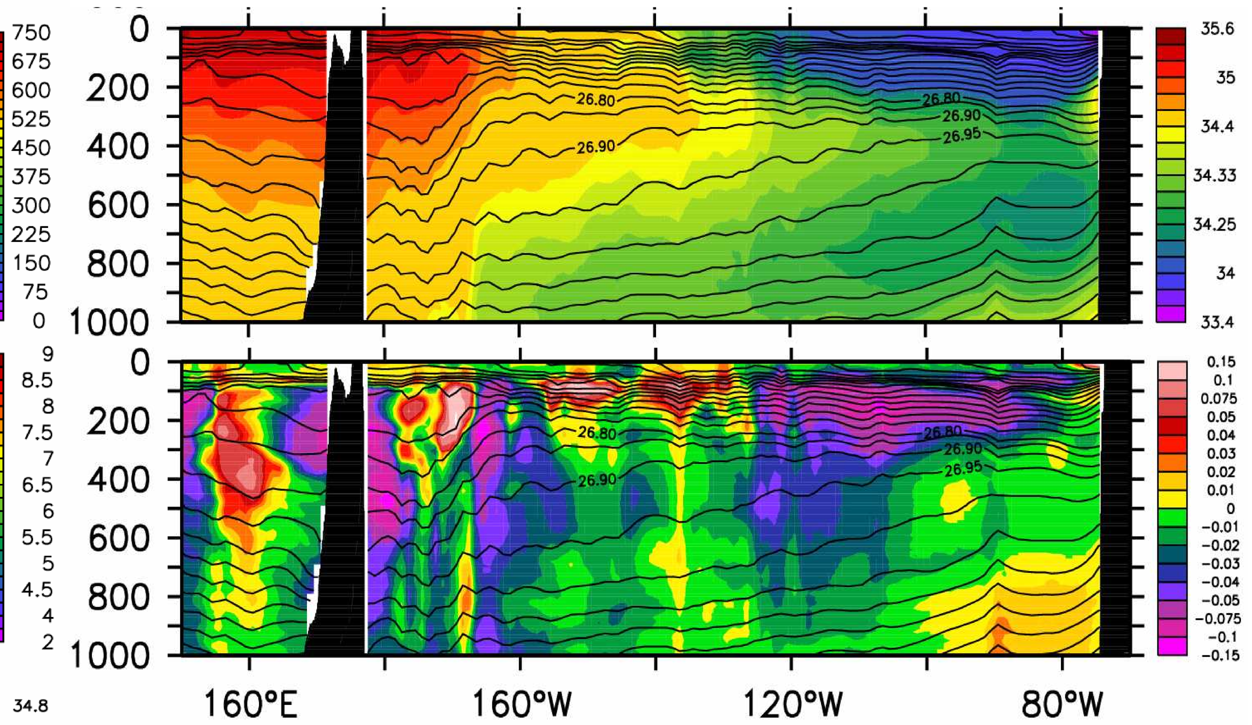
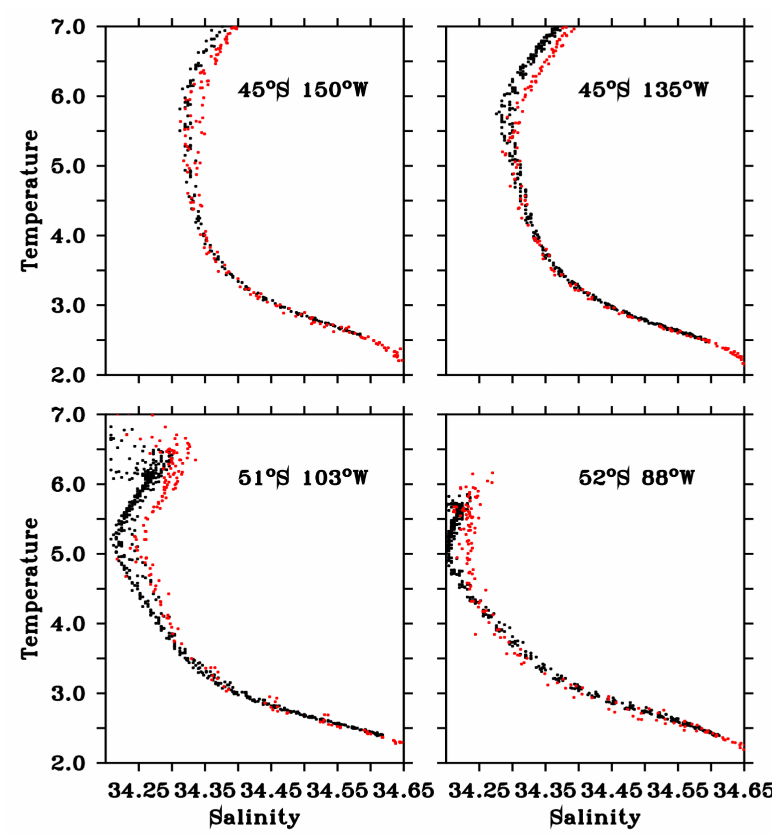


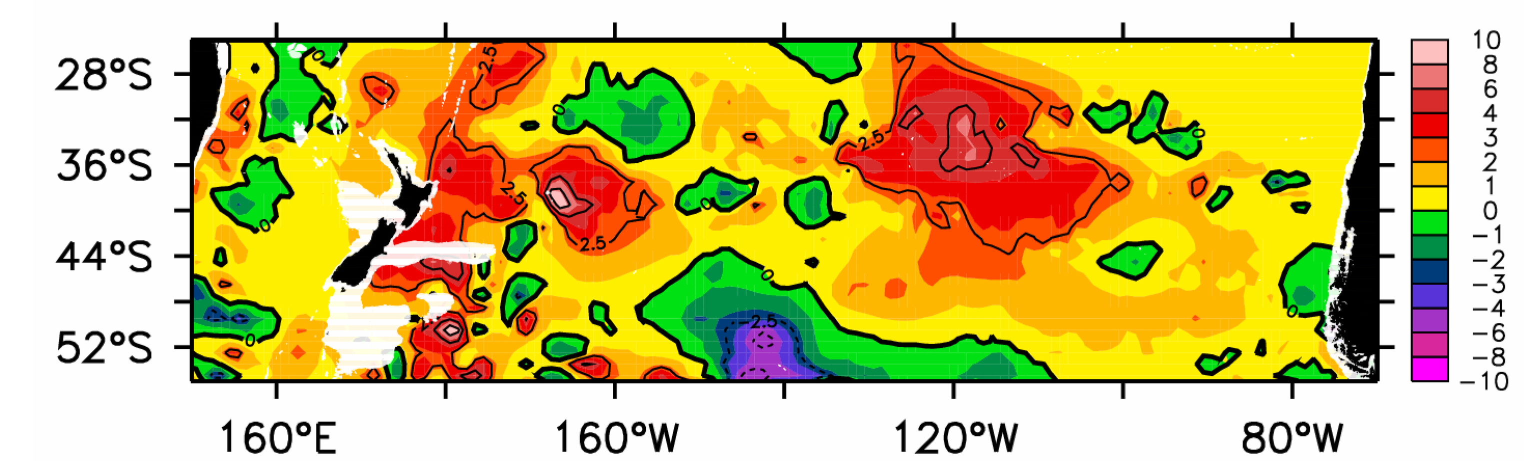


6 Upper: Density (σ_Θ, contours) and salinity (shading) along 40°S from Argo.
Lower: Salinity anomaly (Argo – WOCE) along 40°S.



7 T/S diagrams from Argo float profiles located near WOCE lines show consistent fresh offsets at temperatures warmer than 5°C. All floats used here were new enough so that drift in salinity calibration was not significant.

The salinity signal in sea surface height:



8 The effect of salinity anomaly on sea surface height is calculated as the dynamic height 0/2000 db due to Argo - WOCE T/S anomalies. Anomalies relative to pre-WOCE datasets are larger. A conclusion is that data assimilation systems lacking accurate salinity will incur significant systematic errors due to incompatibility between sea surface height and subsurface density.

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