STS: An Instrument for Extending ARGO Temperature and Salinity Measurements through the Sea Surface

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Introduction

Measurement of sea surface temperature and salinity provide ground truth for satellites, including the upcoming Aquarius Sea Surface Salinity Mission, but also provide key data for determining meteorological fluxes of heat and water. The SBE 41CP CTD, installed on many Argo floats in the world's oceans, is configured and pumped to ensure the highest quality data. To avoid degrading the salinity accuracy by ingesting sea surface contaminants, the pump is turned off at approximately 5 decibars beneath the surface as the Argo float ascends. The trade-off for achieving sensor stability over the life span of the Argo float was the forfeiture of very-near-surface temperature and salinity. To address this need, Sea-Bird Electronics has developed a conductivity sensor designed to make temperature and salinity measurements extending through the sea surface. The sensor, called the STS (Surface Temperature Salinity sensor), has an accuracy goal for satellite ground truth of 0.1 psu, and is capable of an order of magnitude better for assessing surface fluxes.

How Does STS Stay Calibrated?

- STS is a second, free-flushed, conductivity sensor, used in conjunction with the SBE 41CP CTD. Its calibration is expected to drift from fouling as it measures up through the ocean surface film.
- Overlapping data acquired with both conductivity sensors allows the STS calibration to be adjusted, profile by profile, to the stable and accurate 41CP.
- STS is situated next to the 41CP.
  - It samples concurrently at 1 Hz with the 41CP near the float park depth (980-960 db) and again in the upper ocean (20-3 db) just before the 41CP is turned off.
  - STS continues sampling through the ocean surface and for approximately 500 seconds as the float prepares to transmit data.

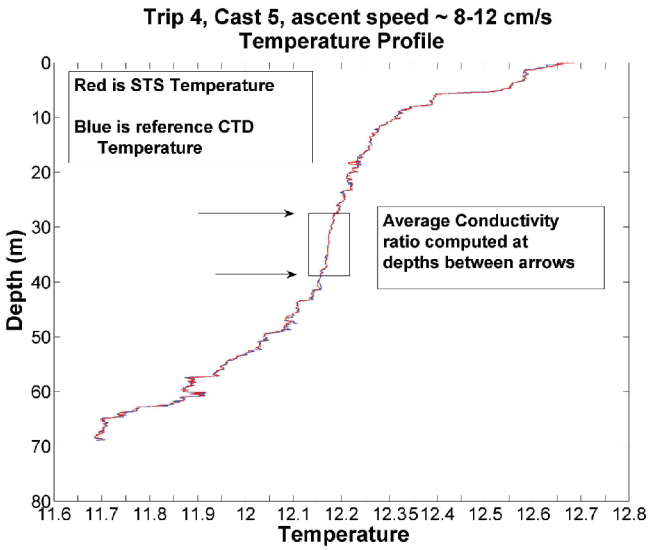
STS sensor module is within the smaller guard with the angled top

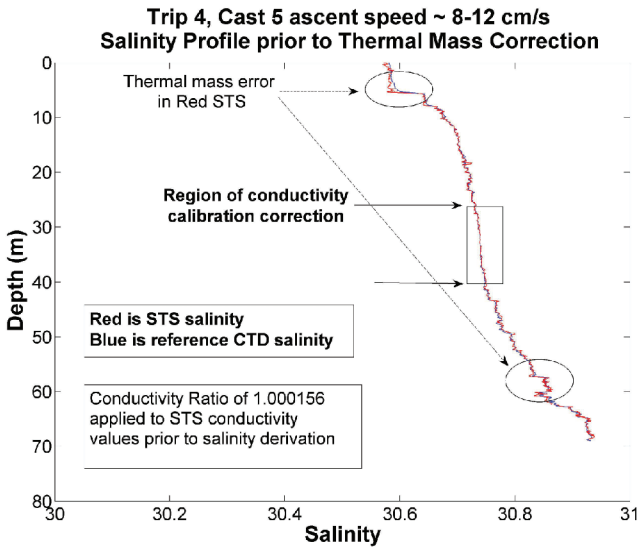
Sea Trials in Puget Sound: 0.01 PSU Accuracy is Realistic

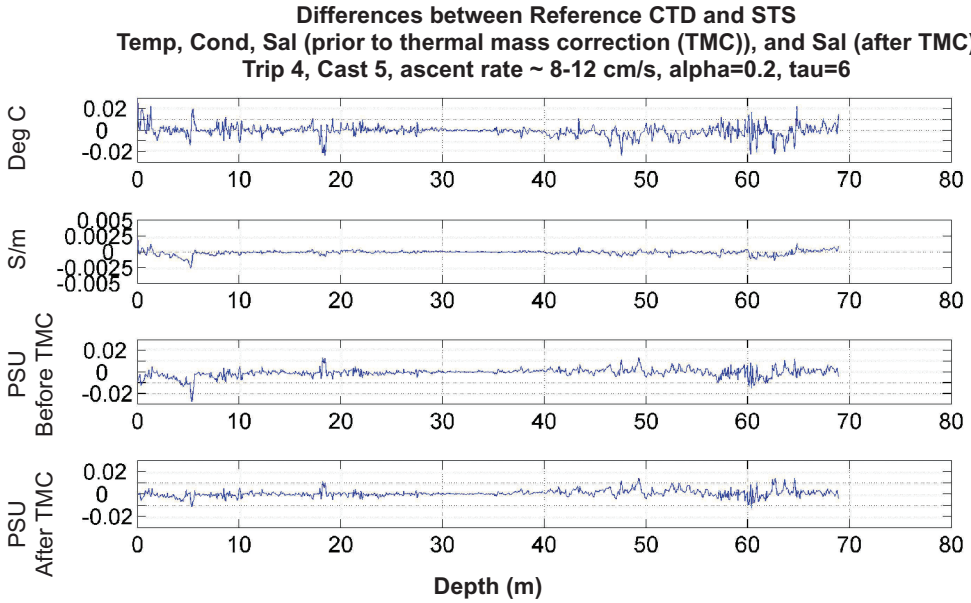
- During STS development, tests in Puget Sound were conducted against a high resolution SBE 49 CTD to assess the free-flushed STS sensor responses, and evaluate data processing corrections as functions of profiling speed.

- To correct for drift, STS conductivity data are multiplied by a factor to obtain agreement with the mean conductivity from the reference CTD in a region of low temperature gradient. The resultant mean STS-derived salinity is within 0.01 psu of the reference salinity along the entire profile.

- Dynamic corrections, which are a function of profile speed (CT alignment, response-time matching, and thermal mass corrections) bring STS values to within 0.01 psu of the reference CTD in regions of steep salinity and temperature gradients.

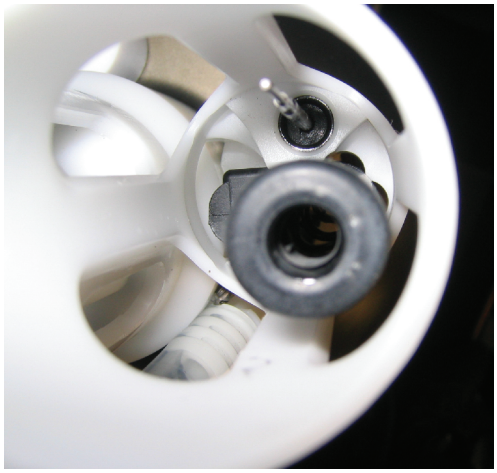






First Deployment in the North Pacific

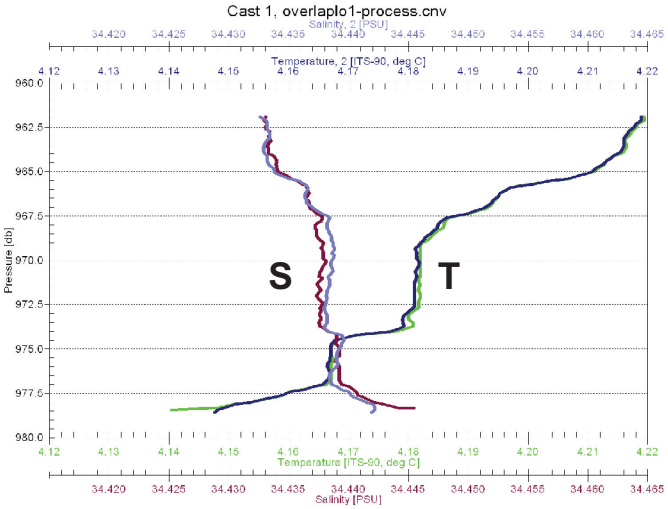
Float 5131 equipped with an STS sensor was deployed off Hawaii HOT-ALOHA time series station in late December 2007 by Dr. Steve Riser's group at University of Washington. As of February 26, 2008, 20 profiles have been obtained.



Prior to deployment, the STS conductivity cell electrodes were damged in a testing procedure. Resultant ocean data have a fixed shift. However, flushing through the cell appears to be slower and is affecting the dynamic correction parameters. Nevertheless, the STS salinity accuracy is well within the Aquarius requirements (0.1 psu). In fact, the salinity differences between processed 41CP and STS data are within 0.005 psu.

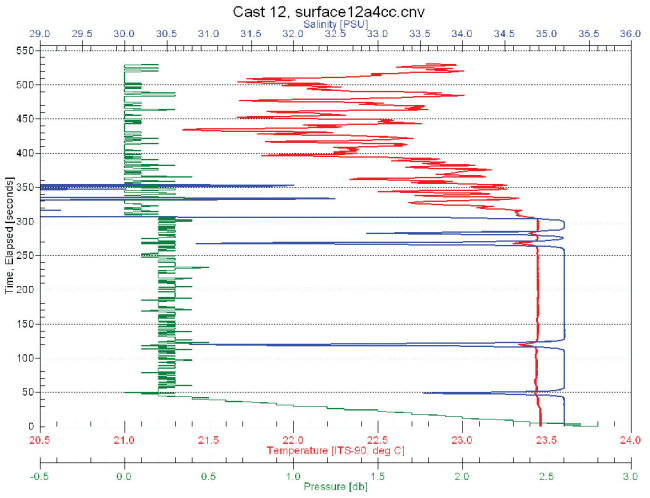
1st STS Ocean Profile

- In the deep overlap section used for calibration adjustment, dynamic corrections remove salinity spikes and thermal mass error to better than 0.005 psu.
- With those bias errors removed, gross calibration adjustment of STS to 41CP conductivity yield mean salinity differences of 0.002 psu.



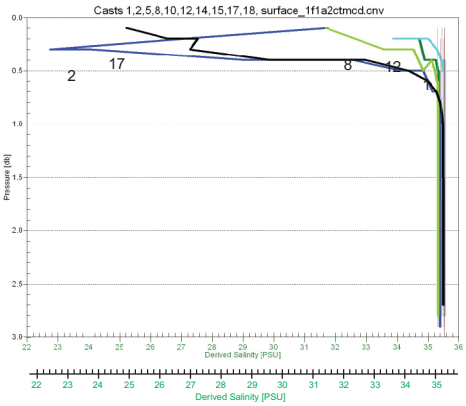
Float Surfacing and Surface Data

- A time series of pressure data (green) as the float surfaces shows a clean ascent to the surface (0-50 sec). We truncate the surface profile at the first pressure inversion, indicating the float is beginning to bob. In the first two winter months and 18 profiles, this scheme truncated profiles within 0.2 dbars of the ocean surface.
- The float bobs for approximately 300 seconds with the STS CTD just submerged, then an air bladder inflates to boost the float and antenna out of the water for telemetry (>300 sec).
- In the STS surfacing profile, a fresh salinity layer (blue) with a cooler temperature (red) is evident. Cooler air temperatures are seen (400 sec) when the STS CTD comes out of water, for telemetry.

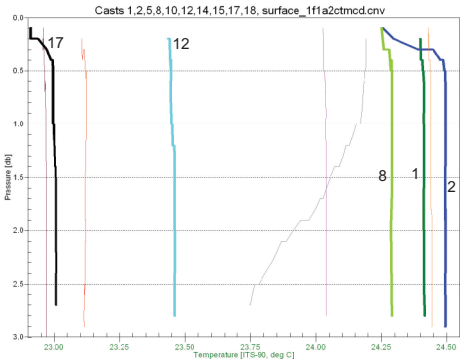


Judging the STS Instrument Performance from Features of the first 18 Profiles

We look here at some oceanographic features in STS surface profiles to evaluate the instrument performance. *A science talk about the data is being given at this meeting by Riser, S.C. and Lagerloef, G. (abstract 081-2411) "High-Resolution Surface Salinity and Temperature Measurements from Argo Floats".*

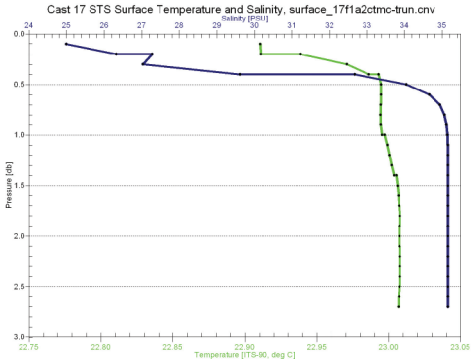


- 12 of 18 profiles exhibit relatively active mixed layers where STS determinations of temperature and salinity to 0.2 dbars are well within the Aquarius sea-surface salinity requirement of 0.1 psu.
- 5 of 18 profiles exhibit a fresh water rain signal trapped within 0.5 meters of the surface.



- The fresh salinity signal is not a computational artifact, and dynamic (spiking) error is not causing the signal.
- The fresh salinity signal could be caused by air bubbles or debris in the conductivity cell, but other profiles exhibiting the most active mixed layers, with presumed higher winds and waves, do not have negative salinity anomalies from bubbles.

Each of the "rain" water profiles is accompanied by a cool temperature anomaly that scales roughly with the salinity defect and has the same sign as the atmospheric temperature difference.



Rainfall estimates implied by the depth and salinity dilution are plausible but high in two cases.

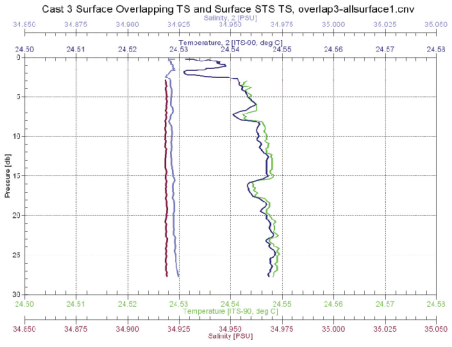
- The highest 6-hour rainfall totals at the ALOHA mooring are 3.5 cm in Jan-Feb 2008.
- Because of present uncertainties about secondary circulations near the float as it surfaces, the structure of the rain signature and the implied rainfall estimates must be viewed cautiously, but we believe the STS is seeing a real rainwater signal.

$$V_0S_0=S_r(V_0+V_r) \Rightarrow V_0(S_0-S_r)/S_r = V_r$$

Profile	Delta Salinity	Depth	Rainfall
#2	10 psu	0.3 m	12 cm
#17	8 psu	0.3 m	9 cm
#8	2 psu	0.3 m	2 cm
#12	1.25 psu	0.3 m	1 cm
#1	0.5 psu	0.3 m	0.4 cm

Fine-scale structures

- STS surface profile 3 is shown here with accompanying SBE 41CP CTD data. Salinity is well mixed (<0.005 psu). The mixed layer appears to be undergoing surface cooling and convection. Possible convective plumes with temperature anomalies of 0.01 deg C and larger are embedded in a more turbulent mixed profile.
- The concurrent capture of these features by both the 41CP and STS CTDs indicate the STS is capable of reporting real oceanographic features at 0.01 psu and 0.01 deg C levels.



Conclusions

- Preliminary data from the first ocean deployment indicate the STS delivers Aquarius-quality data with little effort.
- The STS CTD for Argo floats can be corrected to an accuracy better than 0.01 psu in overlapped regions with the SBE 41CP CTD.
- Surface TS data can be obtained to at least within 0.2 meters of the surface.
- The first deployment seems to show cases of rainwater trapped in the upper 0.5 meters of the ocean. More subtle features of a surface-cooled and convecting mixed layer are also evident. These indicate the STS might usefully assess several ocean surface phenomenon.
- It is possible that secondary circulation near an ascending float distorts features within 0.5 meters of the ocean surface. We will analyze, with scientists, whether the STS design or positioning needs to be reconsidered.

Acknowledgements

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