Remote Measurements & Research Company
214 Euclid Av.
Seattle WA 98122
michael@rmrco.com

Version 2

ROSR INSTALLATION REPORT:
ROSR IN SPURS-2

January 4, 2017

Figure 1: ROSR with rain baffle.

Abstract

This document is a brief description of the Remote Ocean Surface Radiometer (ROSR) instrument, SN#3, deployment in the SPURS2 cruise from Aug 12 to Sep 23, 2016 in the equatorial east Pacific. ROSR provided sea surface skin temperature (SSST) to support the salinity and other measurements taking place. The ROSR system was installed and running by 8/12 and continued reliably for the next days of the experiment. Normally, ROSR employs a sensitive rain sensor and closes a weather shutter door at the first onset of rain. For SPURS2 a fitted rain shield was tested so SSST measurements were possible during rain events. The rain shield was a success and after 8/24 measurements were made continuously without rain interrupts.

The final clean time series has 10260 points from 2016-08-14 (227) 03:01:58.0 to 2016-09-20 (264) 23:41:46.0. The sample rate was 283 sec (4.72 min). The only sources of data loss were times of power interruption from GFI failure. On 8/26 the GFI was replaced and ROSR was plugged into the same UPS used by the hi-power Laser system.

Clean, hand-edited data files are `rosr_spurs_clean.txt` and `ROSR_SPURS2_clean.mat`.
These are available on line at Remote Measurements & Research Co. LLC. Please contact the company for password details.

1 ROSR and data collection

The Remote Ocean Surface Radiometer (ROSR, pronounced ross'er) provides NIST-traceable sea-surface skin temperature (SSST) measurements in support of air-sea interaction studies or satellite calibration and validation activities. Its operational goals are to make observations autonomously from a ship at sea for six months and with a NIST traceable accuracy of +/-0.1 C.

A tiny hole in the inner scan drum looks into a 45° mirror that reflects incoming infrared radiation into the Heitronics IR radiometer inside a waterproof housing, through a transparent window. The scan drum can be pointed to the sea surface at a variety of angles, at the sky, and back into two high precision black-body cavities. This cycle allows correction for reflected sky radiance in the downward looking view. The system is self calibrating. A small amount of contamination can be tolerated by this open air design.

ROSR incorporates a pitch-roll sensor. A measurement cycle is completed once each 285 sec. A sensitive optical rain detector triggers closure of a flap shutter in the presence of precipitation

SPURS research is interested in the effects of rain on the upper ocean. Accordingly, a special rain baffle was designed and fitted to the ROSR main plates (Fig. 1).

An Infrared Seasurface Temperature Autonomous Radiometer (ISAR) from WHOI was also deployed on a shelf just below ROSR. However, that unit did not work properly, failed on Aug 25 and was removed.

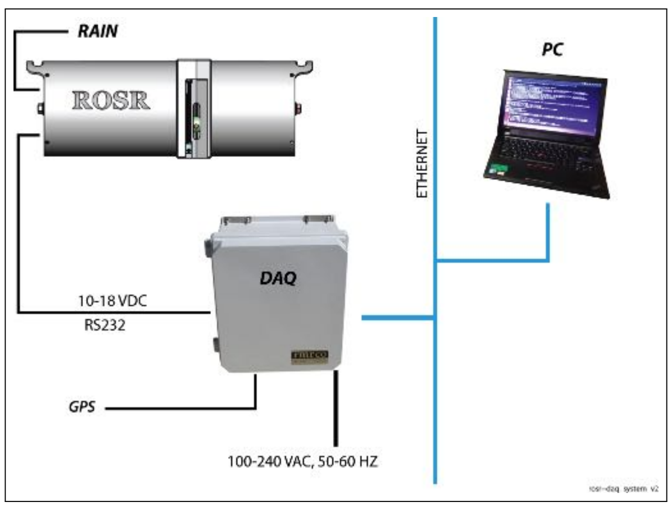

Figure 2: ROSR DAQ system.

The schematic shows the local area ethernet network used for ROSR installations. The Data Acquisition system (DAQ) electronic box was mounted on the ROSR frame. Power and ethernet cables were run from the scientific van to the frame ($\sim$ 25 m). The Lenovo T430 PC with data collection software was mounted in the scientific van.

2 Ancillary Data

1. OSSPRE 2m probe — `osspre2m_flat.txt, osspre2m_flat.mat`
   SBE39 thru-hull probe at 2 m depth. A software bug detected and all records prior to 2016,9,12,5,32,0 were adjusted by -9 min.

2. OSSPRE 3m probe — `osspre3m_flat.txt, osspre3m_flat.mat`
   SBE39 thru-hull probe at 3 m depth. A software bug detected and all records prior to 2016,9,12,5,28,0 were adjusted by -9 min.

3. TSG Temperature 5m bow — `met_flat.txt, met_flat.mat`
   The ship provided a file called "met" with about 80 variables. The met file was sorted for pertinent variables including the Thermosalinograph (TSG) temperature measurement in the bow. The intake hole is at 5 m depth in the bow. Note, the temperature sensor is after an intake tube and the water pump so is expected to be at high. After considerable comparison with the 2 and 3 m osspre probes a correction of +0.05 might be appropriate. However, that correction was not made for these files.

4. Seasnake (Edson) — `ed1min.mat`
   C. Clayson and J. Edson mounted a complete suite of meteorological instruments. The seasnake provided by J.Edson was a precision thermistor in a brass slug. It was suspended from a 3m staff off of the port side of the ship amidships. It was usually in the bow wake. Note that the ROSR ssst measurements were taken to starboard. At the time of this writing the 1-min mat file has 37440 points from 2016-08-22 (235) 00:00:31.0 to 2016-09-17 (261) 00:00:31.0. See figure 4.

5. XBT cast:
   The expendable thermograph (XBT) was dropped from the stern at approximately 21Z. Data were recorded as it fell to around 1000 m. The first 5–10 m are questionable.

6. CTD cast:
   The conductivity-temperature-depth (CTD) cast was taken routinely. The cast began with a soaking at 10 m after which the unit was brought to the surface, probe depth 2 m, then lowered. The maximum depth was typically 1000m. For this cast the ship was fully stopped.

7. uCTD cast:
   The Underway CTD cast was made from the fantail while the ship was underway. As with the CTD it provided a profile of conductivity, temperature and pressure from near the surface down to 500m. The top 10m of these data are considered to be in error.

8. Seasnake (Schnaze):
   The seasnake provided by J.Schnaze was a large rubber hose hanging from a 10 m boom. A SBE probe was fitted into the very end of the hose. Water was pumped on board through holes just behind the probe. This snake suffered in that it was heavier than sea water and thus when the ship slowed or stopped it hung vertically so the probe was deep, ~ 3 m below the surface.

3 Data

Shown below is the ship trackline, 18174 points from 2016-08-14 (227) 03:01:58.0 to 2016-09-20 (264) 23:40:58.0

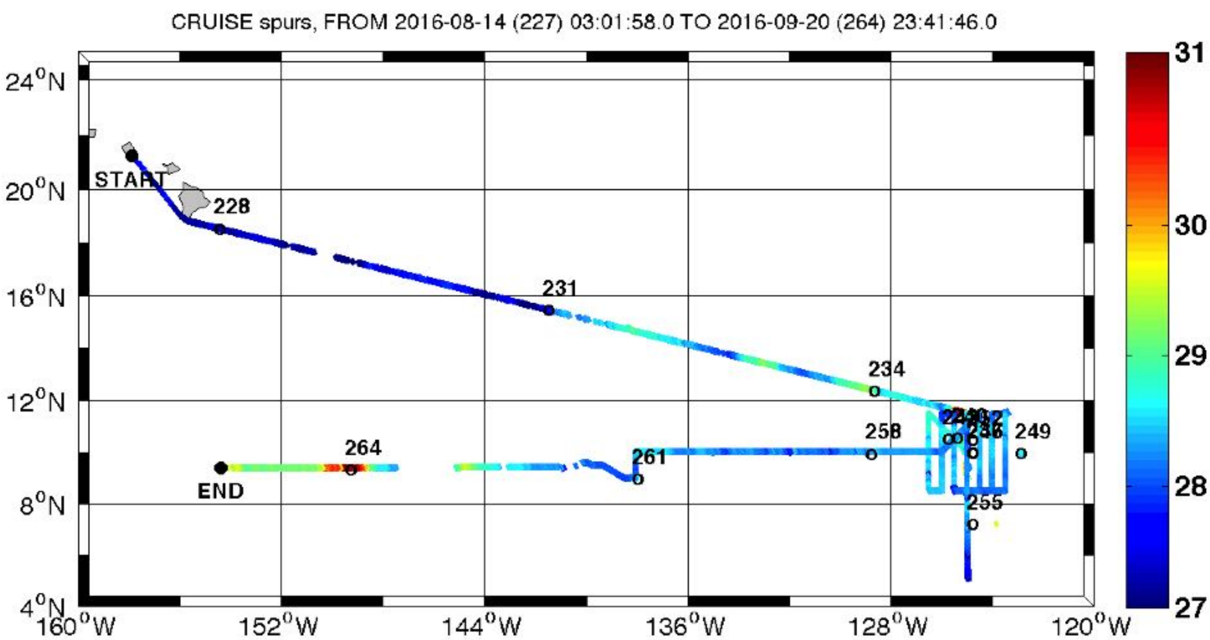

Figure 3: Trackline showing skin temperature and with year days noted.

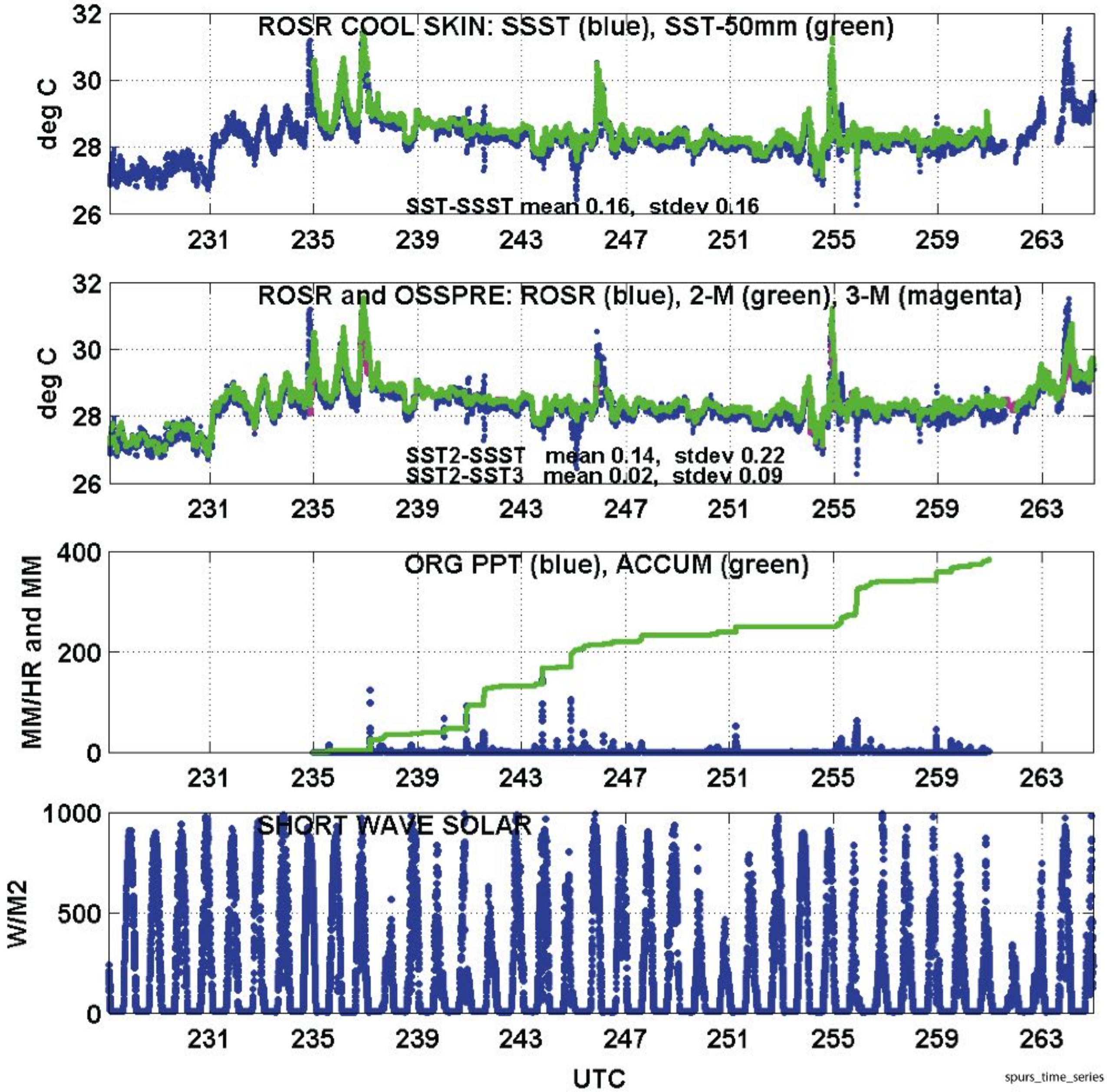

Figure 4: Timeseries for the entire cruise: 2016-08-14,030158 (JD 227) to 2016-09-20,234058 (JD 264).
Top panel—Compares the ROSR ssst with the Edsen sea snake at approximately 50 mm depth.
Second panel: Compares ROSR ssst with the OSSPRE bow probes at 2 and 3 m depth.
Third panel: Shows rain rate and accumulated rain fall from the ORG.
Bottom panel: Shows the solar irradiance.

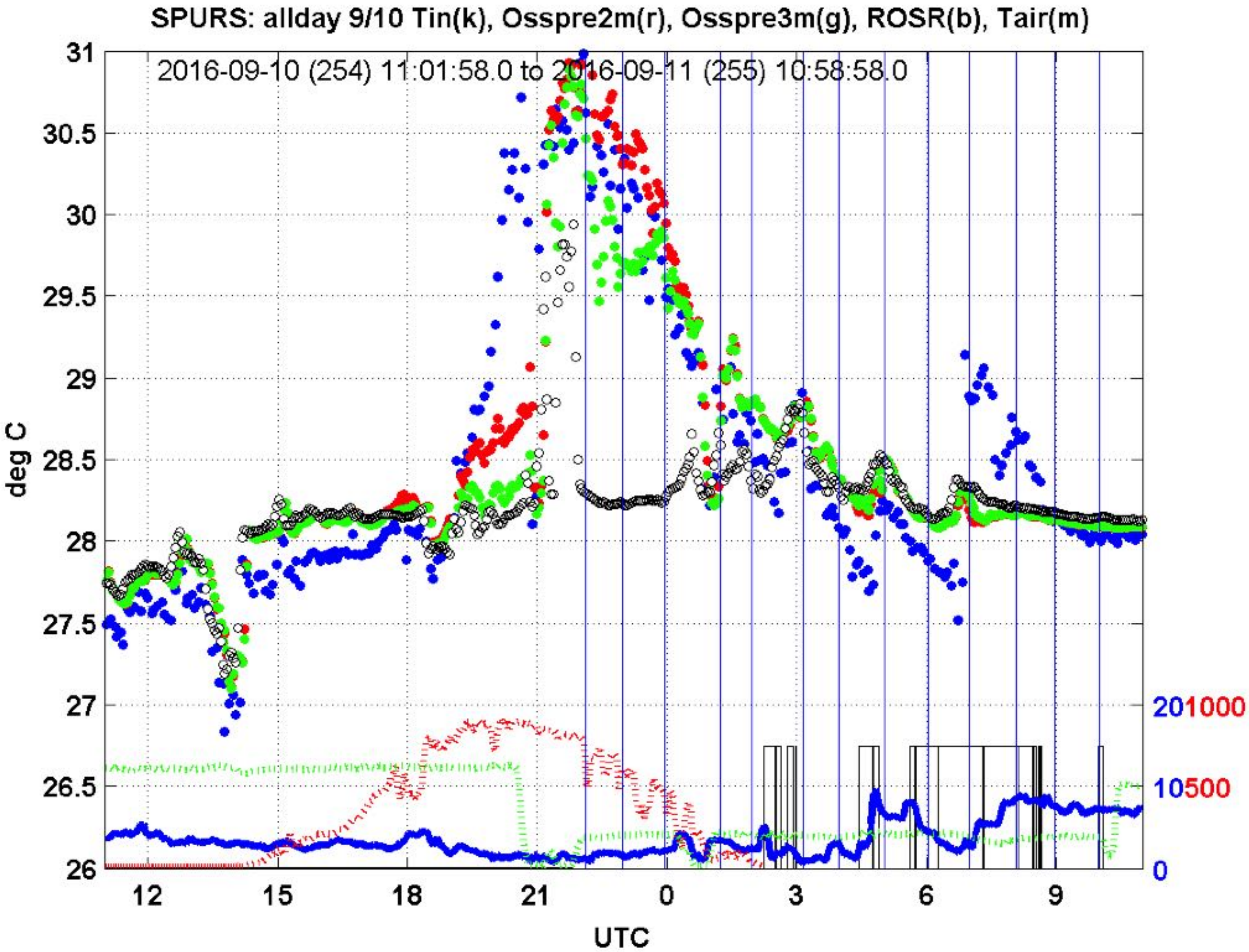

Figure 5: Time series 2016-09-10 (254) 110158— a heated surface layer interrupted by rain.
Upper: Shows the ROSR ssst (blue), snake sst-50mm (open circles), Osspre sst-2m (red), Osspre sst-3m (green).
Lower: Ship speed over ground, kts (green dashed), solar irradiance (red dashed), True wind speed, m/s (blue), and rain presence (black binary). Before sunrise the surface layer was well developed with a cool skin and well mixed below. During mid day the diurnal surface layer developed with a depth dependent time lag. At about 20.5 h the ship speed was reduced which resulted in a mixing of the surface layer. After 02h rain and variable winds complicated the profiles.

APPENDICIES

A Log

Installation Log (Times in UTC, Year 2016)

Aug 11 0000	Reynolds arrives in Honolulu and begins the frame installation.
Aug 11 2300	Frame complete. Install ROSR
Aug 15 0227	Ship departs, begin SPURS2.
Aug 15 21∼	Ground fault power failure. System was down about 3 hrs.
Aug 16 1923	Install rain shield. No noticible difference.
Aug 17 AM	Rain shield came off in the night. We have been having winds and bumpy seas.
Aug 18 1810	Rain shield re-installed.
Aug 22 0500	The internal laser was used to confirm alignment on the ship.
Aug 24 0338	The weather shutter was disabled.
Aug 24 0400	Heavy rain for more than one hour.
Aug 24 1251	Shutter was enabled while rain data are analyzed.
Aug 25 1800	It was noticed the ISAR had failed. Looks like a shutter jam.
Aug 26 03∼	Another ground fault failure disruptured data collection. 13 hrs data loss.
Aug 26 2300	Replaced GFI plug and connected to UPS.
Aug 27 0200	Rain performance looks good. Disable the shutter.
Aug 27 1930	System off to work on ISAR.
Aug 27 2030	Back on. ISAR operation terminated.
	Continue daily data collection and QC
Sep 17 1215	Enable rain shutter.
Sep 20 2340	End data collection

B List of on-board scientists

```
Hasson Audrey audreyhasson@gmail.com
Edson Jim james.edson@uconn.edu
Graham Raymond raymond.graham_jr@uconn.edu
Drushka Kyla kdrushka@apl.uw.edu
Clark Dan clarkdan@u.washington.edu
Thompson Elizabeth elizjthom@gmail.com
Jessup Andrew jessup@uw.edu
Reynolds Michael michael@rmrco.com
Pietro Ben bpietro@whoi.edu
Hasbrouck Emerson ehasbrouck@whoi.edu
Hodges Ben bhodges@whoi.edu
Levang Sam slevang@mit.edu
Meyer Andrew andrew.meyer@noaa.gov
Lindstrom Eric eric.j.lindstrom@nasa.gov
Schnaze Julian jschanze@esr.org
Sprintall Janet jsprintall@ucsd.edu
Kawamoto Spencer skawamoto@ucsd.edu
Trafford Leah trafford@ldeo.columbia.edu
Volkov Denis dlvolkov@gmail.com
```

C On Emissivity

Getting the correct emissivity less straightforward than many people assume. The IR emission from a black body is σT^4 and this is exact, coming from the wavelength integral of Planck's Function. But there are no black bodies in nature and so the emission is scaled by epsilon, the surface emissivity. The ocean surface is a good emitter with a broadband emissivity of 0.99 (see www.cs.odu.edu/ mln/ltrs-pdfs/NASA-99-tp209362.pdf), but this is probably a high estimate. The T in $\epsilon\sigma T^4$ should be the skin SST of the ocean, which can be from -0.5 to + 6K different from the conventional "bulk" SST used in models or conventional measurements. The smaller negative offset is universal, and is wind speed dependent, and the larger positive values are less common and depend on the growth and decay of diurnal heating signatures, which themselves are strongly dependent on wind speed. Of course, smaller positive values are much more common than larger ones. There is a difference in the skin SST and the near surface air temperature, and it is nearly universal that the air is cooler than the ocean skin, typically by 1K. For several decades there was a belief that there was a wind speed dependence of the effective ocean emissivity, but our measurements and subsequent modelling have shown this to be wrong, and the wind speed dependency is negligible.

For conservation of energy, there is a $(1 - \epsilon)$ times the atmospheric emission component of the upwelling IR radiation just above the ocean surface, and this of course is dependent on T and Humidity of the atmosphere. Since the atmospheric transmissivity is wavelength dependent, this atmospheric component is also spectrally dependent, and so introduces a dependence on the T and H profiles.
2012-1-17, P. Minnett, pers. comm

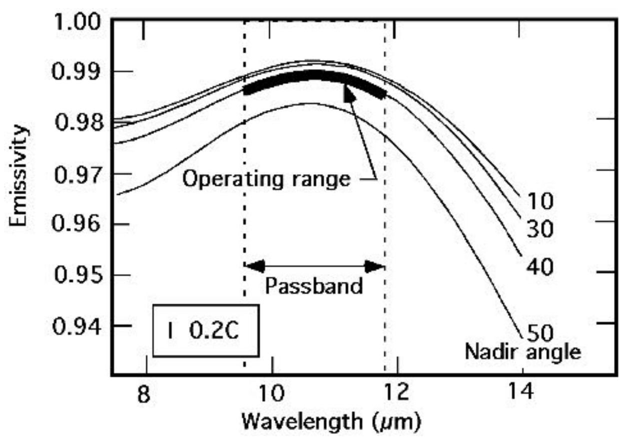

Figure 6: Ocean emissivity as a function of wavelength and pointing angle. The ROSR pointing angle is 45°. The heavy line shows the approximate band pass for the Heitronics IRT and the thickness of the line shows the pointing angle range for a ±1°C error.

D Calibration

The Hart Scientific calibration bath at UW APL was used to calibrate the ROSR before and after the cruise.

D.1 Pre-cruise calibration

Remote Measurements & Research Company
214 Euclid Av.
Seattle WA 98122
michael@rmrco.com

CALIBRATION RESULTS

Instrument	Remote Ocean Surface Radiometer (ROSR)
Serial Number	3
ID	160725
KT15.85	11935
Lead Tech	J. Reynolds
Calibration Start Time	20160724,2300
Calibration End Time	20160725,2200
Location	UW APL
Calibration Type	Jessup calibration water bath.
Results	Attached sheets.
After calibration	UW Dockside Intercomparison then SPURS cruise.
Calibration Slope Correction	1.0084
Calibration Offset	0.116

DISCUSSION:

This is the first calibration of rosr3, newly constructed.

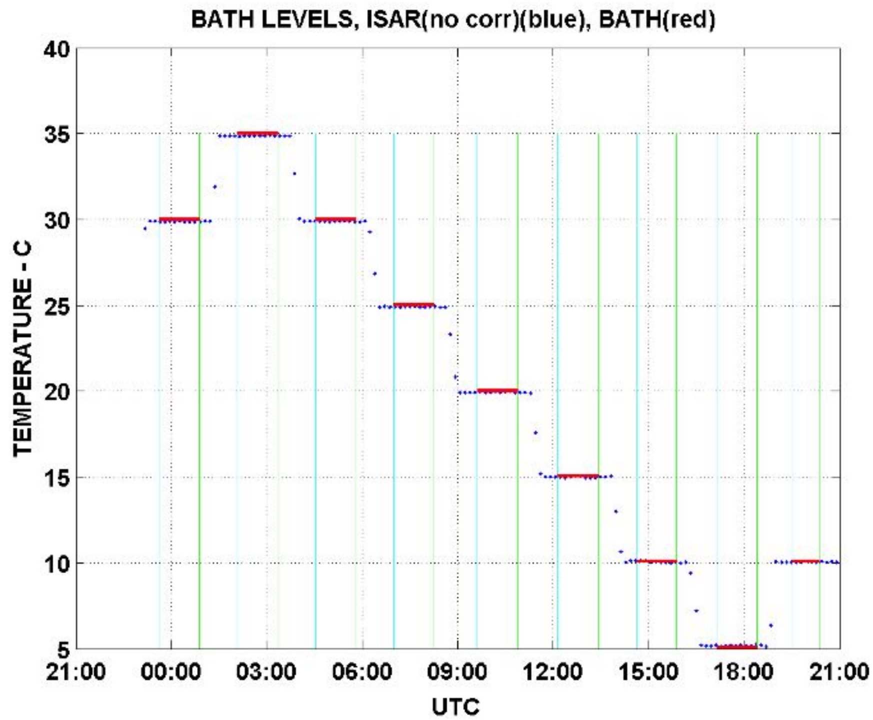

Figure 1: Blue dots are the computed T_{target} with no correction. The points are within 0.01 C of the set point. Cyan and green vertical mark the start and stop times at each set point by the bath.

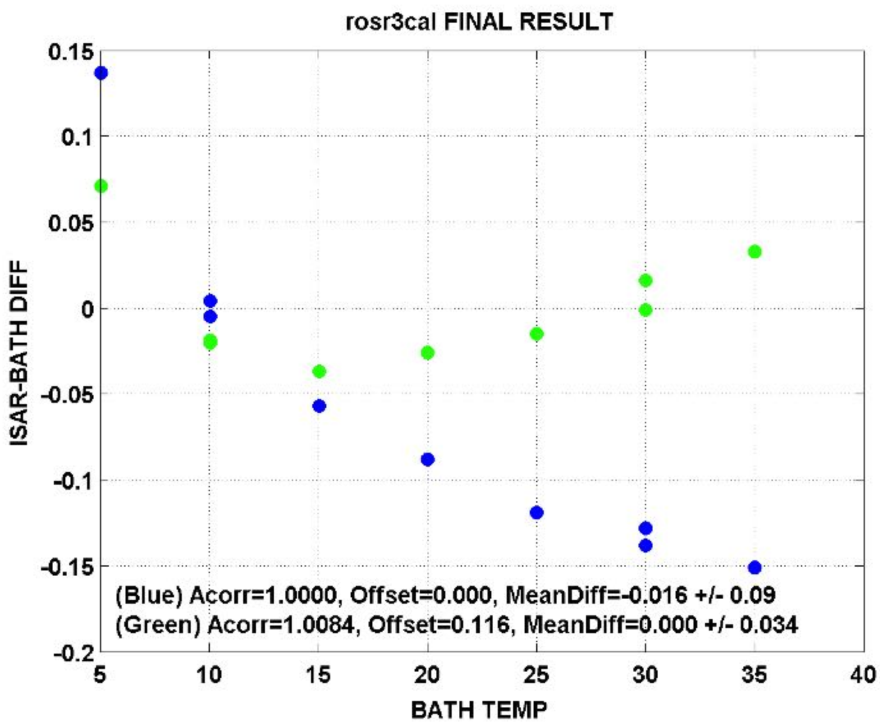

Figure 2: Final result

D.2 Post-cruise calibration

After the ROSR was returned to Seattle it was re-calibrated as before. The calibration coefficients were slightly different. As a check the entire SPURS2 timeseries was re-processed using the post-cal coefficients. The new timeseries compared to the original (new-old) 0.016 $\pm$ 0.054°C.

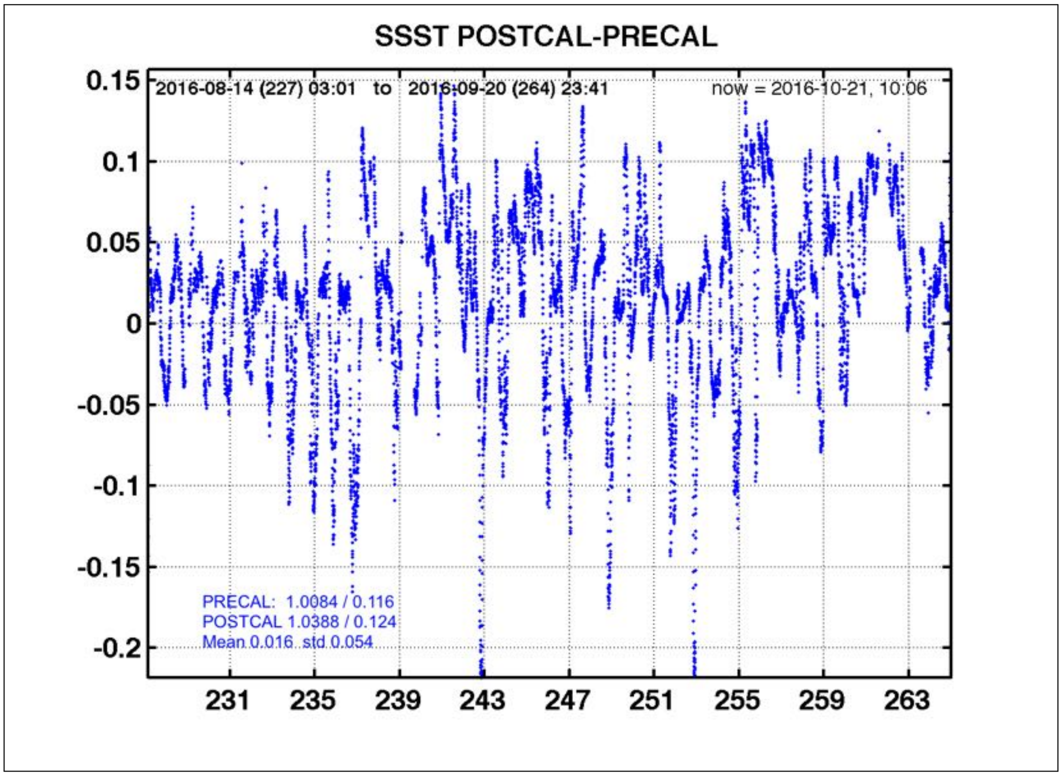

Figure 7: Postcal-Precal SSST differences.

E Post cruise inspection for water ingress

After ROSR was opened and examined for any signs of water ingress or water damage. The photos here show the exposed scan drum and the area around where water salt residue or damage might occur.

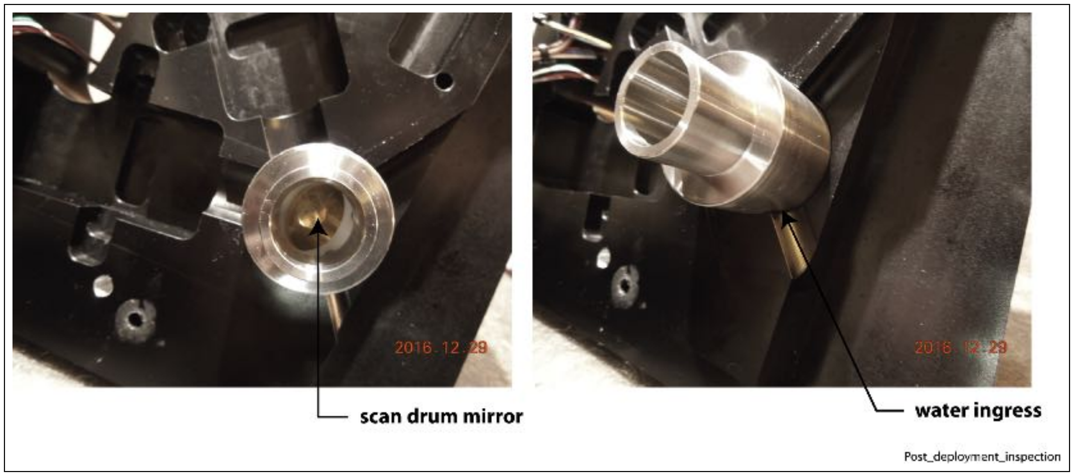

Figure 8: Examination for water ingress.