Examination of SAMOS Sea Temperature Biases

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Overview of SAMOS

- Since 2005, the Shipboard Automated Meteorological and Oceanographic System (SAMOS) initiative has collected and quality- evaluated meteorological and oceanographic observations from research vessels (RVs).
- Data averages are reported every minute (up to 1440 each day) and are subject to automatic quality control processes to test for reasonability, and validity in satisfying meteorological/oceanographic/climatological relationships.
- Select RVs also receive visual quality control testing meant to discover data issues that automatic tests fail to pick up.

Focus of This Study

- We look into specific RVs which feature two sea temperature (TS) sensors.
- These systems can consist of any combination of external intake, hull contact, and internal sensors (Fig. 1).
- Basic looks into the data reveal inherent differences between the two readings, some of which can occasionally spike to multiple ºC.
- We analyze the causes for these biases and their relationship to latitude, time of day, ship speed, and one of the TS readings.
- We also compare the performance of automatic quality control with visual between the RVs.

Fig. 1. Sea temperature instrumentation for the TG THOMPSON. Here, we have (a) internal thermosalinograph, and (b) intake sensor (located near the small hole in the upper half of the image).

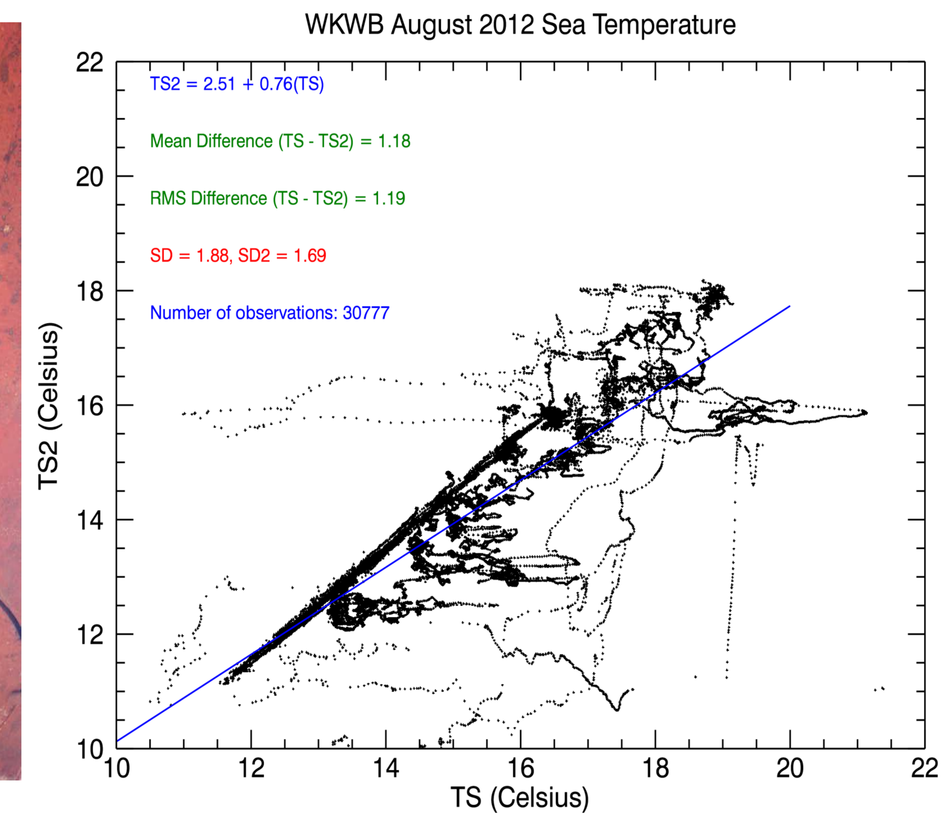

Fig. 2. Both sea temperatures for the NEW HORIZON (automatic QC), in August 2012. Here, irregular data pairs pass testing due to the fact that readings fall within climatological reasonability, leading to unexpected statistics.

Data Information

- Full dataset covers a timespan from 2008-2015, with individual RVs varying in their time coverage.
- Temperatures come in as individual elements of 1440-element arrays labeled "TS" and "TS2".
- RVs record data at latitudes extending from 60ºS to 85ºN.
- Each ship has one internal and one external TS sensor, with the external sensor being of the hull contact or intake subtypes (Fig. 1).
- Eight RVs are studied, 4 of which received visual quality control (all are subject to same automatic tests):
  - Visual: *FALKOR, HI'IALAKAI, HEALY, NANCY FOSTER*
  - Automatic: *ATLANTIC EXPLORER, ROGER REVELLE, NEW HORIZON, TG THOMPSON*

Methodology

- We compare temperature pairs recorded at the same time.
- If one or both of the measurements of the pair is either a missing value (-9999°C) or has a flag other than "Z" (Good data), the pair is discarded.
- Sea temperature scatterplots are produced for each ship for each month where data exists.
- Cumulative plots are also generated for each ship's full dataset to analyze the relationship of temperature differences with ship speed, latitude, sea temperature, and time of day.
- Basic statistics are produced, including the means, standard deviations, and RMS differences of each temperature category (Fig. 2).
- A separate set of cumulative plots is generated invoking a trim in which pairs whose difference is above 1ºC are discarded.
- Differences in mean temperatures will be calculated via (TS – TS2). If TS2 > TS, the difference is negative.
- Cumulative plots are color coded according to Table 1.

Table 1: Color coding rules for cumulative sea temperature plots

COLOR	YEAR
blue dashed line	2008/2009
green dashed line	2010
red dashed line	2011
orange dashed line	2012
purple dashed line	2013
red dashed line	2014 (first half of 2015 for *ATLANTIC EXPLORER and HI'IALAKAI*)
black dashed line	2015 (second half of 2015 for *ATLANTIC EXPLORER and HI'IALAKAI*)

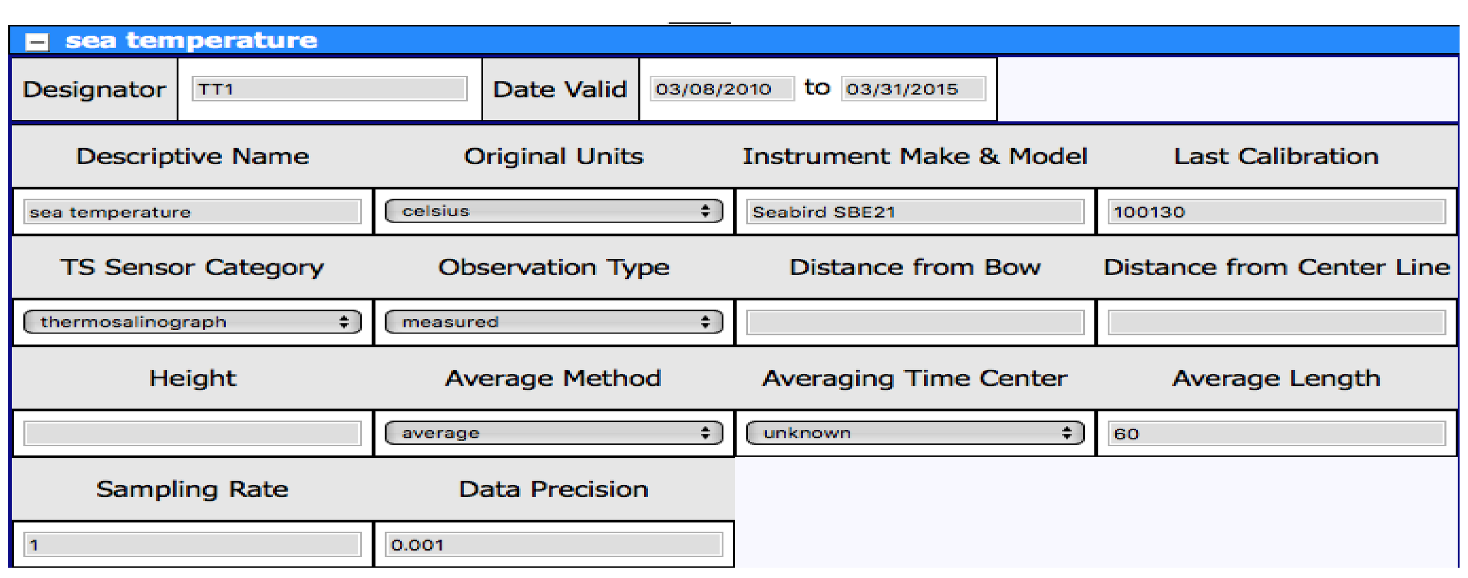

Fig. 3. An example of an incomplete TS metadata listing from the SAMOS database.

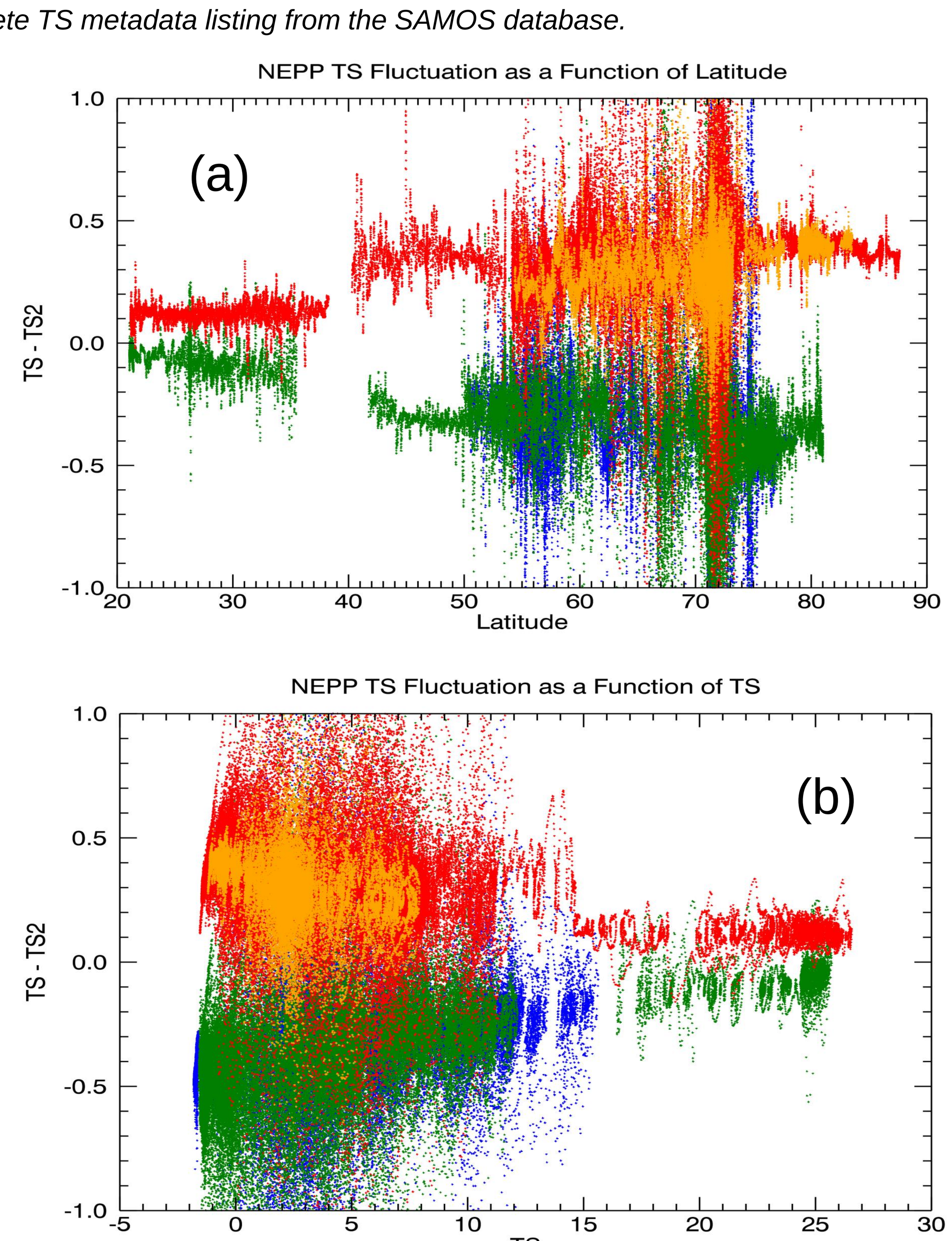

Fig. 5. Relationships for the HEALY of sea temperature difference with (a) latitude, and (b) one of the sea temperature readings. The two plots share an approximately inverse relationship. Note the reflection of data from 2010-2011, which is due to an instrument change in July 2011 that switched the order of the internal and intake sensors.

Causes

- Basic temperature differences are a result of water's exposure to internal ship structure on the way to the internal sensor.
- The effects vary due to the complexity of the flow system, as well as potential exposure to climate-controlled environments less representative of the real conditions.
- This explains why "stable" data differences can still vary from ship to ship.
- Notably large differences occur in automatic QC RVs, and are the result of instrumental malfunctions or undetected instrument shutdown, which occurs frequently in port..

Conclusions

- Highly differing port TS data suggest a need for a flagging mechanism based on stationary ship speed/port presence.
- Visual QC performs much better at picking up questionable data and reduces the absolute value of overall temperature bias by 23%.
- Another flagging mechanism suggested for instrument shutdown instance, as many of our "runoff" regions occur here and are not limited exclusively to the port cases.
- Intake temperature is typically the more accurate of the two due to the effects of internal ship structure on internal TS readings.
- Metadata needs to be more clear in specifying which TS is which, as well as provide insight into the schematics of the water flow system.
- With all considered, TS differences are fairly low in normal cases (<0.5ºC).

Results

Statistics

- The average difference (absolute value) in mean temperature across the 8 RVs was 0.18775º w/ trim, and 0.24359º without it.
- Most data maintained temperature differences under 0.5º, largely concentrating near 0.2º-0.3º (Fig. 6).
- RVs were mostly consistent in terms of which temperature was higher, with any month-to-month changes occurring in cases where automated QC RVs had clusters of highly irregular data.
- The average % change in temperature difference when removing the trim for auto QC ships was 87.76%; for visual QC ships: 17.40%.
- Individual monthly analysis showed higher variations in mean temperature differences, with extreme cases as high as 10°.

Relationships

- Much more consistency was shown by the visual QC data across all analyzed relationships.
- Cumulative one-to-one plots showed strong linearity, and in general, an increase in spread with increasing data concentration.
- For the case of the *HEALY* (which mostly operates in the Arctic), variability increases when temperatures are near the freezing point (Fig. 5).
- Latitudinal plots share an inverse relationship with the temperature plots, (Fig. 5) and exhibit a wave-like pattern where many of the spikes correlate with ports that the ships frequently stop in.
- Highest data spreads tend to occur when ship is at or near stationary speeds.
- No major trends found in relation to time of day.
- Introduction of 1° trim greatly benefited in producing consistent data for automated QC ships (Fig. 4)

Issues with Metadata

- As mentioned earlier, some of the RVs in this set have incomplete sea temperature metadata, failing to fully describe the type of sensor used in each measurement (Fig. 3).
- With this in mind, instrument changes can sometimes go unnoticed and completely reverse the direction of the temperature bias (Fig. 5)
- Consistency is required here, as simple as designating "internal/external sea temperature" under the "Descriptive Name" category. (Fig. 3)

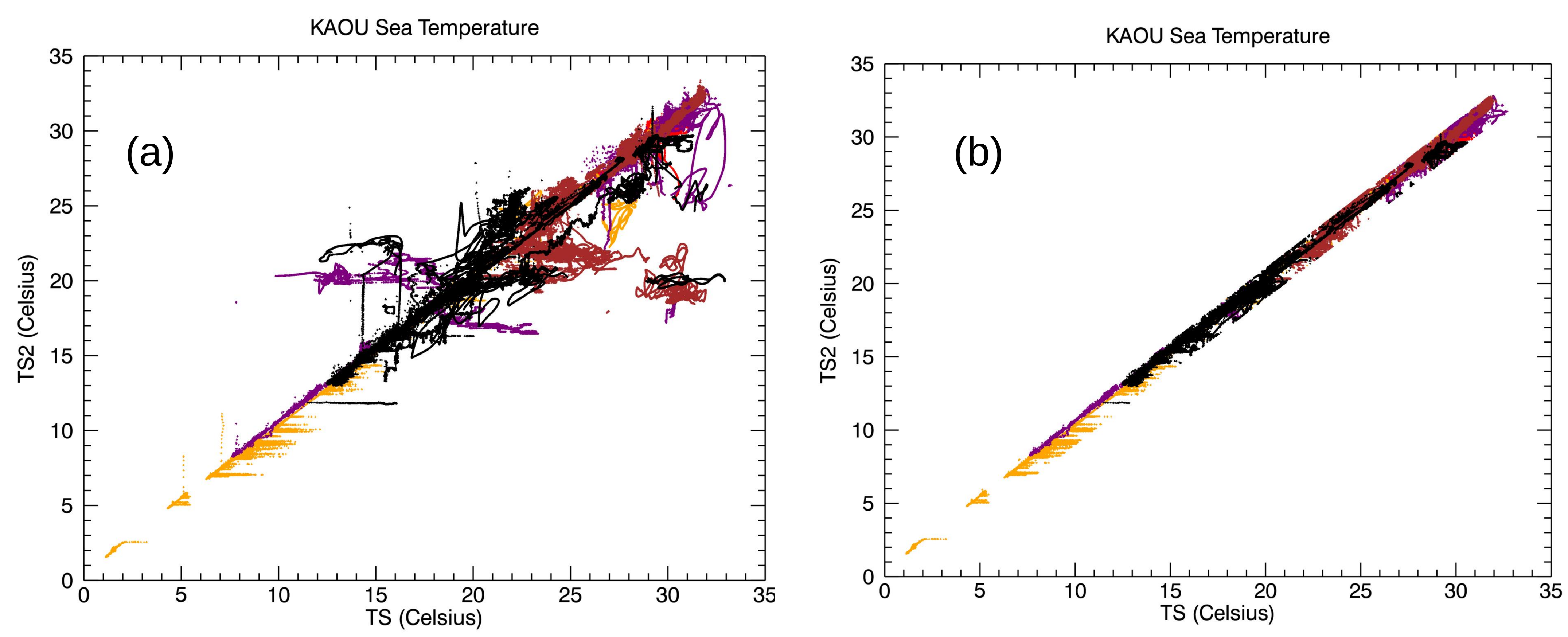

Fig. 4. Cumulative plots of both sea temperatures for the ROGER REVELLE both (a) without, and (b) with, the 1ºC trim applied to the data. Note the contrast, the product of automatic quality control failing to flag this data with large differences, though some success is achieved in 2012 data.

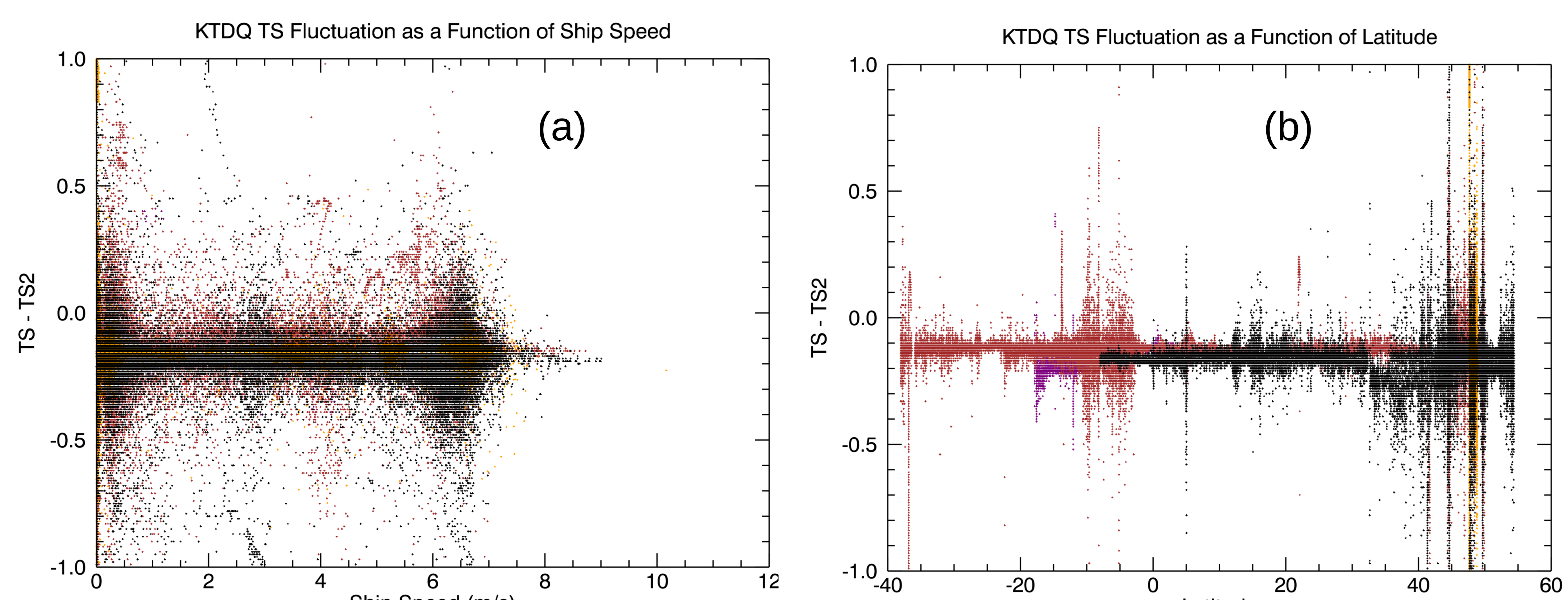

Fig. 6. Relationships for the TG THOMPSON of sea temperature difference with (a) ship speed, and (b) latitude. Note the heavy concentration of widely spread data near zero speeds. These often correlate with the latitudes where spikes occur as the location of a port that the RV stops in. In the case of the THOMPSON, the spikes at high latitudes correlate to a port in Seattle, Washington, USA.

Acknowledgments

- The SAMOS initiative at FSU is base funded by NOAA's Climate Observing Division (cooperative agreement NA11OAR4320199) and the National Science Foundation's Oceanographic Instrumentation and Technical Services Program (grant OCE-1447797). Since 2013, the Schmidt Ocean Institute (SOI) provides annual contract funding to receive SAMOS data processing for the RV *Falkor*.
- We thank the RV technicians for their contributions to SAMOS. Additional operational support for shipboard contributions are provided by WHOI, SIO, NOAA OMAO, USCG, NSF OPP, IM OS, the Univ. of Hawaii, Univ. of Washington, Univ. of Alaska, LUMCON, SOI, and the Bermuda Institute of Ocean Sciences.