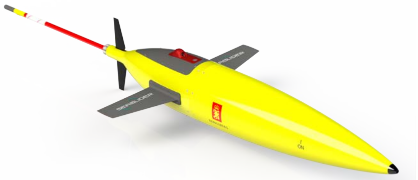
RBR
rbr-global.com

CTD dynamic performance and corrections through gradients

Mark Halverson, PhD

Presentation outline

1) What are dynamic errors?
2) Recognizing errors in data
3) Sensors:
    a) Temperature
    b) Conductivity
4) Correcting dynamic errors with RSKtools



RBR

Reference

Most of the material in this presentation is discussed in a report RBR recently released.

The report is aimed at the Argo float community, but all the ideas and concepts in this presentation are discussed in a general sense in the report.

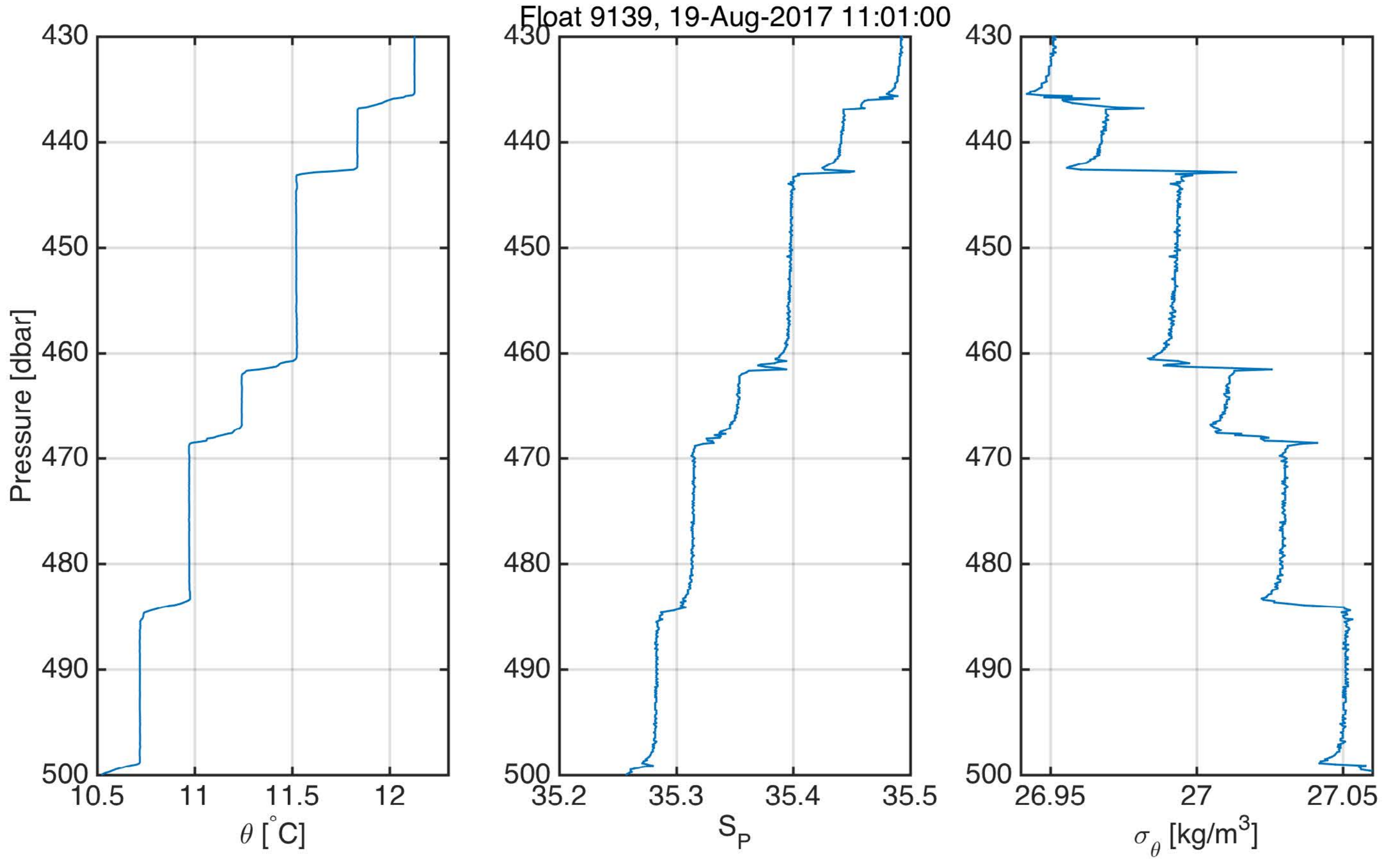
rbr-global.com/about-rbr/publications

RBR

Dynamic corrections for the RBRargo CTD 2000dbar

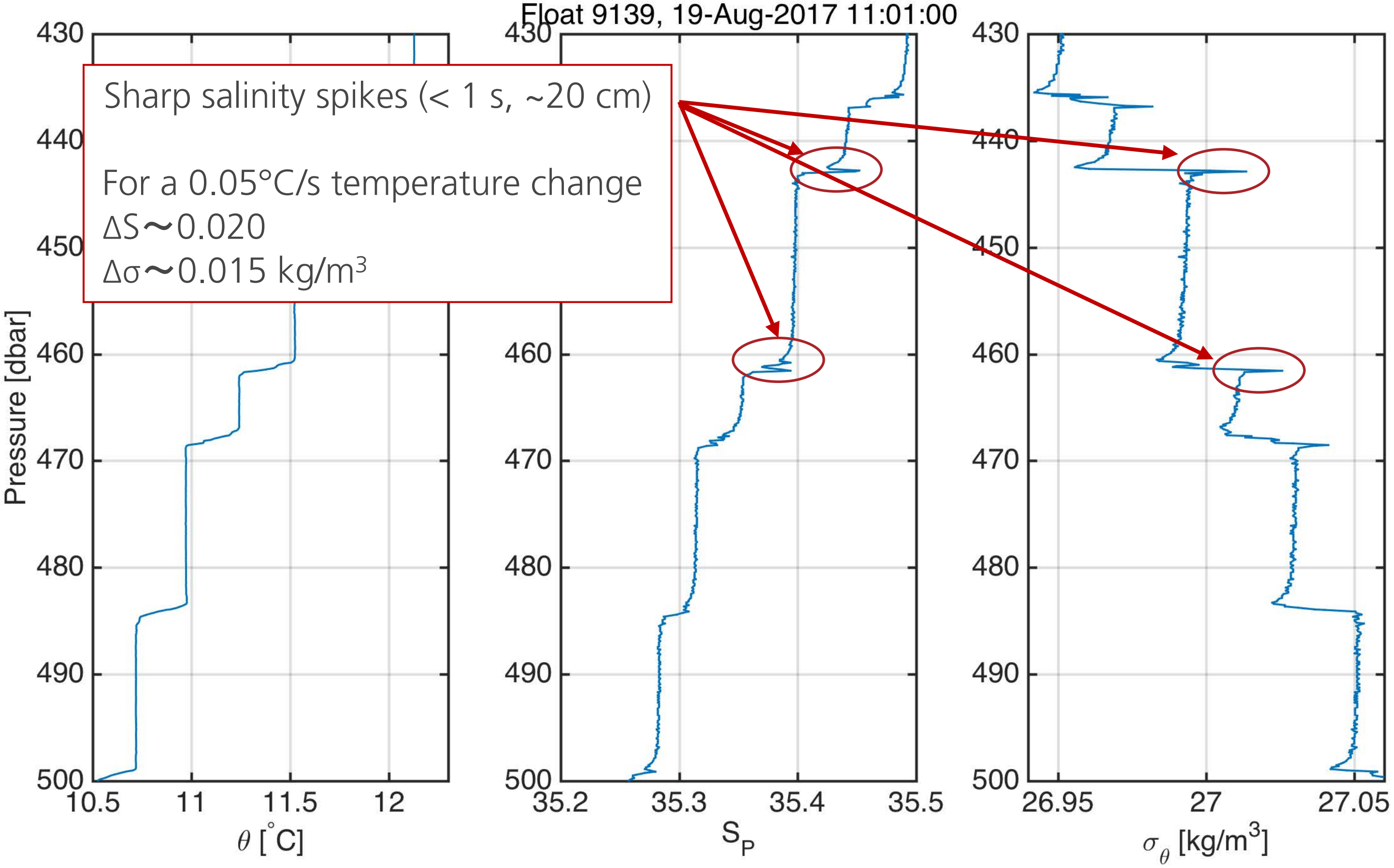
https://oem.rbr-global.com/floats/files/5898249/34668603/1/1586804683000/0008228revA+Dynamic+corrections+for+the+RBRargo+CTD+2000dbar.pdf

Dynamic errors: example from an MRV ALAMO float profiling upward through a T/S staircase

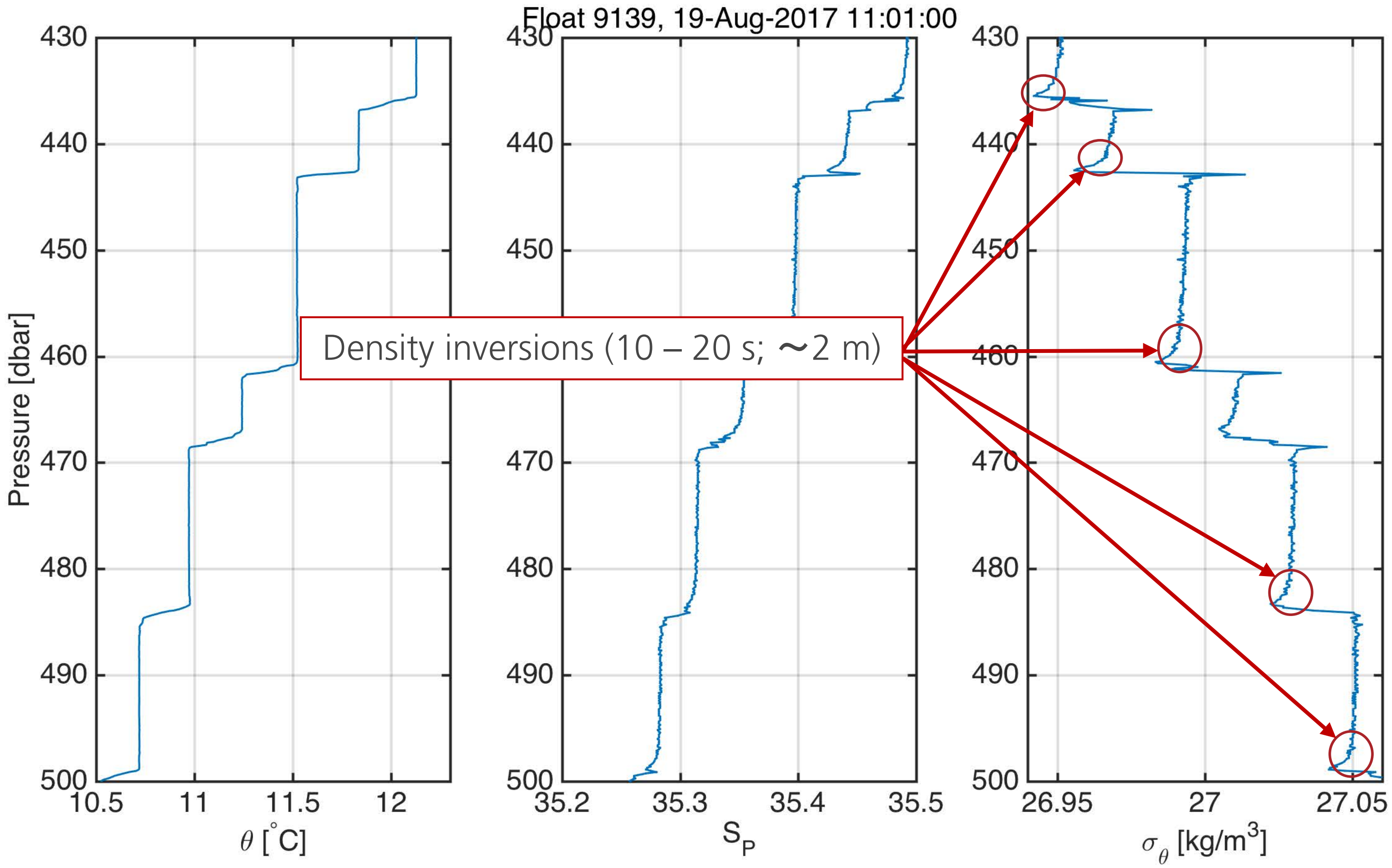


MRV/RBRargo float profile in Caribbean Sea. Data courtesy of Drs. Elizabeth Sanabia (US Naval Academy) and Steven Jayne (Woods Hole Oceanographic Institution).

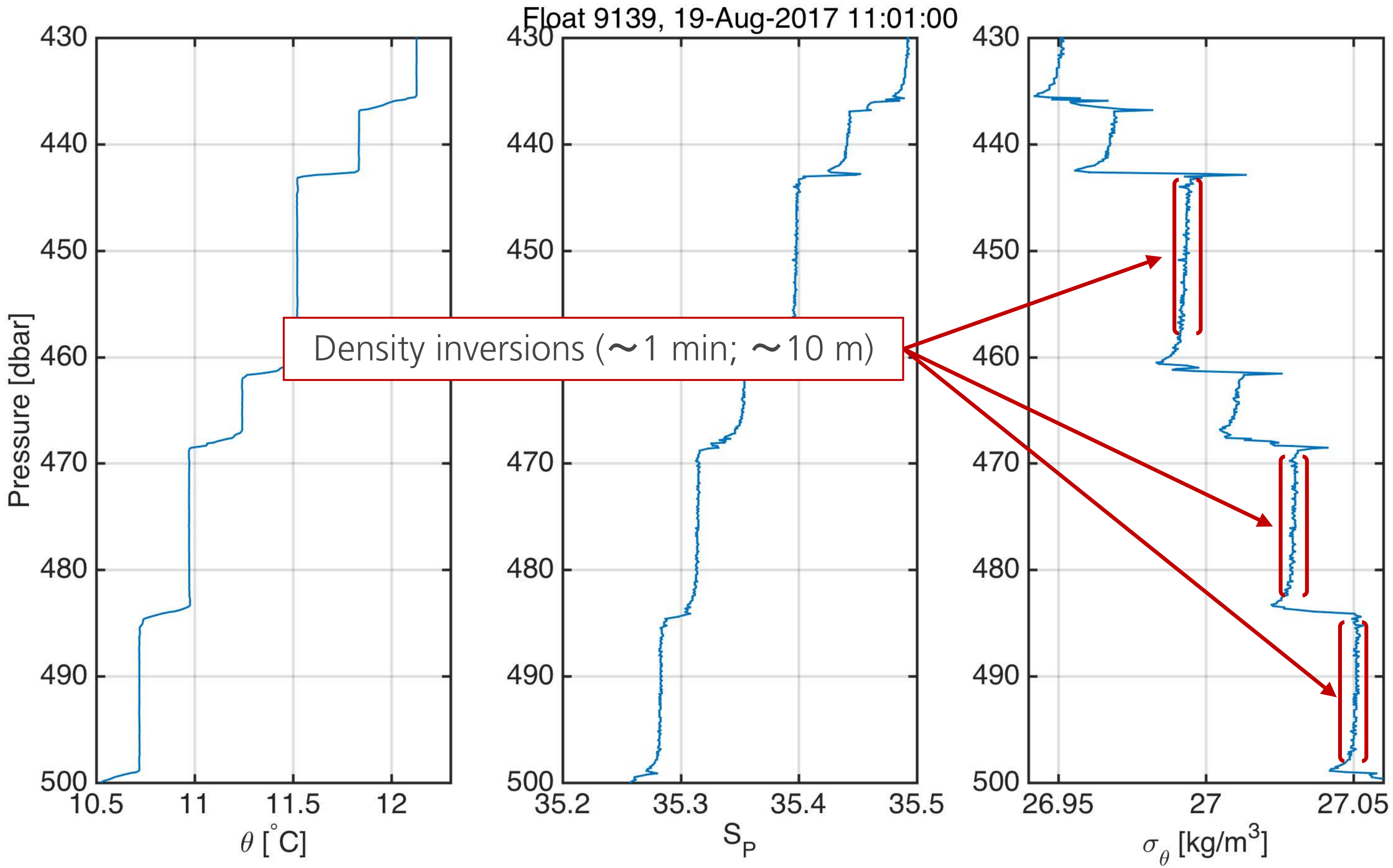
Uncorrected data in a thermohaline staircase



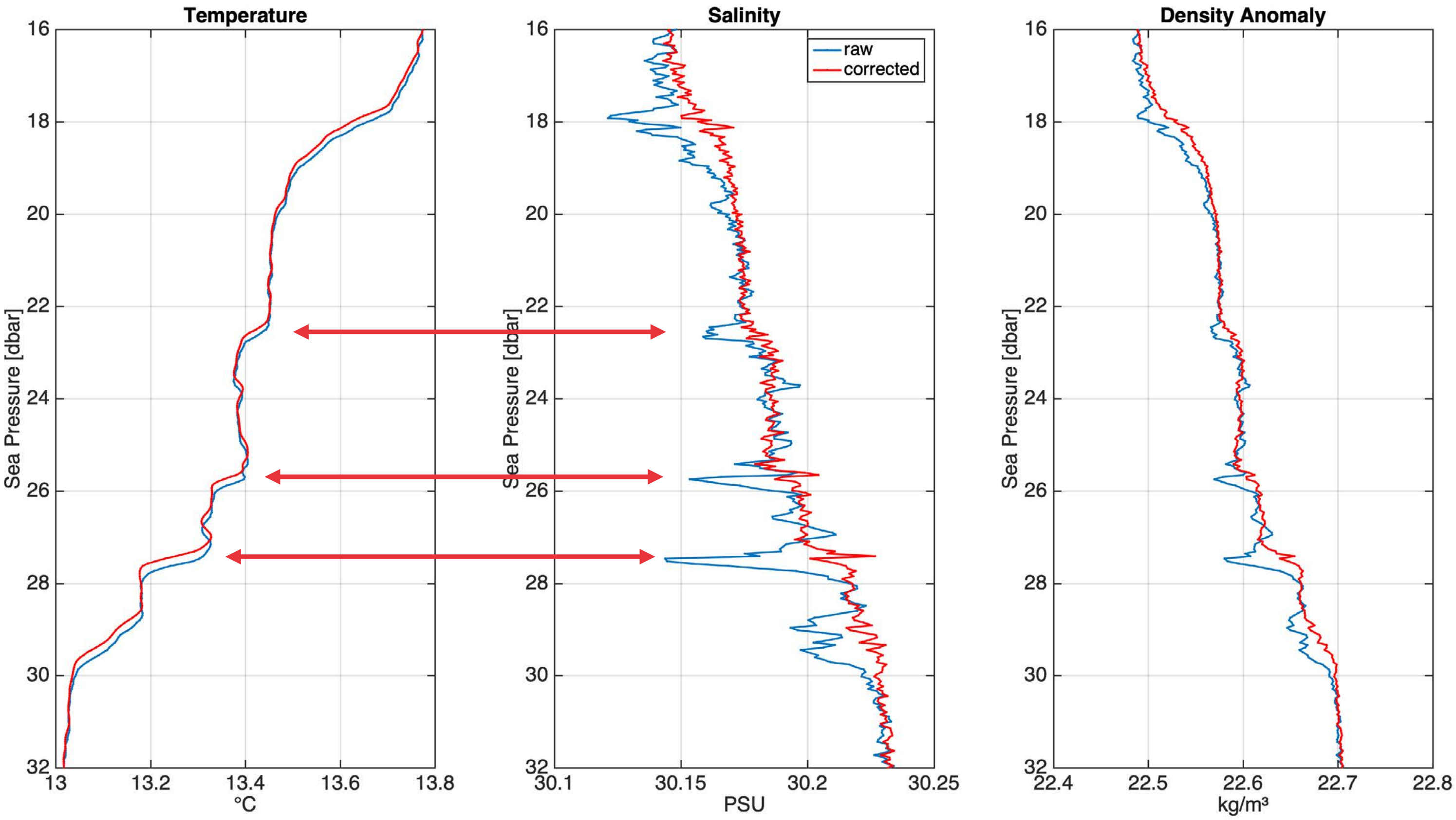
Uncorrected data in a thermohaline staircase



Uncorrected data in a thermohaline staircase



Dynamic errors: example from UW Seaglider in Puget Sound



UW APL Seaglider profile in Puget Sound. Data courtesy of Dr. Jason Gobat (Applied Physics Laboratory, University of Washington).

What causes dynamic errors in CTD measurements?

Profiling through a temperature gradient introduces dynamic errors in temperature and conductivity because it takes time for the sensors to adjust to a changing environment.

1. Finite time for heat transfer.
2. Takes time for water to pass through sensors.
3. Sensors are not physically co-located.

Dynamic errors affect all CTDs (i.e., electrode and inductive).

The impact of dynamic errors is often magnified in derived variables, such as salinity.

RBR

Dynamic errors in CTD data: Summary

- Dynamic response causes errors in measurements
  - Errors can manifest as spikes or as a bias.
- Errors are typically very small relative to the signal
  - Typical error is in the 2nd or 3rd decimal place [i.e., O(0.01 PSU or °C or mS/cm)]
  - If errors are larger, then choose different sensor, instrument, or profiling rate
- Errors may produce misleading scientific results
  - Example: spurious density overturns in profiles
- Errors can be reduced significantly with corrective algorithms

RBR

Primary causes of dynamic errors in CTD sensors

Temperature: Finite time for heat to diffuse through thermistor sting

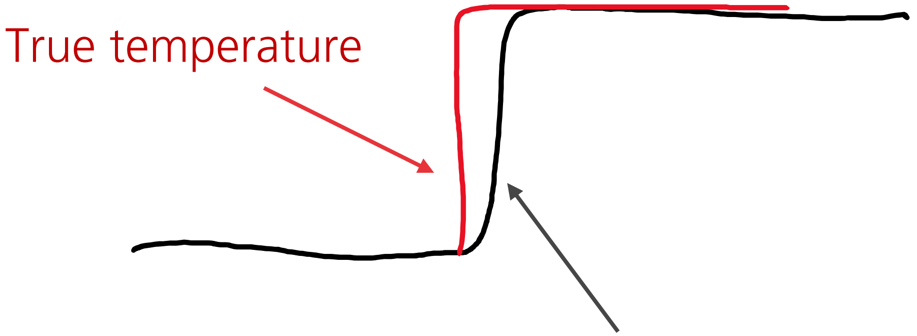
Conductivity: Exchange of heat between cell and water changes conductivity

Temperature + Conductivity: Spatial misalignment causes sensors to encounter water parcel at different times

RBR

Temperature

Cause: Finite time for heat to diffuse through the temperature probe's protective metal "sting" into the thermistor



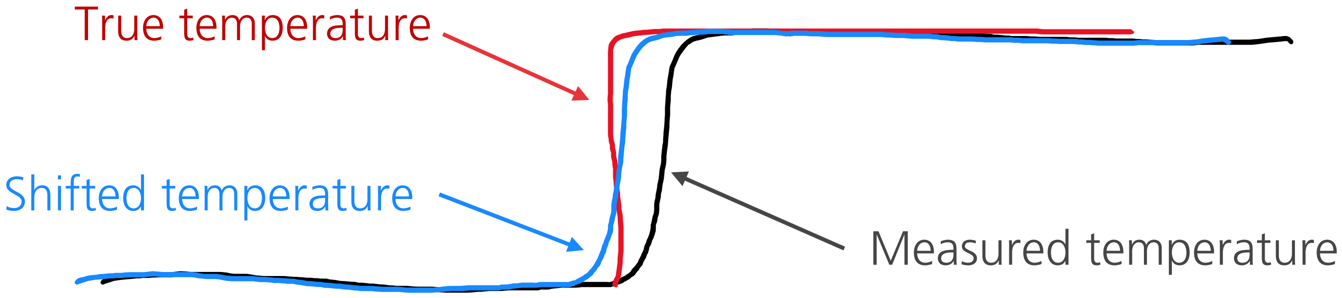
Measured temperature

- Lags true temperature
- High frequencies damped

RBR

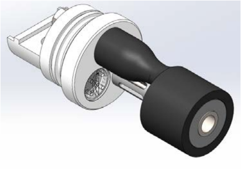
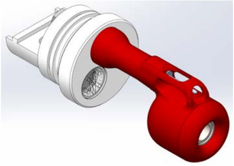
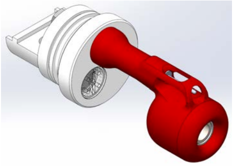
Temperature

Solution: correct phase lag and optionally restore high-frequency energy



RBR

Temperature corrections for RBR instruments

	RBR*concerto* (separate CT) (0.1 s thermistor)	RBR*concerto* (combined CT) (0.1s thermistor)	RBR*concerto* (combined CT) (1 s thermistor)	RBR*argo* (1 s thermistor)	RBR*legato* (1 s thermistor)
Δt	Approx. 0.1 – 0.2 s[a]	0.04 s[b]	0.4 s[c]	0.3 s[d]	1.0 s[e]

[a] The lag here is driven largely by the spatial separation of the conductivity cell and the thermistor, and therefore Δt depends on profiling speed.

[b] Weak dependence on profiling speed.

[c] Largely independent of speed.

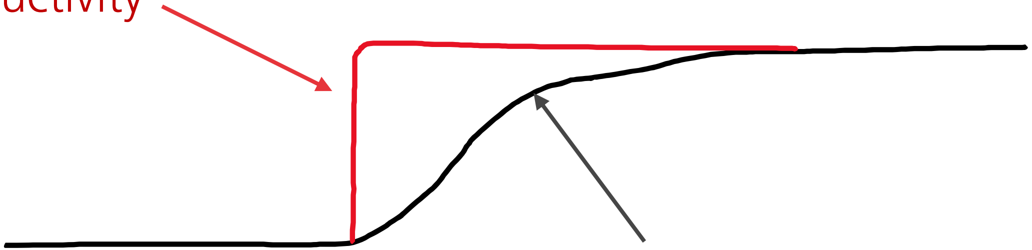
[d] Specific to 11 cm/s profiling speed. Same CTD as the RBR*concerto*.

[e] Slight dependence on speed. Although the RBRlegato uses the same 1 s thermistor as the RBRargo, the thermistor on the RBRlegato is offset in space from the conductivity cell.

Conductivity

Cause: Exchange of heat between cell and water changes conductivity, and conductivity depends strongly on temperature

True conductivity



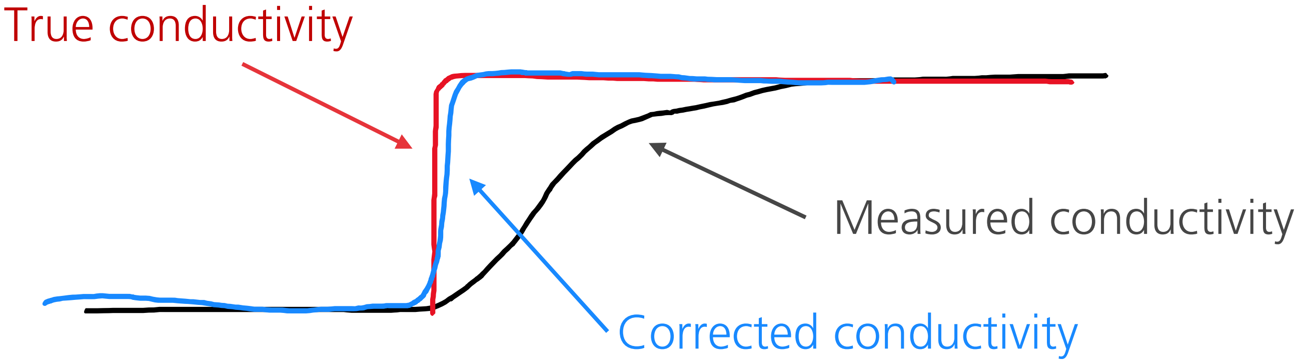
Measured conductivity

- Lags true conductivity
- High frequencies damped

RBR

Conductivity

Solution: correct phase lag and restore high-frequency energy



RBR

Conductivity

Correction formulae:

1) Long time scale errors (~60 s):

$$C_{cor} = \frac{C_{measured}}{1 + ctcoeff * (T_{ctcell} - T_{marine})}$$

[RBR report on dynamic corrections]

2) For short time scale errors (<10 s)

$$C_T(n) = -bC_T(n-1) + \gamma a[T(n) - T(n-1)]$$

$$a = 4f_N\alpha\beta^{-1}(1 + 4f_N\beta^{-1})^{-1}$$

$$b = 1 - 2a\alpha^{-1}$$

$$C_{cor}(n) = C(n) + C_T(n)$$

[Lueck and Picklo (1990)]

RBR

Lueck, R. G. and Picklo, J. J. (1990). Thermal inertia of conductivity cells: Observations with a Sea-Bird cell. Journal of Atmospheric and Oceanic Technology, 7(5):756–768.

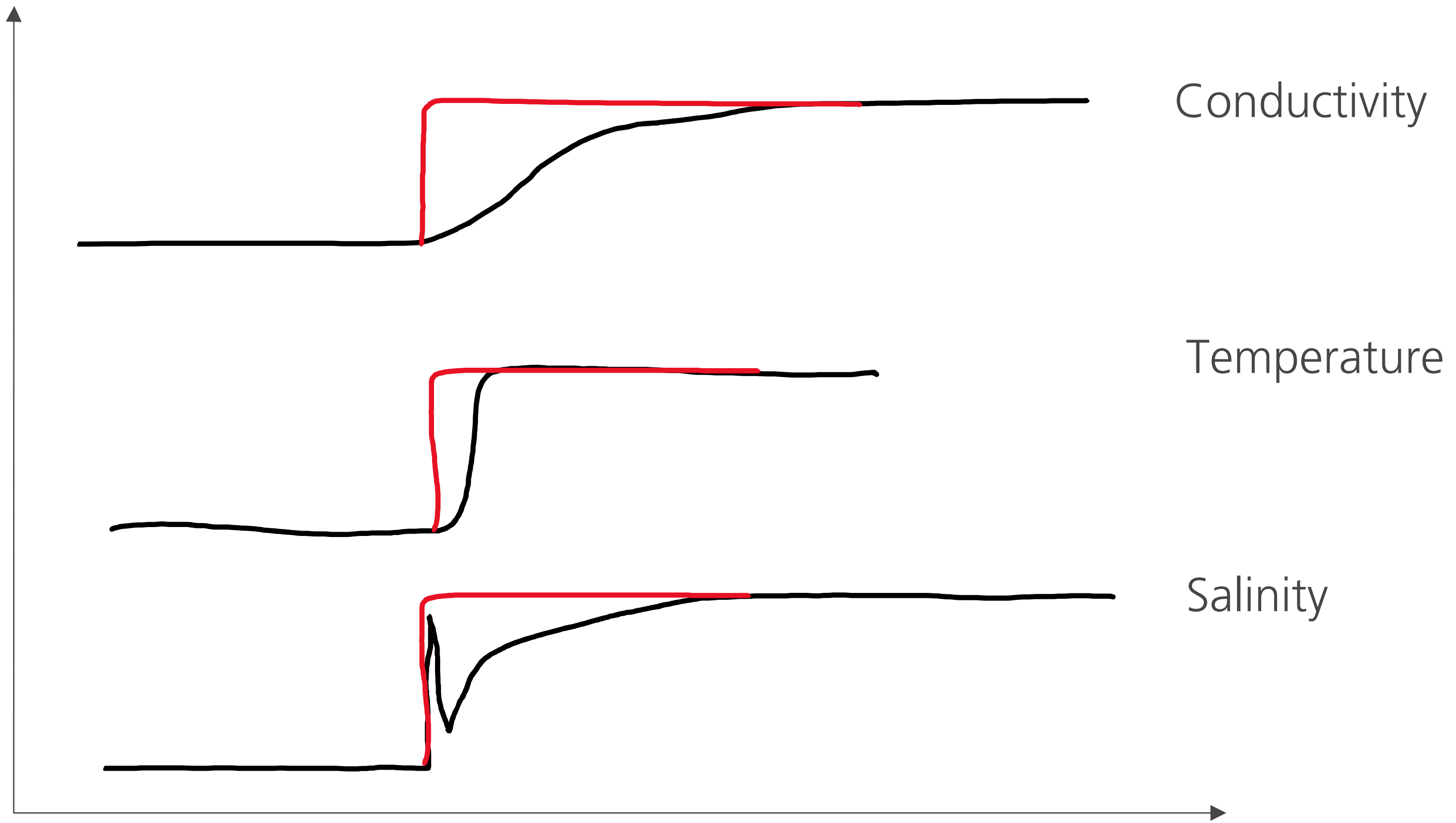
Conductivity corrections for RBR instruments

	RBR*concerto** (separate CT)	RBR*concerto*** (combined CT) (> 10 cm/s)	RBR*argo* (10 cm/s)	RBR*legato***
ctcoeff*	investigating	investigating	2.4×10^{-4} °C^{-1}	investigating
α^*	investigating	investigating	0.08	0.09
β^* ($\tau = \beta^{-1}$)	investigating	investigating	0.13 s^{-1} (8 s)	0.16 s^{-1} (6 s)

*Speed dependent

RBR

Importance of sensor response matching through a T/S step change



RBR

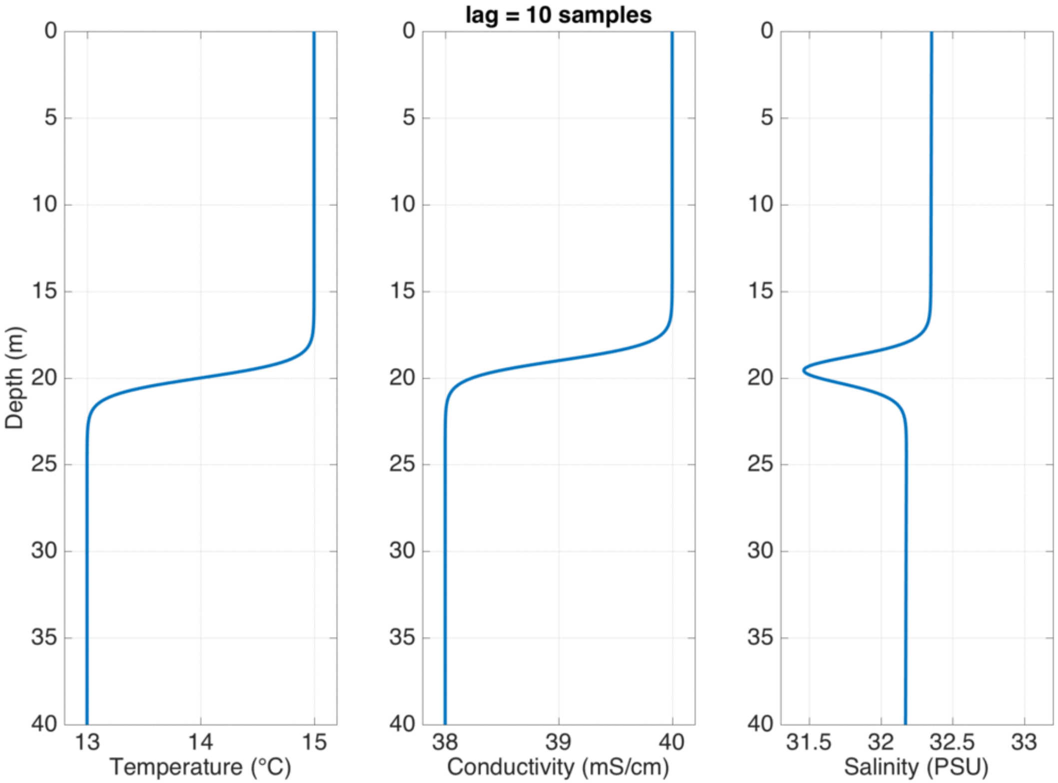
RBR*concerto*, RBR*argo*, RBR*brevio*: conductivity and temperature co-aligned

RBR*legato*: conductivity and temperature offset

CT separation

Spatial mismatch from CT separation causes errors in salinity.

- At a thin gradient, the error appears as a spike.
- Sign of the salinity spike anomaly depends on the sign of the temperature gradient and whether C leads T or vice versa.



RBR

Temperature and conductivity sensor matching

Salinity errors depend on temperature and conductivity errors.
To minimize errors, the response of the sensors should be matched.

Important points:

1. C and T have different response times (C generally faster than T)
    1. Choice must be made: slow down C, or speed up T?
    2. In most applications, best choice is to slow down conductivity. Simply smooth them both C and T with a zero-phase low pass filter. Advantage is that it low-pass filtering reduces noise, whereas sharpening adds noise. The filter details are not critically important.
2. If C and T are not collocated, then one of them must be time shifted to synchronize the measurements. We generally recommend shifting in time as opposed to adjusting phase with filters.

RBR

RSKtools and dynamic corrections

READ

Openers and Readers

- RSKopen
- RSKreaddata
- RSKreadprofiles
- RSKreadburstdata
- RSKreadcalibrations
- RSKfindprofiles
- RSKtimeseries2profiles
- CSV2RSK

PROCESS

Calculators

- RSKderivedepth
- RSKderivesalinity
- RSKderiveseapressure
- RSKderivevelocity
- RSKderiveBPR
- RSKderiveC25
- RSKderiveO2
- RSKderivebuoyancy
- RSKderivesigma
- RSKderiveSA
- RSKderivetheta
- RSKderivesoundspeed

Post-Processors

- RSKcalculateCTlag ←
- RSKalignchannel ←
- RSKbinaverage
- RSKcorrecthold
- RSKcorrectTM ←
- RSKcorrecttau ←
- RSKdespike
- RSKremoveloops
- RSKsmooth
- RSKtrim
- RSKgenerate2D
- RSKcentrebursttimestamp

VIEW & EXPORT

Plotters

- RSKplotdata
- RSKplotprofiles
- RSKimages
- RSKplotTS
- RSKplotburstdata
- RSKplotdownsample

Exporters

- RSK2CSV
- RSK2ODV
- RSK2RSK
- RSK2MAT

OTHER

Miscellaneous

- RSKcreate
- RSKsettings
- RSKaddchannel
- RSKaddstationdata
- RSKappendtolog
- RSKremovecasts
- RSKprintchannels

Help

- Contents
- README.md
- QuickStart/Standard
- QuickStart/Postprocessing

https://rbr-global.com/support/matlab-tools

https://docs.rbr-global.com/rsktools

RBR

RSKtools functions for dynamic corrections

RSKsmooth: Low-pass filter both C and T with a 5-point running mean

```
rsk = RSKsmooth(rsk,'channel',{'conductivity','temperature'},'windowlength',5);
```

RSKalignchannel: Shift temperature ahead by 0.04 s

```
rsk = RSKalignchannel(rsk,'channel','temperature','lag',-0.04,'lagunits','seconds');
```

Remember to compute salinity with corrected data!

```
rsk = RSKderivesalinity(rsk);
```

RSKcalculateCTlag: Compute ideal lag by minimizing salinity spikes

```
lag = RSKcalculateCTlag(rsk,'seapressurerange',[50 60]);
```

RBR

RSKtools: Thermistor sharpening and conductivity thermal inertia correction

RSKcorrecttau: Sharpen signal with Fozdar et al. (1985) algorithm

```
rsk = RSKcorrecttau(rsk,'channel','temperature','tauresponse',0.5);
```

RSKcorrectTM: Correct conductivity for thermal inertia with Lueck & Picklo (1990) algorithm

```
rsk = RSKcorrectTM(rsk,'alpha',0.08,'beta',0.1);
```

Remember to derive salinity after correcting conductivity!

```
rsk = RSKderivesalinity(rsk);
```

RBR

Fozdar, F. M., Parkar, G. J., and Imberger, J. (1985). Matching temperature and conductivity sensor response characteristics. Journal of Physical Oceanography, 15(11):1557–1569.
Lueck, R. G. and Picklo, J. J. (1990). Thermal inertia of conductivity cells: Observations with a Sea-Bird cell. Journal of Atmospheric and Oceanic Technology, 7(5):756–768.

Reference

Most of the material in this presentation is discussed in a report RBR recently released.

The report is aimed at the Argo float community, but all the ideas and concepts in this presentation are discussed in a general sense in the report.

RBR

Dynamic corrections for the RBRargo CTD 2000dbar

rbr-global.com/about-rbr/publications

https://oem.rbr-global.com/floats/files/5898249/34668603/1/1586804683000/0008228revA+Dynamic+corrections+for+the+RBRargo+CTD+2000dbar.pdf

Thank You

Contact Us

RBR
rbr-global.com
info@rbr-global.com
+1 613 599 8900

RBR