

# (Sea)glider data processing - the issues of multi parameter serial data sampling and thermal lag

Sunke Schmidtke

University of East Anglia

s.schmidtke@uea.ac.uk

(Gerd Krahnemann, Pierre Testor, Tomeu Garau, Bastien Queste)

# Biases are everywhere

Random Errors

$$\langle X \rangle = \langle X + \varepsilon \rangle$$

Systematic Errors

$$\langle X \rangle \neq \langle X + \varepsilon \rangle$$

- Internal sampling errors (even in an idealized environment)
- Environmental induced errors
- Calibration induced errors

# Biases are everywhere

~~Random Errors~~

$$\langle X \rangle = \langle X + \varepsilon \rangle$$

Systematic Errors

$$\langle X \rangle \neq \langle X + \varepsilon \rangle$$

- Internal sampling errors (even in an idealized environment)
- Environmental induced errors
- Calibration induced errors

# Biases are everywhere

Systematic Errors



should be corrected to either 'remove' the error, or to mitigate the problem by transforming the systematic error into a



Random Error

# Seaglider measurements

- Guidance and Control (GC)
- Sample (S)

S can have varying amount of Senors switched on e.g.

S1 = Salinity, Temperature

S2 = Salinity, Temperature, Oxygen

S3 = Salinity, Temperature, Oxygen, Biogeochemistry

S4 = Salinity, Temperature, Biogeochemistry

GC – S1 – S2 – S1 – S2 – GC – S1 – GC – S3 – S3 – S4 – S4

## 2.1.2 Data File `.eng` file is the cumulative `.dat` file (`p1230055.dat`)

The **.dat file** is an ASCII text file that is generated by the Seaglider and transmitted to the basestation for further processing; all following lines are differences. It serves as the primary conduit for the science data collected by the Seaglider. The format is designed to minimize transmission size and, while clear text, is not intended for direct interpretation.

The numbers in the data file can be interpreted by the column titles listed in the "columns" line. The meaning of the first 10 columns ("rec" through "GC\_phase") are always present. The remaining columns depend on the sensors installed.

rec: the record number of the individual sample

elapsed: time since the start of the dive

depth: depth, in centimeters, at the start of the sample

heading: vehicle heading at the start of the sample, in degrees (magnetic) times 10

pitch: vehicle pitch angle at the start of the sample, in degrees times 10, positive up

roll: vehicle roll at the start of the sample, in degrees times 10, positive starboard wing down

AD\_pitch: Pitch mass position, in A/D counts

AD\_roll: roll mass position, in A/D counts

AD\_vbd: VBD position, in A/D counts

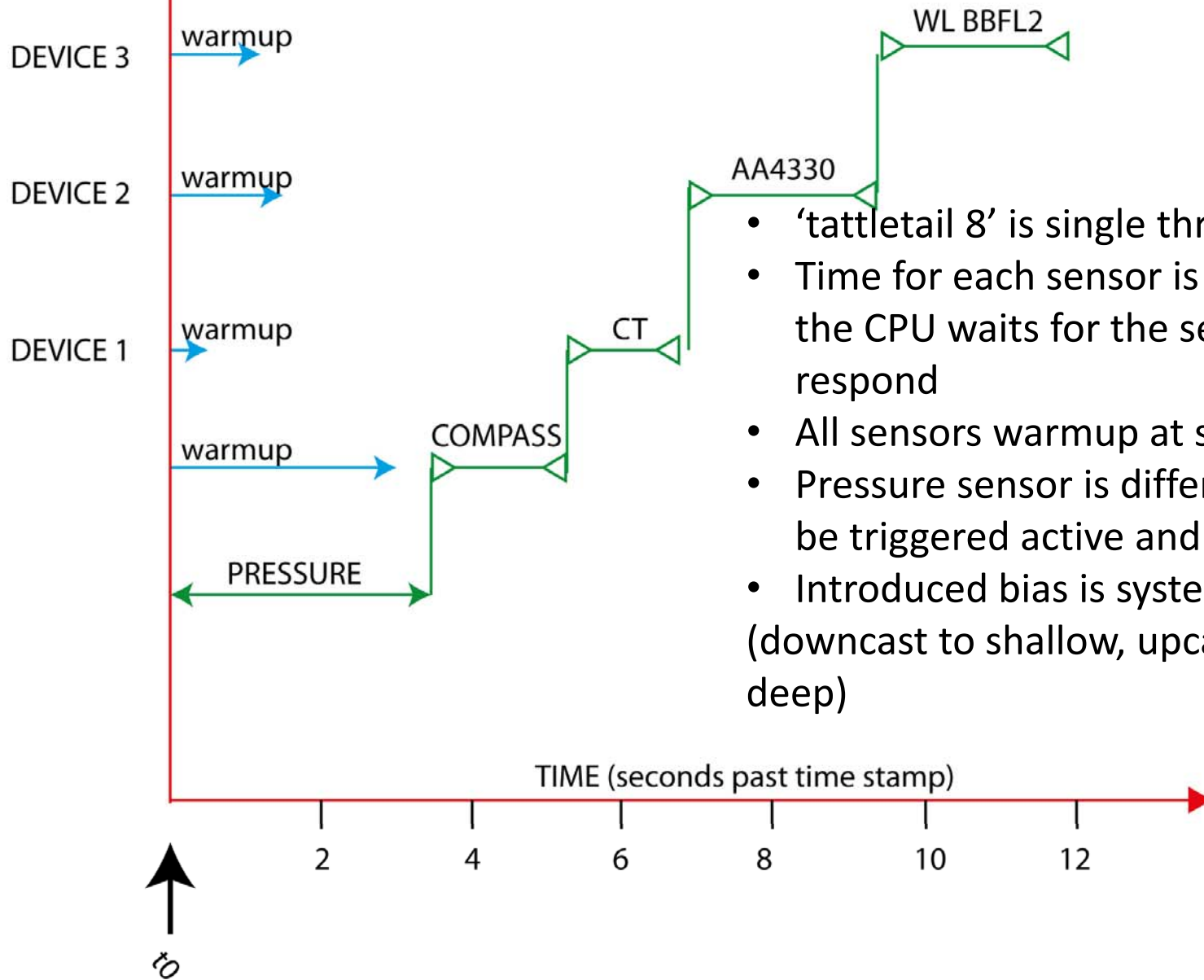
GC\_phase: GC phase, encoded as follows

1: Pitch change

2: VBD change

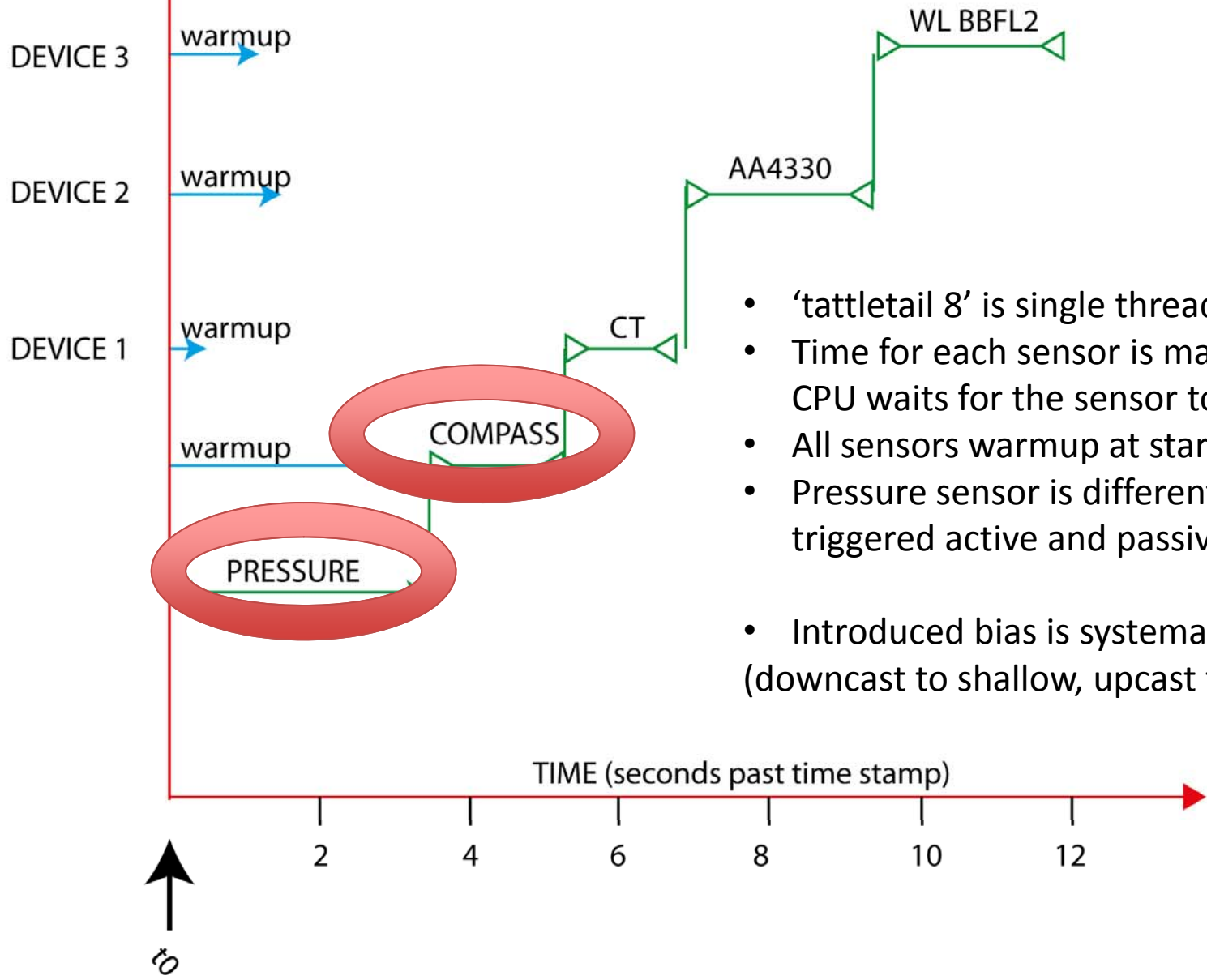
3: Roll

# SeaGlider sampling scheme



- 'tattletail 8' is single thread CPU
- Time for each sensor is max. time the CPU waits for the sensor to respond
- All sensors warmup at start
- Pressure sensor is different, it can be triggered active and passive
- Introduced bias is systematic! (downcast to shallow, upcast to deep)

# SeaGlider sampling scheme



- 'tattletail 8' is single thread CPU
- Time for each sensor is max. time the CPU waits for the sensor to respond
- All sensors warmup at start
- Pressure sensor is different, it can be triggered active and passive
- Introduced bias is systematic!  
(downcast to shallow, upcast to deep)



# Seaglider measurements

5 sec delay at 0.2 m/s vertical speed

1m upward bias on downcast

1m downward bias on upcast

2m bias between down- and upcast

# Seaglider measurements

- GC is safed in .log file
- S is safed in .eng file

further .log file information:

```
$DEVICES,Pitch_motor,Roll_motor, ... ,Compass,RAFOS,Transponder,Compass2
$DEVICE_SECS,17.400,58.150, ... ,1751.924,0.000,9.923,0.000
$DEVICE_MAMPS,261.547,66.729, ... ,8.000,0.000,30.000,0.000
$SENSORS,SBE_CT,WL_BBFL2VMT,AA4330,nil,nil,nil,nil,nil
$SENSOR_SECS,517.802,978.776,1630.502,0.000,0.000,0.000,0.000,0.000
$SENSOR_MAMPS,24.000,105.000,33.000,0.000,0.000,0.000,0.000,0.000
```

# Seaglider measurements

- GC is saved in .log file
- S is saved in .eng file

further .log file information:

```
$DEVICES,Pitch_motor,Roll_motor, ... ,Compass,RAFOS,Transponder,Compass2
$DEVICE_SECS,17.400,58.150, ... ,1751.924,0.000,9.923,0.000
$DEVICE_MAMPS,261.547,66.729, ... ,8.000,0.000,30.000,0.000
$SENSORS,SBE_CT,WL_BBFL2VMT,AA4330,nil,nil,nil,nil,nil
$SENSOR_SECS,517.802,978.776,1630.502,0.000,0.000,0.000,0.000,0.000
$SENSOR_MAMPS,24.000,105.000,33.000,0.000,0.000,0.000,0.000,0.000
```

SENSOR\_SECS / no. observations = best estimate for each sample

# Seaglider measurements

```
$DEVICES,Pitch_motor,Roll_motor, ... ,Compass,RAFOS,Transponder,Compass2  
$DEVICE_SECS,17.400,58.150, ... ,1751.924,0.000,9.923,0.000  
$DEVICE_MAMPS,261.547,66.729, ... ,8.000,0.000,30.000,0.000  
$SENSORS,SBE_CT,WL_BBFL2VMT,AA4330,nil,nil,nil,nil,nil  
$SENSOR_SECS,517.802,978.776,1630.502,0.000,0.000,0.000,0.000,0.000  
$SENSOR_MAMPS,24.000,105.000,33.000,0.000,0.000,0.000,0.000,0.000
```

SENSOR\_SECS / no. observations = best estimate for each sample

shift pressure & time vector for each sensor!

# Seaglider measurements

```
>>>> Reading calibration files <<<<
```

```
  reading sg_calib_constants.m from directory: /data/gliders/sg522/
```

```
>>>> Doing SENSOR analysis <<<<
```

```
Following SENSORS found in glider data:
```

```
sbect active for 43.9267 hours, making 218638 measurements, about 0.72328 seconds pe
```

```
wlbbf12vmt active for 65.8271 hours, making 68538 measurements, about 3.4576 seconds
```

```
aa4330 active for 112.1005 hours, making 167322 measurements, about 2.4119 seconds p
```

```
>>>> Doing COMPASS analysis <<<<
```

```
compass active for 137.0764 hours, making 218638 measurements, about 2.257 seconds p
```

```
>>>> creating new time vector for each sensor <<<<
```

# Thermal lag

Thermal bias is affecting many sensors, most pronounced:

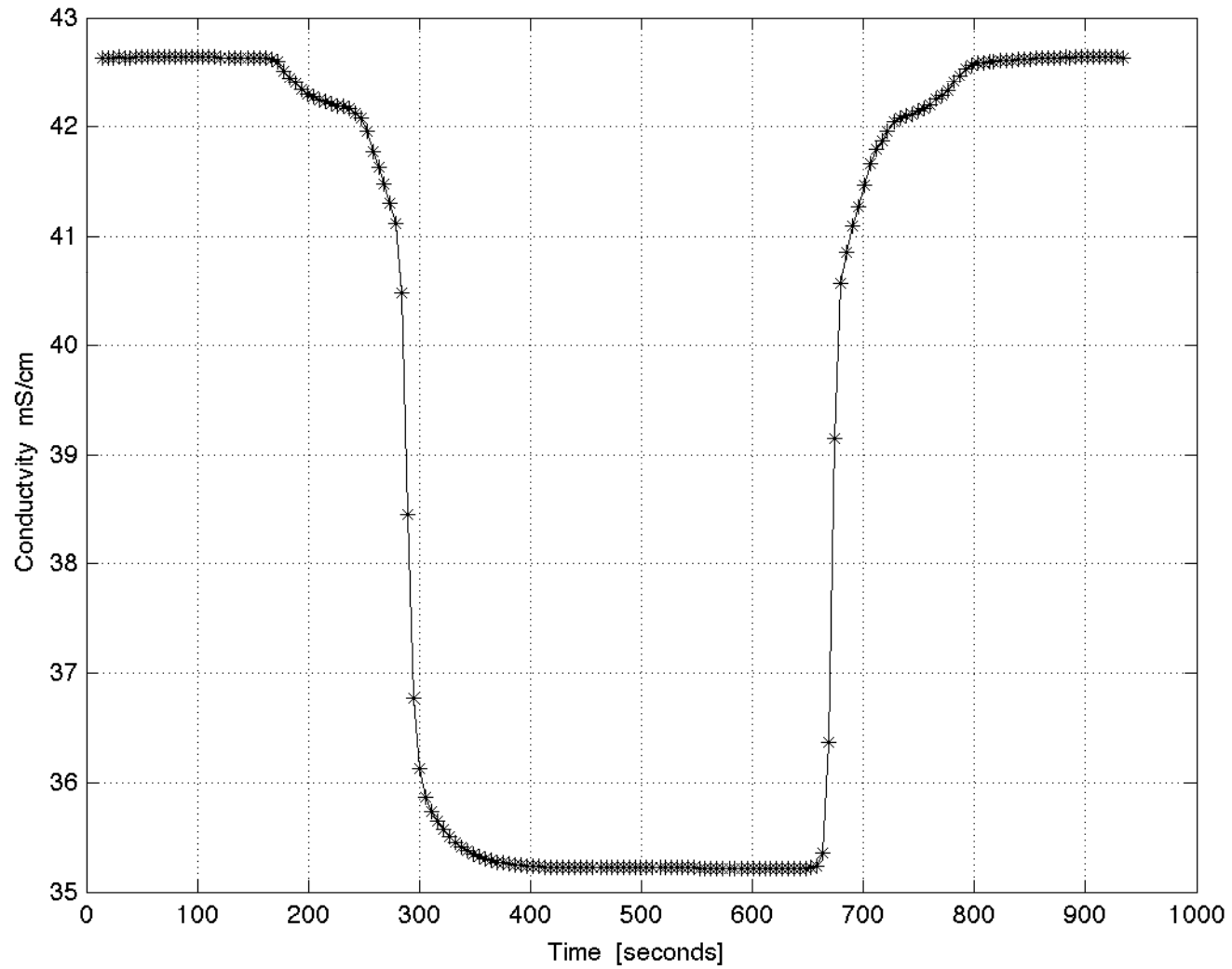
**Conductivity cell** -> Salinity -> Density ->  $N^2$  / Shear /

**Oxygen optode** -> Dissolved Oxygen -> AirSea fluxes / Production

how large is the effect?

(time / pressure)

# North Sea Conductivity

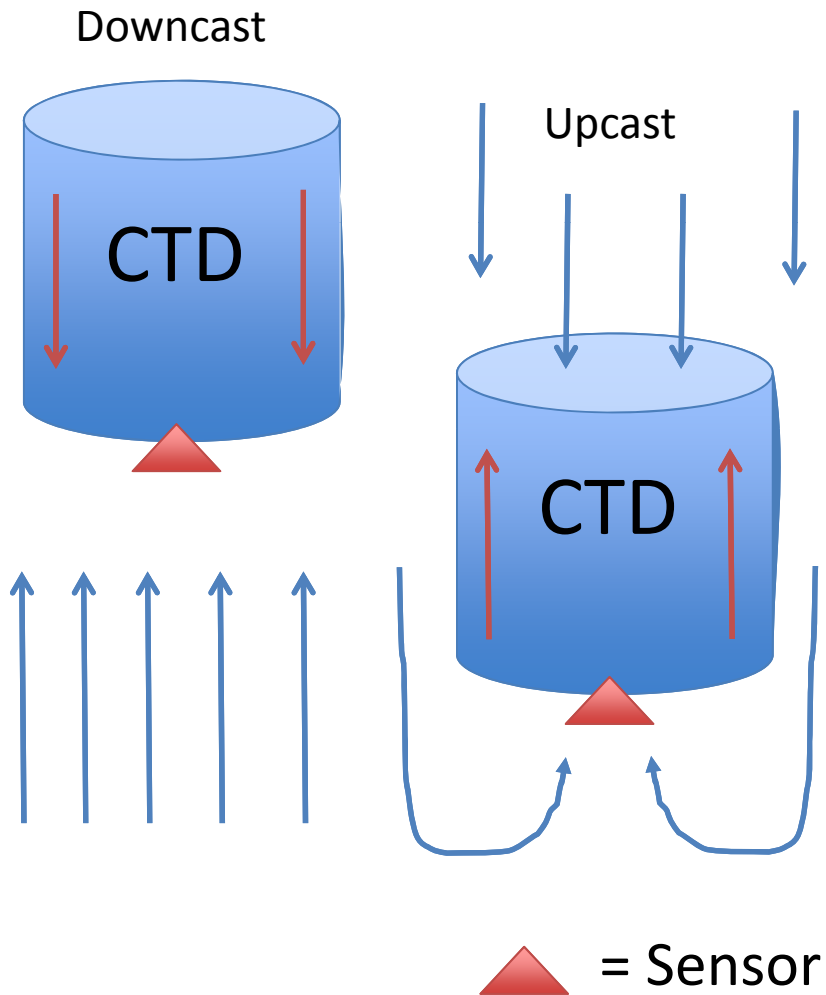


# Thermal lag correction

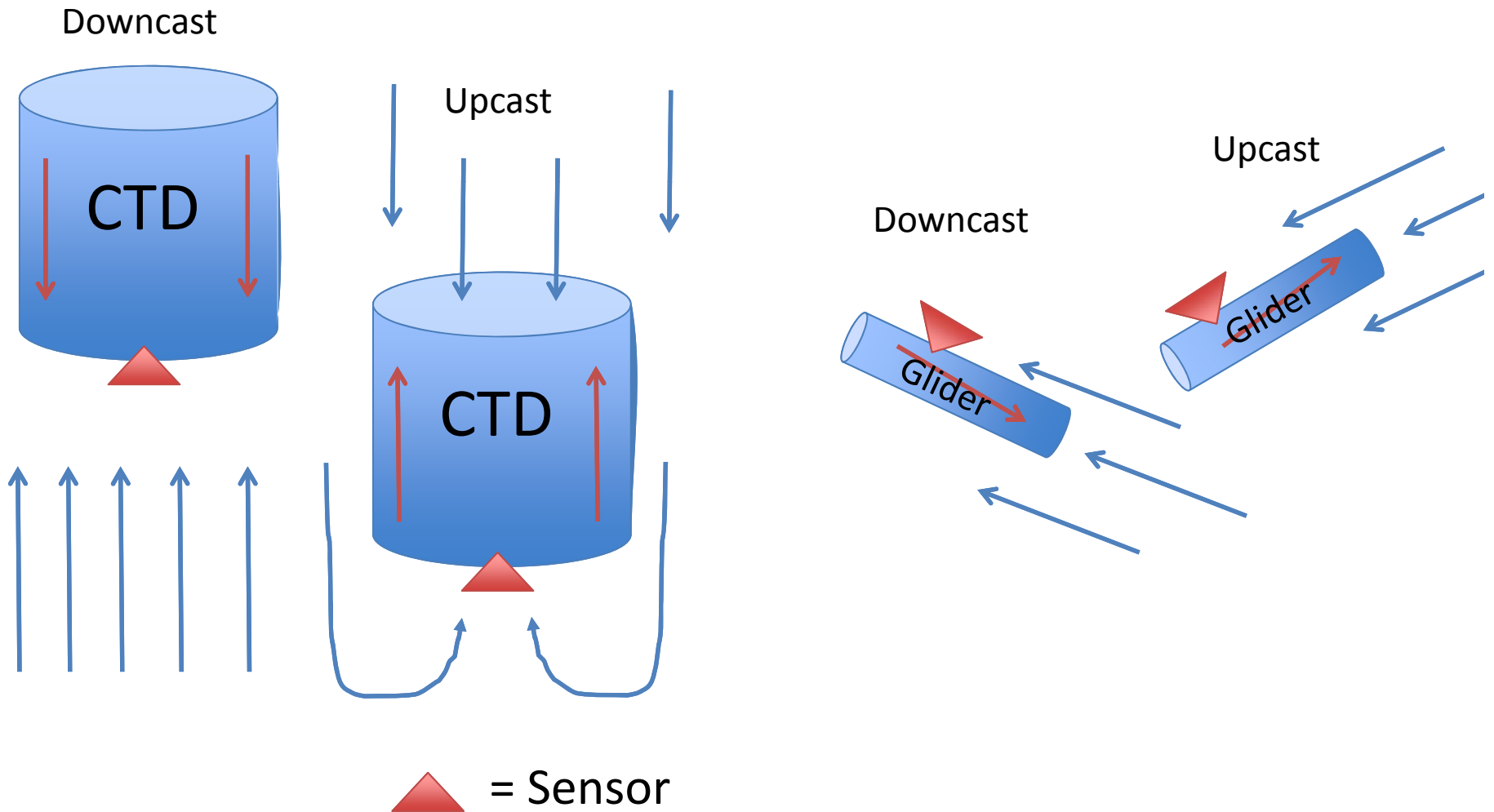
- Lueck, R. G., 1990: ***Thermal inertia of conductivity cells: Theory***. J. Atmos. Oceanic Technol, 7, 741–755.
- Lueck, R. G., and J. J. Picklo, 1990: ***Thermal inertia of conductivity cells: Observations with a Sea-Bird cell***. J. Atmos. Oceanic Technol, 7, 756–768.
- Morison, J., R. Andersen, N. Larson, E. D'Asaro, and T. Boyd, 1994: ***The correction for thermal-lag effects in Sea-Bird CTD data***. J. Atmos. Oceanic Technol, 11, 1151–1164.
- Bishop, C. M., 2008: ***Sensor dynamics of autonomous underwater gliders***. Master thesis at MUN St John's
- Garau, B., S. Ruiz, W. G. Zhang, A. Pascual, E. Heslop, J. Kerfoot, and J. Tintoré, 2011: ***Thermal Lag Correction on Slocum CTD Glider Data***. J. Atmos. Oceanic Technol, 28, 1065–1071.



# up- and down-cast differences



# up- and down-cast differences



# Thermal lag correction

Garau, B., S. Ruiz, W. G. Zhang, A. Pascual, E. Heslop, J. Kerfoot, and J. Tintoré, 2011: *Thermal Lag Correction on Slocum CTD Glider Data*. J. Atmos. Oceanic Technol, 28, 1065–1071.

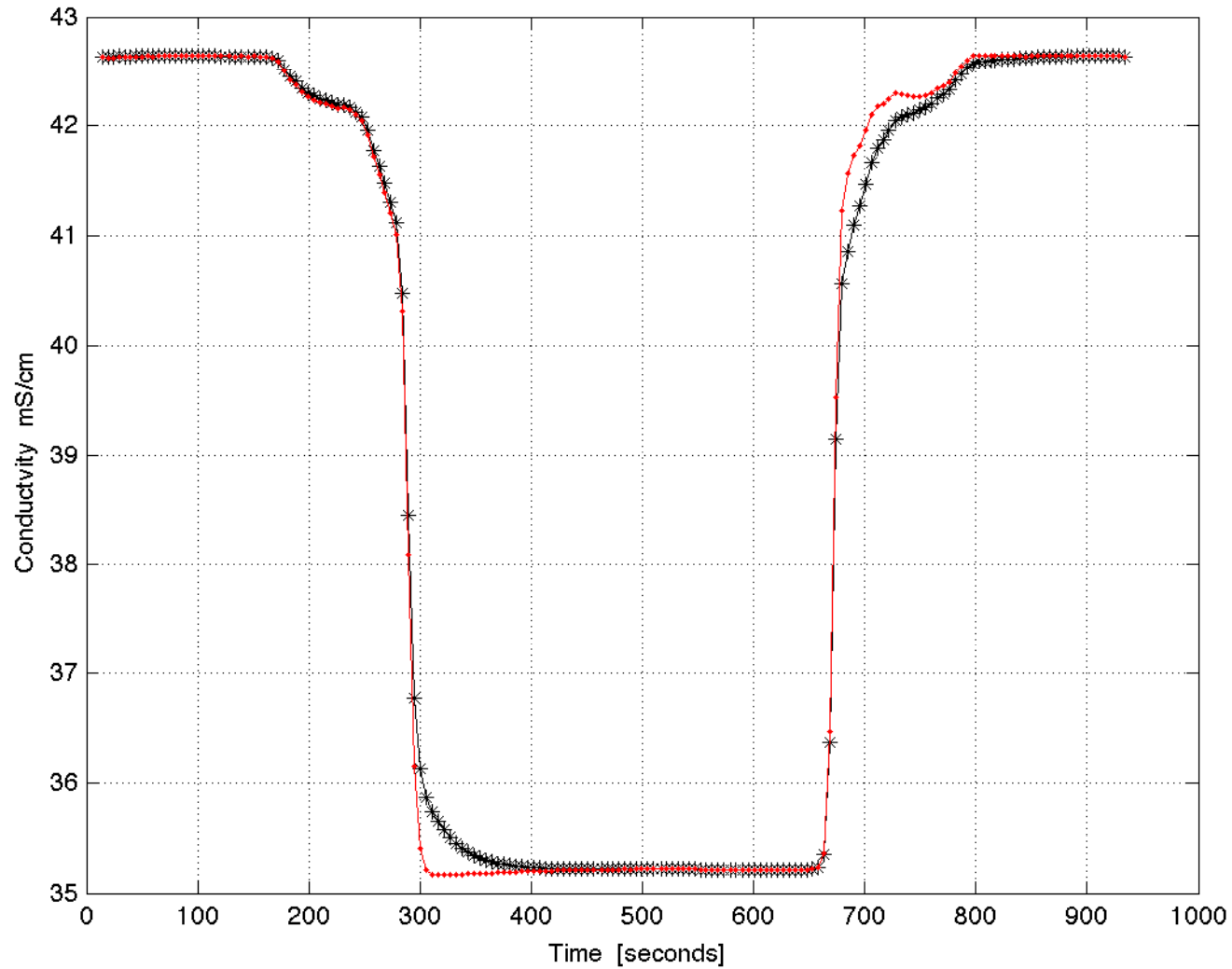
+

use speed through the water and angle of attack of flight model for cell flush speed modeling

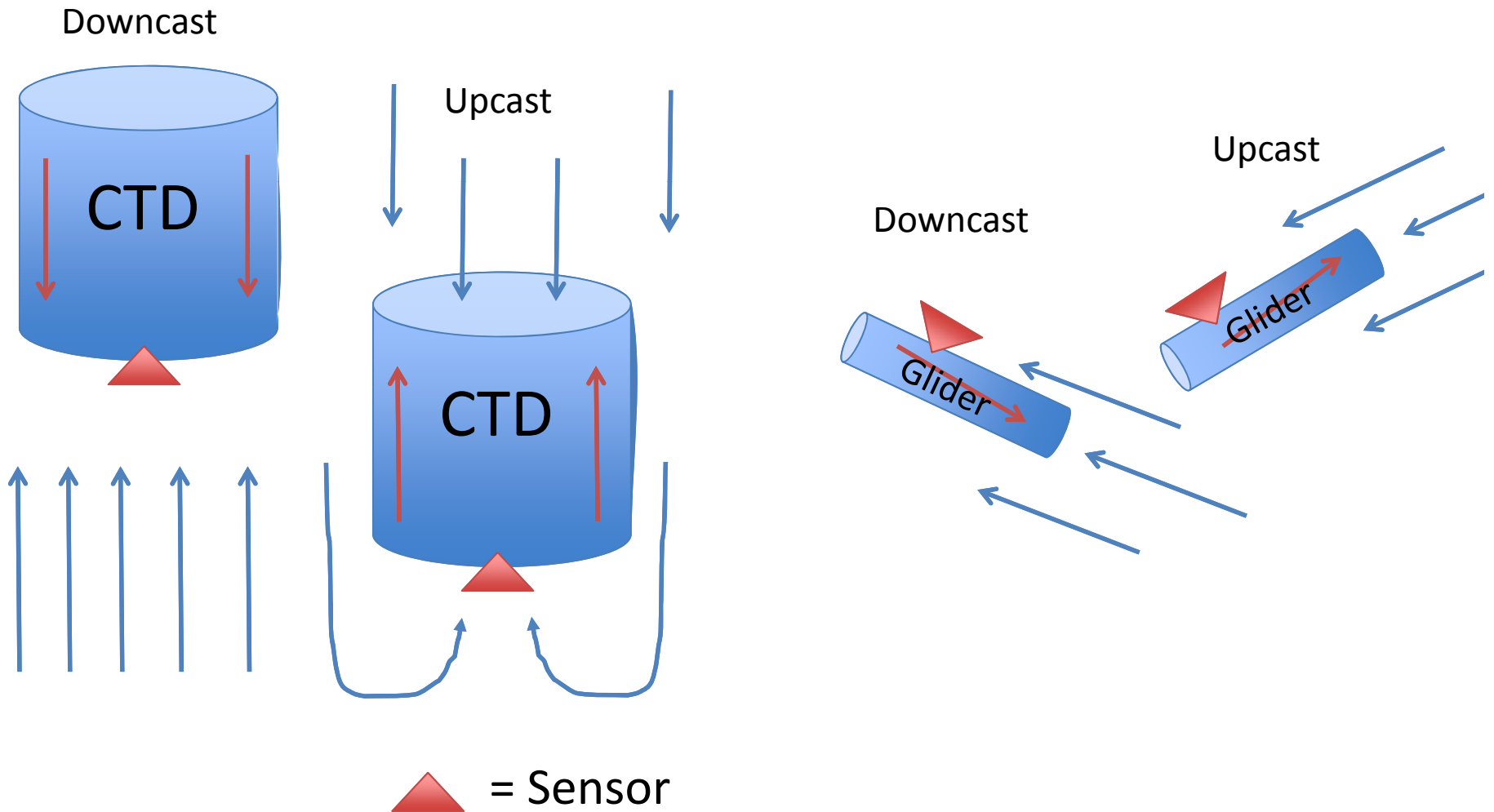
UW / APL hydrodynamic model for Seaglider

Merckelbach et al. 2010 for Slocum Gliders

# North Sea C calibration



# up- and down-cast differences



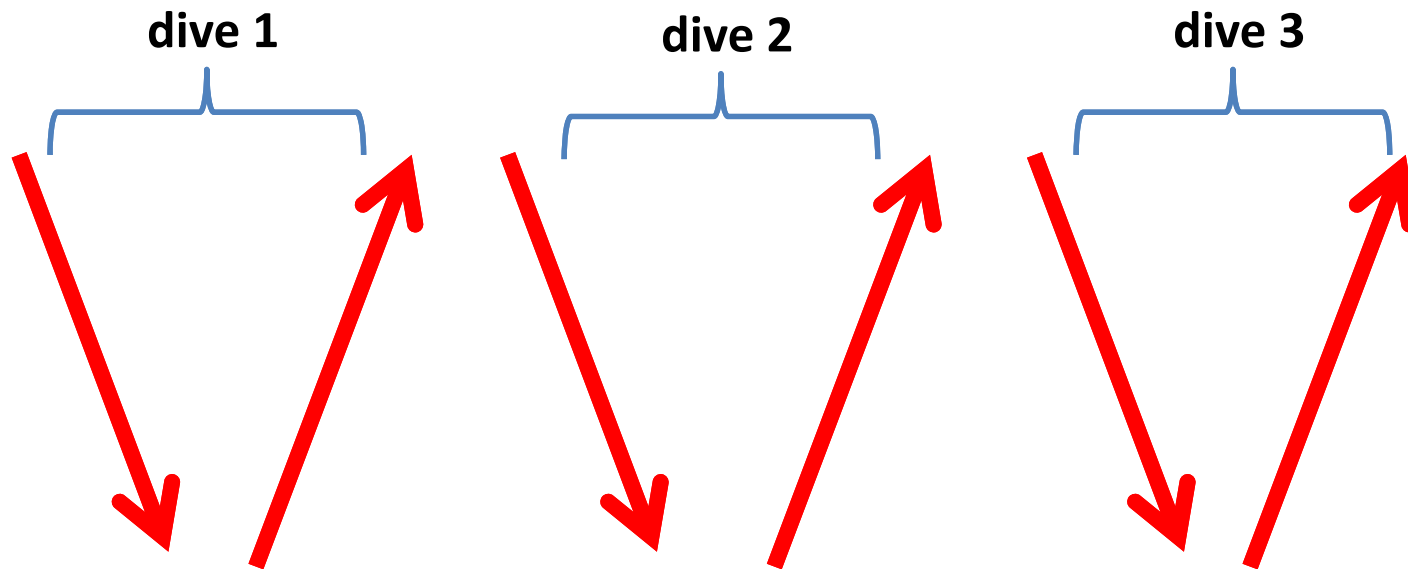
# up- and down-cast differences

Assuming that T/S ratio of water masses changes little in time and space, differences between up- and down-cast are:

- $dT/dt$  changes sign
- $dP/dt$  changes sign
- $dS/dt$  changes sign
- flight parameters (angle of attack,  $U$ , ...)

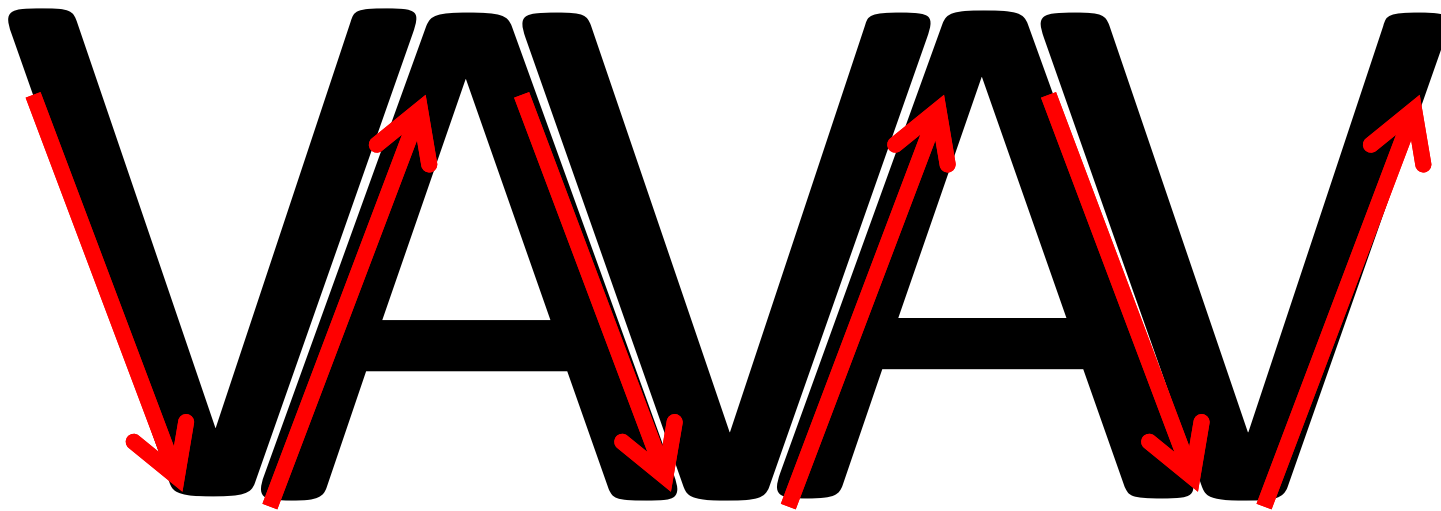
# up- and down-cast differences

Assuming that T/S ratio of water masses changes little in time and space. – true?



# up- and down-cast differences

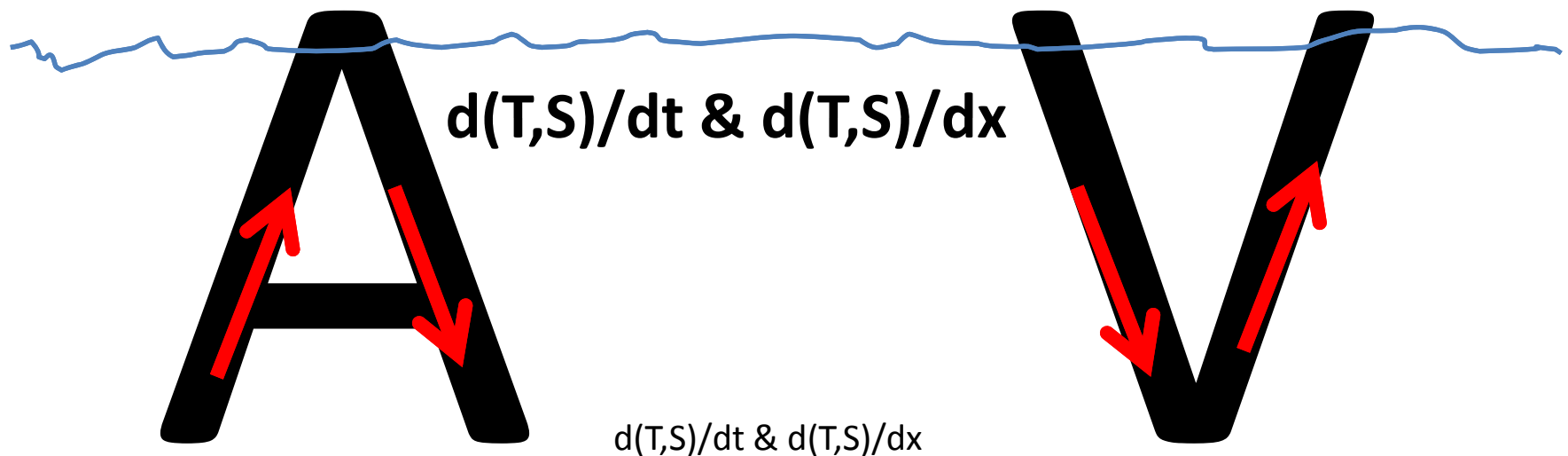
Assuming that T/S ratio of water masses changes little in time and space. – true?



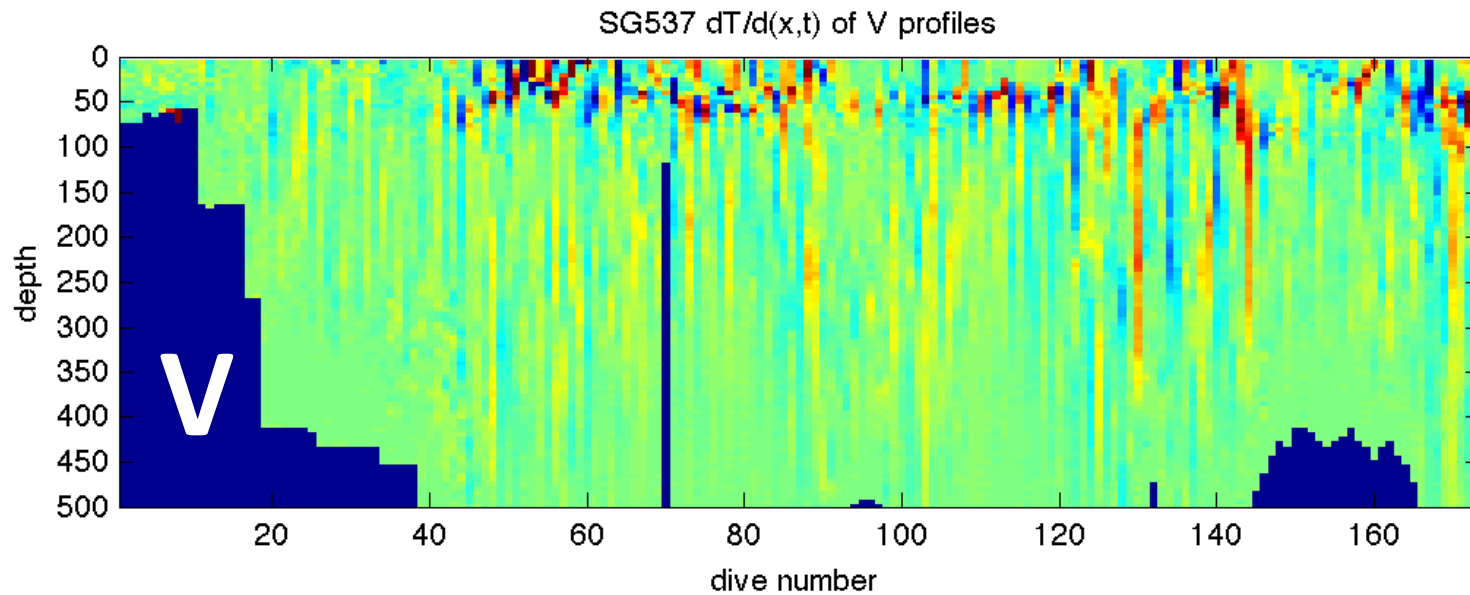
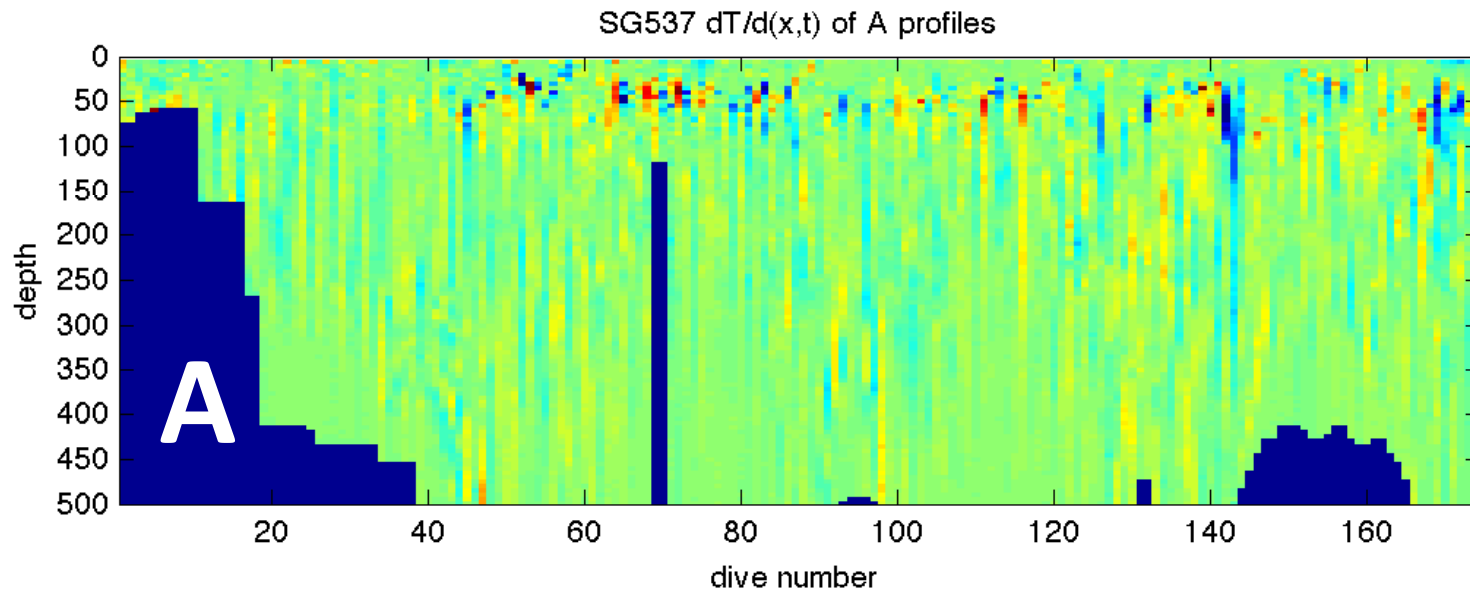


# up- and down-cast differences

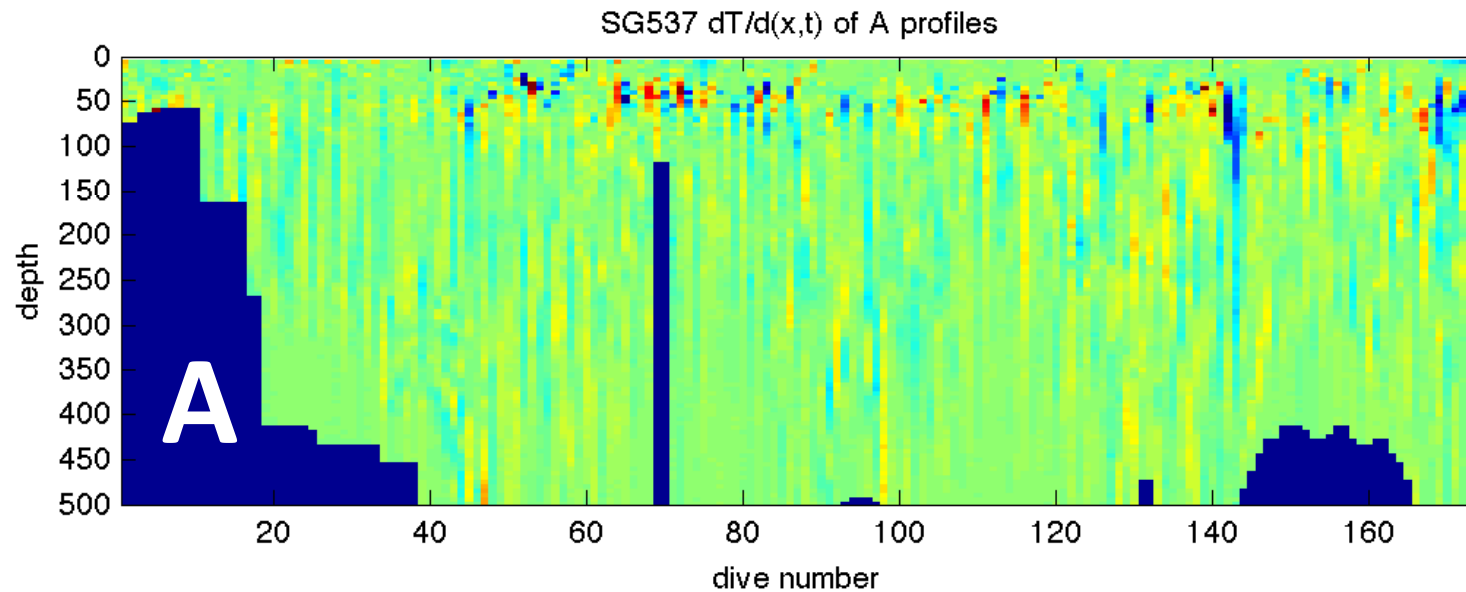
Assuming that T/S ratio of water masses changes little in time and space. – true?



# Comparison of A and V profiles



# Glider A profiles

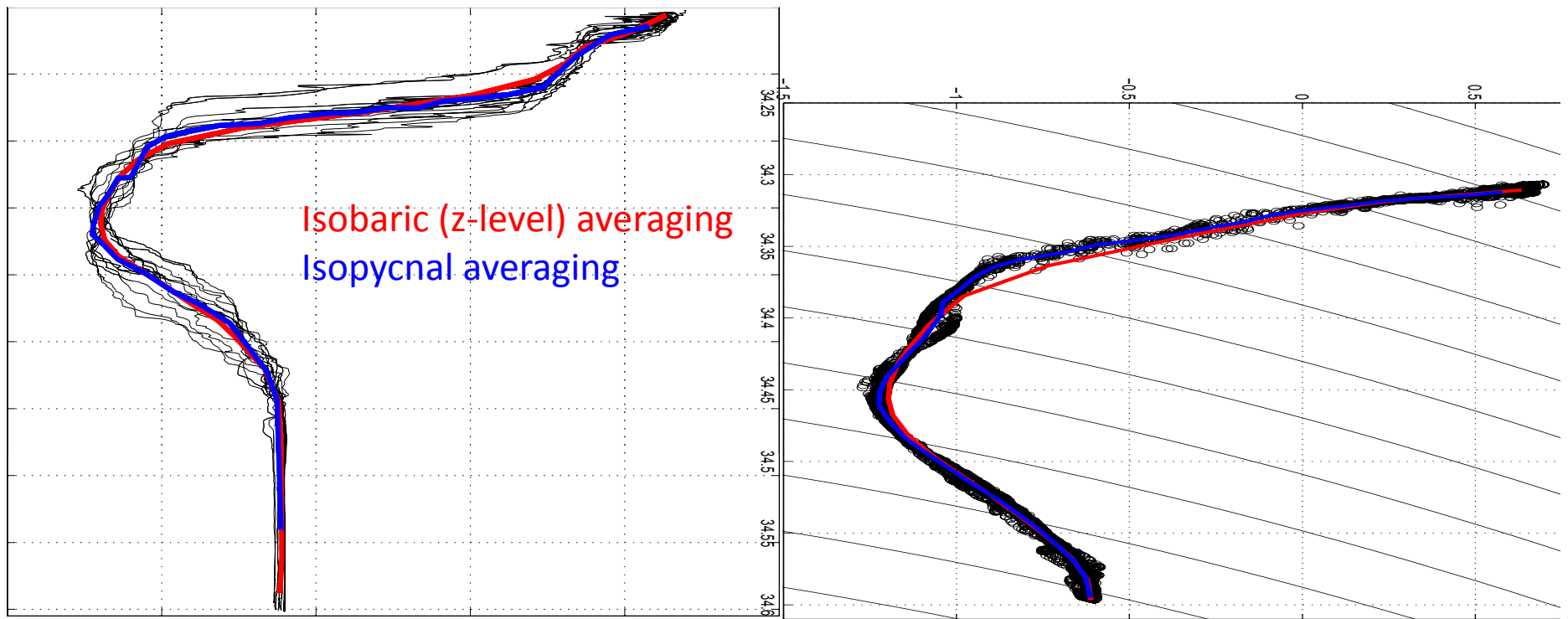


remaining issue: - internal variability, e.g. internal waves

to minimize impact of waves etc. an analysis should be performed in  $\Theta$ - $S$  space rather than on isobars.

# Isopycnal comparison

Yo-yo station, Antarctic Peninsula



# Conclusions?!

- calibration is iterative – calibrate S, calibrate flight model, calibrate S ...
- do not just use up- or down- cast, use one to validate the other!
- averaging high resolution data can be done, if systematic errors are eliminated / mitigated.
- filter for realistic physical ranges (e.g. acceleration through water)
- do not underestimate the effort necessary to calibrate glider data – it is not a CTD, yet.