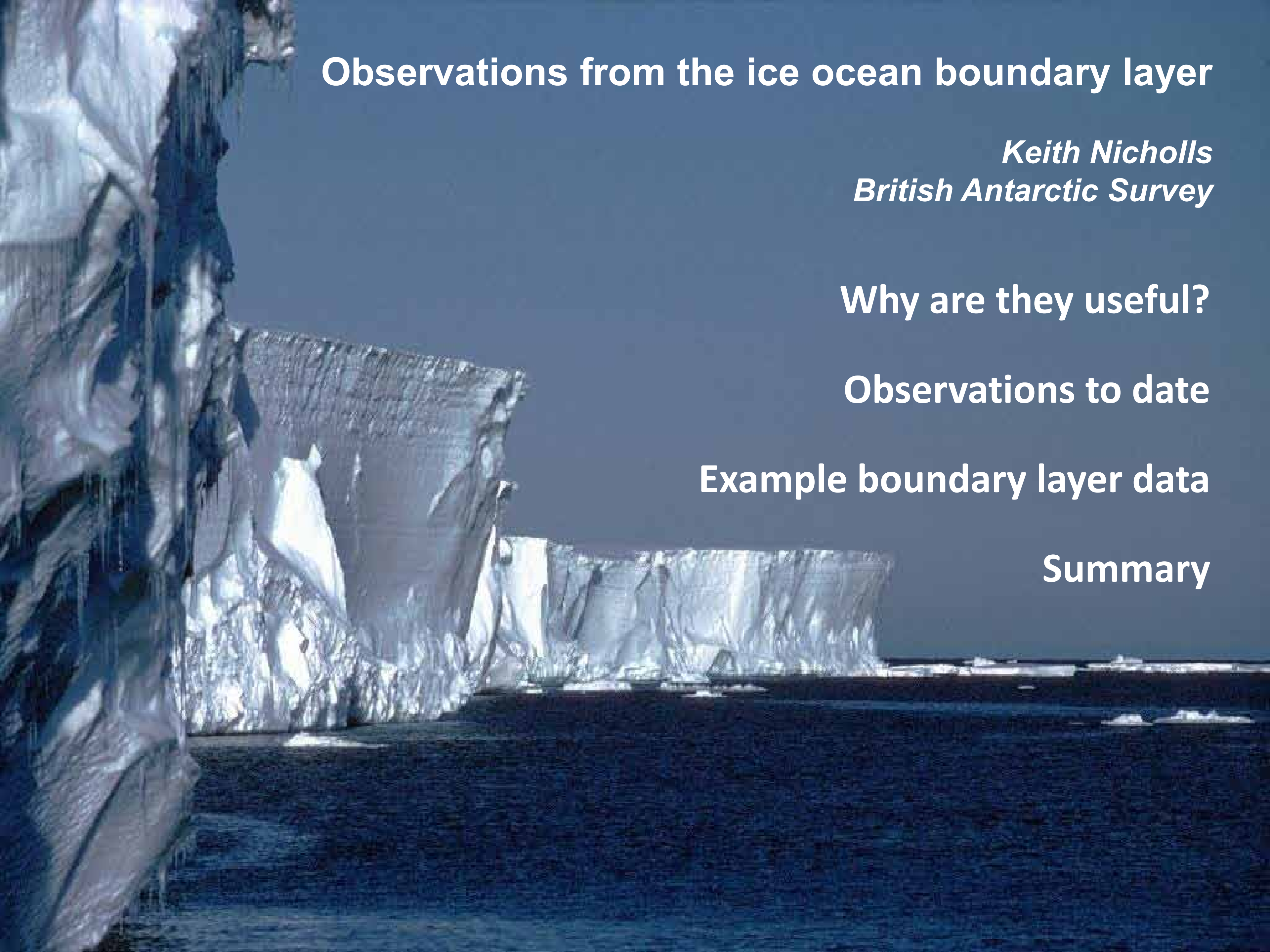


# Observations from the ice ocean boundary layer

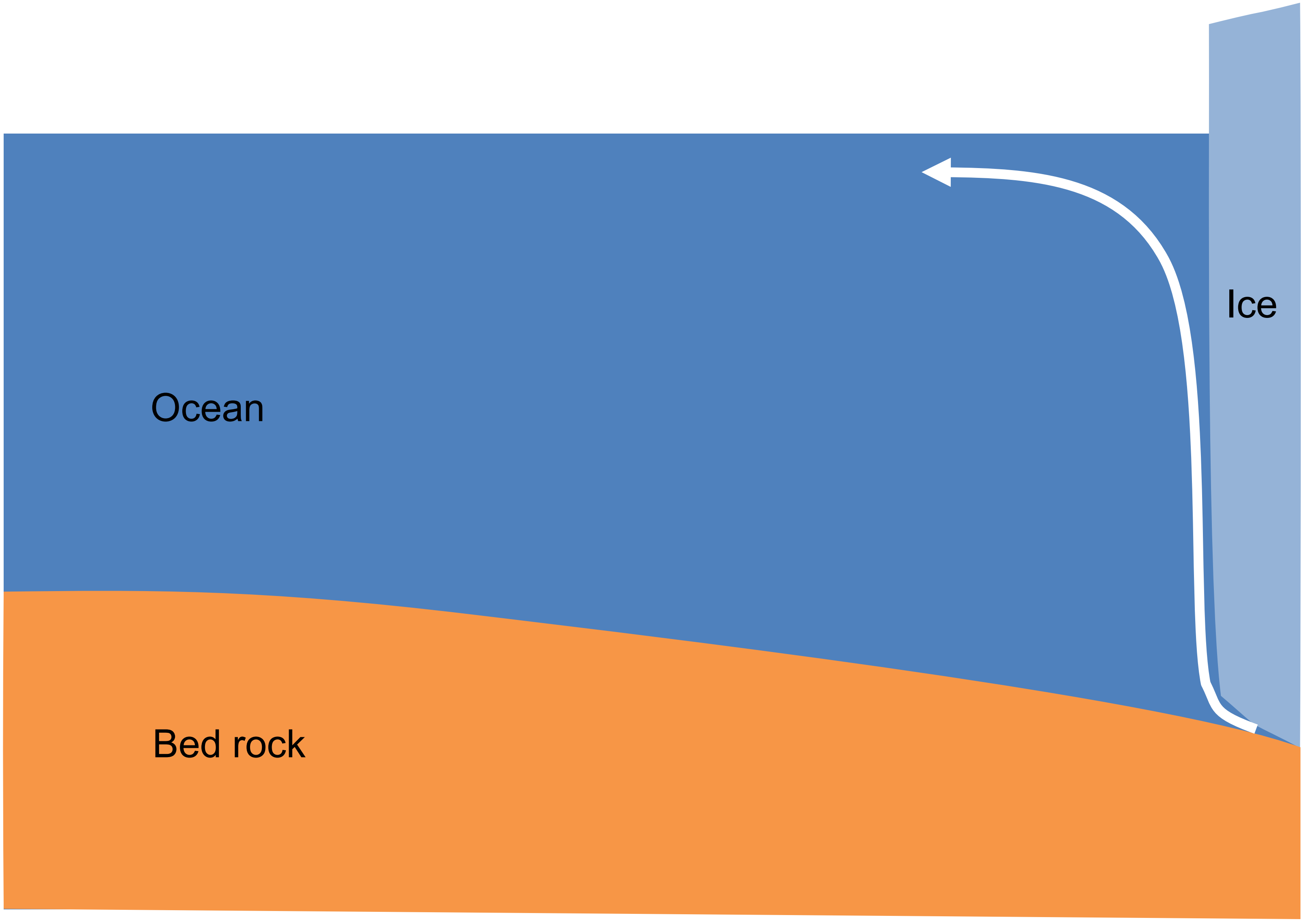
*Keith Nicholls*
*British Antarctic Survey*

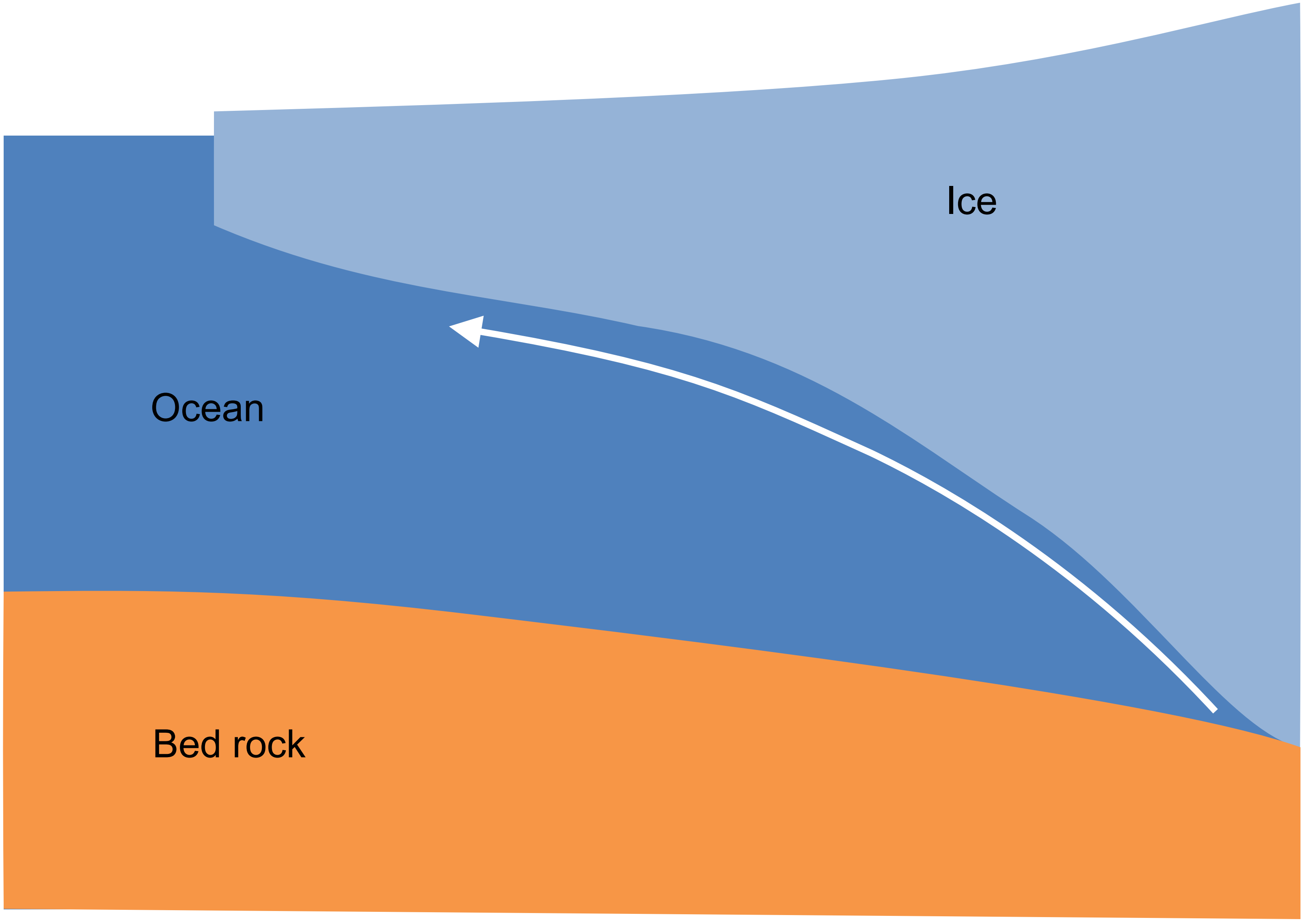
## Why are they useful?

## Observations to date

## Example boundary layer data

## Summary


Ice
Ocean
Bed rock

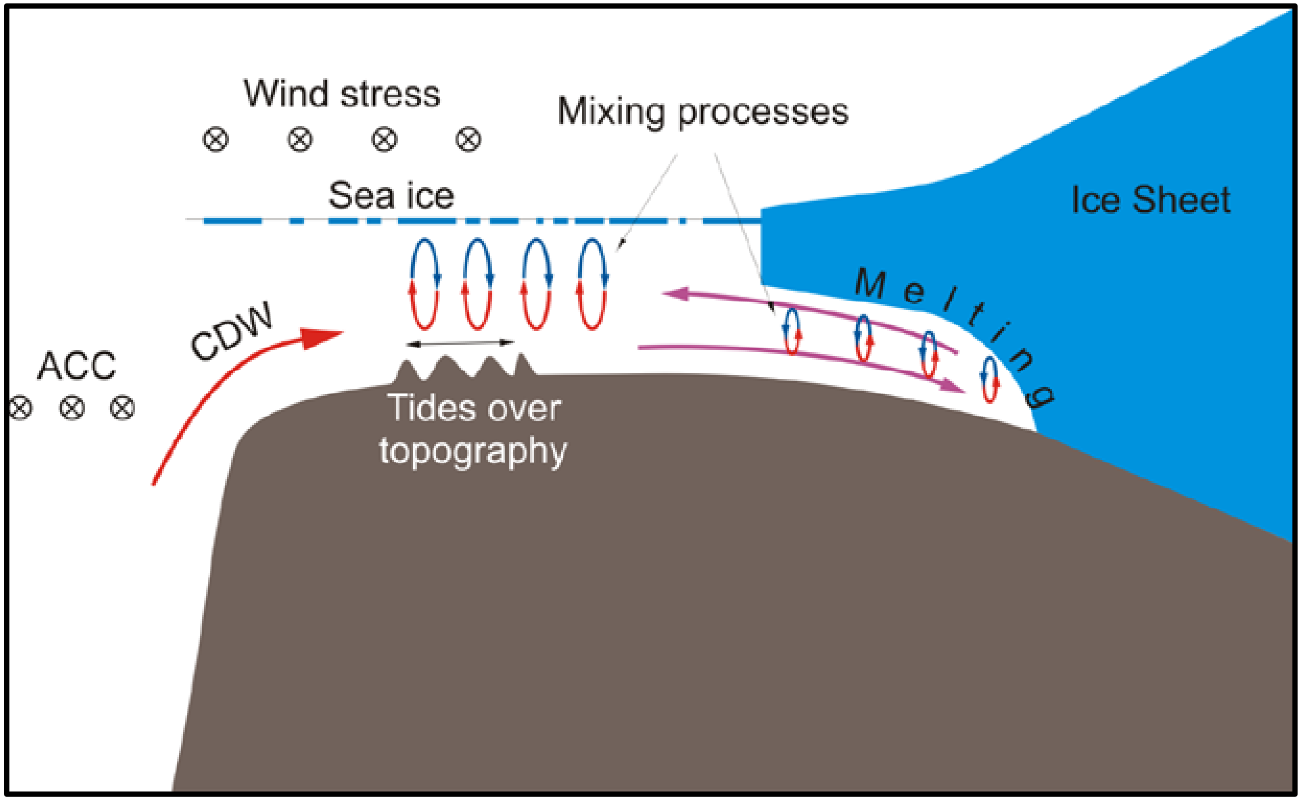

Ice
Ocean
Bed rock

# Need to predict:

**Oceanographic forcing on the ice shelves**

**Response of the ice shelves to that changing forcing**

**Response of the inland ice sheet**




**Lynch-pin is the ability to calculate how fast the ice shelf base will melt given the oceanographic properties in the sub-ice shelf cavity**

# How do we calculate the rate of melting at the ice base?

Conservation of heat:

*Melt rate ~ Heat diffused across boundary layer - heat diffused into ice shelf*

Conservation of salt:

*Freshening at base balanced by salt diffusion across boundary layer*

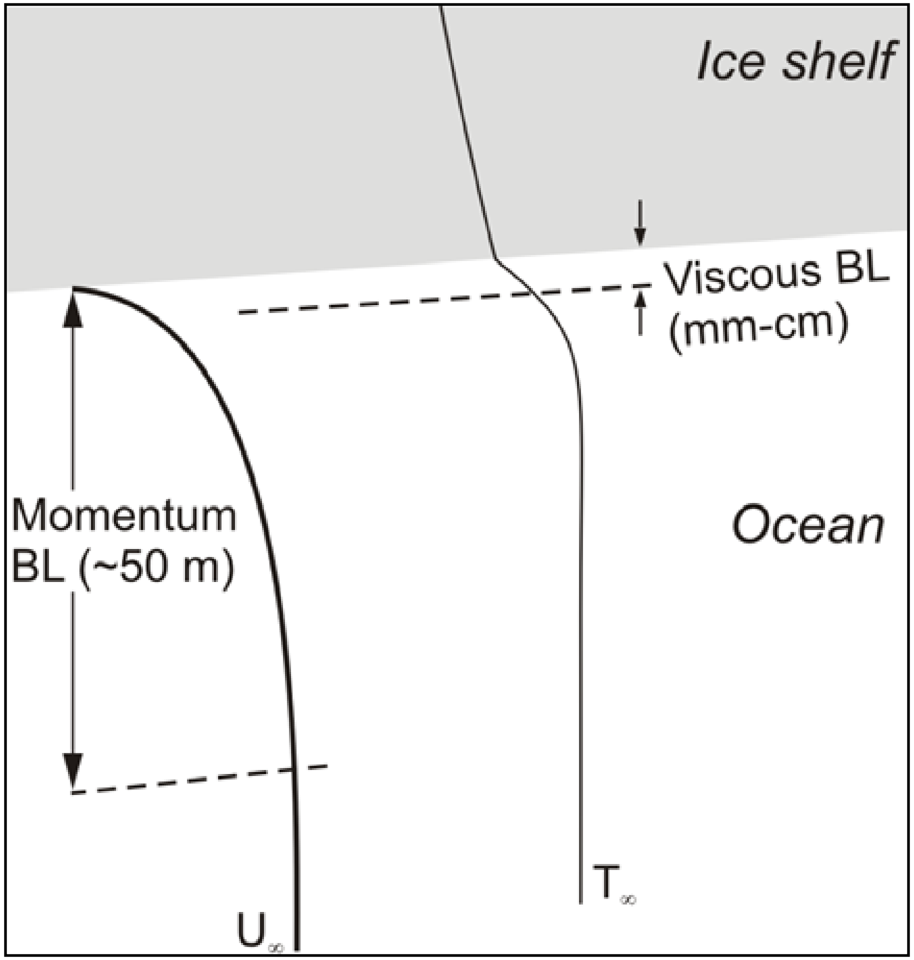
Ice base at the *in situ* freezing point

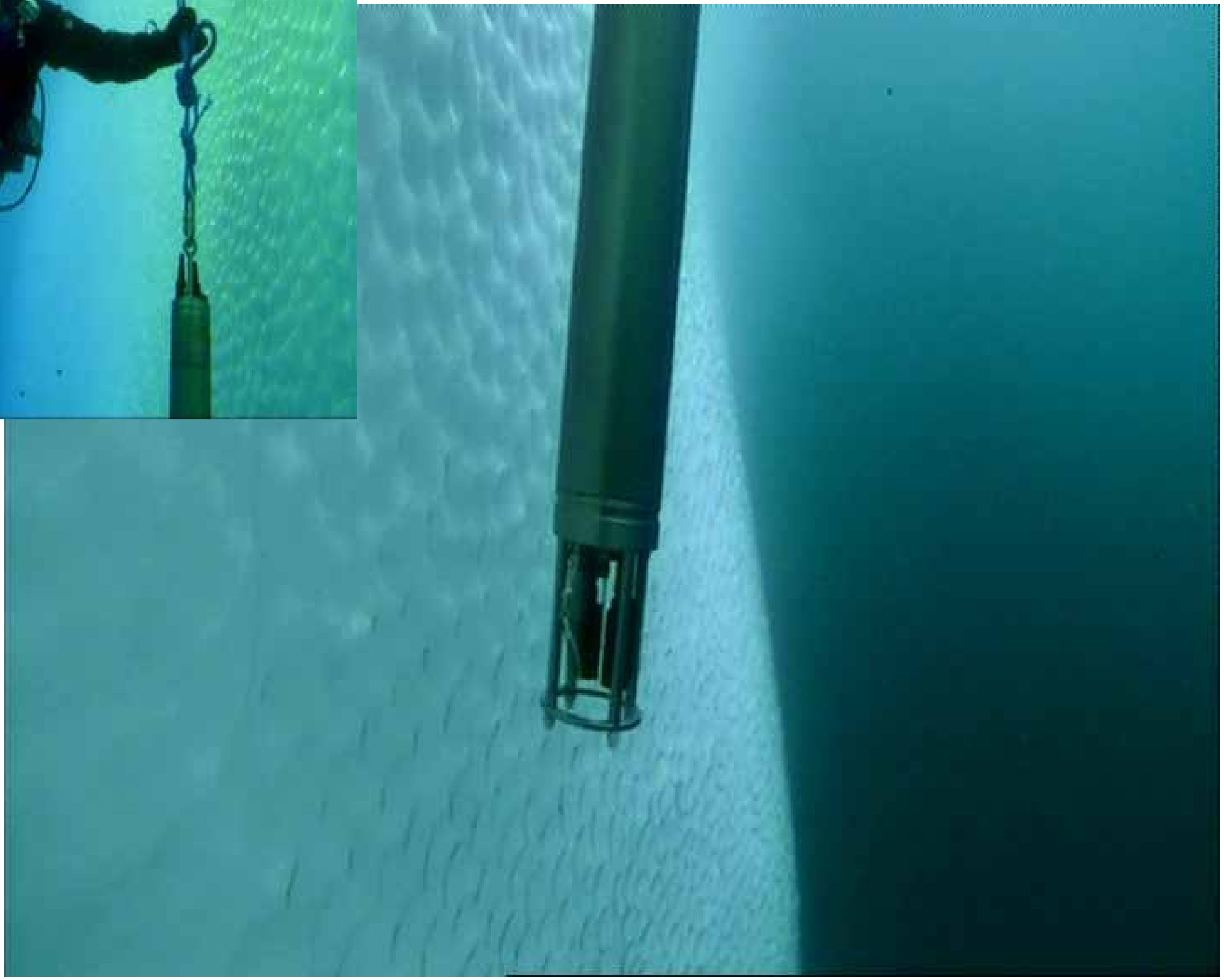
Need parameterisation for bulk transport coefficients for heat and salt

Traditionally used *Kader &Yaglom* (1972)

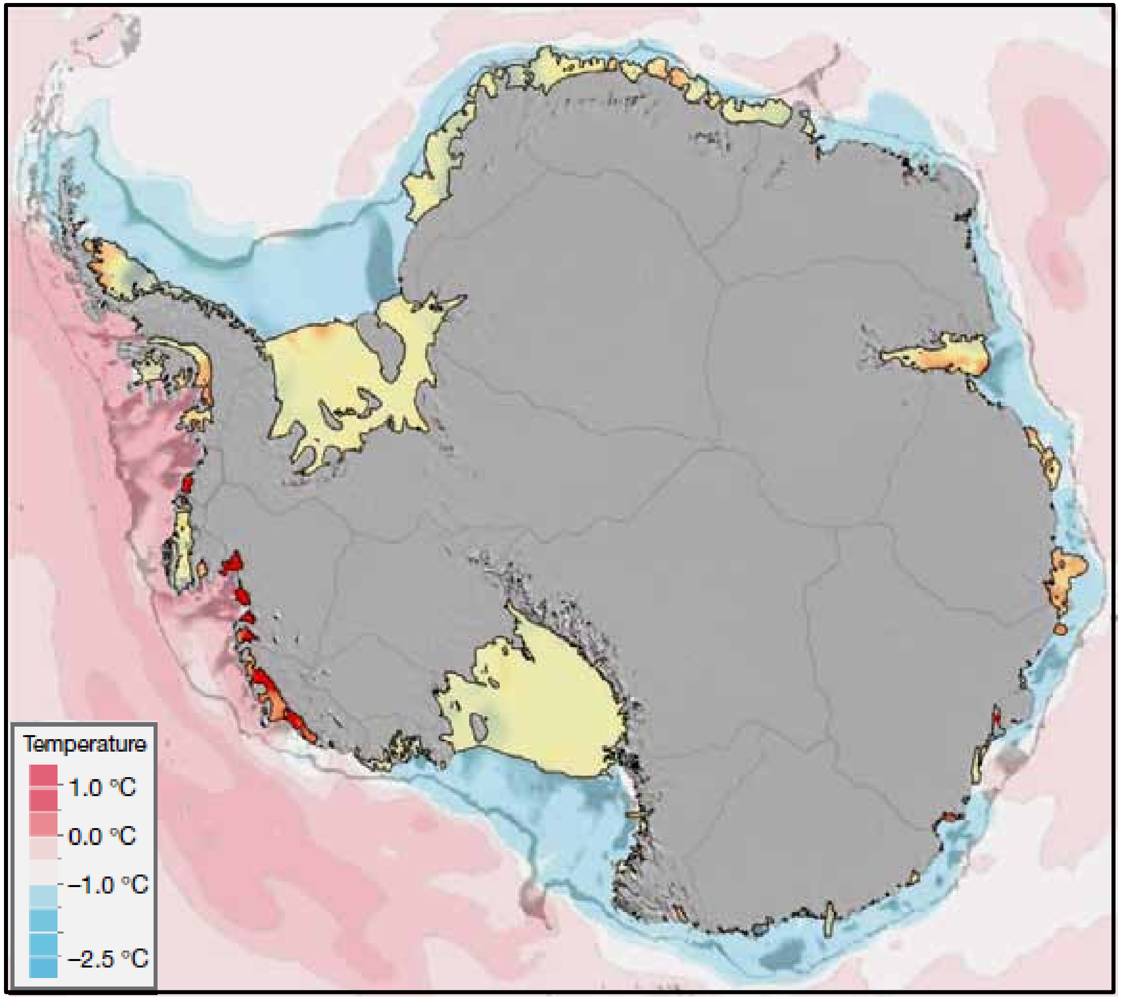
**Parameterisation assumes**

- fully turbulent flow
- neutrally stable
- “smooth, flat” ice base



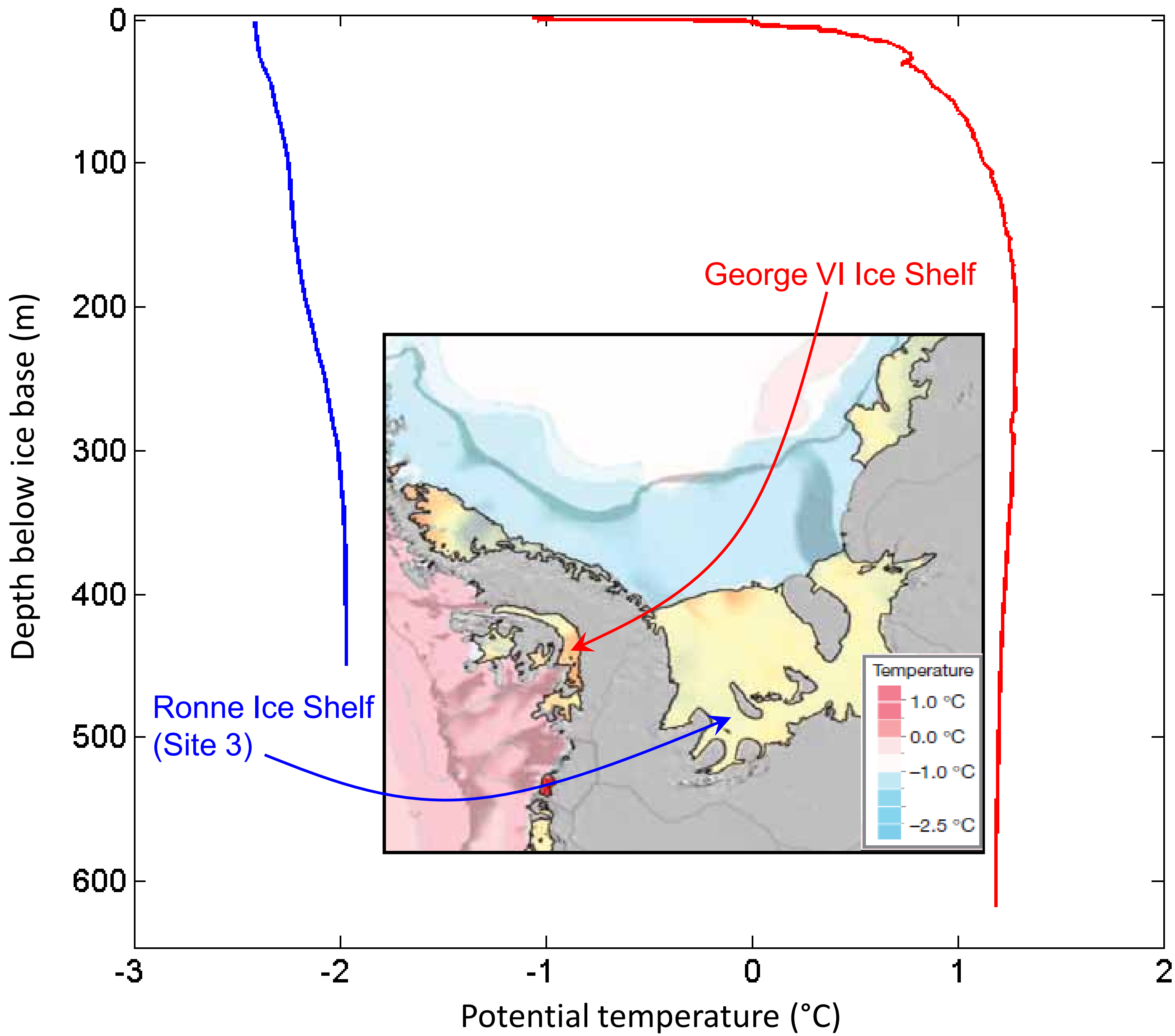


Sea floor temperatures

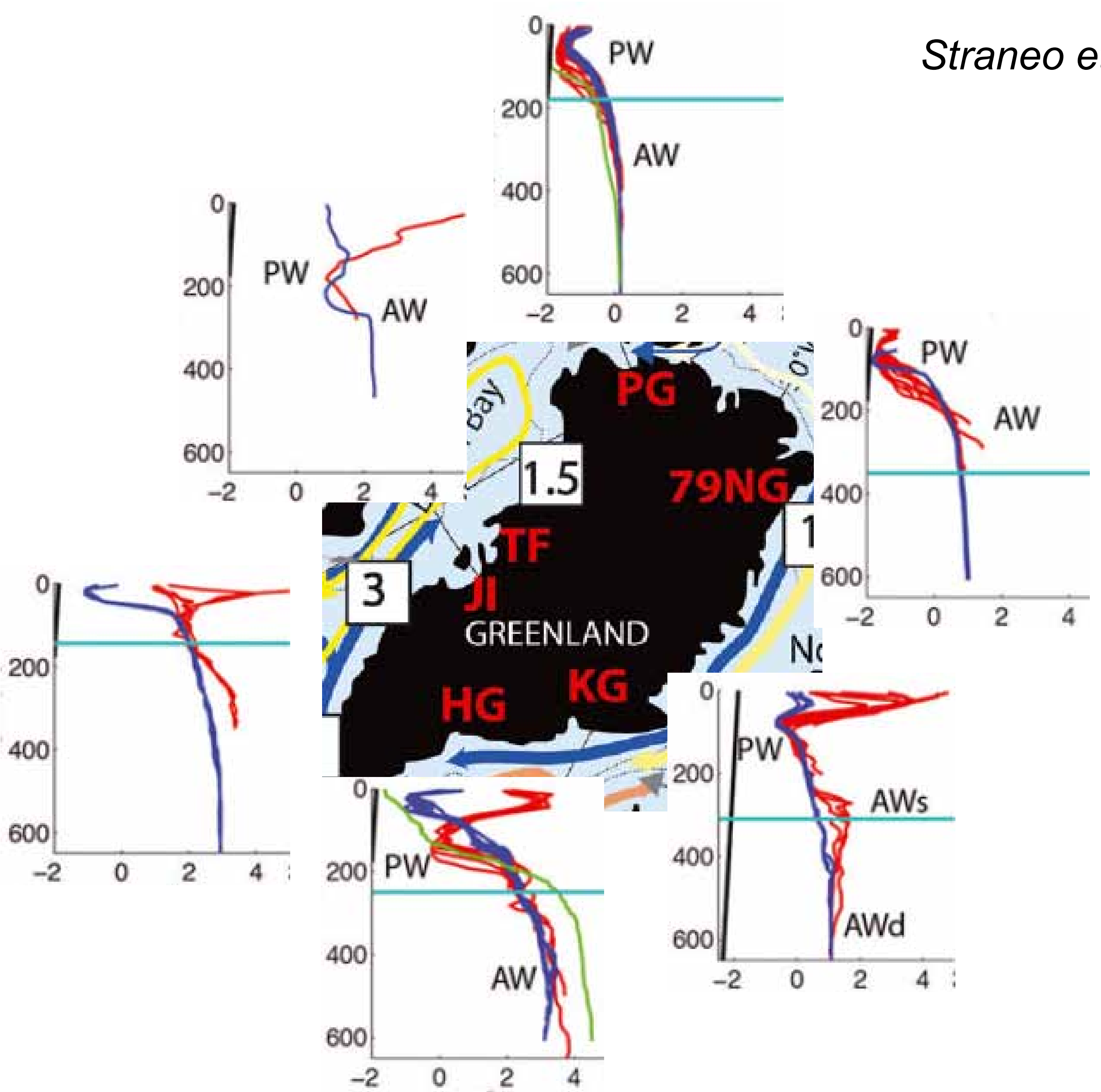



*Pritchard et al*

Warm and cold sectors of the Antarctic continental shelf



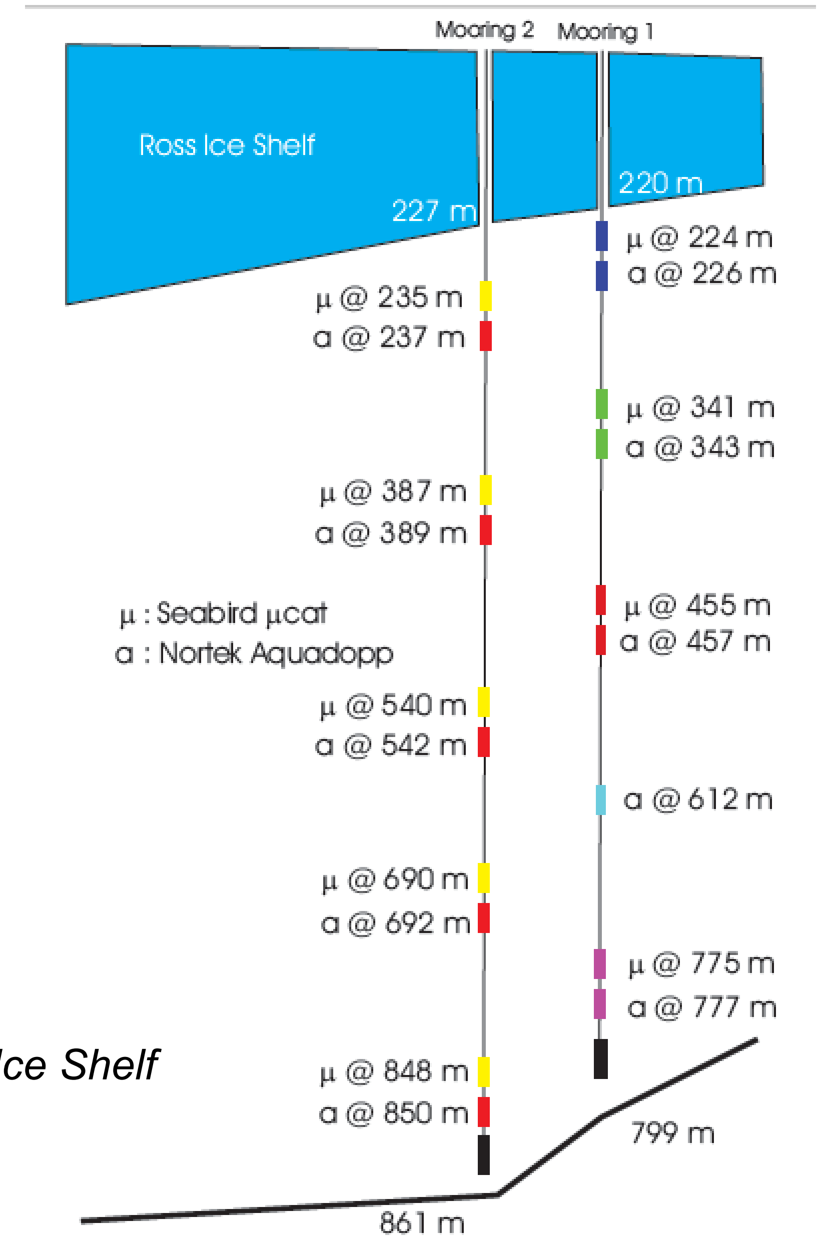
*Straneo et al 2012*



# Moored instruments

Typically point measurements
Some short-term ADCP deployments
Generally focussed on big picture

Must be cabled (rarely recovered)
Major benefits in inductive modems

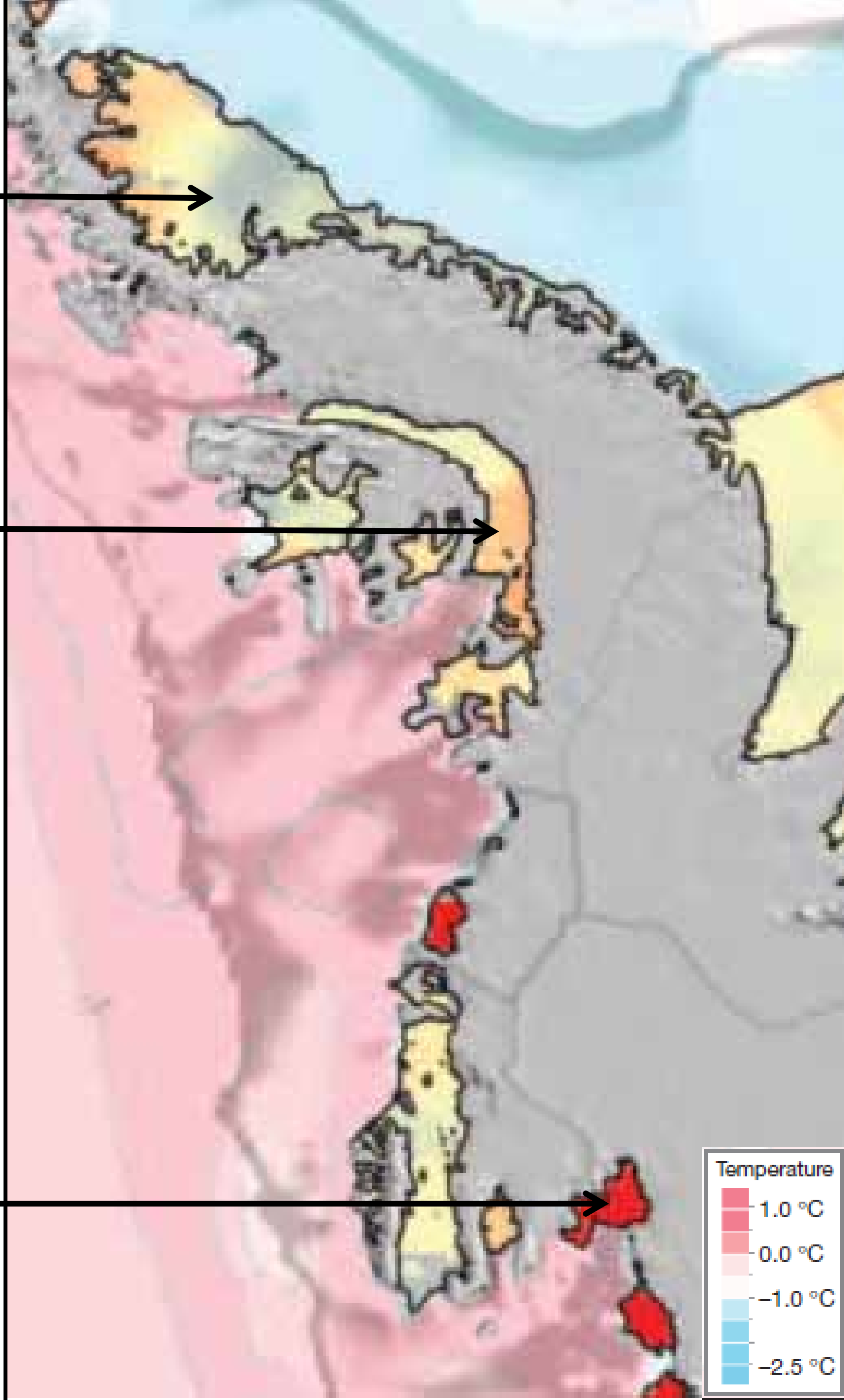



*WHOI and NIWA sites, Ross Ice Shelf*
*Courtesy Craig Stewart*

Larsen C Ice Shelf
(2011-12)

George VI Ice Shelf
(2011-12)

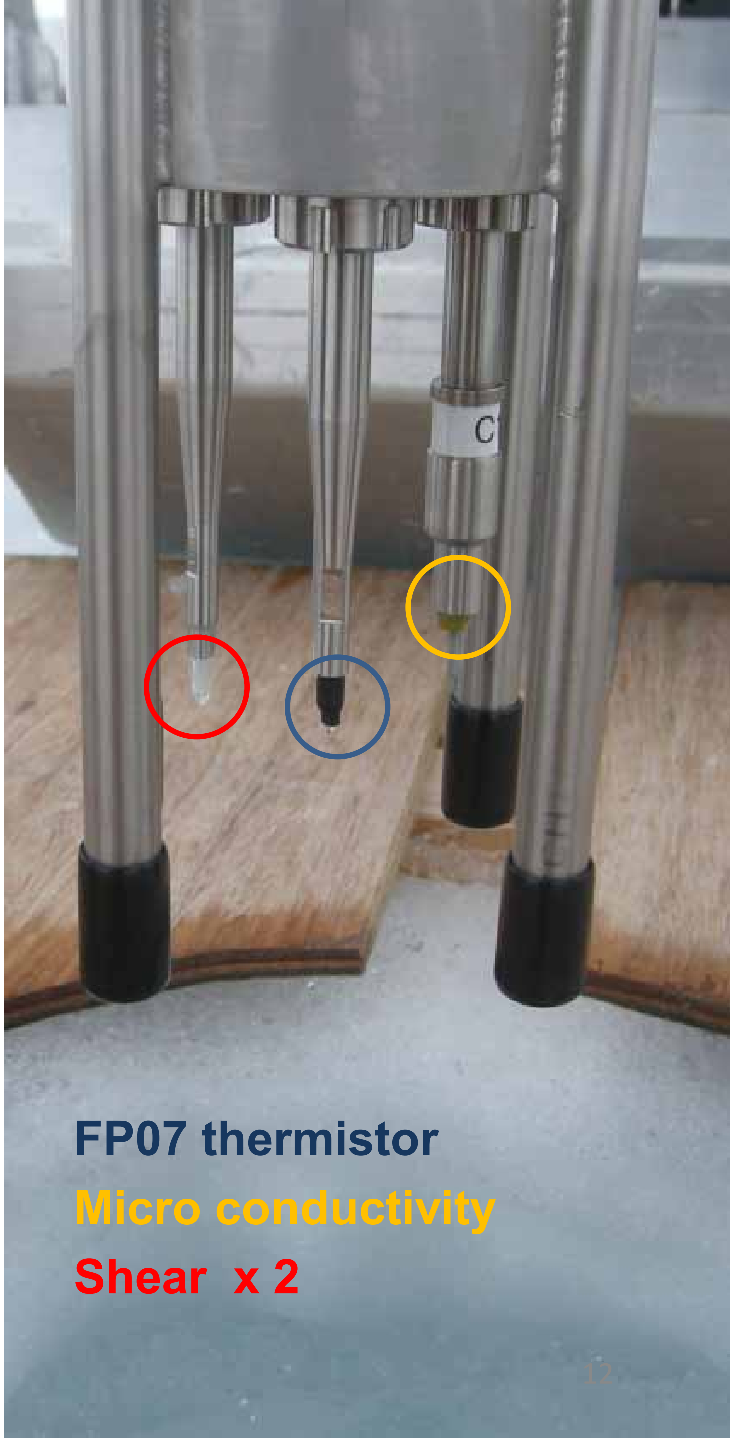
Pine Island Glacier
(2012-13)

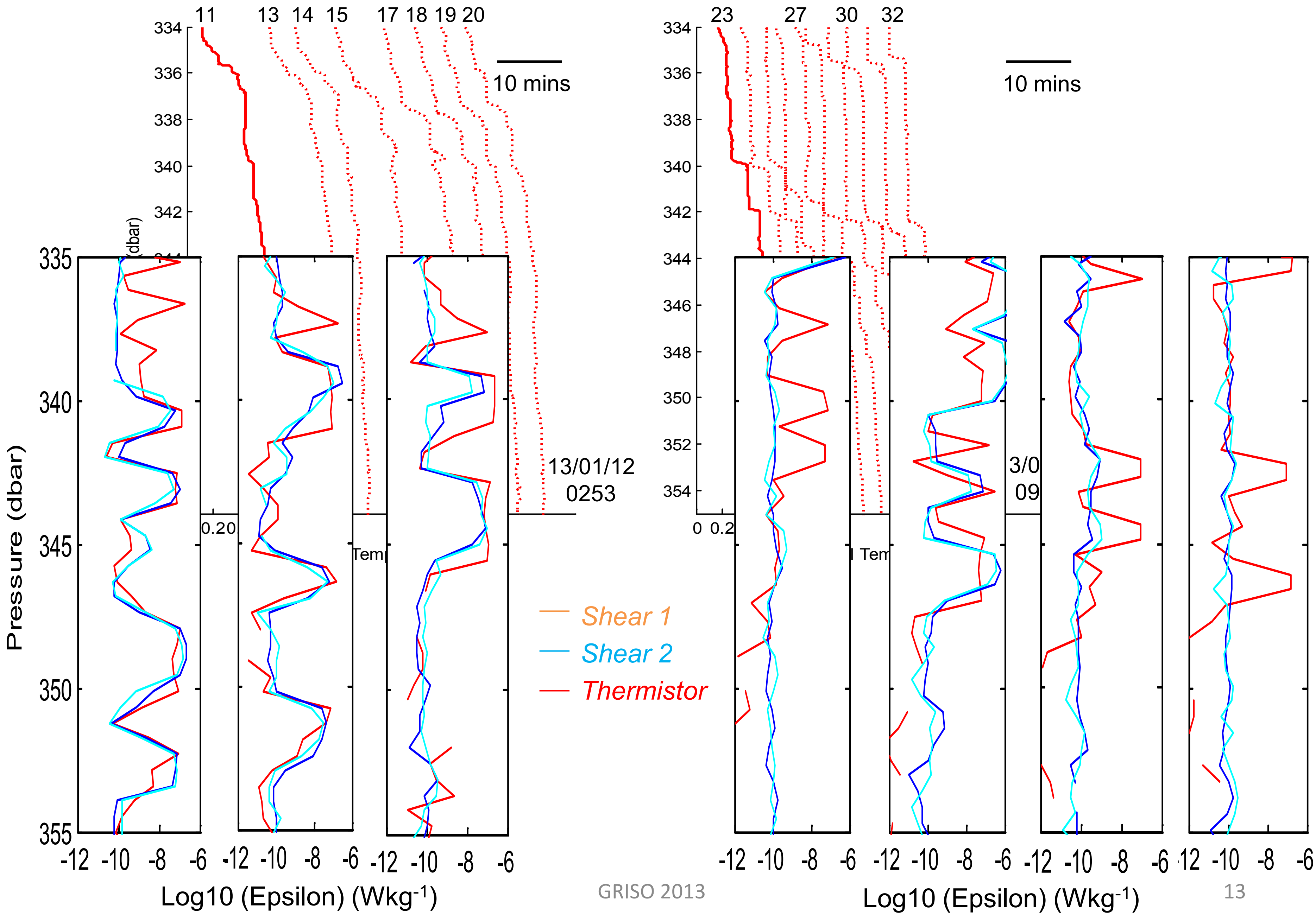



GRISO 2013

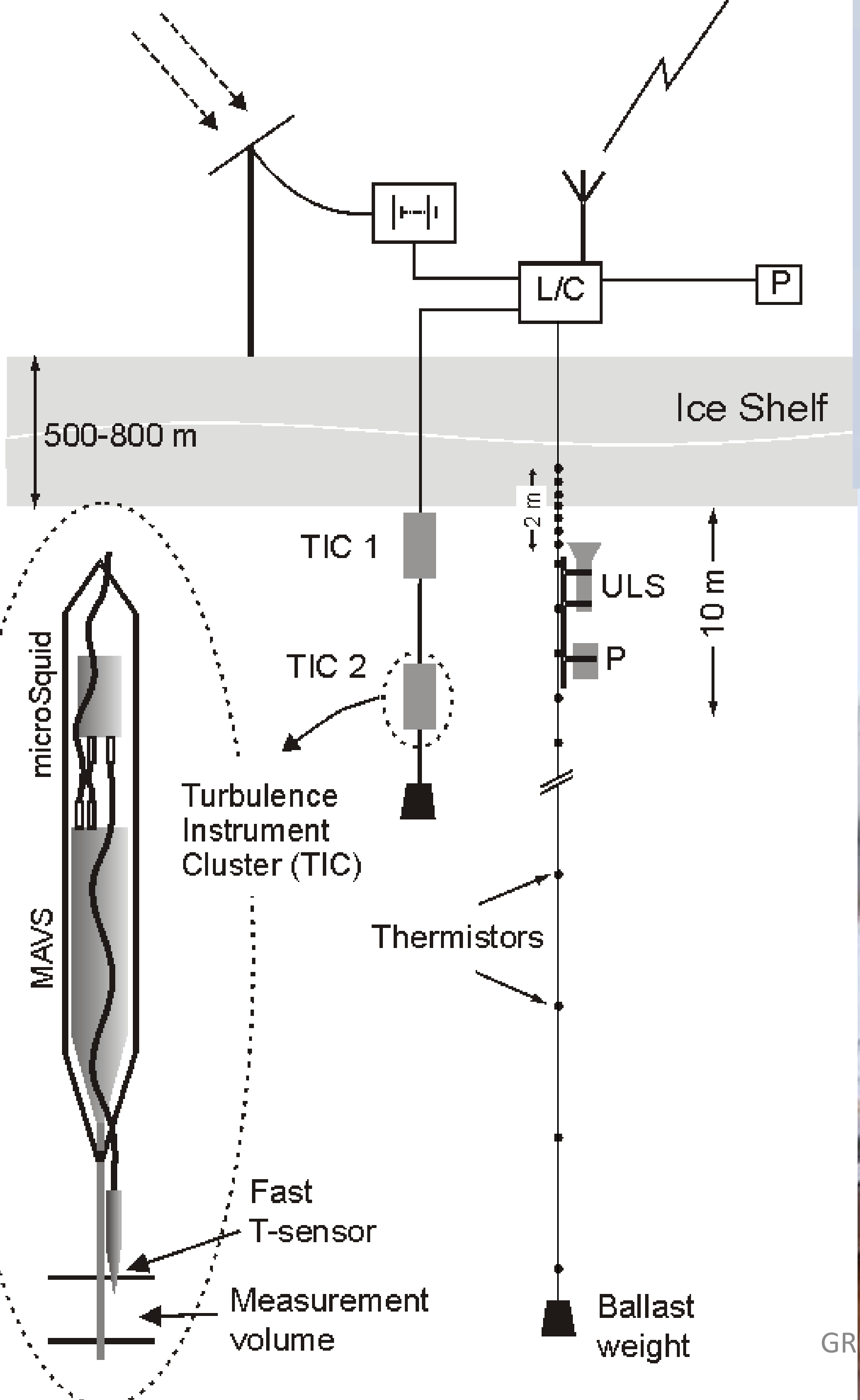
# Microstructure profiling

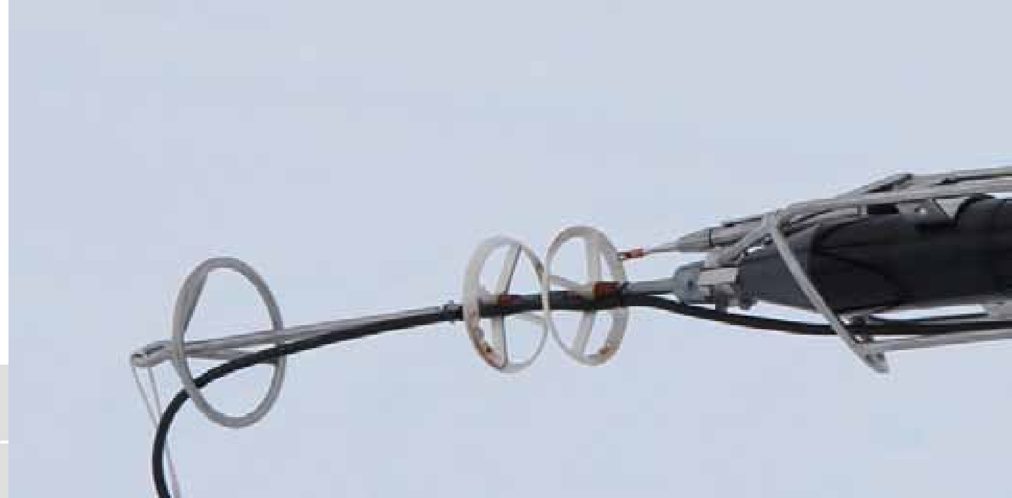
- Rockland VMP 200
- Smoothly moving platform
- Appropriate fall speed
- Sensors at tip sampled at 512 Hz
- Further sensors inside body

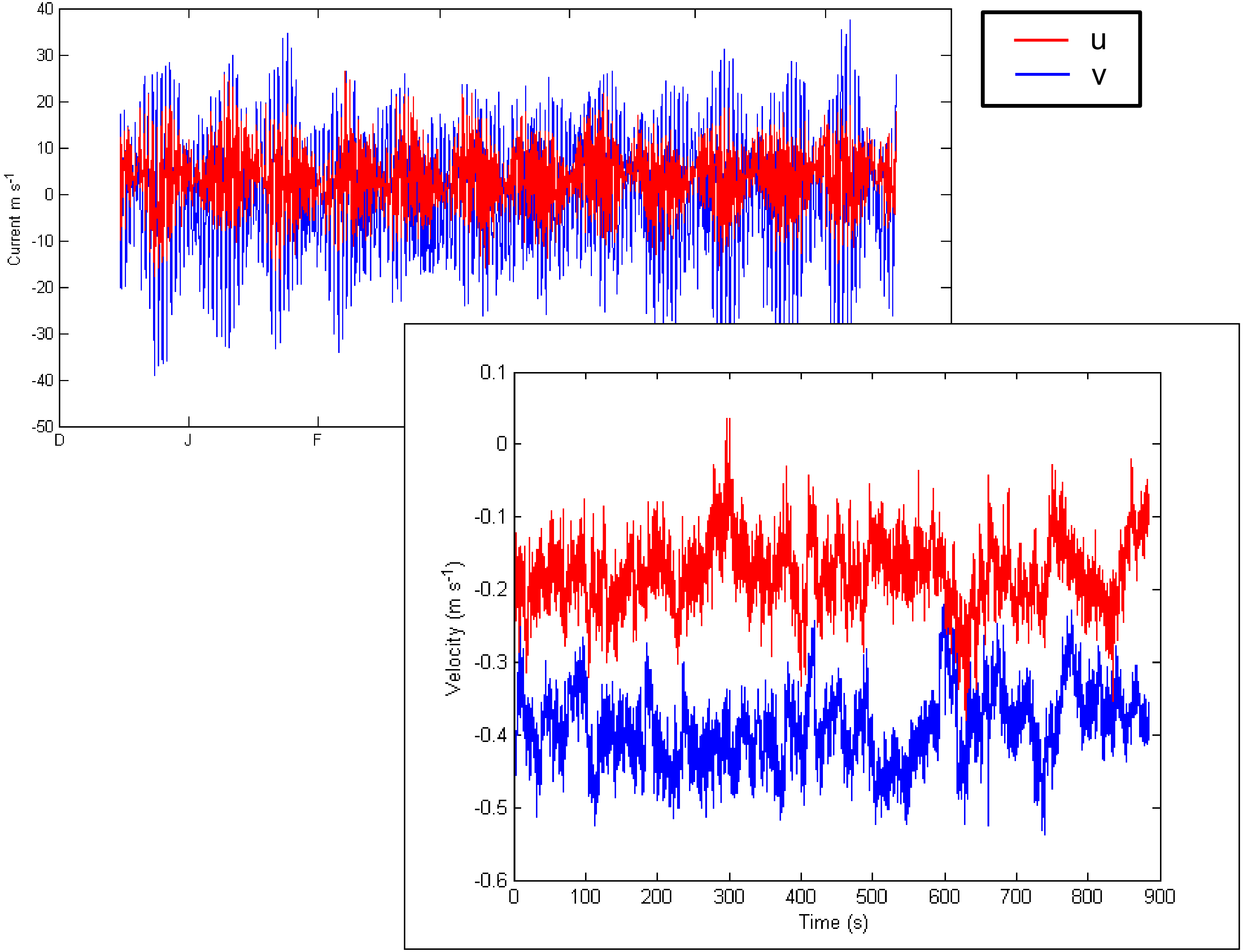




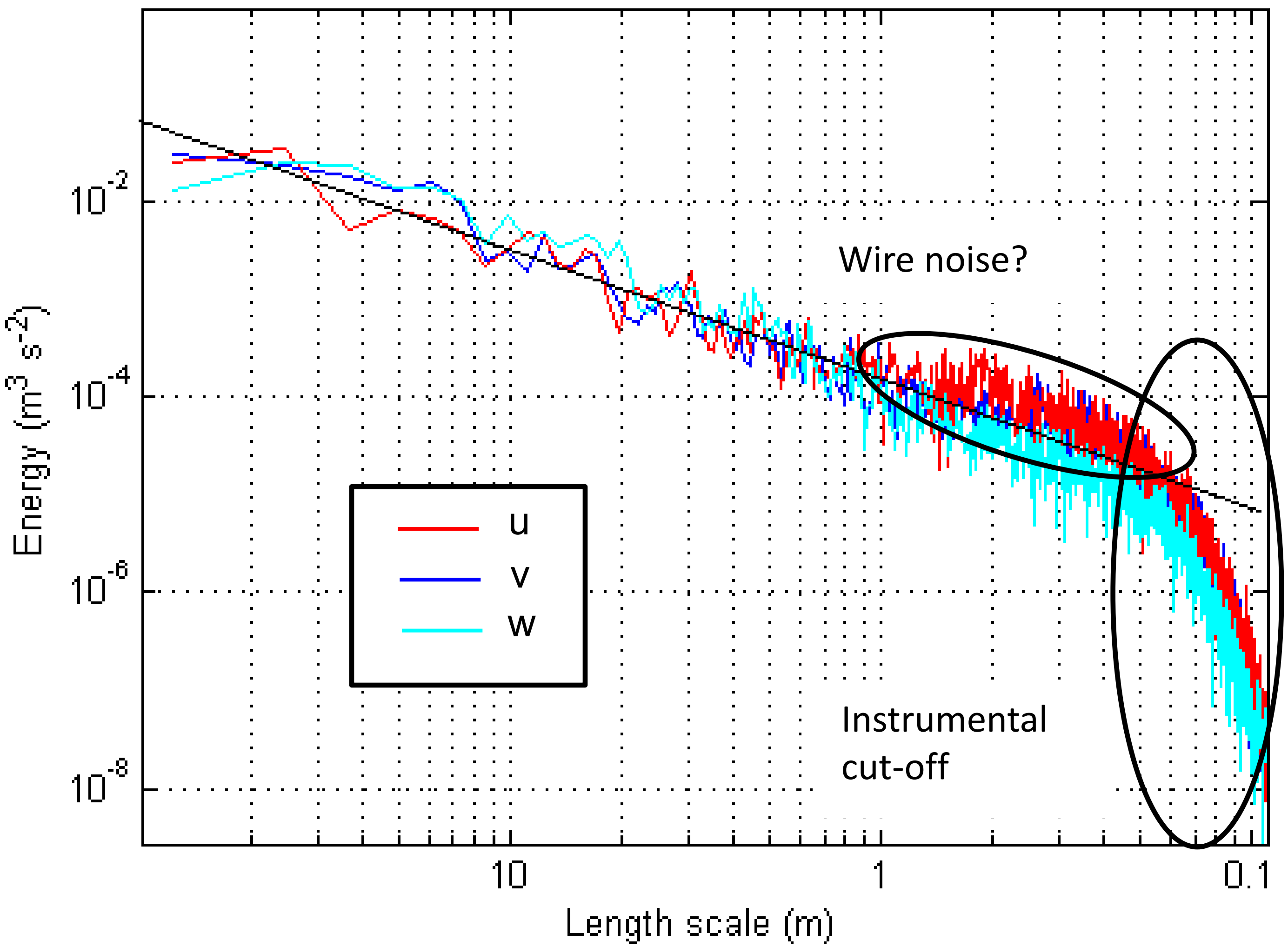
11 13 14 15 17 18 19 20
23 27 30 32
10 mins
10 mins
13/01/12
0253
Pressure (dbar)
Shear 1
Shear 2
Thermistor
Log10 (Epsilon) (Wkg-1)
Log10 (Epsilon) (Wkg-1)


L/C
P
Ice Shelf
500-800 m
2 m
10 m
TIC 1
TIC 2
ULS
P
microSquid
MAVS
Turbulence
Instrument
Cluster (TIC)
Thermistors
Fast
T-sensor
Measurement
volume
Ballast
weight

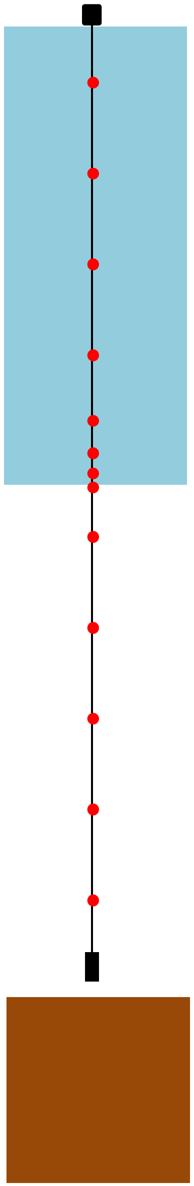


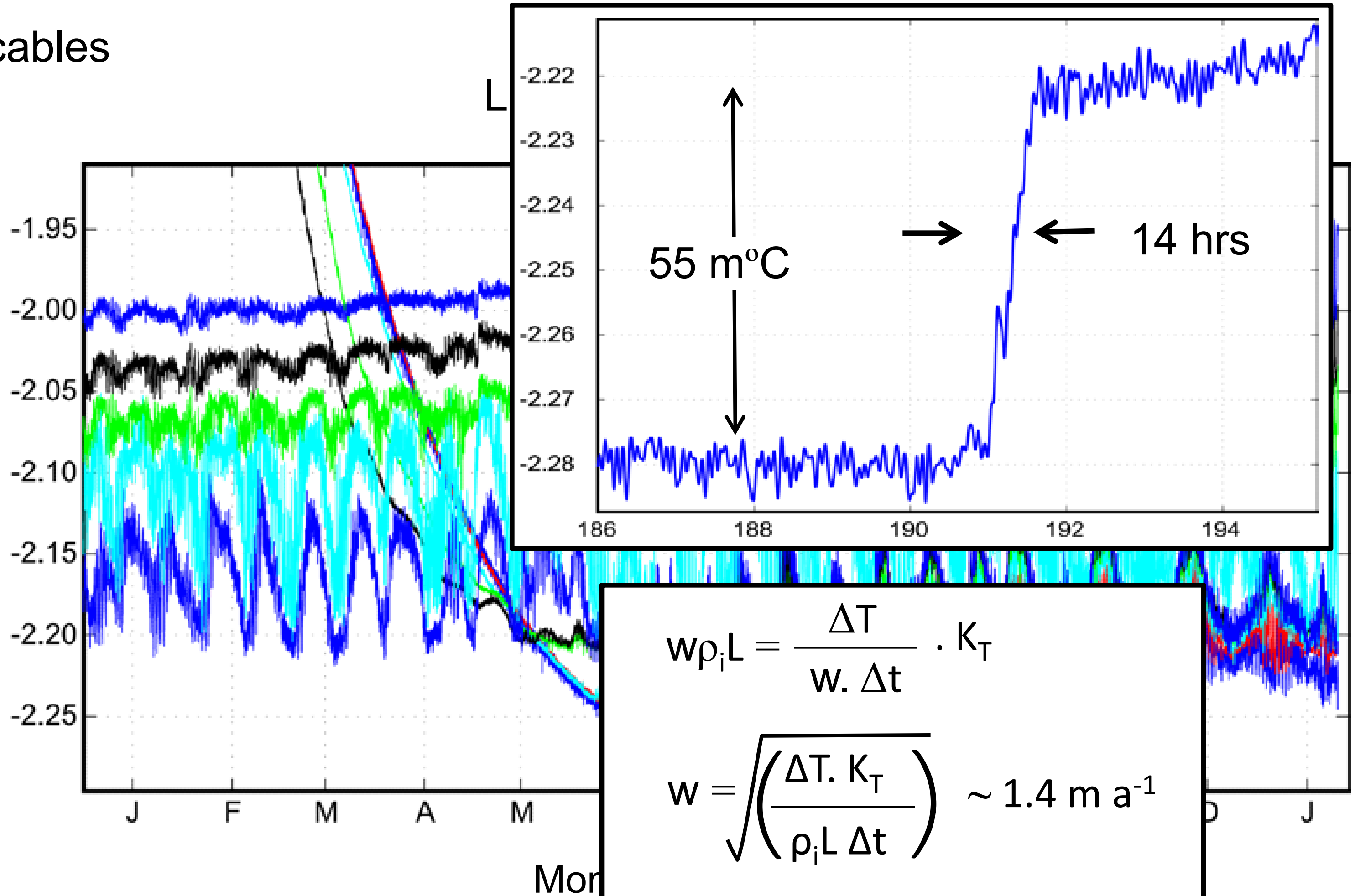


u
v
Current m s-1
D
J
F
Velocity (m s-1)
Time (s)


Wire noise?
Instrumental
cut-off
u
v
w
Energy (m$^3$ s$^{-2}$)
10$^{-2}$
10$^{-4}$
10$^{-6}$
10$^{-8}$
10
1
0.1
Length scale (m)

# Thermistor cables

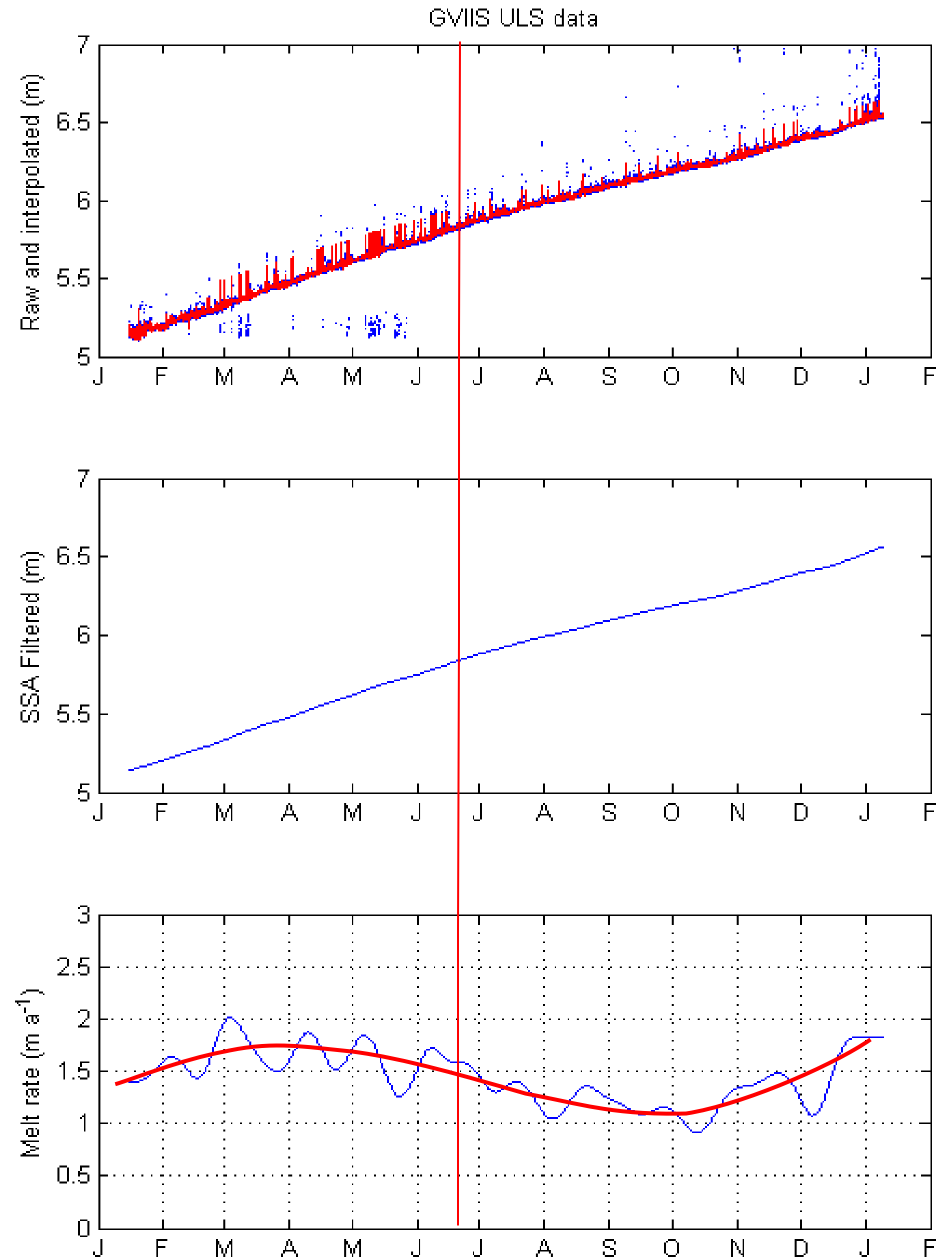


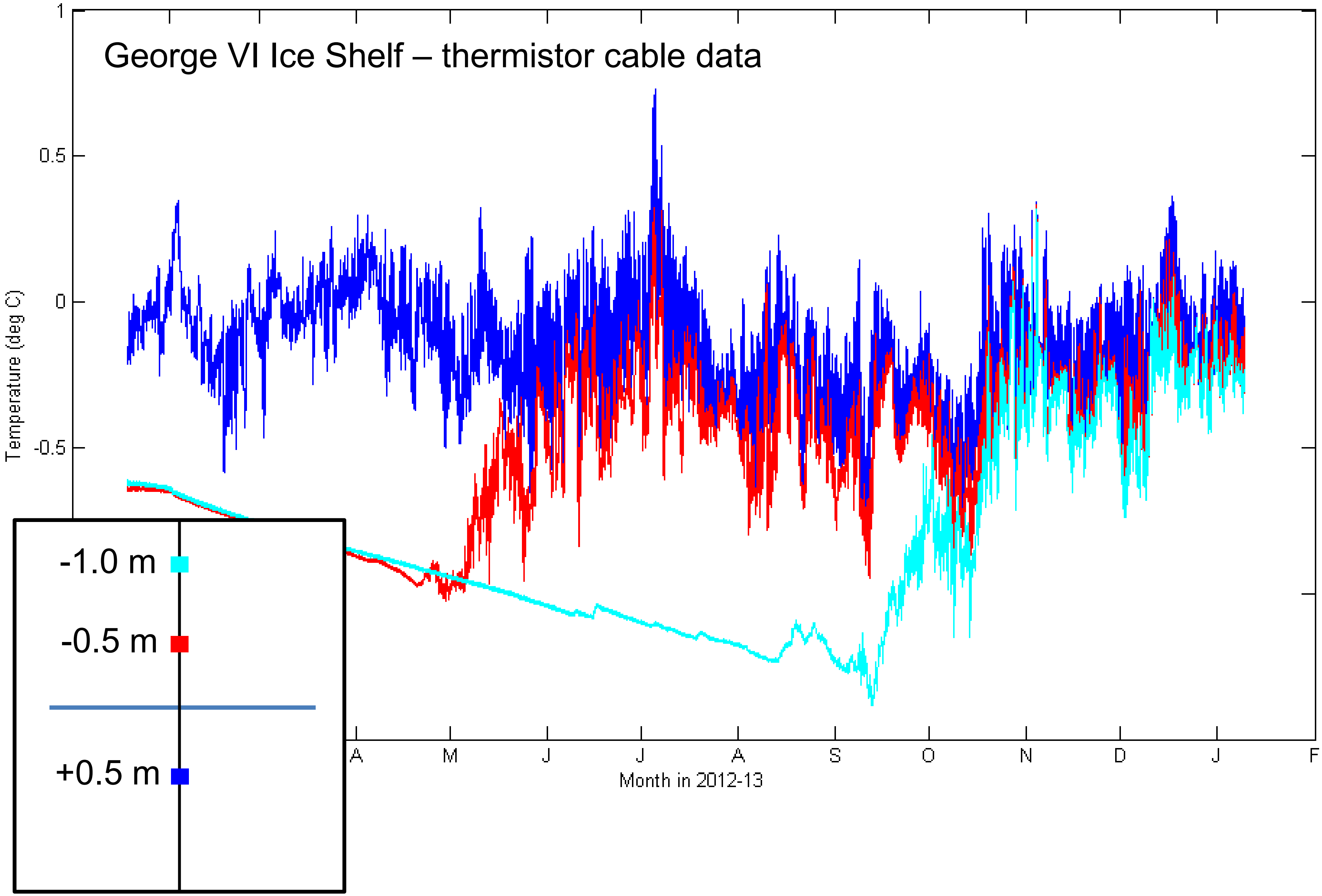



$$w\rho_i L = \frac{\Delta T}{w.\ \Delta t}\ .\ K_T$$

$$w = \sqrt{\left(\frac{\Delta T.\ K_T}{\rho_i L\ \Delta t}\right)} \sim 1.4\ \mathrm{m\ a^{-1}}$$

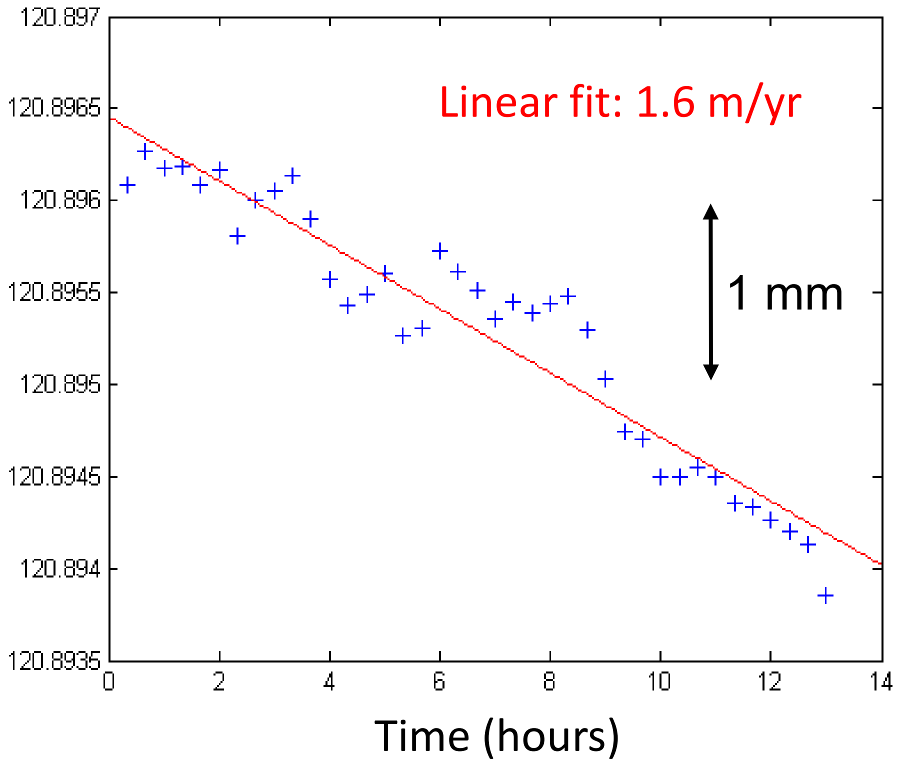
W = melt rate
L = latent heat of fusion
$K_T$ = thermal conductivity
$\rho_i$ = density of ice


GVIIS ULS data
Raw and interpolated (m)
SSA Filtered (m)
Melt rate (m a$^{-1}$)
J F M A M J J A S O N D J F


George VI Ice Shelf – thermistor cable data
1
0.5
0
-0.5
Temperature (deg C)
A
M
J
J
A
S
O
N
D
J
F
Month in 2012-13
-1.0 m
-0.5 m
+0.5 m

Difference between range to internal and range to ice base (m) (Ross Ice Shelf site)

Precision radar




Measures relative vertical motion of internal and basal reflectors to yield thinning rate of ice shelf, vertical strain rate of ice column and therefore basal melt rate.

# AUVs and ROVs

Nereus derivative

SCINI

## Summary

- Greenland sub-ice shelf conditions are similar to the warm shelf sector of Antarctica;
- Very few sub-ice shelf boundary layer experiments to date;
- Appropriate instrumentation is now available;
- Free-fall microstructure profiling  can work through ice boreholes;
- ROVs hold promise for the future;
- Thermistor cables are highly cost effective;
- Melt-rate time series from precision radar.