

The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica

Robert G. Bingham¹, Damon Davies¹, Edward C. King², Stephen L. Cornford³, David G. Vaughan², Jan De Rydt² and Andrew M. Smith²

¹ Glaciology & Cryosphere, School of GeoSciences, University of Edinburgh

² British Antarctic Survey, Natural Environment Research Council, Cambridge

³ Bristol Glaciology Centre, School of Geographical Sciences, University of Bristol

See also poster
that complements
this presentation!



With thanks to the Operations and Logistics staff of British Antarctic Survey, and the other members of the 2013/14 iSTAR traverse:
Tim Gee, James Wake, Jonny Yates (BAS), Thomas Flament, Anna Hogg (Leeds), Peter Lambert (Reading)



THE UNIVERSITY of EDINBURGH



British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

 University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

Introduction: iSTAR

www.istar.ac.uk



NERC Ice Sheet Stability Programme
Investigating the stability of the West Antarctic Ice Sheet



- iSTAR: icSheet TA**s**ticResearch programme
- 6-year £7.4M NERC programme aiming to understand and predict future of ice in Amundsen Sea Embayment (where Antarctic ice loss greatest since 1990s).
- Simultaneous acquisition of ice stream, ice shelf and ocean measurements around Pine Island Glacier and Amundsen Sea Embayment.

www.istar.ac.uk



NERC Ice Sheet Stability Programme
Investigating the stability of the West Antarctic Ice Sheet



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL



University of
BRISTOL



Motivation for project “Dynamic Ice”

- Central question: What controls the dynamic response of Pine Island Glacier?
- Overall goal: development of models that can emulate the recent response with realistic physical processes, and can then be used to project future response (next 200 years)
- Although there have been several surveys of Pine Island Glacier over the last decade (e.g. Vaughan et al., 2006, *GRL*; Operation IceBridge), there are few data on smaller scale bedforms and bed properties – which may be (most?) critical for controlling basal motion.
- Radar and seismic surveys of bed therefore designed to improve knowledge of “smaller” - but critical! - bed features



BG photo: Anna Hogg

The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



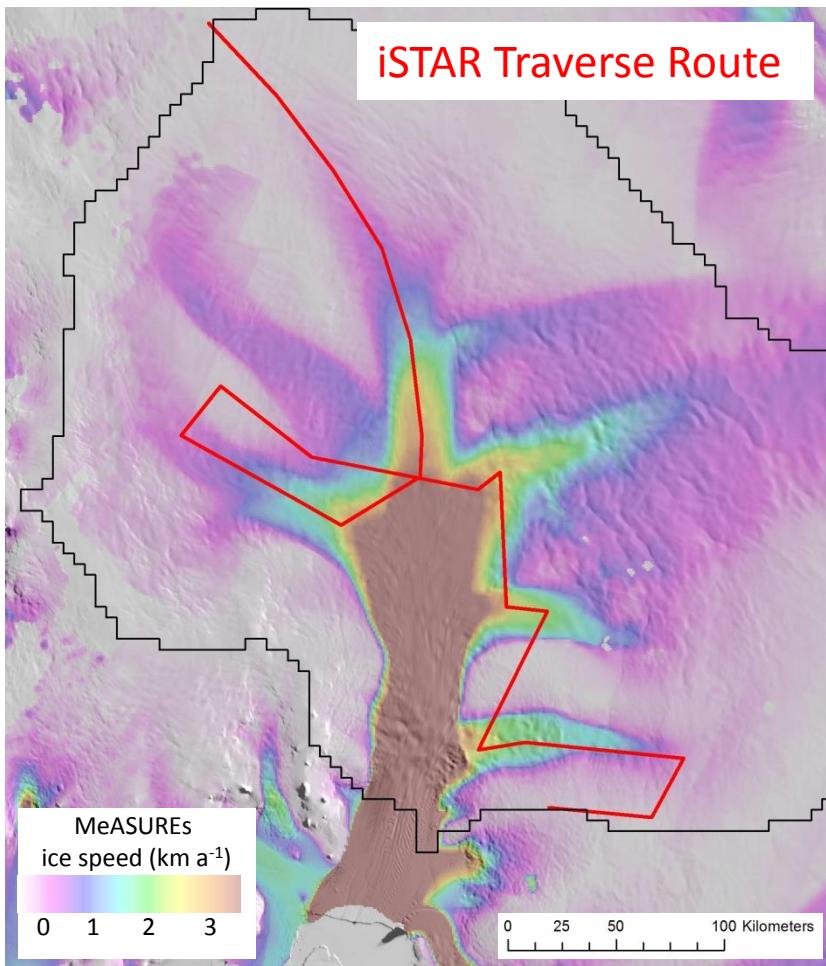
British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL



University of
BRISTOL



iSTAR Traverse 2013/14



- Overall 900 km route designed for complementary science projects from November 2013 to January 2014
- 12 participants



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



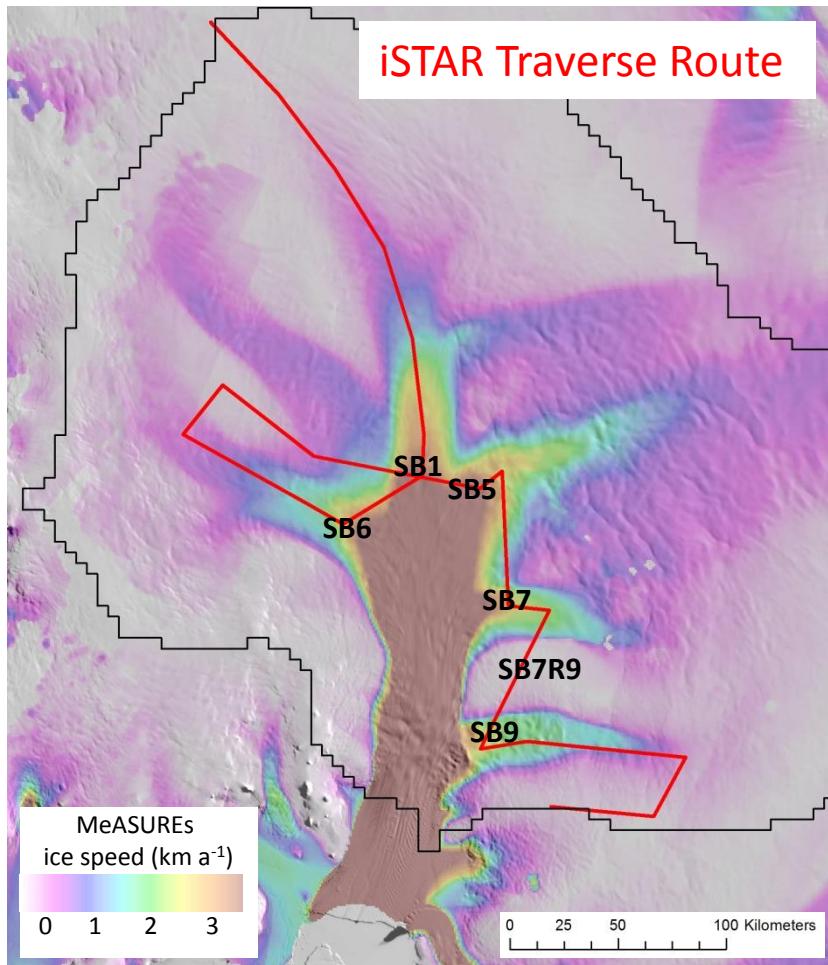
British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA



Radar surveys



- At six of the sites along the route, iSTAR would “pitch camp” for 2-3 days, allowing the four radar operators to radar-survey the site continuously

Sleep-deprived scientists...



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH

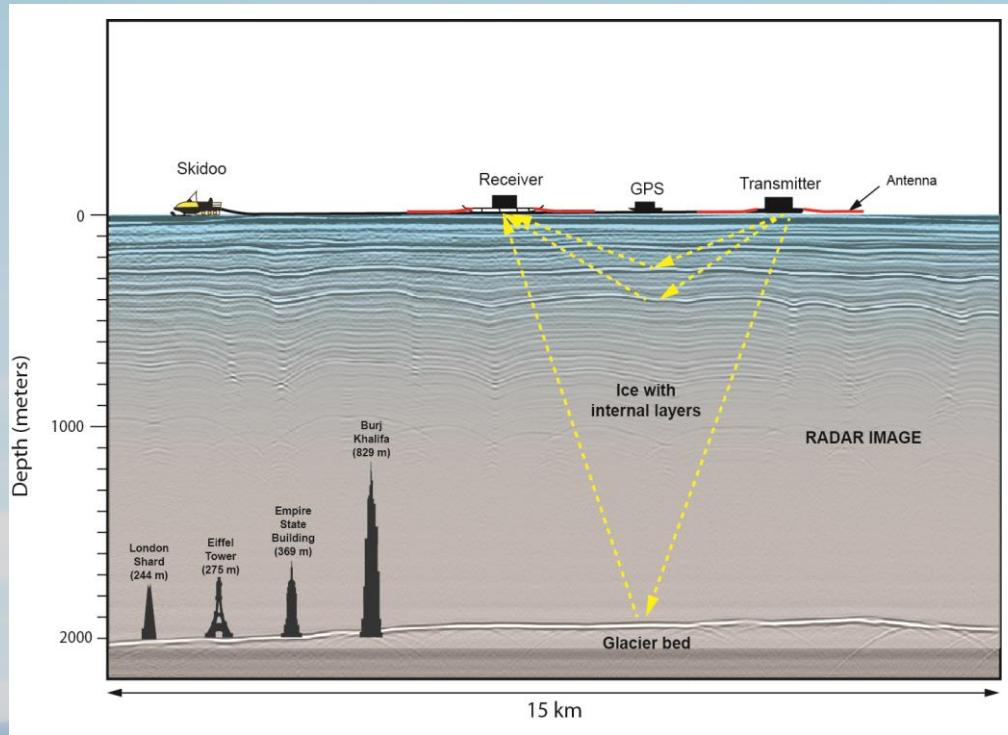


British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

DELORES radar



Central frequency 3 MHz
Sampling interval ± 1 metres
Vertical resolution ± 3 metres



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH

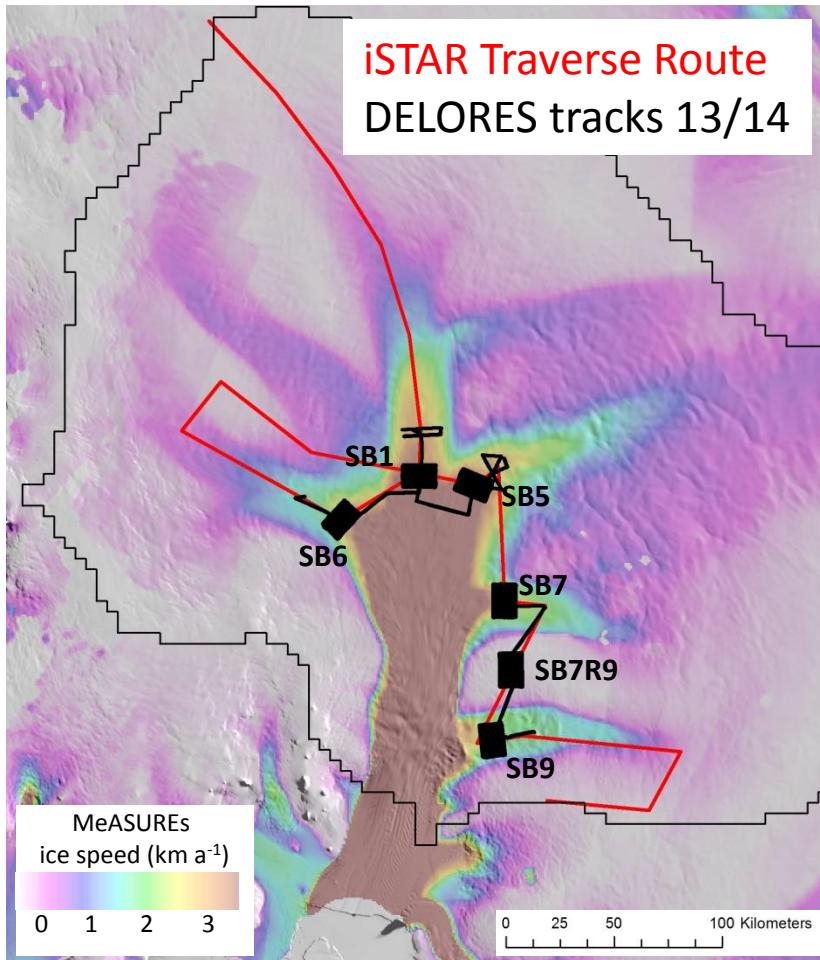


British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

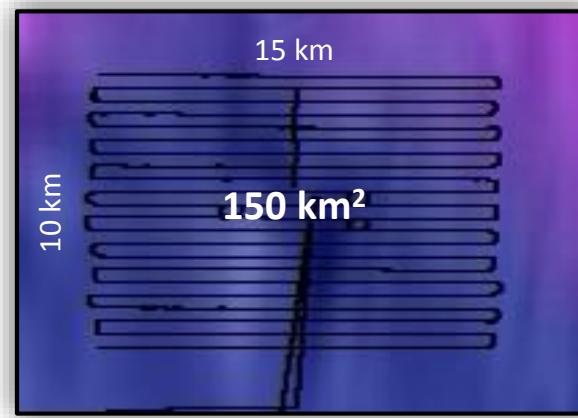
University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

DELORES surveys



- At each main “radar site”, we acquired 22 15-km radar profiles orthogonal to ice flow.
- 0.5 km spacing between profiles
- Along track, after stacking etc., bed soundings were acquired every 4-5 m.



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH

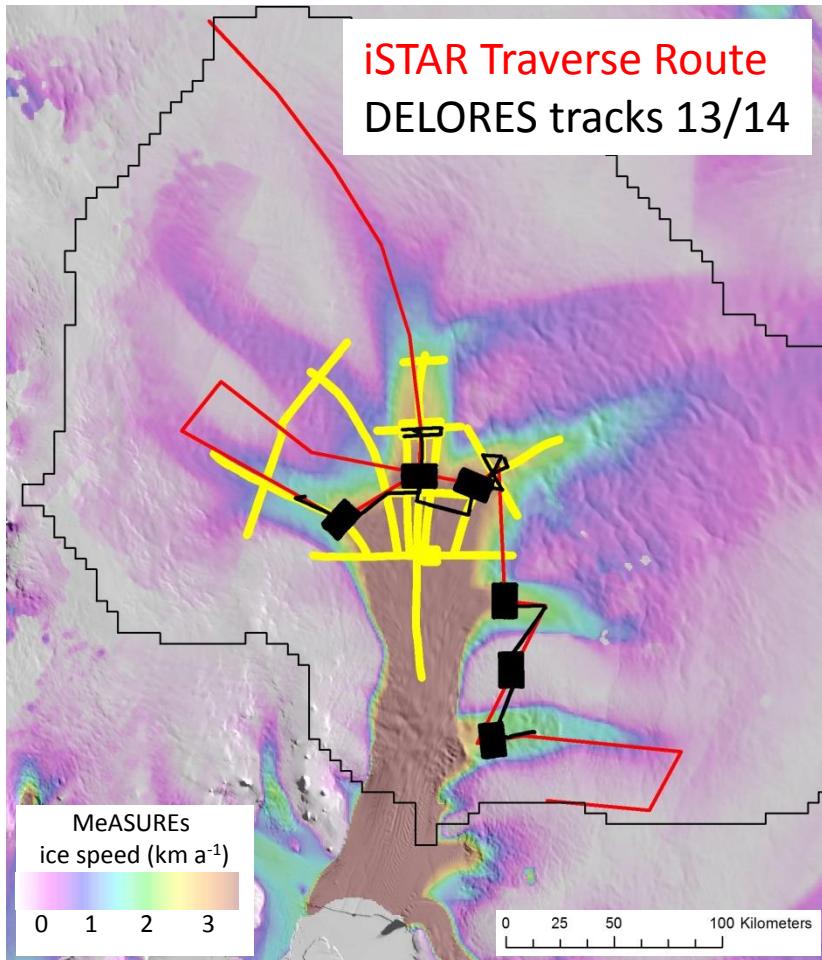


British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

“Repeat” DELORES surveys



- NB - Where iSTAR route was close to 2007/08 DELORES surveys, opportunity taken to “repeat-survey” some radar tracks.

The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

The data

- 6 x 150 km² “grids”
 - Each consisting of 22 15-km profiles across flow, spaced by 500 m
 - 1 in central trunk, 4 in tributaries, 1 in intertributary slow-flow zone
 - 1965 km of radar tracks
- 8 x “repeat profiles”
 - 154 km worth of tracks
 - 5 x profiles orthogonal to ice flow
 - 3 x profiles along flow
 - 7 are repeats from 2007/08 (6 year acquisition gap); 1 is a repeat from 2010/11 (3 year acquisition gap)



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



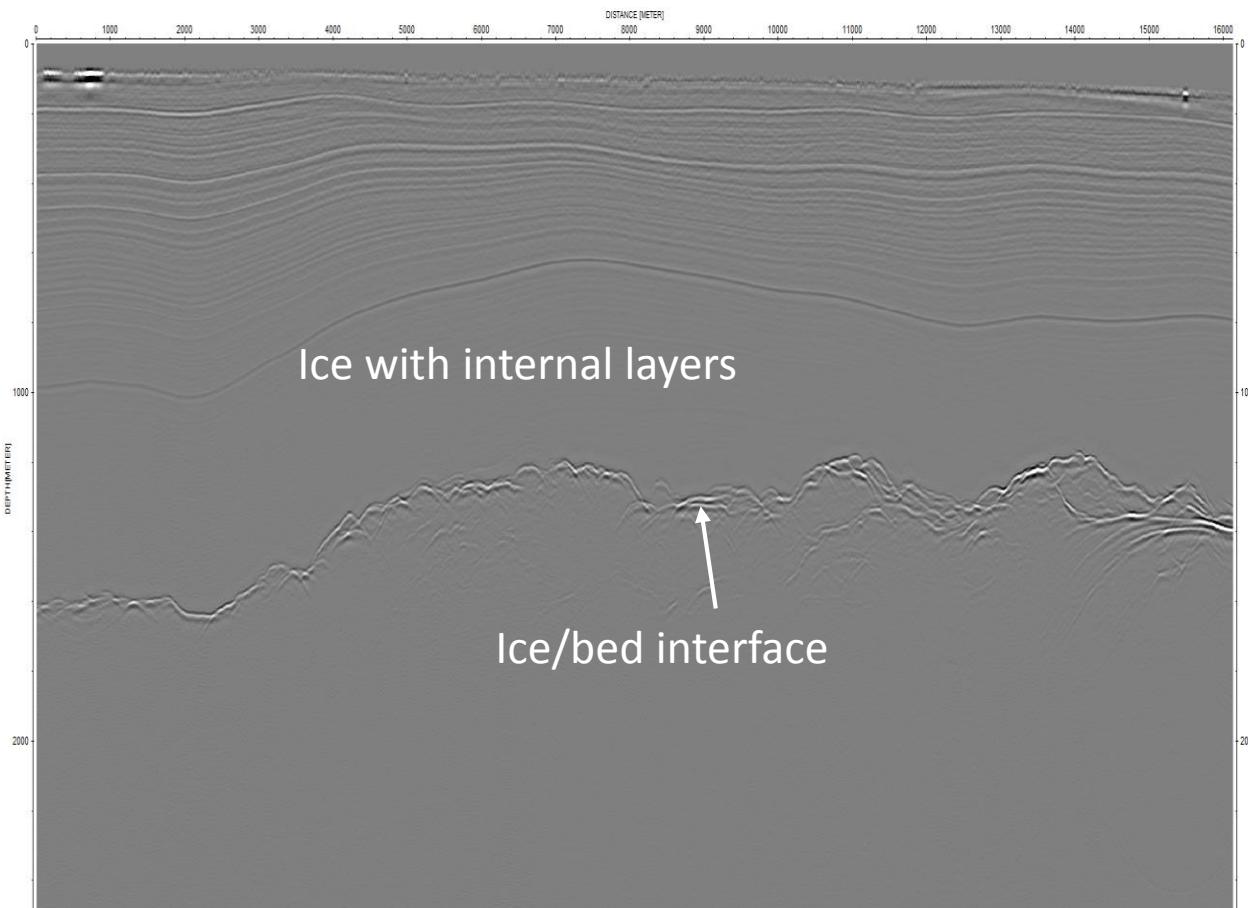
British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

 University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

Results

1. Radargram processing:
 - bandpass filter, gain, migration



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH

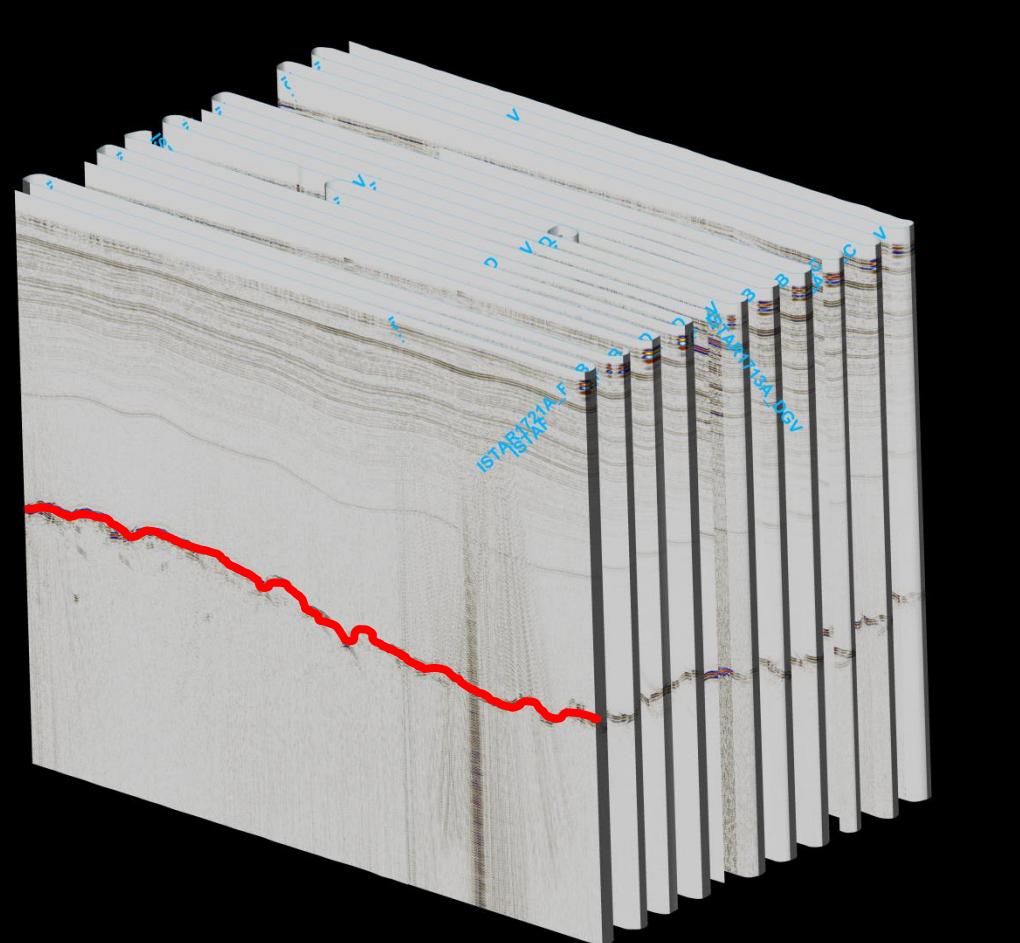


British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

Results



1. Radargram processing:
 - bandpass filter, gain, migration
2. Import SEGY to Schlumberger Petrel™
3. Pick bed (semi-automatic)

The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH

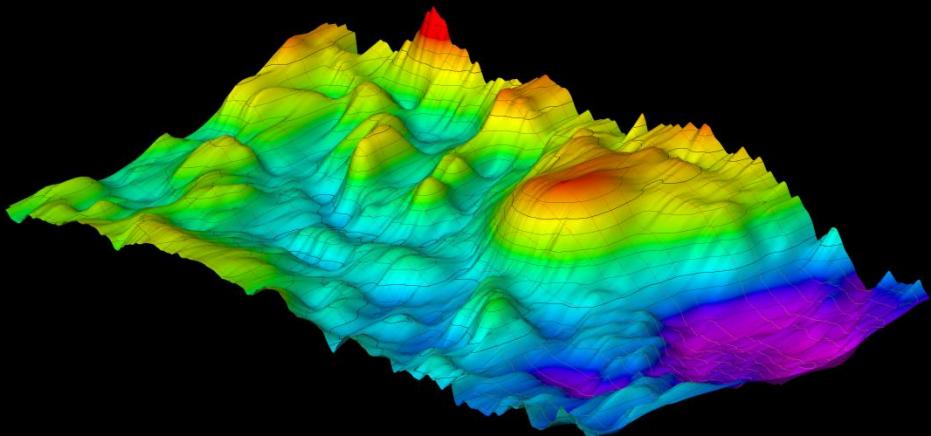


British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

Results



1. Radargram processing:
 - bandpass filter, gain, migration
2. Import SEGY to Schlumberger Petrel™
3. Pick bed (semi-automatic)
4. Create mesh of bed picks
5. Derive DEM
50 m x 50 m

The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



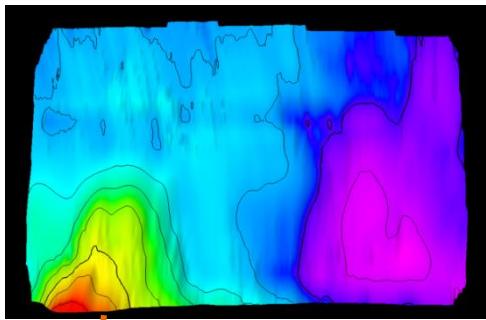
British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL



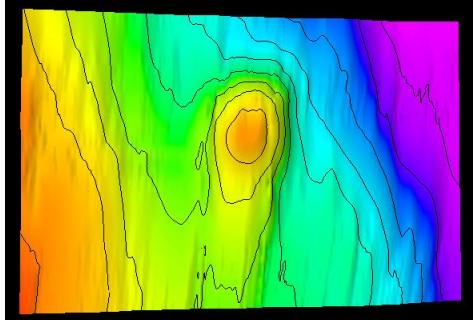
Ve x5

Results

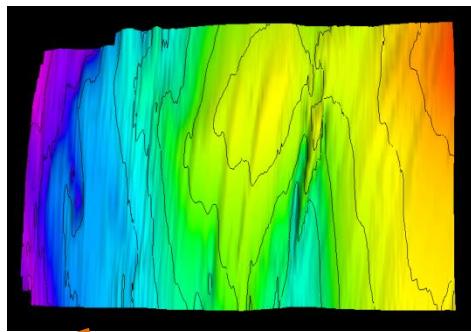
SB6 (Tributary, $v \sim 250 \text{ m a}^{-1}$)



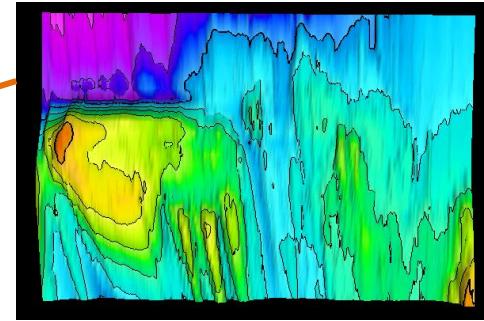
SB1 (Central trunk, $v \sim 375 \text{ m a}^{-1}$)



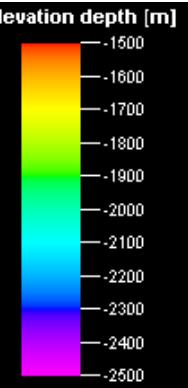
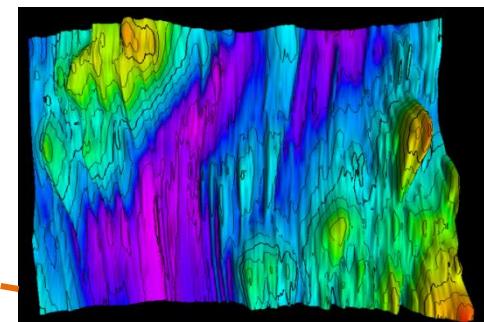
SB5 (Tributary, $v \sim 365 \text{ m a}^{-1}$)



SB7 (Tributary, $v \sim 285 \text{ m a}^{-1}$)

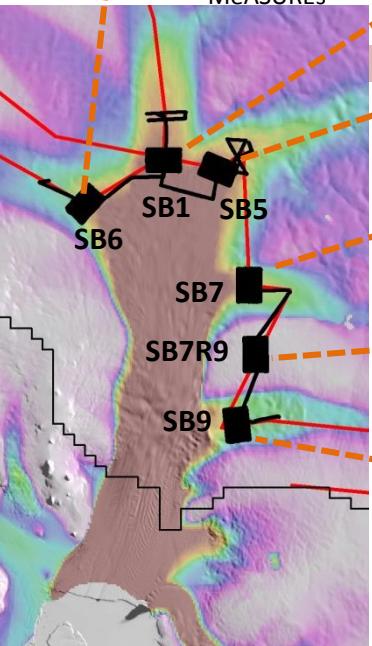


SB9 (Tributary, $v \sim 225 \text{ m a}^{-1}$)

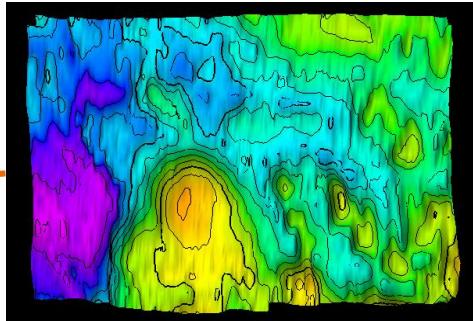


ICE FLOW

MeASURES



SB7R9 (Inter-tributary ridge, $v \sim 10 \text{ m a}^{-1}$)



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

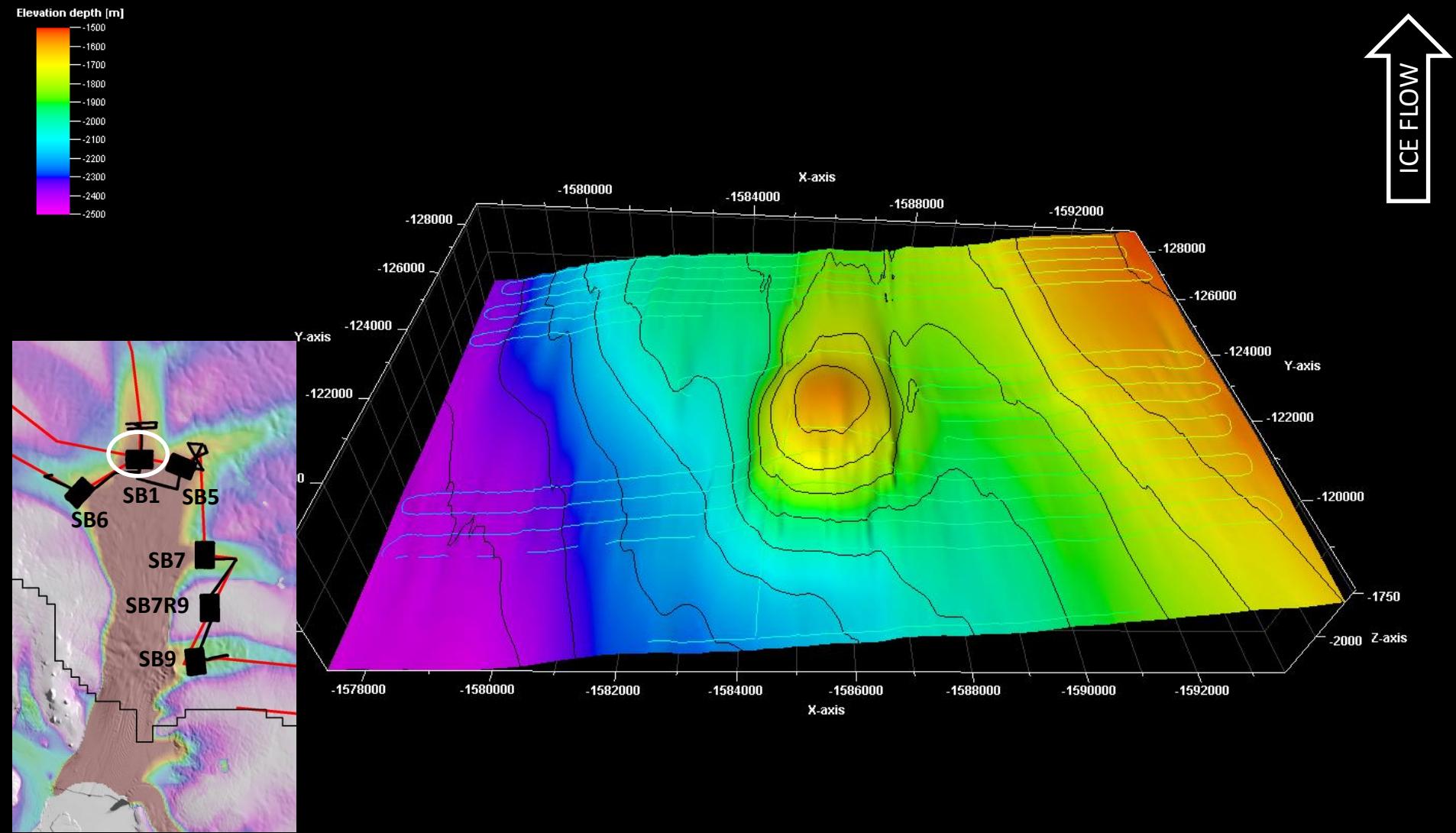


University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT

iSTAR
ANTARCTICA

Results: Main trunk - Site SB1 (istar07)



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH

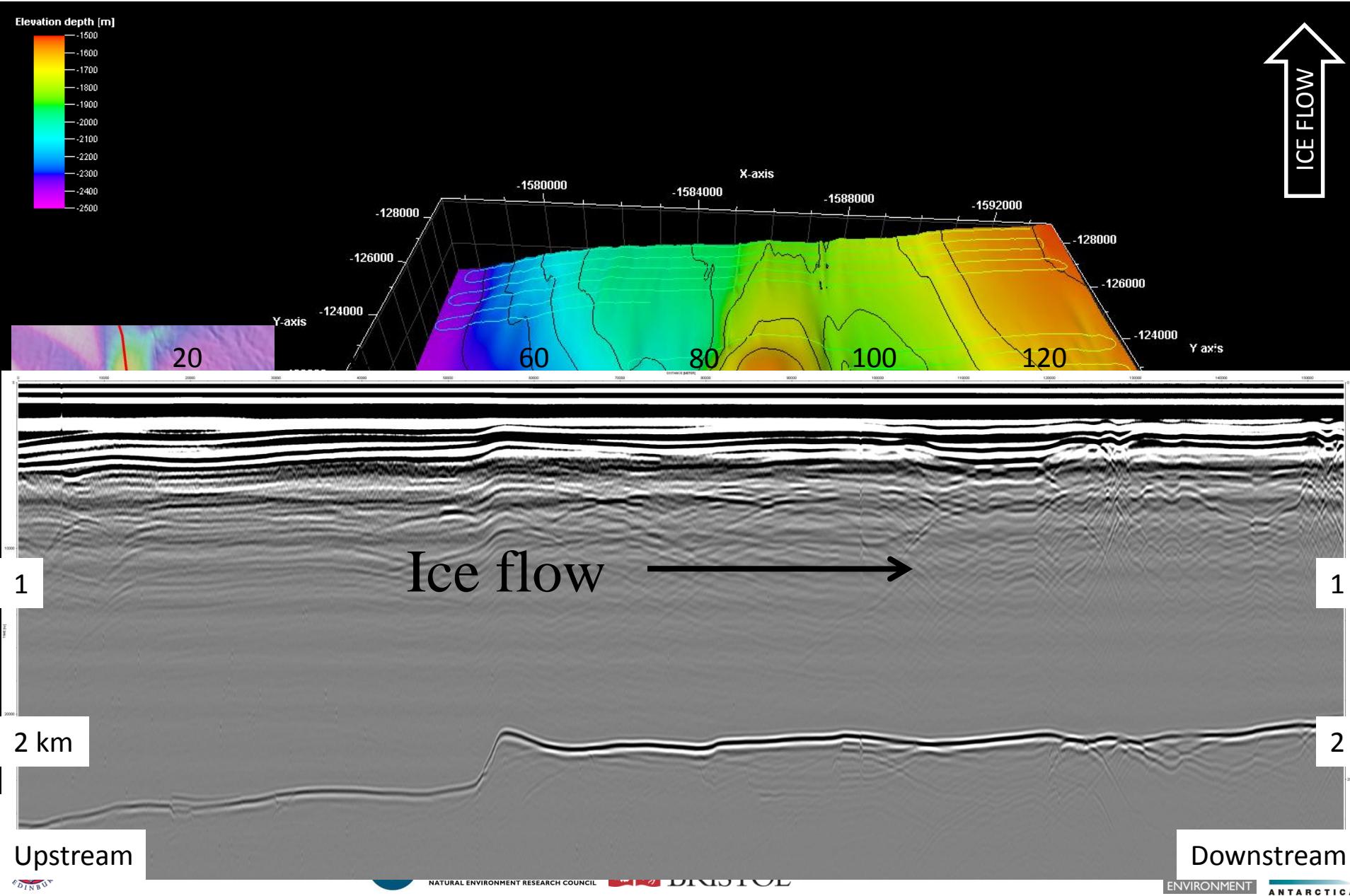


British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

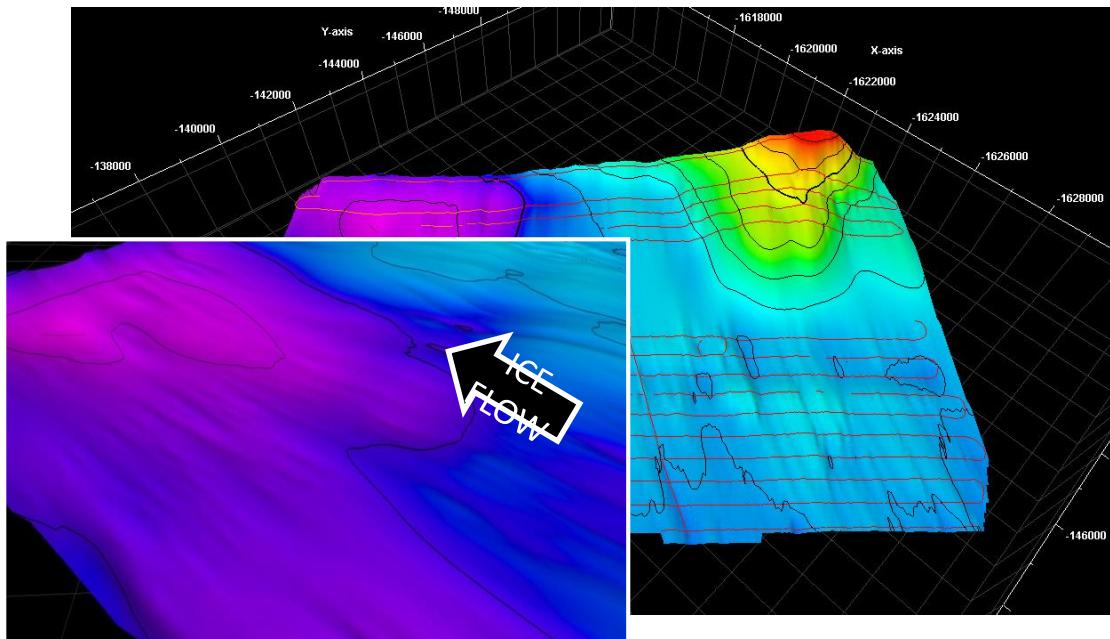
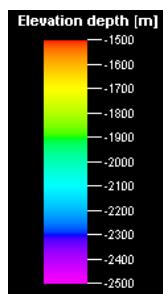
University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

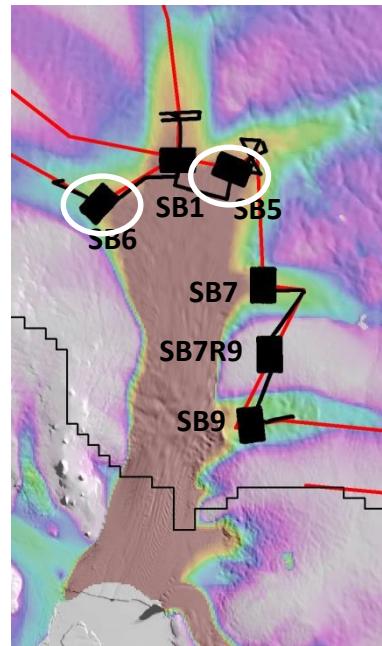
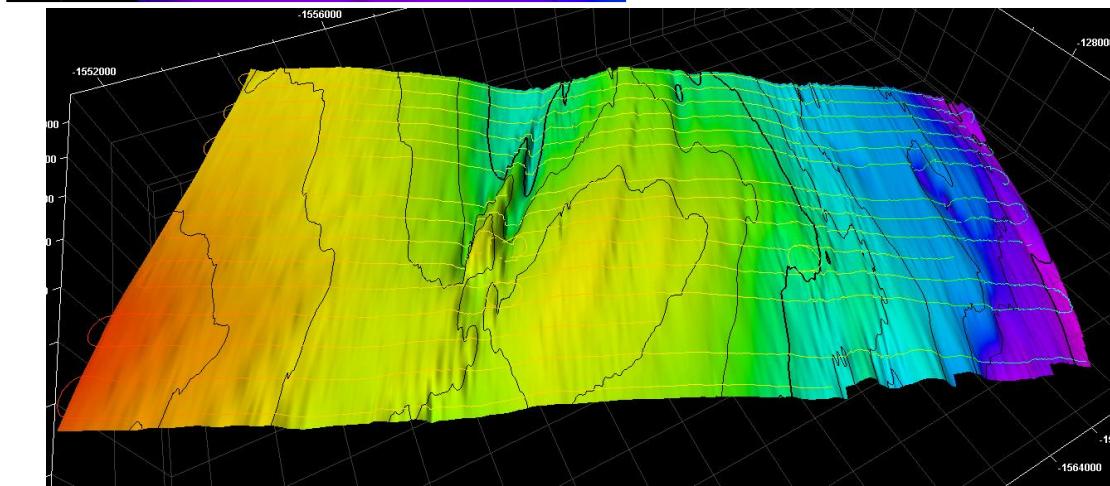
Results: Main trunk - Site SB1 (istar07)



Results: Upstream tributaries - Sites SB6 & SB5 (istar08 & istar13)



ICE FLOW



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



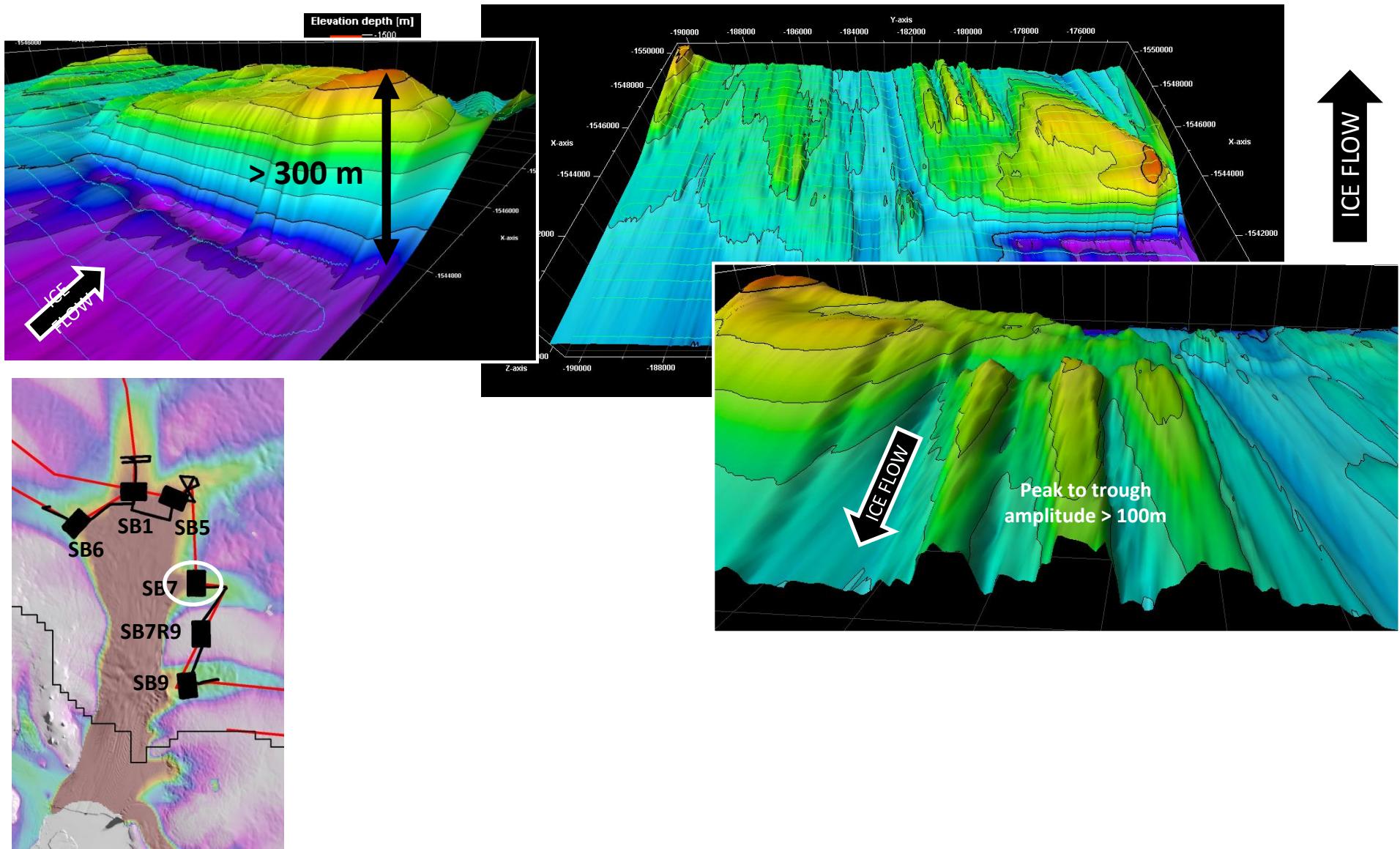
British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT

iSTAR
ANTARCTICA

Results: Downstream tributaries - Sites SB7 & SB9 (istar15 & istar18)



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH

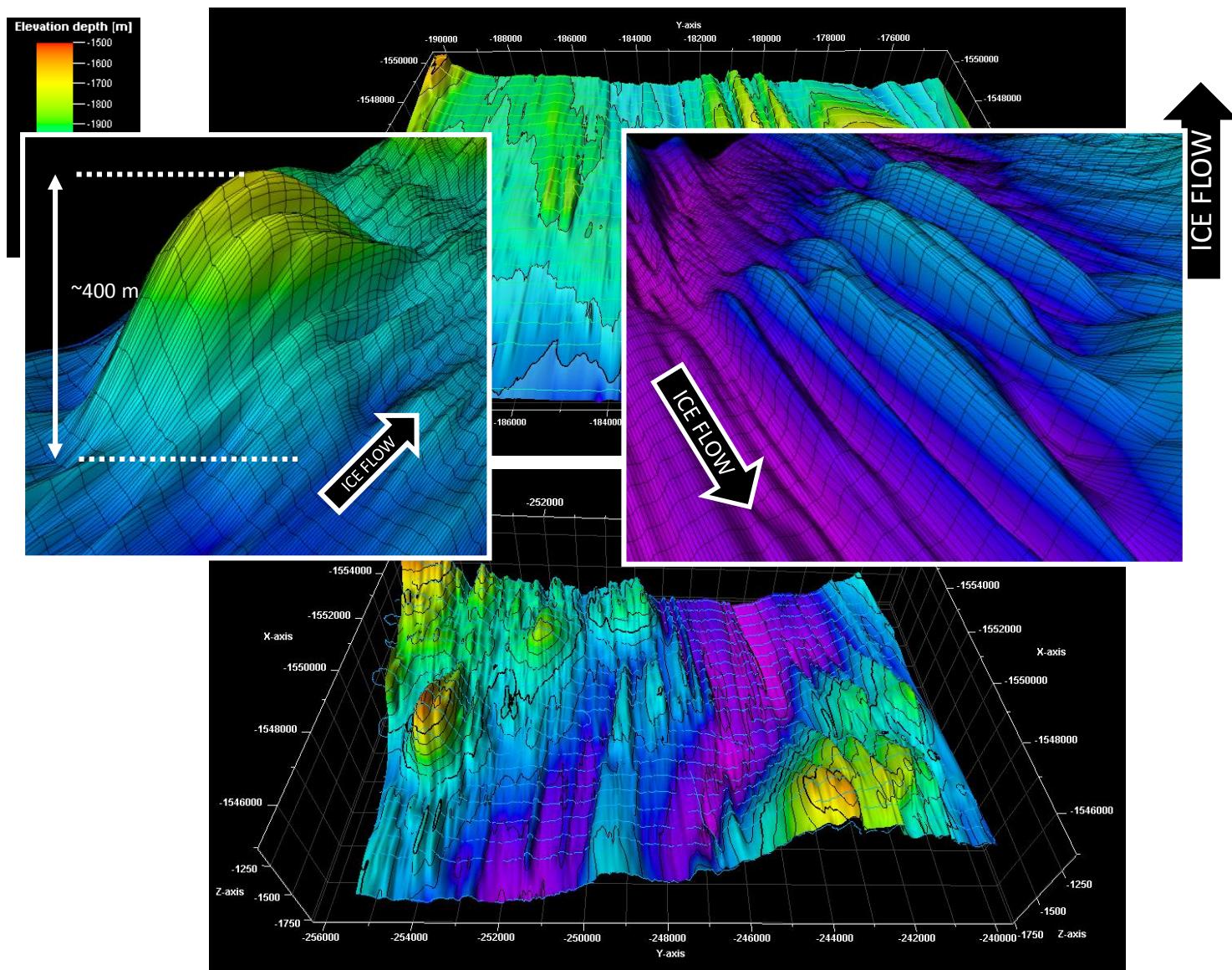
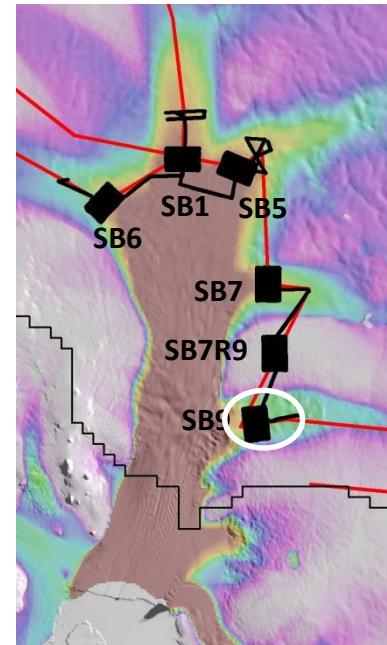


British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
iSTAR
SCIENCE OF THE
ENVIRONMENT
ANTARCTICA

Results: Downstream tributaries - Sites SB7 & SB9 (istar15 & istar18)



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH

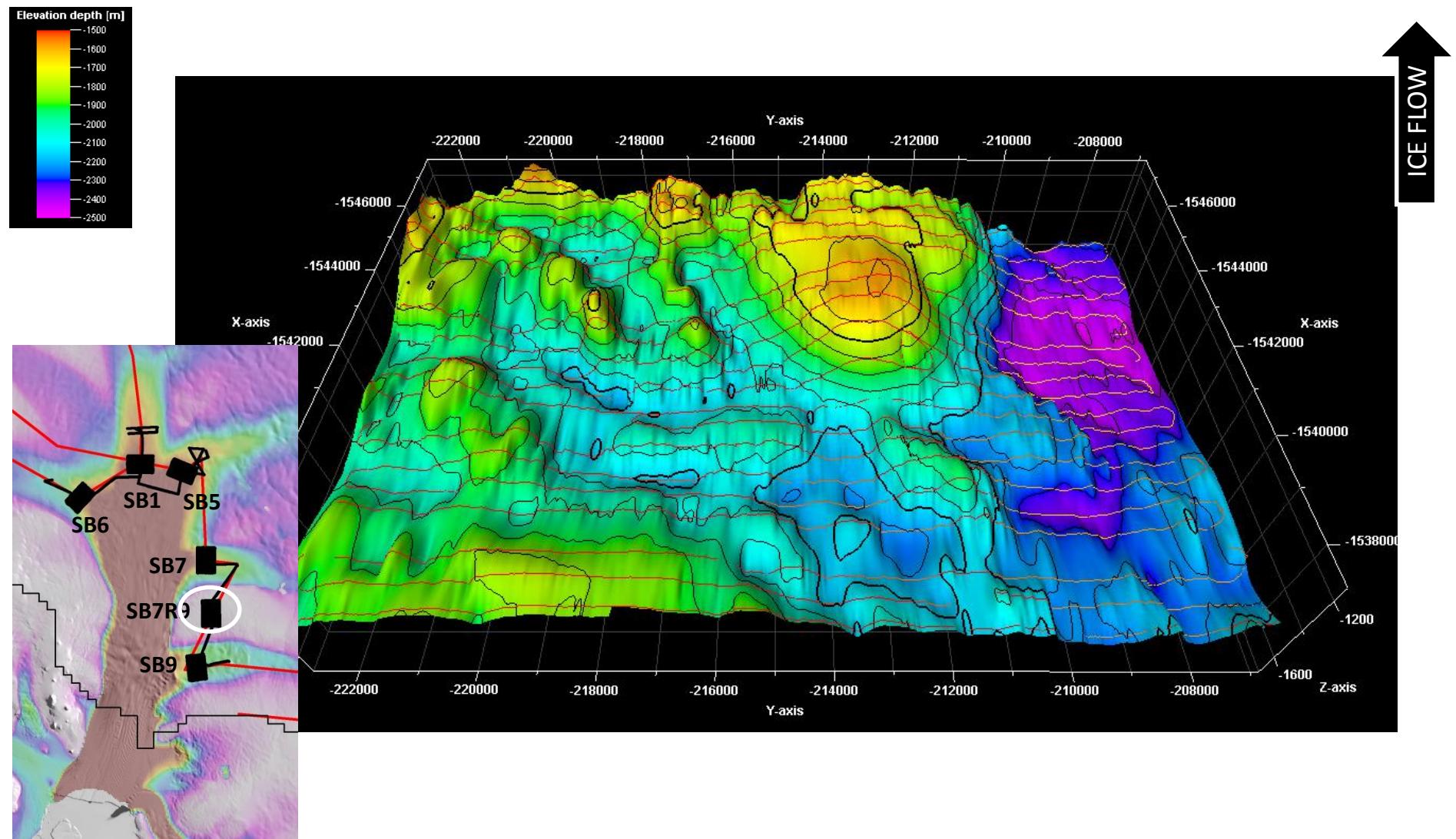


British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
iSTAR
SCIENCE OF THE
ENVIRONMENT
ANTARCTICA

Results: Intertributary ridge - Site SB7R9 (istar17)



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

Conclusions

- 6 x hi-res “bedmaps” recovered from PIG
- ~150 km of “repeat”-surveyed profiles, mostly comparing 2007/08 with 2013/14
- Next steps:
 - This season, active seismic surveys will be undertaken at the same sites
 - Reflectivity of the bed to be calculated using both radar and seismic data – for further improved understanding of bed composition & conditions
 - Detailed comparison of bed geomorphology with offshore marine geophysical data and onshore deglaciated terrains
 - Input to modelling exercises: basal drag; change at the bed.



See also poster
that complements
this presentation!

The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



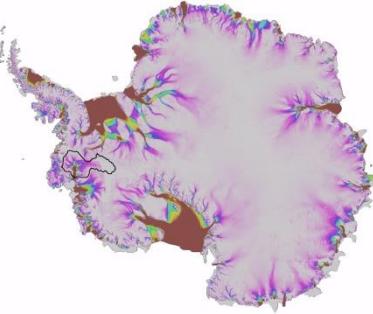
THE UNIVERSITY of EDINBURGH



British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

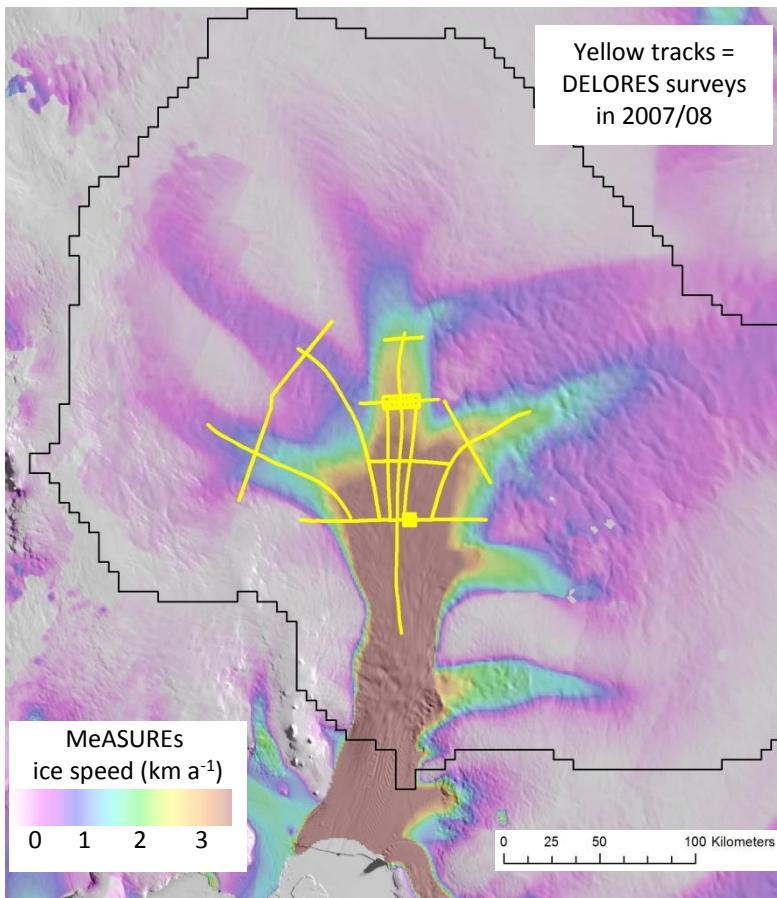
University of
BRISTOL

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA



Methods: 2. Pine Island Glacier

- 4 x reconnaissance field campaigns by BAS since 2006:
 - Preliminary ground-radar surveys
 - GPS measurements
 - Active seismic surveys at selected sites

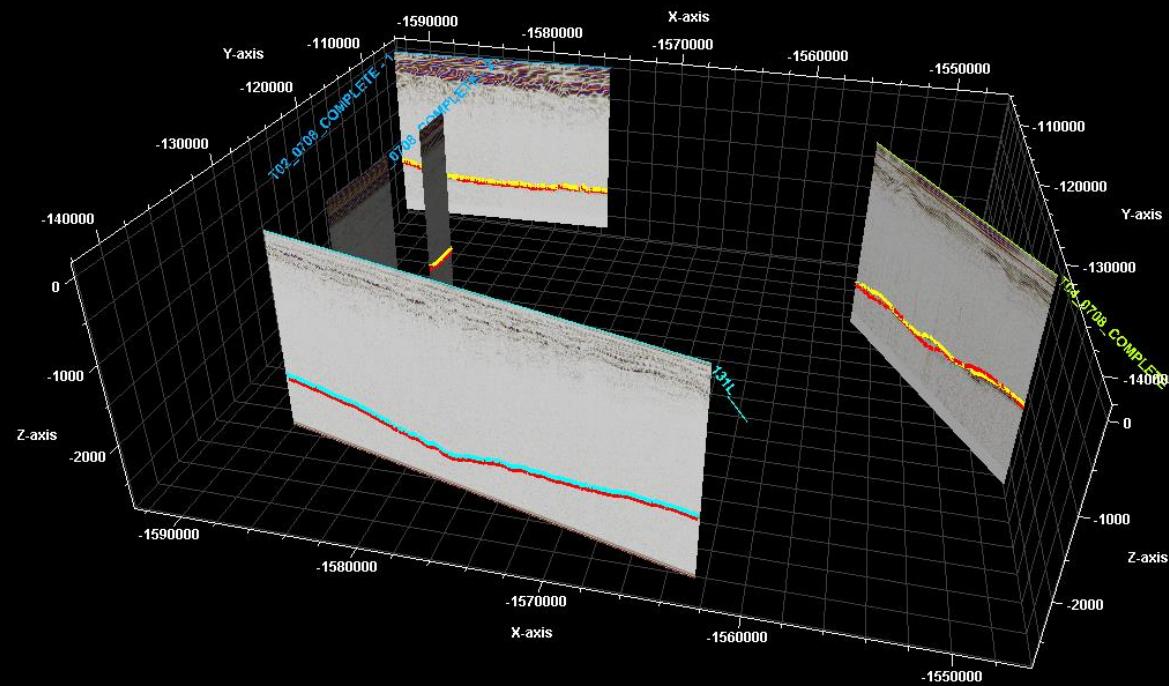


iSTAR traverse of 2013/14 allowed considerably greater efficiency of data acquisition through facilitating larger field party
Operation of tried and tested methods in “siege campaign”!

The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica

V. Preliminary – early work on “repeat surveys”

Repeats with bed picks: T02, L01, T04, T05. looking upstream.
1314 = red pick, 0708 = yellow, 201011 = blue



The nature and dynamics of the bed beneath Pine Island Glacier, Antarctica



THE UNIVERSITY of EDINBURGH



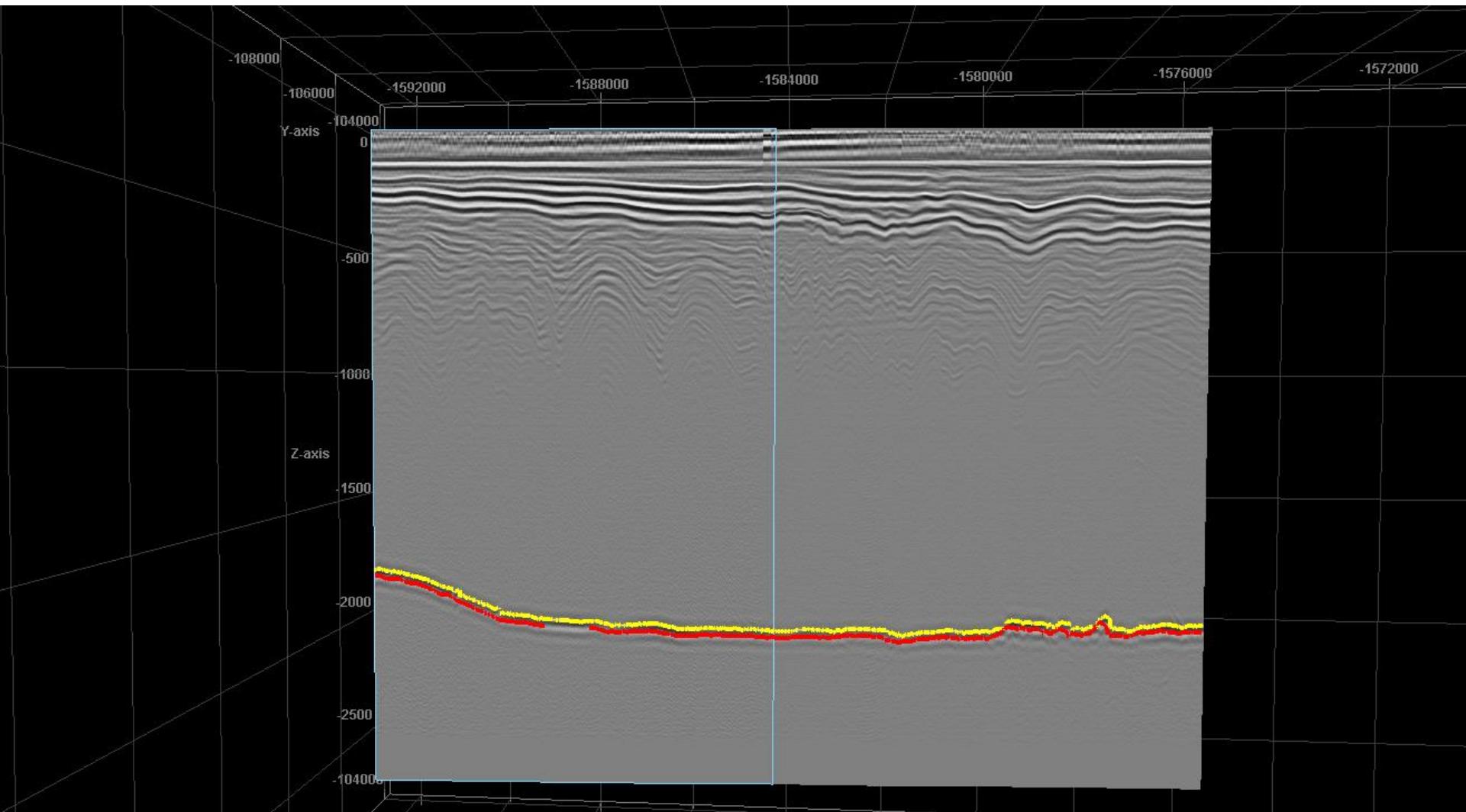
British
Antarctic Survey
NATIONAL ENVIRONMENT RESEARCH COUNCIL

University of
BRISTOL

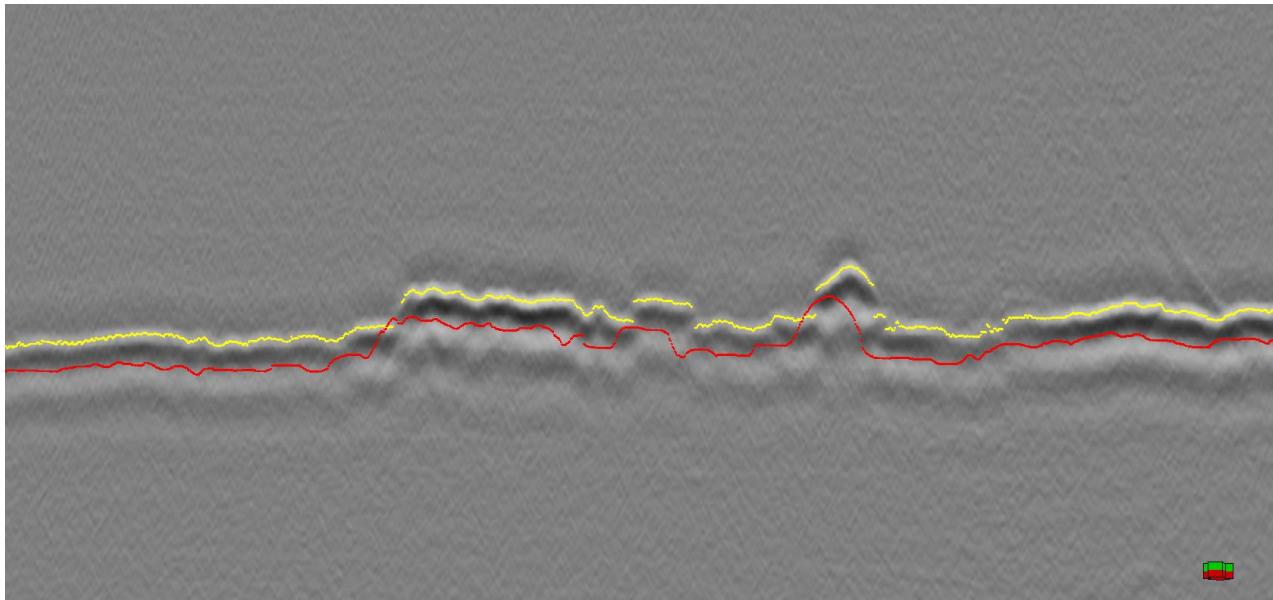
Slide 13 of xx

NERC
SCIENCE OF THE
ENVIRONMENT
iSTAR
ANTARCTICA

Close up of T02 (background radargram is 2007/08 data)



Close up of bed bump on T02 (07/08 radargram)



Close up of bed bump on T02 (13/14 radargram)

