Bedforms and melt(?) beneath Pine Island Glacier: results from the 2011 ground radar survey

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Talk Outline

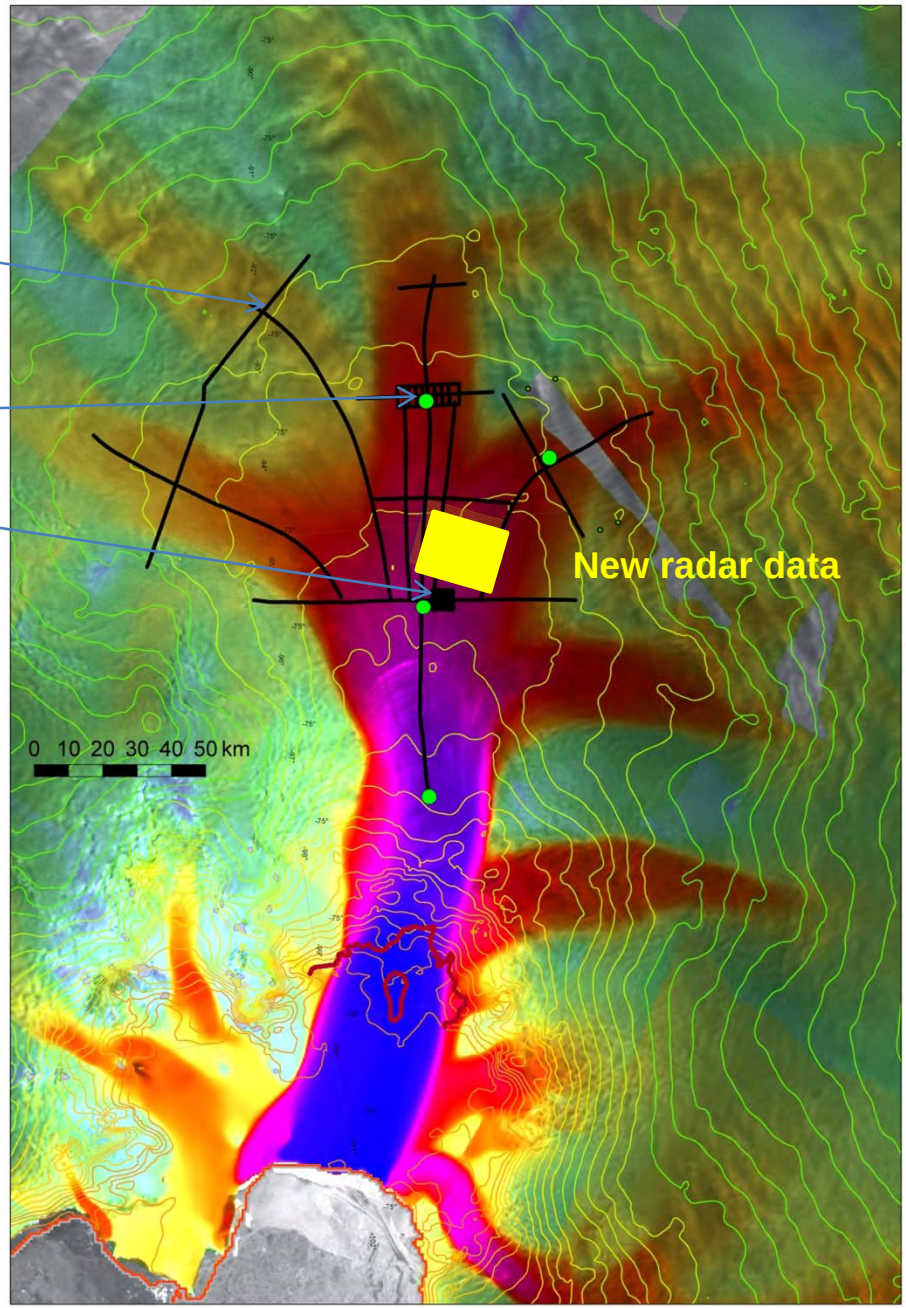
- Basal properties from previous seismic
- New radar grid – acquisition & processing
- Bedforms – shape and size
- Bedform alignment
- Bed reflectivity
- Melt signatures
- Conclusions

Previous work

Radar – DELORES (low frequency)

Seismic

GPS



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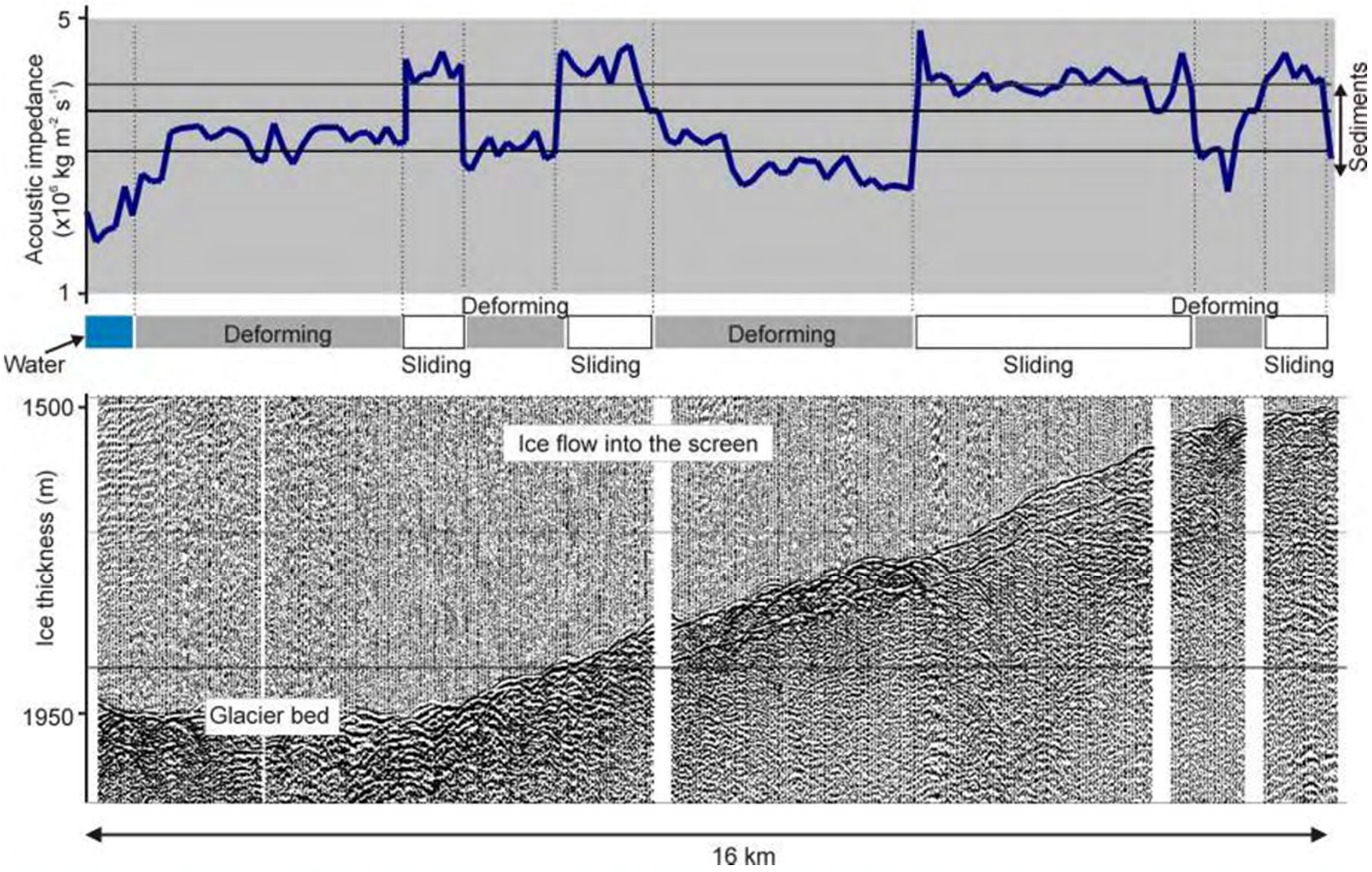
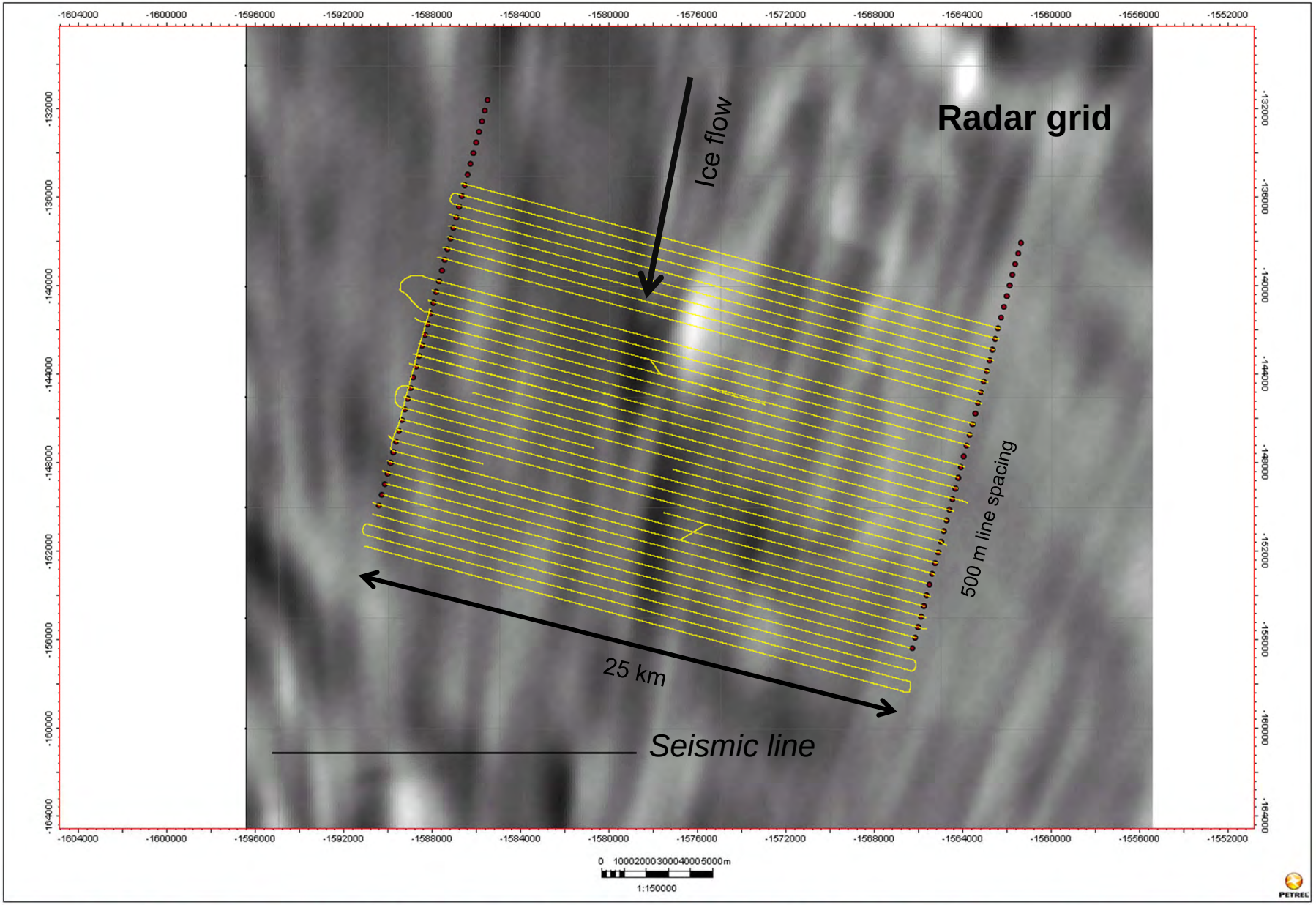
Seismic data



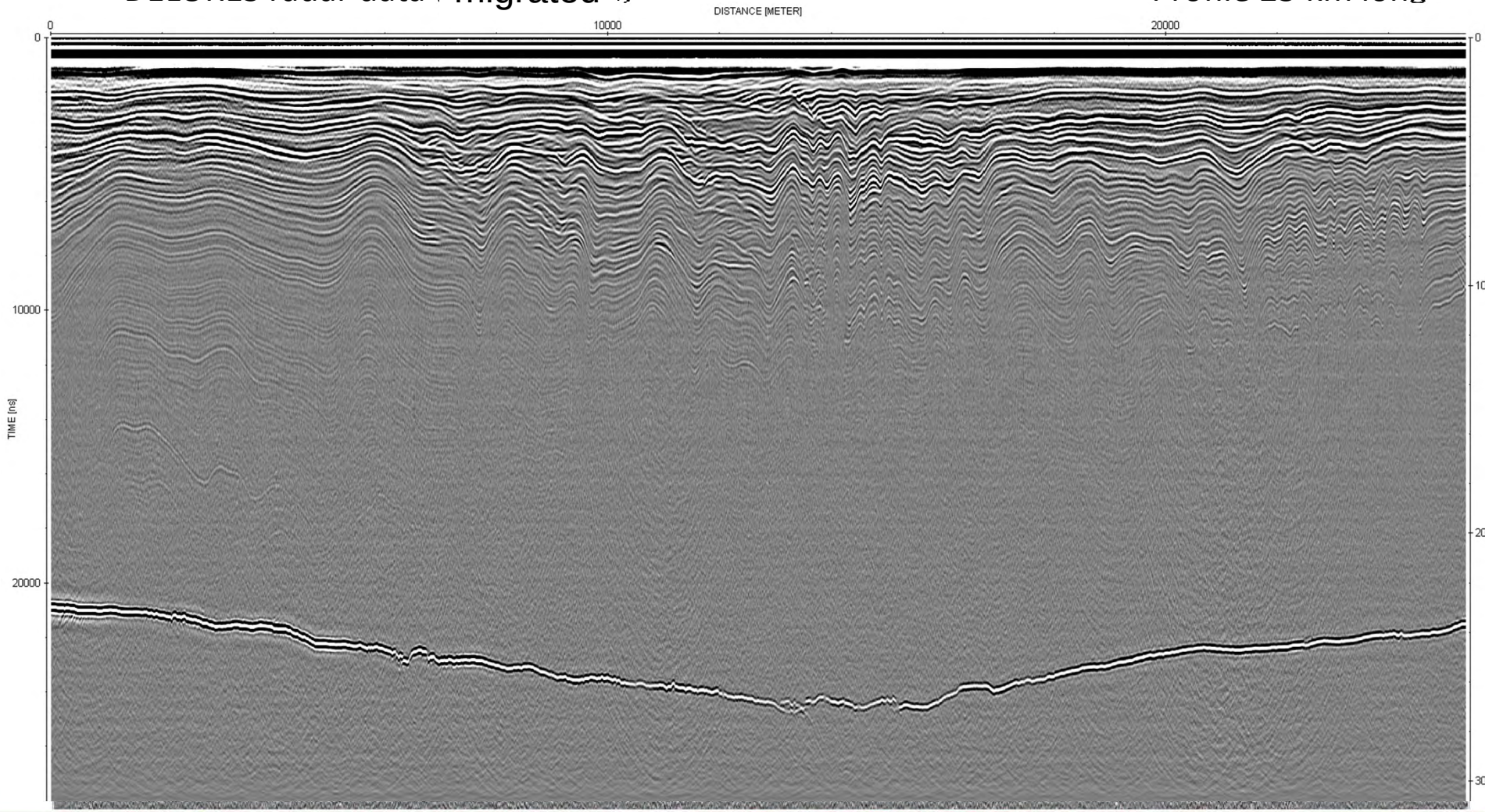
Seismic data - summary

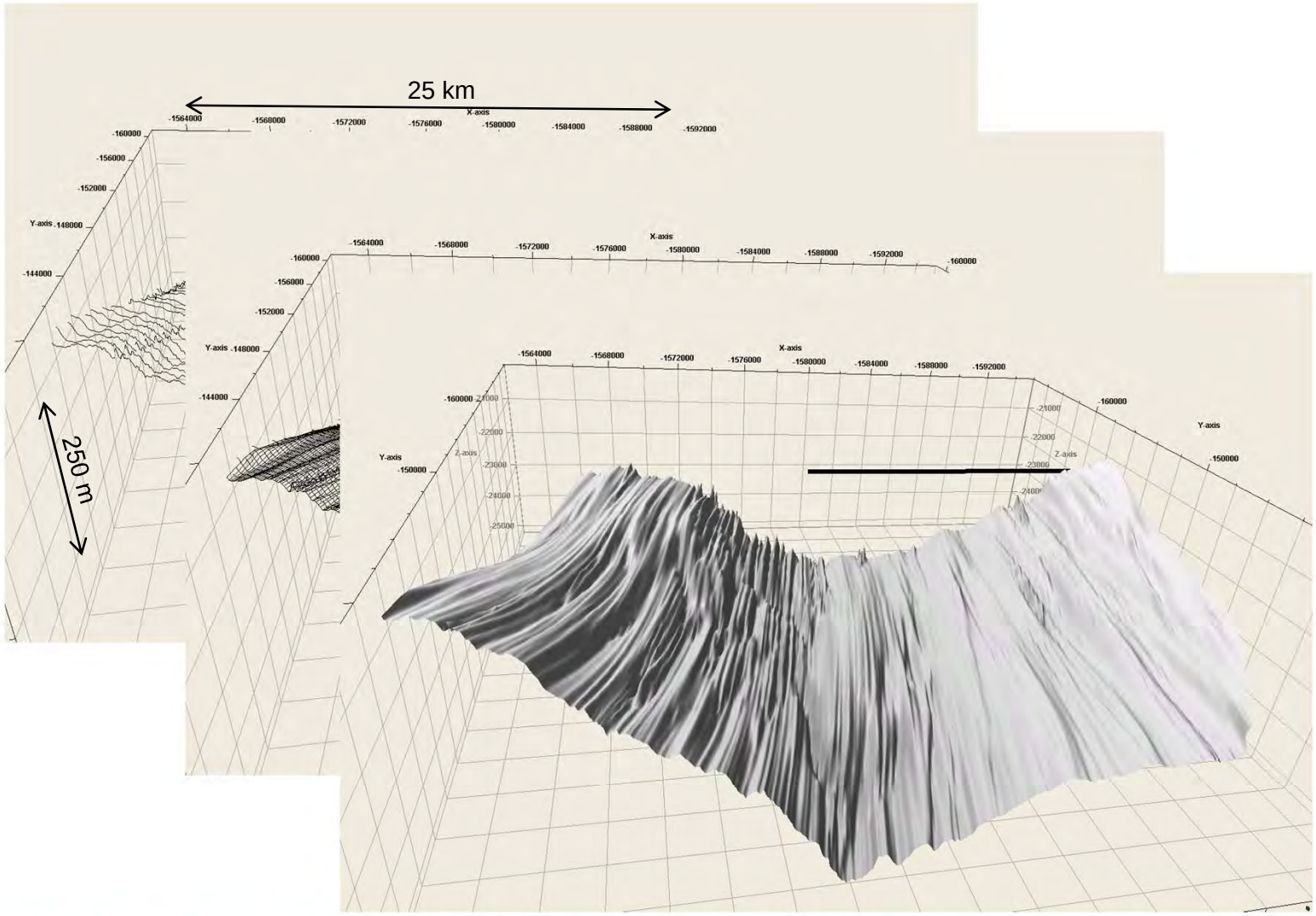
- Bed is mixed: deformation through dilatant till *and* sliding over lodged till
- Types are interspersed
- One patch of very low acoustic impedance suggests water at the bed


Radar grid
Ice flow
500 m line spacing
25 km
Seismic line
-1604000
-1600000
-1596000
-1592000
-1588000
-1584000
-1580000
-1576000
-1572000
-1568000
-1564000
-1560000
-1556000
-1552000
-132000
-136000
-140000
-144000
-148000
-152000
-156000
-160000
-164000
0 1000200030004000 5000m
1:150000
PETREL

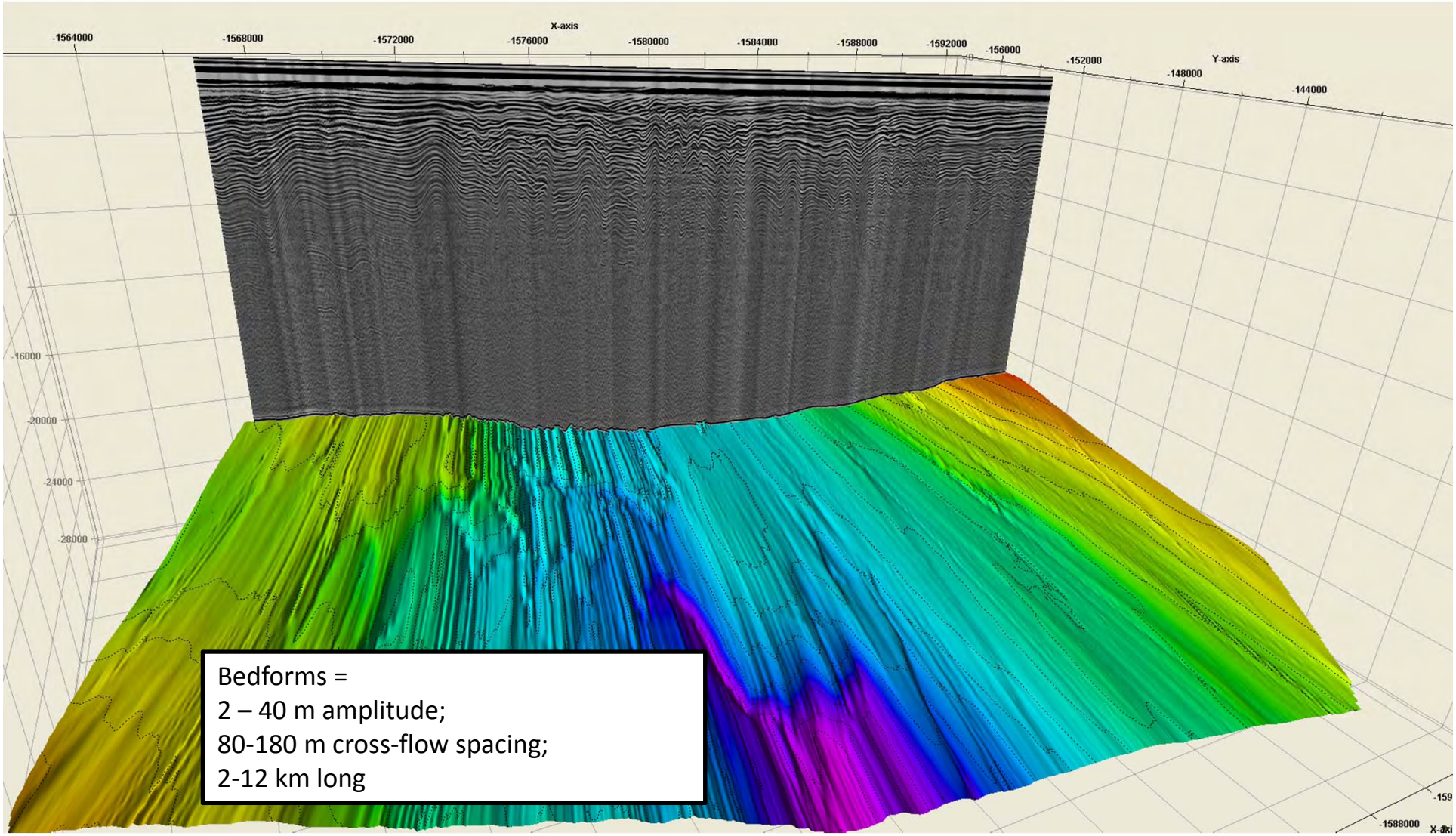
DELORES radar data (migrated)

Profile 25 km long



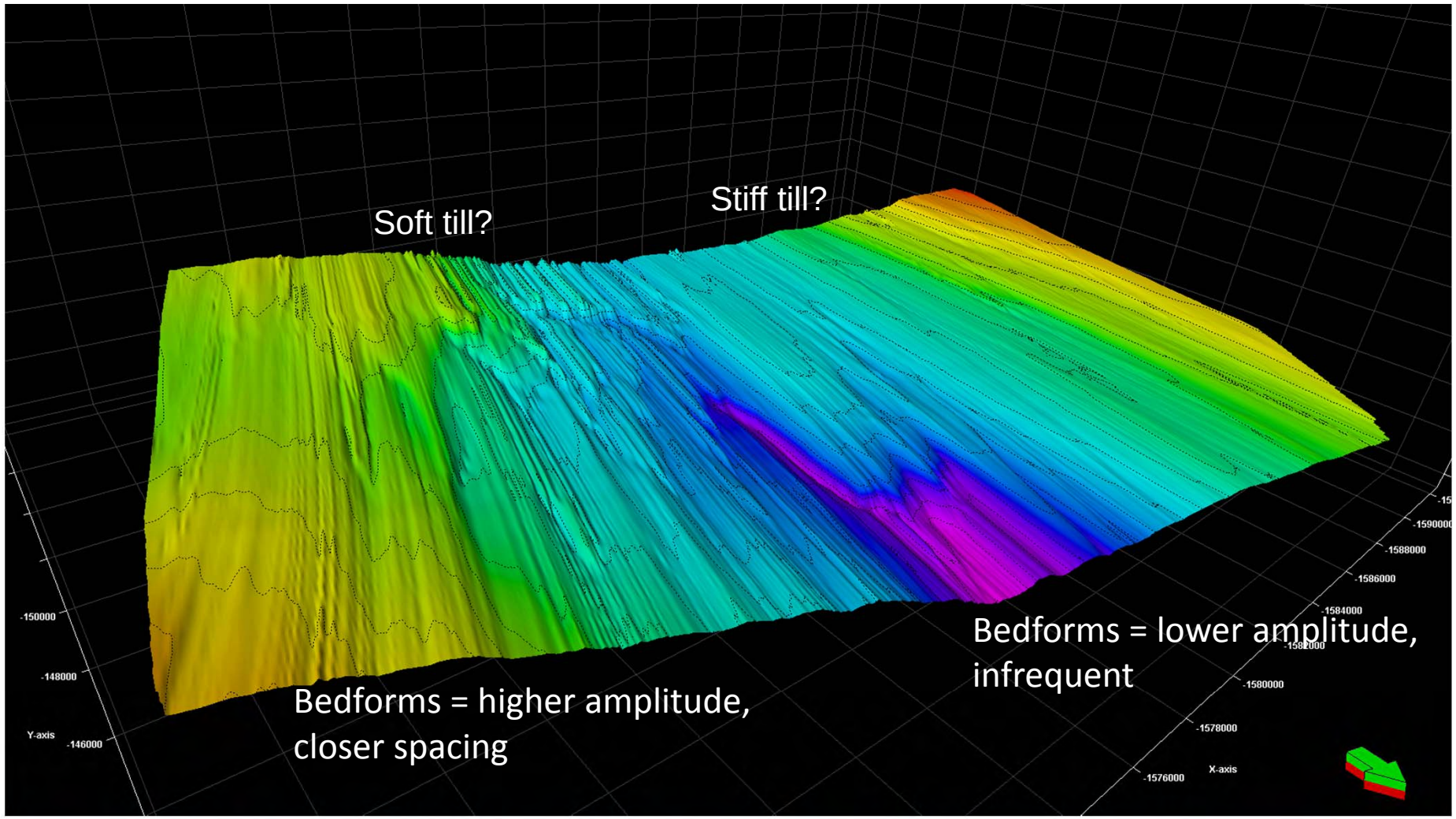

25 km
250 m
X-axis
Y-axis
Z-axis

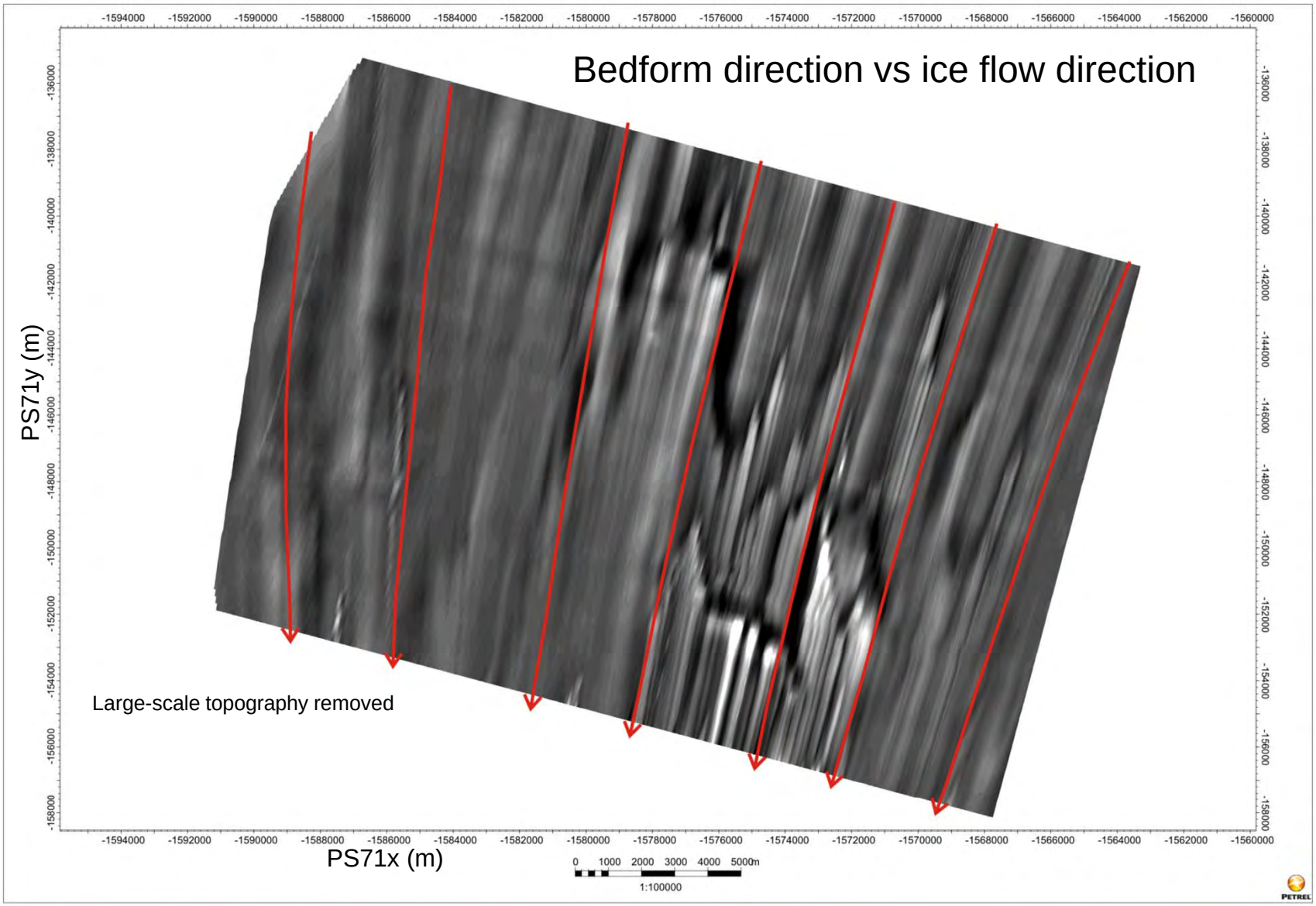
Ice flow into screen. Grid is 25 km across flow x 18 km downflow, 500 m line spacing

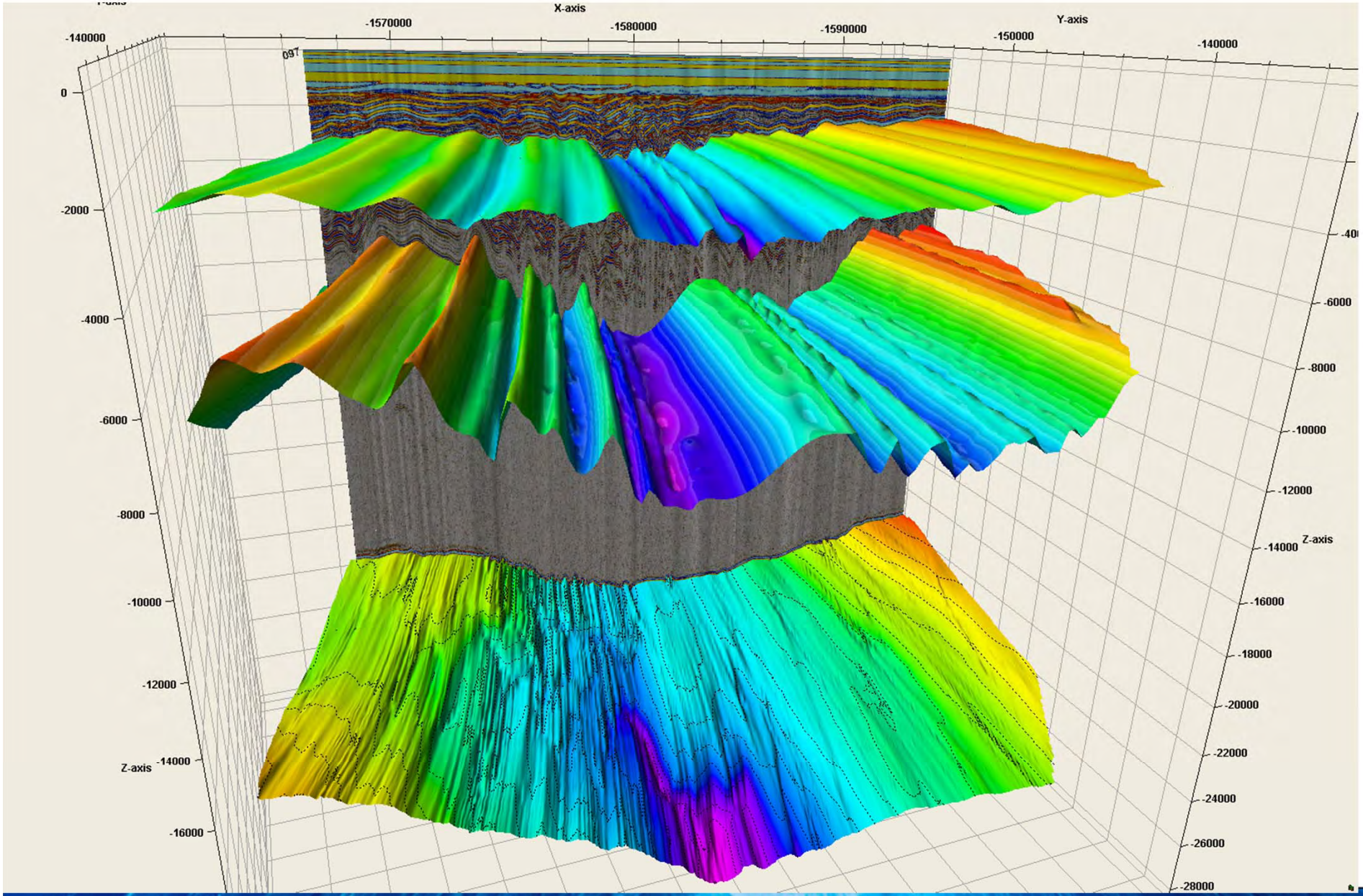


Bedforms =
2 – 40 m amplitude;
80-180 m cross-flow spacing;
2-12 km long

Interpretation of bedform types based on correlation with seismic




Bedform direction vs ice flow direction
Large-scale topography removed
PS71y (m)
PS71x (m)
-1594000 -1592000 -1590000 -1588000 -1586000 -1584000 -1582000 -1580000 -1578000 -1576000 -1574000 -1572000 -1570000 -1568000 -1566000 -1564000 -1562000 -1560000
-136000 -138000 -140000 -142000 -144000 -146000 -148000 -150000 -152000 -154000 -156000 -158000
0 1000 2000 3000 4000 5000m
1:100000
PETREL



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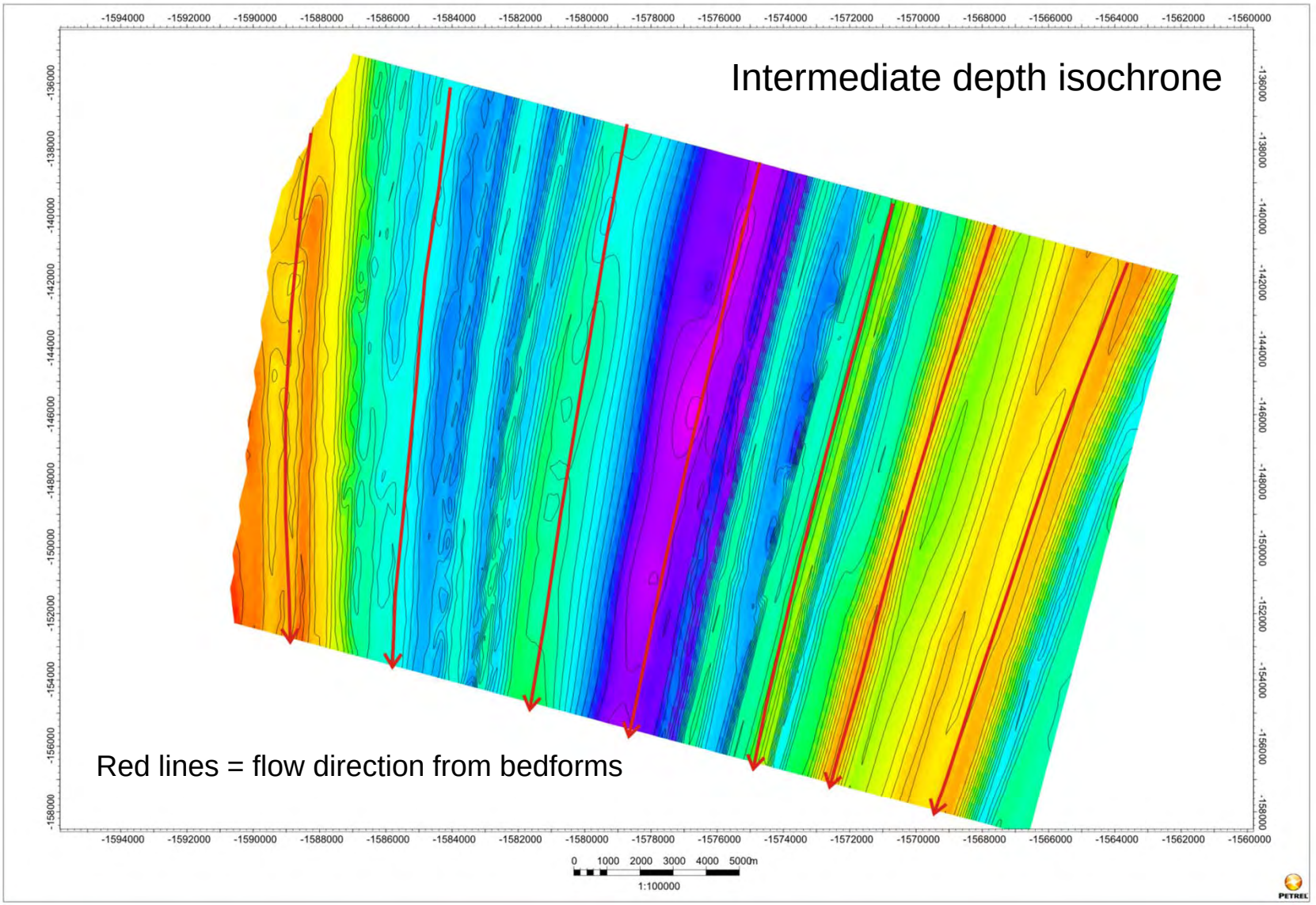
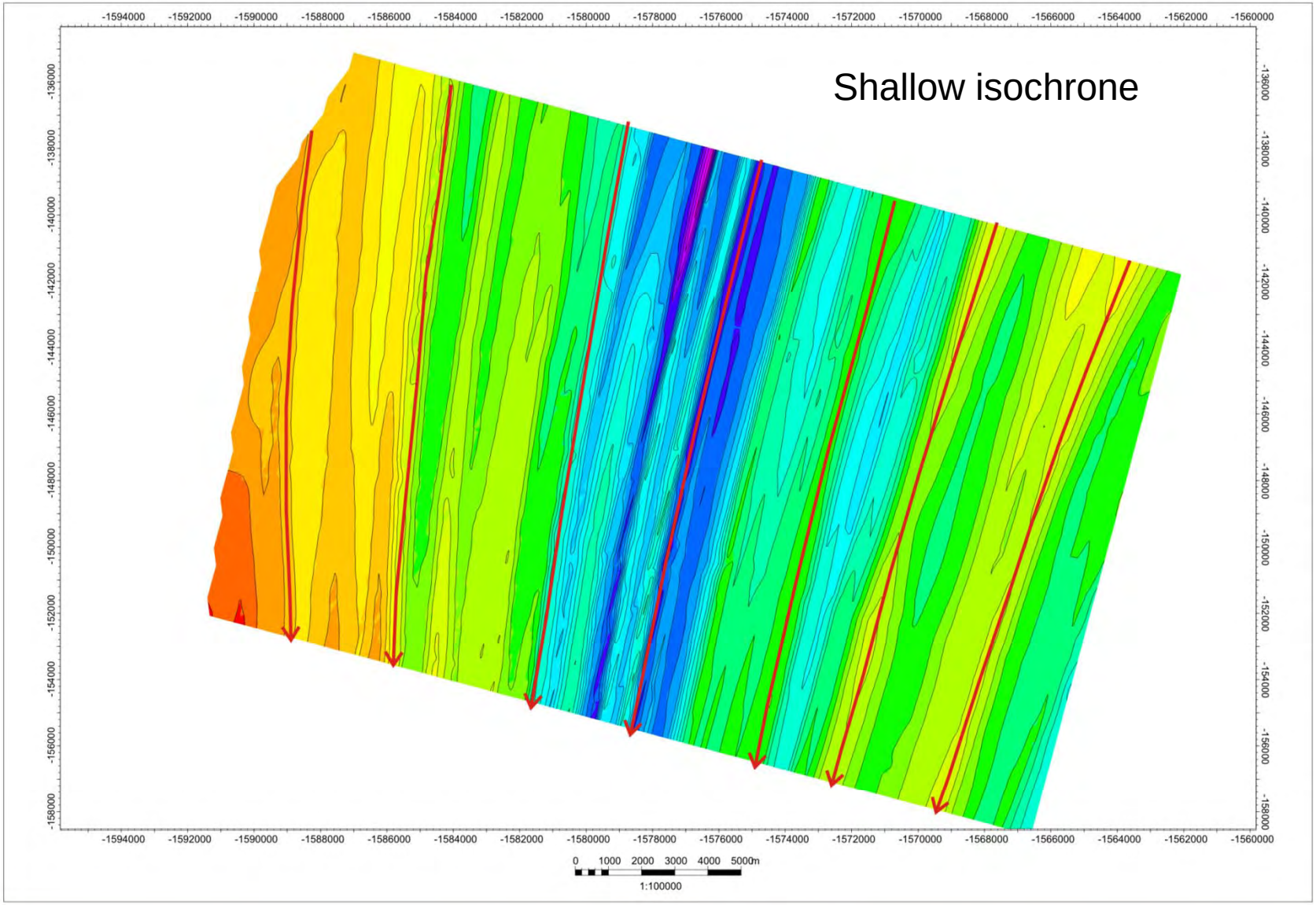
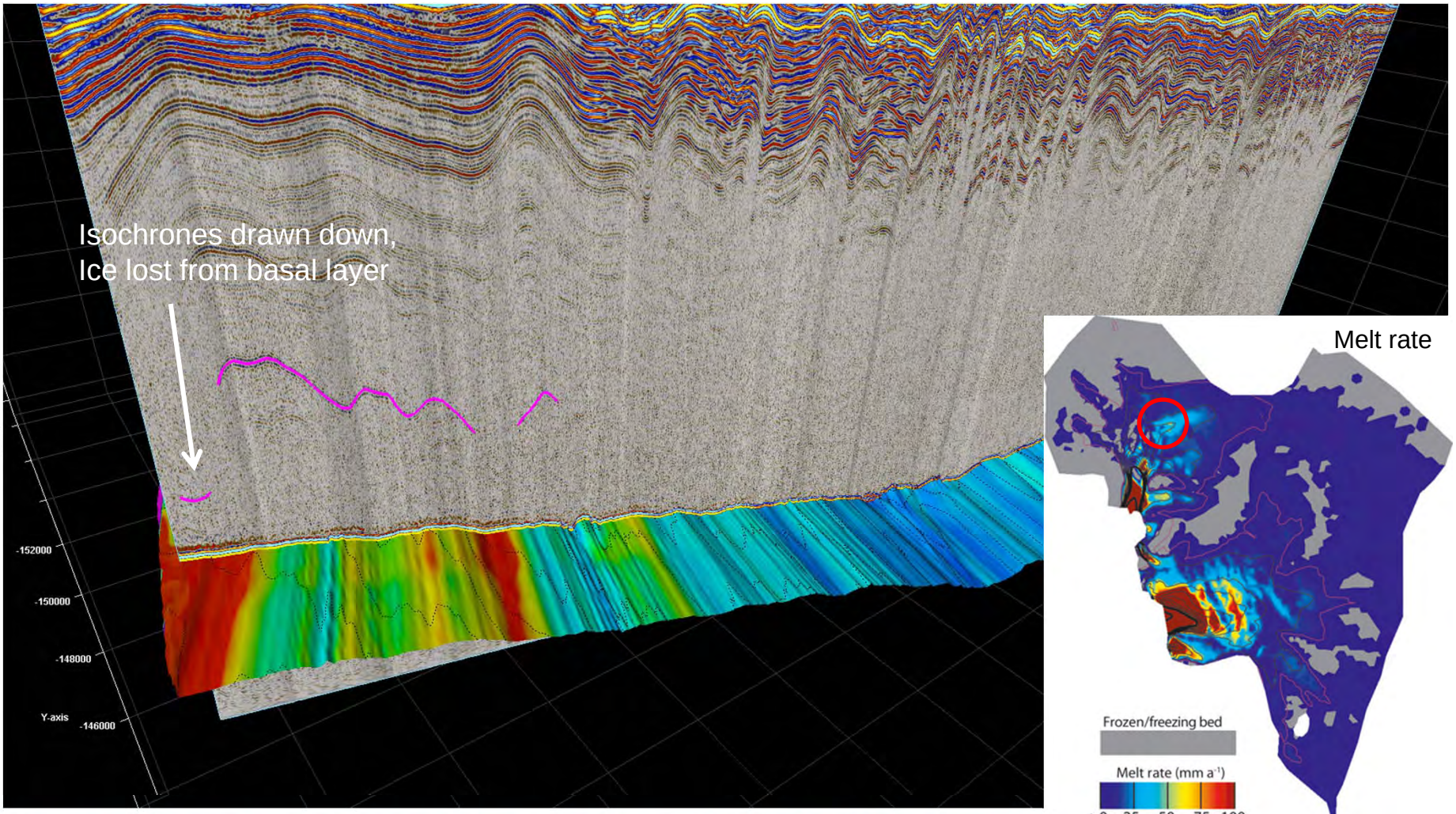
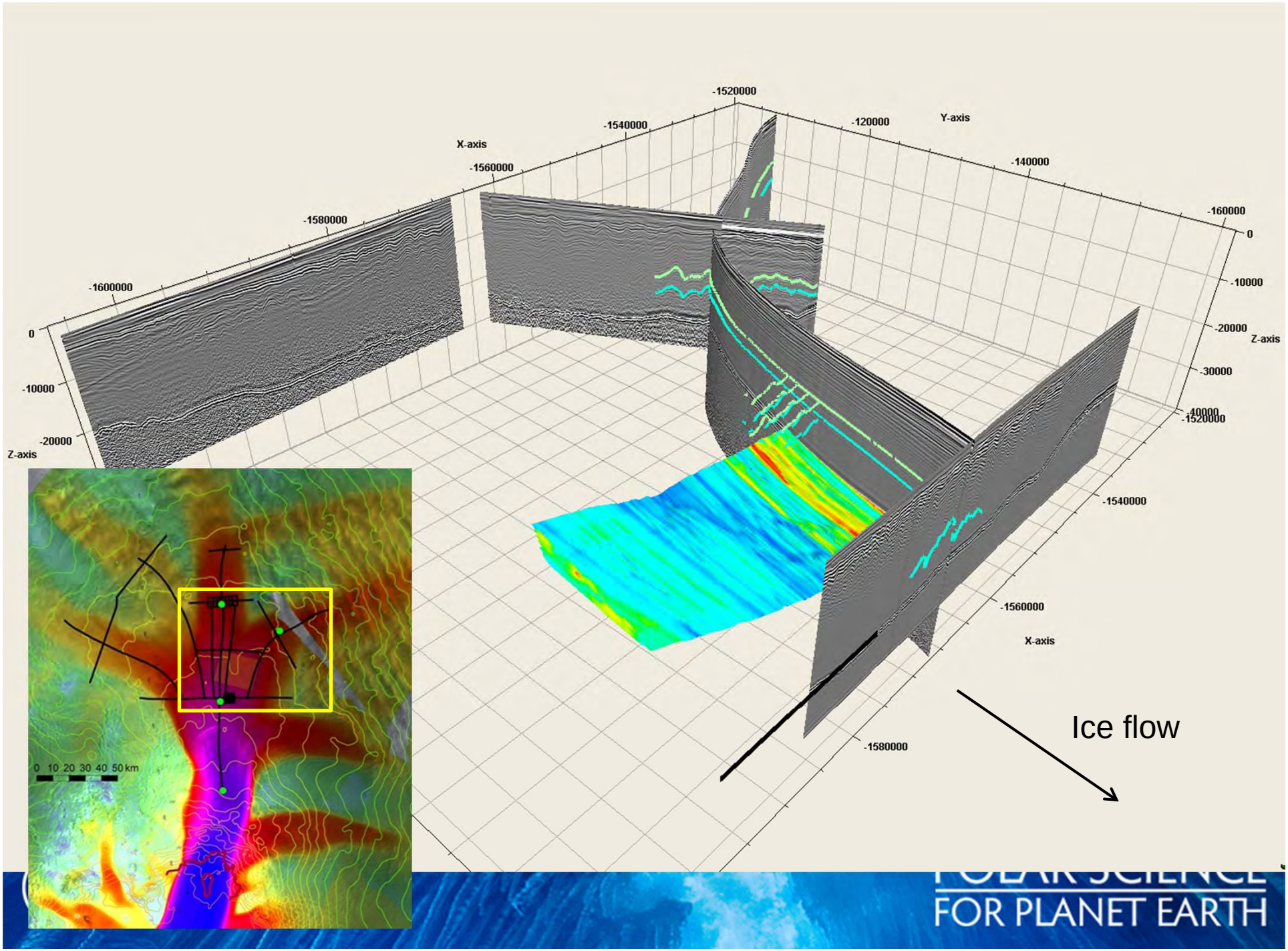
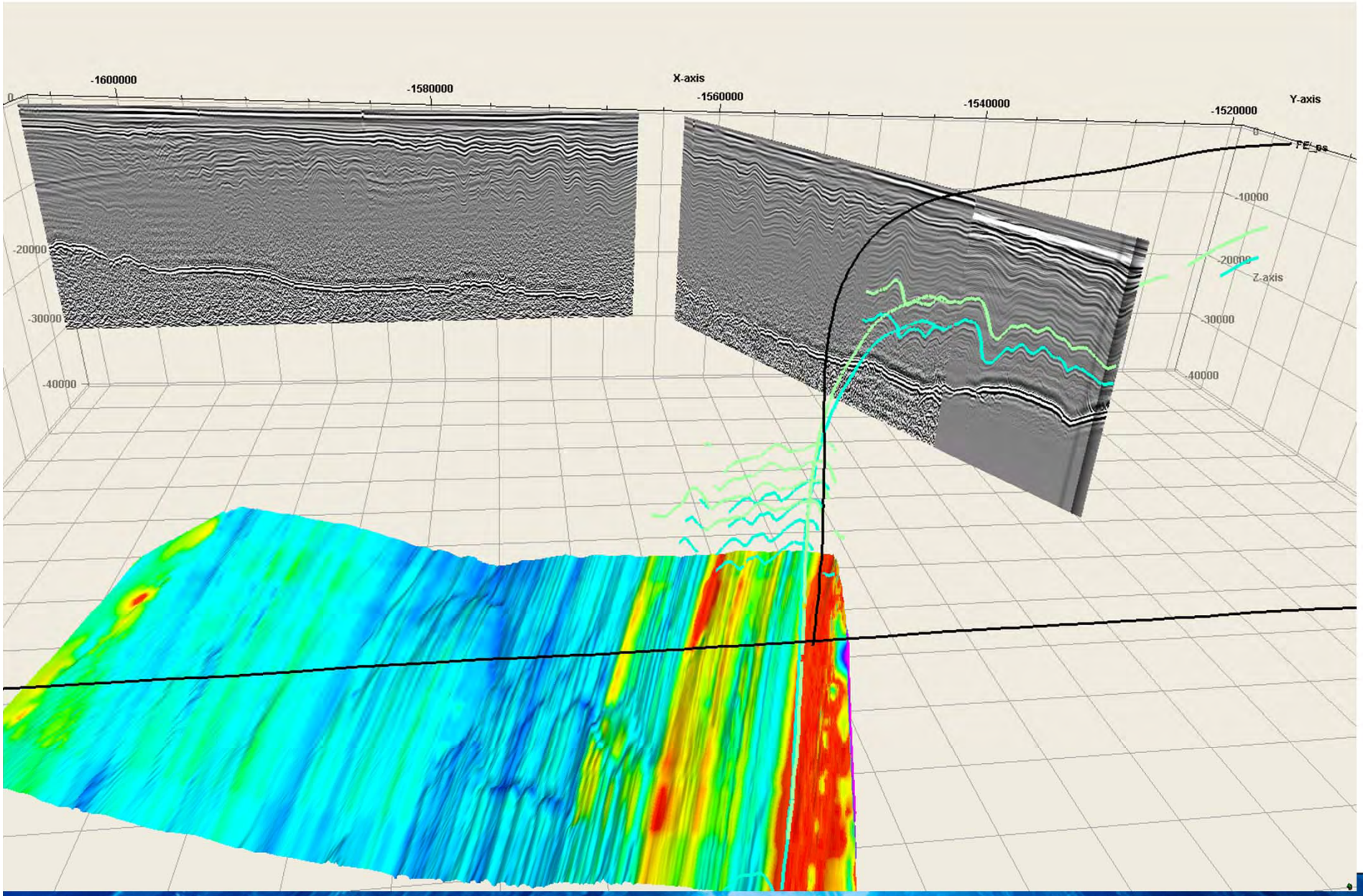

Intermediate depth isochrone
Red lines = flow direction from bedforms
-1594000 -1592000 -1590000 -1588000 -1586000 -1584000 -1582000 -1580000 -1578000 -1576000 -1574000 -1572000 -1570000 -1568000 -1566000 -1564000 -1562000 -1560000
-136000 -138000 -140000 -142000 -144000 -146000 -148000 -150000 -152000 -154000 -156000 -158000
0 1000 2000 3000 4000 5000m
1:100000
PETREL


Shallow isochrone
-1594000 -1592000 -1590000 -1588000 -1586000 -1584000 -1582000 -1580000 -1578000 -1576000 -1574000 -1572000 -1570000 -1568000 -1566000 -1564000 -1562000 -1560000
-136000 -138000 -140000 -142000 -144000 -146000 -148000 -150000 -152000 -154000 -156000 -158000
0 1000 2000 3000 4000 5000m
1:100000

Basal reflectivity: flow-parallel bright zones – what do they mean?




-1520000
-1540000
-1560000
-1580000
-1600000
X-axis
-120000
-140000
-160000
Y-axis
0
-10000
-20000
-30000
-40000
Z-axis
0 10 20 30 40 50 km
Ice flow



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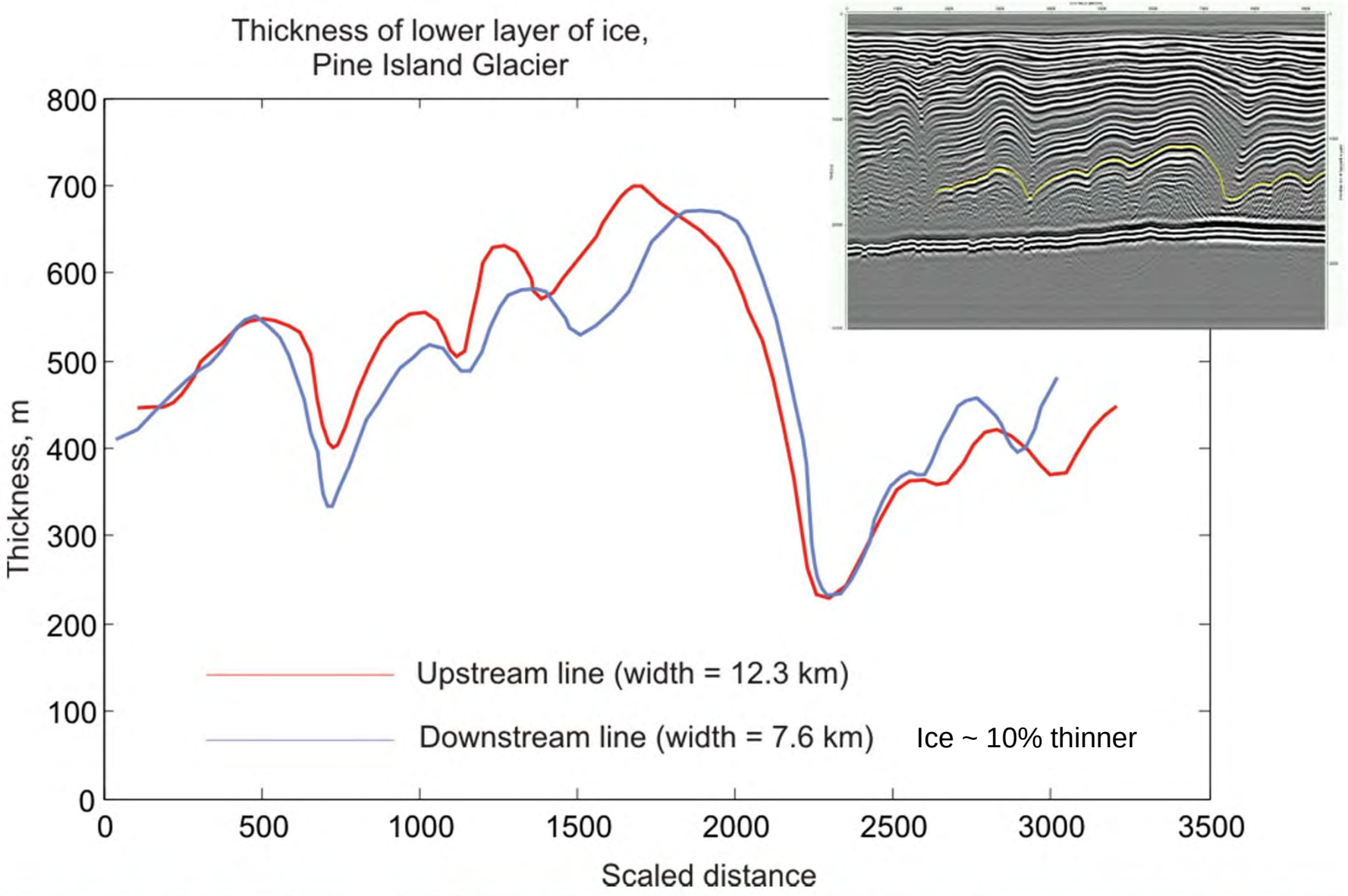
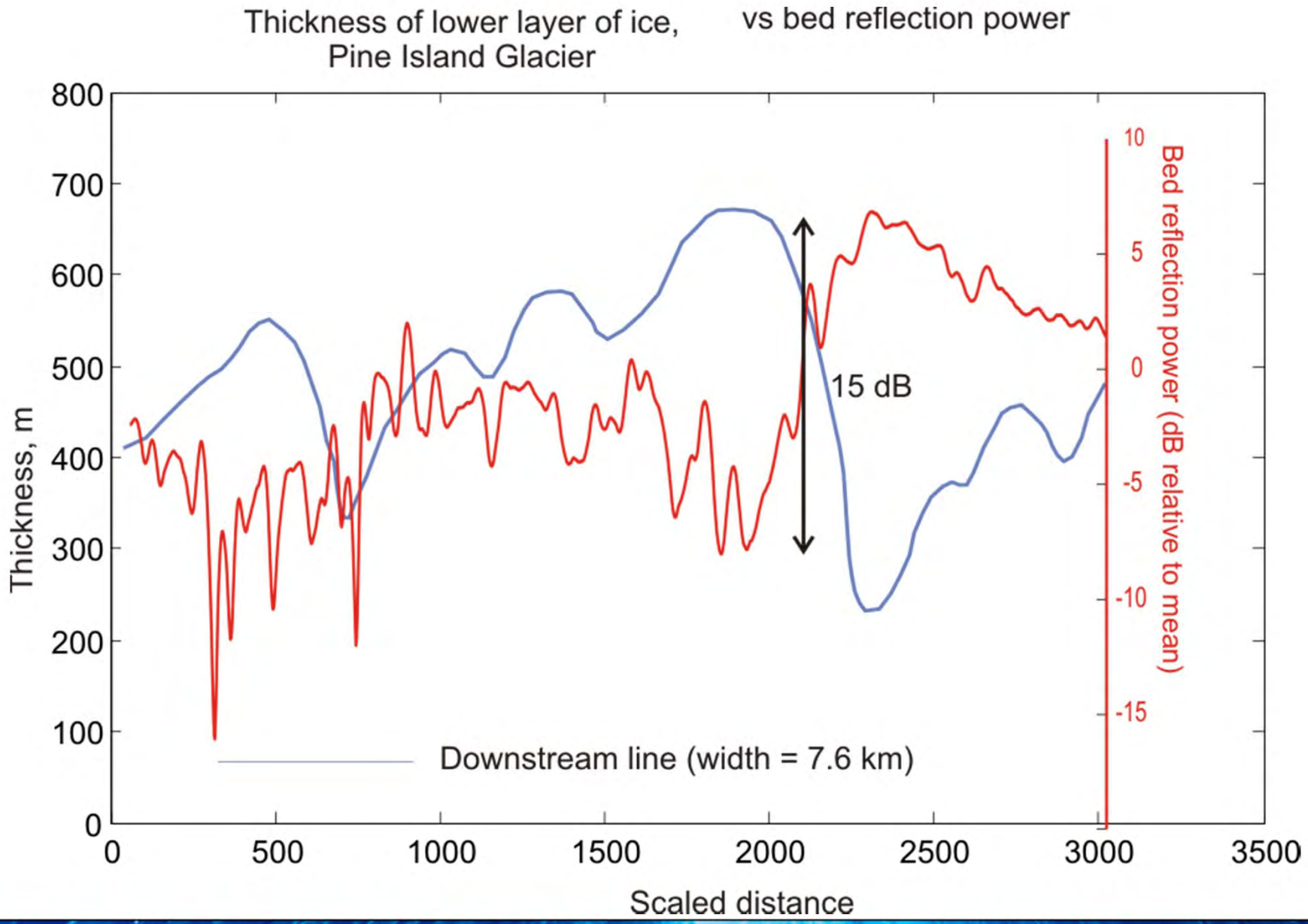
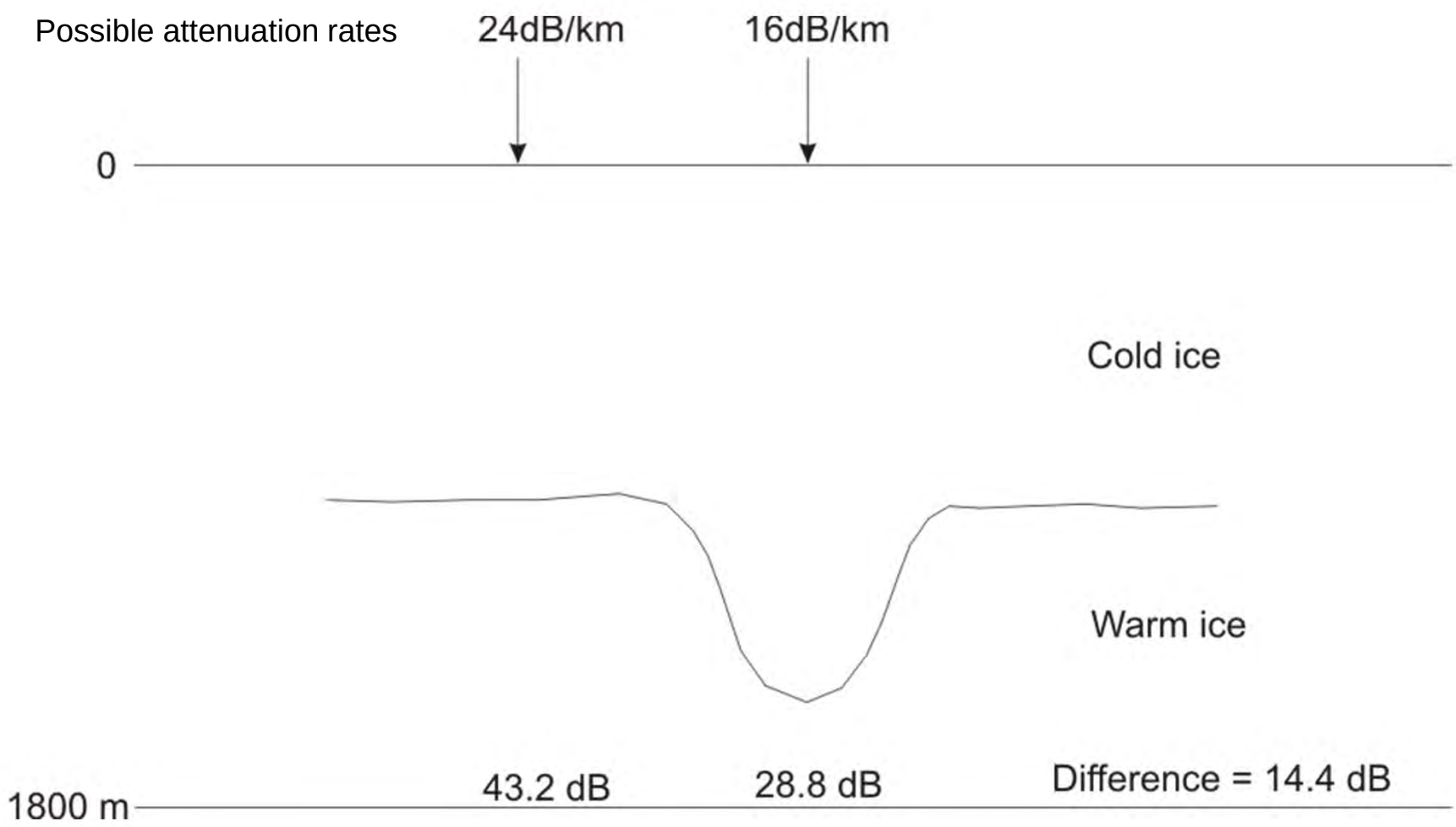
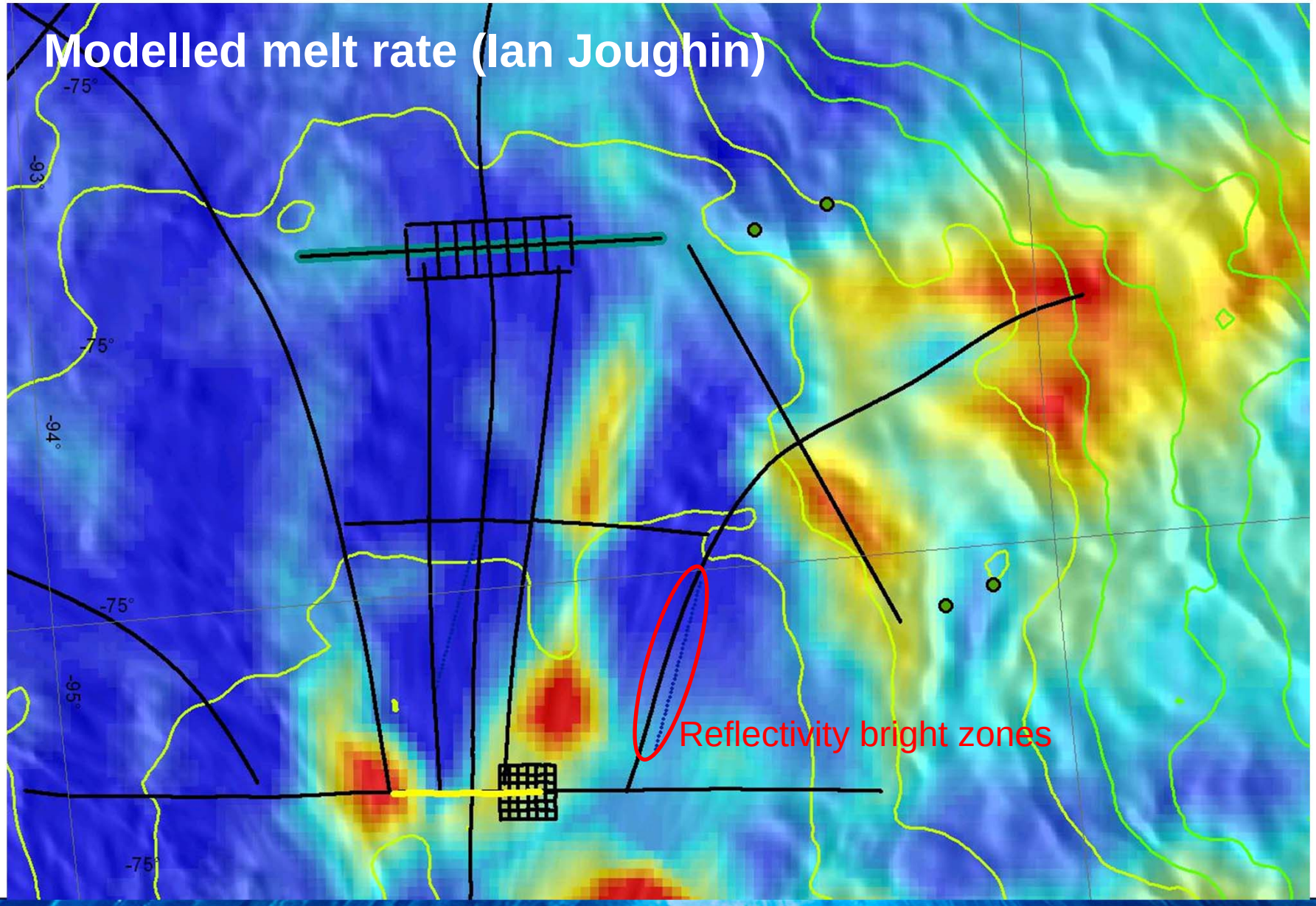

Thickness of lower layer of ice,
Pine Island Glacier
Thickness, m
800
700
600
500
400
300
200
100
0
0
500
1000
1500
2000
2500
3000
3500
Scaled distance
Upstream line (width = 12.3 km)
Downstream line (width = 7.6 km)
Ice ~ 10% thinner


Thickness of lower layer of ice,
Pine Island Glacier
vs bed reflection power
Thickness, m
Bed reflection power (dB relative to mean)
15 dB
Downstream line (width = 7.6 km)
Scaled distance
0
100
200
300
400
500
600
700
800
0
500
1000
1500
2000
2500
3000
3500
10
5
0
-5
-10
-15



Conclusion: apparent water signal could be due to vertical advection of cold ice due to basal melting far upstream

Modelled melt rate (Ian Joughin)



Conclusions

•Pine Island Glacier has a mixed bed of soft (dilatant) and stiff till.

•Proportions in the sample area were c. 50-50.

•Bedforms align exactly with flow indicators; implying either flow stability or rapid reaction times.

•Two linear zones of high basal reflectivity underlying regions of isochrone draw-down suggest active melt at the bed upstream in the tributary, which has produced an en-glacial attenuation anomaly.

•Suggests that a temperature anomaly is being advected downstream – could this have an influence on melting at the grounding line?

Acknowledgements

Thanks to field support and operations staff, and air crews for getting us in and out of such a far-away spot.