MIMO

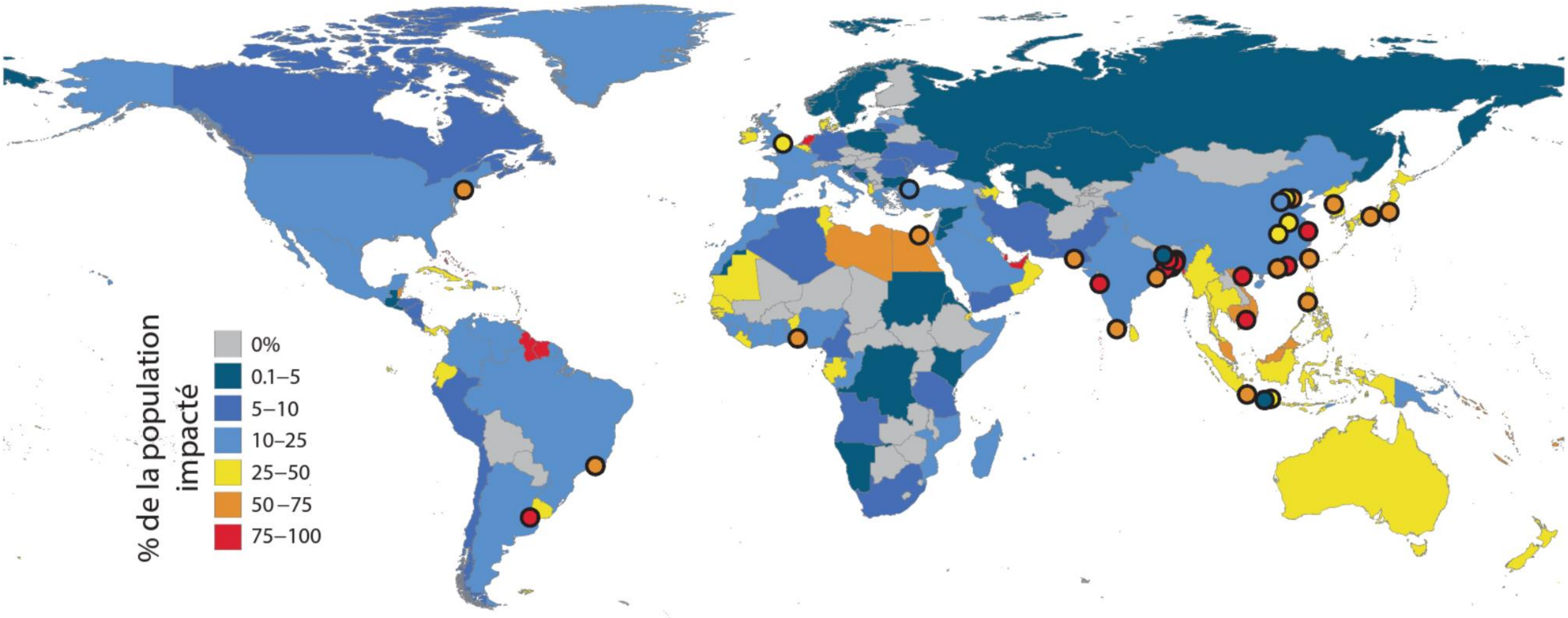
Monitoring Melt where Ice Meets Ocean

ULB - CSL - AWI

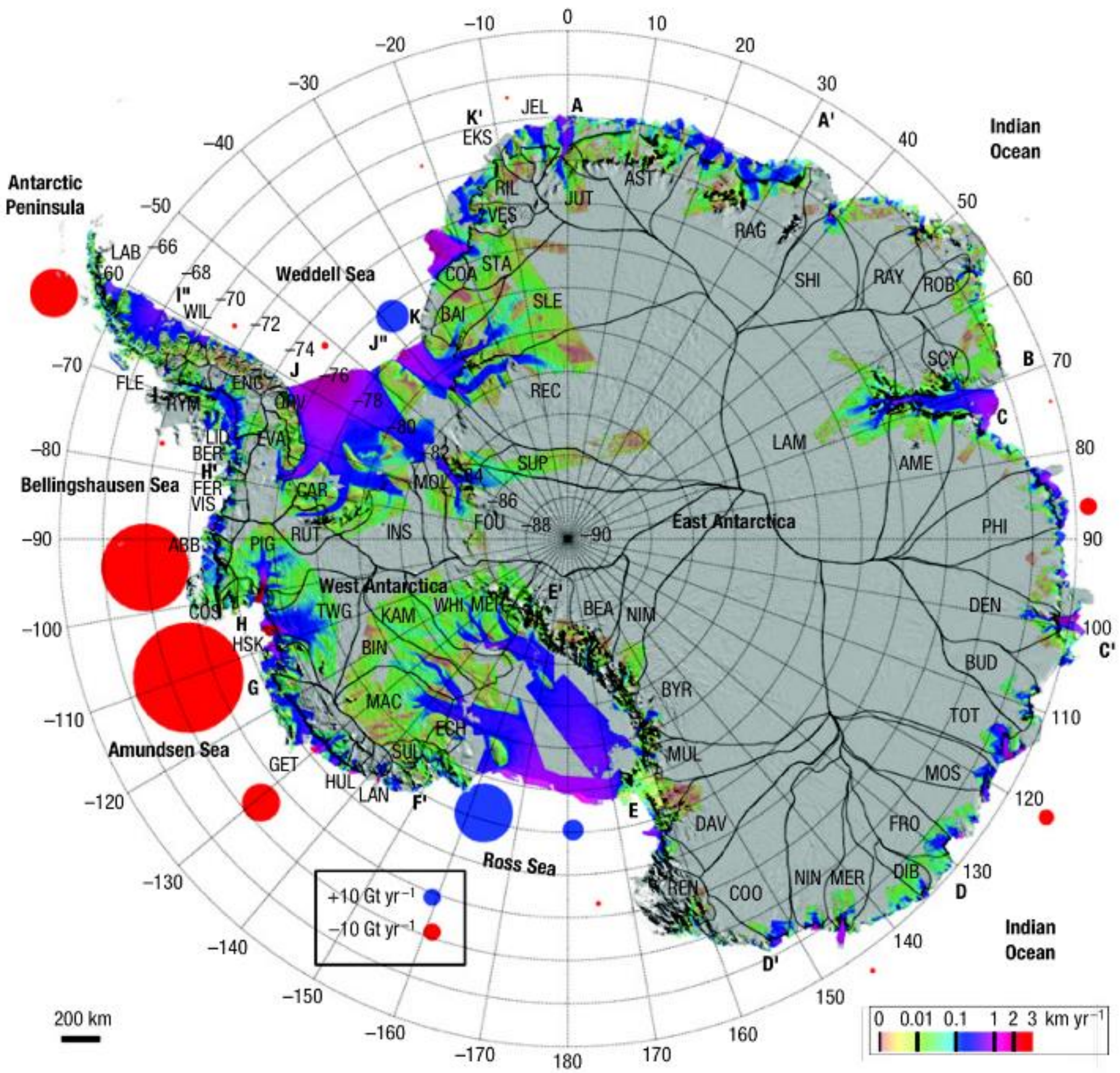
High spatial variability of Antarctic ice shelf mass balance from space and field observations

Frank Pattyn, Sophie Berger, Sainan Sun, Veit Helm, Quentin Glaude, Dominique Derauw, Olaf Eisen

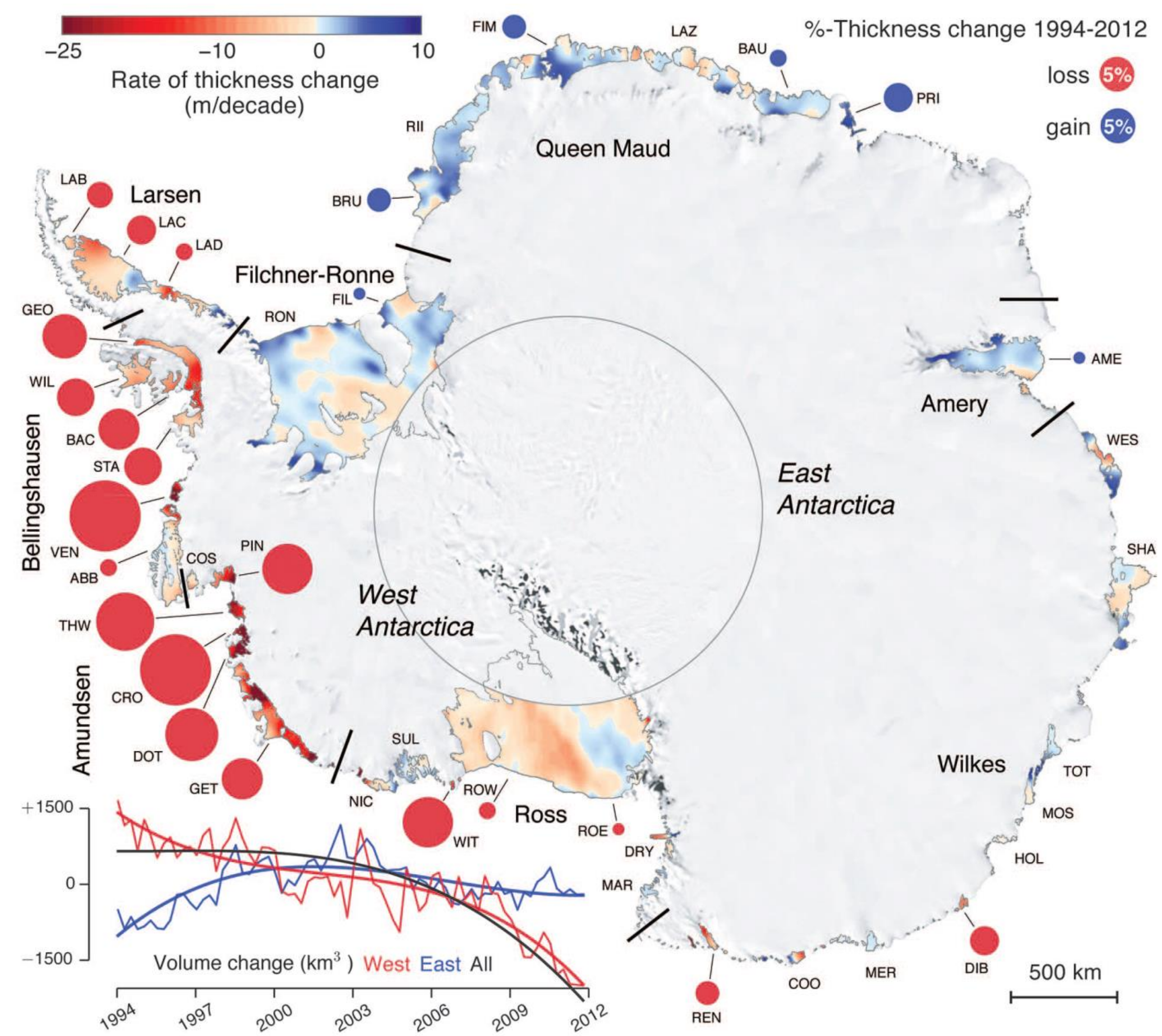
Worldwide sea level rise impact



Ice-sheet mass loss and shelf thinning



Rignot et al., 2008



Paolo et al., 2016

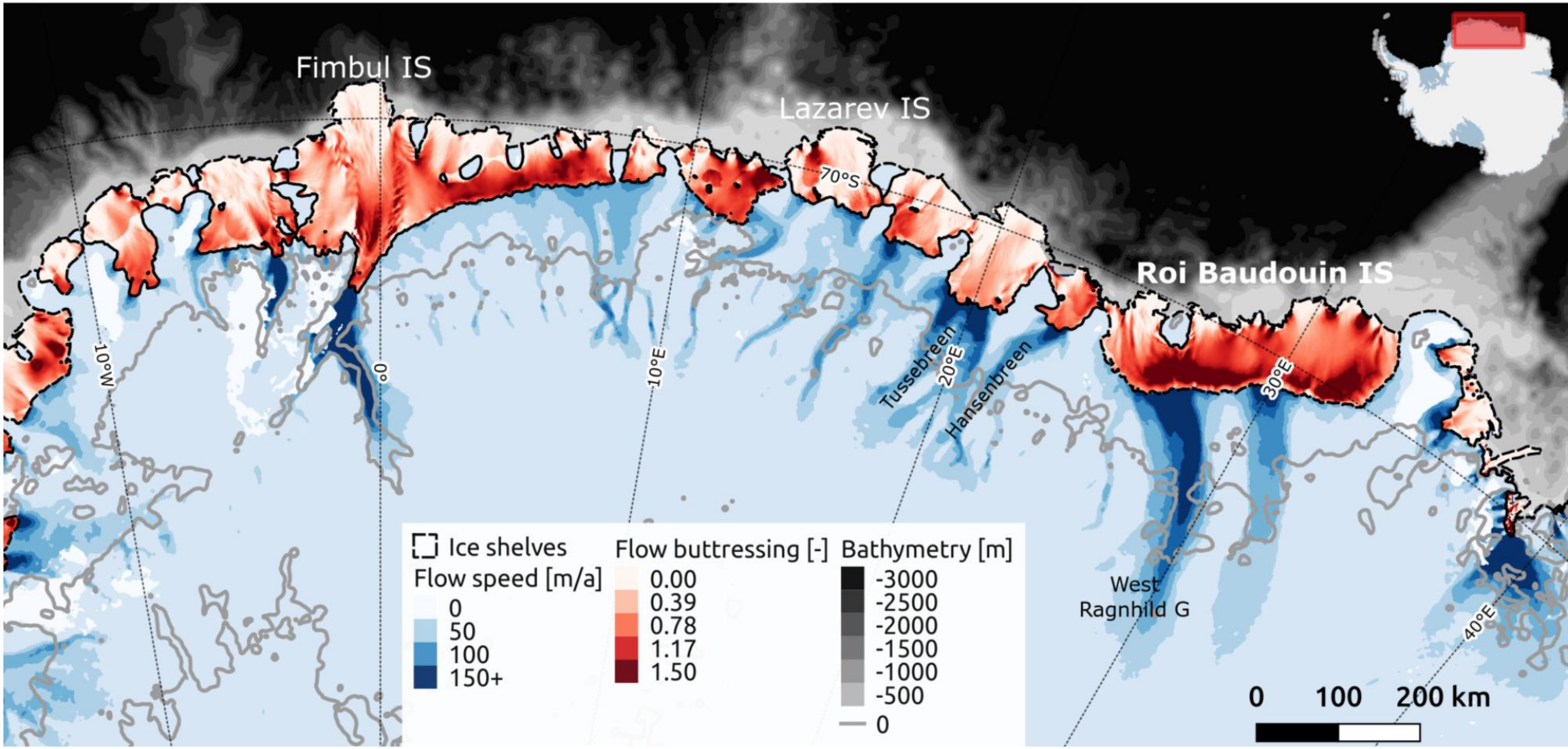
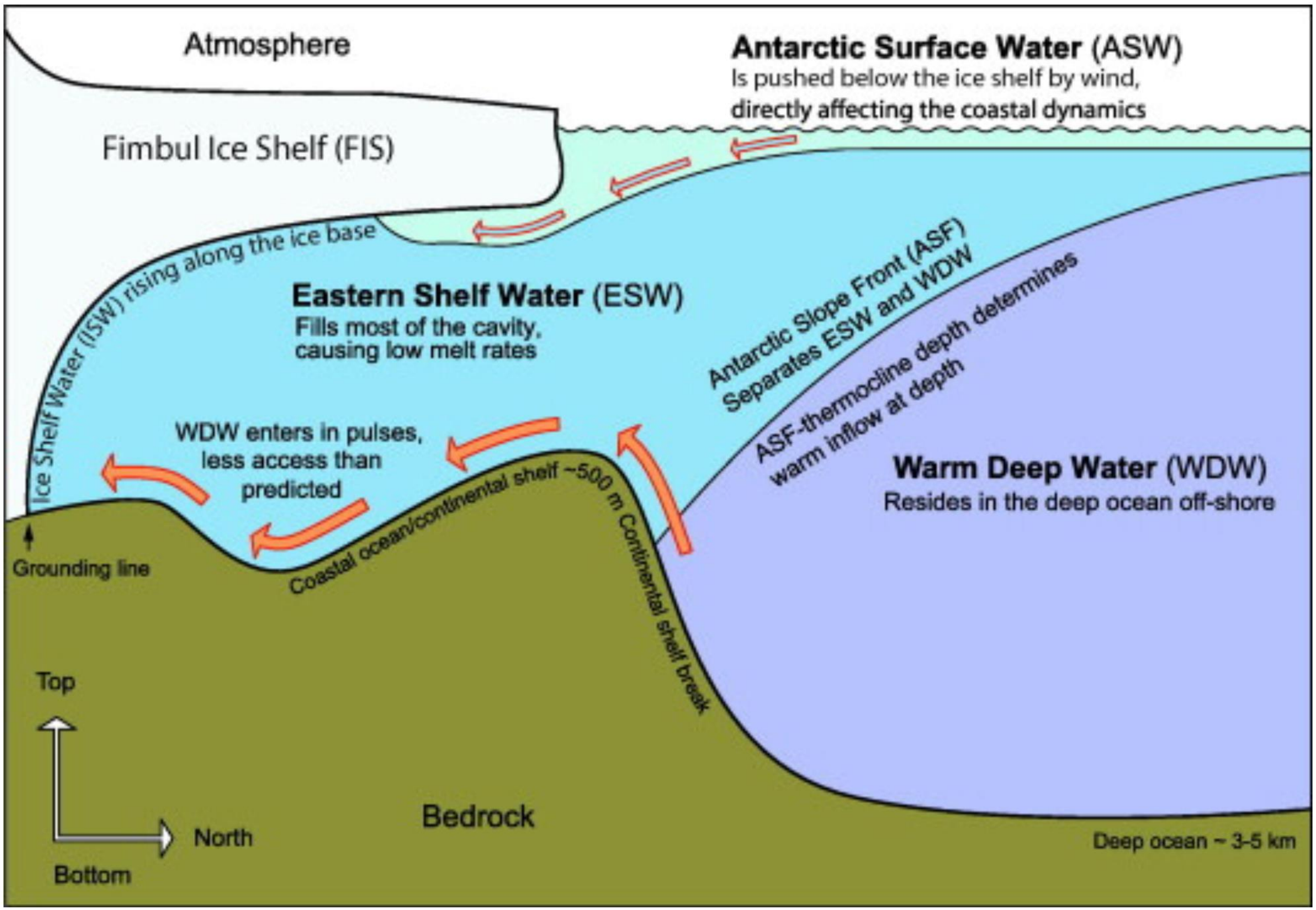


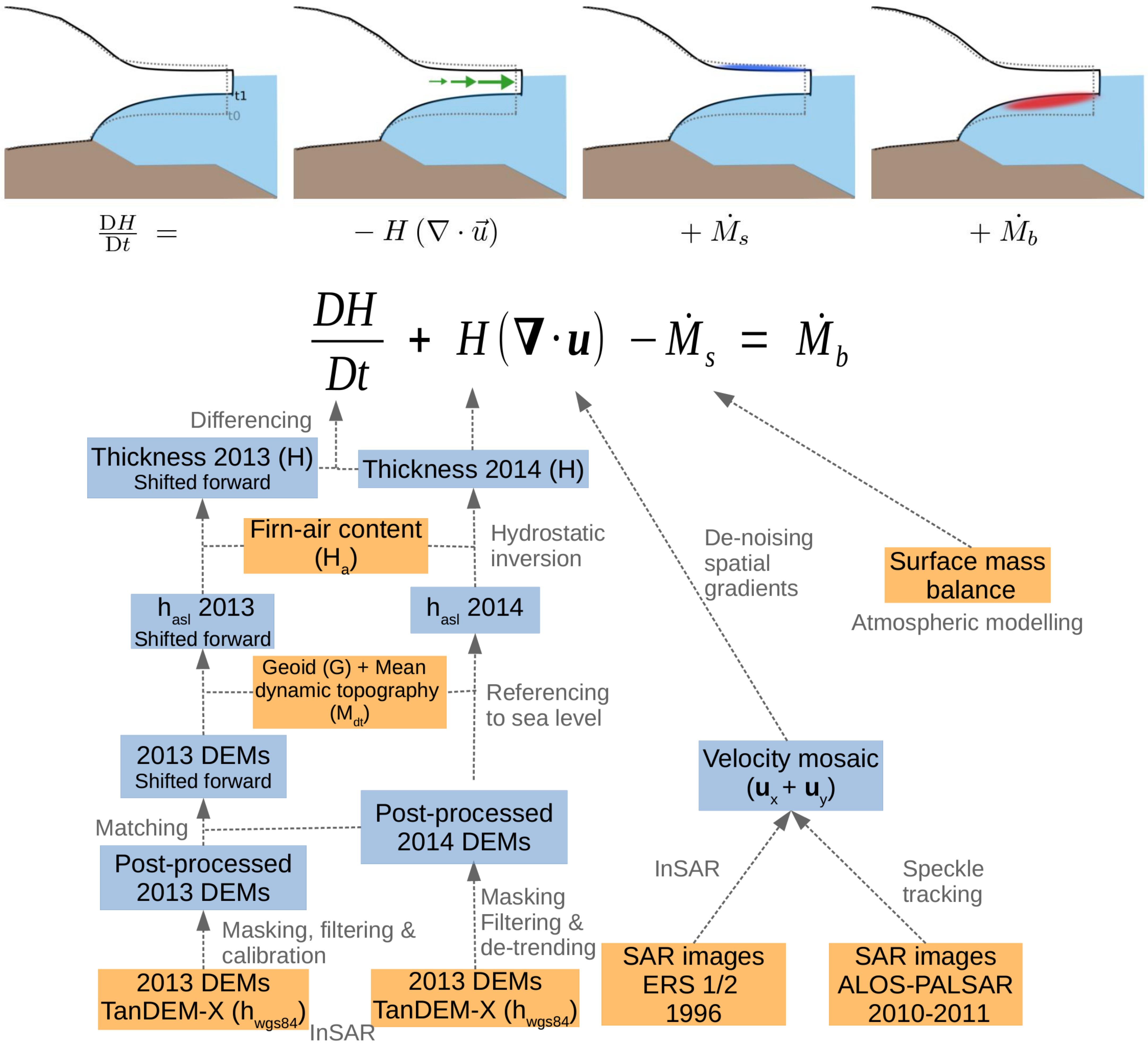
Figure 1.12: Coastal Dronning Maud Land. **Ice shelves** (red): buttressing in the direction of ice flow from Fürst et al. (2016) (ice-shelf outlines from Rignot et al., 2013, Mouginot et al., 2016). **Grounded ice** (blue): flow speed from Rignot et al. (2011). **Seaward side** (grey): seabed from Fretwell et al. (2013). IS and G stand for ice shelf and glacier, respectively.

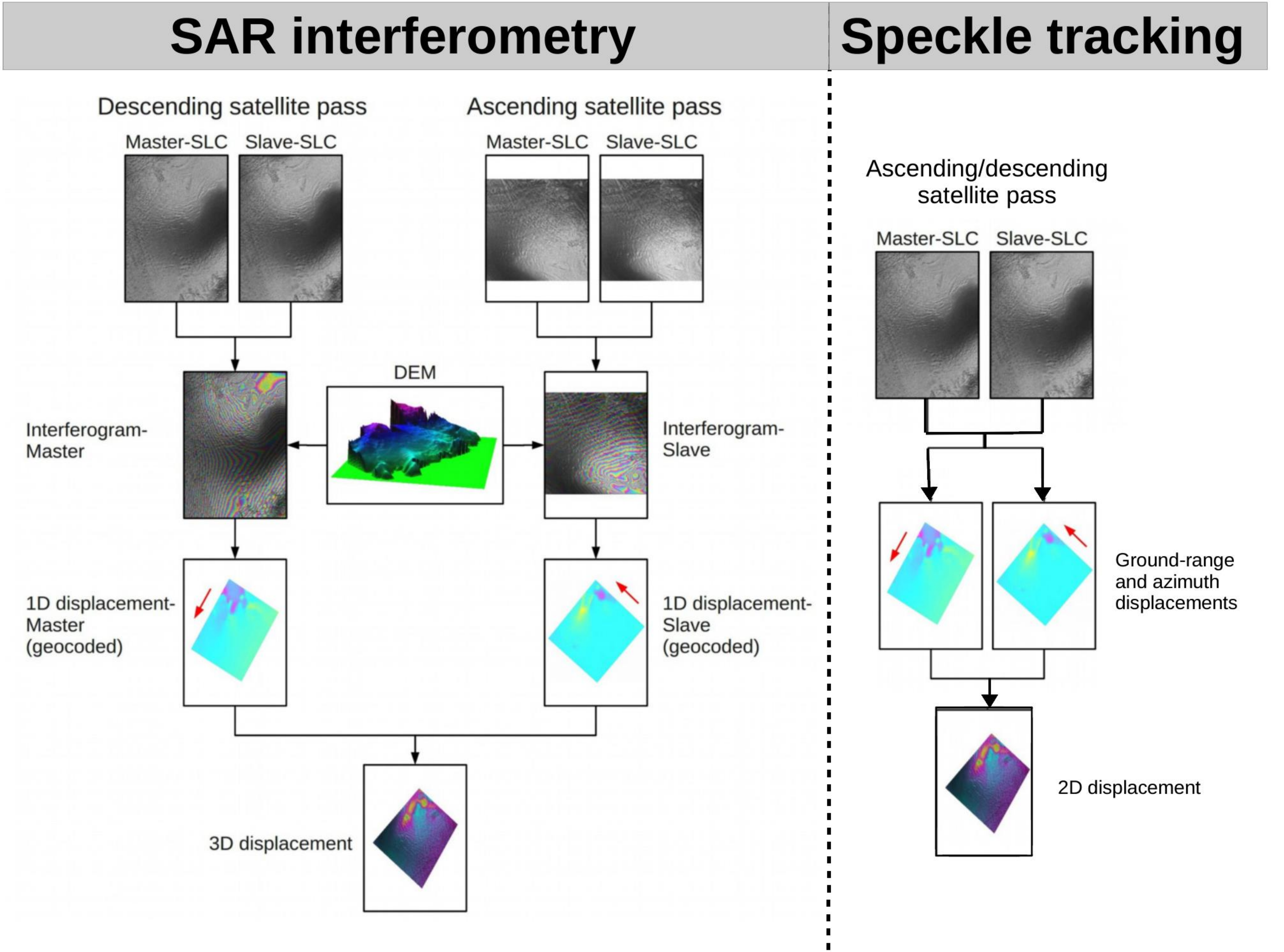
Ice-ocean interaction leads to melting at the grounding line

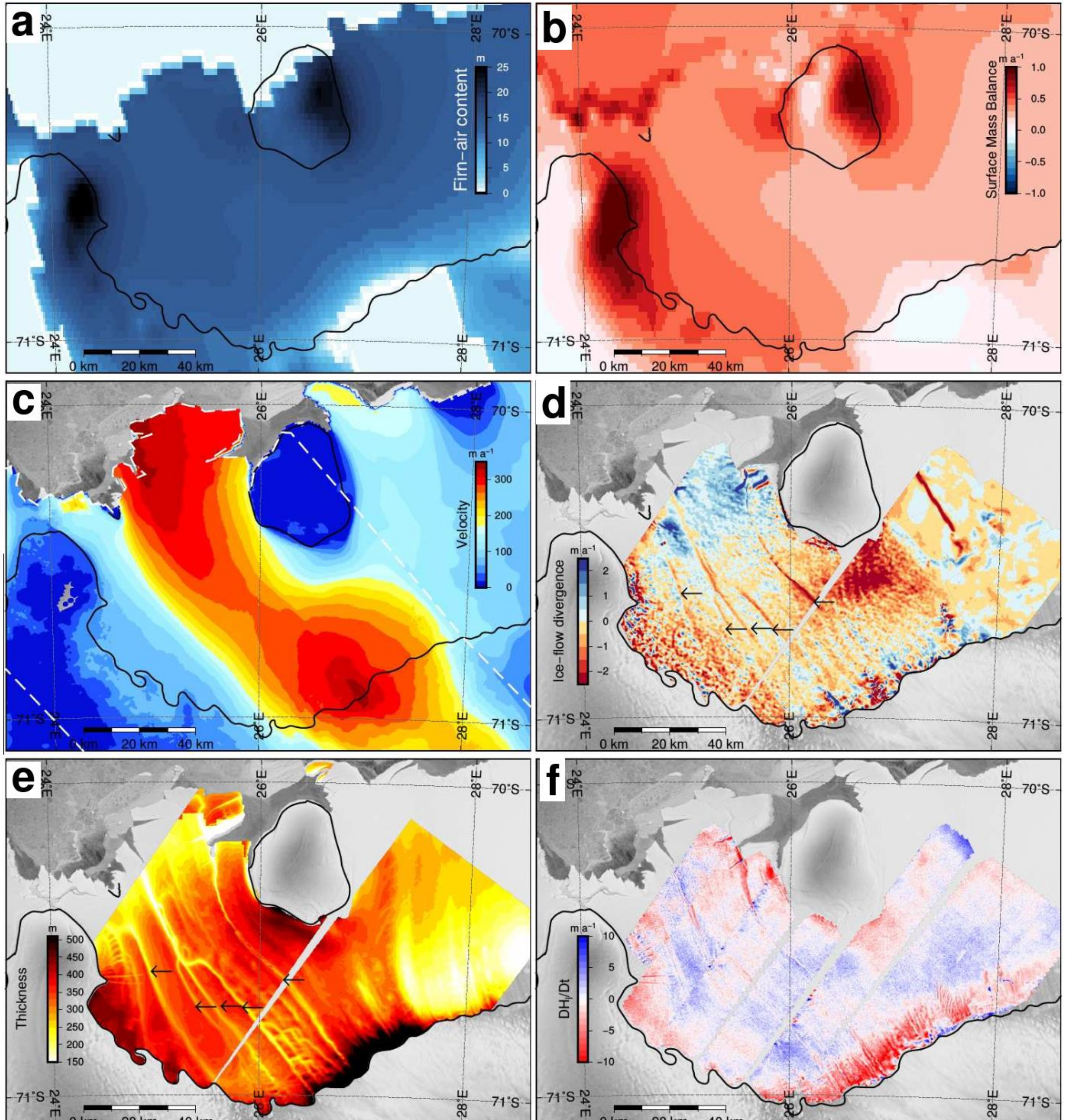


MIMO: Monitoring Melt where Ice Meets Ocean

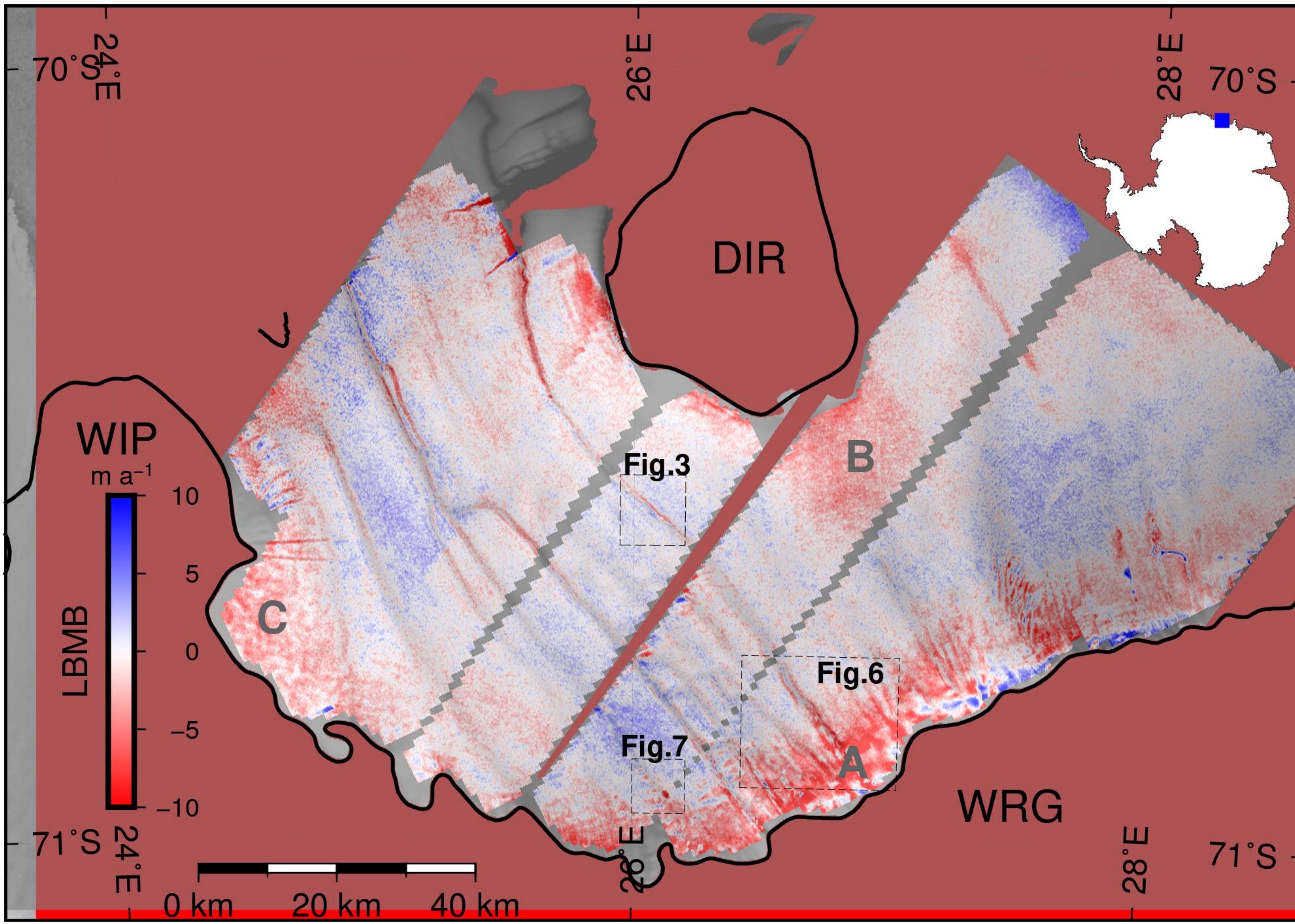
- **quantify basal melt** of ice shelves surrounding the Antarctic ice sheet at high spatial and temporal resolution
    - RBIS ice shelf laboratory
    - Dronning Maud Land ice shelves (monitoring)
- derive **improved parameterisations** for use in ice sheet modelling studies
    - Pan-Antarctic ice sheet modelling (f.ETISh)


t1
t0
DH/Dt =
− H (∇ · u⃗)
+ Ṁs
+ Ṁb
DH/Dt + H(∇·u) − Ṁs = Ṁb
Differencing
Thickness 2013 (H)
Shifted forward
Thickness 2014 (H)
Firn-air content
(Ha)
Hydrostatic
inversion
De-noising
spatial
gradients
Surface mass
balance
Atmospheric modelling
hasl 2013
Shifted forward
hasl 2014
Geoid (G) + Mean
dynamic topography
(Mdt)
Referencing
to sea level
2013 DEMs
Shifted forward
Velocity mosaic
(ux + uy)
Matching
Post-processed
2014 DEMs
Post-processed
2013 DEMs
InSAR
Speckle
tracking
Masking
Filtering &
de-trending
Masking, filtering &
calibration
2013 DEMs
TanDEM-X (hwgs84)
2013 DEMs
TanDEM-X (hwgs84)
SAR images
ERS 1/2
1996
SAR images
ALOS-PALSAR
2010-2011
InSAR


SAR interferometry
Speckle tracking
Descending satellite pass
Ascending satellite pass
Master-SLC
Slave-SLC
Master-SLC
Slave-SLC
DEM
Interferogram-
Master
Interferogram-
Slave
1D displacement-
Master
(geocoded)
1D displacement-
Slave
(geocoded)
3D displacement
Ascending/descending
satellite pass
Master-SLC
Slave-SLC
Ground-range
and azimuth
displacements
2D displacement

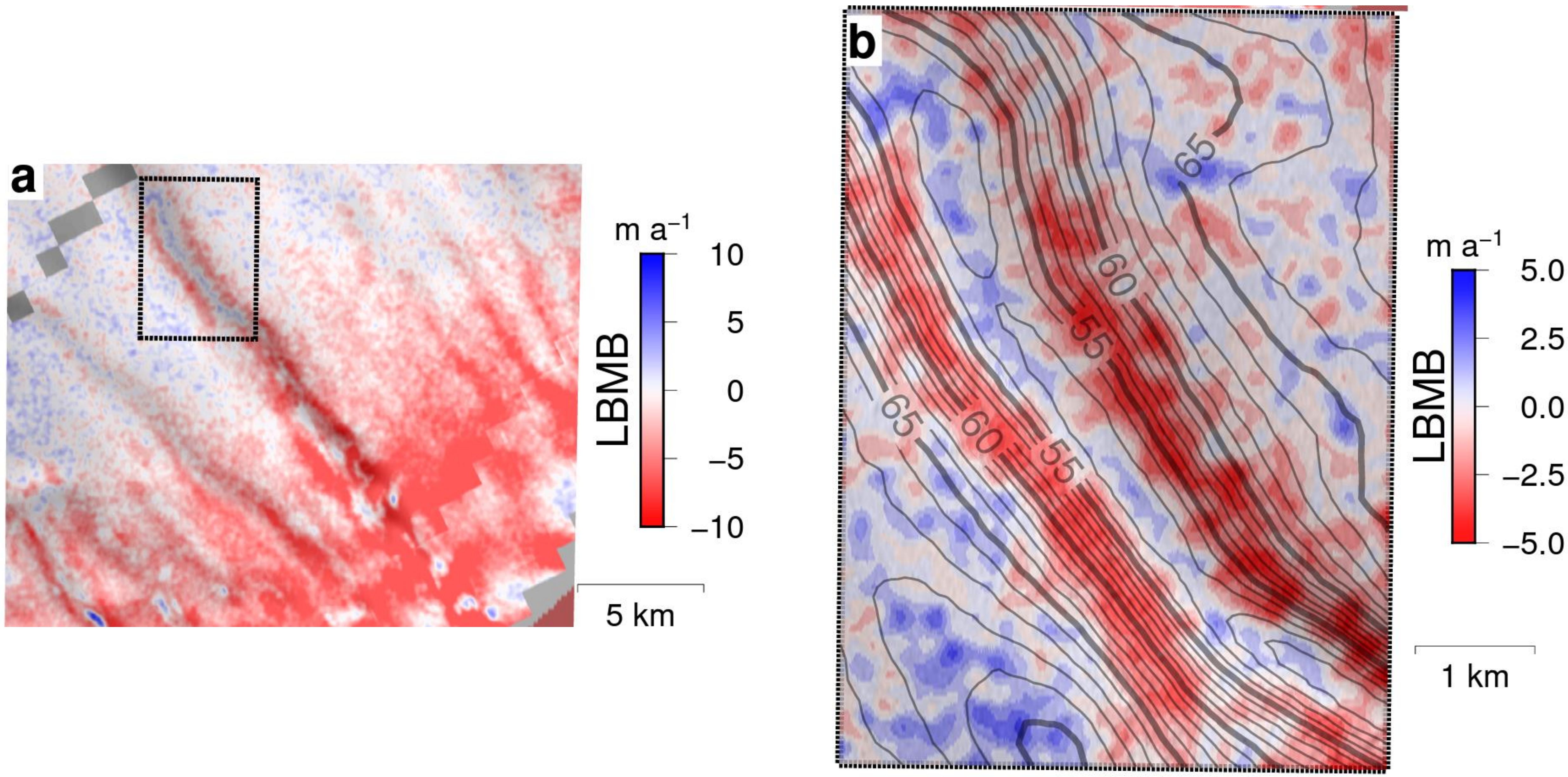


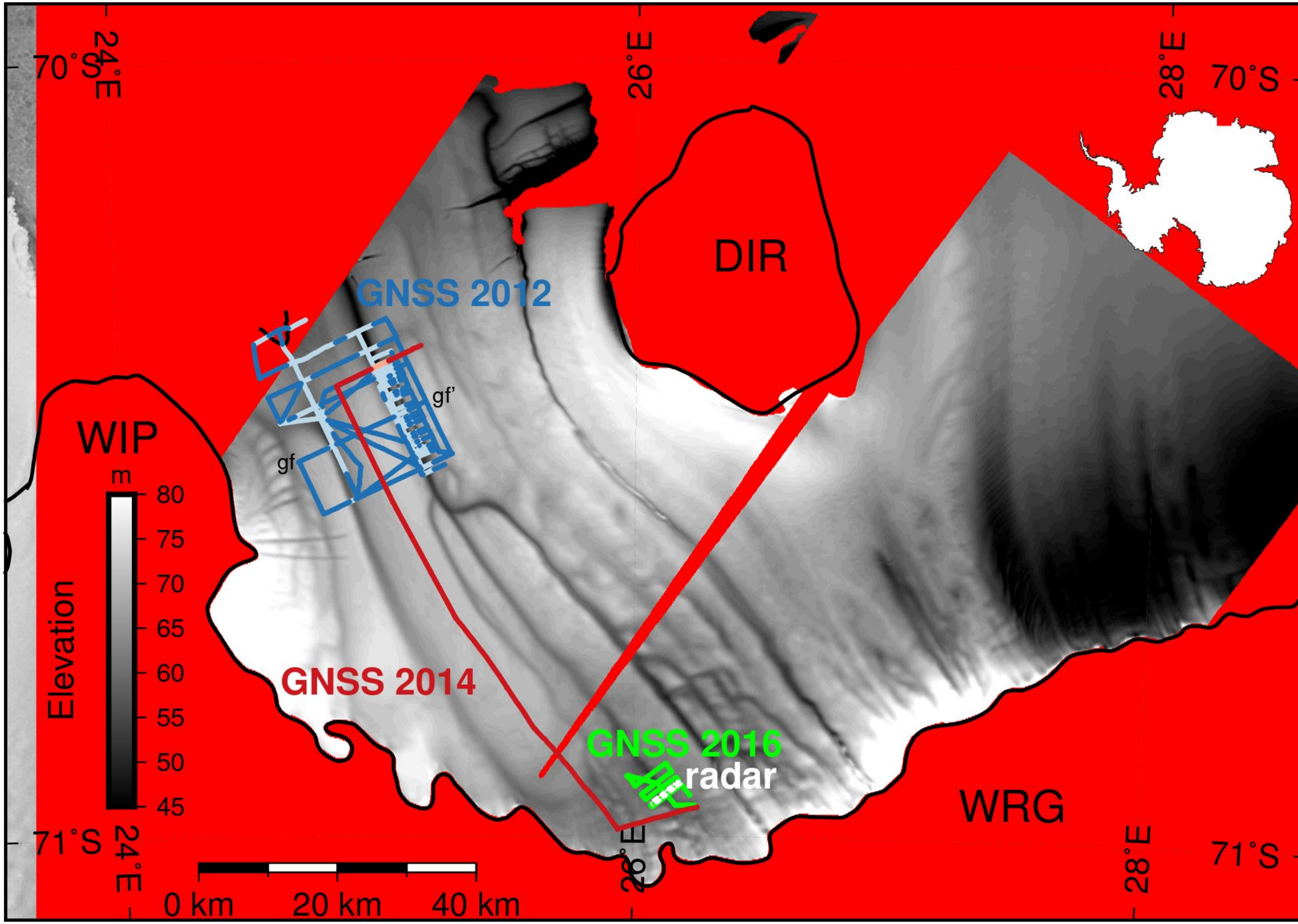
Berger et al., 2017



70°S
24°E
26°E
28°E
70°S
DIR
WIP
m a⁻¹
10
5
0
−5
−10
LBMB
Fig.3
B
C
Fig.6
Fig.7
A
WRG
71°S
24°E
26°E
28°E
71°S
0 km
20 km
40 km

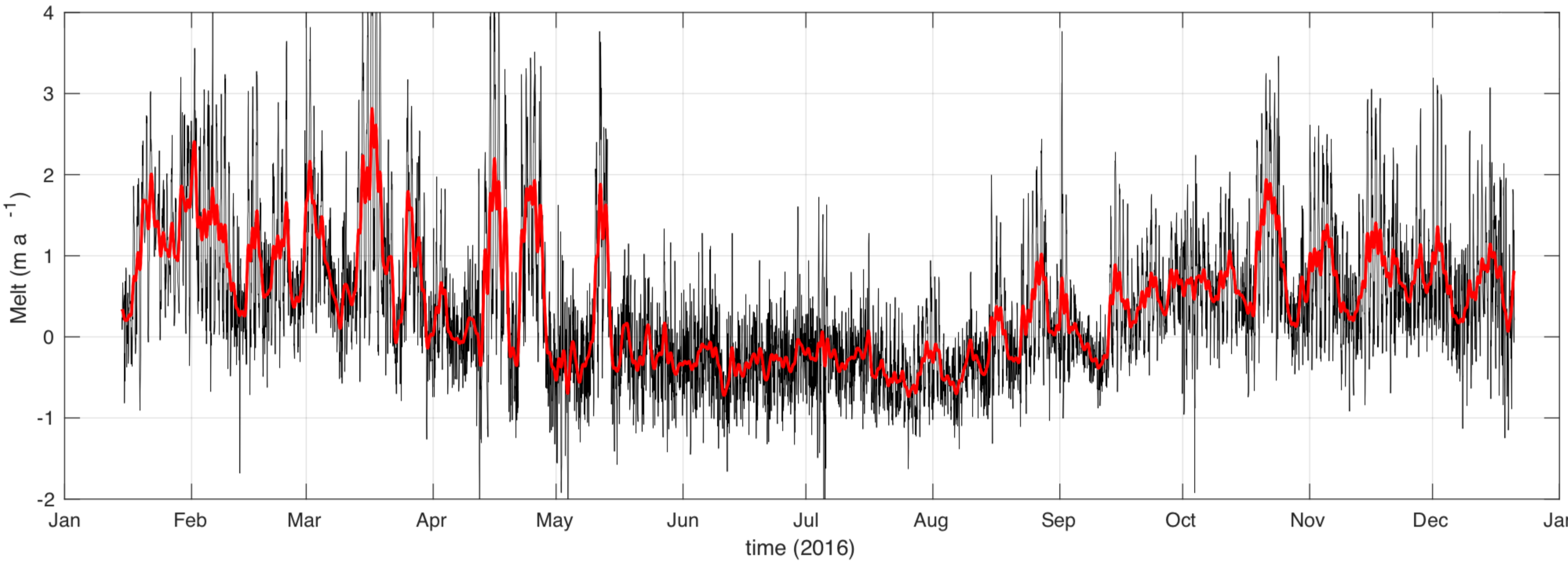
Melt concentrated on channel flanks





70˚S
24˚E
26˚E
28˚E
70˚S
DIR
GNSS 2012
gf'
gf
WIP
m
Elevation
80
75
70
65
60
55
50
45
GNSS 2014
GNSS 2016
radar
WRG
71˚S
24˚E
26˚E
28˚E
71˚S
0 km
20 km
40 km

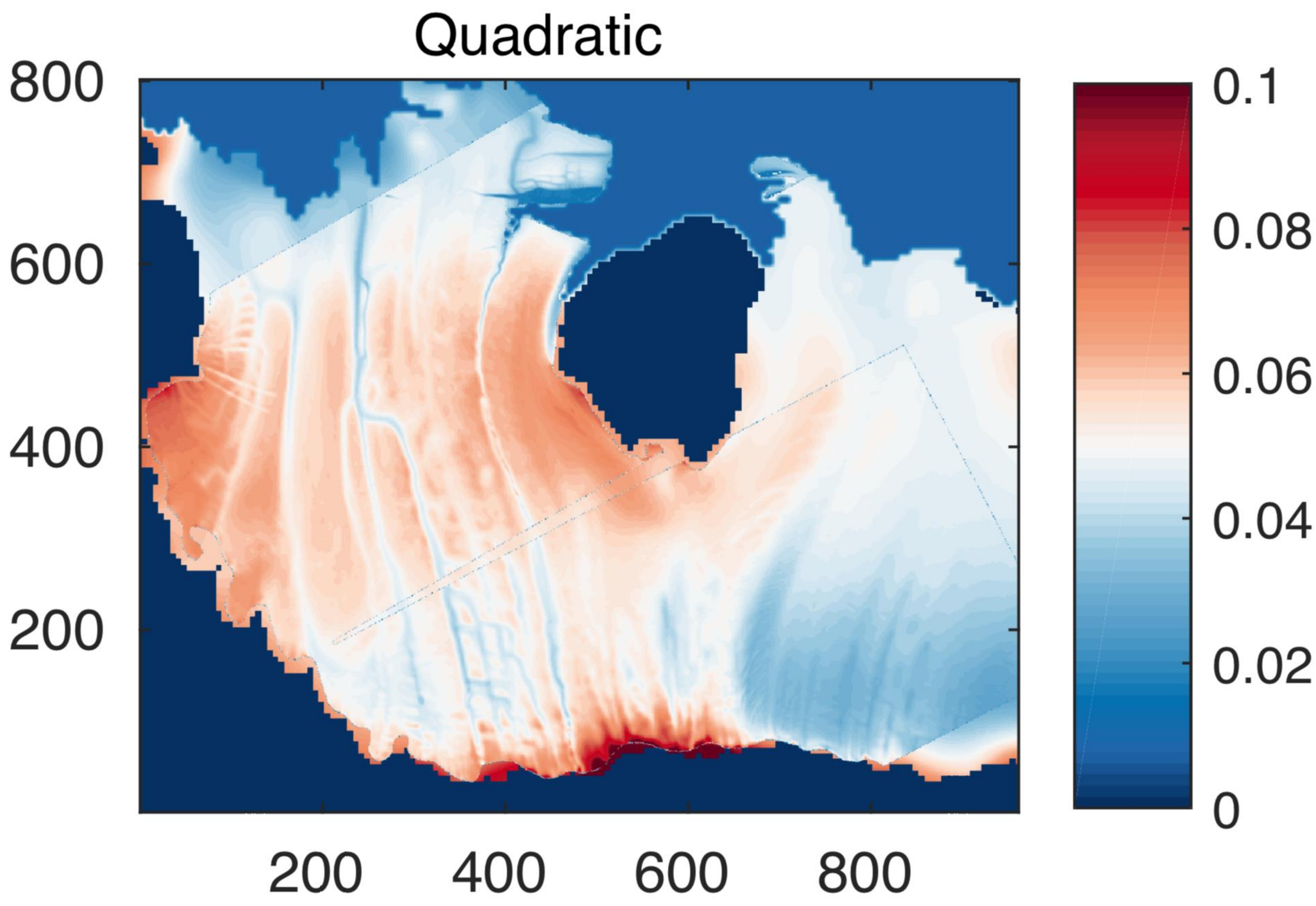
Phase sensitive radar measurements (ApRES)



ApRES time series of ice shelf melt in channel: clear link with tidal signal

Sun et al., in prep

Future work: parametrizations of ice shelf melt

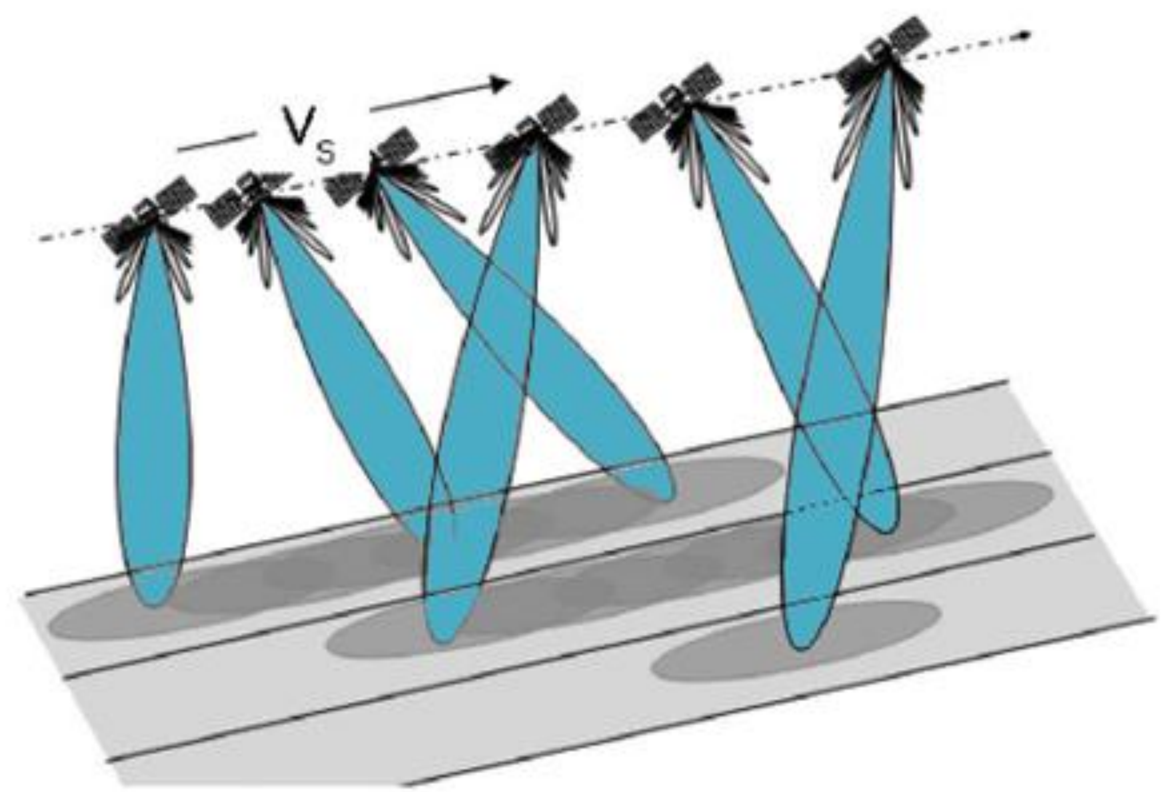


Expected outcome

- High resolution maps of basal ice shelf melt and change of melt in time (monitoring)
- Novel use of Sentinel-1 data for interferometry (TOPSAR)
- New insights into processes leading to ice shelf melt
- New parameterisations of basal melt

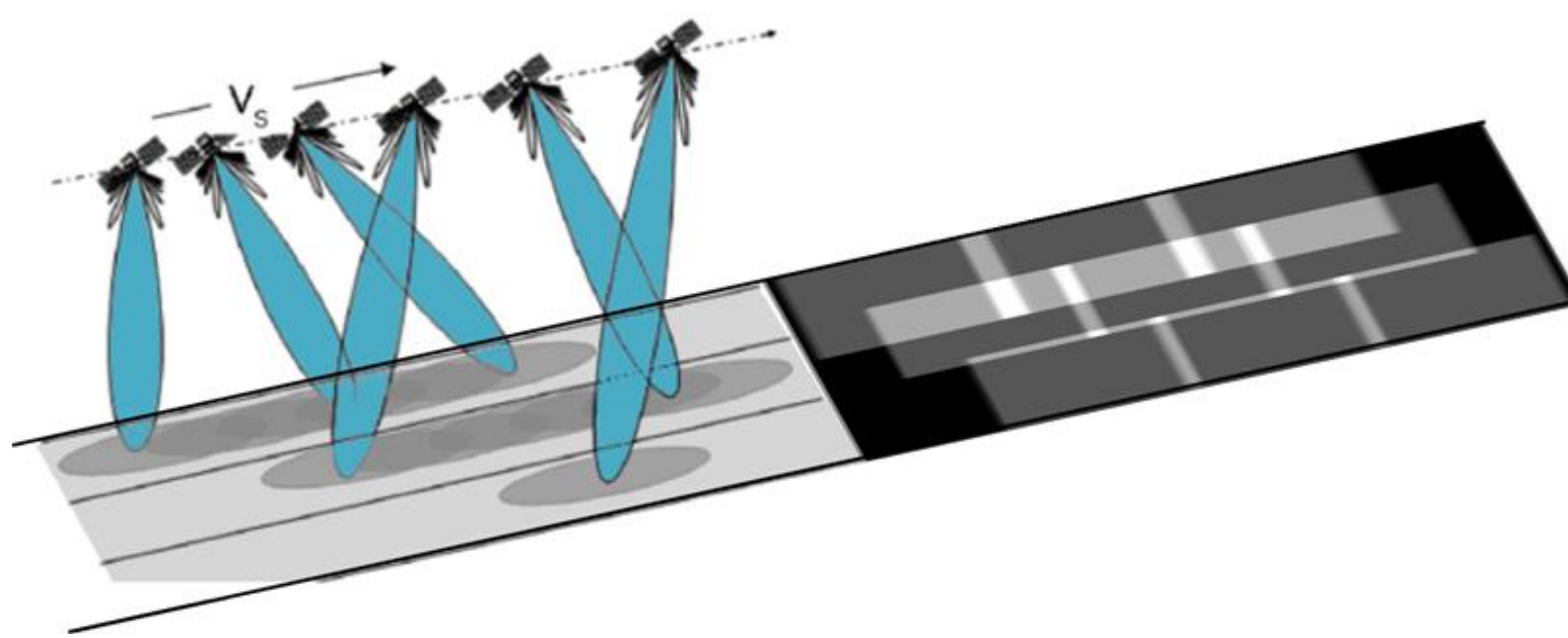
Sentinel-1 DInSAR/Speckle tracking

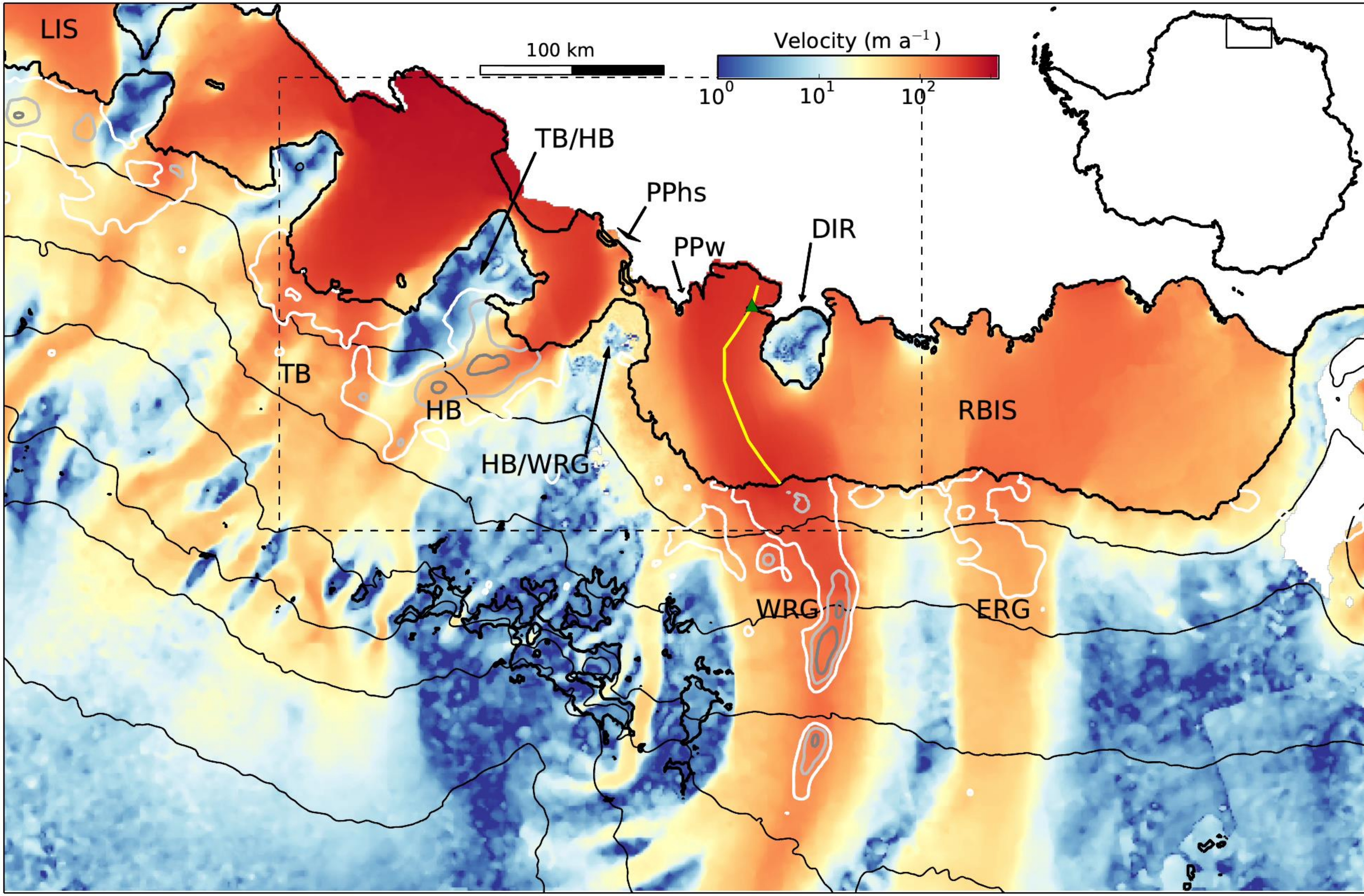
- Sentinel1 TOPSAR acquisition mode is made burst by bursts with varying steering
- InSAR image coregistration precision of ~1/1000 of a pixel~is required…
- Speckle / Coherence tracking must be adapted



Sentinel-1 burst overlapping areas

- Sentinel1 TOPSAR acquisition mode offers new opportunities for non-stationary scenes.
- Burst acquisition mode leads to overlapping areas observed at slightly different azimuthal angles.
- Azimuthal displacements on burst superposition areas lead to specific differential fringe patterns
    - Phd research





ERS velocity map

Favier et al., 2016

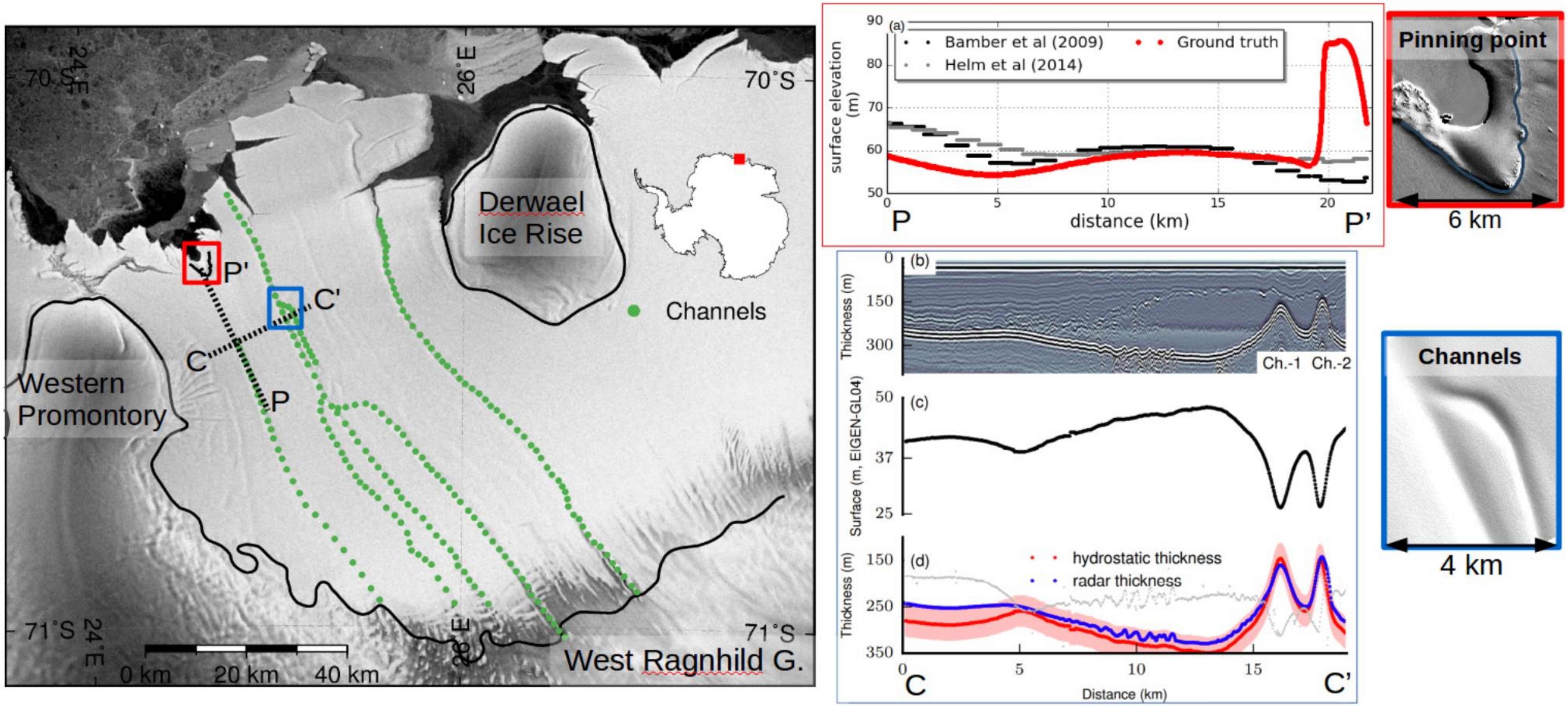
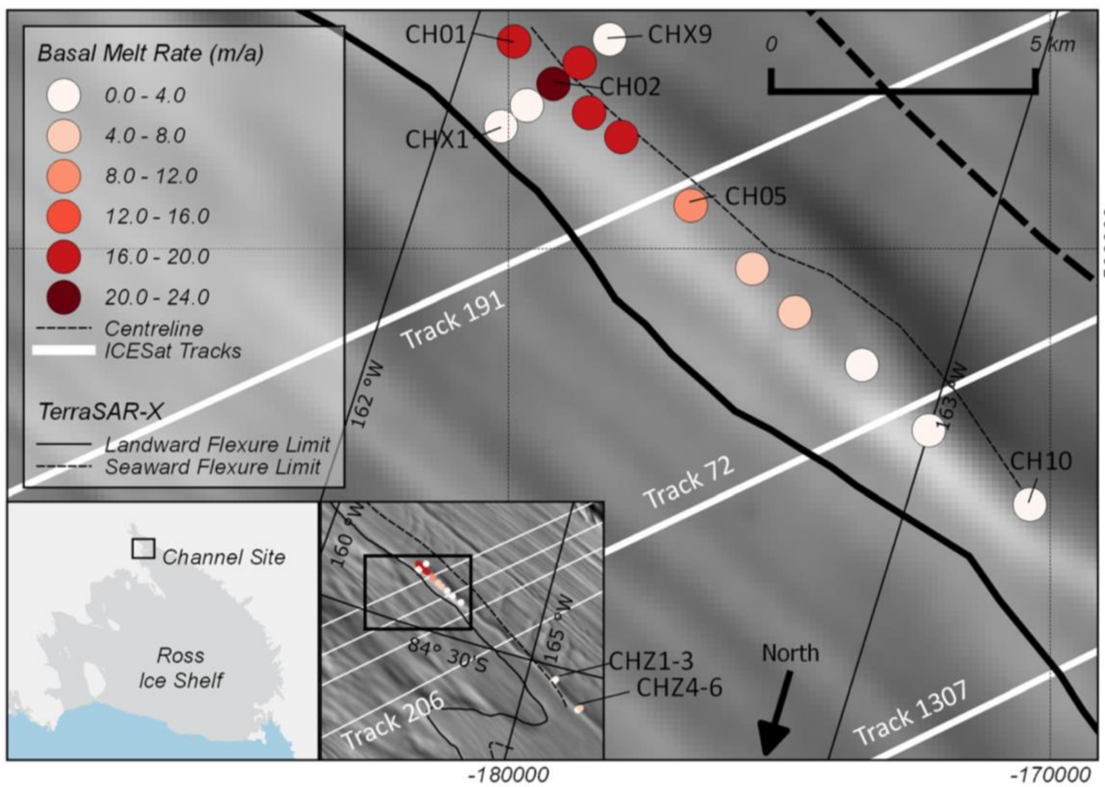
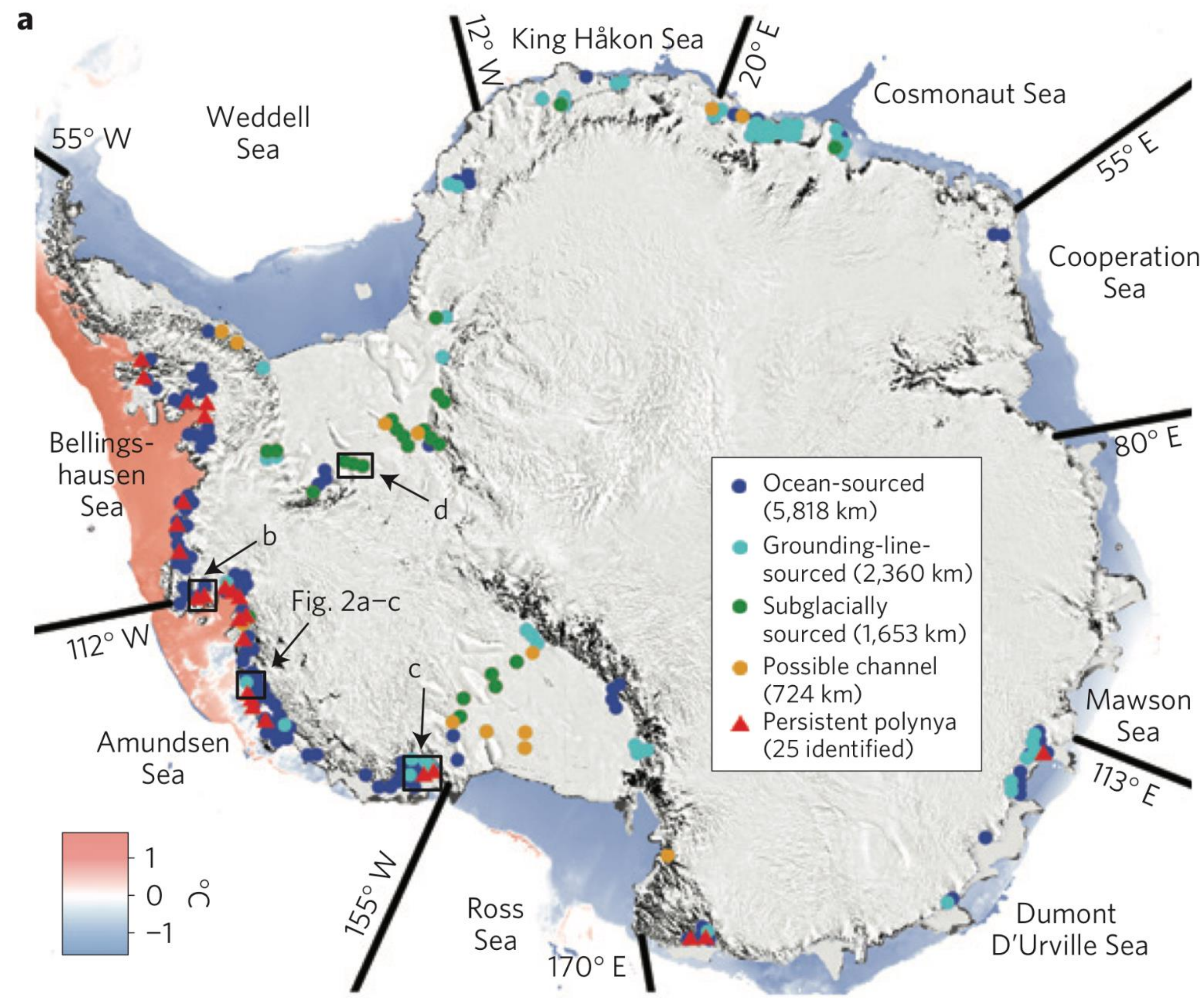


Figure 1.13: <u>Western part of the Roi Baudouin Ice Shelf</u>. (**Map**) Satellite view of the ice shelf with ice-shelf channels and the pinning point outlined. (**a**) Elevation upstream and on top of the pinning point, along the profile P-P'. (**b**), (**c**), (**d**), ice penetrating radar profile, surface elevation and ice thickness of the profile C-C', respectively. Credit: (c-d) subset of Fig. 5 from Drews (2015)

Ice-shelf melt in preferential regions (grounding lines and channels)



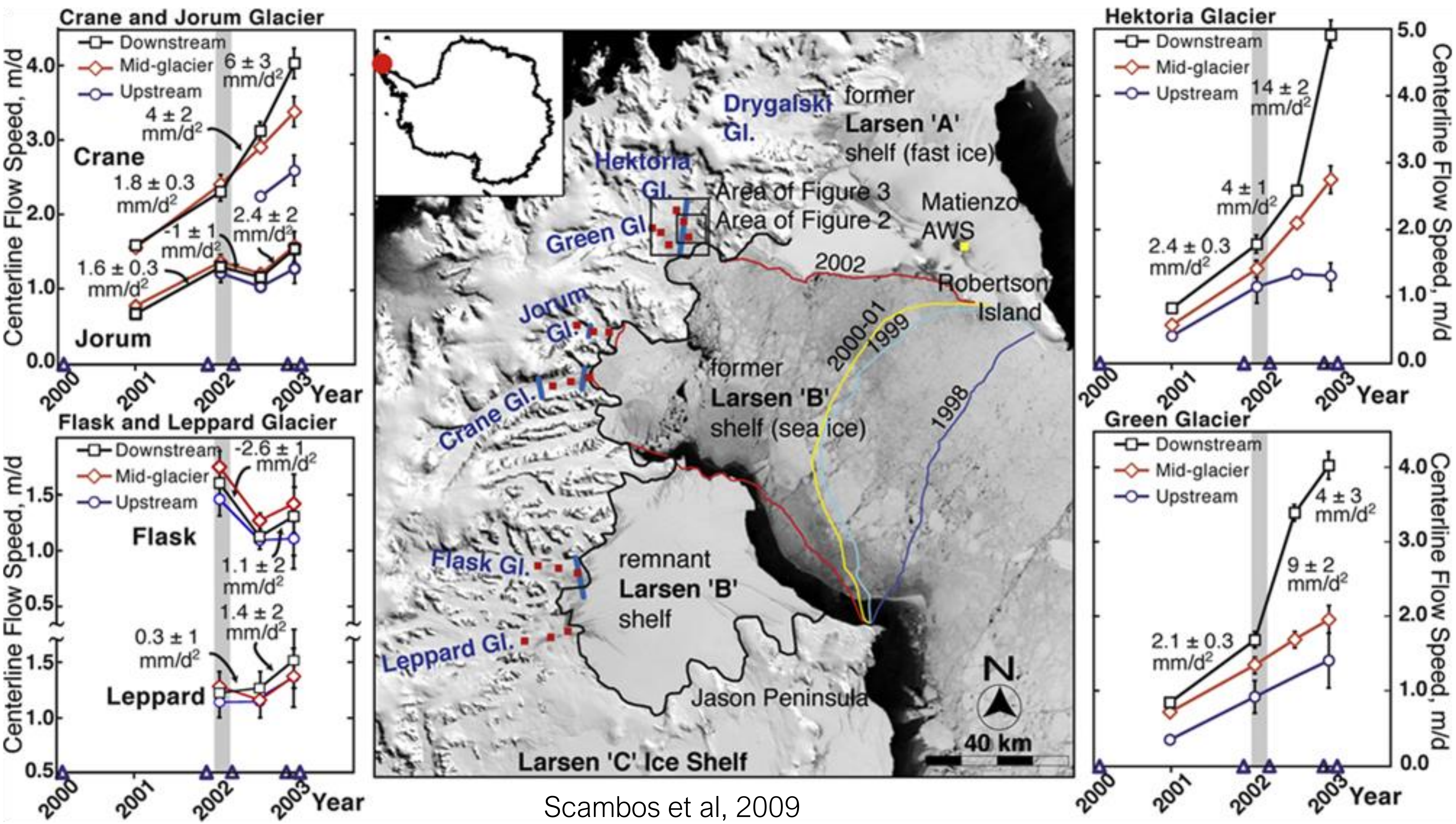
Marsh et al., 2016



2500% more melt in channels than outside

Alley et al., 2016

Breakup of Larsen B ice shelf: natural experiment



Scambos et al, 2009