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Satellite Remote Sensing Investigations into Changing Ice-shelf Extents in the eastern Weddell Sea Sector of Antarctica

EGU General Assembly 2022 session CR4.3:
Ice shelves and tidewater glaciers - dynamics, interactions, observations, modelling

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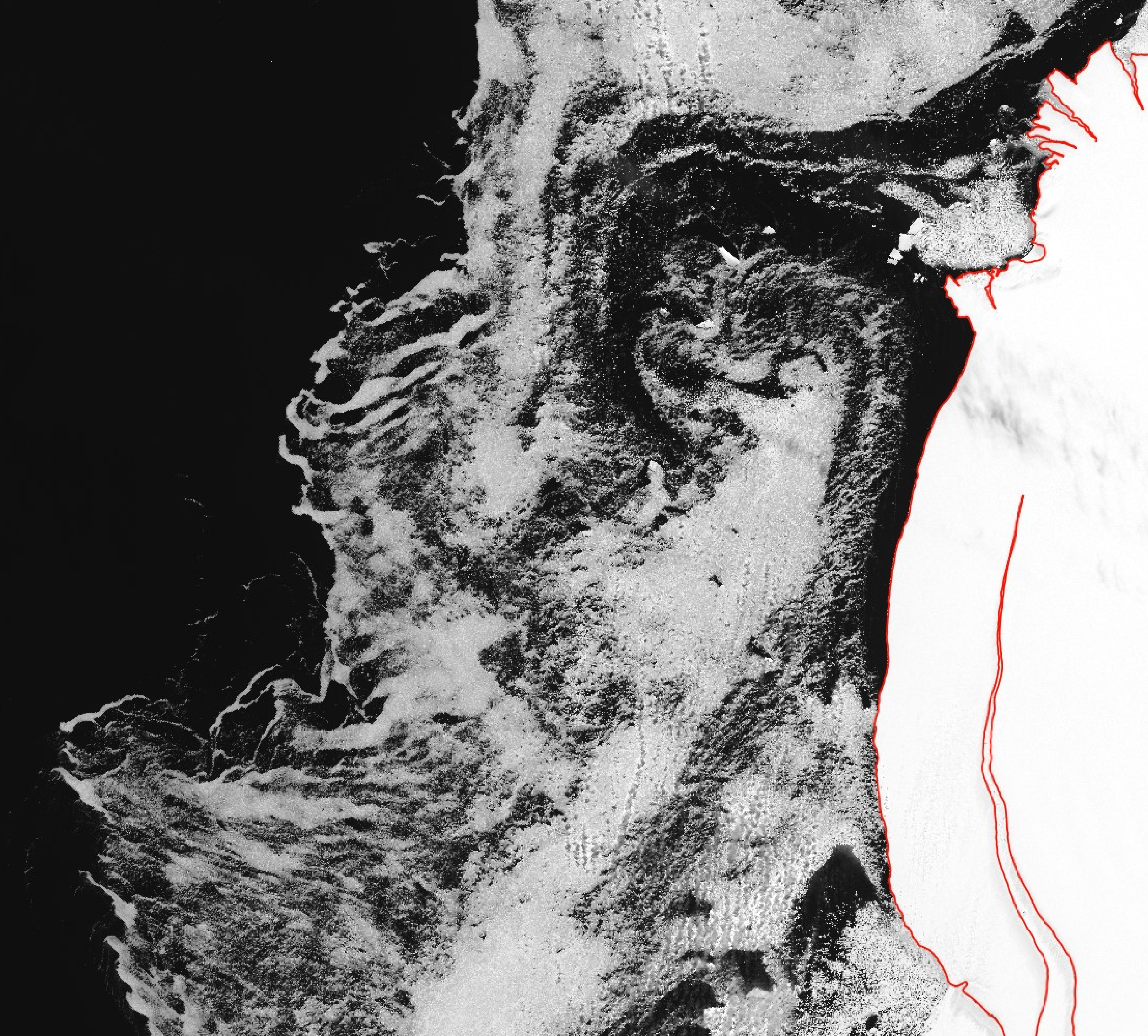
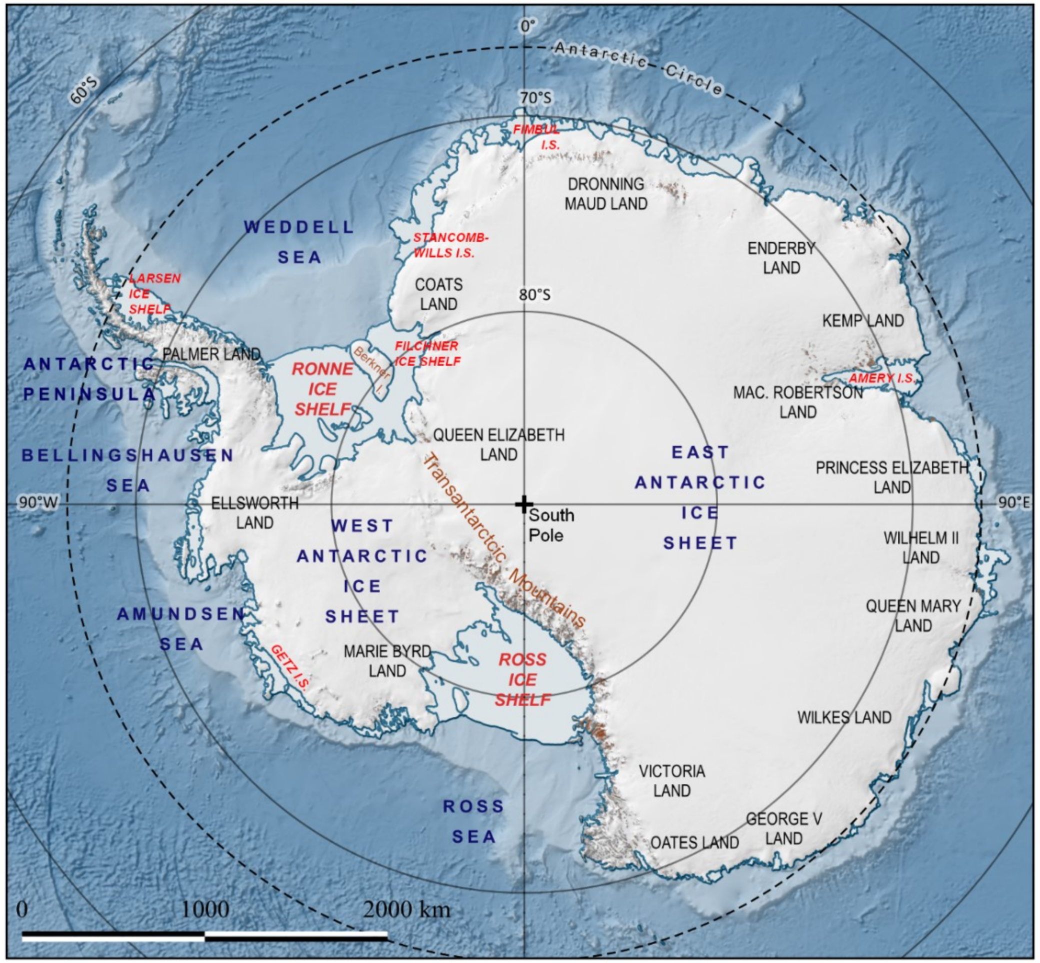
Structure

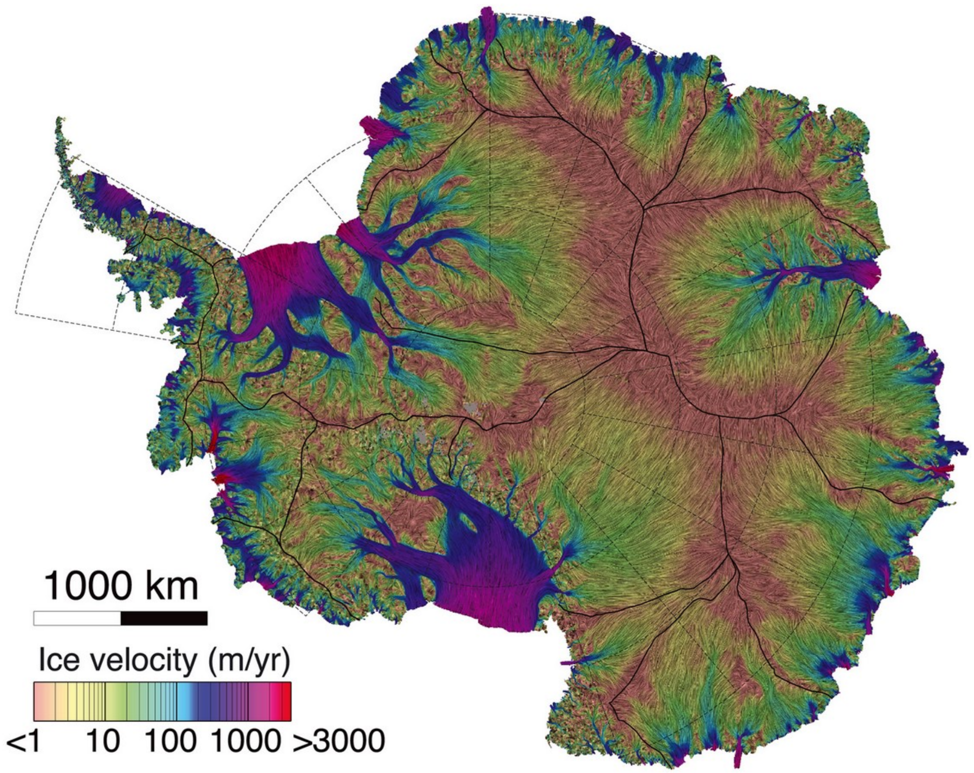


- Background – Antarctic Ice Sheet Mass Balance and Ice Shelf Dynamics
- Methods – Remote sensing for mapping CFLs
- Results in the eastern Weddell Sea Sector

Antarctic Ice Sheet Dynamics



- Satellite observations have shown increasing sea level contributions from an ice sheet in negative mass balance
- Ice mass leaves the Antarctic Ice Sheet by flowing through ice streams into ice shelves
  - Basal melt (55%)
  - Calving (45%)
- Ice shelves buttress the flow of inland ice, so removal leads to increased drawdown of inland ice



(Mouginot et al., GRL, 2019)

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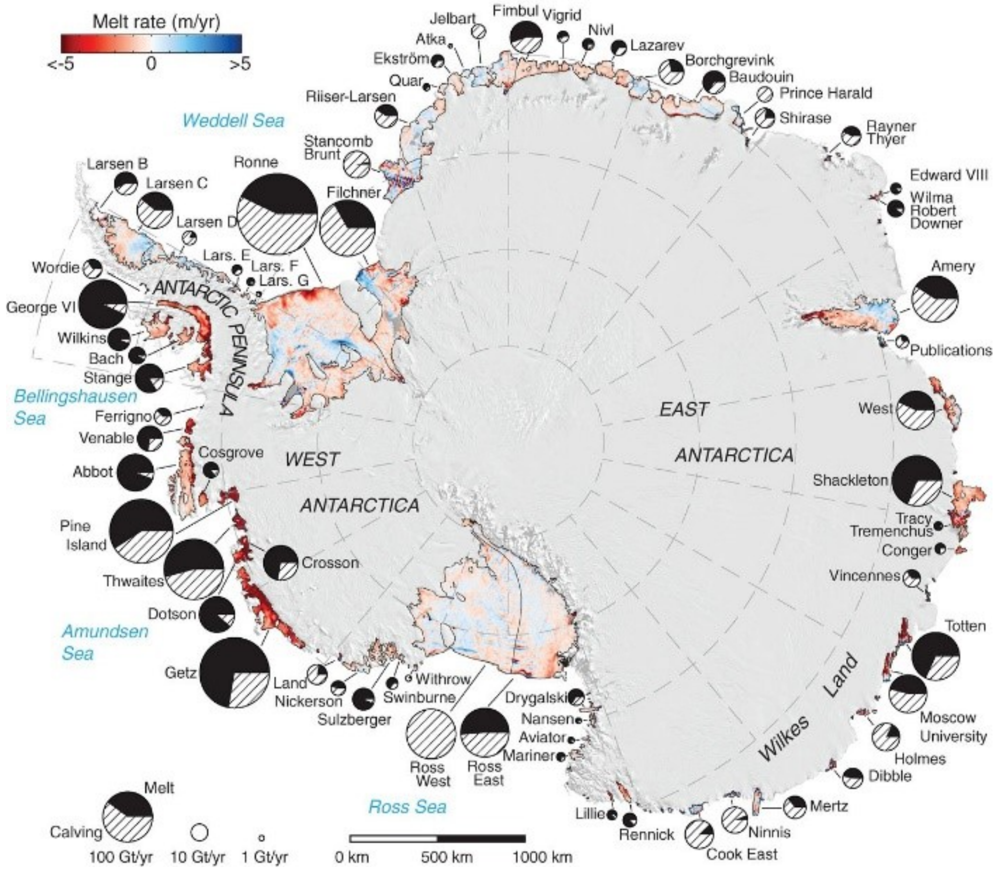

(Rignot et al., Sci., 2013)

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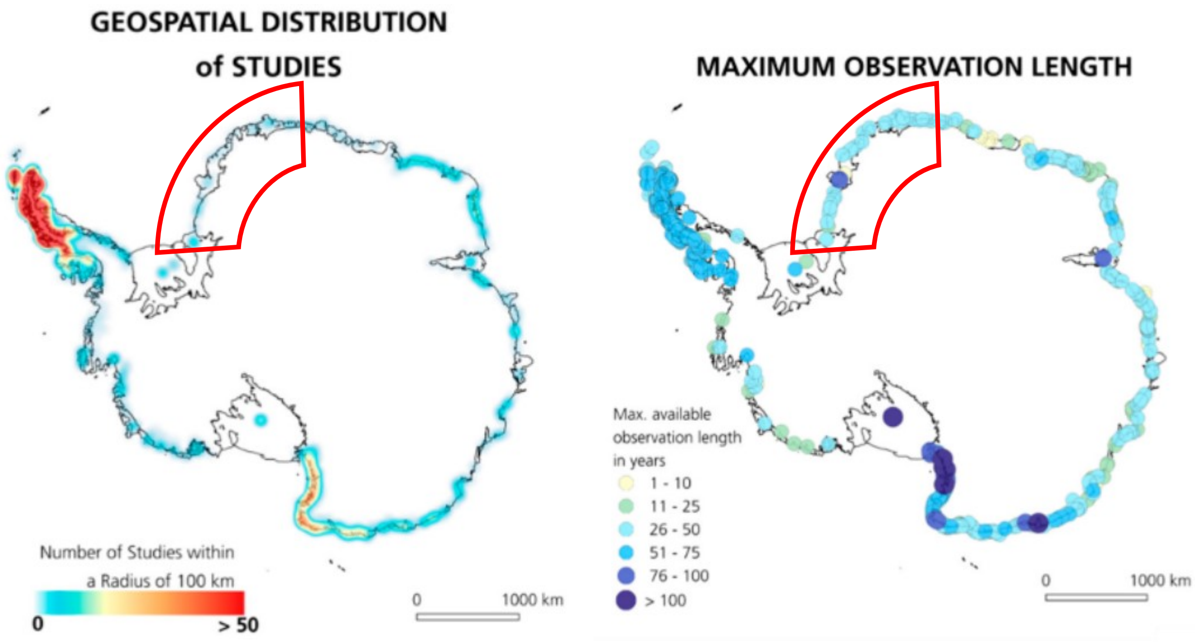
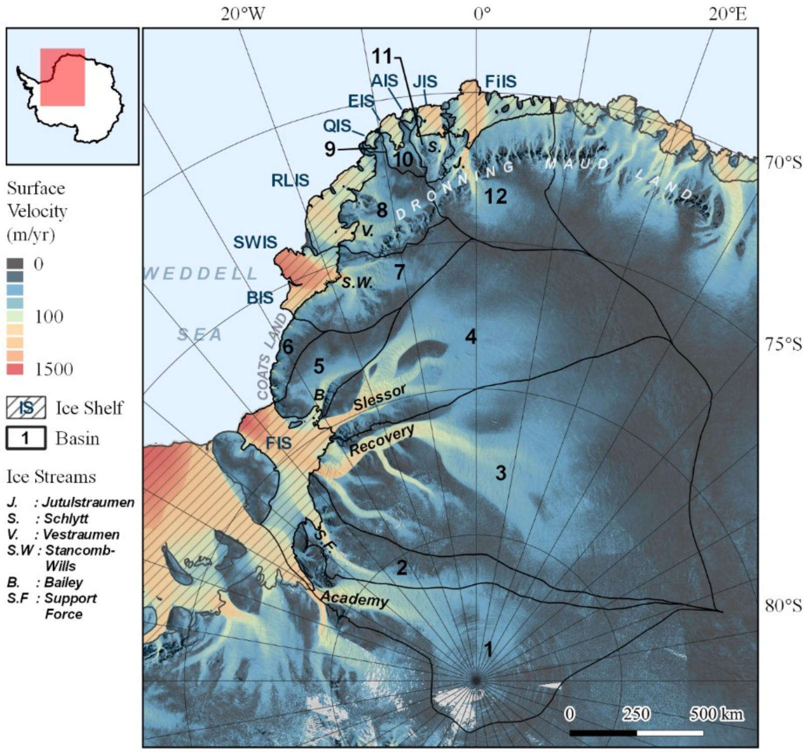
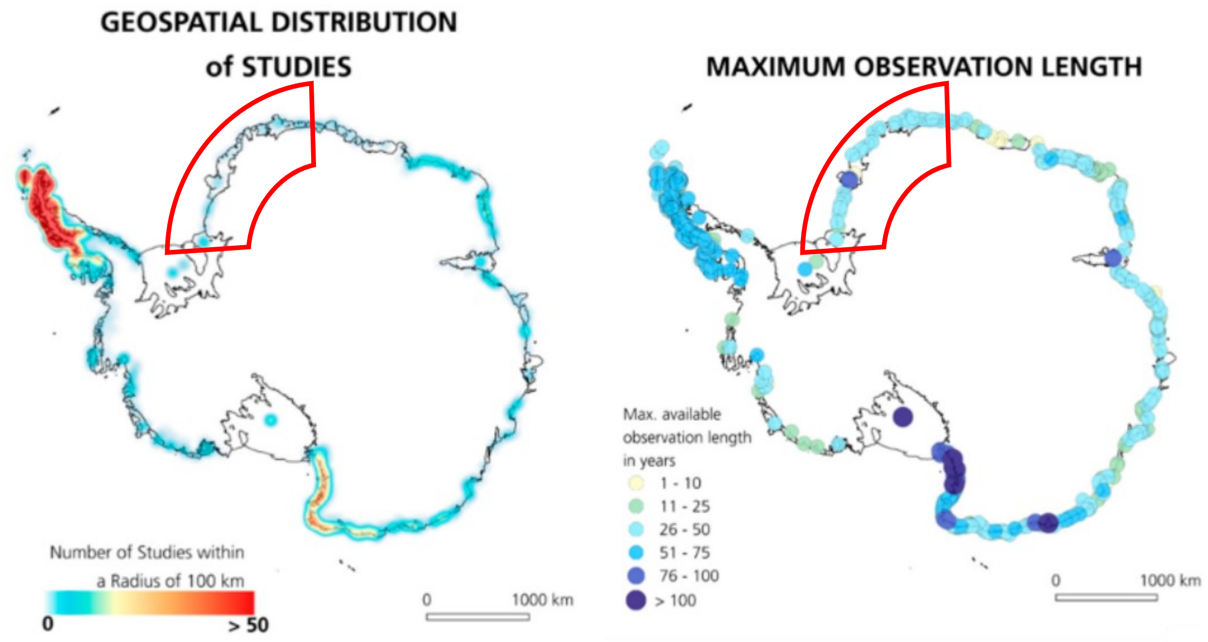


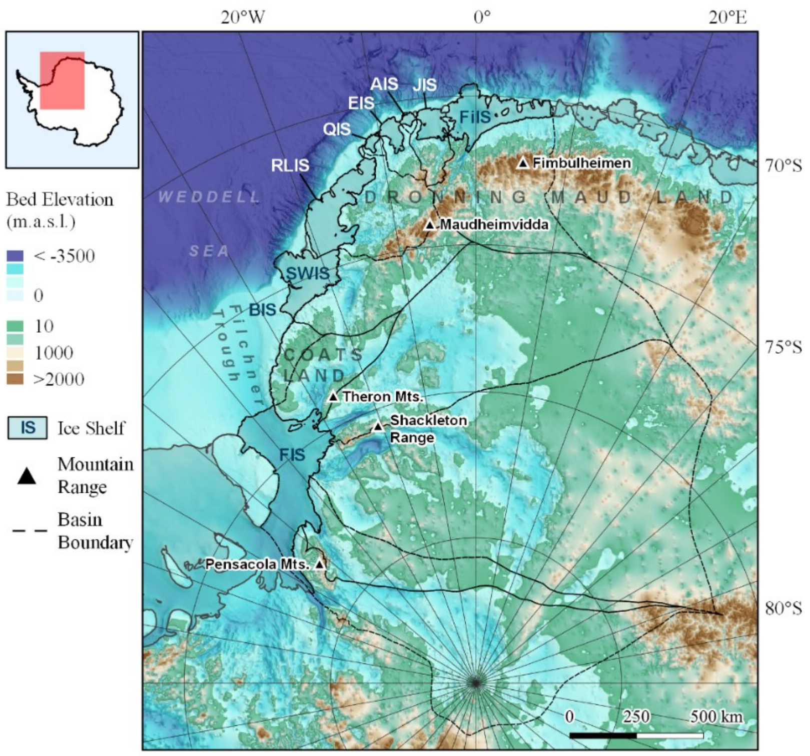


Previous work – Calving Front Locations

- Mapping has been relatively sparse compared to the amount of EO data collected
- Eastern Weddell Sea Sector is one of the least studied regions
- Limited methods used so far to extract calving front locations, mainly manual

(Baumhoer et al., Remote Sens., 2018)





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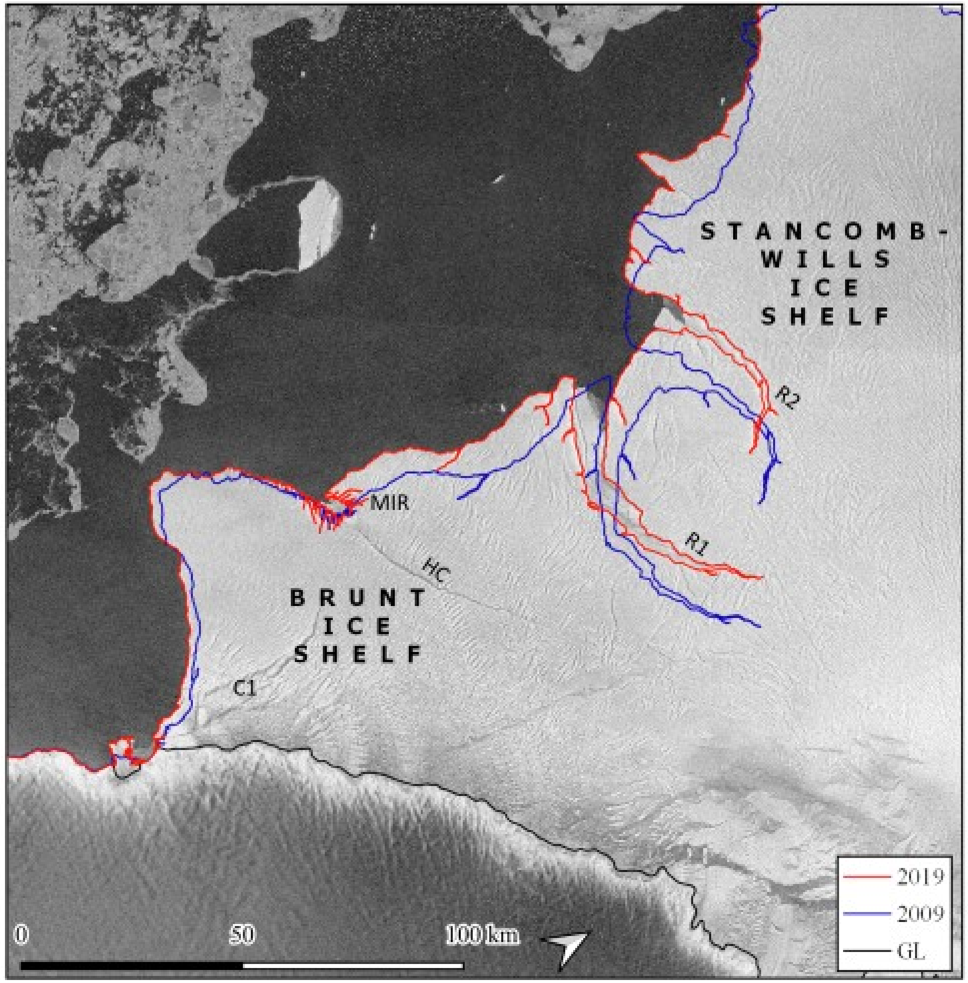
Aims

- To map the changing ice-shelf extents along the eastern Weddell Sea Sector of Antarctica over the past decade
- To analyse the temporal variations in ice-shelf areas since the 1960s, by combining new data with existing datasets
- Explore what oceanic and atmospheric processes may be causing the observed changes to ice shelves in the region

Methods

- Use of optical (Landsat series ETM+ and OLI) and SAR (i.e. Sentinel-1) imagery for mapping CFLs
- Pre-processing of Sentinel-1 (EW and IW) imagery including noise reduction, terrain correction etc.
- Image processing techniques including edge detection and classification
- Use of declassified 1963 Argon imagery and historical MODIS- and Landsat-derived CFL's (Harran et al. 2005, 2018; Miles et al. 2013) to extend the time series

Brunt/Stancomb-Wills Ice Shelf Rifting



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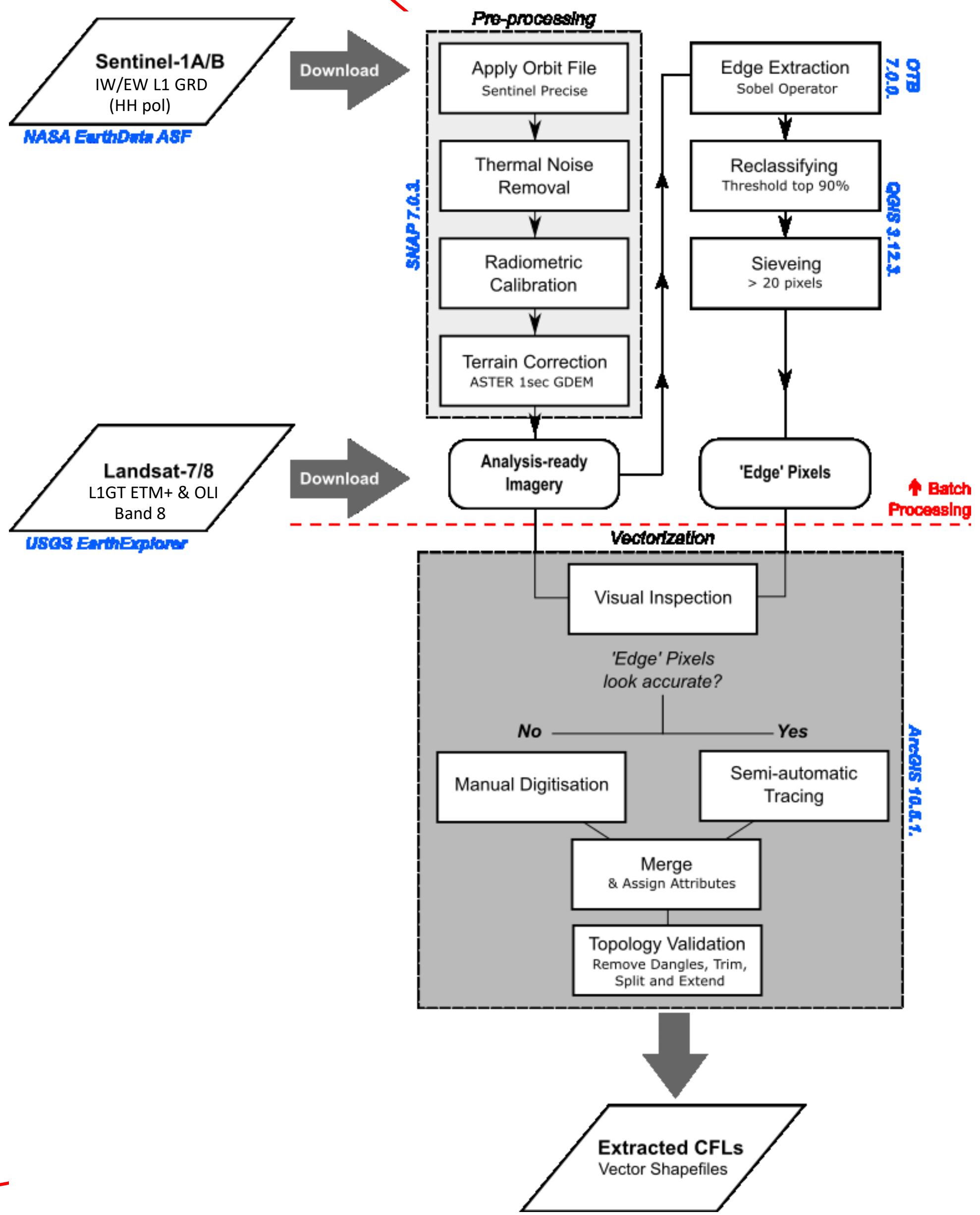

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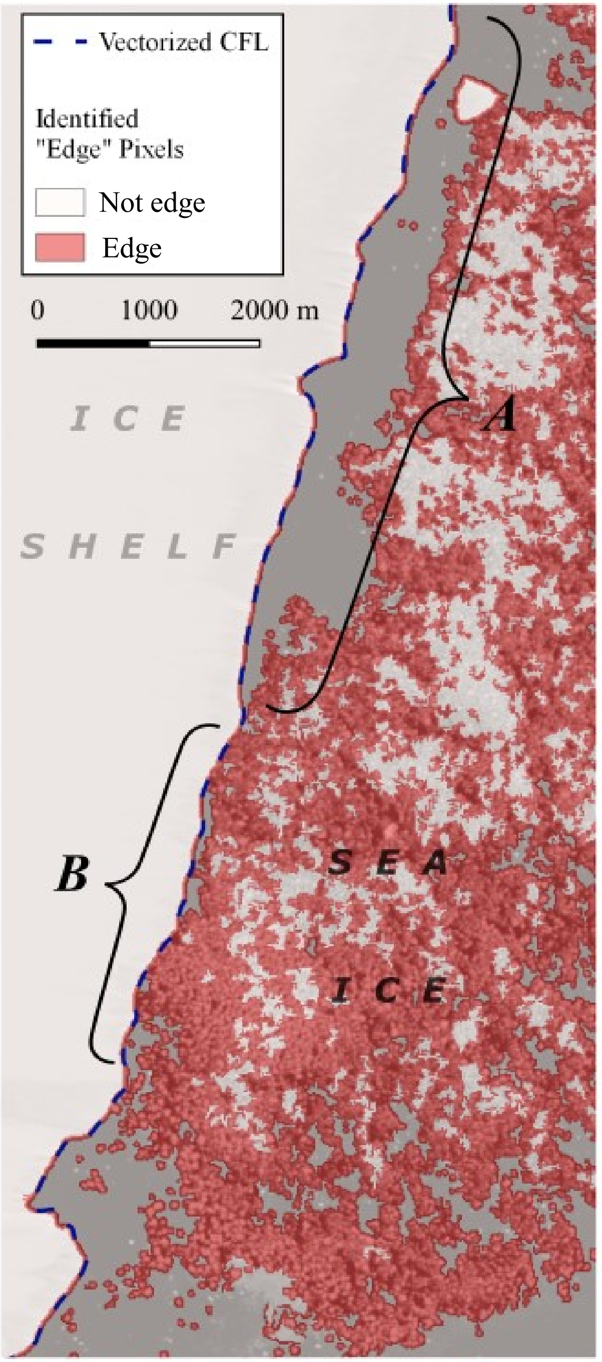
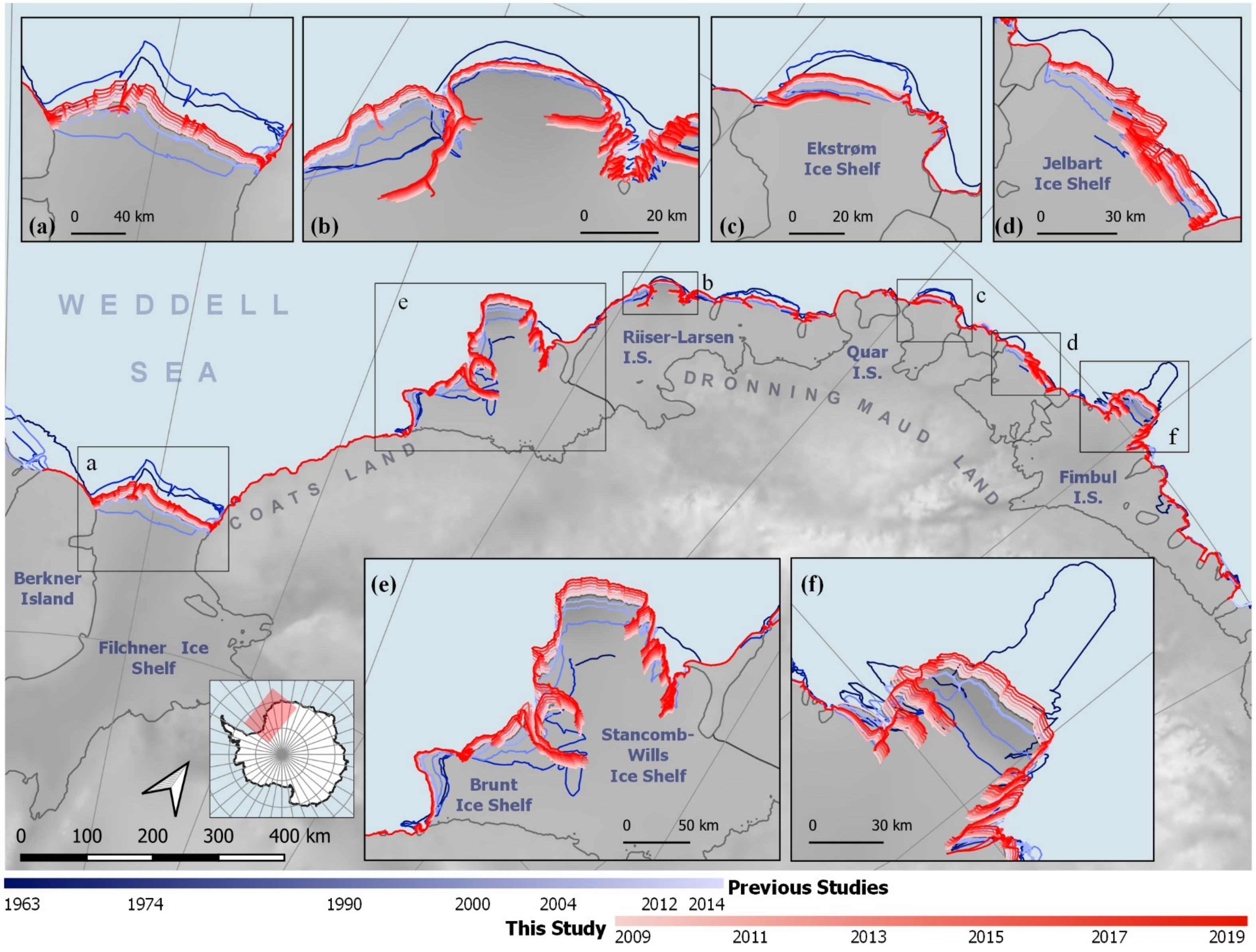
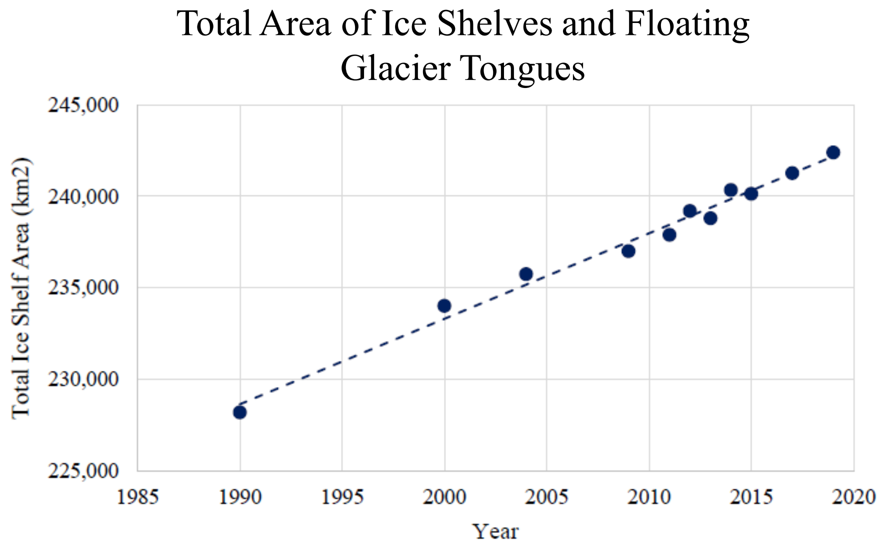


Results



- Broad pattern of synchronous CFL advance over at least the last three decades
- Ice mass loss form the region mainly in large, tabular, calving events
- Calving events mainly occurred 1974 – 1990



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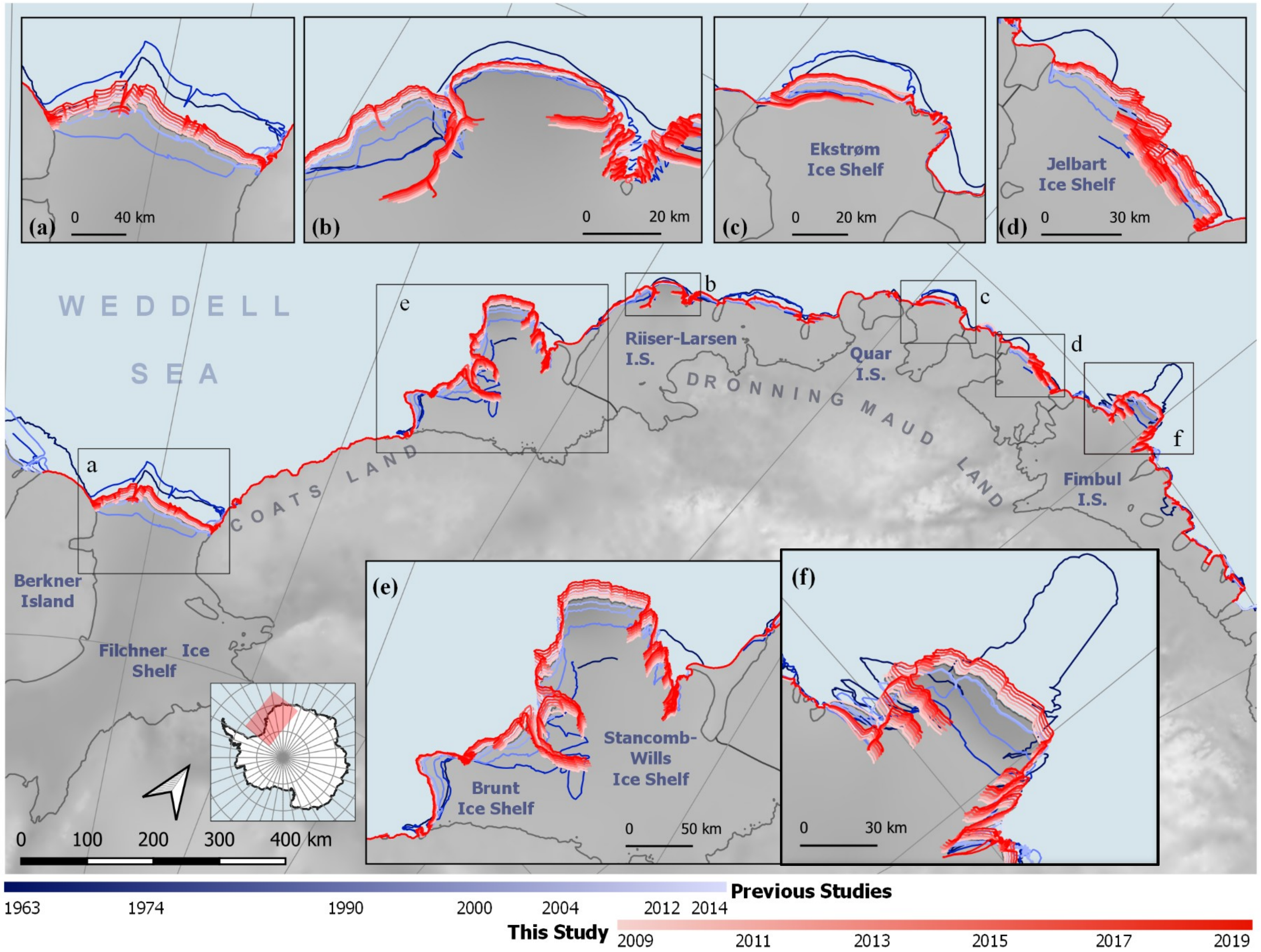
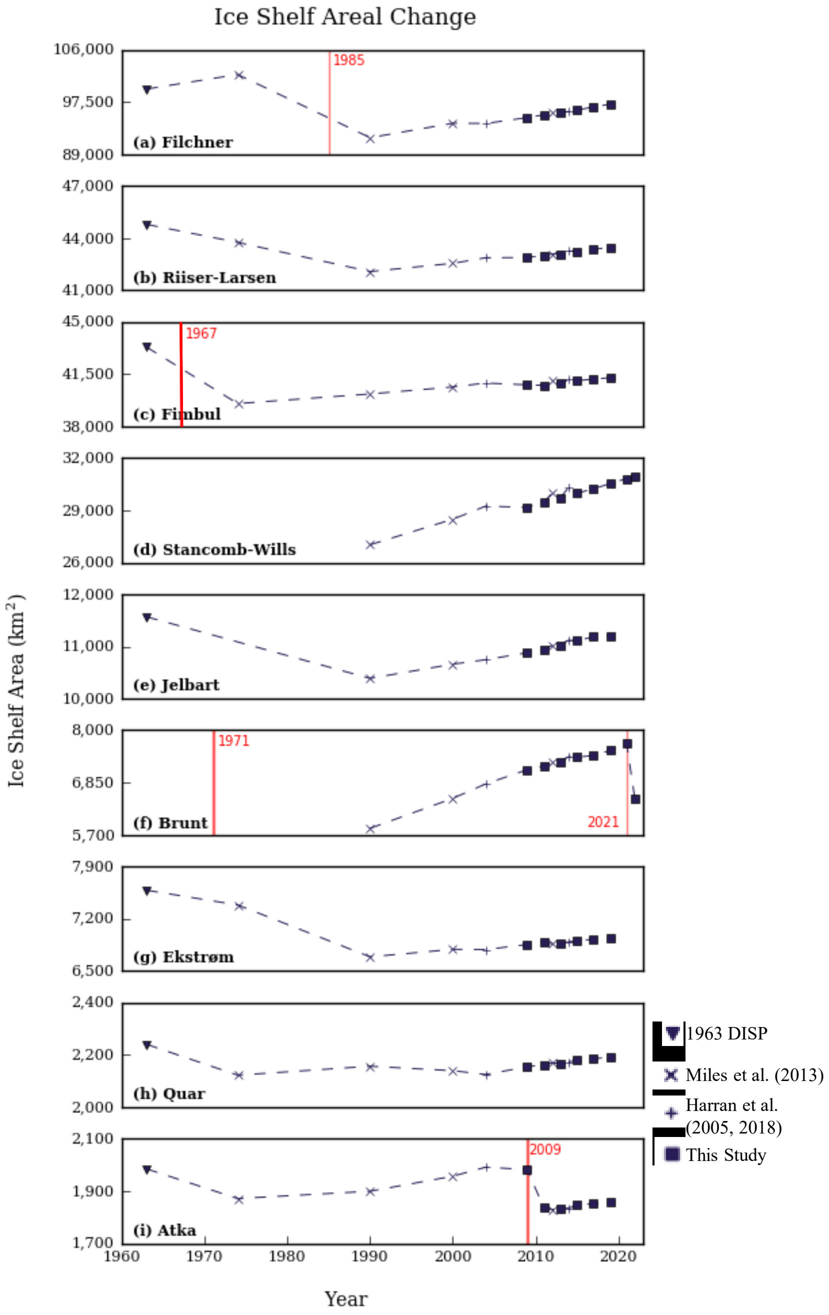
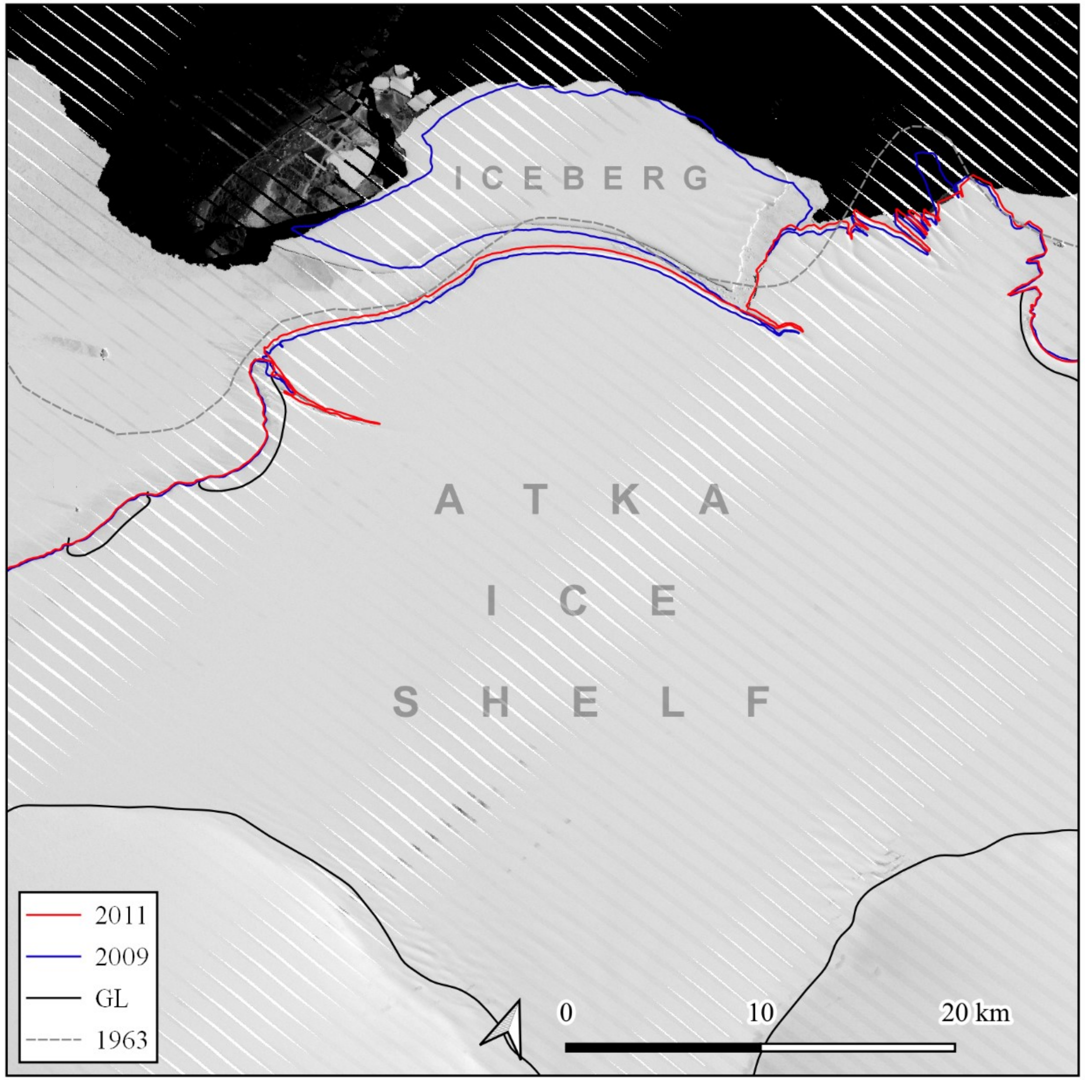


(a) 0 40 km
(b) 0 20 km
(c) 0 20 km
Ekstrøm Ice Shelf
(d) 0 30 km
Jelbart Ice Shelf
W E D D E L L
S E A
Riiser-Larsen I.S.
Quar I.S.
D R O N N I N G M A U D L A N D
C O A T S L A N D
Fimbul I.S.
Berkner Island
Filchner Ice Shelf
a
b
c
d
e
f
0 100 200 300 400 km
(e)
Stancomb-Wills Ice Shelf
Brunt Ice Shelf
0 50 km
(f)
0 30 km
1963 1974 1990 2000 2004 2012 2014
Previous Studies
This Study
2009 2011 2013 2015 2017 2019

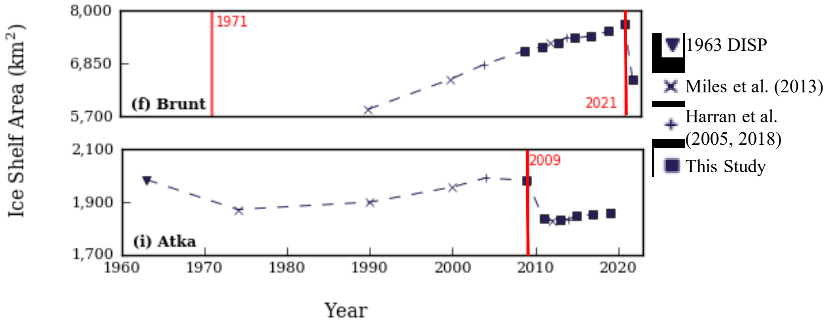


Ice Shelf Areal Change
Ice Shelf Area (km²)
(a) Filchner
106,000
97,500
89,000
1985
(b) Riiser-Larsen
47,000
44,000
41,000
(c) Fimbul
45,000
41,500
38,000
1967
(d) Stancomb-Wills
32,000
29,000
26,000
(e) Jelbart
12,000
11,000
10,000
(f) Brunt
8,000
6,850
5,700
1971
2021
(g) Ekstrøm
7,900
7,200
6,500
(h) Quar
2,400
2,200
2,000
(i) Atka
2,100
1,900
1,700
2009
1960 1970 1980 1990 2000 2010 2020
Year
1963 DISP
Miles et al. (2013)
Harran et al. (2005, 2018)
This Study

Results

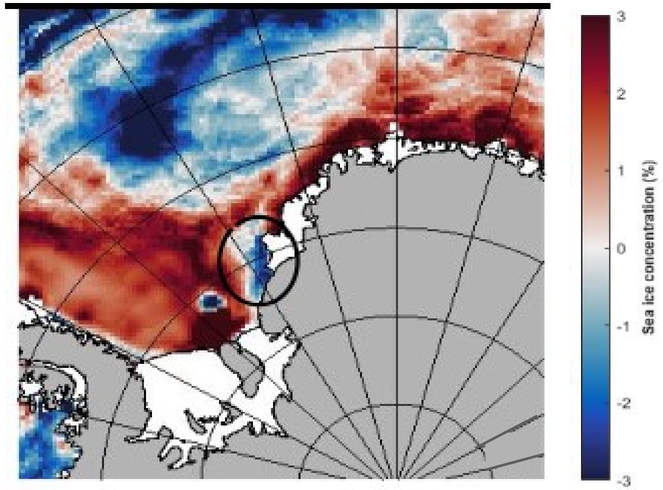


- Two major calving events during the observation period:
  - Atka in 2009
  - Brunt in 2021
- Both events could be anticipated from surface rifts visible in remotely-sensed data
- Brunt and Stancomb-Wills have reached last known maximum extents and so calving was also expected

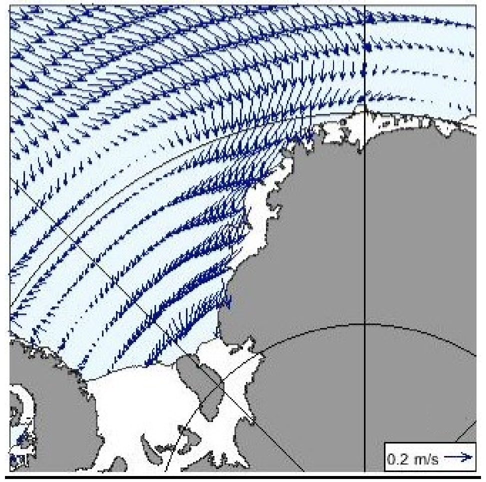


Sea ice and surface wind-speed anomalies 2009-2019, compared to the long-term average

Sea ice concentration anomalies

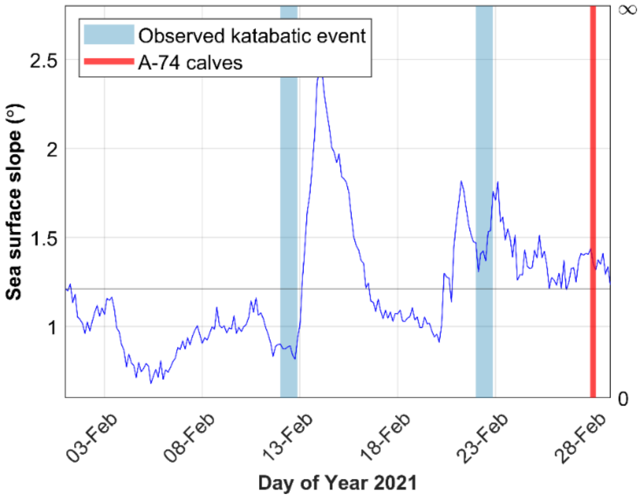


Surface wind speed anomalies

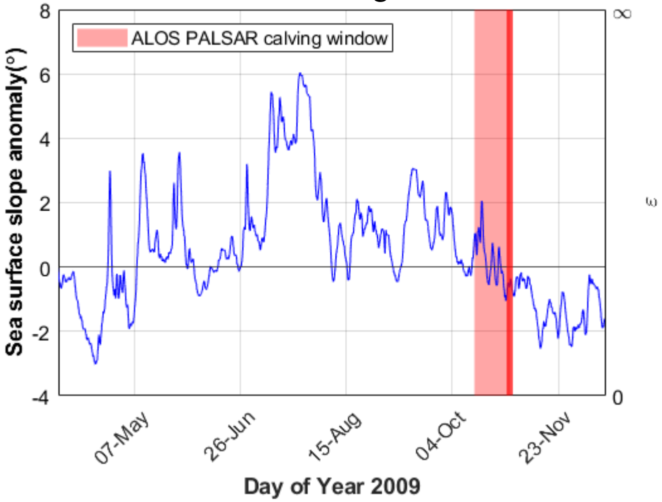


Sea surface slopes prior to calving events

Prior to Brunt IS calving 2021



Prior to Atka IS calving 2009



- Ice shelves may be being stabilised by increasing positive sea ice anomalies, likely due to anomalous north-to-south winds
- Exception is at Brunt Ice Shelf, where sea ice concentrations have been anomalously low over the past decade, particularly during austral summer
- Final calving likely facilitated by sea surface slope anomalies
  (Christie et al., Nat., 2022)

(Data sources: ERA5 Climate Reanalysis Data)

Conclusions

- The large eWSS Ice Shelves are comparatively stable, mainly advancing for the past >3 decades
- The multidecadal to centennial timescales over which the calving processes are occurring mean that any changes resulting from external forcings may take decades to show in the CFL record
- There is some indication that anomalous N-S winds are increasing sea ice concentrations in the eWS, possibly reducing calving rates.
- Anomalous sea-surface slopes likely facilitated in the significant calving of Brunt and Atka ice shelves, but more research is needed to see this impact on other iceberg calving events.

Thanks for watching.

If you have any questions or feedback, they would gladly be taken at Nick.Homer@ed.ac.uk

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