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WP 3 Workshop

Ice shelf mass balance observations : toward a spatially and timely resolved dataset for modelling the future evolution of Antarctica

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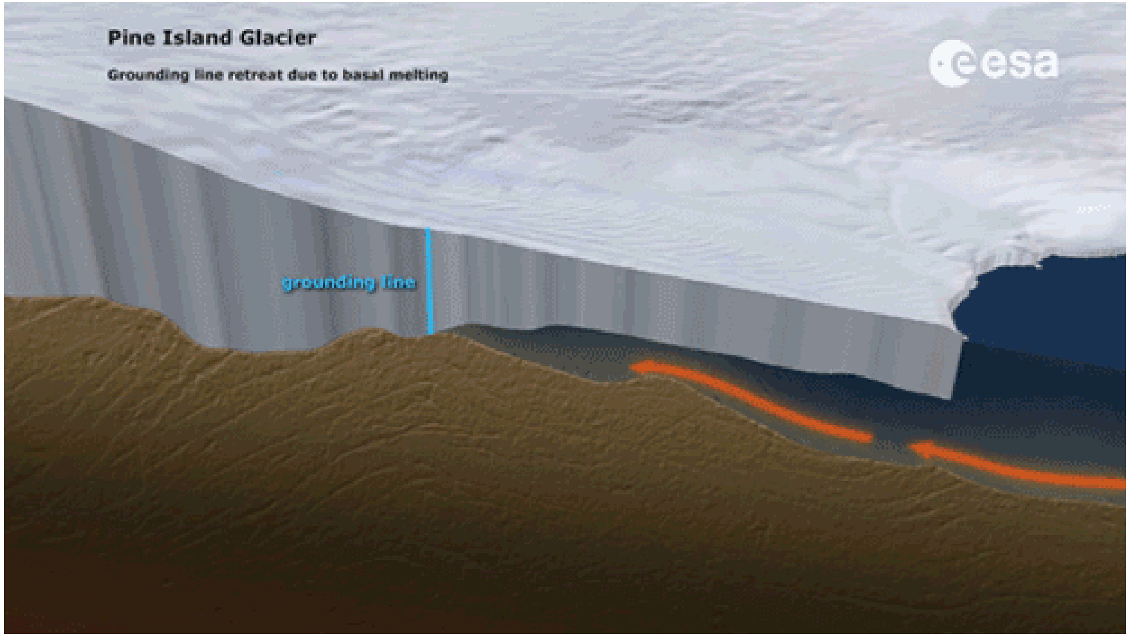
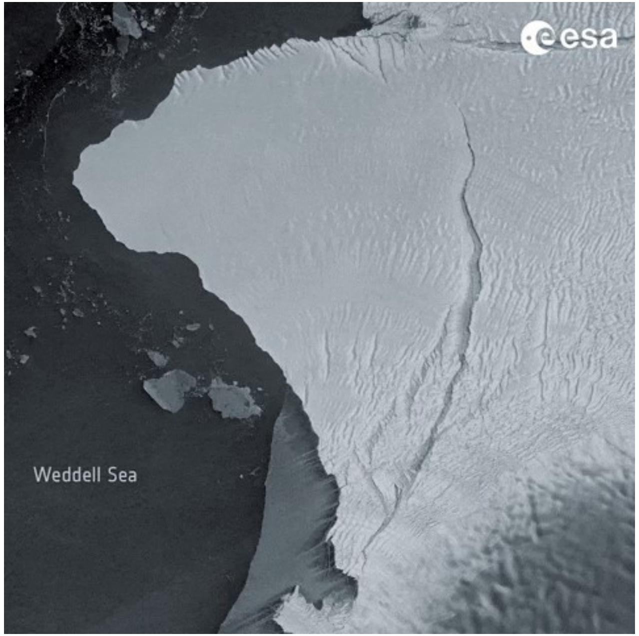
Copenhagen. 23 May 2023

Ice shelf dynamic mass losses

Ice Shelf Basal Melting



Ice Shelf Calving



A81 iceberg breaking away from the Brunt Ice Shelf.

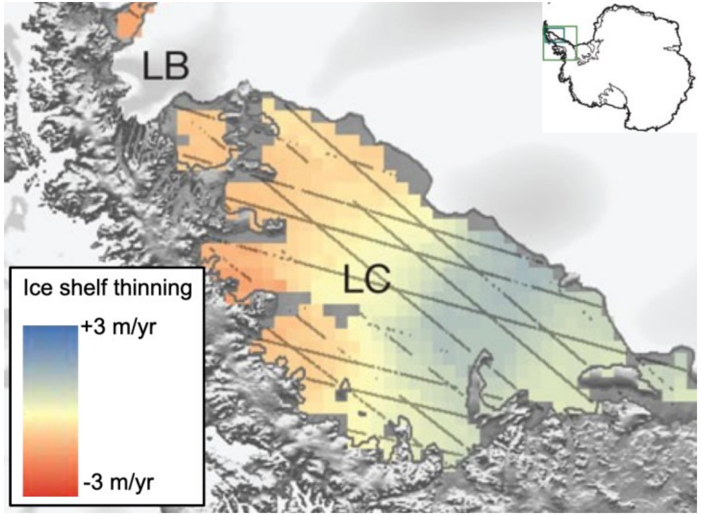
January 2023 - Copernicus Sentinel data (2021-23), processed by ESA

Ice shelf basal melting: Methods

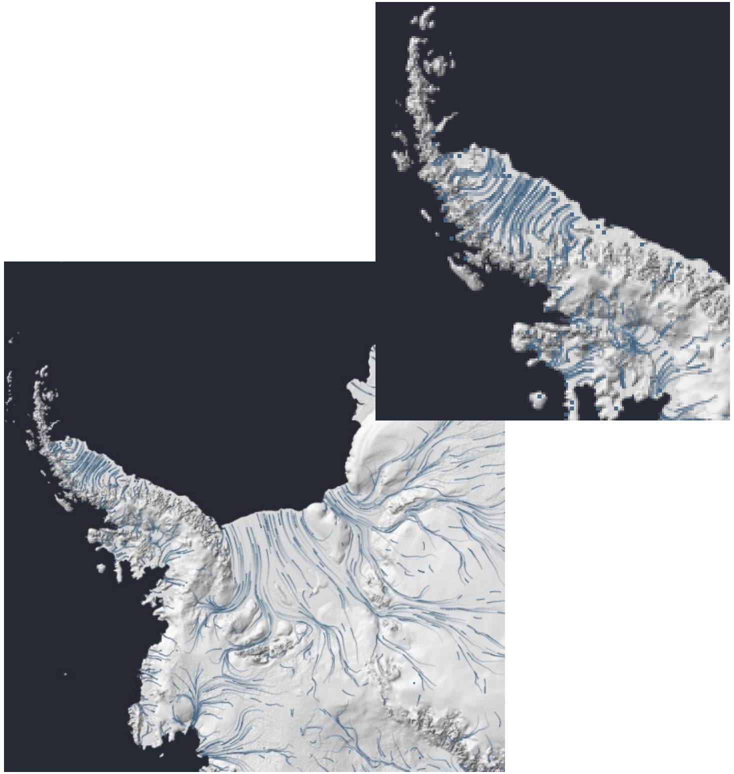
Ice flux divergence — Firn air content

$$\frac{Dh}{Dt} = \frac{(\rho_w - \rho_i)}{\rho_w}\left(\frac{M_s}{\rho_i} - H_i \nabla . v - w_b\right) + \frac{Dh_{air}}{Dt}$$

Thickness changes — Changes in SMB — Basal melting rates

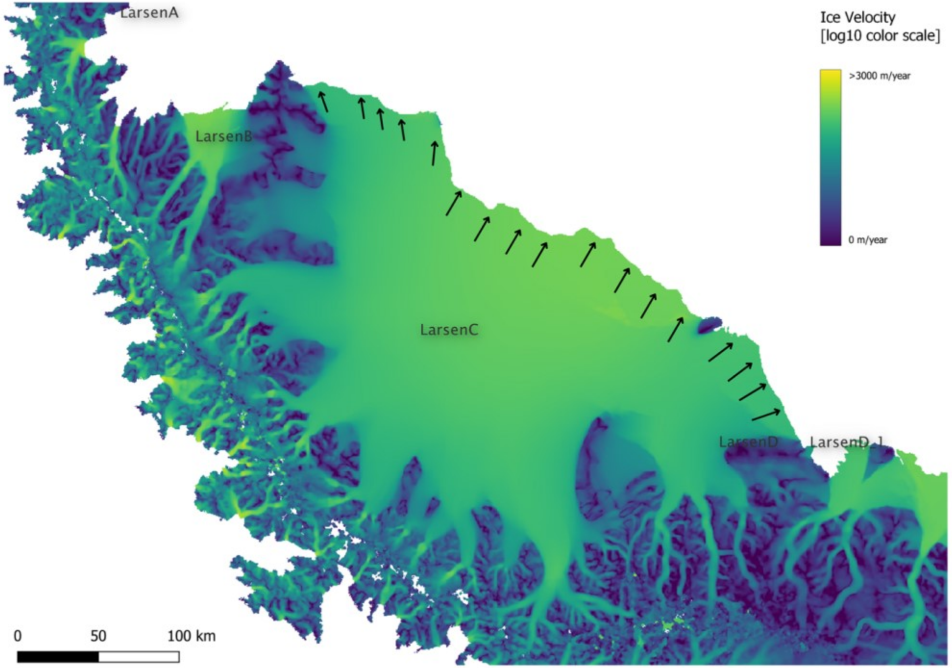


Pritchard et al., 2012



ige-vis.univ-grenoble-alpes.fr/antarctica/index.html

Ice shelf calving: Methods



MEaSUREs InSAR-Based Antarctica Ice Velocity Map, Version 2

Mass budget equation

Basal melt

Grounding line flux

$$dV = BMB + SMB + GLF - CF$$

Volume change

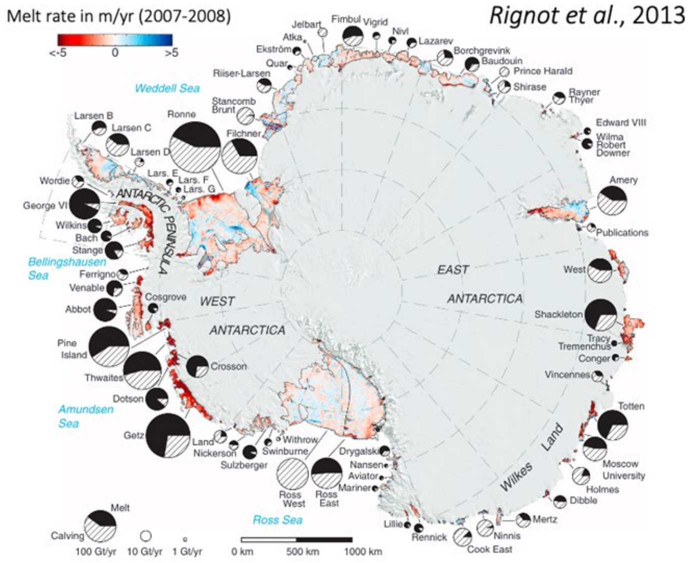
Surface mass balance

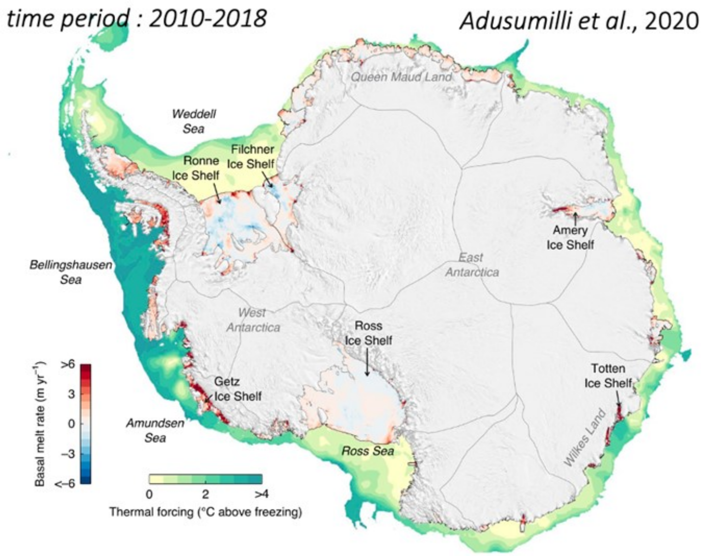
Calving flux

Front line gate

(ice thickness, surface flow velocity)

Ice shelf basal melting and calving: state of the art





- Grid resolution 10x10 km
- Time period 2007-2008

- Average basal melting 2010-2018 in Lagrangian approach (500x500 m)
- Time series 1994-2018 (Eulerian) with grid size 10x10 km

Others: *Depoorter et al.*, 2013; *Pritchard et al.*, 2012

Ice shelf basal melting and calving : new datasets

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Article

Antarctic calving loss rivals ice-shelf thinning

https://doi.org/10.1038/s41586-022-05037-w
Chad A. Greene[1✉], Alex S. Gardner[1], Nicole-Jeanne Schlegel[1] & Alexander D. Fraser[2]

https://doi.org/10.5194/egusphere-2022-1128
Preprint. Discussion started: 1 November 2022

EGUsphere

Widespread slowdown in thinning rates of West Antarctic Ice Shelves

Fernando S. Paolo[1], Alex S. Gardner[1], Chad A. Greene[1], Johan N. Nilsson[1], Michael P. Schodlok[1], Nicole-Jeanne Schlegel[1], Helen A. Fricker[2]

	Calving flux Greene et al., 2022	**Basal melt** Paolo et al., 2022 (submitted)
Grid Resolution	240 m (frontline) or integrated mass changes	2 x 2 km
Time series	1997, 2000 to 2021(yearly)	1992 to 2017 (bi-yearly)
Extent	Antarctica 181 ice shelves	Antarctica 181 ice shelves
Data	open access (MIT licence) https://github.com/chadagreene/ice-shelf-geometry	open-access https://its-live.jpl.nasa.gov

Ice shelf basal melting and calving : new datasets

OCEAN:ICE

Article

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	240 m (frontline) or integrated mass	

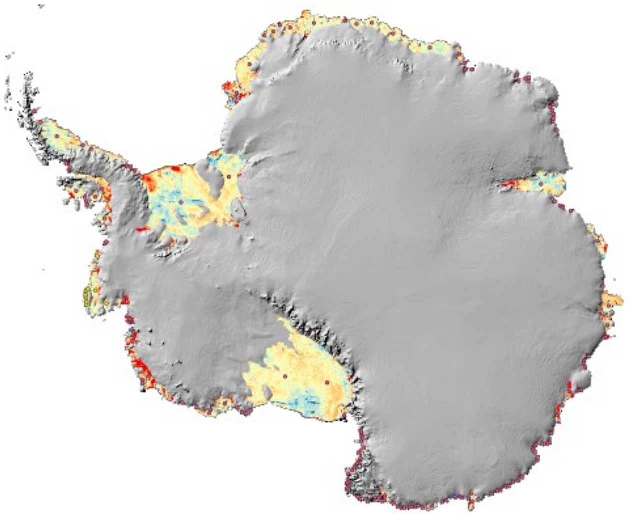
Goal

Provide latest freshwater fluxes estimates from iceberg calving and basal melting

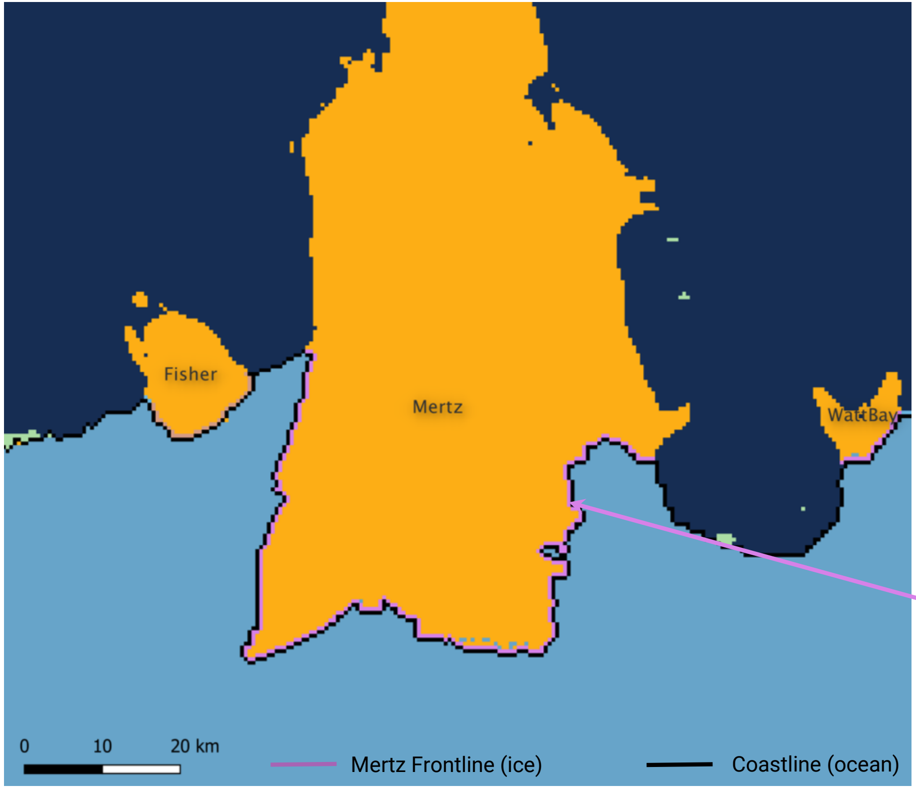
Goal: provide latest freshwater fluxes estimates from basal melting

Basal melt rates

- Use of the Paolo et al., 2023 paper based on altimetry data and Eulerian framework
- Calculation of yearly averages over the entire period of study
- Resampling on the BedMachine grid size and polar stereographic projection
- Calculation of integrated basal melting rates for each ice shelves (correct for pixel deformation in PS projection)



Goal: provide latest freshwater fluxes estimates from iceberg calving



Dataset

- Greene *et al.*,2022 : Integrated value of mass losses for each one of the 181 ice shelves.

Constraint

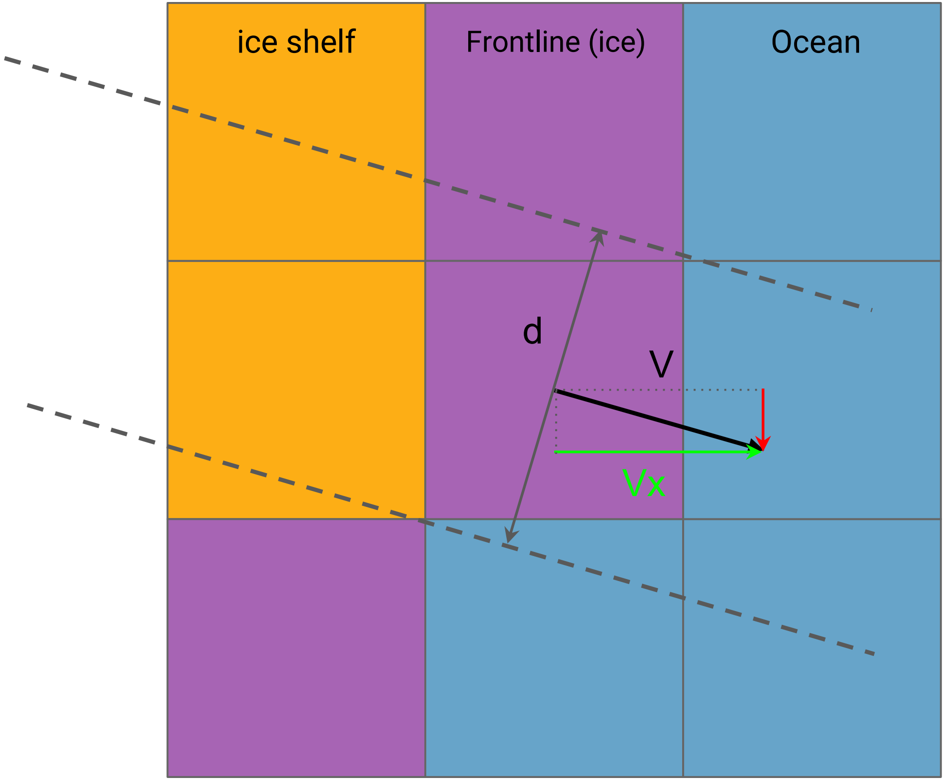
- frontlines need to be fixed for ocean models.

Frontlines database

- Delineate each front independently of the others using Bedmachine mask V3.

Ice shelves frontlines identified with BedMachine V3
Morlighem, M. (2022). MEaSUREs BedMachine Antarctica, Version 3

Goal: provide latest freshwater fluxes estimates from iceberg calving



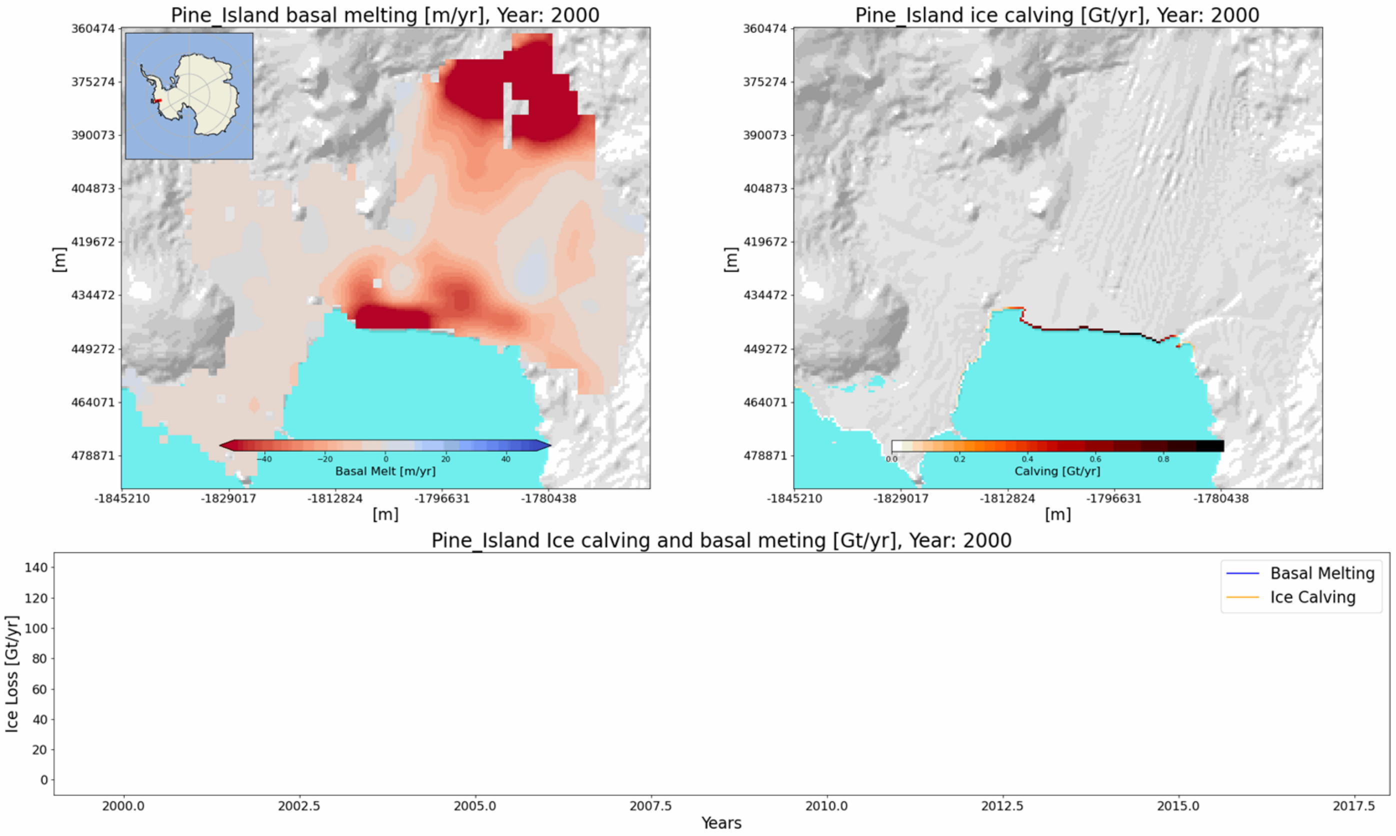
Frontline pixel surrounded by two ocean pixels

Spatialization of the calving fluxes along the frontlines

- For each pixel of the frontline:
  - spatialization coefficient [0,1] based on surface flow velocities,
  - applied this coefficient to the integrated yearly mass loss
- Consider only negative mass losses, *i.e.* calving events.

Results

Comparison of calving vs melting over the entire time period (2000 - 2017)



Results

Comparison of results over similar time periods and same ice shelves groups.

Period 2007-2008	**Rignot et al.,2013**	**Greene et al. ,2022**
Ice Calving [Gt/y]	1081±126	1032±37

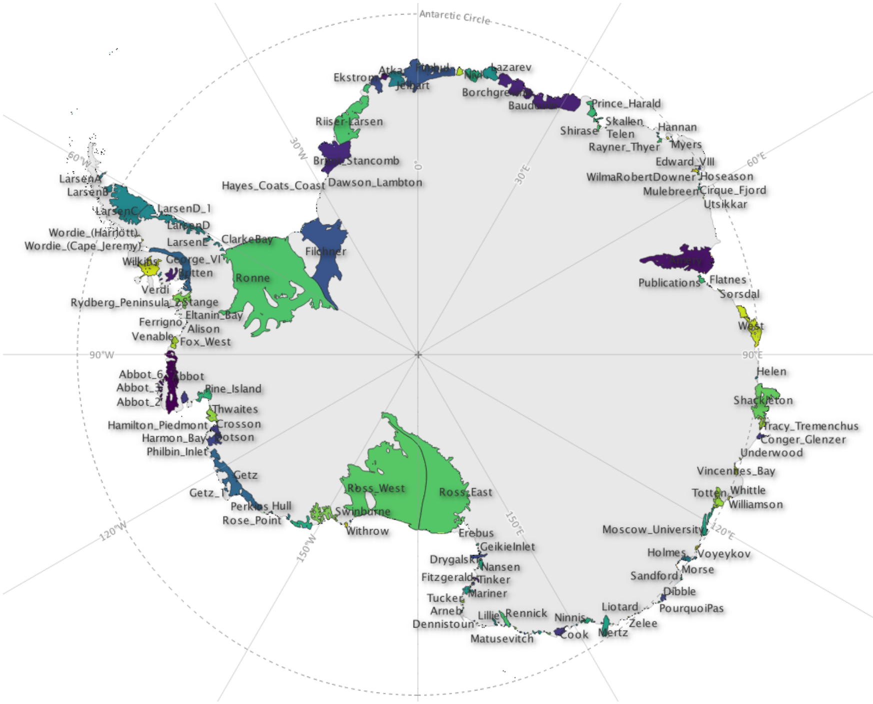
Period 2007-2008	**Rignot et al.,2013**	**Paulo et al., *review***
Basal Melting [Gt/y]	1310±418	1292±388

Period 1994-2017	**Adusumilli et al.,2020**	**Paulo et al., *review***
Basal Melting [Gt/y]	1250±150	968±290

Data products

- **Ice shelves vector file**:
  ice shelves layer (MEaSUREs) and calving data (Greene et al. 2022) merged into a file in *shp/gpkg* format.

- **Integrated basal melt/calving** over the same time period in *csv* format,
- **Spatialized basal melting and calving** in *netcdf* format.



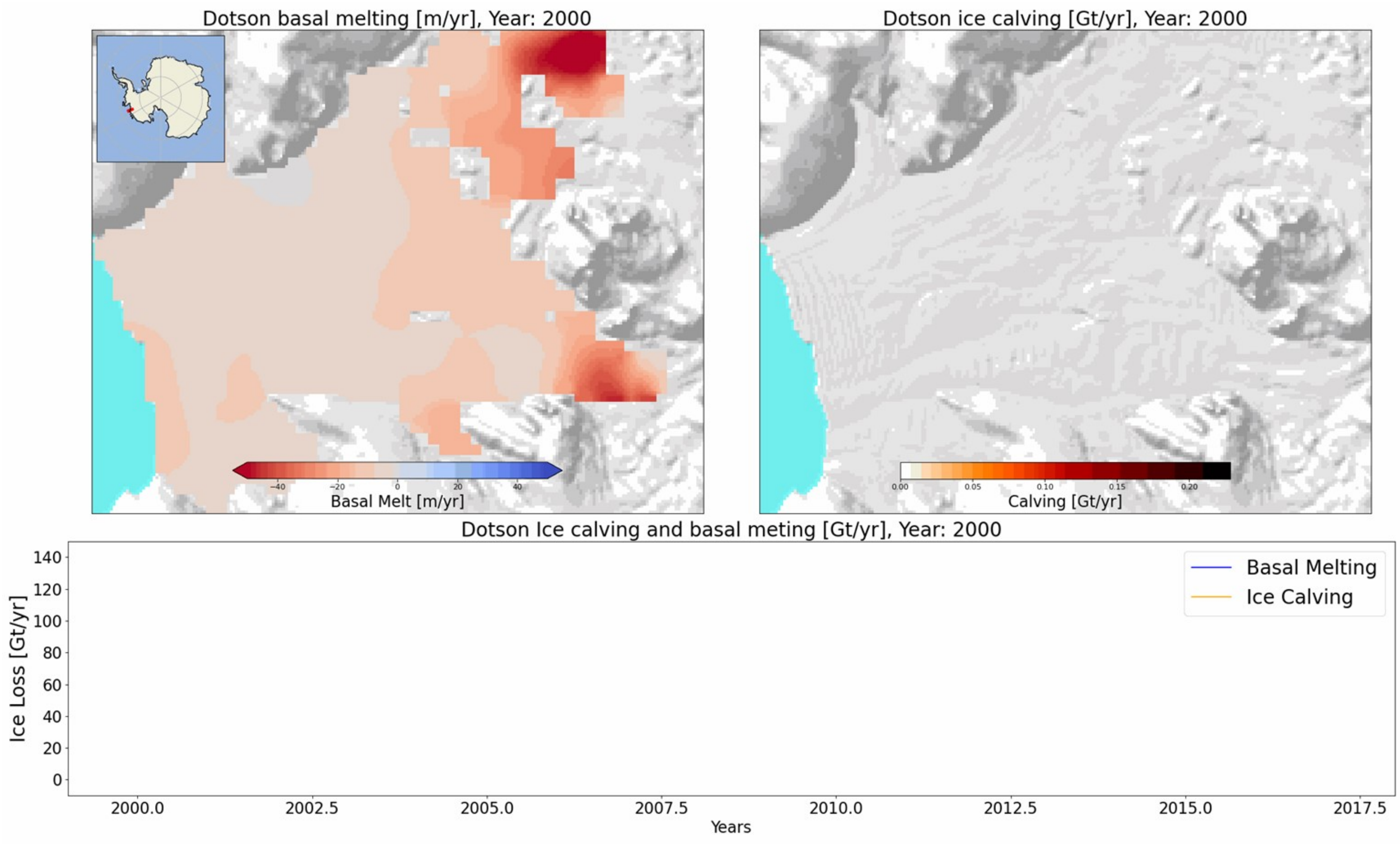
Mouginot et al. (2017). **MEaSUREs Antarctic Boundaries** for IPY 2007-2009 from Satellite Radar, Version 2. Boulder, Colorado USA. NASA NSIDC


Calving front of the Astrolabe Glacier, 2007. B. Jourdain

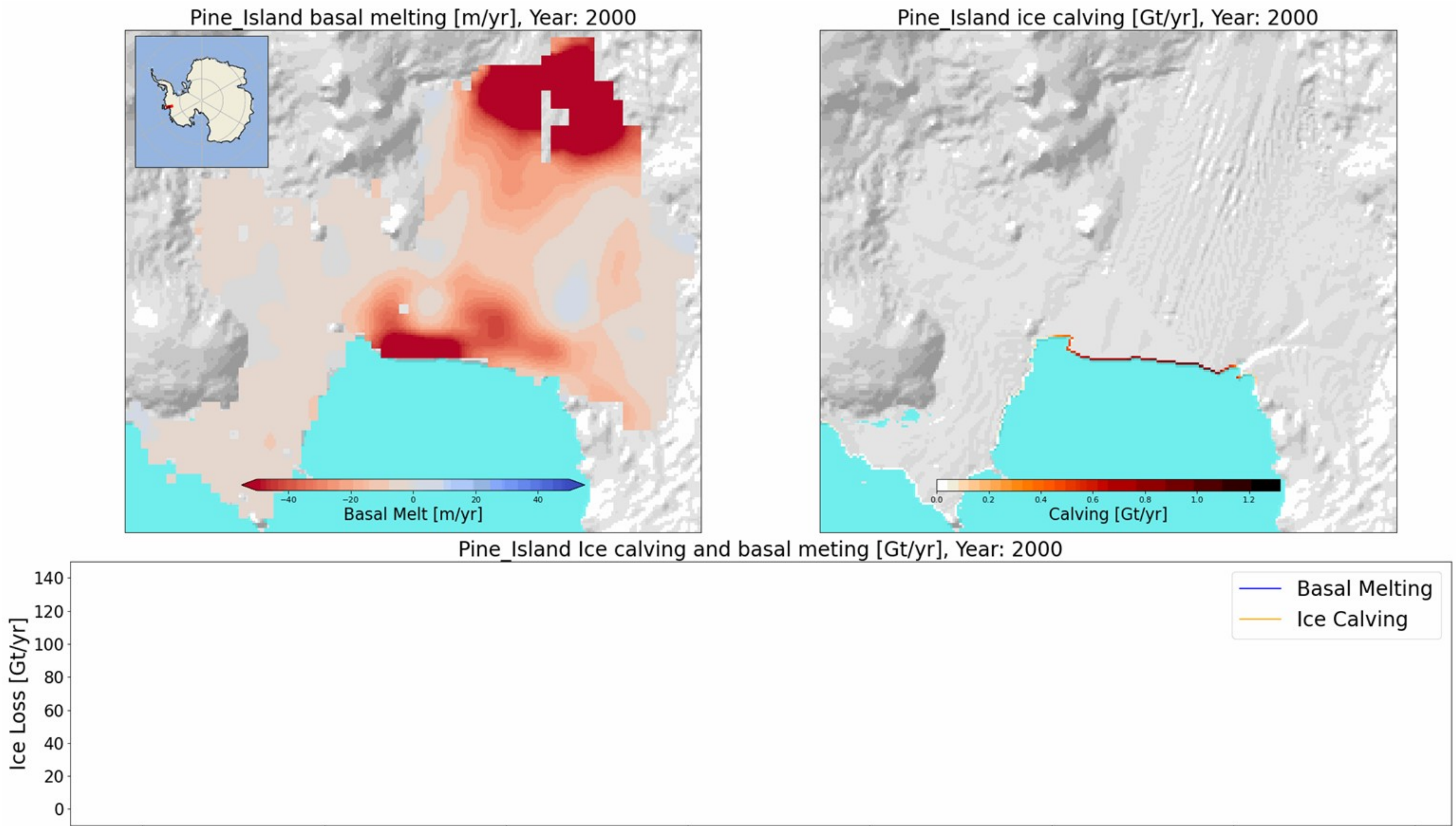
Thank you for your attention

Paolo, F., Gardner, A., Greene, C., Nilsson, J., Schodlok, M., Schlegel, N., and Fricker, H.: Widespread slowdown in thinning rates of West Antarctic Ice Shelves, EGUsphere [preprint], https://doi.org/10.5194/egusphere-2022-1128, 2022.

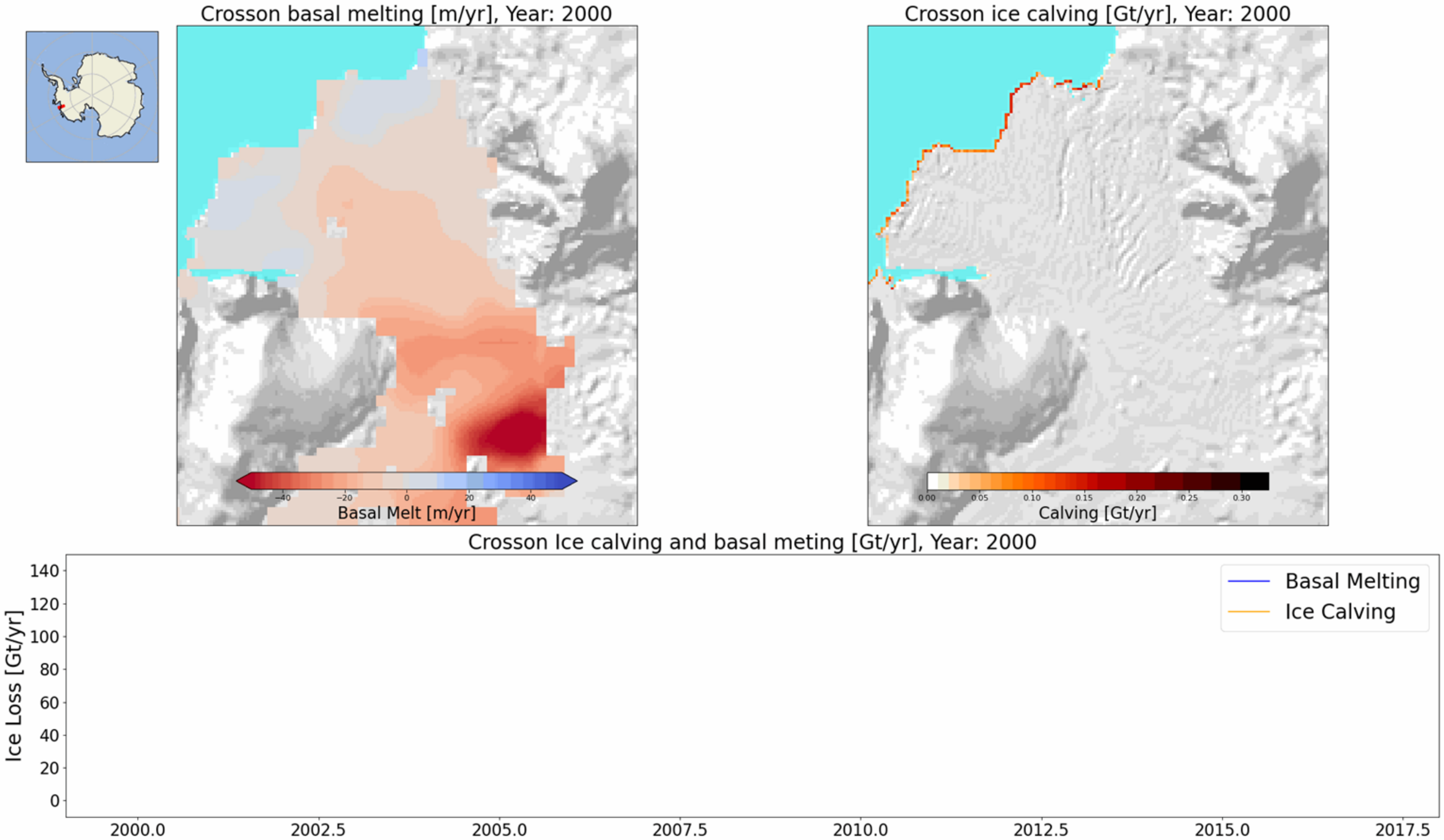
Greene, C.A., Gardner, A.S., Schlegel, NJ. *et al.* Antarctic calving loss rivals ice-shelf thinning. *Nature* 609, 948–953 (2022). https://doi.org/10.1038/s41586-022-05037-w



Dotson basal melting [m/yr], Year: 2000
Basal Melt [m/yr]
−40
−20
0
20
40
Dotson ice calving [Gt/yr], Year: 2000
Calving [Gt/yr]
0.00
0.05
0.10
0.15
0.20
Dotson Ice calving and basal meting [Gt/yr], Year: 2000
Ice Loss [Gt/yr]
140
120
100
80
60
40
20
0
2000.0
2002.5
2005.0
2007.5
2010.0
2012.5
2015.0
2017.5
Years
Basal Melting
Ice Calving

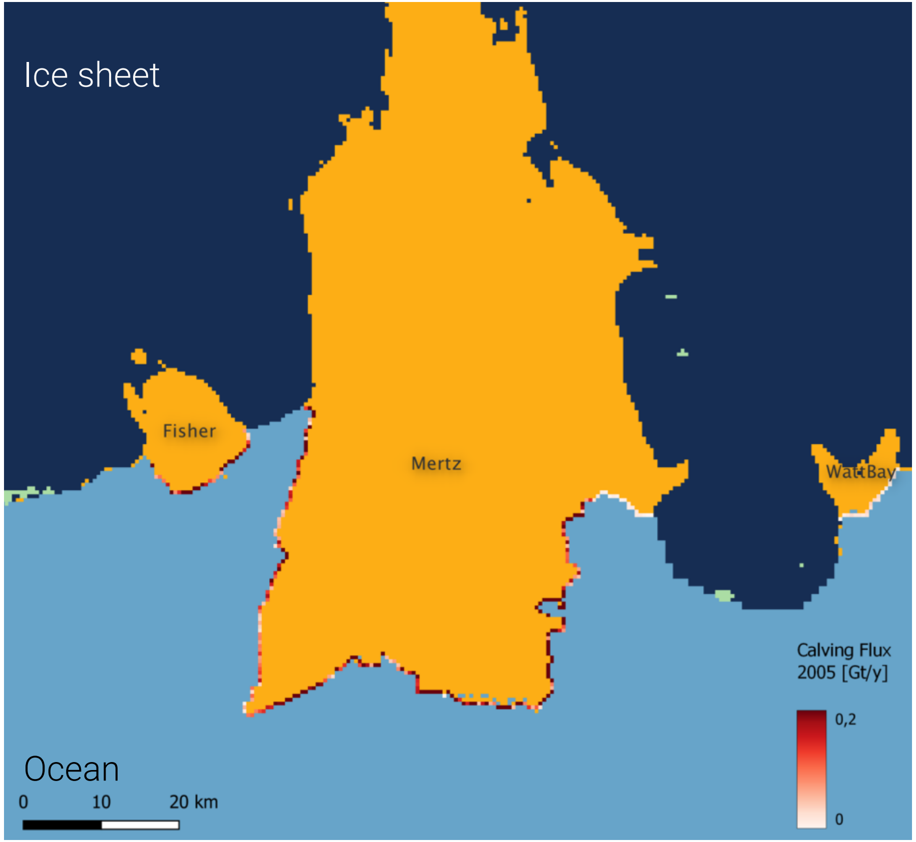


Pine_Island basal melting [m/yr], Year: 2000
−40
−20
0
20
40
Basal Melt [m/yr]
Pine_Island ice calving [Gt/yr], Year: 2000
0.0
0.2
0.4
0.6
0.8
1.0
1.2
Calving [Gt/yr]
Pine_Island Ice calving and basal meting [Gt/yr], Year: 2000
Ice Loss [Gt/yr]
140
120
100
80
60
40
20
0
Basal Melting
Ice Calving



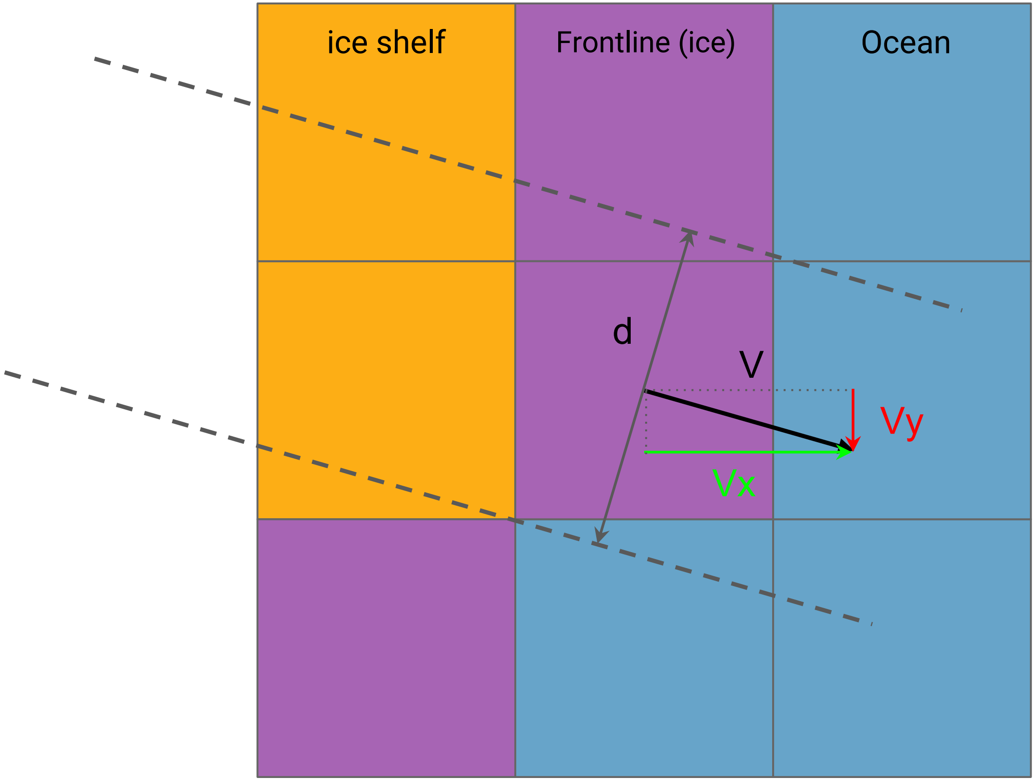
Crosson basal melting [m/yr], Year: 2000
−40
−20
0
20
40
Basal Melt [m/yr]
Crosson ice calving [Gt/yr], Year: 2000
0.00
0.05
0.10
0.15
0.20
0.25
0.30
Calving [Gt/yr]
Crosson Ice calving and basal meting [Gt/yr], Year: 2000
Ice Loss [Gt/yr]
140
120
100
80
60
40
20
0
2000.0
2002.5
2005.0
2007.5
2010.0
2012.5
2015.0
2017.5
Basal Melting
Ice Calving

Calving flux



Calving flux spatialisation

Frontline pixel surrounded by two cean pixels



Calving flux along the frontline for a pixel i (in [Gt/y]):

$$Q_{ci} = [h*d*V / Q_{is}]*Q_{greene}$$

with

- Q_{is} = sum Q_{ci} for the whole Ice shelf.
- h, ice shelf thickness
- V, ice velocity
- d, calving distance
- Q_{greene}, calving flux [Gt/y]

Negative values of IS mass change are considered as calving.