Antarctica‘s melt water – a global player?

Hartmut H. Hellmer
**Tore Hattermann, Keith Nicholls, Svein Osterhus, Gerd Rohardt,
Markus Janout, Mike Schröder**

ice2sea

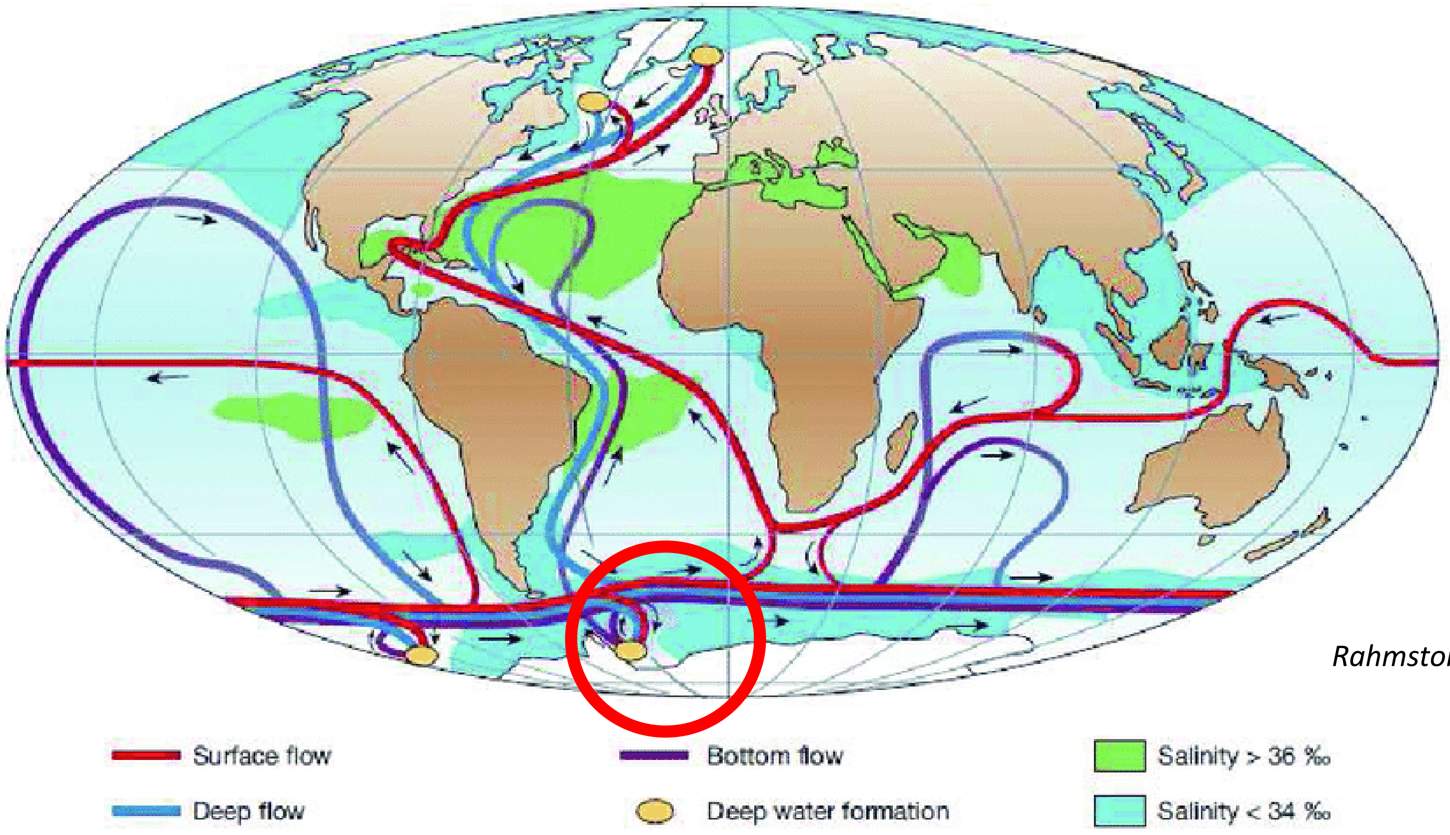
FISP
Filchner Ice Shelf Project

Polar Ocean Seminar, GEOMAR, 16 February 2022


Sea ice

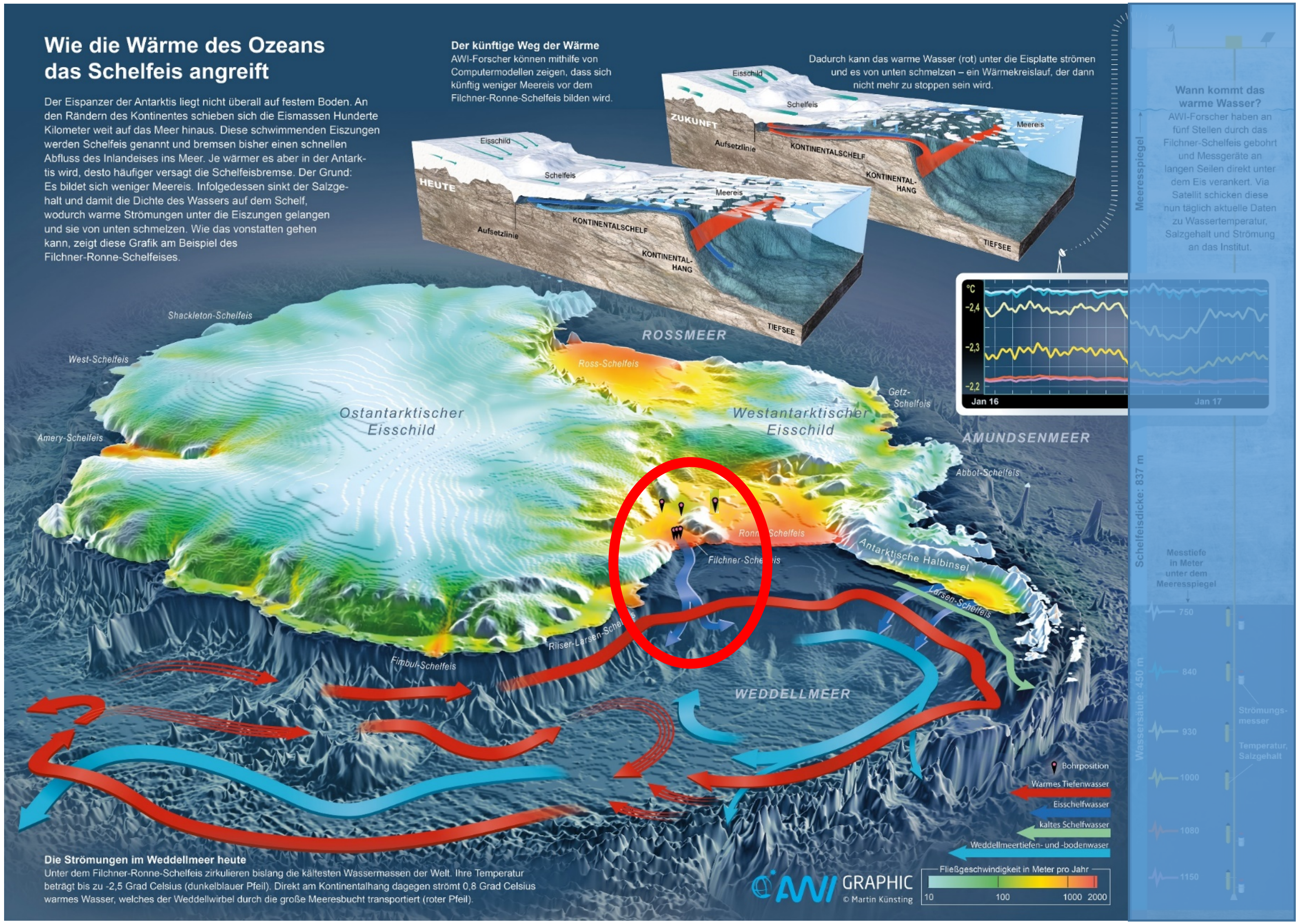
Introduction

Global Conveyor Belt

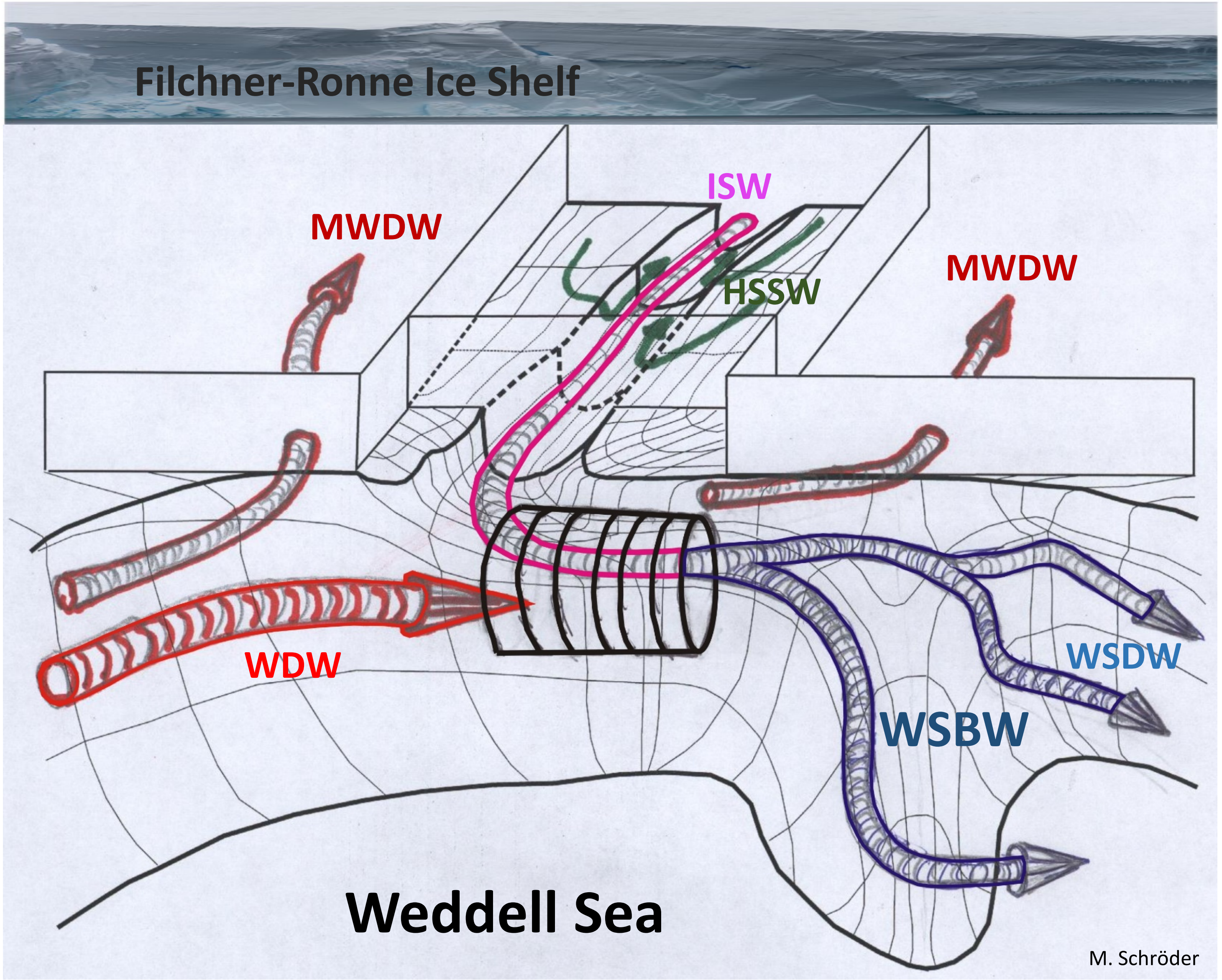


Rahmstorf, Nature (2002)

Introduction

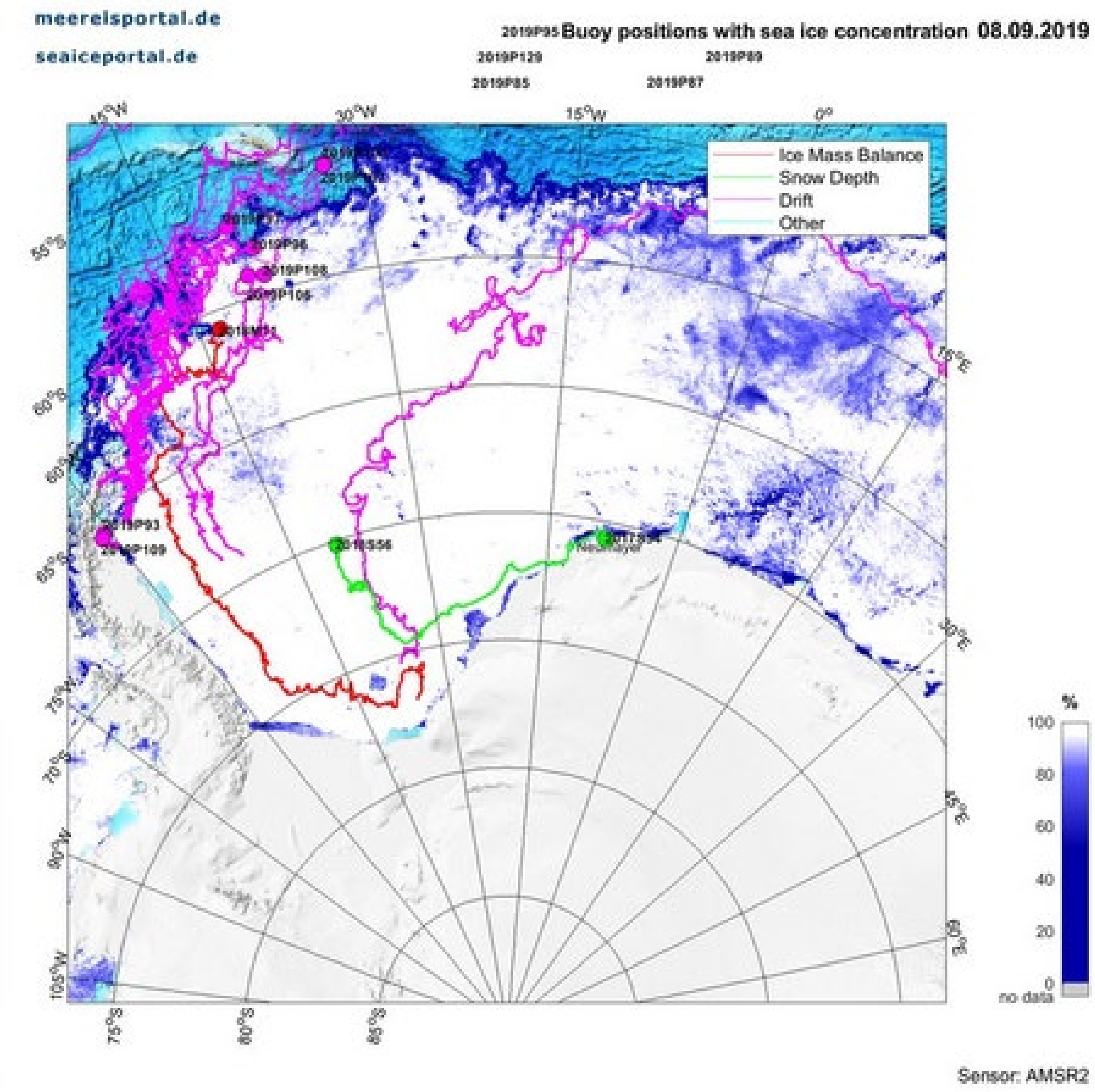


Introduction



WDW: Warm Deep Water
MWDW: Modified Warm Deep Water
HSSW: High Salinity Shelf Water
ISW: Ice Shelf Water
WSDW: Weddell Sea Deep Water
WSBW: Weddell Sea Bottom Water

Sea ice



meereisportal.de
seaiceportal.de
Buoy positions with sea ice concentration 08.09.2019
Ice Mass Balance
Snow Depth
Drift
Other
Neumayer
%
100
80
60
40
20
0
no data
Sensor: AMSR2

Icebergs

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AGU PUBLICATIONS

JGR

Journal of Geophysical Research: Oceans

RESEARCH ARTICLE

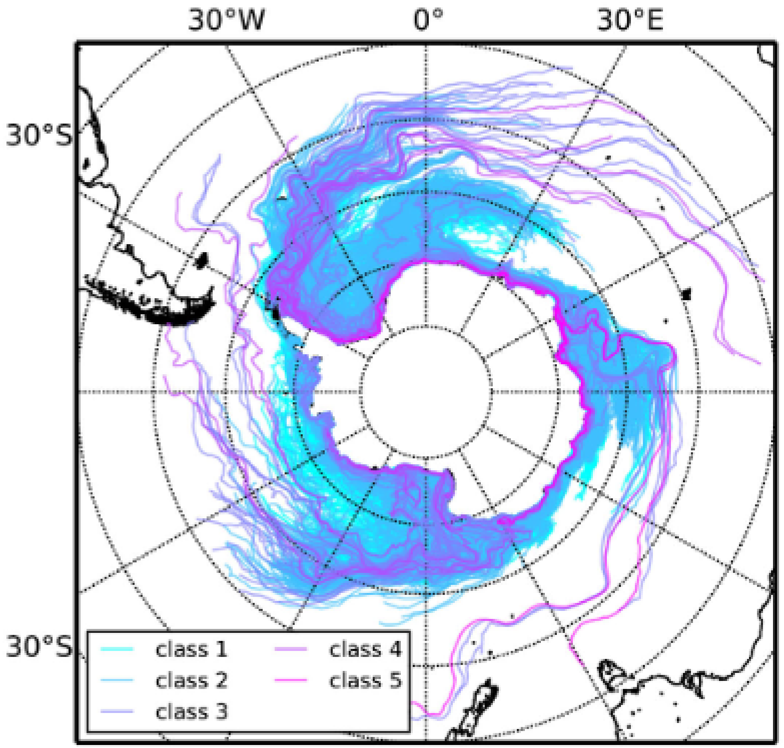
10.1002/2016JC012513

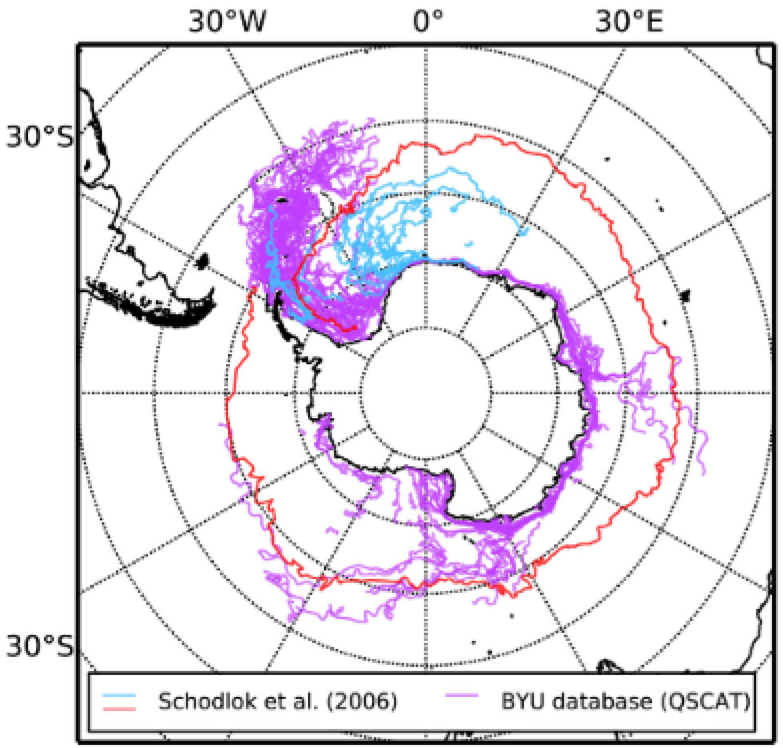
Key Points:
- Initialization with observed iceberg positions and a realistic size distribution
- Drift and melt of small (<2.2 km length) to giant icebergs (≳10 km) is simulated
- Including larger icebergs leads to a northward shift of the freshwater

A simulation of small to giant Antarctic iceberg evolution: Differential impact on climatology estimates

Thomas Rackow[1], Christine Wesche[1], Ralph Timmermann[1], Hartmut H. Hellmer[1], Stephan Juricke[2], and Thomas Jung[1,3]

[1]Alfred Wegener Institute, Helmholtz Centre for Polar and Marine Research, Bremerhaven, Germany, [2]Atmospheric, Oceanic and Planetary Physics, University of Oxford, Oxford, UK, [3]Institute of Environmental Physics, University of Bremen, Bremen, Germany





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Icebergs

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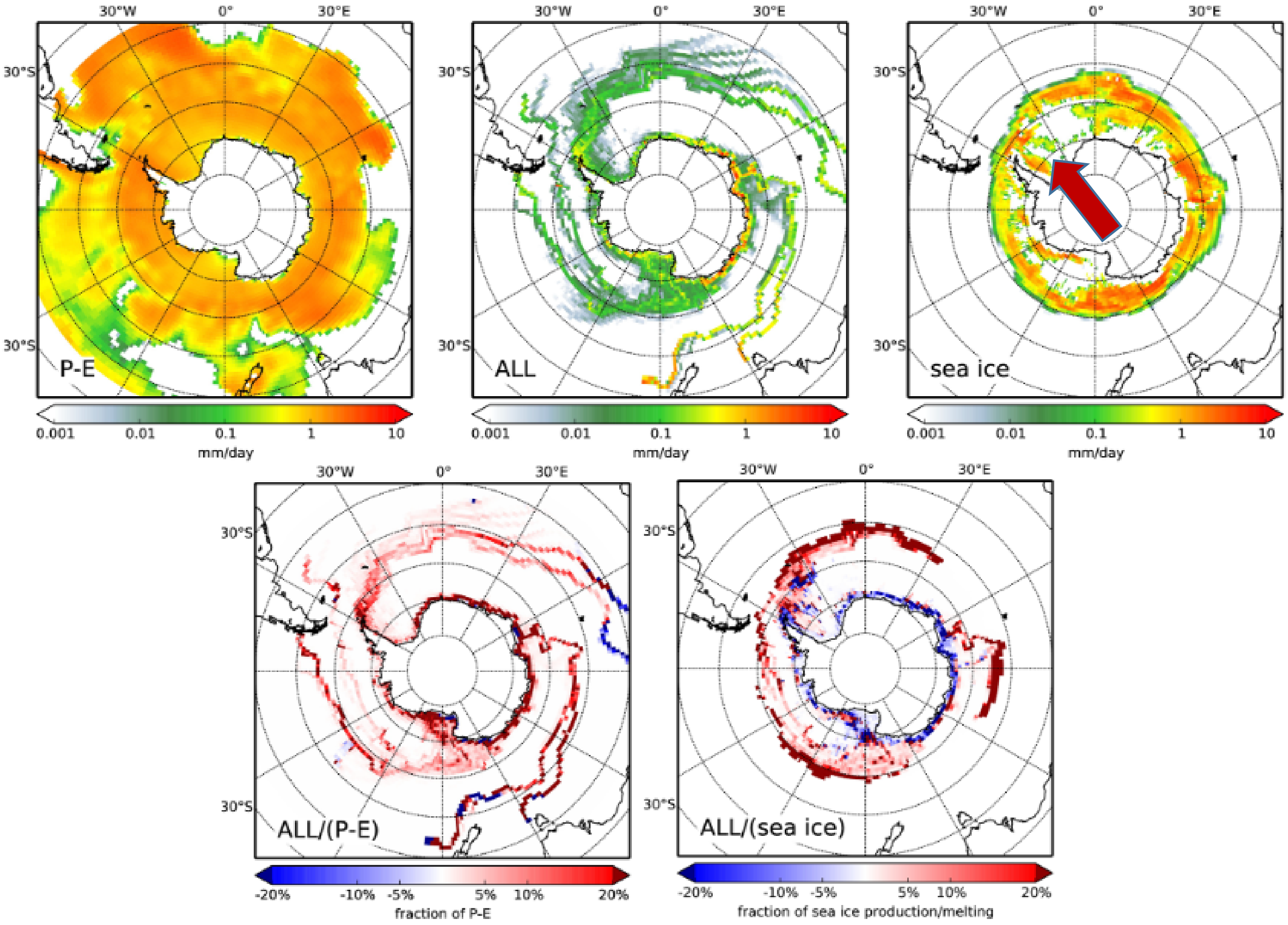
Annual mean (1997-2008)



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Ice shelves

Melting of ice shelves and the mass balance of Antarctica

S. S. Jacobs, H. H. Hellmer
Lamont–Doherty Geological Observatory of Columbia University, Palisades, New York 10964, U.S.A.

C. S. M. Doake, A. Jenkins and R. M. Frolich
British Antarctic Survey, Natural Environment Research Council, Cambridge CB3 0ET, England

Accumulation: Grounded ice	Accumulation: Ice shelf	Accumulation: Total	Attrition: Calving icebergs	Attrition: Ice-shelf melting	Attrition: Run-off	Balance	Reference 1956–67
		1749	–855	–251		+487	Meier (1983)
		2000	–1700	–550		–400	Losev (1963)
1490	356	1885	–1053	–293			Barkov (1971)
		2080	–1450	–200	–10	+420	Bull (1971)
		2000	–2400	–320	–60	–720	Kotlyakov and others (1978)
		2000	–1800			+200	Budd and Smith (1985)
			–2300			–	Orheim (1985)
1468	495	1963					

Table. Melting rates of Antarctic ice shelves

Jacobs et al. (1996)

Feature	Area $10^3 km^2$	Rate $cm\ yr^{-1}$	Melt $Gt\ yr^{-1}$
Ice shelf bases:			
Filchner-Ronne	400	55	202
	400	22	81
		65	23
		190	44
		1000	28
		200	224
		30	138
		500	16
Total melting:			756

Table 1 | Mass balance of Antarctic ice shelves by oceanic sector

Ocean sector	Ice shelves	GLF ($Gt\ yr^{-1}$)	SMB ($Gt\ yr^{-1}$)	CF ($Gt\ yr^{-1}$)	dh/dt ($Gt\ yr^{-1}$)	BMB ($Gt\ yr^{-1}$)	Ice-shelf area ($10^3 km^2$)	SBMB ($m\ yr^{-1}$)	MR (%)
West Indian Ocean	AR, NE, AIS, W*	235 ± 30	49 ± 8	155 ± 22	−11 ± 8	−140 ± 38	174	−0.80 ± 0.22	47
West Indian Ocean+		324 ± 31	—	204 ± 29	—	−179 ± 43	—	—	47
East Indian Ocean	SHA*, VAN, TOT*,	333 ± 16	48 ± 7	213 ± 44	−51 ± 20	−219 ± 48	65	−3.35 ± 0.73	51
East Indian Ocean+	MU, POR*, ADE*, MER, NIN, COO, REN*	508 ± 26	—	306 ± 75	—	−300 ± 80	—	—	50
Ross Sea	DRY, RIS, SUL,	149 ± 16	71 ± 17	153 ± 10	0 ± 0	−67 ± 26	492	−0.14 ± 0.05	30
Ross Sea+		175 ± 16	—	167 ± 15	—	−79 ± 28	—	—	32
Amundsen Sea	LAN*, GET*, CD*,	383 ± 19	55 ± 11	198 ± 43	−156 ± 13	−395 ± 48	56	−7.11 ± 0.87	67
Amundsen Sea+	THW*, PI*, COS	505 ± 24	—	232 ± 50	—	−484 ± 57	—	—	68
Bellingshausen Sea	ABB*, VEN*, GEO*,	139 ± 11	82 ± 16	31 ± 10	−65 ± 43	−255 ± 22	86	−2.98 ± 0.26	89
Bellingshausen Sea+	WOR	174 ± 12	—	41 ± 13	—	−281 ± 23	—	—	87
Weddell Sea	LBC, FRIS, BRL, JFL	334 ± 35	139 ± 23	355 ± 31	0 ± 0	−118 ± 52	608	−0.19 ± 0.09	25
Weddell Sea+		363 ± 35	—	371 ± 33	—	−131 ± 53	—	—	26
Fringing West Antarctica	SUL, LAN*, GET*,	542 ± 23	147 ± 19	232 ± 54	−221 ± 45	−678 ± 53	154	−4.40 ± 0.35	74
Fringing West Antarctica+	CD*, THW*, PI*, COS*, ABB*, VEN*, GEO*, WOR	700 ± 27	—	275 ± 63	—	−792 ± 62	—	—	74
Total surveyed	—	1,573 ± 56	444 ± 36	1,106 ± 141	−282 ± 50	−1,193 ± 163	1,481	−0.81 ± 0.11	52
Total upscaling	—	476 ± 67	—	216 ± 33	—	−261 ± 34	74	−3.53 ± 0.47	55
Total Antarctica	—	2,049 ± 87	—	1,321 ± 44	—	−1,454 ± 174	1,555	−0.94 ± 0.11	52

8/nature10968

Depoorter et al. (2013)

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Ice shelves

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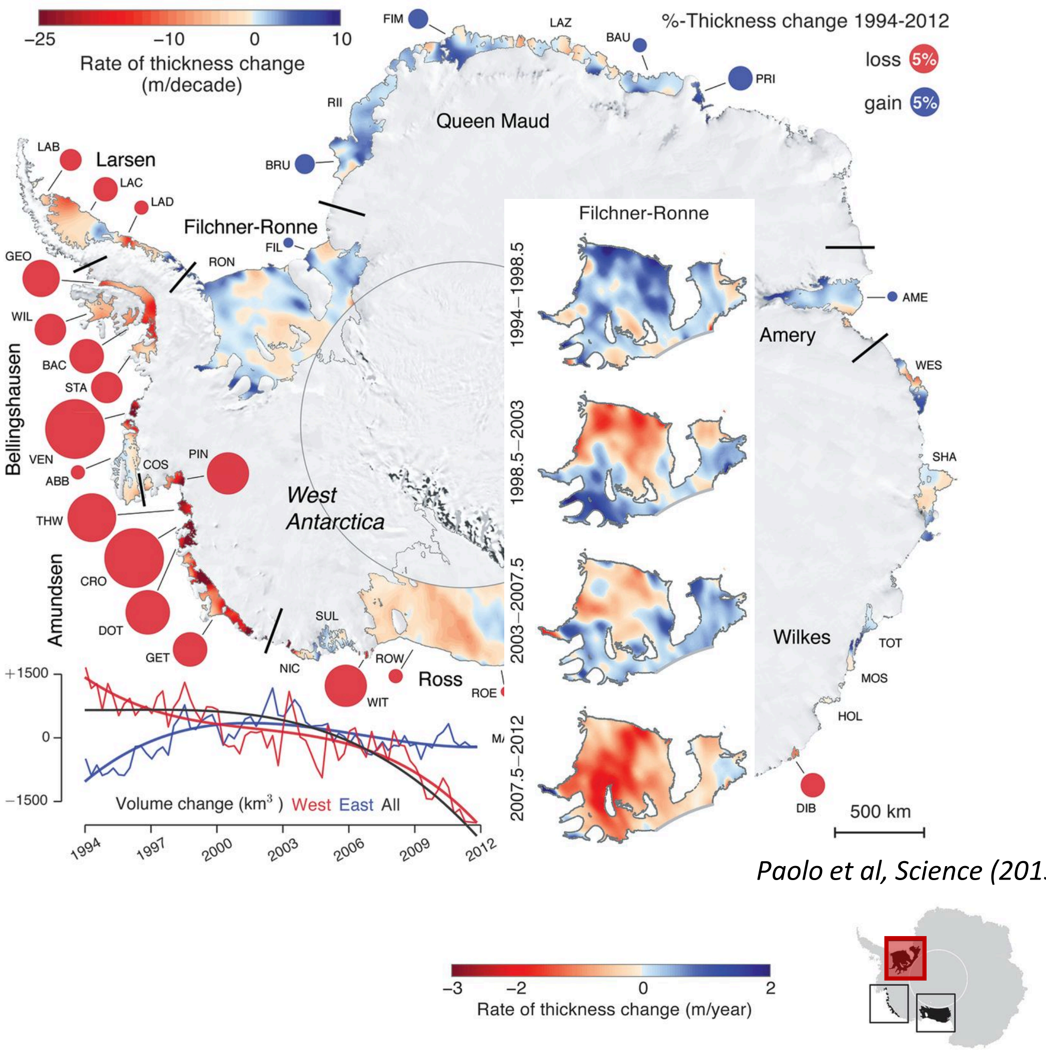
Ice Shelf Thickness Changes (1994-2012)



Paolo et al, Science (2015)

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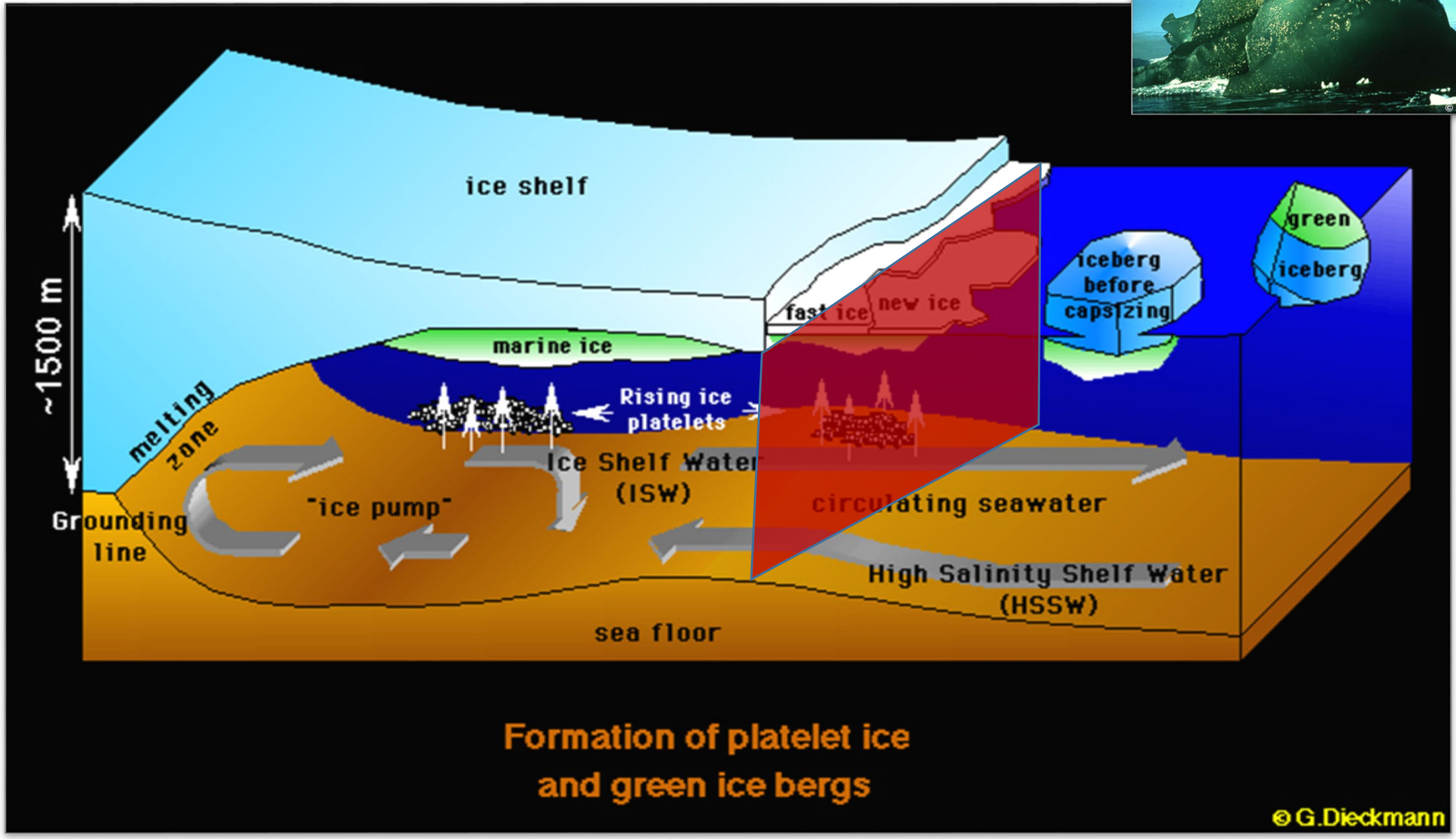
Ice shelves



Observed 1985 in
the eastern Weddell Sea

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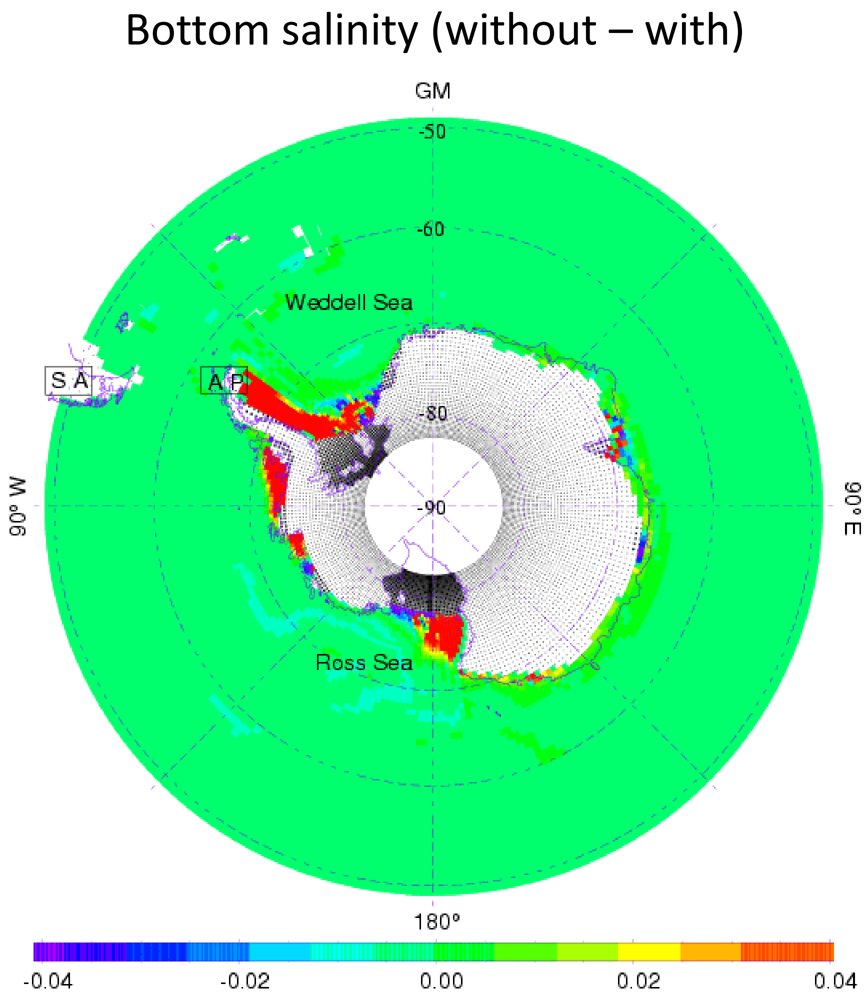
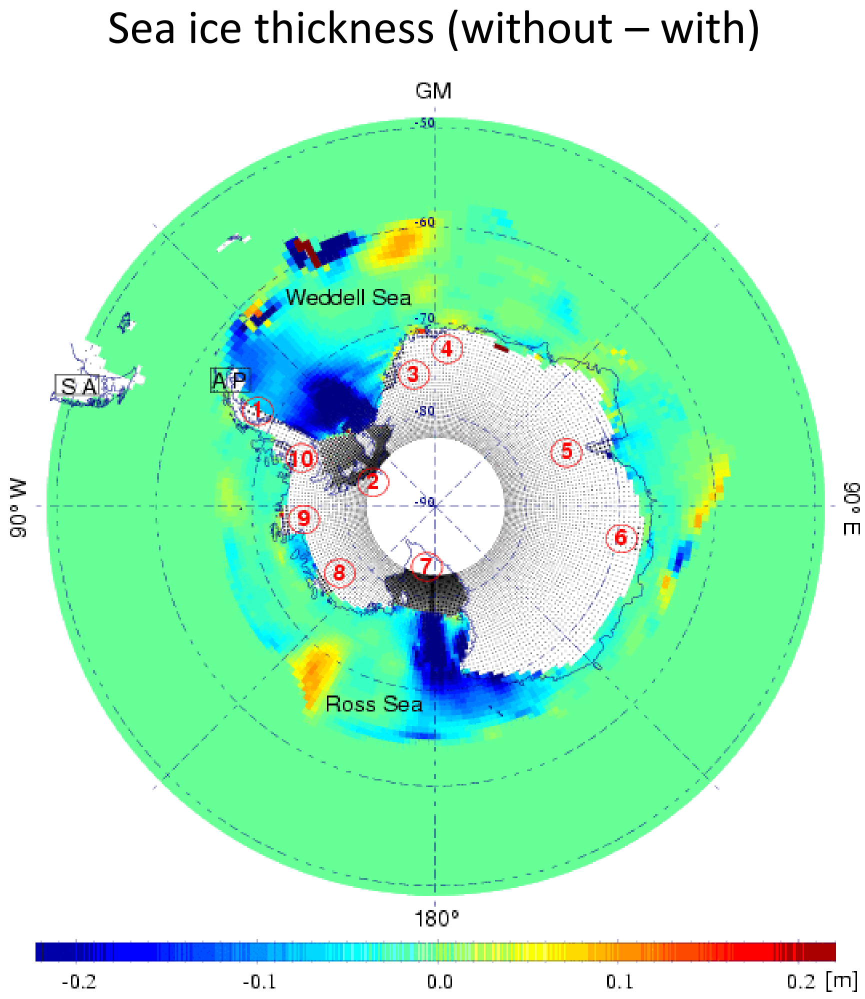
Follow-up - Models





Hellmer, GRL (2004)

September of year 20

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Observations-Sub-Filchner

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2015/16/17

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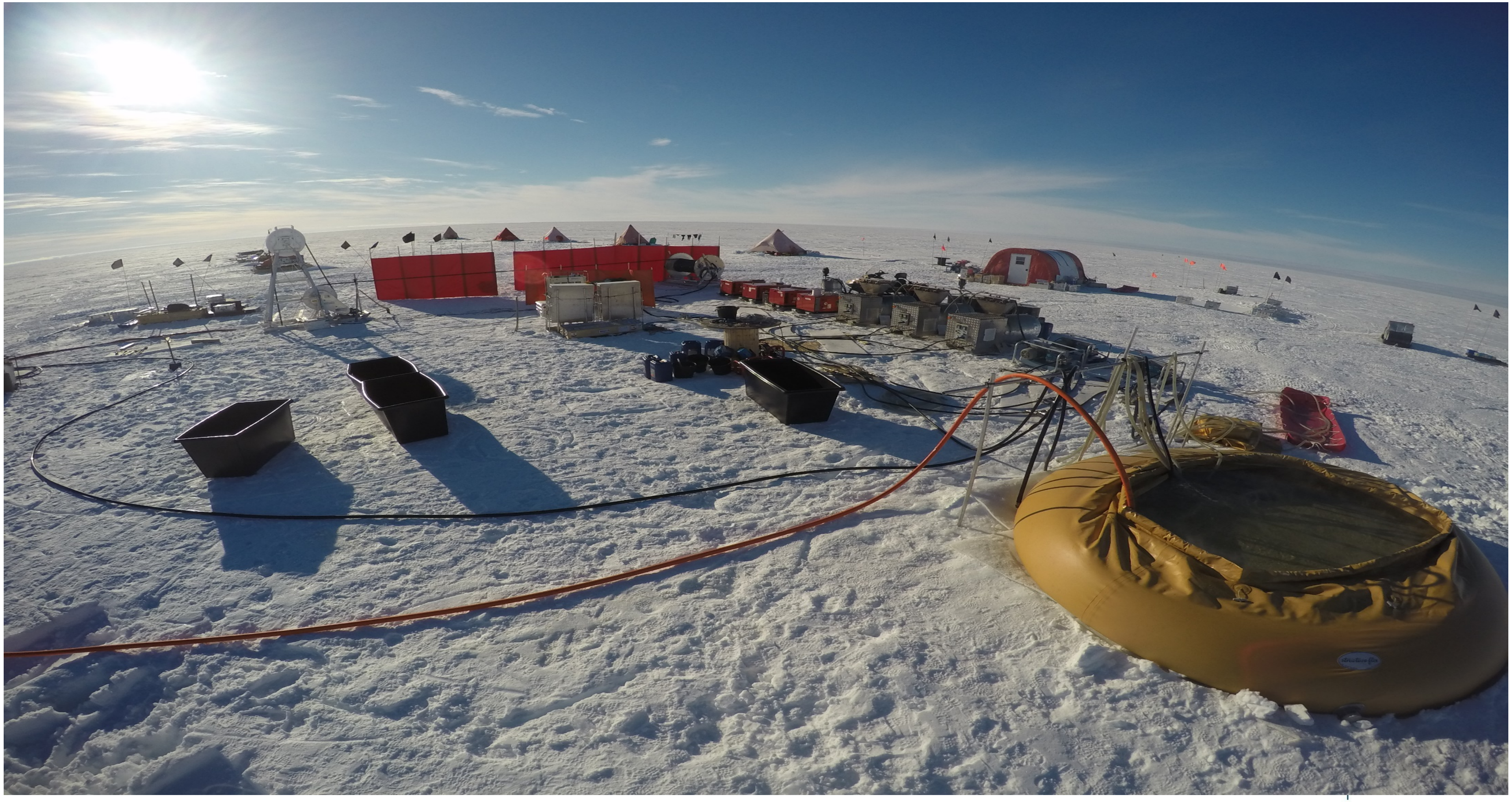
Observations-Sub-Filchner



Credit: T. Hattermann

Observations-Sub-Filchner

Filchner Ice Shelf Project

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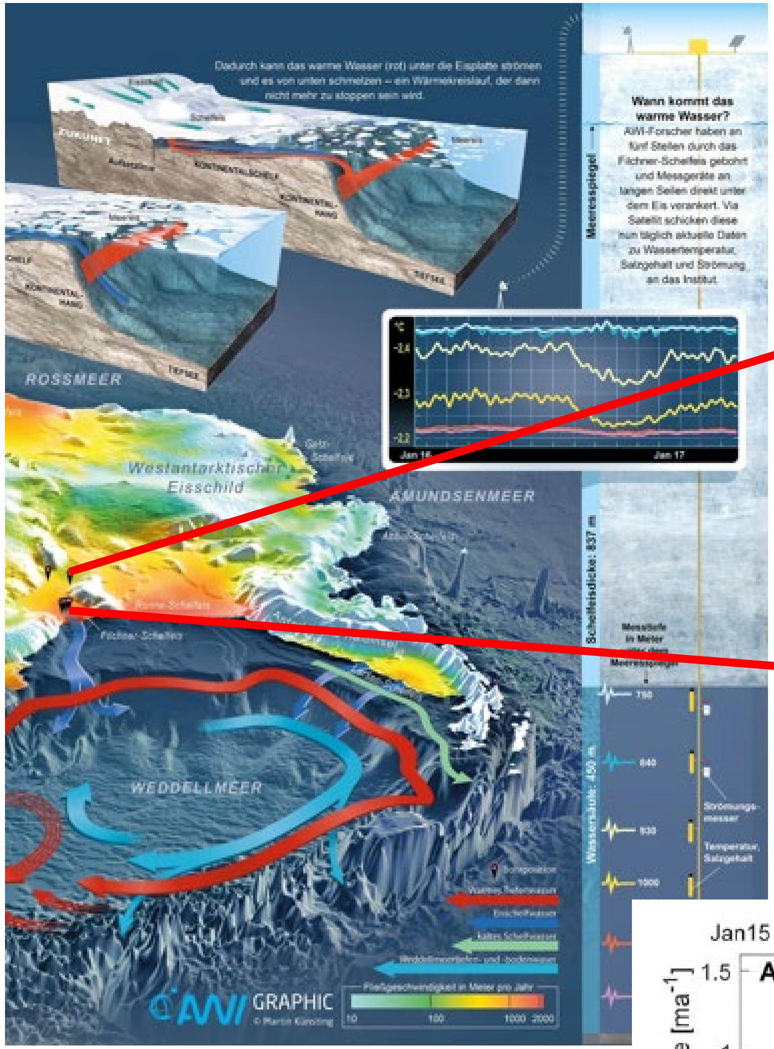
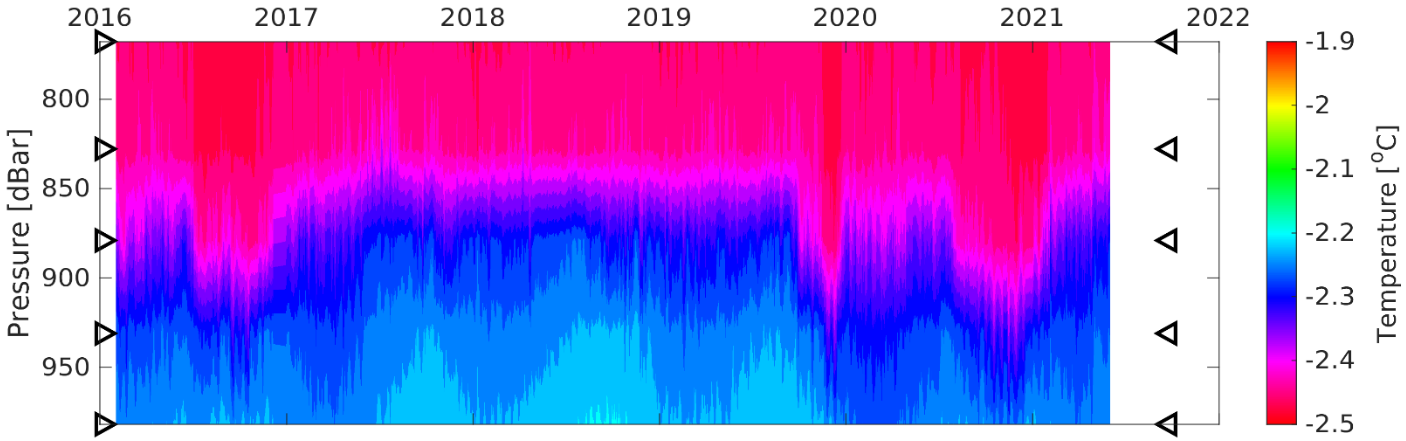
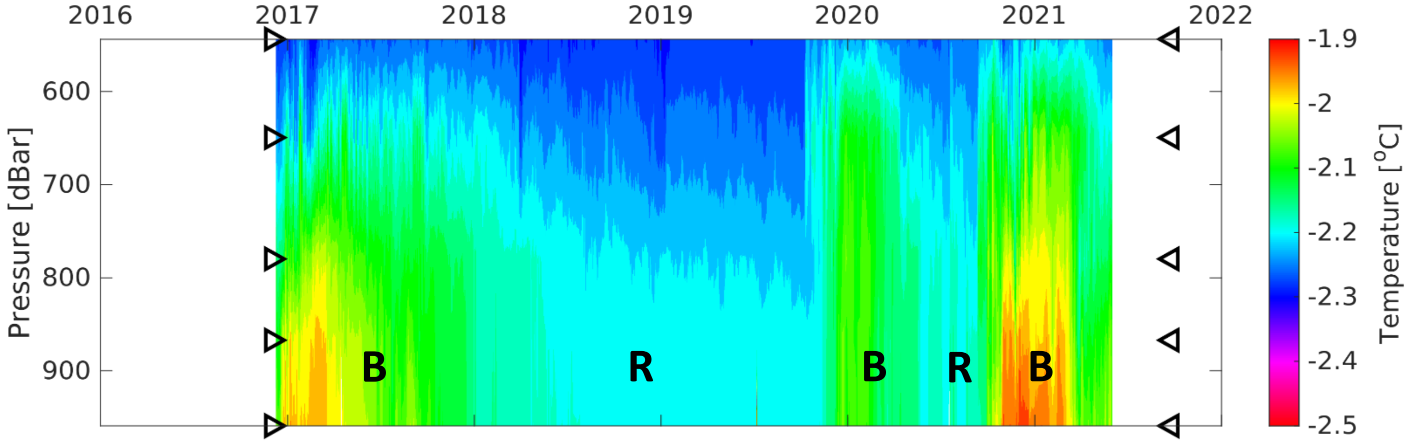




FSW1



FNE1

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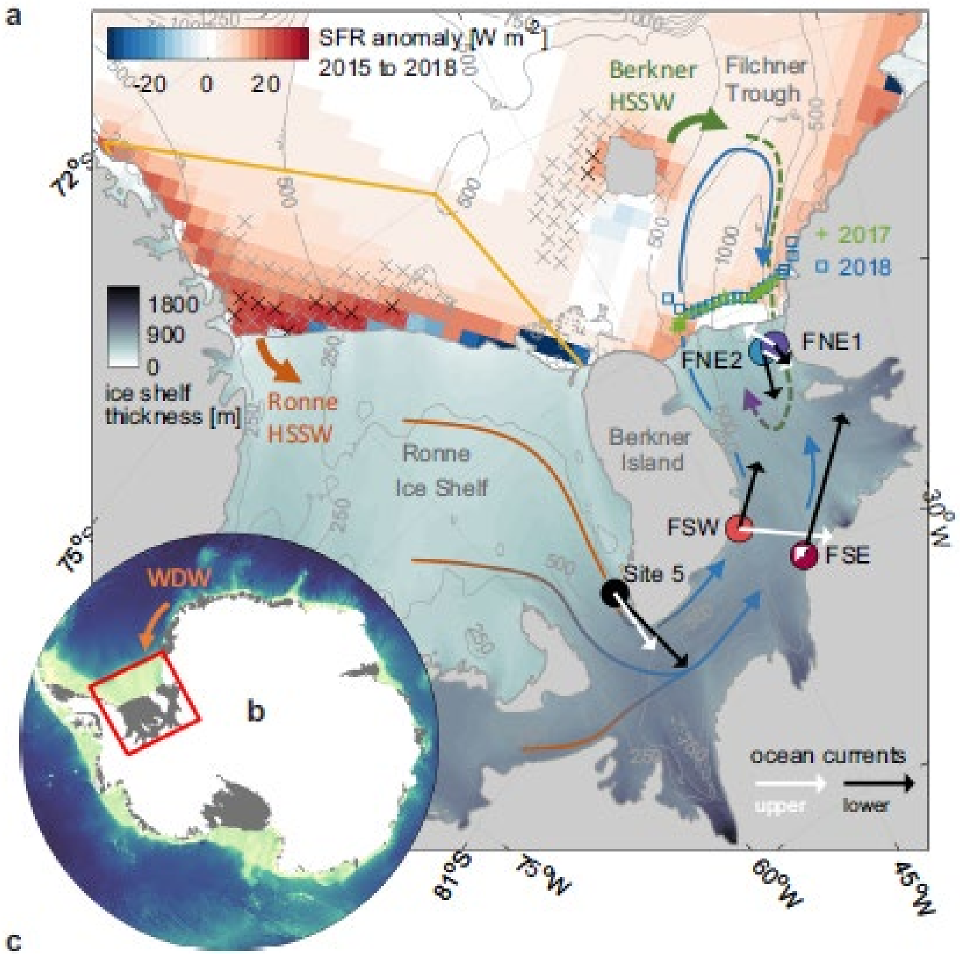
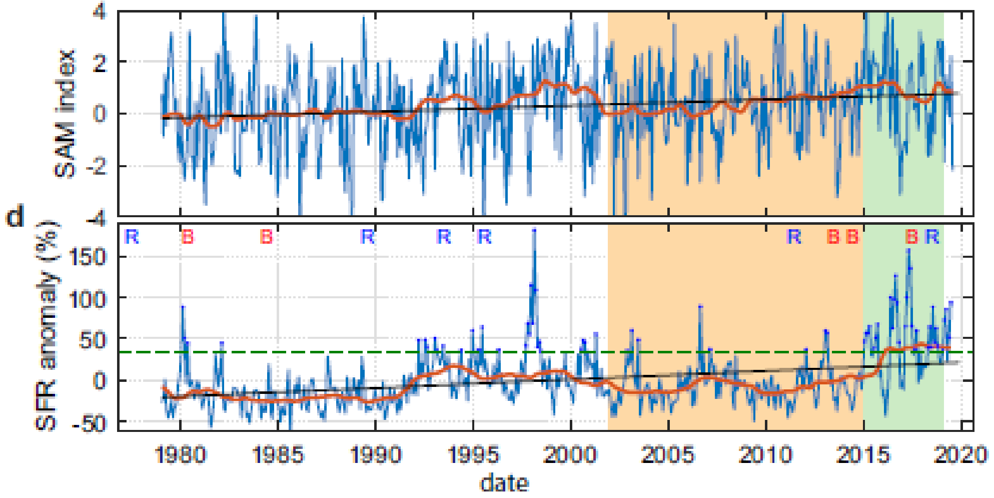


nature COMMUNICATIONS

ARTICLE
https://doi.org/10.1038/s41467-021-23131-x
OPEN

Observed interannual changes beneath Filchner-Ronne Ice Shelf linked to large-scale atmospheric circulation

Tore Hattermann[1,2,3], Keith W. Nicholls[4], Hartmut H. Hellmer[1], Peter E. D. Davis[4], Markus A. Janout[1], Svein Østerhus[5], Elisabeth Schlosser[6,7], Gerd Rohardt[1] & Torsten Kanzow[1,8]



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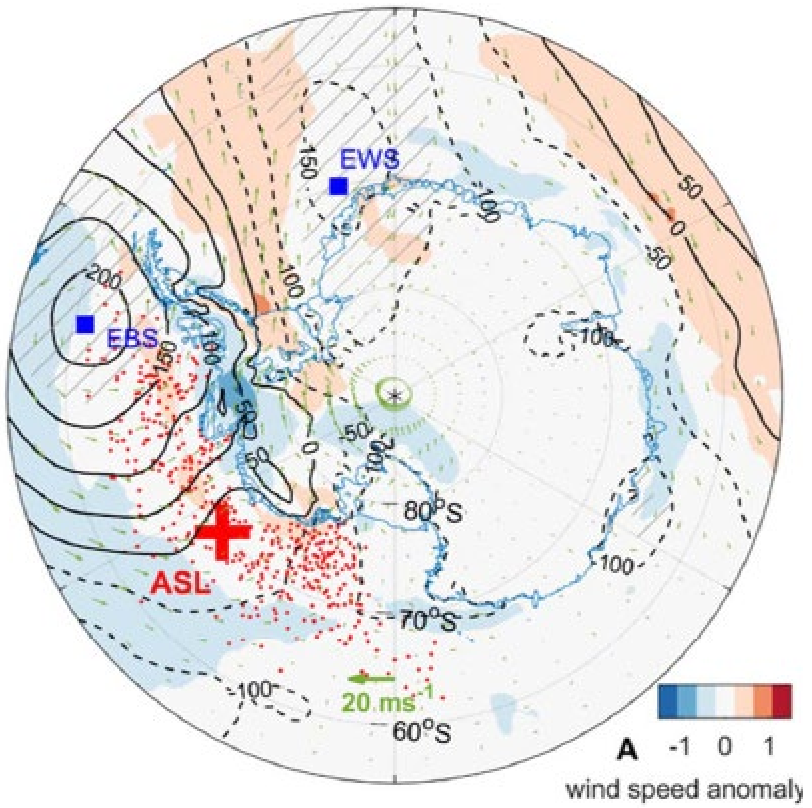
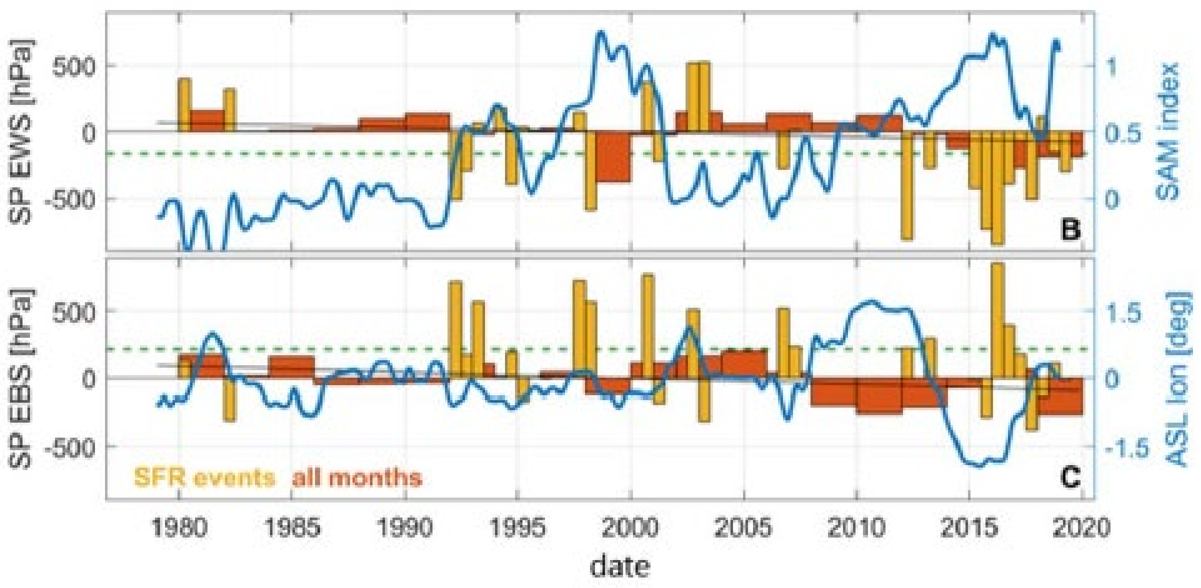
ECMWF ERA Interim





Hattermann et al, Nature Comm (2021)

Wind anomalies -> Sea ice formation -> HSSW salinity -> Cavity circulation -> Ice shelf basal melting

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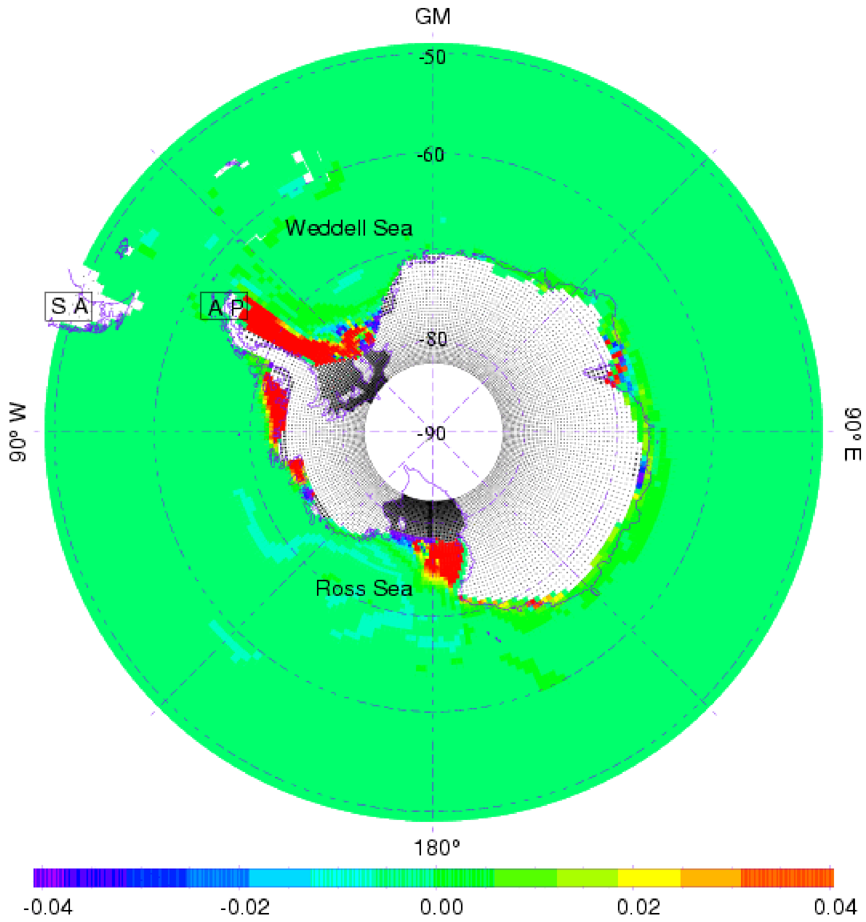
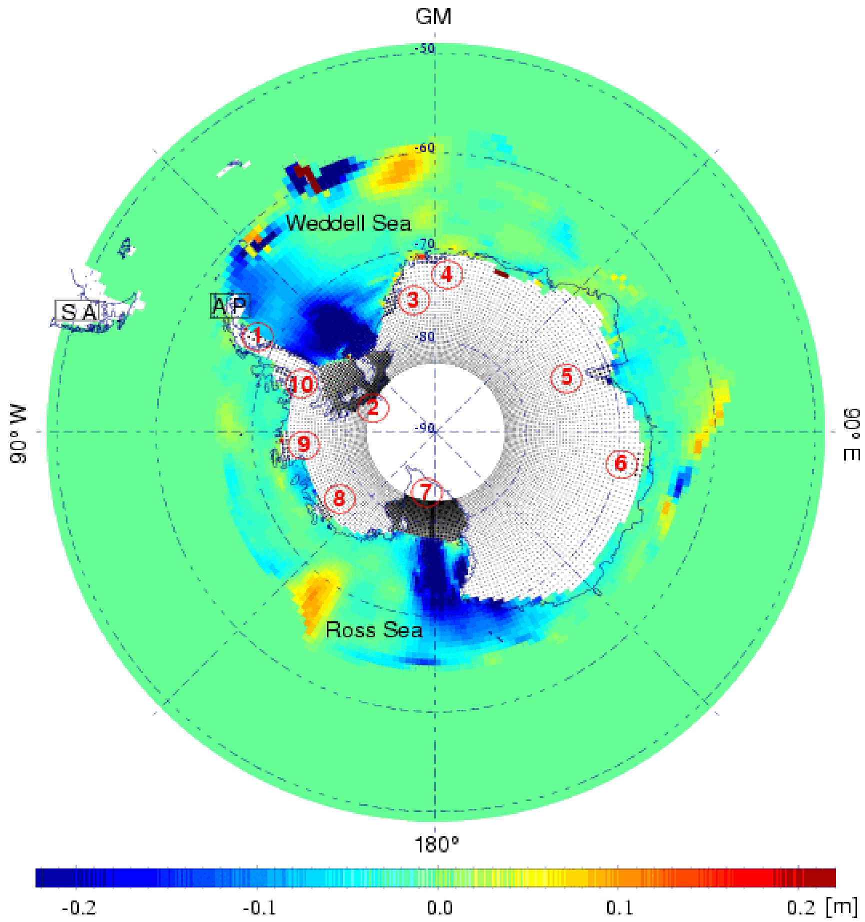
Follow-up - Models

Bottom salinity (without – with)



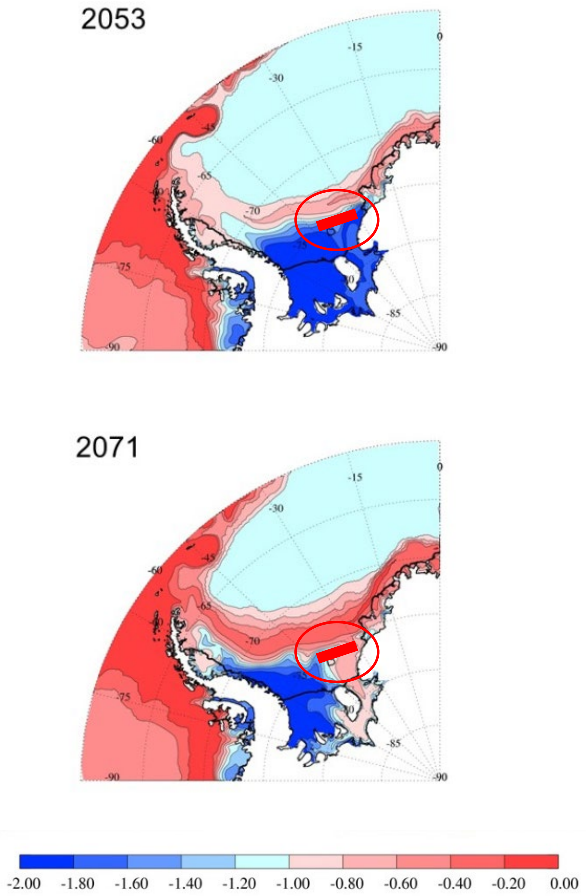
Sea ice thickness (without – with)

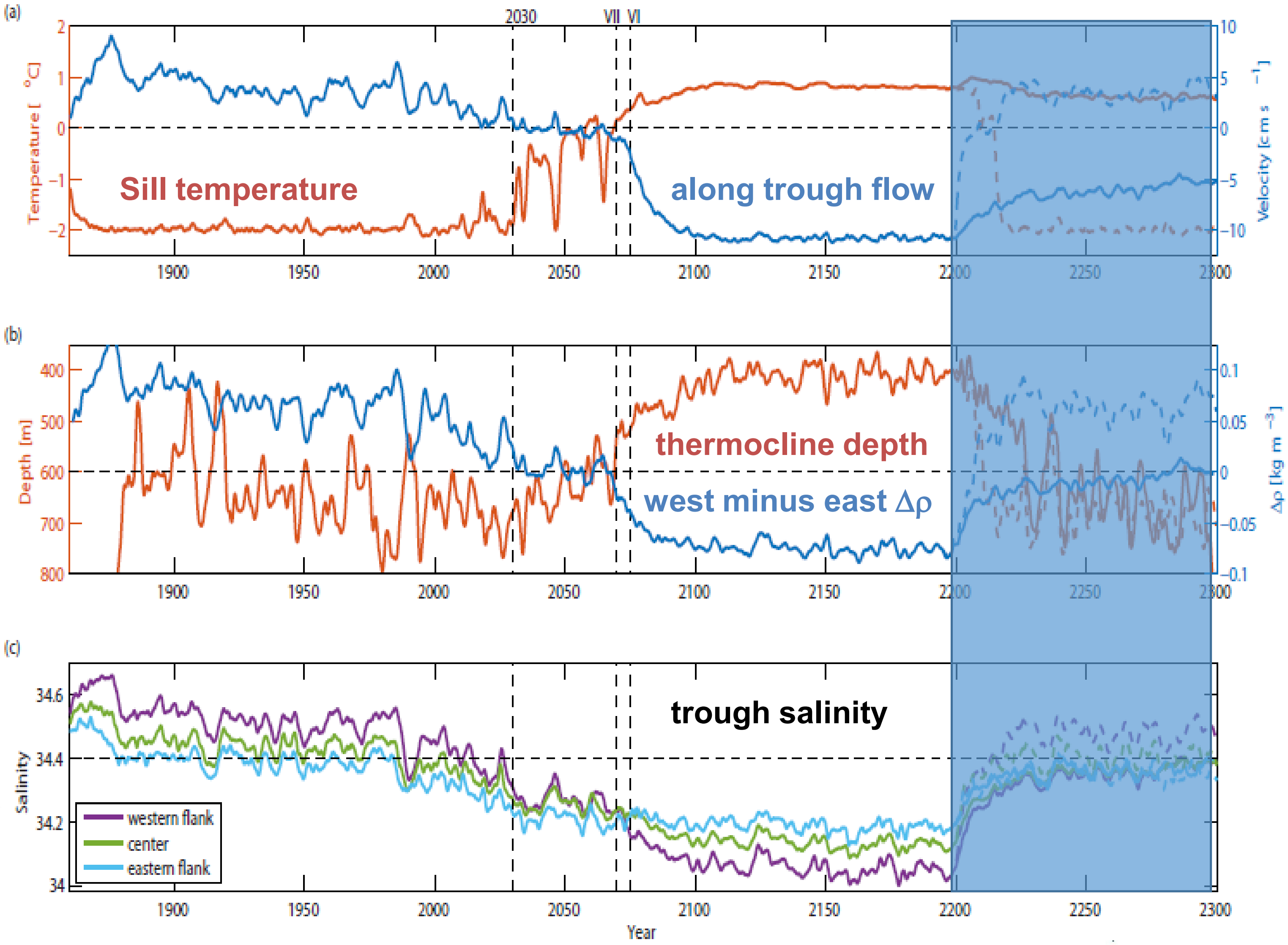


Hellmer, GRL (2004)

September of year 20

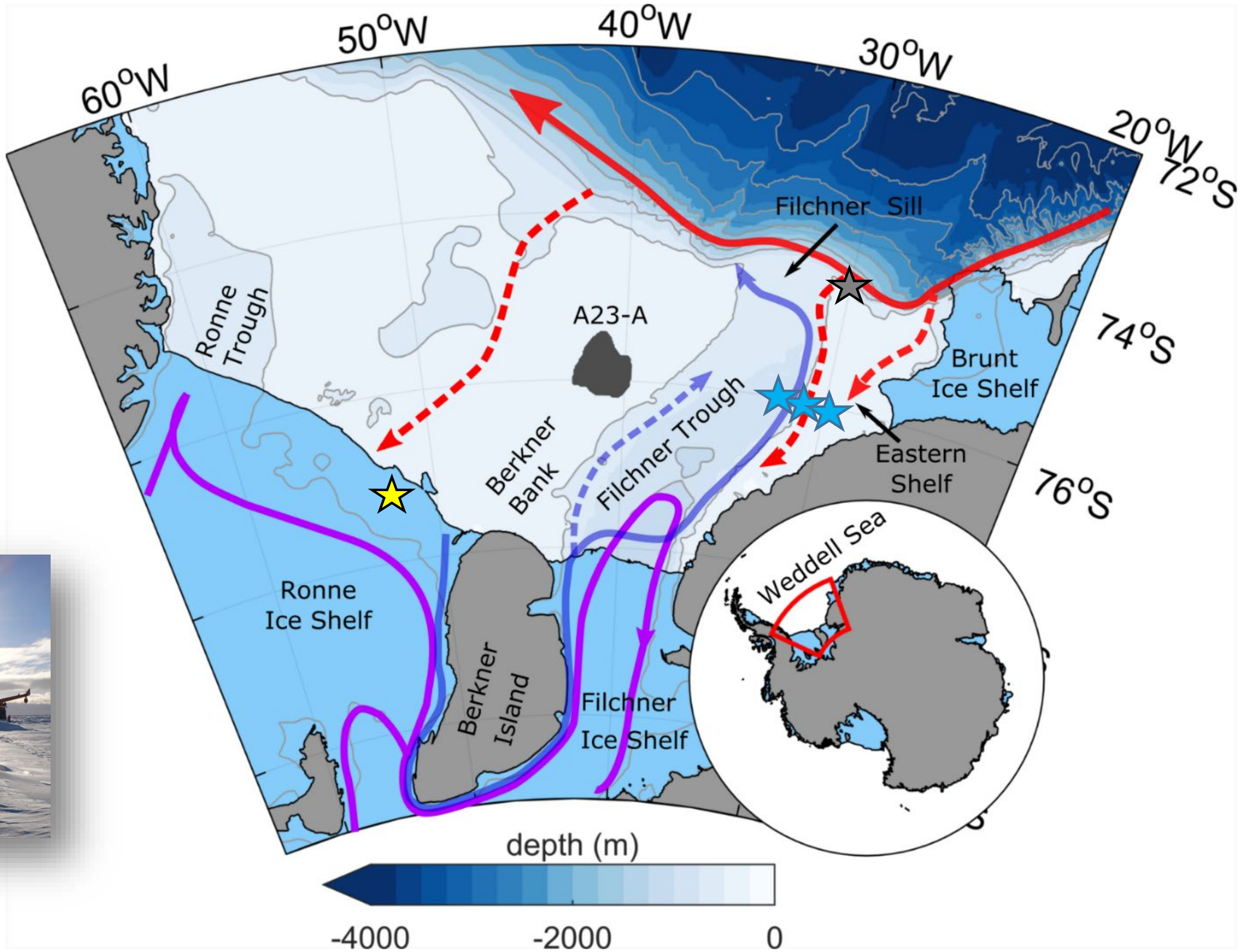
Follow-up - Models





Hellmer et al., J. Climate (2017)

Observations – Filchner Trough

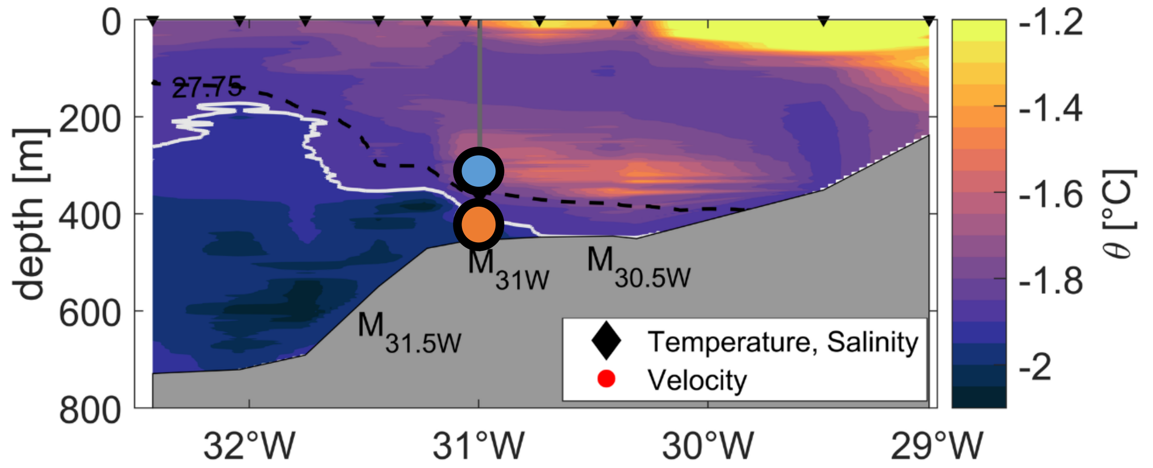


2007-2021

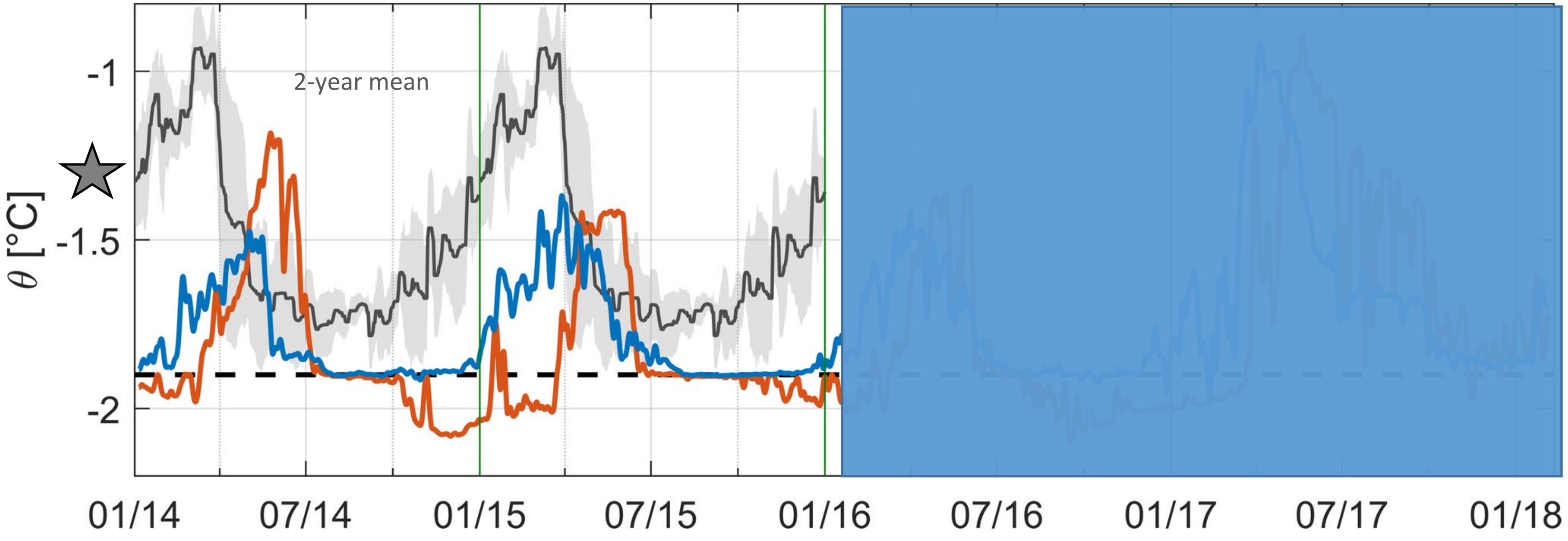
2014-2021

2014 Ronne Depot

Observations – Filchner Trough



- Seasonal (fall-early winter) intrusion of MWDW
- Coherent (one month delay) with slope mooring
- Deep convection in winter
- Intensive and all-winter long MWDW inflow in 2017



Ryan et al., GRL (2020)

3 years more 2021

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Observations – Filchner Trough

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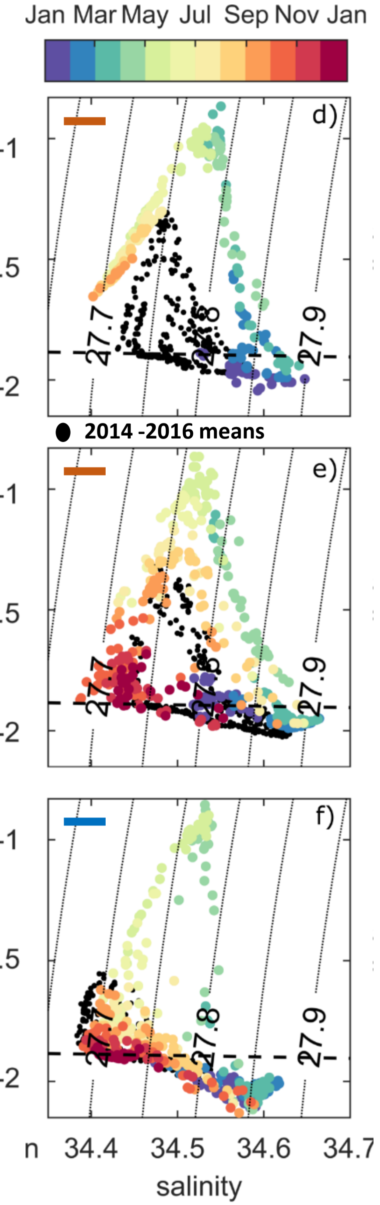
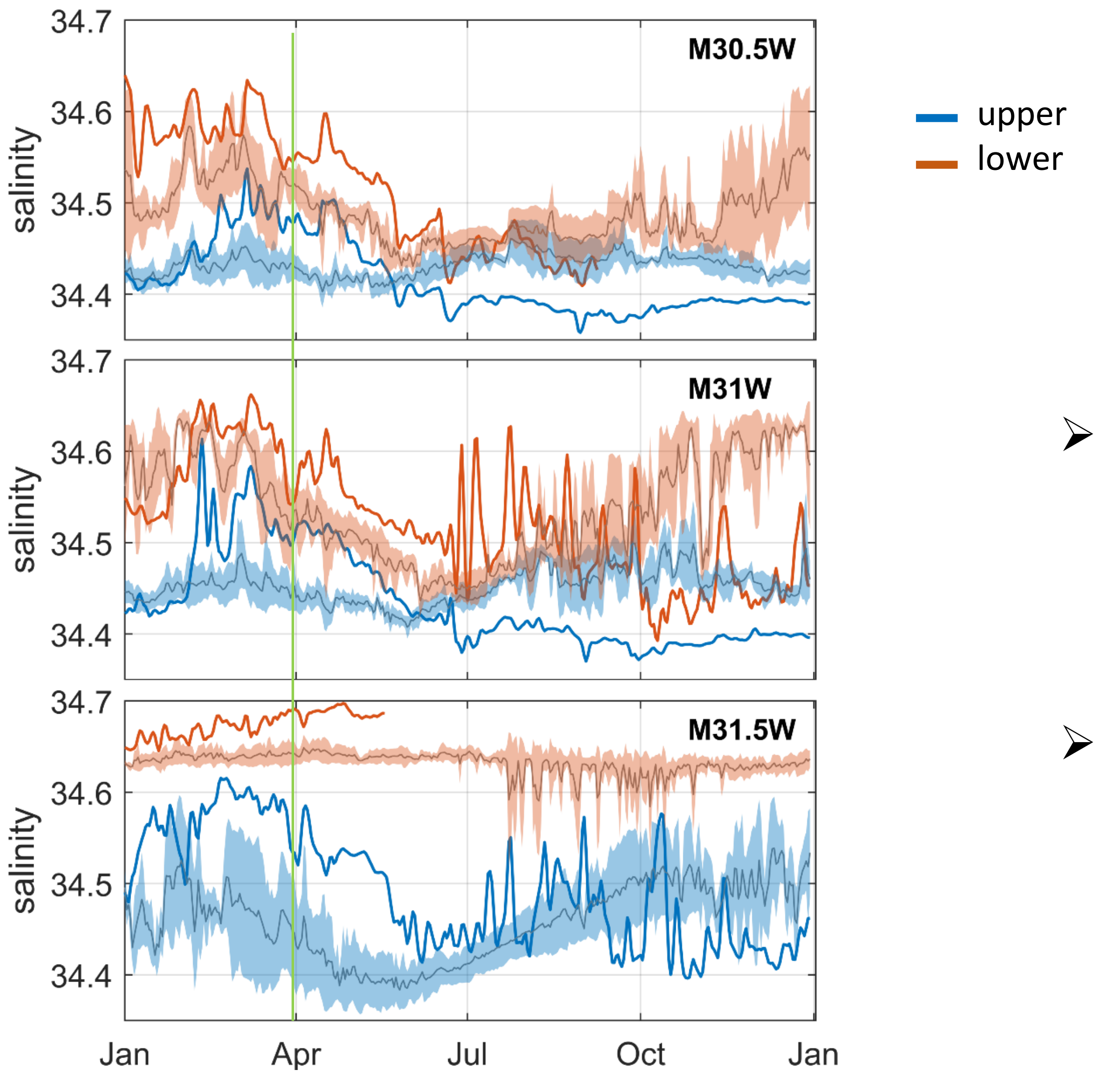
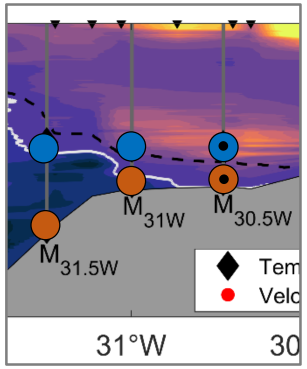
Warm Inflow at 76°S in 2017







- Denser, warmer water enters shelf → from greater depth
- Fresh anomaly during winter especially at upper sensor (380 m)

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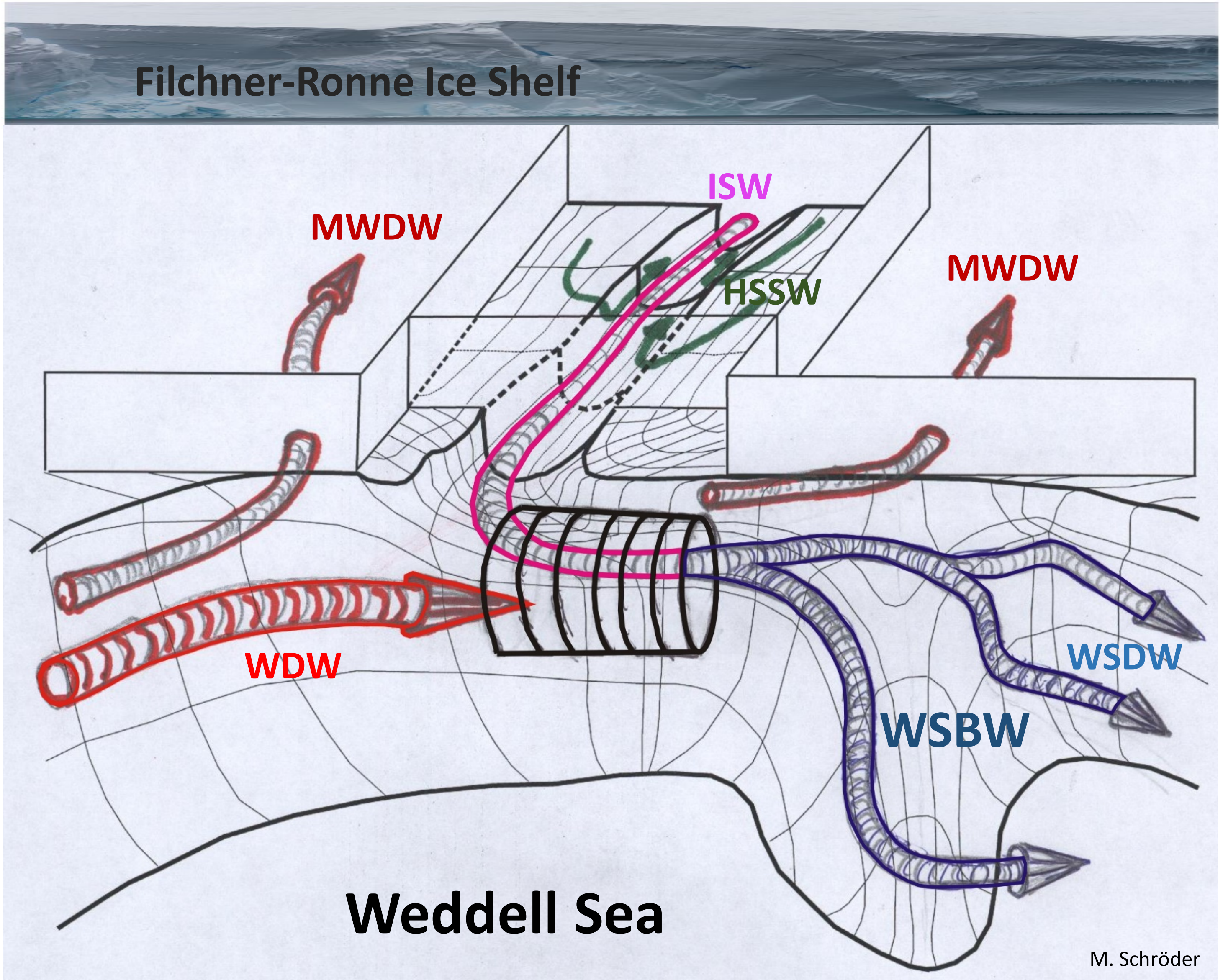
Introduction



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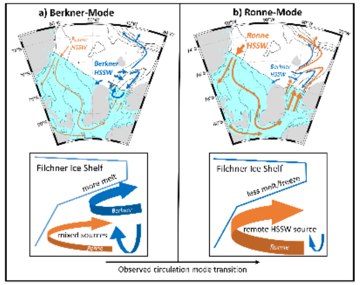
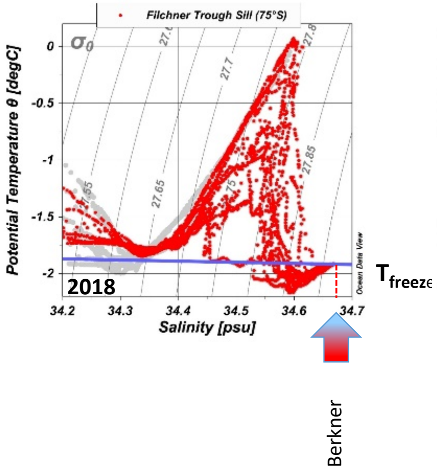
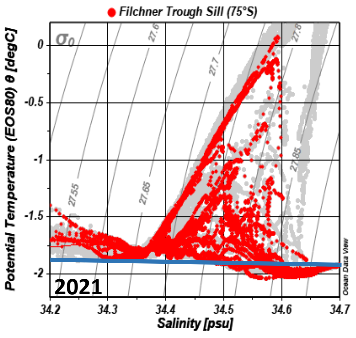
Summary

- FRIS cavity circulation has two modes contolled by the **strength of sea ice formation** in front of Ronne Ice Shelf.
- The two modes are mapped onto the strength of FIS basal melting.
  ➡ Strong **interannual variability** in patterns of basal melting.
- The two modes are mapped onto the ISW outflow in Filchner Trough
  ➡ Strong **interannual variability** in trough density structure.
  ➡ Strong **interannual variability** in ISW flow across the sill.
  ➡ Strong **interannual variability** in WSBW formation???

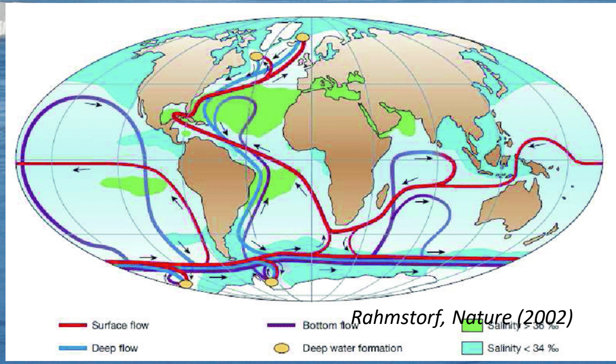
Answers will be provided by the results of the COSMUS moorings!







Antarctica‘s melt water – a global player?

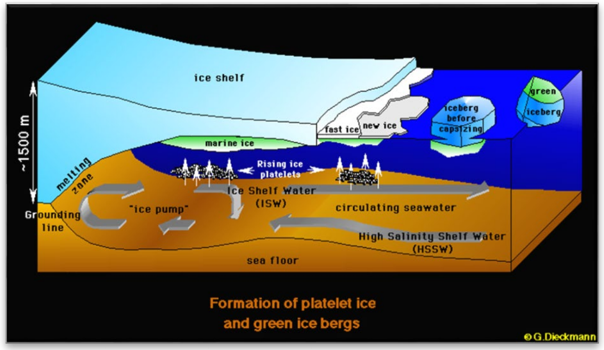


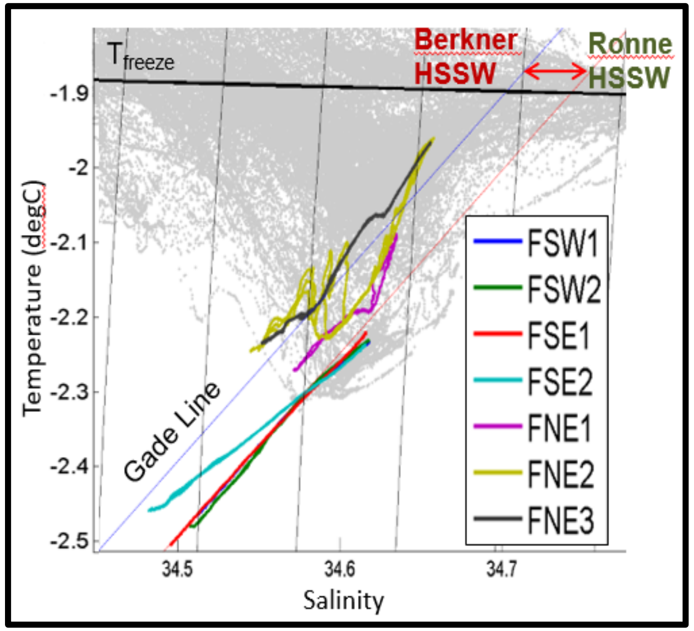
Rahmstorf, Nature (2002)

Yes!

Thank you for your attention!

Observations-Sub-Filchner





Hattermann et al, Nature Comm (2021)