Controls and consequences of rapid environmental change on the atmosphere–sea ice–ocean system in the Larsen Ice Shelf area

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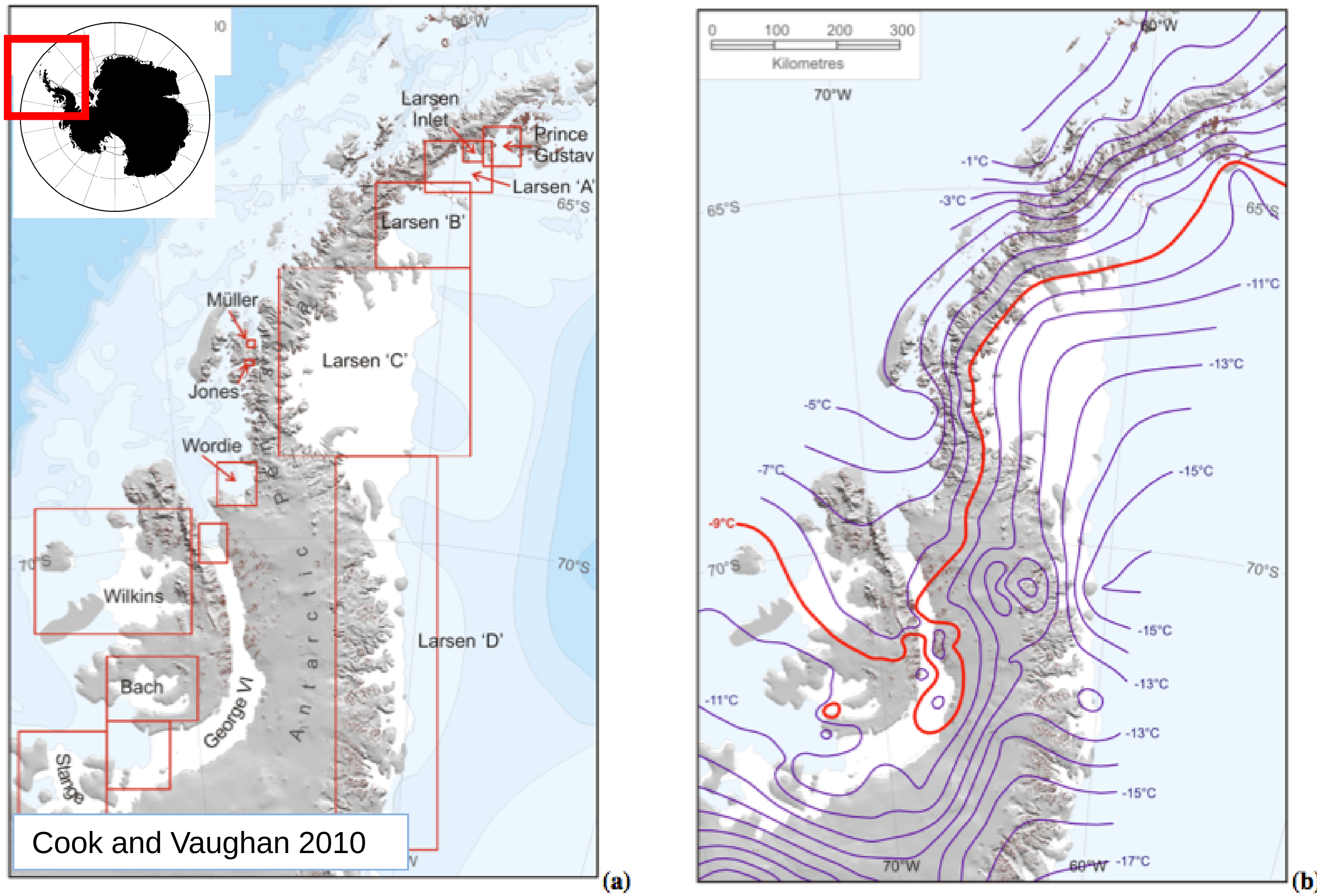
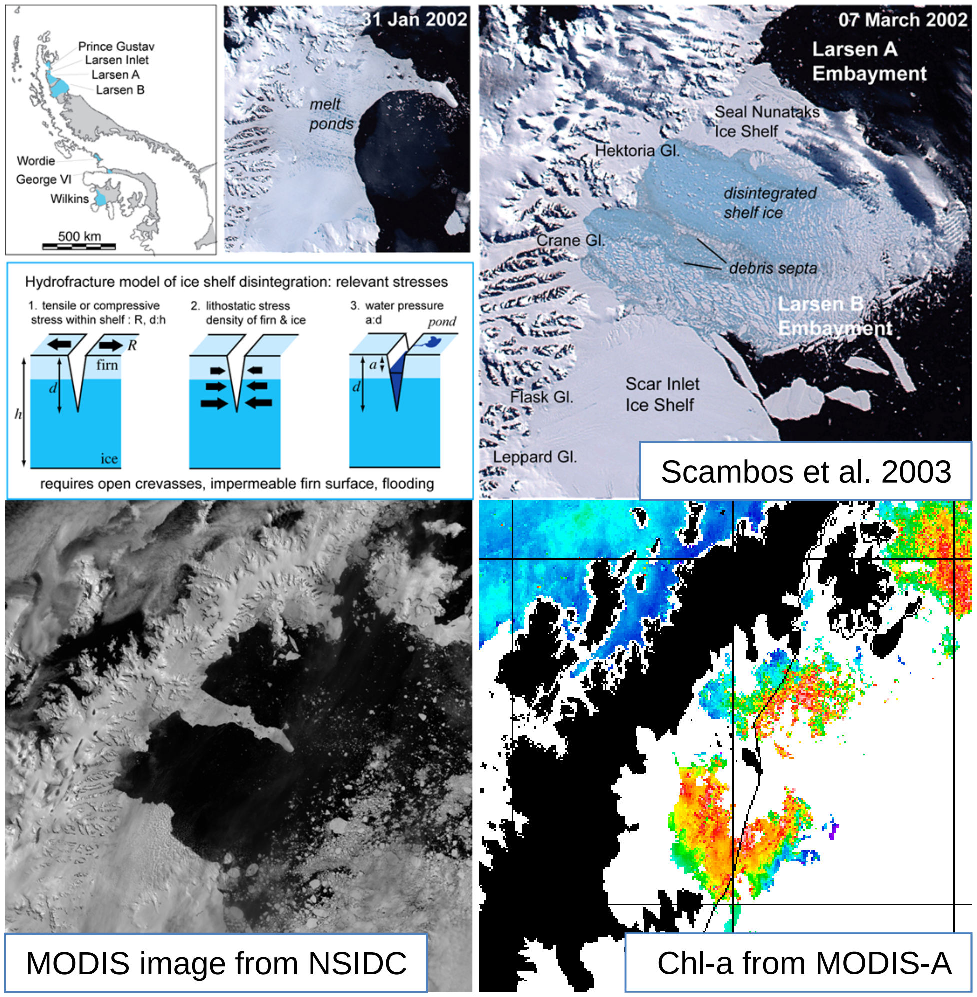
WAIS workshop, October 1, 2013

Antarctic Peninsula – physical setting



Cook and Vaughan 2010

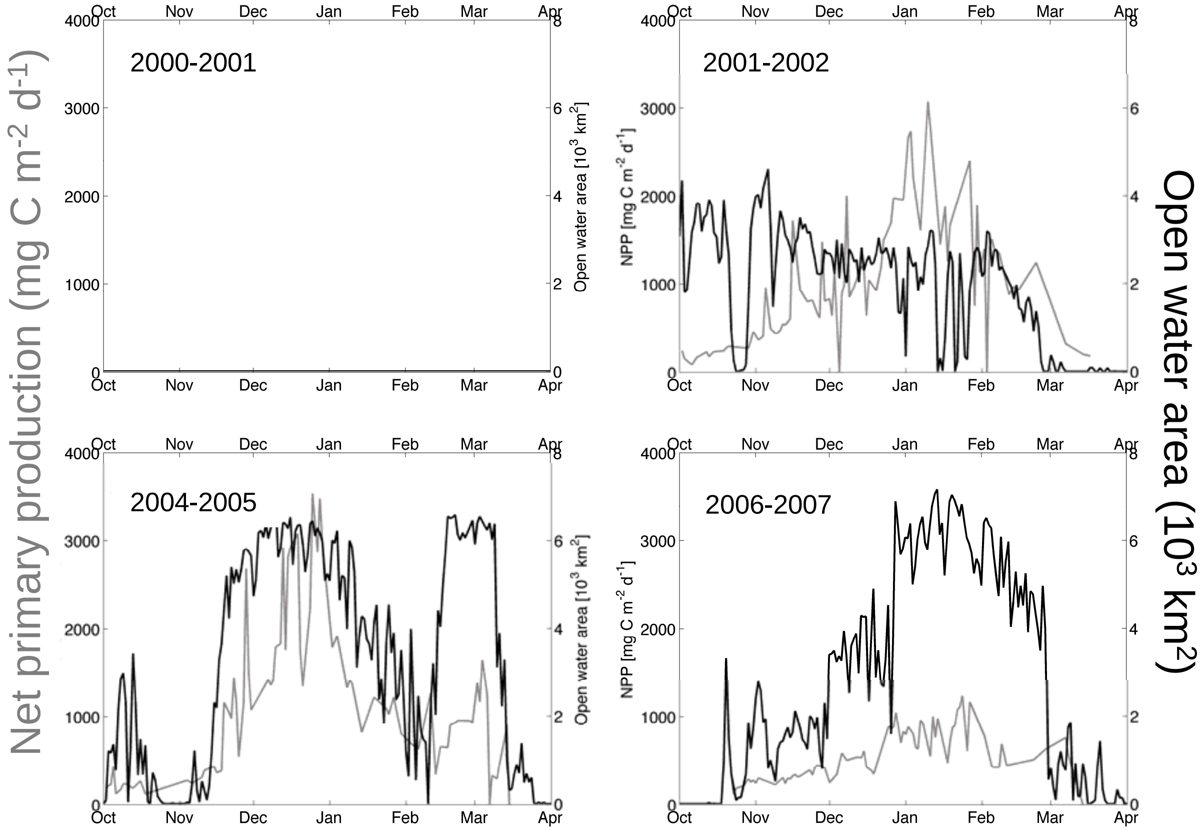
Larsen B collapse: system response



- •Gradual retreat, rapid collapse 2002 (3250km^2)
- •Disintegration attributed to large regional warming, melt (Scambos et al. 2003, van den Broeke 2005)
- •Cryosphere - ocean impacts
- •Ecosystem implications

LARISSA: Marine ecosystem response

Open water area (SSM/I, AMSR-E) and net primary production (MODIS-A, SeaWiFS), Larsen B

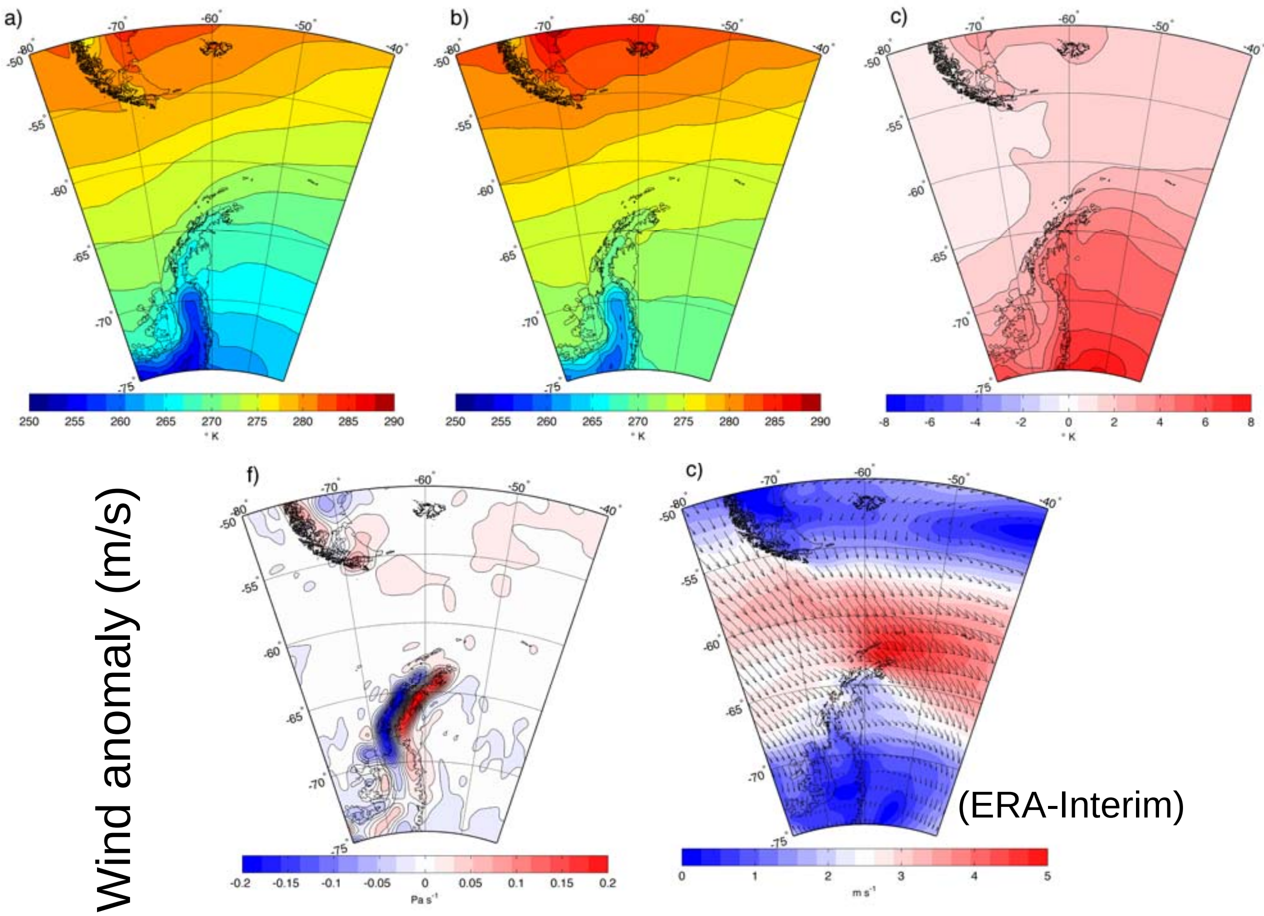


- High rates of primary production
  - Yearly rates reach 200 g C m^{-2} yr^{-1} – new hotspots
- High seasonal and inter-annual variability driven by sea ice (open water area)

Drivers of sea ice variability

Temperature (K)

Wind anomaly (m/s)

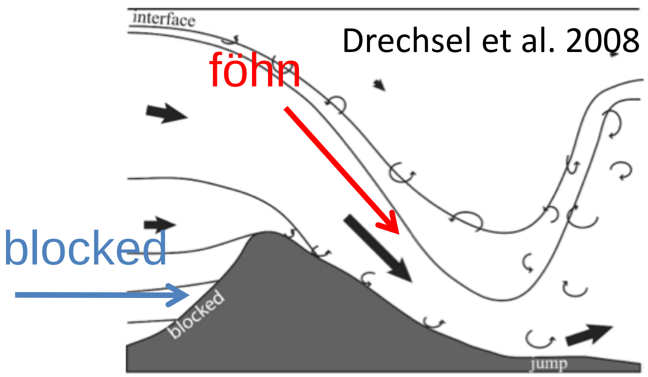


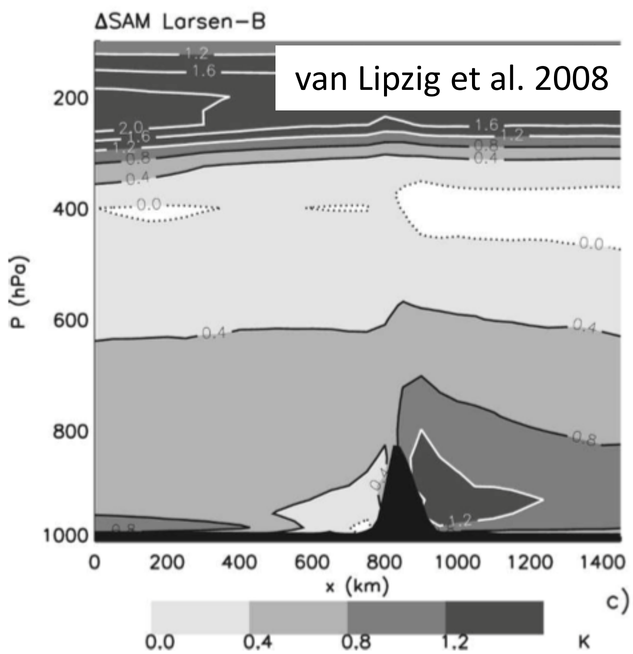
•Open water periods linked to:

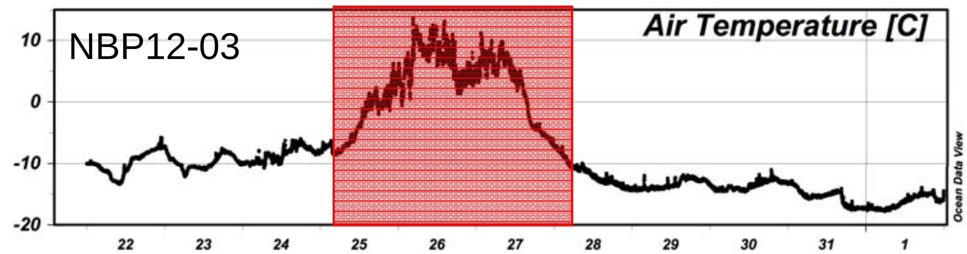
- •stronger SLP gradient
- •higher air temperature
- •enhanced cross-peninsula flow

•intensified polar westerlies, positive SAM (Marshall et al. 2006, van Lipzig et al. 2008)

Föhn mechanism



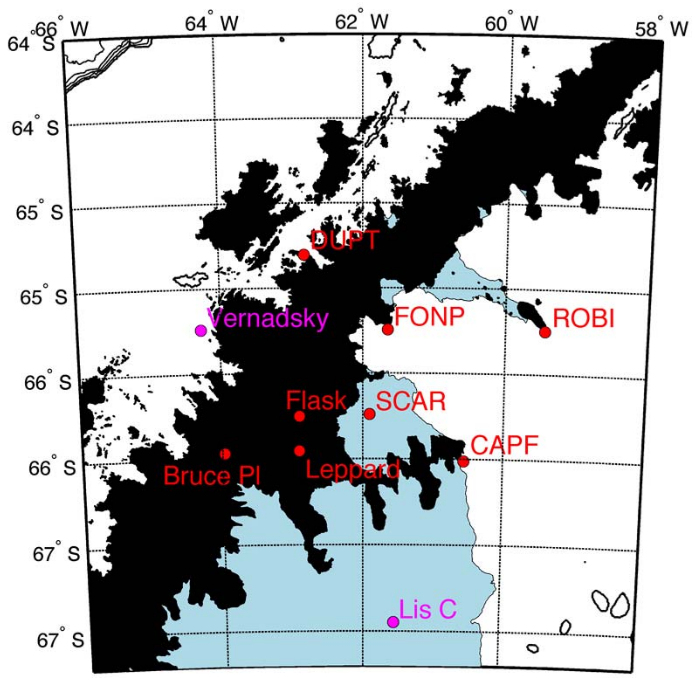


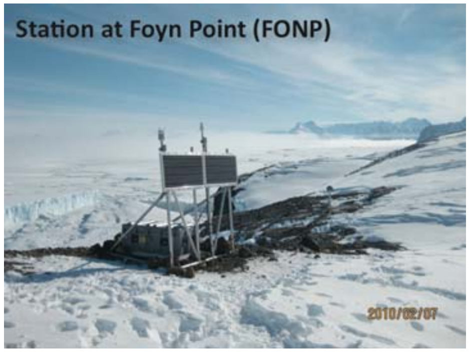


- Synoptic forcing leads to higher incidence of air flow over the peninsula
    - SAM+, stronger low-level westerlies
- Orographically induced ascent of westerlies -> advection of warm, dry air to the surface on the leeward side
- Föhn events persistent over days – weeks

Föhn detection

Map of ground station locations

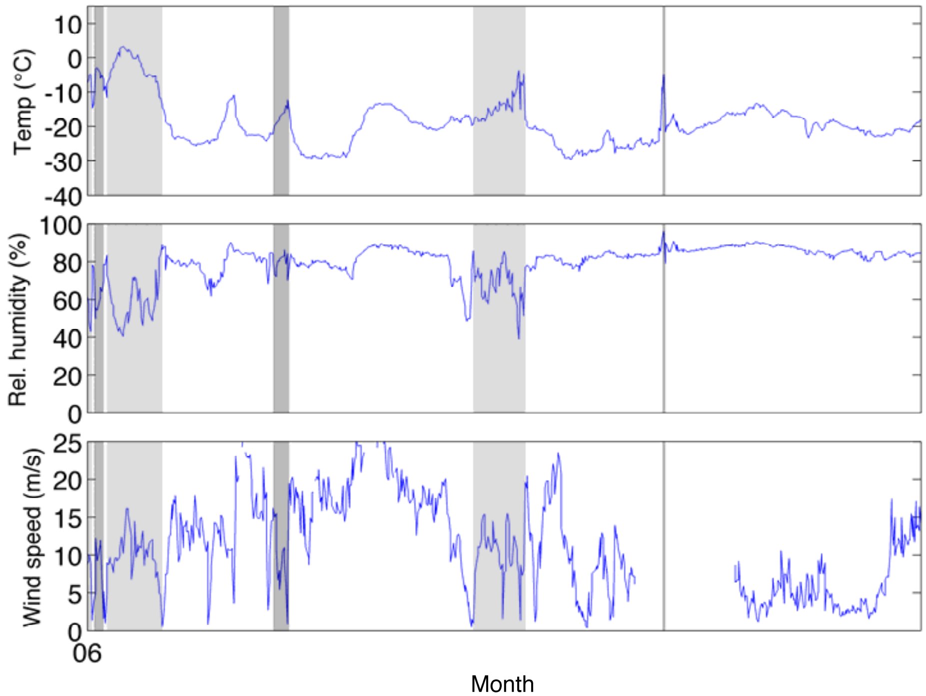




- Following Speirs et al. 2010, others
  - Warming >= 1 ºC / hour
  - Decrease RH >= 5 % / hour
  - Wind speed > 5 m/s
  - Wind direction from W
- Föhn day recorded for events lasting 6 hours or more

Föhn variability

Met observations from Robertson Island with föhn events highlighted (June 2010)



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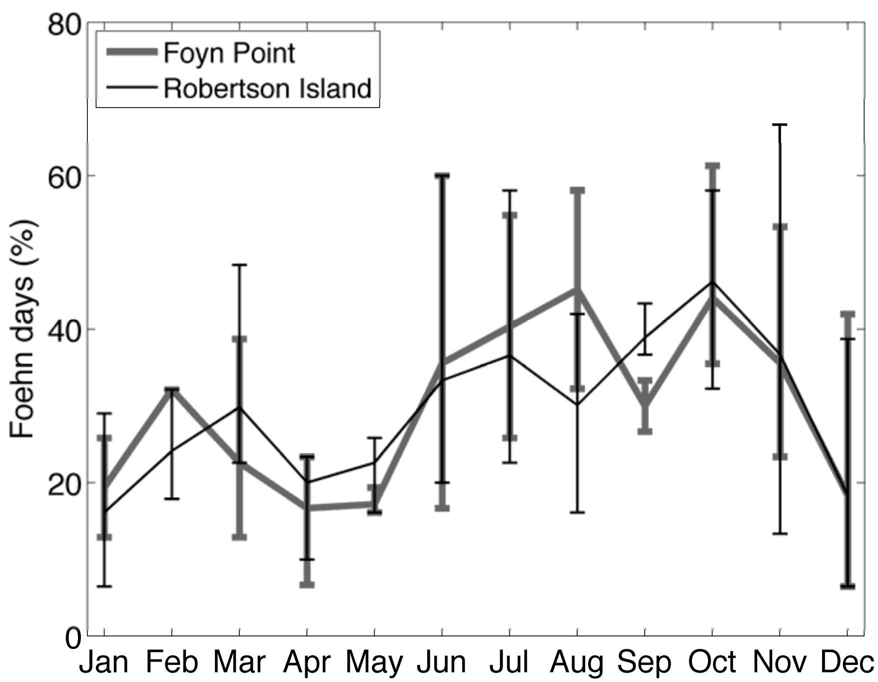
Föhn variability

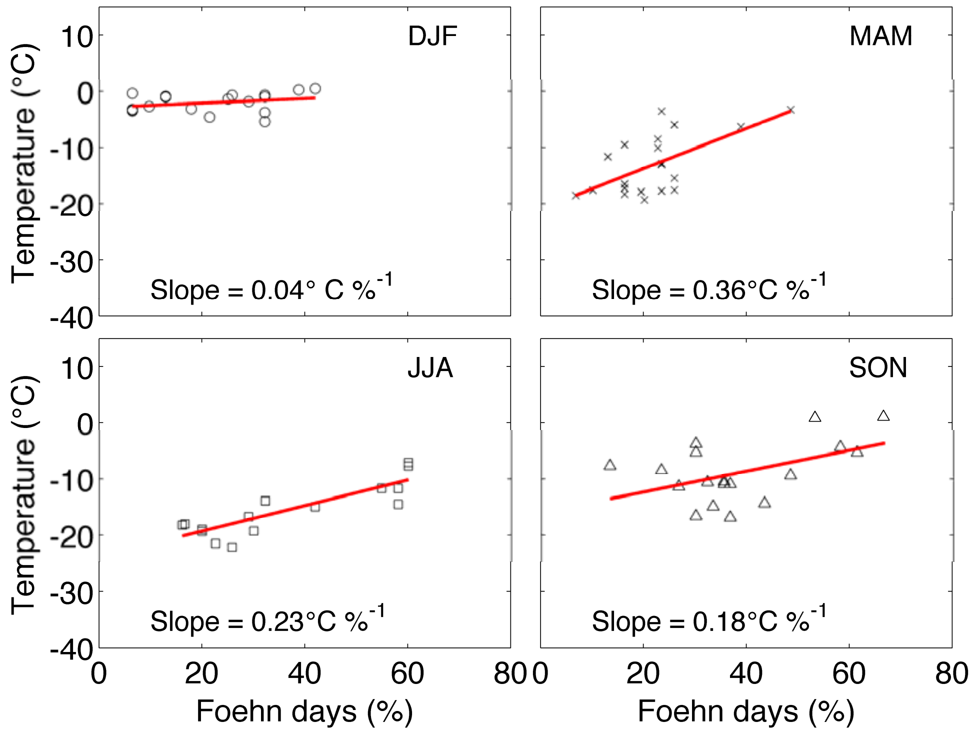
Mean seasonal cycle of föhn days (Jan 2010- Apr 2013) – min, mean, max



- Föhn winds frequently seen in the Larsen B embayment

- Large seasonal and inter-annual variability in wind frequency and duration

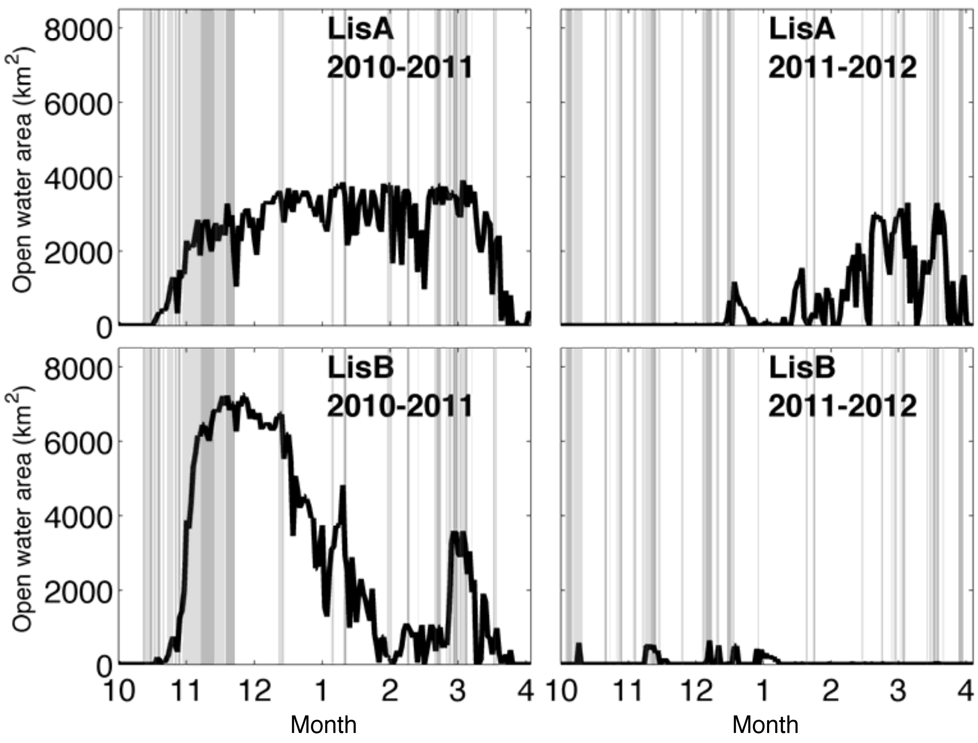
Föhn effect on temperature regime



•Higher frequency of föhn winds impact mean regional temperature

•Weakest response in the summer

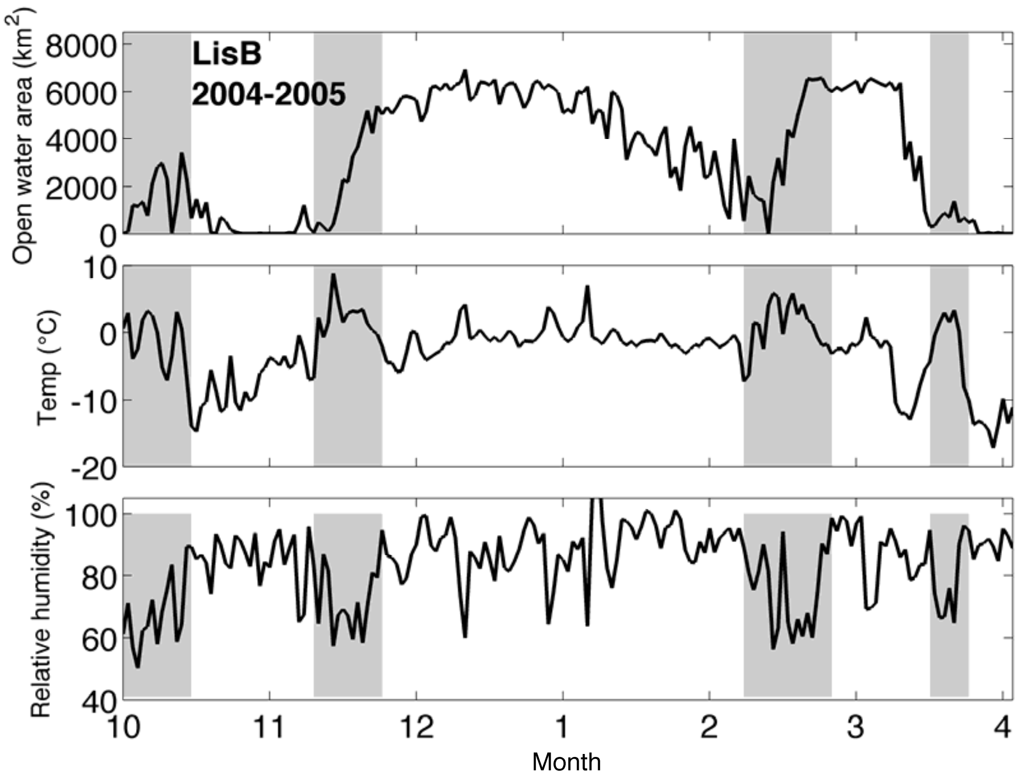
Larsen embayments as polynyas



•Opening of Larsen A, B tied to intensity, frequency of föhn winds

•Larsen B shows rapid response to wind dynamics

Larsen embayments as polynyas



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Föhn forcing and climate

- Positive SAM associated with:
  - Increased percentage of föhn days in the spring
  - Higher mean temperature in the summer

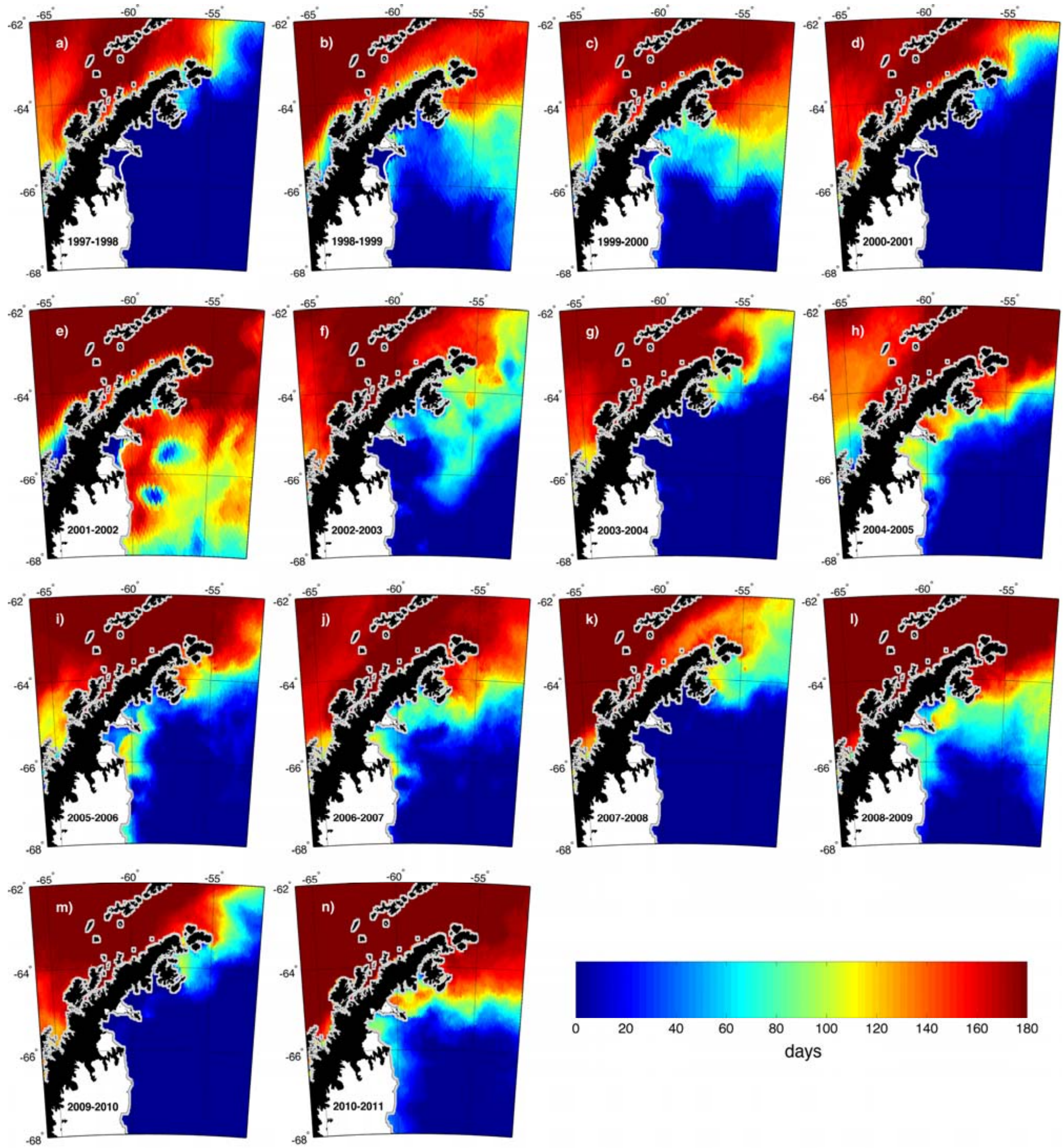
Observation	Season	Nino3.4 (rho)	SAM (rho)
Föhn Days (%)	**DJF**	0.04	0.38
	MAM	0.26	0.27
	JJA	-0.74	0.33
	SON	-0.54	**0.71**
Mean temp (ºC)	**DJF**	-0.5	**0.9**
	MAM	-0.08	-0.12
	JJA	-0.57	0.58
	SON	-0.57	0.45

- Spring: opening of the embayments
- Summer: persistence of open water conditions

Conclusions

- Larsen embayments are hotspots of production – sometimes
- Production constrained by sea ice dynamics
- Sea ice (open water) dynamics function of synoptic circulation, regional effects (föhn)
  - Links to climate (SAM) – spring and summer
- Atmospheric forcing on cryosphere impacts marine ecosystem

Thank you!



a)
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b)
1998-1999
c)
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2010-2011
-65°
-60°
-55°
-62°
-64°
-66°
-68°
0
20
40
60
80
100
120
140
160
180
days