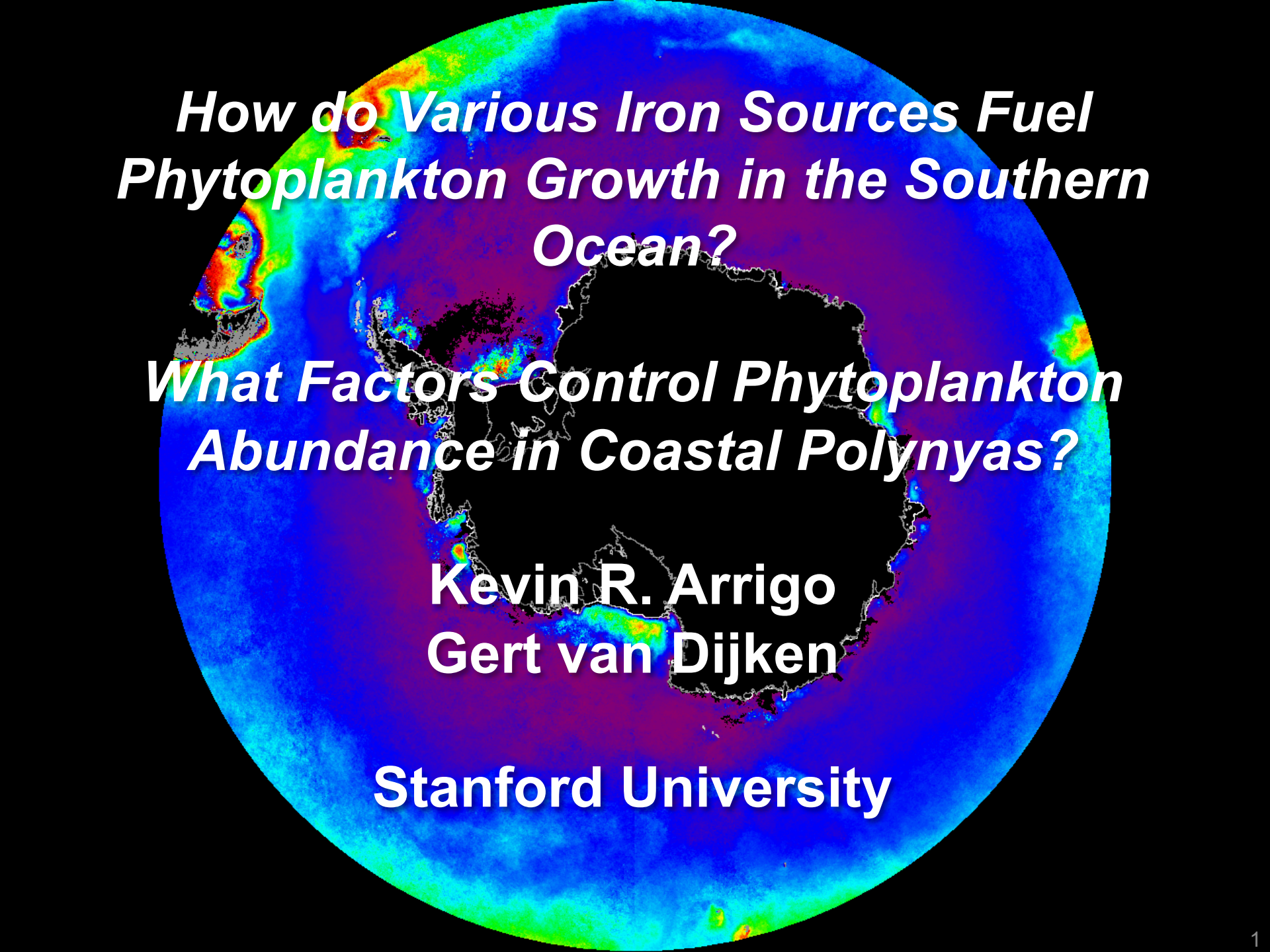


How do Various Iron Sources Fuel Phytoplankton Growth in the Southern Ocean?

What Factors Control Phytoplankton Abundance in Coastal Polynyas?

Kevin R. Arrigo
Gert van Dijken

Stanford University

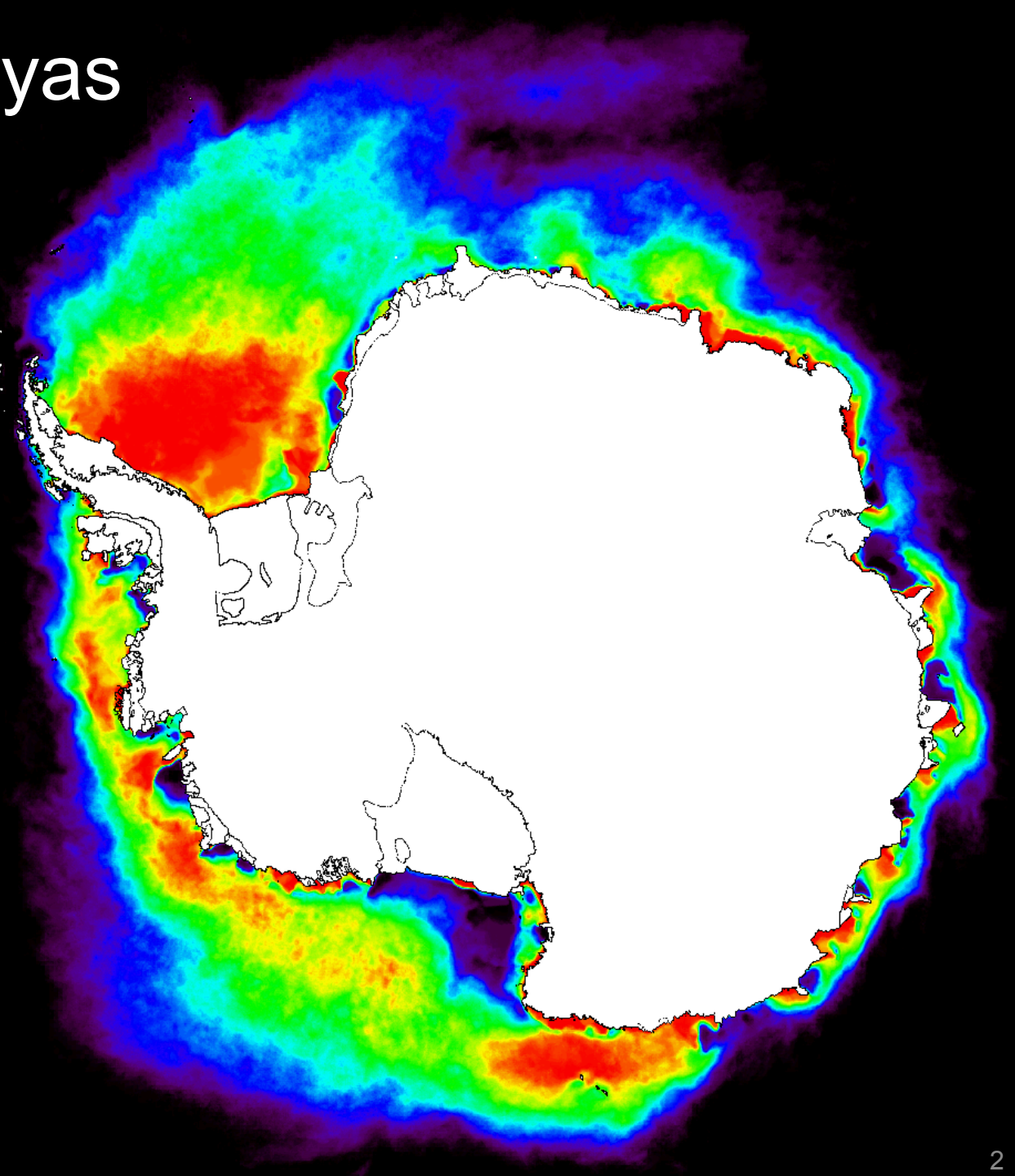
Antarctic polynyas

Areas of open water surrounded by sea ice

Can be identified with SSM/I satellite data

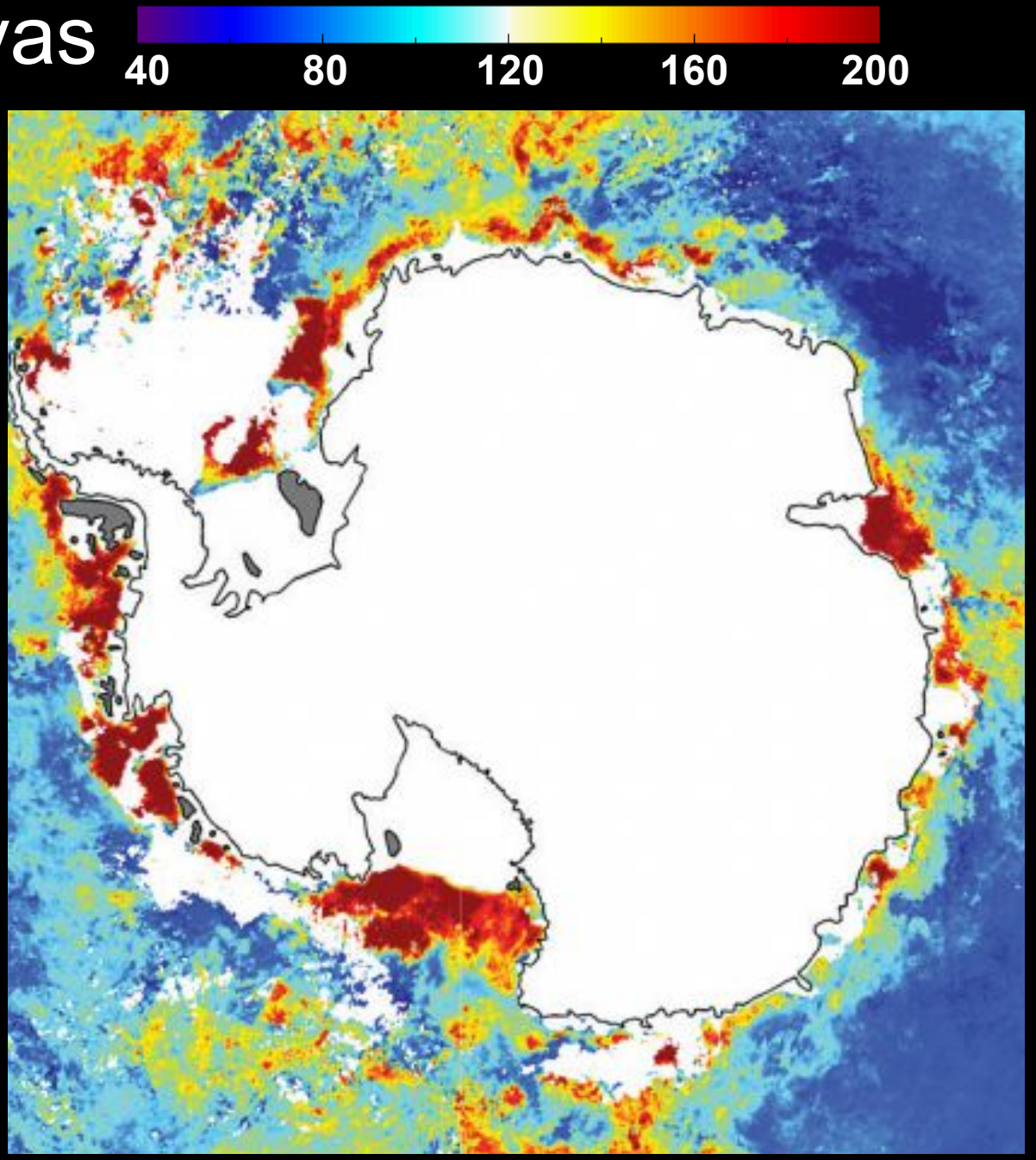
Based on days of ice cover
- Red = Max
- Blue = Min

Polynyas are blue areas near coast



Antarctic polynyas

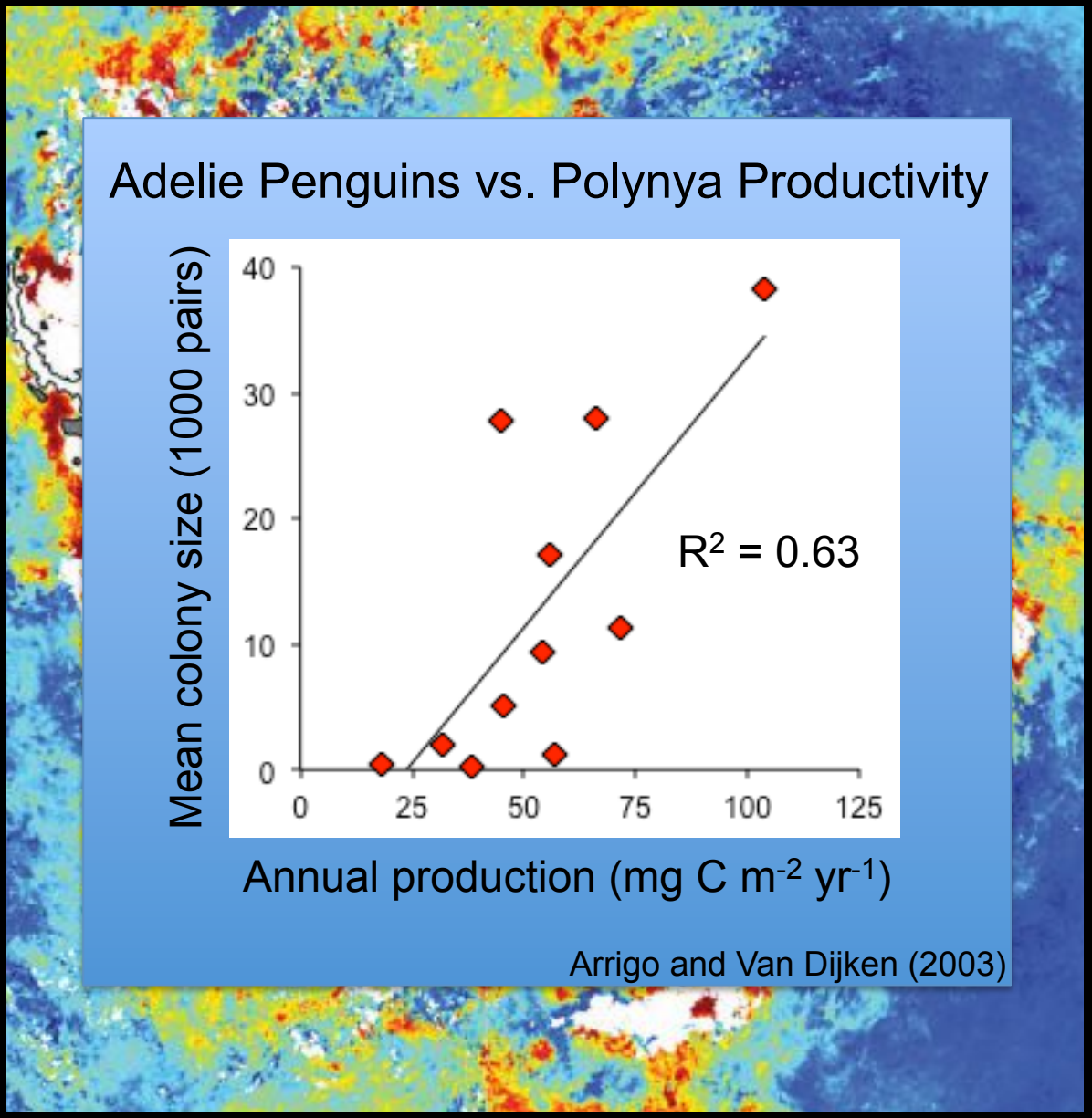
Hot spots of primary production (g C m^{-2} yr^{-1})



Antarctic polynyas

Hot spots of primary production (g C m^{-2} yr^{-1})

Can support high densities of marine mammals and birds



Antarctic polynyas

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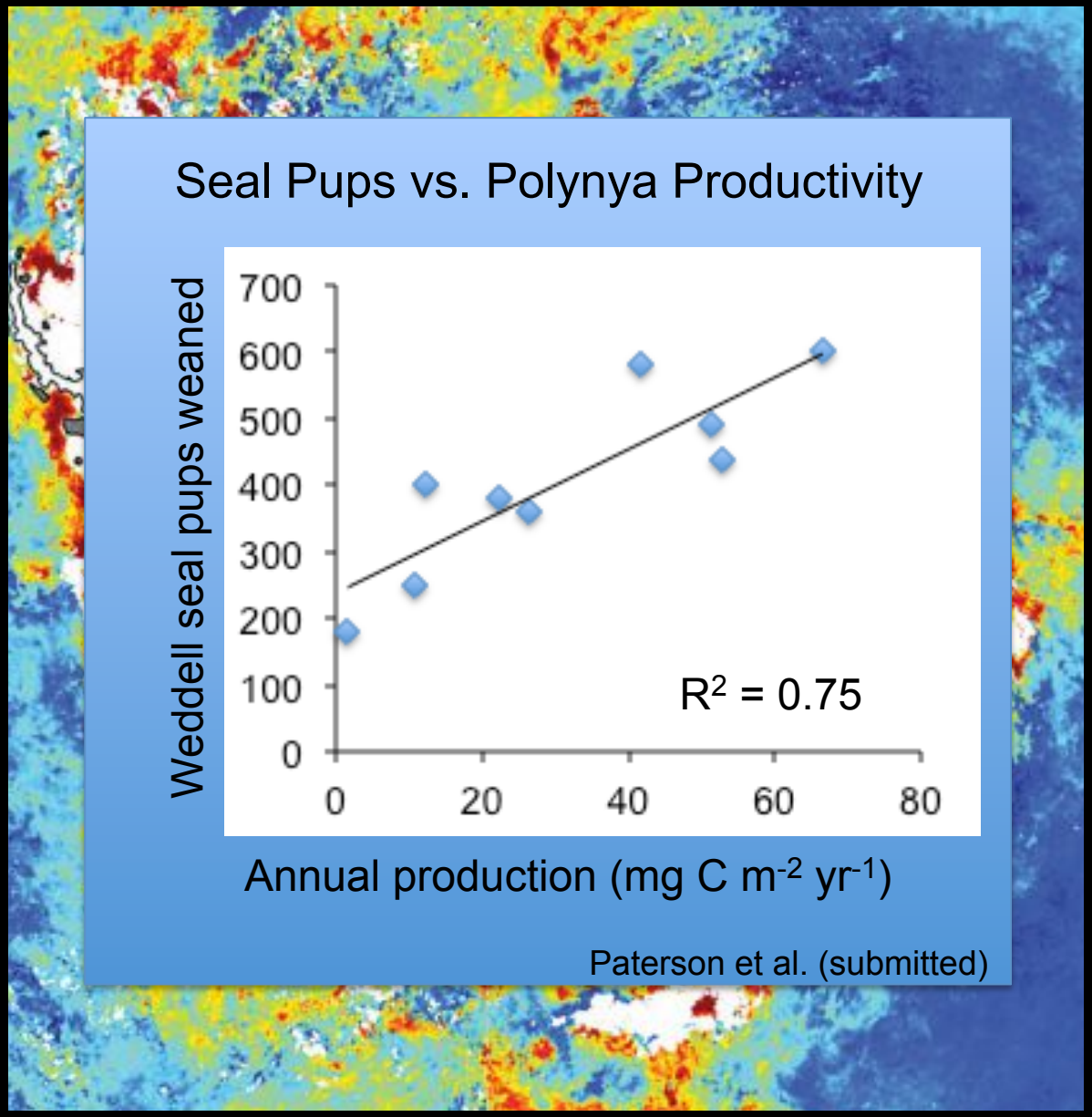
Can support high densities of marine mammals and birds

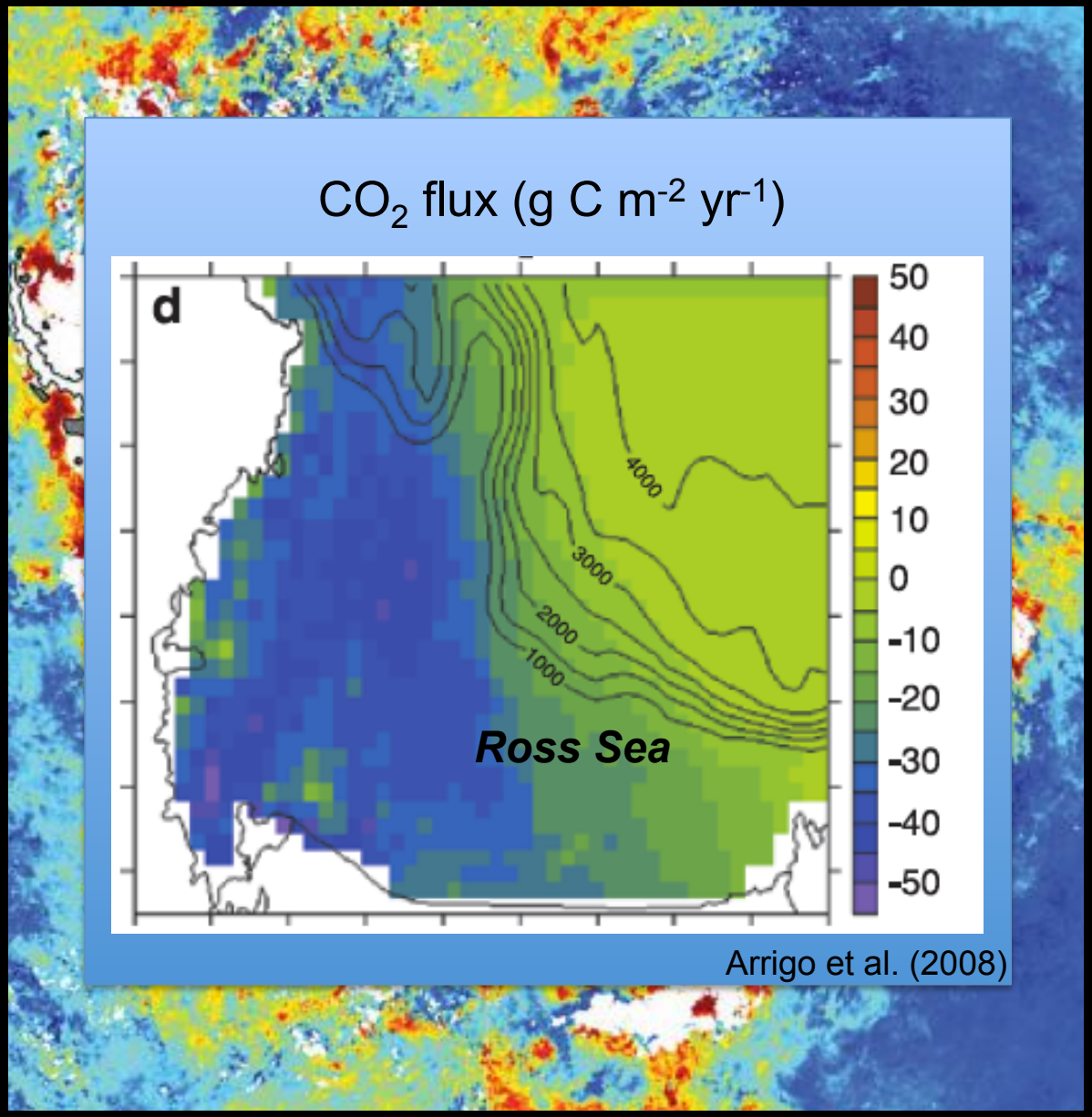


Antarctic polynyas

Hot spots of primary production (g C m^{-2} yr^{-1})

Can support high densities of marine mammals and birds

Large sinks for atmospheric CO_2



Question:

What factors control phytoplankton abundance in Antarctic coastal polynyas?

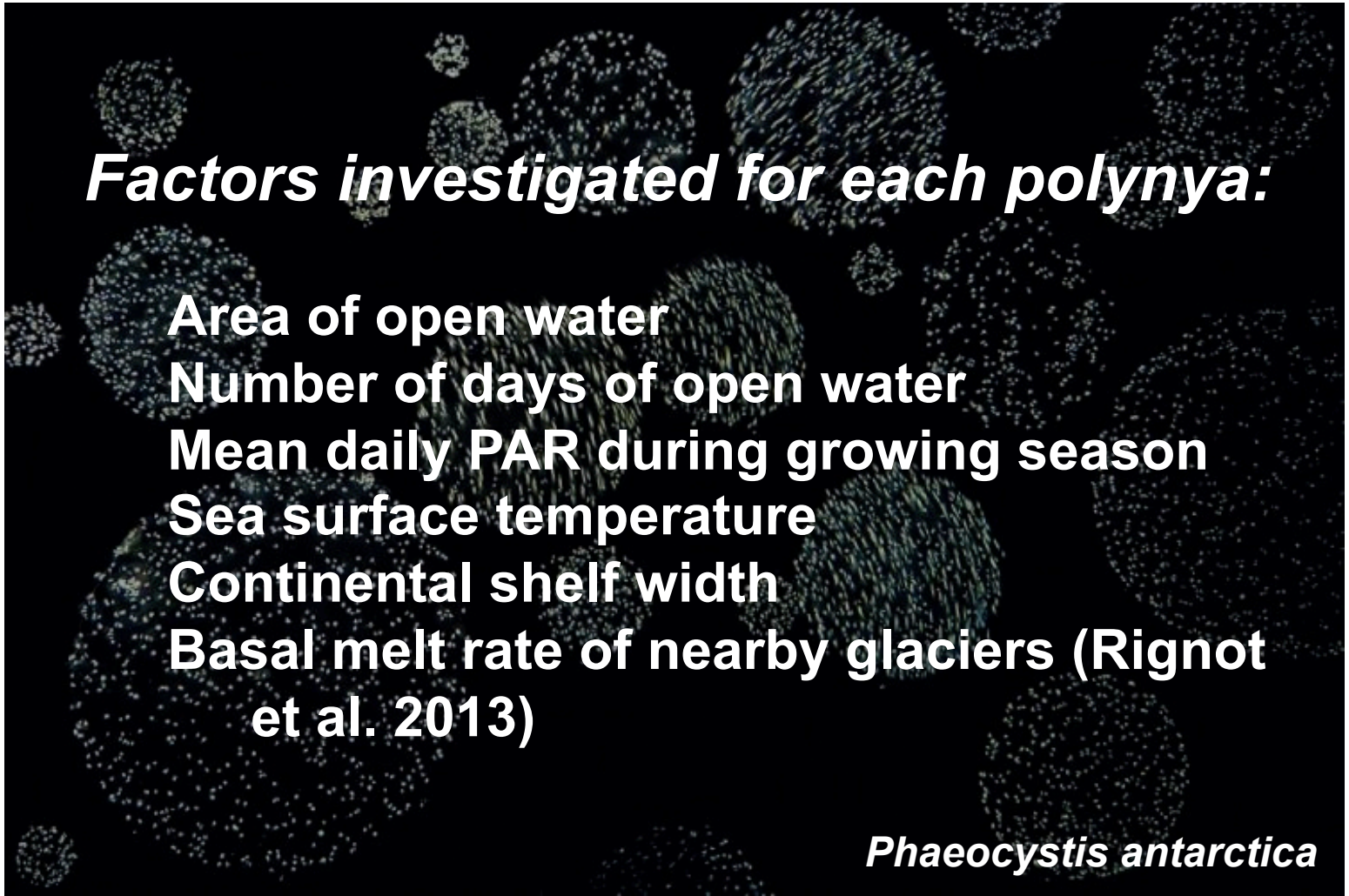
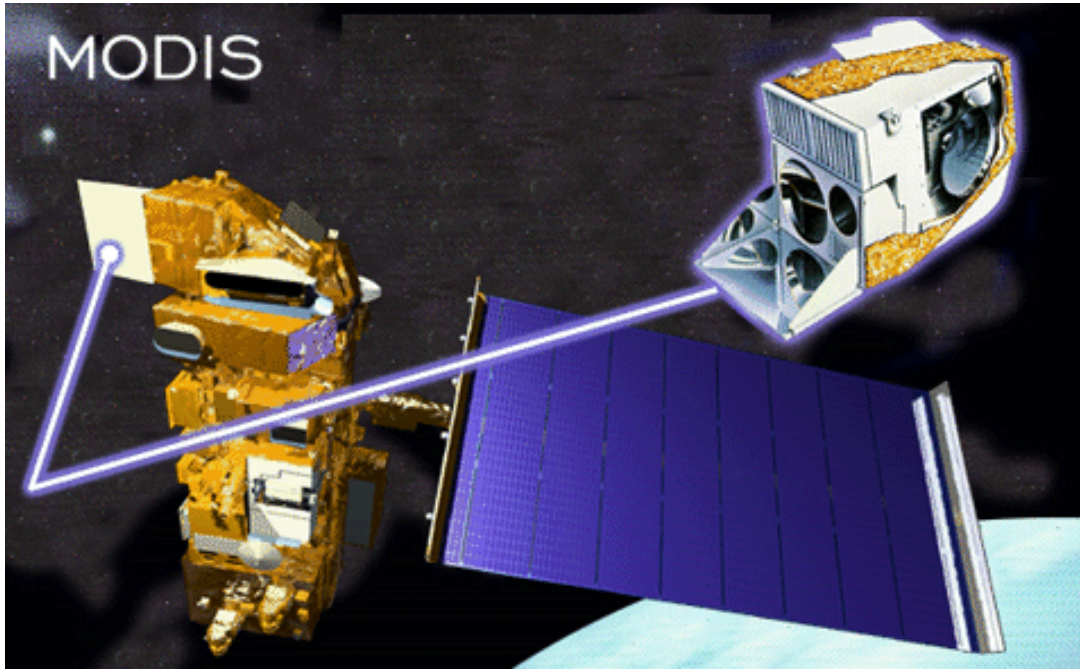
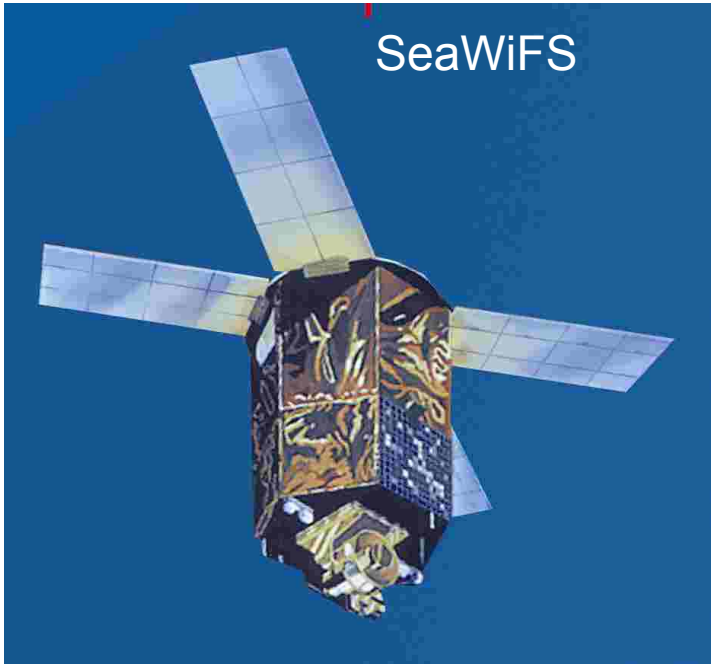


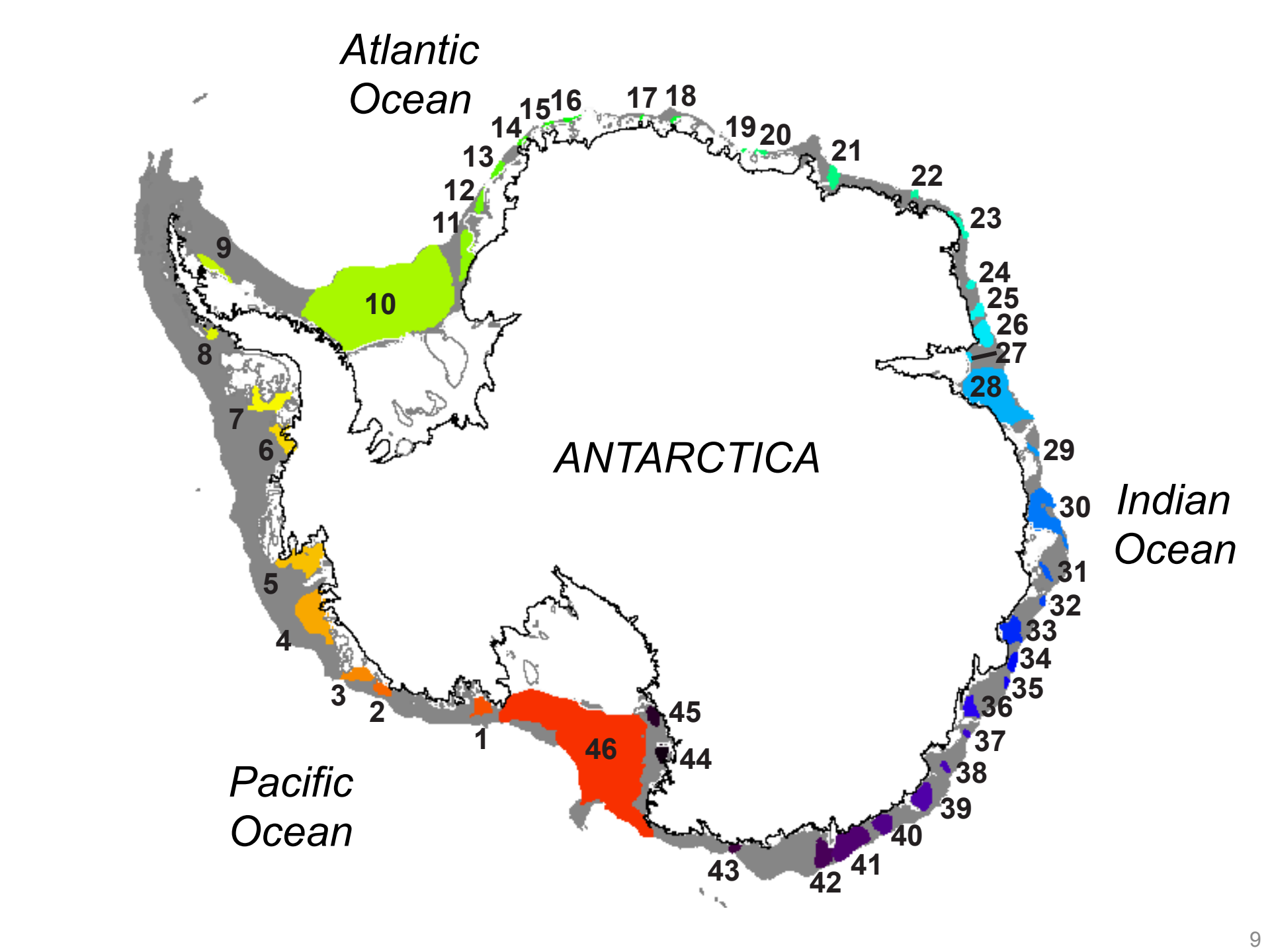
Photo:
John Weller

Approach





For 1998-2013:
Used satellite data to identify polynyas, track changes in sea ice, measure SST and chlorophyll *a* concentration, and calculate primary production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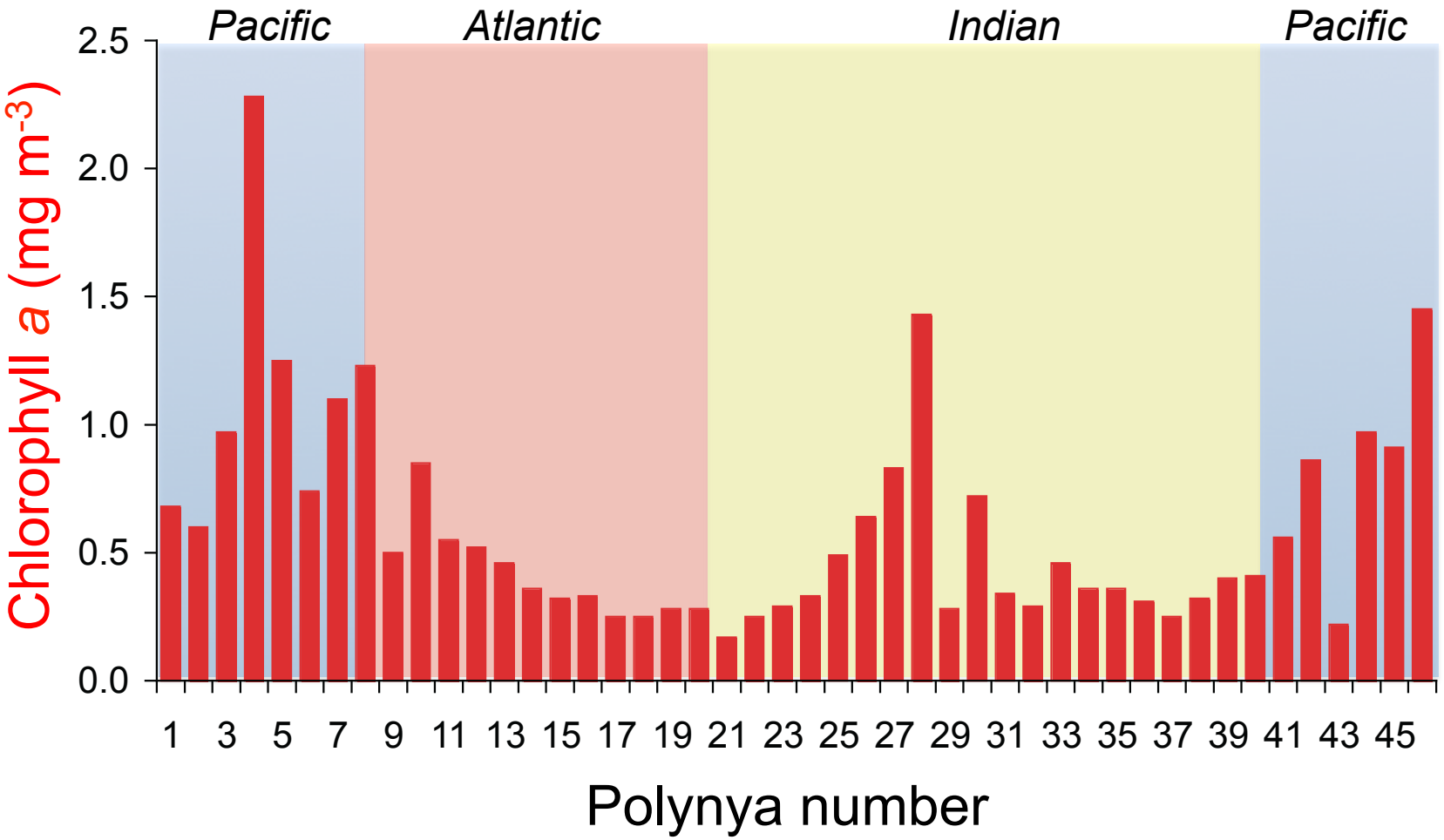
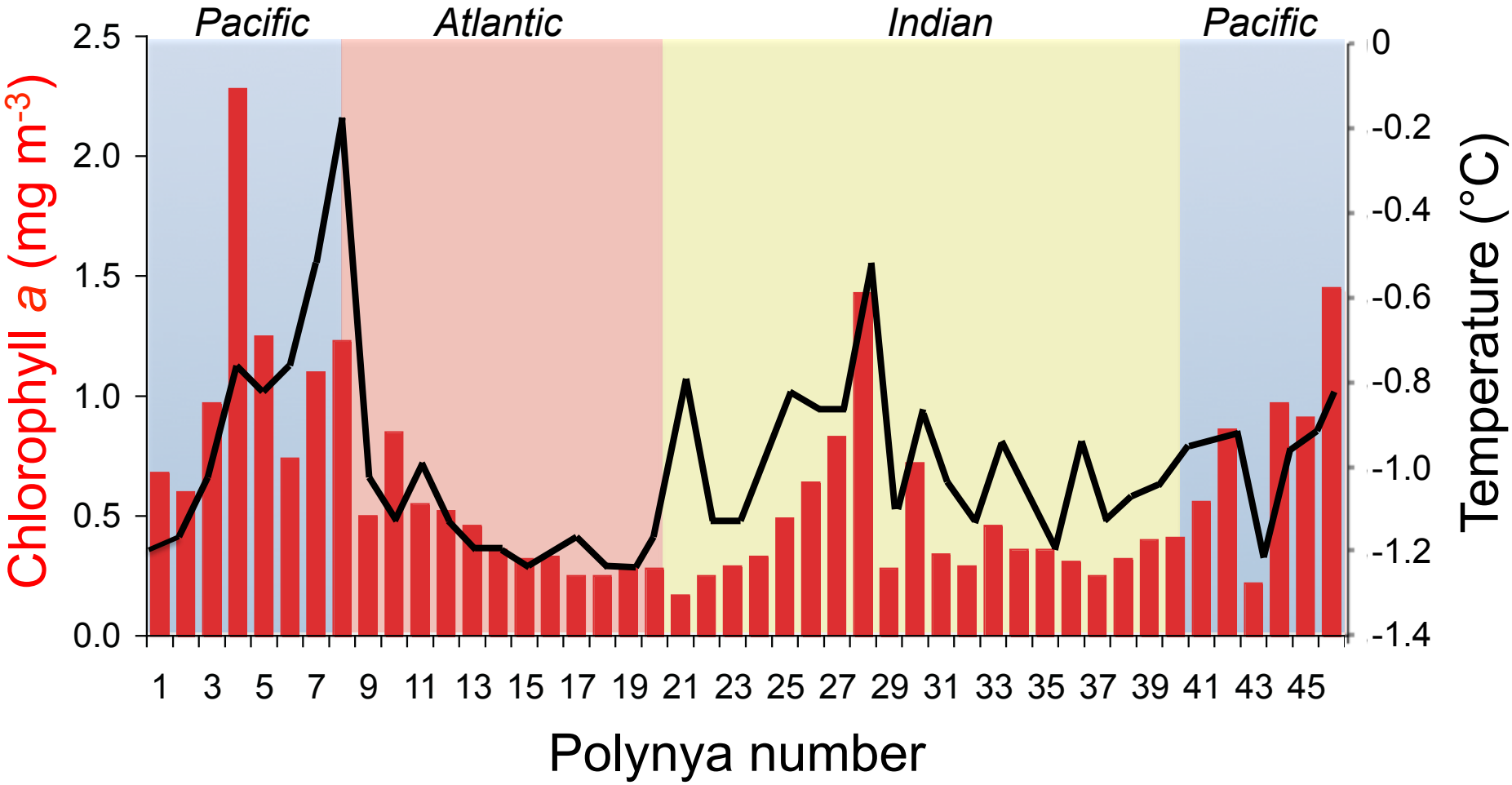
Annual mean phytoplankton abundance in 46 coastal polynyas



Annual mean phytoplankton abundance in 46 coastal polynyas

- Related to annual mean sea surface temperature
- Warmer temperatures promote higher Chl *a*
- Strongest relationship in Atlantic sector



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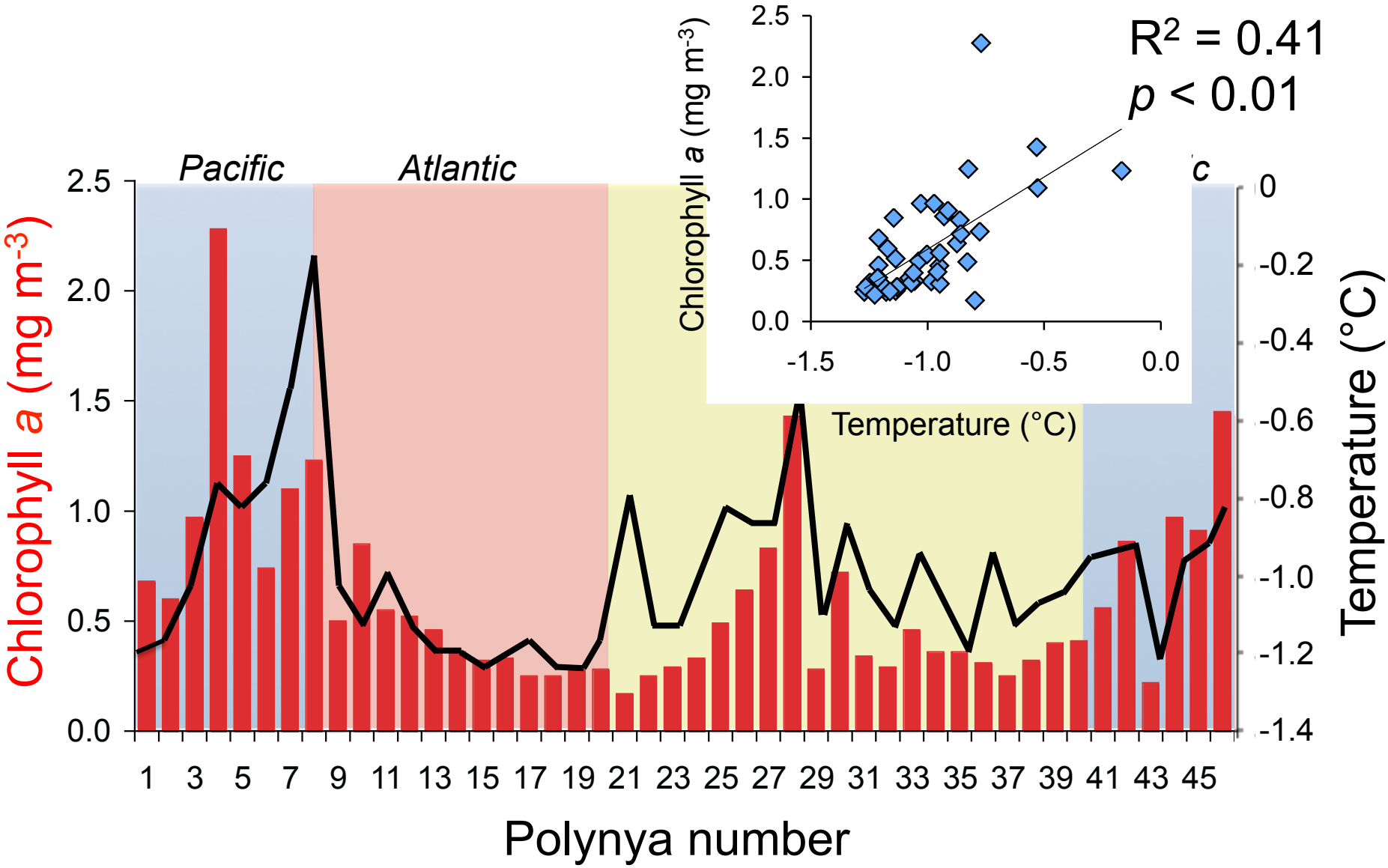
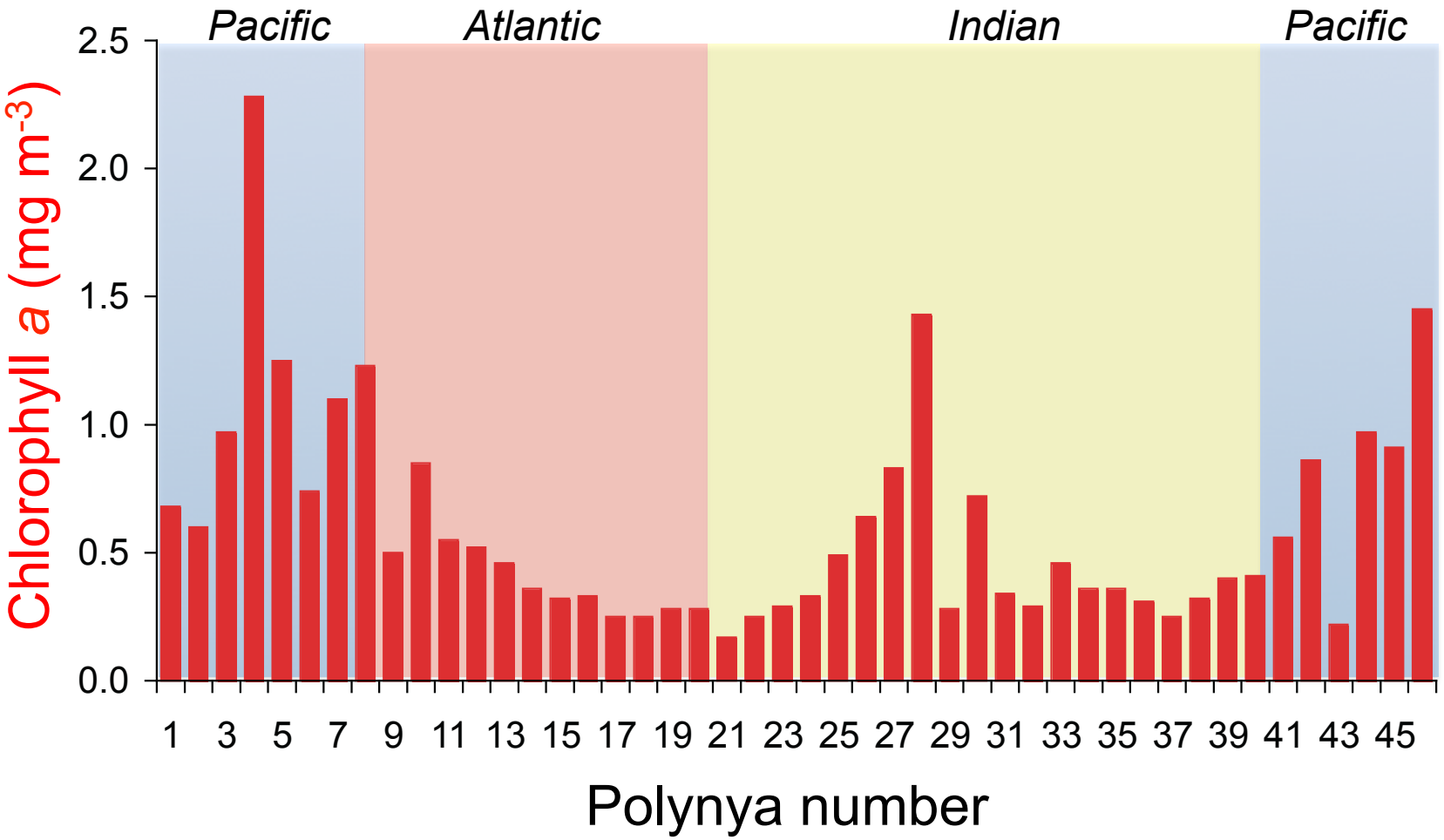
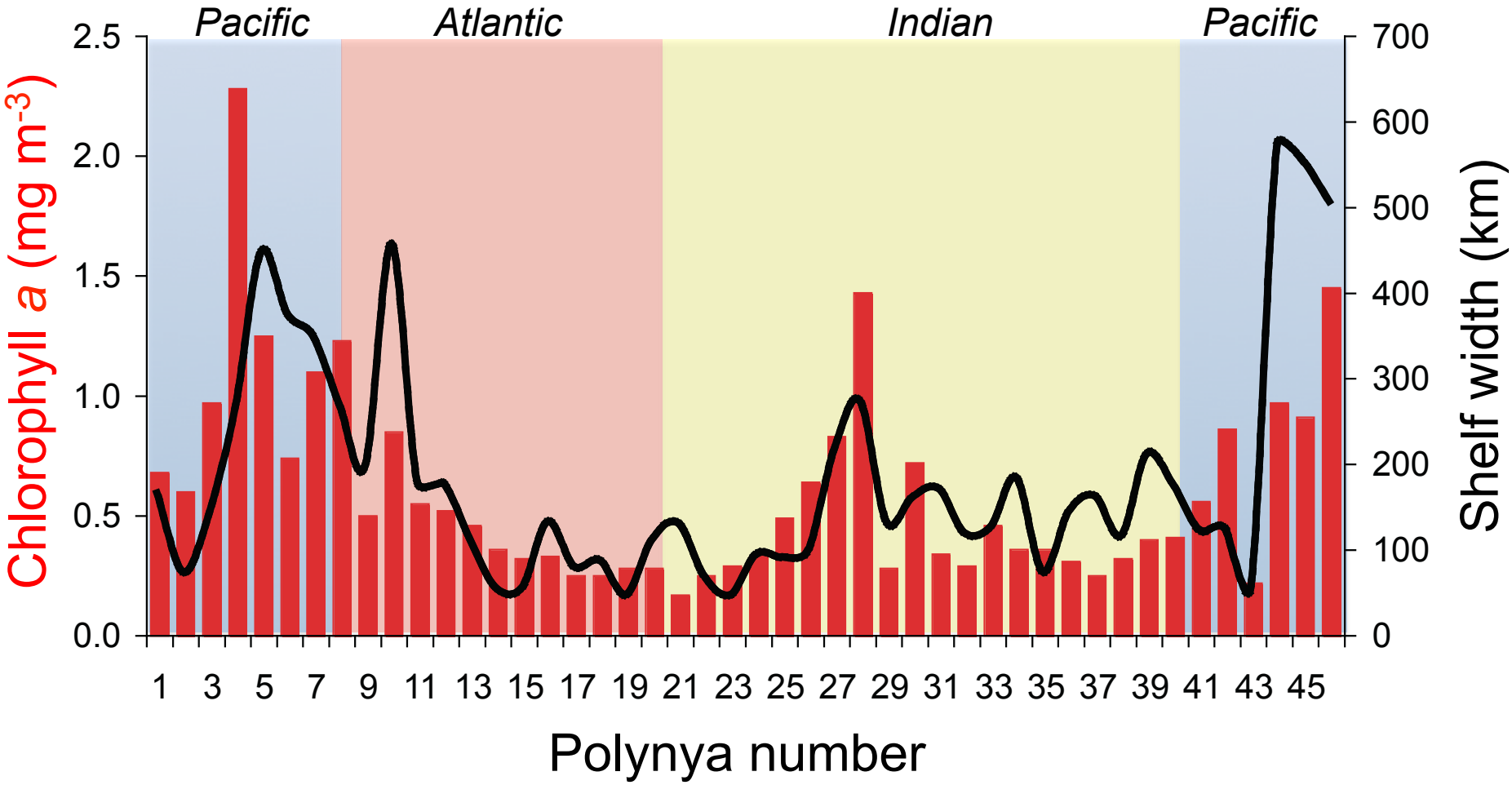


What other factors control phytoplankton abundance in coastal polynyas?



What other factors control phytoplankton abundance in coastal polynyas?

- Related to width of local continental shelf
- Relationship about equally strong in all sectors



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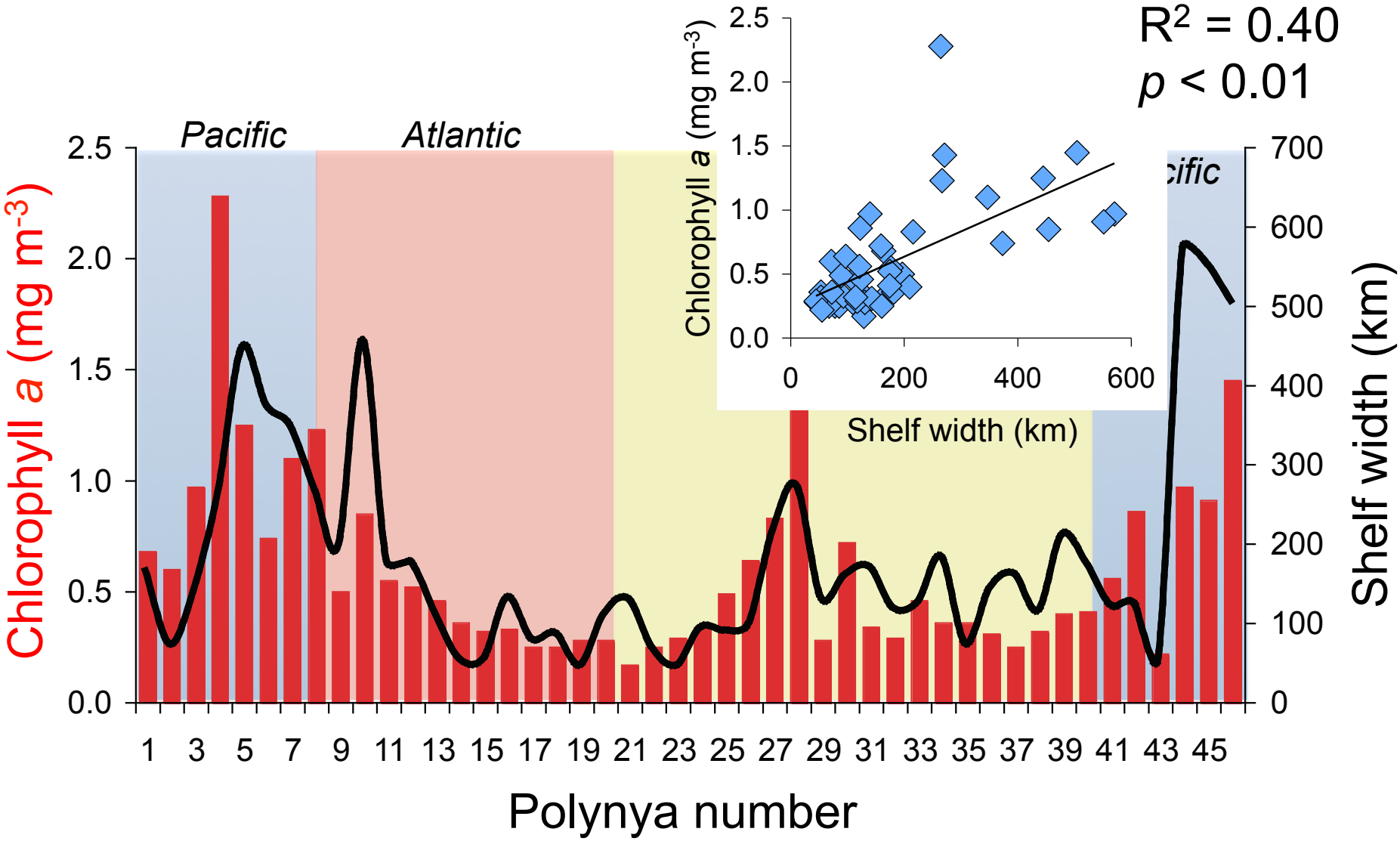
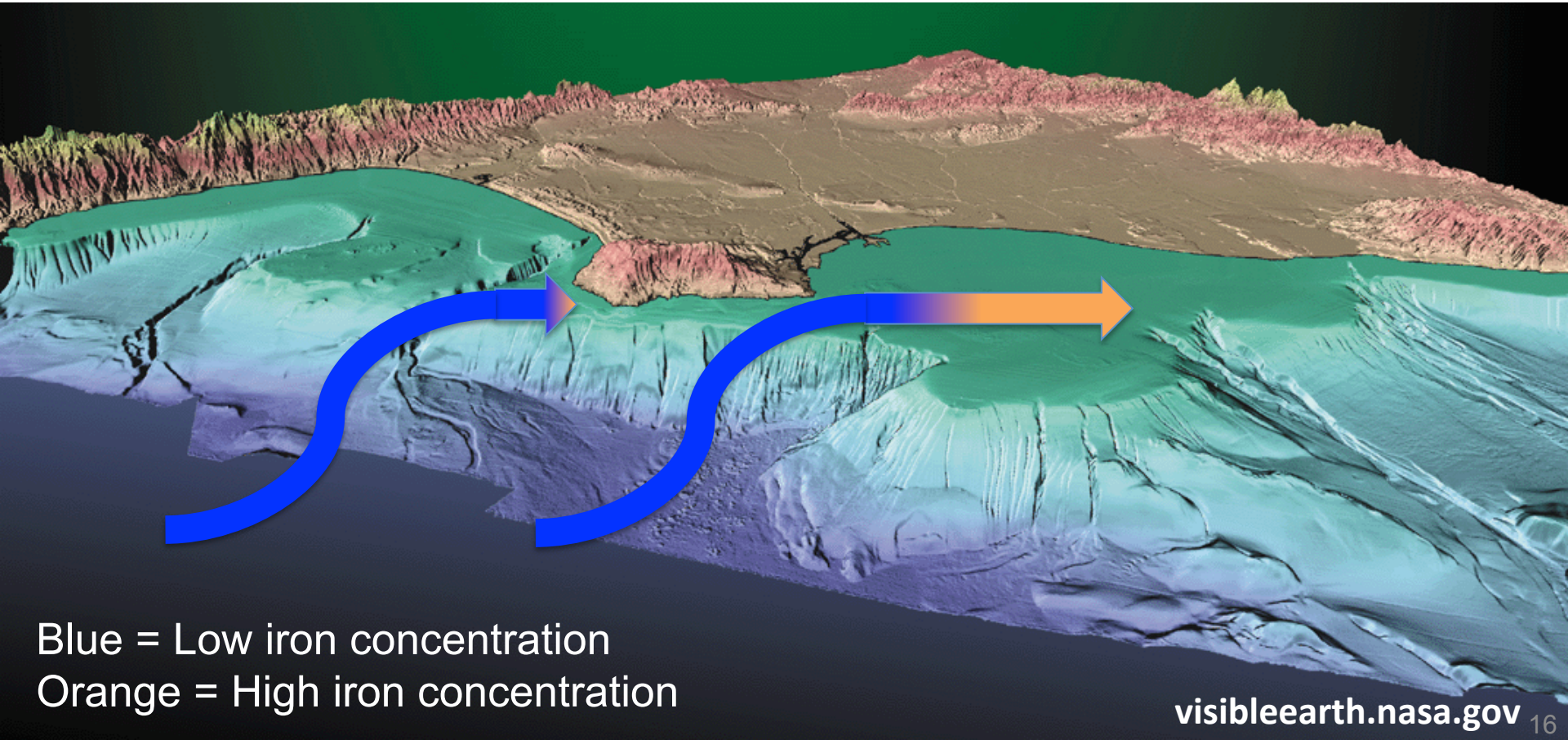


Why the relationship between phytoplankton abundance and continental shelf width?

- Highest seawater iron concentrations are on the shelf
- Wider shelves have larger iron inventory and permit greater entrainment of iron into surface waters (Bruland et al. 2005, Biller et al. 2013)
- More iron = higher phytoplankton biomass



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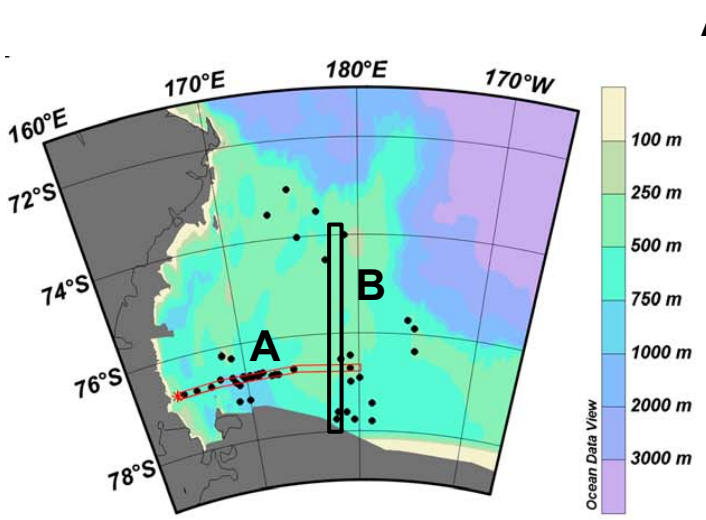
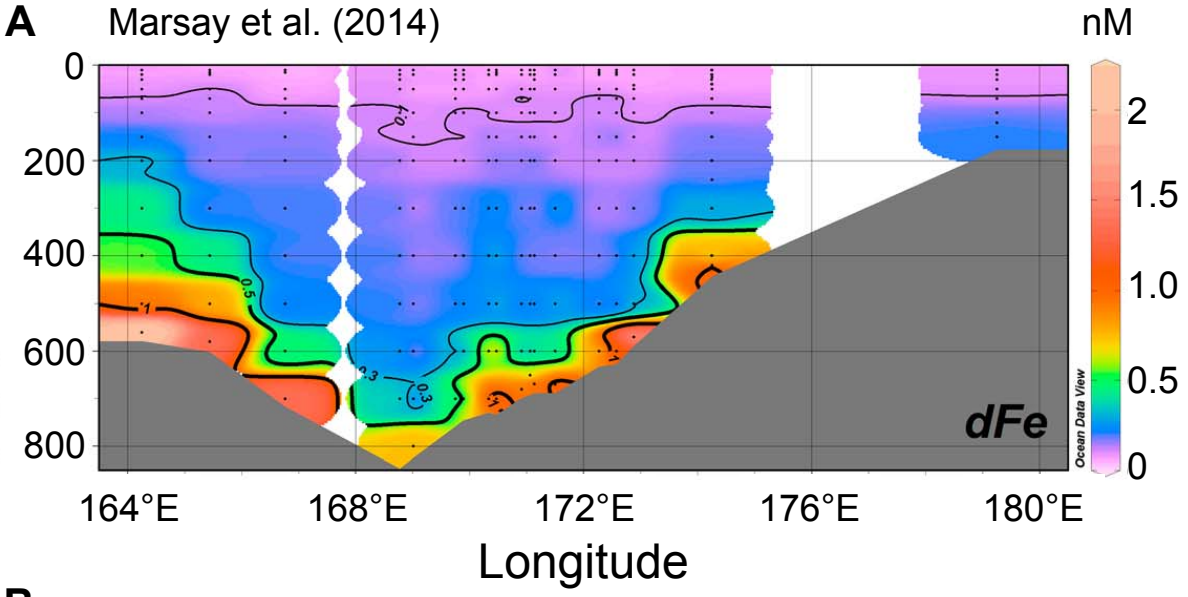
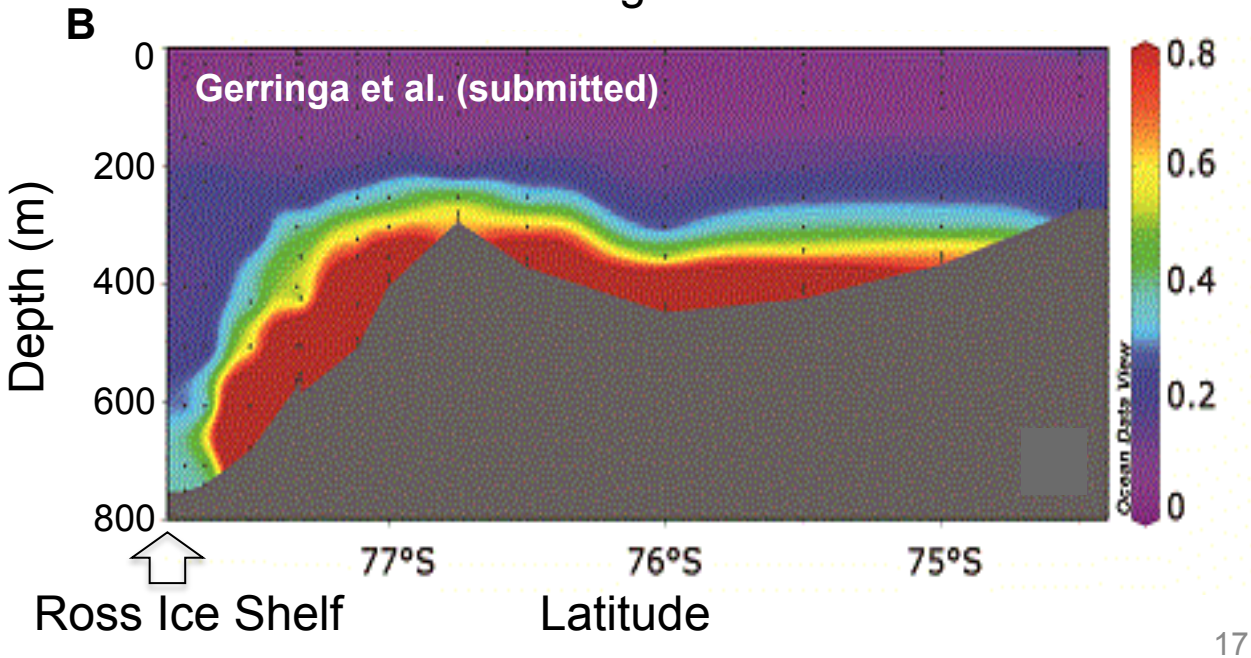




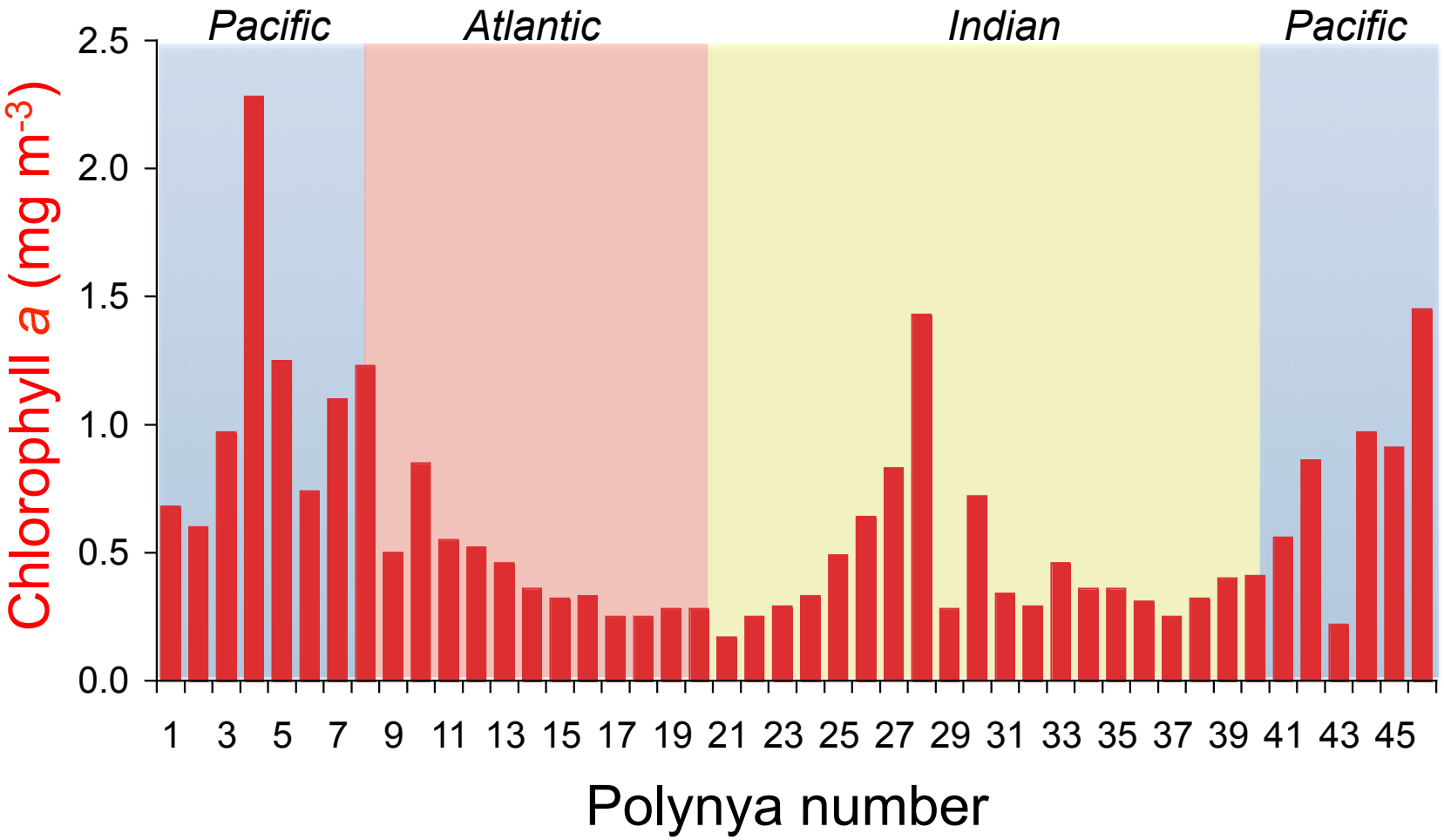
Best example is in Ross Sea

Large continental shelf

Low Fe near RIS

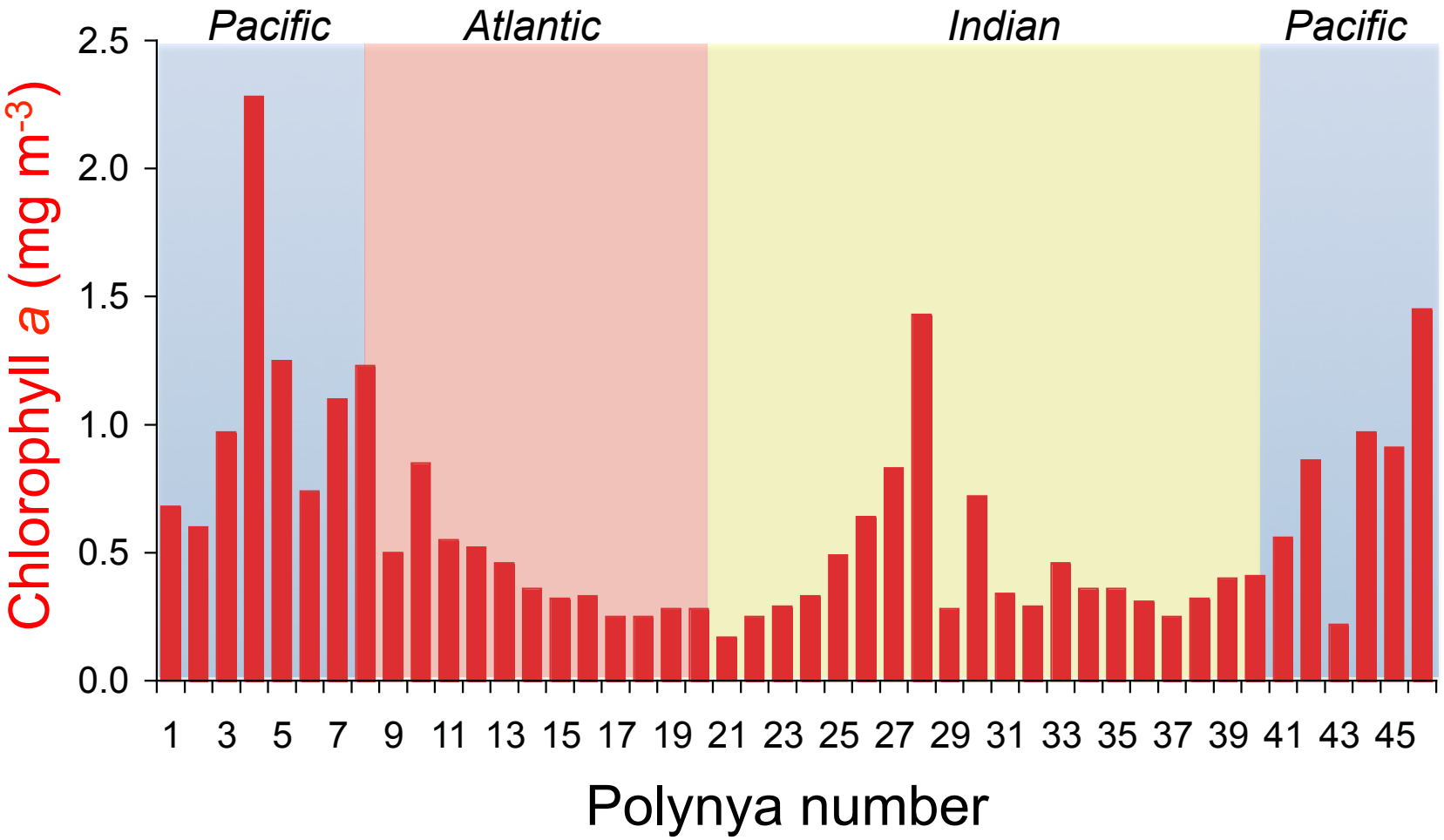


What other factors control phytoplankton abundance in coastal polynyas?



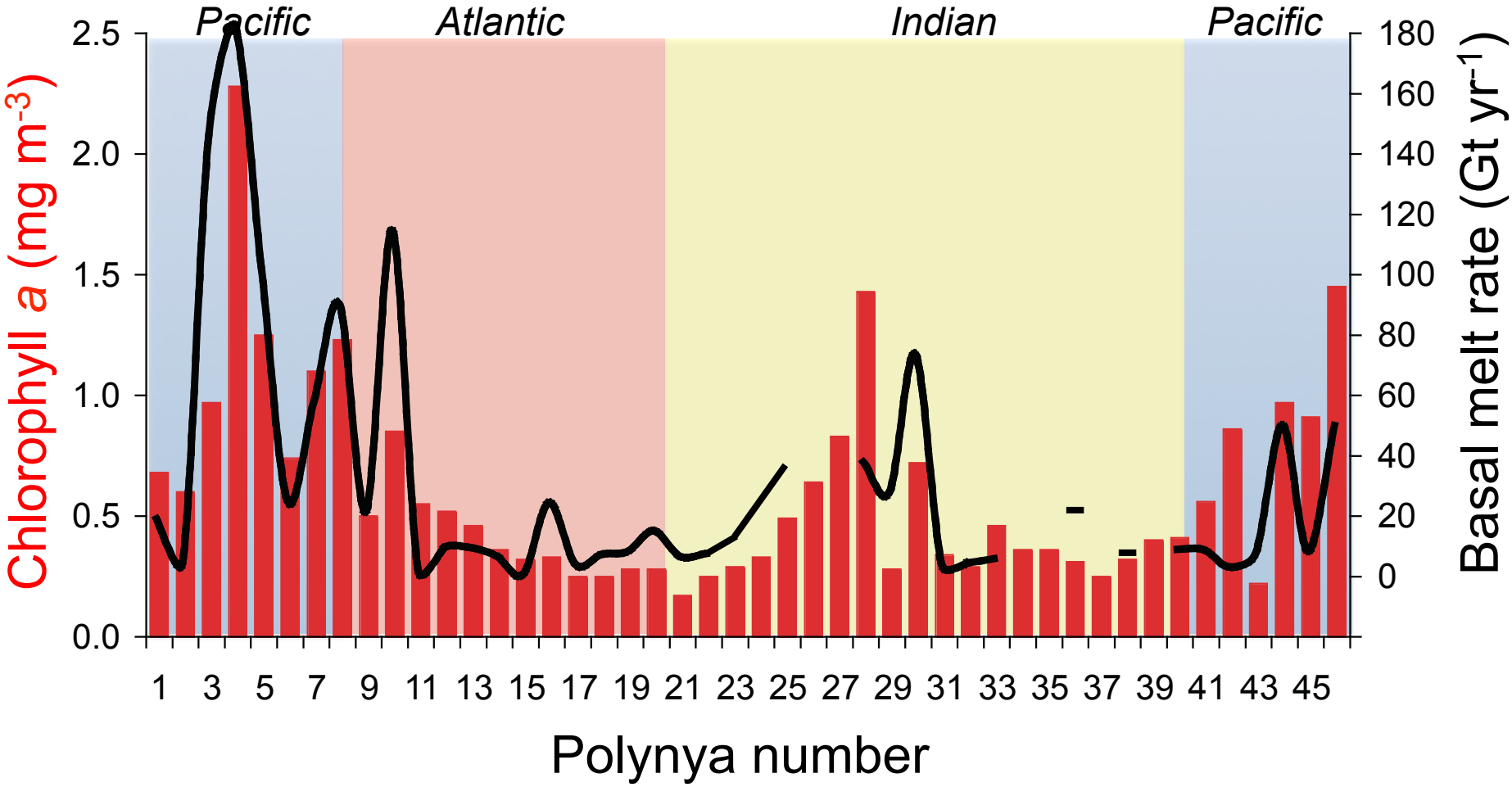
What other factors control phytoplankton abundance in coastal polynyas?

- 39 of 46 coastal polynyas are adjacent to melting ice shelves



What other factors control phytoplankton abundance in coastal polynyas?

- 39 of 46 coastal polynyas are adjacent to melting ice shelves
- Phytoplankton abundance related to basal melt rate
- Relationship strongest in Pacific sector



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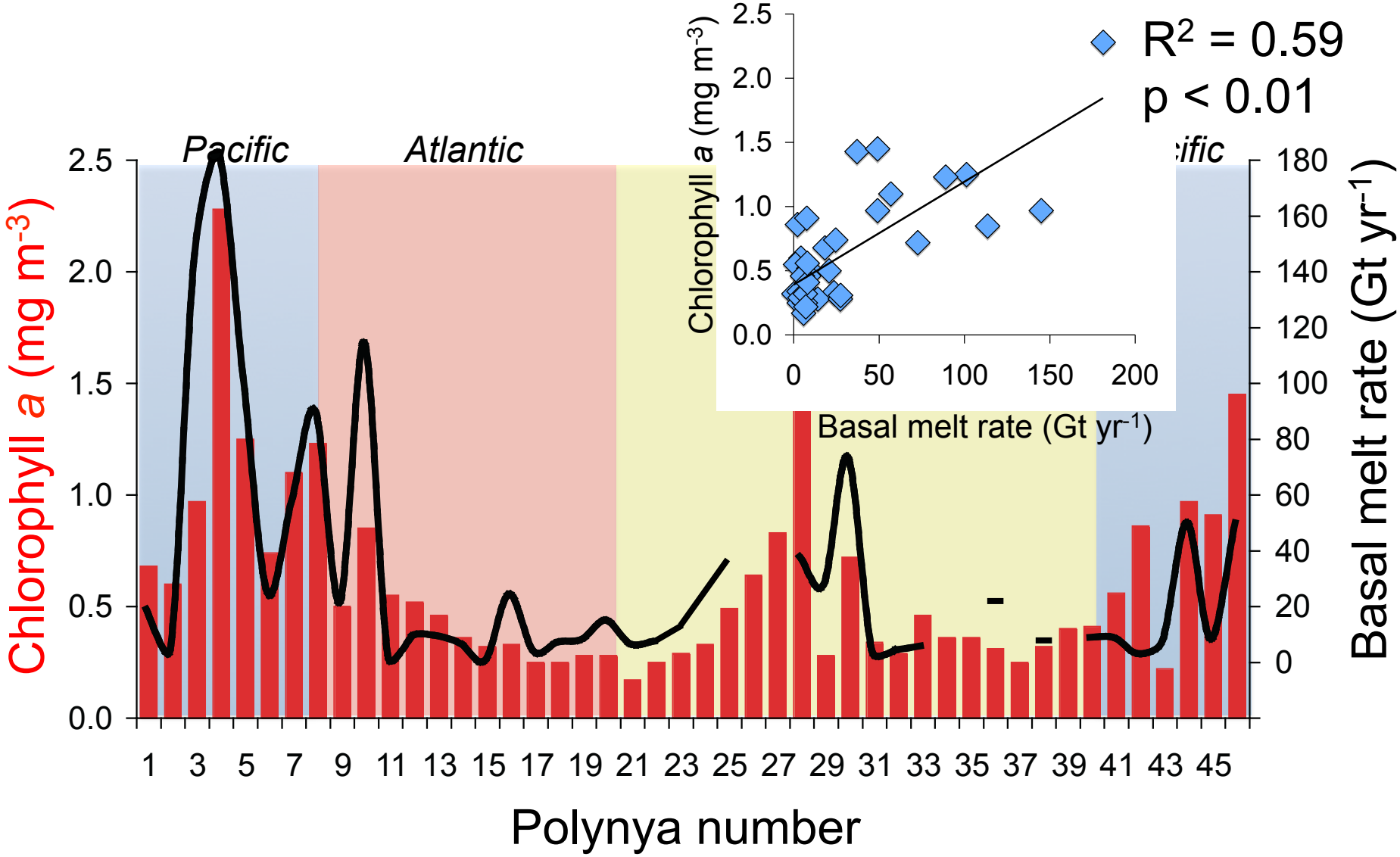
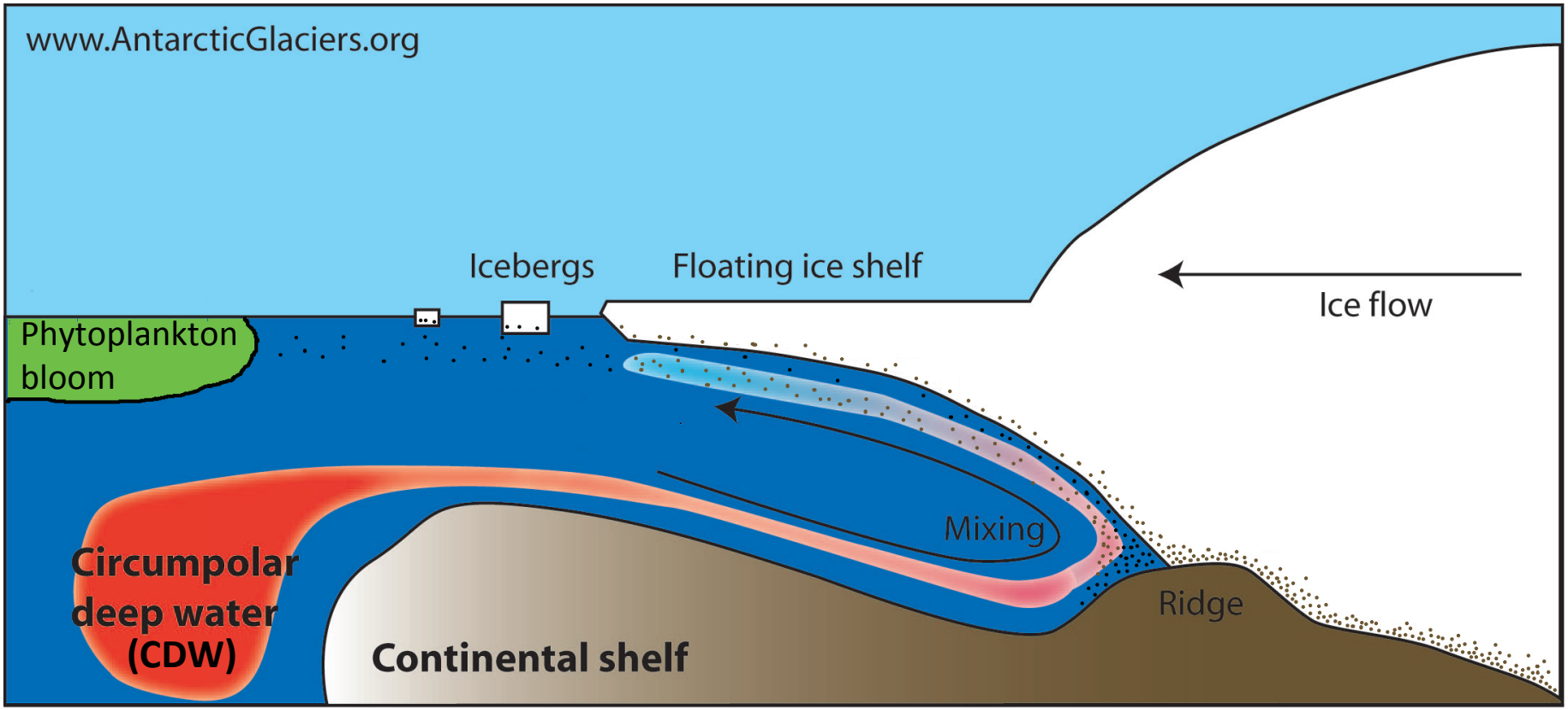


Why the relationship between phytoplankton abundance and basal melt rate of nearby ice shelves?

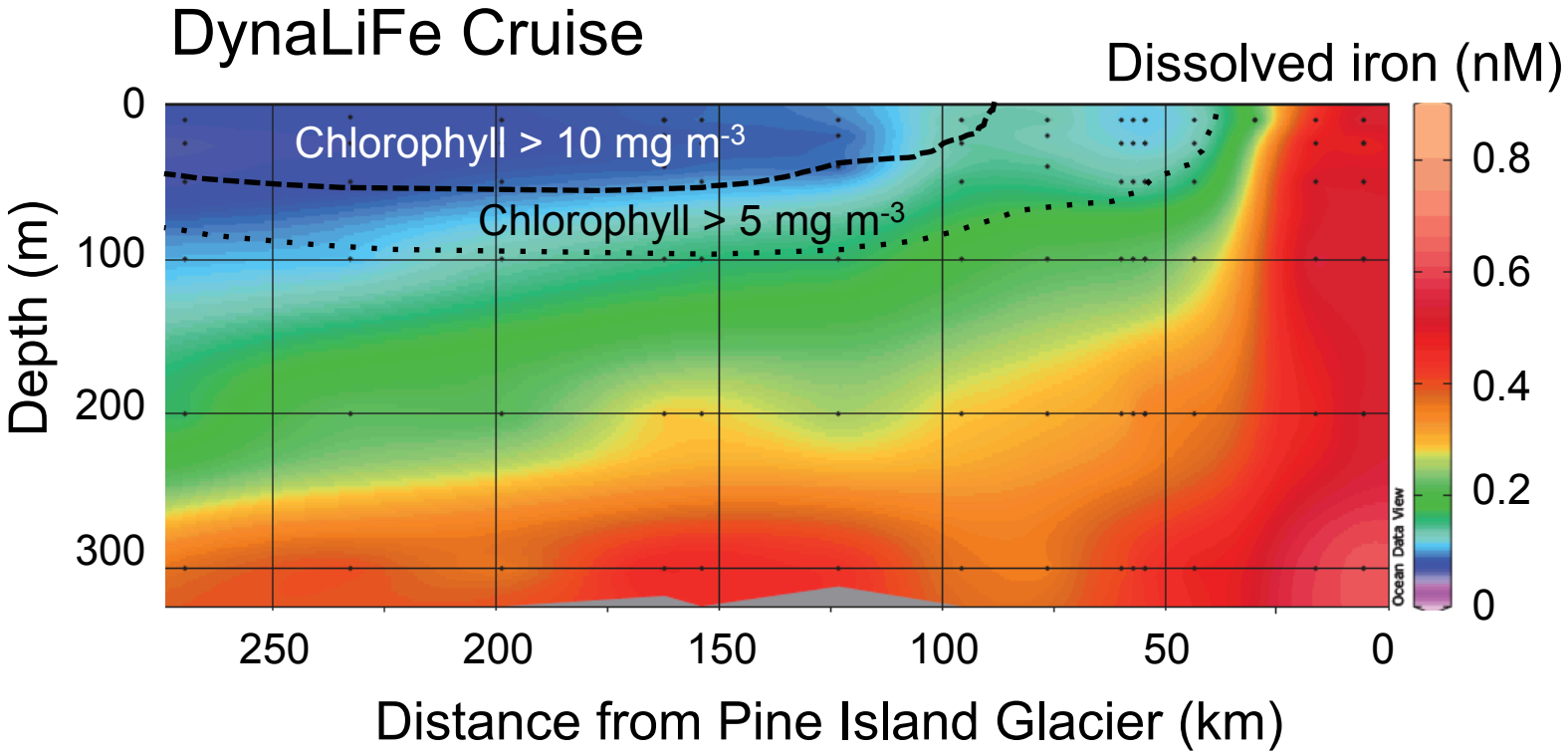
- Ice sheets grind up bedrock as they flow to sea
- Ice sheets accumulate Fe-containing dust
- Particulate and dissolved iron is released into seawater
- Facilitated by upwelling of warm CDW
- Iron taken up by growing phytoplankton



Why the relationship between phytoplankton abundance and basal melt rate of nearby ice shelves?

Best example is in Amundsen Sea

- Most rapidly melting glaciers
- Large Fe flux at face of Pine Island Glacier
- Fe consumed by phytoplankton in surface waters



Modified from Gerringa et al. (2012)

How much variance in chlorophyll *a* can be explained by environmental variables?

Multiple regression model included:

Shelf width
SST
Basal melt rate
Open water area
*Number of days of open water
*Mean daily PAR

*Removed because they had no effect on regression model

Some of the predictor variables were significantly but weakly correlated

Predictor	**Predictor**	**R^2**	***p*-value**
Shelf width	SST	0.19	p<0.01
SST	Basal melt	0.16	p<0.01
Shelf width	Basal melt	0.17	p<0.01
Shelf width	Open water	0.20	p<0.01

Multiple linear regression: $R^2 = 0.77$

Parameter	*p*-value	VIF	% of R^2 explained
Basal melt rate (Gt yr^{-1})	<0.001	1.34	43.6%
Sea surface temp (°C)	<0.01	1.42	24.5%
Shelf width (km)	<0.01	1.67	19.1%
Mean open water (km^2)	<0.05	1.26	12.8%

VIF = Variance Inflation Factor (should be below 2.5)

CONCLUSIONS

Even coastal Antarctic polynyas are iron-limited
- Light does not control phytoplankton productivity

Higher SST increases phytoplankton abundance directly through increased growth rates but possibly also indirectly through increased glacial melting

Wide shelves are more productive than narrow ones
- Greater resuspension of sediment iron

Very productive polynyas require input of glacial meltwater
- Presumably because of additional iron supplies

Future increases in glacial melt are likely to increase biological productivity of coastal ecosystems

THANK YOU!

Ocean Biology and Biogeochemistry

Cryosphere Science Program