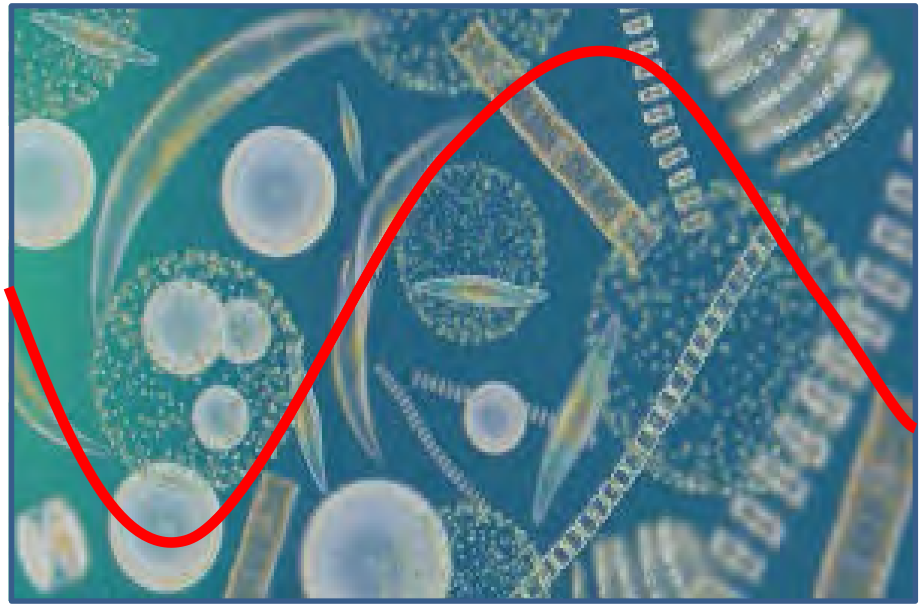
Research highlights from SOCCO: An improved understanding of the seasonal cycle in the Subantarctic Southern Ocean



Sandy Thomalla, Pedro Monteiro, Sebastiaan Swart, Warren Joubert, Marie-Fanny Racault, Alessandro Tagliabue, Nicolas Fauchereau

CSIR our future through science

NRF National Research Foundation

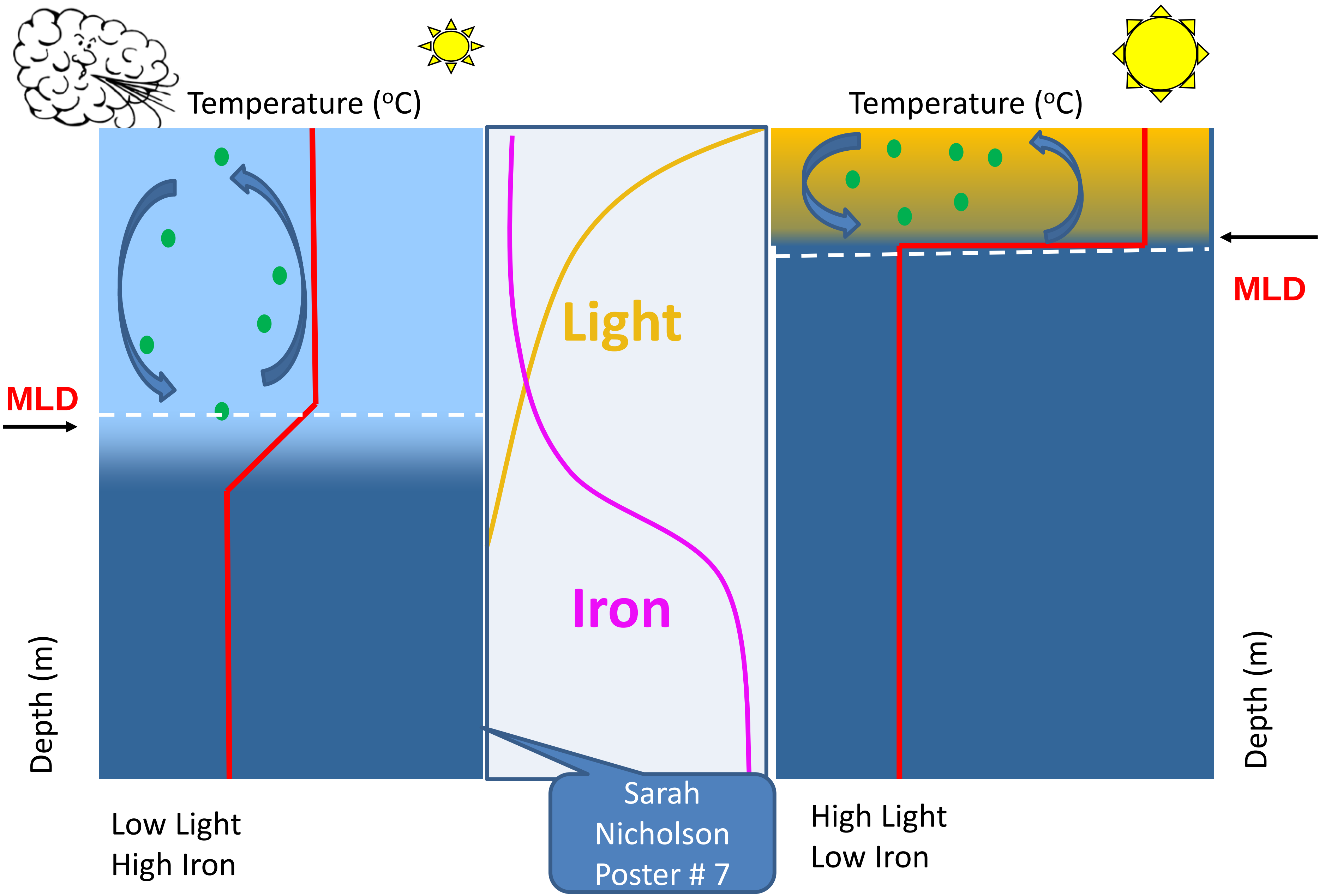
SPES BONA

SOCCO Southern Ocean Carbon and Climate Observatory

Rationale

- The Southern Ocean is the largest HNLC region of the world Ocean
- State attributed to limitation of phytoplankton growth by light and iron (Fe)
- Southern Ocean susceptible to climate change which alters vertical nutrient and light supply through MLD alterations
- A proper understanding of light and Fe limitation is necessary to assess the sensitivity of the system to a change in climate.

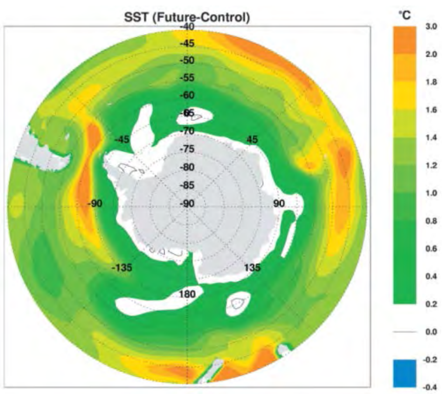
Mixed layer depth, light, Iron and Primary Production

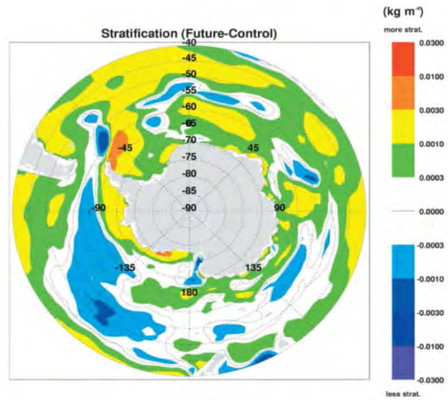


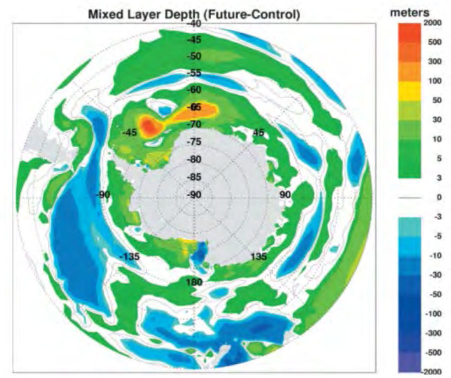
The Southern Ocean and Climate Change

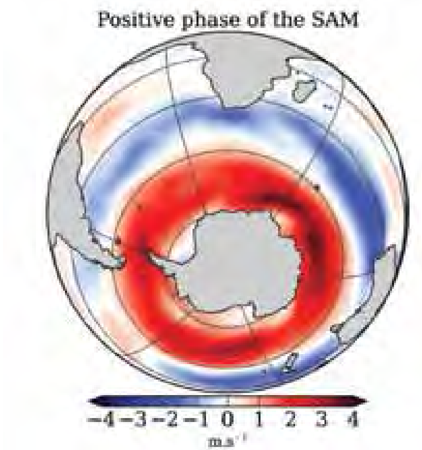
Global models predict:

Boyd et al., 2002









Warming

Increased stratification

Altered mixed layer depths

Intensification & southerly shift of westerly winds

Changes in MLD and Fe and light supply

- We need to understand the sensitivities of the system to change in MLD in order to predict how the carbon pump will respond to climate change

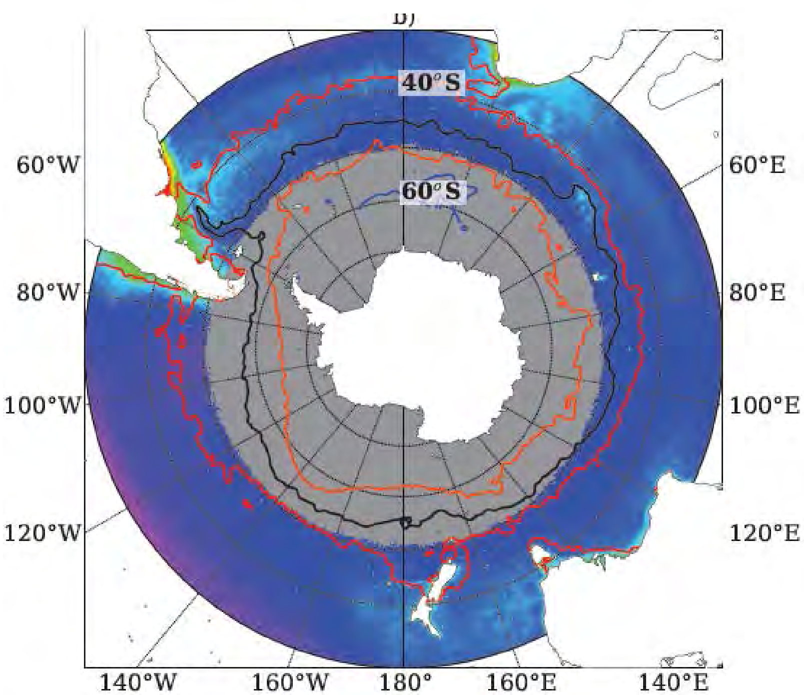
Regional scale characteristics of the Southern Ocean seasonal cycle

Seasonal Time Scales

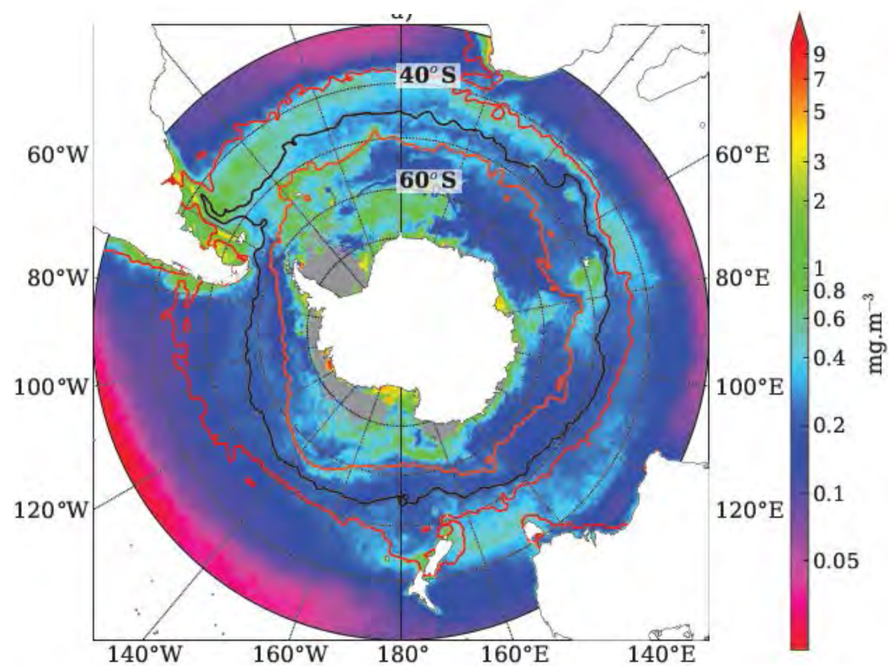
Thomalla et al., 2011 Biogeosciences

- Seasonal evolution of phytoplankton biomass attributed to contrasts in:
  1) Seasonal light supply
  2) Seasonal cycle of Fe availability

Winter

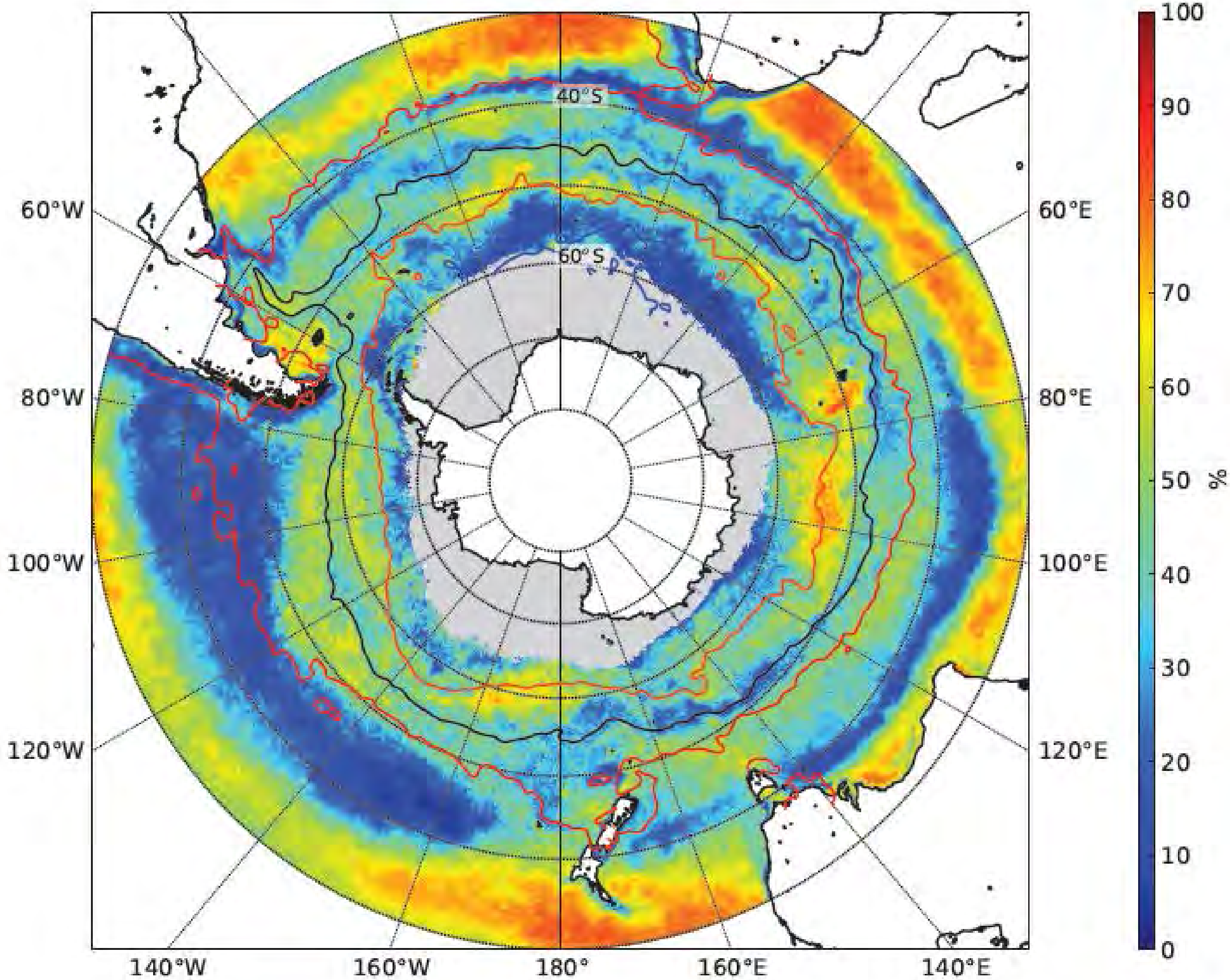


Summer



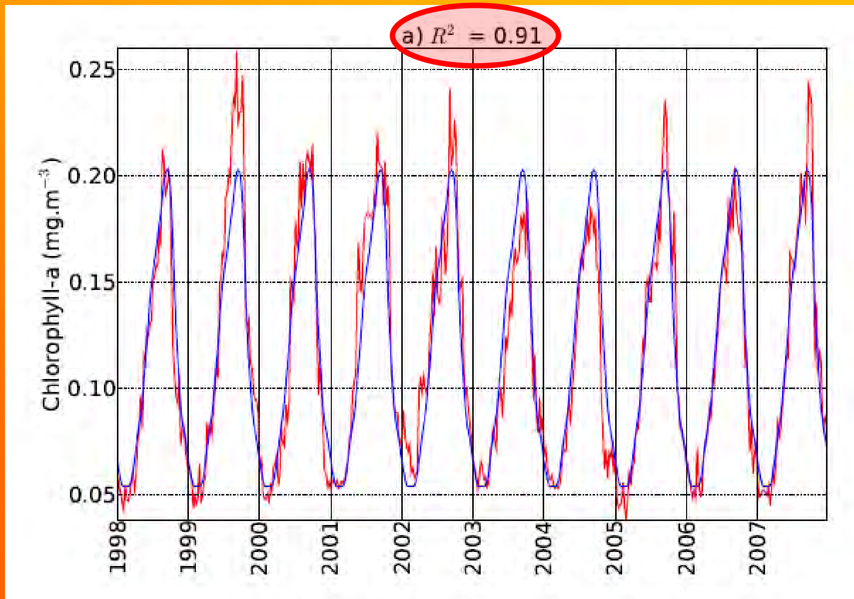
SeaWiFS ocean colour chlorophyll 1998-2007

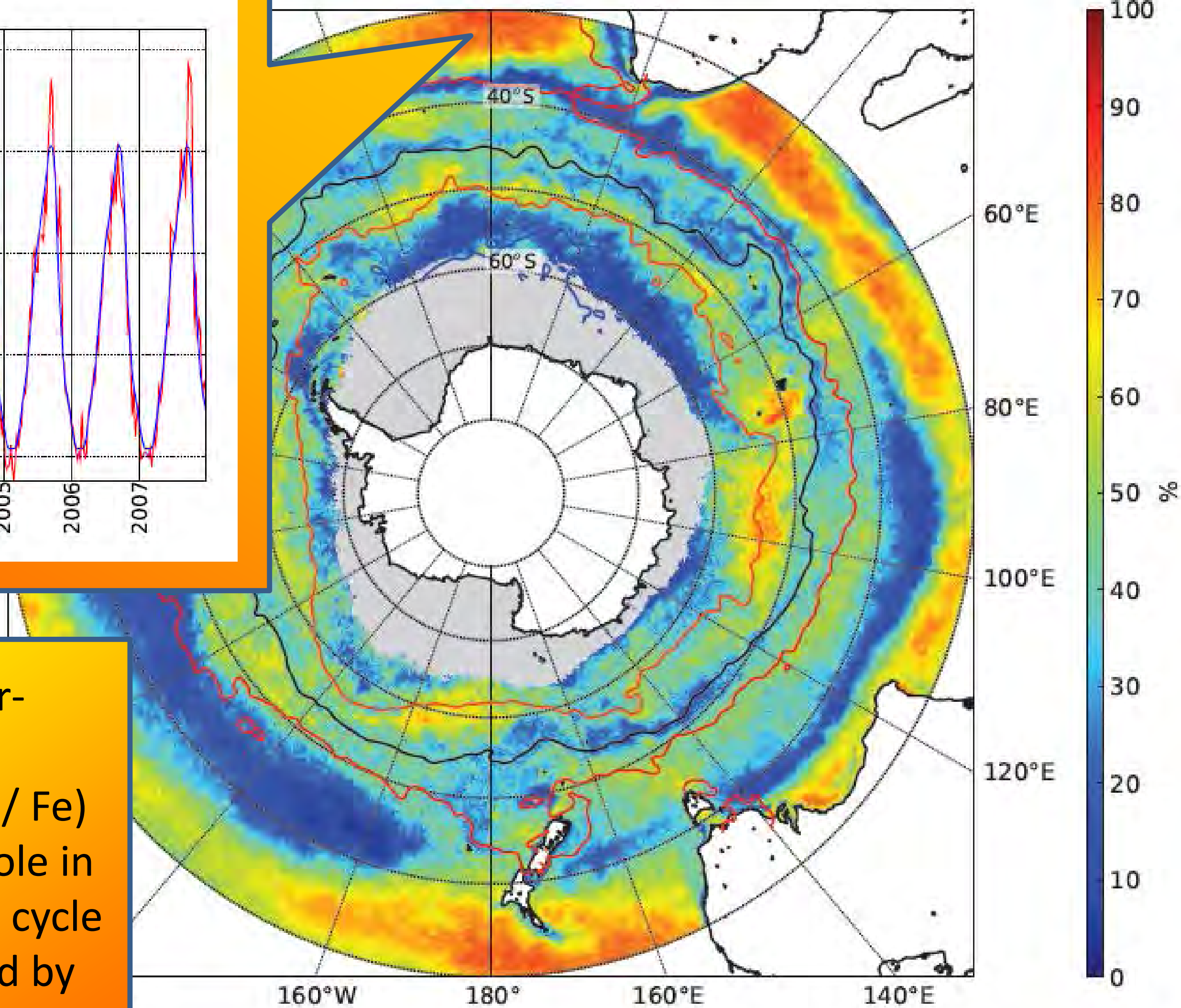
Sub seasonal time scales: Seasonal cycle reproducibility



How well the mean climatological seasonal cycle (from 9 yr) represents the evolution of chlorophyll over each year (i.e. predictable)

High seasonal cycle reproducibility

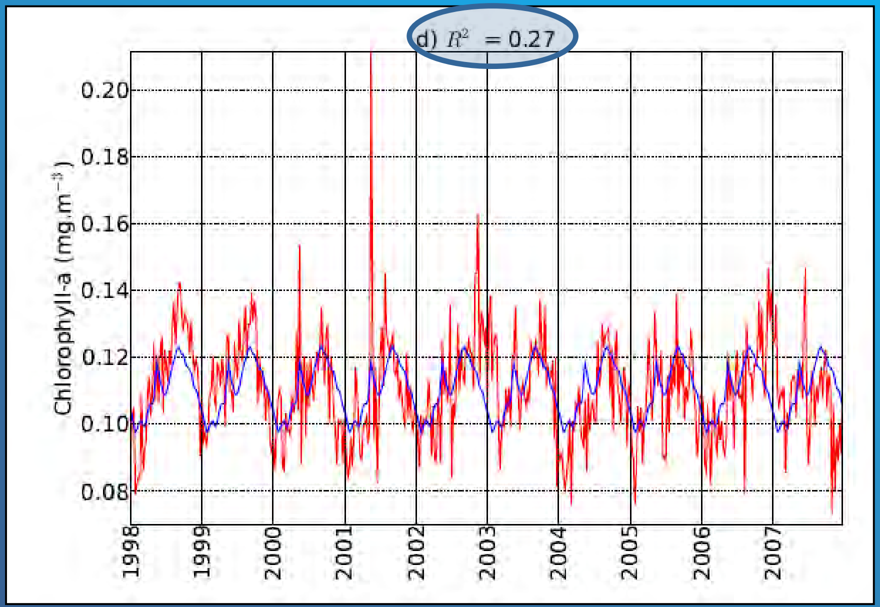


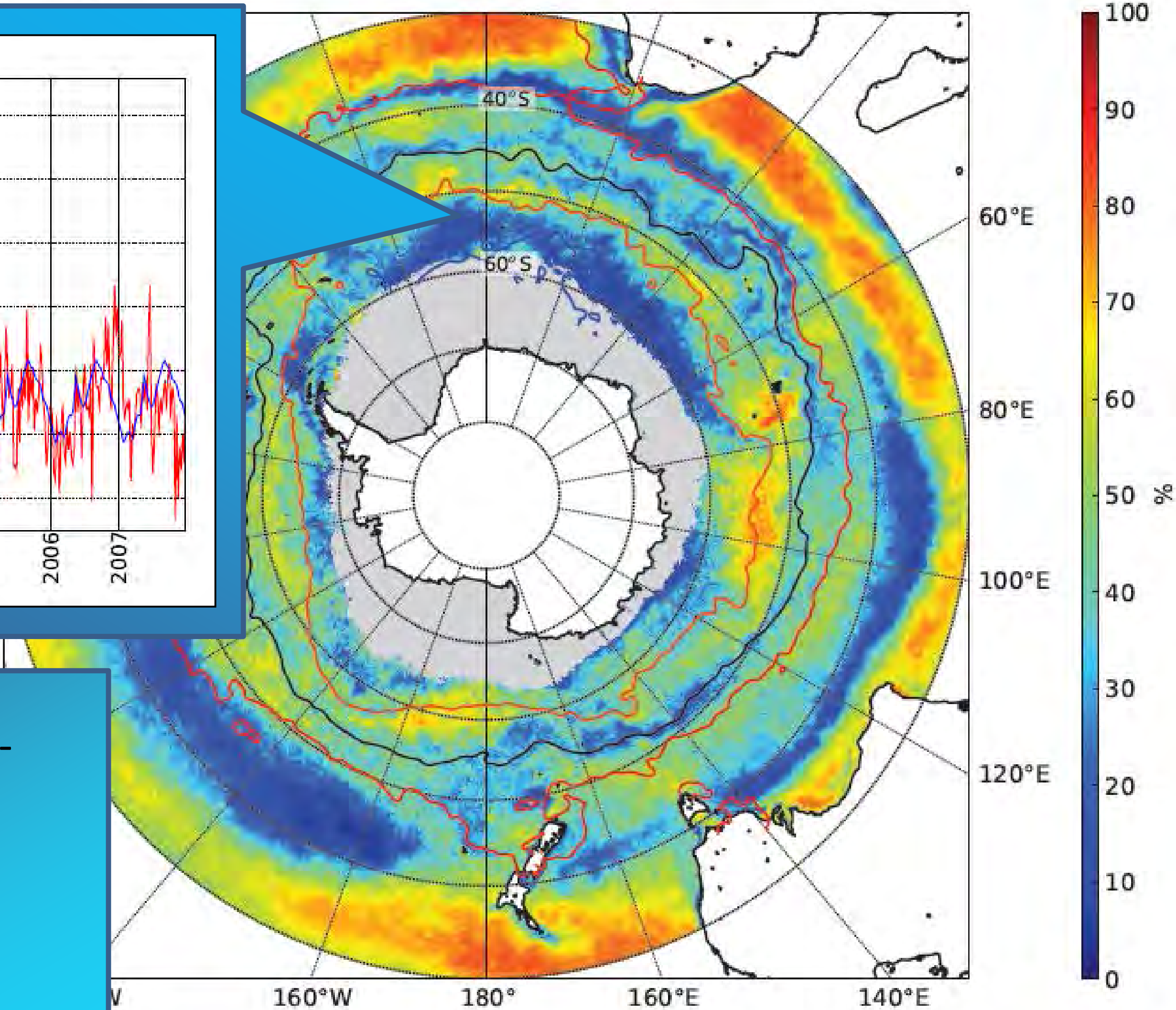


- Low intra-seasonal and inter-annual variability
- Intra-seasonal forcing (light / Fe) does not play a significant role in the phytoplankton seasonal cycle
- Annual time series explained by seasonal forcing of light, heat flux and seasonal MLD.

Thomallla et al., 2011. Biogeosciences

Low seasonal cycle reproducibility

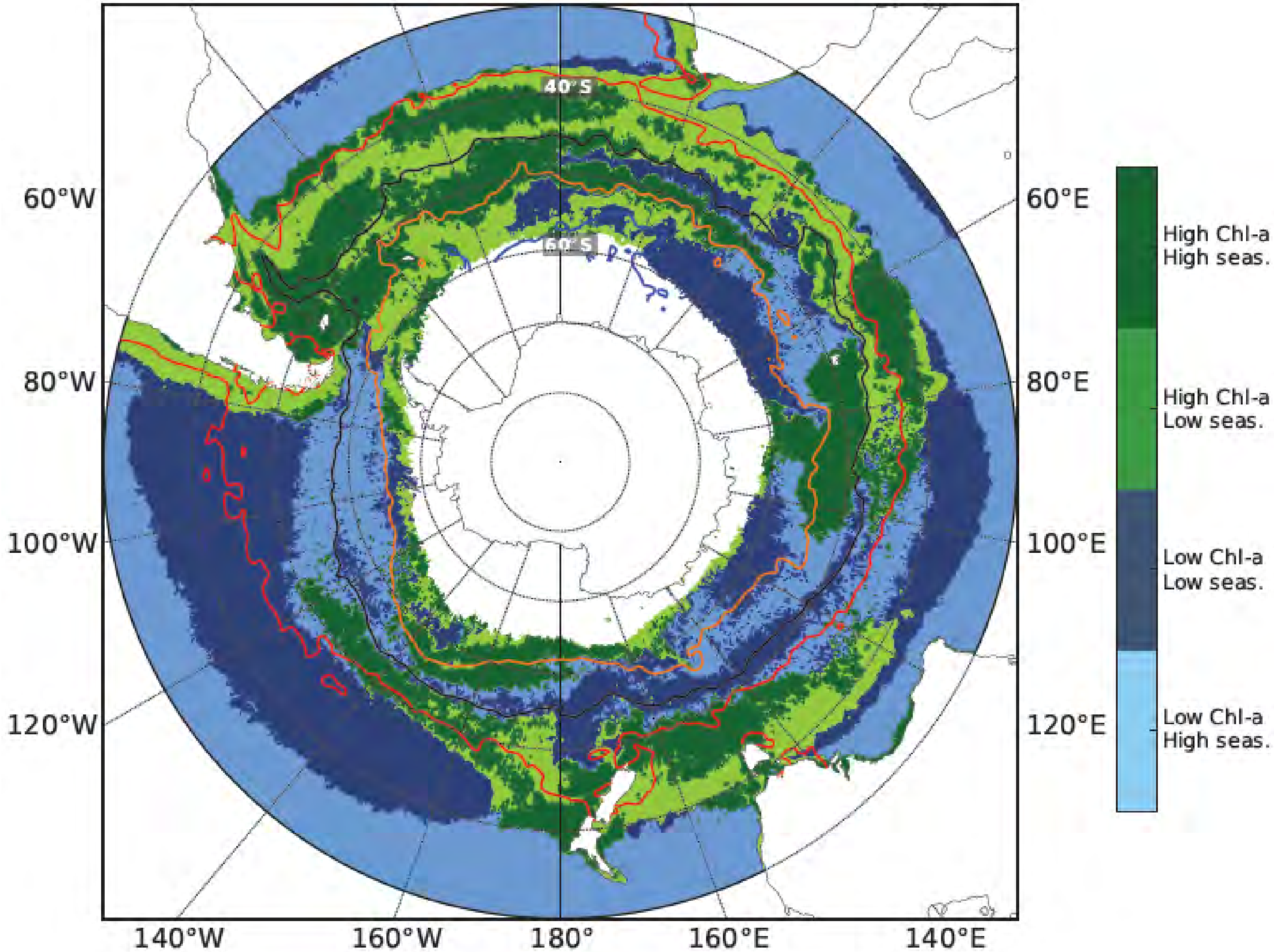




- High intra-seasonal and inter-annual variability
- Intra-seasonal variability in physical forcing mechanisms plays an important role in modulating the seasonal cycle

Thomallla et al., 2011. Biogeosciences

Response of phytoplankton biomass to intra-seasonal variability

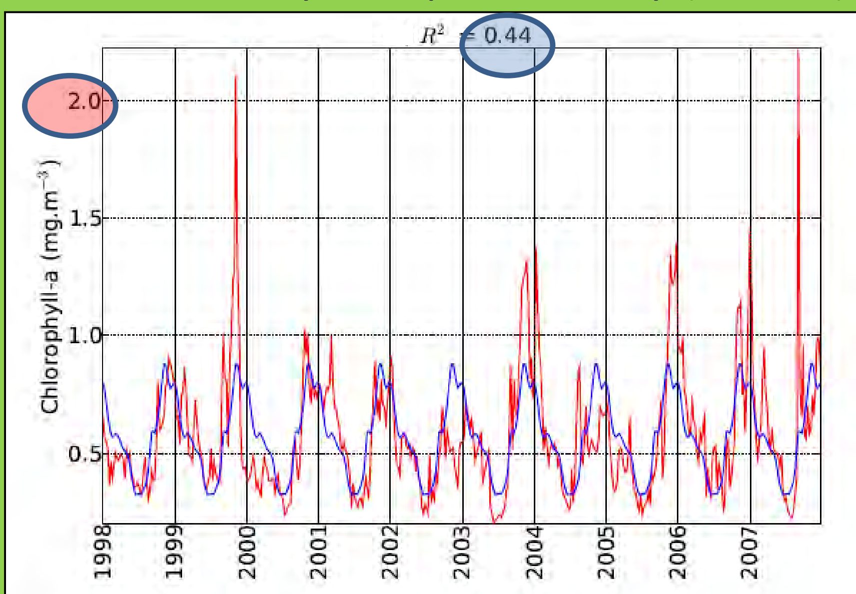


Thomallla et al., 2011. Biogeosciences

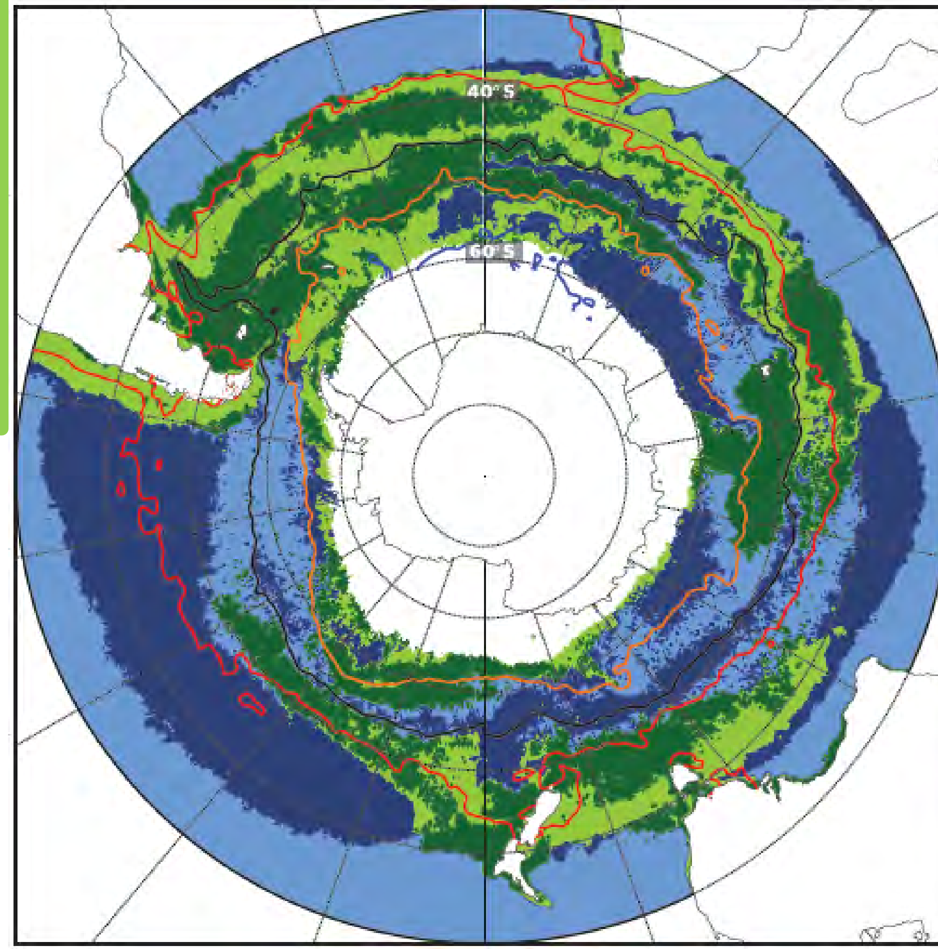
Hypothesis

High summer chlorophyll a direct consequence of high intra-seasonal physical forcing of the MLD driving Fe and light supply at appropriate time scales for phytoplankton growth

Low seasonal cycle reproducibility (R^2 <0.4)



Green = high chlorophyll (>0.25 mgm^{-3})

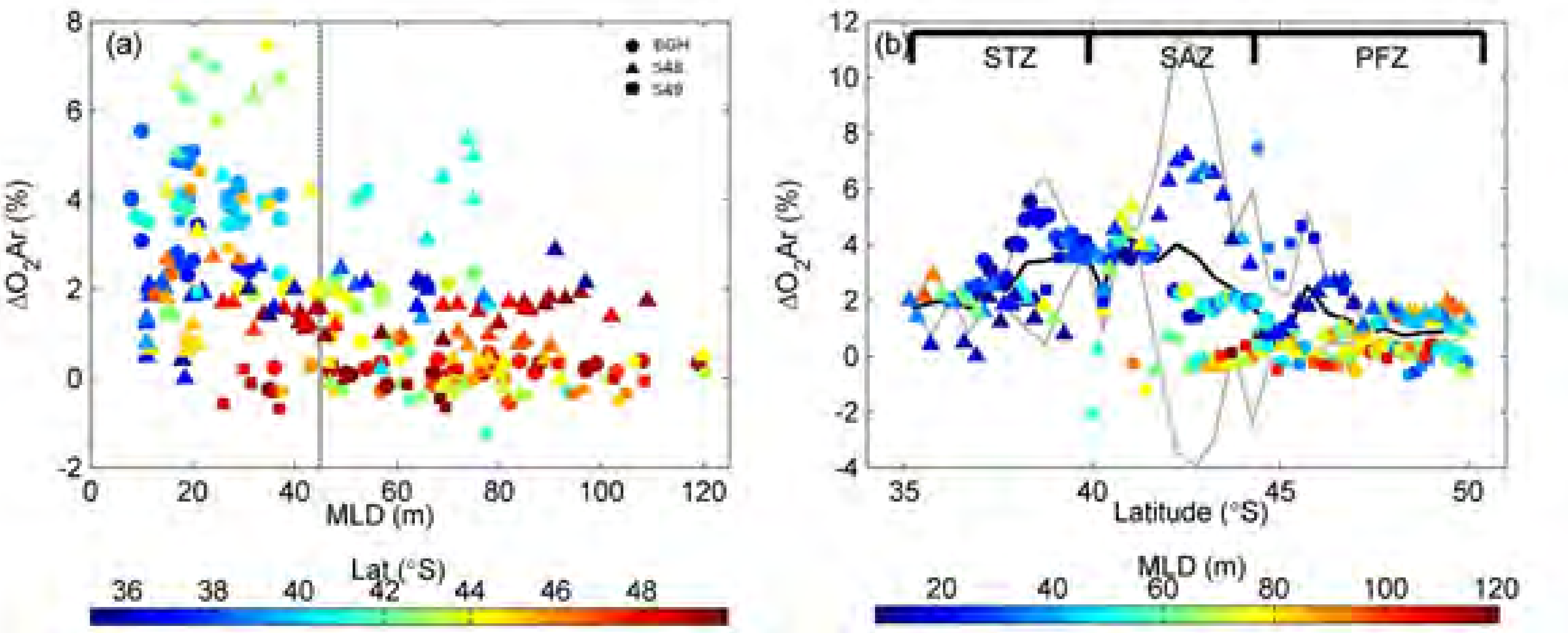


Relief of Fe stress

Thomallla et al., 2011. Biogeosciences

The sensitivity of primary productivity to intra seasonal mixed layer variability in the SAZ

Joubert et al., 2014 Biogeosciences



- Non-linear relationship between production (from ΔO_2/Ar ratios) and MLD
- Highest and most variable production observed in shallow MLDs (< 45 m)
- This region coincides with the SAZ where intra-seasonal MLD variability is high around a mean threshold for light at 45m

Conceptual model

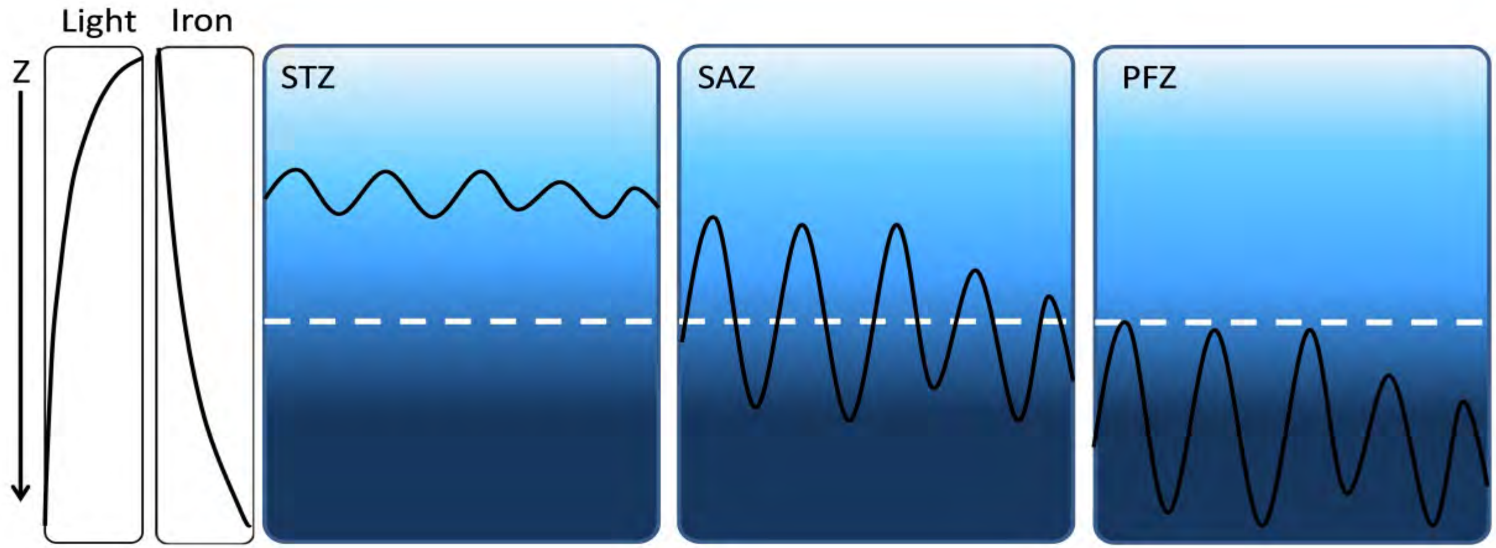
Warren
Joubert
Poster # 4

- SAZ is a transition zone between:

shallow (< 45 m), stratified mixed layers to the north (STZ) = nutrient limited and deep (> 45m), well mixed layers to the south (PFZ) = light limited

- This study showed that elevated, highly variable and **sustained** production in the SAZ is driven by MLD deepening (entraining iron) followed by restratification allowing growth in a high iron and light environment.

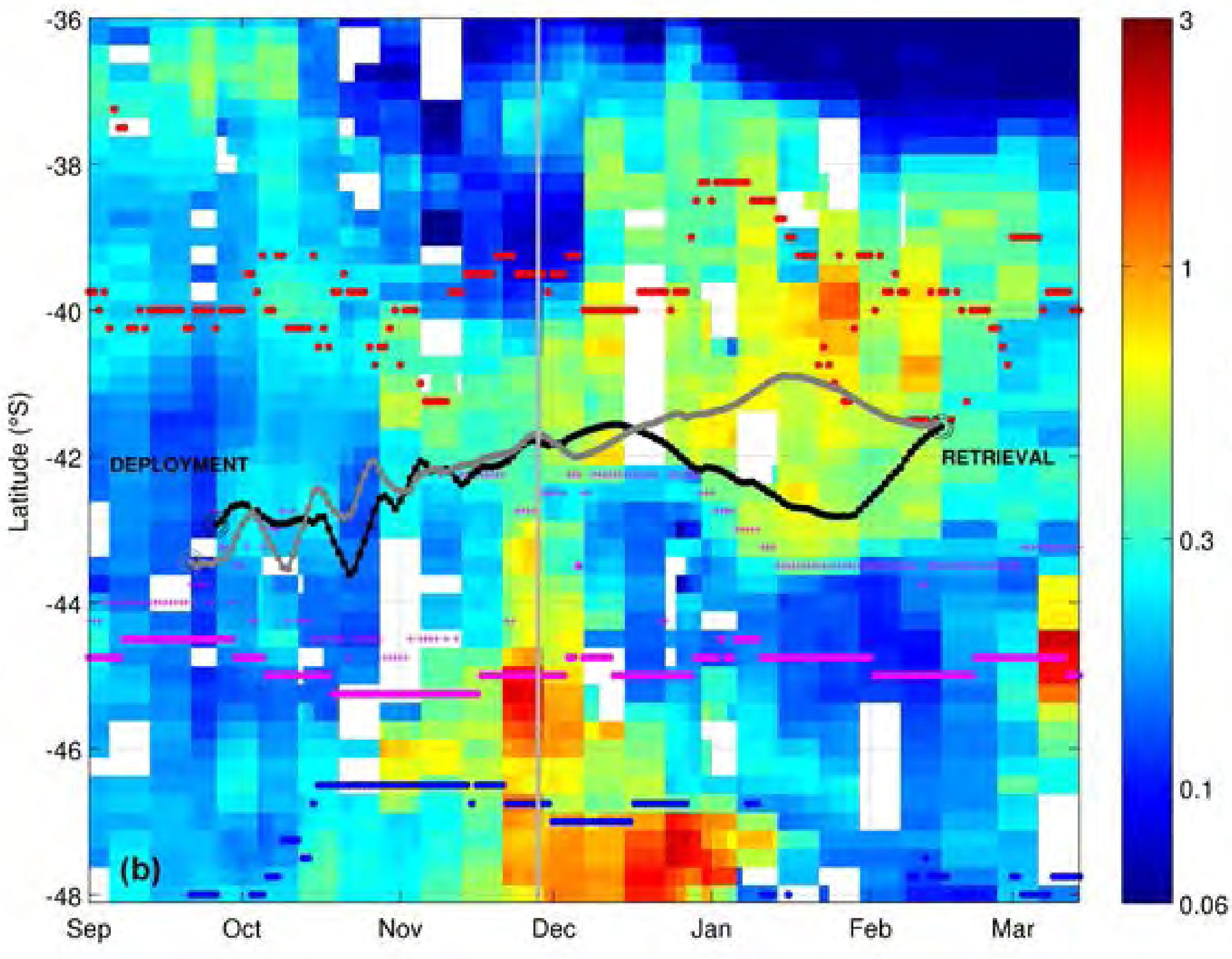
- This study proposed that high MLD variability driven by intra seasonal storms

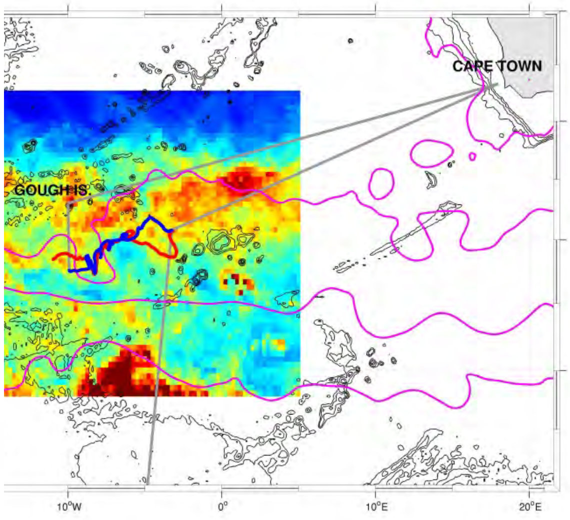


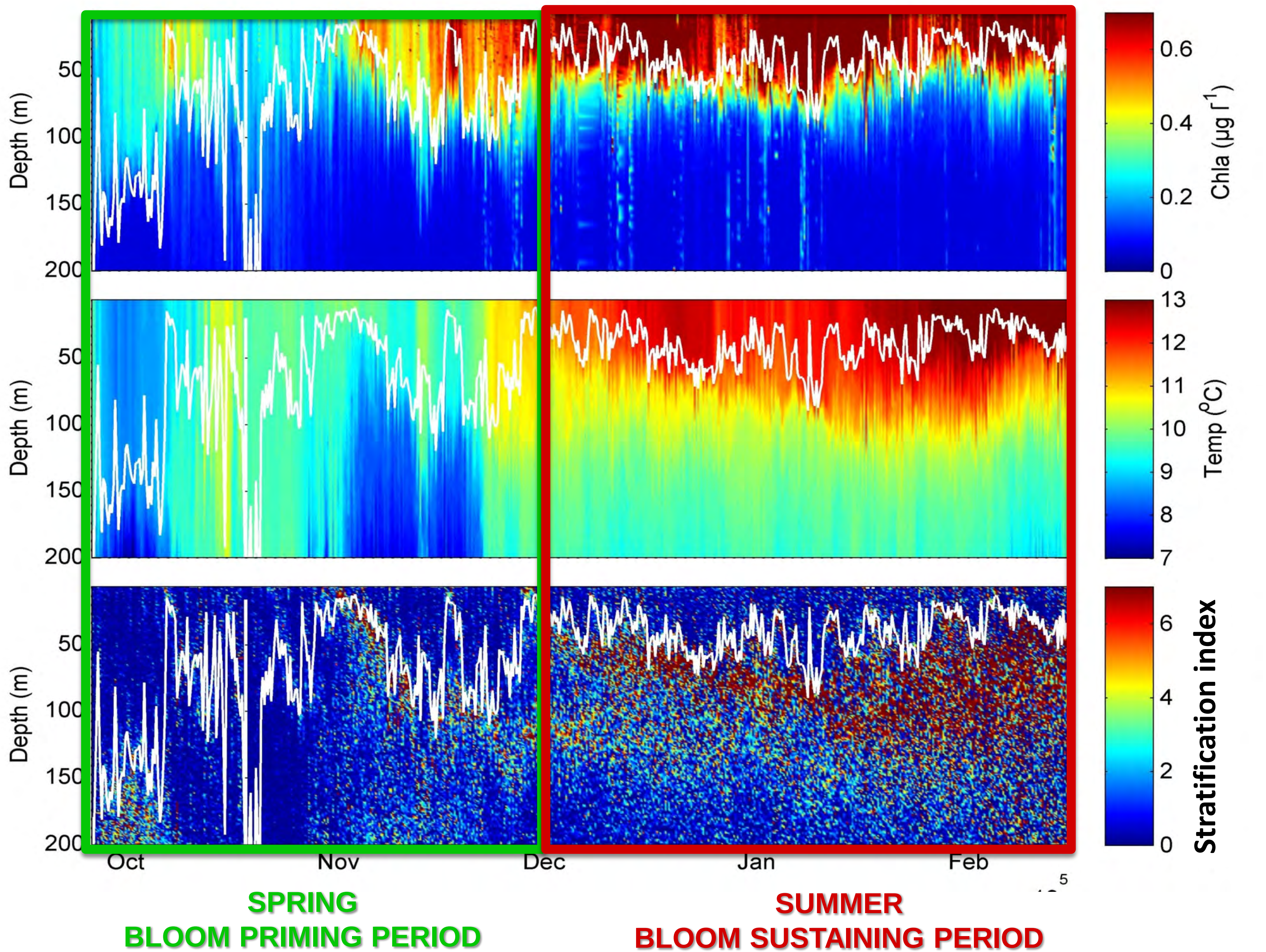
Joubert et al., 2014 Biogeosciences

The Seasonal cycle of mixed layer dynamics and phytoplankton biomass in the SAZ

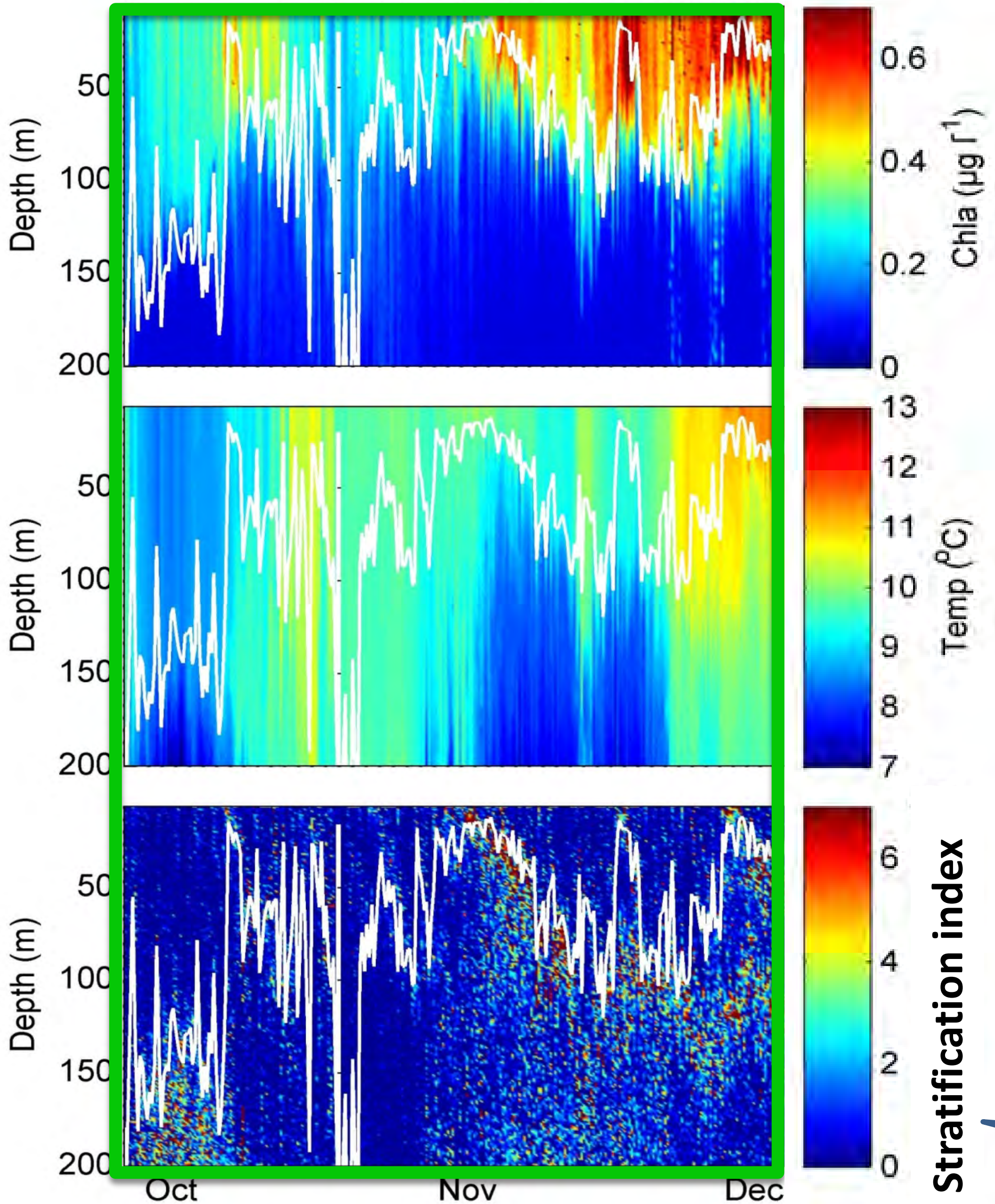
Swart et al., 2014. Journal of Marine Systems







Depth (m)
50
100
150
200
Chla (μg l-1)
0.6
0.4
0.2
0
Temp (°C)
13
12
11
10
9
8
7
Stratification index
6
4
2
0
Oct
Nov
Dec
Jan
Feb
SPRING
BLOOM PRIMING PERIOD
SUMMER
BLOOM SUSTAINING PERIOD



SPRING
BLOOM PRIMING PERIOD

SPRING

1. Eddies drive early stratification and early bloom initiations

2. Eddies act as hotspots for biological activity in the spring

- **If climate models don't include eddies they will overestimate bloom initiation dates**

Marcel du Plessis Poster # 9

SUMMER

1. Extensive warming increases stratification and shoals the MLD

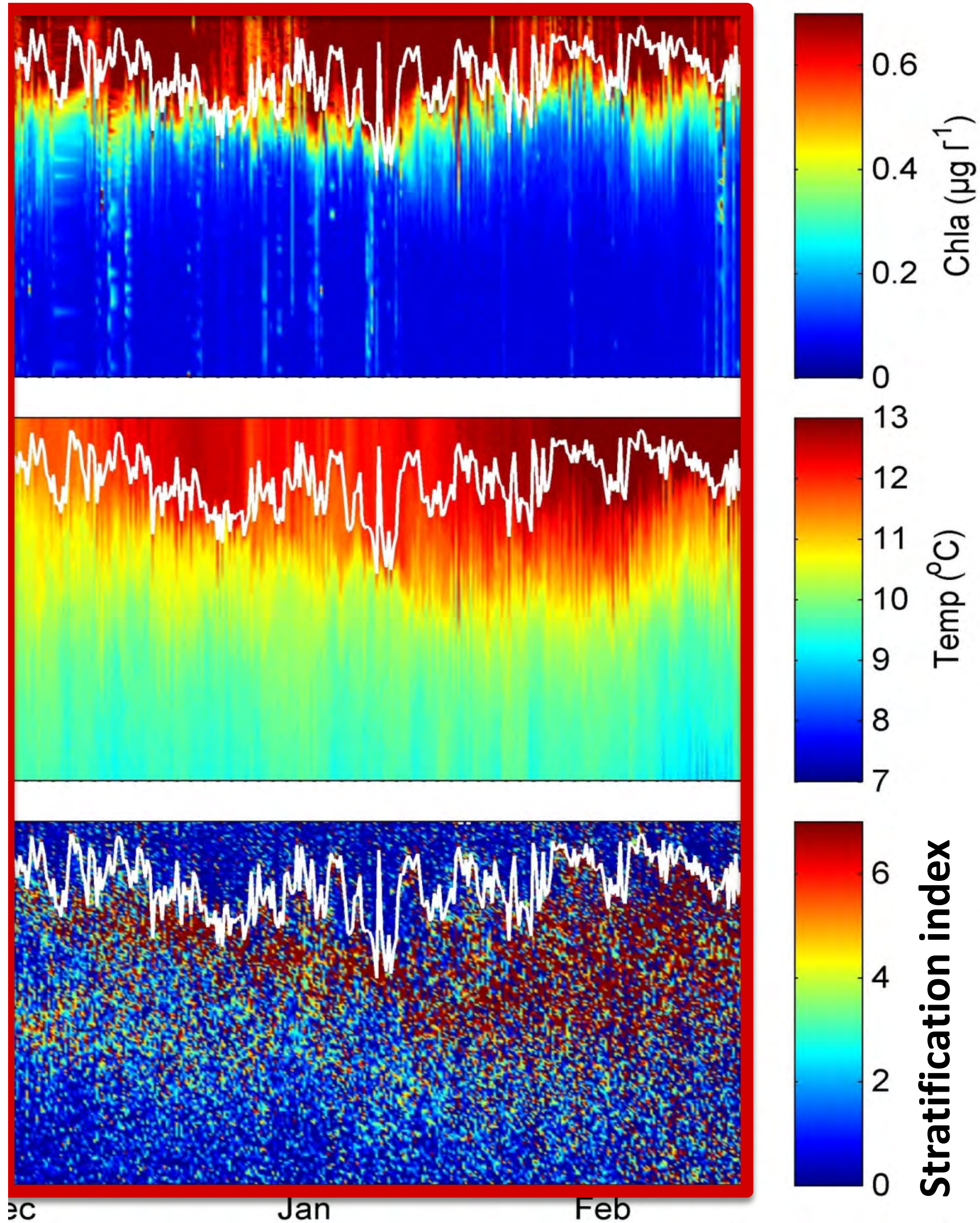
2. Stratification prevents extensive deepening (>80m) of the MLD

3. MLD is still highly variable at subseasonal time scales fluctuating around a threshold of ~40 m

4. MLD fluctuations driven by wind stress from synoptic storm events

5. MLD shoaling driven by heat and eddy stratification

Marcel du Plessis Poster # 9



SUMMER
BLOOM SUSTAINING PERIOD

Primary and Net Community Production from gliders

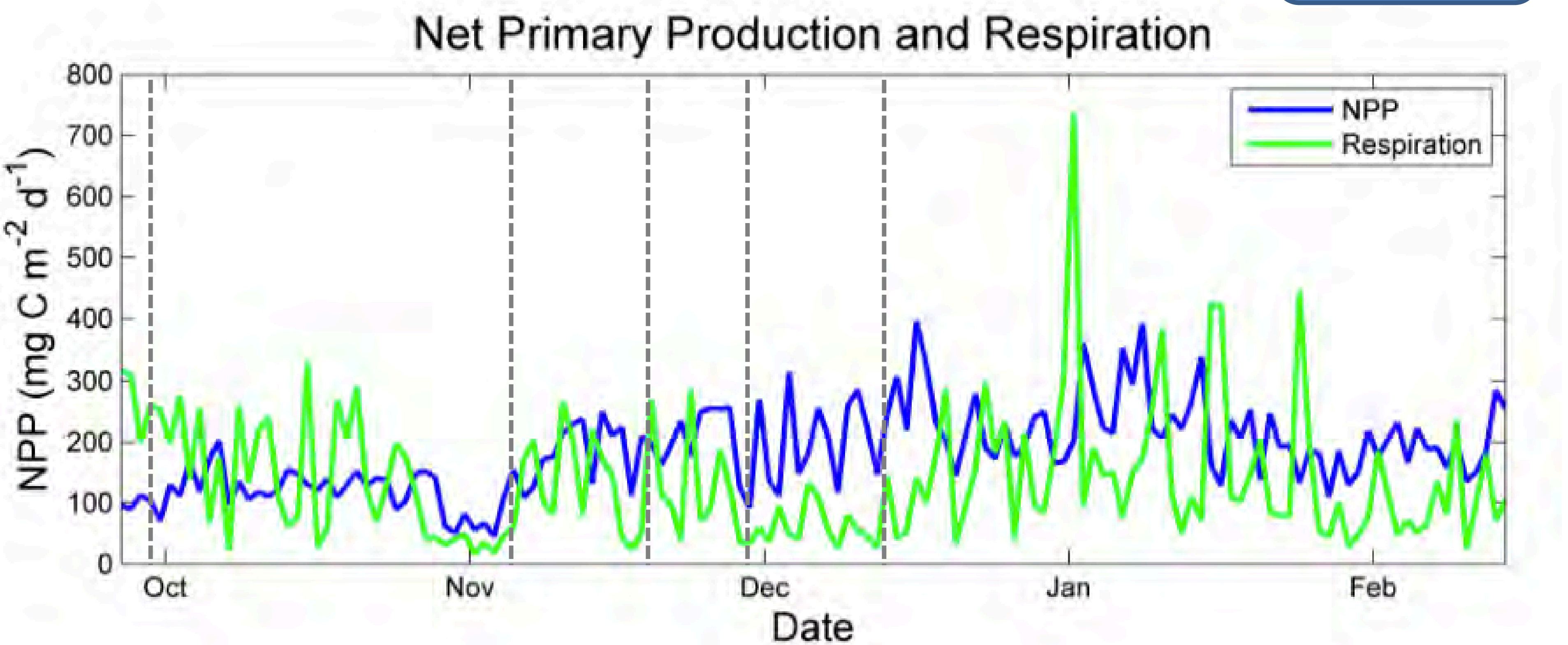
Thomalla, Racault, Swart and Monteiro in progress . J.M.S

Glider bio-optics → chlorophyll and POC

+ glider light, temp and MLD

= Modelled PP, Respiration and NCP

Ceinwen Smith Poster # 6



(NPP from Platt et al., 1980 and 1993)

(NCP and Respiration from Sverdrup 1953)

Conclusions

- Bio-optics sensors on gliders allow us to measure high resolution phytoplankton growth rates

- Our work highlights the sensitivities of PP in the SAZ to climate change

- Climate adjustments to temp and wind in the SAZ will alter the MLD having major implications for the effectiveness of the biological carbon pump


Thank You