# Dust and pyrogenic iron boost phytoplankton blooms

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In memory of Ross Mitchell

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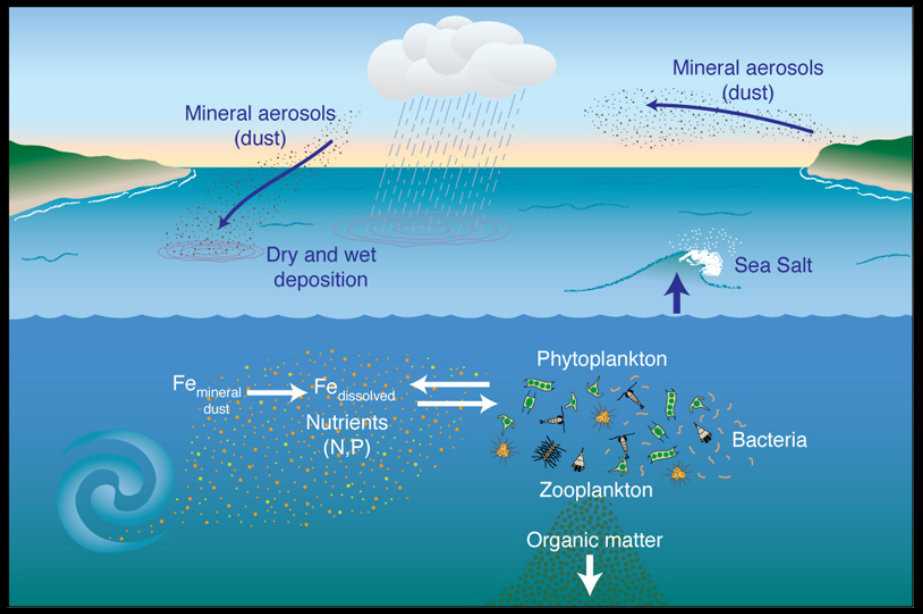
# Introduction

Aerosols can act as a source of iron in anaemic remote oceans like the Southern Ocean.

However, there is a complex chain of processes between the particle uplift in to the atmosphere, its deposition in the ocean and the potential uptake by phytoplankton




- Soil erosion
- Wind uplift
- Atmospheric chemistry
- Wet/Dry deposition
- pH
- Fe solubility and bioavailabilty

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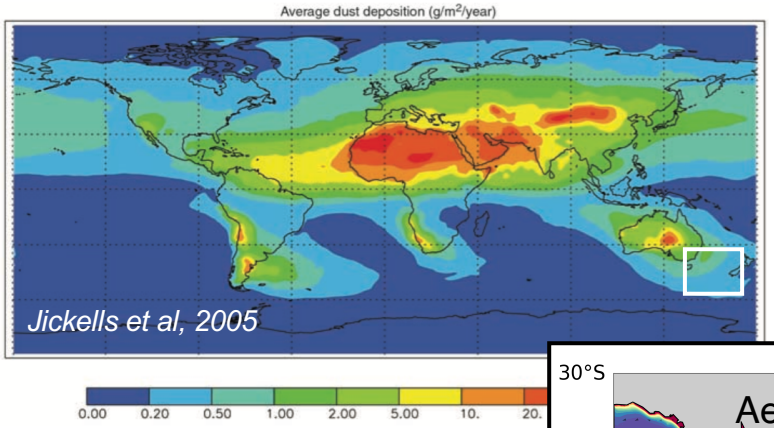
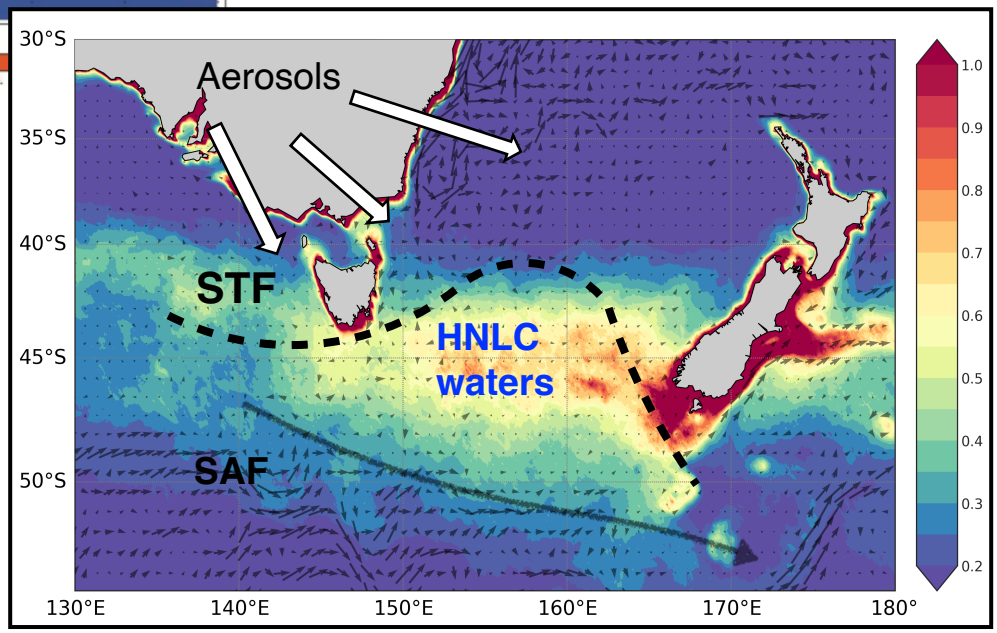
# The Tasman Sea
## A natural lab for aerosol driven fertilisation

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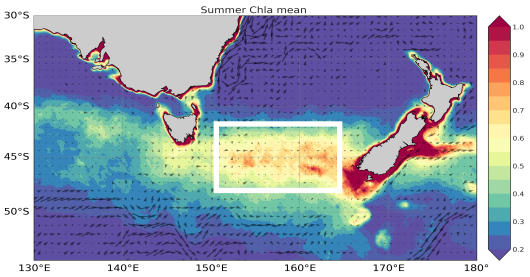
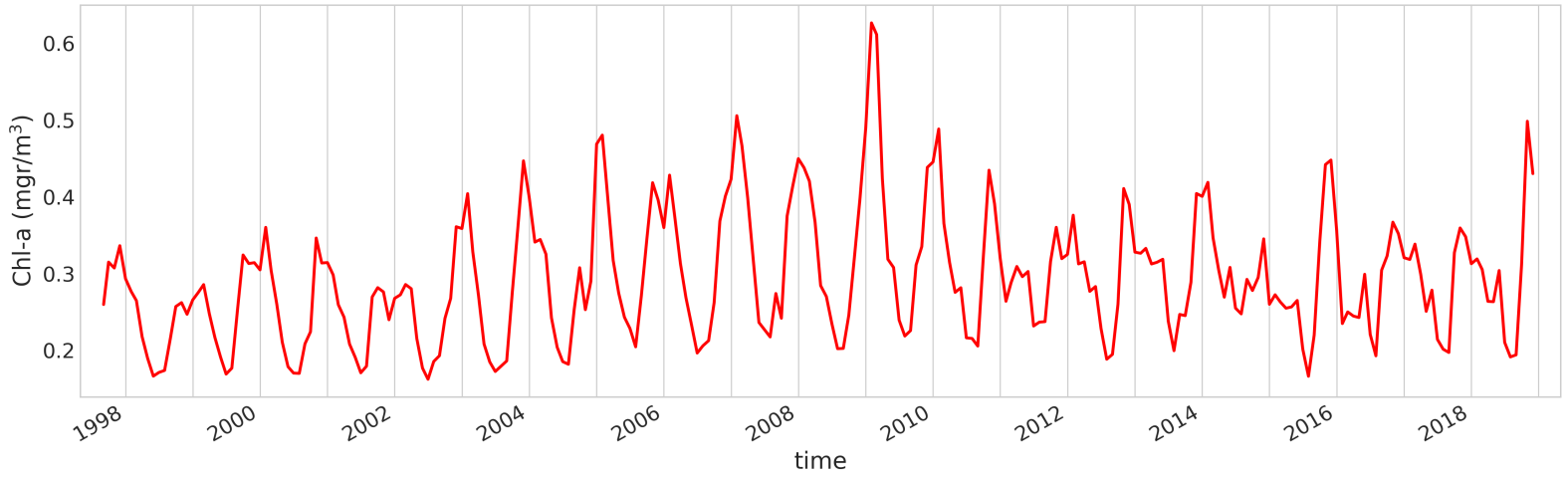
# Observed interannual variability




Strong inter-annual variability and apparent multi-annual trends



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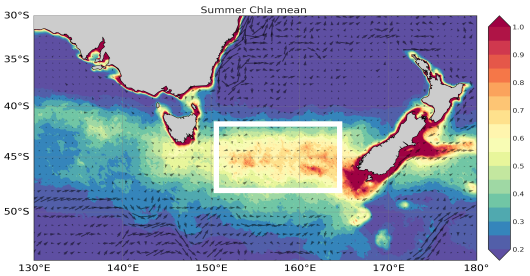
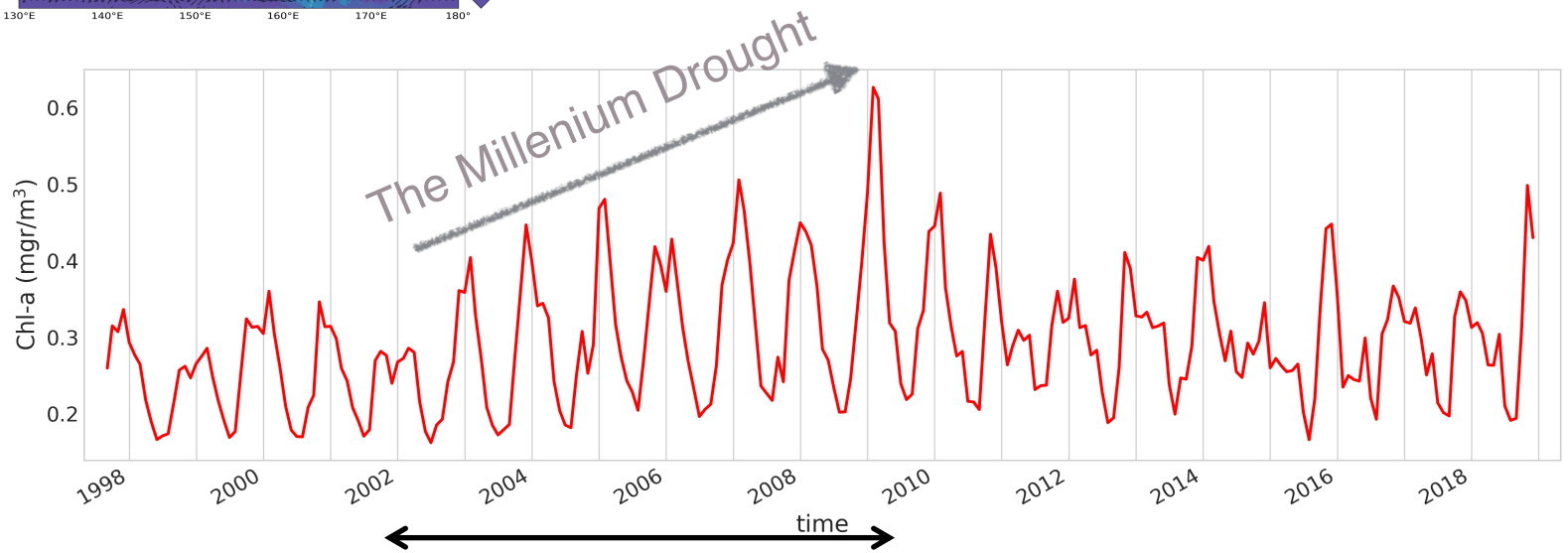
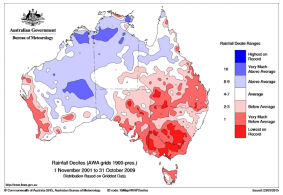



Bloom magnitude increased between 2002-2009, in parallel to a long and severe drought.




Negative rainfall anomalies
Nov 2001 to Oct 2019



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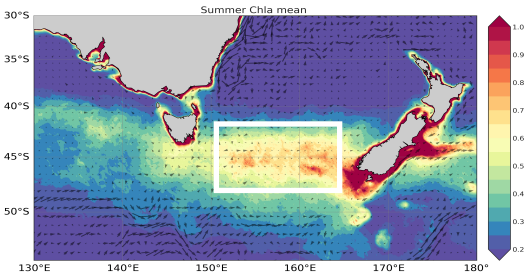
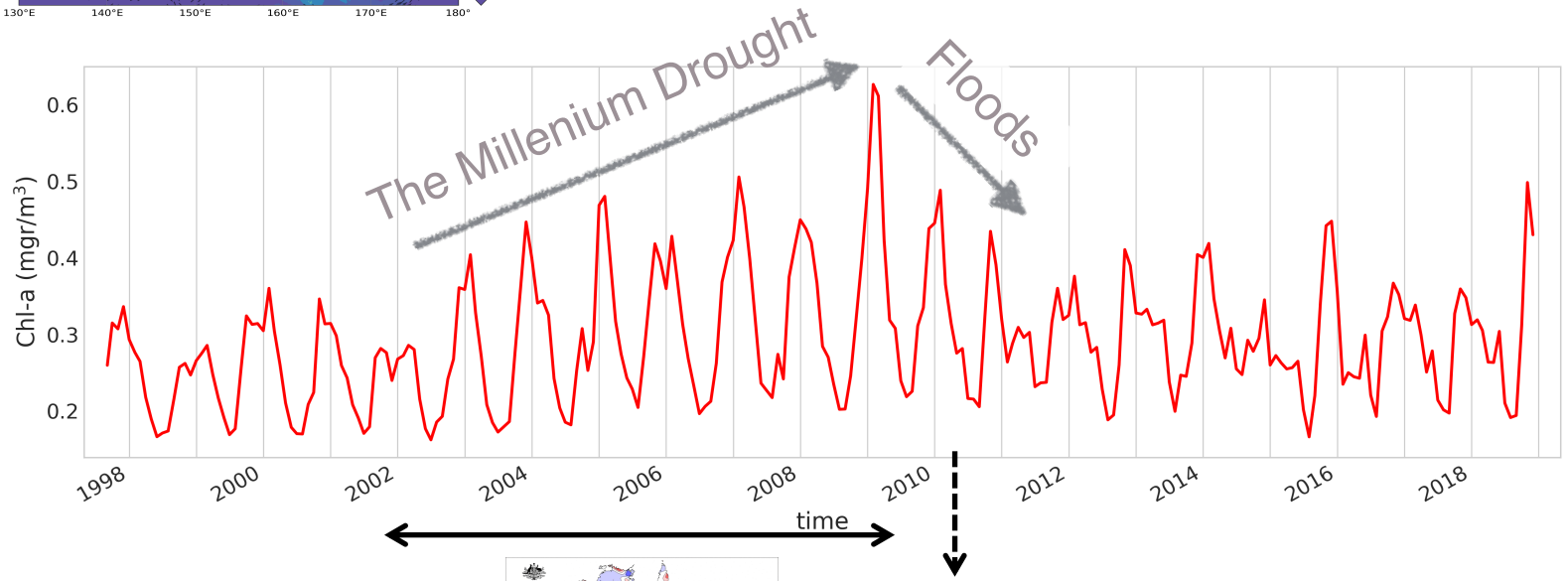
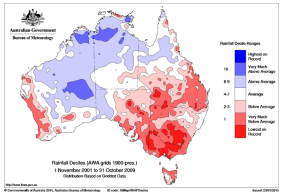


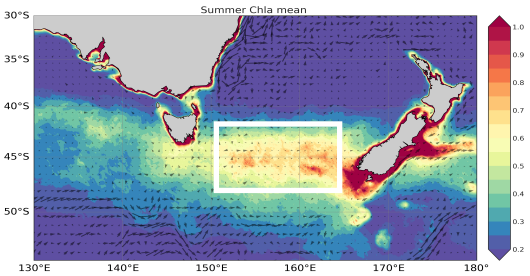

Bloom magnitude quickly decreased in 2011 and 2012, when most arid regions in the south-east flooded.



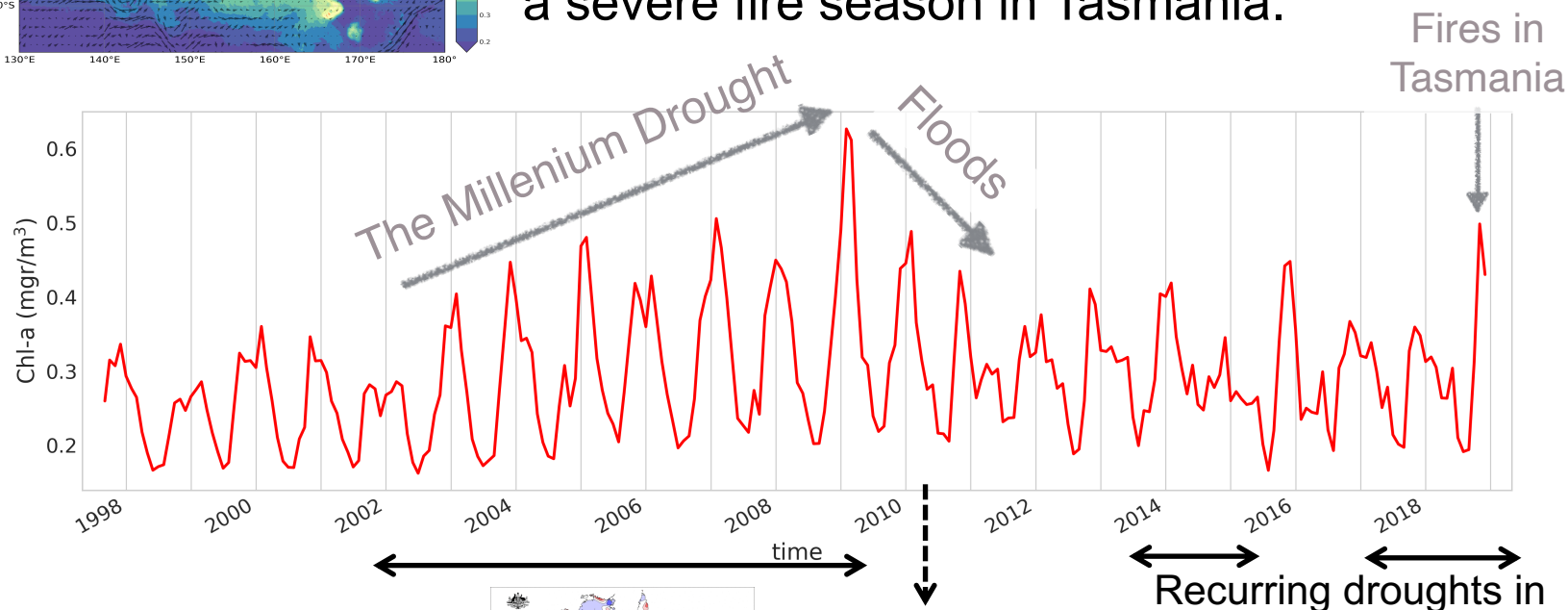



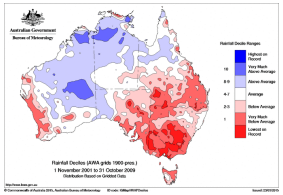
Jan 2011

# Observed interannual variability




Bloom magnitude was high again in 2016, after 1.5 year of drought, and in 2018 after exceptionally dry years and a severe fire season in Tasmania.



Jan 2011

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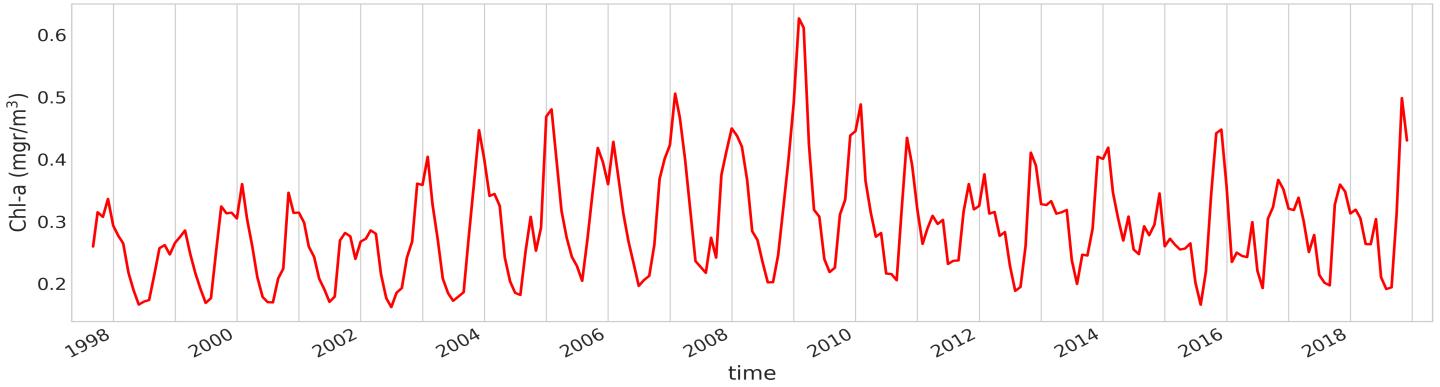
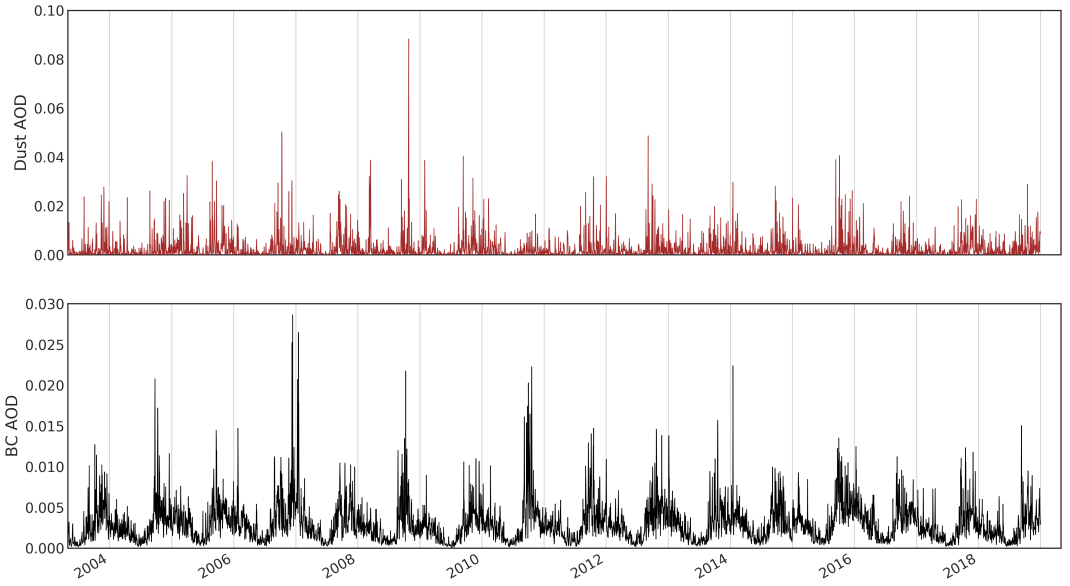
# Dust, ashes and phytoplankton blooms




How high variability in dust and black carbon can influence seasonal phytoplankton bloom?



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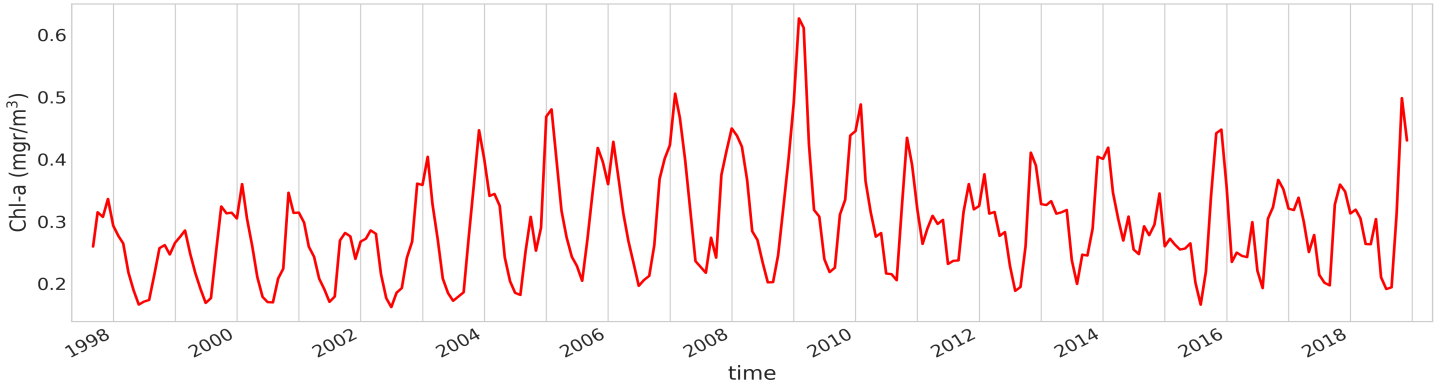


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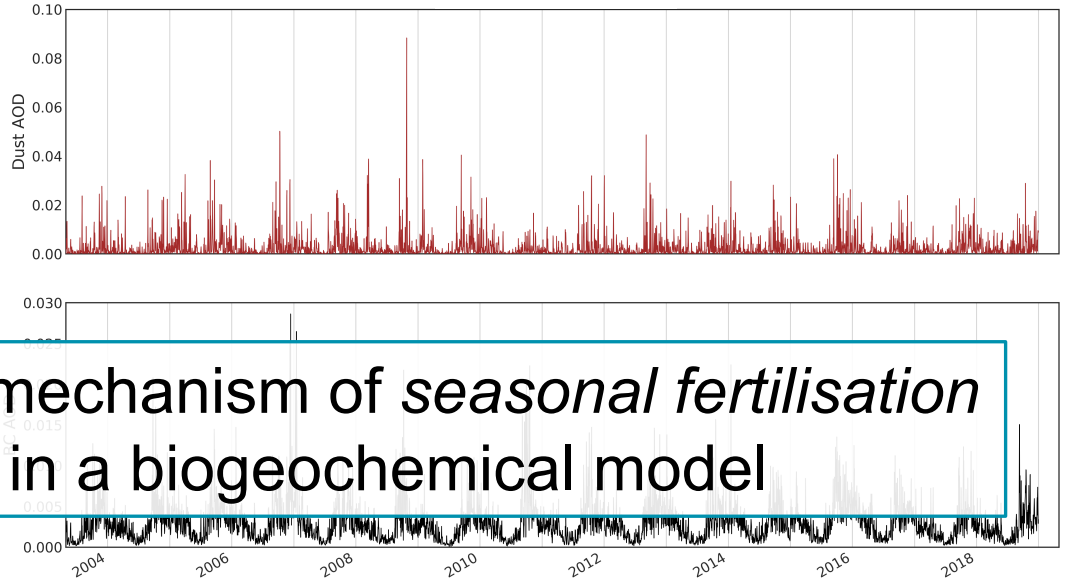
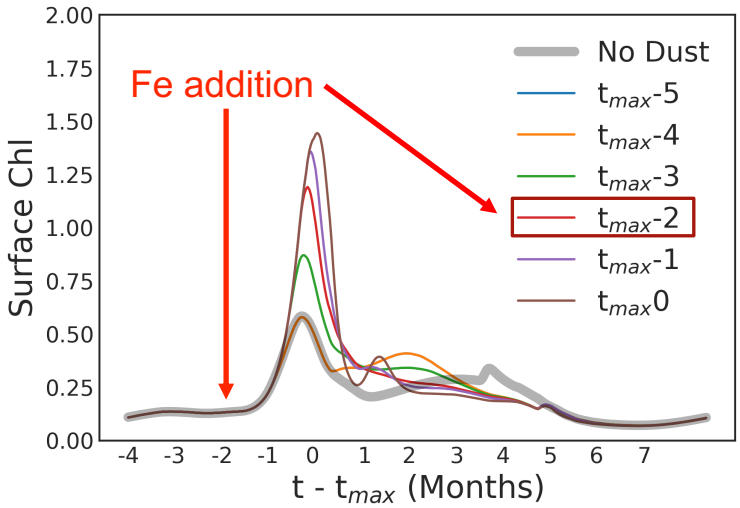
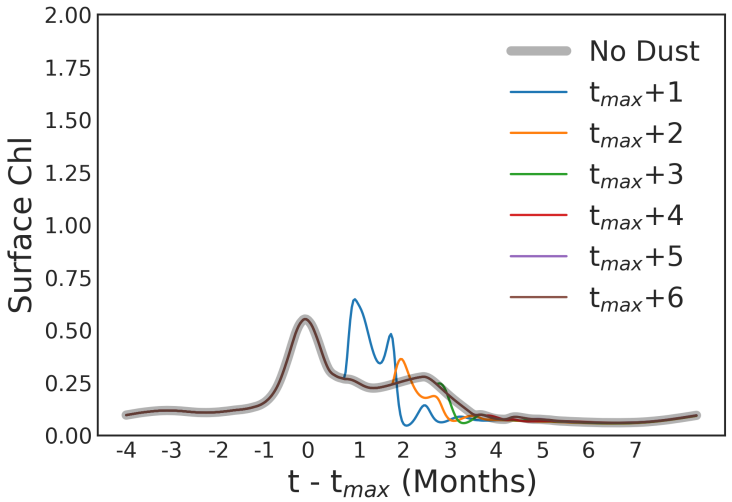



We tested a mechanism of *seasonal fertilisation* using in a biogeochemical model

# Seasonal fertilisation – virtual experiments

- 1D biogeochemical model (details here)
- Fertilisation experiments: Fe deposition during 1 month only

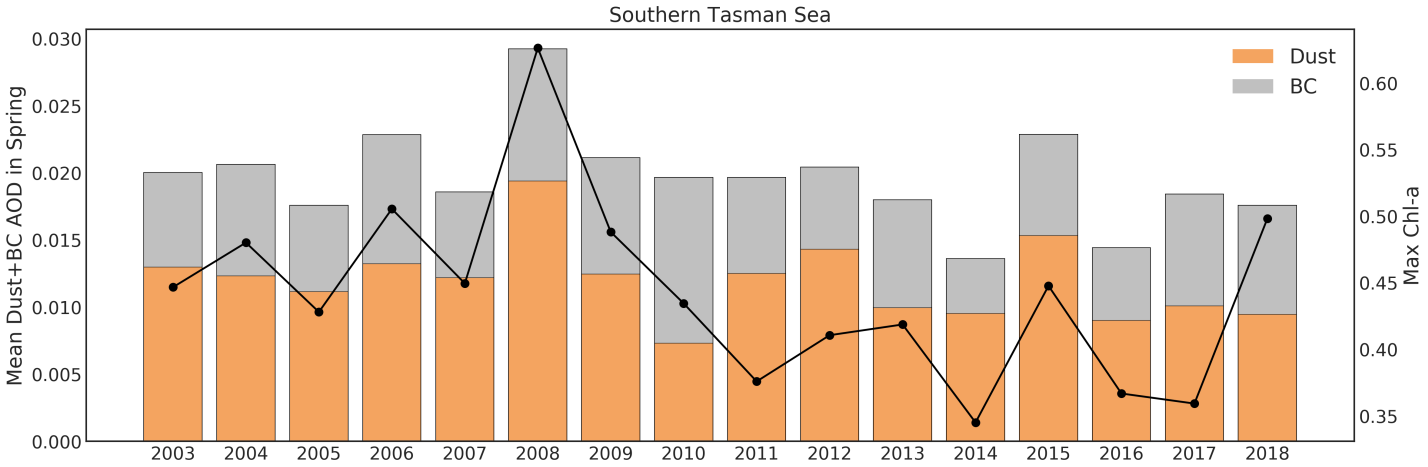



- Deposition in spring replenishes surface waters with Fe and boosts bloom
- Deposition in summer can cause isolated events of fertilisation

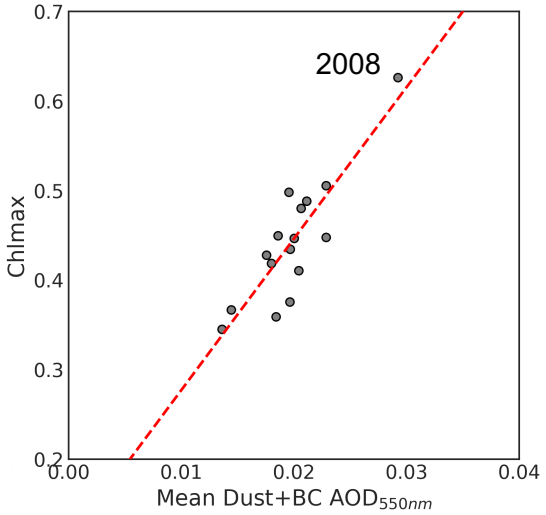
# Seasonal fertilisation – observations

We averaged the spring-to-summer events of strong dust and BC AOD over the region.




**High AOD ≠ Deposition** but there is an evident relationship between averaged AOD and sChl.

- Strong correlation when using **both Dust+BC**, even excluding year 2008
- Weak (<0.5) correlation when using Dust and BC alone (+ details here)
- Some variability cannot be explained by AOD.
- Changes in deposition or MLD also important but not drivers.




Full timeseries: $r^2$=0.74

Without 2008: $r^2$=0.53

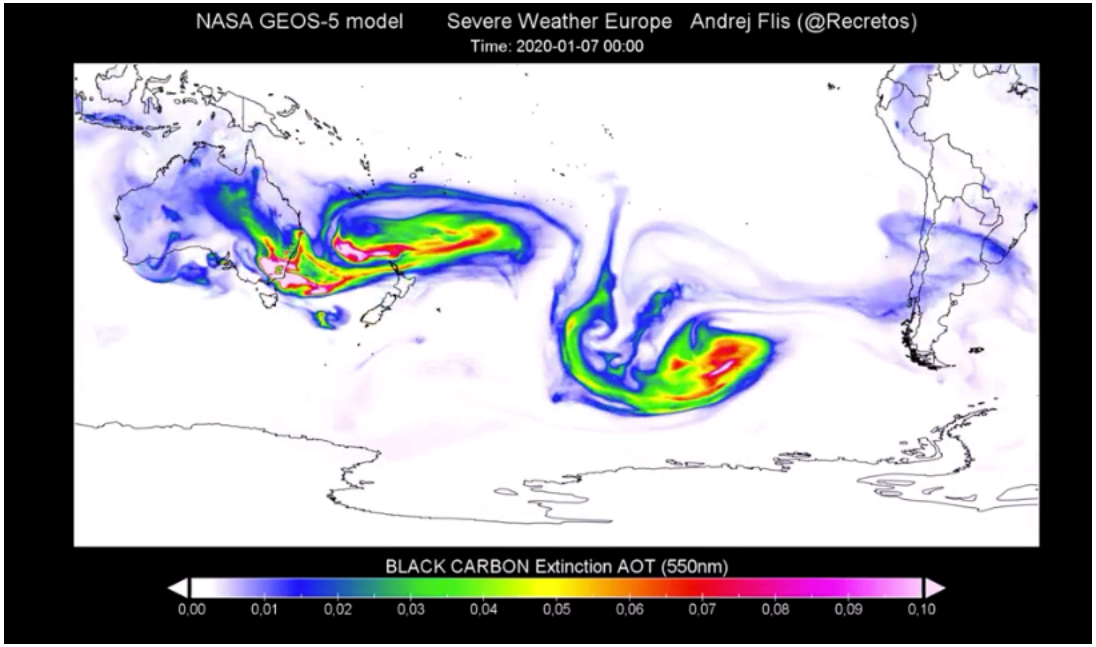
# Conclusions

- **Spring to summer deposition** replenishes the mixed layer with Fe and boosts bloom in a region of weak circulation but strong MLD seasonality.
- Summer responses to dust addition are weak due to Si limitation. Winter responses are absent due to low light.
- Black Carbon alone does not fertilise but it **enhances dust solubility** (i.e. acidity?), hence Fe uptake by phytoplankton.

# Perspectives

- **Droughts, together with bushfires and changes in land-use** over the Australian continent drive Tasman Sea primary production.

- What is the impact of the unprecedented 2019-20 fire season??



# Supplementary slides

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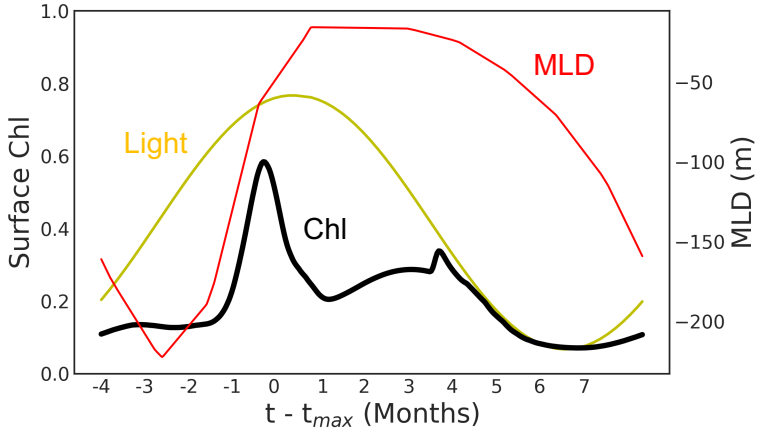
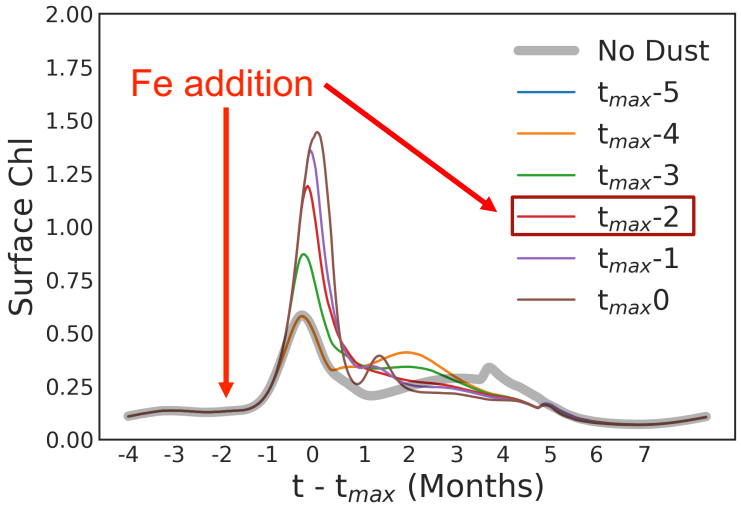
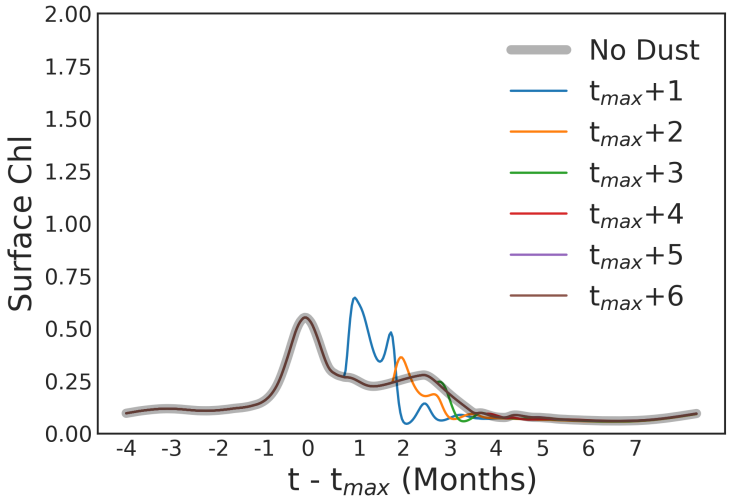
# Seasonal fertilisation – virtual experiments




- 1D biogeochemical model (NEMO- PISCES)
- Seasonal cycle
- Complex BGC - Simplified physics
- MLD and nutrients from observations



# Pre-bloom Fe inventory drives bloom

| | Dust | Black Carbon | Dust + Black Carbon |
|---|---|---|---|
| $r^2$ (2003-2018) | 0.48 | 0.31 | 0.74 |
| $r^2$ (without 2009) | 0.17 | 0.28 | 0.53 |