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Multi-year variability in the Southern Ocean – implications for BGC cycling and decadal forecasting

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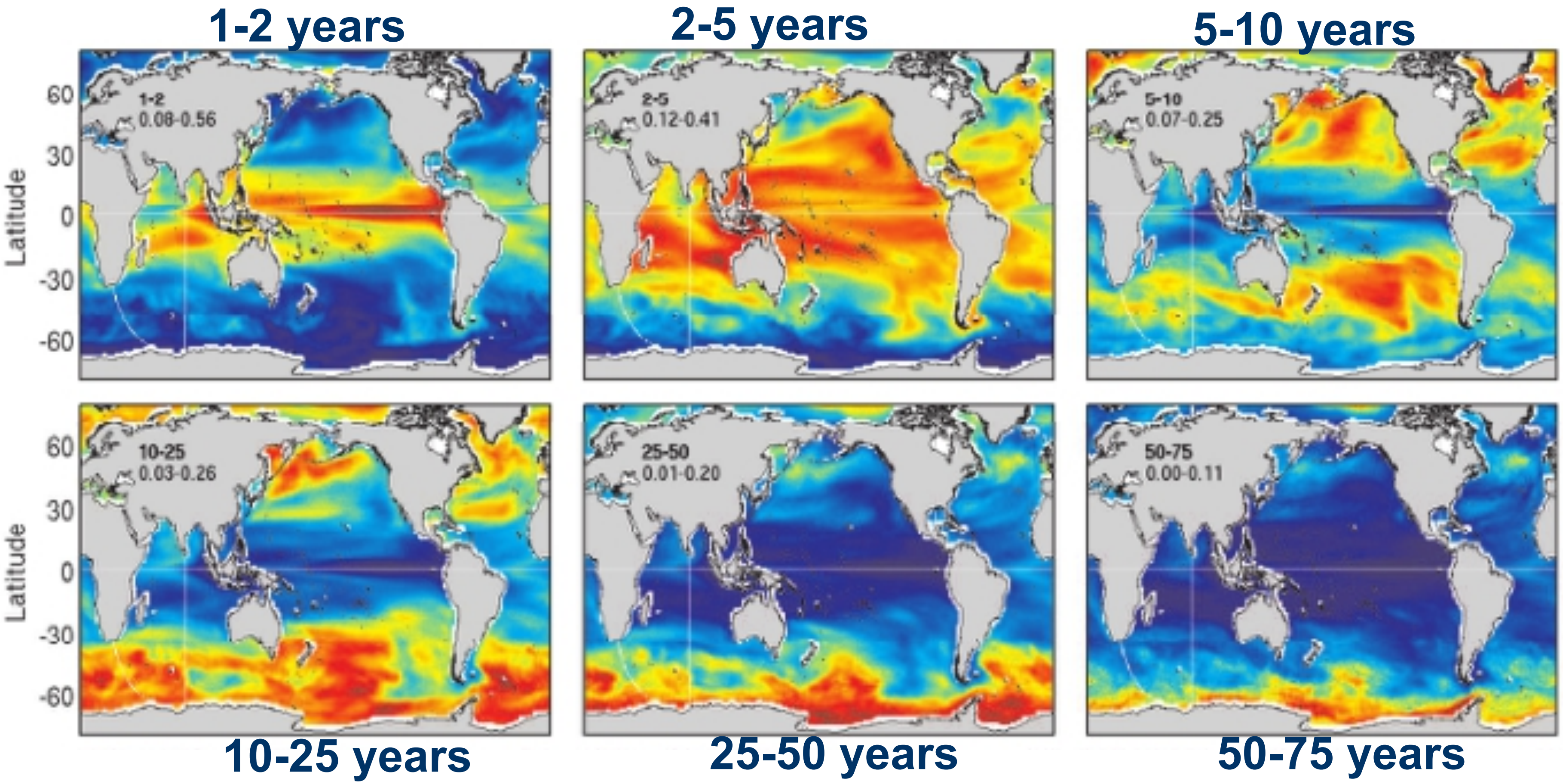
Multi-year variability: Outline and Conclusions

Discuss three different Southern Ocean mechanisms that generate multi-year variability

Conclusions

- Mechanisms of multi-year variability to underpin decadal forecasting systems, which are linked to the SO dynamics
  - the variability affects the thermocline, sea-ice and subduction of mode water
- Potential impacts on BGC cycling and anthropogenic carbon subduction
- Weather is important to coupling of the atmosphere with the ocean, which amplifies the Southern Ocean multi-year variability

CMIP5 multi-model sea surface height variability: Where is the memory of the climate system?



- Variability on short time scales (less than 5 years) mostly in the tropical Pacific (reflects ENSO variability) –> Seasonal forecasting focused on growth of ENSO regimes
- Beyond a few years, the tropical Pacific (ENSO) is not driving variability -> Need to examine extra-tropical ocean variability - in particular, the Southern Ocean

INTRINSIC SOUTHERN OCEAN VARIABILITY

1. Baroclinic disturbances generated in thermocline of the ACC

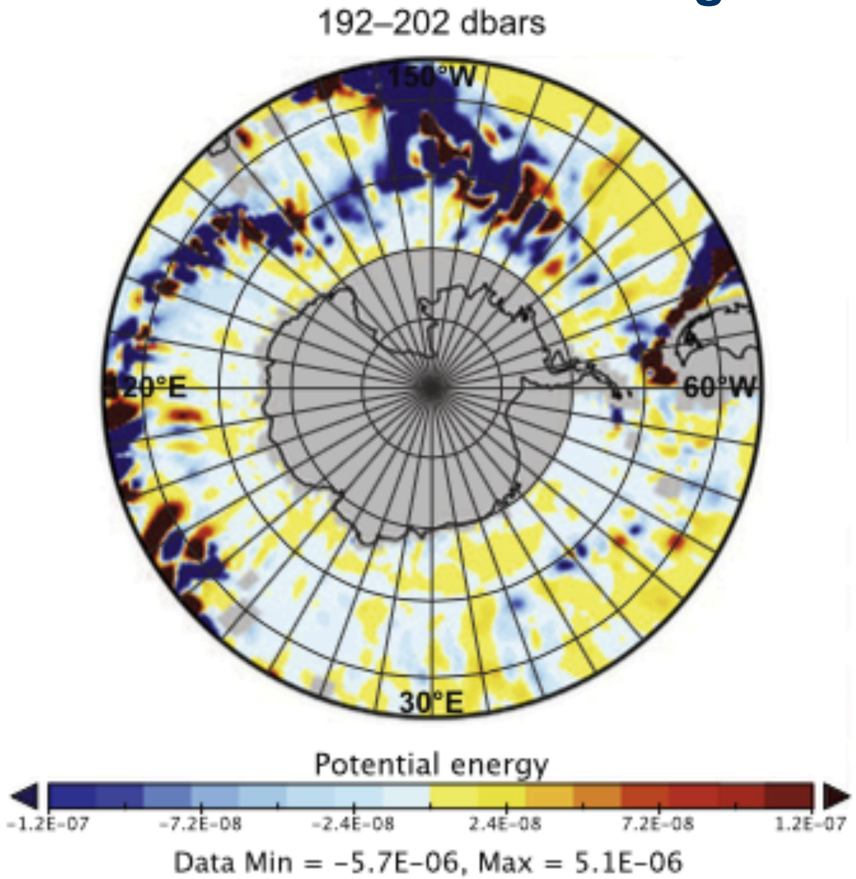
Southern Ocean to Lower Latitude connections

2. Baroclinic disturbances in the thermocline propagating along density fronts

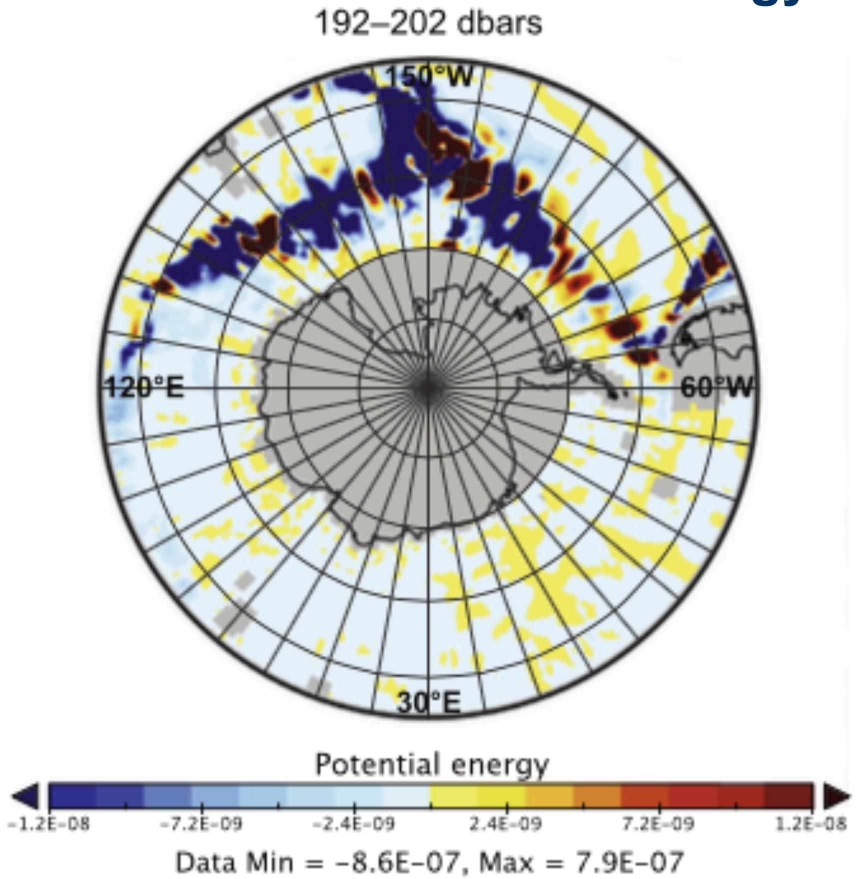
3. Spicy anomalies associated with subtropical mode water subduction propagate in the thermocline and connect the Southern Ocean to tropical Pacific

Southern Ocean Intrinsic Variability: baroclinic waves in the thermocline

CORE2 – Interannual forcing



CORE1 – seasonal climatology



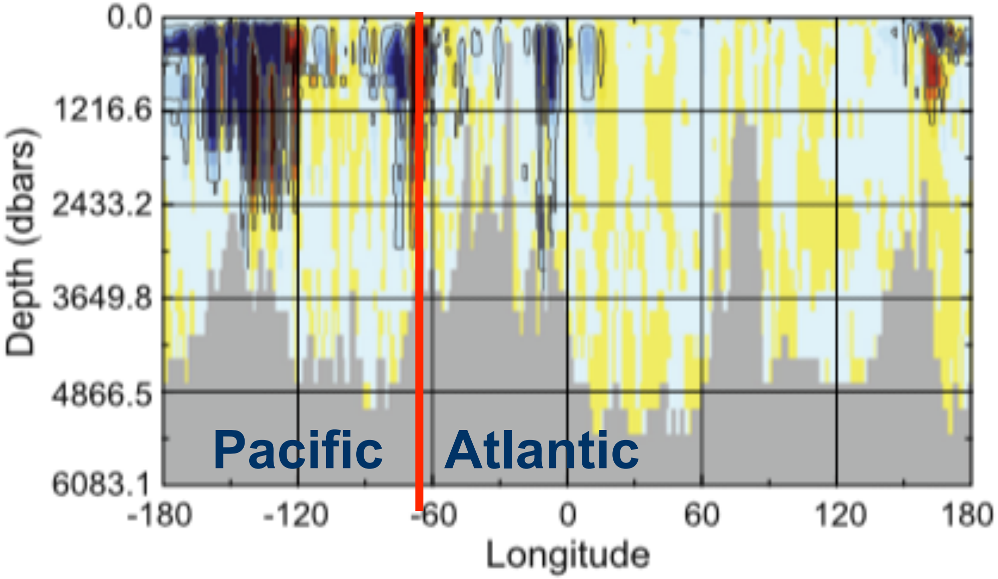
Wave-like features appears in the transfer of energy to and from the mean to transient flow

Like a Rossby wave it wants to propagate to the west but it is transport east with the ACC

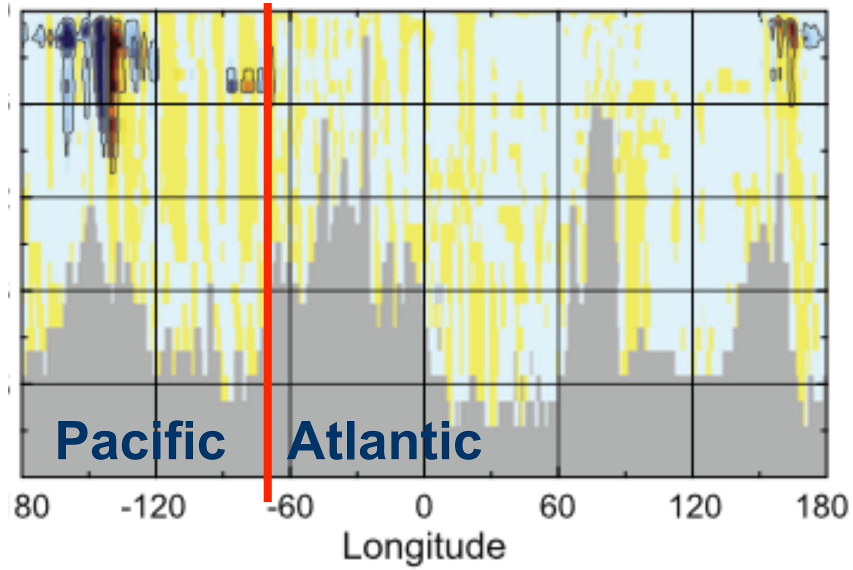
O'Kane et al., 2013

Southern Ocean Intrinsic Variability: baroclinic wave's depth structure at 58°S

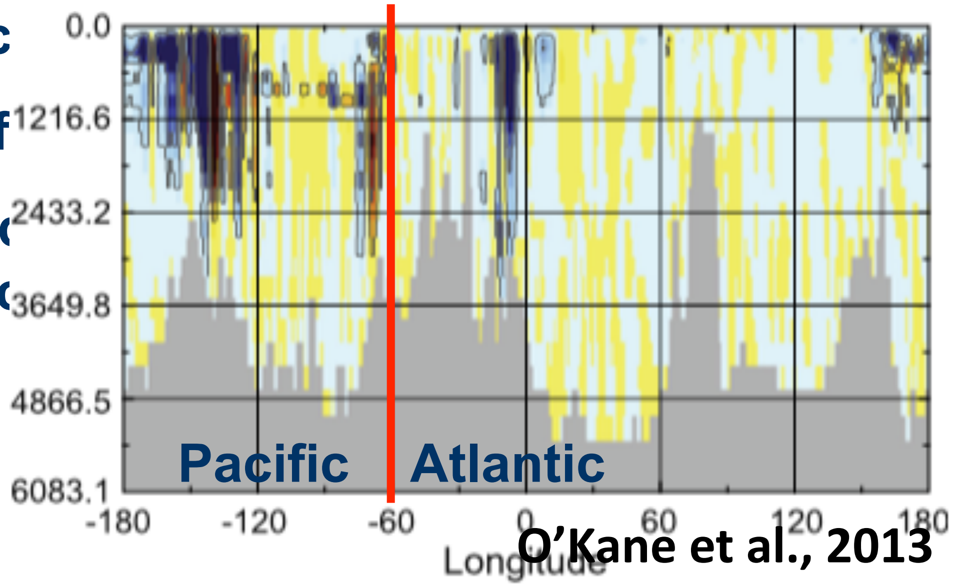
CORE2 –interannual forcing



CORE1 – seasonal climatology



Weather – removal of IAV



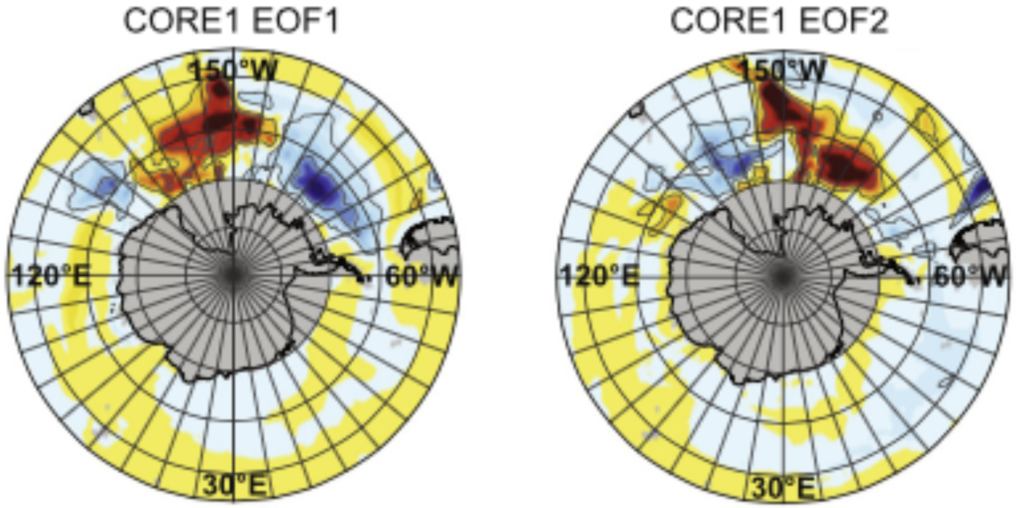
Variability confined to the thermoc

CORE1 variability only in the Pacif

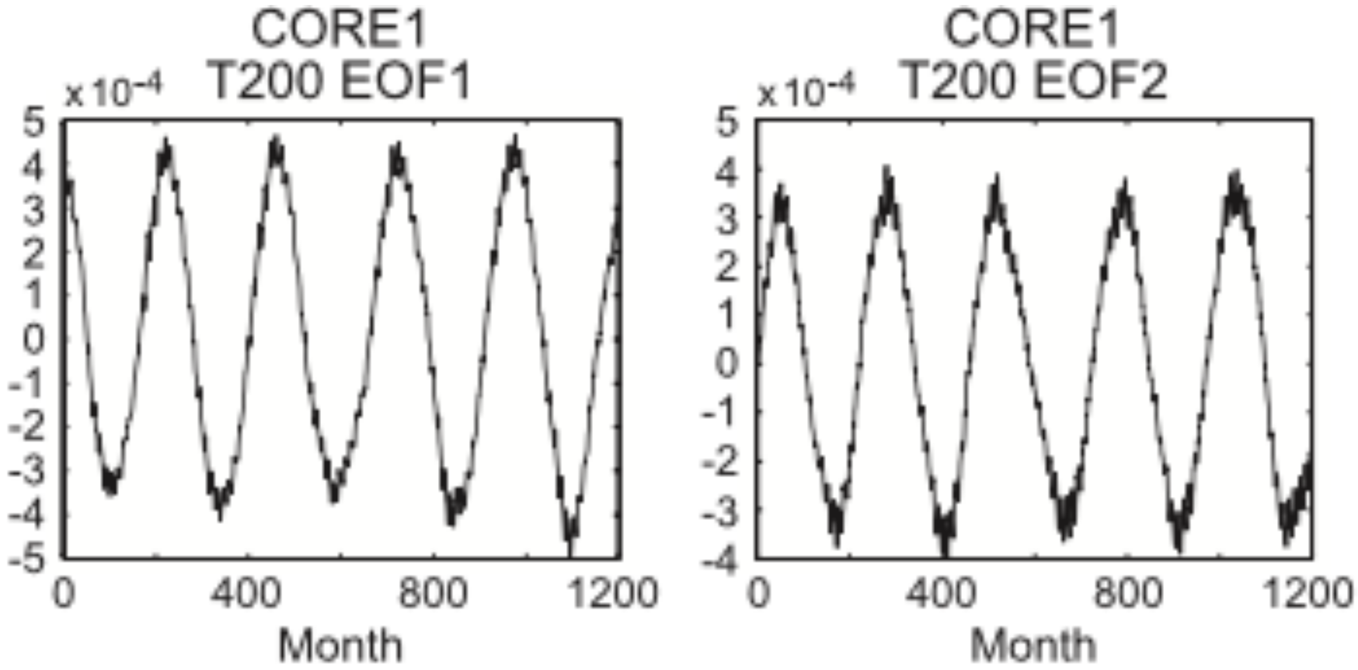
CORE2 amplified variability aroun variability in Atlantic and Indian Oc

O'Kane et al., 2013

Southern Ocean Intrinsic Variability: EOF analysis of the Temperature variability at 200m (CORE1)



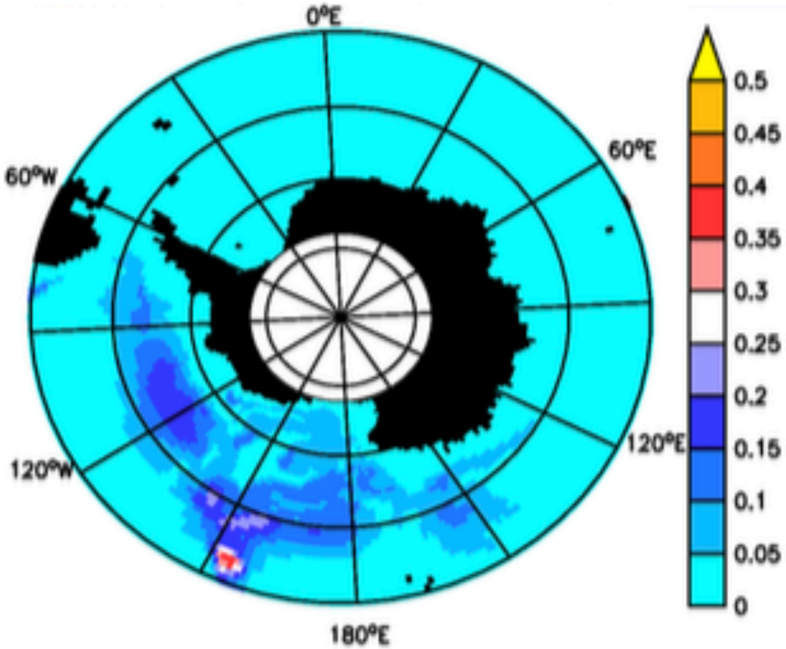
CORE1 – intrinsic mode of variability with a period of 20 years



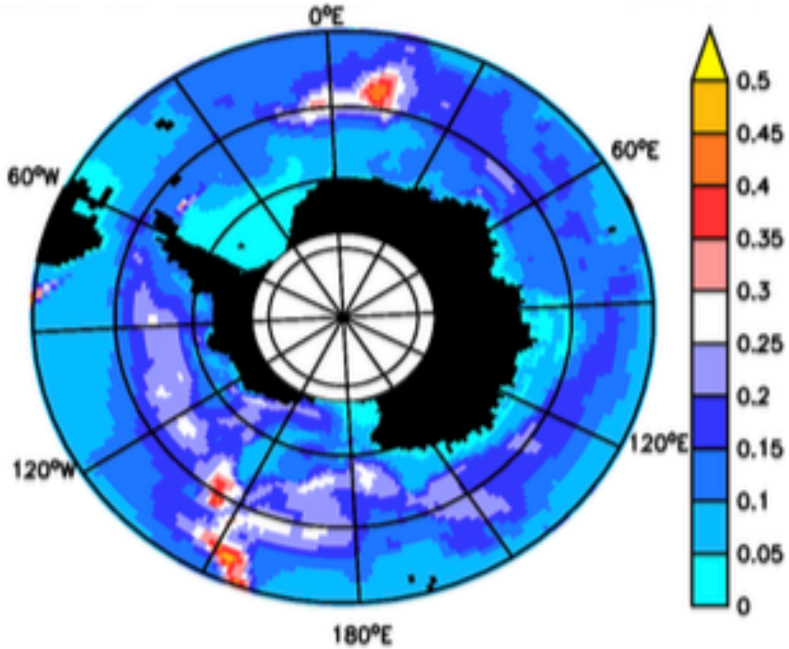
O'Kane et al., 2013

Interannual Temperature variability at 200m: Importance of weather

CORE1: Seasonal Climatology



Weather



The inclusion of weather substantial increases temperature variability in the thermocline

Matear et al., in prep.

Interannual Temperature variability at 200m: Change in character

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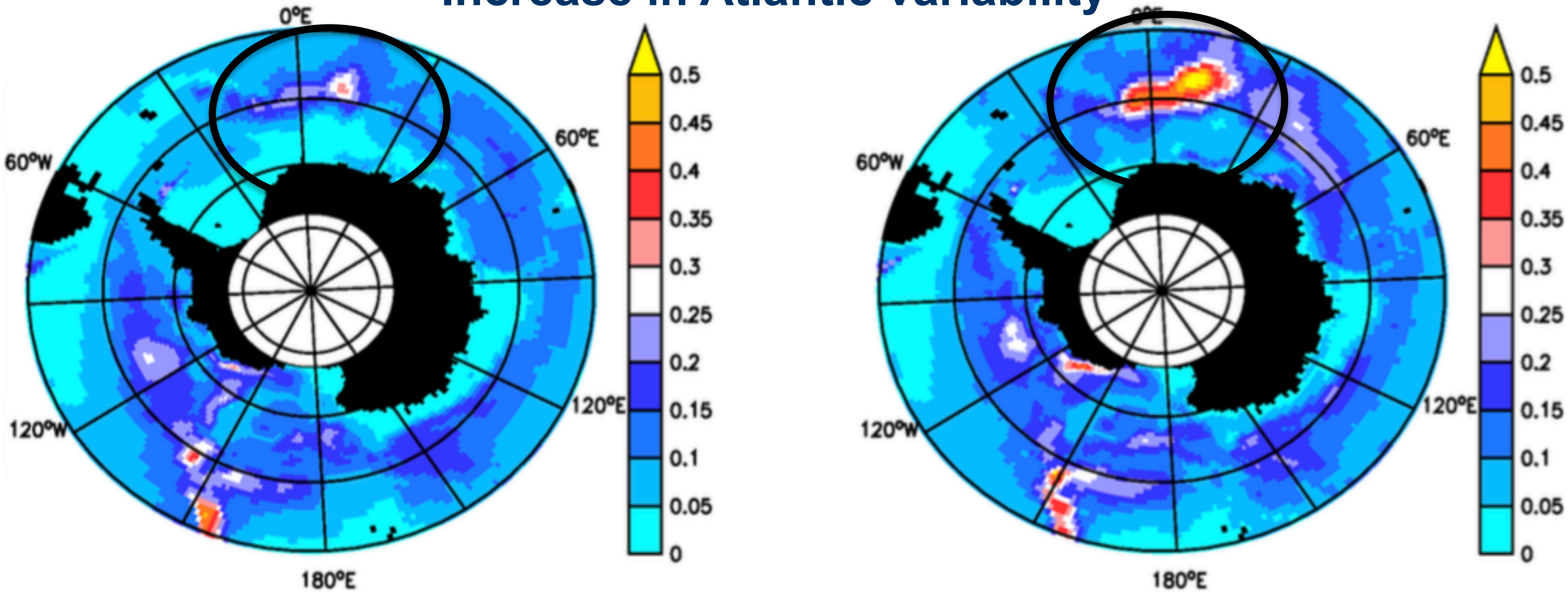
Increase in Atlantic variability



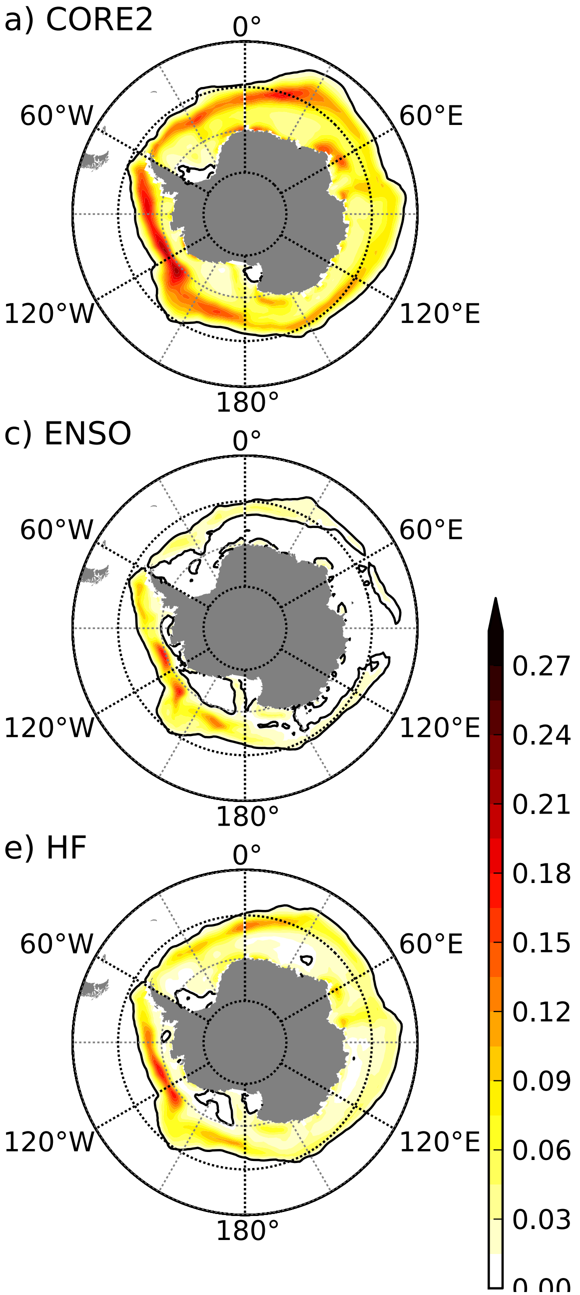
1960s Weather **1990s weather**

Change in the Character of the weather is associated with a change in the magnitude and structure of temperature variability in the thermocline

e.g. increase in Atlantic variability

Matear et al., in prep.

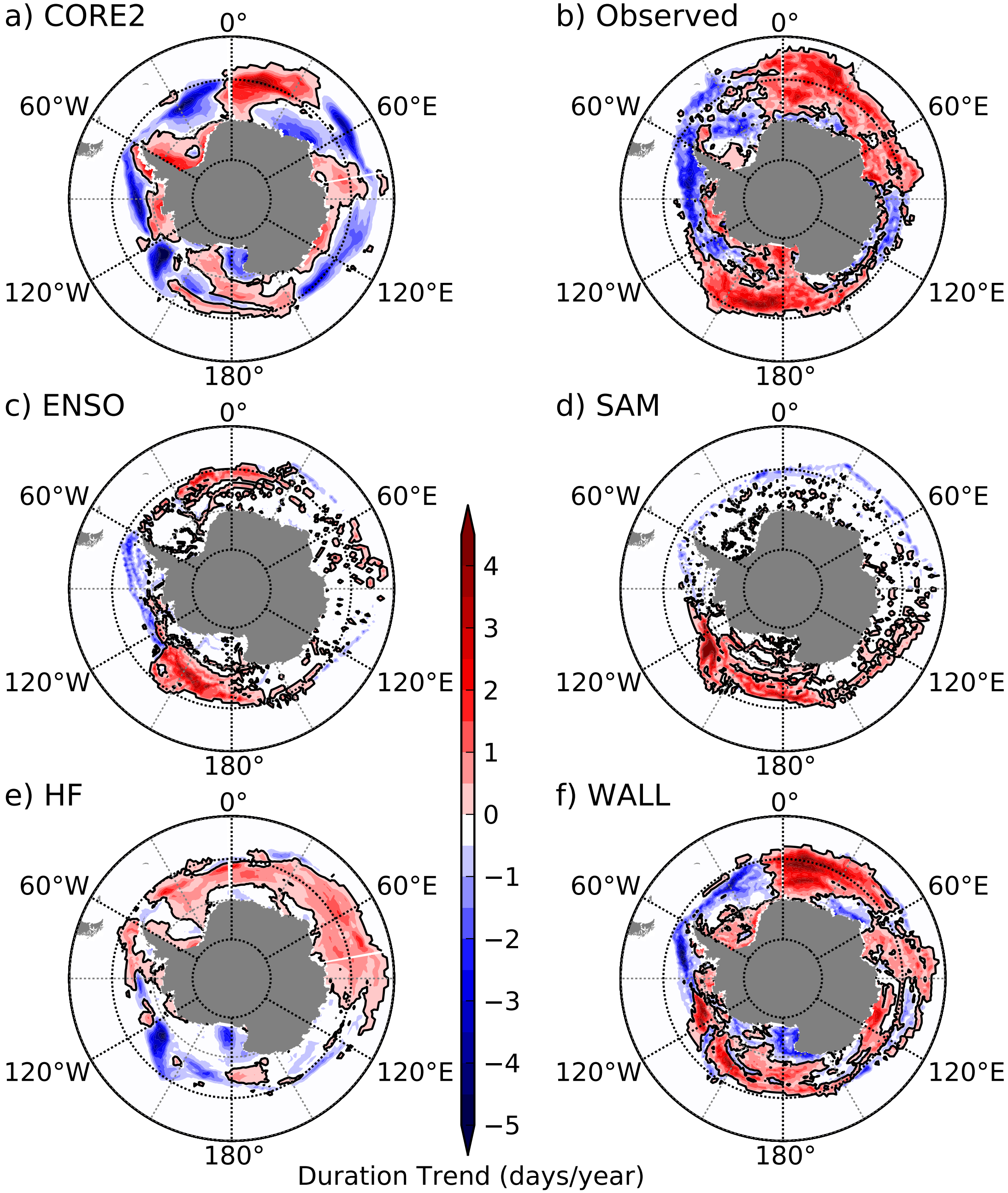
Sea-ice Concentration interannual variability: Importance of weather



Weather produces greater sea-ice variability than SAM or ENSO

Matear et al., in review NComm.

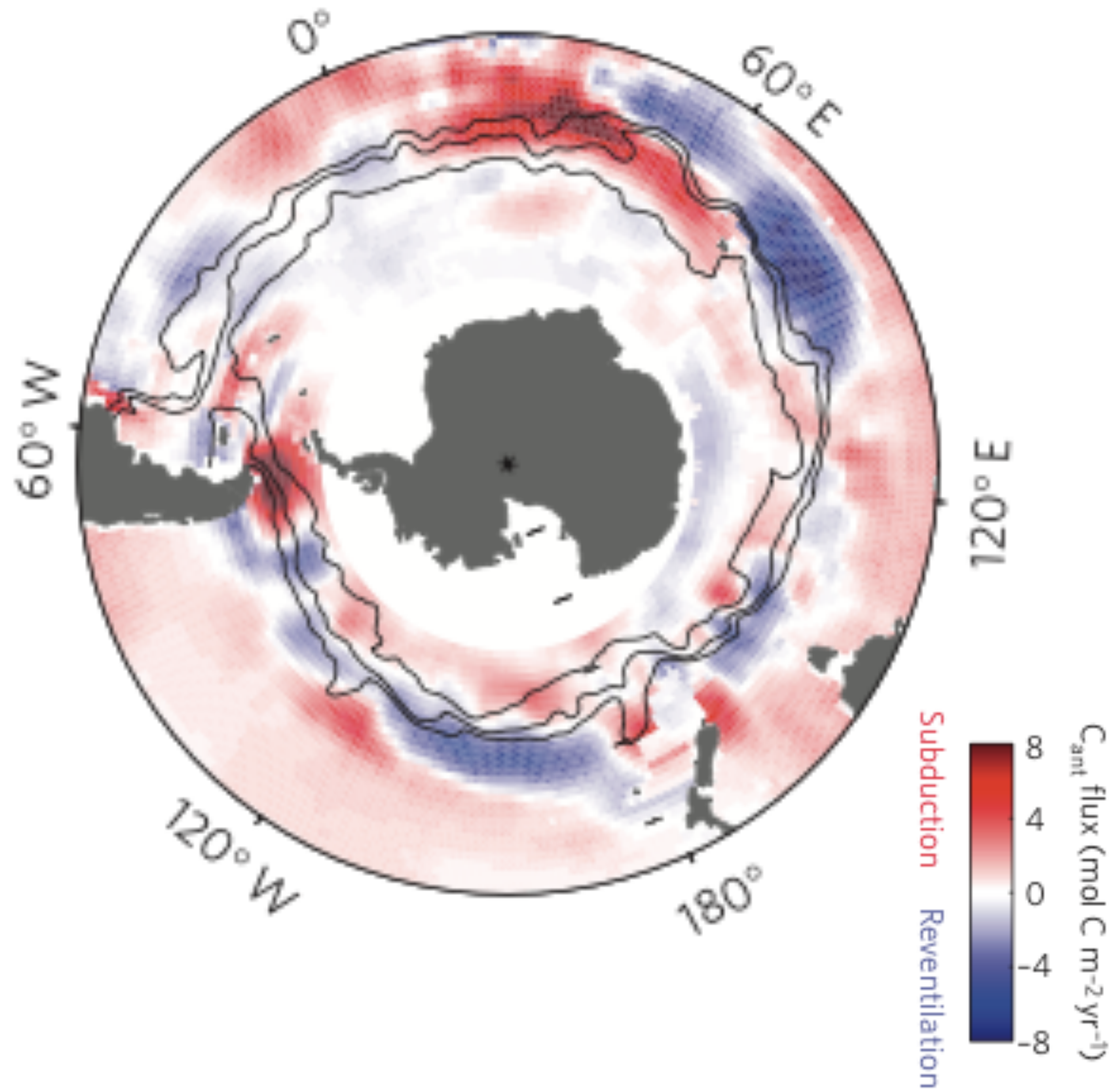
Sea-ice Duration trend (1990-2007): Importance of weather



Weather also produces multi-year trends in sea-ice duration

Matear et al., in review NComm.

Subduction of Anthropogenic Carbon: obsevational analysis



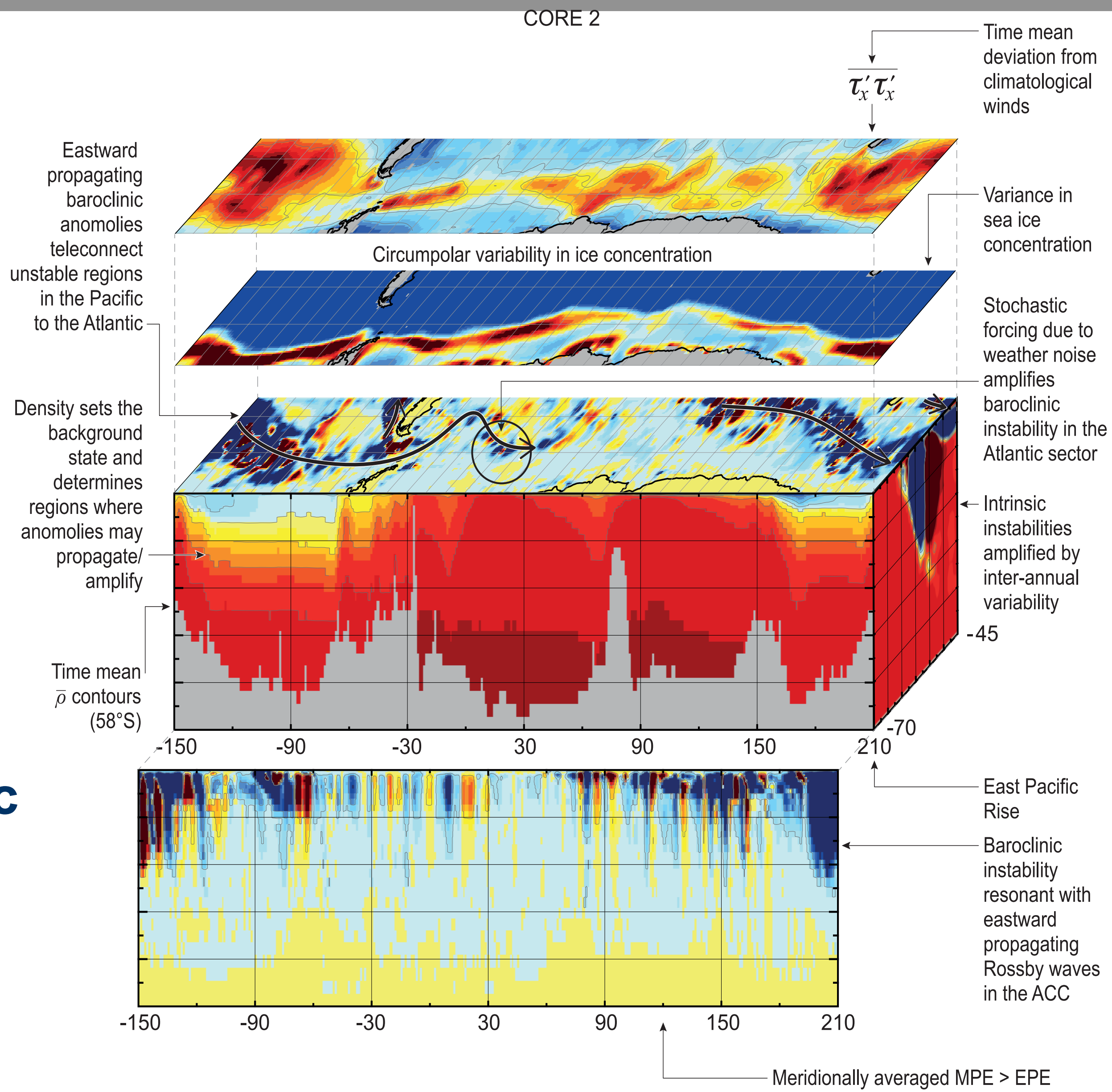
Subduction and reventilation "hot spots" located near the initial growth of the instability

Sallee et al 2012, NG

Southern Ocean Intrinsic and Forced Variability

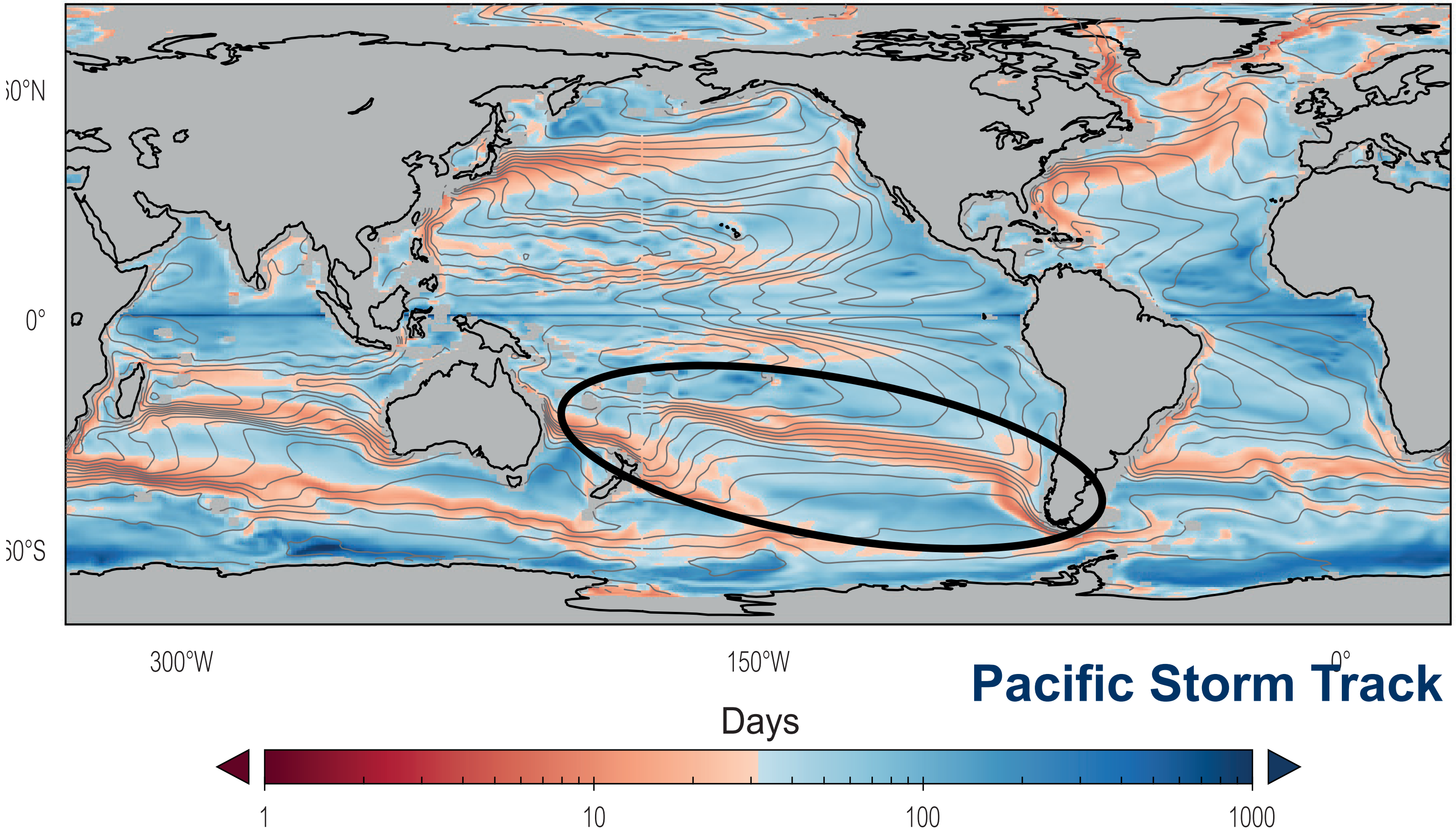
- **Preferred locations where thermocline variability is initiated as baroclinic disturbances**

- **Potential density gradients define waveguides along which the baroclinic disturbances are advected eastward by the mean flow.**



O'Kane et al., 2013

Southern Ocean to subtropics: “Ocean Storm Tracks”

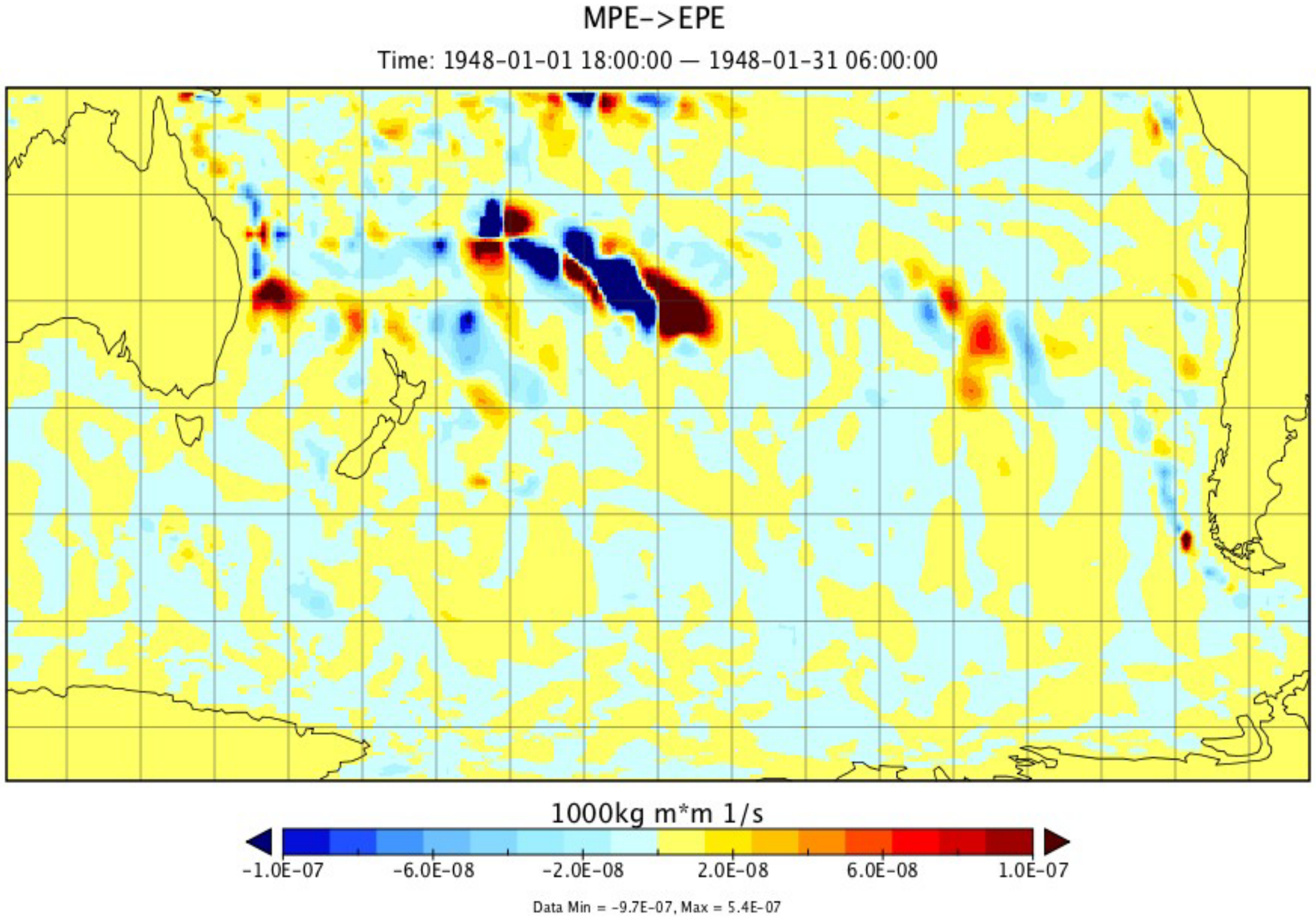


Eady Growth Rate:

Maps the waveguides along which baroclinic waves can propagate

O’Kane et al., 2014

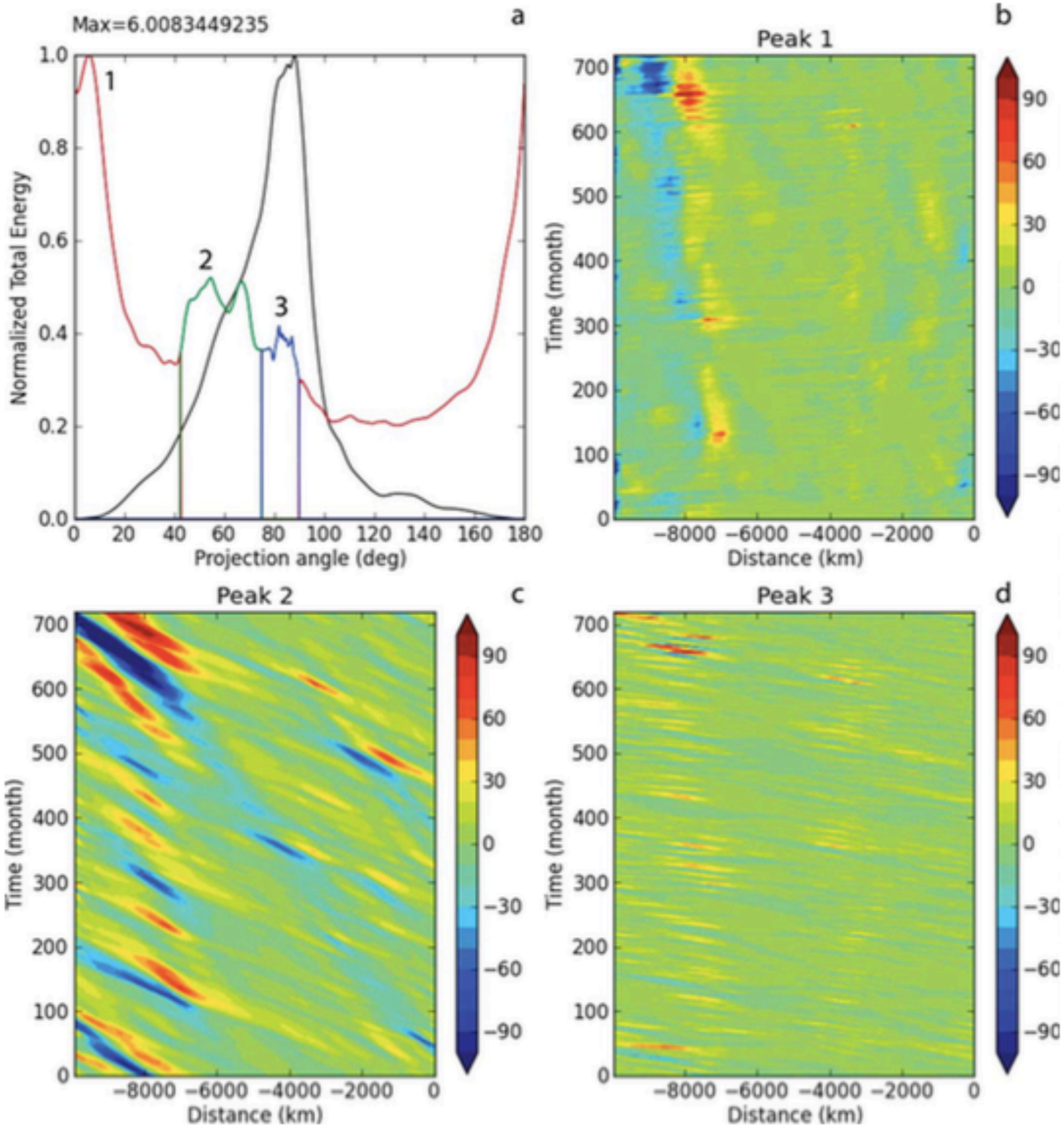
Southern Ocean to subtropics: "Ocean Storm Tracks"



Pacific Storm Track which are baroclinic waves propagating in the thermocline – expression in surface temperature

O'Kane et al., 2014

Pacific Baroclinic Waves: multi-scale with different propagation speeds



Radon Transform:

3 Peaks reflecting different propagation speeds

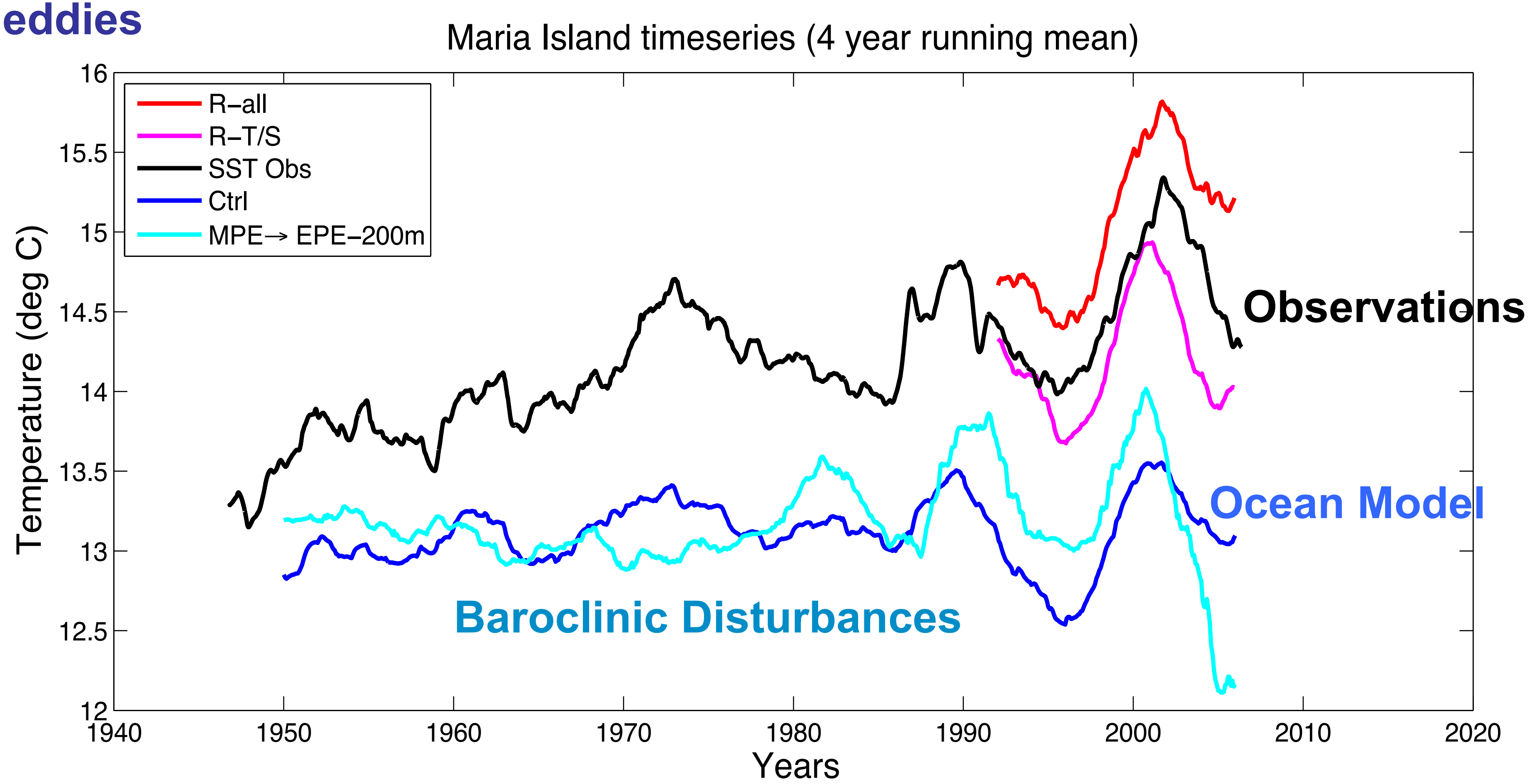
Multi-scale wave which slows down and amplifies at topographic features

Inverse Radon Transform shows the 3 peaks in physical space

Subtropical Response: evidence of a regime change

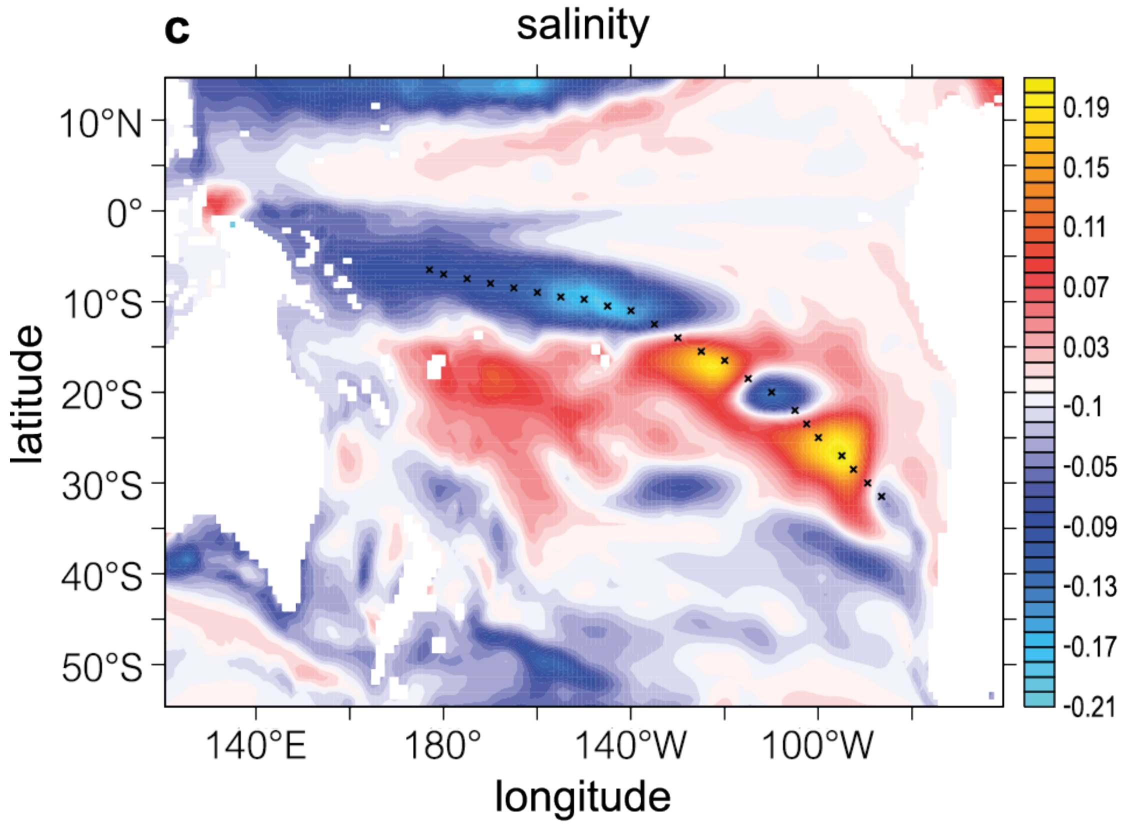
Maria Island SST variability:

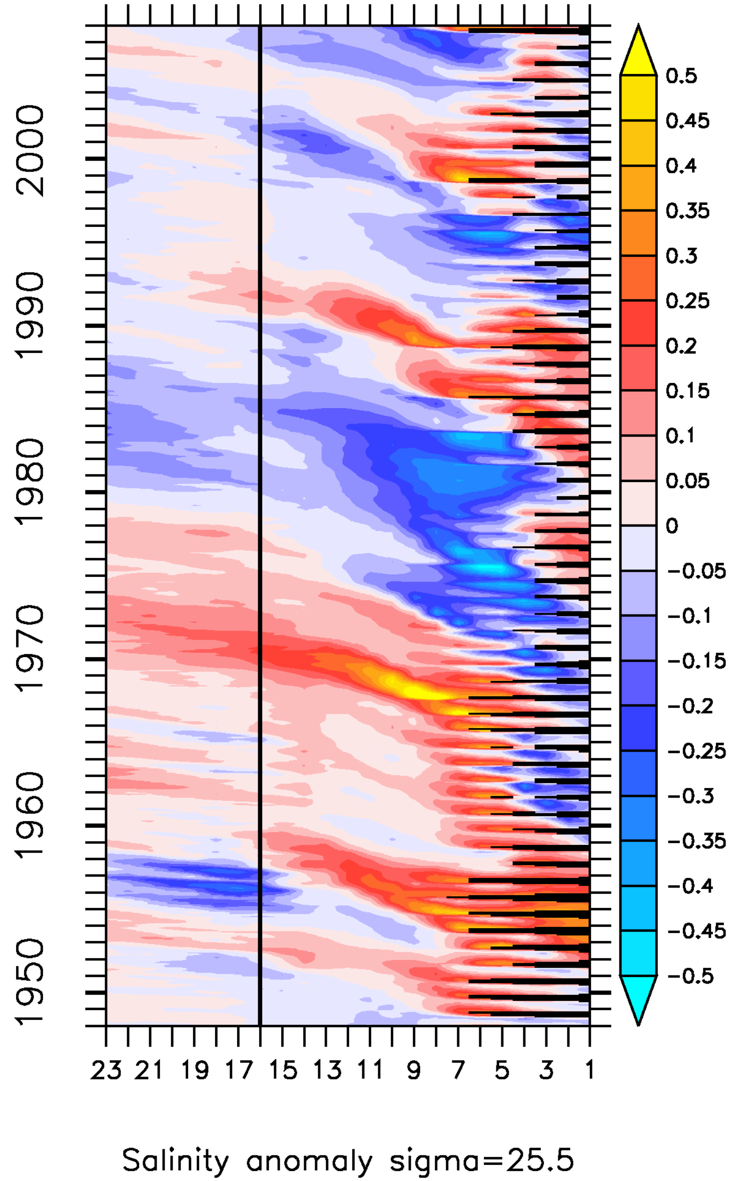
Recent decades show a modest warming trend with a more unstable Tasman Sea thermocline – more variability and more eddies



Sloyan et al., in prep 2015

Southern Ocean to the tropics connection: Spicy anomalies



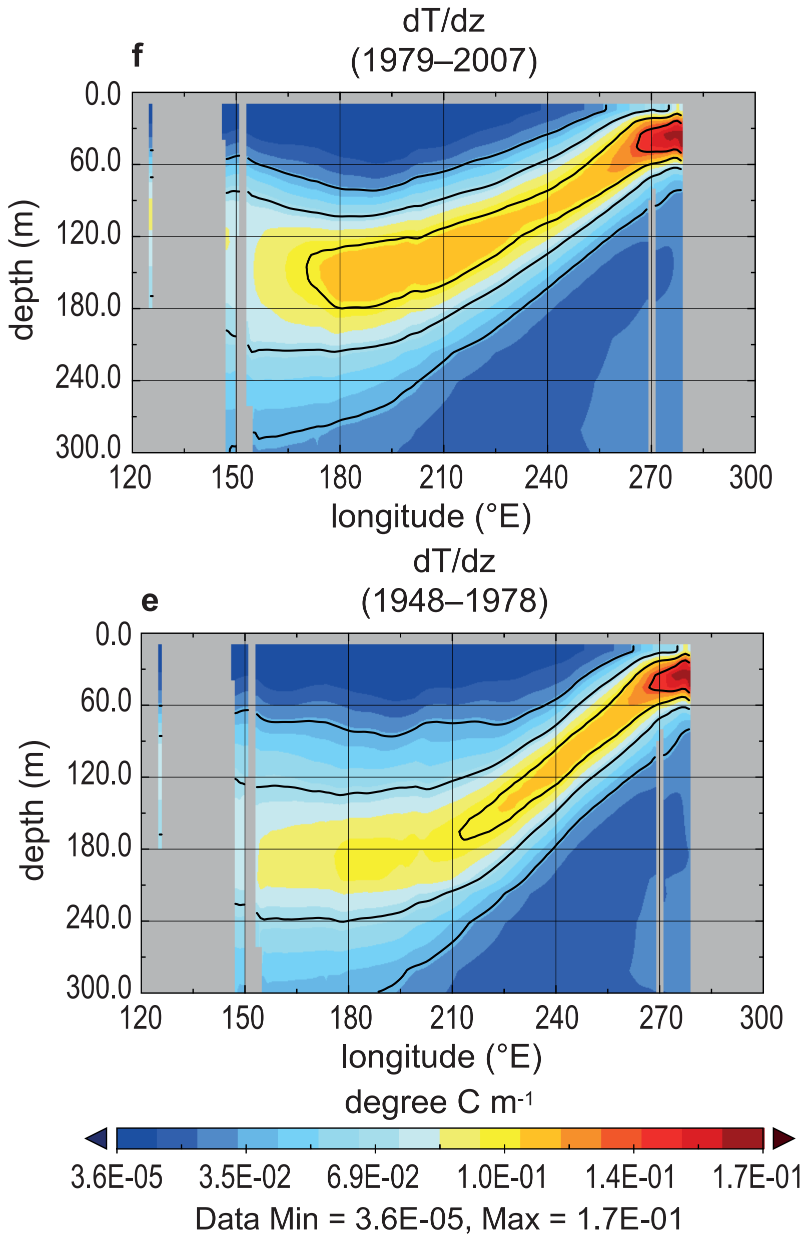


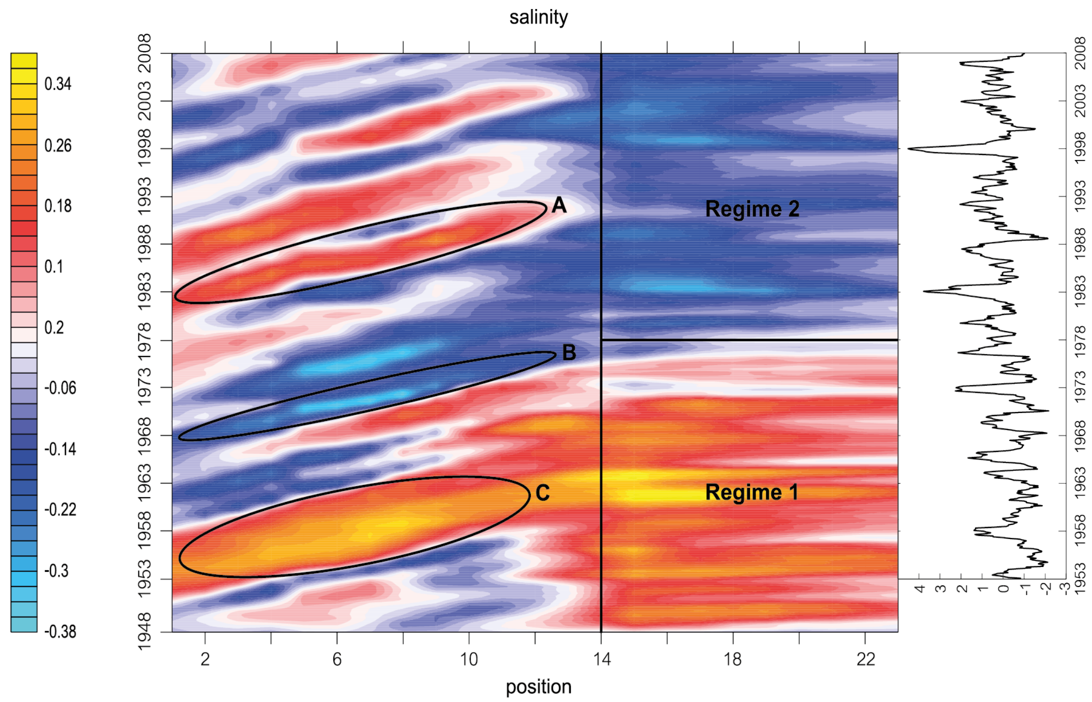
-Spicy (density compensated) anomalies generated at the winter outcropping of Sub-tropical Mode Water

-Propagate to the tropics as shown by the salinity anomalies (takes about 10 years)

O'Kane et al., 2013

ENSO Low Frequency Variability: two regimes





O'Kane et al., 2013

Multi-year variability: Conclusions

Southern Ocean mechanisms that generate multi-year variability that could influence the climate globally

- baroclinic disturbances generated in the Antarctic Circumpolar Current – importance of weather
- baroclinic disturbances generated at the subtropical boundary
- spicy anomalies associated with subtropical mode water subduction

Conclusions

- These mechanisms could underpin decadal forecasting systems, have potential impacts on BGC cycling and anthropogenic carbon subduction
- Weather is important to the atmosphere-ocean coupling, which amplifies the Southern Ocean multi-year variability

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