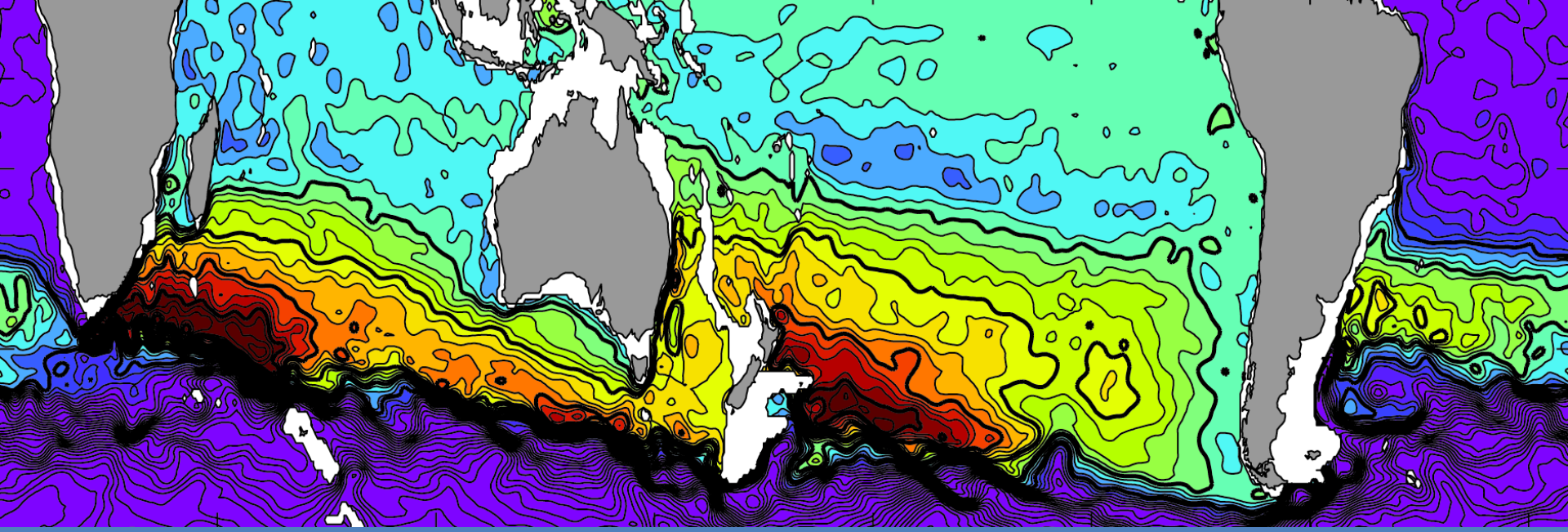


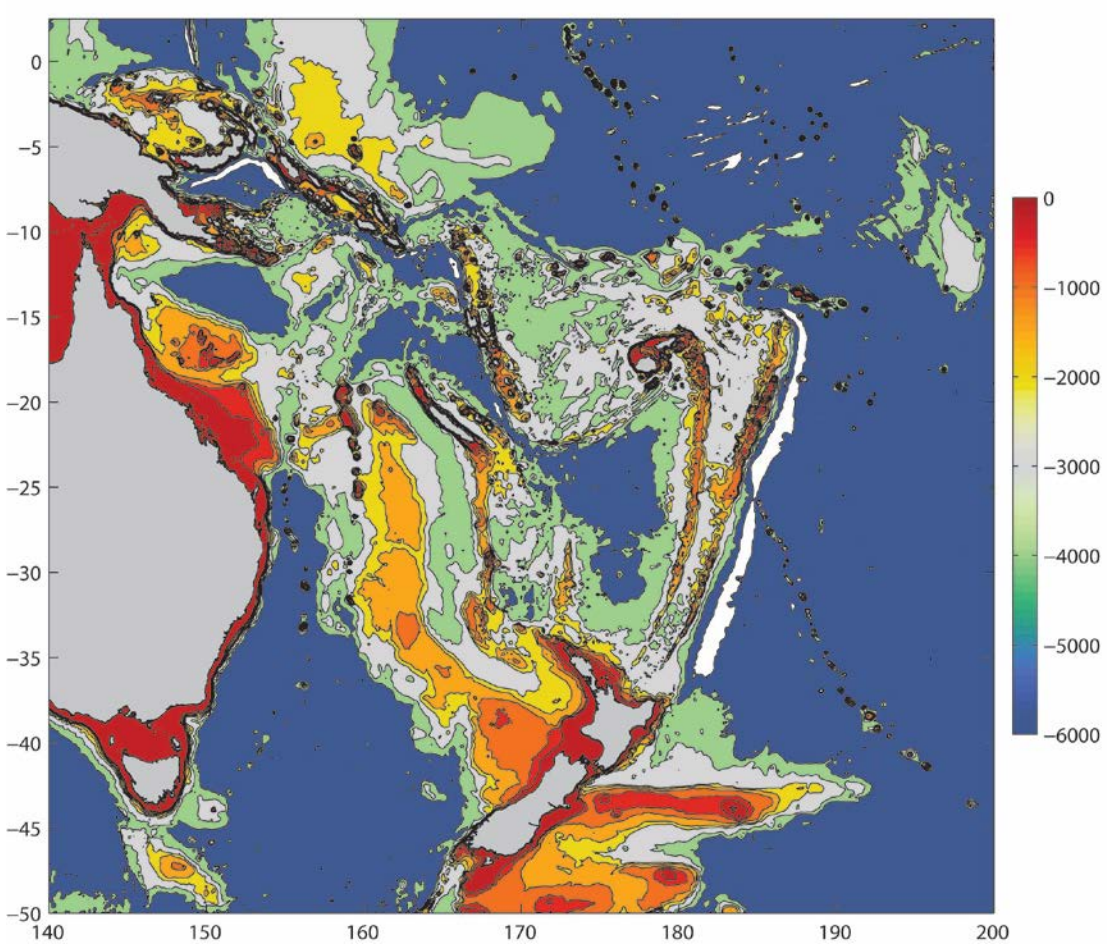
Aspects of the circulation and water mass structure of the southwest Pacific from Argo data

Ken Ridgway, Jeff Dunn, Mark Baird, Peter Oke
CSIRO Marine & Atmospheric Research, Hobart.

IMOS
Integrated Marine Observing System

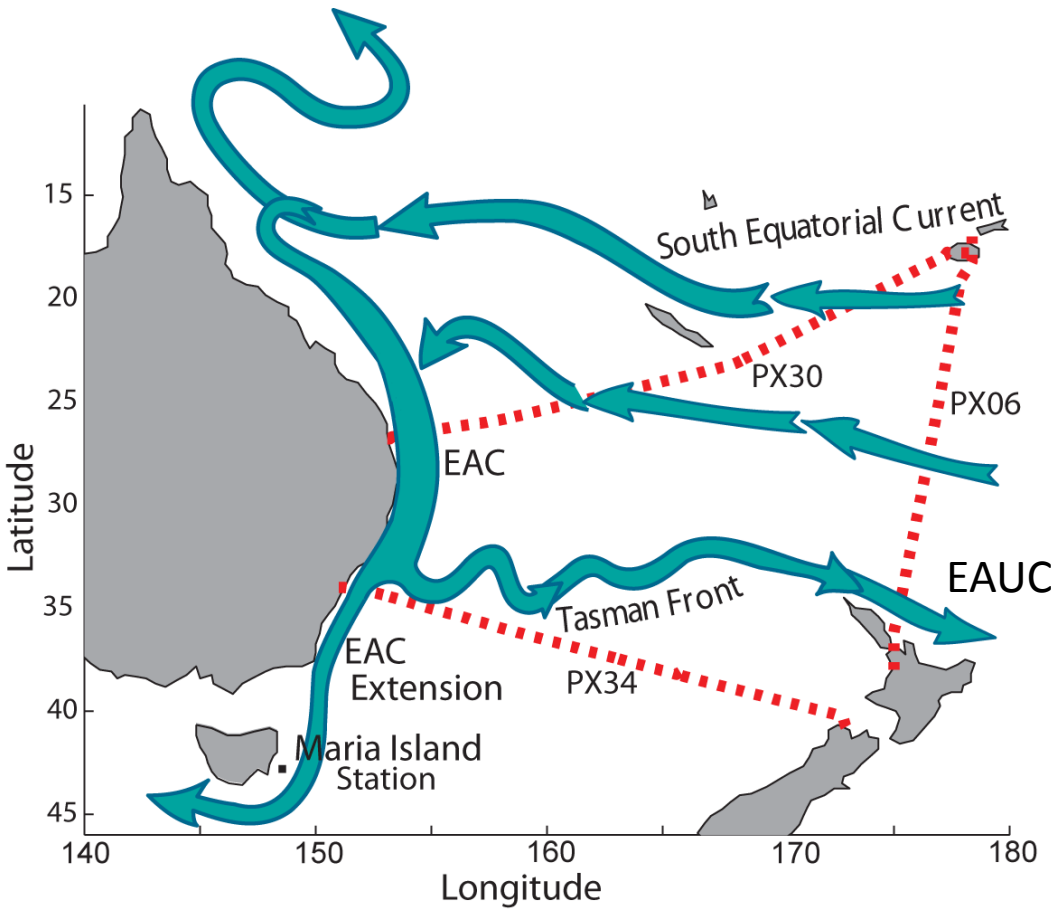
CSIRO

Southwest Pacific Bathymetry



Highly complex topography including ridges, troughs, islands, reefs, seamounts
Major influence on circulation

Complex Tasman/Coral Sea Current System



Western boundary current of South Pacific Gyre

SEC feeds EAC

EAC flow partitioned between
-Tasman Front
-EAC Extension

Outline

- Argo data distribution
- Mean fields from Argo
- Validation of Argo fields
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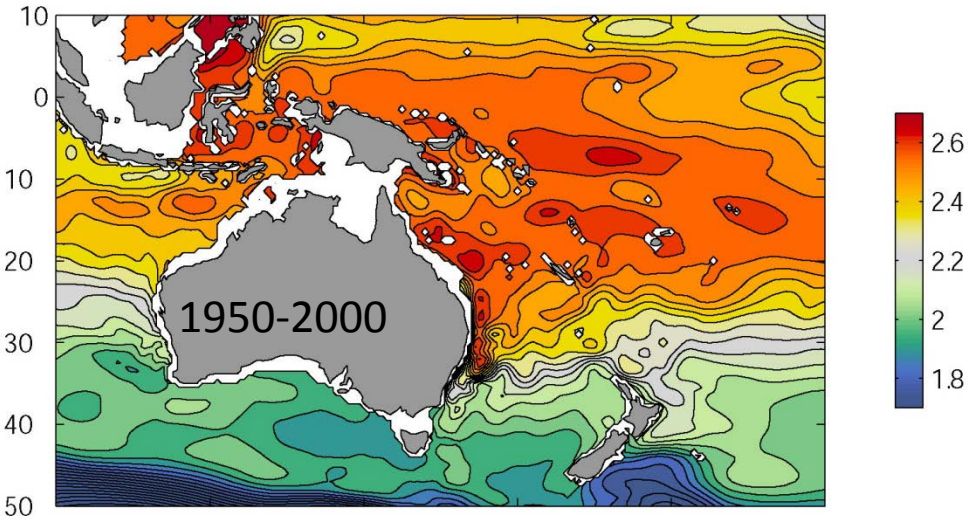
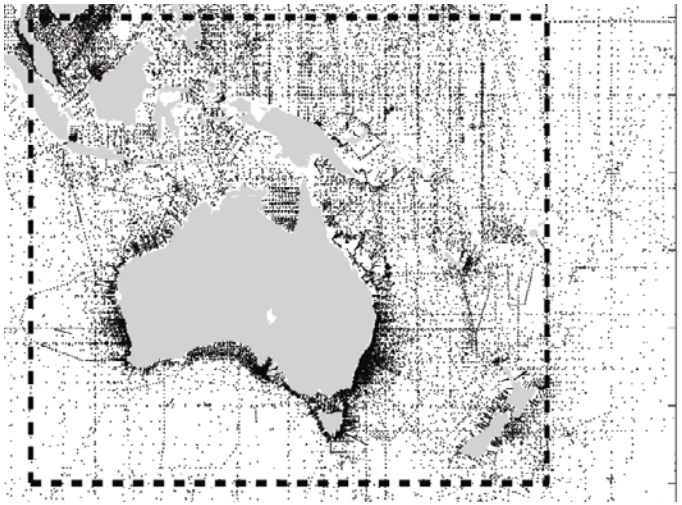
- Seasonal Cycle
- Argo absolute velocity field
- Formation & evolution of Bass Strait Water

Historical Data Distribution

Data distribution from different seasons, years and decades may produce

- features which never actually existed
- overly smoothed fields
- incorrect properties (transport)
- unrepresentative means (aliasing from interannual variability)

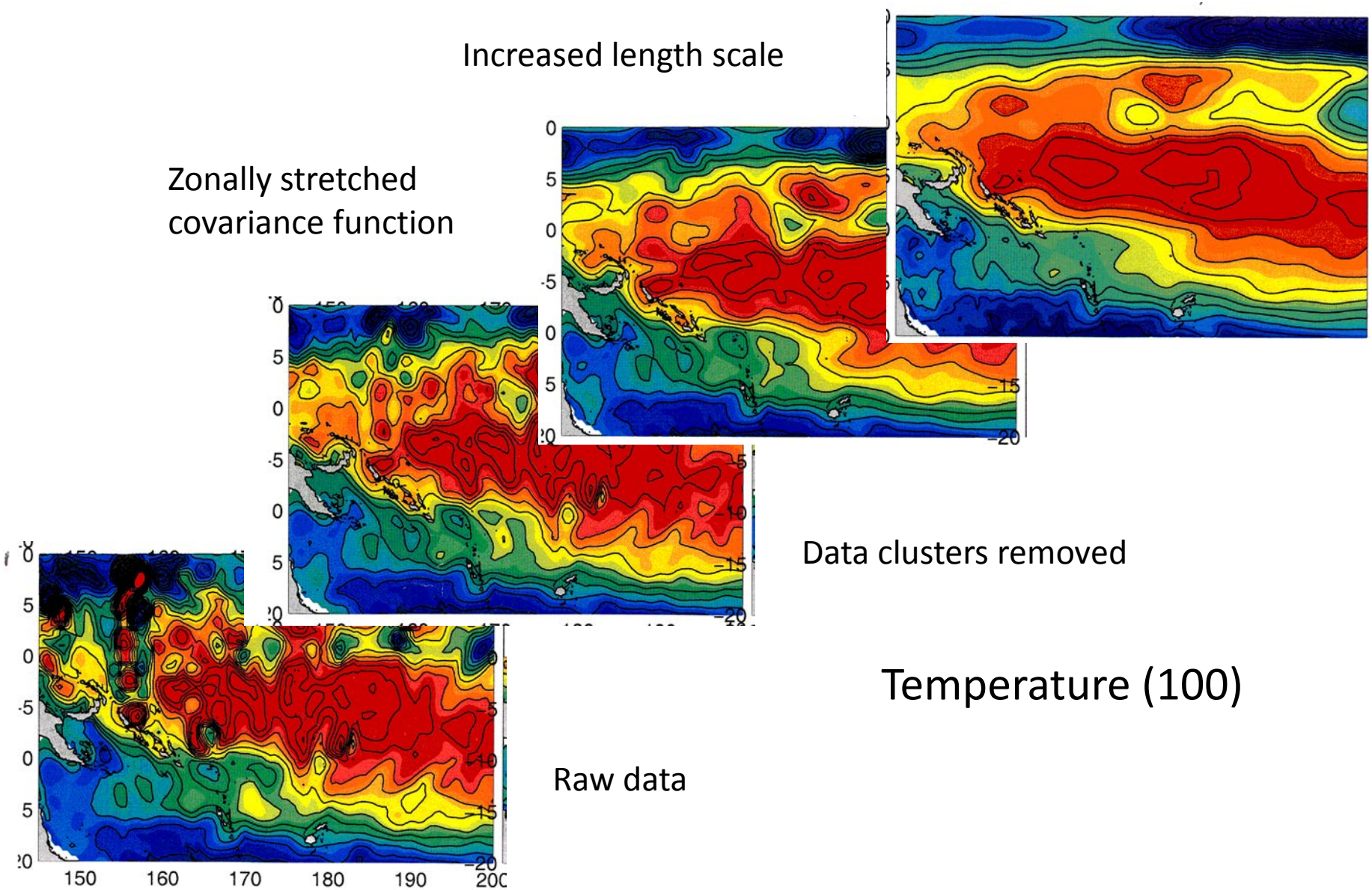




Adjustment of smoothing parameters

Increased length scale

Zonally stretched covariance function

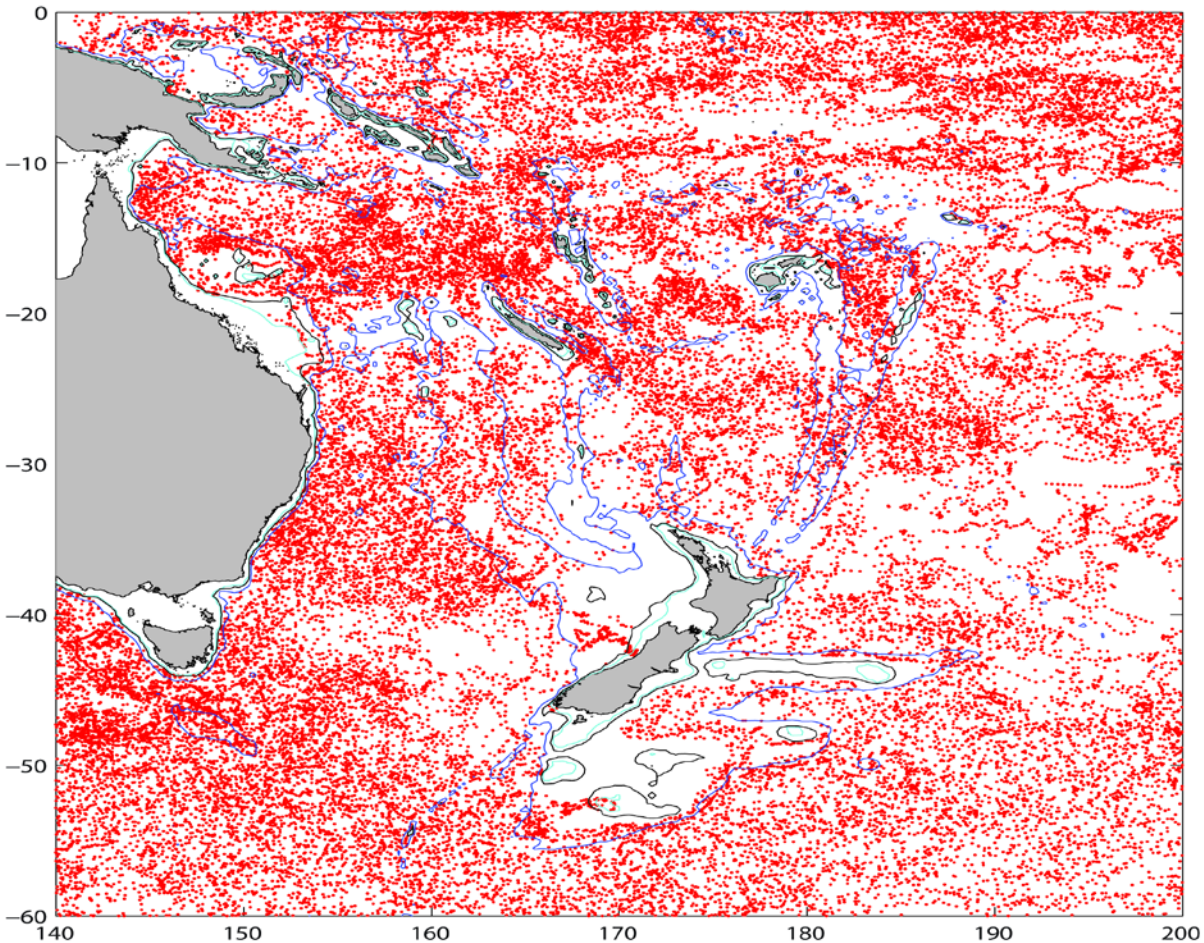


Data clusters removed

Temperature (100)

Raw data

Greatly Increased Argo Coverage



Argo data source allows mean for time-specific period

2004-2013

Outline

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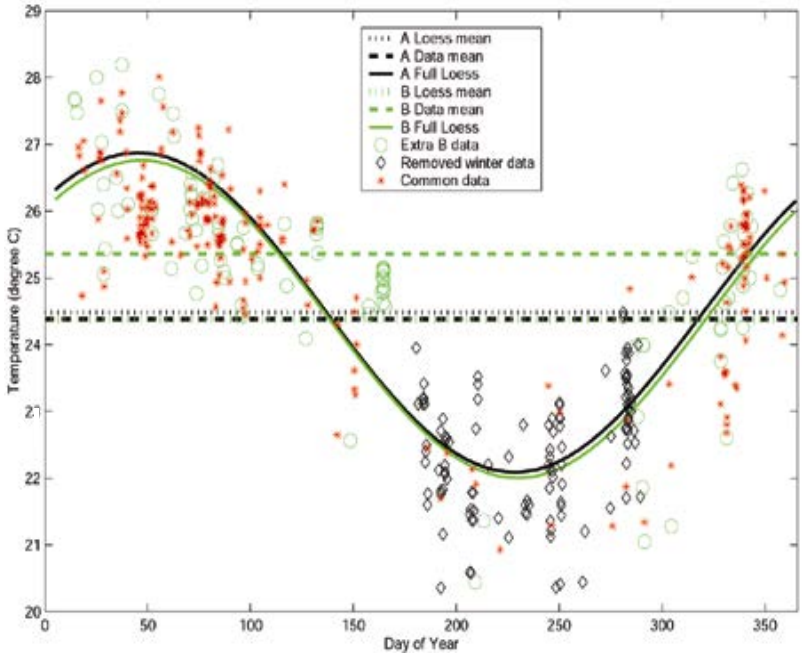
Interpolation Methods – CARS climatology

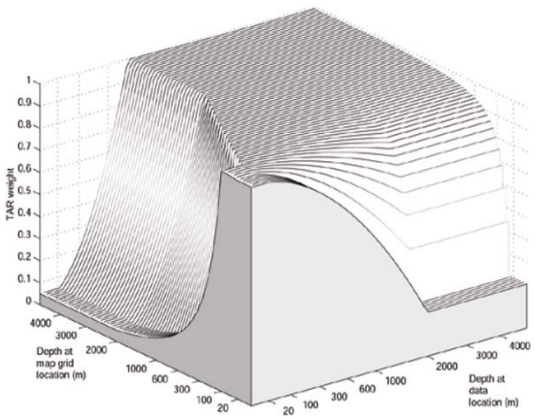
Locally-weighted least squares – Loess

$$\hat{\phi}(x_n, y_n, z_s, t) = a_0 + a_1 x + a_2 y + a_3 x^2 + a_4 y^2 + \sum a_{j+4} X_j(t) + f(t)$$

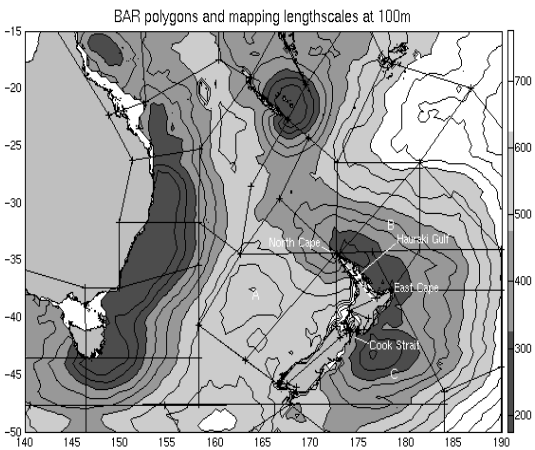
$$X_1 = \cos T,\ X_2 = \sin T,\ X_3 = \cos 2T,\ X_4 = \sin 2T,\ T = 2\pi t/365.25$$



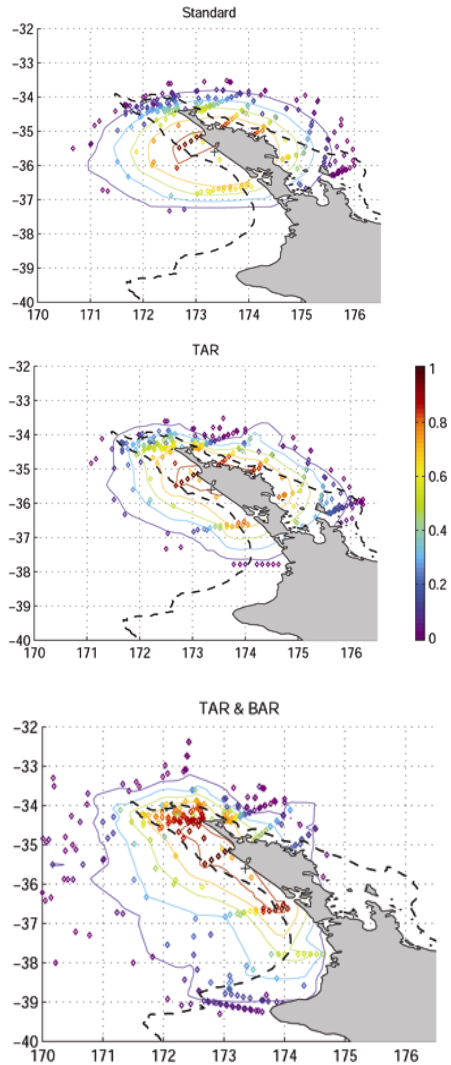
Adjustment for bathymetry and land barriers

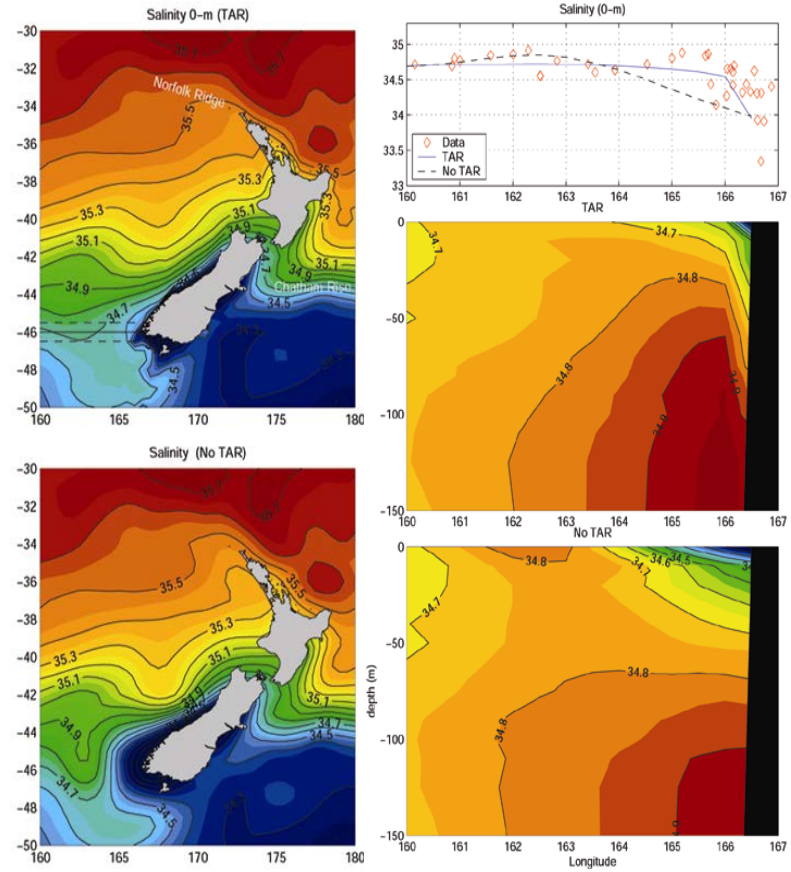


TAR



BAR

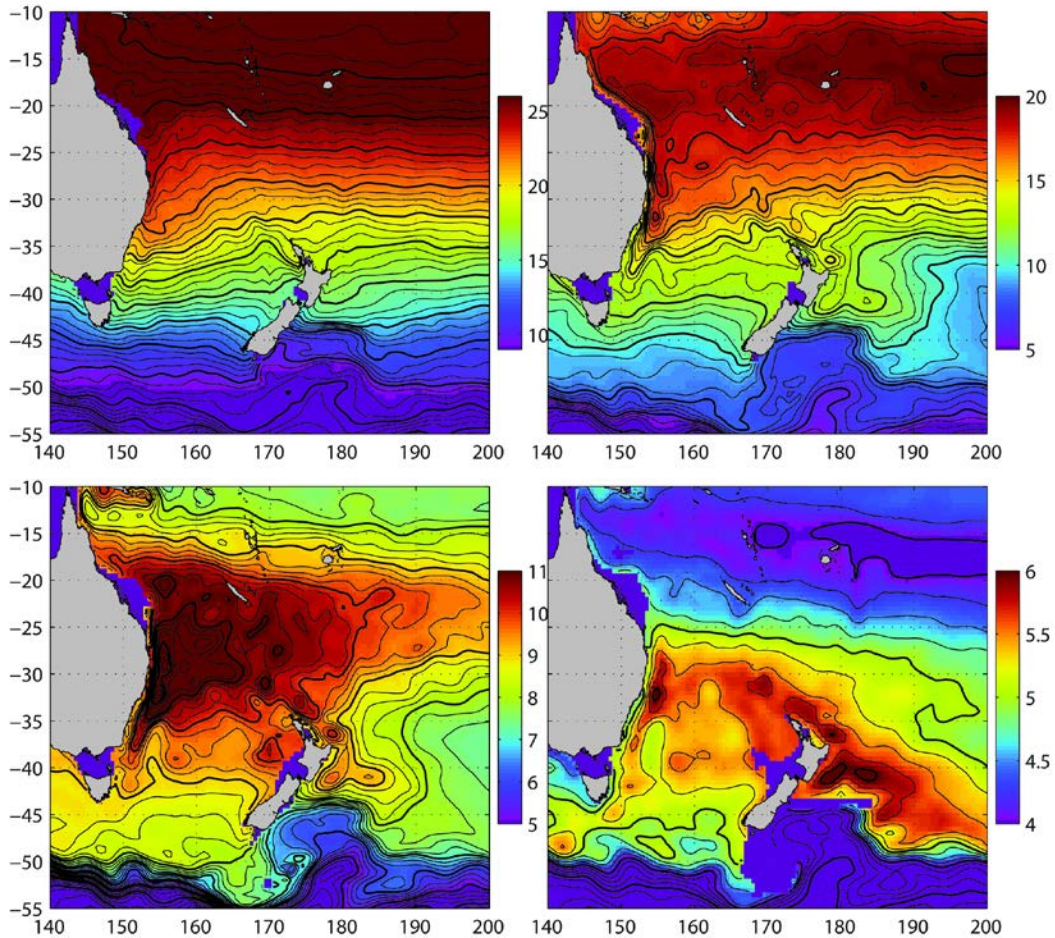




Mapping region is adjusted by the local bathymetry and coastal barriers using the TAR and BAR functions

Increased Argo Coverage (2004-2013)

0-m 250-m



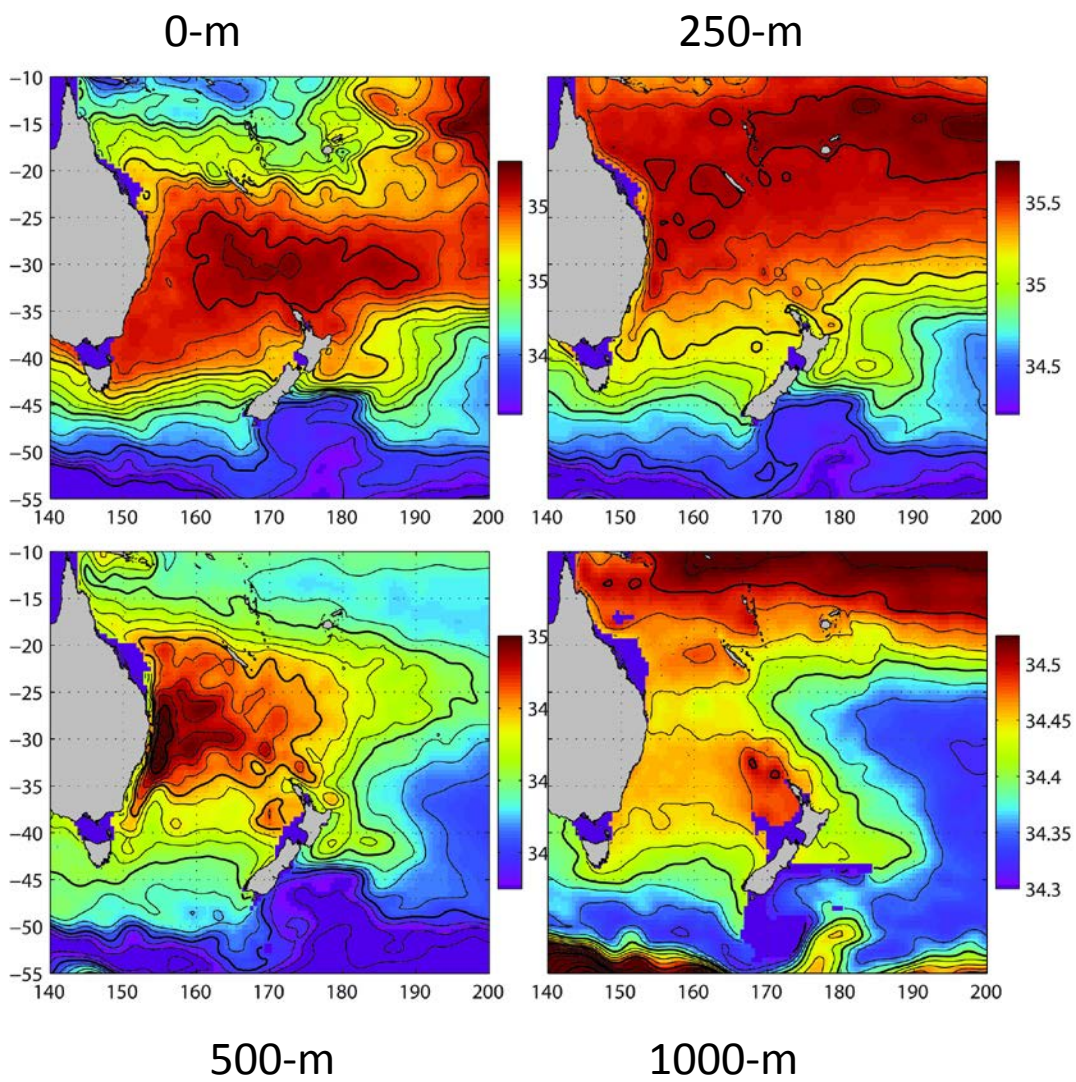
500-m 1000-m

Temperature

- Argo data distribution provides mean fields that capture main regional features
- Little evidence of aliasing from eddies

Reduced smoothing required for interpolation scheme

Increased Argo Coverage (2004-2013)



Salinity

- Argo data distribution provides mean fields that capture main regional features
- Little evidence of aliasing from eddies

Outline

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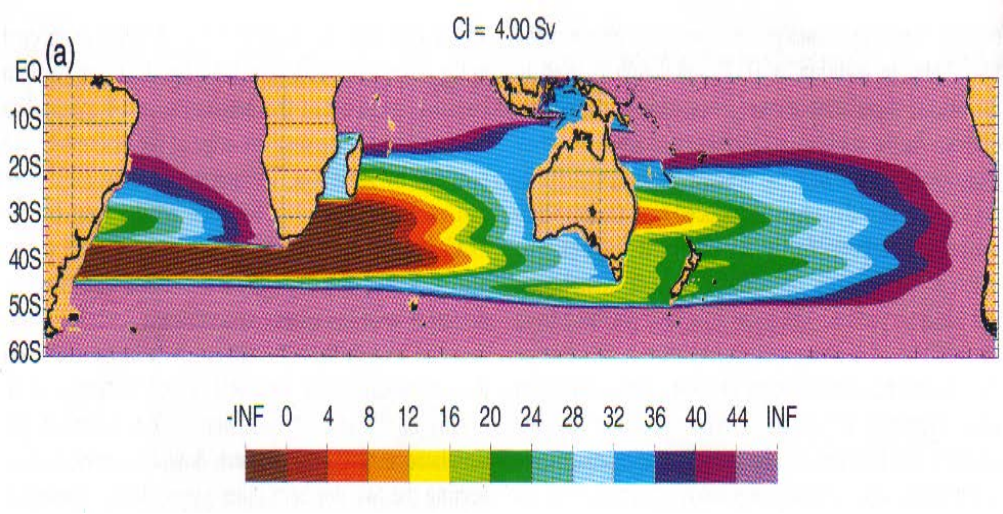
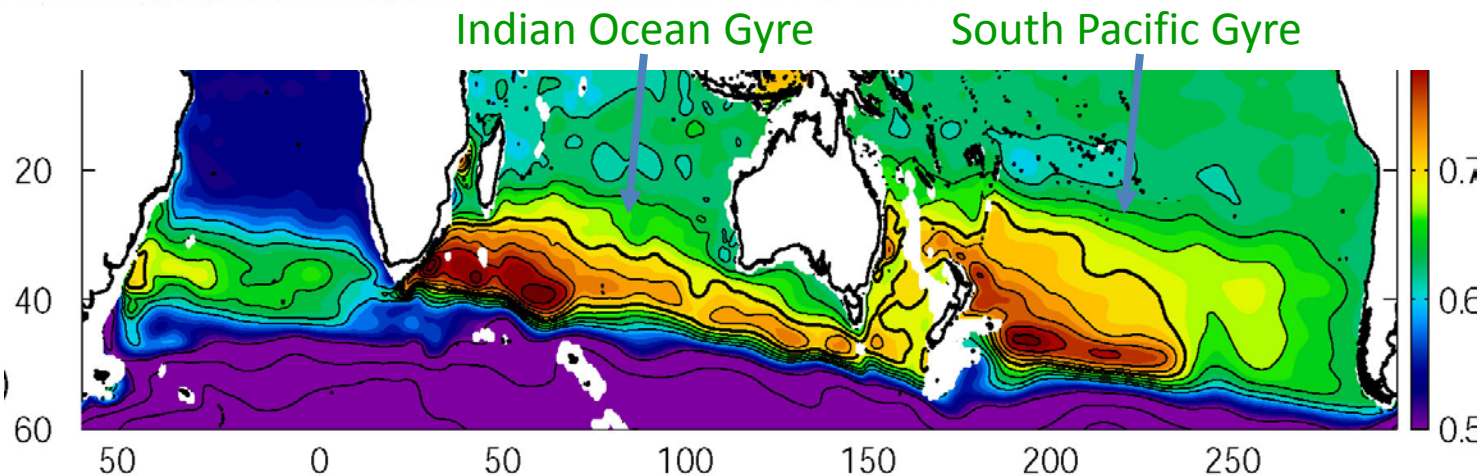
Southern Hemisphere Subtropical 'Super Gyre'



Three southern gyres connected south of Tasmania and Africa to form 'Supergyre'

Results from observations confirms results from range of models

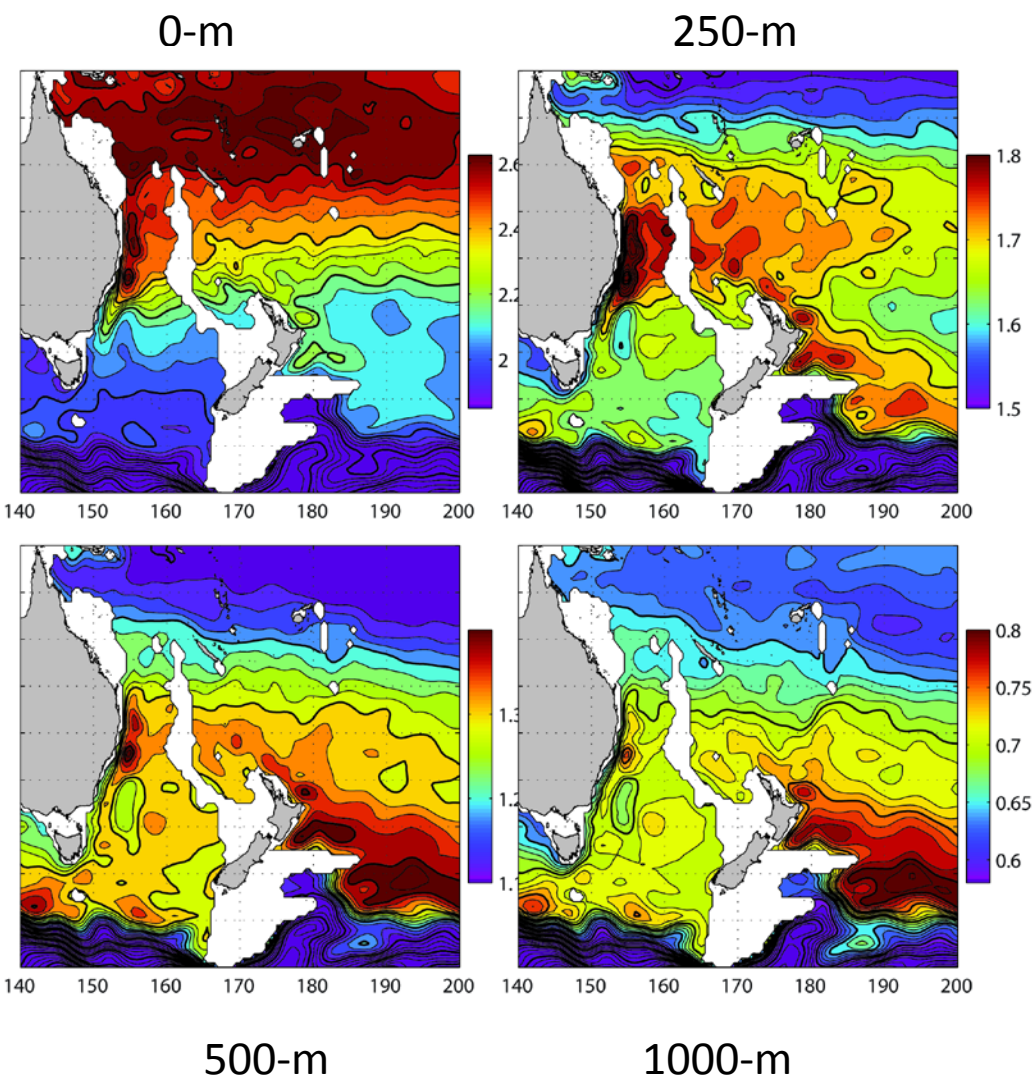


Circulation pattern from CTD casts + Argo profiles

CARS climatology

Ridgway, 2007

Steric Height (relative to 2000-db)

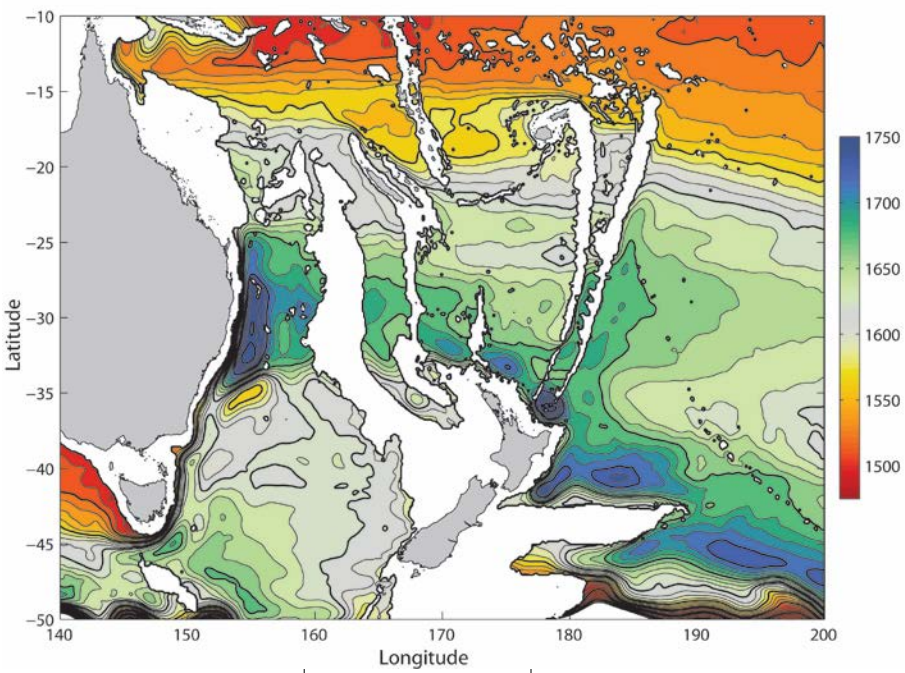


- Argo data distribution provides mean fields that capture main regional features

- SEC
- EAC
- recirculaion
- Topographic steering
- Permanent eddies
- Tasman Outflow

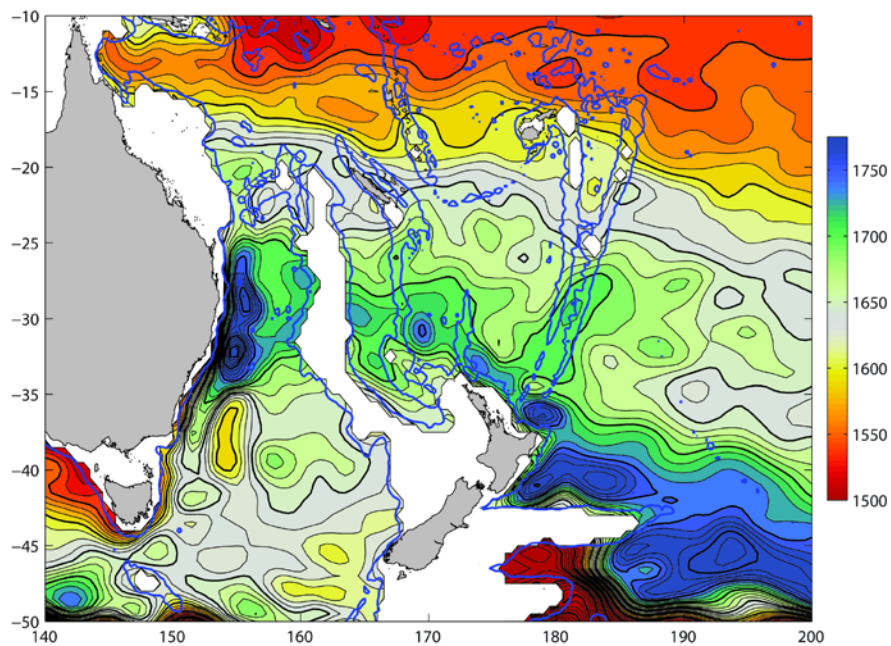
CARS (Argo) compared to Model

Depth-integrated steric height



OFAM3

Depth-integrated steric height (m)



Argo (2004-2012)

Both show depth-averaged flow relative to 2000-m
OFAM provides a very good match to the Argo observations

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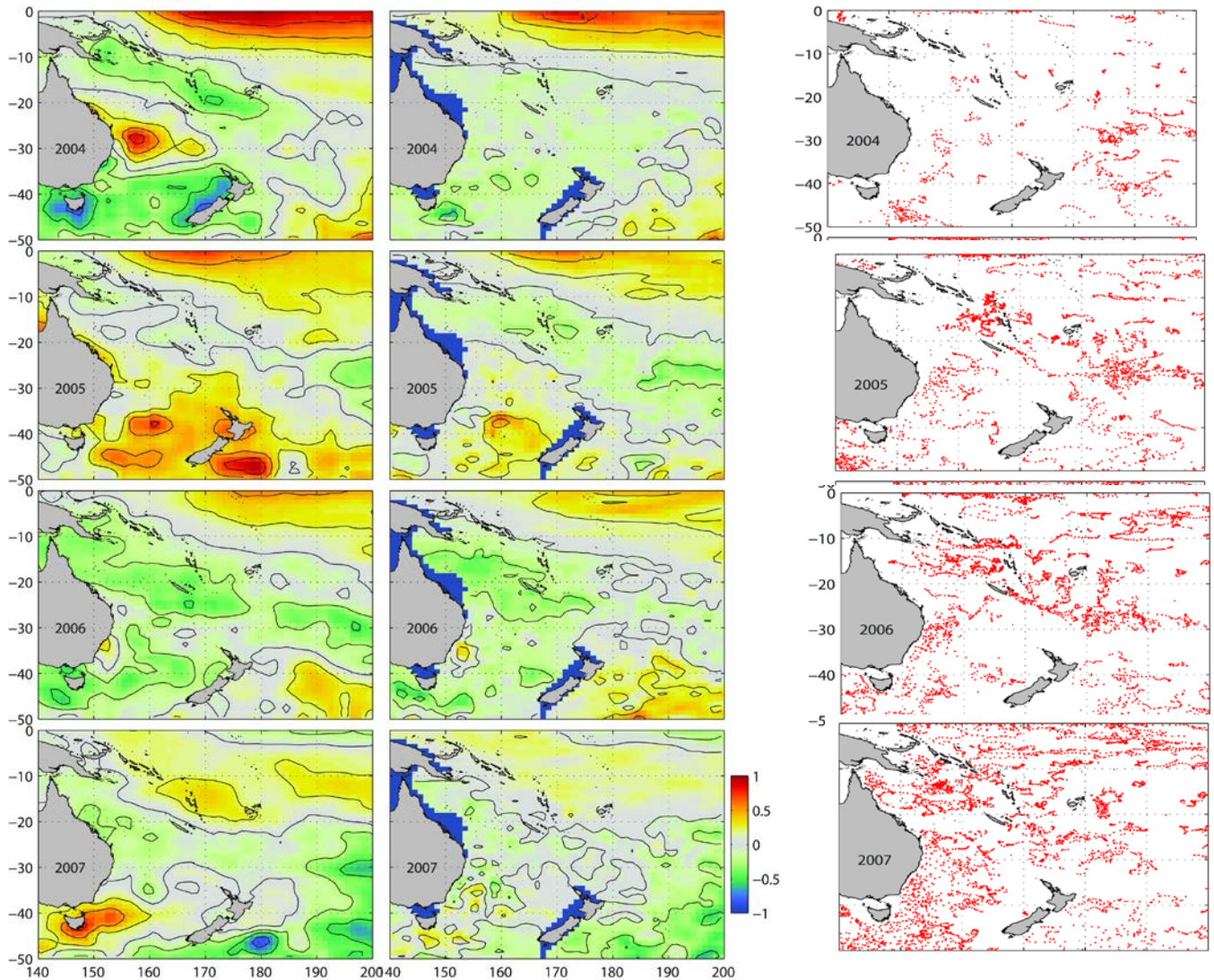
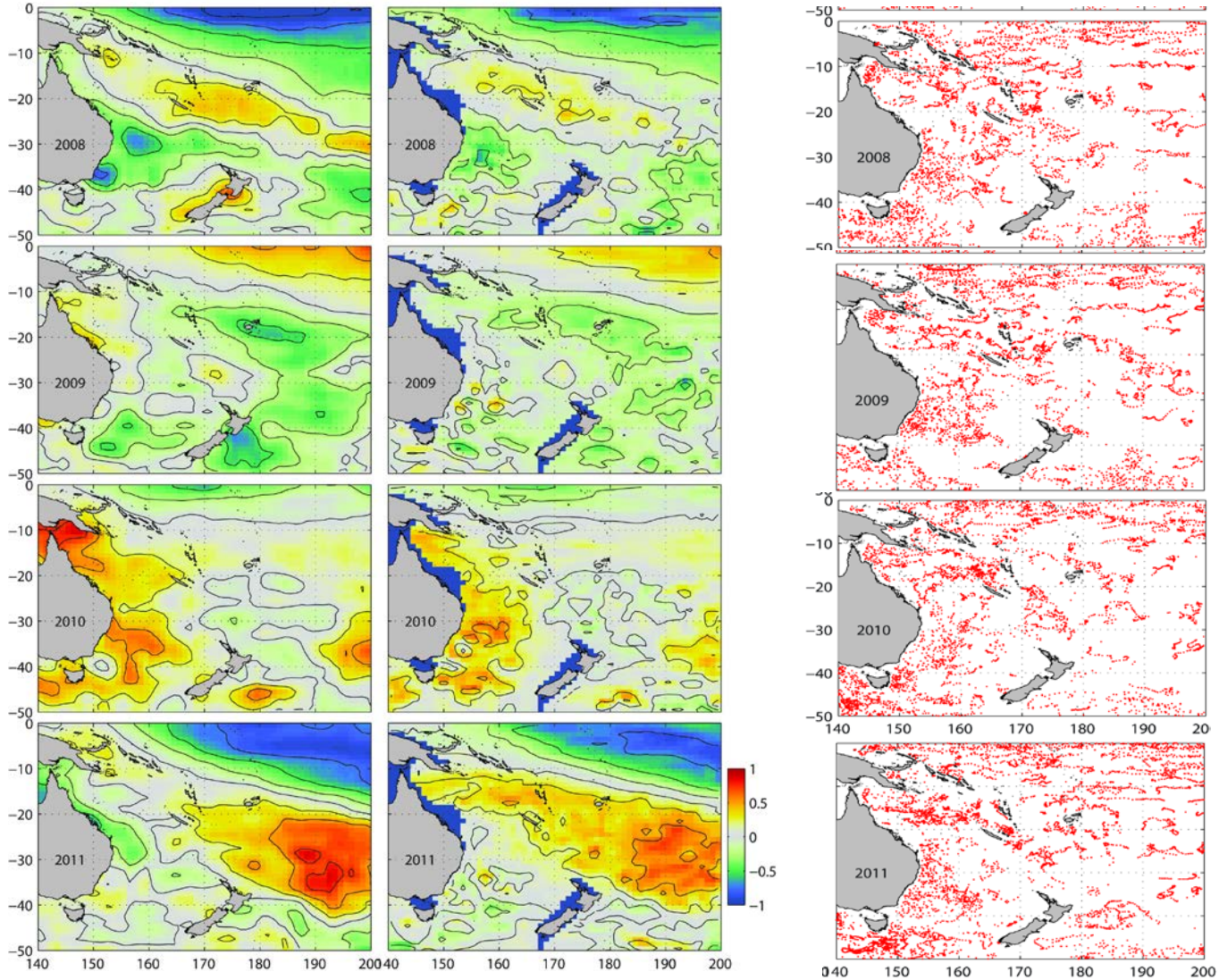
Comparison with Reynolds SST

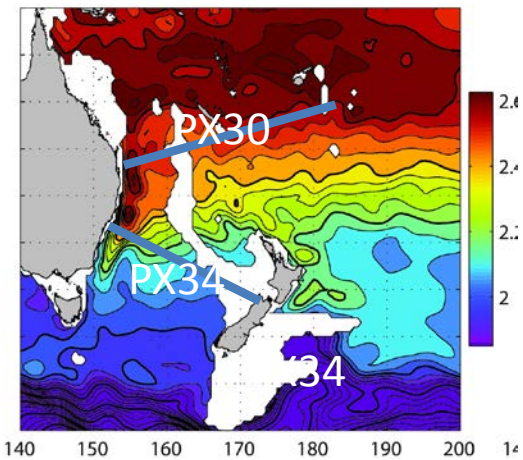


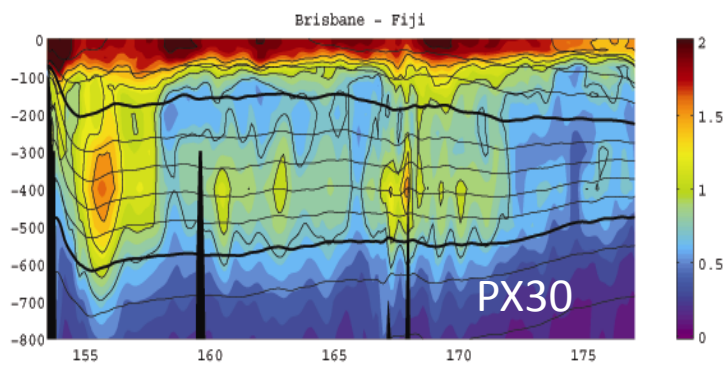
Reynolds Argo

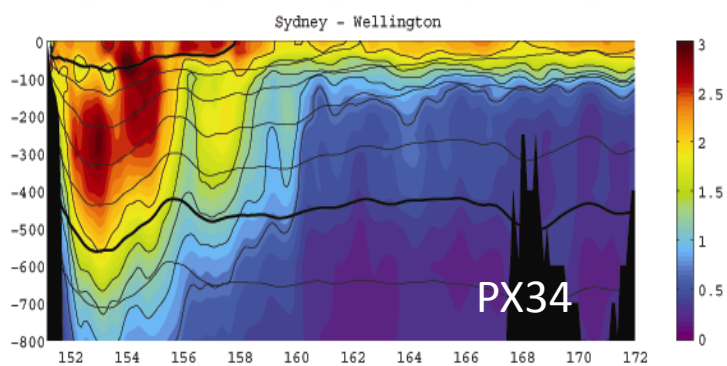
Comparison with Reynolds SST

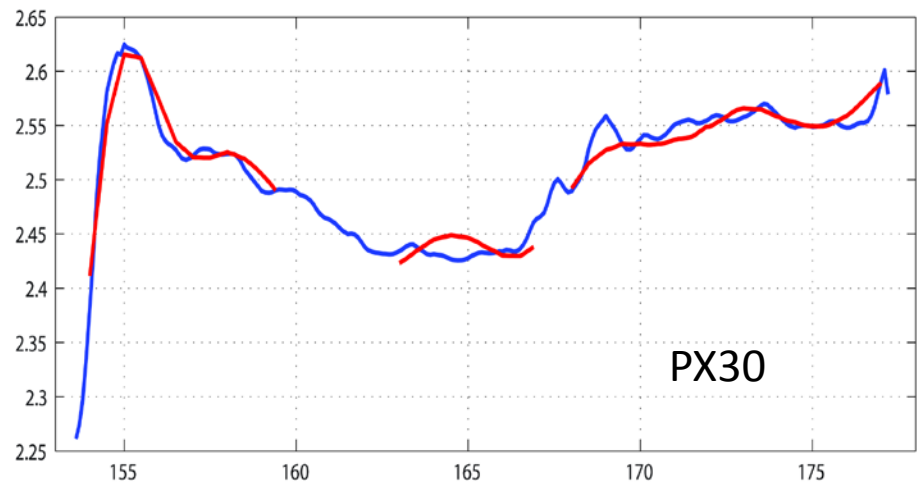


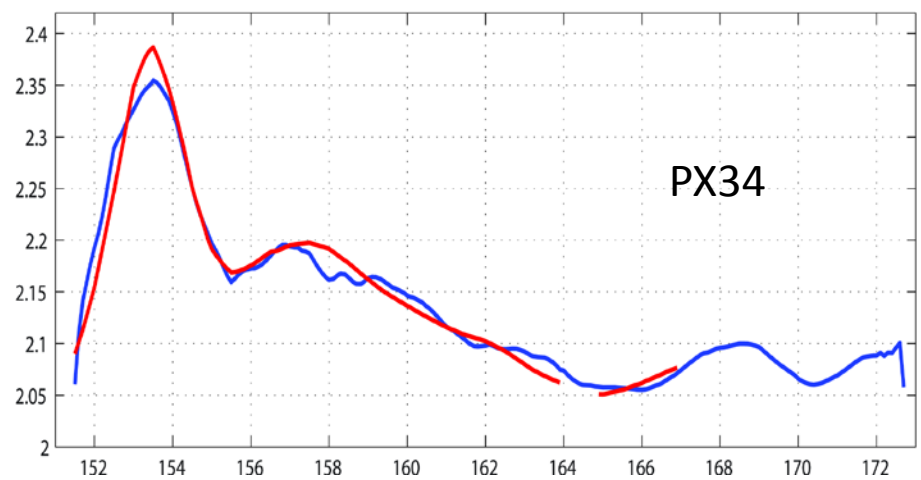
Compare with XBT transects









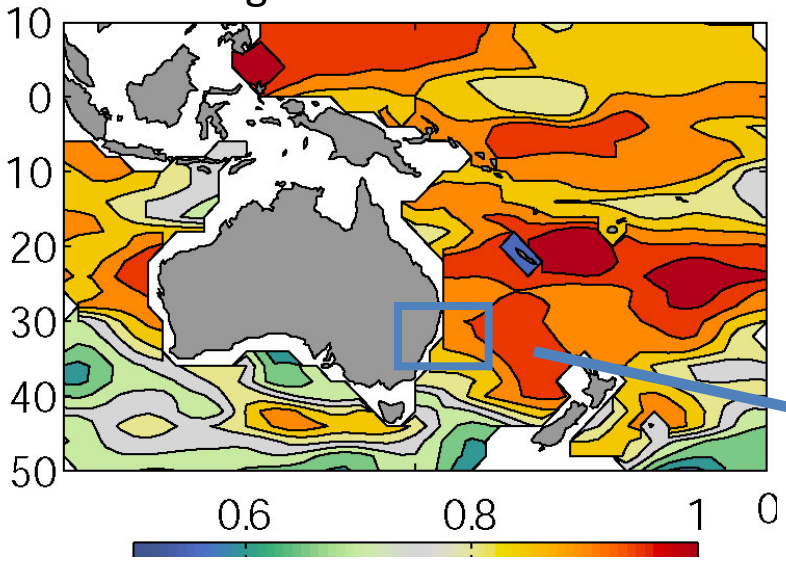


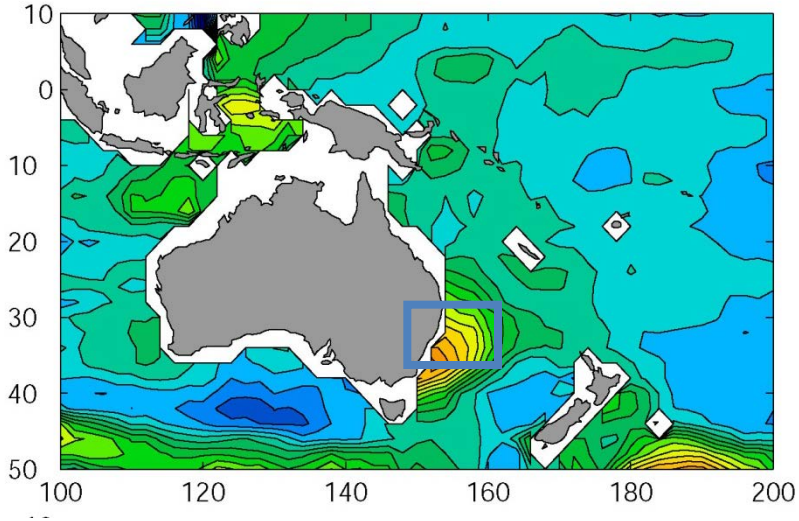
XBT

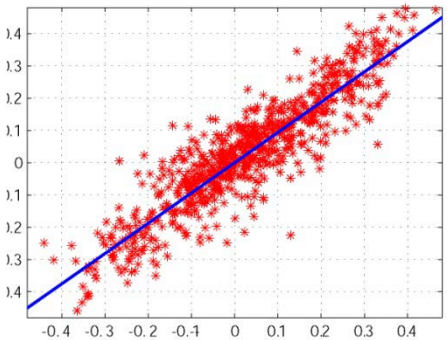
Argo

Relationship between in situ & altimeter height

regression







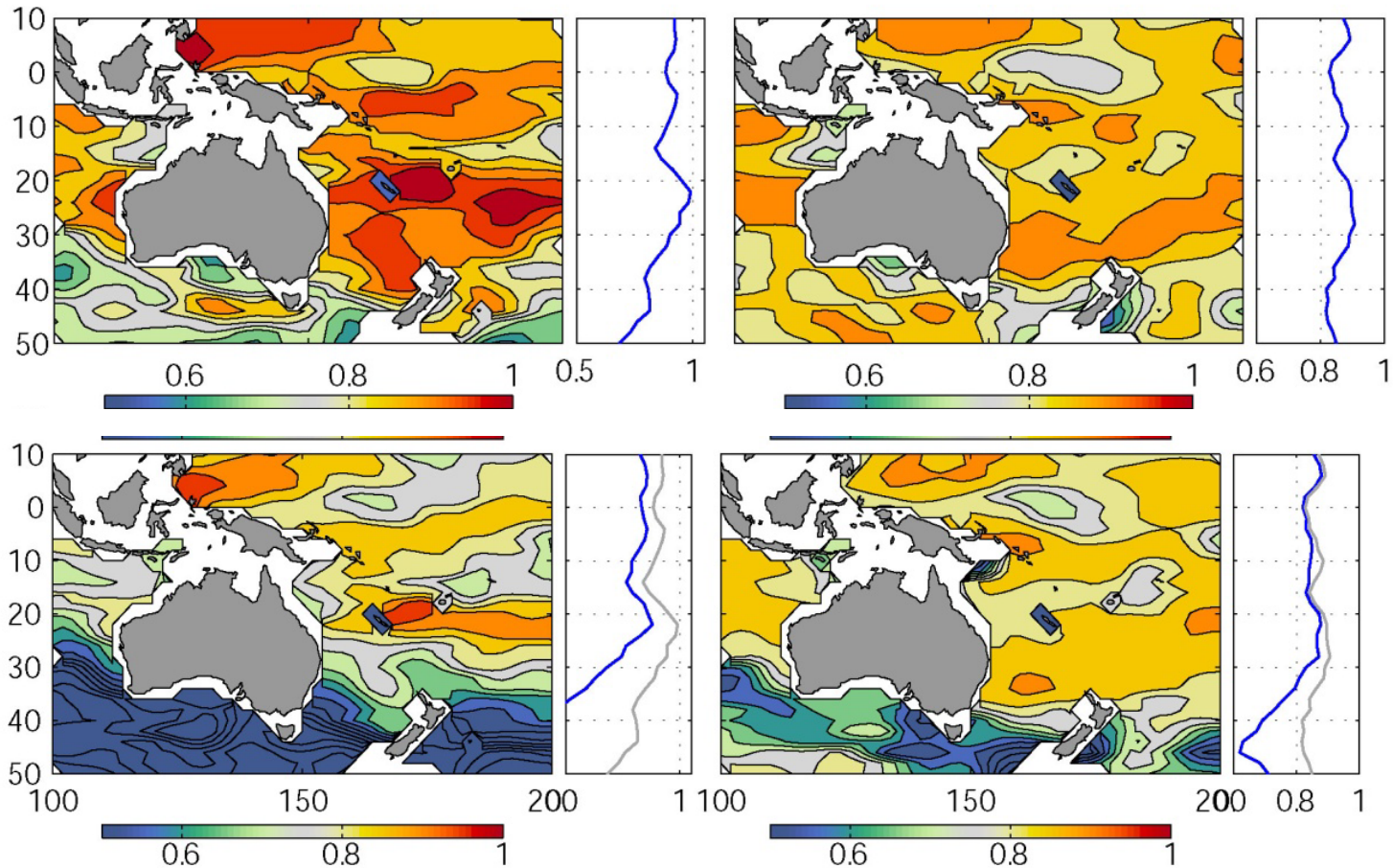
Relationship between in situ & altimeter height

$\phi(y)$

regression correlation

$<h^c_{2000}>$

$<h^c_{700}>$



$$\delta h^i_{2000} = \phi(y)\delta h^a$$

Outline

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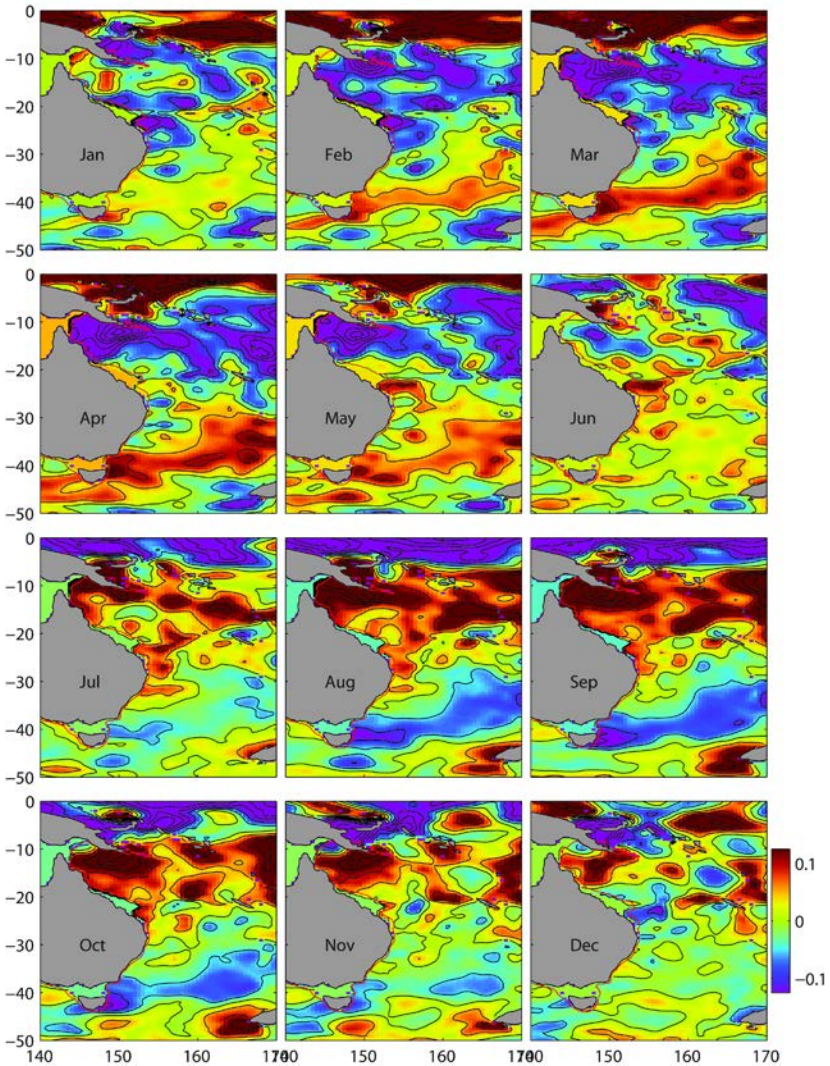
Surface Salinity – Seasonal Cycle



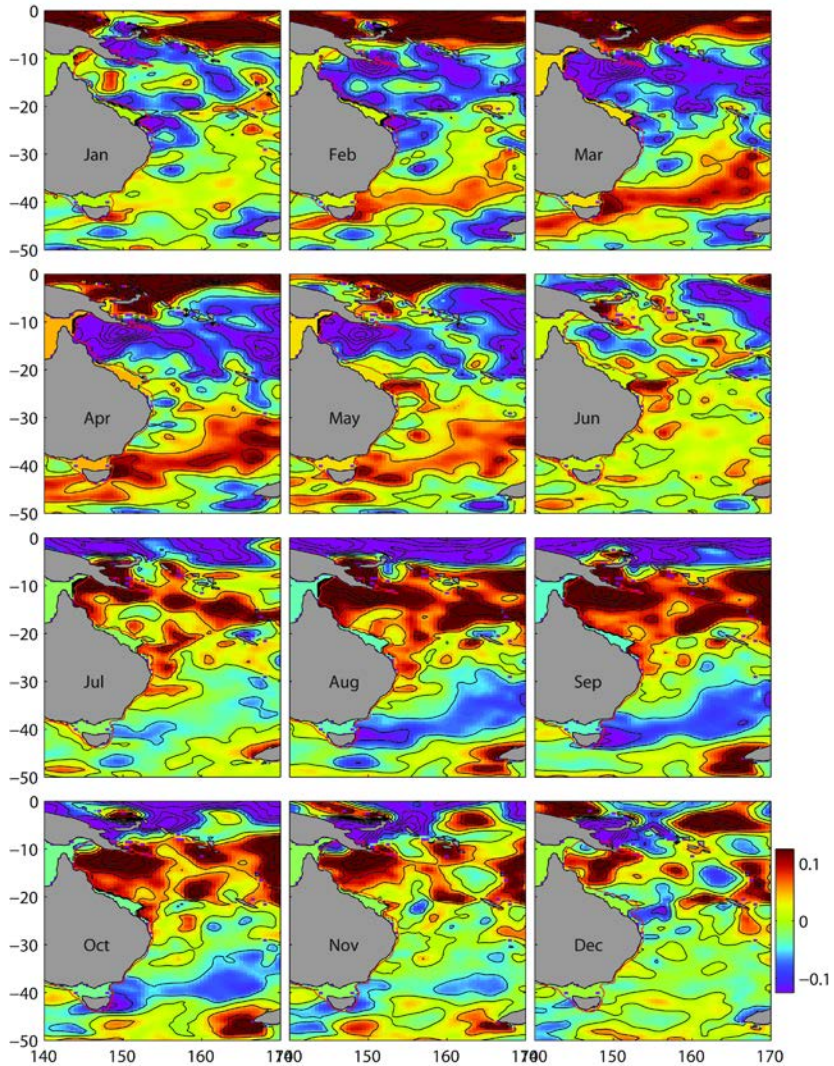
Argo data distribution enables accurate seasonal cycle to be determined

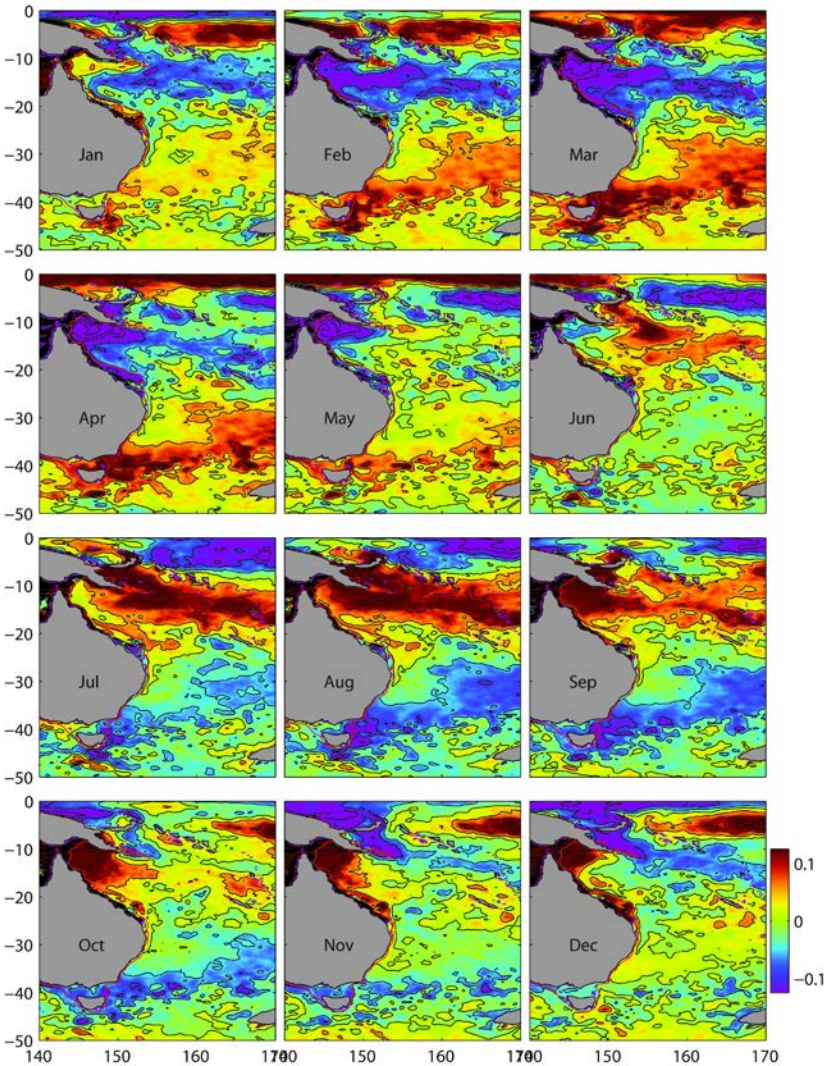
Fitting annual + semiannual harmonics

Monthly seasonal anomalies

Surface Salinity – Matches Model

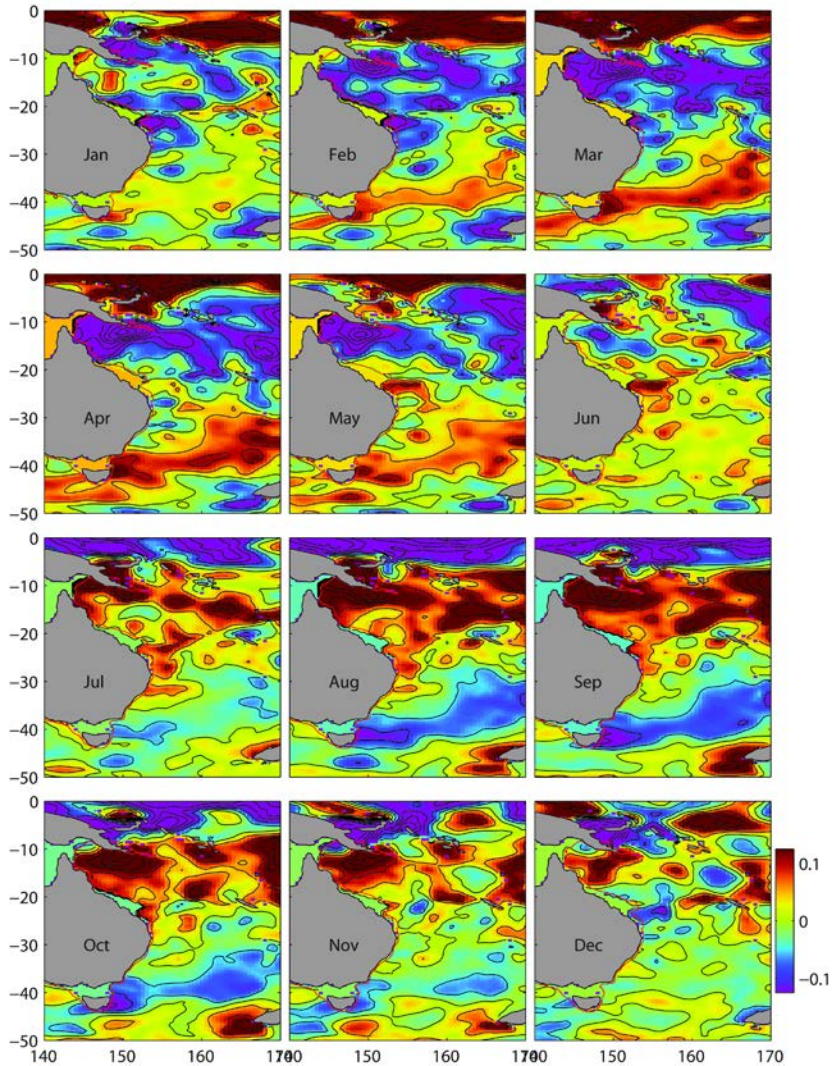
OFAM 3

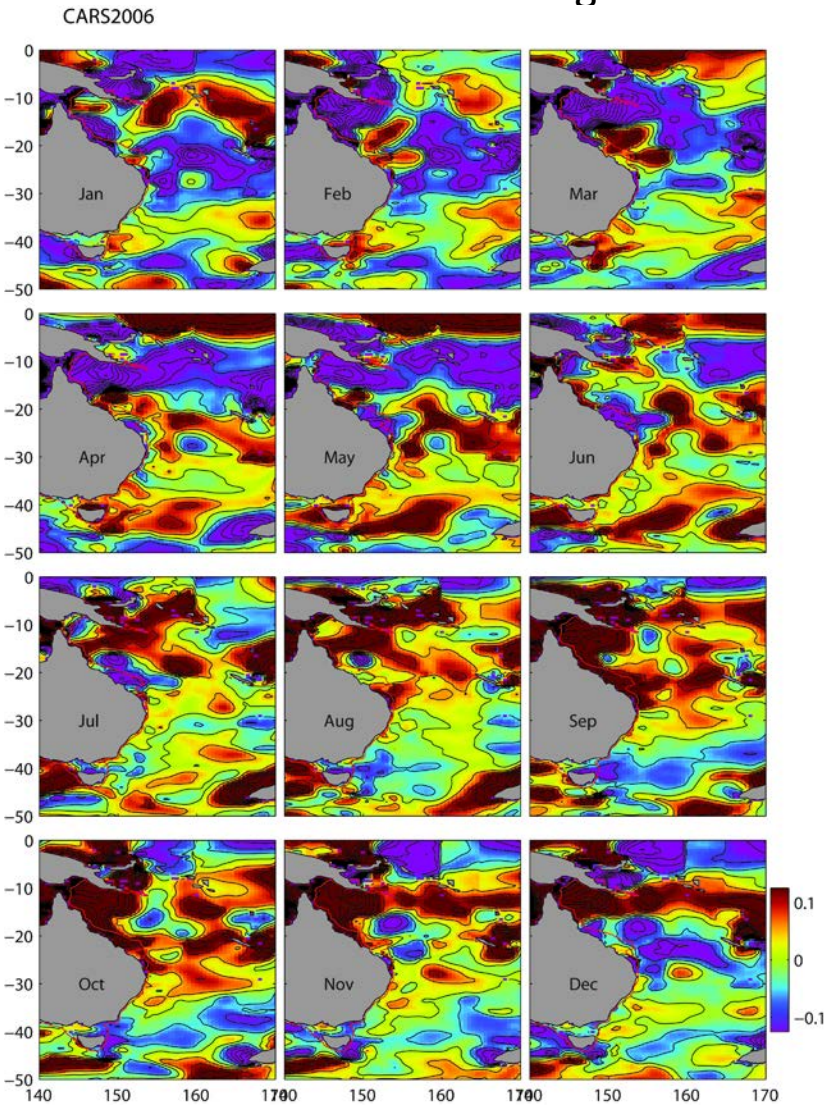




Surface Salinity – Improvement

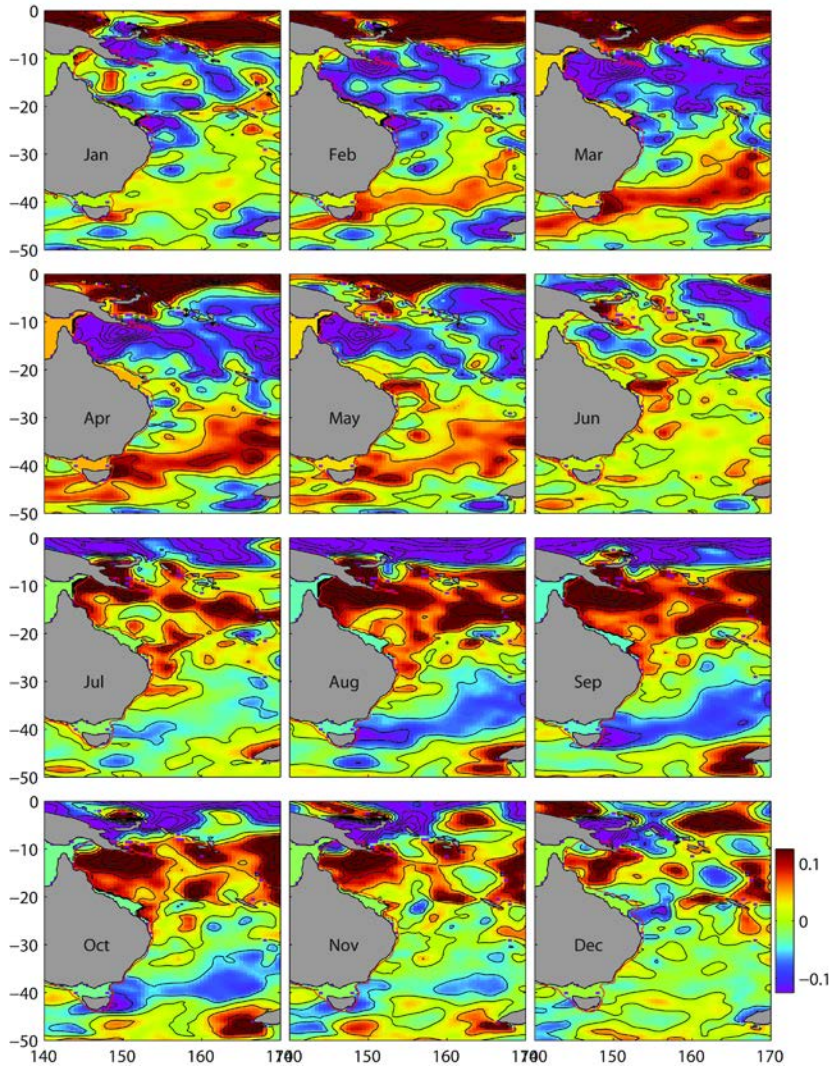
CARS2006 – No Argo

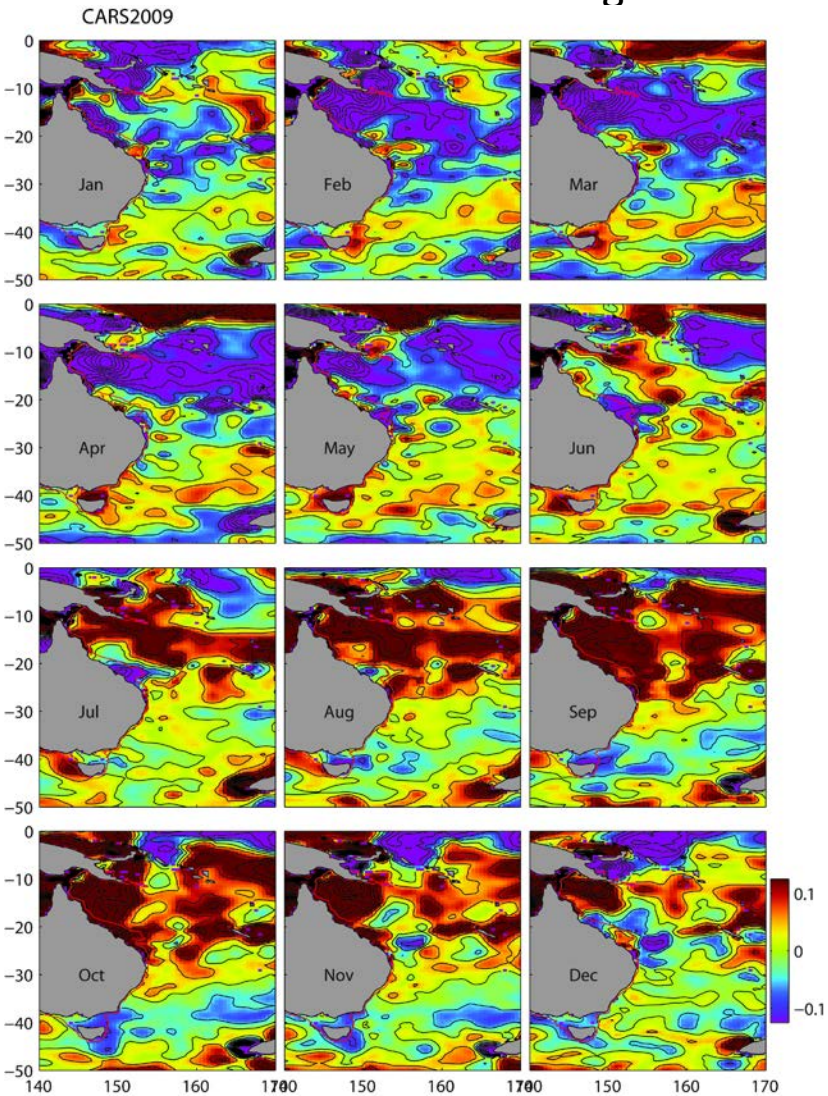




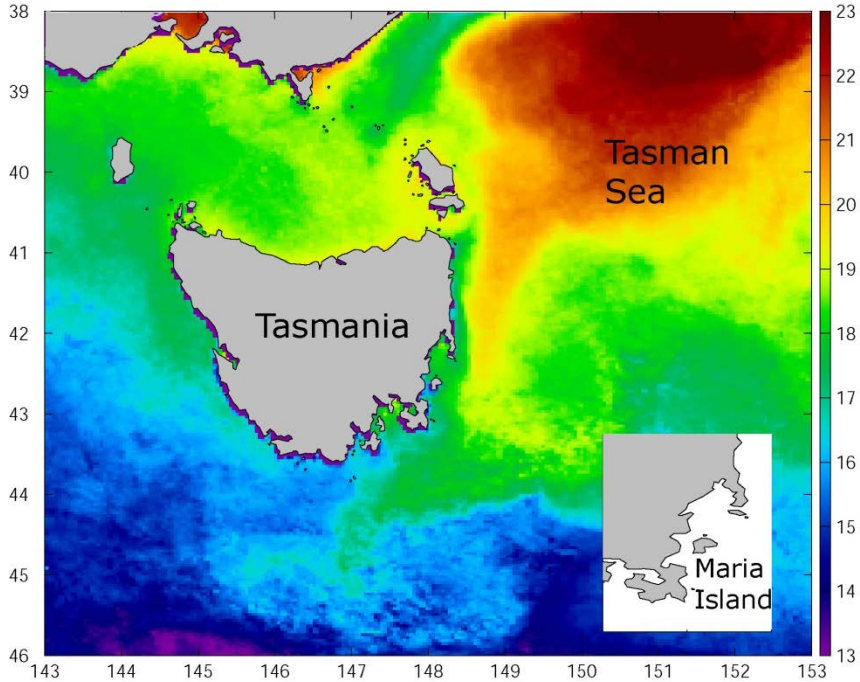
Surface Salinity – Improvement

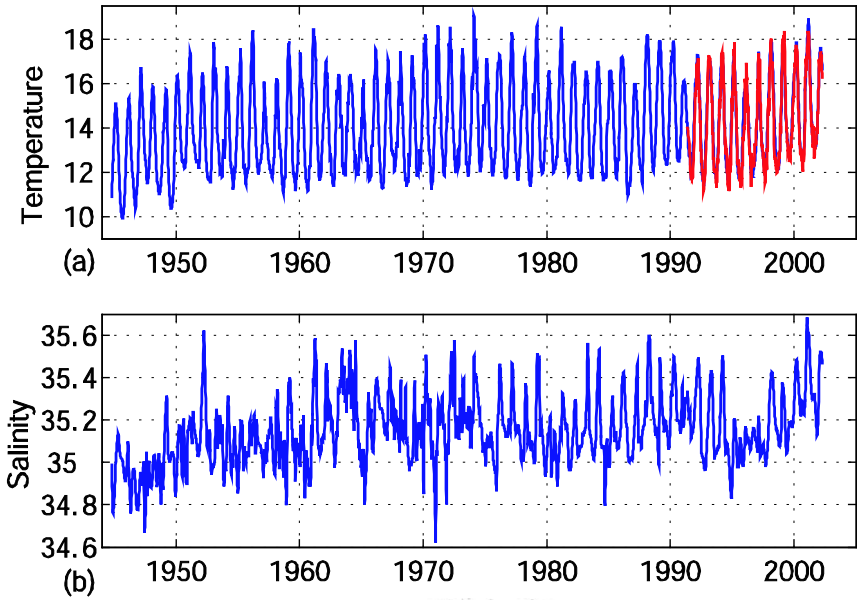
CARS2009 – Incl Argo

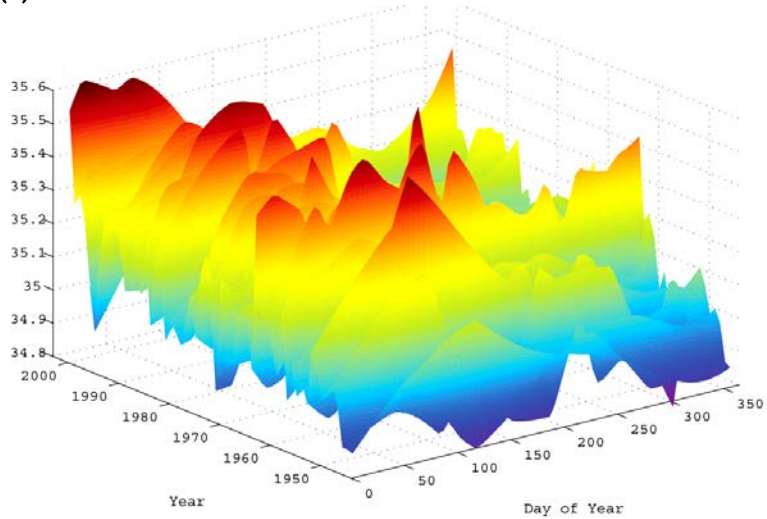




Maria Island Station – Long-term Record
What drives seasonal salinity cycle?



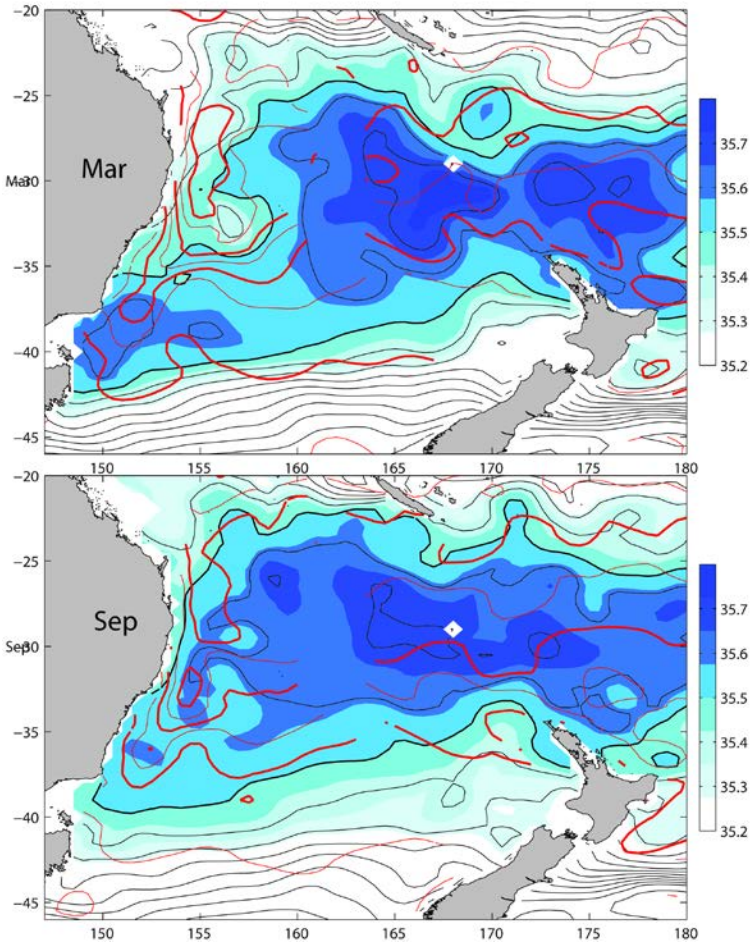




60-year time series at Maria Island

Seasonal to long-term record of EAC flow

What Drives Seasonal Cycle?



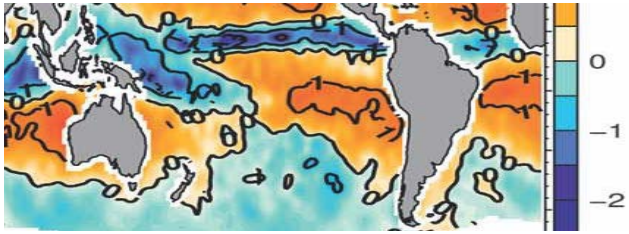
- max southward extension of salinity
- High salinity off Tasmania

- Driven by enhanced EAC & poleward progression of steric height contours

March

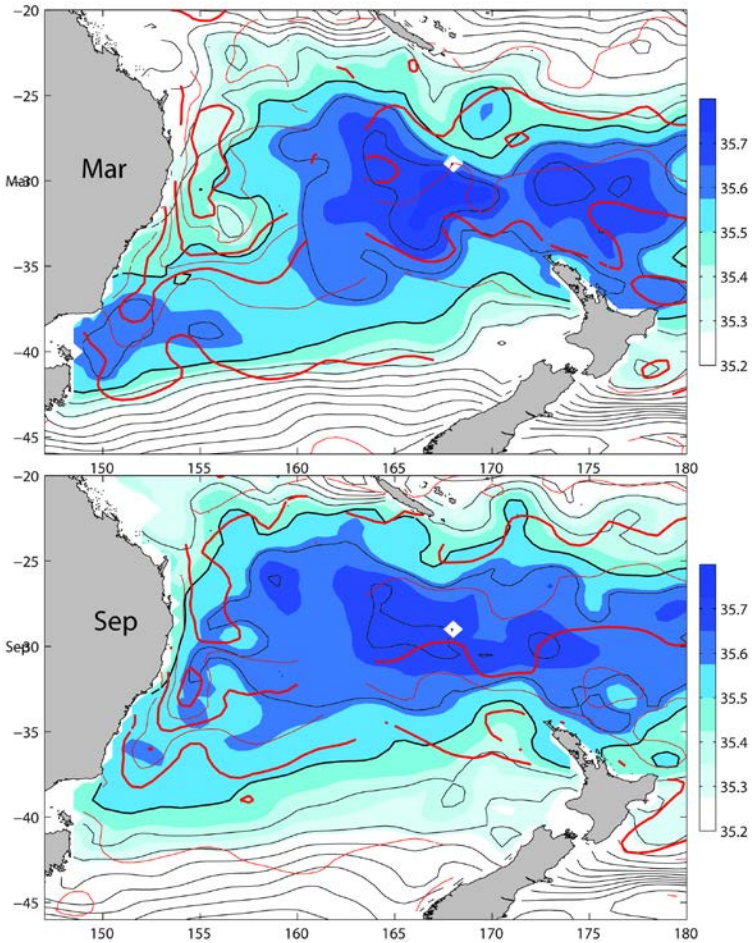
- Equatorward withdrawal of high salinity in tandem with transition of steric height
- Weaker EAC

Sep

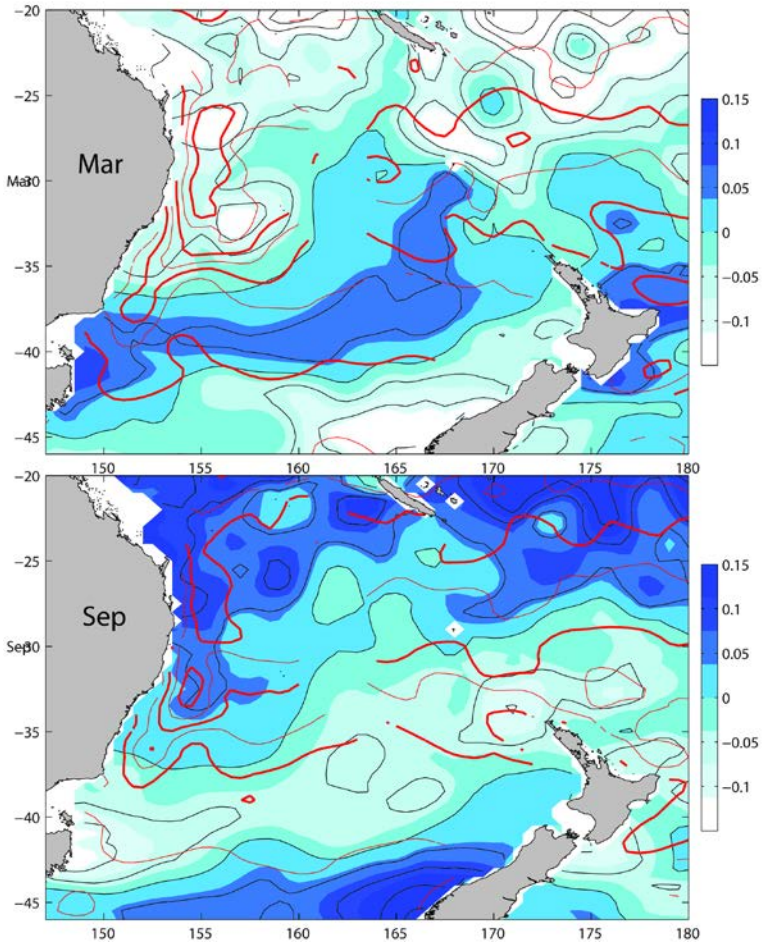


Freshwater flux

Monthly Means

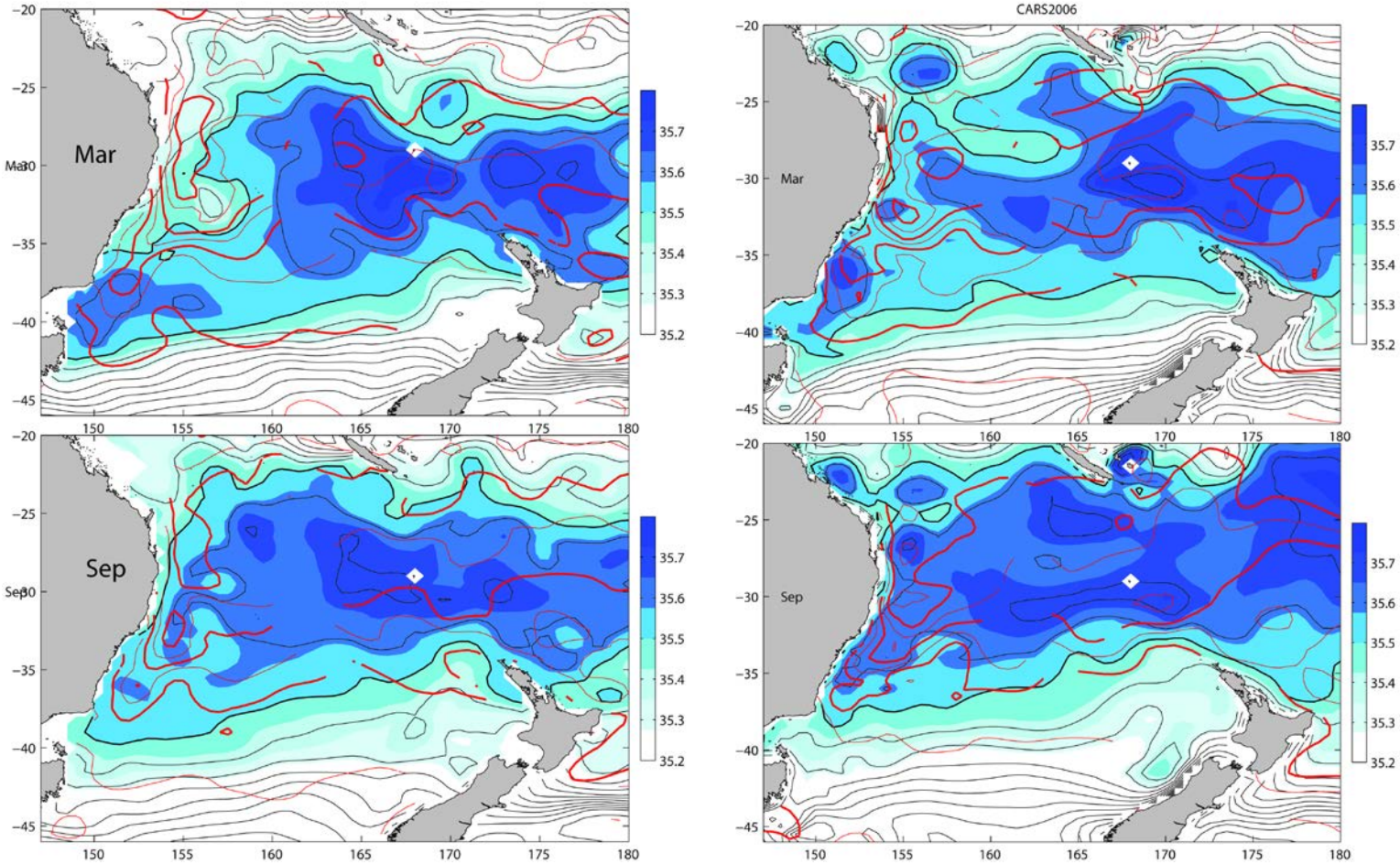


Monthly Anomalies



Argo Maps

CARS2006 – No Argo Data



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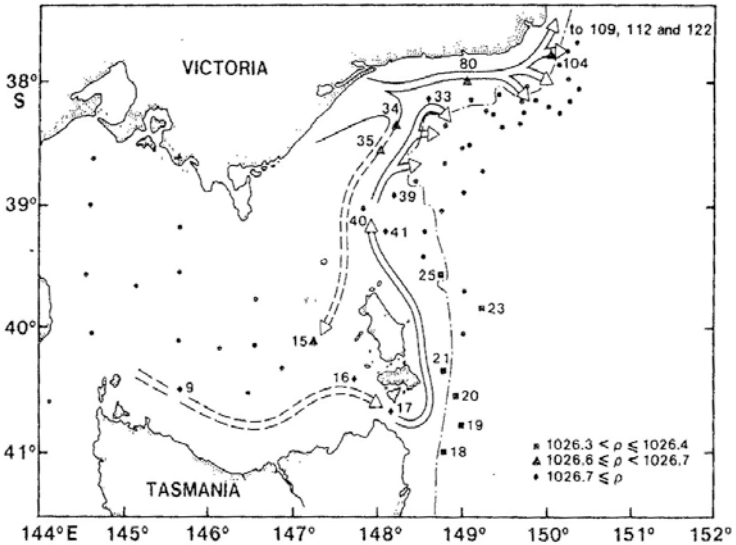
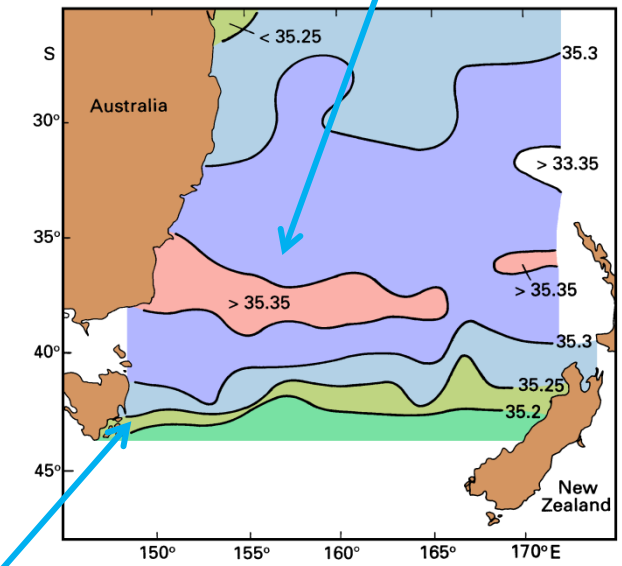
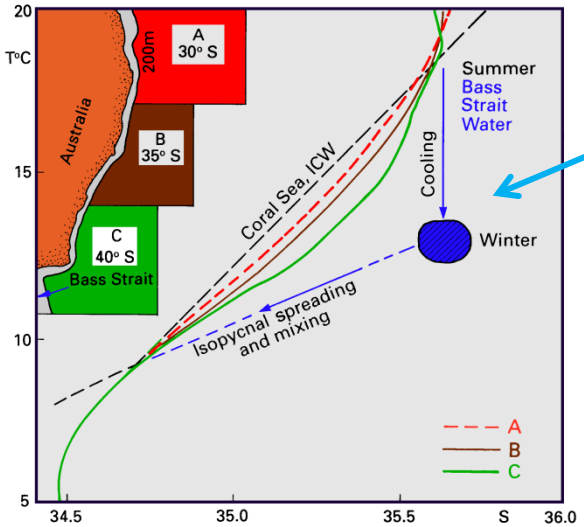
Where does Bass Strait flow to (circa 1991)?



During winter dense Bass Strait water 'cascades' down slope & turns northward. Transport ~0.04 Sv.

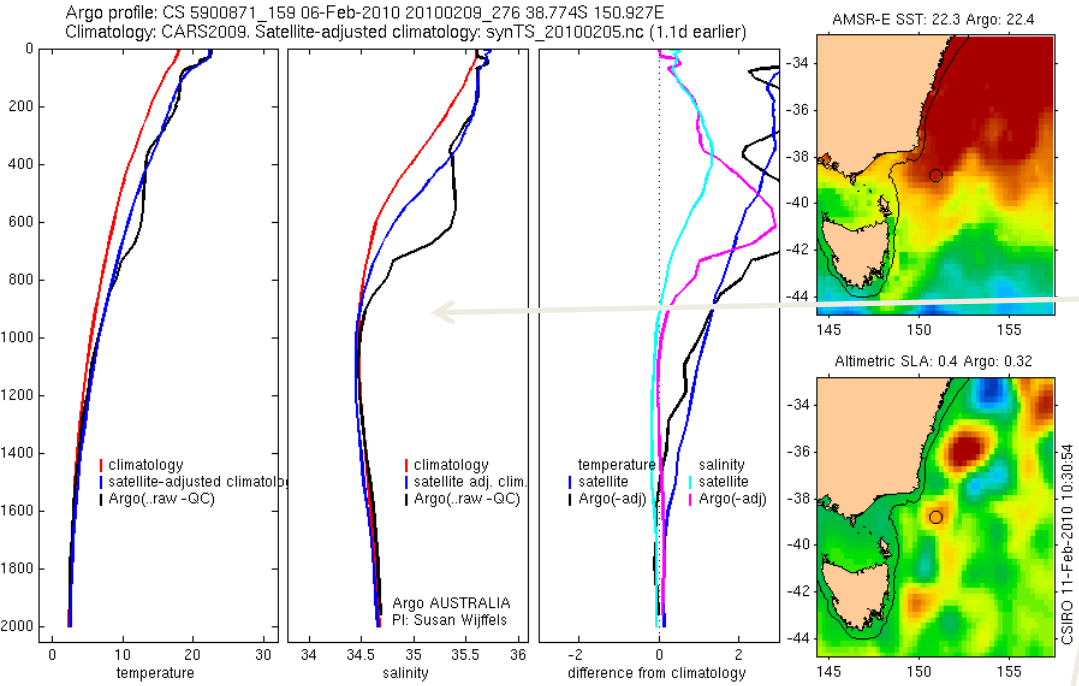
Salinity contours on the 14.5°C isotherm





Settles at stable depth (high S and T)

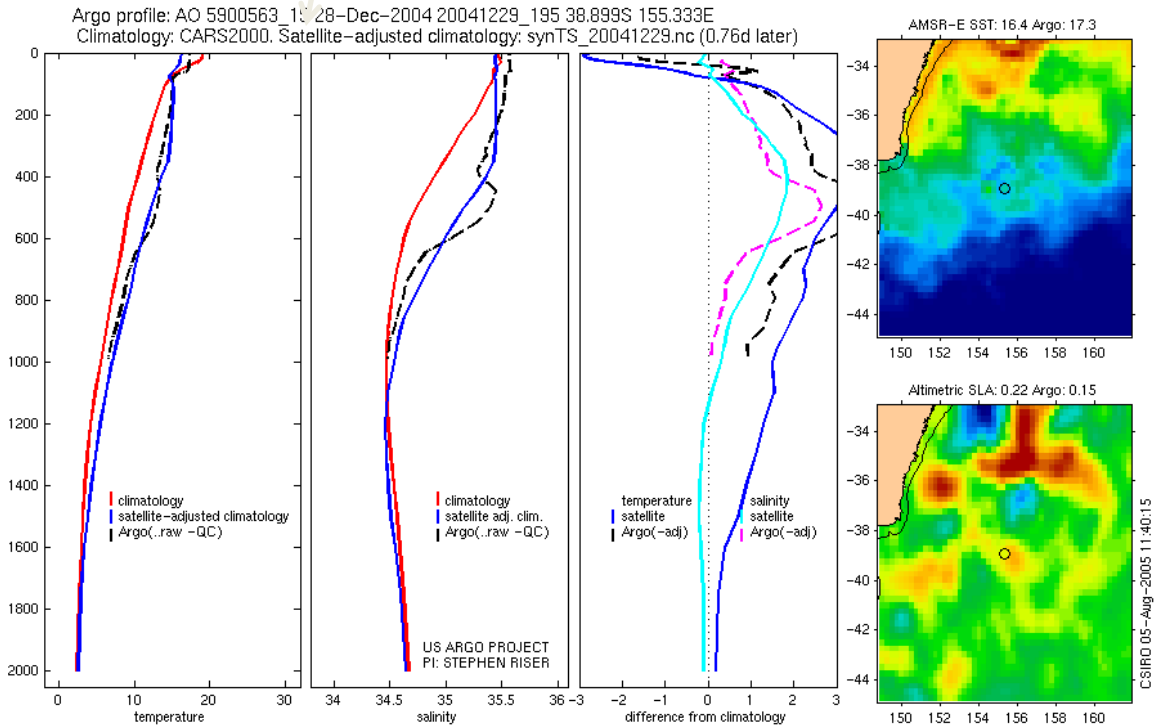
No evidence of BSW south of 40 ° S.



Since 1982, BSW found in 8 Argo profiles:

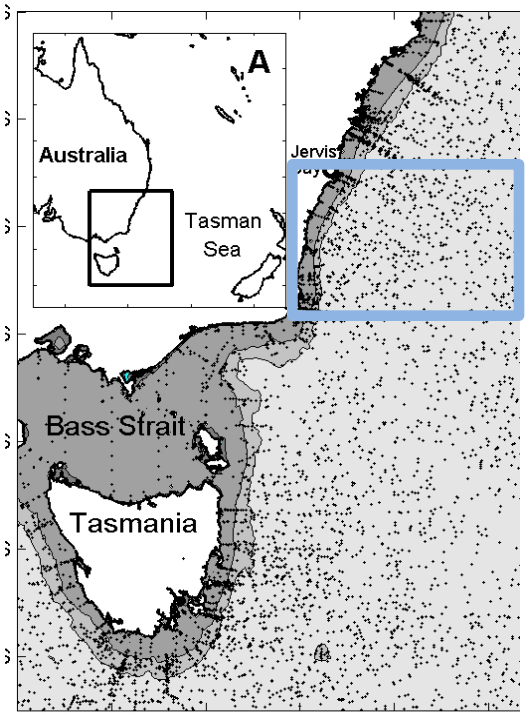
- sequence of 5 in 2010 and
- sequence of 3 in 2004

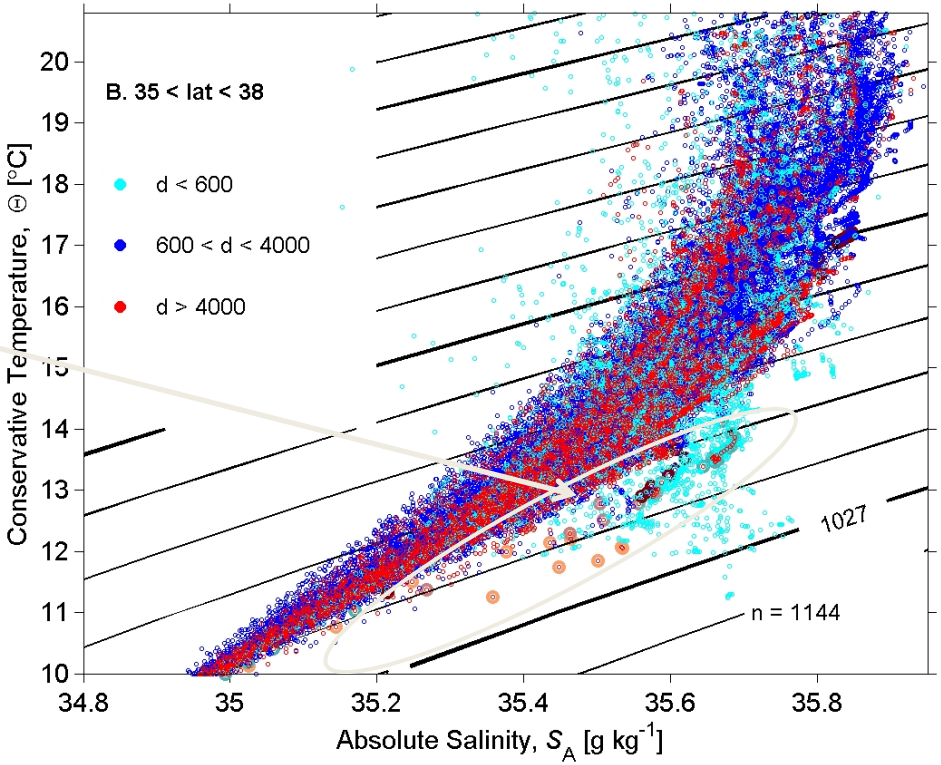
And in one cruise in 1993 (not shown)



Look for BSW in vertical profiles in the western Tasman Sea between Jervis Bay and Eden

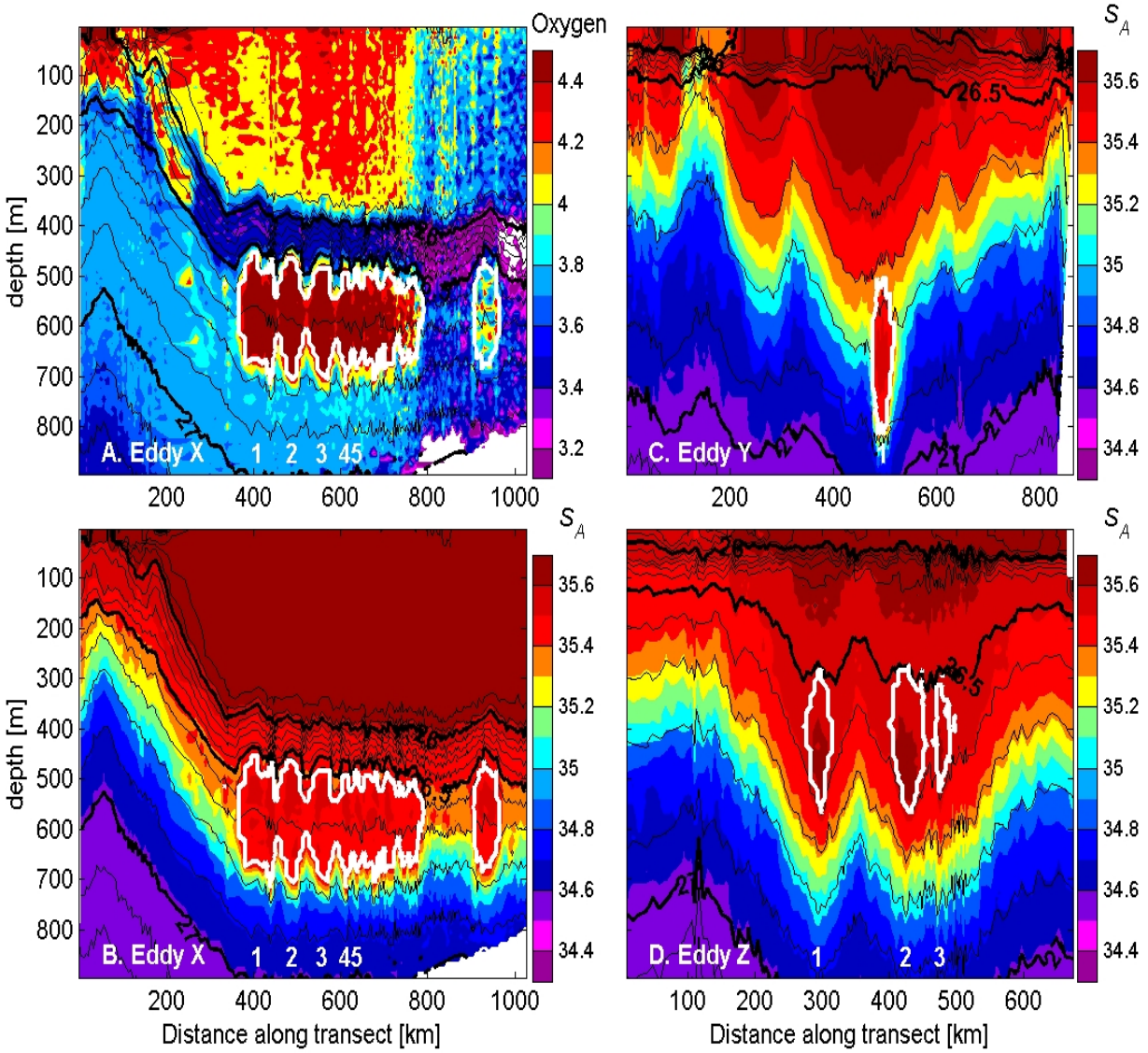
BSW appears as a high salinity water at 1026.7 kg m^{-3},

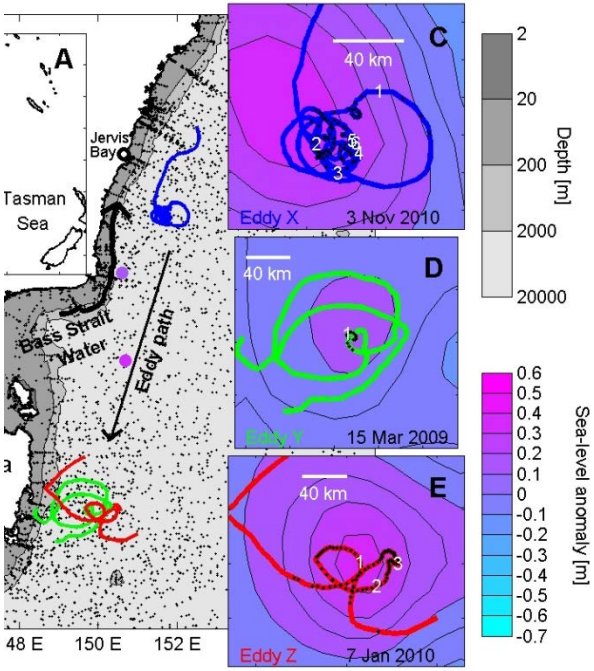




Between 35 & 38 S, lots of BSW in water < 600 m, only two deeper (orange & dark red circles)

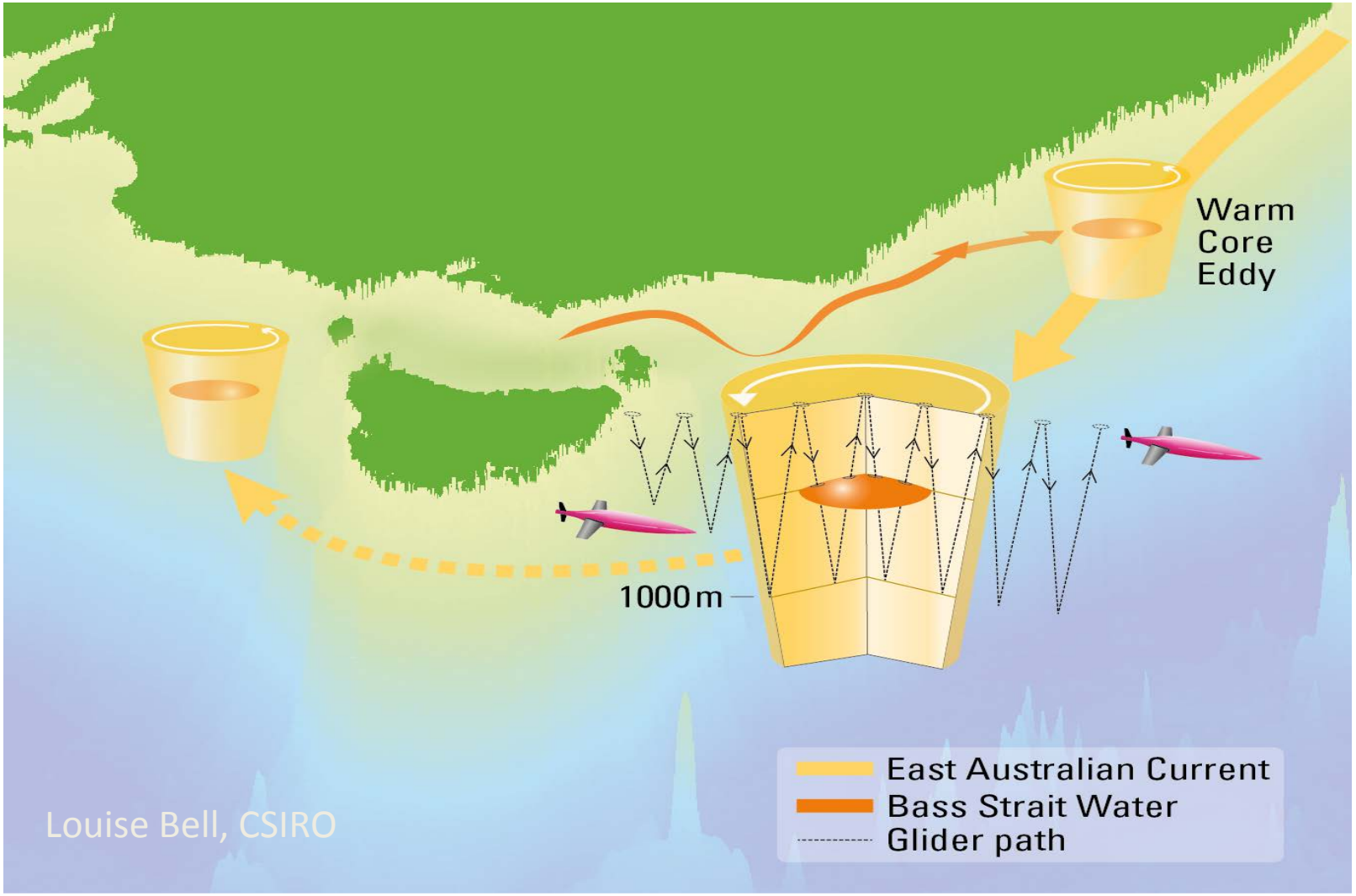
Are there similar anomalies in glider deployments.





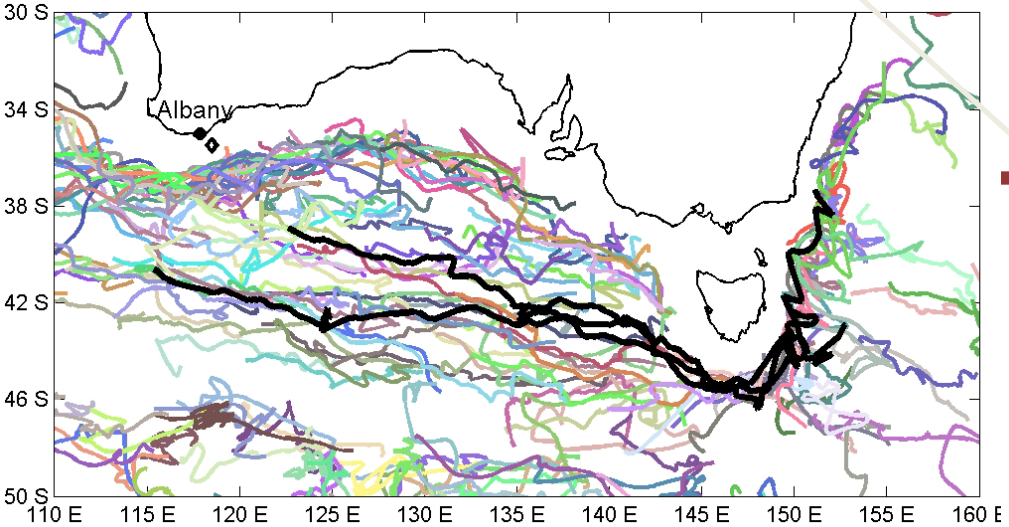
Lenses appear in each of the 4 glider transects reaching the centre of EAC anti-cyclonic eddies.

The southward transport of lenses of BSW at depth in the centre of mesoscale anti-cyclonic eddies.



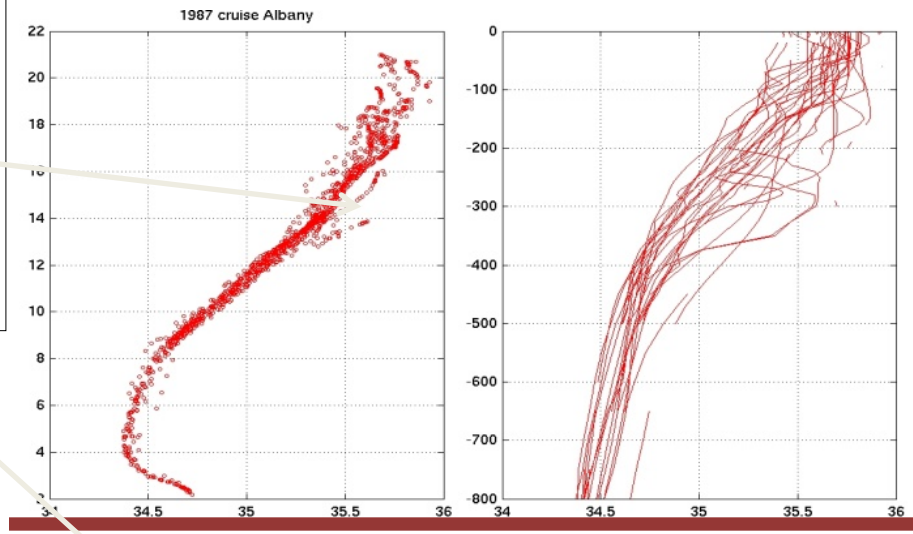
The final fate of the BSW.

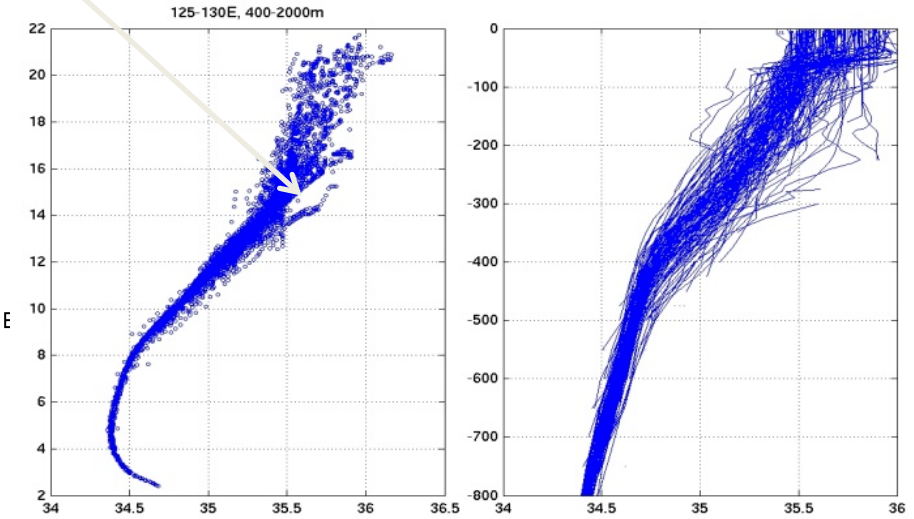
- June 1987 “A lens of mixed water off Albany with salinity and temperature properties of eastern Bass Strait overflow water”
- Analysis of Argo profiles 125-130 E shows 3 profiles with BSW.



With globally the longest uninterrupted westward trajectory of any sub-mesoscale lenses, they may travel much further?

CTDs from 1987 cruise off Albany (Cresswell, 1993)



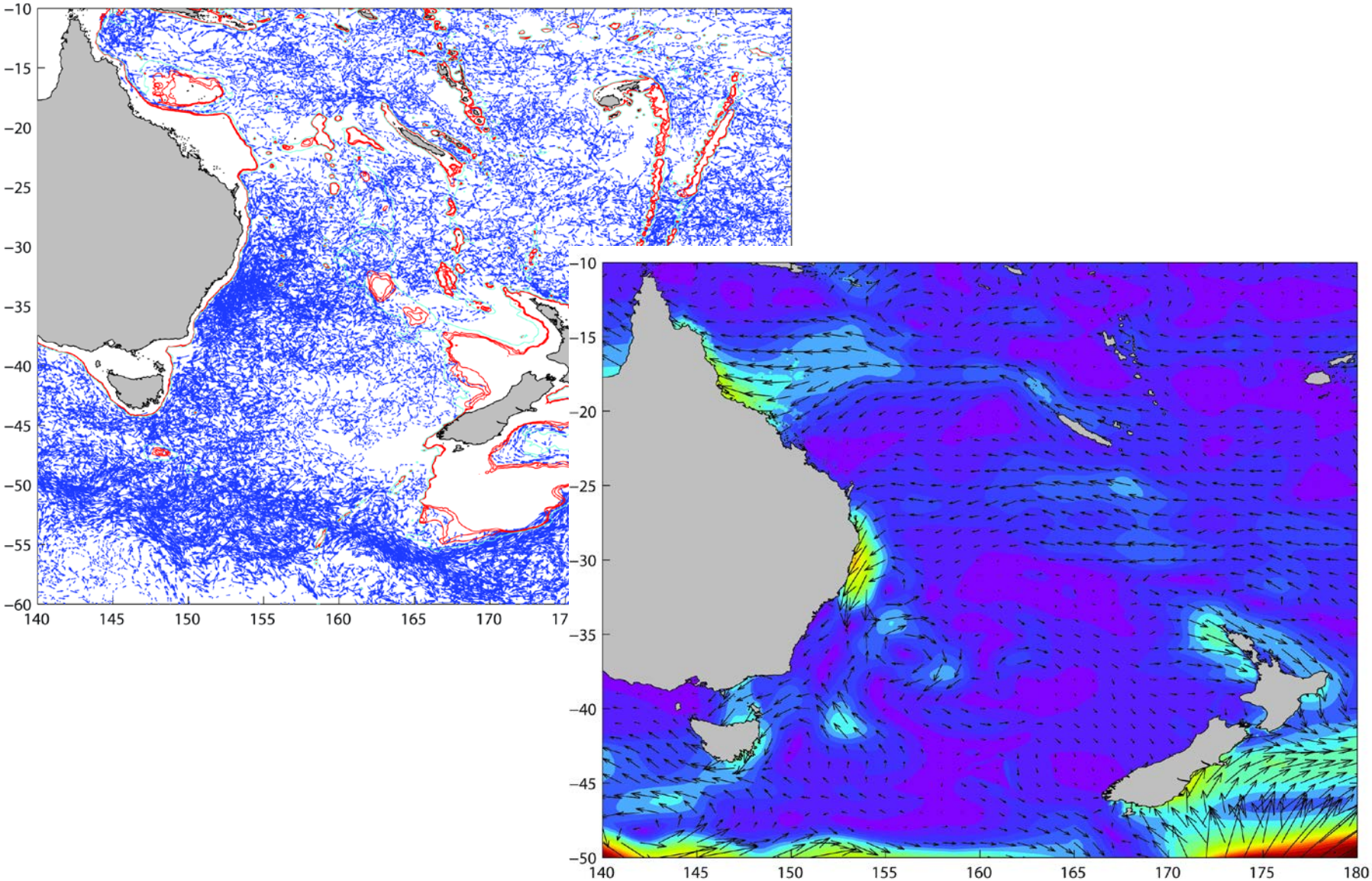


Argo profiles (125-130E)

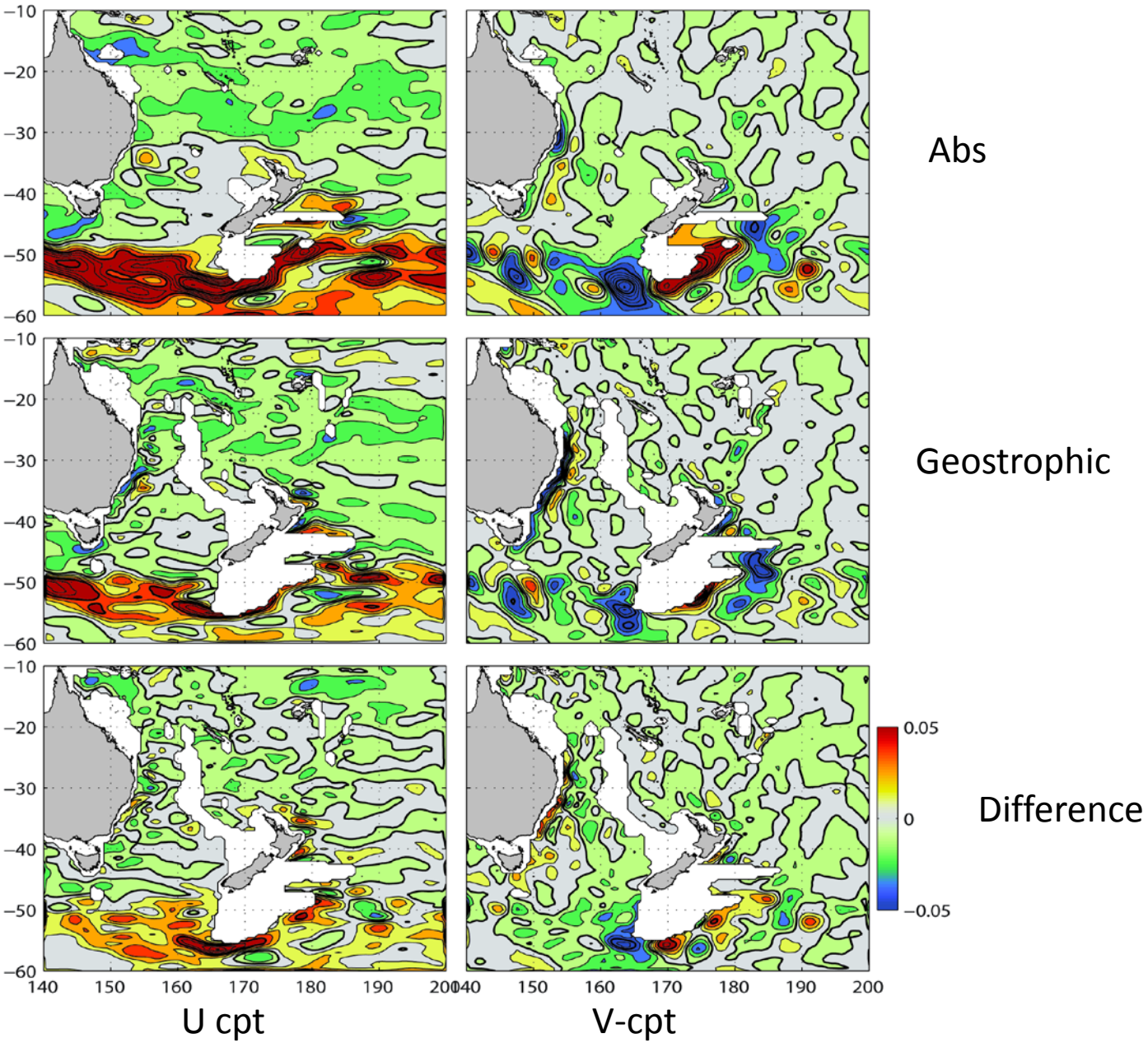
Outline

- Argo data distribution
- Mean fields from Argo
- Validation of Argo fields
- Southwest Pacific Circulation
- Seasonal Cycle
- Argo absolute velocity field
- Formation & evolution of Bass Strait Water

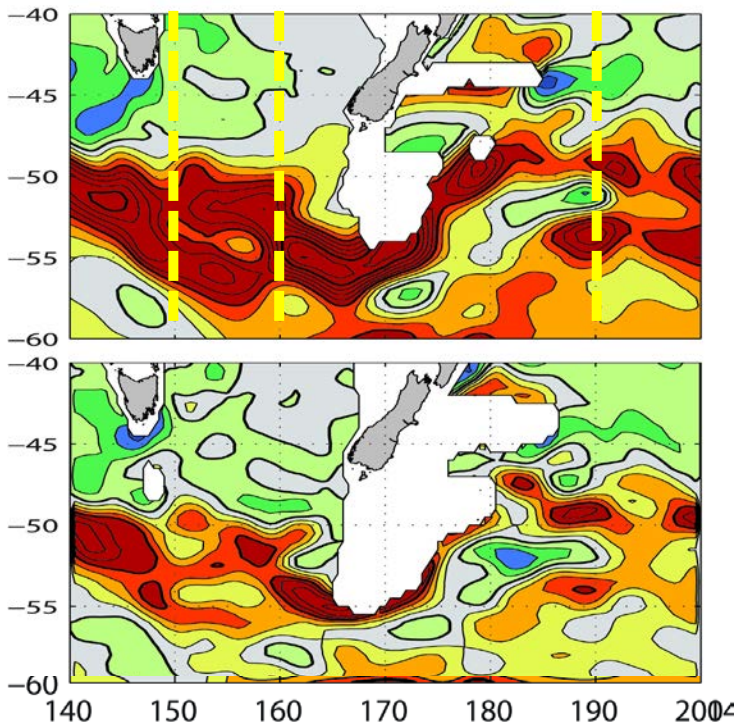
Argo Trajectories- Andro Data

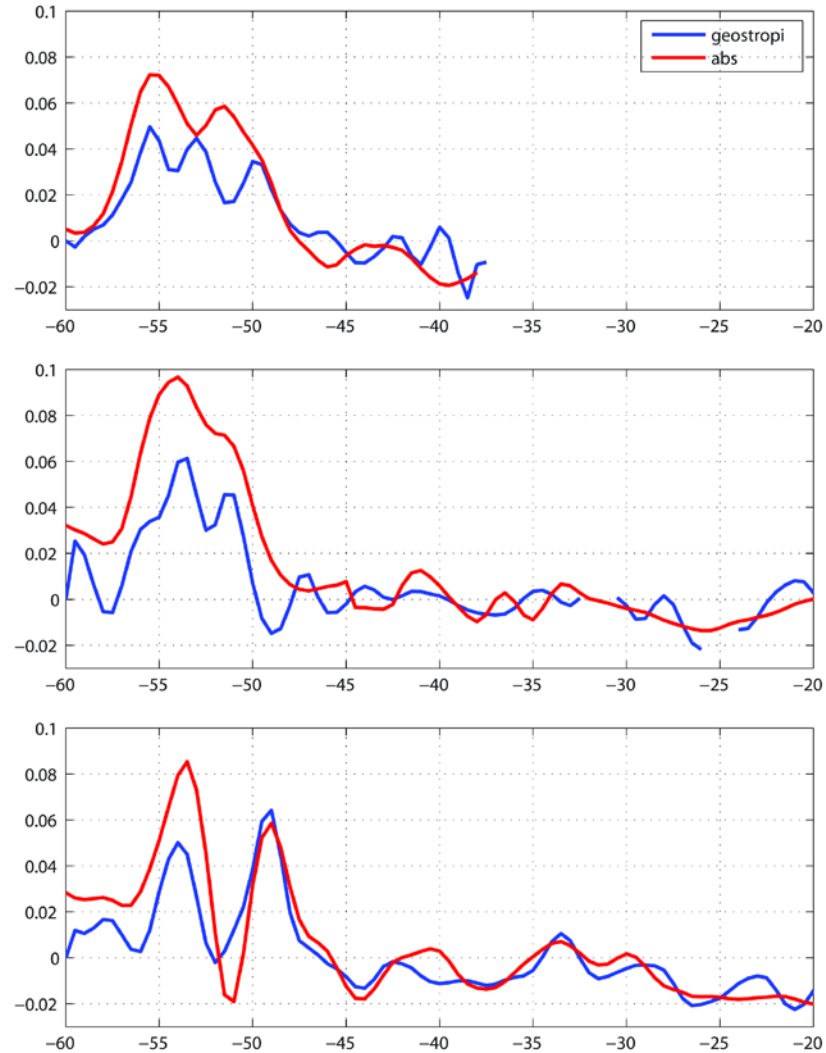


Andro Velocity Components



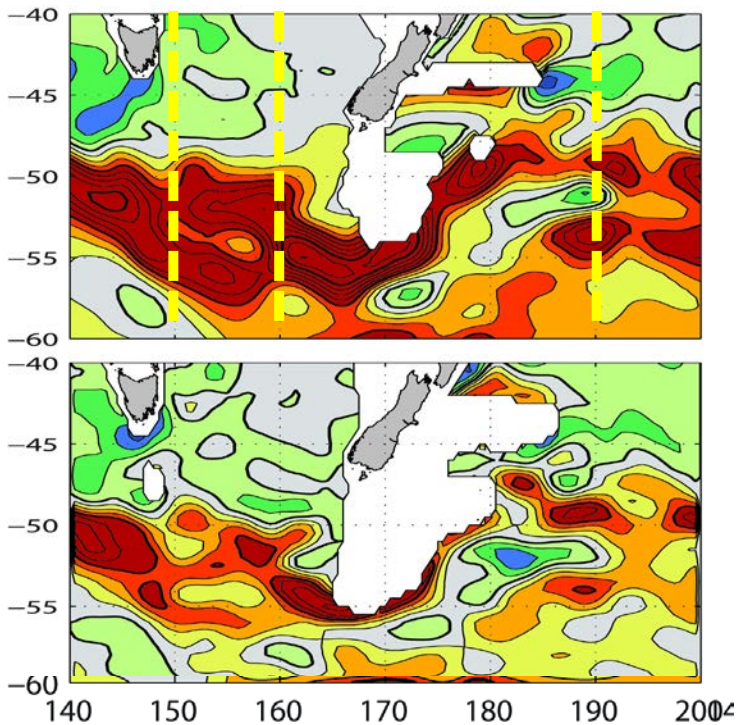
ACC- zonal velocity component

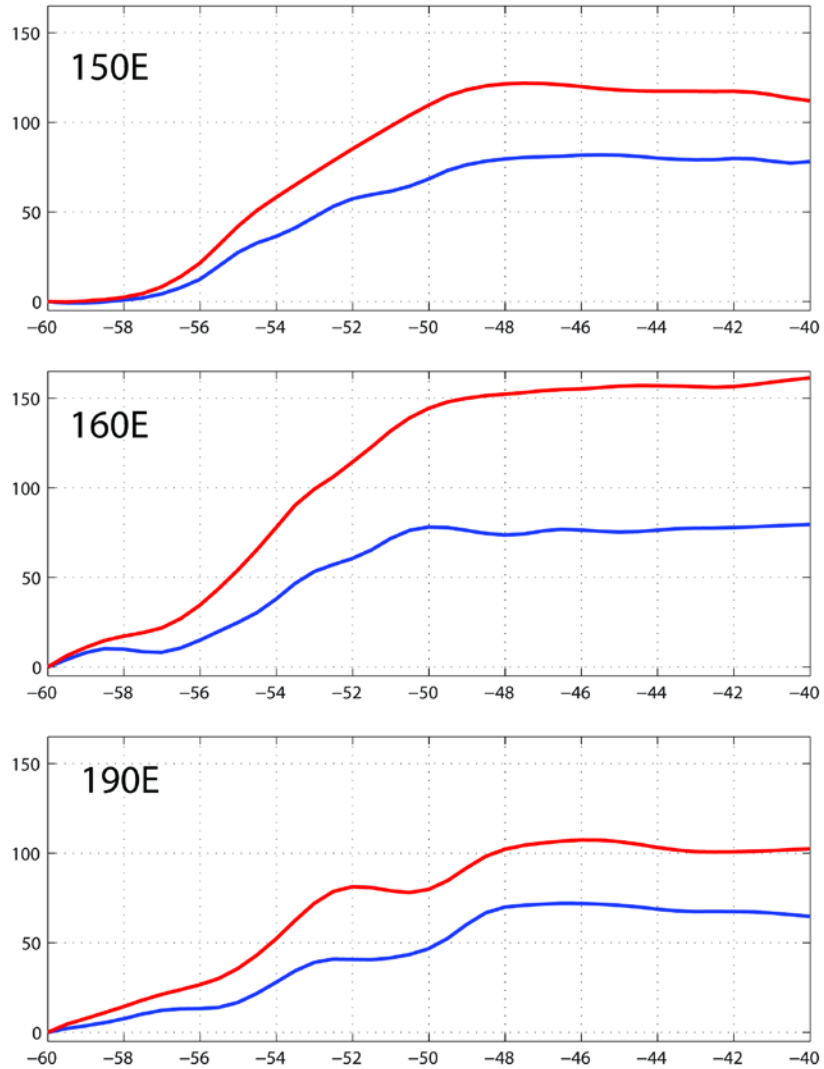




In ACC, absolute currents > geostrophic

ACC- zonal velocity component



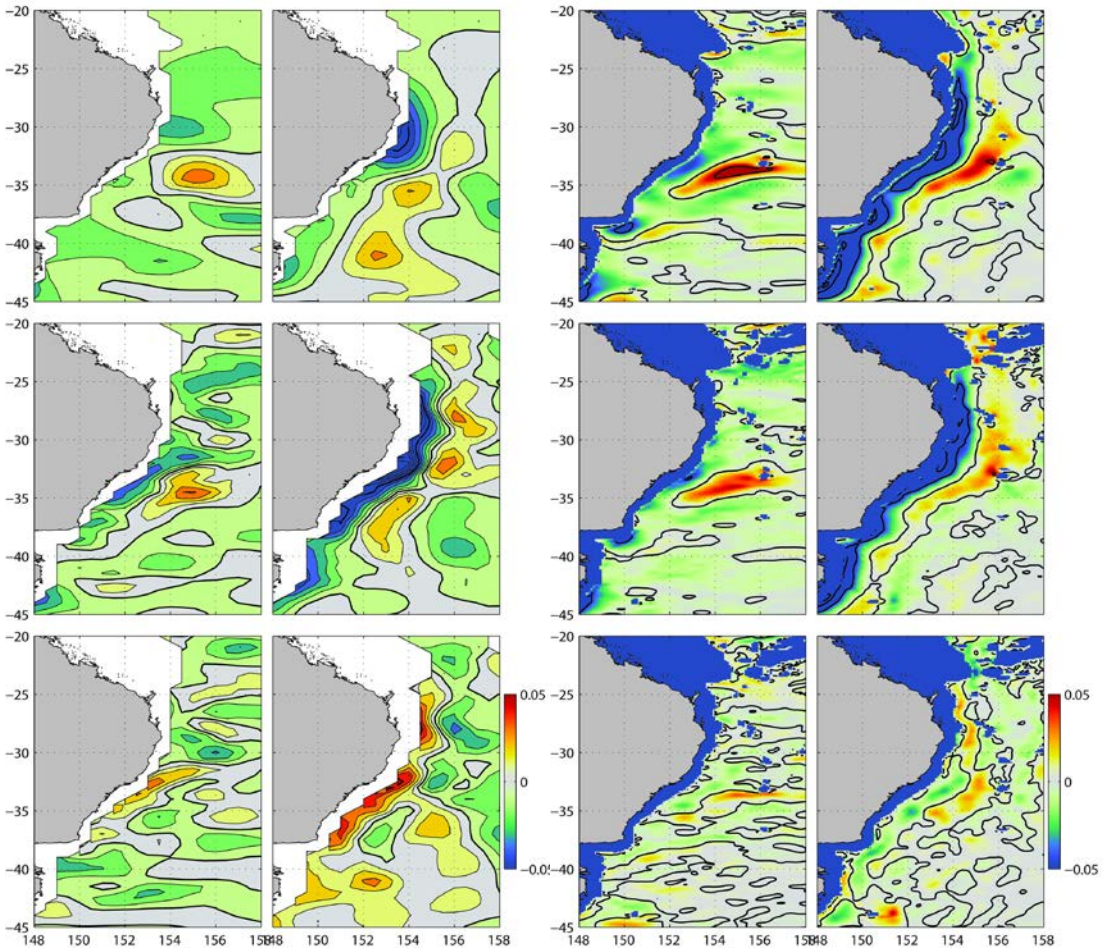


Major increase in ACC transport

EAC Velocity Components

Argo

Model



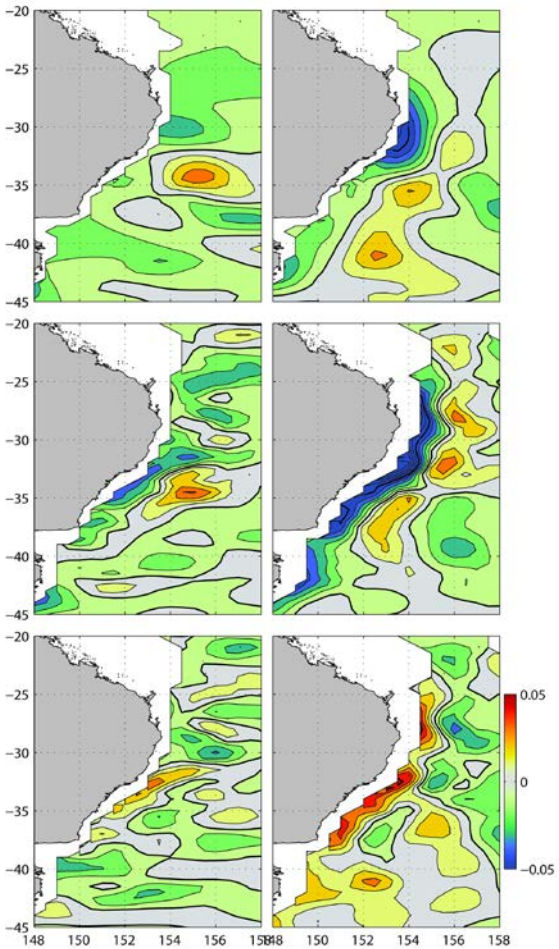
U V U V

Argo data distribution does not fully resolve EAC adjacent to the western boundary

Argo abs currents are weaker than geostrophic at boundary

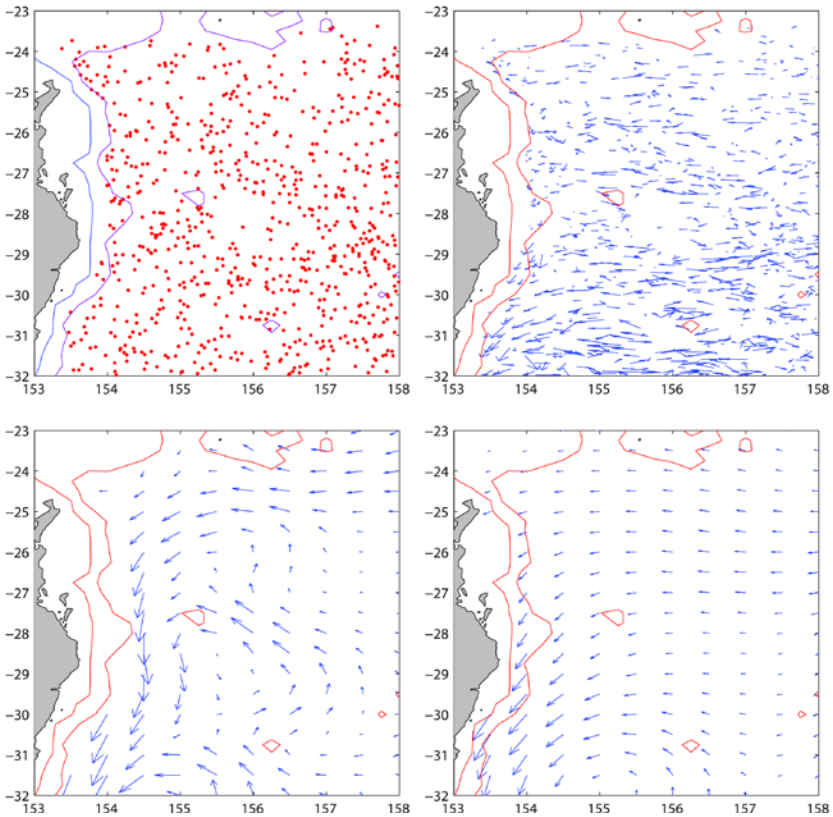
EAC Velocity Components

Argo



U V

Argo data distribution does not fully resolve EAC adjacent to the western boundary

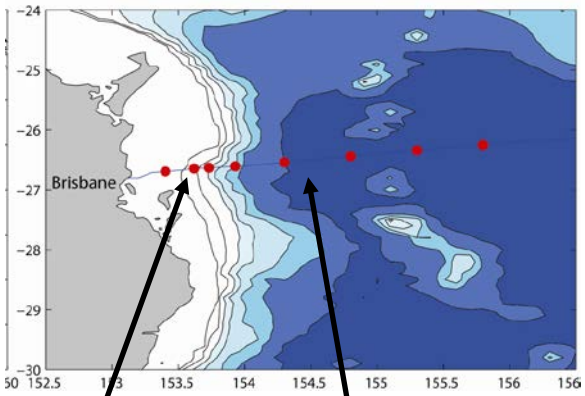


geostrophic absolute

Summary

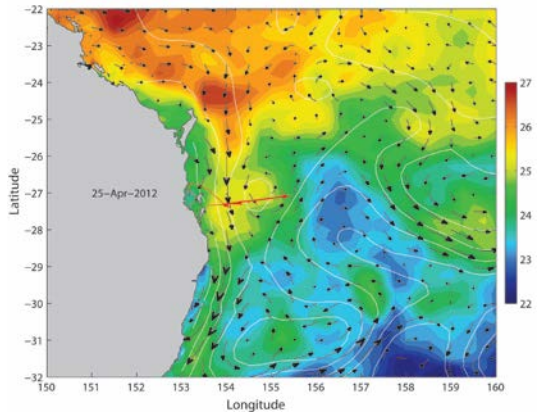
- Argo distribution resolves mean flow
- Convergence of observational and model representation
- Subtle features of temporal (annual) cycle observed
- Argo drift currents – achieved maturity
- Argo complements other data streams (altimetry, gliders)
- Time for climatologies based on time-specific period

Design & Deployment of EAC Array

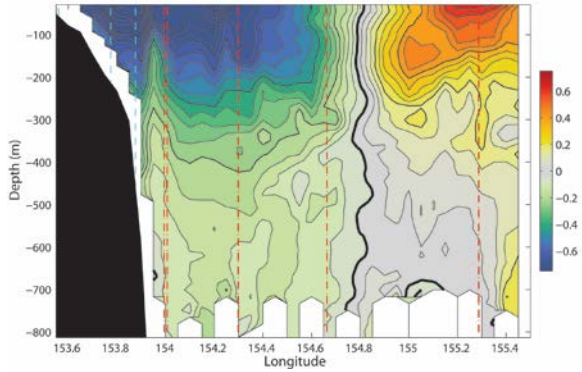


5 deepwater moorings

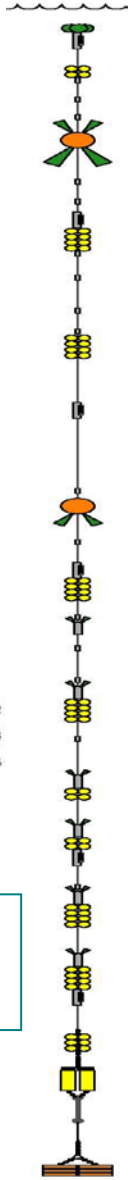
3 inshore moorings



Deployed on RV Southern Surveyor in April 2012



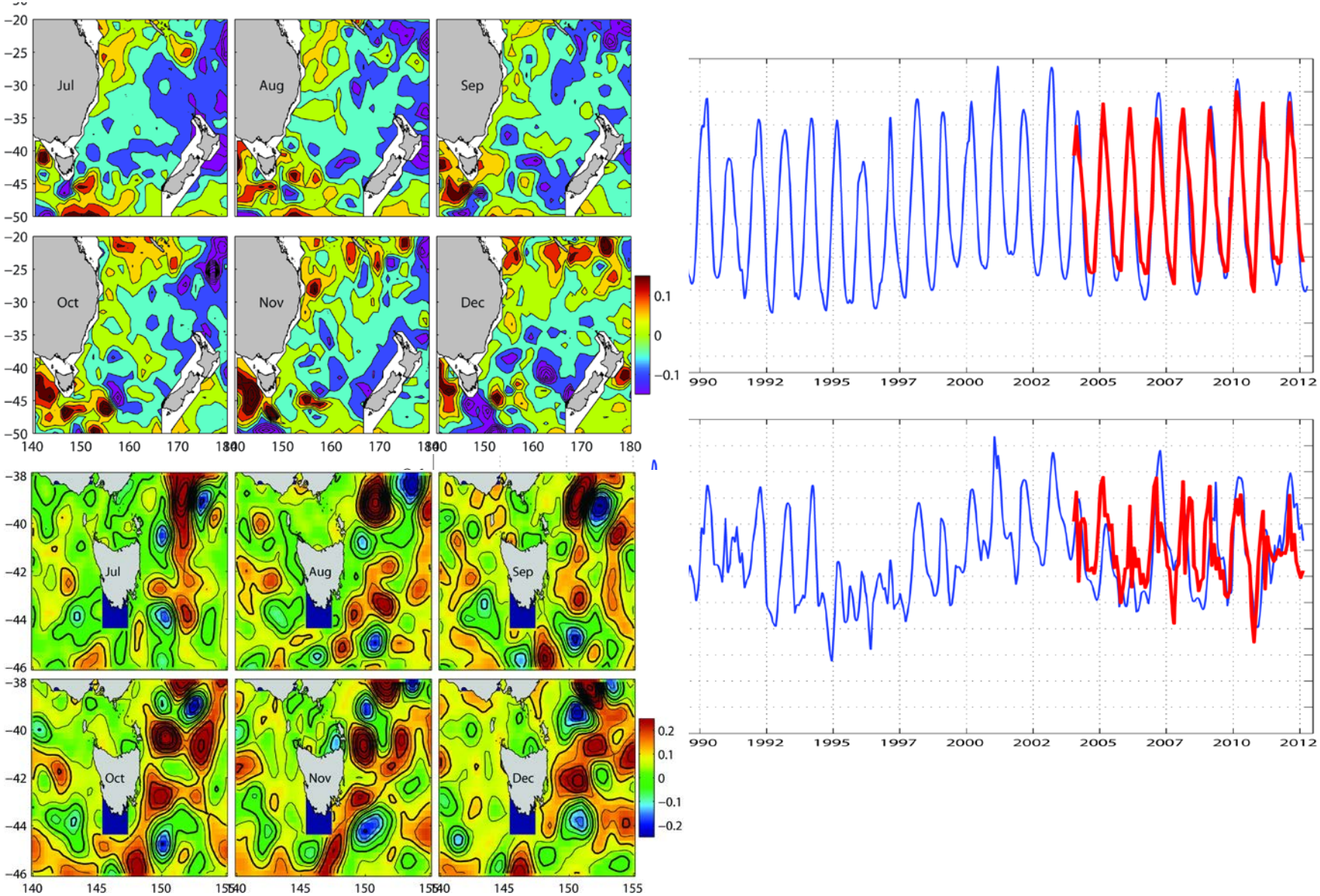
Strong EAC observed during deployment voyage

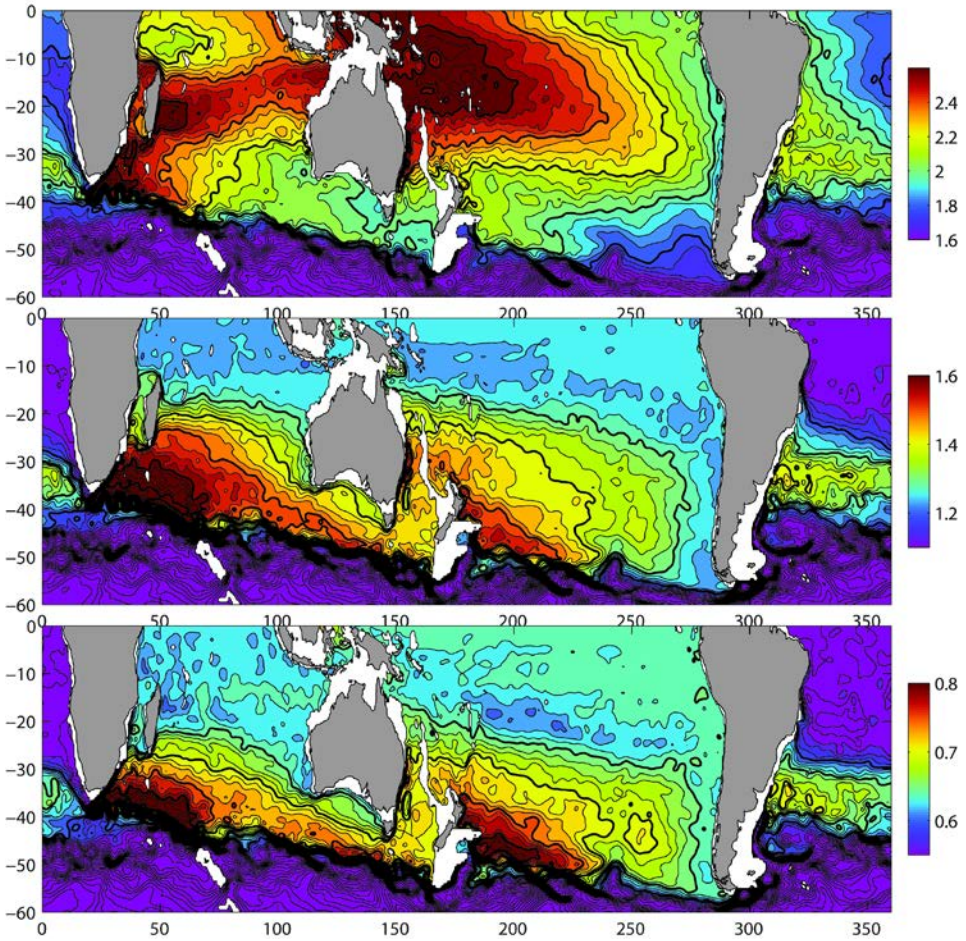


Wonder buoys in sea study

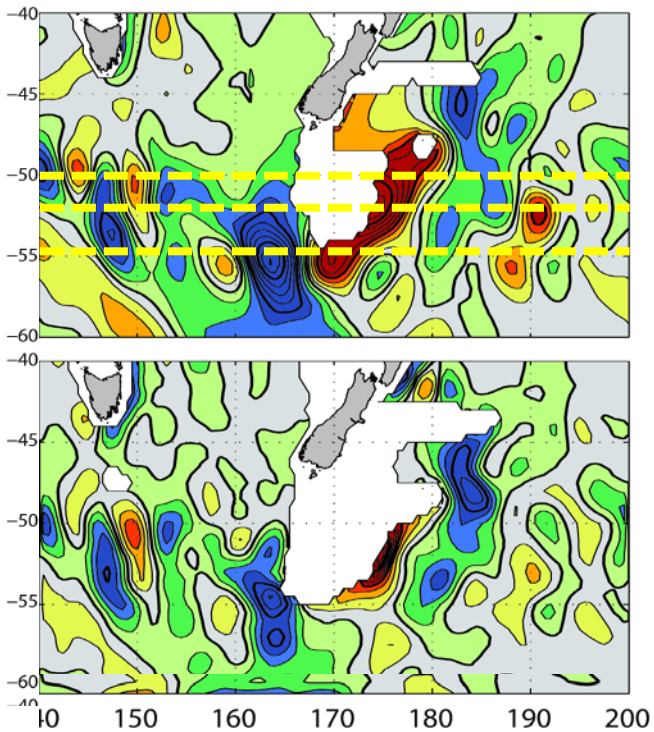
Courier-Mail April 20

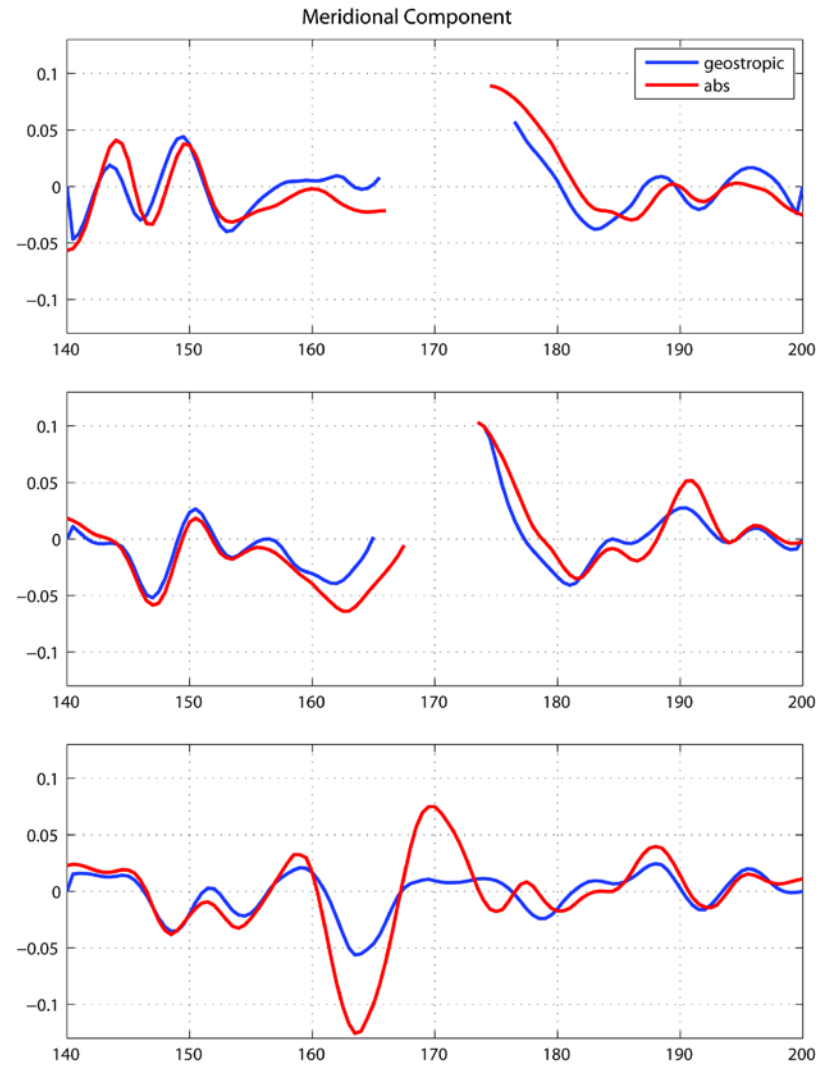
Current meters, ADCP, CTD instruments to capture majority of mass and heat flux of EAC


Jul
Aug
Sep
Oct
Nov
Dec
0.1
0
−0.1
0.2
−0.2
990
1992
1995
1997
2000
2002
2005
2007
2010
2012


0
−10
−20
−30
−40
−50
−60
0
50
100
150
200
250
300
350
2.4
2.2
2
1.8
1.6
1.6
1.4
1.2
0.8
0.7
0.6

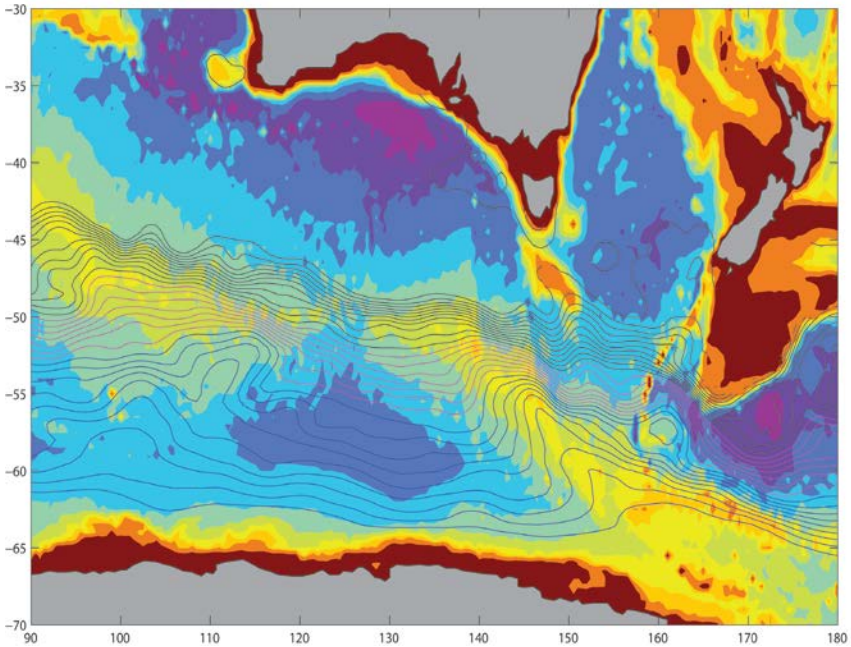
ACC – meridional velocity





Meridional components strongly correlated

Improving Global Climatology with Argo – CARS



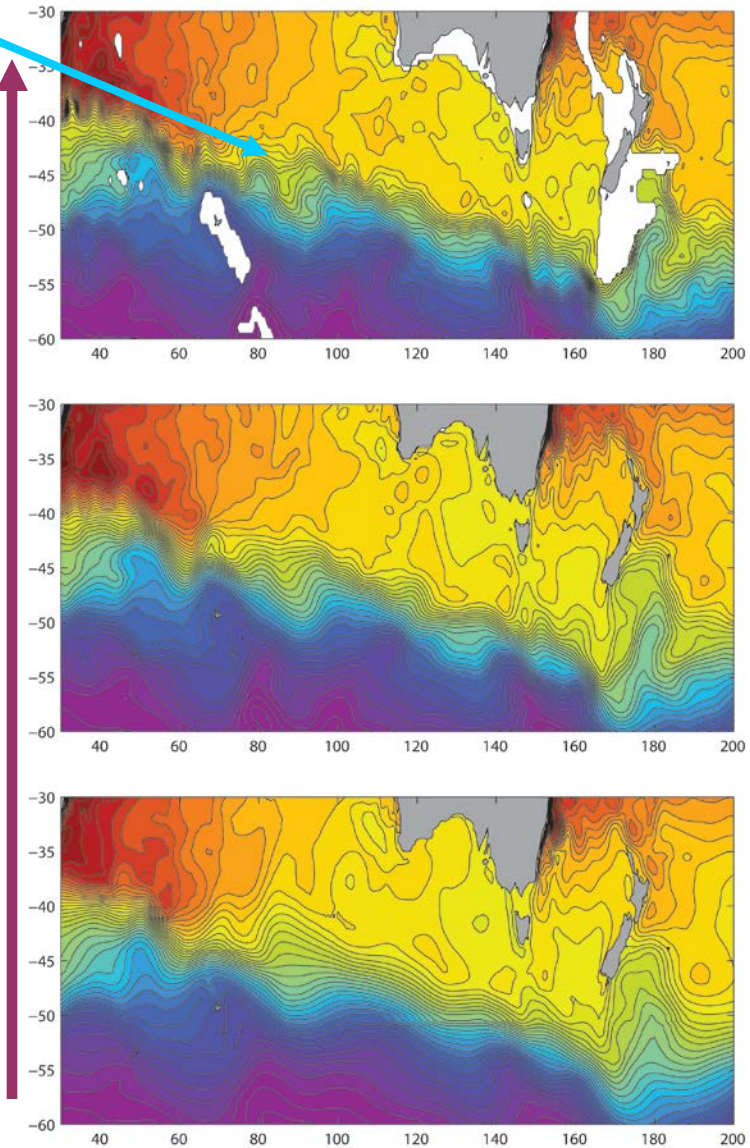
Realistic ACC

2010

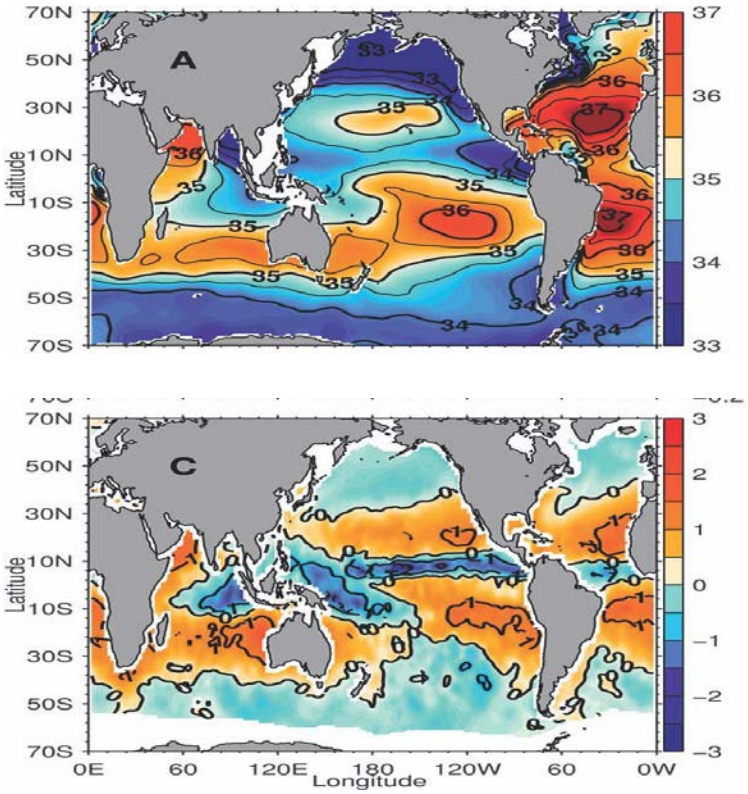
2006

2000

Increasing spatial resolution



Flow of the ACC closely related to underlying topography


A
C
70N
50N
30N
10N
10S
30S
50S
70S
Latitude
0E
60
120E
180
120W
60
0W
Longitude
37
36
35
34
33
3
2
1
0
−1
−2
−3