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Virtual meeting

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Low-frequency variability of Antarctic Circumpolar Current transport in the Pacific sector centered at the Udintsev/Eltanin Fracture Zones and concurrent atmospheric forcing

PHANTOM-2

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SUMMARY

- While estimates of the time-mean ACC transport are converging (observations provide *O*(135-140 Sv) and the latest high-resolution ocean reanalysis *O*(155 Sv)) there is still a great knowledge gap concerning the ACC low-frequency variability (>3 months).

- The central South Pacific centered at the Udintsev/Eltanin Fractures Zones has been shown to be the primary choke point of the Southern Ocean where the major ACC branches are strongly concentrated and guided by prominent submarine topography of the fracture zones.

- This has recently been confirmed from both in situ observations of hydrography and current meter measurements during the 2016-2018 Udintsev Cruises on the KOPRI Icebreaker *Araon* as well as our circumpolar analysis of the updated altimeter data (Park et al., 2019).

- We performed a systematic validation of MERCATOR Ocean's GLORYS12 solution in comparison with in situ observations and CLS/CNES altimeter data; and computed the 3D ACC transport time series (x, y, t) within the central South Pacific region in order to construct the regional transport stream function of ACC.

- EOF analysis of the stream function time series helped identify the major modes of ACC transport variability which were compared with dominent climatic forcing modes in the Southern Hemisphere.

- This work contributes insights on how and why the ACC transport varies at interannual time scales, an important but still not well-documented climate-related issue.

DATA USED

1. Altimetric/Oceanic data

- Altimetric data from CMEMS:
https://resources.marine.copernicus.eu/?option=com_csw&view=details&product_id=SEALEVEL_GLO_PHY_L4_REP_OBSERVATIONS_008_047

- Oceanic reanalysis GLORYS12 from MERCATOR Ocean from CMEMS

- Altimetric ACC fronts from SEANOE:
https://www.seanoe.org/data/00486/59800/ | https://www.seanoe.org/data/00486/59800/

2. Atmospheric/Climatic data

- AA0 (or SAM) index from NOAA:
https://www.cpc.ncep.noaa.gov/products/precip/CWlink/daily_ao_index/aao/aao_index.html

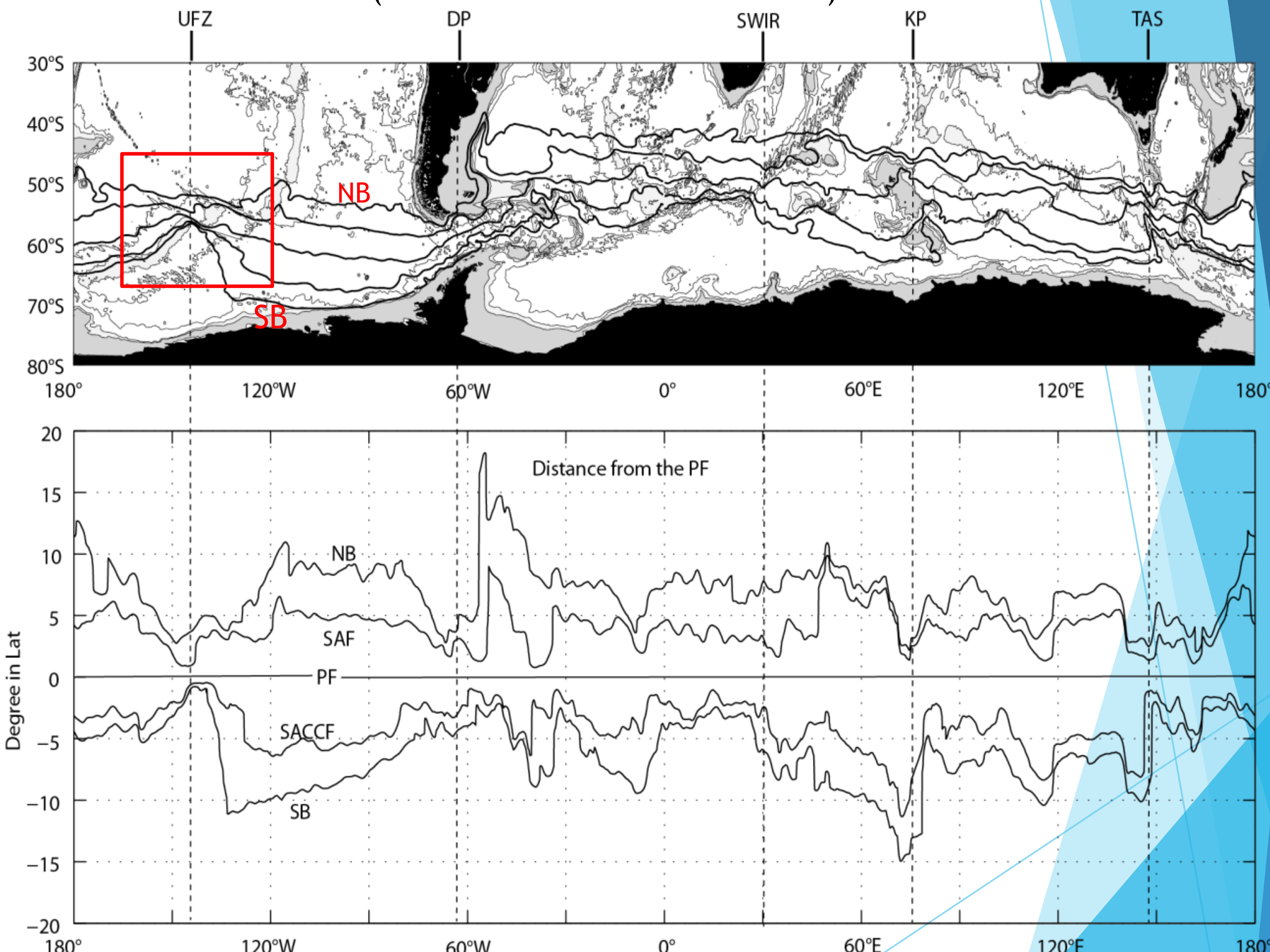
- Canonical ENSO index MEI from NOAA:
https://psl.noaa.gov/enso/mei/

- ENSO Modoki index EMI from NOAA:
http://www.jamstec.go.jp/frsgc/research/d1/iod/DATA/emi.monthly.txt

- Atmospheric reanalysis from NCEP1/NOAA (SLP, GPH, wind etc)
https://psl.noaa.gov/data/gridded/data.ncep.reanalysis.pressure.html

ACC northern boundary (NB) and southern boundary (SB)

(derived from CNES-CLS MDT18)

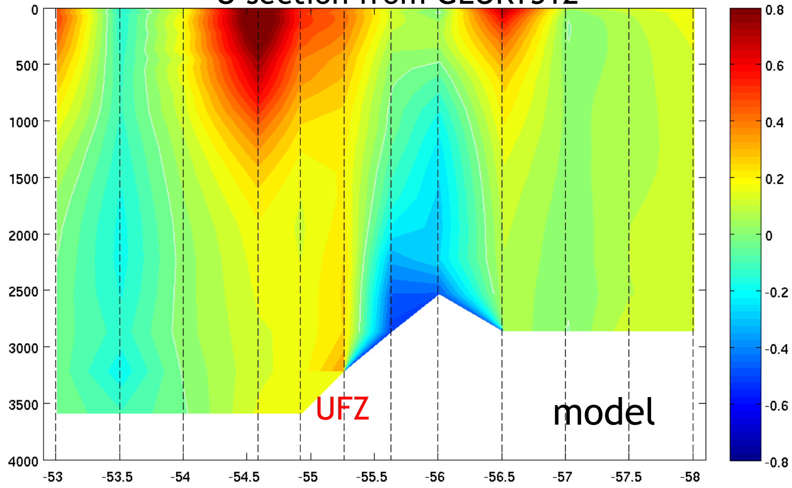


Park et al. (2019)

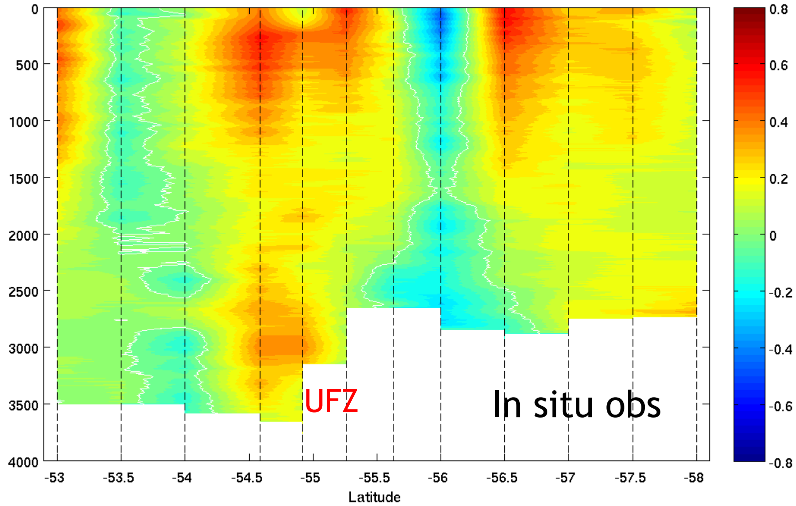
Validation: GLORYS12 and Udintsev observations (2016)

- realistic model reproduction of along-section frontal structure
- reasonable agreement in speed/direction in vertical structure
- but insufficient vertical resolution for a steep bottom topography (e.g., UFZ), negatively affecting bottom flow-topography interaction

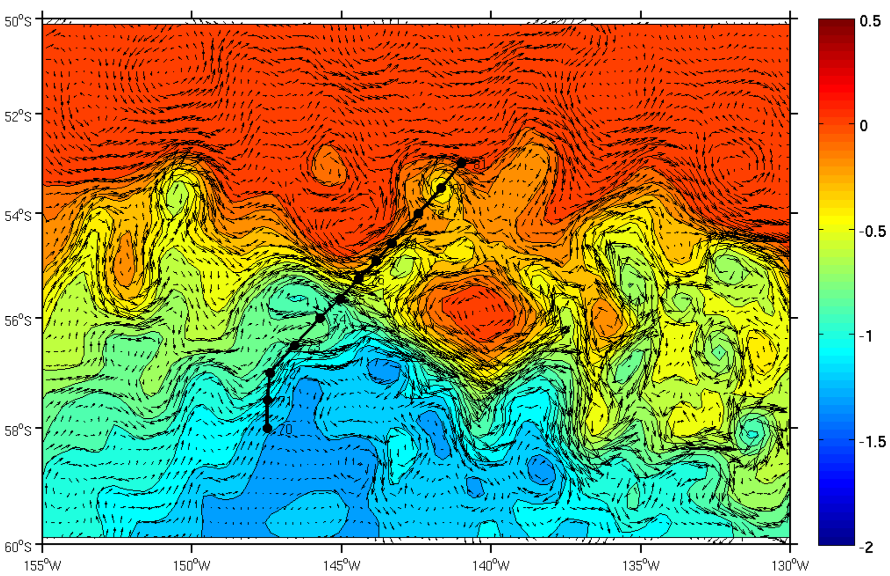
U section from GLORYS12



U section from LADCP



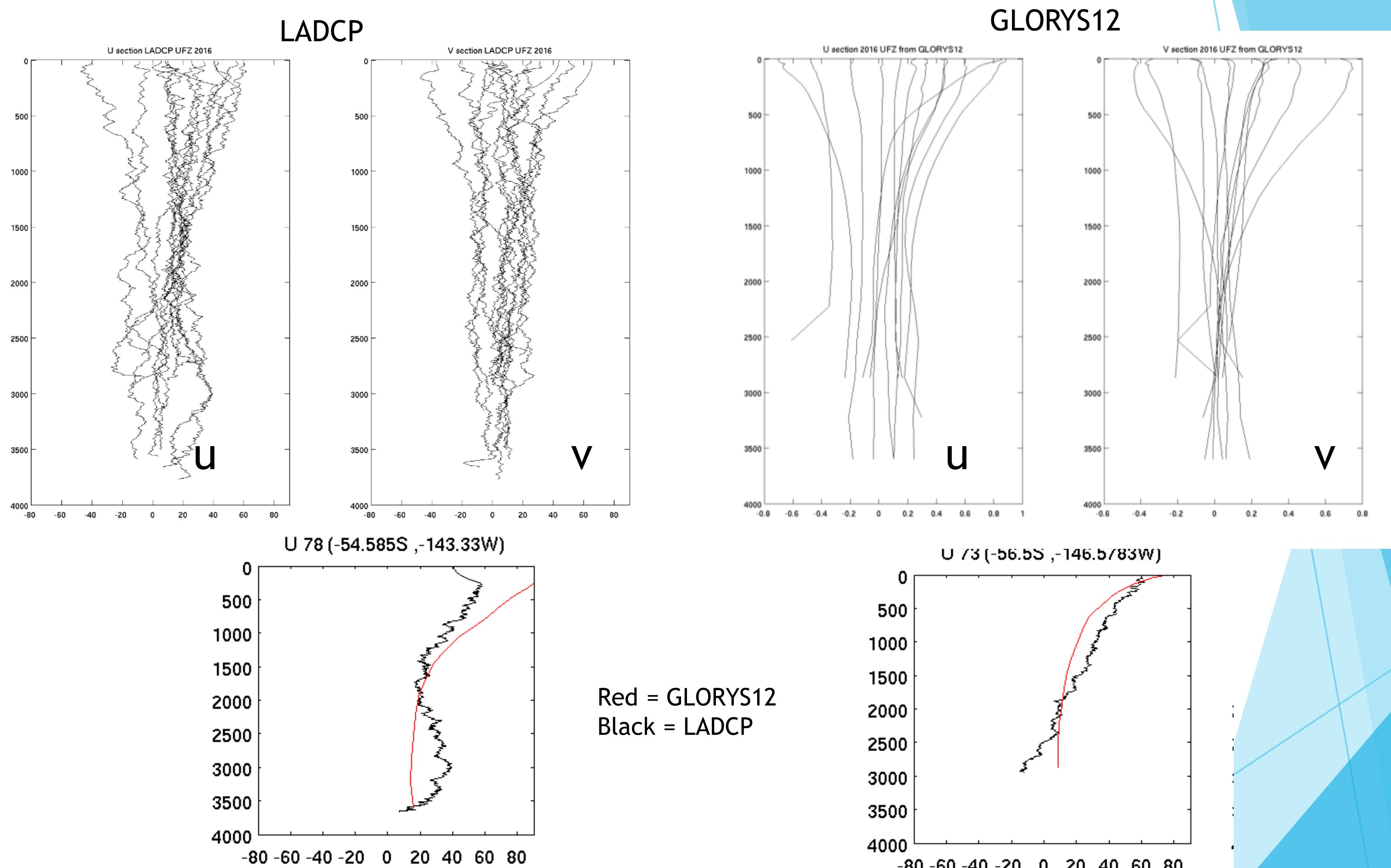
Altimetric Circulation, 14 Feb 2016



2016 Udintsev Cruise CTD Section across the ACC

Validation: GLORYS12 and Udintsev observations (2016)

- Unrealistic equivalent barotropic velocity structure with a monotonic exponentially-decaying profile, consequence of rough vertical resolution in near-bottom layer of the model?

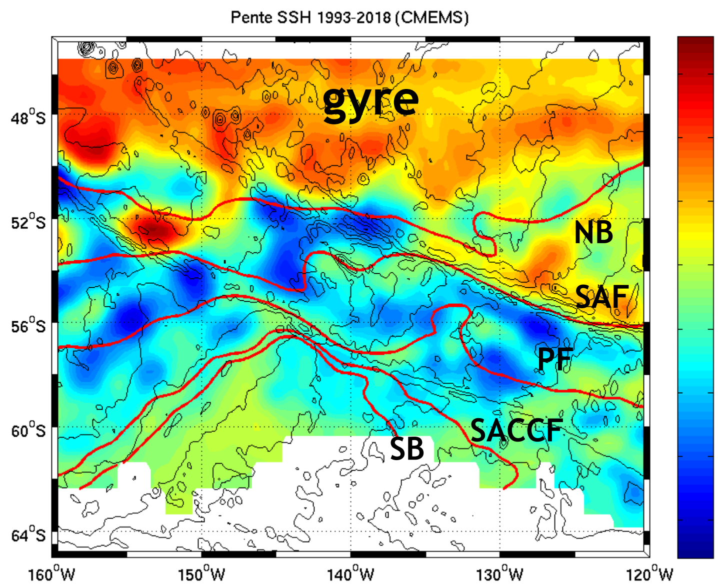


Unlike LADCP observations, the GLORYS12 vertical velocity structure tends to show an exponentially decaying structure, which is the manifestation of an Equivalent Barotropic (EB) tendency in model. Such an EB structure is far from reality for a rough topographic environment such as in the vicinity of the Udintsev Fracture Zone

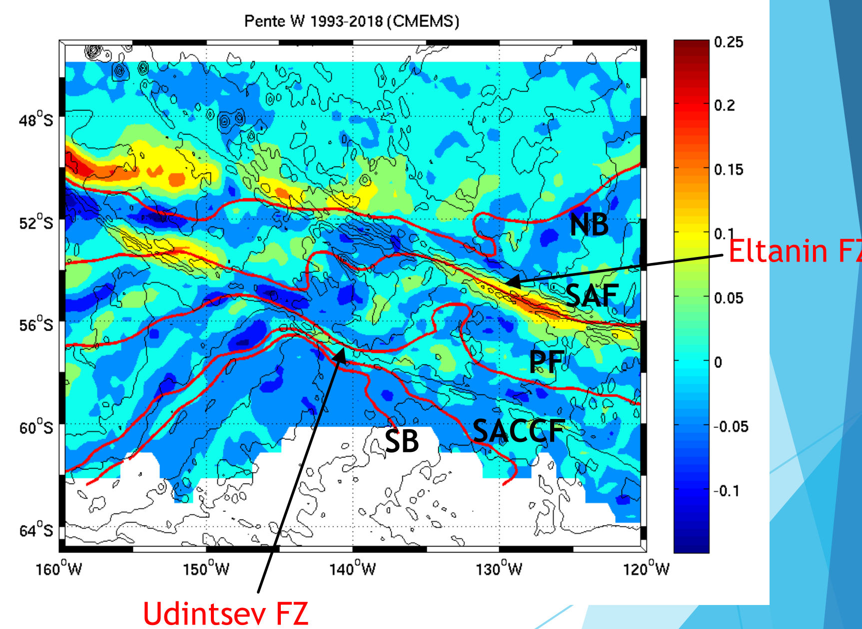
Intensification of the northern part of the ACC over 1993-2018 in South Pacific

- Strengthening of South Pacific subtropical gyre:
  (+SSH north of ACC, -SSH within ACC band)
- Positive velocity trend along the northern boundary of ACC
- Negative velocity trend south of the PF

SSH trend from altimetry



Surface velocity trend from altimetry



ACC fronts (red lines): SAF-N (northern boundary), SAF, PF, SACCF, SB (southern boundary)

- Total transport (U, V) per grid (dx, dy)

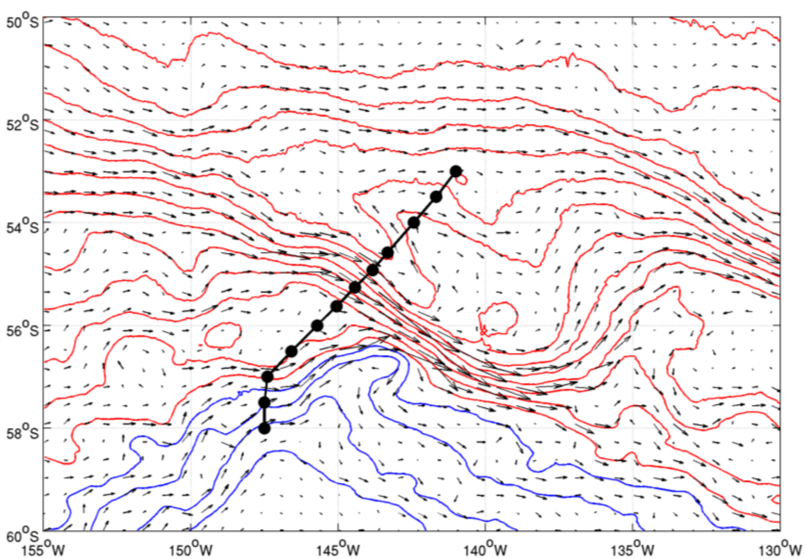
$$U = dy \int_{-h}^{0} u dz \, , V = dx \int_{-h}^{0} v dz$$

- **Transport stream function**

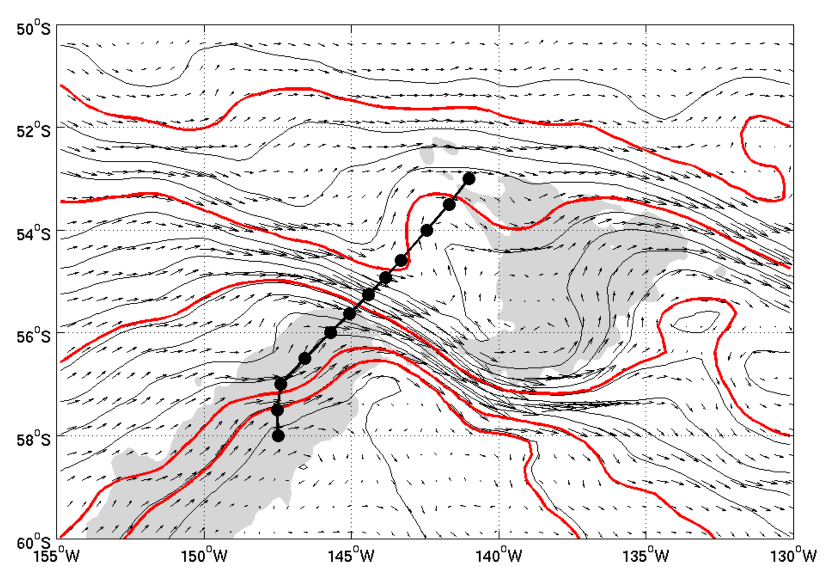
$\boldsymbol{\psi}$ is defined so as to satisfy *the nondivergence of total transport*: $\frac{\partial U}{\partial x} + \frac{\partial V}{\partial y} = 0$

$$U = \frac{\partial \psi}{\partial y} \, , V = -\frac{\partial \psi}{\partial x}$$

Mean ψ, U, V from GLORYS12 (1993-2018)



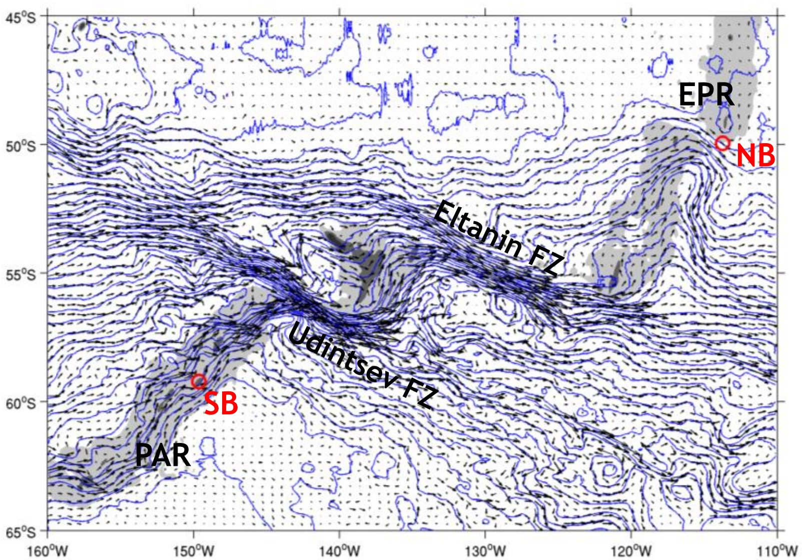
Mean Surface Circulation from Altimetry



Transport stream function (lines) from the model (left) and altimetric MDT (right) show a high degree of similarity, further supporting the EB tendency in model as well as the key role played by satellite altimetry in model assimilation

Mean and Low-Frequency Variability of ACC Transport

Transport stream function climatology (1993-2018)
(lines: stream function, vectors: grid transport)

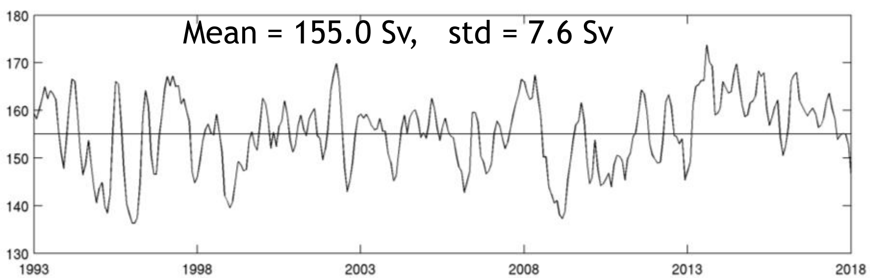


- ACC northern boundary (NB)
  within a deep passage across the EPR
  (49.9513°S, 149.6514°W: northern red circle)

- ACC southern boundary (SB)
  along the submit axis of the PAR
  (59.2084°S, 113°7447°W: southern red circle)

EPR = East Pacific Rise
PAR = Pacific-Antarctic Ridge

ACC transport time series

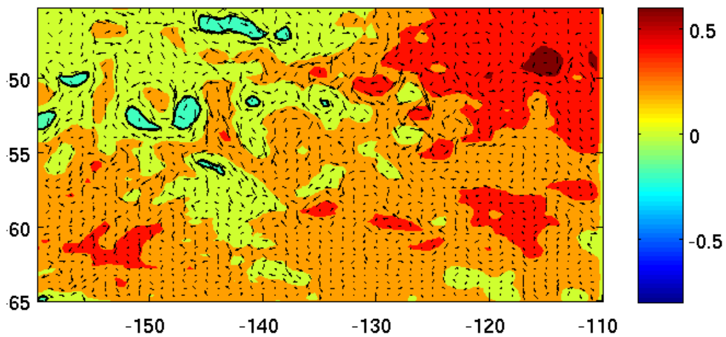


ACC transport through the region is nothing but the stream function difference between NB and SB

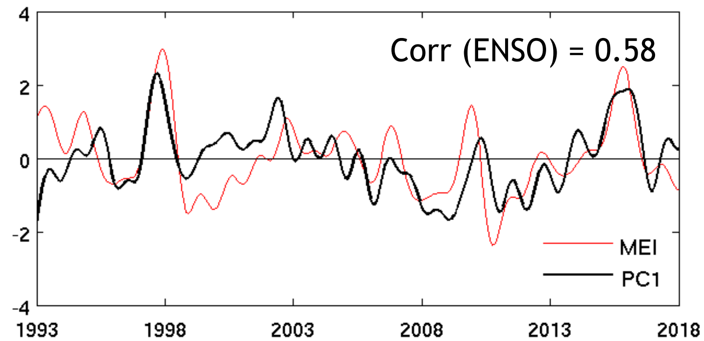
The mean (155 Sv) and std (7.6 Sv) of ACC transport of the region are near-perfect agreement with those estimated at Drake Passage by Artana et al (2019)

EOF Analysis of Transport Stream Function
central South Pacific (160°-110°W, 45°-65°S)

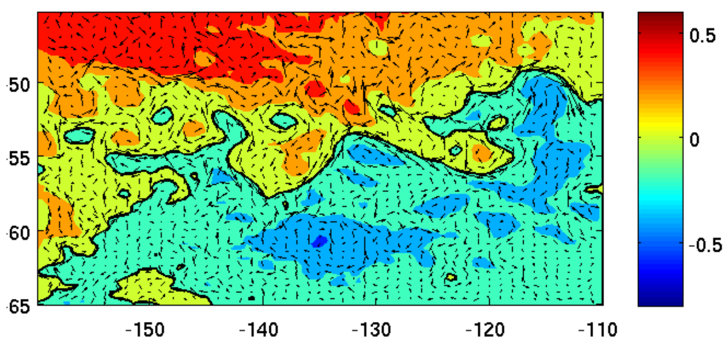
EOF1



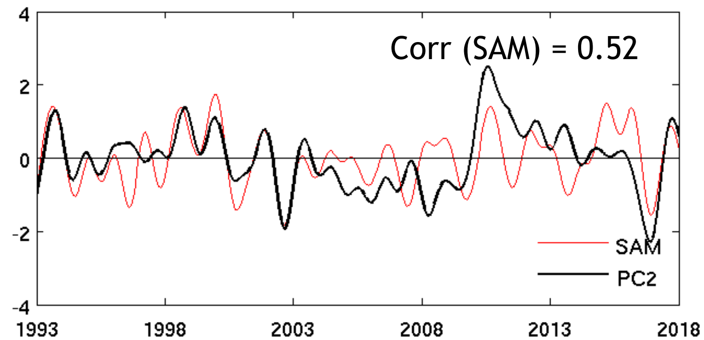
PC1



EOF2



PC2

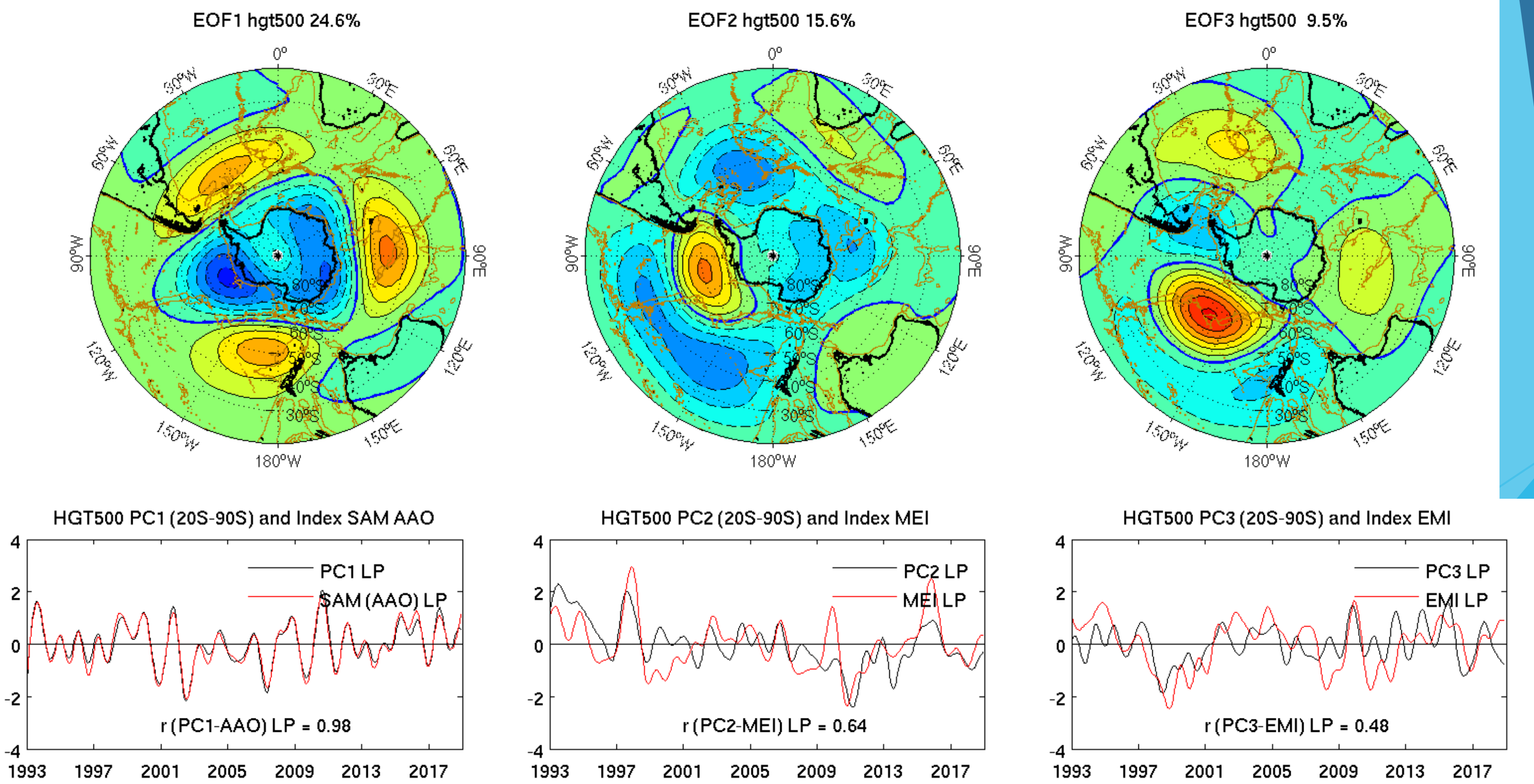


- EOF1 is significanly correlated with ENSO (r = 0.58), affecting the NB of ACC:
  + phase: weakening of the eastward flow along the NB
  - phase: strengthening of the eastward flow along the NB

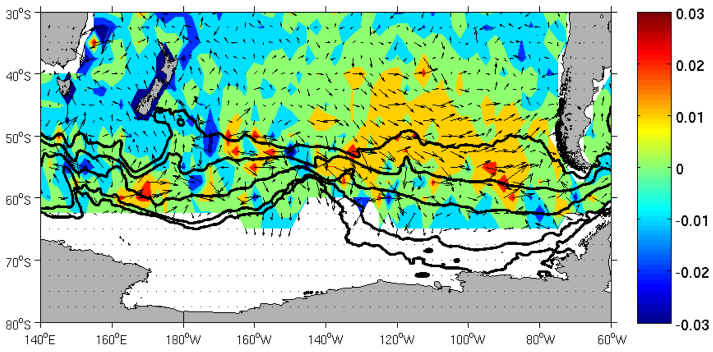
- EOF2 is significanly correlated with SAM (r = 0.52), affecting the central branches of ACC:
  + phase: strengthening of the eastward flow along the SAF/PF
  - phase: weakening of the eastward flow along the SAF/PF

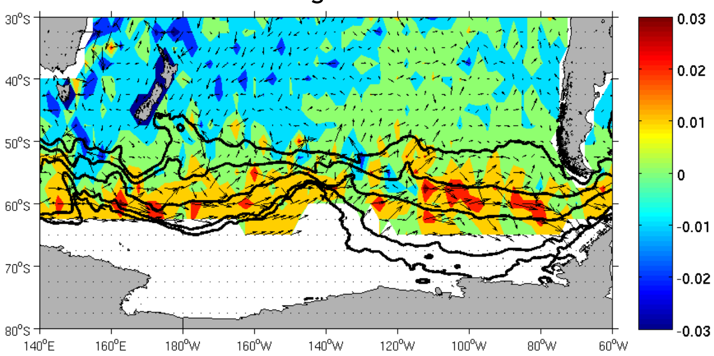
Principal EOF modes of upper troposphere circulation (GPH at 500 hPa)
for the Southern Hemisphere south of 20°S

EOF1 (SAM) vs AAO/NOAA: *r*=0.98
EOF2 (PSA1) vs MEI (canonical ENSO): *r*=0.64
EOF3 (PSA2) vs EMI (ENSO Modoki): *r*=0.48



Response of altimetric surface currents to climatic forcing





- Situated just upstream of Drake Passage, the SE Pacific basin east of 130°W appears as the critical area for controlling the ACC transport at Drake Passage

- Here, the eastward surface flow strengthens for both negative ENSO (or PSA1) and positive SAM phases, but each preferentially impacting different branches of ACC:

ENSO: strongest impact on **ACC northern branches**
SAM: strongest impact on **ACC central branches**

→ Combined –ENSO and+SAM phases thus tend to accelerate the ACC upstream of Drake Passage, and vice versa for the case of +ENSO and -SAM