VARIABILITY OF THE ACC TRANSPORT ACROSS THE KERGUELEN PLATEAU MONITORED FROM 20 YEARS OF ALTIMETER DATA

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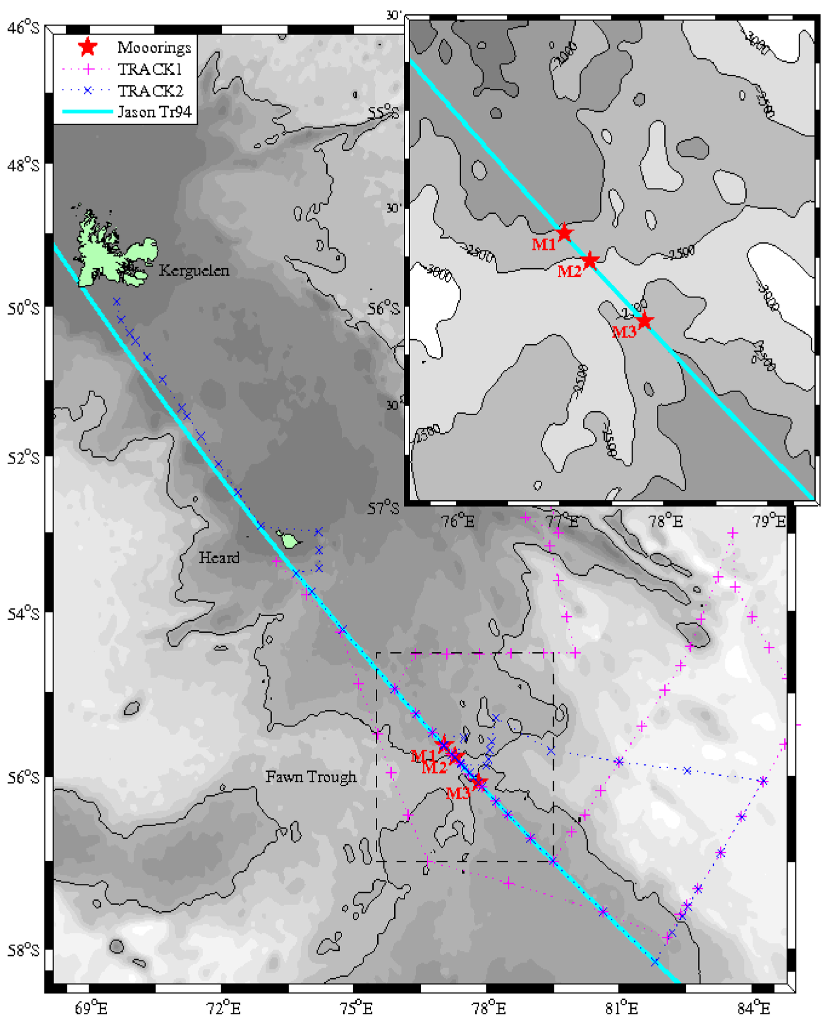
1-INTRODUCTION

The Kerguelen Plateau is a major topographic obstacle to the eastward flowing Antarctic Circumpolar Current (ACC).Whilst approximately two thirds of the ACC transport is diverted to the North, most of the remaining flow engulfs in the Fawn Trough, the only deep passage across the Plateau. As part of the TRACK (Transport Across the Kerguelen plateau) project, three mooring lines of current meters were deployed in the Fawn Trough between Feb 2009 and Jan 2010, underneath ground-track 94 of the Jason-2 satellite altimeter. Full depth CTD-LADCP casts carried out during the deployment cruise were previously analyzed to provide a comprehensive description of the regional circulation (Park et al., GRL, 2009), featuring in particular a transport of ~40 Sv across the Fawn Trough. Here we focus on the transport variability across the Fawn Trough determined from current meter data. We examine to what extent the transport can be directly monitored from along- track satellite altimeter data, and analyze the variability of the current from a now 20-year long archive. The relationship between transport fluctuations at interannual time scales and dominant climate modes of the Southern Ocean (ENSO and the Southern Annular Mode, SAM) is discussed.

2- DATA

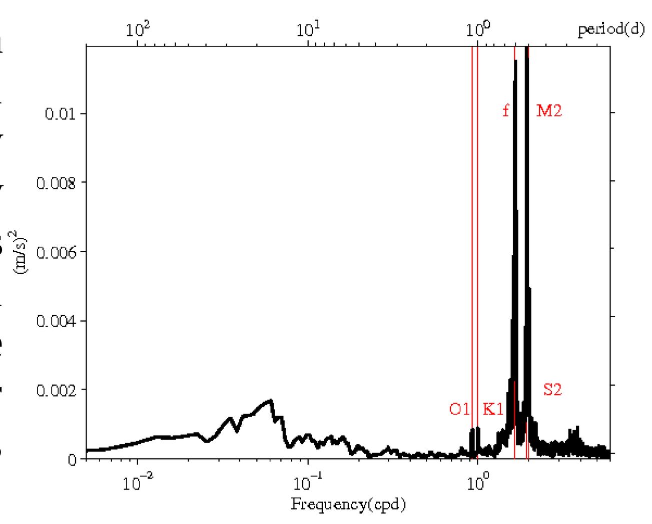


Our main dataset comes from the nearly one year worth of current meter observations from mooring M1, M2 and M3 underneath groundtrack 94 of the Jason 2 altimeter. Each mooring included an upward looking ADCP and 3 current meters underneath.

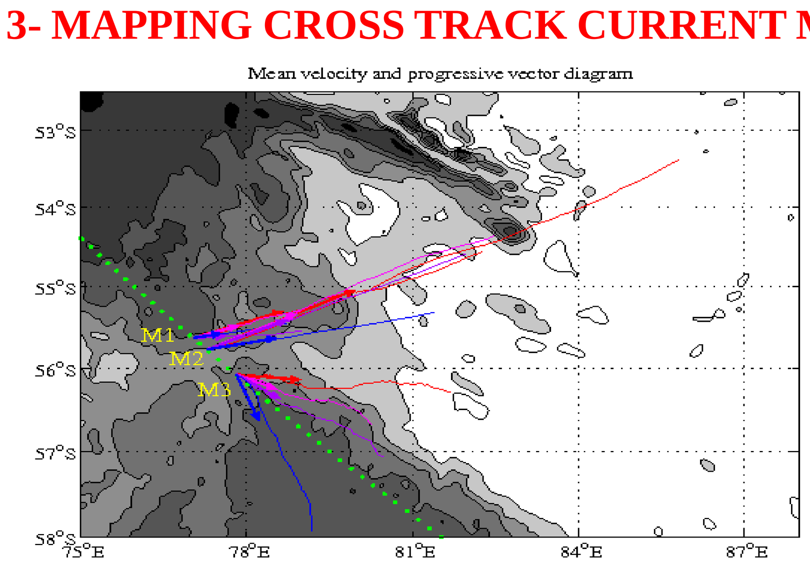
We also use CTD-LADCP sections performed across the Fawn Trough during the deployment (TRACK 1, Feb 2009) and recovery (TRACK2, Jan 2010) cruises.

Altimeter data are delayed time along-track products from AVISO. Finally, simulations from the 1/8° periantarctic configuration PERIANT8, based on the NEMO-LIM coupled sea ice model are also used to assess mapping procedures.

Current meter data included substantial high frequency variability, mostly M2 and S2 tides as well as inertial currents. These are filtered out hereinafter where daily averages are considered



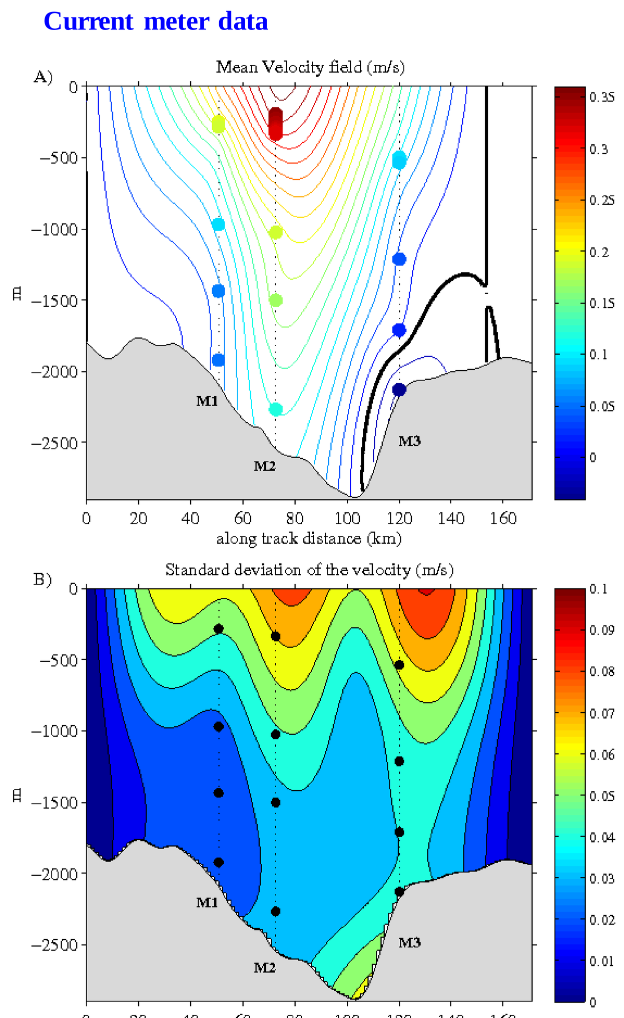
3- MAPPING CROSS TRACK CURRENT METER DATA TO COMPUTE TRANSPORTS

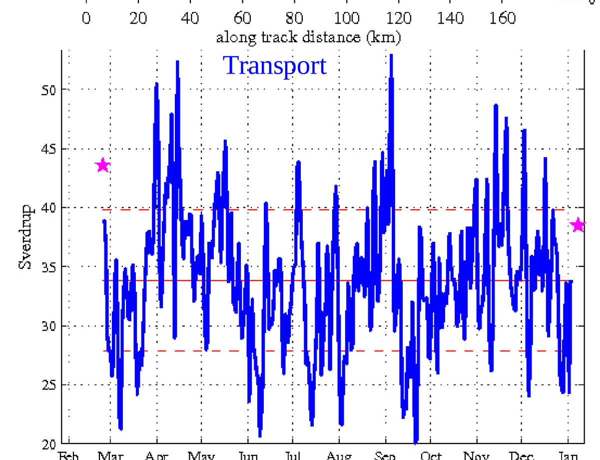


The progressive vector diagram displays a surface intensified flow at mooring M1 and M2, well aligned with the Fawn Trough axis. The vertical structure of the mean flow is clearly equivalent barotropic there.

The situation is different for mooring M3, with a clockwise veering of the current with depth : at depth, the flow does not contribute, on average, to the eastward transport across the section.

Current meter data





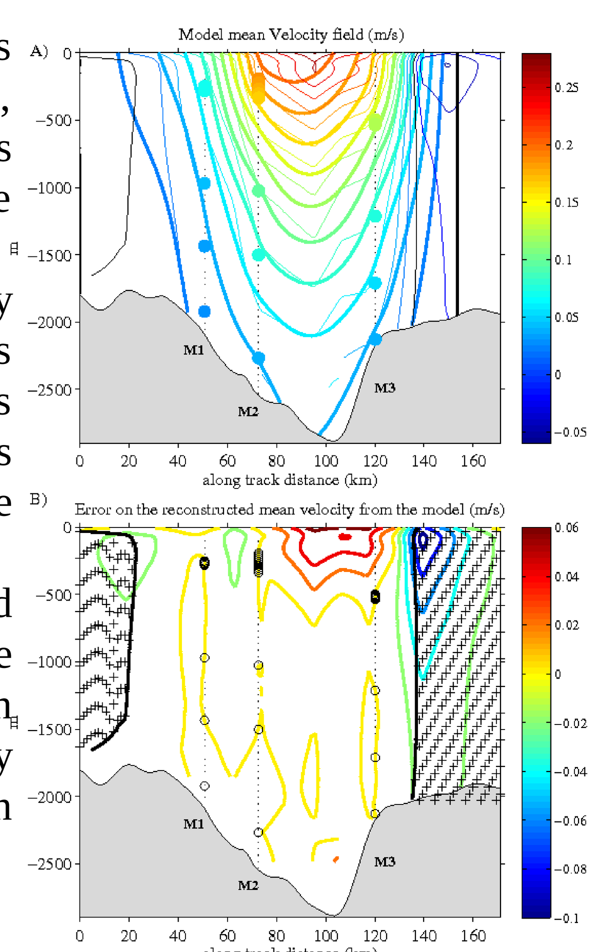
The mean cross track velocity is mapped using biharmonic splines, imposing a null velocity at the edges of the section. The mean flow in the core is 35 cm/s.

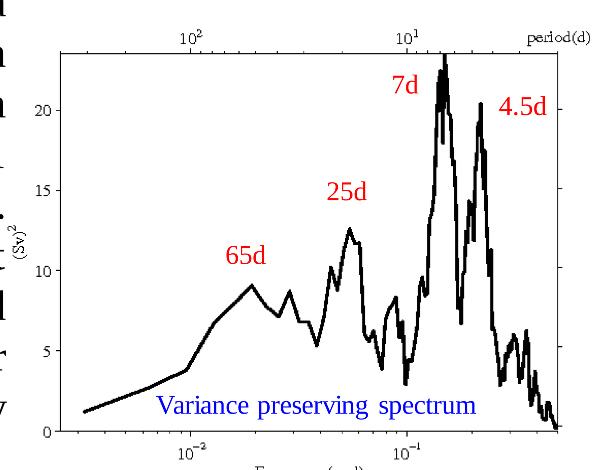
Daily maps of the residual velocity are computed from objective analysis using gaussian decorrelation scales estimated from observations (Lz=1800m, Lx=40km). The maximal variability is 8cm/s RMS.

Mapping procedures were assessed from synthetic data derived from the PERIANT8 simulation. Errors on reconstructed fields are reasonably small (eg 1.5cm/s RMS for the mean field).

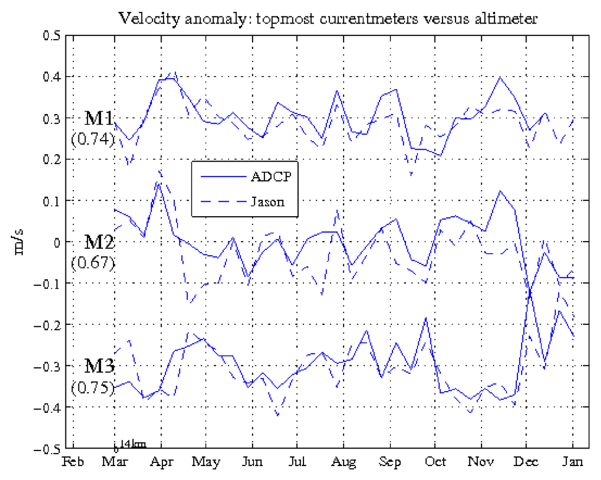
The eastward volume transport ranges between 20 and 53 Sv, with a mean of 34Sv. It is 5Sv smaller than the transport measured from LADCP sections during TRACK1 and TRACK2 (pink stars). Variability is 6Sv RMS, with salient frequencies at 4.5d and 7d (topographic modes?), and broader peaks at 20d and 65d, presumably excited by the winds.

Synthetic data from PERIANT8

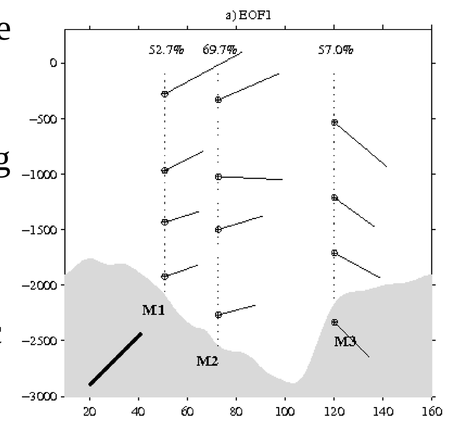




4- MONITORING THE CURRENT VARIABILITY FROM ALTIMETER DATA

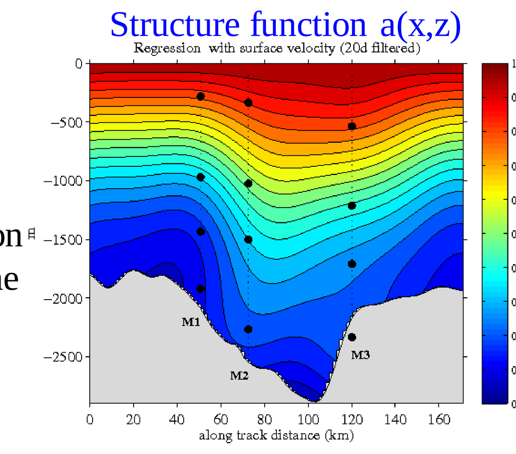


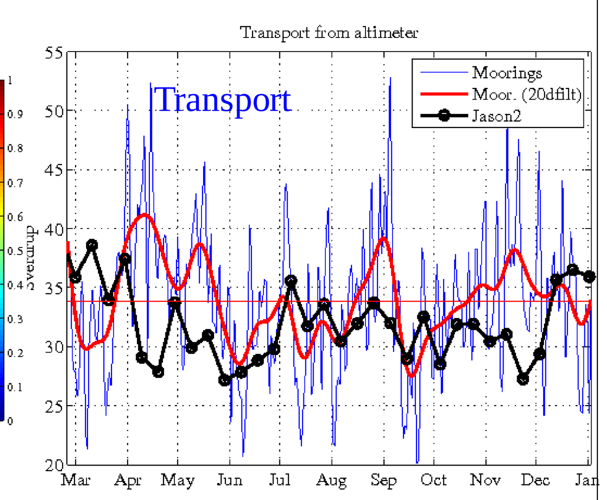
Expectations are good to monitor the flow from altimetry:
- Velocity measurements from topmost instruments at each mooring are significantly correlated with SGVA from altimetry (left)
- Leading EOFS show a predominantly equivalent barotropic structure for the variable part of the flow, even at M3 (right).

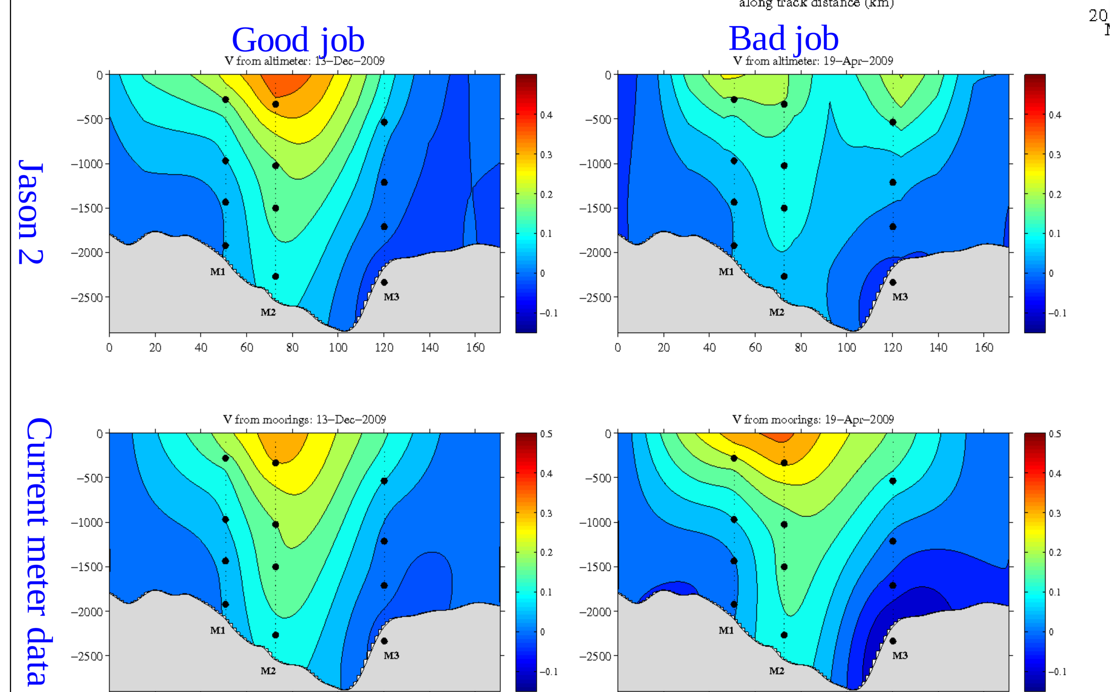


The velocity fied through the section at each satellite pass is estimated according to V(x,z,t) = a(x,z)*Vg'(x,0,t)+Vm(x,z), where a(x,z) is a vertical structure function determined from a regression of the surface currentmeter data onto the velocity measured at successive depths (Vivier and Provost, 1999)

Structure function a(x,z)

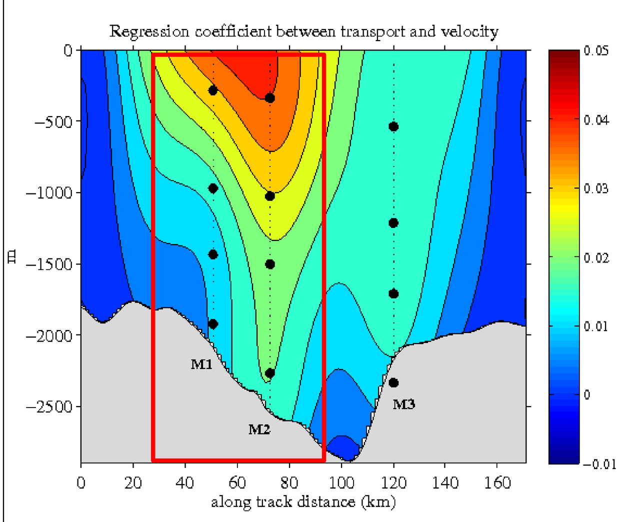






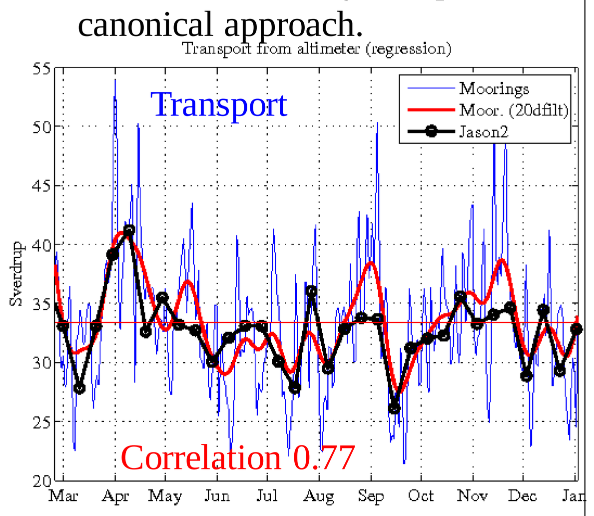
Results are unconvincing at sub-seasonal time scales: the volume transport from Jason is overall poorly correlated with in situ transport (above). A closer look at individual velocity fields at each satellite pass shows that the method performs unevenly, with accurate individual matches on the one hand, and poor matches on the other hand where the structure of the current does not seem well captured (left). The intermittent presence of a shallow winter water layer to the southern half of the domain may hamper this canonical approach.

An alternative 'ad hoc' approach

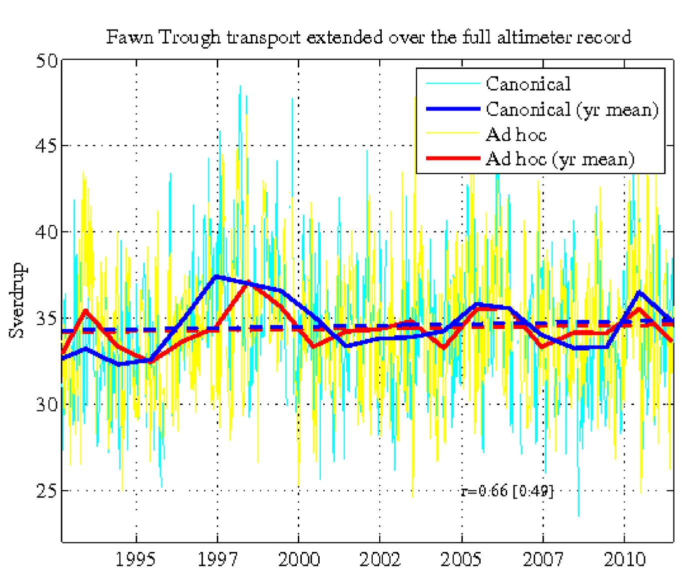


Most of the variance of the transport is contributed by M1 and M2. An option is to regress the surface geostrophic velocity from altimetry at this location with estimated transport.

With this ad hoc approach, the transport from altimetry is well correlated with observations (0.77).



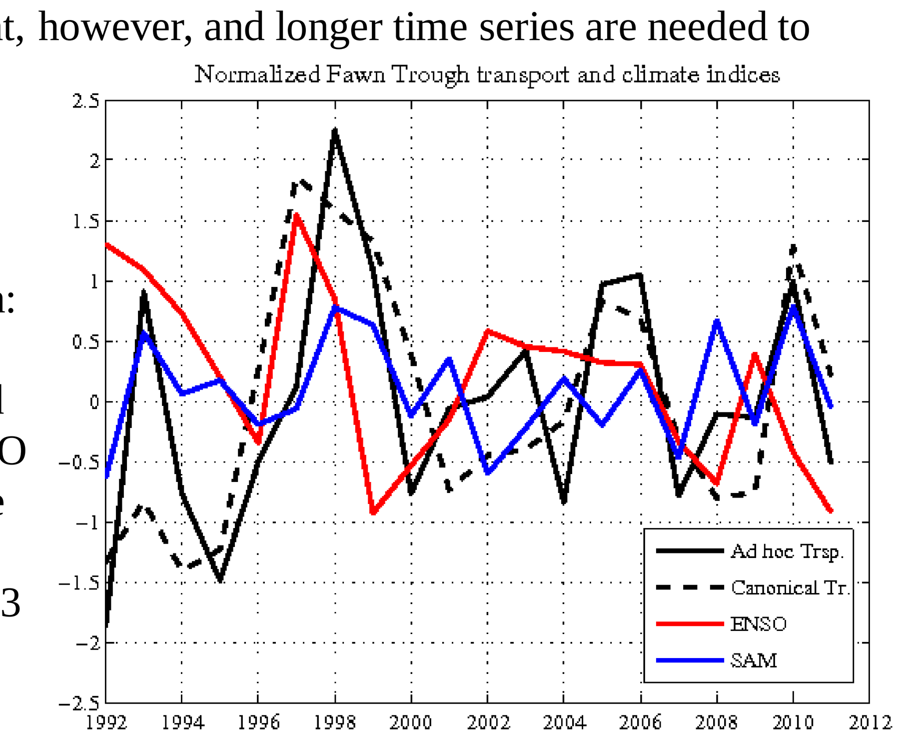
5- VARIABILITY OF THE FAWN TROUGH CURRENT FROM 20 YEARS OF ALTIMETRY



Each of the two methods above (canonical and ad-hoc) has its pros and cons, and it would be difficult to blindly rely on one or the other. Both have been used to extend Fawn Trough volume transport estimates over the full altimeter record (1992-2012). Most encouragingly, they feature consistent year-to-year variations (blue and red curves on the left plot): the correlation coefficient of the corresponding annually averaged series is 0.7 [0.5@95%], which we take as an indication of robustness of transport estimates at such time scales.

Both 20 years series exhibit a slightly positive trend of 0.25 Sv /decade (dashed lines). This small trend is not statistically significant, however, and longer time series are needed to assess its reality.

On the right figure, yearly averaged Fawn Trough current volume transport time series estimated from the two different methods (canonical approach: black dashed, and ad-hoc approach :black solid) have been normalized and superimposed on the multivariate ENSO index (red) and SAM index (blue). The outstanding 1997-98 ENSO coincides with the strongest positive anomaly (~3 Sv) in the Fawn Trough transport, possibly with a lag of one year.



Besides this event, there is no significant correlation of the transport with the ENSO index. The ad-hoc extended transport, on the contrary, displays a statistically significant correlation (0.6) with the SAM index at interannual time scales with lag zero.

6- CONCLUSIONS.

ACC transport through the Kerguelen Plateau (the so called Fawn Trough current) was determined from one year of current meter data from the TRACK program. The flow estimate is 34 +/- 6 Sv RMS, possibly biased low by 5 Sv, which makes it a major branch of the ACC in the Indian sector of the Southern Ocean. The equivalent barotropic vertical structure of current anomalies enables to attempt the monitoring the current from altimetry: application of the methods of Vivier and Provost (1999) shows unconvincing results at subseasonal scales, with overall poor correlation with in situ transport, despite good individual matches where the method proves accurate. An ad-hoc approach based on a regression on the 2 northernmost moorings, which contributes most of the transport variations was instead developed. It yields a correlation of 0.8 between in situ and altimeter derived transport. Encouragingly, transports extended to the full altimeter record (1992-2012) with both methods display consistent (significantly correlated) interannual variations . The apparent trend of 0.25Sv /decade is not statistically significant. Transport time series display a marked signature of outstanding 1997-98 ENSO, associated with a positive anomaly of 3Sv in the annually averaged transport, possibly with a one year lag. The 'ad-hoc' transport estimate features a statistically significant correlation with the SAM at interrannual time scales (contrary to subseasonal scales), suggesting that an intensification of the winds driven by a positive SAM contributes to increase the flow through the Fawn Trough. The dynamical response of the Faw Trough transport at different time scales to the wind forcing is the subject of ongoing works.

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