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Discussions

Interactive comment on "A stable Faroe Bank Channel overflow 1995–2015" *by* Bogi Hansen et al.

Anonymous Referee #3

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A stable Faroe Bank Channel overflow 1995-2015 by Bogi Hansen, Karin Margretha Husgard Larsen, Hjalmar Hatun, Svein Osterhus

— Summary —

This paper documents the long-term timeseries measurements of the FBC overflow using bottom-mounted ADCP moorings at the sill in conjunction with regular hydrographic sections around the Faroe Islands. Although the moorings do not measure stratification within the water column, the combination of the velocity-determined transport timeseries with the spatial CTD surveys allows the identification of watermass changes and the identification of various possible pathways and processes in this long-term climate record.

The principal conclusion from this analysis is that while no significant change in over-

flow transport or density has been seen over the 15 years of continuous monitoring, overflow temperature and salinity have both increased, likely due to 5-10 year earlier changes in the Atlantic Water inflow to the Nordic Seas.

— General Comments —

Because of recent observations by the RAPID array of weakening in the Atlantic Meridional Overturning Circulation (AMOC), this is a good time to revisit the long-term FBC record for evidence of similar changes. The paper does a nice job summarizing the FBC monitoring efforts and combining the moored measurements with the hydrographic surveys.

In general, the paper is well thought out and well constructed, with high-quality and adequately described figures (including those in both the primary document and in the supplement–which are really essential for the understanding of the manuscript). In addition, there is a well-written discussion section reviewing recent literature and the current state of knowledge of the role of the FBC in the AMOC. This section considers various possible connections between the FBC overflow and the southward and northward branches of the overturning and is a valuable contribution to the scientific debate.

A few points (including the discussions of mixing and the brief presentation of new cruise results in Fig.9) are somewhat tangential to the main thrust of the paper, but all of these are interesting and relate in some way to the scientific discussion.

My principal criticisms as a scientific reviewer center on the need for additional analysis of the "kinetic overflow" approach (described in HO2007) to better define random and bias errors, as well as the sensitivity to particular parameter choices. With this manuscript's renewed focus on long-term changes (and a longer companion hydrographic dataset) there is an opportunity to develop increased confidence in the data quality and interpretation.

1) HO2007 developed the "kinematic overflow" (KO) approach required by the lack of simultaneous velocity and CTD measurements and established that (a) the velocity-defined interface does co-vary with a temperature-defined interface (isotherm height), although the relationship is not extremely tight, and (b) velocity at adjacent mooring locations is highly correlated, so that a single mooring could be used to represent the flow through the entire channel. However, both of these relationships introduce some error into the final transport (with an unknown level of reduction due to averaging when computing standard errors).

When investigating long-term trends, the KO calculation is most vulnerable to trends in these possible bias errors, so it is important to construct timeseries of (a) the difference between the annually-averaged velocity interface and a particular isotherm height (e.g., 7 degrees), and (b) cross-stream gradients in hydrographic temperature, density, or isotherm slope.

2) The principal temperature timeseries presented is from the near-bottom measurement at the ADCP location, but more relevant for the AMOC would be the average properties (T, S, and density) of the overflow layer. Apparently no attempt has been made to compute these (using, for example, annual averages from the hydrographic sections), although the relationship between bottom temperature and interface height has been presented in HO2007. From the T-S changes presented in Fig.7, it is clear that the overflow layer has undergone changes, but how do these impact the layer average (using interface definitions based on density, temperature, depth, or average velocity profile)?

3) One particular hole in the KO analysis is the missing transport above the selected interface (the height where the velocity drops to 50% of the maximum). HO2007 pointed out that outflowing water above this level could include contributions from both dense overflow and entrained Atlantic Water from above, claiming that the overflow water in the layer is likely compensated by Atlantic Water below the interface. For volume budgets, all outflowing fluid needs to be included, while from the watermass perspective,

a density-anomaly-weighted transport might be more appropriate. Differences among these choices could have a large impact on the detection of small trends in temporal variability in the presence of a large annual cycle and monthly wind-forced variability. Therefore, it is important to investigate the long-term trends in all of these neglected components.

4) One issue that has not been mentioned in any of the papers or tech reports by the Torshavn/Bergen group is an intermittent contamination and low-velocity bias in 75KHz ADCP data, apparently caused by side-lobe bottom reflections, that has recently been discovered by the Hamburg group maintaining the Denmark Strait transport moorings. See the Quadfasel, Jochumsen, et al, presentation at the Feb 2015 NACLIM meeting linked here: http://naclim.zmaw.de/fileadmin/user_upload/naclim/Archive/Meetings/Annual_meeting_2015/PPT/S1.2-1_Detlef_Q_Overview.pdf

Although the issue seems to be most pressing in the Denmark Strait locations, there is a suggestions that the same issue could at least occasionally influence the FBC moorings. Has any attempt been made to quantify and/or eliminate this? The DS issues seem to vary with instrument version (especially internal processing algorithms), mounting hardware configuration, and local bottom properties. The possibility is important enough that should be addressed (if not in this publication, then another upcoming one) even if the FBC dataset does not require the kind of major corrections applied to the DSO measurements.

— Specific Comment —

p.5,l.6. What is meant by the statement that a barotropic current could introduce a bias in the transport? The moored ADCP measures absolute velocity and is not vulnerable to a level-of-no-motion assumption. Is this referring to the fact that the interface (arbitrarily defined as the level at which the current speed is 50% of the max) will be shifted by a barotropic current? (It will, but so will the true transport.) Or is it related to the possibility of barotropic recirculation making the mooring location less representative of the average transport through the channel. This is indeed a possibility, but can't be diagnosed from measurements at the mooring alone.

— Conclusion —

Since the approach presented here is clearly documented and has been explored from a number of angles, I don't feel that a large amount of revision should be required for publication of the current work. However, the lack of sensitivity analysis on the KO formula and the remaining un-pursued lines of investigation into possible KO biases described above (including water above the velocity-defined interface, velocity-temperature interface differences, and cross-stream gradients) make this unique long-term dataset weaker than it could otherwise be. I'd encourage the authors to follow up these issues.

For example, my calculation "by eye" from Fig.8 of HO2007 suggests that the missing transport above the interface could be 10-15% of the total, and this layer could easily have long-term variability distinct from the lower layer. Certainly, a better estimate than mine can be made from the data.

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