Data quality, artificial 4-cycles

The variational method fits the trajectory best during the middle section of the assimilation period. Due to the separation of the run into 5 year long windows with one year overlap, adjustments show some dependence on the time within each window. Typically the adjustments are strongest in the middle of the window. The dependency is noticeable in regions of stronger adjustments, particularly at the latitudes of the strong western boundary currents. Despite the initial iterations that cover the whole period, a four year periodicity of the corrections results from this dependence of the adjustment that affects interannual variability.

As an example, the Atlantic meridional overturning circulation (AMOC) at 35.5ºN in 1000m depth is shown in Fig.1 for GECCO2 and its corresponding control run. At this latitude, the impact of the 4year periodicity of the adjustments is particularly strong and a regular 4 year cycle is evident. To quantify this regular variability, a 4-year climatology is also shown. While the control run shows hardly any regular variability on this period, the STD of the GECCO2 climatology exceeds 3 Sv.

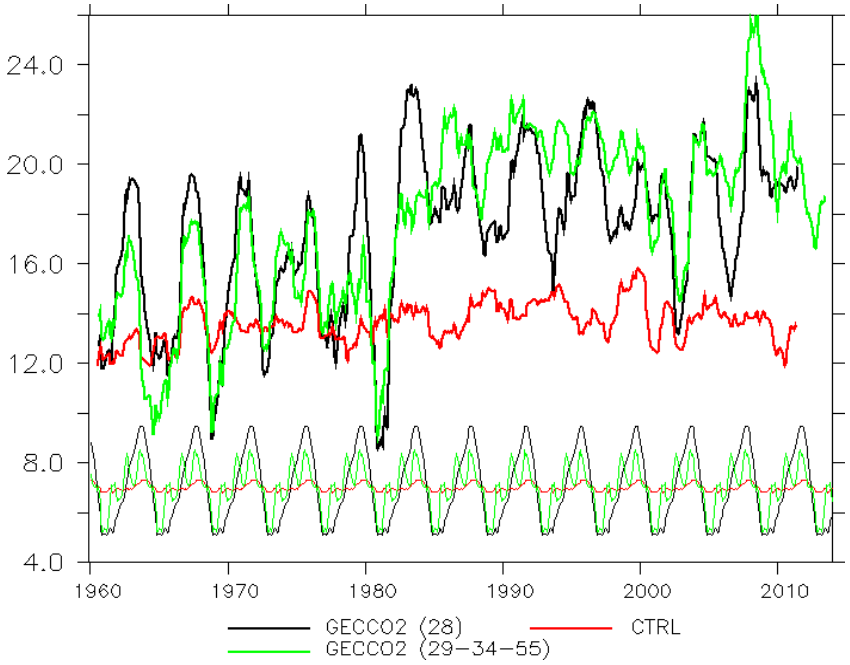

Figure 1 Time series of the 12-months filtered AMOC at 35.5ºN/1000m (bold curves) from GECCO2 (iteration 28), its corresponding control run (CTRL) and an extension of GECCO2 with shifted windows in Sv. The thin curves of regular variability shown centered at 7Sv displays the corresponding 4-year climatologies filtered with a 12-months running mean.

The latitudinal dependence of the AMOC STD is shown in Fig. 2 for the monthly data and after filtering with a 12-month window. The figure also shows the STD the 4-climatologies account for. While the variability is larger for GECCO2 than for the CTRL everywhere in the

Atlantic, the fraction explained by the climatology suggests that only north of 20N the impact of the artificial variability related to the limited window size is relevant. A focus of the artificial variability in the region of the Gulf Stream around 35N is particularly evident for annual means (right panel).

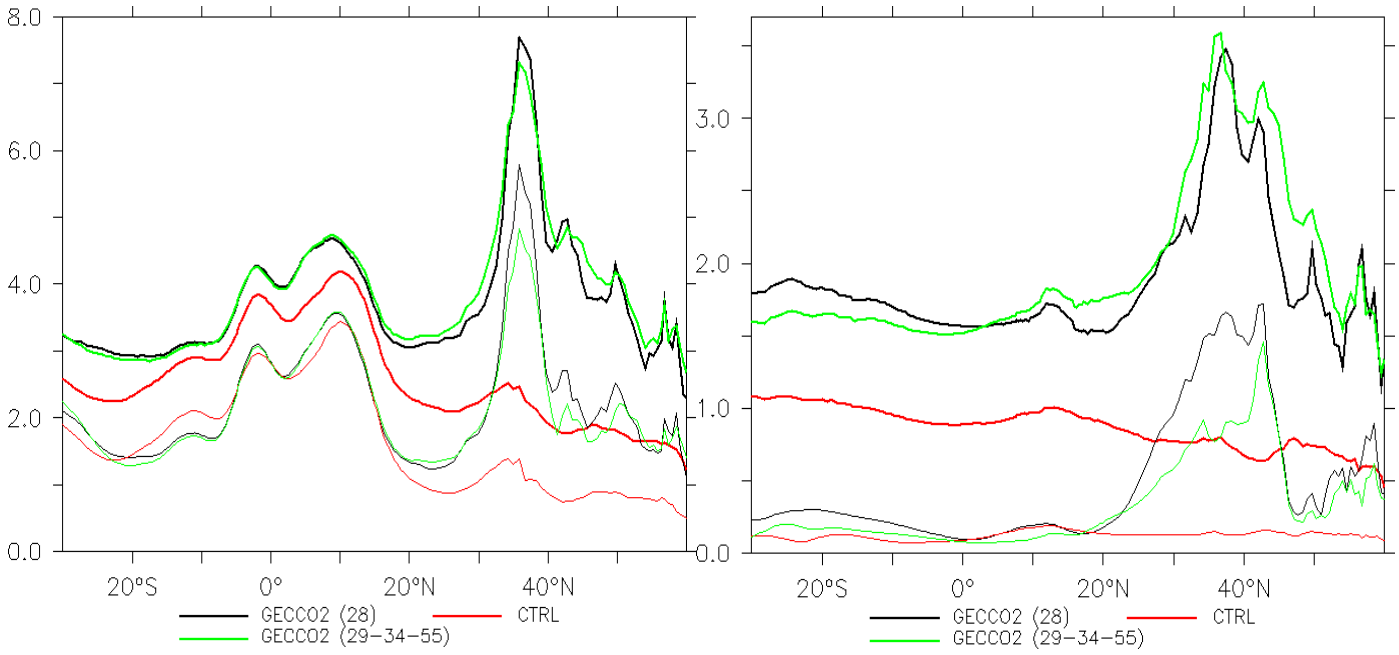

Figure 2 (left) Standard deviation of the monthly mean AMOC from GECCO2 (iteration 28), its corresponding control run (CTRL) and an extension of GECCO2 with shifted windows in Sv (bold curves). The thin lines show the STD of corresponding 4-year climatologies. The right panel shows the same as the left panel after filtering with a 12-months window.

GECCO2, iteration 29-34-55

To overcome the dependence of the size of the adjustments on the time in the window, the windows were shifted by two and after additional iterations by one further year. Ideally, the iterations after the two year shift would turn the 4-year cycles into 2 year cycles and halve the amplitude. The further iterations after a shift of one year would then halve the amplitude once more and leave only seasonal variability. The results after a total of 6 (3+3) additional iterations are included in Figure 1 and 2. Although the amplitude of the regular 4-year cycle is clearly reduced to almost half (left panel of Fig. 2), a substantial fraction of the artificial variability still remains. Nevertheless, in addition to the reduction of the artificial signal the costfunctions are further reduced by 10-15%, which would not have been possible without the shifting.

Iteration 29-34-55 picks up from iteration 23 for the period 1948-1991, from iteration 28 for the period 1992-2008, and from iteration 45 for the period 2009-2014. The windows wer iterated additionally 3 times after each shift. Only the last window, which is the window 2011-2014, was iterated 7 instead of 3 times after the second shift by one year.