Multi-decadal Variability of AMOC in the Community Climate System Model 3 : Depth vs. Density spaces

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Summary

700-yr present-day control integration of the NCAR Community Climate System Model 3 with T85 atmospheric resolution (CCSM3) exhibits two distinct regimes of multi-decadal AMOC variability, i.e. a strong oscillatory regime with ~20 yr periodicity (Danabasoglu 2008) and a weak red-noise-like regime (Kwon and Frankignoul 2012). In this presentation, we emphasize the different representations of the AMOC multi-decadal variability in depth and density spaces with the focus on the strong oscillatory regime. In depth spaces, maximum AMOC amplitude is found near 35°N where the northward Gulf Stream crosses over the deep southward return flow. On the other hand, the AMOC in density space exhibits its maximum around 55°N, which reflects the water mass transformation and deep water formation in the subpolar gyre. Furthermore, the AMOC in the density space reveals distinct contributions from the shallow gyre circulation and deep return flow, unlike in the depth space.

I. Climatological Mean (model years: 150-699)

Fig.1: Mean AMOC. Depth space: maximum near 35°N where the Gulf Stream crosses over the deep southward return flow (Fig. 2a).

Density space: maximum near 55°N emphasizes the water mass transformation and deep water formation in the subpolar gyre (Fig. 2b). Also note the secondary maximum at ~35°N. (Vertical axis is stretched proportional to the mean volume of each density layer in the Atlantic.)

Depth Space **Density Space**

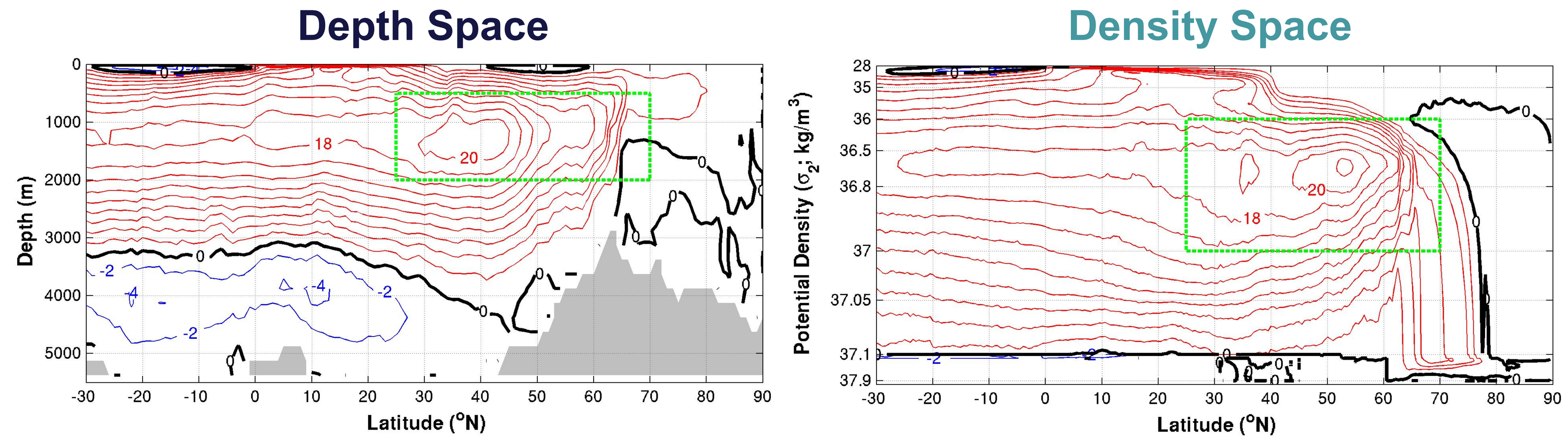
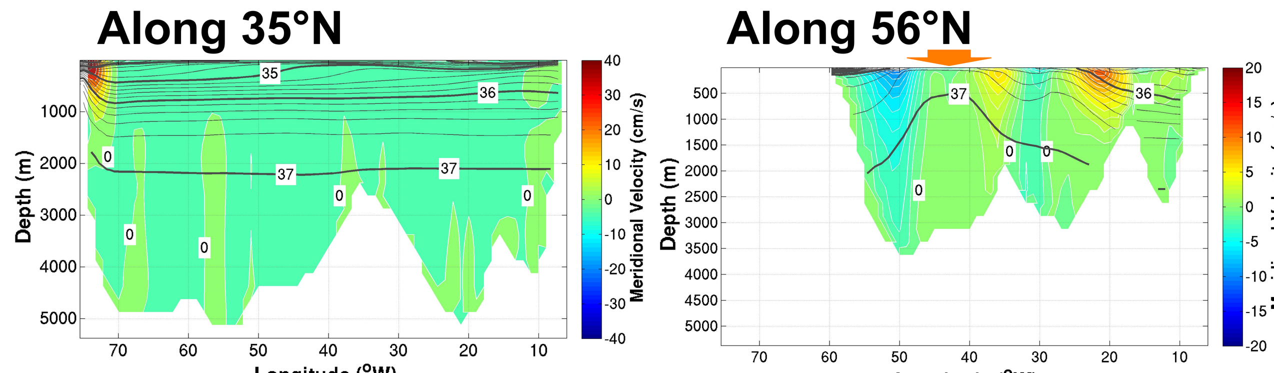


Fig.2: Mean zonal sections for the meridional velocity (color) and σ_2 (contour).

Along 35°N **Along 56°N**

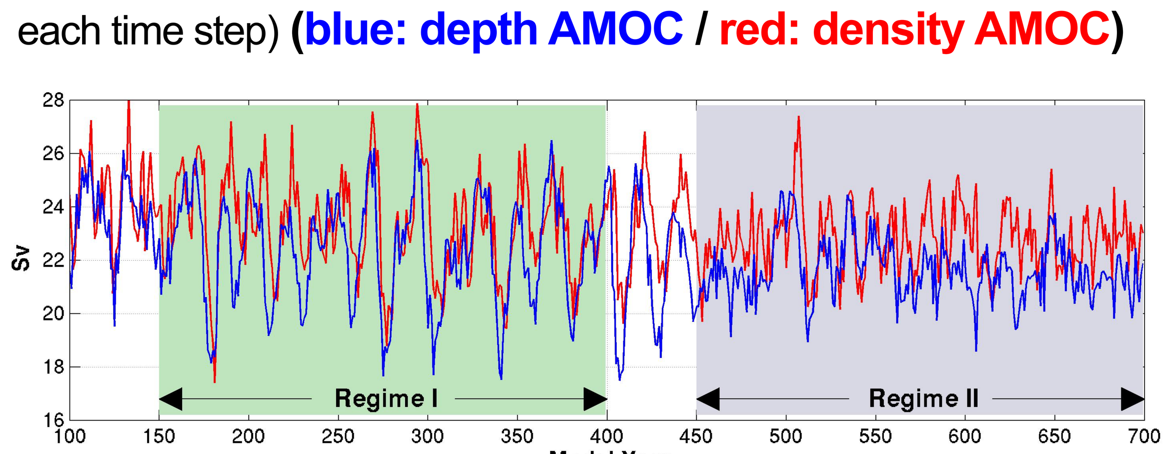


35°N: Shallow Gulf Stream vs. deep return flow concentrated near the western boundary. Also isopycnals are mostly flat. So the zonal average along depth ≈ that along isopycnal.

56°N: Surface intensified North Atlantic Current in the east vs. relatively more barotropic return flow near the western boundary. Doming of isopycnals centered around the main convection site (orange arrow) makes the zonal averages along depth and isopycnal distinct.

II. Maximum AMOC time series

Fig.3: Maximum AMOC (within the green boxes in Fig.1 at each time step) **(blue: depth AMOC / red: density AMOC)**



Regime I: Strong ~20yr oscillation (Danabasoglu 2008).

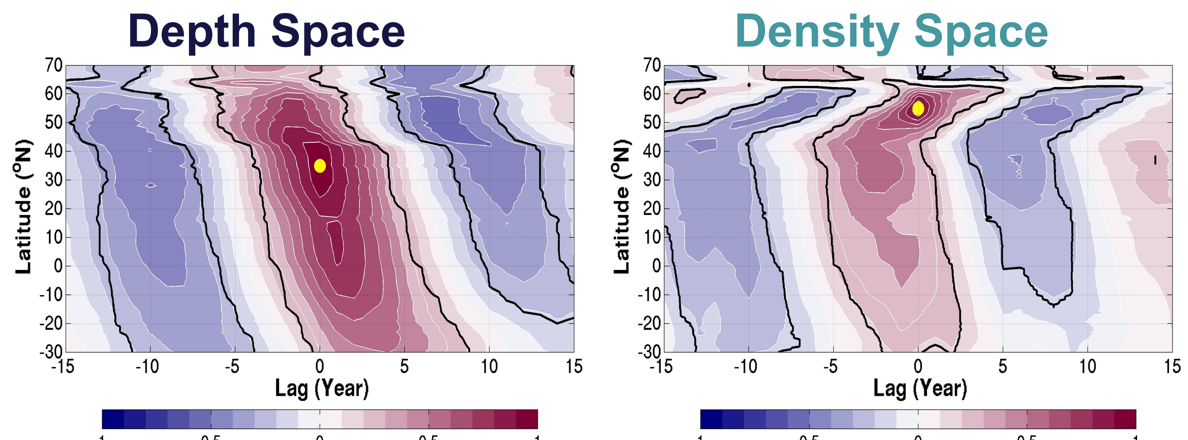
Regime II: Red-noise-like (Kwon and Frankignoul 2012).

Maximum AMOC in depth space leads that in density space by ~2 yrs. (*Why? See the sections III-V.*) The correlation between the two is much stronger in the regime I, the oscillatory regime (***: focus of the rest of this poster***).

Fig.4: Meridional Connectivity in the regime I

Lag-correlations between the maximum AMOC at one reference latitude (yellow dots) and all the other latitudes. Black contours indicate significance at the 5% level.

Depth Space **Density Space**



Depth space: southward propagation (similar to Zhang 2010).

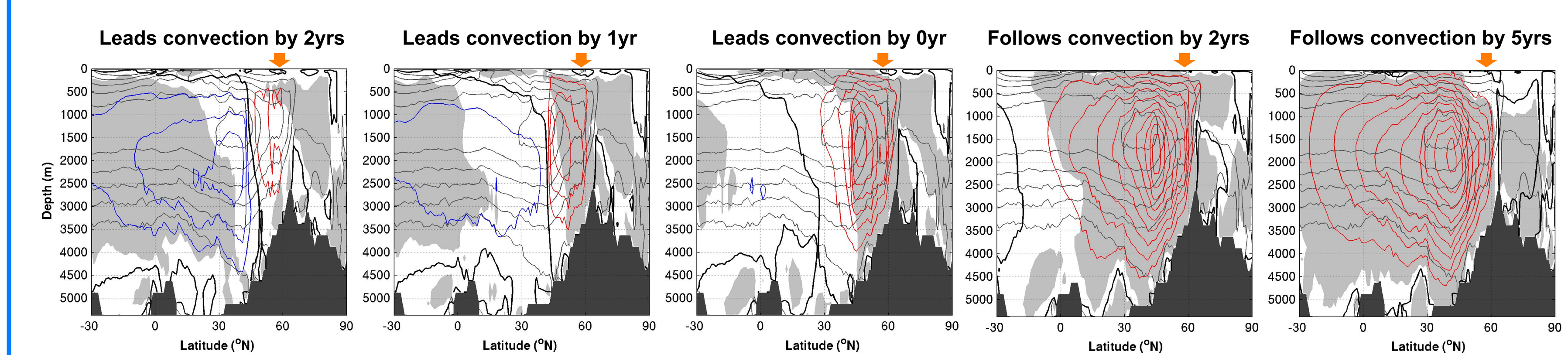
Density space: northward north of 42°N, because of distinct contributions from the shallow northward and deep southward branches. (See sections IV-V.)

III. Evolution of the AMOC in depth space

Fig.5 Lag-regression of the AMOC in depth space on the convection index in the regime I.

Convection index: upper 500 m density averaged in the main convection site (54-57°N, 38-48°W; green boxes in the Fig. 8-9).

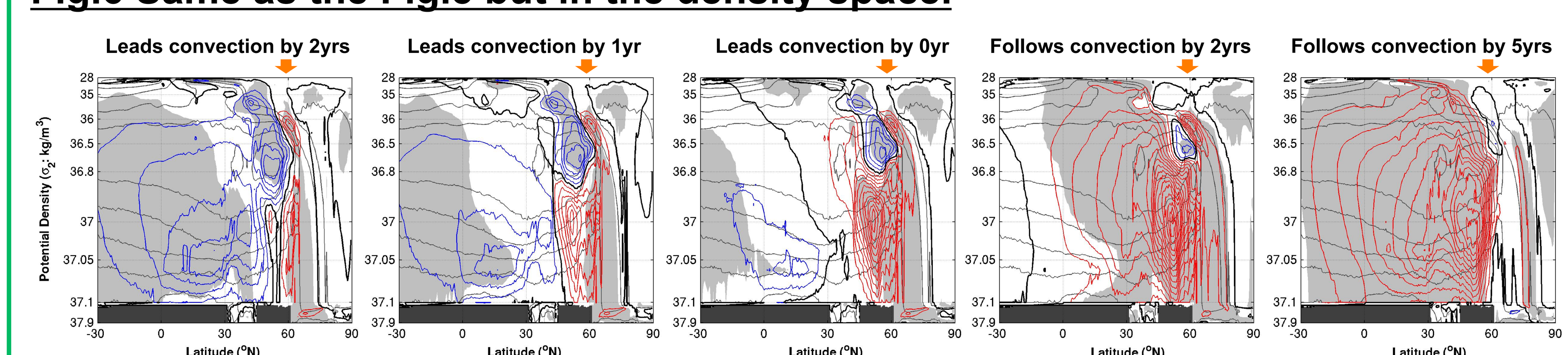
Positive (negative) regressions are plotted in red (blue) contours. Shading indicates significance at the 5 % level. Mean AMOC is also plotted with thin gray contours. The contour intervals are 0.2 and 4 Sv for the regression and mean, respectively. Note that the latitude of convection site is indicated by the orange arrows.



Positive anomaly of AMOC starts near the latitude of convection site and expands southward, which is consistent with the lag-correlation in Fig.4.

IV. Evolution of AMOC in density space

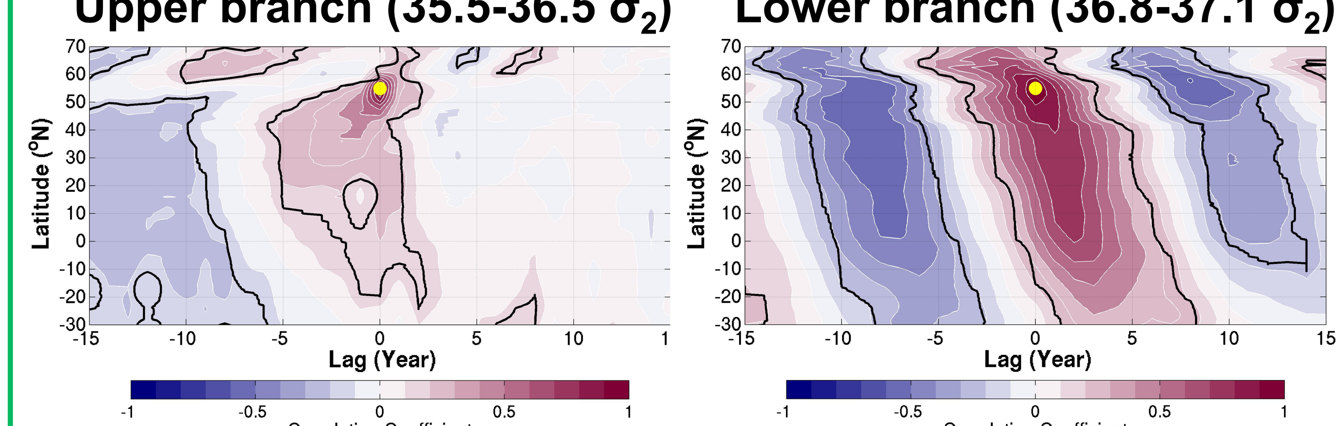
Fig.6 Same as the Fig.5 but in the density space.



Positive anomaly of AMOC starts near the sinking branch as in the depth space, but the AMOC in density surface clearly shows that the southward propagation first occurs in the denser lower branch and eventually expands above to the lighter upper branch.

Fig.7 Same as the Fig.4 in density space but for the upper and lower branches, separately.

Upper branch (35.5-36.5 σ_2) **Lower branch (36.8-37.1 σ_2)**



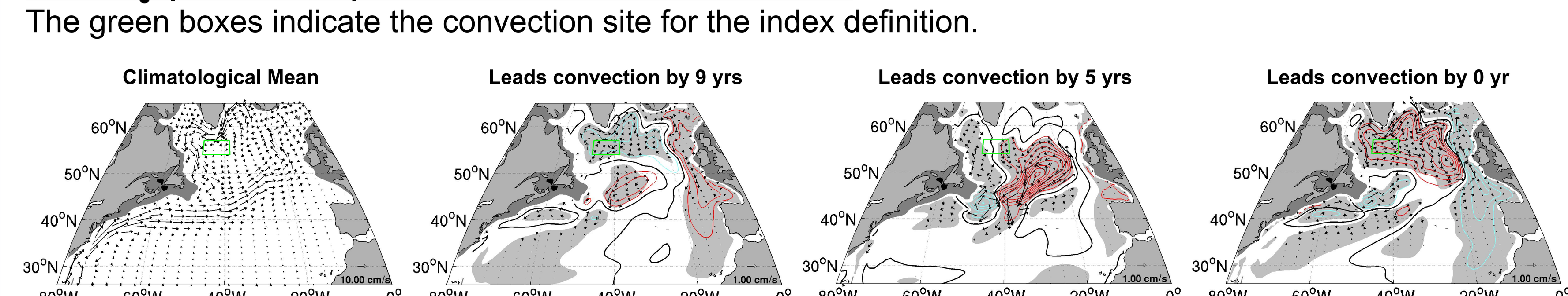
Upper: northward propagation due to the subpolar gyre circulation (Fig.8).

Lower: southward wave propagation/advection along the western boundary (Fig.9).

V. Horizontal view

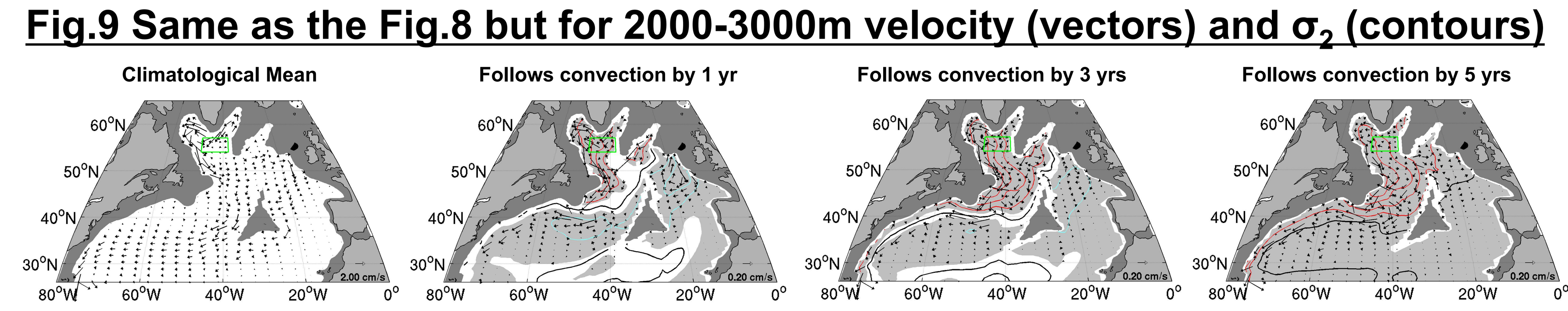
Fig.8 Climatological mean and lag-regressions of upper 500m velocity (vectors) and σ_θ (contours) on the convection index.

The green boxes indicate the convection site for the index definition.



Southward shift of the North Atlantic Current near 35°W generates denser and cyclonic anomalies (: lag=9yr). These anomalies grow and propagate along the subpolar gyre and fill the most of the subpolar gyre to enhance the convection.

Fig.9 Same as the Fig.8 but for 2000-3000m velocity (vectors) and σ_2 (contours)



Mean velocity exhibits the interior pathway of the southward return flow. The dense anomalies following the deep convection first appear near the convection site and propagate southward along the western boundary. The anomalous southward flow develops with the density anomalies.

We gratefully acknowledge the support from the NOAA Climate Program Office.

References

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