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Interactive Comment

Interactive comment on "Mid-pliocene Atlantic meridional overturning circulation not unlike modern?" *by* Z.-S. Zhang et al.

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We sincerely thank the reviewer for the comments. We will take them into account in the revised version. First of all, please let us answer your major comments here.

Actually, the theory of stronger mid-Pliocene AMOC is built on the two essential observations, if we check the history of this theory. One is the strong warming at the North Atlantic surface, the other is the decreased meridional δ13C gradient in the Atlantic during the mid-Pliocene. In 1992, Dowsett et al. (1992, Science) reconstructed the extremely warm SSTs at the North Atlantic surface during the mid-Pliocene warm period (mPWP). They suggested that the extremely warming was likely caused by an increased ocean heat transport. In 1996, Raymo et al. (1996, Mar. Micropaleontol.) found the low δ13C gradient between DSDP Sites 552, 607 in the North Atlantic and

ODP Site 704 in the Southern Ocean/South Atlantic, and thus concluded that North Atlantic Deep Water (NADW) production was significantly stronger in the warm Pliocene relative to the cold late Quaternary. A stronger AMOC can increase northward ocean heat transport to the North Atlantic, and cause large surface warming there. Thus, with these two fundamental studies, the stronger mid-Pliocene AMOC theory was established. This theory was later supported by other δ13C studies (Ravelo and Andreasen, 2000, Geophys. Res. Lett.), and was used to explain other findings, including Nd and Pb isotopes (Frank et al., 2002, Paleoceanography) and carbonate preservation (Frenz et al., 2006, Mar. Geol.). The development of the stronger AMOC theory has been summarized in the introduction of paper.

However, the recent study (Zhang et al. 2013, Nat. Comm.) demonstrated that the two observations, which used to support the stronger mid-Pliocene theory, do not necessitate increased AMOC. They showed that neither an increase in AMOC nor the export of NSW to the Southern Ocean is necessary to explain the weak mPWP δ13C gradient (Hodell et al., 2006, Geochem. Geophy. Geosy). Instead, they suggested that mPWP deep ocean δ13C changes were driven mainly by increased preformed δ13C values in the deep waters originating in the well-ventilated and weakly stratified Southern Ocean. They also showed that increased AMOC and intensified northward ocean heat transport by overturning were unnecessary to explain the magnitude of reconstructed high-latitude North Atlantic warming. Seen in this way, there still lack sufficient evidence to support the theory of stronger mid-Pliocene AMOC.

It should be noticed that, in the current study, we conclude that the “mid-Pliocene AMOC” is not largely different to the present day/Late Quaternary. We do not claim that mid-Pliocene North Atlantic was similar to today’s situation. On the contrary, we do agree that the mid-Pliocene “North Atlantic Ocean” was demonstrably different to the present day. However, the different mid-Pliocene North Atlantic does not have to be explained by an increased mid-Pliocene AMOC. The conceptions, “mid-Pliocene AMOC” and “mid-Pliocene North Atlantic” should be distinguished.

The three simulations (MRI-CGCM2.3, GISS-ModelE2-R and COSMOS), which show large increases in AMOC maximum values, were not neglected in the study. Even in the simulations with these three models (MRI CGCM2.3, GISS-ModelE2-R and COSMOS), the heat transport does not increase much (3%, 4 % and 6%). Seen in this way, even the simulated mid-Pliocene AMOC becomes stronger, it does not necessarily cause large increase in ocean heat transport to the North Atlantic, as suggested by the early stronger AMOC theory. Thus, it is reasonable to conclude that the mid-Pliocene AMOC is similar to the pre-industrial in the PlioMIP models, and the AMOC does not play a dominant role in setting the pattern of North Atlantic SST during the mid-Pliocene.

Interactive comment on Clim. Past Discuss., 9, 1297, 2013.