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Impact of transient freshwater release in the Southern Ocean on the AMOC and climate

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The bipolar ocean seesaw is a process that explains the competition between deep waters formed in the North Atlantic (NA) and in the Southern Ocean (SO). In this picture, the increase in the rate of formation of one of these water masses is made at the expense of the other. However, recent studies have questioned the effectiveness of this process. Namely, they show that adding freshwater in the SO can reduce deep water formation in the SO as in the NA. In this study, we explore the mechanisms and time scales excited by such a SO freshwater release, by performing sensitivity experiments where freshwater input is added abruptly in the ocean, south of 60˚S, with different rates and durations. We find three main processes that respond to these freshwater input perturbations and affect the NA Deep Water (NADW) production: (i) the deep water adjustment, which is equivalent to the bipolar ocean seesaw, (ii) the salinity anomalies spread from the SO and (iii) the increase in Southern Hemisphere wind stress. We show that the process (i) affects the Atlantic in a few years, due to an adjustment of the pycnocline depth through oceanic waves in response to the buoyancy perturbation in the SO. Process (ii) invades the NA in around 30 years, while wind stress from process (iii) increases in around 20 years after the beginning of the freshwater perturbation. Finally, by testing the response of the ocean to a large range of freshwater release rates, we show that for rates larger than 0.25 Sv, process (ii) dominates over the others and limits NADW production after a few centuries, while for rates lower than 0.25 Sv, processes (i) and (iii) dominate over process (ii) and increase NADW production and export in a few centuries or decades. The climatic impact of the freshwater release in the SO is mainly a cooling of the Southern Hemisphere, of

up to 10˚C regionally, which increases with freshwater release rate for a large range of values.