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Detecting climate change in Atlantic meridional overturning circulation: Analyses of climate scenario simulations, stations and hydrographic sections

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A wide range of model studies show that the presence of the Atlantic meridional overturning circulation (MOC) and its associated heat transport produce a substantially warmer climate in Europe than would otherwise be the case. Paleoclimate proxy records suggest that massive and abrupt climate changes have occurred in the Northern Hemisphere, especially during and just after the last glacial, with MOC changes as the most plausible mechanism. Here we demonstrate a systematic approach to detect MOC trends using new climate scenario simulations as well as the available observations at ocean weather ship (OWS) stations and along hydrographic sections. The climate model experiments are carried out for the period 1860-2200 in the framework of the fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). The model was initialized from the end of a pre-industrial control experiment and then forced with observed greenhouse gas and aerosol concentrations for the period 1860-2000. Characteristic temperature and salinity patterns of MOC weakening are derived along hydrographic sections (WOCE-CLIVAR) and ocean weather ship stations (OWS) data in the North Atlantic. These patterns are used to estimate past MOC changes from long-term quality-checked observational temperature and salinity data at the OWS stations taken from the Hydrobase2 data set. We show that temperature trends at mid-latitudes provide useful indirect measure of large-scale changes of deep circulation, with a signal-to-noise-ratio higher than a direct measurement. This offers the possibility of detecting a MOC weakening, as well as reconstructing past MOC. Continuation of measurements is required at the associated OWS locations in order to timely detect a possible future MOC slowdown and to separate the signal from

decadal to multidecadal MOC variability. Such an early detection is necessary since a diminishing MOC may fell to a level below which it would not recover for centuries with substantial changes in the North Atlantic region.