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Southern Hemisphere westerlies as a driver of the early deglacial atmospheric CO_2 increase

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Heinrich stadial 1 (HS1, ∼17.6-14.7 ka), during the early part of the last deglaciation, is characterized by a ∼40 ppm atmospheric CO_2 rise occurring mostly in two abrupt phases of 23 ppm between 17.3 and 16.5 ka and 13 ppm within 100 years at ∼16.2 ka. Each of these CO_2 increase is associated with a decrease in its isotopic composition ($\delta^{13}CO_2$). The underlying mechanisms driving the CO_2 increase and $\delta^{13}CO_2$ decrease remain a subject of intense debate. By performing transient simulations of HS1 with a 3-dimensional carbon isotope enabled model, we show that the HS1 atmospheric CO_2 rise and $\delta^{13}CO_2$ decrease can be explained by enhanced ventilation of Antarctic bottom and intermediate waters resulting from intensified southern hemisphere (SH) westerlies and reduced buoyancy forcing. We further show that this enhanced Southern Ocean ventilation results in atmospheric and oceanic carbon isotopes changes in agreement with paleo-proxy records. Moreover, the associated deep ocean convection increases the southward heat transport, reducing Southern Ocean sea-ice and generating a positive feedback between Southern Ocean warming and atmospheric CO_2 rise. A sensitivity experiment, performed with a global ocean eddy-permitting model, further supports a multi-decadal CO_2 outgassing from the Southern Ocean due to stronger SH westerlies. Our results highlight the crucial role of SH westerlies in the global climate and carbon cycle system with important implications for future climate projections.