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Dansgaard Oeschger Dynamics: Clearly Revealed in a Comprehensive Model of Glacial Climate

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More than 30 years ago, Willi Dansgaard in Copenhagen and Hans Oeschger in Bern established the existence of millennium timescale oscillations in oxygen isotope stratigraphies from Greenland ice cores. This isotopic signal was interpreted as implying large amplitude variations in surface air temperature. Until the publication of Peltier and Vettoretti (2014, GRL) the prevalent view had been that this exclusively ice-age phenomenon, thought to be linked to variability in the strength of the Atlantic MOC, was considered to be forced by the episodic release of freshwater from the continental ice sheets, each oscillation requiring its own freshwater input. In Peltier and Vettoretti (2014) this phenomenon was recovered for the first time in a comprehensive model of glacial climate, specifically the CESM1 model of the NCAR laboratory. Attention was drawn to the fact that individual D-O oscillations, or Bond Cycle clusters of such oscillations, were inevitably preceded by individual Heinrich events. In Peltier and Vettoretti (2014) it was shown that, following the “spin-up” of CESM1 into the glacial state, with continental ice sheet volume held fixed, a sequence of nonlinear unforced and therefor “free” oscillations of the MOC occurred, following a sharp Heinrich event-like sharp suppression of MOC strength. All of the salient characteristics of the D-O process inferred on the basis of ice core evidence from both hemispheres were fully captured in these high (CMIP5) resolution simulations, namely: (i) the pulse shape of the individual oscillations characterized by an extremely rapid shift from cold stadial to warm interstadial conditions followed by a slow return to the stadial state, (ii) the peak-to-peak variations in Greenland surface air temperature of 10-15 degrees Centigrade during individual oscillations, (iii) the “bi-polar see saw” connection between this Northern Hemisphere process and that recorded in the EDML and WAIS Divide ice cores from Antarctica, (iv) the reduced amplitude of the oxygen isotopic swings in the Antarctic ice cores, by approximately a factor of 10, from those in Greenland cores. Because the coupled climate model fully captures the phenomenon, it has been possible to fully understand the dynamical mechanism involved. In Peltier and Vettoretti (2014) this was described as a “kicked” salt oscillator, in which individual D-O cycles involved an oscillatory out of phase relationship between the salinity of the North Atlantic sub-tropical gyre and the salinity of a North Atlantic halocline. As shown more recently by Vettoretti and Peltier (2016, GRL), transitions from cold stadial to warm interstadial conditions involve the opening of a massive “super polynya” north of the southern edge of the sea ice front which, under stadial conditions, extends as far south as the south coast of the Bay of Biscaye. This polynya is opened by the onset of a thermohaline convective instability of the water column beneath the sea ice, which is accompanied by a sharp re-invigoration of the intensity of the MOC, thereby initiating a sharp rise of air temperature over Greenland. Several further issues remain with this now fully articulated theory of the D-O process and these will be summarized.