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The Salt Fingering Trigger of Rapid Climate Change in the Nonlinear Dansgaard-Oeschger Oscillation

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The Salt Fingering Trigger of Rapid Climate Change in the Nonlinear Dansgaard-Oeschger Relaxation Oscillation
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A residual unknown concerning the mechanisms involved in the millennium timescale Dansgaard-Oeschger oscillation that dominated climate system variability during Marine Isotope Stage 3 of the last glacial-interglacial cycle, is that responsible for the extremely rapid transitions from stadial to interstadial conditions that are characteristic of this phenomenon. As demonstrated in Vettoretti and Peltier (GRL, 2016) through diagnostic analysis of the first successful simulation of this phenomenon produced using a high resolution coupled climate model (CESM1, Peltier and Vettoretti, GRL, 2014), these transitions occur as a consequence of the opening of a “super-polynya” in the stadial sea ice lid that initially exists over the North Atlantic south of Denmark Strait in the Irminger Sea Basin. Here we focus on the issue of the physical mechanism that forces the opening of this sensible heat polynya. Although it was conjectured in Vettoretti and Peltier (2016; JCLIM, 2018) that this may have been associated with the onset of a convective instability enabled by the weakening of the pycnocline at 100 m depth beneath the sea ice lid, due to the increasing salinity of the initially cold fresh water of this mixed layer, here we demonstrate through detailed analyses of the stability of the water columns beneath the region where the polynya opens, that the mixing mechanism is actually associated with “salt fingering”. This instability occurs much deeper in the water column near 800 m depth where warm saline water initially overlays colder and relatively fresh water. In the climate model this instability is represented by the POP2 implementation of the KPP parameterization of Large et al (1994) as a significant enhancement of the background diapycnal diffusivity profile that is introduced just prior to the occurrence of the stadial-interstadial transition. This causes the local buoyancy frequency of the water column to vanish locally which triggers the convective adjustment of the column by a sharp increase of diapycnal diffusivity and this in turn effects a vertical flux of heat on the order of Giga joules. We suggest that the improvement of this parameterization based upon Direct Numerical Simulations (DNS) of the associated turbulence will enable us to resolve many of the remaining issues associated with our climate model-based understanding of the D-O process, including the primary controls upon its period.