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The Cryosphere Discussions

Interactive comment on "Methanesulfonic acid (MSA) migration in polar ice: Data synthesis and theory" *by* Matthew Osman et al.

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General Comments

The concentrations of trace constituents measured in polar ice cores record changes in conditions at the time of deposition at the glacier surface. However, there is clear empirical evidence (e.g. from anomalies of volcanic origin that exhibit increasingly gradual onsets with age, changing seasonality of MSA peaks) that some degree of post-depositional redistribution can take place. The current manuscript examines the movement of MSA signals in considerable detail with a combination of empirical data and theoretical analysis applied primarily to a new high resolution dataset from the DIV2010 core. The results of this effort include important new constraints on the envi-

ronmental variables that are most important for determining the depth at which significant MSA migration can take place, an informative linearized model that predicts the evolution of MSA concentration in response to the changes in liquid content imparted by seasonal variations in the impurity loading that are gauged by Na concentrations, and a new determination of the effective diffusivity of MSA that is held responsible for the concentration changes observed in the DIV2010 core. This represents substantial progress beyond previous understanding of impurity migration in polar ice, and will help in the interpretation and design of future sampling efforts.

Specific Comments

The manuscript is well organized and clearly written. I appreciated the examination of site-specific variables contributing to MSA migration, including regression analyses leading to best-fit relationships (figs. 2-4) with the depth at which migration is evident. If the authors could provide some further intuition for the source of the exponents in these power laws, this would be a useful addition to the synthesis subsection (2.5). The description of the DIV2010 MSA record and related variables in section 3 is succinct and informative. The mechanistic treatment of MSA migration is particularly clear and represents an important advance over earlier work, particularly by providing constraints on the effective diffusivity of MSA in the DIV2010 core. The value obtained for this key parameter is one or two orders of magnitude smaller than that typically used to describe compositional diffusion in pure water; this might suggest a significant role for motion along two-grain boundaries rather than only in the liquid veins that line triple-junctions and their associated nodes at 4-grain intersections. The authors appear to have made a conscious decision not to speculate on the details of the precise migration pathways, referring only to "grain-boundary" migration rather than specifying whether they expect the vein–node network or the two-grain boundaries to dominate. A brief comment on the distinctions between these possibilities might be of use for some readers. The paleoclimatic implications are well summarized in the final substantial section of the

paper, prior to the conclusions.

Technical Corrections

I didn't notice many typos or other technical issues requiring the authors' attention. The term "super-cooling" is used throughout, whereas previous authors have taken care to use "under-cooling" instead since super-cooling is most commonly used to refer to liquid in a transient, disequilibrium state. Line 5 of page 27 repeats the word 'in' twice.

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