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Interactive comment on "Stable accumulation patterns around Dome C, East Antarctica, over the last glacial cycle" *by* Marie G. P. Cavitte et al.

Anonymous Referee #2

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This paper uses a suite of internal layers detected by airborne ice-penetrating radar to derive paleo-accumulation rates and their distribution across an area around Dome Concordia station, Antarctica. The paper relies on a companion paper by Parrenin et al. for a one-dimensional model which converts measured internal layer depth and geometry to an estimate of paleo accumulation rate across the region. The paper also compares the derived paelo-accumulation rates with the modern rates from the ECMWF ERA40 model.

My largest concern with this paper are the assumptions that a 1-D model provides an appropriate approximation to the vertical strain rate everywhere in the model domain and that advection from adjacent grid cells can be safely ignored. The manuscript does not go into the impacts of these assumptions in any significant detail, and I think

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Discussion paper

a quantitative analysis of that assumption is warranted.

There are a number of other studies that have aimed to recover non-steady and non-uniform accumulation rate histories from variations of the depth of internal layers, such as Waddington et al. (2007), Parrenin et al. (2006), Neumann et al. (2008), and Koutnik et al. (2016). I note the citation for the Parrenin paper in the manuscript, and include the other citations below.

An approximate advection criteria could be derived from the ratio of the along-track discretization distance of the data (1km; per line 117), the flow velocity (significantly variable spatially), and the length scale across which substantial changes in accumulation rate are expected. If the spatial accumulation rate were uniform in space, the proposed approach would probably work well. However, the authors note that there are substantial accumulation rate differences in the modern field, leading me to question over what length and time scales advection can be neglected. For example, if the flow velocity is on the order of 0.1 m/ yr, ice traverses a 1 km grid cell in 10 ka. This suggest that for time periods longer than some fraction of 10ka, the depth to internal layers in a particular 1km cell is impacted by accumulation rates in the cell(s) upstream. As the flow velocity is increased, the situation is exacerbated.

In addition, it's not clear to me that the model generates a credible vertical velocity profile away from the ice divide. I'd expect that velocity profile and strain rate to vary substantially within a few times the ice thickness. A similar quantitative analysis should be done to support (or update) this assumption.

I see this as the major limiting factor in this manuscript. Either the scope of the inversion could be restricted to those areas for which a 1-D model is appropriate over the time period investigated here (I'd estimate this region to be within a ice thickness of the current divide position, given a flow velocity of 0.01 m/yr and a grid cell of 1km), OR a 2-d inversion could be done building off the literature. As this analysis would directly impact the results of the current study, I am reluctant to endorse the the resulting accumulation rate patterns or history or comparisons with the current accumulation rate field.

Other comments are:

1. The model used in this paper is currently also under review, making it difficult to evaluate the application of the model to the problems posed in this manuscript. In particular, I am concerned about the accumulation rate uncertainties (line 271) and what aspects are and are not included in that analysis.

2.The topic is certainly worthy of study and is scientifically interesting. The stability of ice domes and divides is of primary importance in reconstructing the ice sheet history as well as ice chore chronologies. I'd suggest also reading Marshall and Cuffey (2000) as being relevant to the work presented here.

3. The work using the EMCWF ERA40 model is interesting, and will be relevant to the resulting paleo-accumulation rates. This section is explained clearly, and I don't have substantial comments.

Waddington, E.D., T.A. Neumann, M.R. Koutnik, H.P. Marshall and D.L. Morse. 2007. Inference of accumulation-rate pattern from deep radar layers. Journal of Glaciology, 53(183), 694-712.

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Koutnik, M.R., T.J. Fudge, H. Conway, E.D. Waddington, T.A. Neumann, K.M. Cuffey, C. Buizert, K.C. Taylor. 2016. Holocene accumulation and ice flow near the West Antarctic Ice Sheet Divide ice core site. Journal of Geophysical Research: Earth Surface, 121, pp.1–18.

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