Deep radiostratigraphy of the East Antarctic Plateau: connecting the Dome C and Vostok ice core sites

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ABSTRACT.

SUPPLEMENT 1: CROSSOVER ERROR ANALYSIS

We report crossover errors as the root mean square (rms) deviation of the reflection depths at intersecting transects. Crossover errors are measured within the Dome C district, which uses only HiCARS data, where radar reflections are not affected by aeolian terranes and lake-induced effects, to provide an objective measure of the accuracy of our tracings in areas of conformable stratigraphy. The crossovers are all less than the HiCARS radar reflection depth uncertainties reported for each reflection and therefore validate the uncertainty assessment in this paper. Results are summarized in Table S1. We also calculate crossover errors for reflections traced within the Vostok district, which uses only UT/TUD data, and likewise, show that crossover errors in the area are smaller than the UT/TUD radar reflection depth uncertainties. Results are summarized in Table S2.

SUPPLEMENT 2: RADAR REFLECTION MATCHING ACROSS SYSTEMS

All thirteen radar reflections used in this study are traced in different radar systems, which use different center frequencies, bandwidths and processing steps. As a result, the internal stratigraphy observed by one system might not match one-to-one that of another. As an example of these types of complications, we show here a comparison between the HiCARS and the MCoRDS radar systems (Figure S1). The MCoRDS system has a higher vertical resolution than the HiCARS system (4.5 m and 8.4 m, respectively), therefore a single reflection observed by the HiCARS system can correspond to multiple thinner reflections by the MCoRDS system (Figure S2). In that case, only one MCoRDS-reflection is chosen from the matching set for tracing. We do not believe this to be a significant source of uncertainty, based on the very good match of reflection depths between the two radar systems at the ice core site (refer to Figure 8 in the manuscript).

SUPPLEMENT 3: DEPTH COMPARISON

We compare the connection obtained between the Dome C and Vostok ice cores using radar reflections-only with that obtained using volcanic tie-points in the two ice cores (Parrenin and others, 2012). Both ice cores lack a well established absolute depth uncertainty, which is estimated to sum up to several meters of accumulated error (Parrenin and others, 2012). In order to compare the radar results to the ice core tie-points, we assign a 5 m and 10 m total cummulative depth error between the surface and the last volcanic markers for the Dome C and Vostok ice cores, respectively (Parrenin pers. comm.). The deepest volcanic tie-point reaches 1804 m and 1992 m depth at Dome C and Vostok, respectively, and so the depth error is assigned to increase linearly from 0 at the surface to 5 or 10 m at the bottom. Comparing the core-to-core connections in the depth domain allows us to assess the success of the radar stratigraphy without the added contributions of age-depth chronology uncertainties for each ice core. We also compare the stratigraphic relationship obtained with that of Delmonte and others (2004) which uses dust peaks identified in both cores. We show that, for any of the radar systems used, the radar connection obtained using reflections matches pretty closely that of the core dust and volcanic tie-points (Figure S3). The reflections that deviate beyond their depth uncertainties are the same reflections that showed an age difference between the two cores that fell outside of their total age uncertainty bounds (reflection numbers 1,3 and 5) (Figure 6 in the manuscript). These reflections are mostly likely impacted by the pervasive presence of buried aeolian terranes which affect all depths of the ice column and preclude a successful connection of the two ice cores.

REFERENCES

Delmonte B, Basile-Doelsch I, Petit JR, Maggi V, Revel-Rolland M, Michard A, Jagoutz E and Grousset F (2004) Comparing the Epica and Vostok dust records during the last 220,000 years: stratigraphical correlation and provenance in

Table 1. Radar reflection depth uncertainties at the EDC ice core versus crossover errors in the Dome C district. Our top six reflections span the last glacial cycle; our bottom seven reflections span the penultimate glacial. Reflection depth uncertainties are repeated from Table 1 in the main manuscript.

Reflection	Depth uncertainty (±m) Dome C HiCARS	Crossover depth error (±m) HiCARS Dome C district
1	2.67	1.74
2	2.93	2.11
3	3.56	2.33
4	3.15	3.19
5	3.62	1.70
6	3.90	2.43
7	4.39	2.38
8	4.54	2.41
9	5.04	2.86
10	5.14	2.86
11	5.64	3.06
12	5.92	3.74
13	6.41	4.13

glacial periods. *Earth-Science Reviews*, **66**(1), 63–87 (doi: 10.1016/j.earscirev.2003.10.004)

Parrenin F, Petit JR, Masson-Delmotte V, Wolff E, Basile-Doelsch I, Jouzel J, Lipenkov V, Rasmussen S, Schwander J, Severi M and others (2012) Volcanic synchronisation between the EPICA Dome C and Vostok ice cores (Antarctica) 0–145 kyr BP. *Climate of the Past*, **8**(3), 1031–1045 (doi: 10.5194/cp-8-1031-2012)

Table 2. Radar reflection depth uncertainties at the Vostok ice core versus crossover errors in the Vostok district. Our top six reflections span the last glacial cycle; our bottom seven reflections span the penultimate glacial.

Reflection	Depth uncertainty (±m) Vostok UT/TUD	Crossover depth error (±m) UT/TUD Vostok district
1	13.39	3.21
1	9.99	3.08
3	6.08	4.70
4	5.41	5.03
5	7.72	3.93
6	7.85	5.94
7	6.37	5.22
8	6.86	5.56
9	6.50	6.50
10	14.09	6.27
11	10.56	7.62
12	9.51	6.61
13	10.18	4.78

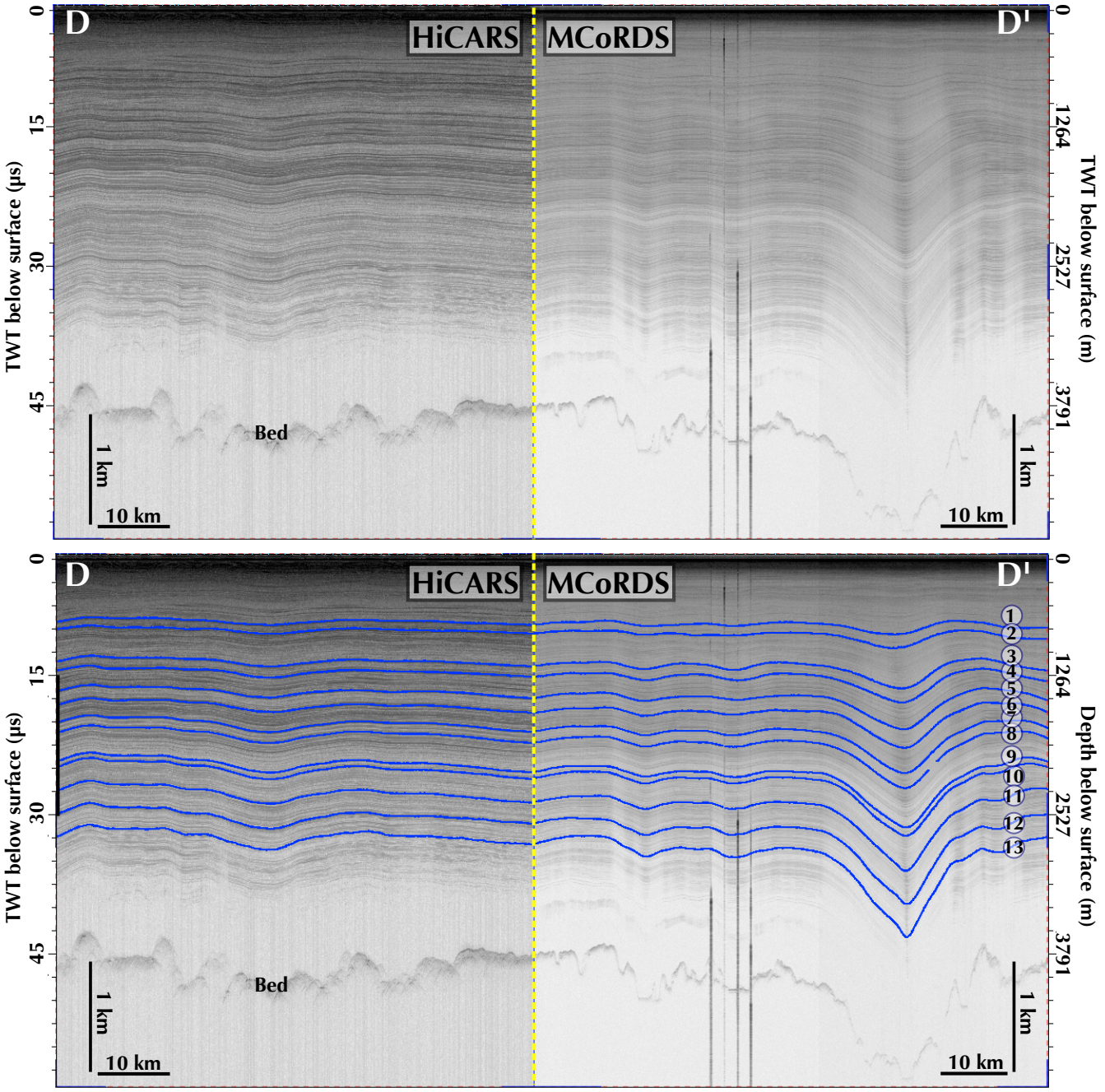

Fig. 1. Reflection matching between the HiCARS and MCoRDS radar systems. Top panel shows the intersecting raw radargrams, bottom panel shows the superimposed radar reflections traced in blue. A dashed yellow line highlights the intersection locations of the two radargrams. Refer to Figure 1 of the manuscript for the location of the transects.

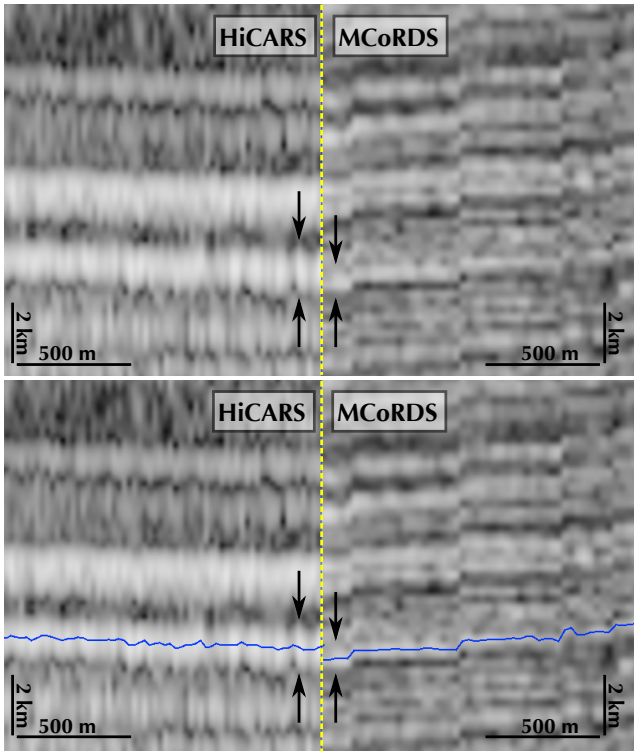

Fig. 2. Reflection matching between the HiCARS and MCoRDS radar systems. Top panel shows the raw radargrams, bottom panel shows the superimposed radar reflections traced in blue. Arrows highlight the difference in thickness of a reflection between systems. A dashed yellow line highlights the intersection locations of the two radargrams.

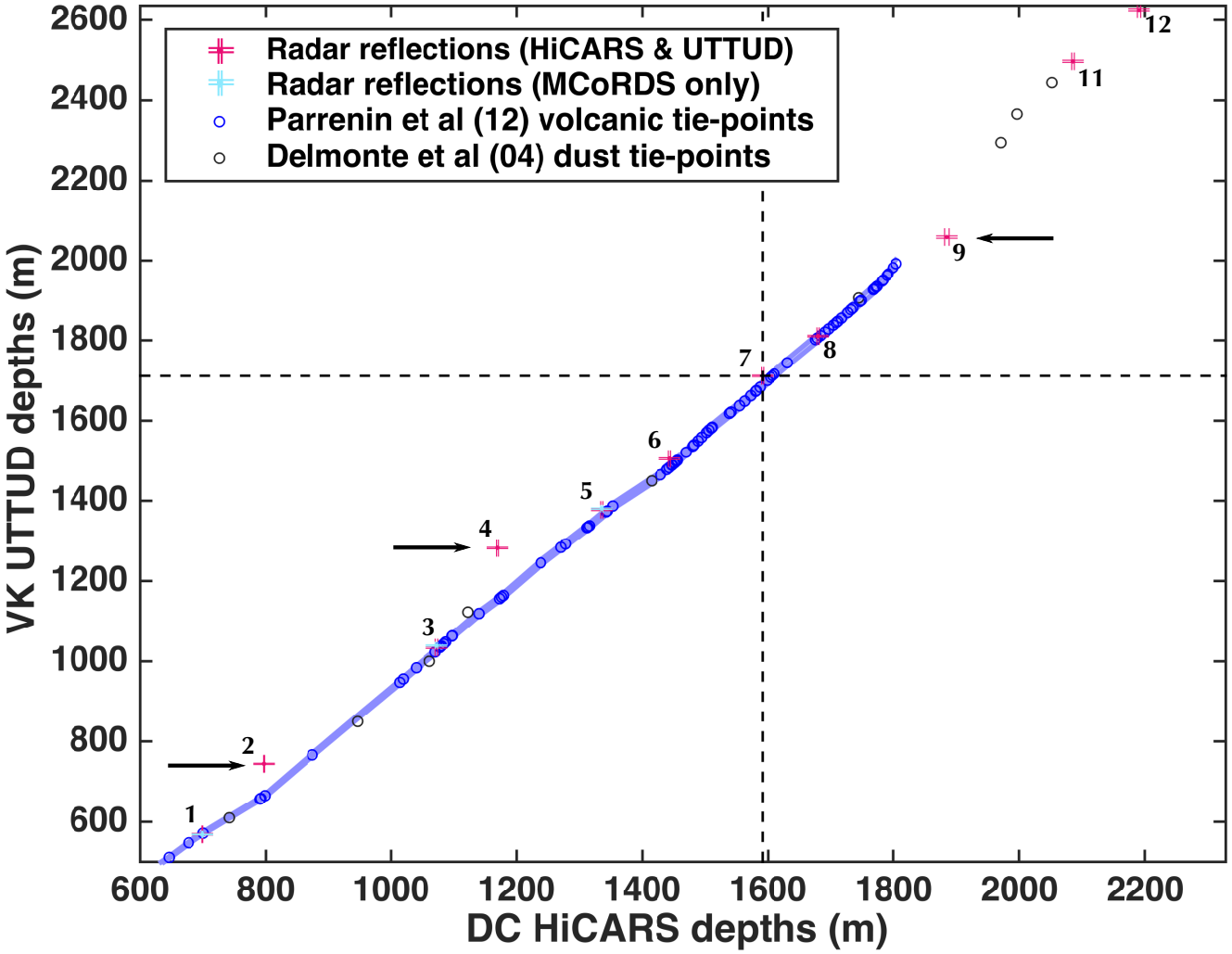

Fig. 3. Connection of the Dome C and Vostok ice core sites, using all radar surveys. In pink and light blue, the radar reflection depths at each ice core site using either the combined HiCARS and UT/TUD systems, or the MCoRDS transect only, respectively; pink and light blue error bars display their total age uncertainties, respectively; in dark gray, the Delmonte and others (2004) Dome C dust tie-points; in dark blue, the Parrenin and others (2012) Dome C volcanic tie-points; the blue band represents the cummulative depth errors for the Dome C and Vostok ice cores (here 5 m and 10 m, respectively). The vertical and horizontal black dashed lines separate reflections belonging to the last glacial from the penultimate glacial. Reflections are numbered as in the manuscript. Most radar reflections agree with the ice core tie-point synchronizations. Black arrows highlight the reflections that do not. Note that reflection numbers 1, 3 and 5 overlap for all radar systems.