AGU PUBLICATIONS

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Supporting Information for

Icequake-magnitude scaling relationship along a rift within the Ross Ice Shelf, Antarctica

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Additional Supporting Information

Dataset S1: Icequake catalog used in this study

Introduction

Text S1 describes the estimation of surface strain rate.
Figure S1 shows surface elevation of WR4.
Figure S2 shows the icequake locations and distance relative to station DR14.
Figure S3 shows the Gutenberg-Richter relationship and cumulative icequakes with time.
Figure S4 shows the ITS_LIVE dataset for WR4.
Figure S5 shows the surface strain rate using the ITS_LIVE dataset for WR4.

Supplementary Materials

Text S1. Estimation of surface strain rates using ITS_LIVE dataset

We download the dataset from the ITS_LIVE website (https://its-live.jpl.nasa.gov/). This data product includes horizontal velocities and their uncertainty estimates between 2015 and 2020. The original product is in geotif format, and the pixel size is about 450 m × 450 m. Figure S2 shows the velocities across WR4. We downsample the image to 2,700 m × 2,700 m pixel size using QGIS for the strain rate analysis. For strain rate, we first set a grid point array every 500 m in east-west and north-south directions, and then compute a 2 × 2 deformation tensor constrained from nearby velocity estimates, and then estimate the principal strain rate axes orientation and magnitude, respectively.

Although the ITS_LIVE product is based on multiple years of measurement, the data is still noisy when looking at a smaller spatial scale (e.g. sub-km). There are also additional double-rift features (most clear in the east-west component of Figure S2) that could be due to artifacts in image processing (*C. Walker*, *personal communication*). We try to reduce the data noise by considering velocity measurement from nearby pixels. We first estimate a mean velocity of the grid point from taking velocity estimates of the 8 neighboring pixels. We use a weighted least squares method with a linear equation to represent the mean velocity (in both east–west and north-south components) with the inverse of velocity uncertainty estimate, which is part of the original data products, for weighting.

To construct the 2 × 2 deformation tensor, we take the mean velocity of each grid point and estimate the relative velocity between grids and their distance:

$$\dot{\boldsymbol{\varepsilon}} = \begin{bmatrix} \dot{\varepsilon}_{xx} & \dot{\varepsilon}_{xy} \\ \dot{\varepsilon}_{yx} & \dot{\varepsilon}_{yy} \end{bmatrix} = \begin{bmatrix} \dot{\varepsilon}_{xx} & \frac{1}{2}\left(\dot{\varepsilon}_{xy} + \dot{\varepsilon}_{yx}\right) \\ \frac{1}{2}\left(\dot{\varepsilon}_{yx} + \dot{\varepsilon}_{xy}\right) & \dot{\varepsilon}_{yy} \end{bmatrix} + \begin{bmatrix} 0 & \frac{1}{2}\left(\dot{\varepsilon}_{xy} - \dot{\varepsilon}_{yx}\right) \\ -\frac{1}{2}\left(\dot{\varepsilon}_{xy} - \dot{\varepsilon}_{yx}\right) & 0 \end{bmatrix},$$

where $\dot{\varepsilon}_{xx} = \frac{\partial V_E}{\partial x}$, $\dot{\varepsilon}_{yy} = \frac{\partial V_N}{\partial y}$, $\dot{\varepsilon}_{xy} = \frac{\partial V_E}{\partial y}$, and $\dot{\varepsilon}_{yx} = \frac{\partial V_N}{\partial x}$. V_E and V_N represent velocity in east-west and north-south, respectively. The first part of the right-hand side is the strain rate tensor, and the second part is the rotation rate tensor. We then calculate the eigenvalues and eigenvectors of the strain tensor for each grid point. The eigenvectors and eigenvalues correspond to the principal strain rate axes orientation and magnitude, respectively. The result of the principal strain rate is shown in Figure 3a, where red and blue represent contraction and extension rate, respectively. Figure S3 shows the principal strain rate, dilatation rate, and shear rate (projected to N5^{o}W) of WR4.

Supplementary Figures

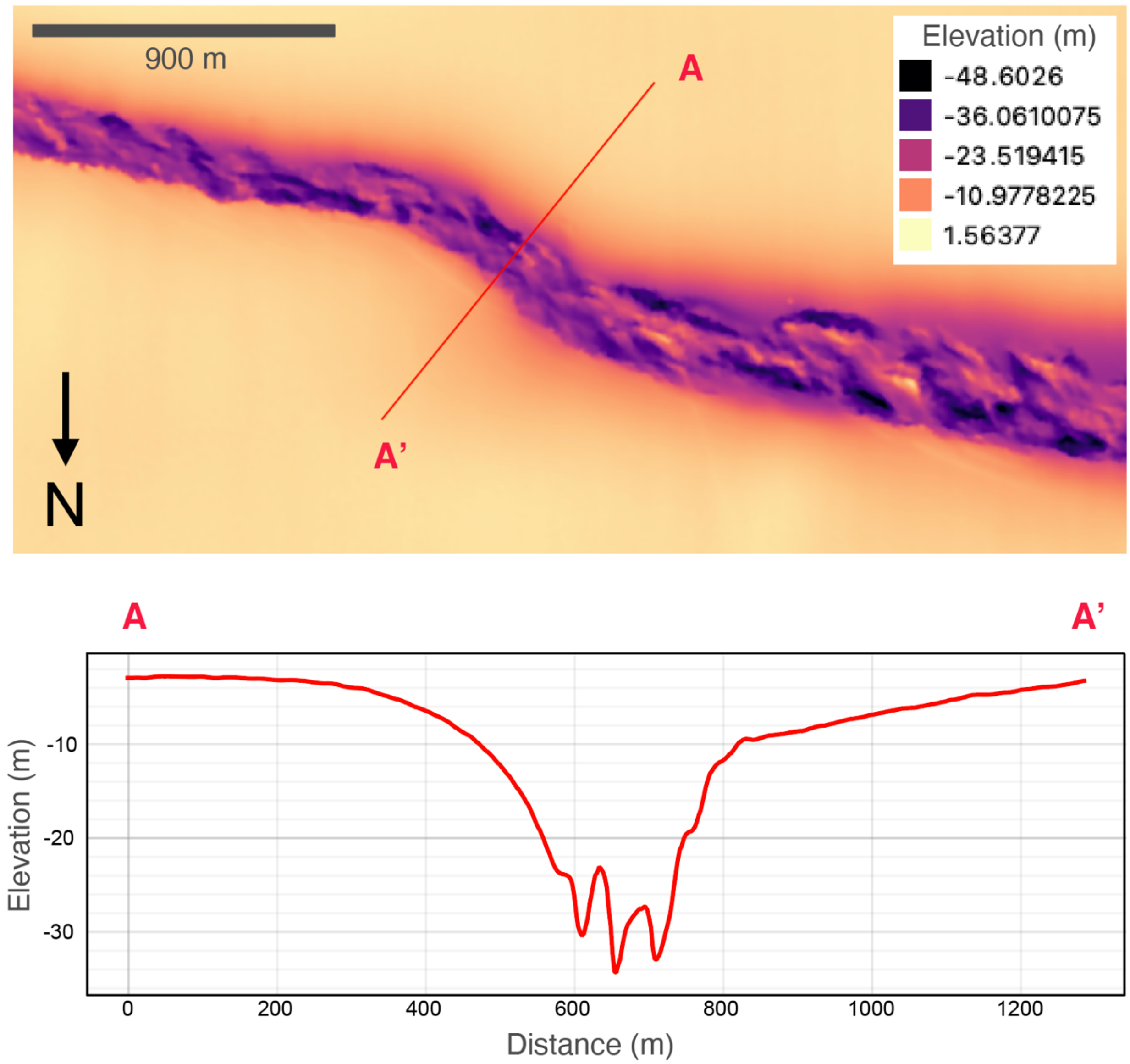

Figure S1. 2m resolution DEM and a rift-perpendicular elevation cross section from WorldView-2 satellite imagery. Color scale shows elevation in meters.

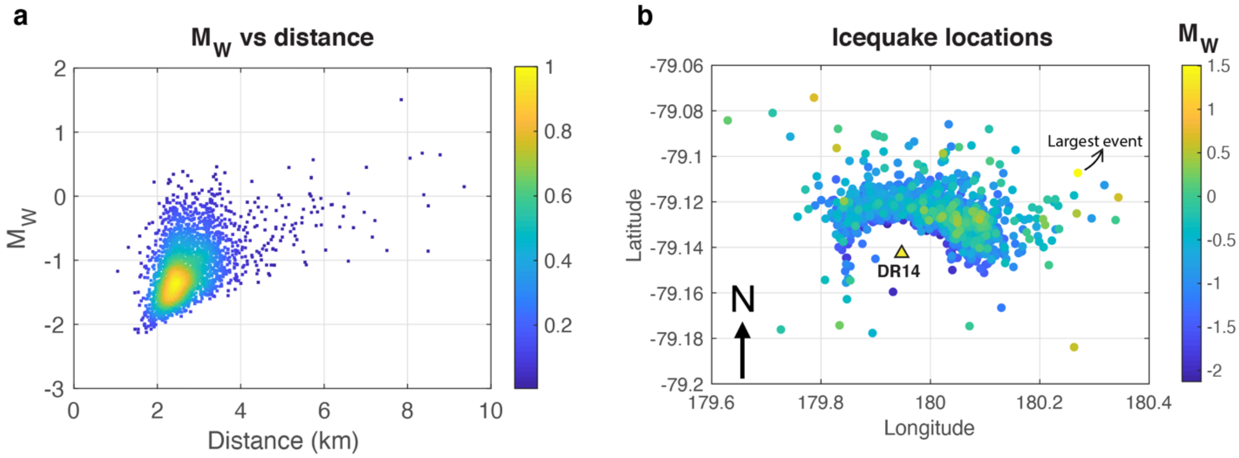

Figure S2. **(a)** Distance versus moment magnitude (M_W) plot. The color represents the icequake population density. The majority of the icequake are between 2 and 4 km distance from station DR14. **(b)** Map view of seismicity color coded with moment magnitude (M_W).

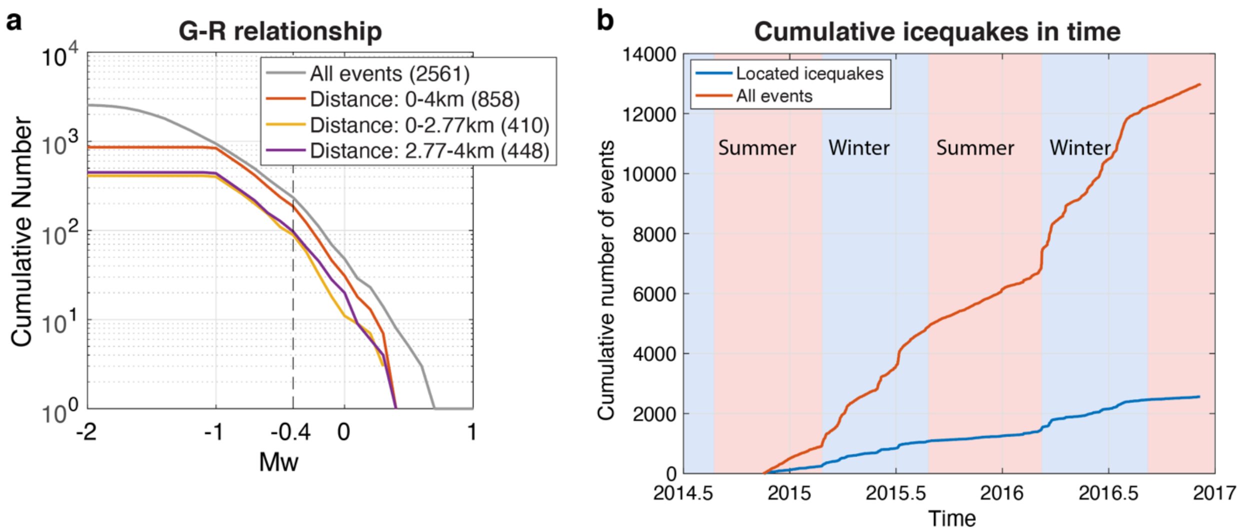

Figure S3. (a) Gutenberg-Richter relationship of all events (grey), WR4 (red), near- (yellow) and far- (purple) sides of WR4. The numbers in the legend represent number of icequakes. The vertical dashed line indicates M_W -0.4, where a change of slope (b-value) occurs. **(b)** Cumulative number of icequakes during observational period. There is higher seismicity production during Antarctic winter.

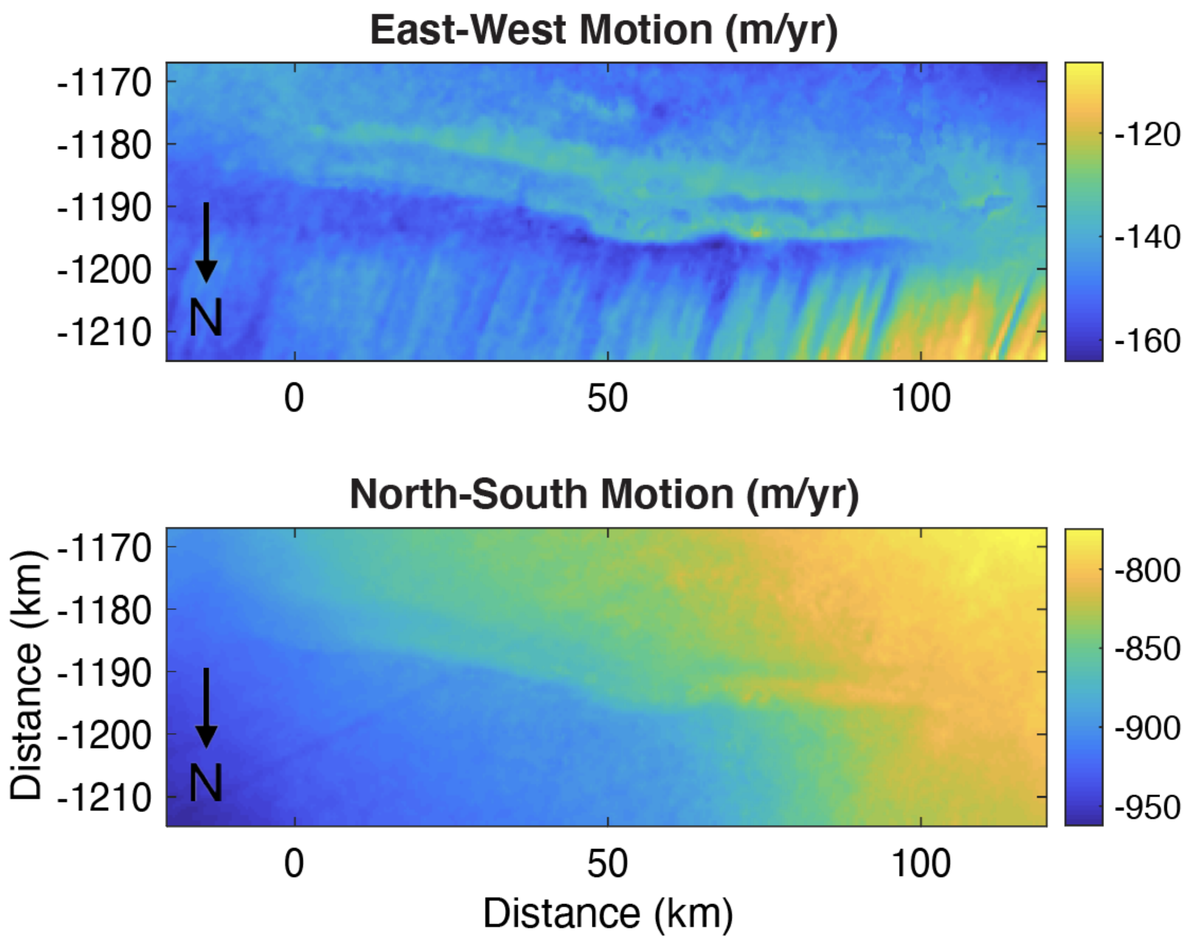

Figure S4. ITS_LIVE velocity in east-west and north-south direction.

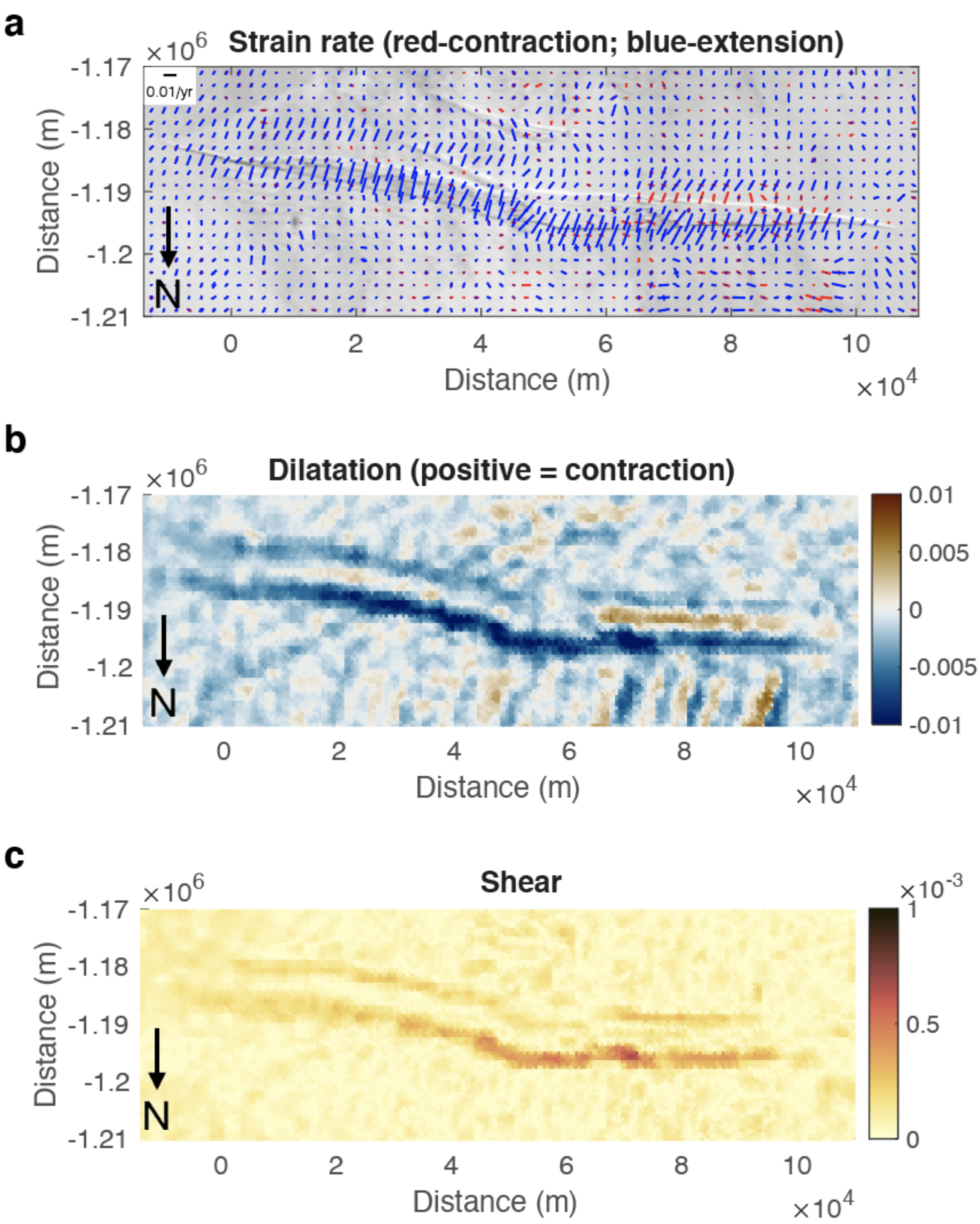

Figure S5. Strain rate along the full extent of WR4. **(a)** The blue and red bars represent extension and contraction rates, respectively, and the direction of the bars indicate the principal axes orientations. The background image is from Sentinel-2 imagery. **(b)** Dilatation rate. The blue and red colors represent extension and contraction, respectively. **(c)** Shear rate projected to N5°E, which represents the amount of shear motion along the east side of WR4.