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News and Views

Recent and imminent calving events do little to impair Amery ice shelf's stability

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Accounting for about half of mass loss in Antarctic, glacier calving is an important ablation process for the ice sheet (Liu et al., 2015). Thanks to the revolutionized era of satellite remote sensing, the 21st century witnessed dozens of prominent calving events. However, calving could occur as a natural behavior of the glacier to maintain itself in a steady state, rather than forced by external environment factors.

At the end of September 2019, another spectacular calving event took place in East Antarctic, shedding an iceberg coded as D28 from the Amery Ice Shelf (the AIS, see Fig. 1). Considering the 60–70 year's calving cycle of the AIS and it has been 56 years since last separation in 1963–1964 (Fricker et al., 2002), we propose the recent and imminent calvings are part of the normal advance-retreat-advance loop, therefore would not do harm to its balance state. To test the above hypothesis, this study quantifies the dynamic response of the AIS to these events by a set of modeling experiments.

The two-dimensional finite-element ice flow model Úa is employed as the experiment platform (Gudmundsson, 2013). To capture the stream-shelf flow dynamics, we select Shallow Shelf Approximation (SSA) with refined unstructured mesh up to 500 m nearby the grounding line. A group of five simulations is conducted, with the first inverse and second control run to eliminate the residual effect of initialization. Afterward the other three calving runs are implemented to mimic the gradual recession of the AIS front, with each following the previous one subsequently after 15 years.

Three diagnostic variables, i.e. volume-above-flotation (VAF), grounded area and discharge flux, are selected to represent the system dynamics, and their temporal evolution are displayed in Fig. 2. For VAF, a clear decrease trend can be detected after each one of three events, with the later one declining at a steeper slope consequently ending up with a lower value. Similar patterns appear in Figs 2b and c as well, but with noise fluctuations superimposed on the general decrease or increase background.

Of particular interest is the reverse trend in the last 5 years for both grounded area and flux. This consistent behavior for all three runs implies they are highly correlated and constrained by the parallel stress regime. In terms of absolute magnitude, the calving3 at the end of the run can lead up to about 4 Gt of VAF, 60 km^2 of grounded area, and 1 Gt/a of flux as the response to all three calvings in a full cycle. On one hand, by comparing four transient runs our model is able to differentiate the responses of the AIS for each calving in the computation domain. On the other hand, such discrepancies are too weak to be detected by satellite in the physical world. For example, Zhou et al. (2019) quantified the latest flux as (61±5) Gt/a. While our modeling estimations (56–58 Gt/a) fall within such interval, even the largest difference among each other (1 Gt) is well below statistical uncertainty (5 Gt).

To illustrate the spatial-varying backstress exerted on the remaining ice shelf, we also predicted the ice thickness changes and flow acceleration. Dynamic thinning causes mass re-distribution thus associated surface elevation changes. The thinning mainly spreads within 100 km upstream of calving1, with a quantity of about 2 m after 40 years. Such scale is beyond the detection capability of modern space altimetry, and the variation should be muted into the basal melting signal. Such dynamic responses also express as the acceleration in a more concentrated way. The outlet of calving1 enhance adjacent velocity by 50–70 m/a, but barely noticeable further upstream. Thanks to the funneling geometry and the accompanying greater lateral drag, the front sectors exert minimal backstress to upstream ice flow, although every potential iceberg blocks do serve as the buttressing plug. With that said, geometry changes in the outer boundary essentially have limited influence on glacier dynamics.

With the bedrock underlie at 550–800 m below the AIS front, there is no potential rumple acting as a sticky point nearby. Therefore we infer the AIS can still restructure itself in a healthy state even experiencing further retreat before the Gillock Island; in other words, the AIS has at least 150 km "safe distance" upstream, which agrees with the findings from the progressive retreat (Gong et al., 2014).

In this study we attempt to assess the effects of the latest and impending iceberg calving on AIS. Given the order of magnitude and spatial distribution of response signals make sense, we assume they are directly resulted from the physical variations

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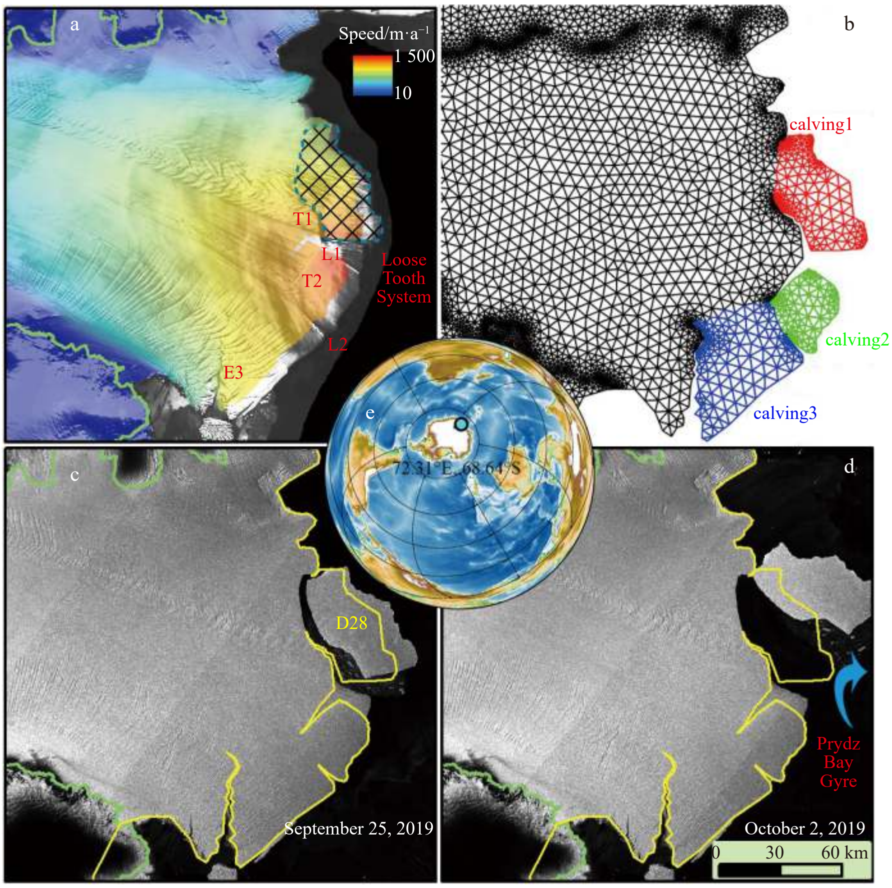

Fig. 1. The Front of Amery Ice Shelf (AIS). a. The “Loose Tooth System”, with two longitudinal (L1, L2), two traversal (T1, T2) rifts and another oblique one in eastern lateral (E3). The hatched area calved off later as D28. MEaSUREs-V2 surface velocity is overlaid on MODIS Mosaic of Antarctica (MOA) 2014. b. The model mesh settings. The red chunk denotes the calving happened in September 2019, and the green and blue one denote the imminent calving events in the current cycle. The mesh is refined in the grounding zone. c. The Sentinel-1 radar satellite captured the birth of D28 on September 25, 2019, with the boundary of the computation domain delineated in yellow. d. On Sentinel-1 radar image of October 2, 2019, the newborn iceberg drifted westward driven by the Prydz Bay Gyre. e. The location and coordinates of this calving event in East Antarctic.

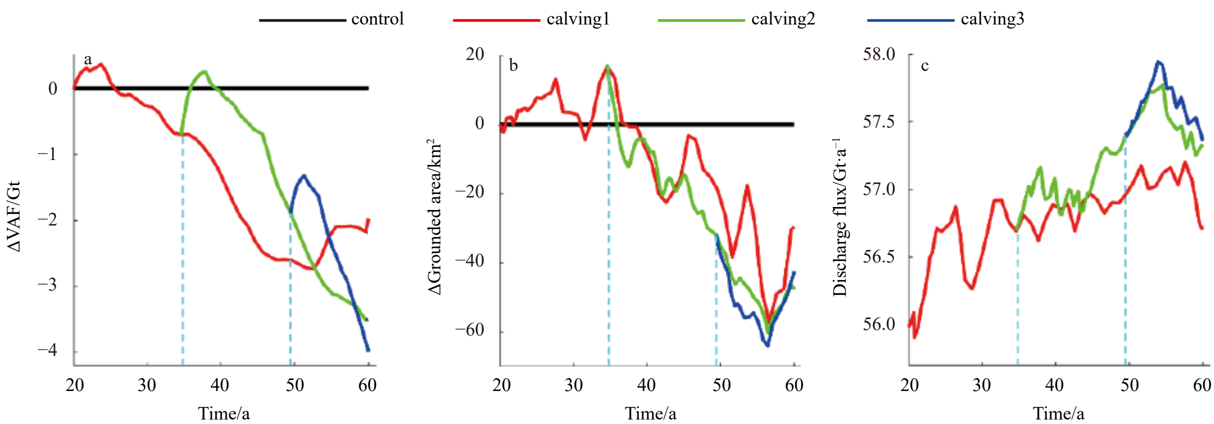

Fig. 2. The three diagnostic variables in transient runs of calving1-3 from t=20 to t=60 a, compared with the control run. a. The volume-above-flotation (VAF), b. the grounded area, and c. the discharge flux. The cyan vertical dash lines correspond to the time of calving2 and calving3.

rather than the numerical artifacts. Not unexpectedly, we find that velocity acceleration (70 m/a), grounding line retreat (–60 km^2), thinning (–2 m) and dynamic mass loss (–4 Gt) all occur as the responses for the front cutting-off. Although our model can resolve such tiny reactions, from a pragmatic point of view, we doubt whether they are measurable by contemporary observational technology if considering uncertainties.

The main argument that there is no direct link between presented calving events and global climate change, is also in accordance with the researcher's opinions from Scripps Institution of Oceanography (Amos, 2019). Despite that the AIS front appears much like its "passive" counterpart in Larsen-C Ice Shelf (Hogg and Gudmundsson, 2017), the response of the remaining section is linked with how strongly the removed iceberg restrained ice flow upstream. This kind of structural support depends on particular bedrock topography in a complex spatio-temporal evolution, which suggests our analysis is fairly case-by-case and cannot be over-interpreted.

Based on the above discussion, we conclude that front geometry variations do not noticeably affect the holistic integrity of the AIS. Combining with the fact that the AIS has appeared roughly in balance with its surroundings ever since 1970 (King et al., 2009), we can safely infer these calving events are natural phenomena rather than an indicator of climate change. Since little information is available about the last major calving about 60 years ago, these events (would) still offer us an excellent opportunity to understand what is starting to happen within one complete calving cycle. In fact, since D28 could pose a threat for shipping, most polar-orbit satellites will keep tracking this particular area, and we would collect relevant data for further investigation.

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