RICE and radars reveal ‘retreat repertoires’

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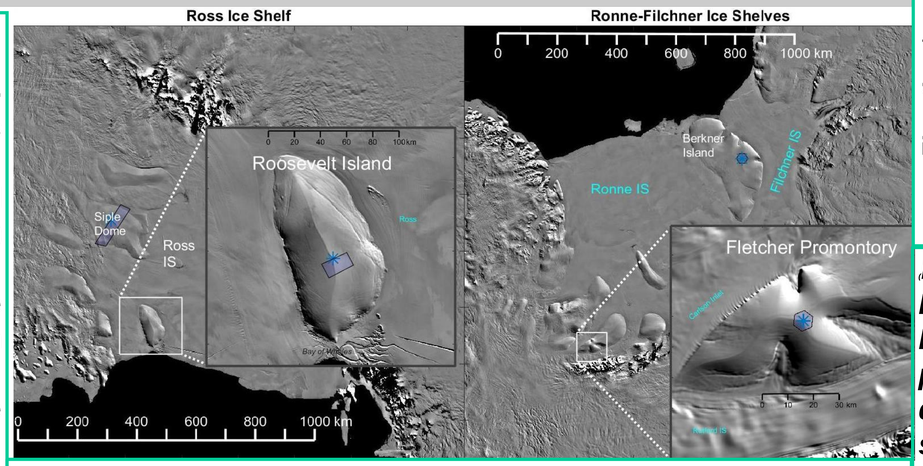
(A) RETREAT ‘REPERTOIRE’:

1. Evidence gathered over the past 30 years indicates that marine ice-sheets (MIS) have a ‘retreat repertoire’: sometimes their retreat is induced by climate change, and sometimes by internal instabilities.
2. MIS retreat varies both temporally - centennial/millennial - and spatially - streams with width and length 20-200 km (e.g. Thwaites) to whole sectors of ice-sheets (west coast of Irish Ice Sheet).
3. Ice rises and buttressing play an important role in nature of the WAIS ‘repeat repertoire’, owing to ice-rises’ many appearances in Ross and Ronne-Filchner Ice Shelves (Fig. 1).
4. Dynamics of ice sheets are not well-enough understood to make predictions of rate and magnitude of SLR in coming centuries.
5. Important because sea-level is now rising about 3 mm/a; a substantial proportion of this is due to flow from AIS. Forecasts suggest sea-level could rise 1 m by 2100 CE.
6. Serious consequences for coastal regions; 1m would displace tens of millions of Bangladeshis, and could turn the 1-in-1000-year flood into a one-in-a-hundred-year flood in many areas of W. Europe.



(Fig. 1) MODIS images of Ross and Ronne-Filchner ice shelves, Roosevelt Island and Fletcher Promontory. Radar survey areas (pulse-echo, pRES) indicated by blue zones, drill sites by blue asterisks. Ice rises are situated in the shelves, buttressing the flow; ice-rise radar surveys produce information about when they were formed and changes in thickness.

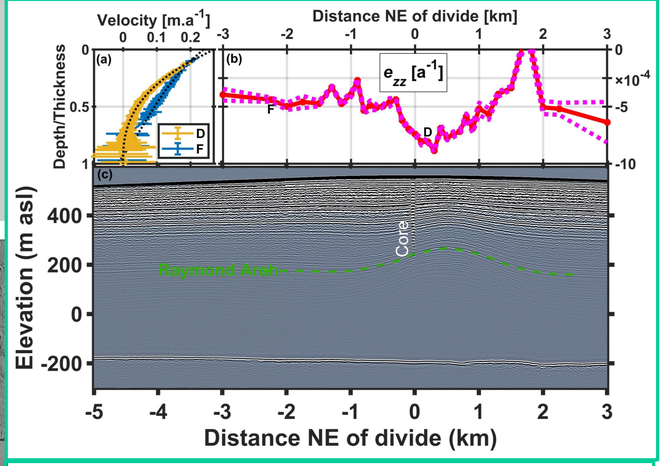
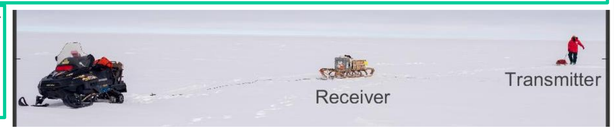


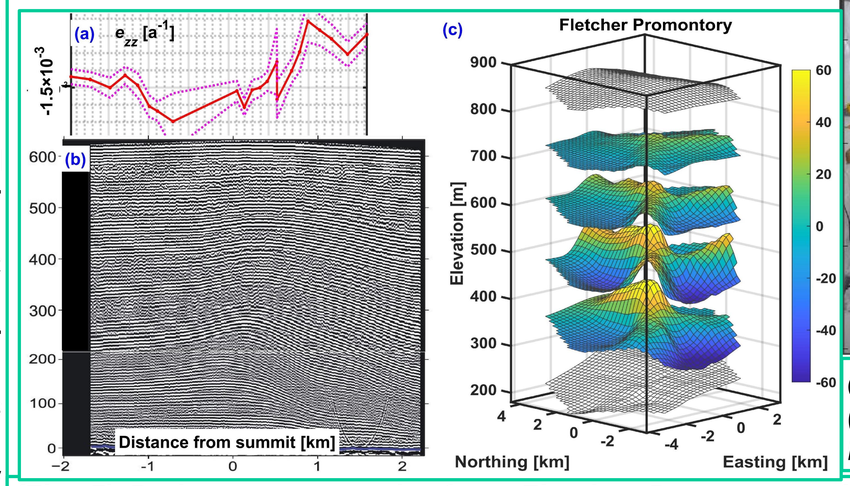
Fig. 2) Results of radar investigations at Roosevelt Island, showing evidence of the Raymond Effect; (a) is vertical velocity plotted against depth, showing a clear difference between divide ‘D’ and flank ‘F’; (b) surface strain-rates plotted across the divide; (c) radargram near the borehole; both (b) and (c) show evidence of the Raymond Effect.

(B) RICE, radars and Raymond Effect:

1. RICE, led by Nancy Bertler, drilled through Roosevelt Island 2010-13 (Fig. 4) and recovered ice: being analysed for information re. GL retreat.
2. This was a result of work by Howard Conway and Brenda Hall, which showed that retreat in western Ross Sea was faster than in east.
3. RICE results show that this is a simplification of Ross retreat history. Modelling by Lowry et al. (2019) indicates more complex retreat (Fig. 6).
4. HC carried out pulse-echo radar (Fig. 3b) surveys, using a theoretical model of Charlie Raymond’s that showed anticlines would develop under ice divides (Fig. 2). – the Raymond Effect leads to Raymond Arches.
5. Anticline amplitude used to date divide relocation and ice thinning. HC suggested divide relocated 3 ka BP and thinning of 300 m.
6. HC and RH went to Roosevelt Island during RICE drilling and did radar work; HC further pulse echo and RH pRES measurements.
7. pRES can measure vertical motion of ice. Both types of measurements confirmed Raymond Effect operating (Fig. 2).
8. Tollý took pRES to Fletcher Promontory (Fig. 3a), where RH had already carried out pulse-radar surveys.
9. Both confirmed that the Raymond Effect operating (Fig. 5), and deduced FP had thinned by 500 m since 5 ka BP.

(Fig. 3b) UW pulse-echo radar at Pole.

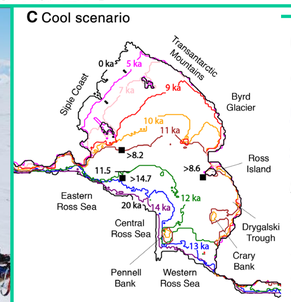




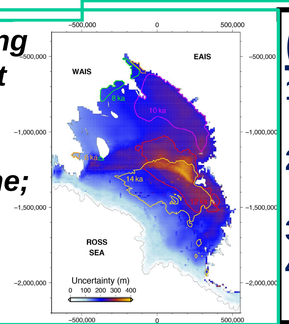
(Fig. 5) Radar survey results from Fletcher Promontory; (a) plots of surface strain-rate measured by pRES with distance from summit; (b) radargram along same line – both show evidence of Raymond Effect; (c) reconstructed isochrone architecture in 3D, showing Raymond Cupolas.

(Fig. 4) RICE camp (a) drill tent from outside; (b) inside drill-tent; (c) Nancy and Sepp Kipfstuhl looking at ice core in drill-tent

Fig. 3a Tollý with pRES at Fletcher Promon-tory triple junction



(Fig. 6) Modelling Ross GL retreat (Lowry et al., 2019). L: GL positions in time; R: variation in shelf thickness from ensemble



(C)SUMMARY AND CONCLUSIONS

Link to further info:

1. WAIS retreat a complex combination of predictable response to climate change and events of lower predictability, owing to flow instabilities, constituting ‘retreat repertoire’
2. Analogy in mid-latitude meteorology is predictable changes between summer and winter and uncertainties arising from storms and hurricanes.
3. In Ross and Ronne-Filchner evolving ice-rise geometry has complex effect on retreat.
4. Research is raising as many questions as answers; which aspects of ice-sheet retreat can be predicted, and which need more data and modelling?