SCIENTIFIC REPORT – NERC GEF Loan 927

Measuring changes in the dynamics of Pine Island Glacier, Antarctica

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ABSTRACT

A brief period of geophysical data acquisition was completed on Pine Island Glacier in 2010-11. The main goals were to continue a record of monitoring changes in the glacier's dynamics and to map a region of fine-scale bed topography and internal ice-stratigraphy. GPS receivers were provided by GEF.

BACKGROUND

Pine Island Glacier

Pine Island Glacier (PIG; Fig. 1) is the largest glacier in the West Antarctic Ice Sheet (WAIS); it is also the one that is changing most rapidly. Ice discharge from PIG increased by ~30 Gt yr^{-1} between 1996 and 2007, and it is currently the greatest single contributor to the mass imbalance (and hence sea-level contribution) of WAIS[1].

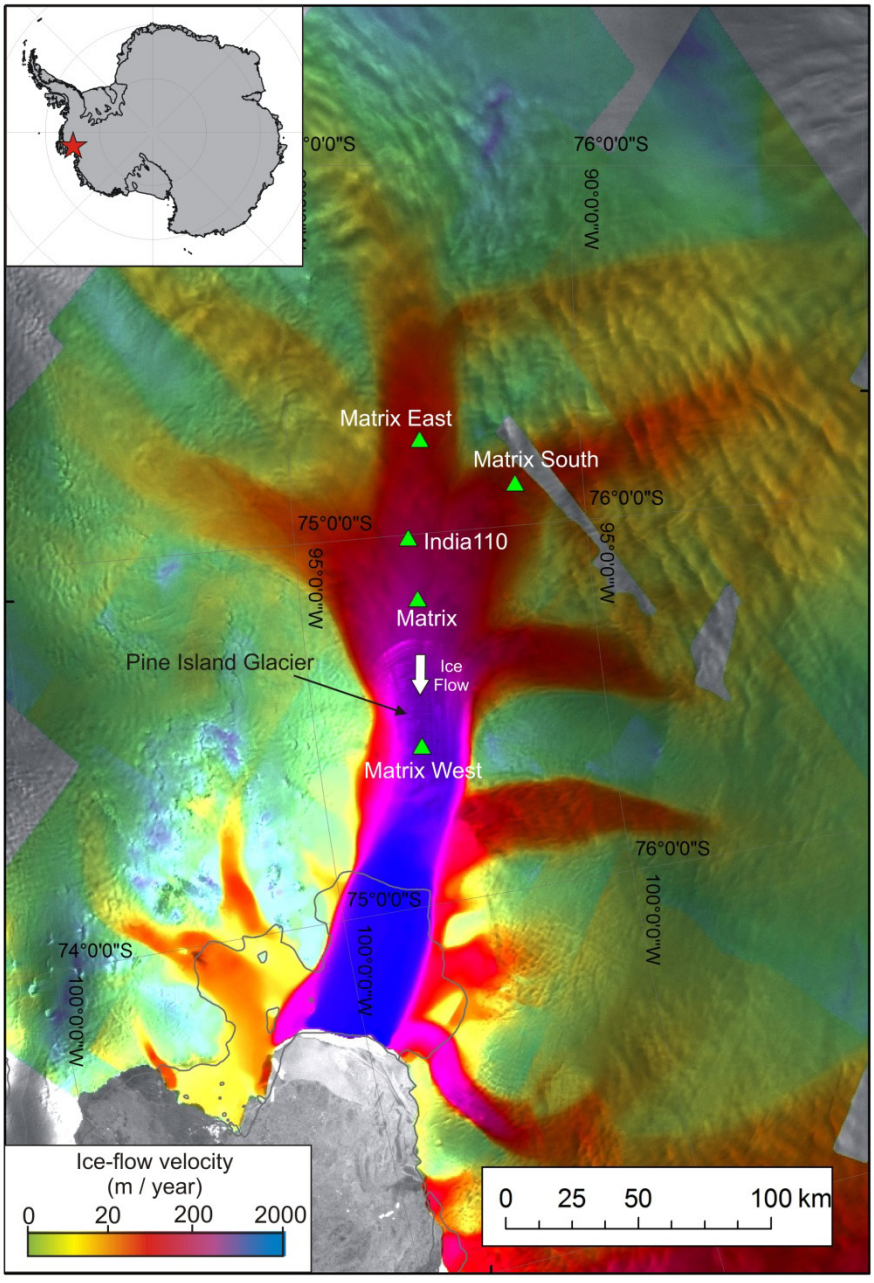

Figure 1. Location map of Pine Island Glacier. Background is satellite imagery, colours show ice flow velocity. Green triangles mark the GPS stations occupied at various times since 2006, including those supported by GEF Loan 927.

Analysis of the first ground-based GPS ice-velocity measurements on PIG, taken during the 2006-07 season, showed that the ice is accelerating much further upstream than had been indicated previously (using satellite Interferometric Synthetic Aperture Radar (InSAR) techniques). Further measurements taken in 2007-08 confirmed that this acceleration had continued and that it was directly related to the increase in overall slope of the glacier[2].

More recent InSAR data continued to show rapid changes in the downstream part of PIG, with major retreat of the grounding line and no reduction in the rate of increasing acceleration. Two further ground-based observation campaigns were therefore proposed, to see if the associated changes persist further upstream (beyond the reach of satellite techniques), and to continue a programme of glaciological investigations and studies of basal conditions.

Three GEF GPS receivers were deployed on PIG during the 2010-11 season and this report covers that loan. Two stations were at the same locations as those occupied during 2006-07 and 2007-08. Deployments were also made during the 2011-12 season, which further extend the time-series of observations.

SURVEY PROCEDURE

Operations

Fieldwork operations during the 2010-11 season were severely curtailed by logistics and weather factors. Pine Island Glacier is a difficult place to work, even by polar ice sheet standards. However, considering its current importance to ice sheet evolution and sea level research, all observations, however brief, are extremely valuable. One new station was occupied for 17 days and two established positions were re-occupied for 12 and 4 days.

Station details

Each station comprised a Leica GPS receiver with antenna mounted on an aluminium pole. Power was provided by a 100 Ah sealed gel lead-acid battery with 40 W solar panel and regulator. Sample rate was 10s.

DATA QUALITY AND PROCESSING

Data recovery was >90%. Data were processed by G.H. Gudmundsson using Bernese PPP software[3]; positions were calculated at 30 s epochs. Linearly de-trended displacements (in-line with ice flow) for the three stations are shown in Figure 2. Processing and presenting the data in this way indicates any deviations from constant along-flow ice velocity.

In Figure 2, most of the variability is probably within the observational errors. The only exception to this is the broad, overall trend at India110 (Fig. 2c) in which generally positive values in the early part of the record, change to negative in the middle and back to positive towards the end. This could be indicating a real seasonal variability in the ice flow[2], or else the effect of bed and/or surface ice topography as the station moves over it.

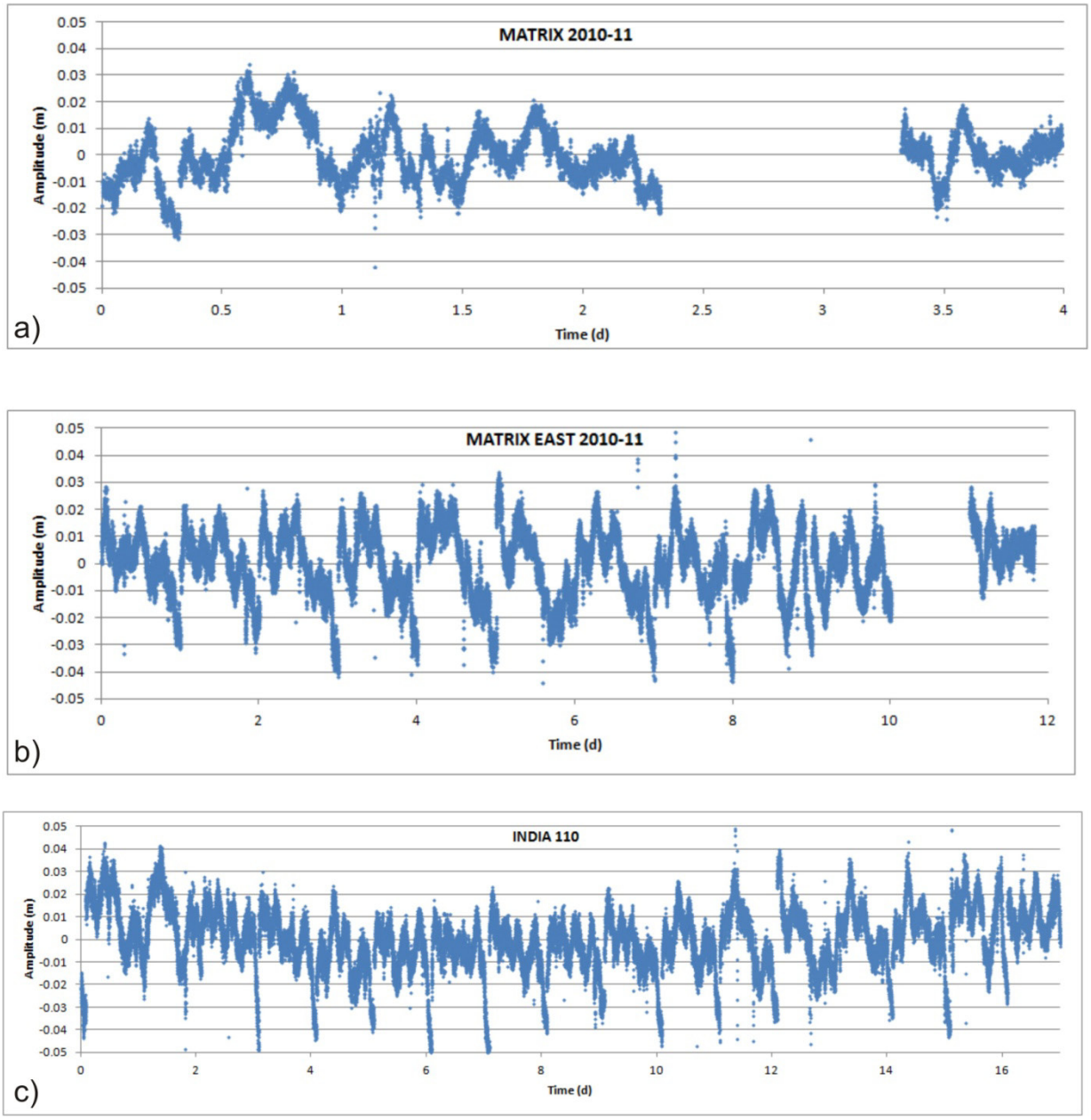

Figure 2. Results of GPS data acquired on PIG in 2010-11 (Loan 927). Graphs show linearly detrended, in-line displacement. Note different horizontal scales.

Data are also available from re-occupation of one of the established positions in the following season (2011-12). These are shown in Figure 3

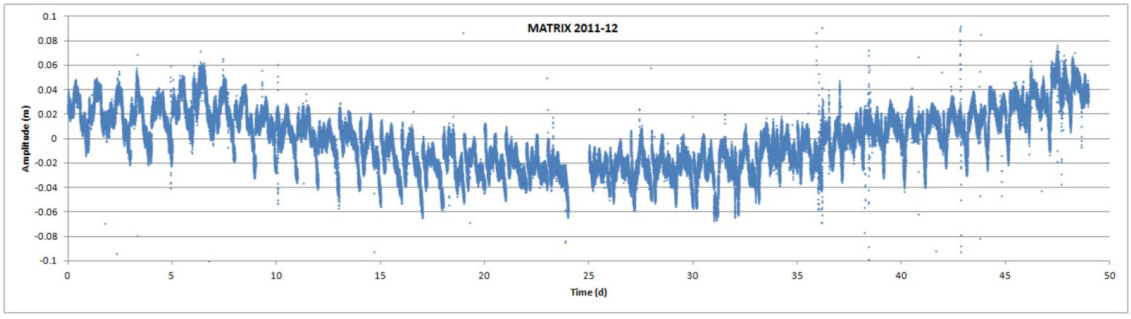

Figure 3. Results of GPS data acquired at Matrix station in 2011-12. Graph shows linearly detrended, in-line displacements.

INTERPRETATION AND PRELIMINARY FINDINGS

Table 1 shows the mean, GPS-derived ice flow speeds for the recording periods at the three stations occupied in 2010-11 (Year 2011). Also included are the equivalent results from 2006-07, 2007-08 and for one station in 2011-12.

Year	Matrix West	Matrix	India110	Matrix East	Matrix South
2007	1962	867		313	
2008	2075	907		325	319
2009					
2010					
2011		1018	631	363	
2012		1029			

Table 1. GPS-derived ice flow velocity (m a^{-1}) at established locations on Pine Island Glacier.

Acceleration has continued at all stations during the period of observations, as illustrated in Figure 4. Until 2012 there was little indication of a change in the acceleration of the glacier, but the single station, processed so far, for 2012 does suggest that the rate of increase may be slowing, in this part of PIG, at least.

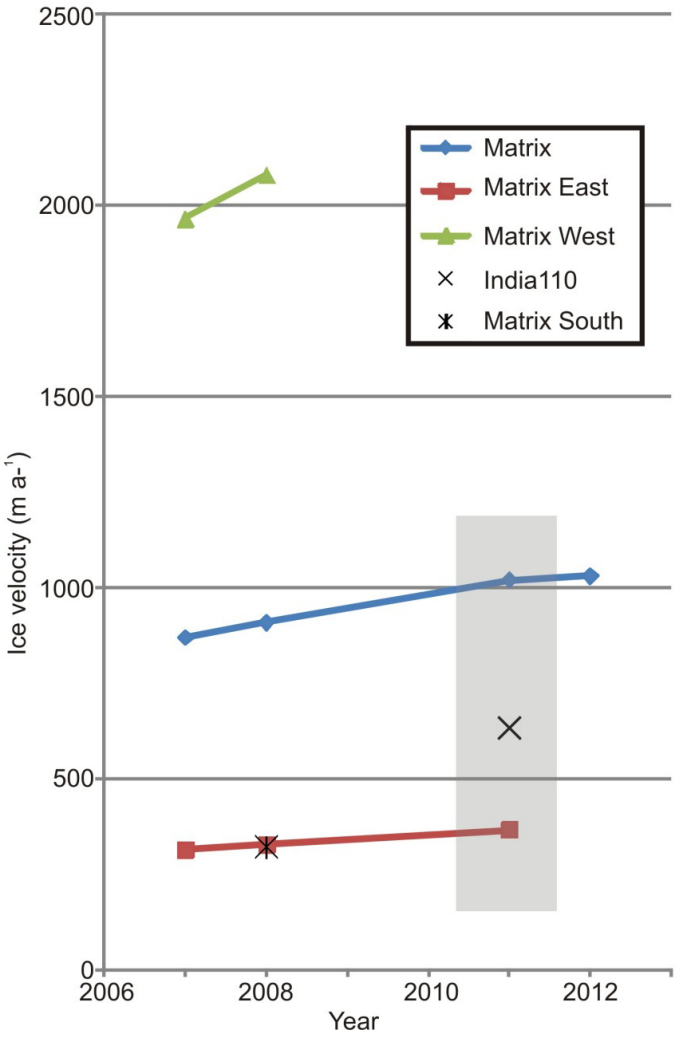

Figure 4. Summary of all ground-based (GPS) ice velocity measurements from Pine Island Glacier. Grey band indicates those from GEF Loan 927.

PROVISIONAL CONCLUSIONS AND FUTURE PLANS

A few basic conclusions are indicated by the data so far. In agreement with satellite observations, ice velocity has continued to increase at all the stations that have seen multiple occupations. Only in the most recent measurement is there any indication that the rate of acceleration may be beginning to reduce. Ground-based GPS measurements complement satellite-derived data in two ways. Firstly, they extend velocity measurements further upstream beyond the satellite limit and secondly, they give continuous records which can indicate seasonal or other short-period variabilities in the ice flow.

Progress on the whole Pine Island Glacier project has been delayed by the departure, and non-replacement, of the person appointed to work on the data. As a result, the plan for future progress with these current data has been revised. The GPS data will be incorporated into projects of iSTAR, NERC's Ice Sheet Stability Research Programme. iSTAR will carry out a more comprehensive 2-year campaign of glaciological and geophysical experiments across the whole Pine Island Glacier drainage basin, including year-round GPS stations, as well as seismic and radar surveys, ice core drilling and accumulation studies. Some of the established GPS locations will be re-occupied as part of iSTAR which will extend the records discussed here.

DATA MANAGEMENT

The data acquired from Loan 927 have been archived with NERC's Polar Data Centre (PDC).

REFERENCES

1. Rignot, E., et al. (2008), Recent Antarctic ice mass loss from radar interferometry and regional climate modeling, *Nature Geosci., 1,* 106–110.
2. Scott, J.B.T. et al. (2009), Increased rate of acceleration on Pine Island Glacier strongly coupled to changes in gravitational driving stress, *The Cryosphere*, **3**, 125-131.
3. See e.g. Gudmundsson, G. H. (2007), Tides and the flow of Rutford Ice Stream, West Antarctica, *J. Geophys. Res.*, 112, F04007, doi:10.1029/2006JF000731.

APPENDIX

Station	Lat (S)	Long (W)	Elev (m)	Input date	Uplift date	Duration (hr)	Sample interval (s)
Matrix	75° 24.2	95° 52.4	648	18/1/2011	22/1/2011	100	10 s
India110	75° 23.4	95° 02.4	694	3/1/2011	21/1/2011	424	10 s
Matrix East	75°27.3	93° 43.1	717	10/1/2011	22/1/2011	290	10 s

Table A. Deployment information for GPS stations occupied during 2010-11 season.