Calving and velocity variations observed by Terrestrial Radar Interferometry at Jakobshavn Isbræ, Greenland, in 2015

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Key points:

- The highly dynamic terminal zone of Jakobshavn Isbræ in Greenland was observed with a Terrestrial Radar Interferometer (TRI) at a sampling rate of 90 seconds for 5 days in early June, 2015.
- Velocity time series show that calving events are characterized by sudden fluctuations in the mélange and smaller variations in the glacier.
- A 1.5 km wide zone in front of the glacier moves in phase with the K1/M2/S2 tides, and there is a distinct phase-lag upstream. This may indicate the location of the grounding line.
- DEM time series show elevation increases at the glacier front before calving events.

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Fig 1. TRI set-up at Jakobshavn Isbræ, Greenland, from 6 to 10 June 2015

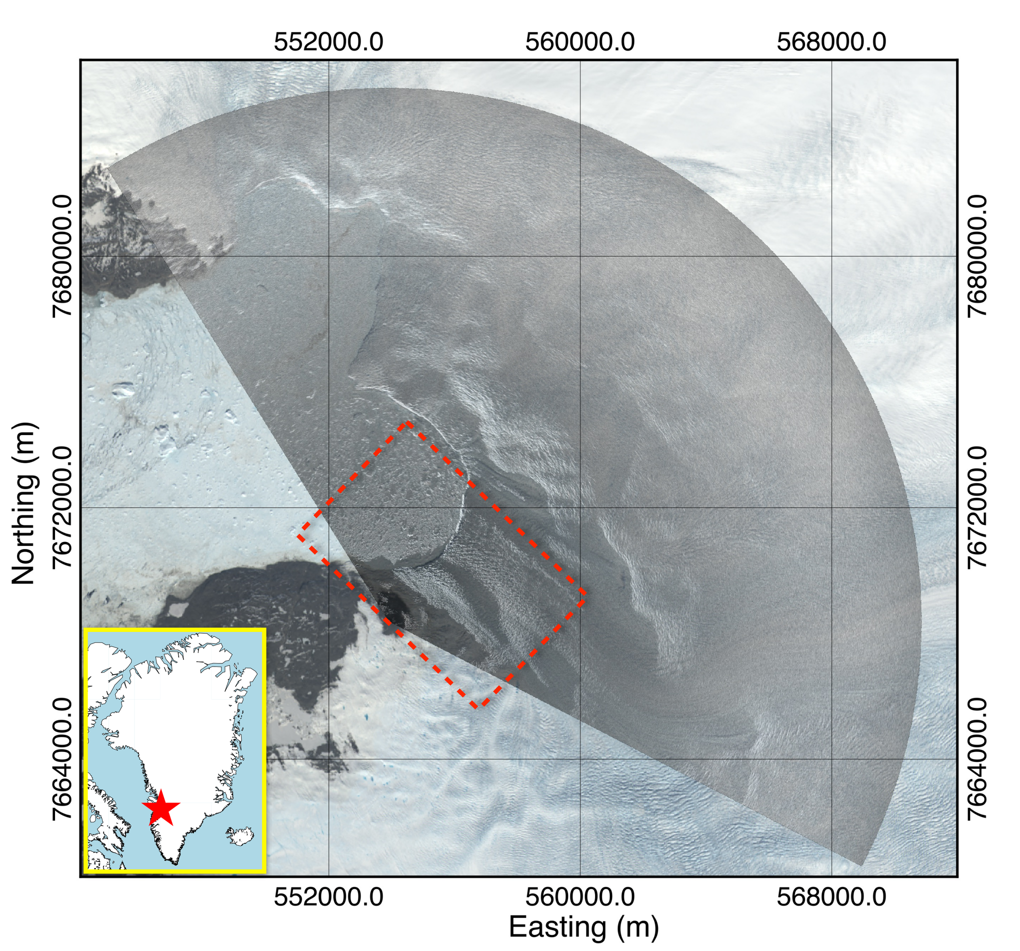

Fig 2. TRI intensity image overlain on a Landsat image (4 June 2015), the radar scanned a 150° arc area at a sampling rate of 90 seconds. Dashed red rectangle outlines the area shown in the figures 3, 7 and 8(a). The coordinates are in UTM zone 22N.

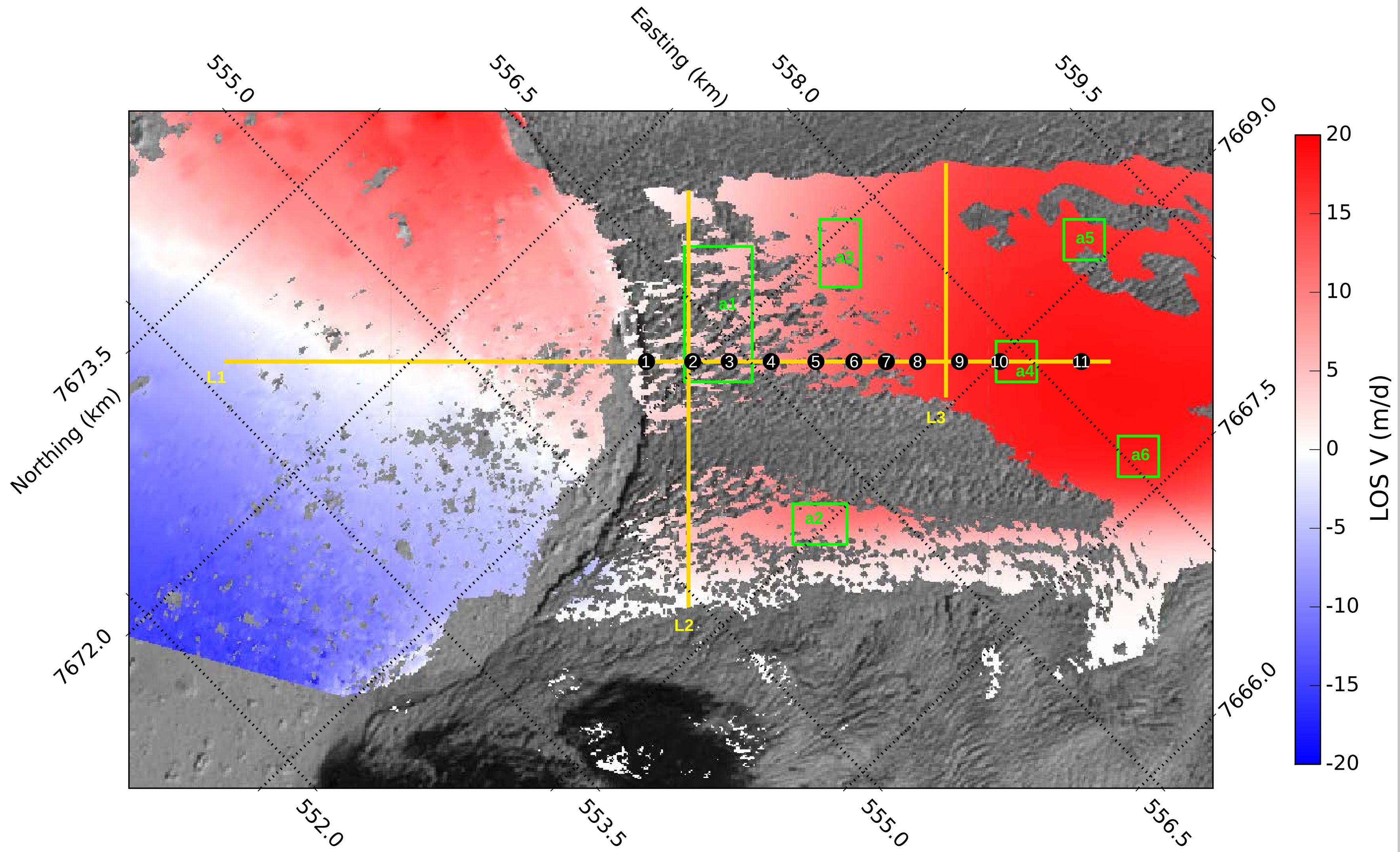

Fig 3. Averaged line-of-sight (LOS) velocity map overlain on a Landsat image, points with less than two days' data are masked out, the velocity is positive if ice moves toward the TRI. Three yellow lines (L1-L3) indicate profiles of velocity in Fig 4. Black balls 1-11 correspond to the points (1)-(11) we plot velocity time series in Fig 5. Six green boxes (a1-a6) outline the samples we use to do power spectral analysis in Fig 6 (a-f).

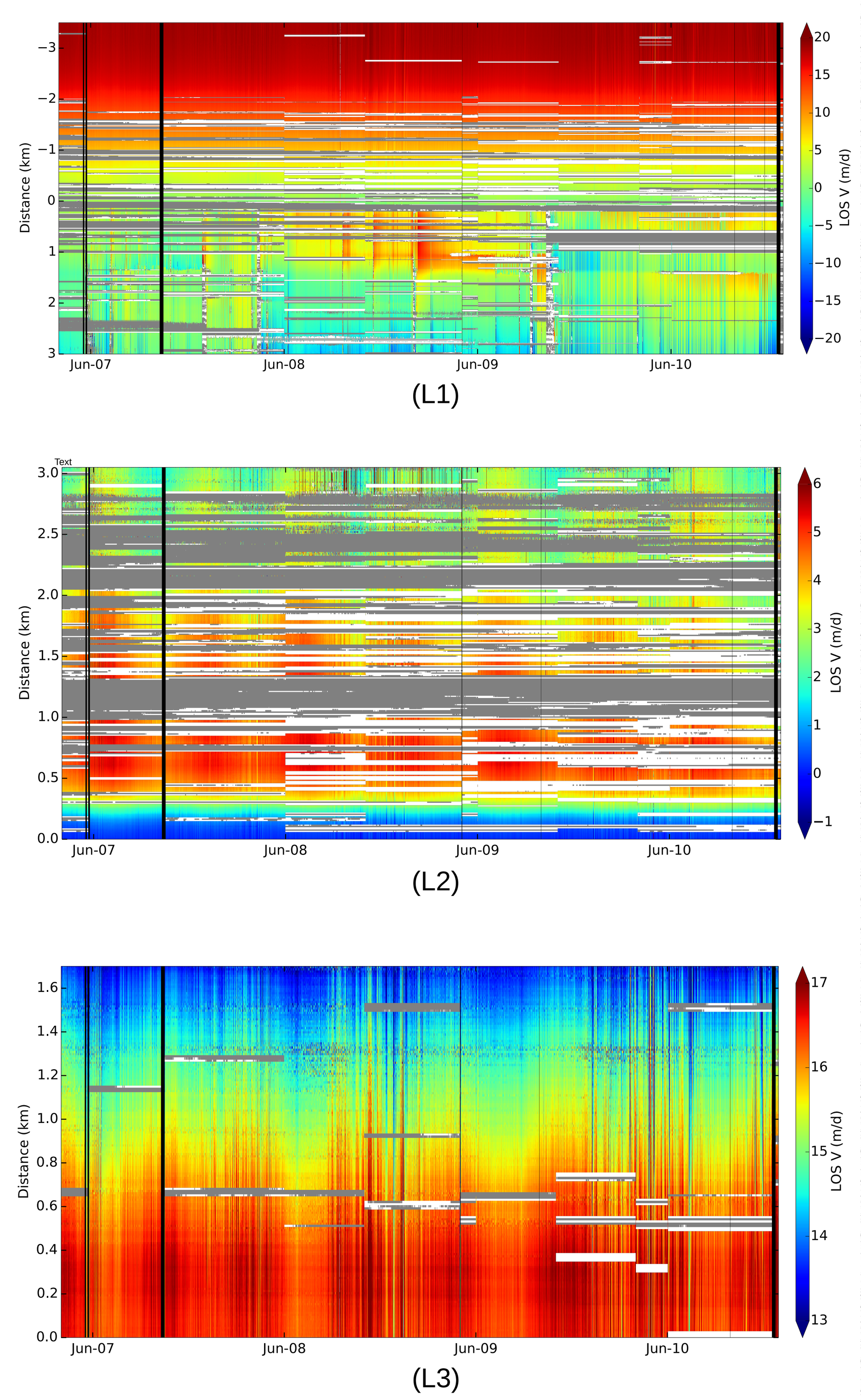

Fig 4. Velocity profiles of L1-L3 on Fig 3. Black vertical bands are data gaps, grey color means the point is under shadow (no measurement), white color means there is no velocity estimate because of low coherence. For L1, Distance is the distance from the cliff, upstream distance is negative. For L2 and L3, Distance is the distance to the starting point on L2/L3 that is close to the TRI. We can see the semi-diurnal variations on L2 and L3.

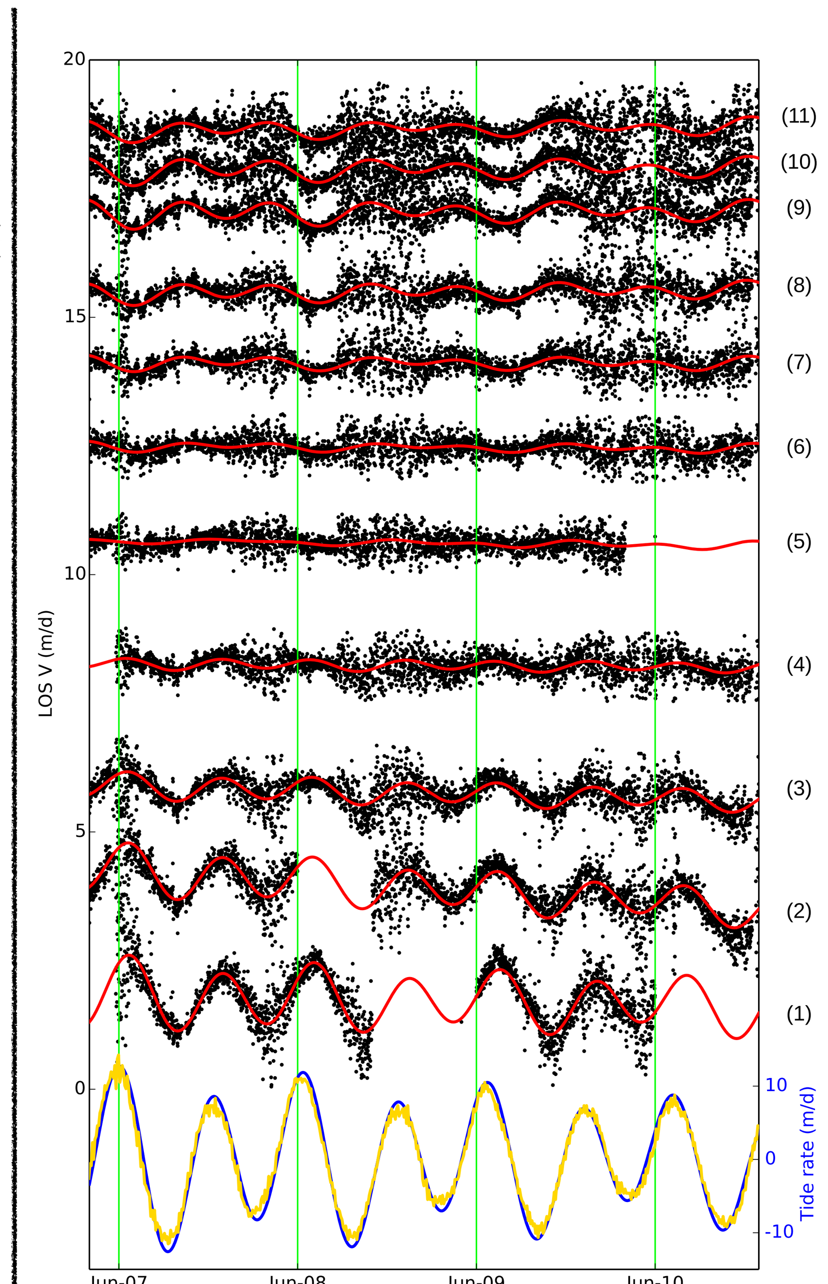

Fig 5. LOS velocity from TRI (black) and tide rate (blue) time series, we use (1) - (11) to indicate different points on Fig 3. Red curves are fitting curves of LOS velocities, by considering linear velocities and three periodic signals with the same frequencies as K1/M2/S2 tidal constituents, tide induced velocity perturbations are analyzed by using inference method described in *Davis et al.* [2014], tide constituents in Ilulissat are based on *Richter et al.* [2011]. We derive the tide height to get tide rate, blue line is the predicted tide rate based on *Richter et al.* [2011], yellow line is the tide rate derived from measured tide height time series (10 minutes' sampling rate) from the mooring at the mouth of the fjord at Jakobshavn. Notice the phase lags increase rapidly between (4) and (5).

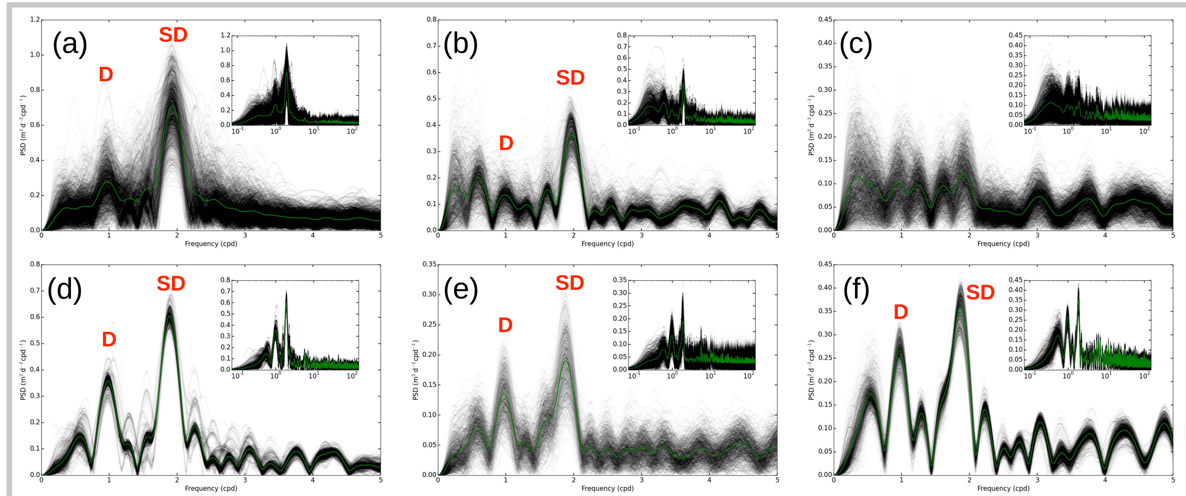

Fig 6. Stacked power spectral density (PSD) estimates of the velocity time series for selected areas, (a-f) correspond to a1-a6 on Fig 3. Green curves are the mean values. We use the Lomb-Scargle method [*Lomb*, 1976; *Scargle*, 1982] to estimate the PSDs, the PSDs shown here are normalized. Except for (c), all other samples show distinct diurnal and semi-diurnal signals (labelled by D and SD).

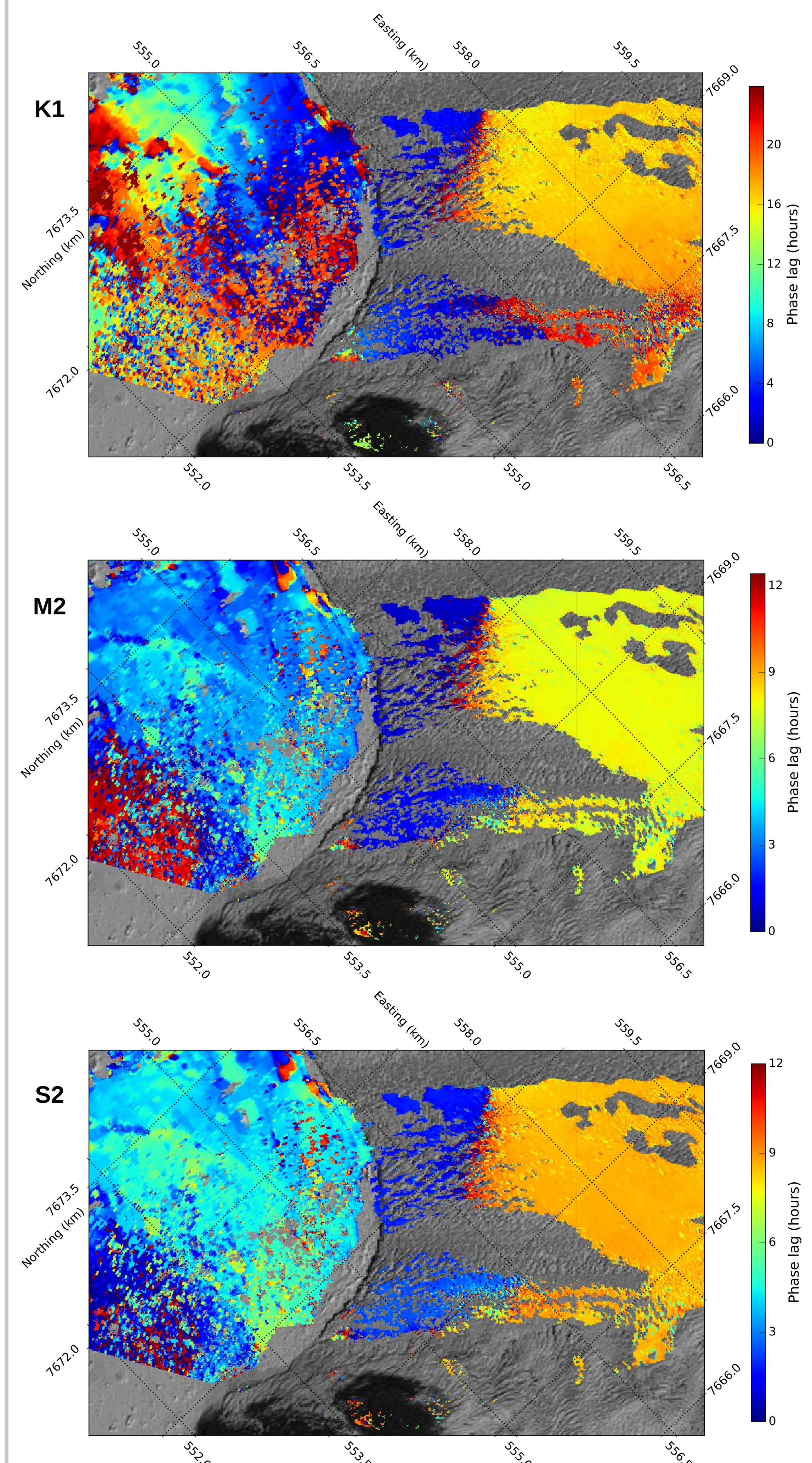

Fig 7. Phase lags for tide constituents K1/M2/S2 overlain on a Landsat image. One color cycle corresponds to one period, so the phase of red is close to the phase of blue.

Richter et al., [2011] extracted major tidal constituents in Ilulissat based on multi-year pressure tide-gauge observations. K1/M2/S2 are the largest three constituents, with amplitudes of 331.1/670.8/273.3 mm. By using only ~4 days' data, we can not determine the complete spectrum of tidal-induced velocity signals. In this research, we focus on these three major tidal constituents, and use the inference method [*Davis et al.*, 2014] to estimate their amplitudes and phases from the velocity time series. Fig 5 shows the fitting curves based on the inference results.

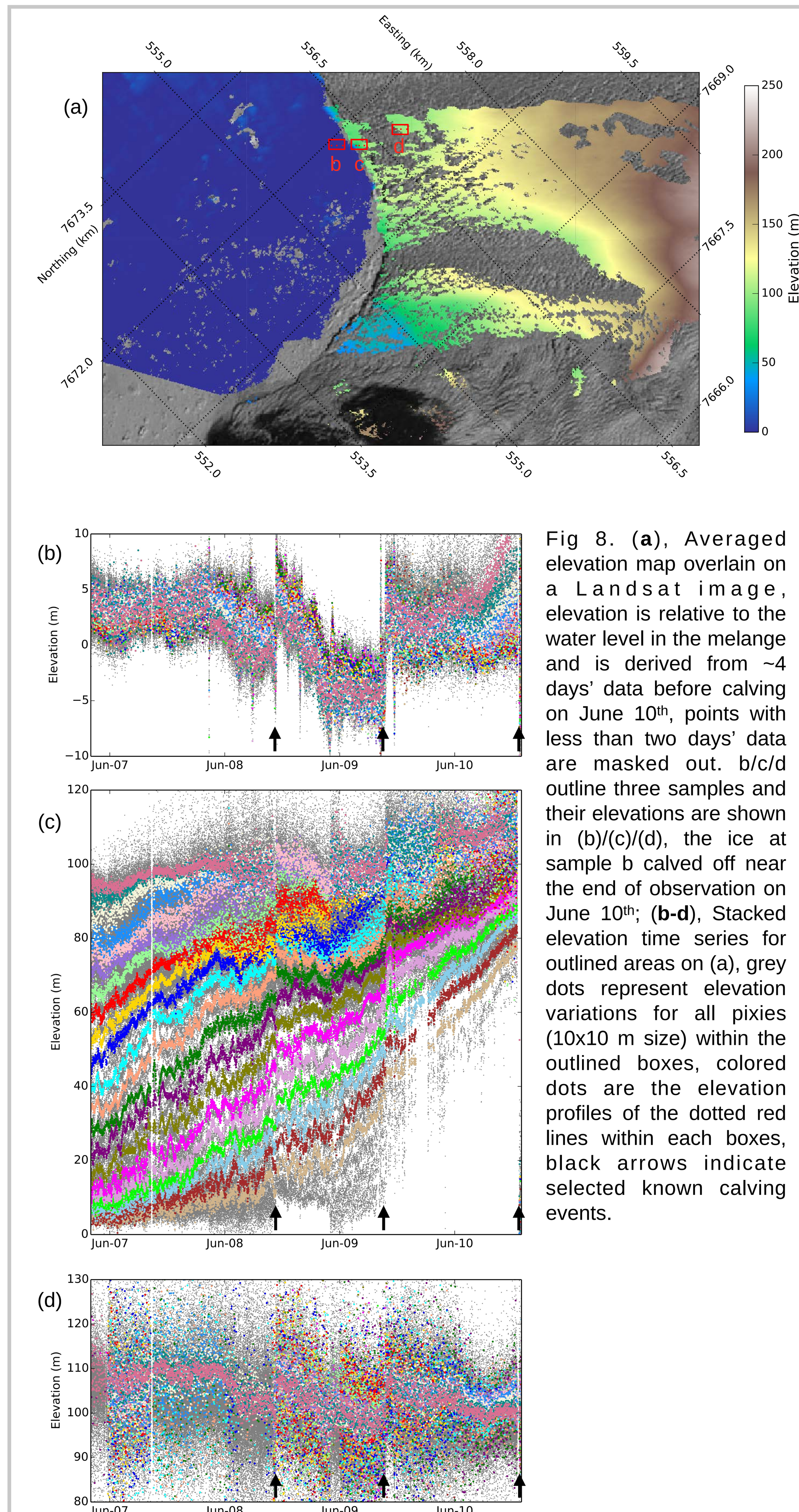

Fig 8. (**a**), Averaged elevation map overlain on a Landsat image, elevation is relative to the water level in the melange and is derived from ~4 days' data before calving on June 10th, points with less than two days' data are masked out. b/c/d outline three samples and their elevations are shown in (b)/(c)/(d), the ice at sample b calved off near the end of observation on June 10th; (**b-d**), Stacked elevation time series for outlined areas on (a), grey dots represent elevation variations for all pixies (10x10 m size) within the outlined boxes, colored dots are the elevation profiles of the dotted red lines within each boxes, black arrows indicate selected known calving events.

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