Cryosat2 altimetry of BC coastal mountain glaciers

Jim Gower
IOS, Sidney, BC, Canada
jim.gower@dfo-mpo.gc.ca

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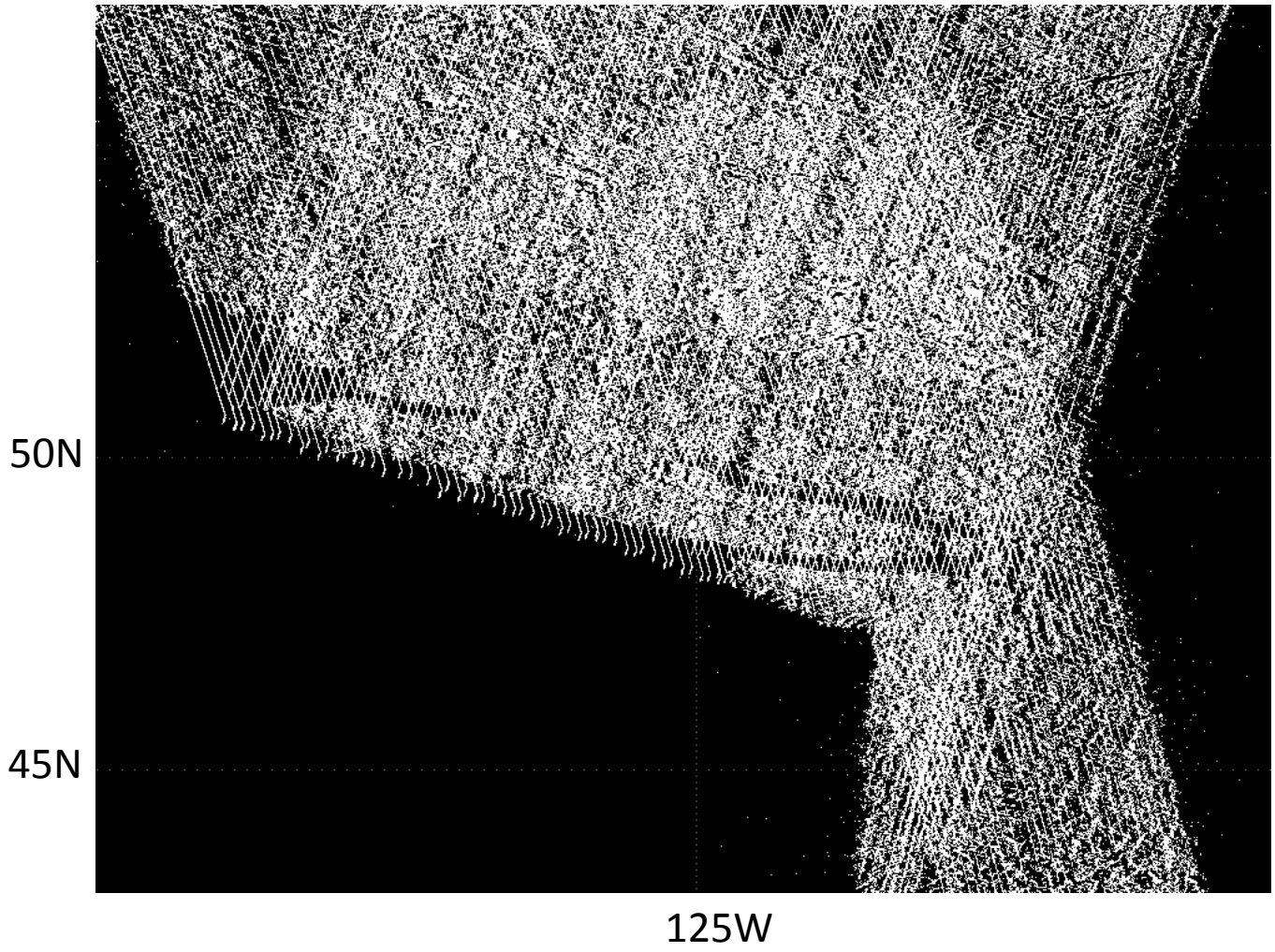
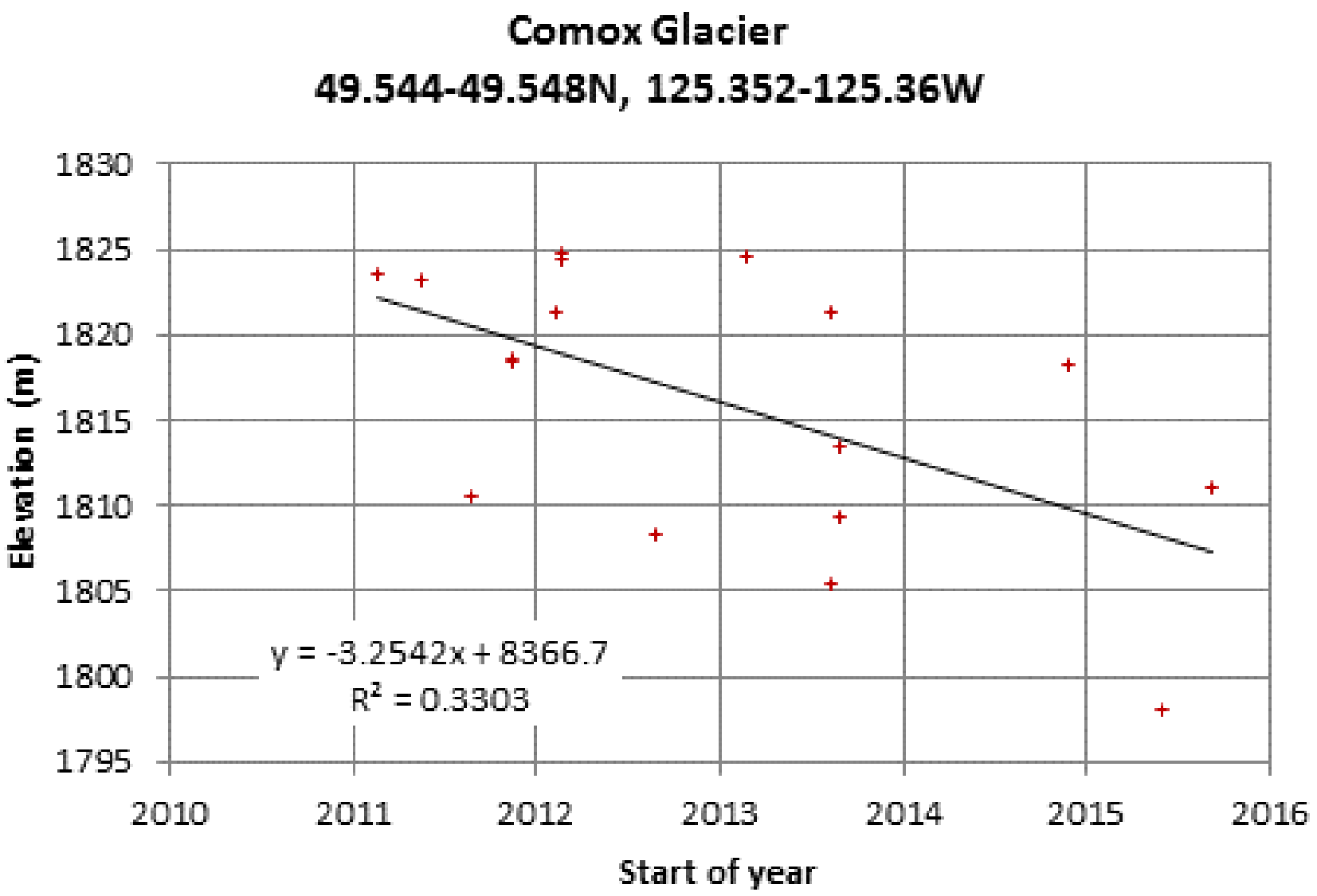


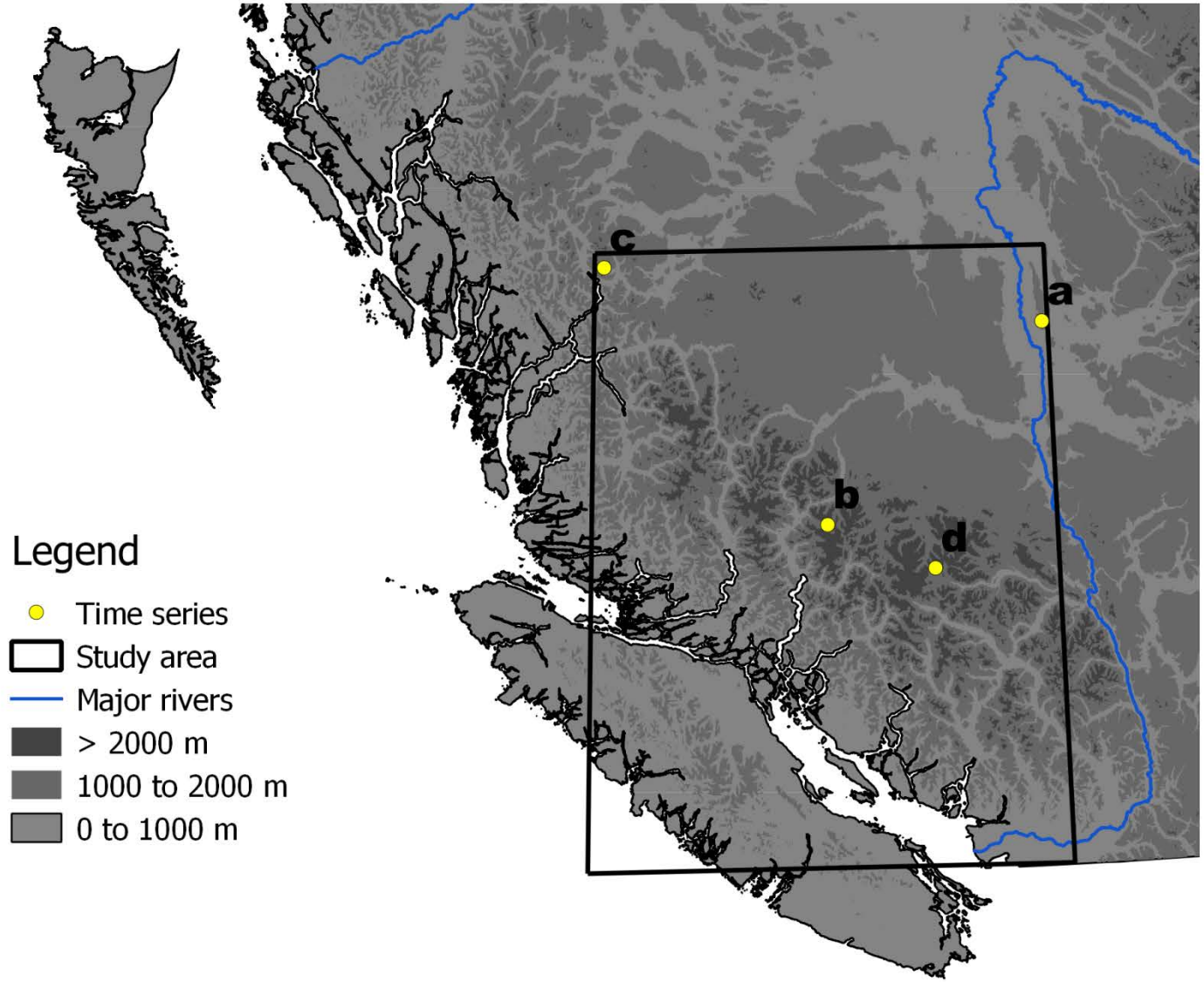
Locations of the Cryosat 2 data set acquired to study synthetic aperture altimetry in coastal areas

Comox Glacier, Vancouver Island, Canada

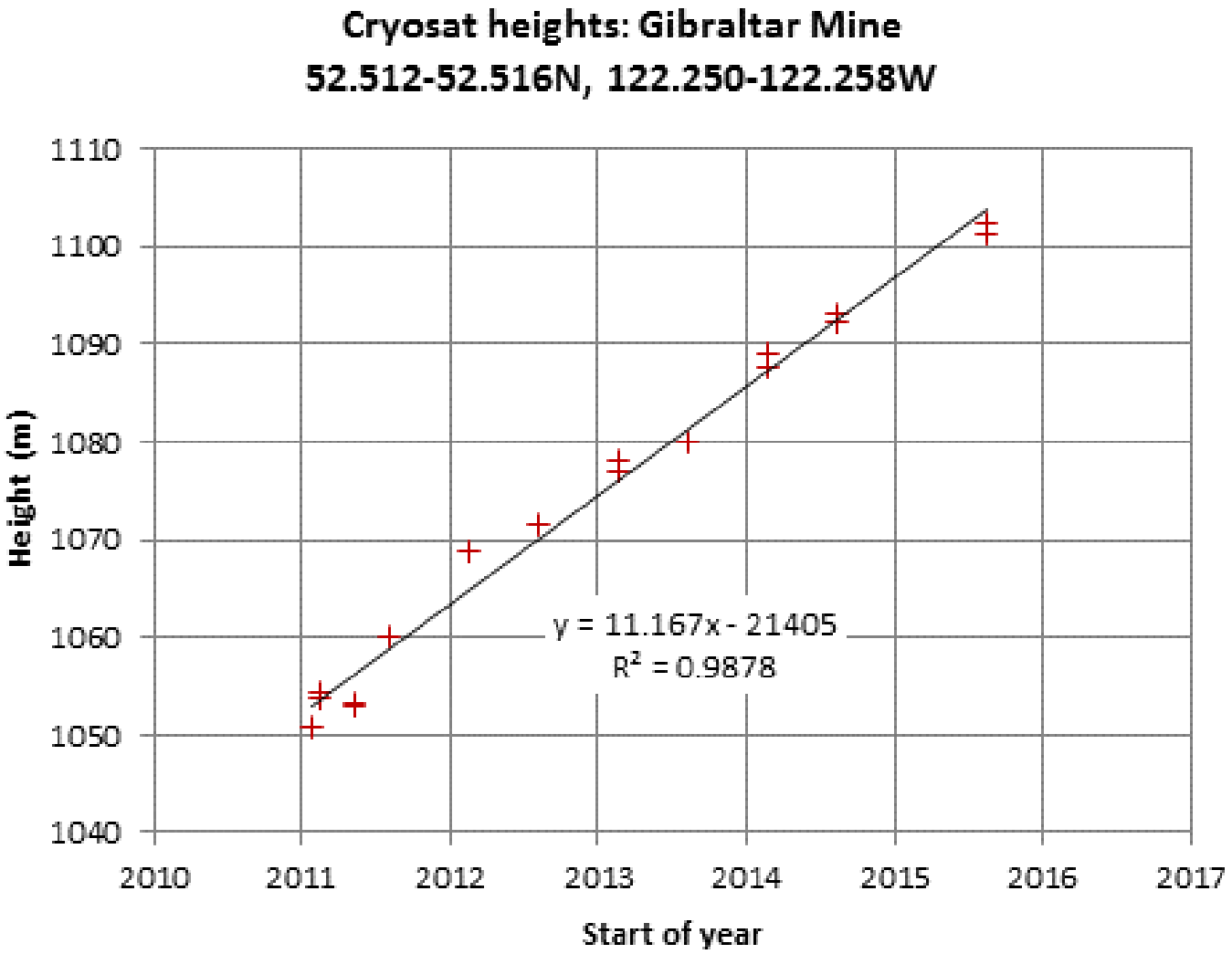


First look at my local Comox glacier

500X500m area. 3 m/year, but scatter=6.5m. P=.016



Study area is 49 to 53N, 127 to 122.8W. We search all 500m by 500m areas in this box looking for significant elevation trends over 2010 to 2016



Example #1: The most significant slope in the data set is a growing (11.2m/year) pile of waste rock at a copper mine (scatter= 2.0m)

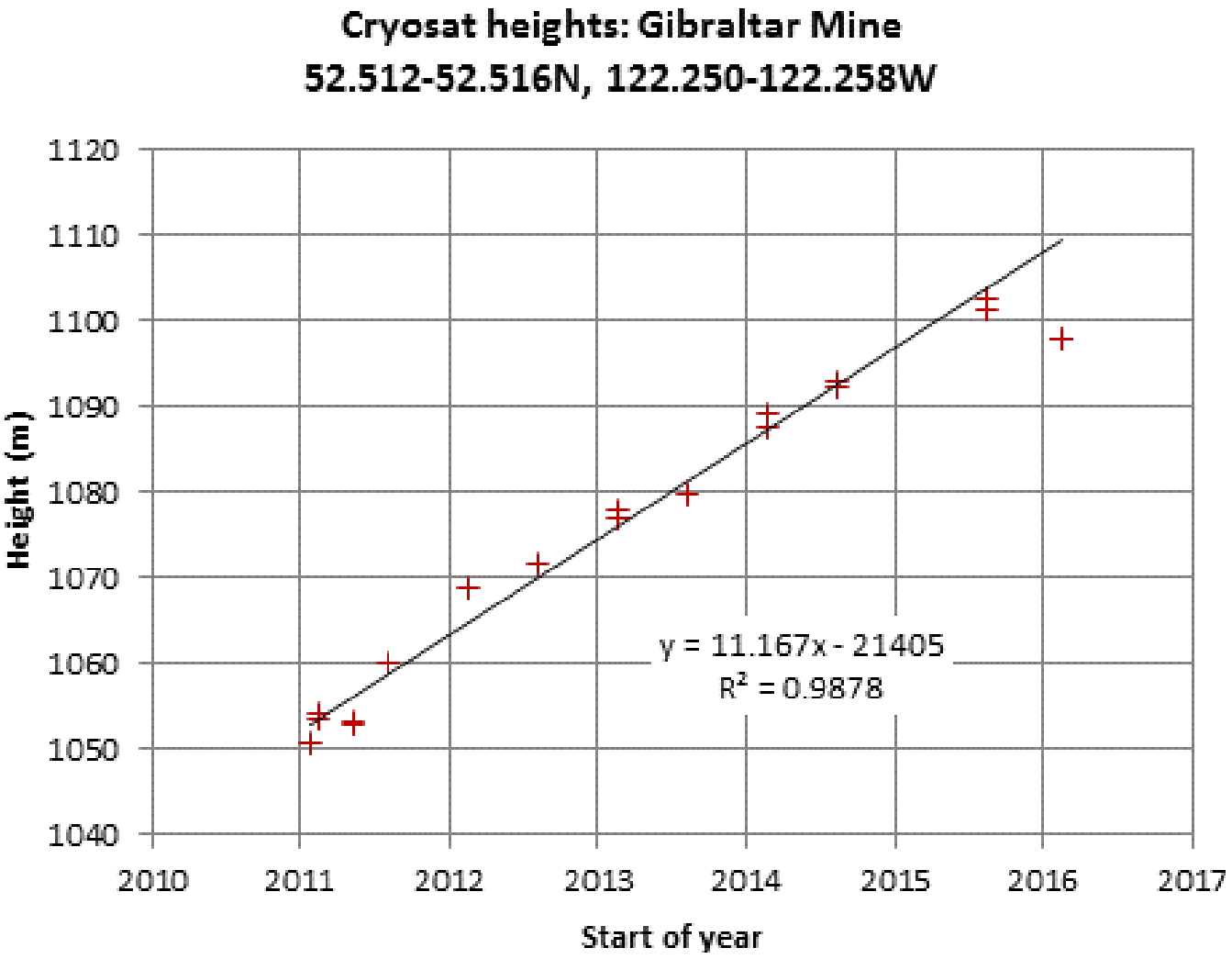
Gibraltar Mines site as shown by Google Maps

“My initial thoughts are you are registering the change in our waste rock dump from the mine, but I would have expected to see the recorded height level off as we build them to a certain height as per our permit.”

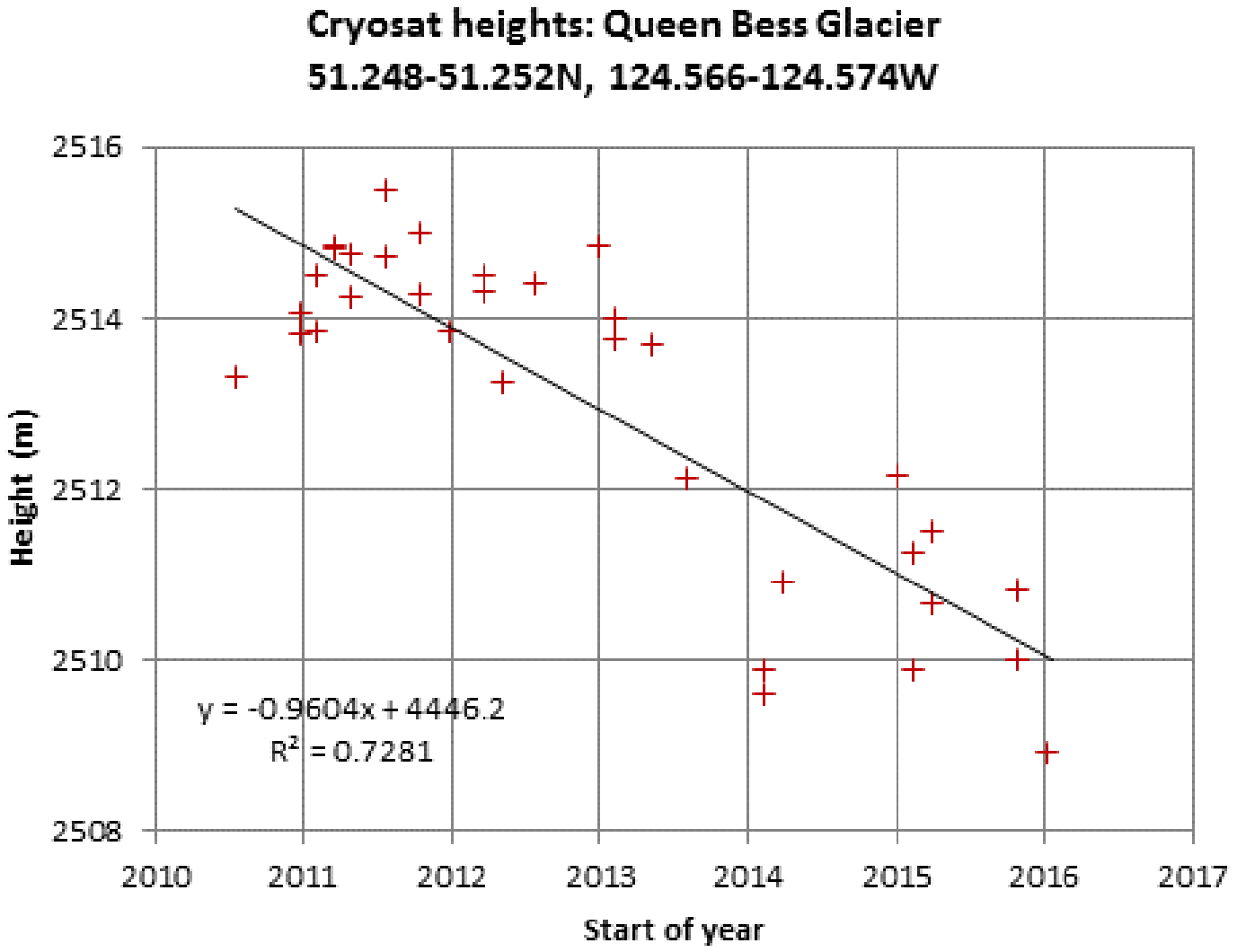
Richard Tremblay, P. Eng. Taseko Mines, 6 Aug 2016

“What you are picking up is our 20 dump which is a waste rock dump. This dump is backfilling a previously mined out pit which is in keeping with your observation of the level starting below grade. Our dumping at that location was completed around Q3 last year so you should not have seen any real increase in elevation since then.”

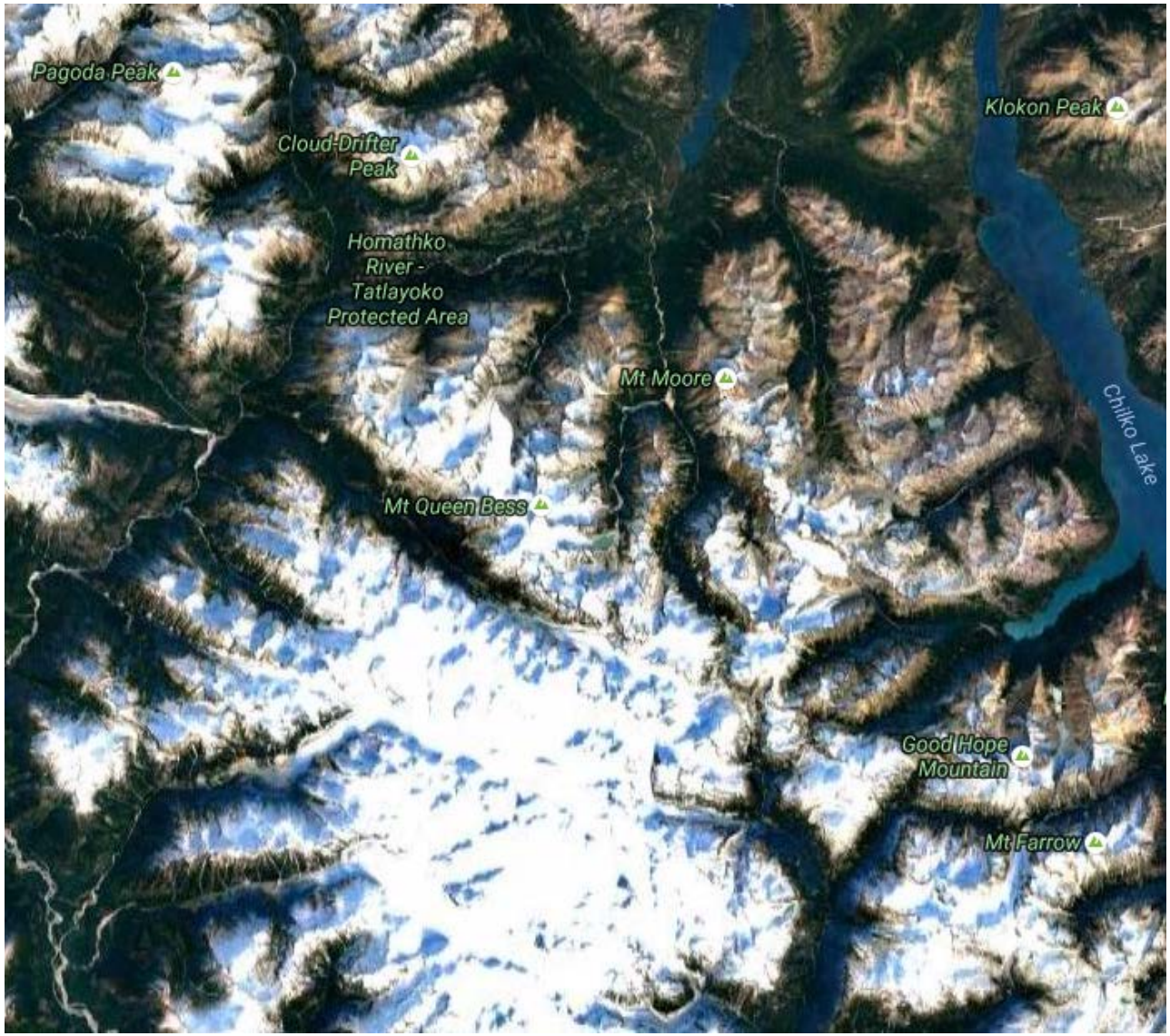
Richard Tremblay, P. Eng. Taseko Mines, 15 Aug 2016



Updated data show no further increase, as promised

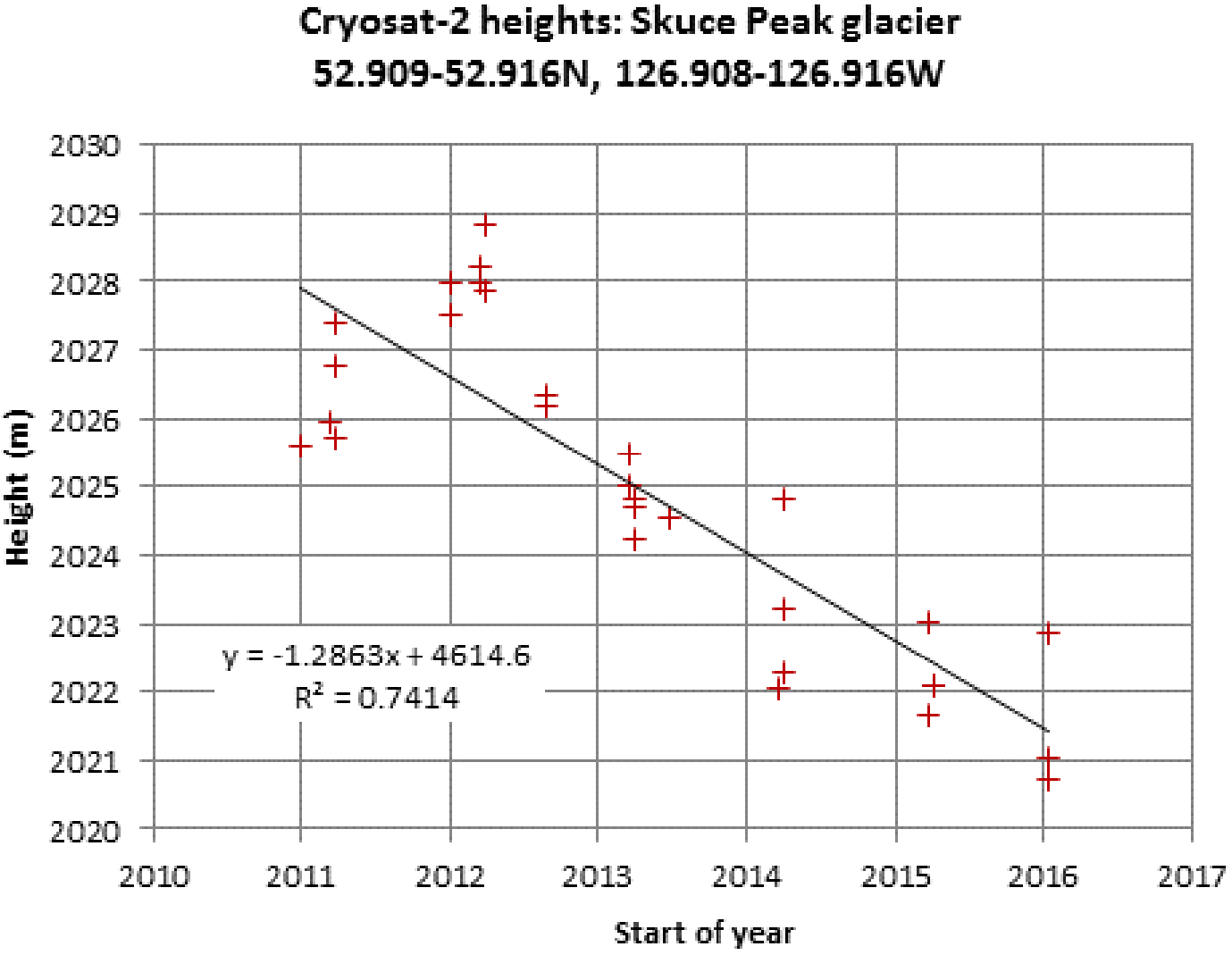


Example #2: Returns from a large glacier give a significant melt rate, 1m/yr over 6 years. Scatter=1.0m

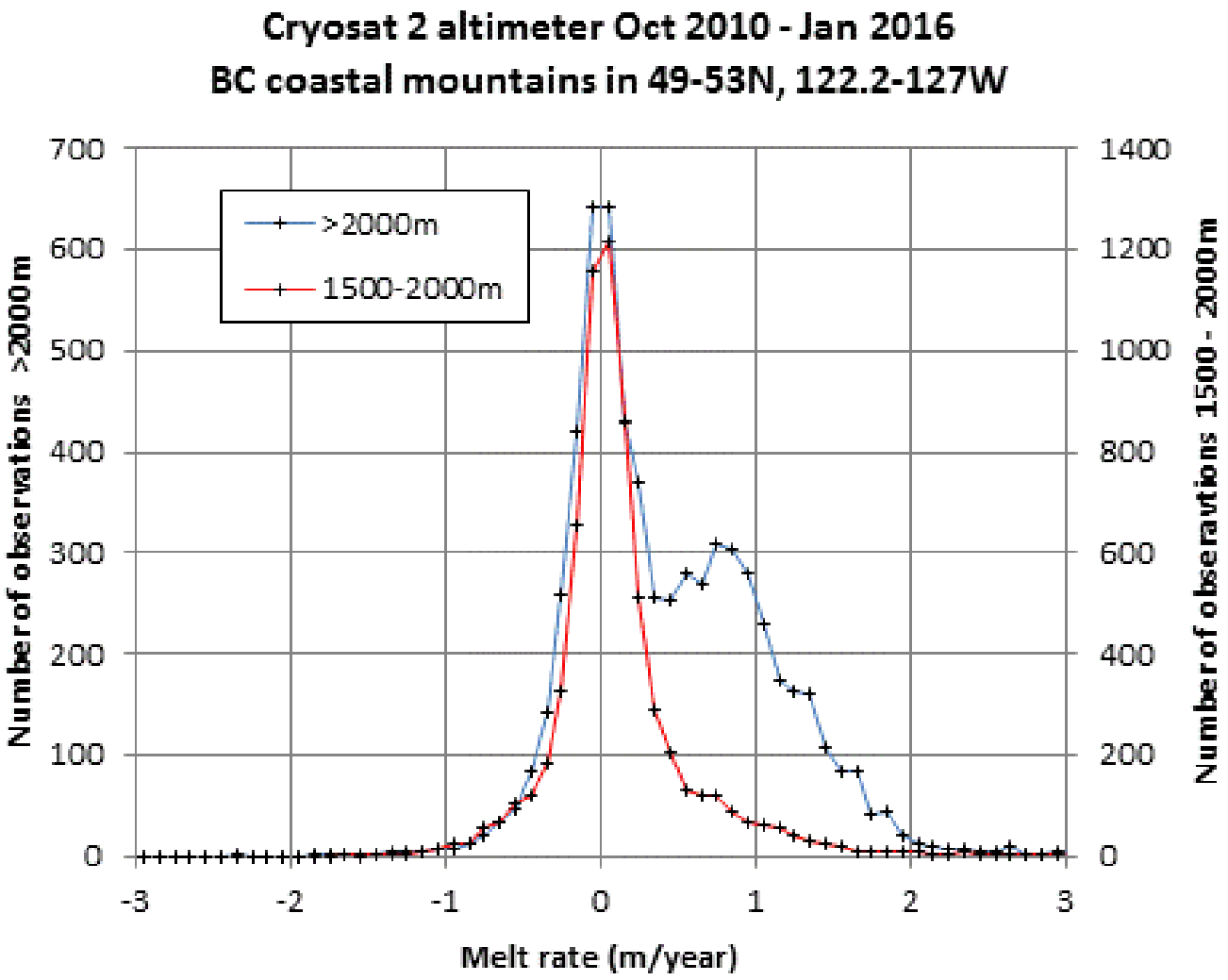


Queen Bess Mt, to the north of the Homathko Icefield

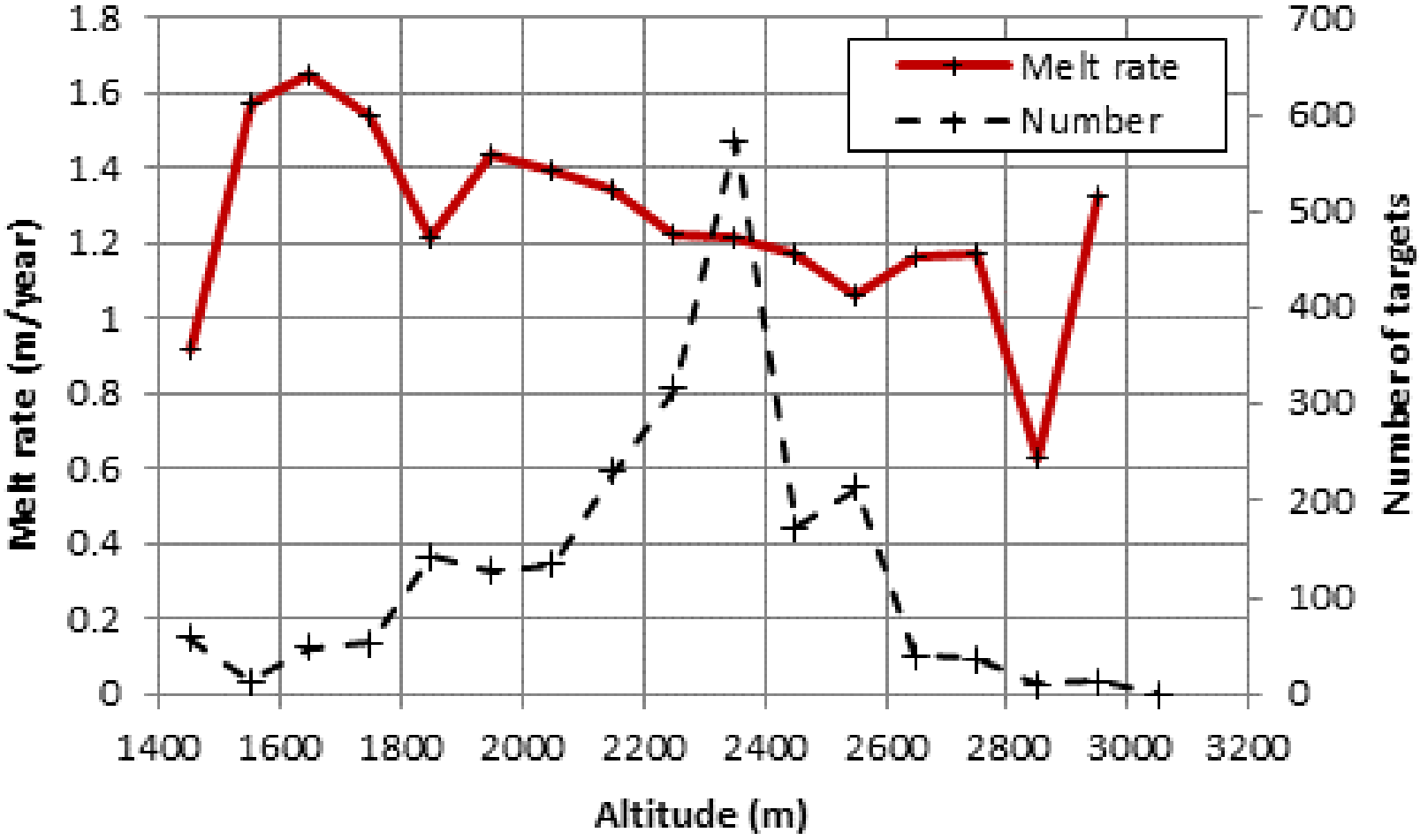
Time series is from a small area in the centre of this image



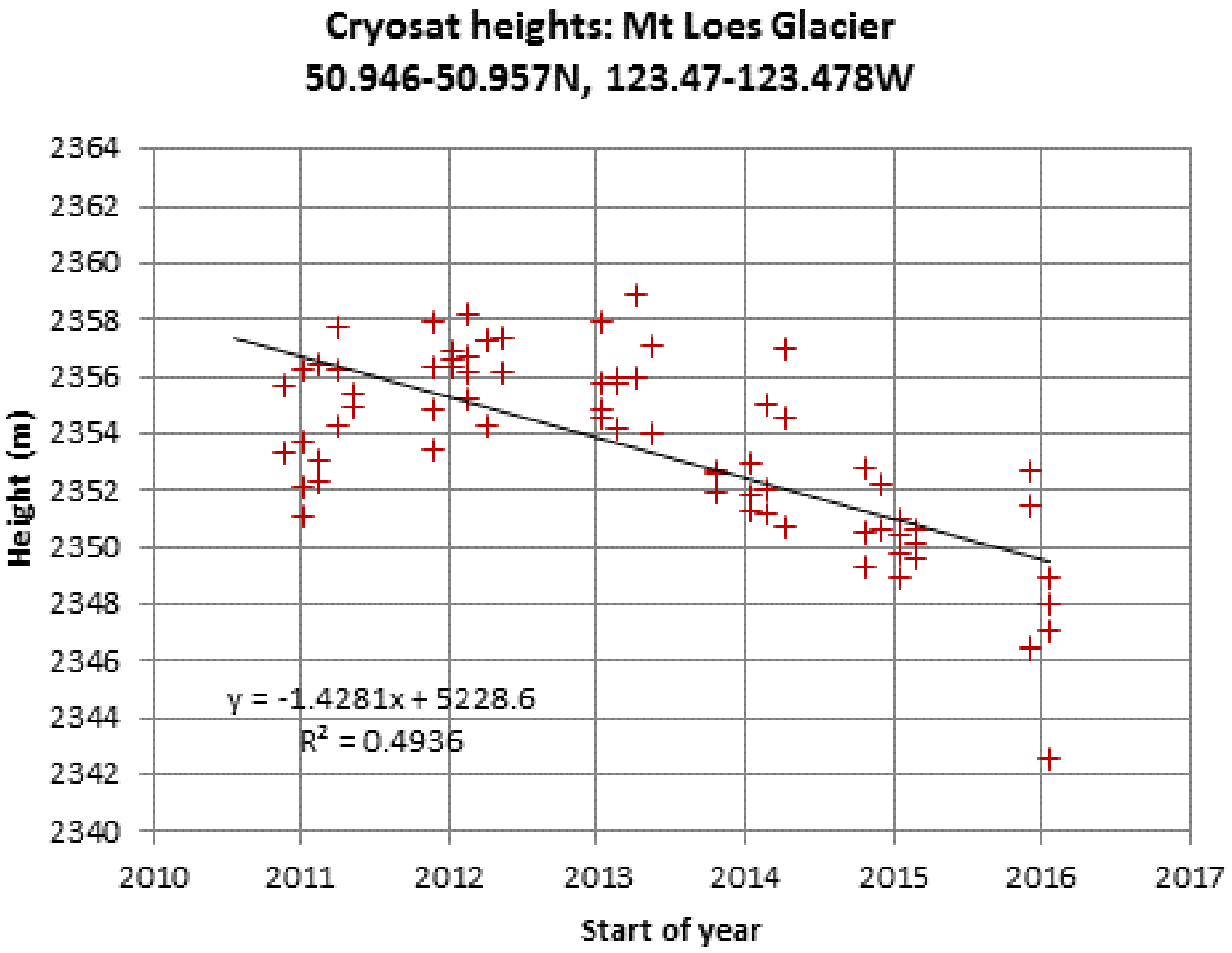
Example #3: Returns from a lower glacier give a higher slope, 1.3m/yr over 6 years, scatter=1.2m.



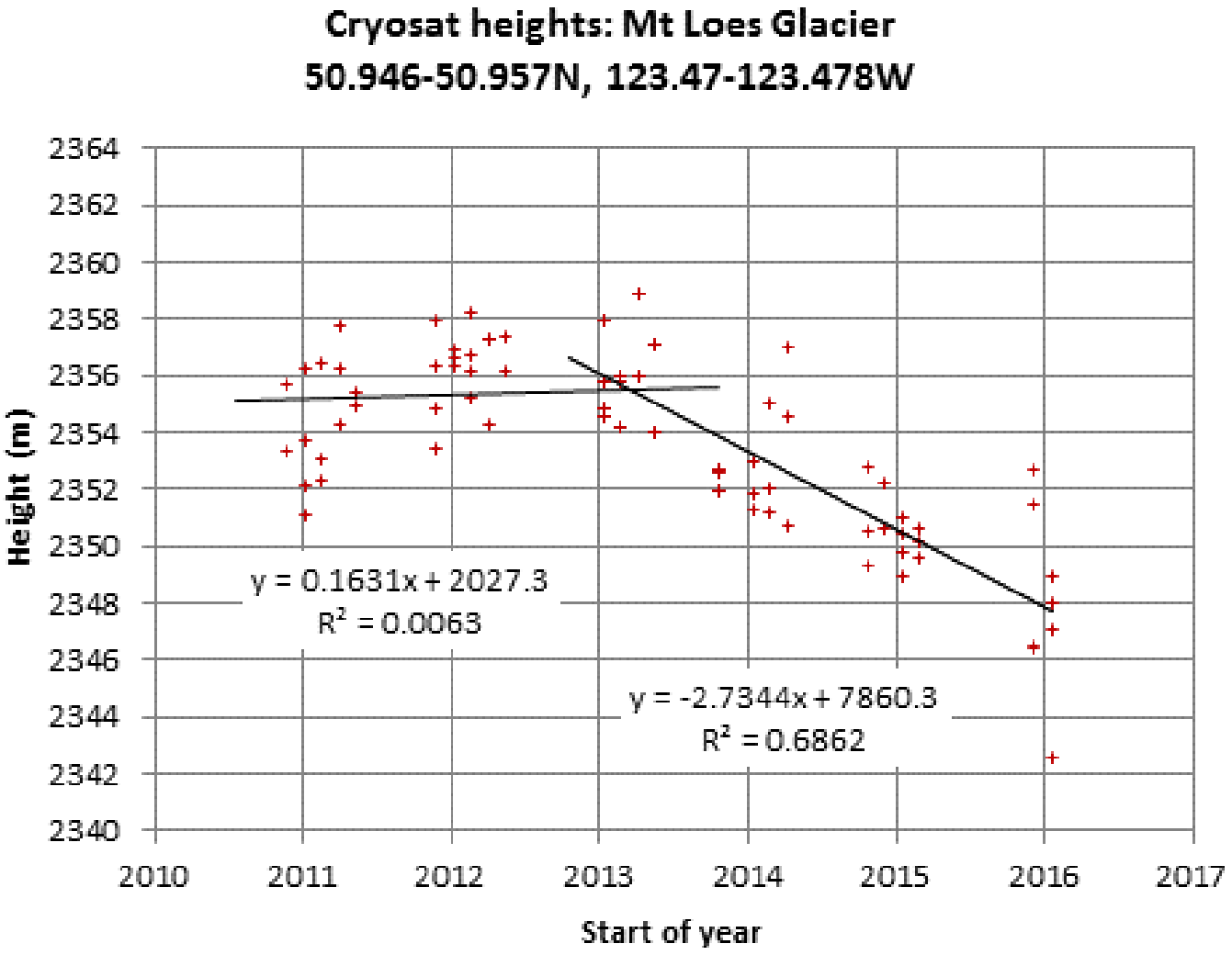
Cryosat2 melt rates for 500m areas for the full time period.
Below 2000m (red): no observed elevation change.
Above 2000m (blue) double peak with melt rates to 2m/year.



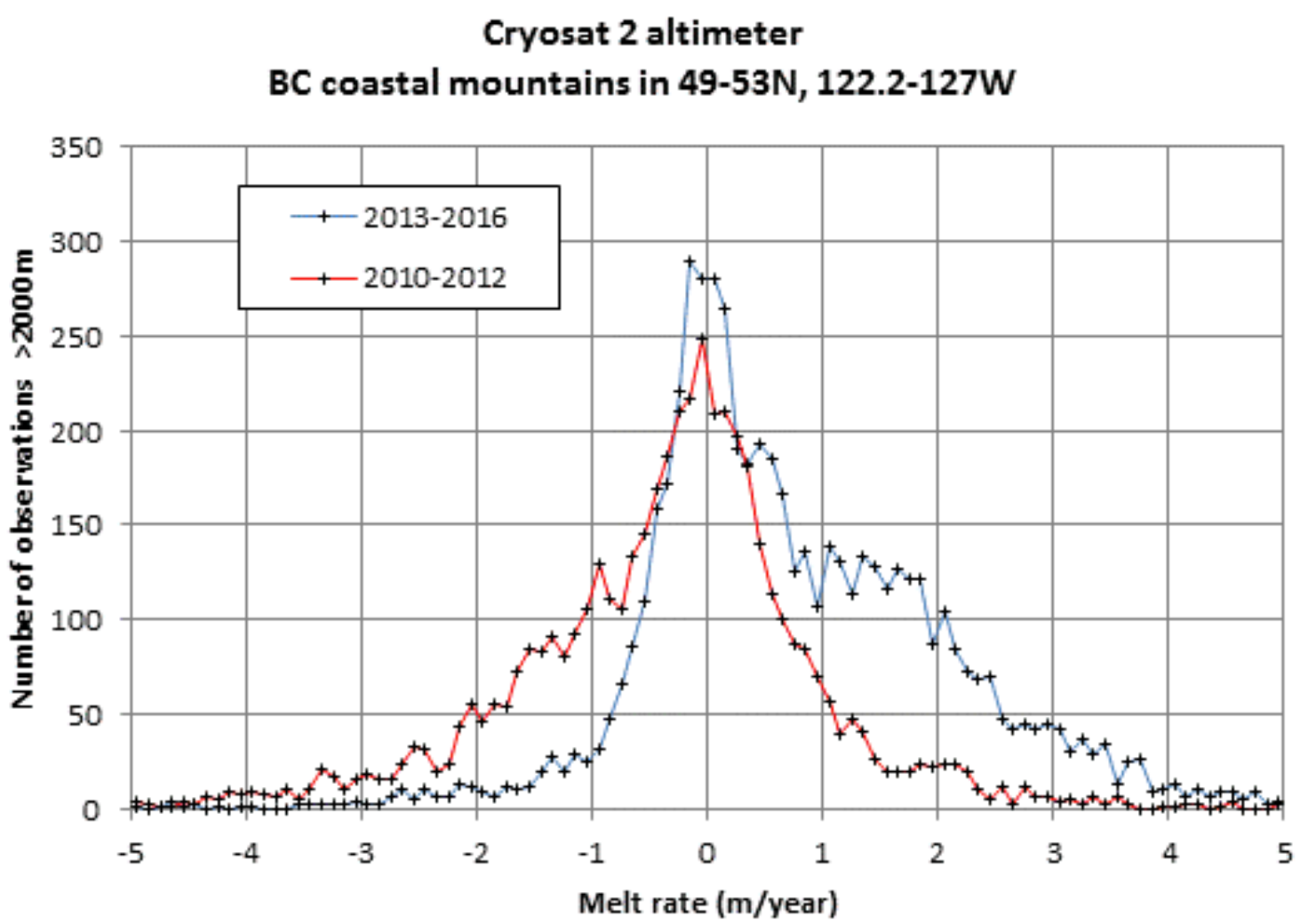
Variation of average melt rate in steps of 100m from 1400 to 3000m elevation (solid red line). Number of sub-regions included in each average (dashed line). Between 1500m and 2800m altitude, melt rates show a roughly linear decrease from 1.6 to 1.0m/year.



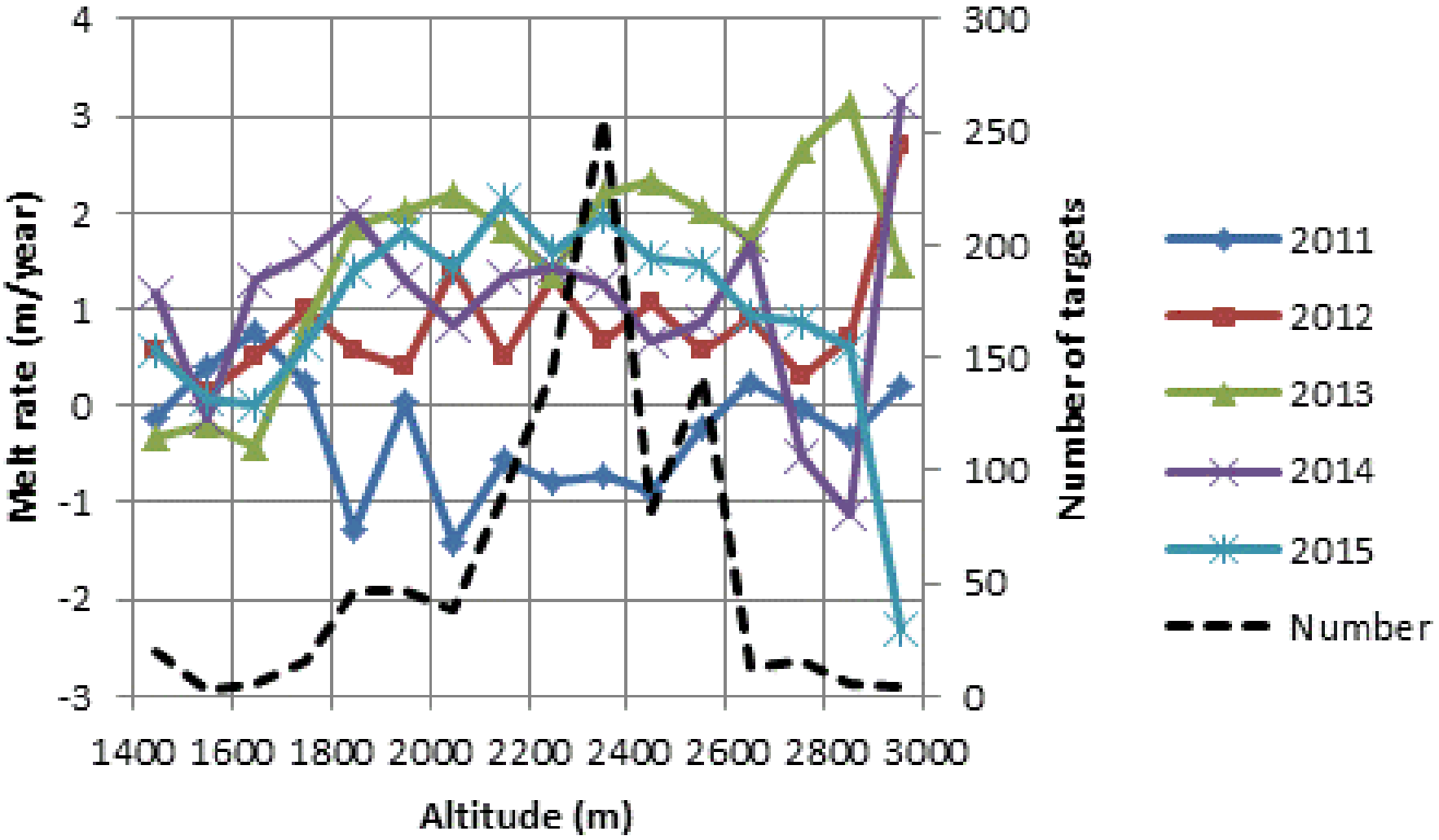
Example #4: This glacier gave many returns with scatter=2.3m. Melt rate of 1.4m/yr, but data suggest change with time. Slow growth in 2010 to 2013, then faster melting.



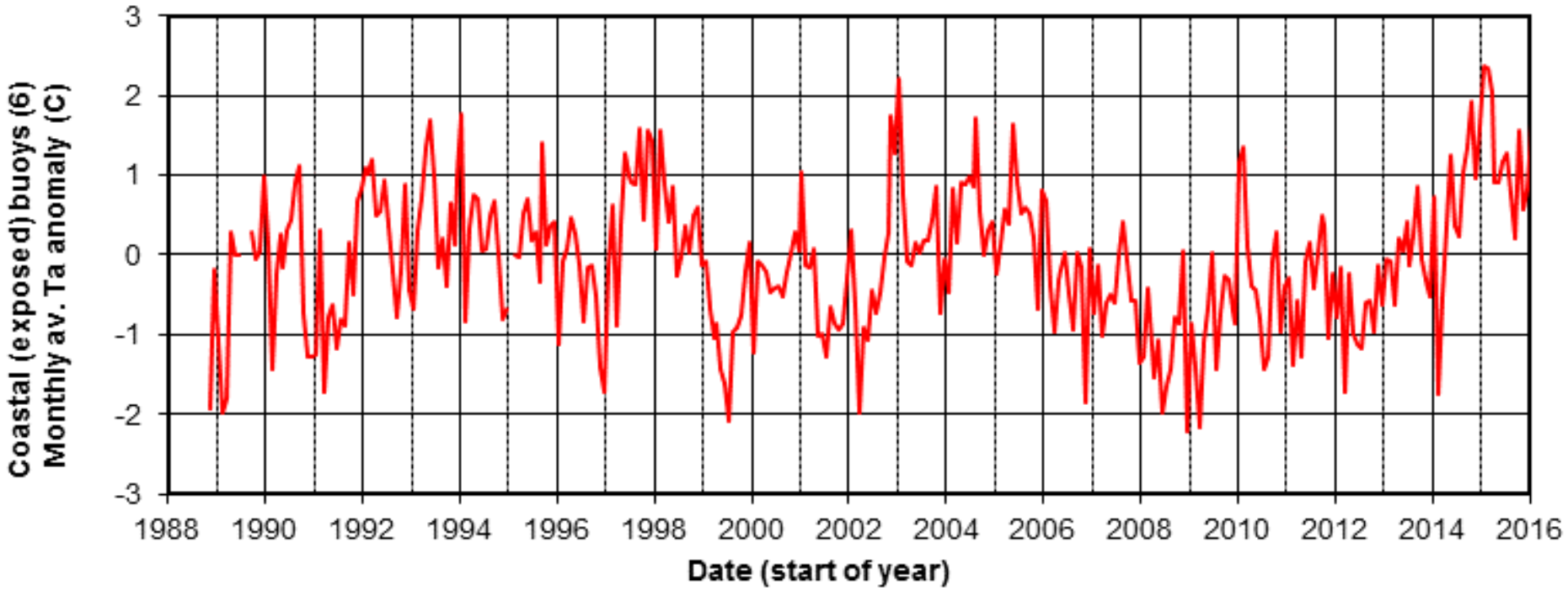
Linear fits suggest no melt before 2013 and 2.7m/year afterwards



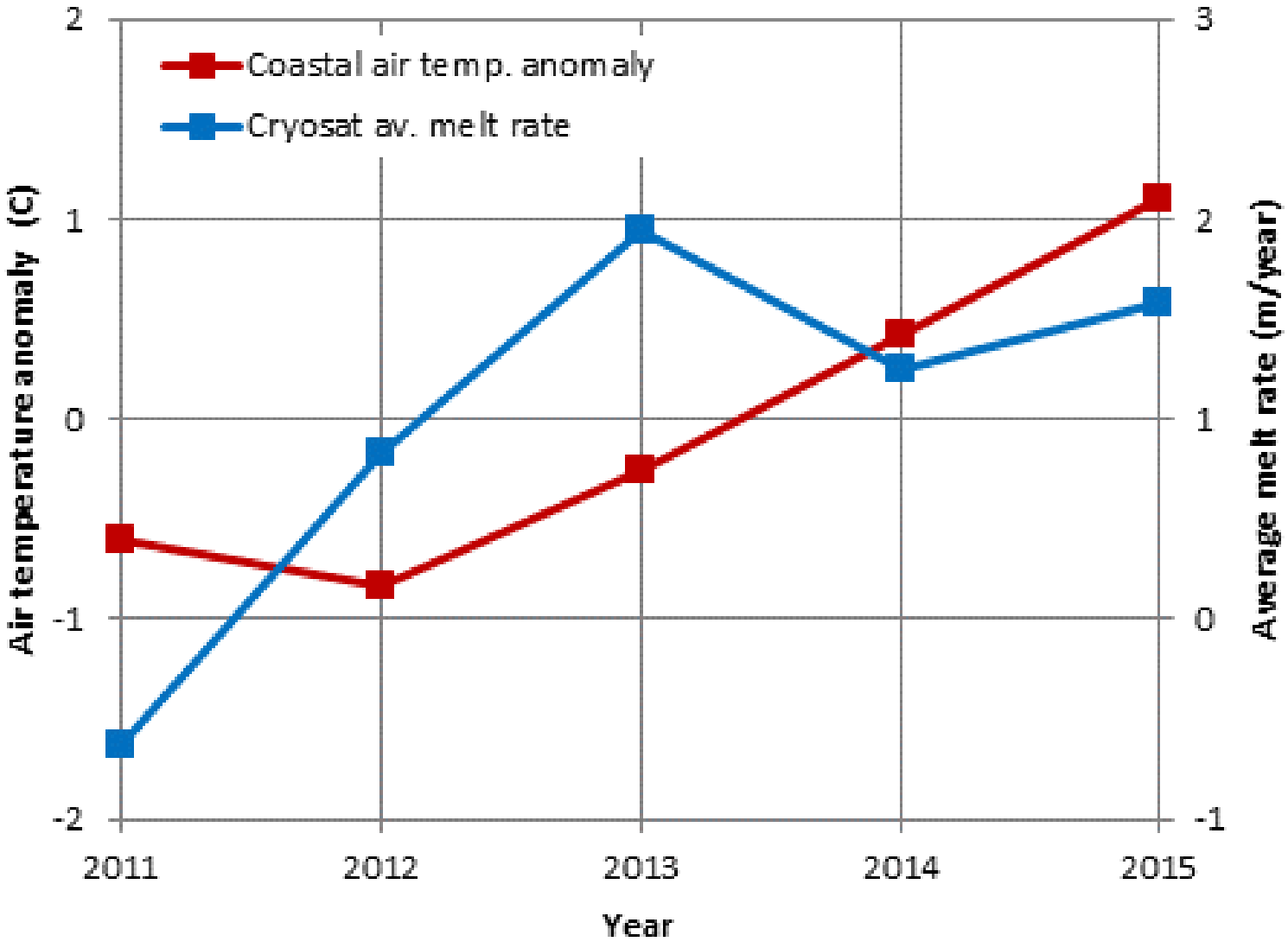
Cryosat2 melt rates for two halves of the time period. Before 2013 (red): tendency for negative melt rates. After start of 2013 (blue) tendency for positive melt rates



Cryosat melt rates by altitude and year showing no melt in 2011 and highest melt in 2013. Few targets give a statistically significant elevation trend outside the altitude range 1800 to 2600m

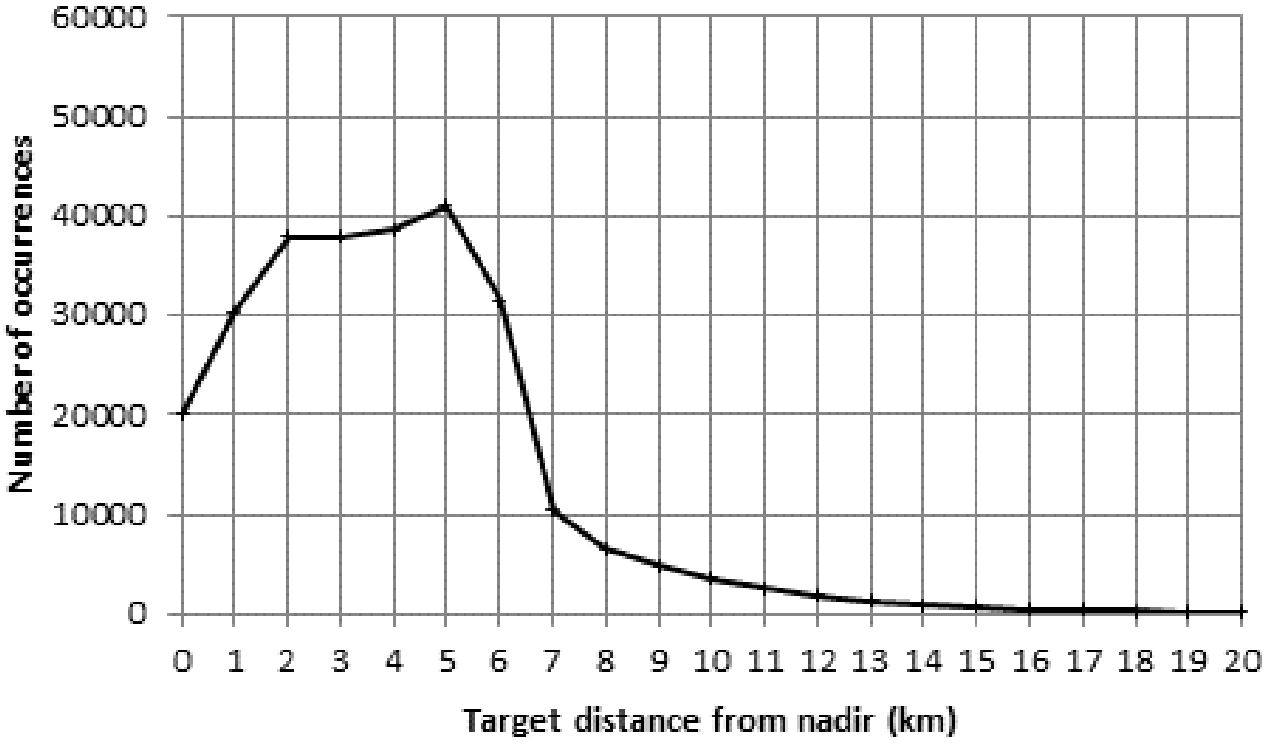


Coastal air temperature anomalies since 1988 show periods of average, cool and warm temperatures. Cool temperatures 2008 to 2013 switched to warm in 2014. El Ninos in 1997 and 2015.



Average Cryosat melt rates for each year, compared to air temperature anomaly for that year.

Cryosat off-nadir returns



Observed Cryosat2 off-nadir target distance distribution. The interferometric method can determine distances out to 6.6km, which is about the half-width of the antenna beam.
Yet data show many targets at distances >10km and some >100km

Three questions

- Off-nadir targets. What limit to allow?
- What does a glacier “target” consist of? How large? How planar? How long will it last?
- Could Cryosat synthesize fan beams to look ahead and behind as well as straight down? (Glacier targets must slope in all directions)

Conclusions

- Cryosat2 provides elevations of small-area targets with enough precision to measure melt rates of glaciers (not just of ice sheets and ice caps) on 2-3 year time scales
- In BC we have an indication of average melt rate varying with time (melting after 2013) and altitude (melt rate drops from 1.5m/y at 1800m to 1m/y at 2800m)
- Other targets may be usefully measured, but Cryosat2 provides little target selection.
- There may be some value for Canadian fisheries in extending the analysis to cover the Columbia River glaciers in eastern BC for upcoming Columbia River Treaty negotiations