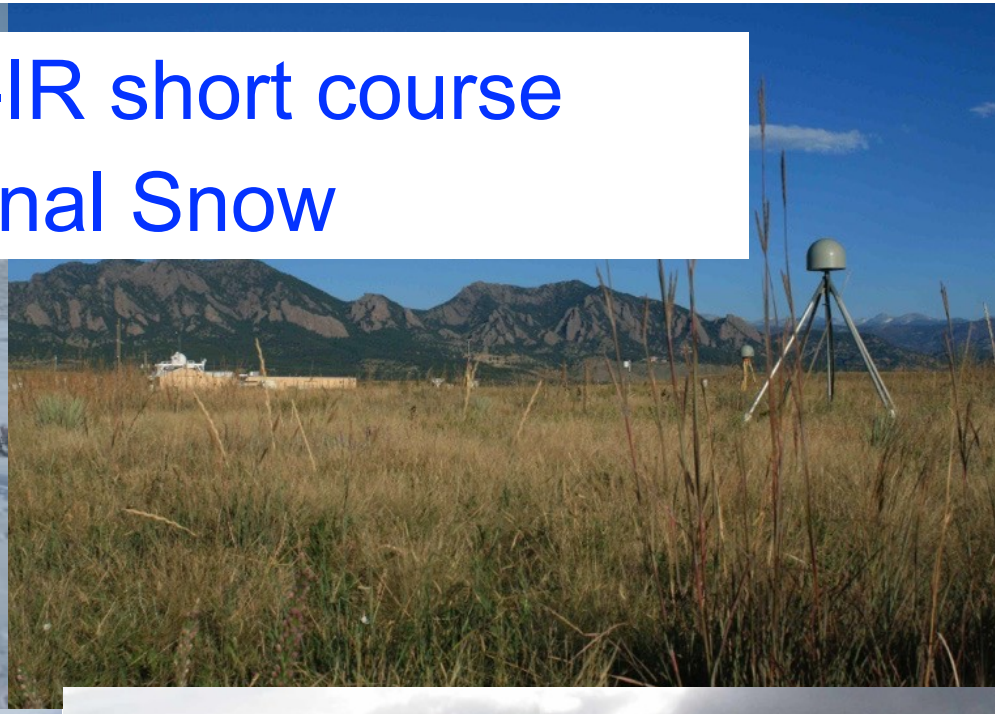
2023 GNSS-IR short course
Seasonal Snow



This is the site where we first successfully measure snow depth in 2009. At that time it was GPS only. Let's move to GNSS generation of receivers.

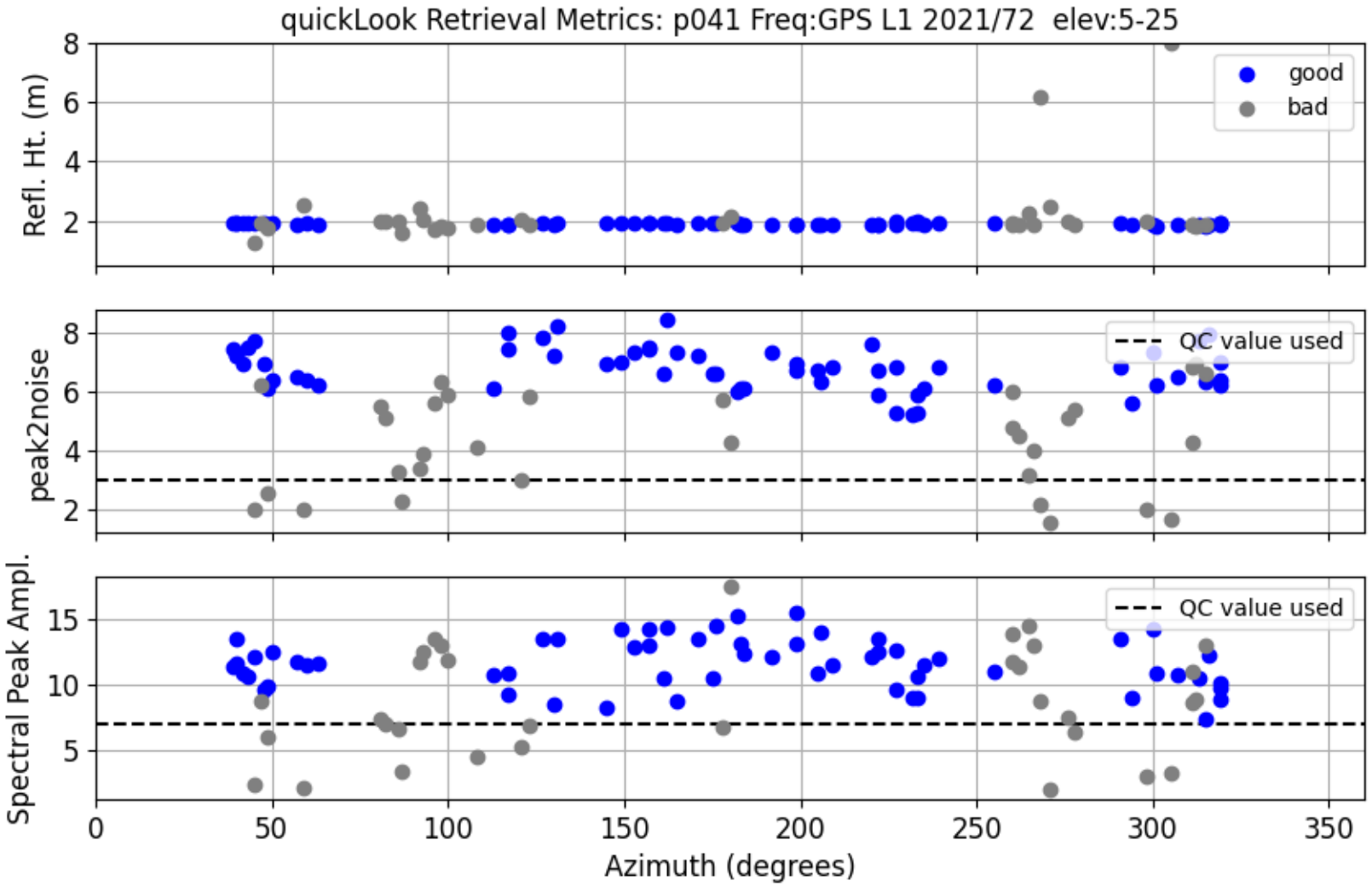
I showed results for this site yesterday in the "how the code works" section.

rinex2snr p041 2020 132 -orb gnss

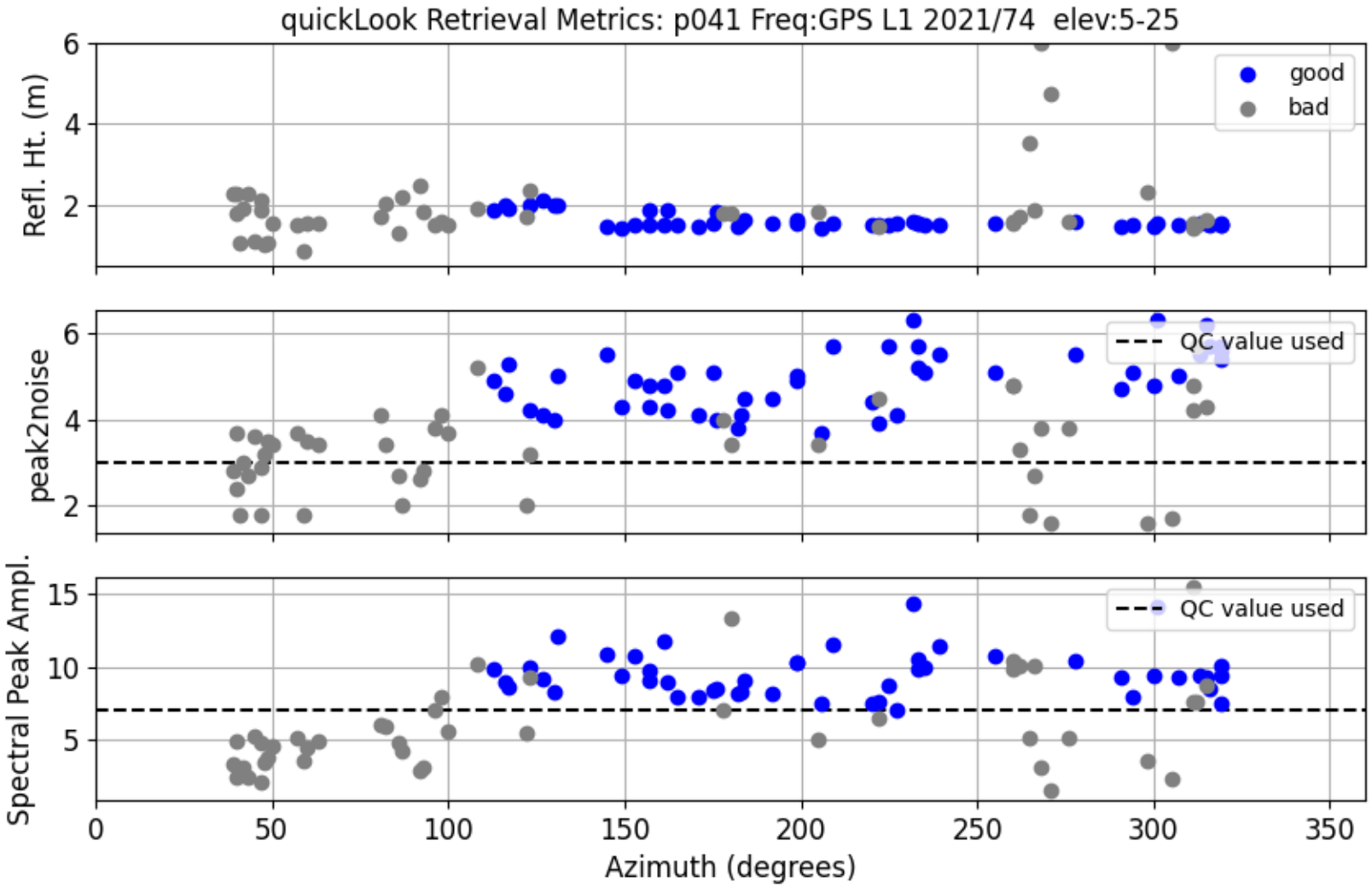
quickLook p041 2020 132

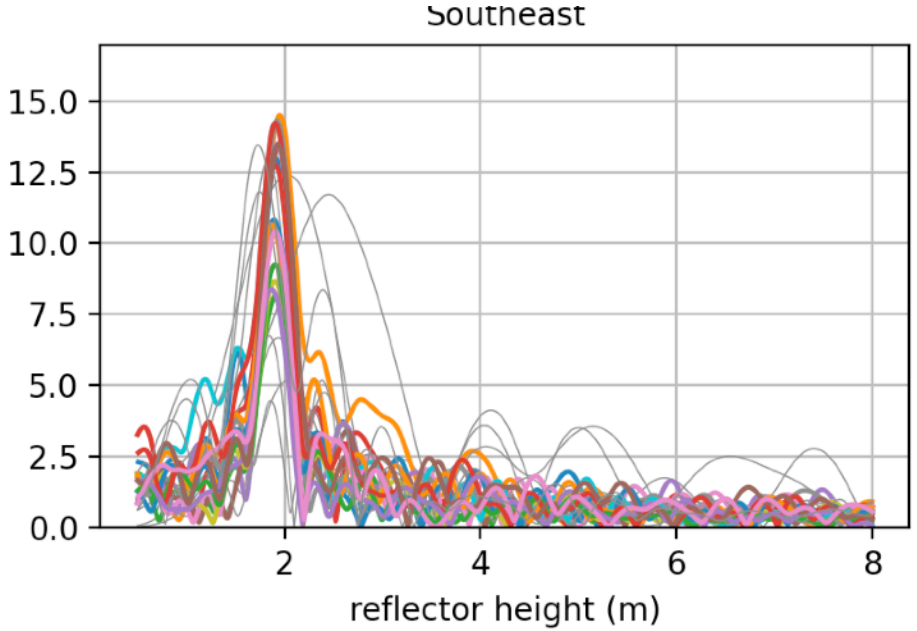
Let's look at quickLook results before and after a snow storm.

Pick a day before it snows-day 72

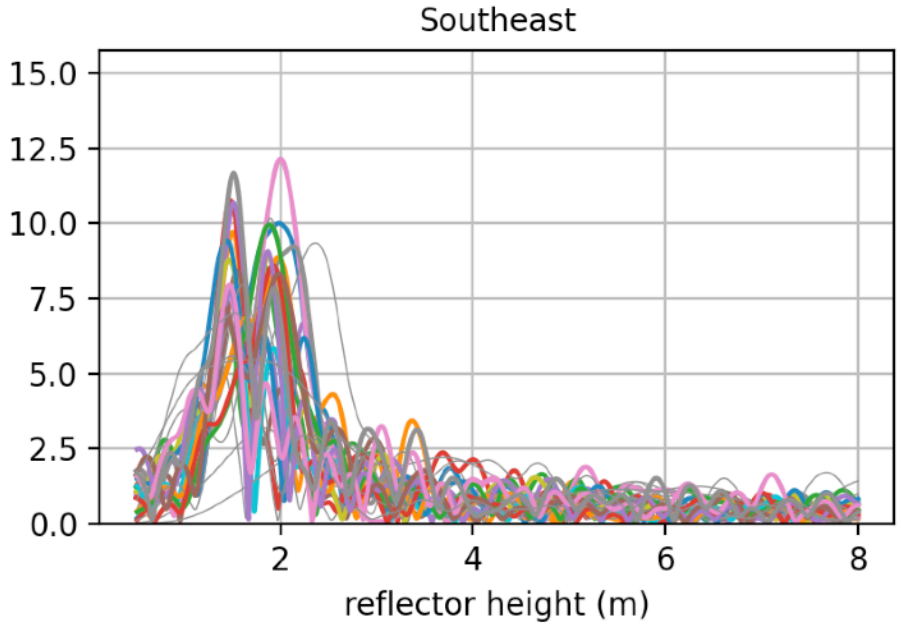


now day 74 - how is it different?





Before it snowed



after it snowed

Compute a snow depth time series

Translate more data, keep our options open for Glonass, Galileo

rinex2snr p041 2020 240 -doy_end 150 -year_end 2021 -orb gnss

Start with the defaults (which are GPS only
all azimuths, and elevation angles from 5-25 degrees)

make_json_input p041 0 0 0

Estimate RH

gnssir p041 2020 240 -year_end 2021 -doy_end 150

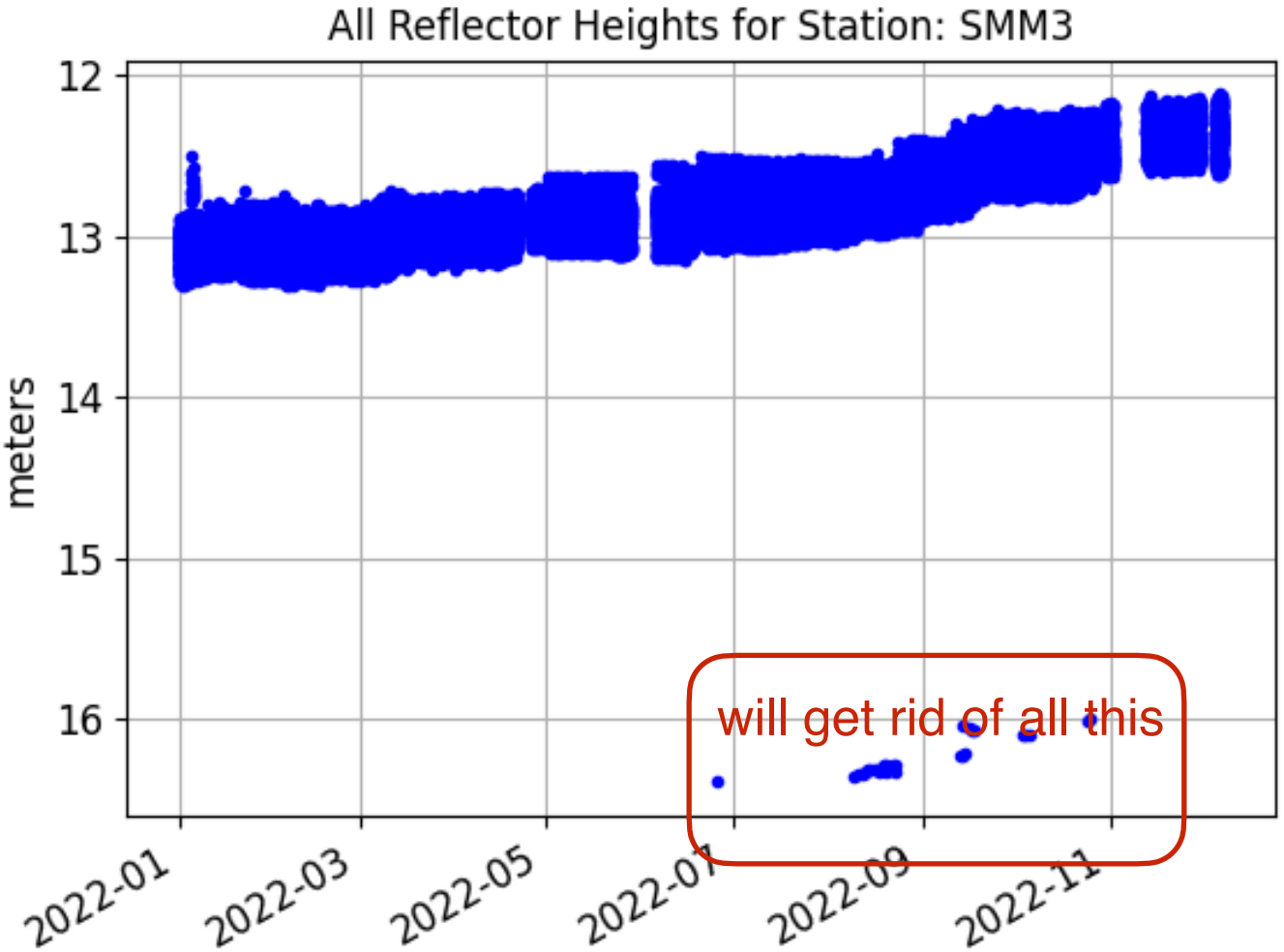
Consolidate

daily_avg p041 0.2 20 ** these are starting points.

0.2 m is the median filter value. 20 is the required number of tracks
if you want to see all your outliers, use a large median filter value.

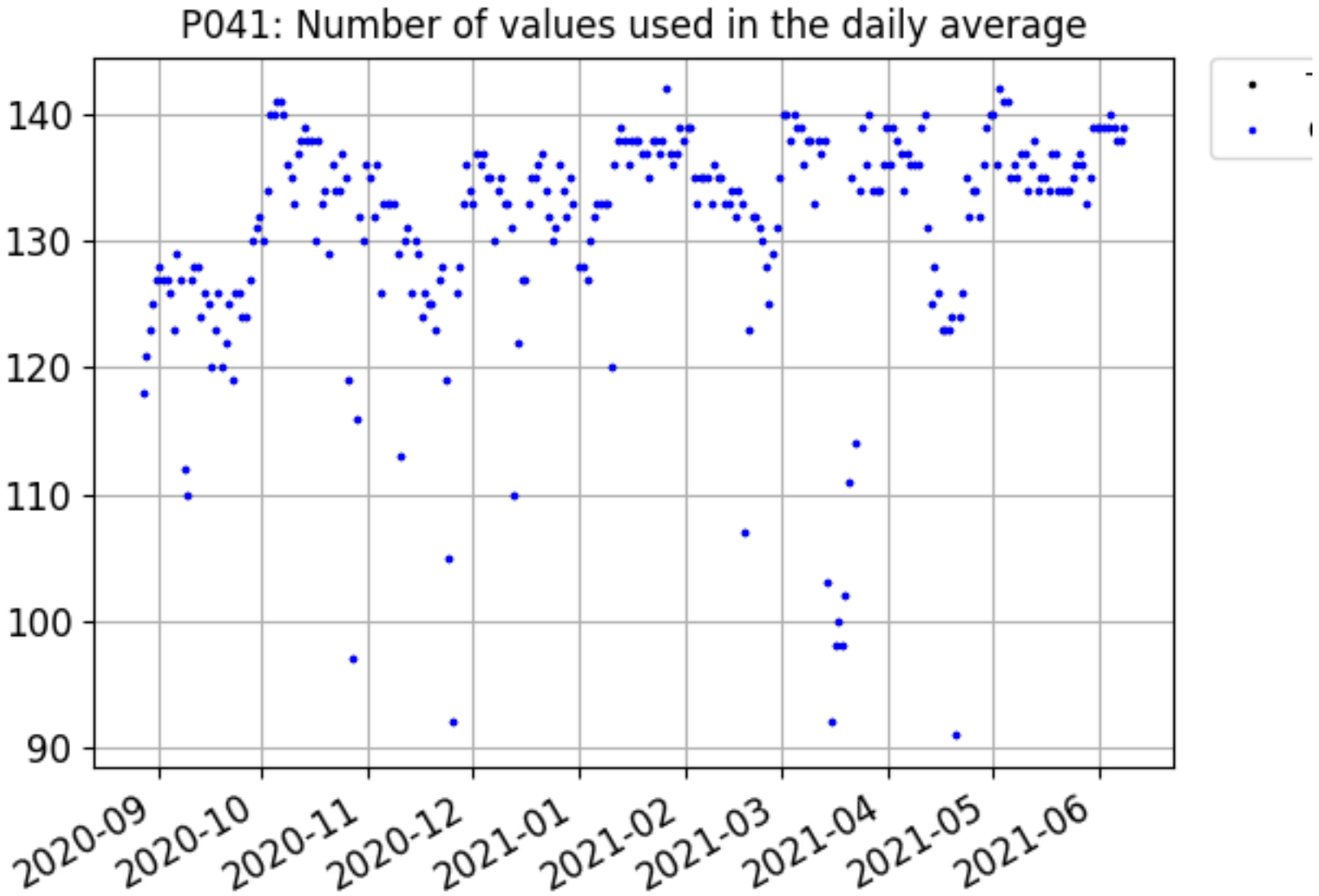
What is a median filter?

1. Compute the median value (MV) each day.
2. Remove all points that fall - in my example - within 0.2 meters from MV.
3. Compute daily average.

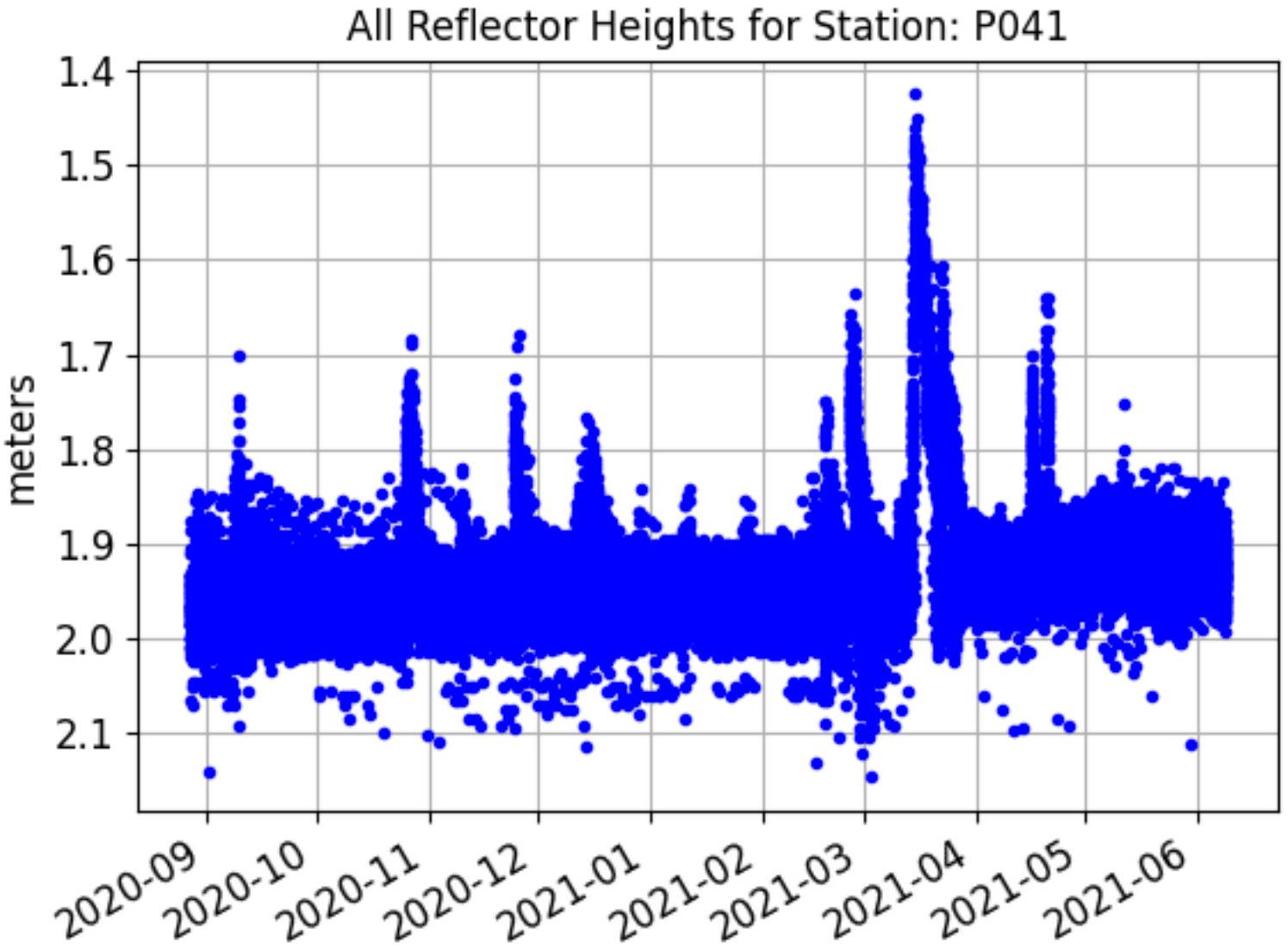


daily_avg p041 0.2 20

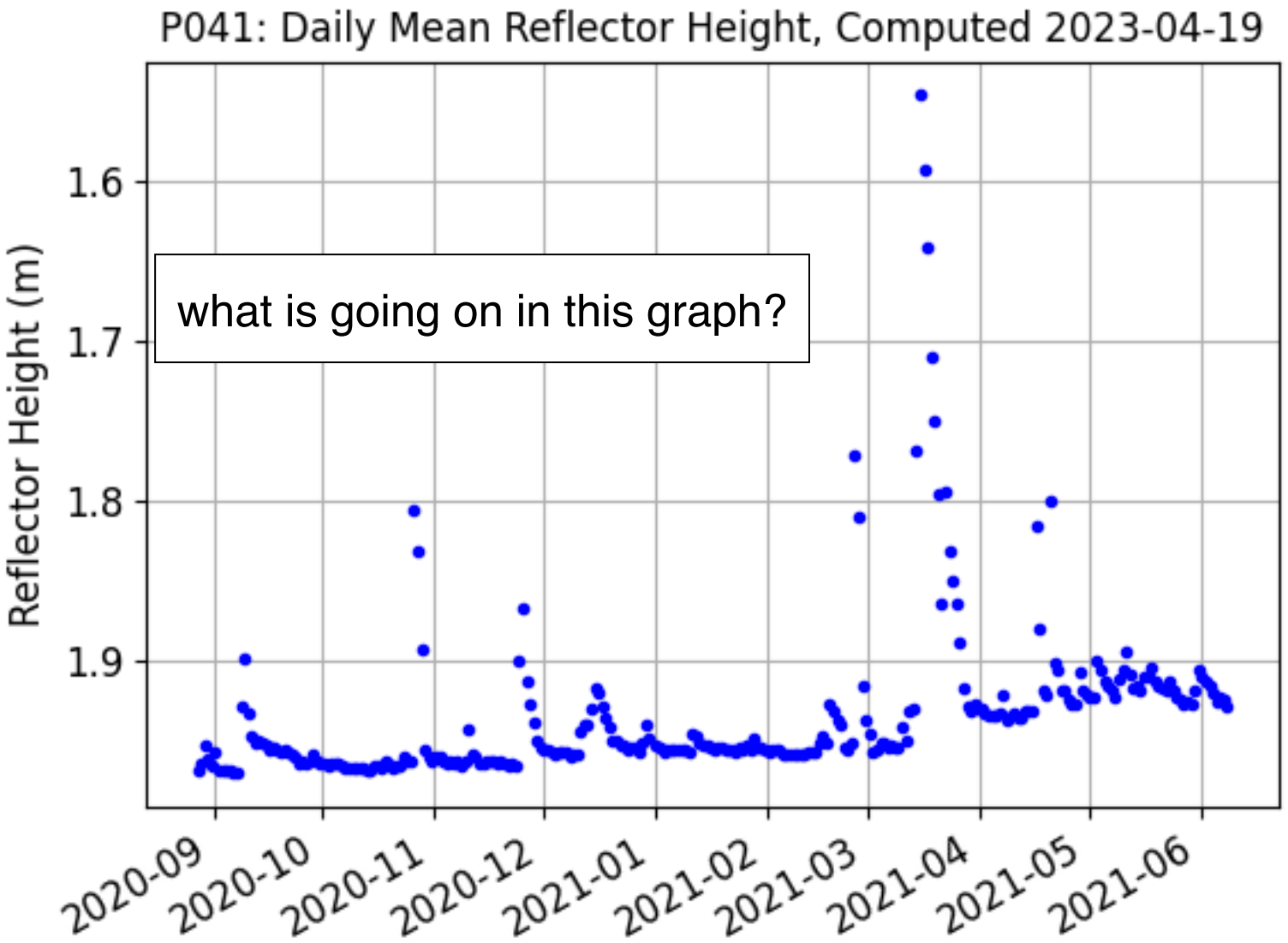
requiring only 20 measurements was too small



all RH for the 2021 (North American) water year



daily averages



snow depth

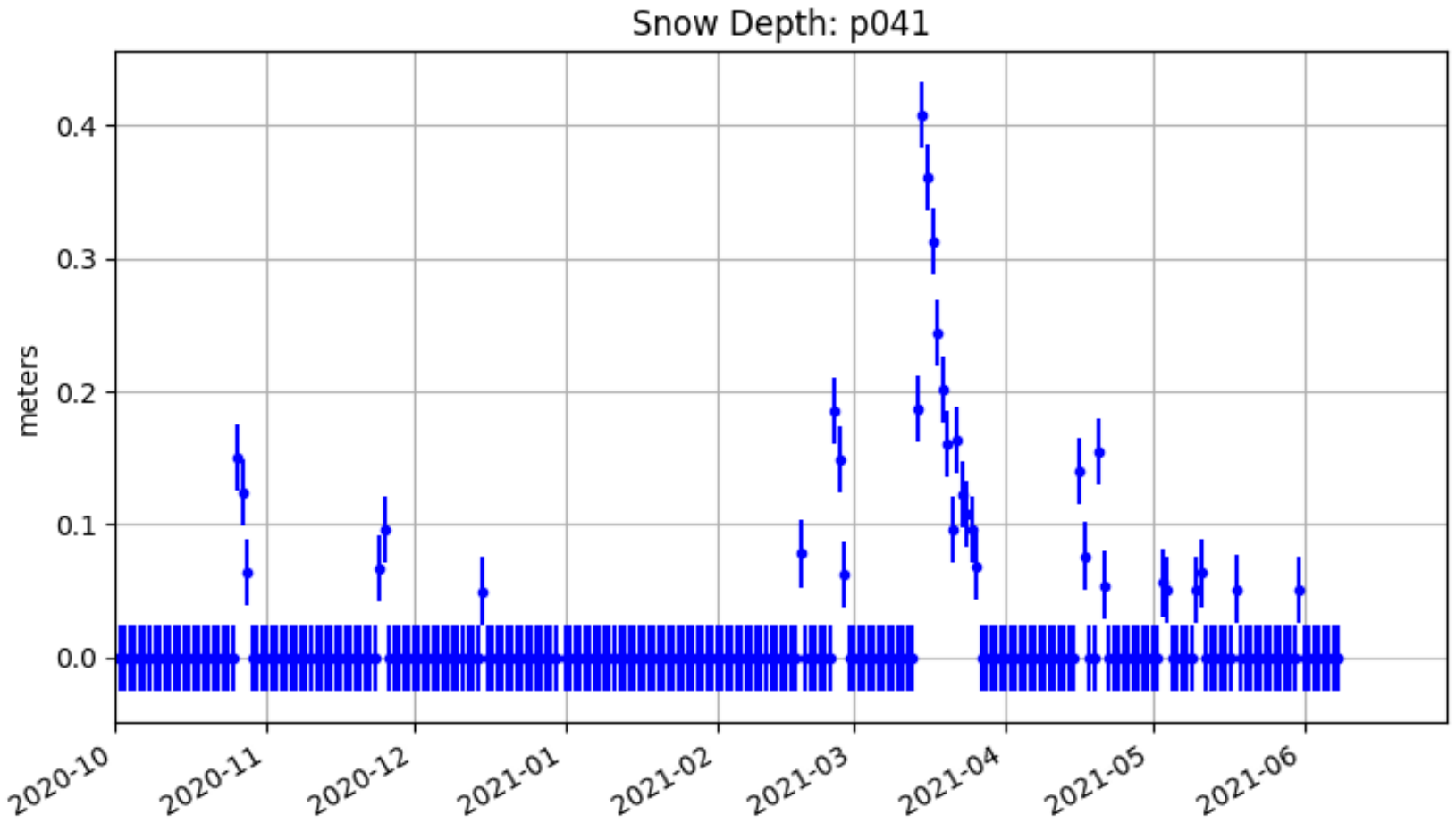
- You need to know what the RH was before snow fell. The code calls this the “bare soil” value.
- We compute snow depth by water year (north American). By default it uses September data to set bare soil, but you are free to set those however you want (often necessary in Alaska, e.g.).
- I am more than willing to host a southern hemisphere water year. Submit a pull request.
- Two options:
  - brute force. average all azimuths together, use -simple T
  - compute averages every 20 degrees of azimuth

For P041, compute snow depth

snow depth p041 2021 (uses daily_avg results)

or

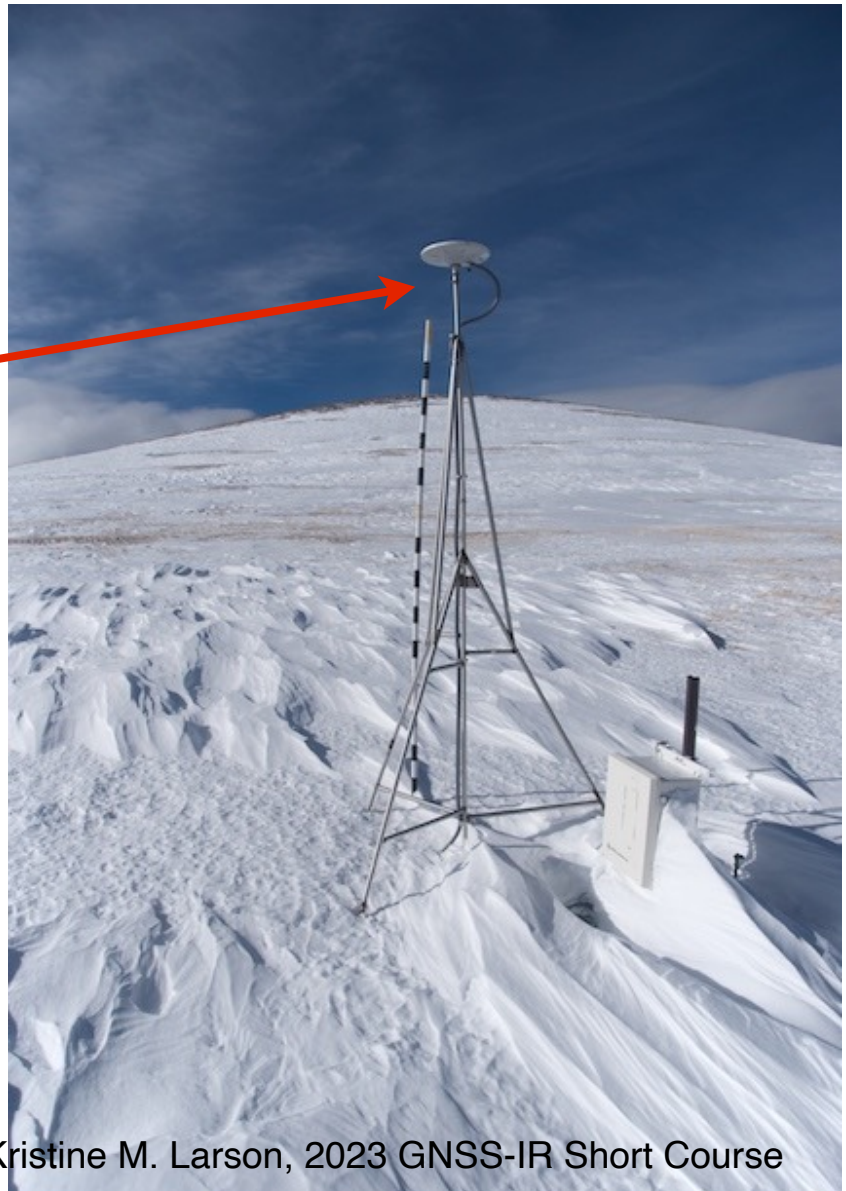
snow depth p041 2021 -medfilter 0.2 -ReqTracks 50



Code does not attempt to resolve snow depth < 5 cm.

Other snow depth issues, from site at Niwot Ridge Colorado

pole 16 is the current technology used by Niwot Ridge to measure snow depth

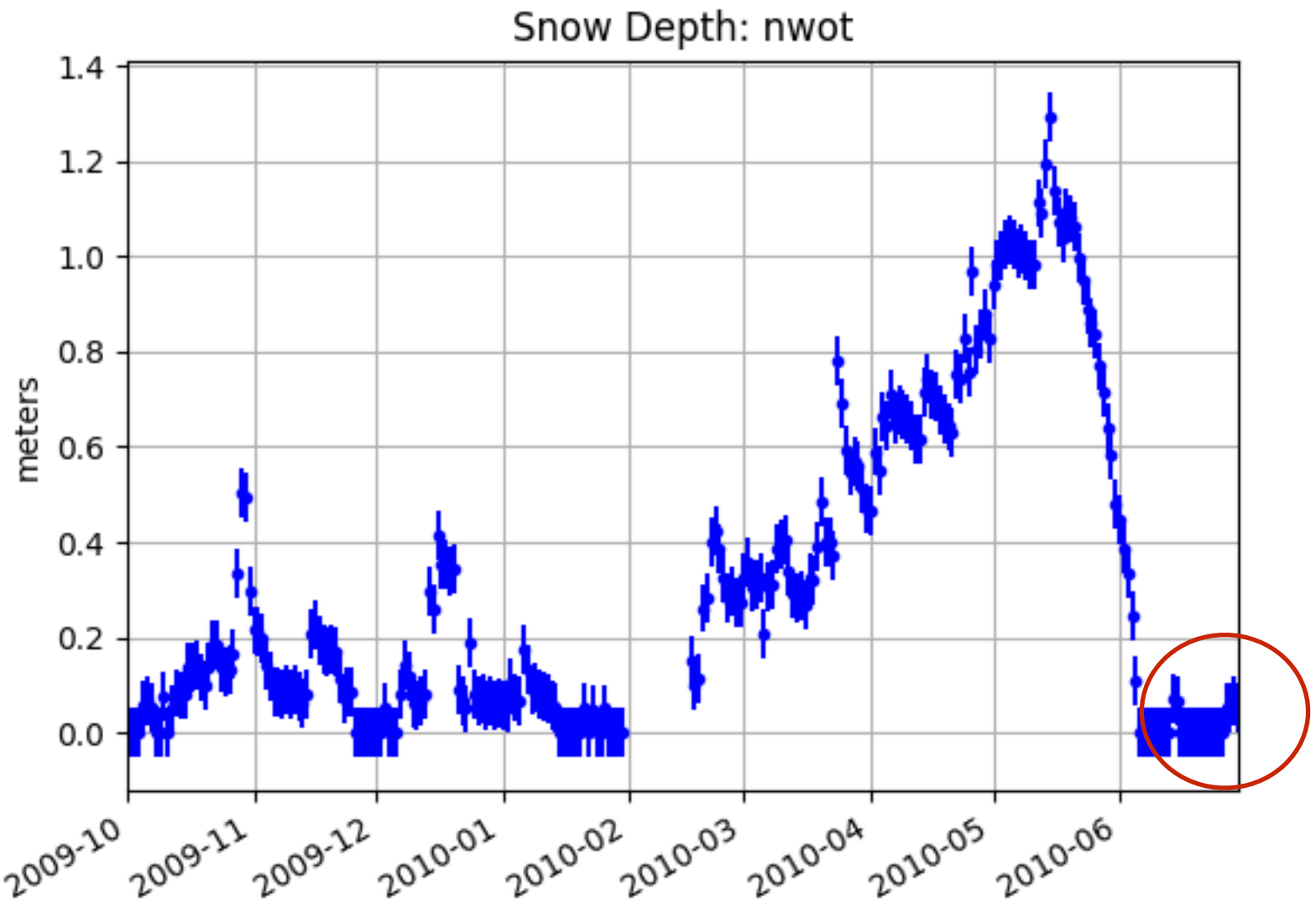


the GPS antenna is more than 3 meters tall

Niwot Ridge

- The details are in the use case online.
- There is a SNOTEL site at Niwot Ridge - should you compare to it?
- This was my site - so there were always L2C data in the file.
- There are no L5 data (or Glonass or Galileo).
- Run rinex2snr and gnssir
- I used daily_avg to consolidate the results.
- First water year,
  - snowdepth nwot 2010

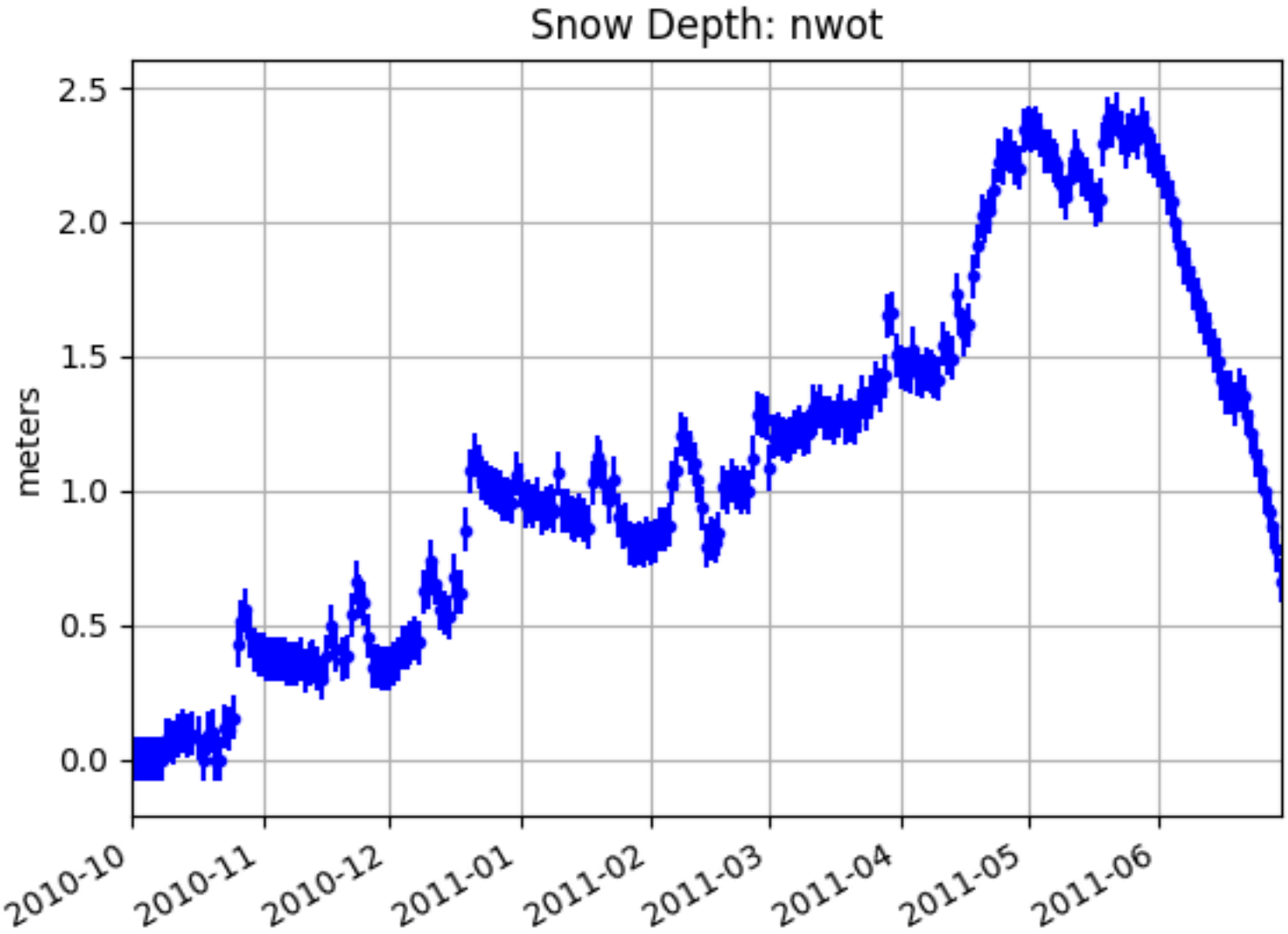
First water year. Ho Hum. Max snow depth of 1.2 meters



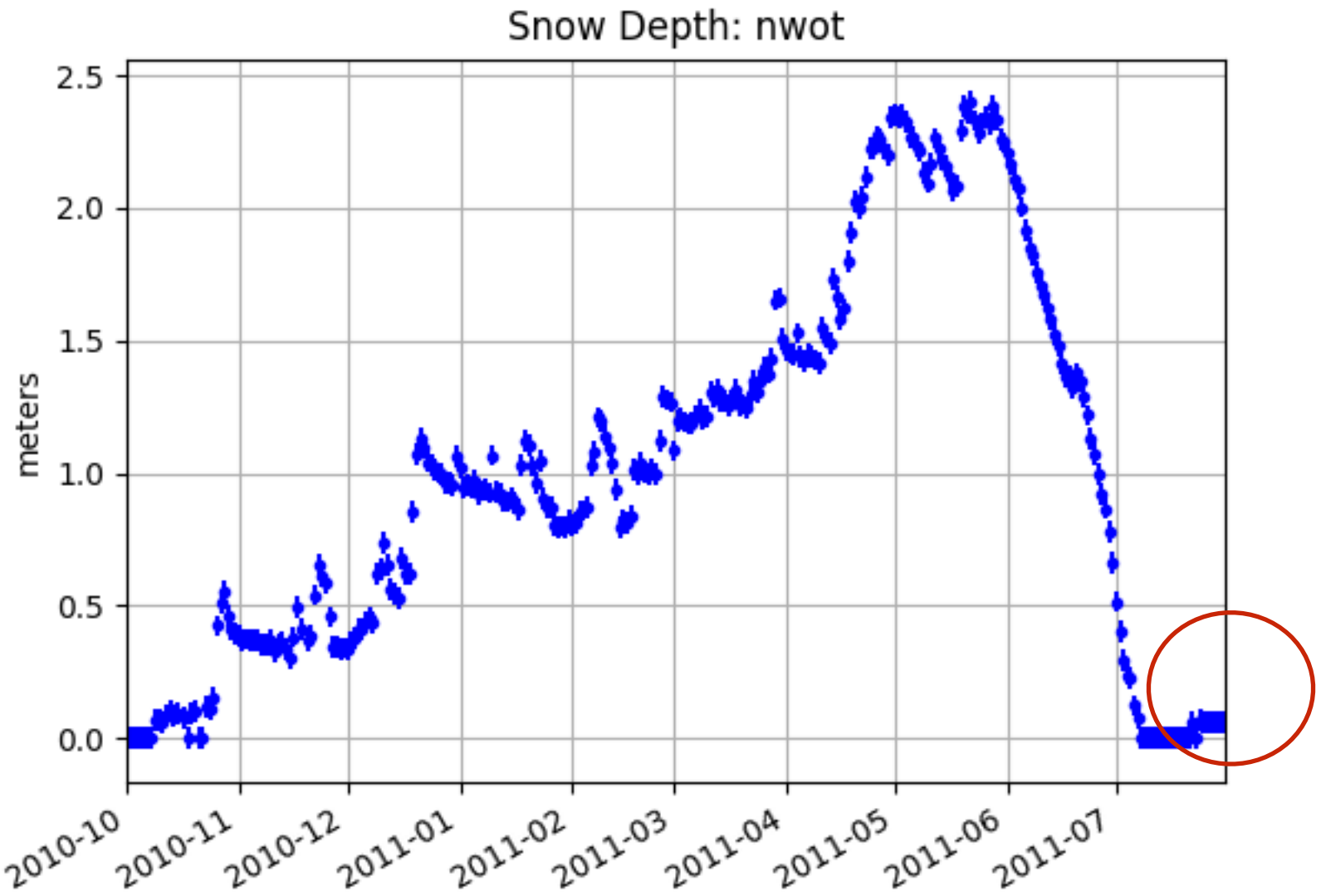
Note: you can define the bare soil dates you want to use.

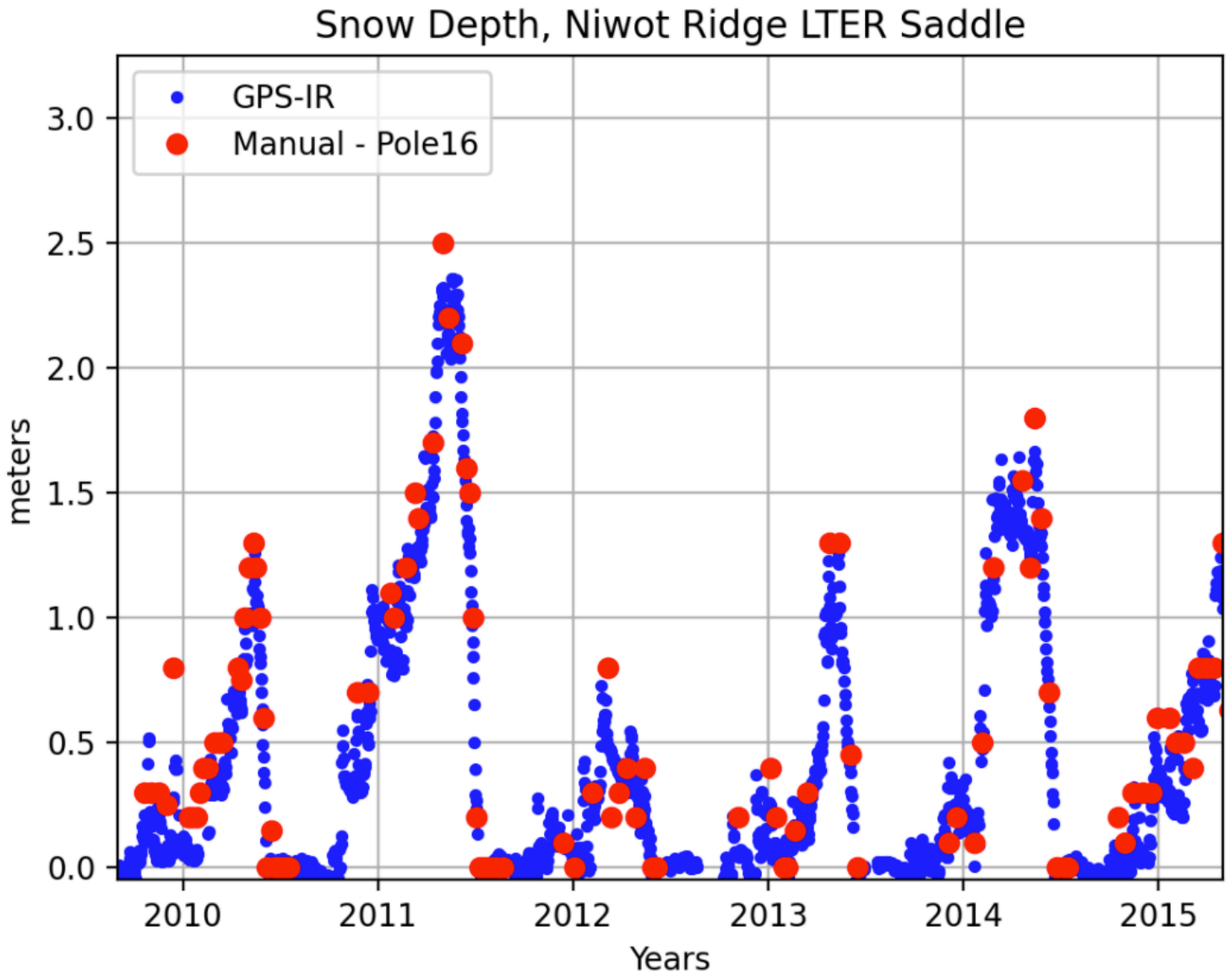
snowdepth nwot 2011

Second year. Cutting off at June 30 is no longer a good idea.



snowdepth nwot 2011 -plt_enddate 2011-07-31

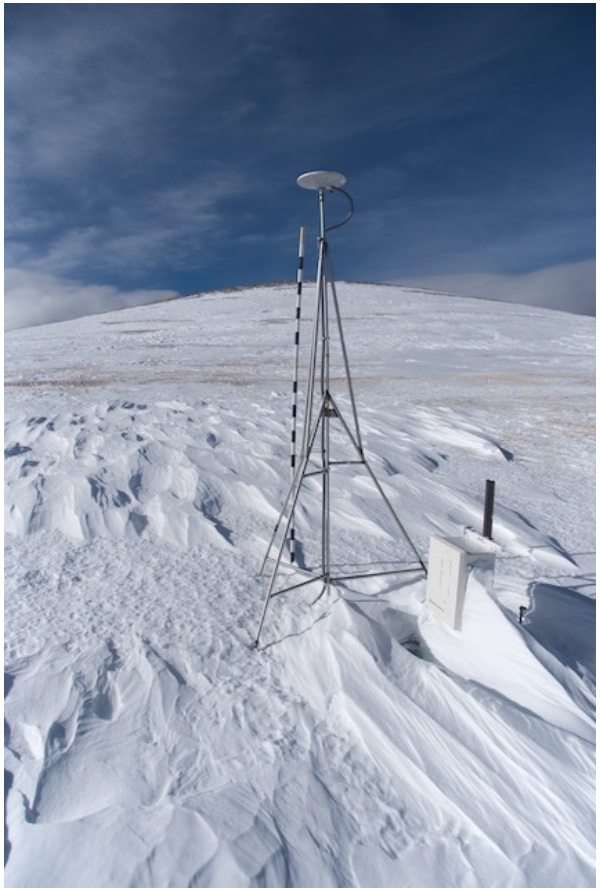




Should they agree exactly? Should it agree with the SNOTEL sensor at Niwot Ridge

this is the SNOTEL site at Niwot Ridge (according to USDA)

our site



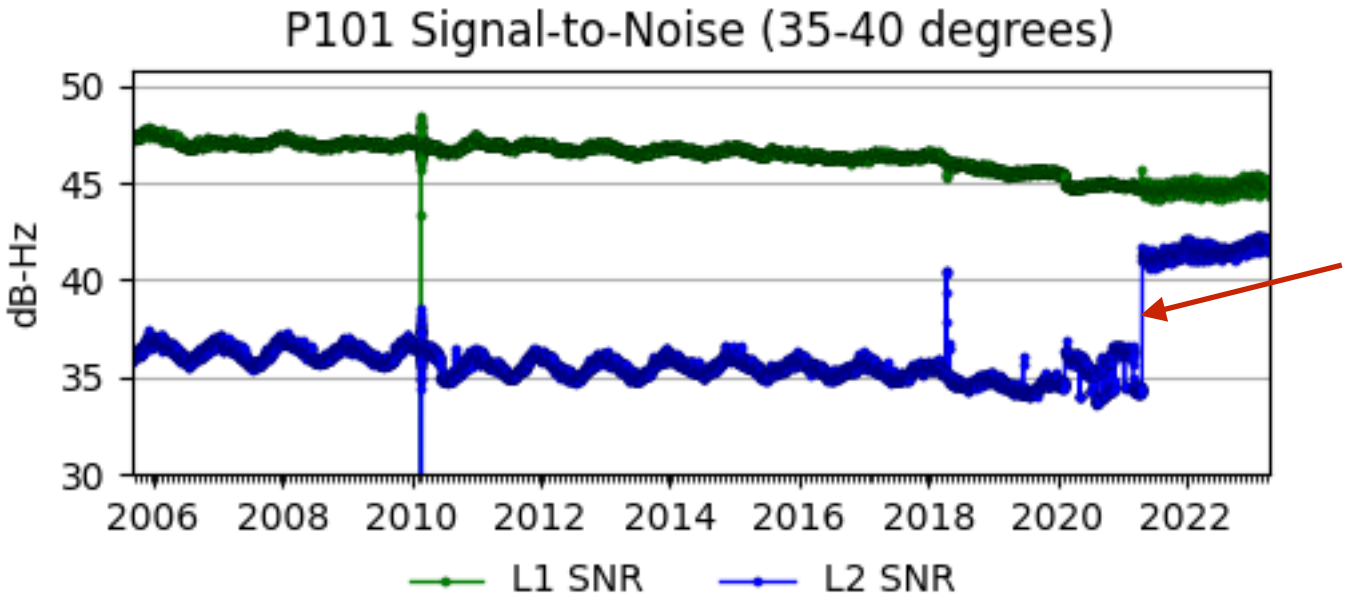
Secondary issue - these sites are not even remotely close to each other. Too many people try to determine accuracy using sites that are in completely different environments or are not colocated.

Let's finish with one of my favorite snow sites

https://gnss-reflections.org/snow?station=p101&product=snow

Annoying things for this site

- UNAVCO has hidden the good L2C data for this site from its original installation. You can access in the highrate data, but you should decimate to 15 sec.
- It is currently running a modern receiver and modern signals are in the 15 second RINEX file.

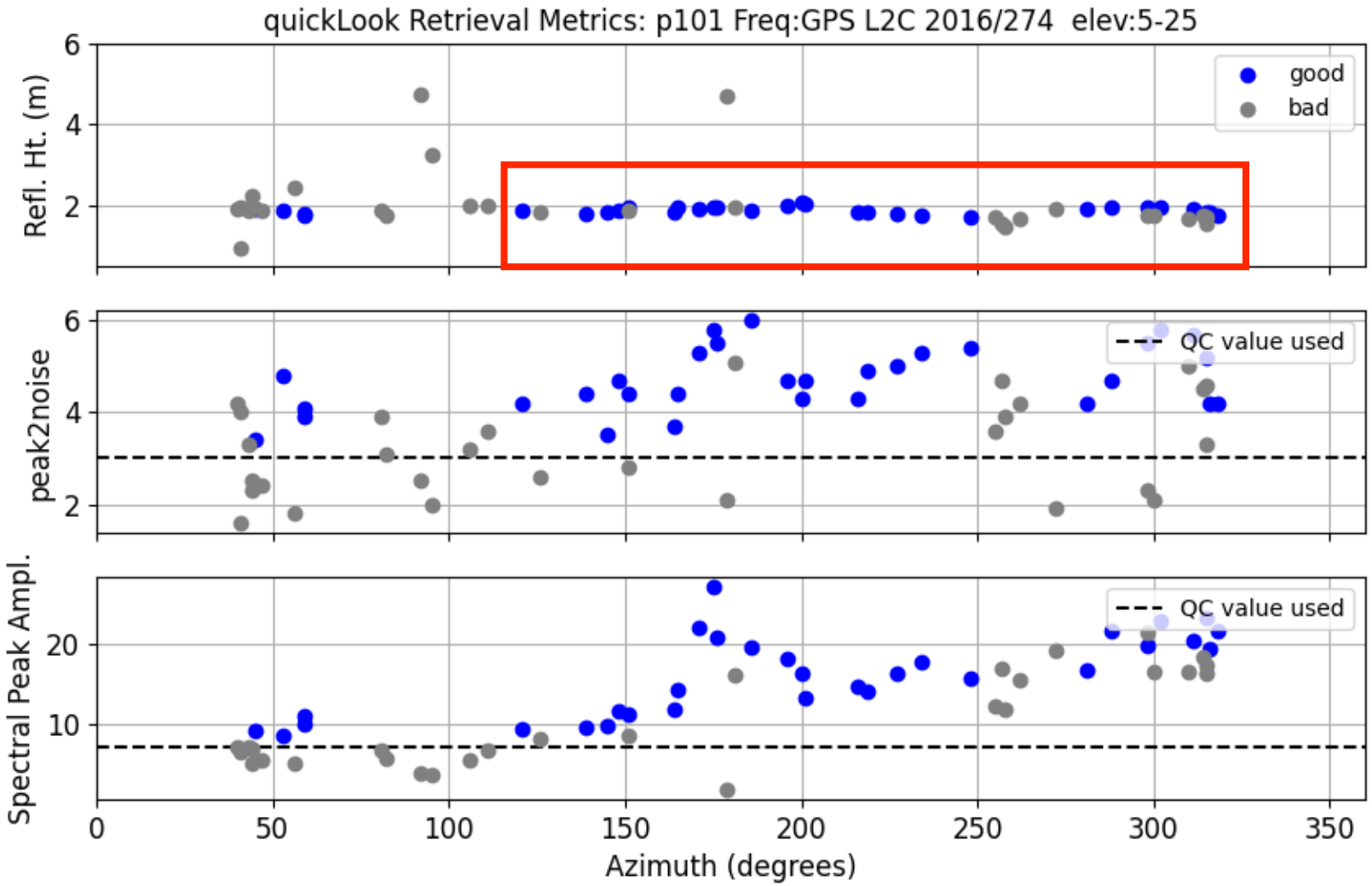


This is when UNAVCO installed a new receiver and allowed users to have easy access to L2C data. You can see a huge improvement in mean SNR stats.

Translate some RINEX files (for the good signals)

```
rinex2snr p101 2016 240 -doy_end 150 -year_end 2017
-rate high -dec 15 -archive unavco
```

quickLook p101 2016 274



Translate some more RINEX files

```
rinex2snr p101 2016 240 -doy_end 150 -year_end 2017
-rate high -dec 15 -archive unavco
```

Define your strategy

```
make_json_input p101 0 0 0 -azlist 120 180 180 260 260 320 -frlist 1 20
```

I only use frequencies 1 and 20 as those are the only ones available in the files (receiver was GPS only at that time)

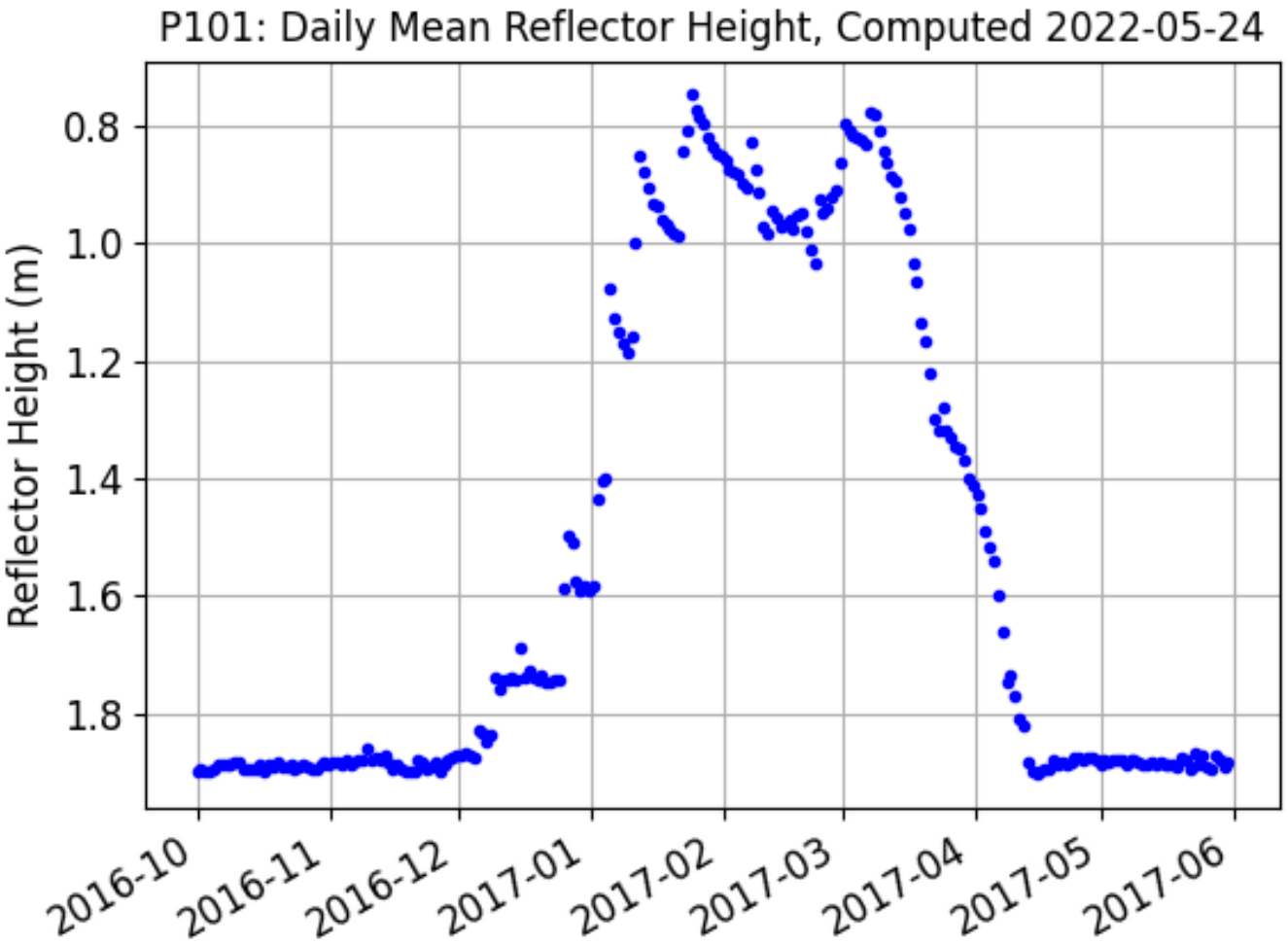
Estimate reflector height

```
gnssir p101 2016 274 -doy_end 150 -year_end 2017
```

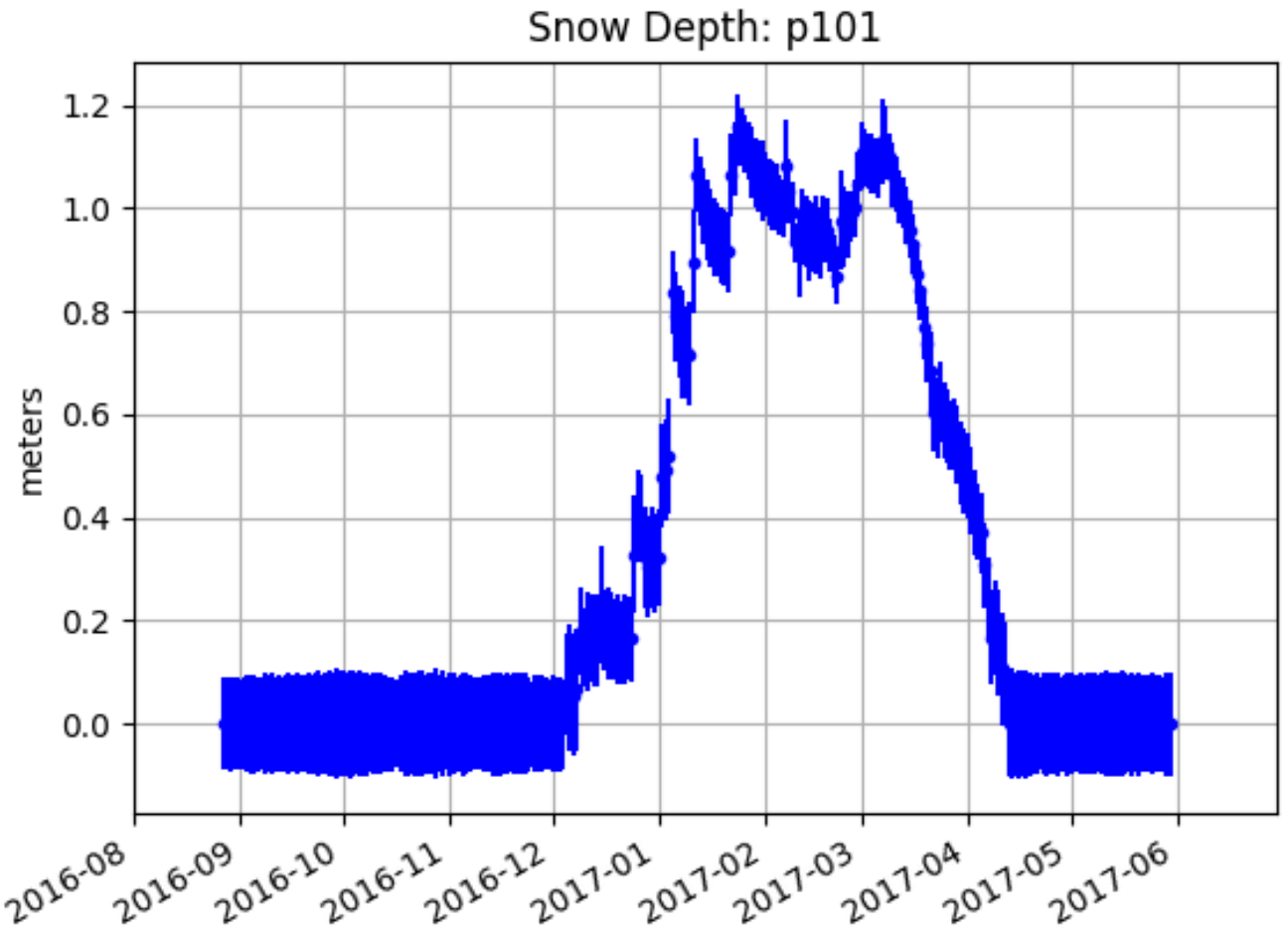
Consolidate

```
daily_avg p101 0.25 30
```

daily_avg p101 -medfilter 0.2 -ReqTracks 30



I am using simple model for the early GPS only data … snowdepth p101 2017 -simple T -medfilter 0.2 -ReqTracks 30



Let's update p101 for the last few years

```
rinex2snr p101 2021 240 -doy_end 150 -year_end 2022
-archive unavco -orb rapid
```

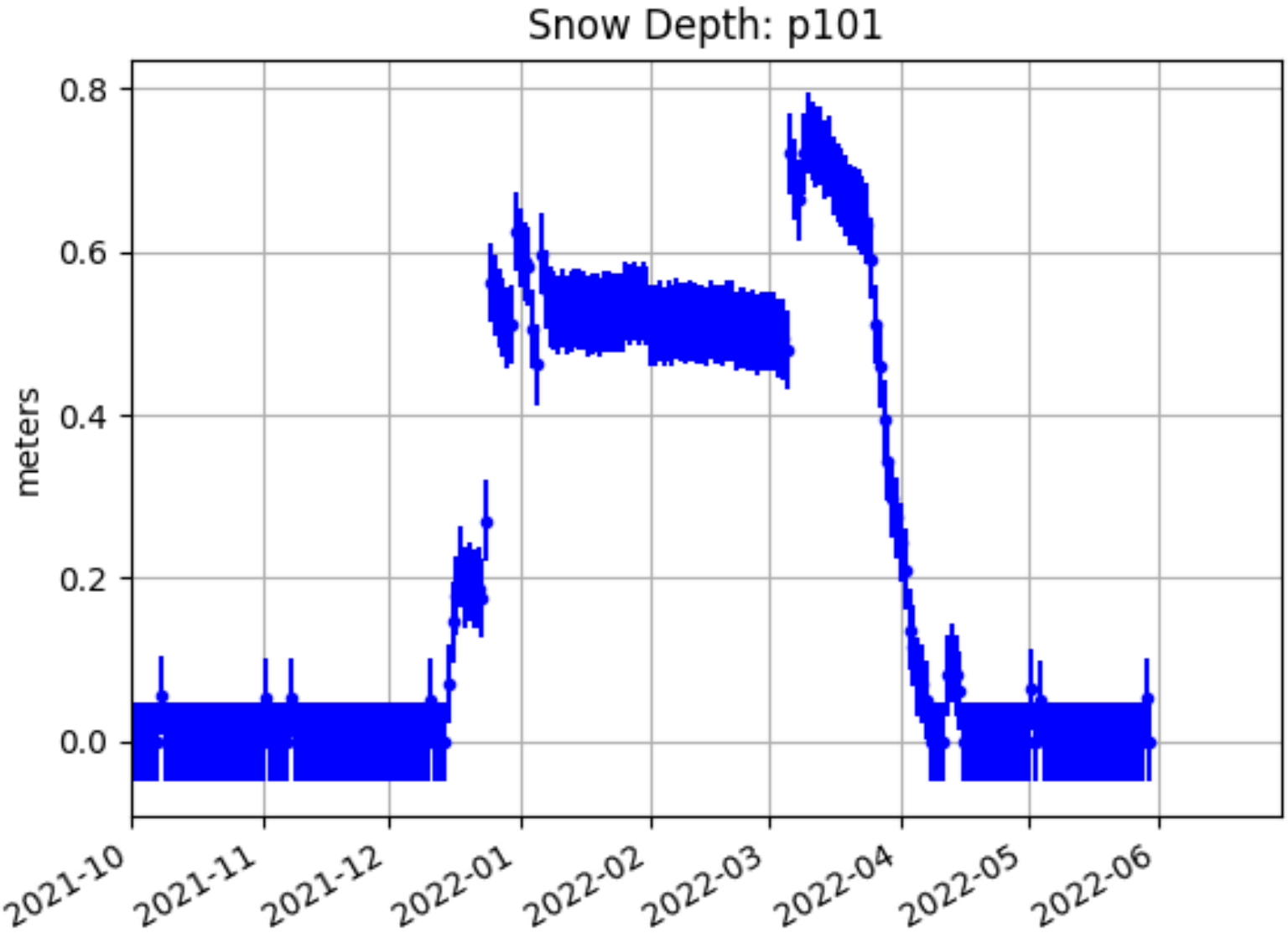
```
rinex2snr p101 2022 240 -doy_end 110 -year_end 2023
-archive unavco -orb rapid
```

Add in more frequencies and run gnssir:

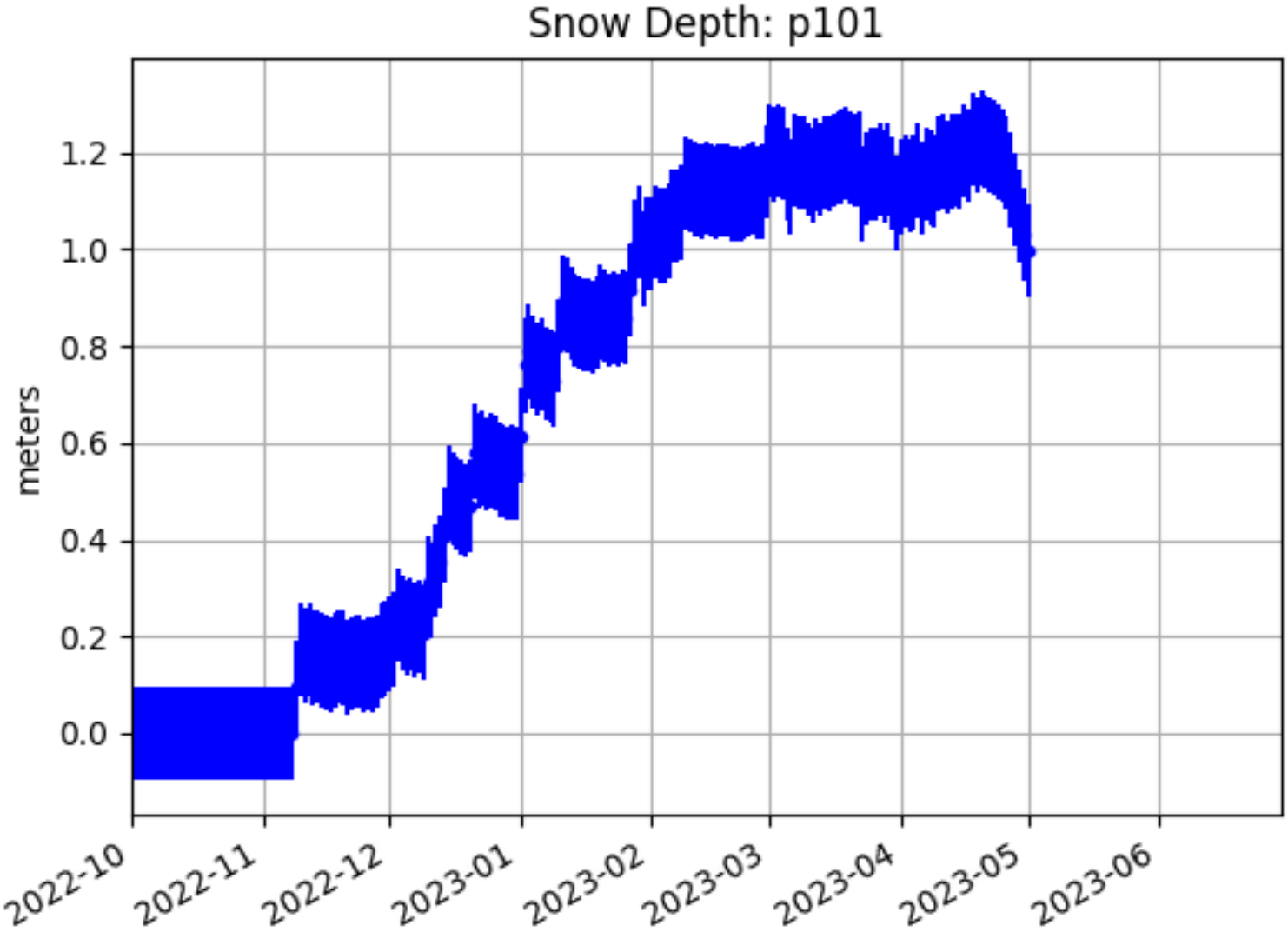
```
make_json_input p101 0 0 0 -azlist 120 180 180 260 260 320
 -frlist 1 20 5 101 102 201 205
```

```
gnssir p101 2021 240 -year_end 2023 -doy_end 110
```

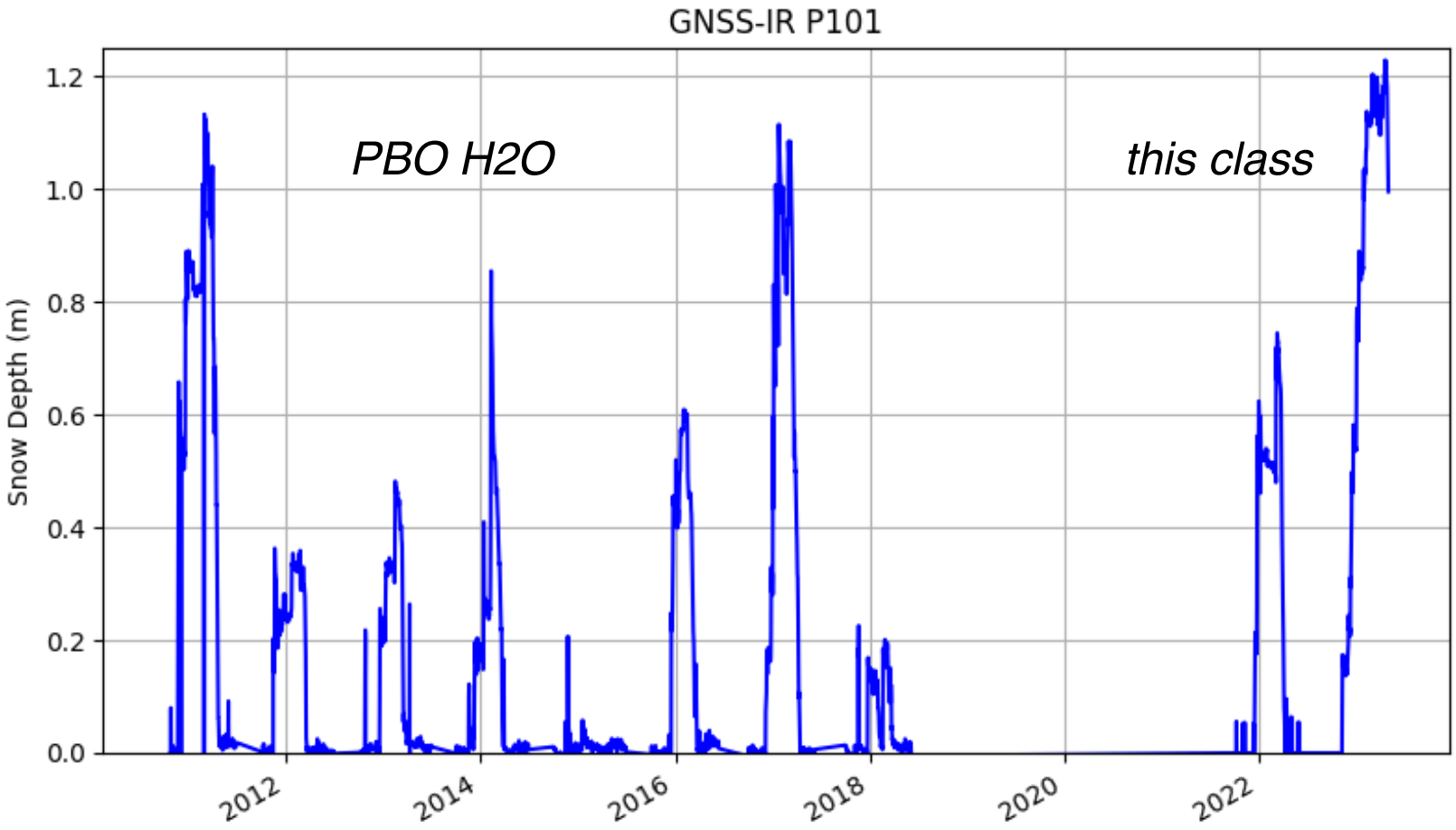
Last year most of the snow was gone by April 1.



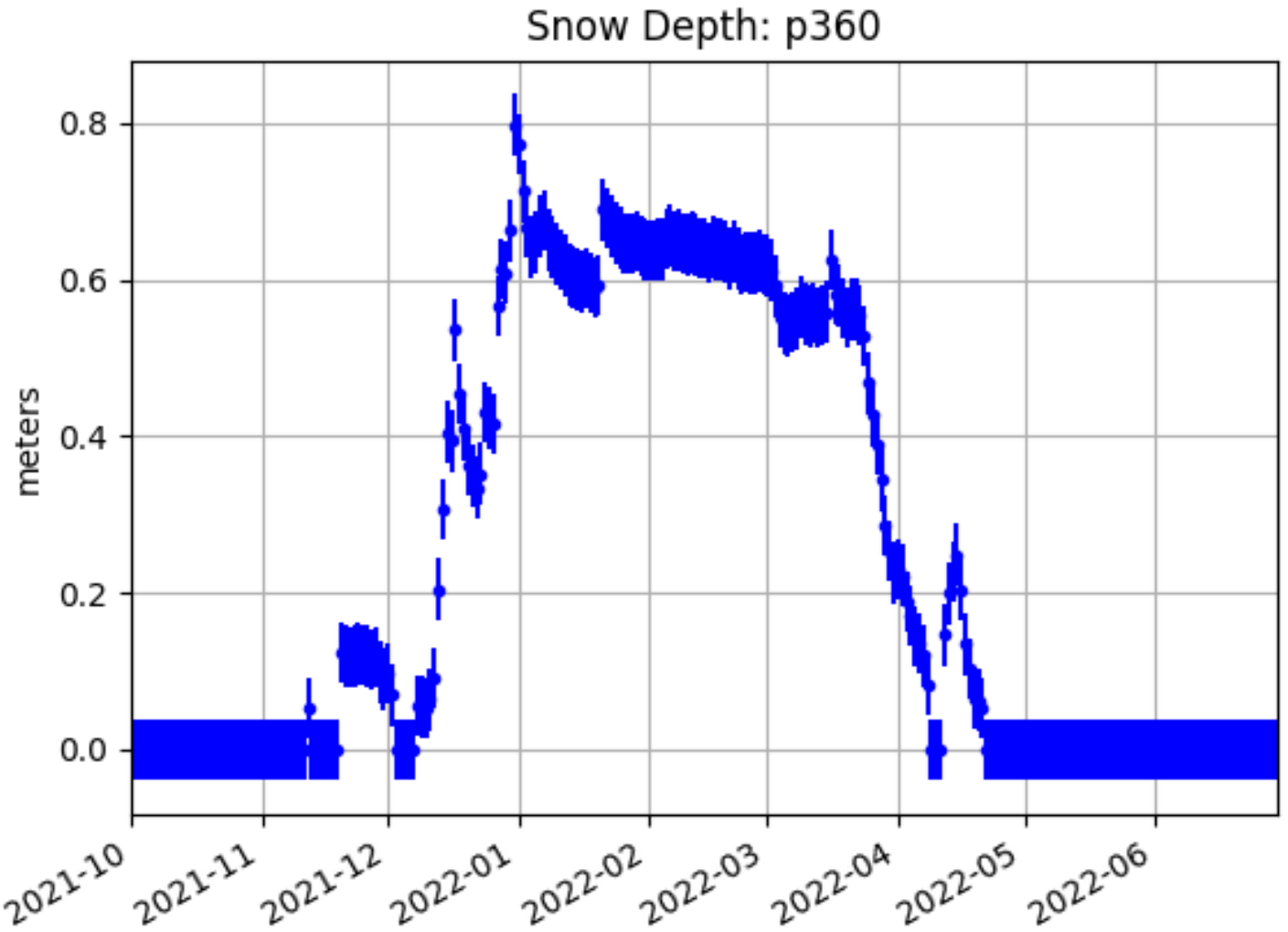
This year there was a lot more snow - and it only began to melt in late April.



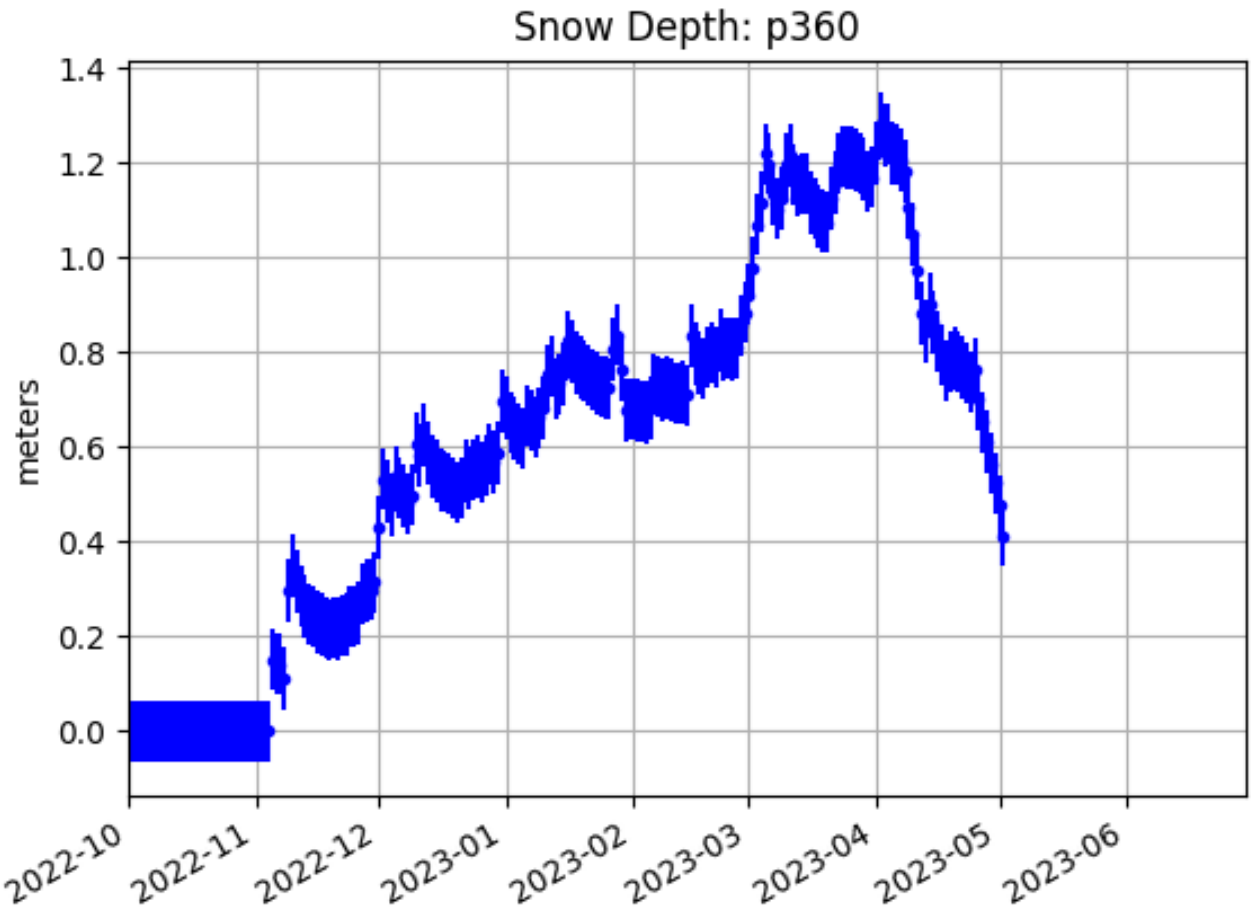
Data for the 2019-2021 water years is available for others to analyze.



Another favorite site: Half Island Park Idaho



This year

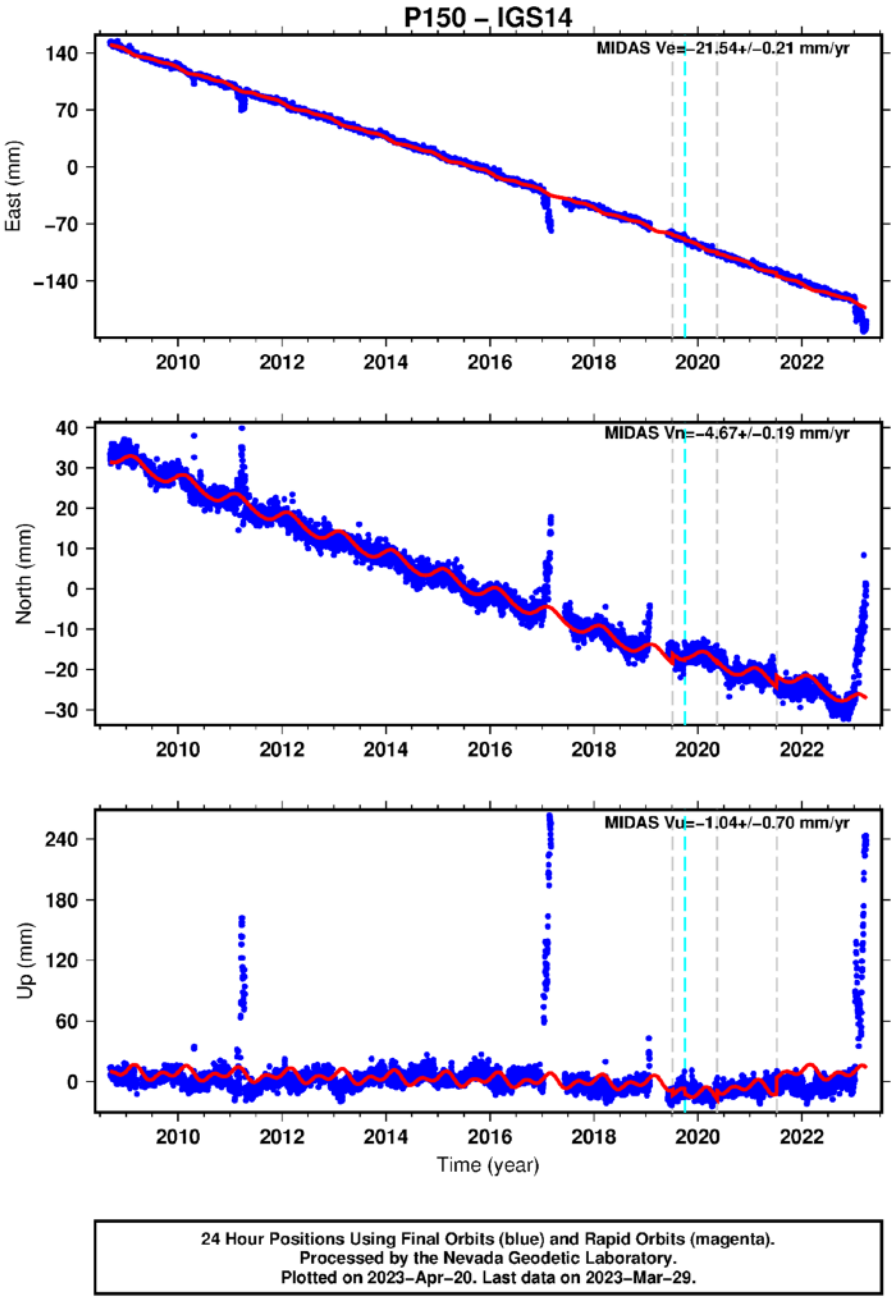

Snow Depth: p360
meters
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
2022-10
2022-11
2022-12
2023-01
2023-02
2023-03
2023-04
2023-05
2023-06

http://geodesy.unr.edu/NGLStationPages/stations/P150.sta

East

North

Up



This is what happens when a GNSS antenna is buried in snow.