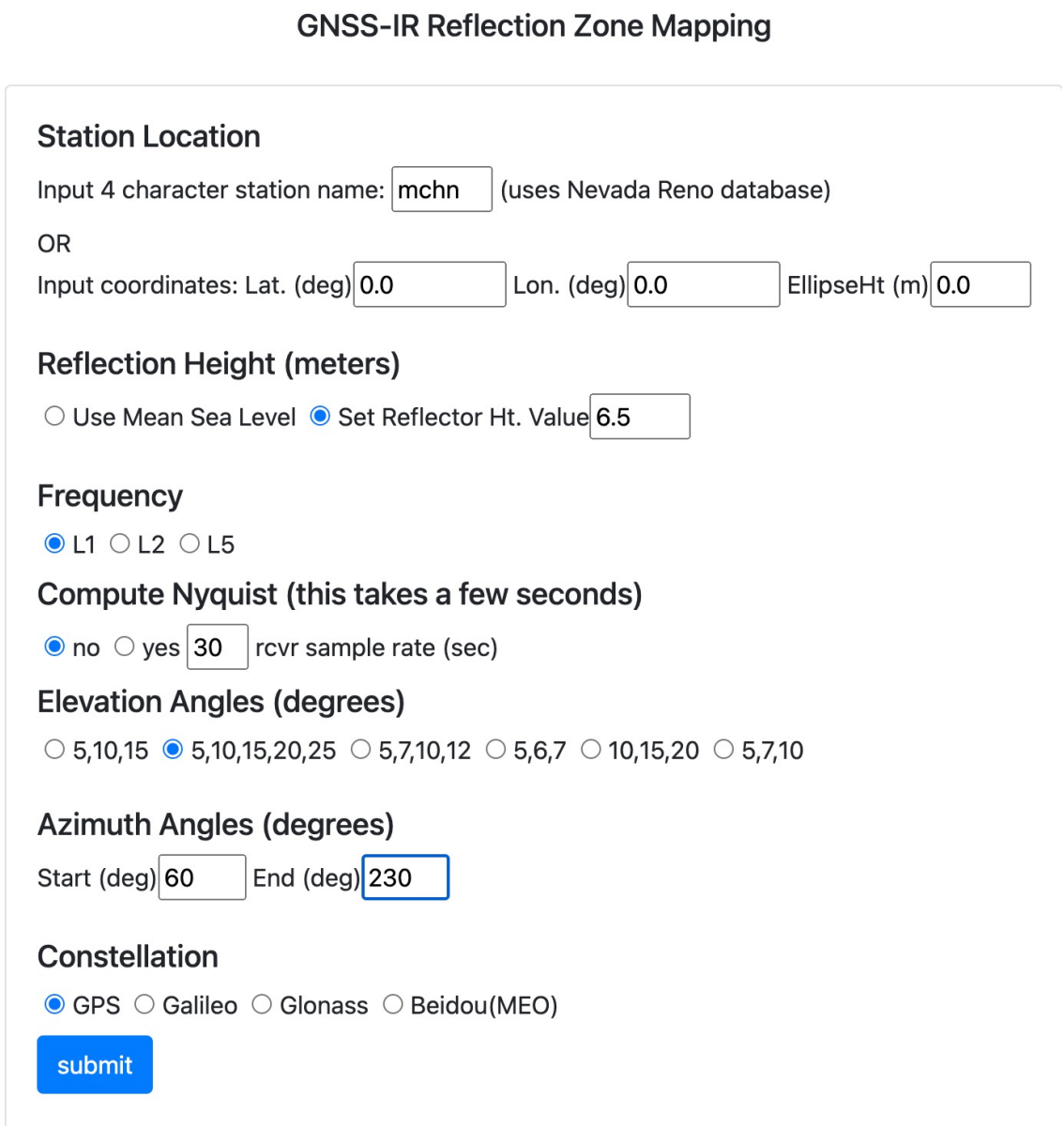
Picking reflection zones

Remember to look at your reflection zones using the app. It's the best way of choosing an appropriate mask.

If you don't know your reflector height the app can calculate mean sea level using the geoid if you know the ellipsoidal height (or it's a known location in the Nevada Reno database)

In an area of high tidal range (and you have an idea on that range) it may be useful to check the maximum and minimum heights as this changes the Fresnel zone area

Same goes for rivers

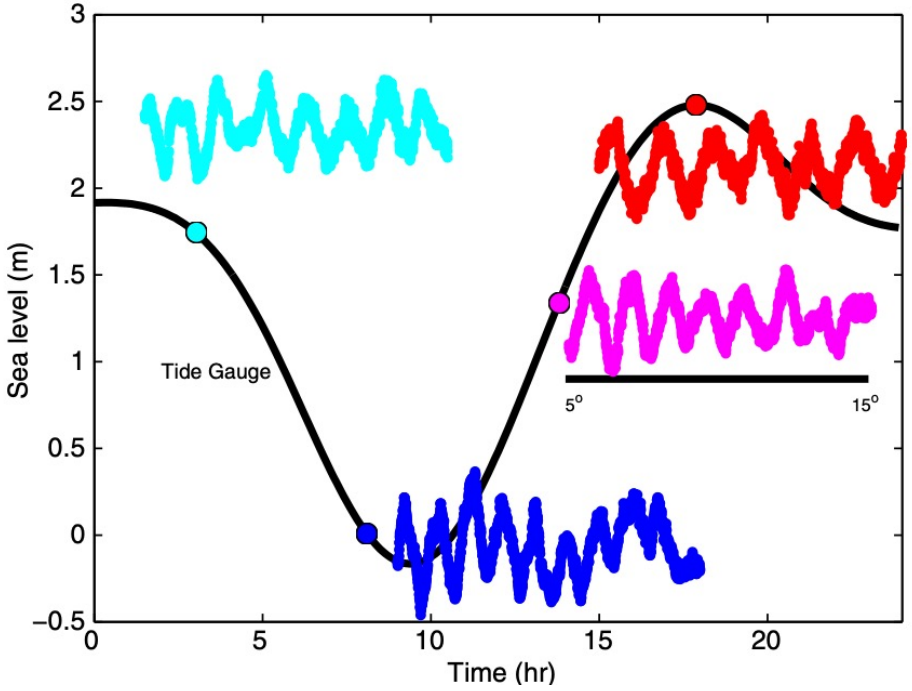


First study

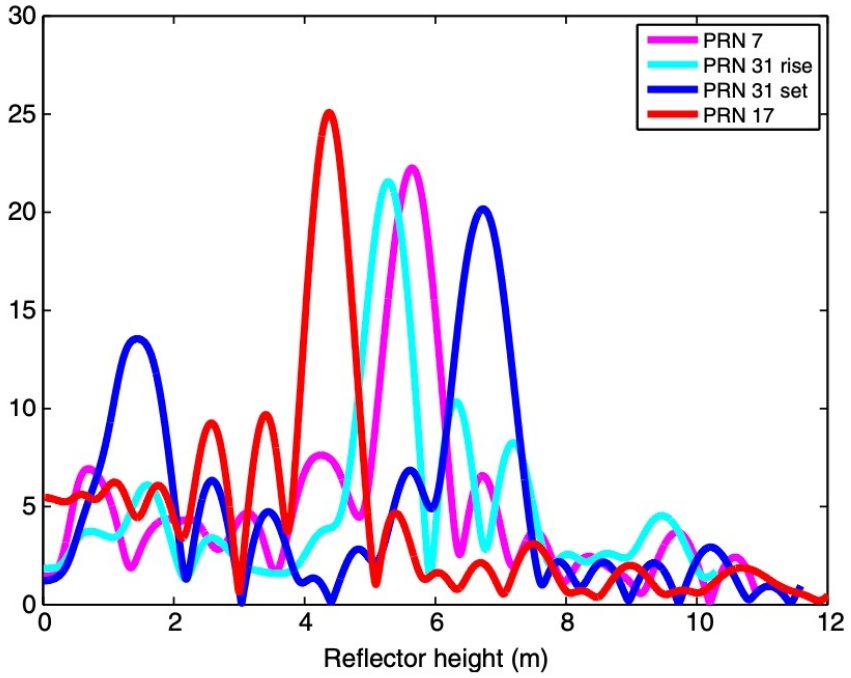
Coastal sea level measurements using a single geodetic GPS receiver

Kristine M. Larson [a], Johan S. Löfgren [b,*], Rüdiger Haas [b]

SNR Data juxtoposed on NOAA data



periodograms - L2C only



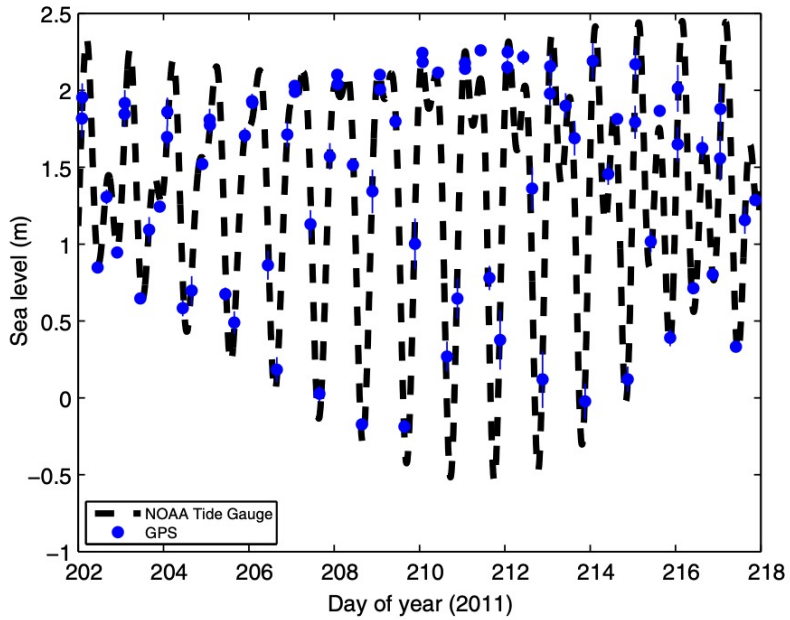
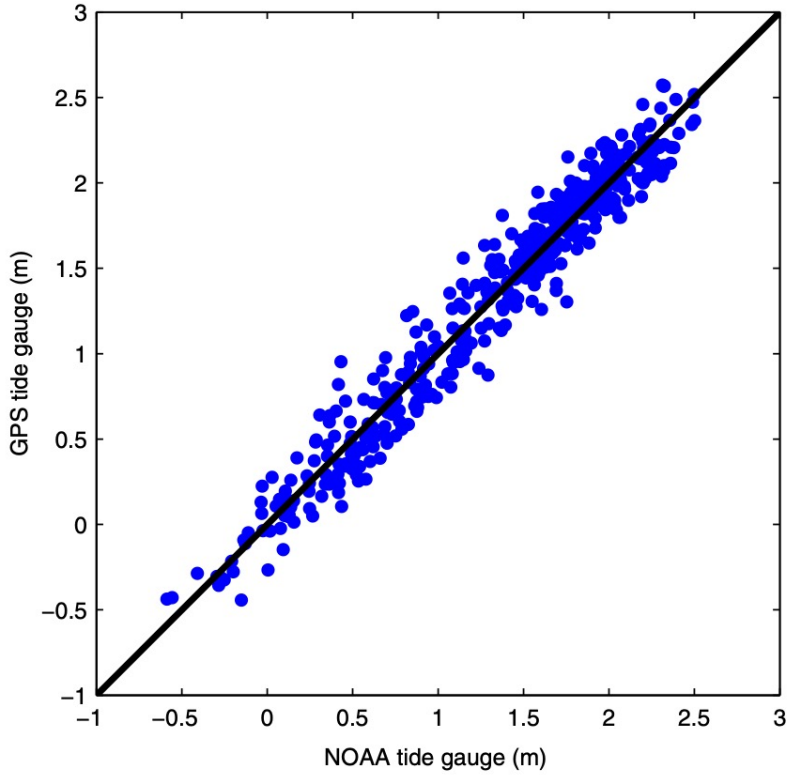
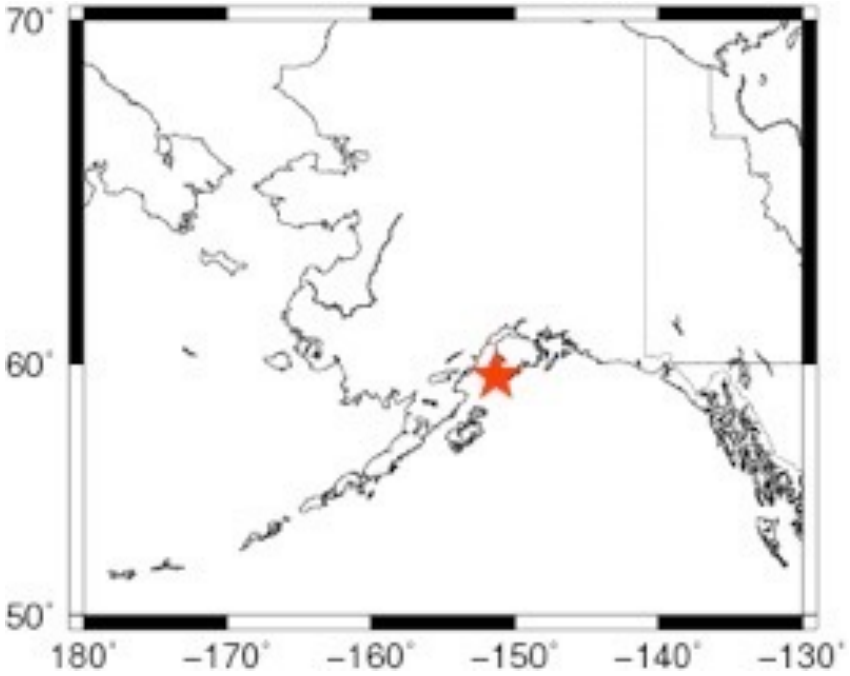
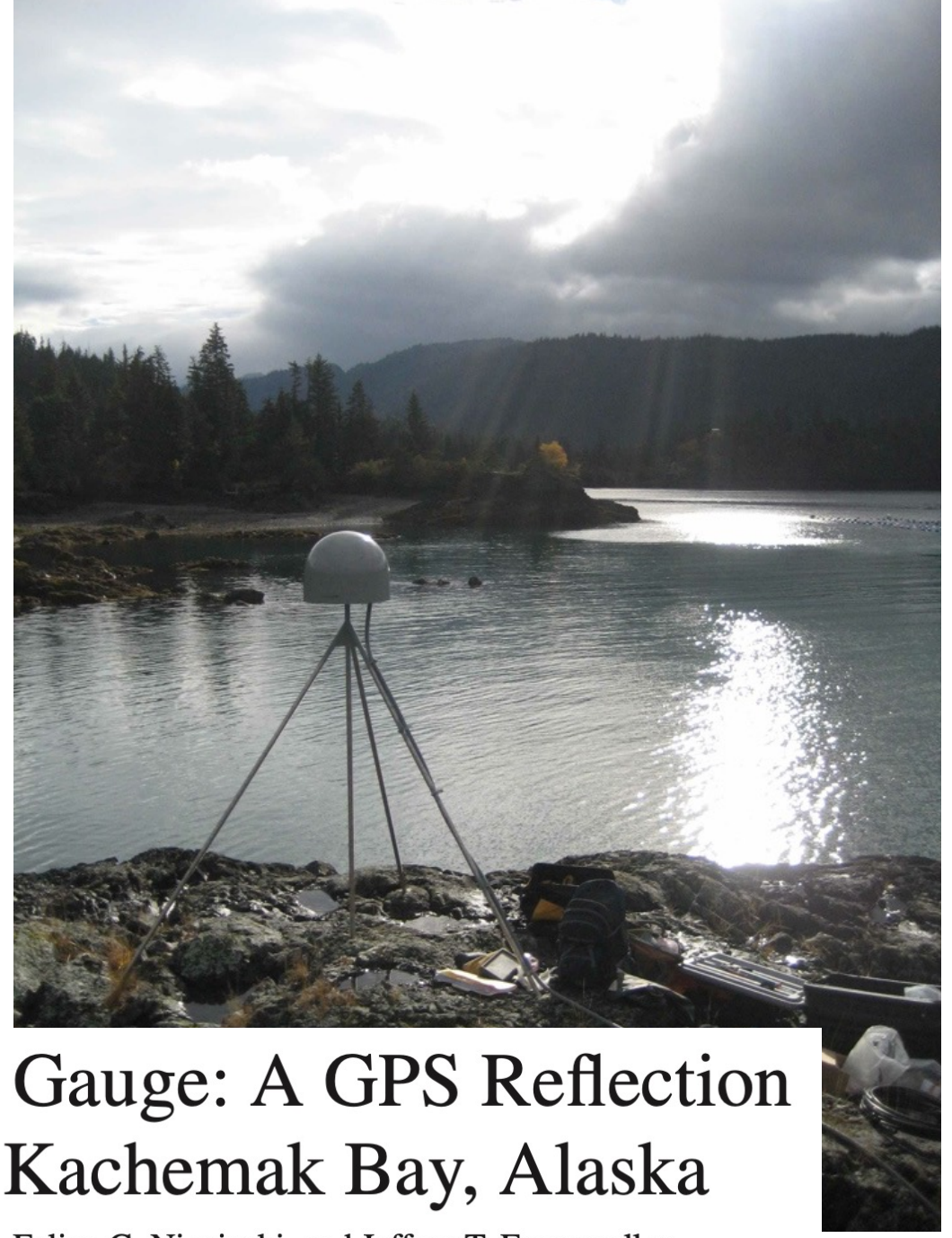


Fig. 11. The Friday Harbor sea level records estimated from GPS (blue dots, 5 per day) and measured by the NOAA (black dashed line) tide gauge. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

correlation was 0.98 for
3 month comparison



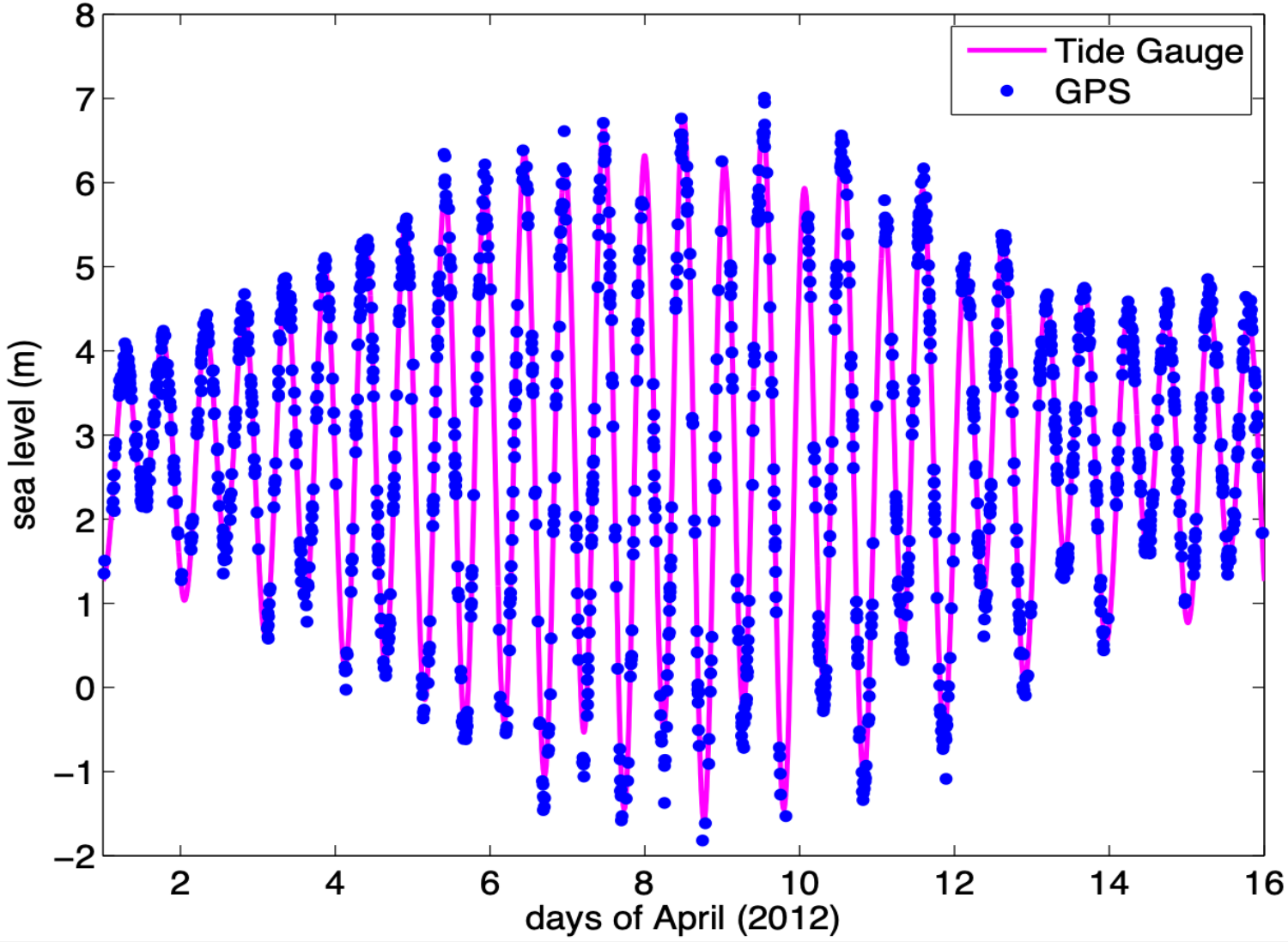




The Accidental Tide Gauge: A GPS Reflection Case Study From Kachemak Bay, Alaska

Kristine M. Larson, Richard D. Ray, Felipe G. Nievinski, and Jeffrey T. Freymueller

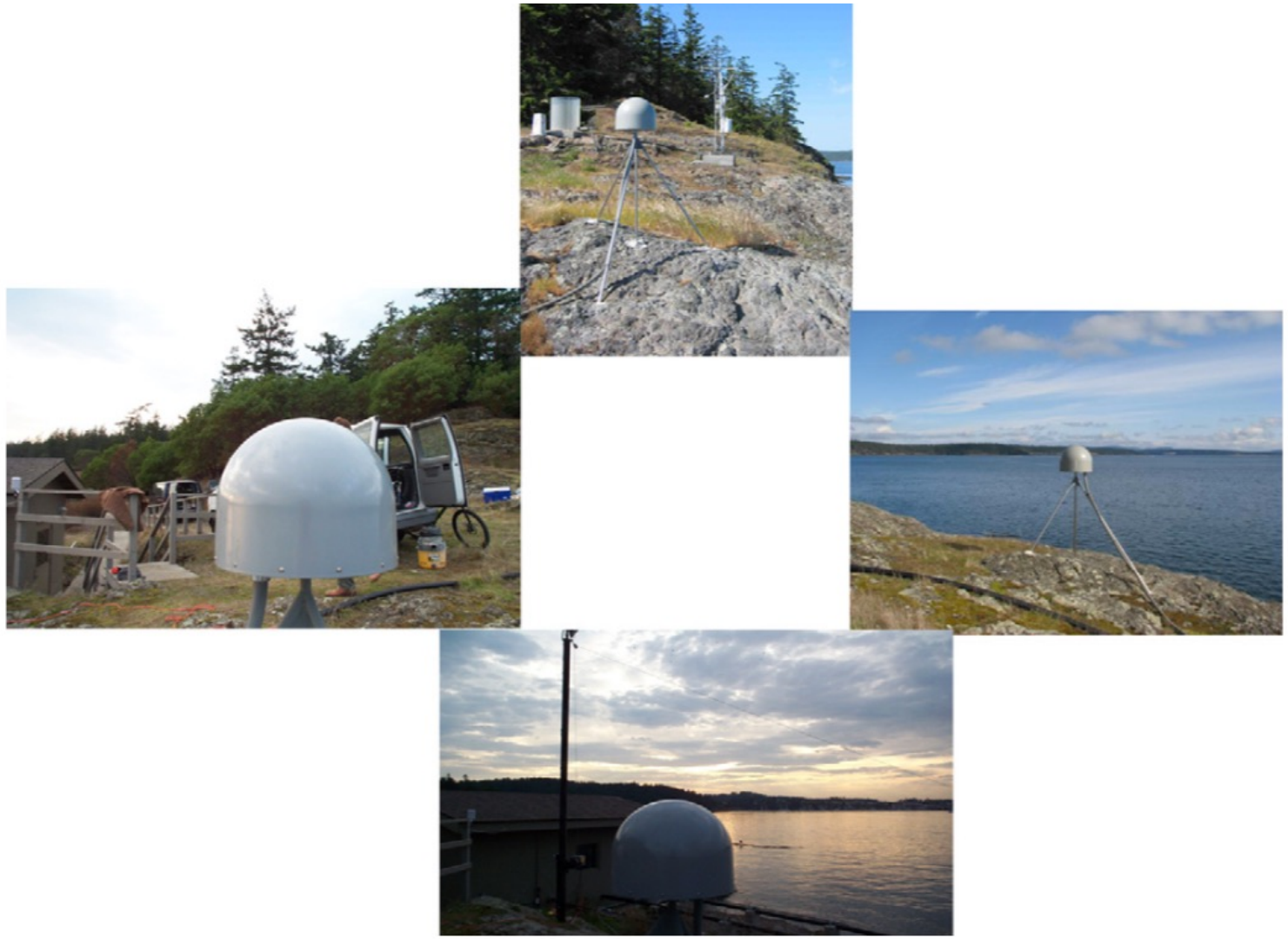
Comparison between GPS-IR and ‘Real’ Tide Gauge



Introduced the concept of the time varying water level effect

In 2017 we looked again at the
Friday Harbor data -
with a view of its long-term
suitability

A 10-Year Comparison of Water Levels Measured with a Geodetic GPS Receiver versus a Conventional Tide Gauge

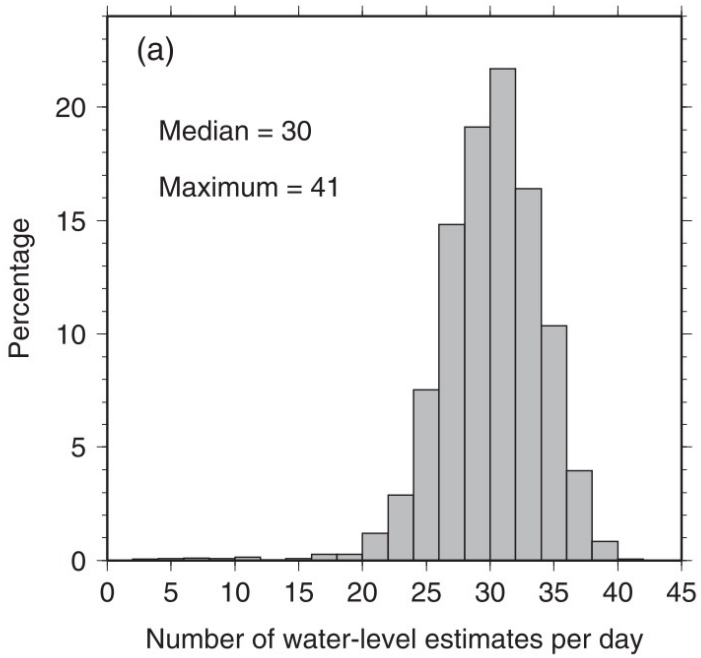


data from 2007-2017 from an older GPS receiver. Only used L1.

TABLE 1. Estimated amplitudes A and phase lags G of selected tidal constituents, based on data collected during 2006–15.

	Acoustic gauge		GPS		
Tide	A (cm)	G (°)	A (cm)	G (°)	Diff (cm)
Sa	6.1	274.8	5.8	277.6	0.37
Ssa	1.5	227.7	1.6	220.1	0.21
Mf	2.0	168.2	2.0	162.4	0.20
Q_1	7.4	250.0	7.5	249.9	0.13
O_1	43.4	258.1	44.0	258.6	0.78
P_1	23.6	278.7	23.1	278.0	0.54
S_1	2.6	31.2	1.6	59.2	1.37
K_1	76.0	280.0	76.0	279.0	1.33
J_1	4.0	311.6	4.0	310.5	0.08
N_2	12.1	342.4	12.0	343.1	0.15
M_2	56.0	10.5	56.4	10.2	0.50
S_2	13.3	36.0	13.2	34.9	0.25
MK_3	1.2	26.8	1.2	33.9	0.16
M_4	1.7	121.2	1.5	121.1	0.17
MS_4	1.0	131.4	0.8	131.4	0.17
M_6	0.5	236.0	0.4	255.1	0.18

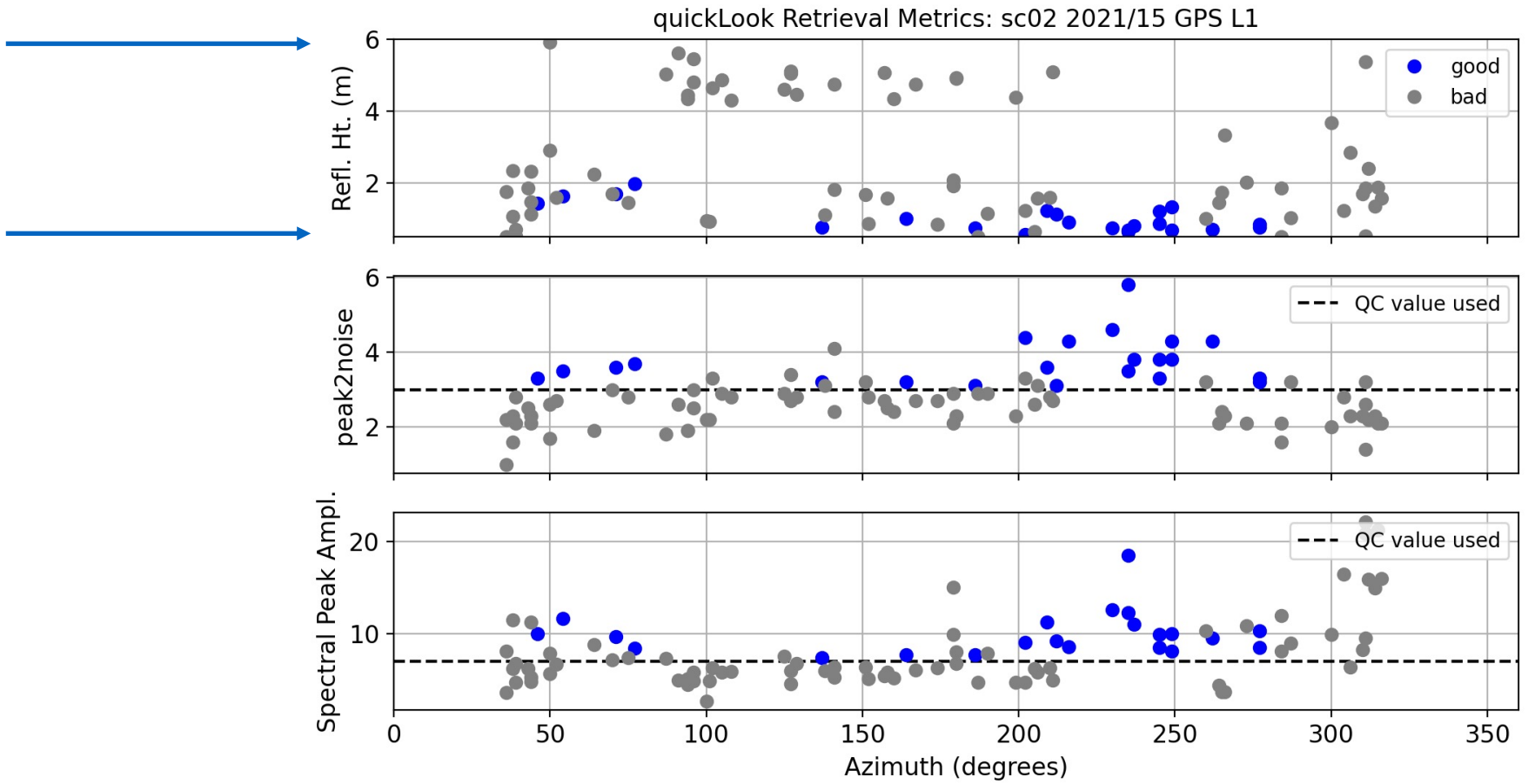
Note only 30 measurements per day



Look at the data from this site using gnssrefl (original defaults)

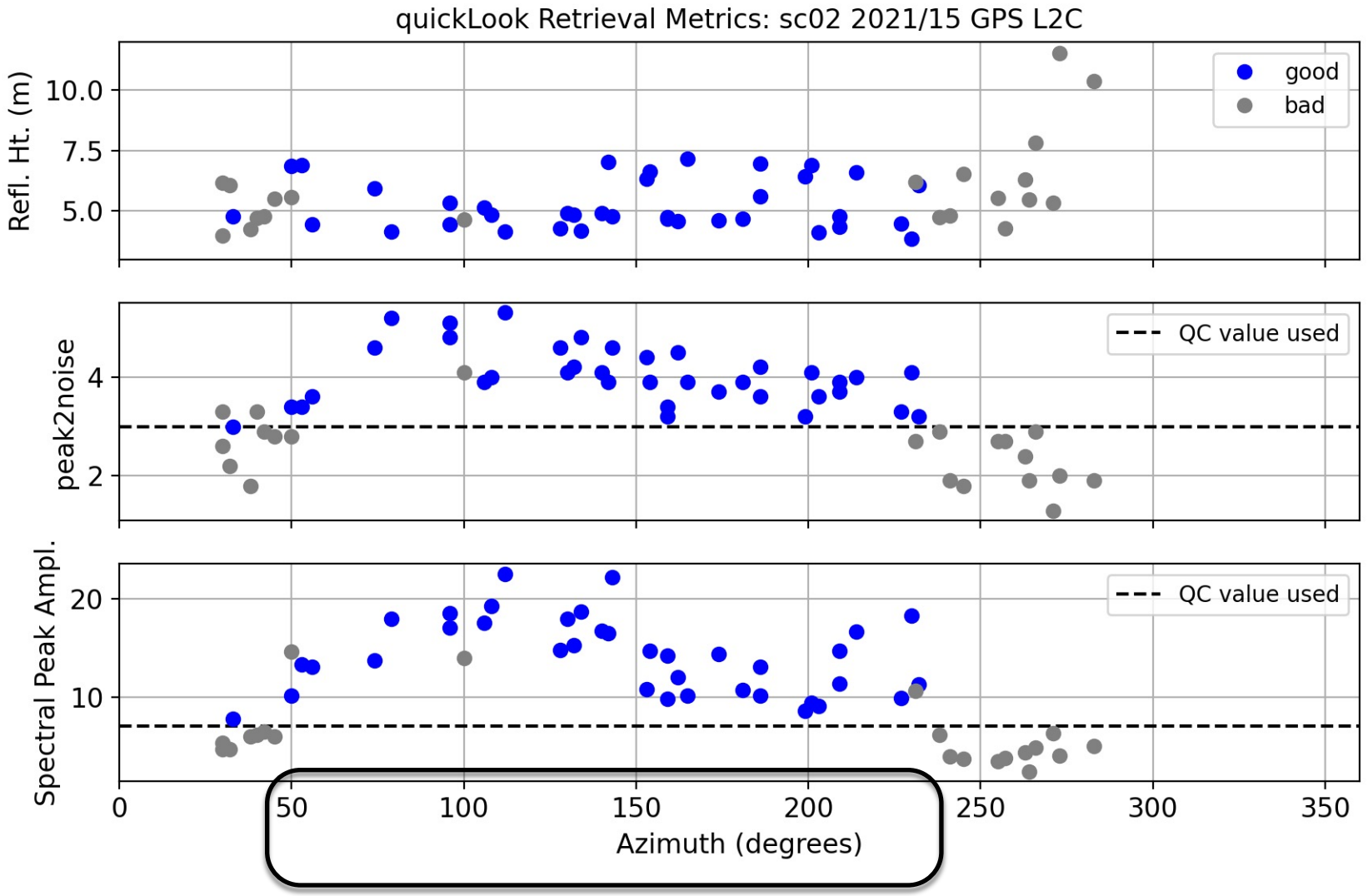
rinex2snr sc02 2021 15

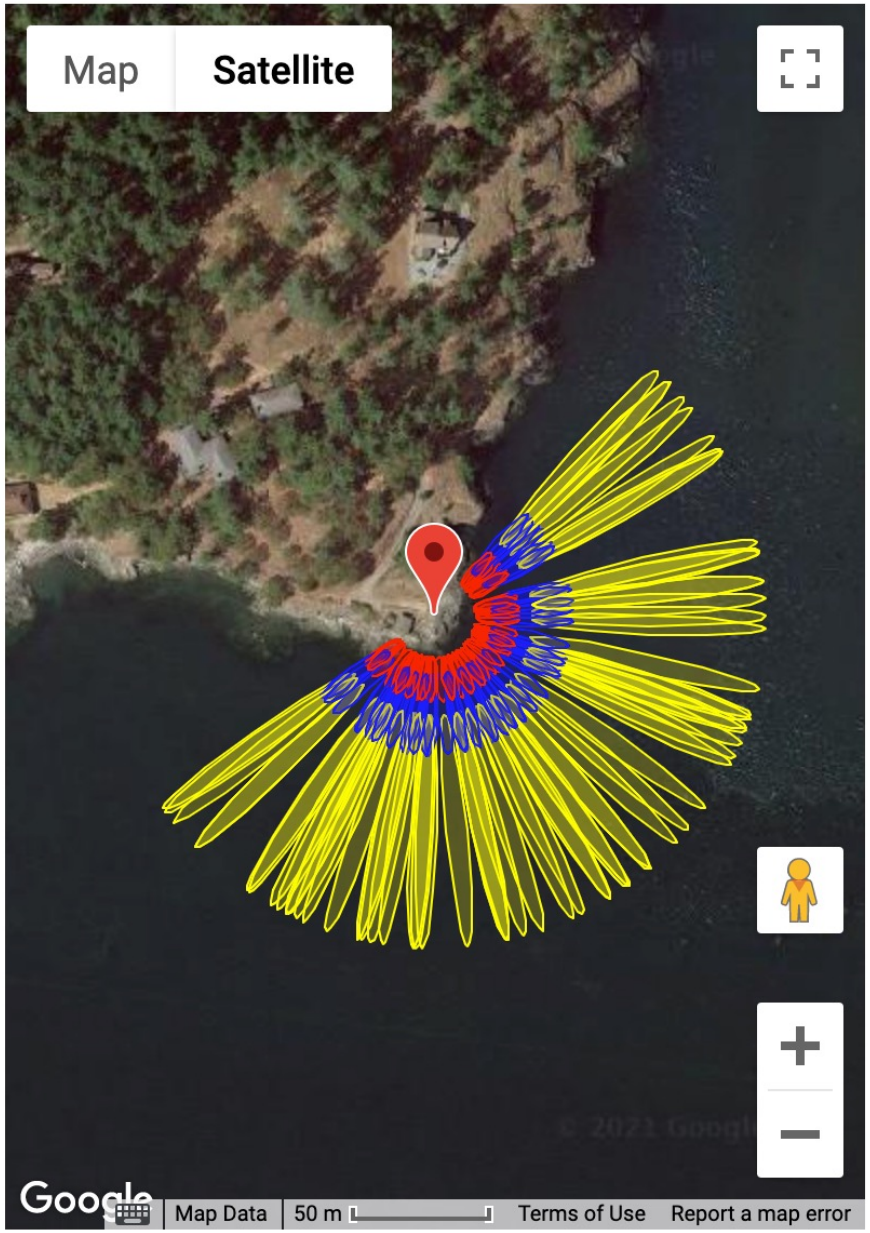
quickLook sc02 2021 15



Better choices

quickLook sc02 2021 15 -e1 5 -e2 13 -h1 3 -h2 12 -fr 20





remember to use the reflection zone tool

Make more SNR files

```
rinex2snr sc02 2021 15 -doy_end 45 -orb gnss
```

Store your analysis strategy (left out fr 206 by accident)

```
make_json_input sc02 0 0 0  -e1 5 -e2 13 -h1 3 -h2 12
-peak2noise 3.0 -frlist 1 20 5 101 102 201 205 207
-azlist 60 90 90 180 180 240 -delTmax 40
```

Analyze the data

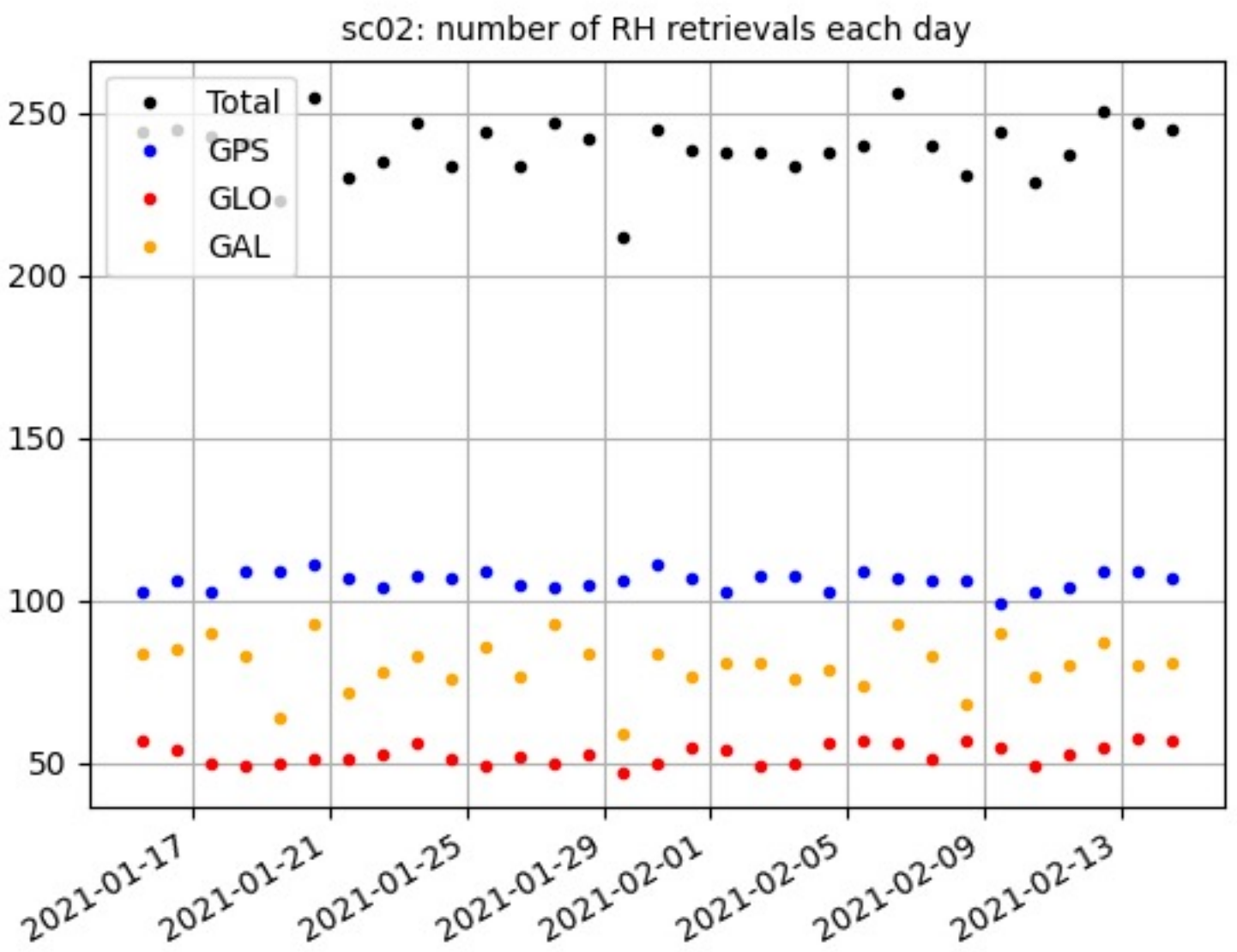
```
gnssir sc02 2021 15 -doy_end 45
```

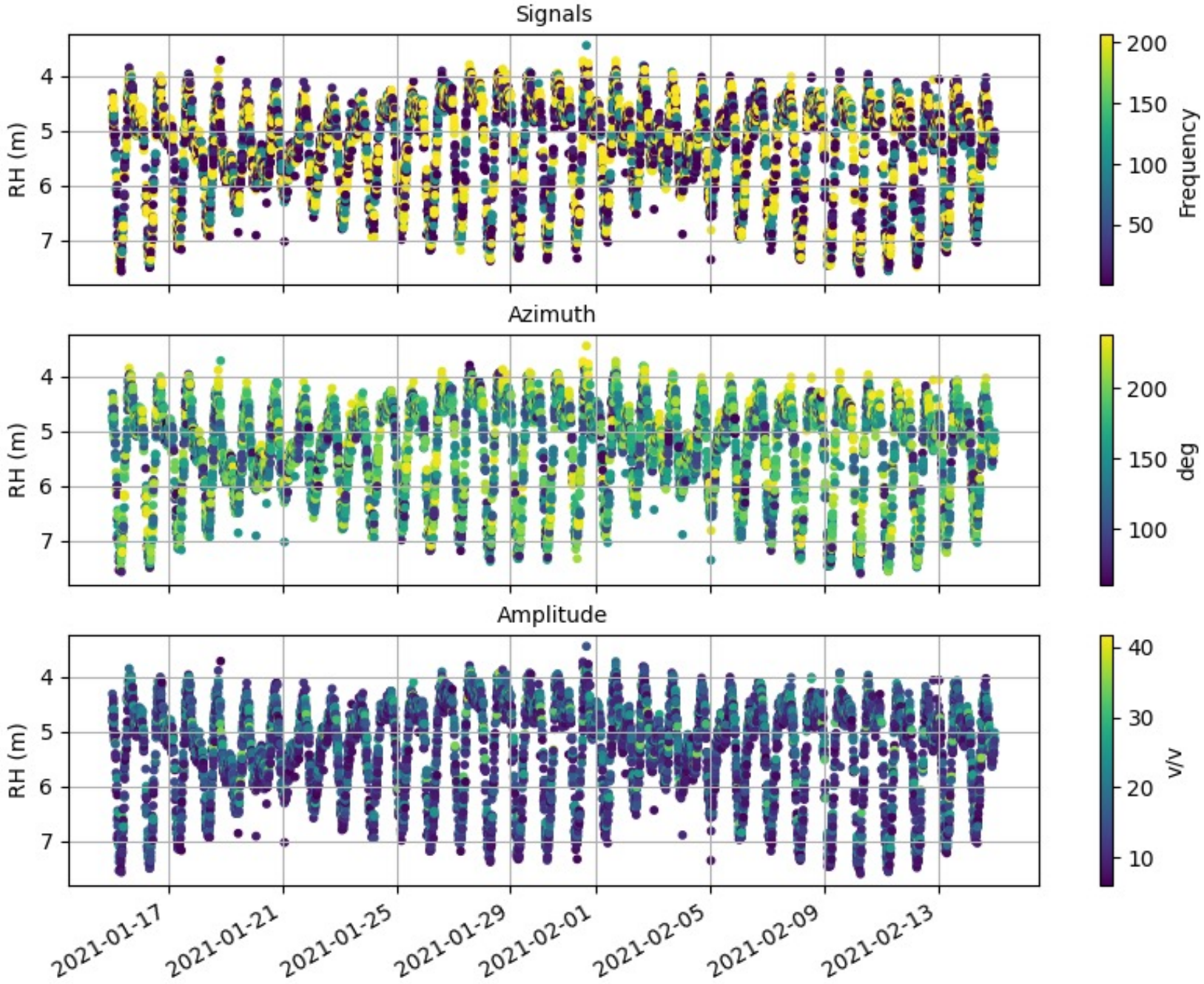
Remember : Use the subdaily module for sites with tidal signals

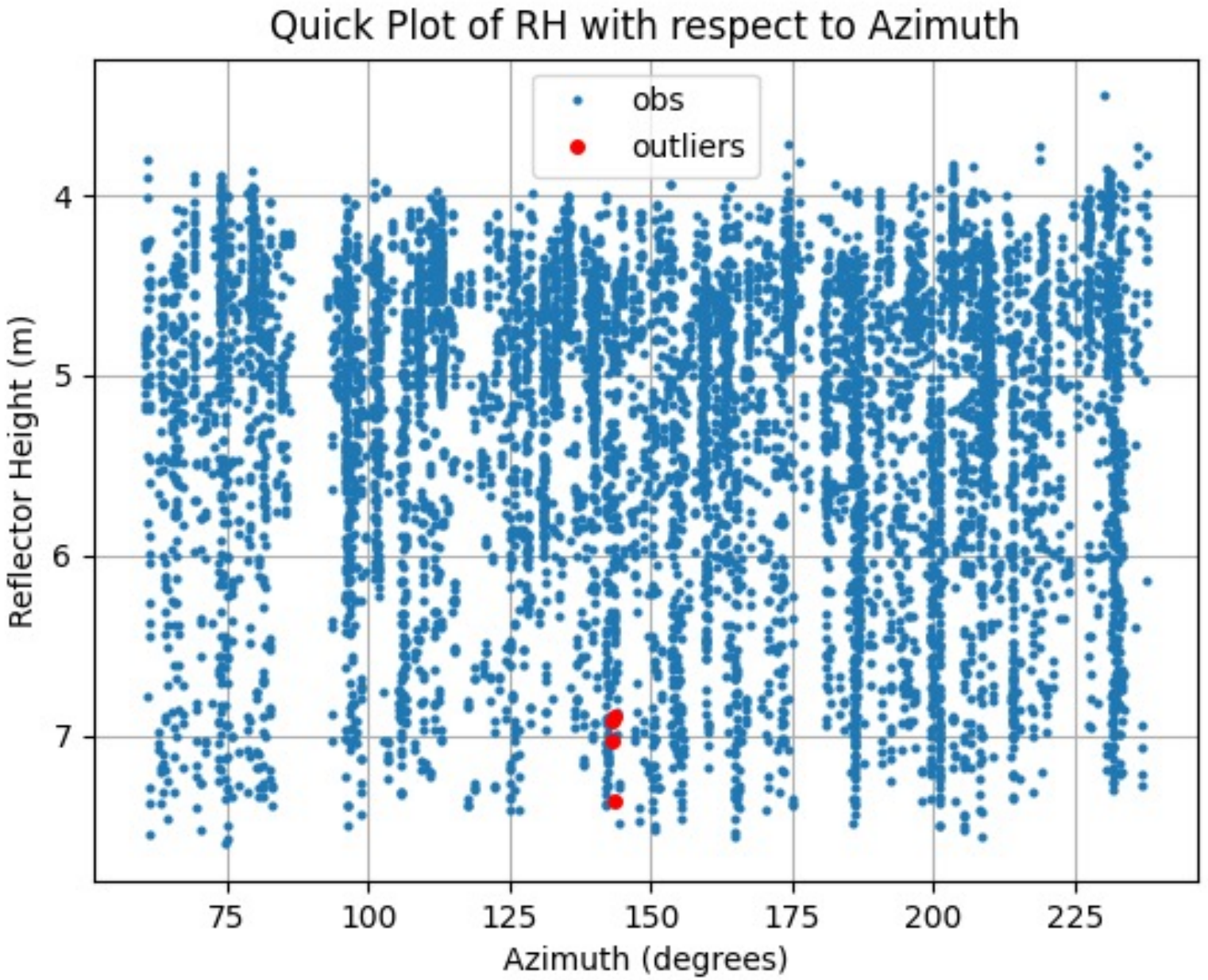
subdaily part I

- First section is to give you feedback on your dataset.
  - Do you have a lot of outliers?
  - Should you go back and change your mask?
  - Should you apply RH restrictions?
  - Which constellations are making the biggest contribution?
- First section removes only the largest outliers (using 2.5 sigma from daily average, which can be changed on the command line).

Compare with earlier study where we only had 35 measurements per day.



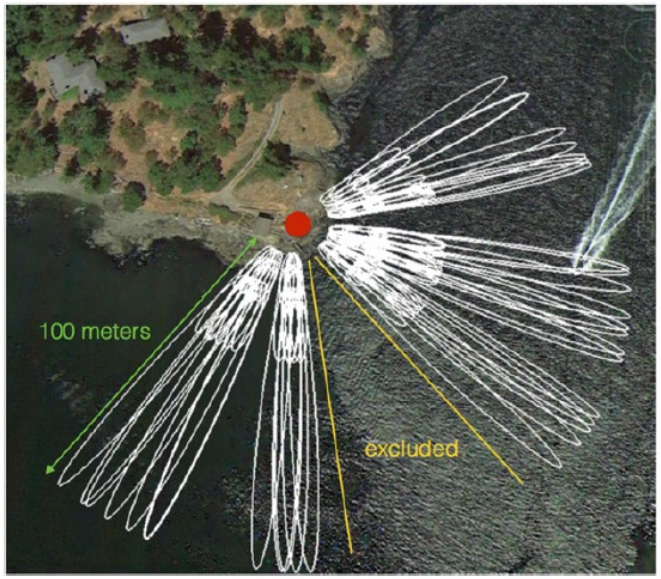

Signals
RH (m)
4
5
6
7
200
150
100
50
Frequency
Azimuth
RH (m)
4
5
6
7
200
150
100
deg
Amplitude
RH (m)
4
5
6
7
40
30
20
10
v/v
2021-01-17
2021-01-21
2021-01-25
2021-01-29
2021-02-01
2021-02-05
2021-02-09
2021-02-13



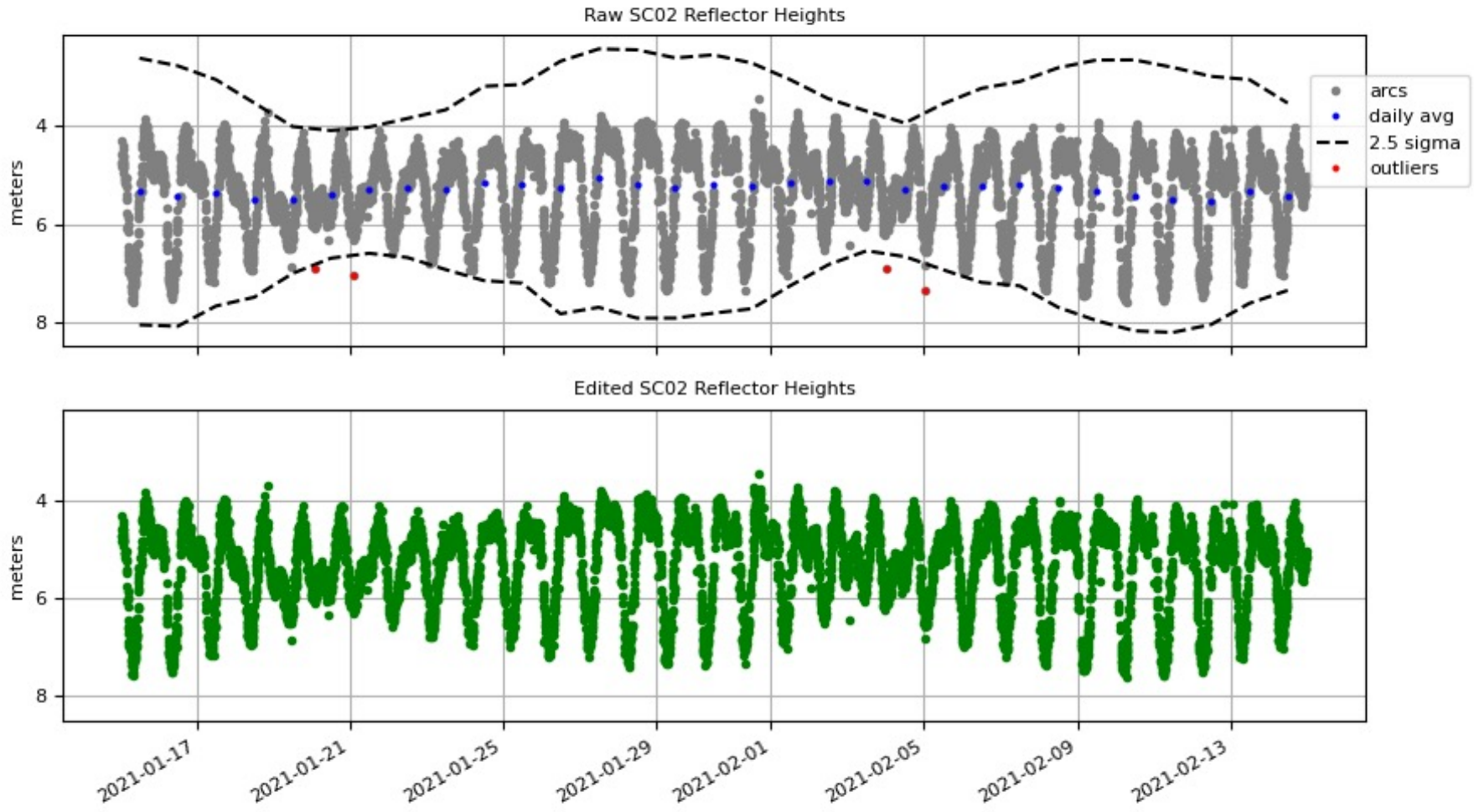
Note : you might ask yourself why those points are considered outliers when there are similar points at the same height and azimuth that are marked as good.

Remember this is an azimuth plot and the time varying aspect does not show up. These outliers are probably when the RH is expected to be low

In fact the azimuth where these outliers show was excluded in the 10-year comparison paper



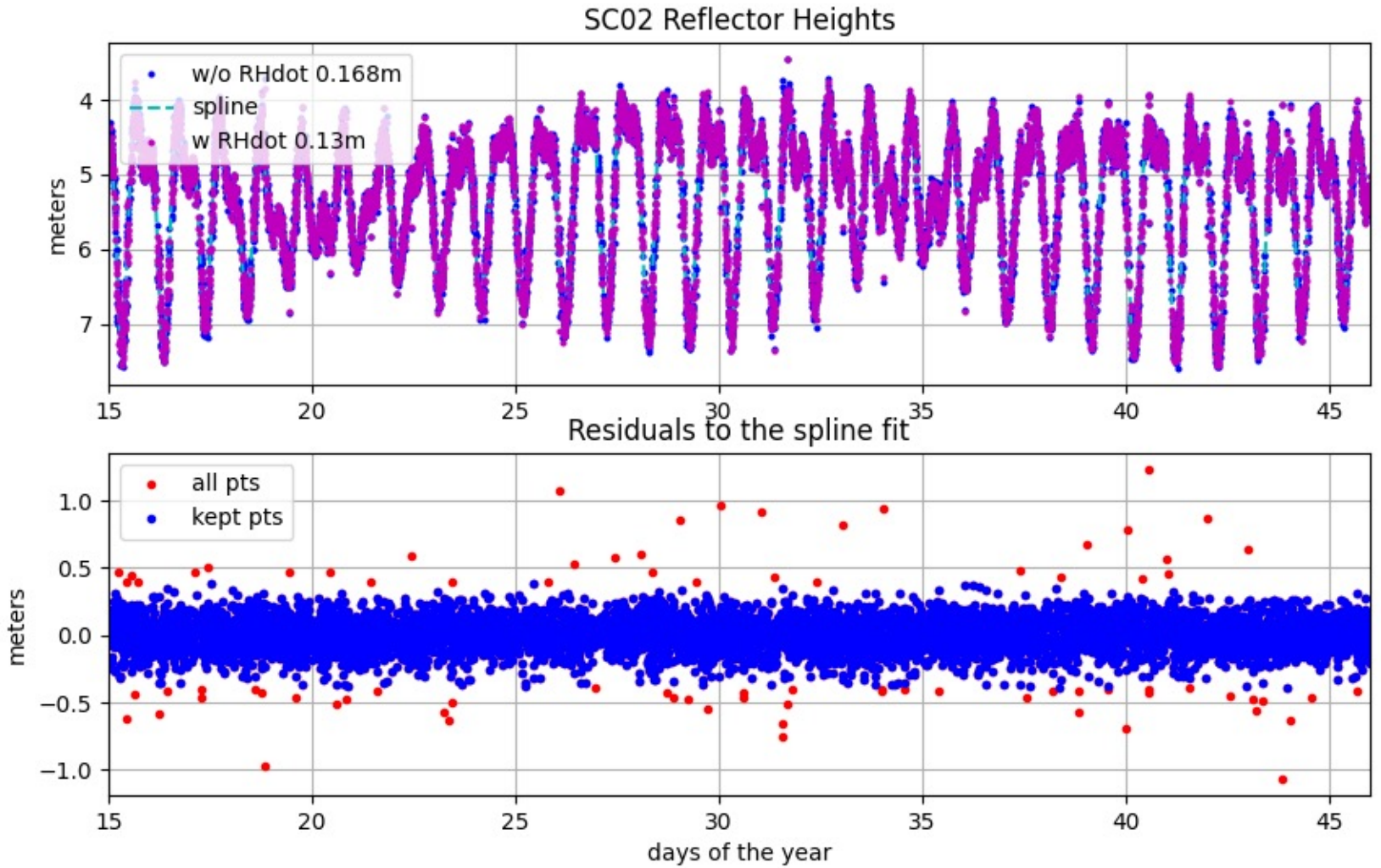
Removes only a few outliers, which means the mask is pretty good



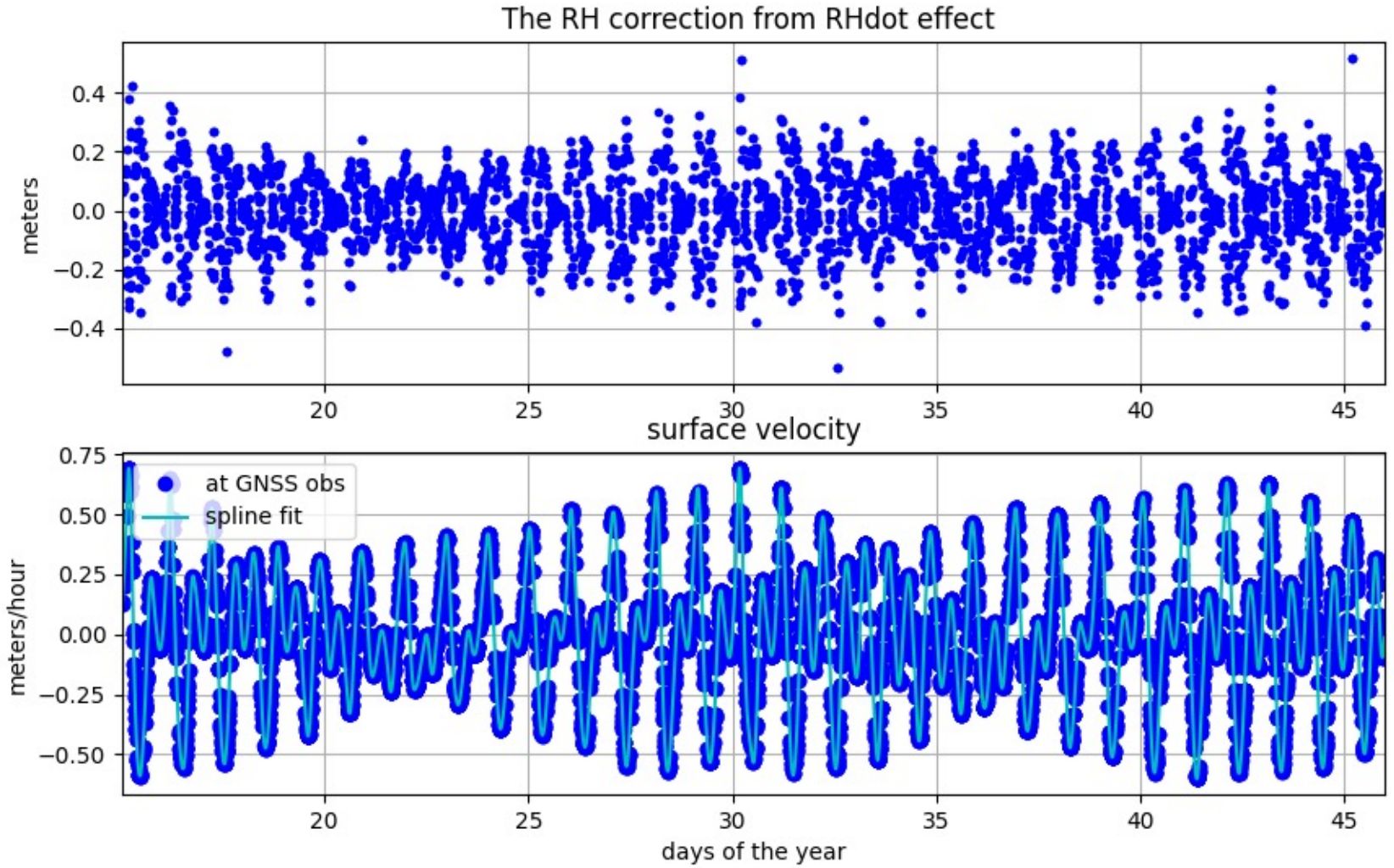
subdaily part II

- Second section
  - Compute and apply RHdot correction
  - this code uses a spline to calculate RHdot.
  - it also uses the spline to remove smaller outliers
  - and to compute and remove inter frequency biases
- After all that, it computes a new spline.
  - you can request evenly sampled RH from that spline, but IT IS A SPLINE FIT. it is not the truth.
  - a spline is smooth and not all water measurements have smooth behavior
  - you control the spline - by setting the number of knots on the command line. but even so, it will still be smooth.
  - It will not be good for tidal harmonic analysis

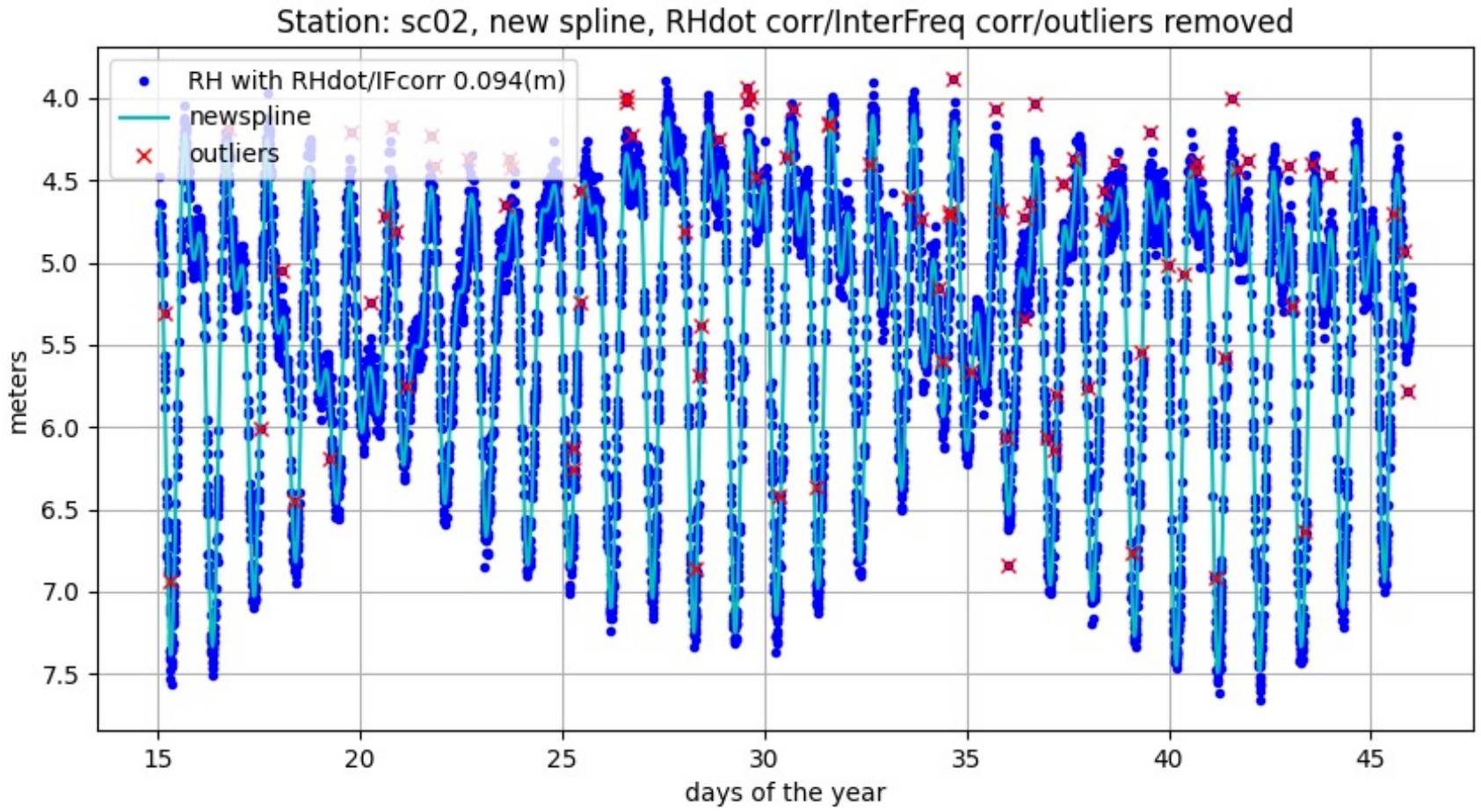
1. fit a spline
2. compute/apply RHdot.
3. Report RMS with and without that correction.
4. Remove 3 sigma outliers



Shows you RHdot and RH correction so you can make sure it isn't doing something stupid.

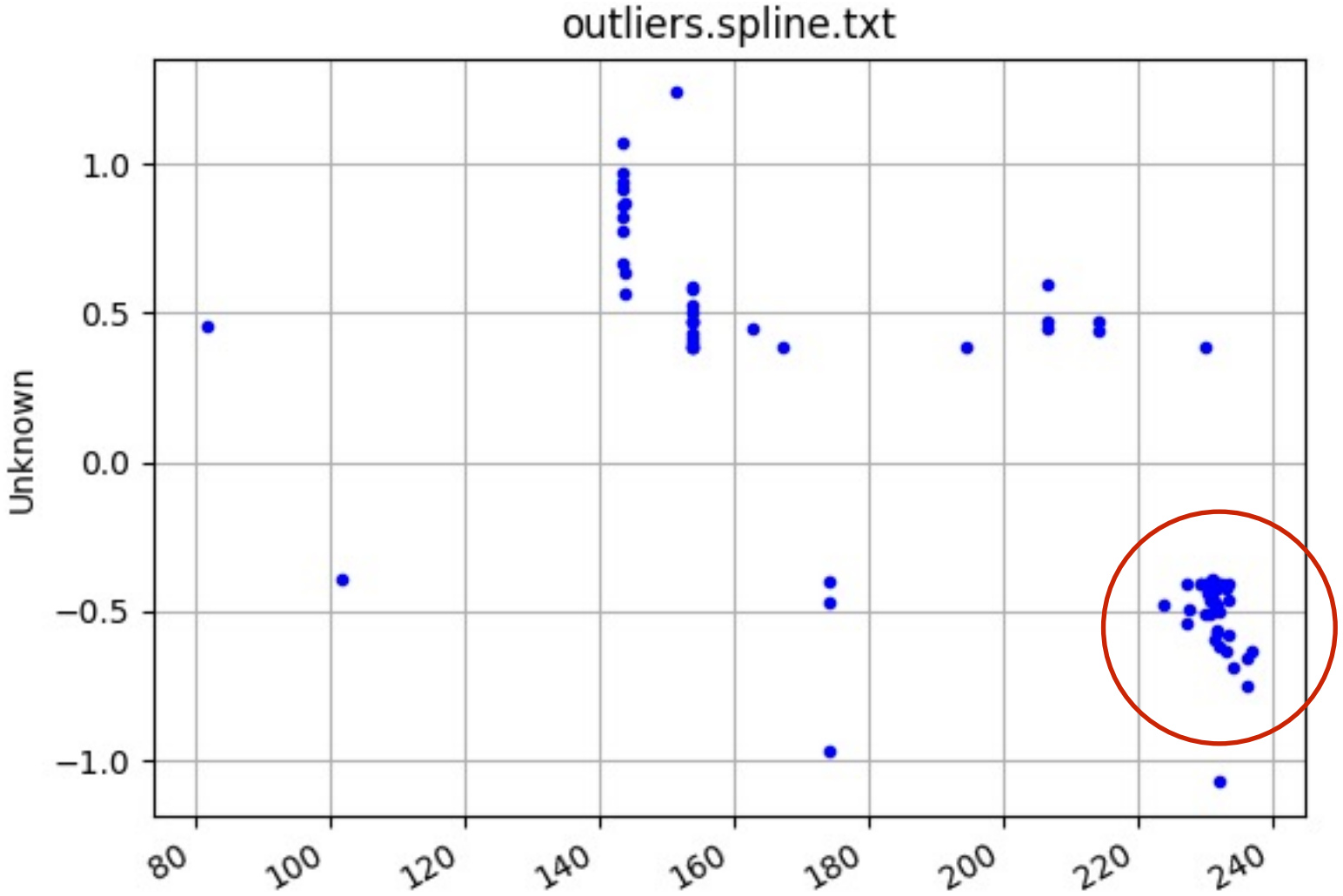


After all the modeling steps, computes new RMS.
You should see things getting better - but again, it is
a comparison with a spline. It is not a comparison with truth.

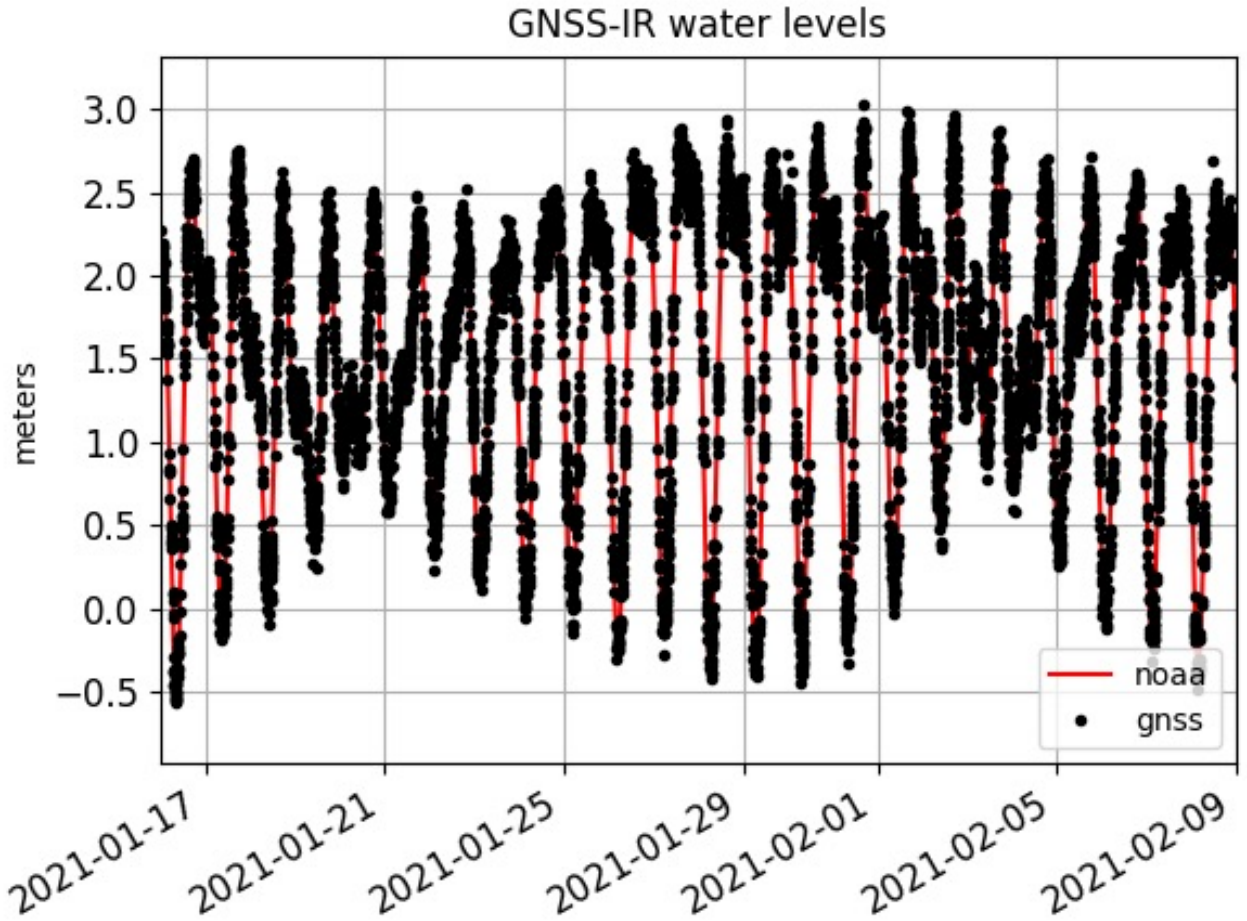


Iterate - where are the outliers coming from
You can exclude those azimuths in subdaily,
but better to fix the json and rerun gnssir

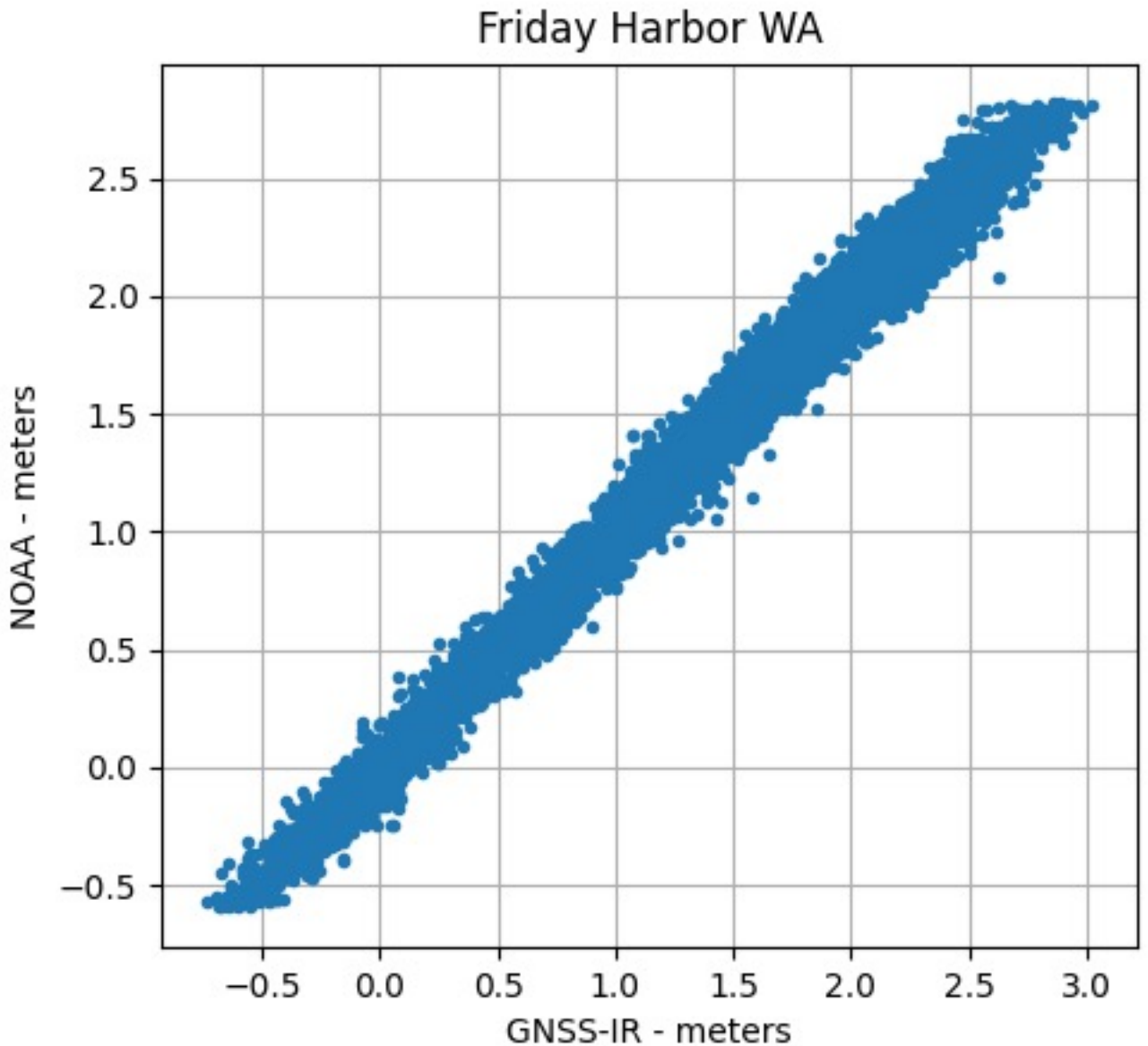
quickplt /Users/kristine/Documents/Research/Files/sc02/outliers.spline.txt 2 4 -xlabel azim -ylabel outlier



If your goal is to understand the accuracy of your sensor, you have no choice but to compare to another sensor - preferably one that is better than GNSS-IR



Correlation is ~0.994



Does it work at taller sites?

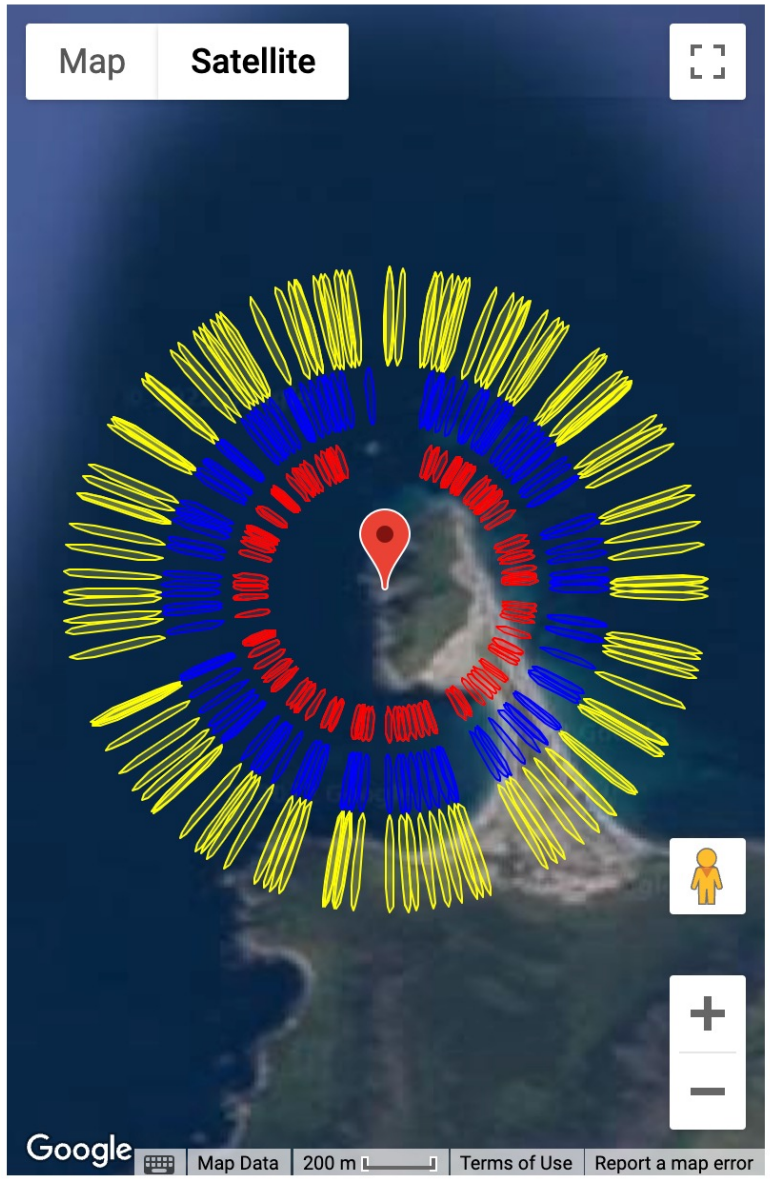
More challenging site

Station ac12

Find proper azimuths using the reflection zone tool
https://gnss-reflections.org/rzones

Note the difficulties to the south

These Fresnel zones are 5-7-10 degrees.

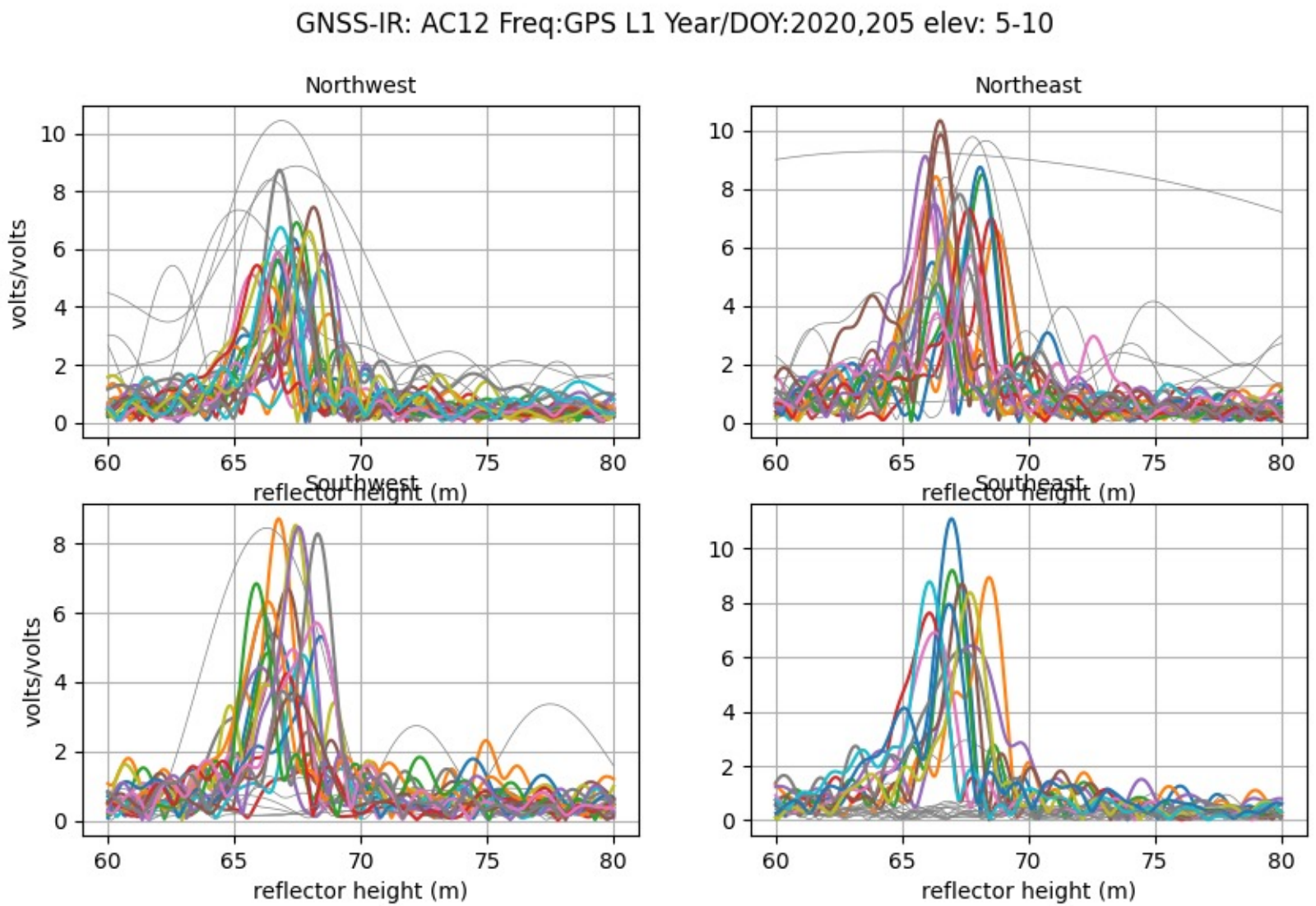


Note: -snr 50 is special mode where you only keep data below elevation angles of 10 degrees.

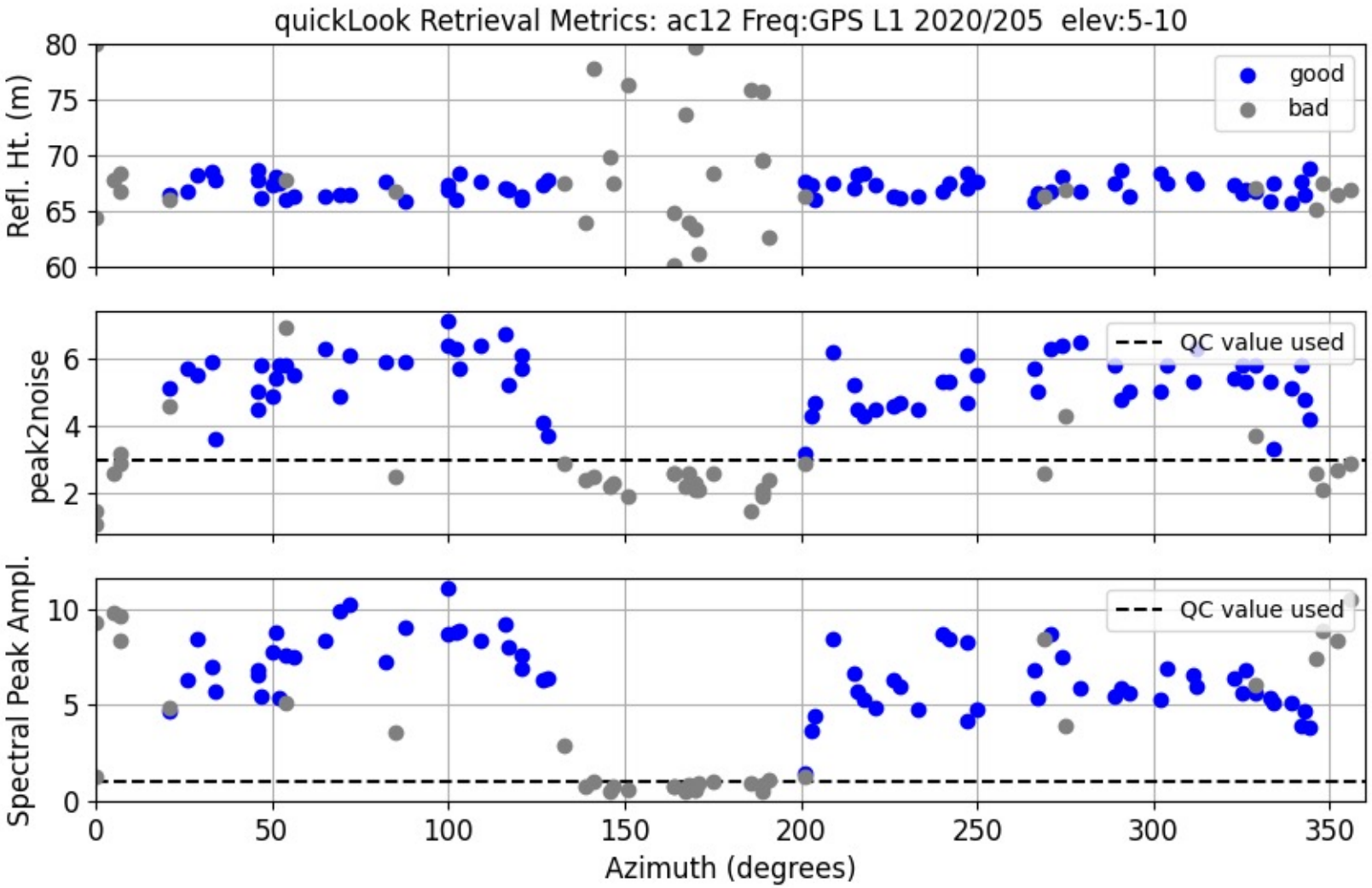
```
rinex2snr ac12 2020 205 -snr 50 -archive unavco -rate high
```

Since the code uses snr 66 as the default, you will need to specify this value in quicklook and gnssir

quickLook ac12 2020 205 -snr 50 -h1 60 -h2 80 -e1 5 -e2 10



Note that it falls apart exactly where we said it would



Note: absolute RH values from quickLook are not the same as gnssir because there is no refraction model in quickLook. Because it is a quick look.

Make more SNR files using rinex2snr

Receiver was GPS only at this time, so no point listing other frequencies

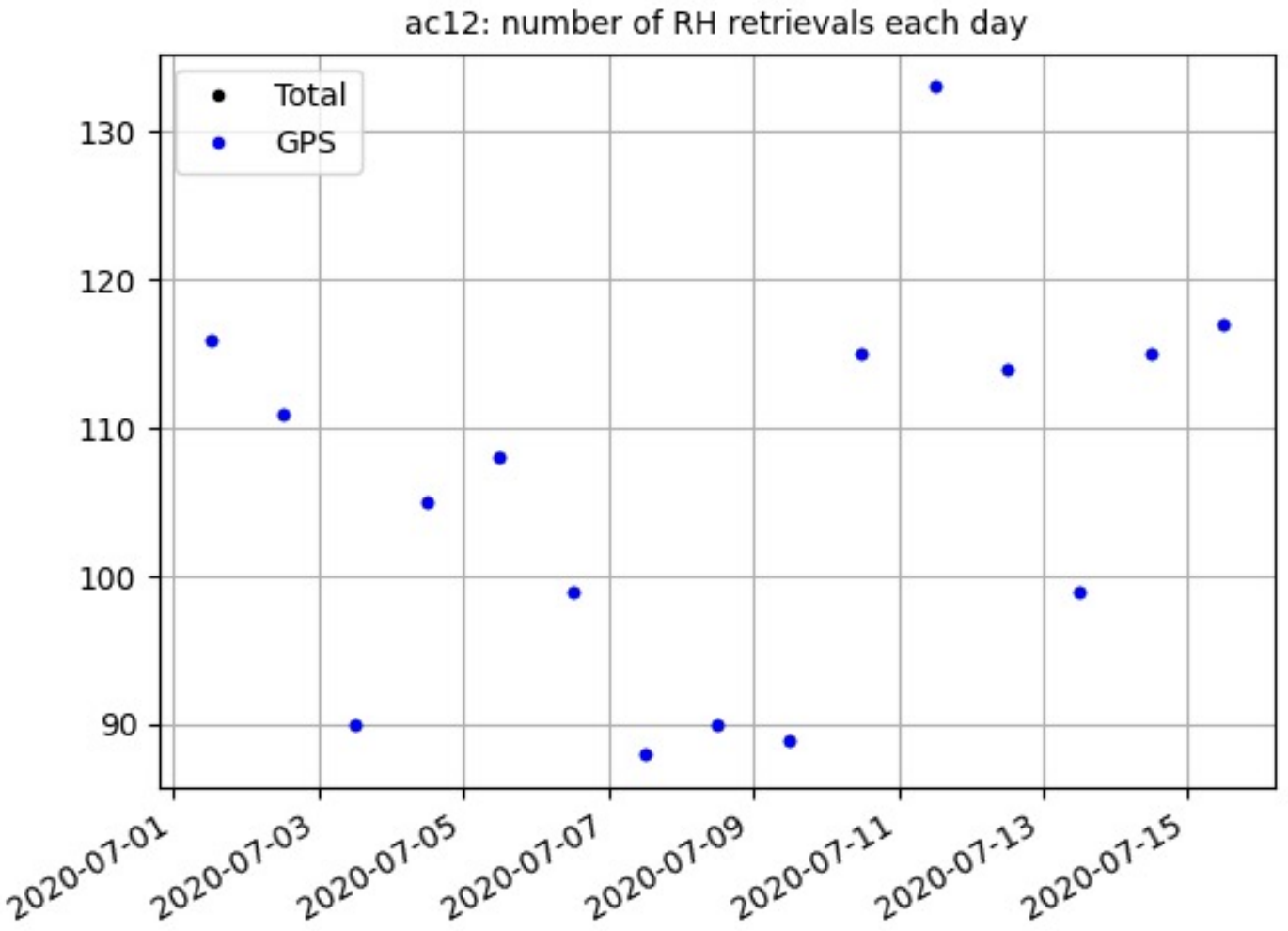
```
make_json_input ac12 0 0 0 -e1 5 -e2 10 -h1 60 -h2 75
-azlist 0 90 90 125 200 270 270 315 315 360 -frlist 1 20 5
```

Decided I didn't need 1 sec after all, used dec option to make the code run faster

```
gnssir ac12 2020 183 -snr 50 -doy_end 197  -dec 2
```

```
subdaily ac12 2020
```

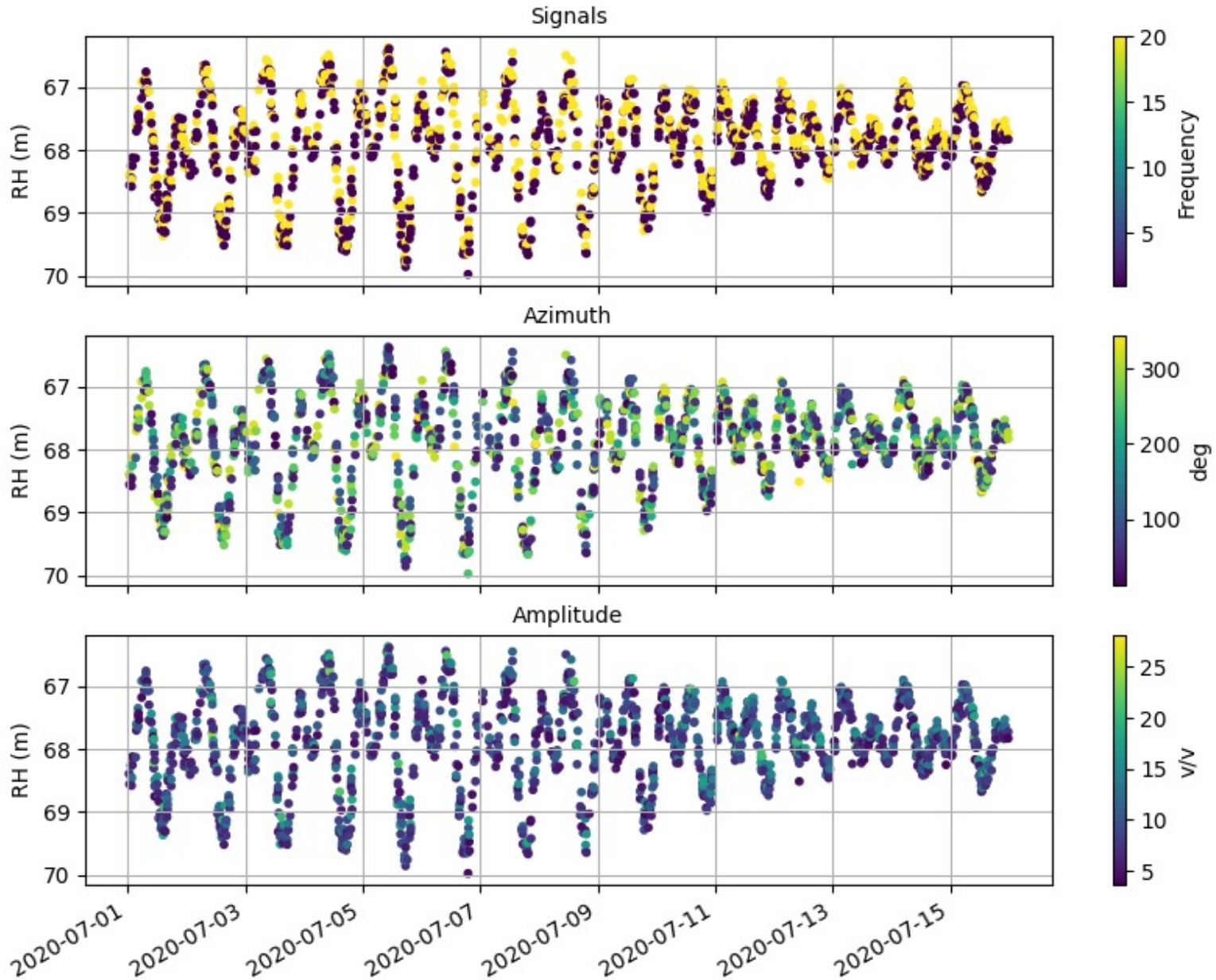
At sc02 we had almost 250 measurements per day. This is GPS only.

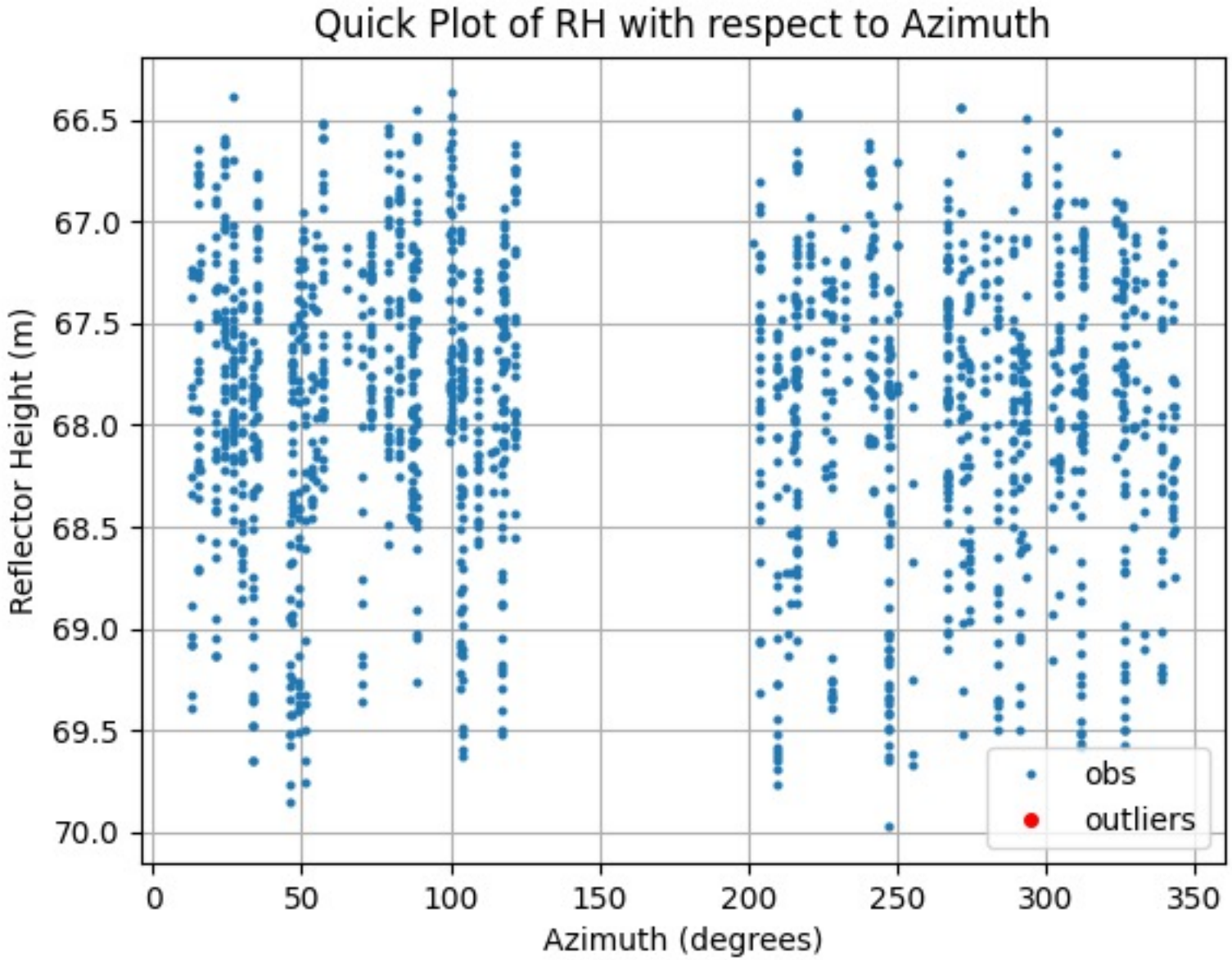


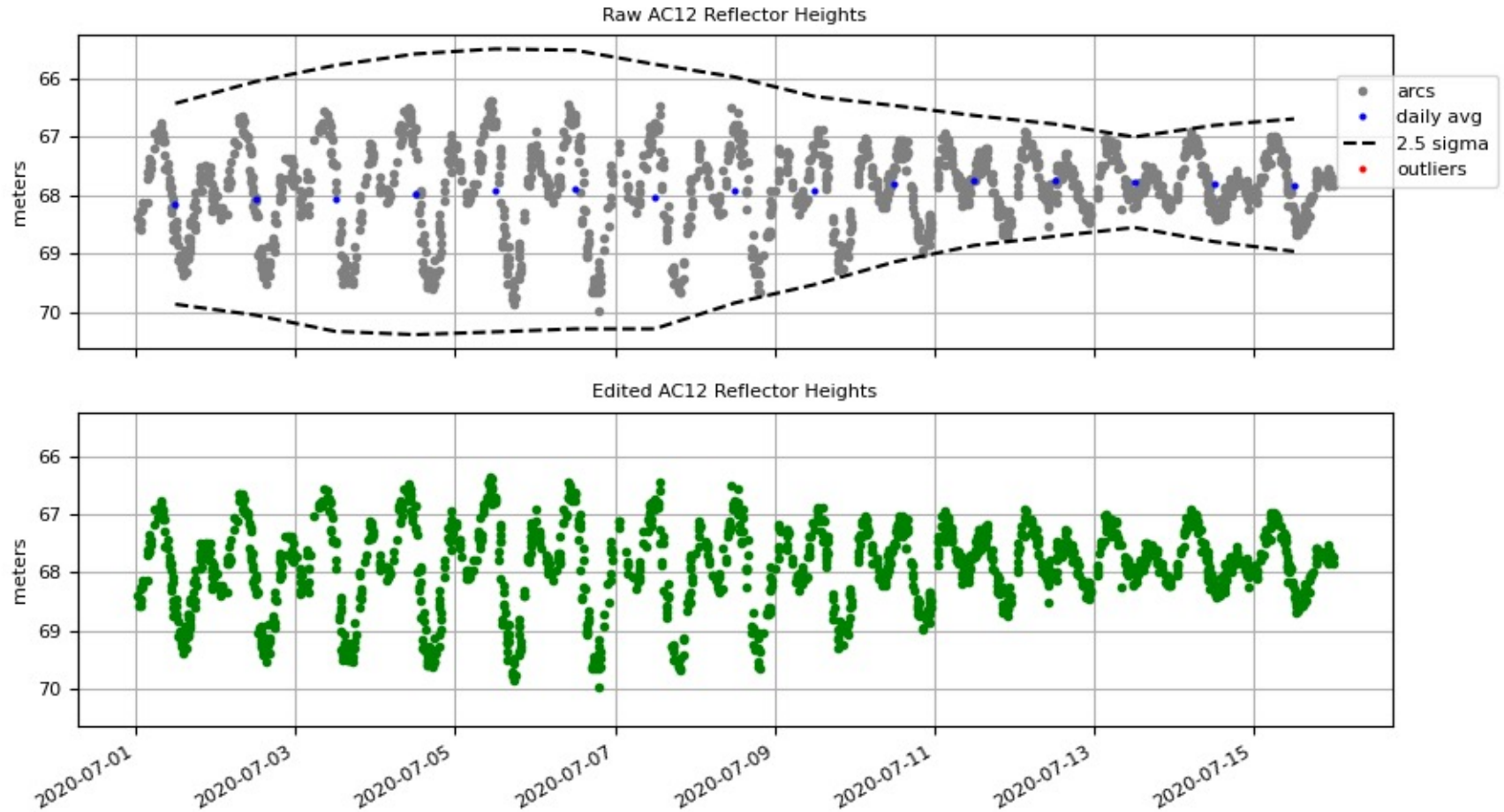
subdaily part 1

The receiver now records GPS, GLO AND GAL

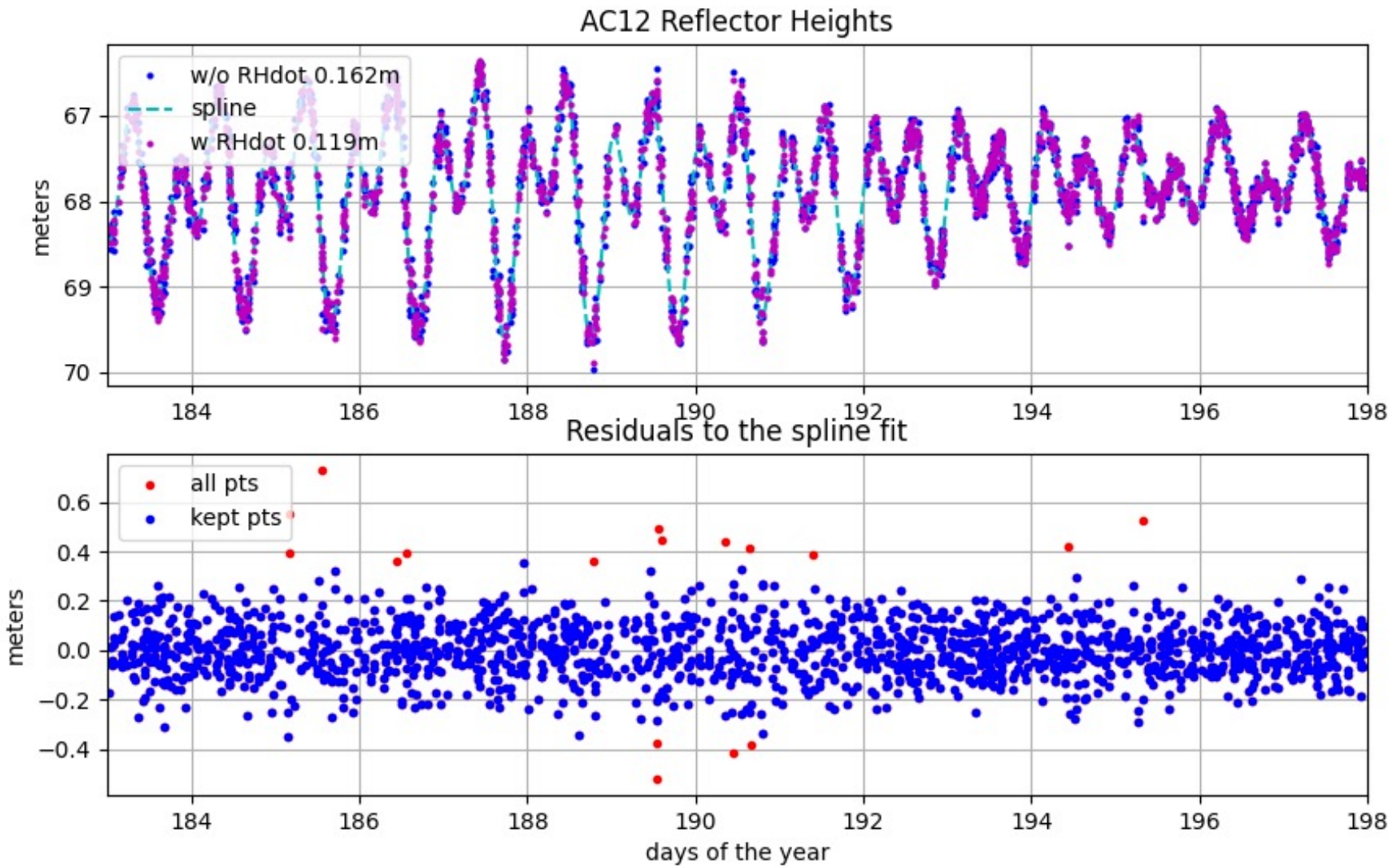
-

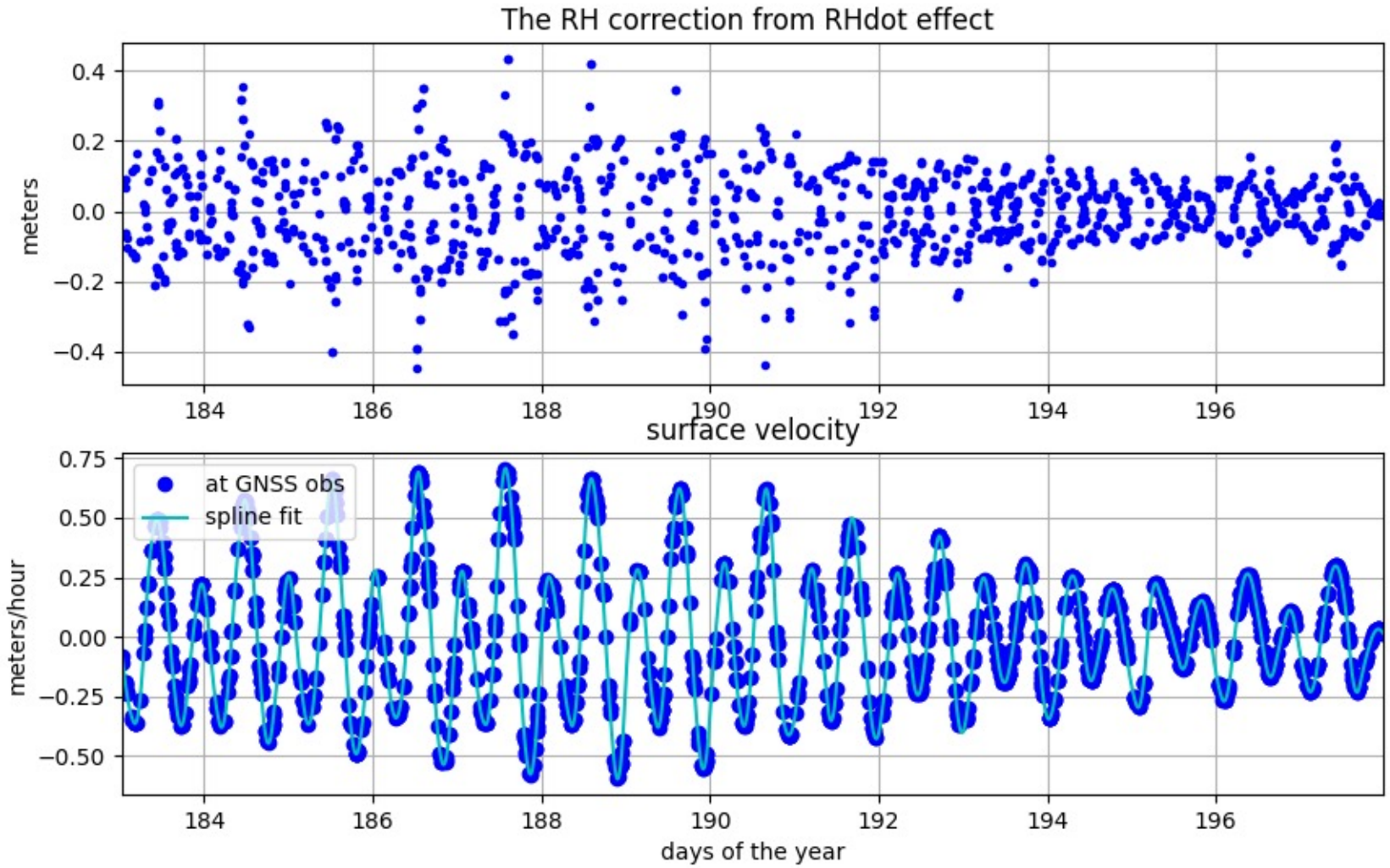

Signals
RH (m)
67
68
69
70
Frequency
20
15
10
5
Azimuth
RH (m)
67
68
69
70
deg
300
200
100
Amplitude
RH (m)
67
68
69
70
v/v
25
20
15
10
5
2020-07-01
2020-07-03
2020-07-05
2020-07-07
2020-07-09
2020-07-11
2020-07-13
2020-07-15


Quick Plot of RH with respect to Azimuth
Reflector Height (m)
66.5
67.0
67.5
68.0
68.5
69.0
69.5
70.0
0
50
100
150
200
250
300
350
Azimuth (degrees)
obs
outliers

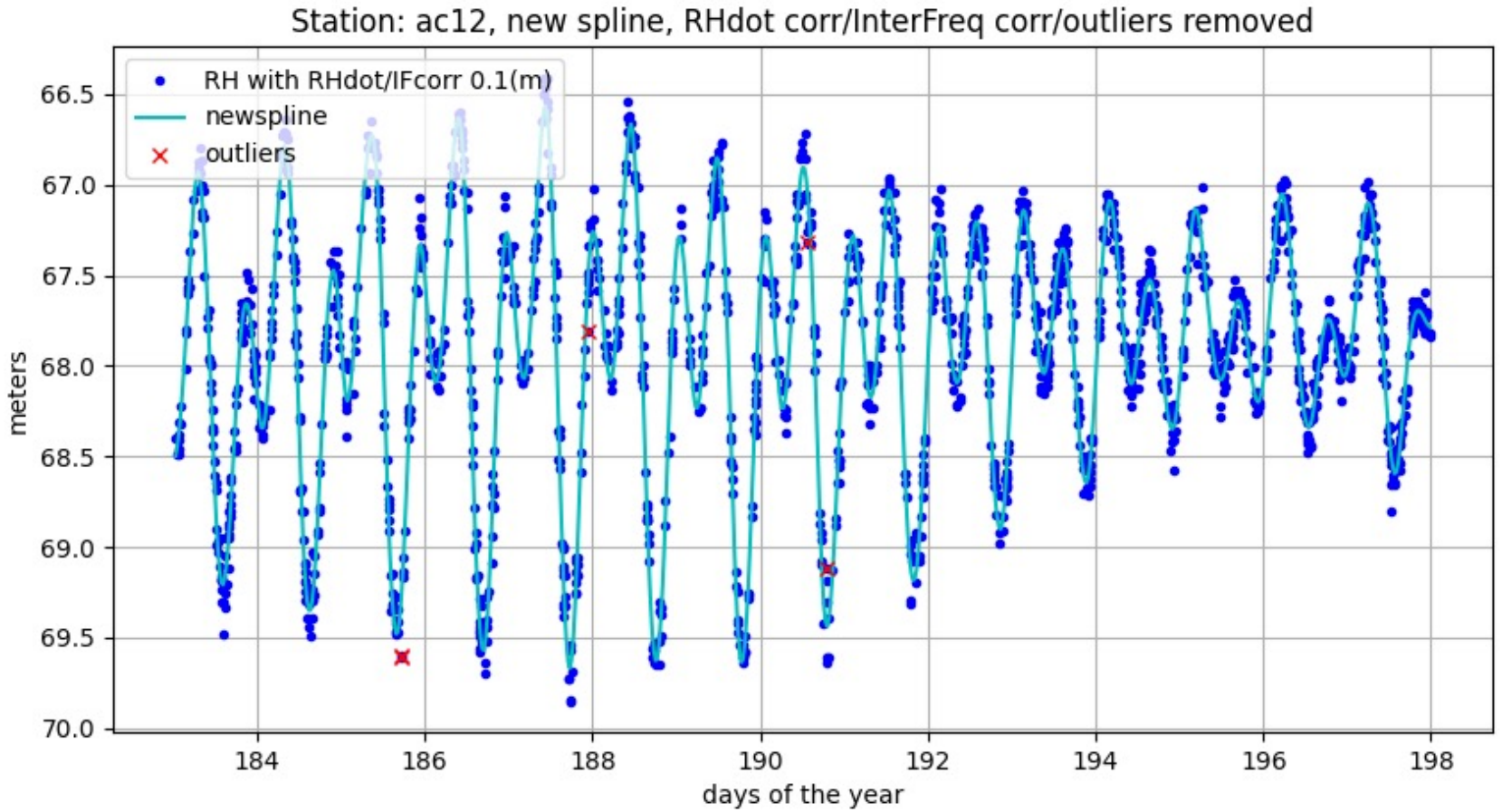

Raw AC12 Reflector Heights
meters
66
67
68
69
70
arcs
daily avg
2.5 sigma
outliers
Edited AC12 Reflector Heights
meters
66
67
68
69
70
2020-07-01
2020-07-03
2020-07-05
2020-07-07
2020-07-09
2020-07-11
2020-07-13
2020-07-15

subdaily part 2




The RH correction from RHdot effect
meters
0.4
0.2
0.0
−0.2
−0.4
184
186
188
190
192
194
196
surface velocity
at GNSS obs
spline fit
meters/hour
0.75
0.50
0.25
0.00
−0.25
−0.50
184
186
188
190
192
194
196
days of the year

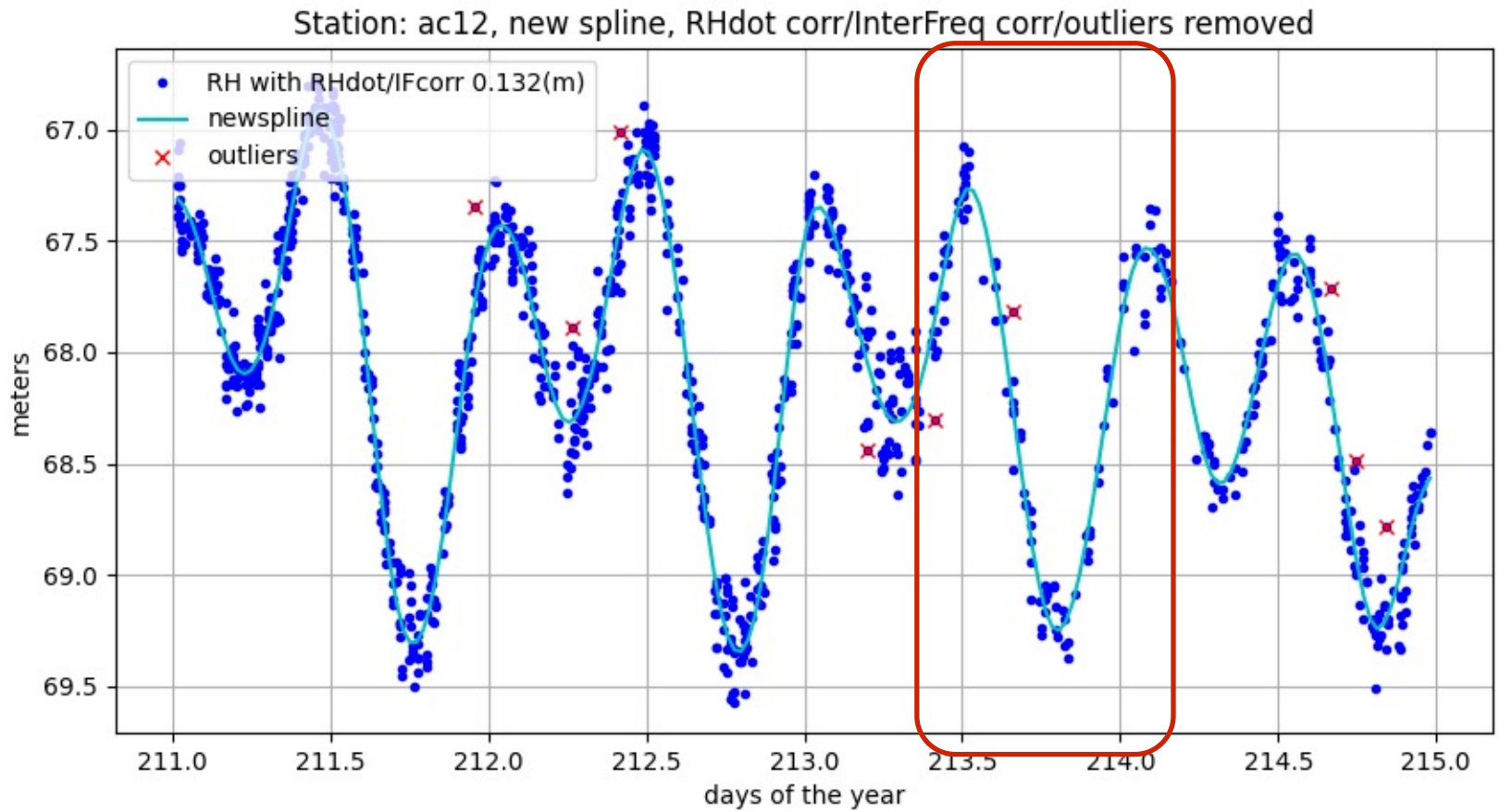
Final corrected RH values



new receiver, multi gnss

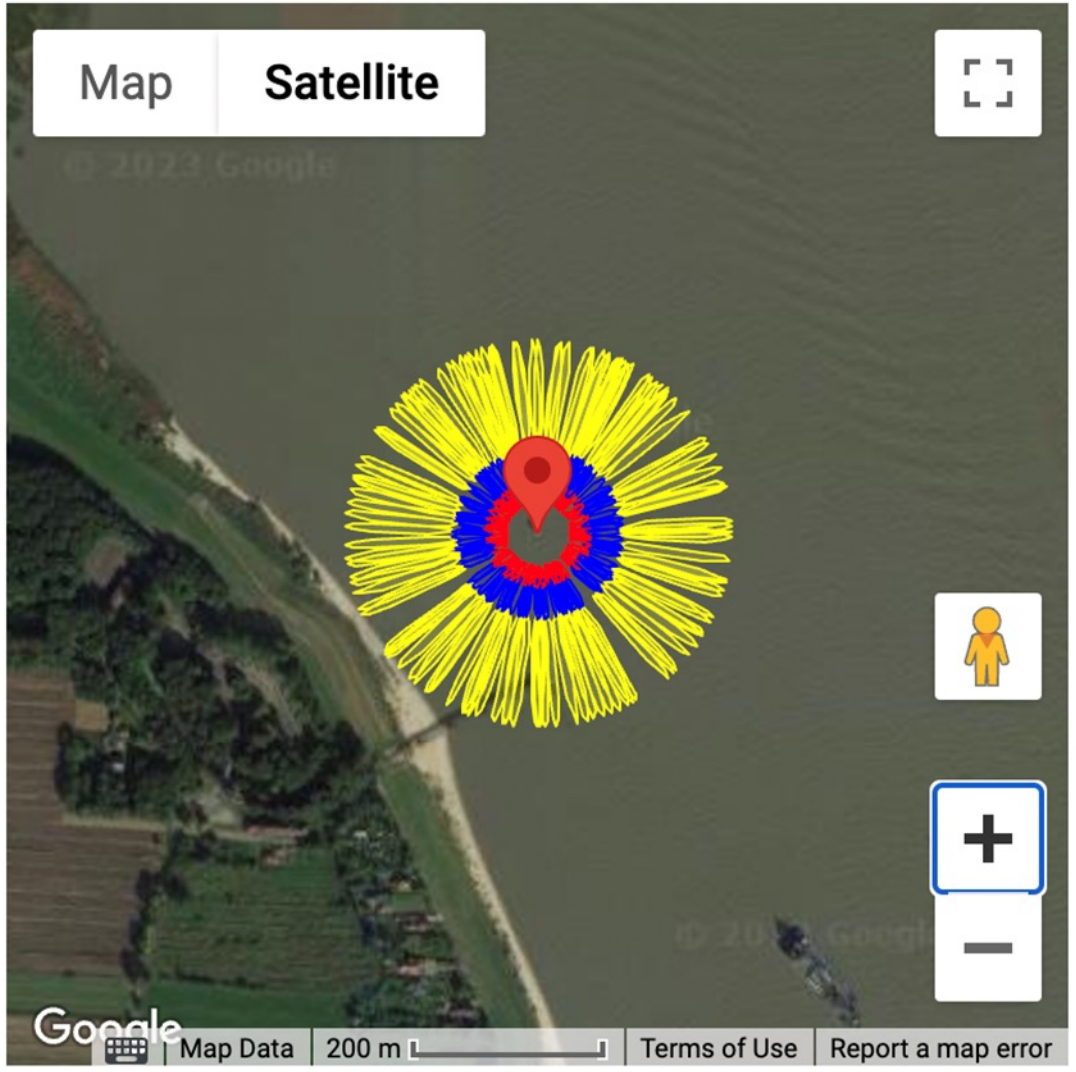
- rinex2snr ac12 2022 211 -doy_end 214 -orb rapid -rate high -archive unavco -dec 2

- make_json_input ac12 0 0 0 -e1 5 -e2 10 -h1 60 -h2 75 -azlist 0 90 90 125 200 270 270 315 315 360 -frlist 1 20 5 101 102 201 205
- gnssir ac12 2022 2011 -doy_end 2014
- subdaily ac12 2022


Station: ac12, new spline, RHdot corr/InterFreq corr/outliers removed
RH with RHdot/IFcorr 0.132(m)
newspline
outliers
meters
67.0
67.5
68.0
68.5
69.0
69.5
211.0
211.5
212.0
212.5
213.0
213.5
214.0
214.5
215.0
days of the year

windy?

Final site TGGO a River Site



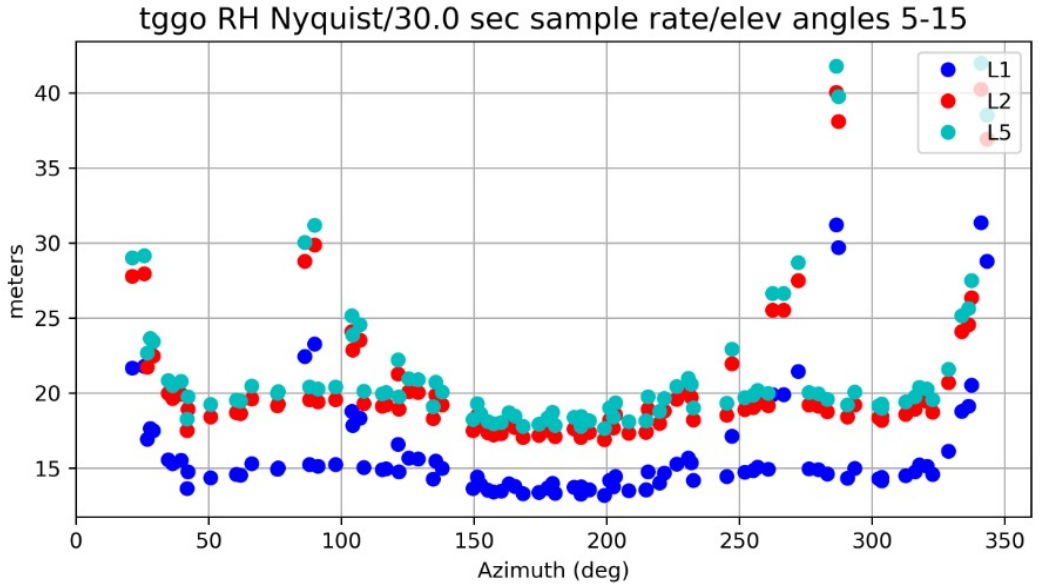
About 12 m above the river

Use RINEX 3 for access to the best signals

- station tggo00deu (the longer station name will tell the code to find RINEX 3 instead of RINEX 2.11)
- archive bfg
- orb rapid (you can also use gnss if you prefer)
- samplerate 15

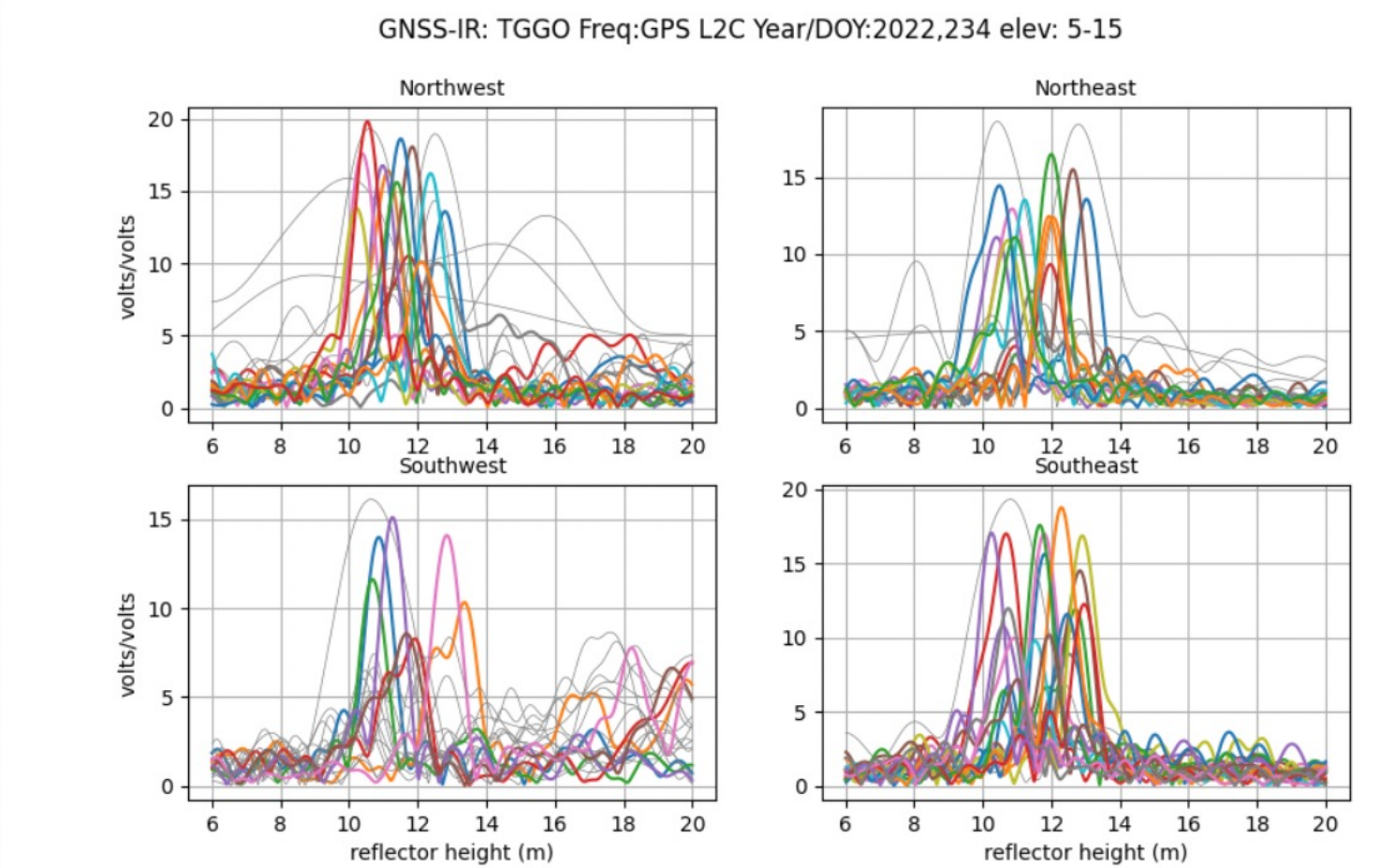
```
rinex2snr tggo00deu 2022 234 -archive bfg -orb rapid -samplerate 15
```

Why 15 seconds?
30 second data violate
the Nyquist for L1 signals

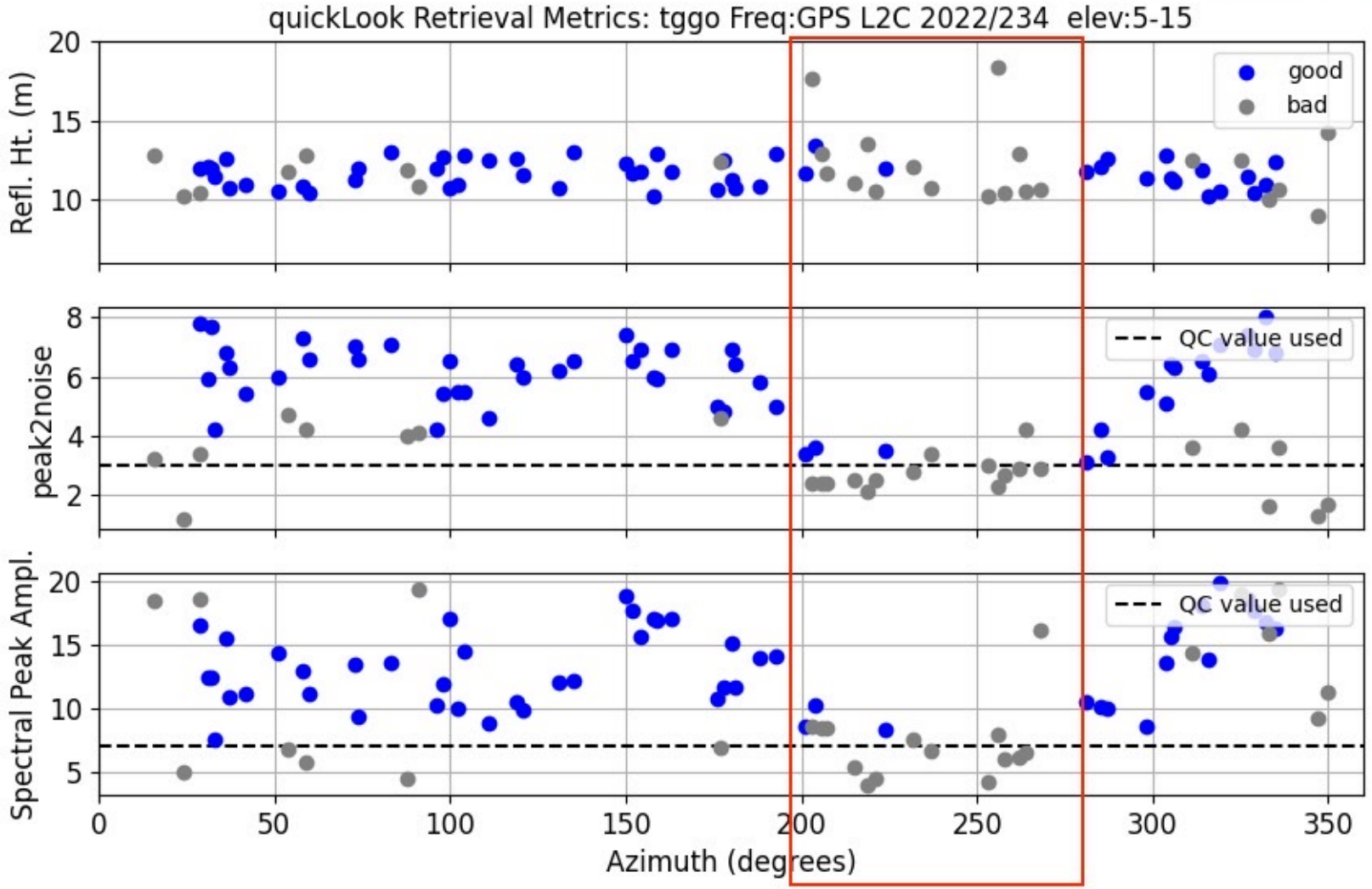


```
quickLook tggo 2022 234 -fr 20 -e1 5 -e2 15 -h1 6 -h2 20
```

The first plot shows periodograms in the four geographic coordinates.



exclude these azimuths



Set your analysis strategy

```
make_json_input tggo 0 0 0 -e1 5 -e2 15 -h1 6 -h2 18 -allfreq
T -azlist 30 90 90 180 270 330
```

Estimate RH

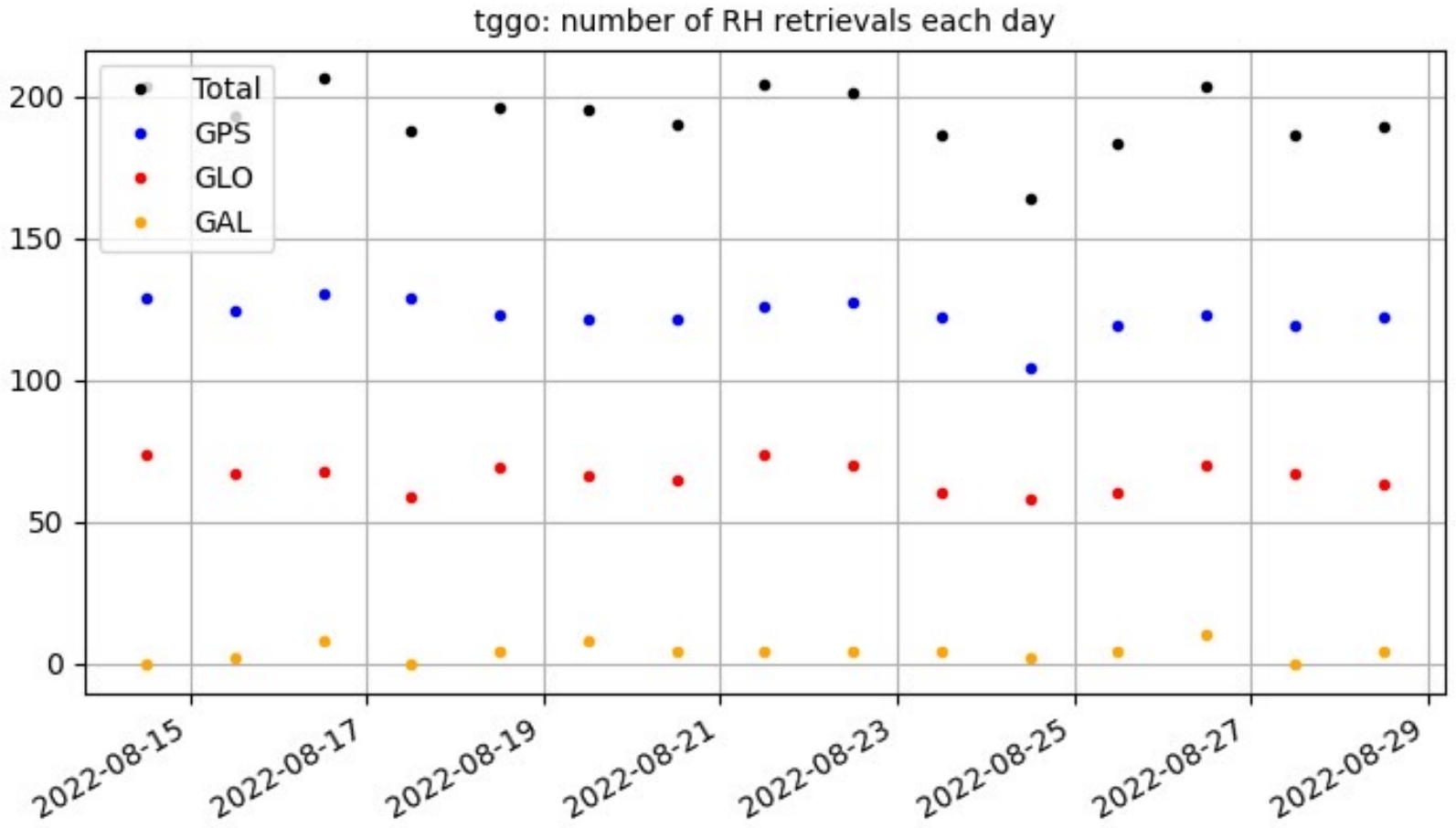
```
gnssir tggo 2022 226 -doy_end 240
```

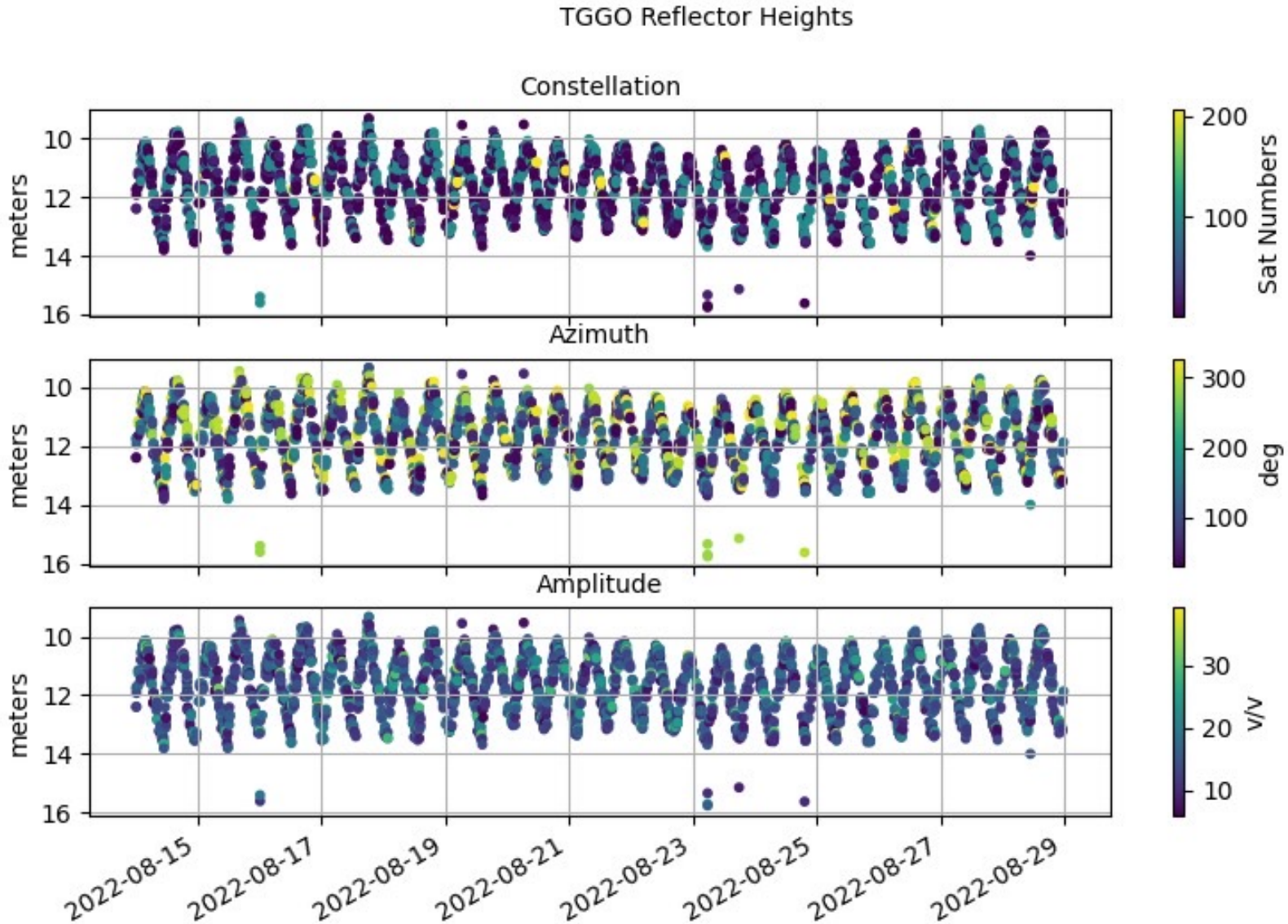
Look at the results - look for things you might need to change

```
subdaily tggo 2022
```

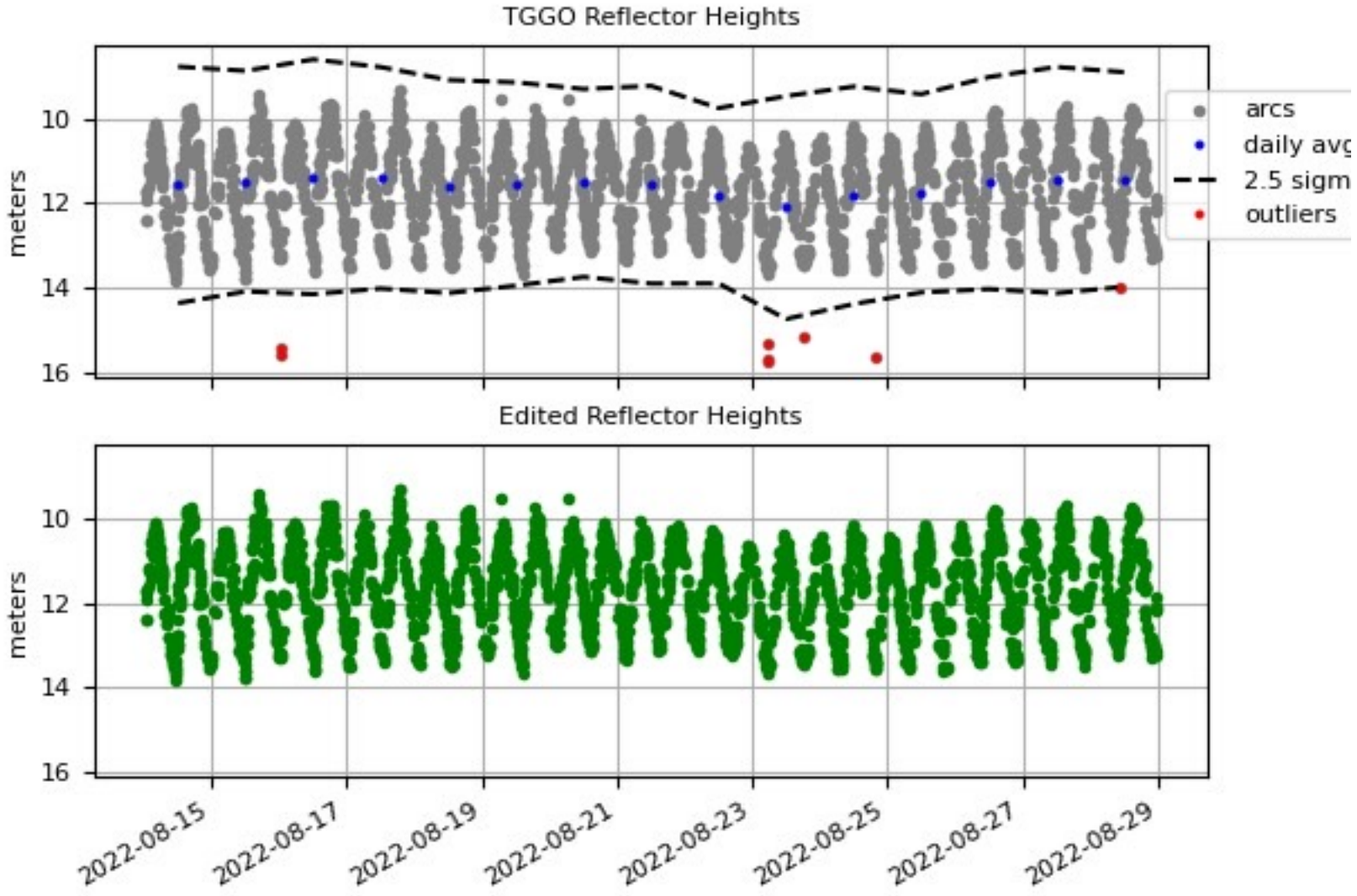
Iterate if necessary

Why doesn’t Galileo contribute much? Old receiver.

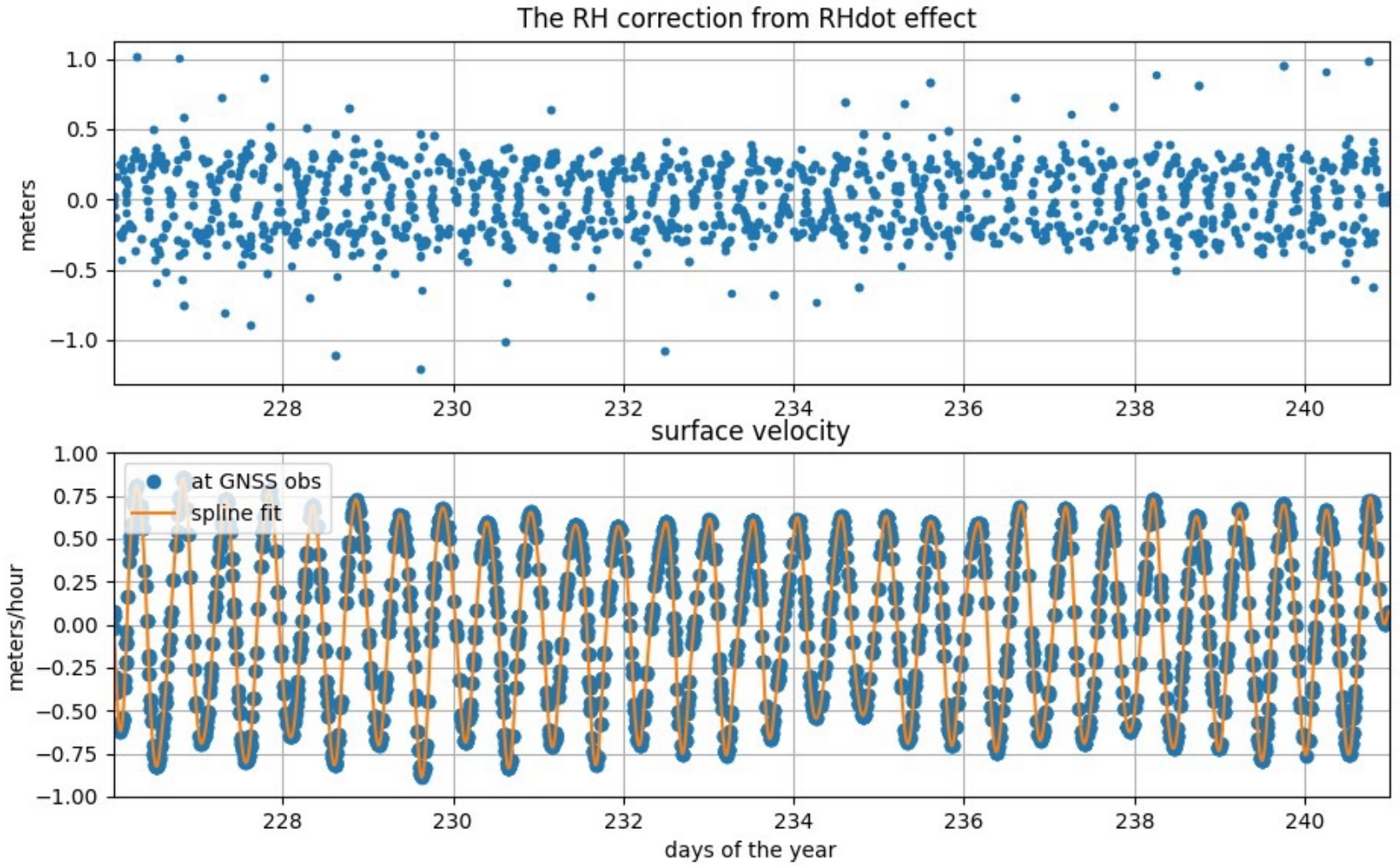



TGGO Reflector Heights
Constellation
Azimuth
Amplitude
meters
10
12
14
16
Sat Numbers
200
100
deg
300
200
100
v/v
30
20
10
2022-08-15
2022-08-17
2022-08-19
2022-08-21
2022-08-23
2022-08-25
2022-08-27
2022-08-29

Remove only the largest outliers in part I of subdaily



Hmm - this looks wrong. RH dot correction has too many outliers.
This is caused by calculation of edot and extrapolation over too long a time period. Especially for some azimuths.



The easy fix is to change the maximum arc length and rerun gnssir.

The easy fix is to change the maximum arc length delTmax and rerun gnssir.

Set your analysis strategy

```
make_json_input tggo 0 0 0 -e1 5 -e2 15 -h1 6 -h2 18 -allfreq T -
azlist 30 90 90 180 270 330 -delTmax 35
```

Estimate RH

```
gnssir tggo 2022 226 -doy_end 240
```

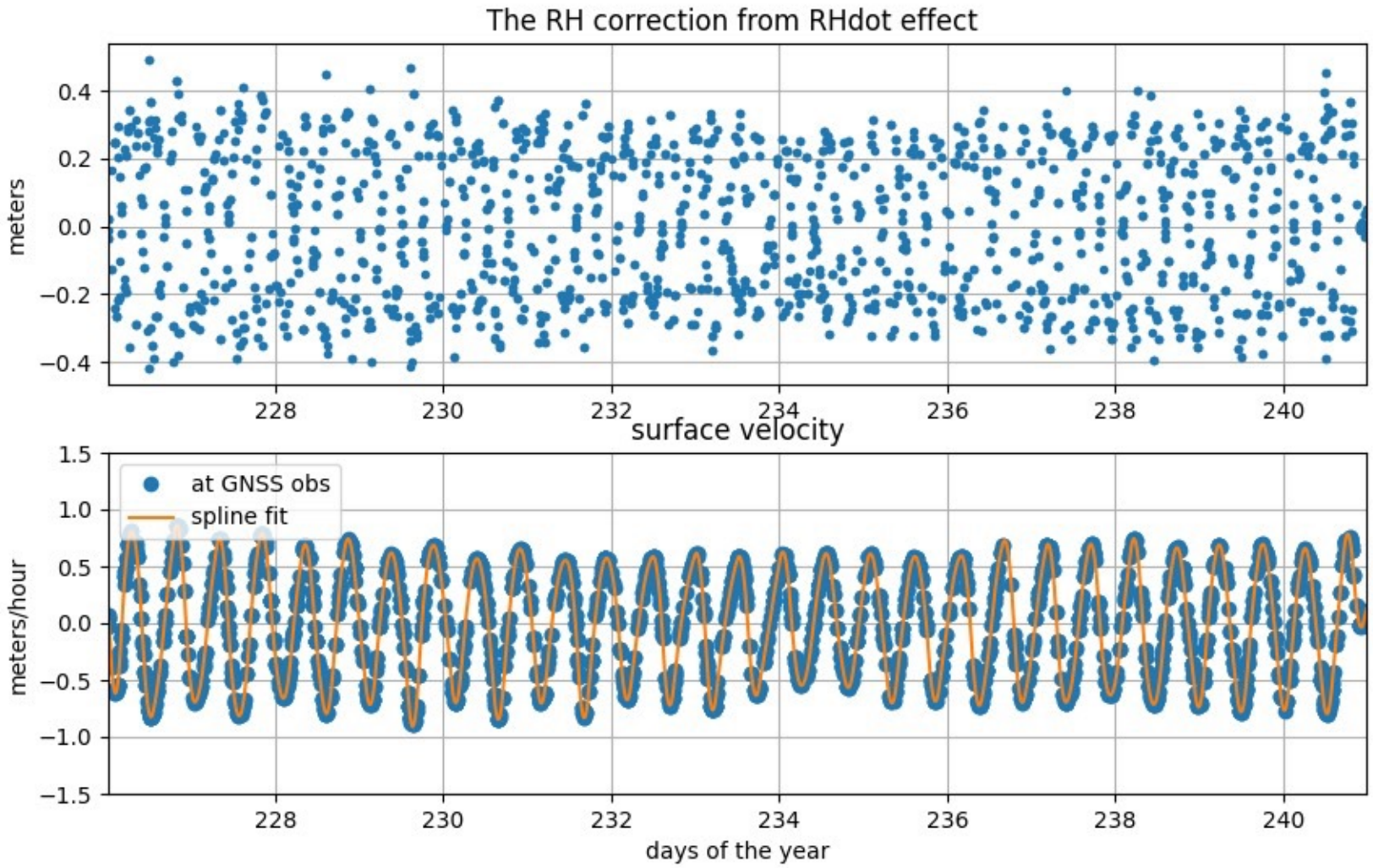
Look at the results - look for things you might need to change

```
subdaily tggo 2022
```

Iterate if necessary

Why haven't I changed the default? That would hurt the soil moisture and snow accumulation users.

Much better


The RH correction from RHdot effect
meters
0.4
0.2
0.0
−0.2
−0.4
228
230
232
234
236
238
240
surface velocity
at GNSS obs
spline fit
meters/hour
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
228
230
232
234
236
238
240
days of the year

Keep in mind - the RMS fits reported by subdaily assume the water levels are smooth. This is not true! Compare with the *truth* for a better assessment of precision.