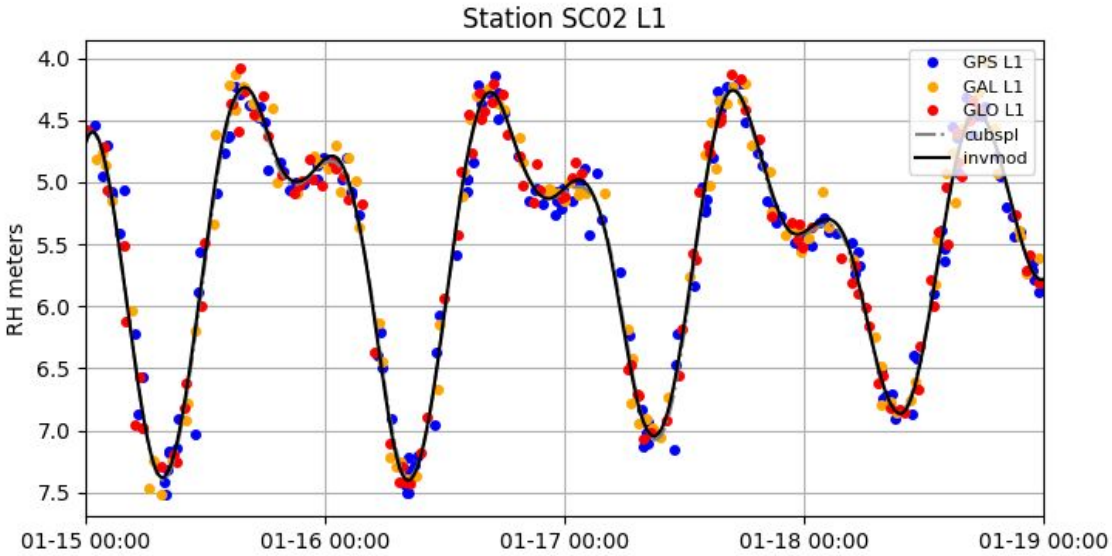
2023 GNSS-IR short course: 'invsnr'



By Dave Purnell
david.purnell.1@ulaval.ca

Postdoc at Université Laval

What is 'invsnr'?

'invsnr' is a physics-informed way of obtaining a smoothly varying reflector height / water level time series at regular intervals

Why is it useful?

- Water levels tend to vary smoothly
- Satellite passes are randomly distributed in time
- Difficult to interpret data points from the same time with different values
- Smoothing reduces the effect of random noise in spectral analysis

When is it useful?

- If you care about sub-daily reflector heights e.g., tides, flooding
- If your signal is smaller or similar magnitude to random noise in measurements

History of 'invsnr'

AGU PUBLICATIONS

Radio Science

RESEARCH ARTICLE
10.1002/2016RS006057

Key Points:
- We present an advanced method for retrieving sea surface heights using

Improving GNSS-R sea level determination through inverse modeling of SNR data

Joakim Strandberg[1], Thomas Hobiger[1], and Rüdiger Haas[1]

Quantifying the Uncertainty in Ground-Based GNSS-Reflectometry Sea Level Measurements

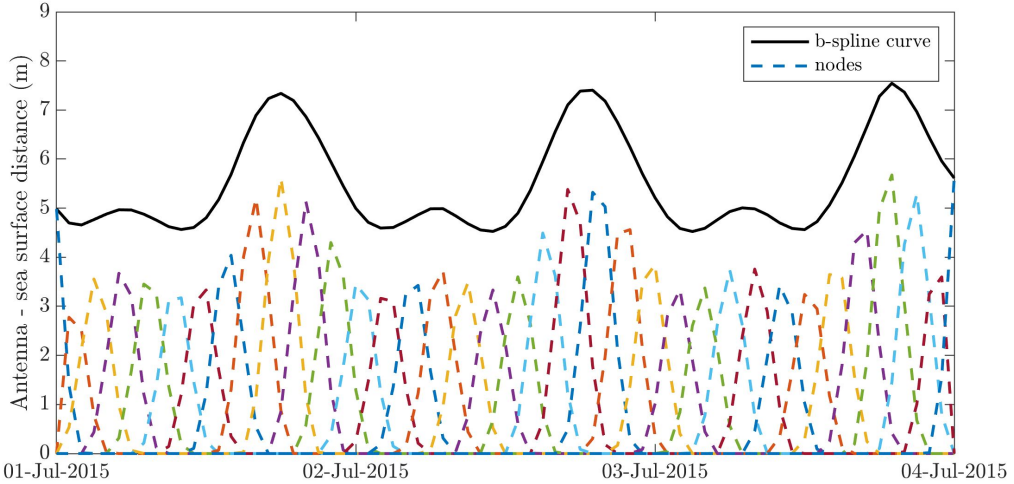
David Purnell, Natalya Gomez, Ngai Ham Chan, Joakim Strandberg, David M. Holland, and Thomas Hobiger

Precise water level measurements using low-cost GNSS antenna arrays

David J. Purnell[1], Natalya Gomez[1], William Minarik[1], David Porter[2], and Gregory Langston[1]

From Strandberg et al. (2016)

- Reflector heights (Water levels) are modeled using a b-spline curve
- The curve is defined by node values with e.g., 12 nodes per 24hr
- Water level measurements can be taken at any time on the curve



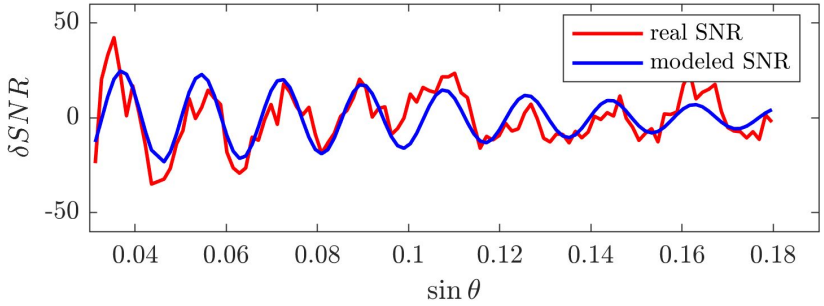
From Strandberg et al. (2016)

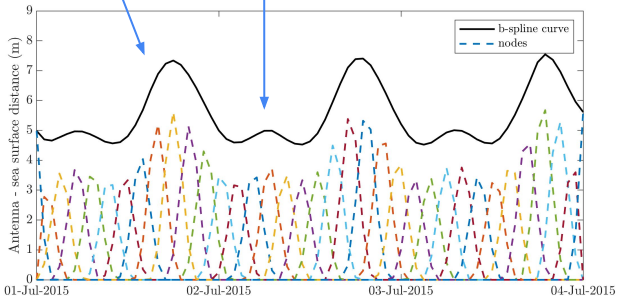
- SNR data is modeled using:

$$\delta\mathrm{SNR} = \left(C_1 \sin\left(\frac{4\pi h}{\lambda} x\right) + C_2 \cos\left(\frac{4\pi h}{\lambda} x\right) \right) \mathrm{e}^{-4k^2 \Lambda x^2}$$

related to antenna gain pattern, surface roughness....

- Inverse method: if real and modeled SNR match, then reflector height model should be good





Improvements

Dominant peak from spectral analysis

dh/dt taken from curve

$$f = \frac{2}{\lambda}\left[h + \frac{\partial h}{\partial t}\frac{tan\theta}{\partial\theta/\partial t}\right]$$

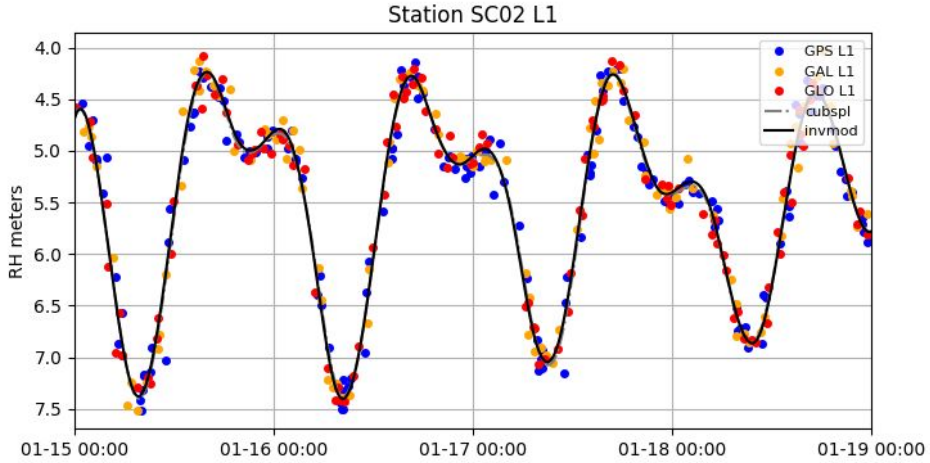
- Node values are first estimated using spectral analysis reflector height estimates (including 'rhdot' correction)

- Simplified spline curve:
  - Regularly spaced nodes (points along curve)
  - Cubic spline interpolation between points

Example: SC02, Friday Harbor, WA

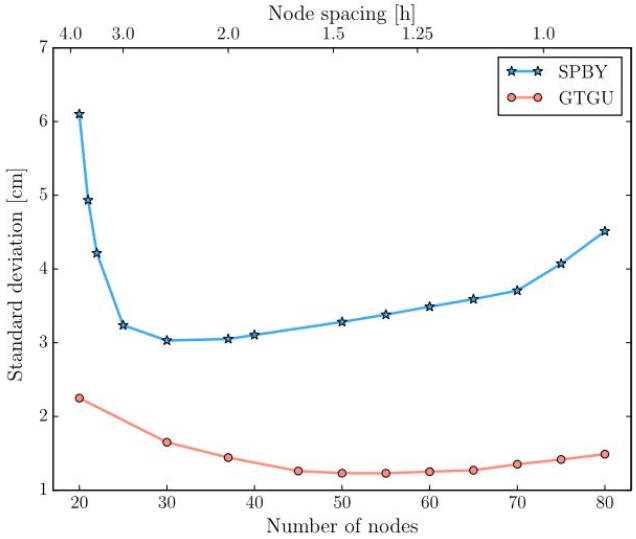
```
rinex2snr sc02 2021 015 -orb gnss -doy_end 045

invsnr_input sc02 3 12 5 13 -a1 60 -a2 240

invsnr sc02 2021 015 L1 -doy_end 018 -pktnlim 6
```

- Azimuth (a1, a2), elevation angle and reflector height limits taken from literature
- More important to get multiple constellations than multiple frequencies, hence '-orb gnss' and 'L1'



Note on parameters: 'knot_space' and 'risky'

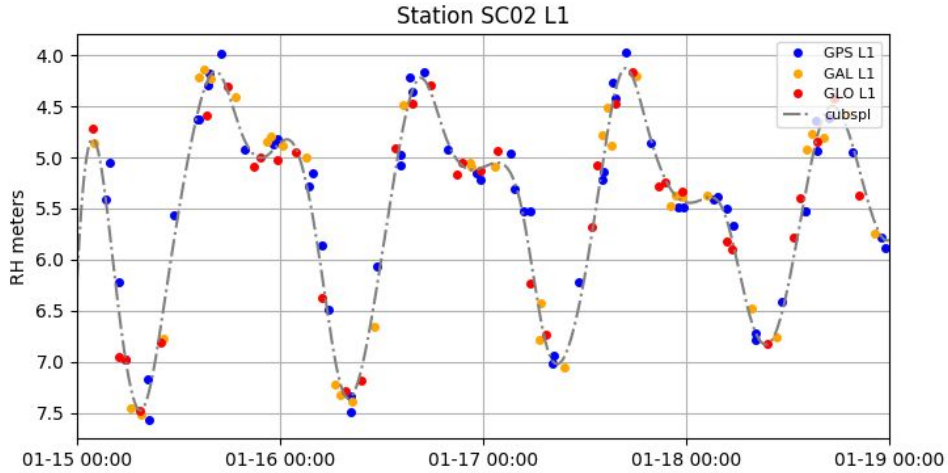
- The time between nodes is set using 'knot_space' (in hours)
- The more frequent the nodes, the more accurate water level representation is theoretically possible
- However, if there is a gap in the data bigger than the node spacing, there might be instabilities (unphysical height variations)
  Note: this is the same problem as 'overfitting' in machine learning



From Strandberg et al. (2016)

Note on parameters: 'knot_space' and 'risky'

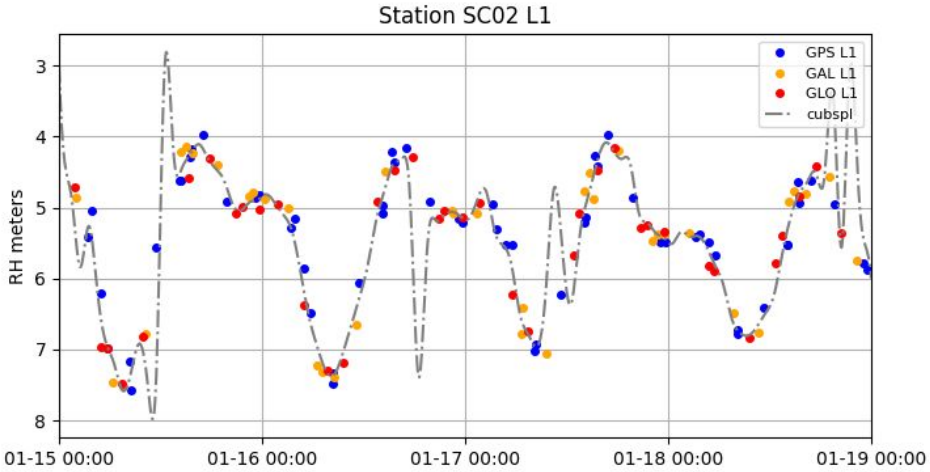
```
invsnr_input sc02 3 12 5 13  -a1 60 -a2 120

invsnr sc02 2021 015 L1 -doy_end 018  -snrfit False
```



Default
knot_space = 3

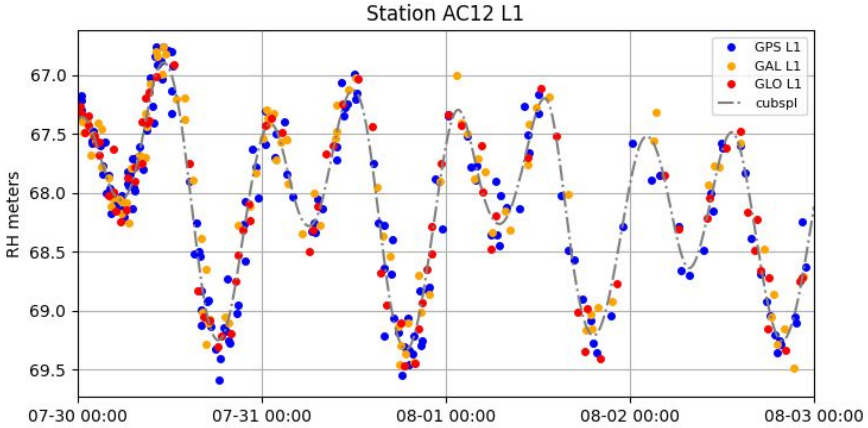
Note on parameters: 'knot_space' and 'risky'

```
invsnr_input sc02 3 12 5 13 -a1 60 -a2 120

invsnr sc02 2021 015 L1 -doy_end 018 -snrfit False -risky True -knot_space
1
```



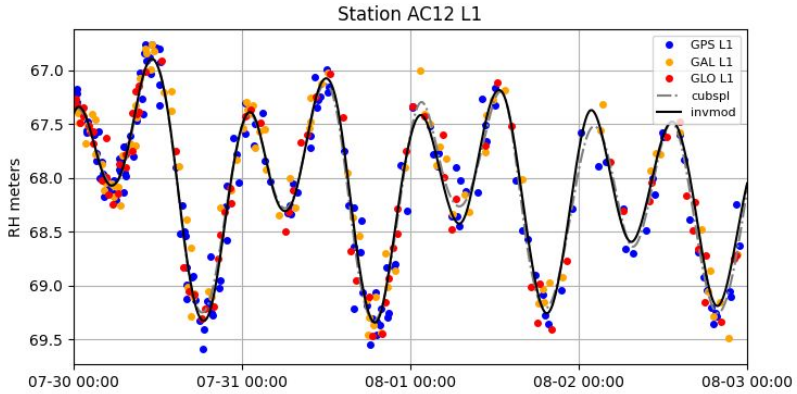
Example 2: AC12, Chernabura, AK

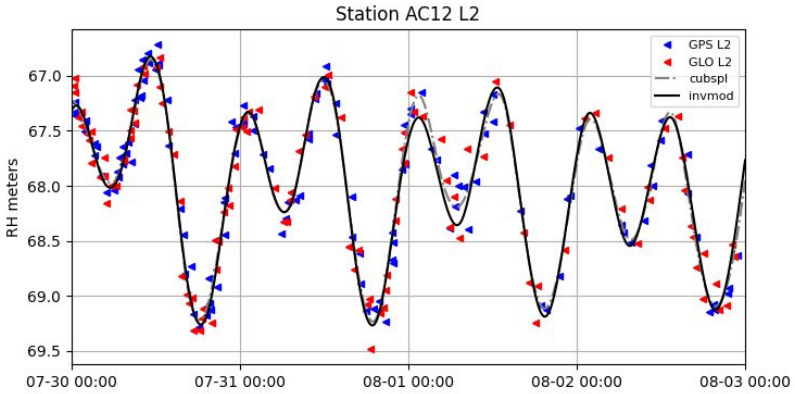
```
rinex2snr ac12 2022 211 -doy_end 214 -orb gnss -rate high -archive unavco -dec 5

invsnr_input ac12 60 80 5 10

invsnr ac12 2022 211 L1 -doy_end 214 -snrfit False -pktnlim 9
```



Example 2: AC12, Chernabura, AK

```
invsnr ac12 2022 211 L1 -doy_end 214 -pktnlim 9

invsnr ac12 2022 211 L2 -doy_end 214 -pktnlim 9
```





Notes & tips

- Don't bother using 'invsnr' if the reflector heights don't look good to begin with!
    - Always start with 'quicklook' or refl zones web app
    - It is very important to have good azimuth and elevation angle masks
- If daily averages are good enough for your application, stick with that!
- If you are installing your own site and you want to use this technique the most important things are:
    - Wide view (azimuth) of surface
    - Multi-constellation data (just GPS is probably not good enough)
- Changing the input value 'roughness' might improve efficiency

If you want to improve the code:

- Better QC options
- Better SNR model (e.g., mpsim by Felipe & Kristine)
- Refraction correction: see work from Thalia Nikolaidou and co-authors

Contact: david.purnell.1@ulaval.ca