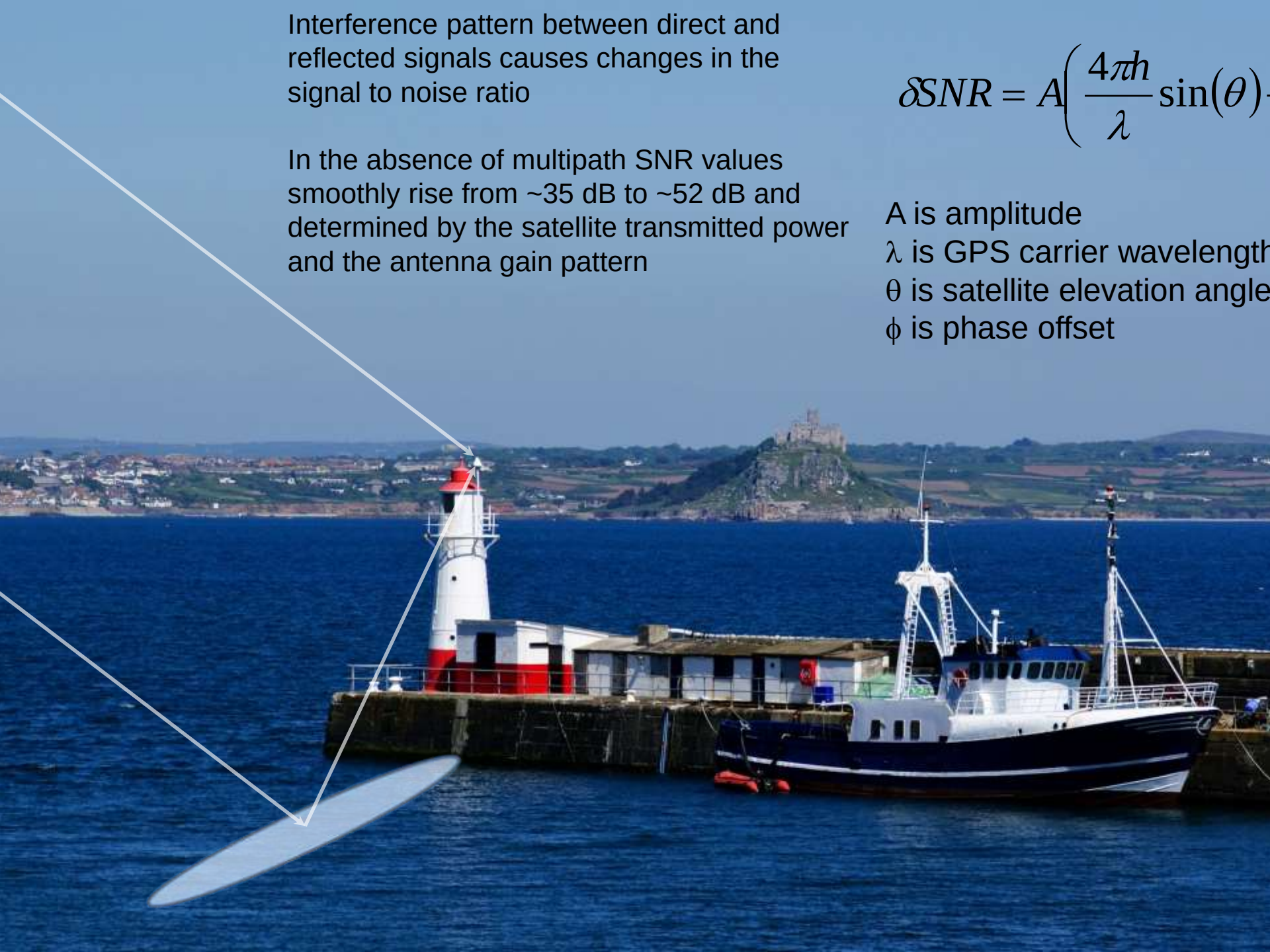
# GNSS for sea level (accidental tide gauges)

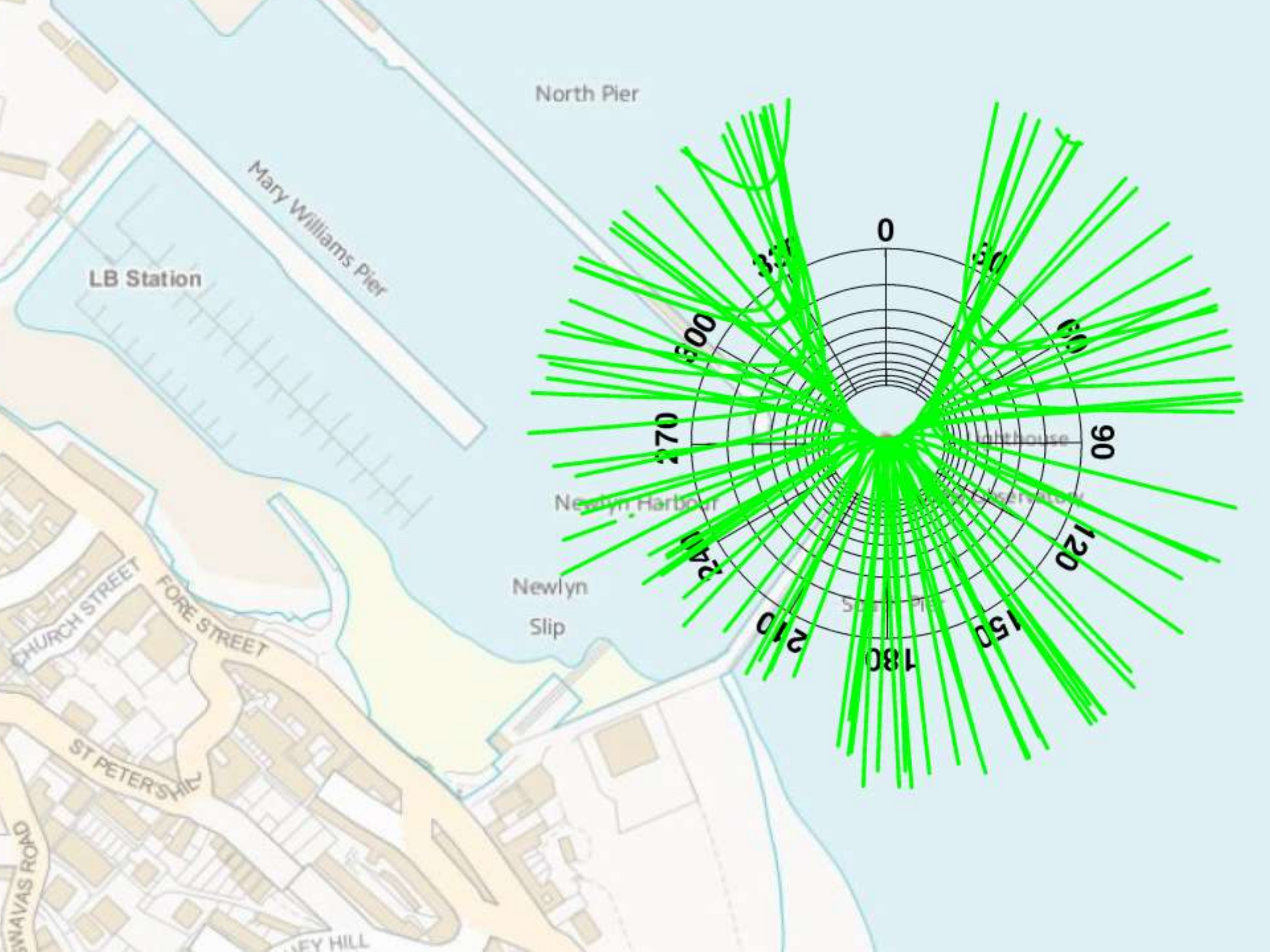
Interference pattern between direct and reflected signals causes changes in the signal to noise ratio

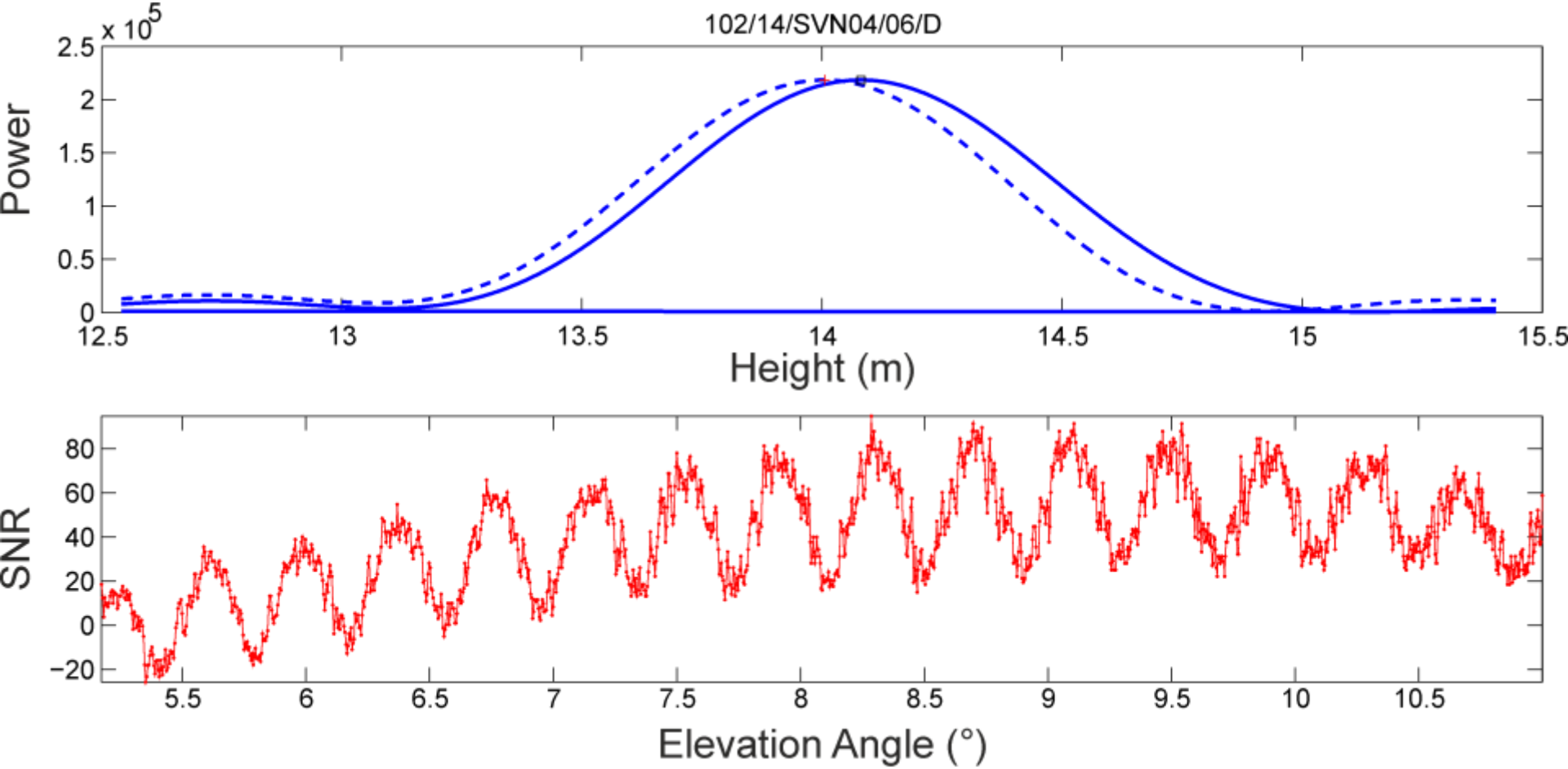
In the absence of multipath SNR values smoothly rise from ~35 dB to ~52 dB and determined by the satellite transmitted power and the antenna gain pattern

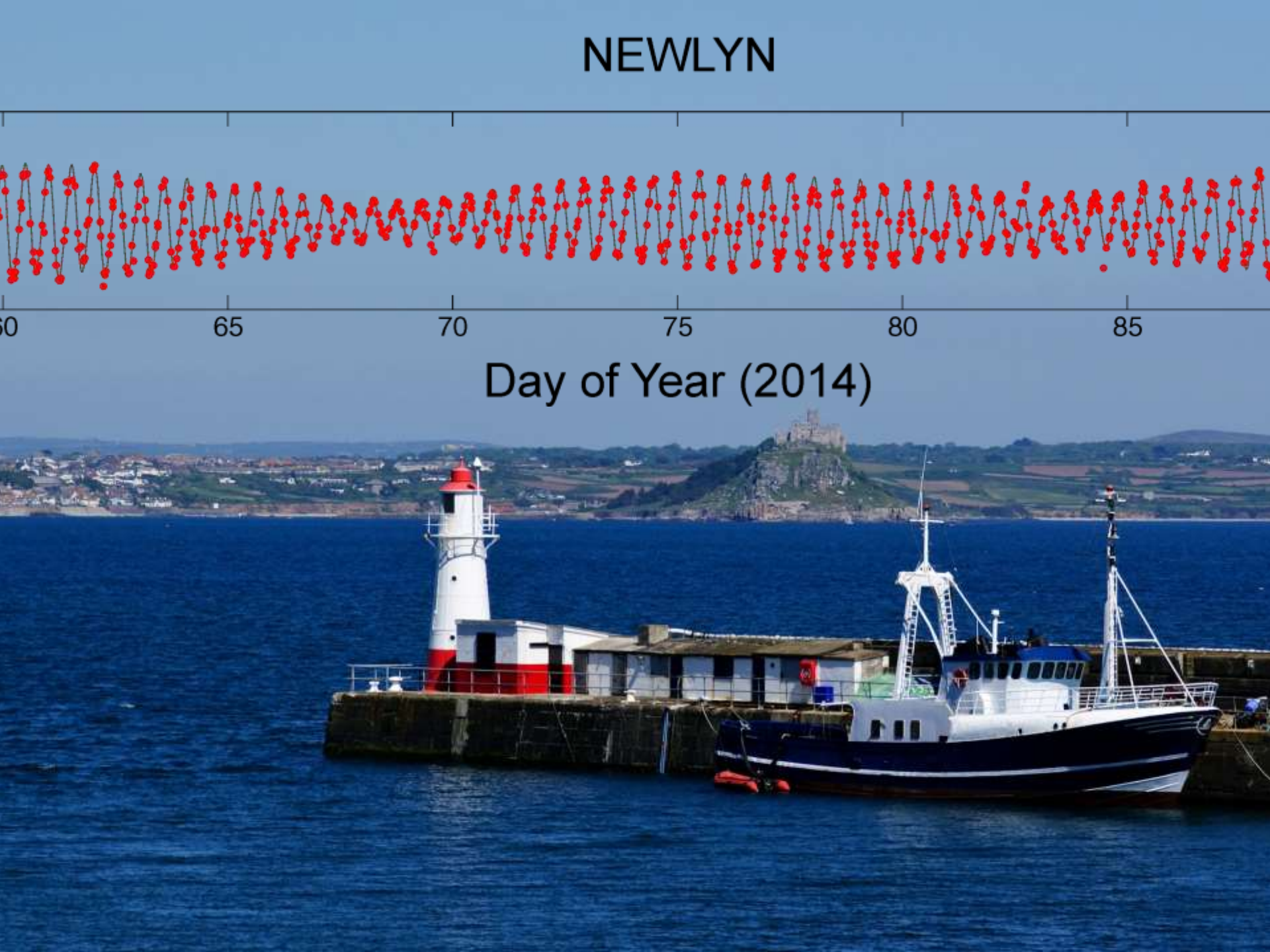
$$\delta SNR = A\left(\frac{4\pi h}{\lambda}\sin(\theta)\right.$$

A is amplitude
$\lambda$ is GPS carrier wavelength
$\theta$ is satellite elevation angle
$\phi$ is phase offset




North Pier
Mary Williams Pier
LB Station
Newlyn Harbour
Newlyn
Slip
CHURCH STREET
FORE STREET
ST PETER'S HILL
0
30
60
90
120
150
180
210
240
270
300
330


102/14/SVN04/06/D
x 10^5
Power
2.5
2
1.5
1
0.5
0
12.5
13
13.5
14
14.5
15
15.5
Height (m)
SNR
80
60
40
20
0
−20
5.5
6
6.5
7
7.5
8
8.5
9
9.5
10
10.5
Elevation Angle (°)

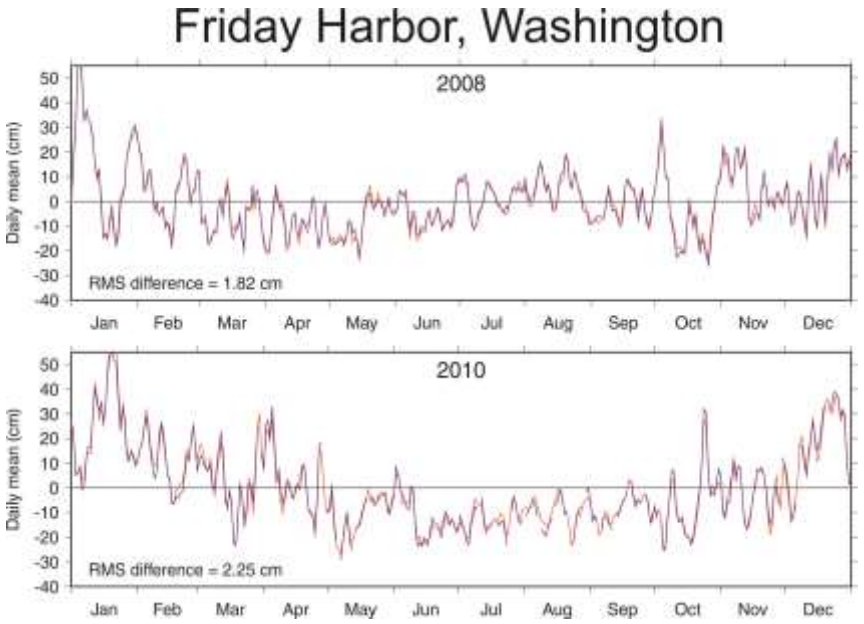

NEWLYN
60
65
70
75
80
85
Day of Year (2014)

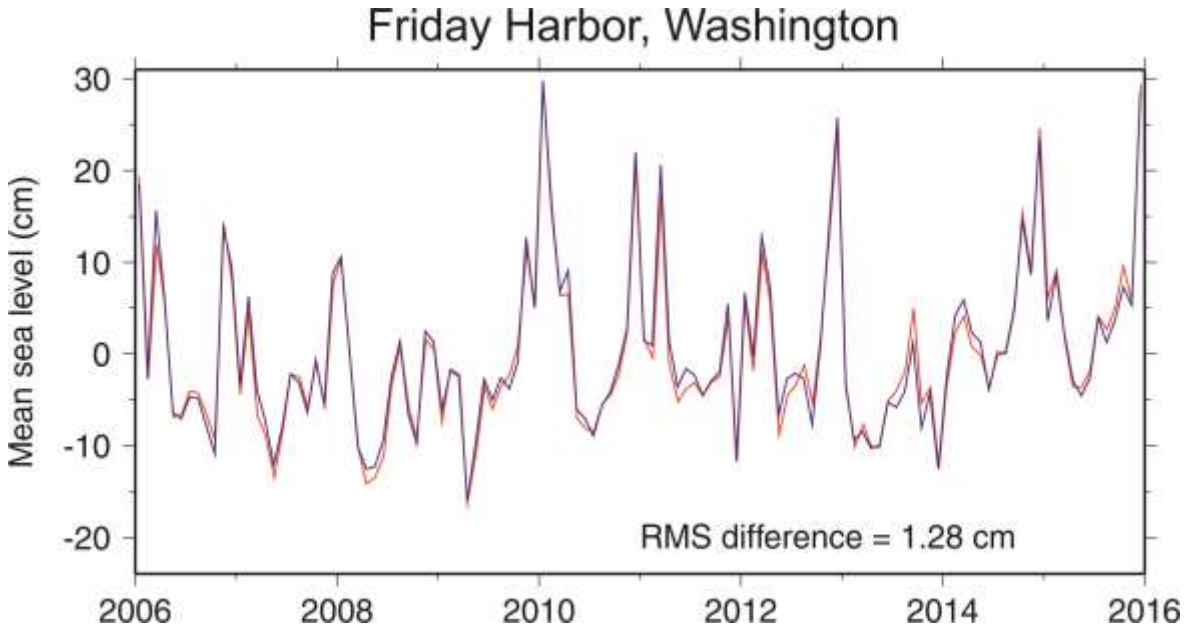
# GNSS - Reflectometry

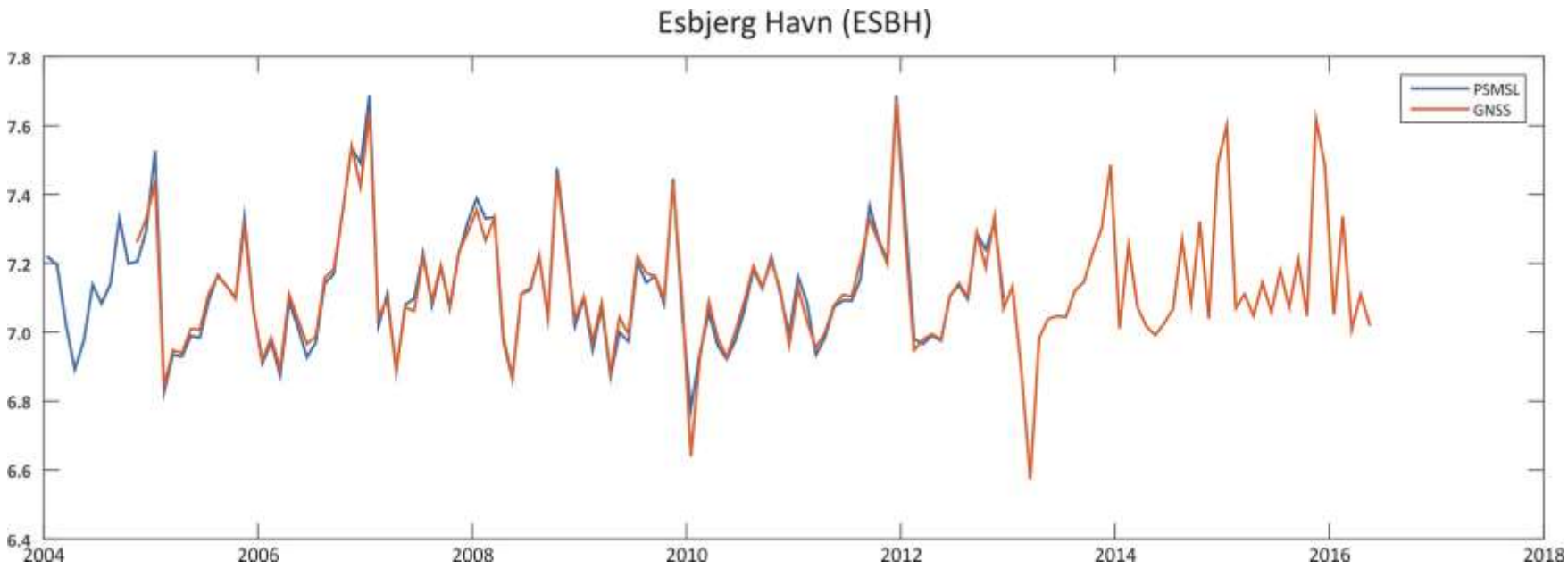
- Several different “flavours” of this
- Pre-existing network sites with unmodified geodetic quality COTS receivers and antennas
- Modify antenna
- Phase tracking receiver
- Twin antenna

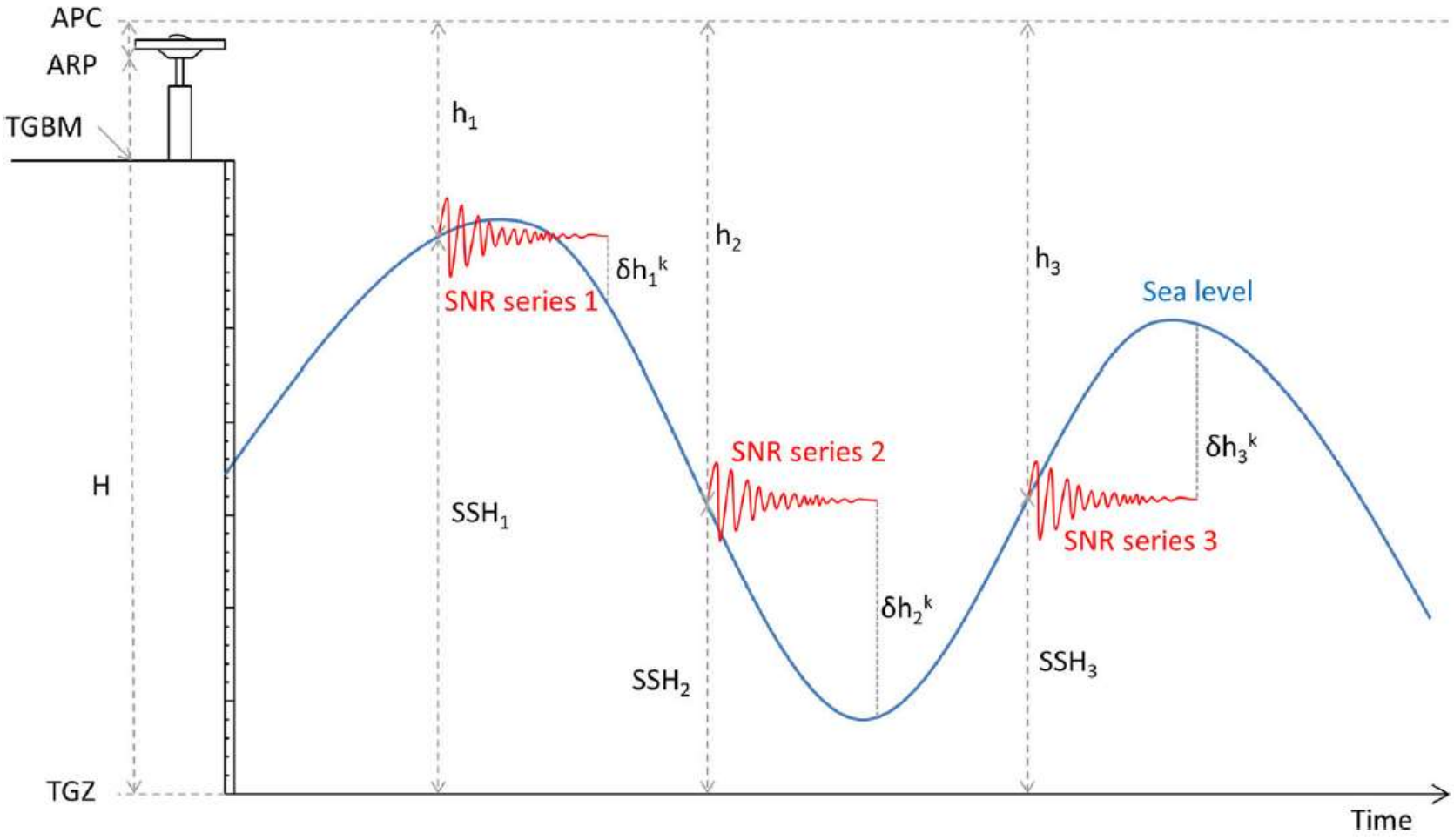
} None of which can be used for land movement studies

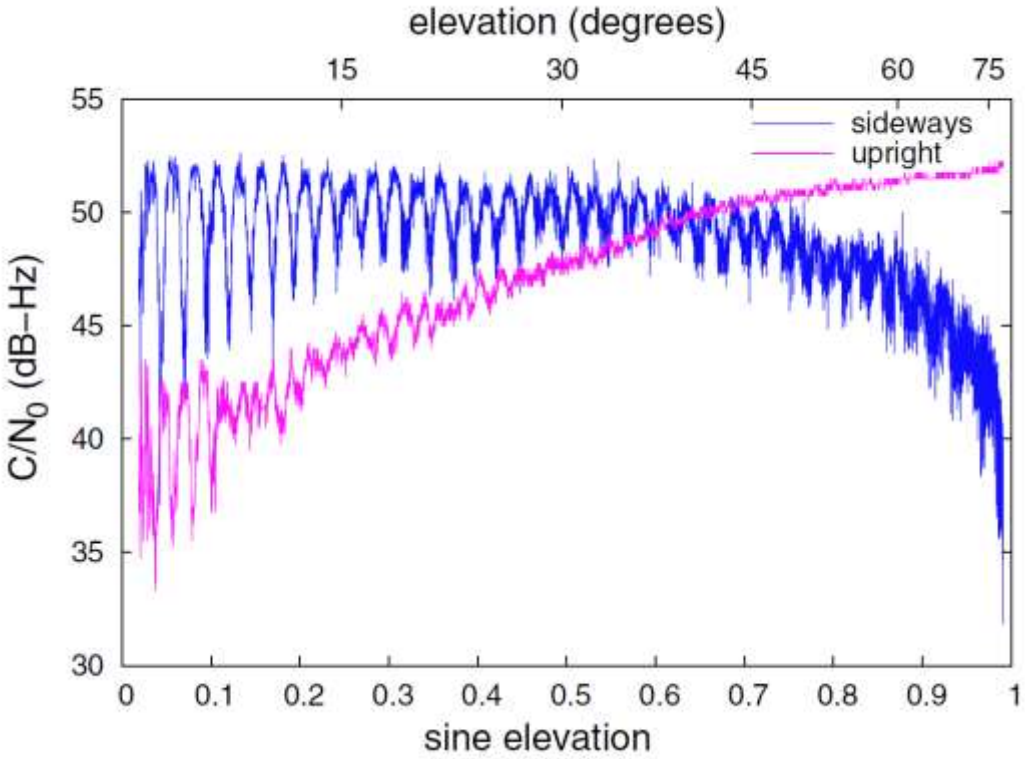
- Readiness for use? Yes and No
- Geographical Scope


Friday Harbor, Washington
2008
Daily mean (cm)
RMS difference = 1.82 cm
2010
Daily mean (cm)
RMS difference = 2.25 cm
Jan Feb Mar Apr May Jun Jul Aug Sep Oct Nov Dec


Friday Harbor, Washington
Mean sea level (cm)
RMS difference = 1.28 cm
2006 2008 2010 2012 2014 2016


Esbjerg Havn (ESBH)
PSMSL
GNSS
7.8
7.6
7.4
7.2
7.0
6.8
6.6
6.4
2004
2006
2008
2010
2012
2014
2016
2018

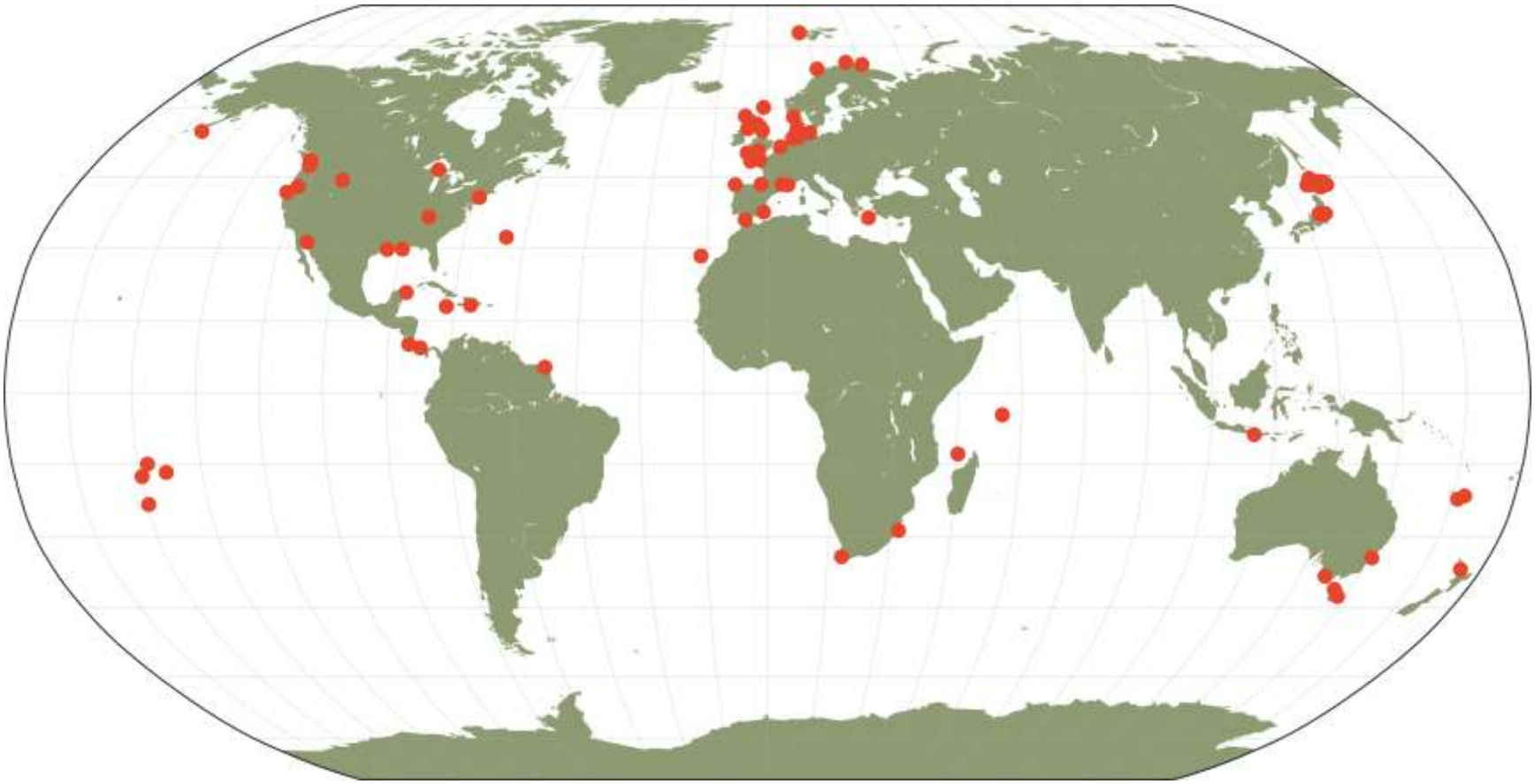

APC
ARP
TGBM
H
TGZ
h1
h2
h3
δh1k
δh2k
δh3k
SNR series 1
SNR series 2
SNR series 3
SSH1
SSH2
SSH3
Sea level
Time


Sideways antenna : mean levelling difference of 5mm RMS 3cm

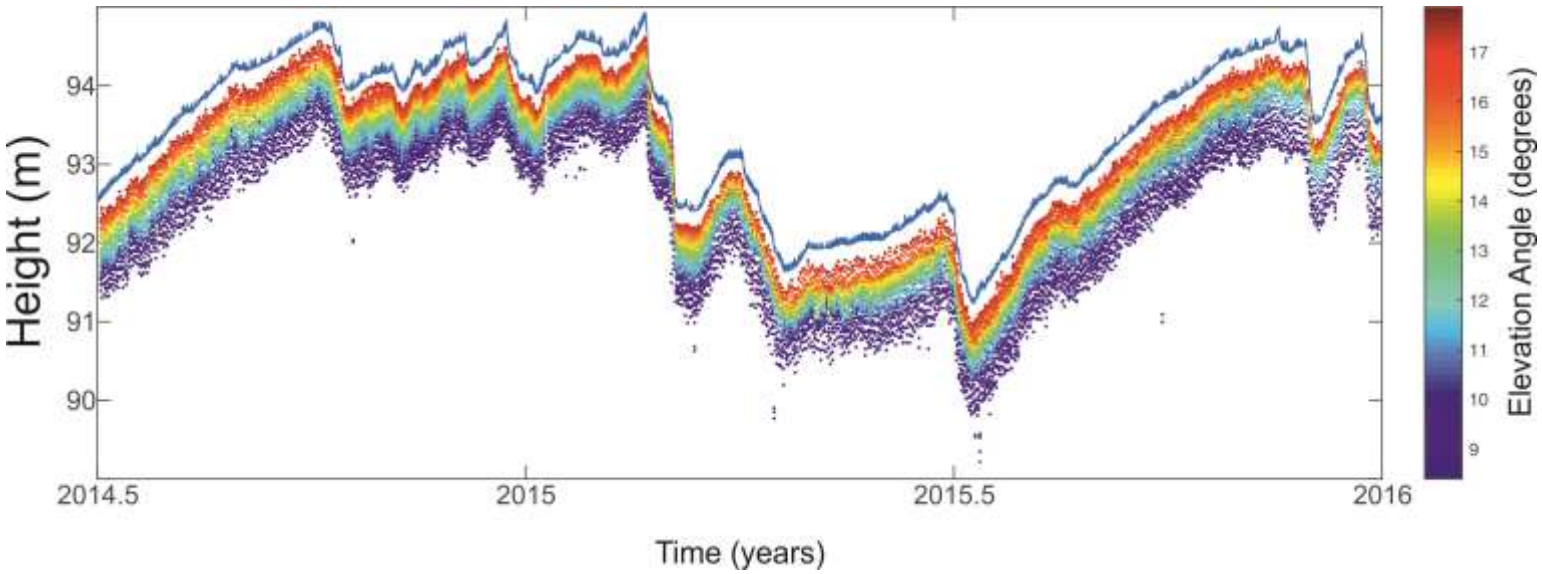
Upright antenna : mean levelling difference 1-2cm RMS 10cm

# Current Reflectometry Sites



# Applicability

- Levelling, reference frame, World Height System, Mean Dynamic Topography, Ellipsoidal heights
    - Need some work
- Tide gauge
    - instrument not in sea so no biofouling
    - Less chance of instrument being broken from shipping
    - Can be on cliff edge, building – security
    - Easier to set up and maintain
    - Currently ~ 10cm RMS (more satellite networks, newer frequencies)
    - Vertical land movement


Height (m)
94
93
92
91
90
2014.5
2015
2015.5
2016
Time (years)
17
16
15
14
13
12
11
10
9
Elevation Angle (degrees)