Detecting Snow Cover on GPS Antenna

ASEN6090 Final Project

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Outline

- Goals
- Sites
- Model
- MP_1 Results
- SNR Results
- Position Results
- Conlusions

Goals

- Generate an index representative of snow cover over GPS antenna.
- Considerations for Reflections study:
  - How much of an effect will Snow cover directly over the antenna have on received signal power from lower elevation angles.

Sites

Sites for Primary Study

- P360 *
- P101 *
- AB33
- P455

** sites have a digital camera installed on site.*

Model

- Basic EM wave propogation (Plane solution to Maxwell's Equations)

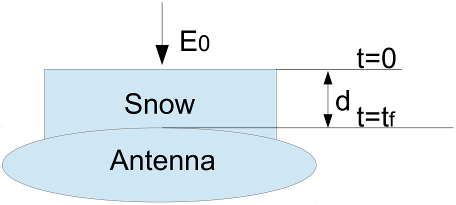
$$E = E_0 e^{j(k.r - \omega t)}, \qquad (1)$$

Where,

$$\frac{\omega^2}{k^2} = \frac{c^2}{\epsilon}$$

However, If ϵ is complex

$$E = E_0 exp[j(Re(k).r - \omega t)] exp[-Im(k).r]. \qquad (2)$$



Model

- Dielectric of Snow?
  - Phase velocity in a medium is dependent on the frequency of the wave-front.
  - As a consequence the dielectric constant of a medium is dependent on the frequency of the EM-wave.
  - Phase velocity of the wave is given by

    $$v = \frac{\omega}{k} = \frac{c}{n}$$

    Where, n is the refractive index of the the medium

    $$n = \sqrt{\epsilon}$$

- Dielectric of Snow for GPS L1 frequency?

Model - ϵ for Snow

- Snow is a mixture of Ice, Air and Water.
- From [1]
  - Consider a 2 component mixture: ice and air
  - Let their volume fractions be p_i and $p_a = (1 - p_i)$
  - let their dielectric constants be ϵ_i and ϵ_a
  - The Dielectric constant of the combination is given by,

$$\epsilon_s E_S = \epsilon_i p_i E_i + \epsilon_a p_a E_a \tag{3}$$

  - Where E_s, E_i and E_a is the mean electric field strength for the EM wave under consideration in the different media.

[1] Y. Ozawa and D. Kuroiwa, "Dielectric Properties of ice, snow and supercooled water" in Microwave propogation in Snowy districts, no. 6, pp. 31-71, 1971

Model - ϵ for Snow

- From [2]
  - The Dielectric constant of the combination is given by,

$$\epsilon_s = \epsilon'_s - j\epsilon''_s$$

Where

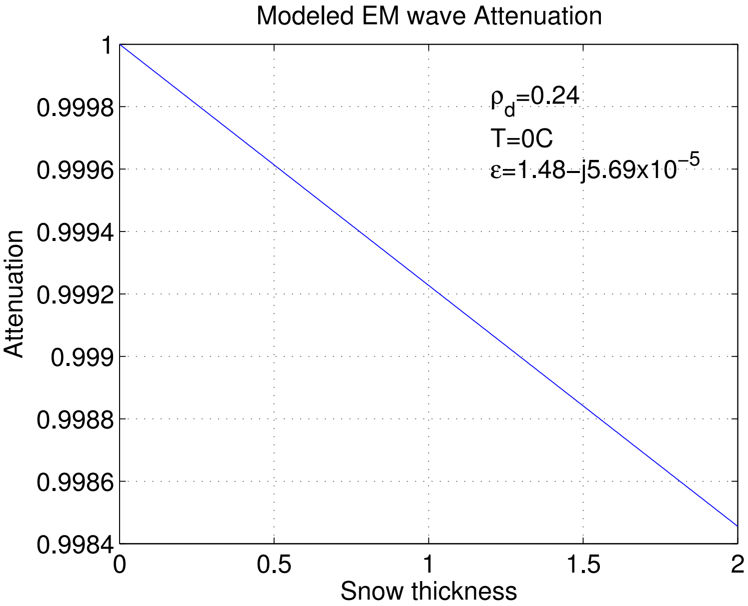
$$\epsilon'_s = 1 + 2\rho_d$$

$$\epsilon''_s = \epsilon'_s \times 1.59 \times 10^6 \times \frac{0.52\rho_d + 0.62\rho_d^2}{7 + 1.7\rho_d + 0.7\rho_d^2} \times (f_{L1}^{-1} + 1.23 \times 10^{-6}\sqrt{f_{L1}})e^{0.036T}$$

  - Where,
    ρ_d is relative density of dry snow
    T is the temperature of snow in Celsius.

[2] M.E. Tiuri, A.H. Sihvola, E.G. Nyfors, M.T. Hallikaiken, "The complex dielectric constant of snow at microwave frequencies", IEEE J Ocean. Eng. OE-9 (5), pp. 377-382, 1984

Model

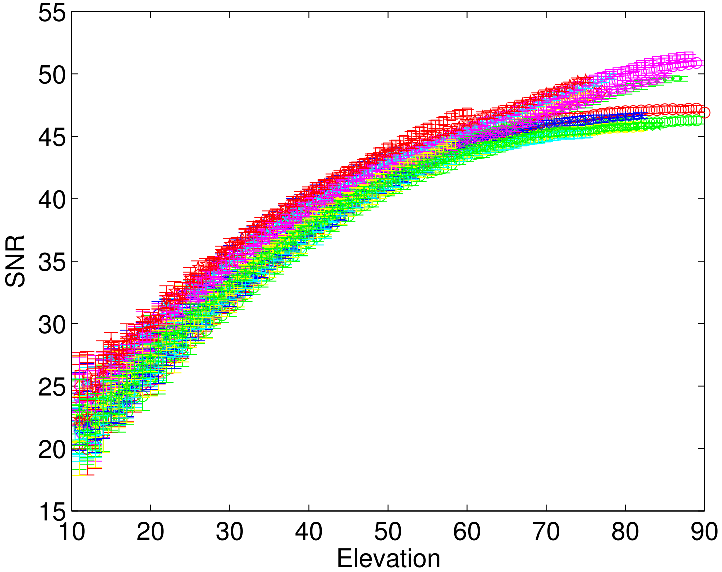


Modeled EM wave Attenuation
1
0.9998
0.9996
0.9994
0.9992
0.999
0.9988
0.9986
0.9984
Attenuation
0
0.5
1
1.5
2
Snow thickness
ρd=0.24
T=0C
ε=1.48–j5.69x10−5

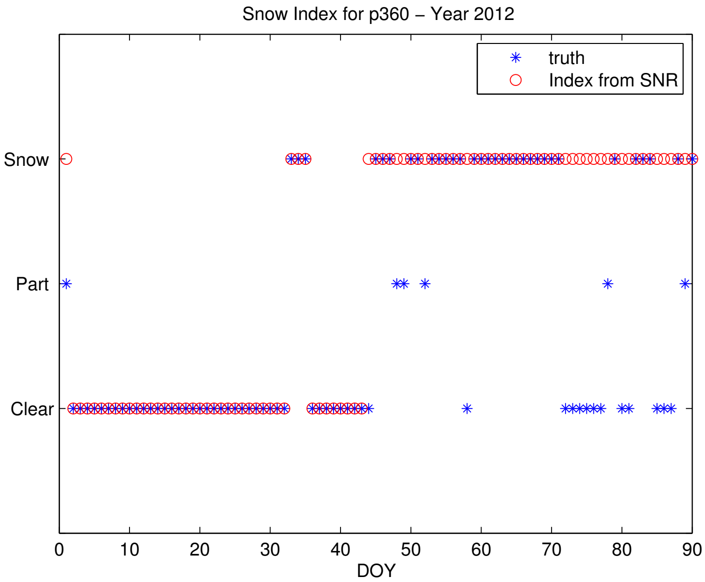
SNR

- Generate a statistical map if expected SNR values w.r.t Elevation angle.
- Data from 2011 DOY 200-250 was used to generate the map
- Each SV was considered seperately
  - Individual Tracks could be tagged as 'Bad'
  - Each SV has varying transmit power

SNR Map



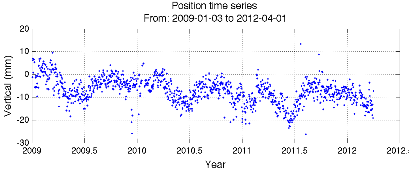
SNR Index

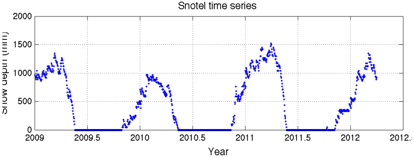


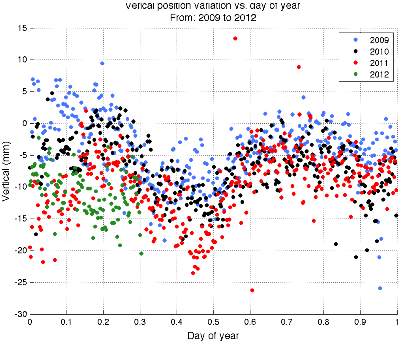
Snow Index for p360 – Year 2012
truth
Index from SNR
Snow
Part
Clear
0
10
20
30
40
50
60
70
80
90
DOY

Position Time Series - P360

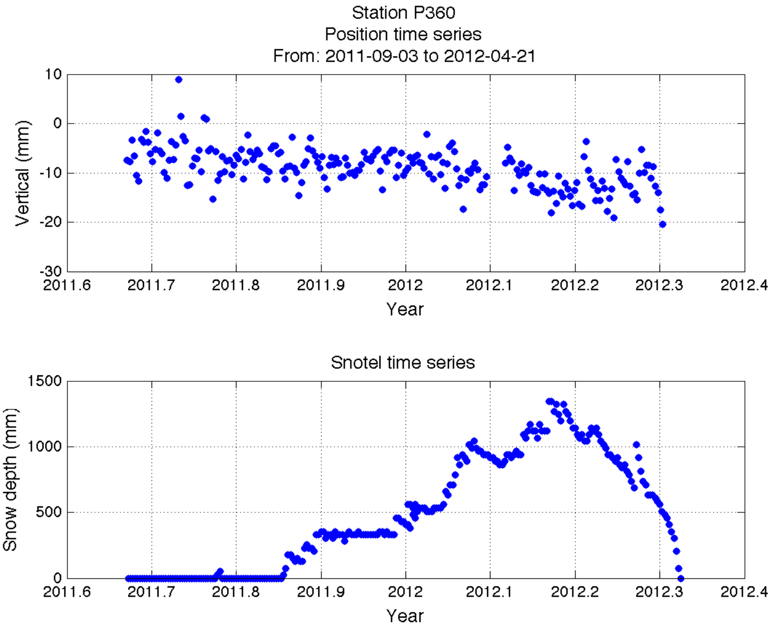
- 2009 to 2012





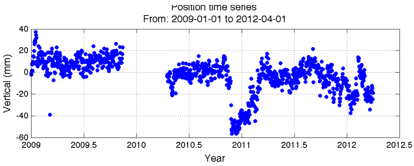


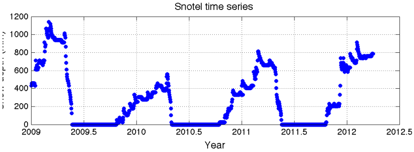
Position Time Series - P360

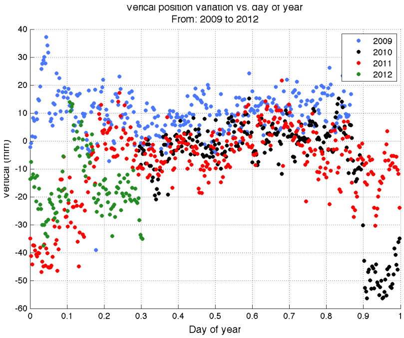


Position Time Series - AB33

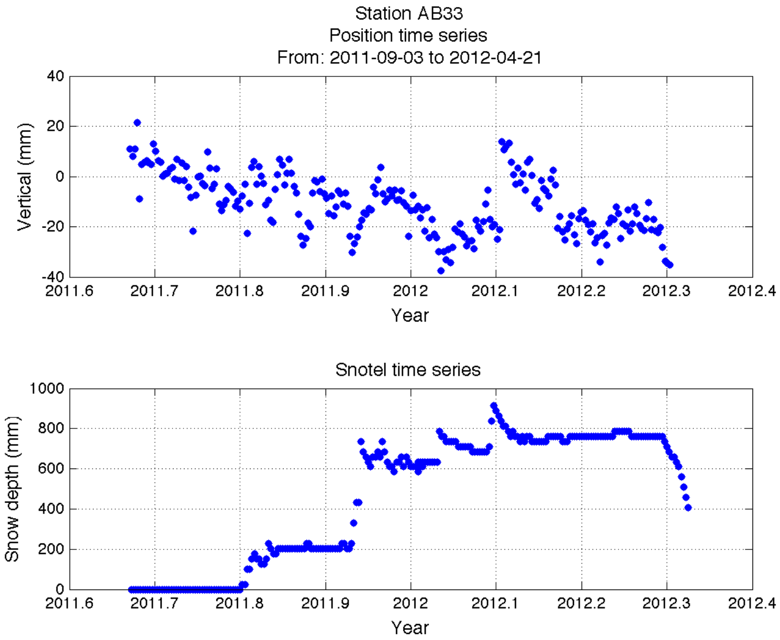
- 2009 to 2012





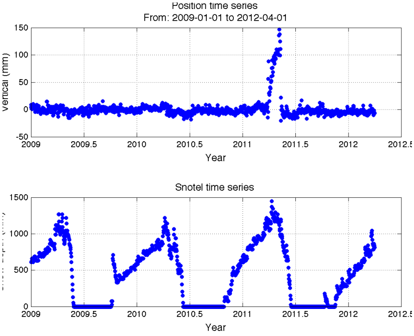


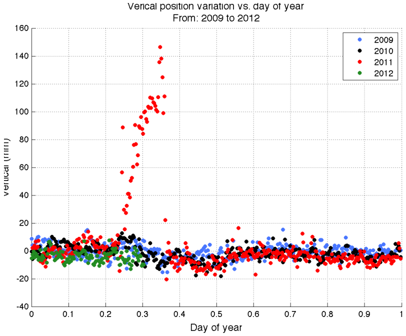
Position Time Series - AB33



Position Time Series - P455

- 2009 to 2012





Position Time Series - P455