Making good from bad:

Can we use GPS multipath to measure soil moisture content?

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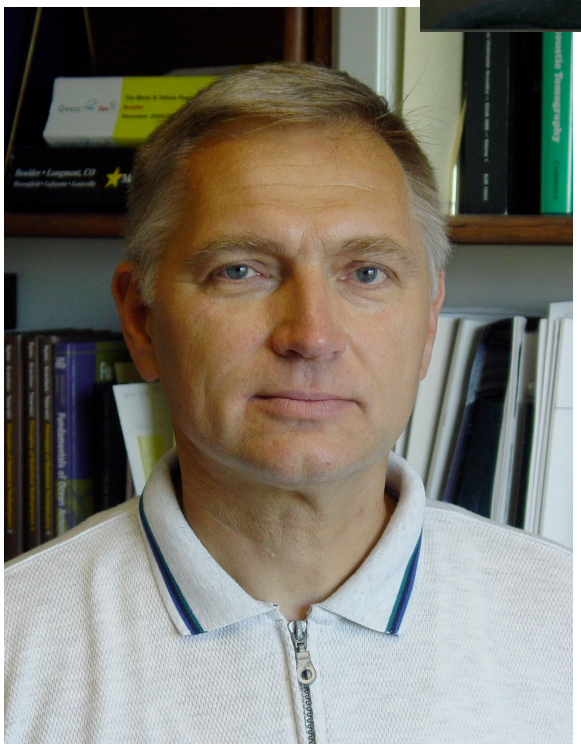

Valery Zavorotny
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Ethan Gutmann, CU

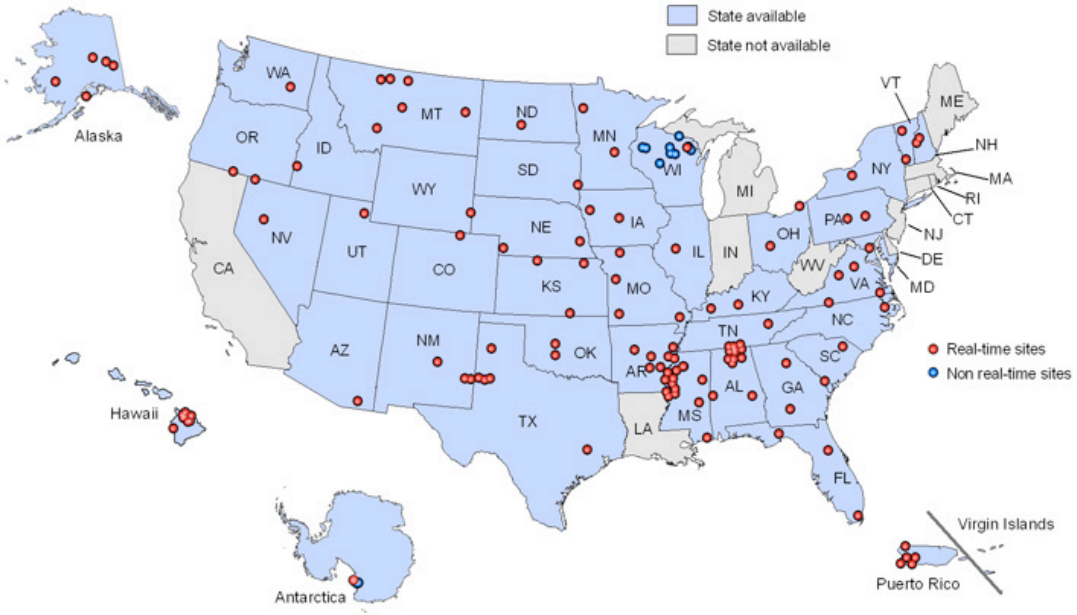
Outline

- Overview on soil moisture
- GPS reflections/multipath
- Results from Tashkent
- Results from Marshall, Colorado
- Conclusions

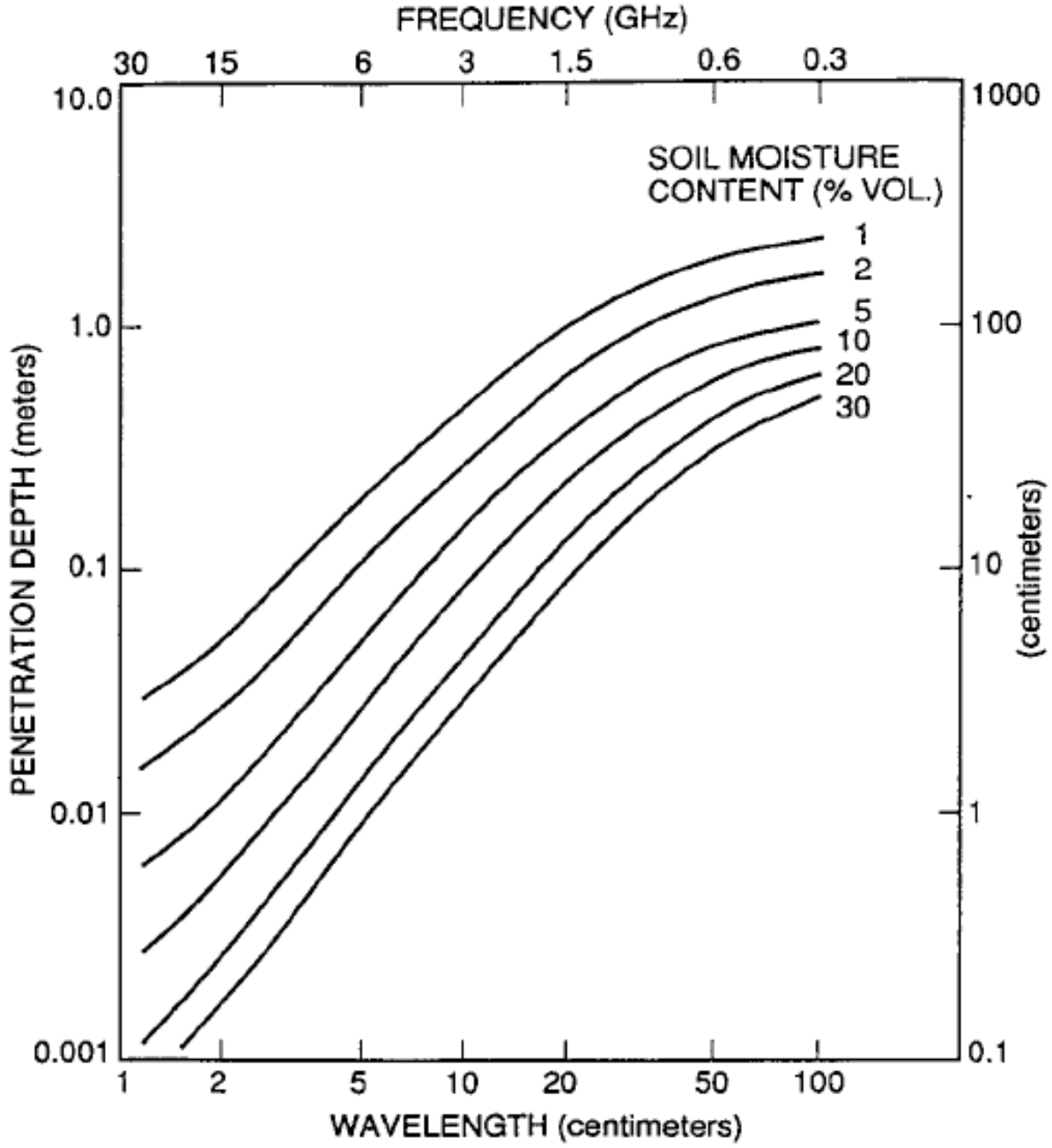
Why measure soil moisture?

- Important measurement for climate system studies.
- Needed for improving models and ground truth for remote sensing studies.
- Current instrumentation is sparse (and data are costly to collect).

SCAN

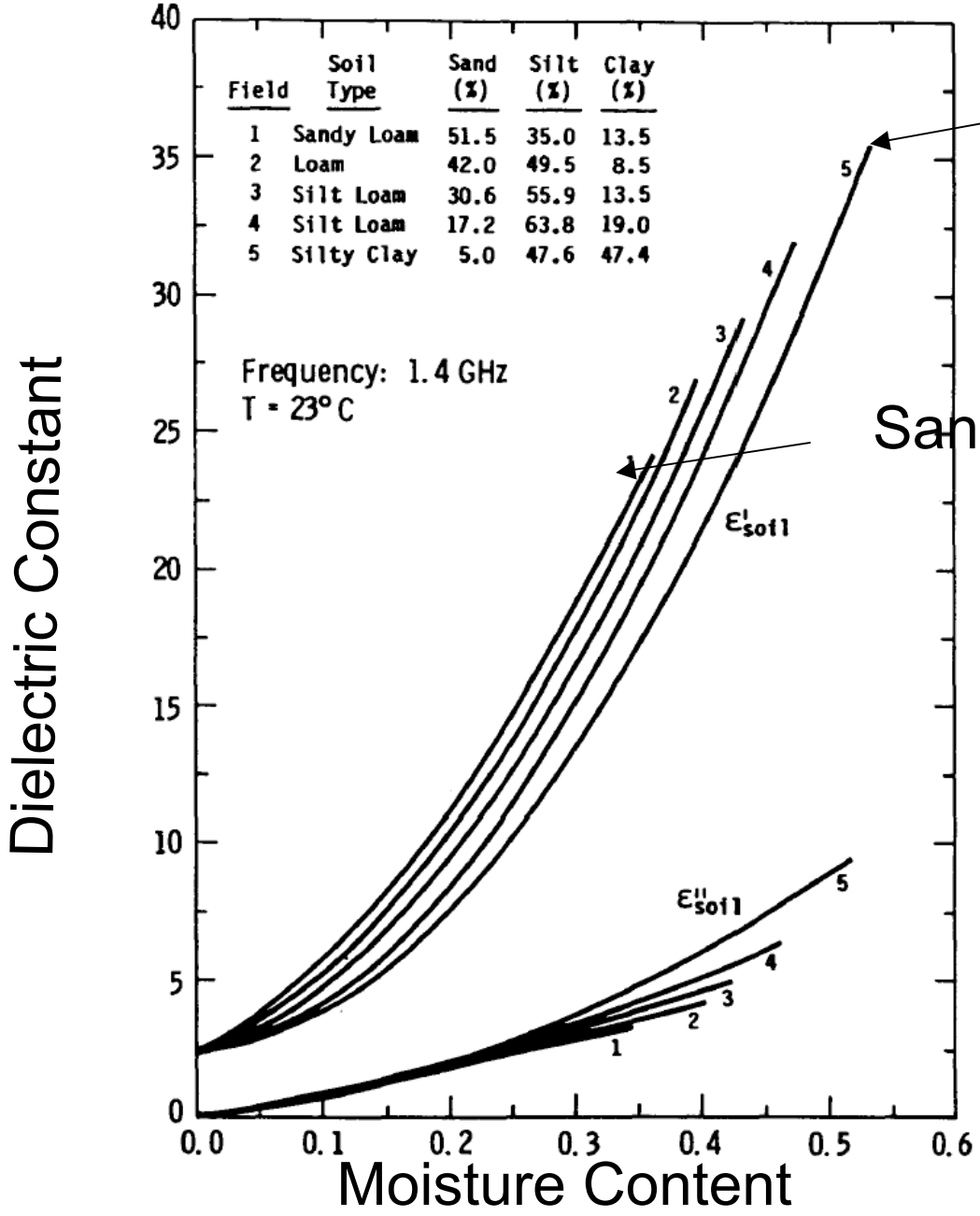


Penetration depth depends on frequency and soil moisture content.



Njoku & Entekhabi, 1996

It also depends on soil type

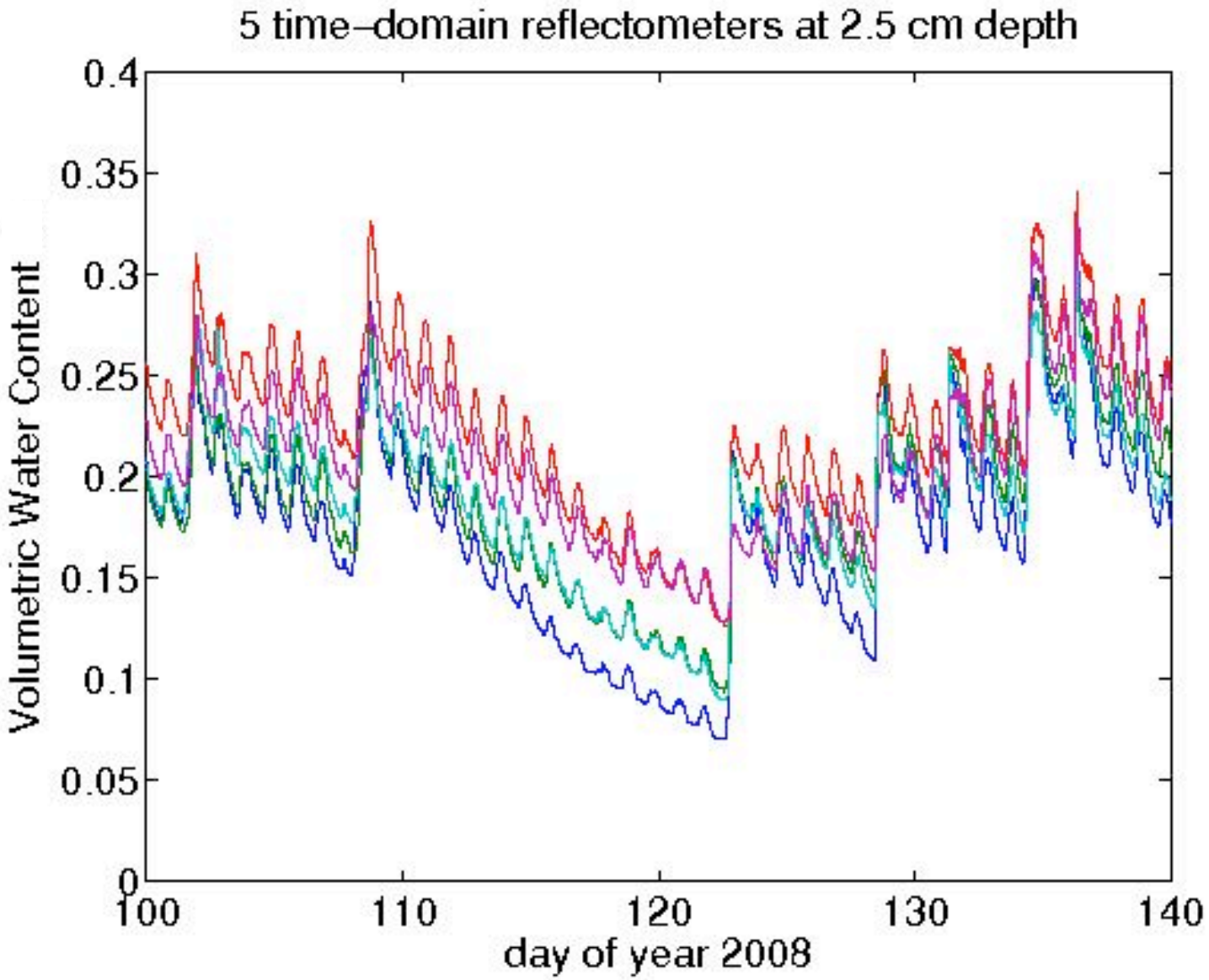


Silty Clay

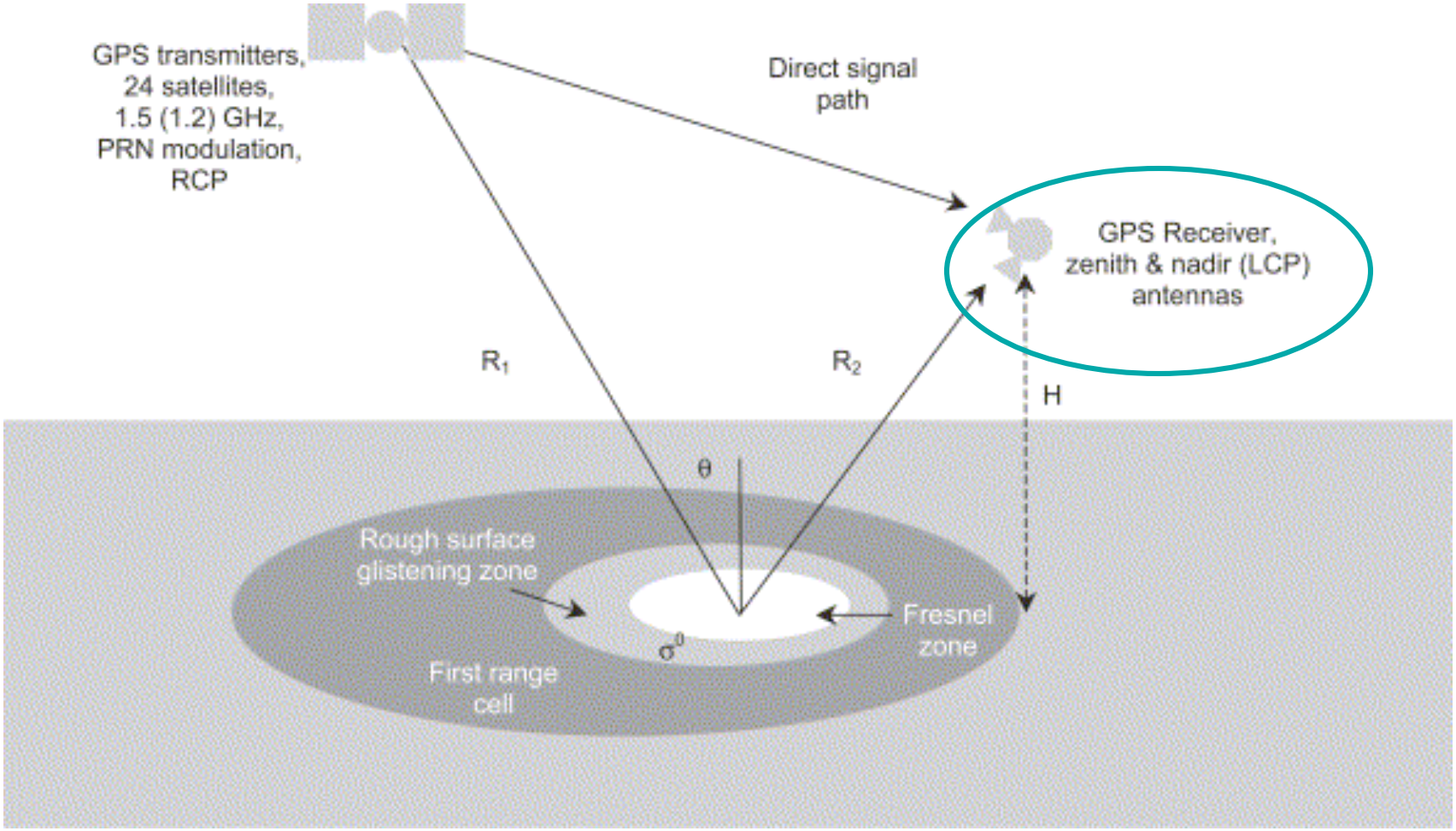
Sandy Loam

Njoku & Entekhabi, 1996

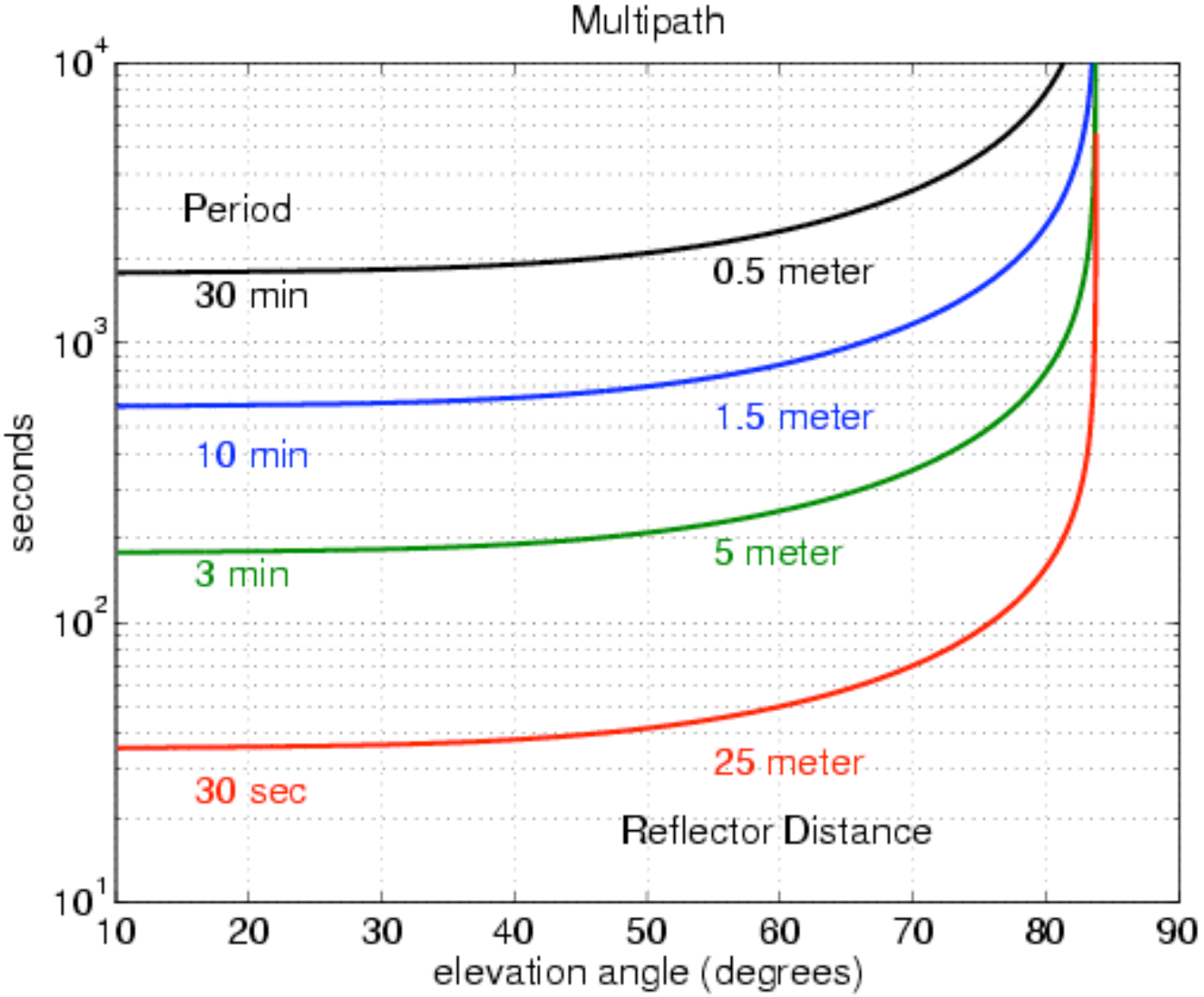
And Soil moisture is highly variable.



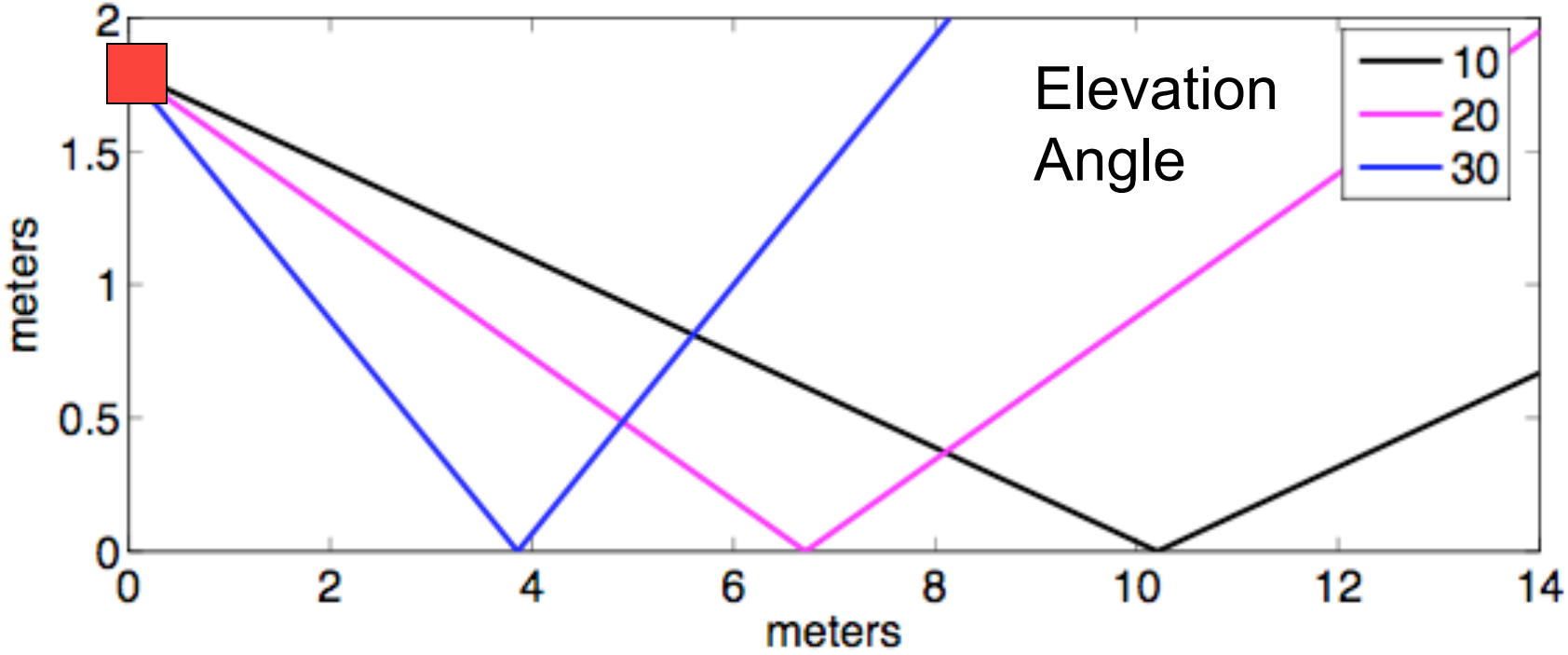
GPS multipath work - the expensive kind



Using geodetic receivers: we know what frequencies are produced by ground multipath



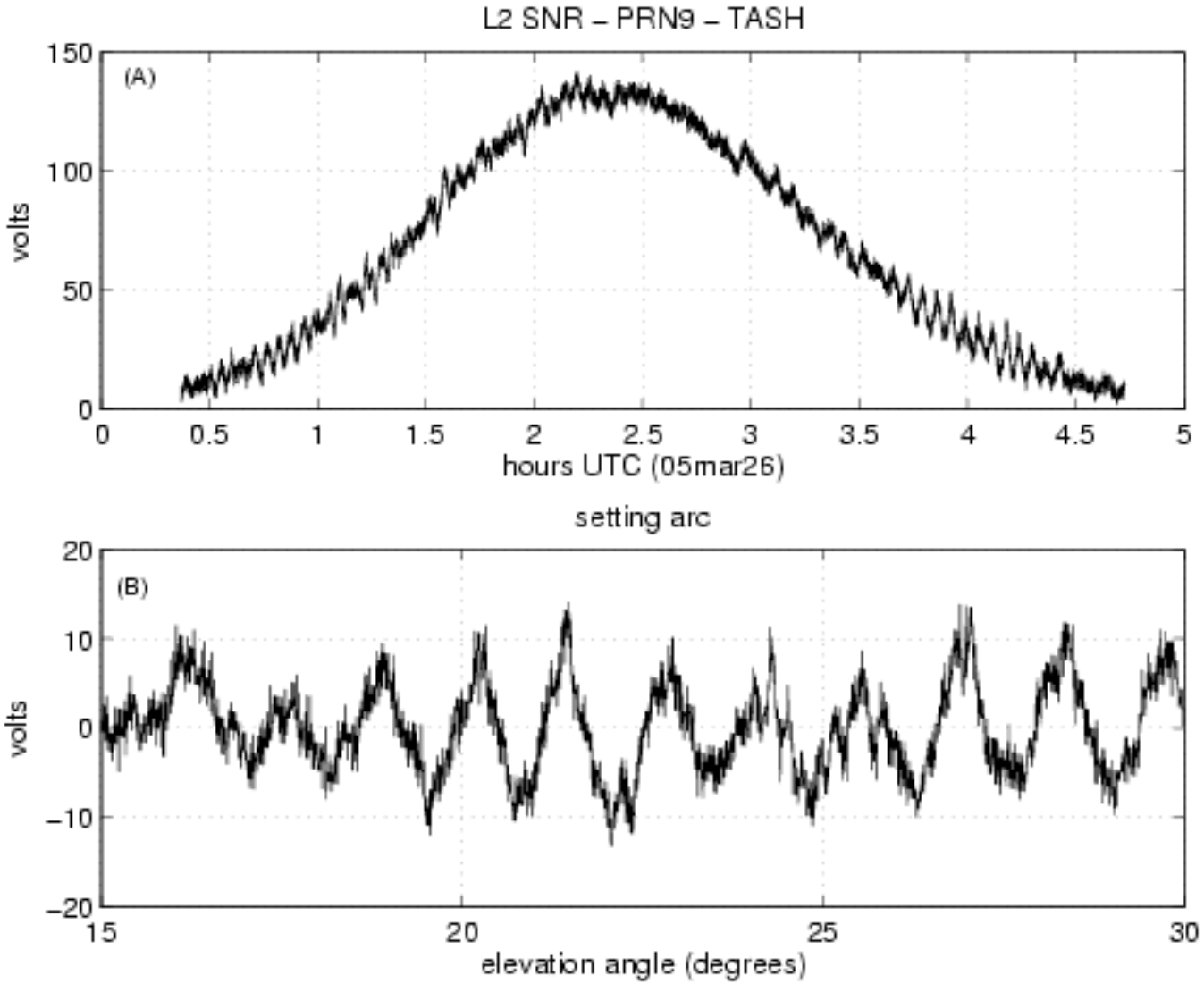
And we know where the multipath reflection point is



Multipath amplitude is a function of surface reflectance, which is related to soil moisture content.

How are we going to quantify multipath?

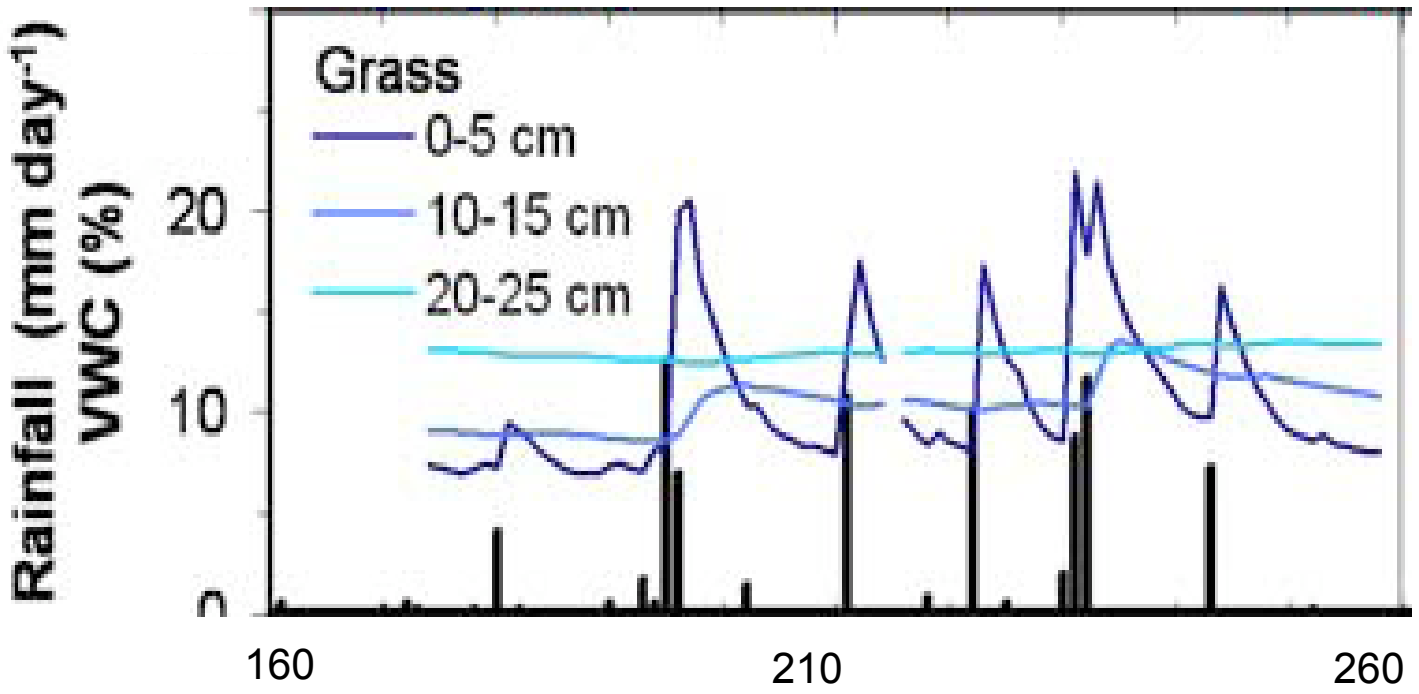
SNR: S1 and S2



SNR data quality

- Source: Bilich, PhD dissertation, 2006; Bilich et al., *Proceedings of the ION*, 2007.
- Good SNR data for:
  - AOA ACT, L1 and L2
  - Trimble NetRS L2 (especially on block IIR-M)
  - Ashtech Z-12 L1

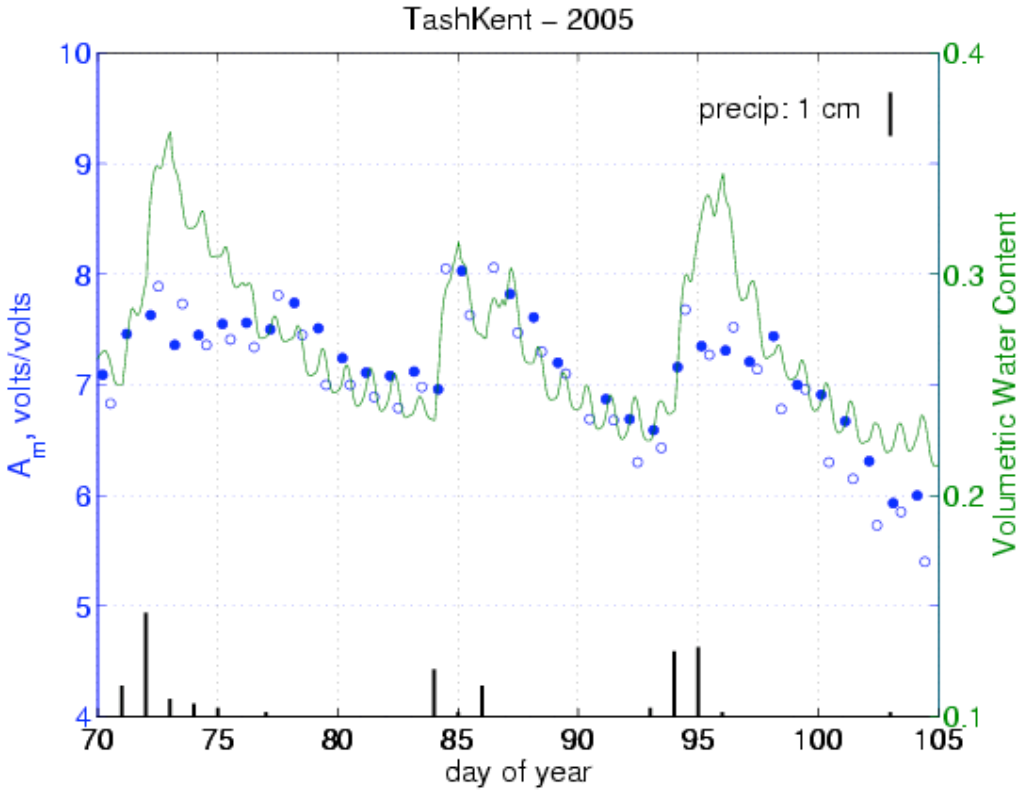
What do soil moisture measurements typically look like?



Kurc and Small, 2004

Results for Tashkent

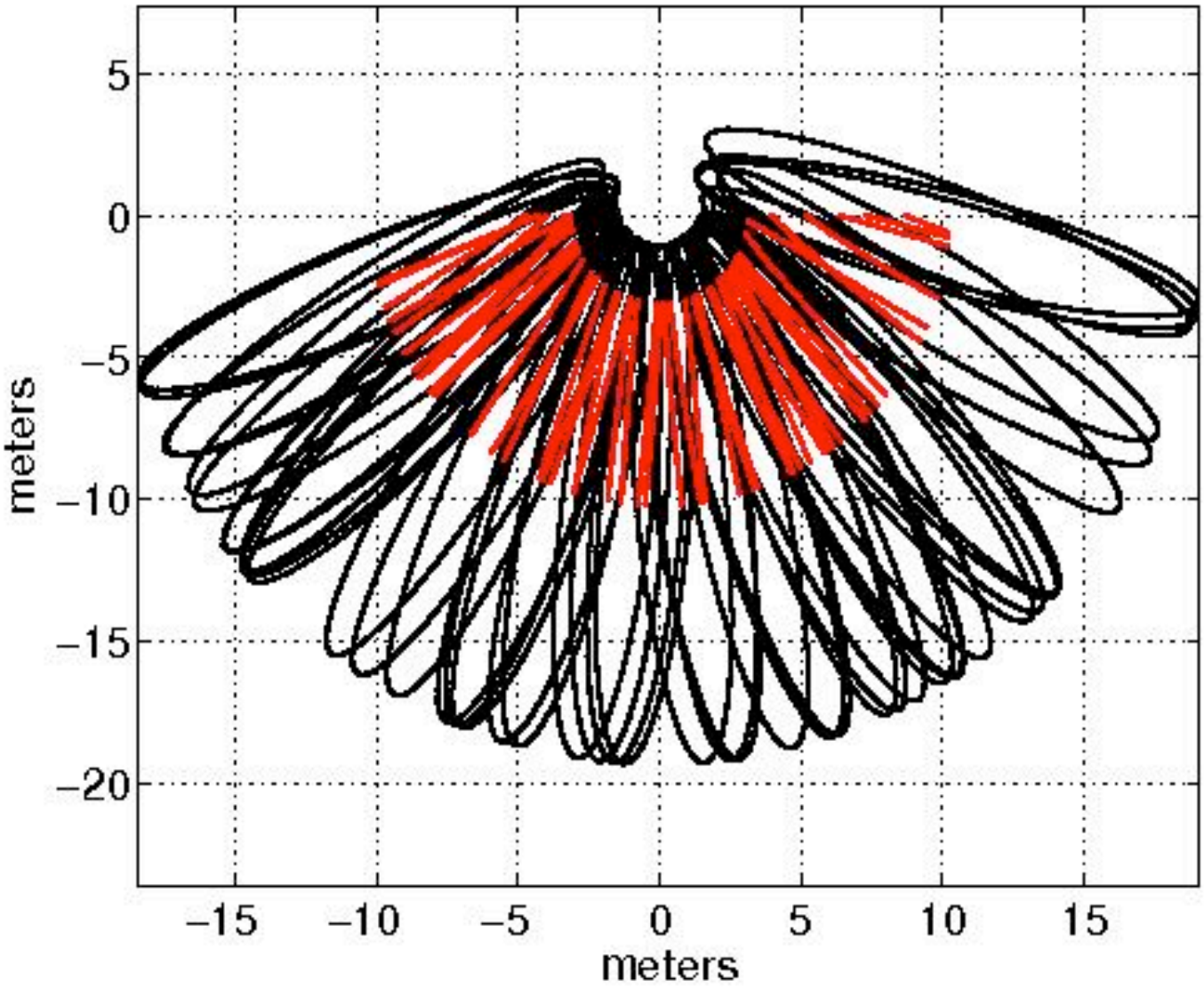
AOA ACT operated by GFZ; 6 meter pillar.



Larson et al., GPS Solutions, online 2007

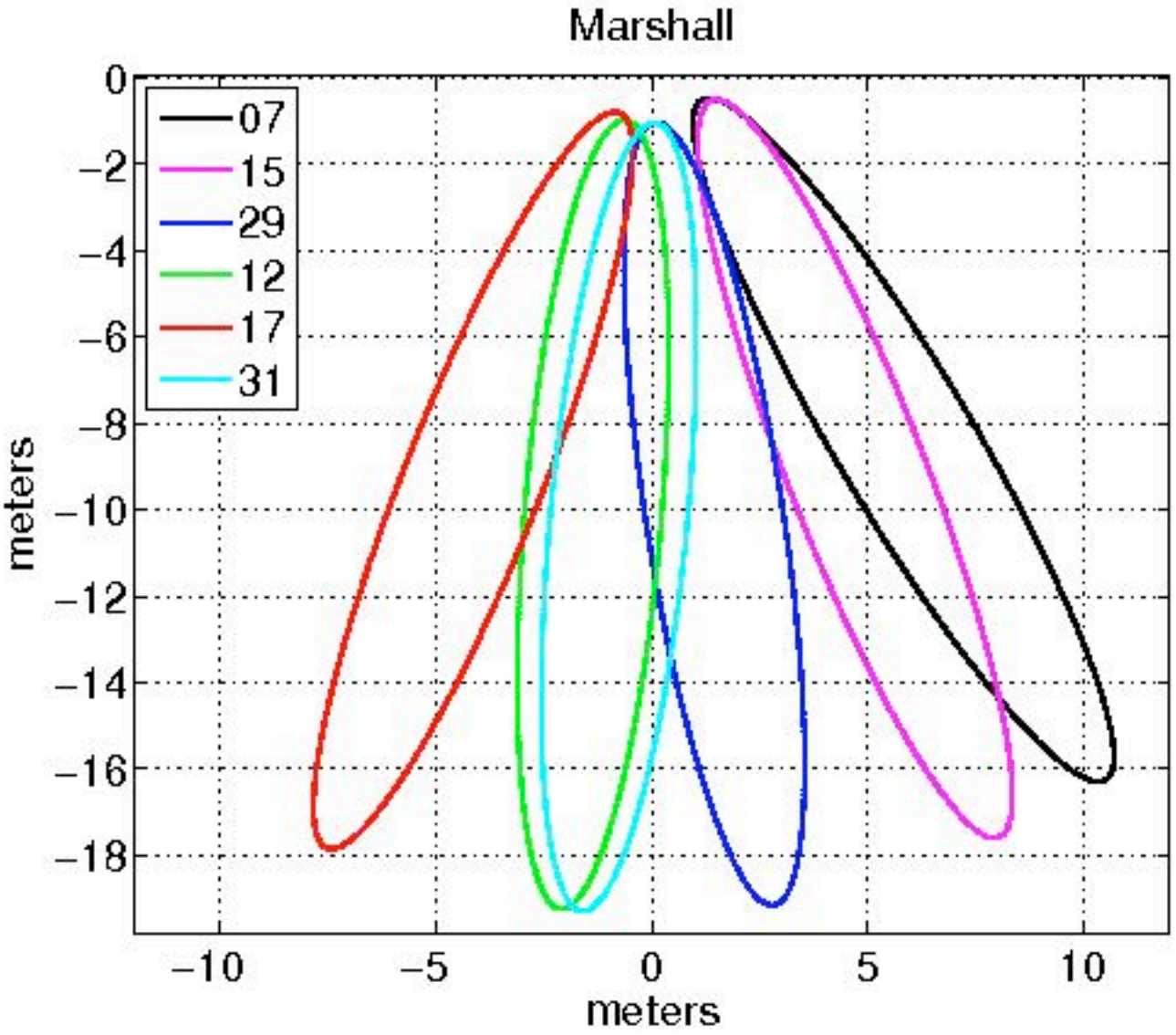
Results for Marshall, Colorado

Fresnel Zone at elevation angle of 10 degrees

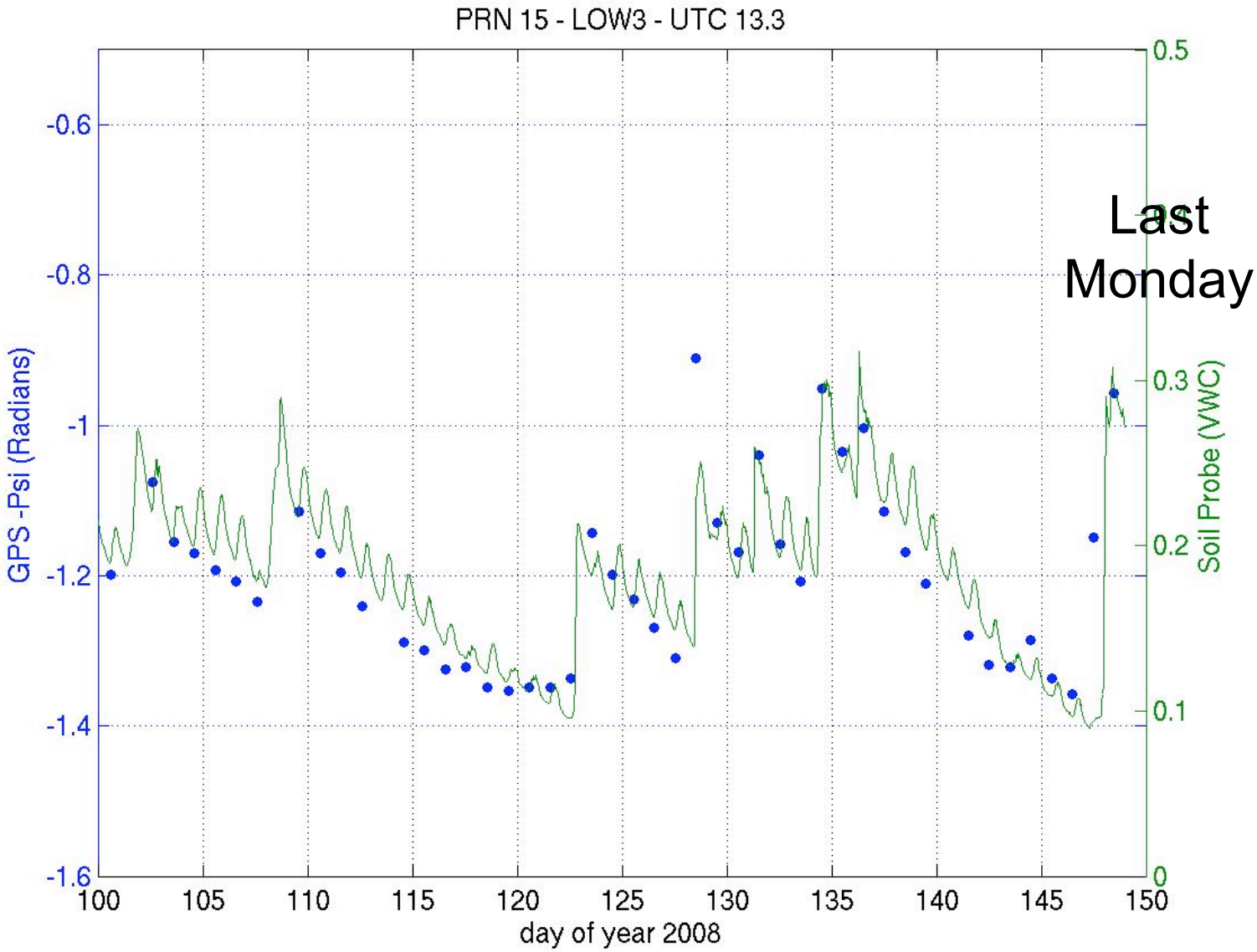


Reflection points, 10-30 degrees.

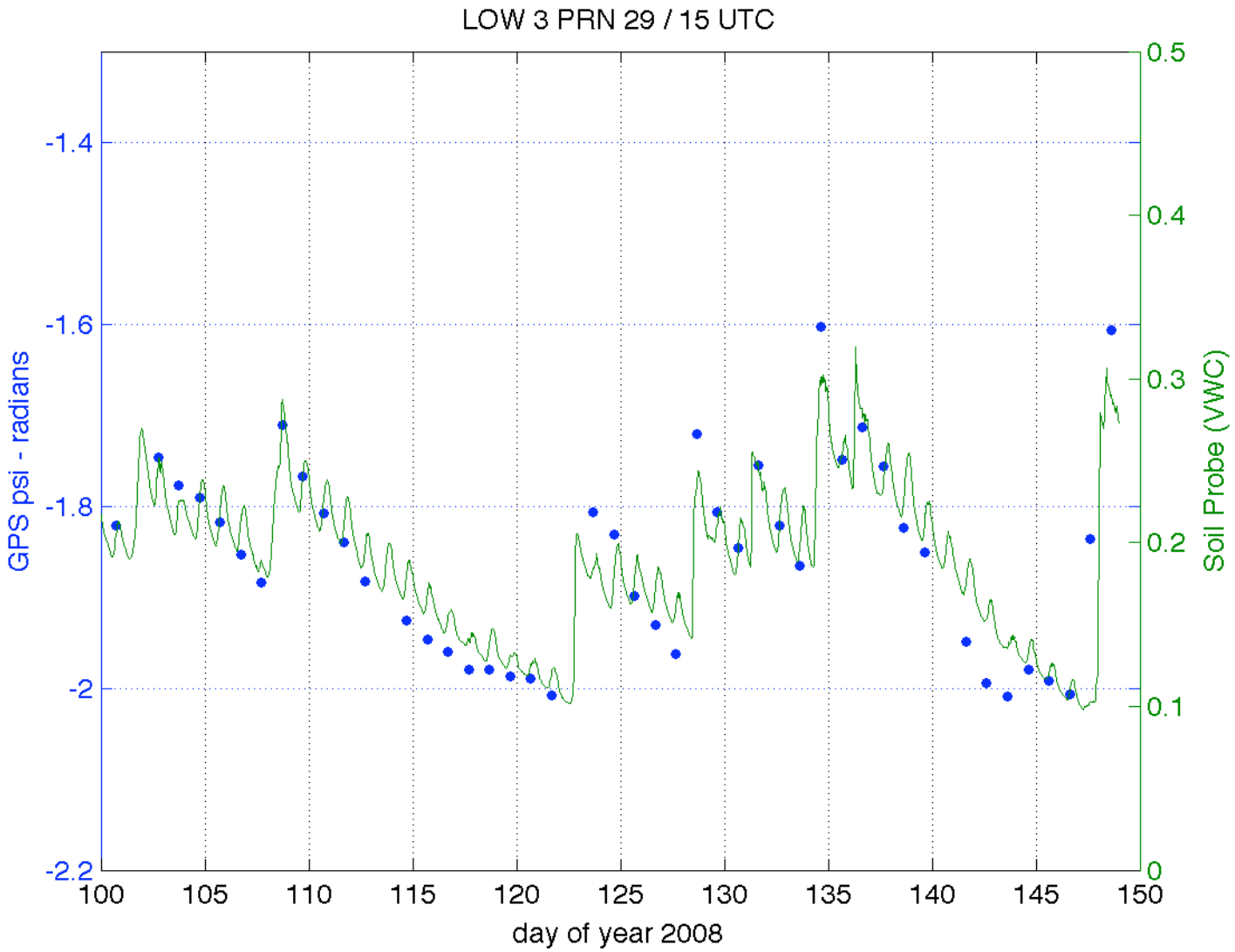
Block IIR-M satellites Fresnel Zones

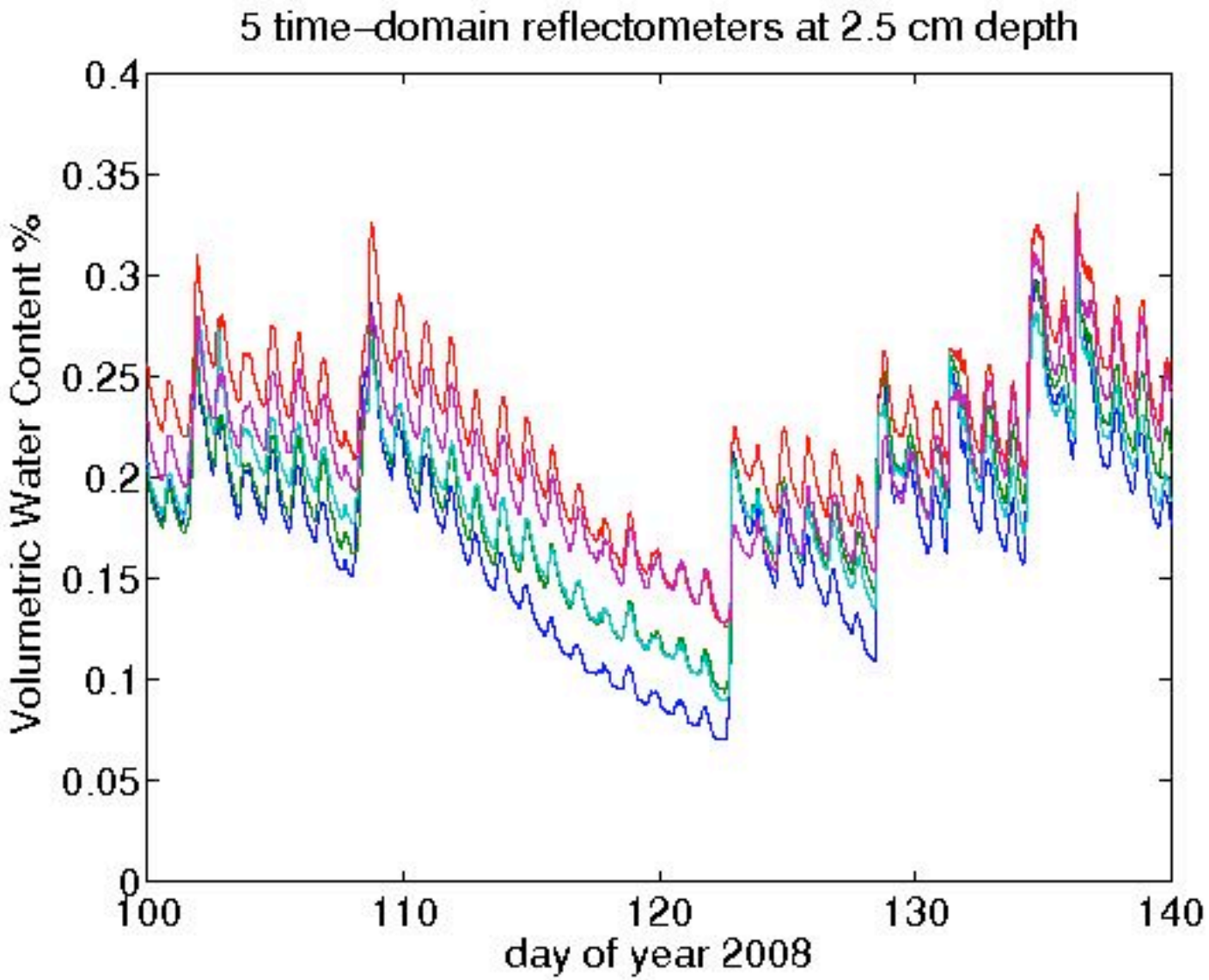


GPS Multipath



Average of 5 time domain reflectometers.


LOW 3 PRN 29 / 15 UTC
GPS psi - radians
Soil Probe (VWC)
day of year 2008
-1.4
-1.6
-1.8
-2
-2.2
0.5
0.4
0.3
0.2
0.1
0
100
105
110
115
120
125
130
135
140
145
150


5 time–domain reflectometers at 2.5 cm depth
Volumetric Water Content %
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
100
110
120
130
140
day of year 2008

Summary

- GPS multipath shows great promise for soil moisture studies.
- Every antenna type will need to be tested/calibrated (i.e. radomes matter).
- Existing GPS receivers/data/monuments can be used, resulting in an extremely economical soil moisture network.
- GPS multipath senses large soil regions (30 by 20 meters), which are of interest to hydrologists and atmospheric scientists.

Summary

- Improved resolution of soil moisture content could lead to multipath corrections for precise positioning.
- The IGS network would be significantly improved for multipath work if online station photos were always available.
- SNR data are (relatively) easy to use - but limited in their utility by lack of reliability on the receiver manufacturer side.

Acknowledgements

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