Jet Propulsion Laboratory
California Institute of Technology

How we can measure snow, sea ice, and other things with reflected GPS signals

Clara Chew, with help from Kristine Larson at CU Boulder

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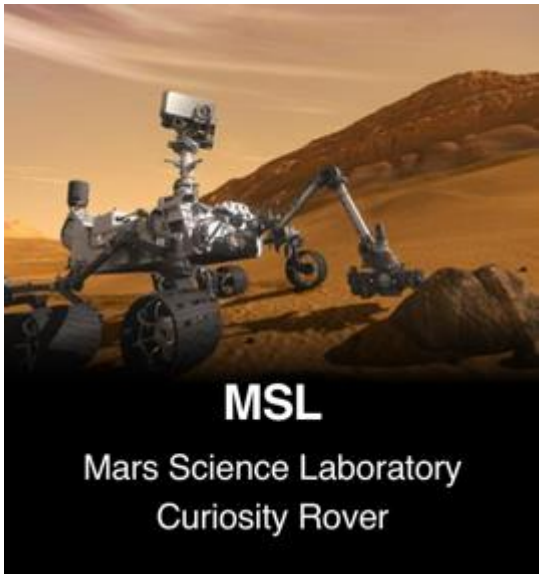
Source: https://www.unavco.org/science/snapshots/cryosphere/2012/bevis.html

What does JPL do?

Solar system exploration

Mars

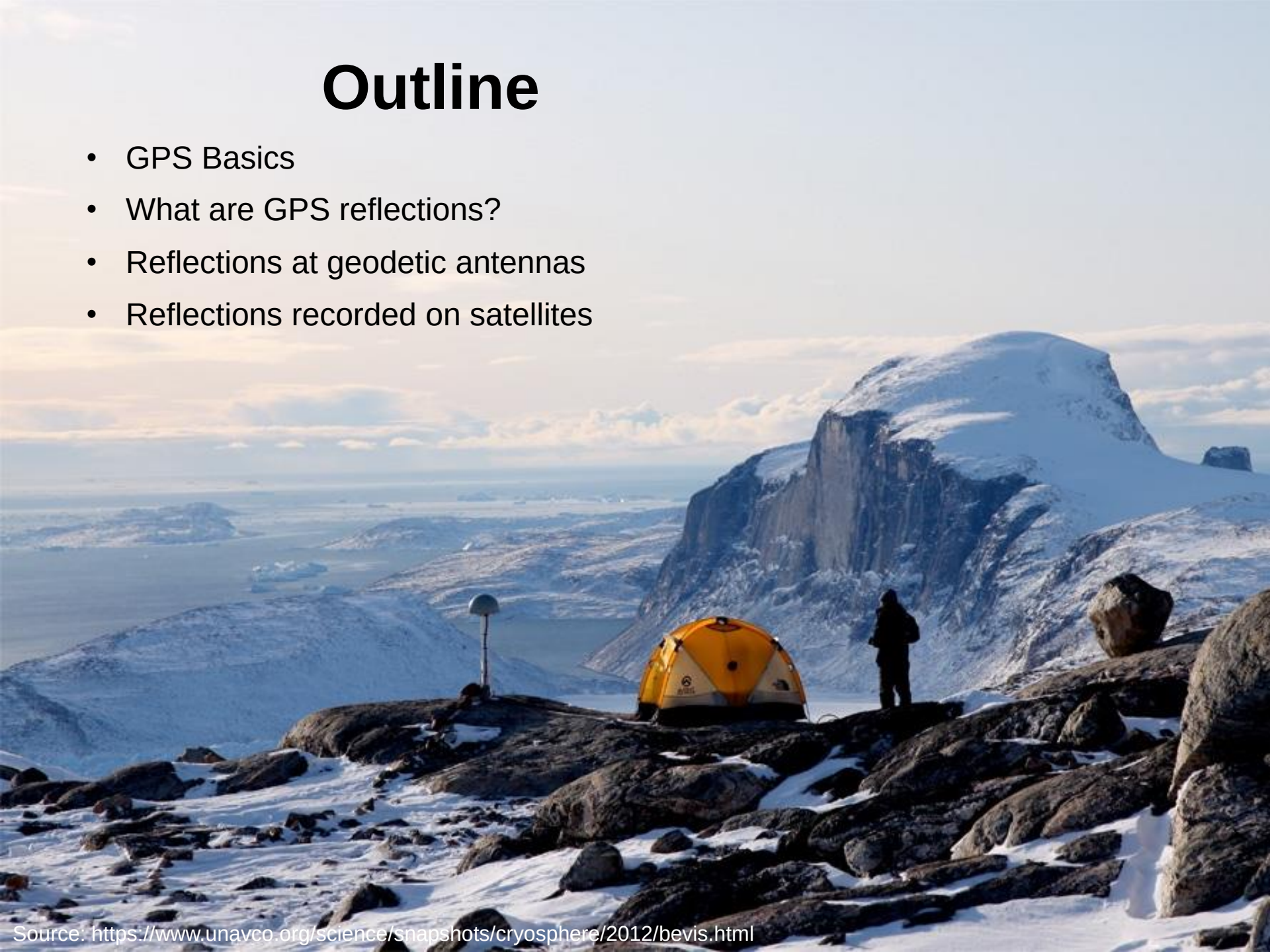


Earth science

Source: jpl.nasa.gov

Outline

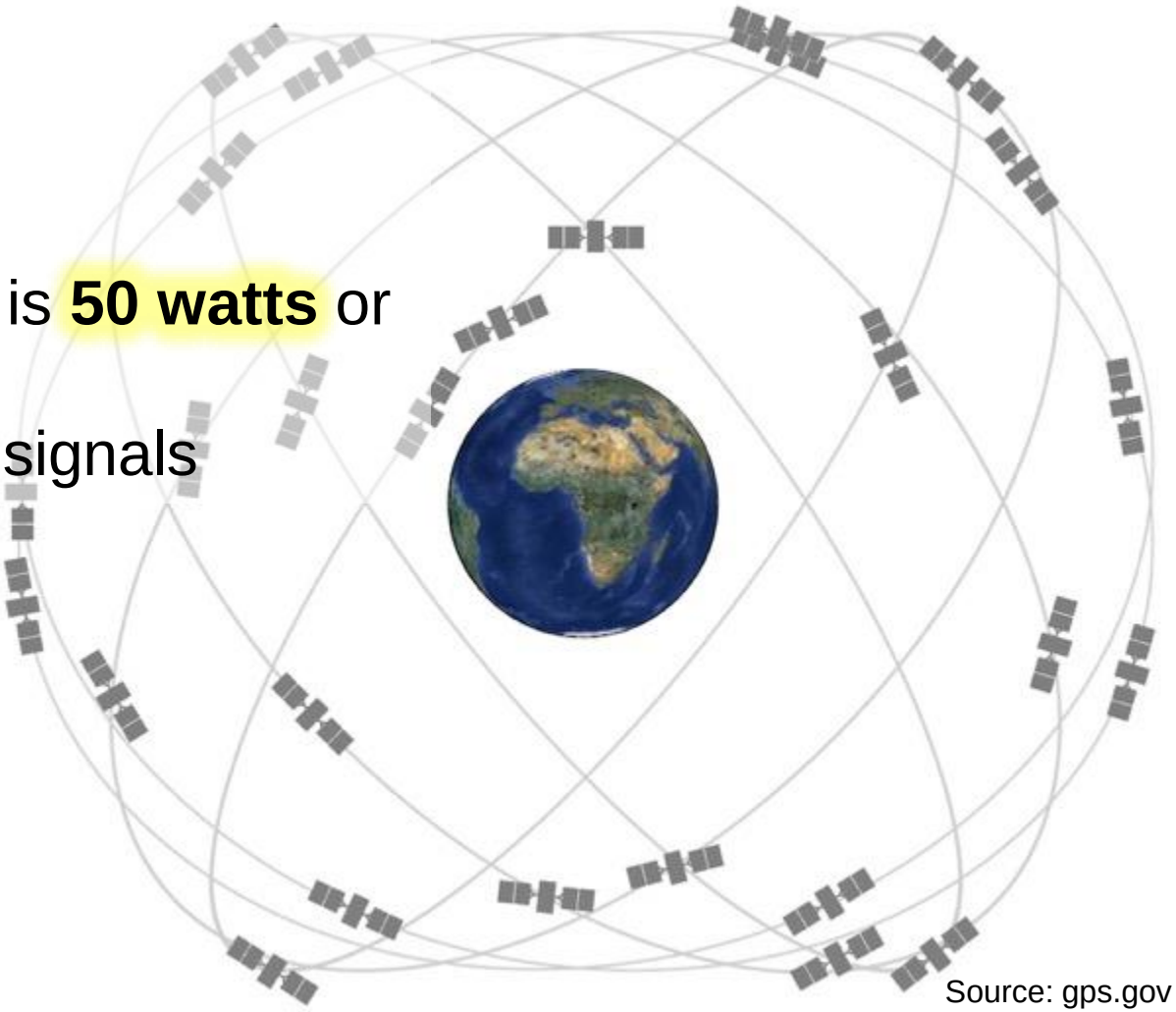
- GPS Basics
- What are GPS reflections?
- Reflections at geodetic antennas
- Reflections recorded on satellites



Source: https://www.unavco.org/science/snapshots/cryosphere/2012/bevis.html

GPS basics

- Up to 32 satellites
- MEO 20,200 km
- Twice a day orbit
- Transmitted power is **50 watts** or less
- L-band microwave signals



Source: gps.gov

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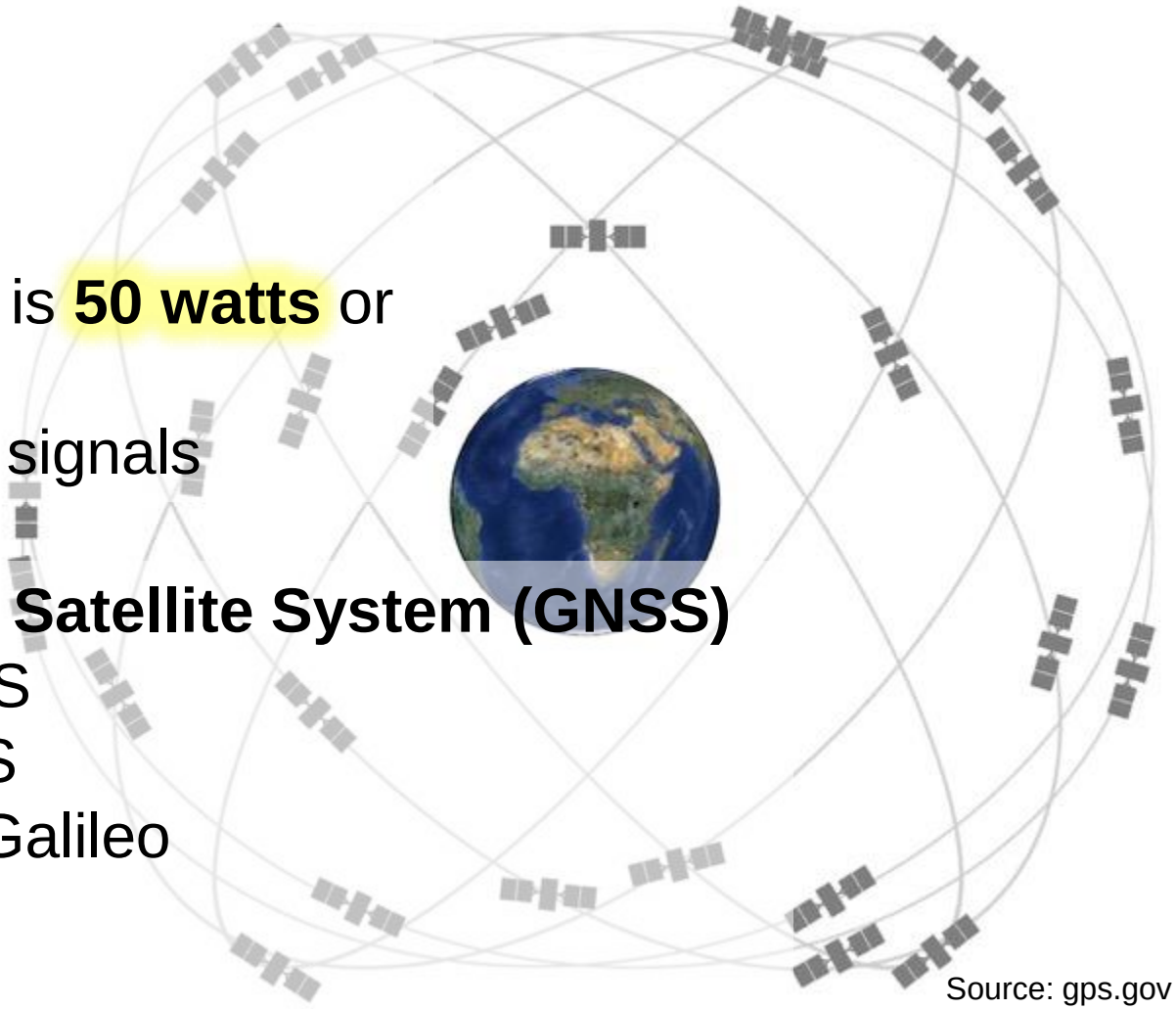


Source: gps.gov

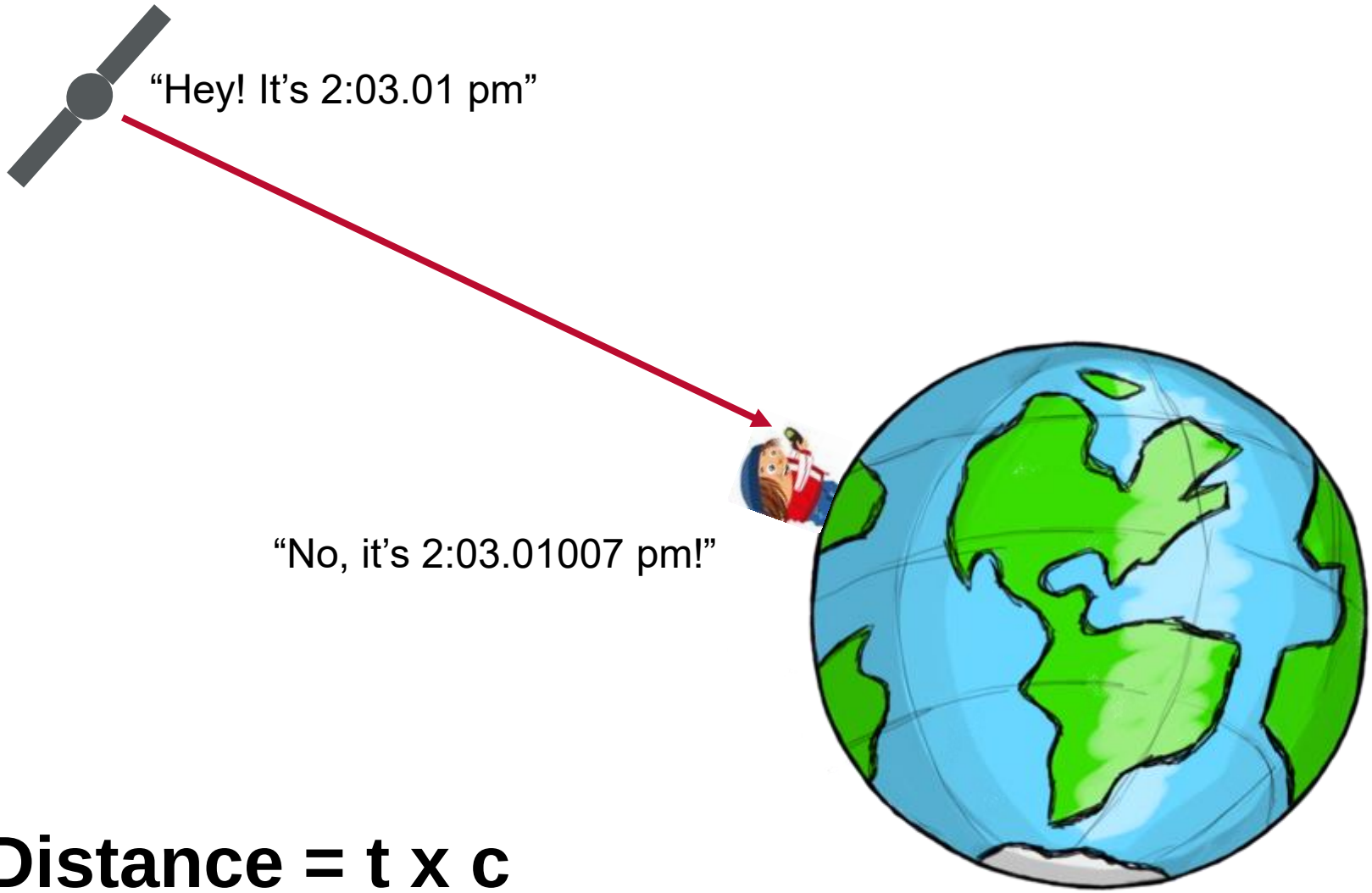
Global Navigation Satellite System (GNSS)

- United States: GPS
- Russia: GLONASS
- European Union: Galileo
- China: BeiDou
- India: IRNSS
- Japan: QZSS

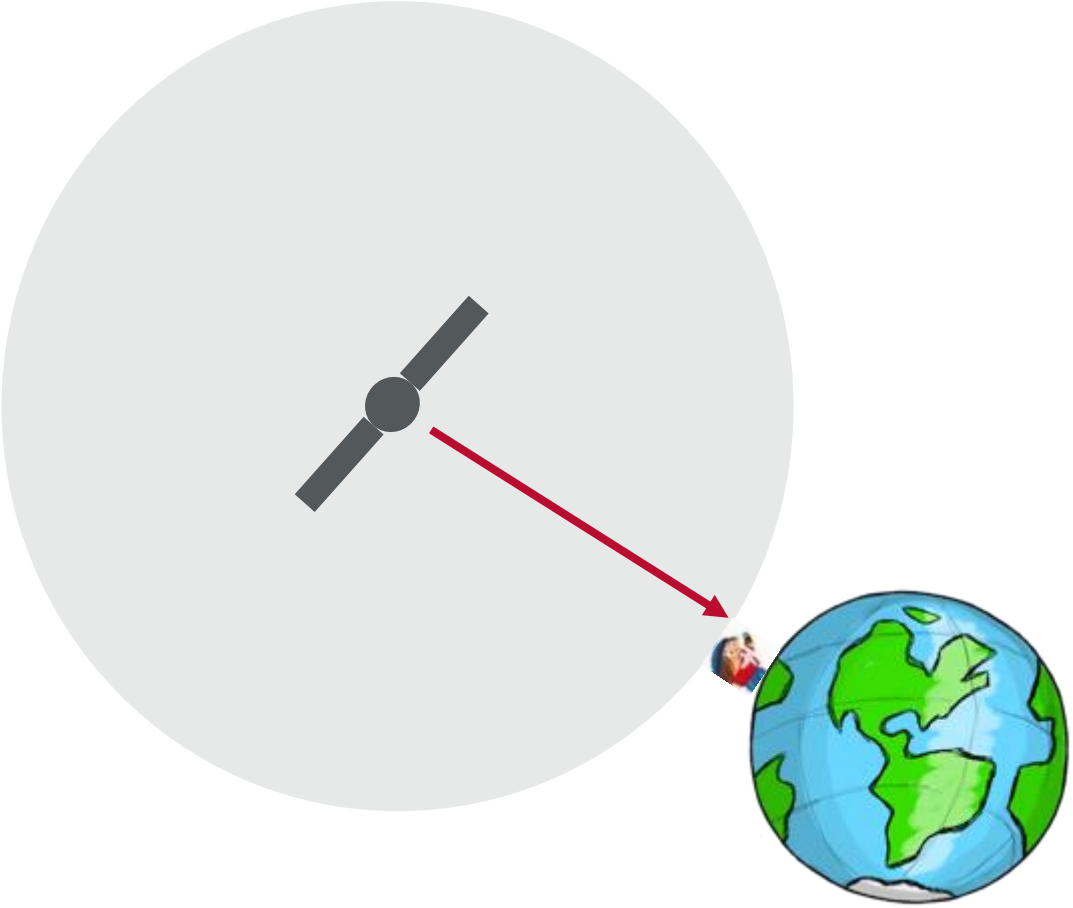
GPS basics

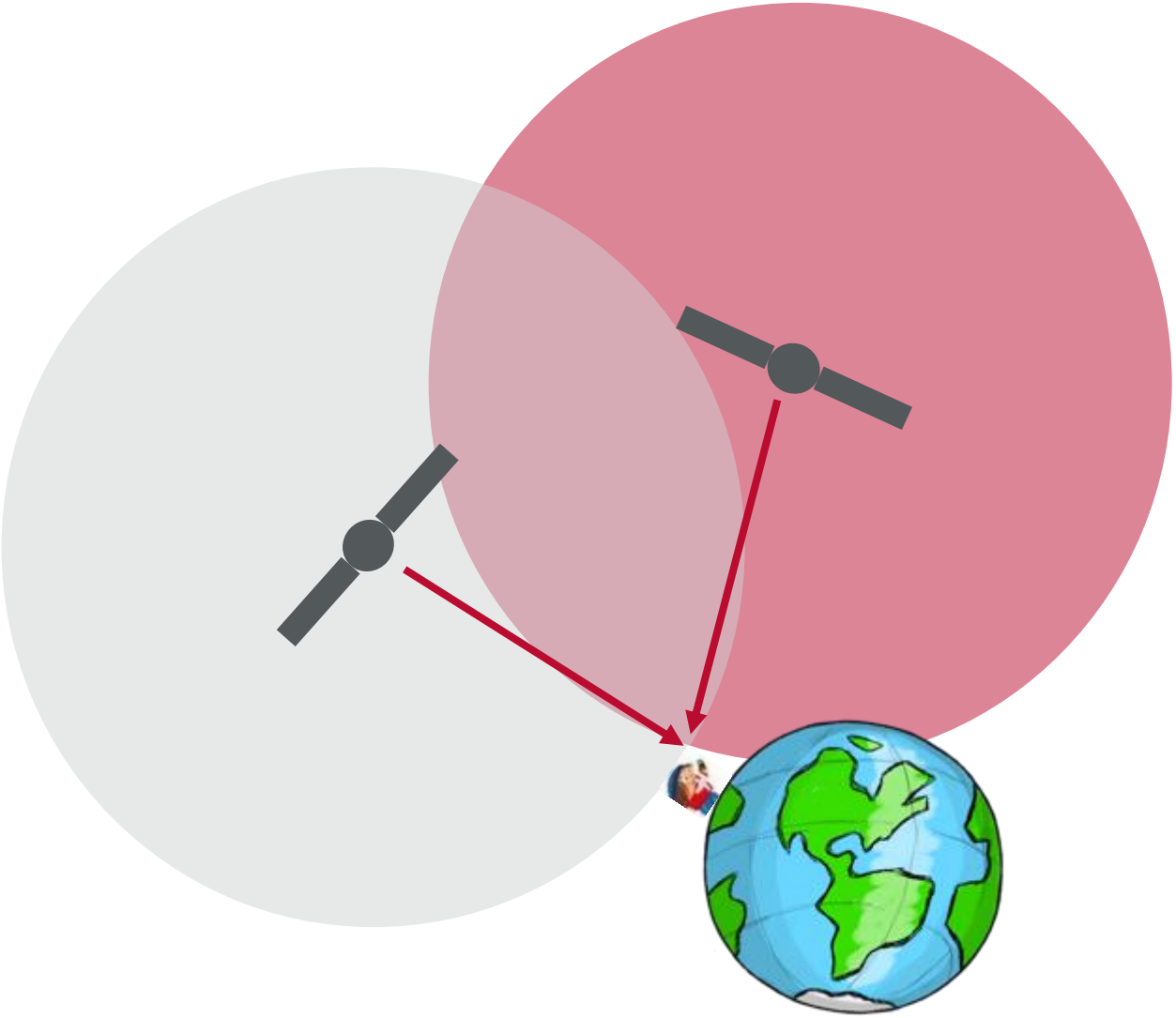
Your phone needs signals from at least **four** satellites at all times to tell you where you are.

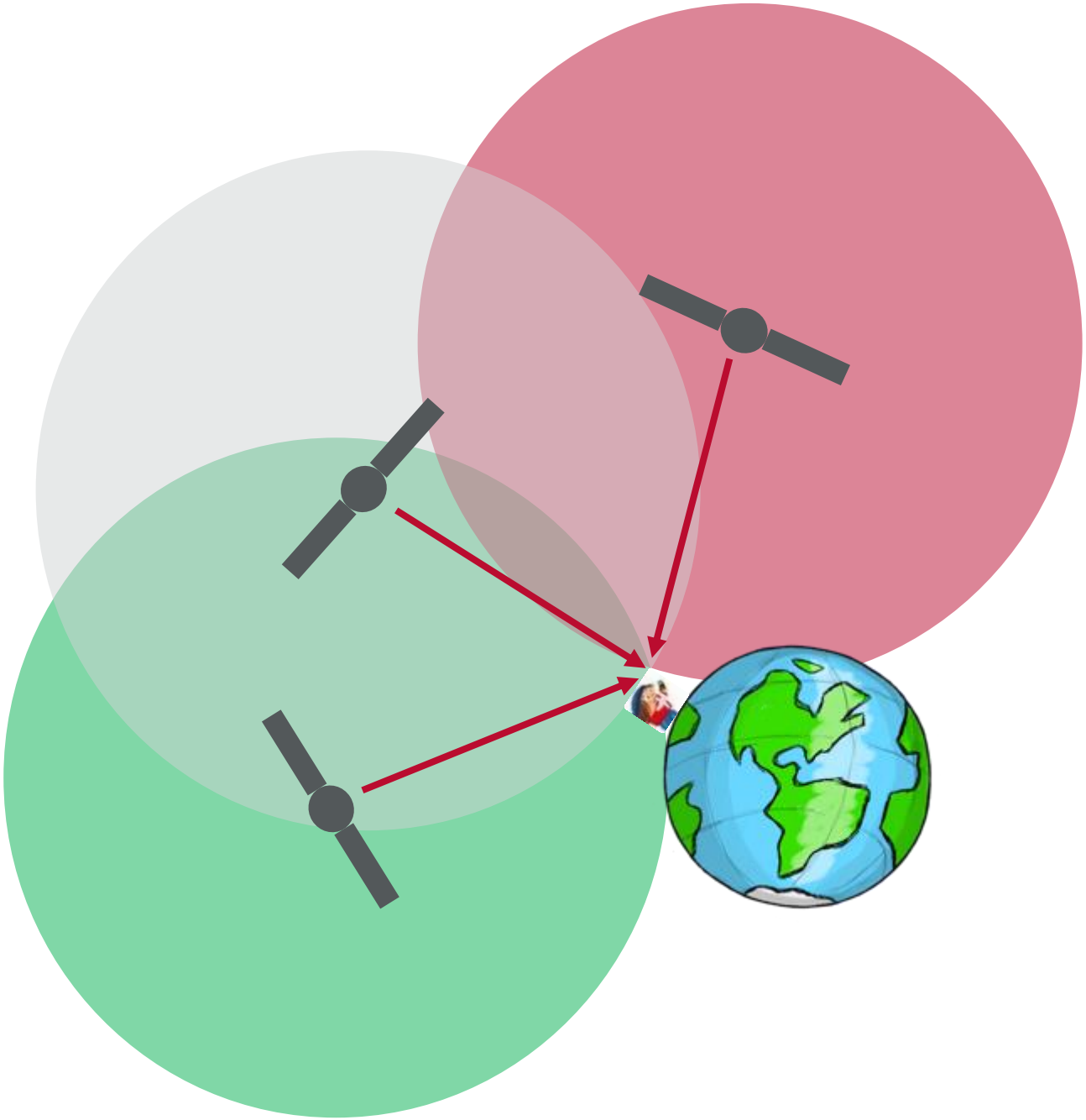
GPS is just a fancy clock.



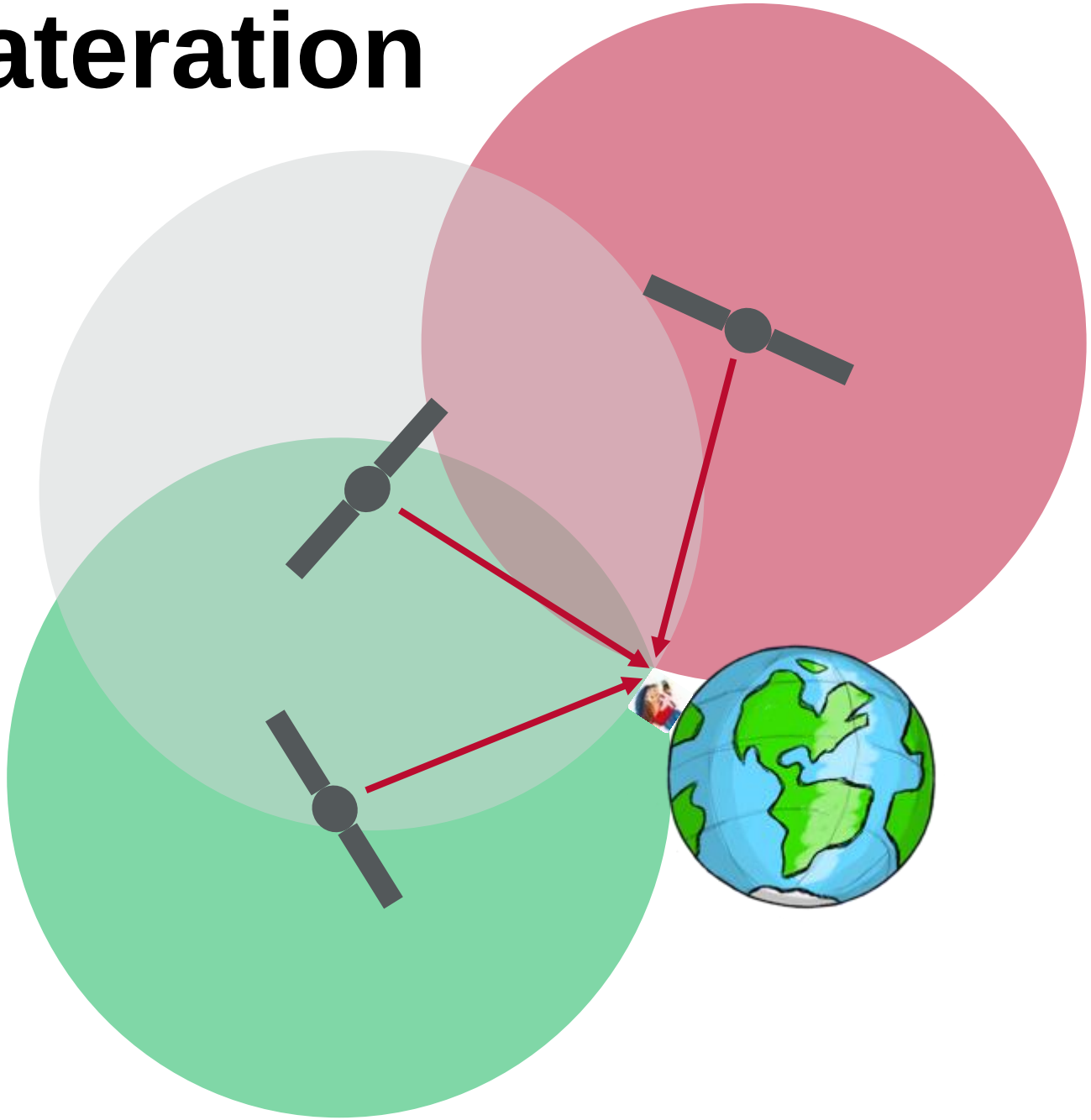
Distance = t x c







Trilateration



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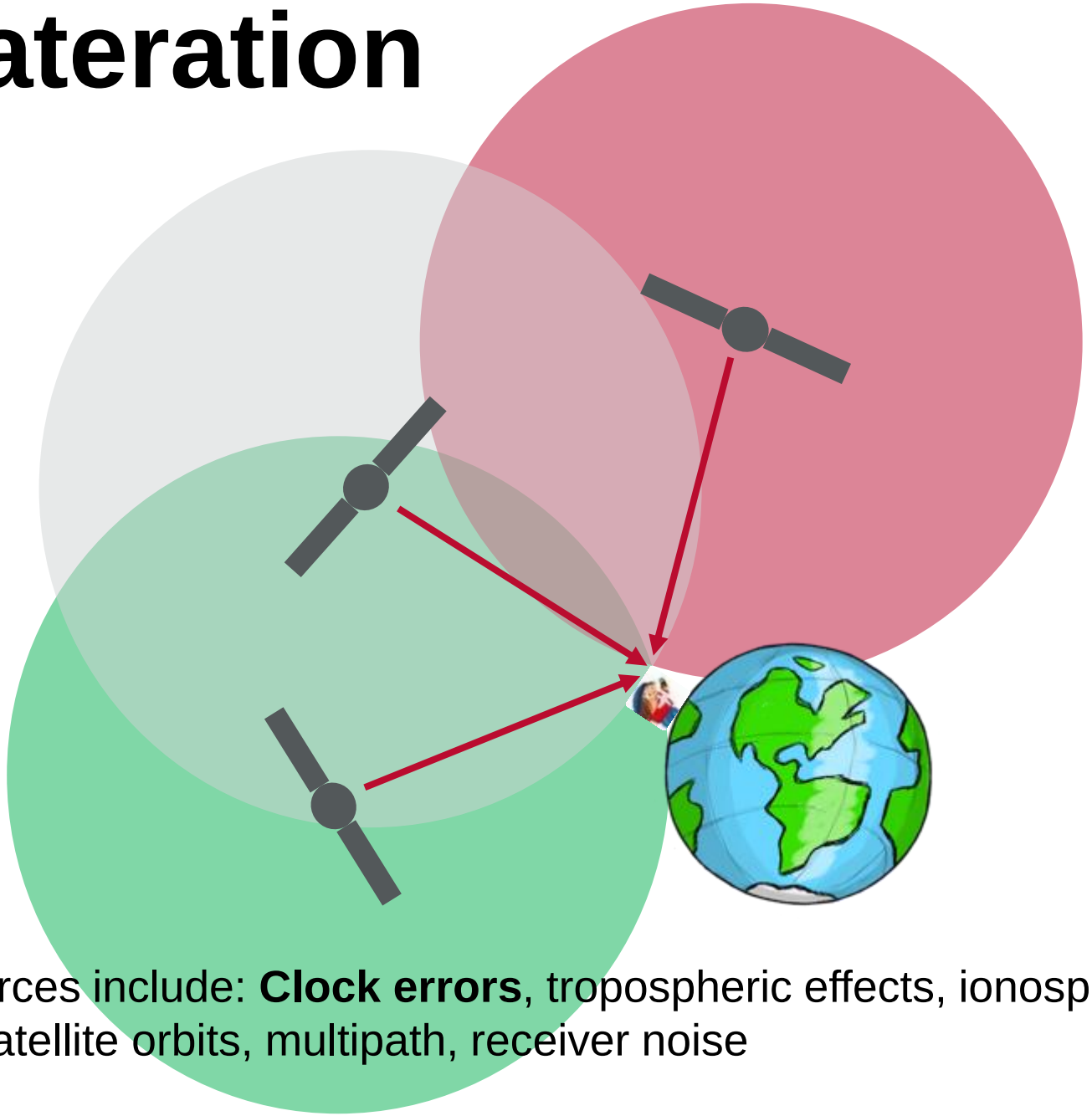
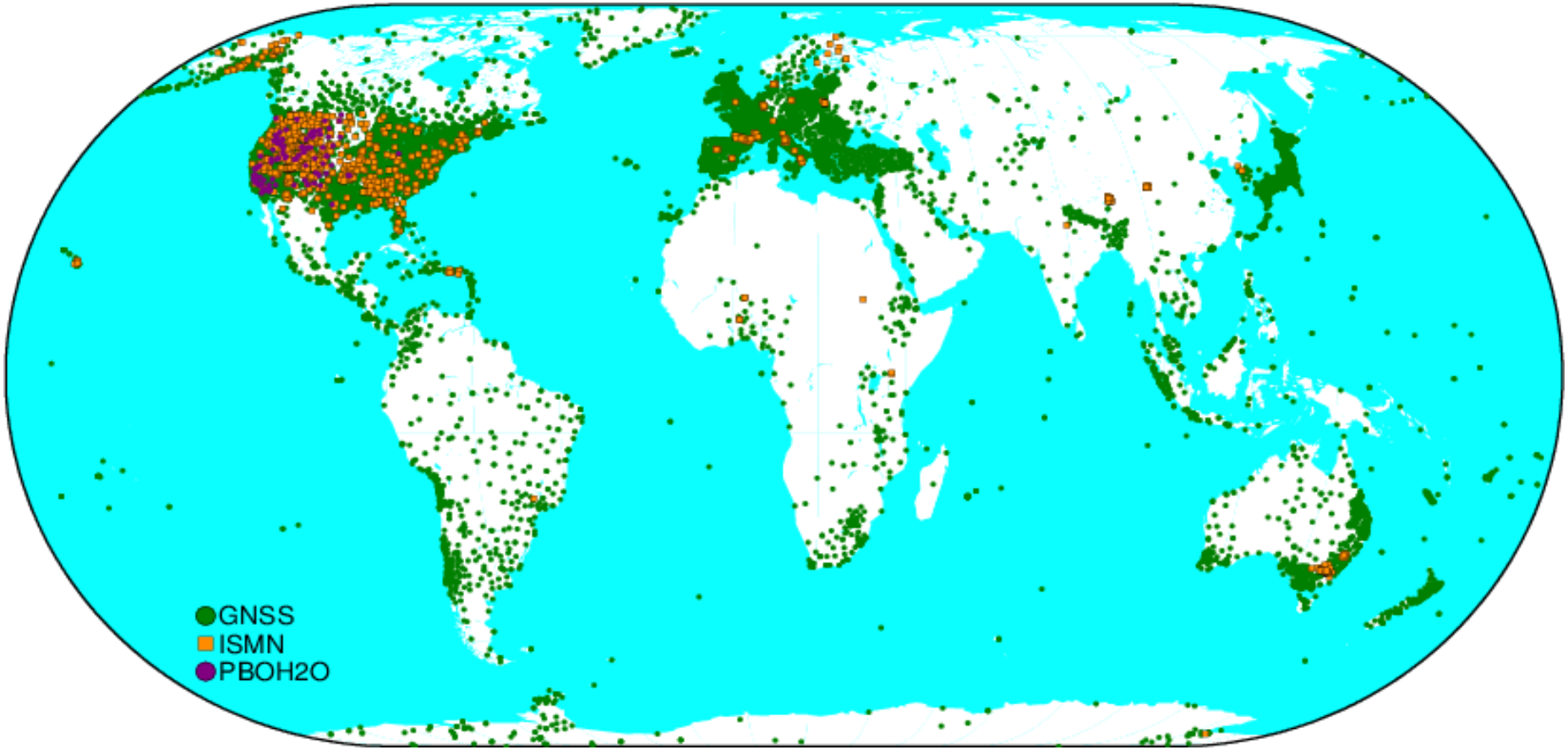


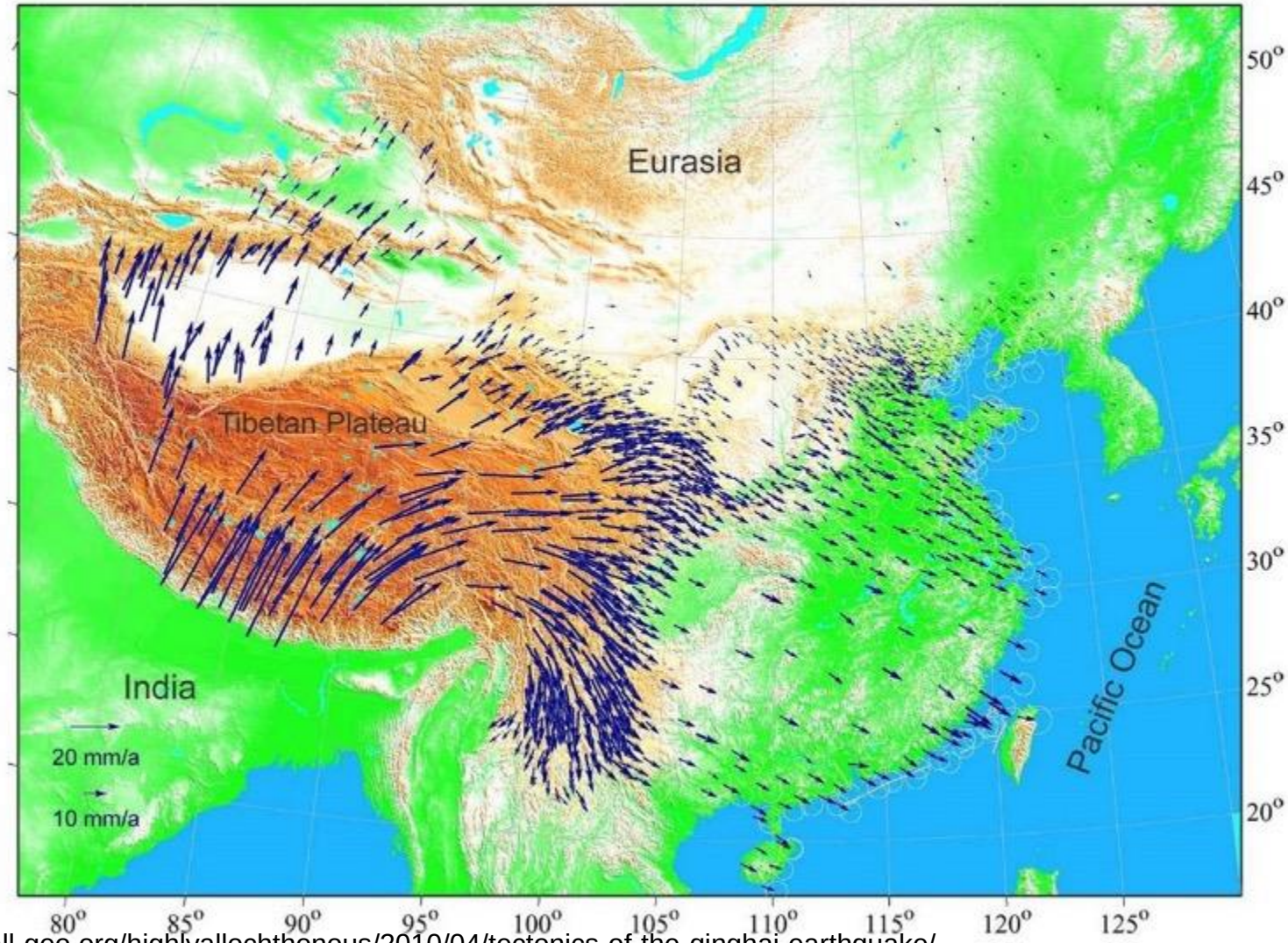
Error sources include: **Clock errors**, tropospheric effects, ionospheric effects, satellite orbits, multipath, receiver noise

Existing geodetic GPS antennas



Courtesy of Kristine Larson

What ‘normal’ people use GPS for: Measuring plate tectonics



Source: http://all-geo.org/highlyallochthonous/2010/04/tectonics-of-the-qinghai-earthquake/

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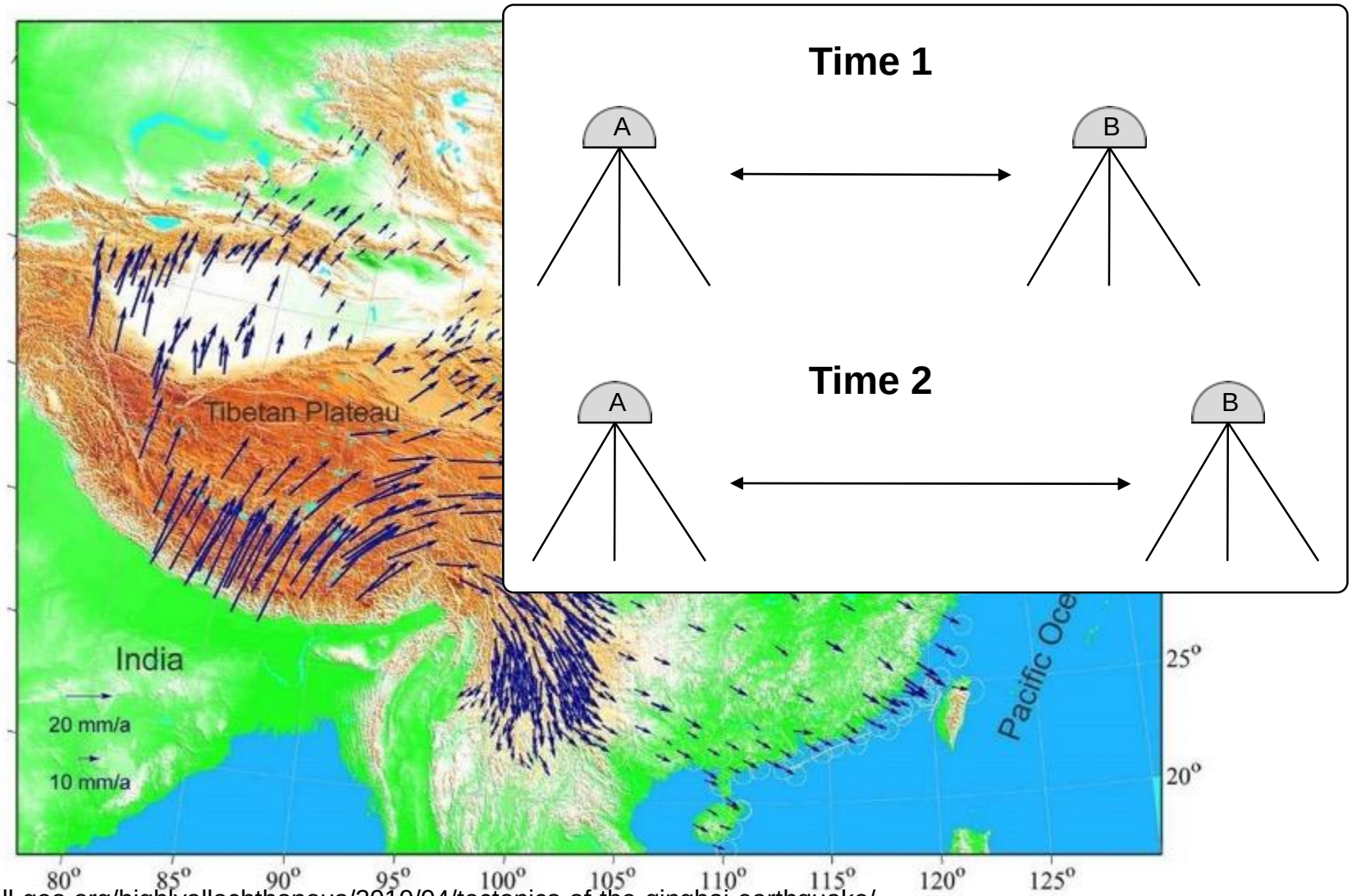

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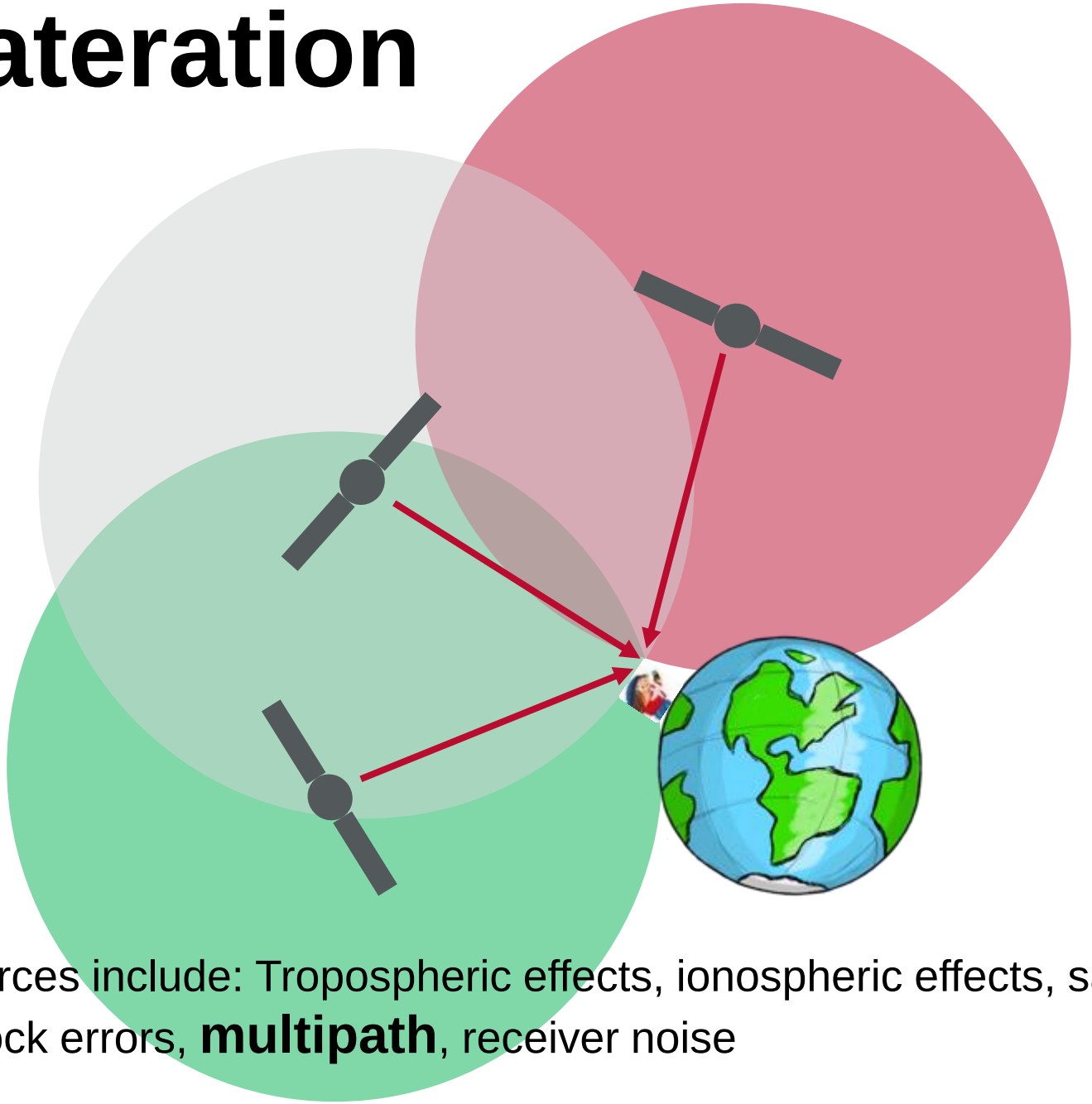

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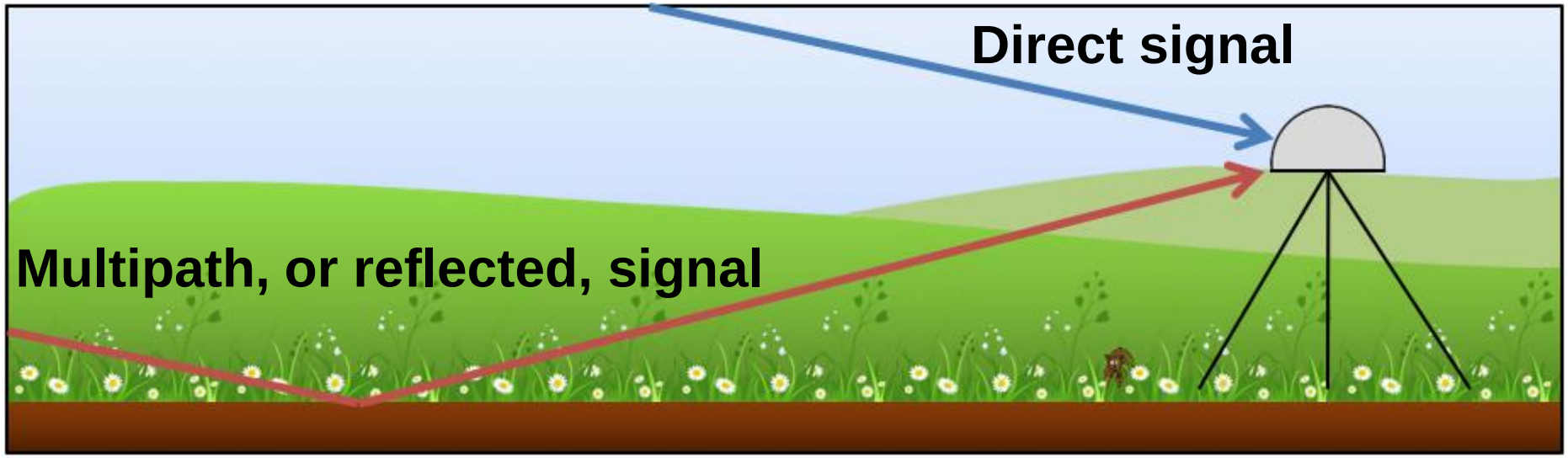
GPS reflections



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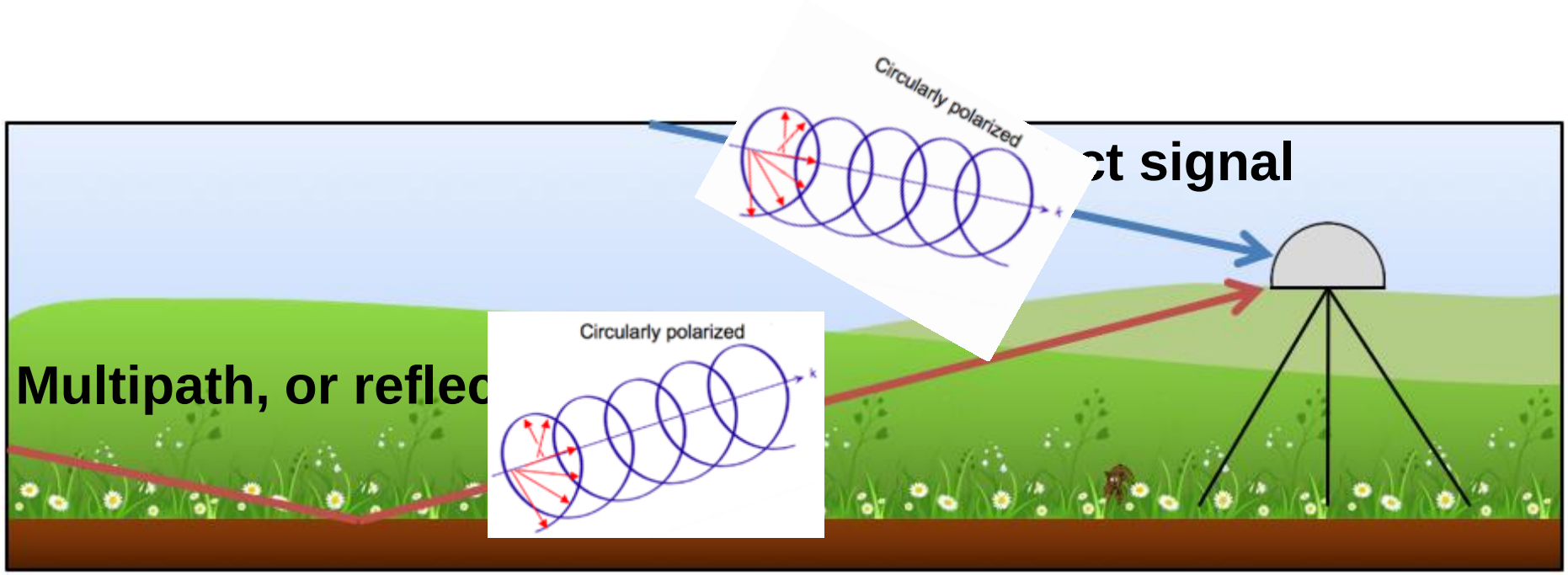
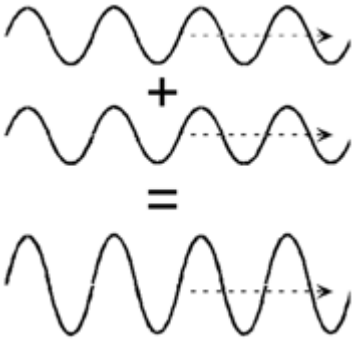
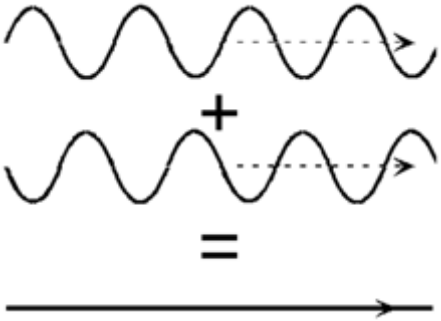


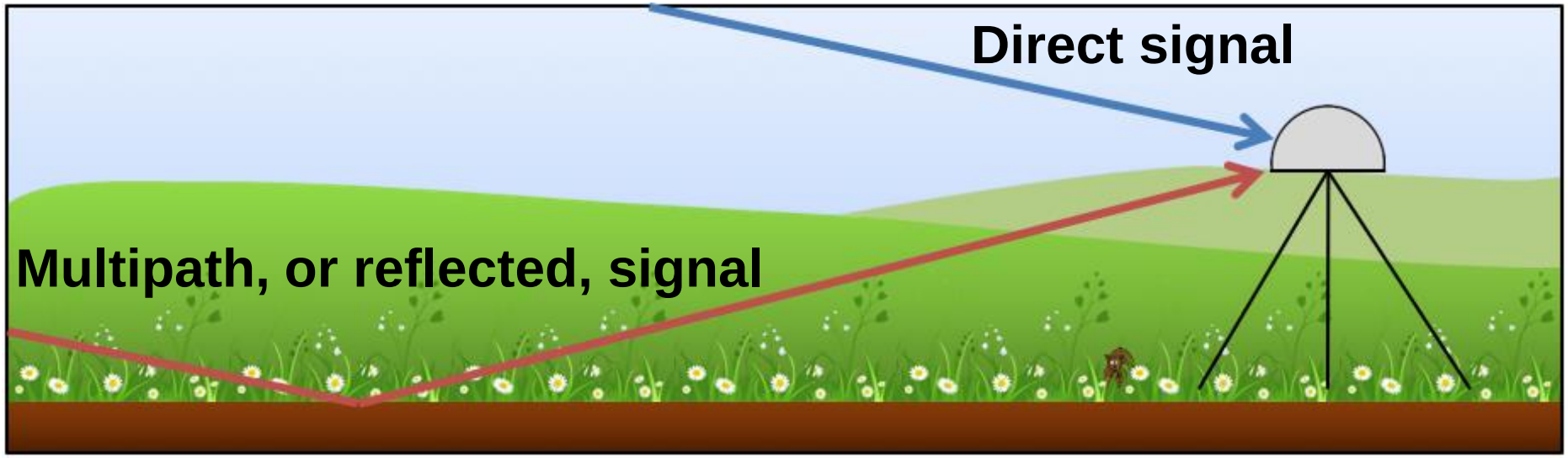
Constructive

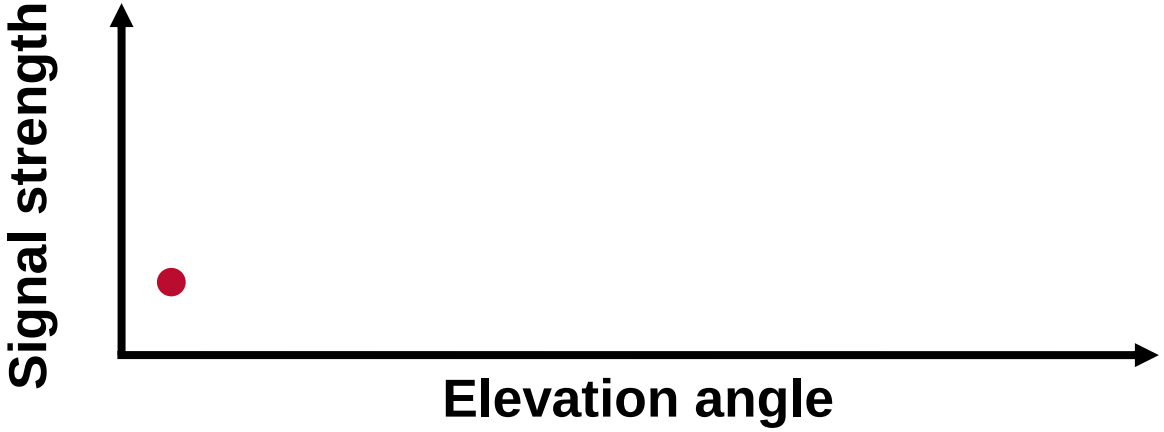


Destructive

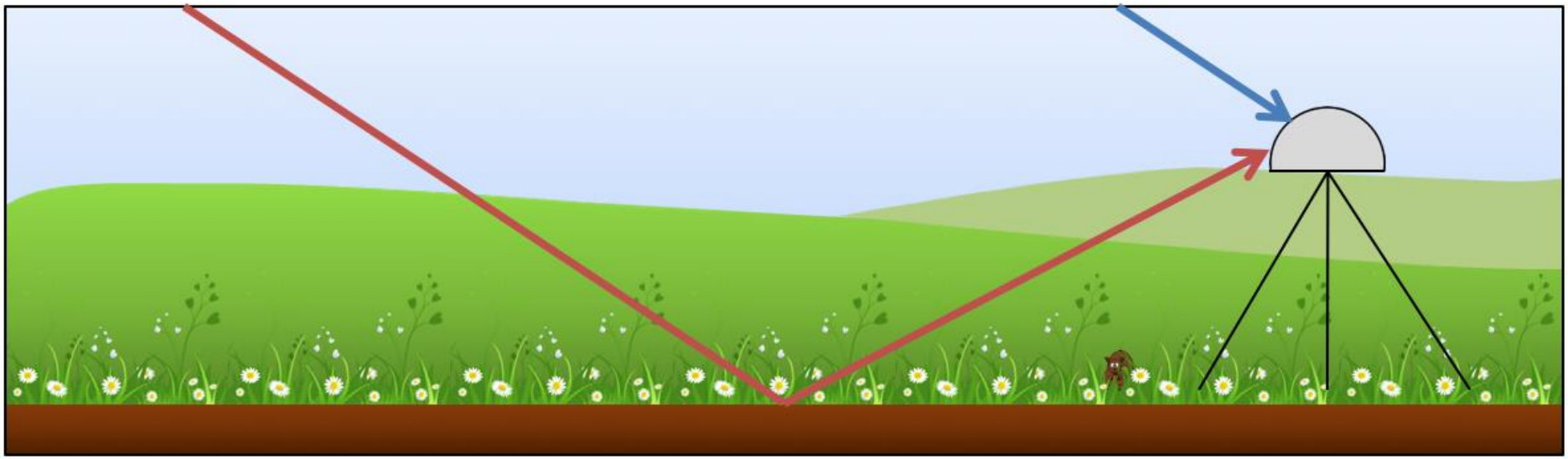


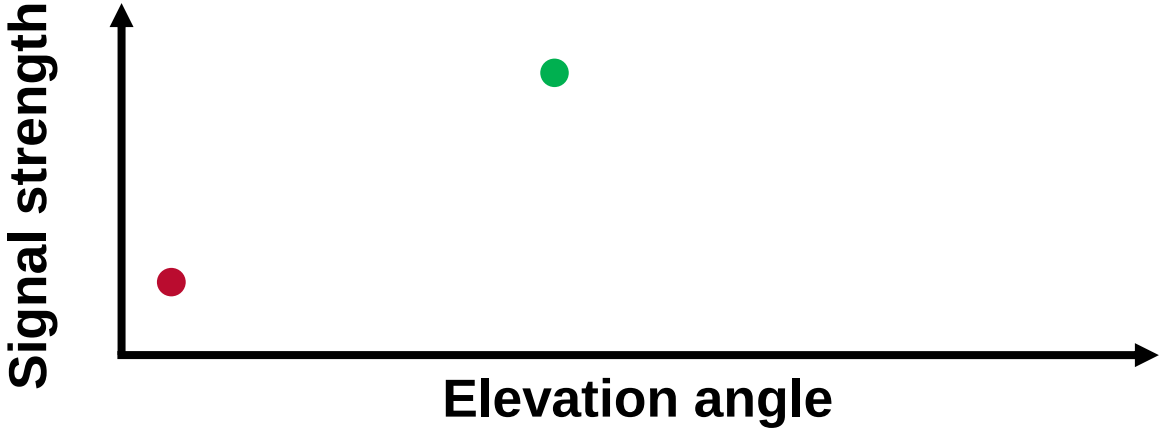
GPS reflections





GPS reflections





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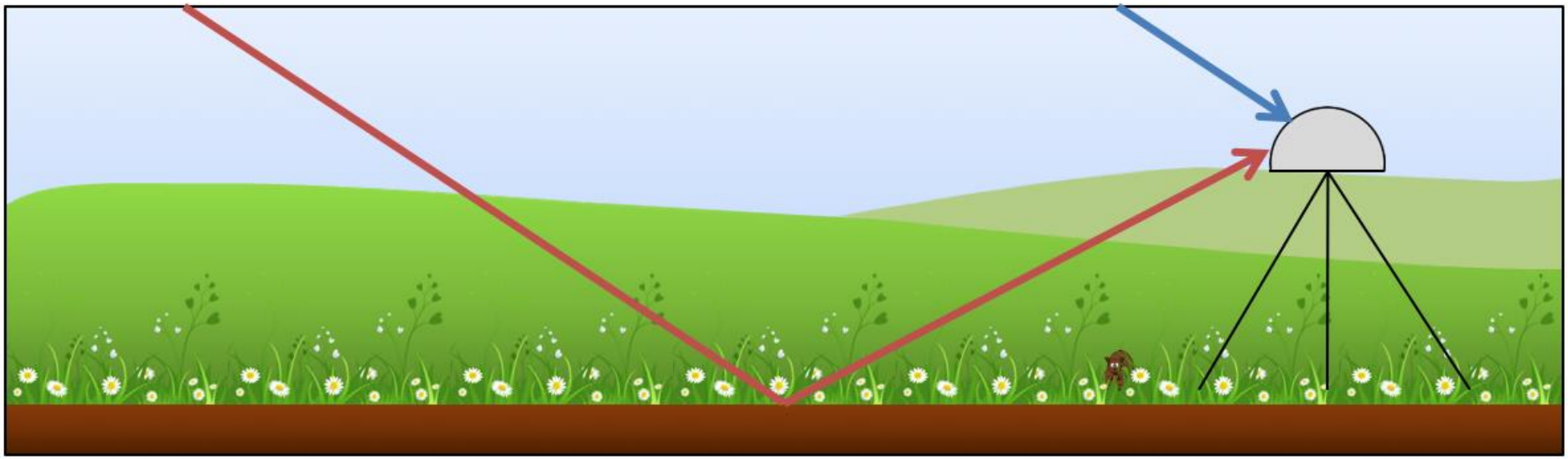

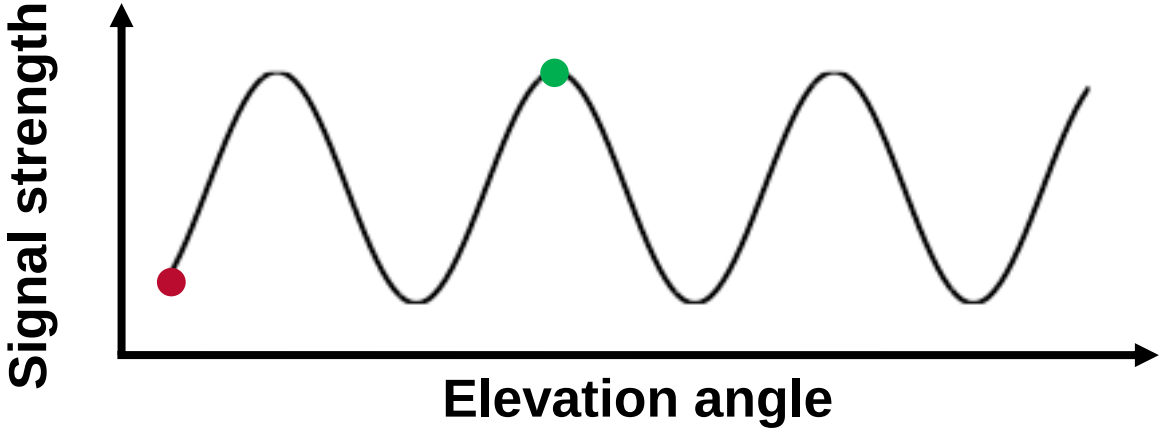

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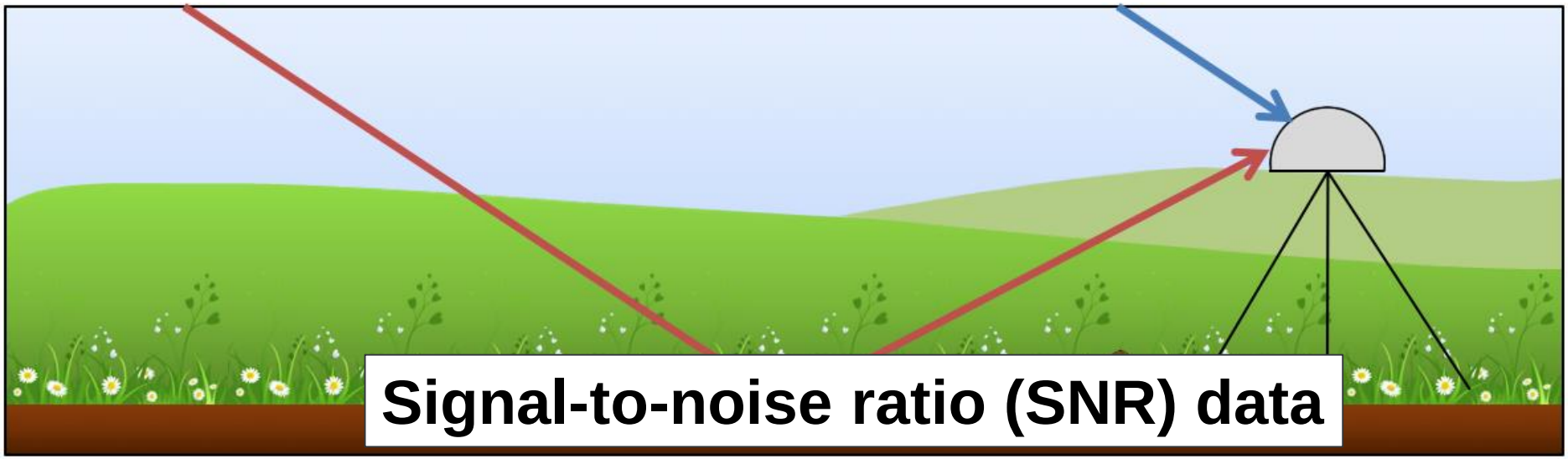
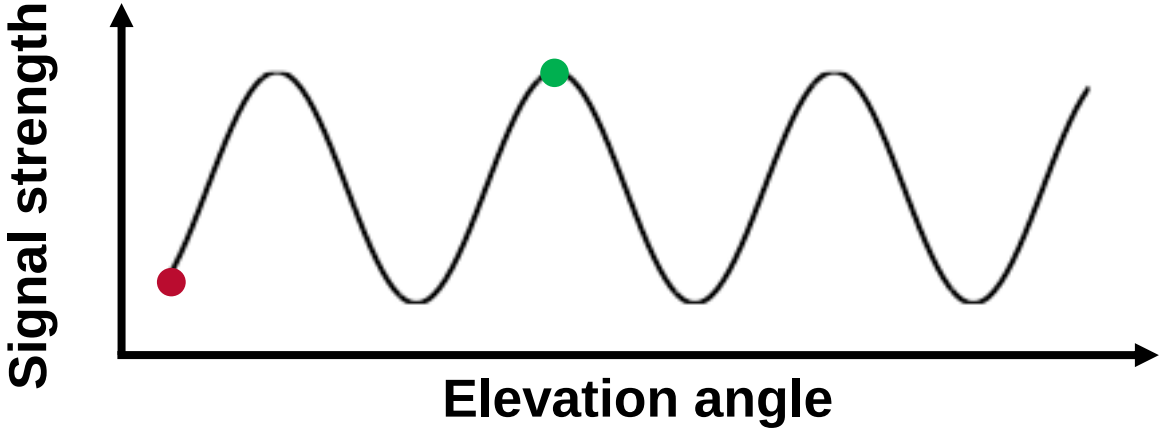
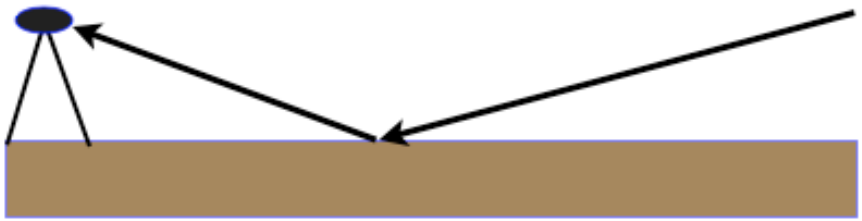
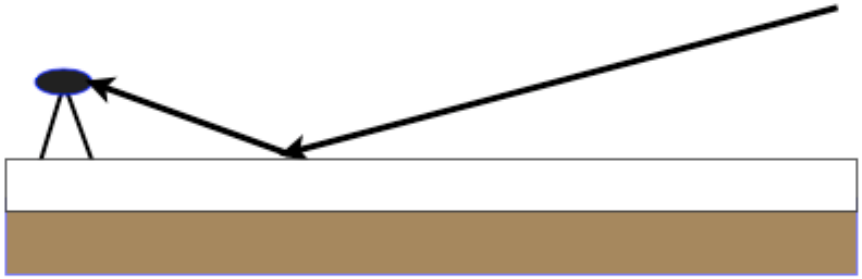




the reflections off bare soil produce this SNR curve

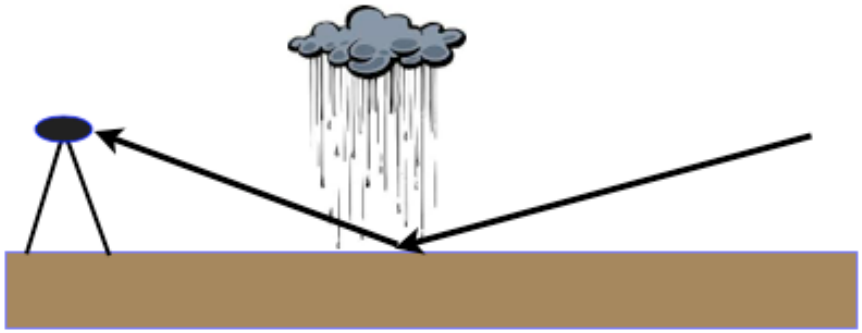


add a snow layer

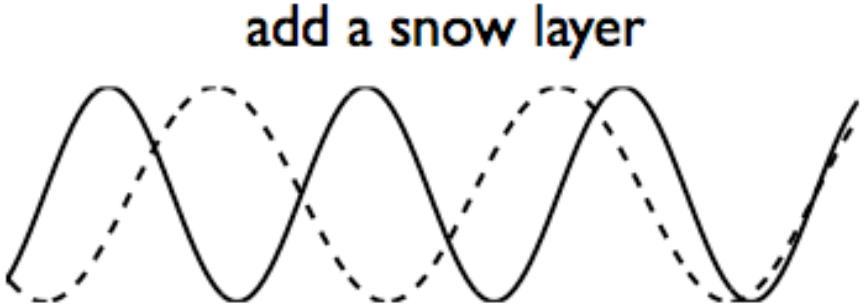


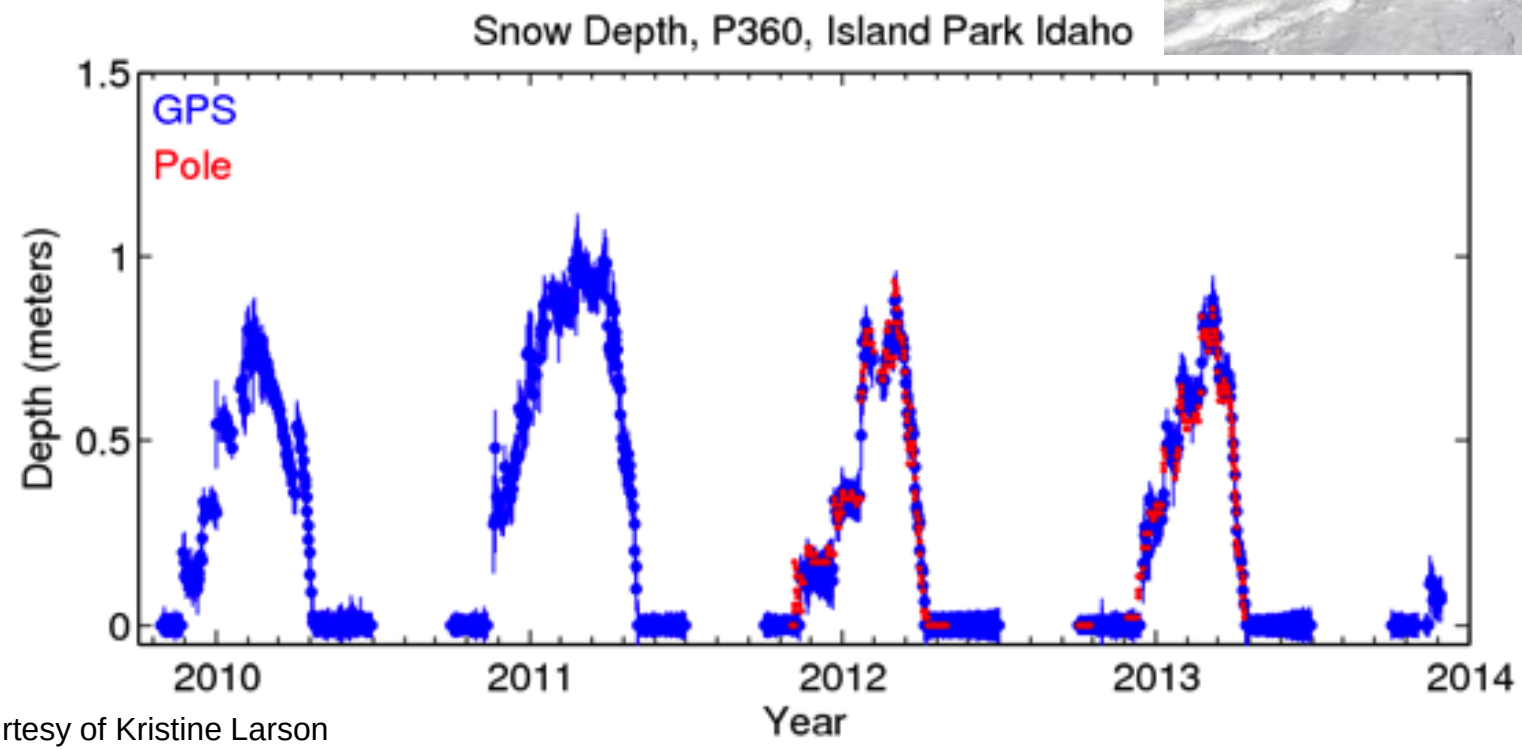
add vegetation

make the soil wet



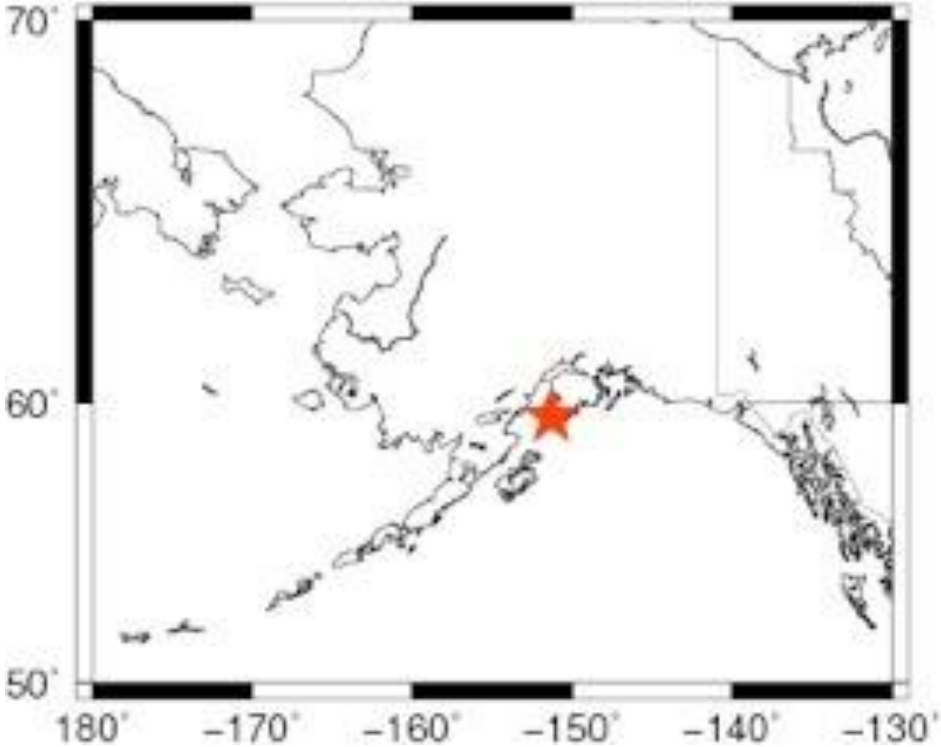
Snow depth sensing





Courtesy of Kristine Larson

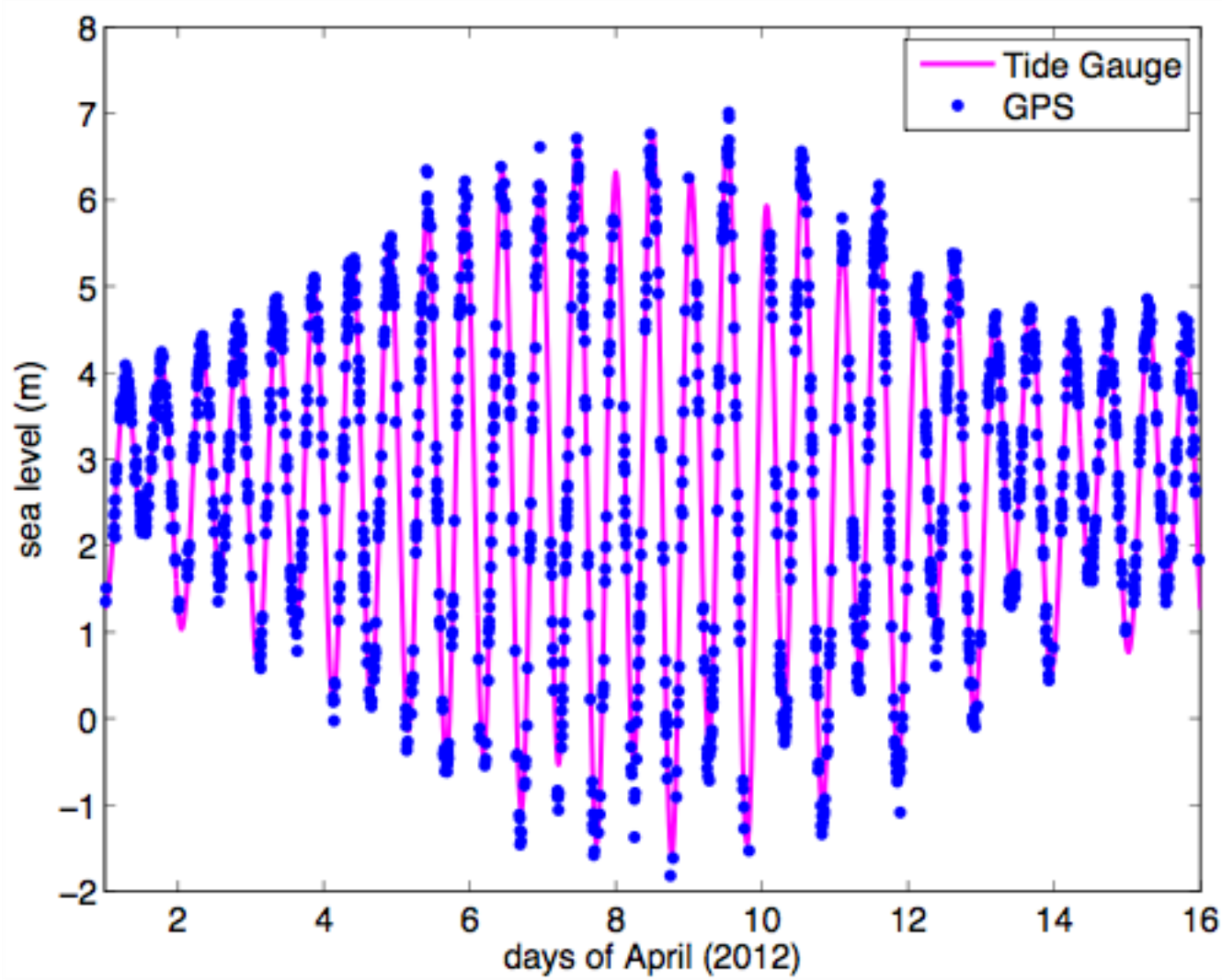
Measuring ocean tides



Courtesy of Kristine Larson

Daily change in water height due to tides: 10 m!

Comparison between GPS and 'Real' Tide Gauge

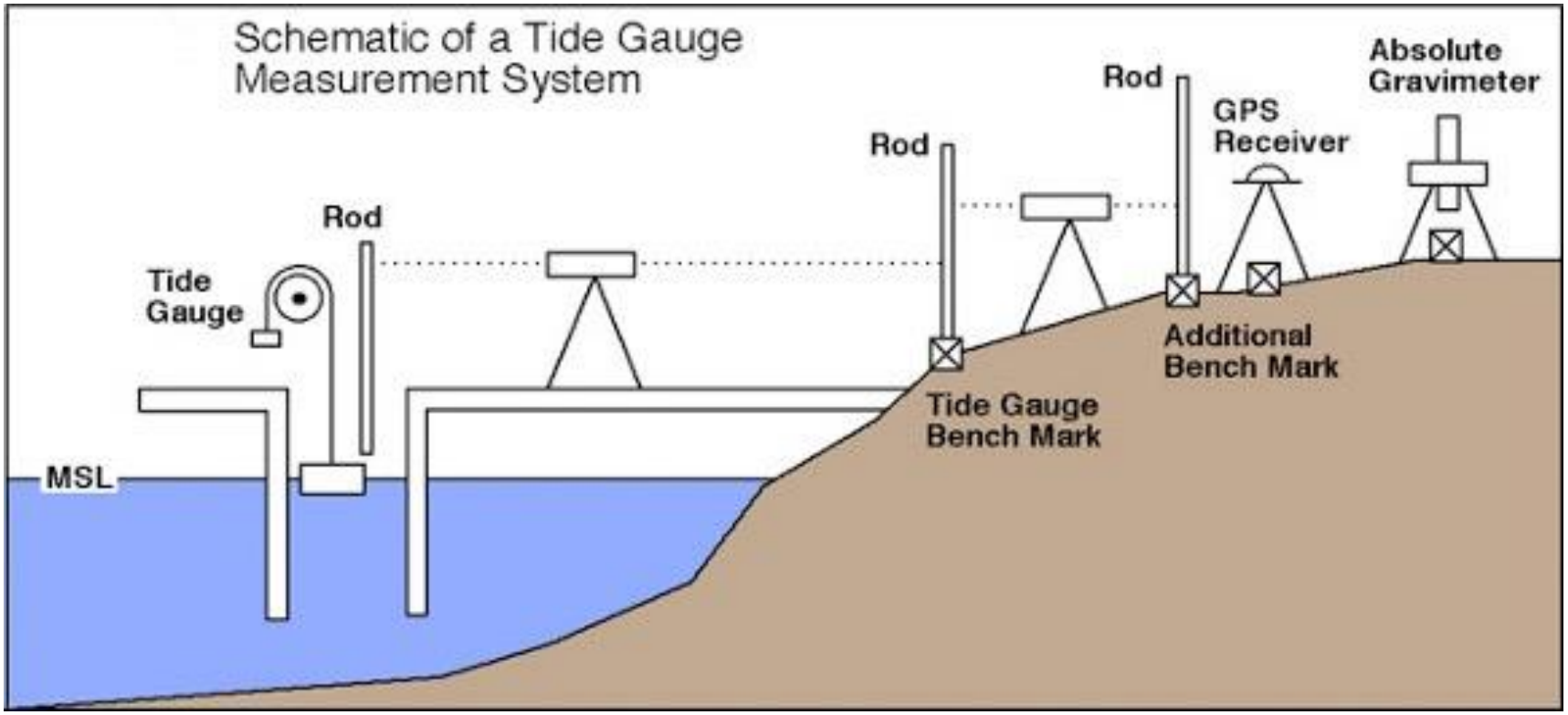


Larson, Ray, Nievinski, and Freymueller, The Accidental Tide Gauge, *IEEE GRSL*, 2013

Greenland needs more tide gauges

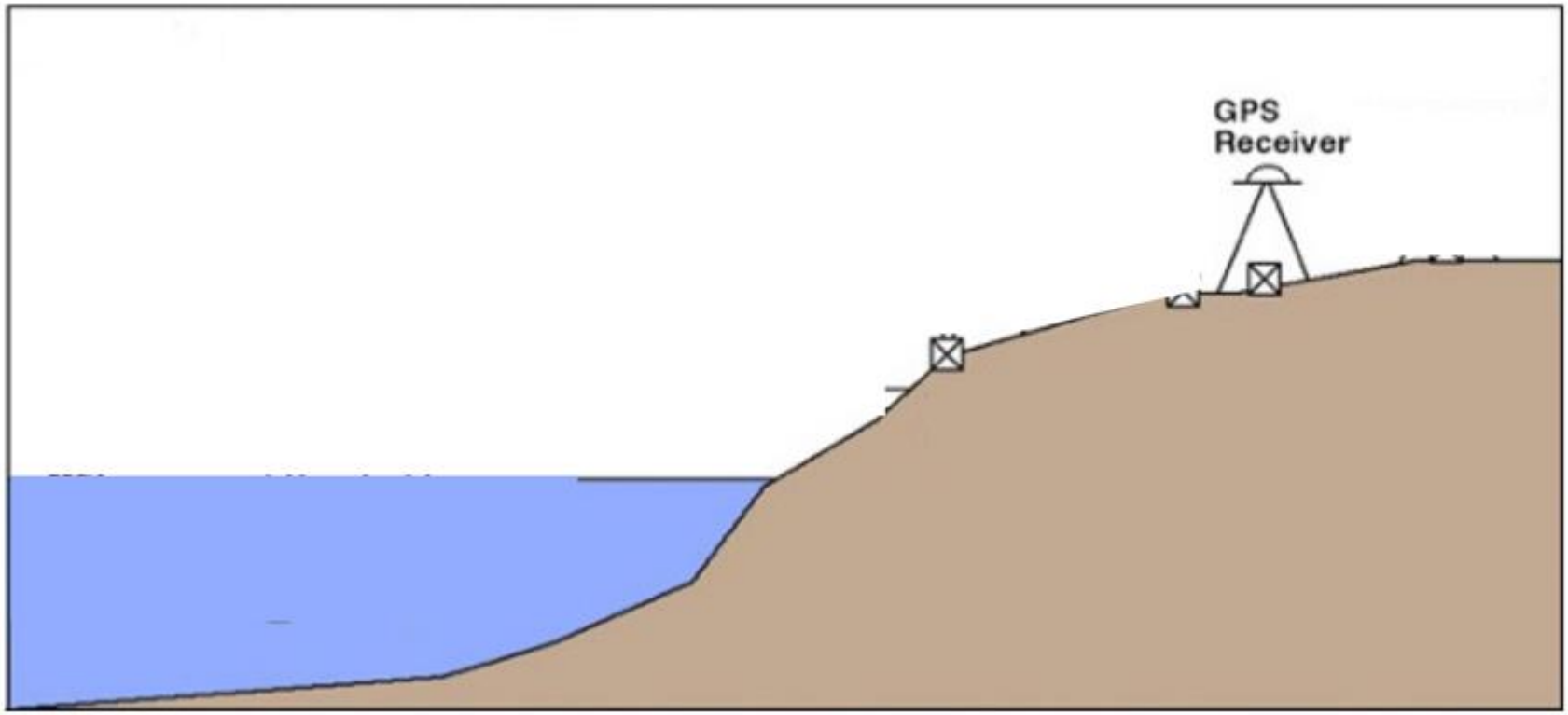
http://www.ioc-sealevelmonitoring.org/map.php

‘Real’ tide gauges are difficult to operate in the cryosphere

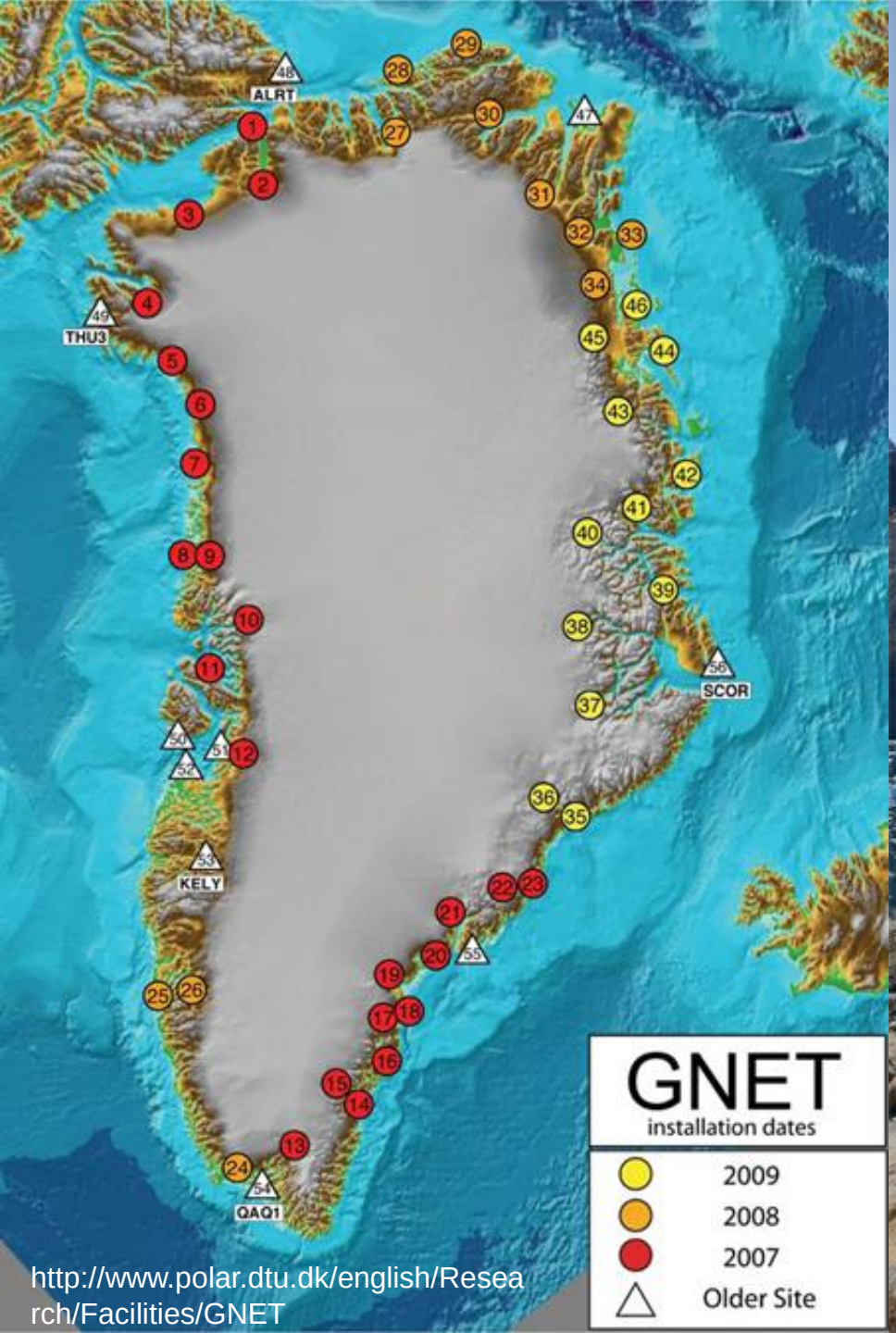


Courtesy of Kristine Larson

GPS tide gauges are more simple



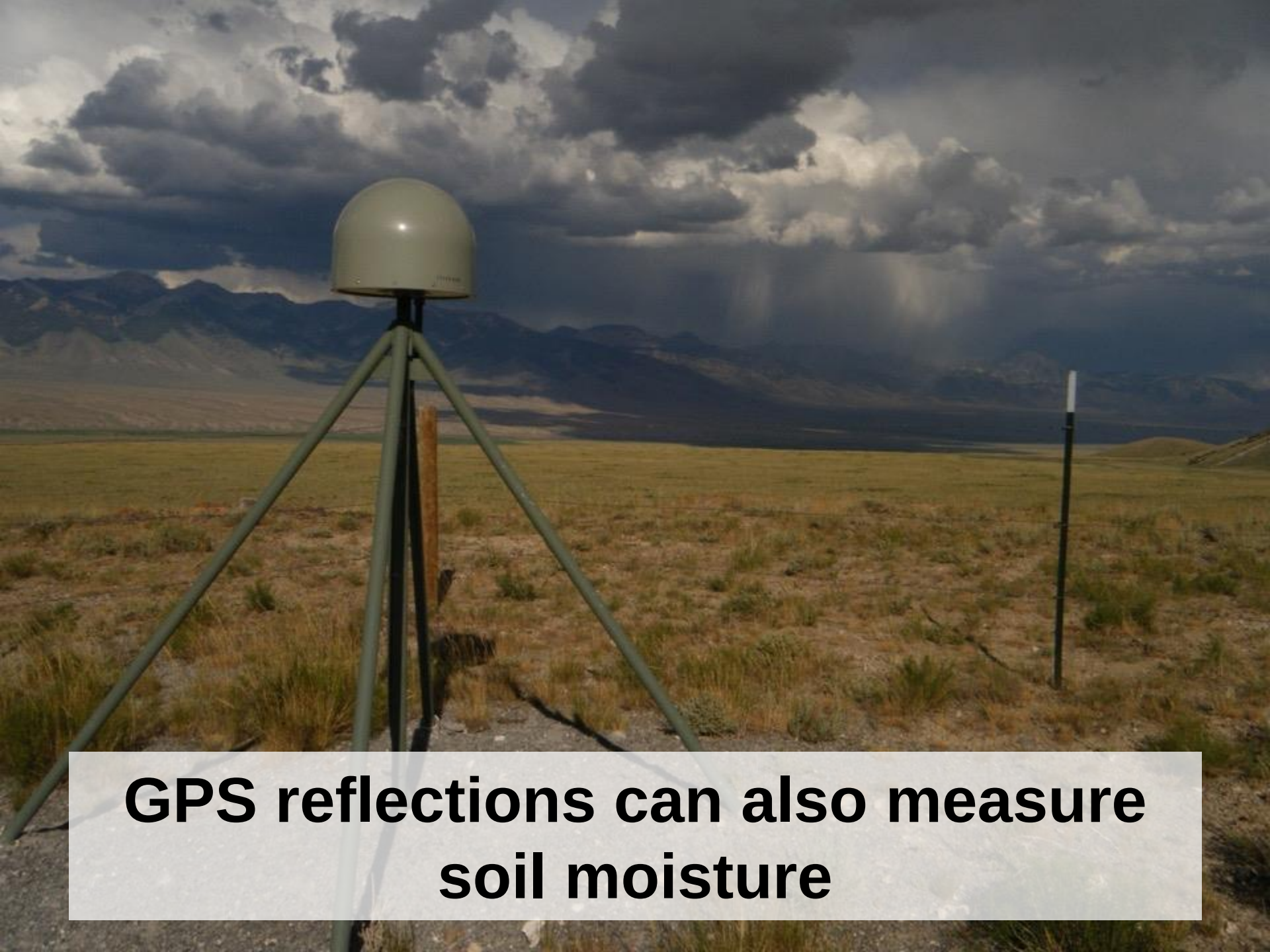
Courtesy of Kristine Larson



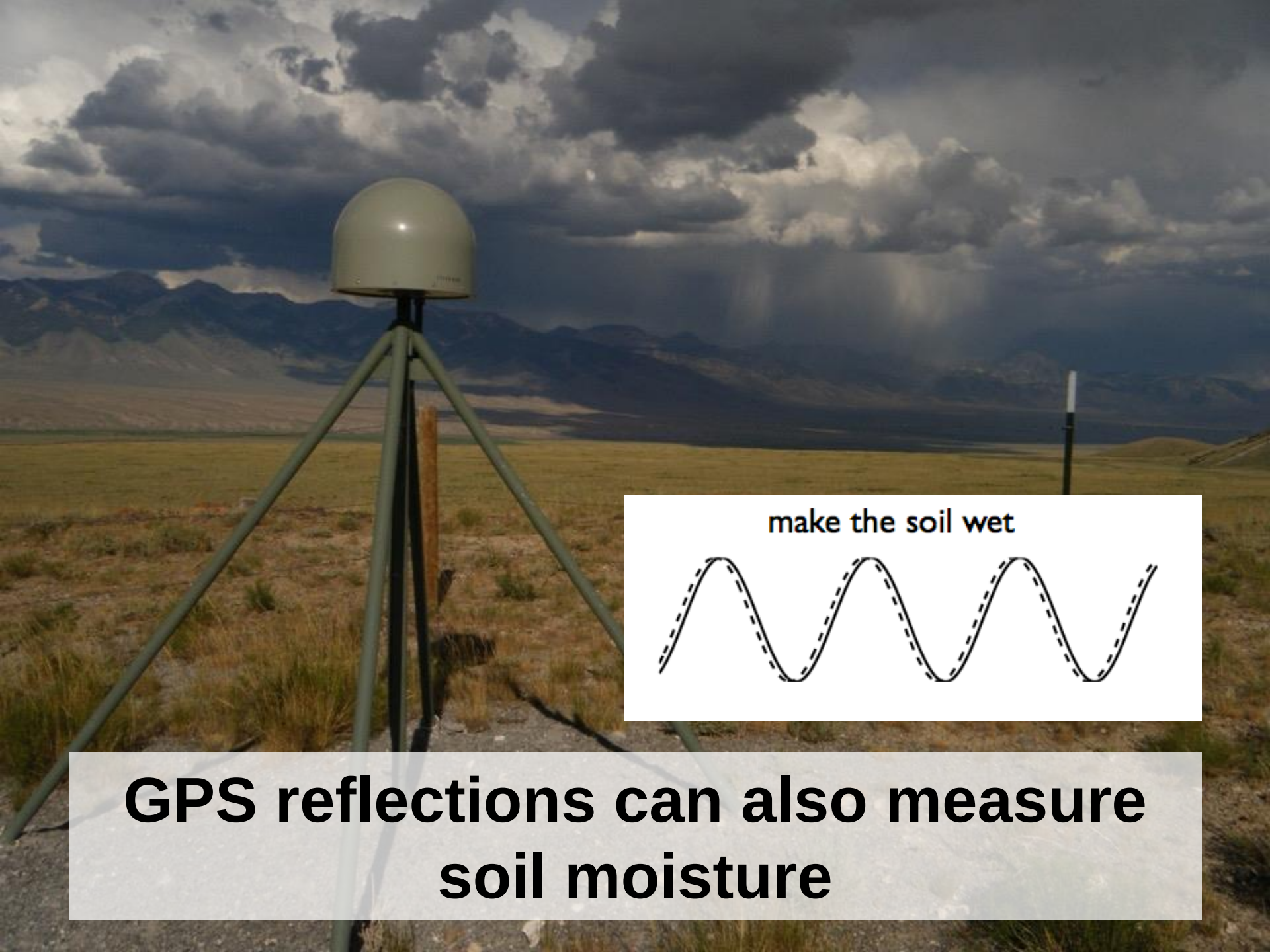
http://www.polar.dtu.dk/english/Research/Facilities/GNET

Source: https://www.unavco.org/science/snapshots/cryosphere/2012/bevis.html

Photo Courtesy: Adam Jenkins



GPS reflections can also measure soil moisture



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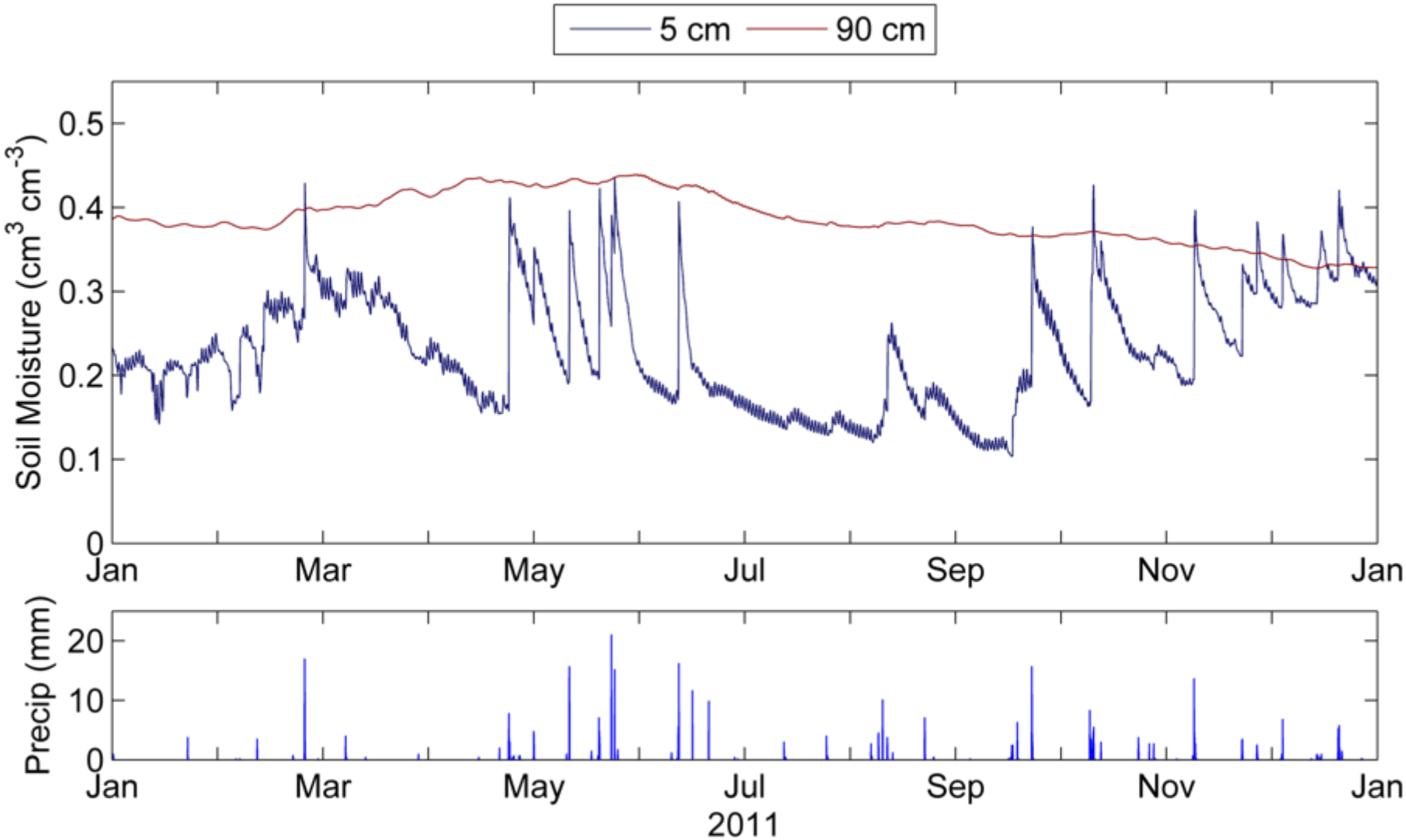
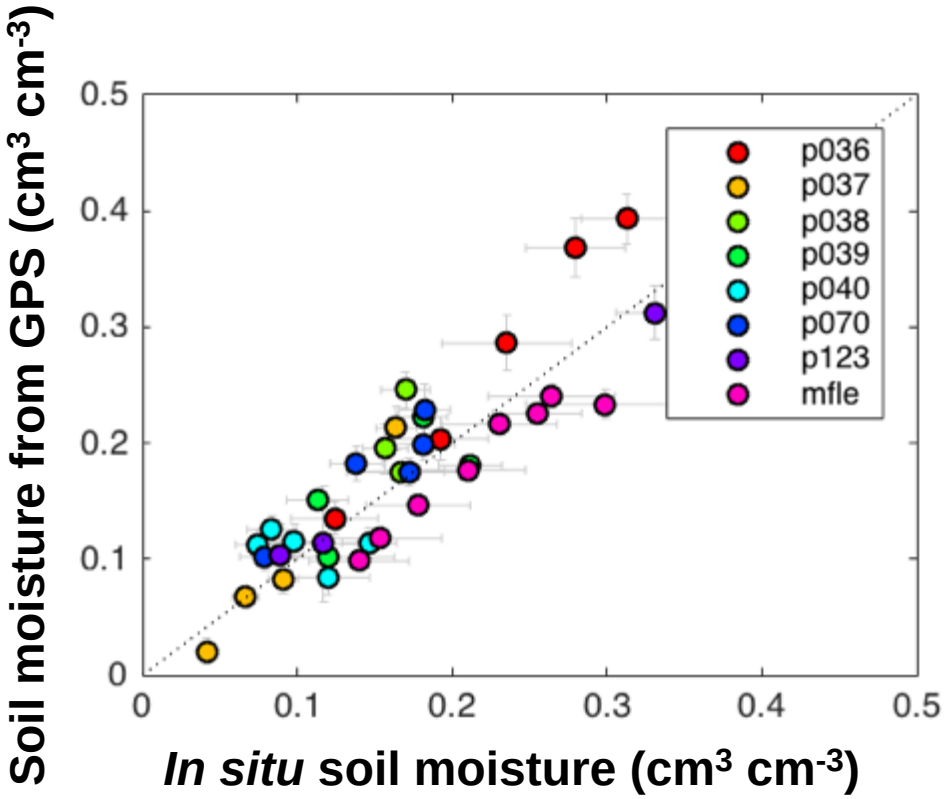
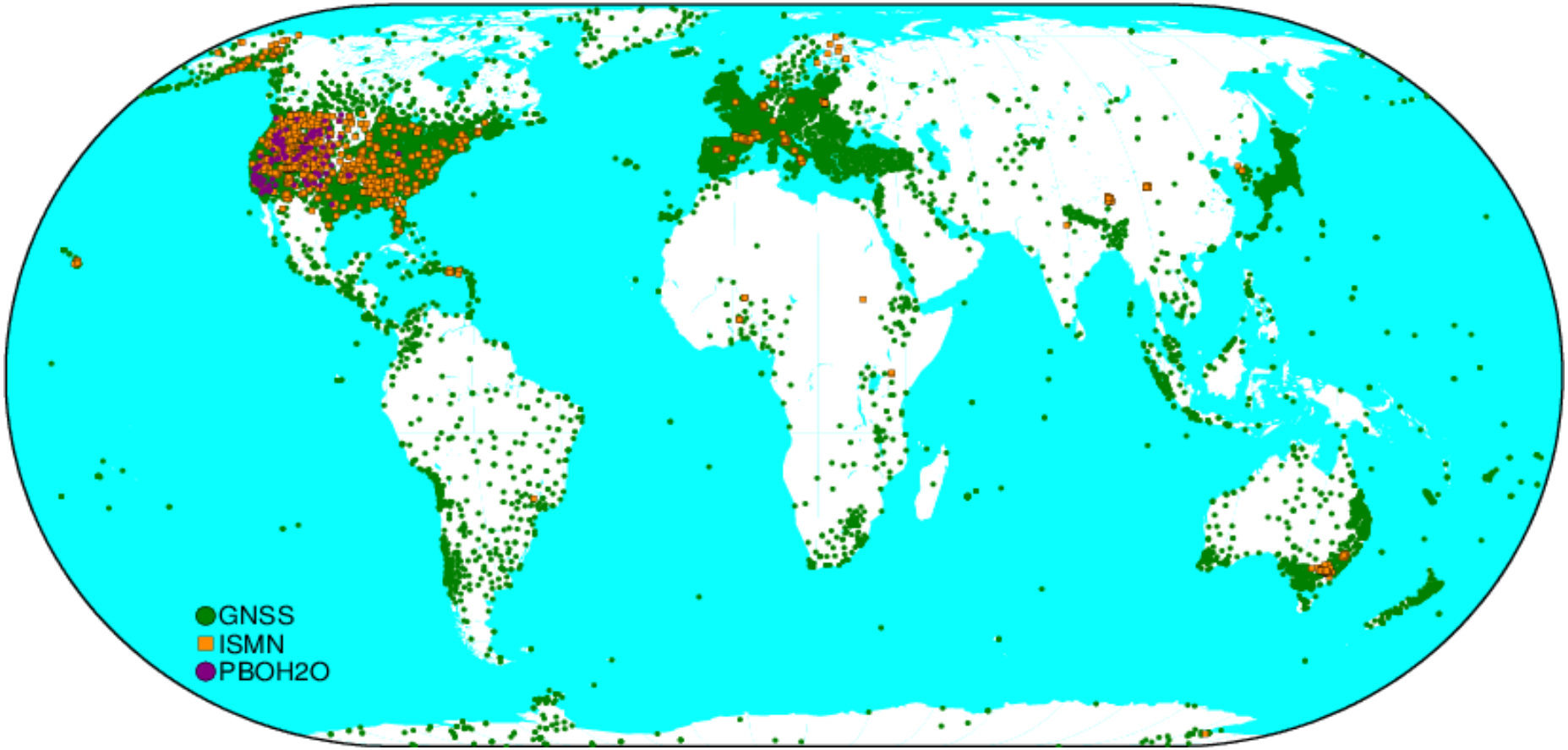
Soil moisture definitions



A GPS reflection soil moisture network is now the 2nd largest soil moisture network of any kind in the world



Existing geodetic GPS antennas



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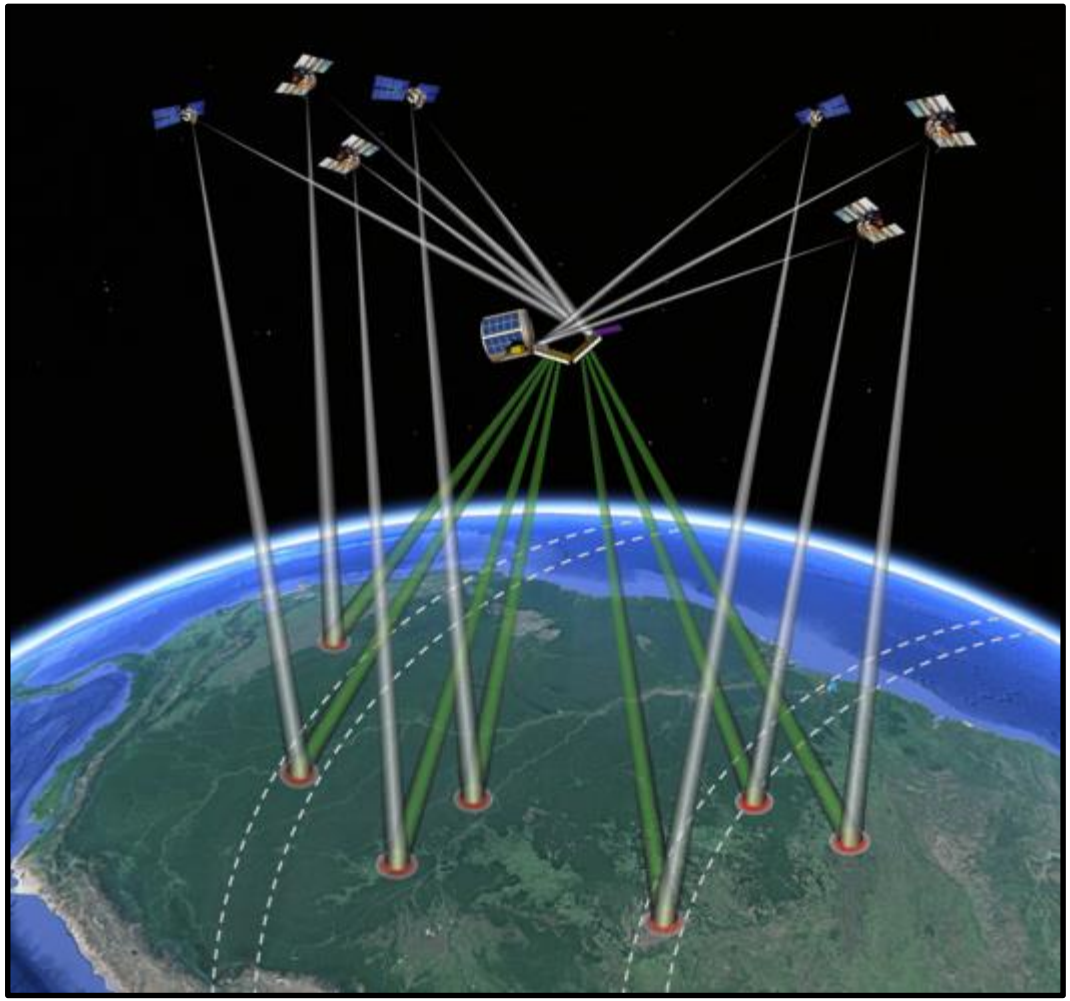
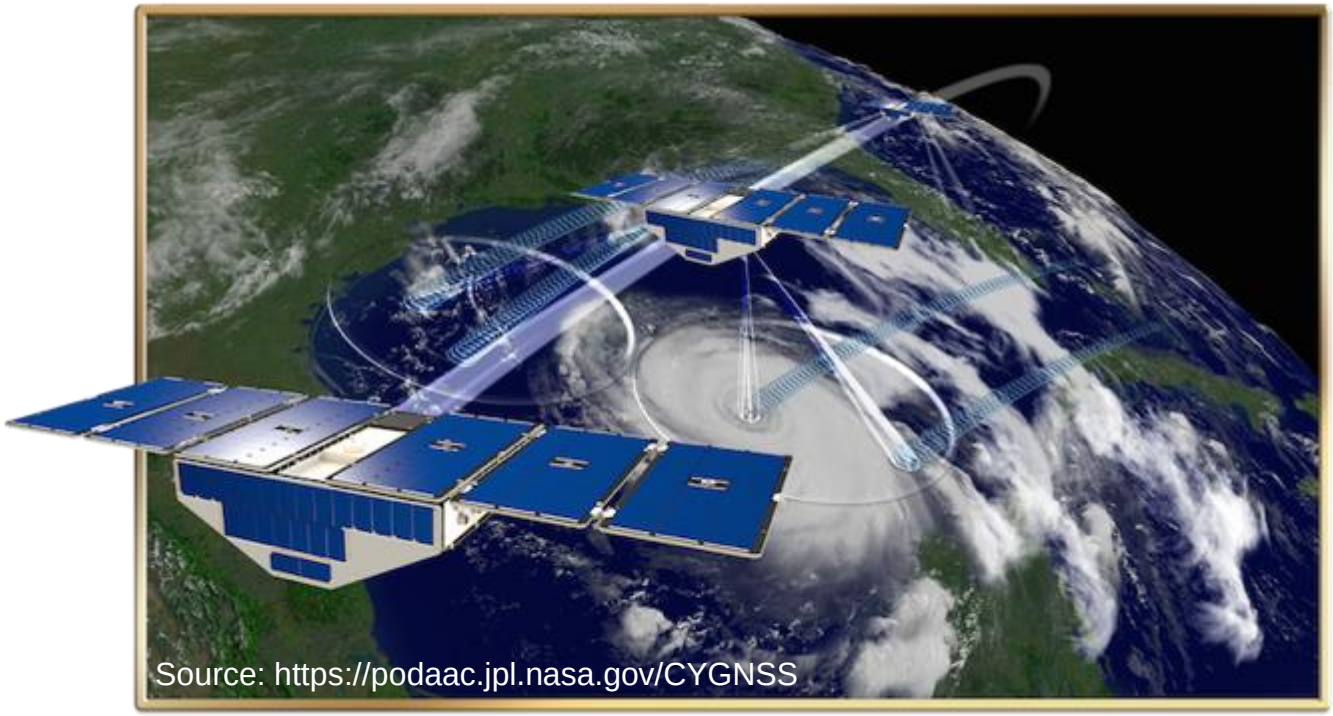
Can we record GPS reflections from space?





Don’t we already have a lot of satellite data?

Traditional remote sensing

- Expensive to launch even one instrument
- Tradeoff between spatial and temporal sampling

Using GPS reflections

- Launch a constellation of satellites for less than one traditional instrument
- Sub-daily temporal resolution, moderate spatial resolution

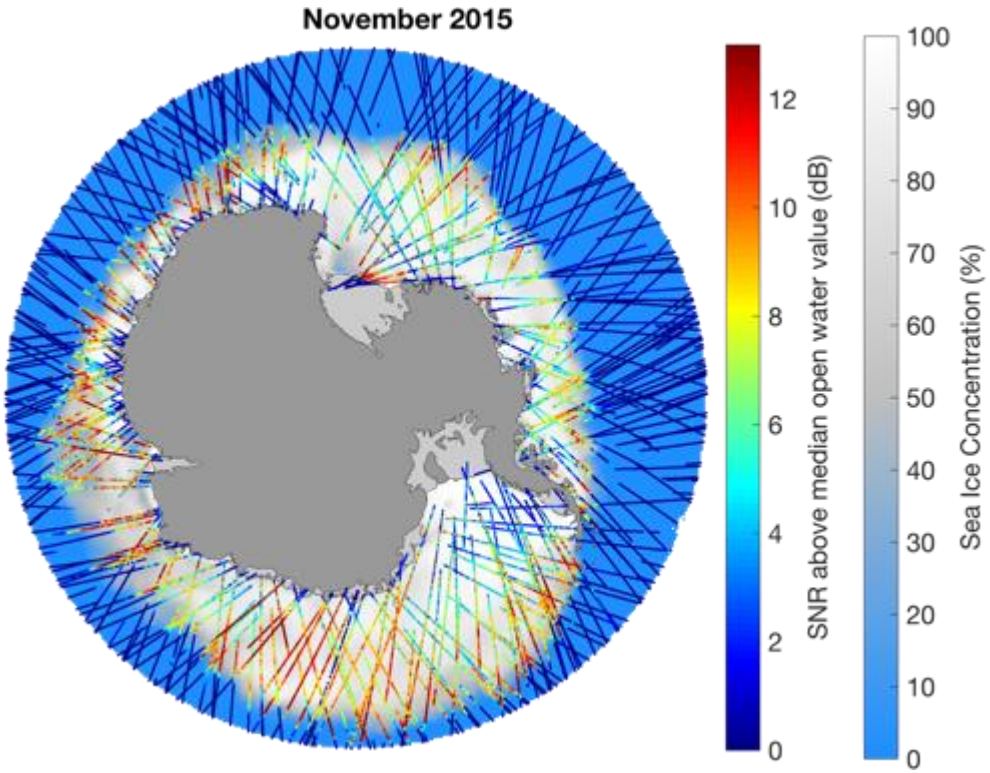
https://www.youtube.com/watch?v=tLWrZFA_wtY

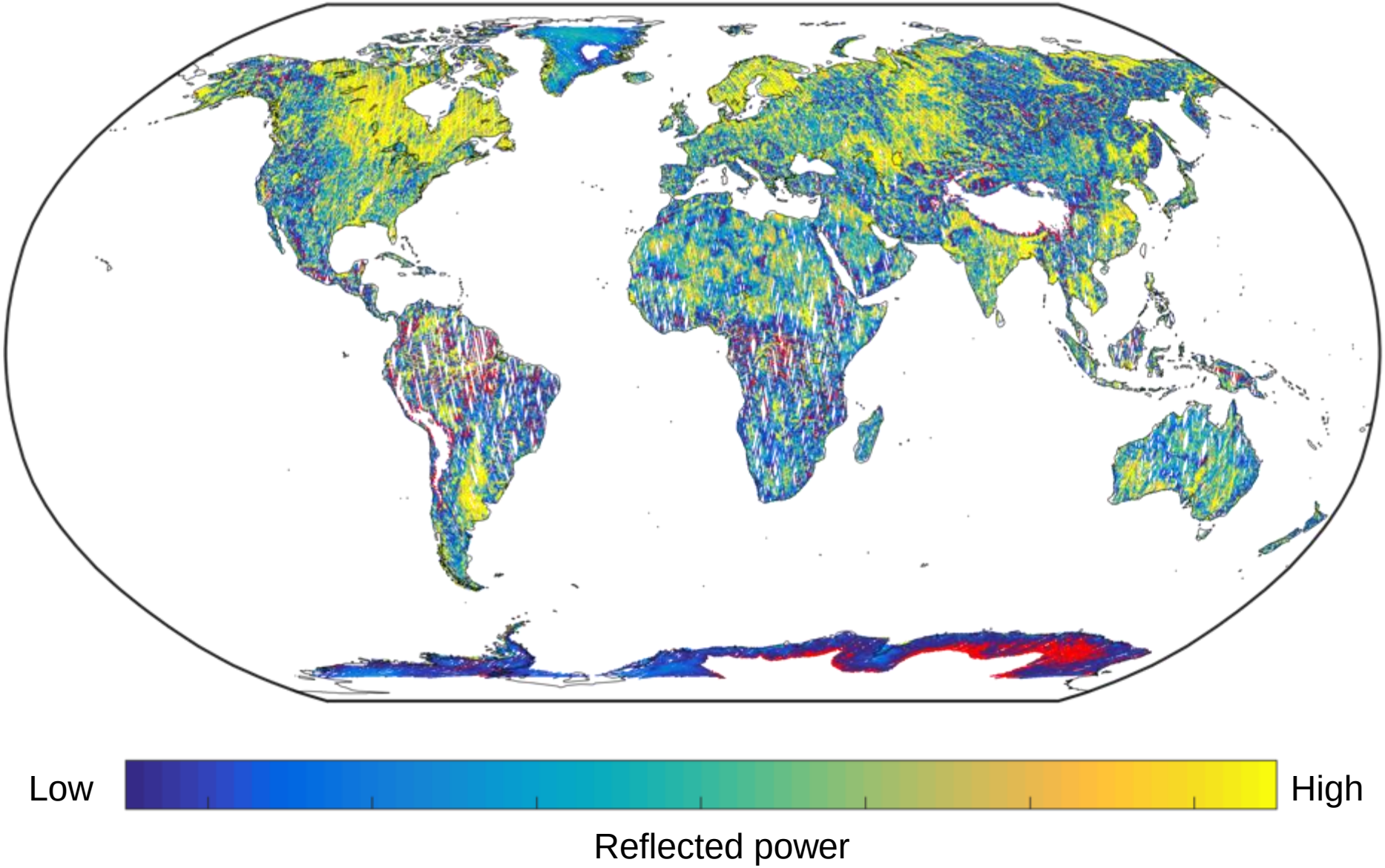
What kinds of things would you want to measure with high spatial and/or temporal sampling?

- **Hurricane winds**

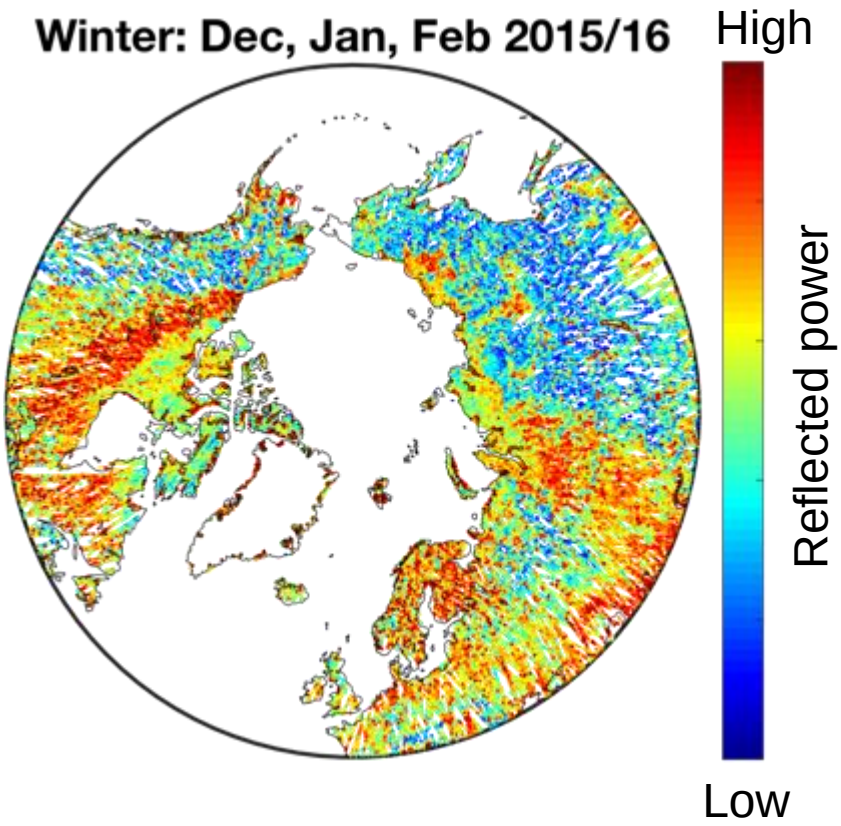
What kinds of things would you want to measure with high spatial and/or temporal sampling?

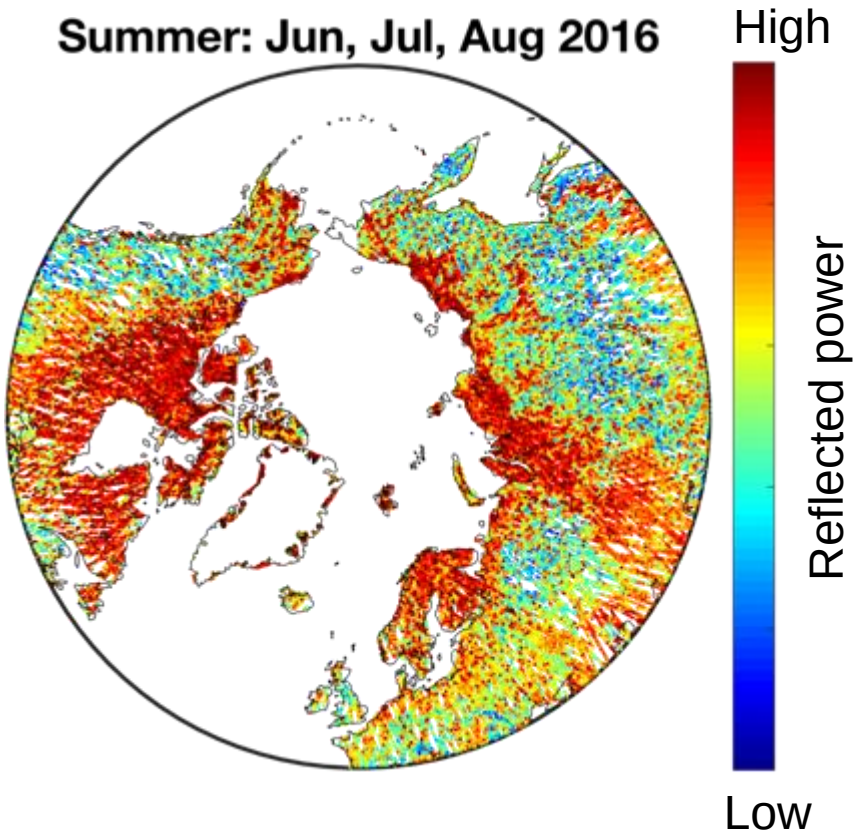
- **Hurricane winds**
- **Sea ice**
- **Landscape freeze/thaw state**
- **Near-surface soil moisture**
- **Flood inundated area**




Low
High
Reflected power

“Free” GPS reflections are observing the freeze/thaw transition in the high latitudes using the receiver on SMAP





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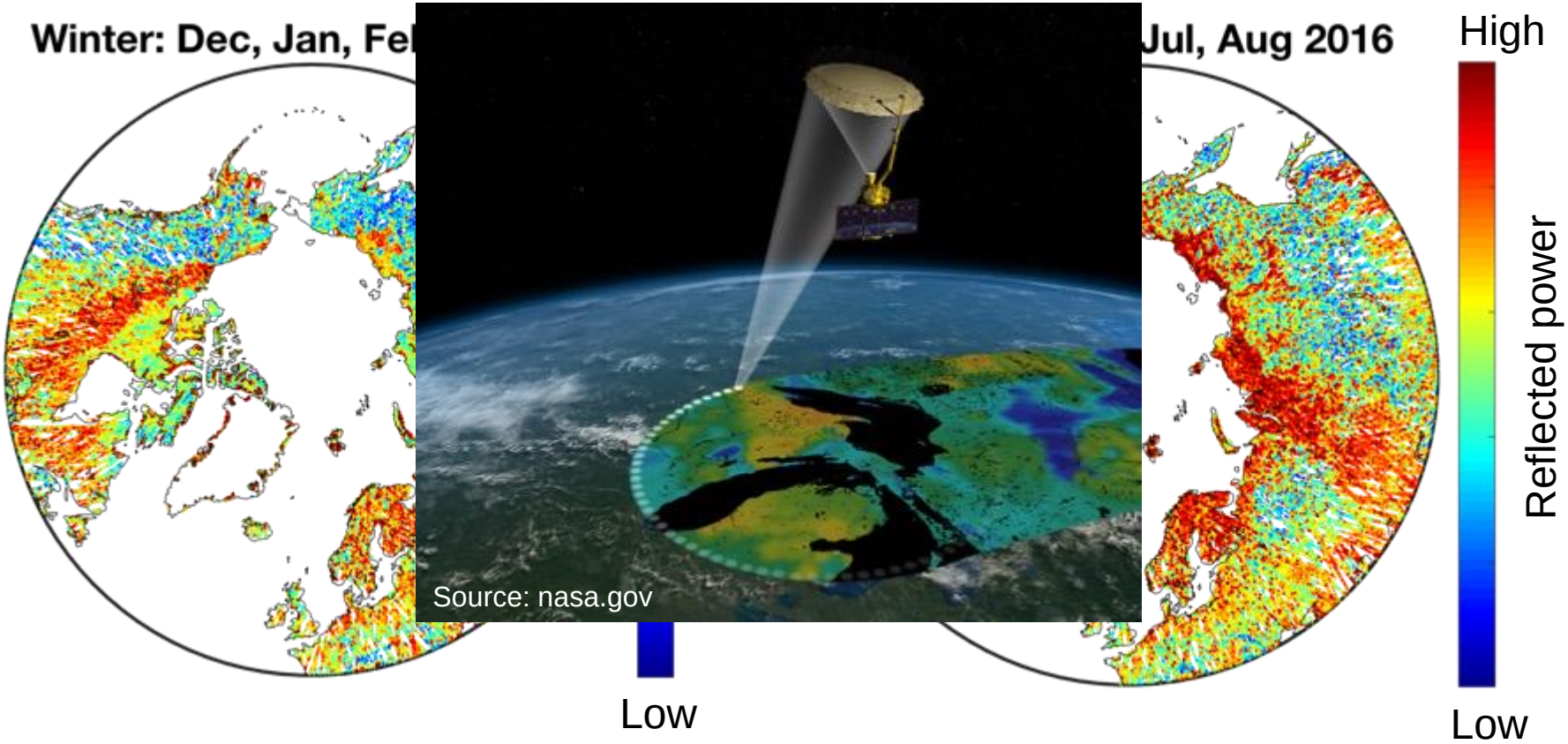
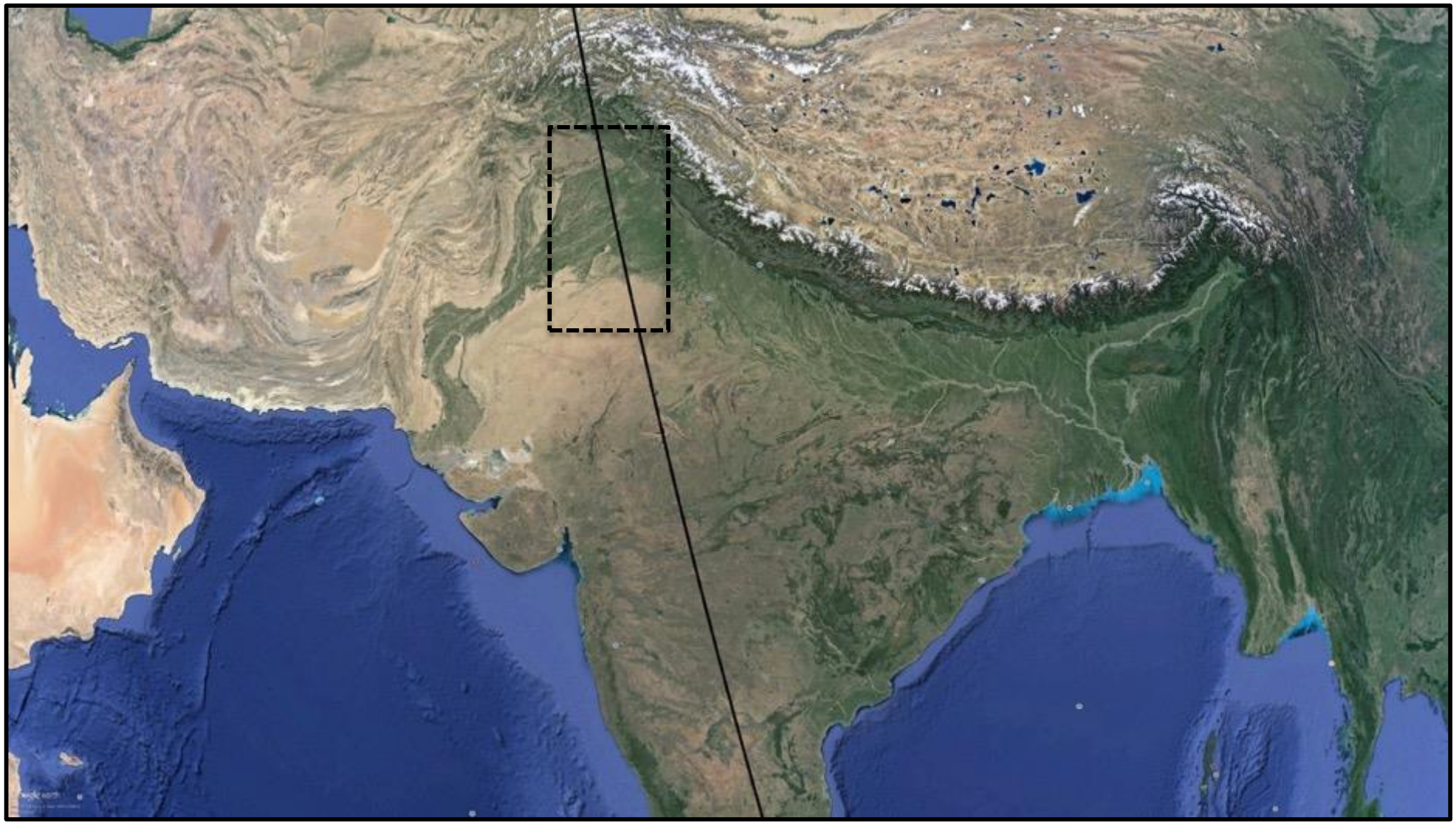


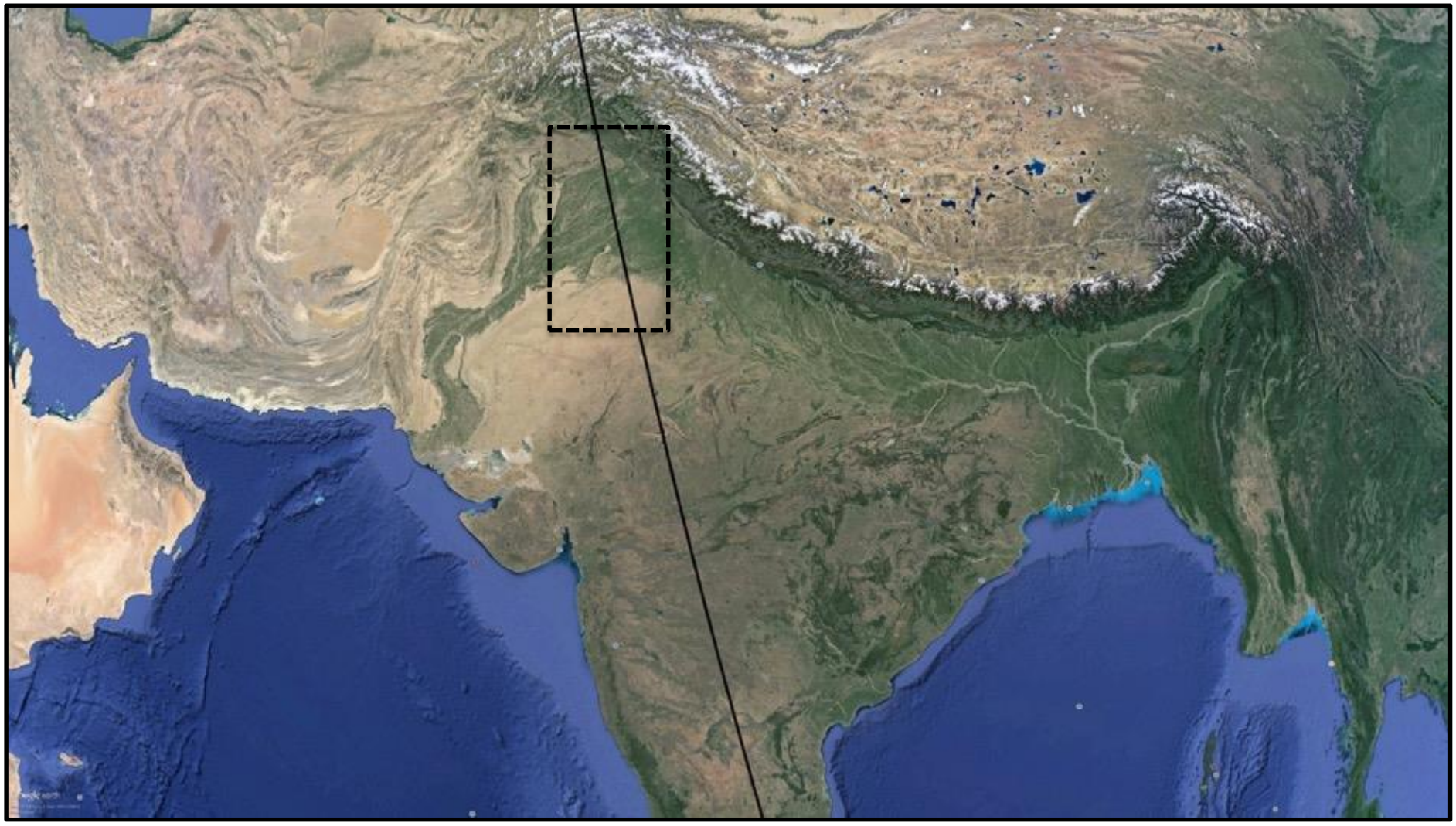


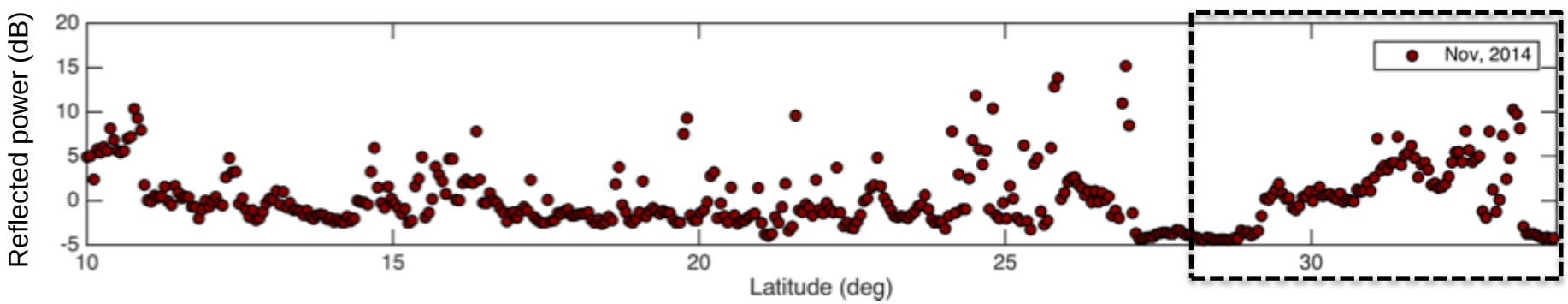
Punjab region of India and Pakistan

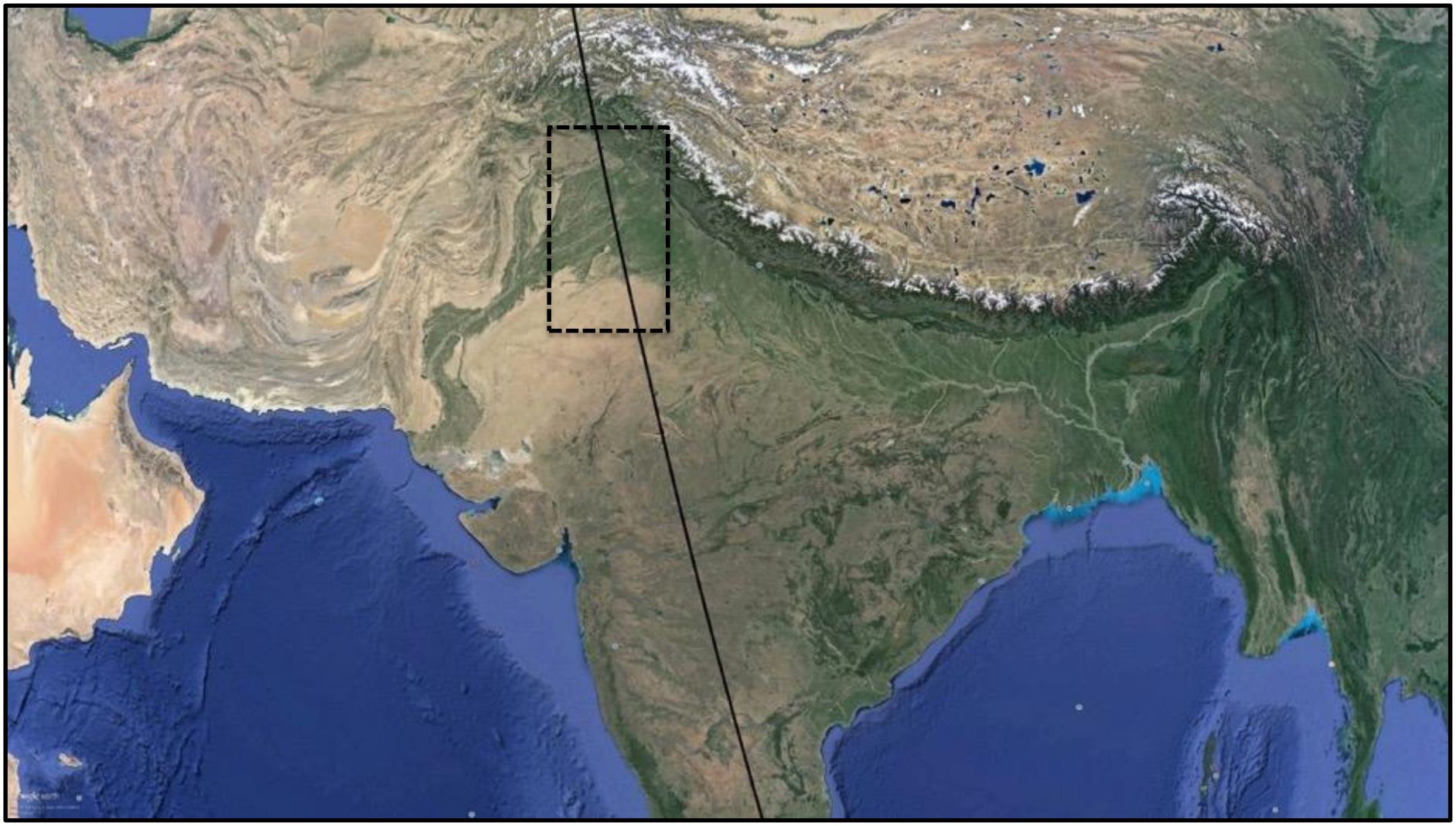
Agricultural region

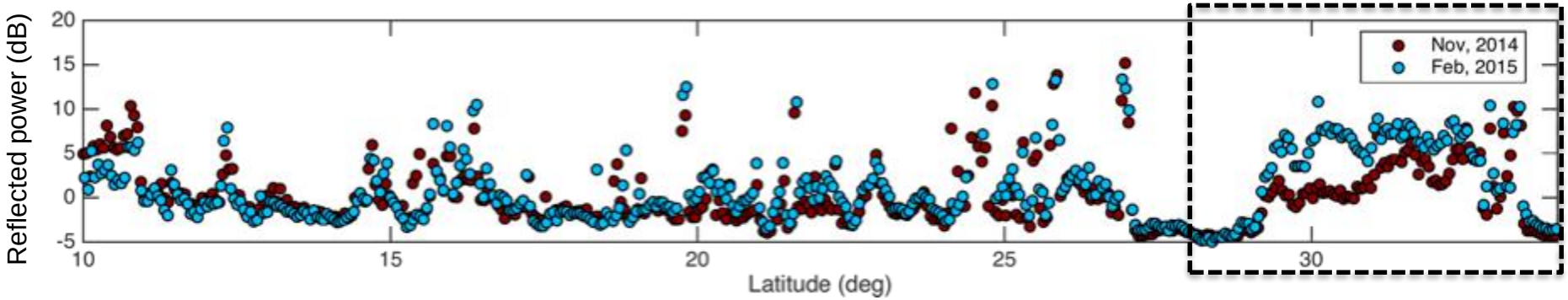
Heavily irrigated during growing season

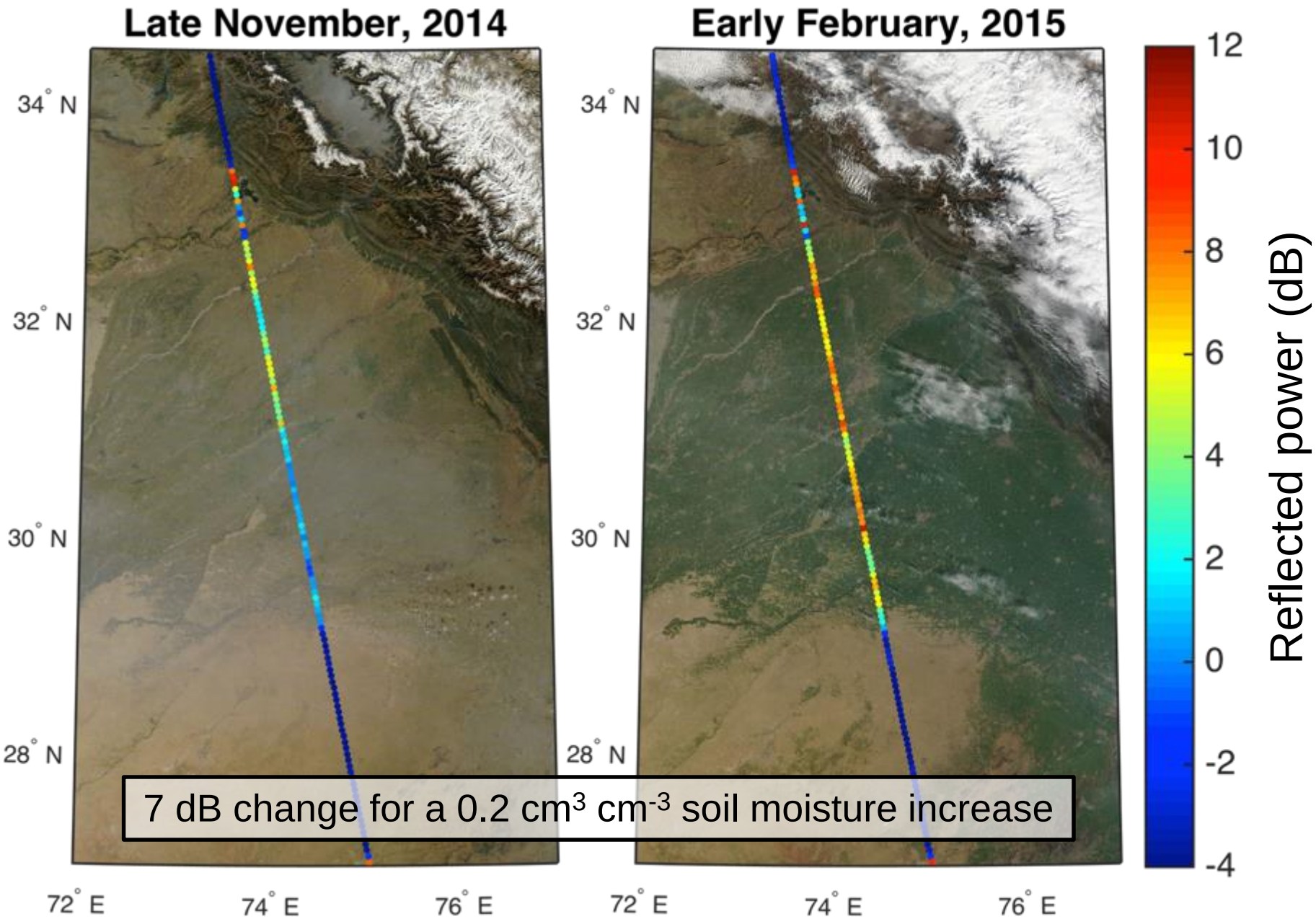
Crops sown in November, harvested in April



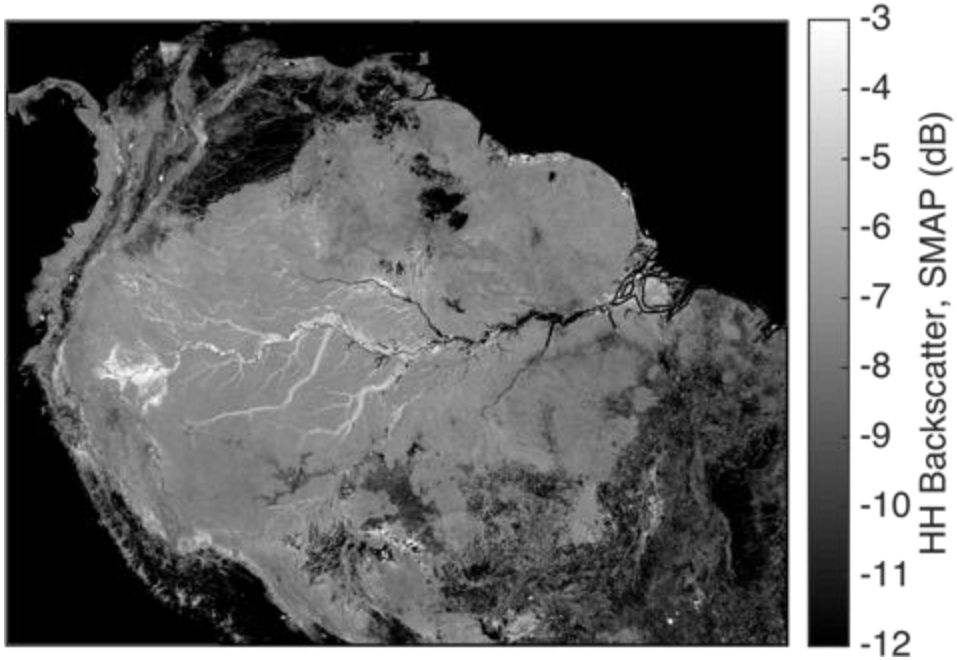

Reflected power (dB)
20
15
10
5
0
-5
10
15
20
25
30
Latitude (deg)
Nov, 2014

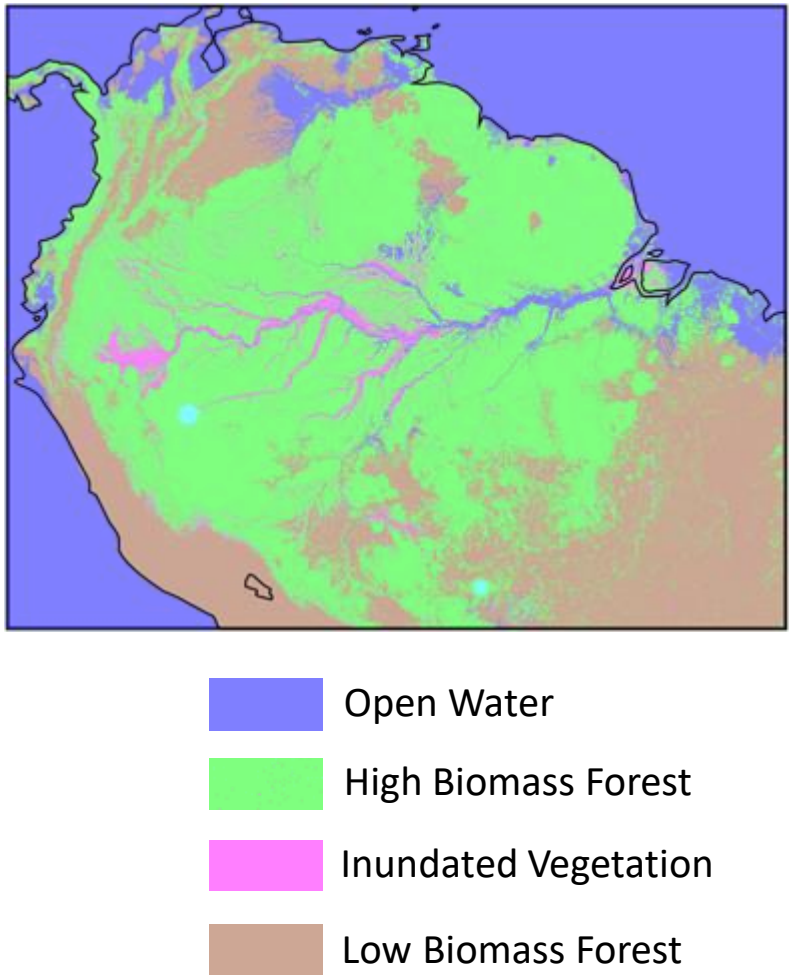



Reflected power (dB)
20
15
10
5
0
-5
10
15
20
25
30
Latitude (deg)
Nov, 2014
Feb, 2015

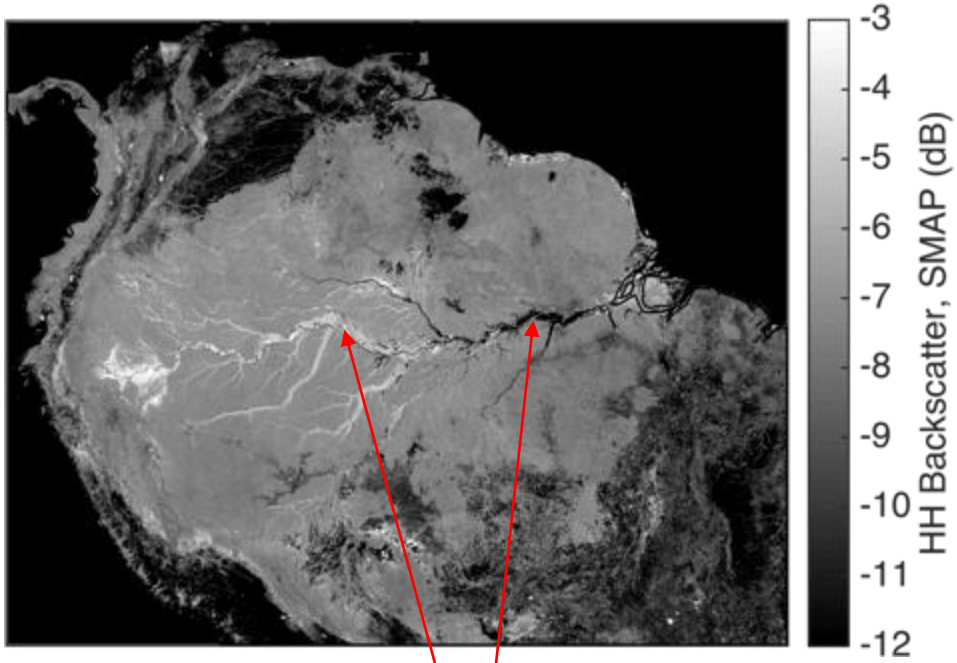


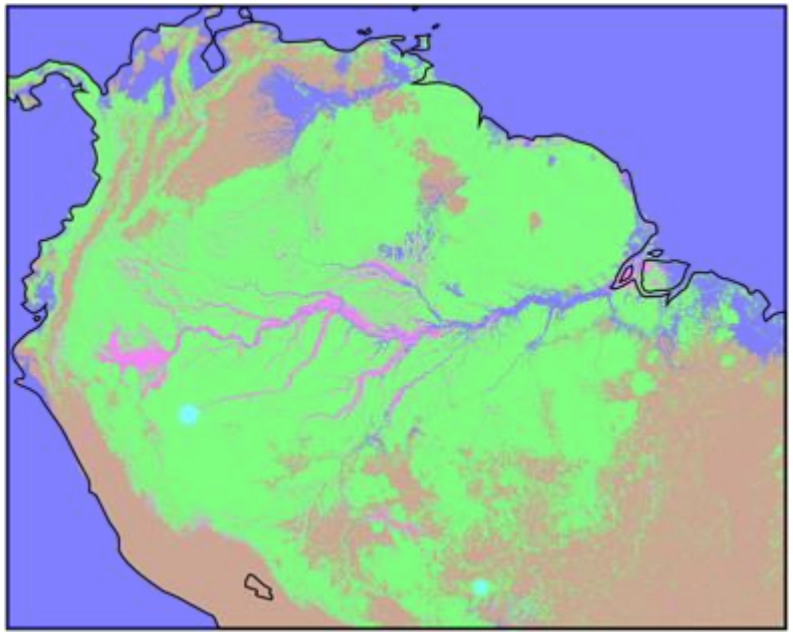
7 dB change for a 0.2 cm^3 cm^{-3} soil moisture increase





Flood inundated area





Traditional radar shows very different responses to water, depending on the overlying vegetation

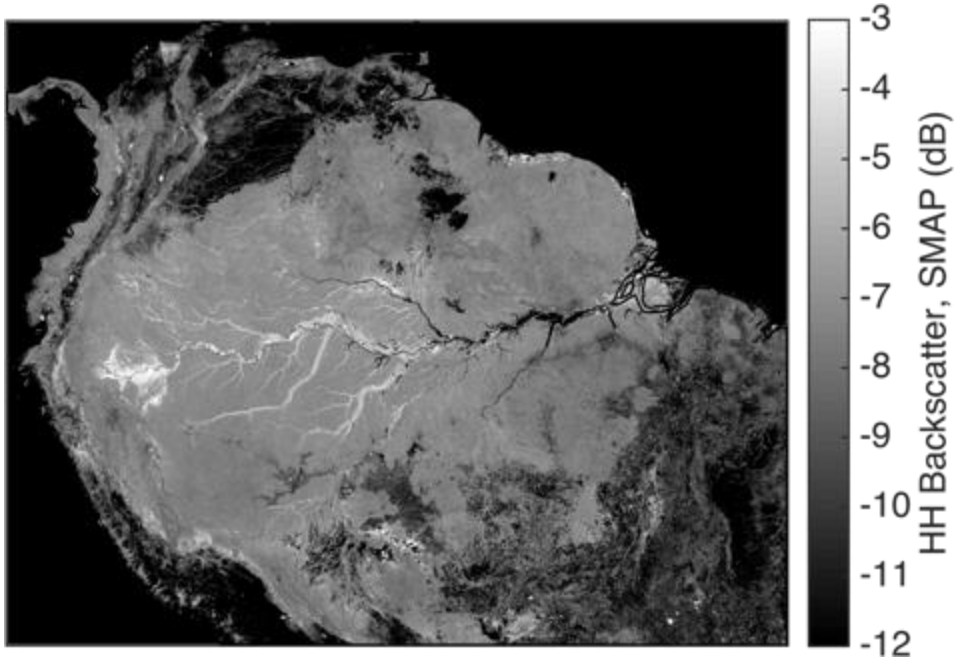
Open Water

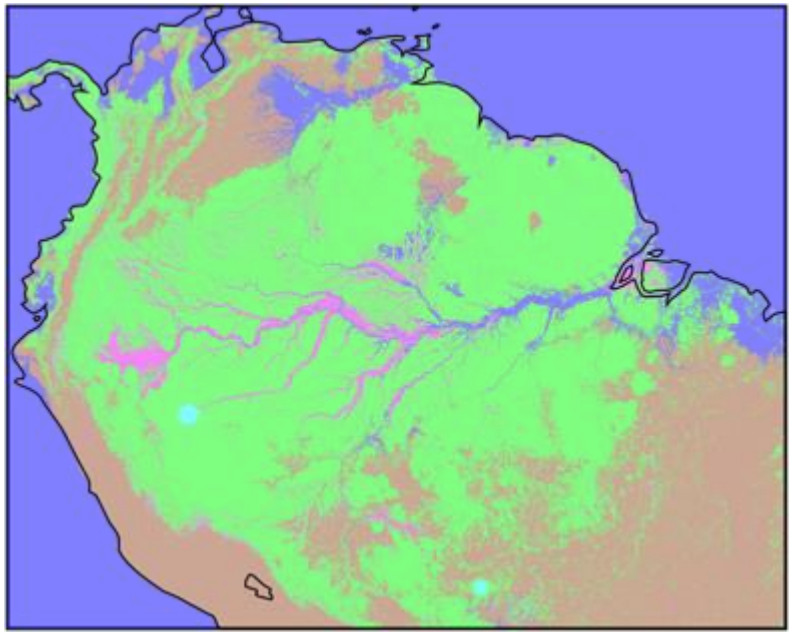
High Biomass Forest

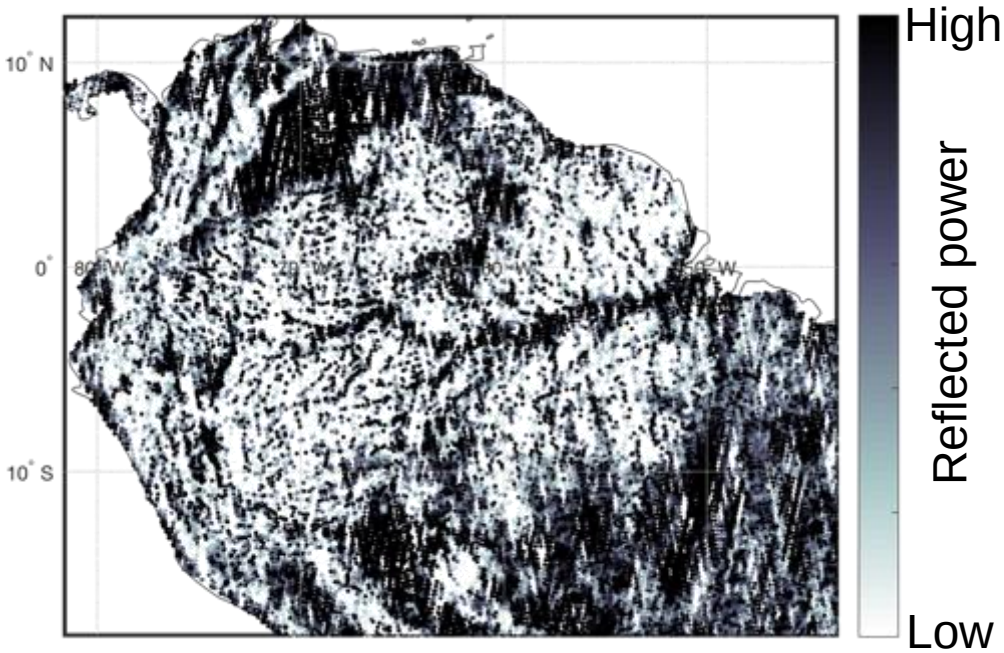
Inundated Vegetation

Low Biomass Forest

Flood inundated area







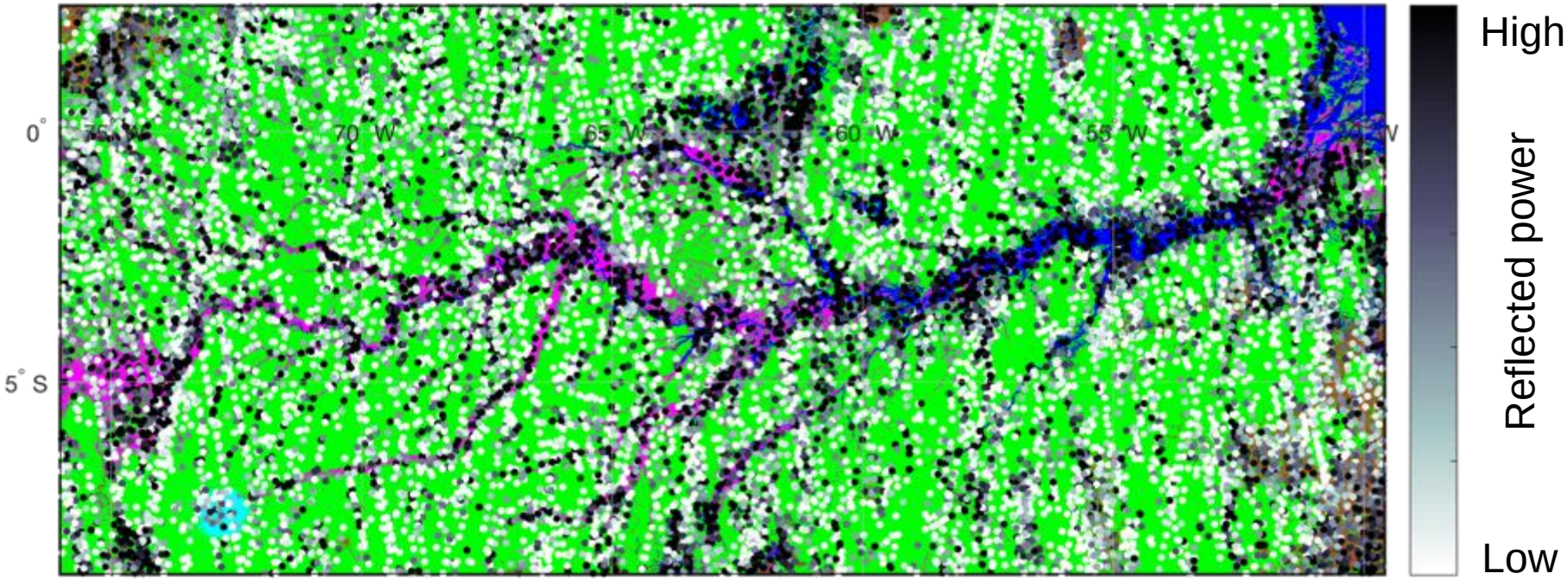
Open Water

High Biomass Forest

Inundated Vegetation

Low Biomass Forest

Flood inundated area



Open Water

High Biomass Forest

Inundated Vegetation

Low Biomass Forest

Conclusions

GPS reflections can be used as an inexpensive and effective remote sensing tool.

Data can be used to sense changes in:
Soil moisture
Flood inundated area
Sea ice
Hurricane winds
Freeze/Thaw state

More work needs to be done to convince the community that this data type is useful.

Source: https://www.unavco.org/science/snapshots/cryosphere/2012/bevis.html

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jpl.nasa.gov