Using GNSS Signals to Measure Soil Moisture, Vegetation Water Content, Snow Depth, Water Levels, Permafrost, and Volcanic Plumes

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Outline

- Multipath
- Ground-based reflectometry
  - Snow
  - Soil Moisture
  - Vegetation Water Content
  - Water Levels
  - (Cryosphere)
- Volcanic Plume Sensing
frequency of signal strength data depends on $H$, the GPS transmit frequency, and the reflecting medium.
EarthScope Plate Boundary Observatory (PBO)

A network of 1100 continuously-operating GPS receivers - deployed to measure ground motions from plate tectonics, earthquakes, and volcanos.

Data are freely available (often in real-time) and are used by geoscientists and surveyors.
Using GPS reflection data from NSF's Plate Boundary Observatory (PBO) to study the water cycle

Snow Depth
Vegetation
Soil Moisture

Snow Depth
Snow markedly influences the land-surface water budget. Snow measurements are needed both to study climate and to predict drought, flooding, and water availability.

Vegetation
Monitoring changes in the organic matter of ecosystems is important for climate and hydrologic modeling applications, validation of satellite estimates of land surface conditions, and testing of ecohydrological hypotheses.

Soil Moisture
Soil moisture controls the movement of rainfall into runoff, the prediction of precipitation and biogeochemical processes, and it influences the land-surface energy balance.

Download all data

http://xenon.colorado.edu/portal
Measuring Snow
Installed a camera to take a picture of this stick every day.
Snow Climatology

PBO $H_2O$: p360

Note: we also provide a SWE product
Monitoring Vegetation Water Content
Peak Vegetation Water Content

relative to 2008-2012 average
Monitoring Soil Moisture
PBO H$_2$O: p038

Vol. Soil Moisture

mm

metSensor precip

mm

NLDAS precip

Jan  Feb  Mar  Apr  May  Jun  Jul  Aug  Sep  Oct  Nov  Dec

updated 27–Oct–2015

2013

release 2.5
What else can you do with reflected GPS signals?

Kachemak Bay, Alaska

GPS site installed by Jeff Freymueller
University of Alaska at Fairbanks
Comparison between GPS and ‘Real’ Tide Gauge

Larson et al., The Accidental Tide Gauge, *IEEE GRSL*, 2013
Fit to tidal coefficients: 7.5 cm for NOAA, 8.4 cm for GPS
Steenbras Dam, Republic of South Africa

GPS Data courtesy of Trignet
Relative Water Level in Reservoir Near SBAS

GPS derived water level

G4R001

water storage (outline added)

water storage data:
Cryosphere applications

Data from the GLISN network

Seismologist not drawn to scale.
On an ice sheet, you can infer firn density.
On permafrost, you are sensitive to changes in the active layer.

Active Layer Thickness ~50 cm at Barrow
SNR Data for Mt. Redoubt, Alaska

GPS site installed by Jeff Freymueller, UAF

Larson, A new way to detect volcanic plumes, GRL, 2013
Why are these data valuable?

Any information about the timing, ascent rate, and height of a volcanic plume is useful for volcano ash dispersion models, which are used to make decisions about global airline routes and closure of airports.
New Applications for GNSS: Validation of satellite sensors, *in situ* data for climate and sea level studies; water management, drought/flooding mitigation; permafrost monitoring; hazards assessments for airports.
Take Home Messages

- The environmental products shown here were derived entirely from GPS data - no ancillary instrumentation was needed; existing instrumentation was used.
- There is no reason this could not be done with GLONASS, Beidou, and Galileo.
- New GNSS sites could be installed to take advantage of GNSS reflectometry.
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