GNSS H_2O: A Global Network of In Situ Hydrologic Sensors Derived from GNSS Data

Susan Owen [1]
Kristine Larson [2], Eric Small [2], Angelyn Moore [1], Sean Hardman [1],
Dana Freeborn [1], Cynthia Wong [1]
1. Jet Propulsion Laboratory, California Institute of Technology
2. University of Colorado, Boulder

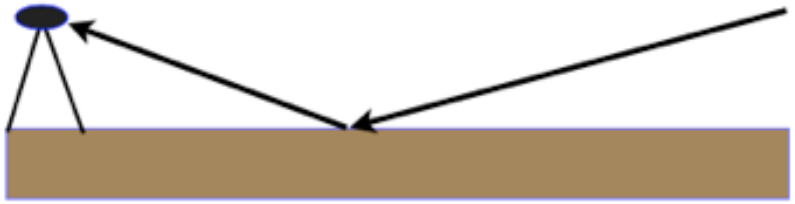
Outline

- GPS and Environmental Signals
- Expanding PBO H_2O to the global GNSS network
- AMIGHO AIST Project

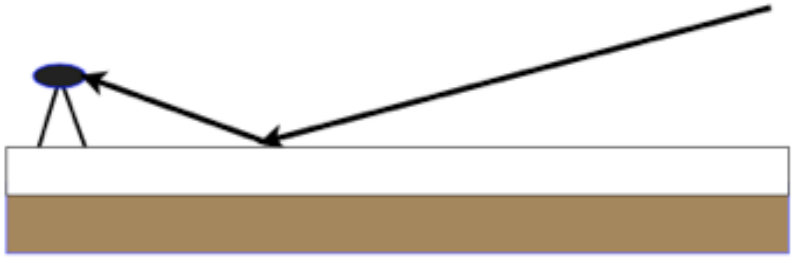
"normal" people measure the distance between multiple satellites and the antenna (in the gray dome) and they estimate the antenna position (X, Y, Z or latitude/longitude/height).

We use the interference pattern created by the direct and reflected signal power to infer changes in the reflecting surface.

the reflections off bare soil produce this SNR curve

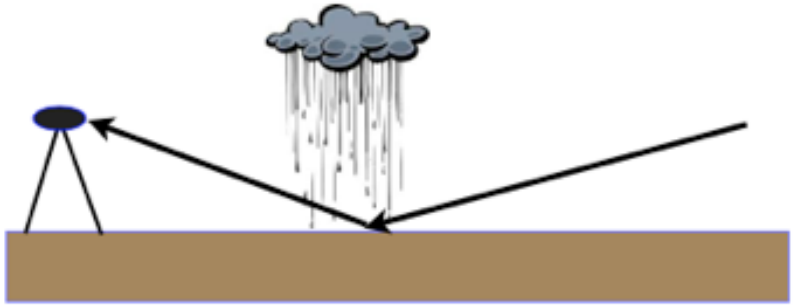


add a snow layer

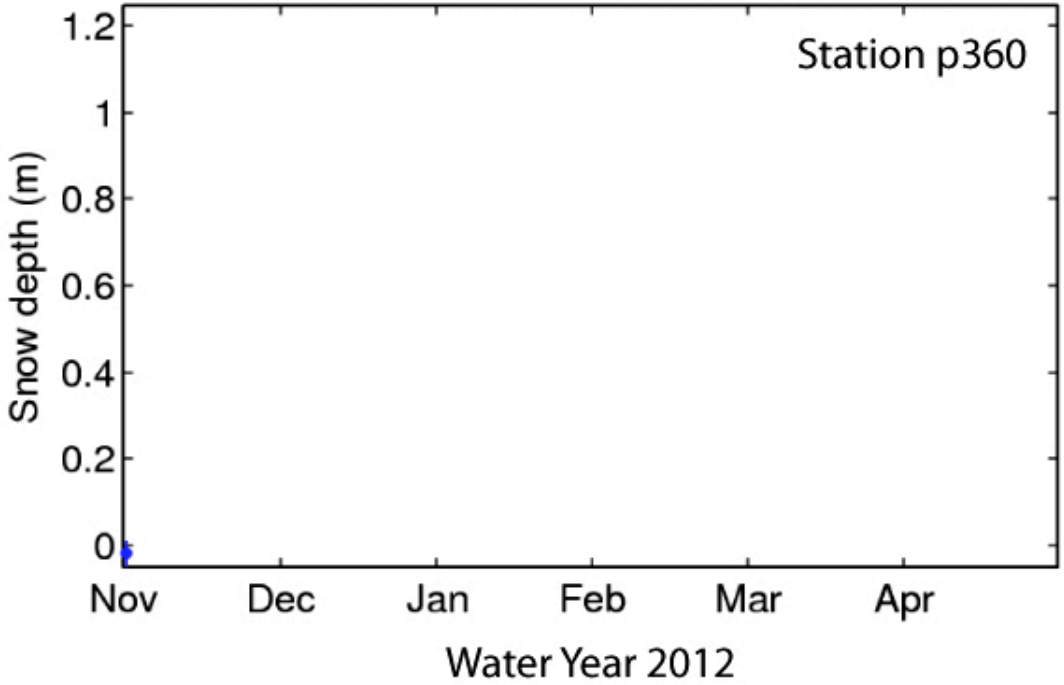


add vegetation

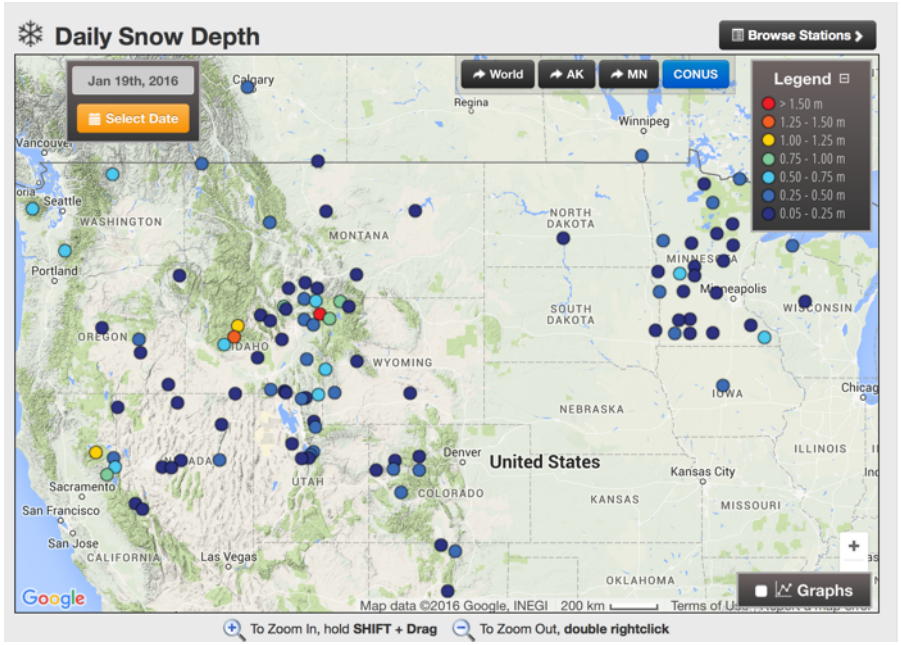
make the soil wet

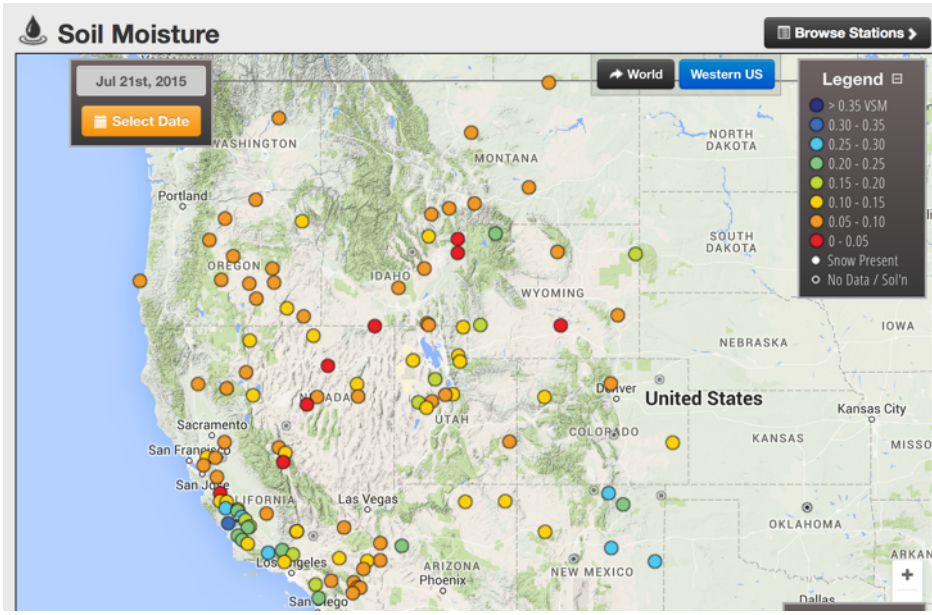


Larson et al., 2008; Larson et al., 2009; Small et al., 2010


Station p360
Snow depth (m)
1.2
1
0.8
0.6
0.4
0.2
0
Nov
Dec
Jan
Feb
Mar
Apr
Water Year 2012

What is PBO H_2O?



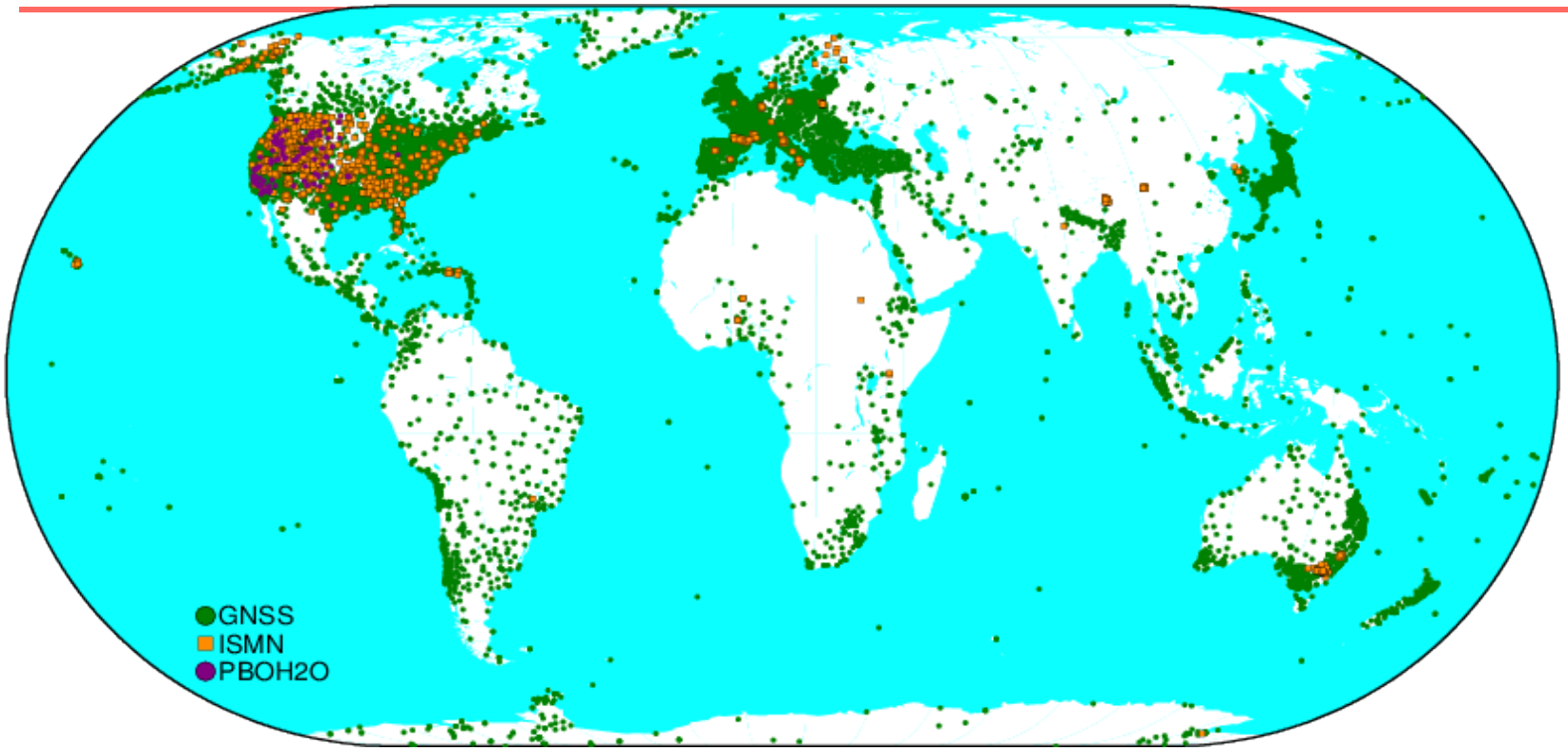


Proto-type GPS reflection system that creates and distributes daily soil moisture, snow depth/SWE, and vegetation water content products. 95% of the data used in PBO H_2O comes from a single network, the Plate Boundary Observatory.

http://xenon.colorado.edu/portal

ESTO
Earth Science Technology Office

GNSS H_2O & AMIGHO



International Soil Moisture Network

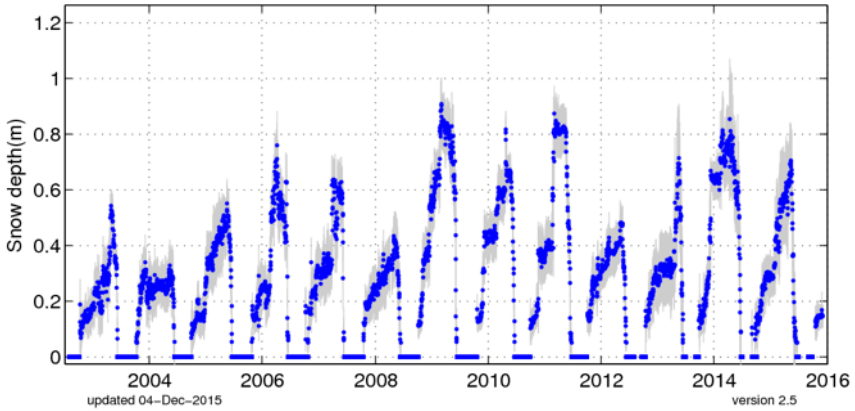
Public GNSS sites

PBO H2O pilot project

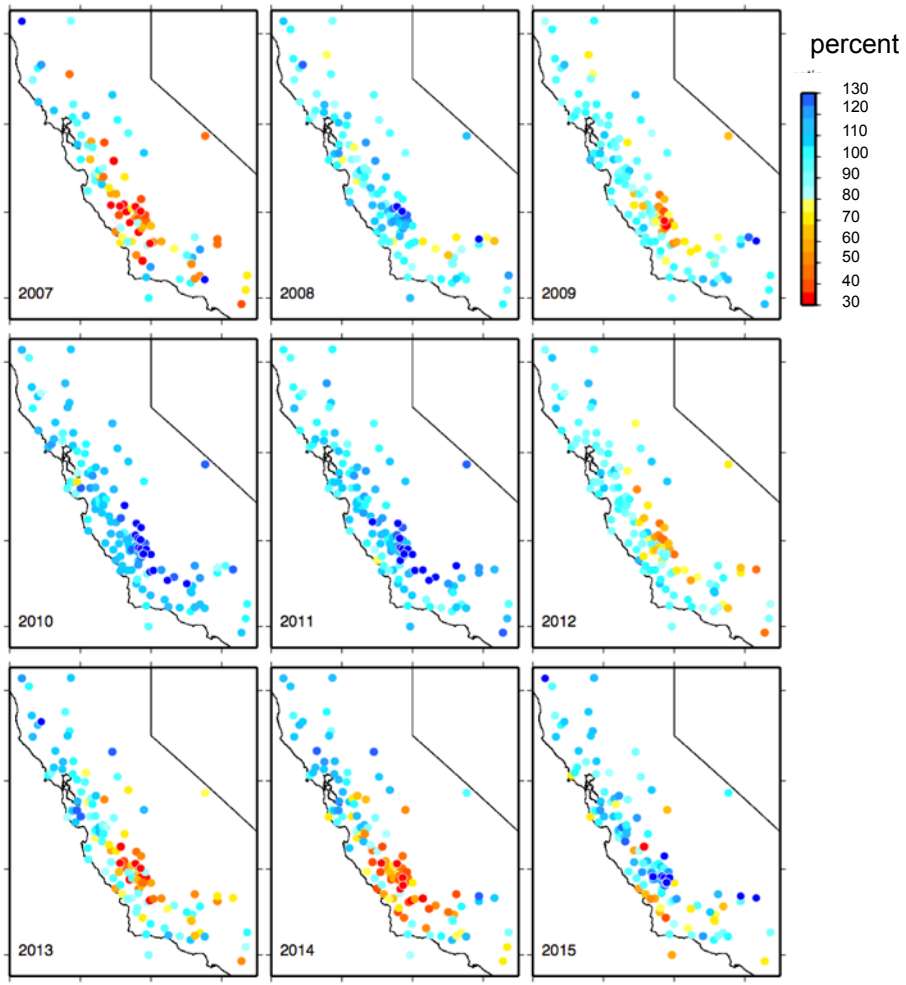
- Enable operators of GNSS networks to provide current and past data to the GNSS H2O system.
- Develop a system to automatically ingest GNSS observations and related metadata to produce data products.
- Enable understanding of GNSS water products through a portal which supports:
  - Visualization.
  - Data mining.
  - Data sharing.

Motivation for GNSS H_2O: New Climate Records

PBO H_2O: sg27



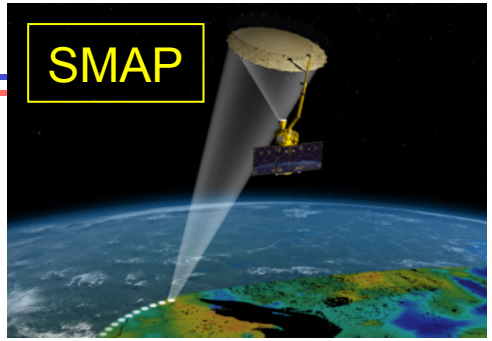
Peak Vegetation Water Content for Drought Monitoring



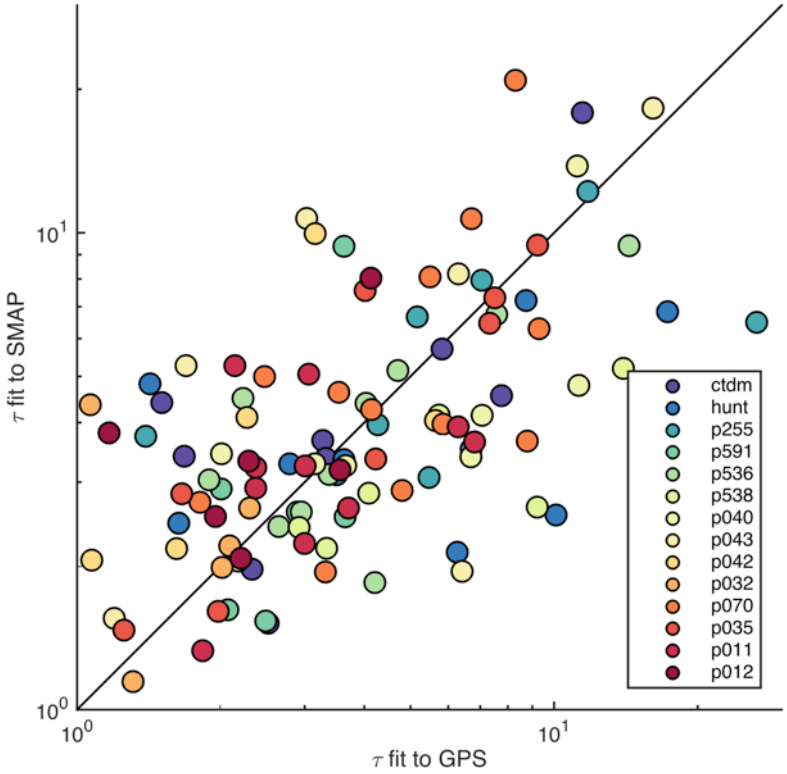
Goal: provide access to thousands of inexpensive GNSS environmental sensors on a global scale, providing long time-scale records for climate studies.

ESTO
Earth Science Technology Office

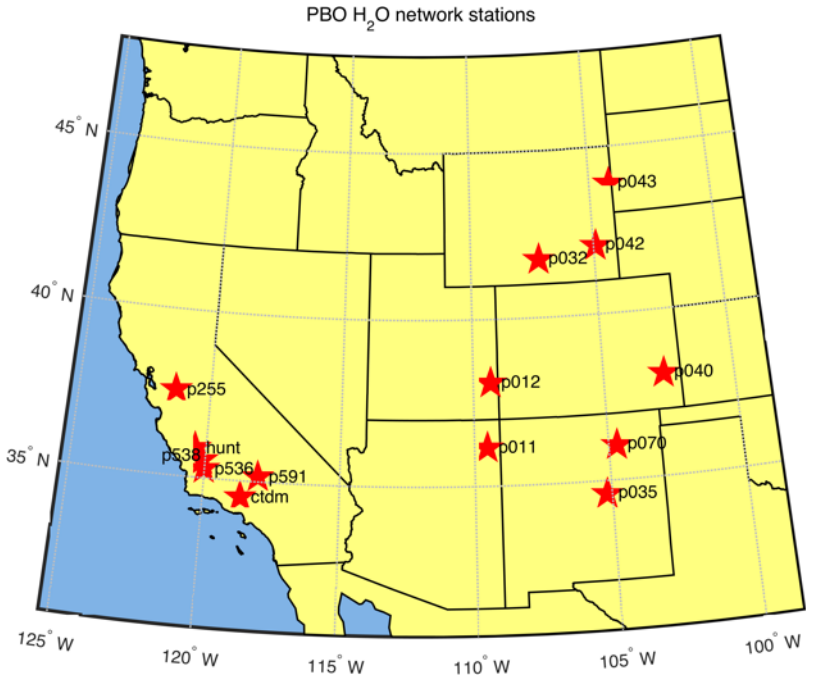
Motivation: Satellite Validation Data



GPS and SMAP drying timescales are similar



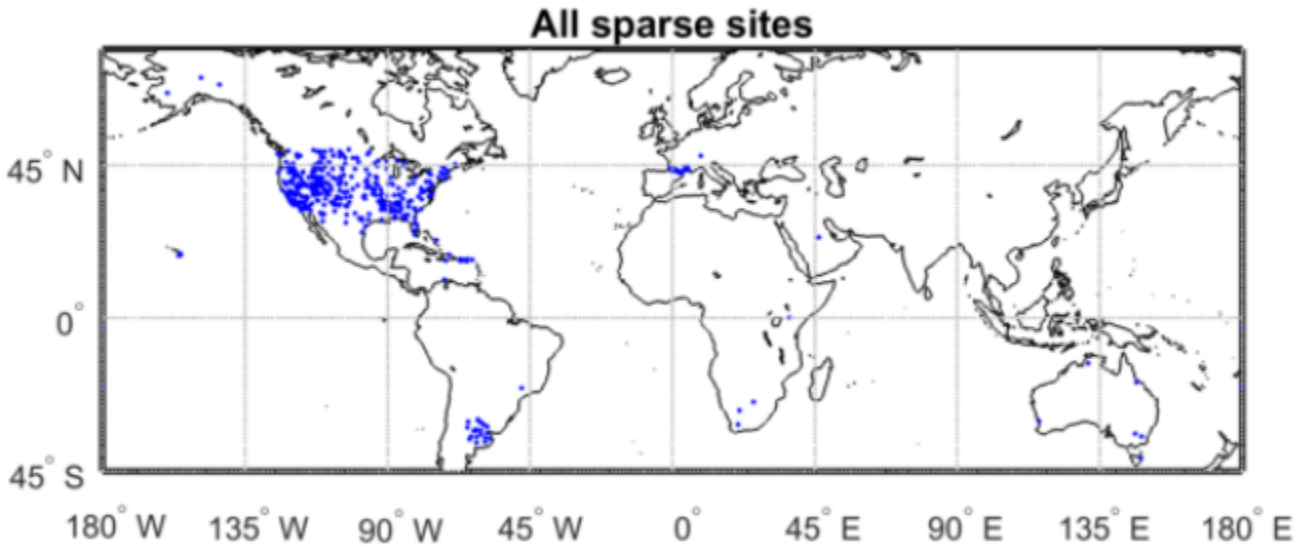
- GPS median: τ = 3.2 days
- SMAP median: τ = 3.3 days



- Also relevant for IceSat-2, NISAR, SWOT validation

SMAP and SMOS “sparse network” validation

- 500 sites
- 90% in US
- 100 from GPS-IR
- GPR-IR on par or better than traditional probes



https://nsidc.org/data/docs/daac/smap/sp_l2_smap/pdfs/SMAP-AP_Assessment_Report_Final.pdf
Al-Yaari et al., 2017

Approach

- Leverage the prototype GNSS hydrologic products system (PBO H_2O) developed using NSF and NASA science funding and operated by the University of Colorado Boulder
  - Heterogeneous code, difficult to expand to new networks
- Leverage Apache OODT for extensibility
  - Design for expansion to global GNSS networks and continued long-term operations
- Develop new technology to automatically ingest new networks
  - Station evaluator
  - Develop automated configuration mechanisms

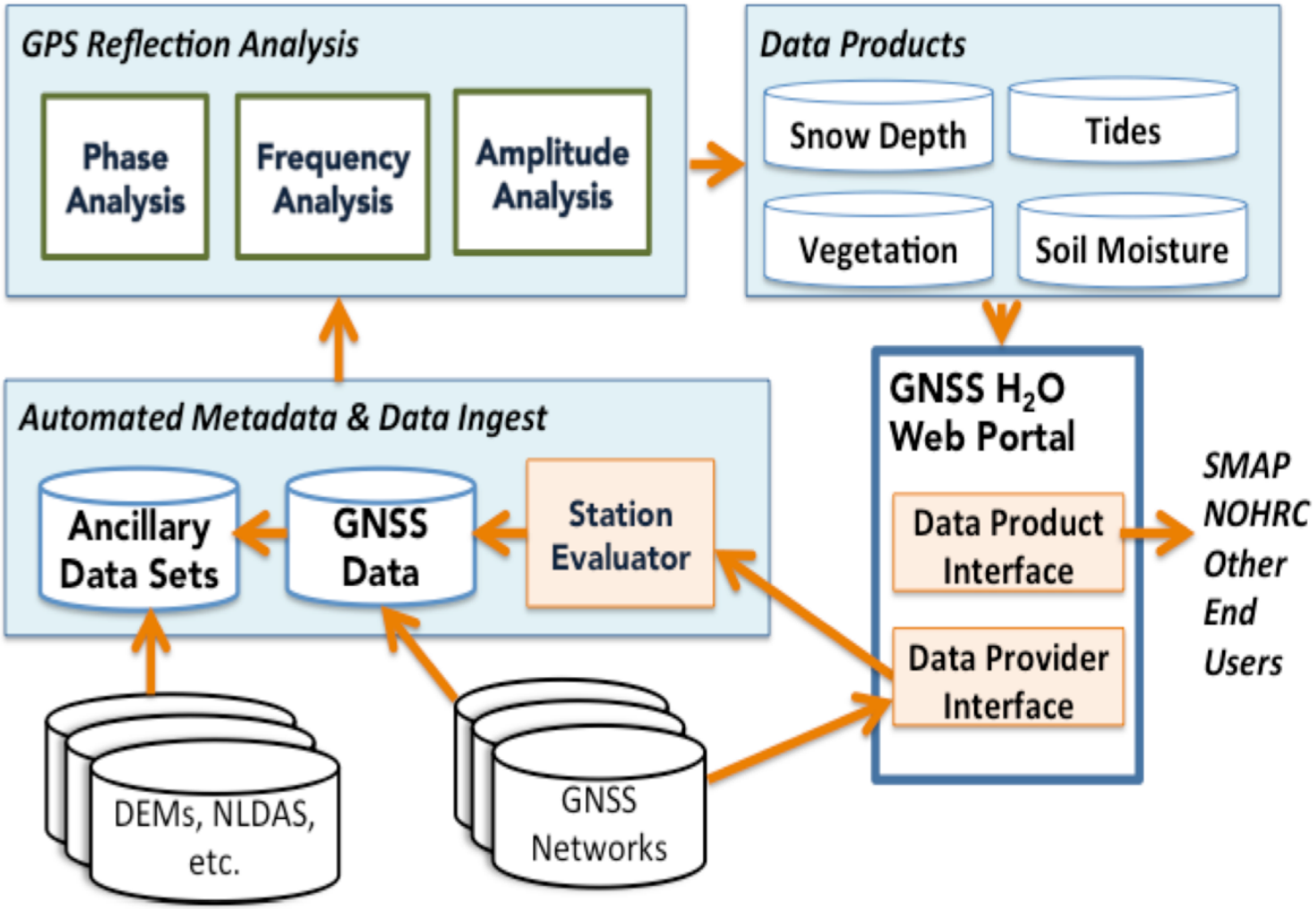
AMIGHO – Automated Metadata Ingestion for GNSS Hydrology with OODT

AMIGHO Task Outline

- Year 1Tasks
  - Implement GNSS Hydrology System using Apache OODT framework using existing algorithms.
    - Migrate existing PBO H2O
    - Re-implement ingest, analysis processes.
    - Re-implement data product production.
  - Identify new GNSS Networks for Ingestion
  - Design Automated Metadata Ingest Technology

- Year 2 Tasks
  - Implement Automated Metadata Ingest Technology
  - Demonstrate Automated System for Ingesting Data
  - Develop New User Interface Tool

Operational Concept for GNSS H_2O



Task Goals for Implementing Automated Metadata Ingestion: Configuration Manager

- Implement a single database for capturing metadata describing a GNSS station, its data, and the site's reflection qualities.
- Implement the automatic configuration layer for the GNSS H_2O system.
  - Integrate the Station Evaluator to determine suitability of a station's reflection data for generating hydrologic products.
  - Modify the configuration of the system accordingly in real-time.

Accomplishments

- Mapped the fields in the current databases to the fields found in the various lists used by the existing processing scripts
- Mapped the output from the Station Evaluator to new database structures
- Implemented software that evaluates a station with the following steps:
  - Validates the metadata
  - Evaluates the station characteristics returned from the Station Evaluator
  - Retrieves a sample of the data and performs a data evaluation
- Implemented software that configures the GNSS H_2O system for accepted stations

Station Evaluator

- With the potential for large networks to be included in GNSS H2O processing, we need automation to mitigate the need for tedious evaluation site-by-site.
- Software can downselect sites that fail basic location criteria – surrounded by pavement, buildings, complex terrain, etc.
- Next, examining the station's data can determine whether it is suitable for snow, soil moisture, and/or vegetation products.
- Determination of the land cover can suggest growing and harvest seasons that may need to be excluded from processing.
- These checks can be performed in software, presented to an operator in a report, and results (azimuth masks, date masks, usable tracks) utilized in new station configuration.

Station Evaluator Components Developed

- Evaluate_OSM
  - New component to query OpenStreetMap for features surrounding the site
- Evaluate_Landcover
  - New component to query for MODIS landcover classification
- Evaluate_DEM
  - New (+/-) component to provide DEM for flatness evaluation
- Evaluate_SNR
  - Developed at CU, relevant to snow and SMC products
  - Evaluates SNR files, develops keep/reject decision for satellite tracks based on periodogram peaks
- Evaluate_Veg
  - New component to recommend suitability of site for Veg product

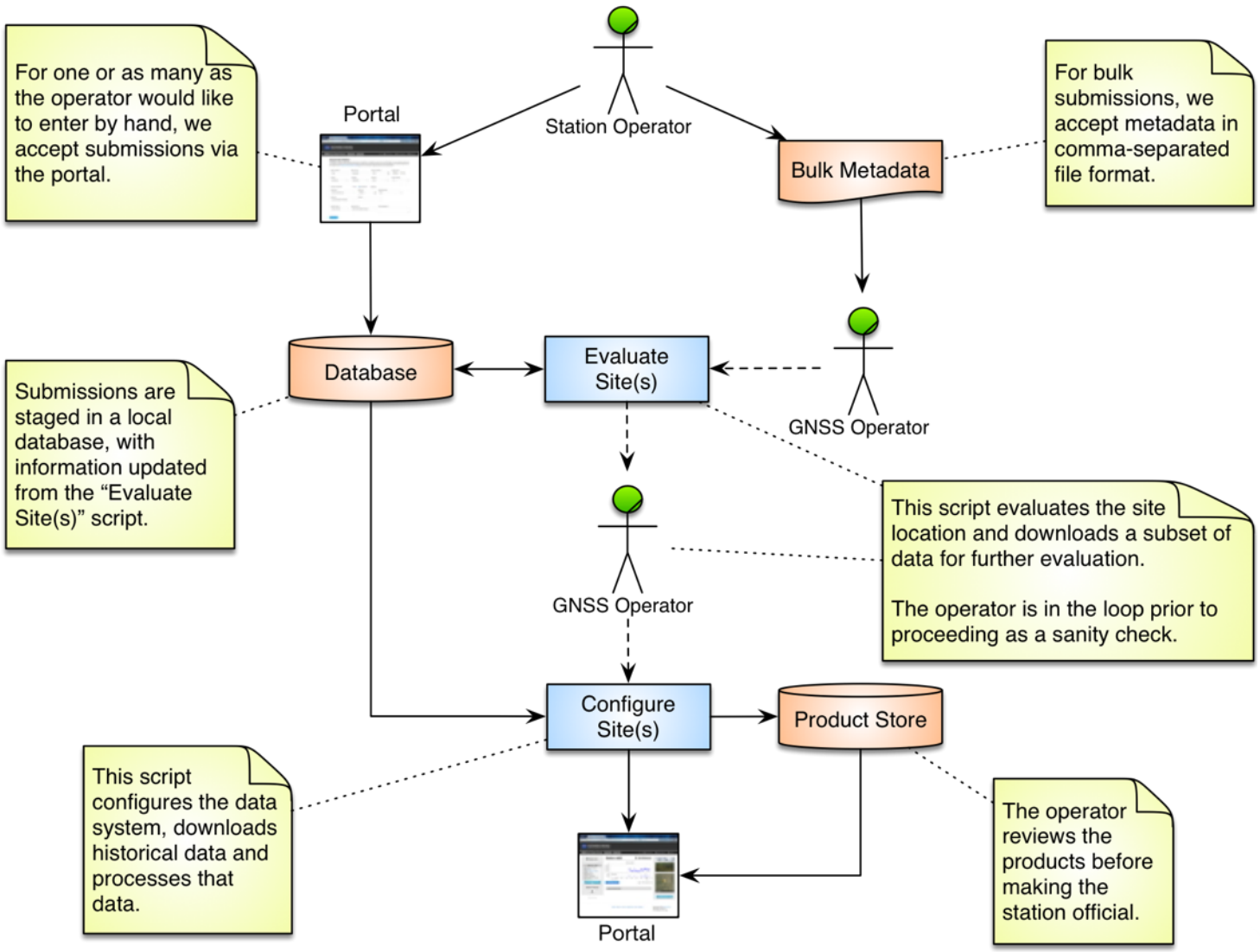
JPL New Technology Report (NTR) submitted by Angelyn Moore and Sean Hardman for “Software to assess characteristics of candidate locations for determining suitability for earth science studies.”

Software searches online sources and produces a human-readable report, or machine-readable JSON output.

Video Capture of Demonstration

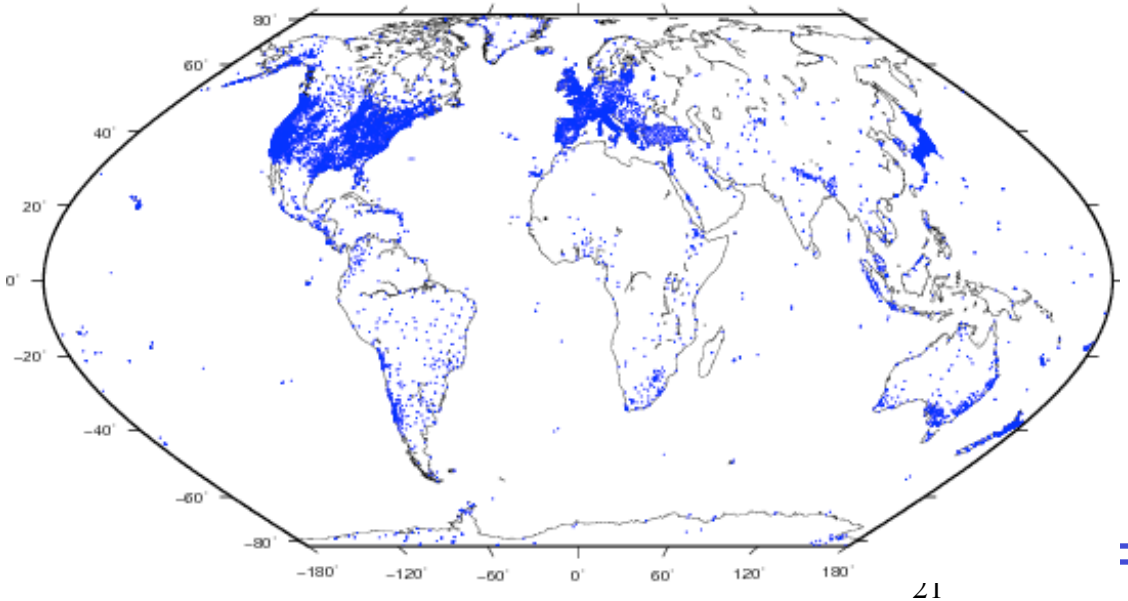
ESTO Earth Science Technology Office

Demonstration Flow



Summary

- PBO H_2O is already one of the largest soil moisture networks in the world; it also provides snow depth (170) and vegetation (370) information in near real time.
- GNSS H_2O has automated many of the labor intensive steps required to add new stations and new networks – enabling a global dataset of *in situ* climate data and satellite validation data.
- The station evaluator software has potential applications for other projects requiring information about site suitability



Funding for developing the GNSS H_2O comes from NASA AIST. PBO H_2O was developed with assistance from NSF and NASA.