GNSS H$_2$O: A Global Network of In Situ Hydrologic Sensors Derived from GNSS Data

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Outline

- GPS and Environmental Signals
- Expanding PBO H$_2$O 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
What is PBO H$_2$O?

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$_2$O comes from a single network, the Plate Boundary Observatory.

http://xenon.colorado.edu/portal
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 $\text{H}_2\text{O}$: New Climate Records

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

GPS and SMAP drying timescales are similar

- GPS median: \( \tau = 3.2 \) days
- SMAP median: \( \tau = 3.3 \) days

Also relevant for IceSat-2, NISAR, SWOT validation

Results from P. Shellito, CU
SMAP and SMOS “sparse network” validation

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

Al-Yaari et al., 2017
Approach

• Leverage the prototype GNSS hydrologic products system (PBO H$_2$O) 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 1 Tasks
  - 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 H₂O
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 H₂O 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 H₂O 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.
For one or as many as the operator would like to enter by hand, we accept submissions via the portal.

Submissions are staged in a local database, with information updated from the "Evaluate Site(s)" script.

This script configures the data system, downloads historical data and processes that data.

For bulk submissions, we accept metadata in comma-separated file format.

This script evaluates the site location and downloads a subset of data for further evaluation.

The operator is in the loop prior to proceeding as a sanity check.

The operator reviews the products before making the station official.
Summary

- PBO H₂O 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 H₂O 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.

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