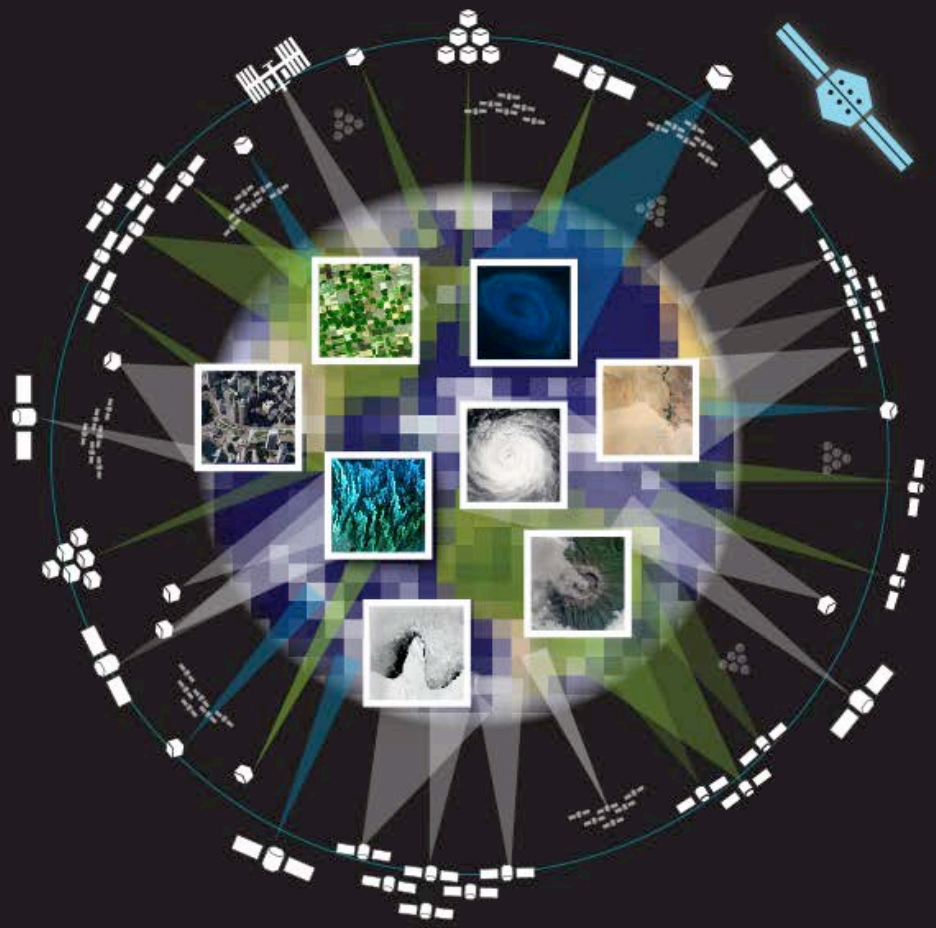


SPACE 2.0
5000 NEW COMMERCIAL EO SATELLITES

WHAT ARE THE OPPORTUNITIES?
WHAT ARE THE CHALLENGES?
HOW SHOULD JPL RESPOND?`

Jason Hyon
May 24, 2016

Chief Technologist, ESTD
Jet Propulsion Lab
California Institute of Technology

Forbes

"$10 billion has been invested into the top 100 privately held new space companies in the past decade… We expect M&A and IPO activity to heat up in the next several years …"

Galaxy Of Players Looking To Make Commercial Space A Big Business

Forbes Thomas Buckley March 2015

Sydney Morning Herald

"…breakthroughs are coming on almost a weekly basis. Two of the hottest segments…small satellites streaming data or images or boosters to get them cheaply into orbit"

Space race 2.0 sucks in $US10b from private companies

Sydney Morning Herald
Julie Johnsson
February 2015

Newsweek

"When launch costs drop, new customers will emerge. But most of the customers that will be interested don't even realize today what impact access to space will have on their business models."

Newsweek Kevin Maney February 2015

WHO IS JOINING THE FIELD?

TELEDYNE BROWN ENGINEERING, INC
A Teledyne Technologies Company

Camera platform on ISS for up to four digital-imaging instruments

Skybox Imaging

24-satellite constellation with high spatial and temporal resolution (including HD video)

GeoOptics

24 - satellite constellation for weather forecasting

PLANET LABS

100-satellite constellation for imaging

Tyvak
A Terran Orbital Corporation

"Complete nanosat solution" (e.g. NASA-funded satellite rendezvous and docking)

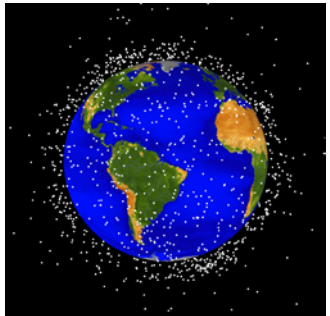
Buzz Words Among Startups and Venture Capitalists (Not NASA)

Growth of the Earth Satellite Population

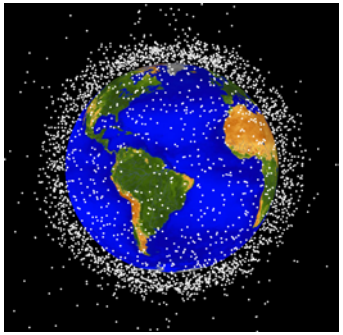
1960

1965

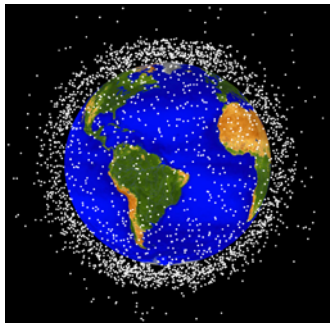
1970



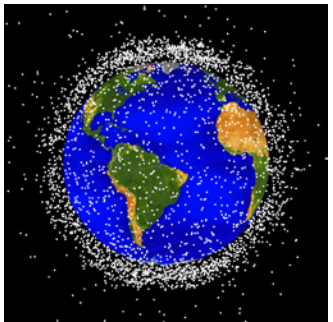
1975



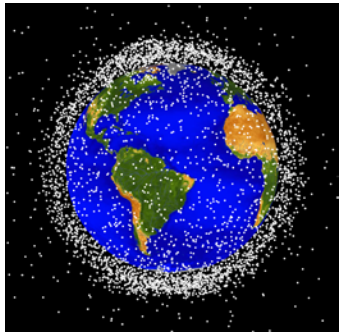
1980



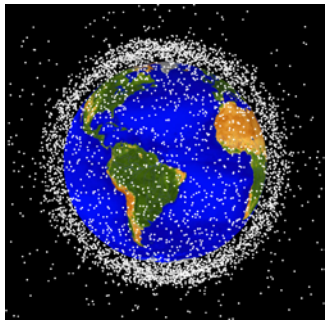
1985



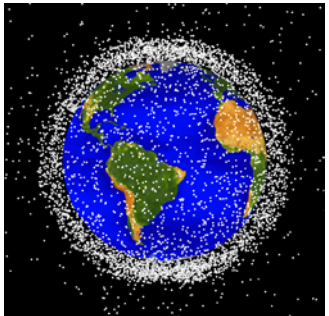
1990



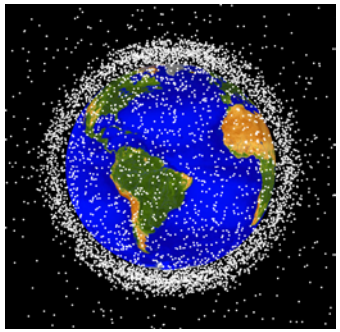
1995



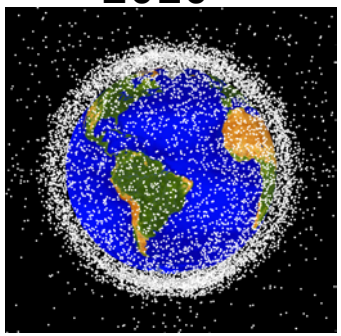
2000



2005



2010



Cataloged objects >10 cm diameter

Courtesy Paul Brandinger, GSFC

WHAT ARE THE TOP WAYS REMOTE SENSING IS BEING USED NOW?

1. Determining soil moisture content using active and passive sensors from space
2. Mapping with laser precision using Light Detection and Ranging technology
3. Catching tax-evaders red-handed by locating new construction and building alterations
4. Spinning the globe with mapping services like Google Earth, Bing Maps and OpenStreetMaps
5. Predicting retail earnings and market share by counting cars in parking lot
6. Snapping aerial photos for military surveillance using messenger pigeons in World War II
7. Charging higher insurance premiums in flood-prone areas using radar
8. Doing the detective work for fraudulent crop insurance claims
9. Searching for aircrafts and saving lives after fatal crashes
10. Detecting oil spills for marine life and environmental preservation

SOURCE: 100 EARTH SHATTERING REMOTE SENSING APPLICATIONS & USES (http://gisgeography.com/100-earth-remote-sensing-applications-uses/)

Data fusion and analytics

Platforms

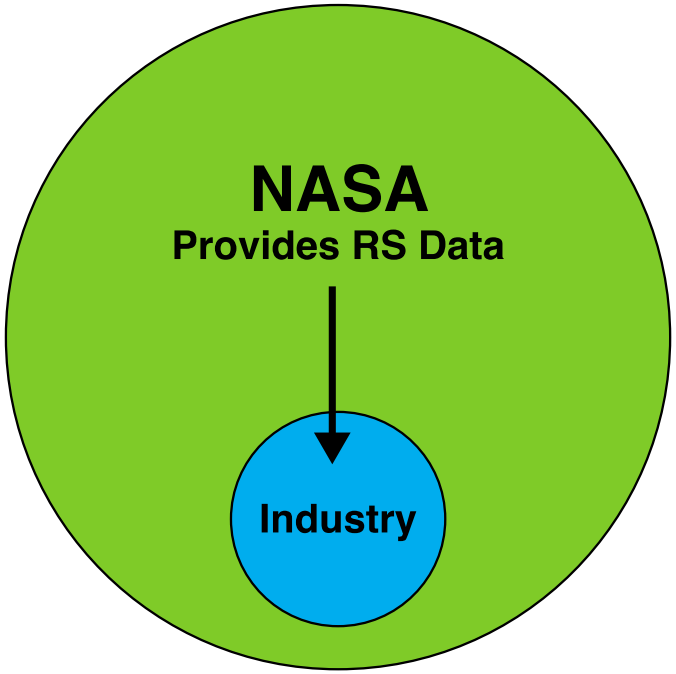
- ESRI
- Google/Skybox
- MapBox

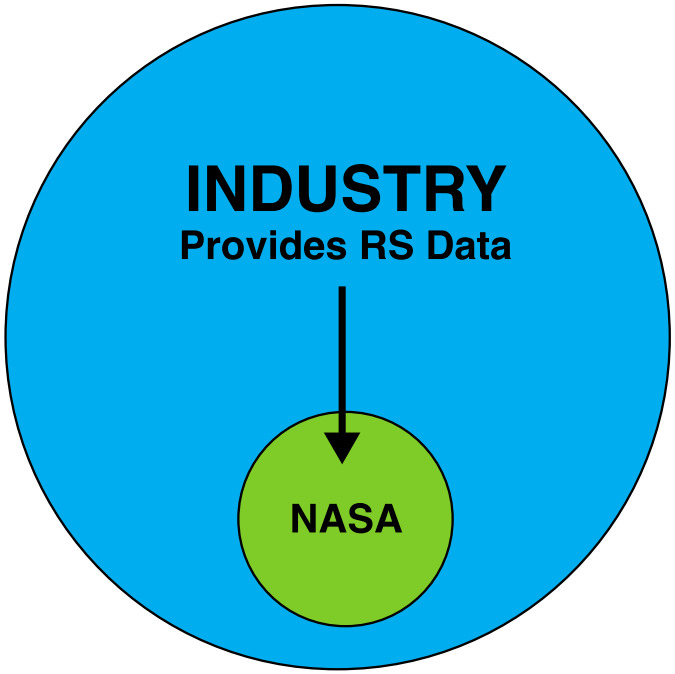
Information products

- SpaceKnow, Astro Digital, Orbital Insight, OmniEarth, …
- Coca Cola, Land-o-Lakes, General Mills, Monsanto, Nestle, …

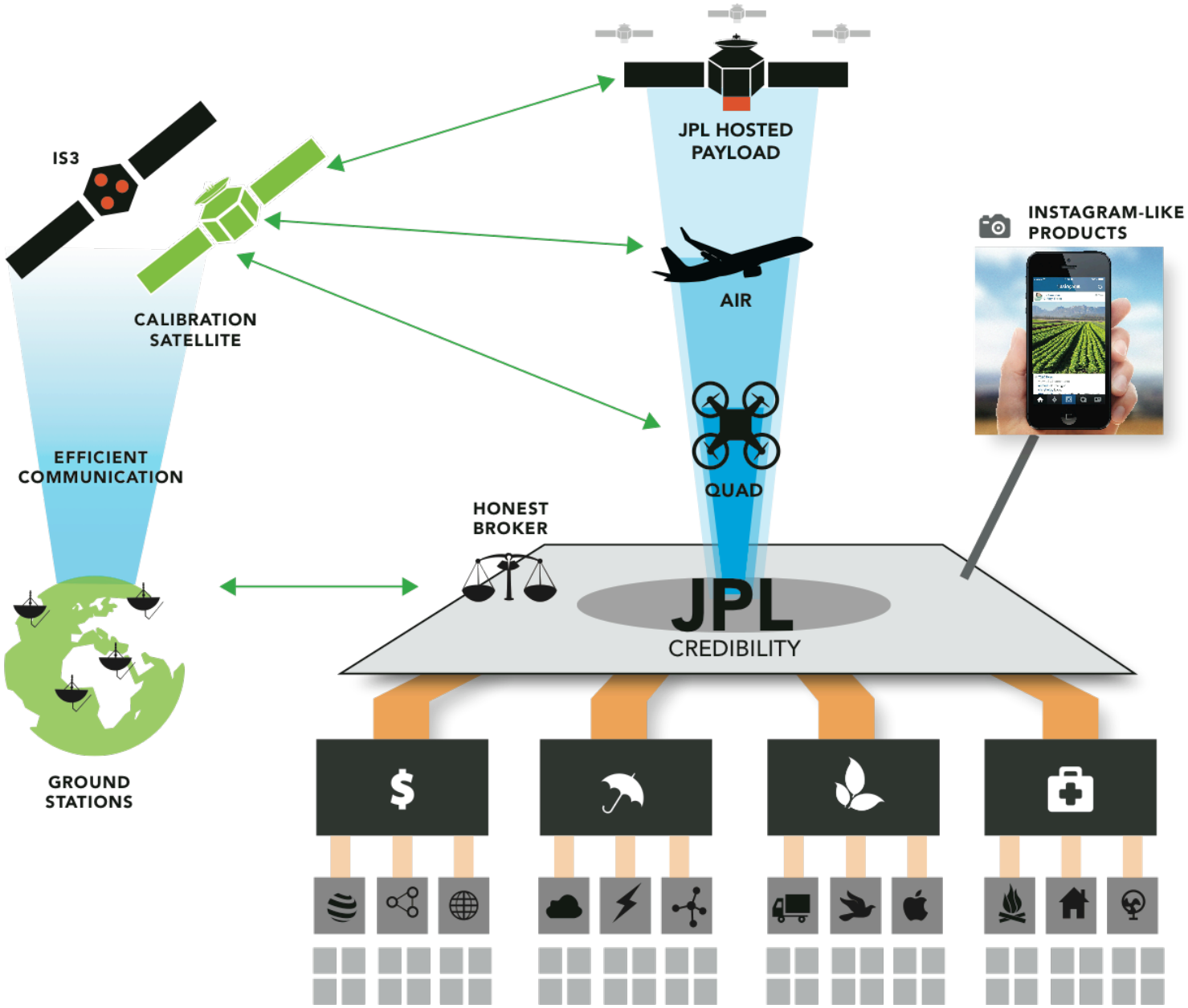
REMOTE SENSING FOR NON TRADITIONAL INDUSTRY

Monsato, Land O' Lakes, Home Depot, Etc.`





OLD **NEW**


IS3
CALIBRATION SATELLITE
JPL HOSTED PAYLOAD
AIR
QUAD
INSTAGRAM-LIKE PRODUCTS
EFFICIENT COMMUNICATION
HONEST BROKER
JPL
CREDIBILITY
GROUND STATIONS

Space 2.0 (Fact Finding)

- Made up of Venture capitalists, startups, and aerospace
  - RS, telecommunication, mining, and space manufacturing
- No new market demands for data
  - Absent on “ebay”, commodity exchange, our scientists to understand data
  - We are very fortunate to have a customer, our scientists
  - Launch cost will not be lower due to higher demands
  - Led mostly by spacecraft/instrument driven startups – no data expertise
  - Much like 1999 era (GeoEye, Ikonos, etc) with cubesats
    - $1,500/m^2 -> $15/m^2 -> $1/m^2
- JPL is perceived as a gold standard
- No bubble unless there is demand for information products from RS data

Consideration on Climate and Big Data

Jason Hyon, Duane Waliser, Dan Crichton

Jet Propulsion Lab

May 24, 2016

Earth Science and Society

- Population: 7B today -> 8B by 2025
- Water and Food scarcity will become more prominent – and demand more attention and more information.
- “Security” in US = (economic & energy security at home) +
  (food & water & natural disaster risk abroad) + residual
- GHG climate change “debate” over – even in the US. Debates will exist over adaptation and mitigation strategies and priorities.
- Overt geo-engineering conversations and proposed actions will exist.

Climate Continuity Measurements

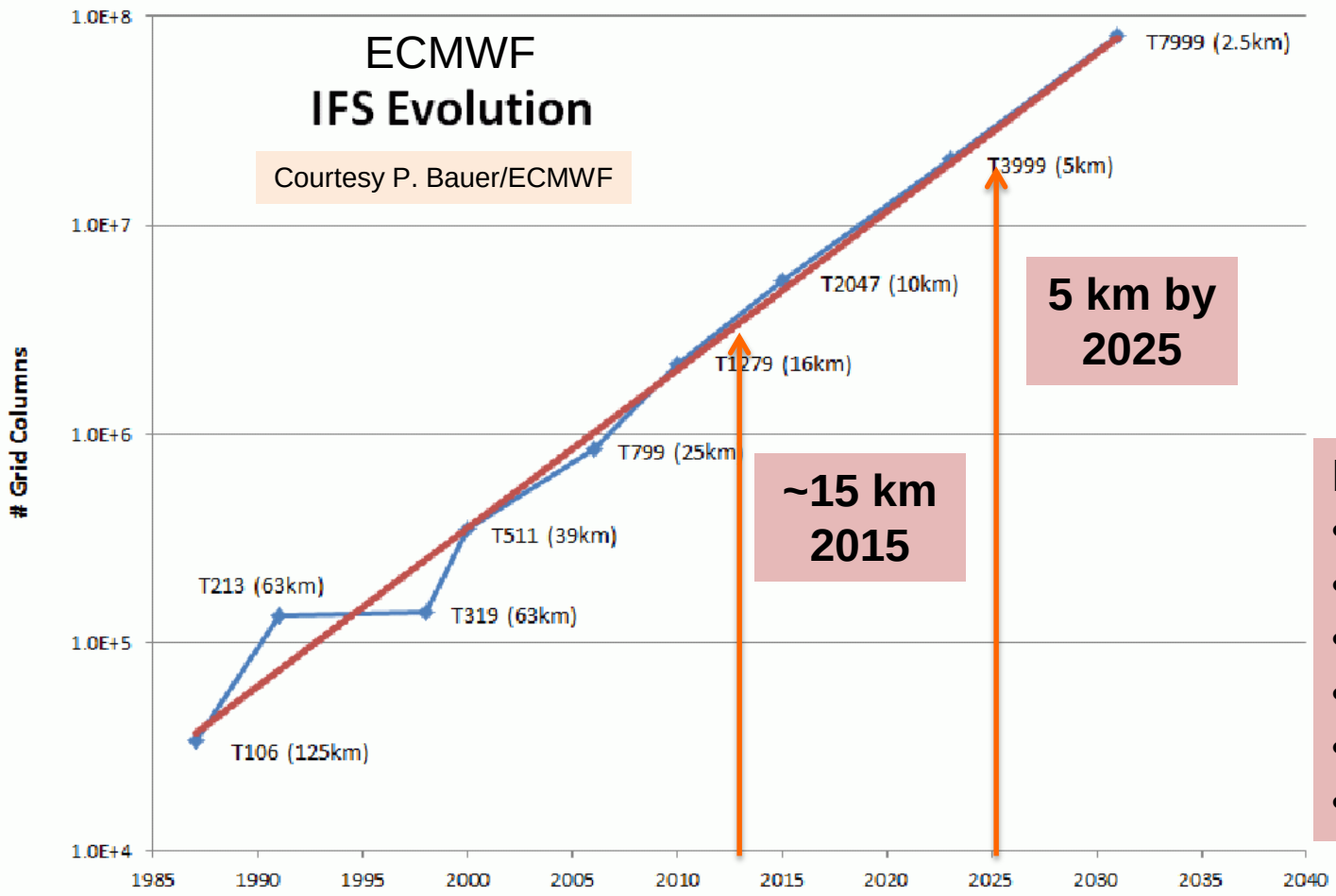
International Cooperation will have been or will nearly be established on a core set of climate continuity measurements (e.g. GEO, CEOS).

Domain	GCOS Essential Climate Variables
Atmospheric (over land, sea and ice)	**Surface:**[1] Air temperature, Wind speed and direction, Water vapour, Pressure, Precipitation, Surface radiation budget. **Upper-air:**[2] Temperature, Wind speed and direction, Water vapour, Cloud properties, Earth radiation budget (including solar irradiance). **Composition:** Carbon dioxide, Methane, and other long-lived greenhouse gases[3], Ozone and Aerosol, supported by their precursors[4].
Oceanic	**Surface:**[5] Sea-surface temperature, Sea-surface salinity, Sea level, Sea state, Sea ice, Surface current, Ocean colour, Carbon dioxide partial pressure, Ocean acidity, Phytoplankton. **Sub-surface:** Temperature, Salinity, Current, Nutrients, Carbon dioxide partial pressure, Ocean acidity, Oxygen, Tracers.
Terrestrial	River discharge, Water use, Groundwater, Lakes, Snow cover, Glaciers and ice caps, Ice sheets, Permafrost, Albedo, Land cover (including vegetation type), Fraction of absorbed photosynthetically active radiation (FAPAR), Leaf area index (LAI), Above-ground biomass, Soil carbon, Fire disturbance, Soil moisture.

- Surf & TOA Radiation Budget
- SST
- Column Water Vapor
- T(z), Q(z)
- Ocean Winds
- Sea Level Height
- Ozone
- CO_2 & Methane
- Aerosol
- Sea Level
- Ocean Color
- Gravity Anomalies / GRACE
- Bio Mass
- Soil Moisture
- Land Cover
- etc

Business – establishing benchmark, doing the same for less $ - OSSE capabilities key

Numerical Weather Prediction Grid Resolution



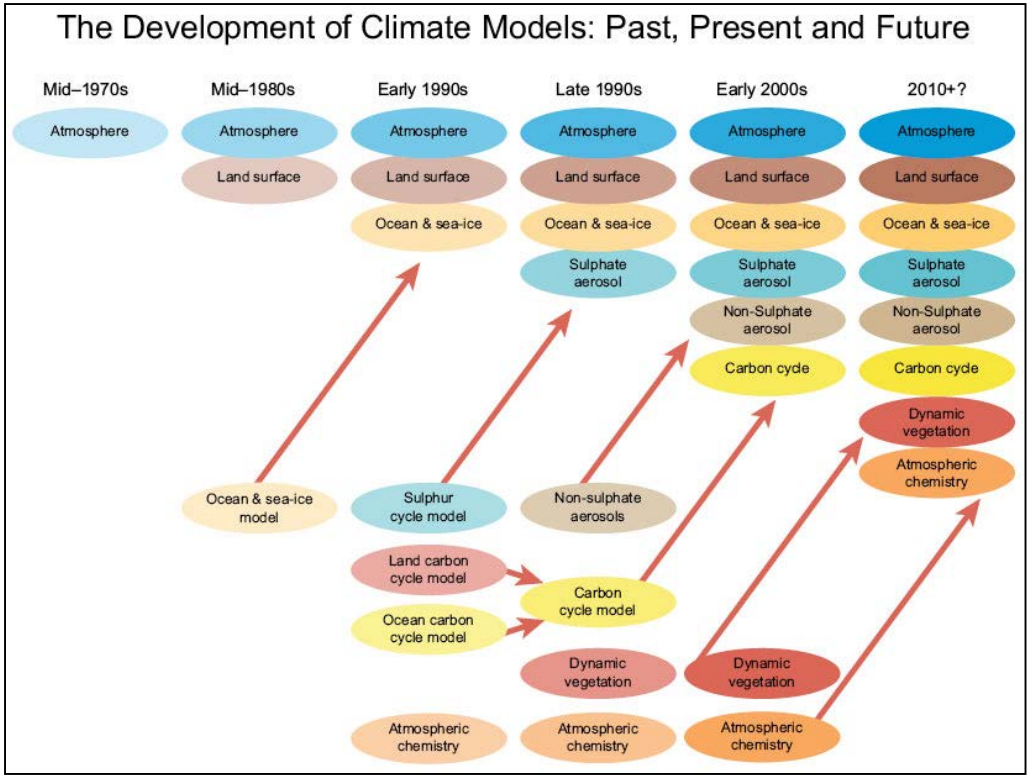
Global Numerical Weather Prediction (NWP) Models at **< 5km** Horizontal Grid Resolution

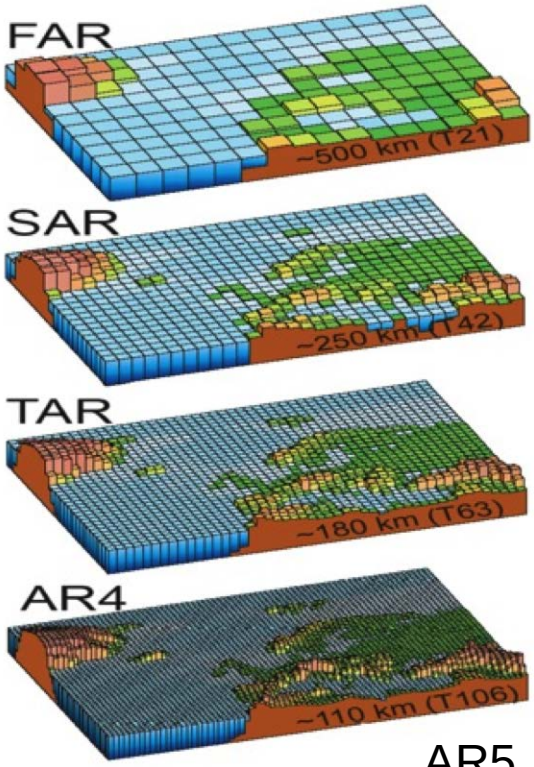
Forecast Expansions

- Longer Leads
- More Products
- More Sectors
- More of Earth Sys
- Better Accuracy
- Greater Reliance

Global Climate Modeling Grid Resolution

Continued development of "Earth System Models"





FAR	500km	1990
SAR	250km	1996
TAR	180km	2001
AR4	110km	2007
AR5	90km	2013
AR6	70km	2019
AR7	**50km**	**2025**

Earth System Science, Coupled Complexity and Need for Multi-variate Process Constraints

Weather/Climate Modeling - 2025

- Weather Forecasting -> Environmental Forecasting at 5km
  Additional emphasis - multi-variate input for assimilation of chemistry, aerosol, land surface and vegetation conditions

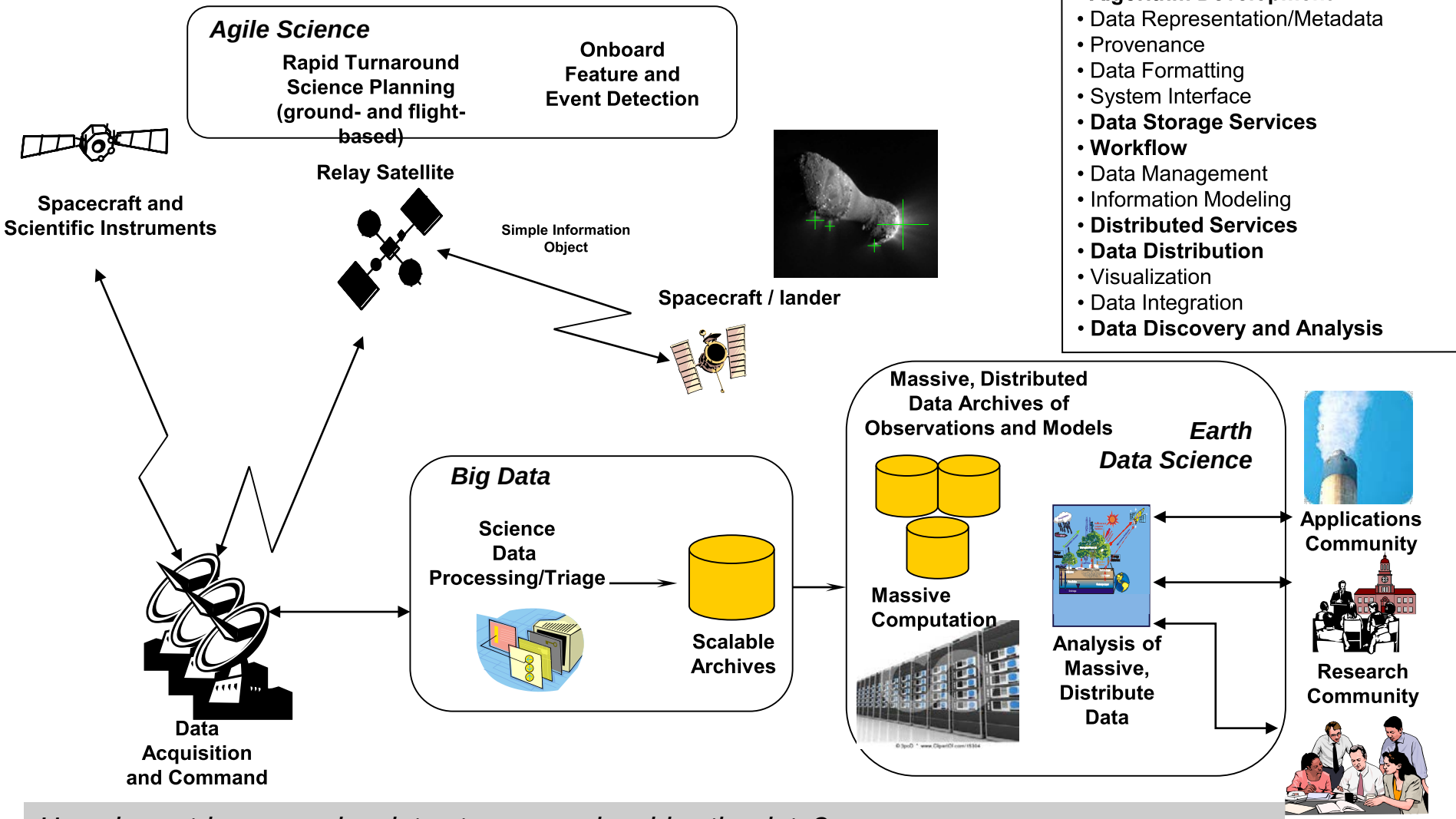
- Climate Modeling -> Earth System Modeling at 50km
  Additional emphasis - multi-variate constraints for developing/evaluating Earth System Processes for chemistry, carbon & water cycles, aerosol, land surface and vegetation conditions and their interactions

- Seamless Prediction –
  Models and prediction systems will more seamlessly blend conventional time scales [*Weather (1-10 days), Subseasonal (2-4 weeks), Seasonal (1-3 months), Decadal (5-20 years)]* and more directly predict environmental/earth system information

Big Data Viewpoint

BIG DATA CONSIDERATIONS

- **Data Processing/Computation**
- Data Triage
- **Algorithm Development**
- Data Representation/Metadata
- Provenance
- Data Formatting
- System Interface
- **Data Storage Services**
- **Workflow**
- Data Management
- Information Modeling
- **Distributed Services**
- **Data Distribution**
- Visualization
- Data Integration
- **Data Discovery and Analysis**



How do we triage massive data streams and archive the data?
How do we quickly update observation plans in response to understanding of newly acquired science data, especially for time-limited missions?
How can we use advanced data science methods to systematically derive scientific inferences from massive, distributed earth science measurements and models?

Summary

Strategic Considerations for 2025

- Synergistic use of multi-variate observations – environmental prediction & earth system science
- Most science / decision-making value/return for investment – our ability to quantify or do relative comparison on this is poor.
- Practical concerns of observations will completely outweigh curiosity driven science; and science will be a means only to pragmatic and immediate societal benefits

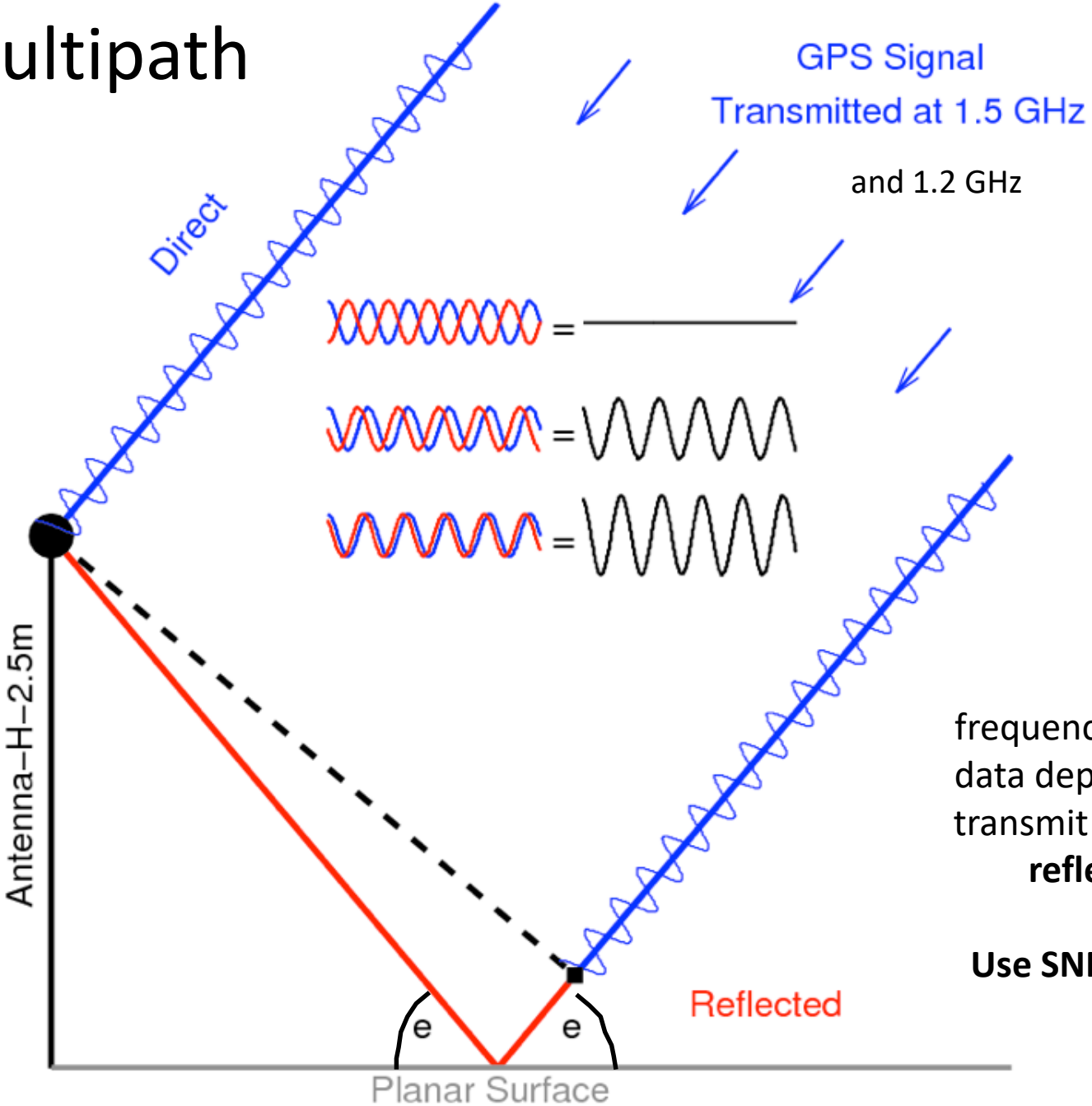
GNSS H2O: Expanding Reflection Research to the Global GNSS Network For Measuring the Water Cycle

Susan Owen

JPL

Kristine Larson (CU Boulder), Angie Moore (JPL), Sean Hardman (JPL), Cynthia Wong (JPL), Eric Small (CU Boulder)

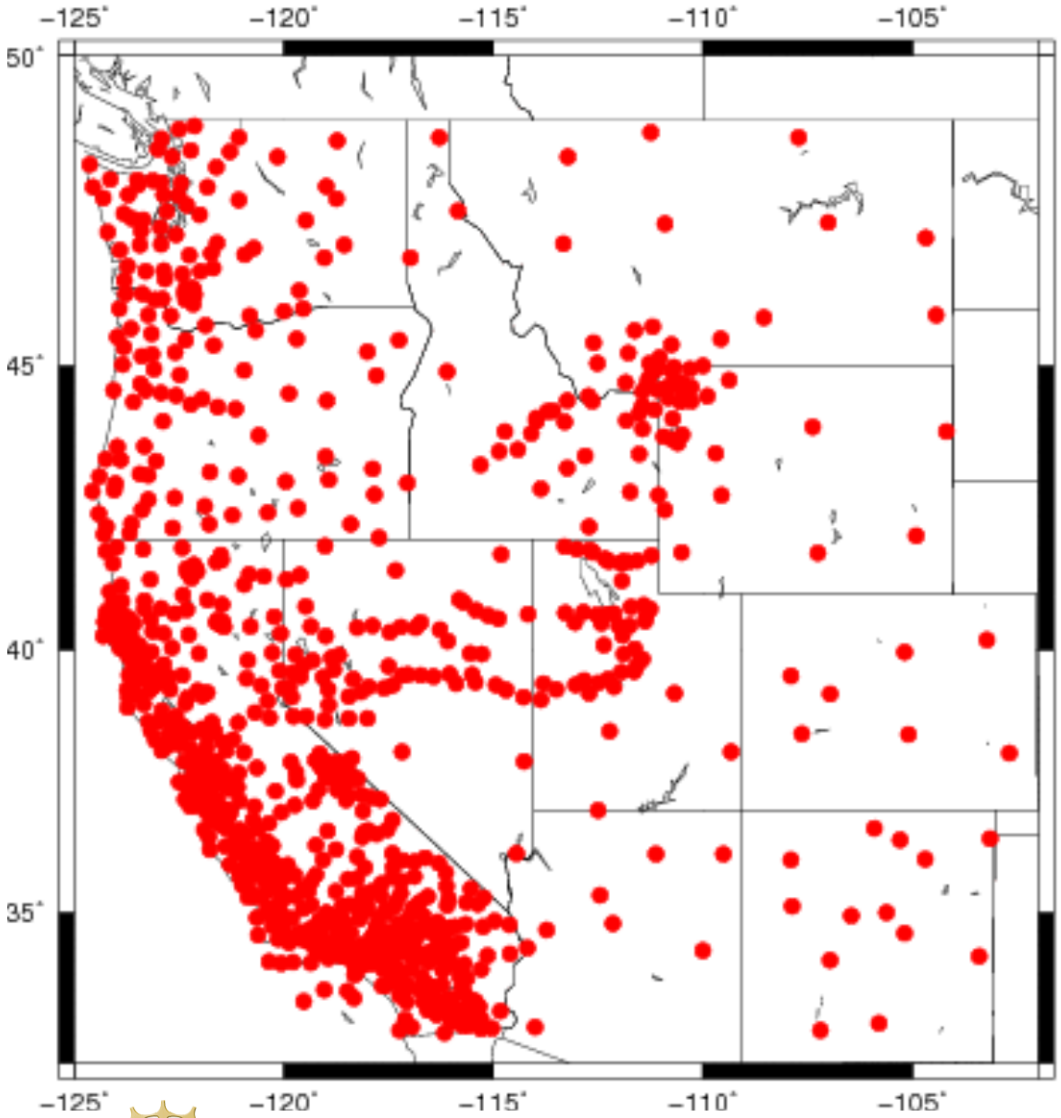
Multipath

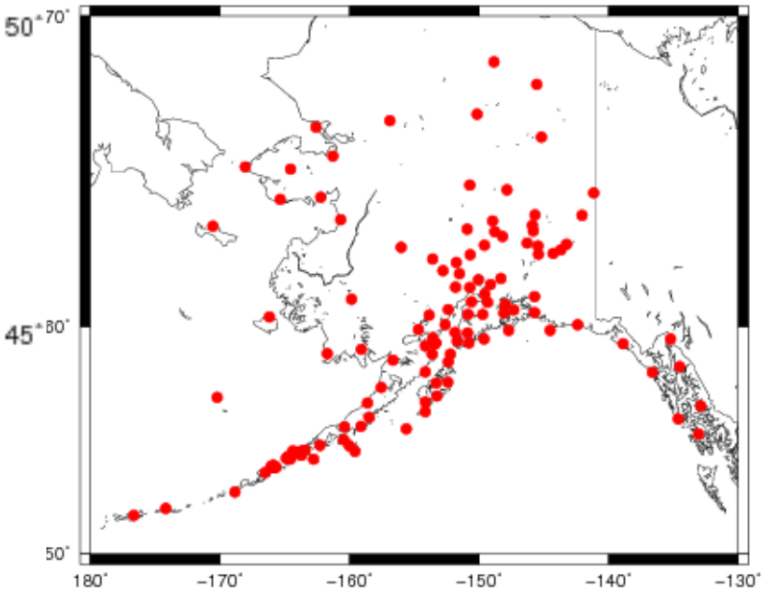


frequency of signal strength data depends on **H**, the GPS transmit **frequency**, and the **reflecting medium**

Use SNR data for GPS L2C

EarthScope Plate Boundary Observatory (PBO)





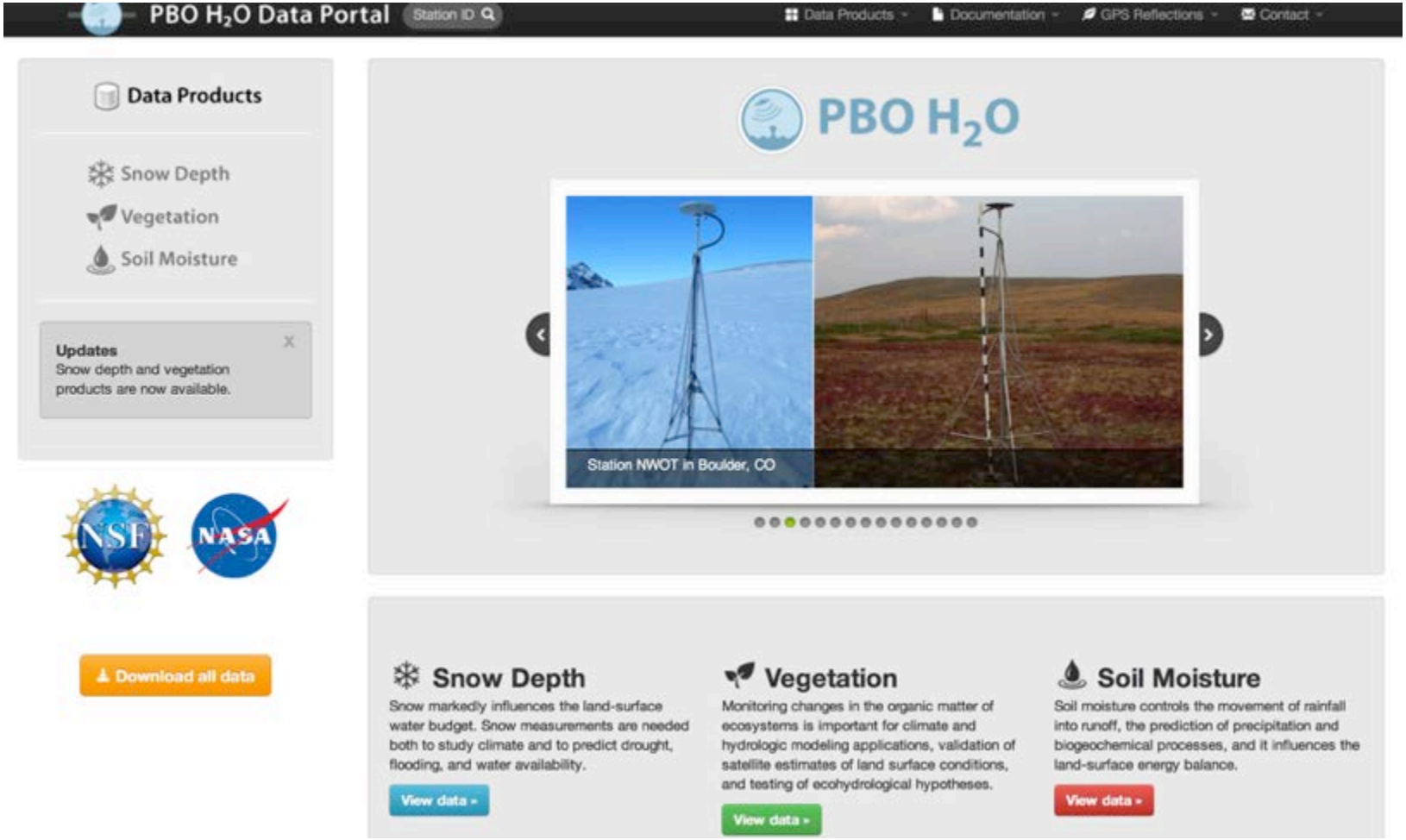
1100 continuously-operating GPS receivers - deployed to measure ground motions from plate tectonics, earthquakes, and volcanos.

Data are <u>freely available</u> (often in real-time) and are used by Earth scientists and surveyors.

PBO data are archived at UNAVCO

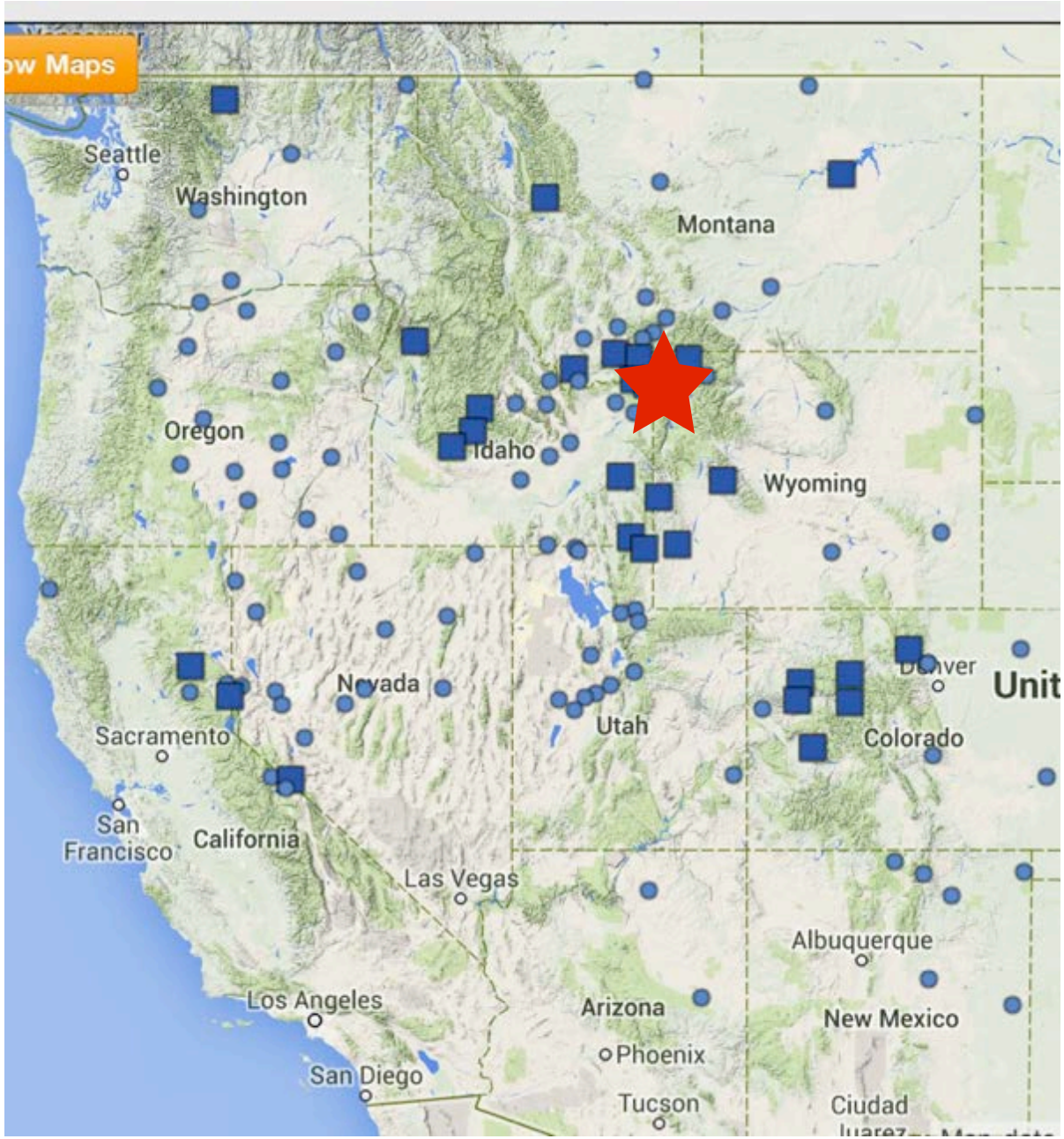
PBO H_2O

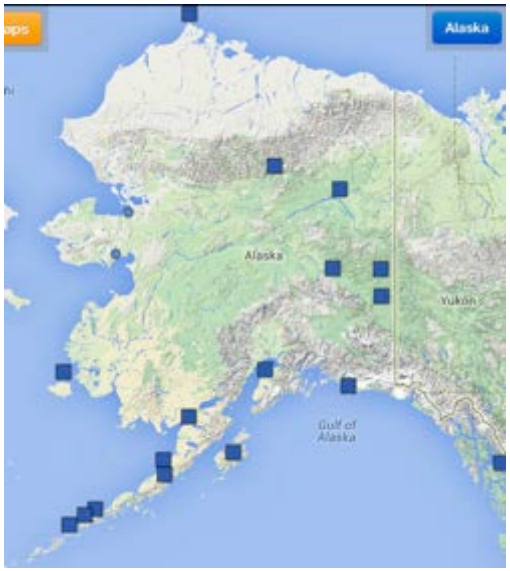
Using GPS reflection data from NSF's Plate Boundary Observatory (PBO) to study the water cycle

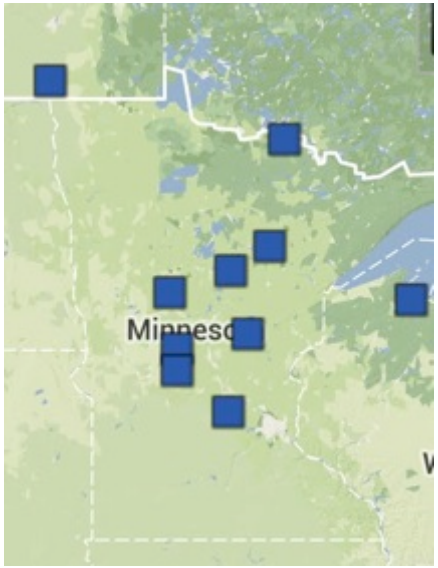


http://xenon.colorado.edu/portal

Measuring Snow

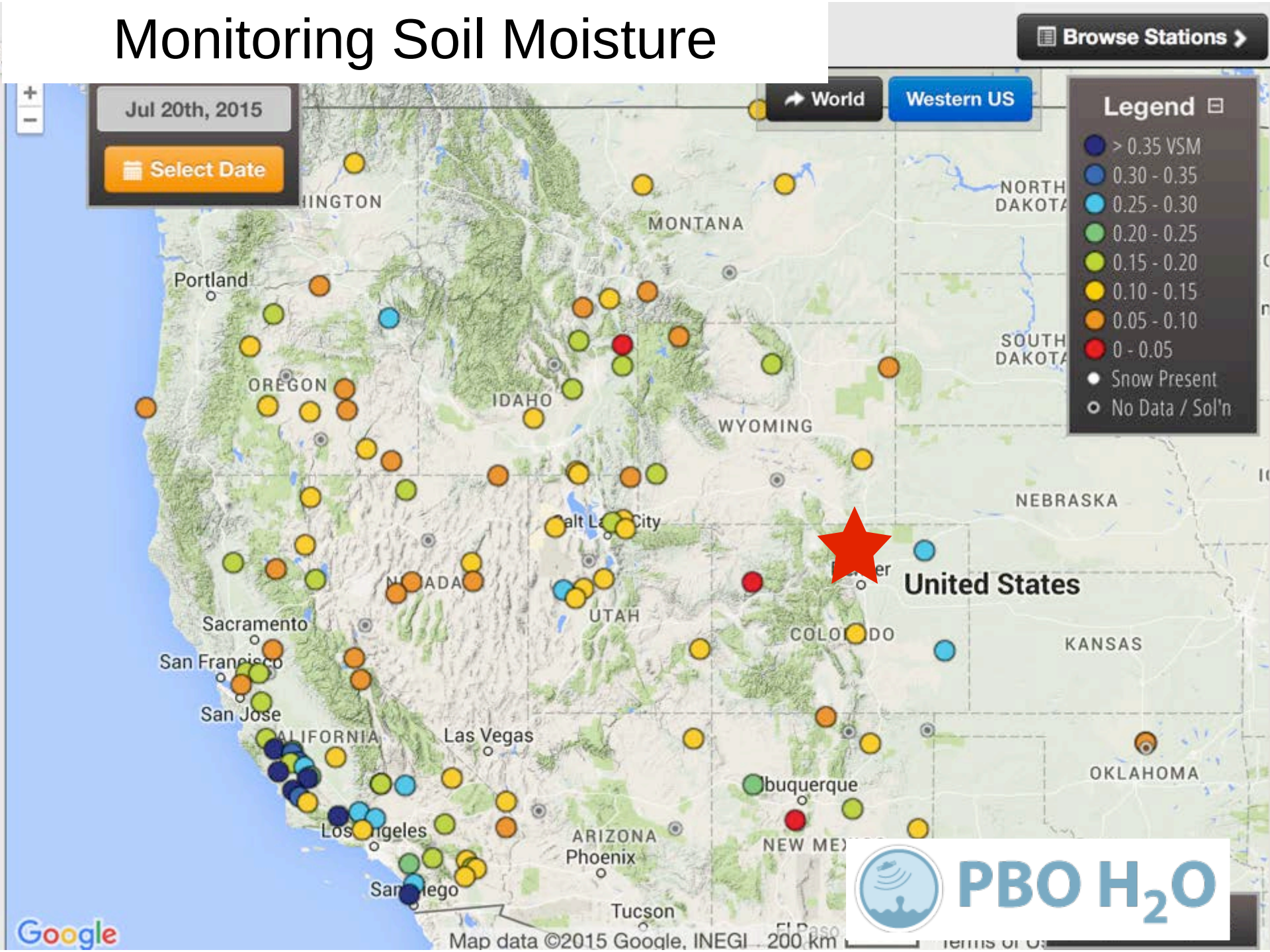




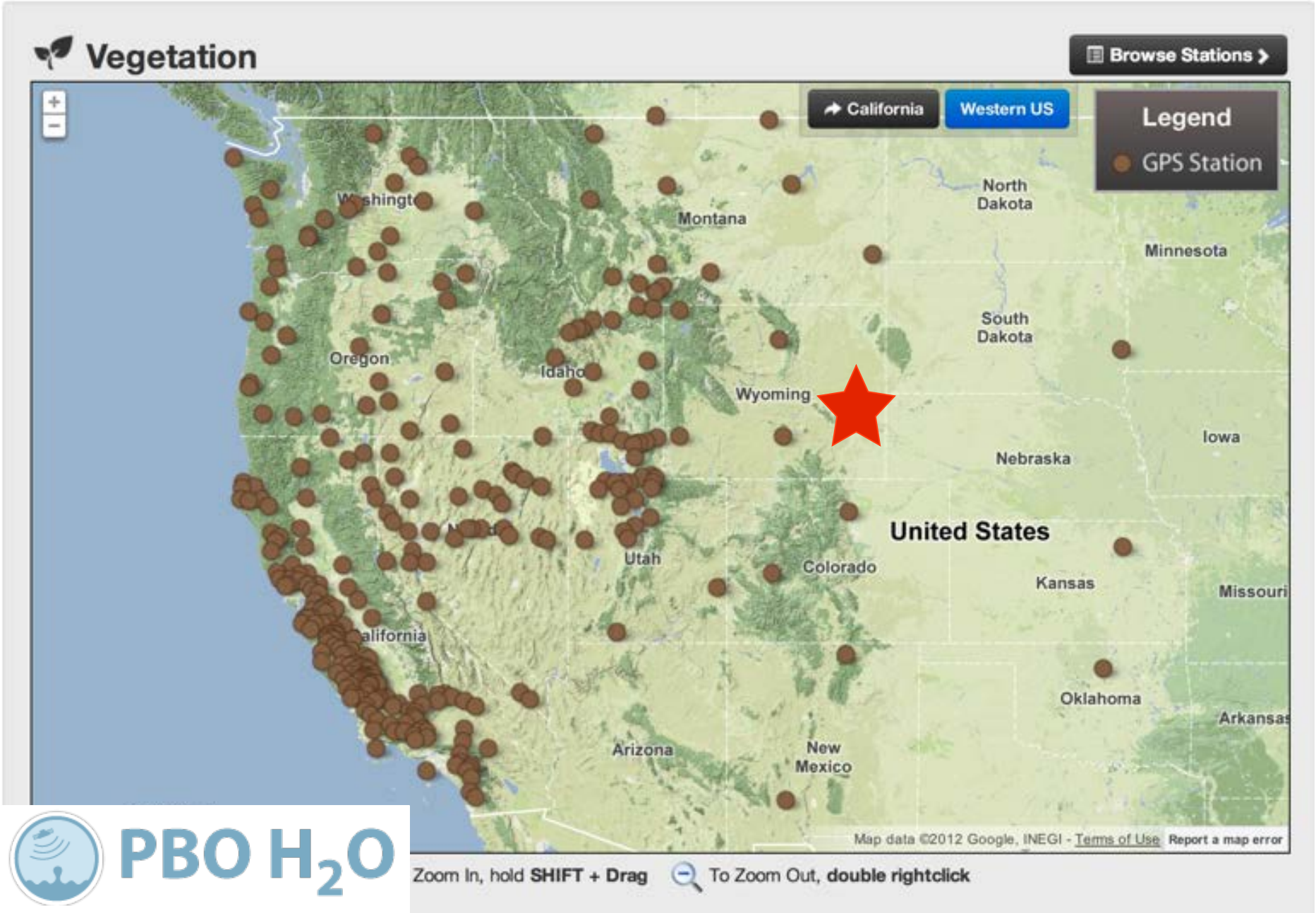


PBO H_2O

Monitoring Soil Moisture



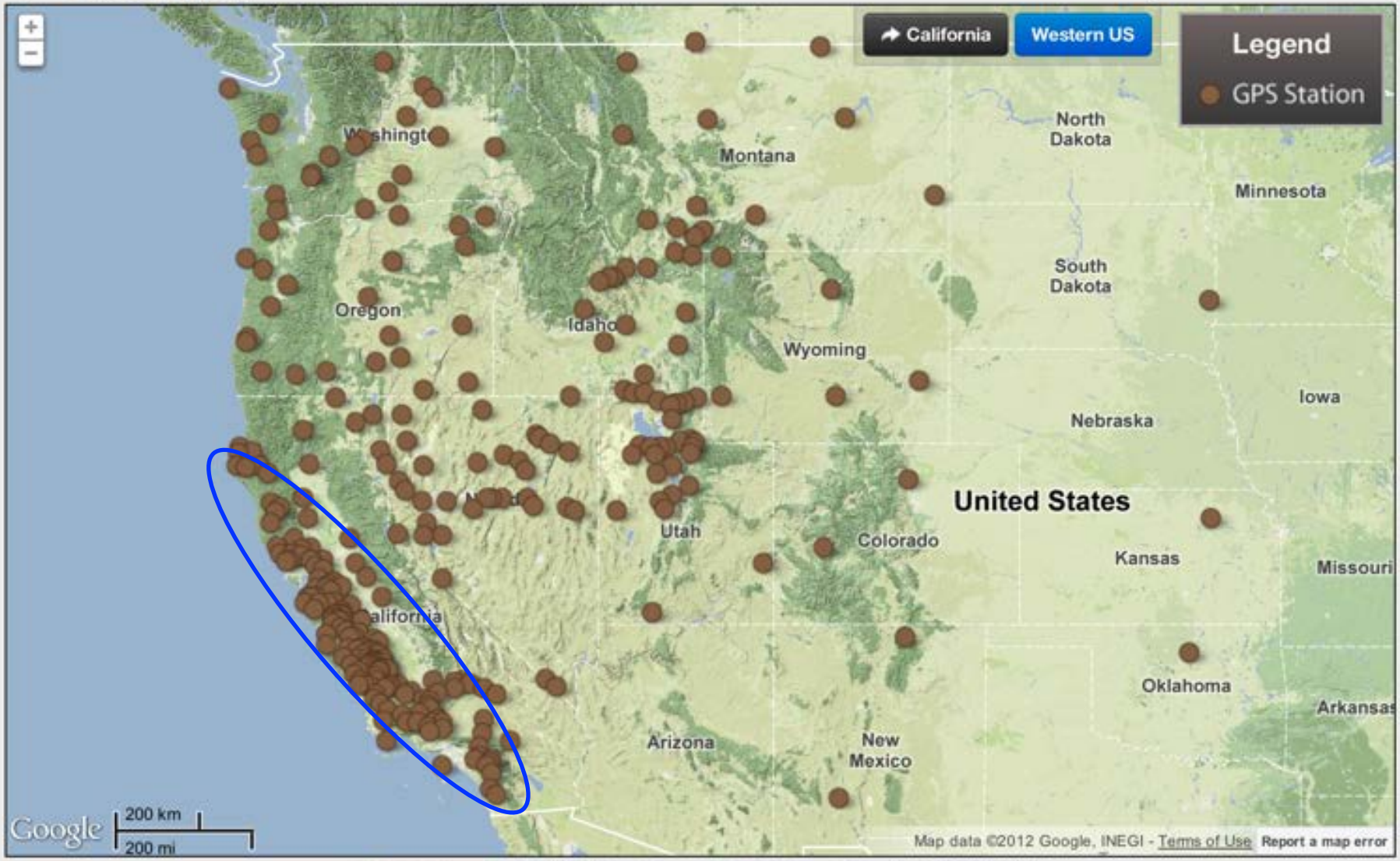
Monitoring Vegetation Water Content



PBO H_2O

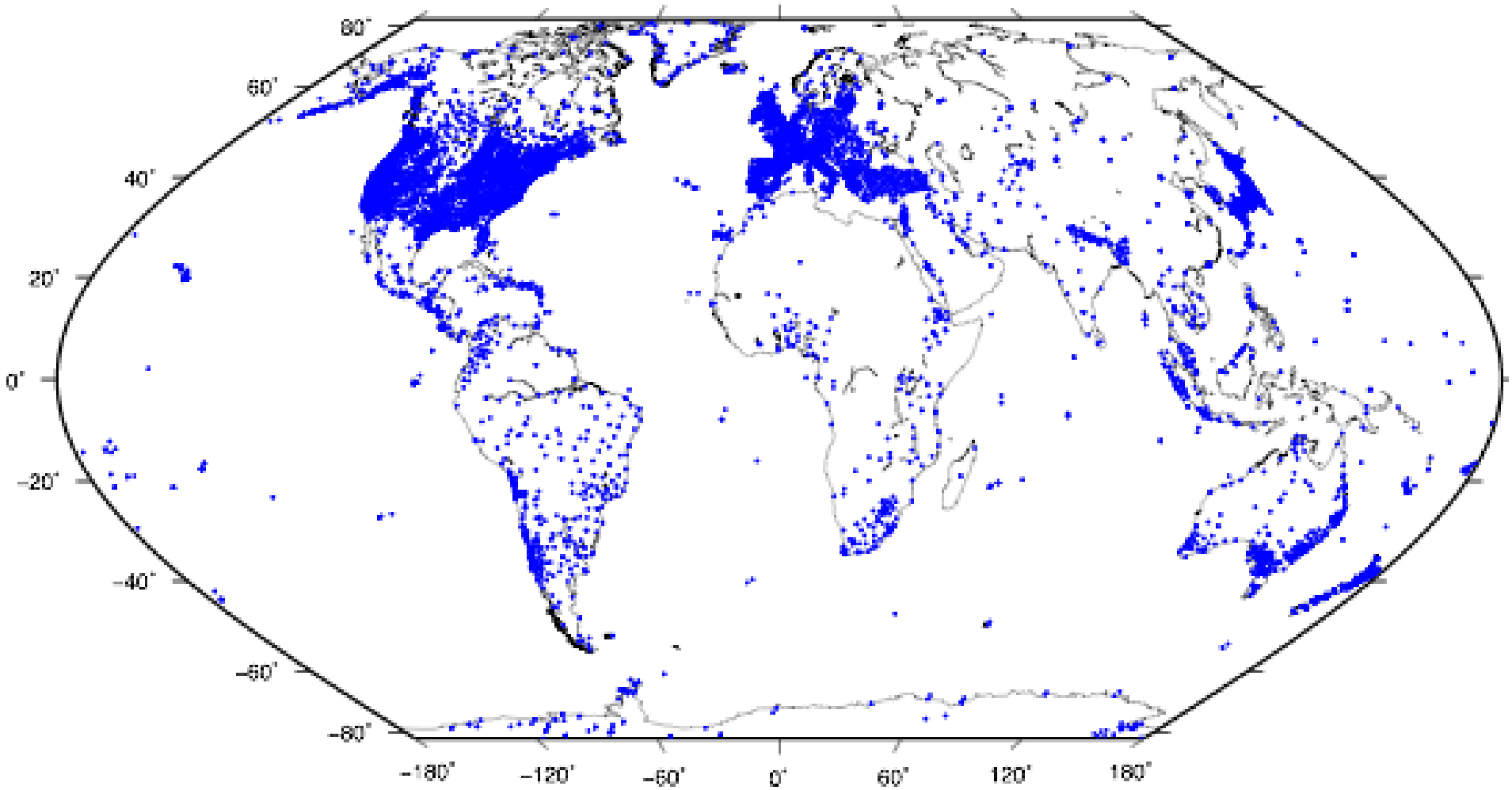
Vegetation

Browse Stations



To Zoom In, hold **SHIFT + Drag** To Zoom Out, **double rightclick**

Going Global: Automating Data Ingestion to bring in diverse GPS Networks



Coming Soon: GNSS H2O

Upcoming IT Challenges

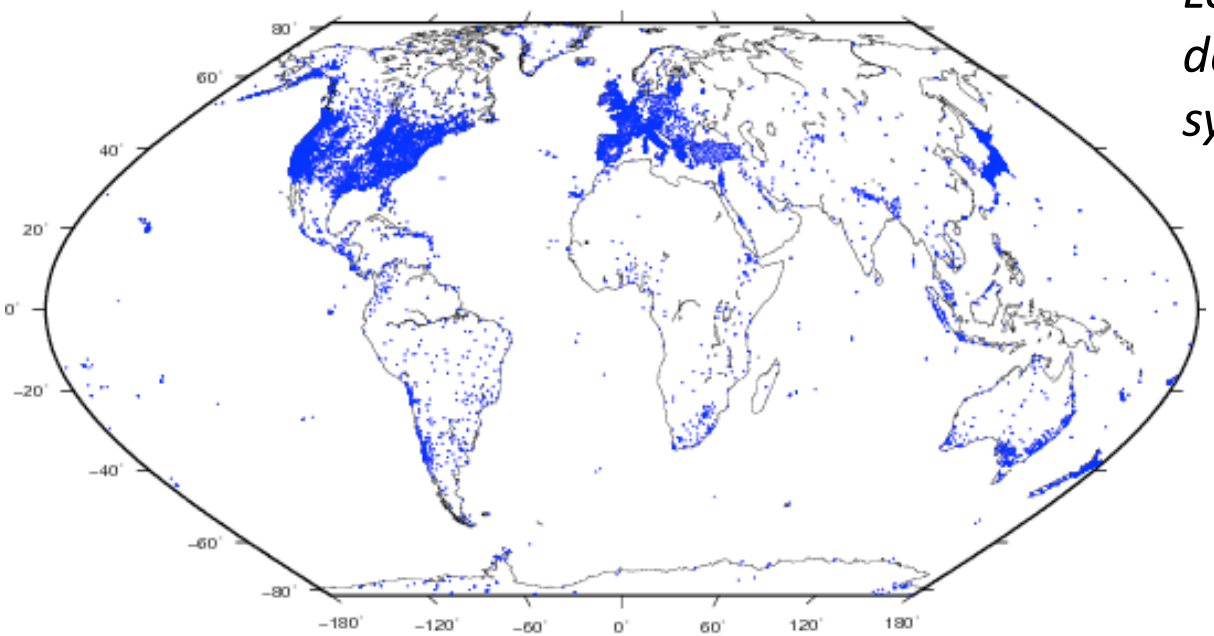
The global GNSS network consists of more than 12,000 stations operated by hundreds of different agencies at a variety of scales (global, regional).

No one archive has all GNSS data. Data formats are well defined, but require that operators use special options when making those data files to be useful for reflection applications.

We need a metadata system that operates in both directions – ingesting data from these networks and communicating to those operators what is needed for a proper GNSS reflection site.

Summary

- PBO H_2O is now 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 will provide a global dataset of *in situ* climate data and satellite validation data.
- GNSS H_2O will expand PBO H_2O, professionalizing the code so that it can operated with many networks and users. An automatic station evaluator will also be developed.



- *Looking for global network data to test GNSS H_2O system.*

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