Ground GNSS Disaster Monitoring, Crustal Deformation, Extreme Weather, & Other Applications: Community-ready Products and Technology Advancement

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[1]Jet Propulsion Laboratory, California Institute of Technology
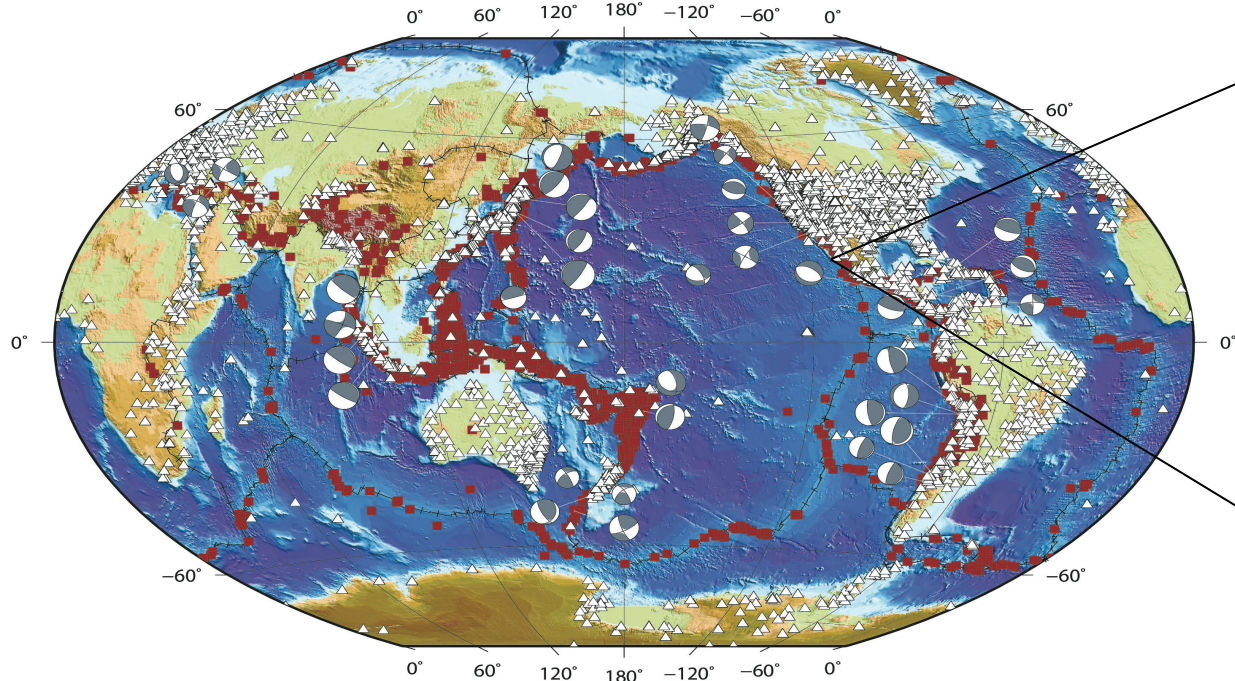[2]Scripps Institution of Oceanography, UC San Diego
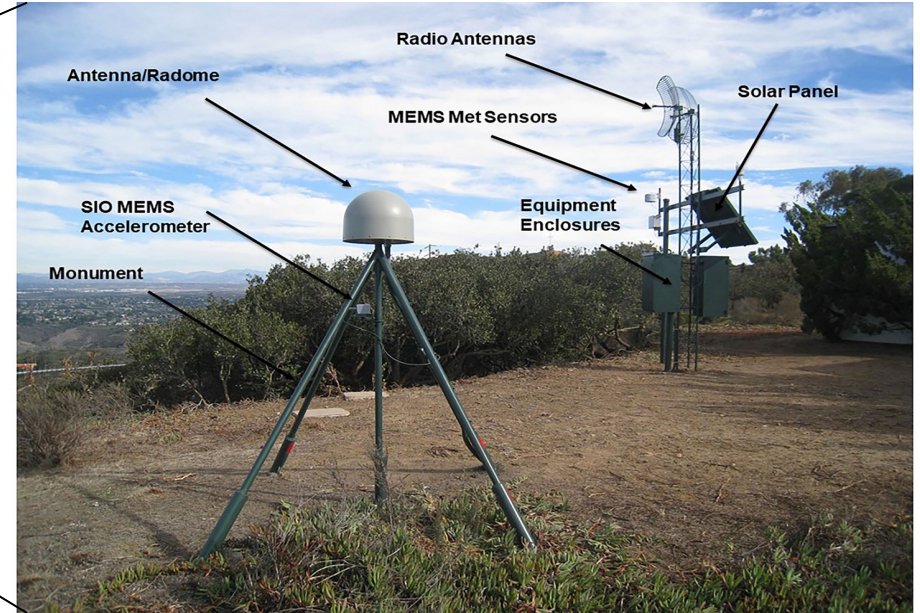
Presented by: Zhen Liu

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Jet Propulsion Laboratory
California Institute of Technology

Continuous GNSS Infrastructure

Typical continuous GNSS station. Deeply-anchored braced monument and antenna/radome of station SIO5 in La Jolla, California for monitoring tectonic plate boundary deformation, GNSS meteorology and hydrology. The monument's vertical leg contains a MEMS accelerometer used for seismogeodesy. In the background are equipment enclosures, solar panels, a radio antenna and meteorological instruments. (photo by D. Glen Offield).

Continuous GNSS stations established for global and regional geodetic applications, earthquakes greater than magnitude five (brown squares) since 1990, major tectonic plate boundaries (black lines), and earthquake centroid moment tensor (CMT) solutions for significant earthquakes observed by GNSS over the last 30 years. (prepared by Dara Goldberg)

Earthquakes   **Tsunamis**   **Drought**   **Subsidence**

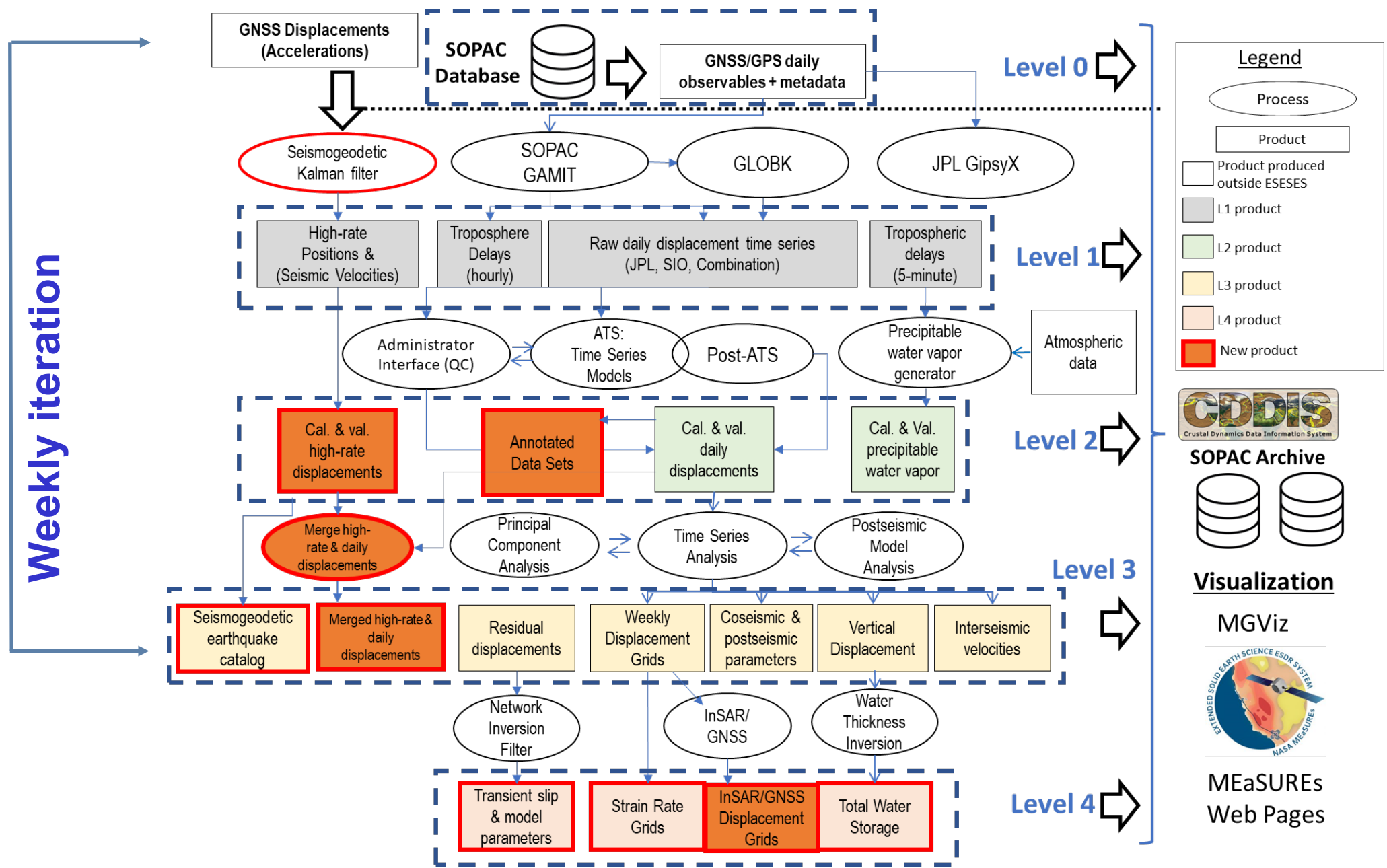**Landslides**   **Sea Level Rise**   **Flooding**   **Atmospheric Rivers**   **Volcanoes**
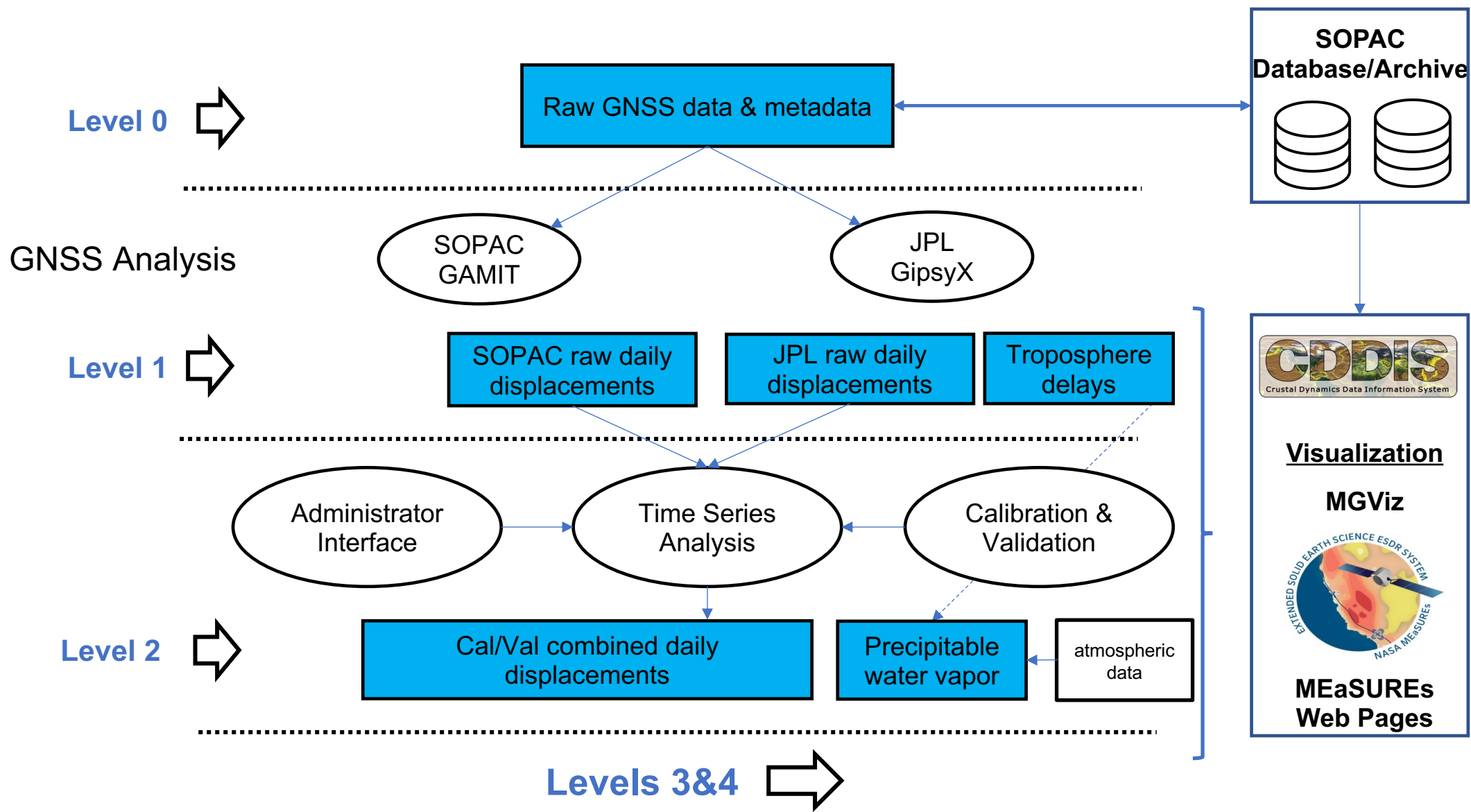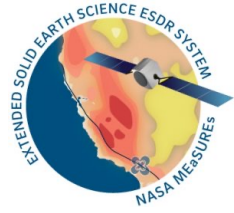
Summer Monsoon
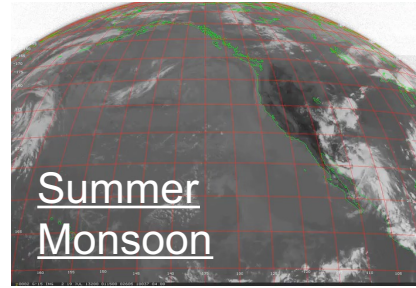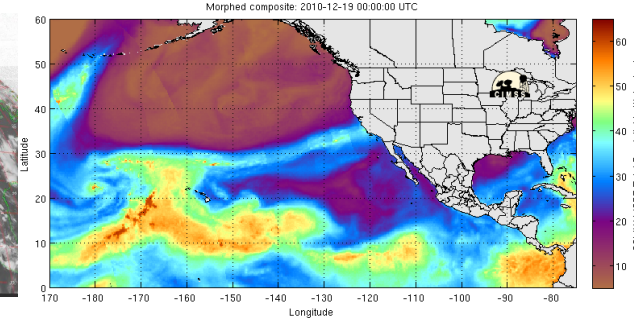
In this talk, we review our hierarchy of mature data products, supported by a ROSES MEaSUREs-17 project and predecessors, which are ready to address increasingly frequent and extreme natural and anthropogenic hazards, as well as ongoing technology improvements in a ROSES AIST-21 project.

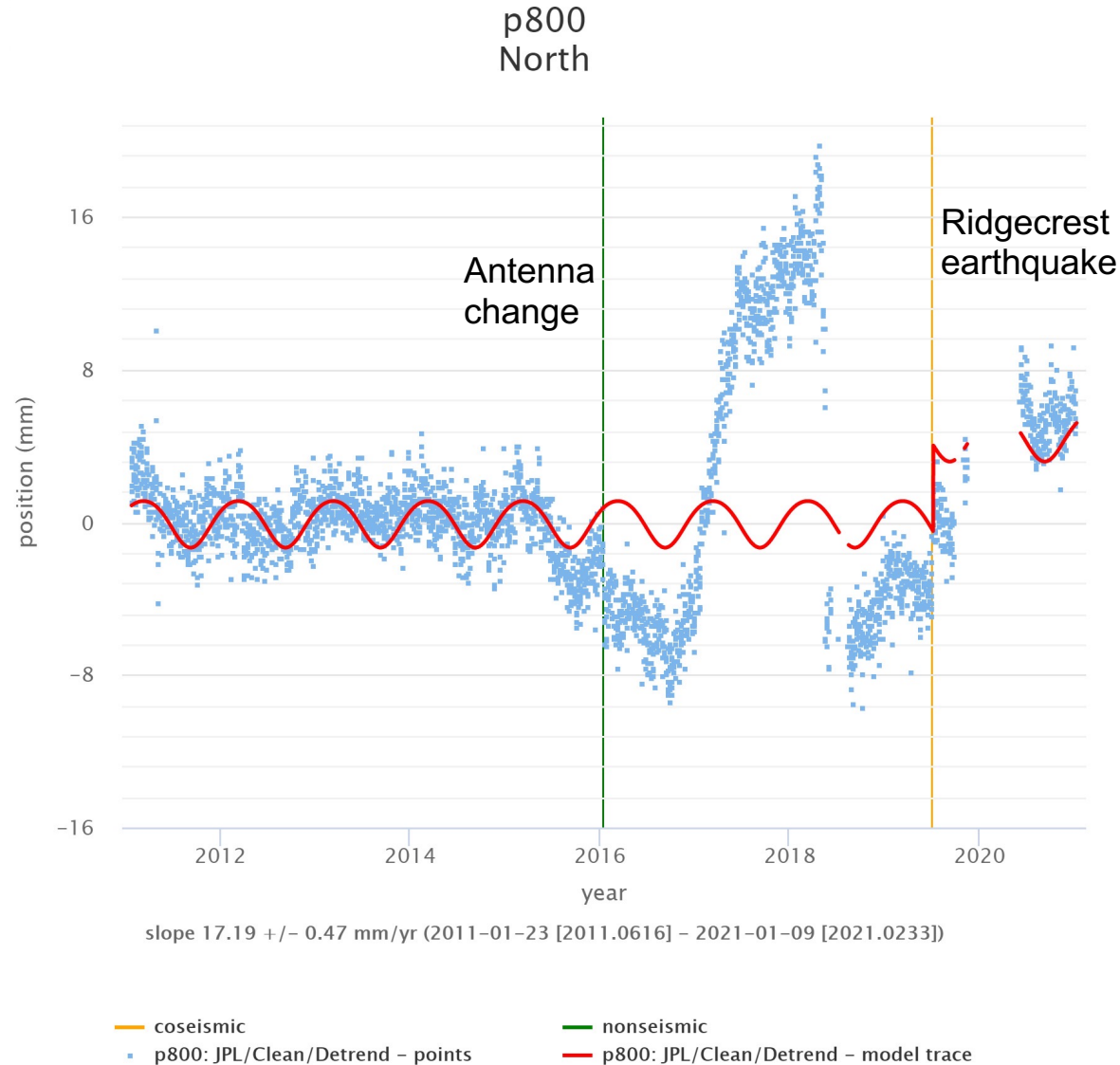MEaSUREs Extended Solid Earth Science ESDR System (ES3) product hierarchy

Weekly iteration

MEaSUREs ESESES Products
Levels 0-2

Level 0

Raw GNSS data & metadata

SOPAC Database/Archive

GNSS Analysis

SOPAC GAMIT

JPL GipsyX

Level 1

SOPAC raw daily displacements

JPL raw daily displacements

Troposphere delays

CDDIS
Crustal Dynamics Data Information System

Administrator Interface

Time Series Analysis

Calibration & Validation

Visualization

MGViz

Level 2

Cal/Val combined daily displacements

Precipitable water vapor

atmospheric data

EXTENDED SOLID EARTH SCIENCE ESDR SYSTEM
NASA MEaSUREs

MEaSUREs Web Pages

Levels 3&4

Level 1 product – displacement time series (QC is essential for down-stream products!)
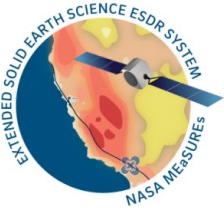
Source: MGViz project portal

p800 North

Antenna change

Ridgecrest earthquake

position (mm)

16

8

0

−8

−16

2012   2014   2018   2020

year

slope 17.19 +/− 0.47 mm/yr (2011−01−23 [2011.0616] − 2021−01−09 [2021.0233])

— coseismic
— nonseismic
· p800: JPL/Clean/Detrend – points
— p800: JPL/Clean/Detrend – model trace

2017-2018

17 May 2018

Photos courtesy of UNAVCO/EarthScope NOTA Station P800, Los Angeles
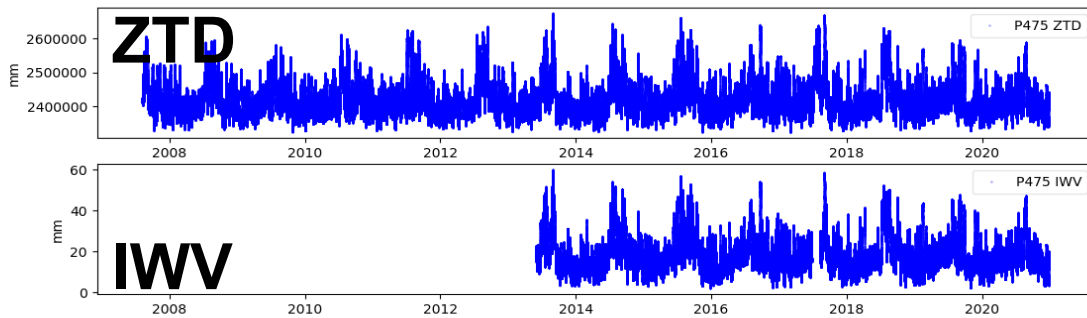
6

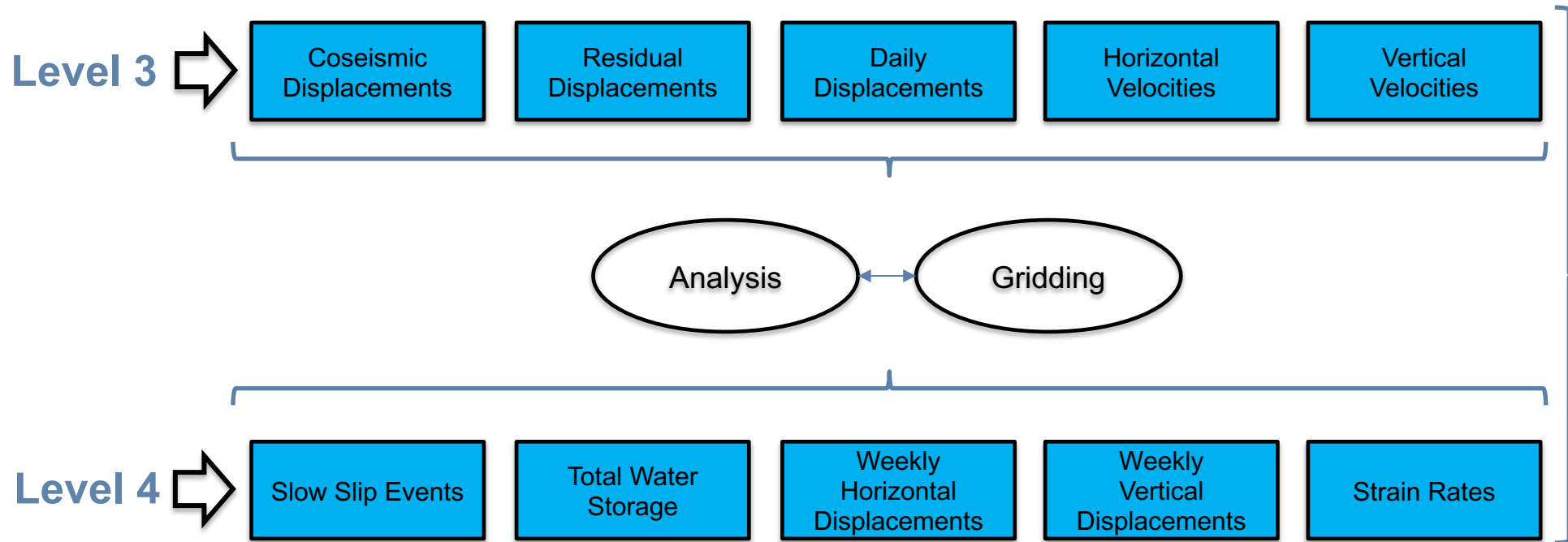# Level 2 ESDR – Cal/Val daily displacement time series (detrended)
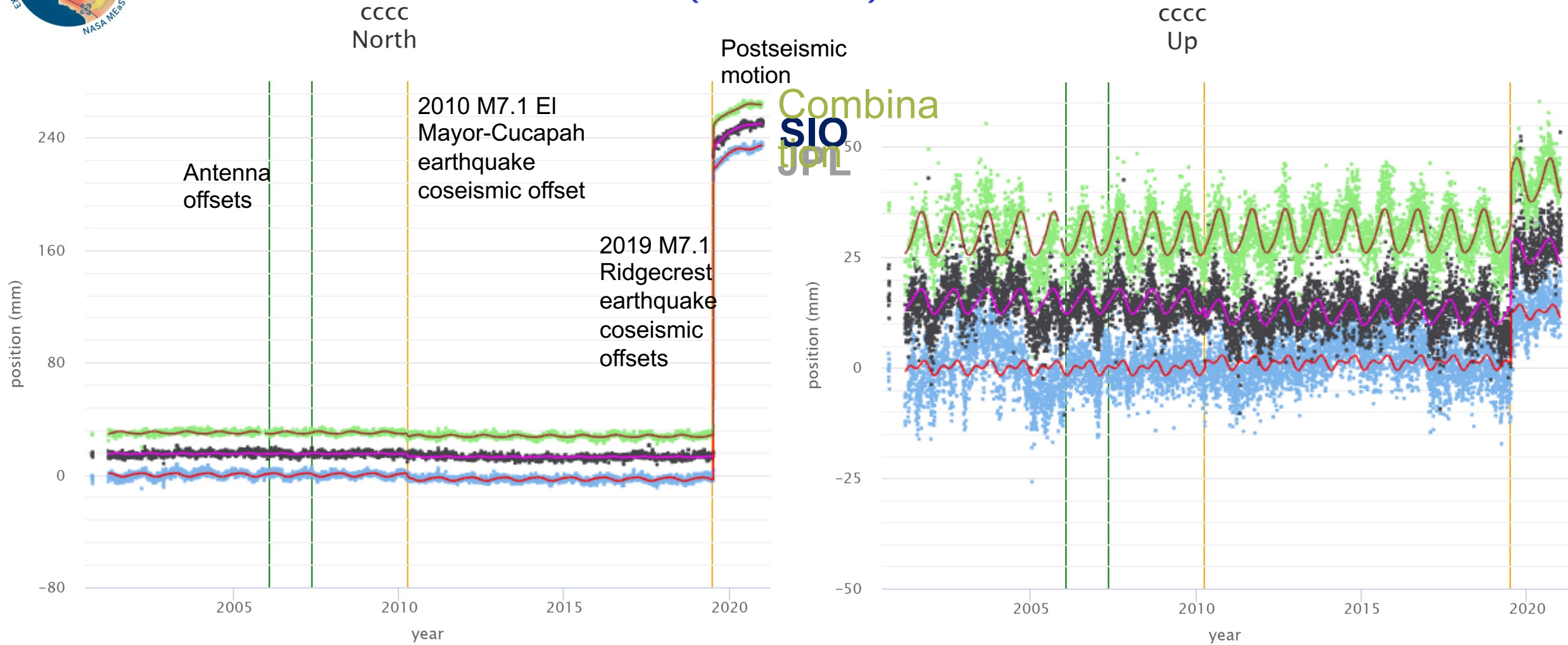
Level 2 product: Cal/Val Troposphere delay (ZTD) & integrated water vapor (IWV)

oldest ZTD since 1992, oldest IWV since 1995
tracking the troposphere on both short (5 minutes to days) and long (years to decades) timescales

MEaSUREs ESESES Products
Levels 3-4

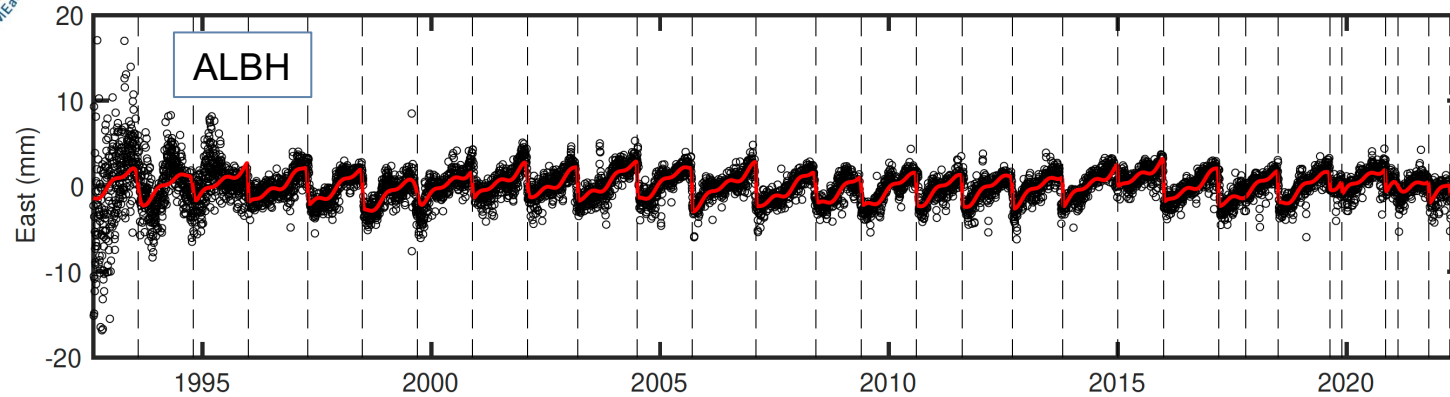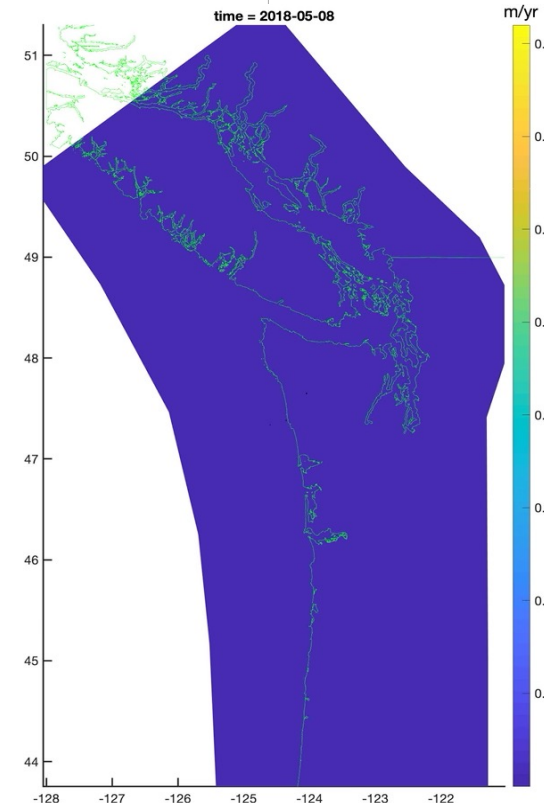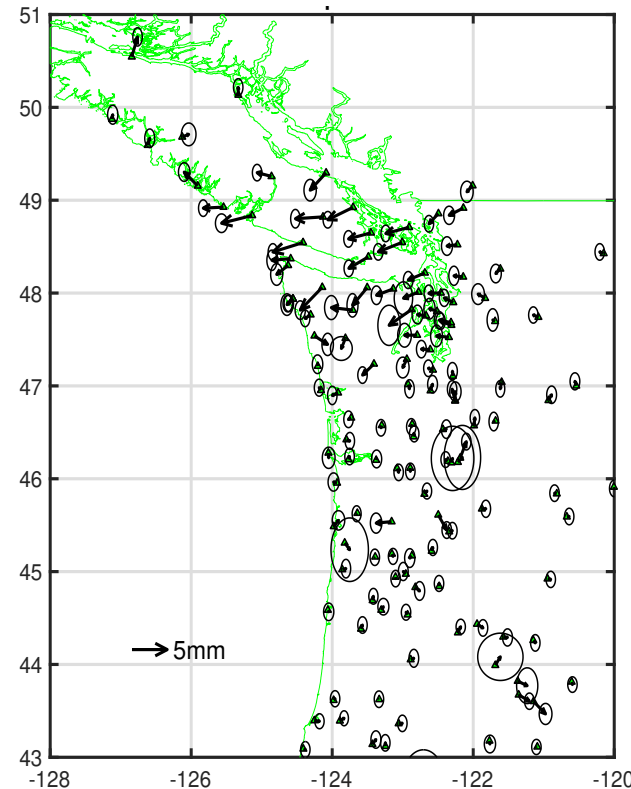# Level 4 product – Residuals displacement time series
Episodic Tremor and Slip (ETS) events

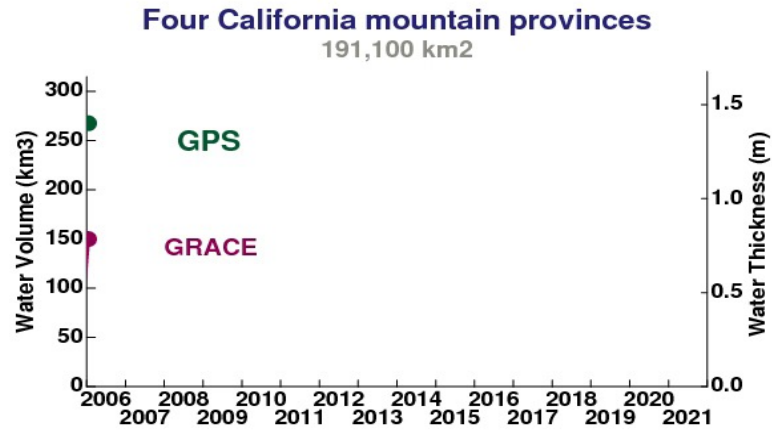**Fault slip models are very sensitive to the quality of level 2 displacement time series!!!**

Science benefits

- Investigate what physical processes underlie slow slip and tremor generation
- Study the connection between time-varying ETS processes and large earthquakes
- Provide constraints on frictional properties of fault zones when combined with physics based rate-and-state models
- Assess any systematic ETS variability throughout an earthquake cycle and its potential for forecasting future M9 megathrust earthquakes in Cascadia and/or other subduction zones
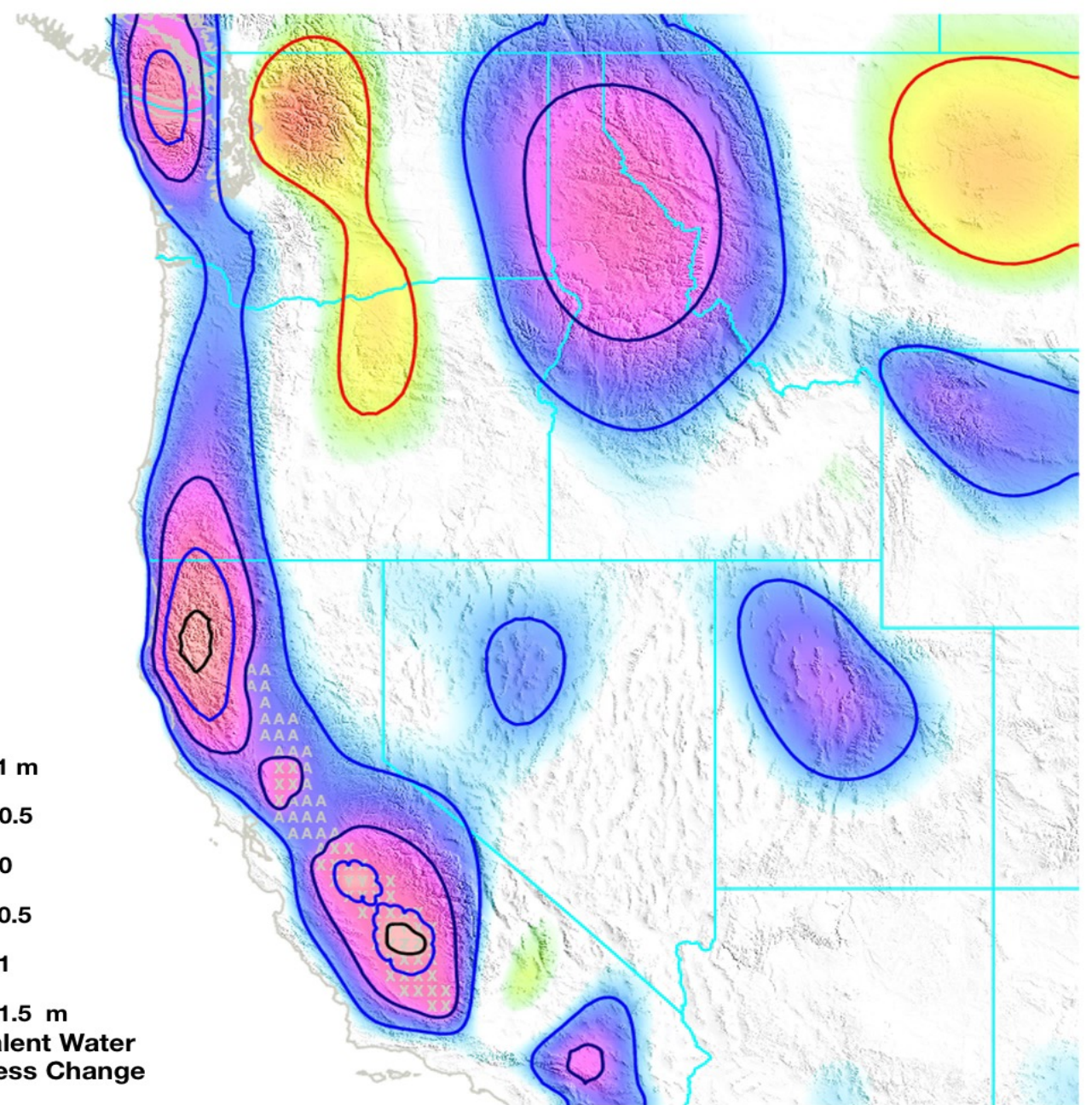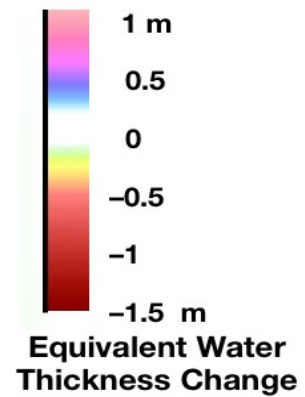
Change in Total Water Storage

Relative to Jan. 2011

January 2006

Inversion of GPS vertical displacements yields water change

MGViz product viewer (mgviz.ucsd.edu) leverages the open source MMGIS technology originally developed to visualize Mars rover instrument data
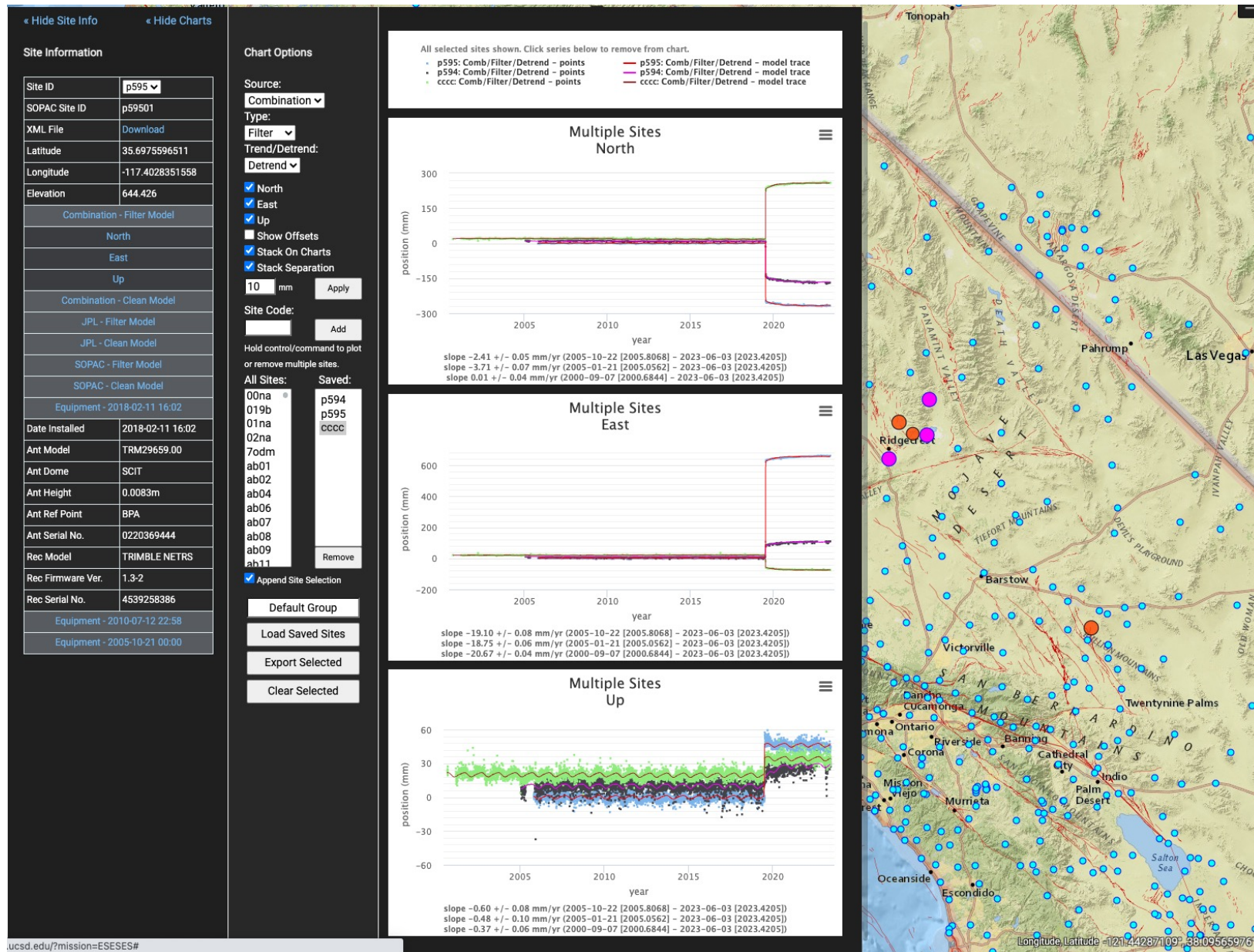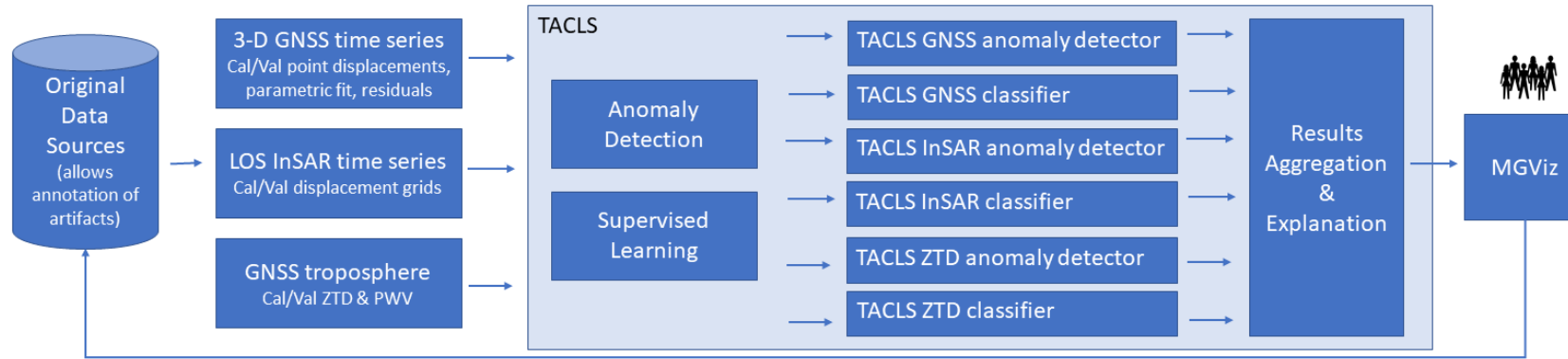
A concurrently running AIST-21 project is implementing a Transient and Artifact Continuous Learning System (TACLS), a rich, collaborative interactive environment where machine learning (ML) models are used to direct the attention of the human analyst to non-physical artifacts and real transient events in crustal and atmospheric observables that require interpretation.

These improvements will benefit all higher level products.
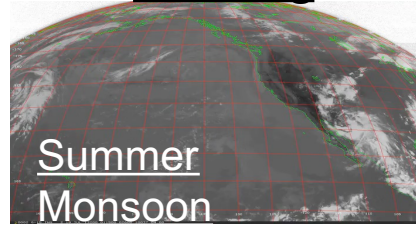
Earthquakes

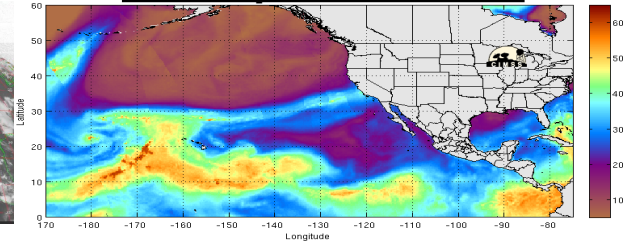**Tsunamis**

Drought

Subsidence

Landslides

Sea Level Rise

Flooding

Summer
Monsoon

Atmospheric Rivers

Volcanoes

Summary

- Our MEaSUREs timeseries products, 3 decades in length at some stations, are mature and benefit understanding of a variety of natural hazards.
- The MGViz products viewer is available at mgviz.ucsd.edu.
- Our AIST product is enabling an interactive environment where machine learning improves the quality of our products.