Geodetic Data, Data Products and GNSS Displacement Time Series Portal

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ABSTRACT

Our NASA MEaSUREs project "Extended Solid Earth Science ESDR System" (ES[3]) is a long-lived collaboration of JPL and SIO (http://sopac-csrc.ucsd.edu/wp-content/uploads/2021/08/ESESES-ATBD.pdf). Using independent software packages, JPL's GipsyX and MIT's GAMIT/GLOBK and a common source of metadata at SOPAC to process GNSS data, we provide four levels of products (Figure 1) beginning with level 1 raw daily displacement time series. Station motions are due to crustal deformation (interseismic), earthquakes (coseismic and postseismic), volcanism, transients (e.g., episodic tremor and slip - ETS) as well as other natural (e.g., subsidence due to drought) and anthropogenic processes (e.g., water and oil extraction). The second level of products includes calibrated and validated displacement time series resulting from a rigorous quality control process. We produce a daily displacement time series that has been corrected for artifacts and outliers; this and a series with the artifacts intact are made available for input to the SCEC community geodetic model. Several sets of time series and their metadata superimposed on a map interface can be viewed at our new MGViz interactive data portal (http://geoapp20.ucsd.edu/?mission=ESESES). The third level of products includes parameters estimated through a time series analysis: coseismic offsets, postseismic decay, interseismic velocities, vertical displacements and residuals, as well as weekly displacements grids reflecting both steady-state and transient motions. The final level of products for the Western U.S includes strain rate grids, modeled ETS transients and total surface water storage for hydro-geodetic research. In parallel to this four-level structure, we provide high-rate seismogeodetic displacements for a catalogue of historical earthquakes useful in developing real-time earthquake and tsunami early warning systems and studying physical processes such as defining the coseismic phase of the crustal deformation cycle as it transitions into early postseismic deformation. Finally, we provide a 5-minute record of tropospheric total delay and atmospheric precipitable water for tracking and better understanding extreme weather such as monsoons and atmospheric rivers and their hazards, for example, to forecast flash flooding. The products are available through NASA's CDDIS and SOPAC archives. In collaboration with David Sandwell's InSAR group, we are in the process of integrating our weekly displacement grids and 5-minute troposphere delays with 6–12-day Sentinel-1 interferograms.

MEaSUREs ESESES Architecture V6

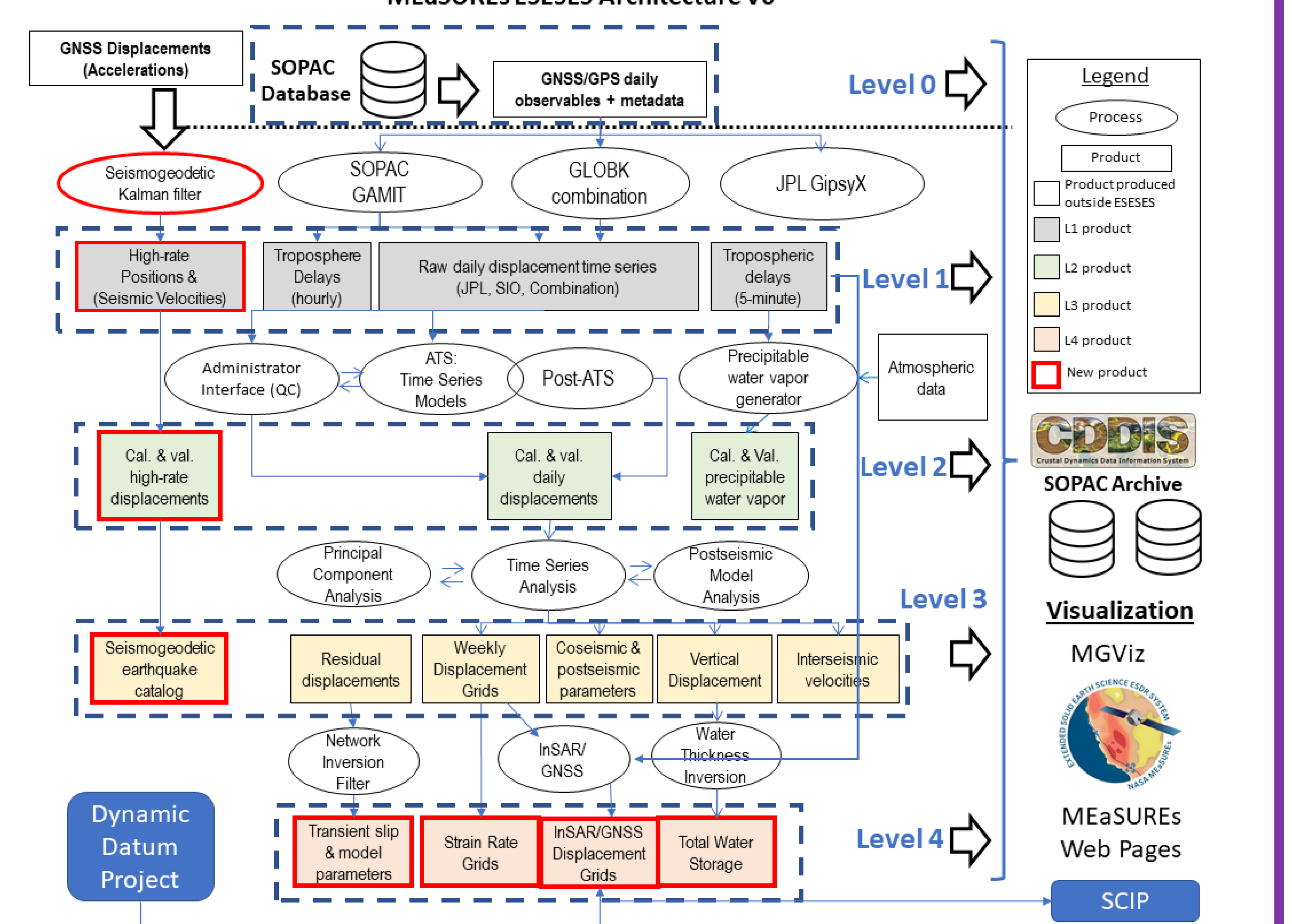


Figure 1. Four levels of products developed by the NASA MEaSUREs ESESES project using two independent software packages and a common source of metadata. The MGViz portal allows for visualization of our daily displacement time series products and metadata on a map background with multiple layers. The products are archived at CDDIS and SOPAC):
CDDIS: https://cddis.nasa.gov/Data_and_Derived_Products/GNSS/SESES_time_series_products.html
SOPAC: http://garner.ucsd.edu (http://garner.ucsd.edu/pub/measuresESESES_products/ &
http://garner.ucsd.edu/pub/timeseries/measures/ats/ (directories WesternNorthAmerica and Global)
Web pages: http://sopac-csrc.ucsd.edu/index.php/measures-2

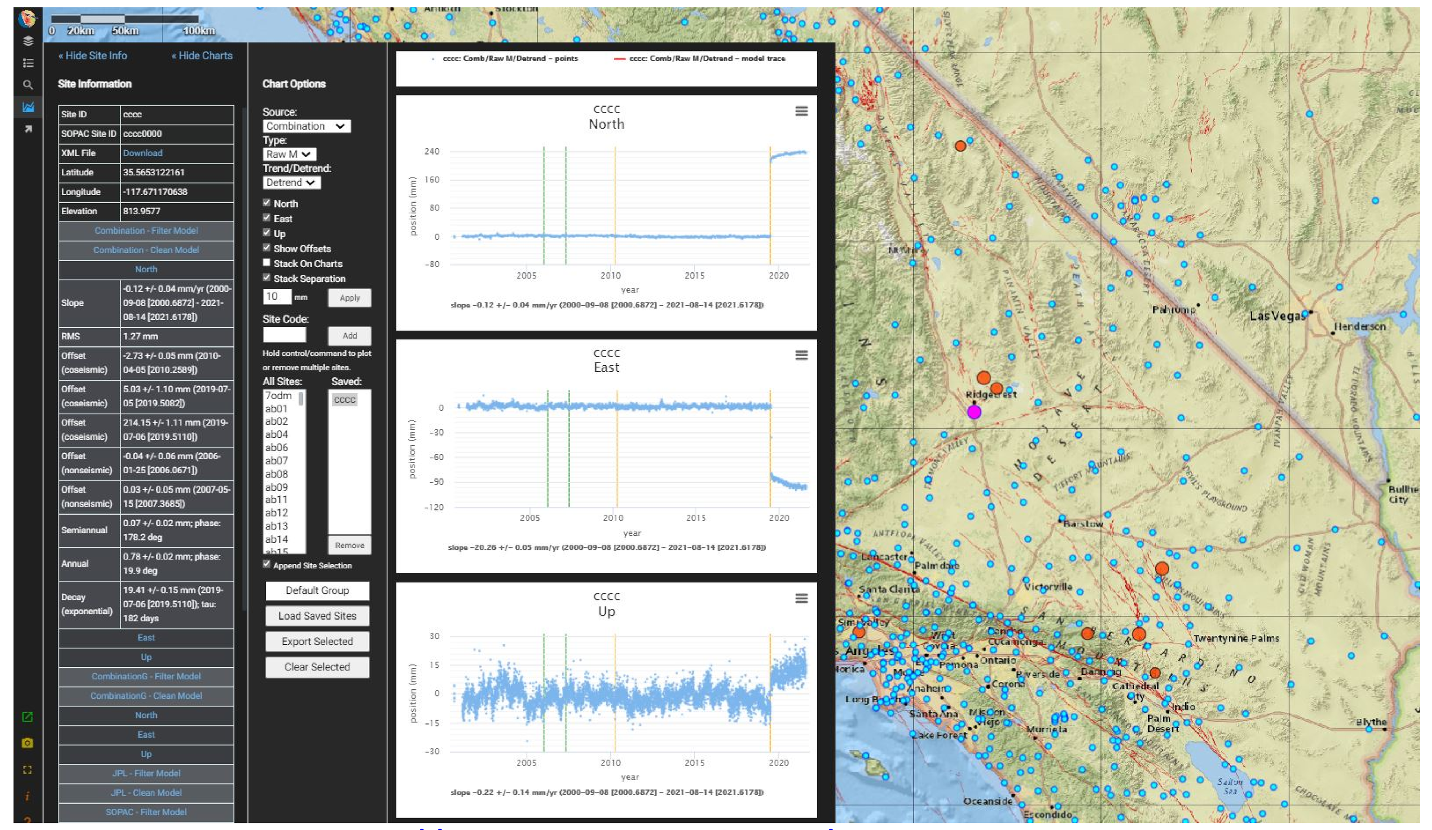


Figure 2. Screen shot of our new **MEaSURES MGViz portal** for daily displacement time series, replacing GPS Explorer. The various time series and all our data products are described in the ESESES-ATBD document section 2.2 – see the link in abstract). A complete listing of current and historical metadata is available in MGViz, along with a number of viewing options.

http://geoapp20.ucsd.edu/?mission=ESESES

5-MINUTE TROPOSPHERE AND PRECIPITABLE WATER

We provide zenith troposphere delays (ZTD) at 5-minute resolution from the GipsyX PPP process in the SINEX_TRO2 format for ~3000 stations (Figure 4) 1992-present, extended weekly with the latest 7 days processed with Final JPL orbits.

We also provide integrated water vapor (IWV) at 5-minute resolution for stations with onsite surface temperature and pressure sensors.

Applications include retrospective studies of extreme weather (e.g., North American Monsoon and Atmospheric River events), and correction of tropospheric artifacts in GNSS/InSAR processing for improved surface deformation maps.

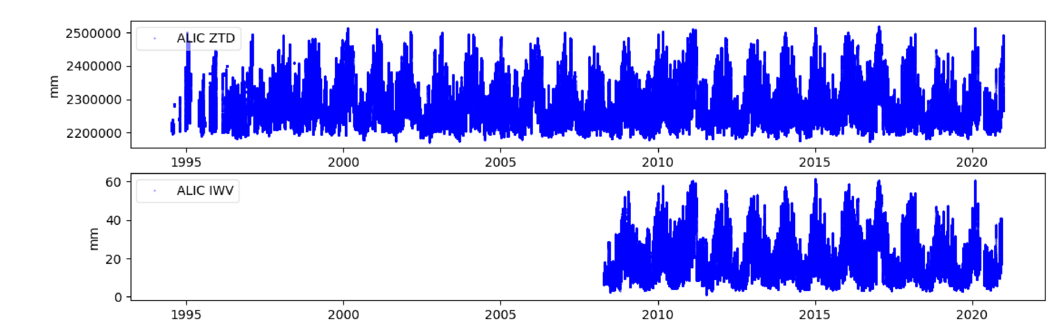


Figure 3. High temporal resolution troposphere delay and precipitable water. 5-minute tropospheric delay from 1995 (top) and precipitable water since 2008 (bottom) at GNSS station ALIC in Australia.

Figure 4. Station distribution for GNSS meteorology. We use data from about 3000 GNSS stations for estimating tropospheric delay and precipitable water with a 5-minute resolution.

The datasets are available from the CDDIS archive:
https://cddis.nasa.gov/Data_and_Derived_Products/GNSS/SESES_time_series_products.html

WEEKLY DISPLACEMENT GRIDS

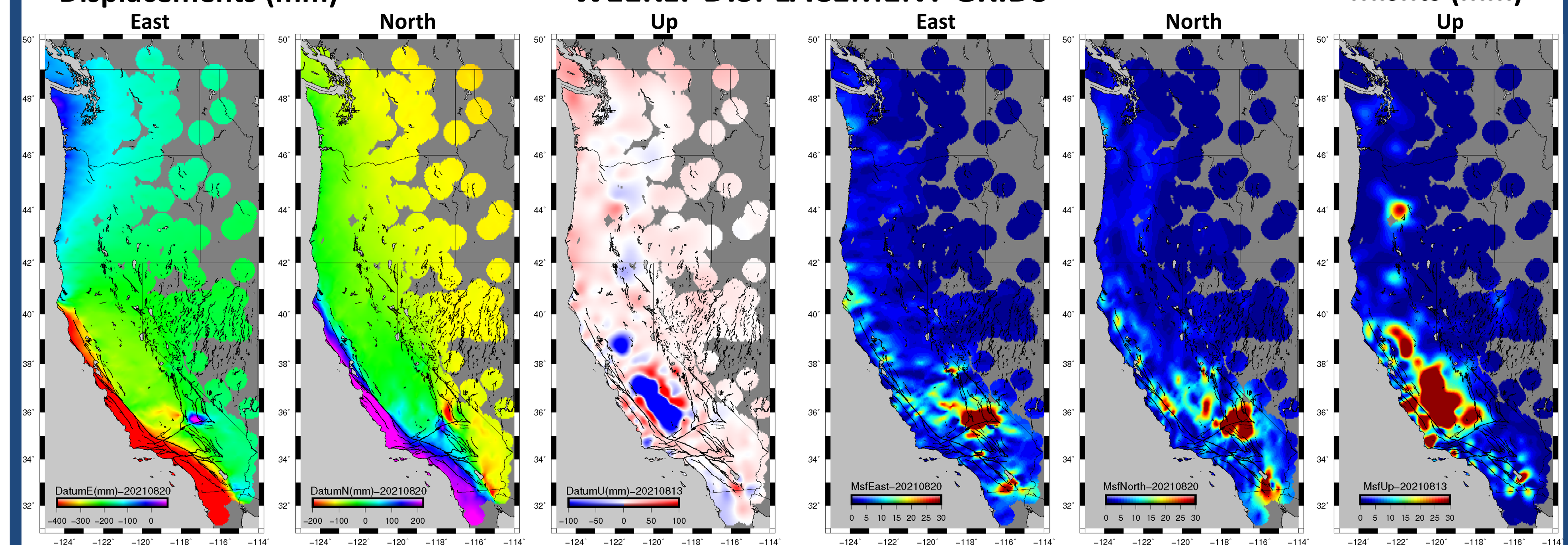


Figure 5. Weekly displacement and misfit grids. Weekly grids of the median-filtered combined displacement time series (ITRF2014) show the effects of steady-state motions and transients (here at 2021-08-20 with respect to 2010-01-01). The steady-state motions for California and Nevada are derived from the horizontal interseismic fault slip model of Zeng and Shen (2017); for Cascadia we use the observed station velocities from the MEaSURES displacement time series analysis. The transients are the residuals between observed and model displacements (Klein et al., 2019). Misfits grids indicate the differences between the interpolated and observed displacements at the GNSS stations. 50 km circles drawn around GNSS stations.

Source: http://garner.ucsd.edu/pub/measuresESESES_products/DisplacementGrids/

Klein, K., Y. Bock, X. Xu, D. Sandwell, D. Golriz, P. Fang, L. Su (2019), Transient deformation in California from two decades of GPS displacements: Implications for a three-dimensional kinematic reference frame, J. Geophys. Res., 124(11), 12189-12223. https://agupubs.onlinelibrary.wiley.com/doi/full/10.1029/2018JB017201
Zeng, Y., & Shen, Z.-K. (2017). A fault-based model for crustal deformation in the western United States based on a combined inversion of GPS and geologic inputs. Bulletin of the Seismological Society of America, 107(6), 2597–2612. https://doi.org/10.1785/0120150362;

GNSS & SEISMOGEODETIC HIGH-RATE EARTHQUAKE ARCHIVE

Table 1. We are populating an archive of GNSS displacements (1Hz) and seismogeodetic displacements and velocities (100Hz) for historical earthquakes, useful for developing earthquake and tsunami warning systems and the physical processes underlying early postseismic deformation. Golriz et al., 2021.

Name/Region	M_w[1]	Fault Mechanism	Origin time (UTC)[2]	Longitude (E°)	Latitude (N°)	Depth (km)
Parkfield, California	6.0	Strike-slip	2004-09-28 17:15:24	-120.366	35.818	8.1
El Mayor-Cucapah, Mexico	7.2	Strike-slip	2010-04-04 22:40:42	-115.295	32.286	10.0
Miyagi, Japan	7.3	Reverse	2011-03-09 02:45:12	143.280	38.329	8.3
Tohoku-oki, Japan	9.1	Reverse	2011-03-11 05:46:24	142.861	38.104	29.0
Fukushima, Japan	6.6	Normal	2011-04-11 08:16:12	140.673	36.946	6.4
Napa, California	6.0	Strike-slip	2014-08-24 10:20:44	-122.312	38.215	11.1
Kumamoto, Japan	7.0	Strike-slip	2016-04-15 16:25:05	130.763	32.755	12.5
Ridgecrest, California	6.4	Strike-slip	2019-07-04 17:33:49	-117.506	35.705	10.7
Ridgecrest, California	7.1	Strike-slip	2019-07-06 03:19:53	-117.599	35.770	8.0
Simeonof, Alaska	7.8	Reverse	2020-07-22 06:12:44	-158.522	55.030	28.0

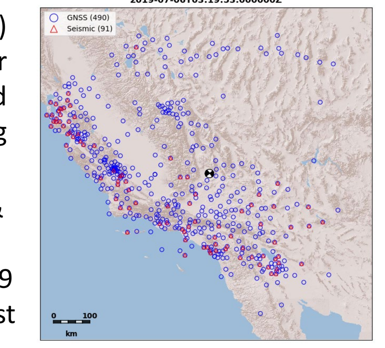


Figure 6. GNSS & seismic stations analyzed for 2019 Mw7.1 Ridgecrest earthquake.

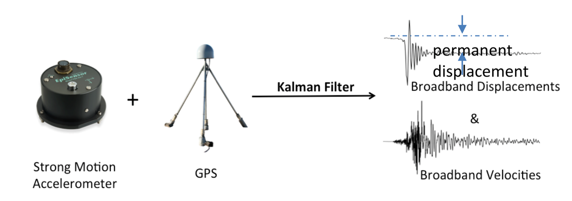


Figure 7. Seismogeodetic method. Broadband seismometer that picks P-waves but doesn't clip in the near field, measures permanent displacements, magnitude doesn't saturate.

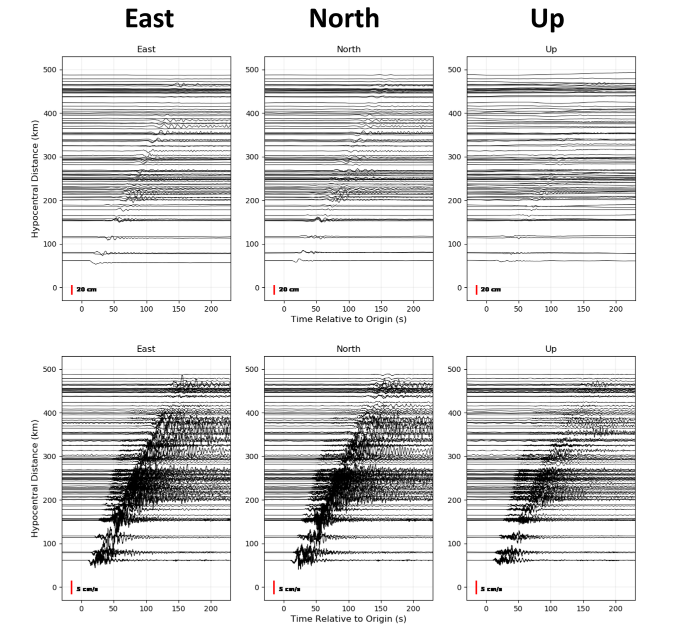


Figure 8. Seismogeodetic waveforms for 2019 Mw7.1 Ridgecrest earthquake Top: 100Hz ENU displacements waveforms; Bottom: 100Hz ENU velocity waveforms

Golriz, D, Y. Bock and X. Xu (2021), Defining the Coseismic Phase of the Crustal Deformation Cycle with Seismogeodesy, in press JGR.

http://garner.ucsd.edu/pub/measuresESESES_products/EarthquakeDisplacements/

TRANSIENTS: EPISODIC TREMOR AND SLIP (ETS)

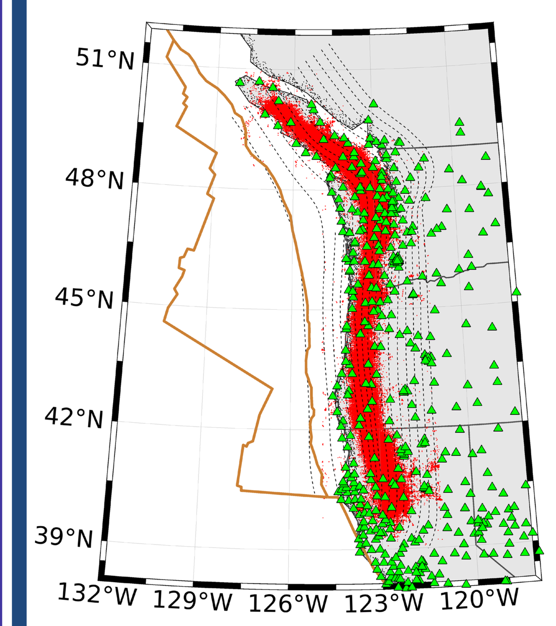


Figure 9. Tectonic settings of Cascadia subduction zone where ETS events occur frequently. Red dots: tremors. Triangles: GNSS sites. Dashed lines: isodepth contours of plate interface.

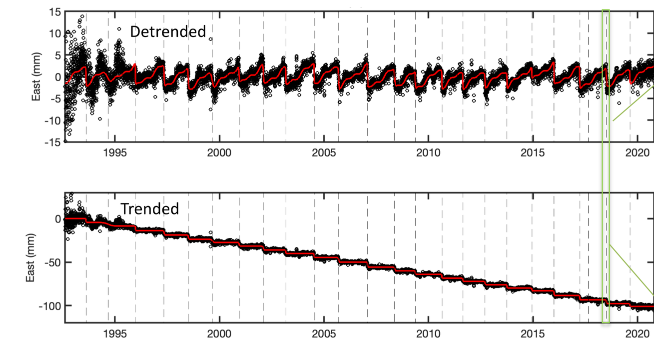


Figure 10. 23 Recurrent ETS signals in east-component of displacement time series at ALBH since 1993. (top) detrended; (bottom) after removing inter-ETS trend. Black dots: GNSS position time series. Red lines: the fit of model consisting of inter-ETS trend, seasonal, and ETS events. Green box shows the 2018 ETS event whose surface displacement and slip are shown in Figure 11.

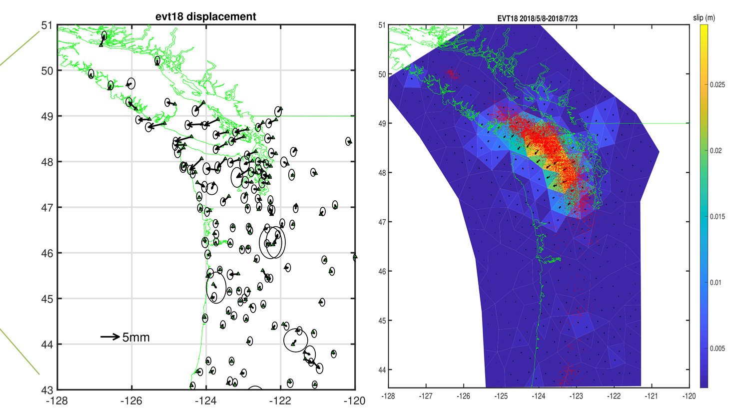


Figure 11. Example of 2018 ETS event. (Left) Accumulated surface displacements with uncertainties; (right) Transient fault slip derived from time-dependent inversion, overlaid with tremor (red dots). Black arrows: fault slip vectors projected to the surface.

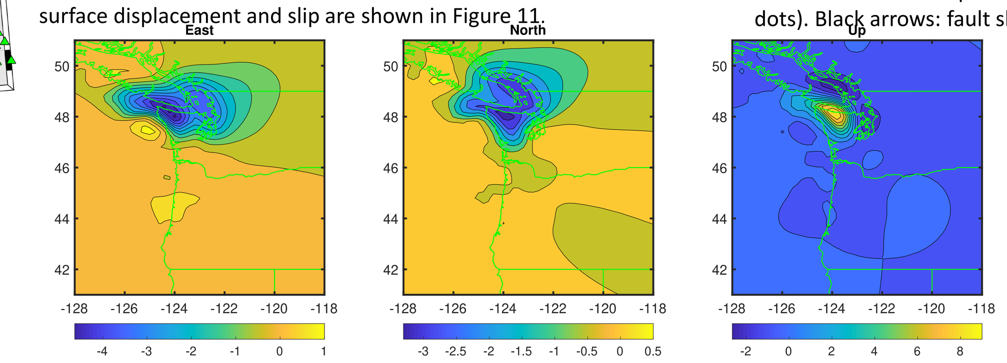


Figure 12. 3-dimensional surface displacement grid from fault slip of 2018 ETS event. From left to right: east, north, up component. Units: mm.

http://garner.ucsd.edu/pub/measuresESESES_products/Transients/

TOTAL WATER STORAGE

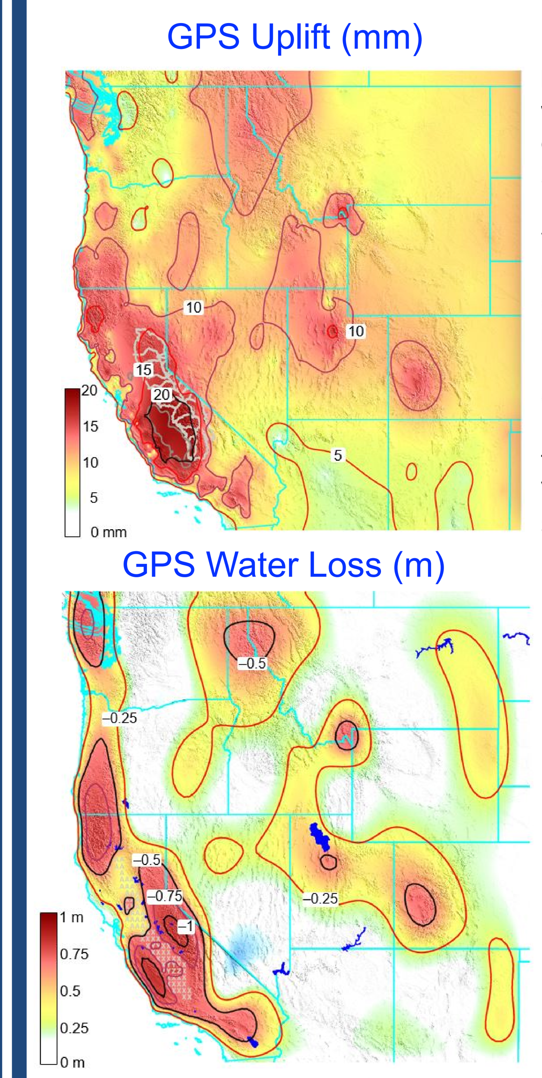
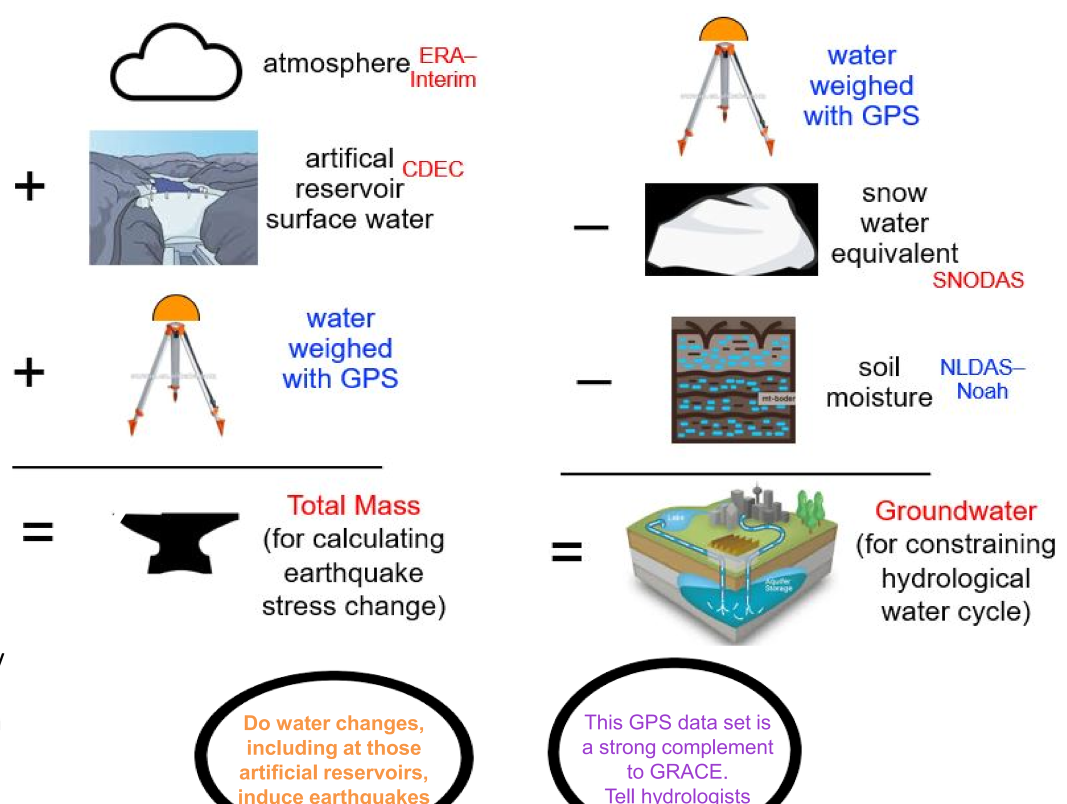


Figure 13. GPS uplift and water loss during harsh drought (Oct 2011 – Oct 2015). No snow in Oct.; Loss of 135 km³ of ground water in California's mountains. (Top) Vertical displacements (mm) interpolated from MEaSURES weighted mean combination; (Bottom) Loss in equivalent water thickness (m). Central Valley groundwater loss is set equal to UCLA model.

Estimates of seven components of water change from January 2006 to June 2021 are publicly available. The data set consists of monthly values of equivalent water thickness (in mm) at 1/4 degree latitude, longitude intervals. Use **wget** command below to access data or contact:
Donald.F.Argus@jpl.nasa.gov



Stress change calculations of Johnson Fu Burgman 2017ab and Zhou Zaliapin et al. AGU 2020 can be done better by explicitly quantifying artificial reservoir surface water.

GPS results demonstrate that the amount of water in the ground to change by more than previously believed;
Not all rain and melting snow runs off;
The hydrology models must be revised.

wget -r -np -nH --cut-dirs=2 -R "index.html*" http://sideshow.jpl.nasa.gov/pub/usrs/argus/measures/west.us/cmby.2021jun/