



OPERA

Observational Products for End-Users from
Remote Sensing Analysis

Fifth OPERA Workshop

September 11, 2025

**Science and Disaster Response Applications with
OPERA Products and Tools**

**Jet Propulsion Laboratory
California Institute of Technology**

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CL#25-3459



Science and Disaster Response Applications with OPERA Products and Tools

**Cole Speed, Bryan Raimbault, &
M. Grace Bato**

*Jet Propulsion Laboratory
California Institute of Technology*

We will demonstrate:

- Disaster applications with OPERA products/tools (C. Speed)
- Science applications with the OPERA DISP (B. Raimbault)
 - OPERA Products in Google Colab
 - Example: Arizona subsidence
- Using DIST-S1 to map wildfire extent: Eaton Fire (M. Grace Bato)

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OPERA Products and Tools for Disaster Response Applications

Cole Speed

Postdoctoral Fellow

OPERA Project Science Team

- OPERA products and disaster response applications
 - Flood extent mapping with **DSWx-S1**
 - Tracking wildfire impact with **DIST-HLS**
 - Landslide detection with **DIST-HLS** and **RTC**
- In-development automated tools for disaster response with OPERA products
 - End-to-end automated workflow
 - OPERA Applications Jupyter Notebooks

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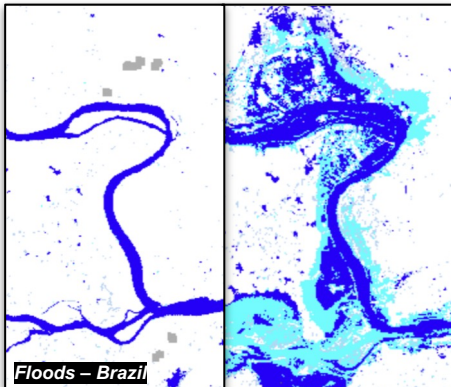
OPERA Products for Hazard Monitoring and Disaster Response

National Aeronautics and
Space Administration



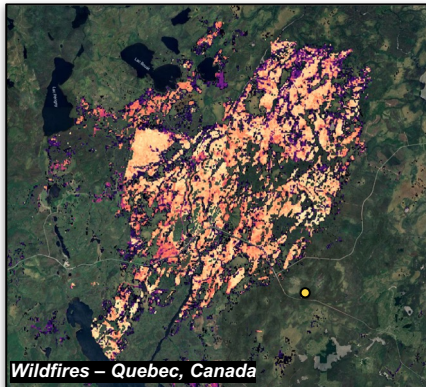
OPERA products enable monitoring and emergency response across a range of disaster-types:

Dynamic Surface Water Extent (DSWx)



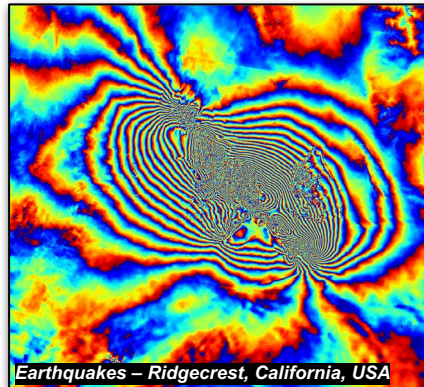
- **Description:** Maps surface water extent using optical (HLS) and SAR imagery (Sentinel-1, NISAR)
- **Coverage:** Near-global
- **Temporal Resolution:** Every few days
- **Spatial Resolution:** 30 m
- **Product Record begins:** Apr. 2023 (HLS), Aug. 2024 (Sentinel-1), Oct. 2026 (NISAR)
- **Disaster Response Applications:** River/coastal/reservoir flooding

Land Surface Disturbance (DIST)



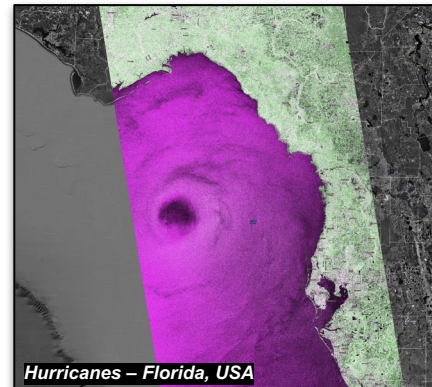
- **Description:** Maps vegetation disturbance using optical (HLS) and SAR imagery (Sentinel-1)
- **Coverage:** Near-global
- **Temporal Resolution:** Every few days
- **Spatial Resolution:** 30 m
- **Product Record Begins:** Jan. 2023 (HLS), Jan. 2026 (Sentinel-1)
- **Disaster Response Applications:** Wildfires, landslides

Surface Displacement (DISP)



- **Description:** Maps land surface displacement (anthropogenic and natural) from SAR (Sentinel-1 and NISAR)
- **Coverage:** North America
- **Temporal Resolution:** Sentinel-1 cadence
- **Spatial Resolution:** 30 m
- **Product Record begins:** Jul. 2016 (Sentinel-1) Nov. 2025 (NISAR)
- **Disaster Response Applications:** Earthquakes, eruptions, landslides

Radiometric Terrain Corrected (RTC) SAR Backscatter



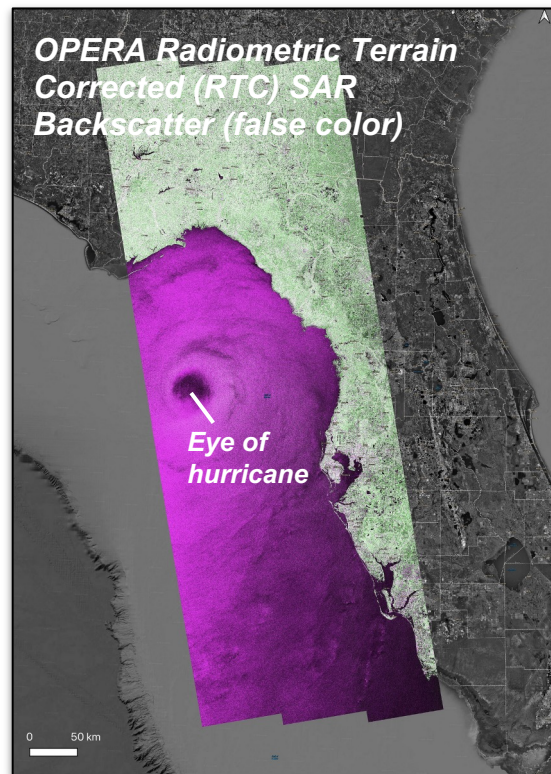
- **Description:** Provides Sentinel-1 radar backscatter corrected for topography. Basis for the OPERA DSWx-S1 products
- **Coverage:** Near-global
- **Temporal Resolution:** Sentinel-1 cadence
- **Spatial Resolution:** 30 m
- **Product Record begins:** Oct. 2023
- **Disaster Response Applications:** Hurricanes, earthquakes, eruptions, landslides, wildfire

OPERA supported NASA response for 13 major disasters in 2024-2025 including hurricanes, earthquakes, landslides, wildfires, and volcanic eruptions.

Application: Flood mapping with OPERA DSWx-S1

Hurricane Helene, September 2024

National Aeronautics and
Space Administration



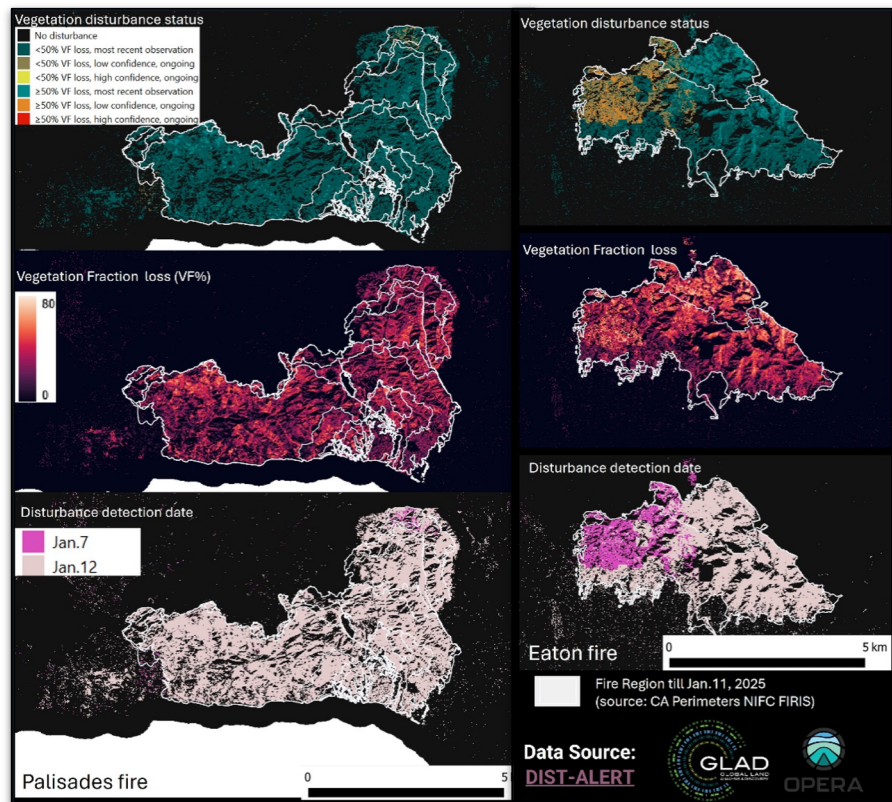
- Hurricane Helene made landfall as Category 4 hurricane on September 26
 - At least 250 fatalities¹
 - Est. \$78B in damage¹
- OPERA RTC product (**Left**) captured hurricane eye approaching Florida coast
- OPERA Dynamic Water Extent from Sentinel-1 (DSWx-S1) captured flood extent due to storm surge (**Right**)
- DSWx-S1 (SAR) can map flood extent **even in the presence of clouds.**

¹Tropical Cyclone Report: Hurricane Helene (AL092024). National Hurricane Center, 19 Mar. 2025.

Application: Wildfire Impact with OPERA DIST-HLS

2025 Los Angeles, CA Wildfires

National Aeronautics and
Space Administration



Credit: K. An, C. Speed, A. Handwerger

- Wildfires impacted large regions of the Los Angeles, CA area in January 2025.
 - At least 30 fatalities¹
 - Est. \$28-53B in damages²
- **OPERA DIST-HLS (optical)** product contains 19 layers detailing the extent, timing, and severity of vegetation/infrastructure disturbance/damage **(Left)**.
- Products are updated with each additional satellite image acquisition, enabling spatiotemporal tracking of disturbance.
- **Upcoming OPERA DIST-S1 (SAR)** product will provide a complementary dataset and enable wildfire tracking **through clouds and smoke**.

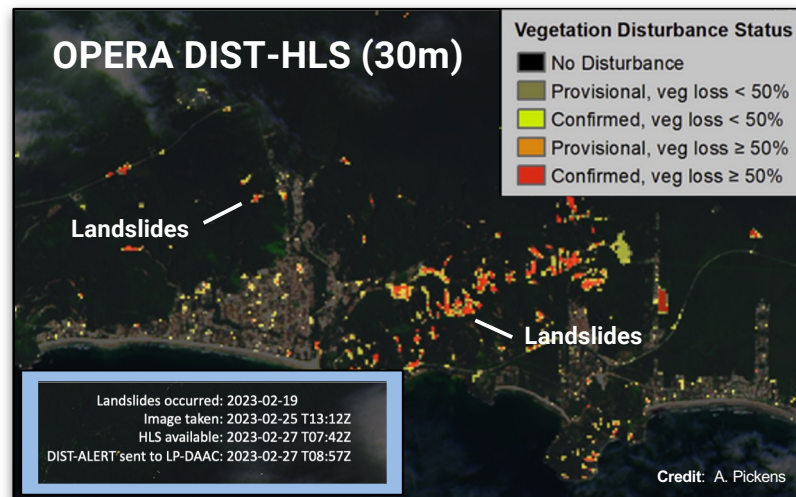
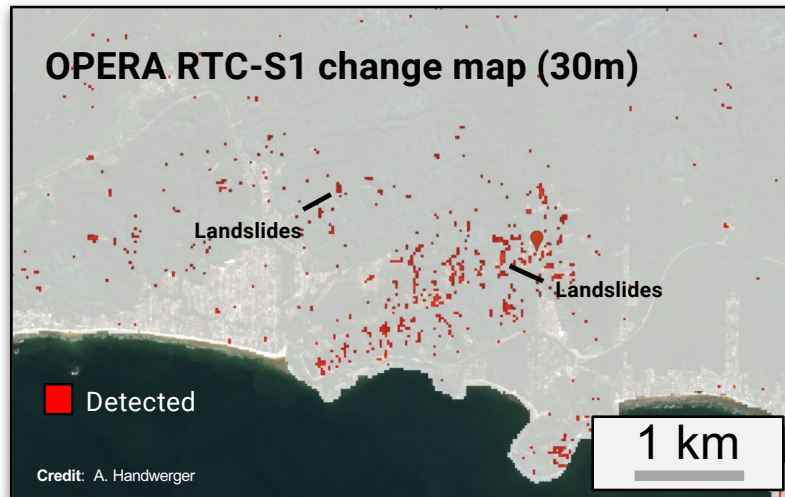
¹County of Los Angeles, Dept. of Medical Examiner, 22 July, 2025.

²LAEDC, Impact of Los Angeles Wildfires and Comparative Study, February, 2025.

Application: Landslide Detection with OPERA RTC/DIST

2023 Floods and Landslides in Brazil

National Aeronautics and
Space Administration



- In February 2023, southeastern Brazil received heavy rainfall resulting in floods and landslides.
 - At least 65 fatalities¹
- OPERA RTC-S1 and DIST-HLS successfully detected landslides impacting the region – an example where **OPERA products derived from multiple sensors (Sentinel-1/HLS)** were integrated to delineate disaster-affected area.
- This ability to utilize and integrate multiple OPERA products for a single response is a key component of latency reduction and delivering useful OPERA products to end-users **more rapidly**.

¹Copernicus Emergency Management Service, GloFAS Bulletin, March 2023.

Reducing latency and increasing impact with OPERA products and disaster response tools



'next_pass'

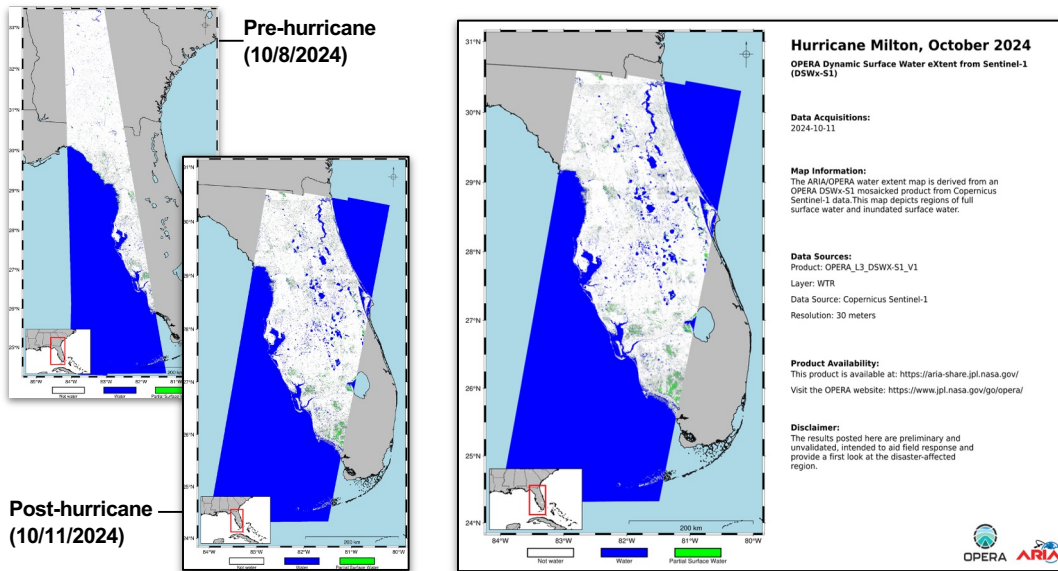
Satellite overpass **forecasting** and **recognition** of relevant OPERA products for disaster response



- Identify OPERA DSWx data over region impacted by Hurricane Milton.

'disasters'

End-to-end automated workflow for generating OPERA products, maps, and layouts



Developers : I. Fenni, E. Havazli, K. An, C. Speed

- Generate mosaicked geotiffs, maps and PDF layouts for internal use and for the end-user.
- Latency in OPERA product delivery is dependent on acquisition and processing time of input data.
- **OPERA disaster response products generated as soon as the input data are available.**

OPERA Applications Notebooks on GitHub

National Aeronautics and
Space Administration

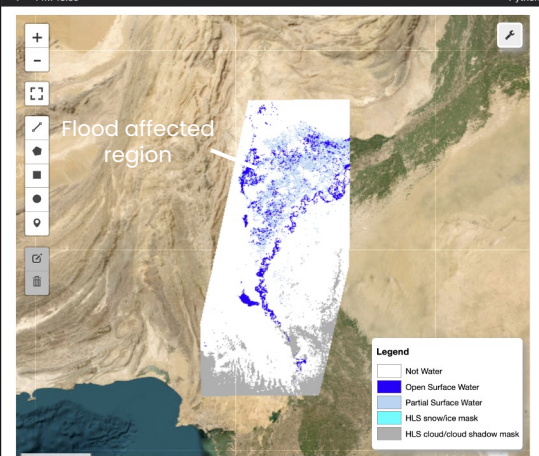


User-friendly workflows for exploring OPERA products and applications

Using Leafmap and Earthaccess to Explore OPERA DSWx-HLS Products

```
m = leafmap.Map(basemap="Esri.WorldImagery")
# m.add_raster(os.path.join(data_directory_Preflood, filename_merged_Preflood), opacity=1)
m.add_raster(os.path.join(data_directory_SynFlood, filename_merged_SynFlood), opacity=1)
legend_dict = {
    'Not Water': '#0000ff',
    'Open Surface Water': '#0000ff',
    'Partial Surface Water': '#b4d5f4',
    'HLS snow/ice mask': '#00ffff',
    'HLS cloud/cloud shadow mask': '#fafaaf'
}
# Add the legend to the map
m.add_legend(legend_title="Legend Title", legend_dict=legend_dict)
m
```

✓ 14m 18.5s Python



ipyleaflet | Tiles (C) Esri -- Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community, Raster file served by localtileserver.

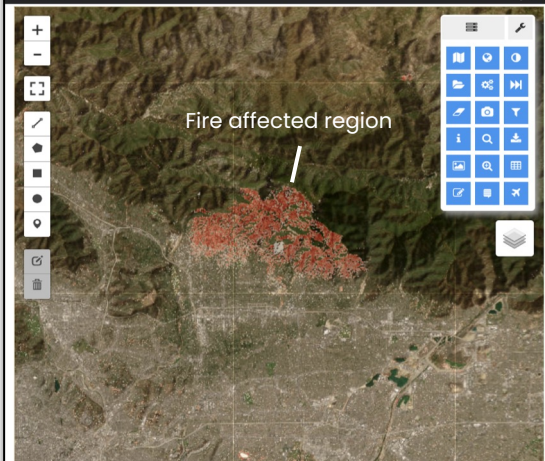
Quantifying Wildfire Impacts Using the OPERA DIST-HLS Product

```
# Add rasters to map
for layer in layers_viz:
    merged_path = os.path.join(filtered_rasters_dir, 'merged', f'{layer}_merged.tif')
    if os.path.exists(merged_path):
        cmap = colormap_dict.get(layer, None)
        m.add_raster(merged_path, layer_name=layer, opacity=0.6, colormap=cmap)
```

```
# Show layer control
m.add_layer_control()
```

```
# Show the map
m
```

✓ 0.4s Python



ipyleaflet | © OpenStreetMap contributors, Tiles (C) Esri -- Source: Esri, i-cubed, USDA, USGS, AEX, GeoEye, Getmapping, Aerogrid, IGN, IGP, UPR-EGP, and the GIS User Community, Raster file served by localtileserver.

- Jupyter Notebook-based workflows are available and continuously in-development for specific disaster-types:
 - Wildfire (DIST)
 - Flooding, landslides (DSWx, DIST).
 - Landslides (RTC, DISP)
- Notebooks integrates data streaming from the NASA CMR to avoid data download requirements.
- Uses interactive map tools (e.g., leafmap) to visualize and explore OPERA products



https://github.com/OPERA-Cal-Val/OPERA_Applications



Science Applications with the OPERA DISP- S1 Product

Bryan Raimbault
Postdoctoral Fellow
OPERA Project Science Team

- OPERA DISP-S1 Products
- Science Application with the OPERA DISP-S1 Product: Tracking Land Subsidence in Arizona
 - Google Colab Notebook Workflow
 - Downloading DISP-S1
 - Displacement layer
 - Reconstruction of the time series
 - Visualization of the time series
 - Extracting subsidence rate/velocities

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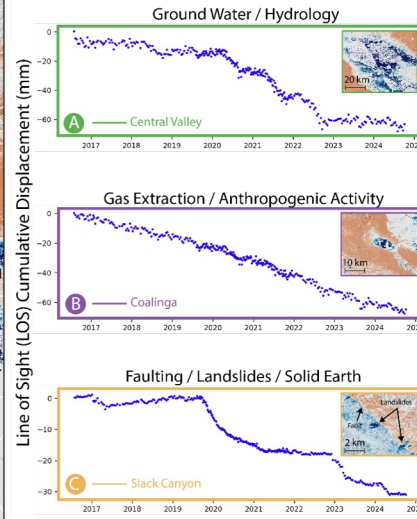
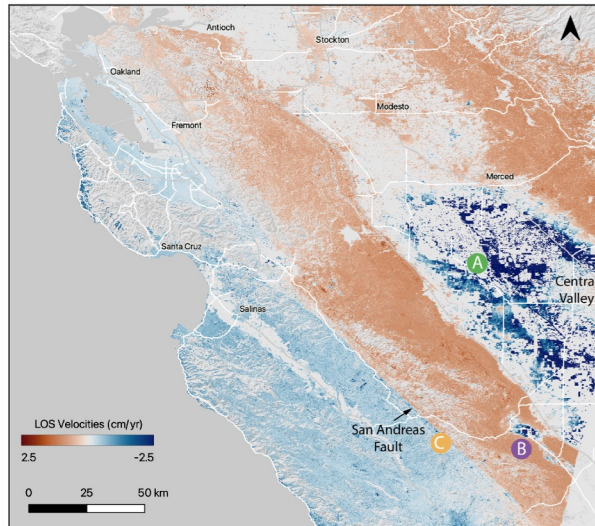
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Revisiting the OPERA DISP-S1 Products

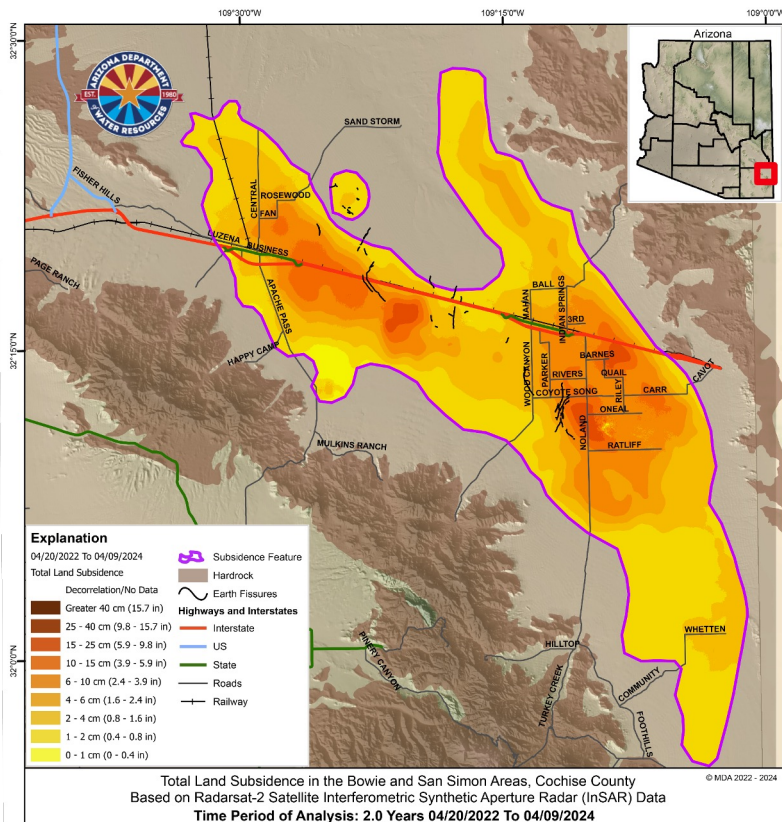
Each OPERA L3 DISP product from Sentinel-1 (DISP-S1) is generated from a sequence of the OPERA L2 CSLC-S1 products.

- **Measurement:** Surface displacement in the radar Line-Of-Sight (LOS)
- **Coverage:** USA and U.S. Territories, Canada within 200 km of the U.S. border, and all mainland countries from the southern U.S. border down to and including Panama
- **Resolution:** 30 m spacing / frame-based (250x 250km - 155x155mi)
- **Latency:** 72 hours (after all inputs are available)

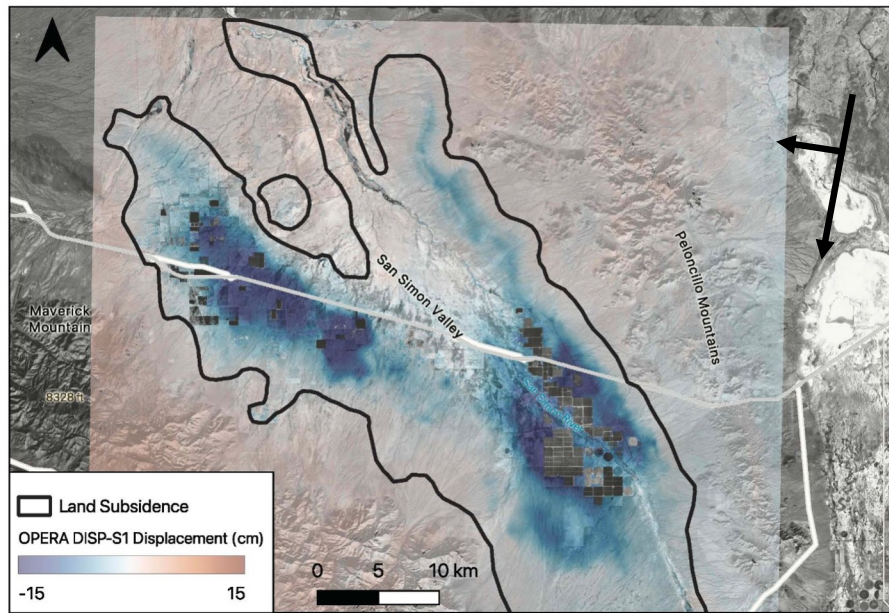


DISP-S1 Science Application: Monitoring Land Subsidence

National Aeronautics and
Space Administration



Example Application: San Simon / Bowie Subsidence Area, Arizona
OPERA DISP-S1 displacement results processed in Google Colab
Cumulative displacement mapping from April 2022 to Sept. 2024



Credit: Arizona Department of Water Resources (www.azwater.gov)

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Presentation Outline and Objectives



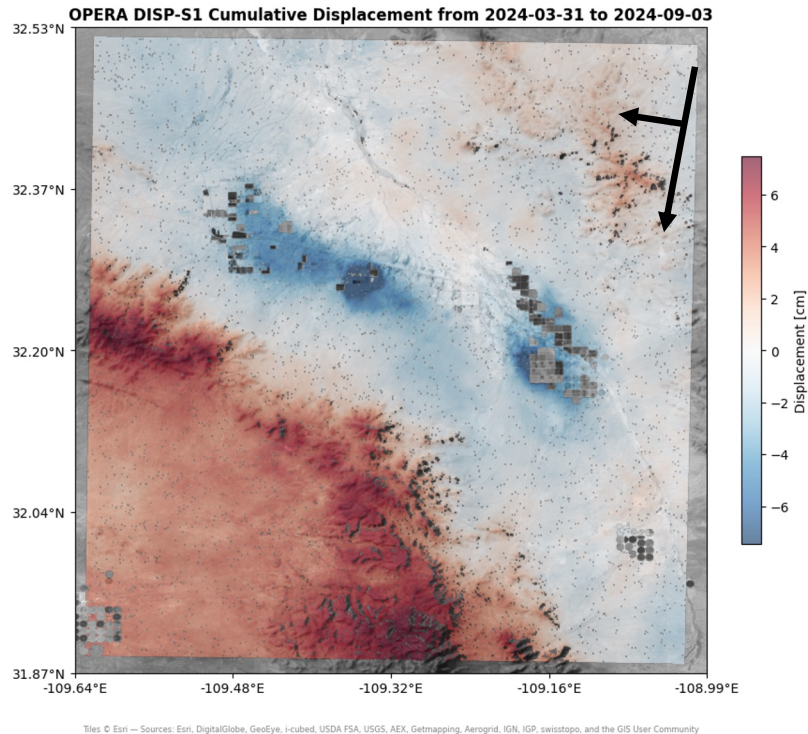
Get your own Displacement Maps and Time Series

1. Open and run the Google Colab workflow (no need to install Python locally)
2. Download OPERA DISP-S1 products
3. Build and view a cumulative displacement time series (Jan 2022 – Sep 2024) for the Bowie/San Simon area in Arizona
4. Estimate land-subsidence rates/velocities
5. Generate GIS-ready time series maps

**Tool used for this presentation:
Google Colab Notebook**

Easily produce results for any area of interest without local setup

Create displacement data ready to use in your projects



Example of displacement (cm) information
contained in a OPERA DISP-S1 file

Google Colab Workflow for Time Series



How to create your own displacement maps and time series on any area?

⚠ Google Account Required ⚠

1. Open Google Colab
2. Scan the QR code to access the notebook
3. Open using GitHub link *or*
4. Drag & drop to upload the notebook

Only the following needed through the notebook:

- **NASA Earthdata Credentials**
- **Frame_ID** (e.g., 34478)
- **Bounding_Box** in WESN
- **Start_Date** in YYYY-MM-DD (e.g, 2022-01-01)
- **End_Date** in YYYY-MM-DD (e.g., 2024-09-15)
- Interactions with plotters

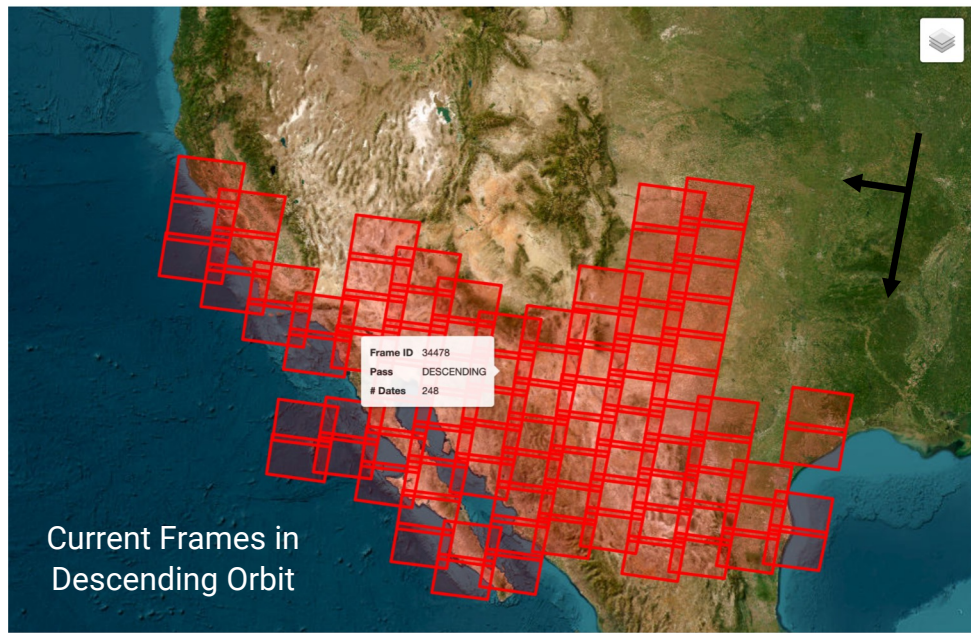
Also works on your local machine if you have Python installed.

Choosing a Frame and Downloading DISP-S1 Files



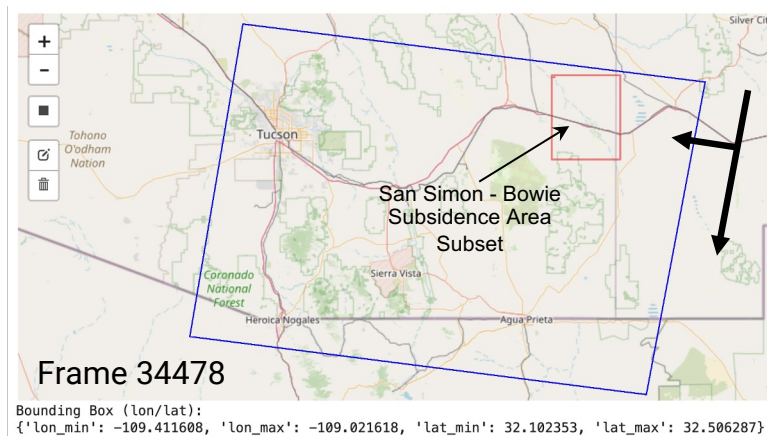
Look out at the Frame numbers corresponding to your Area of Interest (AOI)

⚠ NASA Earthdata Credentials Required (EULA Accepted) ⚠



Granules: 80 (up to 248 for full time range)
File size: ~368 MB → stack size: 28.75 GB
Subset file: ~21.69 MB → stack size: 1.69 GB

Cropping on your AOI is highly recommended!



How to reconstruct DISP-S1 Time Series



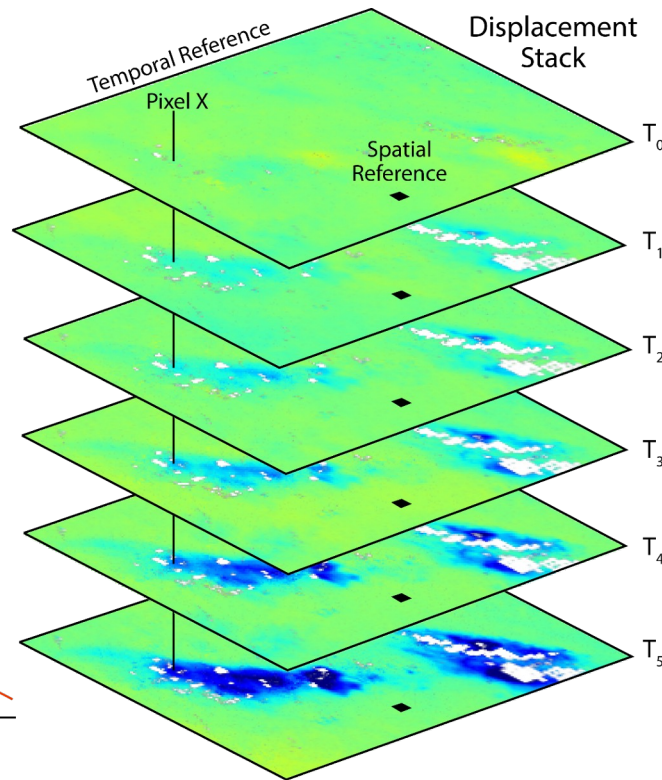
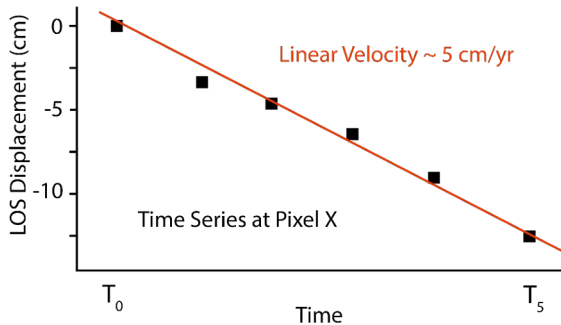
Stacking and Referencing your Displacements Maps

Context: InSAR displacements are relative in **space and time**. Movement is measured with respect to a chosen **reference point**.

- Find a point that is stable during the observation period
- Near the area/object of interest to capture relevant differential motion

Defines the zero-displacement baseline for all pixels.

A noisy or unstable reference affects the accuracy of *all* measurements.



Cumulative Displacement Visualization



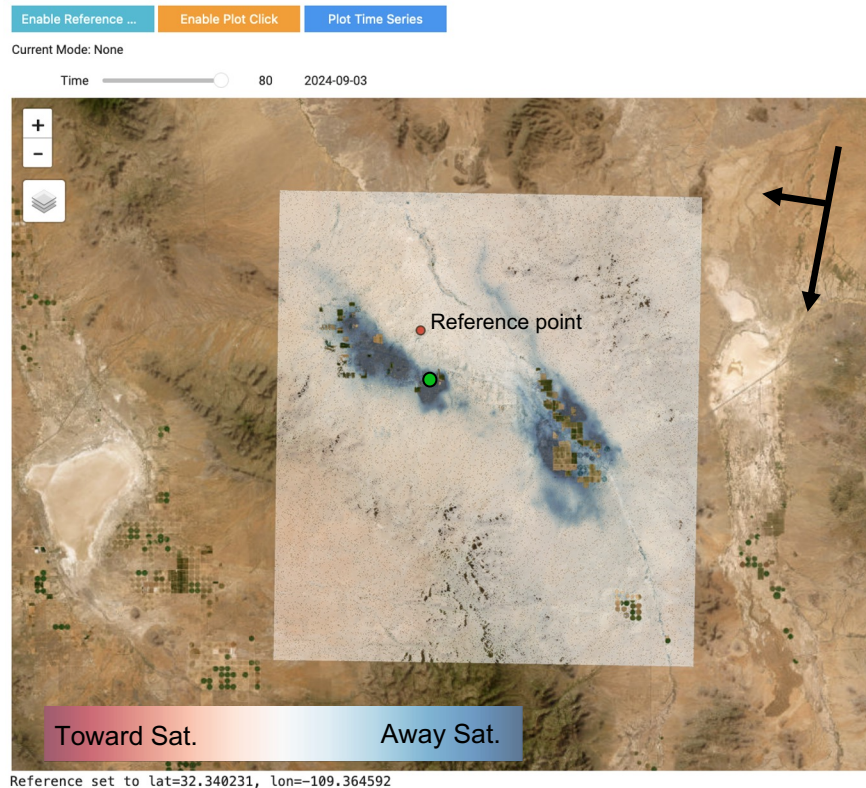
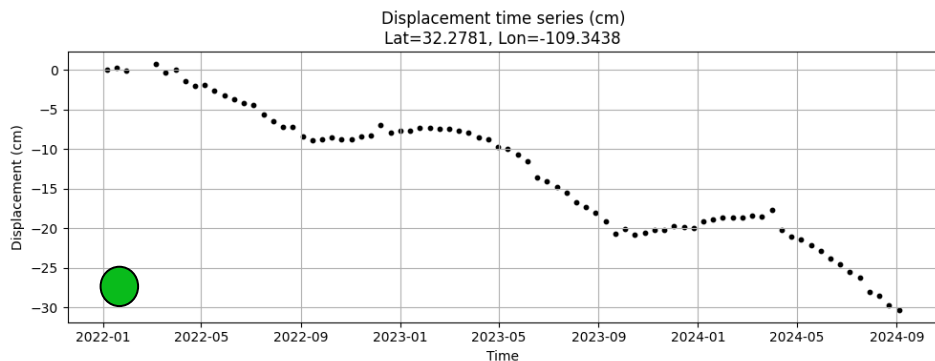
InSAR Time Series Analysis

Colors represent motion in the satellite's line-of-sight (LOS)

Red indicates motion **toward** the satellite

Blue indicates motion **away** from the satellite

Red dot marks the reference point, here set to zero displacement



Extract Linear Velocities and Exportation



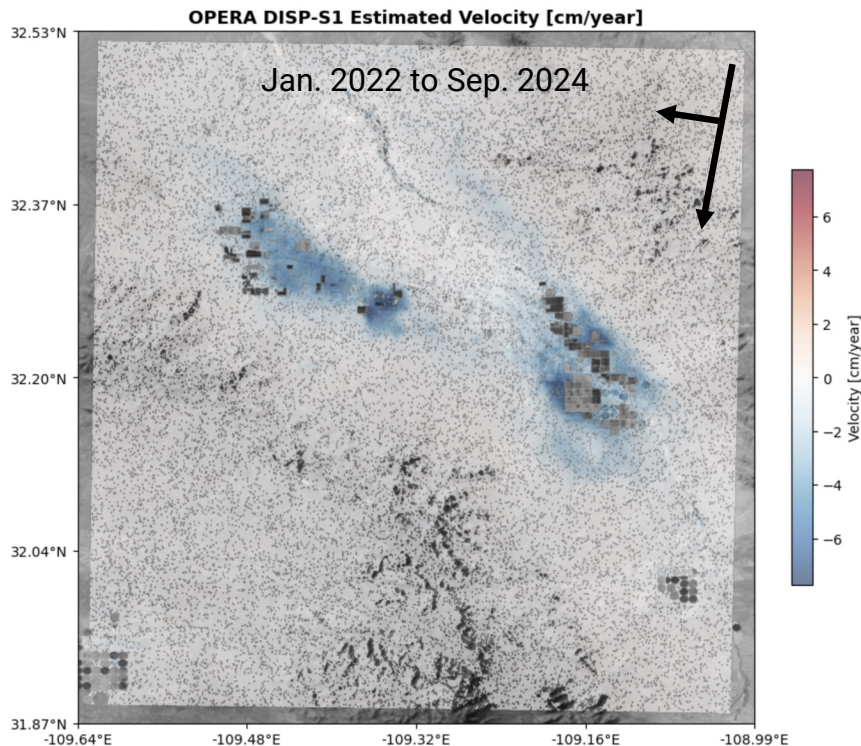
Output Products

- Multi-band GeoTIFF – One band per acquisition date (*cumulative displacement*)
- PNG snapshots – One per acquisition date, with consistent color scale

GeoTIFF files open directly in GIS software (QGIS, ArcGIS Pro, etc.). Each band shows cumulative displacement from the first date to the acquisition date.

MintPy Compatible Outputs:

- velocity.h5 – Average velocity map (*m/year*)
- timeseries.h5 – Displacement time series for each pixel



Tiles © Esri — Sources: Esri, DigitalGlobe, GeoEye, i-cubed, USDA FSA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community



Using DIST-S1 to Map Wildfire Extent: Eaton Fire

Grace Bato

CSLC/DISP Product Validation Lead

OPERA Project Science Team

- Use GIS platform to load DIST-S1 and other auxiliary data

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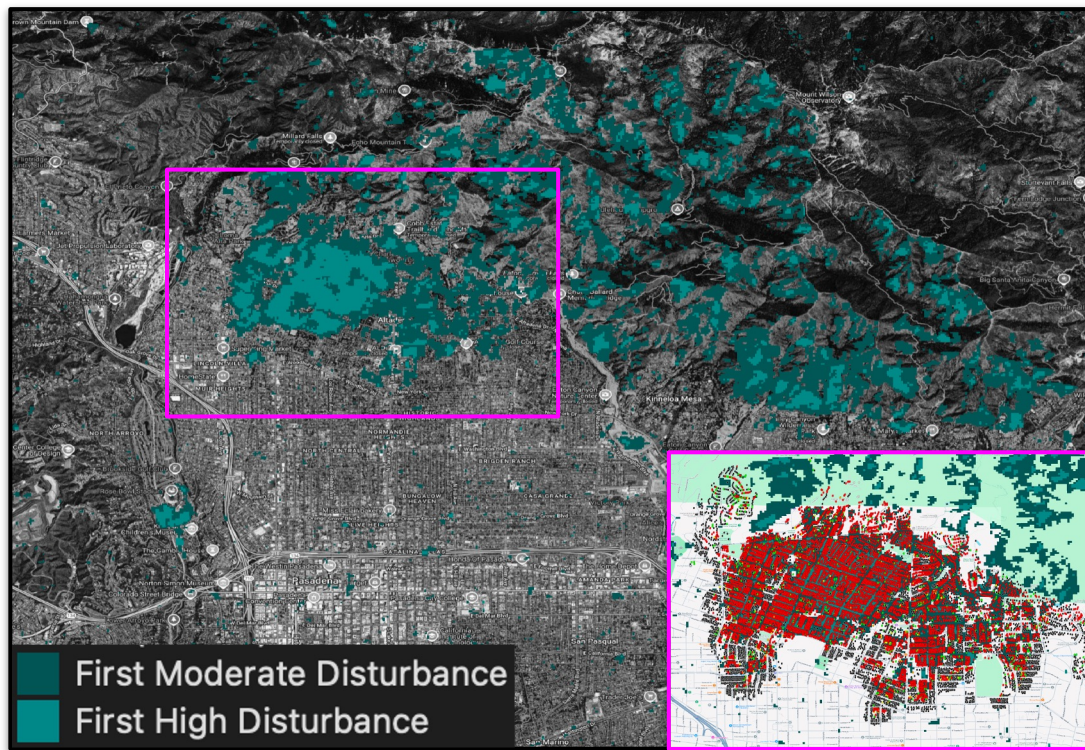
No ITAR information is to be presented.

Goal: Map the Wildfire Extent using DIST-S1

Eaton Fire, Los Angeles 2025



- 1) Download the OPERA DIST-S1 prototype [here](#).
- 1) Load the [auxiliary](#) Damage Inspection (DINS) database to QGIS or other relevant data (e.g. [LA County open datasets](#))
- 1) Overlay the DIST-S1 product

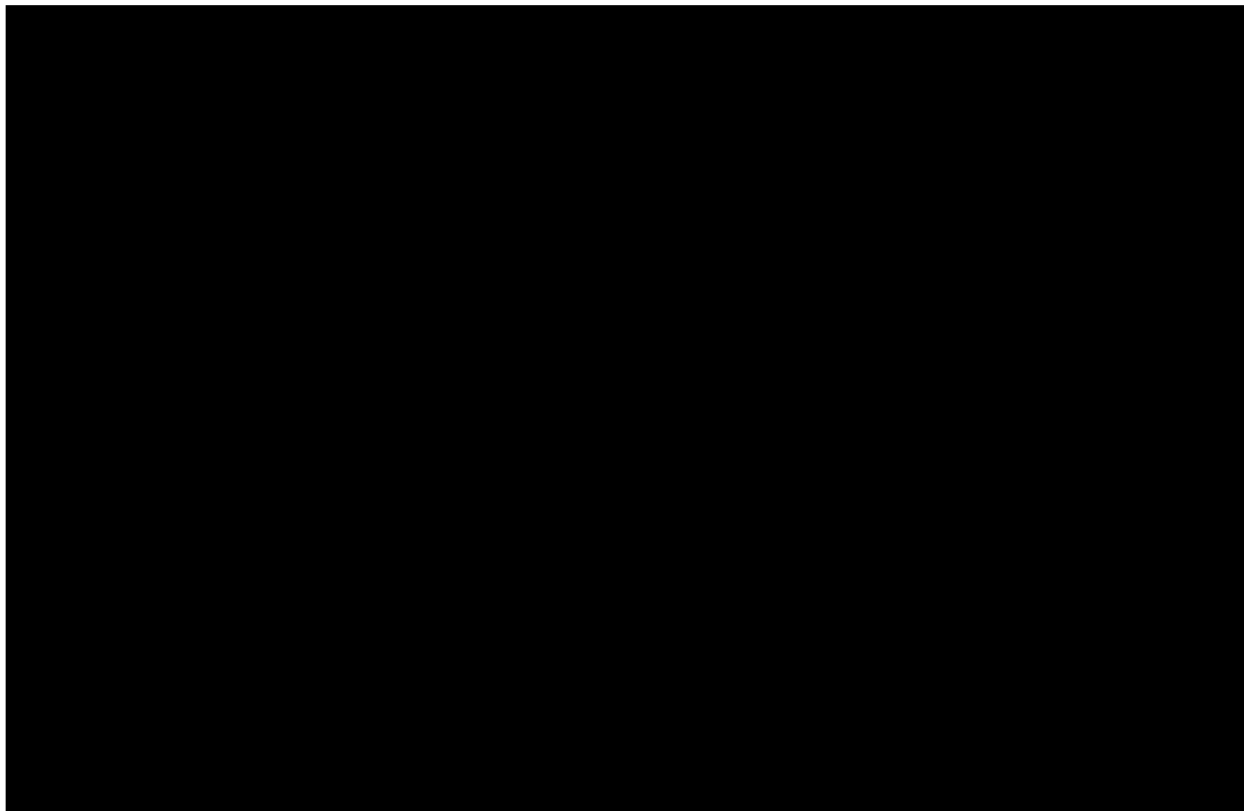


OPERA_L3_DIST-ALERT-S1_T11SLT_20250121T135246Z_20250611T162211Z_S1_30_v0.1_GEN-DIST-STATUS

Goal: Map the Wildfire Extent using DIST-S1

Eaton Fire, Los Angeles 2025

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Conclusion



OPERA transforms satellite observations into faster, more reliable insights, supporting both science and disaster resilience.

Bridging Science and Action

- OPERA delivers analysis-ready, GIS-ready datasets that support cutting-edge science research and hazard monitoring.
- Products are openly accessible, standardized, and interoperable for long-term scientific studies.
- Open-source Jupyter notebooks are available to jumpstart and simplify your science workflow.

Enabling Rapid Disaster Response

- Streamlined python-based tools and workflows accelerate delivery of satellite-derived information to emergency responders, agencies, and partners
- Directly supports the NASA Disasters Response Coordination System (contributed to 13 major disasters in the past year).



Backup

- DISP-S1 Tools
 - ASF Displacement Portal
 - Bowser visualization tool
 - OPERA Utils Package
- NASA Earthdata Credentials
 - Accepting EULA terms

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The OPERA DISP-S1 ASF Displacement Portal

National Aeronautics and
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<https://displacement.asf.alaska.edu/>

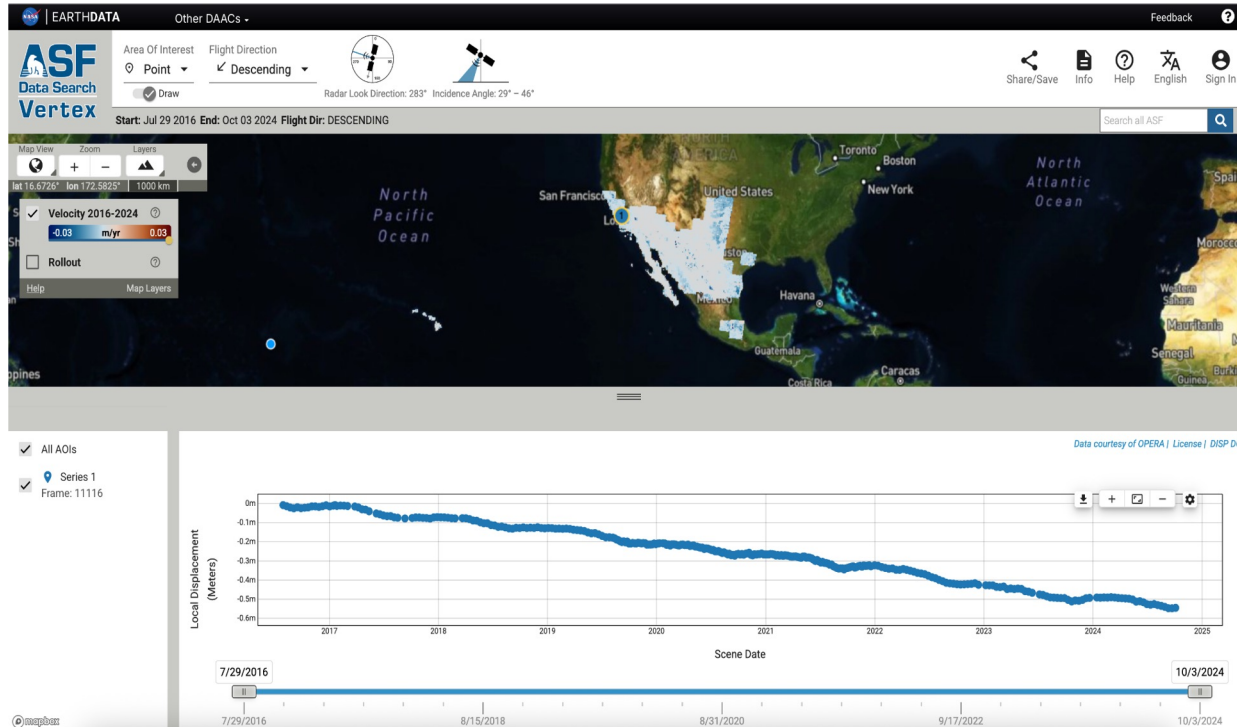
ASF - Displacement Portal

- Open-source web tool for browsing the OPERA-DISP S1 dataset
- Enables intuitive spatial exploration of deformation
- Visualizes local displacement patterns

Caveat & Resources

- See the ASF documentation for details and limitations
- Data represent **uncalibrated displacement (DISP-S1)**: best for local deformation analysis
- Contains **filtered data only**

https://docs.asf.alaska.edu/datasets/disp_faq/



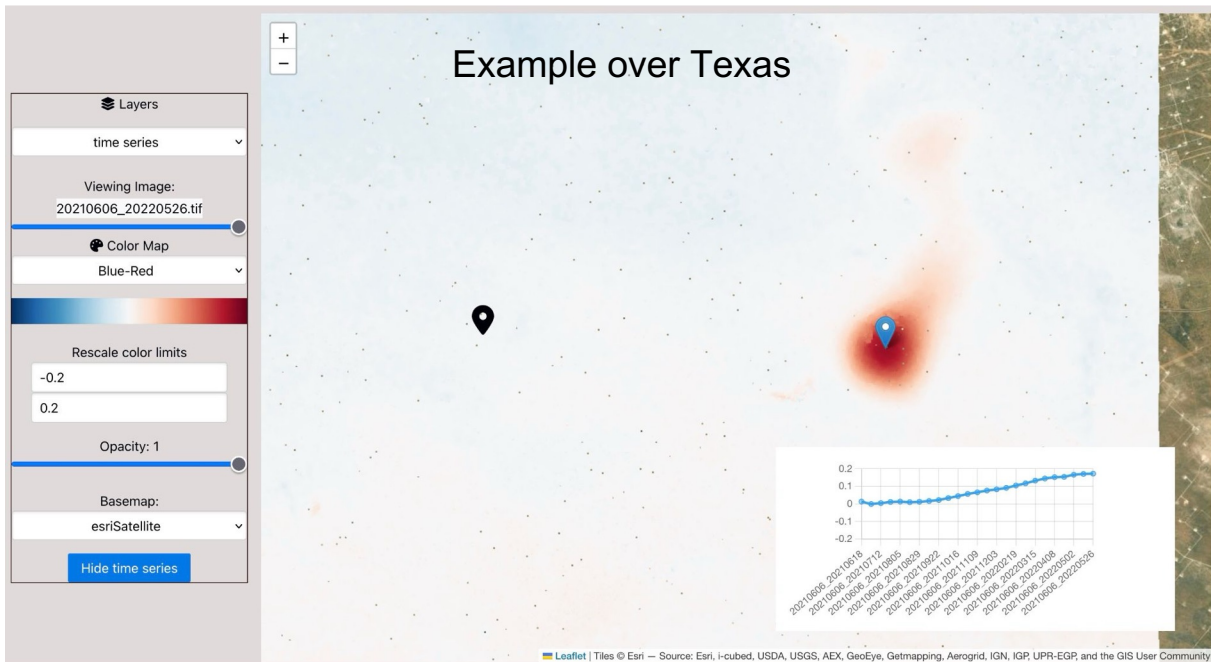
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Browser (<https://github.com/opera-adt/browser>)

Developer : S. Staniewicz



Opera_utils Python Package
(<https://github.com/opera-adt/opera-utils>)

Developers : S. Staniewicz and S. Mirzaee

&

MintPy Python Package
(<https://github.com/insarlab/MintPy>)

For users with Python skills, it provides a rich set of tools to process and visualize OPERA-DISP data

Perfect for advanced analysis beyond the web interfaces



Accepting the End User Licence Agreement (EULA) on your Earthdata NASA Profile

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Alaska Satellite Facility Data Access

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4

AGREE