National Aeronautics and Space Administration

OPERA

Observational Products for End-Users from Remote Sensing Analysis

Fifth OPERA Workshop

September 11, 2025

SAR Disturbance Development Status

This workshop is open to US and non-US participants. The material presented has been cleared for unlimited release. No ITAR information is to be presented.

CL#25-3473

SAR Disturbance Development Status

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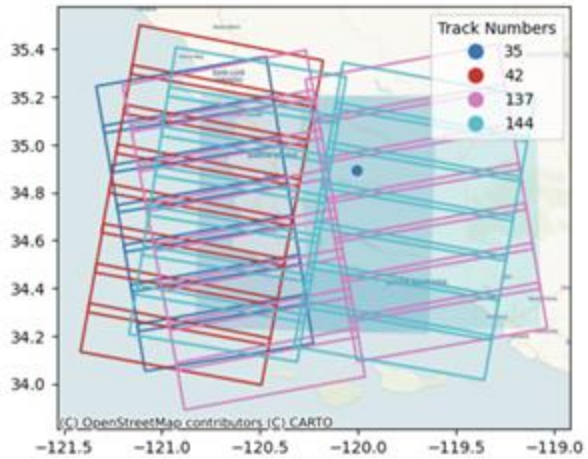
- Product Overview
- Product Usage
- Algorithm Workflow
- Requirements
- Validation
- Application Examples
- Summary and Next Steps

DIST-S1 Product Overview

The OPERA DIST-S1 product has a near global* geographical scope:

Description	Maps surface disturbances using time series radiometric terrain corrected (OPERA-RTC) radar imagery	**Sensor Temporal Sampling****	6-12 days for Sentinel-1
		Pixel Resolution (Northings x Eastings)	30 m
Distribution	Alaska Satellite Facility Distributed Active Archive Center (ASF DAAC)	**File Format**	GeoTiff organized by MGRS Tiles
Sensor	Sentinel-1 A/B/C (SAR)	**Validated Release Date**	Mar. 2026

Southern California



Example Dist-S1 MGRS Tile

and RTC Bursts

* Excluding Antarctica

***Based on Sensor input data availability*

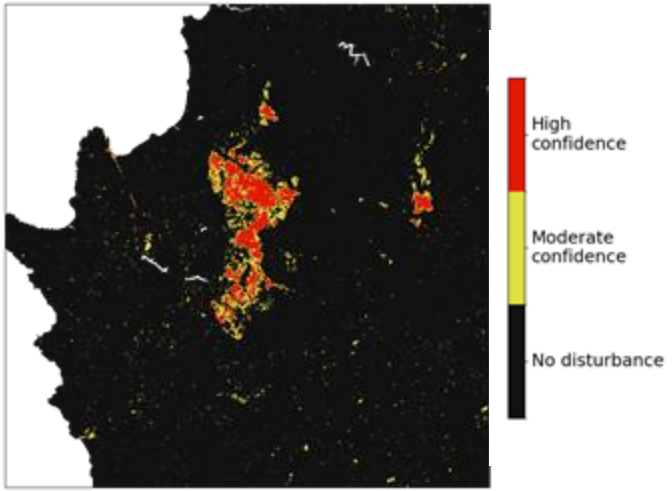
DIST-S1 Product Overview

The DIST-S1 product includes the same key layers as DIST-HLS to facilitate synergistic use

- Disturbance Status (8 bit integer with same encoding for DIST-S1 and DIST-HLS)
  - 0 - no disturbance
  - 1 - first moderate confidence disturbance
  - 2 - provisional moderate confidence disturbance
  - 3 - confirmed moderate confidence disturbance
  - 4 - first high confidence disturbance
  - 5 - provisional high confidence disturbance
  - 6 - confirmed high confidence disturbance
  - 7 - finished moderate confidence disturbance
  - 8 - finished high confidence disturbance
  - 255 - no data

- Metric Value (32 bit float)
  - Dist-S1: Normalized Z-score showing measured change of current acquisition relative to historical baseline in units of standard deviations from the mean. Thresholded to determine low and high confidence disturbance status.
  - Dist-HLS: Vegetation index or Mahalanobis distance (like a normalized Z-score).

Wildfire in Valparaiso, Chile: Feb 4, 2024



DIST-S1 Disturbance Labels
(acquisition: Feb 17, 2024)

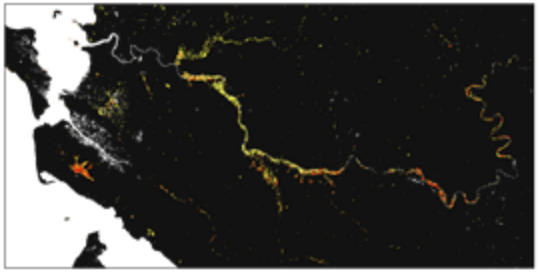
Radar and optical products constructed similarly, but results are expected to differ

Product Usage

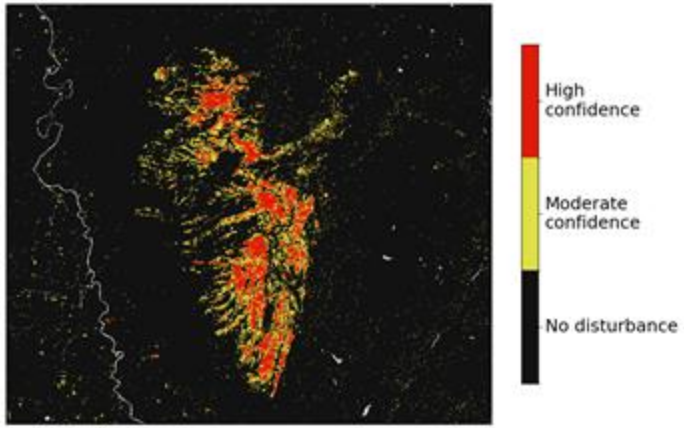
DIST-S1 products can potentially be used for a wide variety of disturbance monitoring:

- *Track* ***anthropogenic and natural vegetation/forest disturbance***
  - ***Operational and post fire support***
  - *Monitor* ***invasive species*** *impacts to forests and vegetation*
  - ***Forest mapping*** *for arbor management*
- *Identify* ***land cover changes*** *that affect* ***water quality***
- *Monitor* ***vegetation health, disturbance, and recovery***
- *Monitor* ***other types of disturbance such as***: ***mining***, ***long term flooding, sandbar development, urban development***

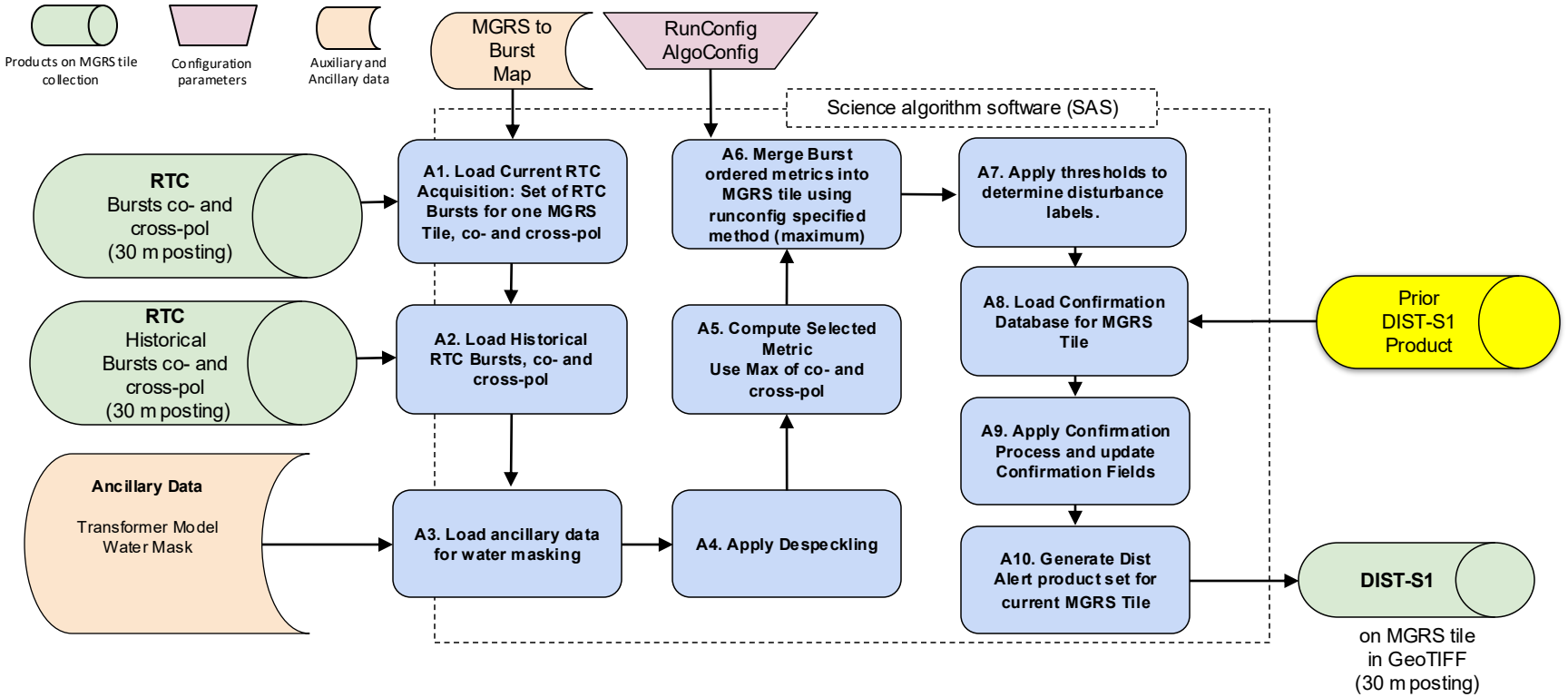
Southwest France Flood: Dec 14, 2023



Park Wildfire in California: Jul 24, 2024



Algorithm Workflow



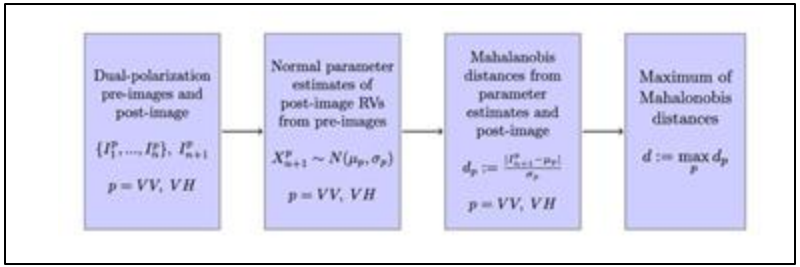
Algorithm concept – disturbance metric

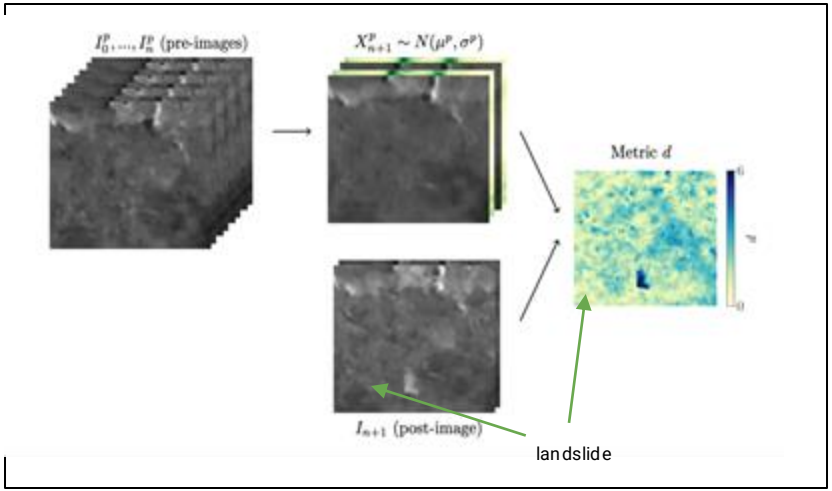
A disturbance *metric* quantifies (per-pixel) how likely a pixel is to be disturbed. Higher metric values indicate more likely to be disturbed. Our metric is a normalized Z-score which measures changes relative to a historical mean and standard deviation.

Our *transformer* model uses a set of pre-images to estimate the historical mean and standard deviation taking advantage of temporal and spatial patterns in the data. From this estimate, our metric is defined as the *deviation* of the *observed* post-image from this distribution as in [1].

The flow chart (upper right) shows how we do this for both polarizations.

The image flow chart (bottom right) shows a visual summary of the *transformer metric* over the tragic New Guinea Landslide in May 2024.





Reference [1]: O. Stephenson et al., *Deep Learning-Based Damage Mapping With InSAR Coherence Time Series*, IEEE Transactions on Geoscience and Remote Sensing, vol. 60, pp. 1-17, 2021

Requirements

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Allocation for Algorithm Execution Time	Spatial Posting	Spatial Extent	Product Accuracy and Quality Notes*
16 hours	30 m	Near global (all landmasses excluding Antarctica) where input sensor data is available	The disturbance (DIST-S1) products, derived from RTC data, shall identify pixels **having at least 50% vegetative structure loss per RTC pixel** (approximately 30 m in size) between a current single-date RTC observation as compared to a set of historical RTC observations. The Disturbance Alert (DIST-ALERT-S1) product shall measure said disturbances with 80% accuracy per validation pixel for at least 80% of all validation products considered.

* L2 accuracy requirements were concurred with sponsor and SNWG-MO

Validation strategy

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- Stratified Set of MGRS Tiles covering different geographic regions and different disturbance types selected by UMD for Validation
    - ~98 Tiles
    - Substratified to 10-20 validation pixels in each tile.
    - Cover range of disturbance intensity according to DIST-HLS detection and including no disturbance
    - Reference data generated by human observers looking at a combination of high-res optical imagery from Planet Labs PBC, and HLS.
    - Quantitative assessment based on Dist-S1 results compared to Reference results to determine measures of precision and recall
- Qualitative assessment of ~10 test cases covering a range of disturbance types
    - Quantitative assessment using precision and recall possible in special cases where reference data can be assembled

Application Example: Eaton, Palisades Fires, Jan 7, 2025

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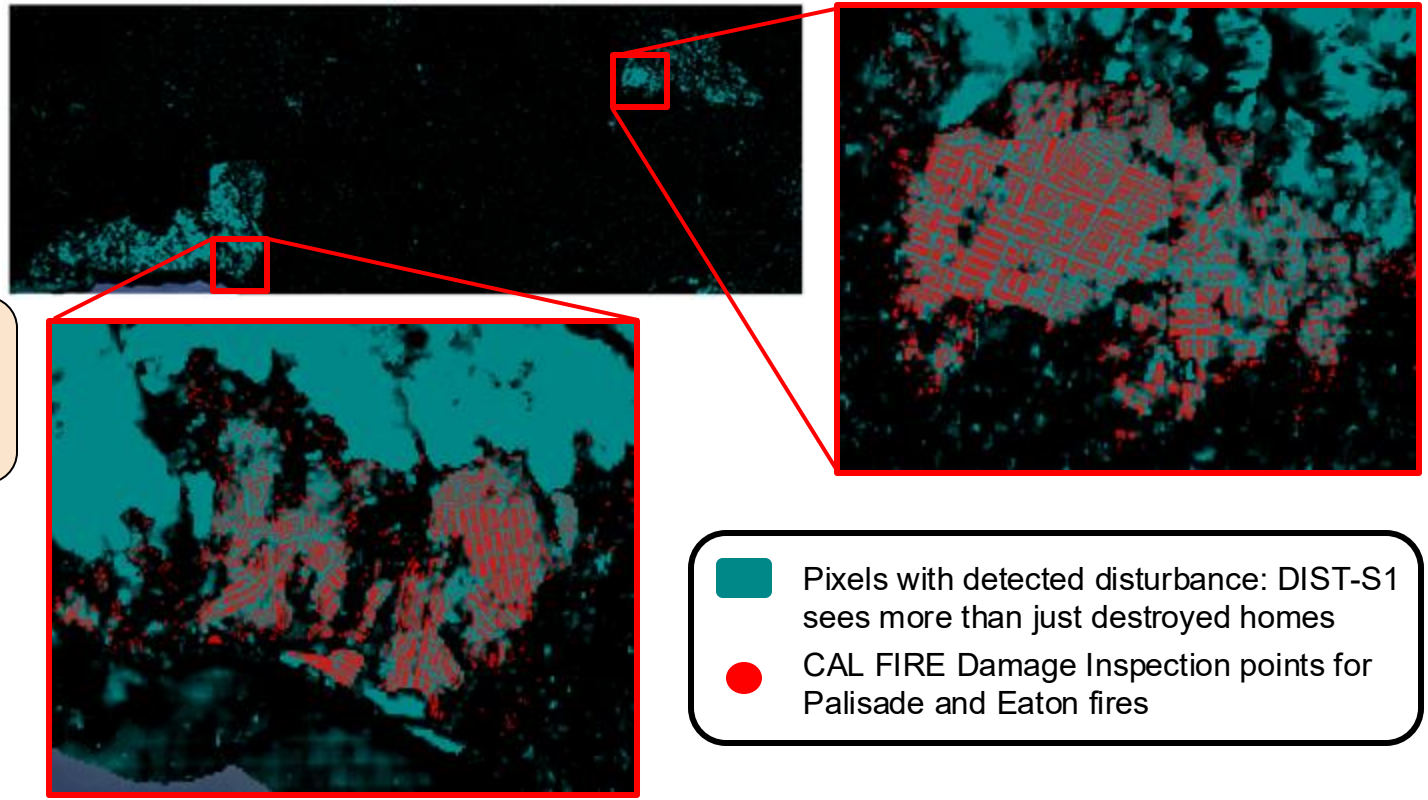
DIST-ALERT-S1
Jan 21, 2025



16,251 homes directly destroyed by the wildfires

Pixels with detected disturbance: DIST-S1 sees more than just destroyed homes

CAL FIRE Damage Inspection points for Palisade and Eaton fires

Papua New Guinea Landslide, May 24, 2024

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UN estimates ~670 killed by the landslide.

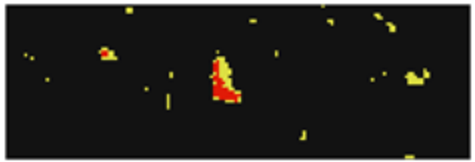
cnn.com(Juho Valta/UNDP Papua New Guinea/AP)

npr.com(Mohamud Omer/AP/International Organization for Migration)

Villagers search through a landslide in Yambali, in the Highlands of Papua New Guinea, on Sunday, May 26, 2024. The International Organization for Migration feared Sunday the death toll from a massive landslide is much worse than what authorities initially estimated.
Mohamud Omer/AP/International Organization for Migration

Dist-S1 sees the landslide area similar to Dist-HLS

DIST-ALERT-S1

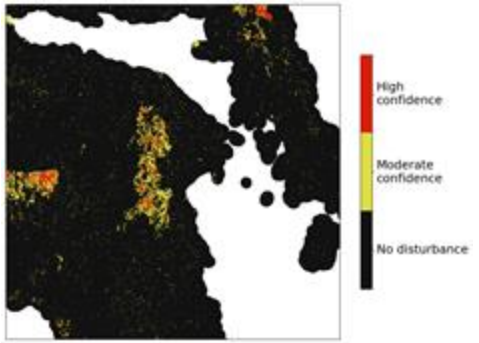


DIST-ALERT-HLS
June 3, 2024

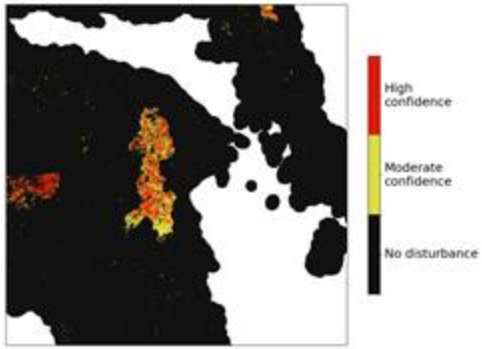
Attica, Greece Fire, Aug 11, 2024

Roughly 32,000 people displaced.

DIST-ALERT-S1
Aug 26, 2024



DIST-ALERT-HLS
Sep 5, 2024



Dist-S1 sees the same fire boundaries as Dist-HLS.

Looking Forward

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Operational OPERA DIST-S1 products are expected to become available in March 2026

Summary

- The OPERA project will generate DIST-S1 products from Sentinel-1 on a near-global scale
- The OPERA team will use OPERA RTC-S1 products as an input and provide users with the highest quality data possible
- We expect OPERA DIST-S1 products will be suitable for a wide range of disturbance tracking applications

Next Steps

- OPERA team recently delivered software required for DIST-S1 production to be used for Calibration and Validation
- Product calibration and validation began in August 2025 and proceeds through the end of 2025. Final delivery of software is scheduled for late January 2026.