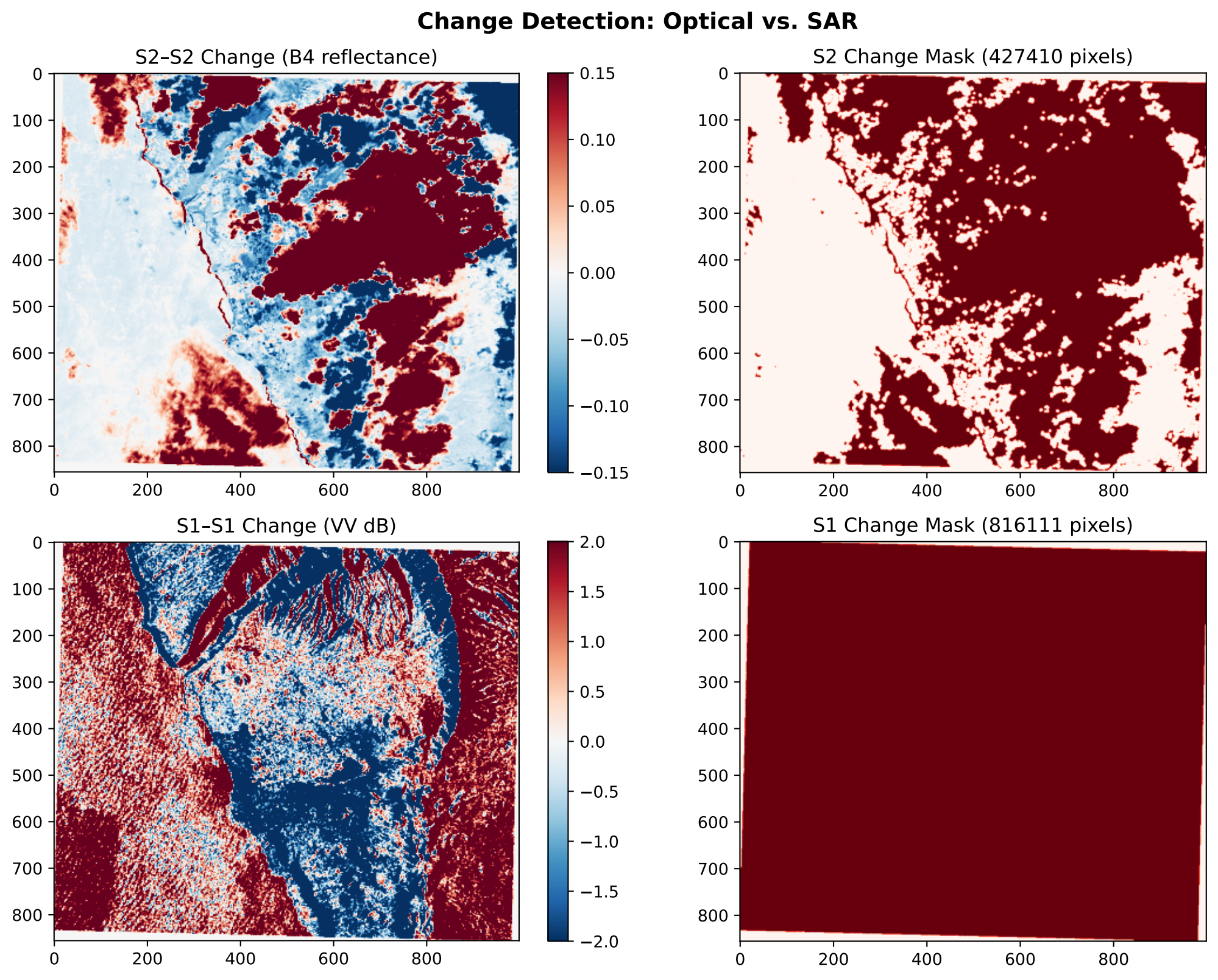
La Palma Volcano 2021
EO–SAR Change Detection Analysis

Project Overview
This report presents automated change detection analysis using Sentinel-2 (optical) and Sentinel-1 (SAR) imagery over the Cumbre Vieja eruption zone, La Palma, Canary Islands.

Temporal Windows:
- PRE Event: 2021-09-01 to 2021-09-15
- POST Event: 2021-12-15 to 2021-12-31

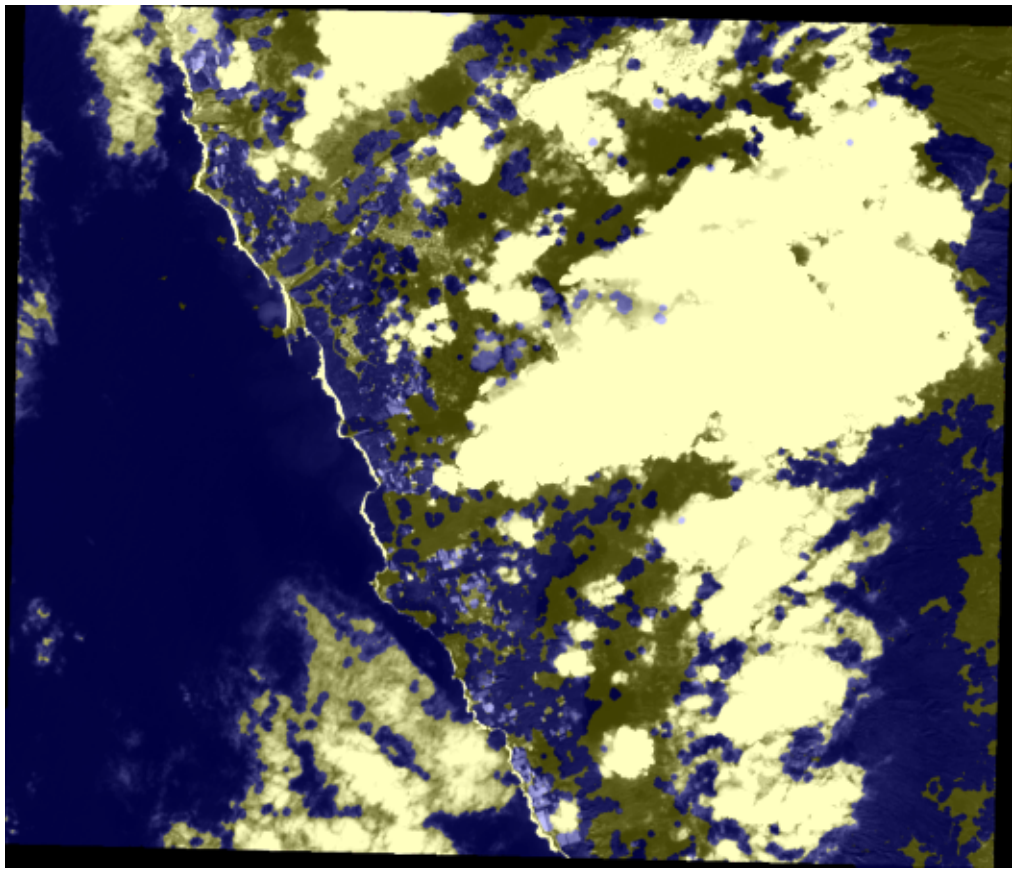
Key Findings:
- Total changed pixels (S2): 427,410
- Total changed pixels (S1): 816,111
- Fusion (S2 OR S1): 816,143 pixels (95.44% of valid grid)
- High-confidence (S2 AND S1): 427,378 pixels (49.98% of valid grid)

Methodology:
1. Automated data acquisition from Google Earth Engine
2. Coregistration to common grid (20 m)
3. Radiometric calibration (S1 → dB)
4. Change mask generation with fixed thresholds
5. Quality checks and fusion

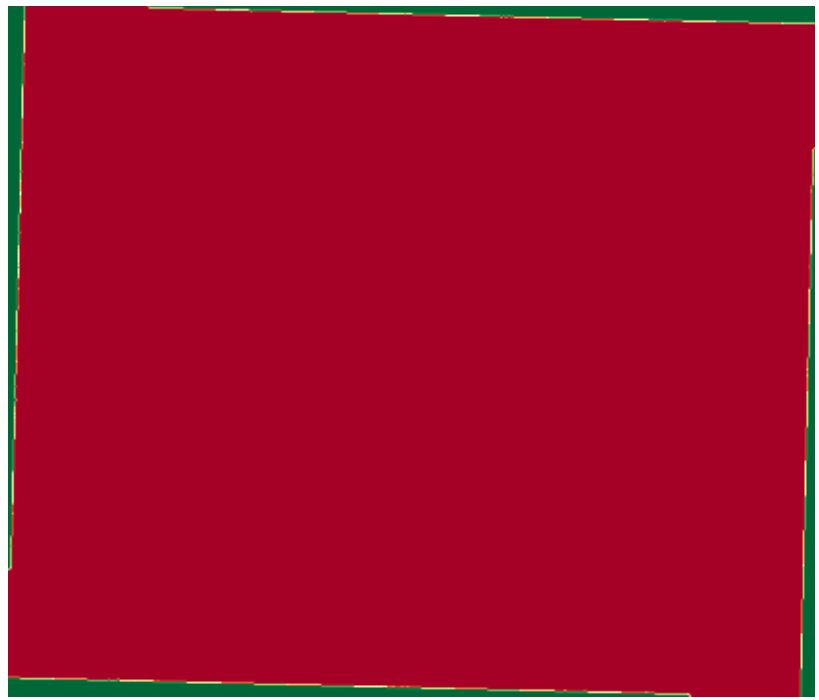

Change Detection: Optical vs. SAR
S2–S2 Change (B4 reflectance)
S2 Change Mask (427410 pixels)
S1–S1 Change (VV dB)
S1 Change Mask (816111 pixels)
0
100
200
300
400
500
600
700
800
0.15
0.10
0.05
0.00
−0.05
−0.10
−0.15
2.0
1.5
1.0
0.5
0.0
−0.5
−1.0
−1.5
−2.0

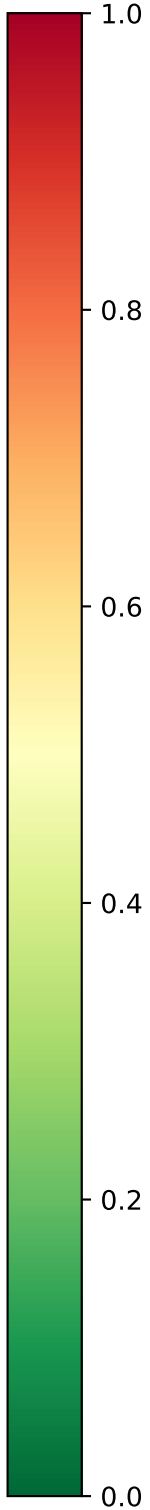
Sensor Fusion & Quality Control

QC Overlay (Red=S2 only, Blue=S1 only, Yellow=Both)



Fusion Mask (S2 OR S1): 816143 pixels





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CHANGE DETECTION STATISTICS

Grid & Validity:
  Total pixels (entire grid)       : 855,144
  Valid pixels (no NaN)            : 855,144
  Coverage                         : 100.0%

Change Detection Results:
  S2-detected change pixels        : 427,410 (49.98% of valid)
  S1-detected change pixels        : 816,111 (95.44% of valid)
  S2 AND S1 agreement              : 427,378 (49.98% of valid)
  S2 OR S1 fusion                  : 816,143 (95.44% of valid)

Sensor Sensitivity:
  S2-only change (not in S1)       : 32 pixels
  S1-only change (not in S2)       : 388,733 pixels

Quality Checks:
  S2 high-variance regions         : 85,515 pixels (potential noise)
  S1 high-variance regions         : 85,515 pixels (potential noise)
  S2 after small-object removal    : 424,650 pixels
  S1 after small-object removal    : 816,111 pixels

RECOMMENDATIONS & INSIGHTS

1. Thresholds Tuning
   • Current S2 threshold (0.08): sensitive to vegetation changes
   • Current S1 threshold (0.15 dB): sensitive to roughness changes
   • Recommendation: Vary thresholds to balance sensitivity vs. false positives

2. False Positive Mitigation
   • High-variance areas often overlap with topographic shadows or layover
   • Apply a spatial filter (e.g., median or bilateral) to pre-process SAR
   • Cross-validate with external datasets (elevation, mask files)

3. False Negative Sources
   • Very fresh lava may have emissivity/backscatter similar to surroundings
   • Use multi-temporal composites instead of single dates for robustness
   • Consider thermal data (MODIS, Sentinel-5P) for supplementary detection

4. Workflow Improvements
   • Implement per-pixel confidence scoring (e.g., Bayesian fusion)
   • Add manual annotation interface for ground-truth validation
   • Expand to multi-sensor time series (e.g., monthly stacks)

5. Operational Deployment
   • Automate report generation to trigger alerts near real-time
   • Integrate with GIS platform for stakeholder visualization
   • Archive all intermediate products for audit trail

CONCLUSION
The fusion of Sentinel-2 and Sentinel-1 enables robust, complementary change detection.
Optical sensors detect surface reflectance changes (vegetation damage), while SAR detects
roughness changes (lava flows). Combined, they provide a comprehensive picture of the
eruption impact over La Palma's landscape.
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