EARTH OBSERVATORY OF SINGAPORE

# Improving the Versatility of Post-Disaster Damage Mapping Algorithms

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# Outline

- Introduction to damage proxy maps
- Existing coherence-based algorithm
- Proposed improvements to the algorithm by using intensity correlation
- Results of testing

# Damage proxy maps

The aim is to produce damage proxy maps.

- Used visually or combined with population and administrative datasets for quantitative assessments.

When a disaster hits, responders need to know:

- Was there any damage at all?
- Where are buildings and infrastructure damaged?
- Are the affected areas accessible? By which roads?
- What is the number of people affected?

Response phase: 72 hours, the sooner the better. We use both ALOS-2 and Sentinel-1, ascending and descending.

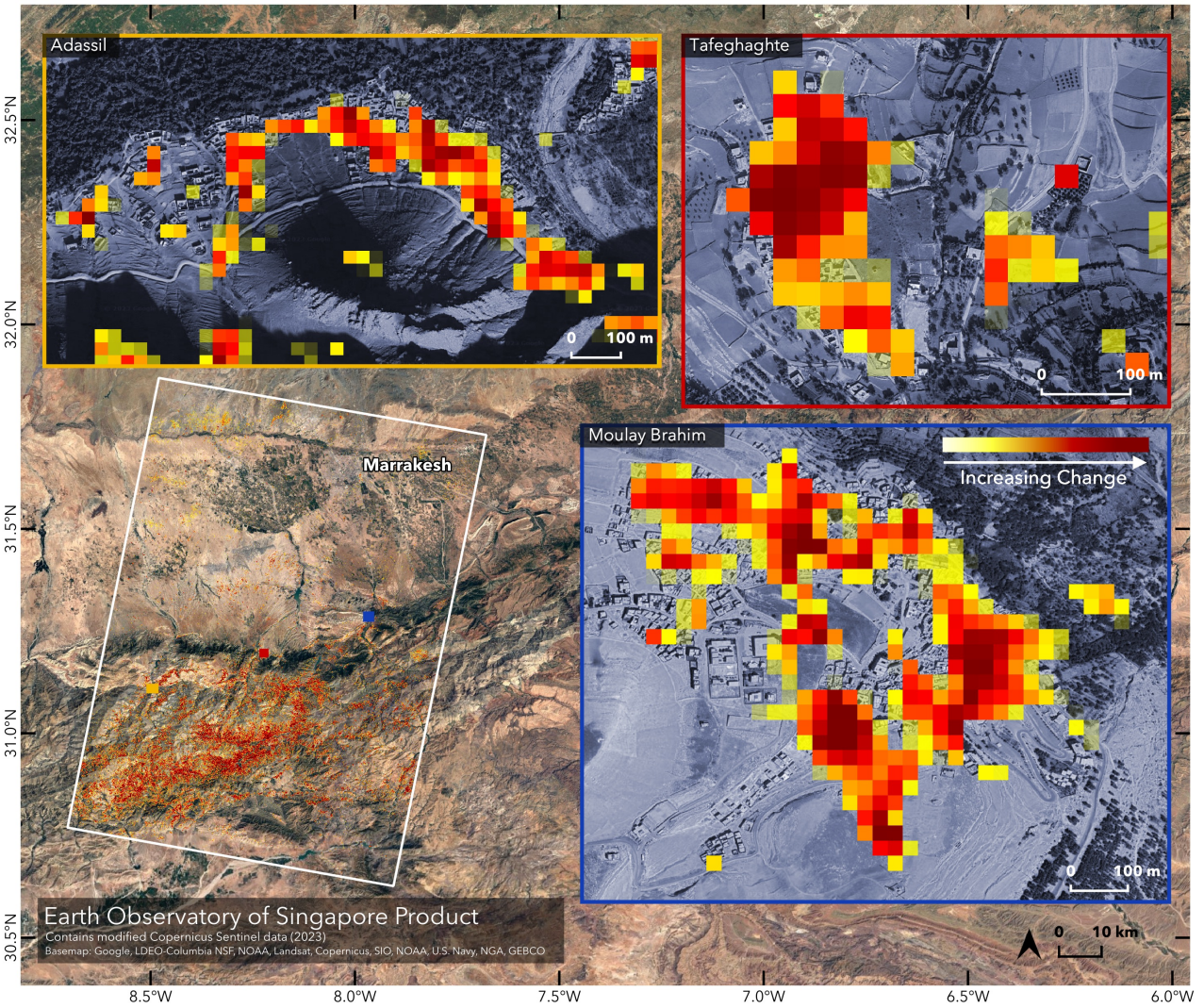
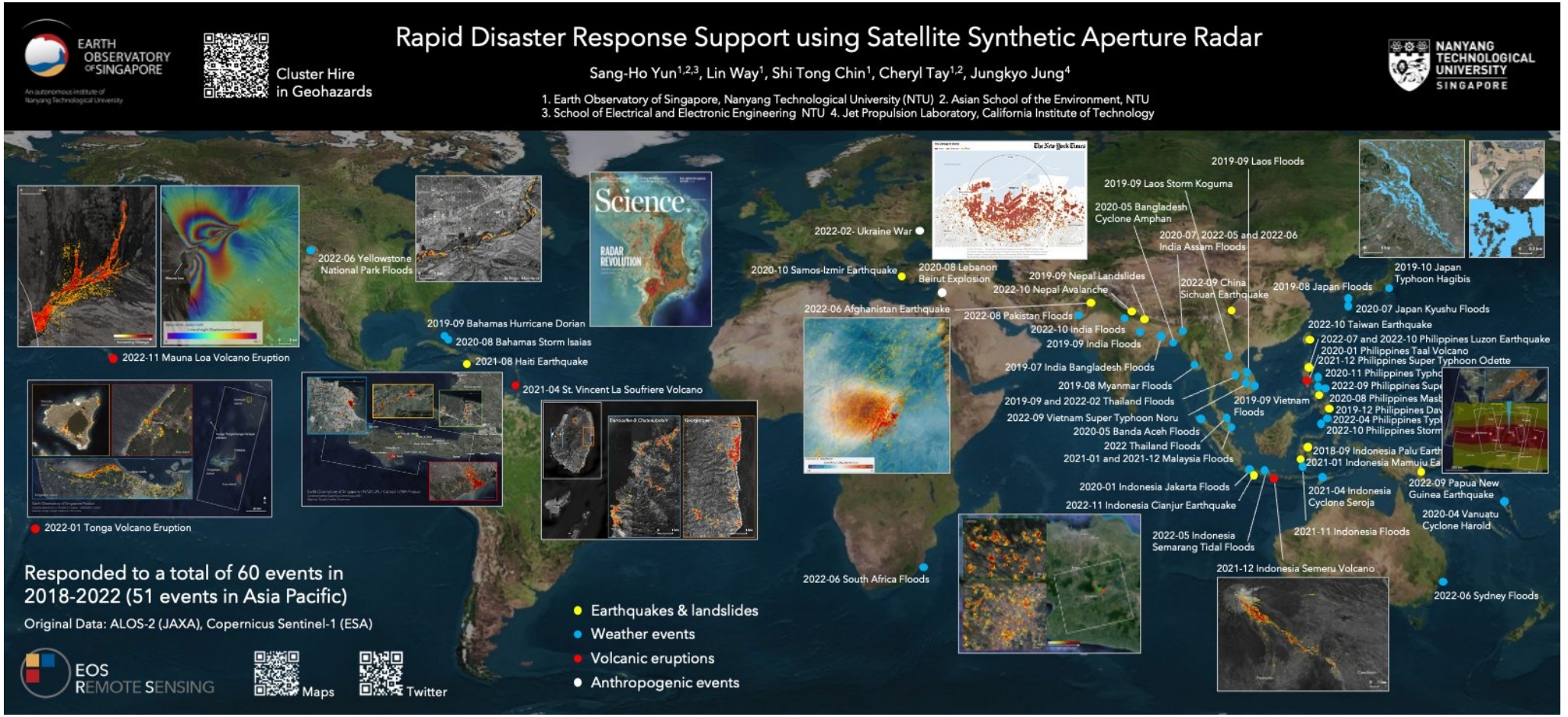



Image credit: EOS-RS Lab, contains modified Copernicus Sentinel data, validated with FirstLook data (Maxar 2023)

# Earth Observatory of Singapore's rapid disaster response team

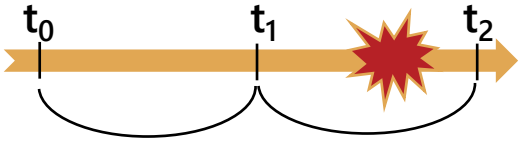
The Earth Observatory of Singapore has an operational system and team producing damage proxy maps.

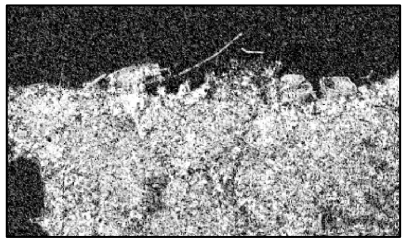


# Existing damage proxy mapping algorithm

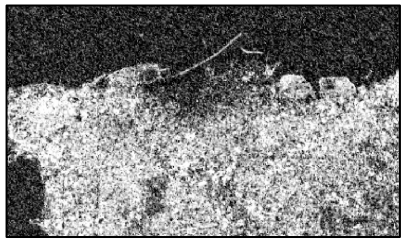
- Existing damage proxy mapping algorithms used operationally are based on coherence change detection.
- Loss of interferometric coherence during the disaster is used as a proxy for damage.

**Scenario with 3 scenes**



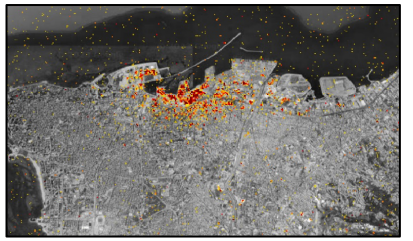



**Pre-event Coherence**



**Co-event Coherence**

**Coherence difference is a simple damage proxy map**



# Existing damage proxy mapping algorithm

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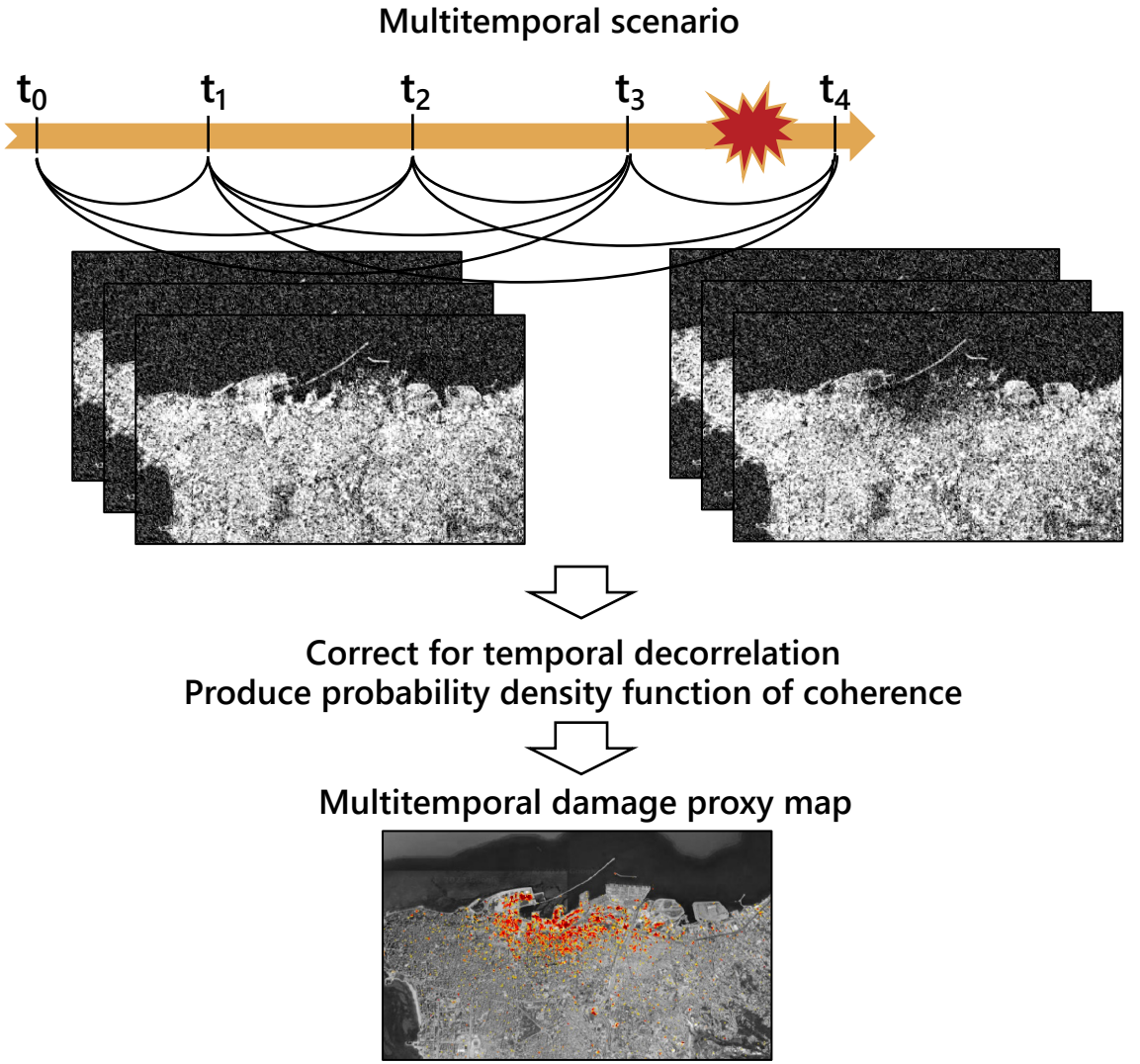
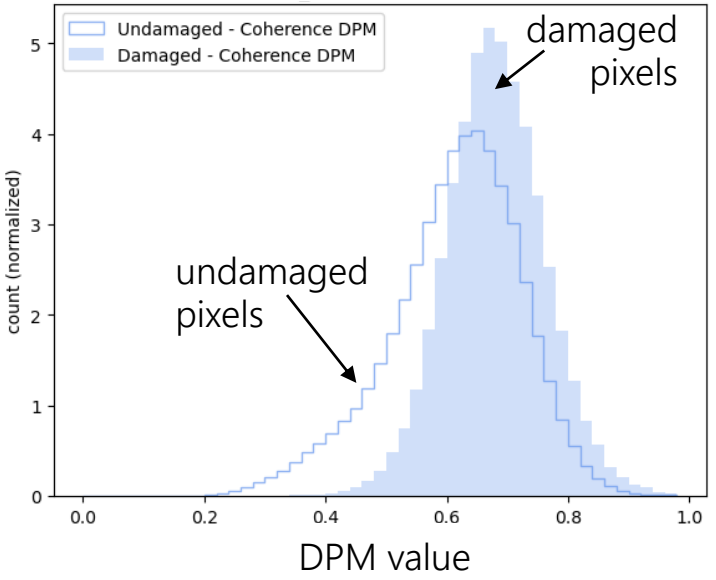
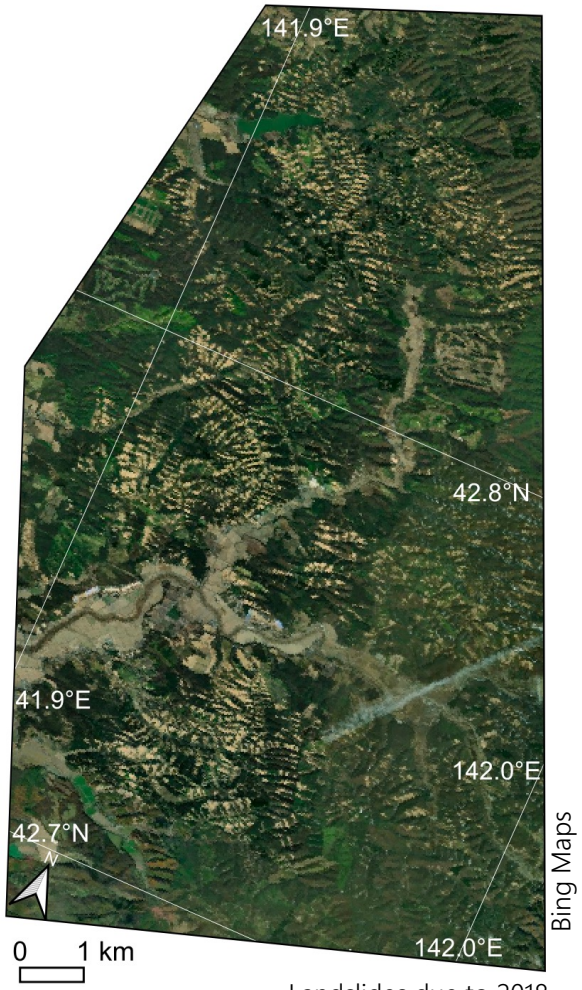
- Loss of interferometric coherence during the disaster is used as a proxy for damage.
- Minimum is three SAR scenes.
- With multiple pre-event scenes we can characterize the reference coherence better and get better results (Jung et al. 2016).



# Improving the damage proxy mapping algorithm

- The existing algorithm works well on urban areas.
- Our next target is to improve the performance on pixels whose coherence is always low (e.g. rural or mixed pixels).




Landslides due to 2018 Hokkaido Eastern Iburi earthquake and typhoon

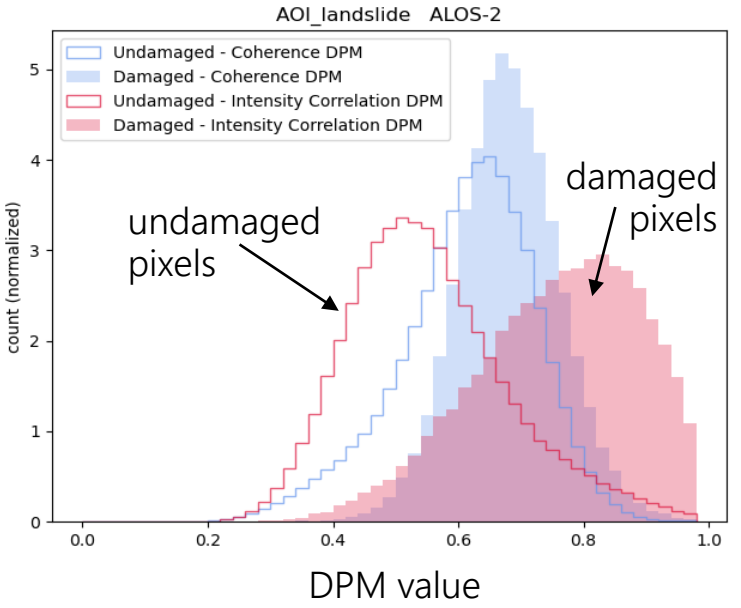
# Improving the damage proxy mapping algorithm

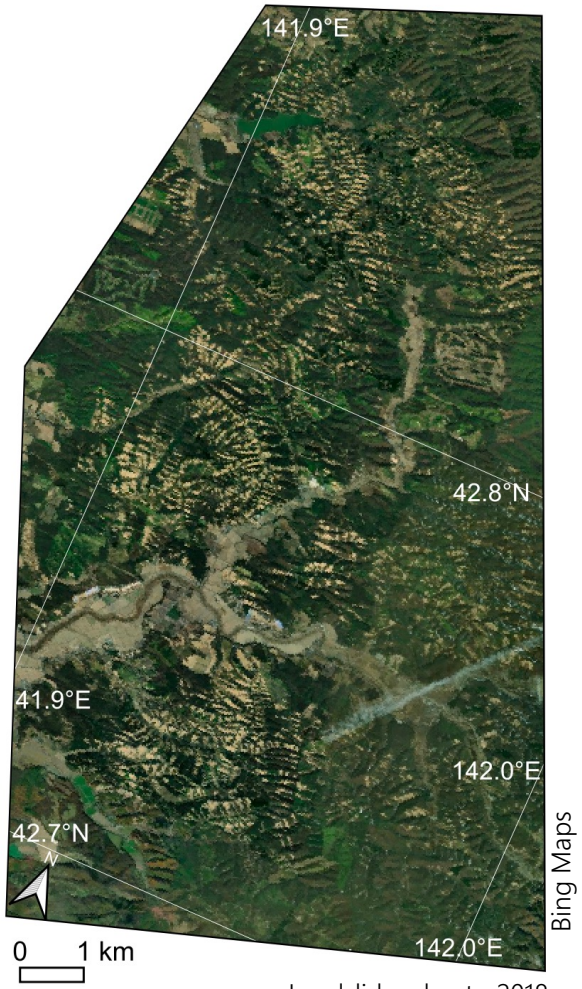
- The existing algorithm works well on urban areas.
- Our next target is to improve the performance on pixels whose coherence is always low (e.g. rural or mixed pixels).
- We will use intensity correlation (Jung & Yun 2020, Remote Sensing)

$$\rho_{m,n} = \frac{\sum I_m I_n}{\sqrt{\sum I_m^2}\sqrt{\sum I_n^2}}$$

$I$ = backscatter intensity, $\Sigma$ = sum over a window, $m$ and $n$ = pair of SAR scenes

- Decrease in intensity correlation is the proxy for damage.



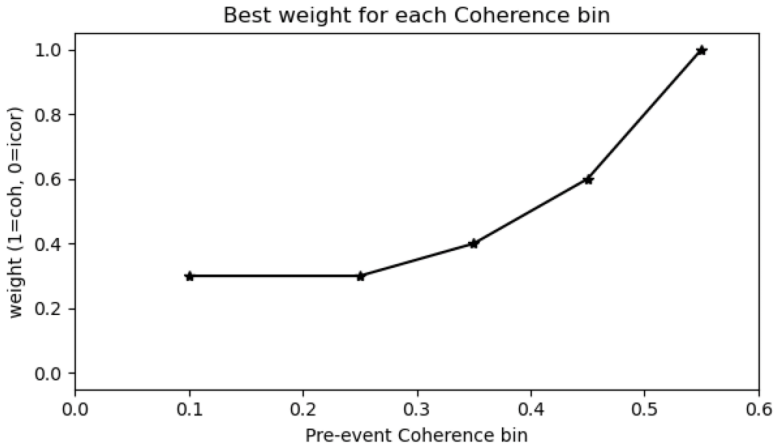

Landslides due to 2018 Hokkaido Eastern Iburi earthquake and typhoon

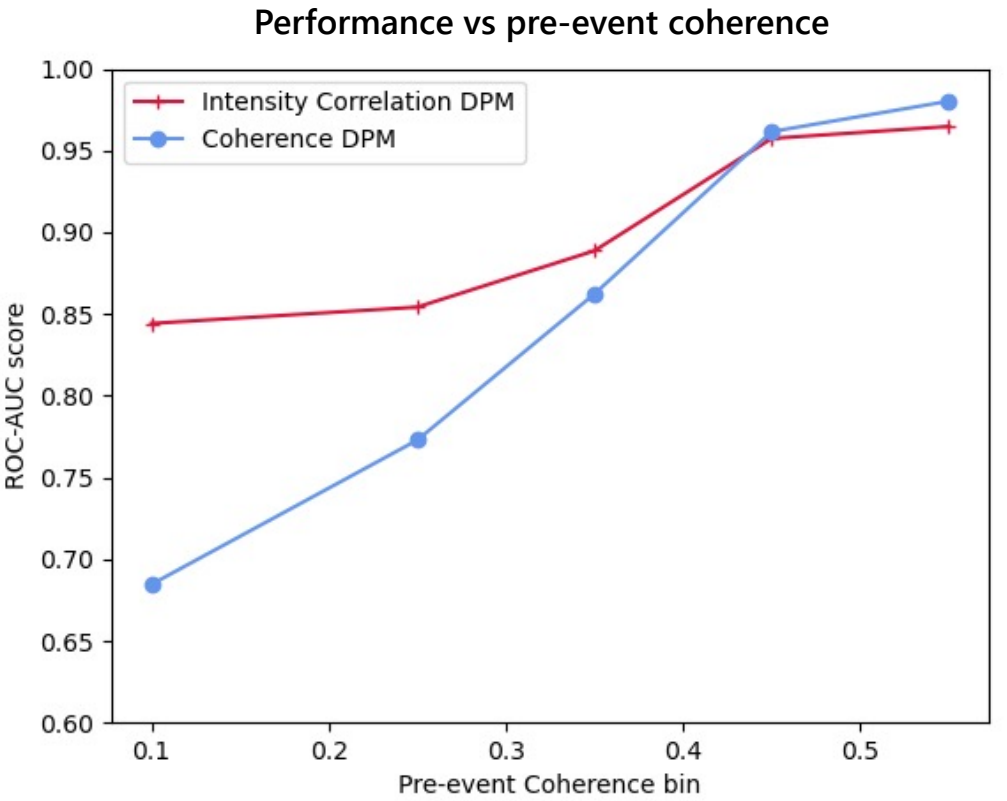
# Joint method using weighted mean

- For high-coherence pixels, coherence is preferred.
- For low-coherence pixels, intensity correlation performs better.
- We propose a joint method that's a weighted mean:

$$DPM = w(\gamma) \times DPM_{coherence} + \big(1 - w(\gamma)\big) \times DPM_{int.corr.}$$

weight $w$ is a function of coherence



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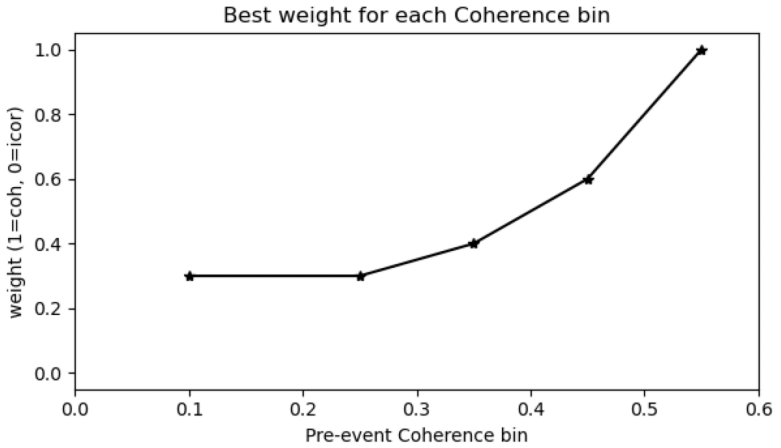
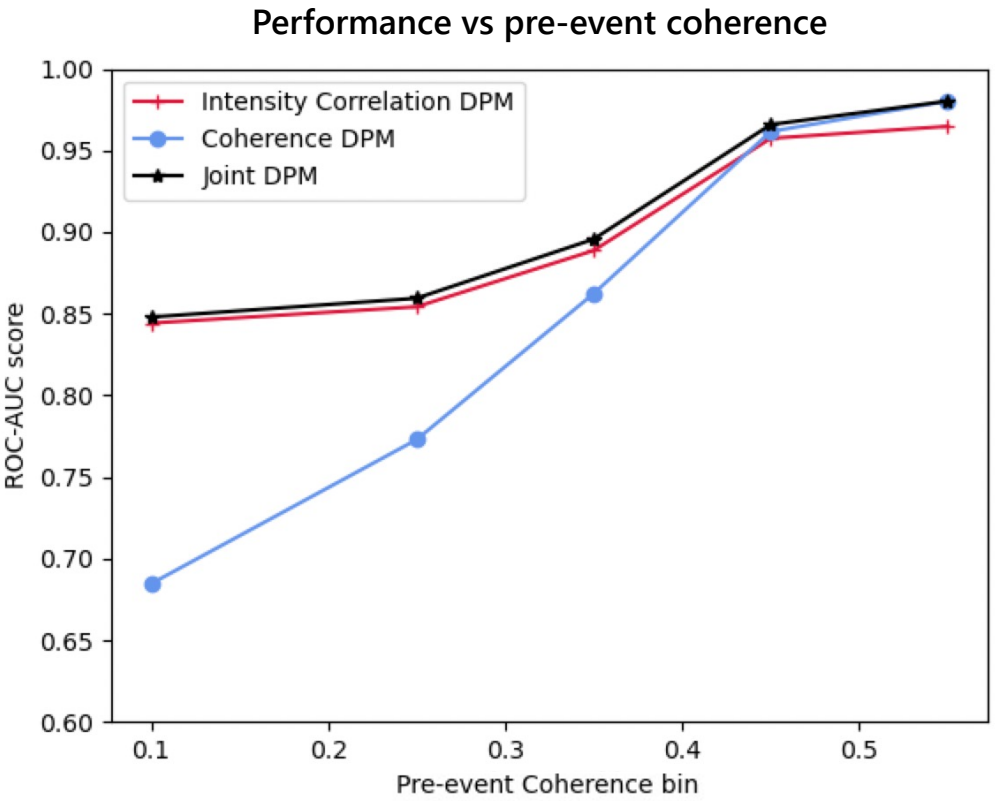


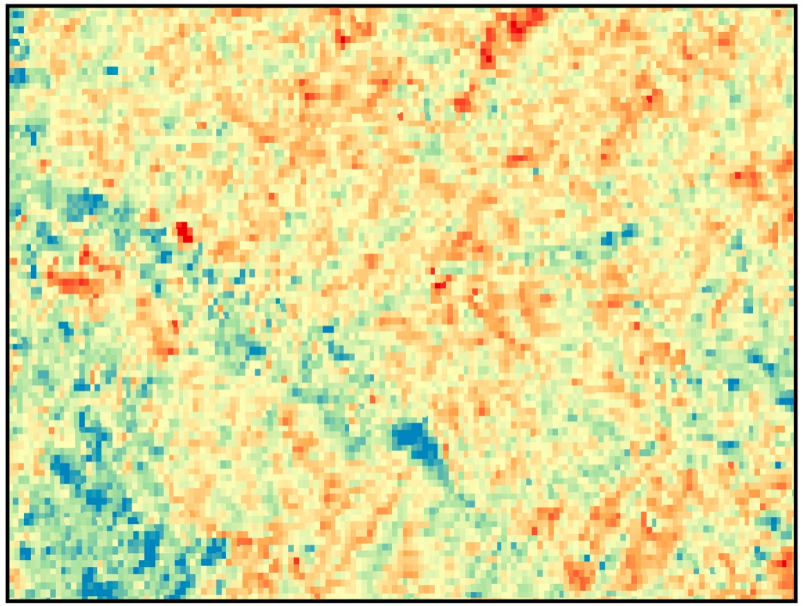
# Results for landslide damage in Japan

- Black polygons show landslides as mapped from aerial photography (credit: GSI Japan).
- The new algorithm (right) shows higher damage proxy values for landslide pixels.

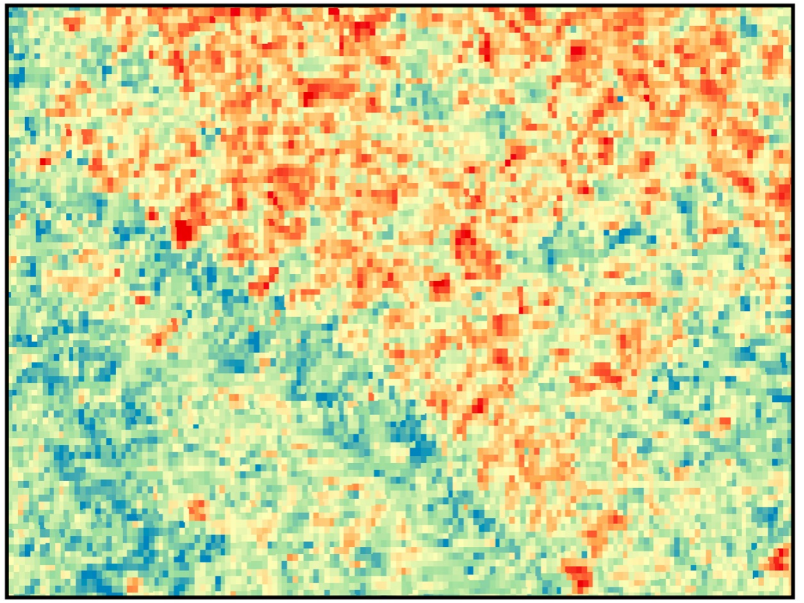
**Optical image post-event (Bing Maps)**

0 1 km

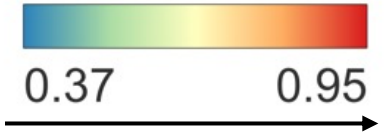
**DPM: existing algorithm**



**DPM: new algorithm**



Input data: ALOS-2 satellite, SM1 mode 3x3m, 17 scenes




**more likely to be damaged**

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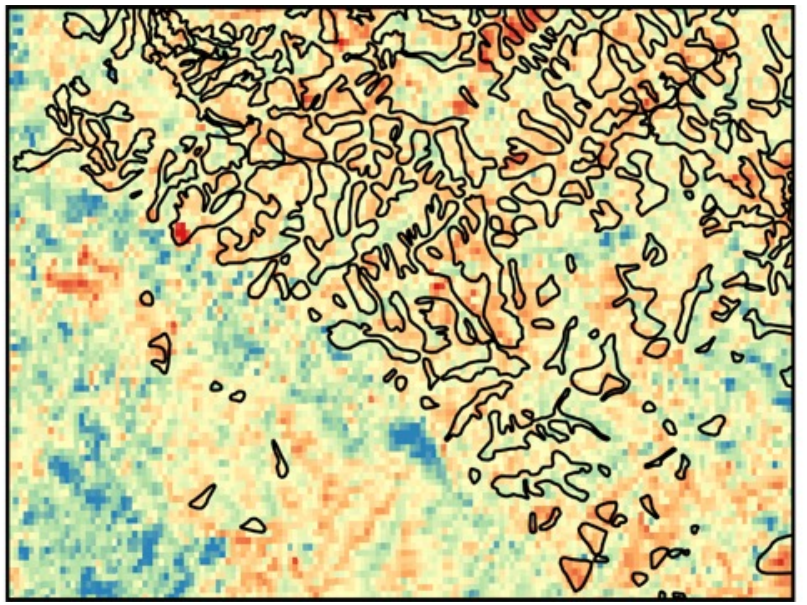

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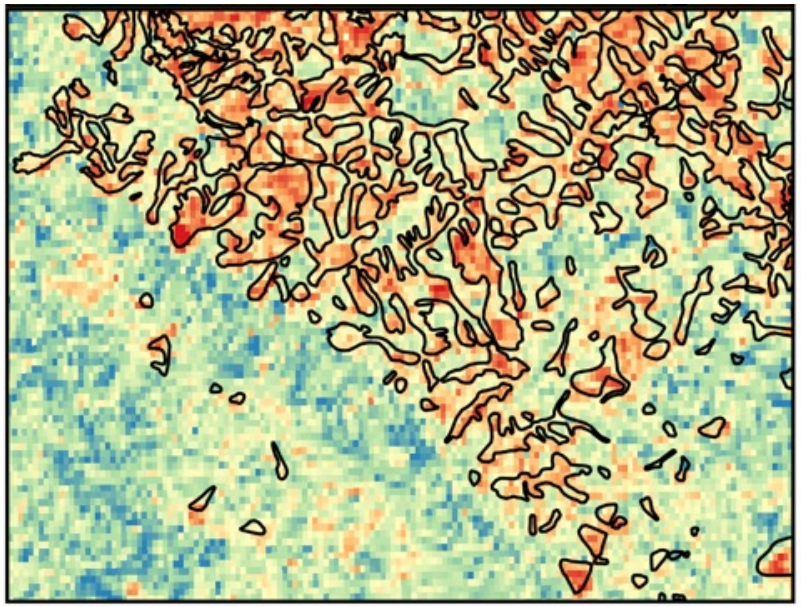

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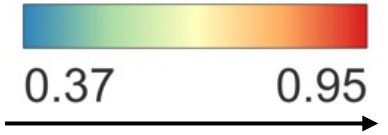


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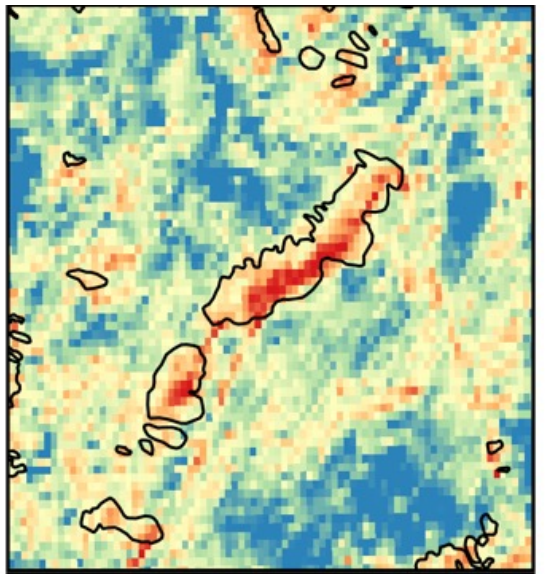

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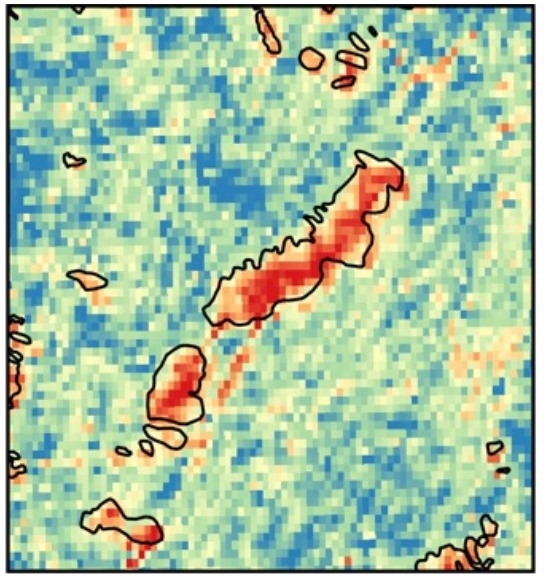


0.37 0.95

**more likely to be damaged**

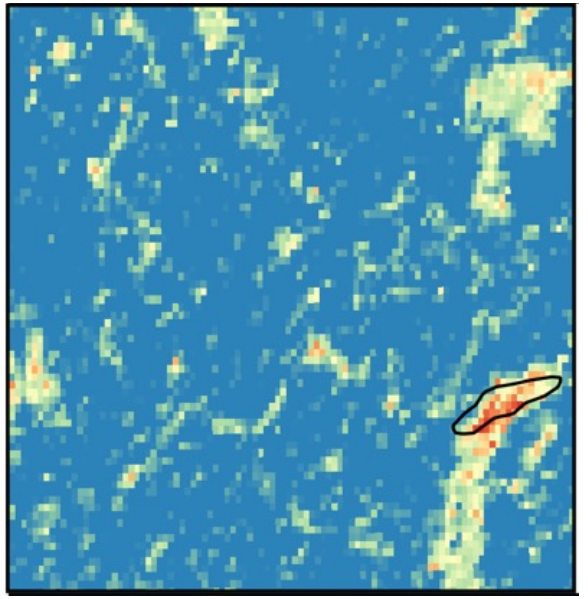
Input data: ALOS-2 satellite, SM1 mode 3x3m, 17 scenes

# Results for liquefaction damage in Japan

- Black polygon shows liquefaction (Watabe et al. 2020)
- The new algorithm maintains the performance of the existing algorithm in urban areas.

**Optical image post-event (Bing Maps)**

**DPM: existing algorithm**



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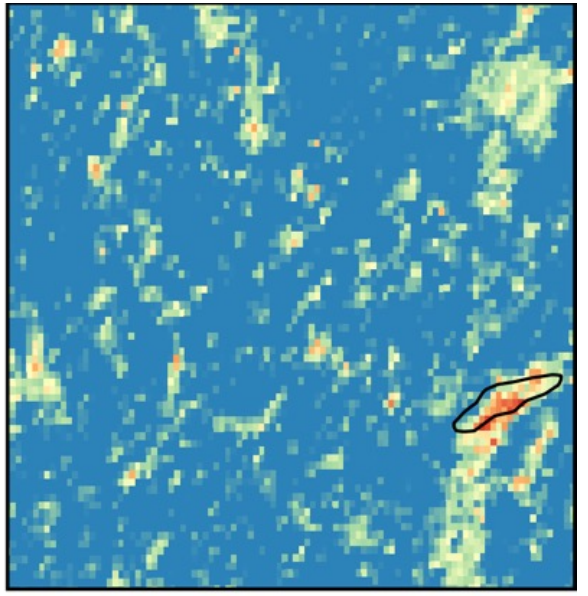
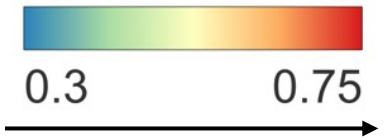
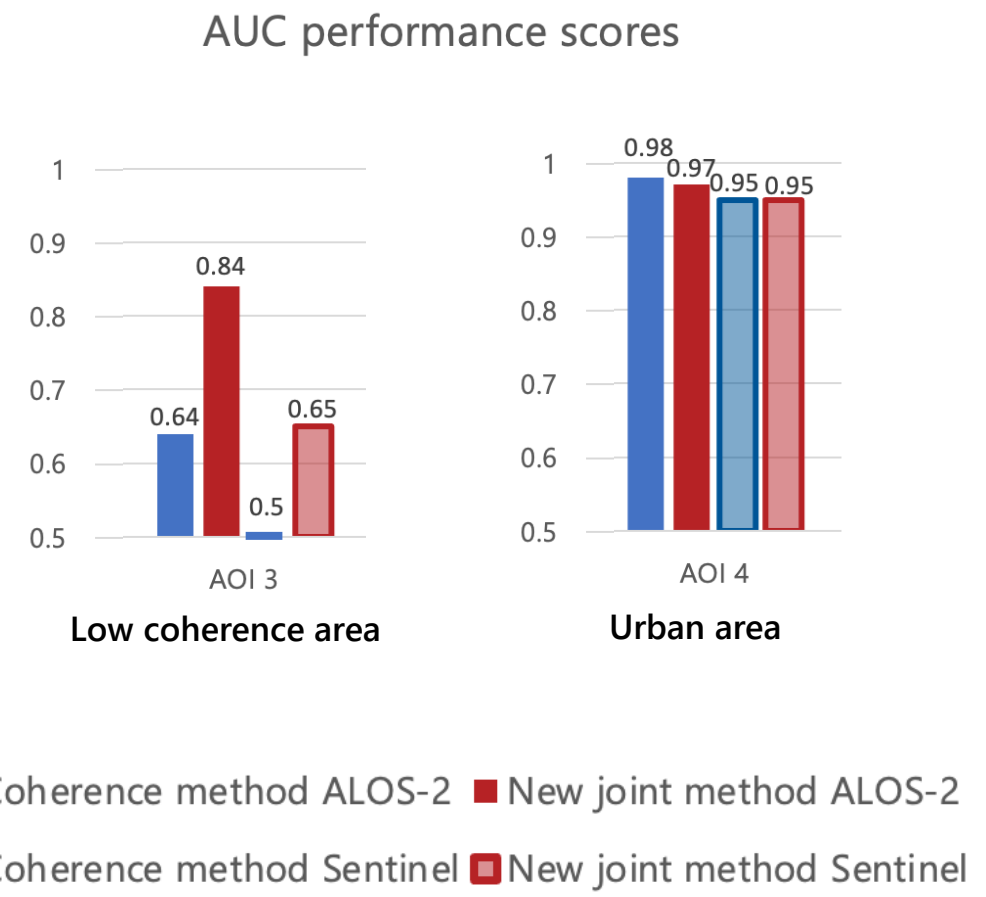



Input data: ALOS-2 satellite, SM1 mode 3x3m, 17 scenes

# Results for landslide and liquefaction damage in Japan

- New method performs better than the benchmark method in the rural areas.
- New method maintains performance in urban areas.
- With the new method, performance is still better in urban areas than rural.
- Same outcome for Sentinel-1.
- Sentinel-1 (5x20m) performance is not as good as ALOS higher resolution (3x3m) stripmap.
- We've found the same things to be true testing on other events, although the exact performance varies.




Input datasets:
ALOS-2 satellite, SM1 mode 3x3m, 17 scenes
Sentinel-1 satellite, IW mode ~5x20m, 18 scenes

# Conclusions

- The new joint damage proxy mapping method which uses the weighted mean of coherence and intensity correlation products performs more consistently than either of those alone.
- Tested on L-band ALOS-2 and C-band Sentinel-1.
- High resolution ALOS-2 data performs better than Sentinel-1 (But response speed is the first priority.)
- Intensity correlation alone usually performs moderately or well -> potential to get damage proxy maps from non-InSAR-capable satellites quickly before coherence data becomes available?

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# Thank you!