Rapid detection of triggered landslides using satellite radar coherence

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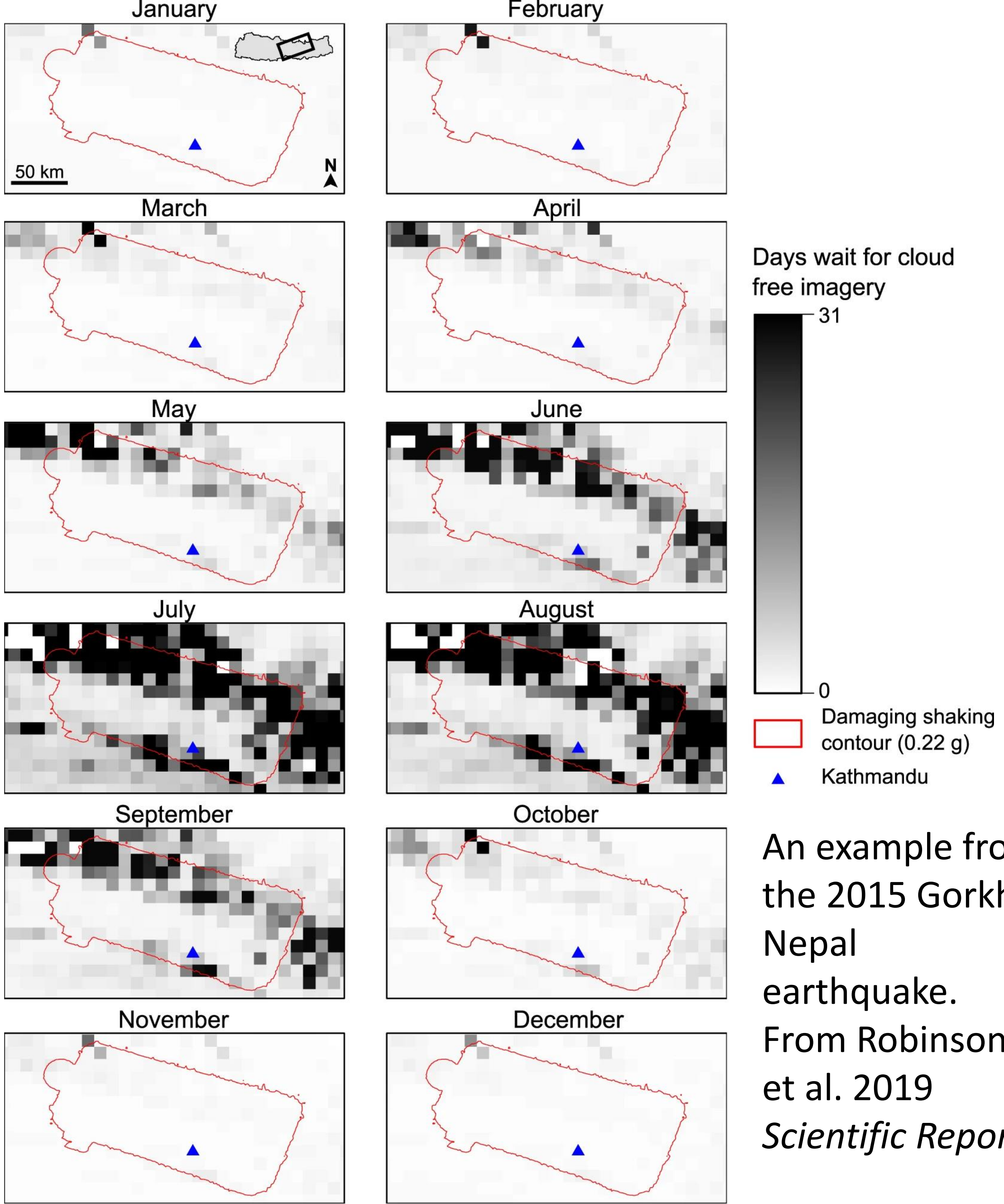
Motivation

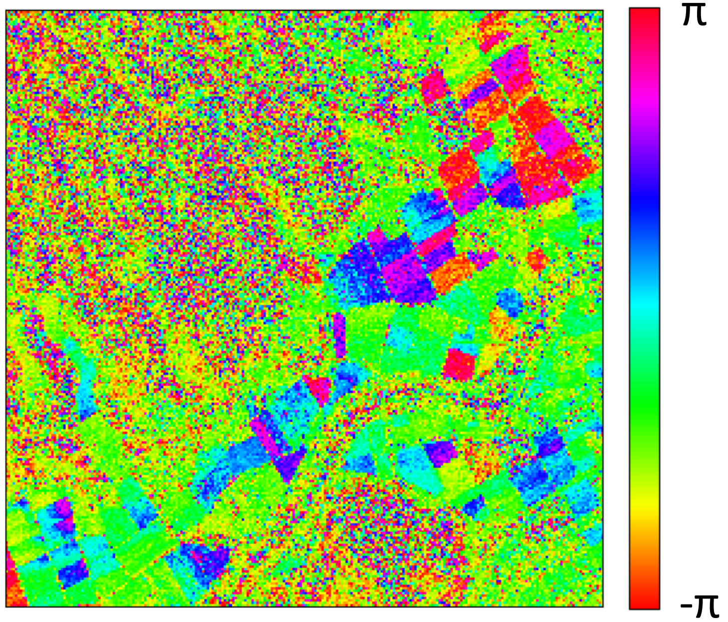
- Information on triggered landslides is needed within days of an earthquake
- When the weather is cloudy, optical satellite imagery cannot be used for post-event landslide mapping



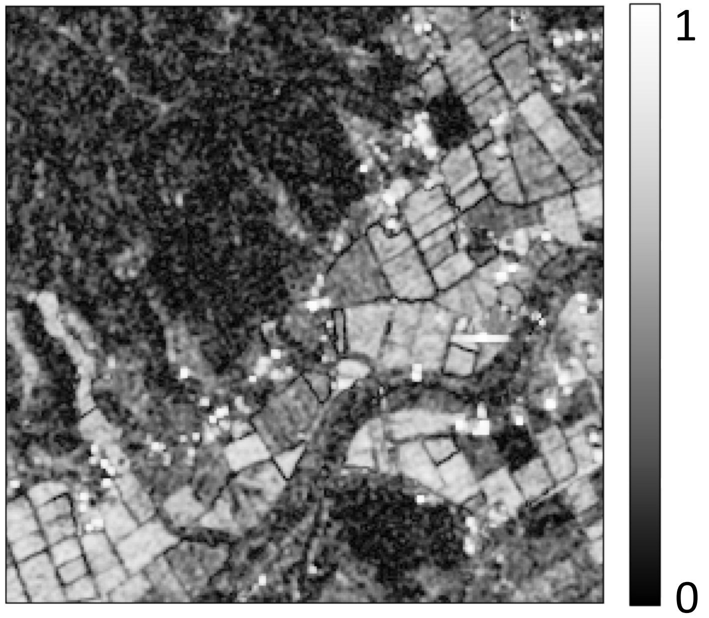
An example from the 2015 Gorkha, Nepal earthquake. From Robinson et al. 2019 *Scientific Reports*

Satellite Radar Coherence

- Sensitive to changes in the ground surface between image acquisition
- Currently used to detect building damage (e.g. Yun et al. 2015)
- Capable of detecting earthquake-triggered landslides (demonstrated by e.g. Yun et al. 2015, Burrows et al. 2019)
- How generally applicable are coherence methods?



Phase Change

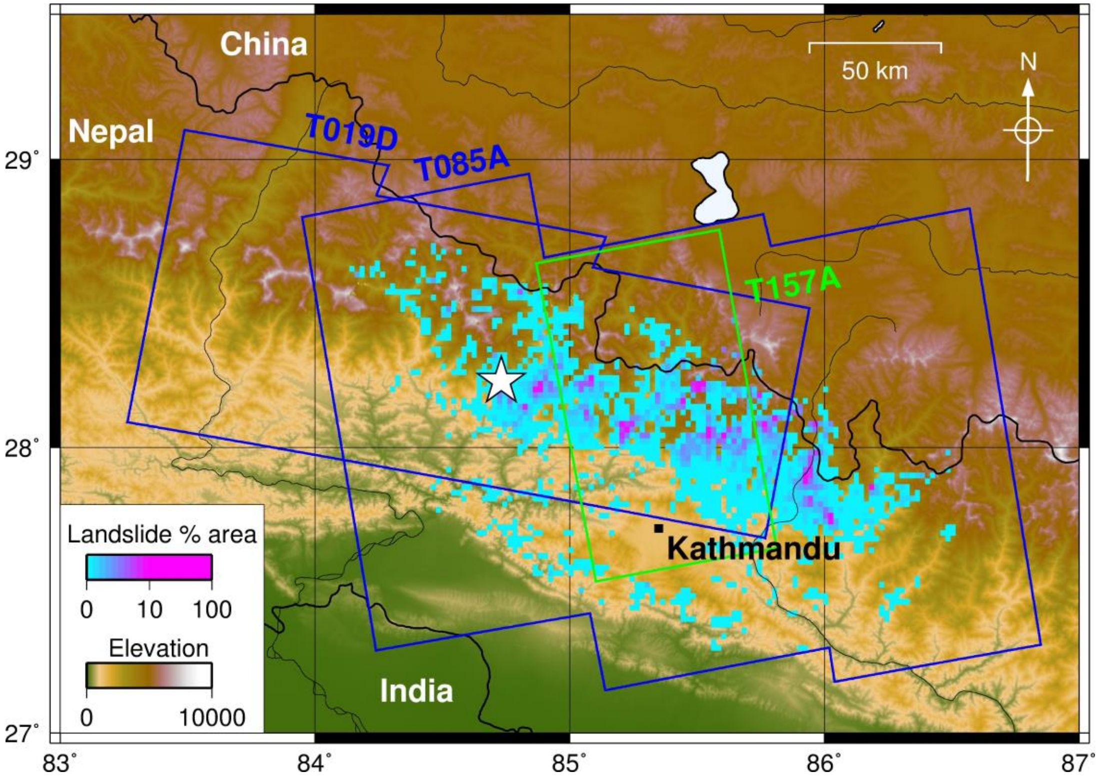


Coherence

ALOS-2 data over Japan
20180809-20180823

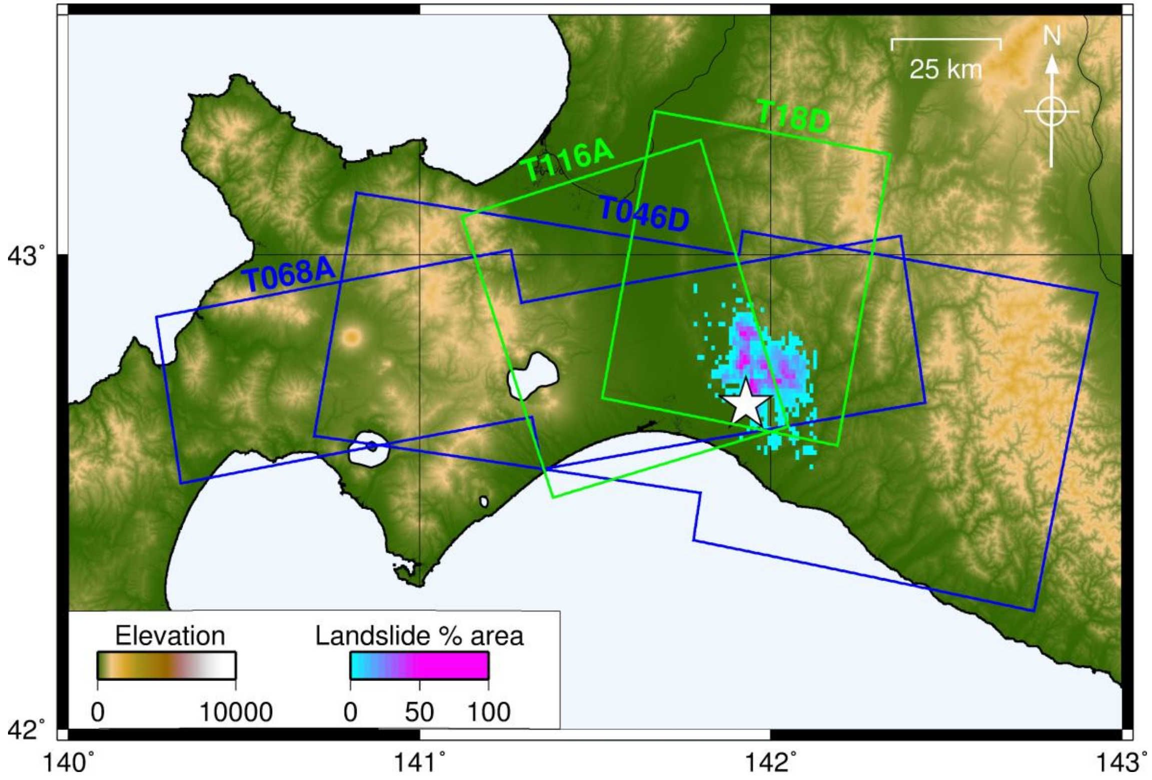
Case Studies

Gorkha, Nepal, 2015



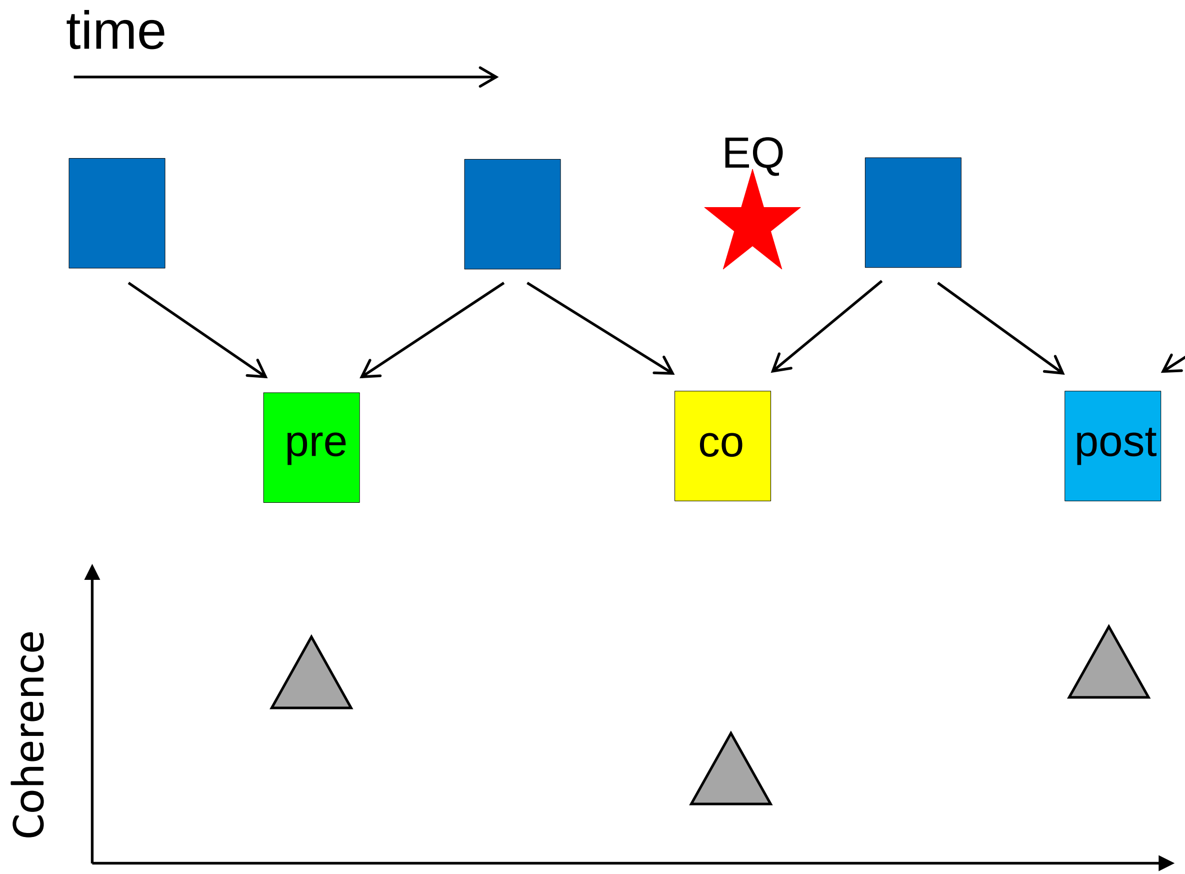
Roback et al. (2018)

Hokkaido, Japan, 2018



Zhang et al. (2019)

Coherence Change in Time

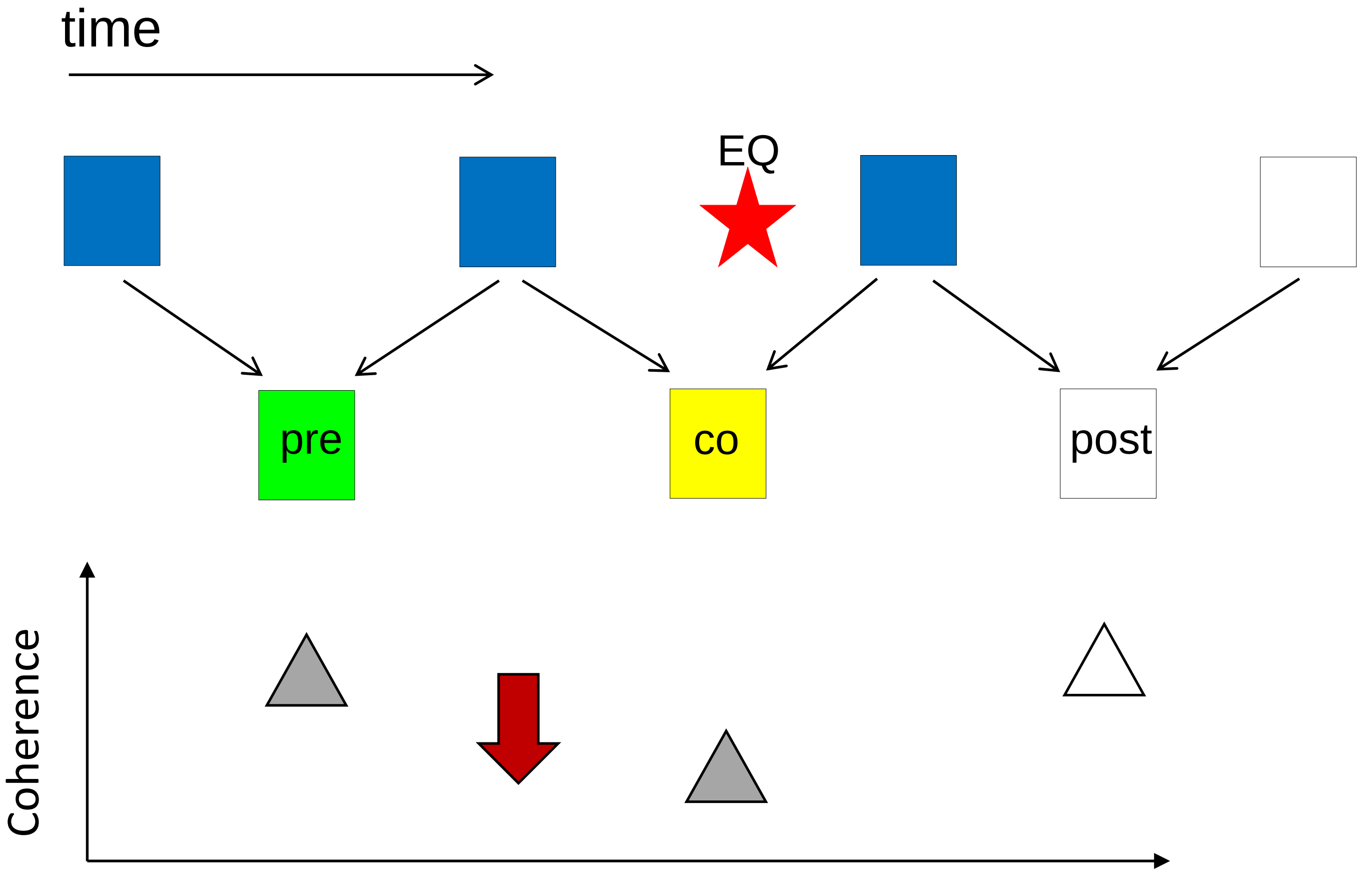


4 SAR images

3 Coherence maps

Expectation for
landslide pixels

The ARIA method



3 SAR images

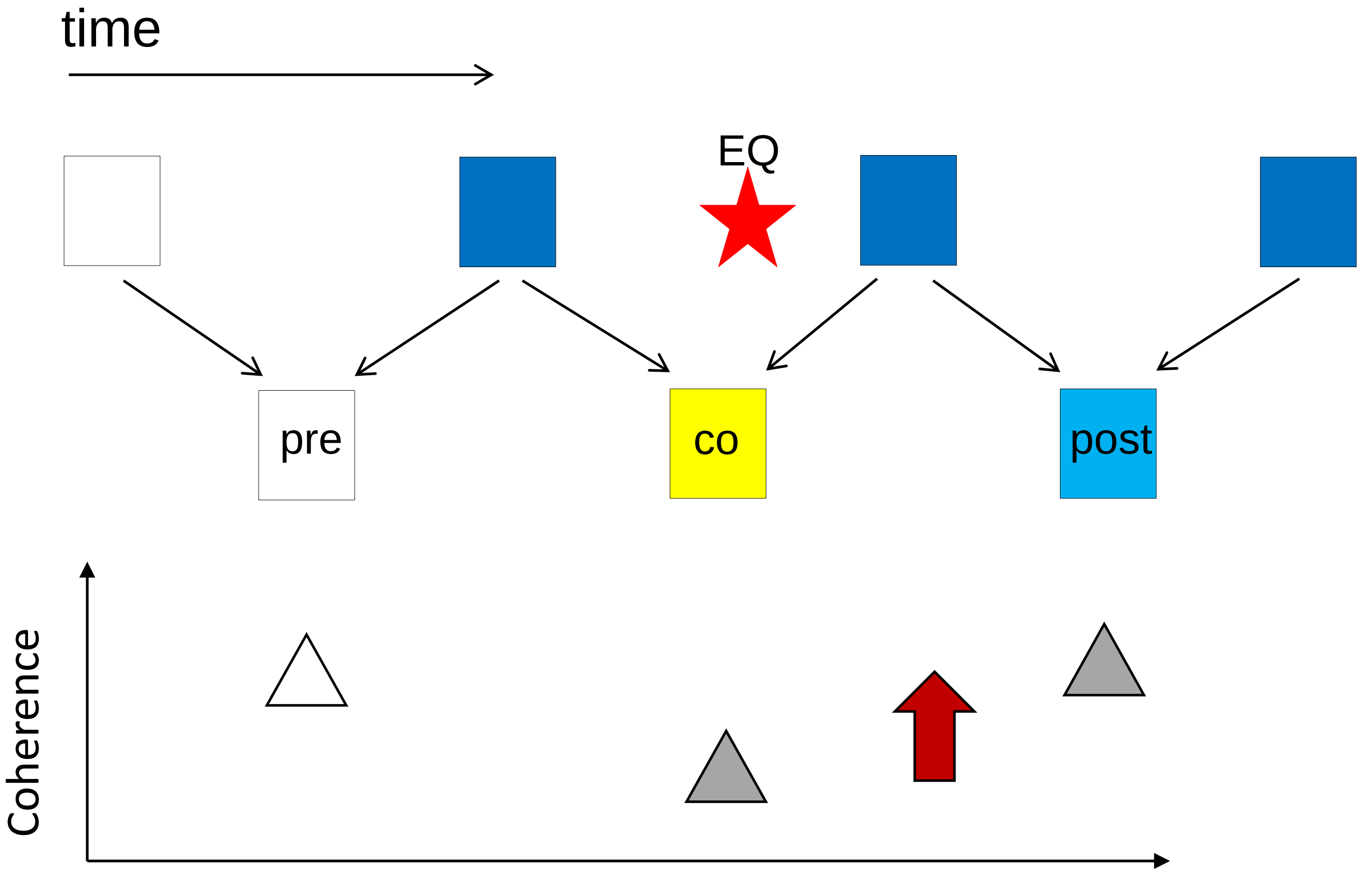
2 Coherence maps

Expectation: Co-event coherence decrease

ARIA = pre - co

Yun et al. (2015)

Modified post-event ARIA method



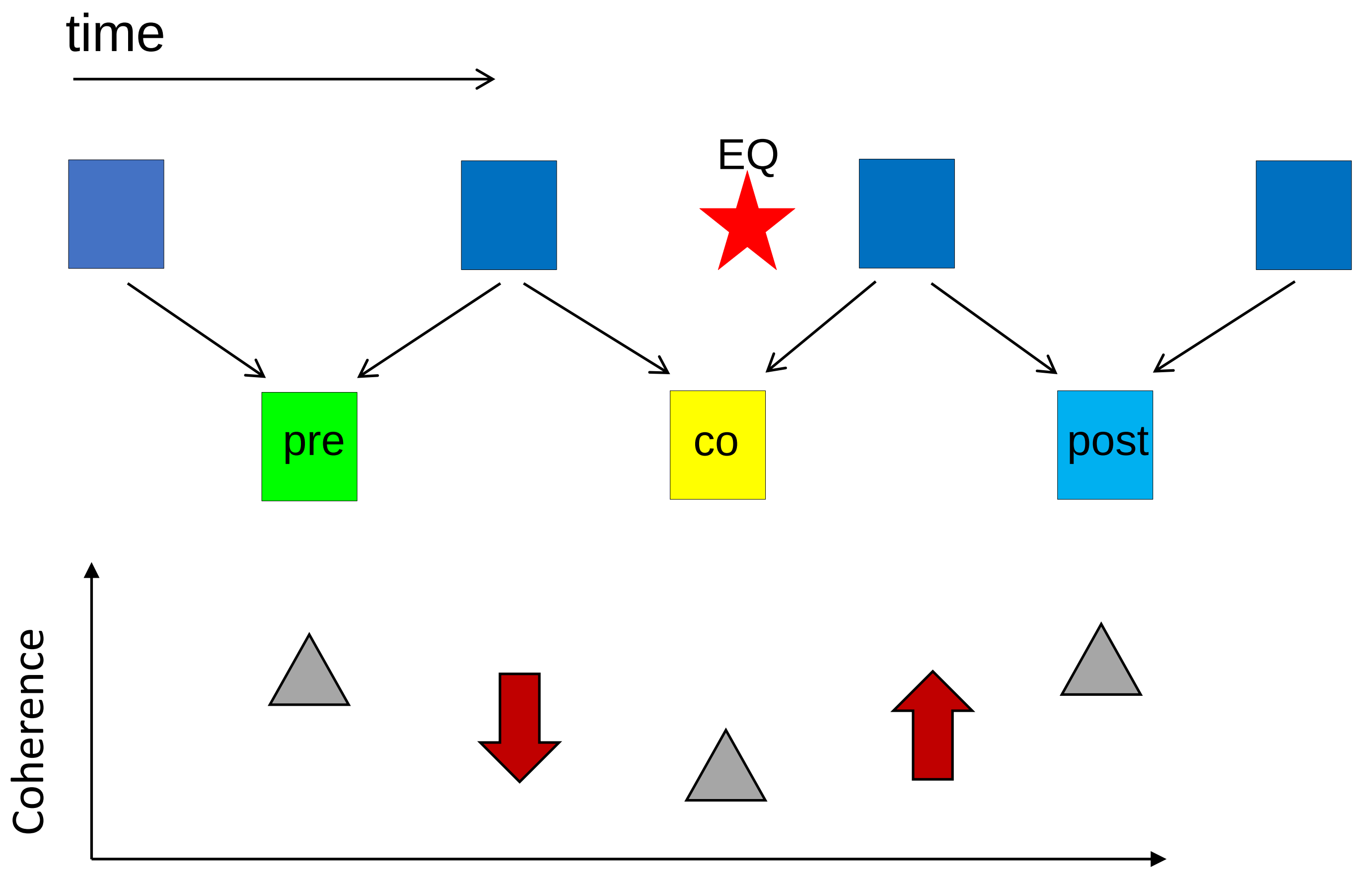
3 SAR images

2 Coherence maps

Expectation: Post-event coherence increase

ARIA post = post - co

Down+up method



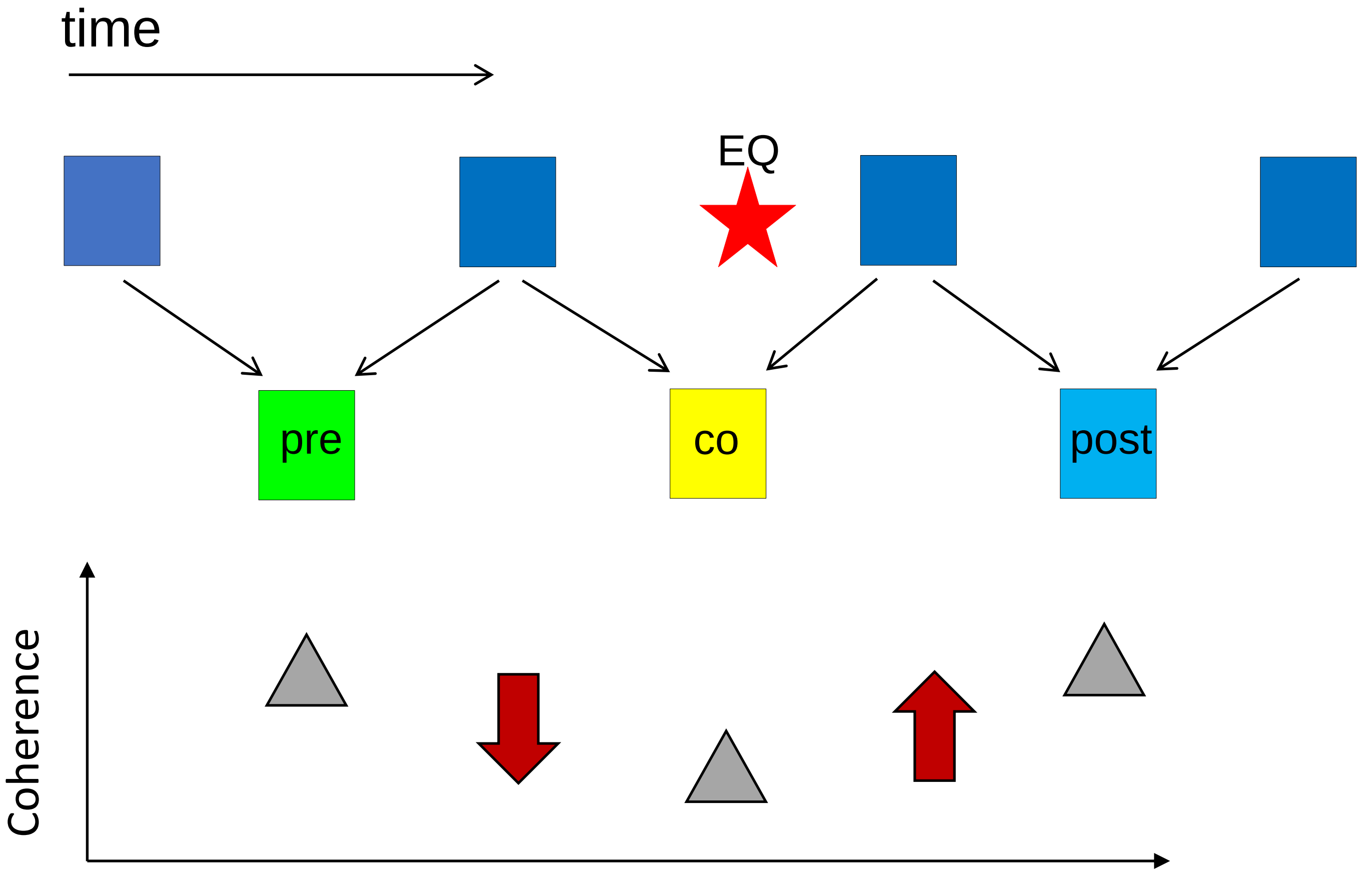
4 SAR images

3 Coherence maps

Expectation: Co-event decrease and post-event increase

Down + Up = (pre - co) + (post - co)

Maximum(Down, up) method



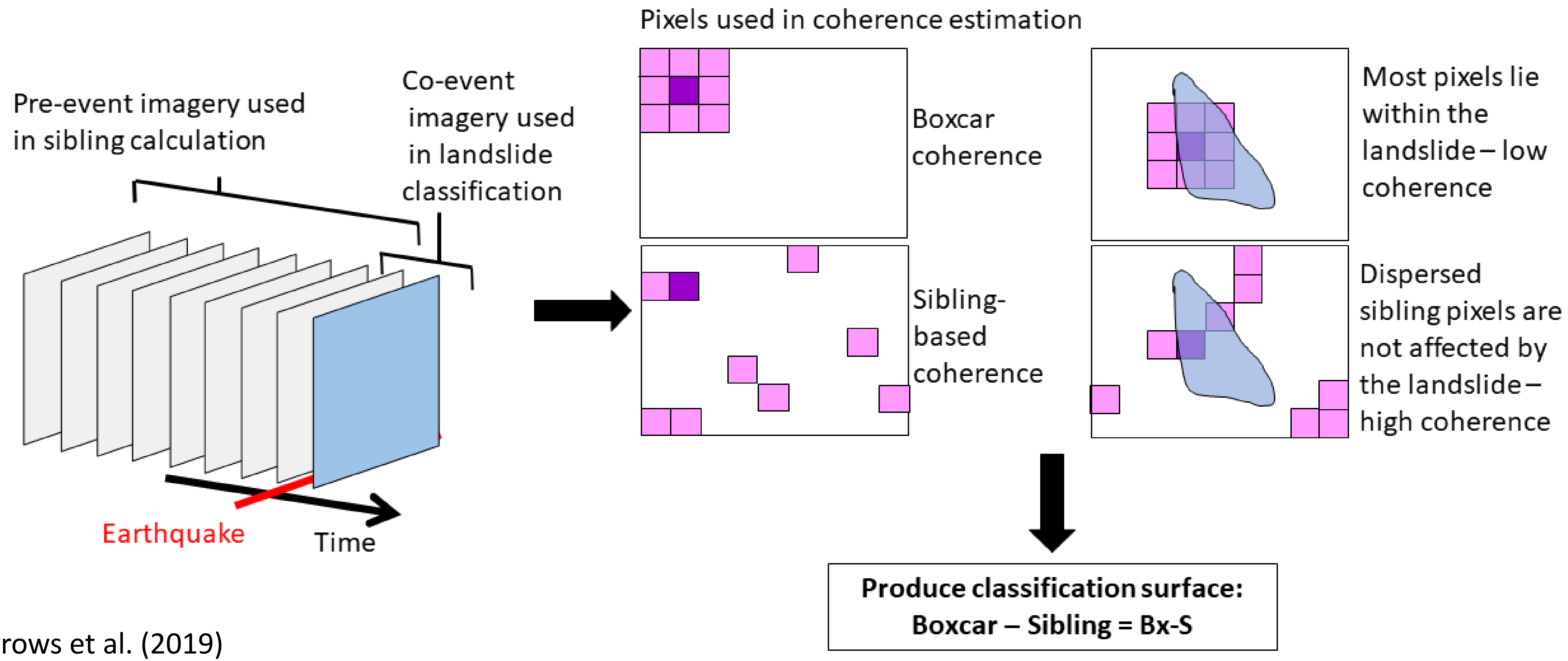
4 SAR images

3 Coherence maps

Expectation: Co-event decrease and post-event increase

Max(Down, Up) = Max((hm pre - co) , (hm post - co))

The Bx-S method



Pre-event imagery used in sibling calculation

Co-event imagery used in landslide classification

Pixels used in coherence estimation

Boxcar coherence

Most pixels lie within the landslide – low coherence

Sibling-based coherence

Dispersed sibling pixels are not affected by the landslide – high coherence

Produce classification surface:
Boxcar – Sibling = Bx-S

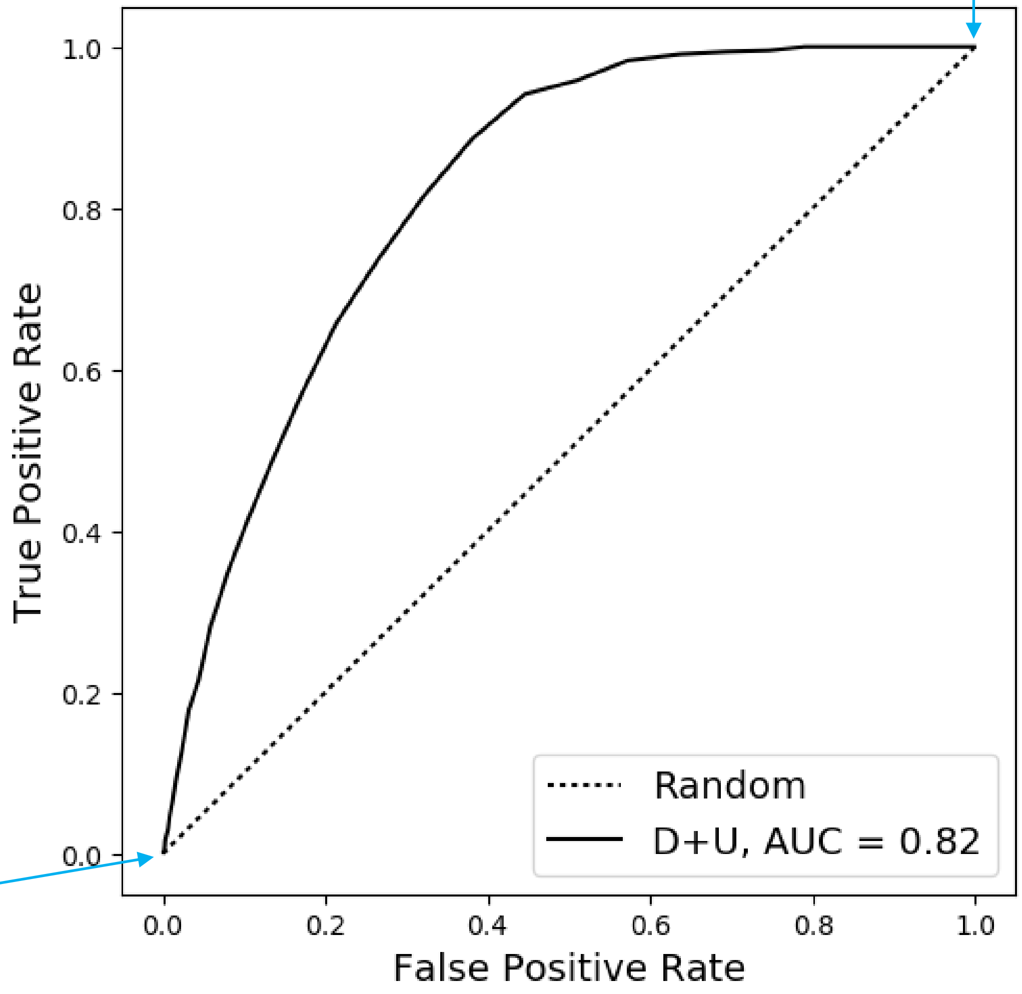
Burrows et al. (2019)

ROC Analysis

- Assess continuous classifiers without applying a threshold
- Area under the curve describes the overall classifier performance

0.5	Random
0.5-0.6	Unuseable
0.6-0.7	Poor
0.7-0.8	Fair
0.8-0.9	Good
0.9-1.0	Excellent

All pixels classified as ‘landslide’



All pixels classified as ‘not landslide’

Result: ROC Analysis

		Hokkaido				Nepal			*Event*
		Sentinel-1		ALOS-2		Sentinel-1		ALOS-2	*Satellite*
		68A	46D	116A	18D	85A	19D	T157A	*Track number*
1 post-event image	ARIA								
	Bx-S								
	Waiting time	8	0	1	1	8	4	7	
2 post-event images	ARIA post								
	Down+up								
	Max(down,up)								
	Waiting time	20	12	15	15	20	16	91	

Result: ROC Analysis

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		Sentinel-1		ALOS-2		Sentinel-1		ALOS-2	*Satellite*
		68A	46D	116A	18D	85A	19D	T157A	*Track number*
1 post-event image	ARIA						0.66		
	Bx-S						0.74		
	Waiting time	8	0	1	1	8	4	7	
2 post-event images	ARIA post								
	Down+up								
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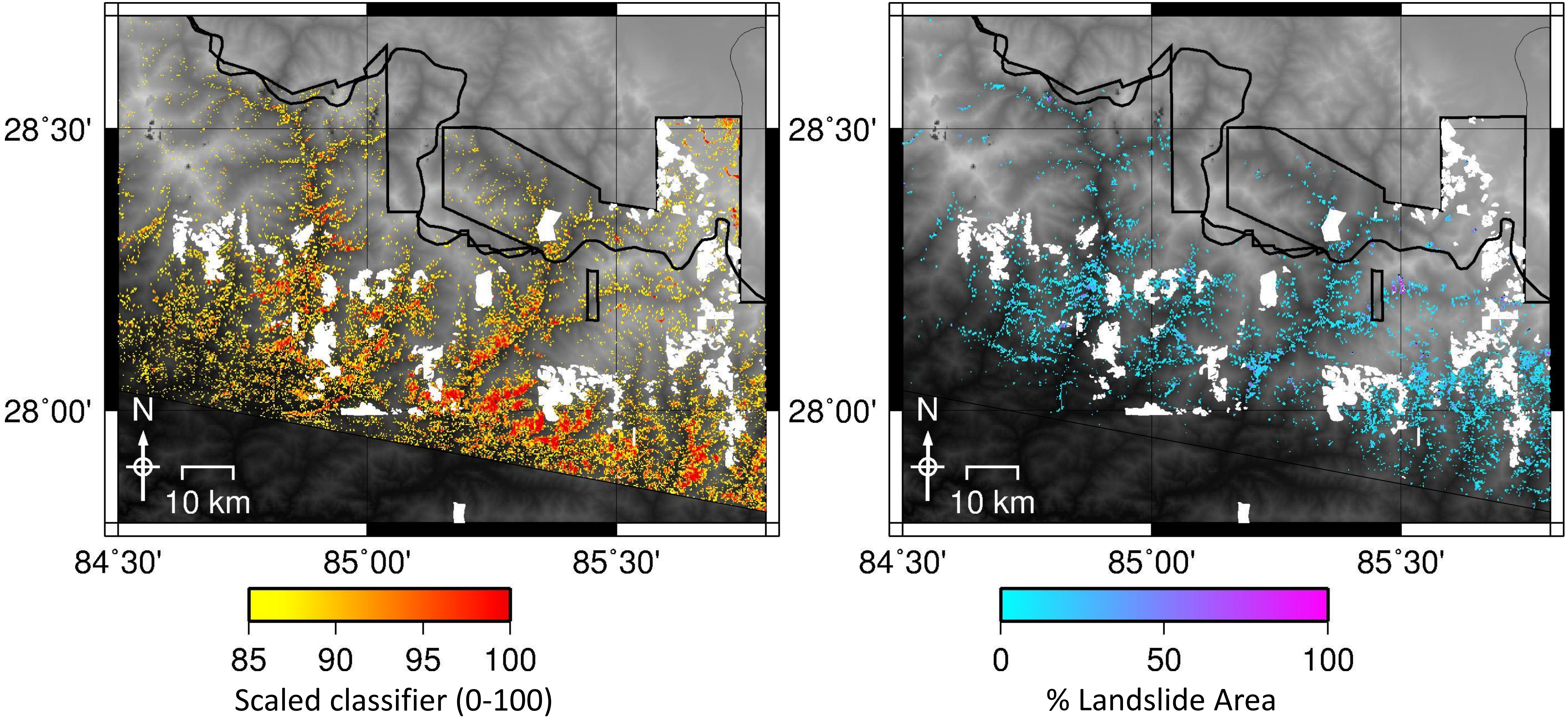
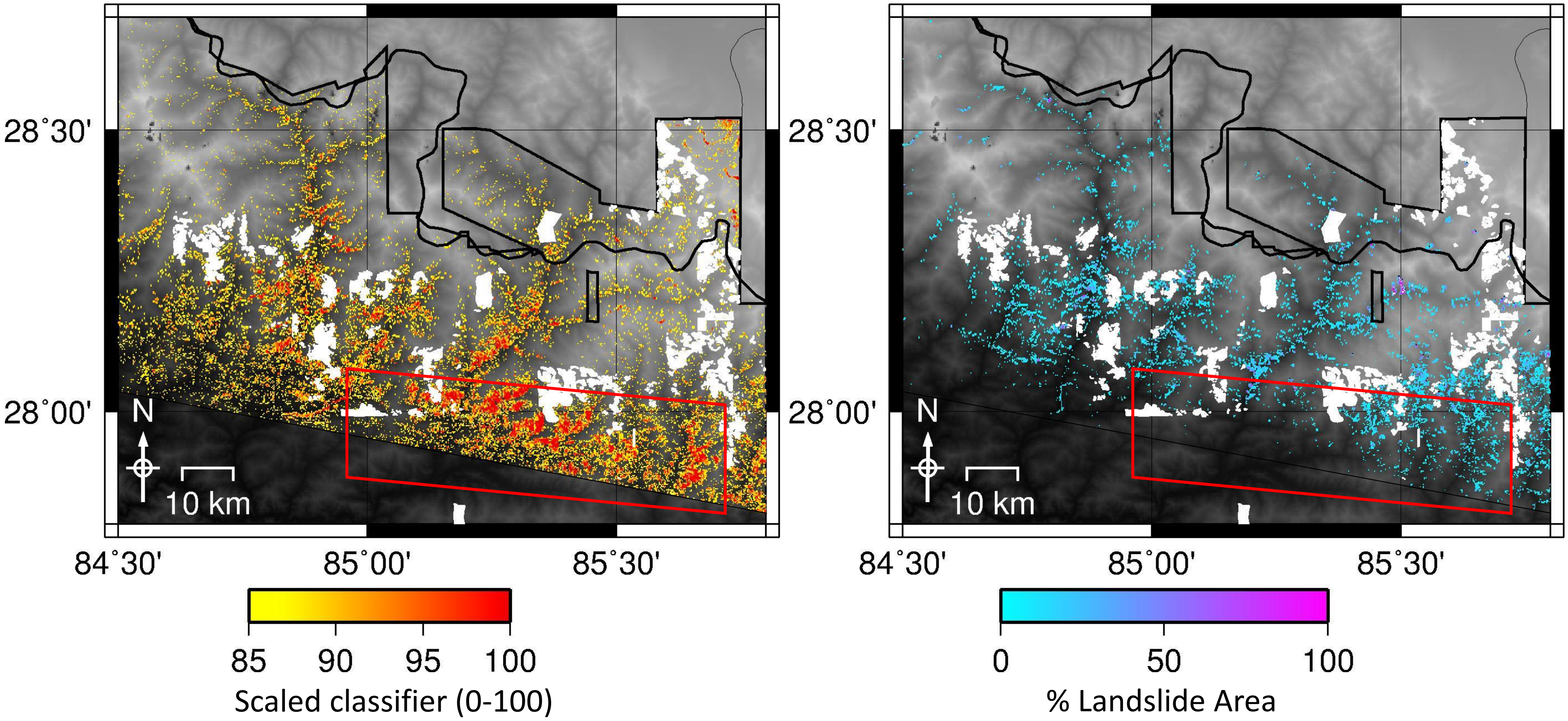
Burrows et al. (2019)

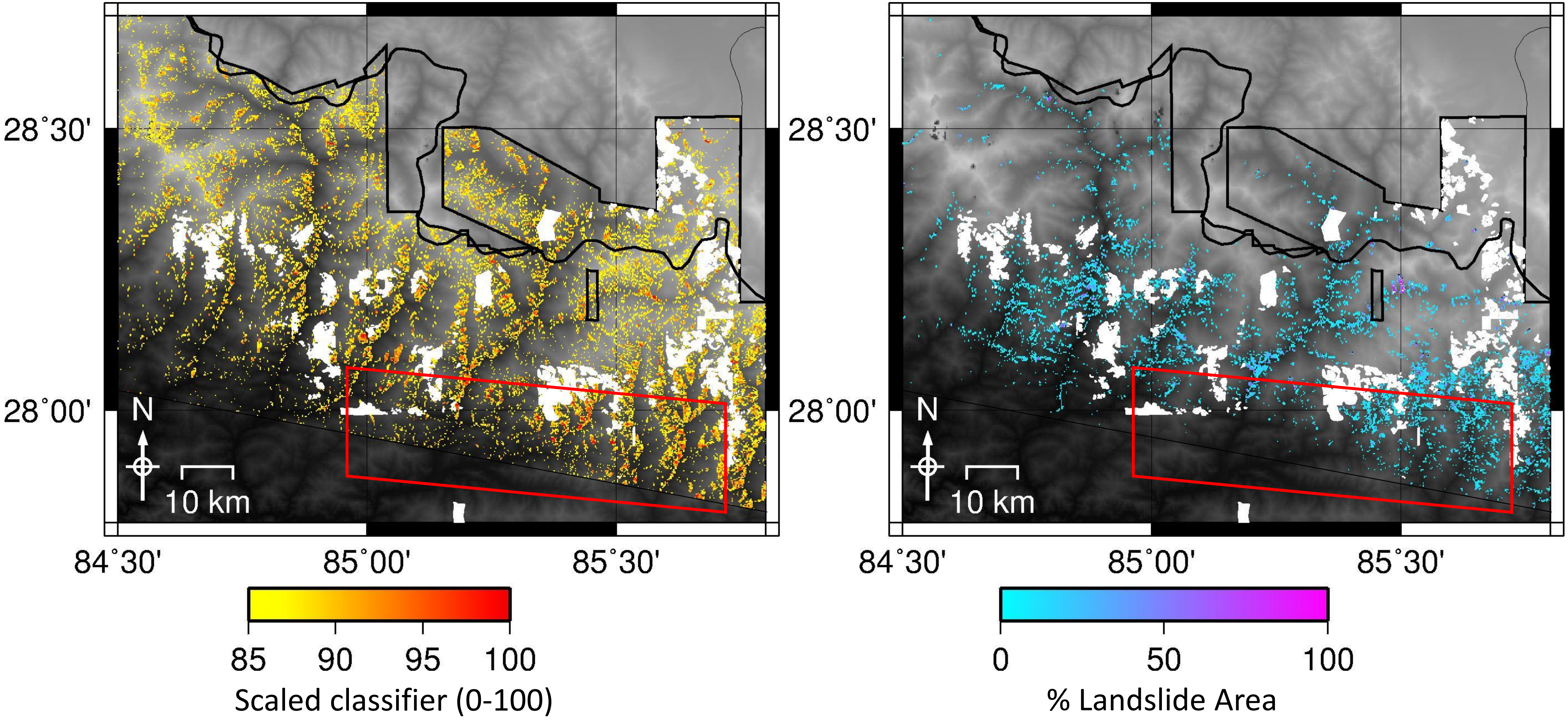
Result: The ARIA method, Sentinel-1, Nepal



Result: The ARIA method, Sentinel-1, Nepal



Result: The Bx-S method, Sentinel-1, Nepal



Result: ROC Analysis

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Event

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Burrows et al. (2019)
Remote Sensing

Result: ROC Analysis

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		68A	46D	116A	18D	85A	19D	T157A	*Track number*
1 post-event image	ARIA	0.54	0.58	0.73	0.83	0.55	0.66	0.76	
	Bx-S	0.58	0.60	0.57	0.46	0.65	0.74	-	
	Waiting time	8	0	1	1	8	4	7	
2 post-event images	ARIA post	0.84	0.82	0.67	0.74	0.61	0.62	0.79	
	Down+up	0.77	0.78	0.72	0.82	0.61	0.68	0.84	
	Max(down,up)	0.80	0.79	0.68	0.84	0.58	0.66	0.80	
	Waiting time	20	12	15	15	20	16	91	

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Result: ROC Analysis

ARIA performs fairly well using ALOS-2 data but poorly with Sentinel-1

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Result: ROC Analysis

Bx-S is the best-performing method in Nepal but performs badly in Hokkaido

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Result: ROC Analysis

Methods incorporating both the co-event coherence decrease and post-event increase in coherence are the most consistent

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		68A	46D	116A	18D	85A	19D	T157A	*Track number*
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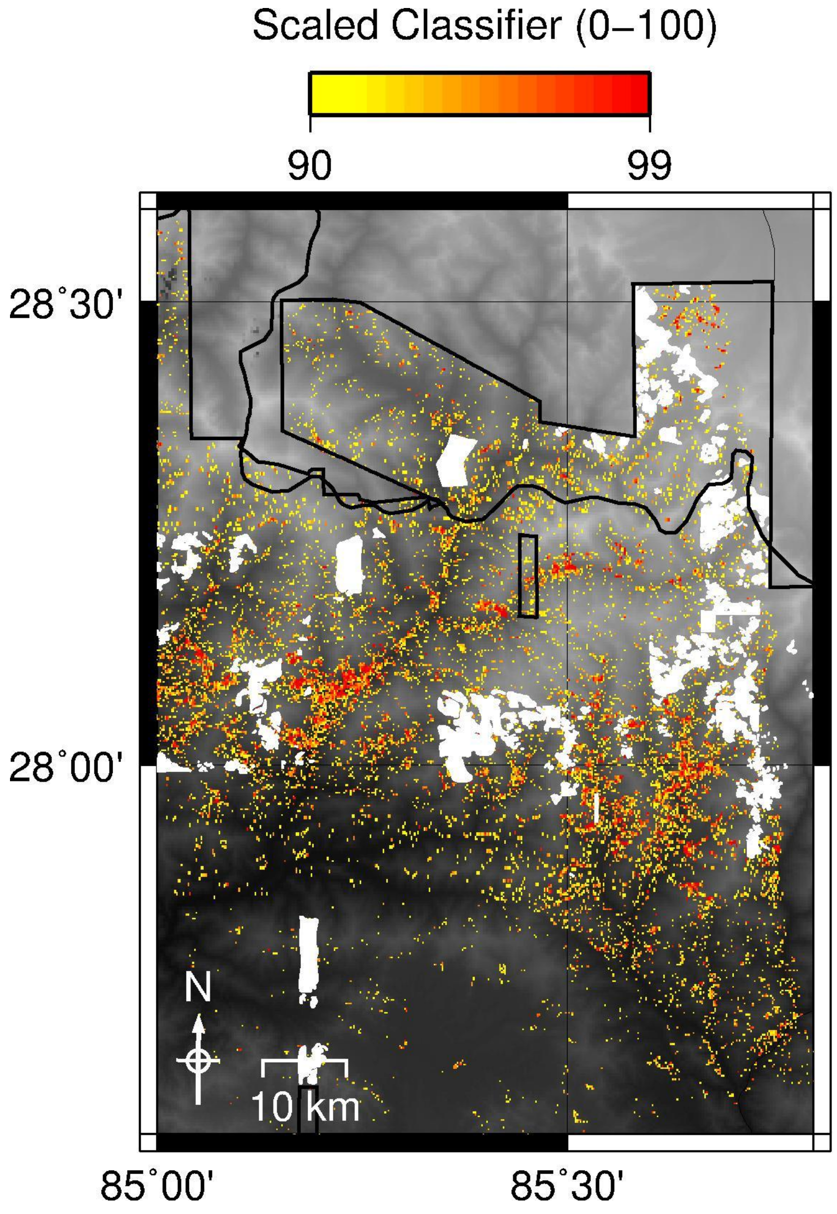
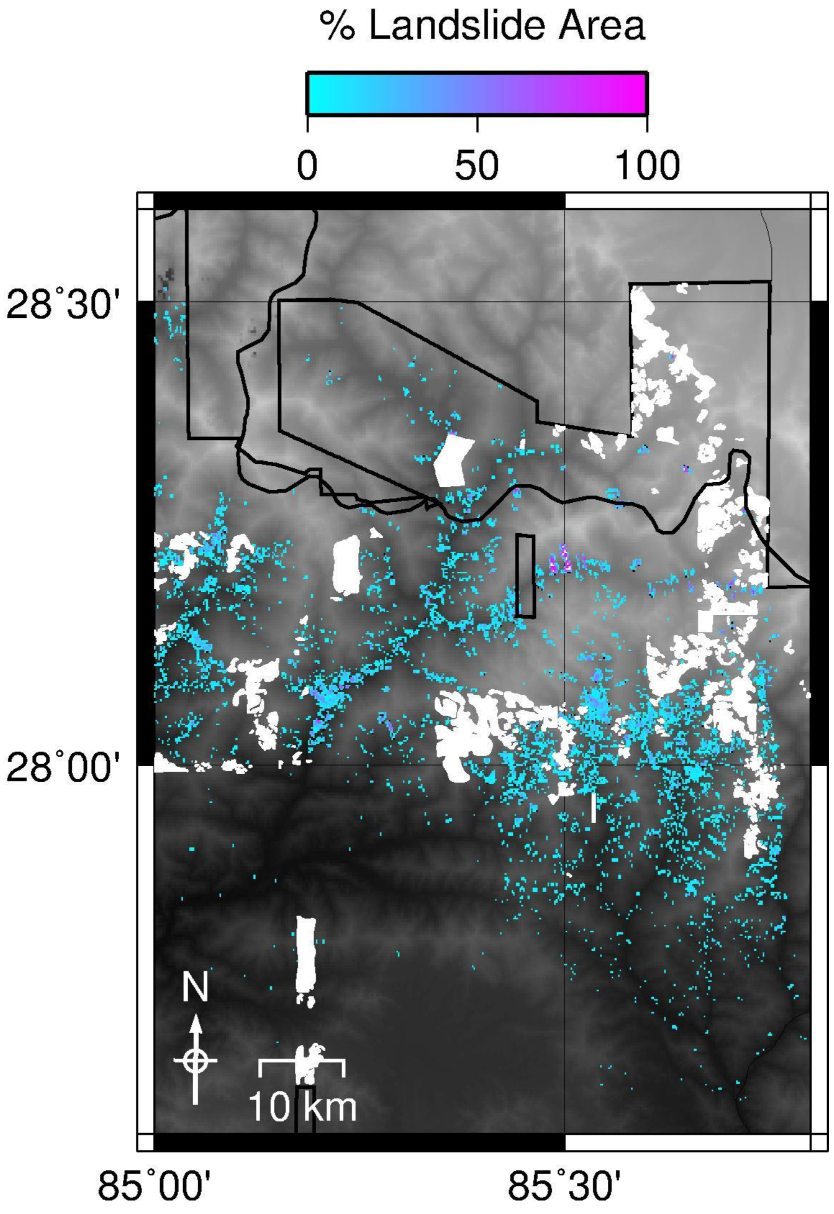
Result: the Down+Up method

ALOS-2

Nepal



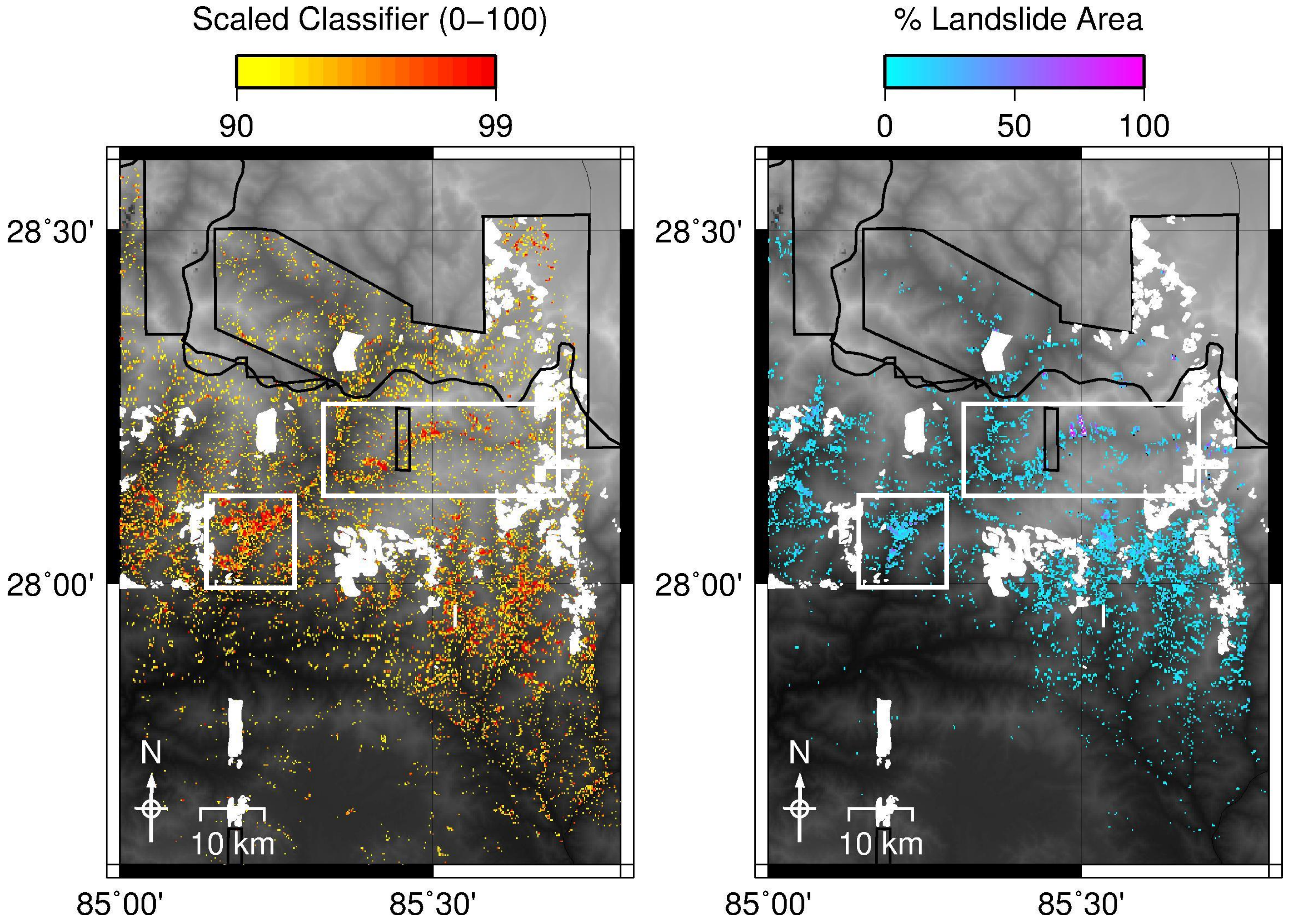


Landslide inventory from Roback et al. (2018) *Geomorphology*

Result: the Down+Up method

ALOS-2

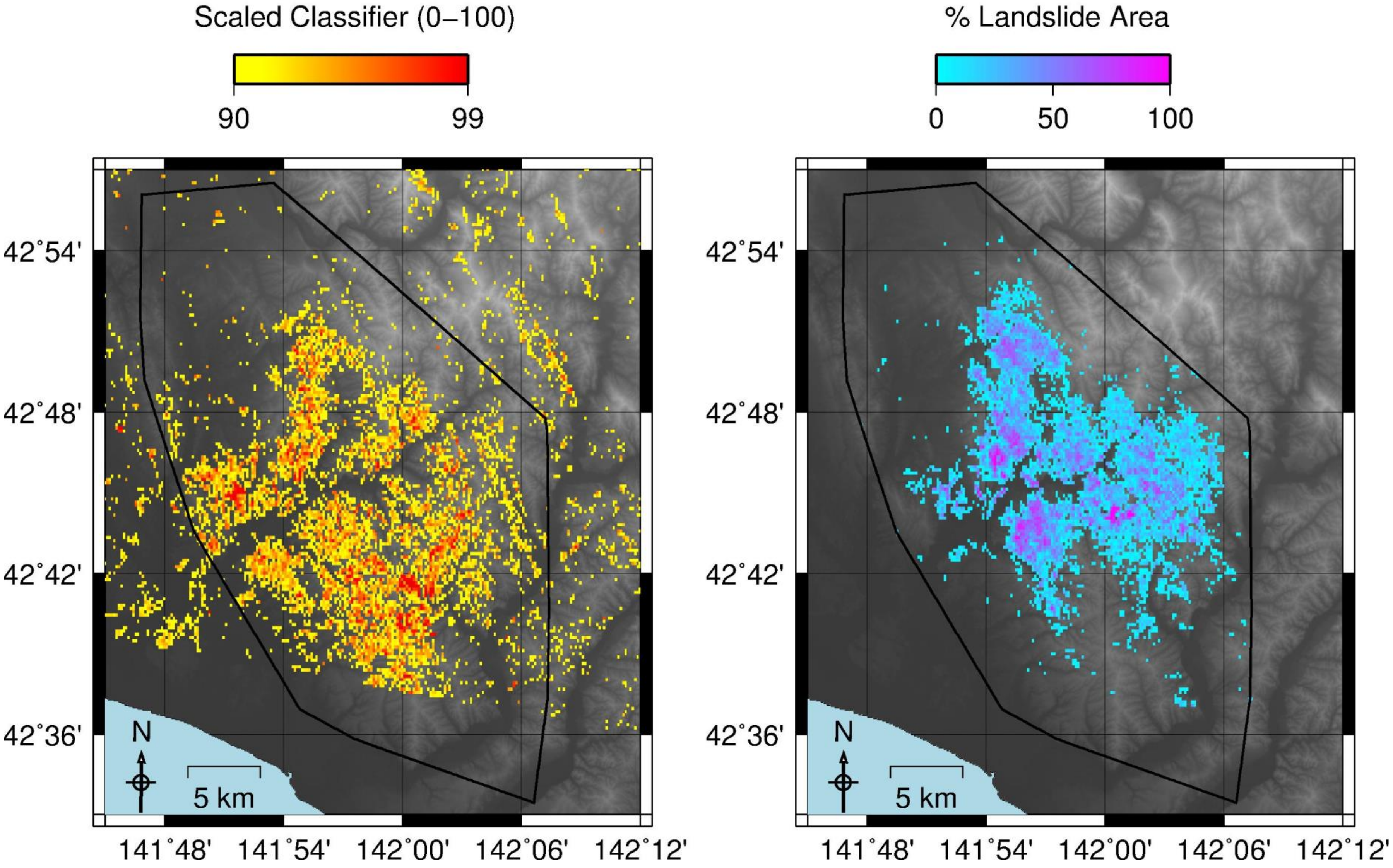
Nepal



Landslide inventory from Roback et al. (2018) *Geomorphology*

Result: the Down+Up method

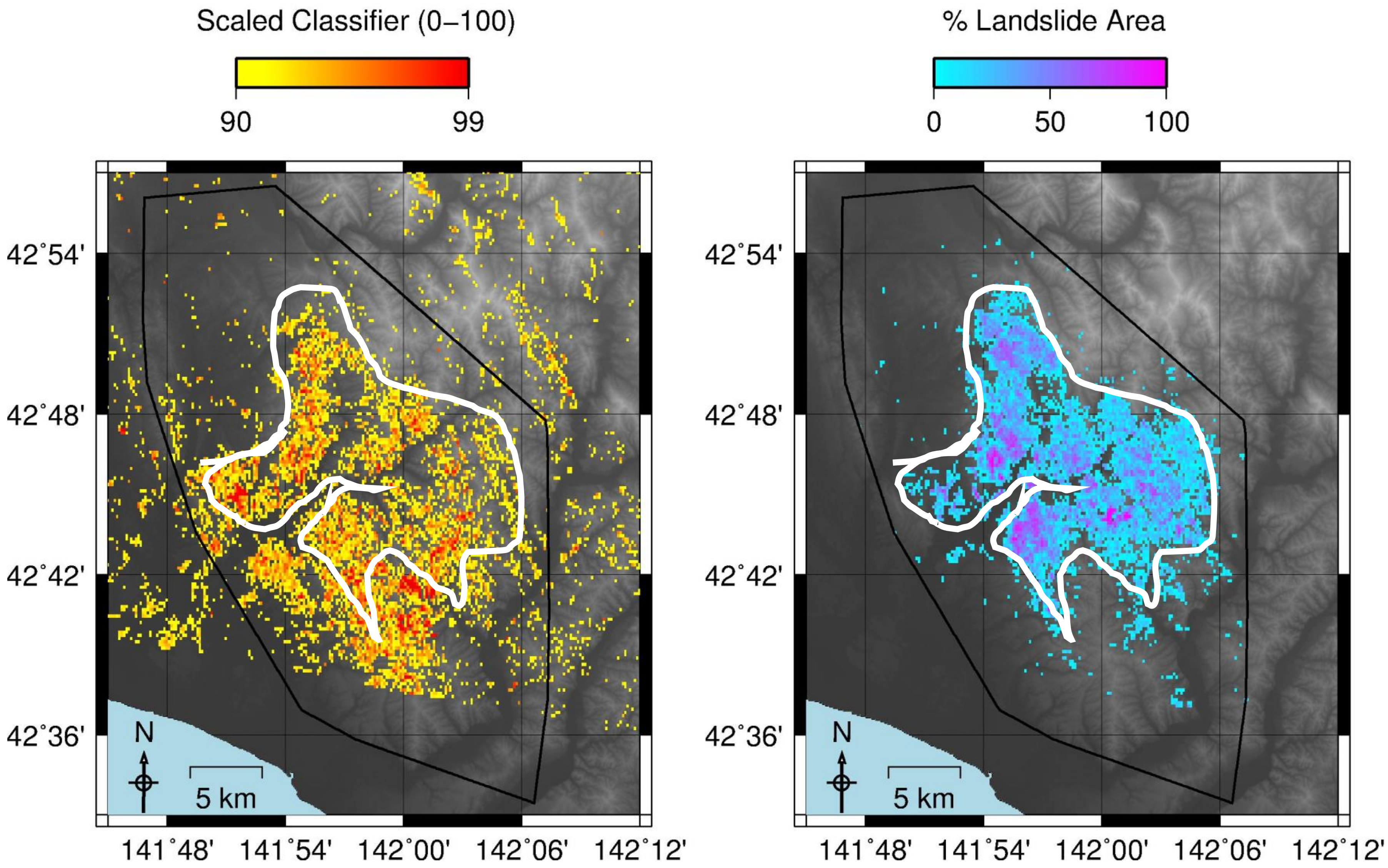
ALOS-2 Hokkaido



Landslide inventory from Zhang et al. (2019) *Landslides*

Result: the Down+Up method

ALOS-2
Hokkaido



Landslide inventory from Zhang et al. (2019) *Landslides*

Conclusions

SAR coherence methods are capable of large-scale landslide detection

With only 1 post-event image: use ARIA with ALOS-2

With only Sentinel-1: use Bx-S

Methods using 2 post-event images are more consistent, but have a longer wait time

Future work: combine more surfaces in a more sophisticated way and test on more events

For more info: Burrows et al. (2019) *Remote Sensing*; Burrows et al. (in prep)

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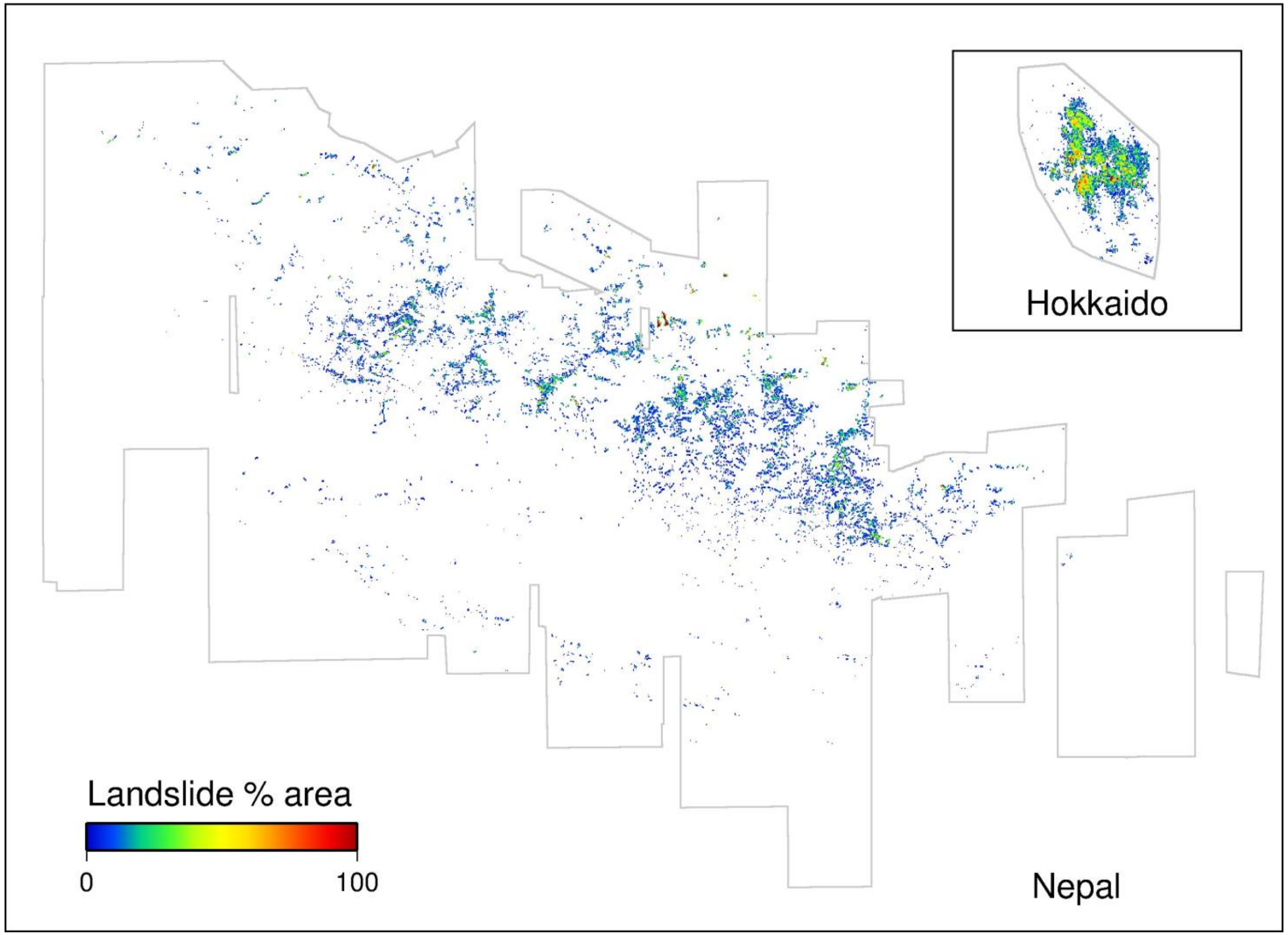
Case Studies: 2015, Gorkha, Nepal and 2018, Hokkaido, Japan

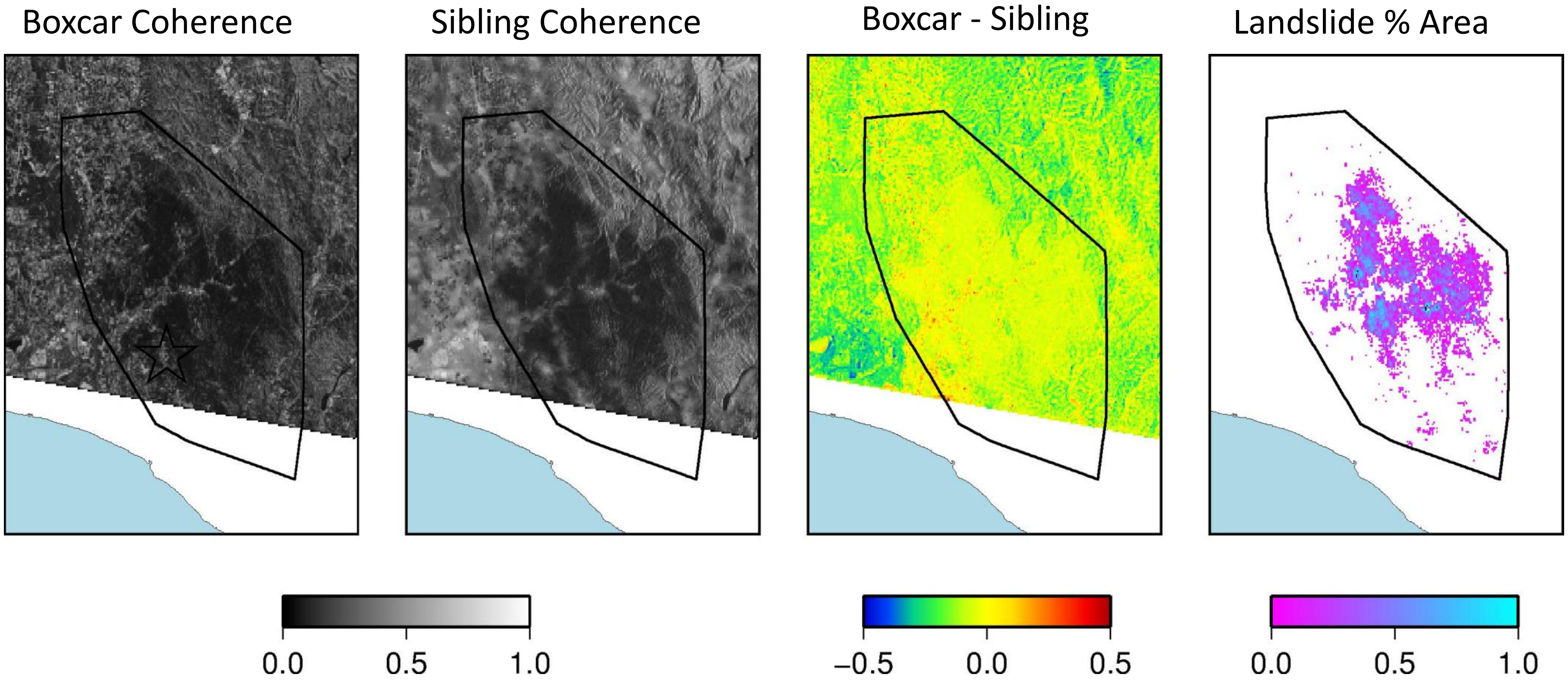


- Different topography
- Different spatial distribution of landslides
- Different lithology
- Different Weather Conditions

Inventory for Nepal from Roback et al. (2018) *Geomorphology*
Inventory for Hokkaido from Zhang et al. (2019). *Landslides*

Result: Bx-S in Hokkaido

Bx-S is the best-performing method in Nepal but performs badly in Hokkaido

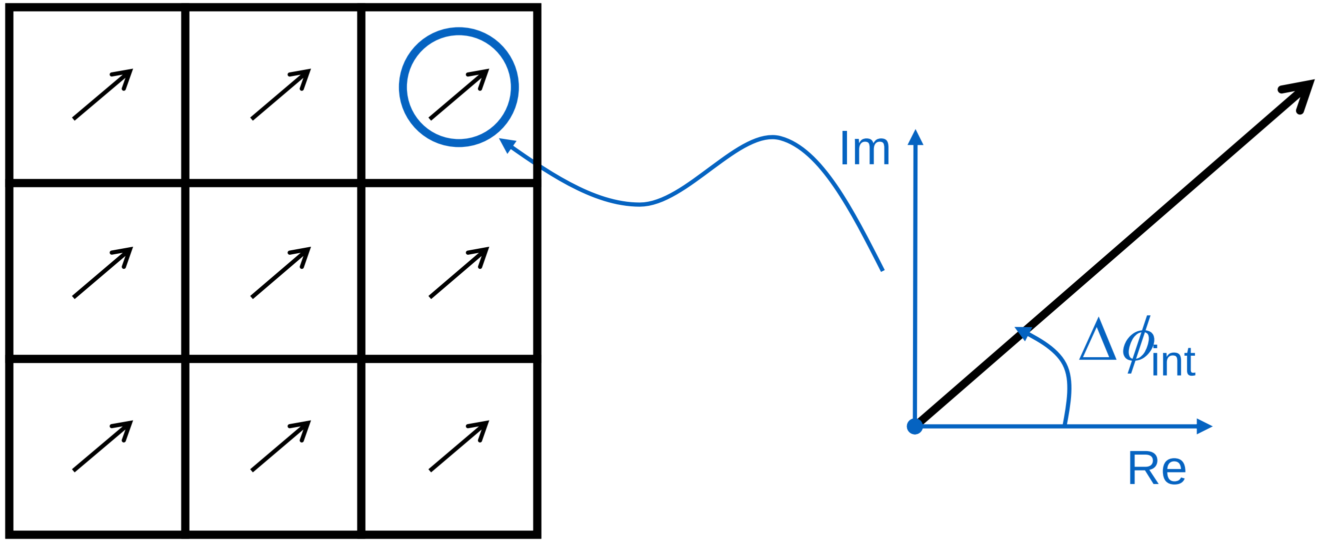


ALOS-2 data

Satellite Radar

Phase change and Amplitude can be visualised as arrows

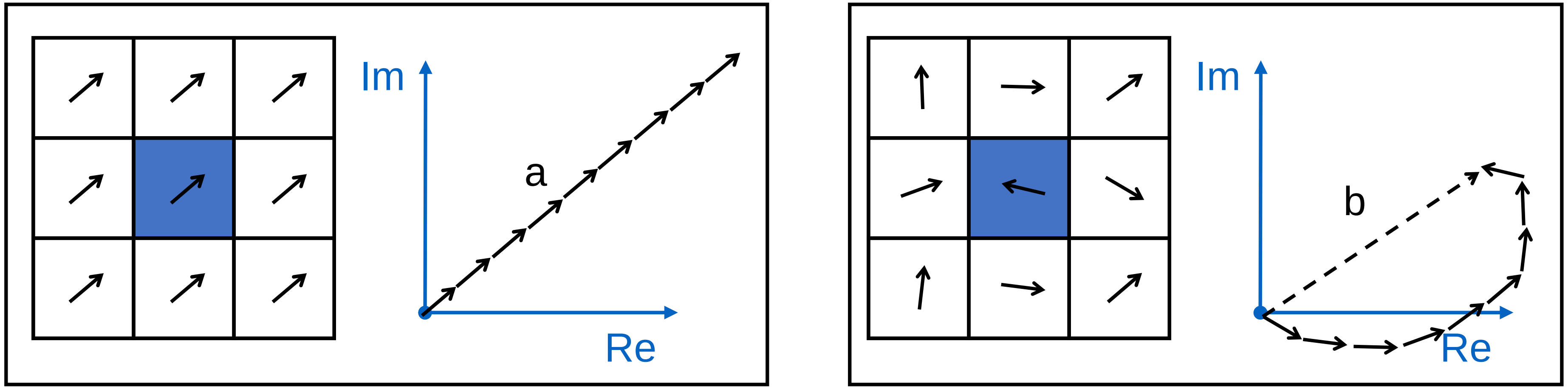
Phase change between two images = arrow direction



Satellite Radar Coherence

The spatial consistency in phase change

Contains information on how the ground surface changes in the time between the acquisition of two images



Coherence = b / a