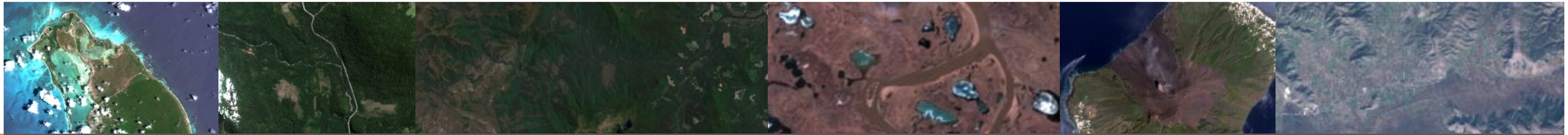


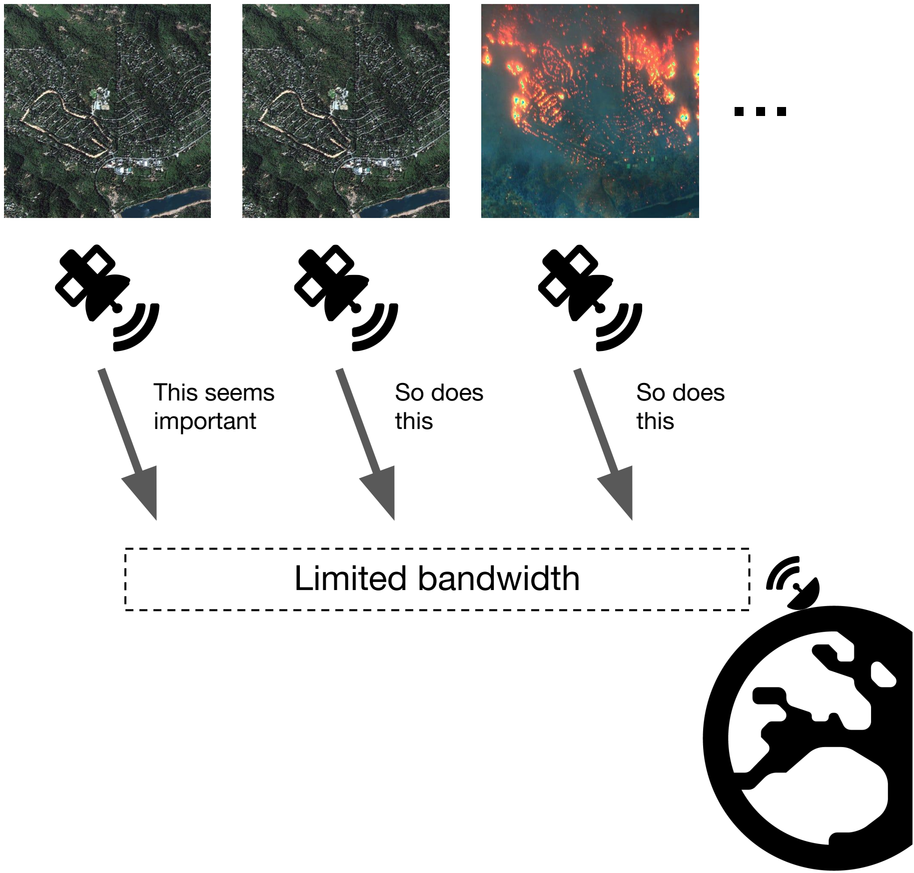
Unsupervised Change Detection of Extreme Events Using ML On-Board

AI + HADR @ NeurIPS 2021

Vít Růžička, Anna Vaughan, Daniele De Martini, James Fulton, Valentina Salvatelli, Christopher Bridges, Gonzalo Mateo-Garcia, Valentina Zantedeschi

- ## **The Problem:**

  Current state of remote sensing:

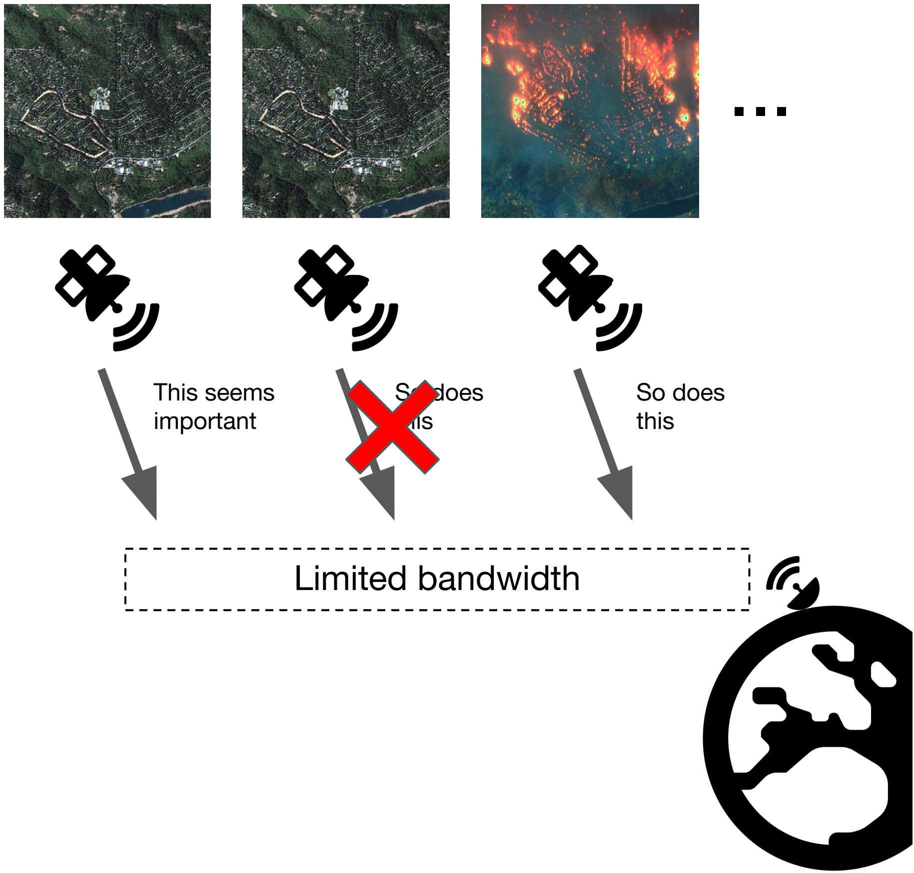


- **The Problem:**

    Current state of remote sensing:

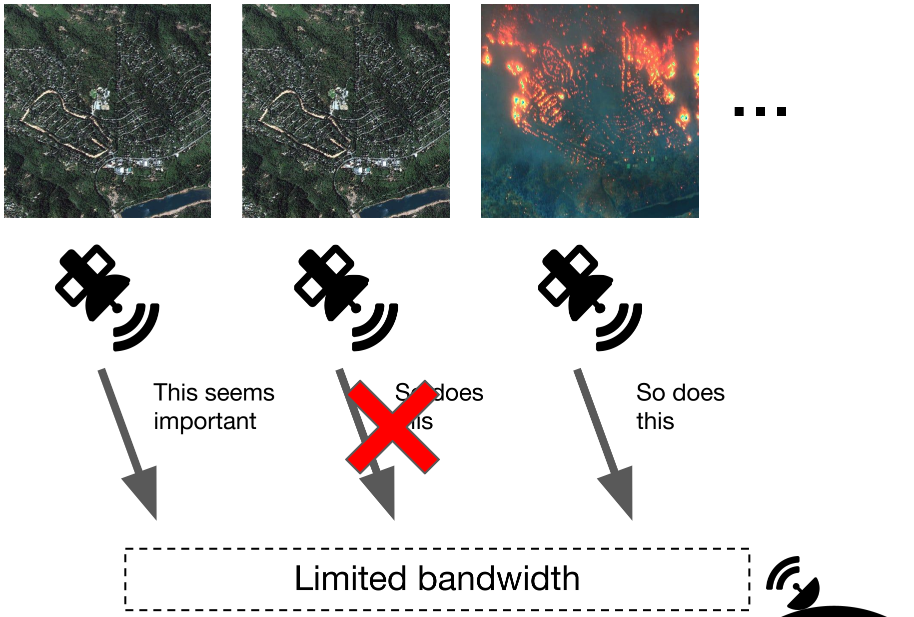
- **The Task:**

    Detection of anomalies on-board



- **The Problem:**

  Current state of remote sensing:



- **The Task:**

  Detection of anomalies on-board

- **The Goal:** Unsupervised Change Detection of Extreme Events on-board of the satellite

Baseline: Detecting change in **image space**

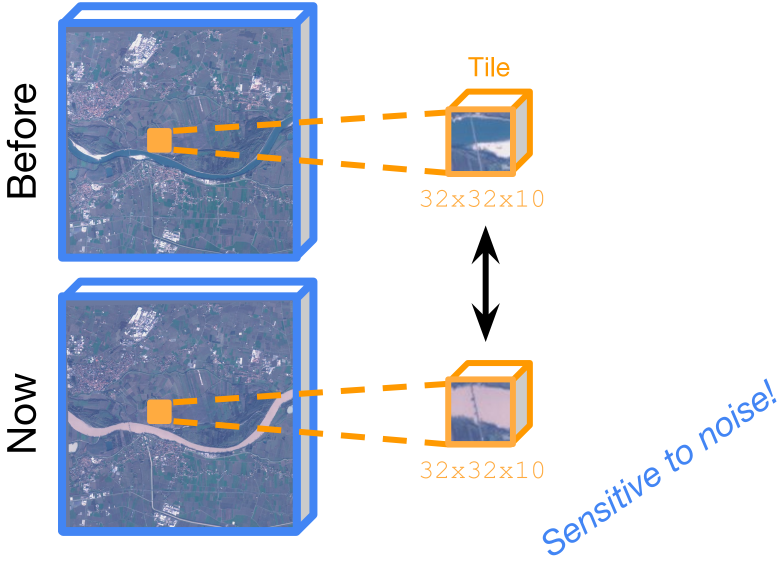


Image space
comparison

Auto-Encoder model:

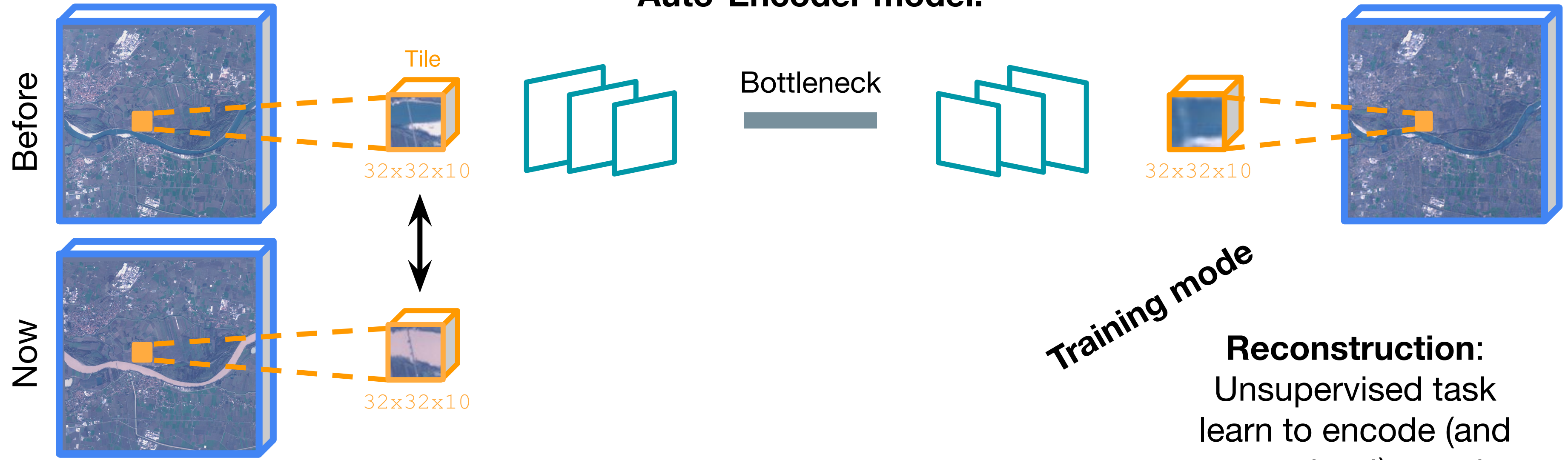
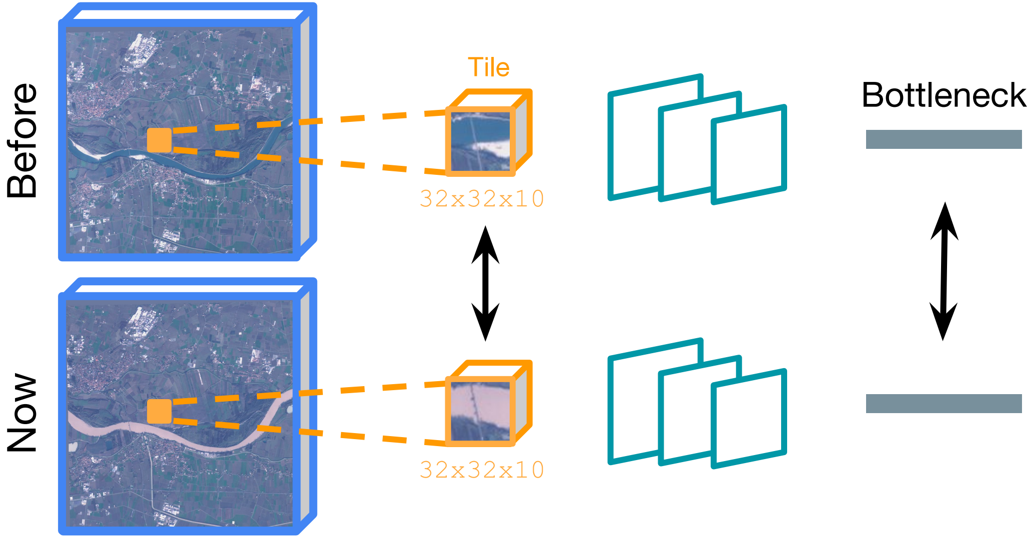


Image space comparison

Reconstruction: Unsupervised task learn to encode (and reconstruct) remote sensing images.

Approach: Detecting change in **latent space**



Latent representation more robust to noise

Inference mode

Image space comparison

Latent space comparison

Memory: Considers longer temporal changes

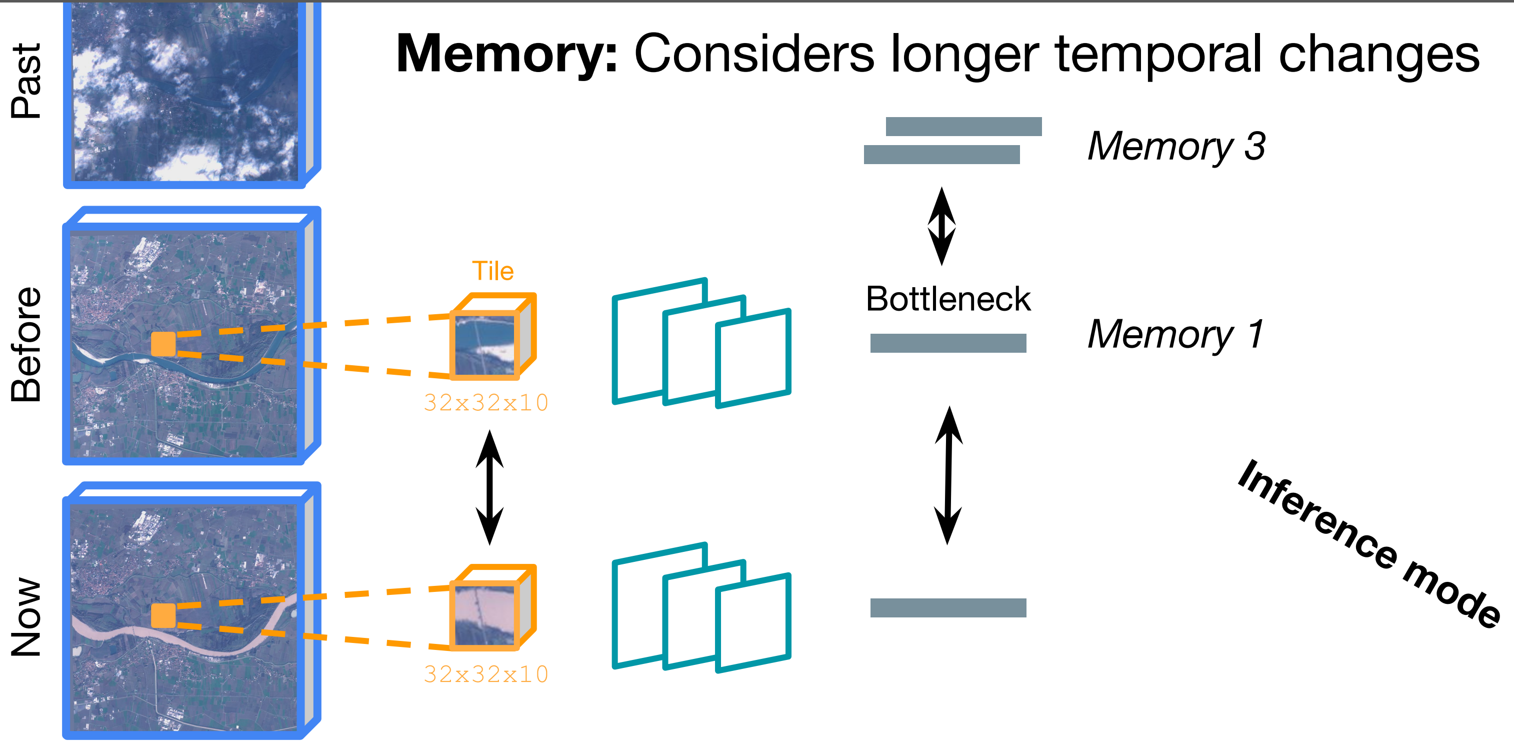
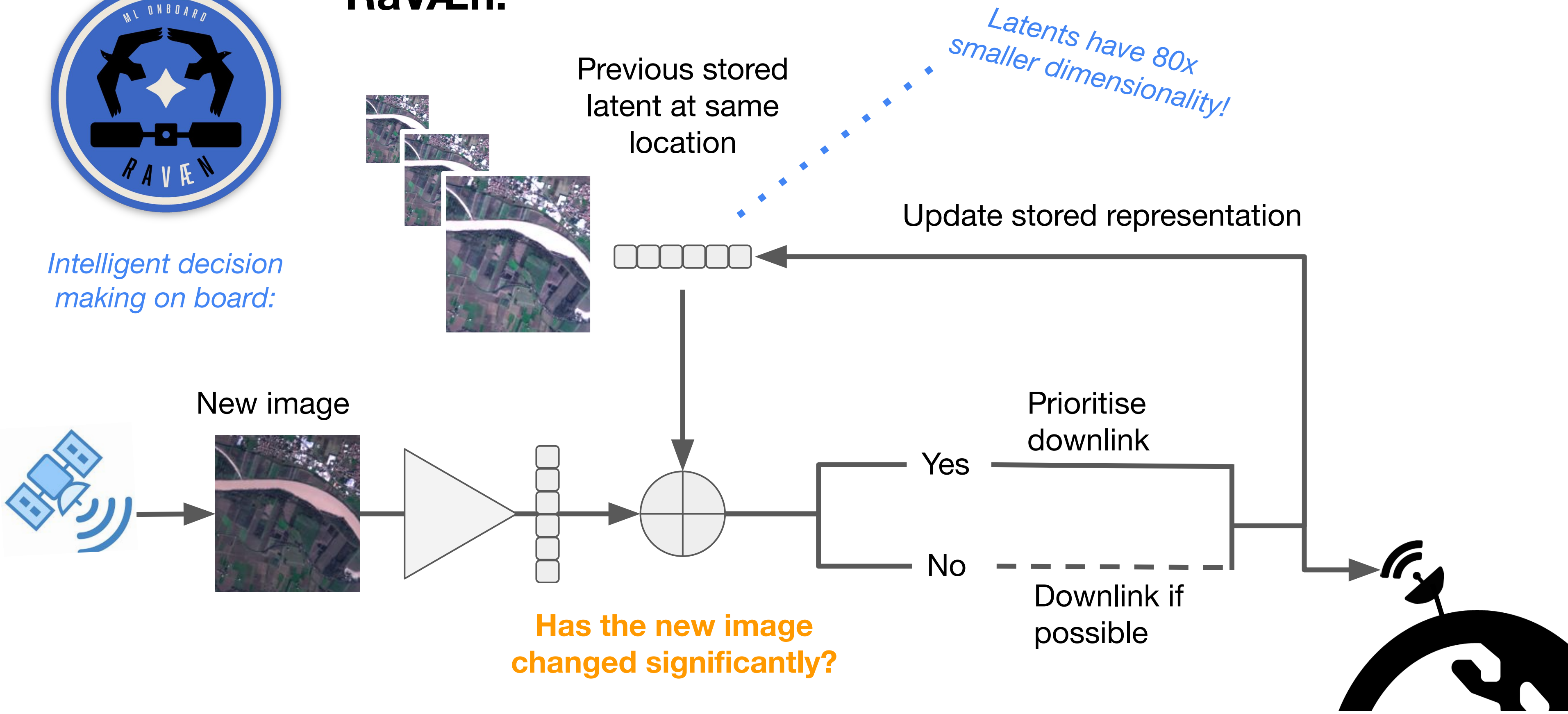


Image space comparison

Latent space comparison

RaVÆn:

Intelligent decision making on board:

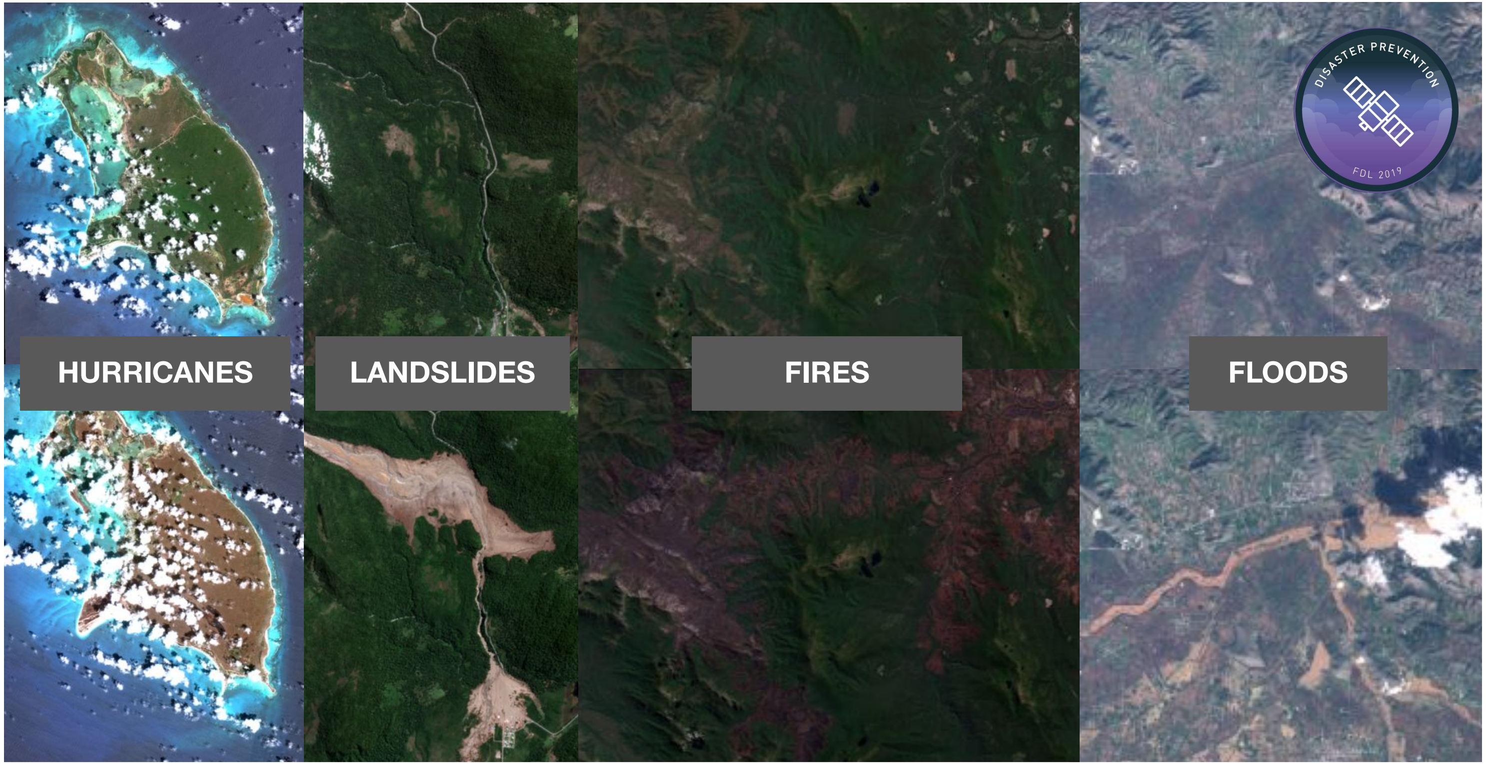


Dataset of Extreme Events

Diverse unlabeled **training** dataset
(233 scenes x 5 timesteps)

And non-overlapping labeled **evaluation** dataset (4 classes, 5 timesteps)

Extreme Event examples



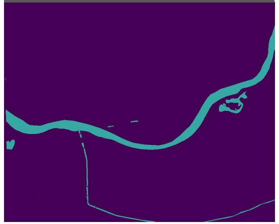
- We want to detect **all kinds of change, not just one**

Prediction example:

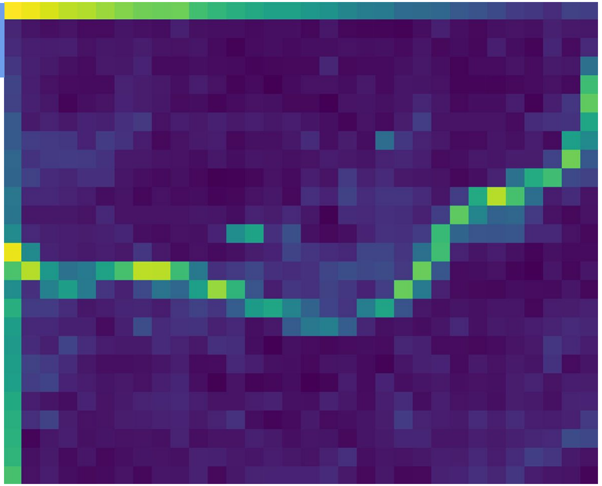
BEFORE

AFTER

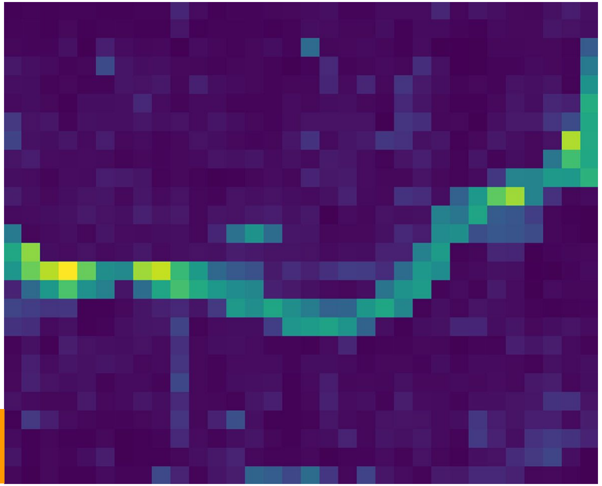
GT



BASELINE:



OURS:



Results

Area under the precision-recall curve shown in percentage. (averaged over 5 runs)

	Landslides	Floods	Hurricanes	Fires
Cos **baseline** (memory 1)	**62.9**	37.8	51.3	81.8
Cos **embedding** (memory 1)	59.9	**44.8**	**67.6**	**83.3**
KL-divergence (memory 1)	25.8	24.7	30.1	73.1
Cos **baseline (memory 3)**	62.2	37.8	57.0	86.5
Cos **embedding (memory 3)**	**75.9**	**44.3**	**72.6**	**91.3**

Results

Area under the precision-recall curve shown in percentage. (averaged over 5 runs)

	Landslides		Floods		Hurricanes		Fires	
Cos **baseline** (memory 1)	**62.9**	- 5%	37.8	+19%	51.3	+32%	81.8	+2%
Cos **embedding** (memory 1)	59.9		**44.8**		**67.6**		**83.3**	
KL-divergence (memory 1)	25.8		24.7		30.1		73.1	
Cos **baseline (memory 3)**	62.2	+22%	37.8	+17%	57.0	+27%	86.5	+6%
Cos **embedding (memory 3)**	**75.9**		**44.3**		**72.6**		**91.3**	

- *Our **proposed method outperforms the baseline solution** in most scenarios when using memory = 1 and **in all scenarios with memory = 3.***

Results on dedicated hardware*

**) Xilinx Pynq, 650MHz ARM*
Cortex-A9 CPU, 512MB RAM
Used on ESA PhiSat-1, OPSSAT, ...

Showing cos embedding with memory 3

Encoding area of 25km²

	Landslides	Floods	Hurricanes	Fires	# params	runtime
small	74.8	**44.5**	**74.8**	90.7	0.4M	**2.1s**
medium	75.8	42.8	73.8	91.2	0.9M	4.8s
large	**75.9**	44.3	72.6	**91.3**	1.5M	13.9s

Results on dedicated hardware*

**) Xilinx Pynq, 650MHz ARM*
Cortex-A9 CPU, 512MB RAM
Used on ESA PhiSat-1, OPSSAT, ...

Showing cos embedding with memory 3 | *Encoding area of 25km^2*

	Landslides		Floods		Hurricanes		Fires		# params	runtime	
small	74.8	-1%	**44.5**	+0.5%	**74.8**	+3%	90.7	-0.6%	0.4M	**2.1s**	
medium	75.8		42.8		73.8		91.2		0.9M	4.8s	**- 85%**
large	**75.9**		44.3		72.6		**91.3**		1.5M	13.9s	

- *While **maintaining the model's performance** (±3%) we show that the **model size and it's runtime can be greatly reduced** (by 85%).*

Conclusions:

- **<u>RaVÆn</u>**: variational autoencoder for **unsupervised change detection**
- Demonstrated that this can be used to detect **new types of disaster hot-spots**
- Developed the RaVÆn library & dataset ready for **public release**
- Achieve **competitive results on constrained hardware** (Xilinx-Pynq)

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Thank you for your attention!

Any questions?

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