Low-Resolution Satellite Imagery Change Detection Model

Samuel Alter | Reveal Global Consulting | 2025-06-06

Agenda

- Background and problem statement

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- Project needs

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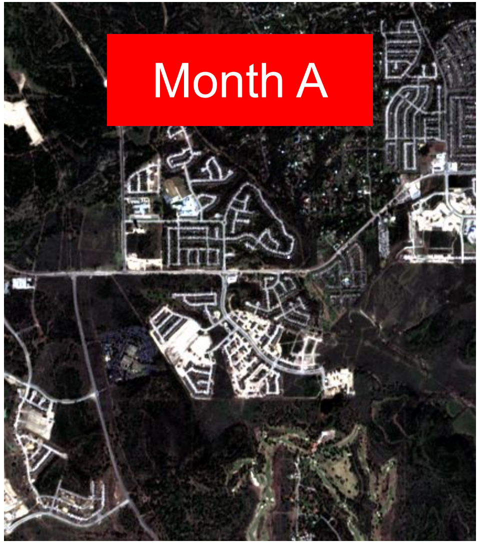

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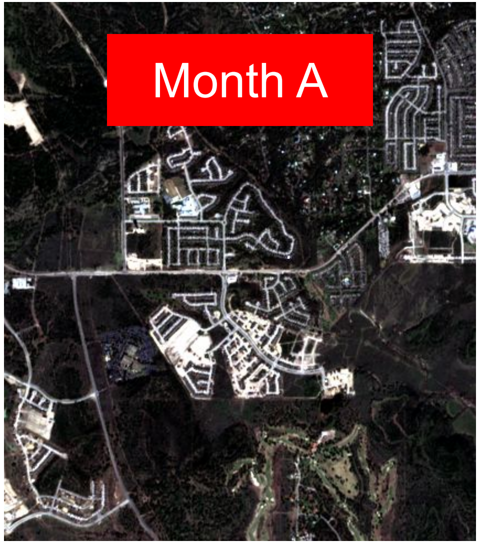

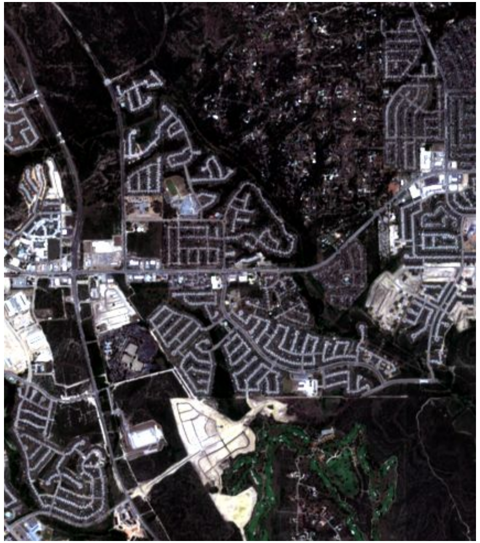

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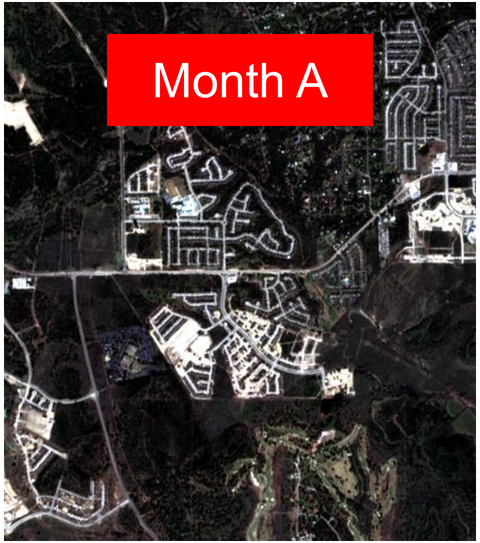

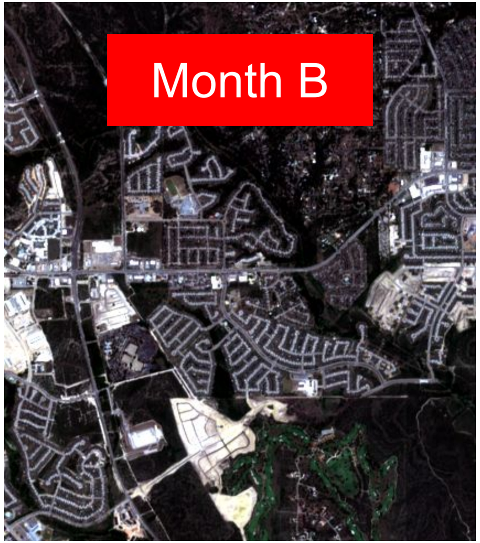

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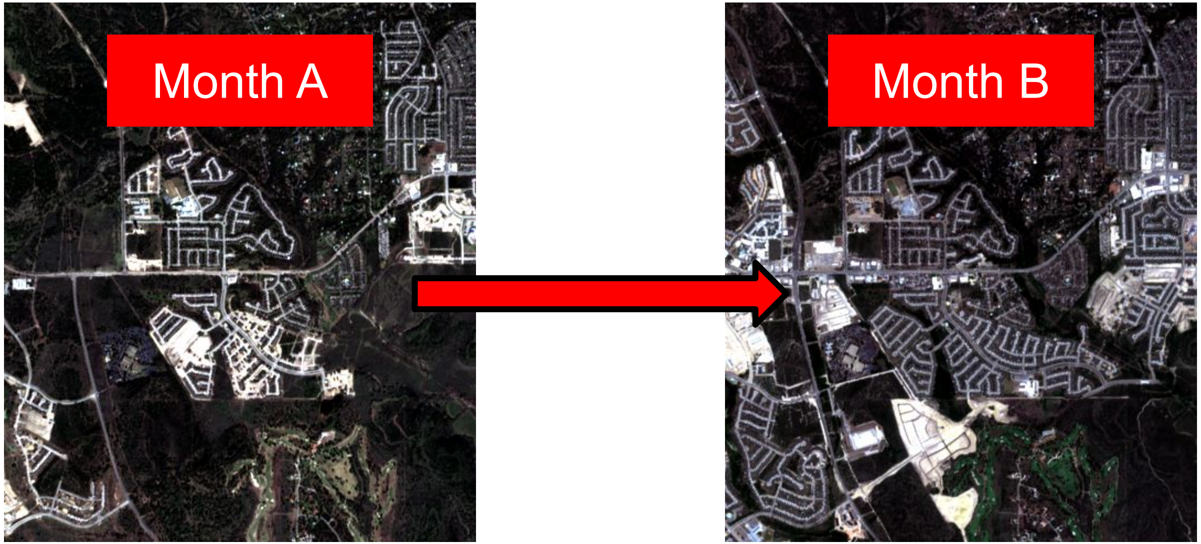

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- High-res imagery is expensive - both in terms of money and compute
- SOC currently provisions a very large area to for their tools to use…
- …Which can get extremely large for places like Harris County, TX (1,780mi^2)...
- …But most of that area does not undergo construction

Problem Statement

Therefore, there is an opportunity to cut costs and decrease the time it takes to track construction.

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Perhaps there is a “filter” that we could run on the intended capture area before provisioning expensive imagery, which could detect areas that actually underwent construction (i.e., detect change).

Problem Statement

Therefore, there is an opportunity to cut costs and decrease the time it takes to track construction.

Perhaps there is a “filter” that we could run on the intended capture area before provisioning expensive imagery, which could detect areas that actually underwent construction (i.e., detect change).

We could train a model that detects change between two time steps.

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Project Needs

- Run cheaply

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- Use readily-available imagery

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- Run cheaply
- Use readily-available imagery
- Potential to slot into the existing workflow of the SOC team and other teams at Reveal

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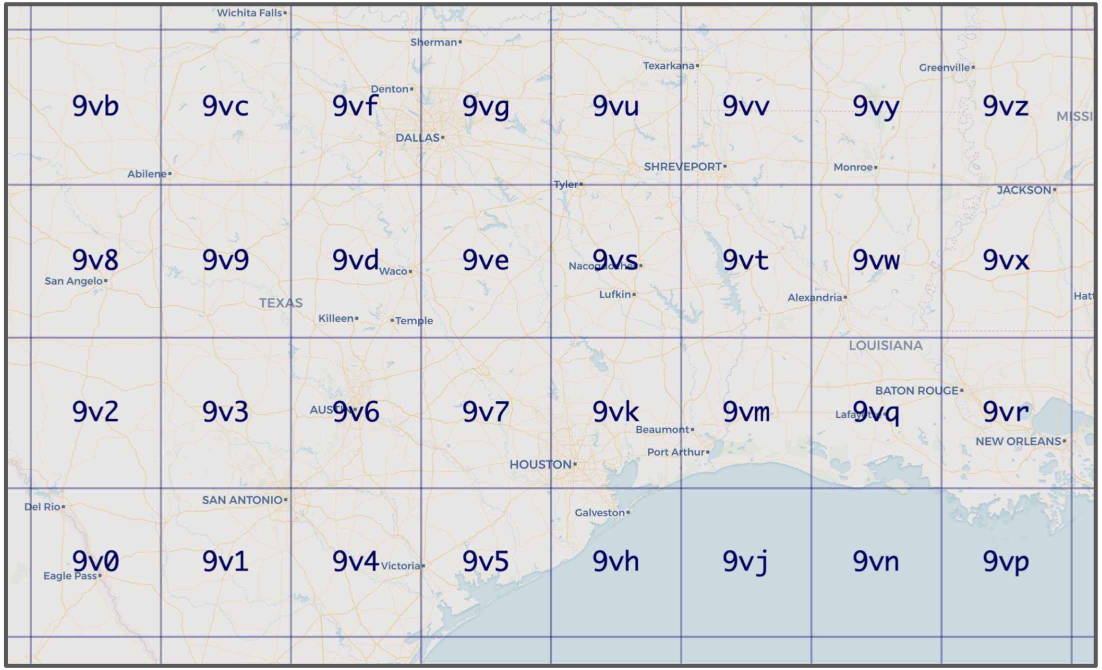

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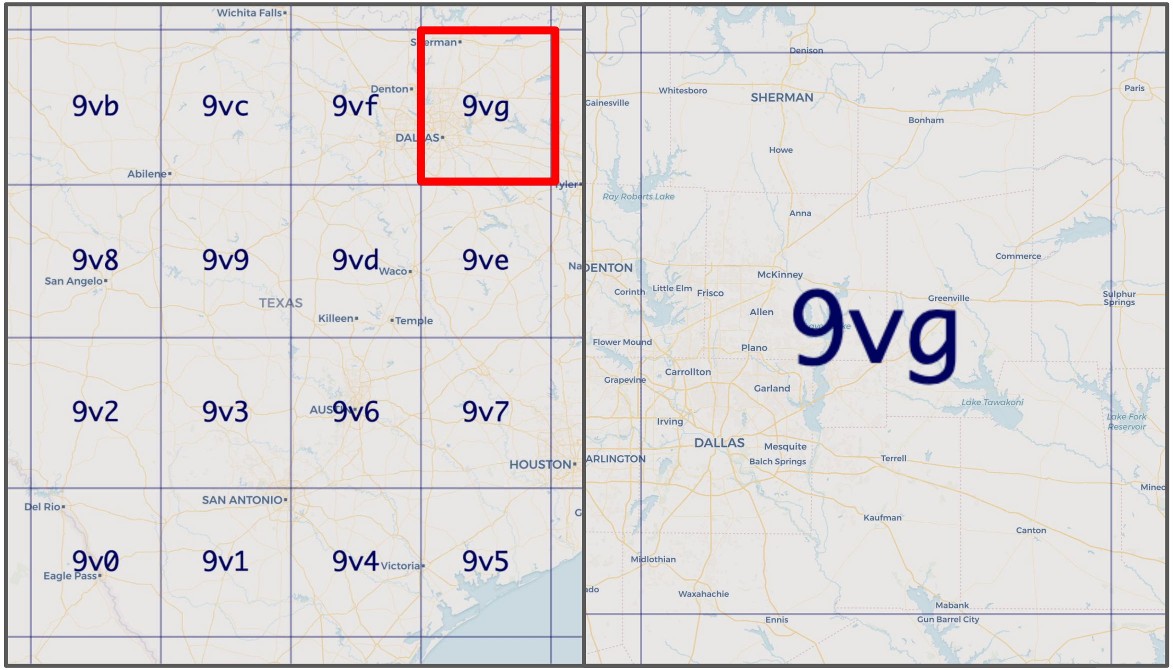

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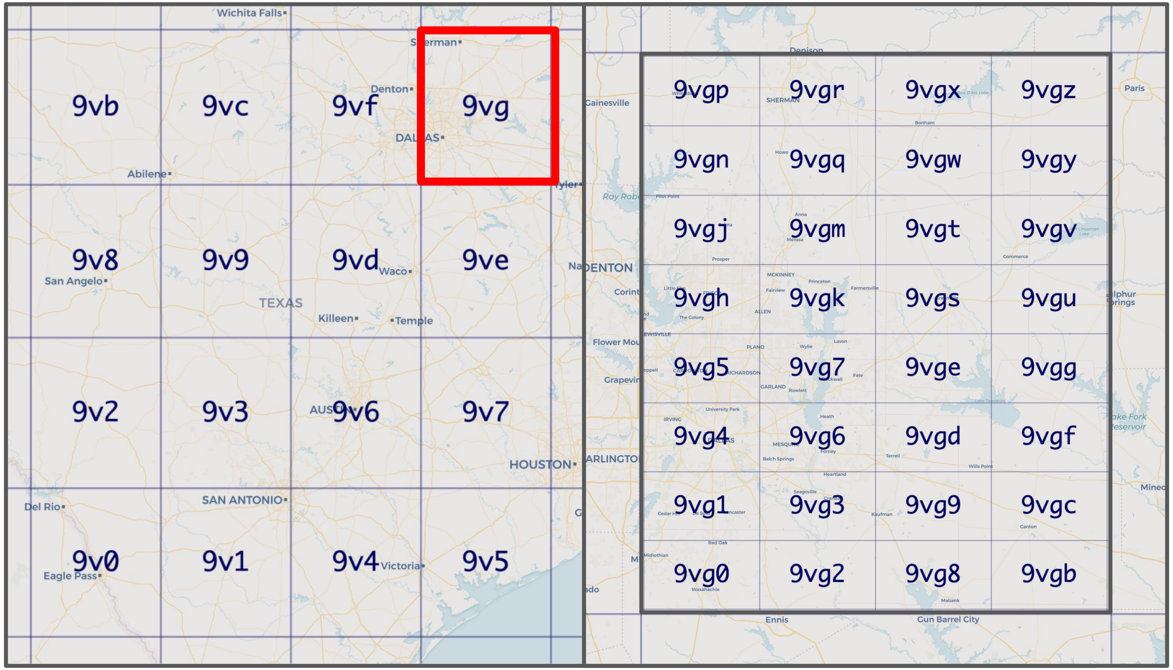

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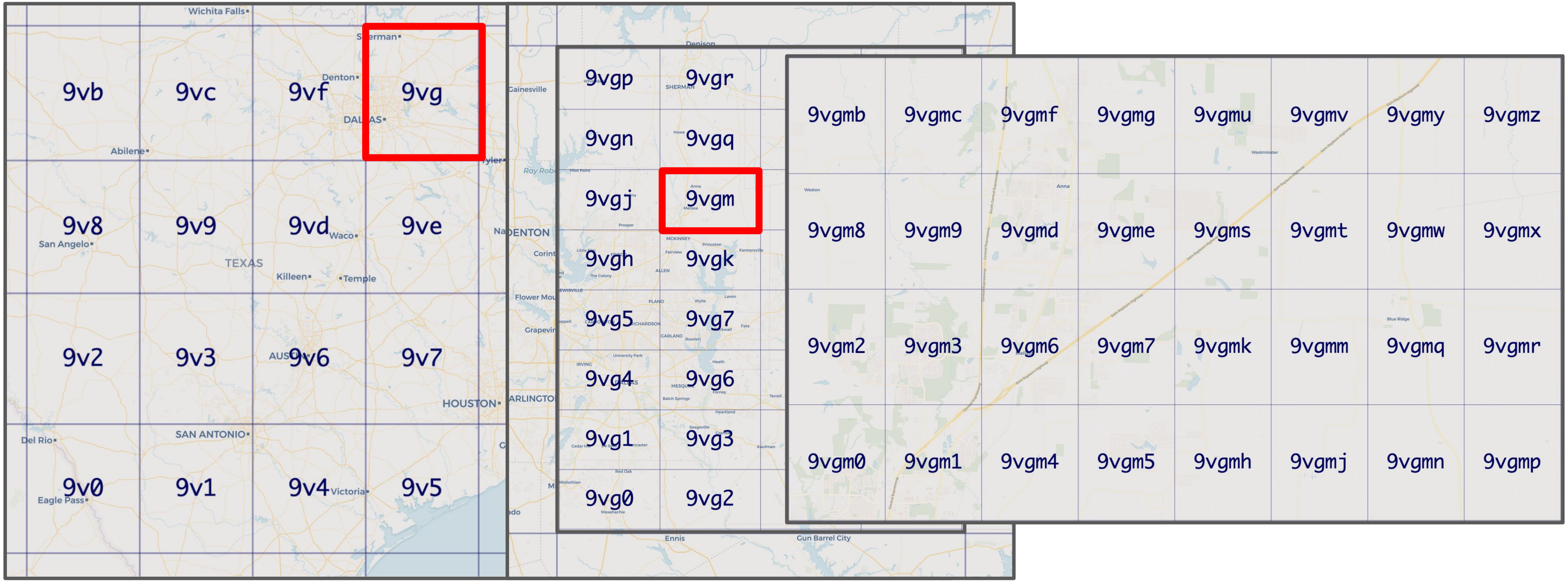

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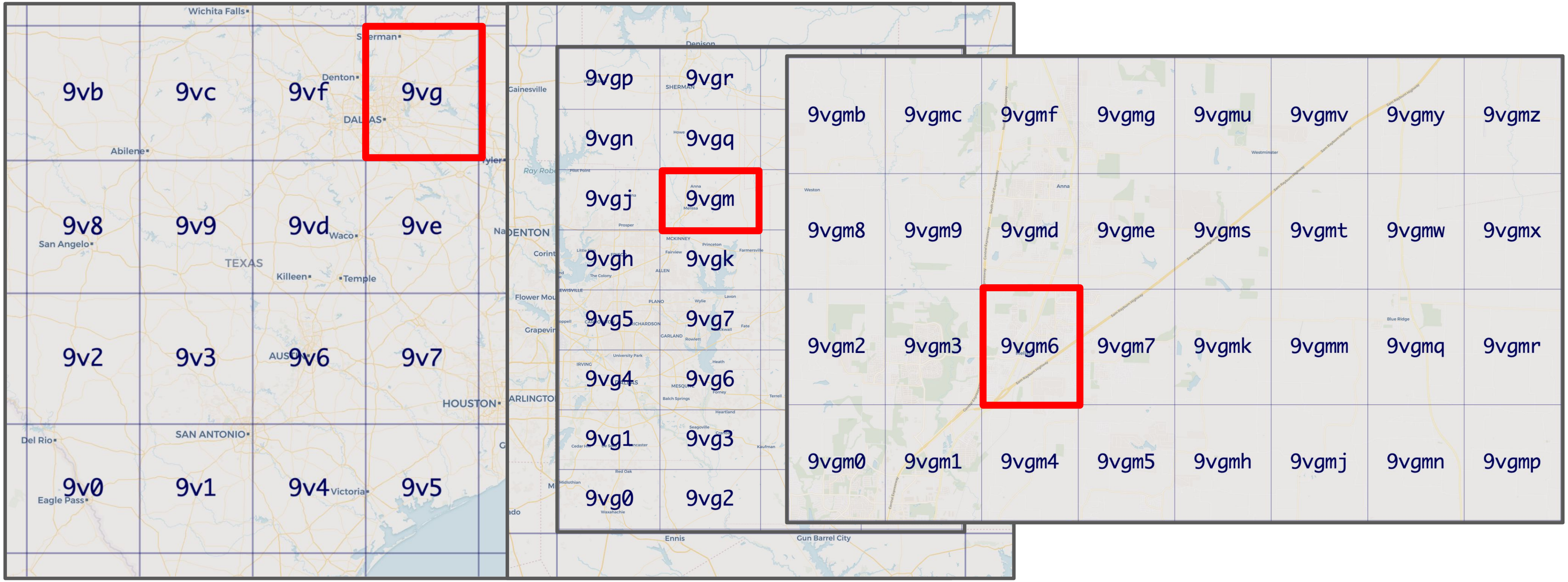

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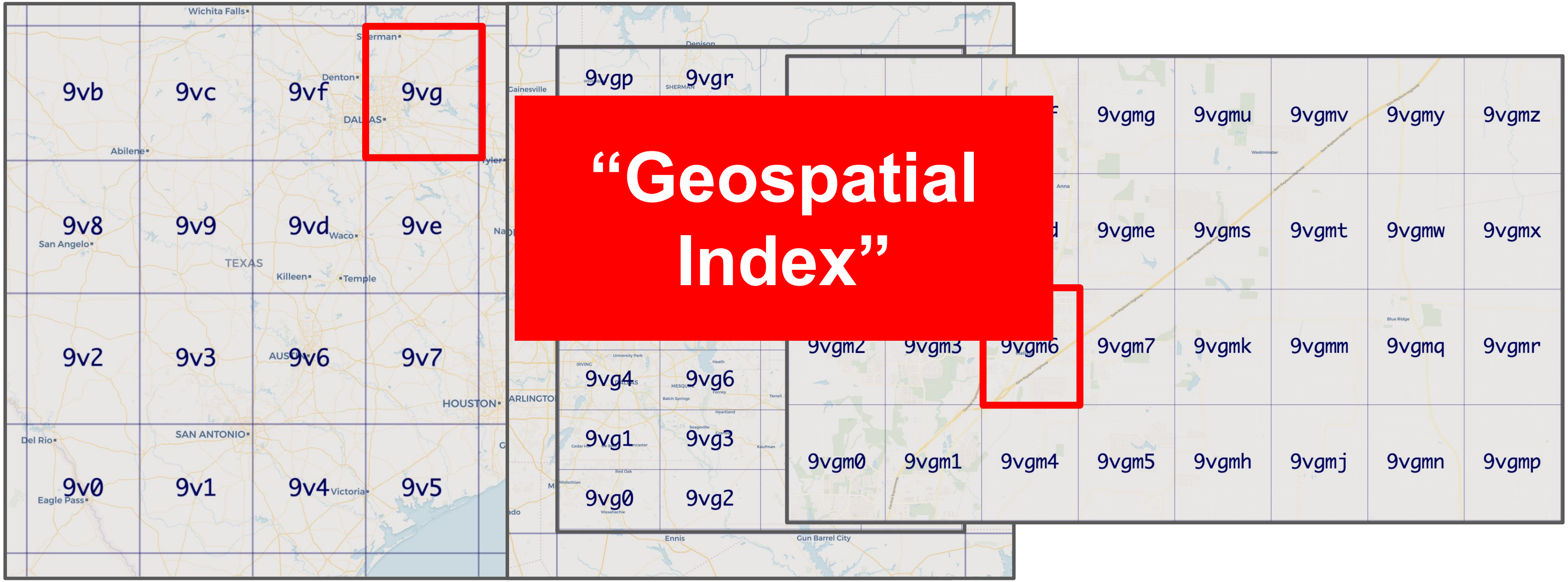

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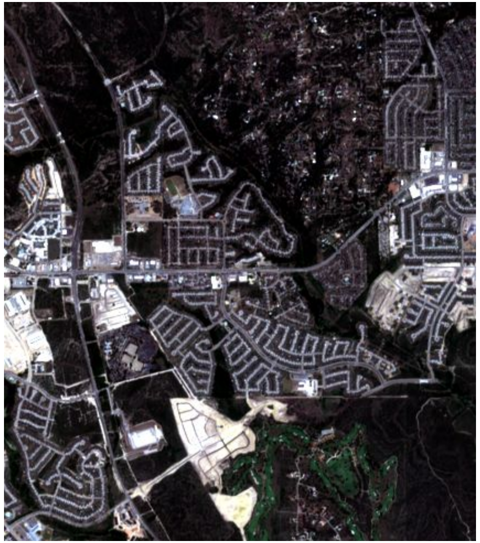

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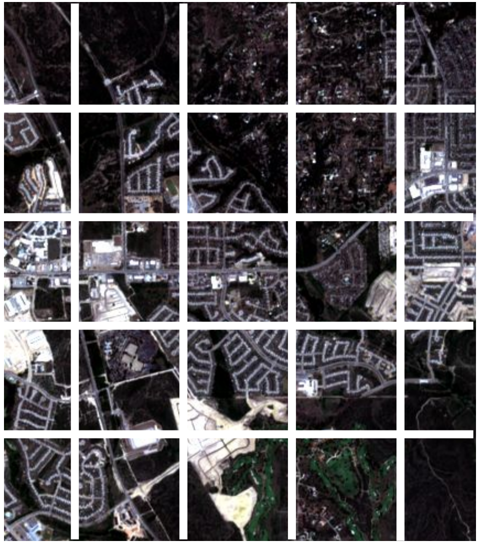

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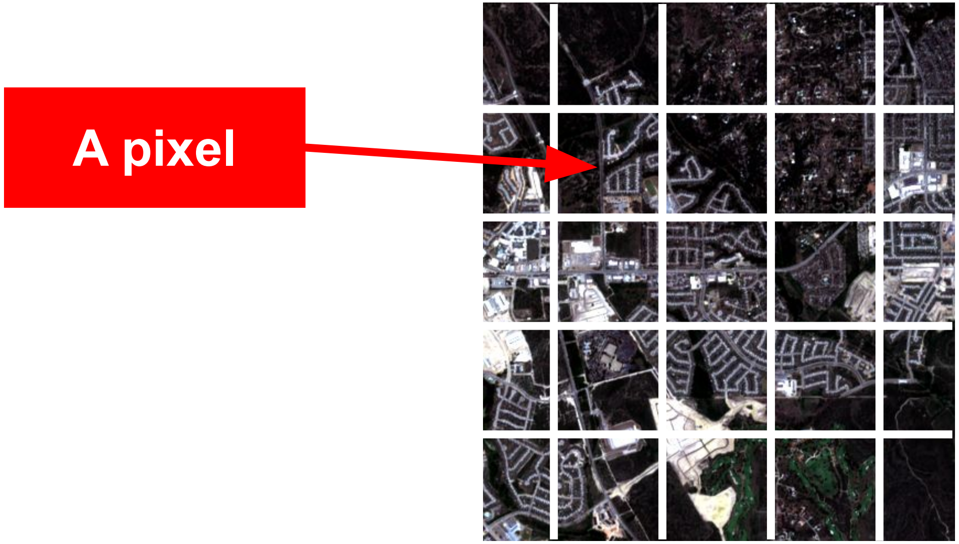

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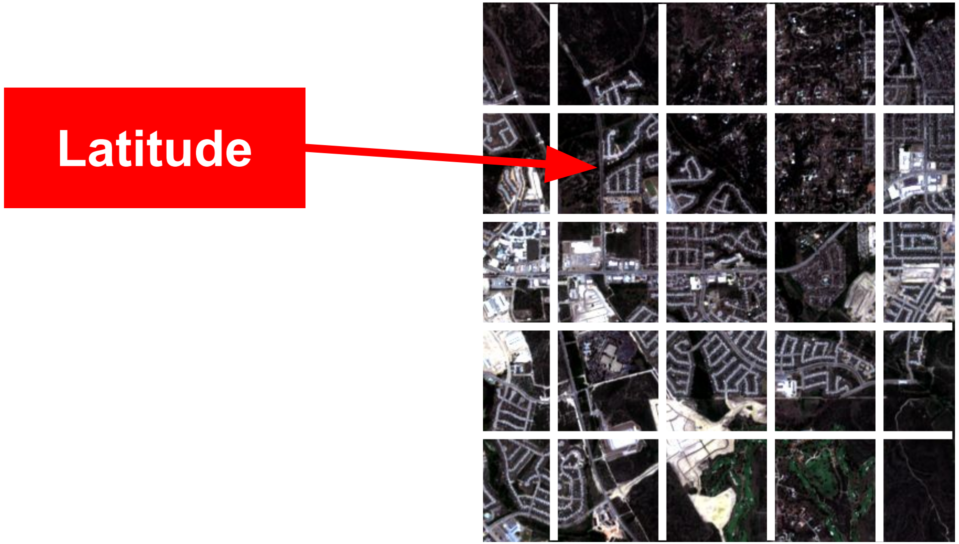

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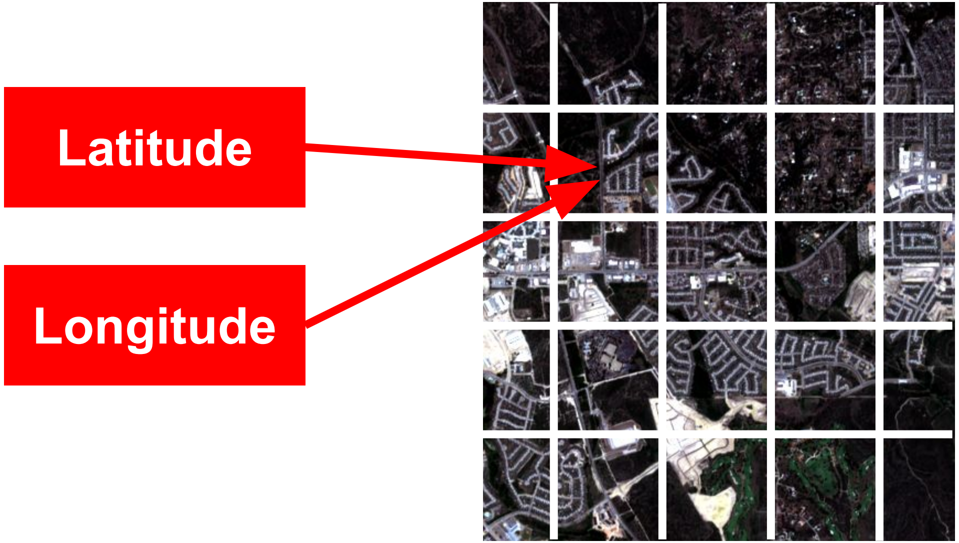

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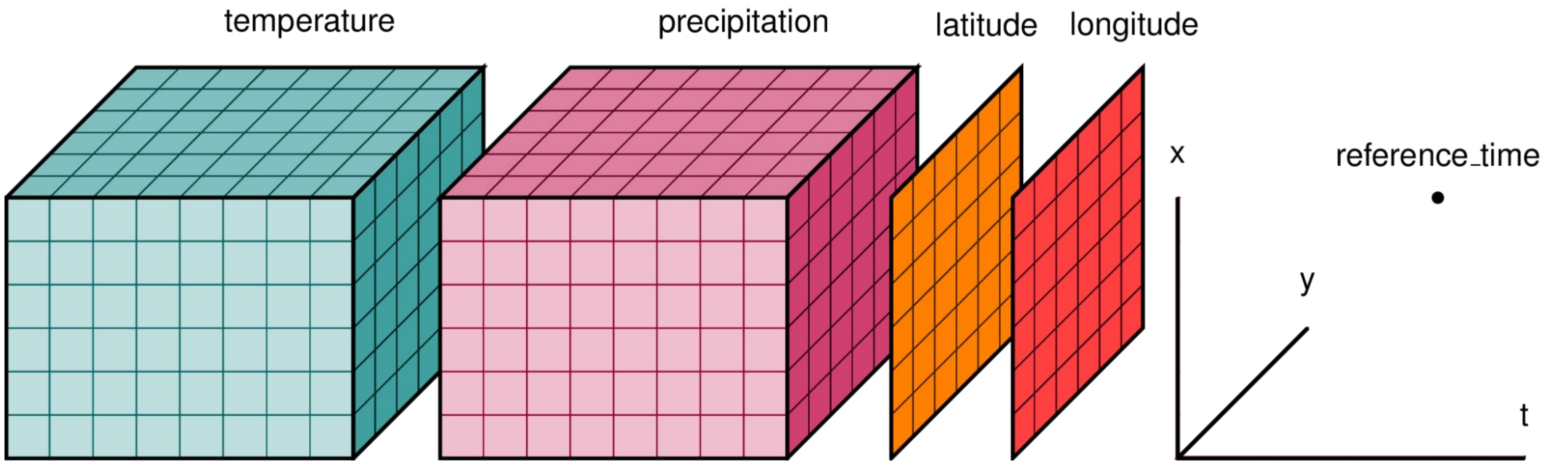

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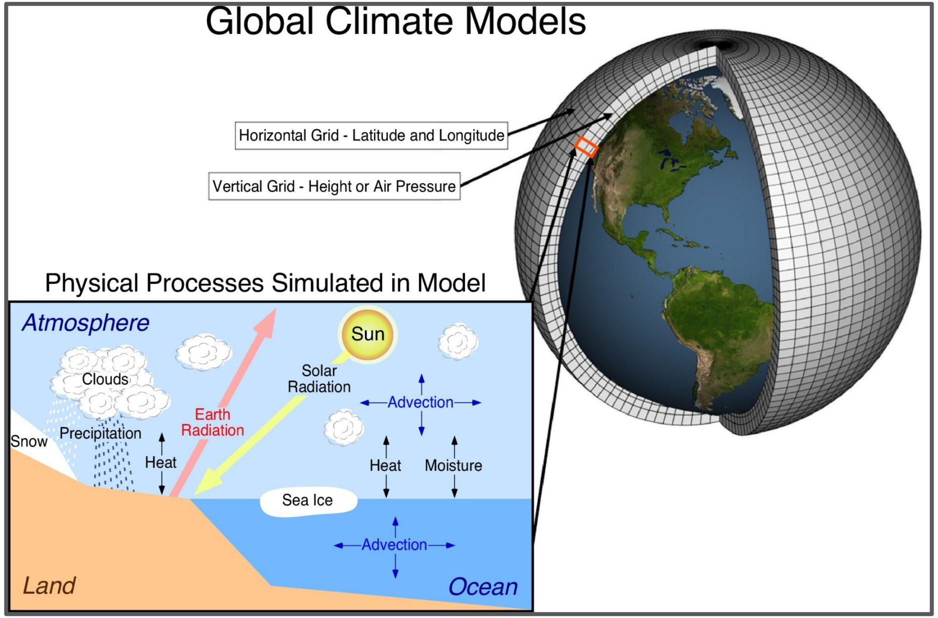

https://pressbooks.bccampus.ca/physgeoglabmanual1/wp-content/uploads/sites/1318/2021/03/Global_Climate_Model-2048x1346.jpg

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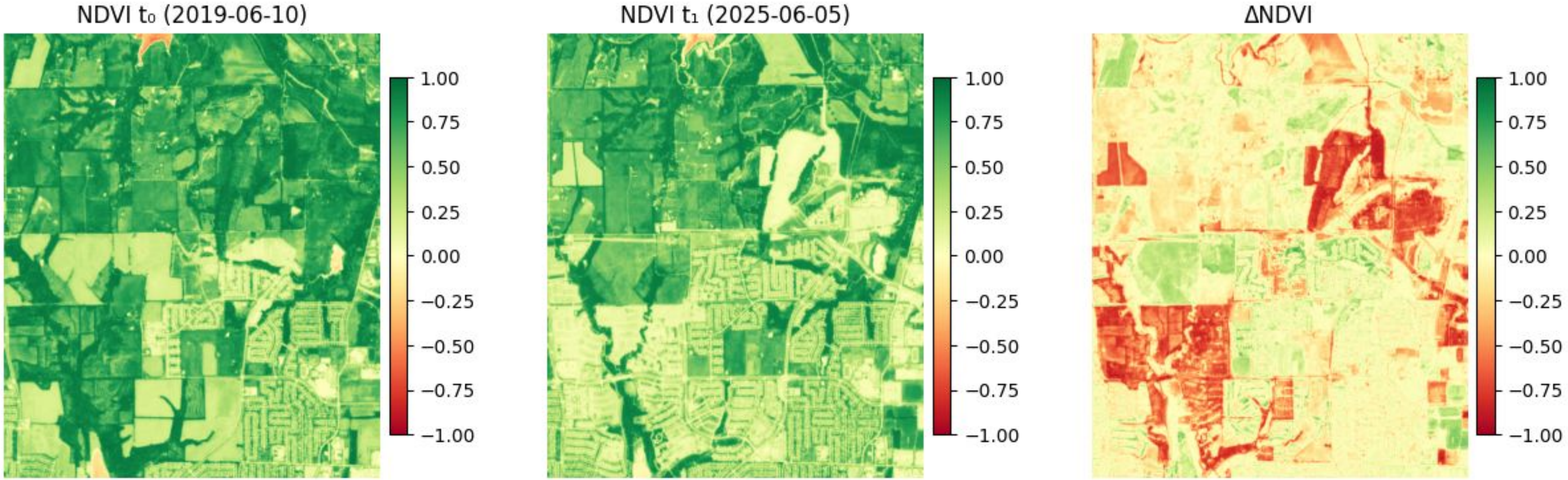

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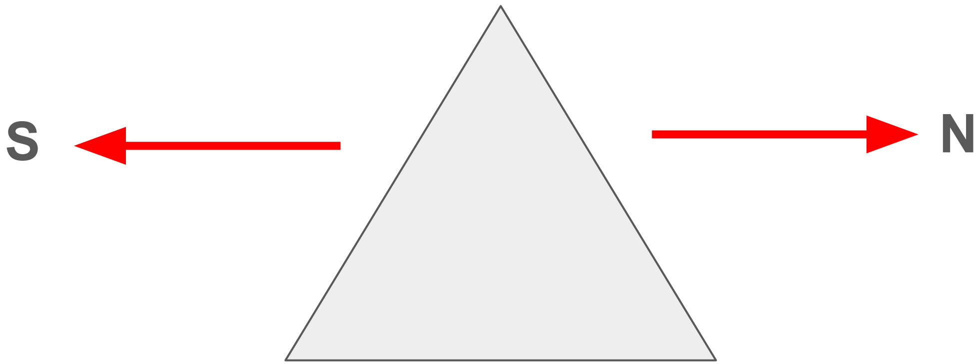

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- Methods overview:
  - Dataset tools

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    - Run training/hyperparameter search

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    - Build the dataset
    - Inspect the dataset
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    - Define architecture
    - Training setup
    - Run training/hyperparameter search
  - Tool to produce results, i.e., “inference”

Methodology - Dataset

- Methods overview:
  - Dataset tools
    - **Build the dataset**

Methodology - Dataset

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Google Earth Engine

https://www.appgeo.com/wp-content/uploads/GoogleEarthEngine.png

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    - Ultra Blue (coastal, aerosol)

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Methodology - Dataset

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- xarray
  - Builds “datacubes”

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https://logodix.com/logo/1048000.png

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https://images.icon-icons.com/2699/PNG/512/pytorch_logo_icon_169823.png

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  - Add time-derived channels (delta-time, day-of-year)

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  - Add NDVI-derived channels to control for seasonal variations

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  - Add time-derived channels (delta-time, day-of-year)
  - Add NDVI-derived channels to control for seasonal variations
  - Replace aspect channel with two channels to control for 350° ≅10°

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Google Earth Engine

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Dataset TL;DR:

Create a multi-dimensional dataset that provides the model cues beyond just visual imagery to help it detect change.

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  - “Fully-convolutional variational auto-encoder”

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  - 128x128→64x64→32x32→16x16, then back out 16→32→64→128

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  - Learns to encode input data into a compressed representation
  - 128x128→64x64→32x32→16x16, then back out 16→32→64→128
  - Preserves 2D structure of inputs

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  - Uses reconstruction error as a proxy for labels: high error → change has likely occurred

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  - Local save of S3 datasets
  - Sets time pairs with 7-day intervals, weighted sampling of these pairs

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- Training key facts
  - “Hard-negative mining”
  - Uses reconstruction error as a proxy for labels: high error → change has likely occurred
  - Local save of S3 datasets
  - Sets time pairs with 7-day intervals, weighted sampling of these pairs
  - Per-patch (128x128) metrics

Methodology - Model

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Trained on Dallas, TX imagery

https://clipartmag.com/images/texas-state-flag-picture-8.png

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Methodology - Model

- Hyperparameter search key facts

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- Hyperparameter search key facts
  - Optuna orchestrates HP search over key parameters like learning rate, weight decay, latent dimension, etc.

https://pic1.zhimg.com/v2-8cfdf2456c0c93971492896e5582bfd2_1440w.jpg?source=172ae18b

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OPTUNA

https://pic1.zhimg.com/v2-8cfdf2456c0c93971492896e5582bfd2_1440w.jpg?source=172ae18b

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  - Optuna orchestrates HP search over key parameters like learning rate, weight decay, latent dimension, etc.
  - Strives to reduce validation loss metric as its target
  - Notifies via email when complete, giving best parameters

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```
----------------------------------------------------------------
        Layer (type)               Output Shape         Param #
================================================================
            Conv2d-1           [-1, 32, 64, 64]           3,776
       BatchNorm2d-2           [-1, 32, 64, 64]              64
              ReLU-3           [-1, 32, 64, 64]               0
 AdaptiveAvgPool2d-4             [-1, 32, 1, 1]               0
            Conv2d-5              [-1, 4, 1, 1]             132
              ReLU-6              [-1, 4, 1, 1]               0
            Conv2d-7             [-1, 32, 1, 1]             160
           Sigmoid-8             [-1, 32, 1, 1]               0
           SEBlock-9           [-1, 32, 64, 64]               0
           Conv2d-10           [-1, 64, 32, 32]          18,496
      BatchNorm2d-11           [-1, 64, 32, 32]             128
             ReLU-12           [-1, 64, 32, 32]               0
           Conv2d-13          [-1, 128, 16, 16]          73,856
      BatchNorm2d-14          [-1, 128, 16, 16]             256
             ReLU-15          [-1, 128, 16, 16]               0
           Conv2d-16           [-1, 18, 16, 16]           2,322
================================================================
Total params: 99,190
Trainable params: 99,190
Non-trainable params: 0
----------------------------------------------------------------
Input size (MB): 0.81
Forward/backward pass size (MB): 6.29
Params size (MB): 0.38
Estimated Total Size (MB): 7.48
----------------------------------------------------------------
```

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Model TL;DR:

The model is designed to generate pixel-wise change-detection heatmaps at resolution equal to the input.
Trained on imagery from Dallas, TX area.

Methodology - Inference

- Methods overview:
  - Dataset tools
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  - **Tool to produce results, i.e., “inference”**

Methodology - Inference

- Inference key facts

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- Inference key facts
  - “Patches” test dataset just like in training

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  - Runs the patches through the saved best model

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  - Runs the patches through the saved best model
  - Builds full-scene heatmap and change mask from the patches

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- Inference key facts
  - “Patches” test dataset just like in training
  - Runs the patches through the saved best model
  - Builds full-scene heatmap and change mask from the patches
  - Produces PDF report with figures and summary tables

Methodology - Inference

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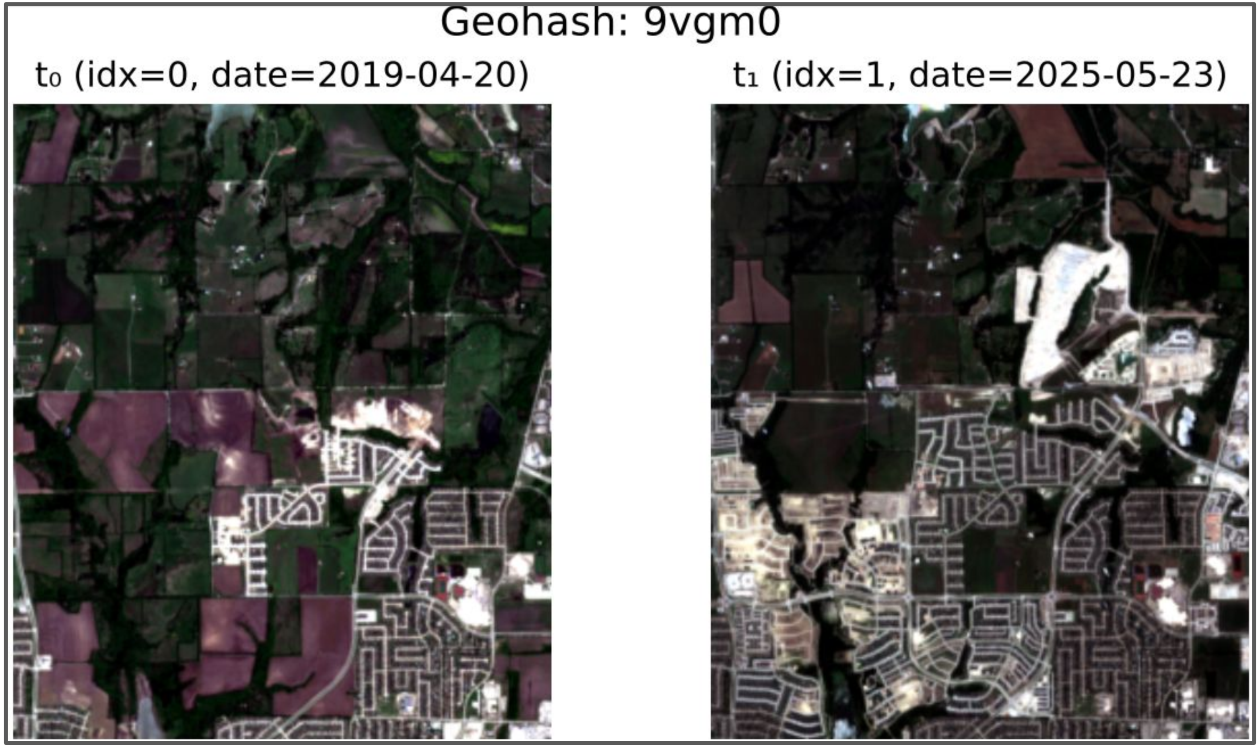
Inference TL;DR:

Runs test dataset through trained model to output full-size heatmap, change mask, before, after, summary tables… all in a PDF report.

Agenda

- Background and problem statement
- Project needs
- Definitions
- Methodology
- **Results**
- Discussion
- Acknowledgements
- Questions

Results - See the Demo!



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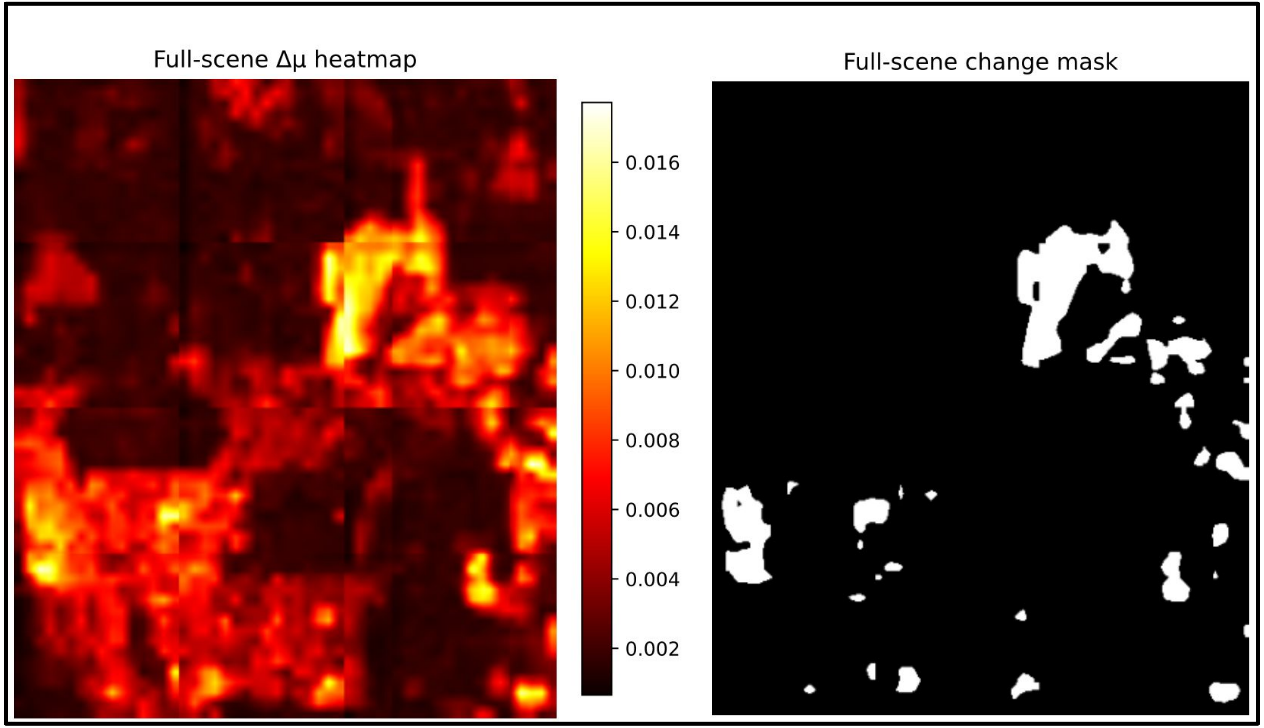

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- With the amount of data I gave it, the model only trained for a couple trials…
- …Suggesting there’s much more room for improvement…
- …Though the model appears to handle cloudless change detection scenes well
- We could expand model training to encompass more landscapes beyond suburban Texas

Discussion

- Did it meet the goals?

  Run cheaply

  Use readily-available imagery

  Potential to slot into workflow of SOC and other Reveal teams

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Acknowledgements

- Thank you to Dwarakh Nayam, Elo Lewis, Lei Peng, DJ Walker, Taylor Wilson, Cameron Milne, Angi Lee, Jackson Chen, and the rest of the Reveal team

Questions?

- Project GitHub link:

  https://github.com/RevealGC/low-res-change-detection/tree/main

- My GitHub:

  https://github.com/sralter

- My LinkedIn:

  https://www.linkedin.com/in/samuel-alter/