



AI and ML on DesignSafe

Krishna Kumar, The University of Texas at Austin

NHERI Computational Symposium, UCLA, 2024.

What is DesignSafe?

- A web-based research platform that enables transformative research to protect human life and reduce damage during natural hazard events

DesignSafe Vision

- A cyberinfrastructure (CI) that is an integral part of research discovery
 - Provide a platform for data sharing/publishing
 - Enable research workflows and access to high performance computing (HPC)
 - Deliver cloud-based tools that support the analysis, visualization, and integration of diverse data types
- Amplify and link the capabilities of natural hazards researchers in the US and abroad



DESIGNSAFE-CI 
NHERI: NATURAL HAZARDS ENGINEERING RESEARCH INFRASTRUCTURE

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RICE

Florida Tech

DesignSafe Components

www.designsafe-ci.org

Data

The screenshot shows the 'DATA DEPOT' section of the DesignSafe website. It includes a sidebar with options like 'Add', 'My Data', 'My Projects', 'Shared with Me', 'Box.com', 'Dropbox.com', 'Google Drive', and 'Published'. Below is a table listing five projects:

Project ID	Project Title
PRJ-3661	NCA-East Extended ground motion database
PRJ-1305	Community Data
PRJ-3617	VaDD Salinates in California from the Peacock Seismogram Approach
PRJ-3609	Research Experiences for Undergraduates (REU), NHERI 2022: Deriving Soil Constitutive Model using Artificial Intelligence (AI) on Untrained Soil Conditions
PRJ-3615	Research Experience for Undergraduates (REU), NHERI 2022: Implementing Physics Constraints into Graph Network-based Simulator for Natural-hazard Predictions

The screenshot shows the 'Learning Center' section of the DesignSafe website. It features a navigation bar with 'Use DesignSafe' and 'Learning Center' tabs. Below are several sections: 'Data Depot', 'Tools & Applications', 'Recon Portal', 'SimCenter Research Tools', 'User Guides' (which is highlighted with a red box), and 'Use Cases'.

Training/User Support

Visit NHERI DesignSafe's YouTube Channel for the Full Archive

Featured Playlists

- DesignSafe Webinars
- SimCenter Series: Studying Coastal Hazards with HydroUQ
- 2021 Joint NSF NHERI WOW and Lehigh RTMD EF User Workshop
- SimCenter Series: Advances in Computational Modeling and Simulation

Data

The screenshot shows the 'SimCenter Tools' section of the DesignSafe website. It displays a grid of icons for different tools: ADCIRC, ANSYS, clevpack, Dakota, MPM, OpenFOAM, OpenSees, and OpenSees-STKO.

The screenshot shows the 'Recon Portal' section of the DesignSafe website. It features a world map with numerous blue dots representing seismic events. A sidebar on the left lists recent events, such as '2022 M 7.0 Earthquake Northern Philippines' and '2022 M 6.0 Earthquake Sariyeh Khorsh village, Iran'.

Simulation &
Data Analytics



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Published Datasets

DATA DEPOT



My Data

My Projects

Shared with Me

Box.com

Dropbox.com

Google Drive

Published

Published (NEES)

Community Data

Help▼

Find in this Dataset



PRJ-2363 | Soil-Foundation-Structure Interaction Effects on the Cyclic Failure Potential of Silts and Clays

Download Dataset

PI Brandenberg, Scott

Co-PIs Stewart, Jonathan

Project Type Experimental

Keywords Cyclic Softening, Fine-Grained Soil, Soil-Foundation-Structure I

[View Data Diagram](#) | [View Project Metrics](#) | [Leave Feedback](#)

Description | Earthquake-induced ground failure has resulted in billions of dollars of damage either "sand-like" or "clay-like" behavior with respect to strength loss during earthquakes. This is understood than "sand-like" soils. Cyclic failure of fine-grained soils are often constrained to the structures, indicating that soil-foundation-structure interaction plays an important role. This project is focused on understanding the cyclic behavior of fine-grained soils.

[Show More](#)

PRJ-2363v2



Report | Data Processing

Report | Digital Data Report (JZB02)

Model Configuration | Centrifuge Model (JZB02)

Sensor Information | Centrifuge (JZB02)

Event | CPT (JZB02)

Event | Fast Data from Spin 2 (Dynamic Shaking Applied)

Data collected at 5000 Hz during shaking

01162019@082639@110817@77.0rpm.bin

01162019@082639@112208@77.0rpm.bin

01162019@082639@113803@76.8rpm.bin

01162019@082639@115034@76.9rpm.bin

01162019@082639@122026@77.0rpm.bin

01162019@082639@125704@77.0rpm.bin



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DATA DEPOT

+ Add

Find in this Dataset



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PRJ-2363 | Soil-Foundation-Structure Interaction Effects on the Cyclic Failure Potential of Silts and Clays

Download Dataset

PI

Brandenberg, Scott

Co-PIs

Stewart, Jonathan

Project Type

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Keywords

Cyclic Softening, Fine-Grained Soil, Soil-Foundation-Structure Interaction

[View Data Diagram](#) | [View Project Metrics](#) | [Leave Feedback](#)

Experiment | Centrifuge Test on Bentonite Clay - Test UCLA JZB01

Cite this Data:

Buenker, J., S. Brandenberg, M. Eslami, D. Abundis, T. Buckreis, J. Stewart. (2020) "Centrifuge Test on Bentonite Clay - Test UCLA JZB01", in *Soil-Foundation-Structure Interaction Effects on the Cyclic Failure Potential of Silts and Clays*. DesignSafe-CI. <https://doi.org/10.17603/ds2-e7s5-b025 v1>

Download Citation: [DataCite XML](#) | [RIS](#) | [BibTeX](#)

31 Downloads 141 Views Details

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Experiment | Centrifuge Testing on Kaolinite Clay - Test UCLA JZB02

Cite this Data:

Buenker, J., S. Brandenberg, J. Stewart, M. Eslami, T. Buckreis, D. Abundis. (2020) "Centrifuge Testing on Kaolinite Clay - Test UCLA JZB02", in *Soil-Foundation-Structure Interaction Effects on the Cyclic Failure Potential of Silts and Clays*. DesignSafe-CI. <https://doi.org/10.17603/ds2-jpwh-nq72 v1>

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Data Depot

Searching Published Datasets

Search <input type="text" value="japan"/>		Natural Hazard Type	All Types	Year Published	All Years	Clear Filters
Project Title		Project PI	Description	Keywords	Date Published	
LEAP-GWU-2022 Experiments: Seismic Performance of Sheet Pile Walls in Liquefiable Soils Experimental		Manzari, Majid	View Description	liquefaction, sheet-pile wall, soils-structure interaction, model tests, round robin tests, centrifuge, experiments, simulations, validation	11/30/2023	
LEAP-RPI-2020: Seismic interaction of a liquefiable soil with a cantilever retaining wall Experimental		Zeghal, Mourad	View Description	Soil liquefaction, retaining wall, model tests, round robin tests, centrifuge, experiments, simulations, validation	11/29/2023	
GEER - M6.6 Hokkaido, Japan Field Research		grant, alex	View Description	Earthquakes, Landslides, Liquefaction, Housing	10/31/2023	



Data Depot

DATA DEPOT

[+ Add](#)

Published

Published (NEES)

Community Data

[Help ▾](#)

Copy

Preview

Preview Images

Download

PRJ-4139 | LEAP-GWU-2022 Experiments: Seismic Performance of Sheet Pile Walls in Liquefiable Soils

 [Download Dataset](#)PI [Manzari, Majid](#)Co-PIs [Zeghal, Mourad](#)Project Type [Experimental](#)Natural Hazard Type [Earthquake](#)Awards [Validation Of Constitutive And Numerical Modeling Techniques For Soil Liquefaction Analysis \(PI: Manzari\) | NSF-CMMI 1635524](#)

PRJ-4139

Experiment | Ehime University Centrifuge Experiments of the Seismic Performance of Sheet Pile Walls in Liquefiable Soils

Cite this Data:

M. Okamura, K. Ono, (2023) "Ehime University Centrifuge Experiments of the Seismic Performance of Sheet Pile Walls in Liquefiable Soils", in *LEAP-GWU-2022 Experiments: Seismic Performance of Sheet Pile Walls in Liquefiable Soils*. DesignSafe-CI. <https://doi.org/10.17603/ds2-03km-9v86> v1

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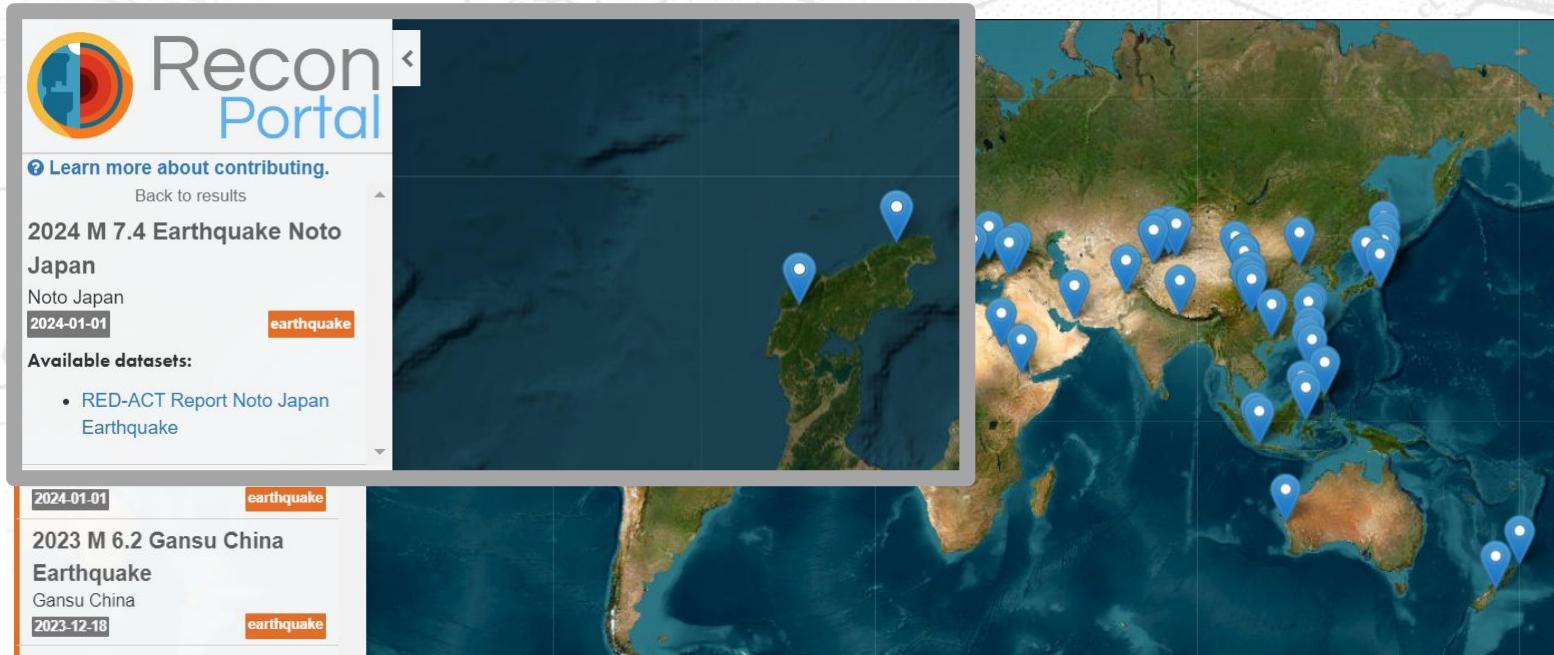
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Reconnaissance Portal

Identifying Datasets from Natural Hazard Events



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Curation Assistance

- Curation and publication guidelines under **User Guides**
 - <https://www.designsafe-ci.org/rw/user-guides/data-curation-publication/>
 - Managing protected/identifiable data – talk to Maria Esteva
- Data transfer methods
 - <https://www.designsafe-ci.org/rw/user-guides/data-transfer-guide/>
 - Web browser/Dropbox/etc (smaller uploads), Globus, Cyberduck
- Virtual Curation Office Hours
 - DesignSafe Data Curators: Maria Esteva and Craig Jansen
 - Tuesday and Thursday at 1 pm Central (or by appt)
 - <https://www.designsafe-ci.org/learning-center/training/>



Tools & Apps: Simulation

TOOLS & APPLICATIONS

Learn About Tools & Applications.

Simulation	SimCenter Tools	Visualization	Analysis	Hazard Apps	Utilities	My Apps
ADCIRC 	ANSYS 	clawpack 	Dakota 	LS-DYNA 		OpenFOAM 
OpenSees 	rWHALE 					

- HPC-enabled simulation codes (Stampede2, Frontera)
- Available through portal or at the Command Line, easy access to HPC allocation (CPUs, GPUs) through DesignSafe



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Tools & Apps: Data Analysis

Simulation [8]	Visualization [9]	Data Processing [2]	Partner Data Apps [5]	Utilities [2]	My Apps [8]
FigureGen 	HazMapper 	Kalpana 	Paraview 	Potree Converter 	Potree Viewer 
QGIS Desktop 3.8.1 	STKO 	VisIt 	Jupyter 	MATLAB 	

- Cloud-based tools for data analysis and visualization
- Access to files in Data Depot



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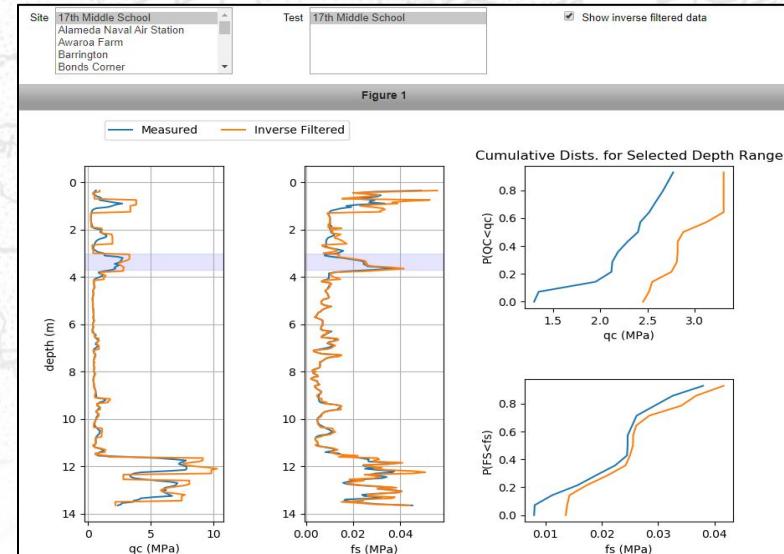
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Jupyter Notebooks

- Electronic notebooks in Python or R
- JupyterHub in DesignSafe
 - Access to Data Depot files
- Interactive data viewer
- Can write scripts for data processing, AI or machine learning
- Publish for use by others



Next Generation Liquefaction



From Scott Brandenberg (UCLA)



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Learning Center



Workspace

Learning Center

Education & Training

Archived DesignSafe Webinars

<https://tinyurl.com/DesignSafe-Webinars>

DesignSafe Tutorials

NEW

Development and utilization of a relational database to support post-earthquake building damage and recovery assessment

March 12, 2021

- [Watch Tutorial](#)

Experimental Data Workflow for Real Time Decision Making Using Python and Jupyter Notebooks

February 3, 2021

- [Watch Tutorial](#)

Leveraging DesignSafe with TAPIS

December 17, 2020

- [Watch Tutorial](#)

Best Practices to Enhance the Quality, Discoverability and Re-Use Potential for Post-Event Reconnaissance Data

November 11, 2020

- [Watch Tutorial](#)
- [Presentation Slides](#)

SimCenter Webinars

NEW

Physical Modeling of Wave Attenuation & Wave Force Reduction by a Mangrove Forest

December 4, 2020

- [Watch Webinar](#)

Computational Frameworks for the Implementation of Performance-Based Wind Engineering

November 23, 2020

- [Watch Webinar](#)

Partial Turbulence Simulation for Predicting Peak Wind Loads on Buildings

October 16, 2020

- [Watch Webinar](#)

Hurricane Loss Analysis for Single-Family Houses Considering Current and Changing Climate Conditions

October 6, 2020

- [Watch Webinar](#)



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DesignSafe: We are here for you!

Available to the Global Natural Hazards Research Community

Analyze,
Simulate
& Share

Start Your
Experiments

Expand
Your Skills

Join the
Community



- Interact with us and the community using the DesignSafe Slack team
- Cite data using DOIs in your reference list!



Please share your feedback, ideas, experiences!



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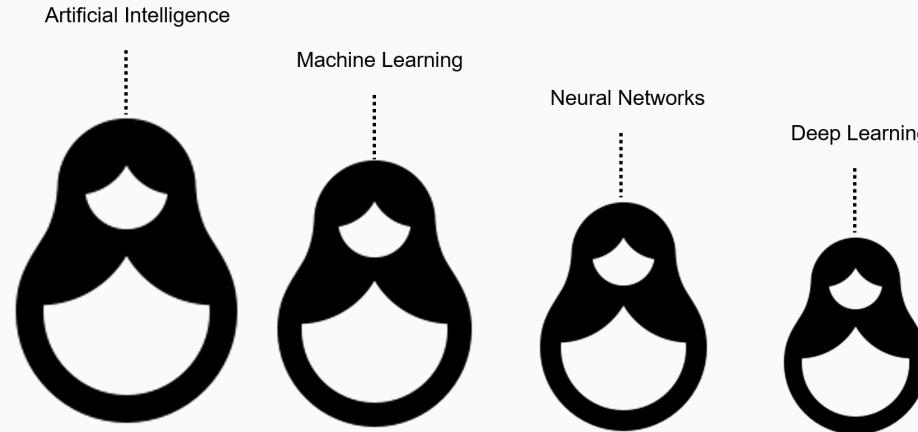
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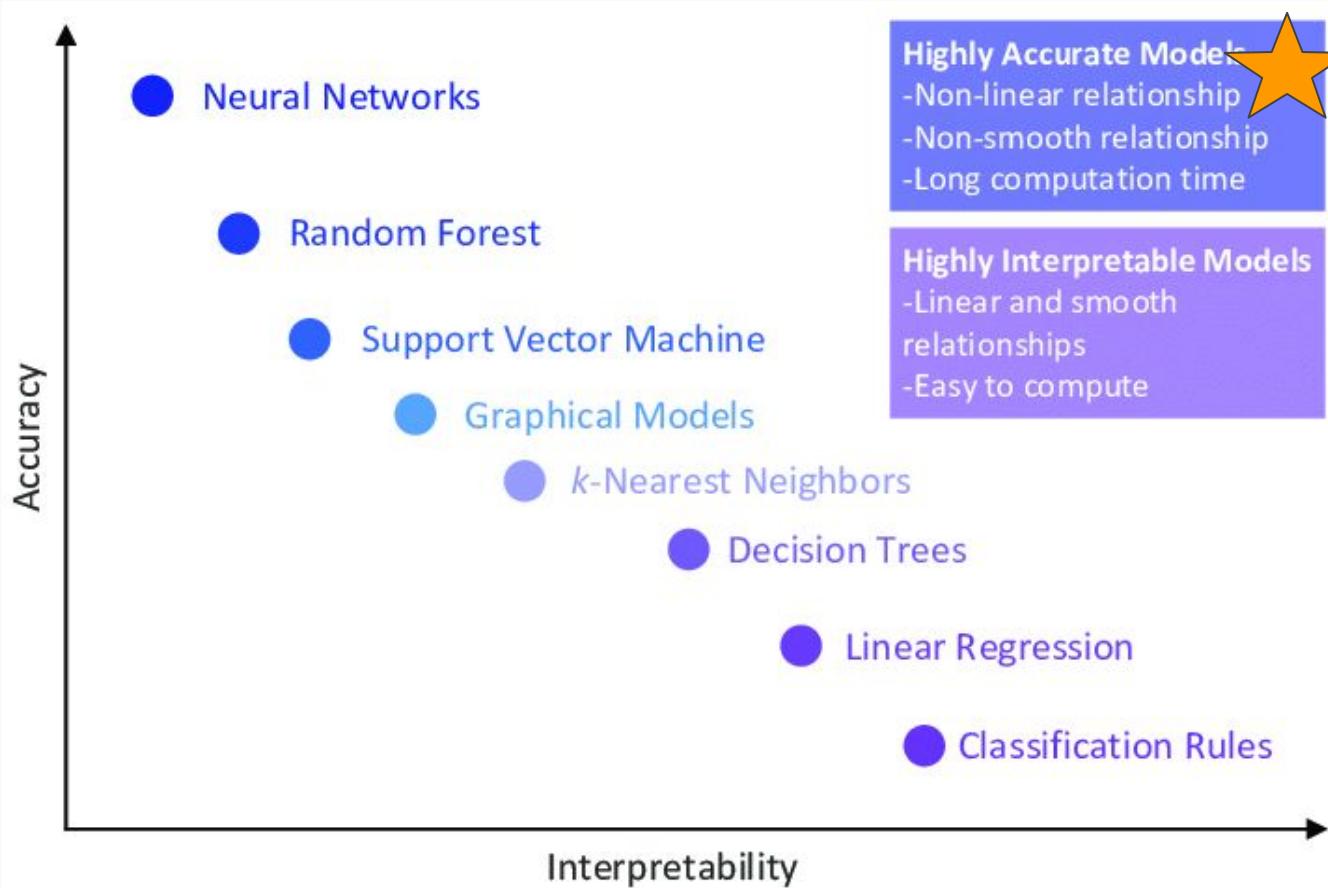
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AI vs Machine Learning vs Deep Learning

- **Artificial intelligence**: build intelligent programs and machines that can creatively solve problems, which has always been considered a human prerogative.
- **Machine learning** is a subset of artificial intelligence (AI) that provides systems the ability to automatically learn and improve from experience without being explicitly programmed. In ML, there are different algorithms (e.g. neural networks) that help to solve problems.
- **Deep learning** is a subset of machine learning, which uses the neural networks to analyze different factors with a structure that is similar to the human neural system.



Interpretability vs accuracy



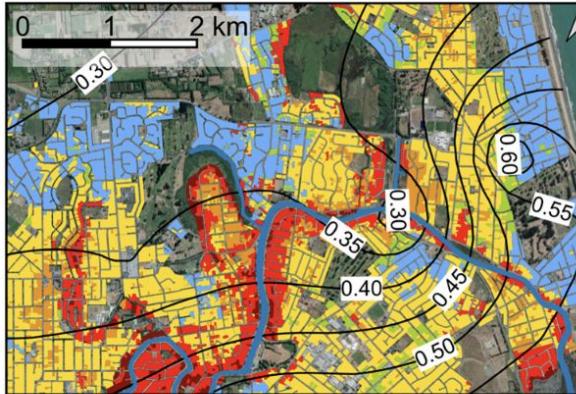
Lateral Spreading

Decision Trees
&
Random Forest

Liquefaction in NZ

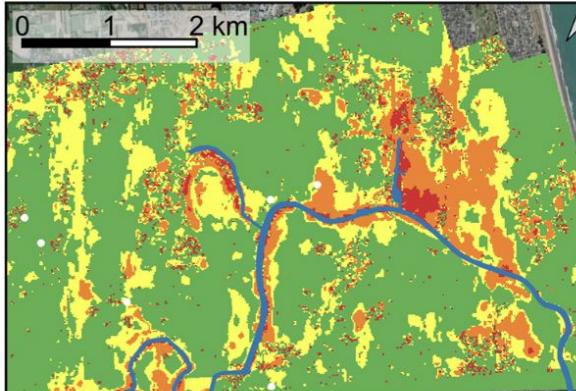
(a) Observed liquefaction related damage

- Conditional median PGA (g)
- No damage
- Minor cracks no ejecta
- No LS - minor to moderate ejecta
- No LS - large ejecta
- Moderate to major LS
- Severe LS



(b) Observed displacement (m)

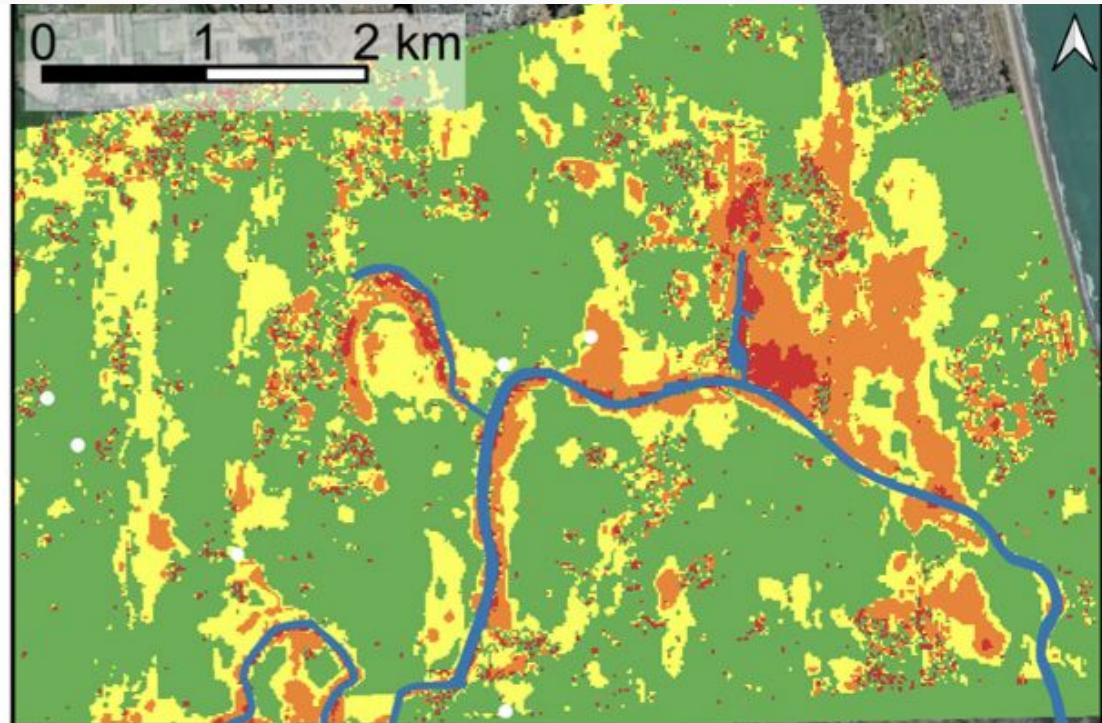
- None (< 0.30)
- 0.30 - 0.50
- 0.50 - 1.00
- > 1.00



Predicting lateral spreading in NZ

Observed
displacement (m)

- None (< 0.30)
- 0.30 - 0.50
- 0.50 - 1.00
- > 1.00



Durante and Rathje, 2021

Predicting lateral spreading in NZ

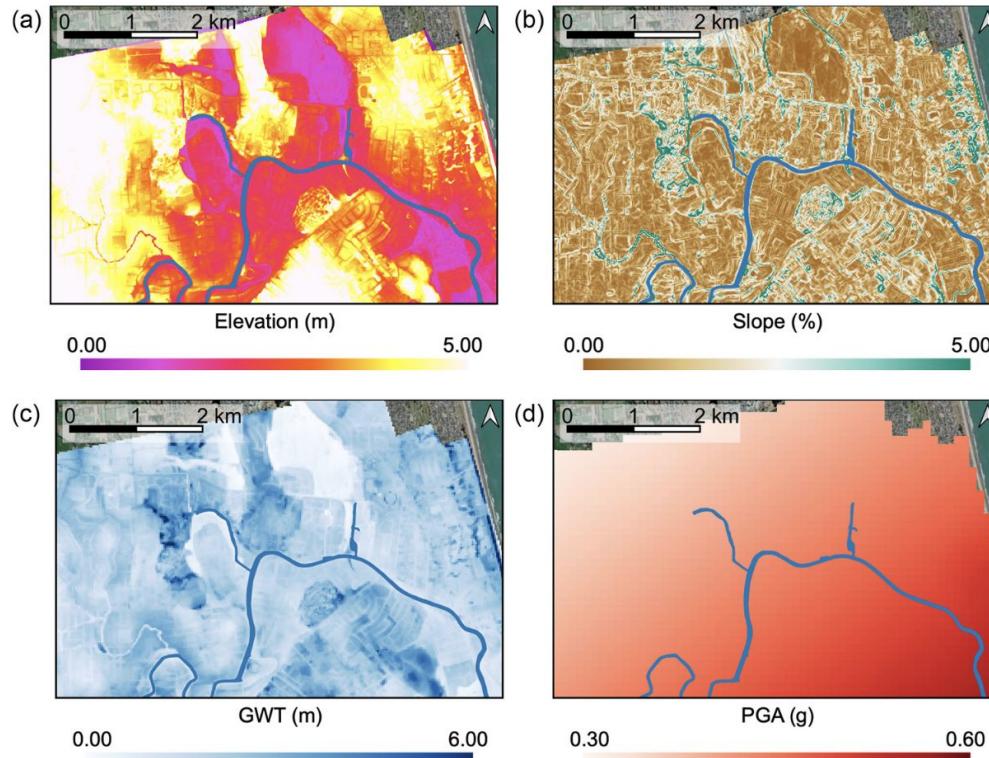
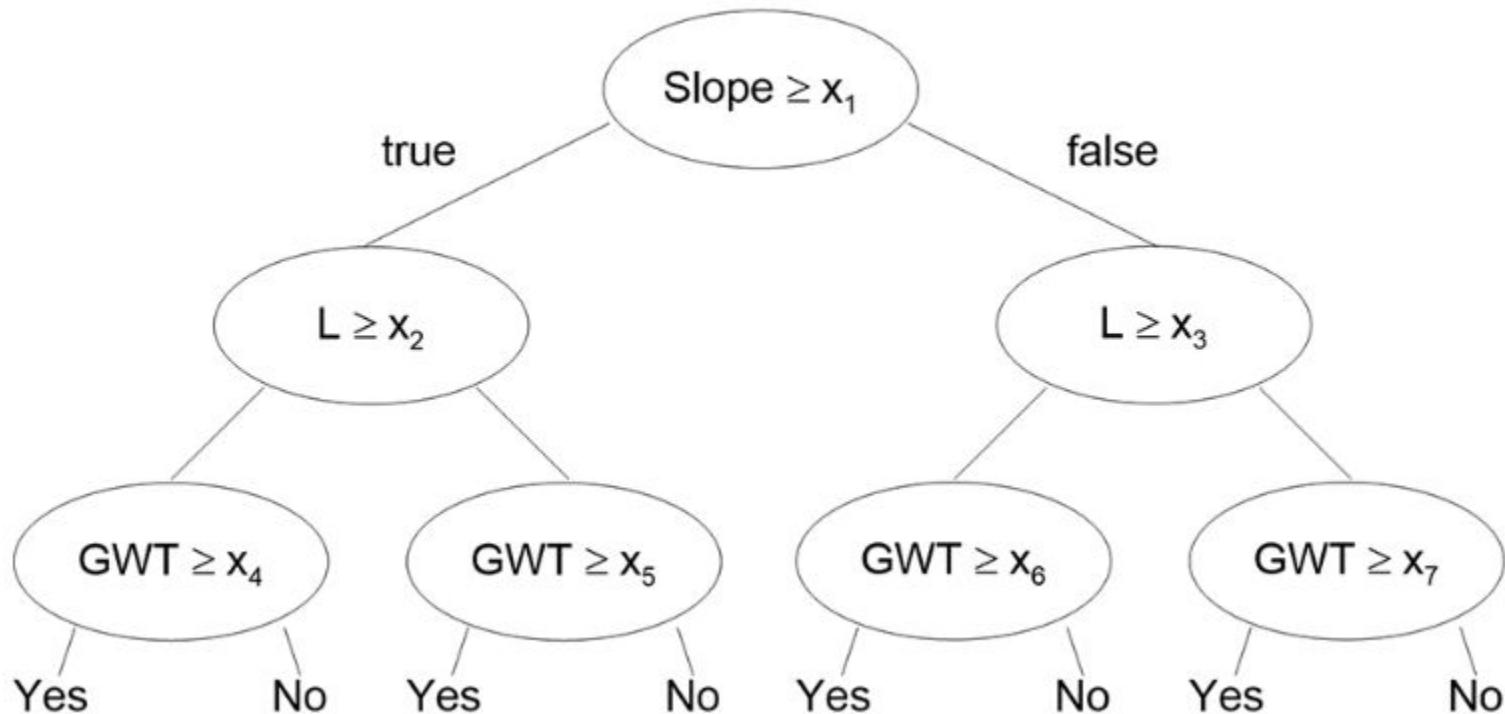


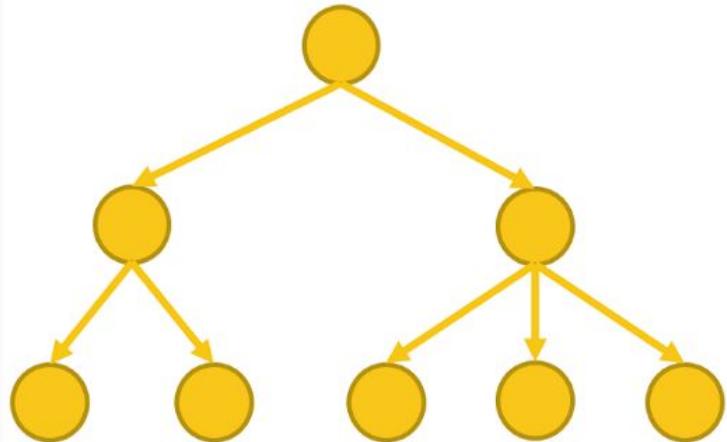
Figure 4. Spatial distribution of geometric and event-specific input features considered in ML models:
(a) ground elevation, (b) ground slope, (c) GWT depth, and (d) PGA.

Classification - Decision Tree

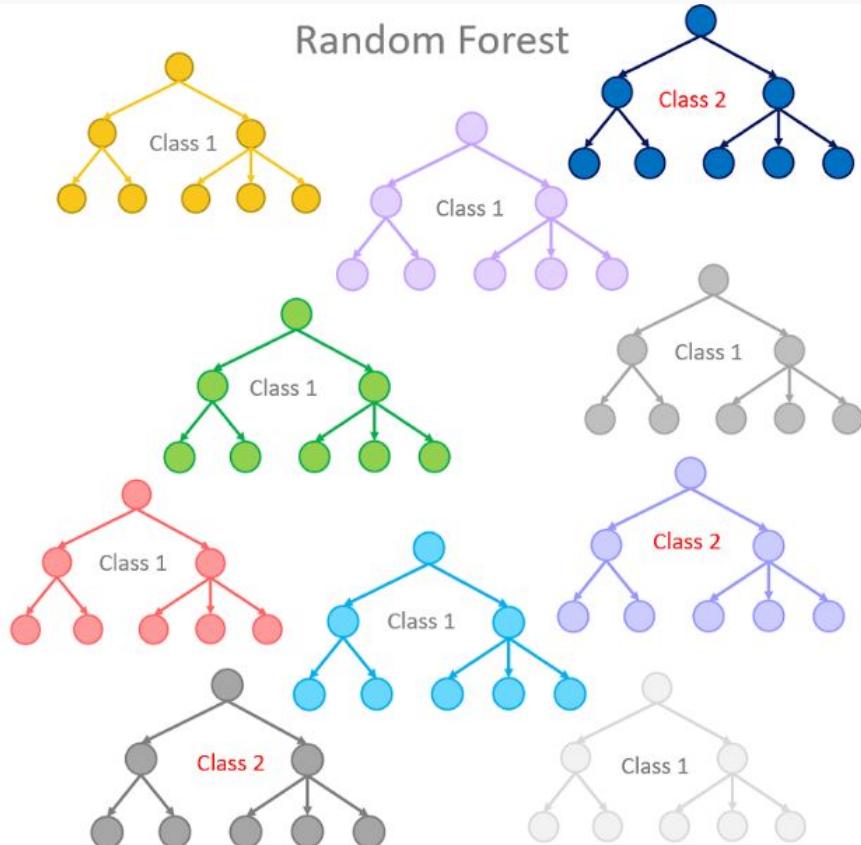


Random Forest

Single Decision Tree



Random Forest



Random Forest model

Table 3. Summary of features used in each RF model analyzed

		Feature					
		L (m)	GWT (m)	Slope (%)	PGA (g)	Elevation (m)	CPT data
No CPT data	Model 0	✓	✓	✓	○	○	○
	Model 1	✓	✓	✓	✓	○	○
	Model 2	✓	✓	✓	○	✓	○
	Model 3	✓	✓	✓	✓	✓	○
CPT data	Model 4	✓	✓	✓	✓	○	✓
	Model 5	✓	✓	✓	✓	✓	✓

GWT: ground water table; PGA: peak ground acceleration; CPT: cone penetration tests.

Durante and Rathje, 2021

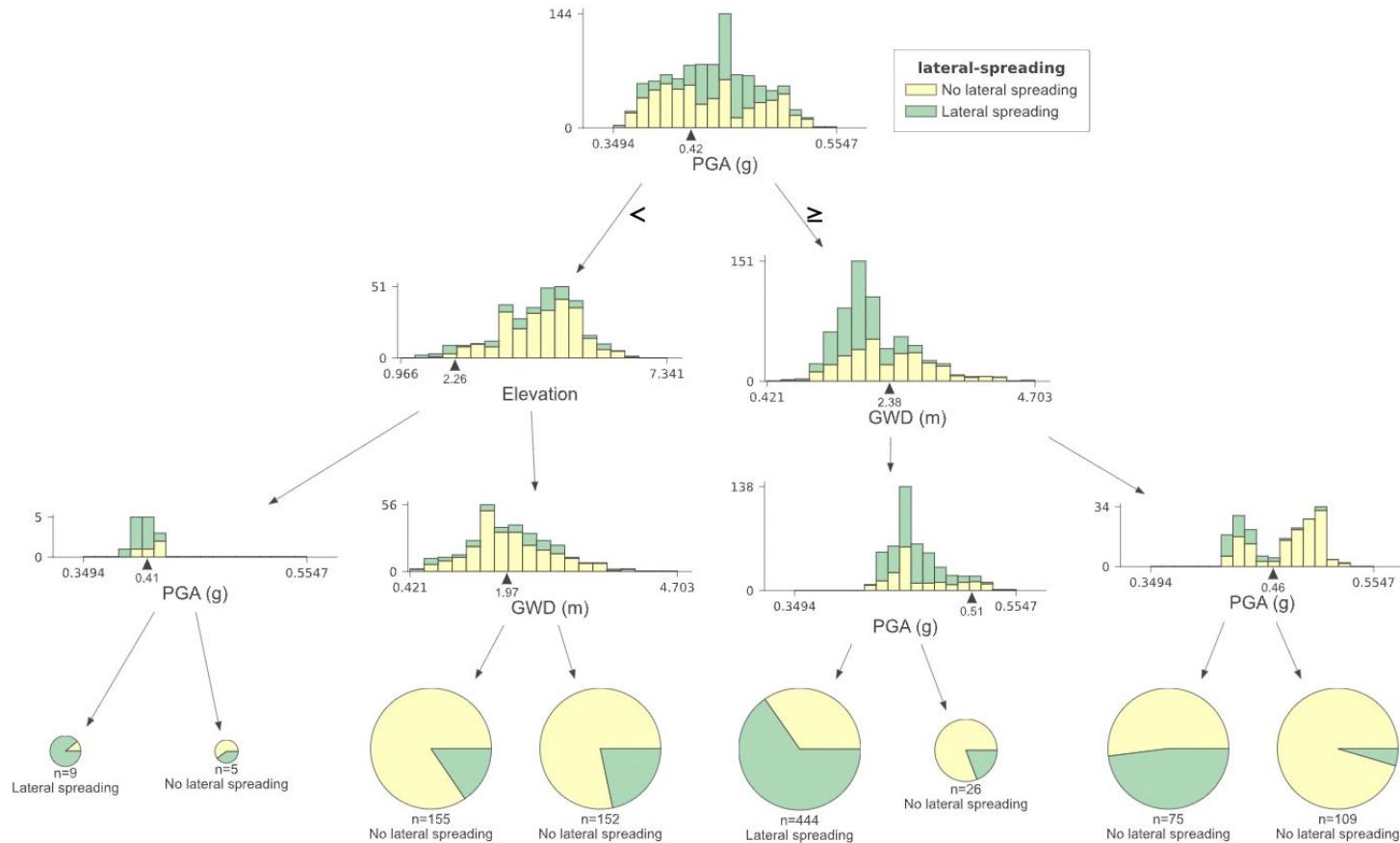
Random Forest - Performance

Table 4. Evaluation metrics for RF models for Yes/No and displacement classification problems

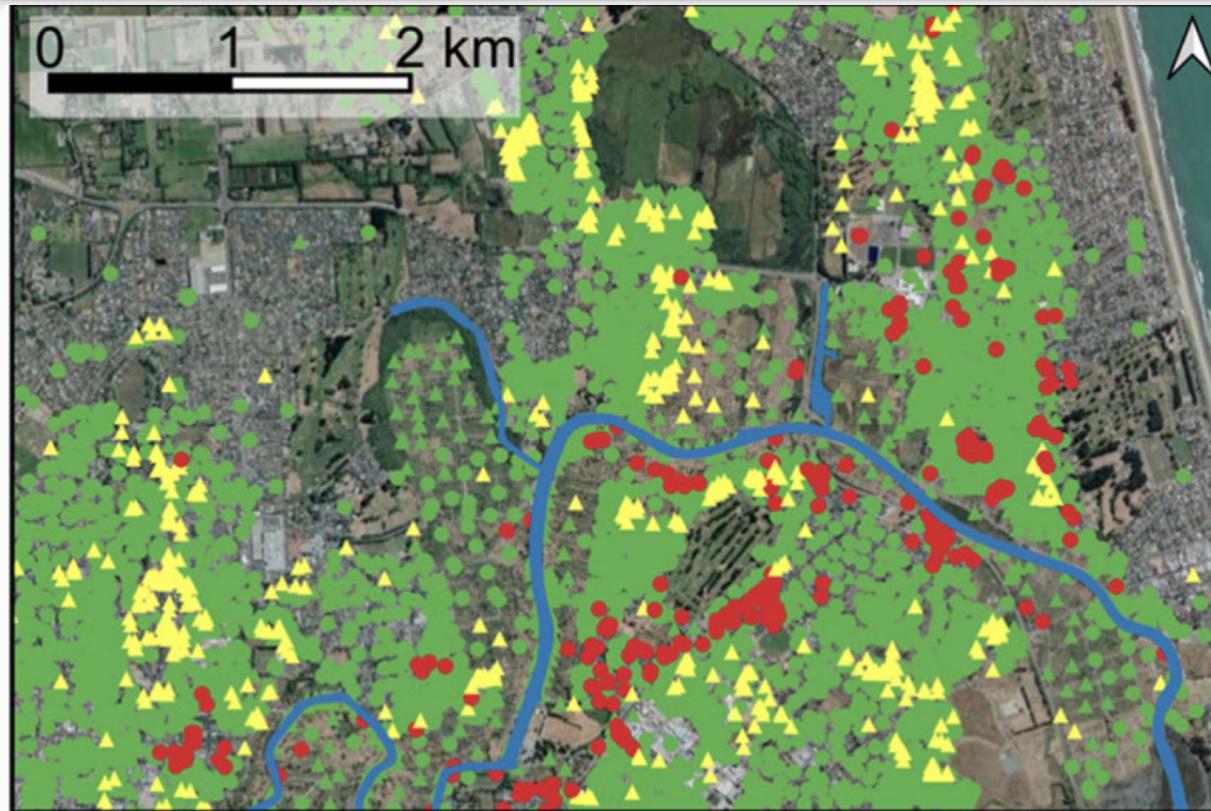
		No CPT data				CPT data	
		Model 0	Model 1	Model 2	Model 3	Model 4	Model 5
Y/N	Accuracy (Overall)	0.76	0.85	0.82	0.88	0.85	0.87
	Recall—Yes	0.58	0.75	0.74	0.82	0.76	0.78
	Recall—No	0.90	0.92	0.88	0.93	0.92	0.93
	Precision—Yes	0.80	0.88	0.82	0.89	0.87	0.89
	Precision—No	0.75	0.84	0.83	0.87	0.84	0.85
	ROC AUC	0.76	0.88	0.84	0.90	0.86	0.88
DISPL	Accuracy (Overall)	0.78	0.88	0.86	0.89	0.88	0.89
	Recall—Class 0	0.88	0.91	0.93	0.92	0.91	0.91
	Recall—Class 1	0.67	0.87	0.79	0.89	0.88	0.90
	Recall—Class 2	0.27	0.42	0.33	0.42	0.53	0.49
	Precision—Class 0	0.79	0.90	0.86	0.92	0.90	0.92
	Precision—Class 1	0.74	0.84	0.84	0.85	0.85	0.84
	Precision—Class 2	0.97	0.98	0.97	0.94	0.95	0.93
	ROC AUC	0.82	0.89	0.87	0.90	0.86	0.88

CPT: cone penetration tests; ROC: receiver operating characteristic; AUC: area under the ROC curve; Y/N: Yes/No Classification problem; DISPL: Class Displacement Classification problem.

Visualizing the first tree in RF



Random forest prediction of lateral spreading



Durante and Rathje, 2021

▲ True Positive (TP) ● True Negative (TN) ● False Positive (FP) ▲ False Negative (FN)

SHAP Value: Contribution of each variable



$$A: v(\{A\}) - v(\{\}) = 10 - 0 = 10$$

$$B: v(\{A, B\}) - v(\{A\}) = 60 - 10 = 50$$

$$C: v(\{A, B, C\}) - v(\{A, B\}) = 100 - 60 = 40$$

$$v(\{\}) = 0$$

$$v(\{A\}) = 10$$

$$v(\{B\}) = 20$$

$$v(\{C\}) = 30$$

$$v(\{A, B\}) = 60$$

$$v(\{B, C\}) = 70$$

$$v(\{A, C\}) = 90$$

$$v(\{A, B, C\}) = 100$$

$$\{\} \rightarrow \{A\} \rightarrow \{A, B\} \rightarrow \{A, B, C\} \parallel A = 10, B = 50, C = 40$$

$$\{\} \rightarrow \{A\} \rightarrow \{A, C\} \rightarrow \{A, B, C\} \parallel A = 10, B = 10, C = 80$$

$$\{\} \rightarrow \{B\} \rightarrow \{A, B\} \rightarrow \{A, B, C\} \parallel A = 40, B = 20, C = 40$$

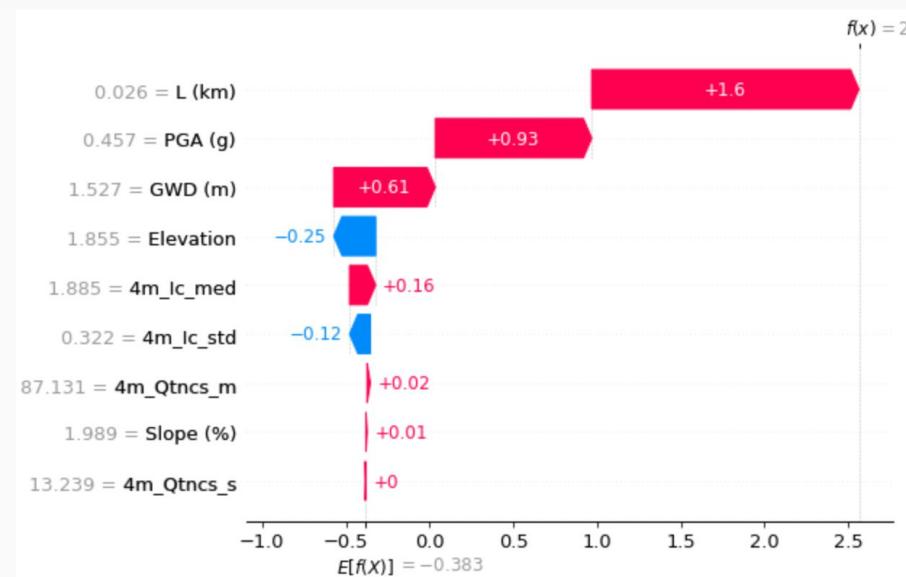
$$\{\} \rightarrow \{B\} \rightarrow \{B, C\} \rightarrow \{A, B, C\} \parallel A = 30, B = 20, C = 50$$

$$\{\} \rightarrow \{C\} \rightarrow \{B, C\} \rightarrow \{A, B, C\} \parallel A = 30, B = 40, C = 30$$

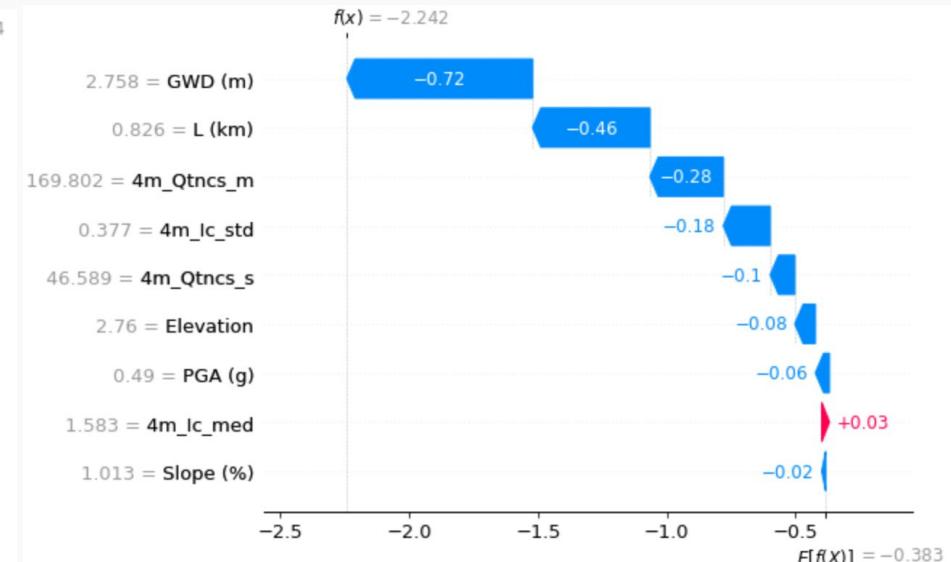
$$\{\} \rightarrow \{C\} \rightarrow \{A, C\} \rightarrow \{A, B, C\} \parallel A = 60, B = 10, C = 30$$

$$A_{avg} = 30, B_{avg} = 25, C_{avg} = 45$$

Random Forest post-hoc explanation

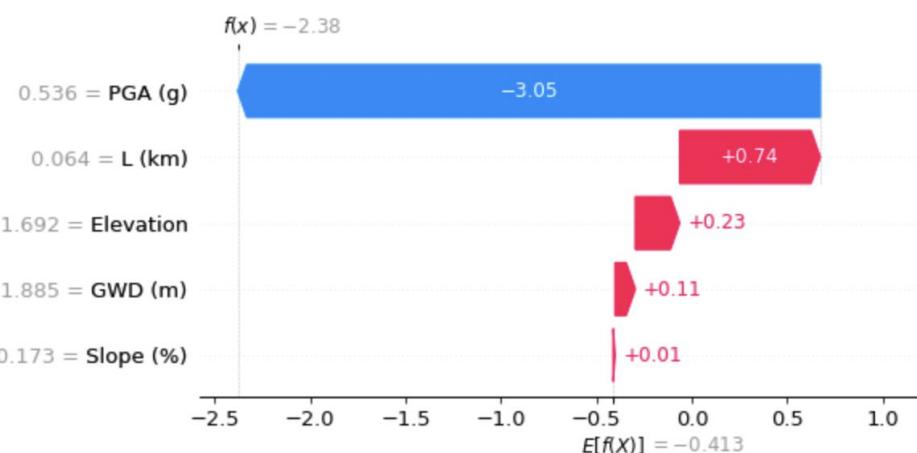


Lateral spreading - Prob (Lat spread) = 90%

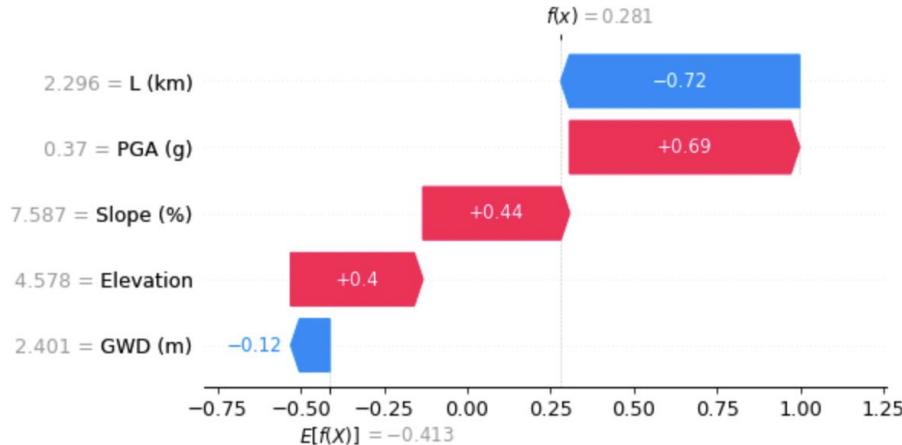


No lateral spreading - Prob (Lat spread) = 7%

Incorrect learning

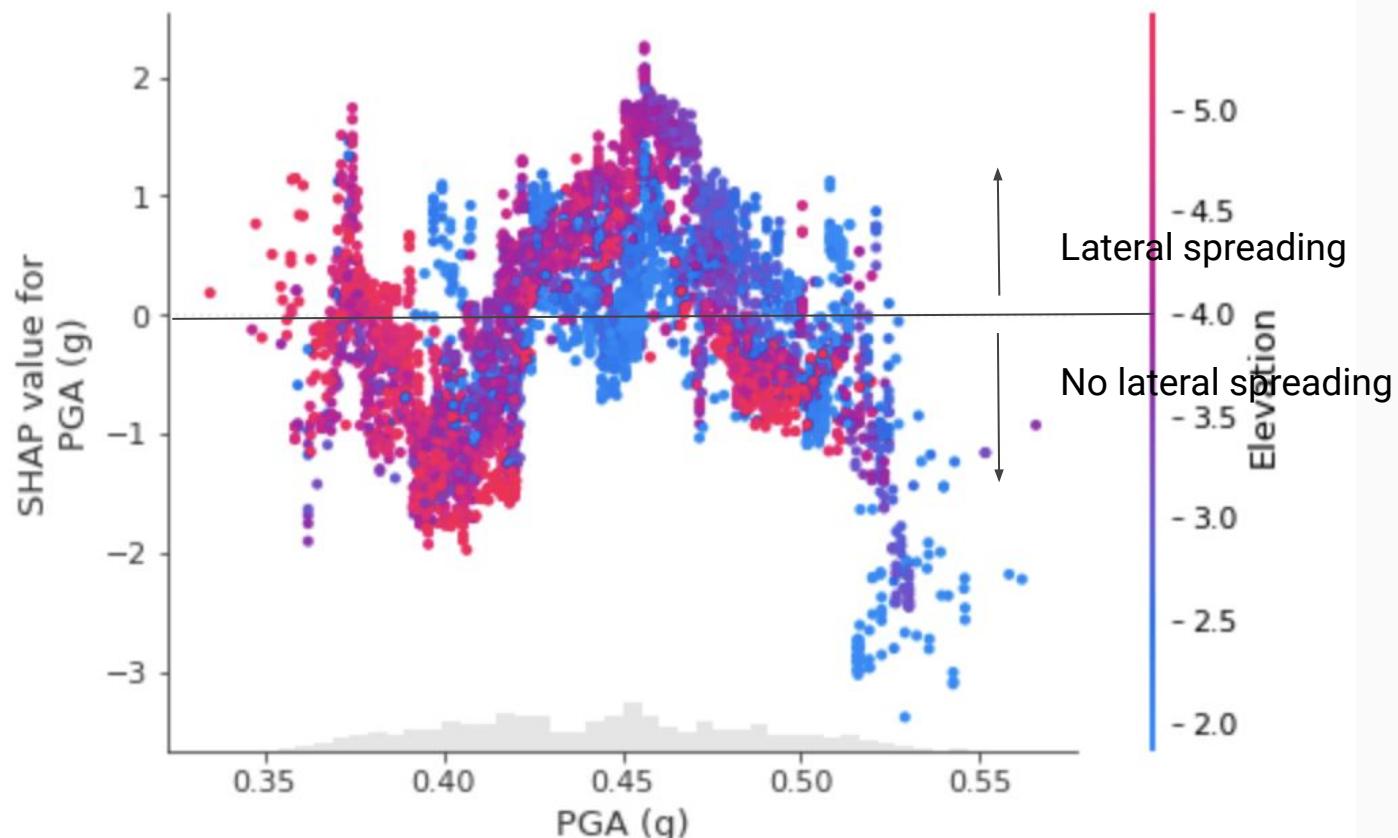


Incorrectly predicting no lateral spreading
Prob (Lat spread) = 8%

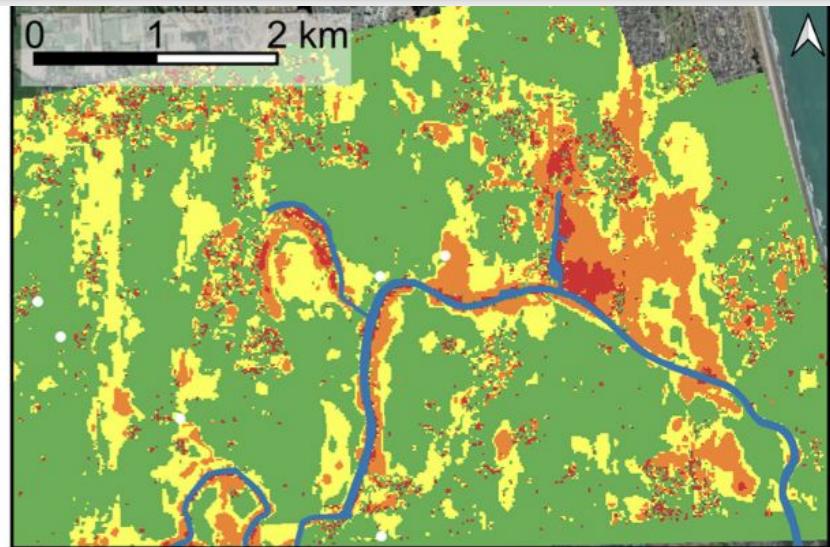
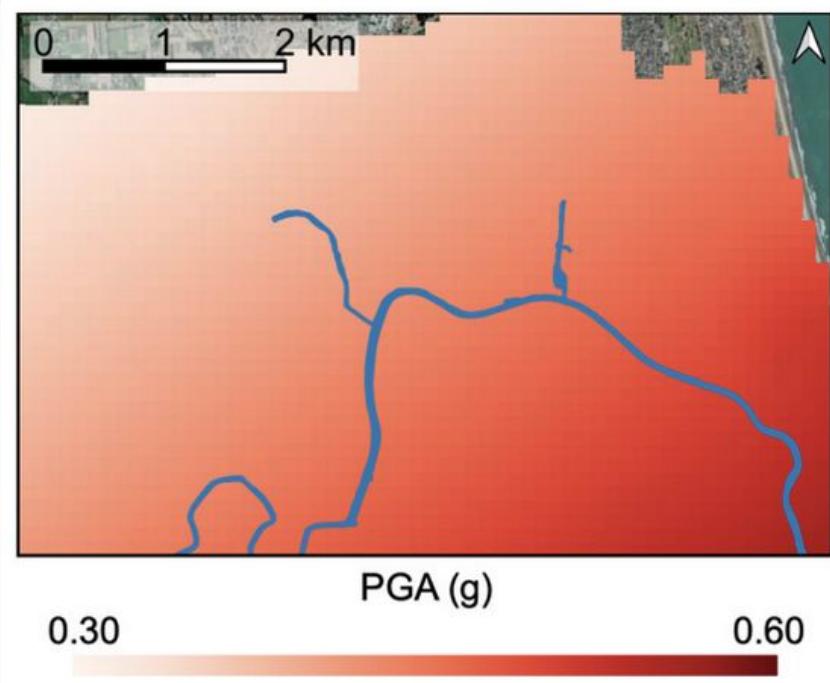


Incorrectly predicting lateral spreading
Prob (Lat spread) = 53%

Why PGA has a bad influence?



Bad learning of PGA relation



Other Examples

AI/ML

- Building Classification
- Graph Network Simulators

Building damage classifier - an explanation



Undamaged



Partially-damaged



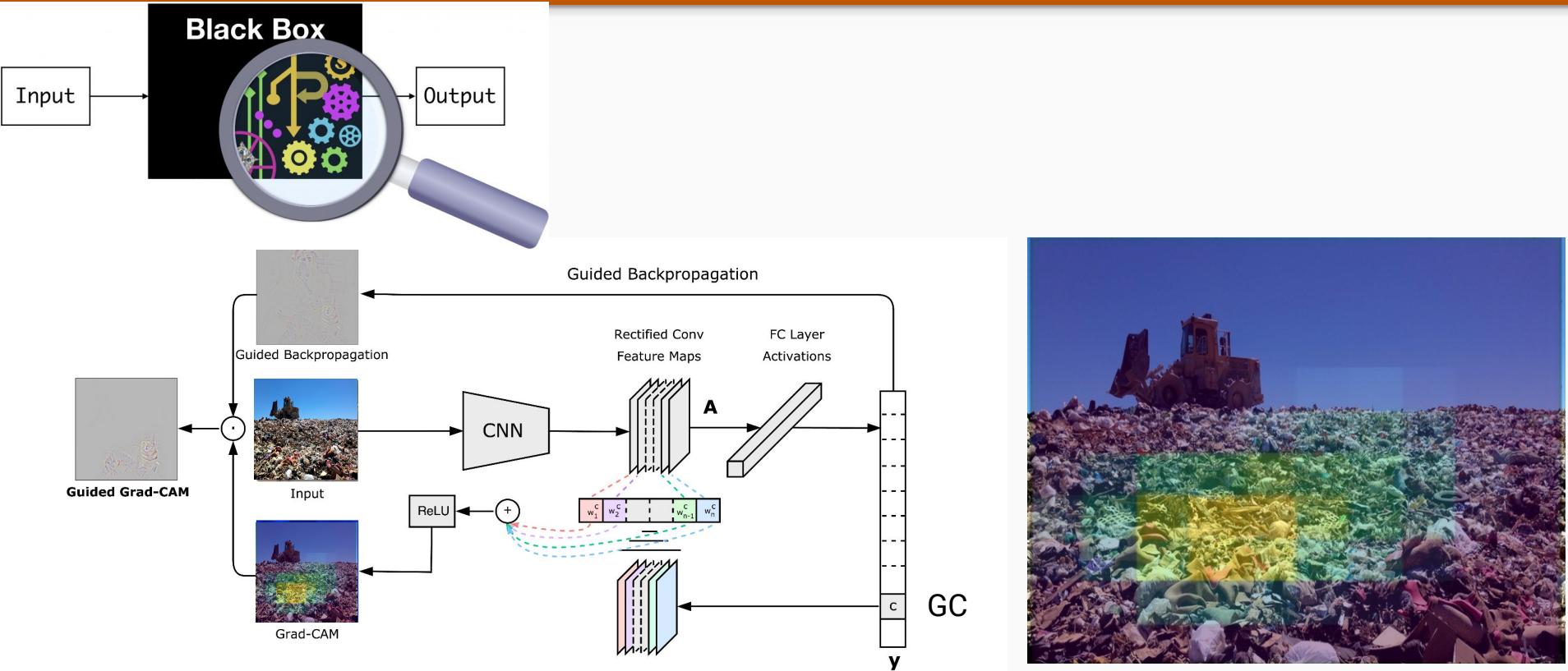
Completely-destroyed

Explaining a building image classifier

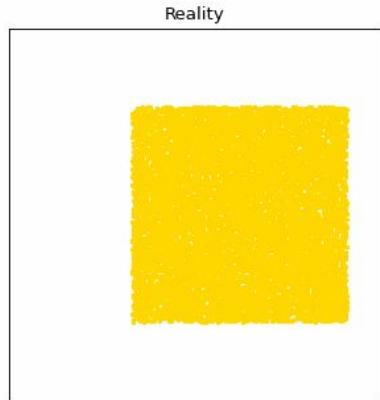
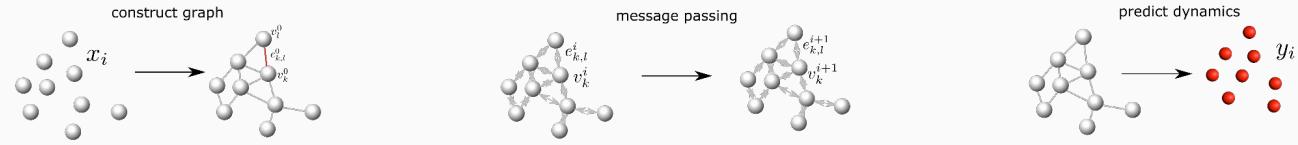
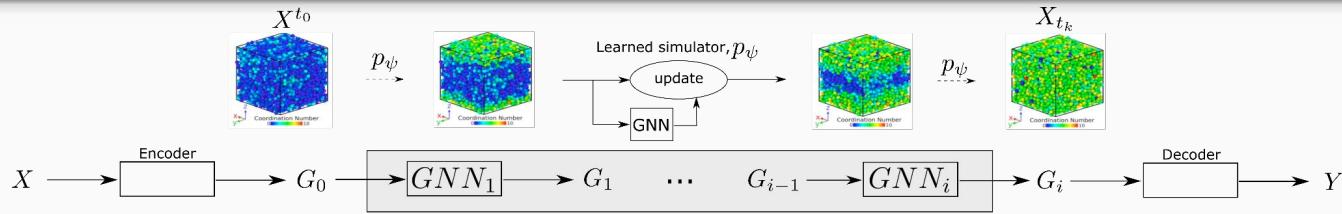


Predicted class: General Collapse
Transfer learning prediction: Ants

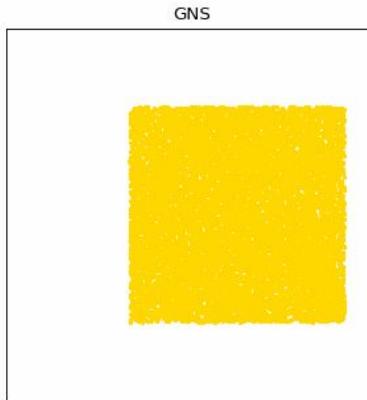
GradCAM Explanation



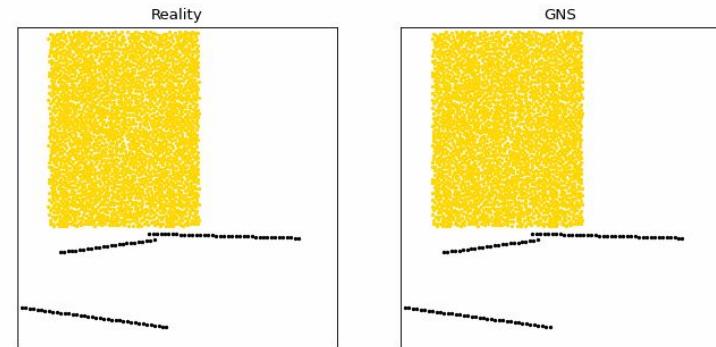
ML prediction of granular flows



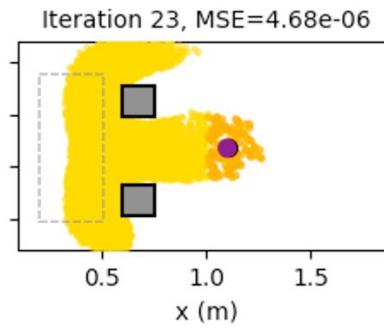
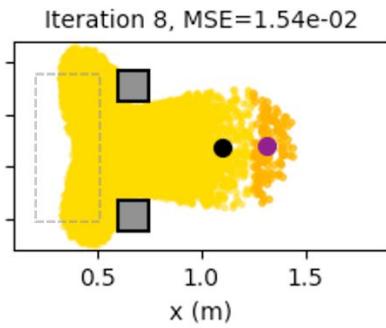
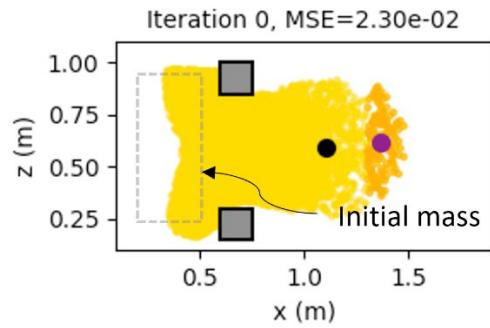
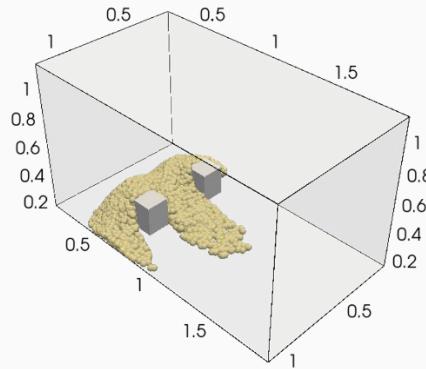
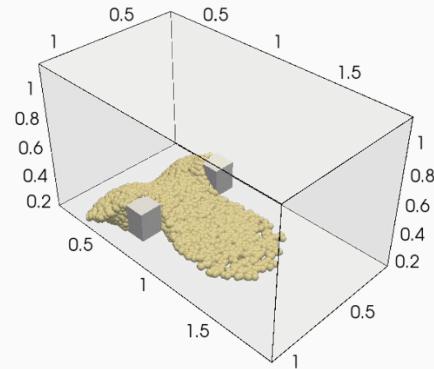
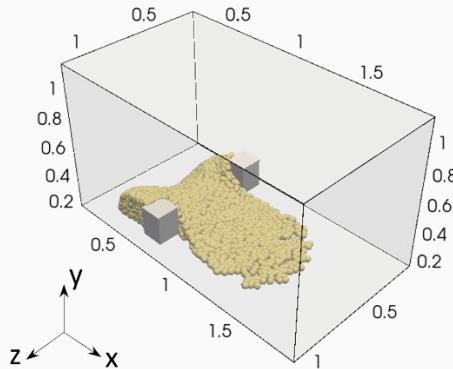
2.5 hours



20 s



GNS based optimization



- GNS prediction
- Flow toe
- Target
- Predicted centroid
- Barrier

NSF Chishiki AI Fellowships

- Fully funded fellowships for working in AI in Civil Engineering
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Hook 'em Horns!

