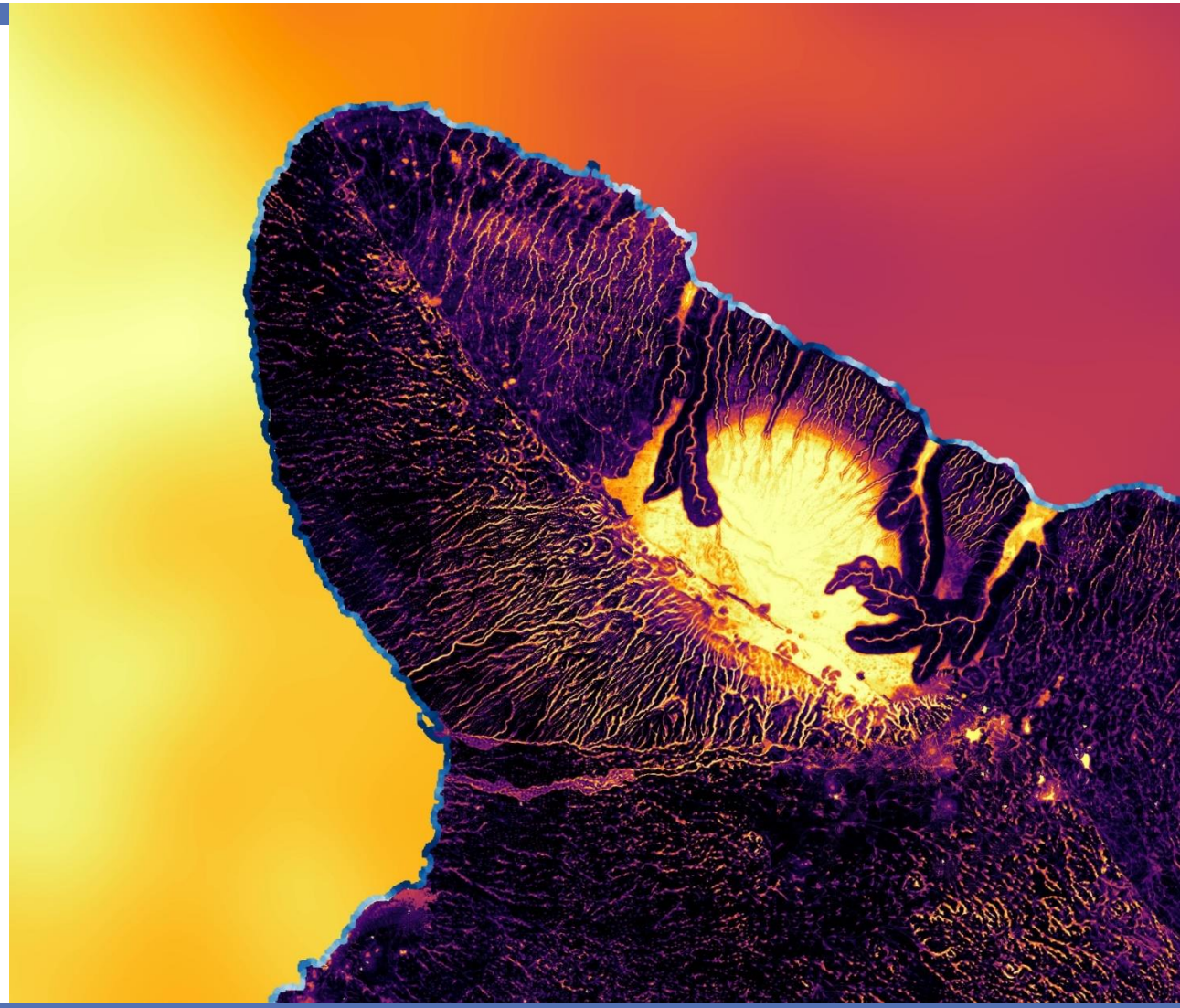
National Aeronautics and Space Administration

Hawai'i Island
Climate

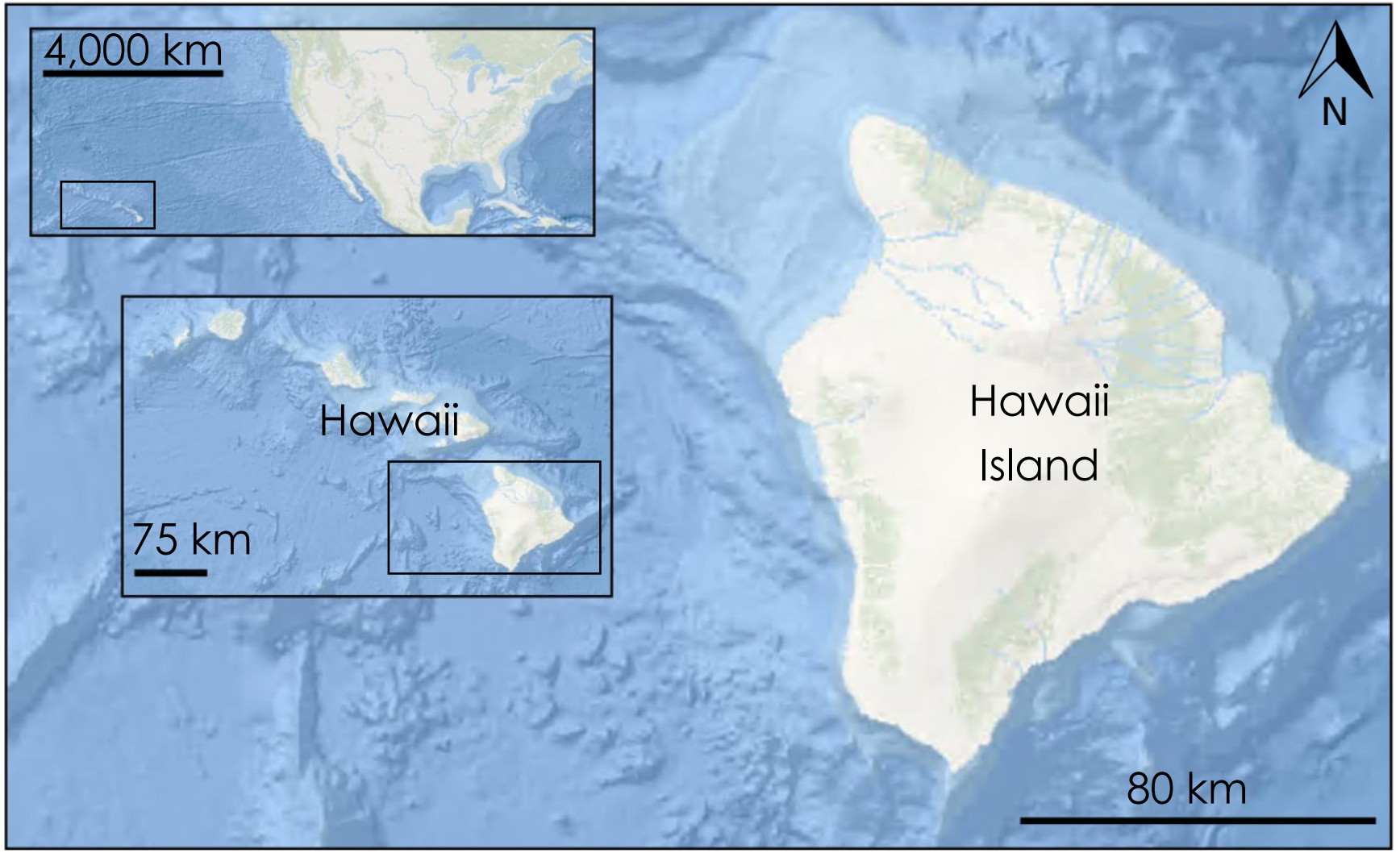
Utilizing Earth Observations to Model Probable Wetland Extents, Model Sea-Level Rise Inundation Risk, and Assess Impacts on Historic Hawaiian Lands

Lisa Tanh
Matilda Anokye
Ian Lee
Connor Racette



Study Area

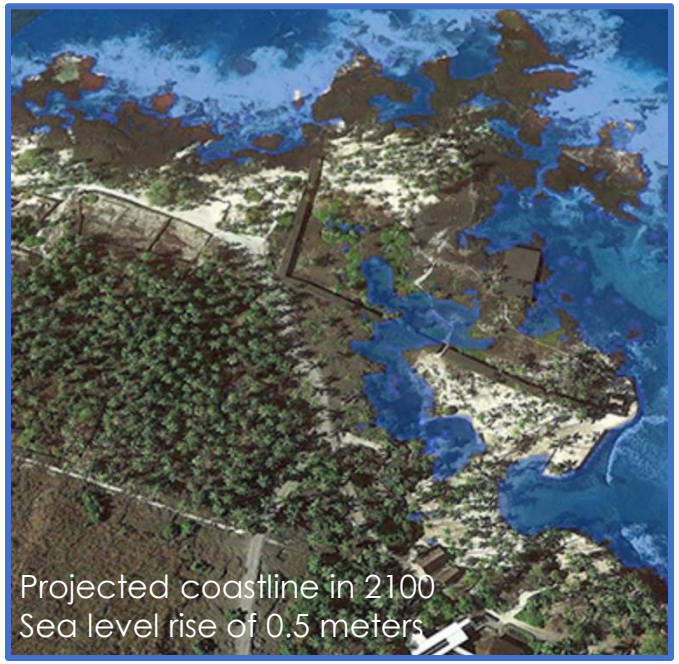
- The Hawaiian Island chain is the most geographically isolated in the world
- Largest Island in the United States
- Home to ~200,000 citizens
- Area of the Island of Hawaii is 4,028 mi^2
- Comprises 266 miles of coastline
- Has a diverse range of landscape features and climate zones



Basemap: Esri, GEBCO, DeLorme, NaturalVue

Community Concerns

Shoreline Erosion & Sea Level Rise



Ecosystems

Historical Sites

Community Property

Image Credits: NPS

Project Partners

- **County of Hawaii**, *Planning Department*
- **State of Hawaii,** *Department of Land and Natural Resources*
- **Arizona State University**, *Center for Global Discovery and Conservation Science*

Image Credits: NPS

Objectives

Create a wetlands extent map

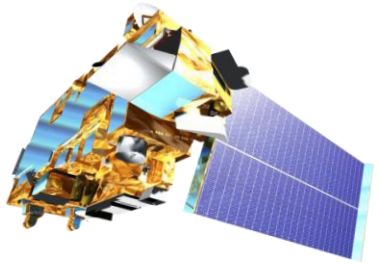
Model short-term flood inundation

Provide insight on sea level rise risk

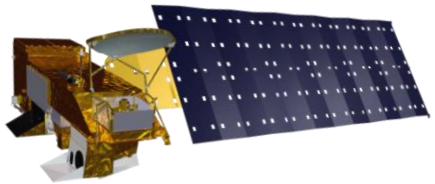
Satellites/Sensors Used

Sea Surface Temperature Anomaly

Terra MODIS



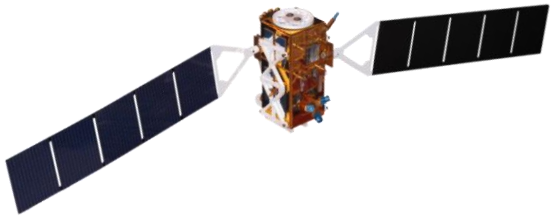
Aqua MODIS, AMSR-E



CORIOLIS WINDSAT, **NOAA-19** AVHRR-3, **GCOM-W1** AMSR2

Historic Flood Maps (Tripathy and Malladi, 2021)

Sentinel-1 C-SAR



2013 — 2022

Sea Surface Height Anomaly

Jason-2 Advanced Microwave Radiometer, POSEIDON-3

TOPEX POSEIDON TMR, SSALT

JASON-1 Microwave Radiometer, POSEIDON-2

JASON-3 POSEIDON-3B, AMR

High Resolution Imagery

PlanetScope

Image Credits: NASA, ESA

Ancillary Datasets Used

Wetland Extent Model

Hydrologic Inputs
- Topographic Wetness Index (TWI)
- Depth to Water (DTW)

Imagery Inputs
- Normalized Difference Vegetation Index (NDVI)

Topographic Inputs
(each at scale of 50m, 150m, and 300m)
- Gradient
- Plan Curvature
- Profile Curvature
- Local Relief (DEV)

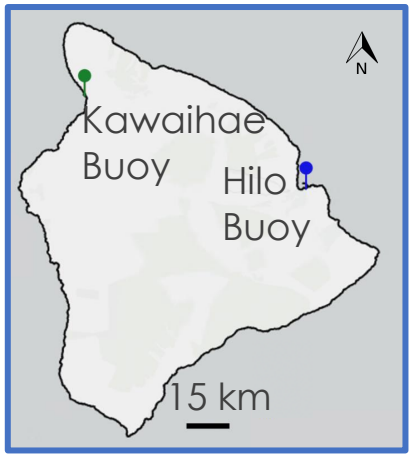
Hawaii Soil Atlas Inputs
- Water Permeability
- PH
- Organic Matter Content

Hawaii Climate Atlas Inputs
- Monthly Mean Precipitation (June & December 2021)
- Monthly Mean Temperature (June & December 2021)

Training Data Inputs
- Known wetland locations (NWI, County Records)
- Known upland locations

(USGS, Planet, Hawaii Climate Atlas, Hawaii Soil Atlas)

Comparison of Tidal Gauges and Sea Surface Height Anomaly



Sea Surface Height Anomaly

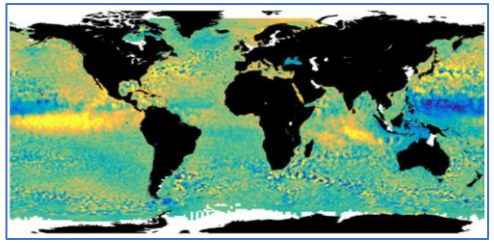
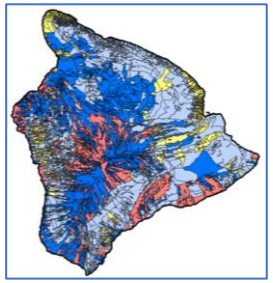


Image Credits: NASA JPL

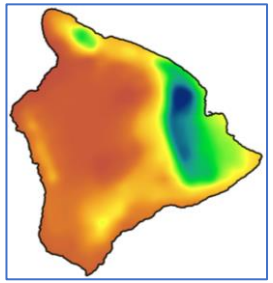
(NOAA, NASA)

Sea Level Rise Model

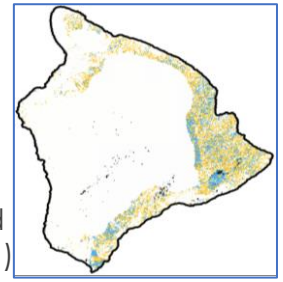
Water Permeability



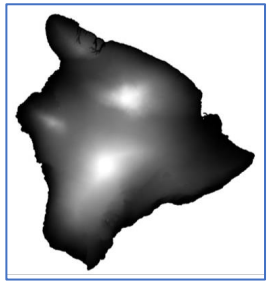
Annual Precipitation



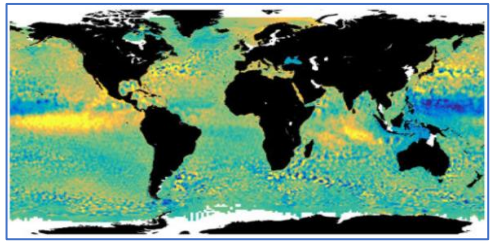
Flood Risk Index
(Tripathy and Malladi, 2021)



DEM



Sea Surface Height Anomaly



Sea Surface Temp Anomaly

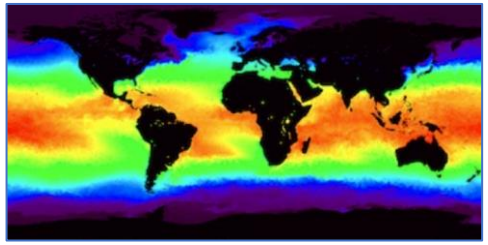


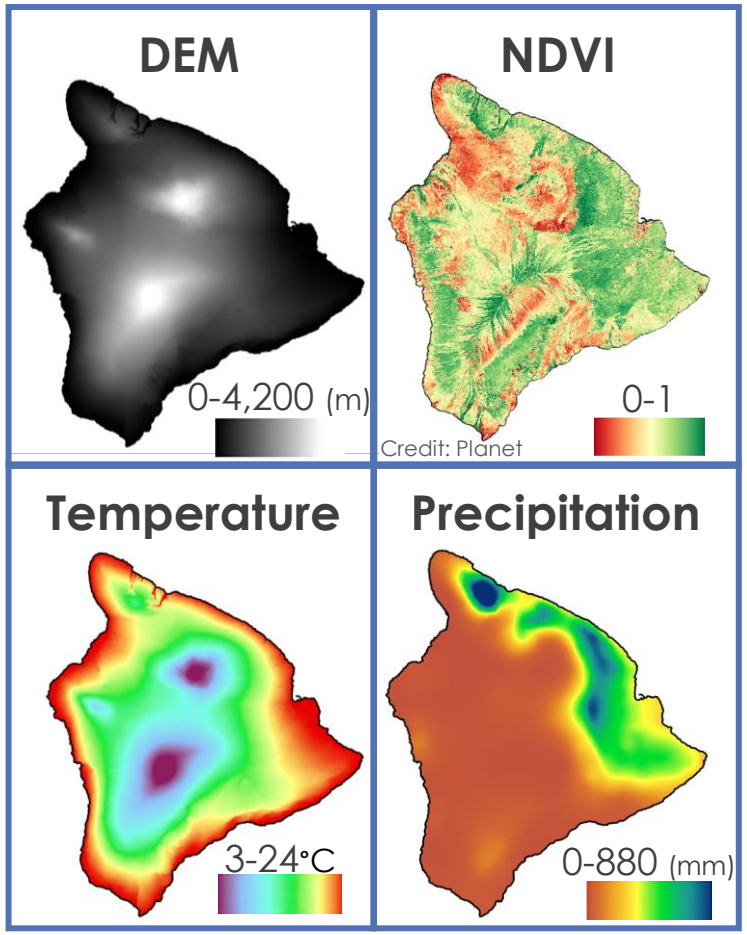
Image Credits: NASA JPL

(Hawaii Soil Atlas, Hawaii Climate Atlas, USGS, NASA)

2013 — 2022

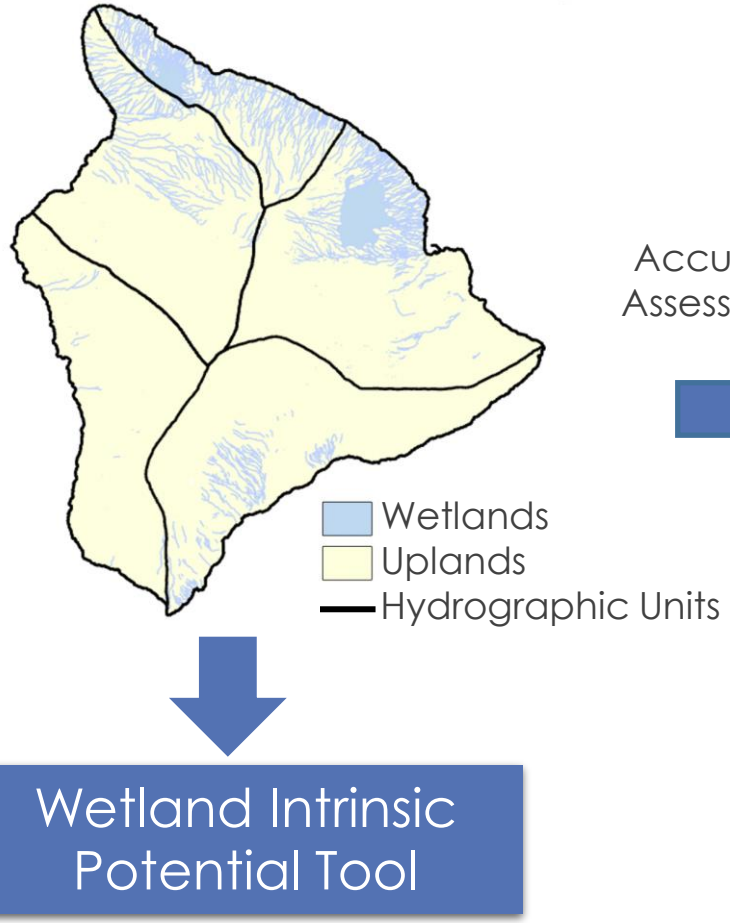
Methods: Wetland Extent Map

Inputs



Train Model

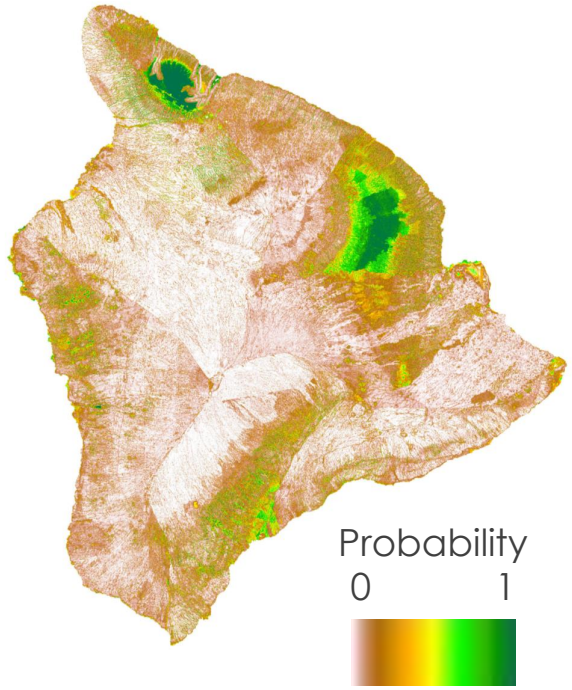
Processing



Wetland Intrinsic Potential Tool

Accuracy Assessment

Outputs



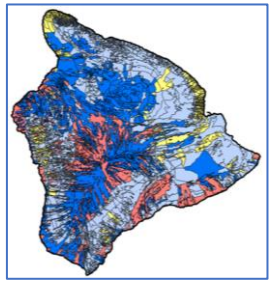
- **Data Acquisition**
- **Build Random Forest and Refine Inputs**
- **Probability Raster of Wetland Extent**

Wetland Intrinsic Potential tool: Miller, D., and Halabisky, M. (2019)

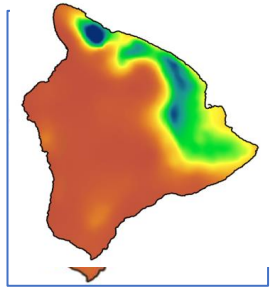
Methods: Sea Level Inundation Model

Inputs

Water Permeability

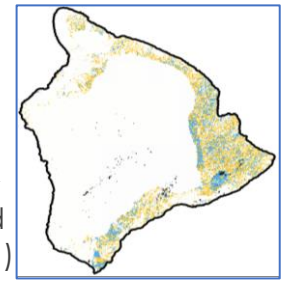


Annual Precipitation

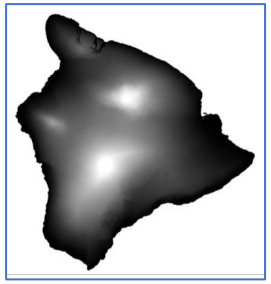


Flood Risk Index

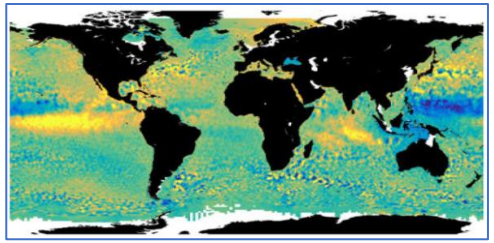
(Tripathy and Malladi, 2021)



DEM



Sea Surface Height Anomaly



Sea Surface Temp Anomaly

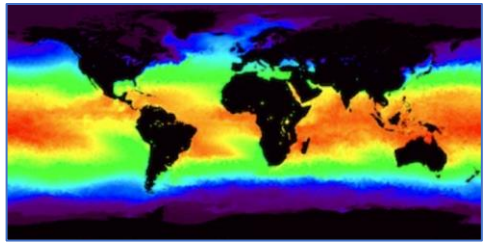
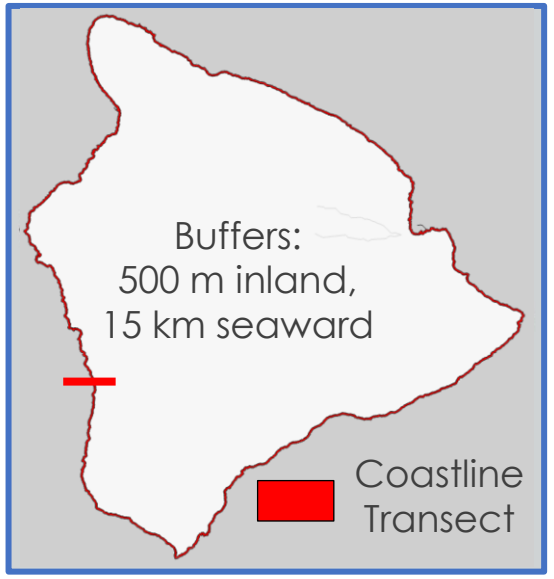


Image Credits: NASA JPL

Train Model

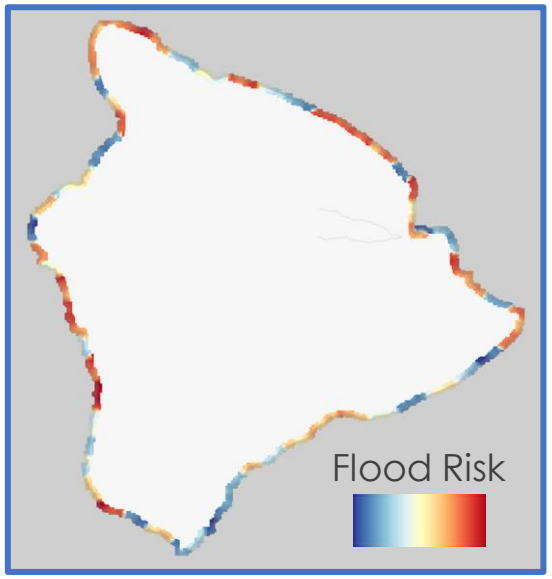
Processing



Random Forest Model

Model tuning

Outputs

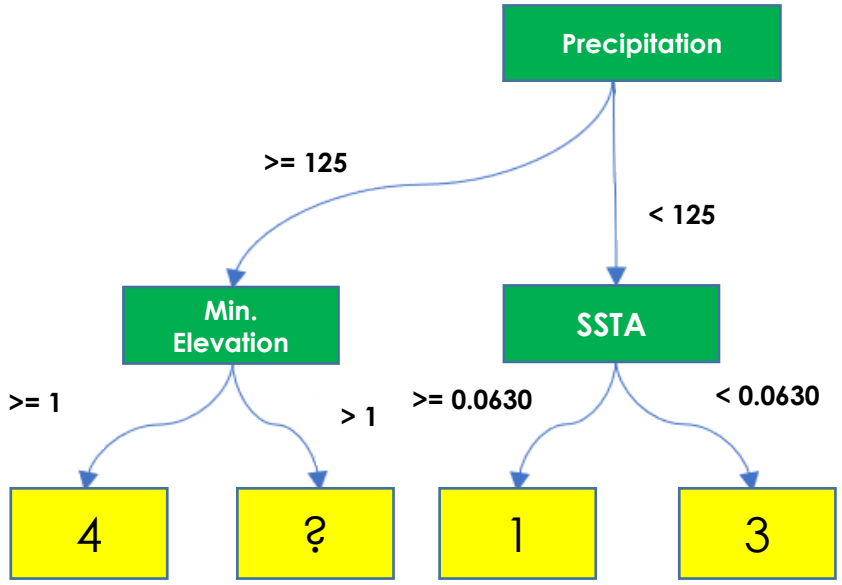


- **Model of shoreline risk projection for the near-term**
- **Ranking features' contribution to flood risk**

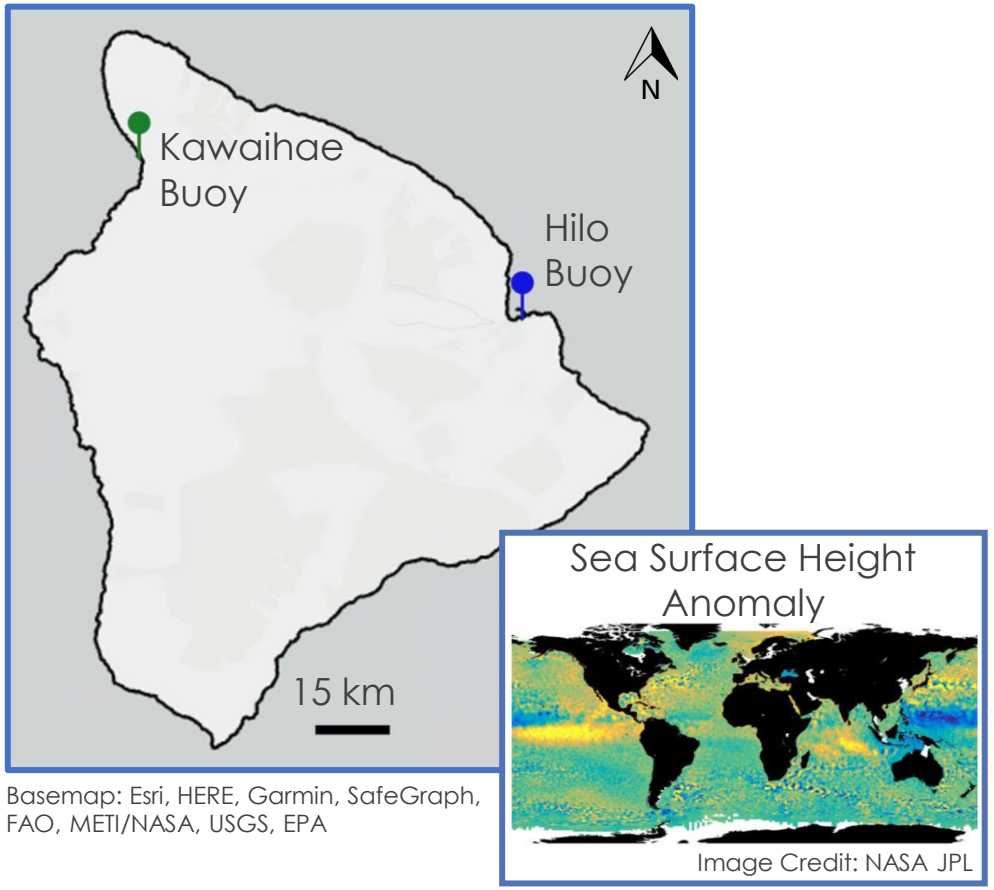
Introduction to Random Forests

Min. Elevation [m]	Absolute Largest Difference in Elevation [m]	Water Permeability	Precipitation [mm]	Sea Surface Height Anomaly [m]	Sea Surface Temperature Anomaly [°C]	Flood Category
0	75	7.8	122	0.0933	0.0603	3
2	100	5.6	124	0.0950	0.0604	3
4	76	7.7	130	0.0932	0.0642	4
4	12	5.0	122	0.0900	0.0633	1

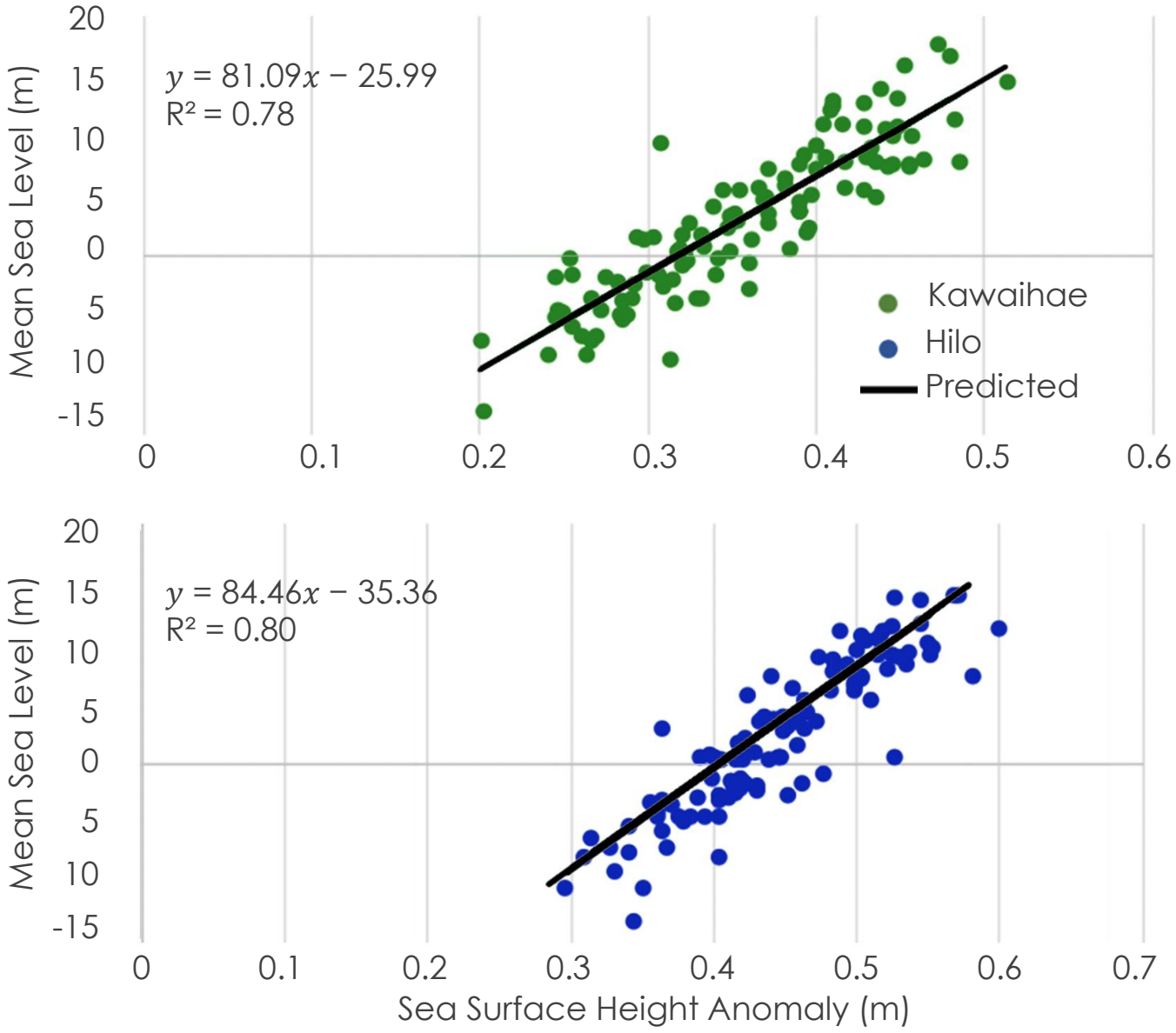
- A "forest" of decision trees that use a subset of the features
- Majority voting system, with each tree independently making a classification based on its own subset of selected features
- Capture nonlinear relationships



Results: Sea Surface Height Anomaly Validation

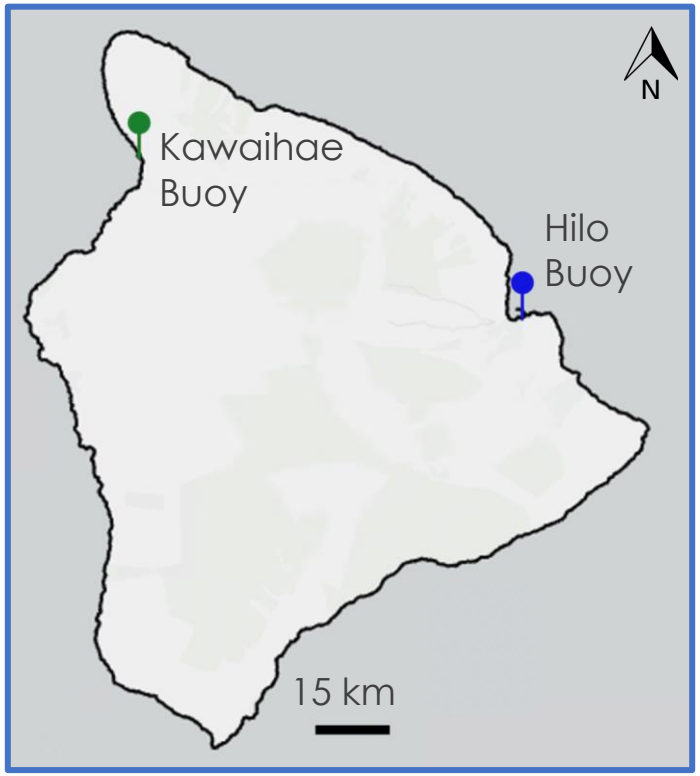


Basemap: Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA



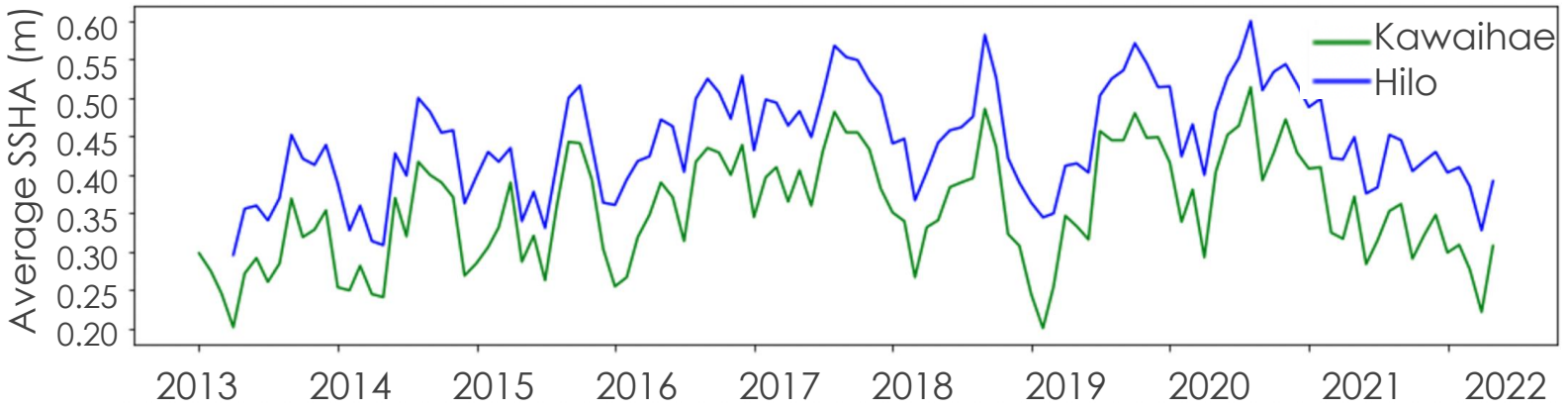
- Linear regression was utilized to predict sea surface height anomaly based on the value of mean sea level
- There is a positive, linear relationship.

Results: Sea Surface Height Anomaly Validation

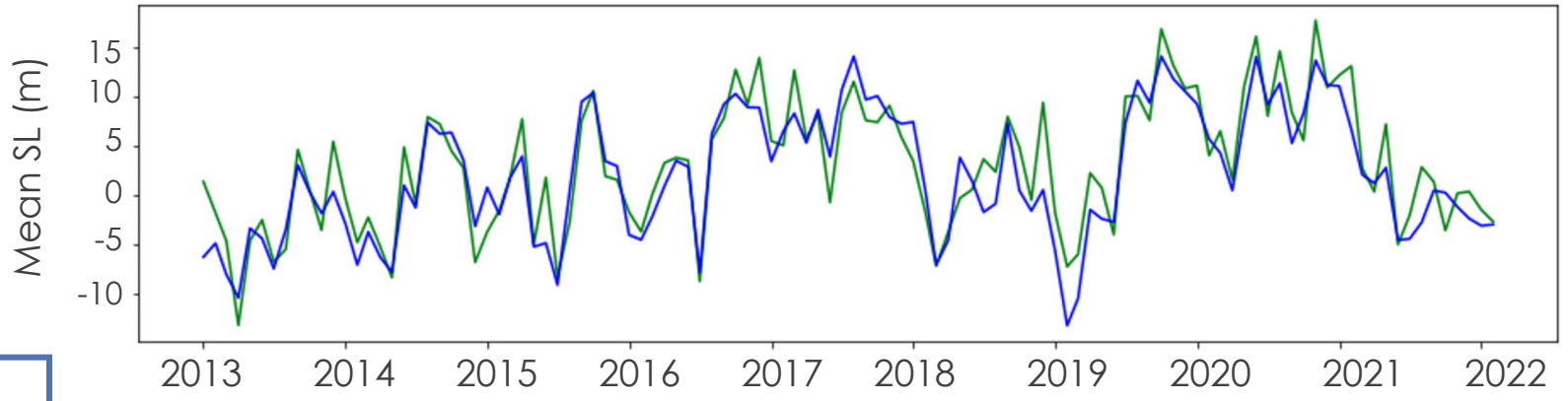


Basemap: Esri, HERE, Garmin, SafeGraph, FAO, METI/NASA, USGS, EPA

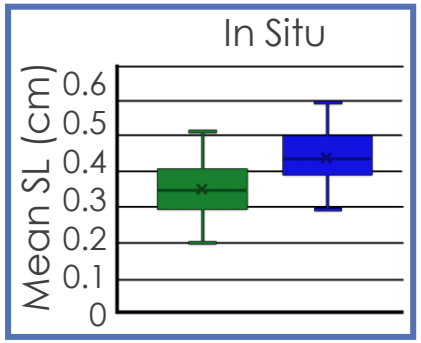
Monthly Sea Surface Height Anomaly (SSHA)

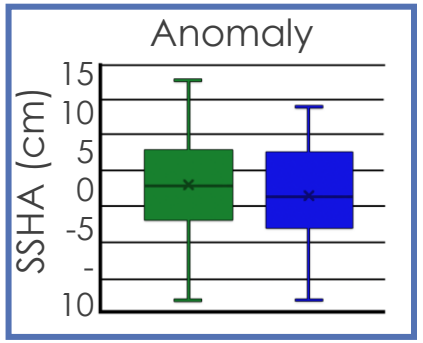


Monthly Mean Sea Level (MSL) Height from Tidal Gauges



Numerical Comparison

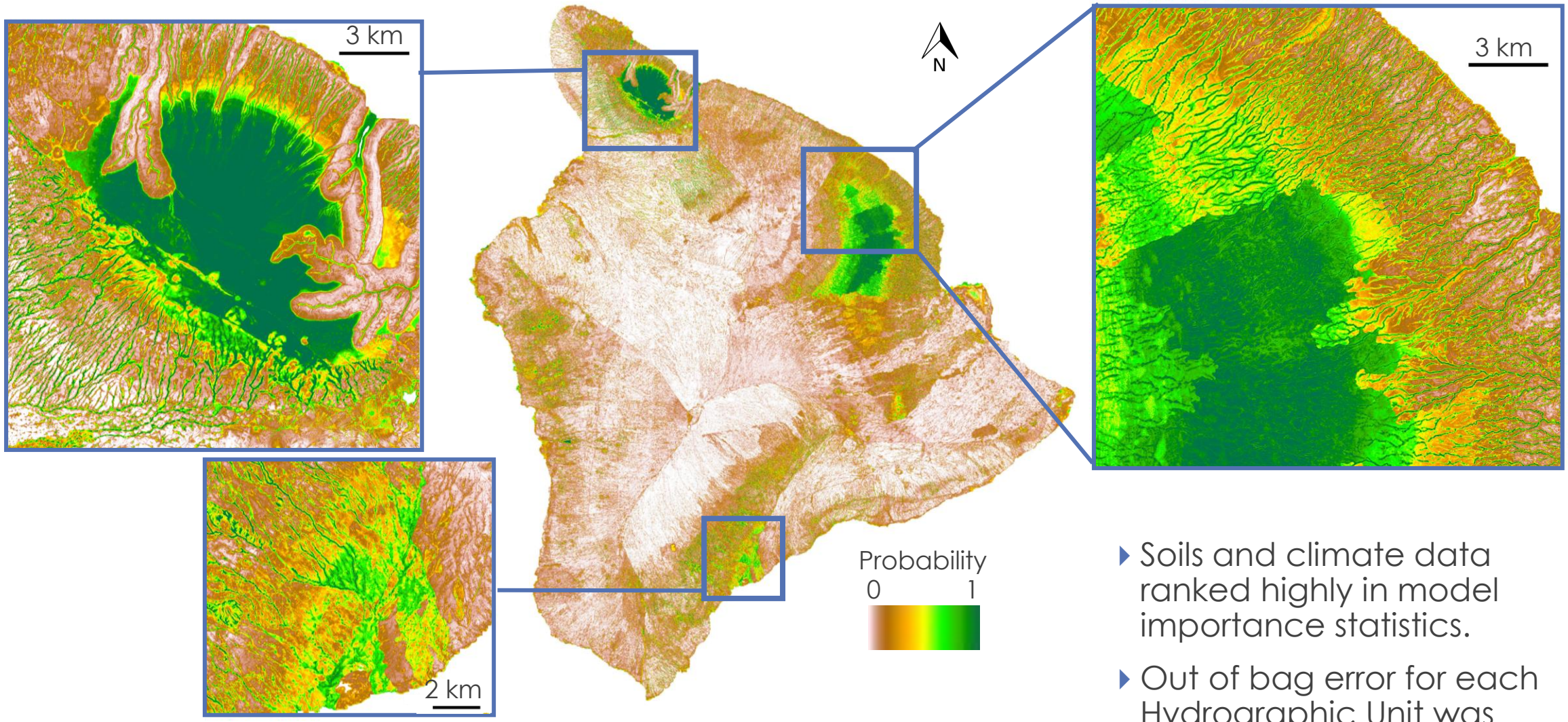




	RMSE	Correlation
Kawaihae	0.30	0.88
Hilo	0.40	0.90

- RMSE: predicted values are close to the observed values
- Correlation: a near perfect, + relationship between SSHA and MSL

Results: Wetland Extent Map

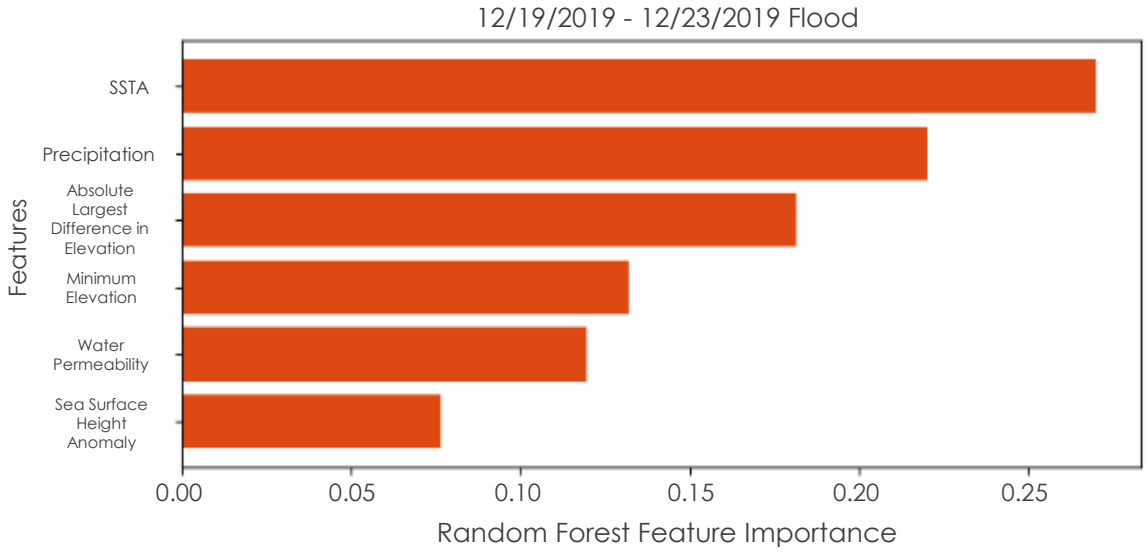


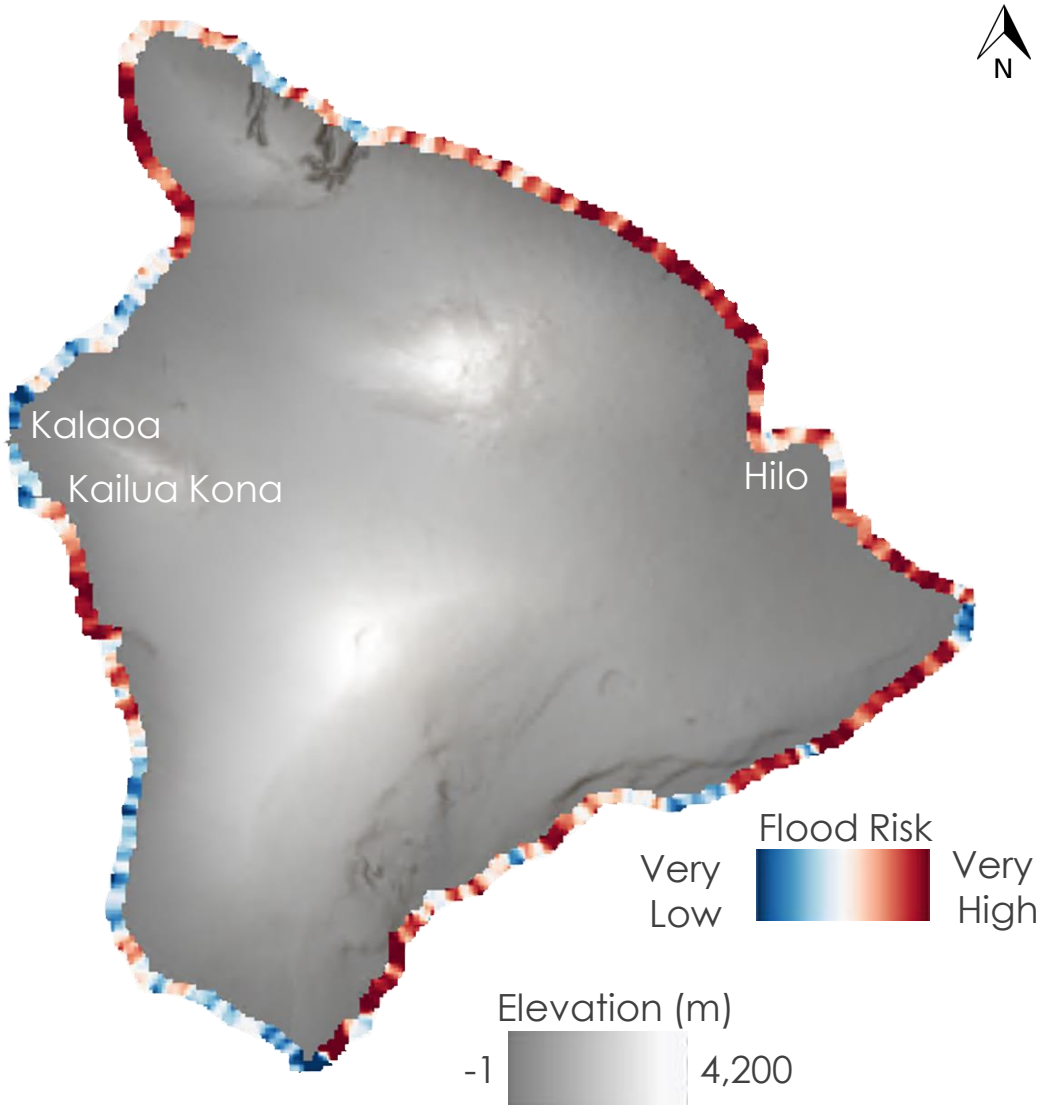
- Soils and climate data ranked highly in model importance statistics.
- Out of bag error for each Hydrographic Unit was under 10%

Wetland Intrinsic Potential tool: Miller, D., and Halabisky, M. (2019)

Results: Sea Level Inundation Model

- Intra-event accuracy: ~90%
- For all 5 events, sea surface temperature anomaly (SSTA) and precipitation had a combined 50% feature importance score
- More data is required for meaningful inter-event and future predictions





Basemap: Esri, NASA, NGA, USGS

ERRORS AND UNCERTAINTIES

Wetland Intrinsic Potential Model

- Due to outdated elevation data (2013) and lack of training data, results varied by Hydrographic Unit.
- Model accuracy dropped for the West side of the Island where climate is drier, and hydrologic data is scarce because of groundwater driven hydrology.
- Current Hydrographic Unit delineations may be problematic.

Sea Level Inundation Model

- Global SSHA is not corrected for areas close to the coast at certain areas.
- SSHA was corrected for tides.
- Global Flood Mapper made no distinction between lava and open water. We mitigated this by using Hawaii Carbon Assessment Landcover Map to find non-vegetated regions and performed pixel-hopping to determine open water connected to the ocean.

Image Credits: NPS

Wetland Intrinsic Potential tool: Miller, D., and Halabisky, M. (2019)
Global Flood Mapper: Tripathy, P. & Malladi, T. (2022)

CONCLUSIONS

Wetland Intrinsic Potential Model

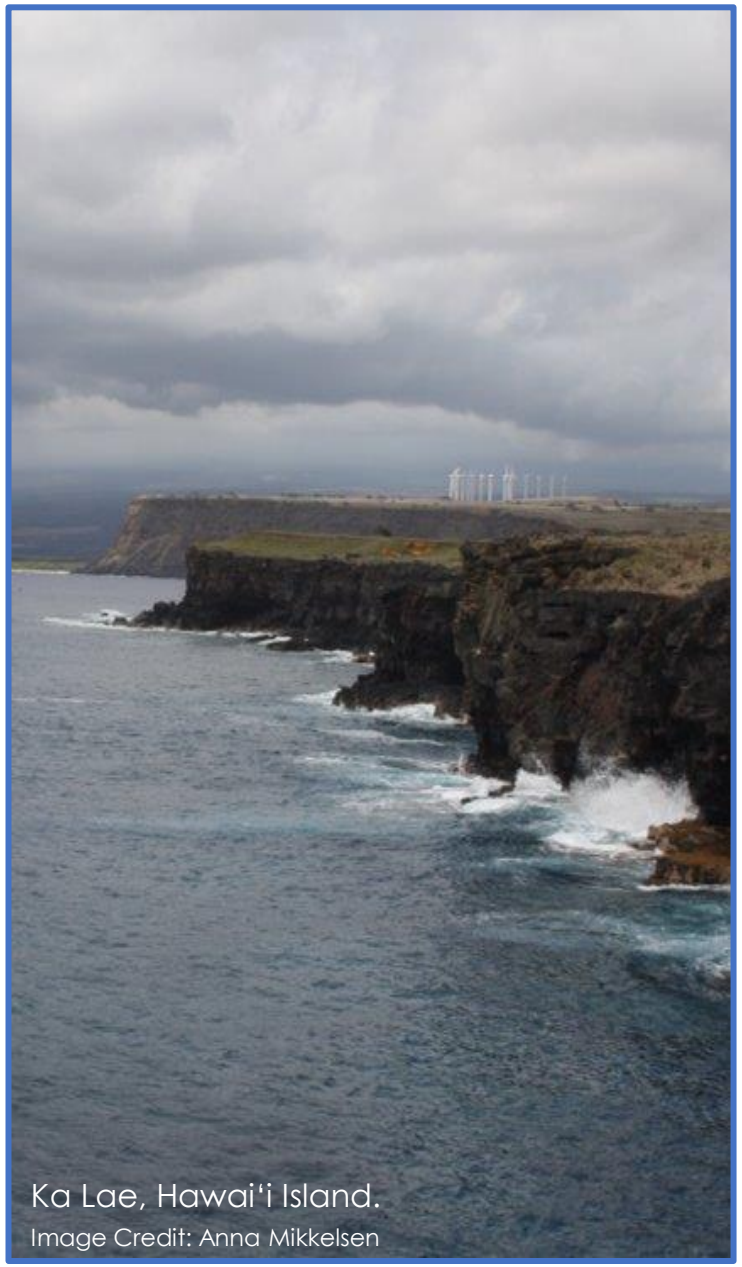
- Hawaii soils atlas and climate atlas data (monthly temperature and precipitation) continually ranked highly in model importance statistics.
- False positives of potential wetland locations were common due to the Island of Hawaii being such a dynamic landscape. Volcanic activity causes frequent changes and having the most recent and highest resolution elevation data would greatly increase model accuracy.

Sea Surface Height Anomaly Validation

- SSHA is a reliable predictor for tide gauge time series due to the high correlation (> 0.7) between SSHA and tide gauge MSL

Sea Level Inundation Model

- Results consistently rank SSTA and precipitation as high importance features
- Random forest excels in interpolation but limited in extrapolation - more data needed
- Feasibility study showing the possibility of using RF and important features for flood prediction
- The validated flood risk index (2019 – 2021) is combined with the wetlands map



Ka Lae, Hawai‘i Island.
Image Credit: Anna Mikkelsen

FUTURE WORK

- The combined interim flood risk index and wetlands can help with near near-term:
  - Prioritization of wetland creation zones
  - Ranking of historical areas
- Refinement of both models with high resolution (temporal and resolution) data
  - SSHA
  - More recent precipitation (rain gauges, etc.,)
- Improvement of Hawaii machine learning models
- Exploration of more features
  - Storm surge
  - Fetch


Pu'ukohola Heiau


A temple and offering tower

Image Credits: NPS

ACKNOWLEDGEMENTS

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- **State of Hawaii, Department of Land and Natural Resources**
- **Arizona State University**, *Center for Global Discovery and Conservation Science*

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- Dr. Jiwei Li (Arizona State University)
- Dr. David Hondula (Arizona State University)

NASA DEVELOP:

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University of Washington:

- Megan Halabisky, *Remote Sensing and Geospatial Analysis Laboratory*

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