# SeeRise: Visualizing Emulated Sea Level Rise on Coastal Regions


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## Introduction

**First Look** 👁️

- Sea level rise is a pressing global issue that comes alongside global warming.
- There are two main contributors for sea level rise: thermal expansion and ice melt.
  - The contributions due to ice melts are poorly understood, leading to large error ranges.
- Sea level rise can have devastating consequences on coastal areas.
  - The world sea level is predicted to rise about 0.5 meters under SSP 245 in 2100.
  - Our visualizations show that half of Sanibel Island is likely to be underwater in 2100!

**Prior Work** 📚

- ClimateBench: climate model emulators with performance comparable to real climate models (which are run on supercomputers) for future projection.
- Rahmstorf: A semi-empirical approach to model sea level rise based on observed temperature trends.

**Description of Data** 🗂️

- Climate model emulator training data: CMIP6.
  - Input: carbon dioxide ($CO_2$), methane ($CH_4$), sulfur dioxide ($SO_2$), and black carbon (BC).
  - Output: surface air temperature (TAS) anomaly.
- Sea level rise data: historical sea-level rise and NASA's Sea Level Projection.
  - Input: temperature anomaly (compared to 1900).
  - Output: sea level change between 2 consecutive years (mm).

**Data Assumptions** 📊

- Keep $CH_4$, $SO_2$, and BC at 2025 (present) levels.
  - It is intuitive to base our predictions on the current situation.
- Linearly increase yearly $CO_2$ concentrations from 2015 to 2100.
  - Linear interpolation makes simple assumptions and is applicable given any valid 2100 $CO_2$ level.

## Methods

**Climate Model Emulators** 🌡️

- Models: Pattern Scaling, Gaussian Process, Random Forest, and CNN-LSTM.
- Trained on historical, SSP 126, SSP 370, and SSP 585.
- Validated on SSP 245.

Cumulative $CO_2$ by 2100 → Emulators Predict TAS → Predict Sea Level Rise

**Sea Level Rise Projection - A Semi-Empirical Approach** 🔮

- Linear fit for yearly change in sea level, regressed on surface air temperature (TAS) anomaly.
  - Temperature anomaly: difference from temperature in 1900.
- Integrate the rate of sea level rise → predict total sea level rise in a year.

$$\frac{\partial H}{\partial t} = \alpha(T - T_0)$$

$$H(t) = \int_{t_0}^{t} \frac{\partial H}{\partial t} dt$$

**Our Steps** 🔎

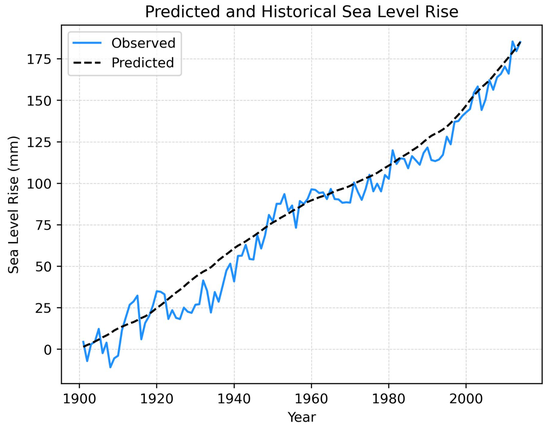
- Estimate $CO_2$ concentration from 2015 to 2100 given concentration in 2100.
- Keep other greenhouse gases at 2025 (present) levels.
- Predict global TAS from 2015 to 2100.
- Calculate average TAS for each year.
- Project yearly change in sea level.
- Take the cumulative sum → total sea level rise.
- Use the median sea level rise to compare with NASA sea level projections.

👉 Scan for our website!

## Results

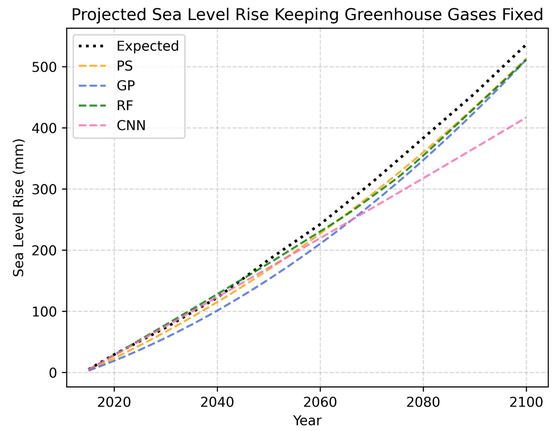
**Proof of Concept - Rahmstorf's Method** 📈

- We show that Rahmstorf's method is a good model of sea level rise.
- Comparison to actual historical sea level rise measured via satellites.
  - MSE: 10.014 $mm^2$, the size of a grain of sand.




**Projected Sea Level Rise - Emulator Comparison** ⚖️

- We then fit the same model architecture to NASA projections trained on TAS from various emulators. When compared to NASA's expected sea level rise values, we are under-predicting.
  - Calculated with cumulative $CO_2$ at 4520 Gigatons in 2100.
  - Calculated keeping other greenhouse gases constant at 2025 levels.
- We can see that Pattern Scaling, Gaussian Process, and Random Forest are all very similar to one another.
- We can see that CNN performs the worst among all the emulators, possibly because of holding the other greenhouse gases constant.

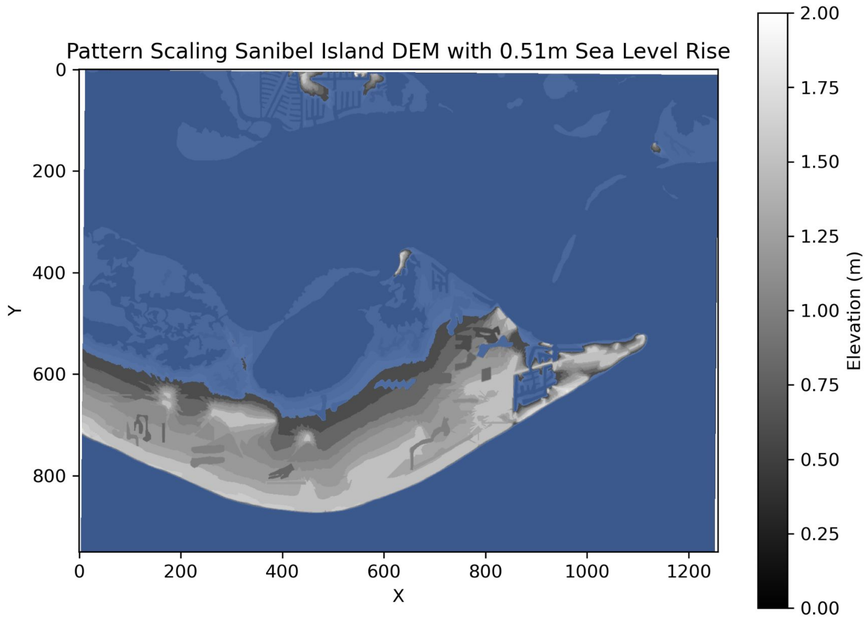



**Visualizing Sea Level Rise in Florida** 🗺️

- See our website for the interactive visualization!
  - How do different levels of cumulative $CO_2$ affect how sea level rise impacts Florida?
- We use a digital elevation model (DEM) based on LIDAR data as high resolution ground truth for impact maps.
- From NASA projections, expected sea level rise in 2100 is 536.4 mm (± about 158 mm for the 66% confidence interval)—roughly the width of a large pizza box (about 20 inches) 🍕!
  - The NASA data is adjusted to start at 2015 like the rest of our data.
- SSP 245 is the most likely climate scenario, making it a good baseline assumption. SSP 245 predicts that the cumulative atmospheric amount of $CO_2$ in 2100 will be about 4520 Gigatons.
  - SSP 245 estimates 2.5-3 ℃ of warming compared to pre-industrial times.
  - We chose SSP 245 because current policies are not on track for the Paris Agreement's goal and the most extreme scenarios seem out of reach, so we assume the "middle of the road" scenario.

**Table: Emulator Prediction Error Comparison**

| Emulator | Predicted (mm) | NASA Predicted - Emulator Predicted (mm) |
|---|---|---|
| Pattern Scaling | 513.6 | 22.8 |
| Gaussian Process | 511.6 | 24.8 |
| Random Forest | 511.3 | 25.1 |
| CNN-LSTM | 417.0 | 119.4 |




## Discussion & Conclusions

- Rahmstorf's 2007 semi-empirical model is a simple assumption.
  - Real-world ice sheet dynamics may not respond linearly to temperature changes. The physics is complicated.
- Under-prediction due to keeping other greenhouse gases constant.
  - Future work can be done on scaling other greenhouse gases input appropriately.

## References


- Climate Model Emulators:
  - Watson-Parris, Duncan, et al. "ClimateBench v1. 0: A benchmark for data-driven climate projections." Journal of Advances in Modeling Earth Systems 14.10 (2022): e2021MS002954.
- Semi-Empirical Sea Level Rise Model:
  - Rahmstorf, Stefan. "A semi-empirical approach to projecting future sea-level rise." Science 315.5810 (2007): 368-370.