EVOLUTION OF EARTH'S CLIMATE ZONES

VISUALIZING SHIFTS ACROSS TIME AND SPACE

Eurogroup Team 003 | CSE 6242 | Fall 2020

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Summary

Problem and Importance:
Earth's climate is changing, but no universally accepted model for unsupervised clustering of exists. This is important to help the public and policy makers plan for a future with a changing climate, a global concern.

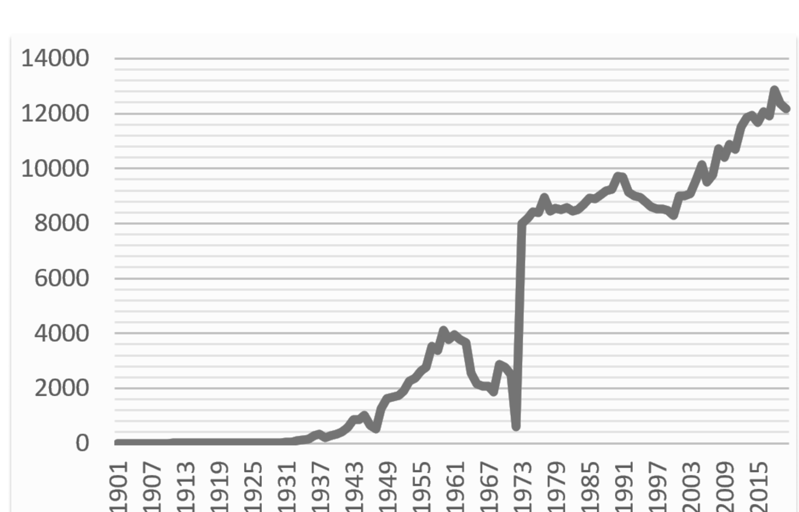
Goal:
1. Develop an interactive, dynamic visualization that clusters areas of the Earth into climate biomes using only weather data, avoiding the use of human heuristics

2. Examine if those clustered biomes exhibit a tendency to shift toward the poles.

Data

Source:
Integrated Surface Dataset detailing hourly weather station observations from 1901 to the present. Obtained and collated from yearly csv files via the National Centers for Environmental Information data website using a Python scraping script.

Inspection & Preprocessing:
Hourly data condensed to daily averages and spreads reducing file size from 1.2 TB to ~34 GB. We removed years below 1974 which lacked a sufficent number of stations (see figure). Although 23 features were available, we chose to retain 5 after analyzing for covariances.



Number of available stations by year

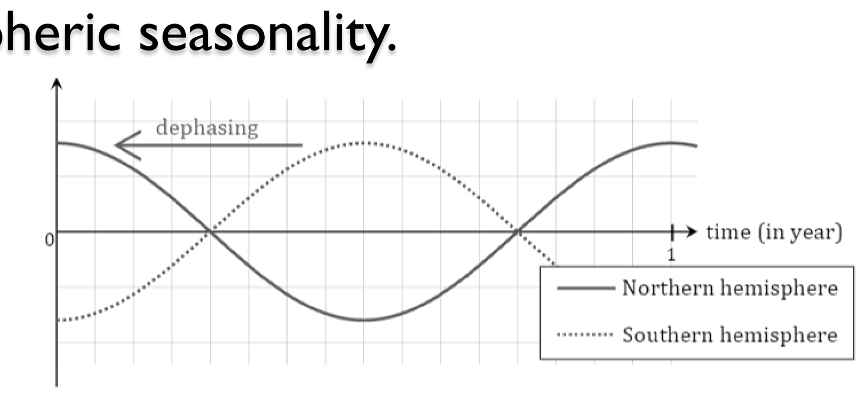
Inference:
Many stations had no data or missing attribute information for certain periods (hours to days). In these cases, we decided to linearly interpolate where possible.

Methodology

Algorithm

Innovation
> Novel use of **Fast Fourier Transform** for **dynamic time warping**
> Based on **clustering analysis** instead of **human heuristics**.

Feature Extraction
We developed tensors (generalized representations of basis vectors and components) to represent each weather component for station-year tuples, using Dynamic Time Warping and Fast Fourier Transforms to dephase hemispheric seasonality.



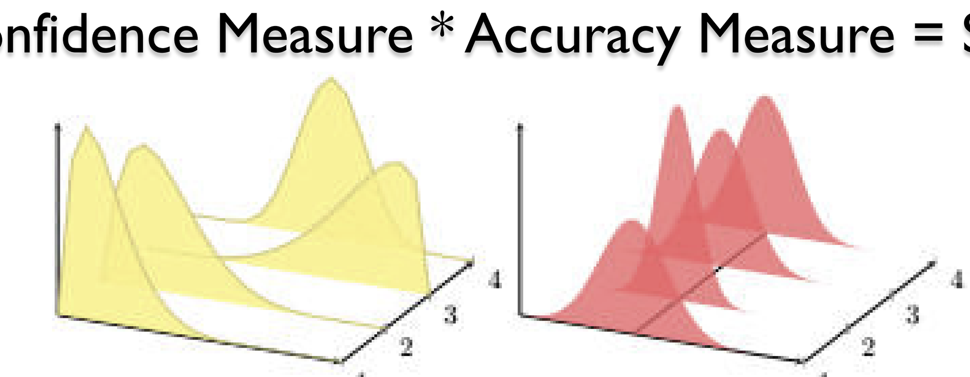
Dephasing

Clustering
> 3-levels of dimensionality reduction (none, ICA, PCA)

> 2-levels based on clustering algorithm (deterministic *k*-means and probablistic Expectation Maximization [EM])
>> *k*-means emphasizes latitudinal variation
>> EM depicts known biomes more reliably

Scoring Metrics
To select the most promising models out of the 900+ we made, we developed 2 scoring metrics and combined them into a single score per model:

Confidence Measure * Accuracy Measure = Score

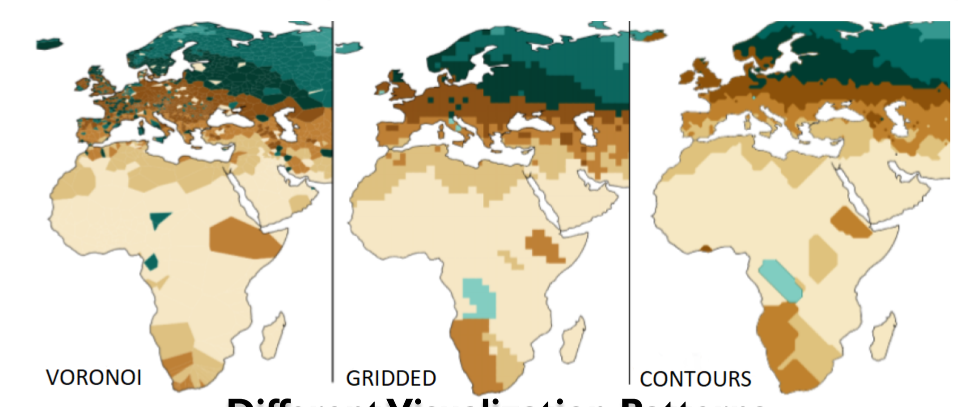


Aligning and scaling the metrics across clusters, assuming Gaussian distribution.

Visualization

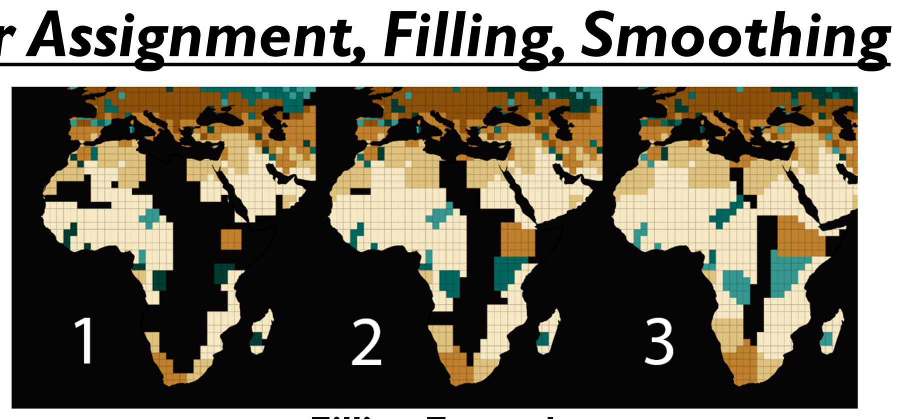
Innovation
> **Animated:** others of this type are static images
> **Interactive:** existing implementations do not have interactivity in their visuals

D3 Contours
After trying other approaches, we settled on contours for max performance and readability.



Different Visualization Patterns

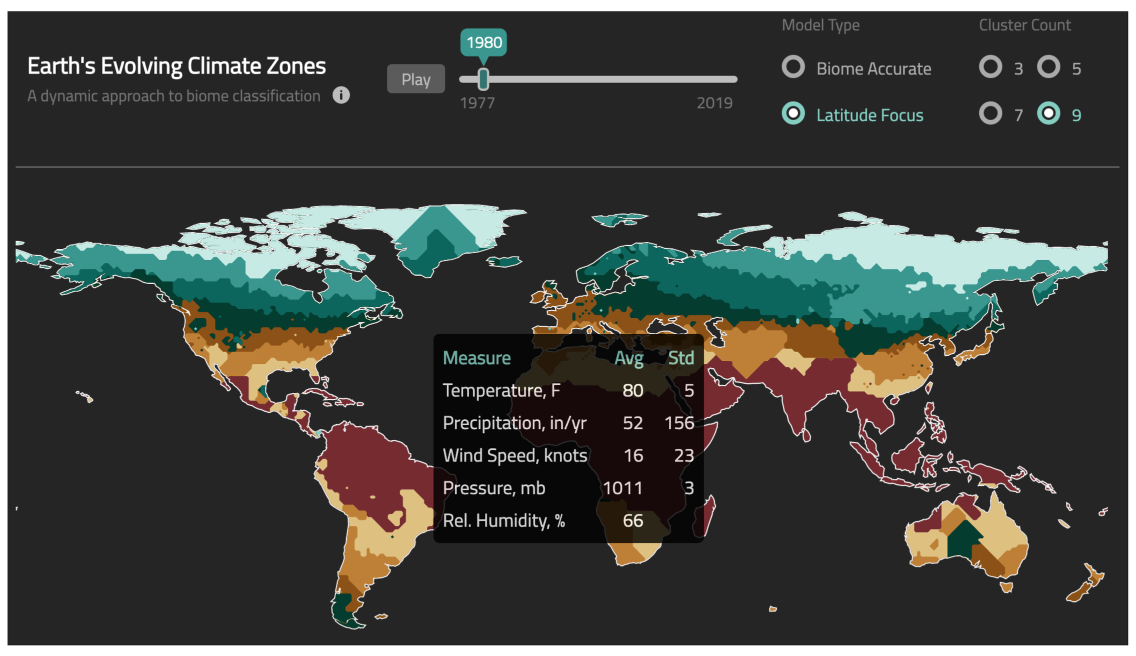
Color Assignment, Filling, Smoothing



Filling Example

> Used clusters' average latitudes to consistently space labels across our chosen color palette.
> CUSUM-like change detection algorithm to reduce spacial and temporal "flickering"
> Fill empty spaces by "growing" the clusters iteratively.

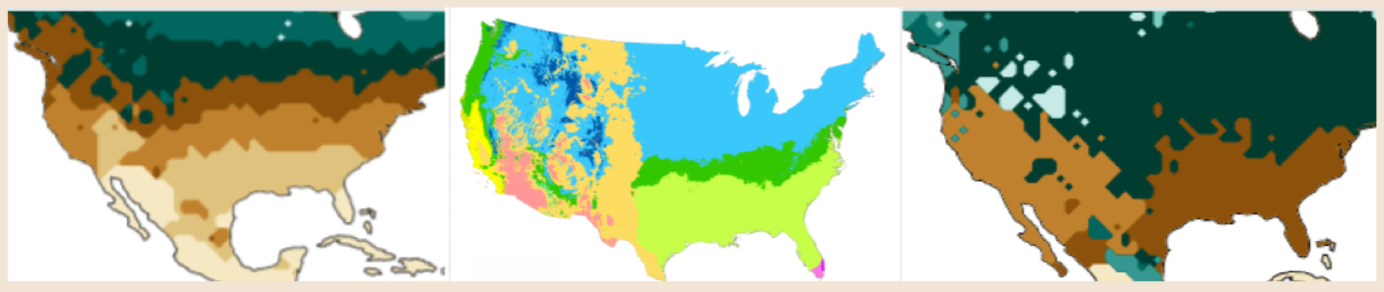
Interactivity
Model-Selection, Map Animation, & Mouse-Events

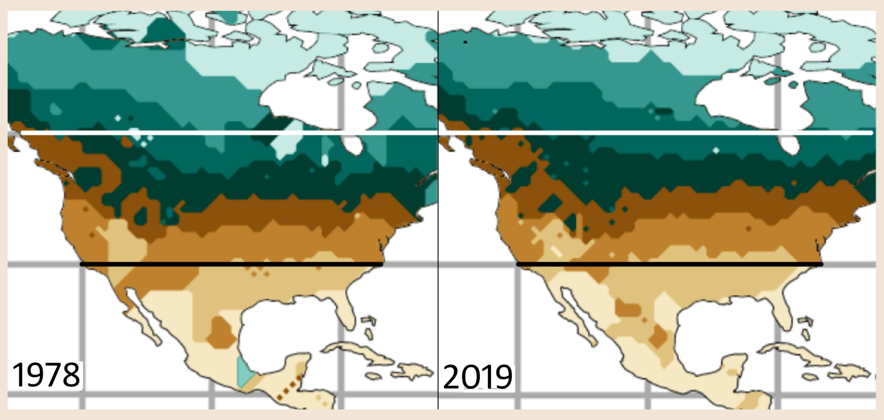


Results and Conclusions

Comparing to Reality
> With a score of 90.31 out of 100, the 9-cluster, *k*-means, low resolution, 3-parameter model without dimensionality reduction performed the best.

> Below is a comparison of how that model (left) and the similar Expectation-Maximization model (right) compare to the Trewartha climate classification model.





A Shifting Climate
Evidence of pole-ward shift is seen in our model outputs. Above, the graphic shows these shifts for the United States over the period from 1978 to 2019. Using the black and white lines as guides the shift is easily noticable.

From simple weather station data, indicating precipitation, temperature, dew point, wind speed, and pressure, we have created dynamic models that accurately classify climate biomes and that illustrate how those biomes are shifting towards the poles.

We believe that the ideas and methodology presented here can help inform the public and policy makers by making it easier and quicker to visualize the changing climate.