Using image machine learning algorithms to study changing upwelling patterns in the Arabian Sea

Jacob T. Zikan
Dartmouth College,
Hanover, NH
Jack Bryne Scholar,
Department of Mathematics

Dr. E. Eli Holmes
NOAA Fisheries &
University of Washington,
Seattle, WA USA

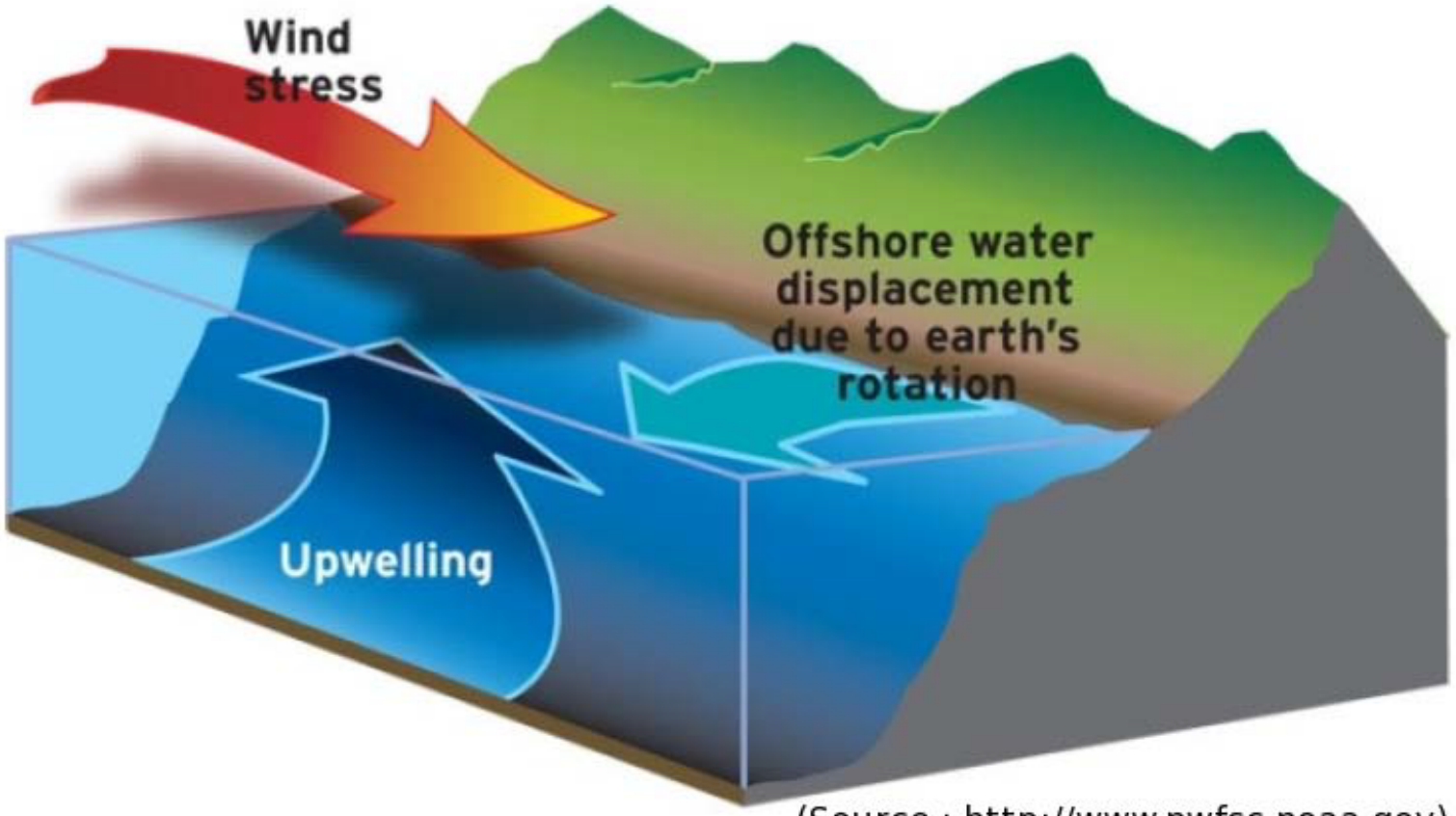
Winter wind map in the N Indian Ocean

This was an undergraduate research project within a larger research project: Development of Predictive Capabilities for Marine Fisheries and Harmful Algal Blooms in Indian Seas (NOAA Fisheries/India Ministry of Earth Sciences)

Kochi, India (E Holme

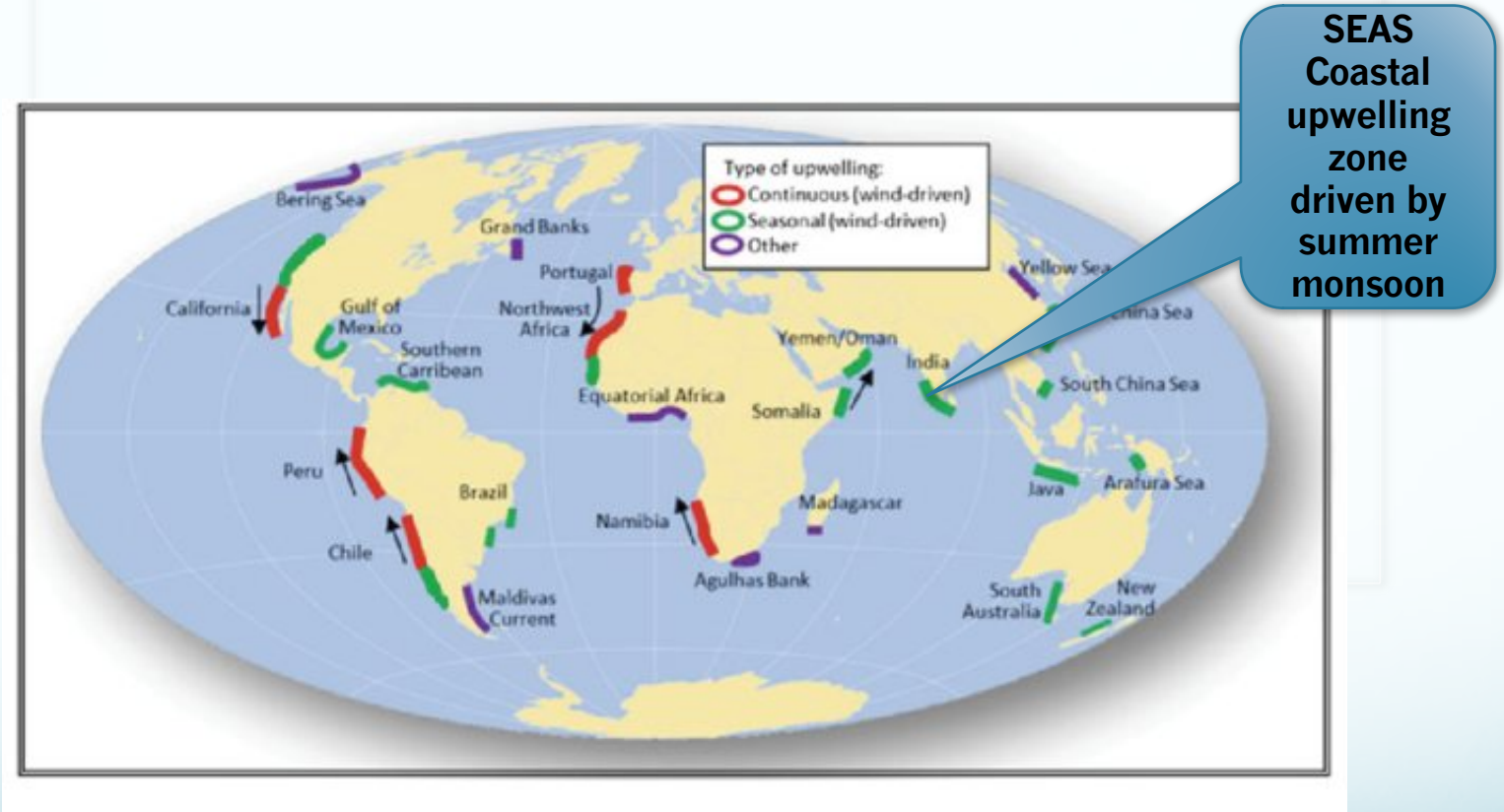
Objective

Coastal upwelling is a process by which winds create surface water displacement that causes cold, nutrient rich, water to come from the ocean floor to the surface



(Source : http://www.nwfsc.noaa.gov)

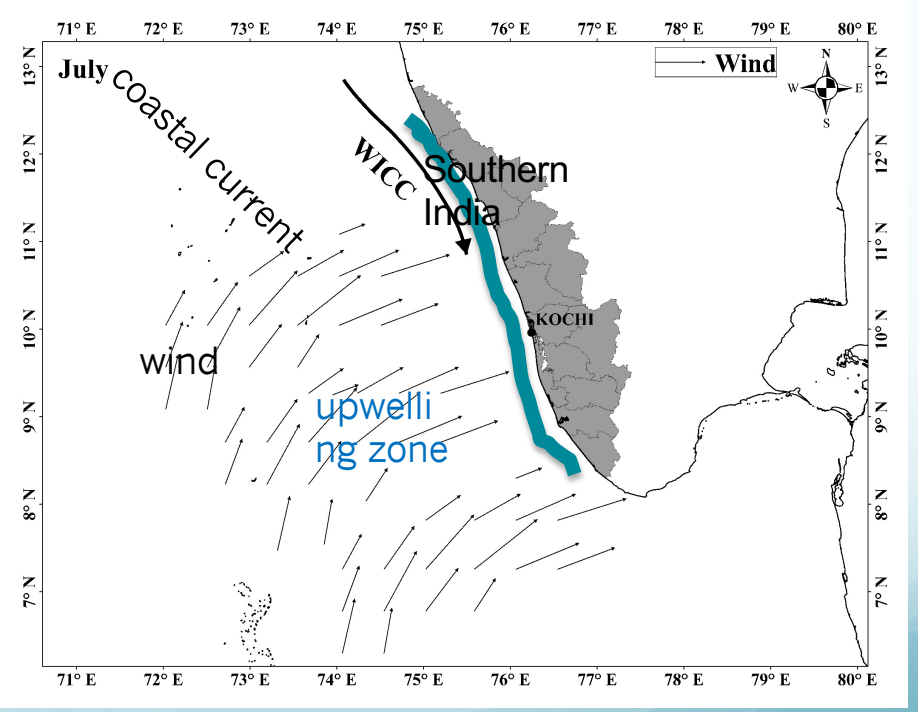
The South east Arabian Sea (SEAS) is one of world's major upwelling zones



Kämpf J., Chapman P. (2016) The Functioning of Coastal Upwelling Systems. In: Upwelling Systems of the World. Springer, Cham. https://doi.org/10.1007/978-3-319-42524-5_2

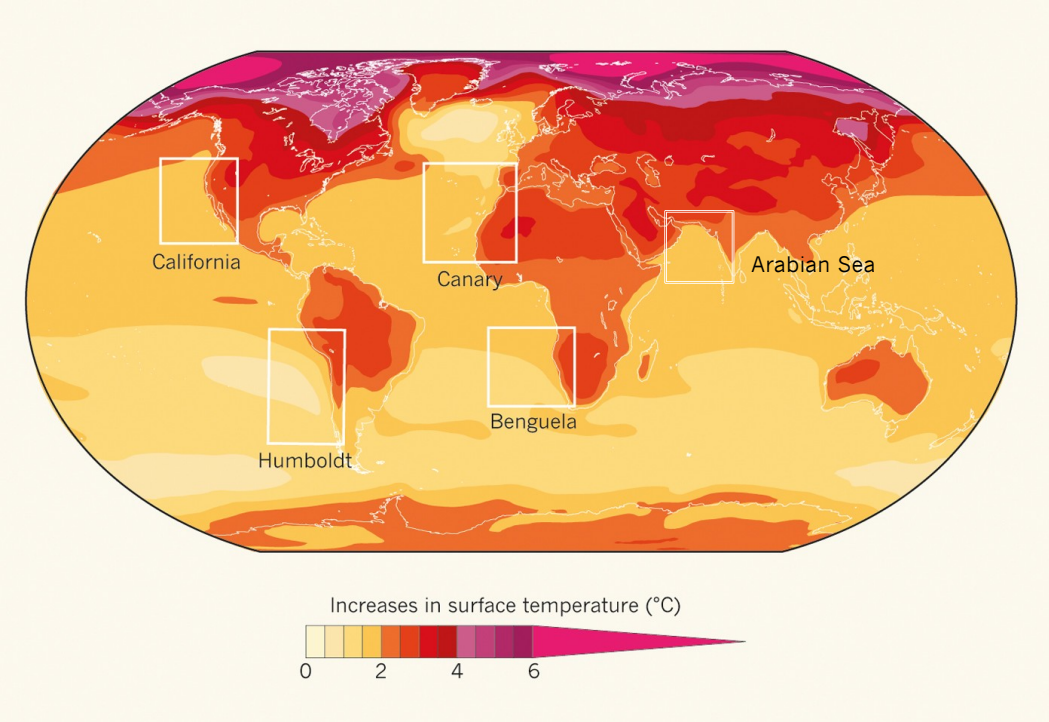
The South east Arabian Sea (SEAS) upwelling system is unique because it is seasonal and driven by the summer monsoon that brings high winds driving into the coast

June to September



The South east Arabian Sea (SEAS) is warming quickly. With this ocean climate change comes changes in upwelling patterns

Projected warming between now and 2050



Di Lorenzo, E. The future of coastal ocean upwelling. *Nature* **518,** 310–311 (2015). https://doi.org/10.1038/518310a

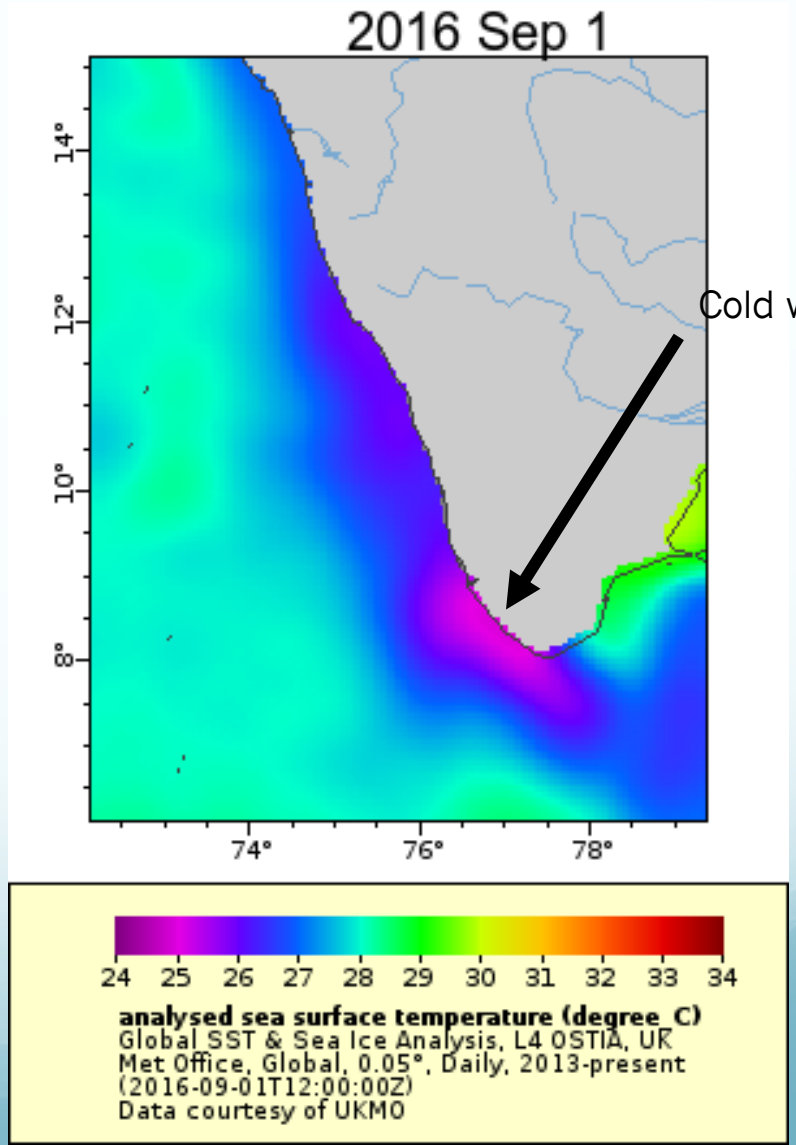
Can unsupervised machine learning help us understand how the upwelling spatial and temporal pattern is changing?

How Do we Quantify an Upwelling Pattern?

One way is by looking at the sea surface temperature.

The cold water is upwelled from the bottom.

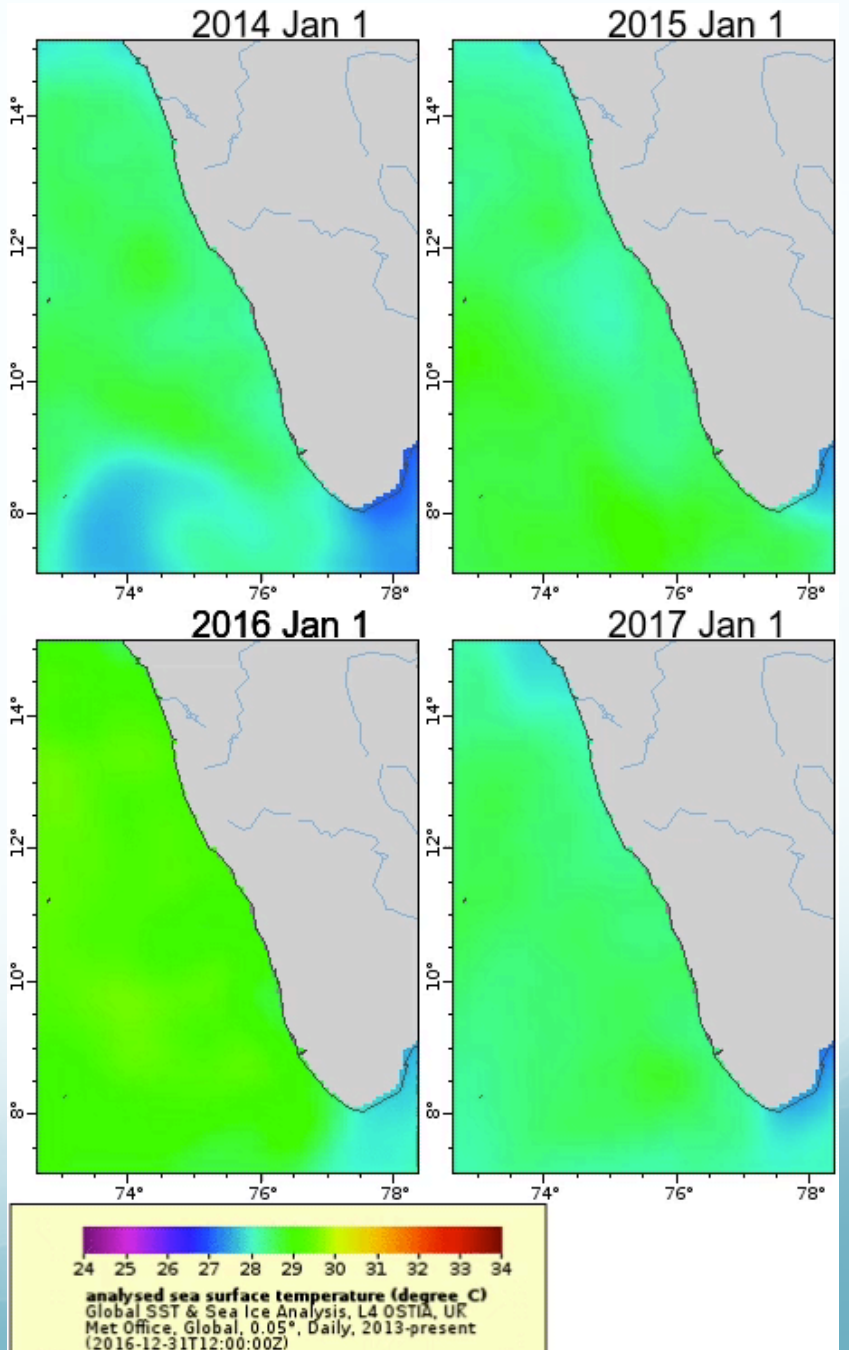
This picture shows strong upwelling.



These patterns change year to year

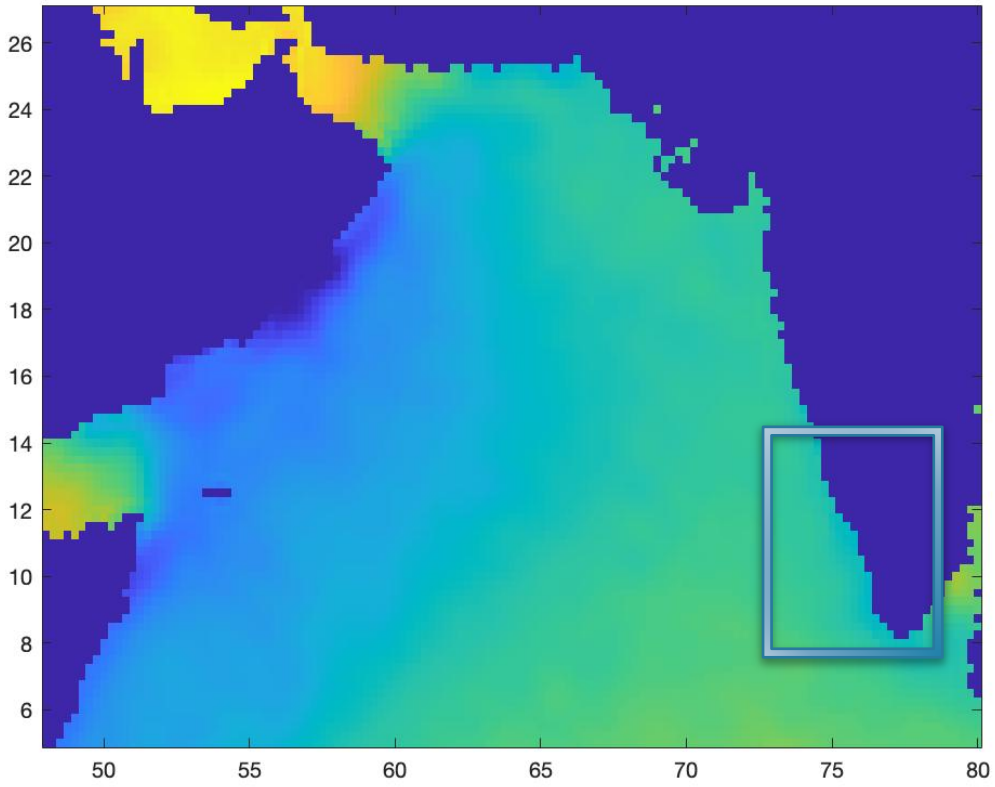
This movie shows the SST pattern over 4 years.

How can we quantify these patterns to understand if the spatial pattern of upwelling is changing?



Monthly SST Data (1979-2019)

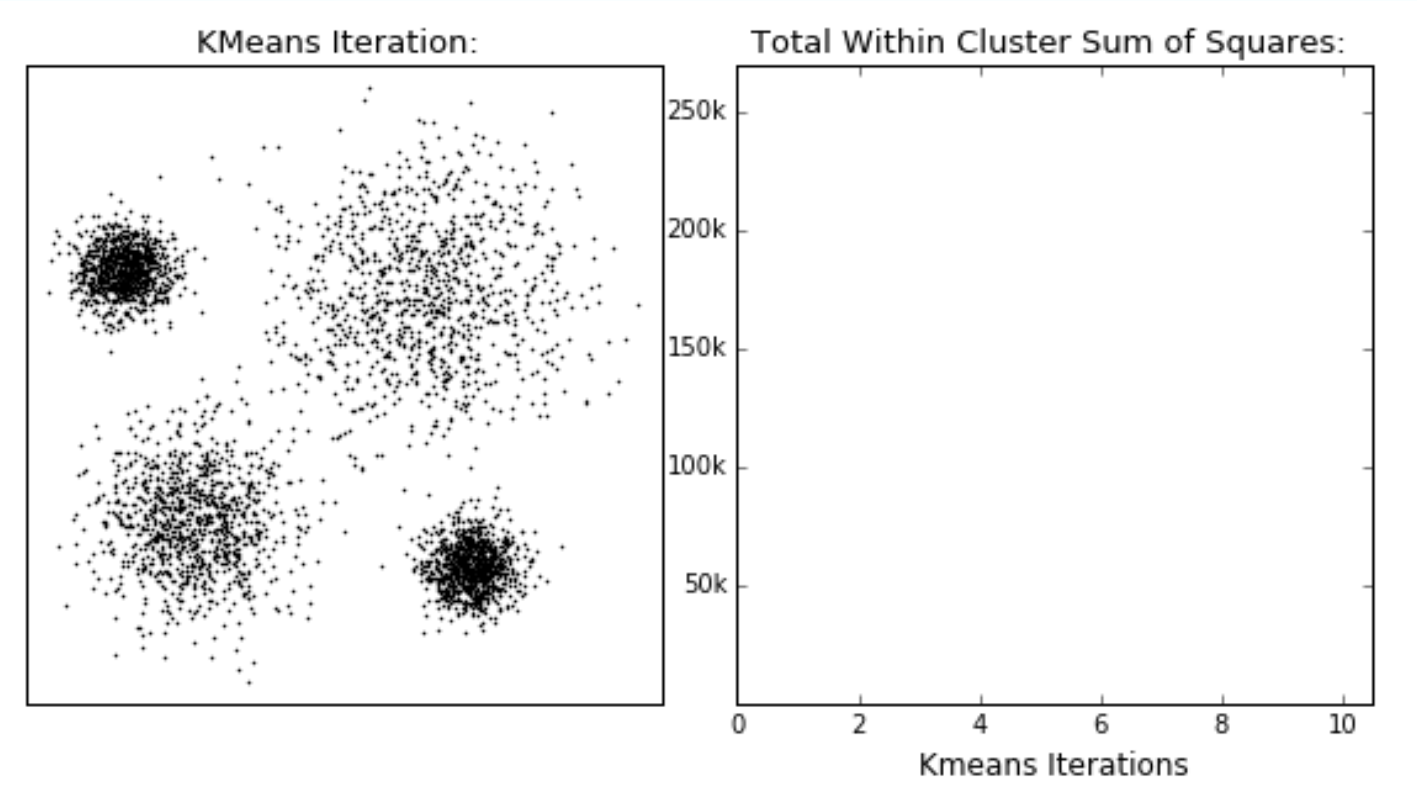
European Centre for Medium-Range Weather Forecasts, Climate Change Service



August 1st, 1979

ERA5: Hersbach, H., Bell, B., Berrisford, P., et al. The ERA5 global reanalysis. Quarterly Journal of the Royal Meteorological Society. 2020; 146: 1999–2049. https://doi.org/10.1002/qj.3803

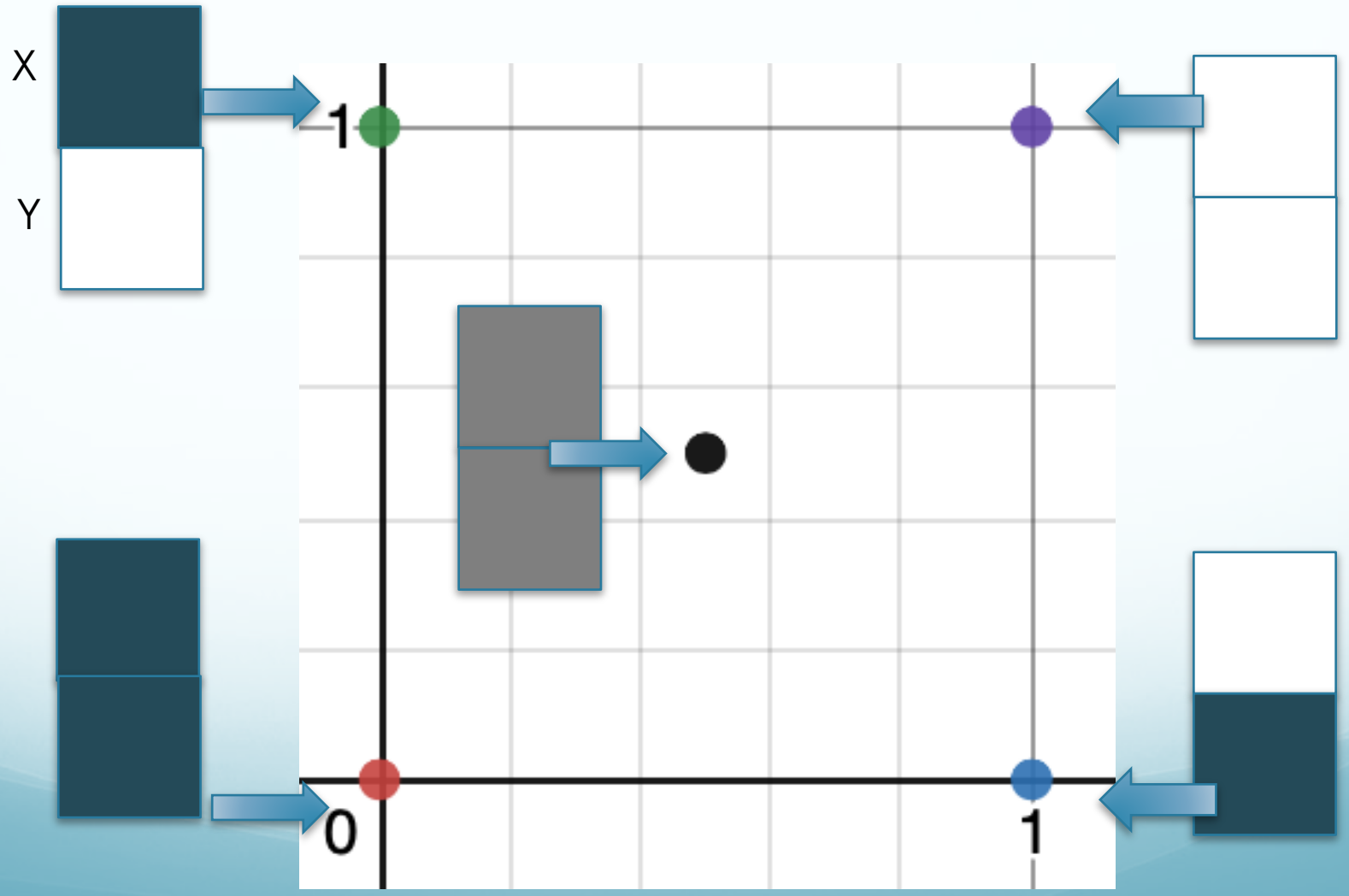
K-Means Process



1. Assign points into groups according closest centroid
2. Calculate mean of points in a group
3. Move centroid to said mean
4. Repeat

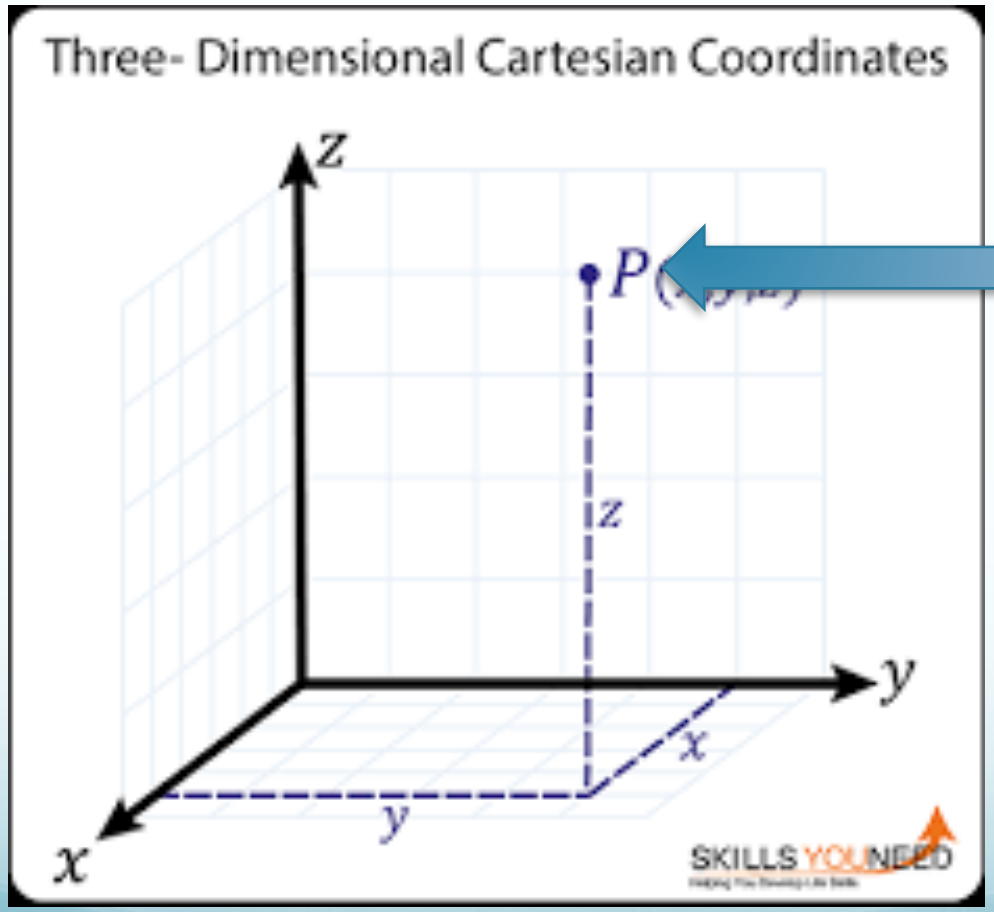
Mapping Images to Space

2 Pixel Image



Mapping Images to Space

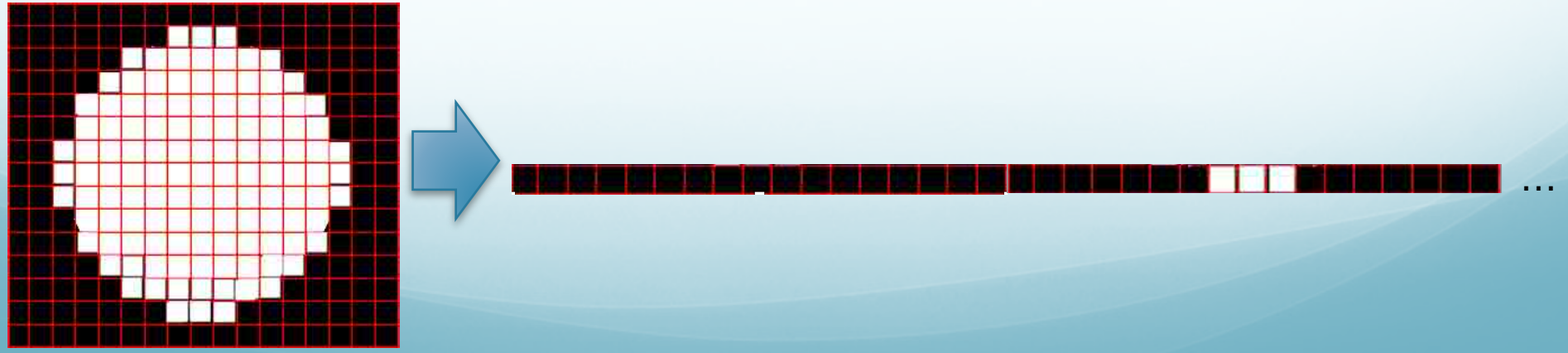
3 Pixel Image



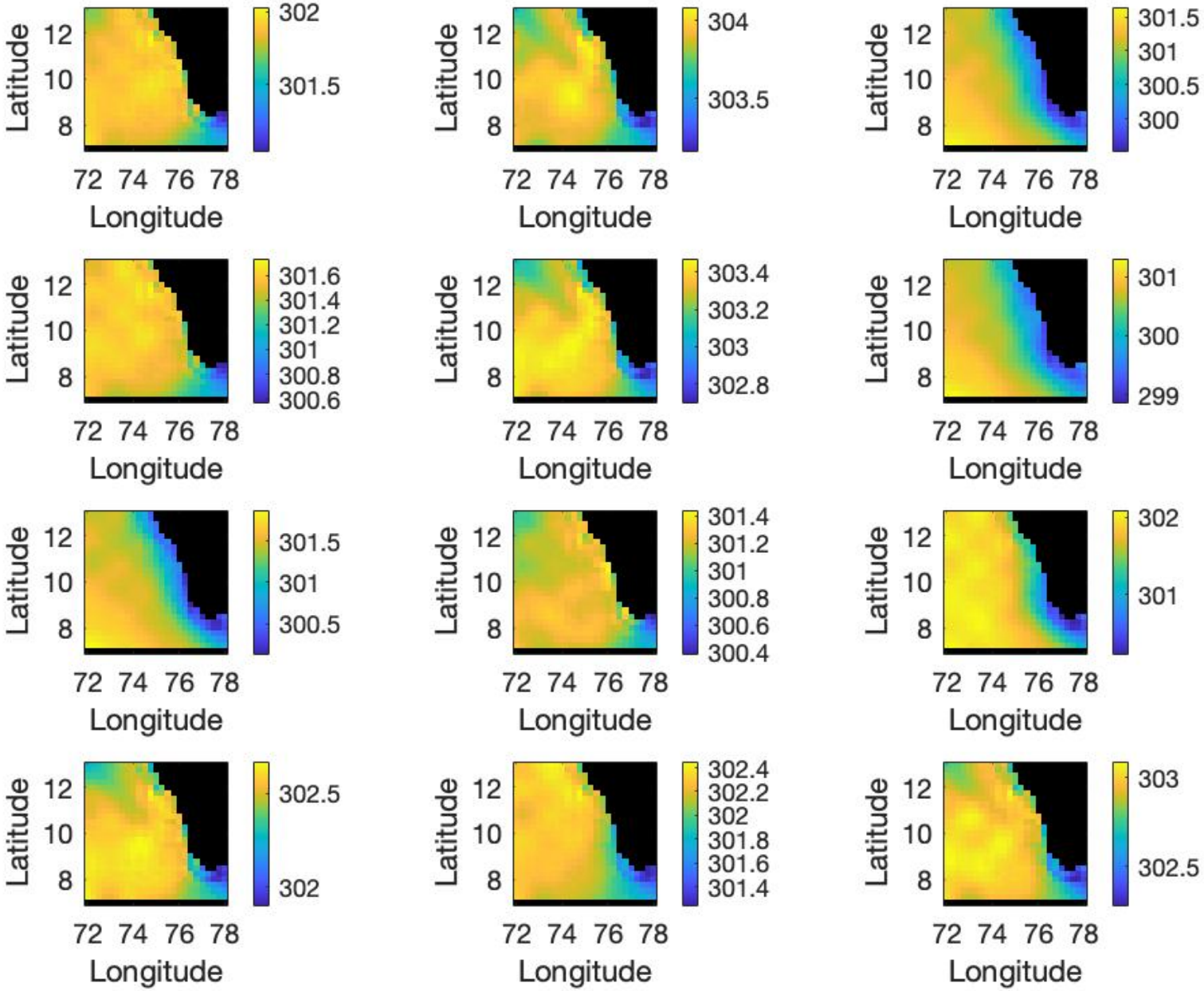
Mapping Images to Space

P Pixel Image

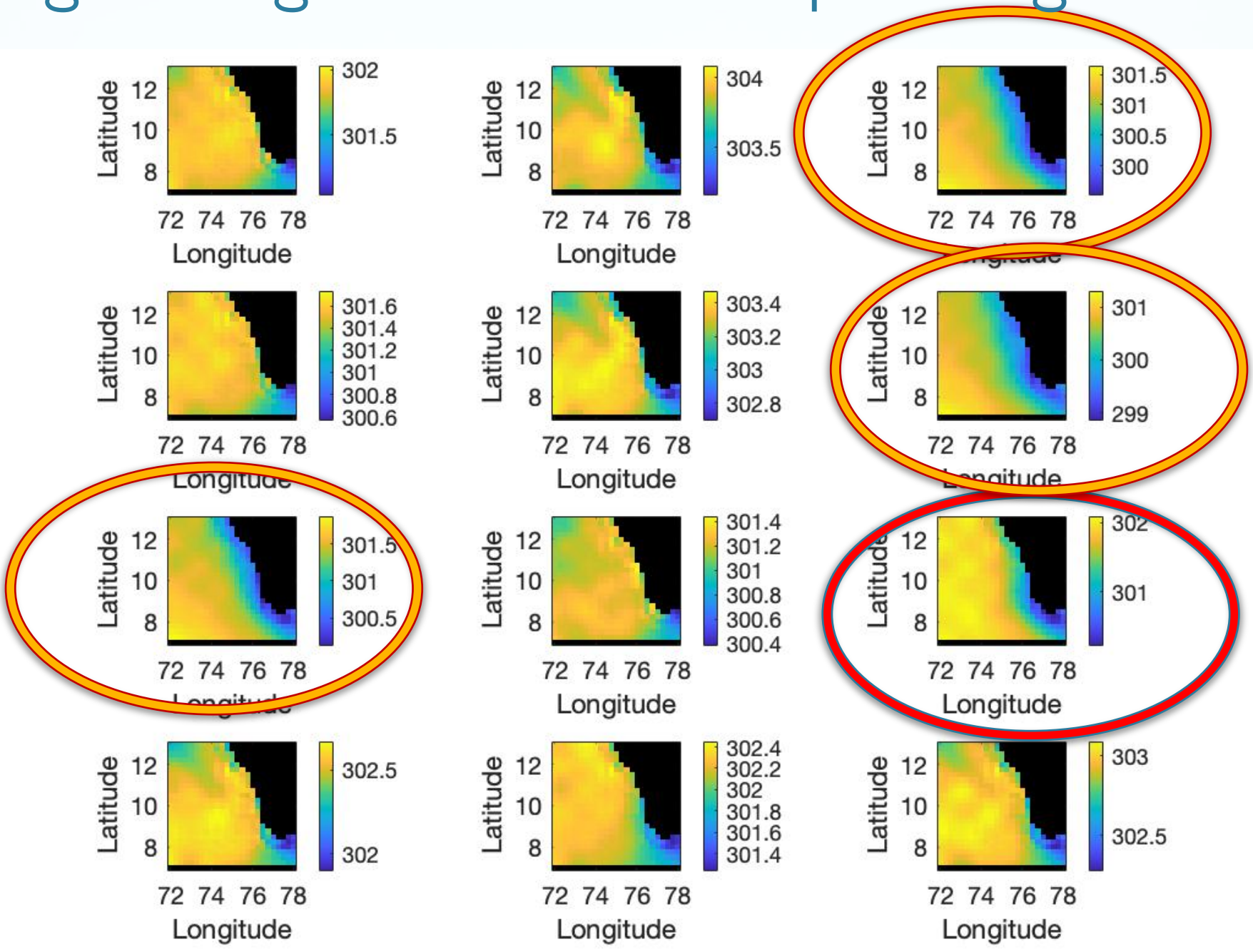
- Unravel each image into a list of its pixel values
- Each pixel in the image is a parameter
  - Therefore, each image can be represented as a vector in R^p
- Group images by clustering them in R^p space using K-Means Algorithm



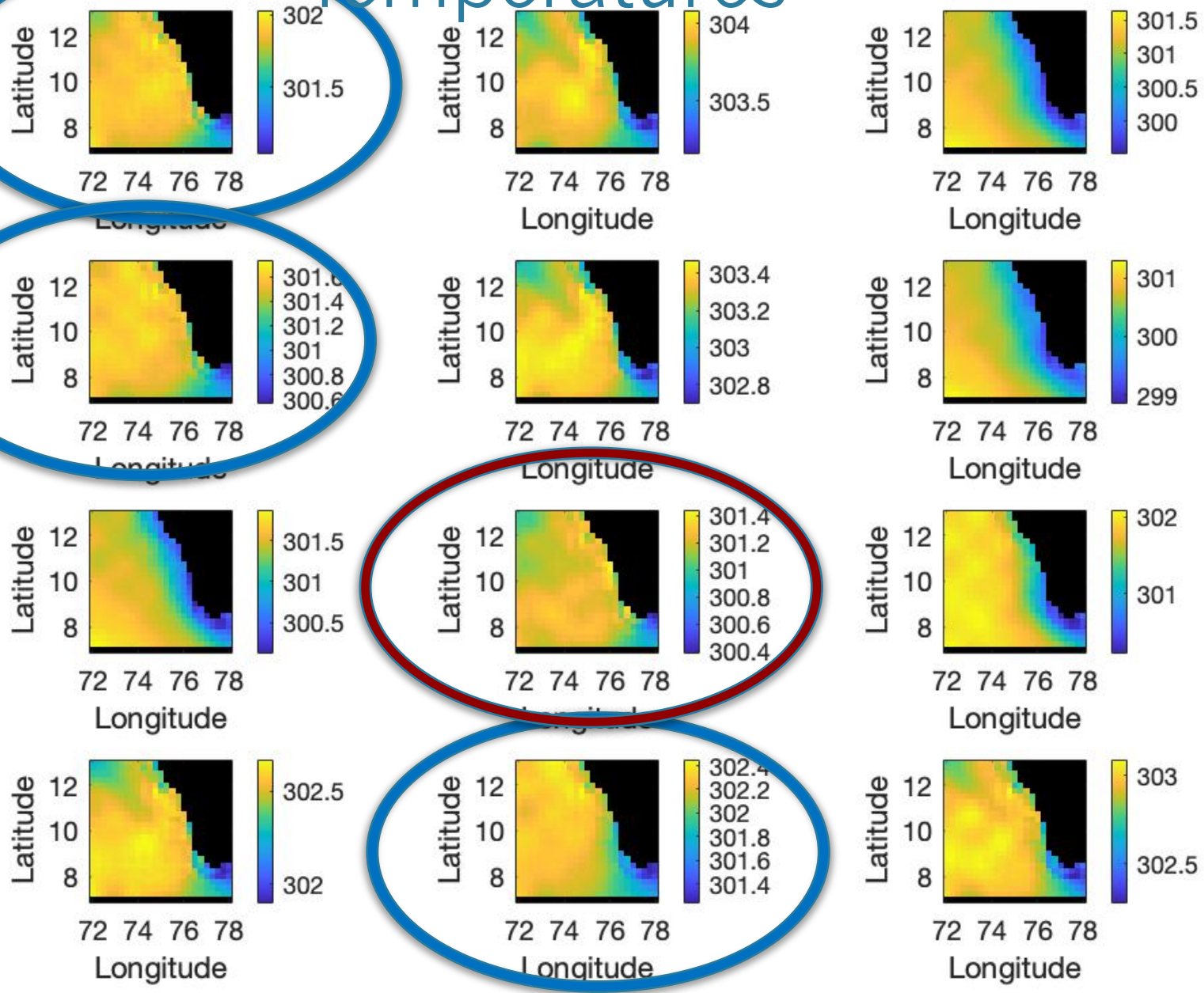
Clusters Selected by K-Means Algorithm



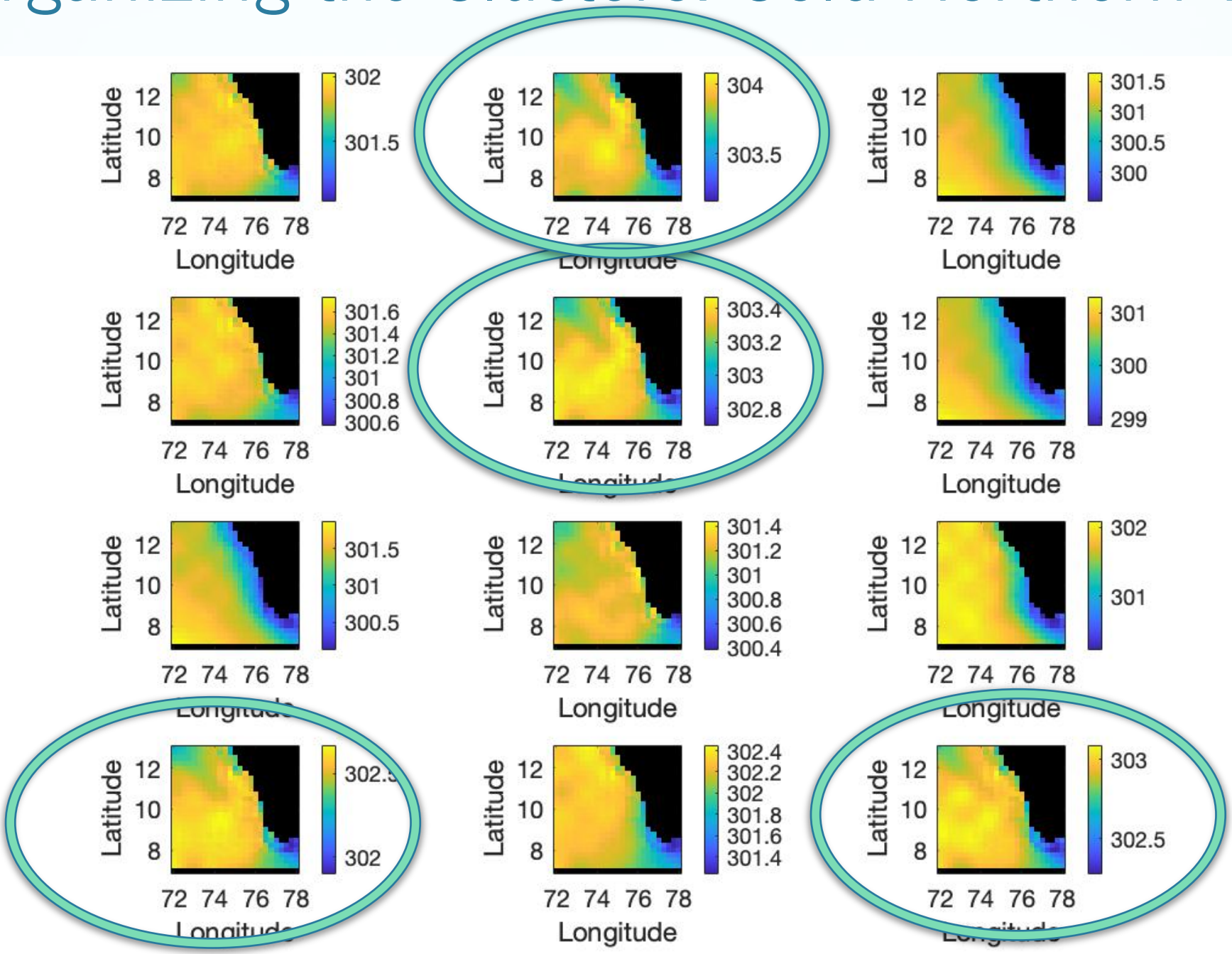
Organizing the Clusters: Upwelling Pattern



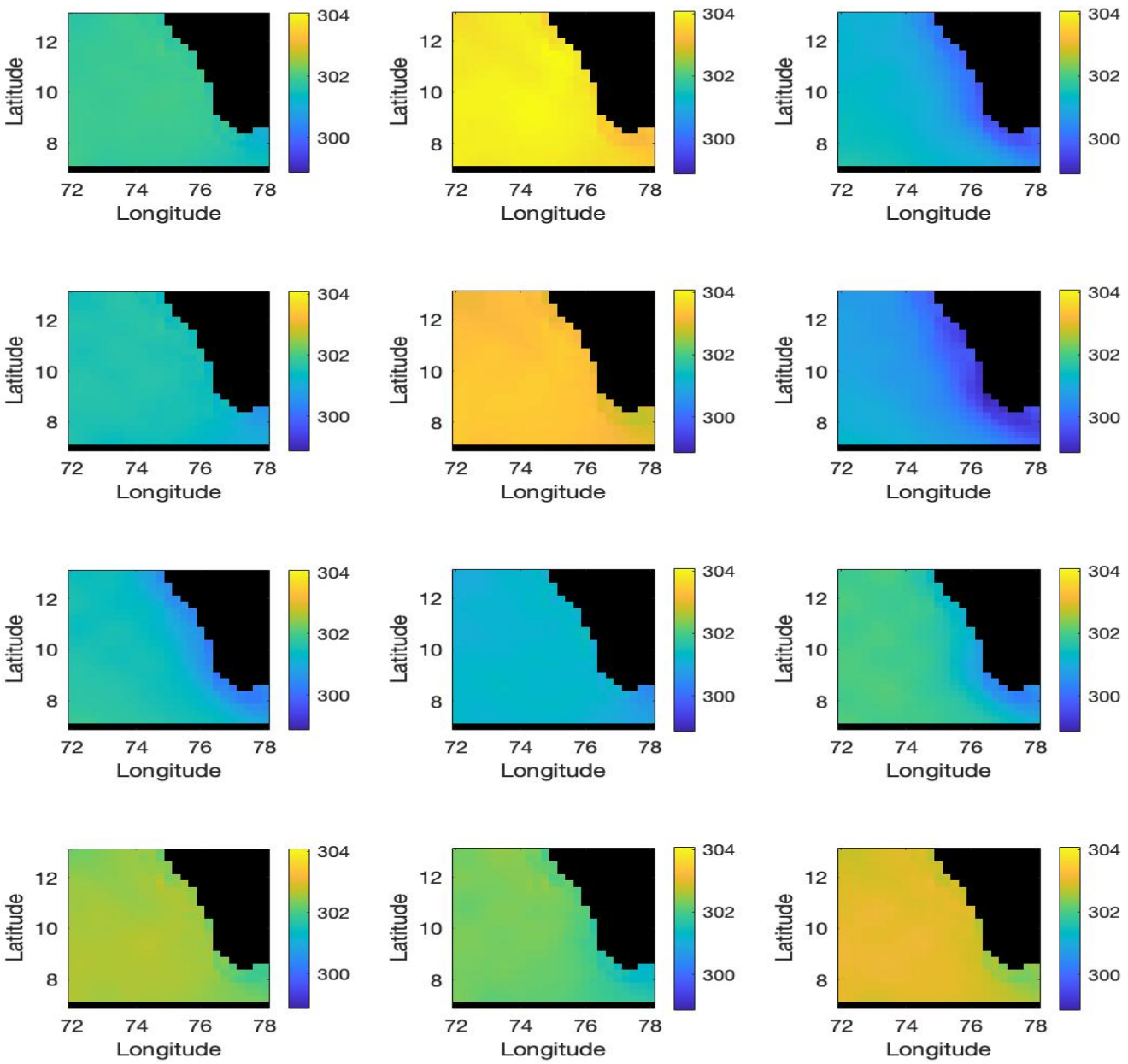
Organizing the Clusters: Unform Temperatures



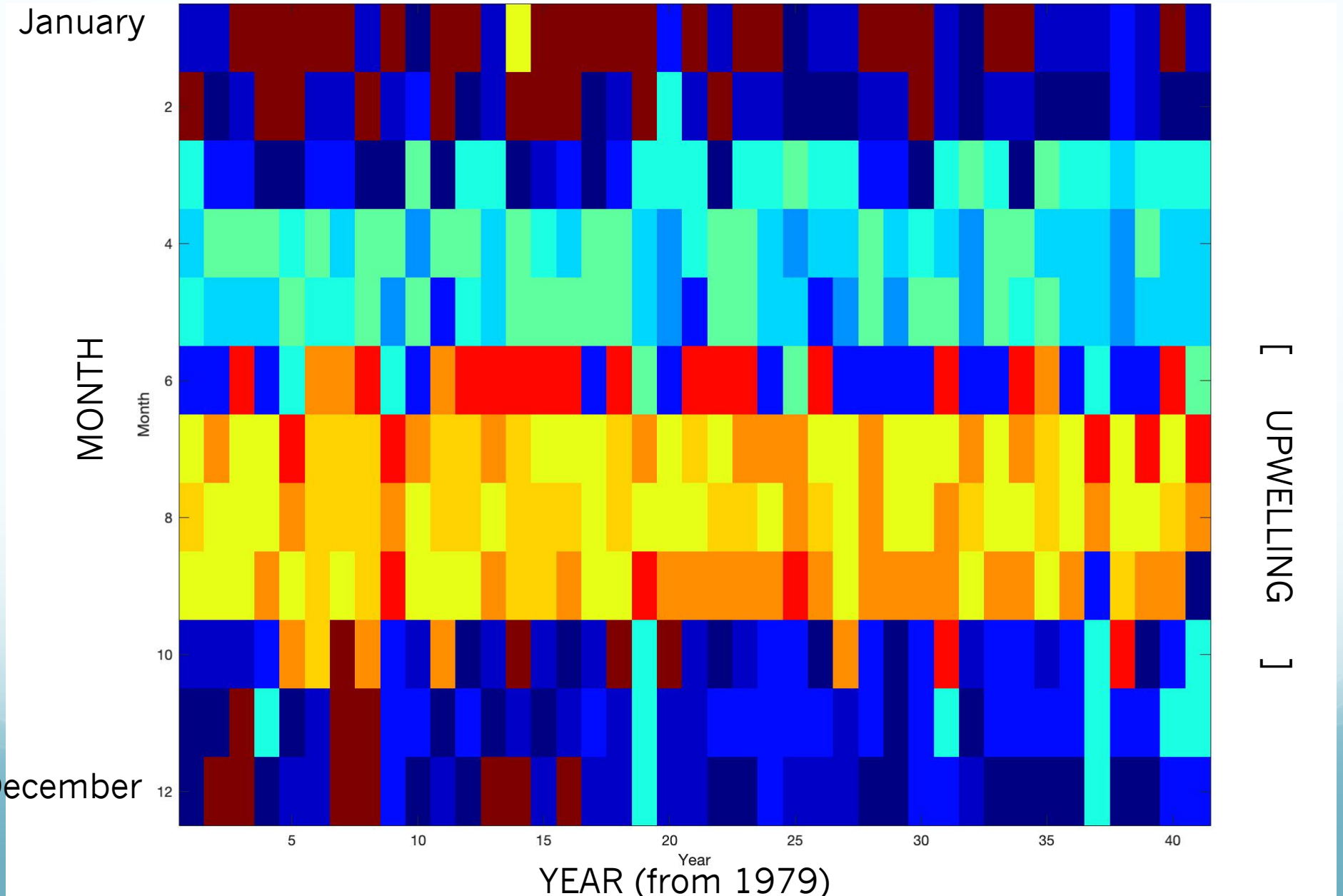
Organizing the Clusters: Cold Northern Ton



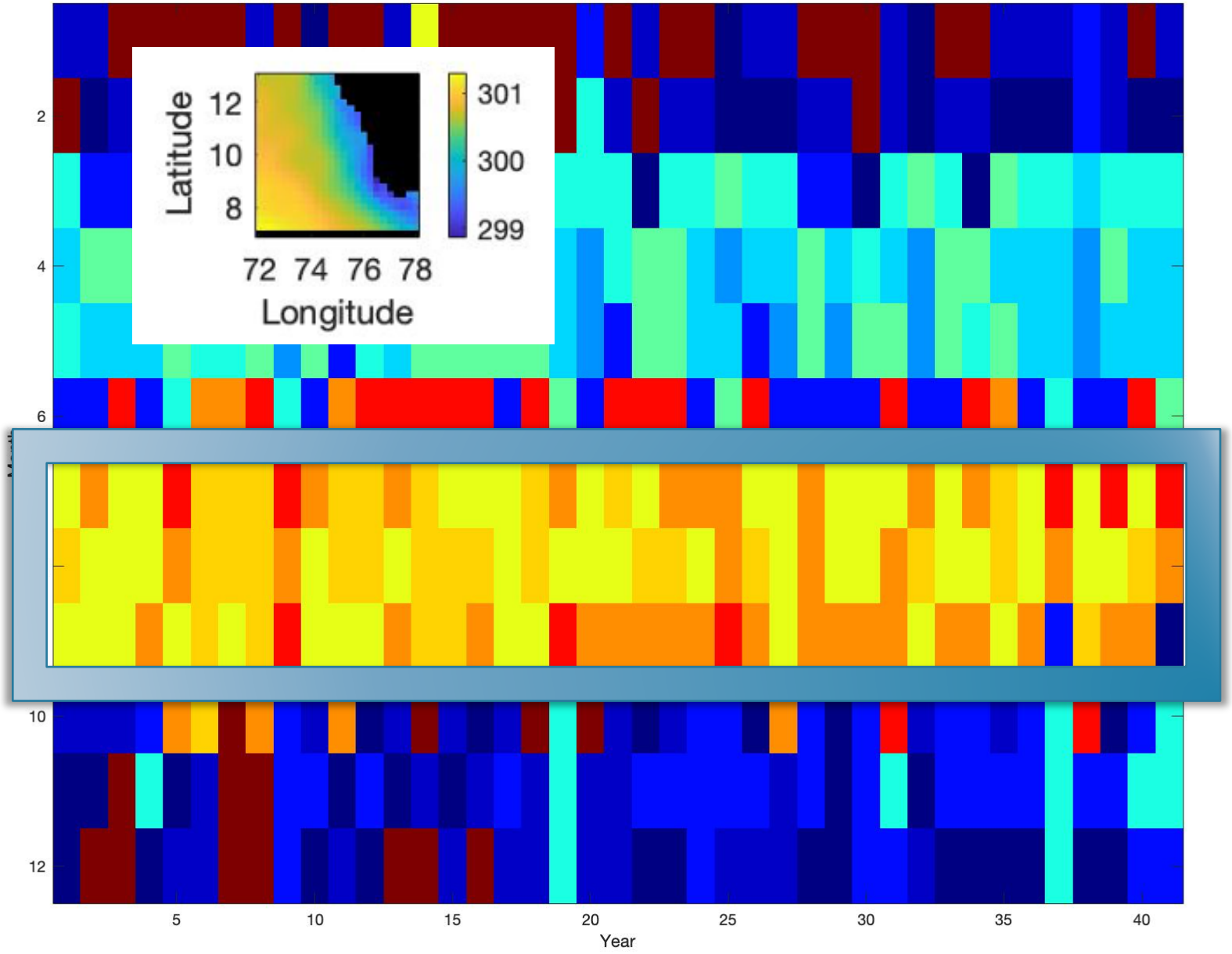
Clusters on Same Temperature Scale



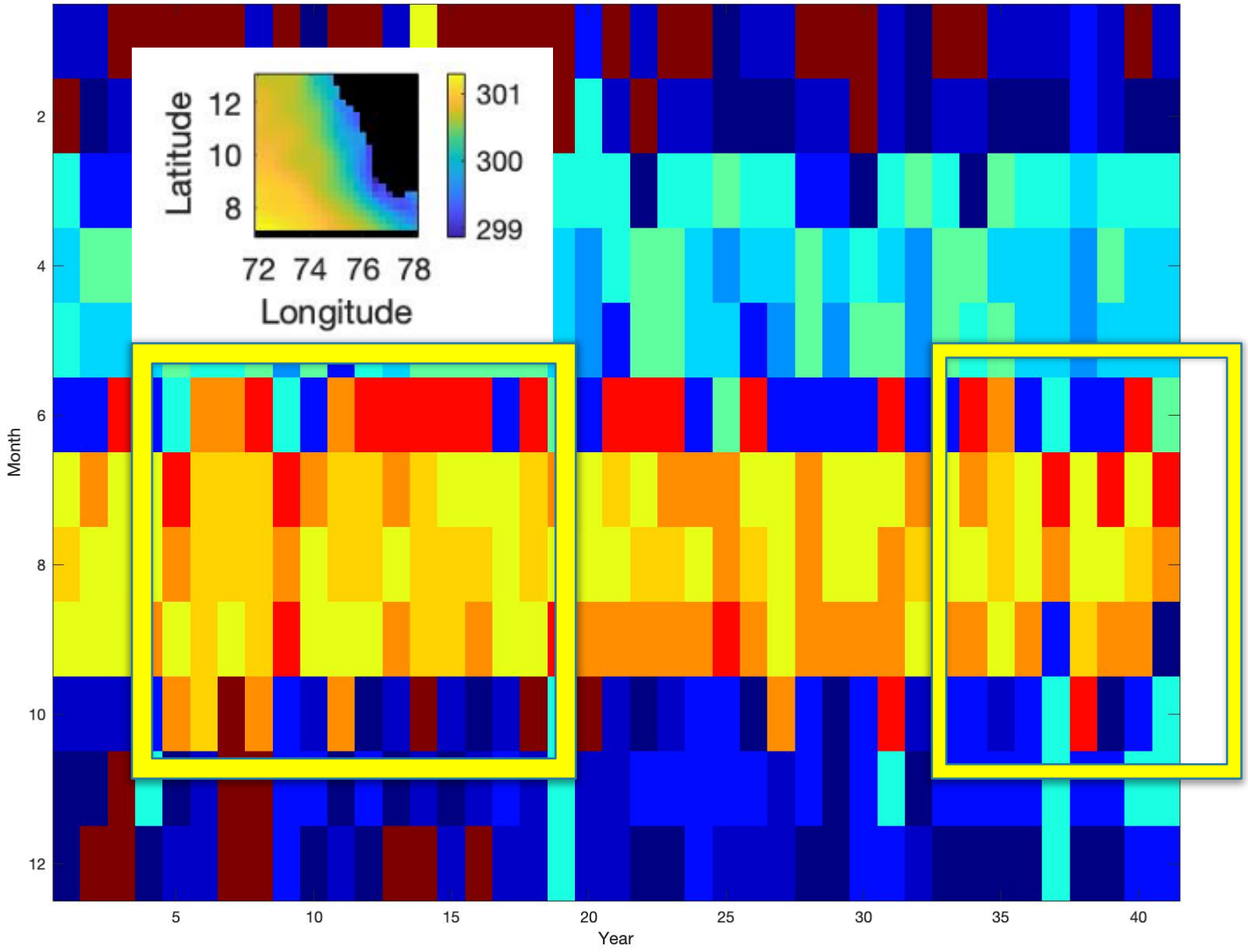
Seasonal and Yearly Pattern



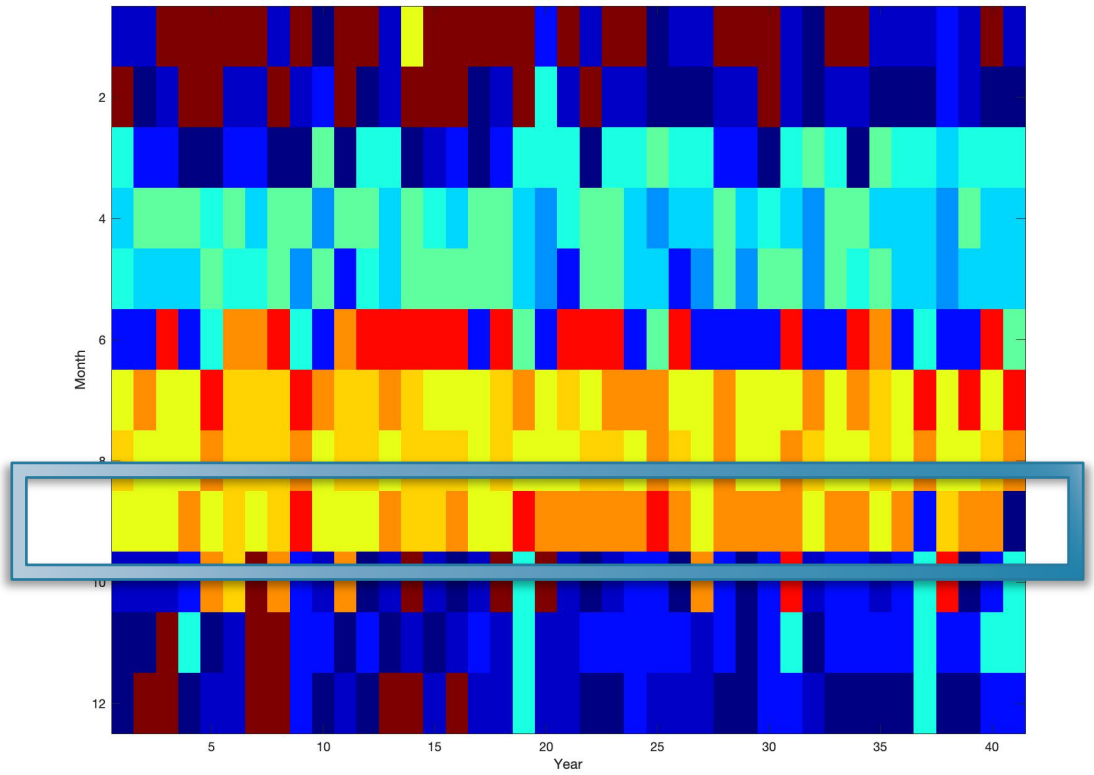
Summer Monsoon = Upwelling = Strong coastal cold zone

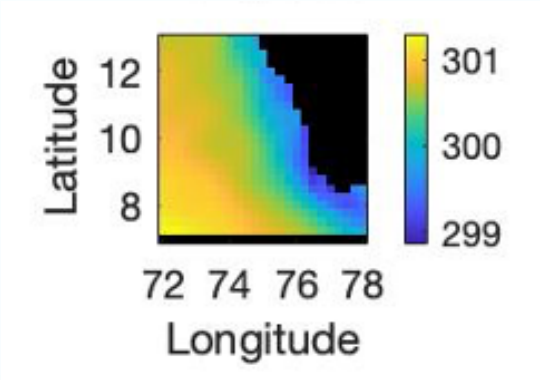


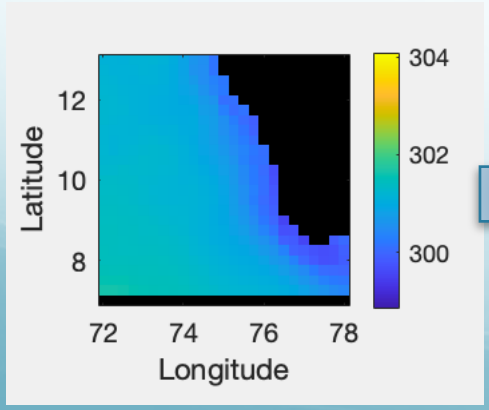
Shorter Upwelling Seasons

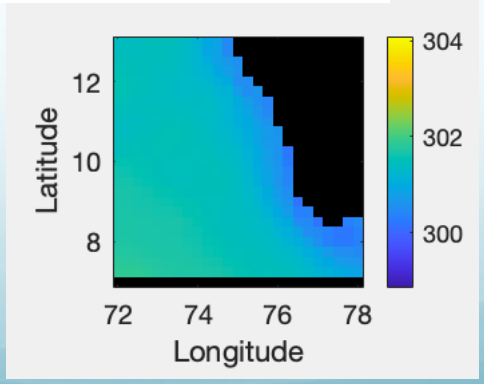


The Sept pattern did not change but the water warmed

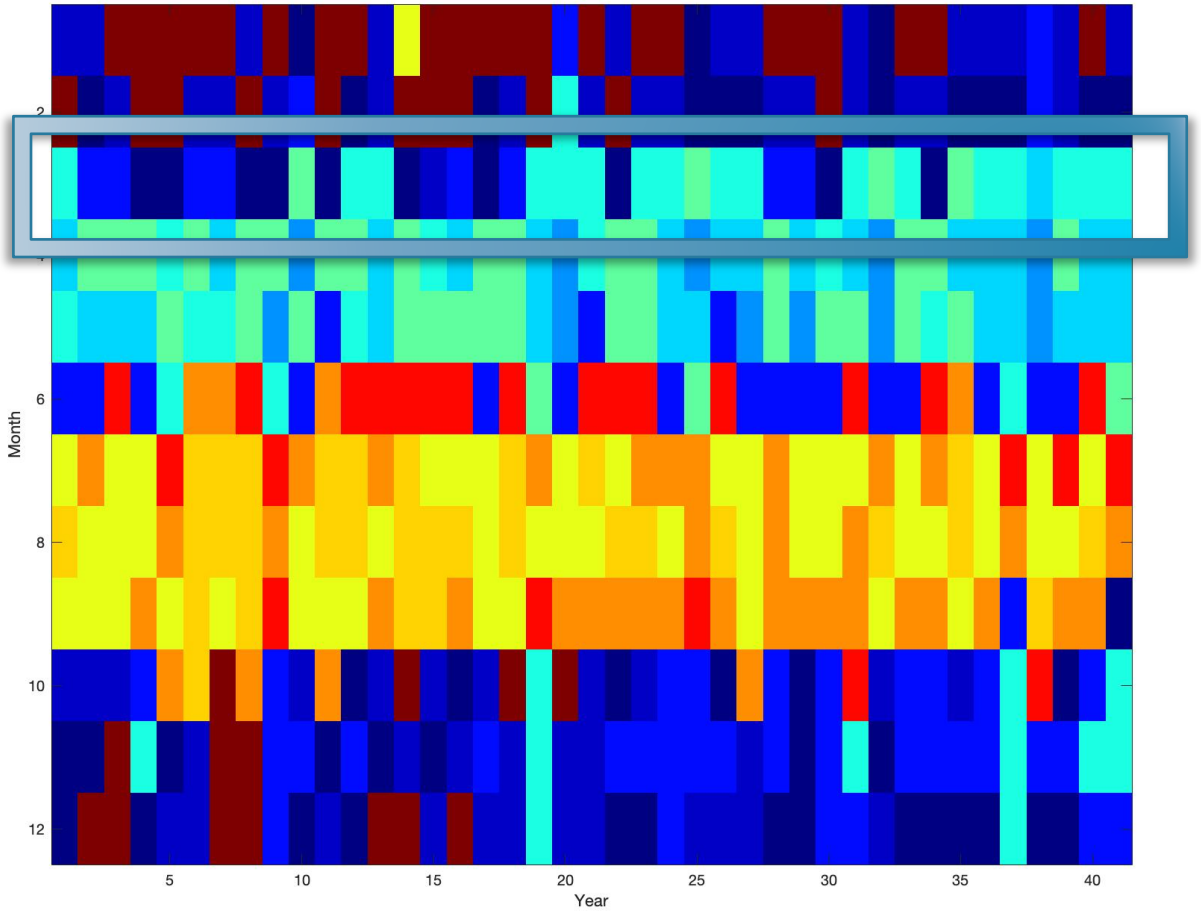








The Pattern of March Temperature Changing



Conclusions

From preliminary study

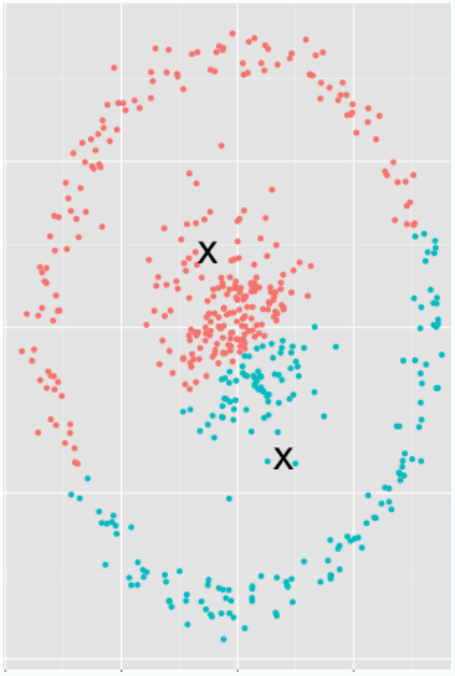
- K-Means was capable of detecting image clusters that make sense
- Upwelling Seasons seem to be changing (Shorter and warmer)
- Shows promise for evaluating how spatial pattern changes

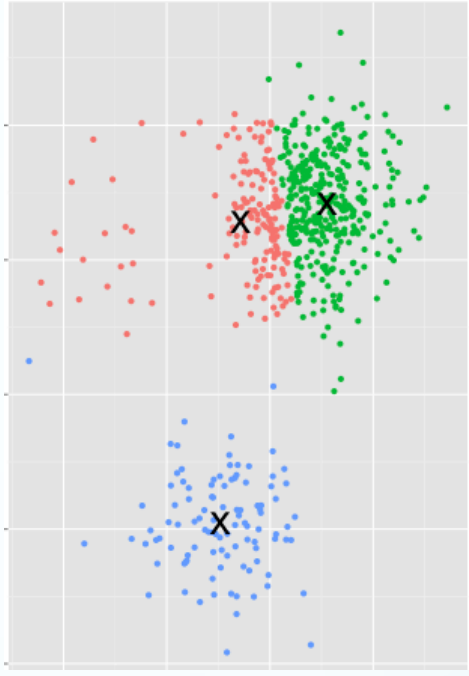
Next Steps (Upwelling Patterns)

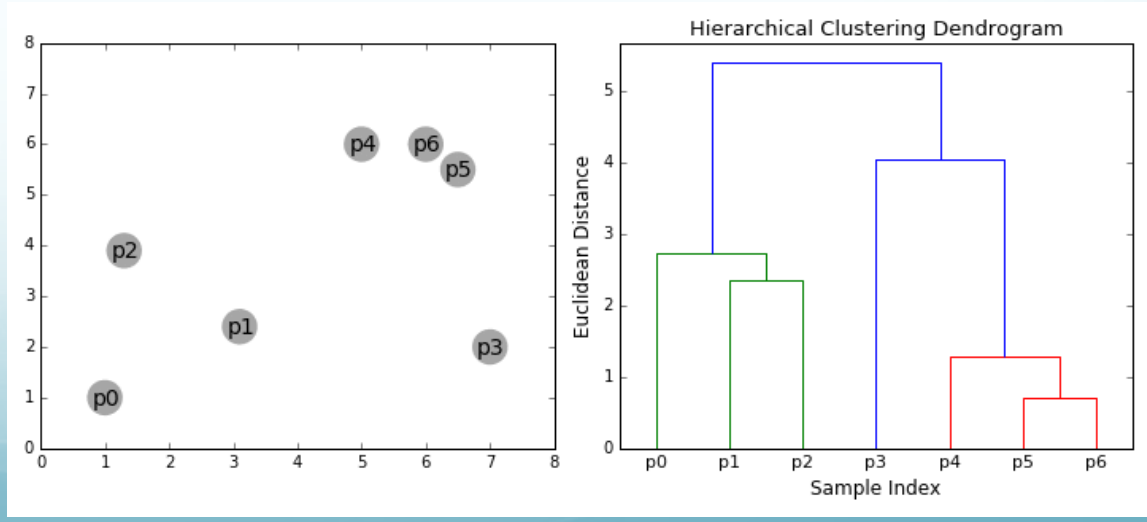
- New types of data (Wind, ect…)
- Analyze daily data and assign to groups
- Questions: Is the stability of the upwelling breaking down?

Next Steps (Algorithms)

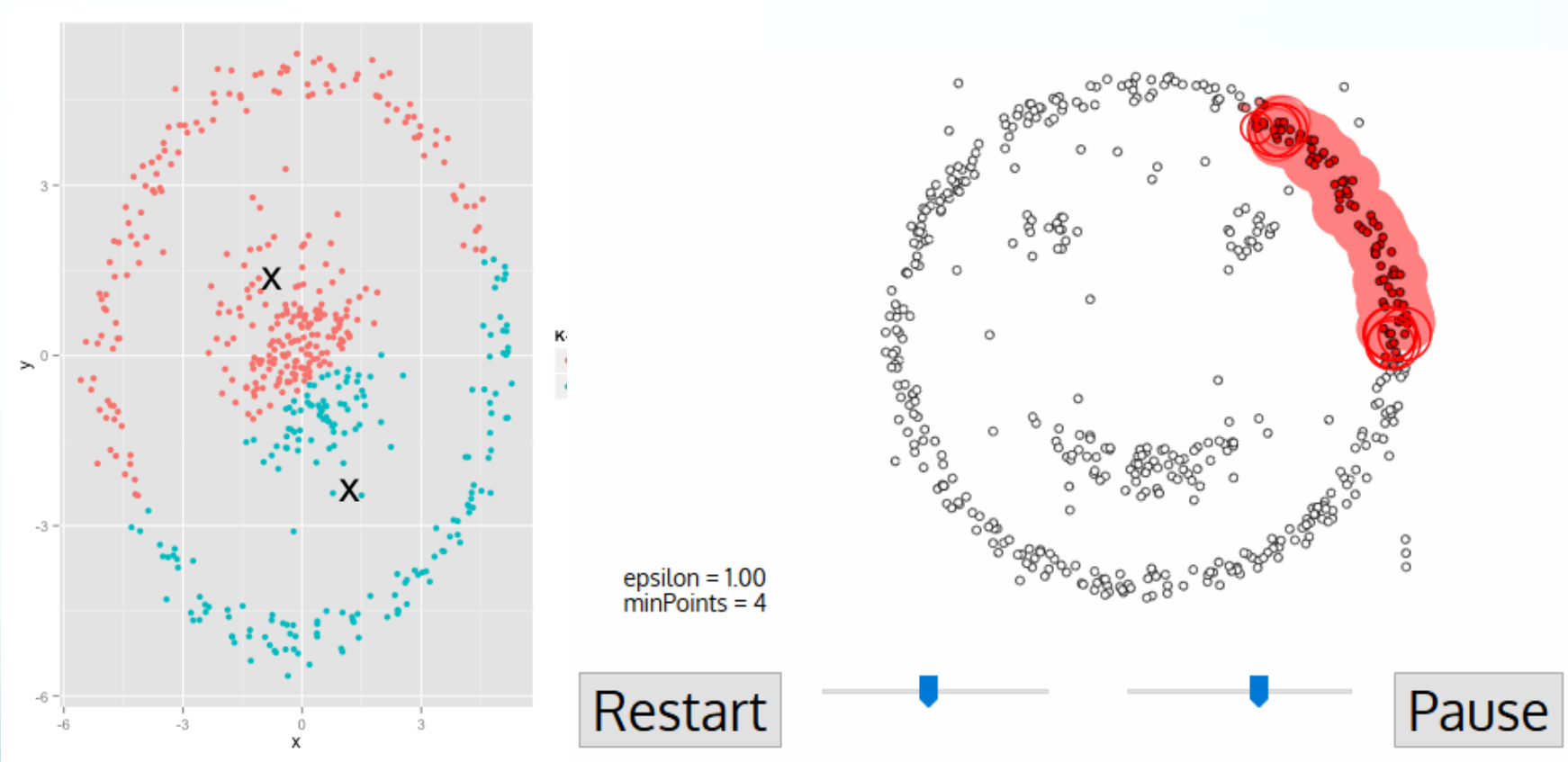
- Using different grouping algorithms
- DBSCAN, Hierarchical clustering…
- Anomaly detection algorithms
- Neural networks







jacob.t.zikan.23@Dartmouth.edu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