Practical Application of Parallel Coordinates to Hurricane Trend Analysis

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Contributions

✓ Validates the effectiveness of parallel coordinates for use in exploratory climate data analysis.

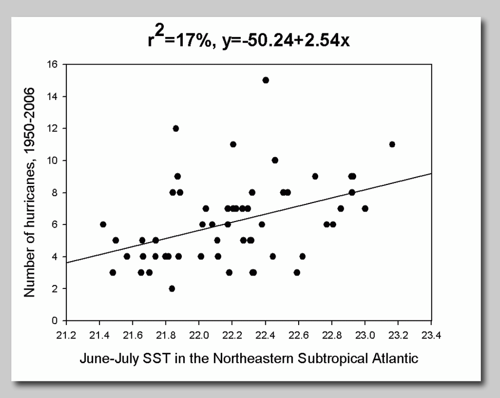
✓ New visualization approach for hurricane trend analysis that provides deeper understanding of environmental factors.

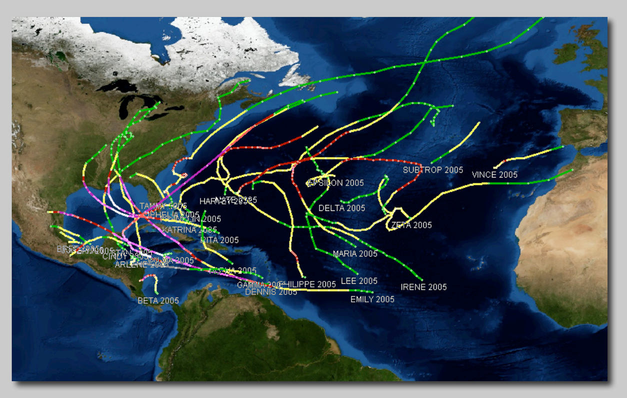
✓ Advanced parallel coordinates interaction framework within a sophisticated application.

Traditional Hurricane Analysis

Weather scientists predict seasonal statistics using statistical analysis and basic plots of climate data.

- Based on the idea that there are predictors (observed up to a year in advance) that affect the creation and development of tropical systems.
  - Examples: sea surface temperature (SST), sea level pressure (SLP), etc.
- Historical data used to identify predictors and estimate their importance using statistical regression.
  - An effective technique for screening data and obtaining quantitative associations.
- Researchers also rely on simple scatter plots or histograms for visual analysis.
  - Require multiple plots or layered plots to analyze multiple variables.
  - Suffer from several perceptual issues.
- Geographical maps are typically used for displaying georeferenced data.
  - Good at highlighting patterns directly related to geographical position.
  - Additional insight can be gleaned using non-geographical representations.
- **MOTIVATION: Researchers need new visualization techniques that are specifically designed to accommodate the simultaneous display of a high number of variables to support exploratory visual analysis.**





Parallel Coordinates Validation: North Atlantic Case Study

We demonstrate the promise of parallel coordinates for enriching the scientists' ability to rapidly discover and thoroughly analyze complex trends in climate data.

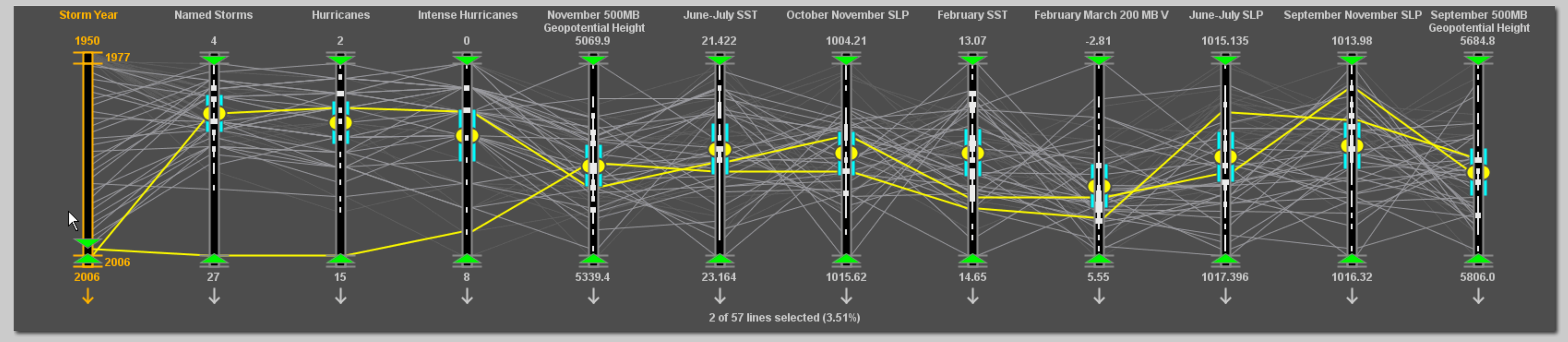
- We analyzed a data set with 16 seasonal North Atlantic predictors provided by Mr. Phil Klotzbach at Colorado State University.
- We collaborated with a hurricane expert, Dr. Patrick Fitzpatrick, to evaluate the effectiveness of our PC application when used in conjunction with traditional analysis methods.

Case Study Workflow

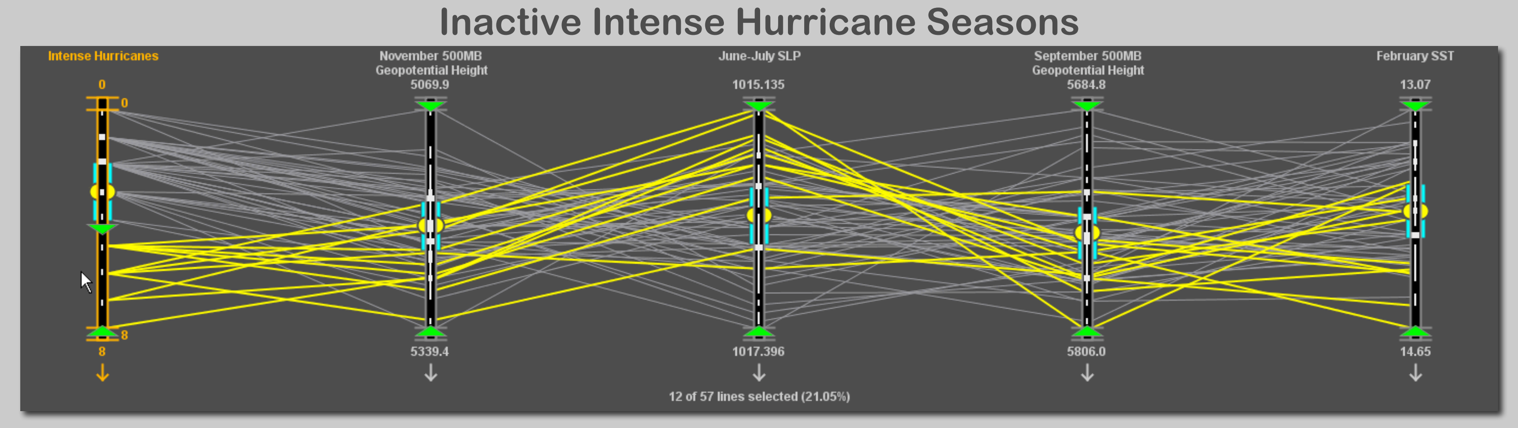
- First, we employed stepwise regression with a "backwards glance."
  - Selects the optimum number of most important variables using a predefined significance value (90% in this study).
  - Stepwise regression can compliment PC plots by isolating significant variables in a quantitative fashion.
  - 16 variables are examined in regression yielding 4 independent variables for each dependent variable.
- Next, we use the applications interactivity to develop a deeper understanding of the multi-dimensional relationships.
  - Chosen predictors are used to populate the PC plot along with the dependent variable.
  - Axes are manually arranged using regression rankings.
- Then, we use the query sliders to stratify the data set into active, normal, and inactive seasons.
  - Statistical indicators are used to identify the normal season range for the dependent variable.

Comparing Busy 2005 and Quiet 2006 Seasons

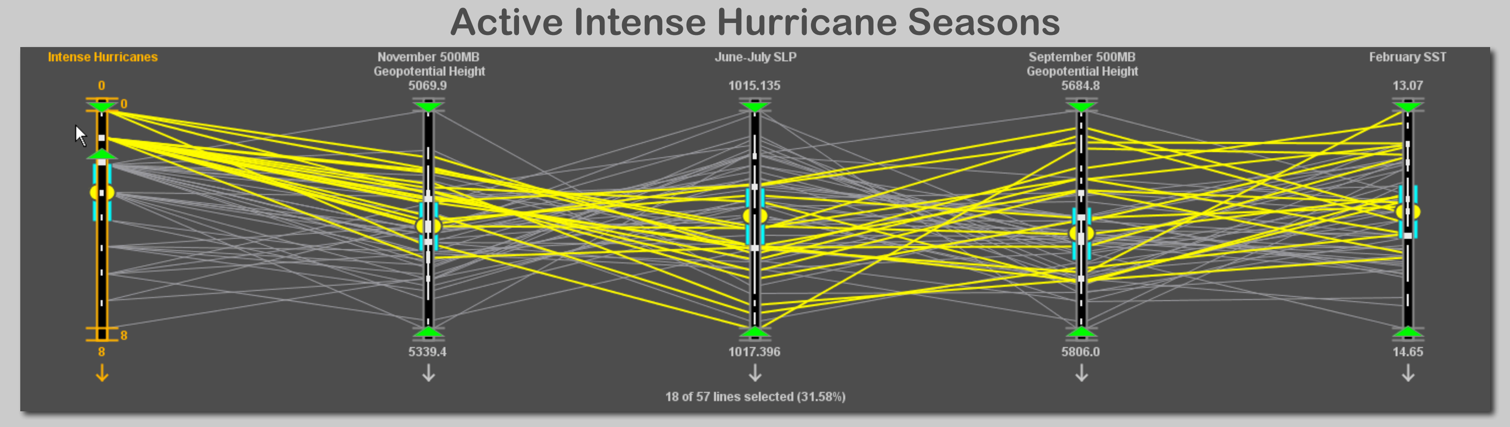
- These seasons were at opposite ends of the spectrum in terms of tropical cyclone activity.
- However, the variable values are nearly the same except June-July SLP and Oct. Nov. SLP.



Inactive Intense Hurricane Seasons



Active Intense Hurricane Seasons



Number of Intense Hurricanes

- An intense hurricane has low-level winds of at least 111 mph.
- Intense hurricanes cause 80% of destruction from tropical cyclones.

- Inactive season PC plot reveals that cold Feb. Atlantic SSTs and high June-July SLP tend to reduce the number of intense hurricanes.
  - September 500mb geopotential heights show no role

- All four predictors play dominant roles in active seasons.
  - Ridge presence in western U.S. and Atlantic show largest influence.
  - Since ridges are a low shear environment, this shows that the lack of upper level troughs is an important factor for seasons with many intense hurricanes.

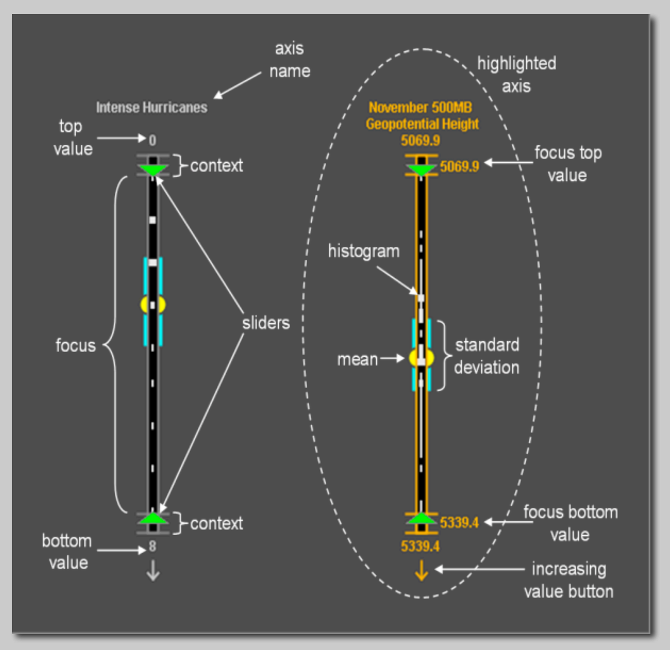
Number of Intense Hurricanes
R2 is 54%

Chosen Variables	Normalized Coefficients c	Sample Mean
Nov. 500-mb Geopot. Ht.	0.345	5213
June-July SLP	-0.315	1016.2
Sep. 500-mb Geopot. Ht.	0.292	5753.3
Feb. SST	0.235	13.8

Extreme Parallel Coordinates

We implemented several fundamental and some unique PC interaction capabilities and representation techniques in our climate study application.

- Implemented in Java 1.5.
- Interactive performance on a MacBook Pro 2.33 GHz.



Axis Widget Detail

- Representation of several key statistical quantities.
  - Mean, standard deviation range, and frequency information are displayed.
- Relocatable Axes
- Axis Inversion
- Details-on-Demand

The Way Ahead

Effectiveness validation and new interaction and representation methods are on the horizon.

- Examination of additional seasonal statistics and data sets.
- Develop more formal validation of PC application effectiveness.
- Formulate advanced interaction capabilities that enhance climate analysis.

References

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[3] A. Inselberg and B. Dimsdale. Parallel coordinates: A tool for visualizing multi-dimensional geometry. In Proceedings of IEEE Visualization 1990, pages 361–378, San Francisco, California, Oct. 1990. IEEE Computer Society.
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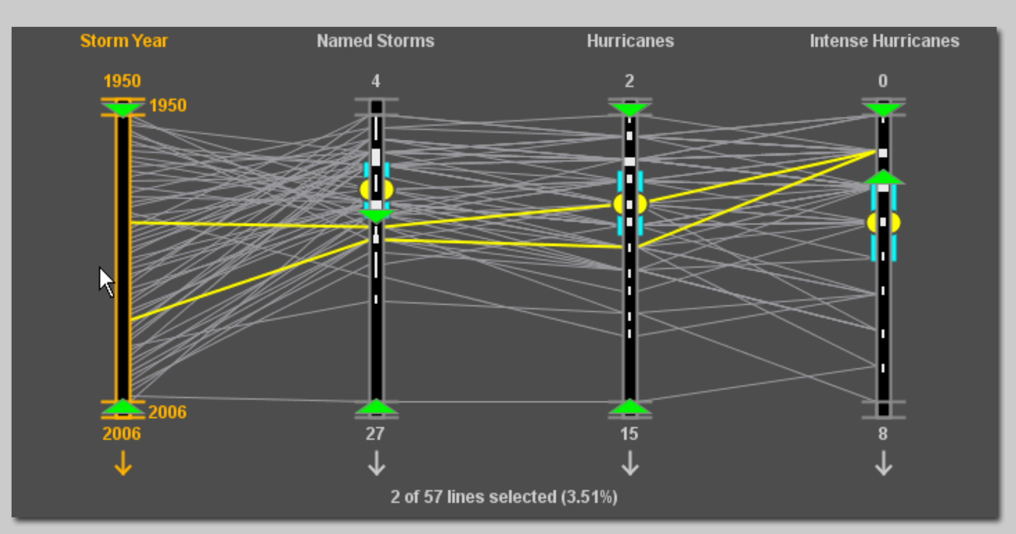
Rapid Visual Queries

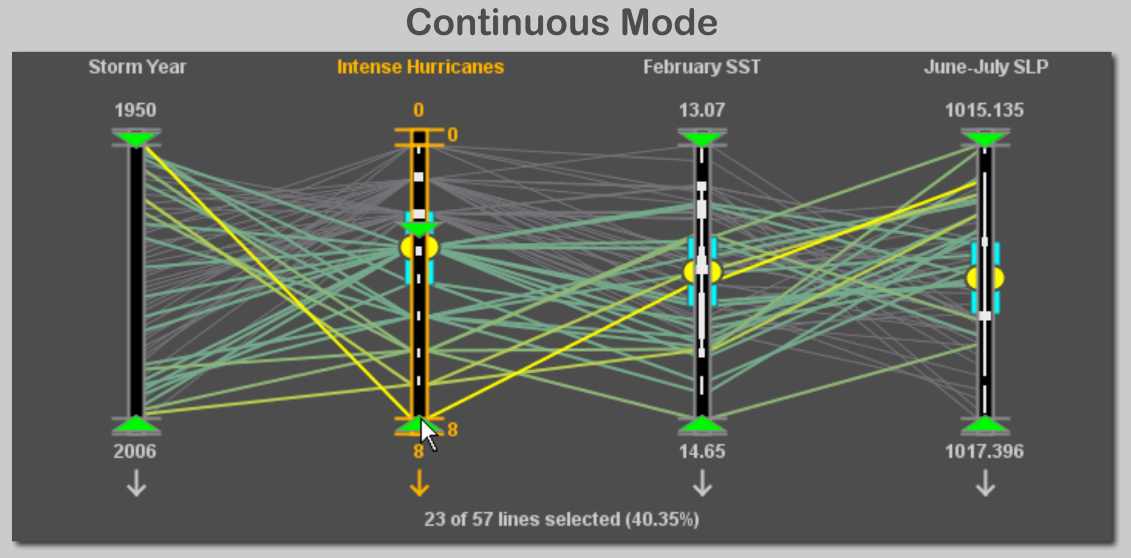
- Using query sliders reveals only 2 years had a high number of named storms and a low number of intense hurricanes.



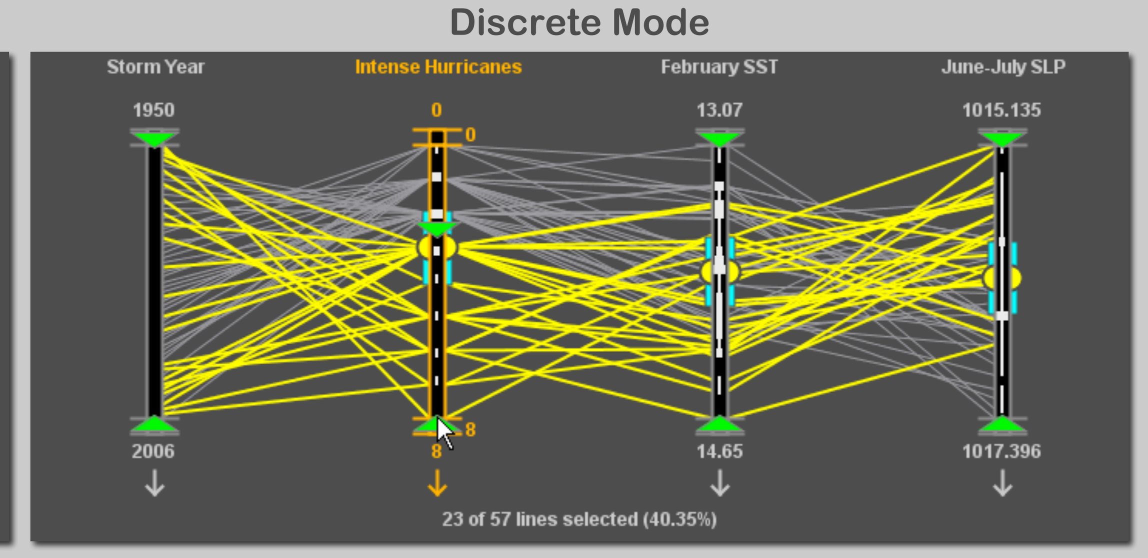
Aerial Perspective Shading

- Innovative line shading scheme is included for quickly monitoring trends due to the multi-dimensional similarities.
  - Simulates human perception of aerial perspective whereby objects in the distance appear dull while objects nearer to the eye seem more vivid.

Continuous Mode

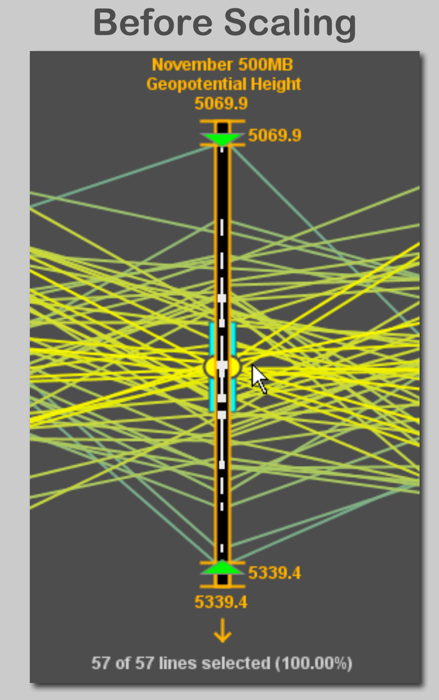


Discrete Mode

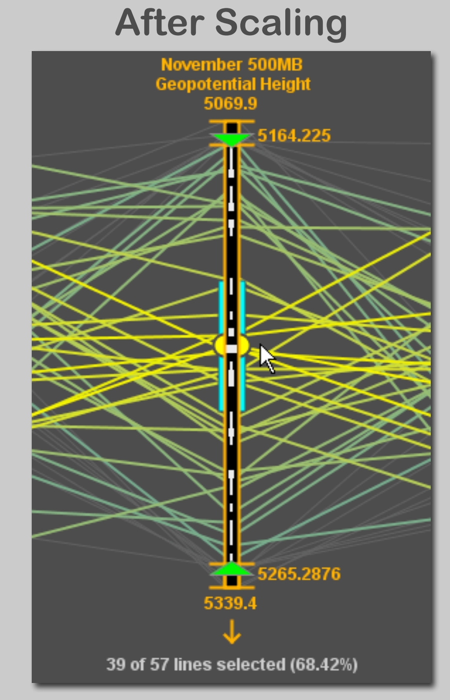


Axis Scaling

Before Scaling



After Scaling



- Focus+Context
- Interactively tunnel through data.
  - Observe a smaller subset of the original data.
- Dynamic modification of the minimum and maximum axis limits.
- Implemented with the mouse wheel functionality.