The Effect of Color Scales on Climate Scientists' Objective and Subjective Performance in Spatial Data Analysis Tasks

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Introduction

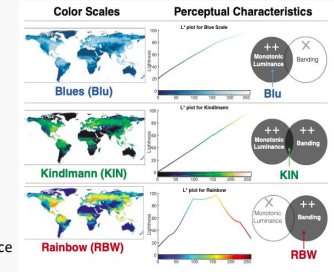
- Geographical maps encoded with rainbow color scales are widely used by climate scientists
  - De facto standard
- Evidence from literature show many shortcomings of rainbow color scale
- This study:
  - Explains potential reasons for the mismatch between theory and practice
  - Compares the effect of various color scales on performance accuracy
  - Investigates how user confidence with the rainbow scale influences performance accuracy and subjective impressions

Background Information

- Researchers focused exclusively on color scales for 2D scalar fields
- Two critical perceptual characteristics of a good color scale:
  - Luminance Monotonicity: increments in luminance should be monotonic with increase in value
  - Banding: the perception of bands of hues
- Researchers used 3 color scales in this study:
  - Blues (Blu)
  - Kindlmann (KIN)
  - Rainbow (RBW)

Color Scales and Their Properties

- Blues:
  - Single hue (blue)
  - Monotonic
  - No banding
- Kindlmann:
  - Monotonic
  - Banding
  - Alternative to RBW
- Rainbow:
  - Non-monotonically varying luminance
  - Banding

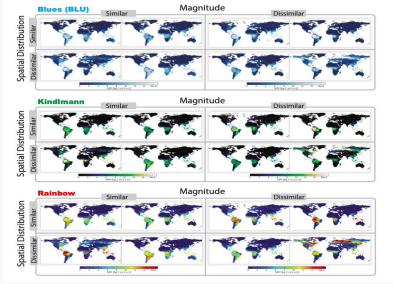


Study Design

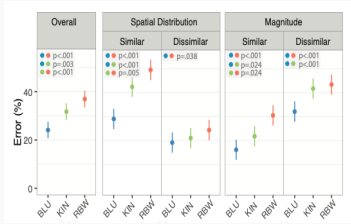
- 39 climate scientist participants
- Each was asked to complete 3 tasks on 4 map pairs using 3 color scales
  - Task 1: judge magnitude similarity in overall Gross Primary Productivity (GPP) between map pairs
  - Task 2: judge GPP spatial distribution similarity between map pairs
  - Task 3: judge maximum GPP spatial distribution difference between map pairs
- Participants also rated familiarity, preference, perceived accuracy, and comfort

Selection of Stimuli

- Map pairs differ in magnitude and spatial distribution
- Grouped based on difference in magnitude and spatial distribution
- Co-varied rows and columns

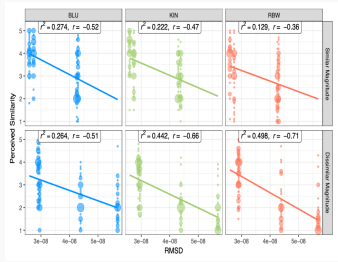


Results (Task 1) – GPP Magnitude Difference



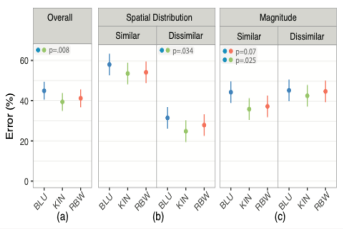
- % error in judging GPP magnitude plotted for each color scale is shown
- Overall effect: BLU < KIN < RBW
- Spatial distribution: BLU < KIN < RBW
- Magnitude: BLU < KIN < RBW
- Summary: monotonic luminance has positive effect, hue banding has negative effect on magnitude comparison

Results (Task 2) – Degree of Similarity



- Perceived similarity (rated on a Likert scale) is shown for each scale
- Y-axis: perceived similarity
- X-axis: computed dissimilarity
- Similar magnitude: BLU > KIN > RBW
- Dissimilar magnitude: RBW > KIN > BLU
- Summary: on average all 3 color scales provided equal benefit

Results (Task 3) – Maximum Difference



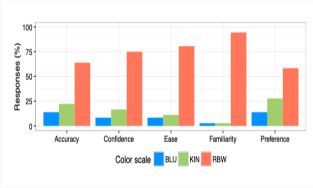
- % error in identifying the most dissimilar region is shown
- Overall: KIN < RBW < BLU
- Spatial distribution: KIN < RBW < BLU
- Magnitude: KIN < RBW < BLU
- Summary: hue banding enables more accurate judgements of differences in spatial distribution

Analyzing Subjective Performance Measures

- Another goal of the study was to compare the perceived accuracy and confidence of the scientists with objective performance:
  - confidence
  - perceived accuracy
  - ease of use of the color scales
  - familiarity
  - preference

Results

- Overall usage confidence:
  - RBW > KIN > BLU
- Overall perceived accuracy:
  - RBW > KIN > BLU
- Objective performance (average % of error):
  - RBW → 37.4%
  - KIN → 31.4%
  - BLU → 24.7%



Analysis Summary

- Who:
  - 39 anonymously-chosen climate scientists
- What:
  - Spatial data
  - Measure effectiveness of different color scales in climate modeling tasks
  - Subjective performance measures
- How:
  - counterbalanced user-study design
  - 3 different tasks of map pairs
  - 3 color scales co-varying in luminance monotonicity and hue banding

Critique

- Strengths:
  - Straightforward and well thought-out design study
  - Good selection of color scales that covaried in luminance monotonicity and hue banding
  - Nicely explores the limitations of rainbow color scale despite its popularity
- Weaknesses/Limitations:
  - Extremely small sample size (n=39, 3 color-blind participants)
  - Use of a *de facto* RBW scale with BLU or KIN scales
  - Confounding variable in RBW/KIN scale: pop-out effect?