



Next**GEN**

AWDE Ensemble Display Literature Review

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Topics

- Introduction
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- Definition
- Identified Domains
- Weather Ensemble Displays
- Summary
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Introduction

- AWDE conducted a literature review to gather information regarding the use of ensemble displays.
- This briefing provides the findings from the literature review including ensemble displays used throughout various domains.



Approach

- The literature review was conducted by:
 - Using various key words, such as multiple data display, to search the internet and several data bases. Databases include:
 - Science Direct database.
 - Google Scholar database.
 - All relevant articles were organized into folders by domain (i.e. weather, finance).
 - A spreadsheet was used to document all relevant articles. Information in the spreadsheet includes:
 - Title of article
 - Key words
 - Short summary
 - Domain
 - Source



Objectives

- Identify domains that use ensemble displays.
- Identify the types of ensembles displays used in the various domains.
- Identify issues in interpreting and using ensemble display data.
- Identify the benefits ensemble displays provide.



Ensemble Definition

- A group of items viewed as a whole rather than individually.
- Ensemble can be produced by:
 - Using different data sources.
 - Using different versions of the same model.
 - Using different initial conditions.
- In the weather industry, an ensemble is a collection of two or more forecasts for the same time period.



Domains and Ensemble Displays

- Financial Domain: Fan Plot
- Oceanography and Census/Population: Choropleth Mapping
- Medical: 3D Orientation Image
- Meteorology:
 - Hurricane Cone of Uncertainty
 - Plume Chart
 - Spaghetti Plot
 - Fan Plot
 - Box and Whisker Plot

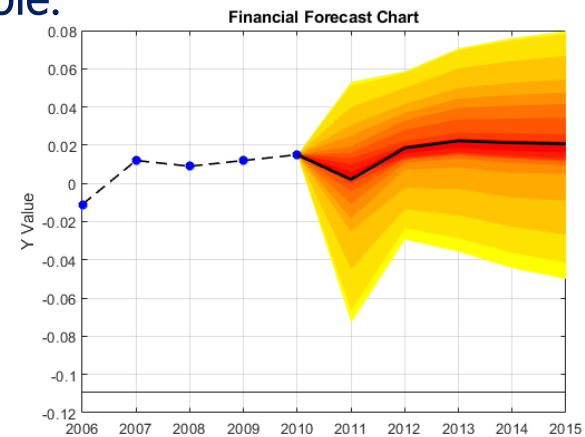


Financial Domain

Description:

- Type of display: Fan plot.
- Includes historical, current, and forecast data.
- Provides a mean and fan plot of forecast data.

Example:



Benefits:

- Uses color to draw the user's eyes to the most probable options.
- Provides a quick glance on certainty in the data.
- Provides a mean of the data.
- Provides "dots" to easily correlate historical data to the year.
- Provides a hashed line to connect the historical data to easily see trends.
- Provides historical, current, and forecasted data.

Issues:

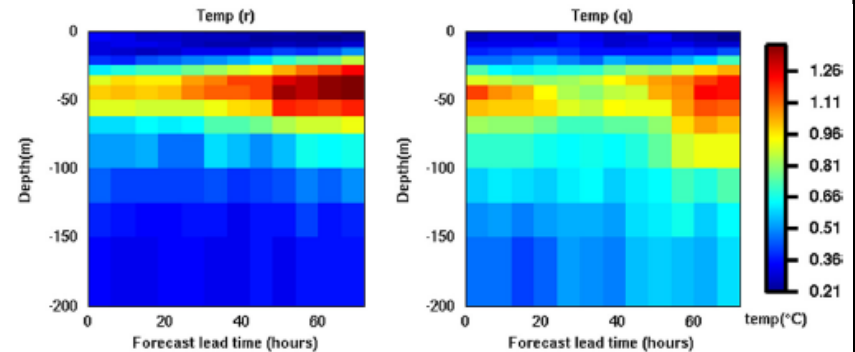
- Providing a range of data is difficult for users to interpret.
- Including the mean may cause the user to disregard less probable options.
- The colors are difficult to distinguish from one another.
- Specific data points are not available.

Oceanography

Description:

- Type of display: Choropleth map.
- Ocean temperature map.
- Areas are shaded in proportion to measured values.

Example:



(5)

Benefits:

- Provides a legend that correlates to the colors in the map.
- Easy for the user to see the changes in data based on color gradient.
- Colors convey additional information (i.e. blue cold, red hot).
- Can easily represent large amounts of data over any size of space.
- Provides the capability to easily interpret high level information with a quick glance.

Issues:

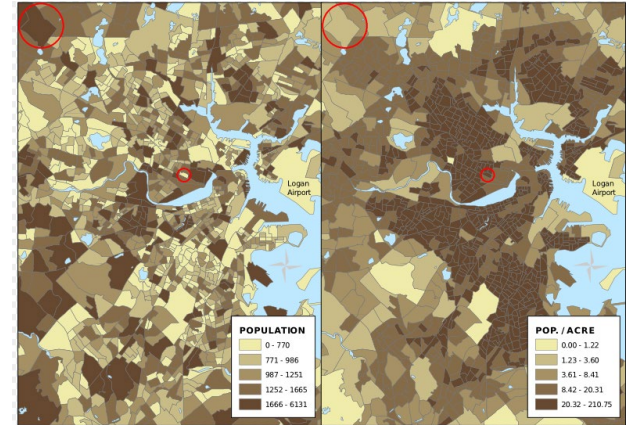
- Detailed information is not provided such as exact temperature readings.
- Does not accurately depict data over an area by using blocks of color.
- Give perception of an abrupt change at the boundary of the shaded unit.
- Certain ranges of colors are difficult to distinguish from one another (i.e., .21-.51)
- No capability to declutter by toggling on/off certain ranges of data.

Census/Population

Description:

- Type of display: Choropleth map.
- Population Density map.
- Areas are shaded in proportion to measured values.

Example:



(2)

Benefits:

- Provides legends that correlate to the colors in the maps.
- Easy for the user to see the changes in data based on color gradient.
- Can easily represent large amounts of data over any size of space.
- Provides the capability to easily interpret high level information with a quick glance.

Issues:

- Detailed information is not provided such as the exact population in area.
- Give perception of an abrupt change at the boundary of the shaded unit.
- Certain ranges of colors are difficult to distinguish from one another (i.e., 987-1251 and 1252-1665)
- No capability to declutter by toggling on/off certain ranges of data.

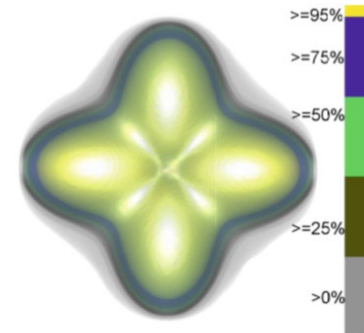


Medical Field

Description:

- Type of display: 3D orientation image.
- Uses area, direction, length and additional geometry to indicate uncertainty.
- Medical imaging uses measurements taken from different angles to construct the best CT or MRI image.

Example:



(4)

Benefits:

- Shape of the image provides a reference of what the image is displaying.
- Provides a legend to aid user in interpreting the data.
- Use of color distinguishes between ranges of data.
- Colors are easy to distinguish from one another.

Issues:

- Blurred colors are difficult to interpret and do not correlate to the legend.
- Users previous experience with diagnosing a specific problem or viewing clear scans may influence interpretation of image.
- Use of visual cues such as depth and perspective make it difficult to interpret and compare data.
- Data may overlap and cover pertinent information.

Weather Ensemble Displays

- Hurricane Cone of Uncertainty
- Plume Chart
- Spaghetti Plot
- Fan Plot
- Box and Whisker Plot



Hurricane Cone of Uncertainty

Description:

- Type of display: Cone of uncertainty.
- Shows certainty estimates (increasing to decreasing or vice-versa) over a period of time.

Example:



Benefits:

- Provides a quick glance on certainty in the data.
- Quick analysis of most probable storm track.
- Easy to determine possible location of the storm at specific times.

Issues:

- Users misinterpret the size of the cone as correlating to the size of the storm.
- Cone contains the path of the storm center but does not show the storm size.
- Not all possible tracks are shown.
- Mean line becomes a focus point and all probabilities are not considered.
- People outside the cone have a false sense of security and can be impacted by the storm.

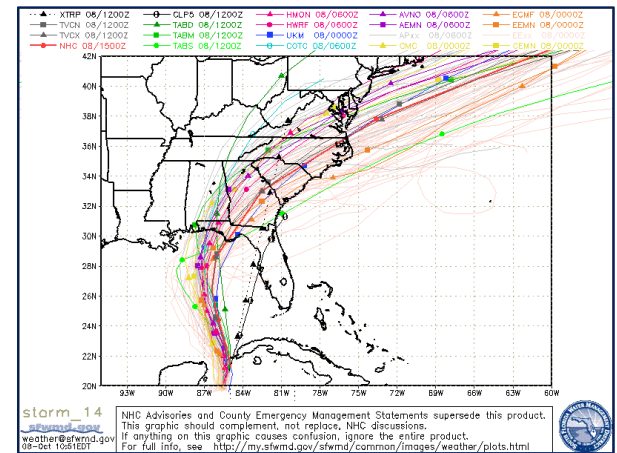


Plume Chart

Description:

- Type of display: Plume Chart.
- Depicts all probabilities of potential model values.

Example:



Benefits:

- Depicts all or a majority of the data including outliers.
- Easy to determine if the data are in agreement.
- Uses color coding to differentiate between the data.
- Provides a legend that clearly correlates with data presented in the display.
- Provides the capability to toggle on/off, to de-clutter, and view specific data sets.

Issues:

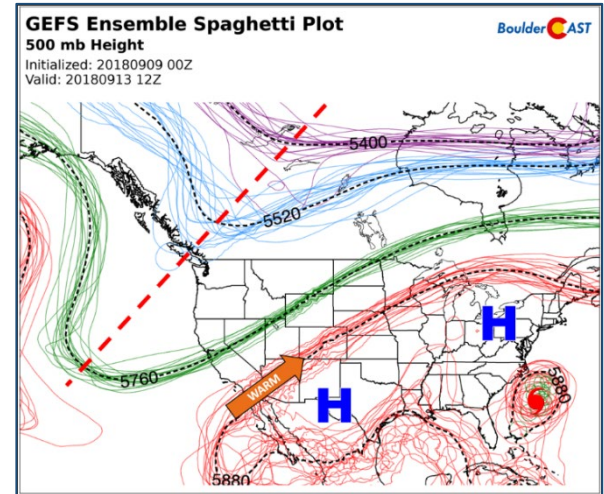
- Data is cluttered making it difficult to differentiate between the data.
- Users may disregard the outliers as potential paths of the storm and focus on the predominate path.
- Difficult to make a decision based on the wide range of data.

Spaghetti Plot

Description:

- Type of display: Spaghetti plot.
- Simultaneously displays predictions from multiple models.

Example:



Benefits:

- Depicts all or a majority of the data including outliers.
- Easy to determine if the data are in agreement.
- Uses color coding to differentiate between some of the data.
- Provides a legend that clearly correlates with data presented in the display.
- Includes icons and numbers to provide the user additional information.

Issues:

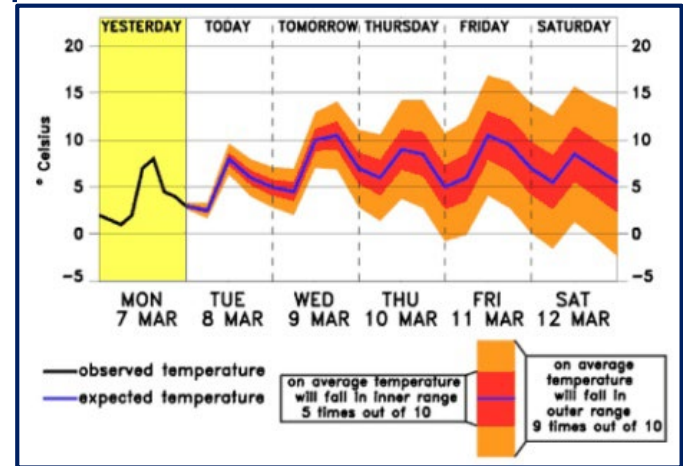
- Data is cluttered making it difficult to differentiate between the data.
- Mean line can cause users to become focused only on one probability ⁽¹⁾.
- Difficult to make a decision based on the range of data.

Fan Plot

Description:

- Type of display: Fan plot.
- Includes historical, current and forecast data.
- Displays range of data for forecasted time period.

Example:



Benefits:

- Provides a quick glance on certainty in the data.
- Use color coding to differentiate between probabilities.
- Provides a legend to aid in interpreting data.
- Provides a line to connect the historical data to easily see trends.
- Provides historical, current, and forecasted data.

Issues:

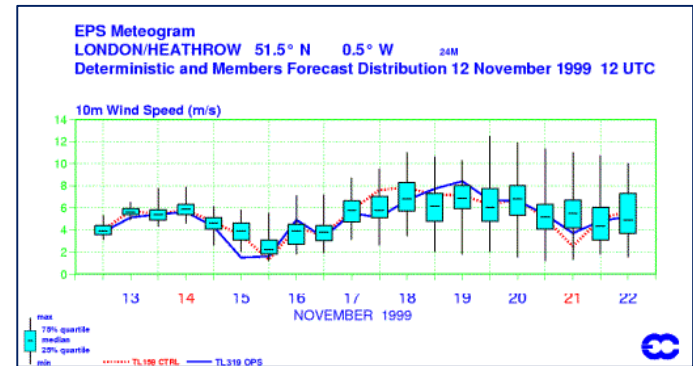
- Specific data points are not available.
- Provides a range of data that is difficult for users to interpret.
- Including the observed value line may cause the user to follow the expected value line and disregard less probable options.

Box and Whisker Plot

Description:

- Type of display: Box and whisker plot.
- Graphic way to display median, quartiles, and extremes of a data set.

Example:



(3)

Benefits:

- Provides summary information for large data sets to display the trends in the data.
- The spread and symmetry of the data can be ascertained in a glance.
- Outliers can quickly be identified since they are shown outside the box.

Issues:

- Specific data points are not available.
- Box and whisker plots only provide a simple summary which includes the median, quartiles, and minimum and maximum data points.
- The line in the box indicates the median which users may interpret as the mean.



Summary

Objective 1: Identify domains that use ensemble displays.

After conducting the literature review, it was found ensemble displays are not used in many domains. The predominant domains that use ensemble displays are the financial, oceanographic, census/population mapping, medical, and meteorology fields.

Objective 2: Identify the types of ensembles displays used in the various domains.

The most typical types of ensemble displays used in domains identified are fan charts, choropleth mapping, 3D orientation image, hurricane cone of uncertainty, spaghetti plot, plume, fan plot, and box and whisker plot.



Summary Continued

Objective 3: Identify issues in interpreting and using ensemble display data.

Issues in interpreting and using ensemble displays are:

- Increased time and workload to process all the possible forecast options and make a decision considering all the data including the outliers.
- Mean line becomes a focus point and all probabilities are not considered.
- Data is often cluttered and not easily differentiated.
- Color-coding of display can be misinterpreted if colors used have a different meaning than the information being conveyed.
- Expertise can influence the users interpretation of the information displayed.



Summary Continued

Objective 4: Identify the benefits ensemble displays provide.

The benefits using ensemble displays include:

- Depicts all or a majority of the data including outliers.
- Shows multiple model probabilities over a time period.
- Easy to determine if the models are in agreement.
- Provides a visual display for people to make decisions that are costly and have a high impact on health and safety.
- Features such as icons, icons combined with numbers, framing and borders, color coding and toggle on and off ensemble members allow users tools to help interpret the information.



Next Steps

- Develop Mock-ups of potential ensemble displays.
- Conduct interviews to determine how users would use ensemble displays in an operational environment to support decision-making.
- Potential users are:
 - Pilots (GA and HEMS Pilots)
 - Traffic Flow Managers (TFM)
 - Dispatchers
 - Center Weather Service Units (CWSU)s
 - National Aviation Meteorologists (NAM)s



Recommended Ensemble Features

Based on AWDE's literature review, the following features are best design practices, and should be incorporated when designing ensemble displays.

- Legend to clearly identify the information displayed.
- Colors need to represent user mental models. For example, **red** = hot and **blue** = cold, **red** = alert and **yellow** = warning.
- Colors need to be distinguishable from each other.
- Ability to toggle on and off features such as data points, mean, etc.
- Ability to show all data points including outliers.



References

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2. https://en.wikipedia.org/wiki/Choropleth_map#/media/File:Choropleth-density.png
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4. Potter, K., Rosen, P., & Johnson, C. R., (2011). From Quantification to Visualization: A Taxonomy of Uncertainty Visualization Approaches. *International Federation for Information Processing Advances in Information and Communication Technology* (377), 226-249.
5. Wei, M., et al., The performance of the US Navy's RELO ensemble, NCOM, HYCOM during the period of GLAD at-sea experiment in the Gulf of Mexico. *Deep-Sea Res. II* (2013), <http://dx.doi.org/10.1016/j.dsr2.2013.09.002>.

