Uncertainty and Spatial Transformations in Complex Visualizations

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Imagine a meteorologist preparing a weather forecast. In addition to years of experience and a vast store of domain knowledge, the forecaster has access to satellite images, to computer–generated weather models and programs to display them in a variety of ways, and to an assortment of special-purpose tools that provide additional task-relevant data. There is no shortage of data, yet despite this array of resources, the task remains very challenging. One source of complexity is the uncertainty inherent in these data, uncertainty that takes many forms. Why are two weather models making different predictions? Are the models based on many observations or just a few? Are there enough observations in the model to trust it? Is one model more reliable than another in certain circumstances, and if so, what are they? Which one, if either, should he believe? How long ago were these data collected? How have things changed since the data were originally displayed? What is the real location of this front, and how is it affected by other changing variables, such as wind direction and speed, which may also have changed?

To complicate matters further, the uncertainty in the data is not explicitly represented; rather, the visualizations indicate that the data *are* exactly as they *appear*. Figure 1, below, shows an example of the problem. The visualizations shows the output of a computational weather model that attempts to predict what the weather will be sometime in the future. The model data itself is highly uncertain, yet it is displayed as if it were certain. The visualization thus invites the forecaster to map uncertain data to certain values, yet to do so would most likely lead to erroneous predictions. How does he manage this incongruity, in order to develop the most accurate forecast possible?

I suggest that in order to understand these complex visualizations, experts use spatial transformations (cognitive operations that a person performs on an internal representation (e.g., a mental image) or an external visualization (e.g., a computer-generated image)) to add their own understanding of uncertainty. For example, a forecaster may mentally move around the location of a front and play with different scenarios in conditions of uncertainty. I have gathered data on two different domains that use complex visualizations: METOC (Meteorological and Oceanographic) forecasting and fMRI (functional Magnetic Resonance Imagery) and explore how the process of spatial transformations reduces the amount of internal uncertainty for experts in these domains.

Importantly, I will show a variety of different methods that can be used from in vivo protocol analysis to after-action interviews.

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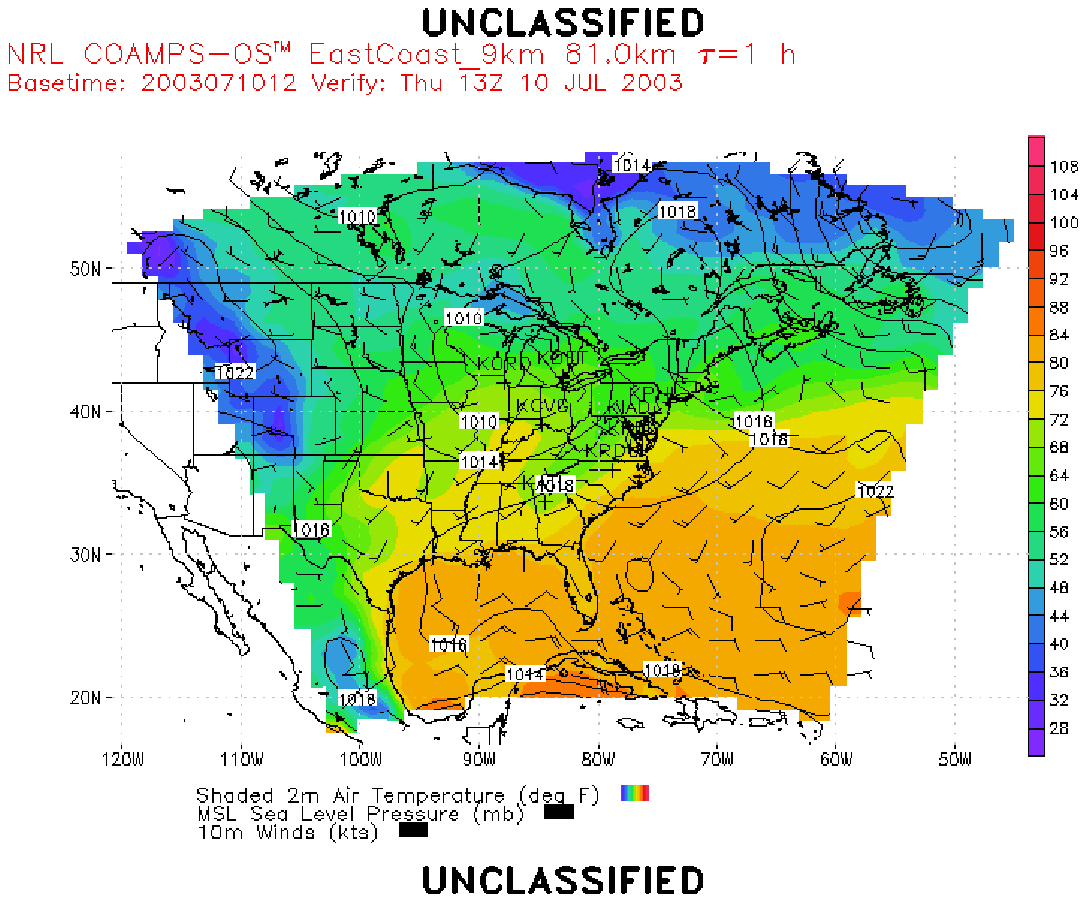

Figure 1: Example of a COAMPS Product Showing Temperature (color coded), Sea Level Pressure (iso-lines), and Wind Speed and Direction (wind-barbs). This visualization came from http://hail.nrlmry.navy.mil/COAMPS-bin/COWEB_vis_main.tcl?user=coamps.