VISUALIZATION OF UNCERTAINTY AND ENSEMBLE DATA: EXPLORATION OF CLIMATE MODELING AND WEATHER FORECAST DATA WITH INTEGRATED VISUS-CDAT SYSTEMS

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To explore the relationships present in numerical predictions of the atmosphere, climate and weather researchers produce "ensemble datasets" which combine multiple prediction models run using numerous parameter perturbations and varying initial conditions. These data sets mitigate as well as describe the uncertainty present in the data by providing insight into the effects of parameter perturbation, sensitivity to initial conditions, and inconsistencies in model outcomes. As such, massive amounts of data are produced, creating challenges both in data analysis and in visualization. This work presents an approach to understanding ensembles by using a collection of statistical descriptors to summarize the data, and displaying these descriptors using variety of visualization techniques which are familiar to domain experts. The resulting techniques are integrated into the ViSUS/Climate Data and Analysis Tools (CDAT) system designed to provide a directly accessible, complex visualization framework to atmospheric researchers.

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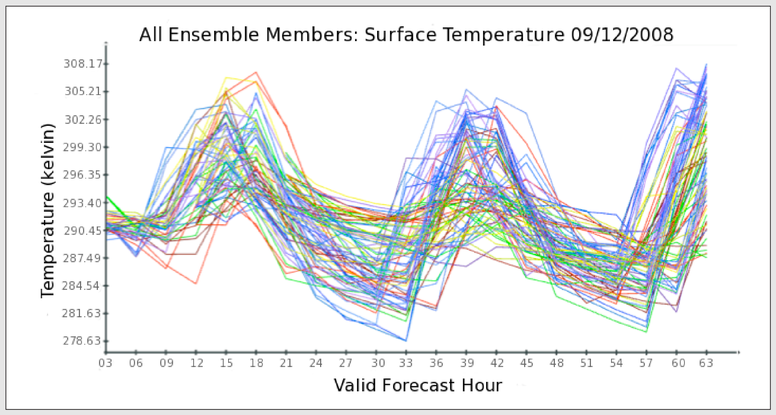
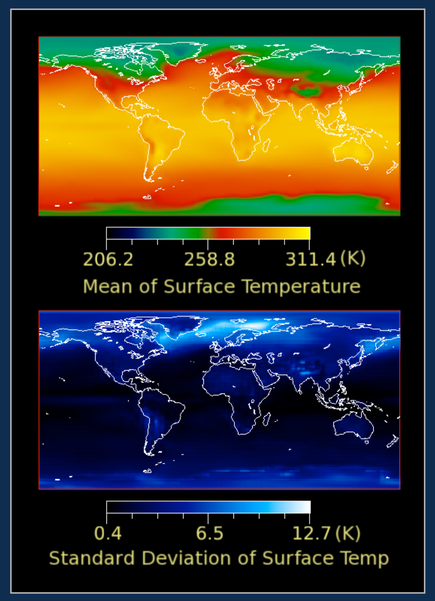
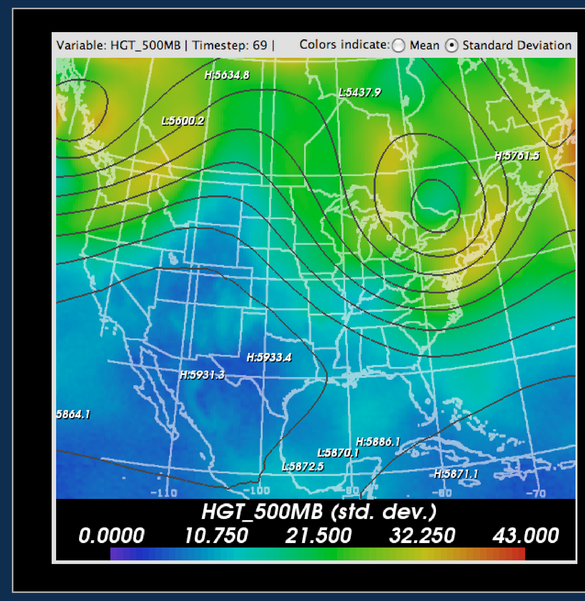
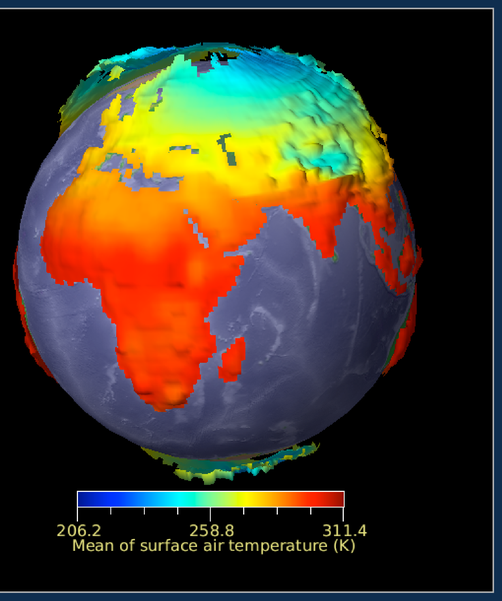


Above: An ensemble dataset combines multiple models, parameter perturbations, and initial conditions to create a collection of members that describes the possible outcomes of a simulation. Each ensemble member predicts a number of variables across a spatial domain and through time. The complexity of the ensemble is revealed when presenting all members at once and demonstrates the need for better visualization tools to improve understanding.

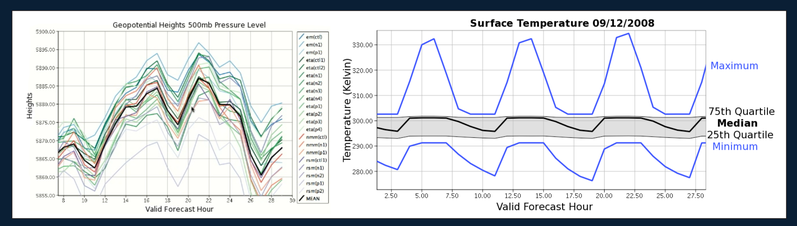




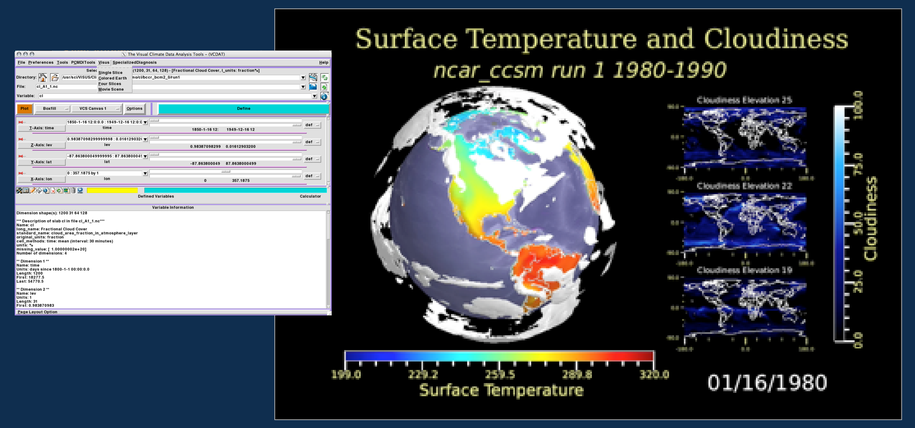


Above left: Mean and standard deviation are two statistical descriptors which effectively summarize the results of an ensemble dataset. Mean presents the average of all ensemble members while standard deviation describes the variation across the collection. This variation can also be termed "uncertainty", and indicates the level of confidence, or trustworthiness of the data.

Above right: Combining the visualization of mean and standard deviation compactly presents a summary of the data. Colormaps, heightfields and isocontours are examples of techniques for visualization and are tools familiar to atmospheric scientists.



Left: Two dimensional charts present the data by removing the spatial component, either through summarization across space, or the selection of specific locations. These charts reveal more information than mean and standard deviation by showing individual model runs or the range of outcomes. This is important, for example, when the data is not normally distributed, or the variation between ensemble members is high and further investigation is warranted.



Left: ViSUS/CDAT is the framework used to visualize ensemble data and is developed as a collaboration with the Earth System Grid Center for Enabling Technologies (ESG-CET), A Scalable and Extensible Earth System Model for Climate Change Science, and the climate modeling community in general. CDAT, or the Climate Data Analysis Tools, are a set of utilities specifically designed for the needs of climate researchers, providing advanced data analysis combined with the ability of reading specific data formats, supplying geospatial information and supporting a high level user interface. ViSUS is an integrated 3D visualization package, providing sophisticated visualization techniques seamlessly to climate scientists. The incorporation of ViSUS with CDAT provides a flexible system for the visualization of large ensemble datasets and is founded on the tight integration of 3D visualization tools, statistical data analysis techniques and compelling metaphors.