Visualizing Ensemble Data in Scale Space

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Abstract

Ensemble visualization has become an important means for analyzing the ensemble simulation results. One challenge in ensemble visualization is the overwhelming amount of details that disguise important large-scale features. This poster applies the scale space methods to ensemble data visualization. Features extracted from data like extrema points, maximal/minimal curvature points, and contours are constructed and shown in scale space. This helps remove small features at a high scale in visualization and facilitates the comparison between ensemble members and the identification of differences at varying scales, making it easier to focus on features of a certain size and the key differences among separate ensemble members. The results show that our method is useful in a research environment, in particular, for feature tracking and identification of large-scale phenomena within ensemble data sets.

Objectives

- To design a framework for visualizing 2D and 3D geospatial ensemble data in scale space.
- To design several methods for tracking features in scale space.
- To improve comparison between ensemble members in scale space with contours, isosurfaces, and key points.
- To allow users to interactively select different scales at different locations of the same data.

Scale Space Construction

2D Scale Space

If 2D data can be represented as the equation *f(x, y)* with *x* and *y* being coordinates, then the scale space data can be calculated as [1] [2] [3] [4] [5]:

$$f(x,y) = f_0(x,y) * G(x,y,\sigma) = f(x,y) * \frac{1}{2\pi}\theta^{-\frac{x^2+y^2}{2\sigma^2}}$$

3D Scale Space

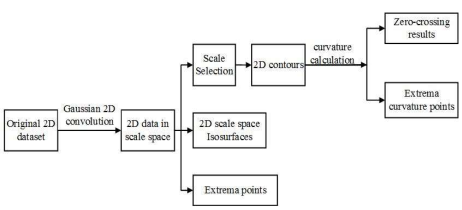
If 3D data are defined as *f(x, y, z), x, y* and *z* being 3D coordinates. Then the scale space data are calculated as:

$$f(x,y,z) = f_0(x,y,z) * G(x,y,z,\sigma) = f(x,y,z) * \frac{1}{2\pi}\theta^{-\frac{x^2+y^2+z^2}{2\sigma^2}}$$

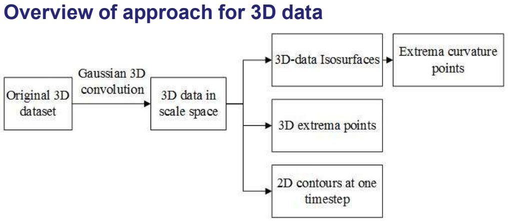
In above, * denotes convolution, *G* is the Gaussian filter, σ is the standard deviation of the Gaussian filter, which is also called the scale space parameter and decides the degree of coarseness of the resulting image.

Techniques

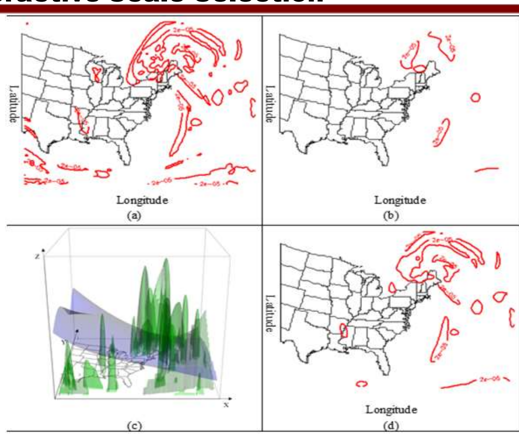
Overview of approach for 2D data



Overview of approach for 3D data

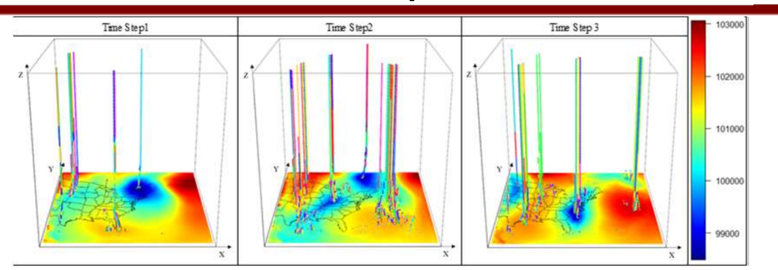


Interactive Scale Selection



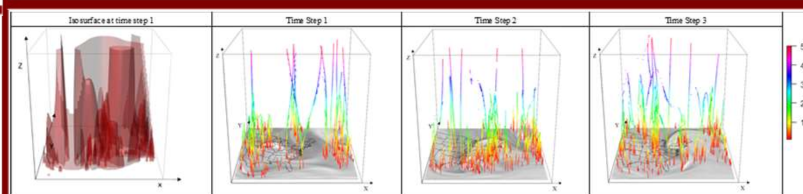
Interactive scale selection. (a) Contours where only low scale is selected. (b) Contours where only high scale is selected. (c): Interactive scale selection allows the user to select an arbitrary scale surface (in blue), which intersects the 2D scale space isosurface (in green) of absolute vorticity from the weather data at multiple scales. The x axis is longitude, y is latitude, and z is scale. (d): Resulting contours with the user-selected scale surface.

Extrema Points Evolution Scale Space

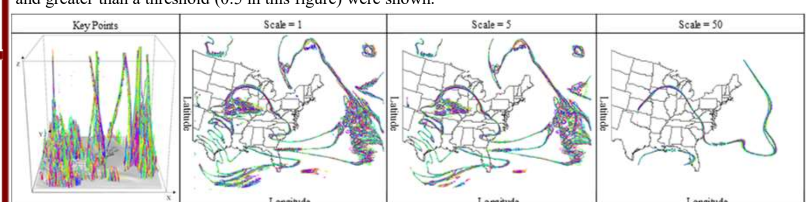


Extrema points evaluation in scale space. The mean sea level pressure of the cyclone data was used. Three time steps are shown in three columns. The images show the evolution of minima-maxima of 30 ensemble members differentiated by color in scale space. The z axis represents scale, x is longitude, and y is latitude.

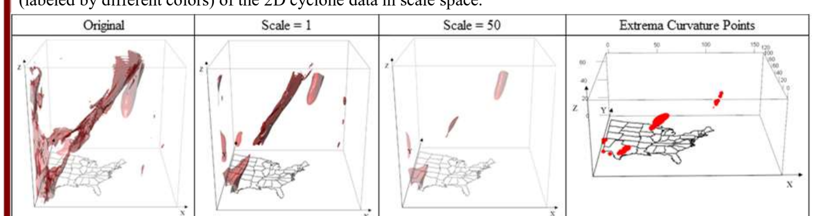
Isosurface, contours, and curvature Extrema points, evolution in scale space



Left picture shows the isosurface of absolute vorticity value at time step 1 in scale space, the isovalue is set to 0.0001s-1. The three pictures to the right show contour curvature extrema points evolutions of absolute vorticity value at time steps 1, 2, and 3 in scale space. Scale increases along z axis, x is longitude, and y is latitude. Rainbow colors represent scales ranging from red to purple. Those points whose curvatures are local extrema and greater than a threshold (0.5 in this figure) were shown.



Contour curvature extrema points visualization (left) and contour visualization for 30 ensemble members (labeled by different colors) of the 2D cyclone data in scale space.



Isosurfaces and extrema curvature points visualization for one ensemble member of the 3D cyclone data in scale space. Specific humidity was used. In isosurface visualization, the 3D data is visualized at original, scale 1 and scale 50 respectively. In extrema curvature points visualization, extrema on Gaussian curvatures are visualized. In this figure, z axis represents time steps, which increase from bottom to top. The x axis represents longitude, and y axis represents latitude.

Evaluation

- This tool has the ability to diagnose the areal extent of all features within the ensemble framework.
- This extrema value approach can provide research meteorologists with a new method of tracking features of different scales, accomplishing a primary research objective of this study.
- This scale selection component of the work allows users to gain an understanding of the dominant scale in place over a region.
- The three dimensional rendering makes it difficult to overlay multiple ensemble members or multiple contour levels.

Conclusion

- This tool allows for feature tracking not only in space but also in scale and time.
- Scale space is an effective tool for reducing complexity and filtering small features in large ensemble data.
- Scale selection is the key to scale space data exploration.
- 3D data visualization in scale space remains challenging.

Acknowledgement

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Reference

[1] A. P. Witkin, "Scale Space Filtering," in Artifical Intelligence (IJCAI), 1983, pp. 1019–1022.

[2] T. Lindeberg, Scale-Space Theory in Computer Vision. 1994.

[3] T. Lindeberg, "Scale-space theory: a basic tool for analyzing structures at different scales," J. Appl. Stat., vol. 21, pp. 225–270, 1994.

[4] T. Iijima, "Basic theory on normalization of a pattern (in case of typical one-dimensional pattern)," Bull. Electr. Lab., vol. 26, pp. 368–388, 1962.

[5] M. Felsberg and G. Sommer, "The monogenic scale-space: A unifying approach to phase-based image processing in scale-space," J. Math. Imaging Vis., vol. 21, pp. 5–26, 2004.