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A topological approach for quantitative comparisons of ocean model fields to satellite ocean color data

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HIGHLIGHTS

- A topological metric is introduced for comparing differing but related geophysical fields.
- The metric is demonstrated by comparing satellite ocean color data to model salinity.
- The metric allows quantitative comparison of spatial characteristics of observed and modeled fields.

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ABSTRACT

In an effort to more fully employ underutilized satellite observations in ocean modeling, this work demonstrates a method for quantifying the agreement between time-evolving spatial features evident in fields of differing, but functionally related, variables that are more commonly compared qualitatively via visual inspection. This is achieved through application of the Modified Hausdorff Distance metric to the evaluation of ocean model simulations of surface salinity near riverine sources using satellite ocean color data. The Modified Hausdorff Distance is a metric from the field of topology designed to compare shapes and the methodology provides quantitative assessment of similarity of spatial fields. The Mod-

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Shape comparison
Hausdorff distance

ified Hausdorff Distance can be applied for comparison of many geophysical and ecological fields that vary spatially and temporally. Here, the utility of the metric is demonstrated by applying it to evaluate numerical simulations of the time-evolving spatial structure of the surface salinity fields from three ocean models in the vicinity of large riverine sources in the northeast Gulf of Mexico. Using the Modified Hausdorff Distance, quantitative comparison of modeled sea surface salinity contours to contours of a gridded satellite-derived ocean color product is made under the assumption that the modeled fields are related to optically significant quantities that indicate the spatial extent of riverine influenced water. Three different ocean models are evaluated and are compared individually to the satellite data. The sea surface salinity values and ocean color index values that most closely match (lowest Modified Hausdorff Distance score) are identified for each model. The Modified Hausdorff Distance scores for these best pairings are used to both determine the degree to which surface salinity fields from the models match the satellite observations and obtain an empirical relationship between the two variables for each model. Furthermore, the best pairings are compared between models allowing key differences in the simulated riverine water distributions to be distinguished. The Modified Hausdorff Distance proves a robust and useful diagnostic tool that has the potential to be utilized in many geophysical applications and facilitates the use of satellite ocean color data for quantitative evaluation of hydrodynamic ocean models.

1. Introduction

For decades satellite sensors have been used to detect the color of the ocean surface by measuring light reflectance in different spectral bands (McClain, 2009). These ocean color data products have been utilized to identify and analyze ocean features that affect pigment and particulate content of the water and hence the ocean color, including oil spills, algal blooms and river plumes (e.g. Hu et al., 2004; Androulidakis and Kourafalou, 2013; Liu et al., 2013; Hu et al., 2015). They have also been integrated into observation and detection systems for harmful algal blooms and oil spills (e.g. Stumpf et al., 2003; Brekke and Solberg, 2005; Hu et al., 2016). With both broad spatial and frequent temporal coverage, satellite ocean color observations also have the potential to be valuable resources for numerical ocean modeling, however the ocean circulation modeling community has not fully capitalized on the utility of this data.

Satellite ocean color data have been used for ocean model assessment qualitatively, as patterns evident in the ocean color are often similar to, and may generally be visually compared to, features in dynamical fields (e.g. Binding and Bowers, 2003; Gregg et al., 2003; Chassignet et al., 2006; Liu et al., 2011; Schiller et al., 2011). Quantitative comparisons generally rely on point-wise differences that demand the same field be used and/or an empirical relationship between different but related fields is determined (e.g. Binding and Bowers, 2003; Gregg et al., 2003; Gregg, 2008; Mariano et al., 2011; Chaichitehrani et al., 2014; Zhang et al., 2014). While the types of statistical measures derived from point-wise comparisons (e.g. biases or correlations) are useful, they do not necessarily provide comparison of spatial distributions and/or shape that are related to circulation patterns or dynamical processes, and neither are they expressly designed for such a purpose. In an effort to more fully utilize the vast amount of remotely sensed data for ocean model assessment and analysis, the objective of this work is to apply and demonstrate the potential of a metric called the Modified Hausdorff Distance (MHD) to quantitatively compare spatial and temporal patterns derived from satellite ocean color