Geophysical Research Abstracts
Vol. 14, EGU2012-4617, 2012
EGU General Assembly 2012

Flexible Representation of Spatio-Temporal Random Fields in the Model Web

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The Model Web envisions an infrastructure for coupling environmental models in the Web. In environmental sciences, the phenomena of interest are usually not well-bounded objects, but rather continuous phenomena in space and time. These phenomena are commonly referred to as spatial or spatio-temporal fields and are often modelled as random variables. Currently, spatio-temporal fields are usually represented and exchanged as raster data. Besides the communication overhead this imposes, exchanging rasters has also other drawbacks. For example, the interpolation method used to calculate the raster values as well as the original observations the raster originates from are usually not part of the resulting data. Furthermore, the interpolated values are commonly single moment estimates of the random variables such as their expectation values. Thus, the natural randomness in the interpolated variables and interpolation uncertainties are also not available any more after interpolation.
We propose a new model for exchanging spatio-temporal random fields as the original sample data plus information about the model of spatial or spatio-temporal variance describing the random field. This allows to communicate the complete random variables and their associated uncertainties opposed to single estimates. In addition, this approach suggests a particular interpolation method to calculate rasters from the field. The desired raster resolution and projection can then be chosen by the user of the field data. This is advantageous to the classical approach, as transformations between coordinate reference systems typically distort the given raster and changing the raster's resolution usually imposes a second model assumption on the interpolated field data.
Using a standardized language to describe spatio-temporal random fields allows for a fully machine readable approach. Depending on the target application, one can thus easily obtain one to several simulations of the field reflecting its random nature instead of a single interpolated grid based on a single moment estimate of the underlying distribution with a fixed resolution and coordinate reference system. We present an extension of FieldGML, a language based on the Geography Markup Language (GML) for representing spatial fields, and UncertML, the Uncertainty Markup Language, where spatial and spatio-temporal variance is described by means of the kriging procedure assuming underlying Gaussian distributions. Prototypical implementations are provided for web-processes within the UncertWeb project and as a R package building on top of the widely used packages sp, gstat and spacetime for spatial and spatio-temporal random fields.