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Downscaling climate information for local disease mapping

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Abstract

The study of the impacts of climate on human health requires the interdisciplinary efforts of health professionals, climatologists, biologists, and social scientists to analyze the relationships among physical, biological, ecological, and social systems. As the disease dynamics respond to variations in regional and local climate, climate variability affects every region of the world and the diseases are not necessarily limited to specific regions, so that vectors may become endemic in other regions. Climate data at local level are thus essential to evaluate the dynamics of vector-borne disease through health-climate models and most of the times the climatological databases are not adequate. Climate data at high spatial resolution can be derived by statistical downscaling using historical observations but the method is limited by the availability of historical data at local level.

Since the 90s', the statistical interpolation of climate data has been an important priority of the Agrometeorology Group of the Food and Agriculture Organization of the United Nations (FAO), as they are required for agricultural planning and operational activities at the local level. Since 1995, date of the first FAO spatial interpolation software for climate data, more advanced applications have been developed such as SEDI (Satellite Enhanced Data Interpolation) for the downscaling of climate data, LOCCLIM (Local Climate Estimator) and the NEW_LOCCLIM in collaboration with the Deutscher Wetterdienst (German Weather Service) to estimate climatic conditions at locations for which no observations are available. In parallel, an important effort has been made to improve the FAO climate database including at present more than 30,000 stations worldwide and expanding the database from developing countries coverage to global coverage.

1. Introduction

In the present situation where global environment and world population are strictly inter-related, the disease dynamics may be altered due to various socio-environment-economic factors. Scientists need to better understand how the dynamics of the diseases respond to variations in regional and local climate. Climate variability affects every region of the world and the diseases are not necessarily limited to specific regions, so that vectors may become endemic in other regions. The area of human health impacts of climate is an extremely complex one, which requires the interdisciplinary efforts of health professionals, climatologists, biologists, and social scientists to analyze the relationships among physical, biological, ecological, and social systems relevant to health impacts.

However, one of the obstacles in the development of multidisciplinary activities is the data acquisition and management as they require very large and long-term data sets with many variables. As an example, table 1 shows the kind of needs concerning the climatological, ecological and health data (American Academy of Microbiology, 1999). Climate data are essential at local level to evaluate the dynamics of vector-borne diseases through health-climate models. Most of the times the climatological databases are not adequate to use in human health models. Climate data at high spatial resolution can be produced by statistical downscaling using historical observations but the method is limited by the availability of historical data at local level.

In practice, three main problems arise: (i) lack of climate data for a specific meteorological station; (ii) lack of climate data for a location where no meteorological station is established; (iii) lack of appropriate software for spatial interpolation of climate data. Based on its previous experience in the use of climatic data for spatial modelling and mapping of crop pests and diseases as a function of environmental conditions (Bernardi, 2001), the FAO approach is provided here below.

2. Material and Methods

FAO, founded in 1945, has the mandate to raise levels of nutrition and standards of living, to improve agricultural productivity, and to better the condition of rural populations. Among other activities, FAO collects, analyses, interprets and disseminates information relating to nutrition, food, agriculture, forestry and fisheries (www.fao.org).

The Agro-meteorology Group is part of the Environment and Natural Resources Service of the Department for Sustainable Development, which is the FAO focal point for environmental data. The Group maintains a large world-wide climatic database to provide needed inputs for various applications. During recent years, the database was made available to a larger audience by developing agrometeorological software and disseminating climatic data through intranet and internet. However, despite the large number of stations contained in the database (more than 30,000 stations worldwide), very often climatic information cannot be found for a specific location or area, so that we need the help of geostatistics. Geostatistics is a branch of statistics that deal specifically with spatial data. It means that each data value is associated with a location in space (geographic coordinates) and there is at least an implied relationship between the location and the data value. In a very simplistic way, it can be viewed as a methodology for interpolating data on an irregular pattern or, in another way, the estimate of missing values at one point in space based on the known values and characteristics of neighbouring entities. In the recent years, geostatistics had a very wide of applications (Hartkamp et al., 1999) and spatially interpolated climate data on grids, often referred to as ‘climate surfaces’, are used in many applications, particularly in environmental, agricultural and biological sciences. The spatial resolution of the climate surfaces used in a particular study depends on the needs for that application and on the data available. For many applications, data at a fine (≤ 1 km^2) spatial resolution are necessary to capture environmental variability that can be partly lost at lower resolutions, particularly in mountainous and other areas with steep climate gradients (Hijmans et al., 2005).

The statistical interpolation of climate data has been an important priority on the Agro-meteorology Group to improve the availability of climate data at local level, required for agricultural planning and operational activities. To develop spatial interpolation tools, an important effort has been made to improve the FAO climate database and expanding the database from developing countries to global coverage (FAOCLIM2, 2001). Agroclimatic data are also used to assess the potential agricultural impact of global climate change and as a source of information for FAO’s Global Information and Early Warning System on Food and Agriculture. It is mainly in crop yield forecasting for food security that the Agro-meteorology Group has been led to use spatial interpolation techniques: yields are estimated using station values of climatic and agronomic variables, but food production data must be presented by districts and provinces. Area averaging, estimate of missing data and gridding are among the most useful applications of spatial interpolation techniques to agroclimatology and agrometeorology.

3. Results

There are many methods of spatial interpolation including, for instance, the method of "inverse distance weighting" and the method of Thyssen's polygons also known as “nearest neighbour” method, to name just a few. Co-kriging will allow carrying out an optimum estimation taking more than one variable into account, i.e. taking advantage of the relations between the variables to improve the estimation. For instance, altitude is an important additional variable when estimating temperatures. When no additional variables are used, in addition to longitude and latitude, co-kriging is equivalent to the classical kriging. In collaboration with the Catholic University of Louvain

(Belgium), in 1995, FAO developed the first spatial interpolation software for climate data based on co-kriging method (Bogaert et al., 1995).

In 1996, the FAO Harare based Regional Remote Sensing Project developed the Satellite Enhanced Data Interpolation (SEDI) method to assist, originally, with the interpolation of rainfall data gathered at station level with the Meteosat satellite Cold Cloud Duration (CCD) images (Gommes and Hoefsloot, 1998). SEDI takes advantage of the correlation between the point data to be mapped (e.g. rainfall) and an “environmental variable”, that is available as a grid, for instance a digital terrain model. At a later stage the method was applied to other parameters as well (e.g. potential evapotranspiration and altitude, crop yields and Normalized Difference Vegetation Index, NDVI). SEDI is a simple and straight forward method for “assisted” interpolation and can be applied to any parameter of which the values are available for a number of geographical locations, as long as a “background” field is available that has a negative or positive relation to the parameter that needs to be interpolated. The method was a component of IGT software (Hoefsloot, 1996); it was later included into WINDISP software (Pfirman and Hogue, 1998). Three requirements are a prerequisite for the successful application of the SEDI method:

- the availability of the parameter to interpolate as point data at different geographical locations (e.g. rainfall, potential evapotranspiration, crop yields);
- the availability of a background parameter in the form of a regularly spaced grid (or field) for the same geographical area (e.g. CCD, NDVI, altitude);
- a relation between the two parameters (negative or positive; rainfall/CCD is positive, PET/altitude is negative). A Spearman rank correlation test can reveal whether a relation exists, and how strong this relation is.

In 2002, LOCCLIM (short for Local Climate) software was developed to provide an estimate of climatic conditions at locations for which no observations are available and, to achieve this, the programme uses the stations of FAOCLIM 2.0. Next to a "no questions asked" automatic mode, the "workbench" mode gives the user full control over the interpolation procedure (Inverse Distance Weighting, IDW). Inputs can be taken from the keyboard (location specified either by co-ordinates or by a click on a map) or from user-provided ASCII files. Output can be in the form of ASCII files or user-defined georeferenced grids. The software also provides estimates of growing season characteristics based on a comparison of rainfall and potential evapotranspiration according the Franquin's method (Cocheme and Franquin, 1967). Estimates of monthly, 10-daily and daily values of common climate variables are given together with error estimates, using a number of options to correct for regional variability, altitude dependency and horizontal gradients of the variables. For any given location LOCCLIM searches for the nearest stations that fulfil given criteria (absolute number, maximum distance, altitude constraints). The altitude of the desired location can either be given by the user or taken from a built-in digital elevation model (DEM) with a spatial resolution of 10 km and an altitudinal resolution of 20 m. The results of spatial interpolation strongly depend on the station data used. Under some circumstances the reliability of the results is questionable and LOCCLIM warns the user. The workbench mode allows for a fine tuning of the interpolation by consideration of the warnings and error estimates.

In 2005, the NEW_LOCCLIM was developed in collaboration with the Deutscher Wetterdienst (German Weather Service), more specifically the Global Precipitation Climatology Centre (GPCC). The software now includes nine interpolation methods (IDW, kriging, Shepard, thin-plate splines, etc.). While the main aim of LOCCLIM was the investigation of local climate conditions at any location on earth based on the FAOCLIM database, NEW_LOCCLIM aims at the preparation and investigation of climate maps. One of the most useful additions is the possibility for users to interpolate their own data and to prepare maps (grids) at any spatial resolution. Besides maps of the interpolated variables, NEW_LOCCLIM offers maps of useful supplementary information like horizontal and vertical gradients, estimated errors, portion of variance explained by gradients, as well as warnings in case of sparse or strange data and extrapolations. All maps can be superposed with geographic information such as boundaries, rivers, roads, railway tracks and station information (altitude, co-ordinates, estimated local errors, gradients and strange-data warnings). A statistics sheet provides both grid and station statistics as well as altitude dependencies. A single-point mode allows for the investigation of the mean annual cycle (monthly, dekadal, and daily resolution) of 8 climate variables at a time as well as the estimation of growing season characteristics like number of growing seasons per year, lengths, begin dates, averages and aggregates of climate variables during growing season.

4. Discussion

Despite the advances in remote sensing and the recent and significant improvement in the availability of high resolution satellite-base databases, including multi-resolution and multi-temporal satellite images (Dooley J., 2005), major difficulties to obtain actual meteorological data at ground level due to the continuing deterioration of meteorological station networks do exist, particularly in developing countries. While through the Internet users can access hourly meteorological data from automatic stations in various countries of the world, in contrast, many developing countries still struggle just to measure basic meteorological variables at a single station. The activities of the FAO Agro-meteorology Group over the last thirty years (Gommes et al., 2004) have focused on the availability and collection of global datasets and on the methods to estimate climatic conditions at locations for which no observations are available. A major effort is now devoted to develop integrated tools allowing more value-adding to the climate and meteorological data (Agrometshell, 2006).

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CLIMATE	**ECOLOGY**	**HEALTH**
Increased temporal resolution	Long-term monitoring	Long-term surveillance
Increased spatial resolution	Historical data (long term)	Better reporting
Local topography	Better "meta-data"	Access to historical data
More input from "user" groups (ecology and health)	Bench scale assessments of factors related to climate change (i.e., temperature, humidity, salinity, etc.)	Conversion of data to electronic formats
Integration of forecasts		Demographic and socio-economic information
Forecasting sequential Climate events		

Table 1. Needs concerning the climatological, ecological and health data for interdisciplinary study (from American Academy of Microbiology, 1999).