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A GIS tool for accessing climate data relevant to building practitioners

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ABSTRACT

Maintenance of building façades and related systems should be an on-going process. Nonetheless, maintenance prioritisation issues are often neglected due to the lack of available tools to assess vulnerability to climatic effects and susceptibility to deterioration. How is climatic information currently accessed and used and what are the existing means to assess climate loading effects? A Geographic Information System (GIS) platform [ESRI ArcGIS 9.3] was proposed as an appropriate tool to integrate climatic design information and other analyzed climate data in a geographical context and allow users ready access to climate information pertinent to building practitioners. On the basis of this effort climatic design data used for building codes and standards, such as degree days, 15 minute, one day and annual rainfall, driving rain wind pressure and related loads were made available in the GIS platform. This climatic design data provides basic information from which derivative climate parameters can be developed and from which relevant climate load projections can be extracted for use by building designers, practitioners and maintenance experts.

KEYWORDS

GIS, climate design data, building systems, design and maintenance

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1 INTRODUCTION

Maintenance of building façades and related systems should be an on-going process. Nonetheless, maintenance prioritisation issues are often neglected due to the lack of available tools to assess vulnerability to climatic effects and susceptibility to deterioration. What are the current means employed to access climate information? Key components of the building systems that are most in need of maintenance interventions ought to be identified to prevent premature catastrophic failure, to sustain the health and safety of the occupants, and to maintain the serviceability of the system over its service life. Maintenance prioritisation ensures effective deployment of limited or insufficient funds.

1.1 The need

The design and sizing of mechanical, heating, ventilation and air-conditioning systems is influenced directly by expected loads upon the systems, occupant functional requirements as well as legal and building operational regulations and frameworks. Amongst the climatic loadings, temperature and humidity are of primary concern having significant impact upon the required capacity of heating and cooling systems. Wind loads affect the efficiency of air-intake and handling units ; potentially altering building pressurisation and effective operation of functional services such as elevators.

Buildings are making an ever-increasing use of weather-driven renewable energy sources such as integrated wind turbines, solar panels and enhanced day lighting techniques. The design, maintenance and longer-term performance and broader adoption of these technologies depend upon the availability of reliable climate information including temperature data, solar radiation exposure and cloud-cover information, as well as wind intensity projections.

Data on wind, solar radiation, temperature, moisture and precipitation is essential to properly evaluate the design and effects of maintenance on all building envelope components. This is significant when considering the expected performance of “green” walls and roofs since implied seasonal loadings may be drastically different from those expected with more conventional configurations.

Knowledge of the combined effects of wind, moisture and thermal loads on façade systems permits the determination of the response of the wall including the hygrothermal performance, dilation at the panel joints, susceptibility to water penetration or the product of combined responses that act to deteriorate the façade system. Hence, evaluating climatic effects in combination with wall response permits establishing the most severe combinations most likely to deteriorate the façade and thus provides a basis for prioritising maintenance programs for high-rise buildings. The process can be used to establish risk of deterioration from climatic effects among the different walls for a given building façade, between the level of risk among different buildings in a given climate, or for comparing the relative effects of similar façades exposed to different climate loadings.

The effects of moisture and other climate parameters on the deterioration of façade components are well known; spalling of masonry caused by freeze-thaw action, spalling and degradation caused by salt migration, damage due to expansion of materials or components; loss of adhesion or rupture of jointing products from joint movement. Likewise, water penetration of the façade from wind-driven rain to the interior causes failure of interior finishes, damage to gypsum plasters, mould or mildew growth and degradation of the thermal performance of insulation.

1.2 Background

Over the past 20 years the geo-information field , once a highly specialized niche domain, has evolved to a technology having a broad effect on society and its interaction with nature. Geographic Information Systems (GIS) applications range from simple navigation to critical and extremely complex tasks, such as infrastructure risk management, prediction and mitigation of the effects of natural disasters.

This broadened GIS use is partially due to the increased availability of Geographic Positioning Systems (GPS) and greater access to georeferenced data. In North America most levels of government provide some level of “free-of-charge” access to geospatial data [e.g. GeoGratis, 2010, USGS National Map, 2010]. Historically, access to GIS data in Europe has been restricted by financial or legal barriers and as a result, European data often originated from U.S. based systems.

Various GIS initiatives have evaluated the interface of the natural and built environments, usually focusing upon a specific material or degradation processes [Inkpen *et al.*, 2001, 2008, Cole *et al.*, 1999, 2003a-c, 2004] with the intent of identifying geographically susceptible regions for the occurrence of the particular phenomenon. These works demonstrate the inherent capabilities as well as the ever increasing computational capabilities of GIS.

Numerous climate datasets and buildings related design tools have been developed [Hui and Cheung, 1997, ASHRAE, 2009, RETScreen, 2010]. An integral, and obviously required, characteristic of these tools is georeferenced climate data. Despite this potential direct linkage to GIS-based systems, to-date there have been relatively few initiatives to create GIS enabled climate data sets [Agnew and Palutikof, 2000, Mitchell *et al.*, 2004,] and equally as few efforts specifically focused upon implementing GIS relative to building-level data [Kyle *et al.*, 2008, Hallberg *et al.*, 2008].

1.3 Continually altered context

The rising perception of the significance of climate change and the potential impacts upon infrastructure and buildings has resulted in several initiatives to monitor the impacts of future climate effects and to project potential longer-term changes [DEFRA, 2010, Environment Canada, 2008, IPCC, 2007, NASA, 2010]. The outputs of these efforts, while not explicitly aimed at assisting with the development of climate design data, if properly considered will contribute to the design and construction of more durable and climatically responsive buildings.

1.4 Approach

The intent of the work described herein was to create a tool that put Canadian climate design data in a GIS context. The GIS platform that was used to integrate climate information in a geographical context is ESRI ArcGIS 9.3. The ArcGIS database was populated with all necessary climate information as obtained from the National Building Code of Canada [NBCC, 2010], to provide basic information from which derivative climate parameters can be developed and from which relevant climate data can be extracted for building designers, practitioners and maintenance experts.

The remainder of this paper describes the nature of the dataset, the preparation and processing required to migrate the data to the GIS context, as well as the results of the exercise.

2 NATIONAL BUILDING CODE OF CANADA 2010 DATASET

Appendix C of the National Building Code of Canada [NBCC, 2010] provides recommended design data for a number of locations throughout Canada. This document acknowledges the yearly and seasonal variability in climate loadings and the potential long-term shift in climate regimes. Table 1 lists the climatic parameters used in the developed tool and includes a short description of the parameter as well as the number of weather stations sampled.

Table 1. Composition of the NBCC 2010 Climatic Data Subset as Implemented

<i>Climatic Parameter</i>	<i># of weather stations sampled</i>	<i>Description and (units)</i>
Heating degree-days	1030	Degree-days below 18 °C

15 min. rain 1/10	485	Annual maximum 15 min. rainfall – 10 year return period (mm)
One-day rainfall	3500+	Annual maximum one-day rainfall- 50 year return period (mm)
Annual rainfall	2051	Total annual rainfall (mm)
Annual precipitation	2051	Total annual precipitation (mm)
Driving Rain	2051	Driving rain wind pressure - 5 year return period (Pa)
Snow Load Ss	2000+	Total annual snow load - 50 year return period (KPa)
Snow Load Sr	2000+	Total annual snowload (rain-on-snow) - 50 year return period (KPa)
Hourly wind pressure 1/10	400+.	Average hourly wind pressure – 10 year return period (KPa)
Hourly wind pressure 1/50	400+.	Average hourly wind pressure – 50 year return period (KPa)

This national model dataset is representative of the nature of the raw data sampled as well as the statistical analysis employed and traditional historically-based probabilistic assessment. The final determination of the content of the document is made via consultation with various domain experts, and the document is, as such, consensus driven. The current, 2010, version of the climatic design data has directly considered climate change effects in the determination of distributions for various design parameters, most notable being the intensity of precipitation events.

3 GIS TOOL AND DATASET PREPARATION

The principal software package used for this work was ESRI ArcGIS Desktop 9.3 from Environmental Systems Research Institute, Inc [ESRI, 2010]. Two additional tools, Spatial Analyst and ArcReader, were used during the development to add specific functionality and ease-of-use.

ArcGIS Desktop is a collection of products that runs on desktop computers and is used to create, import, edit, query, map, analyze and publish geographic information. It allows examination of various data relationships, permits testing of predictions. ArcGIS Desktop includes ArcView, ArcEditor and ArcInfo; providing progressively greater GIS functionality.

Spatial Analyst is an extension to ArcGIS Desktop , providing tools for comprehensive, raster-based spatial modeling and analysis. This tool permits the derivation of new information from existing data, spatial relationship analysis, development of spatial models and complex raster operations.

ArcReader is a free, easy-to-use desktop mapping application that allows users to view, explore and print maps and globes. Users of ArcReader can view high-quality interactive maps authored by higher-level ArcGIS Desktop products and published with the ArcGIS Publisher extension. The availability and quality of the data typically represent significant limitations to GIS implementation. In this particular case, the datasets had been pre-processed for representation and required only a minor verification for consistencies and/or anomalies. The project approach used was to interpolate the dataset with various weather station locations. Within the ArcGIS framework there are various interpolation methods available. For this initiative, and as is commonly the case in other climate data analysis, Inverse Distance Weighting (IDW) was used. IDW is a multivariate interpolative process whereby values are assigned to unknown datapoints by using values from scattered set of known datapoints. IDW is well suited for this type of analysis since the data is very predictable and consistent across the country. IDW is able to represent the data and interpolate a smooth distribution of unknown points. The control values for the interpolation analysis were chosen primarily by trial and error, aimed at generating results with adequate cartographic appeal to the audience and users. This process required considerable computing time and fine tuning . Once the results are complete, the whole mid-level product is packaged to be viewed using ArcReader.

The data manipulation process used for the migration of the design dataset to the ArcGIS context is presented in Fig. 1. A basic description of the steps taken to reach the final products is as follows:

- **Interpolation** - Inverse Distance Weighting is used to estimate data values at locations without data, based upon the distances to populated datapoints;
- **Reclassification** – the interpolated dataset is transferred to a raster file while maintaining the original raw data;
- **Conversion** - the raster file is converted to a polygon file containing specific attributes; and
- **Clipping** – limits the displayed map to a specified desire border, e.g. to the map of Canada.

The mapping capabilities of the ArcGIS system permit various layer selections and further combination of loads and effects; the colour selection and control over the ramping gradation.

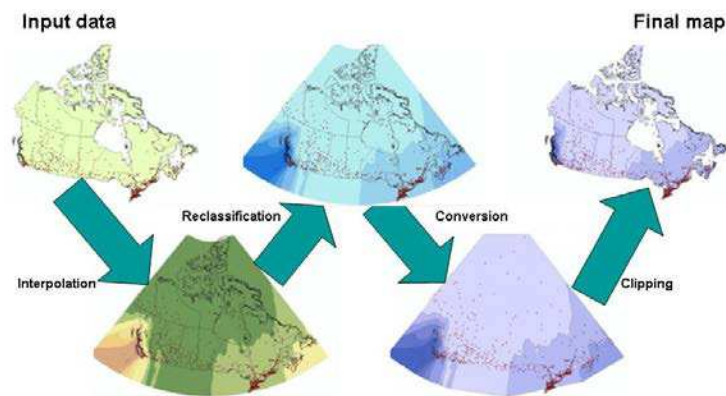


Figure 1. Process diagram for the dataset preparation and migration in ArcGIS 9.3

4 RESULTS

The procedure described in Section 3 was applied to each of the design parameter datasets listed in Table 1 of Section 2. Figures. 2 to 4 present results for a sampling of these parameters.

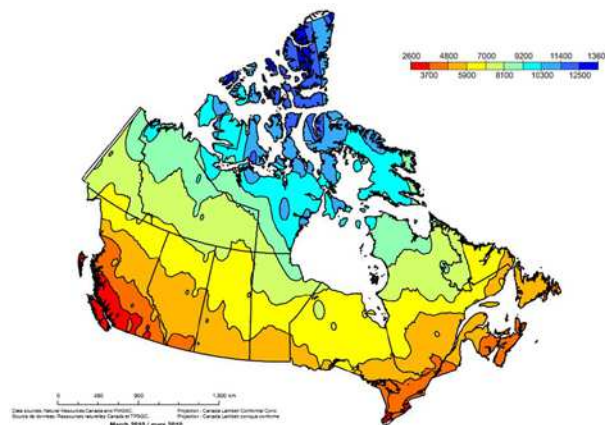


Figure 2. Canadian design data for degree-days below 18 °C



Figure 3. Canadian design data for annual snowload (rain-on-snow) - 50 year return period (KPa)



Figure 4. Canadian design data for driving rain wind pressure - 5 year return period (Pa)

5 DISCUSSION

This system provides National Building Code of Canada climate design data, a consensus-based dataset borne from recent climatic observations as well as historical weather records and tendencies. As such, it fulfills the minimum data requirements for typical building climate design considerations in Canada.

At the highest level, this system offers a visualization of the macroclimate of any particular region in Canada, and at the lowest level, it provides climate information on a meso (building) scale and basic information needed to determine the microclimate loads on a building, its façade and systems.

Many observers believe that climate change is having a greater, and more rapidly occurring, impact upon many design parameters than originally predicted. In some regions of Canada, long-standing design and construction practices are no longer perceived to adequately address climatic conditions and loadings and the usefulness of design data that is based, even in-part, on historical climate records is being questioned.[PIEVC, 2008, Auld and MacIver 2007].

With traditional approaches, the validity of such a stance (or climate design data itself) can only be substantiated with long-term data collection and comparisons of climate and weather observations relative to the climate design data that had been used. If the effects of climate change are as pressing as suggested, the time requirements to project and validate climate design data must be shortened. In the interim, if there are concerns about the adequacy of any projected climate loadings, at any stage of

a building's service life, designs should meet requirements beyond the limits of datasets comparable to that described in this paper. Climate design databases, in conjunction with GIS interfaces, provide basic information from which derivative climate parameters can be developed and relevant climate load projections can be extracted for use by building designers, practitioners and maintenance experts. Regardless of the basis of the databases, there will be an increasing role for GIS-based systems to provide building practitioners with current, historical and projection information on climate loadings.

6 SUMMARY

An ESRI ArcGIS 9.3 Geographic Information System (GIS) platform was proposed as an appropriate tool to integrate climatic design information and other analyzed climate data in a geographical context and allow ready access to climate information pertinent to building practitioners. On the basis of this effort climatic design data used for building codes and standards, such as degree days, 15 minute, one day and annual rainfall, driving rain wind pressure and related loads were made available in the GIS platform. This climatic design data provides basic information from which derivative climate parameters can be developed and from which relevant climate load projections can be extracted for use by building designers, practitioners and maintenance experts.

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