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BIOMETEOROLOGY AND ADAPTATION GUIDELINES FOR COUNTRY STUDIES

H. Auld[1*], D. MacIver[1], N. Urquizo[2] and A. Fenech[1]

[1] Meteorological Service of Canada, Toronto, Ontario, Canada
and
[2] Rainmakers Environmental Group, Thornhill, Ontario, Canada

1. INTRODUCTION

The study of biometeorology has long recognized that the atmosphere has a powerful influence on the natural environment, including the biological and human world. The atmosphere affects everything from the kinds of plants and animals that live in certain regions to the socio-economic activities that can be undertaken in those regions.

Adaptation science describes the study of the adjustments that are possible in practices, processes or structure of systems in order to adjust to changes (Watson et al 1996). From an atmospheric perspective, these changes can include shifts in climate, declines in air quality or changes in UV levels. The term “adaptation” has been more commonly associated with the climate change issue. With growing concern over the implications of climate change for ecosystems and communities and the recognition that some amount of climate change will be inevitable, adaptation science has tended to focus on measures needed to reduce vulnerabilities to future climate change.

Commission IV was initiated at the 1999 ISB Congress. This Commission—*Biometeorology and Adaptation in the Context of Climate Change and Biodiversity*—is new and has as its scope the integration of biometeorology adaptation science for climate change and biodiversity into international conventions, agreements and agencies. Commission IV was primarily designed to investigate and improve the interlinkages and transfer functions between the many science sectors of biometeorology and the Conventions on Climate Change and Biological Diversity using adaptation science as the portal (MacIver et al, 2002). Commission IV embarked on two pilot projects as its starting platform. The first consisted of a literature assessment of potential biometeorological research with adaptation in the context of climate change and biodiversity (MacIver et al 2002). The second project, the Integrated Mapping Assessment Project or IMAP, represents a pilot county-type study.

IMAP was launched in Canada by Environment Canada and University of Toronto in January 1999 (Auld et al 2000) to better understand the interactions between the various atmospheric change issues—climate, high impact weather, air quality, acid precipitation and UV radiation—and issues affecting ecosystem health, land use, the economy and human health. A significant number of these issues build on the science of biometeorology. For example, results from the project have proven very powerful in assessing regional vulnerabilities to climate change. The 6 steps developed for the IMAP guidelines are recommended for consideration for country studies (i.e. for application and testing in other countries).

* *Corresponding author address*: H. Auld, Meteorological Service of Canada-Ontario Region, 4905 Dufferin Street, Toronto, Ontario, M3H 5T4; e-mail: heather.auld@ec.gc.ca

2. INTEGRATED MAPPING AND ASSESSMENT PROJECT (IMAP)

IMAP is a process to guide the assessment of multiple issues within numerous geographical scales (i.e. issues by scale matrix). The process involves first collecting scientifically sound maps using an assessment framework, functionally linking the thematic mapped surfaces and then analyzing and interpreting the spatial or temporal correlations. Maps can be functionally linked using several integration methodologies, including transfer functions, GIS integration algorithms, critical threshold approaches, and lifestyle selection criteria.

The IMAP process is useful for environmental impact assessments and the prediction of changes in the environment using scenarios of future atmospheric change. While the atmospheric change issues include climate, high impact weather, air quality, acid precipitation and UV radiation issues mentioned earlier, the environmental change issues could include habitat change, risks to our built environment, morbidity or mortality trends, land use change, biodiversity threats, economic opportunities, etc.

3. IMAP GUIDELINES

The guidelines developed for IMAP provide a methodology for linking complex and integrated issues and scales using maps. The 6 steps in the guidelines consist of the following:

i) *Map collection and matrix assignment*: Identify and assemble maps on a number of environmental and atmospheric issues by scale;
ii) *Broad collaboration*: Establish rules or guidelines for the contribution and sharing of maps by multi-disciplinary partners;
iii) *Sound science*: Assess maps for quality, gaps and integration potential.
iv) *Integration methodologies*: Apply transfer functions or other integration methodologies. For example, overlay maps only if the information describes similar spatial scales, especially when

scientific evidence suggests a knowledge link between mapped fields.

v) *Open sharing*: Electronically share and make accessible all products, maps and results from analyses for assessments, education and decision-making.

vi) *'Living' IMAP process*: Update IMAP collection, partnerships and integration methodologies. Present and publish results.

4. MAP COLLECTION

A selection of atmospheric maps were assembled at various scales, ranging from local to global. With the exception of climatology and high impact weather maps, many of the atmospheric change maps were scale-dependent and often only appropriate for use at national or global scales. On the other hand, maps depicting biological issues covered a range of spatial scales from local to global.

Since the initial pilot project focussed on southern Ontario, where a plethora of mapped information is available, the assessment placed an emphasis on mapping products appropriate at this regional decision-making scale. Southern Ontario, with a population of about 9 million, accounts for slightly under a third of Canada's population, about 45% of Canada's industries and 25% of its agricultural capacity. As a result of the varied economic activities that take place within the region and its concentration of urban areas, the study region is faced with a multitude of health and biological concerns ranging from land use change, endangered and invasive species, loss of habitat, significant climate and air quality issues, high acid deposition rates and a significant population and infrastructure sensitive to weather anomalies and extremes.

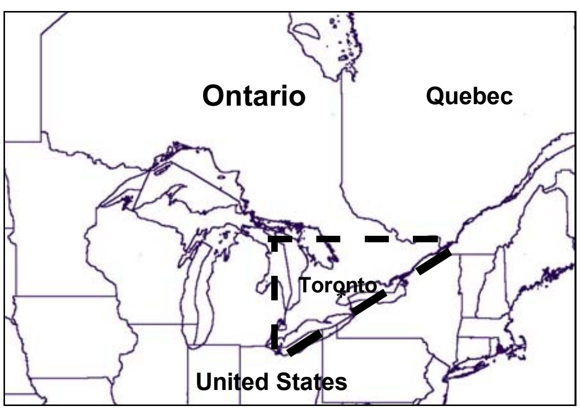

Figure 1. *Study area - southern Ontario, Canada*

5. SOUND SCIENCE, COLLABORATION, OPEN SHARING AND A 'LIVING' IMAP PROCESS

One of the 6 steps in the IMAP guidelines requires that participation be inclusive and that all contributing partners share mapped products and engage in collaboration and cooperative networking. Contributed mapped products must withstand or be based upon peer review and be subjected to a formal assessment before integration. Once integration methodologies are applied and results and conclusions documented, the final steps again focus on peer-review and testing by decision-makers.

A number of lessons emerged from the map assessment process. First, map scale is critical for integration studies. Maps should be connected only when there is a knowledge link between an atmospheric variable and a biological or human health parameter. Transfer functions and other integration methods, depending on the issue and map under consideration, are essential to adjust atmospheric predictor maps to similar scales. Second, there is a tendency for atmospheric information to be mapped by issue (e.g. acid deposition, climate, ground level ozone) and its issue-specific scale of analysis. For example, published maps of acid deposition tend to be analyzed on national or continental scales, ground level ozone may be mapped on a regional to national scale while climate or weather maps can be analyzed down to regional scales. On the other hand, biological fields tend to be mapped on a range of scales, commonly at the local and regional levels. Third, in Canada, mapping gaps exist for some atmospheric issues. For example, regional maps of fog frequencies are dated or non-existent and maps depicting atmospheric distributions of toxics were often only available for specific study dates and regions. Finally, for climate change studies, it was concluded that the IMAP process and its 6 step guidelines yield results that are also directly beneficial for climate change outreach, education and consultation. Because the IMAP process is designed to serve decision-makers, it is able to deliver regional scale information on climate-weather and climate change sensitivities that are compelling and relevant. Hence, it was concluded that the 6 steps in the IMAP guidelines are well worth consideration for country study assessments on climate change and other atmospheric change issues (e.g. air quality).

6. INTEGRATION METHODOLOGIES

In the IMAP process, four integration methodologies were used to transform maps to similar scales for biometeorological analysis. These include:

- transfer functions:
- Geographical Information Systems (GIS) integration algorithms:
- empirical critical threshold approaches:
- lifestyle selection criteria:

Transfer functions can be described as physical-based or functional relationships between atmospheric variables and a resultant environmental impact or response. Empirical transfer function methods provide one means for "downscaling" GCM simulations to the required local and regional scales. General Circulation Models (GCMs), with their coarse spatial resolution and limited accuracy at temporal scales, are insufficient for evaluating the potential impact of climate change on regional areas and decision-making scales for issues such as productivity of agricultural crops, species richness, or biodiversity potential. For example, a study

(MacIver et al 2000, MacIver 1998) for southern Ontario linked forest biodiversity to accumulated growing degree (heat) information using growing degree day maps and forest biodiversity database information. Using this transfer function and the output from a GCM, it is possible to then relate projections of growing degree days under climate change scenarios to future biodiversity potential.

Traditional GIS integration methodologies refer to computer-based tools for mapping and analyzing information or databases that are referenced by spatial or geographic coordinates. GIS technologies have emerged over the last decade as a very powerful tool that allows users to integrate their multi-disciplinary databases in ways that support biometeorological analysis. Normally, databases or information that will be incorporated into a particular GIS project will need to be transformed or manipulated in ways that make the surfaces compatible with other GIS-generated maps under consideration (e.g. integration of GIS wildlife and GIS climate maps). All GIS fields or databases must first be transformed to the same map scale and projection. In many cases, considerable technical expertise and resources are needed to transform all imported fields before any integration can occur.

Critical threshold approaches scientifically relate maximum values of atmospheric variables to expected or empirical environmental changes or damages. In air quality studies, these approaches, often called critical load approaches, describe maximum amounts of pollutants that ecosystems can tolerate without being damaged (often, refer to the most sensitive ecological systems). Other examples would include studies linking land use change to climate or heat units (Auld et al 2000), extreme loads used for design of infrastructure and its potential failure, acidification and forest ecosystems.

The fourth methodology, referred to as lifestyle selection criteria, allows clients or users of atmospheric maps to select personal threshold criteria and to integrate issues for decision-making based on these thresholds. A prototype to deliver this methodology, currently called Lifestyle Meteorology, allows an individual, municipality or agency using the system to integrate a number of atmospheric, environmental, socio-economic or other mapped fields derived from a variety of electronic published formats. The prototype was designed to allow users to integrate mapped data for decision-making.

7. LIFESTYLE METEOROLOGY PROTOTYPE

For the average decision-maker, traditional GIS approaches can be expensive, technologically challenging and "out of reach" for the "small" user. Today, many decisions are made without the benefit of multi-disciplinary or complete information because the relevant knowledge is either not accessible or readily available. For example, at the municipal level, lifestyle decisions include economic opportunities for the location of industry, expansion of communities or the location and design of buildings. For the individual, significant lifestyle decisions include future locations for retirement, preferred workplace decisions or family relocations into areas that would avoid or reduce environmental health sensitivities (e.g. asthmatics with air quality exposure concerns). Given the future projections of aging populations, the proportion of the population with flexibility to choose where they live and retire will increase. Similarly, as work activities become more electronic or "wired", it seems plausible that individual workplace decisions will become more flexible, with more employees choosing to live in a locality for reasons other than proximity to the workplace.

The Lifestyle Meteorology methodology and prototype allows individuals with varying lifestyles to profile and assess the impacts of the physical and chemical atmosphere from one locale to the next. The Lifestyle Meteorology prototype uses the map collection and methodologies developed in IMAP. One of the objectives of the Lifestyle Meteorology Project is to enable more informed decisions at the individual decision-making level. One means of achieving this objective is to make all types of scientifically sound mapped information readily available to all users and decision-makers electronically.

One of the challenges facing the Lifestyle Meteorology Project was the need to develop software that could make already mapped information readily accessible to all users, regardless of their computer type and comfort with technology. This meant the need for prototype software that was inexpensive, quick, easy to use, visual and not requiring components with exclusive licensing agreements. In addition, the software had to be able to ingest and integrate maps from a wide variety of formats, whether a scanned map from an article saved in GIF or JPEG formats or mapped output from a complex GIS package.

The prototype software was developed by KB Webworks to run on a relatively inexpensive commodity desktop PC or small web server. The software was configured with Linux, Hughes Technologies Mini SQL (MSQL) and Apache Web Server software. The prototype software also was configured with access controls and limited functionality to reduce the possibility of intrusion. It contained automated scripts to perform daily backups of data and log rotations from the web server. The prototype was able to ingest maps from numerous formats and to overlay and display the maps on a number of scales. The Lifestyle Meteorology software allowed a user to integrate selected maps according to specific sensitivity criteria, such as their individual health concerns. Figures 2 and 3 illustrate some scenario "runs" using the Lifestyle Meteorology prototype.

The results shown in Figure 2 assumes an individual sensitive to "excess" summer heat, either for budget and air conditioning cost reasons or for personal outdoor comfort reasons. Figure 2 depicts those communities that meet the user specified threshold conditions for summer heat. By highlighting each point or community, the user is able to interrogate site-specific information.

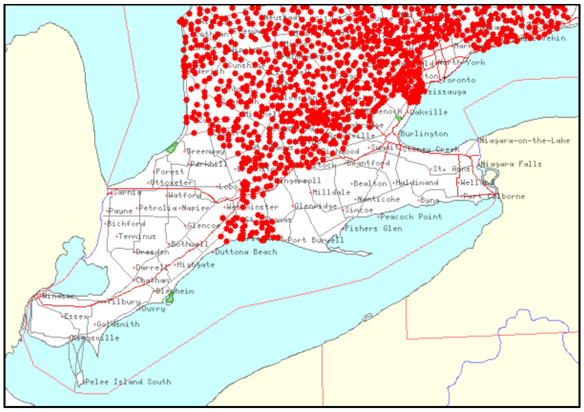

Figure 2. *Locations in southern Ontario with cooling degree days (CDD) ≤ 250*

In comparison, the results shown in Figure 3 assume multiple selection criteria for a number of atmospheric issues, including heat, poor air quality, toxics, and distances to major highways for access reasons. In this case, the user enters specific threshold values that are acceptable to their lifestyle and health concerns for biometeorological variables such as cooling degree days, number of days of ozone exceedances, lead deposition amounts and distances from major highways. As shown in Figure 3, now only a few areas in southern Ontario contain communities that meet the acceptable conditions for these multiple criteria.

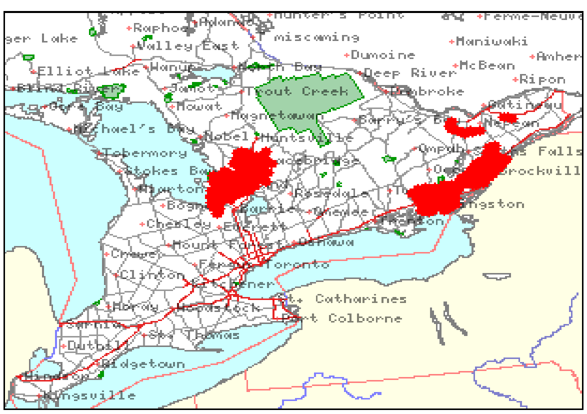

Figure 3. *Locations within southern Ontario that satisfy the following criteria: (1) CDD ≤ 250, (2) days with poor ozone ≤ 5-10 days/year (where hourly ozone maxima reach or exceed 82 ppb), (3) ≤ 0.1 mg/m^2 of lead deposition/year and (4) distances ≤ 20 km from major multi-lane highways.*

8. CONCLUSIONS AND FUTURE DIRECTIONS

The IMAP framework provides an assembly platform for linking multi-disciplinary issues on a range of scales from local to global. The IMAP process also allows national and global issues, such as climate change, to be down-scaled to the regional decision-making level. The 6 steps in the IMAP guidelines have the potential to provide valuable country study assessments on a variety of atmospheric change issues. In addition, the Lifestyle Meteorology prototype is an effective integration and delivery mechanism designed to make the IMAP map collections readily accessible to all users and to enable more informed decision-making on integrated and complex issues.

Both the Lifestyle Meteorology prototype and IMAP are ongoing projects and future versions will continue to expand the suite of maps accessible to users. Future work will address medical applications, wildlife and habitat management and sustainable community planning.

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