GEOSPATIAL OBJECT-BASED HEAT METRICS TO SUPPORT URBAN ENERGY EFFICIENCY PROGRAMS

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ABSTRACT:

In an effort to support municipal plans to reduce green house gas emissions and improve urban energy efficiency, this paper describes HEAT (Home Energy Assessment Technologies) Phase II results from newly developed HEAT Scores and energy metrics for 9000+ homes in The City of Calgary, Alberta, Canada. HEAT integrates advanced geospatial and visualization technologies for residential waste heat monitoring and GHG estimation, based on *geospatial object-based image analysis* (GEOBIA) of individual homes from high-resolution thermal airborne imagery (TABI 1800).

1. INTRODUCTION

As part of The Calgary Climate Change Accord (2009), The Calgary Community green-house-gas (GHG) Reduction Plan (2010), and The City Sustainability Direction (2011), The City of Calgary, Alberta, Canada is seeking an implementation strategy to reduce greenhouse gas (GHG) emissions and promote low-carbon living that is cost-effective, actionable and reaches a wide city audience. Recent literature shows that effective feedback increases public awareness and helps to significantly reduce energy consumption and GHG emissions (Darby, 2006). This is further supported by a host of energy-use monitoring systems appearing on the market. But how can one know if their house or community is energy efficient, where are the inefficient areas located, and what can be done about them? One remote sensing method to improve energy efficiency is to use a thermal sensor to conduct heat loss surveys (Weng, 2009).

The HEAT (Home Energy Assessment Technologies) Geoweb Decision Support Service (GDSS) will allow residents to visualize the amount and location of waste heat leaving their homes and communities, and guide them to save their money and reduce their green-house-gas (GHG) emissions, as easily as clicking on their house in Google Maps (Hay et al, 2011; Blaschke et al, 2011). HEAT integrates advanced geospatial and visualization technologies for residential waste heat monitoring and GHG estimation, geospatial-object-based feature extraction, a GIS, a geospatial database and web-server, GHG-emission and energy-use models, and new world-class (Alberta-built) high-resolution airborne thermal infrared imagery (TABI 1800 - *Thermal Airborne Broadband imager*). The TABI-1800 is a recently developed airborne thermal infrared (TIR) sensor with a swath width of 1,800 pixels in the 3.7 - 4.8 micron spectral region, a thermal resolution of 0.05 °C, and the ability to collect up to 175 km^2 per hour at 1.0 m spatial resolution. This is three to five times larger and faster than most other airborne TIR sensors (ITRES, 2011).

2. STUDY AREA AND DATA

Building on the HEAT Phase I pilot project developed for 368 homes in the Brentwood Community of Calgary, Alberta Canada (Hay et al, 2011), this research describes HEAT Phase II results from newly developed HEAT Scores and energy metrics for 9000+ homes in a study site located in the SW quadrant of the City. Phase III (2013) will scale the project to the full City of Calgary (450, 000 homes). Metrics are derived from a TABI 1800 (36 flight line) mosaic of The City of Calgary (23 km x 35 km) acquired at night (00:00 to 04:30) on April 16, 2011, and from corresponding Calgary cadastral GIS layers and associated attributes.

3. METHODOLOGY

Heat Scores
Heuristically developed GEOBIA methods are applied to the Calgary TABI 1800 mosaic to extract roof-objects from a high-resolution TIR airborne scene (Rahman et al, 2012). Thermal statistics for these objects are then calculated including newly developed *HEAT Scores*. Heat Scores are values ranging from 1-100 that allow a user to meaningfully compare the waste heat of one or more houses (shown on a HEAT Map), with all other mapped houses in their community and city. For example, a HEAT Score of 82 means that this house *wastes less HEAT* than 82% of all other houses in this city. A relative descriptor is also associated with each HEAT Score, which for 82% would state "...Low Waste Heat..." HEAT Scores are calculated based on the *z-score* or *standardized score*, which indicates how many standard deviations an observed value, (in this case the average roof top temperature), is above or below the population mean. For the HEAT Score, this represents the average of all the average roof top temperatures in the city. Similarly, the population represents all the houses in the city. The City HEAT Score and Community HEAT Score is calculated based on the average HEAT Score of all houses in the City and community respectively.

4. PRILIMINARY RESULTS

The HEAT website provides waste-heat and energy-use metrics, information and visualization tools including HEAT Scores, Hot-Spot detection, and energy-use models in a multi-scale interface ranging from the individual house to the full City (Figure 1). As part of this research, our objective is to further evaluate individual HEAT Scores with more complex Nationally based EnerGuide Ratings (Energuide, 2011) and structural information for individual homes (e.g., size, area, age, material types, etc) to establish meaningful, but simplified web-based visual tools to encourage urban energy efficiency.

5. CONCLUSIONS

The HEAT pilot project is a free Geoweb Decision Support Service that provides meaningful feedback to residents in the form of HEAT Scores, maps, statistics and images. These decision support tools can be used to help save residents' money, and reduce their waste heat and GHG emissions. Multiscale analysis of HEAT Scores and metrics can also be conducted over space and time from individual houses to communities and cities thereby providing support to Government and municipal Energy Efficiency and Ecological Footprint programs.

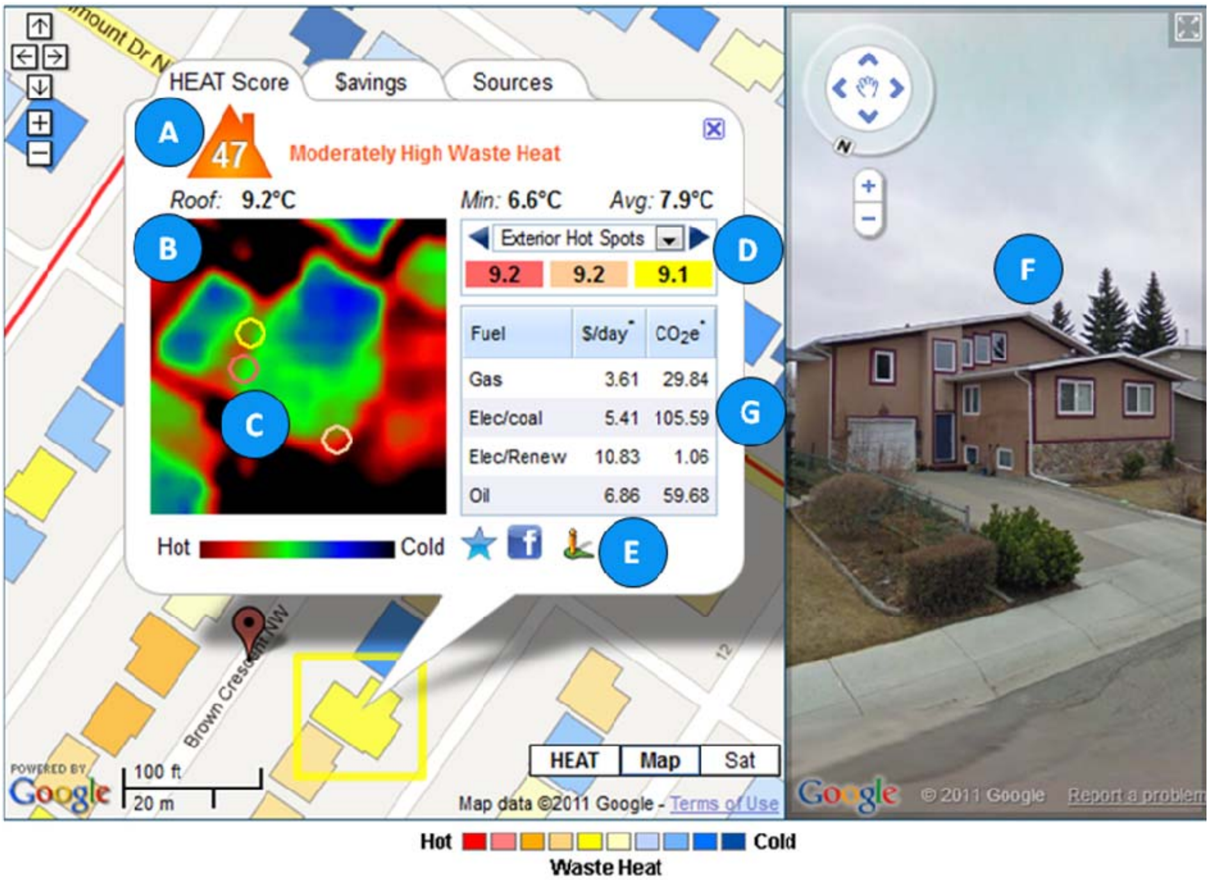

Fig 1: The House HEAT Map (thermal bubble) overlaid on the residential HEAT map (colored polygons) shows (A) the house HEAT Score (47/100), (B) the moused-over roof temp (9.2°C), (C) three Hot-Spots (circles) and (D) their real temperatures (9.2 – 9.1°C), (E) the Google Street View icon linked to (F) the corresponding house Street View, and (G) the Fuel and GHG Table estimating the cost per day to heat the house with different fuel types, and their associated green house gases (CO_2e).

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To evaluate the HEAT GeoWeb platform, please login as (*beta*) to http://www.wasteheat.ca with the password *beta* (no italics).

References

Blaschke, T., Hay, G. J., Weng, Q., and Resch, B. 2011. Collective Sensing: Integrating Geospatial Technologies to Understand Urban Systems - An Overview. *Remote Sens.* 3, no. 8: 1743-1776. [Free download at: http://www.mdpi.com/2072-4292/3/8/1743/]

Darby, S, 2006. The Effectiveness of Feedback on Energy Consumption; Report published by Environmental Change Institute; University of Oxford: Oxford, UK. Available online: http://www.eci.ox.ac.uk/research/energy/downloads/smart-metering-report.pdf - (last accessed November 10, 2011).

Energuide, 2011. What is the EnerGuide Rating System? http://oee.nrcan.gc.ca/residential/personal/new-homes/upgrade-packages/energuide-service.cfm - (last accessed November 10, 2011).

Hay, G. J.; Kyle, C.; Hemachandran, B.; Chen, G.; Rahman, M. M.; Fung, T. S.; Arvai, J. L. 2011. Geospatial Technologies to Improve Urban Energy Efficiency. *Remote Sens.* 3-7. 1380-1405. [Free download at: http://www.mdpi.com/2072-4292/3/7/1380/].

ITRES, TABI 1800 spec sheet, http://www.itres.com/assets/pdf/TABI-1800.pdf - (last accessed November 10, 2011).

M. M. Rahman, G. J. Hay, B. Hemachandran, A. Tam and S. Mah, 2012. GEOSPATIAL OBJECT BASED MOSAICING OF HIGH-RESOLUTION THERMAL AIRBORNE IMAGERY (TABI 1800) TO IMPROVE ROOF SHAPE AND THERMAL STATISTICS. Conference proceedings of GEOBIA 2012. May 7-9 Rio de Janeiro, Brazil.

Weng, Q. 2009. Thermal infrared remote sensing for urban climate and environmental studies: Methods, applications, and trends. ISPRS Journal of Photogrammetry and Remote Sensing. Vol 64, pp 335-344