Summer in the City

Forecasting and mapping human thermal comfort in urban areas

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eScience use-case

• eScience in meteorology: high-resolution ($100m^2$) weather forecasting
• requires and generates lots of data

Will show that escience has become an indispensable tool for researchers.
Mostly sunny tomorrow

- Traditional weather forecasts no longer good enough.
- **general demand for high resolution forecasts** (extremes in) temperature, thermal comfort, …
- Weather conditions can be strongly influenced by **the local environment**.
Urban weather

The construction of modern cities leads to an amplification of temperatures: the Urban Heat Island

This can lead to dangerous situations during heat waves, even in the Netherlands.
Research question

Can we do neighborhood scale (urban) weather forecasts?

This requires:

- a high resolution forecast model (WRF)
- detailed urban database for the Netherlands
- observations for model validation
Data requirements

Urban morphology (100 m²):
- mean building height
- std. dev. building height
- plan fraction
- frontal area (4 orientations)
- histogram of building height

Social-economic data (km²):
- population density
- car ownership
- gas and electricity use

General surface data:
- land use (25 m²)
- soil type (100 m²)
- urban fraction (25 m²)

Observational data:
- High-resolution spatial patterns of urban temperature
- Long time series
Methodology

• Inventory and combine datasets
• Process and convert to usable format
• Calculate relevant statistics

Tools:
• GDAL (Geospatial Data Abstraction Library) www.gdal.org
• PostgreSQL database
• PostGIS with raster extension www.postgis.net
• QGIS (visualization)
• Javascript (Leaflet, OpenLayers, ncWMS, …)
Dutch Kadaster:
All buildings, roads, and for each land parcel the allowed land use.

file format: GML
Height map of the Netherlands

- AHN / OHN
- Lidar based
- Separation in elevation and object height
- 50 cm resolution (5 cm vertical)

raster data
Height map of the Netherlands

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- 50 cm resolution (5 cm vertical)

Raster data
Photos

Aerial photographs of the Netherlands in RGB+I

- Summer 2008
- NDVI: (I-R)/(I+R)
- 22 cm / 6m resolution

raster data
Demographics

Demographic data from the Dutch Statistical Office (CBS)

- 12000 regions
- 200 statistics per region: population, income, energy use, ...

ESRI shapefiles
Observations

- Network of custom meteostations
- Crowd sourced observations from Wunderground
- Official meteostations

Excel, CSV, NetCDF

G Steeneveld, R van Haren, personal communication
Project status

- urban data collection and processing finished, functional model setup
- observations collected for 2014 and 2015, measurements ongoing

Scientific output:
- daily forecasts for summer 2015 (online)
- statistical analysis of urban heat effect (online)
- thermal comfort app
High resolution forecasts

- daily 100m resolution, 48 hour forecasts have been run for Amsterdam
- 3 months of forecasts and observations ready to be analyzed (~0.5TB)
- first results look promising
High resolution forecasts

- daily 100m resolution, 48 hour forecasts have been run for Amsterdam
- 3 months of forecasts and observations ready to be analyzed (~0.5TB)
- first results look promising.
Urban heat island climatology

Heat wave impact assessment:

<table>
<thead>
<tr>
<th>demographic</th>
<th>$UHI$ 95$^{th}$ Percentile</th>
<th>Percentage $UHI$ 95$^{th} &gt; 4^\circ C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>all ages</td>
<td>3.4$^\circ C$</td>
<td>31%</td>
</tr>
<tr>
<td>younger than 14</td>
<td>3.4$^\circ C$</td>
<td>31%</td>
</tr>
<tr>
<td>older than 65</td>
<td>3.3$^\circ C$</td>
<td>26%</td>
</tr>
</tbody>
</table>

www.met.wau.nl/SummerInTheCity
Thermal comfort App

Provides a forecast of *thermal comfort* at your current location:

- statistical downscaling of an operational weather forecast (GFS)
- based on the high resolution datasets
- thousands of installs!

Implementation: gert sterenborg
Summary

Presented a use case on high resolution weather forecasting, and our efforts to make forecasts at an intra-urban scale possible.

Take-home eScience experience:

- Lots of high (and low) quality data has become available, allowing new applications.
- Scientific application only limited by our ability to process and analyze it!
URBAN HEAT ISLAND PROFILE
Urbanization

1900

2012

10 km
UHI statistics

Statistics are derived from:
- a network of amateur meteorologists (Weather Underground)
- official KNMI weather stations

And then fitted to green fraction ($\gamma$, [%]) and population density ($\rho$, [#/$km^2$]):

\[
\begin{align*}
\text{UHI } 50^{th} &= -0.019 \gamma + 1.007 \rho^{0.124} \\
\text{UHI } 95^{th} &= -0.032 \gamma + 1.965 \rho^{0.138}
\end{align*}
\]

G Steeneveld, R van Haren, personal communication
Datasets

Kadaster TOP10NL:
• All buildings, roads, and for each land parcel the allowed land use.
• 30 GB of GML (1.7 GB zipped)
• Imported using GDAL

PostgreSQL database size:
1 GB for buildings (~3 million entries)
2 GB for land use (~2 million entries)
Datasets 2

Aerial photographs of the Netherland in RGB+I
- 22 cm resolution, ~TB of TIFFS
- Using an overview at 6m resolution 7GB
- imported using raster2pgsql

PostgreSQL database:
- 6 GB (300K tiles of 516mx558m)
Dataset3

CBS demographic data
• 50 MB ESRI shapefile
• 12K regions
• 200 demographic indicators per region.
• Imported using shp2pgsql

PostgreSQL database:
• 150 MB
Urban morphology

all: > 500 addresses per km$^2$

high density: > 2500 addresses per km$^2$