Motivation & determination of world-wide future weather data and heatwaves

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On behalf of:
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Future weather data and heatwaves: structure of the presentation

- **Purpose** of the future Weather datasets generated for the Annex 80
- **Methodology**: selected cities, data source, validation
- **Results**
  - Expected changes in "Typical Meteorological Years"
  - Future heatwaves (Anaïs Machard – following presentation)
Future weather data and heatwaves: motivation

The world is facing a rapid increase of air conditioning of buildings. This is driven by multiple factors, such as urban growth and climate change.

It is the motivation of the Annex 80 to develop, assess and communicate solutions of resilient cooling and overheating protection (...) to withstand, and also prevent, thermal stress and building cooling demand increase due to higher ambient temperatures and increased frequency and severity of heat wave events.

The WEATHER DATA TASK FORCE of the IEA EBC Annex80 was created to agree on a common and scientifically robust methodology to produce sets of weather data of characteristics climate zones worldwide.

The purpose of the data is to carry out building performance simulations to assess thermal stress and building cooling demand in present and future periods.

Future weather data and heatwaves: what kind of future weather data?

Two kinds of weather files are needed:

1) Typical Meteorological Years
2) Weather files including heatwaves

For present and future periods
For representative climate zones

Source: (IPCC). Climate Change 2001: The scientific basis. Contribution of Working Group I
Future weather data and heatwaves: climate projections and emission scenarios

- The analysis of future climate is based on projections of climate models.

- Assumptions for climate models are the greenhouse gas concentration scenarios developed by the Intergovernmental Panel for Climate Change’s (IPCC) assessment reports (AR).

- 5th AR, released four Representative Concentration Pathways (RCPs) in 2014, which are identified by their associated warming effect (radiative forcing) in the year 2100.

Selected RCP:
RCP8.5: Assumes a ‘business-as-usual’ approach (worst case scenario)

Selected periods
- Historical 2010s: (2001-2020)
- Future med-term 2050s: (2041-2060)
- Future long term 2090s: (2081-2100)

20-years: minimum recommended length of time for climate change impact assessment studies.

Future weather data and heatwaves: what methodology?

Need downscaling:
To obtain higher resolution data

Statistical downscaling (Morphing Method) using Future mean value (GCMs) to modify observed weather data

Dynamical downscaling Using RCMs models forced by boundary conditions from a GCM model

General Circulation Models - GCM
Spatial resolution: 150-600 km

Regional Climate Models - RCM
Spatial resolution: down to 2.5 km
Future weather data and heatwaves: advantages of dynamical downscaling using RCMs

Summer Precipitation


RCMs allow representation of extreme events such as heatwaves, which is not possible with other weather generators based on statistical downscaling (i.e. METENORM).

Future weather data and heatwaves: CORDEX datasets

CORDEX: COrdinated Regional Downscaling EXperiment
Project sponsored by World Climate Research Program (WCRP) to provide regional-scale climate projections for impact assessment and adaptation studies

Several climate models and socio-economic projections worldwide, within the IPCC AR5 timeline

Specifications of the CORDEX data used:

GCM-RCM models: MPI-ESM-LR/REMO
Model combination that is closer to the median temperature of all climate models projections.

Data resolution:
- Minimum 3h temporal frequency
- Minimum 25 km spatial resolution

Variables:
- Dry-bulb air Temp
- Relative humidity
- Global horizontal irradiation
- Wind Speed
- Atmospheric pressure
Future weather data and heatwaves: bias-correction of RCM data

**Goal**: to reduce long term bias associated with climate model data

<table>
<thead>
<tr>
<th>Hourly historical observations (20-years ideally, 5 years minimum)</th>
<th>Bias-correction methods:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hourly CORDEX climate data (same period for which observations are available)</td>
<td></td>
</tr>
</tbody>
</table>

**Bias-correction methods**:

1) Solar Irradiation: Quantile delta mapping (QDM) (Cannon et al., 2015)

2) Rest of climate variables: Multivariate Bias Correction (MBC) (Cannon, 2018)

**RCM Observations**

**Bias-corrected RCM**

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Future weather data and heatwaves: Selecting representative cities

**Criteria**:

1. At least one city for climate zones considering the ASHRAE classification

<table>
<thead>
<tr>
<th>CZ</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0A</td>
<td>Extremely Hot Humid</td>
</tr>
<tr>
<td>0B</td>
<td>Extremely Hot Dry</td>
</tr>
<tr>
<td>1A</td>
<td>Very Hot Humid</td>
</tr>
<tr>
<td>1B</td>
<td>Very Hot Dry</td>
</tr>
<tr>
<td>2A</td>
<td>Hot Humid</td>
</tr>
<tr>
<td>2B</td>
<td>Hot Dry</td>
</tr>
<tr>
<td>3A</td>
<td>Warm Humid</td>
</tr>
<tr>
<td>3B</td>
<td>Warm Dry</td>
</tr>
<tr>
<td>3C</td>
<td>Warm Marine</td>
</tr>
<tr>
<td>4A</td>
<td>Mixed Humid</td>
</tr>
<tr>
<td>4B</td>
<td>Mixed Dry</td>
</tr>
<tr>
<td>4C</td>
<td>Mixed Marine</td>
</tr>
<tr>
<td>5A</td>
<td>Cold Humid</td>
</tr>
<tr>
<td>5B</td>
<td>Cold Dry</td>
</tr>
<tr>
<td>5C</td>
<td>Cool Marine</td>
</tr>
<tr>
<td>6A</td>
<td>Cold Humid</td>
</tr>
<tr>
<td>6B</td>
<td>Cold Dry</td>
</tr>
</tbody>
</table>

© ASHRAE
Future weather data and heatwaves: Selecting representative cities

Criteria:
1. At least one city for climate zones considering the ASHRAE classification
2. Cities with high population and growth
3. Cities in different continents

Future weather data and heatwaves: Selected cities

<table>
<thead>
<tr>
<th>CLIMATE ZONE</th>
<th>City</th>
<th>Population 2022</th>
<th>Change % (since 2021)</th>
<th>Country</th>
<th>Continent</th>
</tr>
</thead>
<tbody>
<tr>
<td>0A</td>
<td>Singapore</td>
<td>6,039,577</td>
<td>0.80%</td>
<td>Singapore</td>
<td>Asia</td>
</tr>
<tr>
<td>0B</td>
<td>Abu Dhabi</td>
<td>1,539,830</td>
<td>1.86%</td>
<td>UAE</td>
<td>Asia</td>
</tr>
<tr>
<td>1A</td>
<td>Guayaquil</td>
<td>3,092,355</td>
<td>1.62%</td>
<td>Ecuador</td>
<td>South America</td>
</tr>
<tr>
<td>2A</td>
<td>Sao Paulo</td>
<td>22,429,800</td>
<td>0.86%</td>
<td>Brazil</td>
<td>South America</td>
</tr>
<tr>
<td>3A</td>
<td>Buenos Aires</td>
<td>15,369,919</td>
<td>0.74%</td>
<td>Argentina</td>
<td>South America</td>
</tr>
<tr>
<td>3A</td>
<td>Rome</td>
<td>4,297,977</td>
<td>0.46%</td>
<td>Italy</td>
<td>Europe</td>
</tr>
<tr>
<td>3B</td>
<td>Los Angeles</td>
<td>3,985,516</td>
<td>0.05%</td>
<td>California</td>
<td>North America</td>
</tr>
<tr>
<td>4A</td>
<td>Brussels</td>
<td>2,109,631</td>
<td>0.67%</td>
<td>Belgium</td>
<td>Europe</td>
</tr>
<tr>
<td>4A</td>
<td>Gent</td>
<td>n/a</td>
<td>n/a</td>
<td>Belgium</td>
<td>Europe</td>
</tr>
<tr>
<td>4A</td>
<td>London</td>
<td>9,540,576</td>
<td>1.22%</td>
<td>UK</td>
<td>North America</td>
</tr>
<tr>
<td>4C</td>
<td>Vancouver</td>
<td>2,631,690</td>
<td>0.97%</td>
<td>Canada</td>
<td>Europe</td>
</tr>
<tr>
<td>5A</td>
<td>Toronto</td>
<td>6,312,974</td>
<td>0.93%</td>
<td>Canada</td>
<td>North America</td>
</tr>
<tr>
<td>5A</td>
<td>Copenhagen</td>
<td>1,370,131</td>
<td>0.85%</td>
<td>Denmark</td>
<td>Europe</td>
</tr>
<tr>
<td>5A</td>
<td>Vienna</td>
<td>1,960,023</td>
<td>0.78%</td>
<td>Austria</td>
<td>Europe</td>
</tr>
<tr>
<td>6A</td>
<td>Montreal</td>
<td>4,276,526</td>
<td>0.68%</td>
<td>Canada</td>
<td>North America</td>
</tr>
<tr>
<td>6A</td>
<td>Stockholm</td>
<td>1,679,050</td>
<td>1.36%</td>
<td>Sweden</td>
<td>Europe</td>
</tr>
</tbody>
</table>

Future weather data and heatwaves: Summary of methods and outputs

**Method:** EN ISO 15927-4:2005 standard

- Typical Meteorological Years (TMYs)
  - **Method:** Using Observations
  - TMYs are constructed from the 12 most representative months (“Best months”) from the multi-year period.

**OUTPUT 1:**
- Statistical analysis of the 20-years periods

**OUTPUT 2:**
- Weather files including heatwaves (HWs)
  - **Method:** Ouzeau et al., 2016
  - Based on relative temperature thresholds to detect heatwaves

**RM projections (CORDEX) + Bias-adjustment (Using Observations)**

**Hourly bias-adjusted datasets of:**
- Dry-bulb air Temp
- Relative humidity
- Global horizontal irradiation
- Wind Speed
- Atmospheric pressure

**For 20-years periods:**
- Historical: (2001-2020)
- Future medium term (2041-2060)
- Future long term (2081-2100)
Future weather data: Projected changes in climate variables

Drybulb air Temperature change

- TMYs well represent the 20-year period trend.
- The air temperature is consistently higher in the future for all the cities.
- Higher increase in the long term that in the mid-term TMY

Relative Humidity change

High variability in the sign of future changes in relative humidity.

Increasing RH:
- Singapore (CZ: Extremely Hot Humid)
- Guayaquil (CZ: Very Hot Humid)
- Buenos Aires (CZ: Warm Humid)
- Los Angeles (CZ: Warm Dry)
- Vancouver (CZ: Mixed Marine)

Decreasing RH:
- Sao Paulo (CZ: Hot Humid)
- Abu Dhabi (CZ: Extremely Hot Dry)

Global solar radiation is reduced in the future TMYs of the majority of the cities.

This is in agreement with the 20-years projections.

Same results found in other studies.
It can be explained by increasing aerosol concentrations and increasing cloudiness

The changes in wind speed are minimal for most of the cities.

The 2090s-TMY of Vancouver (CZ: Mixed Marine) has the largest decreases in mean wind speeds of 0.7 m/s.
Future weather data: References and data availability

The outcomes of this work will be made soon available through a data paper (in progress).

The following datasets will be available for download from the IEA EBC Annex80 webpage:

- 20-years hourly datasets
- TMYS in EPW format
- Weather files including heat waves in EPW format

For each city and time period analysed

Weather Data Task force: Institutions contributing to the data generation

- Politecnico di Torino, Italy
- La Rochelle Université & CSTB, France
- Brunel University London, United Kingdom
- Concordia University, Canada
- Natural Research Council of Canada
- Fraunhofer Institute for Building Physics IBP, Germany
- Lawrence Berkeley National Laboratory, California
- CIMEC/ CONICET, Argentina
- Federal University of Santa Catarina, Brasil
- Institute of Building Research & Innovation, Austria
- Belgian Building Research Institute (BBRI), Belgium
- University of Liege, Belgium
- KU Leuven, Belgium
- Aalborg University, Denmark
- University of Gävle, Sweden
- ENEA, Italy

REFERENCES:


Thank you!

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