Erasmus+ Action Type: KA220-HED - Cooperation partnerships in higher education
Climate change, cities, communities and Equity in health Cli-CC.HE
Project Reference: 2021-1-IT02-KA220-HED-000032223

2nd Transnational Project Meeting: “Methodology and toolkit”

Ascoli Piceno, November 22-23, 2022

Session 1:Healthy urban planning Teaching Methodological Guidelines (R2) and Educational Toolkit for healthy urban planning and urban participation(R3)

Heath and Climate Profile Model and proposal for the Toolkit

Roberta Cocci Grifoni, Salvatore Carlucci, Ioanna Kyprianou, Giandomenico Vurro, Graziano Enzo Marchesani

What is the Climate Profile?

Reconstruction of climate features characterising a specific location

THEORY

CLIMATE MODELLING | MICROCLIMATE MODELLING | BIOCLIMATIC ASSESSMENT

SUITE OF TOOLS
e.g. Ladybug

APPLICATION

Ladybug	Honeybee	Butterfly	Dragonfly	Spider
Climate Visualization + Analysis	Building Energy, Daylight + Comfort Modelling	Airflow Modelling (CFD)	Climate Modelling (heat island, future climate)	Web Visualization (sunpath, shadows, gbxml viewing/editing, rad viewer)

Climate Modeling

S&TR, 2017

Mathematical equations **defining** the Earth's physical system on a temporal scale;

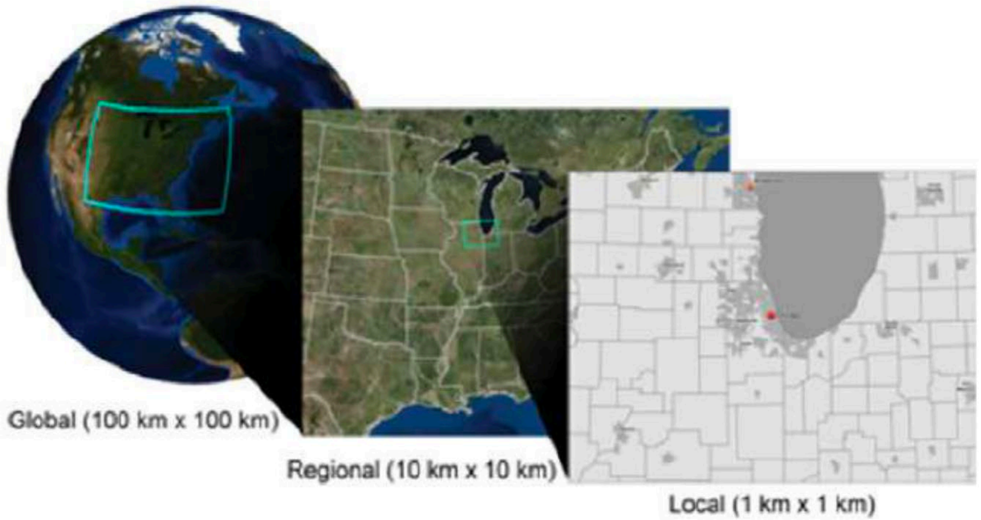
Global Climate Models (GCMs) simulate the **interactions** among the atmosphere, ocean, land surface, and ice;

GCMs' horizontal resolution is in the order of 100km.

GCMs' resolution is **too coarse** to provide actionable climate change information at the local scale.

Regional Climate Models (RCMs) focusing on a smaller area can provide higher-resolution climate data, **up to 500m.**

To run RCMs the input climate data for their simulation needs to bee tuned. This process is called **Downscaling**.



Kotamarthi et al., 2021

Downscaling techniques

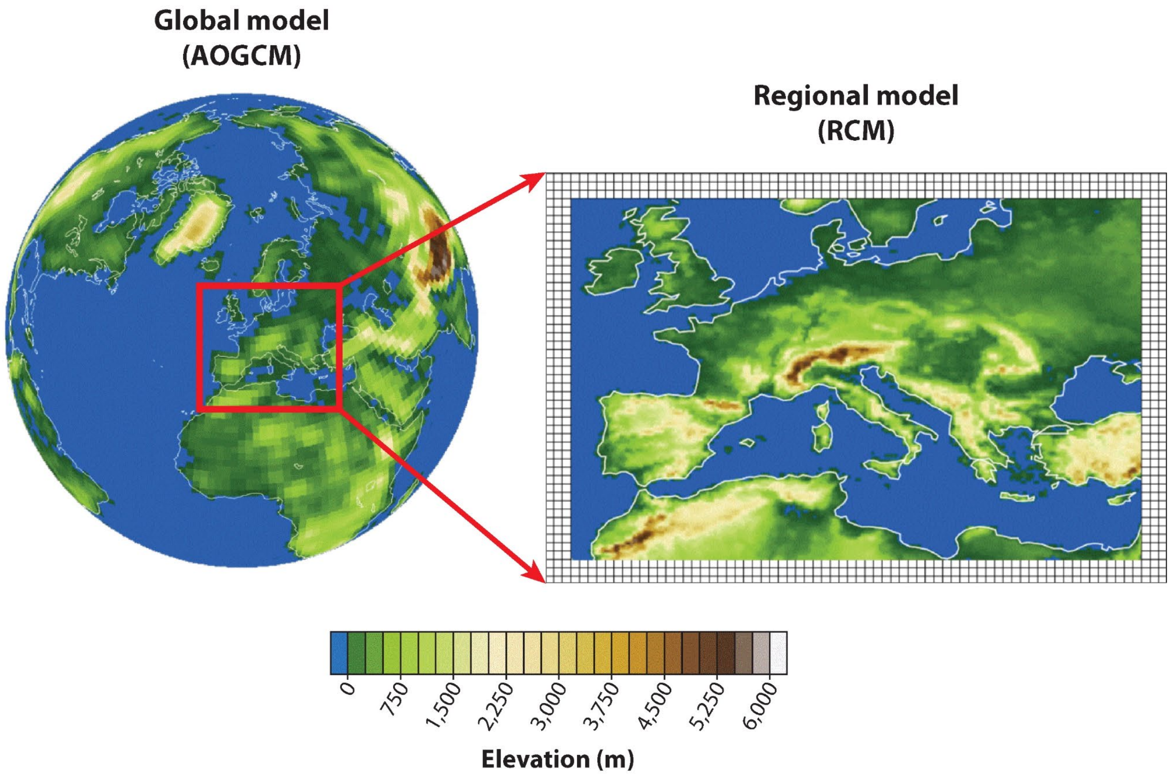
Dynamical Downscaling

A **finer-scale** climate model (RCM) runs simulations adopting data from coarser GCM.

The most common approach is **“on-way nesting.”** The output data from the GCMs are used as the **Initial Boundary Conditions (ICs)** and **Lateral Boundary Conditions (LBCs)** for the RCM.

Better results over regions with **complex topography** and **coastlines** and **significant differences** in **land surface processes**.

It requires **a lot** of **computational power** and **data storage**, in addition to some **expertise** for its implementation.



Giorgi & Gutowski, 2015

Downscaling techniques

Empirical/Statistical Downscaling

A **statistical relationship** between data from GCMs and observation at a finer scale is established.
There are three main statistical methods:

- Regression techniques
- Weather typing schemes
- **Weather generators**

It is **less demanding** in computing resources than the dynamical downscaling, and weather generators can create **sub-daily data**.

Some **specialist knowledge** is required, and each method has its **challenges**.

Weather Generators: CC World Weather Generator

A **statistical Excel-based tool** that adopts the **"Morphing." This method** adjusts the design of weather data according to three algorithms:

- Shift: $x = x_0 + \Delta x_m$
- Linear stretch: $x = \alpha_m x_0$
- Shift and stretch: $\boldsymbol{x} = \langle \boldsymbol{x_0} \rangle_m + \Delta \boldsymbol{x_m} + (\mathbf{1} + \boldsymbol{\alpha_m}) + (\boldsymbol{x_0} - \langle \boldsymbol{x_0} \rangle_m)$

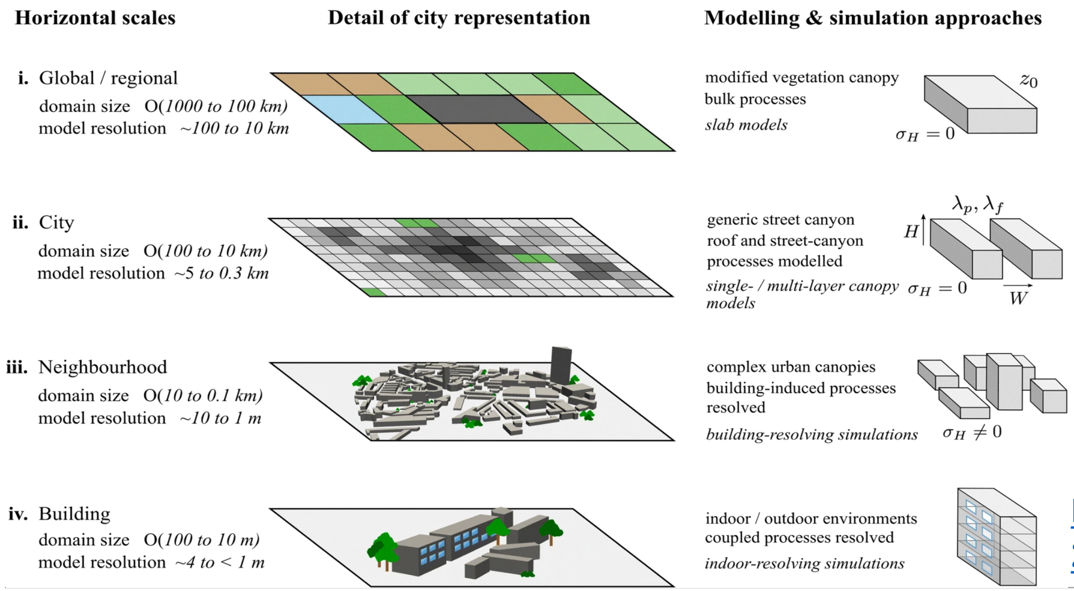
$\boldsymbol{x_0}$ is the present-day climate variable, $\boldsymbol{\Delta x_m}$ is the shift, and $\boldsymbol{\alpha_m}$ is the stretch.

Future climate files have the **same variability** and character as the **present climate** since the **baseline weather file** represents the **current climate**.

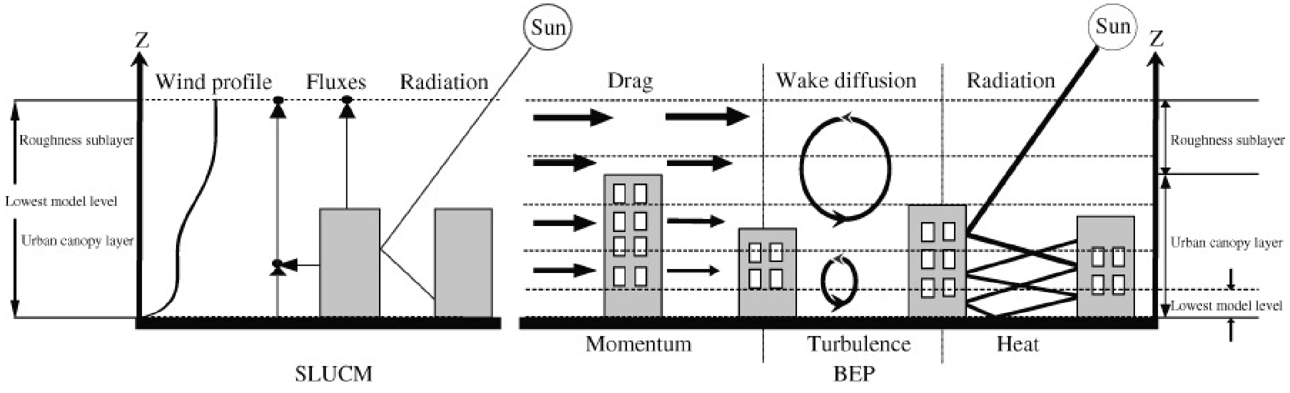
Co-funded by the Erasmus+ Programme of the European Union

Urban Climates

Urban growth affects the **atmospheric processes** developing consequently distinct **urban climates**.
Urban climates **range** over **different** time and horizontal **space scales**.
Phenomena related to these climates can be **studied** by adopting **different tools** at different **scales**.



[Hertwig et al., 2020]



[Chen et al., 2011]

RCMs, to describe the **urban environment** and induced climate phenomena, adopt **three schemes**:

- Bulk parameterization
- Single-layer Urban Canopy Model (SLUCM)
- Multi-layer Building Effect Parameterization (BEP)

The **level of detail** increases, moving from the **simplest Bulk** to the **most detailed** and complex **BEP**

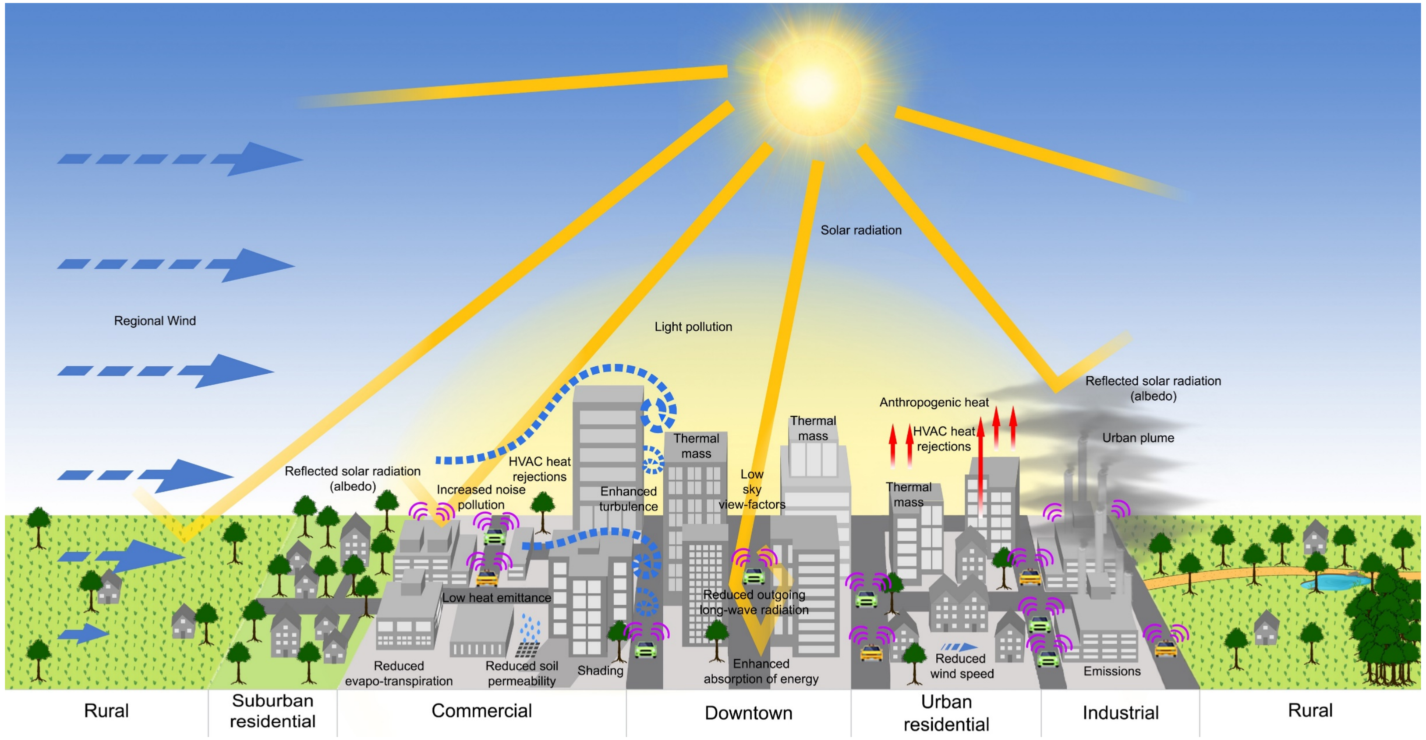
Co-funded by the
Erasmus+ Programme
of the European Union

Microclimate modeling

The parameterizations adopted by RCMs cannot capture all the features and the fluxes flowing through the city.

Modeling of the **microclimate** is needed to have a **very high-resolution representation** of urban and **built environment behavior** under **climate-induced phenomena**.

CFD tools are usually adopted to run these simulations, but they are **computationally demanding** and **time-consuming**.



Vurro 2022, work in progress

These simulations are needed to **test** planning and urban design **proposals** and predict urban developments' impacts on local climate and building thermal behavior.

Urban heat island effects are largely studied through this approach.

Common tools include ENVI-met, RayMan, Autodesk, Ladybug, etc.

Co-funded by the Erasmus+ Programme of the European Union

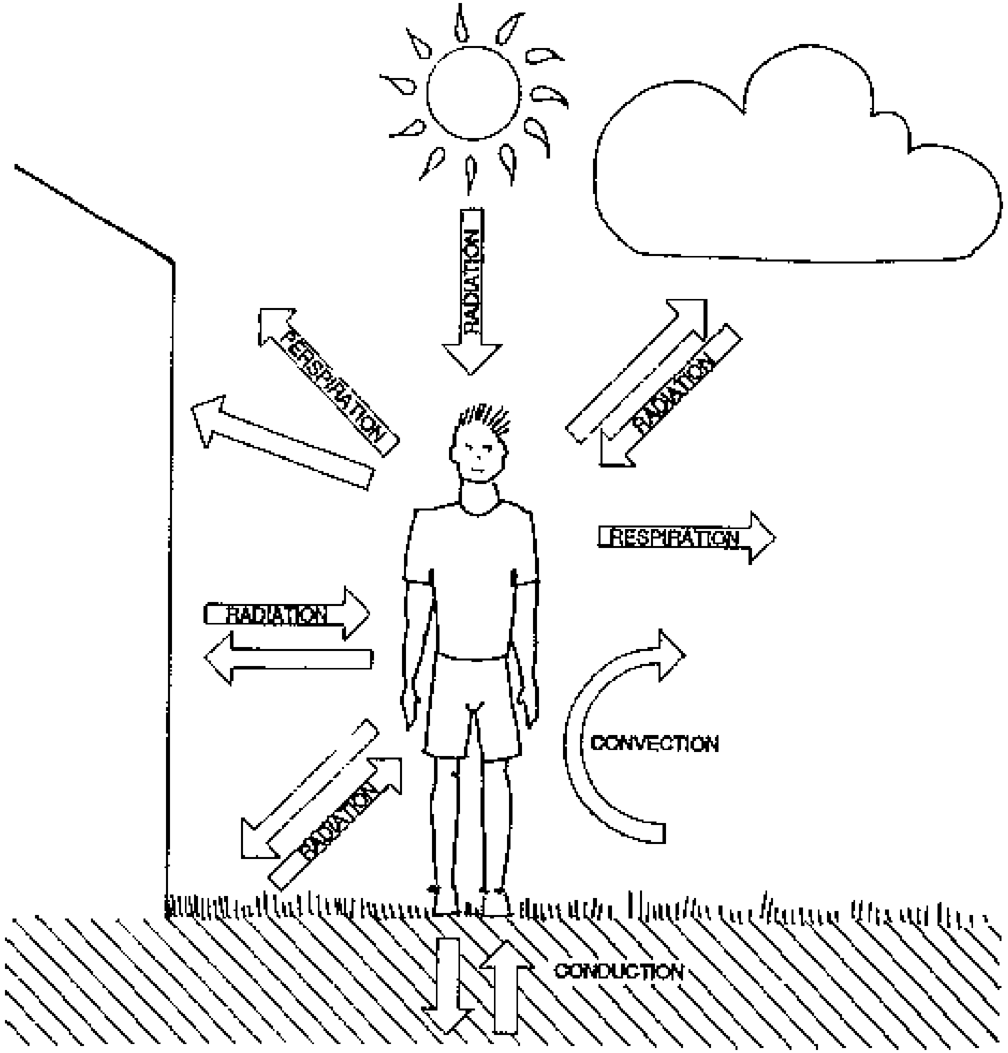
Bioclimatic assessment

The study of the effect of **climate** on the **human body** defines human bioclimatology.

The general well-being of individuals is affected considerably by the **bioclimatic conditions**.

The need for human **thermal balance modeling** resulted in the development of bioclimatic models.

Common indicators computed by bioclimatic models are the UTCI Universal Thermal Climate Index (**UTCI**) and Physiological Equivalent Temperature (**PET**).

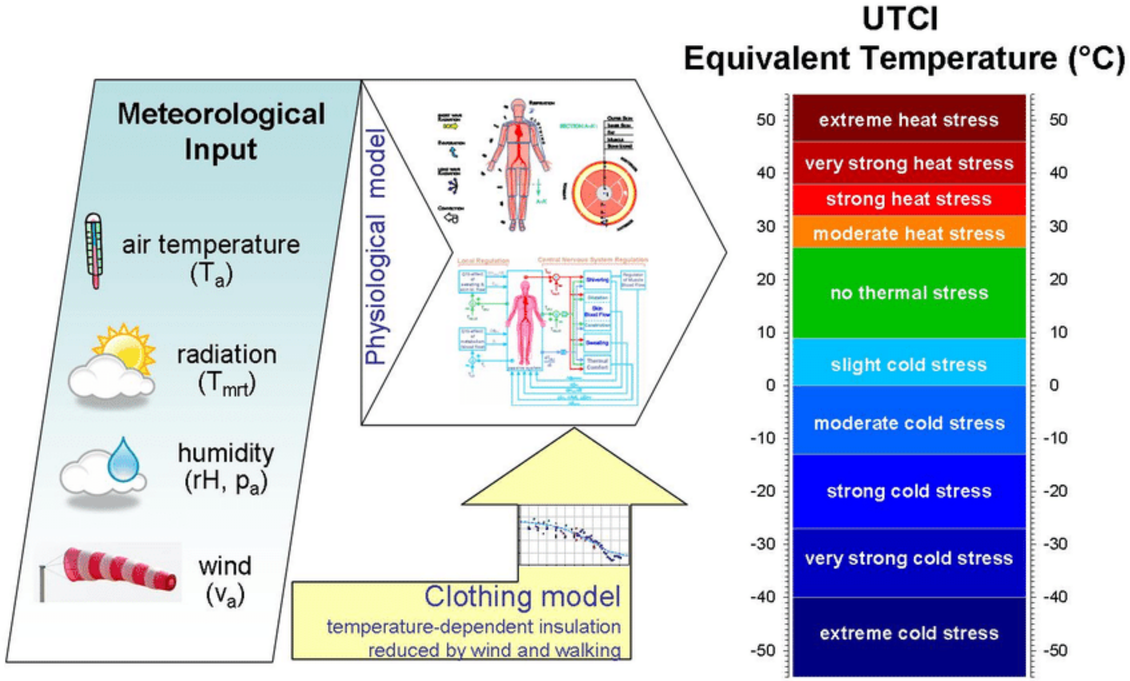


SKAT, 1993

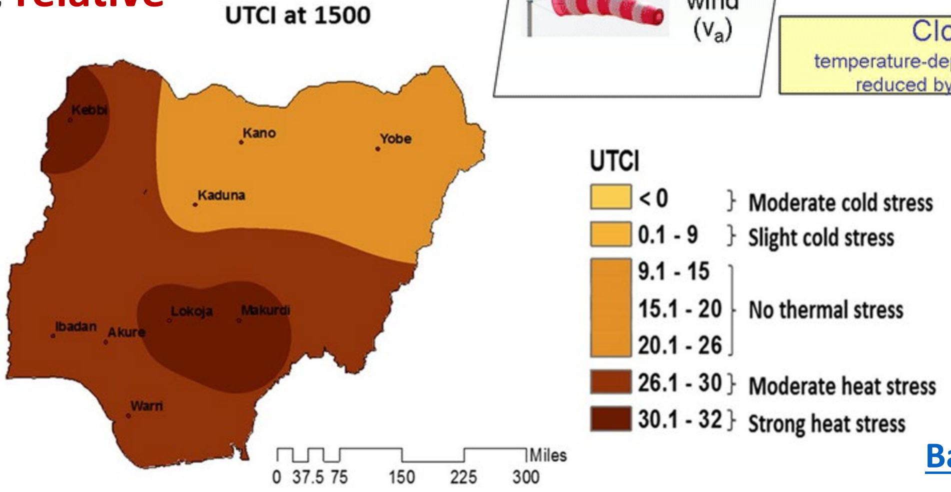
Bioclimatic assessment - UTCI

The UTCI is a measure of the human **physiological response to the thermal environment**. It describes the synergistic heat exchanges between the thermal environment and the human body, namely its **energy budget**, **physiology** and **clothing**.

The UTCI considers four meteorological parameters: **air temperature**, **mean radiant temperature**, **relative humidity** and **wind velocity**.



Bröde et al., 2011



Balogun et al., 2019

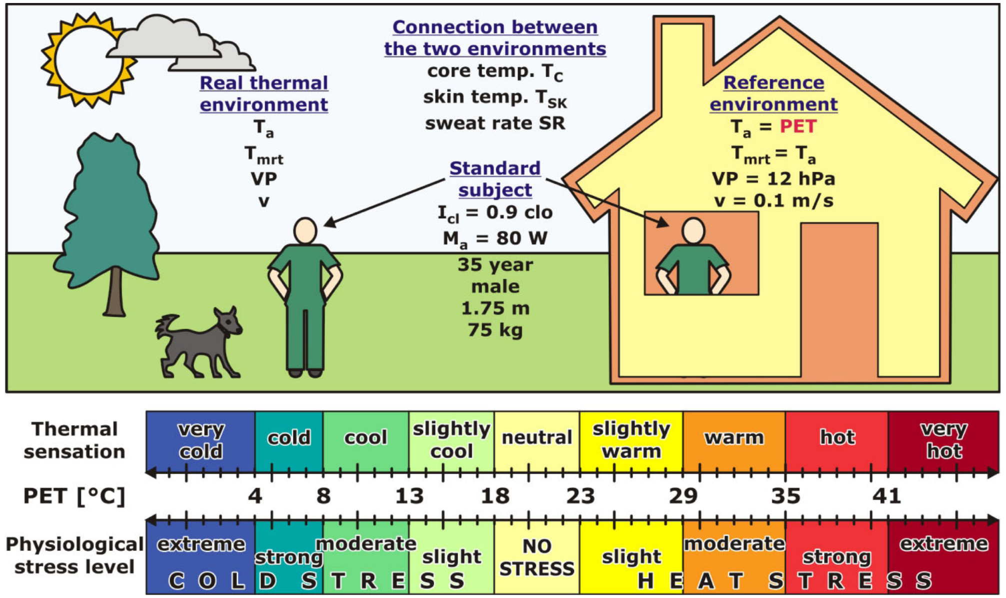
Co-funded by the Erasmus+ Programme of the European Union

Bioclimatic assessment - PET

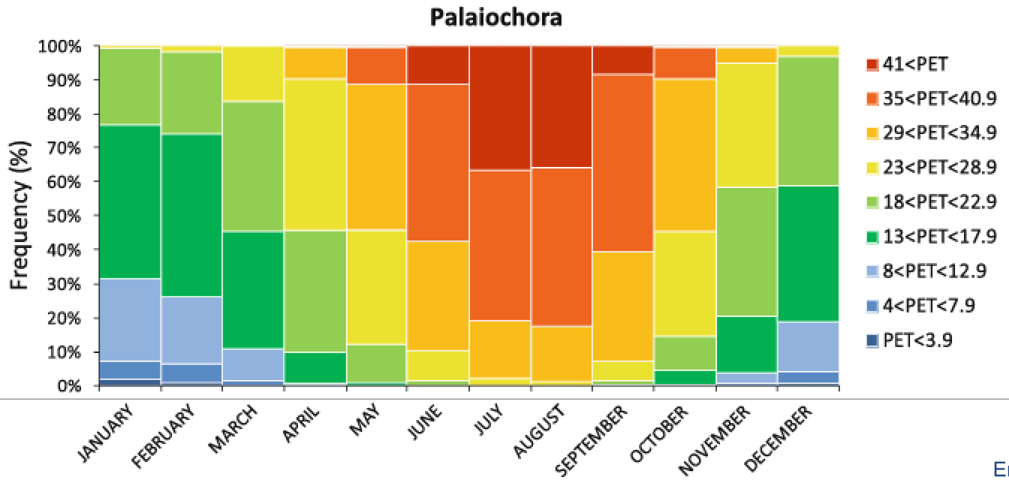
PET is defined as the air temperature at which, in a typical indoor setting (without wind and solar radiation), the **heat budget** of a standardized human body is **balanced** with the same core and skin temperature as under the complex outdoor conditions to be assessed.

The standardized person is characterized by a work **metabolism** of 80 W of light activity, in addition to basic metabolism; and by 0.9 clo of heat resistance as a result of **clothing.**

It also considers four meteorological parameters: **air temperature**, **mean radiant temperature**, **air humidity** and **wind velocity**.



Kántor et al., 2016



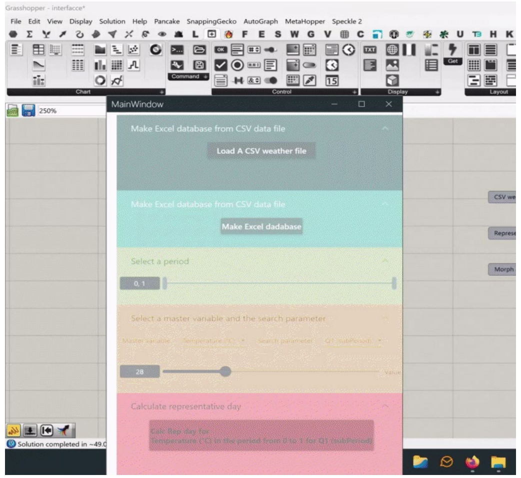
Bleta et al., 2013

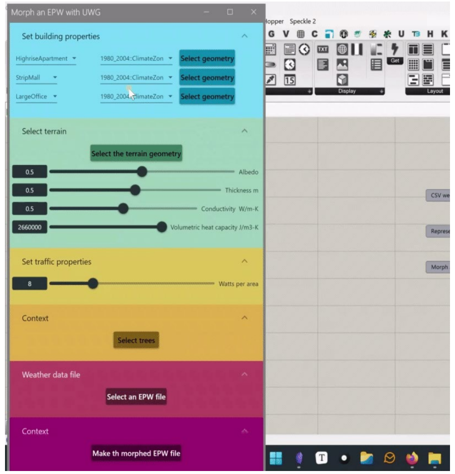
Co-funded by the
Erasmus+ Programme
of the European Union

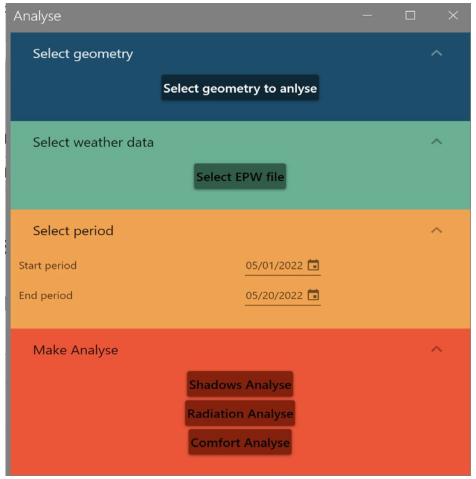
Ladybug suite of tools

Advanced approach /
Develop a user-friendly interface to evaluate:

1_Climate scenario_ starting from actual data
2_Data morphing_starting from a rural EPW file to account urban conditions based on defined urban parameters.
3_Universal Thermal Climate Index_UTCI



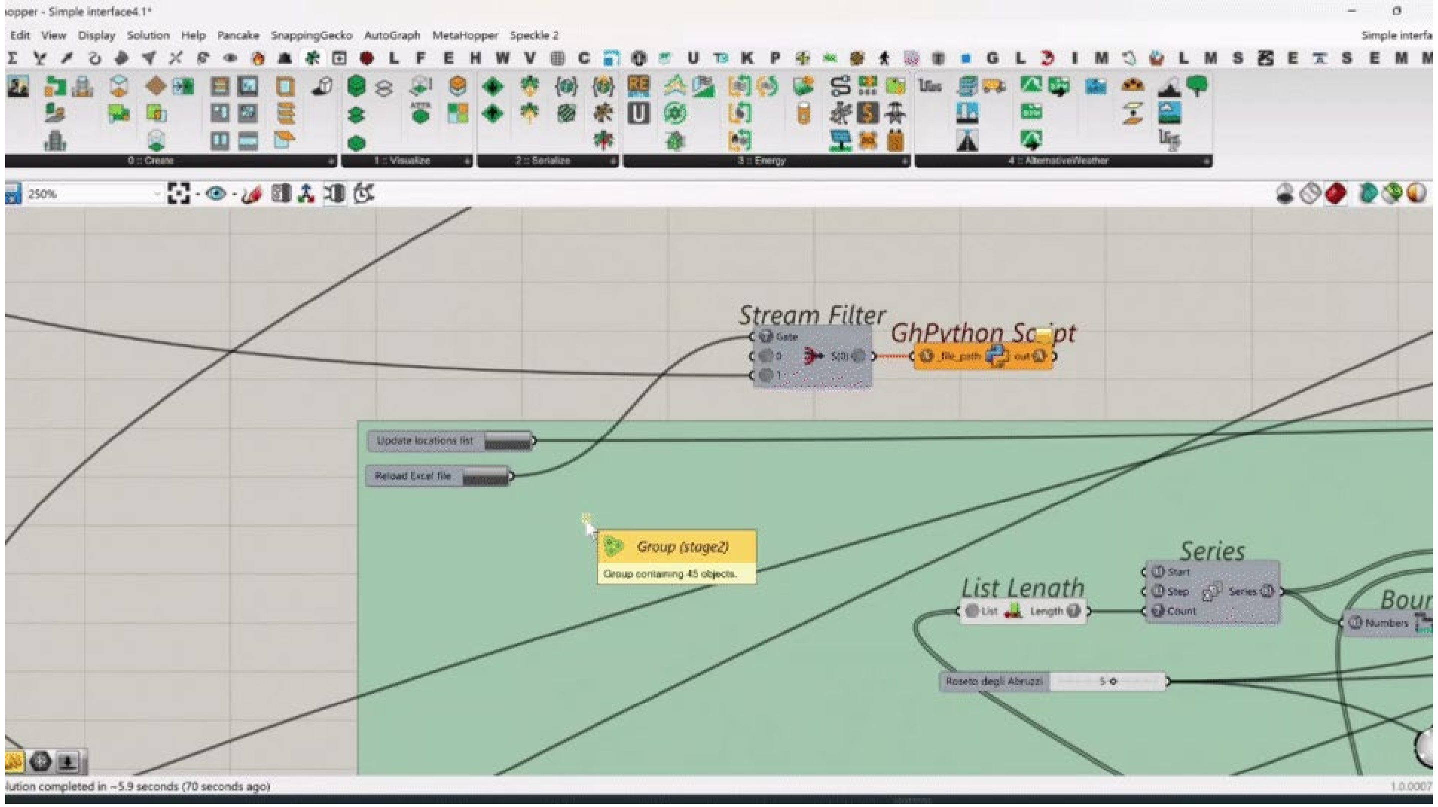




Co-funded by the
Erasmus+ Programme
of the European Union

Ladybug suite of tools

Common Grasshopper interface / Our simplified interfaces



Behind the simplified user interfaces there is a workflow implemented through visual programming to manage the parametric logic

Knowing this complex phase, we have created simplified graphical user interfaces

Ladybug suite of tools

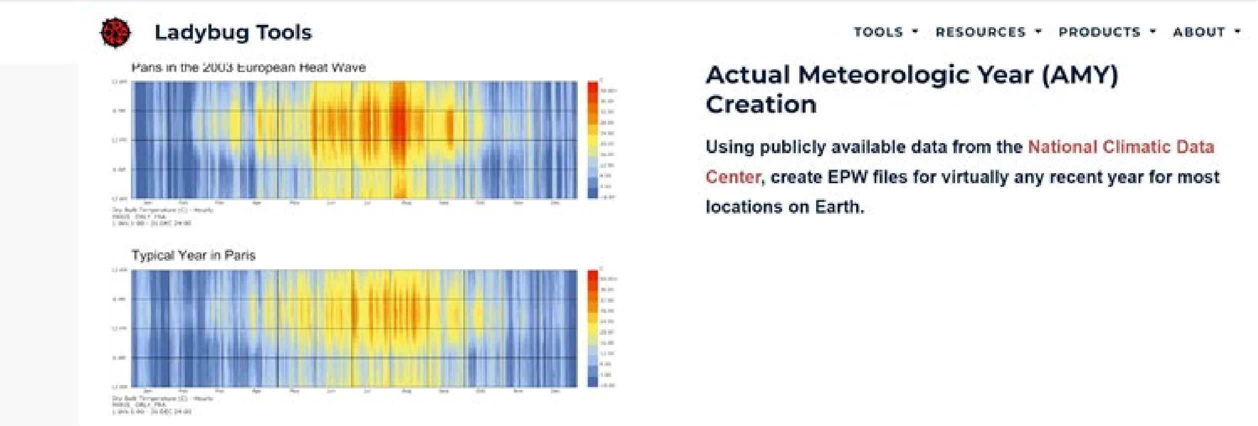
Ladybug

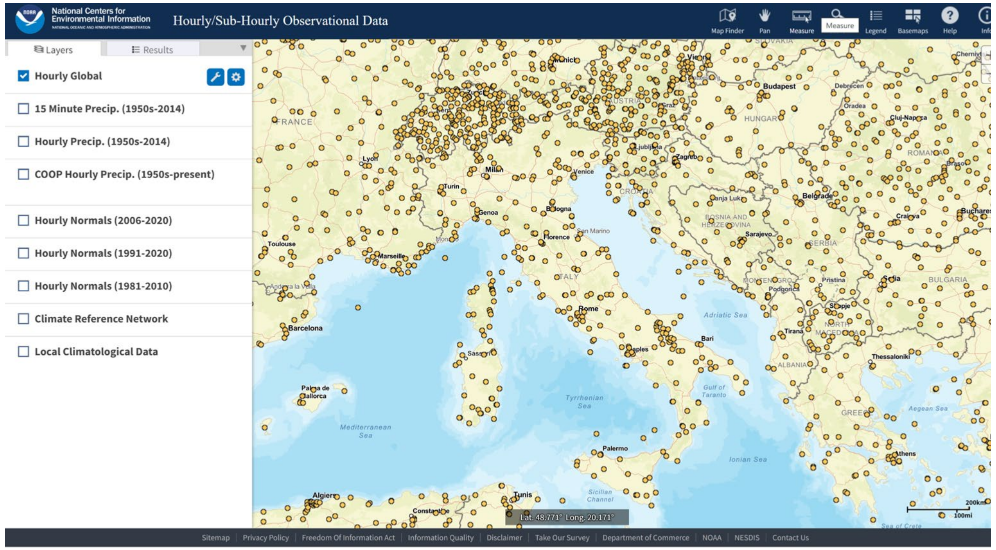
Ladybug performs detailed analysis of climate data to produce customized, interactive visualizations for environmentally-informed design.

Advanced approach /

The so-called "advanced approach" is the spatial and temporal downscaling that is the core for the evaluation of Meteorological scenarios and climate profile

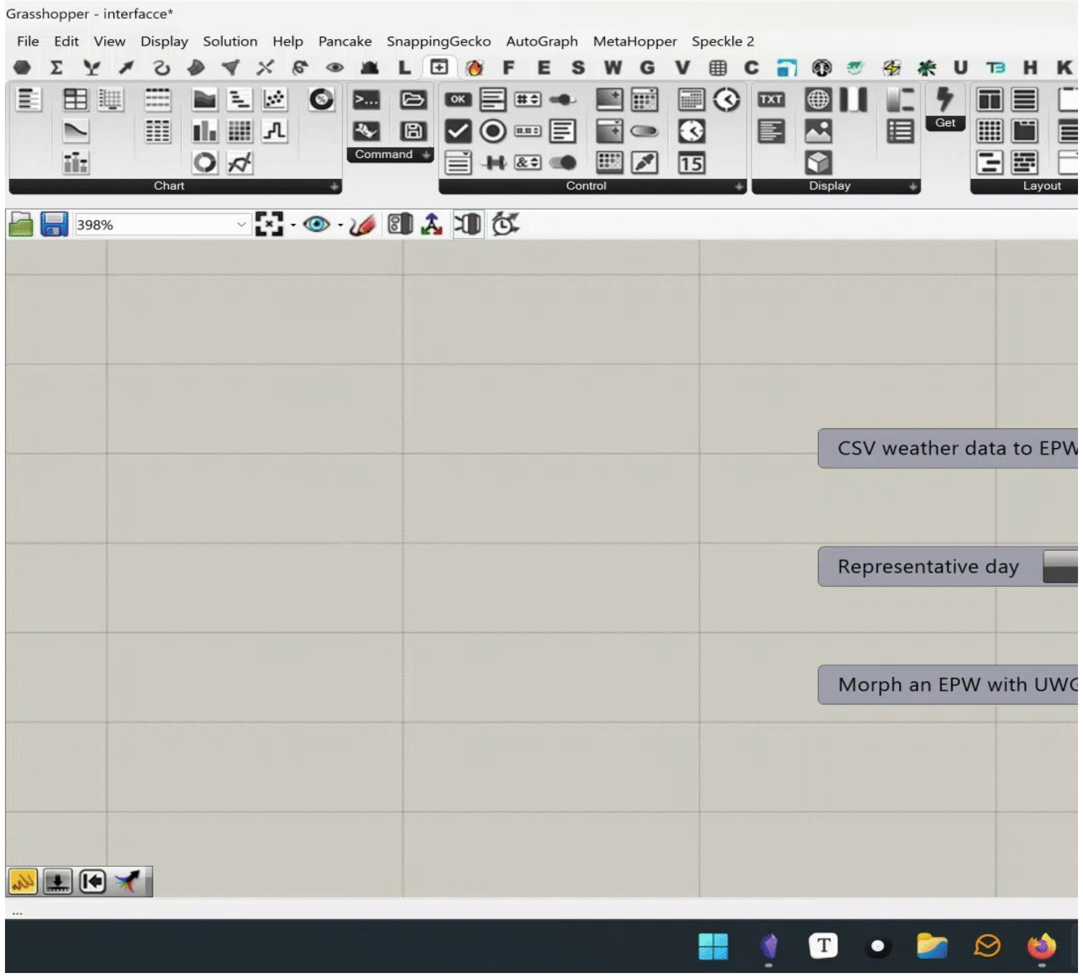
Meteorological scenarios are consistent and complete data sets of the meteorological variables.





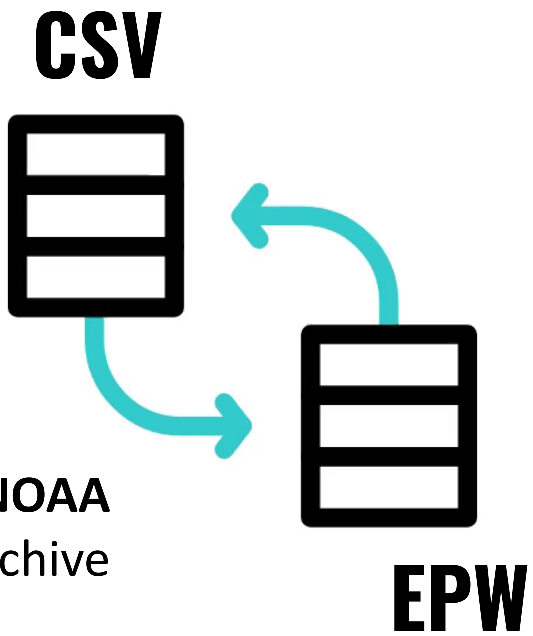
Co-funded by the Erasmus+ Programme of the European Union

1) Make EPW file / user-friendly interface



Ladybug

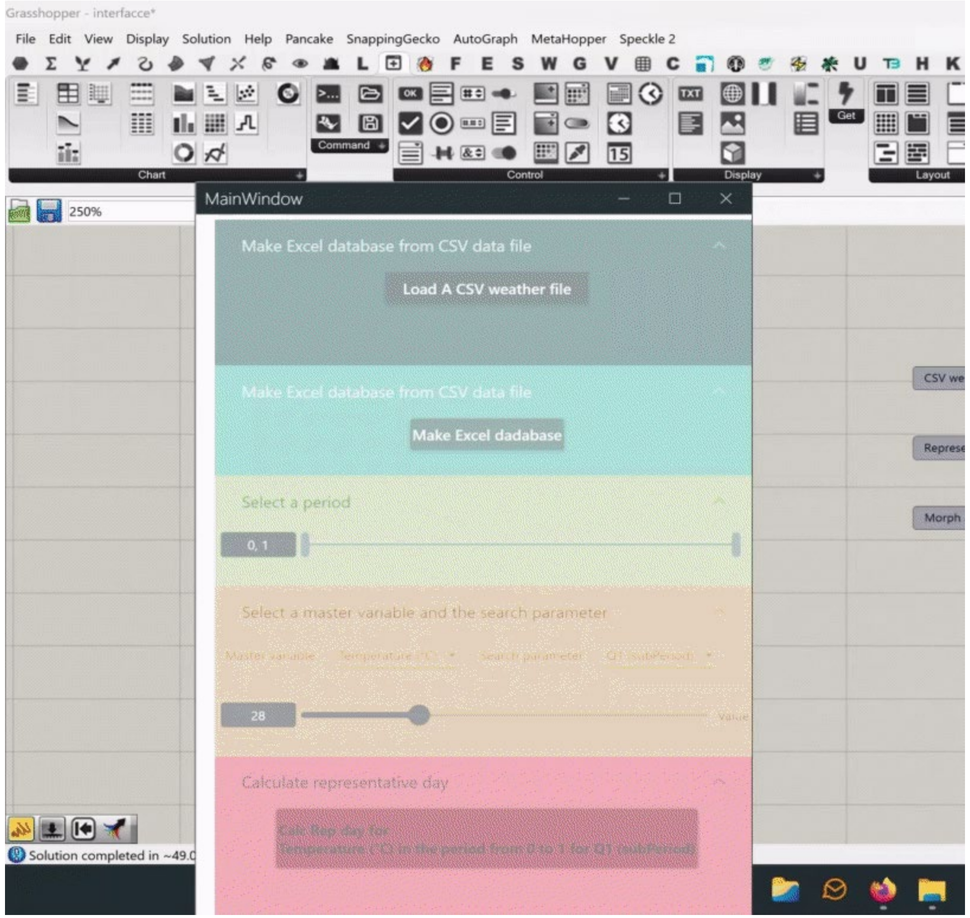
Ladybug performs detailed analysis of climate data to produce customized, interactive visualizations for environmentally-informed design.



From **WWO** or **NOAA** archive

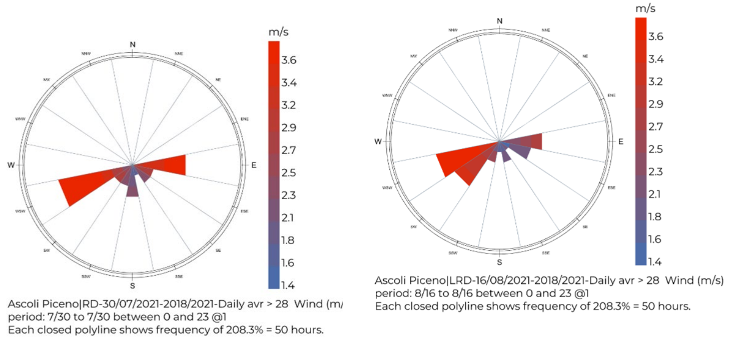
Co-funded by the Erasmus+ Programme of the European Union

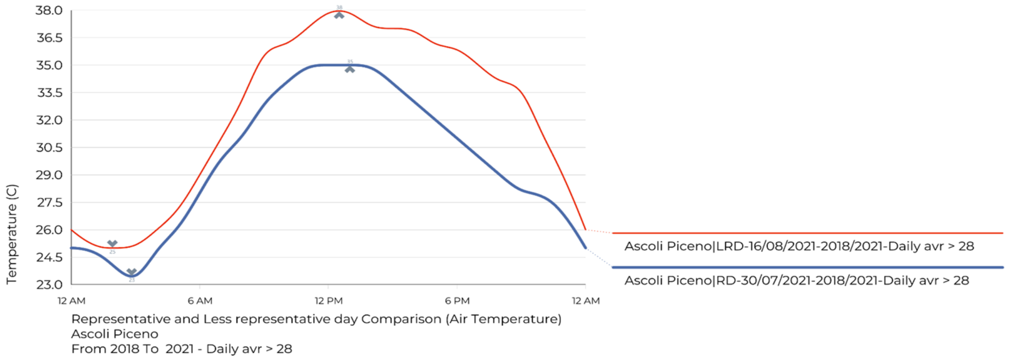
1)Representative scenarios / user-friendly interface



Ladybug

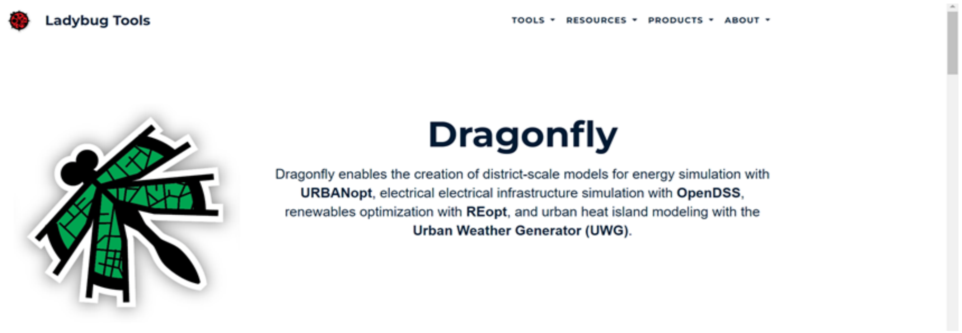
Ladybug performs detailed analysis of climate data to produce customized, interactive visualizations for environmentally-informed design.





Co-funded by the Erasmus+ Programme of the European Union

2) data morphing interface / examples



Urban Weather Generator (UWG) [Bueno et al, 2012]

Building Energy Model that has been integrated in the Town Energy Balance scheme applied to control volumes in the urban canopy and boundary layers

UWG estimates the hourly urban canopy air temperature and humidity using weather data from a rural weather station

Robustness

Different weather stations (often times data is not available for a site that captures climate conditions upwind of the city)

All weather: rainy, dry/cloudy, and dry/clear

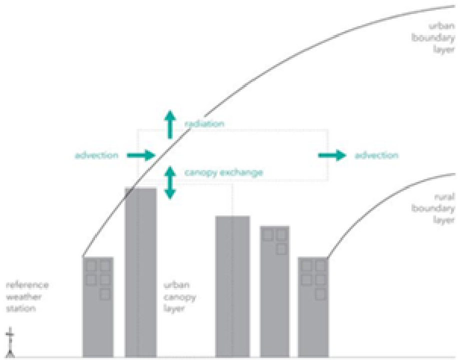
Versatility

Output is a morphed weather file [epw] that is compatible with many building performance simulation programs

Reliability

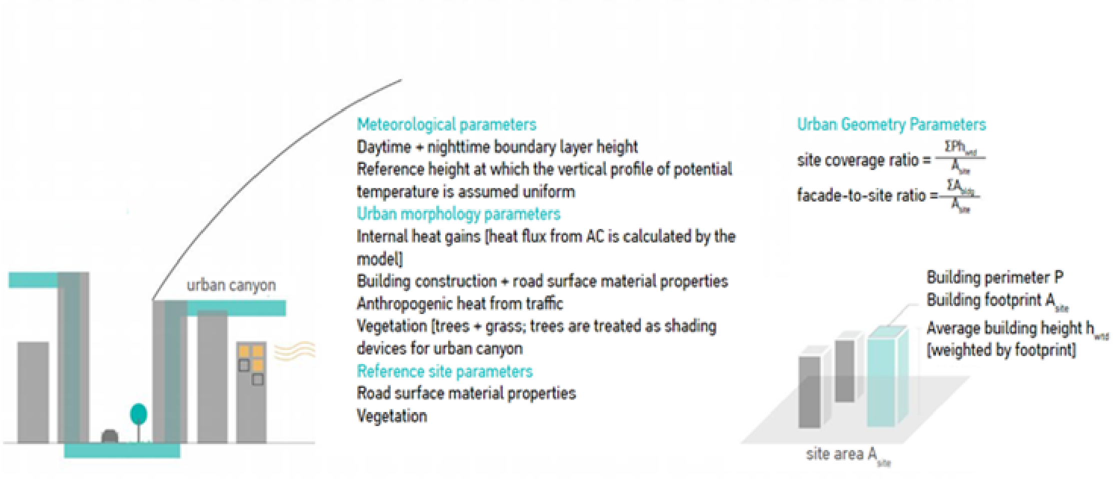
Results are comparable to a more computationally expensive mesoscale atmospheric model yet computationally efficient

Simplifications and assumptions of the model prevent it from capturing very site-specific microclimate effects



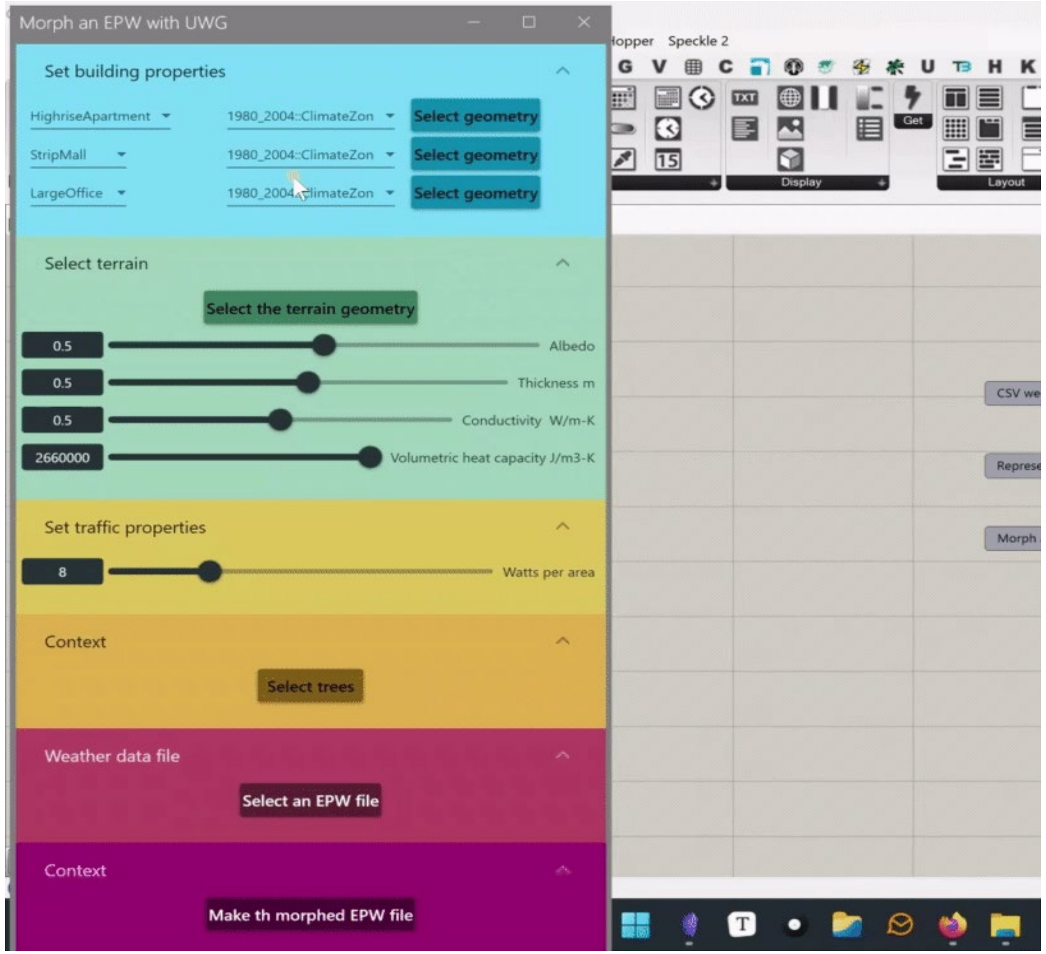
Urban Weather Generator (UWG): Required Parameters

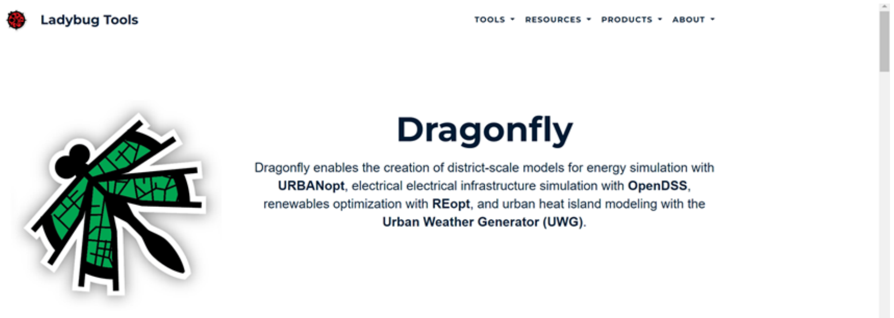
Input parameters include urban morphology, geometry, and surface materials as well as meteorology

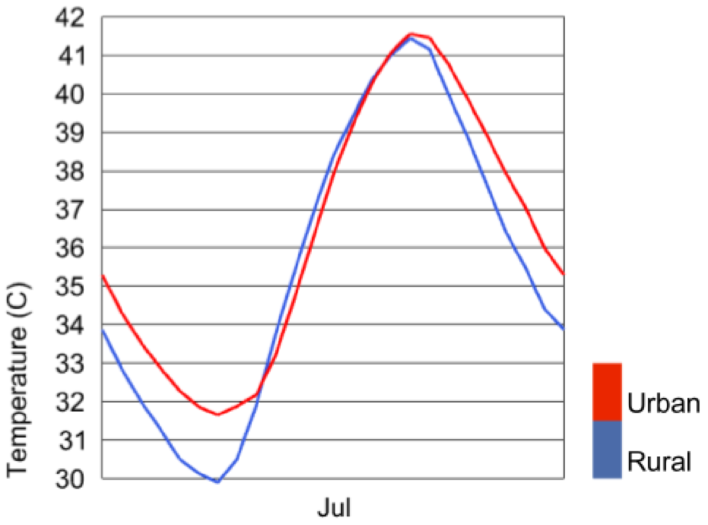


Co-funded by the Erasmus+ Programme of the European Union

2) data morphing interface / examples

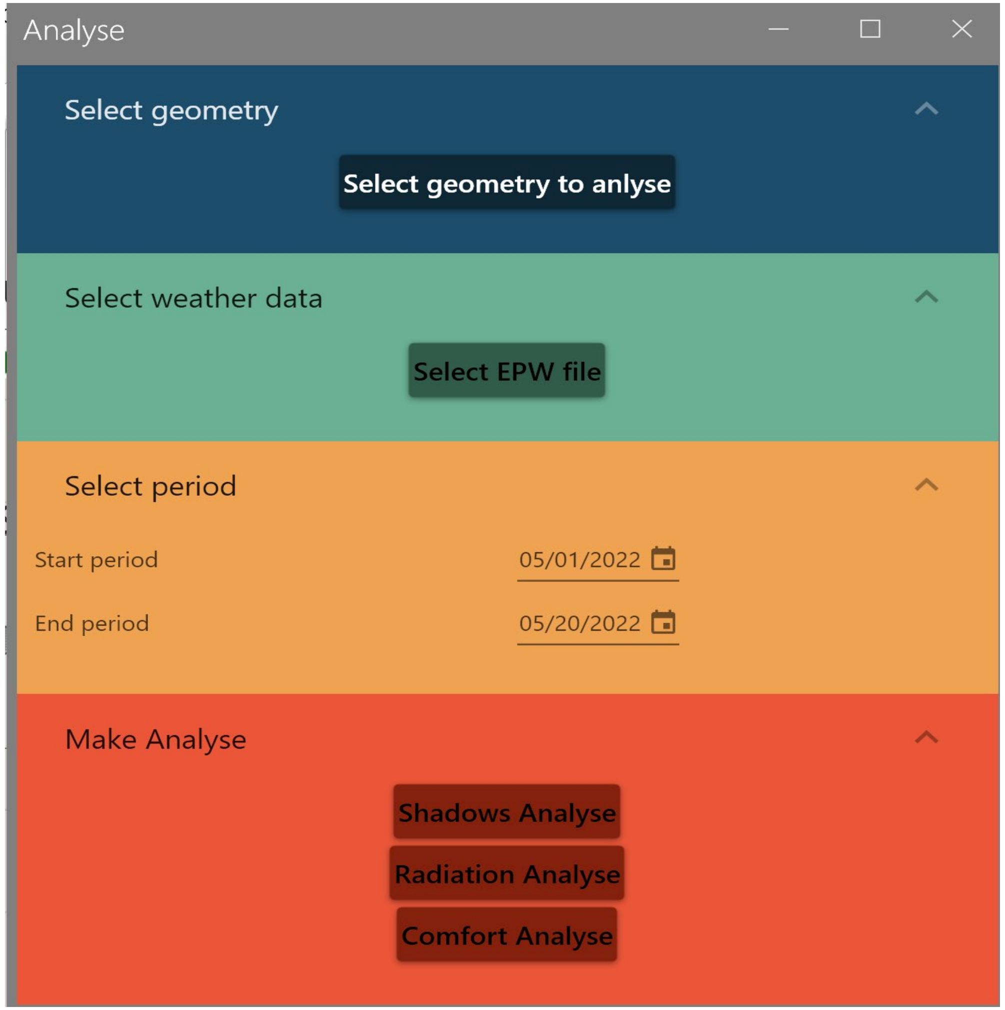






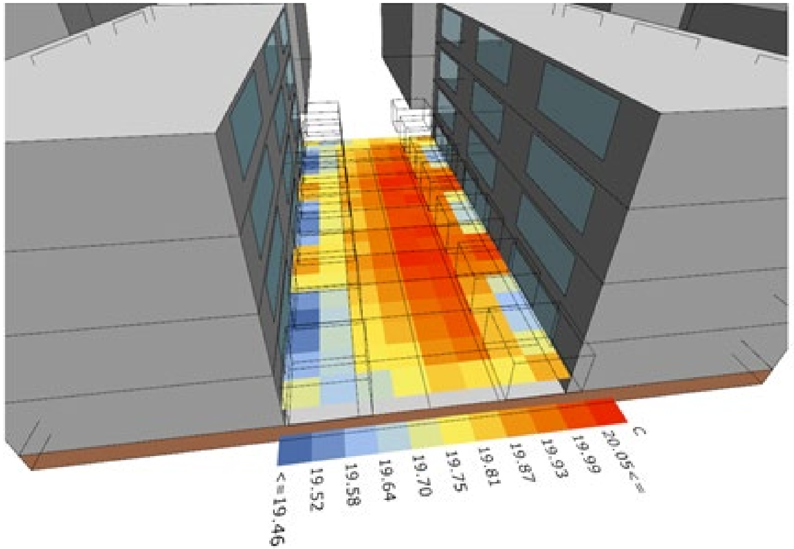
Co-funded by the Erasmus+ Programme of the European Union

3)Comfort evaluation / UTCI



Ladybug

Ladybug performs detailed analysis of climate data to produce customized, interactive visualizations for environmentally-informed design.



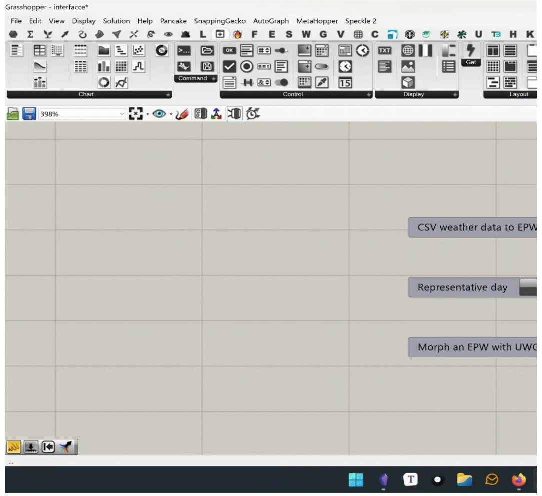
Co-funded by the
Erasmus+ Programme
of the European Union

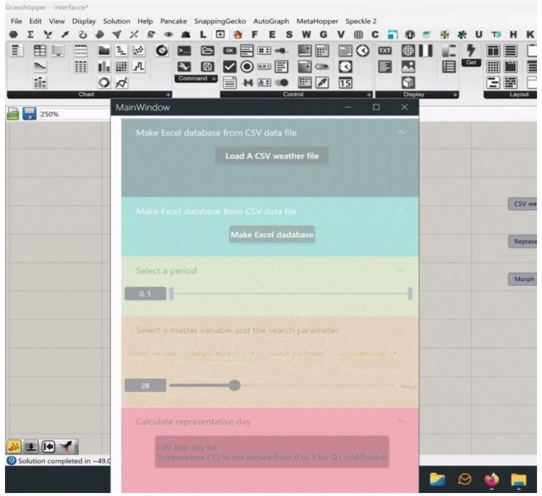
Ladybug suite of tools|userfriendly interface

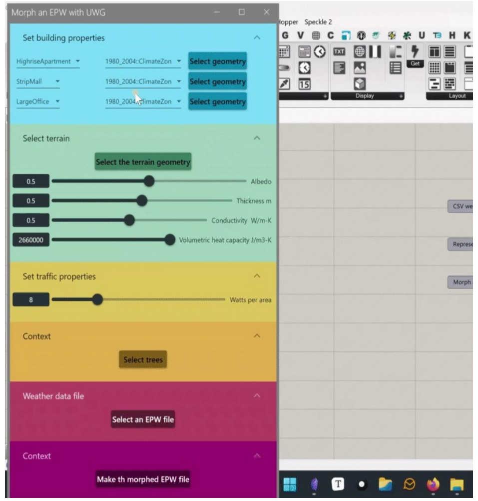
Ladybug

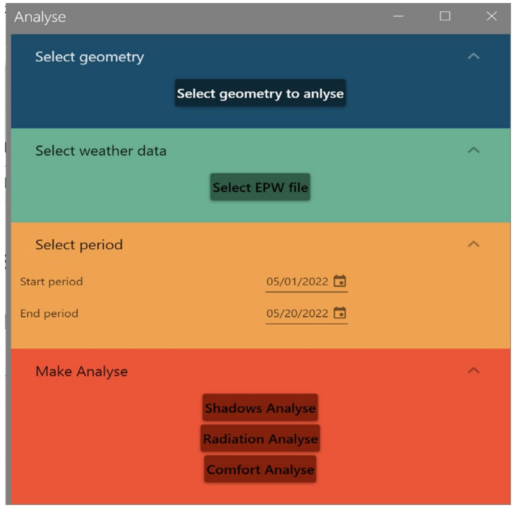
Honeybee

Dragonfly









Co-funded by the
Erasmus+ Programme
of the European Union