Towards Context & Climate Sensitive Urban Design An integrated simulation and parametric design approach

Aymeric Delmas, Michael Donn, Virginie Grosdemouge, Marjorie Musy, François Garde

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An integrated simulation and parametric design approach

Aymeric DELMAS
PhD Candidate at PIMENT 1/CRENAU 2, Research Engineer at IMAGEEN
aymeric.delmas@imageen.re

Michael Donn 3, Virginie Grosdemouge 1, Marjorie Musy 4 and François Garde 1

1 PIMENT - Le Tampon, 97430, Reunion Island
2 CRENAU - Nantes, 44000, France
3 School of Architecture VUW - Wellington, 6140, New Zealand
4 CEREMA Ouest - Nantes, 44000, France

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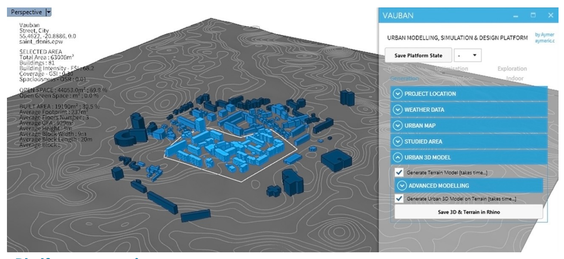
DESIGN PLATFORM & FRAMEWORK

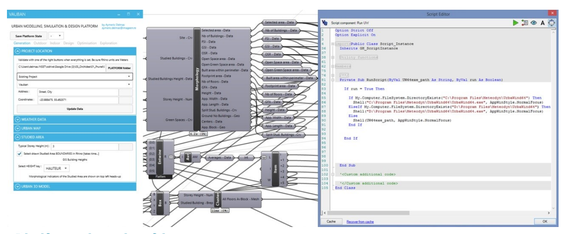
Supporting urban bioclimatic design

To implement the concept of integrated design, an urban **modelling**, **simulation and design** platform was developed. It embeds a design framework built upon the strengths of **parametric modelling** and existing **building performance simulation** tools.

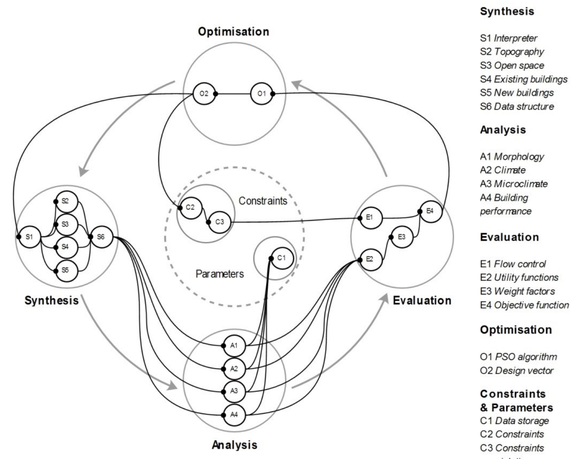
The **centralisation** of the synthesis, analysis, evaluation and optimisation **activities** in a single interface helps to support the integrated design concept. Data exchange and treatment allow **informing** both the simulation tools and the design process in terms of context and climate consideration.



Platform overview
Rhino's viewport integrated user interface and urban 3D model



Platform levels of transparency
User interface, directed acyclic graph and textual code



Design framework
The context and climate sensitive urban design framework

SYNTHESIS

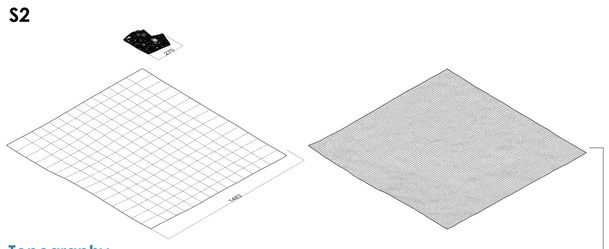
Parametric generation of the urban environment

Rhinoceros Grasshopper

Parametric modelling & Data treatment

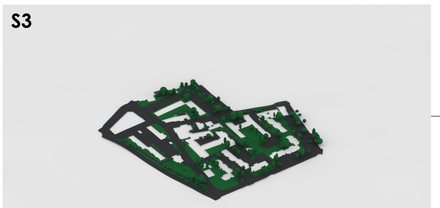
The parametric modelling capacities of the software pair Rhinoceros-Grasshopper are used to generate a synthesis model of **interrelated urban elements**. Topography, buildings, open spaces and natural elements are connected with each other in an algorithmic relation.

S2



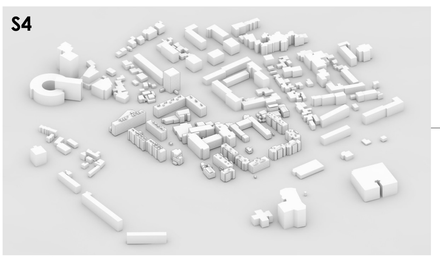
Topography
A sampling script allows matching measured elevation (3m grid) of the studied area with larger satellite elevation of the surrounding terrain (SRTM 30m grid)

S3



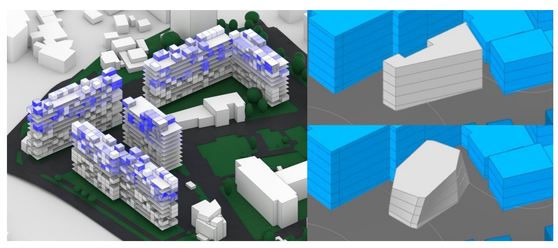
Open spaces & natural elements
are modelled based on measurements (or GIS data) of their boundaries. Trees are modelled as ovoids based on surveyed characteristics (height, width, density)

S4



Buildings
are modelled based on their footprints and heights. Surrounding buildings of the area of interest are selected based on height and distance criteria

Combined urban 3D model
Vauban neighbourhood, case study located in St-Denis, La Réunion



Bioclimatic strategies & new building blocks
Generative definitions of context sensitive blocks and urban interventions are integrated and can be optimised

ANALYSIS

& simulation of the outdoor and indoor conditions

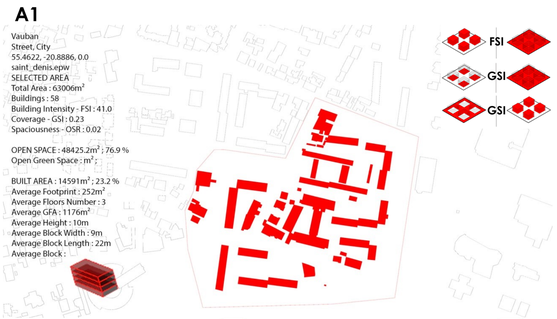
Ladybug Honeybee UrbaWind

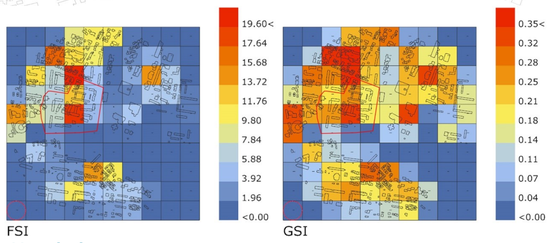
Thermal, solar & airflow

The **complex relationships** between **form** and **environmental performance** are analysed thanks to several mathematical models with different level of fidelity. All analysis models use the unique parametric synthesis urban model so that any **morphological**, topological or data change will influence the whole data.

The **dynamics of the urban microclimate** and its effects on outdoor and indoor conditions is captured by using **specific simulation tools** (UrbaWind for the CFD airflow, Radiance for solar irradiation, EnergyPlus for indoor and outdoor thermal conditions)

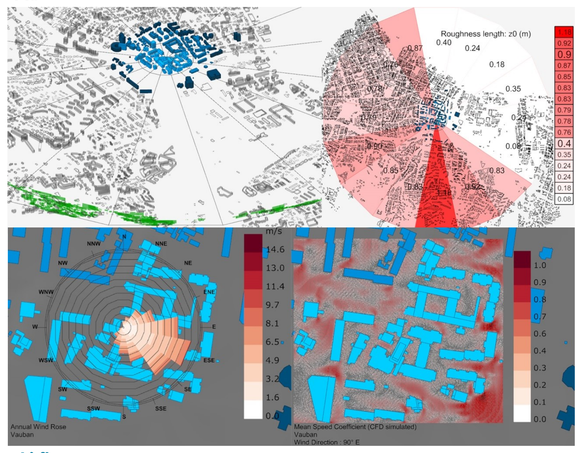
A1



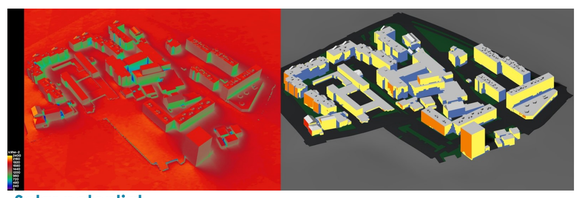


Morphology
indicators such as building intensity (FSI), coverage (GSI) and spaciousness (OSR) are calculated at the neighbourhood and urban scales to link form with performance

A3

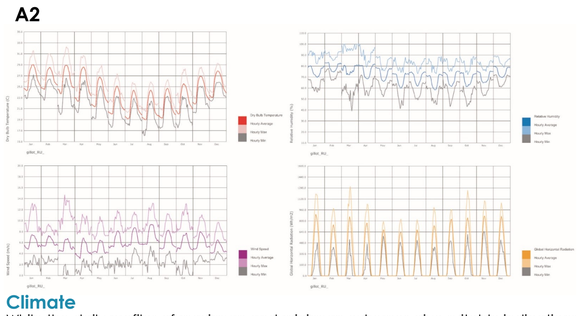


Airflow
Top: directional morphometric estimation of the frontal area and roughness length
Bottom: regional wind rose and simulated wind speed coefficient (90° wind)

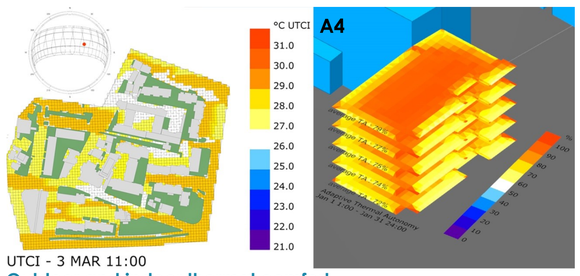


Solar potential
Annual solar potential mapped on 3D and categorised potential of the facades

A2



Climate
While the daily profiles of maximum and minimum extremes give suitable indications when design conditions should be taken into account; average daily profiles represent good conditions criteria for balanced design



Outdoor and indoor thermal comfort
Time-specific UTCI map and indoor adaptive thermal autonomy map for January

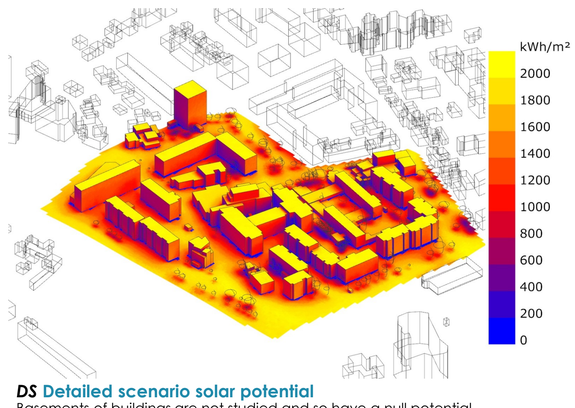
PARAMETRIC STUDY

Impact of modelling simplification on solar potential

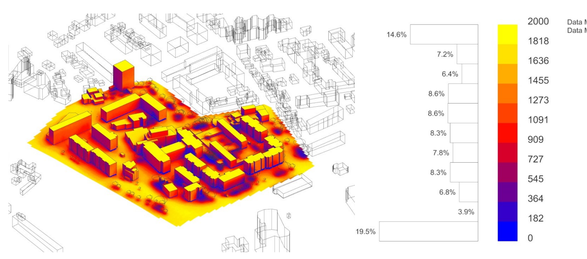
The **parametric generation** of the urban environment and its constitutive elements allows running similar simulation with various scenarios. Here the most detailed 3D model is simplified gradually to assess the **impact of each modelling scenario on the solar potential of more detailed ones**.

Radiance parameters	ab=2, ad=1000, as=16, ar=98, grid size=1m
DS Detailed scenario	Ovoid trees, detailed ground materials distribution (asphalt/grass), extended surrounding, sampled topography
S1 Spherical trees	*DS* with simple trees instead of ovoid trees
S2 No trees	*S1* with trees removed
S3 All asphalt	*S2* with all asphalt ground instead of the asphalt/grass distribution
S4 Lambertian ground	*S3* with 20% reflective lambertian ground instead of all asphalt
S5 First surrounding	*S4* with extended surrounding removed, only first radius of surrounding buildings kept
S6 No surrounding	*S5* with no surrounding buildings
S7 Unsampled terrain	*S6* with SRTM (30m precision) terrain instead of 3m sampled terrain
S8 Flat terrain	*S7* with flat terrain instead of SRTM terrain

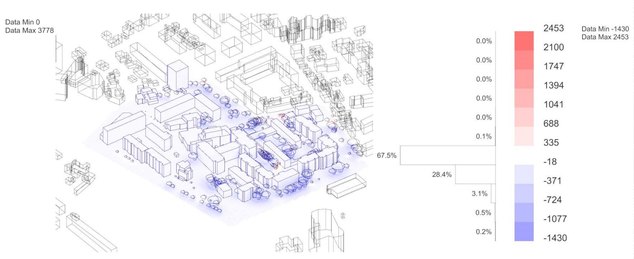
Radiance and geometric parameters of the simulated scenarios



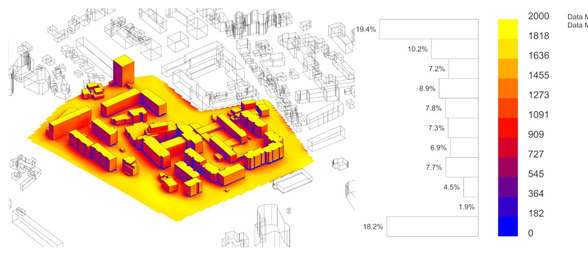
DS **Detailed scenario solar potential**
Basements of buildings are not studied and so have a null potential



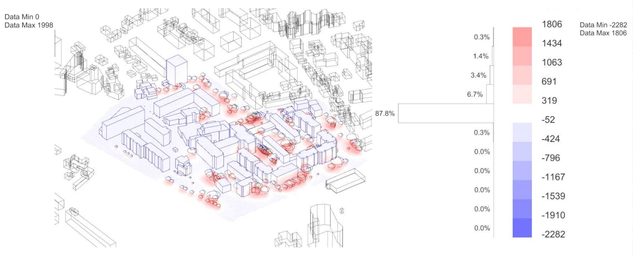
S1 **Spherical trees scenario potential**



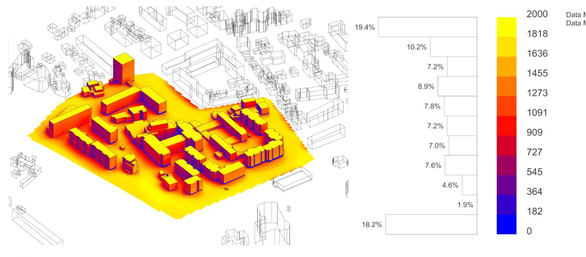
S1- DS **Absolute potential difference**



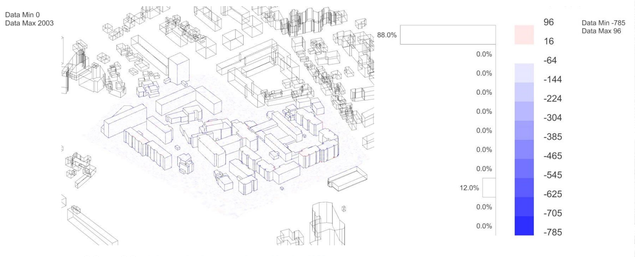
S2 **No trees scenario potential**



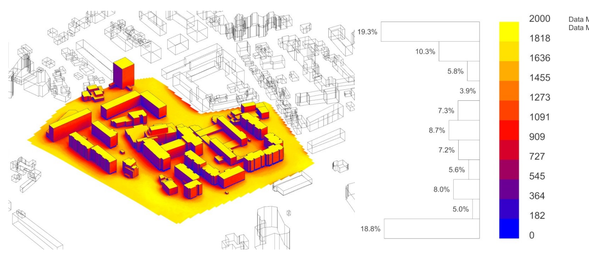
S2 – S1 **Absolute potential difference**



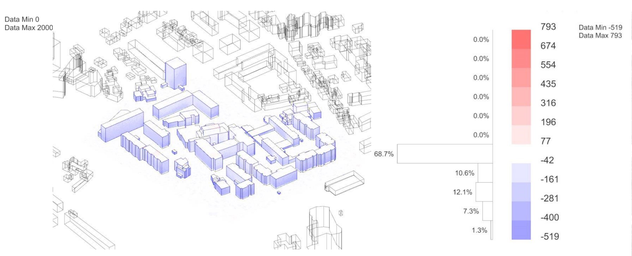
S3 **All asphalt scenario potential**



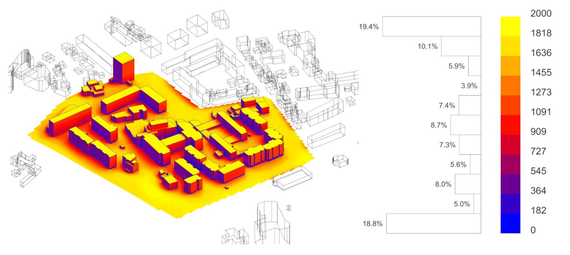
S3 – S2 **Absolute potential difference**



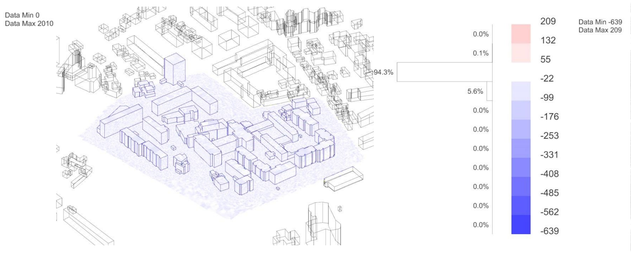
S4 **Lambertian ground scenario potential**



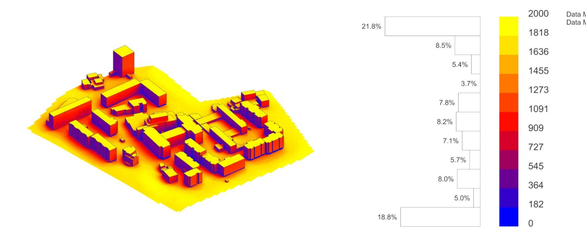
S4 – S3 **Absolute potential difference**



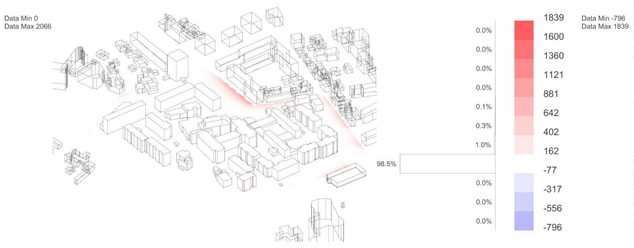
S5 **First surrounding scenario potential**



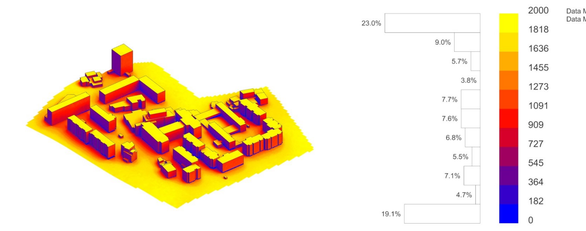
S5 - S4 **Absolute potential difference**



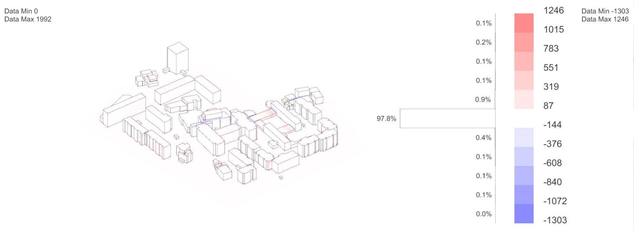
S6 **No surrounding scenario potential**



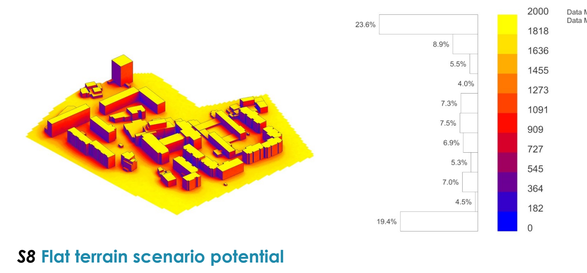
S6 – S5 **Absolute potential difference**



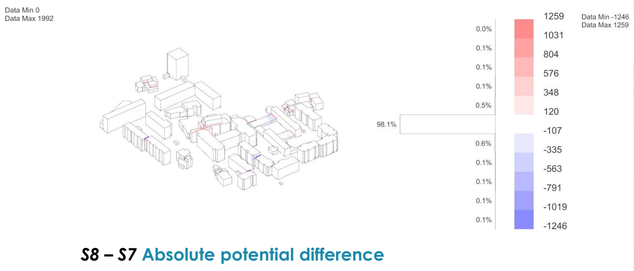
S7 **Unsampled terrain scenario potential**



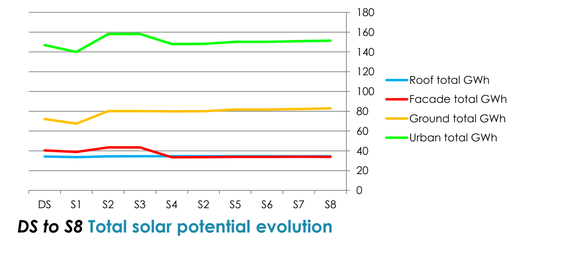
S7 – S6 **Absolute potential difference**



S8 **Flat terrain scenario potential**



S8 – S7 **Absolute potential difference**



DS to S8 **Total solar potential evolution**

This parametric study demonstrates how the conjunction of simulation and parametric modelling can **inform** a digital design process with **precise mapping of microclimatic conditions**. Here the link between form, materiality and solar potential is sequentially represented and shows the importance of modelling practice. From this case, the integration of **trees** and appropriate **ground material** could represent **significant strategies to reduce the local UHI** effects due to solar collection.