GR01_HW02

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March 5, 2018

Introduction

Climate Analysis+Vernacular architecture

The following paper studies the relationship between climatic conditions and the development of building strategies that properly respond and manage interior comfort.

Considering two cities as cases to study: Buenos Aires (Argentina) and Sapporo (Japan), this document will portrait both climates by analyzing weather information (?) in order to understand the changing cycles of temperature, radiation, relative humidity and how they correlate with each other.

Figure 1: (from the authors)

Furthermore, it will analyze references of vernacular architecture to understand how the strategies implemented manage to provide a solution with a deep understanding of the environmental conditions as well as it's cultural ideas with limited resources and low energy consumption.

For this, the examples under analysis are not limited to the current city territory. Each will be contrasted with different solutions from near areas (to recognize the cultural influence) as well as with solutions from far places, that nevertheless share the same Koppen Climate Class.

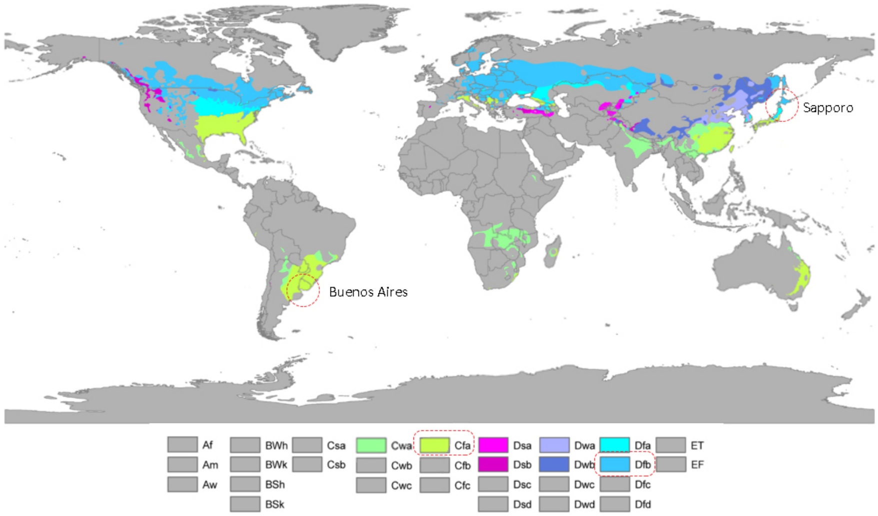


Figure 2: Koppen world class(**?**)

Chapter 1

Sapporo_Japan

Sapporo is catalogued within the *Humid continental climate* according to the Koppen world classification and within the *Mild/cool summer* subtype, with temperatures that normally range from -3°C in the coldest months and close to 25°C during the warmest months. Although there is a similar trend between the global horizontal radiation and the dry bulb temperature, they do not show the same peak at the same periods of the year.

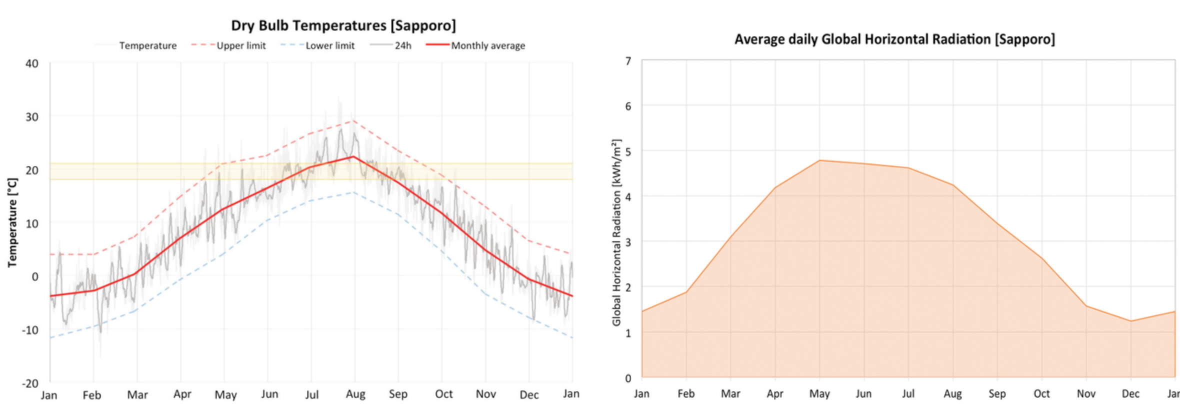


Figure 3: (From the authors)

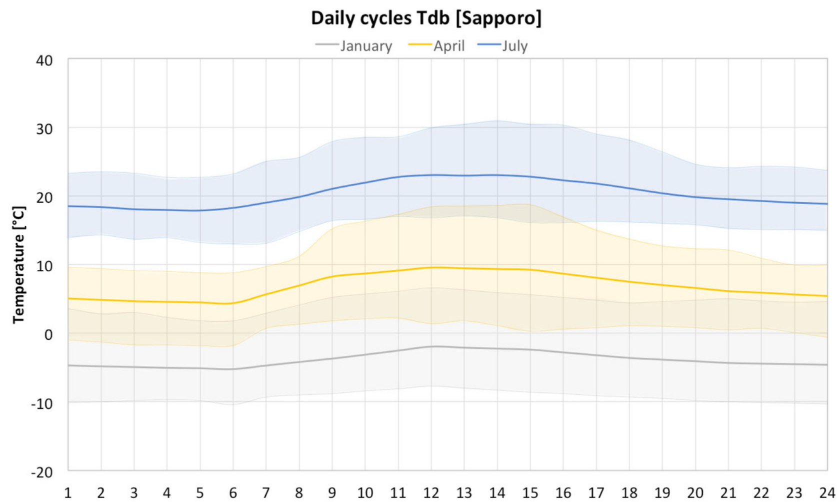
Figure 4: (From the authors)

Through the analysis of the *Temperature daily cycle* it is possible to seized how much the temperatures during day and night varies. January (cold season), July (warm season) and April (mid-season), where chosen as the months that can better represent the yearly behavior of the city. From the graph below we can notice a clear seasonal distinction in the city; with temperature averages barely overlapping. While the range of temperature remains close to constant for January (small thermal gradient between day and night), for April and July the trend for the max temperature results more discontinuous and higher differences between day and night are registered.

As a final part of the climatic analysis, the graph below shows the distribution of the hourly data plotted in the psychrometric chart as well as the gaussian distribution of the quantities T and X. This analysis contains also the information of the daily cycles for the three months previously chosen plus the month of October, to have a clearer idea of the different periods of the year. Heating and cooling periods can be easily recognize with highlighted red and light blue areas.

Having established some of the main characteristics that described climatic conditions of Sapporo, a series of examples of vernacular constructions from north and south Japan will be confronted regarding material selection and design strategies to overcome climatic changes, with examples of Ale, in Sweden. From both, it can be concluded the necessary strategies that can be implemented nowadays in these kind of climate.

Japanese vernacular architecture expresses its understanding of the climate conditions at different scales and for different zones; whether it is sloping roofs (found in the north) adapted for snow, or smaller and



	Jan	Feb	Mar	Abr	May	Jun	Jul	Ago	Sept	Oct	Nov	Dic
Max	6.6	5.2	10.3	18.7	25.3	27.7	30.9	33.5	24.8	20	14.6	13.2
Min	-10.4	-15.3	-7.2	-1.8	2.7	9.3	13	14	10.1	3.2	-5.4	-9
Central	-3.8	-10.1	3.1	16.9	22.6	18.4	17.9	19.5	14.7	16.8	9.2	4.2
Max daily variation	17	20.5	17.5	20.5	22.6	18.4	17.9	19.5	14.7	16.8	20	22.2
Average	-3.9	-2.8	0.3	6.9	12.4	16.4	20.3	22.3	17.5	11.8	4.8	-0.6

Figure 5: (from the authors)

lower houses with raised floors of the south, we can find a range of interior schemes such as flexible internal partitions which allow a partial control of the dimensions of the rooms, permeable and movable skins, proper orientation and thick vegetation in the borders of each plot, they have developed several strategies that help mitigate the environment and improve the interior comfort.

The image below shows L-shaped hedges as buffer barriers made of pine trees, of around 15 meters high, which serve as windscreen to protect from the cold winter winds and snowstorms in Shimane Prefecture, in western Japan. Furthermore, in northern parts the use of windscreens is carry out with straw screens of similar height which are placed during winter months and might cover entire houses or villages.

Traditional Japanese houses have developed from two main original typologies. A pit dwelling house (left image) and a raised floor house (right image). The first one was used to stand cold weathers by digging a hole in the ground, the house remains semi-buried and the sloped roof structure is made of wood covered with a thick layer of straw. It uses the earth thermal mass to maintain small interior temperature variations.

The raised floor house, originally created as a place to store grains from harvest to protect it from spoiling for heat or humidity, has also advantages that improve comfort during summer. Made from wood, largely available; remains cool in summer and warm in winter, it has a permeable exterior facades, which permit houses to "breathe" and the raised floors from the ground allow air movement from around and beneath it, as well as isolate the house from humidity, and reduce damages in case of flooding.

Other typologies where further developed which considered large sloped roof, covered with tiles or wide cornices protect the house from summer sun. Moreover, other methods such as garden with water elements, exploit the possibility of evaporative cooling and create a fresh breeze towards the house. A traditional urban house called minka may presents a high sealing in the kitchen area with a skylight on top that serves as an exit for hot air coming from the house(**?**). The sound of running water and wind chimes that move with the slightest breeze creates an illusion of coolness in the environment.

The **Shoshoin temple** is an interesting example of response to changing weather conditions; with a roof made up of triangular timbers that expand during wet weather to protect the interior from rain, and shrink

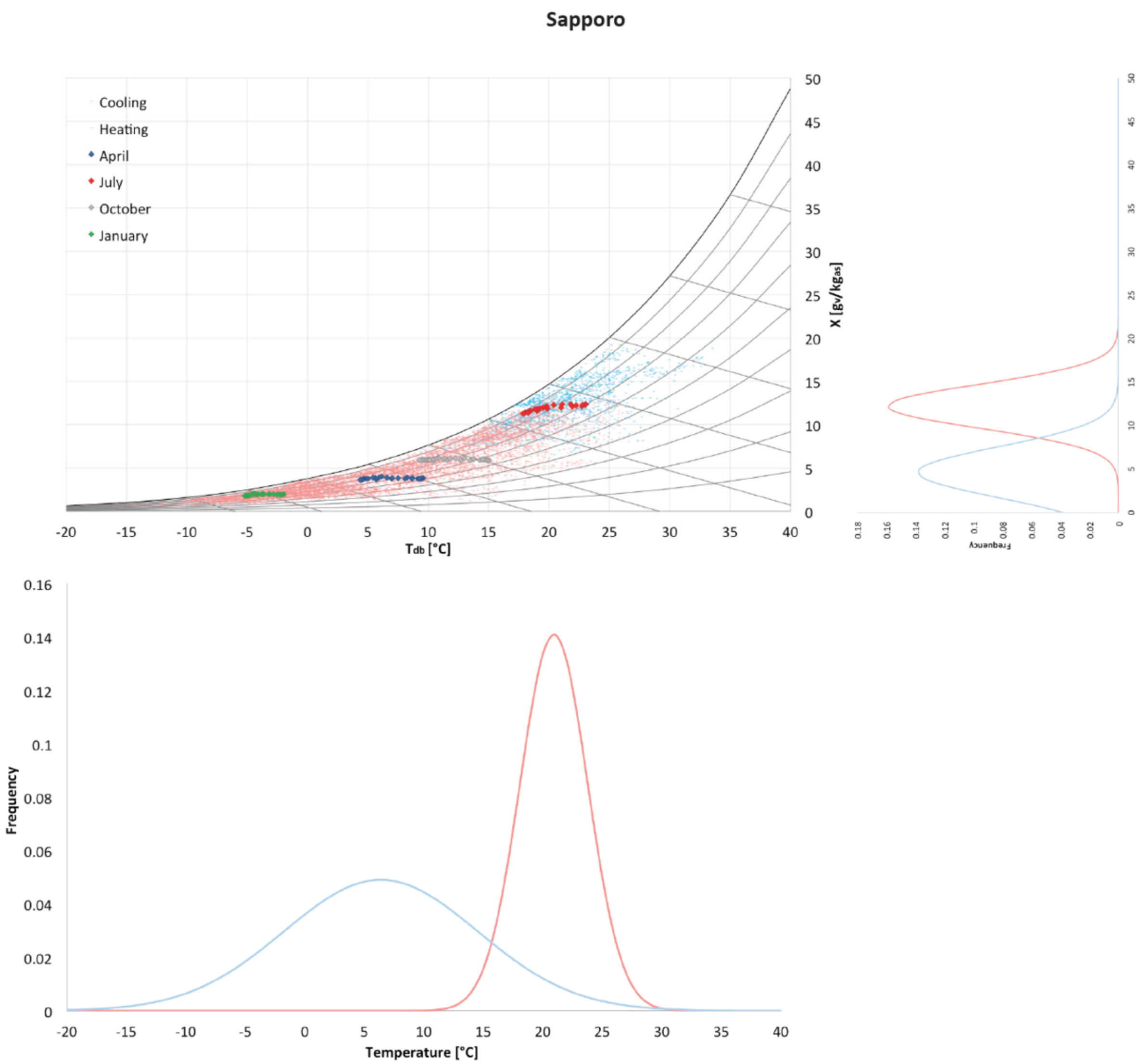


Figure 6: (from the authors)

during hot, dry weather to improve ventilation and allowing hot air to scape outside.

For the case of Sapporo, who's initial development started in the mid's 1800 with a first group of ex-samurai, that responded to a military interest of defending the northern frontier, the first dwellings where influenced as much for the traditional Japanese architecture as it was for the constructive techniques used in the United States. (?)

It is said that these dwellings are one of the first eclectic/modern constructions of Japan and cannot be truly recognize as neither Japanese or non Japanese. White clapboards, glass windows and pivoted doors are not suggest American roots while the persistent use of wood for walls and joint details rather than brick prove its Japanese heritage.

The need for a house that could provide thermal comfort during the winter made the initial proposals change from thin paper exterior walls of traditional Japanese houses in the south into thick wooden or stone wall

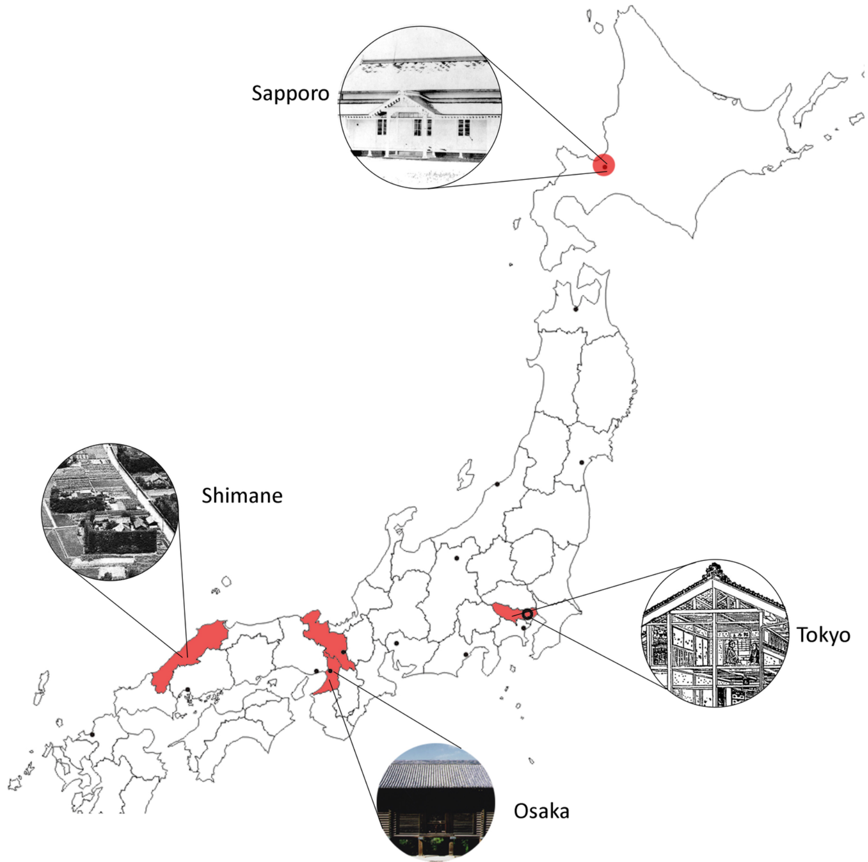


Figure 7: Building locations (from the authors)

houses. Over time, these unsuccessful houses suffer changes, like adding a chimney.

Vikings Farmstead_Sweden

Two main features can be easily recognized in the image below: the material selection and the roof shape. The snow weight is an important issue which both buildings solve with a tilted tiles covered roof (one with wood, the other with ceramic). Both construction also used wood as the main structural material, which provides good thermal insulation during winter periods and a certain permeability for ventilation for summer.

Buenos Aires_Argentina

Buenos Aires belongs to the humid subtropical zone according to the Koppen world classification and has temperatures that range normally from 10°C during winter up to 25°C during summer. We can recognize a smaller temperature range and a higher peak value of global horizontal radiation compared to Sapporo.

Figure 8: Shimane Prefecture (?)

Since the seasonal temperature variation is smaller for Buenos Aires, we can recognize in the graph below a greater overlapped of the daily temperatures values which means that we find a higher ranges of temperatures all year round. Max and min values can be seen for all the month (higher range is set in July). Both in winter and in summer periods very high thermal gradient can be registered and the peaks can be seen in the early afternoon.

As for Sapporo, the graph below shows the distribution of the hourly data plotted in the psychrometric chart as well as the gaussian distribution of the quantities T and X. The heating and cooling periods are highlighted with red and light blue areas.

For the case of Buenos Aires, it was interesting to correlate with examples from the "Hot Summer, Cold Winter regions"(?) of southeast China in order to compare among the two, the different solutions given by each site, and again, weight the influence of cultural and climatic conditions on the solutions provided by each site.

Two main periods can be recognize as producers of vernacular constructions in Argentina, before and after the colonization, however, both of them share a common main material: earth.

Initially, construction in the north west of the current country were mainly made of rock and earth. The

Figure 9: Original Typologies(?)

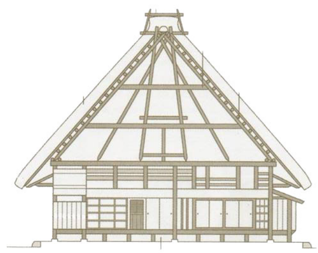


Figure 10: Japanese minka (?)

Figure 11: Shoshoin Temple(?)

image below shows a construction called Kallanka, a building made mixing mainly earth and rocks joined by mud (wood was not available). The amount of materials alternate at different heights to give stability and elasticity to withstand thermal expansions of the materials as well as the changing temperatures of the different seasons. Thick walls and small windows maintain internal conditions with smaller daily and seasonal variations compared to the outside.

After the Spanish arrivals, construction were greatly influenced by the colonial architecture and the use of

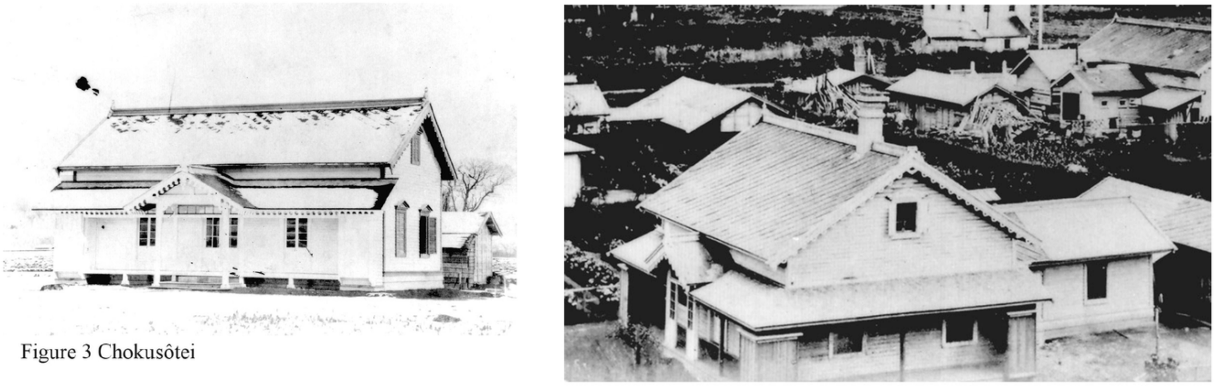


Figure 12: Sapporo dwellings (?)

Figure 13: Vikings Farmstead(?)

adobe mud bricks. “La casa chorizo” is a typical dwelling of Buenos Aires and Rosario, that have nowadays extended to other cities. It is a urban typology consisting mainly of a lateral patio, a gallery that connects all rooms and provides shade and protection from the rain and a backyard with vegetation.

Its particular long shape comes from the plots distribution within the city, which greatly affects the amount of sun received by each one. It’s origin can be traced back to the roman house with internal patios which help introduce sunlight and proper ventilation into the different rooms which connect directly to it. In the middle of this patio were located water ponds.

Siheyuans_China

An example from the same Climatic class of Buenos Aires is studied in order to compare the similar and different solutions developed at different sites and from different culture. Siheyuans (courtyard surrounded by buildings on four sides) is the name of residences that were arrayed next to each other with one side connected to the main street in southeast China

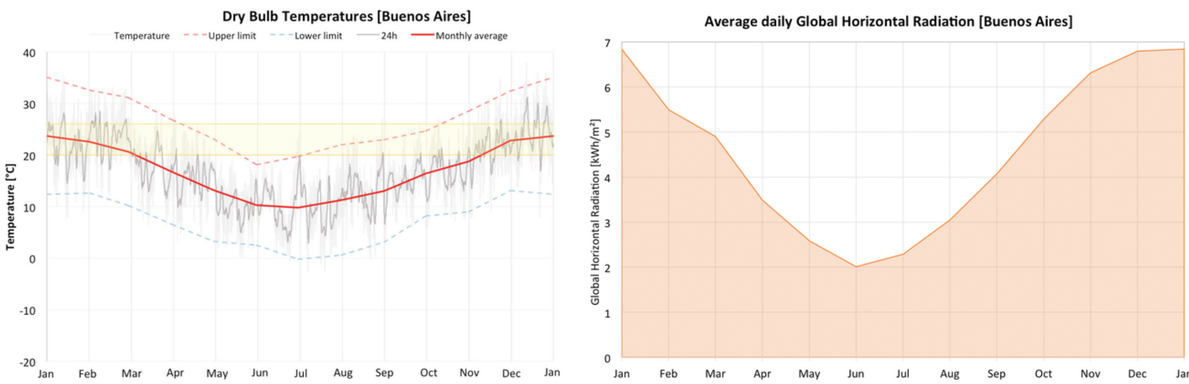
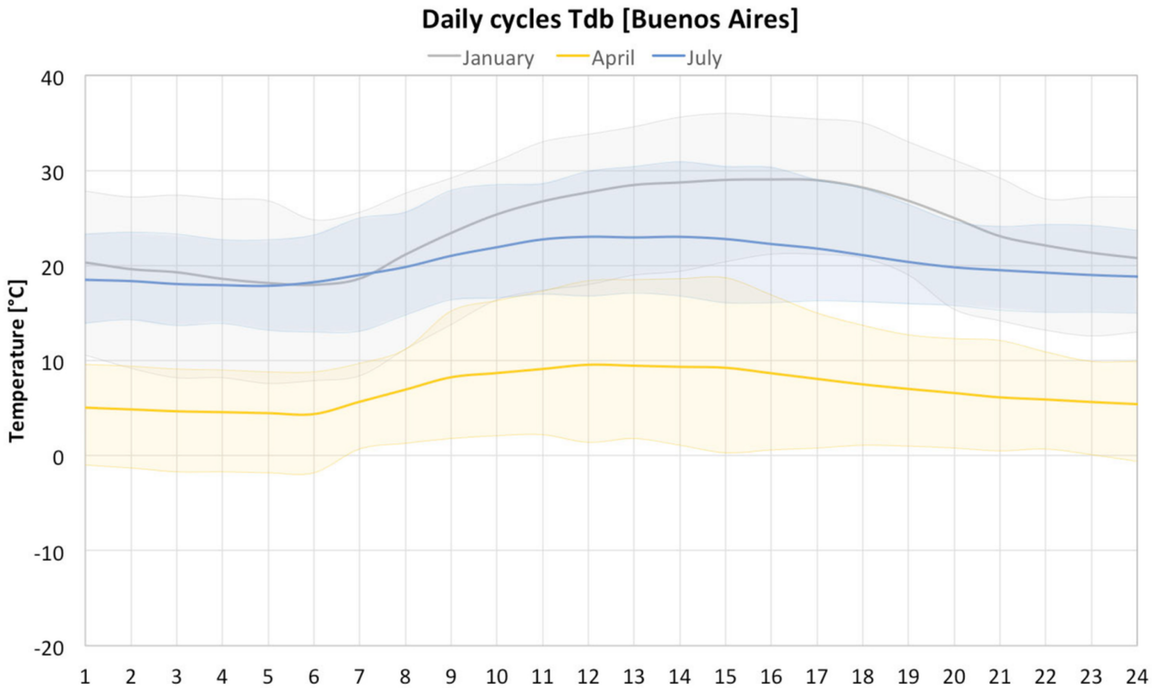


Figure 14: (from the authors)

Figure 15: (From the authors)

Although they have different organizations, it is important to point out the use of patios for climate control in both typologies; “Siheyuans” and “Casa chorizo”. While courtyards are implemented as in the north and south of China, in the south part of the country they have a more compact condition to control solar gains Since it creates narrow street that provide shade and white surfaces that reflect solar rays as well as shaded



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Max	36	32.8	33	28.6	25.6	19	24.2	23.8	27.2	26.9	30.8	38
Min	7.6	9	6.2	3.2	2	0	-2.6	-2.6	-0.2	6	7.3	9
Central	28.4	23.8	26.8	25.4	23.6	19	21.6	21.2	27	20.9	23.5	29
Max daily variation	28.4	23.8	26.8	25.4	23.6	19	26.8	26.4	27.4	20.9	23.5	29
Average	23.7	22.6	20.6	16.7	13.2	10.3	9.8	11.3	13	16.4	18.8	22.8

Figure 16: (from the authors)

verandas to cool down during hot weather.

Like wise, we can trace many similarities with Japanese vernacular architecture previously studied. Skylights are implemented to bring daylight into the house and allow the hot air to scape through the top of the building.

Chapter 2

Proposal of optimisation strategies

Sapporo

Characterized by a continental climate with rigid winters and hot summers. The majority of the temperatures range from 0°C to 25°C. The comfort hours, that don't need any energetic strategy, are 6.2% according to ClimateConsultant. In order to bring up this number we could implement the following strategies:

- The glazings should minimise conductive losses by having a low U-factor (hence, adopting double or triple glazings with thermal break frames). Since the priority is to increase solar gains, the majority

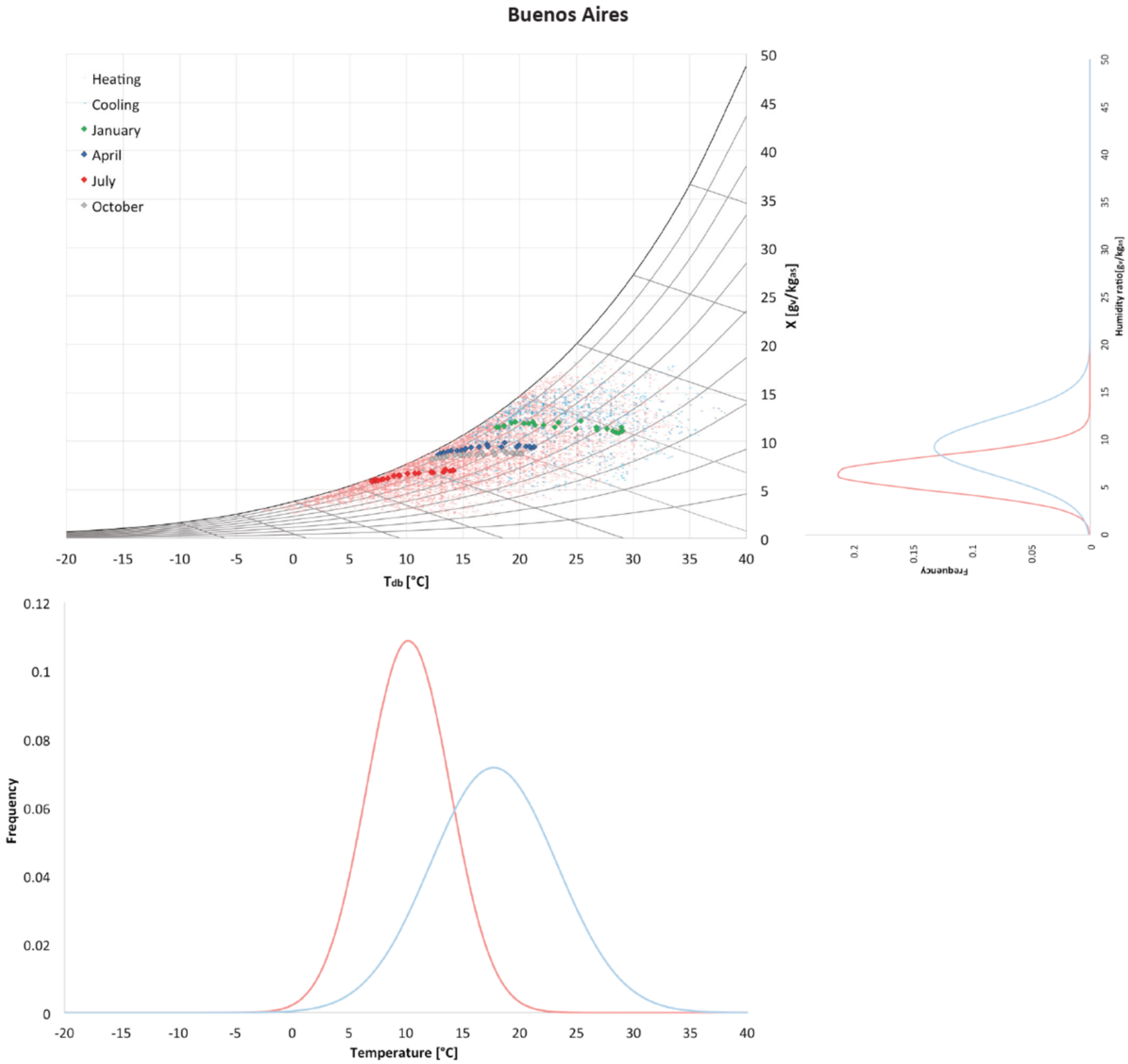


Figure 17: (from the authors)

of the glazed area should be facing south to maximise winter sun exposure. This technology should be coupled with a solar shading that allows to fully shade during summer. For an horizontal exposition the best shading strategy is an horizontal overhang. Since in Sapporo the winter can be snowy the implementation of louvers in the horizontal overhang would contribute in reducing the static load on the shading device. Moreover, it should be avoided to plant trees in front of passive solar windows, while there is no problem in having them beyond 45° from each corner.

- Internal heat gains can highly impact on heating needs, for this reason keeping the building well tight and highly thermally insulated (with $U_{wall} < 0.2$ W/m^{2}K) would decrease the heating needs during winter while preventing the heat to enter during summer. The final outcome would be to increase the thermal comfort of the users while decreasing the energy needs.
- Organize floorplan so winter sun penetrates into daytime use spaces with specific functions that coincide

Figure 18: Buildings Map (from the authors)

with solar orientation to maximise the sun contribution.
- Insulating blinds or operable window shutters will help reduce winter night time heat losses.
- Small well-insulated skylights (less than 3% of floor area in clear climates, 5% in overcast) reduce daytime lighting energy and cooling loads.

Buenos Aires

Temperate climate with cold winters and hot summers. The comfort hours, that don't need any energetic strategy, are 12.9% according to ClimateConsultant. In order to bring up this number we could implement the following strategies:

Figure 19: Kallanka(?)

Figure 20: "Casa chorizo" Plan and section view(?)

Figure 21: "Casa chorizo" interior (?)

Figure 22: Hot summer, Cold winter Region. China(?)

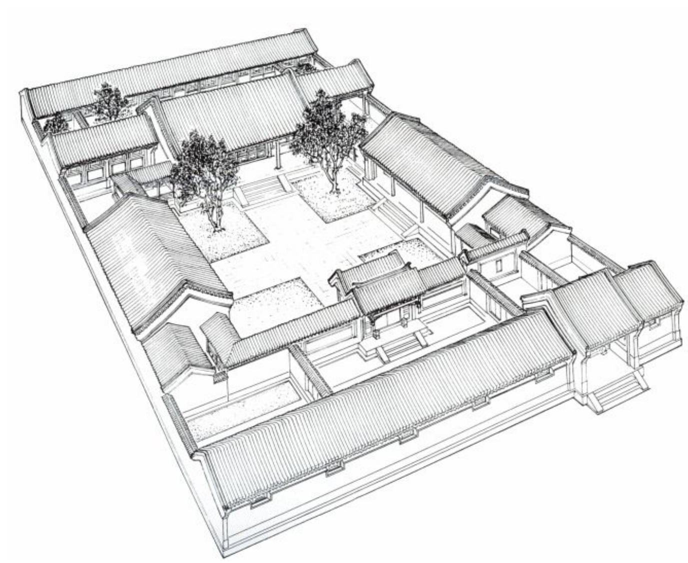


Figure 23: Siheyuans(?)

		HEAT SOURCES			
	Main strategies	**Conduction**	**Ventilation**	**Radiation**	**Moisture transf.**
WINTER (cold season)	*Increase heat gain*	*Improve heat storage when available*	Improve indirect gains from warm soil or sun	Improve solar gains	-
	Reduce heat loss	Reduce heat transfer from inside	Reduce air exchanges and infiltrations	(*)	-
SUMMER (hot season)	*Reduce heat gain*	Reduce heat transf. from out to inside Reduce heat storage.	Reduce air exchanges and infiltrations of hotter external air	Reduce solar gains	-
	Increase heat loss	Increase heat transf. from in. to outside	Improve air exchanges and infiltrations of colder external air	Increase radiant losses (cooling)	Use evaporative cooling

Figure 24: Watson and Labs matrix for Sapporo

- Face most of the glass area north, since Buenos Aires is in the southern hemisphere this would increase passive solar gains during winter.
- Provide double-glazed windows with reflective coating on west, north, and east orientations to control

Figure 25: Horizontal louvered overhangs

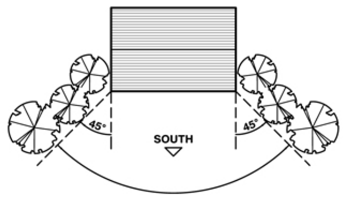


Figure 26: Vegetation is ok beyond 45° from the passive windows

		HEAT SOURCES			
	Main strategies	Conduction	Ventilation	Radiation	Moisture transf.
WINTER (cold season)	*Increase heat gain*	*Improve heat storage when available*	Improve indirect gains from warm soil or sun	Improve solar gains	-
	Reduce heat loss	Reduce heat transfer from inside	Reduce air exchanges and infiltrations	(*)	-
SUMMER (hot season)	*Reduce heat gain*	Reduce heat transf. from out to inside Reduce heat storage.	Reduce air exchanges and infiltrations of hotter external air	Reduce solar gains	-
	Increase heat loss	Increase heat transf. from in. to outside	Improve air exchanges and infiltrations of colder external air	Increase radiant losses (cooling)	Use evaporative cooling

Figure 27: Watson and Labs matrix for Buenos Aires

solar gains during the hot season. West and east windows should be coupled with vertical shading systems while on the north side horizontal overhangs should be used. Leave clear glasses on south for maximum passive solar gain and to minimise daylighting energy needs.

- Exploit night cooling by opening windows during the night in order to have a colder building during summer mornings.
- A compact geometry would be preferrable because it lowers the heating exchange surface. Moreover, a long and narrow geometry can help maximising the cross ventilation effect.

Chapter 3

Recent examples of climate responsive architecture

Buenos Aires Ciudad Casa de Gobierno (Fostern + Parterns)

As Foster claims, "sustainability relates very strongly to local resources and climate, and Buenos Aires Ciudad Casa de Gobierno is a great demonstration of how architecture can work with nature via passive environmental means to naturally reduce energy use. Shading louvres on the east and west protect the interior from direct glare, while courtyards allow sunlight into the heart of the building; in this way, its design is very much a response to place and climate".

The thermal mass of the concrete soffits helps to regulate temperature, and chilled beams were also added to help keep the space cool at the hottest times of the year. Every aspect of the scheme was designed in response to the local climate, including the composition of each façade.

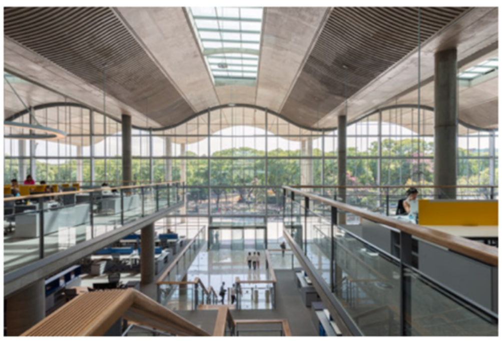


Figure 28: Ciudad casa de Gobierno(**?**) (**?**)

Q1 Building, ThyssenKrupp Quarter (Chaix & Morel et associés and JSWD Architects)

This project is a good example of responsive façade in temperate-cold climates, where the solar gains during summer and winter have a determinant role in the energy consumption of the building. A complex sunshading system makes the lack of air conditioning possible in the glazed structures. Stainless steel louvers and fins open and close based on the sun's path to maximize views out, while reducing glare and cutting down on heat gain (http://www.architectmagazine.com/design/buildings/thyssenkrupp-quarter_o).

The great concept here was to create these vertical fins, which can twist from 0° to 90°, made by horizonal cantilevered slats which can rotate assuming different inclination.

University building in Kolding, Denmark (Henning Larsen)

Another example of responsive façade where the external shading system assumes a fundamental role.

The Kolding Campus is fitted with dynamic solar shading, which adjusts to the specific climate conditions and user patterns and provides optimal daylight and a comfortable indoor climate spaces along the façade. The solar shading system is fitted with sensors which continuously measure light and heat levels and regulate the shutters mechanically by means of a small motor (https://www.archdaily.com/590576/sdu-campus-kolding-henning-larsen-architects).

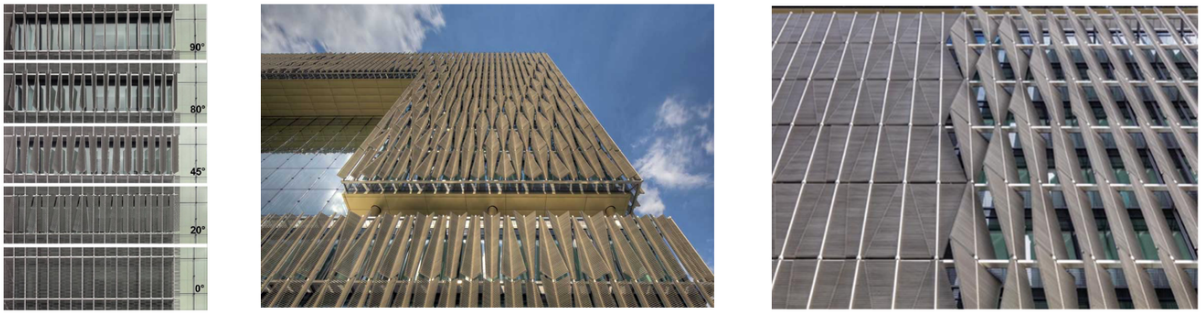


Figure 29: Q1 Building(?)

Each panel is made of a perforated metal sheet.

The 13,700 m2 building has a ventilation system integrated into the ceiling planes, efficient LED lighting, photovoltaics and solar-heating panels. The central atrium is lit through a large skylight above and is dominated by several stairs and catwalks. Thanks to its sustainable features, the building's energy demands are reduced by 50 percent compared to similar buildings in Denmark (https://inhabitat.com/climate-responsive-university-building-meets-denmarks-strict-new-building-codes/).

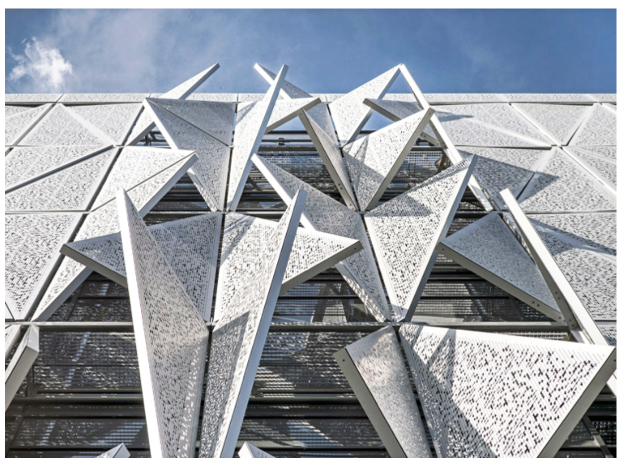


Figure 30: University building in Kolding(?)

Gifu Media Cosmos, Japan (Arup in collaboration with Toyo Ito)

As we can see, the peculiarity of this building is the globe's geometry and the wood grid on the ceiling.

The globes' geometry forms a 'bell-mouth' which enhances air flow inside the building. Non-dazzling daylight is filtered through the polyester globes, bringing in natural light whilst ensuring an optimal reading environment. Experiments showed that this passive design would reduce the building's energy consumption by 40% (https://www.arup.com/projects/gifu-media-cosmos).

Figure 31: Gifu Media Cosmos (?)

Passive house, Changxing (Peter Ruge Architekten)

Passive House Bruck sets new standards of sustainability through the design of a passive house in Southern China: Passive House Bruck is the first housing of its kind to be realized in the country's damp, warm, southern climate with approximately 95% energy saving and certification by the German Passivhaus Institut (https://www.peter-ruge.de/project/passive-house-bruck-changxing-p-r-china/language/en/).

The well-insulated building envelope which maintains optimal indoor temperatures throughout the year is complemented with a highly efficient ventilation system, triple-glazed, floor-to-ceiling windows and shading achieved through the introduction of coloured terracotta rods. (https://inhabitat.com/energy-efficient-46-unit-passivhaus-bruck-building-opens-in-china/).

The apartment building achieves 95% energy savings over other comparable buildings of its size and incorporates some of the most up-to-date sustainable technologies and strategies. The well-insulated building envelope which maintains optimal indoor temperatures throughout the year is complemented with a highly efficient ventilation system, triple-glazed, floor-to-ceiling windows and shading achieved through the introduction of coloured terracotta rods. The fixed terracotta rods create an interesting pattern and provide optimal shading.

Figure 32: Passive house, Changxing (?)

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