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Cold Climate Responsive Architecture and Effects of the Sun Path

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ABSTRACT
As the quote by Vitruvius indicates, designing buildings in harmony with their climates is an age-old idea. To design in conformity with climate, the designer needs to understand the microclimate of the site, since all climatic experience of both people and buildings is at this level. Besides adjusting the building design to the climate, it is also possible, to a limited extent, to adjust the climate to the needs of the building. We cannot agree with Mark Twain when he said, "Everyone talks about the weather but no one does anything about it." It is easy to see how man changes the microclimate by such acts as replacing farmland and forest with the hard and massive materials of cities, irrigating a desert and making it a humid area, and constructing high-rise buildings to form windy canyons. Unfortunately, these changes in the microclimate are rarely beneficial since they are usually done without concern for the consequences.
Most serious, however, are the changes we are making to the macroclimate. Large-scale burning of fossil fuels is increasing the amount of carbon dioxide in the air. Carbon dioxide, like water vapor, is transparent to solar energy but not to the long-wave radiation emitted by the earth's surface. Thus, the ground and atmosphere are heated by the phenomenon known as the ***greenhouse effect***. The heating of the earth might create very undesirable changes in the world's climates. Also, various chemicals are depleting the ozone layer, and large-scale cutting of tropical forests might also be creating worldwide changes in climate.
To properly relate buildings to their microclimate and to make beneficial changes in that microclimate, we must first understand the basics of climate.
Keywords- building thermal performance, thermal performance, sun path

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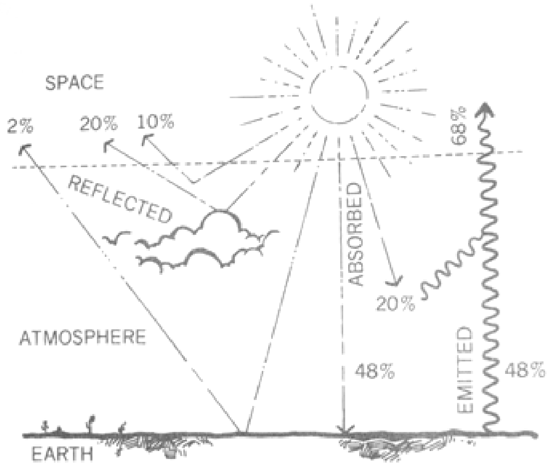
I. INTRODUCTION

1.1 CLIMATE

The climate or average weather is primarily a function of the sun. The word "climate" comes from the Greek "klima," which means the slope of the earth in respect to the sun. The Greeks realized that climate is largely a function of sun angles (latitude) and, therefore, they divided the world into the tropic, temperate, and arctic zones.

The atmosphere is a giant heat machine fueled by the sun. Since the atmosphere is largely transparent to solar energy, the main heating of the air occurs at the earth's surface. As the air is heated, it rises and creates a low-pressure area at ground level. Since the surface of the earth is not heated equally, there will be both relatively low- and high-pressure areas with wind as a consequence.

A global north-south flow of air is generated because the equator is heated more than the poles. This global flow is modified by both the changes in season and the rotation of the earth.



The atmosphere is mainly heated by contact with the solar heated ground. On an annual basis, the energy absorb by the earth equals the energy radiated by back into space. In the summer there is gain while in winter it is loss.

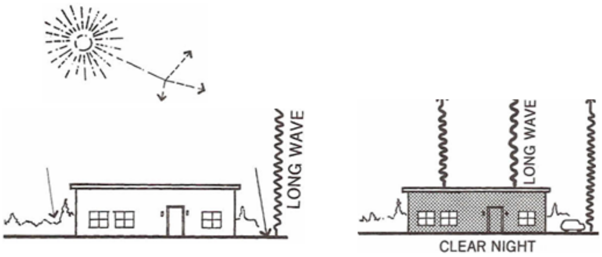
The rotation of the earth deflects the north – south air currents by an effect known as coriolis force.

Another major factor affecting winds and, therefore, climate is the uneven distribution of land masses on the globe. Because of its higher heat capacity, water does not heat up or cool down as fast as the land, and the farther one gets from larger bodies of water the more extreme are the temperatures.

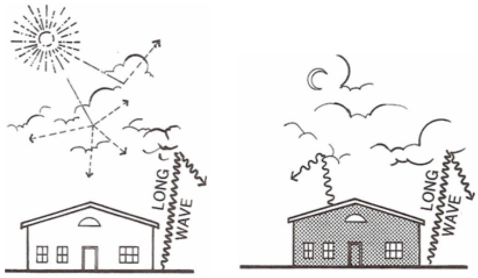
Mountain ranges not only block or divert winds but also have a major effect on the moisture content of the air. A good example of this important climatic phenomenon is the American West. Over the Pacific Ocean solar radiation evaporates water, and the air becomes quite humid. The wester-lies blow this moist air over land where it is forced up over the north south mountain ranges. As the air rises, it cools at a rate of about 3.6 degree F for every 1,000 feet. When the temperature drops the relative humidity increases until it reaches 100 percent, the saturation point. Any additional cooling will cause moisture to condense in the form of clouds, rain, or snow. On the far side of the mountains, the now drier air falls and, consequently, heats up again. As the temperature increases, the relative humidity decreases and a rain shadow is created. Thus, a mountain ridge can be a sharp border between a hot, dry and a cooler, wetter climate.

Mountains also create local winds that vary from day to night. During the day, the air next to the mountain surface heats up faster than free air at the same height. Thus, warm air moves up along the slopes during the day. At night, the process is reversed: the air moves down the slopes because the mountain surface cools by radiation more quickly than the free air. In narrow valleys, this phenomenon can create very strong winds up along the valley floor during the day and down the valley at night.

Also at night there is little moisture to block the outgoing long wave radiation; consequently, nights are cool and the diurnal temperature range is high - more than 30°F. On the other hand, in humid and especially cloudy regions, the moisture blocks some solar radiation to make summer daytime temperatures much more moderate below 90°F. At night, the outgoing long-wave radiation is also blocked by the moisture, and consequently, temperatures do not drop much. The diurnal temperature range is, therefore, small-below 20°F. It should be noted that water has a much stronger blocking effect on radiation when it is in the form of droplets (clouds) than in the form of a gas (humidity).
The various forces in the atmosphere interact to form a large set of diverse climates.



Since dry climates have little moisture to block radiation, day time temperatures are high and night temperatures are low. The diurnal temperature range is, therefore, large.



Water in the form of humidity and especially in the form of clouds blocks both solar and long wave radiation. Thus, in humid or cloudy climates, the day time temperatures are not as high and night temperatures are not as low. The diurnal range is, therefore, small.

1.2 MICROCLIMATE

For a number of reasons, the local climate can be quite different from the climate region in which it is found. If buildings are to be relate properly to their environment, they must be designed for the microclimate in which they exist. The following factors are mainly responsible for making microclimate deviate from the macroclimate:

1. Elevation above sea level: The steeper the slope of the land, the faster the temperature will drop with an increase in elevation. The limit, of course, is a vertical ascent, which will produce a cooling rate of about 3.6 degree F per 1,000 feet.

2. Form of land: South facing slopes are warmer than north facing slopes because they receive much more solar radiation . For this reason ski slope are usually found on the north slopes of mountains. South slopes are also protected from the cold winter winds.

3. ***Size, shape, and proximity of bodies of water:*** As mentioned before, large bodies of water have a significant moderating effect on temperature, they generate the daily alternating land and sea breezes, and they increase the humidity.

4. ***Soil types:*** The heat capacity, color, and water content of soil can have a significant effect on the microclimate. Light-colored sand can reflect large amounts of sunlight, thereby reducing the heating of the soil, and, thus, the air, but at the same time greatly increases the radiation load on people or buildings. Because of their high heat capacity, rocks can absorb heat during the day and then release it again at night. The cliff dwellings of the Southwest benefited greatly from this effect.

5. ***Vegetation:*** By means of shading and transpiration, plants can significantly reduce air and ground temperatures. They also increase the humidity whether or not it is, already too high. In a hot and humid climate, the ideal situation is to have a high canopy of trees for shade, but no low plants that could block the breeze. The stagnant air from low trees and shrubs enables the humidity to build up to undesirably high levels. In cold climates, plants can reduce the cooling effect of the wind. Vegetation can also reduce noise and clean the air of dust and certain other pollutants.

6. ***Manmade structures:*** Buildings, streets, and parking lots, because of their number and size, have a very significant effect on the microclimate. The shade of buildings can create a cold north like orientation on what was previously a warm southern exposure. On the other hand, buildings can create a cold north like orientation on what was previously a warm southern exposure. On the other hand buildings can create shade from the hot summer sun and block the cold winter winds. Large areas of pavement, especially dark colored asphalt, can generate temperatures as high as 140 degree F. The heated air then migrates to overheat adjacent areas as well.

II. COLD CLIMATE

2.1 CLIMATE CHARACTERISTICS

A cold climate is defined as a region with approximately 5,400 to 9,000 heating degree-days. A building constructed in cold climates should ideally have healthy and comfortable indoor thermal conditions and a reasonable fuel economy with the heating methods locally employed .The key to reaching that goal is good insulation and sunshine exposure, which helps to keep the warm air inside the building. The ancient Greeks employed this technique by realizing that the winter sun had a low arc in the southern sky, due to the tilt in the Earth at the season, allowing windows in the walls to capture much needed heat from the sun A traditional building is usually built just below the brow of a hill on the southward slope. This way the building is protected by the hill and by surrounding shelterbelts of trees (Oktay). The north face of the building typically has few openings while the south contains the main openings to maximize sun exposure. Orientation is important because it affects which sides of the buildings receive the most sunlight and how long the sun stays with those sides. The long axis of the building should ideally stretch east to west. The north end receives the least amount of sunlight and, consequently, has lower temperatures (Oktay). This is why storage rooms, toilets, and kitchens typically are located at the north end of many buildings. The south end is much warmer and generally will house the living room, bedrooms, and study areas. To minimize and reduce heat loss many rooms contain low ceilings, thick stonewalls, small windows, and centrally located heating. The difference between thick walls in cold and hot climates is that in hot climates the walls outside are meant to shade the interior from the intense heat, whereas, in cold climates the walls inside are meant to insulate and keep heat in. The chart below was created to show the optimal comfort temperature for a cold region at different times of the day.

In a cold climate, using the right type and amount of insulation is key to conserving heat loss and energy and it is the ultimate goal of cold climate architecture. Both hot and cold climate-responsive architecture use special techniques and designs to help get the most benefit out of the natural environment.

2.2 COMFORT REQUIREMENTS OF COLD CLIMATES

BUILDING AND URBAN DESIGN IN COLD CLIMATES

Cold regions are defined as regions with average temperatures during the winter months (November through march) below freezing zero deg C (32 deg F) and with cool –to-comfortable summer conditions. In such regions the main climatic design concerns are to minimize heating energy in the buildings, preventing dis-comfort from drafts, and minimize cold discomfort outdoors. Summer comfort issues in these regions are minor in comparison with the winter problems and it is assumed that just good ventilation can ensure indoor comfort.

Outdoor cold discomfort is strongly affected by the wind speed which together with the air temperature , determines the so-called windchill. Hence the importance of wind protection in open public spaces such as streets, winter playgrounds and parks with winter activities.

Improving the urban microclimate in cold cities can have a significant economic value In this respect, the possibilities of outdoor recreation and sport activities for children. Adults, and the elderly, as well as minimizing the discomfort, inconvenience, and the dangers involved in urban mobility in winter, may have an impact on the attractiveness of the city, especially for the population segments which have more options of employment elsewhere.

In cold cities and villages it is essential to enable the inhabitants to make easy and economical daily journey to work , shops, schools and so on. The attainment of these objectives requires access and affects the design of housing, employment, urban services and recreation.

Objectives in cold cities:

a) Pedestrian protection through the design of colonnades, covered arcades and galleries, through- block passages , connected atriums, and underground walk-ways.

b) Optimized accessibility by reducing outdoor walking distances to transit facilities, parking lots, major retail centers, schools, and recreation centers.

c) Integrated development through guidelines and policies promoting improved microclimate through appropriate urban forms and solar access, higher-density mixed-land uses, transportation corridors, and so forth.

d) Conception of public spaces in relation to seasonal use: design and management of civic spaces and neighborhood parks to maximize year-round use. This can be achieved by multifunctional use of the major elements in the area.

e) The issues of cold cities are discussed at two scales: (a) the building itself and the site around it, and (b) the urban scale.

2.3 DESIGN CONSIDERATIONS

- Build against a South or Southeast facing hill with evergreen trees to North and West, to buffer cold winds.
- Build small and compact. Gloves not boxes.
- Proportions: longer East-West than North-South, by about 1 1/4 to 1; 1 1/2-two stories with basement/semi-basement.
- Consider a duplex; it shares heat. House partition walls will deaden any neighbor noise.
- Insulate heavily from the surrounding ground
- Insulate everything, heavily! Insulated curtains all windows/skylights, overkill in roof and outside walls.

- Minimize glass. Glass mostly on South and Southeast sides, downstairs and basement. Small skylights upstairs for light. Keep eaves short on South, so that you do not block sky light.
- Add glass solarium to South side with winter entry through solarium.
- Build a heavy mass floor (cob, adobe, brick, woodblock on adobe) and a central mass heater/rocket stove/mass stove. Avoid fireplace use in coldest weather.
- Keep ceilings very low in snug spaces.
- Use strawbale or balecob on the north and west walls. Round the outside corners to reduce surface area, cut heat loss by wind and eliminate drafts.
- Create a closeable and heatable snug space for desking, handwork, etc.

1. BUILDING AND EXTENDED SITE DESIGN IN COLD CLIMATES

In cold regions buildings are heated continuously for months during the winter. The heating season is long and the temperature difference between the heated buildings and the outdoors is large.
Consequently, at the building scale, the main concern is to minimize the heat loss from the building. It means the provision of high levels of insulation to the walls, roofs and windows of the building. Heat capacity or thermal mass, has minor impact on the heating energy use, except in buildings heated by passive solar systems.

2. SUPER INSULATED BUILDINGS

A bask approach to energy conservation in Cold regions is to insulate the building to a level higher than what is conventional. The availability of modern insulating materials, such as various plastic foams, and of highly insulated glazing, makes the realization of super-insulated buildings in cold regions an economic proposition,

Sciefert(19871 describes the trend toward super-insulated buildings in Alaska, The walls' details include an exterior wind breaker which is permeable to water vapor (to prevent condensed water accumulation within the insulation). The insulation material is a fireproof Phenolic plastic foam, with thickness equivalent to 33 cm (13") of mineral wool in the walls and to 45 cm (18") in the ceiling.

As the insulation level of a building in a cold climate is increased, the role on the ventilation as a source of heat loss, at rates required to maintain the indoor air at satisfactory hygienic and healthy quality, becomes more crucial. In super-insulated buildings the energy spent on heating the ventilation air may account for close to one-half of the total heating load. One way to minimize this source of heat loss is to install in the ventilation system an air-to-air heat exchanger, which extracts heat from the exhausted air, and prewarms the intake air.

Another issue encountered in cold regions, which potentially may cause severe problems, is that of condensation within the insulating materials of the walls and die roof. The moisture content of the outdoor cold air ii very low. Water vapor generated in the building by its occupants elevates the moisture content and vapor pressure of the indoor air. A vapor pressure gradient is thus created across the building's envelope between the indoor and the outdoor surfaces, which rends to drive the indoor moisture into the envelope's materials, especially into the insulation. An effective vapor barrier on the inner side of the external wall and the ceiling's insulation, such as a polyethylene sheet, is therefore essential to prevent vapor migration into the insulation materials.

3. PRESSMAN (1988) SUGGESTS THE FOLLOWING PRINCIPLES FOR URBAN DESIGN IN COLD CLIMATES:

- High density in the residential, retail, and commercial sectors of the city, in order to reduce the transportation needs and the space-heating requirements. High urban density implies more intensive use of the land.
- Accommodating diverse uses in the same building/complex: residences, offices, and shops, in order to enable people to work and shop in the same building complex where they reside.
- Mixed land use on the urban scale: mixing residential, offices, retail, industrial, and recreation land uses within the same neighborhood. The objective is to reduce the need for commuting. Pressman suggests that such mixed land use will enhance self-sufficiency of the neighborhood because a broader range of services can be made economically viable with improved accessibility.
- Promoting public transit through urban planning, as this is the most energy-efficient form of movement. To be cost-effective it must serve a high-density-area.
- Complementary location of various urban functions. Complementary functions should be grouped according to relative compatibility: residential and work areas linked by a variety of movement modes, recreational zones accessible from both employment and dwelling zones.

Note: Concerning the recommendations for multiuse buildings and mixed land uses one has to take into account potential disturbances which may result from such planning policies: noise, dirt, and loss of privacy, resulting from the free access of nonresidents to the nonpublic parts of the building complex.
The impact of the following urban design elements on the urban microclimate is as below:

• Location Preferences for new neighborhoods in cold regions
• Street Layout
• Urban configuration and density

4. USE OF LONG AND HIGH BUILDINGS AS WINDBREAKS

High and long multistory buildings, oriented in specific ways with respect to the winter wind direction, can protect lower buildings on their leeward from the winds. A curved convex, or a wide, V-shaped, long building with a general cast-west axis, blocks the northern winds and thus creates a sheltered area to its south. A series of such buildings can protect a large area where lower buildings can be built. The open areas between the lower buildings are also protected from the winter winds by the high buildings to the north.

5. MIXED-USE IN BUILDINGS AND/OR URBAN ZONES IN COLD REGIONS

Urban planning policy in a cold climate which allows to mix residences with other land uses, such as offices and retail stores, within the same building, enables the residents living in the building, whose working places are in the same building, to move between home and workplace without the need to go outside and be exposed to the harsh weather. The residents can also do their shopping in the stores or go co some offices as customers, without living in the sheltered environment.

This design solution is not only more convenient for the residents but it also reduces the needs for travel and thus the load on the urban traffic system.

Land-use mixing is, of course, a general issue in urban planning and not limited to cold climates. However, because of the harsh climate in the winters of such regions, this planning approach has special appeal in this climate type and therefore deserves special attention, land use mixing may create, however, some problems. Noise is often created by patrons of the nonresidential .sections of the building: clients coming to the offices, customers of the stores, and so on. Snow removal vehicles create noise while clearing the streets. Trucks bringing merchandise to the stores generate dirt, in addition to the noise, and so on.

Therefore, such land-use mixing requires some form of spatial separation between the different uses to minimize such problems. This separation can be accomplished by two basic design solutions: vertical or horizontal separation, or a combination of the two.

6. URBAN PARKS IN COLD REGIONS

In cold regions the main climatic considerations m designing public park areas arc to provide access to the sun and protection from the wind.

In places where the winter wind direction is from the northwest, high and dense lines of evergreen trees (e.g., conifers) on the north and west borders of, the open space can provide wind protection without blocking the winter sun. Belts of evergreen shrubs along the trees will prevent wind penetration below the trees' canopy.

U-shaped belts of high evergreen shrubs around benches, open to the south and with deciduous trees with high trunks behind it, can provide pleasant seating places year-round in cold regions. This is because they will he exposed to the sun and protected from the wind in winter while enjoying the shade of the trees in summer. Such design details of the benches can increase the prospects of their use during sunny days in winter.

Wind protection with solar exposure around facilities for various forms of winter sports, such as ice skating on frozen ponds, can also encourage the use of the parks in winter, thus enhancing year-round use of the park.

Whenever it is desired to use the urban parks also during the winter, they should be located in naturally sheltered and sunny areas. Topographical sheltering by hills to the north, west, and cast of the park area on he supplemented by belts of evergreen trees.

Snowfall Problems at the Urban Scales

One of the problems often encountered in cold regions with high snowfall is that of snow blockage of local streets and highways. Urban planning involves the organization of the snow removal from highways and local streets and finding (or creating) locations for its dumping.

Sterten (1988) points out that drifting snow and snow accumulation create problems on all types of roads, especially for access from the road to the houses. He recommends that natural elements, as well as man-made elements, should be used to protect houses and outdoor utilized areas from wind and snowdrift.

To the extent that the snow is not removed from the building's site often enough it reduces the freedom of movement in the area and the possibilities of various winter activities on the site. Some building configurations, like a series of V-shape buildings open to the south, with intervals between them, can "direct" the snowdrift to locations allocated for snow deposition.

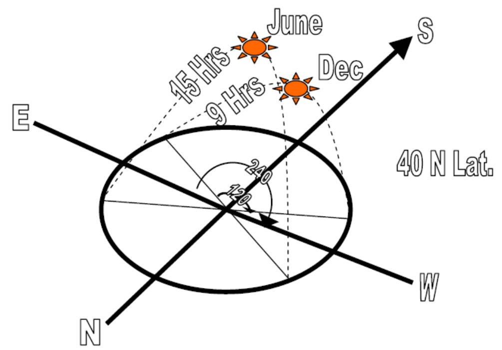
The division of responsibility for snow removal between the city governments and the citizens is often affected by the annual cumulative snowfall, as well as by the economic conditions of the country- A survey of the regulations and practices in different cities, presented by the mayor of Sapporo at the conference, found that m many cities where the cumulative snowfall is less than 2 m (6.5‘) the main responsibility is on the citizen, except for snow removal from public streets, while in cities with snowfall of more than 2 m {6.5') the city governments assume the primary responsibility.

III. SUN PATH DIAGRAMS

The sun is the brightest star in the Earth's solar system. Not only does the sun give us light, but is also a valuable source of heat energy. The sun can be considered the 'life giver' of all living things on Earth, for without the sun, many living organisms would cease to exist. However, the sun does create some problems for us. For example, extreme heat is undesirable as it may cause a sudden increase in bodily temperature. Hence, people have always sought ways to harness the sun's power and yet at the same time reduce the detrimental effects of it. Before explaining the part on how architects come up with designs of buildings to control the sun's energy, it is important to give a short summary of the relationship between the sun and the earth as this will affect the architects' knowledge of the sun's effect on building design.

ROTATION

The Earth rotates about on a fixed plane that is tilted 23.5° with respect to its vertical axis around the sun. The Earth needs 23hrs 56mins to complete one true rotation, or one sidereal period, around the sun. A sidereal day (period) is the time taken for a given location on the earth which is pointing to a certain star to make one full rotation and return back pointing to the same star again. Since the speed of the Earth's rotation is constant throughout the year, the Earth's sidereal day will always be 23hrs 56mins. The solar day, on the other hand, is the time needed for a point on earth pointing towards a particular point on the sun to complete one rotation and return to the same point It is defined as the time taken for the sun to move from the zenith on one day to the zenith of the next day, or from noon today to noon tomorrow. The length of a solar day varies, and thus on the average is calculated to be 24hrs. In the course of the year, a solar day may differ to as much as 15mins. There are three reasons for this time difference. Firstly it is because the earth's motion around the Sun is not perfect circle but is eccentric. The second reason is due to the fact that the Sun's apparent motion is not parallel to the celestial equator. Lastly, the third reason is because of the precession of the Earth's axis.



The rotation of the earth about its axis also causes the day and night phenomenon. The length of the day and night depends on the time of the year and the latitude of the location. For places in the northern hemisphere, the shortest solar day occurs around December 21 (winter solstice) and the longest solar day occurs around June 21 (summer solstice). In theory, during the time of the equinox, the length of the day should be 0equal to the length of the night. This will be further discussed in the later part too.

REVOLUTION

It is generally accepted that the earth's complete revolution around the Sun is 365 days. However, to be exact, the number of days the earth takes to revolve around the sun actually depends on whether we are referring to a sidereal year or a tropical (solar) year. A sidereal year is the time taken for the earth to complete exactly one orbit around the Sun. A sidereal year is then calculated to be 365.2564 solar days. A tropical year is the time interval between two successive vernal equinoxes, which is 365.2422 solar days. The difference between the two is that tropical year takes into consideration precession but the sidereal year does not. Precession is the event where the earth's axis shifts clockwise in circular motion which then changes the direction when the North Pole is pointing.

The difference between the sidereal and the tropical year is 20mins. This difference is negligible in the short run, but in the long run will cause time calculation problems. Thus readjustments to calendars must be made to correct this difference. Hence for simplicity, the average time the earth takes to move around the sun in approximately 365 days. This path that the earth takes to revolve around the sun is called the elliptical path.

SOLSTICE

The earth is tilted 23.5^o, so is the ecliptic, with respect to the celestial equator, therefore the Sun maximum angular distance from the celestial equator is 23.5°. At the summer solstice which occurs around 21st of June, the North Pole is pointing towards the sun at an angle of 23.5^o as shown in figure 1.3. Therefore the apparent declination of the sun is positive 23.5^o with respect to the celestial equator.

At the Winter solstice which occurs around 21st December, the North Pole is pointing away from the sun at an angle of 23.5^o. Therefore the apparent declination of the sun is negative 23.5^o with respect to the celestial equator.

SEASON

Seasons are caused by the Earth axis which is tilted by 23.5^o with respect to the ecliptic and due to the fact that the axis is always pointed to the same direction. When the northern axis is pointing to the direction of the Sun, it will be winter in the southern hemisphere and summer in the northern hemisphere. Northern hemisphere will experience summer because the Sun's ray reached that part of the surface directly and more concentrated hence enabling that area to heat up more quickly. The southern hemisphere will receive the same amount of light ray at a more glancing angle, hence spreading out the light ray therefore is less concentrated and colder. The converse holds true when the Earth southern axis is pointing towards the Sun.

SUN'S APPARENT MOTION

The Earth rotates and revolves around the sun in a counter clockwise direction. However, when we look at the Sun on earth, it appears to be moving in a clockwise direction. This phenomenon is known as the apparent motion of the sun.

4.2 SUN PATHS

INTRODUCTION

Have you ever wondered why the sun rises in the east and sets in the west? For centuries, this natural phenomenon has always amazed mankind. Being the closest star to us, the sun certainly brings about a great interest for everyone to study its movement and behavior, especially its position at different times of the day and month during the year. However, we first have to understand that viewing the sun from different locations on the earth, the sun will rise and set from a different point on the horizon and move along different paths across the sky.

Though knowing that the sun rises in the east and set in the west, do you know that the sun does not rise exactly due east or sets exactly due west? Instead the sun may rise further north of east or further south of east, depending on which part of the earth you are at. To understand where you stand on the earth, it is specified by the latitude and longitude coordinates.

On a globe model, lines of latitude are circles of different sizes. The largest circle is the equator, whose latitude is zero, while at the poles- at latitudes 90° north and 90° south (or -90°), the circles shrink to a point as shown below (a).Whereas for longitude they are lines, or arcs, extend from pole to pole as shown in the diagram below (b).

The base values for the latitude and longitude are the equator and the prime meridian respectively. The latitude and longitude will have significant effects on the sun path and hence affects the behavior of the sun's lighting and heating characteristics. After explaining the latitudes and longitude, we are going to position ourselves, as observers to be in the latitude of 0 degree and 90 degrees North. Now looking from an observer's point of view, we will try to measure the position of the sun with reference to the horizon.

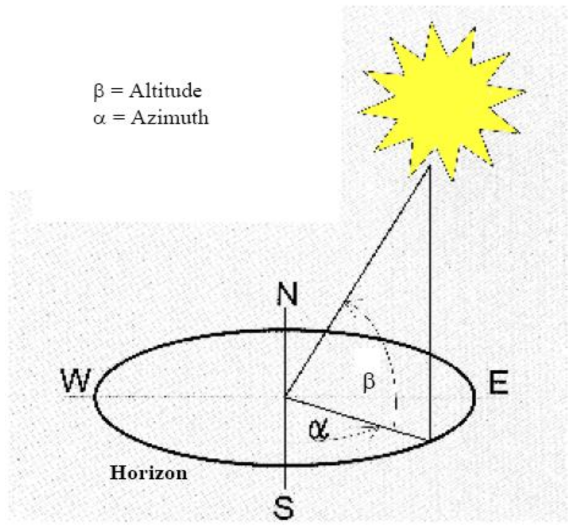


Figure 2.1c Azimuth and Altitude

To measure the angle of the sun in its motion across the sky, we need to take its altitude and azimuth reading. Altitude is the angular distance above the horizon measured perpendicularly to the horizon. It has a maximum value of 90^0 at the zenith, which is the point overhead. Azimuth the angular distance measured along the horizon in a clockwise direction. The number of degrees along the horizon corresponds to the compass direction. Azimuth starts from exactly north, at 0 degrees, and increases clockwise. The example below illustrates the sun angles for 56 degrees North latitude (Northern Hemisphere). The altitude as you can see from the figure below is symbolized by β starts from the horizon while the azimuth is symbolized by α which starts from the South Pole and travels clockwise.

Depending on the day of the year and the latitude of the observer, it affects where the sun exactly rises or sets, or how long the sun is above the horizon. As seen from the 2 diagrams above the sun does not necessarily rise due East or set due west. The location of the sun in the sky is described as having two components: its daily movement around the horizon and its height above the horizon (altitude). Its altitude varies with the seasons and location of the observer. At 40 degrees latitude, Figure 2.2a, during the equinox the sun rises due east, while during solstices the sun rises due south east or north east. At 65 degrees latitude, Figure 2.2b, the sun rises further south of east during the winter solstice and further north of east during the summer solstice.

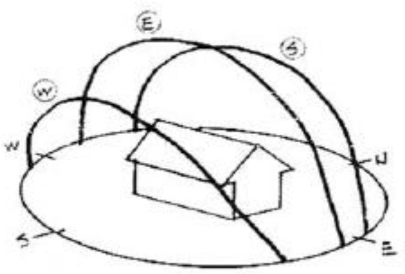


Figure 2.2a

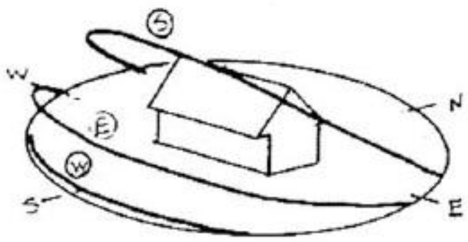


Figure 2.2b

The sun's daily path across the sky on or about the 21st day of each month is indicated by means of seven curved lines. The path is highest in June and the lowest in December. The sun travels across the earth's sky along 7 main paths. Each of the other five paths is for two months in the year. For instance, the path on the March 21 is the same as on September 23.

We observe the sun in the northern hemisphere with regards to its paths. The tilt of the earth causes the seasons which constitutes the difference in the sun paths.

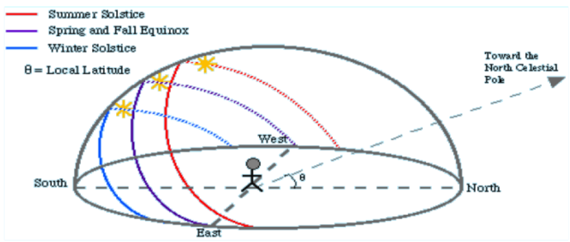


Figure 2.2c The sun in the sky in the northern hemisphere

The sun paths are different due to factors such as the:
1) Location (local latitude)
2) Rising and setting position (based on the time of the year)
3) Duration of the day and night

During the summer solstice, on the 21st of June, the sun will be traveling at the highest path across the sky (shown as the red line). In the morning, the sun will rise due north of east, th n crosses the meridian due south at noon and setting a little due north of west. The duration of the day is longer relative to the night as the sun across the sky. The sun's maximum altitude will occur at noon (calculated by the latitude of the observer's location plus 23.5o).

Each day the path of the sun becomes lower until the day when the duration is exactly 12 hours; this will be the September equinox, 21st September (shown as purple line). The sun will rise at exact east and set at exact west.

The sun path is the lowest in the sky during the winter solstice. The sun will rise south of East and set at the south of West in any of the day in that time of the year. It reaches nearest to south at noon .

The duration of the day will be much shorter relative to the altitude of the sun will gradually be higher. The duration of the day will increase to eventually 12 hours at the equinox (shown as purple line above).

The ever changing path of the Sun is a result of our seasons. The earth as a whole receives the same amount of sunlight everyday and every year. The apparent movement of the sun around the earth is relative and due to the earth's rotation and orbit. The seasonal difference in daily path of the sun are due to the tilt of the earth's axis.

IV. CONCLUSION

This report was made to find out how to choose an optimal house orientation and still have a clever design that can saved a lot of energy. Even though on some parts of the world a good orientation of the house can reach more than 50% in savings, in Denmark, because of its geographical position and weather condition the solution is not that effective. However, with an accurate investigation of the sun conditions and environment on the plot and implementation of proper technical solutions in design the energy consumption is reduced with at least 20% and in some cases even up to 40%.

The idea of orientating the house towards sun in Denmark still has to be developed and well-advertised. For now it can only be considered as a future solution. People have to be much more informed in order to start thinking more not only about design of the house, but as well about its efficiency. Spending more money does not necessarily mean that it is better. Finding a balance between money spent, pay-back and solution has to be much more questioned and examined. Mostly this symbiosis between client and architect is needed to come up with the best product.

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