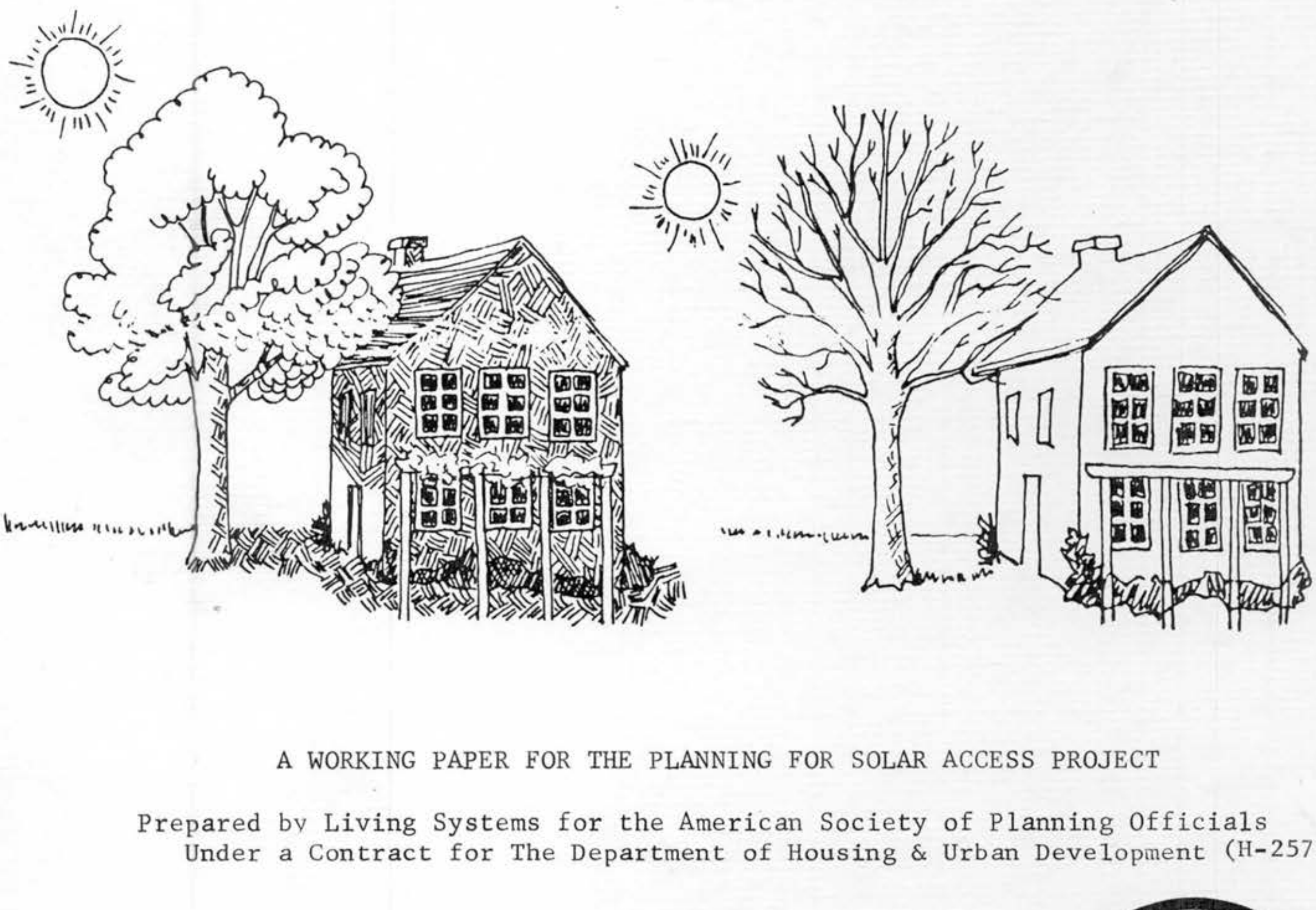
ENVIRONMENTAL FACTORS

EFFECTING

SOLAR SYSTEM DESIGN

(TASK 3.3)



A WORKING PAPER FOR THE PLANNING FOR SOLAR ACCESS PROJECT

Prepared by Living Systems for the American Society of Planning Officials
Under a Contract for The Department of Housing & Urban Development (H-2573)

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ASPO: PLANNING FOR SOLAR ACCESS

TASK 3.3: ENVIRONMENTAL FACTORS EFFECTING SOLAR SYSTEM DESIGN

A. INTRODUCTION

The first section of this chapter described the basics of heat flow, the many types of solar systems, skyview requirements for different solar systems, their applications to five housing types; and a brief discussion of planning for optimal solar access. In this section the environmental factors effecting solar access are described. The impact of these factors on solar systems will be evaluated in detail in Task #4.

B. A BRIEF DESCRIPTION OF THE ENVIRONMENTAL FACTORS EFFECTING SOLAR ACCESS

There are many environmental factors that can have a significant effect on solar system performance and therefore on planning for solar access. These impacts can be either beneficial or adverse depending on the local climate and site. The purpose of this section is to list the factors and the nature of the impact, leaving the calculation of the magnitude of the specific impacts to TASK 4.

The environmental factors chosen include: microclimate, topography, latitude, surface, vegetation, and finally an evaluation of man's impact on these factors. Each sub-section includes an initial discussion of how environmental factors effect both solar heating and natural cooling applications and will be used later in evaluations for different building climate zones.

1) Climate —

We are all familiar with the local climate and have an image of what it is like. These images are often overly general, e.g. hot, dry summers and cold, wet winters and tend to neglect the many small scale microclimatic conditions which may vary widely. An extensive study of the microclimate of the Neotoma Valley in Ohio vividly illustrates the dramatic changes that occur in a small area because of different environmental factors, fig. 1. Thus, although generalizations are useful, they may tend to mask the influence of local variations which may significantly increase or decrease individual heating or cooling requirements.

FIGURE 1.
MACROCLIMATE VS MICROCLIMATE

Climatic Factor	Ohio's 88 Stations	At 109 Neotoma Valley Stations
Highest annual temperature	91-102^{o}F	75-113^{o}F
Date of occurrence	17-19 July	25 Apr.-19 Sept.
Lowest January temperature	-6 to -20^{o}F	+14 to -26^{o}F
Frost free period, days	138-197	124-276

The design and construction of a development will create a new microclimate, which can be better or worse than the existing climate depending on the skill and understanding of the designer and his analysis of local microclimatic conditions.

a. Skyview

The concept of skyview includes all types of radiation exchange between a solar collector and the local site. It includes direct beam shortwave solar radiation, diffuse radiation, long wave radiation, and reflected solar radiation. These broad definitions are particularly important for passive system design and natural cooling.

The direct solar radiation received is one of the most important factors in solar system design. A nearly constant 430 BTU/HR/FT^2 strikes the outer atmosphere as direct solar radiation. Typically about 50% of this solar radiation is reflected or absorbed in the atmosphere before it reaches the surface of the earth, fig. 2.

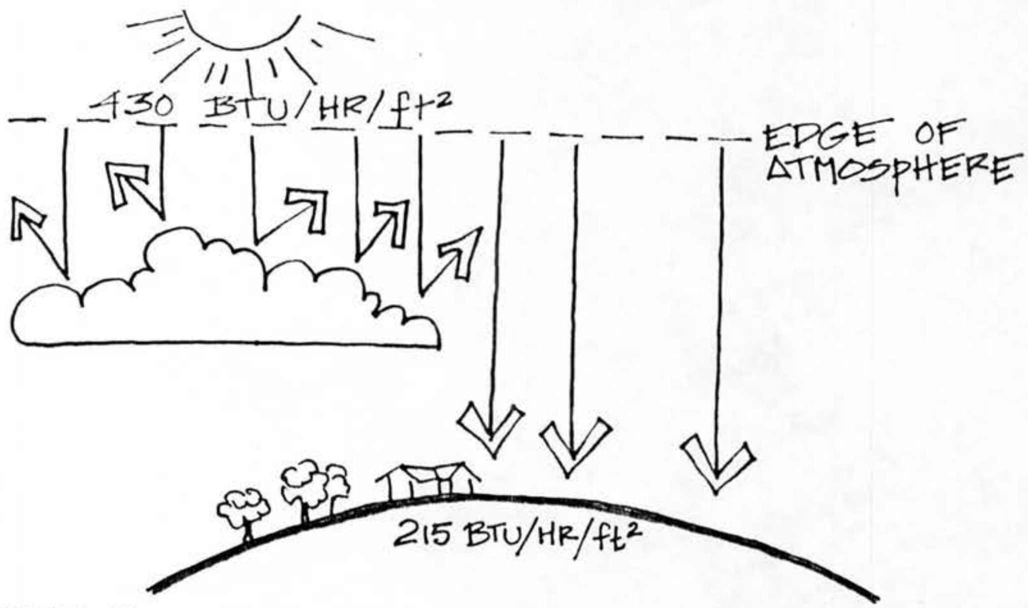


FIGURE 2. RADIATION IS DIMINISHED BY ABSORPTION & REFLECTION

Of the radiation that is reflected some may still reach the earth as diffuse radiation. The amount of radiation absorbed and reflected varies with the composition of the air (water vapor, dust, smog, etc.), and also with the position of the sun. As the length of the sun's path through the atmosphere increases, the amount of reflection and absorption also increase, fig. 3.

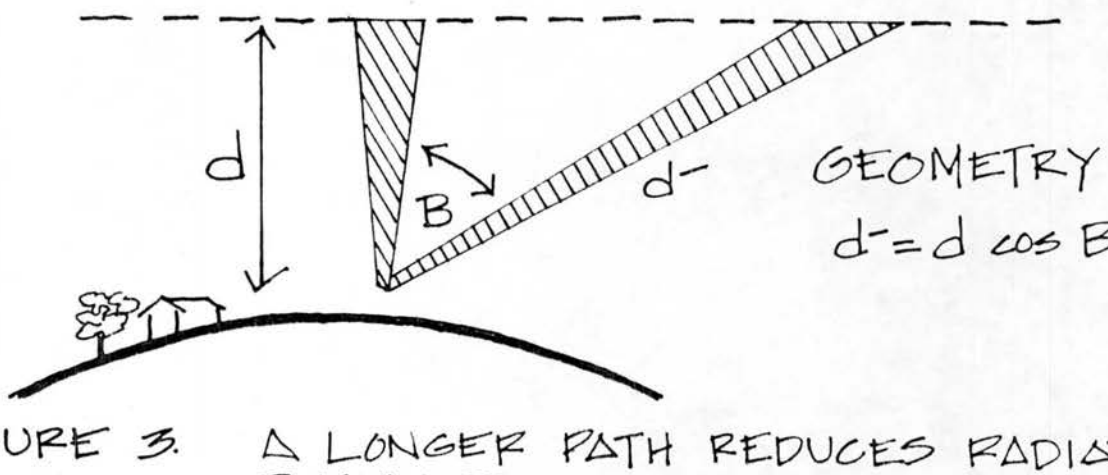


FIGURE 3. A LONGER PATH REDUCES RADIATION RECEIVED

The amount of direct solar radiation received by a surface varies as the sun changes orientation both during the day and throughout the year. The sun's height (altitude) and direction (azimuth) describe its changing path in the sky and can be used to calculate the amount of direct solar radiation a collector will receive during a year, fig. 4.

Orientation for direct radiation is critical for concentrating collectors as most cannot utilize diffuse radiation, fig. 5.

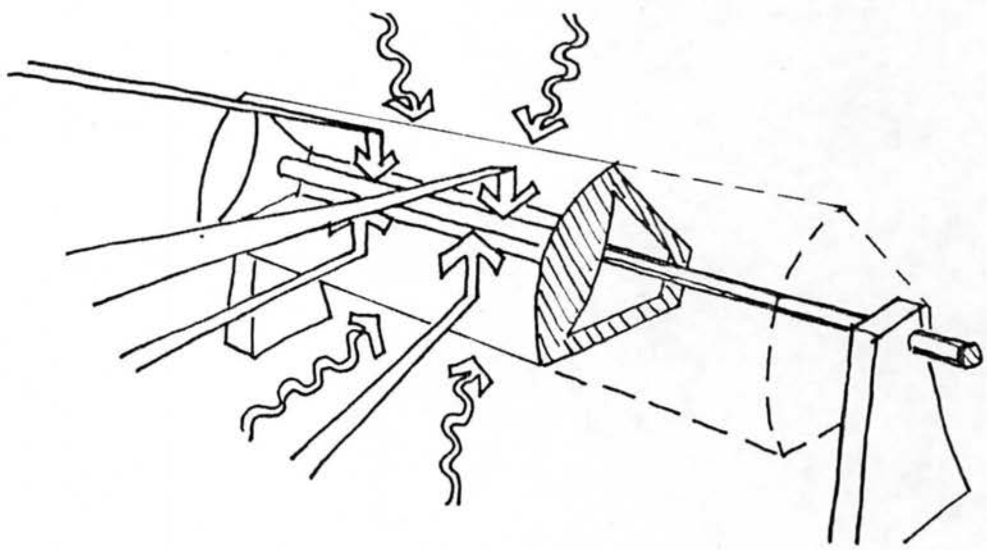


FIGURE 5. MOST CONCENTRATING COLLECTORS USE ONLY DIRECT RADIATION

Diffuse Radiation

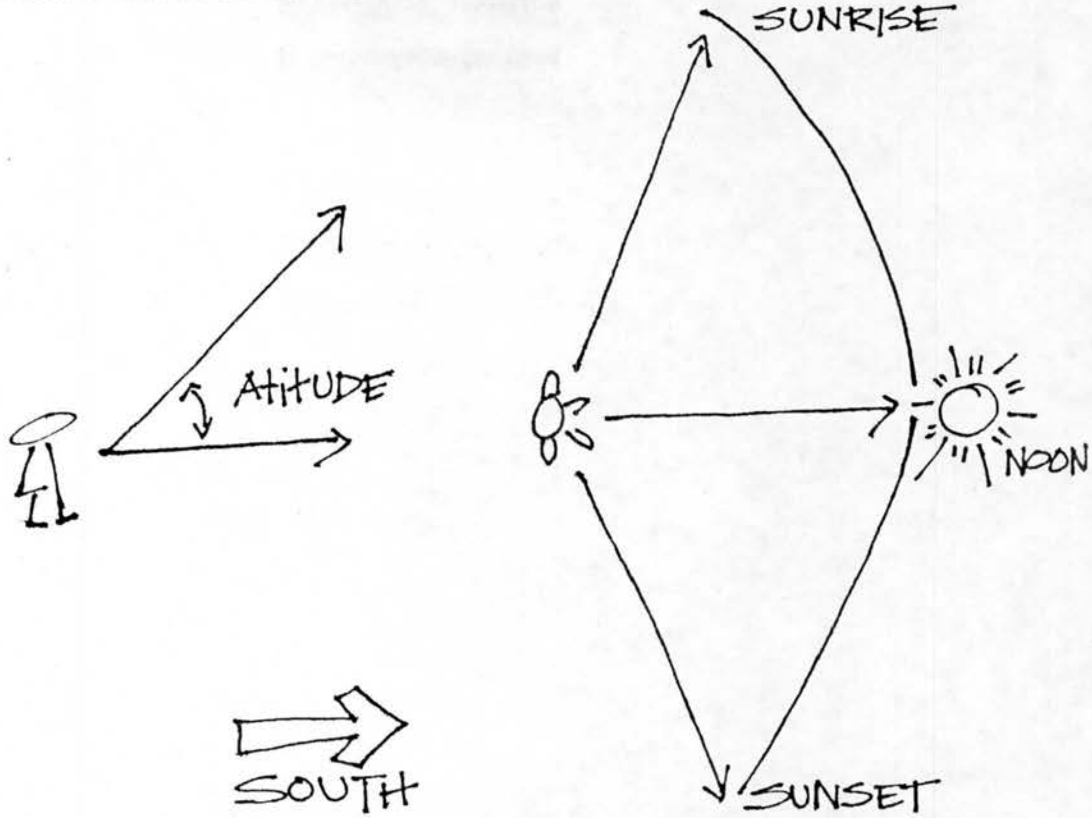
Diffuse radiation can be used by most other solar collectors. It is affected by many of the same factors as direct radiation. Diffuse radiation can be used effectively in areas where direct sun is not common. Even with full clouds diffuse radiation may be on the order of 100 BTU/hr/sq.ft., and this can assist or provide full heating in some areas.

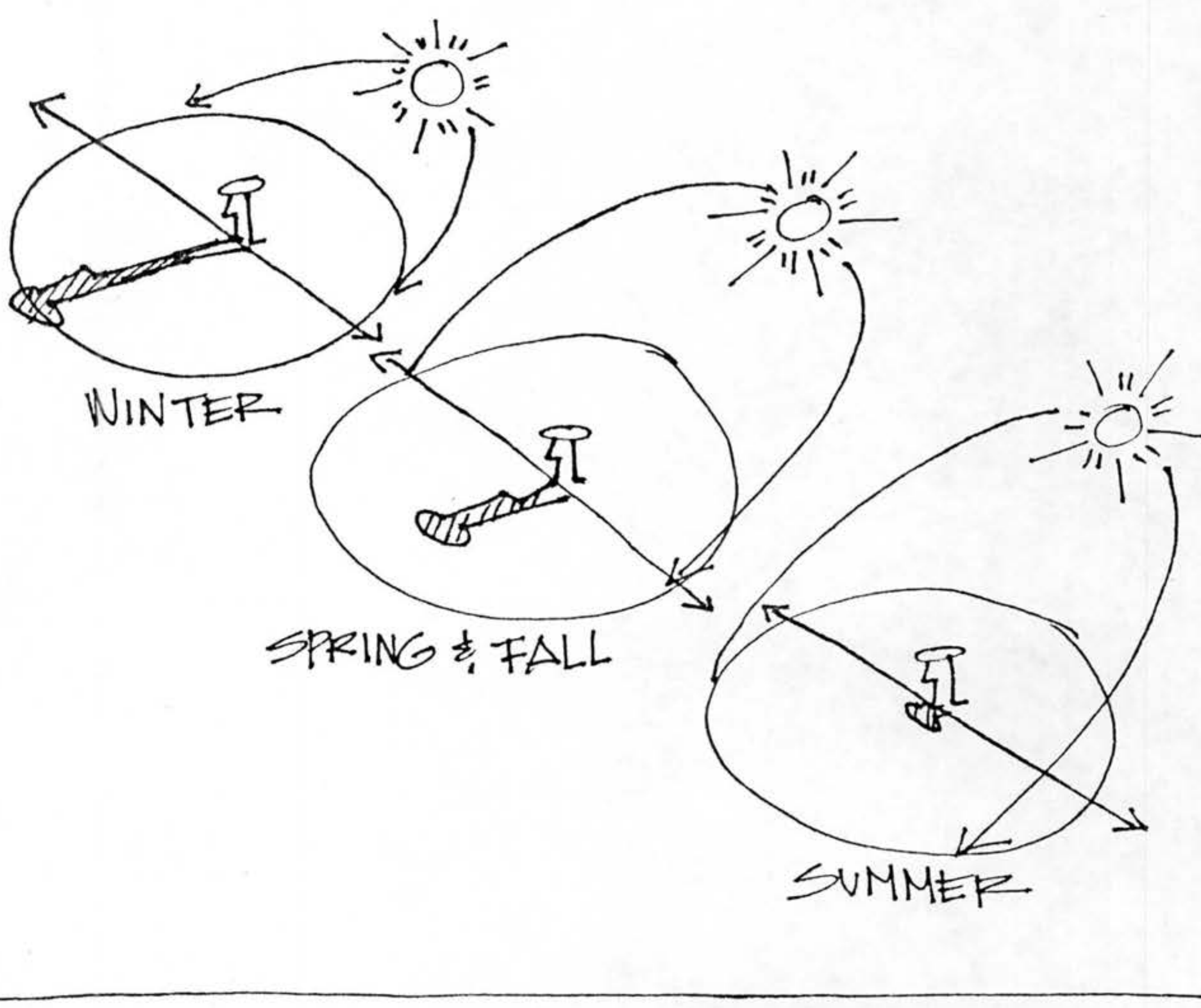
Long Wave Radiation

Long wave radiation is emitted by the earth and also by water vapor, carbon

FIGURE 4.

THE SUN'S PATH





dioxide, and particles in the atmosphere. The difference between energy radiated from the earth and that received from the atmosphere is the net radiative heat loss. This is highest in the desert where the amount of dust and water vapor in the atmosphere is very low, fig. 6.

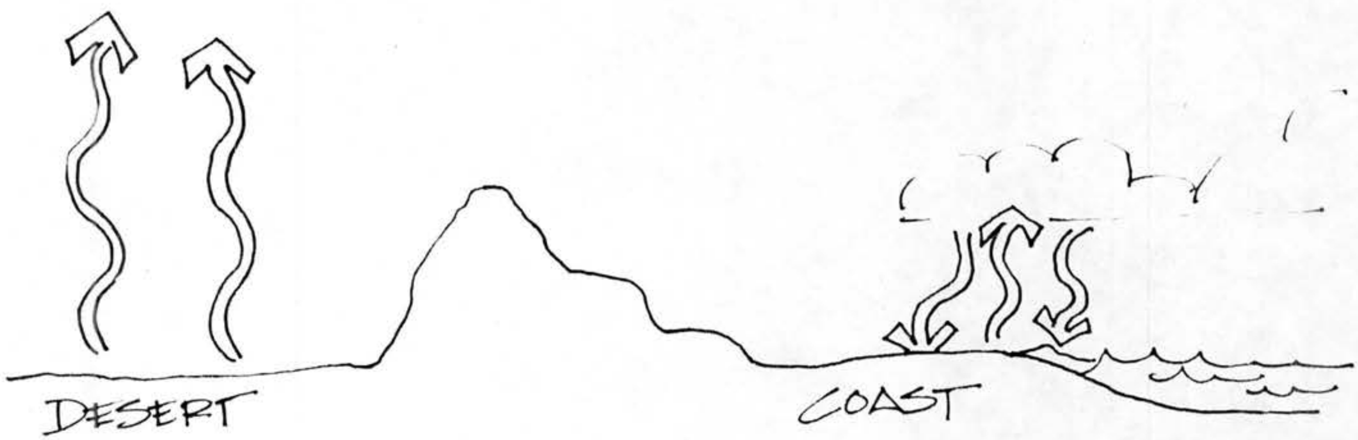


FIGURE 6. OUTGOING RADIATION

Where the net radiative loss is fairly high, due to low atmospheric moisture levels, very effective cooling can be achieved at night. During the day some heat can be released to the cool north sky in some areas.

In planning cities the long wave energy exchange is very important as it is a key factor in human comfort outdoors. The canyons formed by buildings trap and reradiate both short and long wave radiation. This effect can also be noticed when standing next to a wall, fig 7.

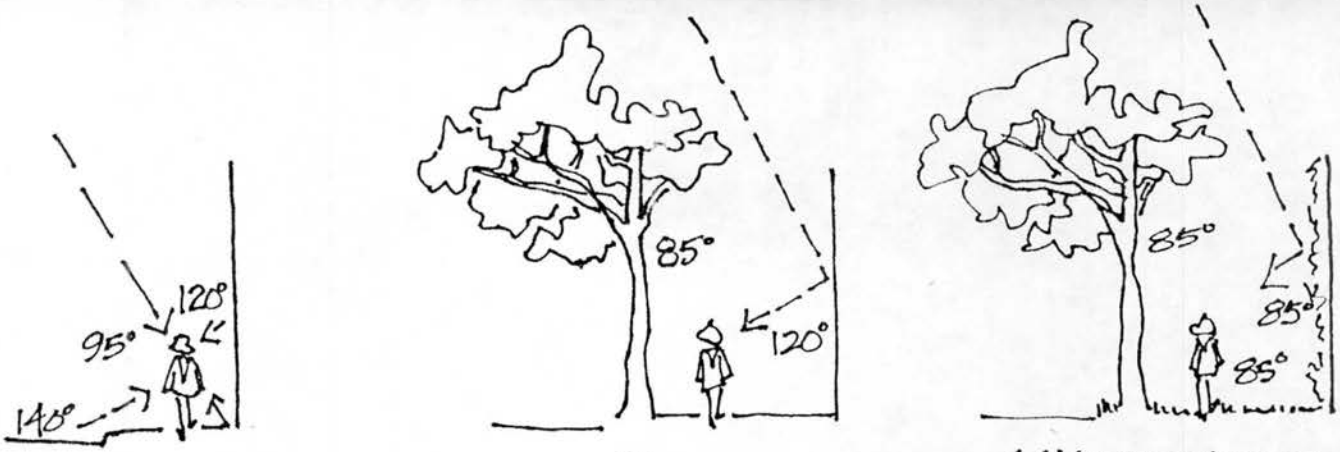


FIGURE 7. SOL-AIR TEMPERATURE—90° BASE TEMPERATURE

Reflected Radiation

Reflected solar radiation can be important in some cases. For example, a house on the east side of a lake will receive increased radiation in the afternoon, when it may or may not be desirable, fig. 8.

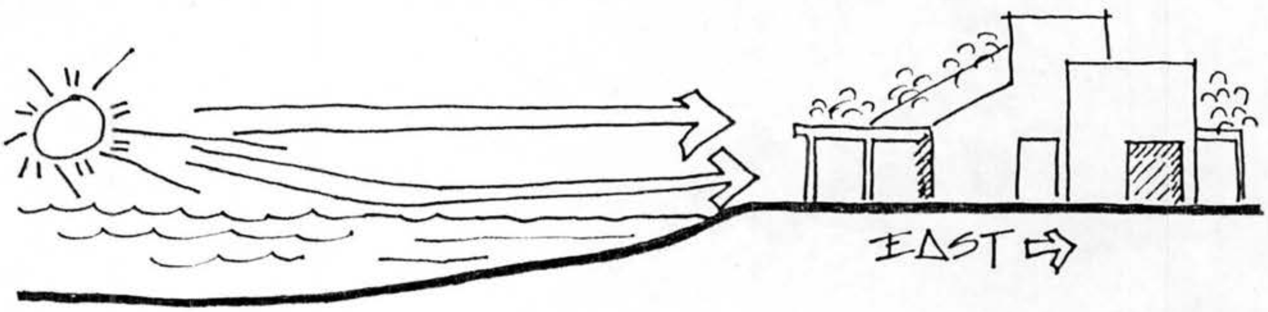


FIGURE 8. REFLECTED RADIATION

Snow or other bright surfaces can cause similar effects. New snow may be as reflective as a mirror and can double the radiation received by a south wall, fig. 9., in northern latitudes where heating is critical.

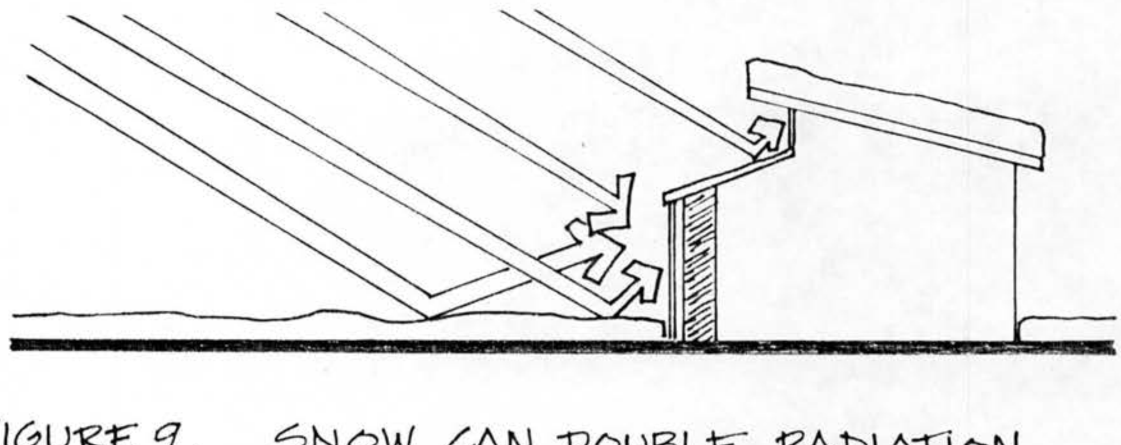


FIGURE 9. SNOW CAN DOUBLE RADIATION

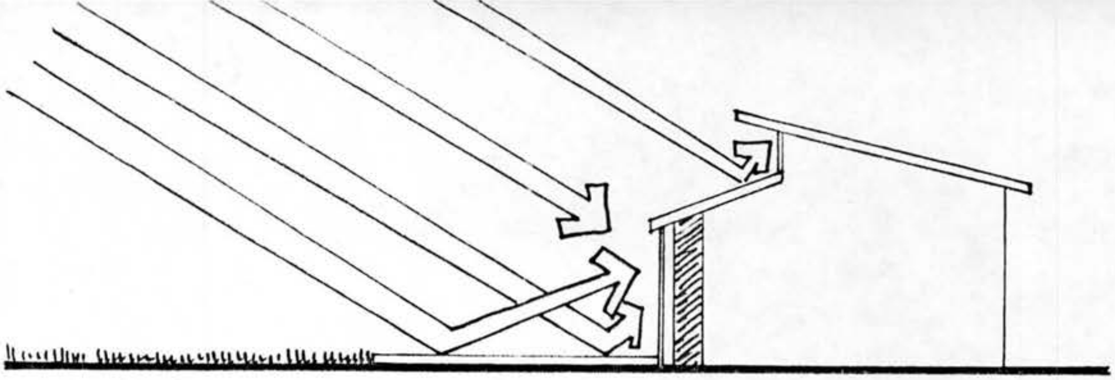


FIGURE 10. LIGHT SURFACES INCREASE RADIATION

A concrete patio or graveled driveway can also increase radiation recieved on a solar collector, figure 10.

b. Air Temperature

The need for heating and cooling is in part determined by the air temperature. Often only heating degree days (based on hours under 65^{o}F) have been used for house design. Yet solar system design is not really this simple and more detail such as percent of sunshine, wind speed, etc., is needed for optimal design. The maximum, minimum, mean temperatures, as well as their distribution, are needed, fig. 11. These factors all play an important role in sizing both active and passive collectors, thermal mass, and storage units. Low temperatures may be critical if the solar system would be damaged by freezing.

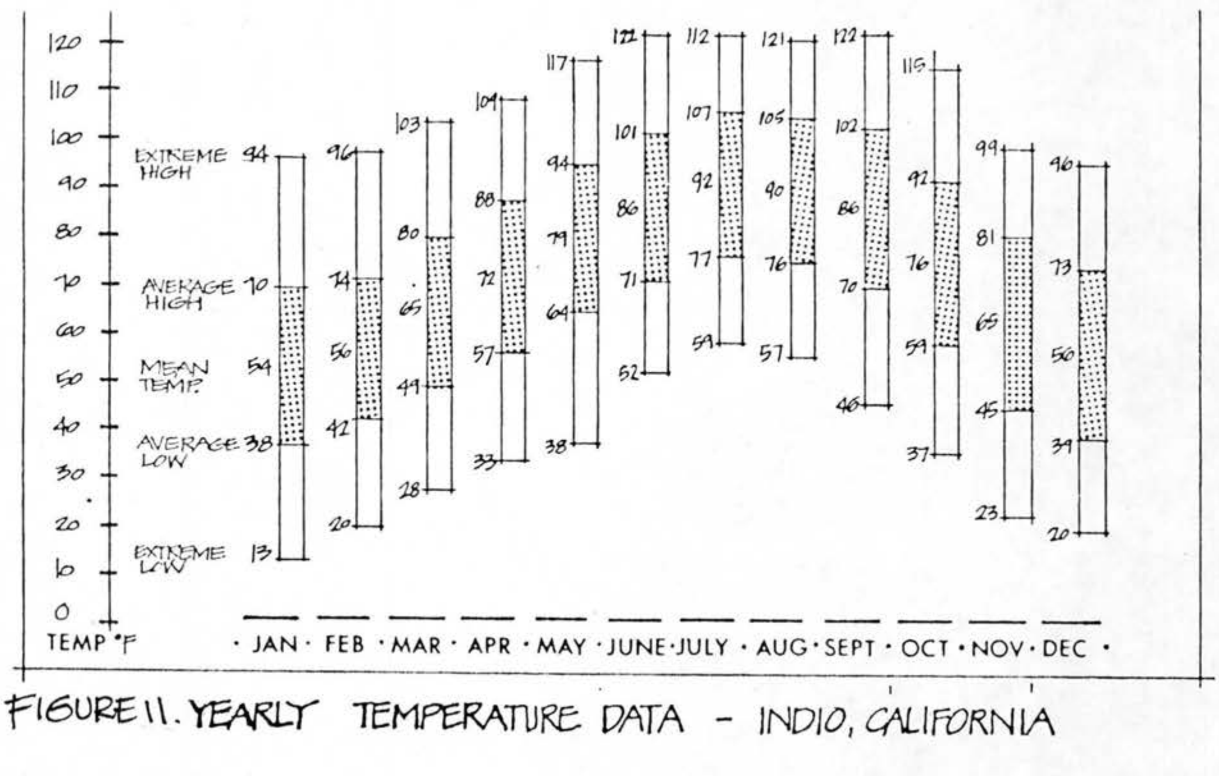


FIGURE 11. YEARLY TEMPERATURE DATA - INDIO, CALIFORNIA

c. Wind

The effects of wind, like radiation, can be either beneficial or adverse. During the heating season it is desirable to reduce the wind's impact while during the cooling season it may be desirable to maximize it. Through careful planning and design of buildings and cities we can often do both.

The most common use of wind is to provide ventilation and to carry heat away from exterior walls and surfaces. It will extend the performance of a passive or active cooling system, fig. 12.

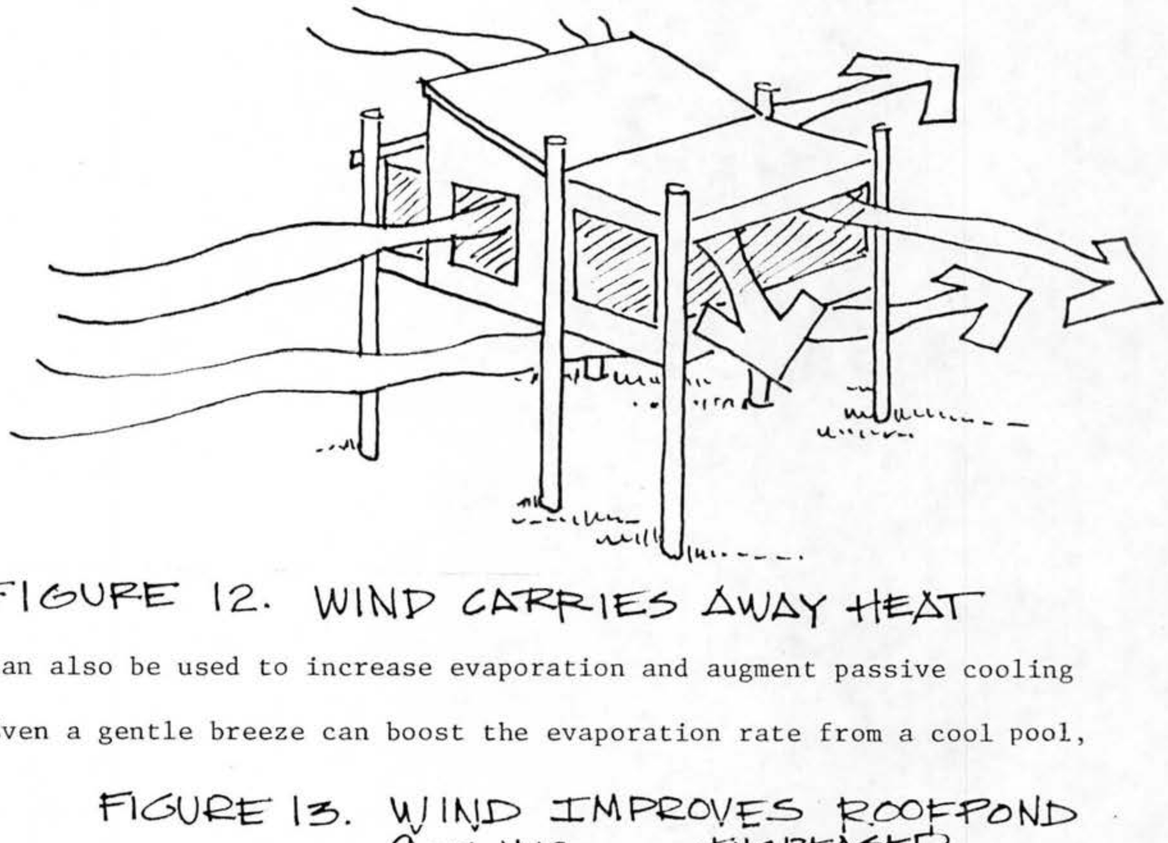
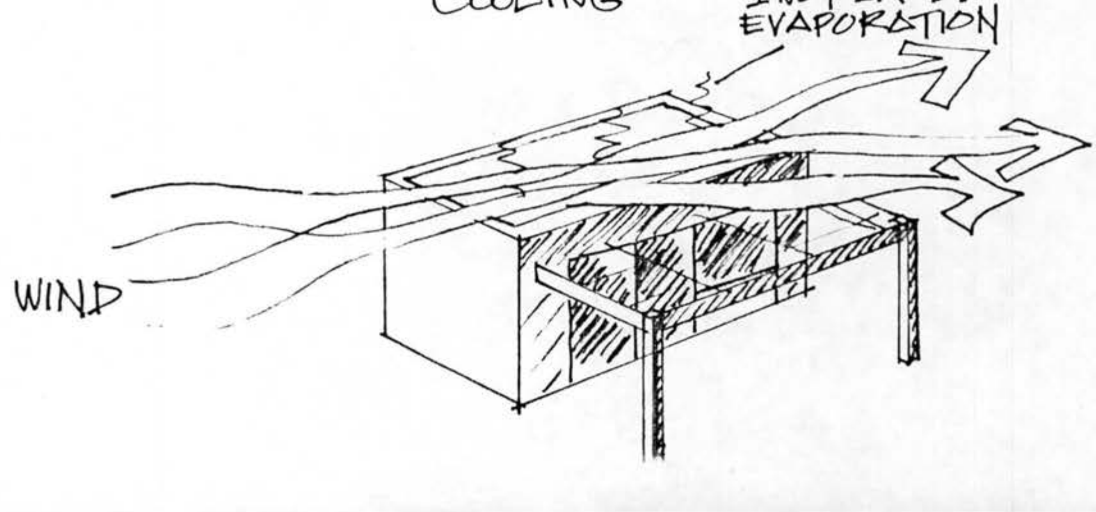


FIGURE 12. WIND CARRIES AWAY HEAT

Wind can also be used to increase evaporation and augment passive cooling systems. Even a gentle breeze can boost the evaporation rate from a cool pool, fig. 13.

FIGURE 13. WIND IMPROVES ROOFPOND COOLING



The use of cooling breezes is dependent on several other factors including: noise, smell, dust, insects and security. Vegetation is one of the best methods to reduce problems caused by odors, noise, and dust, fig. 14.

FIGURE 14. TREES PROVIDE A FILTER

Insects can be controlled without losing needed ventilation if screens are used carefully. Screens significantly reduce wind speed and when these losses are too large a screened porch may be needed to increase wind flow through windows. Security can be maintained by effectively using grills, vents, screen doors, fences, and building design, fig. 15.

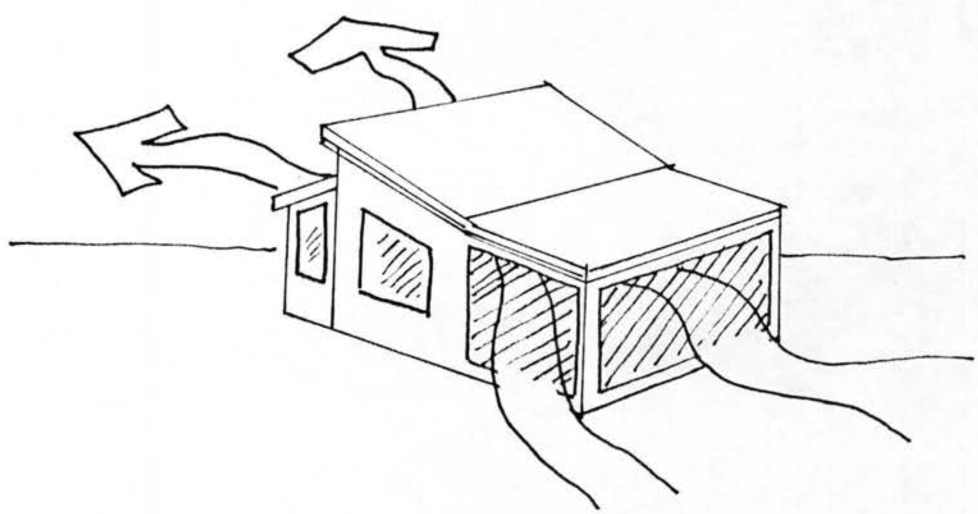


FIGURE 15. SCREENED PORCHES INCREASE VENTILATION

The occurrence of destructive winds effect the design of solar systems, structures, neighborhoods and cities. The potential for destructive winds should be evaluated carefully and steps to mitigate the hazards should be taken. The map below depicts areas in the U.S. where destructive winds are common. fig. 16.

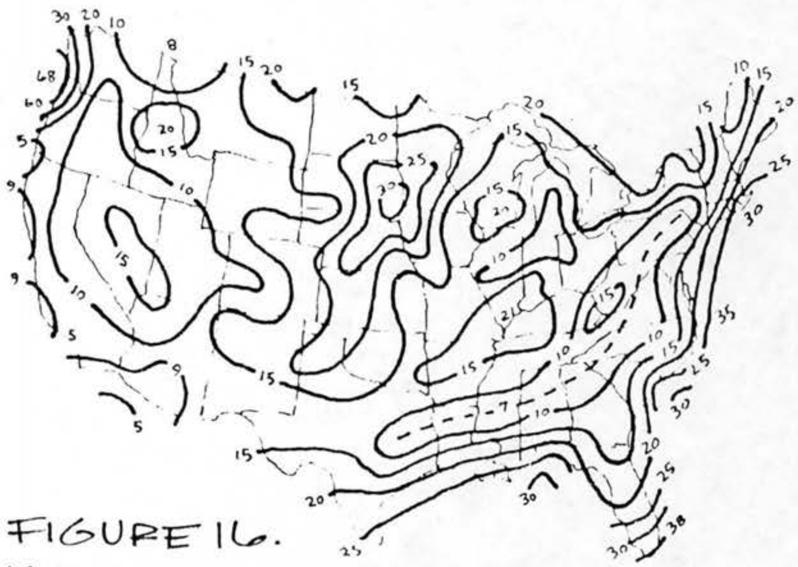


FIGURE 16.

WIND PRESSURE AGAINST EXPOSED WALLS (LB./SQ. FT.)
PREDICTED 25-YEAR FREQUENCY

d. Humidity

The highs, lows and means of moisture in the air effect both human comfort and system performance, and must be accounted for in design. The condensation of water vapor in the air in the form of clouds, rain, or dew releases the heat of condensation and reduces the cooling. Conversely evaporation of water on the surface or through vegetation will reduce the air temperature. For example, if the humidity is low evaporative cooling can be used to augment roof pond performance. Local water bodies and vegetation both contribute to humidity and cooling. They may be emphasized or minimized to optimize local conditions, fig. 17.

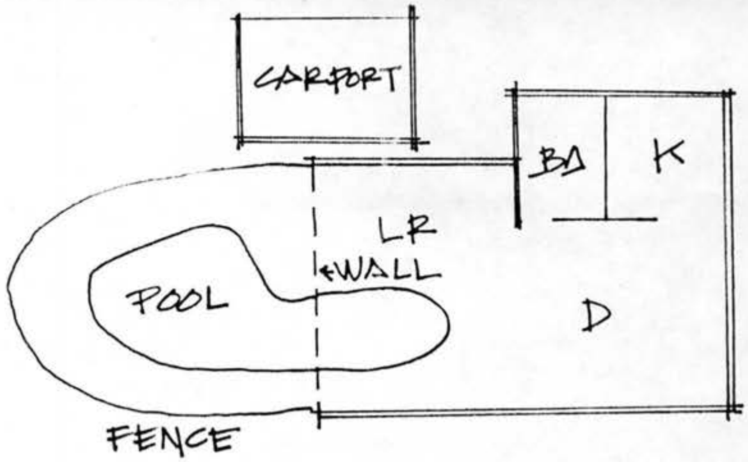


FIGURE 17. ALBERT FREY'S DESERT HOUSE WITH POOL INSIDE/OUTSIDE

e. Cloud Cover

Cloud cover increases long wave radiation exchange with the earth's surface and tends to reduce nighttime cooling. This can be helpful on winter nights when clouds can reduce heat loss significantly. In the summer it may be less welcome as it will reduce natural cooling.

Where radiation is desired clouds or fog produce an adverse impact upon the performance of a solar system. The frequency of cloudiness and time of occurrence of fogs may dictate several factors of the solar system design, fig 18.

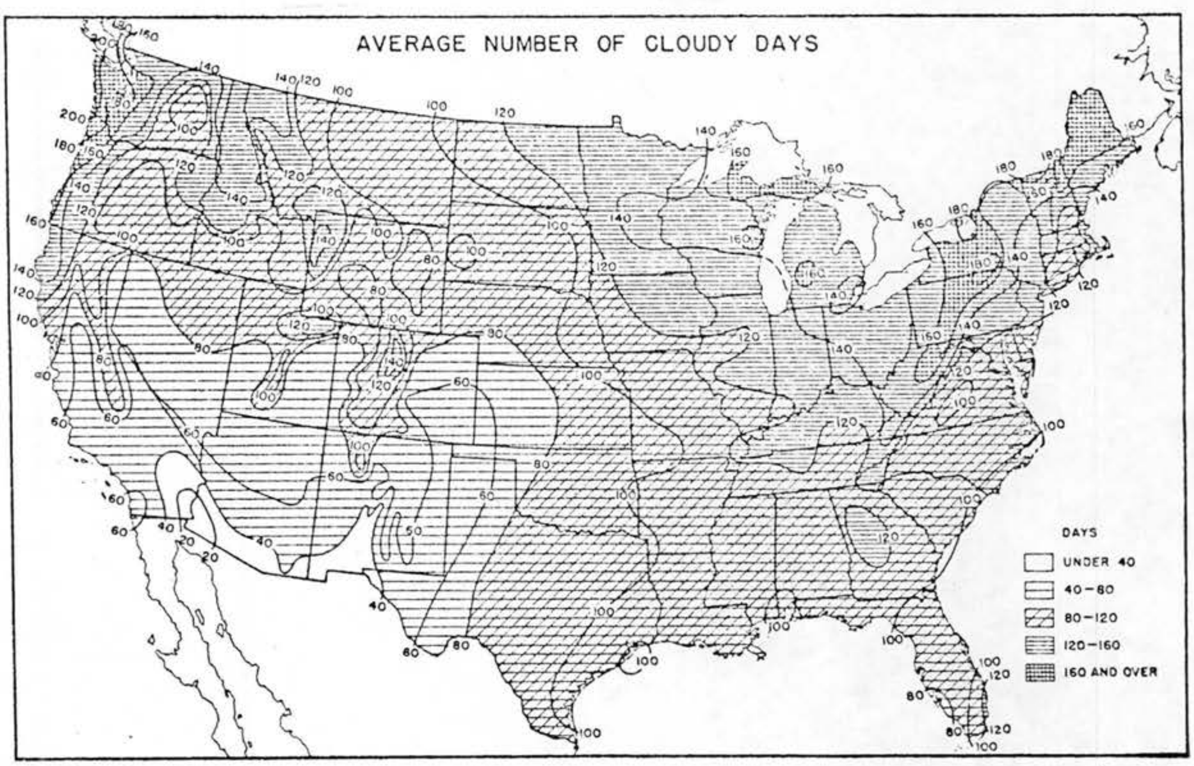


FIGURE 18a

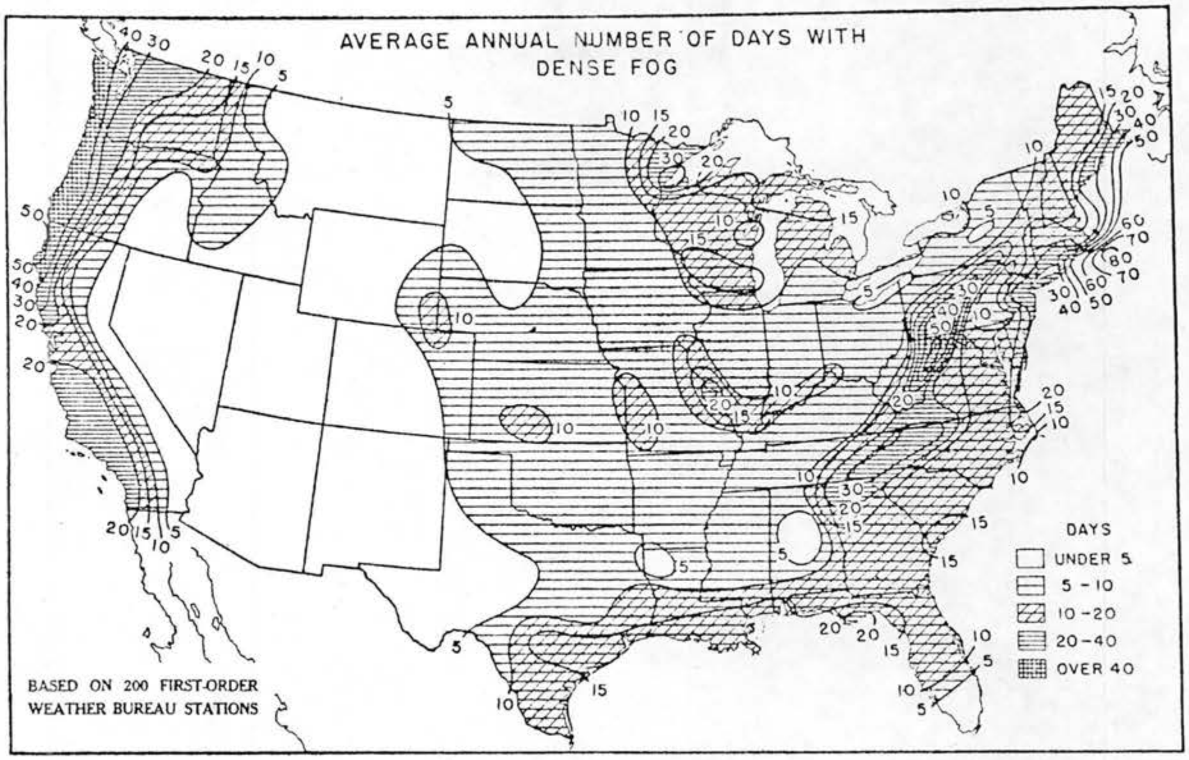
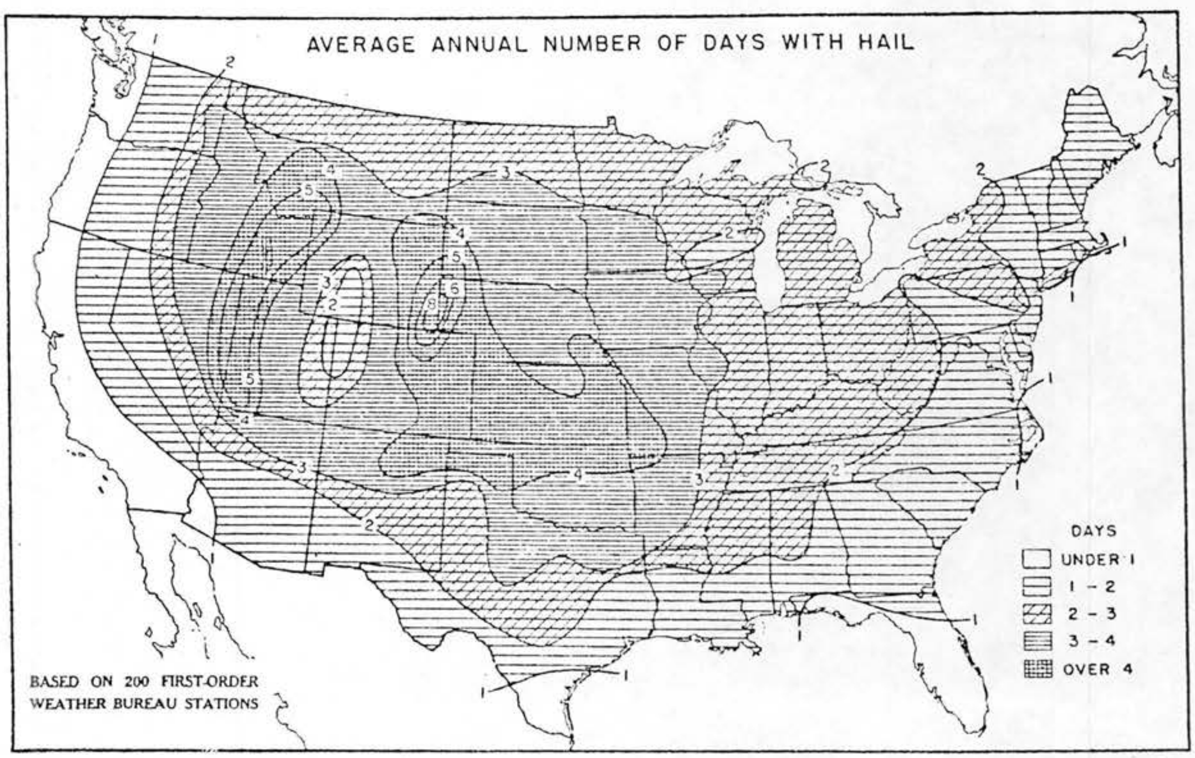


FIGURE 18b

f. Precipitation

Precipitation effects solar system design in several ways. The most important impact may be that from hail which may damage several types of glazing. The following map shows the pattern of hail occurrence in the U.S., fig.19.

FIGURE 19



Snow can be used for added insulation in colder areas. It can add considerable resistance to heat flow through the roof and lower walls of a house, fig. 20.

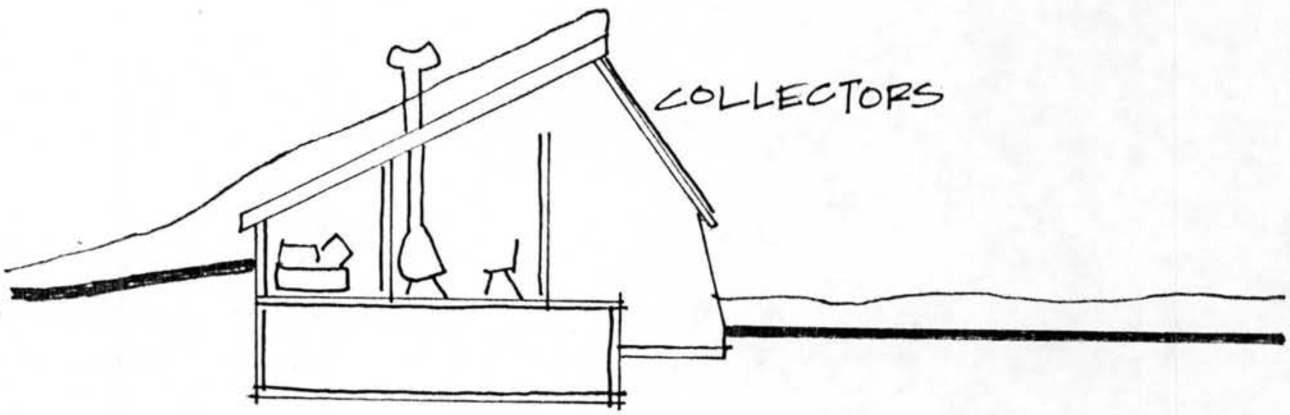


FIGURE 20. THE OUROBOROS HOUSE USES SNOW FOR INSULATION

Yet snow can also block solar collectors and design should allow for access for clearing them, fig. 21.

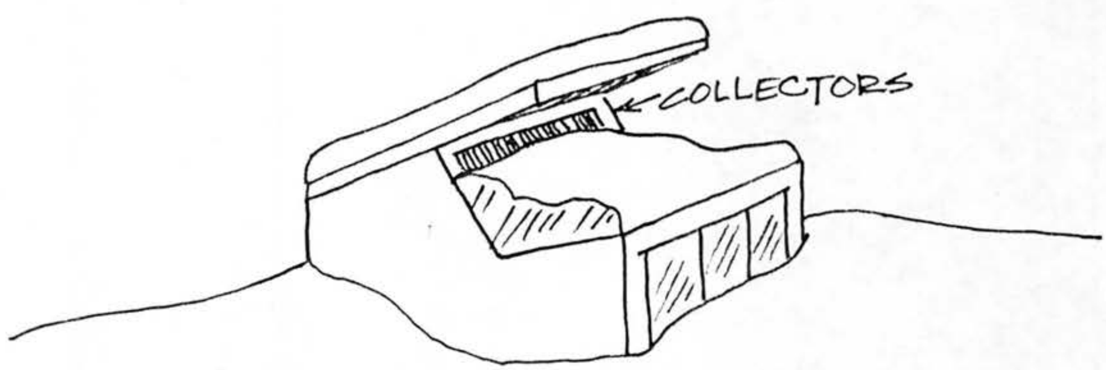


FIGURE 21. SNOW OBSTRUCTING COLLECTORS

The amount of snow is critical in structural design of collectors which must be able to withsand snow loads, fig. 22.

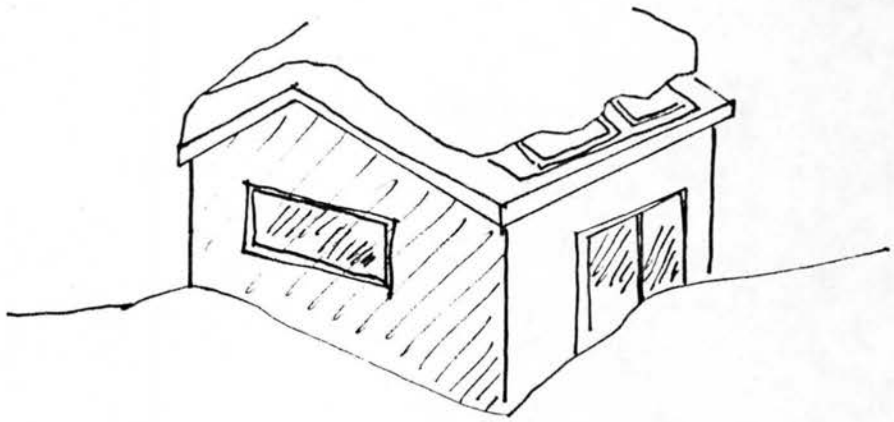


FIGURE 22. SNOW LOADS MUST BE CONSIDERED

Rainfall can be used for cleaning collectors. It also determines the detailing needed for flashing and run off control around collectors. In addition, the type and nature of precipitation effects to a certain extent the rate of deterioration of collectors and systems.

g. Air Quality —

Dust, air pollution, and smog in the air also play a role in solar system design. They increase absorption and reflection of sunlight in the atmosphere and also soil collector surfaces. Areas of high pollution levels may require frequent cleaning and maintenance. Dust can cut radiation received by a horizontal collector 5 - 10 %.

2. Topography

The topography of a site exerts a considerable influence on the daily and seasonal patterns of solar radiation. On a steep north facing slope little direct radiation is received at anytime during the year, while a south facing slope will consistently receive direct sun, fig. 23.

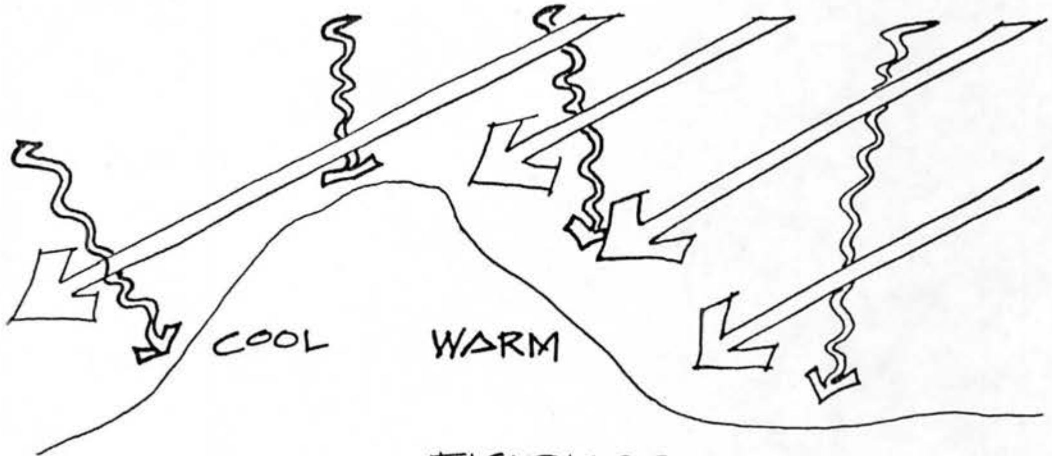


FIGURE 23.
TOPOGRAPHY DETERMINES RADIATION RECEIPT

Proper site orientation can also be used to influence air temperatures. Heating in the winter months can be maximized by ensuring a good southern exposure and minimized in the summer by reducing the eastern and western exposure. The topographic relief is another influence on air temperatures. Hill slopes and valleys channel the fluid flow of air movement so that the site selection process in relation to cold air drainage for example, can be used to minimize the amount of heating needed, fig. 24.

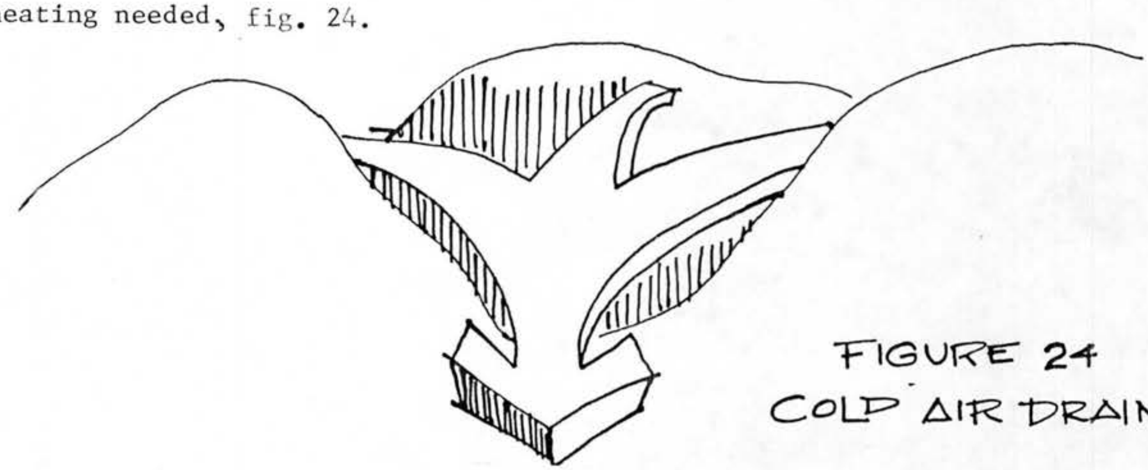


FIGURE 24
COLD AIR DRAINAGE

The shape of the landscape is a major factor in wind flow. Streets and houses can be designed to take advantage of known local wind patterns that will either enhance or detract from heating or cooling requirements, fig. 25.

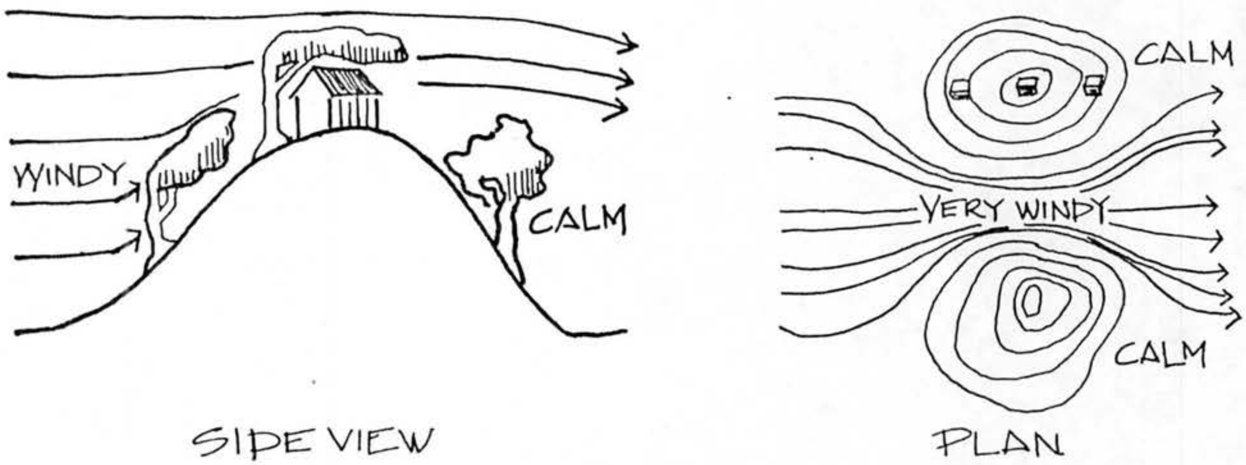


FIGURE 25. HILLS EFFECT WINDFLOW

As air masses rise as a result of topography their temperature cools by expansion due to lower pressure. When an air mass descends it becomes warmer. The warm Foehn andChinook winds are a result of this adiabatic warming, fig 26.

FIGURE 26. AIR MASSES CHANGE TEMPERATURE WITH ALTITUDE

Topographic features such as hillsides, buildings and trees can also reduce the skyview for radiative cooling systems, fig. 27. A detailed discussion of this effect will be included in Task #4.

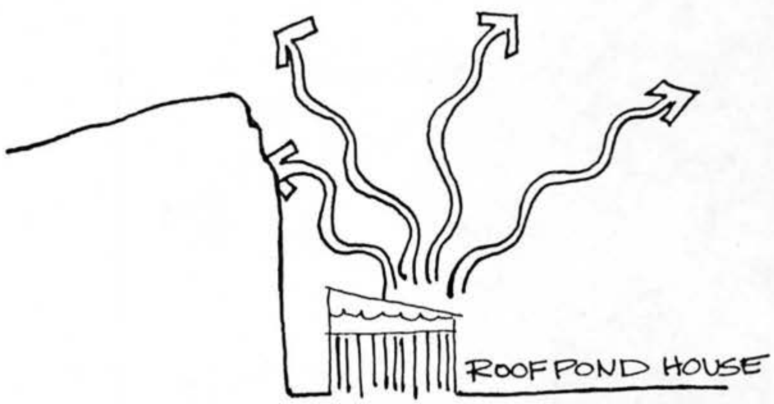


FIGURE 27. CLIFFS CAN REDUCE NIGHT SKY VIEW

3) Latitude

Latitude has a direct effect on solar radiation. In higher latitudes, the sun's path is lower in the sky during the winter and it shines for a much shorter period, fig. 28.

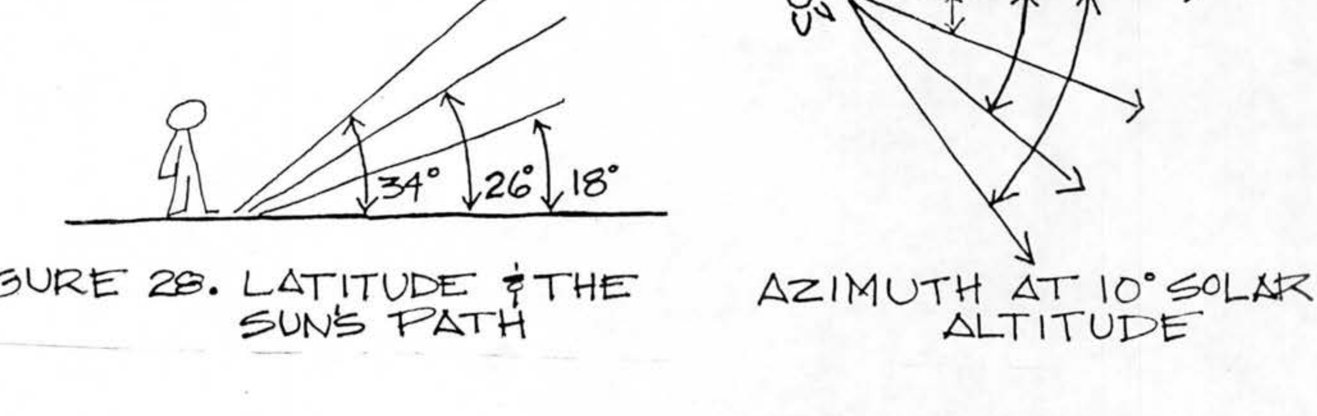


FIGURE 28. LATITUDE & THE SUN'S PATH

4. Surface

Air temperature is strongly effected by the type of surface that the sunlight strikes. Dark surfaces increase local air temperatures as much as 60°-70°F higher than a lighter color. If the surface is damp, the temperature will be much cooler than a dry surface of the same color. A body of water such as a lake, pool, or stream, serves to reduce local air temperatures and can be a useful in moderating high temperatures, fig 29.

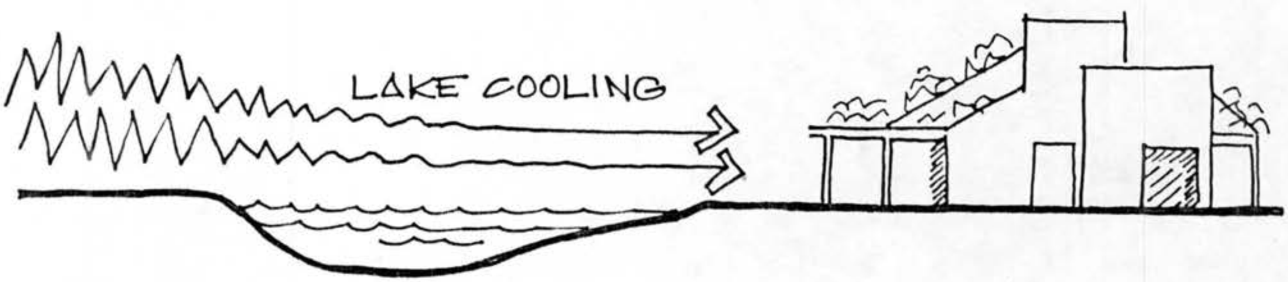


FIGURE 29. COOLING FROM NEARBY WATER

Vegetative cover will assist in reducing air temperatures mainly by shading the ground surface, and increasing cooling by evaporation. Vegetation types vary considerably in their ability to augment heating or cooling, fig. 30.

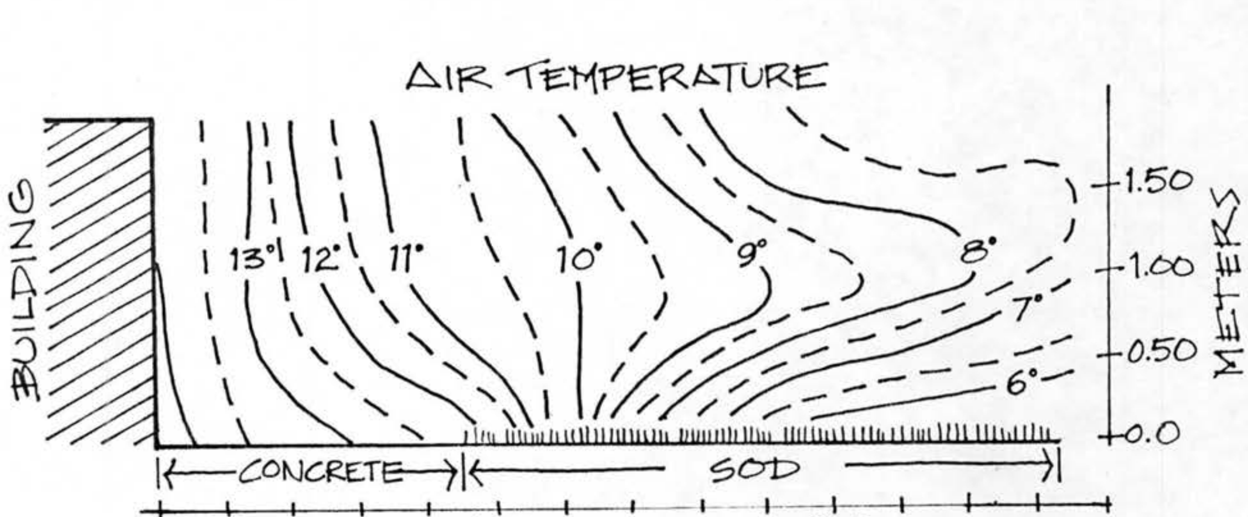


FIGURE 30. VEGETATION & TEMPERATURE

Soil temperatures are important in solar system design for both heat loss and heat storage calculations. A concrete slab can be a fairly large source of heat loss when uninsulated. When insulated, the slab functions as an integral heat storage mass. The energy stored in the earth can also be used for heating if effective heat transfer can be set up. The heat pipe, which use a vapor cycle to move energy very effectively works very well for soil heat systems. They have been used in Sweden to help heat houses and in the U.S. to melt ice on highways, fig. 31.

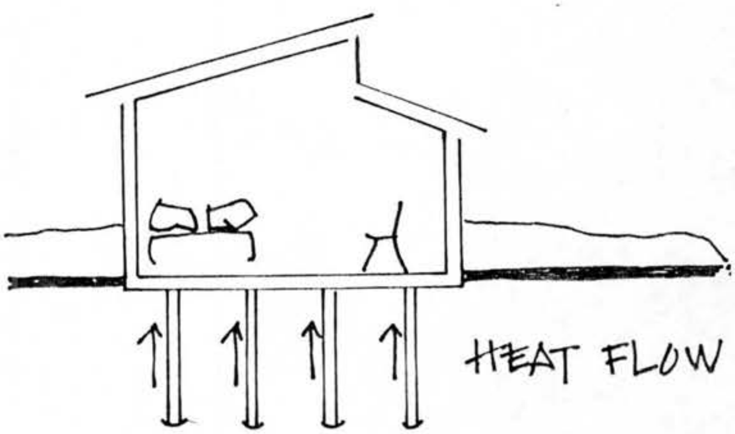


FIGURE 31. HEAT PIPES MAKE THE EARTH'S HEAT USUABLE

5. Vegetation

Vegetation has various effects on solar system design. The use of deciduous vegetation for shading, protecting from summer sun is probably most common. The time of leafout in the spring and leaf drop in the fall may be important solar system design factors, fig. 32.

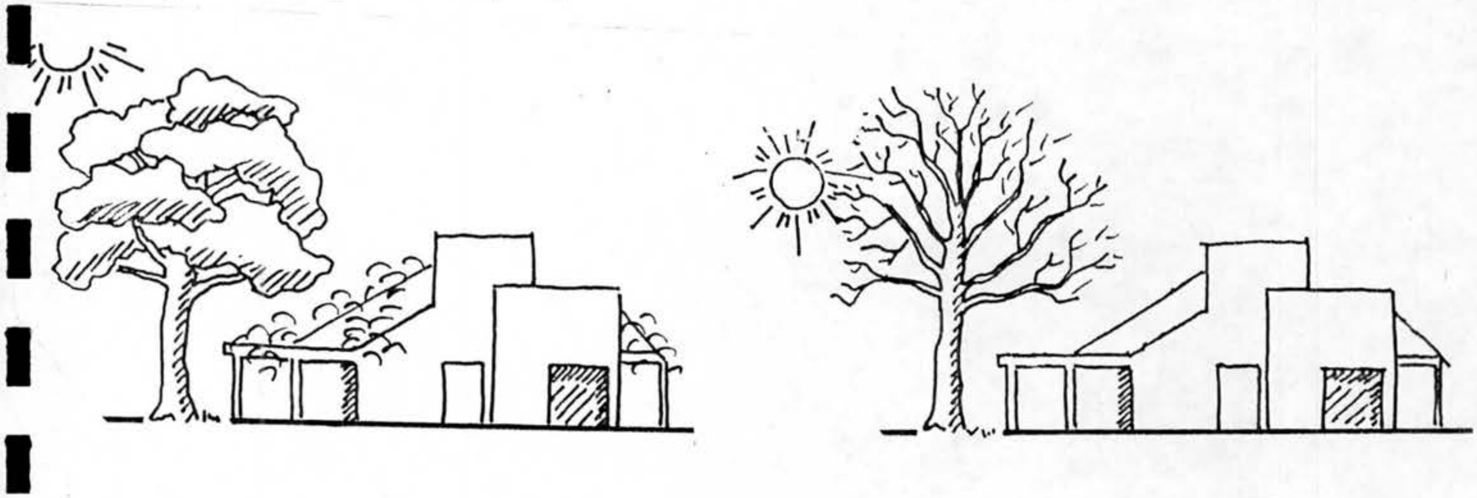


FIGURE 32. TREES FOR ALL SEASONS

Vegetation near structures can reduce net infrared radiation losses much as it blocks direct solar radiation gains. This can reduce the effectiveness of radiative and evaporative cooling by increasing the infrared radiation exchange between the system and the vegetation, fig. 33.

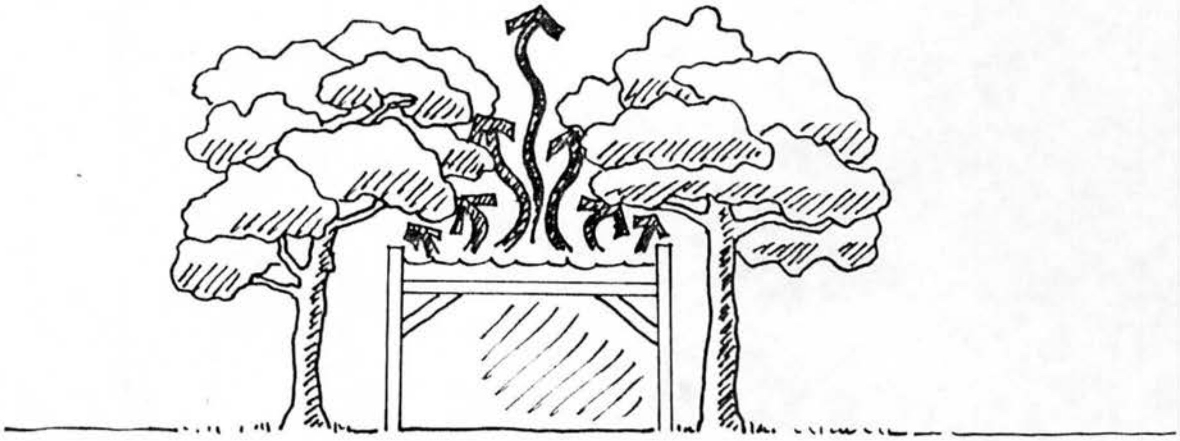
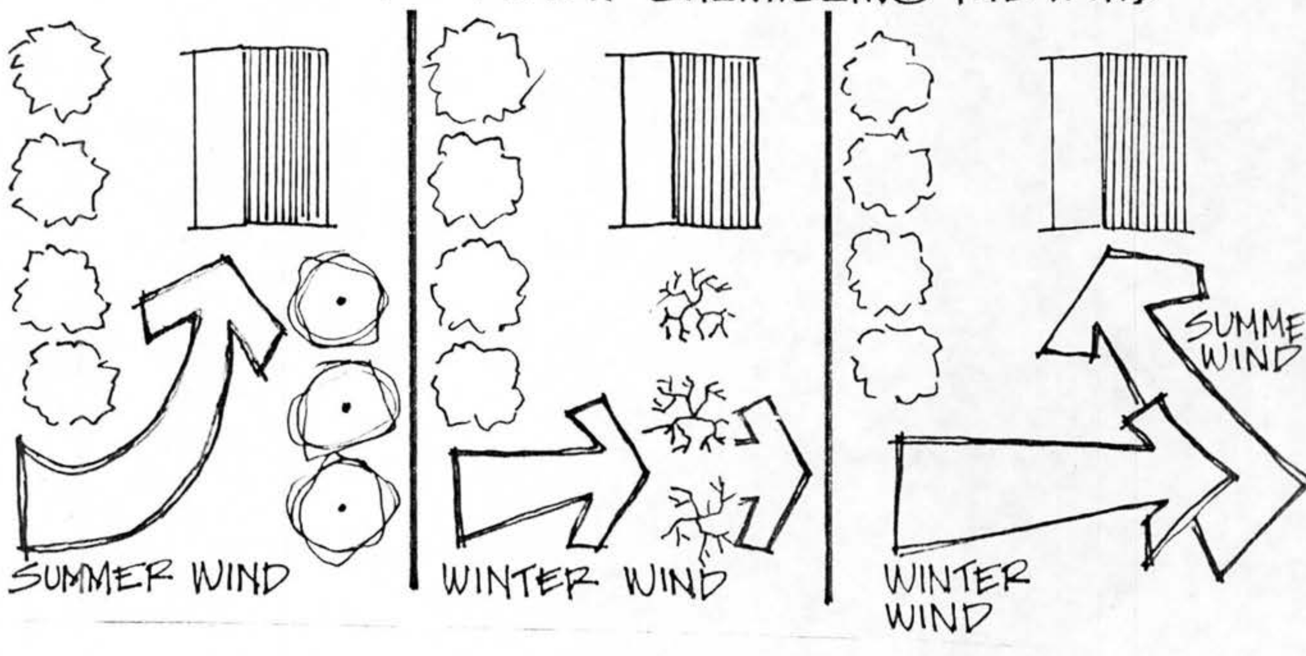


FIGURE 33. TREES CAN REDUCE NIGHT SKY RADIATION

Vegetation is also used to channel winds through structures and increase cooling. Windows and openings can be effectively situated to take advantage of these cooling breezes, particularly in the hot humid areas of the East and Southeast, fig. 34.

FIGURE 34. CHANNELING THE WIND



The loss of heat and comfort through conduction and infiltration caused by cold winter winds can be reduced by careful design. Reductions in energy use for heating of up to 30% have been reported from the use of wind breaks. fig.35.

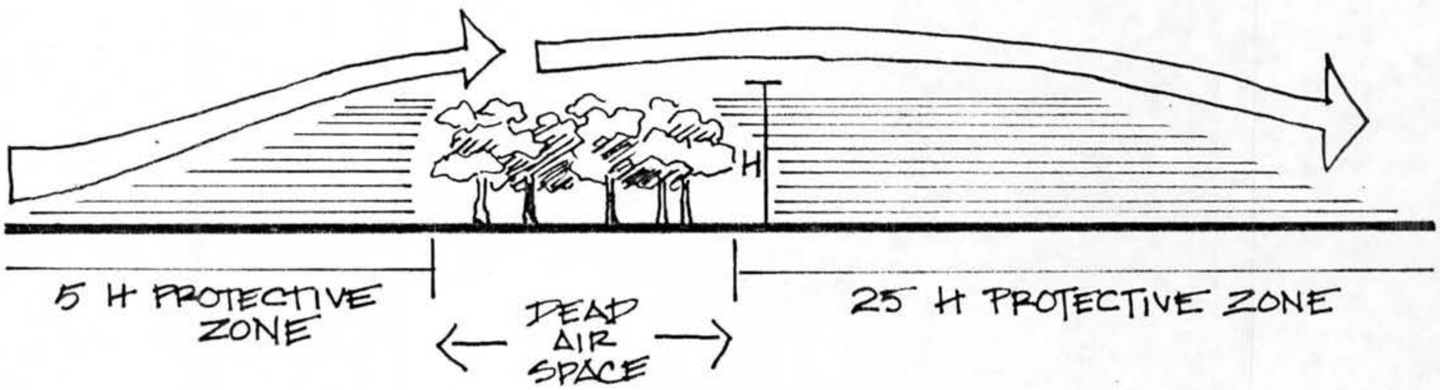


FIGURE 35. WIND BREAK

The placement of houses will change where heating is a predominant factor. Exposed sites and areas of down slope cold winds should be avoided. When exposed sites can not be avoided, vegetation can be used to modify the effects of the climate, fig. 36.

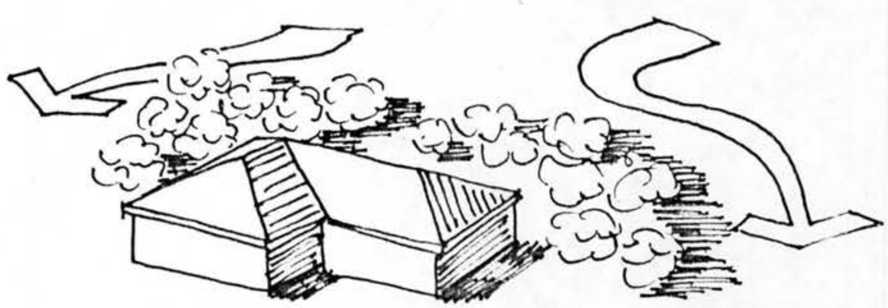


FIGURE 36. VEGETATION PROPERLY PLACED CAN DEFLECT RATHER THAN DAM COLD AIR FLOW

6. Human Impact —

Human impact on the local and even global climate has been extensively documented. Several smaller scale impacts may require consideration in solar system design. Although the impacts of cities on climate have been acknowledged for many years, systematic studies of these effects have only recently been completed. Four main factors contribute to the change in urban climate: change in air flow; added heat input; change in surface materials; change in atmospheric make up. The predominant effects include: warmer temperatures (1-3°F); lower humidity (2%-8%); increased dust (10x+); increased cloudiness (5%-10%); increased winter fog (100%); decreased radiation (15%-25%); decreased wind speed (20%-30%); increased precipitation (5%-10%), fig. 37.

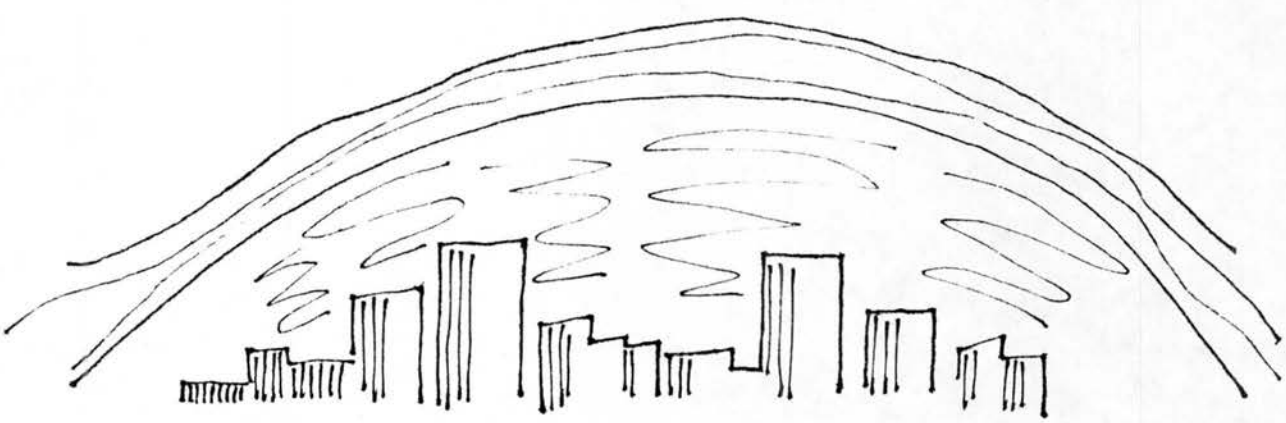
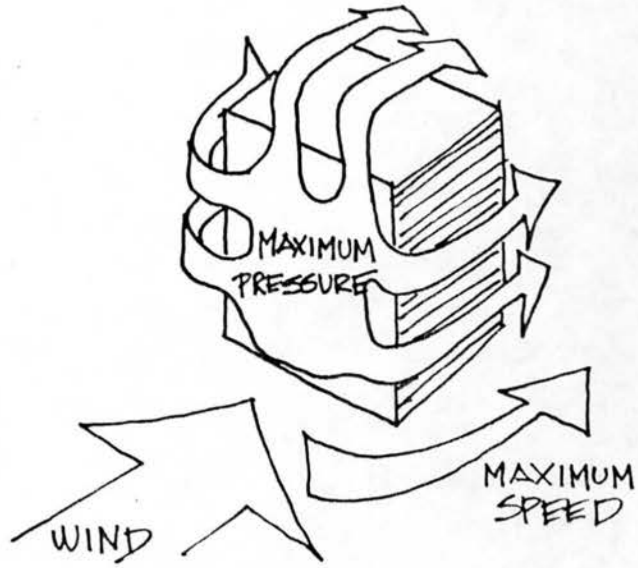


FIGURE 37. URBAN HEAT ISLAND

Man's construction activities may have a significant impact on local micro-climate. Buildings particularly effect the wind flow and radiation balance. Streets and buildings can reduce energy use and increase human comfort if they are well designed, fig. 38.



BUILDINGS EFFECT ON WIND

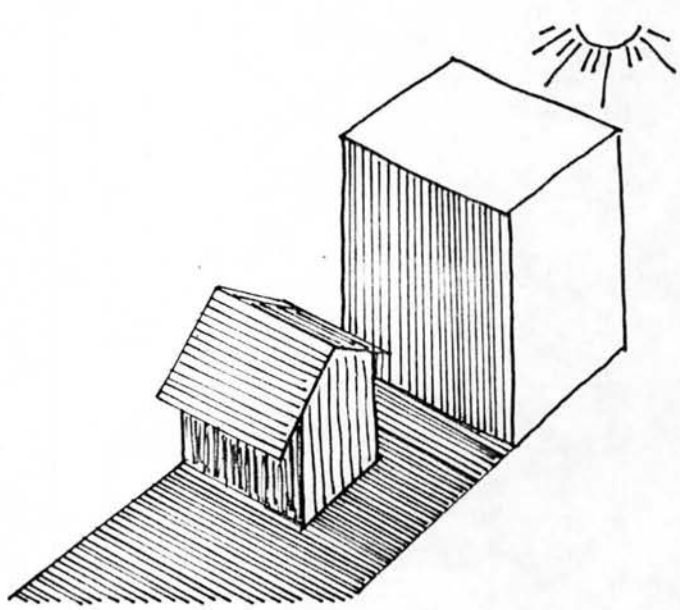


FIGURE 38. SHADING IS OFTEN TOTAL