Building to Suit the Climate
A Handbook

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Foreword

Worldwide economic growth and the associated boost to prosperity have led to considerably increased building activity, especially in Asia and the Arab countries, and also in Russia and South America. Because there is such a strong desire to improve the standard of living rapidly, architecture and urban development change within a few years, while building culture in “old Europe” developed over decades or even centuries.

The International Style, which was enormously popular in Europe and America, produced an architecture that was detached from climatic aspects, architecture that was concerned primarily with formal language, in a period that saw dealing with climatic demands through technology and energy as a demonstration of technical skill. Unfortunately this often led to unbalanced solutions that consumed enormous quantities of electricity and fossil fuels to meet ever-increasing demands for comfort. The aim today must be for architecture that responds to climatic conditions in a similar way to traditional building methods. It really does make better sense to meet climatic challenges through the approach to building, rather than dealing with them exclusively through technology.

In China, India or the Arab world, the main problem is comfort in summer, especially because of the intense sunlight. Another challenge is the high humidity in tropical and subtropical terrain. Here the air has to be dehumidified, which usually requires a great deal of energy and technology.

Using passive energy sources such as soil sensors for cooling, or regenerative active systems such as solar cooling, involves examining the ambient climatic conditions very precisely. When looking for appropriate solutions, it makes only limited sense to transfer concepts from Europe and North America to countries in other climate zones.

In order to be able to develop holistic concepts that work in other countries and climate zones, equal attention must be paid to both climatic and cultural matters such as religion and tradition, or requests relating to comfort. Other aspects are economic factors and also technical matters such as the availability of technology, for example, energy prices or the expertise available for maintenance and operation.

Climatic conditions that are often extreme have to be addressed intensively when seeking holistic approaches. Attempts should therefore be made even in the early stages of planning a building to include climatic aspects such as irradiation, air temperatures, humidity conditions and the wind situation in the concept for the building. If cultural aspects are to be addressed appropriately, it is essential to study traditional building methods and also to come to terms with current local trends.

Aims of this book

In international projects, the rapid development of building activity means that the time available for planning is increasingly short. There is often a lack of planning experience when it comes to considering climatic influences.

This book aims to support architects and engineers when planning buildings in an international context, especially in the conceptual phase. To that end it offers a comprehensive analysis of the interplay between the climate and the building structure and the exterior of the building, as well as with technology inside the building and the energy concept. It is also intended to provide a companion for students while studying, and to open up areas of work for them all over the world.

The book's principal focus is on detailed climatic analysis as a basis for architecture with a future. This demonstrates the challenges and potential for a particular location, and shows the relevance to planning of individual climatic elements such as solar radiation, temperature, humidity and wind. An architectural climate classification defines climate zones on the basis of air temperature and absolute humidity. These key factors enable a first general view of climatic aspects of building planning.

The climate as it relates to building is examined, taking the cities of Moscow, Munich, Shanghai, Bangalore and Dubai as examples – as typical representatives of their climate zones – and readers are given tips on planning strategies.

The structure of the book

Chapter 1 defines climate as the key value in climate-oriented architecture. This is followed by climatic classification through building-climatic criteria; these make it possible to draw consequences for spatial conditioning by combining the building-specific climate parameters air temperature and absolute humidity, providing a first general view for building planners. Climatic differences arising from latitude, closeness to the sea or height are also shown.

The interplay of climatic elements such as temperature, solar radiation, absolute humidity and wind speed is examined and presented in detail. In addition, comfort criteria in the interior climate in terms of temperature and humidity are explained, with particular emphasis on recommendations in the international standard ASHRAE-55.

In subsequent chapters, the cities of Moscow, Munich, Shanghai, Bangalore and Dubai are taken as examples of the five climate zones “cool”, “temperate”, “subtropical”, “tropical” and “desert”, and function as a basis for climate analysis. To make the material more accessible, the diversity of the ecozones (according to Schultz 2002) is described. This is followed by planning tips on the placing and cubature of buildings, and also facade construction. These chapters also offer suggestions for room conditioning concepts that can be implemented in the different climate zones. In conclusion, the energy-saving potential of each location is indicated. The climate graphs in these chapters are location-specific, and so relate only to the city given as an example, while planning strategies apply to the particular climate zone in general. Particular climatic features can be taken from the architectural climate classifications in the “Climate” chapter and the city tables in the appendix and related to the cities presented.

All the graphs in the book relating specifically to climate and location were created with the interactive *ClimateTool* from the global climate data base Meteonorm. This tool makes it possible to analyse climate factors such as solar radiation, temperature, humidity, wind and light from the point of view of building, and apply them in a way that is useful to planners for any location in the world. It also provides the basis for the building climatology-related climate classification presented in the book, and for the city tables in the appendix.

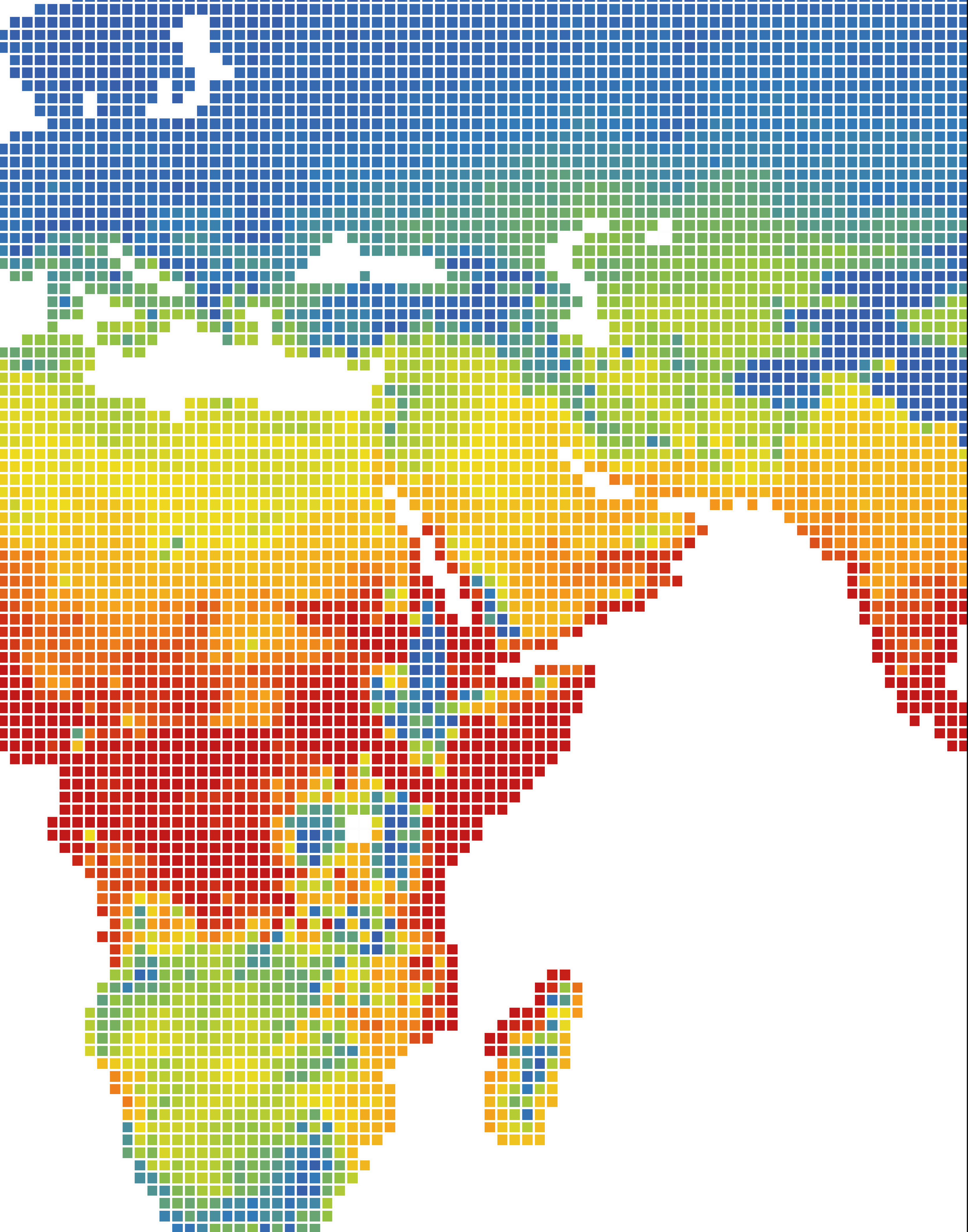
Chapter 7, “Economics”, examines energy-relevant costs during the construction process, and lists typical costs for heat and sun protection measures, as well as room conditioning and energy generation components. In addition, special features arising from interaction with the climate are presented in terms of economics.

The glossary explains essential terms on the themes of “outdoor climate”, “building energy systems”, “building skin”, “light”, “indoor climate”, “room conditioning” and “energy generation”. A diagram puts the terms in context for each of these subject headings, thus providing a survey of the interplay between the individual aspects. Terms from the glossary can be found in the margin in each chapter, and the relevant term in the main text is identified by a preceding arrow.

We wish all our readers an exciting trip round the world!

Munich, June 2011

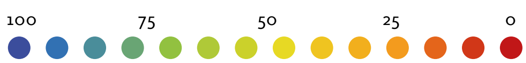
Gerhard Hausladen, Petra Liedl, Mike de Saldanha



Climate

Climate and building for the future

The 21st century is characterised by climatic and demographic alterations. The predicted climatic changes will have major implications for building planning in the future. The population explosion in comparatively young states will demand extensive construction projects, which the standard European concepts will be insufficient to meet. The architecture of the future will need to be based on detailed climatic analysis, taking into account the impact of solar radiation, temperature, humidity and wind on buildings. Only close attention to the climate and the local architectural tradition can produce fully adequate buildings and optimal energy concepts.



Nights per year with an average temperature lower than 20 °C [%]

Introduction

The word climate is derived from the ancient Greek verb *klínein* ("to incline"). It describes the tilt of the Earth's axis. Climate, as opposed to weather, refers to the state of the Earth's atmosphere as established by statistics, over a period of time, which may be as long as several decades. These statistics describe the climate elements relevant to a location, a region or the whole Earth. There are three different types of climate: macroclimate, mesoclimate and microclimate – distinguished mainly by the size of the area involved.

Climate elements and climate factors

The climate of the Earth is determined by the sun's radiation, without which life on Earth would not be possible. We describe the climate in terms of climatic elements. The most significant of these are ↙ air temperature, precipitation, ↙ air humidity, population, wind and ↙ solar radiation. Climate factors are processes and situations that produce, maintain or alter a climate. They include a location's latitude, the distribution of land and sea, the local and trans-regional wind systems, and altitude.

↙
outdoor air temperature p. 142

absolute air humidity p. 142

global radiation p. 142

Atmospheric circulation

The Earth's atmospheric circulation is determined by the radiation level, the rotation of the Earth, and the distribution of water and land masses. As the radiation balance varies between latitudes, there is a permanent temperature gradient between the equator and the poles. This creates differences in air pressure. The greater this difference in air pressure, the more air flows from the high pressure area to the low pressure area. This creates strong winds (Fig. 1.1). Coriolis force causes the air streams to flow to the right in the northern hemisphere, and to the left in the southern hemisphere. The circulation systems are more pronounced in the southern hemisphere due to the distribution of land and sea.

Macroclimate

A macroclimate exists over very large geographical areas and long periods of time. It is identified and assessed using solar radiation distribution, the terrain height, the distribution of land and sea, and global circulation. Areas with similar climates are grouped together as climate zones. Macroclimates interact closely, influencing each other in a variety of ways. The global climate is created by the dynamic interaction between macroclimates.

Mesoclimate

The spaces and units of time involved are significantly smaller for a mesoclimate than they are for a macroclimate. Regional climates – one form of mesoclimate – are characterised primarily by their natural and cultural features: mountains, valleys, coasts, islands, wooded areas, cities and villages. Climates determined by landscape or location features are described as landscape climates or location climates. The urban climate is very important from an architectural point of view.

Microclimate

A microclimate may exist for only a very short space of time, and is a climate in the smallest unit of space and in the lowest atmospheric layer. It is influenced by terrain, distance from the ground surface and the ground surface's composition and flora. In a city, it is primarily determined by construction materials, development density, vegetation, horizon obstruction, and air streams. The microclimate can be recorded and described by only taking measurements because it is constantly changing.

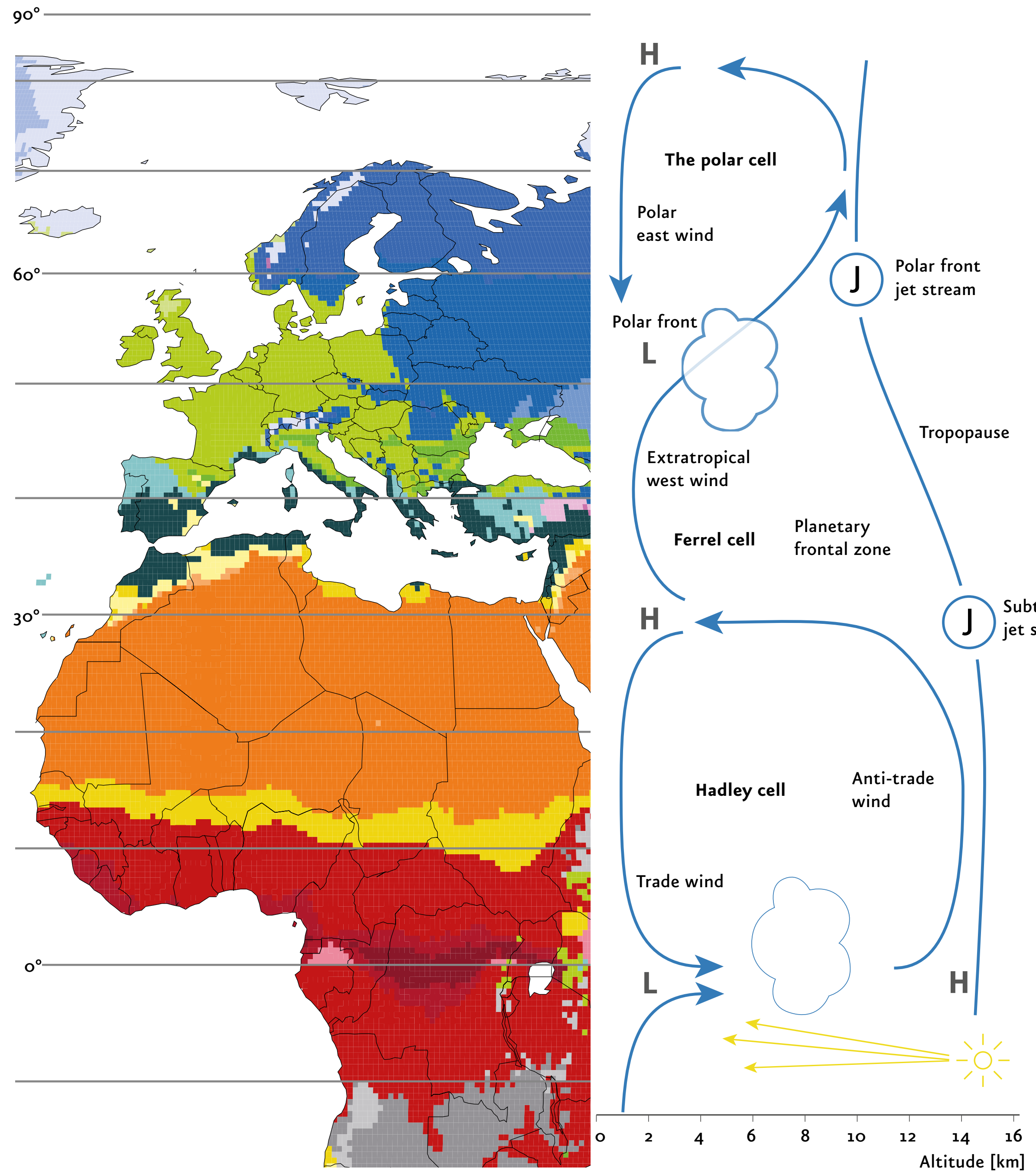


Fig. 1.1 The creation of climate zones

The sun is the motor that drives the climate. The different amounts of energy received by different places on Earth and the resulting wind systems create a variety of climate zones. Moist air rises from the equator, warmed by the high incidence of solar radiation. This creates an area of low pressure near the ground – the equatorial trough – combined with an area of high pressure at a very high altitude. As the air rises, the water vapour it contains condenses, creating clouds. If the water vapour saturation point is exceeded, it rains. This leaves masses of dry air, which flow towards the poles, sinking back to earth again when they reach the tropical regions. This results in an area of high pressure with little air movement – the horse latitudes. As the dry air masses descend, they warm up and absorb moisture – creating large, dry desert areas. At ground level, the air flows in the direction of the equator, creating the “trade winds” and closing the circle. This air circulation pattern is known as the Hadley cell (according to Schönwiese 2003). The colours denote the effective climate classification according to Köppen and Geiger, and show climate zones structured according to latitude.

Climate Elements

The climate is described in terms of climate elements. The climate elements that have an impact on architecture are solar radiation, air temperature, air humidity and precipitation, and wind.

Solar radiation

↙
heating energy demand p. 144
room climate p. 150
daylight provision p. 148
glazing percentage p. 146
global radiation p. 142
sun protection p. 146
solar cooling p. 154
photovoltaics p. 154
orientation p. 144

As a source of light and energy, solar radiation is an important planning factor – it reduces the ↙ heating energy demand, and is the major influence on the ↙ room climate in summer. A good plan should include sufficient ↙ daylight provision and good views, as well as controlling the effect of solar heating. The indoor daylight provosion is determined by the outdoor light levels together with the ↙ glazing percentage and the form of glazing used.

The ↙ global radiation level is composed of the direct solar radiation level plus the diffuse sky radiation level. Latitude is the major factor in changes in day length, the angle of radiation incidence (Fig. 1.2) and the type and intensity of solar radiation received throughout the year (Fig. 1.3). This influences the degree of shade from nearby structures and the amount of sun striking the facades, meaning that the latitude largely governs the daylight situation and the ↙ sun protection concept. The efficiency of solar heat gain, ↙ solar cooling and ↙ photovoltaic systems also depends on this. The azimuth and the angle of elevation of the sun in relation to the facade – and, therefore, the intensity of solar radiation received by the building – result from the building's ↙ orientation.

Temperature

↙
night ventilation p. 152
concrete core activation p. 152
cooling tower p. 154
storage mass p. 144
earth piles/ groundwater utilisation p. 154
earth pipes p. 154

The outdoor air temperature depends on solar radiation and the temperature of incoming air masses. The average temperature over the year influences a building's configuration, its heat protection and the ventilation and cooling systems required.

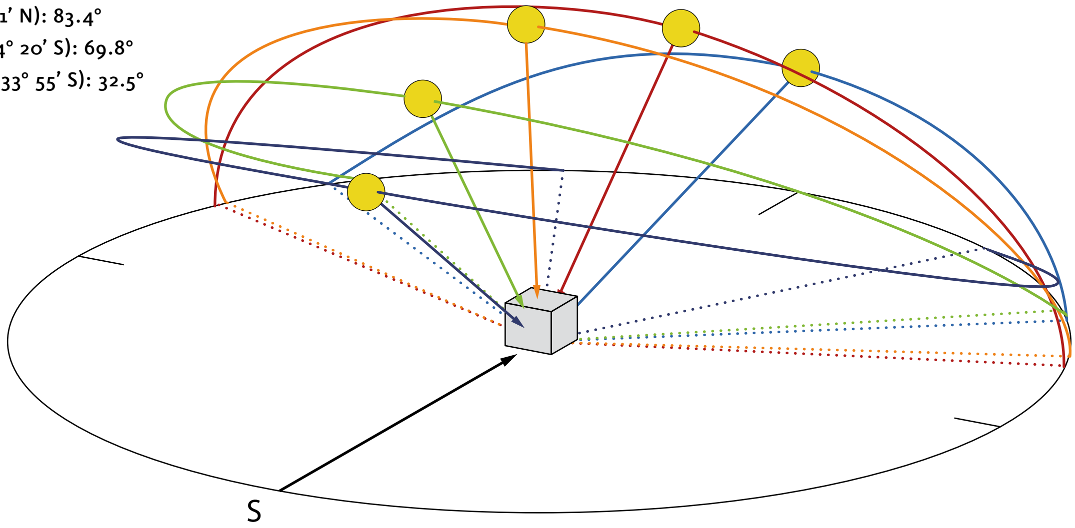
Changes in temperature throughout the day determine the practicality of passive cooling strategies such as ↙ night ventilation and ↙ concrete core activation with free ↙ recooling. Efficient night cooling requires low night temperatures and free ↙ storage mass. The frequency of days with extreme weather should also be taken into account, as it has implications for the effectiveness of passive cooling systems and for the configuration of the technology used.

A building's ability to make use of renewable heating or cooling may depend on the composition of the building ground and the soil layers beneath it. The major factor in the thermal utility of the soil is its moisture content: flowing groundwater is ideal.

The average annual temperature goes down into the soil to a depth of about 10–15 m. The soil temperature can be accessed as a source of heat or cold via tube registers, probes, ↙ piles or ↙ earth pipes.

Maximum sun elevation angle on 21 June, 12:00

- Oslo (59° 55′ N): 53.5°
- Rome (41° 53′ N): 71.2°
- Bilma (18° 41′ N): 83.4°
- Kinshasa (04° 20′ S): 69.8°
- Cape Town (33° 55′ S): 32.5°



Maximum sun elevation angle on 21 December, 12:00

- Oslo (59° 55′ N): 6.6°
- Rome (41° 53′ N): 24.5°
- Bilma (18° 41′ N): 47.7°
- Kinshasa (04° 20′ S): 61.4°
- Cape Town (33° 55′ S): 79.1°

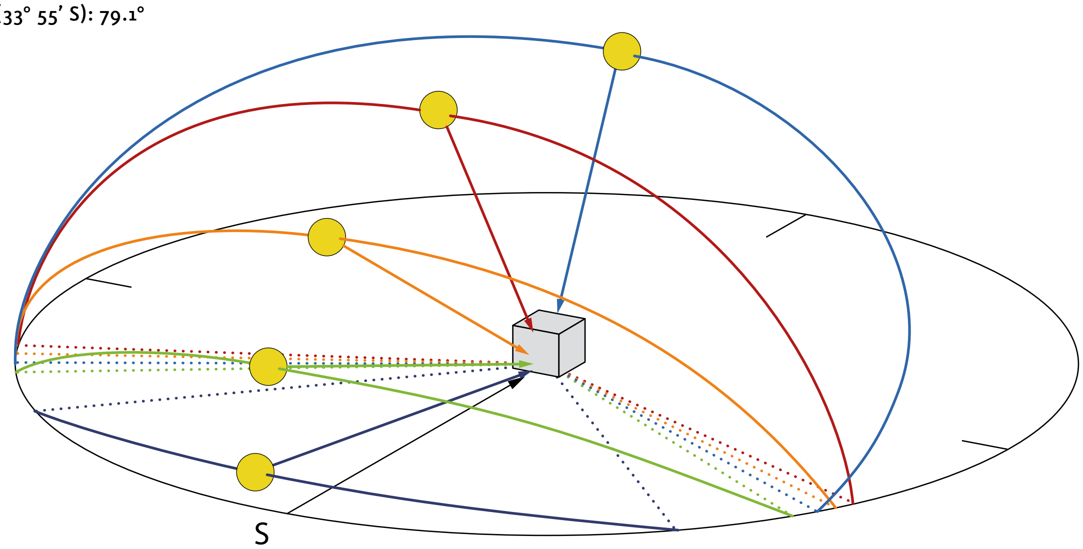


Fig. 1.2 Course of the sun
The course of the sun on 21 June (top) and on 21 December (bottom) with the sun's angle of elevation and azimuth angle for locations at different latitudes but similar longitudes.

Air humidity

There are two different measurements of air humidity: relative and absolute air humidity. Absolute air humidity, which is location-specific and is determined primarily by proximity to the ocean and by precipitation levels (Fig. 1.5), is an important factor in the room climate and in the outflow of moisture from indoor spaces. While the air's absolute water vapour content changes very little over the course of the day, relative air humidity is affected by the temperature. Minimum values of absolute humidity are reached on especially cold days, while maximum values occur at high temperatures.

↙ **(de)humidifying** p. 150

dew point temperature p. 142

decentralised ventilation system p. 152

Whether air inflow has to be ↙ dehumidified or ↙ humidified depends on the absolute humidity level. ↙ Dew point issues can also significantly reduce the effectiveness of surface cooling systems, making dehumidifying the air inflow essential. Where the outdoor air is humid, ↙ decentralised ventilation system may require condensate drainage.

Depending on the location, the precipitation frequency, the monthly precipitation rate and the maximum precipitation levels may represent important planning data. Levels of solar radiation and cloud cover influence the temperature, particularly at ground level. During the day, clouds can reduce solar radiation incidence; on a cloudless night, the temperature goes down significantly.

Wind

The wind situation onsite is a critical factor in construction planning. The relevant aspect is the pressure and suction exerted by the wind on the building skin. The airflow around a building is determined by the prevailing wind situation, the building's shape and its surroundings. Meteorological data, however, provide only a generalised picture of wind direction and wind strength onsite. The major factor is the microclimate situation created by the terrain, the shape and proximity of the surrounding buildings, and the surrounding vegetation. The surrounding development can produce jet effects that increase ↙ wind speeds.

↙ **wind speeds** p. 142

The areas acted on by the wind's pressure and suction can be incorporated into natural ventilation plans if ventilation and exhaust openings are positioned in aerodynamically optimised positions.

While the major wind systems recur with the seasons, regional winds are heavily influenced by the topography. The role of local winds is demonstrated by places that belong to a certain climate zone geographically having a significantly different local climate.

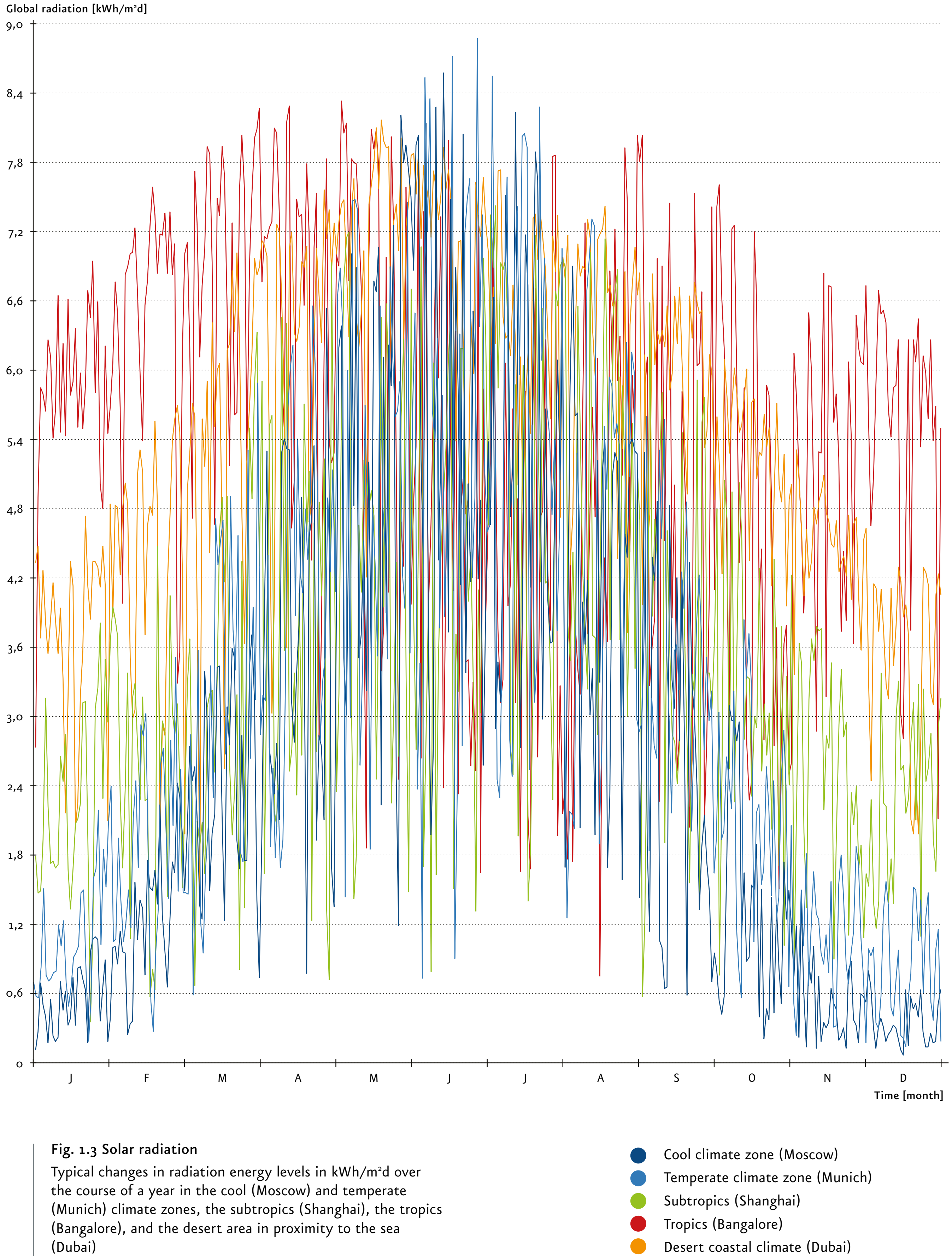


Fig. 1.3 Solar radiation

Typical changes in radiation energy levels in kWh/m²d over the course of a year in the cool (Moscow) and temperate (Munich) climate zones, the subtropics (Shanghai), the tropics (Bangalore), and the desert area in proximity to the sea (Dubai)

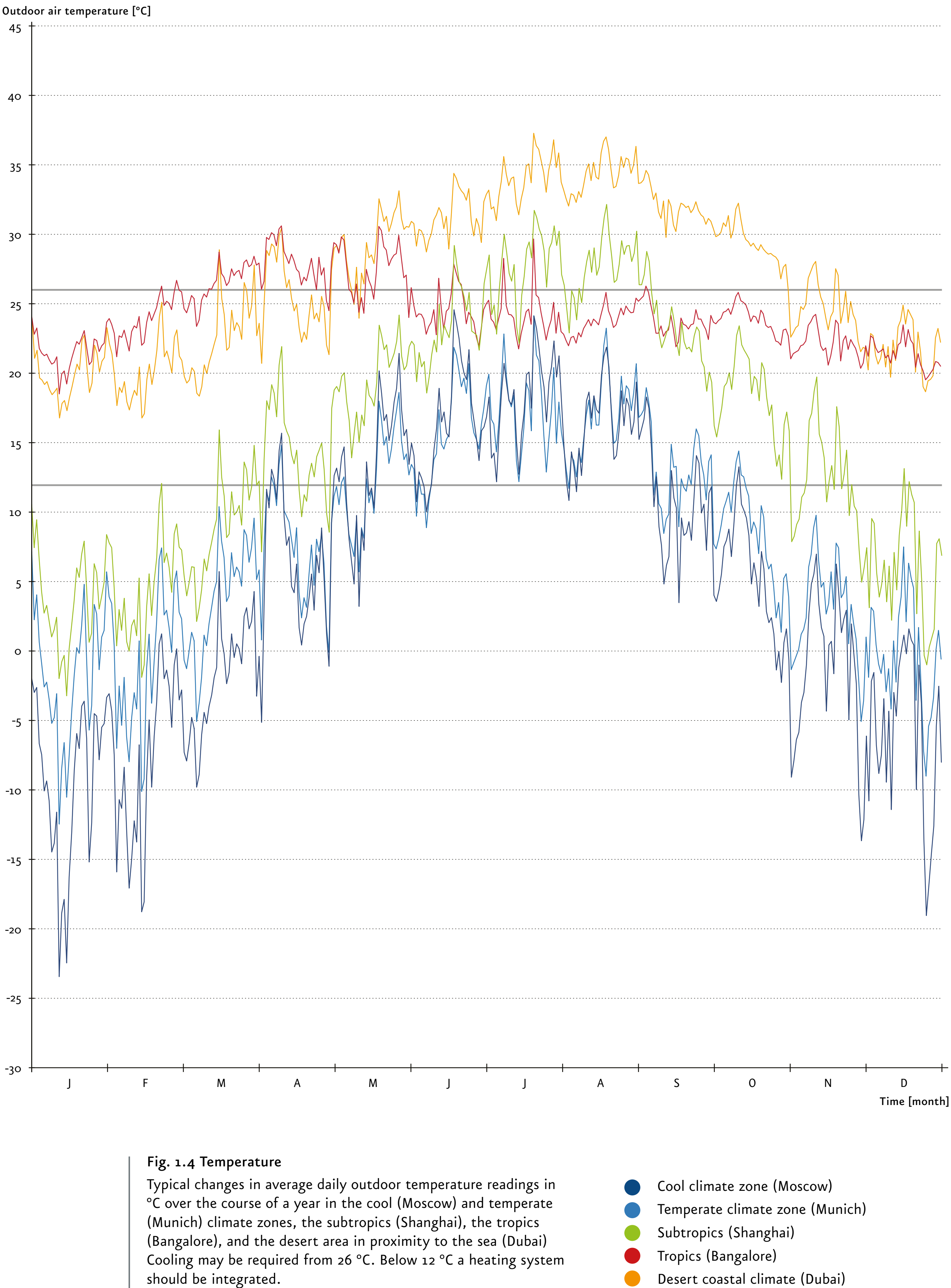


Fig. 1.4 Temperature

Typical changes in average daily outdoor temperature readings in °C over the course of a year in the cool (Moscow) and temperate (Munich) climate zones, the subtropics (Shanghai), the tropics (Bangalore), and the desert area in proximity to the sea (Dubai) Cooling may be required from 26 °C. Below 12 °C a heating system should be integrated.