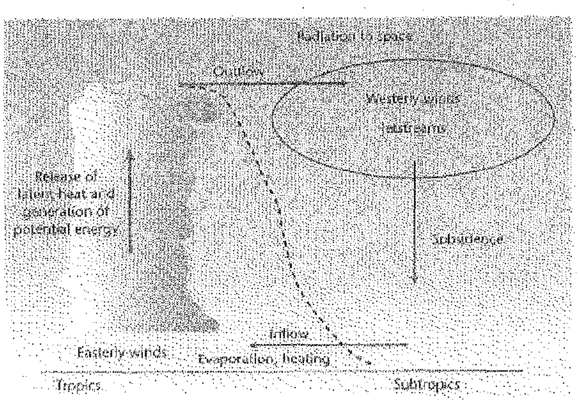
Appendix

Climate Processes

The atmosphere

Each location on the globe has a climate that reflects primarily the basic geographical characteristics of latitude, altitude, aspect and continentality. Locations nearer the poles have a pronounced seasonal cycle of heating and cooling and marked difference in day length between summer and winter. In the tropics, where day length and solar heating are more uniform throughout the year, it is humidity and rainfall that are better markers of seasonality. Altitude and aspect can cause significant variations in local climate over relatively short distances. Inland locations tend to have greater ranges of climate characteristics between summer and winter than those at similar latitudes closer to the coast.

In addition to the basic geographical controls over local climate there are also the influences of the global pattern of weather systems and their seasonally varying distribution. Mid-latitude cyclones, subtropical anticyclones, monsoon systems and tropical cyclones are a few of the weather systems that are important in different locations. The influence of weather systems at any location varies during the year because of the characteristic seasonal patterns of frequency and intensity.



The weather systems have their origins in the motions of the atmosphere and the oceans that are constantly acting to redistribute heat and energy around the globe, particularly in response to the seasonally changing solar heating and the ever-present cooling to space. Primarily, the atmosphere and the oceans are acting to transfer excess heat from the tropics to polar regions. In each hemisphere the rate of poleward energy transport is a maximum during winter when the temperature contrast between the pole and the equator is a maximum.

The motions of the atmosphere are complex because of the role of water vapour and latent energy, and because of conservation of absolute angular momentum on the rotating Earth. In the tropics a direct meridional circulation in each hemisphere (the Hadley Cell) is driven by release of latent heat in regions of deep atmospheric convective clouds. Over tropical latitudes warm moist air converges at the surface and, through the release of latent energy in regions of active convection, ascends buoyantly to the high atmosphere. The air in the high atmosphere flowing away from the equator develops westerly momentum (manifest as the westerly jetstreams of subtropical latitudes) because of the conservation of absolute angular momentum on the rotating Earth. The main features of the meridional Hadley Cell are shown in Figure A.1.

Poleward of the Hadley Cell, it is the asymmetry of troughs and ridges of the generally westerly flow that achieves energy transfer to higher latitudes. The net effect of warm air flowing poleward and cold air flowing equatorward is an overall transfer of heat poleward. Also, generally there is ascending air ahead of trough systems and sinking air in the region ahead of ridges. Therefore, in middle latitudes the horizontal circulation is characterized by large-scale westerly currents but the vertical meridional circulation is indirect, with sinking air in the subtropics and rising air poleward in the mid-latitudes.

At the surface, anticyclonic high-pressure systems are favoured in the sinking air ahead of the upper ridges and cyclonic systems are favoured in the ascending air ahead of upper level troughs. The characteristic circulation of the mid-latitudes is for a westerly flow with slowly moving trough and ridge systems, and transient eddies at the surface recognized as cyclones and anticyclones. The main features of the atmospheric circulation are shown in Figure A.2.

Clouds and their ever-changing characteristics and patterns of spatial distribution in the atmosphere are an important feature of the climate system. Clouds reflect incoming solar energy to space and so modify the amount of solar energy absorbed locally by the earth-atmosphere system. A change in the pattern of cloudiness will also change the pattern of longwave radiation to space, including the local rate of energy loss from the earth-atmosphere system. Clouds with high cold tops emit less radiation than clouds with low warmer tops; regions of cloud-free air emit maximum radiation consistent with the generally higher temperature at the surface of the Earth.

Clouds also provide a direct energy source to the atmosphere. Latent energy is released as water vapour condenses during cloud formation, and clouds generating precipitation provide a net release of latent energy to the atmosphere. Clouds are embedded in weather systems, either within layers of ascending air or in zones of convective instability. In both situations the released latent energy is converted to potential energy in the rising air. The direct release of latent energy in clouds drives meridional overturning and regions of cloudiness have a significant influence on the atmospheric circulation.

Surface exchange processes

Solar radiation is partially absorbed by the atmosphere but it is direct heat transfer and evaporation of moisture (latent energy) from the underlying surfaces that are the major sources of energy to drive the atmospheric circulation. Over the oceans there is an abundant source of latent energy and it is wind speed that is an important factor in regulating evaporation and the rate of energy transfer. Over land, the rate of evapotranspiration is a function of both wind speed and the surface characteristics; high soil moisture and a vegetated surface provide a high rate of evapotranspiration while dry soil has a very low rate.

The processes for absorption of solar radiation at the Earth's surface change depending primarily on whether the surface is land or ocean. Over land, incoming solar radiation is absorbed at the surface and the rate of conduction through the underlying earth is slow. At a depth of a few metres there is very little temperature change through the year. Soil materials conduct heat slowly and have a relatively low thermal capacity. As a consequence, the surface warms rapidly under the influence of seasonally increasing solar radiation. During winter, when solar radiation is at a minimum, land surfaces continue to emit longwave radiation but conduction of heat from the underlying soil is relatively slow and the land surface temperature cools.

By contrast, over the oceans solar radiation penetrates into and is absorbed in the surface layers of the oceans. The water has a relatively high thermal capacity and wind-driven mixing of the ocean surface distributes excess heat through the upper layer. During winter the wind-driven

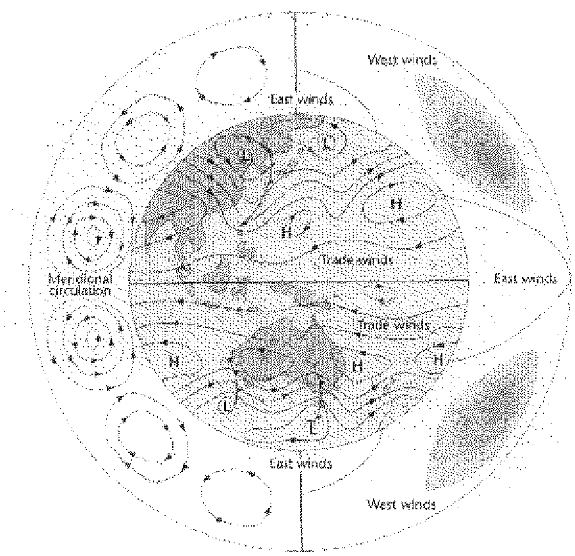


Figure A.2
A schematic representation of the essential features of the mean large-scale circulation of the atmosphere, showing a typical pattern of surface atmospheric pressure and (in greatly exaggerated vertical scale) the zonally averaged meridional (left) and zonal circulations (right) (Tegart and Zillman, 1990)