1.5 The land surface (Lithosphere)

Land surface is an important interactive component of the climate system. It covers 29 per cent of the Earth's surface. Significant exchanges of heat, moisture, and momentum occur between the atmosphere and the land surface, including its biosphere. It is also the surface on which people live. The heat storage factor of land surface with respect to atmospheric temperature variations is much less than that for the oceans. Land has a lower specific heat than the ocean, and its rigidity restricts heat transport to deeper levels. As a result, the depth of the soil layer which is important for energy exchange interactions with the atmosphere is only several meters for the annual-cycle time scale. A cave 20 meters underground will remain at the same temperature all year round. Because of the small heat capacity of the land surface, variations in atmospheric temperature just above the surface are much larger over the land than over the ocean. The energy and momentum exchanges between land surfaces and the atmosphere are similar to those for an ocean surface. Heat and latent heat (water vapour) exchanges depend on temperature and water vapour pressure differences between the land surface and the lower atmosphere, roughness of the land surface, and surface atmospheric wind speed. The latter may be characterized by wind conditions in the lowest ten meters of the atmosphere (the atmospheric 'mixed layer').

Radiation transfer is the other important energy exchange. The amount of solar radiation absorbed by a land surface depends on both the amount of solar radiation coming through the atmosphere (a highly variable quantity as discussed before) and the albedo (reflectivity) of the land surface which is also highly variable. The albedo ranges from five to 90 per cent and depends on the type of cover for the land surface as shown in Table 1.2. The infrared radiation transfer is the net of the infrared radiation emitted by the land surface (which is close to the maximum 'black body' value and thus dependent only on temperature) and the total downward infrared radiation produced by the atmosphere. Because of the small heat capacity of the land surface, the radiative, sensible, and latent energy transfers come close to balancing most of the time.

Table 1.2: Typical range of the albedo of various surfaces.

Surface type	**Albedo**
Ocean	0.05-0.15
Fresh snow	0.75-0.90
Old snow	0.40-0.70
Sea ice	0.3-0.6
Soil	0.05-0.40
Desert	0.20-0.45
Cropland	0.18-0.25
Grassland	0.16-0.26
Deciduous forest	0.15-0.20
Coniferous forest	0.05-0.15
Snow covered coniferous forest	0.13-0.3

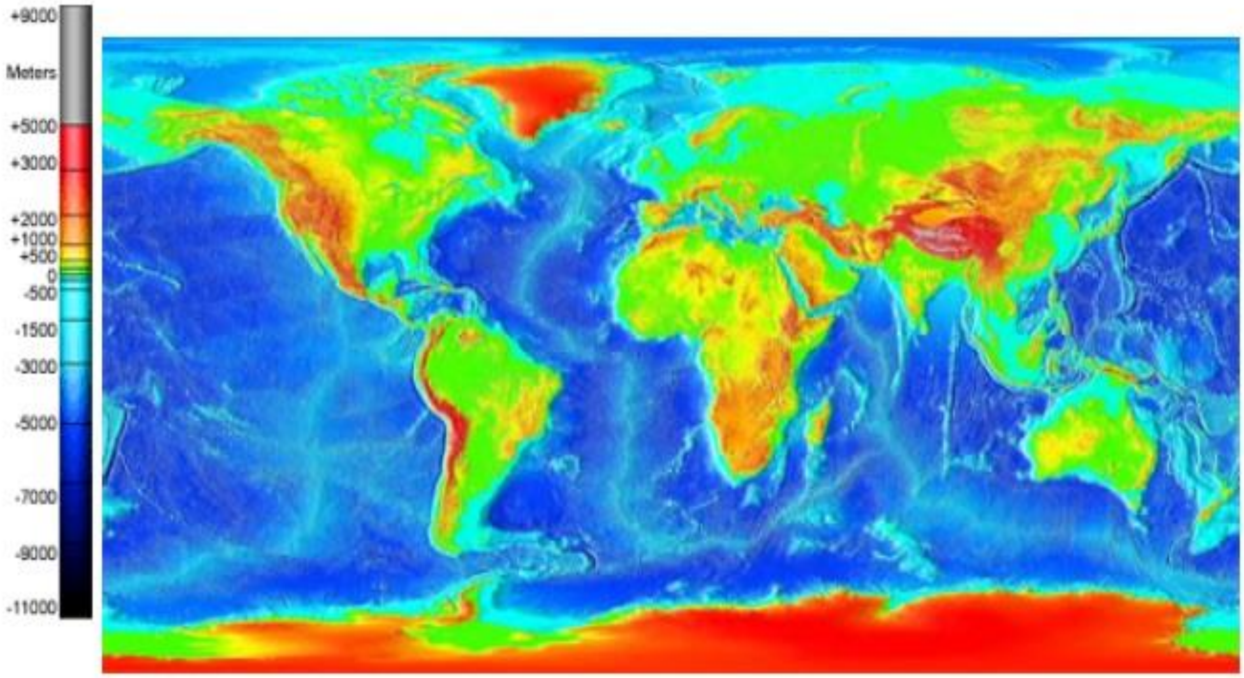

Figure 1.7: High resolution map of the surface topography.

Topography of the land surface has a pronounced effect on large-scale atmospheric circulations. particularly in the Northern Hemisphere. The Rocky Mountains, which are oriented north-south transect the Northern Hemisphere westerlies, and the Tibetan Plateau with its extreme height and aerial extent affects flow over a large area. Topography is a factor in the wave patterns in the upper tropospheric horizontal wind flow (shown in Figure 1.7), and also has major effects on surface temperature and rainfall. Alteration of land surface by human activity is an important factor in climate change that adds to the effects of human-produced changes in the radiative characteristics of the atmosphere.

Urbanization, cultivation for agriculture, irrigation, and deforestation change the albedo of land surfaces and the surface sensible and latent heat transfers. These factors can also greatly influence the local aspects of climate change.

1.6 The Biosphere

The biosphere is a component of the climate system that has a distinct role in the interactions of both the oceans and land surface with the atmosphere. Vegetation on the land surface and both plant and animal life in the oceans are all relevant elements of the biosphere component that interact with the atmosphere.

Climate conditions of the atmosphere have a direct effect on the type of terrestrial plant growth at the Earth's surface. The nature of the plant cover in turn feeds back on the atmospheric condition by influencing the sensible and latent energy transfers from a land surface, as well as surface layer turbulence in the atmosphere (through its roughness properties). Furthermore, land vegetation is a significant reservoir for carbon with a total carbon content nearly equal to that in the atmosphere. Changes in the amount of land vegetation due, for instance, to forest cutting and burning or simply seasonal changes have a direct impact on the carbon dioxide concentration in the atmosphere. Along with dissolved inorganic carbon and calcium carbonate solids, plant and animal life have key roles in the ocean, in sensible heat. Recall that in the global mean, the latent energy transfer from the Earth to the atmosphere was much larger than the sensible heat transfer (see figure 1.8).

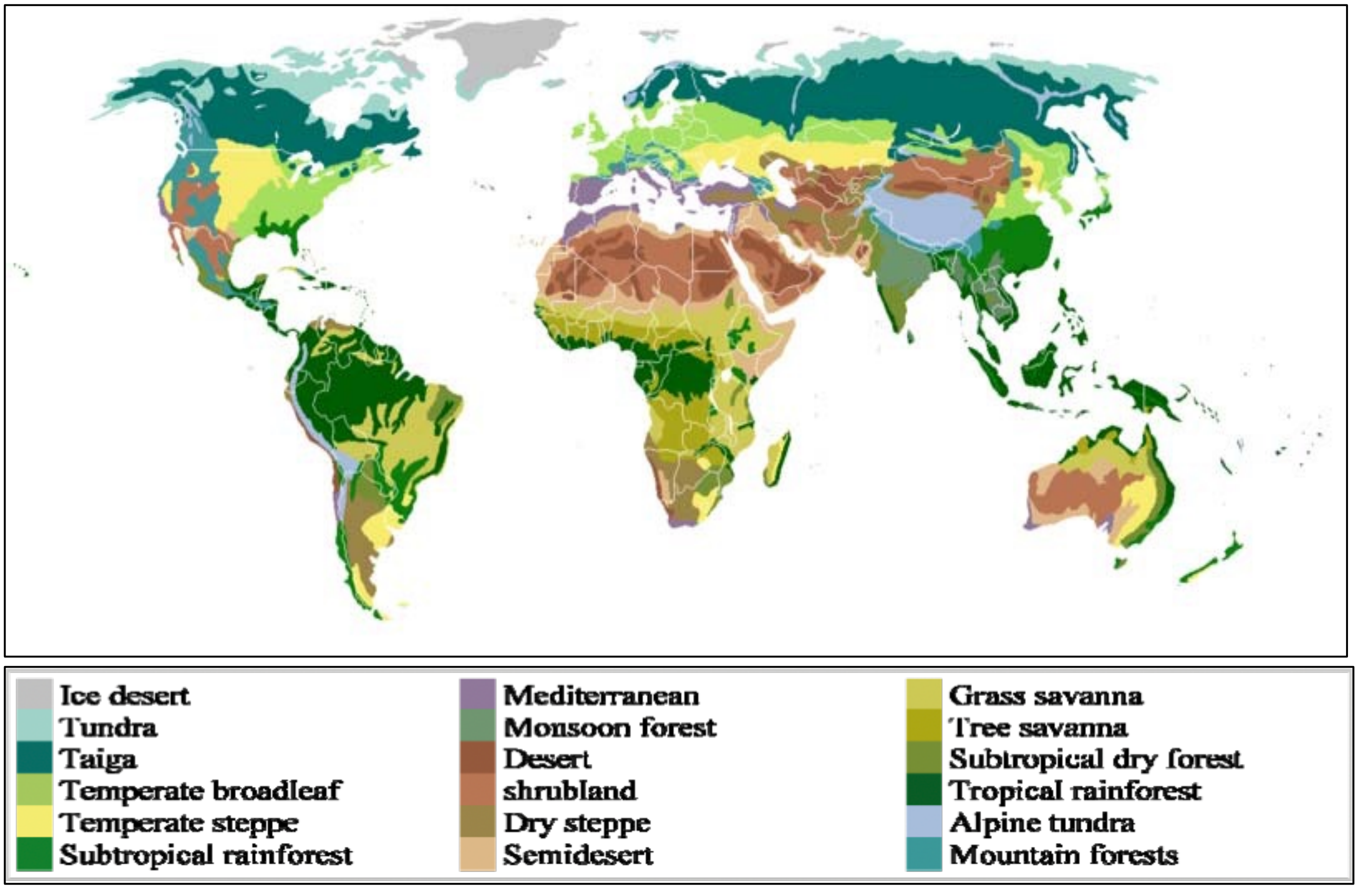

Figure (1.8): Terrestrial biomes.