only energy but also a wealth of *information* about the environment within which it originated and through which it subsequently propagated. Since the early 1960s, virtually all areas of the atmospheric sciences have been revolutionized by the development and application of *remote sensing* techniques — that is, measurements of atmospheric properties and processes at a distance, using radiation sensors placed in space, on aircraft, and/or on the earth's surface.

As we shall see, the interactions of various forms of EM radiation with the environment are extremely rich and complex. Consequently, there are few important atmospheric variables that cannot be directly or indirectly estimated from the vantage point of a satellite in orbit if one is clever enough in the design of both the instrument and the analytical techniques. Today, there are large parts of the globe — especially the oceans, polar regions, and sparsely populated land areas — where meteorologists depend almost entirely on satellite observations for up-to-date information about temperature and humidity structure, wind, cloud cover, precipitation, etc.

The three images in Fig. 1.3 give just a hint of the variety of information contained in satellite observations of the atmosphere at different wavelengths. Panel (a) is a snapshot of the Eastern Pacific at a wavelength in the visible part of the spectrum. This is essentially the view of Earth you would see with the naked eye if you were on board a spacecraft, except that it's in black and white. The source of the illumination is of course the sun, and brightest areas in the image correspond to highly reflective features, such as clouds and snow. The ocean, which is not very reflective of sunlight, appears very dark. Land areas fall in between. Images of this type are primarily useful for observing the extent and evolution of cloud features associated with storms and other atmospheric circulations. Also, by observing the cloud coverage over time, it is possible to estimate what fraction of the sun's energy, on average, is absorbed by the earth and atmosphere.

Panel (b) shows the same scene but the image was taken at an infrared wavelength for which the cloud-free atmosphere is very transparent. The shades of gray in this image give an indication of the *temperatures* of the various surface and cloud features visible from space. Light shades correspond here to cold temperatures, and dark shades correspond to warm temperatures. Note that many of

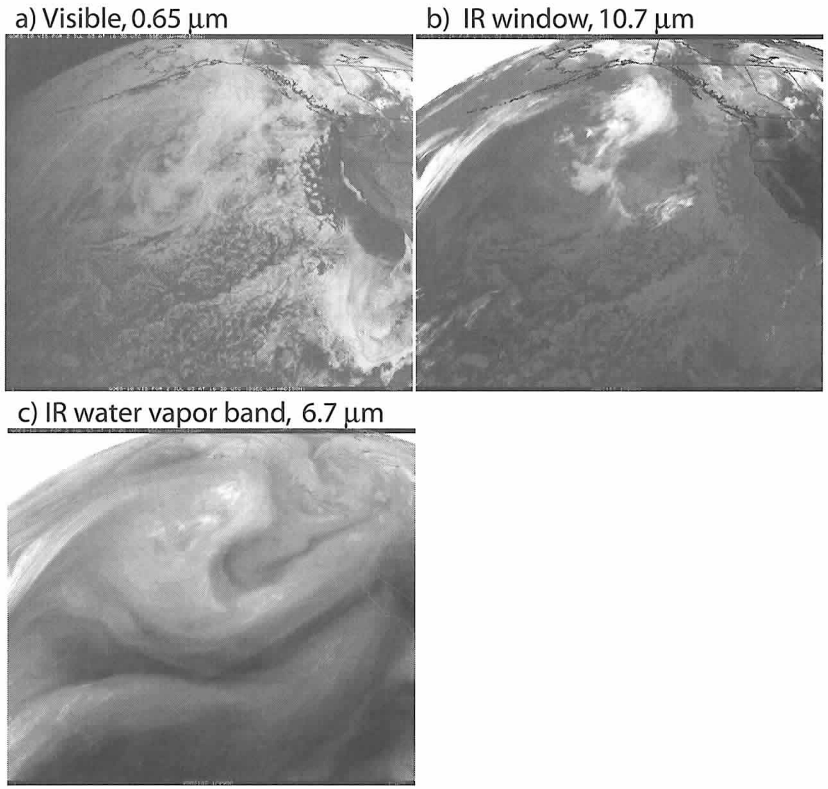

Fig. 1.3: Geostationary satellite images of the Eastern Pacific taken at the same time but at three different wavelengths.

the bright clouds seen in panel (a) appear dark in panel (b), indicating that their tops occur at a low, warm altitude. Other clouds, such as those in the upper center of the image, appear bright, indicating that they have high, cold tops. Rain clouds are usually deep and therefore have cold tops, so infrared images can often help distinguish deep precipitating clouds from shallow nonprecipitating clouds. The California lowlands appear as the darkest shade, so we can conclude that they have the warmest temperatures in this image. The Sierra Nevada mountain range, however, is visible as a light streak parallel to the coast, because the surface temperatures at high elevations are much cooler than those in the lowlands.

Panel (c) is very similar to panel (b) except that it was taken at an