This is a book about satellite oceanography and so this chapter about satellite-based measurements of wind and phenomena related to the wind does not attempt to address the topic from the meteorologist’s point of view. For that there are texts devoted to satellite meteorology (e.g., Kidder and Vonder Haar, 1995). Instead, the objective is to review briefly, from the oceanographer’s perspective, the circumstances in which knowledge of wind above the ocean is important for marine science and to assess whether, and in which circumstances, satellite data can provide it more appropriately than other sources.

The first section (Section 9.1) outlines different sensors and methods used to measure the wind field over the ocean from satellites, summarizing the more detailed treatment of techniques given in the companion volume MTOFS (Robinson, 2004). Section 9.2 identifies the variety of situations where wind data are important for the study of oceanographic processes. Many of these are topics discussed in detail in other chapters, so the discussion here is about the extent to which satellite wind measurements are preferable to the use of alternative data sources. Section 9.3 is a more substantial section about hurricanes over the ocean, how they are monitored by remote sensing, and particularly how satellite ocean data from all types of sensor can be used to reveal the impact of a hurricane’s passage on the structure of the water column. The final section (Section 9.4) explores the use of fine-resolution radar mapping of wind distribution and its potential for operational exploitation, especially in relation to the location and planning of offshore wind power installations.

9.1 MEASURING WIND OVER THE SEA FROM SATELLITES

Everyone has first-hand experience of the effect of the wind blowing over a water surface. Gentle winds produce small ripples, which become steeper and longer as the
wind increases. We learn to read the strength of the wind in the roughness of the sea surface. In a similar way, the remote sensing of winds over the sea is possible because microwave sensors can detect the mean square slope of short waves and thence quantify the wind speed.

It is the use of microwaves in C, X, and Ku bands, with frequencies between 5 GHz and 20 GHz that has proved to be most effective for measuring wind speed. Figure 2.20 shows how radar backscatter at these wavelengths (between 1 and 6 cm) varies with incidence angles at different wind speeds. For oblique-viewing radars the measured radar backscatter cross-section, $\sigma_0$, increases with the increasing amplitude of short surface waves at the Bragg wavelength, comparable with the radar wavelength, which grow with increasing wind (as discussed in chapter 9 of *MTOFS*). Wind can therefore be measured by three different types of active radar instrument and also by passive microwave radiometry (as described in the four following subsections). Liu and Xie (2006) provide a review of the subject.

There are other remote-sensing methods used by satellite meteorologists to measure wind speed at higher altitudes, such as tracking clouds and new techniques using lidar. However, these have little direct relevance to oceanography, for which it is surface wind that interacts with the ocean and is of particular interest.

### 9.1.1 Scatterometry

Scatterometers are the most effective sensors for mapping the distribution of wind speed and direction. Different instrument designs and how they work are explained in chapter 9 of *MTOFS*. Essentially they measure the oblique backscatter, $\sigma_0$, from the same patch of sea viewed from several directions. They then use an empirical model such as CMOD4, which specifies $\sigma_0$ for different wind speeds and viewing directions relative to the wind, to retrieve an estimate of wind speed and direction (Stoffelen and Anderson, 1997).

At the time of writing two scatterometers are in operation (see Table 2.9). NASA’s SeaWinds Ku-band scatterometer on QuikScat was deployed in 1999 and has delivered high-quality data since then, based on mature Ku-band backscatter models (Donnelly *et al.*, 1999; Ebuchi *et al.*, 2002). Its conically scanning antennas sweep out a swath of about 1,400 km, providing about 90% global coverage each day, and two samples a day of the wind vector at many places, with a spatial resolution of 12.5 km. Figures 9.1 and 9.2 show examples of the wind field as detected on the same day by QuikScat from, respectively, its morning (ascending) passes and evening (descending) passes on August 9, 2008. The time of acquisitions is later towards the west. The main wind patterns are captured well, and comparison between morning and evening passes shows the changes that occur within about 12 hours. QuikScat data are capable of measuring high wind speeds effectively (Liu, 2002) and have made a significant impact on ocean weather prediction (Von Ahn *et al.*, 2006).

The C-band ASCAT on MetOp was launched in 2006 and declared operational on May 15, 2007 as part of Eumetsat’s new polar system (Gelsthorpe *et al.*, 2000; Figa-Saldaña *et al.*, 2002). An evolution from the AMI scatterometer on ESA’s