

Remote Sensing - Satellite, Radar, VHF Radar, LDV, ADCP, and ADV

The distortion of flow around a physical sensor may affect the measurement, particularly of current, and a remote sensing technique may be preferred over a direct contact. But some problems require such a large view or are so inaccessible that remote sensing by radar or by satellite may be necessary. The problems of ground truth, atmospheric distortion, and scattering model are critical to these measurements. It is well beyond this course to consider the construction of satellite sensors but the assimilation of data from these sensors is appropriate.

Altimeters provide profiles along their flight paths that to first order can map instantaneous sea level. By geostrophy, surface slope in sea level causes a horizontal pressure gradient that is balanced by current shear. Thus the change in sea level across the Gulf Stream by about 1/2 meter is directly related to the Gulf Stream current of about 3 knots. The waves on the sea surface, principally due to wind, are both a problem for precise sea level measurements and a signal of waves (through altitude variance) that can be used to map winds. Geodetic effects, atmospheric refraction (the wavelength of radar waves may vary with temperature and humidity), and orbit uncertainties come into the altimeter measurements. Often the problem that limits utility of altimeter measurements is the spacing of the paths and the frequency of repeat passes.

One of the older remote measurements has been radiometer measurement of surface temperature. First from aircraft, later from satellites, the surface temperature can be determined by two or more infrared detectors. The assumption is that the radiating surface is a black body and the ratio of two points on the spectrum defines the temperature of the body. Atmospheric absorption is a major problem for this observation and becomes more so as the amount of atmosphere through which the observation is made increases. Water vapor is the principal culprit since there are no absorption bands for the diatomic gases in the infrared but there are for H₂O and CO₂. By adding a third detector the water vapor absorption can be determined and subtracted. But it is still a difficult measurement. Modern sensors such as the AVHRR do a very good job. Rain is still a problem, but as in so many cases, the problem can be turned into a rain sensor which provides valuable information in its own right.

Scanners of various types have been flown, both multispectral and imaging, generally focussed on the land such as LandSat. But although SeaSat only flew for a short while, its images were extraordinary. Promises to replace SeaSat have been made for 15 years and SeaWiifs is still promised as of February 1997. Imaging satellites do not see through clouds. But they can see internal wave signatures, probably through modulation of reflectivity by stretching and compressing the ambient surface waves.

The real contributor to wave measurements has been Synthetic Aperture Radar (SAR). The radar obtains scattering images with amplitude and direction information. Scattering from waves relies on the Bragg relation, that the scattering occurs when the spacing of the scatterers (the wind waves) is an integral number of radar wavelengths. Only when the Bragg condition is satisfied is there appreciable scattering. Work by Bill Plant and others has shown that there is backward propagation of wind waves at a reduced amplitude which shows in the SART images and is real. A great deal of effort has gone into the scattering model for this process. It works for aircraft (and balloon) instruments and for land based instruments.

By varying the frequency and by measuring the Doppler shift in the scattered frequency, the wave spectrum can be determined from land-based radar or VHF radio transmitters. The Doppler shift can be compared to the expected wave speed and a current determined from the difference in the observed from the expected. Thus a radar or VHF radar (CODAR or OCSR for example) can measure current as well as waves. Furthermore, if the water is shallow, the shallow water waves propagate at a different speed from the same wavelength in deep water so the depth of the water can be determined in some cases. This is a new field that is just being validated now (1995-7).

Acoustic remote sensing for current by Doppler is well established with the ADCP. Velocity profiles almost to the surface or to the bottom are routine from fixed and moving platforms. Wideband permits higher accuracy in shorter averaging periods to replace the older narrow band ADCPs. Single level vector current meters like the SonTek ADV are permitting turbulence measurements to be made acoustically, a regime only available to LDVs and hot wires before.