

1. REMOTE SENSING OF COASTAL AND OCEAN STUDIES

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The term "Remote Sensing" literally means detection of objects from a distance. However, in modern space sciences, its usage is restricted to mean detection of features at or near the earth's surface from space using electromagnetic radiation. Remote sensing is often considered as opposite of astronomy. In astronomy, we observe the space from earth to know more about the space, while in remote sensing, we observe earth from space to know more about the earth. Interpretation of ordinary black-and-white photographs of earth's terrain taken from aircrafts is as much remote sensing as is estimation of sea surface winds from satellite signals. The electromagnetic radiation, which is the basic agency carrying information from the earth to the satellite (or aircraft) extends from waves as short as gamma rays or X-rays to very long waves like radio waves. Not all waves of the electromagnetic spectrum can be used in remote sensing. Waves shorter than ultraviolet rays get quickly scattered by the earth's atmosphere and hence the information carried by them from the earth's surface cannot reach the sensors on board

satellites or aircrafts (and vice versa). Hence, they cannot be used in remote sensing. Similarly, long waves like radio waves are also not used in remote sensing because of their poor information carrying capacity. Only visible, infra-red and microwave radiation find use in remote sensing.

Coastal and open oceans are commonly studied by ships. These studies involve measurement and interpretation of physical, chemical, biological and geological parameters of the ocean in different seasons. While the ships are slow and expensive, oceans are vast and dynamic. It is thus not possible to have simultaneous measurements of any oceanic parameter even over a region as small as 1000 sq. km. One can neither make a single ship move fast enough to cover the entire area in one day, nor afford 100 ships stationed in such an area (one ship per 10 sq. km.). Satellite on the other hand, circle the entire earth in a couple of hours and simultaneously send all observations to a ground receiving station for online data processing. It is needless to say then, that remote sensing alone holds the key to any further progress in oceanography.

Although satellites give repeated and synoptic picture of the entire ocean, they lack the precision and accuracy associated with the shipboard observations. Besides, all oceanic parameters are not amenable to remote sensing. Only those parameters, which manifest themselves on the ocean

surface can be sensed by a satellite. We shall discuss here the geophysical parameters relevant to coastal and open ocean which are currently retrieved by remote sensing with a fairly reliable degree of accuracy. Though we shall briefly touch upon the physics underlying their retrieval, a thorough discussion of algorithms used for their retrieval would lie beyond the scope of this introductory lecture.

1. SEA SURFACE TEMPERATURE (SST)

SST is the most commonly measured parameter by ocean community and it is also easily amenable to remote sensing. Every object emits electromagnetic radiation by virtue of its temperature and sea surface is no exception. The temperature of the earth is such that most of the radiation emitted by it is in the thermal infra-red region (just as in the case of the sun, most of the radiation emitted by it is in the visible region). The radiation emitted by different parts of the earth is again proportional to their temperatures (by a very rough approximation). This is the basic theory around which algorithms to retrieve SST are developed. Like visible radiation, infra-red radiation is also affected by clouds (though less significantly). This requires atmospheric corrections to be applied to such data. At present, sea surface temperatures are routinely being retrieved from the sensor called AVHRR (Advanced Very High

Resolution Radiometer). The accuracy is 1 degree centigrade and the resolution is 1 km. In India, we have ground receiving station for AVHRR data and expertise exists in India to retrieve SST from AVHRR data.

SST can also be retrieved from passive microwave data. The physics behind retrieving it is the same as that of retrieving it from infra-red data. The microwave radiation has an advantage over infra-red in terms of its smooth passage through the earth's atmosphere. Being a long wave radiation (compared to infra-red), it is not obstructed by clouds and other constituents of the atmosphere. At present we don't have access to any on-line passive microwave data in India. The Indian Remote Sensing Satellite also does not have any passive microwave sensors. Moreover, the SST retrieved by AVHRR has a much higher resolution than what can be achieved by microwave sensors.

2. OCEAN COLOUR

The term ocean colour is used to designate the concentration of chlorophyll, suspended sediments and dissolved organic yellow matter in the sea water. These substances have a direct bearing on the fertility of the sea. Each one of these substances has a unique "Spectral Signature". This means that each of them absorb and reflect the incident sunlight in a unique way. This results in the sea water acquiring peculiar colours depending upon the relative abundance of one or more of these substances. Ocean colour sensors

receive and record reflected (visible) radiance from the sea water in specific channels. These channels are designed by taking into account the spectral signatures of these substances. Satellite scans a huge area of the ocean and identifying these specific spectral signatures pertaining to ocean colour is a complex activity. This is more so because the atmosphere intervening the satellite and the sea surface significantly alters the recorded radiance. Many algorithms are developed by which concentration of chlorophyll and other constituents in the sea water can be retrieved from the ocean colour data, but most of these algorithms are valid only for a limited region in the ocean. A global algorithm for ocean colour is yet to be developed. Since ocean colour sensors work in the visible region, they give no information in areas beneath clouds.

There are no satellites at present which carry ocean colour sensors. The last sensor called CZCS (Coastal Zone Colour Scanner) on board NIMBUS series of satellites has stopped functioning since 1986. The ocean-colour community is looking forward to the next sensor called SEAWIFS which is scheduled to be launched on board LANDSAT sometimes in 1991.

3. WAVES

There are many sensors proposed to study ocean waves and almost all of them have shown promising results in the

preliminary trials. These sensors belong to the microwave region of the electromagnetic spectrum. Microwave sensors belong to two categories viz, active and passive. Active sensors illuminate a part of the earth's terrain, receive back the reflected radiation (called the back-scattered radiation) and record them. The passive sensors record only the naturally emitted microwave radiation of the earth. One of the active sensors used to study waves is called the scatterometer which basically measures the back-scattering coefficient of the water surface.

Rougher the sea surface, more the wave activity and hence, higher the back-scattering. Another active sensor is called the altimeter which only measures its vertical distance from the sea surface while passing over it. This sensor gives the topography resulting from the wave activity. Both scatterometer and the altimeter were deployed on the experimental satellite called SEASAT and had given promising results. Unfortunately, there were no other remote sensing satellite thereafter dedicated to the ocean studies (despite the success of SEASAT) and the ocean-community had to rely on data from other satellites which were not specifically designed for ocean studies. At present, both scatterometer and altimeter are deployed on ERS-1 (the European Remote sensing satellite) and the data can be available to Indian Ocean Community through a collaboration between ISRO (Indian Space Research Organisation) and ESA (European Space Agency).

Another novel sensor called SAR (Synthetic Aperture Radar) is also an active sensor which can estimate waves. This is also deployed on ERS-1. SAR is often called the sensor of the future as its function is not fully understood. SAR has often given unexpected parameters like bottom topography very clearly for which it was neither intended nor operated. It is a purpose-built device which simulates a very wide aperture by manipulating its viewing geometry. The purpose is to increase resolution on the ground by virtue of which, it can sense even ripples on the sea surface besides wave direction and internal waves. The algorithms for SAR onboard SEASAT have generated immense interest and curiosity about it.

4. SEA SURFACE WINDS

Winds are not directly measured by remote sensing. They are estimated only indirectly through their effect on the sea surface. The scatterometer mentioned above which estimates waves has another mode of operation in which it measures winds. The main idea in this case is to use the windspeed-wave slope relationship to arrive at winds. The passive microwave sensor called SMRR (Scanning Multifrequency Microwave Radiometer) onboard NIMBUS series of satellites was specially designed to measure scalar winds through its channels at 18 and 21 GHz. This uses the polarization characteristics of naturally emitted microwave radiation of the sea surface. It is observed that polarization

components of such radiation decreases as sea surface becomes progressively ruffled due to winds. In this case, the instrument was found to be insensitive to windspeeds below 7 meters per second. The current satellite that carries a similar radiometer with improved precision in wind estimates is called DMSP and belongs to US Air Force. There is at present no way by which we can get passive microwave data from this satellite. There are plans to include passive microwave instrumentation in the proposed Indian Satellite called IRS-2.

5. SURFACE CURRENTS

Surface currents are estimated by a sensor called altimeter. As said earlier, altimeter merely measures its distance from the earth to an accuracy exceeding 7 cm. The surface currents produce slopes on the sea surface over long distances which are not discernible by human eye. Altimeter senses these slopes and currents can be computed from them with the help of Coriolis equation. Altimeter is deployed on board ERS-1. A proposed US satellite named TOPEX due in 1992 will be carrying altimeter exclusively with its supporting instrumentation. It will be a dedicated civil satellite designed solely for oceanographic research.

These are the only oceanic parameters which are amenable to remote sensing and for which retrieval strategies exist to an acceptable degree of reliability. We have not discussed here the remote sensing of meteorological parameters

like rainfall, cloud content or atmospheric profiles of humidity and temperature. We have also left out a discussion on sea-ice mapping through remote sensing as we never encounter sea-ice in seas around India. So far, Indian remote sensing programme have not laid emphasis on oceanography. It is more oriented toward geological mapping and development of agriculture and forestry. Similar is the case at international levels too. Oceanographic payloads scheduled on conventional satellite often get low priority, postponed or even cancelled. This leaves oceanographers with old satellite data which serve only academic interests. Alternately, they have to be content with data from other satellites which were launched keeping land-use in view. Such data when applied over oceans give erraneous results.

Nevertheless ocean remote sensing is going to play increasingly important role in future because of the impact ocean has over weather as no useful prediction can be made about weather without regard to the state of ocean.