"REMOTE SENSING OF THE OCEANS"

by Kurt R. Stehling

The oceans cover about 70% of the earth's surface. Many significant events, such as waves and swells, biological growth and currents take place and can be observed in the top few centimeters of the water; floating objects and pollutants are also, obviously observable surface manifestations. Moreover, in very clear water and during a sunny day, features can be discerned below the surface to depths of 50-100 feet. Indeed, surface and subsurface features can often be more clearly discerned from some height than from a surface platform. Many shipwrecks, shoals, reefs and the like have been observed from aircraft, being invisible, however, to the ship based observer.

Because of their wide global distribution, many parts of the oceans being geographically remote, on the one hand, and because so much can be "seen" of their features on the other, remote observation, or "sensing", from aircraft or spacecraft, becomes economically practical.

No claim for such sensing should of course be made for subsurface measurement capability, physical-chemical measurements and these other in-situ quantitative measurements that are done routinely by oceanographic research vessels.

Nevertheless, a strong case can be made for Earth Resource Application Satellites (ERAS) whose prime purpose would be Ocean Observation, using, within their payload and data handling limitations, every remote sensing tool that technology can provide.

A polar-orbiting satellite can cover every spot on the earch (i.e. oceans) twice during a 24 hour period. A synchronous spacecraft can cover an entire ocean continuously. The many millions of square miles observed in this manner would require a staggering cost in ship time (at a typical cost of about $4,000/day) for similar coverage - (although the ship would naturally have the 3-dimensional capability so necessary for many ocean analyses).

An important limitation of many sensors is their day-time-only and clear sky capability, whereas oceanographers generally want all-weather and 24 hour observations. This limiting feature can be obviated by combining a variety of instruments, each with its peculiar (e.g. - cloud cover penetration) capabilities, or perhaps, devising a sensor with all-weather 24 hour seeing capability. The latter is a utopian concept if high resolution imagery is desired, although feasible for certain spectrophotometric or radiometric narrow-band scanning.

The necessary pressure for development of a remote ocean scanning system will have to come from the ocean and marine user community, whether scientist, engineer or fisherman. The meteorologist is also interested since much weather (e.g. - hurricanes) is the peculiar result of air-sea interaction.

Amalgamating and sorting what these users would like to see, and what probably can be seen, in one manner or another, we arrive at the following list of "observables":

- sea state
- long period swells
- seismic waves (tsunamis)
- ocean currents (direction and hopefully, velocity)
- thermal distribution (also related to currents)
- plankton and other similar organisms, sea "weed"
- fish schools, large herds of mammals (bio luminescence)
- pollutants (e.g. - oil, phenols, etc.)
- mud, silt
- saline/fresh water distribution in deltas and estuaries
- ice bergs and sheets
- air/sea interactions (violent storms, fog, clouds, precipitation)
- shoals, reefs, sunken vessels, etc. (in clear shallow water)

It may also be possible to infer, after much experience, from surface observations, certain subsurface phenomena, including currents, upwellings and the like.

To accomplish any or all of the above objectives, we can draw upon a wide variety of sensors (unclassified) already developed or in the advanced laboratory stage. The following is a list of such sensors and the oceanographic parameters they can measure best, under what circumstances, and to serve what purpose:

1. Microwave Radiometer - 5-10cm, wavelength region. Depends on emission from surface of water. can measure:

   Surface temperature, ±1°C (better in future)
   Sea State: May be possible when emissivity anomalies are understood
   Chemical Water Differences: e.g. - fresh vs saline, pollution, etc. - possibly Sea ice distribution: already achieved from aircraft with remarkable results.

   Spatial Resolution: Dependent on satellite altitude and antenna aperture. 20 n.m. should be achievable from 300 n.m. orbit with 10,000 cm^2 antenna at 5cm wavelength. A line-trace image is formed. An overall footprint or swath of about 600 n.m. should be possible.

Now, if a microwave radiometer system were combined with a video sensor of the sort already in use on TIROS, for example, yielding resolutions of about 400-500 n.m., we would have a versatile and useful all-weather sensor system. The microwave radiometer would yield, almost, all-weather ocean surface data and, if multi-band, atmospheric data, while the video would show concurrent cloud distribution and probably some ocean features. If the video system could be further improved to increase resolution, reduce the "footprint" and achieve low-light-level scanning capability, the utility of the system would be even further enhanced. Another big step forward in sophistication would accrue if the video system had multi-wavelength (i.e. - color) perception.

Synchronous, or 24-hour and equatorial spacecraft should not be ruled out for complementary purposes. With the former craft a continuous, (albeit low resolution for the near future) surveillance of about 1/3 of the globe - such as most of the Pacific ocean - is possible with video, only, scanning. Air/Sea or weather features rather than intrinsic oceanographic features would be observable. The equatorial vehicle could yield more continuous detail of the interesting tropical ocean/weather phenomena - such as hurricanes.

In general, the lower the satellite altitude, the greater the spatial resolution - that is, more detail can be seen, since a smaller area or field of view is observed. However, the intrinsic angular resolving power of the sensor (whether optical or microwave) is determined by the aperture of the entrance lens, or aerial.

Other sensors, besides the above microwave video combination, are of course feasible and available, and in some cases, have special virtues that make them useful for certain ocean sensing applications. However, because of their general overall limitations, such as clear weather operation, they are only briefly listed here:

Photography: A lens/film system yields the highest spatial and color resolution at least for the foreseeable future. Gemini photos, taken with a "simple" camera are examples. However, requires manned spacecraft, or other spacecraft retrieval system, or cumbersome on-board film development and scanning. Strictly daylight and clear sky limited.

I.R.: radiometry or imagery - limited by atmospheric absorption, cloud cover, rain, etc. Excellent for meteorological purposes and could be a useful companion reference radiometer with a microwave ocean scanning spacecraft.

Radar: Synthetic aperture (for greater resolution), radar altimeter and scatterometer. Radar - i.e. - ground-pointing sensor - is an active rather than passive technique. Permits detection of sea-state characteristics, waves and swells, sea-land interface and, in the sub- 3 cm region, air/sea interactions. Laser radar is a possibility. Has serious limitation of bulk and heavy power demands, data management and interpretation.

Spectroscopy: - multi-wavelength radiometry or photography in the visible or near - Infrared spectral regions can yield much information on surface sea water condition, including biota, oil-slicks, and other non-sea water substances. Could permit analysis of surface phosphorescence and fluorescence. Strictly clear weather limited.

Polarimetry: - has certain utility for analysis of sea surface state. Suitable for visible region only and for clear weather and sunlight.

These represent the most important complement in the stable of actual or possible sensors. The rapid development of solid-state technology, image analysis and communications technology no doubt will result in a variety of high resolution, relatively low cost and versatile detectors. At the moment however, "the complete oceanographic spacecraft sensor system" seems to be the microwave/video combination, with possible ancillary infrared sensing.

Murkshe, Keynote Speaker Kurt Stehling and Emens discussing the technical, economic and socilogical ramifications of remote oceanographic sensors - very interesting!