Satellite sensors monitor health of coastal waters

Coastal CRC scientists have teamed up with the US National Aeronautic and Space Administration (NASA) and the European Space Agency (ESA) to monitor the condition of Australia's tropical wetlands, estuaries and coasts using sensor mounted on satellites and aircraft.

Scientists from eight Australian research organizations are pioneering new imaging techniques to monitor changes to coastal ecosystems, including satellite radar that 'sees' through heavy cloud cover. Data from the remote sensing project will be used by natural resource management agencies to assess the condition of Moreton Bay, Port Curtis and the Fitzroy River regions.

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Remote sensing - measuring light and other forms of radiation reflected from land and sea - involves special sensors carried in aircraft or satellites which measure reflected light from the sun, or signals from a radar transmitter.

Project leader Dr Stuart Phinn, a University of Queensland remote sensing scientist with the Coastal CRC, says current approaches used to map and monitor coastal environments can be vastly improved when used in conjunction with remote sensing techniques.

"Remotely sensed images can be used to record changes to 'indicators' that measure the health of coastal waterways and their surrounding environments," says Dr Phinn. "For example, we can measure the amount of suspended sediment, the level of organic material in water, or the distribution of seagrass beds. Work is underway to develop techniques that will monitor future outbreaks of algal blooms in Moreton Bay.

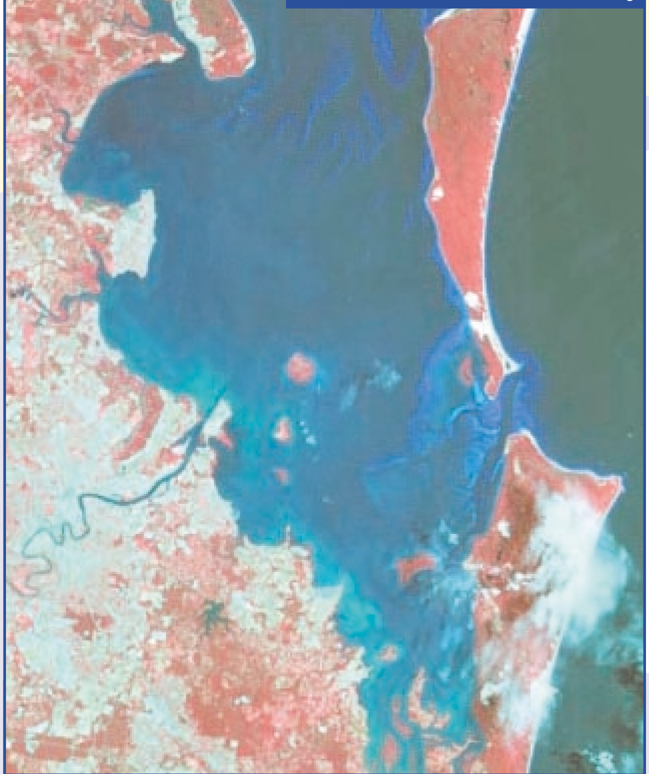
Remote sensing can map features such as vegetation, soils, water and submerged seascapes. As the chemical, biological and structural characteristics of these features react differently with light they can be measured by the sensors. Synthetic aperture radar (SAR) can produce images containing information about topography, vegetation height and density. The SAR sends a pulse of energy to the ground, after which it measures the strength of the return signal. The signal is used to calculate the distance of the ground from the sensor and the characteristics of the surface it has reflected.

"While the techniques are not new, they haven't been used at a scale to monitor the health of coastal ecosystems. For example, plants have a particular light signature. All plants contain chlorophyll, a chemical pigment that absorbs red and blue light. The more red and blue absorbed, the greener vegetation will appear to us, and the healthier it is. Similarly, the amount of sunlight reflected from water depends on materials on the surface or suspended in the water column. So we can use images to estimate the extent and condition of indicators such as mangroves, seagrasses, suspended sediment and blue-green algae," says Dr Phinn.

The remote sensing project involves collaboration between scientists and postgraduate students from CSIRO Divisions' of Land and Water, Marine Research, and Mathematics and Information Sciences, The University of Queensland Departments' of Geographical Sciences and Planning, and Marine Botany, Griffith University's School of Environmental Sciences, and the Australian Institute of Marine Science. Key government agencies involved include Queensland's Departments' of Natural Resources and Primary Industries, the Environmental Protection Agency and numerous local councils in south-east and central Queensland.

According to Dr Arnold Dekker, a Coastal CRC remote sensing scientist with CSIRO Land and Water in Canberra, it is difficult, if not impossible, to monitor rapidly changing conditions over large areas, such as an algal bloom or flood, that that occur in Australia's tropical or subtropical estuaries. "A range of remotely sensed data are now available to cover small areas in detail, or the entire earth in a day, with sensors designed specifically for vegetation or water quality monitoring," says Dr Dekker.

Source: Australian Centre for remote sensing

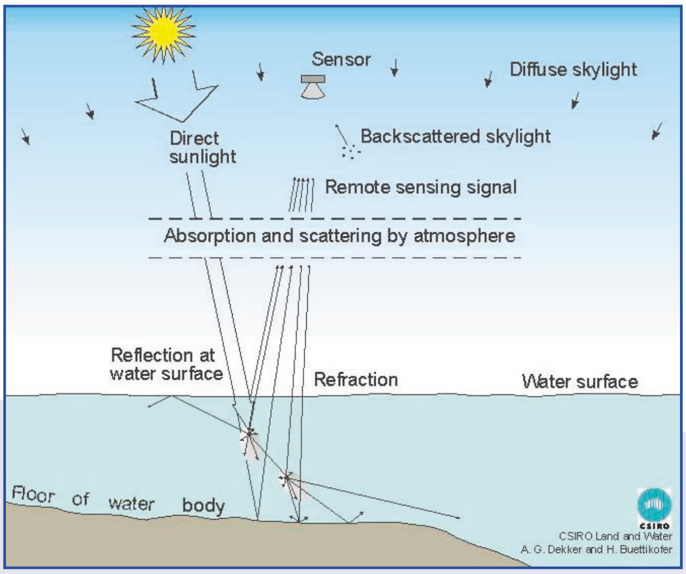


Landsat Enhanced Thematic-mapper images of moreton bay at 9 December 1999. These images are being used to map the extent and changes in the Lyngbya bloom.

Recent field and image data collection has been undertaken by the team, which includes CSIRO's Dr Alex Held and Griffith University's Dr Pat Dale, for Moreton Bay. The researchers collected field data for mangroves and seagrasses, while a NASA aircraft flew over the study site collecting data using radar and a very high precision imaging sensor. These data sets will be combined to develop algorithms for mapping the area's biological and physical properties. The maps are then analysed by scientists and resource managers to help them understand the condition of the area.

HOW DOES REMOTE SENSING WORK?

Aircraft remote sensing can provide data in great detail enabling features as small as one meter in diameter to be resolved. Aircraft can also target specific areas or events, such as a flood plume at a river mouth, and can carry state-of-the-art sensors. A disadvantage is that operating costs are high. Satellite sensors on the other hand provide a greater range of resolutions (10 meters to 5 kilometres) covering significantly larger areas (10,000 square kilometers) - but data collection costs are significantly lower. Satellites revisit an area to collect images at interval between five and 16 days. Persistent cloud cover, or short-term events such as flooding, are problematic for these sensors. There are a number of commercial imaging satellites now in operation that can provide increased opportunities for collecting images.



Different sensors are able to detect different types of electromagnetic radiation. Sensors are often defined by the type of radiation they can detect, such as visible, infrared, thermal infrared and microwave radiation. The amount of light detected is a function of the range of wavelengths, or bands, to which a sensor is sensitive. For example, multi-spectral sensors measure up to 10 bands while hyper-spectral sensors measure more than 10 bands. The number and range of bands measured by a sensor determine which environmental features will be most readily detected. Properties of vegetation condition can be measured from visible blue, red or green light, while the biomass or moisture content can be measured by infrared wavelengths.

PROCESS INVOLVED IN THE USE OF REMOTE SENSING

1. Sensors pass over a designated area measuring specified types of reflected or emitted radiation.
2. Data are fed into computers that use specialised programs, or algorithms, to process the data. The algorithm used depends on the area under investigation and the type information to be estimated.
3. Information from a measurement of reflected electromagnetic radiation to a map representing special variation in an environmental variable such as seagrass density or mangrove cover. Field data are used to assess the level of accuracy or error associated with the maps.
4. Images are then interpreted by scientists and resource managers to understand the current condition of the survey area, and can be compared with information from previous surveys to determine what changes may be taking place.

LIMITATIONS TO REMOTE SENSING

Spatial versus temporal scale

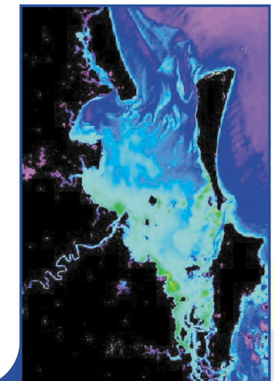
There is a trade-off in acquiring satellite image data sets for coastal monitoring. The most frequently available meteorological images often have coarse resolution of one kilometer. Higher special resolution data for earth resource monitoring are collected every 5-16 days.

Cloud cover

Coastal areas are prone to cloud cover, restricting the use of passive forms of remote sensing relying on reflected sunlight. However, increased frequency of satellites and availability of aircraft sensors can increase the number of images acquired. Using radar sensors that can penetrate clouds and haze makes it possible to map and monitor coastal environments under all conditions.

Costs and timeliness of data

Information extraction from remotely sensed that are involved at acquisition field data collection for calibration image processing and analysis in him is true costs of using remotely sensed after can be large. These problems can be overcome by careful approach to the planning and use of remote sensing methodology.



Estimates of suspended sediment concentration in Moreton Bay derived from a Landsat ETM image taken in December 1999. Research is underway to improve limitations in the procedure used to produce this map.

For example, the shallow sand banks in the eastern Bay were erroneously labeled as high concentrations of suspended sediment.

Image Source: Australian Centre for Remote Sensing

Interpretation of features in the water column

Features in the water column must be interpreted extremely carefully. For example estimation of chlorophyll or suspended sediments can be confusing in shallow waters leading to wrong results. These features must be interpreted with sophisticated algorithms that take water depth into account. Problems arise in the mapping of features below the water surface if there is a lot of material in the water column. Sub-surface remote sensing applications in turbid coastal environments are therefore extremely limited.

How does the coastal CRC use remote sensing to improve management of the coastal zone?

The CRC remote sensing projects commence with a survey to determine the spatial information needed for coastal resource monitoring and management. This survey is used to drive the selection and evaluation of image sets and processing methodologies for delivering the required information. These techniques can then be integrated into ongoing monitoring and management programs.

An example of this process is in the ecosystem health monitoring program of Moreton Bay. Here remote sensing is used to provide a broad scale indication of ecosystem health indicators which can only be obtained at specific (limited) locations from ground surveys. This information will direct future strategic management within the Moreton Region.

Airborne radar (AirSAR) image (taken from the DC-8 aircraft, shown above) of Lake Coombabah captured for the purpose of mapping flooded areas beneath mangrove canopy to help with mapping of mosquito breeding habitat.

Image and Photo Source: NASA Jet Propulsion Laboratory

Providing the decision-making tools, understanding and knowledge necessary for the effective management and ecosystem health of Australia's coastal zones, estuaries and waterways
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Established capabilities of remote sensing

Coastal and near shore environments have been the focus of remote sensing activities for more than 25 years. The following list of environmental characteristics are regularly monitored using various forms of remote sensing:

Terrestrial

- land cover and land use in coastal areas
- extent and composition of wetland (mangrove and saltmarsh)
- vegetation density and biomass

Water Surface

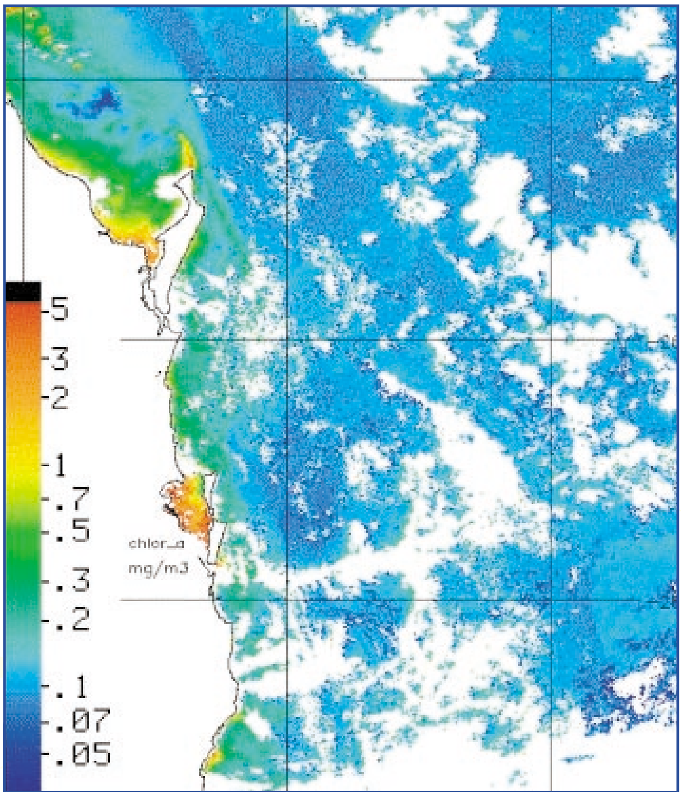
- roughness of sea surface
- extent and type of an algal bloom
- extent of an oil spill

Water Column

- extent of dissolved and particulate organic matter
- extent of suspended sediments (inorganic matter)
- extent of algal pigments (providing biomass and algal concentration)
- transparency and vertical attenuation of light
- bathymetry and seabed relief

Underwater Substrate (sea/estuary/rivers)

- type of substrate (such as sand, mud, seagrass, macroalgae and coral)
- condition and abundance of seagrass
- condition of coral



Map derived from the Sea-Wifs satellite showing estimates of surface concentrations of chlorophyll-a in the ocean off South East Queensland (5/4/2000). These maps are being used to assess the development and growth of algal blooms within Moreton Bay.

Image courtesy of Australian Institute of Marine Science, original data provided by NASA/Orbimage

FIELD VERIFICATION (GROUND TRUTHING)

While remote sensors can distinguish different features on the ground there is no way to interpret what the features are unless they are matched up with known features. Scientists verify features by observing them and taking samples while in the field.

Assessing the accuracy of remote sensing can be conducted using the same sensors carried in planes and satellites to directly measure the amount of radiation that certain objects reflect. However, it is often undertaken by matching known sites of a feature, such as mangroves, with their appearance in an remote sensed image. Scientists also correlate measurements of features, such as water turbidity, at different locations with values in the image of an area.