PREDICTION AND MONITORING OF OCEANIC DISASTERS USING MICROWAVE REMOTE SENSING TECHNIQUES

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Abstract

The disasters in oceans take place either due to oil spills or due to cyclones. It is possible to monitor the spread of the oil spills and to predict cyclones by measuring wind velocities and wind direction. This can be done using microwave remote sensing techniques.

The microwave remote sensing techniques provide useful tools for the prediction and monitoring of oceanic disasters, which would be difficult to predict and monitor by other techniques. This is because the microwave remote sensing techniques can be used by both day and night and can penetrate clouds so they have all weather capability.

The microwave sensors used for monitoring oil spills are the passive sensors like microwave radiometers at suitable frequencies like L band and C band. The spread and the extent of the oil spill could be imaged using scanning radiometers. The microwave radiometers could also be used for measuring speed of the winds and the direction of the winds on the ocean surface. Thus knowing these parameters it is possible to predict the direction of cyclones.

Using Active microwave sensors like Altimeters, Scatterometers and Synthetic Aperture radar the oil spills can be monitored and the wind speed, wind direction and the significant wave height can be obtained which help in predicting the movement of cyclones and determining their intensity.

Keywords ; Microwave remote sensing; Radar; Altimeter; Scatterometer; Radiometer; Emissivity; Scattering; Coefficient; dielectric constant

INTRODUCTION

The oceanic disasters are of two types –one is man made and other is natural. The man made disasters include the disasters created by oil spill over sea surface.

The spilling of oil over the sea surface changes the electrical properties of the surface over seawater. The physical properties of the oil spill will be characterized by the density of oil. The spread of the oil spill can be measured by remote sensing techniques. The electrical parameters that characterize the oil spill are the dielectric constant, emissivity and scattering coefficient.

Out of these three parameters the emissivity and scattering coefficients help in monitoring of the thickness of the oil spill and the extent of oil spill. The emissivity and scattering coefficient are function of the dielectric constant of the material. Here the dielectric constant of the mixture of seawater and oil will be different as compared to the dielectric constant of seawater. Thus the presence of an oil spill can be detected by measuring the “Brightness temperature” of sea surface and the “scattering coefficient” of sea surface.

In case of disasters that are natural in oceans like cyclones, the prediction and monitoring is possible using microwave remote sensing techniques. The formation of cyclones is related to winds on the ocean surface including their speeds and directions. Also the temperatures of ocean surface, the wave heights of the ocean as well as the knowledge of the combination of the wind profile and wave profile prior to formation of cyclone and later the level of these profiles which can be monitored with the help of passive and active microwave sensors, will give indication of cyclone, its intensity.

The electrical parameters like brightness temperature and scattering coefficient can be obtained using two types of sensors. They are:

Passive Sensor and Active Sensor

The Passive Sensors include Radiometers at different frequencies both imaging and non imaging. The Active sensors include Radars (both Real Aperture and Synthetic Aperture), Scatterometer and Radar Altimeter.

The parameters, which are measured with the help of Radiometers, are the wind speed and wind direction over sea surface. This can give an indication of the build-up of cyclones as this gives the measurement of sea state. The moisture content in the atmosphere can also be monitored along with the direction of the variation of the moisture as well as water content in the clouds.

The active sensors like Scatterometers and Real and Synthetic Aperture Radars give the sea state and the Radar Altimeter gives the significant wave heights.

For oceanic disaster monitoring and prediction the knowledge of sea state, ocean circulation, shallow water topography are of high priority. Apart from this, for oil pollution monitoring, retrieval of geophysical parameters of the ocean and the study of the ocean geoids are also important. The, latter two are considered to be an input for meteorological prediction.

Using radar altimeter data, World Ocean mean monthly Significant Wave Height and surface winds have been studied and ocean swell generation, propagation and dissipation observed. SAR and SLAR data have been used to detect major bottom topographical features for sea and to study interaction of sea waves with e.m. Waves. Similarly, Scatterometer, Altimeter and Radiometer data have been used to obtain the ocean surface wind: wind speed and direction, significant wave height and ocean surface current and direction. Atmospheric water vapour, liquid water content and sea surface temperature have been obtained using radiometer data from NIMBUS, COSMOS &. SEASAT. Monitoring of oil spill over ocean has been done using X band SLAR and Scatterometer data. Ocean geoids have been studied in Gulf Stream, Gulf of Mexico and at other places using G EOS-3 and SEASA T data.

The need for accurate and timely prediction of monsoon in the Indian region is considered to play important role for ocean management and cyclone study.

The wind speed, Significant Wave Height and swell have been studied in Indian Ocean, Bay of Bengal and Arabian Sea using Altimeter. Global maps of sea surface temperature were processed and compared with climatological maps using SEASAT - SMMR data. Global measurements of wind speed using same sensor' data have also been done. SEASAT data have also been used to obtain sea surface topography over Indian region.
The Table 1 gives the list of ocean parameters, which can be studied using microwave remote sensing. These parameters provide information about the prediction and monitoring of the disasters in ocean.

MEASUREMENT OF THE SEA STATE

Studying of the sea state or the wave condition in the sea is not only important for several oceanic engineering applications but also for the coastal engineering problems. With an increasing emphasis on the coastal and ocean resources the sea state information becomes critical.

A number of theoretical studies, have been completed where relationship have been established for estimating wind speed, wind direction, wave characteristics etc. to a considerable level of accuracy. Some of the important results are:

a) Theoretical and statistical representation of waves *is* possible for modelling wave spectra etc.
b) SEASAT Altimeter data has been used to observe ocean swell generation, propagation and dissipation.

In India the efforts to monitor these parameters have been made:
Where

a) SEASAT radar data has been used to obtain wind speed and, to some level of significance, the wave height and swell in the Indian Ocean, Bay of Bengal and Arabian sea
b) Ground studies have also related wind speed and wave height in a cyclone and surface winds and sea waves in a hurricane field.

The thrust area has to be to retrieve ocean wave spectrum using SAR data and forecast ocean wave characteristics from the spectrum. Retrieval of average height from radar altimeter data to verify wave models will be another area of study for prediction and monitoring of the disasters.

Table 1 and 2 give information about the relation between sea state and wave heights and condition of sea.

Table 1 Ocean Parameters to be measured for Prediction and Monitoring of Oceanic Disasters

Ocean
Sea State Measurement
Topography in shallow seas
Ocean Circulation
Oil Pollution
Geophysical Parameter Retrieval
Ocean geoid studies

Table 2 World Meteorological Organization sea state

Sea State	**Wave height** **Feet**	**Meters**	**Descriptive term**
0	0	0	Calm, glassy
1	0-1/3	0-0.1	Calm, ripped
2	1/3-12/3	0.1-0.5	Smooth, wavelets
3	2-4	0.6-1.2	Slight
4	4-8	1.2-2.4	Moderate
5	8-13	2.4-4.0	Rough
6	13-20	4.0-6.0	Very rough
7	20-30	6.0-9.0	High
8	30-45	9.0-14	Very High
9	over 45	over 14	Phenomenal

Table 3 Sea Surface Descriptors

Sea State	**Wind Speed Km**	**Wave Height** $H_{1/3}$**, ft**	**Duration / fetch h/nmi**
1 (smooth)	< 7	1	1/20
2 (slight)	7-12	1-3	5/50
3 (moderate)	12-16	3-5	15/100
4 (rough)	16-19	5-8	23/150
5 (very rough)	19-23	8-12	25/200
6 (high)	23-30	12-20	27-300
7 (very high)	30-45	20-40	30/500

Ocean circulation studies in relation to monsoon

The monsoon will be predicted based on the information of the surface wind speeds and current. The microwave remote sensing techniques can be used for obtaining this information.

The SEASAT sensors have been used for this study like and the Altimeter, Scatterometer and radiometers have been used for measurement surface wind speed to an accuracy of 1.2 m/sec. The wind direction can be predicted up to 1.2^0 accuracy. The altimeter can be used to give wave height up to 0.5m. In India the SAMIR payload on BHASKARA Satellite has been used to derive, wind velocities and wind direction.

Thus these instruments can be used, to predict the cyclone as well as monitor the wave height, which will in turn monitor the cyclone.

The future trend will be to develop an ocean general circulation model. The prediction of the ocean surface parameters could be used for modelling the sub-surface processes. An important area of effort would be to understand the relation of the oceanic surface phenomena to the monsoon.

DETERMINATION OF GEOPHYSICAL OCEANIC PARAMETERS BY PASSIVE MICROWAVE RADIOMETRY

Using passive radiometry one can obtain - wind speed, liquid water, water vapour, sea surface temperature, etc. as an input to the forecasting. The efforts to determine the parameters by passive microwave radiometry, mainly on the emissive characteristic of the targets has been going on extensively since NIMBUS.

a) The Scanning Multifrequency Microwave Radiometer (SMMR) onboard NIMBUS-7 and SEASAT has been used extensively for global Sea Surface Temperature mapping.
b) Sea Surface Temperature (SST), atmospheric water vapour, liquid water content etc. were estimated using radiometers at 3.5, 10.6, 22.2 and 37.5 GHz frequencies

The Indian experiments were initiated with the SAMIR (onboard BHASKARA-I & II) and were followed up with the use of SMMR data. Some important results are:

a) Ocean surface wind speed was retrieved from the 19 GHz brightness temperature
b) The brightness temperature from 5AMIR was used for retrieval of atmospheric water vapour and liquid water content over oceans. The retrieved water vapour information was found in good agreement with ground observations under MONEX -79 experiment. Fig 1 shows the SAMIR payload, which was flown onboard BHASKARA satellite.
c) Global SST maps and global wind speed measurements have been

processed using SEASAT -SMMR data. The wind speed is accurate up to 1.5-2.5 m/s in different regions have been estimated.

DETECTION AND MEASUREMENT OF OIL SPILLS OVER OCEANS

One of the major problems in ocean areas is the oil spill from - tankers and ships, from pipelines etc. These spills need' to be detected and monitored not only to maintain a clean ocean environment but also to prevent damage to the coastal land areas.

Microwave backscatters from oil films have shown *its* potential for detection and monitoring of oil spills. Considerable work has been done in this regard. Most of the experiments have been conducted with SLAR/SAR and Scatterometers. Some interesting results are:

a) High incidence angle (near 80°) and multi -polarisation SAR *is* found useful for monitoring oil spills
b) Scatterometers at 13.3 GHz frequency have been used for detecting *oil* spills
c) The extent of oil spill and thickness of oil spill can be monitored using radiometers.

PROPOSED SENSOR COMBINATION

From the literature survey the optimal parameters of the possible combination of sensors with their electrical parameters, which will provide the required information about the oceanic disasters is given in Table 4. These sensors will provide inputs for all those parameters, which are required to be measured for prediction and monitoring of disasters as given in Table 1. The Table 5 also gives the oceanographic parameters and the sensors. In this table the type of sensor required for each parameter is mentioned. The space borne sensors, which have been used for study of oceans and atmosphere dated back to 1968. The space borne microwave remote sensing missions starting from 1968 to till date are listed in Table 6 and 7.

From the Table 4 to 7 one can observe that for different missions there have been typical sensors for different applications and the mission along with the sensors and broad data are given in Table 8. The details of various satellite platforms for microwave remote sensing missions for study of ocean and useful for prediction and monitoring of disasters is given in Table 9. The details of the SEASAT mission are given in Table 10 and Table 11 gives the details of ERS 1 mission.

From the above discussion, it is clear that the sensors for the satellite missions dedicated to prediction and monitoring of oceanic disasters will have to be a package of:

a) An imaging radar – SAR
b) An altimeter
c) A Scatterometer
d) A passive microwave radiometer

The proposed sensor combination for a ocean monitoring satellite (OMSAT) will include the four sensors as given above. These sensors will be able to meet the requirement of prediction and monitoring of the ocean disasters. Initially the first OMSAT mission could be a simple mission using only three microwave sensors like altimeter, Scatterometer and radiometers along with a optical payload for ocean colour monitoring. The Table 12 gives the payload combination for OMSAT-1A. The OMSAT missions required to have combination of all the four microwave sensors and different types of combination for different OMSAT missions is given in Table 13A and 13B. The specification of proposed bus for the OMSAT series of satellites is given in Table 14.

For monitoring and predicting of oceanic disaster, the requirements are for:

a) SAR: The imaging radar is also useful for certain oceanographic and meteorological applications. The suggested specifications are given in Table 15.
b) Altimeter: The Ku-band (13.9 GHz) at 5 Km: resolution and nadir view *is* optimal for all the applications. The broad specifications are given in Table 16 and Fig 2.
c) Scatterometer: The wind Scatterometer is required for two applications under oceanography. The 14 GHz Scatterometer with 25km resolution *is* optimal. A look angle of 25° - 55° with any polarisation is suitable for both the applications. The specifications are given in Table 17. The antenna configuration is given in fig 3.
d) Radiometer: Passive microwave radiometer is an important sensor for oceanographic and meteorologic applications. Multifrequency (at 1.6, 4.0, 6.6, 10.6, 18, 21, 31, 37, 60, 90, 140 & 183 GHz frequency) with about' 10km resolution and like polarisation are optimal for the applications. A look angle of 48° is suitable for most of the applications. Only in the case of oil pollution the resolution requirement is 2km (or better).

The combination of these sensors will need a Spacecraft bus, which will cater to the weight and power requirement of the payloads and housekeeping. The proposed specifications of the spacecraft are given in Table 18. The conceptual OMSAT configuration in given in Fig 4.

CONCLUSION

The oceanic disaster can be predicated and monitored by using microwave remote sensing techniques. The combination of sensors one can predict and monitor the cyclone disaster. IN case of oil spill it is not possible to predict but one can detect the oil spill and keep on monitoring the extent of oil spill as well as the thickness of layer of oil can be monitored. The combination of Radar, Scatterometer, Altimeter and Radiometers can be used for predication and monitoring of cyclonic activities.

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