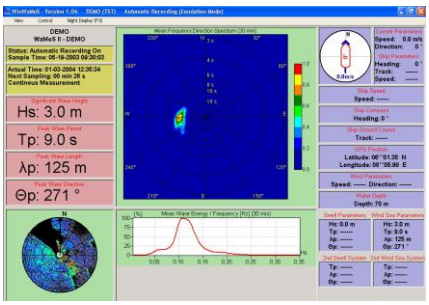
A Technical Description of the WaMoS II Wave Radar System

The WaMoS II, is an operational wave monitoring system for surveying the ocean's wave field. Mounted on a ship, oil rig, or on shore, it is a proven instrument that measures the wave energy, its directions and heights, as well as the speed and direction of surface currents. The system consists of conventional navigational X-band radar connected to a high speed video digitizing device, and a standard PC. The analogue radar video signal is read out and transferred through the digitizing device to the PC for storage and further real time processing. The data can then be viewed immediately, transported by removable media, or viewed on-line by modem/telephone or Internet.



The wave measurements are based upon the backscatter of microwaves from the ocean surface that are visible as 'sea clutter' on nautical radar. From that observable sea clutter, an analysis is carried out to determine the directional wave spectrum and the surface current direction and speed. Sea state parameters such as wave height, periods, lengths, and directions, and surface current speed and direction are measured. Comparisons between in-situ data and the WaMoS II consistently demonstrate strong correlations, and verify the capabilities of the WaMoS II system for measuring absolute wave heights.

The WaMoS II needs a minimum wind speed of about 3 metres/second to provide the wave and current information. Then the system easily detects wave lengths from 20 metres to 600 metres, and wave periods from 5 seconds to 40 seconds.

The WaMoS II has been installed on a range of platforms and ships around the world, and a list of the installations is available upon request. Data sets from some of these installations, many with independent comparisons, are available.

WaMoS II is type approved by the classification societies Det Norske Veritas and Germanischer Lloyd with respect to the accuracy of the data output and functionality. The WaMoS II does not affect the navigational performance of the radar unit from which the data stream is taken, so the radar can be used for both wave measurements and navigational purposes.

The WaMoS II has been purchased by the German French, Canadian, and Chinese navies in order to support ship navigation under harsh weather conditions.

OceanWaveS/Rutter participates in various national and international research projects, and new developments are under continuous independent review. For example, software tools have been developed to detect and measure individual waves to measure bottom topography in shallow seas.

WaMoS II data capture system

For wave and current monitoring purposes the radar requirements are:
(1) A minimum antenna rotation speed of 24 rpm (antenna rotation time: *RPT* < 2.5 s),

(2) A maximum radar pulse length of 80 nsec,
(3) A minimum antenna length of 4ft.

These requirements allow the radar to obtain images with a range resolution of 8.5 metres and an angular resolution of 0.9° every 2.5 seconds. The standard WaMoS II analysis uses a sequence of 32 radar images, so that waves in the range of 0.025 Hz to 0.2 Hz can be detected. This frequency range corresponds to wave periods from 5 seconds to 40 seconds. The operating range of WaMoS varies from 0.1 kilometres to 3 kilometres depending upon the wind speed and the installation height. The minimum wind speed required for operational measurements is 3 metres/second, and the recommended installation height of the radar antenna is from 8 metres to 100 metres above the water, the higher the better.

WaMoS II data processing

In order to infer the wave and surface current information from the sequence of radar images, an inverse modeling technique is applied. This technique can be separated into the following steps:

1. **Image Transformation:** For the data analysis a sub-image of 1 km by 2 km is extracted out of the full polar radar image and transformed into Cartesian coordinates.

2. **Discrete Fourier Transformation:** The sequence of radar sub-images is transformed into a 3-D image spectrum by using a discrete Fourier Transformation.

3. **Surface current determination**: The surface current is obtained by minimizing the distance between the position where the spectral energy is located in the measured 3-D image spectrum, and its theoretical position given by the dispersion relation for linear surface gravity waves.

4. **Filtering the 3-D image spectrum:** The associated ocean wave energy is separated from the background noise by applying the dispersion relation as a band pass filter.

5. **Determination of the 2-D image spectrum**: Integration of the 3-D image spectrum over the positive frequency domain is used to obtain a non-ambiguous directional 2-D image spectrum.

6. **Determination of the 2-D wave spectrum:** Transformation of the 2-D image spectrum into a 2-D wave spectrum is done by using a Modulation Transfer Function (MTF).

7. **Computation of the directional wave spectrum**: Transformation of the 2-D wave spectrum is made from the wave number space into the frequency direction space. From the 2-D wave spectrum all important sea state parameters can be derived in real time.

8. **Estimation of the significant wave height:** Due to the non-linearity of the imaging mechanism of ocean waves, the significant wave height cannot be determined directly from radar images. However, WaMoS II can measure the wave heights by means of an internal calibration, with accuracies of about 80%. To reach an acceptable accuracy of 90% or better, a different method is recommended. The basic idea of this method is to relate the measured signal-to-noise ratio (*SNR*) linearly with the significant wave height

$$H_s = A + B\sqrt{SNR}$$

of the observed wave field. Therefore, for an initial period the wave heights of an independent in situ sensor or numerical wave model are required. Applying this relation to the WaMoS II data H_s is given by:

Where *A* and *B* are calibration constants derived from the radar installation. The calibration constants are determined within a short calibration period (1-2 windy days) by means of a least squares method, and leads to high level of accuracy.

The table gives the names and symbols of the major sea state parameters and the corresponding ranges and accuracies provided by a standard WaMoS II. The numbers are derived from direct comparisons between a WaMoS II and independent in situ sensors (downward looking laser or wave buoy).

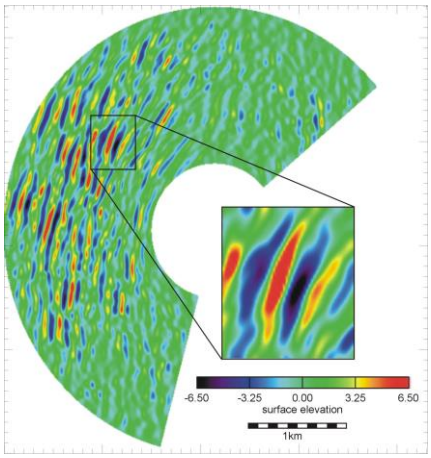
Name	Symbol	Range	Accuracy
2-D wave number spectrum	$\boldsymbol{E}^{(2)}(k_x,k_y)$	-	-
2-D frequency direction spectrum	$\boldsymbol{E}^{(2)}(f,\theta)$	0.025-0.21 Hz, 0-360°	-
1-D frequency spectrum	$S(f)$	0.025-0.21 Hz	-
Significant wave height	Hs	Above 0.5m	+/- 10%
Mean period	T_{m02}	4 - 20 s	+/- 0.5 s
Peak period	T_p	4 - 20 s	+/- 0.5 s
Mean wave direction	$\theta(f)$	0 - 360°	+/- 2°
Peak direction	θ_p	0 - 360°	+/- 2°
Integrated wave spreading	Spr	0 - 90°	-
Peak wave length	λ_p	40 - 600 m	-
1st peak period	T_{p1}	5-40s	+/- 0.5 s
1st peak wave length	λ_{p1}	40 - 600 m	-
1st Peak direction	θ_p	0-360°	+/- 2°
2nd peak period	T_{p2}	5-40 s	+/- 0.5 s
2nd peak wave length	λ_{p2}	40-600 m	-
2nd peak direction	θ_p	0-360°	+/- 2°
Surface current velocity	U	0-20 ms^{-1}	+/-0.2 ms^{-1}
Surface current direction	θ_U	0-360°	+/- 2°

Sea state plays a very great role in the performance of ships at sea, however measurement of wave height, speed, and direction is often made by purely observational means. This method is notoriously inaccurate, especially at night, in conditions of reduced visibility, or where observer is under stress. The WaMoS wave radar system is unique in that, for the first time, an accurate, and real time measure can be made of sea state while a vessel is underway. Areas where this knowledge of sea state are essential include:

- Evaluation of vessel performance, particularly new or experimental vessels, during ship trials. The system has been bought by several Korean shipyards for this purpose.

- Vessel management activities such as
  1. Determining safe limits for helicopter and flight deck operations.
  2. Determining safe limits for deployment and retrieval of small vessels such as RIB's.
  3. Optimizing inter-ship transfer of materiel.
  4. Determining safe limits for exposing personnel to on-deck operations.
  5. Establishing SOP's for firing ordinance in higher sea states.
  6. Determining the safe limits for vessel maneuvers, and to minimize hull stress, slamming, and rolling.

- Learn more about open ocean conditions including the occurrence and frequency of "rogue waves", as well as ground-truthing wave models.



For more information about WaMoS II, contact:
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