Verification of Ensemble Ocean Wave Prediction using Ensemble Weather Prediction Results

Background

Ocean wave predictions play an important role for the management of harbor constructions, ship navigations, and fuel loading and unloading. In the conventional method, ocean waves are predicted by a numerical ocean model with surface wind fields, which are estimated by a weather prediction model with deterministic initial atmospheric conditions, although it is difficult to know the whole atmospheric state accurately. Recently, it is recognized that small initial condition errors grow in the model atmosphere and contaminate the predictions. In order to consider such a chaotic system, ensemble weather predictions are expected to improve the accuracy of medium-range forecasts. In the ensemble system, a weather model is integrated a number of times, starting from slightly perturbed initial conditions (say, dozens of ensemble members), and each member produces a different weather scenario. In a similar way, the ensemble ocean wave predictions are expected to improve the accuracy because the ocean wave predictions are strongly affected by the input wind fields. In the ensemble approach, it is very important to extract useful information (ex. the probability density function (PDF)) from prediction results because we get a lot of outputs from an ensemble system.

Objectives

To examine the accuracy and the efficiency of the ensemble ocean wave prediction method. We also aimed to show the estimation method of the PDF of the predicted ocean wave heights.

Principal Results

Ensemble ocean wave predictions were carried out with each wind fields of 25 ensemble members, which were provided from the Japan Meteorological Agency (JMA) ensemble weather system. The calculated area was the west part of the North Pacific Ocean (115~165E, 10~160N). Four-day predictions were performed every day with an initial condition at 21: 00 (local time) during four months (from Mar. to June, 2001).

1. Ocean wave reproduction

Firstly, we reproduced the ocean wave fields with the objective analysis wind fields during the four months. The wave results showed a good agreement with wave gauge observations (Fig-1). The reproduced ocean wave fields were used as the reference to examine the accuracy of the ensemble wave prediction.

2. Prediction errors and accuracy

The standard deviations (SD) of the wave heights of ensemble members showed a good correlation with wave height prediction errors. That meant that the prediction error can be estimated from the SD of wave heights in advance. We verified the accuracy of the probabilistic forecasts by using several scoring measures, and showed that ensemble ocean wave predictions improved the prediction probability of 25~30% (Fig-2).

3. PDF estimation

We showed that the wave heights PDF of ensemble members were well approximated by Weibull distribution.

Future Developments

We will verify the efficiency of the ensemble predictions as a case study of a harbor construction management.

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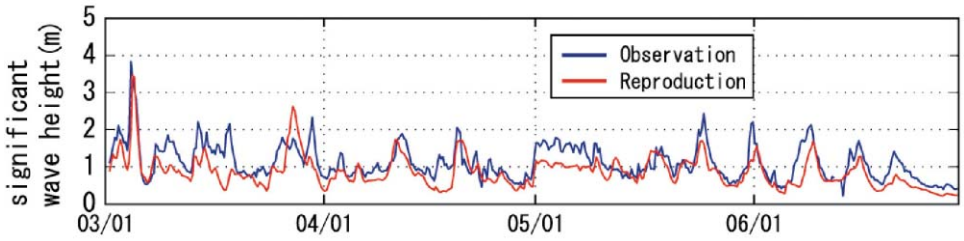
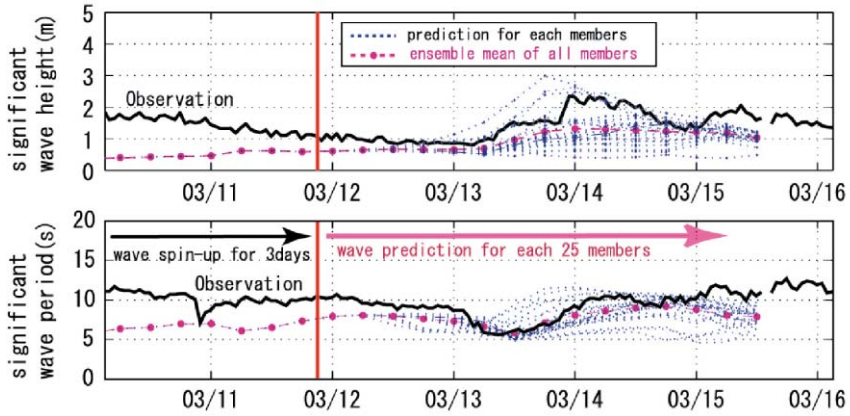
Reference

Mori N. and H. Hirakuchi, 2003, “Verification of Ensemble Ocean Wave Prediction using Ensemble Weather Prediction System”, Abiko Research Lab. Rep. No. U03017, P.28



(a) Comparison of significant wave heights between wave gauge observation and the reproduction with weather objective analysis (March to June; 4 months)



(b) predicted results for each 25 members, ensemble mean, and wave gauge observation
（upper： significant wave height (m), lower： significant wave period (s)）

Fig.1 Comparison between wave gauge observation and predictions.

The horizontal grid size of the ocean wave model is 0.5deg （about 55km）.
(a) The blue line shows the wave heights observed at a Japanese coast. The red line shows the reproduced wave heights driven by the wave model with wind fields of JMA weather objective analysis. These results show good agreement, and the correlation of them is about 0.85.
(b) The thick black line is the observation, the dotted blue lines are predicted results for each of 25 members, the red line with red circles is the ensemble mean of all members. The initial time of these predictions is 21:00, 11th Mar., 2001. Before starting the prediction, we ran the model with the objective analysis wind fields for three days to reproduce the initial wave fields (for wave spin up).

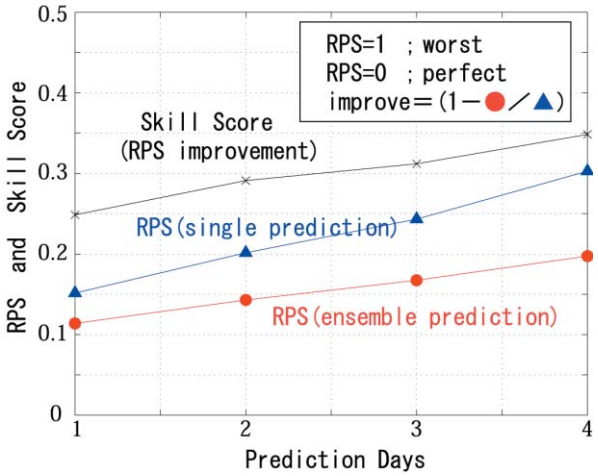


Fig.2 Ranked Probability Score (RPS) and Skill Score of RPS

Forecast verifications are examined from the Ranked Probability Score (RPS) which is defined by the mean value of Brier score for the multiple category. The Brier Score is the quadratic scoring measure (= E[(p-X)**2]) for thequantitative evaluation of probabilistic forecasts, where E is the expectation, p is theforecast probability of the occurrence of the event, and X is a value equal to 1 or 0 depending on whether the event occurred or not. Fig-2 shows RPS with 6 ranked category (0<1<2<3<4<5 m of wave heights).
The RPS values of ensemble prediction(●) is smaller than that of the conventional single prediction(▲), which means that the ensemble prediction shows better performance than the single prediction. The RPS skill score (×) shows that the ensemble method improves the forecast probability by 25～35% over the single prediction, and is effective for medium prediction range.