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REPORT OF THE WORKSHOP ON

# ASSIMILATION OF SATELLITE WIND AND WAVE DATA IN NUMERICAL WEATHER AND WAVE PREDICTION MODELS

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# Report

## of workshop on assimilation of satellite wind and wave data in numerical weather and wave prediction models

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## B4 Data assimilation in wave models

K. Hasselmann

In contrast to atmospheric data assimilation, no systematic investigations have yet been carried out on operational methods for assimilating wave data in wave models.

Komen (1986) has demonstrated in one case of a swell forecast for the Dutch coast the striking improvement which can be achieved by updating the model forecast with swell observed some distance off shore. Cardone (1985) has similarly applied a mix of subjective and objective updating techniques, using in situ wave measurements, to update fixed site wave forecasts. In operational wave forecasting it is also common practice to subjectively modify model forecasts on the basis of wave observations. A wave data assimilation experiment with SEASAT altimeter wave height data has recently been carried out by Esteva (1986) (see also Appendix B8). However, the translation of these methods into routine objective data analysis and assimilation techniques is a task which has still to be addressed.

The wave data assimilation problem differs in some important aspects from the problem of assimilating atmospheric data:

1. The assimilation of wave observations in a wave model can provide a useful improvement of the forecast, but is not essential. A wave model can be operated stably using only observed and forecast surface winds as external driving field. For predicted wind fields of finite error, the error in the wave field remains limited and does not grow with time.

2. Since the wave model is externally driven by the wind field, it requires no initialization cycle. Thus no additional problems are created by introducing the wave observations into the model continuously in time rather than only at certain 'synoptic' times.

3. The 'region of influence' of a given wave observation cannot be specified a priori, but is a dynamic variable which depends in general on the state of the sea and the frequency and propagation directions of the individual spectral components. Swell components from a distant storm have lateral and longitudinal correlation scales which grow linearly with the distance the swell has travelled from the storm (cf. Fig. 1 and SWAMP, 1985). On the other hand, the correlation scales of a local windsea which has had time to adjust to a quasi-equilibrium form (cf. Hasselmann et al., 1976) is governed by the scale of the wind field. To properly account for these different dynamical regimes in the data assimilation cycle, a wave model would need to keep track of the wave age (or some equivalent variable) of the individual spectral components (cf. Fig. 2).

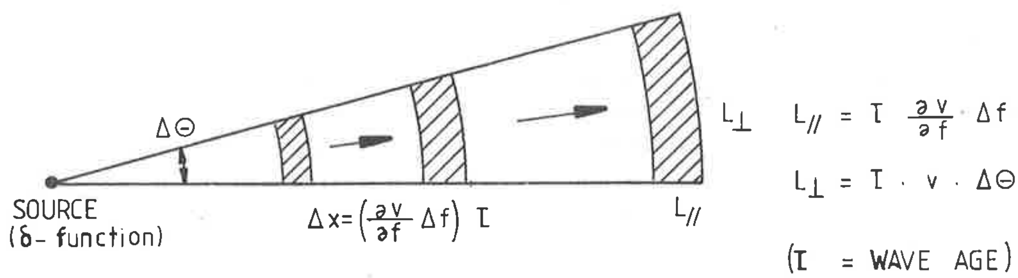


Fig. 1: Distant swell limit of representative region of a wave spectrum measurement of given frequency and directional resolution $\Delta f$, $\Delta\theta$, respectively (for a well developed local windsea, $L_{\|} \sim L_{\perp} \sim$ wind field scale).

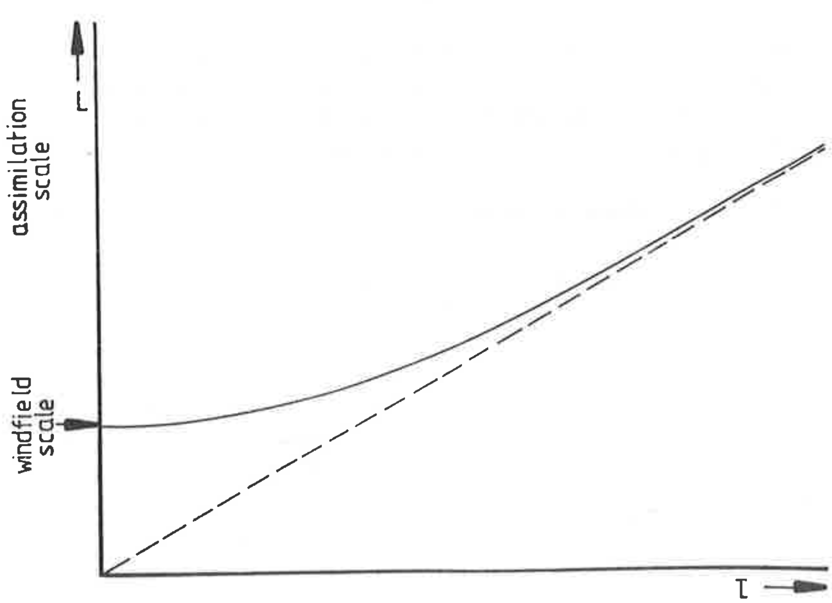


Fig. 2: Schematic dependence of spatial scale $L$ ($L_{\perp}$ or $L_{\|}$) of region of influence of a wave measurement on wave age $\tau$.

4. Ideally, an update of the wave model forecast with wave observations should not be limited to the wave field. Discrepancies between predicted and observed wave data imply errors in the wind field which generated the waves. Depending on the wave age, the relevant wind errors can have occurred a few hours or several weeks in the past. The invertion of wave observations into wind information, and the insertion of this information into an atmospheric data assimilation and analysis cycle, poses a challenging problem.

5. Wave models predict the two-dimensional (frequency direction) wave spectrum at each grid point. However, wave measurements normally do not yield the full 2d spectrum, but some subset of variables, such as the 1d frequency spectrum or the significant wave height. A satellite SAR yields a 2d image spectrum, but this is nonlinearly related to the 2d wave spectrum, and the mapping parameters depend moreover on the local wind velocity (cf. Hasselmann et al., 1985). Thus the reconstruction of an optimally estimated 2d wave spectrum from observations at a given measurement site normally requires a first guess input spectrum from the wave model. In the case of SAR data, an input wind field is also required. The required wave data assimilation system must therefore be of the structure indicated in Fig. 3, in which the sensor algorithms are fully integrated into the wind and wave analyses and assimilation cycle.

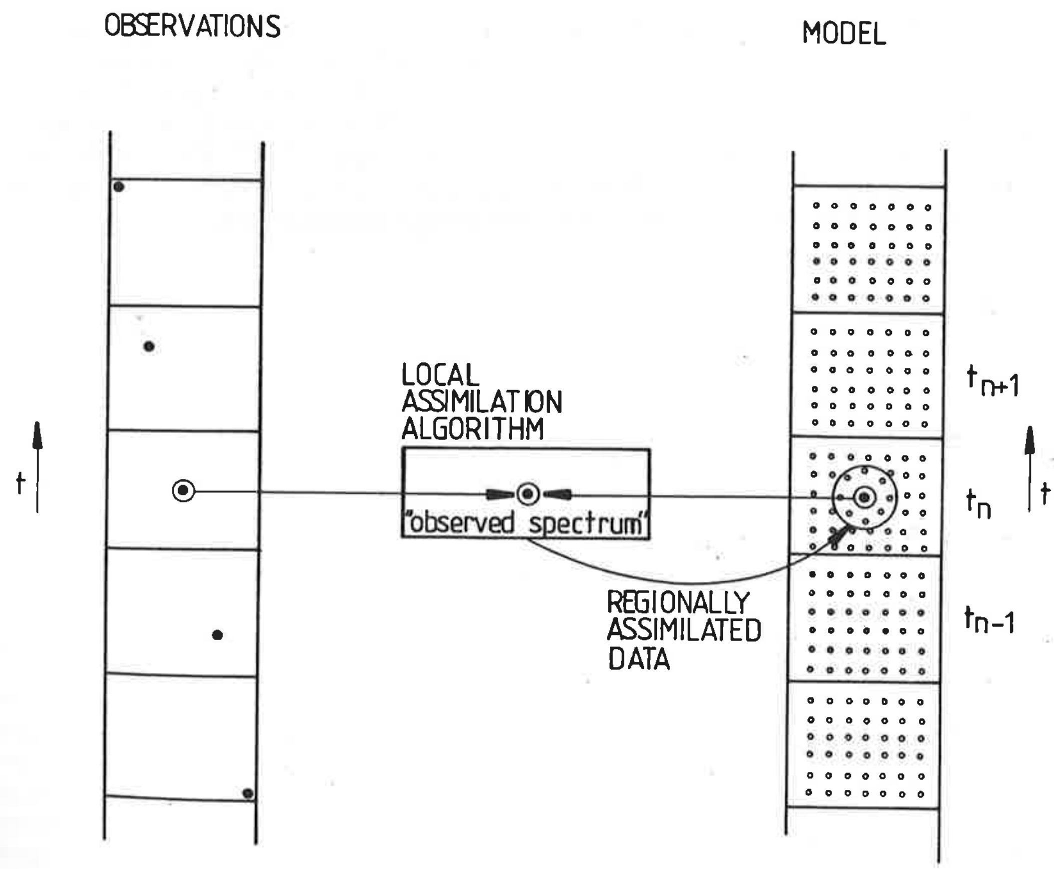


Fig. 3: Data flow for wave data assimilation system. At each time step, model data is required to construct the best guess 'observed spectrum' from the (incomplete) wave observation. The observed spectrum is then regionally 'scattered' as it is assimilated in the model.

The development of a completely objective wave data assimilation system will clearly require considerable research effort. The SEASAT data should provide an invaluable test data set for gaining experience in these techniques.

## References


Cardone, V.J., 1985: The present status of operational wave forecasting. Symposium on measuring ocean waves from space, Johns Hopkins, Baltimore, April 15 - 17, 1986 (to be published).

Esteva, D.C., 1986: Assimilation of significant wave height estimates into wave model. (to be published - Abstract in AGU Spring Meeting 1986).

Hasselmann, K., D.B.Ross, P. Müller, and W. Sell, 1976: A parametric wave prediction model. J.Phys.Oceanography, 6, 200 - 228.

Hasselmann, K.,R.K. Raney, W.J. Plant, W. Alpers, R.A. Shuchman, D.R. Lyzenga, C.L. Rufenach, and M.J. Tucker, 1985: Theory of SAR ocean wave imaging: A MARSEN view. J.Geophys.Res., 90, 4659 - 4686.

Komen, G.J., 1985: Introduction to wave model and assimilation of satellite data in wave models. Conference on the use of satellite data in wave models, Alpbach, Austria, 10 - 12 June, 1985, ESA SP-44, pp. 21 - 26.

The SWAMP group: J.H. Allender, T.P. Barnett, L. Bertotti, J. Bruinsma, V.J. Cardone, L. Cavaleri, J. Ephraums, B. Golding, A. Greenwood, J. Guddal, H. Günther, K. Hasselmann, S. Hasselmann, P. Joseph, S. Kawai, G.J. Komen, L. Lawson, H. Linné, R.B. Long, M. Lybanon, E. Maeland, W Rosenthal, Y. Toba, T. Uji, and W.J.P. de Voogt, 1985: Ocean Wave Modeling, Part 1: The Sea Wave Modelling Project (SWAMP). Principal results and conclusions. Plenum Publishing Corporation.