ASSIMILATION OF OBSERVATIONS INTO COASTAL AND NEARSHORE CIRCULATION MODELS

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Award: N00014-93-C-0047

LONG-TERM GOALS

Enhance forecasting capabilities of circulation models through the development of assimilation technologies and associated parameters for observations of nearshore processes important to coastal regions.

OBJECTIVES

Develop an assimilation capability for fields of surface currents from Doppler radar systems. Continue the investigation and testing of an assimilation capability for surface wave effects. Use observations of coastal and shelf parameters to determine spatial decorrelation scales. Ascertain changes in these scales when determined from fields from prognostic simulations of a fine-scale, regional model. Aid in the testing of a scheme for producing fields of oceanographic variables from disparate data.

APPROACH

Data Assimilation for Doppler Radar Currents: An approach was taken in which the Doppler radar current data acted as if there were an additional layer of water overlying the ocean surface. A pseudo-shearing stress resulting from the difference between the model-predicted velocity and the Doppler radar velocity at a given grid cell was added to that of the wind in order to force a model. The assimilation scheme was optimized in a fashion to minimize the added shearing stress at a given grid cell while still producing the same overall work throughout all the grid cells. Tests were performed using observations and a model of the Monterey Bay region.

Data Assimilation of Multiple Wave Effects: Further research was conducted into wave-generated, wave-average flow fields, and an existing assimilation scheme was enhanced to include wave dissipation effects. Additional test simulations were performed to compare with information from the literature and to determine the impact of multiple wave effects on nearshore circulation.

Decorrelation Scales for Salinity and Temperature: Data sets of salinity and temperature (S and T) for five levels in the vertical were obtained from the Chinese for the Yellow Sea. These data were used to calculate the decorrelation scales for T and S at the surface of the water column, at 20-25 m, and at 45-50 m. Decorrelation scales were determined for all the observations, data in a longshore direction, and data in the cross-shelf direction.

WORK COMPLETED

Report Documentation Page

Form Approved
OMB No. 0704-0188

1. REPORT DATE **30 SEP 1997**	2. REPORT TYPE	3. DATES COVERED **00-00-1997 to 00-00-1997**

4. TITLE AND SUBTITLE **Assimilation of Observations into Coastal and Nearshore Circulation Models**	5a. CONTRACT NUMBER
	5b. GRANT NUMBER
	5c. PROGRAM ELEMENT NUMBER
6. AUTHOR(S)	5d. PROJECT NUMBER
	5e. TASK NUMBER
	5f. WORK UNIT NUMBER
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) **HydroQual, Inc,1 Lethbridge Plaza,Mahwah,NJ,07430**	8. PERFORMING ORGANIZATION REPORT NUMBER
9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)	10. SPONSOR/MONITOR’S ACRONYM(S)
	11. SPONSOR/MONITOR’S REPORT NUMBER(S)

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public release; distribution unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT

15. SUBJECT TERMS

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
a. REPORT **unclassified**	b. ABSTRACT **unclassified**	c. THIS PAGE **unclassified**	**Same as Report (SAR)**	**5**	

Doppler Radar Assimilation: A high resolution regional model was developed for the Monterey Bay region, Doppler radar currents were obtained that covered the model domain, and tests simulations were performed to assess different schemes for assimilating the observed currents into the model. A journal paper was generated based on the results.

Assimilation of Wave Effects: Based on comments of individuals in the wave research community, the existing model with wave assimilation was modified to include wave dissipation but exclude the advective fluxes of momentum due to Stokes drift. Test simulations were conducted to assess the impact of such changes, and a paper was generated describing the results.

Decorrelation Scales: Scales of variations were considered for the Louisiana-Texas (LATEX) shelf and the Yellow Sea. Scales of variability were determined for the LATEX shelf, and e-folding spatial scales for late summer were calculated for salinity and temperature at depths down to 50 m for the Yellow Sea. A high resolution regional model for the Yellow Sea was developed and calibrated based on observed currents and tidal elevations.

Table 1. Root mean square differences (cm/s) for a 210 hr period during August 1994 between model-predicted and observed Doppler currents for three stations in the Monterey Bay region.

	Station W		Station C		Station E	
	East-West	North-South	East-West	North-South	East-West	North-South
No Assimilation of Doppler Currents	15.6	28.8	14.4	16.0	20.4	16.6
Non-Optimized Assimilation	13.4	18.5	11.5	12.7	15.8	11.0
Optimized Assimil.,	12.7	18.3	10.6	12.2	15.6	10.3

RESULTS

Doppler Currents: The rms differences shown in Table 1 indicate that the assimilation technique allows the model to reproduce the trends and variations of the Doppler current data. The results show that the optimization approach results in a more gentle nudge of the model toward the Doppler currents with a much reduced stress level when compared to a non-optimized assimilation technique. However, Table 1 also indicates that there are still some significant differences between the Doppler currents and the model surface currents. Further investigation suggests that errors in the Doppler current data may be the primary reason that the model does not better respond to the continuous assimilation of the Doppler data. The divergence of two adjacent grid cells in the model based only on the Doppler currents indicate highly variable and large divergences and convergences. These results suggest the additional processing of HF Doppler current data so as to further minimize errors in such data and to make the data more useful for various applications (Eremeev et al., 1992a, 1992b). Work concerning this is being pursued with those at Old Dominion University.

Assimilation of Wave Effects: Our results point that the most critical factor for including wave effects is the specification of viscous effects associated with surface wave dissipation. The vertical viscous effects as determined by the Mellor-Yamada turbulence closure scheme reflect vertical shearing viscosities on the spatial and temporal scales of geophysical fluid dynamics, but such viscosities are shown to be far too large for viscous effects for wave source terms in the momentum equations. Our tests show that wave-related viscosities might be determined in many cases by an appropriate scaling of the Mellor-Yamada viscosities. But for breaking waves, a totally different turbulent closure scheme might need to be developed for assessing wave-related viscosities. Data show that the Reynold's stress in water under breaking waves has relatively large values at the very surface of the water column. This suggests a non-parabolic-like structure of eddy viscosity under breaking waves, unlike that given by the Mellor-Yamada and similar schemes.

Another factor for circulation models with wave effects is the inclusion of the Stokes drift in the appropriate terms in the momentum equations. The results of certain shallow-water simulations with unreasonable results were found to be the result of excluding Stokes drift in the non-linear advective terms in the momentum equations (following the conventions of the wave research community). However, there is a precedent for considering such effects of Stokes drift: the impact of Stokes drift in the non-linear advective of momentum has been used for decades in the study of Langmuir circulation. In most situations, we would not expect the lateral variations of the Stokes drift to have much of an impact on the horizontal flux of momentum. But the exceptions are those situations in which the Stokes drift induces a balancing flow, and we have found that it is very important to include Stokes drift in the non-linear advective terms to obtain reasonable predictions of the wave-averaged flow field.

Decorrelation Scales: The scales of variability over the LATEX shelf show distinct cross-shelf and longshore differences, with longshore scales being considerable longer during most times of the year. Scales and changes in scales can be related to seasonal variations of forcing. Decorrelation scales for the Yellow Sea are more complex due to the basin-like character of the Yellow Sea and the large fluxes of freshwater in the basin. Spatial scales for August are shown in Fig. 1. There are distinct variations with depth, and there are considerable differences between the scales for T and S. For shallow water, we would expect decorrelation scales to be longer in the longshore direction and shorter in the cross-shelf direction. This is true for salinities in the Yellow Sea, but just the opposite is true for temperature.

IMPACT/APPLICATIONS

We now have a means for ingesting Doppler radar currents into models, but we have also shown that further processing of the radar currents needs to be performed. The amplitudes and variations of Doppler radar currents can be very erroneous, with the magnitudes of errors at times the order of the currents. Work with those at ODU has generated a technology that can be included in Doppler systems to further process the data to provide more reasonable current fields.

The model with the major wave effects is the first of its kind, and interest expressed by researchers and engineers has been widespread. Wave-related flow in coastal regions is very important, and this model and others based on its dynamics will likely become a standard in the near future.

The nearshore, shallow-water, decorrelation scales are seen to be very different from those in deeper water. Knowledge of the variability in depth and in longshore versus cross-shelf directions will aid developers of assimilation techniques for coastal areas in generating schemes applicable to these shallow-water regions.

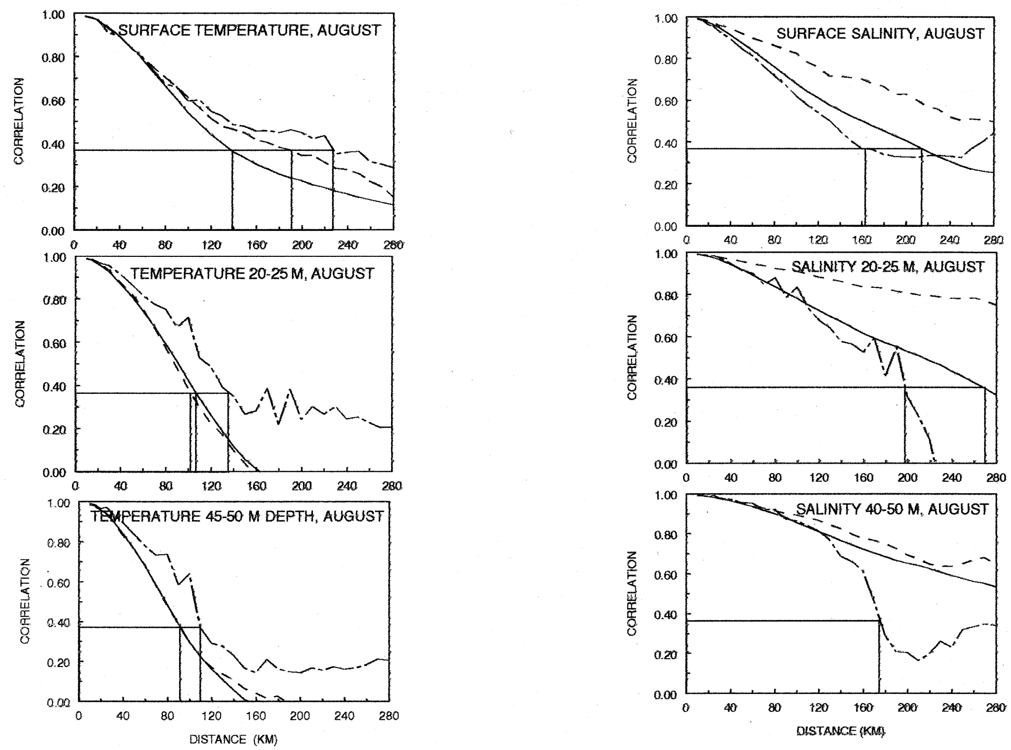

Fig. 1. Spatial correlations in the Yellow Sea based on data for August. Horizontal and vertical lines represent decorrelation scales in terms of e^{-1}. Solid line - all data; dashed line - data from longshore transects; dashed-dot line - data from cross-shelf transects.

TRANSITIONS

None to data.

RELATED PROJECTS

The following individuals have worked with us on the above research through related projects at their own institutions: 1. Optimization schemes for the assimilation of observations at open boundaries (as applied to the Monterey Bay and Yellow Sea regional models): Dr. Igor Shulman, USM. 2. Development of data reconstruction methods based on disparate observations (post processing of Doppler radar currents): Dr. A. D. Kirwan, ODU. 3. Numerical simulations of physical processes within the Monterey Bay region (application of the Monterey Bay regional model): Dr. J. Paduan, NPGS. 4. Current, wind, and temperature observations in the Yellow Sea (for verifying the Yellow Sea model): Dr. G. Caille, Ga. Tech. Univ.

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