Delft University of Technology
Department of Civil Engineering
Group of Fluid Mechanics

# Transfer of ocean modelling capability to two scientists of the National Institute of Oceanography of India

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| PROJECT REPORT | Delft University of Technology<br>Department of Civil Engineering<br>Group of Fluid Mechanics |
| Project title | NORAD IND-013 |
| Project description | Transfer of ocean modelling capability to the National Institute of Oceanography of India |
| Customer | Ship Research Institute of Norway<br>Marine Technology Centre<br>Trondheim, Norway |
| represented by | O.G. Houmb |
| Project leader | dr. L.H. Holthuijsen |
| work carried out by | dr. L.H. Holthuijsen<br>dr. N. Booij |
| Conclusion | Two scientists from the National Institute of Oceanography of India have been trained to use the storm surge model DUCHESS and the wave model DOLPHIN. The results are published separately in two reports. |
| Status of report | progress report |
| City/date: | Delft, March 20, 1985 |

Contents

## 1. Introduction

In the framework of the NORAD-INDO13 project, two scientists of the National Institute of Oceanography of India (NIO) visited the Delft University of Technology during a period of 3½ months (October 16th, 1984 to February 28, 1985). The objective of this visit was to transfer know-how on numerical ocean modelling to NIO and to familiarize these scientists with the operation of two models. These are the numerical storm surge/tide model DUCHESS and the numerical wave model DOLPHIN. Both models have been developed at the Delft University of Technology.

The two NIO scientists were dr. N. Bahulayan from the Physical Oceanography Department, who studied the storm surge/tide model DUCHESS and mr. S. Mandal from the Ocean Engineering Department, who studied the wave model DOLPHIN.

The activities mentioned above were more extensive than originally planned. Firstly, the documentation on the models which was sent to NIO to prepare the scientists had been misplaced sothat the NIO scientists were not prepared to the expected level. In addition one of the scientists was designated to this study at a very late moment (due to unforeseen circumstances). This implied a more extensive training program than foreseen. Secondly, more model development was required than foreseen since it was decided during the scientists' visit to
(a) develop a parametric hurricane wind field model
(b) attempt to finalize the experimental phase of the wave model and
(c) include shallow water effects in the wave model.
Objective (a) was fully attained, objective (b) was achieved to a very large extent and objective (c) was achieved but the modifications were not tested. In addition, bathymetries of the Arabian Sea and of the Bay of Bengal were digitized.

## 2. Planning and activities

The visit of the two scientists has been very successful in the sense that know-how has been transferred to a larger extent than planned.

The stay of the NIO scientists was originally planned to be 3 months (Houmb et al., 1982). This planning was changed to 2½ months to give the NIO scientist the opportunity to implement the DUCHESS and DOLPHIN models on the ND 540 computer of the OCEANOR company in Norway. This computer is, from an operations point of view, identical to the ND 520 computer at NIO transferred under this NORAD-IND013 program.

This planning proved to be too optimistic because

1. the reduction of 3 months duration to 2½ months was not based on a reduced work load,
2. an extensive programming and digitization effort was added to the planned work load and
3. the period included a holiday period (Christmas and New Year of 1984/1985)

The one-month extension from 2½ months to 3½ months gave the opportunity to the NIO scientists to successfully conclude their training at the Delft University of Technology.

## 3. Transfer of ocean wave model

### 3.1 Preparation

The scientist from NIO who was assigned to the wave model transfer (mr. S. Mandal) was provided with the text of two basic courses in wave theory:

(a) Short wave theory by J.A. Battjes

(b) Ocean wave theory by L.H. Holthuijsen

These courses are given at the International Institute of Hydraulic and Sanitary Engineering in Delft. They are roughly equivalent to the courses on ocean waves given at the Delft University of Technology.

In addition to this basic training this NIO scientist studied the system documentation of the wave model DOLPHIN extensively. This documentation refers to a number of key references in the literature on wave forecasting which were also studied by him.

This scientist reviewed the subject matter in his report (Mandal, 1985).

### 3.2 Model development

The numerical wave model DOLPHIN was implemented at the Delft University of Technology as an experimental model when this scientist started his training at the University. The model had previously been tested extensively as regards its propagation characteristics but the generation and dissipation aspects were not fully tested.

The DOLPHIN model was put through a large number of test by this scientist to study the wave generation and dissipation characteristics. This testing program resulted occasionally in a reprogramming of the model either because some numerical errors were found or because some processes were considered too expensive in terms of computer effort. In addition a number of small coding errors were found and corrected.

Finally, the DOLPIN model was used by this scientist to run the academic test cases of the SWAMP study (Allender et al., 1981). This study has been carried out by an international group of wave modellers who have agreed on a number of hypothetical geographical situations in which waves were forecasted to obtain an intercomparison between various wave models (10 models in total). These are all deep water test cases. The DOLPHIN model was put through the same cases except the hurricane test which would have required additional time in the training program of this scientist. The results of the tests with the DOLPHIN model agree well with the results of the other models. They are described in this scientists report (Mandal, 1985).

Input data for a severe storm on the North Sea were released by the British Meteorological Office in Brackwell (U.K.) and studied by this scientist. Initial trials were run with this storm but they were not completed.

### 3.3 Items transferred

The items transferred to this scientist are

a. soft-ware of the DOLPHIN model
   - system documentation
   - main program with sample problem
   - subroutines (deep water version)
   - subroutines (shallow water version)

b. data for severe North Sea storm
   - geography of North Sea and NE North Atlantic
   - wind history over 80 hours*
   - wave observations*

c. copies of about 70 publications and reports pertinent to ocean wave predictions, including the SWAMP report (see Appendix).

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* transferred under the condition that these data will be used only for academic purposes and that in any publication using these data the source should be acknowleged (British Meteorological Office).

## 4. Transfer of storm surge model

### 4.1 Preparation

The scientist from NIO who was assigned to the storm surge model transfer (Dr. N. Bahulayan) had good knowledge of the shallow water equation and had previous experience with explicit numerical models of that equation. He was provided with the following material:

(a) program documentation of the DUCHESS program, containing also the equations used in the model;

(b) user documentation of DUCHESS;

(c) source text of DUCHESS (Fortran 77).

The NIO scientist concentrated on the following subjects:

- implicit computing technique,
- input procedures,
- error handling procedures.

The subject matter is reviewed in the report (Bahulayan, 1985).

### 4.2 Model development

The DUCHESS model is an operational model, so only minor changes were necessary in view of the experience gained during the transfer period. A few corrections were made, and an echo of the bottom levels read by the program, in order to facilitate debugging of the input.

A separate model was built by the NIO scientist and the second author in order to provide DUCHESS with wind data. It is a model that transforms time dependent cyclone parameters into wind stress fields. Due to some misunderstanding concerning DUCHESS air pressure fields are not generated by the cyclone model, but that can easily be improved later on.

After some initial tests with artificial data a first test with a real situation was done with a very coarse model of the North Sea. As the results showed, the model provided realistic values in the North Sea except and near the Straits of Dover, which is due to the coarseness of the grid. Boundary conditions and bathymetry were taken from a model kindly provided by the Rijkswaterstaat (Netherlands Public Works Department). The tests showed that the transfer of wind stress fields from the cyclone model worked correctly.

Using the maps mentioned in appendix II bottom grids were prepared for the Arabian Sea and the Bay of Bengal. Boundary conditions were taken from Schwiderski (1979). Dr. Gerritsen of the Delft Hydraulics Laboratory helped in using the Schwiderski tables. It appeared that the tides computed by DUCHESS using the above data were in good agreement with Schwiderski's data. The models, both with mesh size of a half degree were somewhat too coarse to get good results with the cyclones. The tight training schedule did not permit a discretization of finer models.

It was originally planned to test the nesting procedure available in DUCHESS for a region along the west coast of India, but this was also cancelled due to lack of time.

The results are described in Bahylayan (1985).

## 4.3 Items transferred

The items transferred to this scientist are:

(a) the DUCHESS model:
  - program documentation
  - user documentation
  - source text

(b) cyclone model
  - documentation
  - source text

(c) copies of a few publications and part of Schwiderski's report (kindly provided by Delft Hydraulics Lab.).

## 5. Computer operations

The model development and testing took place on the Amdahl 470V/7-B of the Delft University of Technology. Communication with the computer was through CRT-terminals using the VSPC-system (virtual storage personal computing) and with IBM job control. The program coding was mostly in FORTRAN IV and in FORTRAN '77. Training in computer operations was short thanks to the basic experience of the scientists. Coding training was not required since the scientists are proficient in FORTRAN.

Transfer of the DOLPHIN model and the DUCHESS model to the ND 520 computer of NIO was discussed between mr. Lonseth of OCEANOR (Norway), the NIO scientists and the present authors.

## 6. References


Allender, J.H. et al. (1981), "Sea wave modelling project (SWAMP)", Proc. Symposium on Wave Dynamics and Radio Probing of the Ocean Surface, Miami, 1981, Plenum Press.

Bahulayan, N. (1985), "Numerical experiments on tides and surges with DUCHESS model", Delft University of Technology, Department of Civil Engineering, Group of Fluid Mechanics, Rep. No. 2-85.

Houmb, O.G. et al. (1982), "Report from trip to India in November 1982", IND013.

Mandal, S. (1985), "A numerical wave prediction model DOLPHIN: theory and test results", Delft University of Technology, Department of Civil Engineering, Group of Fluid Mechanics, Rep. No. 3-85.

Schwiderski, E.W. (1979), "Global Ocean tides, Part I, 'Semilinear principal lunar tides (M2)', Atlas of tidal charts and maps", NSWC TR79-419. Naval Surface Weapons Centre, K05, Dahlgrun, Virginia, 22448.

Appendix I

Copies of the following publications and reports were transferred to the National Institute of Oceanography of India in Goa.

1. 'Ocean Wave Theory' - IHE lecture notes, by L.H. Holthuijsen (1982).
2. 'GONO, A coupled hybrid wave prediction model', by Janssen et al. (1983).
3. 'SWAMP-1982', Part 1 and Part 2.
4. 'A parameteric wave prediction model', by Hasselmann et al. (1976).
5. 'A spectral model of tropical cyclone wind waves', by R.J. Sobey and I.R. Young (1982).
6. 'State-of-the-art wave prediction methods and data requirements', by V.J. Gardone and D.B. Ross (1979).
7. 'An engineers review of wave forecasting and hindcasting techniques', by L.H. Holthuijsen, (1983).
8. 'A wind waves prediction model in the Adriatic Sea', by L. Cavaleri and P.M. Rizzoli, (1977).
9. 'A wave prediction system for real time sea state forecasting' by B. Golding, (1982).
10. 'Wind wave prediction in shallow water: Theory and applications', by L. Cavaleri and P.M. Rizzoli, (1981).
11. 'Buoy observation of directional wave parameters', by A.J. Kuik and L.H. Holthuijsen, (1981).
12. 'Short and long wave directional spectra', by S.E. Sand, (1981).
13. 'Directional spectra of ocean waves in generation area', by H. Mitsyasu, (1981).
14. 'The synthesis of directional wave spectra', by N. Hogben, (1981).
15. 'Directional wave spectra observed during JONSWAP 1973', by Hasselmann et al. (1980).
16. 'Depth limited significant wave height: A Spectral Approach', by C.L. Vincent, (1982).
17. 'Measurements of wind-wave growth and swell decay during the Joint North Sea Wave Project (JONSWAP)', by K. Hasselmann et al. (1973).
18. 'A hybrid parametrical wave prediction model', by Gunther et al. (1978).
19. 'Application of the parametrical wave prediction model to rapidly varying wind fields during JONSWAP 1973', by Gunther et al. (1978).

20. 'Ocean wave prediction by a hybrid model - Combination of single parameterized wind waves with spectrally swells', by P.S. Joseph, S. Kawai and Y. Toba, (1981).

21. 'Ocean wave prediction model by combination of a similarity-based parameters with swells (TOHOKU-Model)', by Y. Toba, S. Kawai, and P.S. Joseph (1981).

22. 'Hurricane wind and wave forecasting techniques', by C.L. Bretschneider and E.E. Tamaye, (1976).

23. 'A comparison of parametric and spectral hurricane wave prediction products', by D. Ross and V. Cardone, (1978).

24. 'A comparison of various numerical wave prediction techniques', by D.T. Resio and C.L. Vincent, (1979).

25. 'Observing and predicting hurricane wind and wave conditions', by D. Ross, (1979).

26. 'Wind fields during gales in the North Sea and the gales of 3 January 1976', by J. Harding and A.A. Binding, (1978).

27. 'Some measurements of the directional wave spectrum', by J.A. Ewing, (1968).

28. 'Directional spectra of ocean surface waves', by H. Mitsyasu and S. Mizuo, (1976).

29. 'Hindcasting the directional spectra of hurricane-generated waves', by V.J. Cardone et al. (1976).

30. 'Directional wave spectra observed during JONSWAP 1973', by D.E. Hasselman et al. (1980).

31. 'Directional spectra of wind waves in growing stage', by M. Yamaguchi and Y. Tsuchiys, (1981).

32. 'Directional spectra in shallow water', by L. Cavaleri, (1981).

33. 'Directional wave spectrum for the design of harbour structures', by Y. Goda, (1982).

34. 'Similarity of the wind wave spectrum in finite depth water. Part 1: Spectrum form', by E. Bouws et al. (1983).

35. 'Determination of severe wave conditions for ocean systems in a 3-dimensional irregular seaway', by S.P. Kjeldsen, (1983).

36. 'Parametric modelling of joint probability density distributions for steepness and asymmetry in deep water waves', by D. Myrhaug and S.P. Kjeldsen, (1983).

37. 'On the balance between growth and dissipation in an extreme depth-limited wind-sea in the southern North Sea', by E. Bouws and G.J. Komen, (1982).

38. 'Wave climate synthesis and extreme value estimation: The NMI Approach', by N. Hogben, (1981).

39. 'Estimates of 50 years wave heights from visual observation', by N. Hogben, (1981).

40. 'Long-crestedness of wind-waves in deep water', by J.A. Battjes and L.H. Holthuijsen, (1981).

41. 'Effects of short-crestedness on wave loads on long structures', by J.A. Battjes, (1982).

42. 'Synthesis of design climate', by J.A. Battjes, (1983).

43. 'Verification of linear theory for particle velocities in wind waves based on field measurements', by J.A. Battjes and J. v. Heteren (1984).

44. 'On the theory of the equilibrium range in the spectrum of wind-generated gravity waves', by S.A. Kitagorodskii, (1983).

45. 'The sampling variability of estimates of spectra of wind-generated gravity waves', by M. Donelan and W.J. Pierson, (1983).

46. 'Wave-turbulence interactions in the upper ocean. Part 2: Statistical characteristics of wave and turbulent components of the random velocity field in the marine surface layer', by S.A. Kitaigorodskii, (1983).

47. 'Observations of wind-waves and swells at an exposed coastal location', by J.A. Ewing, (1980).

48. 'A growth-staged scaling model for the wind-driven sea', by J.W. Sanders, (1976).

49. 'Wave parameter studies and wave groups', by H. Rye, (1979).

50. 'Wave grouping studies by means of correlation techniques', by H. Rye and E. Lerrik, (1981).

51. 'On the existence of a fully developed wind-sea spectrum', by Komen et al. (1984).

52. 'A similarity relation for the nonlinear energy transfer in the finite-depth gravity wave spectrum', by K. Herterich and K. Hasselmann (1980).

53. 'Nonlinear contributions to the frequency spectrum of wind-generated water waves', by G.J. Komen, (1979).

54. 'On the nonlinear transfer in a gravity-wave spectrum. Part 1: General theory', by K. Hasselmann, (1962).
55. 'On the nonlinear transfer in a gravity-wave spectrum. Part 2: Conservation theorems, wave-particle analogy, irreversibility', by K. Hasselmann (1963a).
56. 'On the nonlinear transfer in a gravity-wave spectrum. Part 3: Evaluation of the energy flux and swell-sea interaction for a Neumann Spectrum', by K. Hasselmann, (1963b).
57. 'Improved methods of computing and parameterizing the nonlinear energy transfer in a gravity-wave spectrum', by Hasselmann et al. (1984).
58. 'A narrow band of high swells over Arabian sea as a precursor of monsoon', by A.K. Mukherjee and T.R. Sivaramakrishnan, (1976).
59. 'Wave characteristics of the seas around India', by P.S. Srivastava and M.D. George, (1976).
60. 'Winter swells over Bombay High area', by A.K. Mukherjee et al. (1977).
61. 'Meteorological service to offshore oil operations', by A.K. Mukherjee
62. 'Swells off Paradeep during south-west monsoon', by K.K. Varma and P.S. Srivastava, (1981).
63. 'Swells in relation to sea surface temperature during MONEX 1979', by A.K. Mukherjee and B.L. Sharma.
64. 'Waves over the Arabian sea during the south-west monsoon', by A.K. Mukherjee and T.B. Sivaramakrishnan, (1982).
65. 'On the meaning of phase spectra', by E.R. Funke, (1981).
66. 'Observations of the power spectrum of ocean waves using Clover-leaf Buoy', by H. Mitsuyasu et al. (1980).
67. 'A review of methods to establish the wave climate for breakwater design', by J.A. Battjes, (1984).
68. 'Verification of numerical wave propagation models for simple harmonic linear water waves', by Berkhoff et al. (1982).
69. 'Prediction of shallow water spectra', by J.I. Gulling, (1972).
70. 'Numerical model for nonstationary shallow water wave spectral transformations', by J.H. Chen, (1983).
71. 'Observations of the directional distribution of ocean wave energy in fetch-limited conditions', by L.H. Holthuijsen, (1983).
72. 'Numerical experiments on wave statistics with spectral simulation', by Y. Goda, (1970).

73. 'Wave-interaction theory of ocean waves', by K. Hasselmann, (1968).
74. 'HISWA'-users' manual 1985.
75. 'Measurements of wave induced pressure over surface gravity waves', by D. Hasselmann et al. (1982).
76. 'The wave model EXACT-NL', by S. Hasselmann and K. Hasselmann, (1982).
77. 'Transition of Mechanically generated regular waves to wind waves under the action of wind', by M. Hatari and Y. Toba, (1983).

## Appendix II

Maps transferred to National Institute of Oceanography of India in Goa.

Admirality Charts of the Hydrographer of the Navy, Ministry of Defense, Taunton, United Kingdom

| Catalogue number (1984) | Name |
|---|---|

### West Coast of India:

| | |
|---|---|
| 707 | Bombay to Muscat |
| 708 | Bombay to Cape Comorin |
| 1486 | Approaches to Gulf of Khambhat |
| 1509 | Coondapoor to Vengurla |
| 2736 | Gulf of Cuth to Vijaydurg |
| 4705 | Arabian Sea |

### East Coast of India:

| | |
|---|---|
| 814 | The Sandheads : False point to Matla river |
| 828 | Cochin to Vishakhapatnam |
| 829 | Bay of Bengal - northern portion (Krishnapatham to Bassein river) |
| 859 | Matla river to Elephant point |
| 2058 | Puri to the Sand heads |
| 2060 | Kalingapatnam to Puri |
| 2061 | Kakimada to Kalingapatnam |
| 2062 | False Divi Pt to Kakimada |
| 2063 | Madras to Fals Divi point |
| 2069 | Point Calimere to Madras |
| 4706 | Bay of Bengal |

### North Sea

| | |
|---|---|
| 4140 | North Sea |