Producing Surf Forecasting Parameters from Delft3D

Y. Larry Hsu
Kacey L. Edwards
Richard A. Allard
Ocean Dynamics and Prediction Branch
Oceanography Division

February 24, 2010

REPORT DOCUMENTATION PAGE

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instructions, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing this collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden to Department of Defense, Washington Headquarters Services, Directorate for Information Operations and Reports (0704-0188), 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302. Respondents should be aware that notwithstanding any other provision of law, no person shall be subject to any penalty for failing to comply with a collection of information if it does not display a currently valid OMB control number. **PLEASE DO NOT RETURN YOUR FORM TO THE ABOVE ADDRESS.**

1. REPORT DATE (DD-MM-YYYY) 24-02-2010	2. REPORT TYPE Memorandum Report	3. DATES COVERED (From - To)

4. TITLE AND SUBTITLE

Producing Surf Forecasting Parameters from Delft3D

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER
0603207N

6. AUTHOR(S)

Y. Larry Hsu, Kacey L. Edwards, and Richard A. Allard

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER
73-5097-C0-5

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)

Naval Research Laboratory
Oceanography Division
Stennis Space Center, MS 39529-5004

8. PERFORMING ORGANIZATION REPORT NUMBER

NRL/MR/7320--10-9213

9. SPONSORING / MONITORING AGENCY NAME(S) AND ADDRESS(ES)

Space & Naval Warfare Systems Command
2451 Crystal Drive
Arlington, VA 22245-5200

10. SPONSOR / MONITOR'S ACRONYM(S)

SPAWAR

11. SPONSOR / MONITOR'S REPORT NUMBER(S)

12. DISTRIBUTION / AVAILABILITY STATEMENT

Approved for public release; distribution is unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT

The software for generating surf forecasting parameters from Delft3D output is upgraded to handle cases in curvilinear grid and spherical coordinates. Standard NAVO surf output such as the 6-panel surf plot is now generated automatically. Major code improvements are made to eliminate any manual input or change to produce operational output.

15. SUBJECT TERMS

Delft3D	Surf model
Nearshore	Modified surf index

16. SECURITY CLASSIFICATION OF:			17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON Y. Larry Hsu
a. REPORT Unclassified	**b. ABSTRACT** Unclassified	**c. THIS PAGE** Unclassified	UL	13	**19b. TELEPHONE NUMBER** (include area code) (228) 688-5260

CONTENTS

1. INTRODUCTION

The one-dimensional (1D) Navy Standard Surf Model (NSSM, or SURF 3.2) has been shown to be very robust (Hsu, et al., 2002), but it can produce inaccurate wave and longshore current estimations for areas with complicated bathymetry. Since SURF assumes parallel bottom contours in the surf zone, it cannot account for longshore variations of bathymetry or forcing. Only 2D or 3D nearshore models should be used for such cases. The Delft3D modeling system, developed by Delft Hydraulics, has been chosen to replace the 1D surf model. Delft3D is a complete coastal hydrodynamic modeling system, capable of simulating hydrodynamic processes due to waves, tides, rivers, winds and coastal currents (Roevink and Banning, 1994). The evaluation and validation of Delft3D in nearshore applications using field data sets have been conducted (Hsu et al., 2007; 2008).

Delft3D does not produce operational surf forecasting parameters including maximum and significant breaker height, breaker type statistics, percent of breaking, surf zone width, number of surf lines and modified surf index (MSI), as specified in the Joint Surf Manual (COMNAVSURFPAC, 1987). Hsu et al. (2006) documents the software development for producing those parameters from Delft3D output in Cartesian coordinates. Because of the increasing complexity of Delft3D applications at NAVO, there is need to improve the software to handle cases using curvilinear grids and spherical coordinates. Complete code automation for generating standard NAVO 6-panel surf plots is also needed. This report describes the details of the surf code improvements.

2. Delft3D OUTPUT FILES

As described in the Delft3D-FLOW manual (Delft Hydraulics, 2005), the results of FLOW and WAVE computations are stored in:

- map file: <trim-runid.def> and <trim-runid.dat>
- wave file: <wavm-runid.def> and <wavm-runid.dat>

These files use the binary NEFIS format and, therefore, are not easily readable. In our software, MATLAB routines provided by Delft3D are used to read the binary data. All necessary input needed (cross-shore values of distance, depth, significant wave height, mean wave angle (relative to beach) and longshore current; beach angle, peak wave period, mean wave direction (Nautical), wind speed and direction (Nautical), and tide) to derive the standard surf parameters can be obtained from the trim- and wavm-files. If the roller option is tuned on, then significant wave height needs to be derived from the wave energy term in the trim-file instead of the wavm-file. When the roller option is on, radiation stresses and gradients of these stresses are computed in Delft3D based on the wave energy and roller energy replacing the conventional wave forces as derived from the WAVE (SWAN) model.

3. SOFTWARE DESCRIPTION

To compute surf forecasting parameters, our approach is first to produce input files similar to what the 1D surf model requires and computes and then to adopt the existing routines in SURF 3.2 to produce the surf output. There are two major parts of

the software. The first part converts the Delft3D output into surf input data using Matlab. The second part computes the surf forecasting parameters using Fortran.   The original Delft3D surf code was developed for a Cartesian coordinate setup with a constant beach heading for the whole domain.   But for a curvilinear grid, the beach heading change with location as shown in Fig. 1.
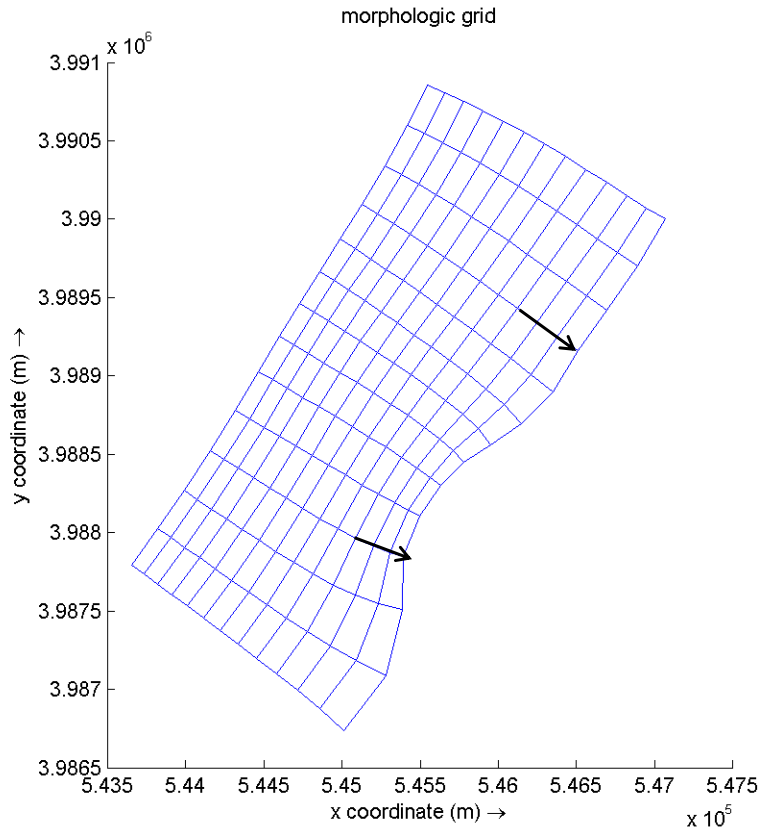

Fig. 1 Beach headings and curvilinear grid

Because many Navy surf parameters are defined relative to the beach normal, as viewed from an offshore observer, vector analysis is used in tracking the relative angles. To compute the relative angles, a beach vector is first defined by specifying grid indices of starting (offshore) and end (shore) points. A beach vector and a perpendicular unit coast vector (with magnitude of one) are illustrated in Fig. 2.   To compute the longshore current from a current vector, the dot product (a term in vector analysis) between coast unit vector and current vector is used to get the projection.   The relative angle between a wave and beach is computed from the atan2 function which gives the angles from –pi to +pi. In Fig. 2, wave and longshore current heading towards the left of a vessel facing the beach is labeled as left flank. The sign convention is positive towards right and vice versa. The beach orientation angle is defined as the compass heading towards the beach.

Examples and definitions of beach orientation (heading) and the Nautical wind and wave directions conventions are included in Appendix A.
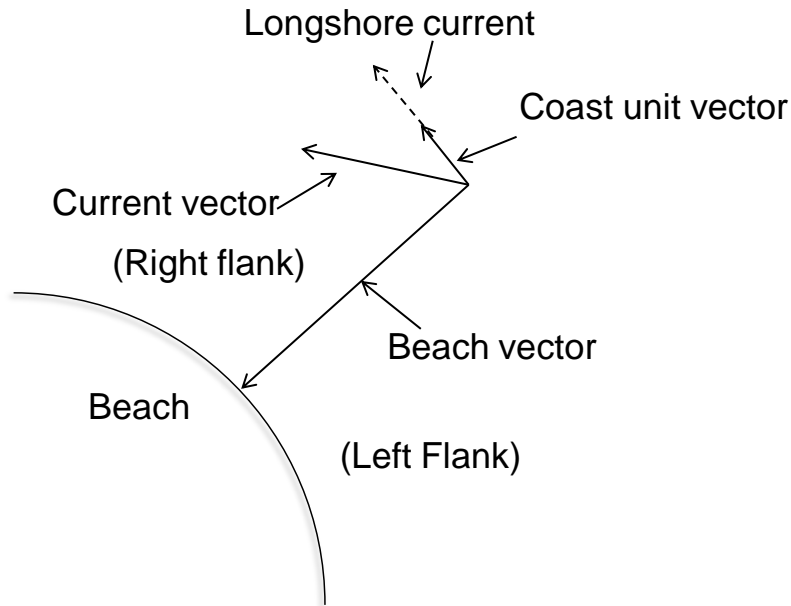

Fig. 2 – Definition of beach vector and coast unit vector

In general, the starting point for a surf computation should begin around 30 ft (9m) depth or deeper. This is because for most operational conditions, waves generally have low percent of breaking at this depth. In most cases, the beach vector can start from the offshore boundary of the Delft3D grid. The choice of the starting point, given it is deeper than 30 ft, should not alter the results much. To compute the breaker statistics accurately, it is necessary to have enough grid resolution in the cross-shore dimension in nearshore zone, say less than 33 ft (10 m). The Delft3D domain decomposition feature with a nested higher resolution nearshore grid is ideal in setting up surf computations. In general, the nearshore grid line in a curvilinear case is almost perpendicular to the coast and is used in defining the beach orientation. If the grid orientation is deviated too much from the beach normal, then it should not be used. Those points can be easily edited out from the list defined in the MATLAB script.

To help describe the objective of the software, a sample surf summary from SURF 3.2 is presented in Appendix B. The first part of the summary is the input information consisting of beach orientation, offshore significant wave height, mean wave period, mean wave angle, wind speed, wind direction and tide. These input parameters will be produced as header information in our surf input file. The second part starting with "Coded Surf Forecast Follows" is what surf code is going to produce from Delft3D results. It consists of listing the depth, significant wave height, mean wave angle and longshore current as function of cross-shore distance.

To illustrate the software structure, Fig. 3 shows the flow chart of the MATLAB code to convert Delft3D output to surf input. In addition to trim- and wavm-files, the date and time information is read and used for output files and graphics. It is noted that the code has improved so that no manual input or changes are needed.

```
                          ┌─────────────────┐
                          │  Date and time  │
                          │ and plot options│
                          └─────────────────┘
                                   │
                                   ▼
┌─────────────────┐      ┌─────────────────────┐      ┌──────────────────────┐
│ Delft3D NEFIS   │      │ Convert Delft3D binary│     │ Produce output:      │
│ format data:    │      │ Data to ASCII format  │     │ d3d.list and         │
│ wavm-runid.dat  │─────▶│ (qd_open.m and        │────▶│ d3d_datetime_MN.dat  │
│ wavm-runid.def  │      │ qd_read.m)            │     │ files                │
│ trim-runid.dat  │      └─────────────────────┘      └──────────────────────┘
│ trim-runid.def  │                │
└─────────────────┘                ▼
                          ┌─────────────────┐
                          │ Produce 2D plots│
                          │ for wave heights│
                          │ and currents    │
                          └─────────────────┘
```
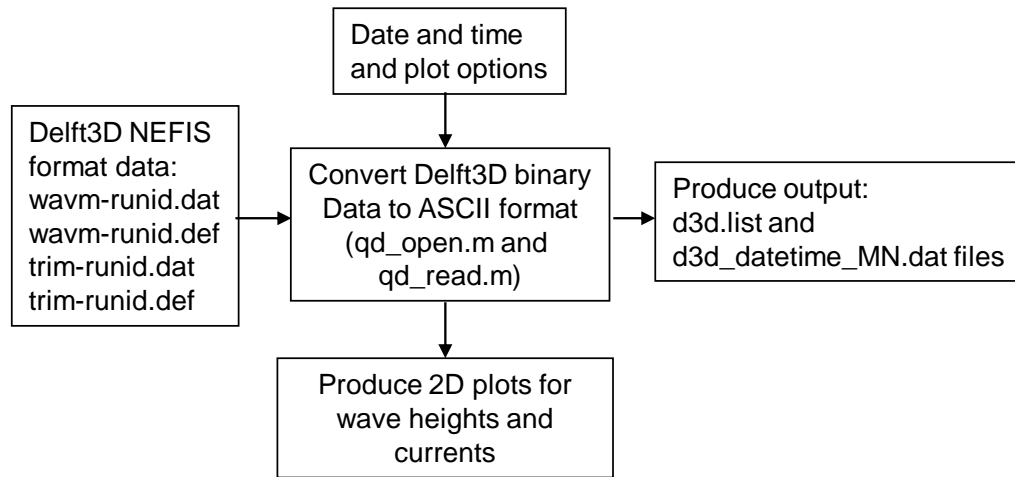
Fig. 3 – Flow chart for generating surf input from Delft3D output

Two types of output files are generated. The first one is called d3d.list; it lists data filenames for different locations. A sample is given here:

```
d3d_2007091701_M14_N2.dat
d3d_2007091701_M14_N3.dat
d3d_2007091701_M14_N70.dat
------------
```

The numbers in the filenames represent the date, time and position of the data, e.g., d3d_ 2007091701_M14_N70.dat is for the ending point at M=14 and N=70 of the beach vector. The second type of file, as listed in d3d.list, consists of cross-shore data and header information for a particular location. An example file follows.

2007091701_M14_N70.dat:

```
% datetime, M, N, xdistance(ft), ydistance(ft)
1997101814 14 70 1.640400e+002 3.936960e+002
% beach (N), sig. wave height (ft), peak_wave_period,  mean_wave_direction(N),
wind_speed (knots), wind_angle (N), tide(ft)
  270.0    7.4    6.0    71.9    22.7    25.1    -0.0
% distance(ft), depth(ft), sig. wave height(ft),longshore current(knots), mean wave angle
 2788.68   27.16    7.36   -0.10  -18.08
 2755.87   27.00    7.33   -0.09  -18.56
 2723.06   26.84    7.33   -0.09  -18.67
```

```
2690.26    26.68    7.35    -0.09    -18.83
2657.45    26.53    7.36    -0.09    -18.93
2624.64    26.37    7.37    -0.09    -19.01
2591.83    26.21    7.38    -0.09    -19.07
2559.02    26.05    7.39    -0.09    -19.11
2526.22    25.90    7.40    -0.08    -19.13
2493.41    25.74    7.40    -0.08    -19.12
2460.60    25.58    7.41    -0.08    -19.12
2427.79    25.42    7.42    -0.07    -19.12
………………………………………………..


………………………………………………..
 328.08    6.33    3.43    -1.70    -8.49
 295.27    5.80    3.34    -1.60    -8.14
 262.46    3.82    3.24    -1.36    -7.32
 229.66    0.48    2.70     0.00    -5.00
```

3.2 Surf Forecasting Parameter Computation

Fig. 4 shows the flow chart of the main Fortran program for the surf computation, where the subroutine names are listed in parenthesis. Subroutines are adopted from SURF 3.2 to compute surf forecasting parameters.
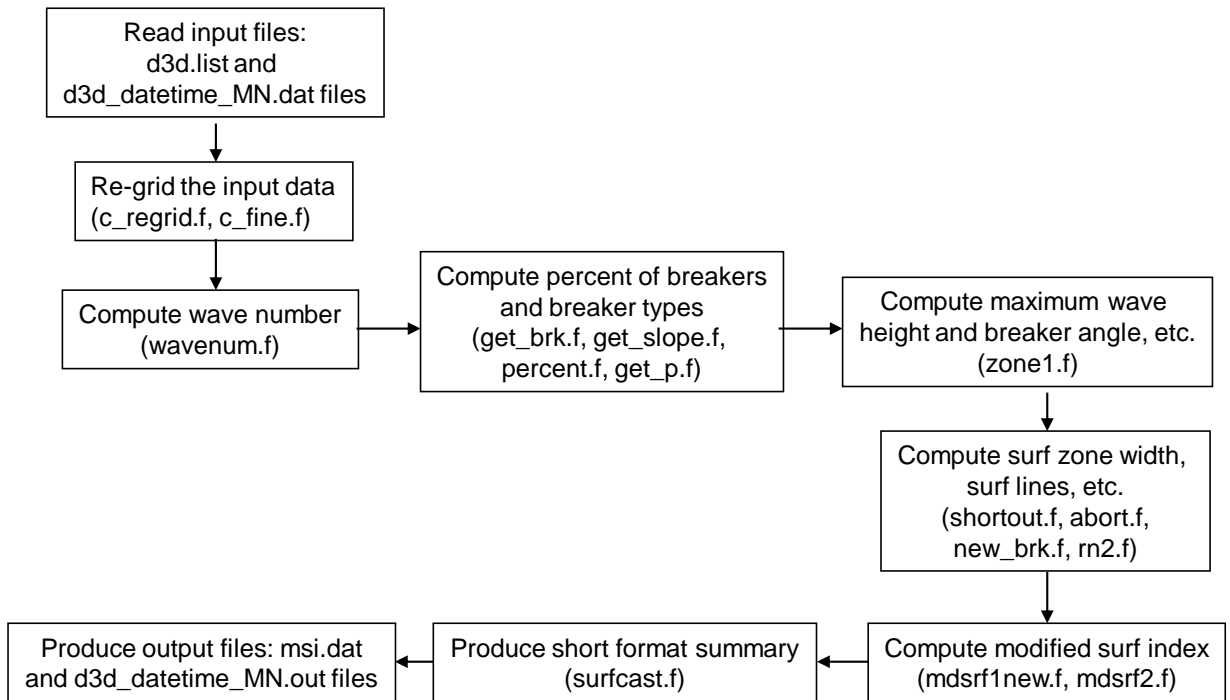

Fig. 4 – Flow chart for computing surf forecasting parameters

Two types of output files are generated by this software. The first type of file is named with an "out" extension:

d3d_2007091701_M14_N2.out
d3d_2007091701_M14_N3.out
d3d_2007091701_M14_N70.out
d3d_2007091704_M14_N2.out
d3d_2007091704_M14_N3.out
d3d_2007091704_M14_N70.out

……………

The "out" file format and information are identical in content to the SURF 3.2 summary as listed in Appendix B.   A sample "out" file from Delft3D results is given here:

```
      *****  *****  Coded Surf Forecast Follows  *****  *****

 Significant Breaker Height                       alfa =    4.9 ft
 Maximum Breaker Height                          bravo =    7.5 ft
 Dominant Breaker Period                       charlie =    8.0 sec
 Dominant Breaker Type                           delta = Spilling Surf
 ( 98% Spilling,   2% Plunging,   0% Surging)
 Breaker Angle (toward left flank)                echo =   12.9 deg
 Littoral Current (toward left flank)          foxtrot =    1.7 kts
 Number of Surf Lines                            golf1 =    4.2
 Surf Zone Width                                 golf2 =  538.0 ft
 Average Wave Length                                   =  126.7 ft
 Wind Speed                                     hotel1 =   10.0 kts
 Wind Direction                                 hotel2 =   46.0 deg

 Modified Surf Index =      7.2
```

Units are in feet and knots as in SURF 3.2. The second type of output file is called msi.dat; it consists of all the surf forecasting parameters and some other information including date, time, tide, wind speed and direction, and location information. A sample msi.dat is given below:

```
%Pohang test
%M, N, datetime, x(ft), y(ft), MSI,  sig. breaker(ft), max. breaker(ft)
%max. current(knot), breaker angle, zone width(ft)
%spilling, plunging, surging, wind (knots),   wind_dir (N) tide(ft)
 92 51 2008022712 1789653 13081623  10.2  4.7  7.3 -1.8 -11.5 276.0  0.1 98.8  1.1 10.0 70.0  0.79
 92 51 2008022718 1789653 13081623   7.4  3.9  6.0 -1.0  -7.3 224.0  0.3 98.8  0.8 10.0 70.0  0.42
 92 51 2008022800 1789653 13081623   6.4  4.3  6.6 -0.6  -3.9 248.0  1.1 98.4  0.6 10.0 70.0  0.65
 92 51 2008022806 1789653 13081623   5.2  3.6  5.6 -0.7  -4.3 210.0 59.2 40.8  0.0 10.0 70.0  0.75
 92 51 2008022812 1789653 13081623   6.5  4.1  6.2 -0.7  -4.5 236.0  0.6 98.7  0.7 10.0 70.0  0.84
 92 51 2008022818 1789653 13081623   7.0  4.1  6.2 -0.9  -5.8 234.0  5.3 94.4  0.3 10.0 70.0  0.41
 92 51 2008022900 1789653 13081623   7.5  3.8  5.8 -1.1  -7.5 220.0  3.3 96.3  0.4 10.0 70.0  0.56
 92 51 2008022906 1789653 13081623   5.6  2.8  4.3 -1.0  -7.1 156.0 47.5 52.5  0.0 10.0 70.0  0.79
 92 51 2008022912 1789653 13081623   6.0  3.4  5.1 -0.9  -6.1 192.0 50.8 49.1  0.0 10.0 70.0  0.87
```

4. SAMPLE RESULT

  The process of running the surf model and producing a NAVO 6-panel surf plot is completely automated. In Fig. 5, a sample 6-panel plot for a case in southern California using a curvilinear grid and Spherical coordinates is presented.
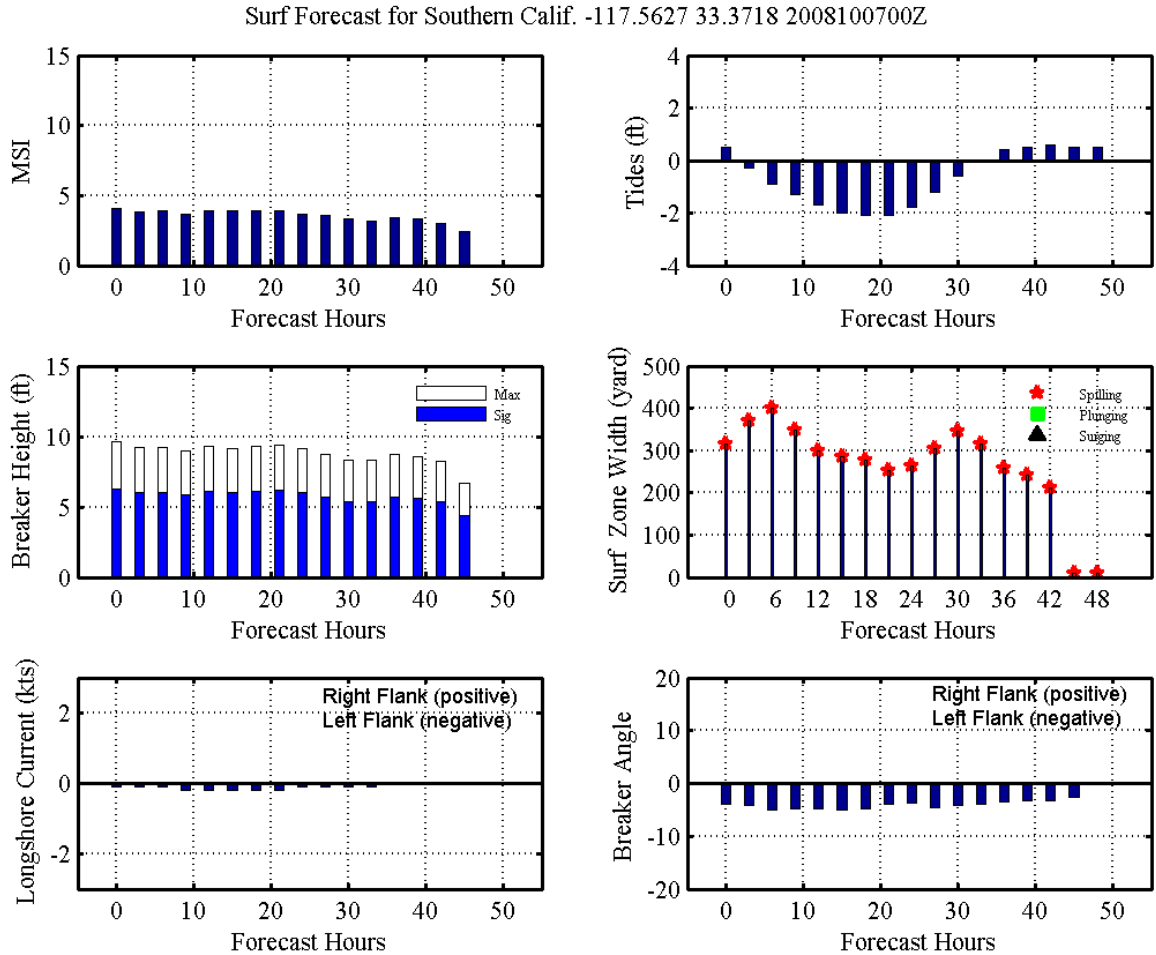

Fig. 5 – Sample NAVO 6-panel plot from a case for Southern California in curvilinear grid and Cartesian coordinate

5. SUMMARY

      The upgraded surf software for generating surf forecasting parameters from Delft3D output can now be used for cases in curvilinear grid and spherical coordinates. Standard NAVO surf output such as the 6-panel surf plot is generated automatically. Major code improvements are made to eliminate any manual input or change. It can be easily integrated into Delft3D operational scripts.

ACKNOWLEDGEMENTS

REFERENCES

COMNAVSURFPAC/COMMANSURFLANT, Instruction 3840.1B, Joint Surf Manual, 02 January 1987.

Hsu, Y.L.,T.R. Mettlach and M.D. Marshall, 2002: Validation test report for the Navy standard surf model, NRL formal report, NRL/FR/7322-02-10008, 28pp.

Hsu, Y.L., J.M. Kaihatu, J.D. Dykes and R.A. Allard, 2006: Evaluation of Delft3D performance in nearshore flows, NRL memorandum report, NRL/MR/7320-06-8984, 24pp.

Hsu, Y.L., J.D. Dykes and R.A. Allard, 2006: Software development for producing standard Navy surf output from Delft3D, NRL memorandum report, NRL/MR/7320-06-8990, 20pp.

Hsu, Y. L. J.D. Dykes and R.A. Allard and D. W. David, 2007: Validation test report for Delft3D, NRL memorandum report, NRL/MR/7320-08-9079, 42pp.

Mettlach, T.R., M.D. Marshall and Y.L. Hsu, 2002: Software design document for the Navy Standard Surf Model Version 3.2, NRL mem. report, NRL/MR/7320-02-8289, 184pp.
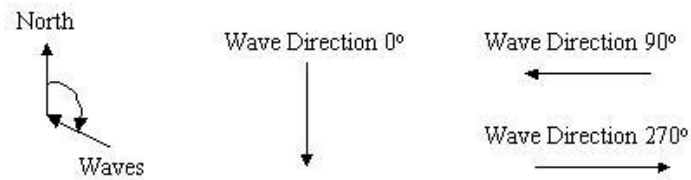
Roelvink, J.A. and Van Banning, G.K.F.M., 1994: Design and development of Delft3D and application to coastal morphodynamics. Proceedings of Hydroinformatics'94 conference, Delft.

APPENDICES

Appendix A. Beach orientation and wave/wind direction definitions.
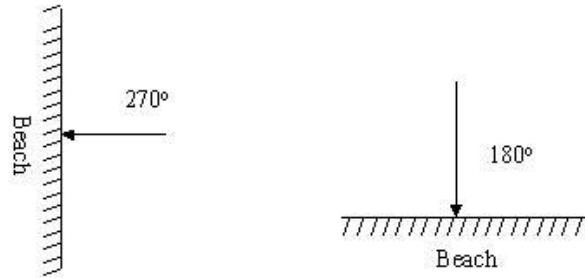
(a) Beach Orientation Definition. Arrows show sight lines from deep water toward the beaches.

(b) Wave Direction Definition.   Directions are those from which waves come in degrees relative to North.

Appendix B. – Sample SURF 3.2 output showing the standard Navy surf forecasting output

Test Case 1 Output File - case1.out

```
    *****  *****  Surf Forecast  *****  *****

Navy Standard Surf Model    Version 3.2
Date and Time of Forecast: 01/01/2001   0100
Session Logged to file case1.out
Landing Zone Name          = case 7 beach
Sight Line                 =   0.0 deg
Equilibrium Beach Sediment = medium sand
Wave Input Depth           =  25.0 ft
Sea  Height, Period, Direction =   0.0 ft,  0.0 sec,   0.0  deg
Swell Height, Period, Direction =   3.0 ft, 10.0 sec, 160.0  deg
Wind Speed                 =  10.0 kts
Wind Direction             = 240.0 deg
Tide Level                 =  -1.0 ft


Internally Generated Spectrum Used
Starting Depth             =  24.0 ft
Output Interval            =   5.0 ft
Computational grid spacing =   2.0 ft
Significant Wave Height Offshore =     3.0 ft
Peak Period                      =    10.0 sec
Average wave direction           =   -20.0 deg
Percent of Breaking Waves is less than  5.0 %  at starting depth.


    *****  *****  Coded Surf Forecast Follows  *****  *****
 Significant Breaker Height                      alfa =   3.6 ft
 Maximum Breaker Height                          bravo =   5.5 ft
 Dominant Breaker Period                         charlie =  10.0 sec
 Dominant Breaker Type                           delta = Spilling Surf
 ( 84% Spilling,  16% Plunging,   0% Surging)
 Breaker Angle (toward left flank)               echo =   11.9 deg
 Littoral Current (toward left flank)     foxtrot =   1.5 kts
 Number of Surf Lines                            golf1 =   2.0
 Surf Zone Width                                 golf2 = 246.0 ft
 Average Wave Length                             = 120.9 ft
 Wind Speed                               hotel1 =  10.0 kts
 Wind Direction                           hotel2 = 240.0 deg

 Modified Surf Index =       7.2

   *****  *****  Detailed Surf Output Follows  *****  *****

 Indx   Dist   Water  Sig Brkr  Max Brkr  Prcnt  Brkr   Littoral
       Offshore Depth  Height    Height   Brkng  Angle  Current
        (ft)    (ft)    (ft)      (ft)    waves  (deg)   (kts)

   1   302.4    9.3   3.57      5.46     5.2   -12.7    0.12
   2   297.4    9.1   3.57      5.47     5.5   -12.6    0.07
   3   292.4    9.0   3.57      5.47     5.9   -12.5    0.01
   ..........
```

10