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Airflow over le Suroit using the Computational Fluid Dynamics package Vectis

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Abstract.

This report describes the simulation of the air flow around the French research ship "Le Suroit", using the Computational Fluid Dynamics package "Vectis". The model was run for a wind speed of 14 m/s blowing directly over the bows of the ship. The effects of the disturbance to the air flow, caused by the ship's hull and superstructure, are calculated for an anemometer sited on a 10 m mast mounted well forward in the bows of the ship.

AIRFLOW OVER LE SUROIT USING THE COMPUTATIONAL FLUID DYNAMICS PACKAGE VECTIS

(VECTIS REPORT NUMBER 3.1/9)

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AIRFLOW OVER LE SUROIT USING THE COMPUTATIONAL FLUID DYNAMICS PACKAGE VECTIS

B. I. Moat and M. J. Yelland
February 1996
Phase 5 run time 3 October 1995 to 20 October 1995

1. Introduction

This document is a brief summary of the calculation of velocity errors at two anemometer sites on the French research vessel Le Suroit. An Institute of Oceanographic Sciences Deacon Laboratory, I.O.S.D.L., 10 m mast was mounted on Le Suroit and a Solent sonic anemometer was located 0.65 m above it's top. A propeller anemometer was located on a 2m pole on the port side of the bow. A 14 m/s wind was simulated for the ship "head-to-wind".

2. Model dimensions, wind profile and convergence

2.1 Introduction

The following section describes the dimensions of the ship and tunnel (section 2.2), the logarithmic wind profile used in the model (section 2.3) and the monitoring locations used to test for convergence (section 2.4).

2.2 The ship geometry and wind tunnel dimensions

The wind tunnel used is the standard x = length (-300 to 300), y = height (0 to 150) and width z = (-150 to 150). the floor is specified as a wall boundary with roughness length $4.5*10^{-4}$ m The sides and roof of the tunnel are specified as zero gradient boundaries. The mesh file used is "suroit.mesh2".

The locations of the anemometer sites are those used on the "SOFIA" cruise, (Kent and Pascal, 1992). Using the Vectis model origin, the locations are:

Solent sonic anemometer (x = 23.707, y = 16.082, z = -0.2286)

Propeller anemometer (x=19.578, y = 7.2476, z = -4.79)

Vectis and Femgen files are located under:

/epoch/cfd/archive/version3.1/suroit/suroit_0deg/newlog1_3.1.9/

The pre-processing phases of Vectis were worked through with only minor problems with phase2. The phase2 mesh lines had to be modified five times to totally eradicate small holes that appeared in the bow geometry.

2.3 Wind profile used

The wind profile used is newlog1 which has been used on R.R.S. Discovery 3.1/7, (Moat *et al.*, 1996), and models the profile used on R.R.S. Charles Darwin 1.6/13.

2.4 Convergence

The velocity and pressure were monitored at seven positions

1) (-200,20,100) MON.0
2) (0, 20,100) MON.1
3) (-200,10,100) MON.2
4) (0, 10, 100) MON.3
5) (200, 10, 100) MON.4
6) (200, 20, 100) MON.5
7) (24, 16, -0.3) MON.6 (close to Solent sonic anemometer position)

These monitoring positions are shown in figure 1

A graph of total velocity against time step is shown in figure 2. A file containing all output variables was examined for the last 116 time steps. All values had steadied to the third significant figure.

2.5 Conclusions

The velocity at the monitoring locations was shown to have converged and a post processing file was written at time step 93.647 seconds.

3.0 Data extraction from phase 6 of Vectis

3.1 Introduction

A post processing file was written at Vectis phase5 at time step 93.647 seconds and checks were performed to validate the free stream velocity abeam of the ship (section 3.2). The shape of the wind profile was examined, (section 3.3).

3.2 Checks on the free stream velocity

A vertical plane close to the edge of the wind tunnel (z=100m) was examined to determine whether free stream flow existed abeam of the ship. If the flow at the edge of the tunnel changes in the region of the ship then this implies that the tunnel is blocking the flow. The run would have to be repeated with a broader tunnel. However, if the velocity (at a given height) on the plane does not vary along the tunnel it can be defined as a free stream plane.

Free stream velocities can then be extracted to compare with those from the anemometer locations.

Lines of horizontal velocity data were extracted along the tunnel at ($-300 \leq x \leq 300$, y = 10, 20 and 30 m, z = 100), shown in figure 3. The graph is shown in greater detail in figure 4, giving velocity data at ($-50 \leq x \leq 50$, y = 10, 20 and 30 m, z = 100) i.e. directly abeam of the ship. The difference between velocity at the inlet and outlet is *0.042 m/s at a height of 10 m, 0.007 m/s at 20 m and 0.12 m/s at 30 m, which indicates a very small change down the tunnel. These results show a free stream flow exists on a plane at z=100 m.

3.3 Checks on the logarithmic profile

As previously mentioned the logarithmic profile used in this study corresponds to that used in the Discovery 3.1/7 run, (Moat *et al.*, 1996). The profile is equivalent to Le Suroit steaming at 2.91 m/s into a true 10m wind of 10.87 m/s, giving an apparent U10 of 13.78 m/s. Vertical velocity profile data were extracted at the inlet and outlet of the tunnel as a means of examining the degeneration of the initial velocity profile along the tunnel.

Profile data were extracted at a free stream plane close to the inlet (x=200, $0 \leq y \leq 150$, z=100) and close to the outlet (x=-200, $0 \leq y \leq 150$, z=100) and are shown in figure 5. Figure 6 shows the difference between the inlet and outlet profiles. There is a maximum of -0.32 m/s at a height of 2m, but over most heights the difference is less than 0.1 m/s which shows that the profile changes very little along the tunnel.

3.4 Conclusions

The wind profile used for Le Suroit run 3.1/9 does not degrade down the tunnel. Checks on the free stream velocity at y = 10 m, y = 20 m and y = 30 m, 100m abeam of the ship, showed that a free stream velocity plane existed and that the ship was not blocking the air flow in the tunnel. Free stream velocities abeam of the anemometer positions were used to calculate velocity errors at the anemometer sites.

4.0 Le Suroit cruise 'SOFIA'

4.1 Introduction

This section investigates the error in the wind speed measurements from a Solent sonic anemometer, located above a 10 m mast mounted in the bow, and a propeller anemometer, located 2 m above the deck on the port side of the bow. The run is at 0 degrees to the wind.

4.2 Lifting of the airflow

This section deals with the amount the airflow is raised by the time it reaches the anemometer site. The height raised is calculated by plotting the path of a massless particle, which originated a long way upstream of the ship, through the anemometer site (figure 7). A few upstream sites are chosen until the most accurate path through the anemometer site is found. The (x,y,z) co-ordinates of the start and end of the path can be extracted from phase 6 with the use of the PLN command. This gives the height of the point (Z_{origin}) in the free stream flow that the particle originated from, and the height of the anemometer , Z_{anemom}. Since the anemometer position is already known, it acts as a check that the path is that of the air reaching the anemometer.

The vertical planes (K planes) of data may not coincide exactly with the plane of the anemometer. The approximate centre plane of the model is K24.

K23 z = -0.36 m

Solent sonic anemometer at z=-0.2286 m

K24 z = -0.10 m

Plane K23

location	x (m)	y (m)	z (m)
Solent sonic	23.707	16.082	-0.2286
Z_{anemom}	23.723	16.019	-0.36453
Solent - Z_{anemom}	-0.014	0.032	-0.12429
Z_{origin}	120.20	15.217	-0.36453
Z_{anemom}-Z_{origin}	-96.477	**0.802**	0

Table 1 Table showing the amount the air is raised when it reaches the Solent sonic anemometer site.

Plane K24

location	x (m)	y (m)	z (m)
Solent sonic	23.707	16.082	-0.2286
Z_{anemom}	23.721	16.050	-0.10431
Solent - Z_{anemom}	-0.014	0.032	-0.12429
Z_{origin}	120.23	15.283	-0.10431
Z_{anemom}-Z_{origin}	-96.509	**0.767**	0

Table 2 Table showing the amount the air is raised when it reaches the Solent sonic anemometer site.

Interpolate between planes K23 and K24 to find a height corresponding to z=-0.22 m

$$0.767 + \left(\frac{0.1286}{0.26022}\right) * 0.035 = 0.784 \text{ m}$$

For the Solent sonic, the air flow has been raised by 0.784 m from its original height before it reaches the anemometer location.

Plane K17 is closest to the propeller anemometer.

K16 z = -4.0459 m

K17 z = -4.7478 m Anemometer at z = -4.79 m

K18 z = -5.4495 m

propeller	19.578	7.2476	-4.79
Z_{anemom}	19.519	7.2541	-4.7478
Propeller- Z_{anemom}	0.059	-0.0065	-0.0422
Z_{origin}	120.13	5.558	-4.7478
Z_{anemom}-Z_{origin}	-100.611	**1.6961**	0

Table 3 Table showing the amount the air is raised when it reaches the Solent sonic anemometer site.

For the propeller anemometer, the air flow has been raised by 1.6961 m from its original height before it reaches the anemometer location.

4.3 Free stream velocities

A value of the wind speed in free stream conditions is needed in order to obtain a wind speed error at the anemometer site. The free stream site used is that towards the edge of the tunnel directly abeam of the anemometer site. The free stream velocity is taken from the profile at the height at which the air originated, i.e. the anemometer height minus the amount the air has been raised. The precautions of 1) using a free stream profile at the anemometer position rather than at the inlet, and 2) allowing for the amount of lifting of the air flow, make little or no significant difference. However, they would be necessary for results taken at a height where the profile is steep or in a tunnel where the profile degrades significantly along its length.

Figure 8 shows the free stream profile directly abeam of the Solent sonic anemometer, at (x=23.707, $0 \leq y \leq 150$, z=100), which gives a free stream velocity of 14.15 m/s at y=15.298 m. Figure 9 shows the corresponding profile for the ships propeller anemometer, at (x=19.578 , $0 \leq y \leq 150$, z=100), which gives a free stream velocity of 13.22 m/s at y=5.5515 m.

4.4 Velocities at the anemometer locations

For both anemometer locations velocity data were extracted along lines in the x, y and z directions. Figures 10 and 11 show the lines of data through the Solent sonic and ship's anemometer sites respectively. The figures show data within $\pm$ 4 m of the anemometer location in order to illustrate the rate of change of velocity with location. More detailed figures are used to extract the velocities at the anemometer locations. The results for both anemometers are summarised in Table 4.

The percentage wind speed error is given by:

$$\text{error} = \left(\frac{\text{average velocity}}{\text{free stream}} - 1 \right) * 100 \qquad (1)$$

Anemometer	Velocity from each direction	Average velocity (m/s)	Free stream velocity (m/s)	% error
	14.100 (x)			
Solent Sonic	14.096 (z)	14.105	14.149	-0.3089
	14.120 (y)			
	10.63 (z)			
Propeller	11.74 (x)	11.5467	13.22	-12.657
	12.27 (y)			

Table 4 Velocity and error estimates at the anemometer sites.

4.5 Rates of change of velocity at the anemometer locations

This section examines the rate of change of velocity around the anemometer site using figures 10 and 11. This gives an indication of the accuracy of the wind speed errors and of the suitability of the location for taking reliable wind speed measurements. The rate of change of velocity is given in terms of change per cell and per meter in Table 5.

Anemometer	Velocity data line	Rate of change of velocity per meter (ms^{-1}/m)	Rate of change of velocity per cell ($ms^{-1}/cell$)
Solent sonic	along (x)	0.045	0.0347
	up (y)	5.625	0.0637
	across (z)	0.005	0.0002
Propeller	along (x)	1.45	0.6309
	up (y)	5.445	2.455
	across (z)	4.455	3.283

Table 5 Rate of change of velocity close to the anemometer sites.

4.6 Conclusions

A free stream plane exists at 100m abeam of the ship and the wind profile does not degrade down the tunnel.

There are small rates of change across the Solent sonic anemometer site which is suitable for obtaining good wind speed measurements, whilst the propeller anemometer is located at a site of high velocity change and cannot be suitable for obtaining good wind speed measurements.

5. Summary

The wind profile used for Le Suroit 3.1/9 does not degrade down the tunnel. Checks on the free stream velocity at y=10 m, y=20 m and y=30 m, 100m abeam of the ship, showed that a free stream plane existed and that the ship was not blocking the airflow in the tunnel. Free stream velocities abeam of the anemometer positions were used to calculate velocity errors at the anemometer sites.

For the Solent sonic location the wind speed was reduced by -0.3089 % and lifted by 0.784 m. There was very little change in velocity in all three directions close to the anemometer site which suggests the results are reliable and the anemometer is in a well exposed position.

For the propeller anemometer, the wind speed was reduced by 12.7 % and lifted by 1.7 m. There were large changes in velocity in all three directions close to the anemometer site. Any small discrepancies in the phase6 data extraction, the anemometer position or the local geometry could lead to significant changes in the results. The site is not well exposed and is not suitable for obtaining good wind speed measurements.

6 References

Kent, E. C. and Pascal, R. W. 1992. *Project SOFIA - I.O.S. Cruise report*, Internal Report 92/7, James Rennell Centre, Southampton, UK.

Moat, B. I., Yelland, M. J. and Hutchings, J. 1996. *Airflow over the R.R.S. Discovery using the Computational Fluid Dynamics package Vectis*, SOC Internal report 2, Southampton Oceanography Centre, Southampton, U.K.

7 Figures

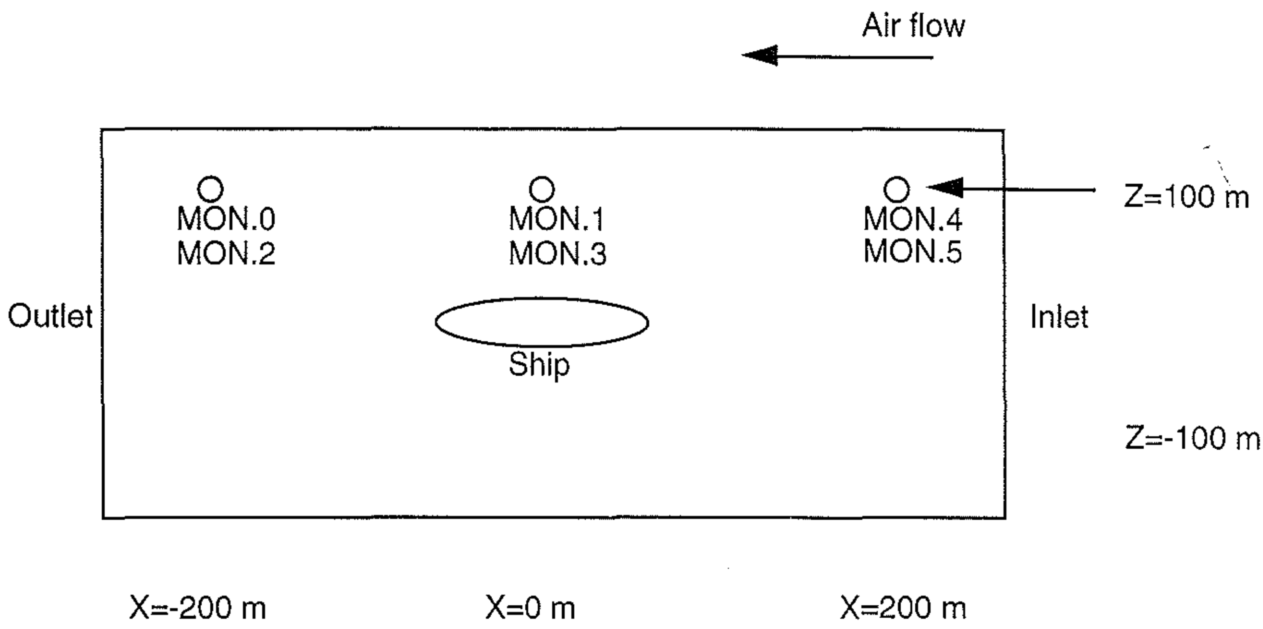


Figure 1 The locations of the six monitoring points

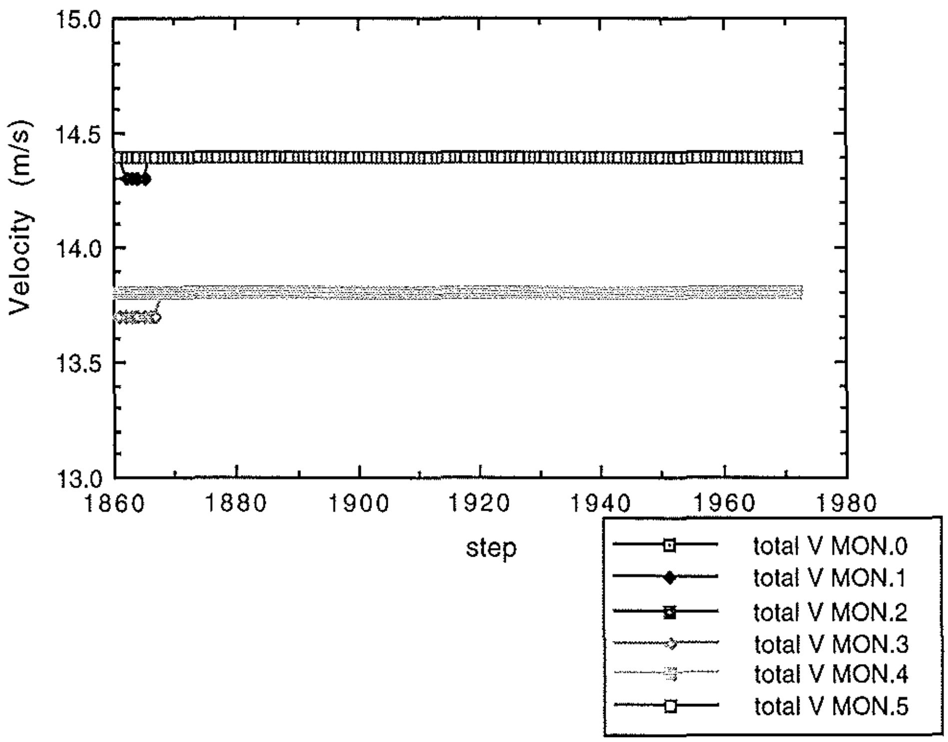


Figure 2 Total velocity for each monitoring location.

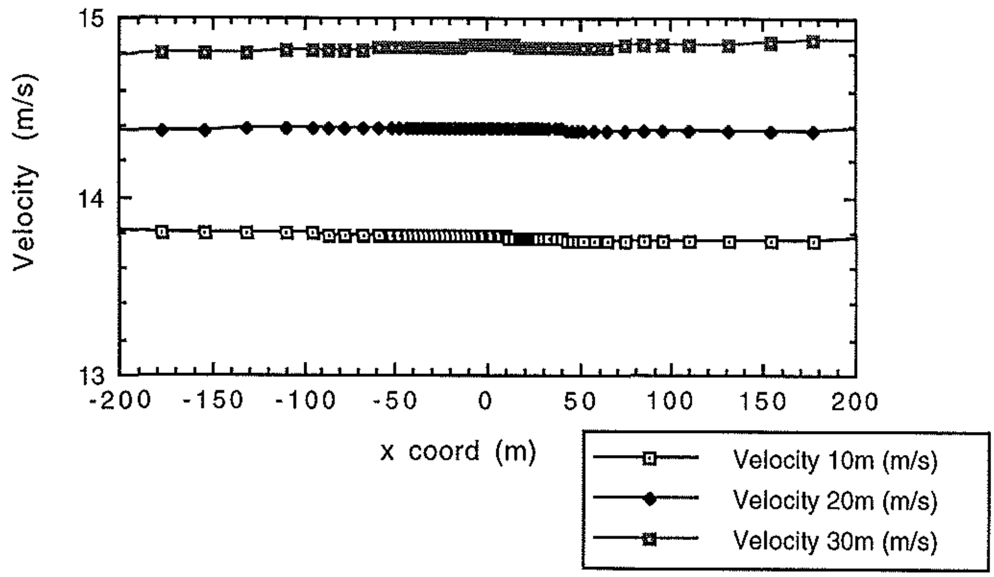


Figure 3 Total velocity data at y=10 m, y=20 m and y=30 m along the tunnel at a constant offset z=100 m.

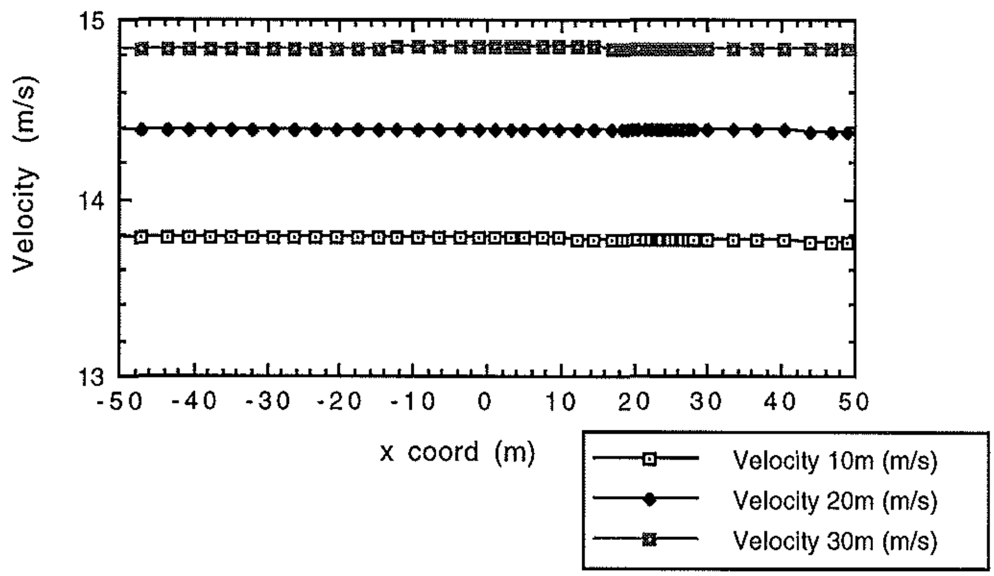


Figure 4 Total velocity from -50 to 50 m, as in figure 4, directly abeam of the ship.

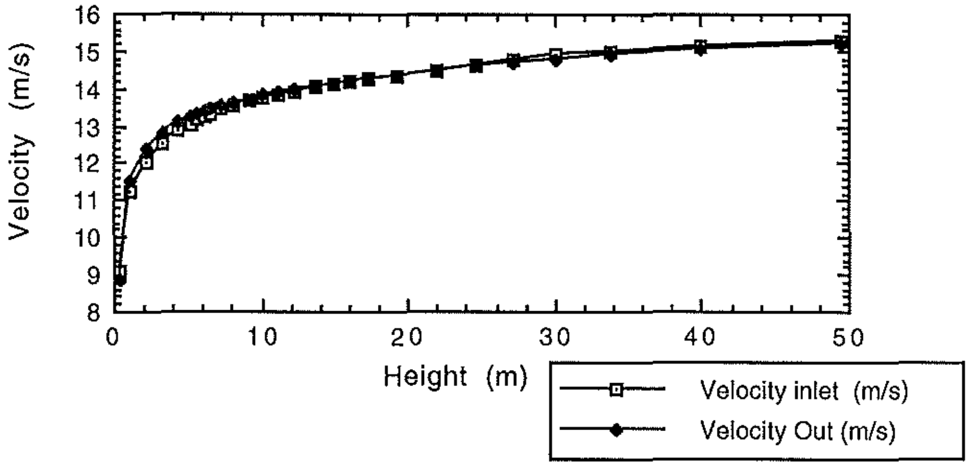


Figure 5 Free stream profile taken close to the inlet, (x=200, 0≤≤y≤50, z=100), and close to the outlet, (x=-200, 0≤y≤50, z=100).

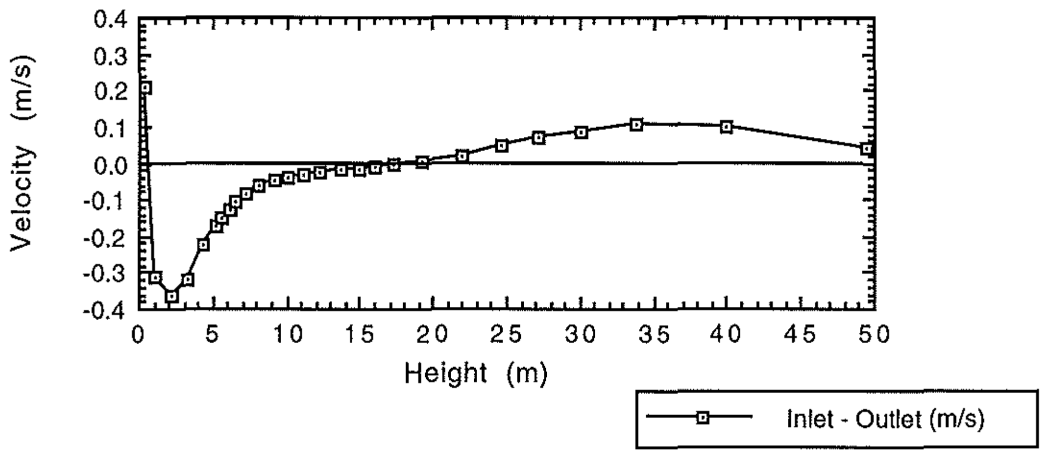


Figure 6 Velocity profile at the inlet minus velocity profile at the outlet for Suroit 3.1/9.

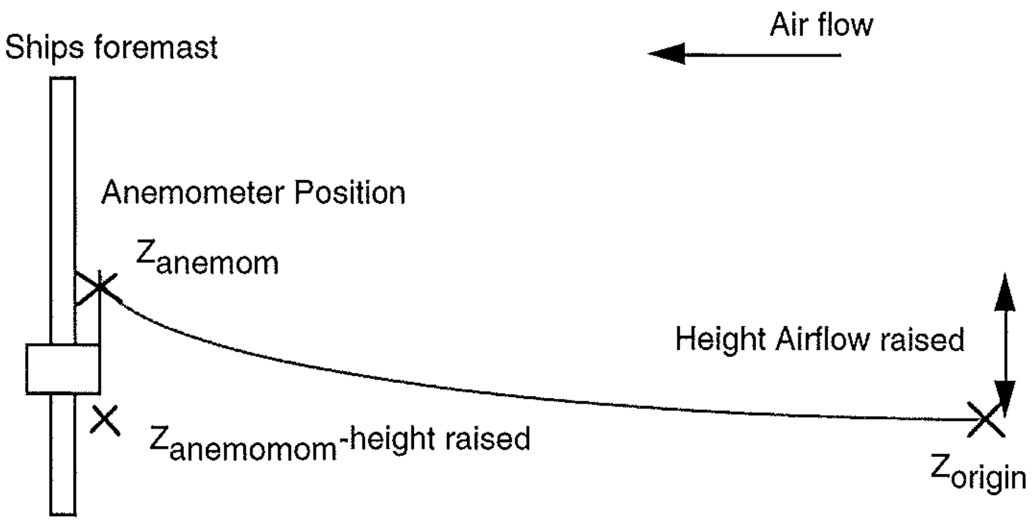


Figure 7 Diagram showing the locations used in calculating the height the air was raised and the height the free stream velocity was interpolated from.

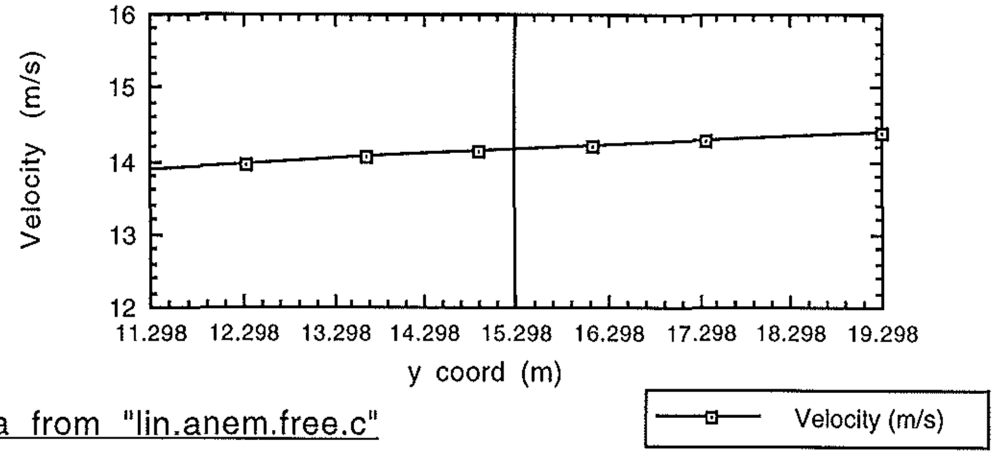


Figure 8 Free stream velocity calculated at 15.298 m, from a vertical velocity profile directly abeam of the anemometer location, (x=23.707, 0≤y≤150, z=100). This gives a free stream velocity of 14.15 m/s for the Solent sonic anemometer.

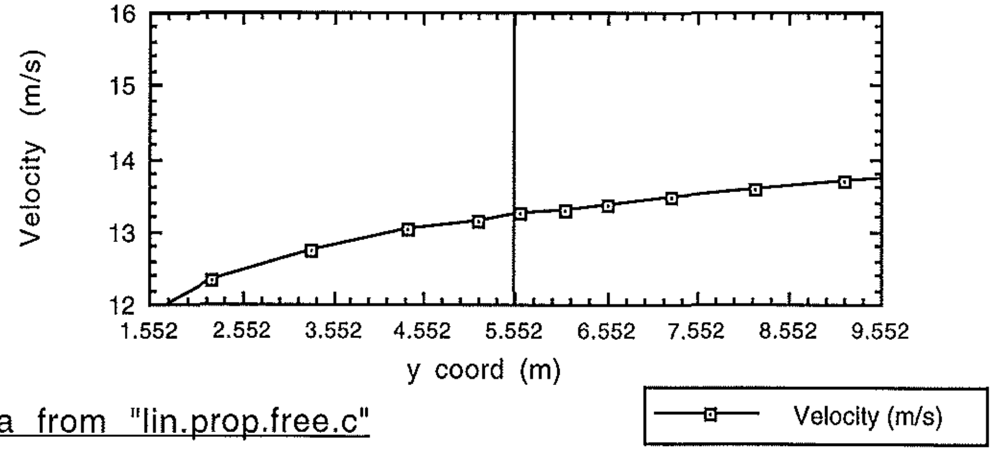


Figure 9 Free stream velocity calculated at 5.552 m, from a vertical velocity profile directly abeam of the anemometer location, (x=23.707, 0≤y≤150, z=100). This gives a free stream velocity of 13.22 m/s for the Propeller anemometer.

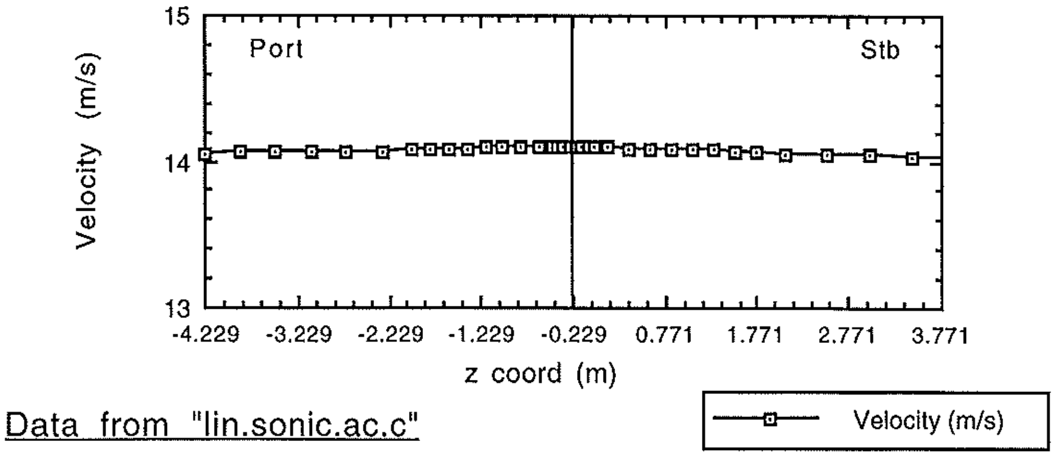


Figure 10 a) The total velocity across the Solent sonic anemometer site.

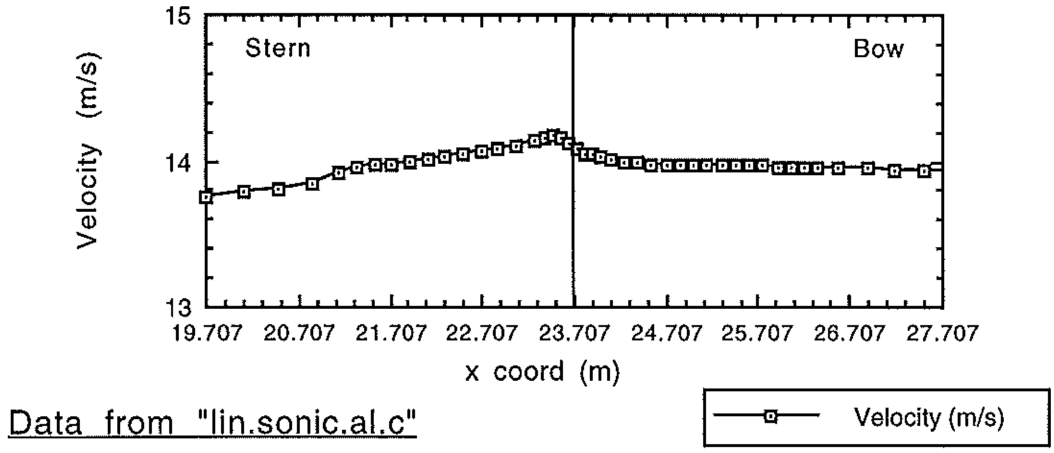


Figure 10 b) The total velocity along the Solent sonic anemometer site.

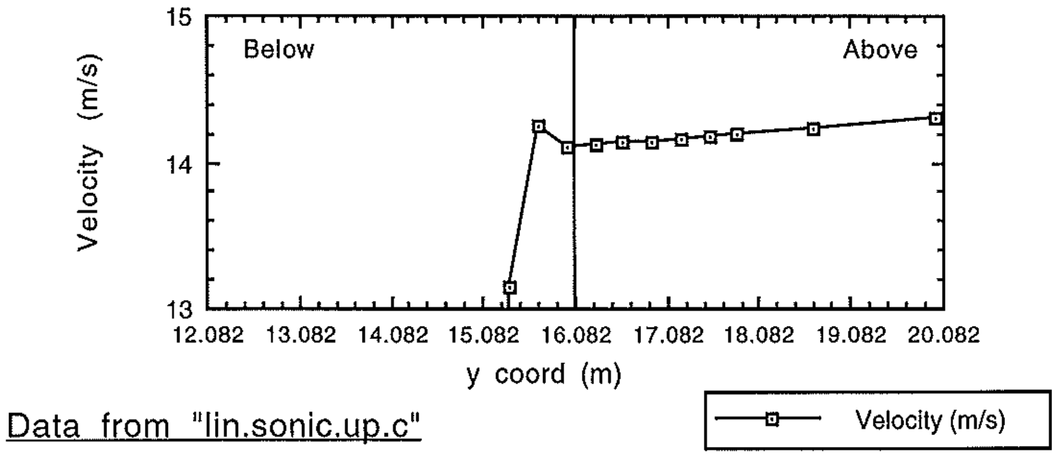


Figure 10 c) The total velocity vertically at the Solent sonic anemometer site

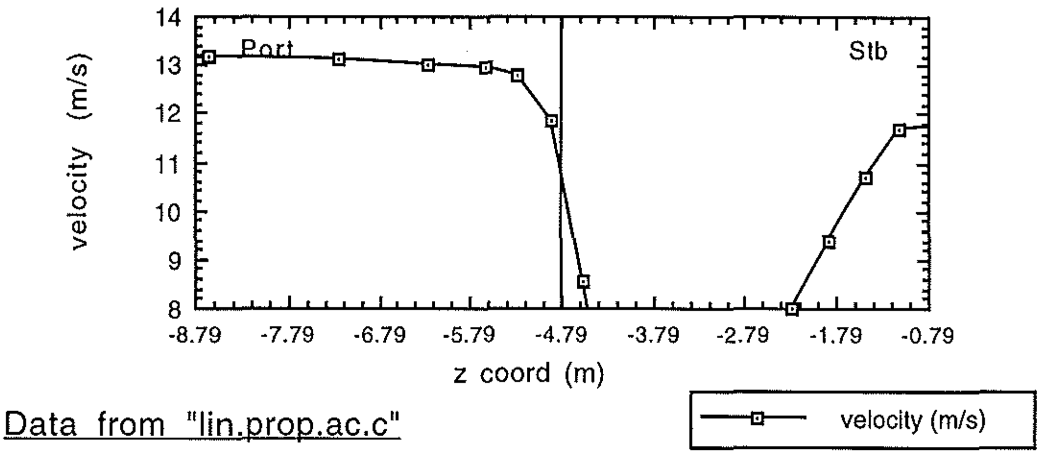


Figure 11 a) The total velocity across the propeller anemometer site.

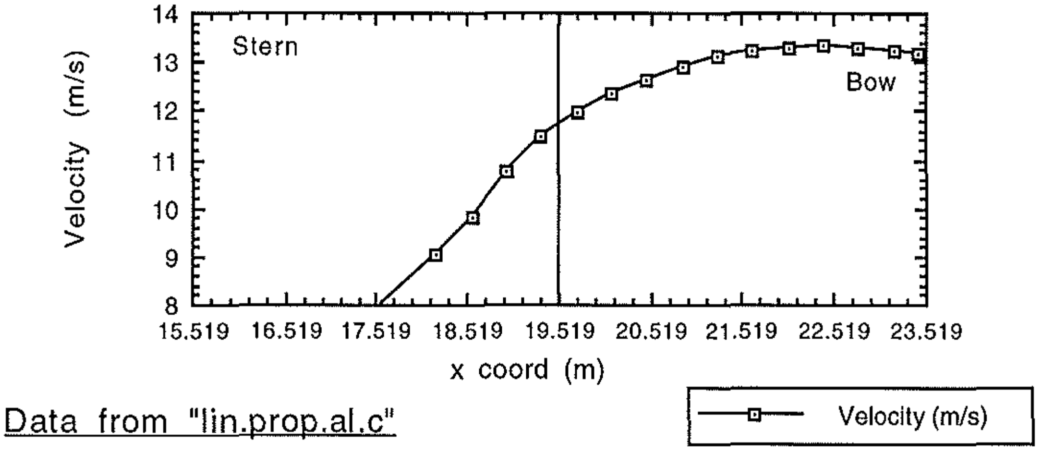


Figure 11 b) The total velocity along the propeller anemometer site.

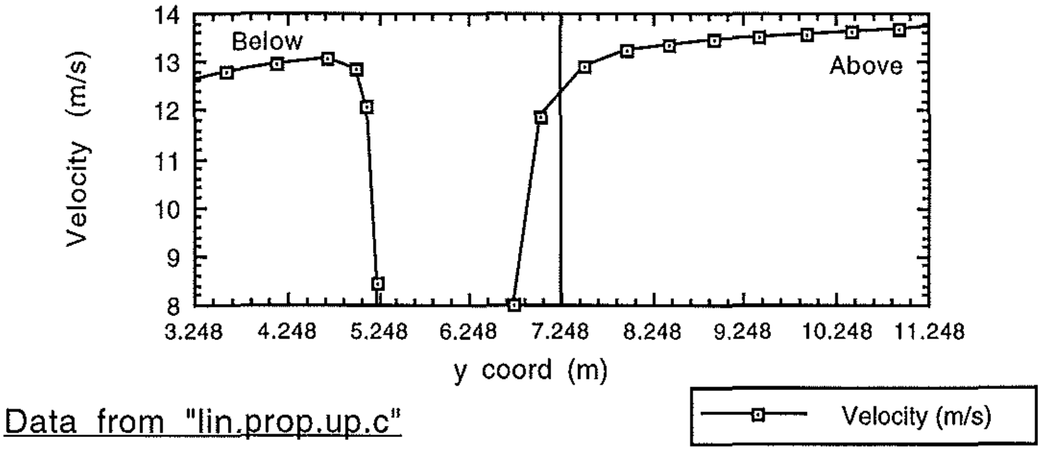


Figure 11 c) The total velocity vertically at the propeller anemometer site.

Appendix 1 Le Suroit 3.1/9 summary sheet, MAIN.INP and MESH file

1.1 Le Suroit 3.1/9 summary sheet

Summary of Le Suroit Run 3.1/9

Version of Vectis used Version 3.1 (phase 5 version 3.112)

Run Name/Number 3.1/9

Ship Name Le Suroit

Date of Run 03/10/95 to 20/10/95

Dimensions of tunnel **x, y, z,** 600(along)*150(up)*300(across)

Orientation of ship Centre line along z = 0, bow towards x = +ve

Direction of flow x = +ve to -ve

Problems with geometry No

Airflow Parameters

Airflow angle relative to the bow 0 degrees

Airflow type (logarithmic or uniform) logarithmic

Log profile name/number newlog1

Airflow speed at 10m (U_{10}) 13.78 m/s

Roughness length of sea 0.00045 m

Run started from a steady Restart file No

Steady state monitoring points at:

inlet yes
mid-tunnel yes
outlet yes

Lines of data offset from the centre line of the tunnel by 100m compared at:
inlet yes
mid-tunnel yes
outlet yes

Free stream Velocity
Was a control tunnel used? No

Name N/A

Free stream velocity calculated from:

200m upstream	No
100m abeam	Yes
Identical location in control tunnel	No

Results of Run:

The Solent sonic anemometer under reads by 0.3089 % and the air is raised 0.784 m. There is very little change in velocity in all three directions close to the Sonic anemometer site, giving the impression of a reliable velocity reading from Vectis phase 6. The propeller anemometer under reads by 12.657 % and the air is raised 1.696 m. There are large changes in velocity in all three directions close to the propeller anemometer.

Archived in directory:

/epoch/cfd/archive/version3.1/suroit/suroit_0deg/newlog1_3.1.9

Comments.

1.2 Le Suroit 3.1/9 MAIN.INP file

```
!VECTIS_MAIN_INPUT MODULAR VERSION 2.114
##JRCOC Analysis of the suroit  with the "newlog1" profile 27th SEPT.
#
#
EQUATIONS
EQN_U_MOMENTUM
EQN_V_MOMENTUM
EQN_W_MOMENTUM
EQN_PRESSURE
EQN_TURBULENCE_ENERGY
EQN_TURBULENCE_DISSIPATION
#
#
U_MOMENTUM
    5    2    0    2   -6            NSWEEP LORDER ISOLVE1 ISOLVE2 INDEX
  0.100  0.500  0.250  0.750  1.100  0.900  0.500  URFINIT URFREF URFMIN URFMAX URFINC
URFDEC  URFDWN
#
#
V_MOMENTUM
    5    2    0    2   -6            NSWEEP LORDER ISOLVE1 ISOLVE2 INDEX
  0.100  0.500  0.250  0.750  1.100  0.900  0.500  URFINIT URFREF URFMIN URFMAX URFINC
URFDEC  URFDWN
#
#
W_MOMENTUM
    5    2    0    2   -6            NSWEEP LORDER ISOLVE1 ISOLVE2 INDEX
  0.100  0.500  0.250  0.750  1.100  0.900  0.500  URFINIT URFREF URFMIN URFMAX URFINC
URFDEC  URFDWN
#
#
PRESSURE
   10    1    3    2   -8            NSWEEP LORDER ISOLVE1 ISOLVE2 INDEX
  0.100  1.000  1.000  1.000  1.000  1.000  1.000  URFINIT URFREF URFMIN URFMAX URFINC
URFDEC  URFDWN
#
#
TURBULENCE_ENERGY
   10    1    0    2   -6            NSWEEP LORDER ISOLVE1 ISOLVE2 INDEX
  1.000  1.000  1.000  1.000  1.000  1.000  1.000  URFINIT URFREF URFMIN URFMAX URFINC
URFDEC  URFDWN
#
#
TURBULENCE_DISSIPATION
   10    1    0    2   -6            NSWEEP LORDER ISOLVE1 ISOLVE2 INDEX
  1.000  1.000  1.000  1.000  1.000  1.000  1.000  URFINIT URFREF URFMIN URFMAX URFINC
URFDEC  URFDWN
#
#
ALGORITHM
PISO                                 ALGORITHM
#
#
SOLUTION_CONTROL
   T                                 LSTEADY
  -1    1.00000E-06                     MAXIT SORMAX
  0.00000E+00  8.00000E+01  1.00000E+00          TSTART TEND TCYCLE
    7    7                           NMINOR NMAJOR
```

```
#
#
REFERENCE_POINT
   10    10    10                       I/J/KREF
#
#
MONITORING_POINT_XYZ
   -200   20   100                      X/Y/ZMON
MON.0                                   FNMON
#
#
MONITORING_POINT_XYZ
    0    20     100                     X/Y/ZMON
MON.1                                   FNMON
#
#
MONITORING_POINT_XYZ
   -200   10   100                      X/Y/ZMON
MON.2                                   FNMON
#
#
MONITORING_POINT_XYZ
    0    10     100                     X/Y/ZMON
MON.3                                   FNMON
#
#
MONITORING_POINT_XYZ
   200    10     100                    X/Y/ZMON
MON.4                                   FNMON
#
#
MONITORING_POINT_XYZ
   200    20     100                    X/Y/ZMON
MON.5                                   FNMON
#
MONITORING_POINT_XYZ
   24     16      -0.3                  X/Y/ZMON
MON.6                                   FNMON
#
#
CHECKPOINT
   F    F    T    1                     CPREAD1 CPREAD2 CPDUMP ITDUMP
   F                                    POSTPRO
#
#
LINK_FILE
LINK.DAT                                LFNAME
#
#
CROSS_LINK_TIMEREGION
   1    0.00000E+00                     MREG TREG
#
#
INLET_OUTLET_BOUNDARY
    12    1    2    1    3              MBNIODS NTPROF IOFOPT MZDIODS KPRTYPE
 3.00000E+02  0.00000E+00 -1.50000E+02           AIPROF OFFSET
 0.00000E+00  0.00000E+00  1.00000E+00           AIPROF VECTOR1
 0.00000E+00  1.00000E+00  0.00000E+00           AIPROF VECTOR2
    2    14                             NXIPROF NYIPROF
 0.000E+00  3.000E+02
 0.000E+00  2.000E+00  3.600E+00  5.300E+00  1.041E+01  1.500E+01   YIPROF
```

2.060E+01 2.600E+01 3.100E+01 3.900E+01 5.100E+01 1.040E+02 YIPROF
1.370E+02 1.500E+02
0.00000E+00 TPROF
-8.92000E+00 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-8.92000E+00 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.17000E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.17000E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.28000E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.28000E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.33300E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.33300E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.38000E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.38000E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.41600E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.41600E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.44400E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.44400E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.47300E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.47300E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.49800E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.49800E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.51800E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.51800E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.52600E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.52600E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.53200E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.53200E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.53300E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.53300E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.52800E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
-1.52800E+01 0.00000E+00 0.00000E+00 1.01000E+05 2.93000E+02 5.00000E-02 1.00000E-01
0.00000E+00 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
#
#

```
INLET_OUTLET_BOUNDARY
    11    1    1    2    1              MBNIODS NTPROF IOFOPT MZDIODS KPRTYPE
 0.00000E+00  1.00000E+00  0.00000E+00  0.00000E+00      T/U/V/WPROF
#
#
ZERO_DIMENSIONAL_DATA
   1                              NBZD
    1    1                          NZDBSPEC KBTYPE
 0.000E+00  7.836E+05  0.000E+00  2.930E+02  1.010E+05  5.000E-02  1.000E-01  0.000E+00
 0.00000E+00  1.00000E+00  0.00000E+00  0.00000E+00
#
#
ZERO_DIMENSIONAL_DATA
   2                              NBZD
    1    1                          NZDBSPEC KBTYPE
 0.000E+00 -7.836E+05  0.000E+00  2.930E+02  1.010E+05  5.000E-02  1.000E-01  0.000E+00
 0.00000E+00  1.00000E+00  0.00000E+00  0.00000E+00
#
#
WALL_BOUNDARY
   1                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
   2                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
   3                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
   4                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
   5                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
   6                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
   7                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
   8                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
   9                              MBNWDS
 2.930E+02  0.100E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
  10                              MBNWDS
 2.930E+02  4.500E-04                   TEMP ROUGHNESS
#
WALL_BOUNDARY
  18                              MBNWDS
```

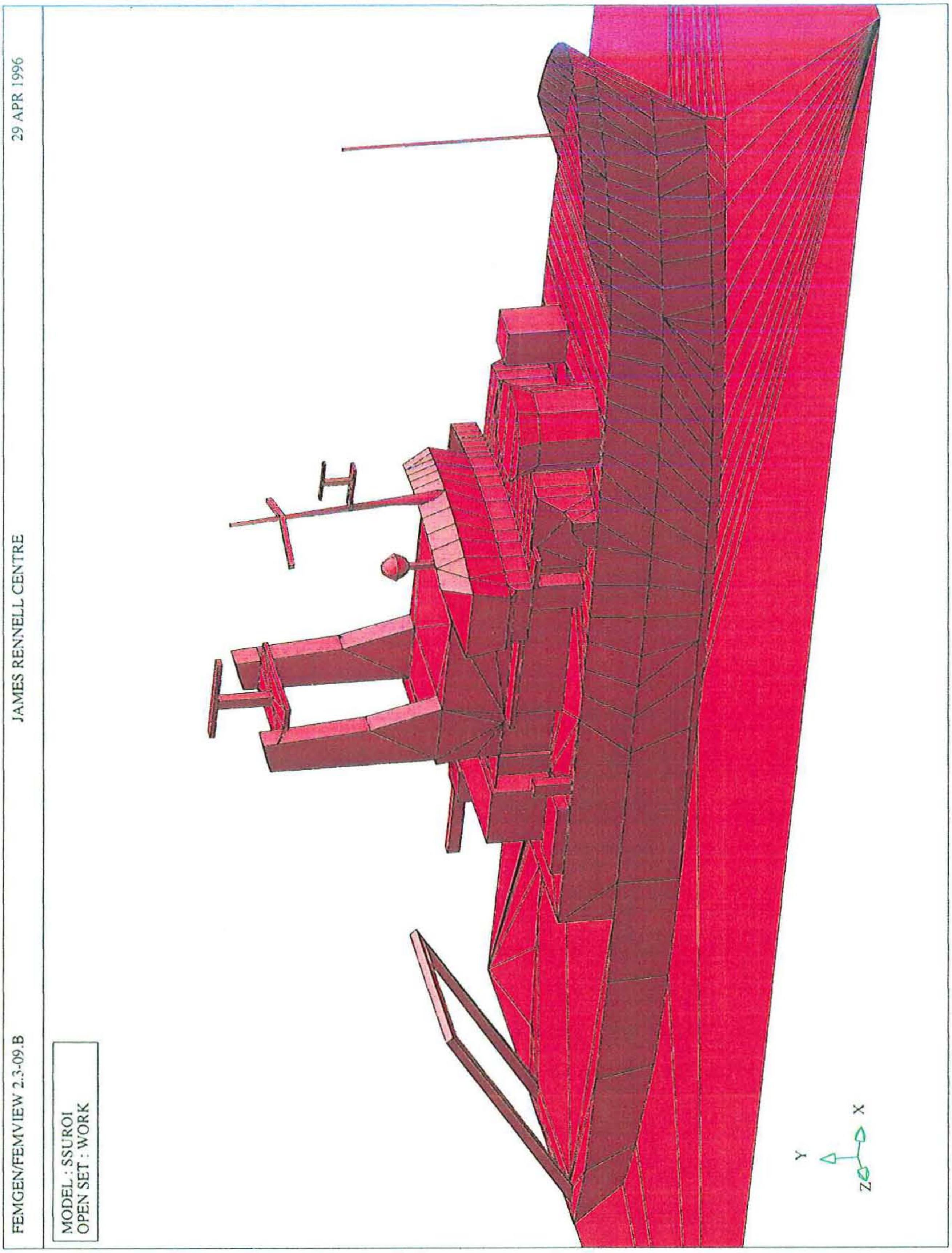
```
 2.930E+02  0.100E-04                    TEMP ROUGHNESS
#
WALL_BOUNDARY
   23                          MBNWDS
 2.930E+02  0.100E-04                    TEMP ROUGHNESS
#
WALL_BOUNDARY
   27                          MBNWDS
 2.930E+02  0.100E-04                    TEMP ROUGHNESS

#
INITIAL_CONDITION
 0.000E+00 0.000E+00 0.000E+00
 0.000E+00 0.000E+00 1.000E+00 0.000E+00 0.000E+00 0.000E+00 0.000E+00
 1.000E+00 1.000E-01 1.010E+05 2.930E+02 0.000E+00
 0.00000E+00 1.00000E+00 0.00000E+00 0.00000E+00
#
#
SWIRL_REGION
    0     0     0     0     0     0      ISWIRLS ISWIRLE JSWIRLS JSWIRLE KSWIRLS KSWIRLE
#
#
GLOBAL_INTEGRATION
    1   1000     1   1000     1   1000      IGINTS IGINTE JGINTS JGINTE KGINTS KGINTE
#
#
PRANDTL_NUMBER
 7.0000E-01                          PRHL
#
#
SPECIES_DATA
 1.1400E+02                          WEIGHT
  2.5000E+03  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00   CPCOEFF
  6.6055E-06  4.5297E-08  -1.2064E-11  1.6092E-15  0.0000E+00  0.0000E+00   VTCOEFF
#
#
SPECIES_DATA
 2.8000E+01                          WEIGHT
  1.1000E+03  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00   CPCOEFF
  6.7055E-06  4.5297E-08  -1.2064E-11  1.6092E-15  0.0000E+00  0.0000E+00   VTCOEFF
#
#
SPECIES_DATA
 3.0000E+01                          WEIGHT
  1.3000E+03  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00   CPCOEFF
  6.8055E-06  4.5297E-08  -1.2064E-11  1.6092E-15  0.0000E+00  0.0000E+00   VTCOEFF
#
#
SPECIES_DATA
 3.0000E+01                          WEIGHT
  1.3000E+03  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00  0.0000E+00   CPCOEFF
  6.9055E-06  4.5297E-08  -1.2064E-11  1.6092E-15  0.0000E+00  0.0000E+00   VTCOEFF
```

1.3 Le Suroit 3.1/9 MESH file

```
!VECTIS_MESH_INPUT_V1.100
VECTIS mesh generator input file
MODEL_NAME = suroit.tri1
SETS_NAME = suroit.sets2
TYPES_NAME = suroit.types2
REFINEMENT_DEPTH =  0
PATCH_TYPE =  3
IJK_BLOCK =  22  57   2  21  15  32   2   1
IJK_BLOCK =  45  53  12  20  21  26   2   2
IJK_BLOCK =  35  35  15  21  22  25   2   2
IJK_BLOCK =  35  35  16  16  27  28   2   2
IJK_BLOCK =  41  47   7  10  28  30   2   2
IJK_BLOCK =  48  52   7  10  28  29   2   2
IJK_BLOCK =  50  56   7  10  26  27   2   2
IJK_BLOCK =  53  56   7  10  22  25   2   2
IJK_BLOCK =  50  55   7  10  20  21   2   2
IJK_BLOCK =  47  51   7  10  18  19   2   2
IJK_BLOCK =  41  46   7  10  17  18   2   2
MESH_COORDINATES
  78  35  46
   1  78   1  35   1  46
   3
-3.72001E+02
-3.36001E+02    1
-2.95038E+02    1
-2.55051E+02    1
-2.20004E+02    1
-1.90025E+02    1
-1.65004E+02    1
-1.42036E+02    1
-1.20011E+02    1
-1.00008E+02    1
-5.45463E+01    5
-4.89004E+01    1
-4.50003E+01    1
-2.00002E+00   15
 4.17277E+00    3
 6.23219E+00    1
 1.79861E+01    5
 2.33627E+01    7
 2.40281E+01    2
 2.82469E+01    7
 4.55001E+01    5
 5.00001E+01    2
 5.47351E+01    1
 6.00034E+01    1
 1.00051E+02    4
 1.20008E+02    1
 1.42021E+02    1
 1.65003E+02    1
 1.90015E+02    1
 2.20009E+02    1
 2.55031E+02    1
 2.95031E+02    1
 3.36051E+02    1
 3.72031E+02    1
   3
-5.00001E+00
-5.00001E-01    1
```

4.95333E+00	5
6.79802E+00	4
8.65953E+00	2
1.16730E+01	3
1.30515E+01	1
1.80021E+01	4
2.60001E+01	3
2.83305E+01	1
3.16871E+01	1
3.60507E+01	1
4.39053E+01	1
5.50001E+01	1
1.30033E+02	4
1.59061E+02	2
1.68041E+02	1
3	
-1.65001E+02	
-1.57501E+02	1
-1.35001E+02	1
-1.10001E+02	1
-9.00001E+01	1
-7.20001E+01	1
-5.40001E+01	1
-4.00001E+01	1
-3.40371E+01	1
-2.20001E+01	1
-1.75001E+01	1
-1.40001E+01	1
-1.15001E+01	1
-5.79338E+00	3
-3.68801E+00	3
-4.92034E-01	4
2.84047E-02	2
3.68831E+00	4
5.88084E+00	3
1.15011E+01	3
1.40014E+01	1
1.75005E+01	1
2.20011E+01	1
3.00021E+01	1
4.00031E+01	1
5.40041E+01	1
7.20051E+01	1
9.00031E+01	1
1.10021E+02	1
1.35011E+02	1
1.57501E+02	1
1.65001E+02	1

1.4 Le Suroit Model



Le Suroit