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Airflow over the R.R.S. Discovery using the Computational Fluid Dynamics package Vectis

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Abstract.

This report describes the use of the Computational Fluid Dynamics software "Vectis" for studying the air flow around ships. Measurements of wind speed obtained from ship-borne instruments can be subject to systematic errors, caused by the disturbance of the air flow by the ship's hull and superstructure.

The use of the "Vectis" software is described for a simulation of the air flow over the R.R.S. Discovery. The magnitude of the wind speed error is calculated for an anemometer sited on the foremast platform of the ship.

AIR FLOW OVER THE R.R.S. DISCOVERY USING THE COMPUTATIONAL FLUID DYNAMICS PACKAGE VECTIS

(VECTIS REPORT NUMBER 3.1/7)

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Ben Moat, Margaret Yelland and Jim Hutchings
February 1996
Phase 5 run time 11th Aug 1995 to 21st Aug 1995

1. Introduction

Accurate wind measurements at sea are required for satellite validation and climate research. The anemometers deployed on N.E.R.C. research ships are very accurate, but the wind stress to wind speed relationships found differ from one ship to another. It is thought that the wind stress can be accurately measured and that the largest source of error lies in the measurement of the true wind speed. Wind speed errors of the order of 10% would account for the difference in the wind stress to wind speed relationships obtained from the Charles Darwin cruise 43 and the Discovery cruises 199 to 201 (Yelland and Moat, 1996). This study examines the error in wind speed measurements caused by the distortion of the airflow by the hull and superstructure on the Discovery (for example, the air may be lifted and/or accelerated over the bows of the ship before it reaches the foremast). The computational fluid dynamics package "Vectis" (Hutchings, 1995c) is used to model the airflow over the Discovery when the ship is head to wind.

Section 2 describes the model of the flow of air over the Discovery which was performed using Vectis phase5 (version 3.121) on a Silicon Graphics power Indigo^2, 'solstice'. Section 3 describes the extraction of data in phase6 of Vectis. Data were extracted for the locations of the anemometers used on cruises D199 to D201 (a Solent sonic on the foremast and the ship's anemometer on the monkey island), and the results are presented in section 4. The Solent sonic anemometer position was changed slightly for cruises D213 and D214 and a brief summary of the corresponding wind speed errors is given in section 5.

2 Description of model

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 tunnel used is the standard 0-degree tunnel of dimensions x = length (-300 to 300 m), y = height (0 to 150 m) and z = width (-150 to 150 m). 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 "disco.mesh1".

The locations of the anemometer sites are those which were used on Discovery cruises 199, 200 and 201. Using the Vectis model origin, the locations are:

Solent sonic anemometer x = 33.3 m, y (height) = 18.76 m, z = 2.3 m

Ship's anemometer x = 7.25 m, y (height) = 15.27 m, z = -5 m

The actual height of the Solent sonic anemometer relative to the waterline was measured as 18.5 m, due to a difference between the draught of the Discovery during the cruises and that of the ship plans and hence on the model. The anemometer position is accurate relative to the local geometry of the foremast (Figure 1).

The Femgen model located under:

/epoch/cfd/archive/version3.1/discovery/discovery_0deg/newlog_3.1.7/discovery_files_3.1.7/DISCO1.G20

is a model of Discovery with no wind tunnel surround. The model has been translated in the negative x direction and merged with a standard tunnel in phase1 of Vectis. The translation (-44,0,0) brought the coordinate origin to the centre of the ship.

A visit was made to Discovery to verify the accuracy of the ship geometry. Details are in the Discovery visit report, Appendix 3.

2.3 Wind profile used

The rate of development or degradation of the wind profile along the tunnel is different in phase5 version 3.112 than in the phase5 (version 2.121) used in "Vectis 1.6". Profiles input in the older version would become more uniform along the length of the tunnel (Hutchings, 1995b), whereas the later version of phase5 is capable of sustaining a logarithmic profile which is virtually unchanged along the tunnel. The profile used for the Discovery was designed to reproduce the 'newlog' profile used for the Darwin run 1.6/13 (Hutchings, 1995a). The wind profile used for the Charles Darwin was logarithmic below 50 m (roughness length $4.5*10^{-4}$ m), and uniform from 50 m upwards. This type of profile was found to degrade least along the tunnel in version 1.6. The flow was directly over the bows of the ship. The wind speed at a height of 10 m (U10) as specified in the Discovery MAIN.INP file was 13.75 m/s.

Figure 2a) shows the velocity profiles at position x=33.3, $0 \leq y \leq 150$, z=100 for both the Charles Darwin and the Discovery runs and the difference between them is shown in Figure 2b). This shows a good agreement between the two profiles at a position 100 m abeam of the Discovery Solent sonic anemometer site.

2.4 Convergence

The velocity and pressure were monitored at six positions (Figure 3):

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) (33, 17, -2) MON.5 (close to Solent sonic anemometer position)

A graph of total velocity against time step is shown in Figure 4. A file containing all output variables was examined for the last 400 time steps. All values had steadied to the third significant figure.

2.5 Conclusions

The model used a wind profile which reproduces the 'newlog' profile used in the Charles Darwin run 1.6/13. The run was shown to have converged, and a post processing file was written for the extraction of data.

3 Data extraction from phase6 of Vectis

3.1 Introduction

A post processing file was written at time step 81.4 seconds (after more than 1100 iterations) 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) and compared to that of a real surface layer profile (section 3.4).

3.2 Checks on the free stream velocity

A vertical plane close to the edge of the wind tunnel (z=100 m) 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 ($-250 \leq x \leq 250$, y=10, z=100) and ($-250 \leq x \leq 250$, y=20, z=100), shown in Figure 5. The graph is shown in greater detail in Figure 6, giving velocity data at ($-50 \leq x \leq 50$,y=10 and y=20, z=100) i.e. directly abeam of the ship. The difference between velocity at the inlet and outlet is 0.083 m/s at a height of 10 m, and 0.001 m/s at 20 m, which indicates a very small change down the tunnel. Lines of data along the tunnel at heights of 10 m and 20 m give sample means of $\bar{U}_{10}$ = 13.8 m/s and $\bar{U}_{20}$ = 14.5 m/s respectively, with corresponding sample standard deviations of 0.027 m/s and 0.015 m/s. These results show that free stream flow exists on a plane at z=100.

3.3 Checks on the logarithmic profile

Vertical velocity profile data were extracted at the inlet and the 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 7a). Figure 7b) shows the difference between the inlet and outlet profiles. There is a maximum of -0.32 m/s at a height of 2 m, 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 Comparison of the tunnel wind profile to a surface layer profile.

It has already been stated that the velocity profile used in this run was designed to reproduce the one used for the Charles Darwin. This section looks at how this profile compares to a real surface layer profile over the ocean. The real wind profile is logarithmic and the friction velocity, **U***, can be related to the neutral 10 m wind speed, $\mathbf{U_{10}}$, by an empirical relationship such as that given by Smith (1980):

$$1000 * \left(\frac{U*}{U_{10}}\right)^2 = 0.61 + 0.063 * U_{10} \qquad (1)$$

which is shown in Figure 8.

The lowest 40 meters of the tunnel profile (abeam of the anemometer site) can be represented by a straight line fit to the graph of $\mathbf{U_Z}$ against **ln(Z)** (Figure 9):

$$U_Z = A + B * \mathrm{LN}(Z) \qquad (2)$$

where A=11.522 and B=0.97997. This can be equated to the neutral wind profile:

$$U_Z = \left(\frac{U*}{k}\right)\ln\left(\frac{Z}{Z_0}\right) \qquad (3)$$

$$U_Z = -\left(\frac{U*}{k}\right)\ln(Z_0) + \left(\frac{U*}{k}\right)\ln(Z) \qquad (4)$$

where Z_0 is the roughness length and k, the von Karman constant, has a value of 0.4. Equating the ln(Z) terms in equations (2) and (4) gives an expression for the friction velocity of the wind tunnel profile:

$$U* = B * k \qquad (5)$$

For B=2.6279, the friction velocity is 0.392 m/s. It can be seen from Figure 8 that this should correspond to a 10 m neutral wind speed of 10.87 m/s, whereas that in the tunnel is

13.78 m/s. This suggests that the profile used is equivalent to a ship steaming at 2.91 m/s (5.82 knots) directly into a true 10 m wind speed of 10.87 m/s.

Figure 10 shows the slab profile (representing the ship's speed), the true wind profile and their resultant profile. Also shown is the wind tunnel profile at the anemometer site. Figure 11 shows the difference between the resultant profile and the wind tunnel profile. The maximum difference is -1.2 m/s below a height of 0.5 m, but at most heights the difference is about ±0.02 m/s. This verifies the idea that the profile used represents a relative 10 m wind speed of 13.78 which is the resultant of a ship speed of 2.91 m/s and a true $\mathbf{U_{10}}$ of 10.87 m/s. The profile characteristics are summarised in table 1.

Profile	**U*** (m/s)	$\mathbf{U_{10}}$ (m/s)
tunnel profile	0.392	13.78
true profile	0.392	10.87
ship speed	-	2.91

Table 1 The velocity profile characteristics.

3.5 Conclusions

The wind profile used for the Discovery run 3.1/7 does not degrade down the tunnel and reproduces the profile used for the Charles Darwin 1.6/13. The profile used in this study is equivalent to the Discovery steaming at 2.91 m/s into a true 10 m wind of 10.87 m/s, giving an apparent $\mathbf{U_{10}}$ of 13.78 m/s. Checks on the free stream velocity at y = 10 m and y = 20 m, 100 m 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. Discovery cruises D199-201

4.1 Introduction

This section examines the error in the wind speed measurements from a Solent sonic anemometer, located on the bow foremast, and a propeller anemometer, located on the monkey island, as used on Discovery criuises D199, D200 an D201. The run is at 0 degres to the wind profile, i.e head to 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 12). 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 phase6 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 centre plane of the model is K24. K26 is closest to the Solent sonic.

K25 $z = 0.9900$ m

K26 $z = 1.9907$ m Solent sonic anemometer at $z=2.3$ m

K27 $z = 2.9909$ m

location	x (m)	y (m)	z (m)
Solent sonic	33.300	18.760	2.3000
Z_{anemom}	33.312	18.820	1.9907
Solent - Z_{anemom}	-0.12	-0.06	0.3093
Z_{origin}	120.480	17.786	1.9907
Z_{anemom}-Z_{origin}	87.168	**1.034**	0

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

For the Solent sonic, the air flow has been raised by 1.034 m from its original height before it reaches the anemometer location. Since the plane used for the Solent sonic was offset from the anemometer location by about 30 cm to one side, the results for the adjacent planes were also calculated. For K25 the height raised was 1.027 m, and for K27 the height raised was 1.039 m: these are not significantly different from the K26 value. Given the accuracies of the various locations, a value of 1 m should be used when correcting data from the ship.

For the ship's anemometer, the local planes are:

K18 $z = -6.01$ m

K19 $z = -5.01$ m ship's anemometer at $z = -5$ m

K20 $z = -4.01$ m

location	x (m)	y (m)	z (m)
ship's anemometer	7.25	15.274	-5
Z_{anemom}	7.169	15.299	-5.01
ship's - Z_{anemom}	0.081	-0.025	0.01
Z_{origin}n	80.03	12.265	-5.01
Z_{anemom}-Z_{origin}	72.861	**3.034**	0

Table 3 Table showing the amount the air is raised when it reaches the ship's anemometer site.

For the ship's anemometer, the air flow has been raised by 3 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 13 shows the free stream profile directly abeam of the Solent sonic anemometer, at ($x=33.3$, $0 \leq y \leq 150$, $z=100$), which gives a free stream velocity of 14.322 m/s at $y=17.786$ m. Figure 14 shows the corresponding profile for the ship's anemometer, at ($x=7.25$, $0 \leq y \leq 150$, $z=100$), which gives a free stream velocity of 13.992 m/s at $y=12.265$ m.

4.4 Velocities at anemometer locations

For both anemometer locations velocity data were extracted along lines in the x, y and z directions. Figures 15 and 16 show the lines of data through the Solent sonic and ship's anemometer sites respectively. The figures show data within ± 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 velocity at the ship's anemometer site is different when obtained from a line of data along the z direction compared to the values obtained from the other two directions. This may be a feature of the Vectis phase6 LIN command (section 4.6). The results for both anemometers are summarised in Table 4.

The percentage wind speed error is given by:

$$\text{error} = \left(\frac{\text{average velocity}}{\text{free stream}} - 1 \right) * 100 \qquad (6)$$

Anemometer	Velocity from each direction (m/s)	Average velocity (m/s)	Free stream velocity (m/s)	% error
Solent sonic	14.246 (x)			
	14.253 (y)	14.250	14.322	**-0.503**
	14.250 (z)			
Ship's	14.825 (x)			
	14.850 (y)	14.800	13.992	**5.775**
	14.725 (z)			

Table 4 Velocities and error estimates at the anemometer sites.

4.5 Rates of change of velocity at the anemometer site

This section examines the rate of change of velocity around the anemometer site using Figures 15 and 16. 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)	0.0025	0.0025
	up (y)	0.034	0.0125
	across (z)	0.425	0.0095
Ship's	along (x)	0.655	0.550
	up (y)	0.775	0.125
	across (z)	0.225	0.060

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

The rate of change of velocity per meter is very small around the Sonic anemometer site which illustrates that the anemometer is mounted in a well exposed position. The wind speed error would change from 0.5% to 0.2% or 0.8% if the anemometer location was changed by a meter in the z direction (a velocity change of 0.4 m/s). The ship's anemometer (located above the bridge) gives very high rates of change of velocity. This anemometer is in a region of high airflow distortion due to the size and proximity of the surrounding structures: it is a bad site for measuring wind speed and the results extracted from the model may also be affected (section 4.6).

4.6 Errors in phase6 data extraction

All data extraction from phase6 of Vectis is achieved by the use of the LIN command. The start and end co-ordinates of the required line of data are specified by the user. A file is created which holds positional and velocity data for each cell along the line. The two constant co-ordinates (y and z, say, for a line along the tunnel) are assigned the values input to the LIN command, whereas the x co-ordinate and the velocity values are those of the centre of the cell intersected. The y and z co-ordinates may be specified to be those of an anemometer location, and will appear as such in the LIN output file, but the velocity values could be those from slightly different co-ordinates. This will happen in some or all directions unless the anemometer is located at the exact centre of a cell.

In regions where the flow changes little between cells the effect is insignificant, as in the area around the Solent sonic. However, in the region of the ship's anemometer the effect is to cause discrepancies in the results obtained from the lines of data taken in three directions. If reliable results are required in such an area, a tighter mesh must be used. Figure 17a) shows a horizontal plane with a line of data written through a cell structure containing an area of Iforce=1 and Ideep =1. Figure 17b) shows the effect of decreasing the cell size to Iforce=2 and Ideep=2.

This problem does not affect the calculation of the free stream value, since the velocity changes very little either across or along the tunnel. Only a vertical line of data in the free stream region is needed, and the user interpolates between the velocities of the cell centres above and below the required height.

4.7 Conclusions

For the Solent sonic location the wind speed was reduced by 0.5% and lifted by 1 m. There was very little change in velocity in all three directions close to the anemometer site, which suggests that the results are reliable and that the anemometer is in a well exposed position.

For the ship's anemometer, the wind was increased by 5.8% and lifted by 3 m. There were large changes in velocity in all three directions close to the anemometer. 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.

5. Discovery cruises D213 and D214

5.1 Introduction

On Discovery cruises D213 and D214 the Solent sonic anemometer position was 0.3 m lower than on cruises D199 to D201.

Solent sonic position for D213 and D214 x=33.3 m, **y(height)=18.46 m**, z=2.3 m

All validation of the wind profile and free stream velocity is shown in section 2.3. This section just gives a brief summary of the amount the air is raised and the velocity error at the new Solent sonic anemometer site.

5.2 Height air raised and velocity errors

The plane used is the same as in section 2.3, i.e. K26.

location	x (m)	y (m)	z (m)
Solent sonic	33.3	**18.46**	2.3
Z_{anemom}	33.336	18.451	1.99
Solent - Z_{anemom}	-0.036	0.009	0.31
Z_{origin}	121.12	17.393	1.99
Z_{anemom}-Z_{origin}	-87.82	**1.058**	0

Table 6 Table showing the amount the air is raised when it reaches the Solent Anemometer site.

The air is raised by 1 m from a location 87.82 m upstream of the anemometer location.

Anemometer	Velocity data lines (m/s)	Average velocity (m/s)	Free stream velocity (m/s)	% error
Solent sonic	14.246 (x-axis)	14.246	14.300	**-0.378**
	14.242 (y-axis)			
	14.249 (z-axis)			

Table 7 Velocity Error estimates at the Solent Anemometer site.

The velocity at the Solent Sonic on D213 and D214 under reads by 0.38%.

5.3 Summary

With the ship head to wind on Discovery cruises 199 to 201 the Solent sonic anemometer under read by 0.5 %. For cruises D213 and D214 the Solent sonic under read by 0.38 %. There is no significant change in the amount the airflow was raised; 1.034 m for D199 to D201, and 1.058 m on D213 and D214.

6. Summary

The model was shown to have converged. Quality control checks on the free stream conditions abeam of the ship showed that there was no blockage of the flow in the tunnel. The wind profile did not degrade significantly along the length of the tunnel. The model was found to be satisfactory.

The study of the wind speed errors on Discovery cruises D199 to D201 showed the Solent sonic anemometer to be in a well exposed position and that data logged by the anemometer could be classed as reliable. Large rates of change at the site of the ship's anemometer mean that data logged by the anemometer cannot be classed as reliable and should not be used for obtaining good wind speed measurements. The measured wind speed is reduced from the free stream value by 0.5 % for the Solent sonic, and increased by 5.8 % for the ship's anemometer.

For Discovery cruises D213 and D214 the Solent sonic anemometer location is 0.3 m lower than on D199 to D201. The wind speed for the Solent sonic location is reduced by 0.38 % in comparison to the free stream value.

7. References

Hutchings, J. 1995a. *Airlow over the R.R.S. Charles Darwin*, Vectis report 1.6/13, Southampton Oceanography Centre, (Unpublished Report).

Hutchings, J. 1995b. *Control tunnel evaluating the newlog Boundary profile.*, (Unpublished Report), Vectis Report 1.6/5, Southampton Oceanography Centre, UK.

Hutchings, J. 1995c. *User notes for investigating the wind fields around research ships with version 1.6 of Vectis*, Internal report 95/5, James Rennell Division, Southampton Oceanography Centre, UK.

Yelland, M.J. and B.I. Moat, 1996: *Improving wind observations - modelling the air flow around ships,* UK WOCE Newsletter "SIGMA", 19.

8. Figures

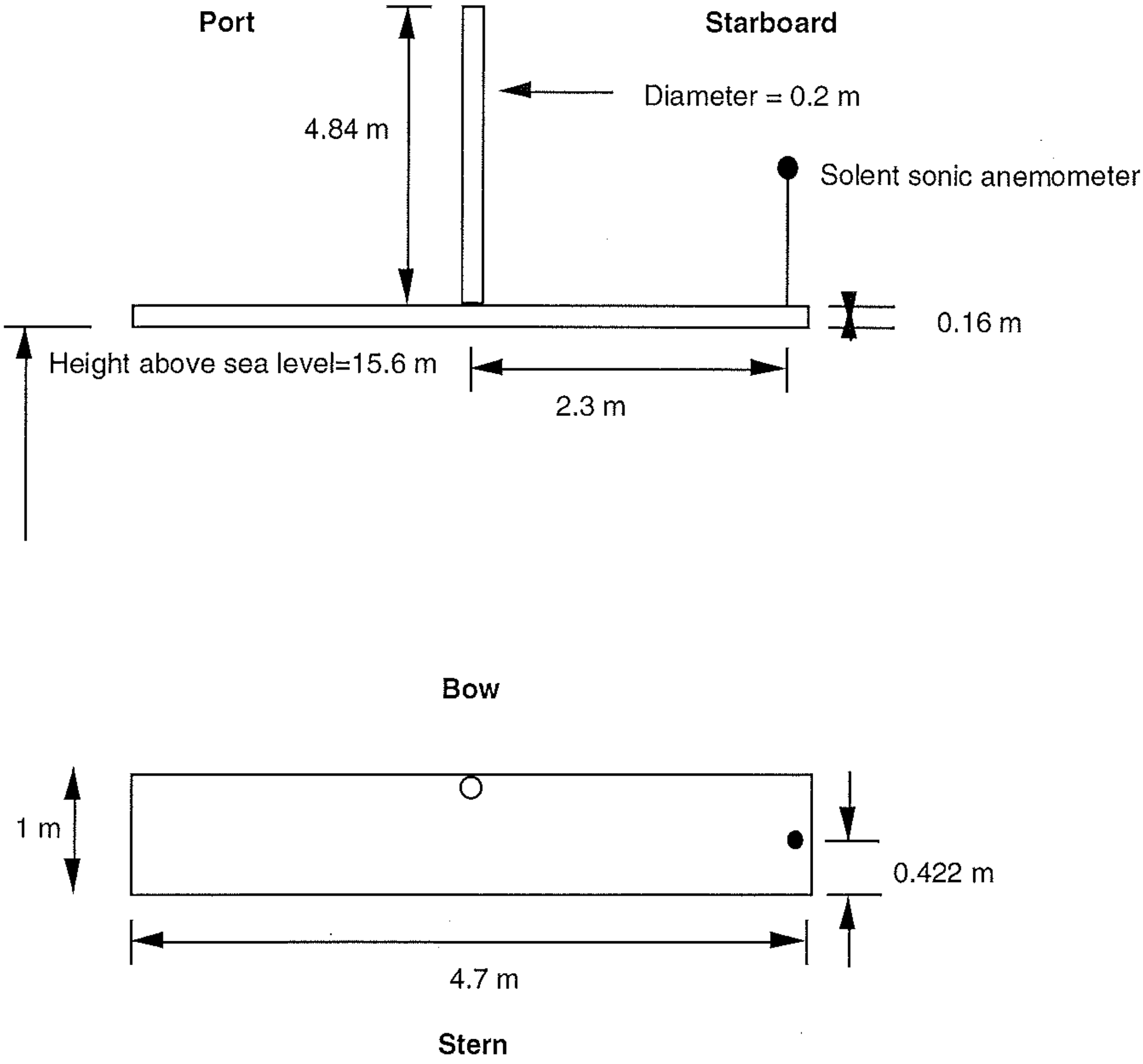


Figure 1. The location of the Solent sonic anemometer relative to the foremast on R.R.S. Discovery cruises D199 to D201.

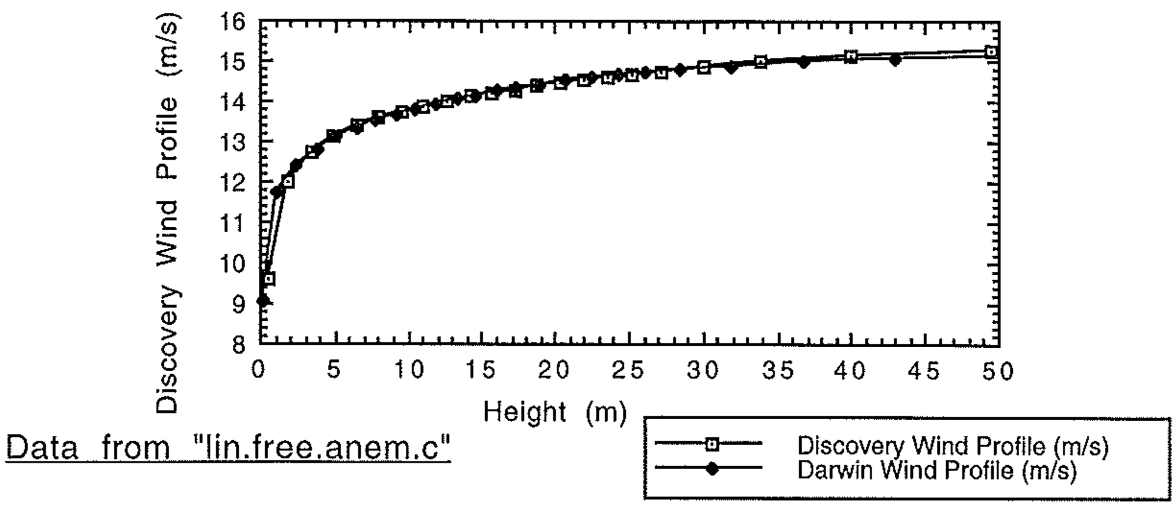


Figure 2a). The wind profile from Discovery 3.1/7 and Darwin 1.6/13 100 m abeam of the Solent sonic anemometer.

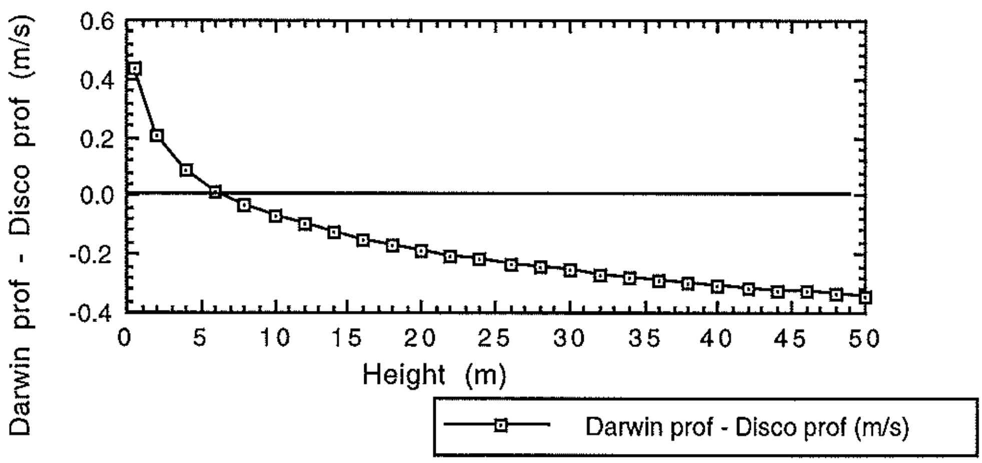


Figure 2b). The difference between a logarithmic fit to the first 50 m of the wind profile used on R.R.S. Charles Darwin 1.6/13 and a logarithmic fit to the first 50 m of the wind profile used on R.R.S. Discovery 3.1/7.

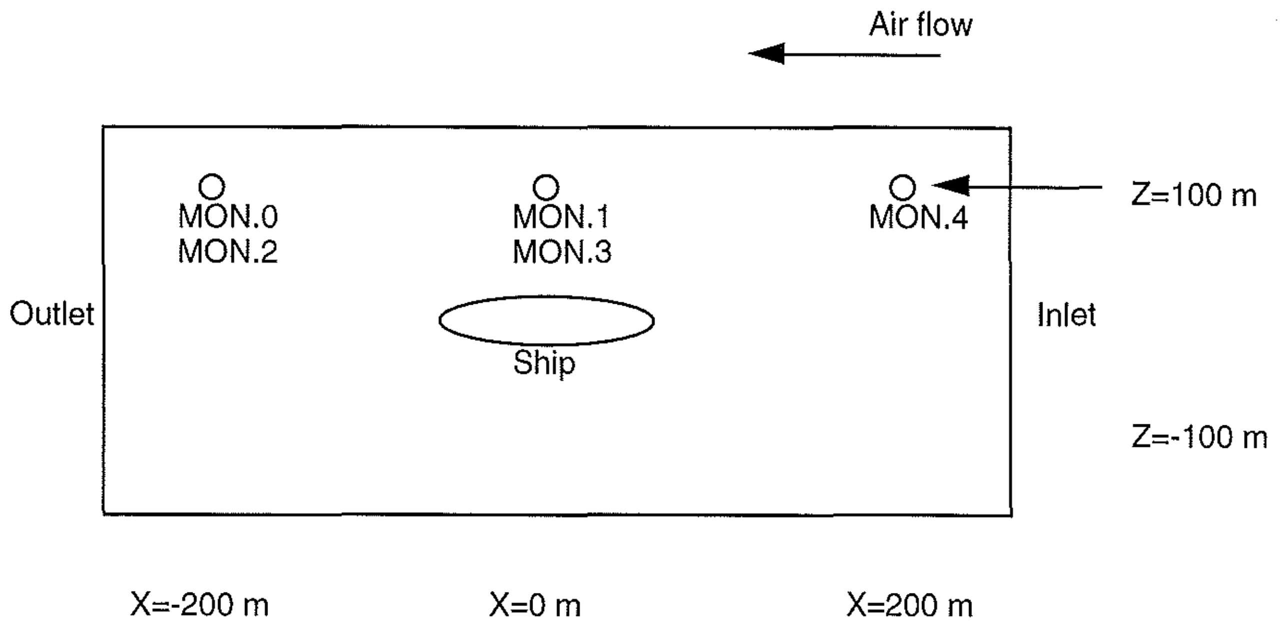


Figure 3. The locations of the six monitoring points.

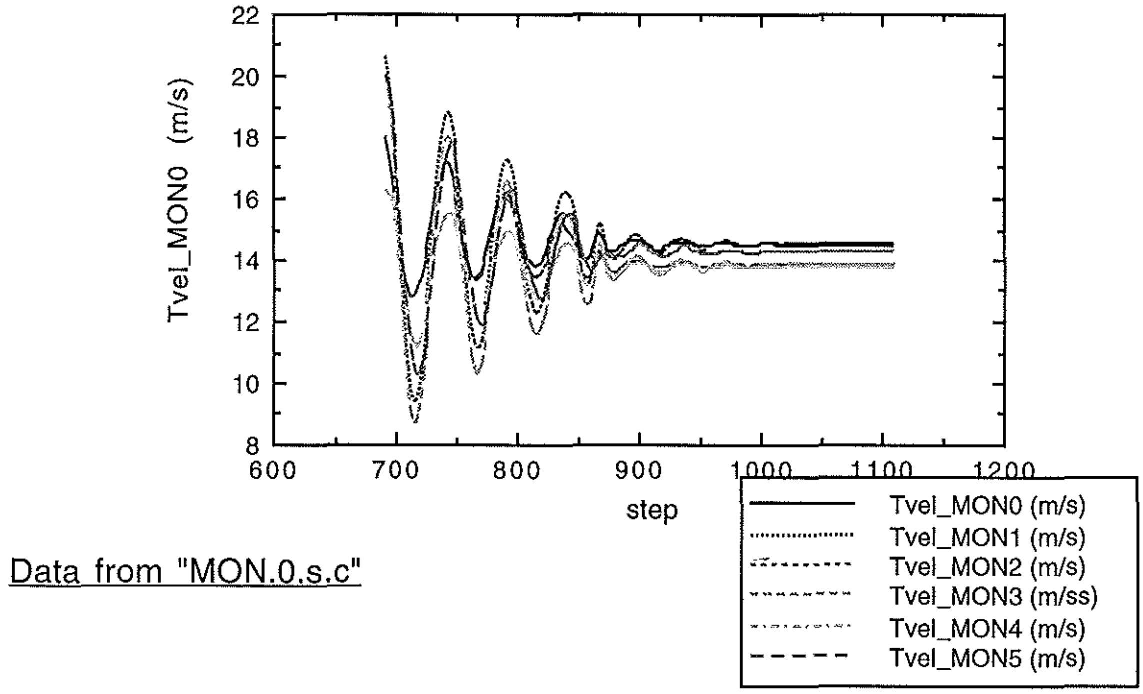


Figure 4. Total velocity for each monitoring location.

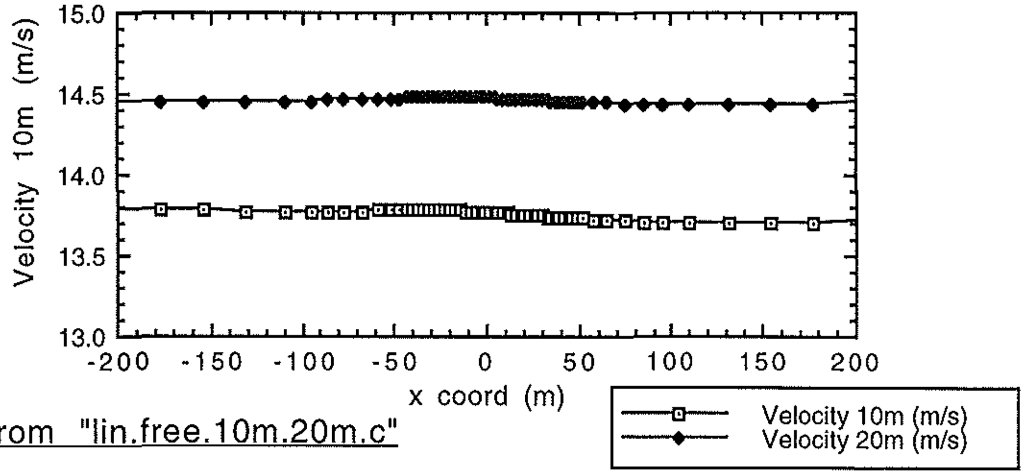


Figure 5. Total velocity along the tunnel at a constant offset z=100 and at heights of y=10 m and y=20 m.

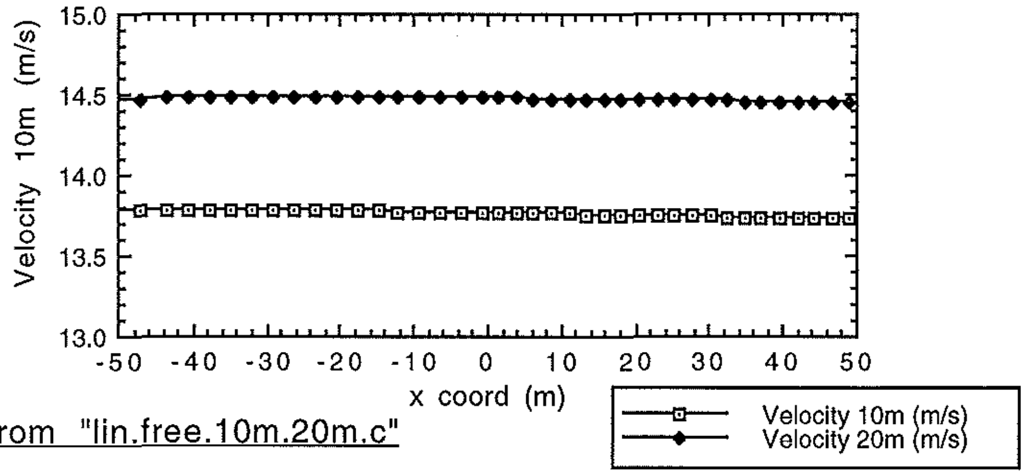
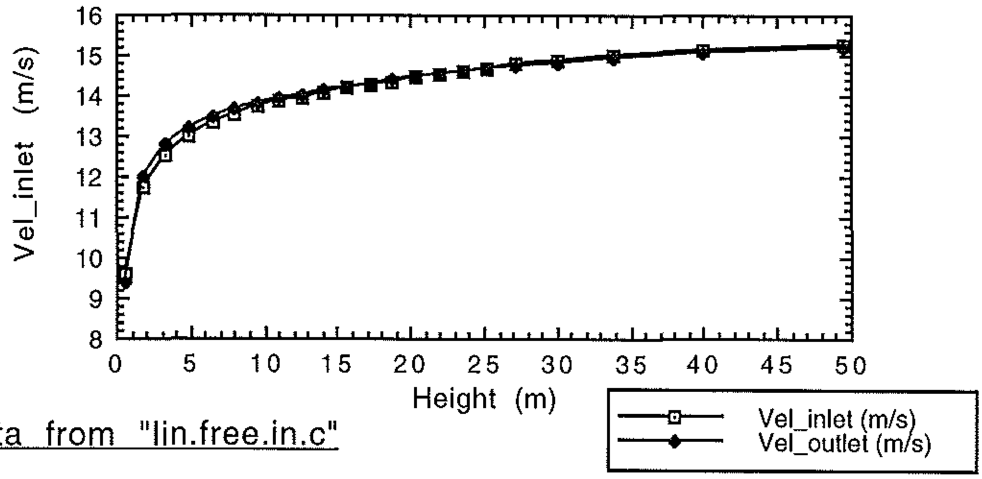
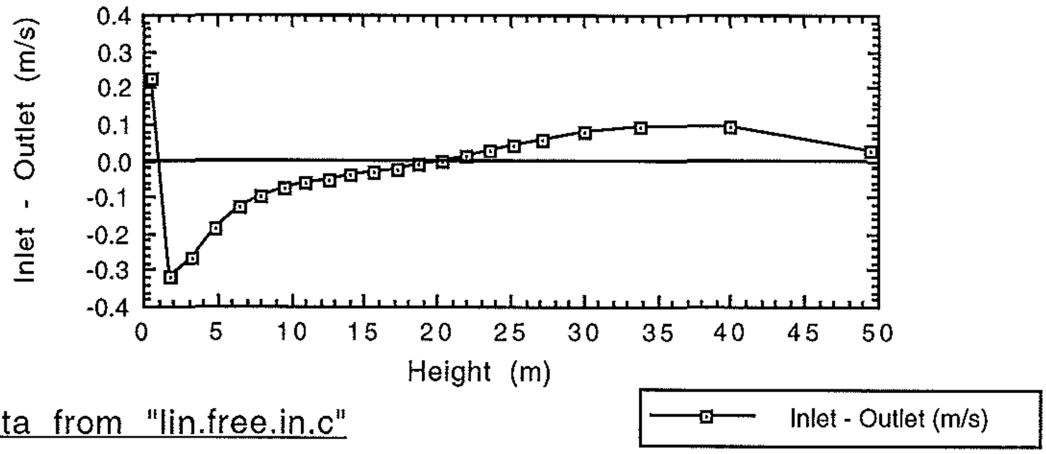


Figure 6. Total velocity from -50 to 50 m, as in Figure 4, directly abeam of the ship.



Data from "lin.free.in.c"

Figure 7a). Free stream profile taken close to the inlet (x= 200, $0 \leq y \leq 50$, z=100), and close to the outlet (x= -200, $0 \leq y \leq 50$, z=100).



Data from "lin.free.in.c"

Figure 7b). Velocity profile at the inlet minus velocity profile at the outlet for Discovery 3.1/7.

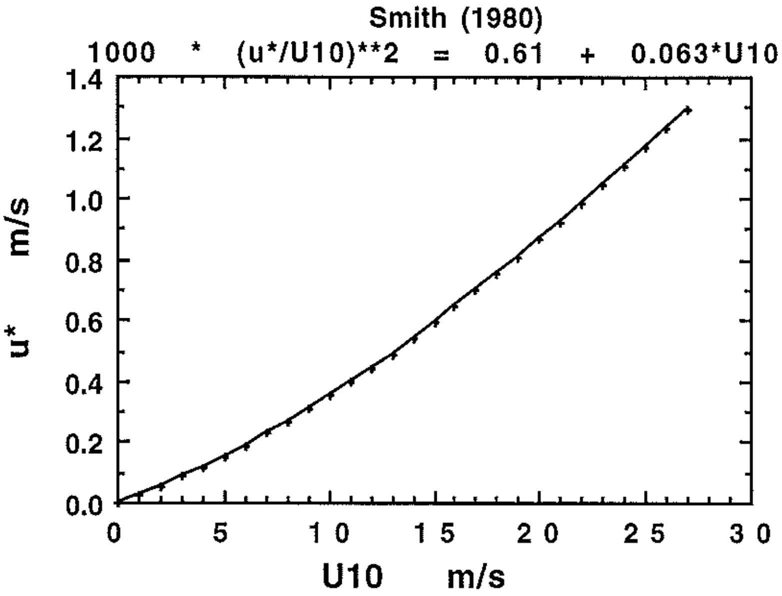


Figure 8. Empirical relationship relating friction velocity, U*, to the neutral 10 m wind speed, U10, given by the Smith (1980) relationship.

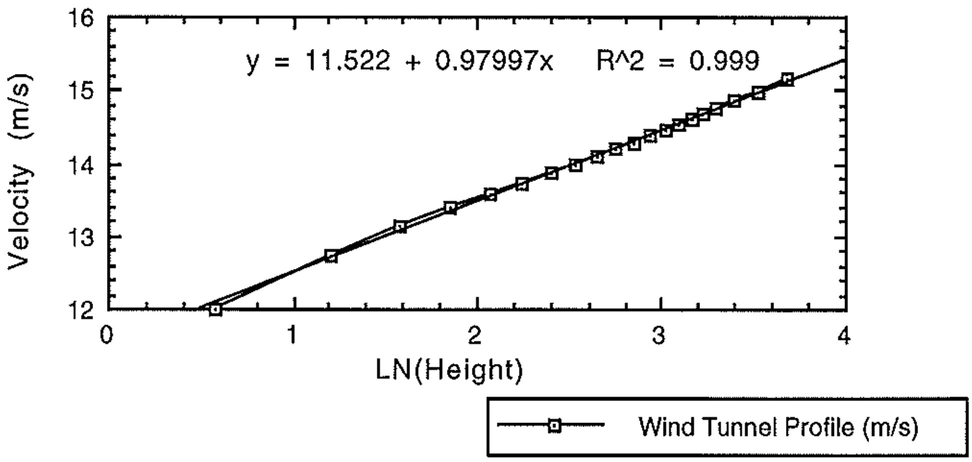


Figure 9. A logarithmic fit to the boundary profile abeam of the Solent sonic anemometer.

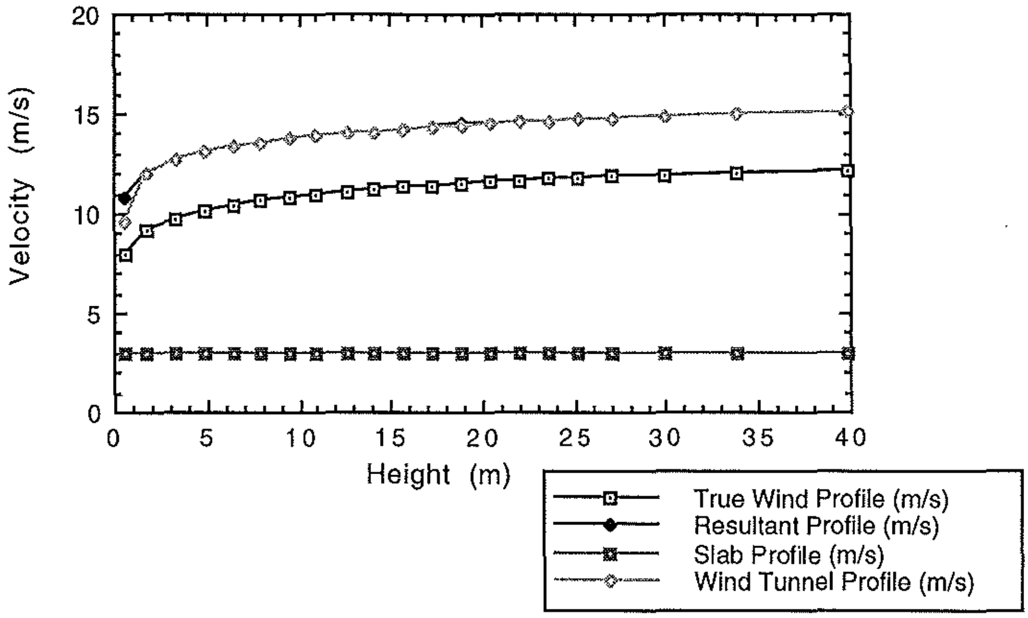


Figure 10. The wind tunnel profile, the slab profile (representing ship's speed) and the true wind profile and their resultant profile.

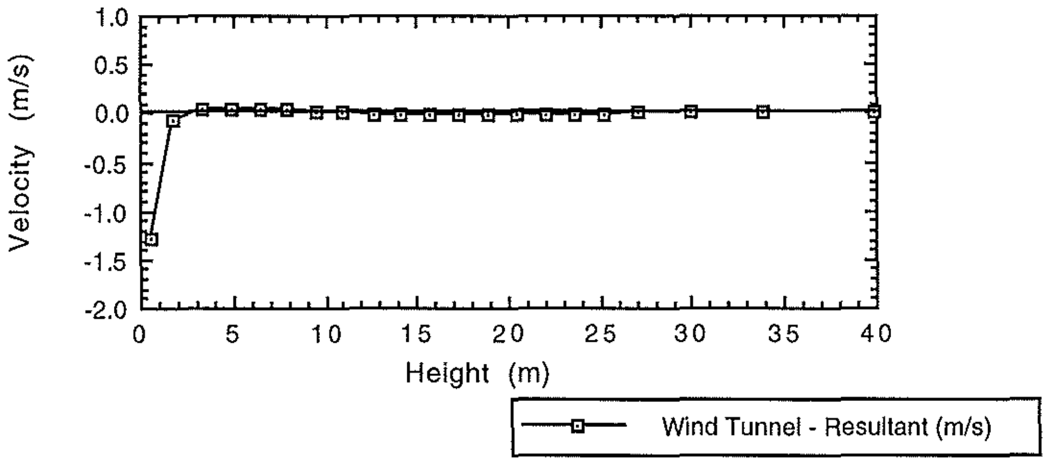


Figure 11. The difference between the wind tunnel profile and the resultant profile.

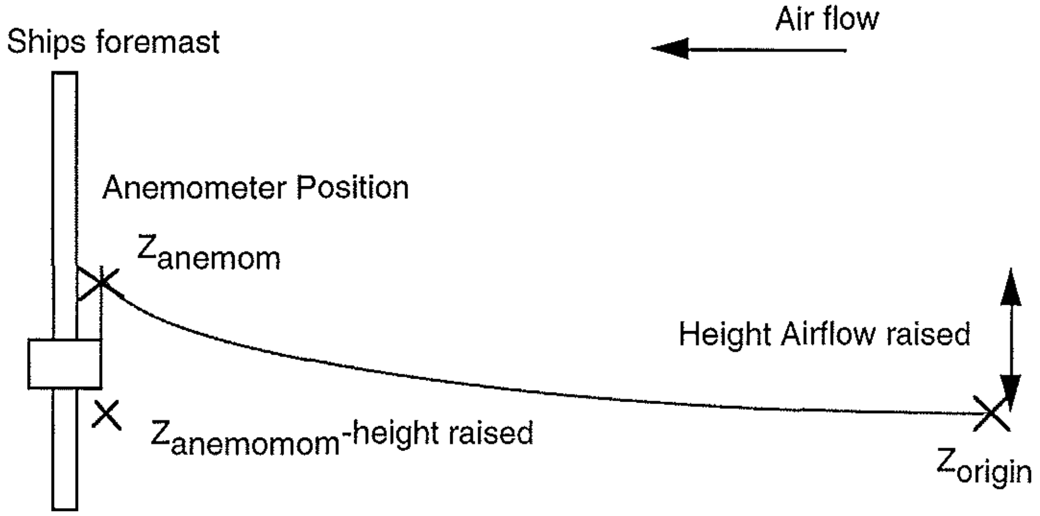


Figure 12. Diagram showing the locations used in calculating the height the air was raised.

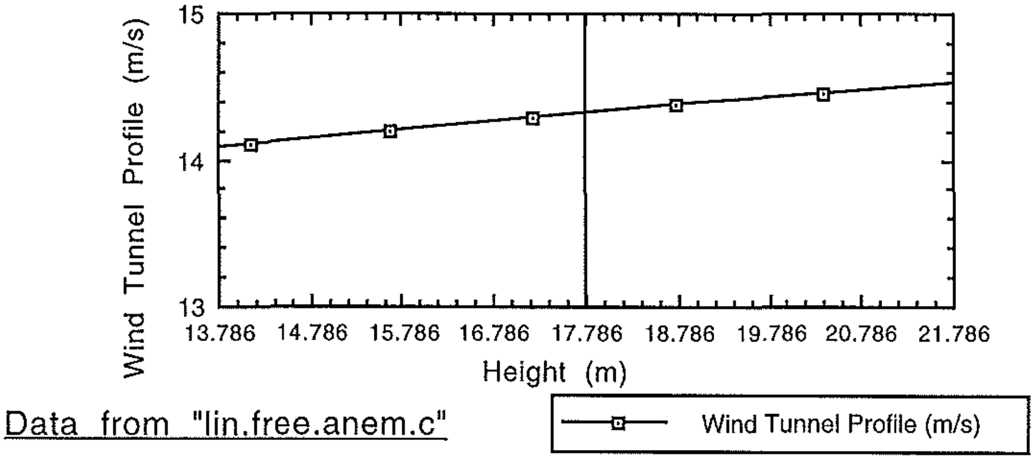


Figure 13. Free stream velocity calculated at 17.786 m, from a vertical velocity profile directly abeam of the anemometer location. (x= 33.3, $0 \leq y \leq 150$, z=100). This gives a free stream velocity of 14.322 m/s for the Solent Sonic anemometer.

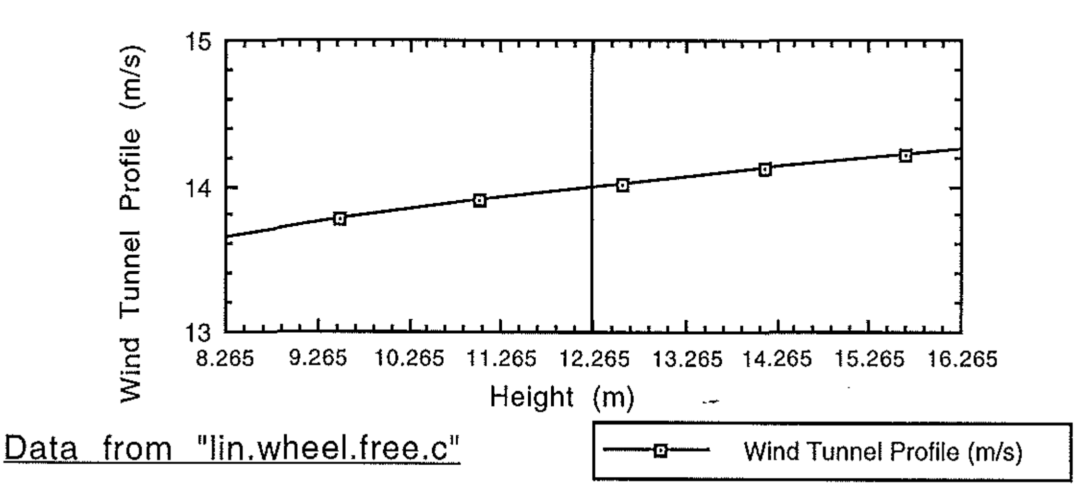


Figure 14. Free stream velocity calculated at 12.265 m, from a vertical velocity profile directly abeam of the anemometer location. (x= 7.25, $0 \leq y \leq 150$, z=100). This gives a free stream velocity of 13.992 m/s for the ship's anemometer.

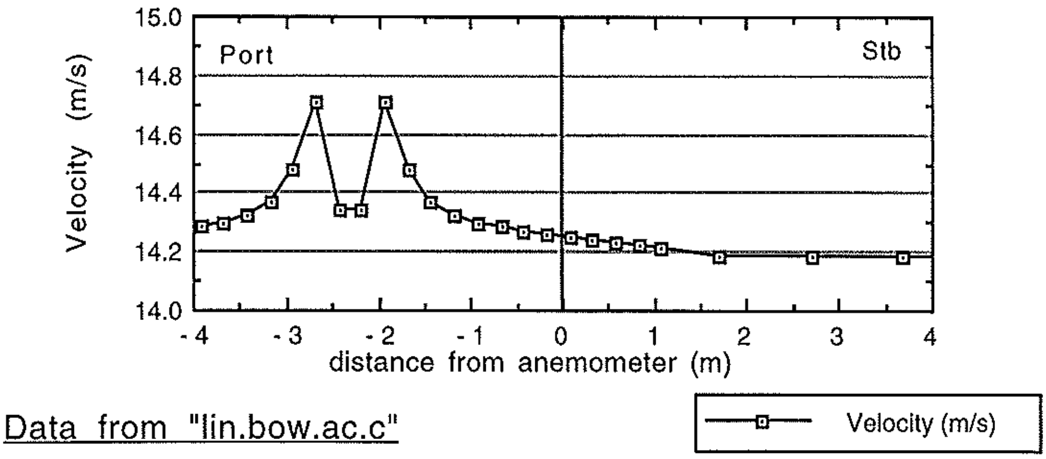


Figure 15a). The total velocity across the Solent sonic anemometer site.

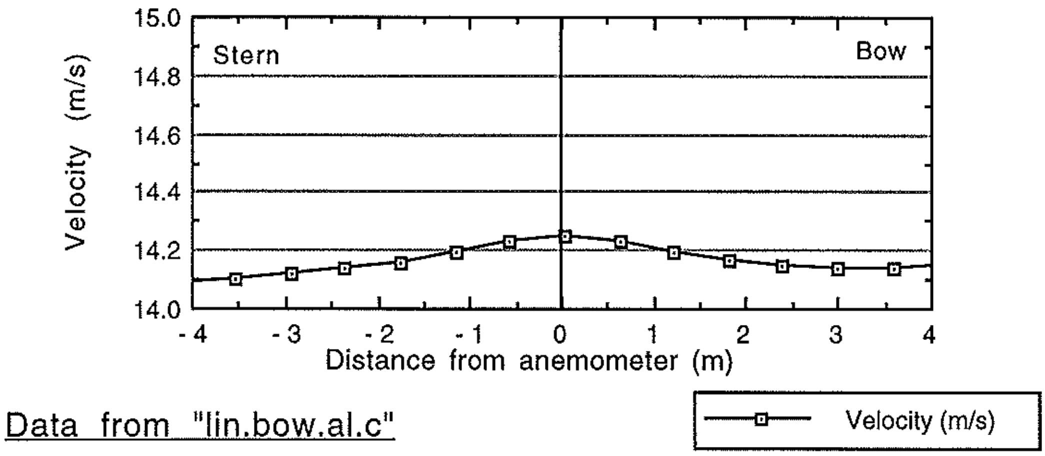


Figure 15b). The total velocity along the Solent sonic anemometer site.

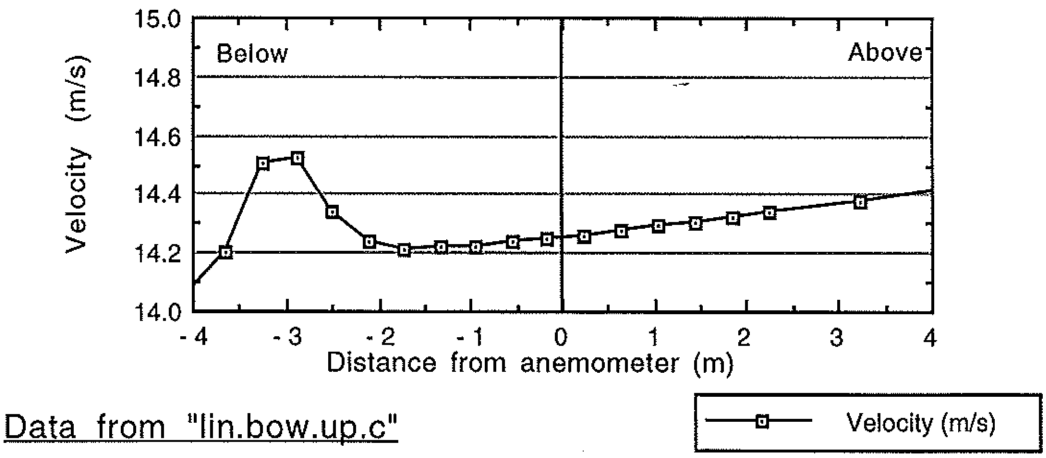
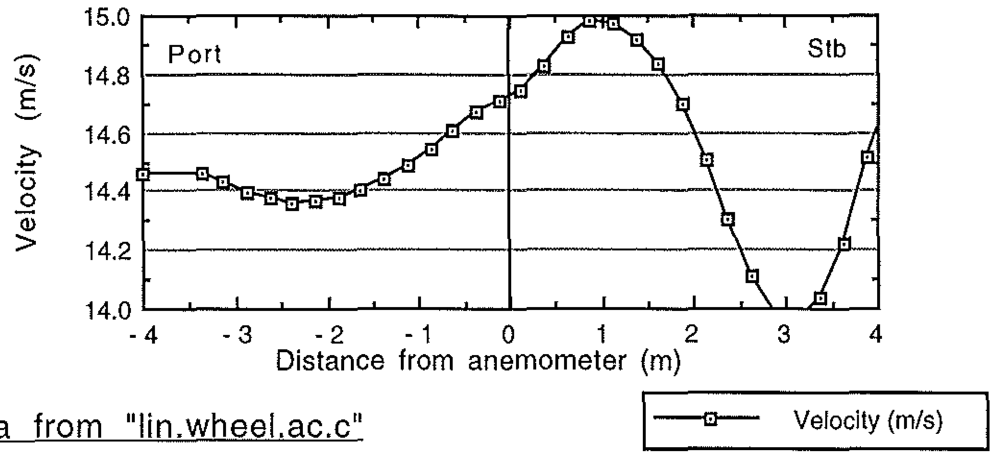
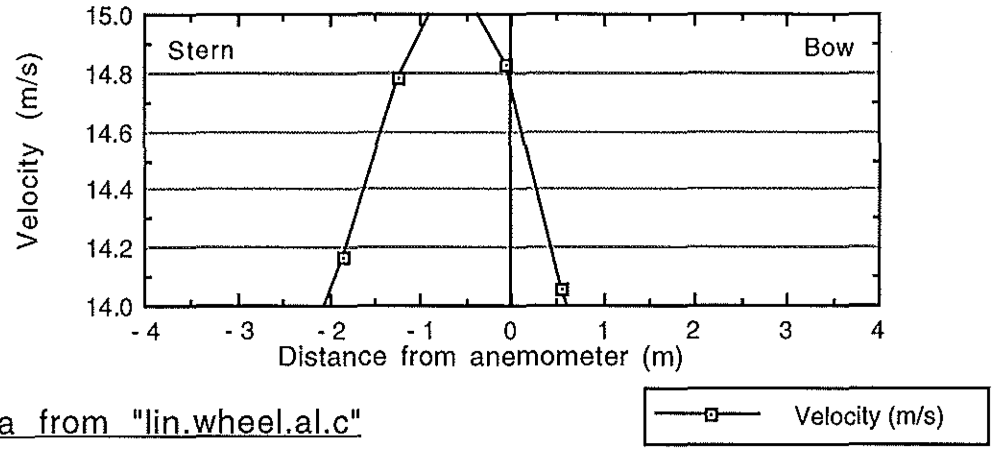


Figure 15c). The total velocity along a vertical line through the Solent sonic anemometer site.



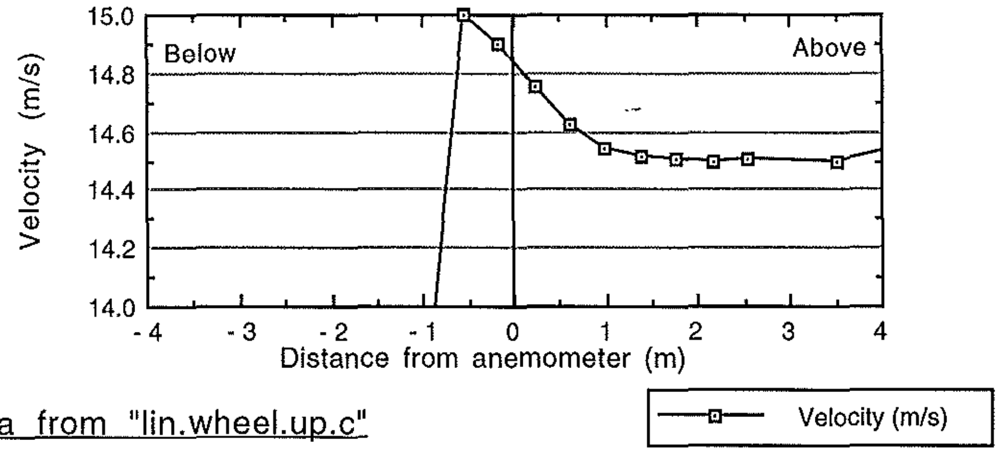
Data from "lin.wheel.ac.c"

Figure 16a). The total velocity across the ship's anemometer site.



Data from "lin.wheel.al.c"

Figure 16b). The total velocity along the ship's anemometer site.



Data from "lin.wheel.up.c"

Figure 16c). The total velocity along a verical line through the ship's anemometer site.

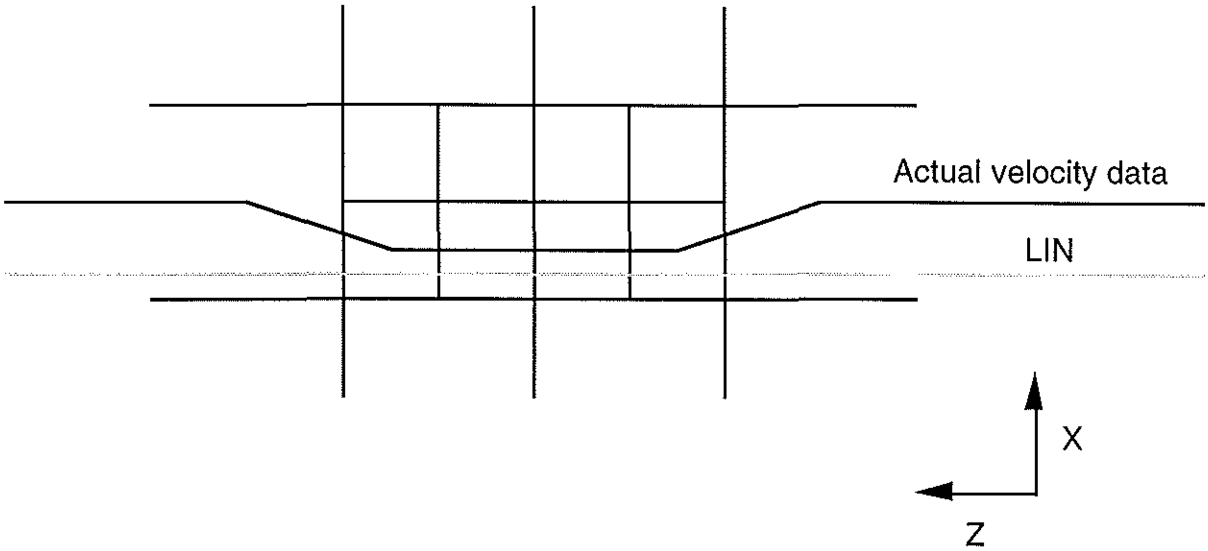


Figure 17a). The phase6 LIN method of velocity data extraction, showing a horizontal plane with a line of data written through a cell structure reducing to Iforce=1 and Ideep =1. The pale line shows the apparent position of the data as given in the output file. The darker line shows the actual position of the data.

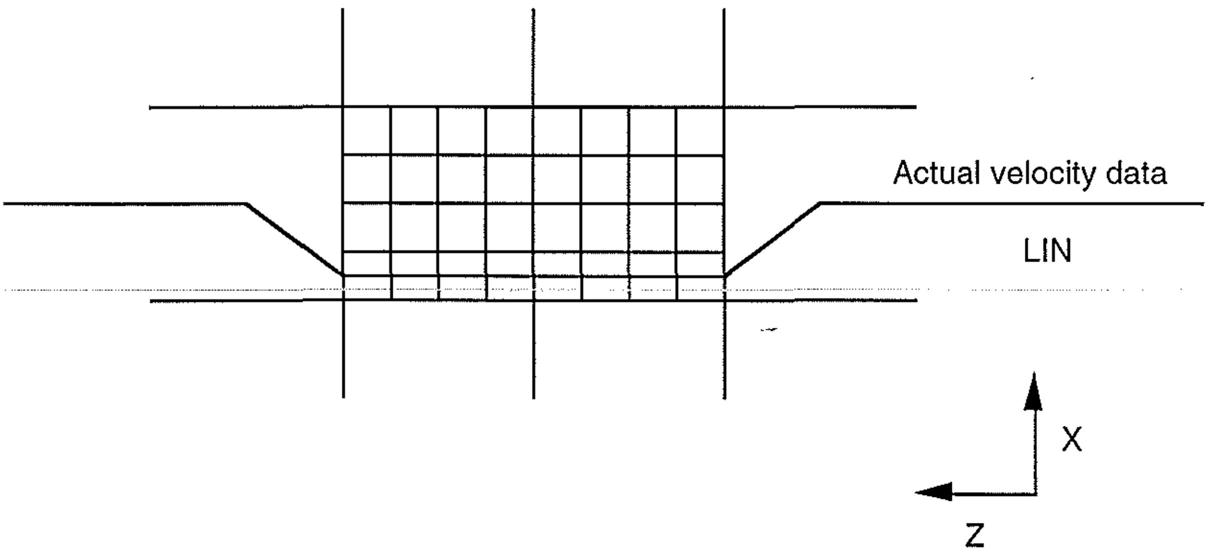


Figure 17b). The phase6 LIN method of velocity data extraction, showing a horizontal plane with a line of data written through a cell structure reducing to Iforce=2 and Ideep=2. It can be seen the extraction errors are reduced with the tighter mesh.

Appendix 1. Summary sheet, MAIN.INP and MESH file

1.1 Discovery 3.1/7 summary sheet

Summary of R.R.S. Discovery Run 3.1/7

Version of Vectis used	Version 3.1 (phase5 version 3.112)
Run Name/Number	3.1/7
Ship Name	R.R.S. Discovery
Date of Run	11/8/95 to 21/8/95
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	see Discovery visit report

Airflow Parameters

Airflow angle relative to the bow	0 degrees
Airflow type (logarithmic or uniform)	logarithmic
Log profile name/number	newlog1
Airflow speed at 10 m (U_{10})	13.8 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 100 m 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:		
200 m upstream	No	
100 m abeam		Yes
Identical location in control tunnel	No	

Results of Run:

The Solent sonic anemometer (as positioned for cruises D199 to D201) under reads by 0.503 % and the air is raised 1.034 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 phase6. The ship's anemometer over reads by 5.775 % and the air is raised 3.034 m. There are large changes in velocity in all three directions close to the propeller anemometer.

The position for the Solent sonic anemometer on cruises D213 and D214 caused it to under read by 0.378 %. The airflow was raised by 1.058 m.

Archived in directory:
/epoch/cfd/archive/version3.1/discovery/discovery_0deg/newlog1_3.1.7

Comments.

Model run by Jim Hutchings up to phase5. Details of geometry and mesh problems are not known. Some discrepancies between the model and the actual ship are described in the Discovery visit report. For example, a small frame located on the bow is on the starboard side on the model whilst on the ship it is on the port side.

1.2 Discovery 3.1/7 MAIN.INP file

```
!VECTIS_MAIN_INPUT MODULAR VERSION 2.114
##JRCOC Analysis of the discovery with the "newlog"profile 10th aug.
#
#
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  8.50000E+01  1.00000E+00            TSTART TEND TCYCLE
    2     2                               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
    33     17      -2                      X/Y/ZMON
MON.5                                      FNMON
#
#
CHECKPOINT
   T    T    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
    7     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
    8    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
  11                                 MBNWDS
 2.930E+02  4.500E-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 Discovery 3.1/7 MESH file

```
!VECTIS_MESH_INPUT_V1.100
VECTIS mesh generator input file.
MODEL_NAME = discovery.tri2
SETS_NAME = disco.sets2
TYPES_NAME = disco.types1
REFINEMENT_DEPTH = 0
PATCH_TYPE = 3
IJK_BLOCK = 16 53 2 12 16 32 2 1
IJK_BLOCK = 32 34 14 19 22 25 2 2
IJK_BLOCK = 45 48 9 15 21 27 2 2
IJK_BLOCK = 33 33 14 14 18 20 2 2
IJK_BLOCK = 32 37 9 13 16 32 2 2
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  1 68  1 30  1 47
  3
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-5.45463E+01    5
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-2.00002E+00   15
 4.55001E+01   20
 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
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 2.20009E+02    1
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 2.60001E+01    5
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3.50111E+00	7
1.15011E+01	8
1.40014E+01	1
1.75005E+01	1
2.20011E+01	1
3.00021E+01	1
4.00031E+01	1
5.40041E+01	1
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9.00031E+01	1
1.10021E+02	1
1.35011E+02	1
1.57501E+02	1
1.65001E+02	1

Appendix 2. Additional Figures

Figure 1. An angled view of the R.R.S. Discovery as generated in Femgen, displaying the anemometer locations.

Figure 2. An angled view of the R.R.S. Discovery as generated in Vectis phase6. The figure displays a vertical section of velocity vectors through the Solent sonic anemometer site (plane K26). Velocity scale 11.3 m/s to 16.3 m/s.

Figure 3. An angled view of the R.R.S. Discovery as generated in Vectis phase6. The figure displays a vertical section of velocity contours through the Solent sonic anemometer site (plane K26). Velocity scale 11.3 m/s to 16.3 m/s.

Figure 4. A view of the R.R.S. Discovery generated in Vectis phase6. The figure displays a vertical section across the tunnel (plane I46) of velocity contours through the Solent sonic anemometer site. Velocity scale 11.3 m/s to 16.3 m/s.

Figure 5. A view of the R.R.S. Discovery generated in Vectis phase6. The figure displays a vertical section across the tunnel (plane I46) of velocity contours through the Solent sonic anemometer site. Velocity scale 13.5 m/s to 14.5 m/s.

Figure 6. An angled view of the R.R.S. Discovery as generated in Vectis phase6. The figure displays a vertical section down the tunnel (plane K19) of velocity vectors through the ship's anemometer site. Velocity scale 11.3 m/s to 16.3 m/s.

Figure 7. An angled view of the R.R.S. Discovery as generated in Vectis phase6. The figure displays a vertical section down the tunnel (plane K19) of velocity contours through the ship anemometer site. Velocity scale 11.3 m/s to 16.3 m/s.

Figure 8. A view of the R.R.S. Discovery generated in Vectis phase6. The figure displays a vertical section across the tunnel (plane I35) of velocity vectors through the ship's anemometer site. Velocity scale 11.3 m/s to 16.3 m/s.

Figure 9. A view of the R.R.S. Discovery generated in Vectis phase6. The figure displays a vertical section across the tunnel (plane I35) of velocity contours through the ship's anemometer site. Velocity scale 11.3 m/s to 16.3 m/s.

Figure 10. A view of the R.R.S. Discovery generated in Vectis phase6. The figure displays a vertical section across the tunnel (plane I35) of velocity contours through the ship's anemometer site. Velocity scale 14.5 m/s to 15.5 m/s.

Figure 1

R.R.S. Discovery

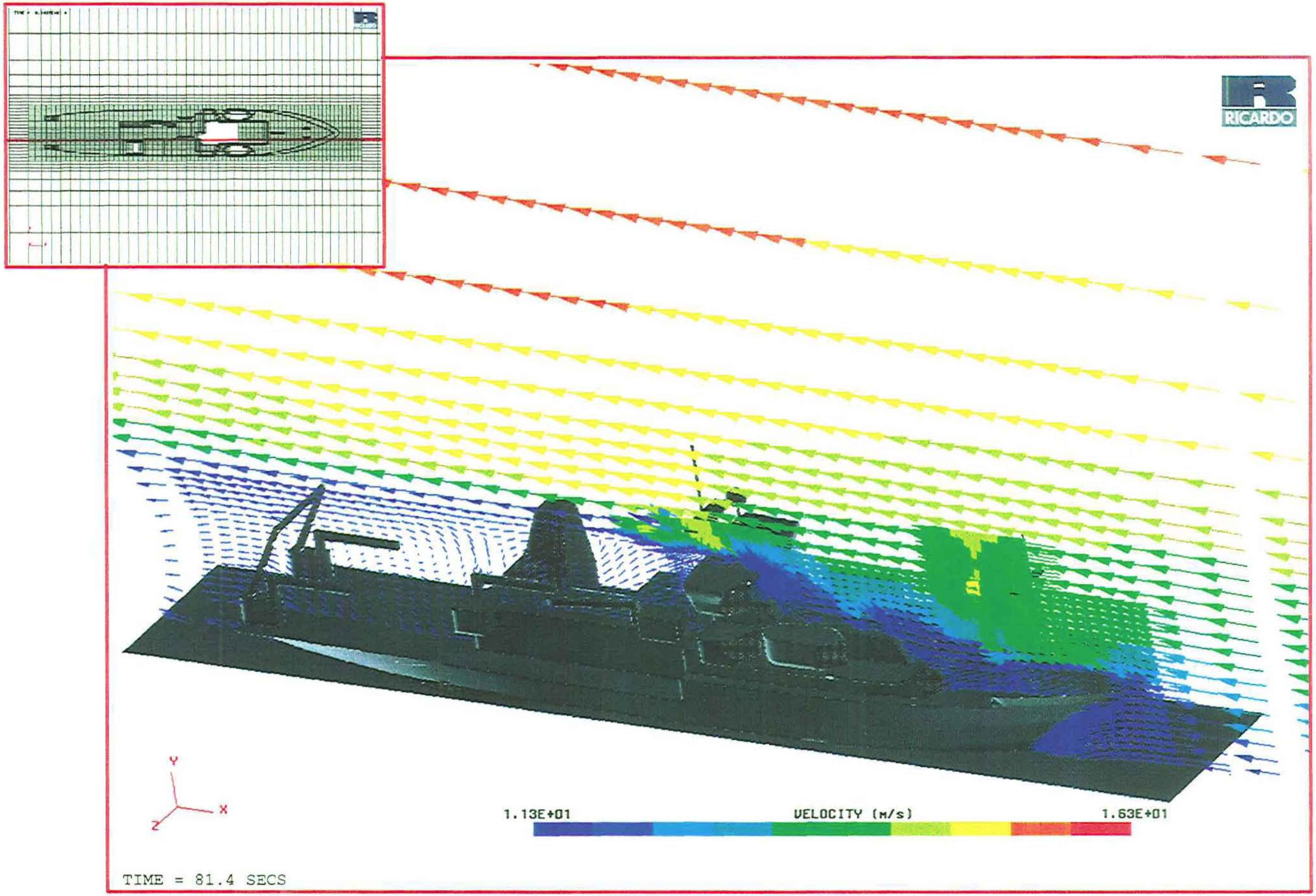


Figure No. 2 Velocity vectors on R.R.S. Discovery on the plane indicated

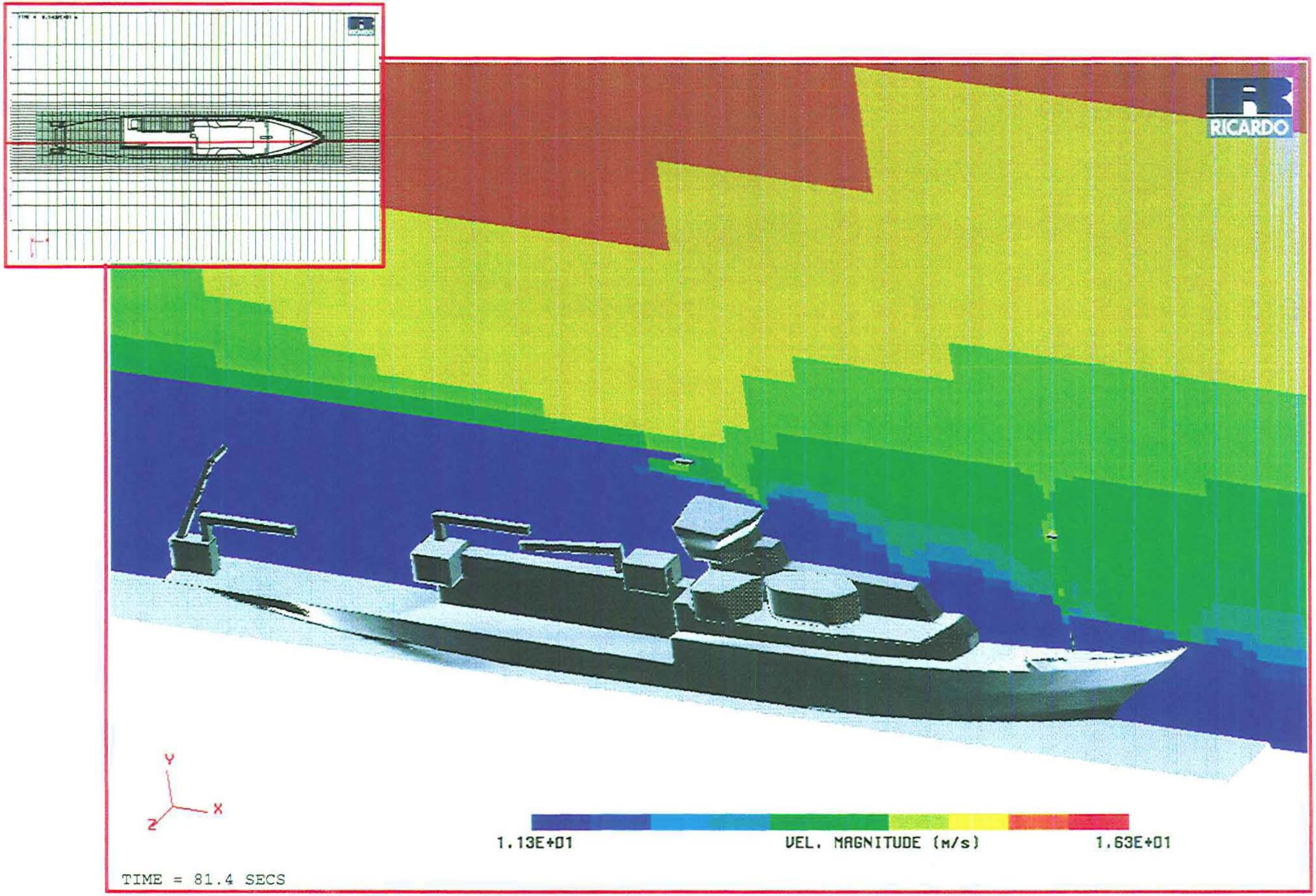


Figure No. 3 Velocity vectors on the R.R.S. Discovery on the plane indicated.

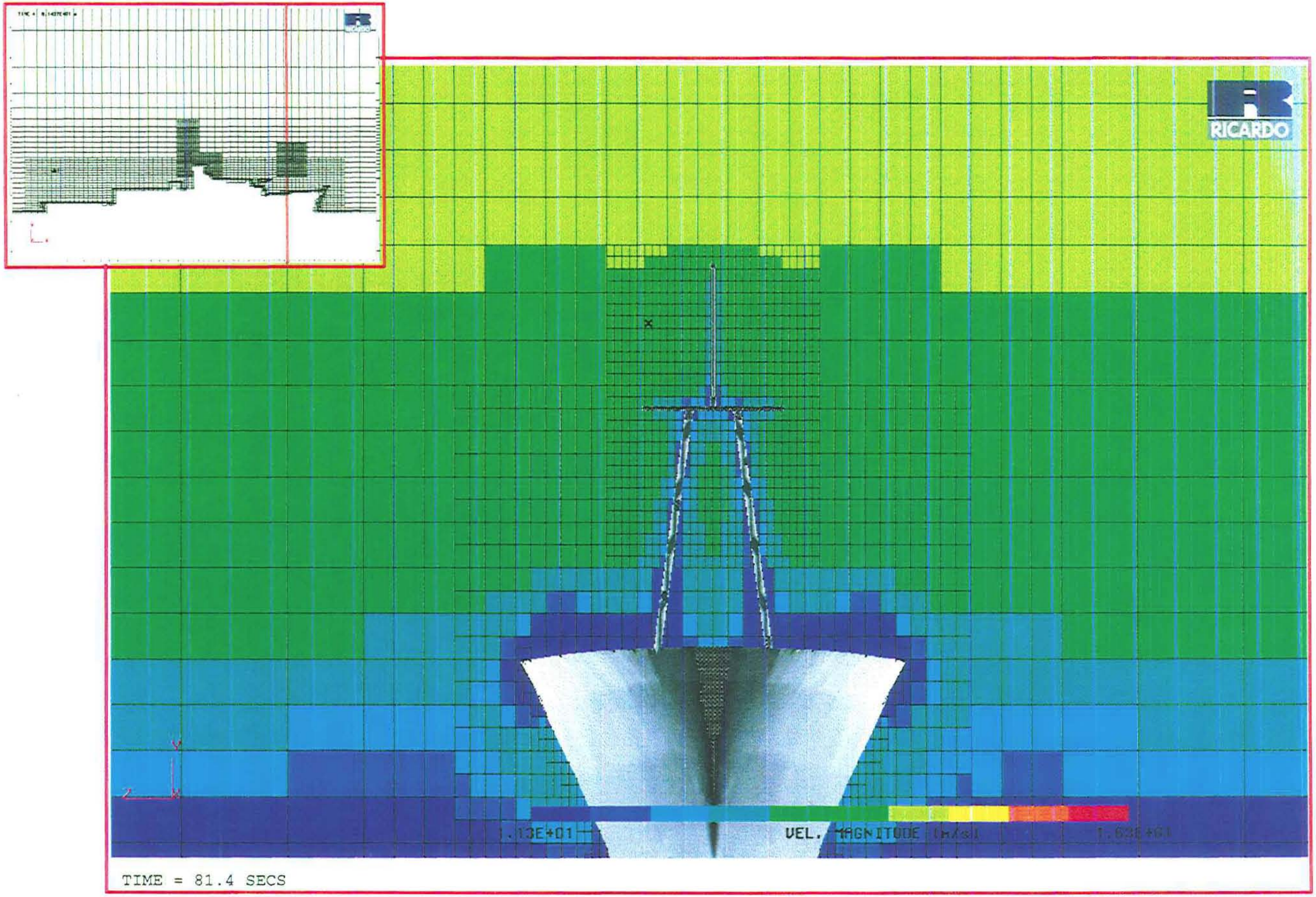


Figure No. 4 Velocity contours on R.R.S. Discovery on the plane indicated

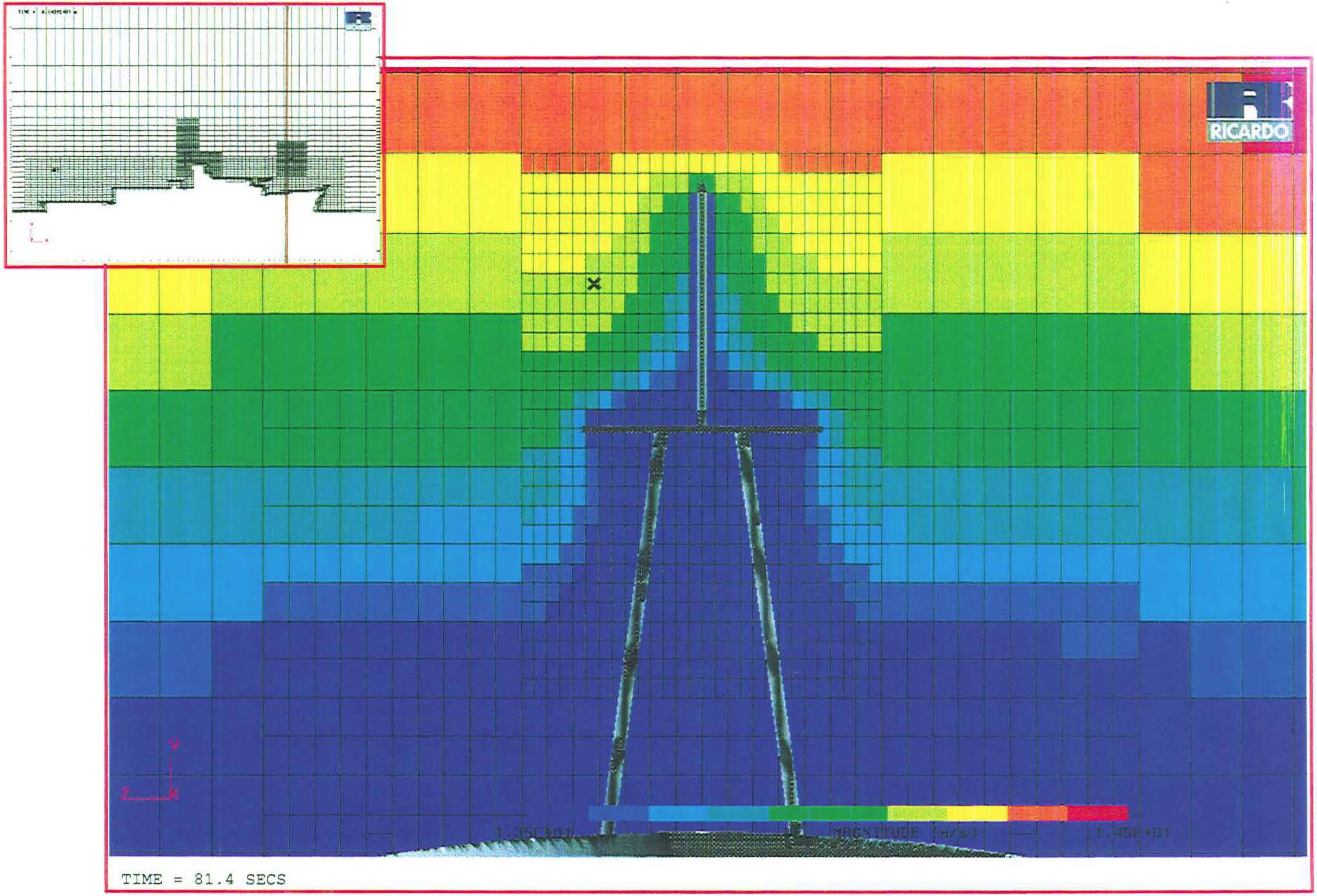


Figure No. 5 Velocity Contours on R.R.S. Discovery on the plane indicated

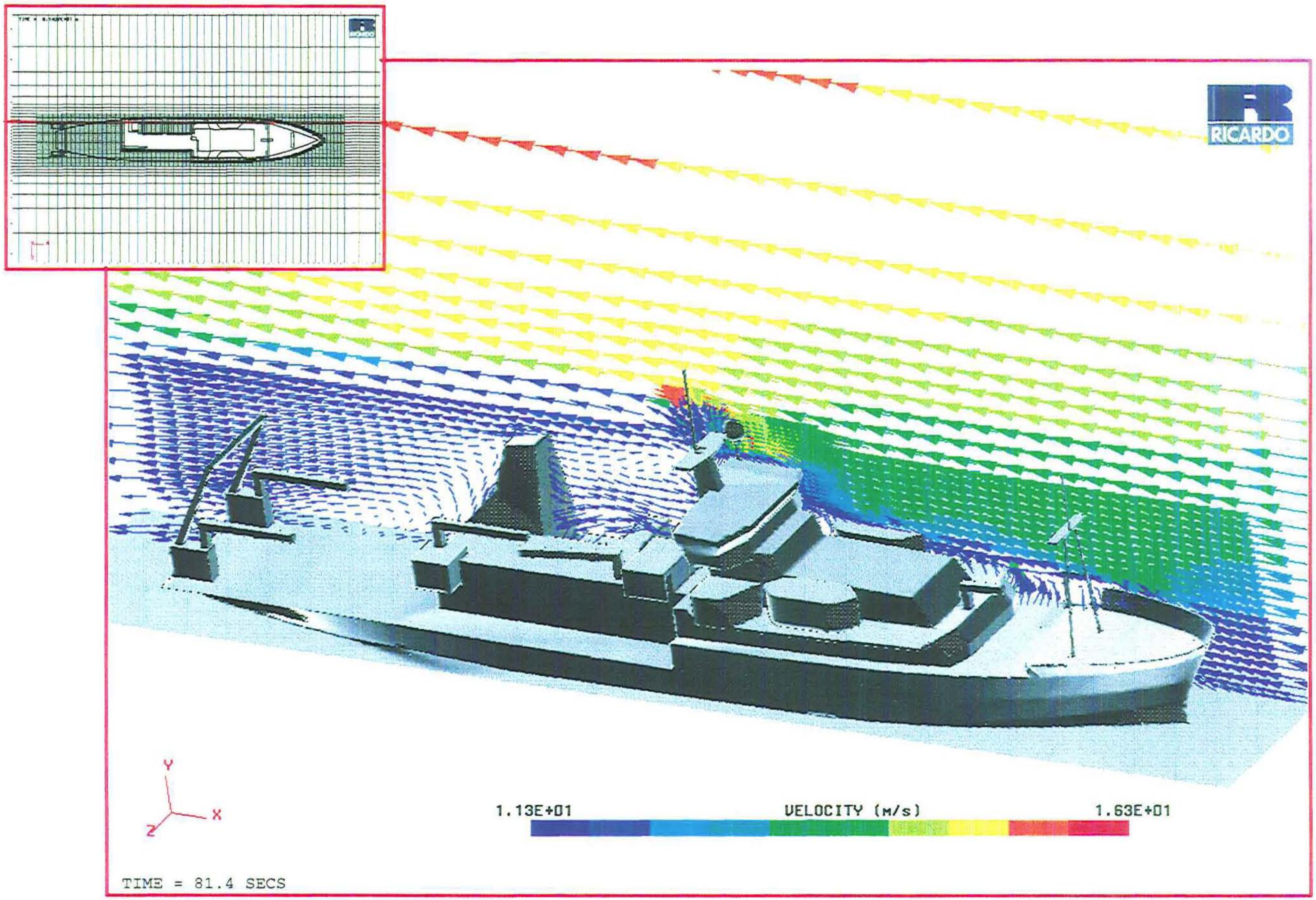


Figure No. 6 Velocity vectors on the R.R.S. Discovery on the plane indicated.

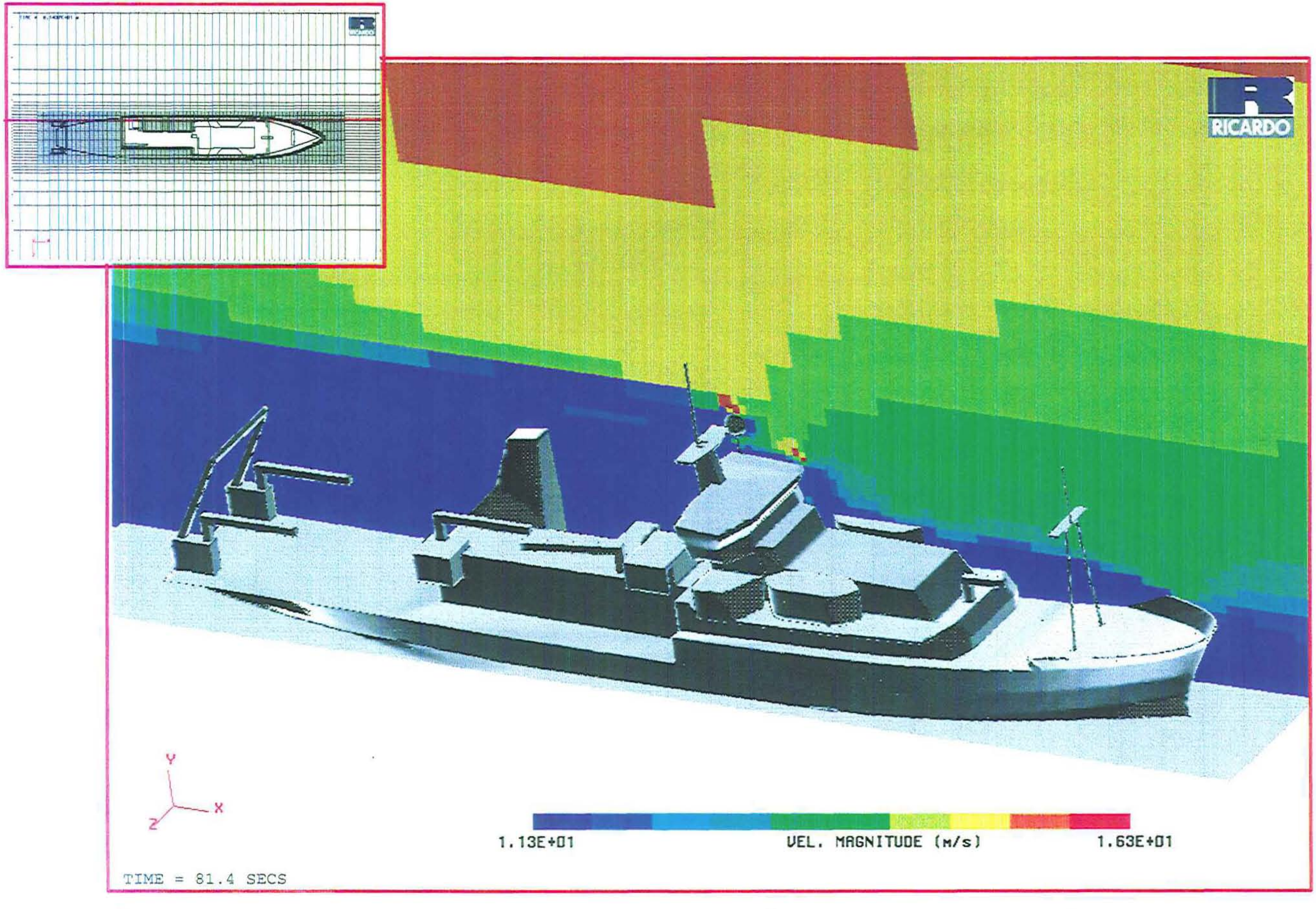


Figure No. 7 Velocity vectors on the R.R.S. Discovery on the plane indicated.

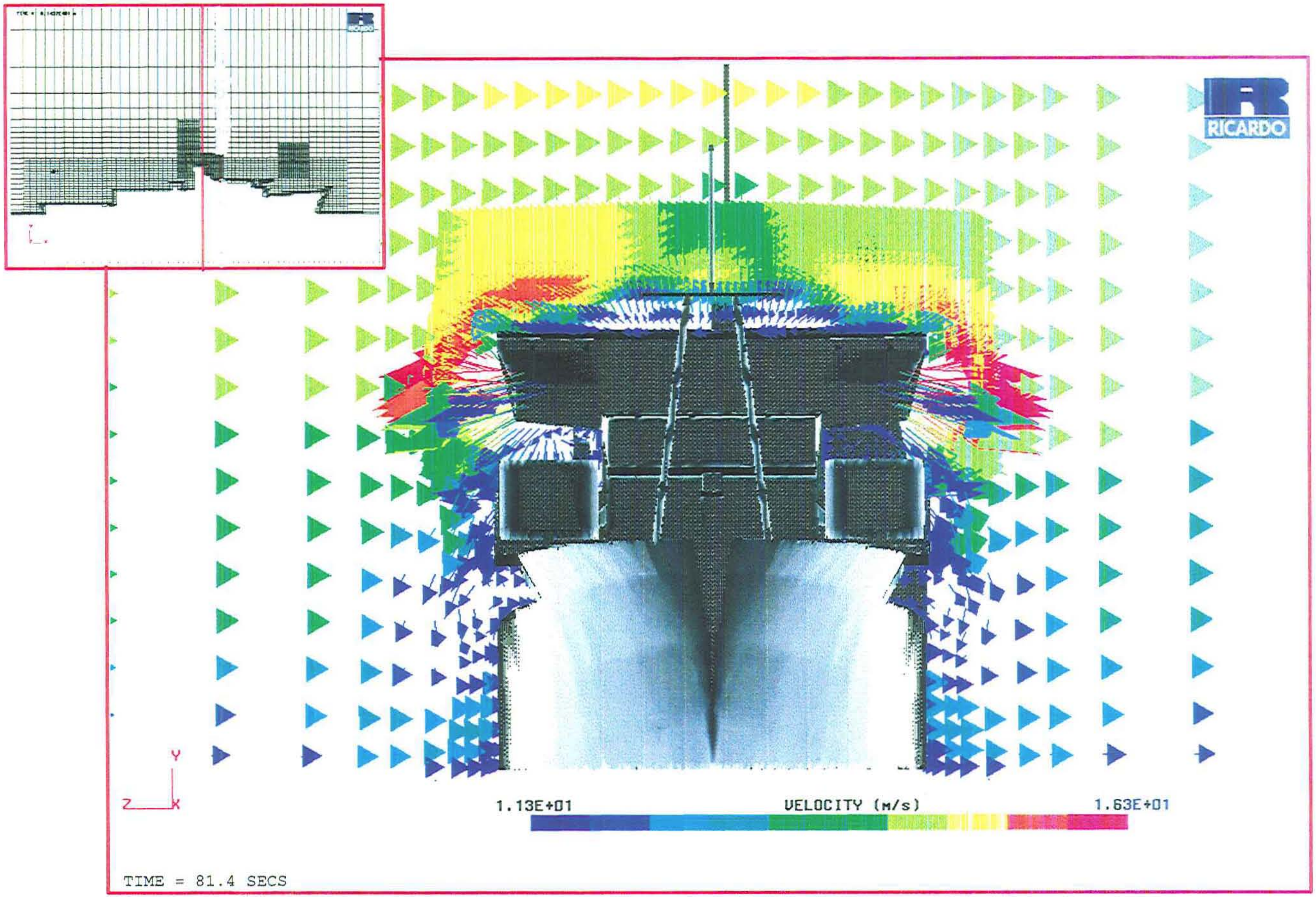


Figure No. 8 <u>Velocity vectors on the R.R.S. Discovery on the plane indicated.</u>

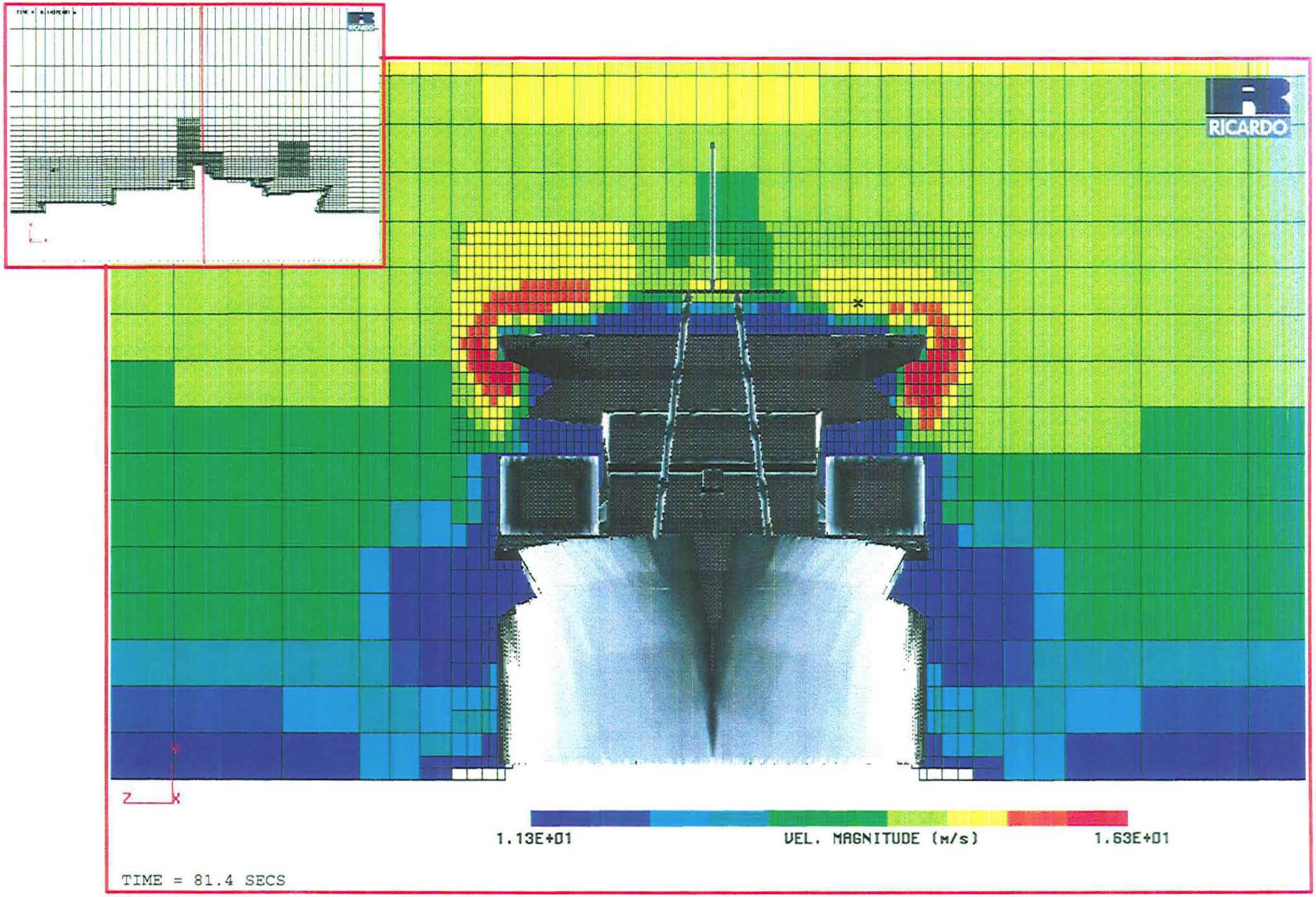


Figure No. 9 Velocity vectors on the R.R.S. Discovery on the plane indicated.

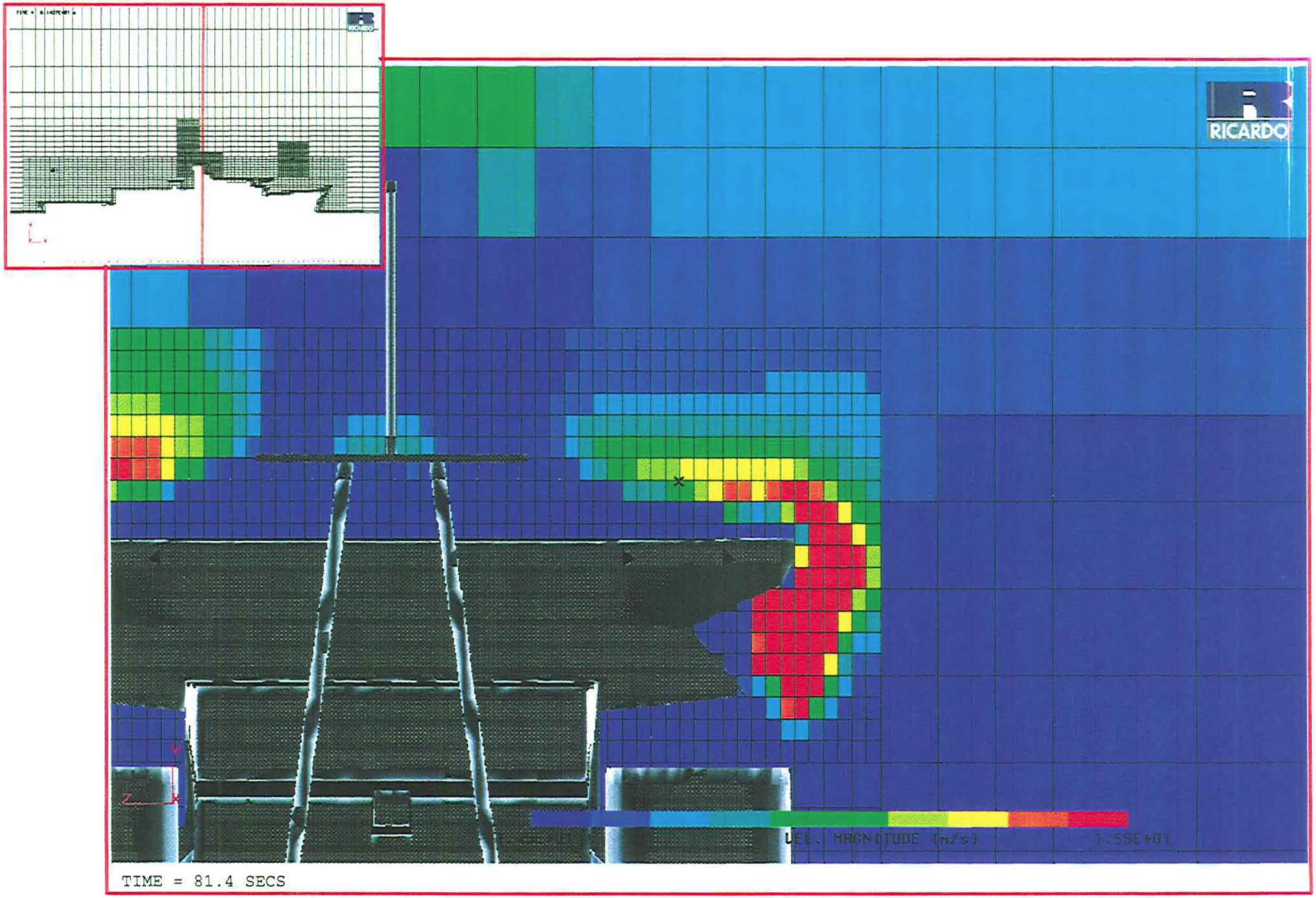


Figure No. 10 Velocity vectors on the R.R.S. Discovery on the plane indicated.

APPENDIX 3. DISCOVERY VISIT REPORT

September 1995

1. Introduction

The Discovery was visited on the 22nd September 1995 whilst in Dock in Southampton. This document illustrates the measurements made of the local geometry of the foremast and the monkey island. The figures illustrated in this report show a comparison between model dimensions, enclosed within brackets, and dimensions taken on the visit. Most figures are to scale.

2. Description of figures

Figure 1 : Overall dimensions of the foremast on Discovery. The figure shows three elevations of the foremast at a scale of 1:100. Two aft facing spotlights have been neglected, as have the rails around the platform. The navigation lights are shown in greater detail in Figure 2, and the lower platform dimensions are given in Figure 3.

Figure 2 : Dimensions of the navigation lights on the foremast. Three navigation lights are present with heights described in Figure 1. Scale 1:10.

Figure 3 : The lower foremast platform. The height of this platform is described in Figure 1. Note : Dimensions excluded from this figure are not known. Scale 1:20.

Figure 4 : Forecastle deck, plan view. Distances of structures were measured relative to the tip of the bow rail in order to validate the positioning of the superstructure. Not to scale.

Figure 5 : Monkey island plan view. The anemometer location is displayed on the port wing of the monkey island. The measurements are made on the deck, not from the solid rail. Scale 1:50.

3. Summary

The foremast platform geometry is very accurate. The length of the mast is 0.16 m shorter in the model and it's diameter has been increased to a relative diameter of 0.20 m to account for the frame surround. The model platform dimensions are out by approx. 0.07 m in length, 0.06 m in width and 0.08 m in depth, whilst the platform height relative to the deck is only 0.05 m higher in the model than on the ship. The navigation lights and lower platform are not present in the model and are illustrated here for future use.

The lengths measured on the foredeck compared to the model show a maximum and minimum difference of 4.7 % and -0.3 % respectively.

The monkey island dimensions compared to the model show an overall error of 2.8 % in width, and an error -0.3 % in length.

The model has not been altered since the visit.

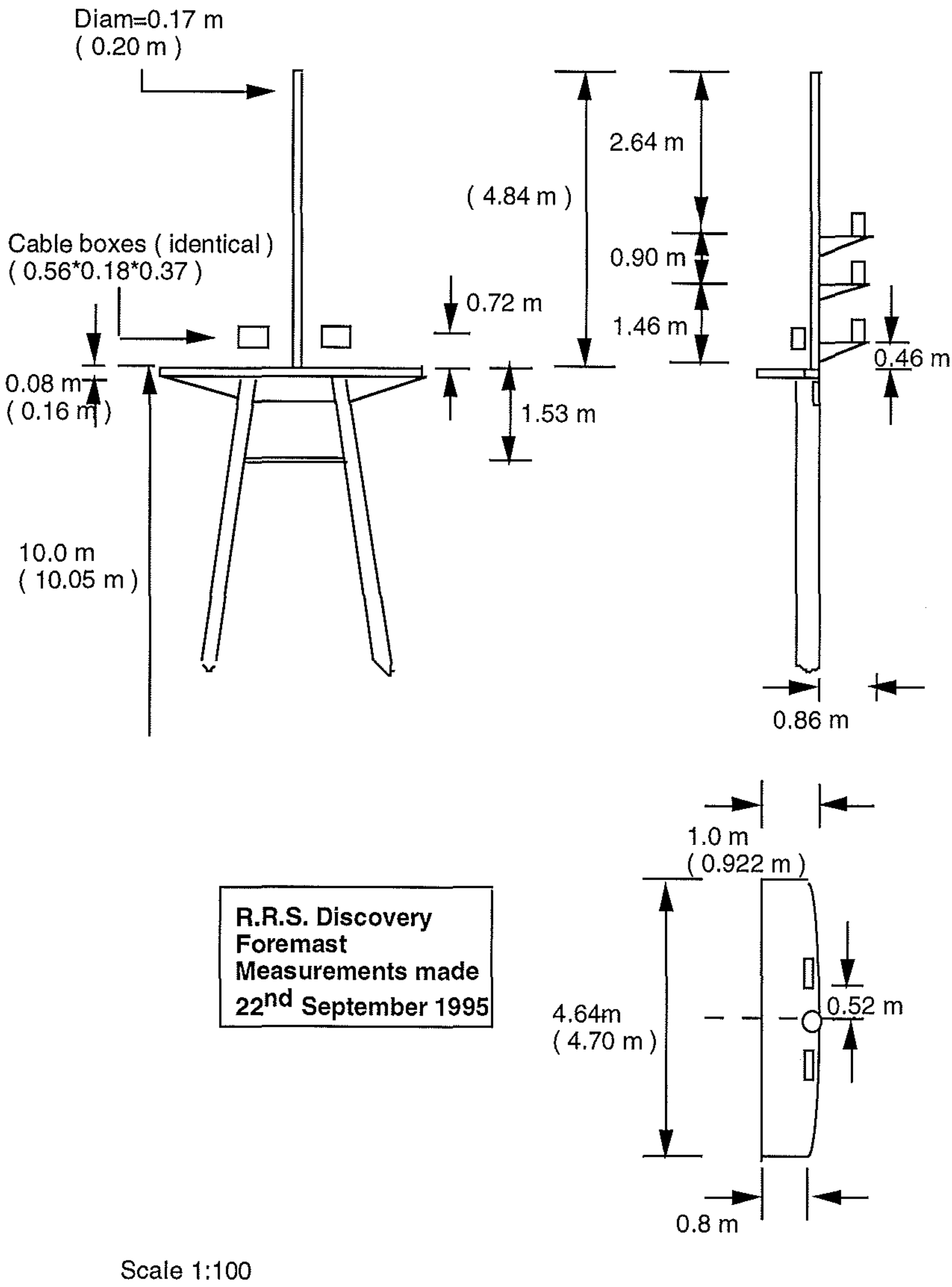


Figure 1. Dimensions of the foremast.

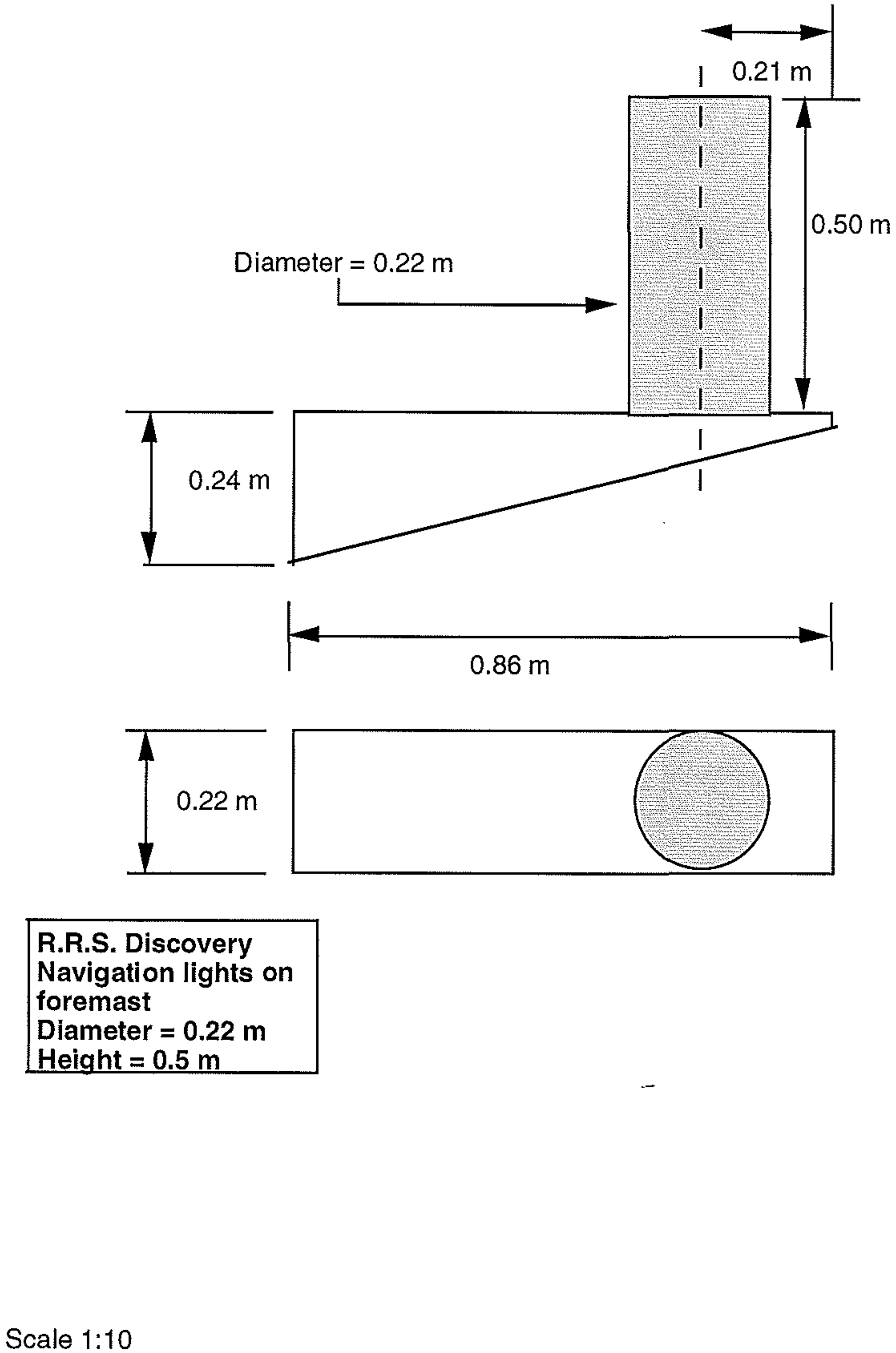
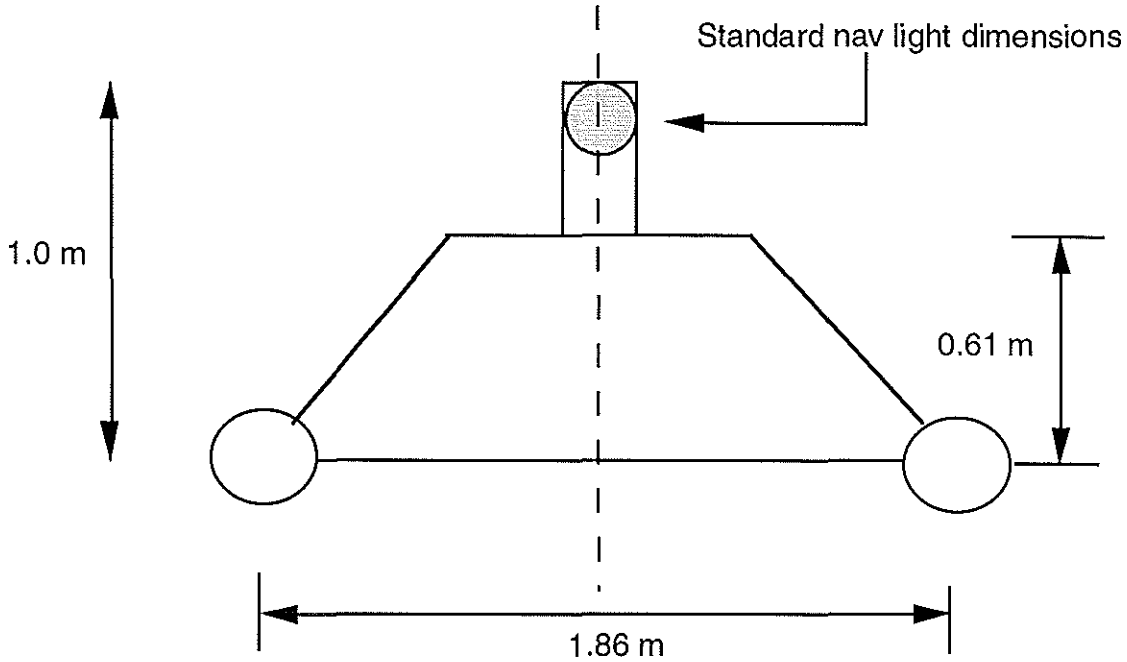


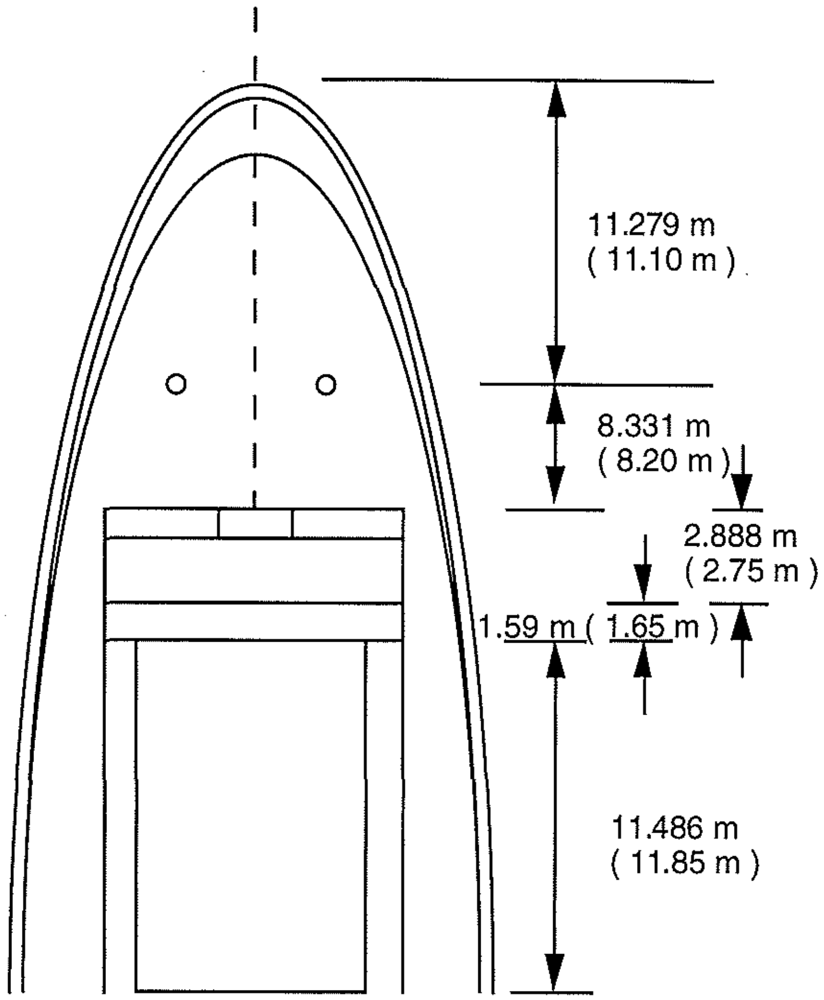
Figure 2. Dimensions of the foremast navigation lights.



R.R.S. Discovery
Lower foremast platform

Scale : 1:20

Figure 3. Dimensions of the lower platform on the foremast.



R.R.S. Discovery forecastle deck

Note : not to scale

Figure 4 Forecastle deck, plan view.

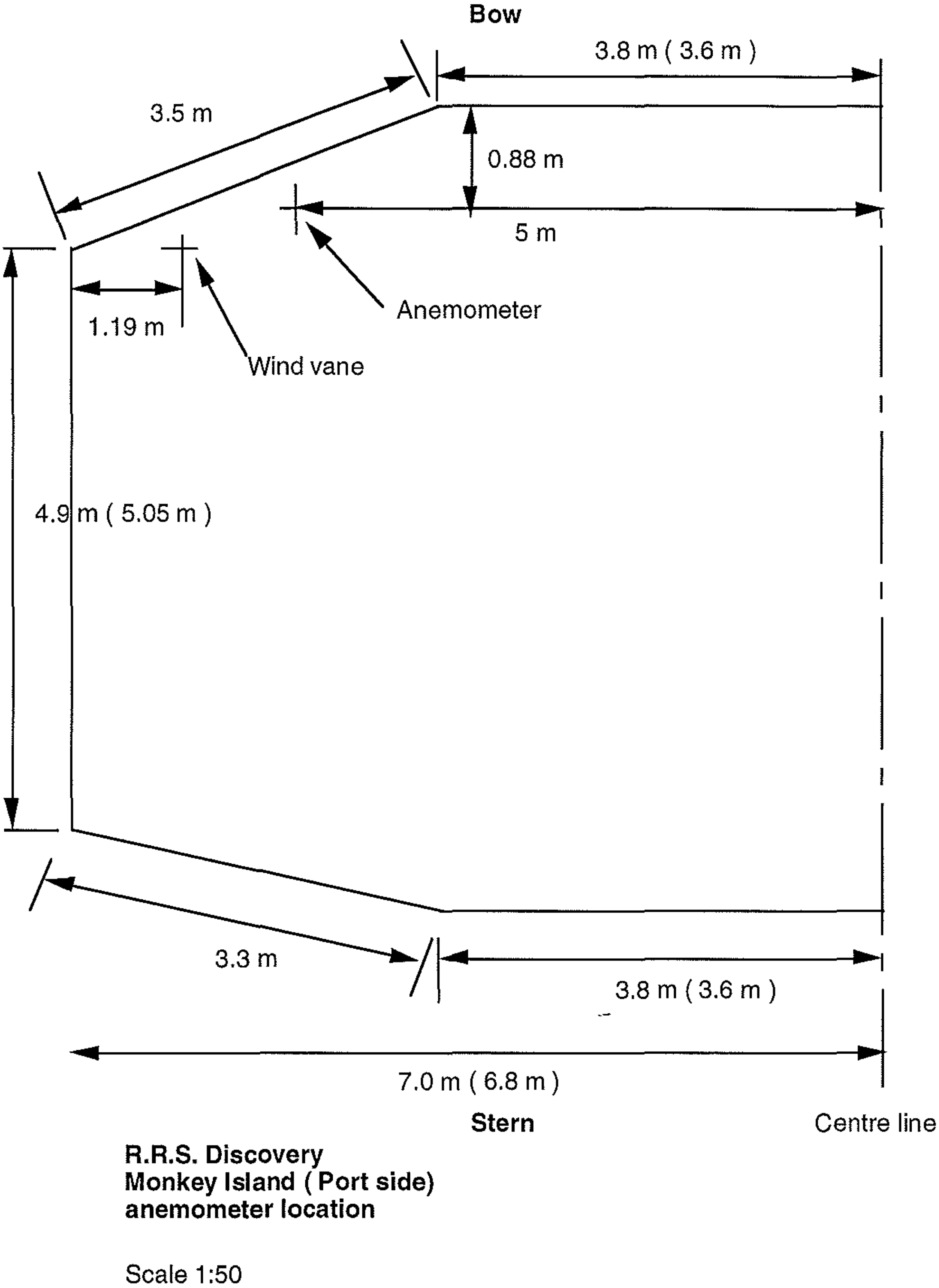


Figure 5. Plan view of the monkey island.