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CHEVRON
Gorgon Development

**Measurement and Model Prediction
of
Ocean Currents and Tides
at
Barrow Island,
North Western Australia**

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Contents

Introduction	5
1.1 Scope of Work.....	5
2 ADCP Deployments	6
3 Drifting Buoy Deployments.....	7
4 GCOM3D Simulations for the Experimental Period.....	9
4.1 Model Description	9
4.2 Model Forcing	10
4.2.1 Meteorology.....	10
4.2.2 Bathymetry	10
4.2.3 Tides.....	10
4.3 Model Predictions.....	10
5 Comparison of Measurements and GCOM3D Predictions.....	18
5.1 Tides	18
5.2 Currents	18
5.3 Drifting Buoy Tracks.....	18
6 Conclusions.....	19

Table of Tables

Table 1: ADCP and Drifting Buoy Deployment Locations	7
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Table of Figures

Figure 1: Mooring configuration.....	6
Figure 2: Location of the 3 ADCP moorings and the 4 drifter releases.....	8
Figure 3: The large grid used to model the propagation of tides and wind-driven currents and large scale circulations (if any) into the Barrow Island region.	11
Figure 4: Near surface currents predicted by GCOM3D at 0200 on 6/9/2005	12
Figure 5: Near surface currents predicted by GCOM3D at 0400 on 6/9/2005	13
Figure 6: Near surface currents predicted by GCOM3D at 0600 on 6/9/2005	14
Figure 7: Near surface currents predicted by GCOM3D at 0800 on 6/9/2005	15
Figure 8: Near surface currents predicted by GCOM3D at 1000 on 6/9/2005	16
Figure 9: Near surface currents predicted by GCOM3D at 1200 on 6/9/2005	17
Figure 10: Comparison of predicted (green) and observed (red) sea levels at site ADCP1.	20
Figure 11: Comparison of predicted (green) and observed (red) sea levels at site ADCP3.	20
Figure 12: Comparison of near surface East-West current speeds predicted by GCOM3D (green) with observations at site ADCP1 (red).....	21
Figure 13: Comparison of near surface North-South current speeds predicted by GCOM3D (green) with observations at site ADCP1 (red).....	21
Figure 14: Comparison of near surface East-West current speeds predicted by GCOM3D (green) with observations at site ADCP2 (red).....	22
Figure 15: Comparison of near surface North-South current speeds predicted by GCOM3D (green) with observations at site ADCP2 (red).....	22
Figure 16: Comparison of near surface East-West current speeds predicted by GCOM3D (green) with observations at site ADCP3 (red).....	23
Figure 17: Comparison of near surface North-South current speeds predicted by GCOM3D (green) with observations at site ADCP3 (red).....	23
Figure 18: Progressive vector diagram comparison of near surface currents predicted by GCOM3D (black) with observations at site ADCP1 (magenta).....	24
Figure 19: Progressive vector diagram comparison of near surface currents predicted by GCOM3D (black) with observations at site ADCP2 (magenta).....	25
Figure 20: Progressive vector diagram comparison of near surface currents predicted by GCOM3D (black) with observations at site ADCP3 (magenta).....	26
Figure 21: Wind speed (m/s) for the duration of the ADCP deployments.....	27
Figure 22: Wind direction (deg from) for the duration of the ADCP deployments.	27
Figure 23: Comparison of drift tracks predicted by GCOM3D (darker colour) with actual tracks (lighter colour).....	28

Introduction

Global Environmental Modelling Systems (GEMS) has been contracted to carry out simulations of the dredging of the Materials Offload Facility (MOF) and the LNG shipping access channel for the Chevron Gorgon Development at Barrow Island.

The work is being undertaken using two sophisticated numerical computer models:

- a) The GEMS 3D Coastal Ocean Model (GCOM3D) to simulate the complex three-dimensional ocean currents surrounding Barrow Island; and
- b) The GEMS 3D Dredge Simulation Model (DREDGE3D) to determine the fate of particles released into the water column during the dredging operations.

In order to produce reliable predictions of the fate of turbid plumes during the dredging it is critical to have accurate predictions of the ocean currents and tides around Barrow Island. The ocean circulation around Barrow Island is very complex, mainly due to the shallow reefs and shoals to the north and south of the island affecting the flood and ebb of the tide from the open ocean on the west to the eastern side of the island.

Accordingly further field measurements were carried out on the eastern side of the island to better understand the behaviour of the ocean circulation around the island. These field measurements involved:

- a) The deployment of 2 Acoustic Doppler Current Profilers (ADCP) by GEMS for approximately 18 days to cover a full spring to neap tidal cycle,
- b) The deployment of a third ADCP by MetOcean Engineers; and
- c) The deployment of several drifting buoys which were tracked by boat.

The second phase of the work involved running GCOM3D for the period of deployment of the ADCPs, driven by tides and Bureau of Meteorology (BOM) winds, and comparing the model predictions with the data.

1.1 Scope of Work

The Scope of Work was:

- a) Prepare ADCP current moorings
- b) Deploy ADCP moorings off the eastern coast of Barrow Island
- c) Deploy and track a series of Lagrangian drifters
- d) Extract gridded BOM data for the region and time of ocean current measurements.
- e) Run GCOM3D for the period of ocean current measurements (approx. 3 weeks) driven by winds and tides.

- f) Extract data from current meters and analyse to produce time series of currents at specific depths.
- g) Develop Lagrangian time series from drifter data.
- h) Compare GCOM3D predictions with drifter and current meter data and produce a technical report.

2 ADCP Deployments

The ADCPs and basic mooring components are shown schematically in the mooring design in Figure 1.

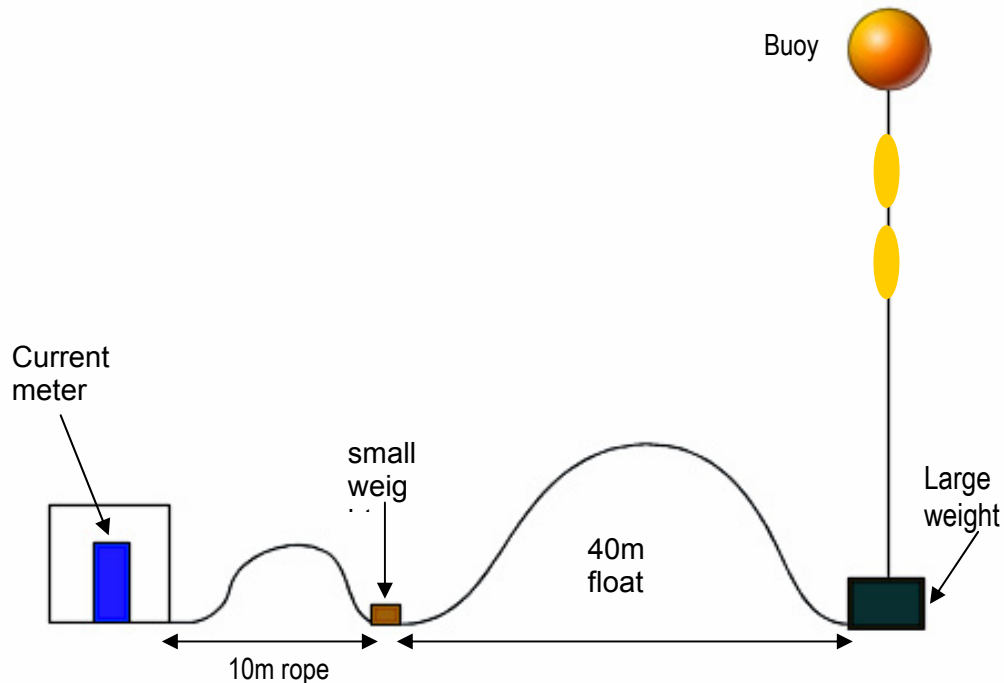


Figure 1: Mooring configuration

The mooring locations are defined in Table 1 and marked in Figure 2.

The ADCP's deployed by GEMS were from RDI Instruments in the USA and were calibrated and supplied by their agent in Australia (Underwater Video Systems).

The work boat "the Gun", and diving and logistics support for the mooring deployments was provided by RPSBBBG.

3 Drifting Buoy Deployments

The Australian Maritime Safety Authority (AMSA) Search and Rescue (AUSSAR) in Canberra provided wireless tracked drifting buoys (known as SAR datum buoys) for the lagrangian drifter experiments. These buoys are cylindrical, approximately 30cm long and 4cm diameter. The heavy battery for the wireless transmitter sits in the base of the cylinder and as a result only 2-3cm of the cylinder is above water. Accordingly, although yellow in colour, they are difficult to see in the open ocean. A thin wireless aerial protudes above the cylinder approximately 20cm and transmits in the range 119.05 to 119.35 Mhz. A wireless receiver on deck can then detect the direction of the buoy from the boat and the signal strength gives an indication of proximity. These buoys have been used world-wide for many years by Search and Rescue authorities to provide information on surface currents at incident locations. The SAR buoys are subject to very low windage due to there design and rely on wireless detection, rather than vision, for determining there position.

The release points for the SAR datum buoys are defined in Table 1 and the tracks are shown in [Figure 2](#).

Table 1: ADCP and Drifting Buoy Deployment Locations

Instrument	Deployment Latitude	Deployment Longitude	Duration	Average wind speed during deployment (m/s)	Average wind direction during deployment (deg from)
ADCP 1	-20.72375	115.61598	17 days	n/a	n/a
ADCP 2	-20.83332	115.50960	17 days	n/a	n/a
ADCP 3	-20.89968	115.50013	17 days	n/a	n/a
Drifter 1	-20.83332	115.50960	2 hours	3.8	80
Drifter 2	-20.93920	115.47323	5 hours	3.9	53
Drifter 3	-20.80220	115.48358	5 hours	4.4	60
Drifter 4	-20.80287	115.48422	12 hours	6.0	26

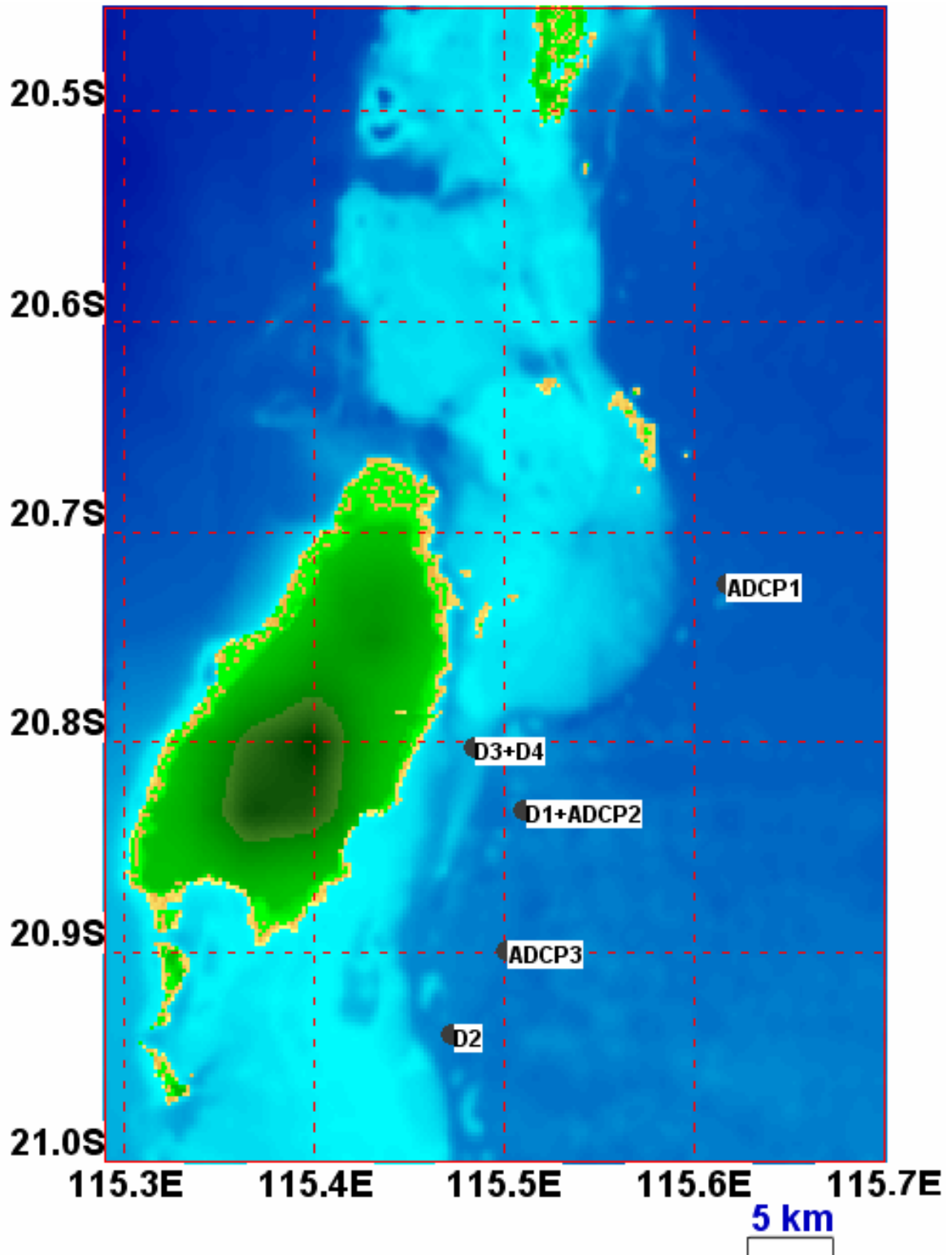


Figure 2: Location of the 3 ADCP moorings and the 4 drifter releases.

4 GCOM3D Simulations for the Experimental Period

4.1 Model Description

The dominant influences on the circulation in the waters surrounding Barrow Island are the local wind and tides. This circulation can be simulated to a high level of accuracy using the GEMS three-dimensional ocean model (GCOM3D).

GCOM3D is a state-of-the-art 3D primitive equation ocean model, which has been developed by GEMS to study and predict ocean currents on or near the continental shelf and in harbours and estuaries anywhere on the globe. GCOM3D includes the non-linear advection terms and is driven by wind stress, atmospheric pressure gradients, astronomical tides, depth and terrain dependent bottom friction, and ocean thermal structure (where relevant). For high-resolution studies over small regions GCOM3D can be nested in larger domains and still runs relatively fast on any modern computer (PC or UNIX).

For search and rescue applications and the tracking of buoyant discharges the surface ocean currents from GCOM3D are used. For oil spill modelling, water quality, sediment transport and other marine discharge studies, which often require an understanding of the vertical variation of the currents, the full three-dimensional current field is used.

GCOM3D is the longest serving three-dimensional ocean model in Australia. It was the first 3D ocean model to be used on a consulting job (Geelong Ocean Outfall, 1984) and has since been continuously developed in the research world and since the formation of GEMS in 1993.

GCOM3D has been used by the Australian Maritime Safety Authority in Canberra, as the national ocean forecast model for search and rescue, (and oil spill prediction) for the past three years. During this time the model has been used at many locations around the Australian coastline and verified against SAR buoys (surface drifters) with only three cases in three years producing incorrect results. These cases have since been shown to be due to the influence of the East Australian Current, which has now been incorporated via the routine inclusion of satellite altimeter data from the NOAA satellites.

4.2 Model Forcing

Model forcing includes both wind and tides concurrently. In addition, as stated in the previous section, GCOM3D routinely uses satellite data to define forcing from sea level variations deriving from large-scale ocean circulation properties (such as the Leeuwin Current on the West Australian coast).

4.2.1 Meteorology

GCOM3D can be driven with gridded atmospheric model output or single station data. For this study 3-hourly gridded data from the BOM operational forecast model (LAPS – Limited Area Prediction System) was obtained for the experimental period.

4.2.2 Bathymetry

The bathymetric data sets held by GEMS were updated with bathymetry acquired by Chevron. The GEMS database has been developed from a range of sources including data from Geoscience Australia (formerly AUSLIG) and oil company surveys. Of particular relevance to this project is that the original 3D bathymetric survey of the Gorgon field is included together with the Apache Energy 3D bathymetric survey from south of Barrow Island to the Montebello Islands.

4.2.3 Tides

Tidal forcing was based on data from the GEMS Australian region gridded tidal data base which has been developed with extensive modelling programmes. The tidal data for this project was enhanced with data from a high resolution tidal modelling project carried out by GEMS for Apache Energy in 1998.

4.3 Model Predictions

To verify GCOM3D a bathymetric grid covering the region in [Figure 3](#) was set up at 500 metre resolution. Tidal data for the model boundaries was extracted from the GEMS database and winds from the Bureau of Meteorology were used to force GCOM3D.

A second grid (see Figure 4) was setup on a 100 metre grid surrounding Barrow Island and nested inside the larger grid (note that for the dredge plume modelling a higher resolution 50m grid was used)

GCOM3D was run for the month of September 2005, on both the large and nested grids, producing half-hourly currents at between 5 and 15 levels in the water column (depending on the depth).

[Figures 4](#) to 9 show the simulated flood and ebb cycle during spring tides at 2 hourly intervals.

Note that the purpose of these figures is to illustrate the circulation pattern around Barrow Island and so the current vector scaling in these figures varies for each figure in order to give a good illustration of the current direction, even at low current. For a more detailed understanding of the current speeds reference should be made to the ADCP results and the comparisons with GCOM3D predictions.

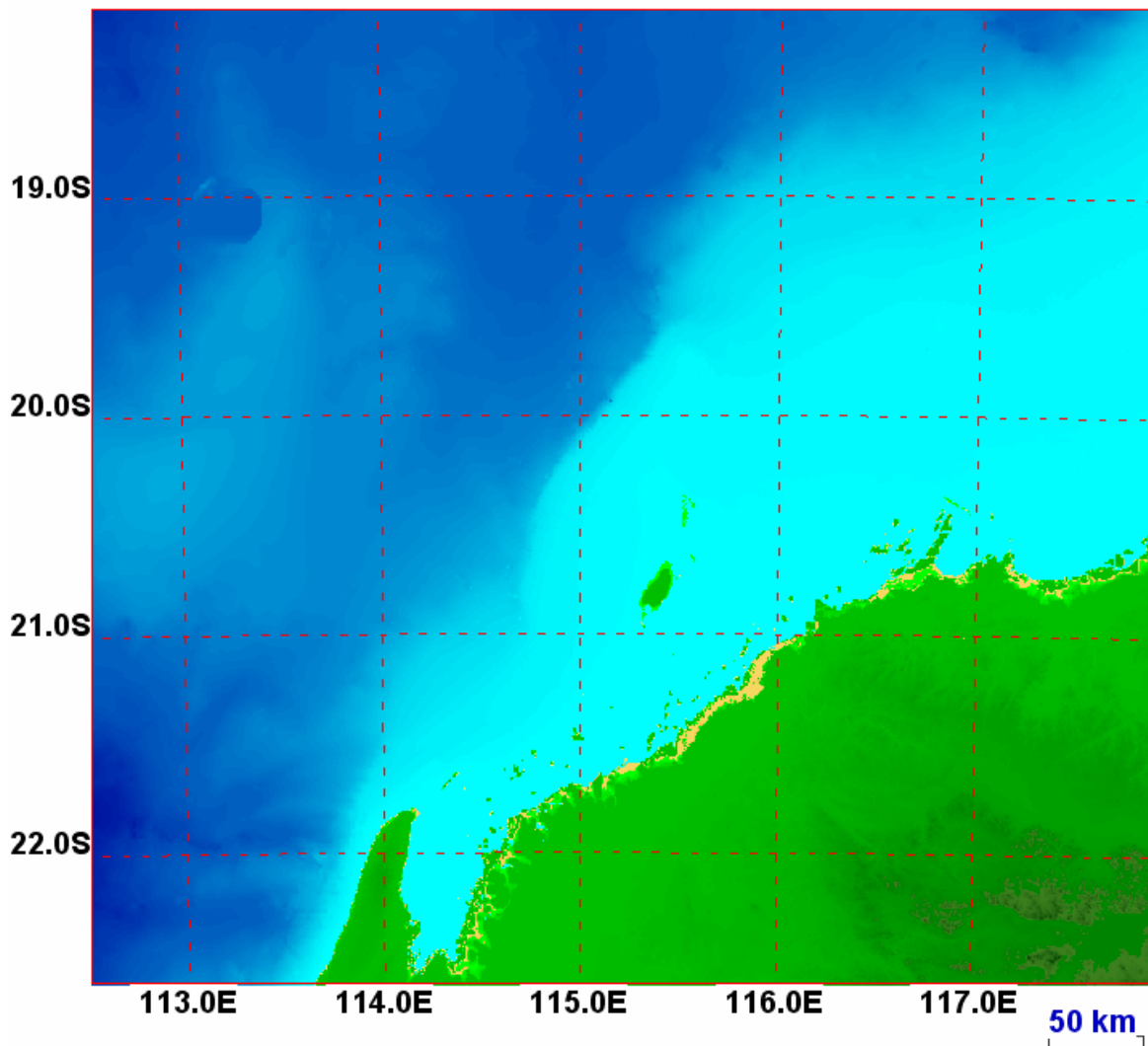


Figure 3: The large grid used to model the propagation of tides and wind-driven currents and large scale circulations (if any) into the Barrow Island region.

GC3M3D - the GEMS 3D Coastal Ocean Model Tidal and wind driven currents at 1 (m)

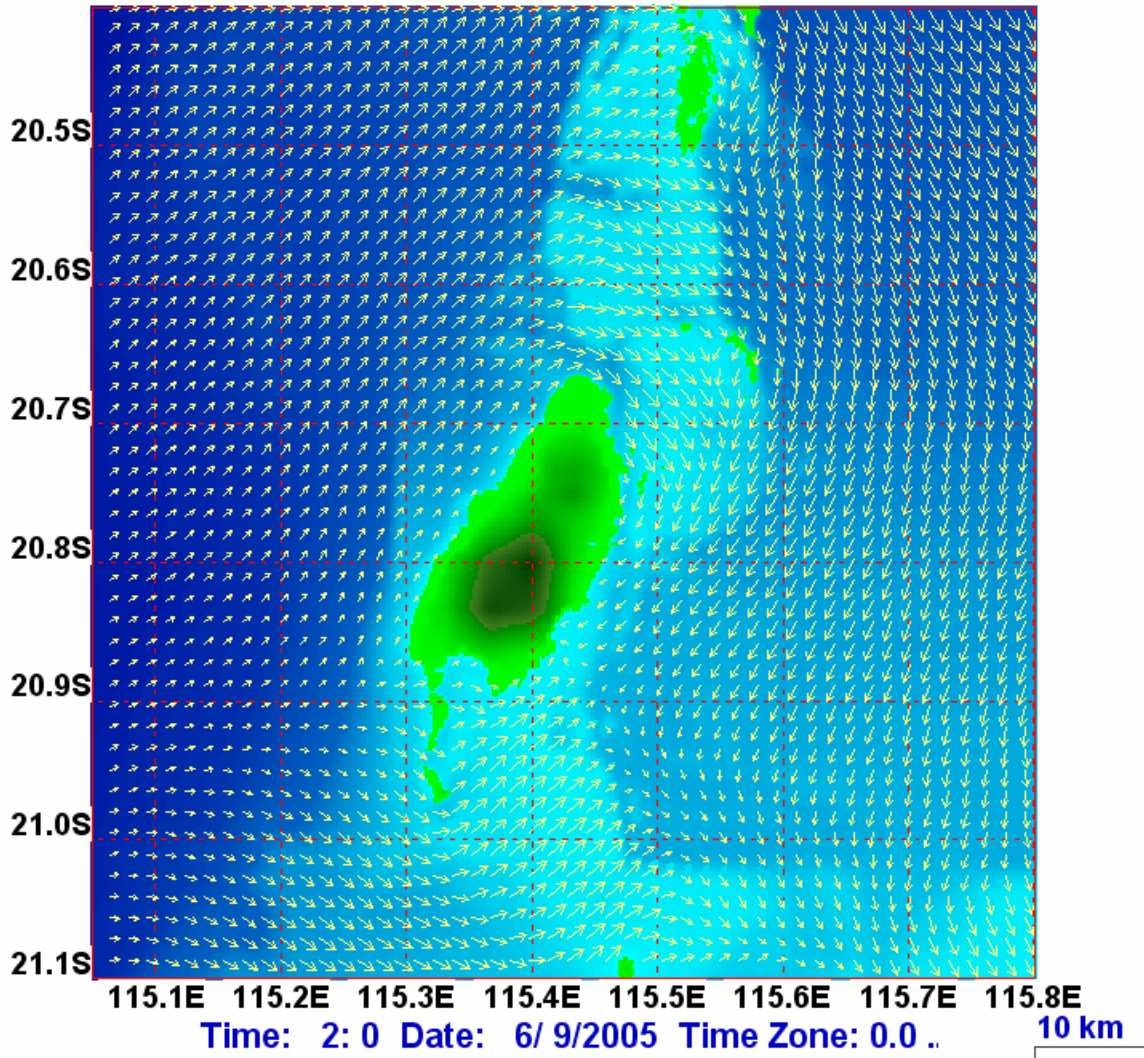


Figure 4: Near surface currents predicted by GC3M3D at 0200 on 6/9/2005

GCOM3D - the GEMS 3D Coastal Ocean Model

Tidal and wind driven currents at 1 (m)

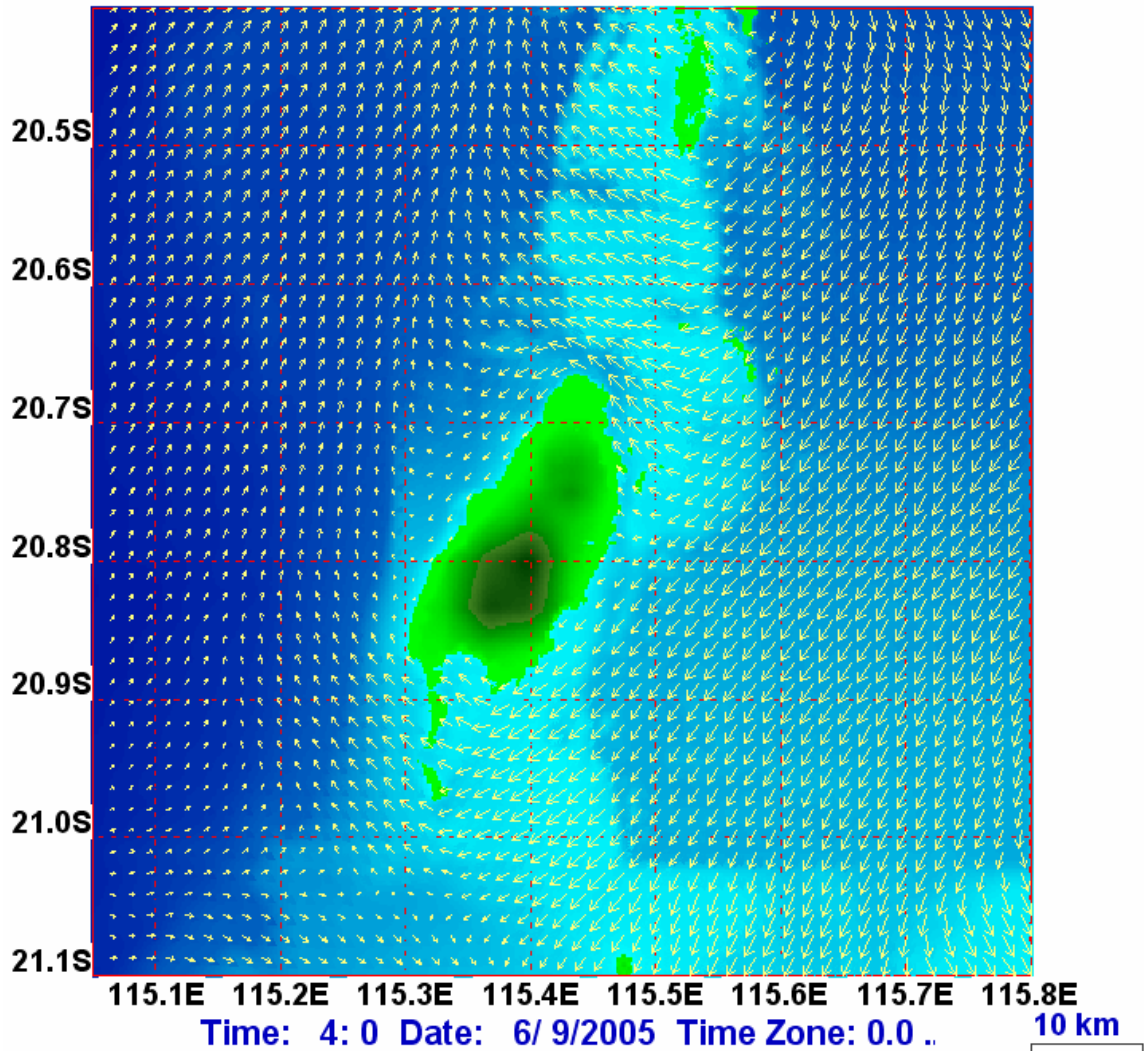


Figure 5: Near surface currents predicted by GCOM3D at 0400 on 6/9/2005

GCOM3D - the GEMS 3D Coastal Ocean Model

Tidal and wind driven currents at 1 (m)

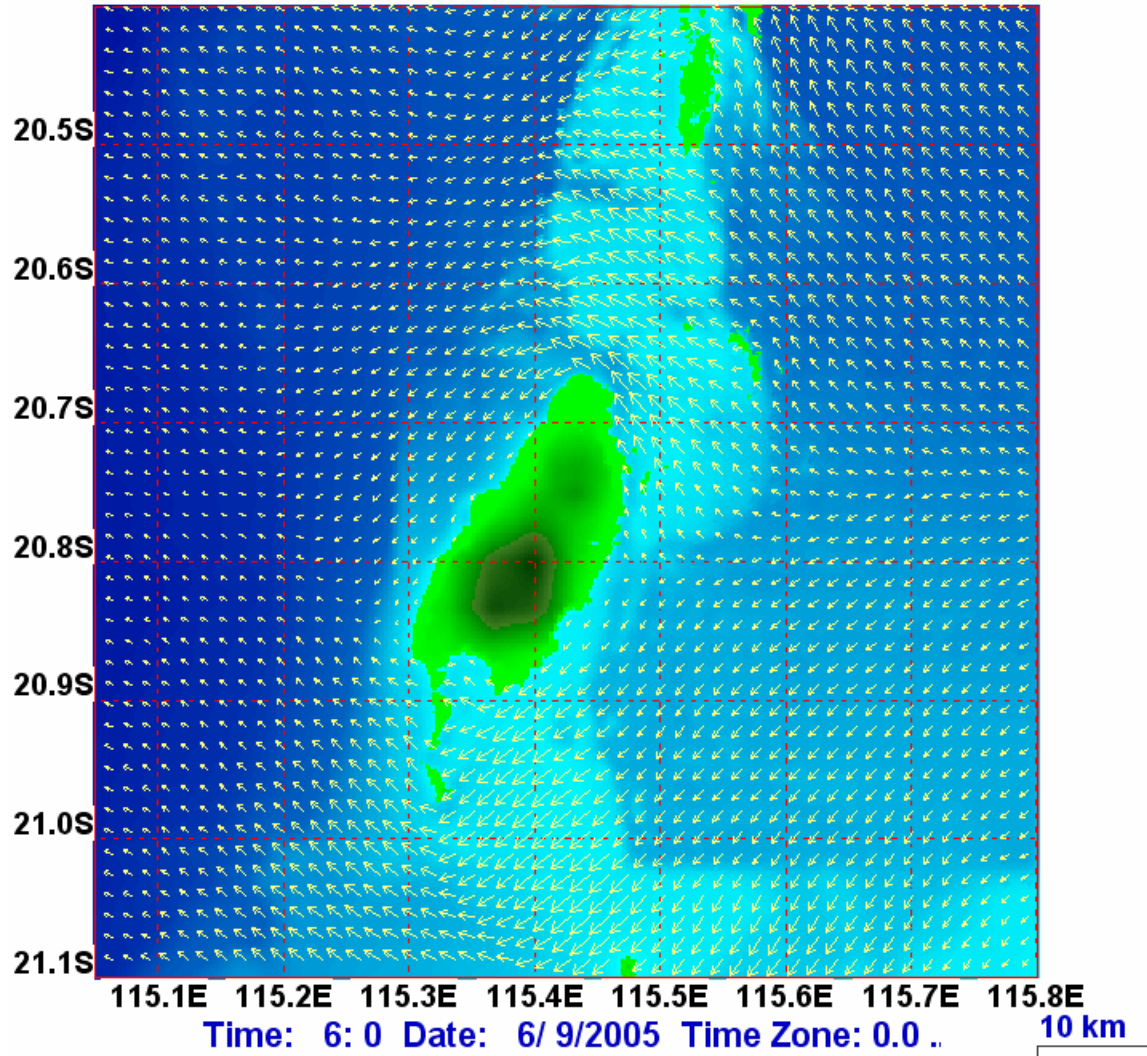


Figure 6: Near surface currents predicted by GCOM3D at 0600 on 6/9/2005

GCOM3D - the GEMS 3D Coastal Ocean Model

Tidal and wind driven currents at 1 (m)

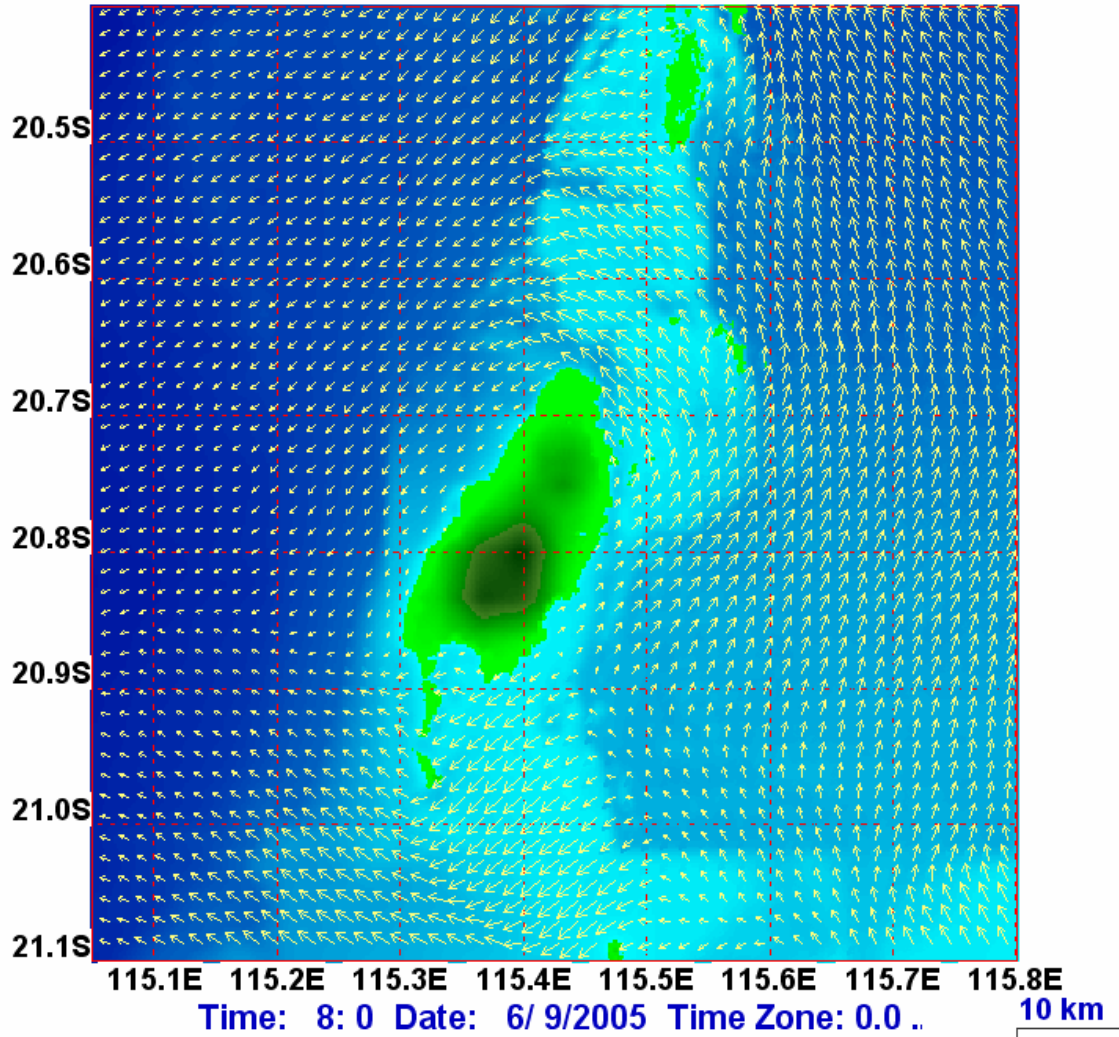


Figure 7: Near surface currents predicted by GCOM3D at 0800 on 6/9/2005

GCOM3D - the GEMS 3D Coastal Ocean Model

Tidal and wind driven currents at 1 (m)

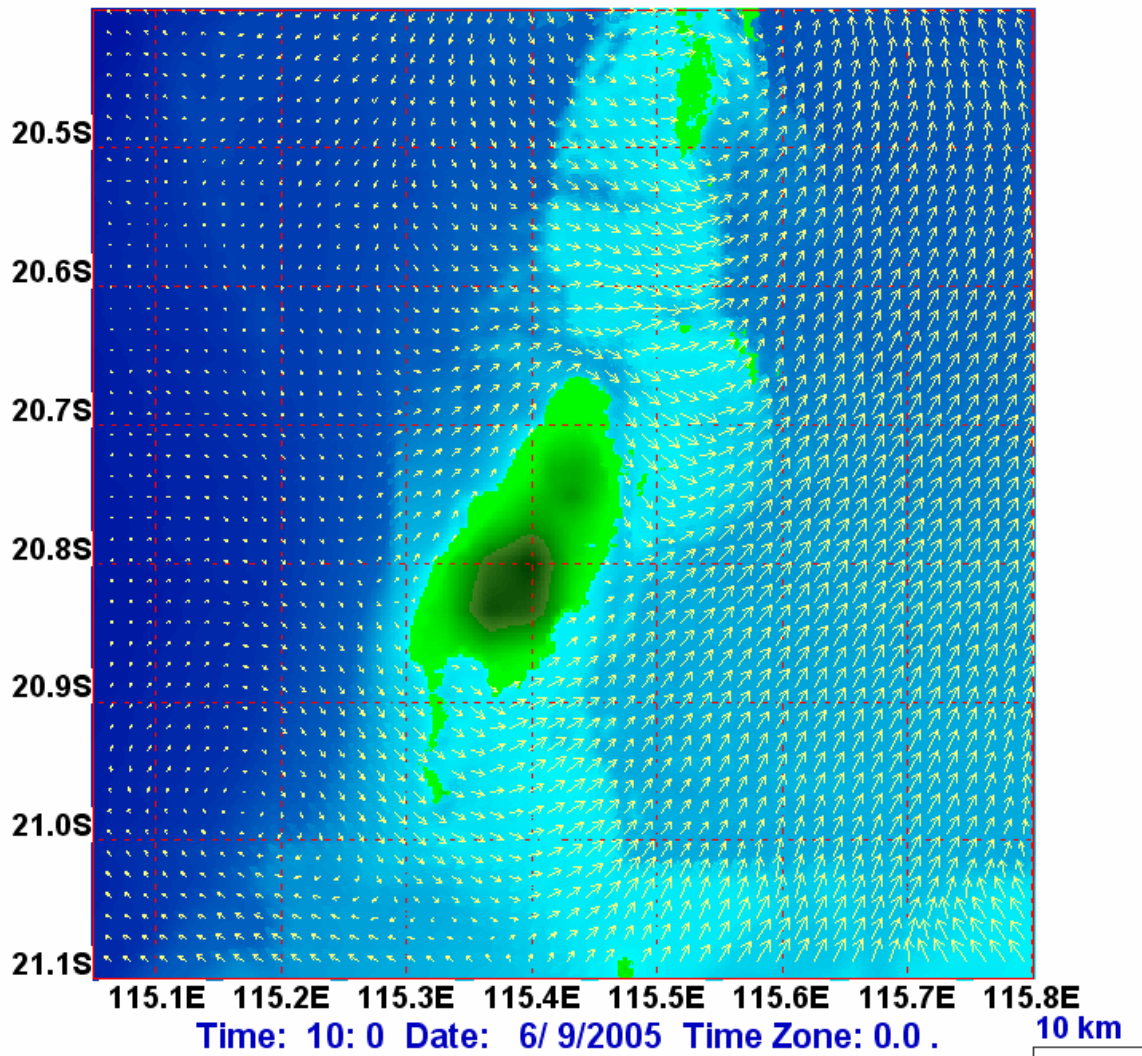


Figure 8: Near surface currents predicted by GCOM3D at 1000 on 6/9/2005

GCOM3D - the GEMS 3D Coastal Ocean Model Tidal and wind driven currents at 1 (m)

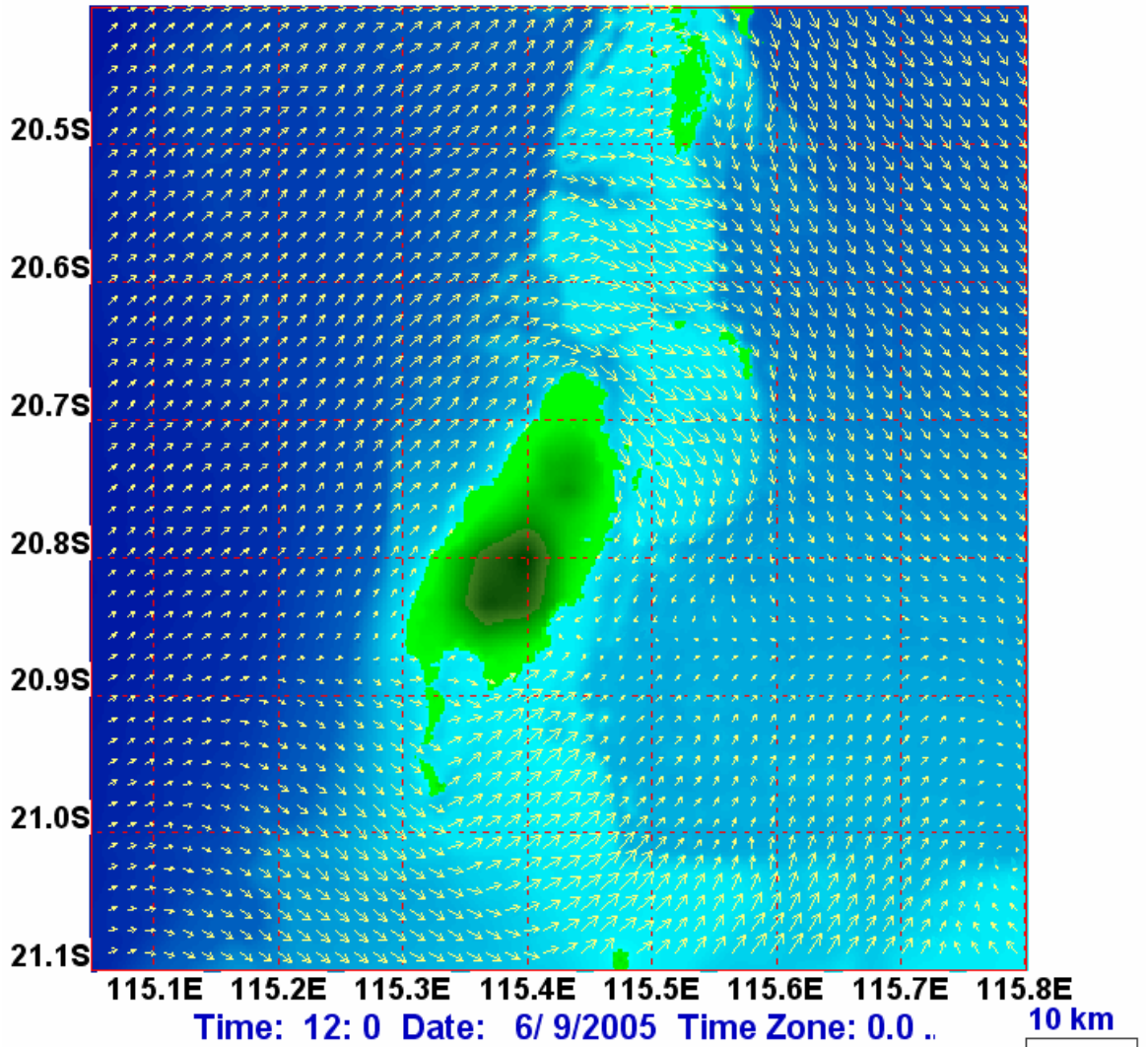


Figure 9: Near surface currents predicted by GCOM3D at 1200 on 6/9/2005

5 Comparison of Measurements and GCOM3D Predictions

5.1 Tides

The MetOcean ADCP did not measure tidal levels so comparisons were only available at the two GEMS sites. [Figures 10](#) and 11 show the comparison of measured and predicted sea levels for the 18 days of the deployment at these sites.

5.2 Currents

Time series comparisons of near surface ocean currents predicted by GCOM3D with observations at the three ADCP sites are presented in [Figures 12](#) to 17.

An alternative method of comparison is progressive vector diagrams which show the movement of a particle if the currents at a site were constant throughout a region. Figures 18 to 20 show progressive vector diagrams for each of the three ADCP sites comparing model predictions with measurements.

For most of the experimental period the winds were from the north-east, inducing a wind-driven current residual towards the south. The wind speeds and directions for the 17 days of ADCP measurements are given in Figures 21 and 22 respectively.

5.3 Drifting Buoy Tracks

Comparisons of drift tracks predicted by GCOM3D with the four drifting buoy tracks are presented in [Figure 23](#).

6 Conclusions

The agreement between GCOM3D model predictions of sea levels, currents and drifting buoy tracks and observations is very good in all cases. Prior to this work the manner in which the flood and ebb tide circulated on the eastern side of Barrow Island was not well understood.

In particular, various results have been presented for the meeting of the flood tide on the east of Barrow Island after flowing around the southern and northern end of the island. The combined results of the ADCP measurements and drifters now indicate that GCOM3D is simulating the circulation around Barrow Island with a good level of accuracy.

Examination of the circulation shows that the shallow bathymetry to the north and south of Barrow Island restricts the flow of the flood tide from the open ocean to the coast. Consequently the mass transport of water to the coast, east of Barrow Island, during the build up of high tide is derived from flows around the north and south of Barrow Island and from water flowing south-east (varies) in the gap between the Montebello Islands and the Burrup Peninsular. This latter flow is induced because of the limited mass transport possible across the shallow areas to the north and south of Barrow Island.

In the vicinity of Barrow Island the flood tide flows around the north and south ends of the island and generally meets anywhere between Dugong Reef and the Lowendal Shelf and then combines to flow towards the coast. The meeting of the two components of the flood tide is dependent on the spring-neap tidal cycle and the strength of the southerly winds.

A further outcome of the study is the knowledge that GCOM3D can reliably be used to simulate currents to study other processes such as the fate of dredge plumes, or any other marine discharges around Barrow Island.

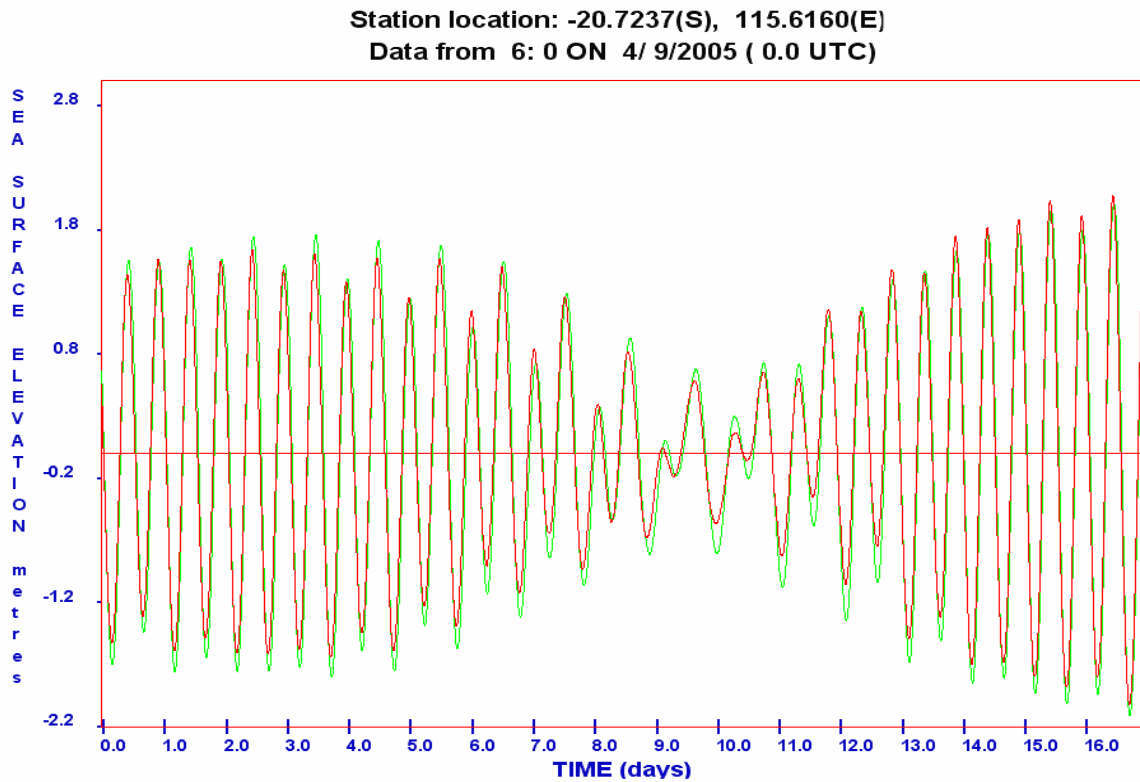


Figure 10: Comparison of predicted (green) and observed (red) sea levels at site ADCP1.

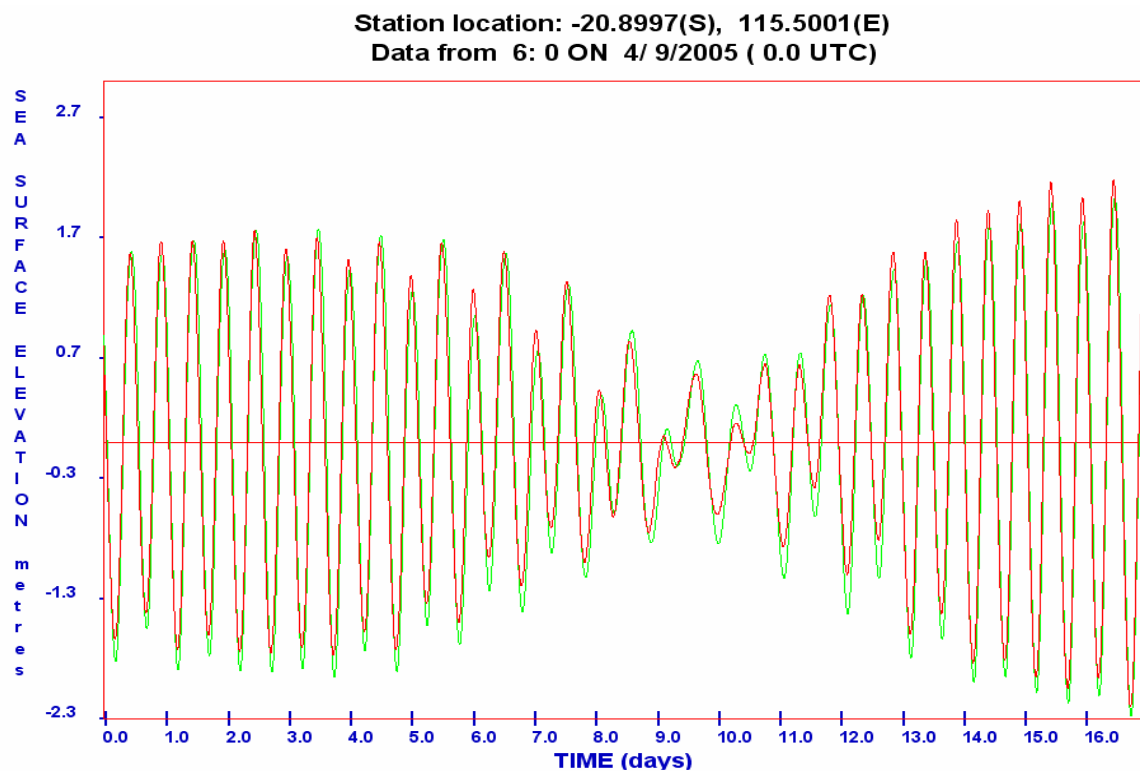


Figure 11: Comparison of predicted (green) and observed (red) sea levels at site ADCP3.

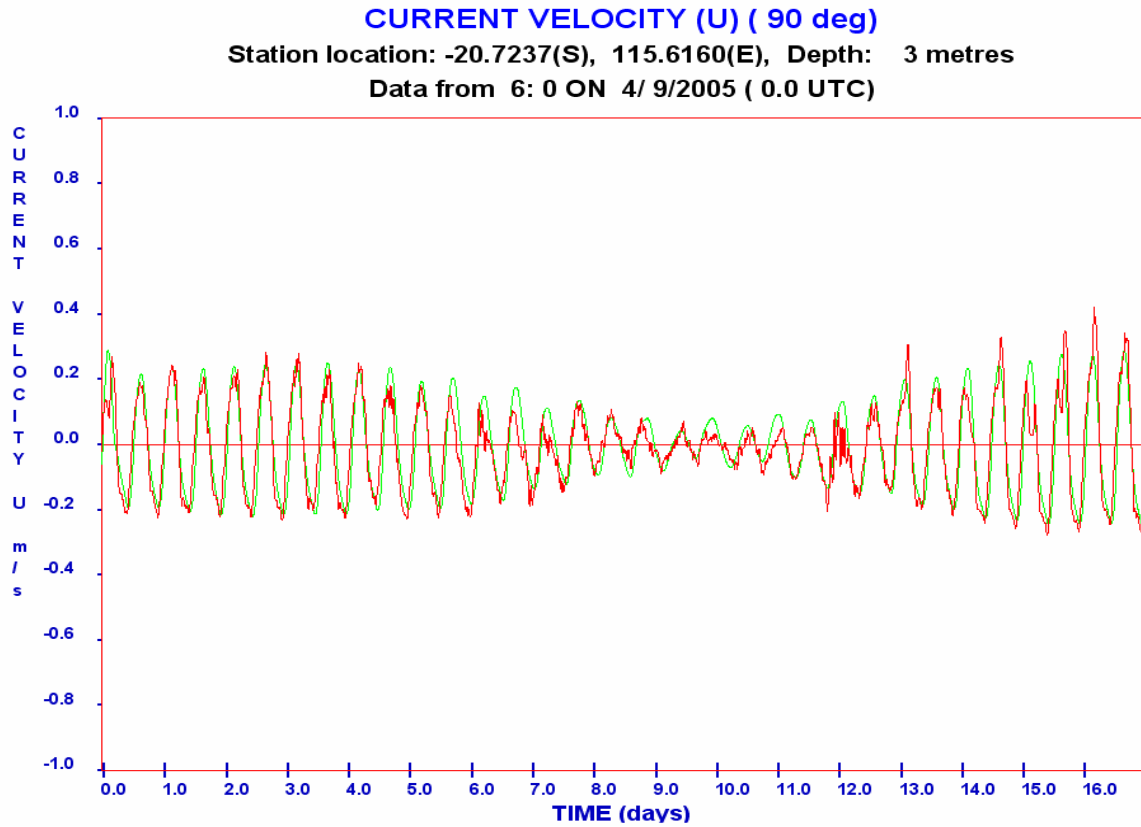


Figure 12: Comparison of near surface East-West current speeds predicted by GCOM3D (green) with observations at site ADCP1 (red).

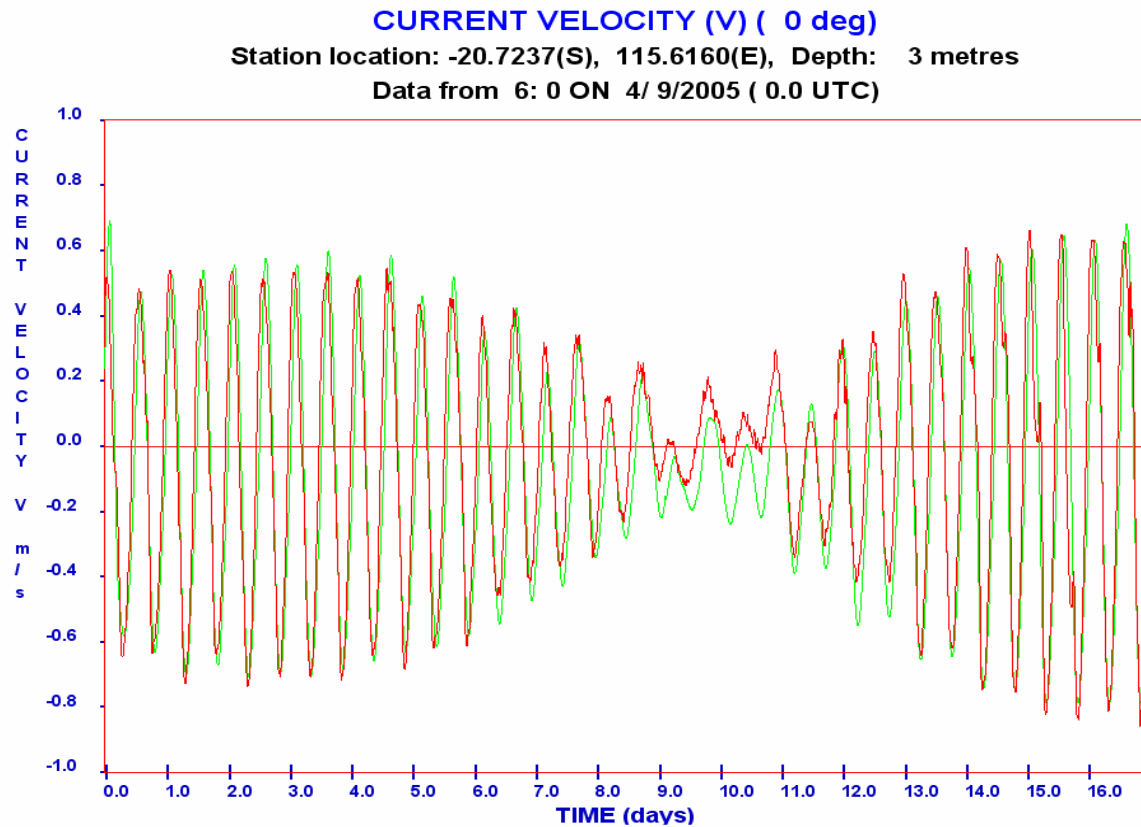


Figure 13: Comparison of near surface North-South current speeds predicted by GCOM3D (green) with observations at site ADCP1 (red).

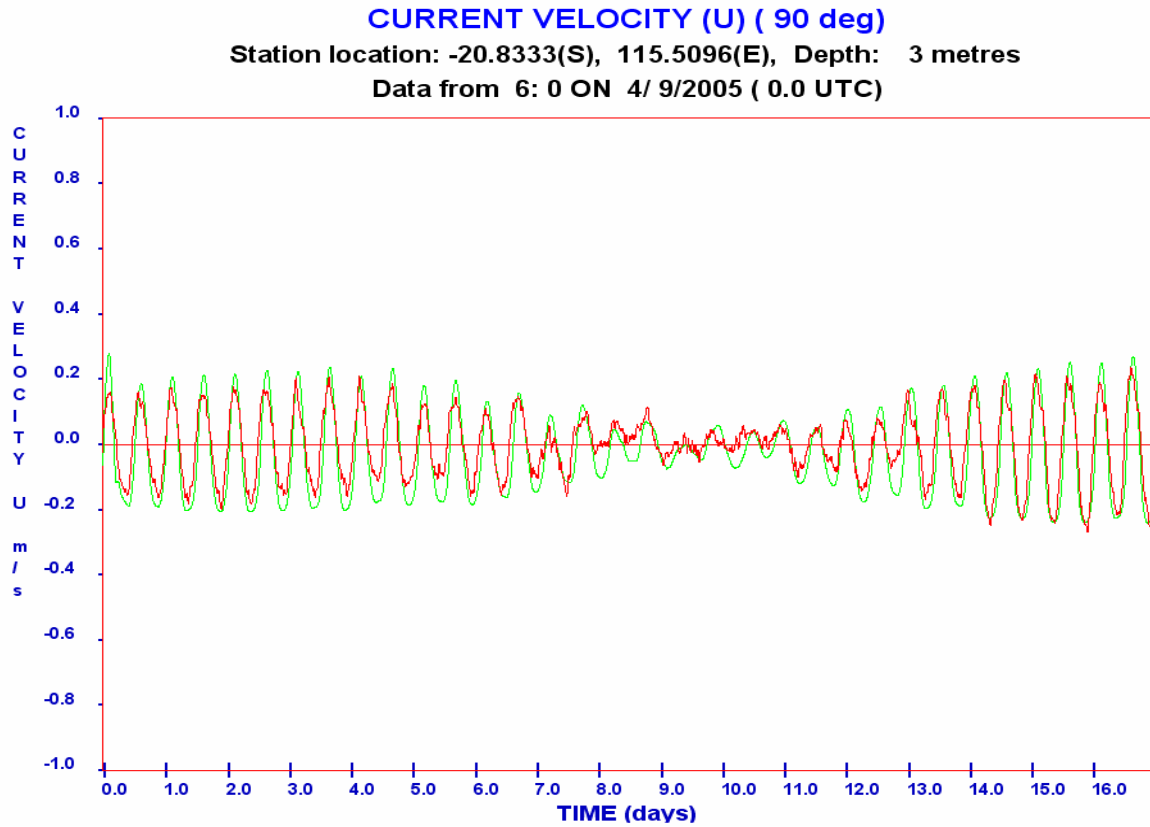


Figure 14: Comparison of near surface East-West current speeds predicted by GCOM3D (green) with observations at site ADCP2 (red).

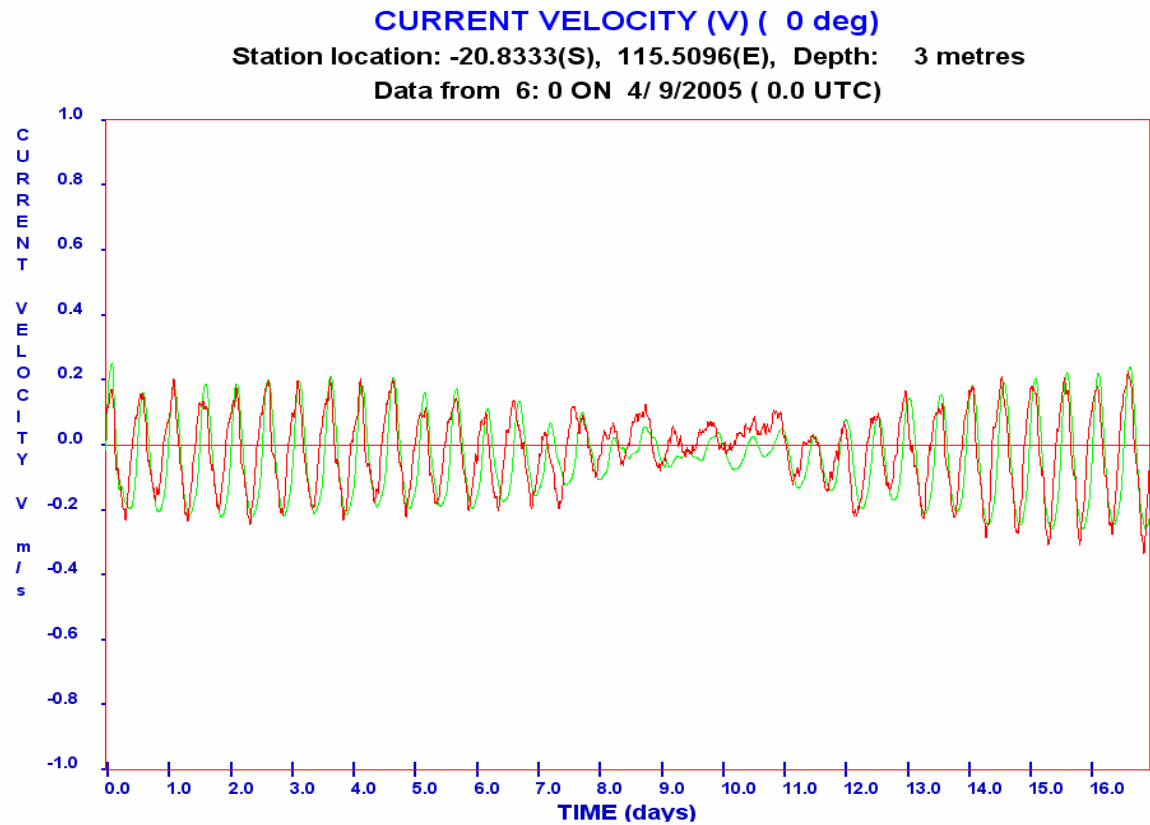


Figure 15: Comparison of near surface North-South current speeds predicted by GCOM3D (green) with observations at site ADCP2 (red).

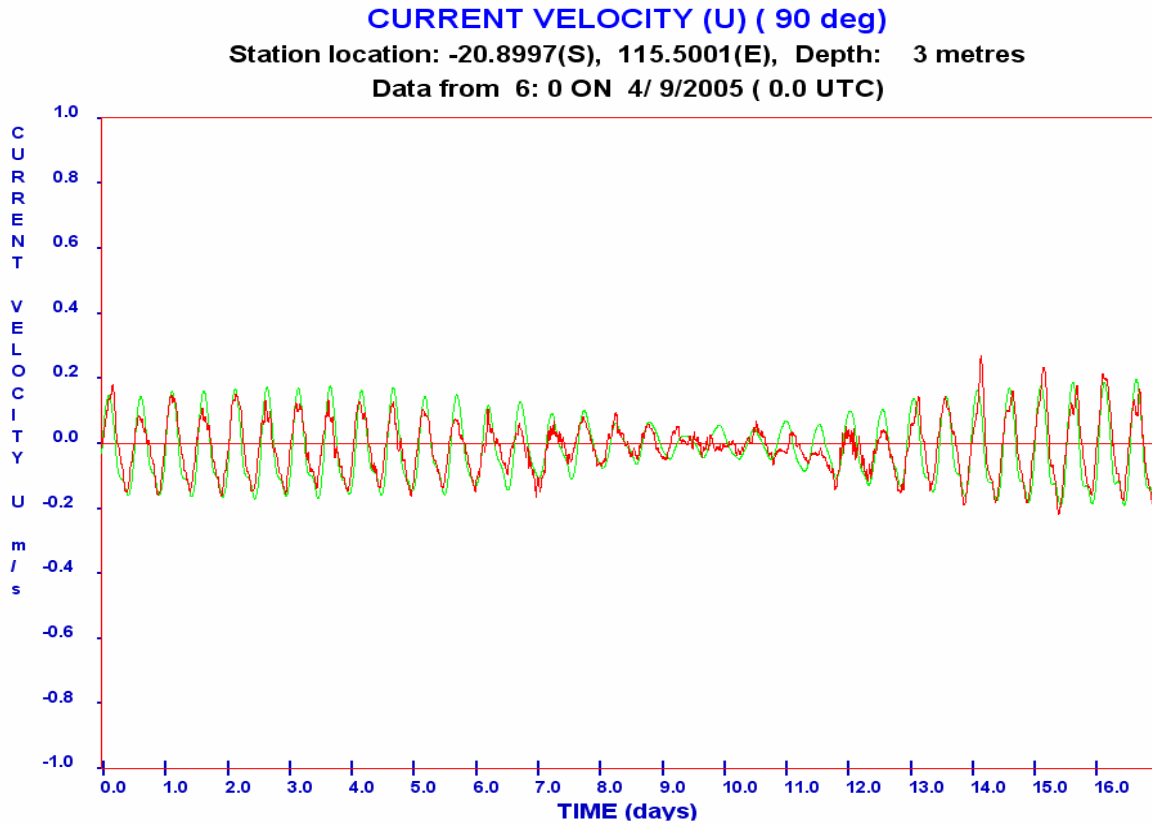


Figure 16: Comparison of near surface East-West current speeds predicted by GCOM3D (green) with observations at site ADCP3 (red).

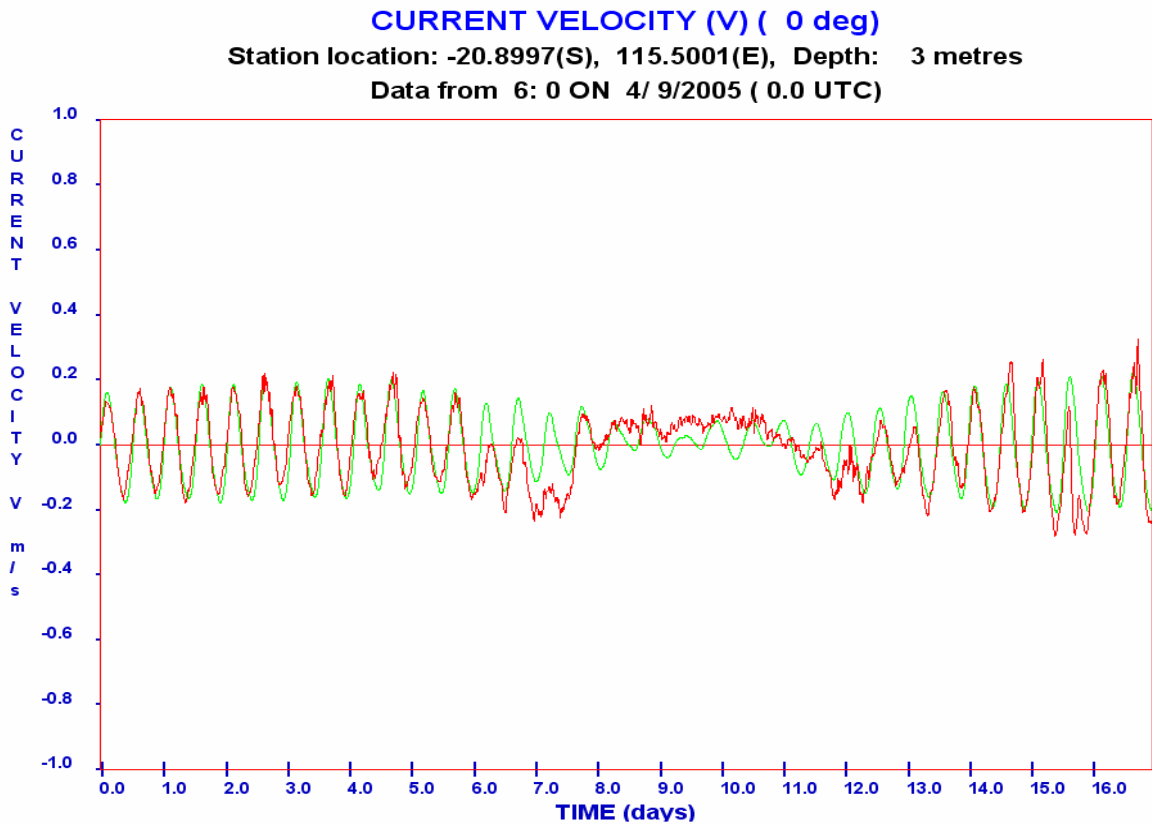


Figure 17: Comparison of near surface North-South current speeds predicted by GCOM3D (green) with observations at site ADCP3 (red).

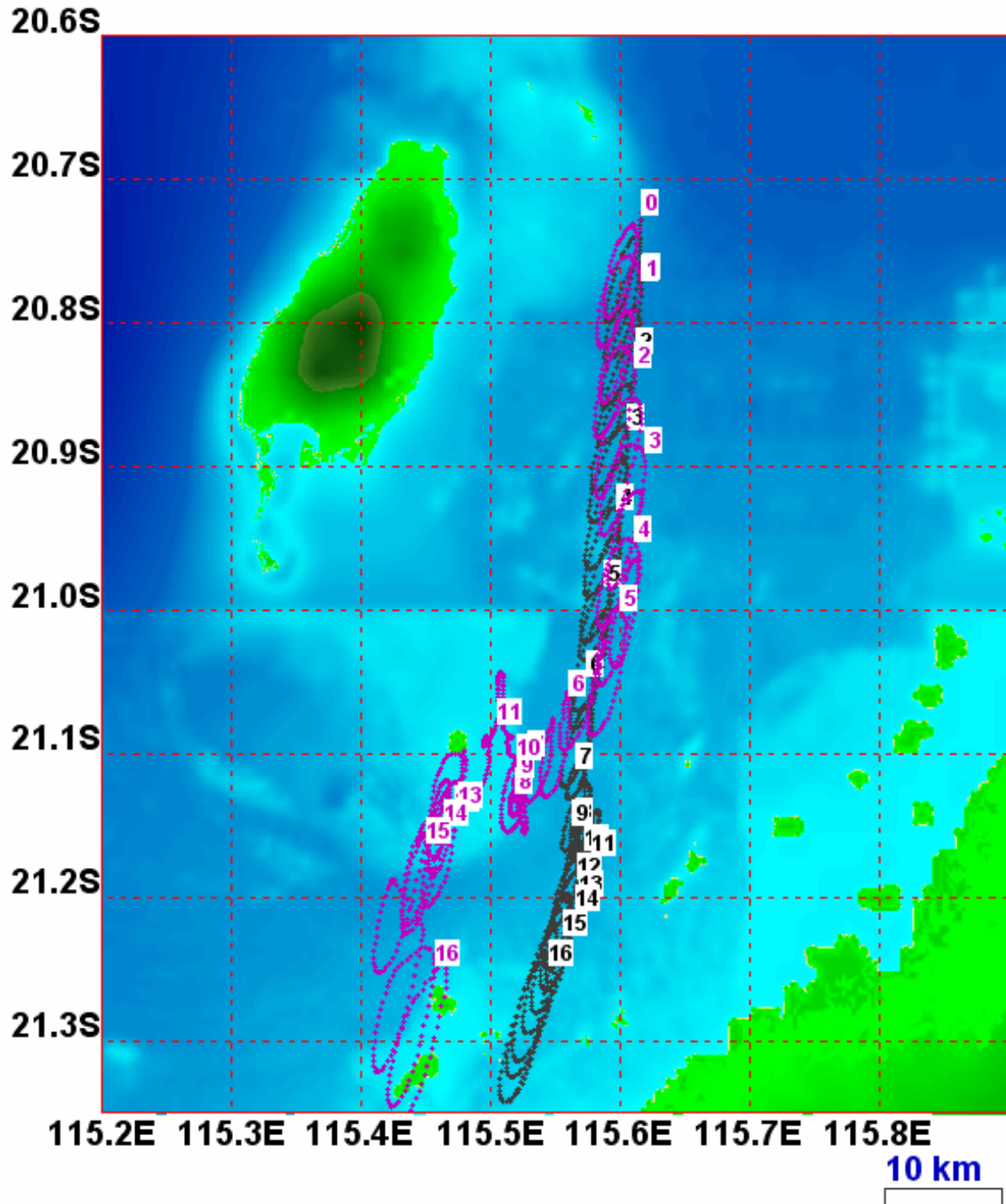


Figure 18: Progressive vector diagram comparison of near surface currents predicted by GCOM3D (black) with observations at site ADCP1 (magenta).

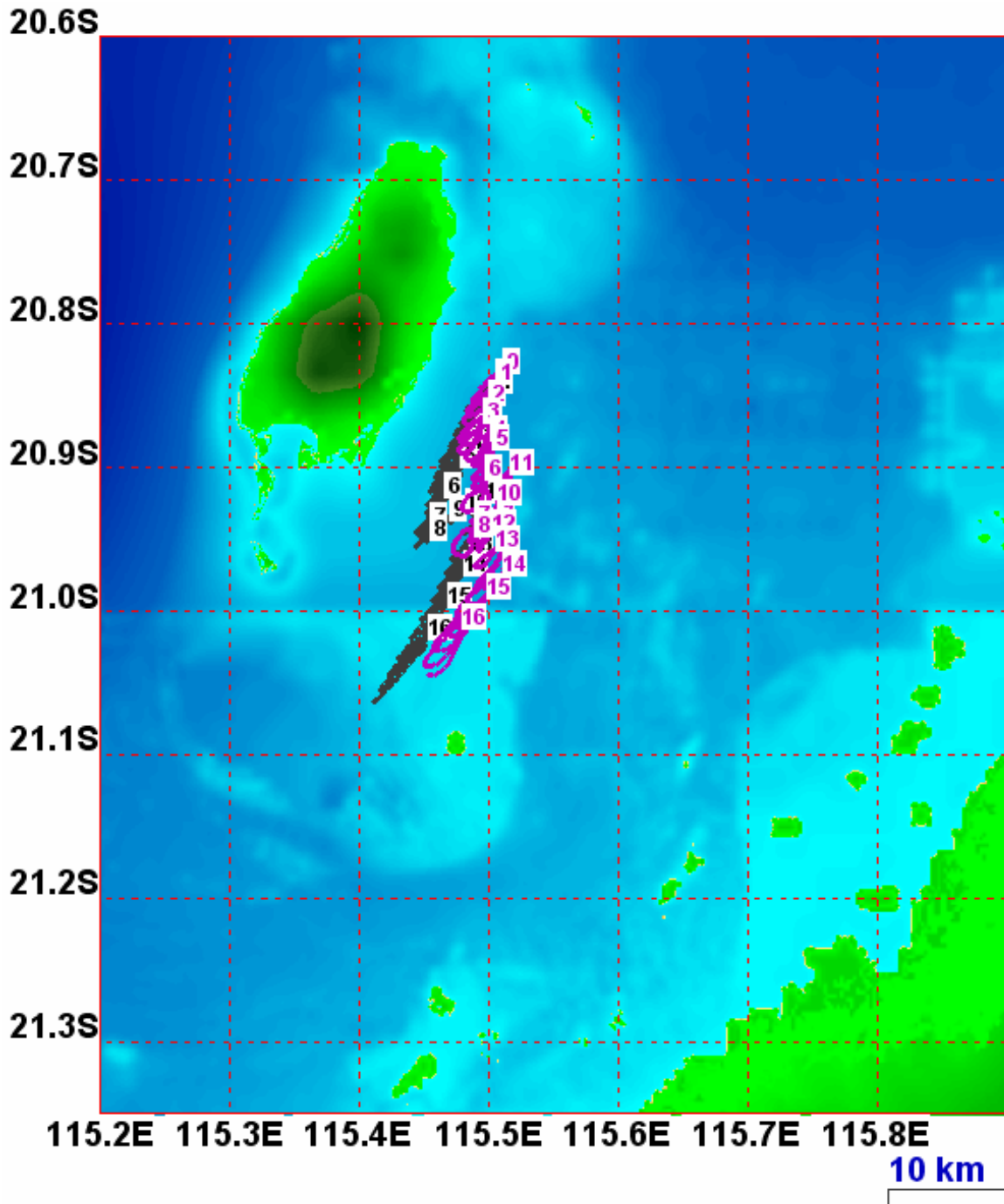


Figure 19: Progressive vector diagram comparison of near surface currents predicted by GCOM3D (black) with observations at site ADCP2 (magenta).

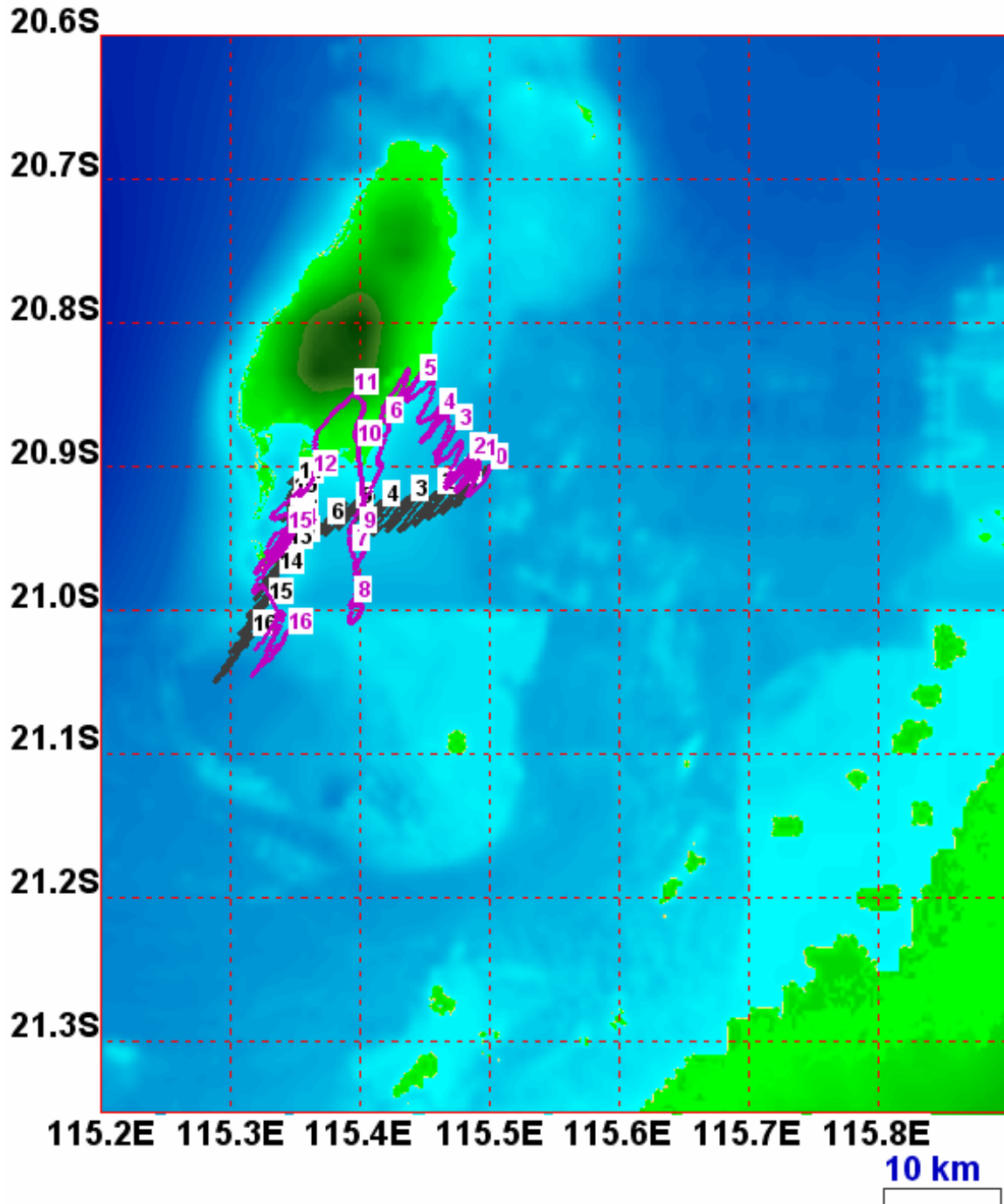


Figure 20: Progressive vector diagram comparison of near surface currents predicted by GCOM3D (black) with observations at site ADCP3 (magenta).

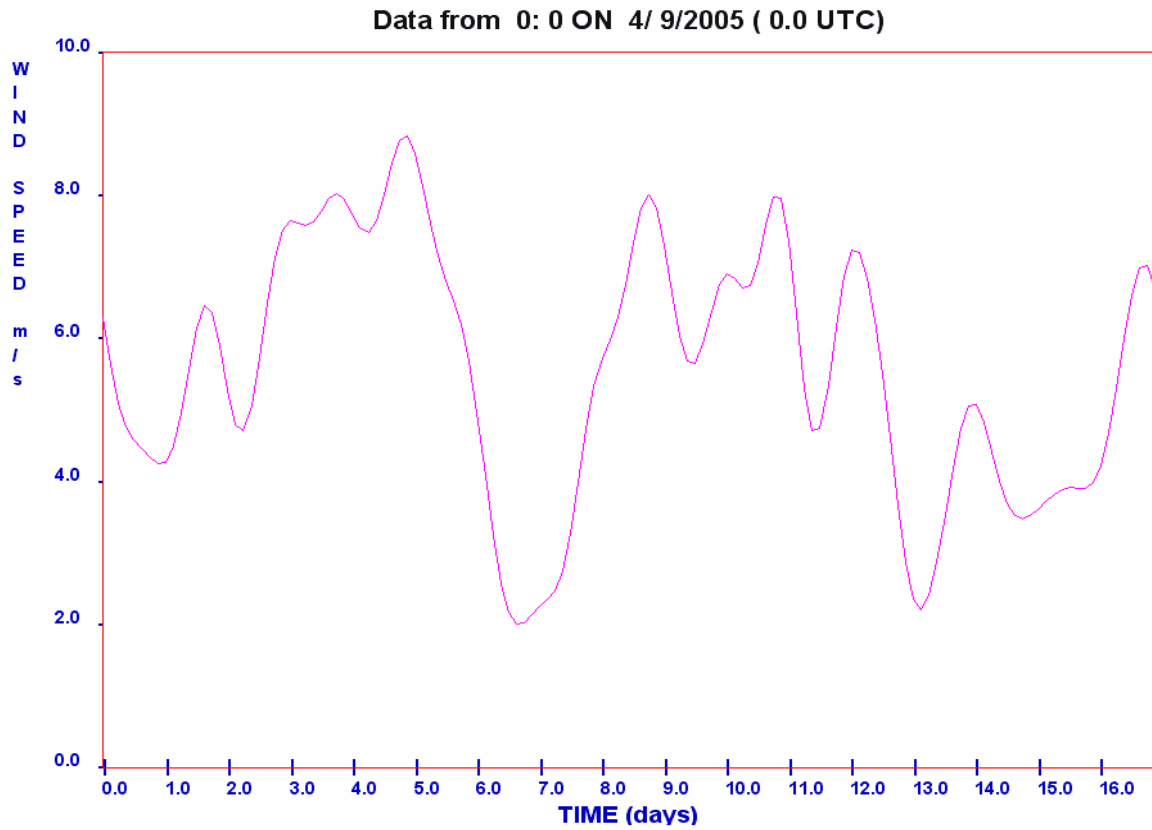


Figure 21: Wind speed (m/s) for the duration of the ADCP deployments.

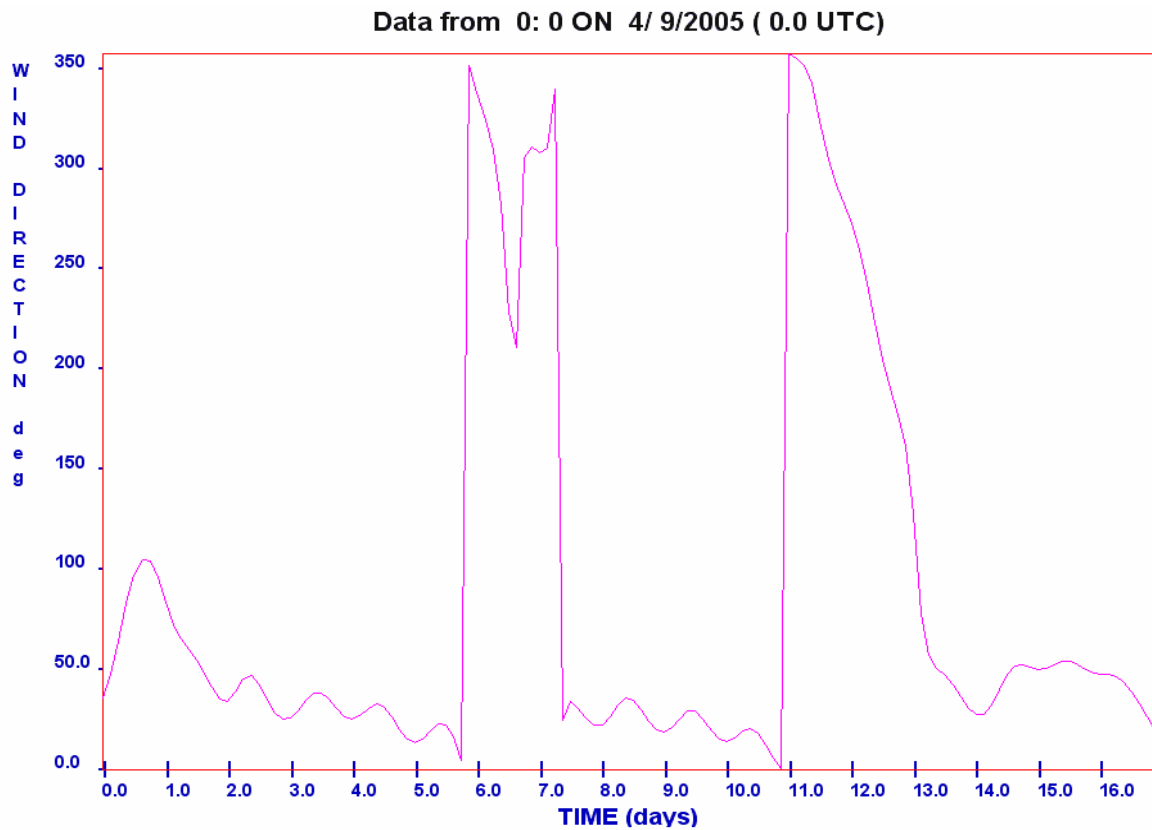


Figure 22: Wind direction (deg from) for the duration of the ADCP deployments.

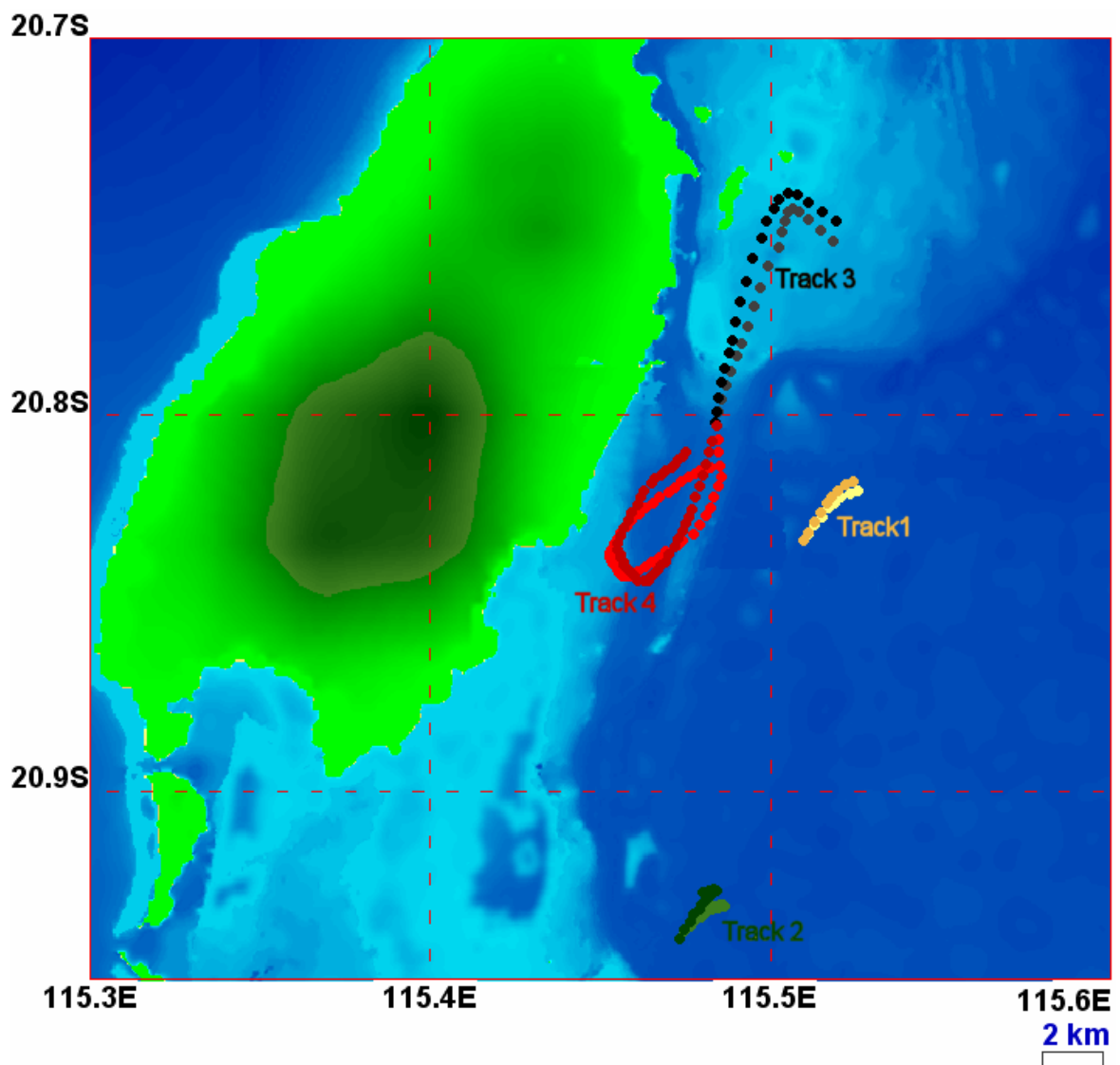


Figure 23: Comparison of drift tracks predicted by GCOM3D (darker colour) with actual tracks (lighter colour).