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Current Measurements in the York River near the Coleman Bridge

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Contract Report to
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Norfolk, VA

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Subcontract Agreement No: 35

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INTRODUCTION

In support of Tidewater Construction Corporation's project to widen the George P. Coleman Bridge, current measurements were conducted in the York River between Gloucester Point and Yorktown, Virginia, along both sides of the bridge. The objective was to sample the currents at approximately 10 feet below the water surface during maximum ebb and flood flow, at enough locations to resolve cross-river variations in the flow field. This objective was well satisfied with multiple surveys conducted during ebb, slack, and flood phases of the tidal flow, each survey providing current data at multiple depths. Significant cross-river variability was documented.

The study date, 16 May 1995, was chosen in order to sample the relatively strong predicted tidal currents associated with a spring tide, this one corresponding to the full moon of 14 May 1995. Of course, the currents that were actually measured reflect not only astronomical forcing, but the influence of wind and freshwater runoff as well. In fact, the wind during ebb sampling was blowing strongly enough upriver to generate widespread whitecapping and may have reduced the current relative to what it would have been on a calm day.

DATA

Currents were measured with a 1200 kHz acoustic Doppler current profiler (ADCP), towed in a catamaran vehicle by the R/V Langley. The tow line and fixed rudders on the catamaran were configured so that the ADCP followed alongside the vessel, well away from wake influence. Raw current velocity data, recorded in the field at 1.2 s intervals, consisted of 4-ping averages of along-beam velocity components.

Satellite navigation data, provided by a differential GPS system and tagged with the sequential number of the most recently acquired ADCP ping ensemble, were recorded at 6 s intervals.

Water level at the Tidewater Construction tide staff near the Yorktown shoreline was read from the boat approximately 20 times during the course of the current measurements. The tide staff on the Gloucester Point shore was unreadable; at lower water levels, the scale had either worn off or was obscured by marine growth, while higher levels occurred under conditions of darkness and strong currents that made it unsafe to maneuver the vessel into viewing range. (If there is interest, we could probably establish a correlation between this TCC tide staff and a continuously recording tide gauge maintained by VIMS.)

PROCESSING

With the ADCP system used in this study, a single acoustic ping produces a vertical profile of current velocity data throughout the usable portion of the water column in a fraction of a second. However, the error associated with single-ping data is unacceptably large, approximately 13 cm/s. Averaging over time reduces the error by the inverse square root of the number of pings averaged, but a tradeoff against horizontal resolution arises, as longer averaging intervals correspond to longer segments of sampling track. A good compromise was reached with 30-s averages. Typically, these contained 100 pings, reducing the error to approximately 1.3 cm/s, and at vessel speeds of 2 to 2.5 m/s, the corresponding segment of track over which data were averaged was 60 to 75 m.

For each 30-s sample, velocity components were rotated from the measurement coordinate system, in which directions are referred to magnetic north, into east and north components referred to true north. ADCP "bottom-track" velocity data were subtracted from raw water column velocities to remove the apparent current contribution of underway sampling. High quality bottom track data were obtained throughout the field study.

Position fixes for each velocity profile were determined by taking the midpoint time of the 30-s average, and finding the corresponding latitude and longitude within the 6-s GPS navigation files by linear interpolation.

RESULTS

Currents measured during six separate surveys are presented in this report. Each survey included a transect across the river along one side of the bridge and a return transect along the other side. Data locations along a typical survey track are shown in Figure 1. Whenever the vessel passed near enough to the tide staff at the south end of the bridge, a water level reading was logged. These observations are plotted in Figure 2.

Vector maps representing the flow field observed on each survey have been produced by plotting a current vector emanating from the location of each data point. These maps follow Figure 2. The four maps on each page show currents at four different depths on the same survey; the depth is noted at the top of each map along with the survey time. Data at 3 m depth correspond to the sampling depth of approximately 10 feet specified in the contract. In each map, the maximum current speed at the given depth is noted.

In the survey at 1506 EST, ebb flow was well developed all along the survey track at all depths shown. By 1606 EST, a reduction of ebb flow near the north shore was observed, while currents in the southern portion had reached the strongest speeds measured during this ebb. Two hours later at 1806 EST, weakened but still well-defined ebb continued in the southern two-thirds of the river, while flood was well underway in the northern third.

By 1902 EST, currents in the southern portion had turned to flood, but flood had already advanced in the northern portion to considerably stronger speeds. The flow field had become substantially more uniform across the river by 2123 EST, when the strongest flood currents were measured. Uniform flow continued in the 2241 EST survey, but by then the strength of the flood current was waning.

SUMMARY

Maximum currents measured in the along-bridge transects on 16 May 1995 were 81 cm/s during ebb and 90 cm/s during flood at a depth of 3 m. Although sampling was conducted during a relatively strong spring tide, these values should not be regarded as upper limits for currents that may be encountered near the bridge. For example, local wind patterns over the York River, as well as those over the continental shelf influencing water transport in and out of Chesapeake Bay, may significantly affect currents at the bridge site. It is possible that wind effects on the sampling day could have weakened the tidally driven currents, whereas under other conditions, wind effects could strengthen the currents.

For comparison with the measured currents, National Ocean Service (NOS) predictions for tidal currents are available for three locations near the Coleman Bridge. For 16 May 1995, maximum ebb currents predicted for the three sites were 80, 70, and 120 cm/s, and maximum predicted flood currents were 90, 120, and 120 cm/s.

Figure 1: Example of data locations (o) along bridge (line) for one survey

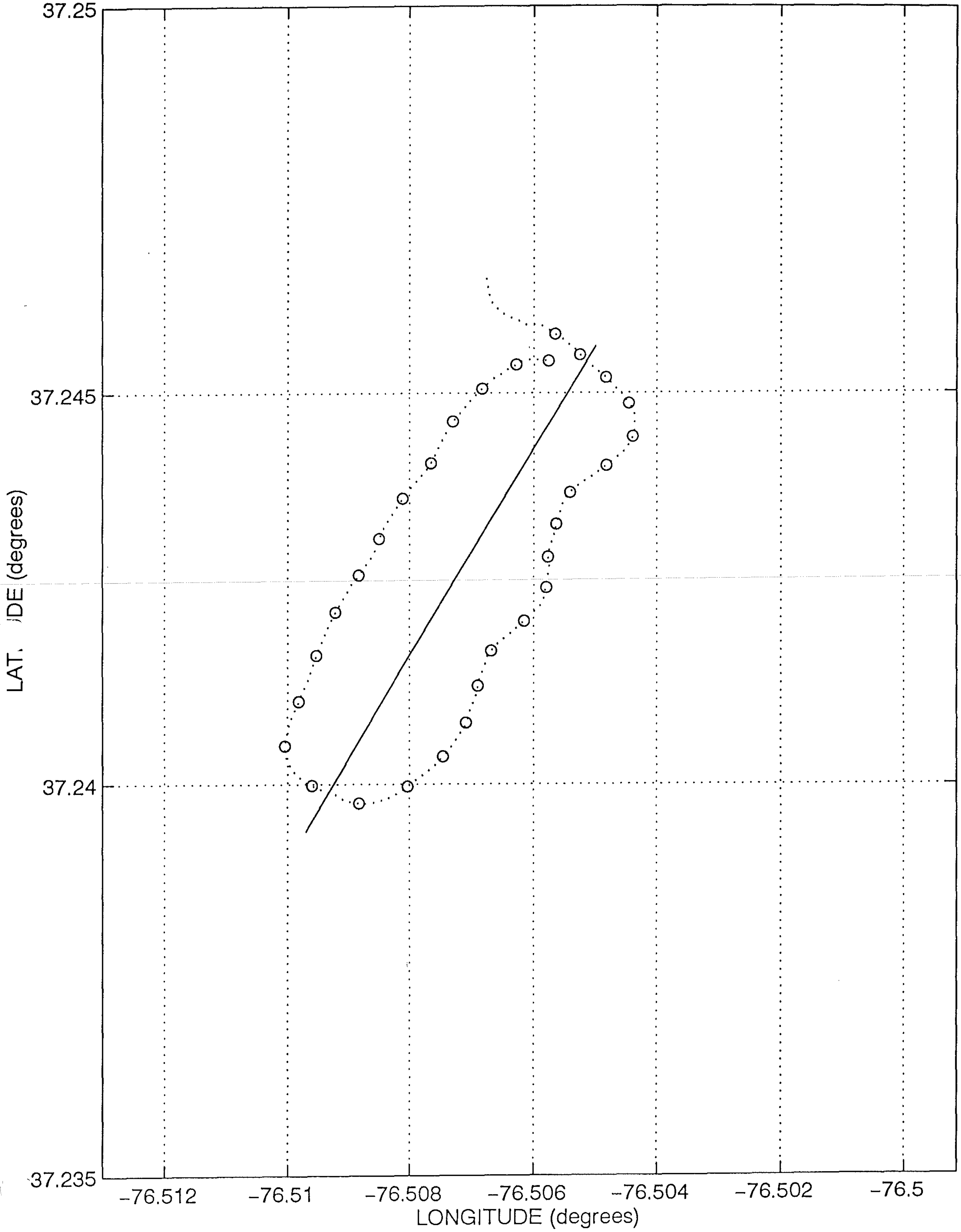
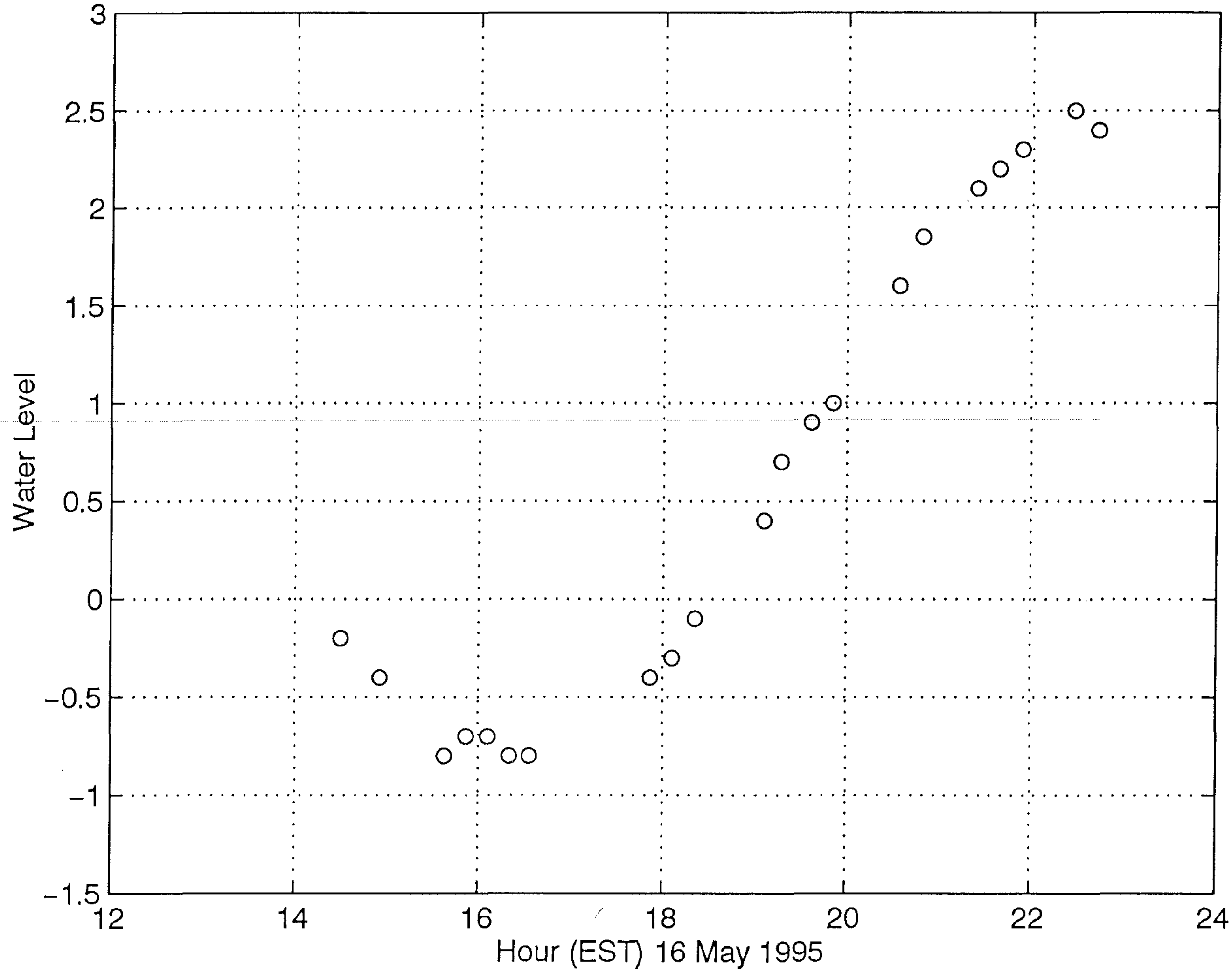
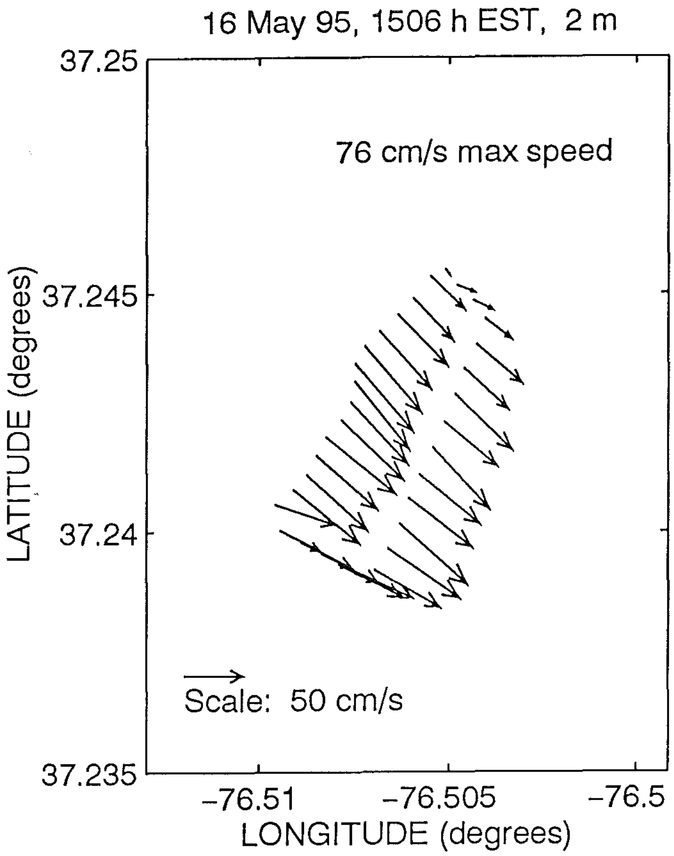
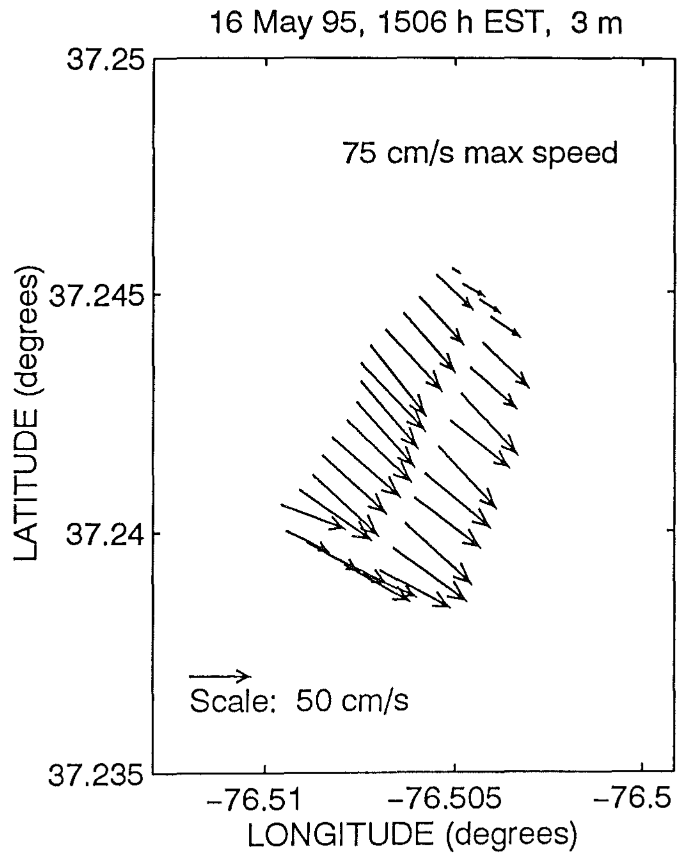
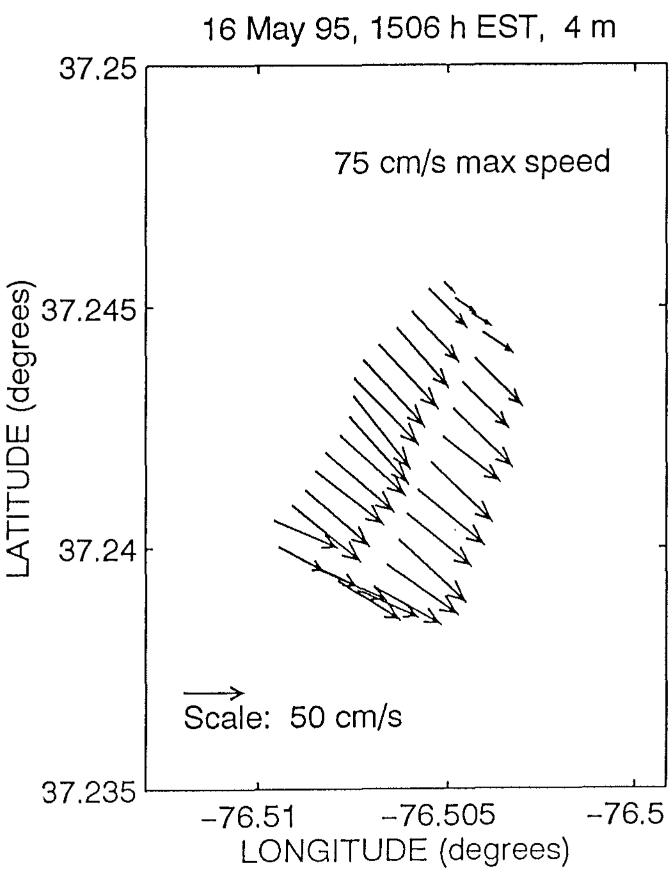


Figure 2: Surface elevation at TCC Tide Staff, Yorktown




16 May 95, 1506 h EST, 2 m
76 cm/s max speed
Scale: 50 cm/s
LATITUDE (degrees)
LONGITUDE (degrees)
37.25
37.245
37.24
37.235
-76.51
-76.505
-76.5


16 May 95, 1506 h EST, 3 m
75 cm/s max speed
Scale: 50 cm/s
LATITUDE (degrees)
LONGITUDE (degrees)
37.25
37.245
37.24
37.235
-76.51
-76.505
-76.5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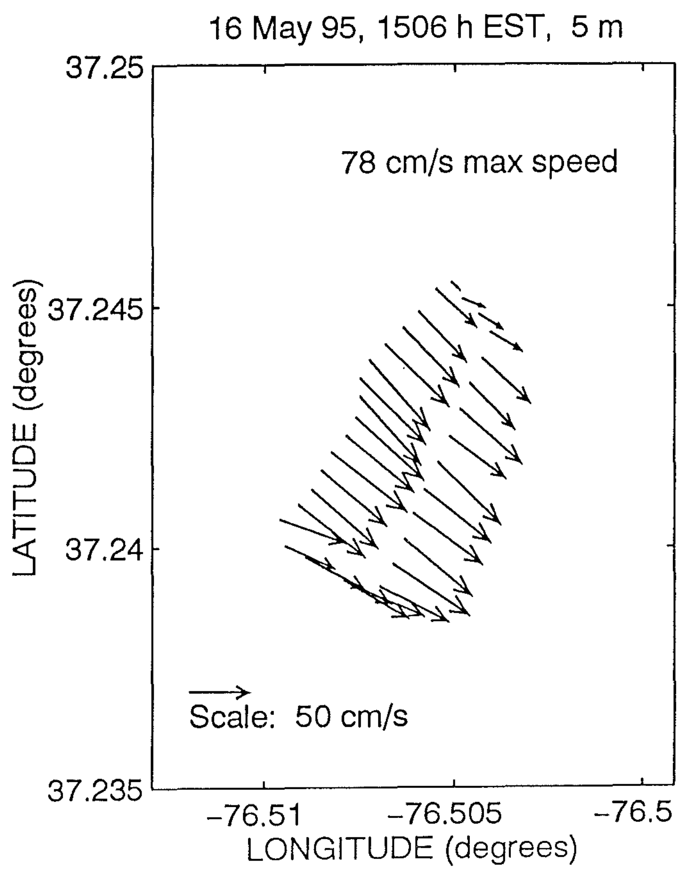
75 cm/s max speed
Scale: 50 cm/s
LATITUDE (degrees)
LONGITUDE (degrees)
37.25
37.245
37.24
37.235
-76.51
-76.505
-76.5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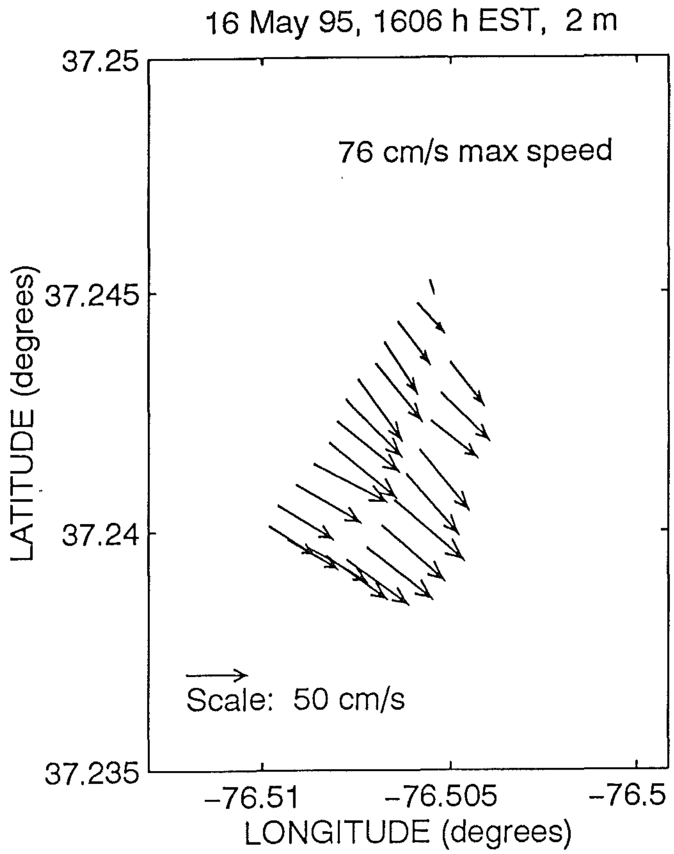
78 cm/s max speed
Scale: 50 cm/s
LATITUDE (degrees)
LONGITUDE (degrees)
37.25
37.245
37.24
37.235
-76.51
-76.505
-76.5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76 cm/s max speed
Scale: 50 cm/s
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37.25
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37.24
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LONGITUDE (degrees)
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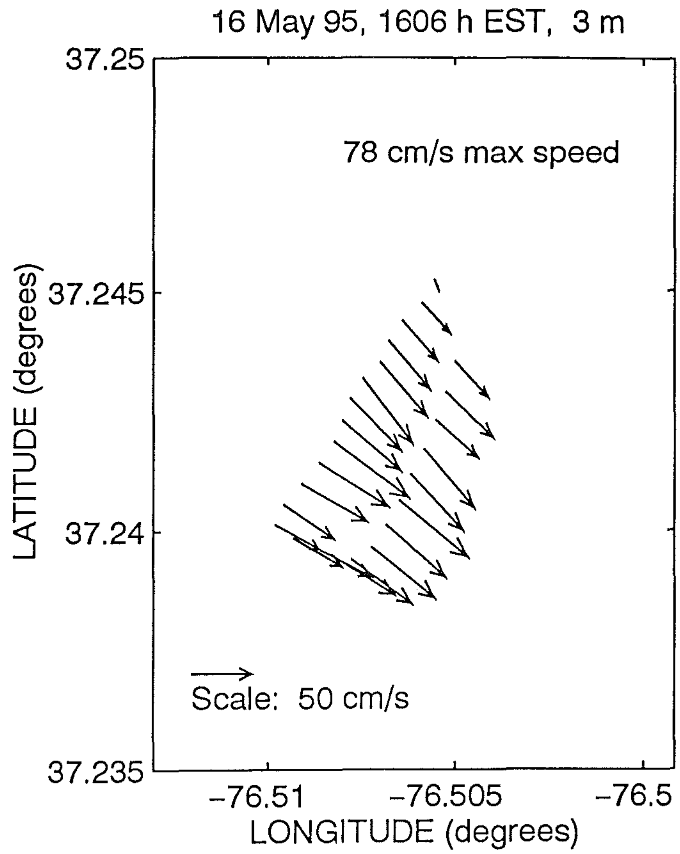
-76.505
-76.5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78 cm/s max speed
Scale: 50 cm/s
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37.24
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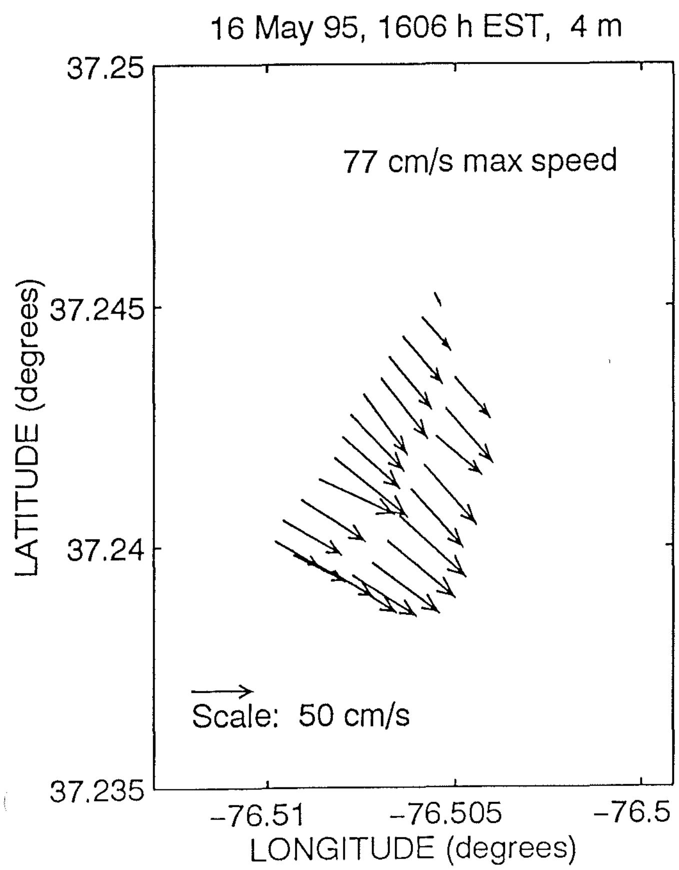
LONGITUDE (degrees)
-76.51
-76.505
-76.5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77 cm/s max speed
Scale: 50 cm/s
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37.24
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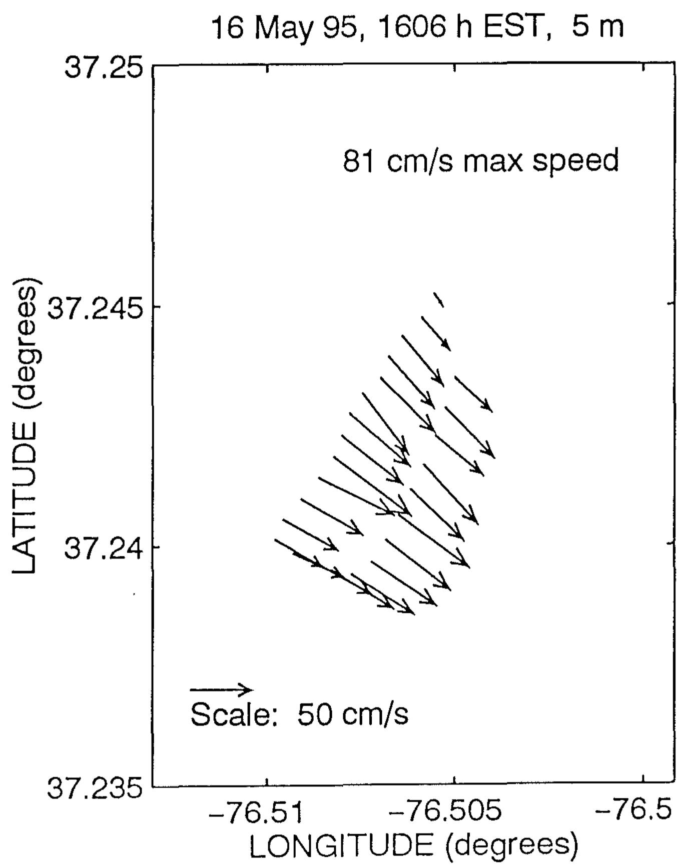
LONGITUDE (degrees)
-76.51
-76.505
-76.5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81 cm/s max speed
Scale: 50 cm/s
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37.24
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LONGITUDE (degrees)
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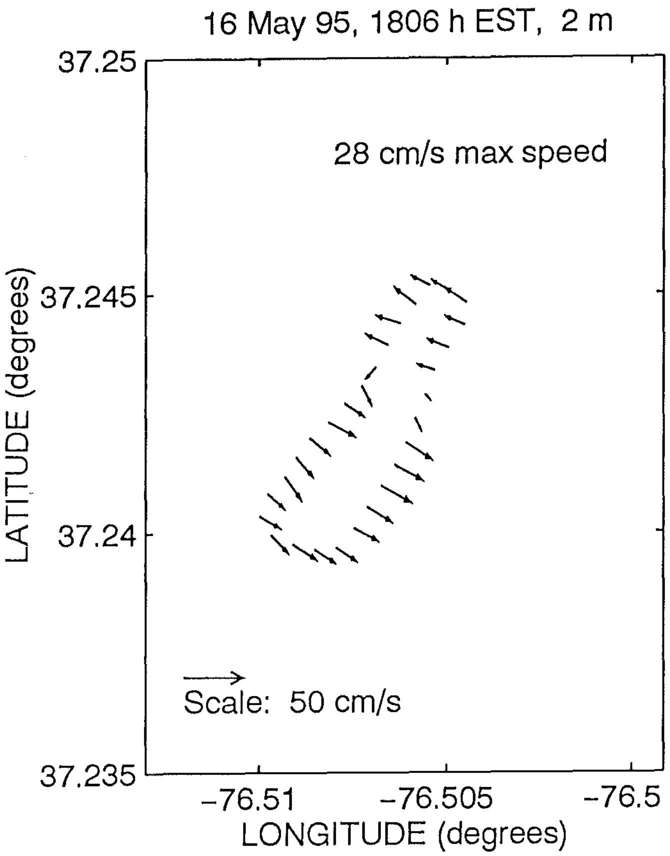
-76.505
-76.5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28 cm/s max speed
Scale: 50 cm/s
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37.24
37.235
LATITUDE (degrees)
−76.51
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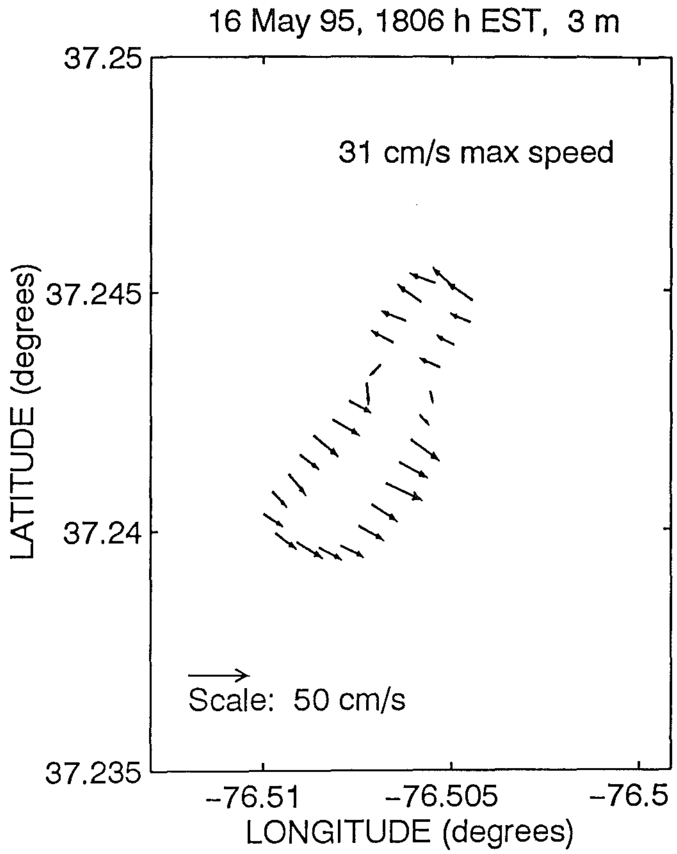
−76.5
LONGITUDE (degrees)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31 cm/s max speed
Scale: 50 cm/s
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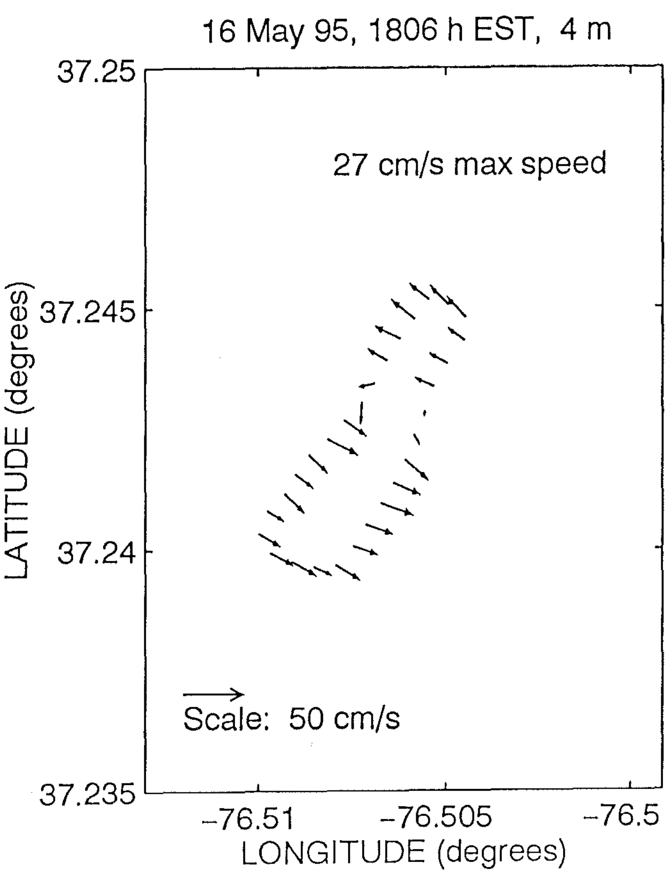
LONGITUDE (degrees)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27 cm/s max speed
Scale: 50 cm/s
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37.235
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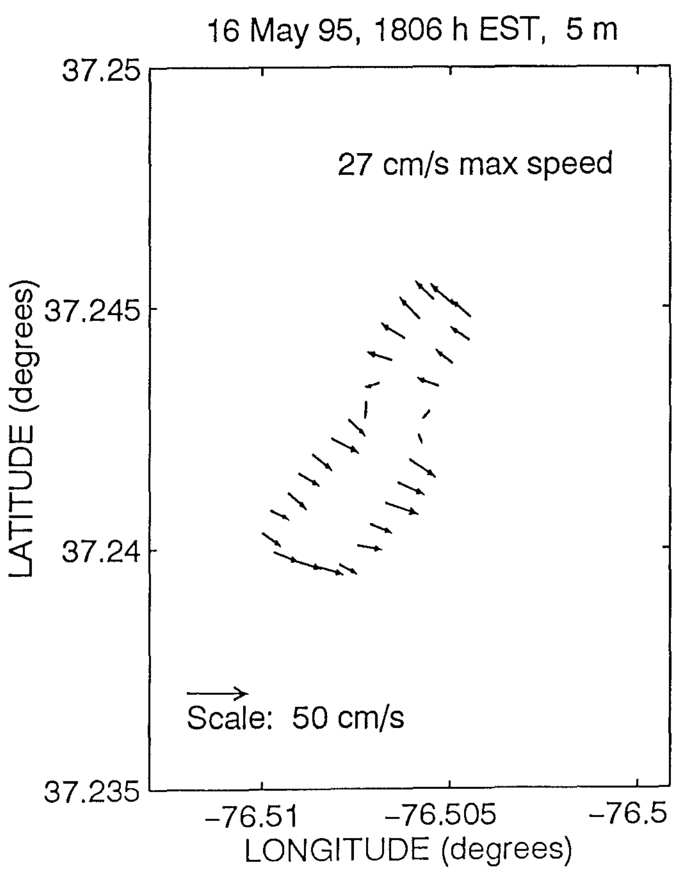
−76.51
−76.505
−76.5
LONGITUDE (degrees)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27 cm/s max speed
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37.235
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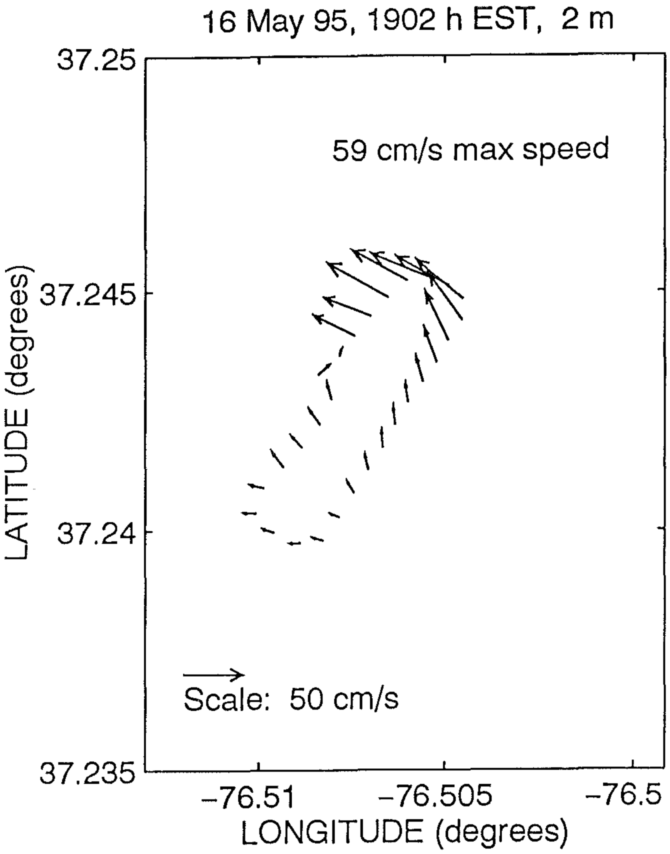
−76.505
−76.5
LONGITUDE (degrees)


16 May 95, 1902 h EST, 2 m
59 cm/s max speed
Scale: 50 cm/s
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37.24
37.235
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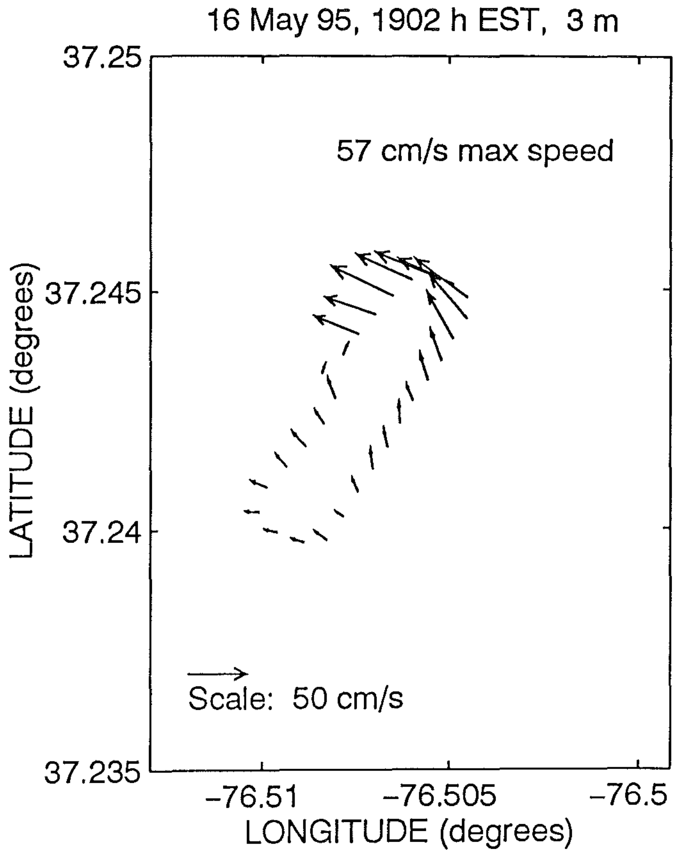
LONGITUDE (degrees)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57 cm/s max speed
Scale: 50 cm/s
37.25
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37.24
37.235
LATITUDE (degrees)
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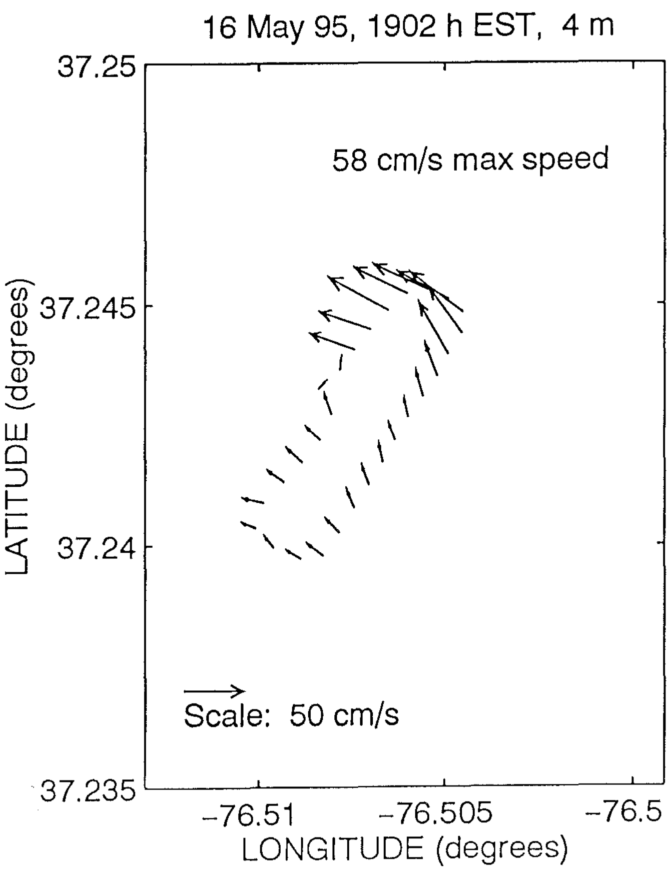
−76.5
LONGITUDE (degrees)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58 cm/s max speed
Scale: 50 cm/s
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LATITUDE (degrees)
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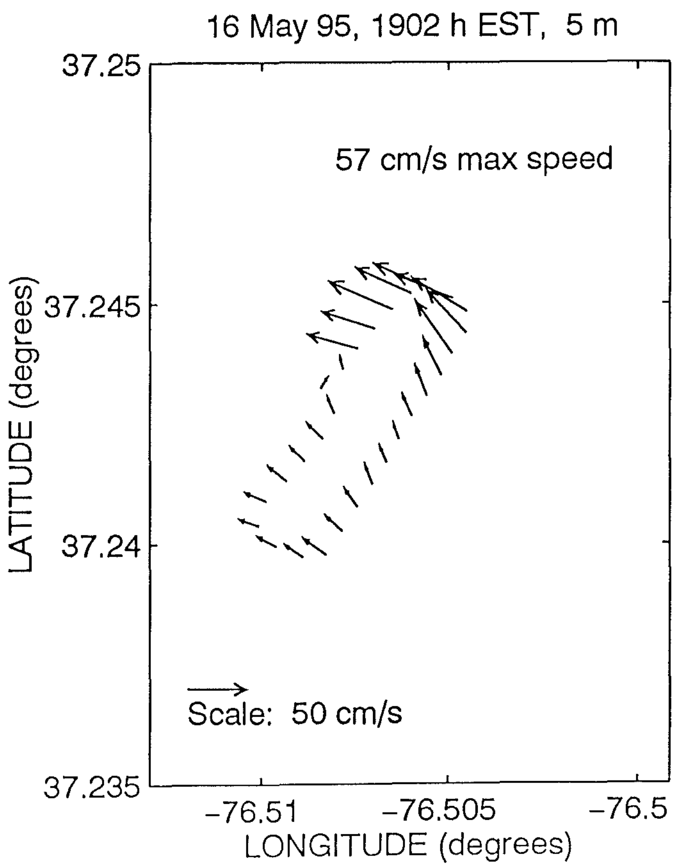
−76.5
LONGITUDE (degrees)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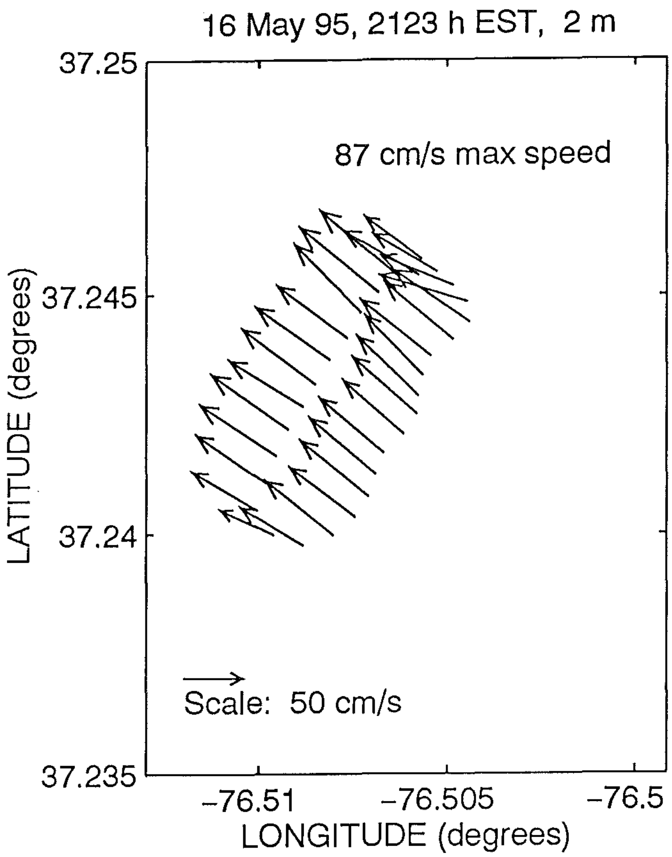
57 cm/s max speed
Scale: 50 cm/s
37.25
37.245
37.24
37.235
LATITUDE (degrees)
−76.51
−76.505
−76.5
LONGITUDE (degrees)


16 May 95, 2123 h EST, 2 m
87 cm/s max speed
Scale: 50 cm/s
LATITUDE (degrees)
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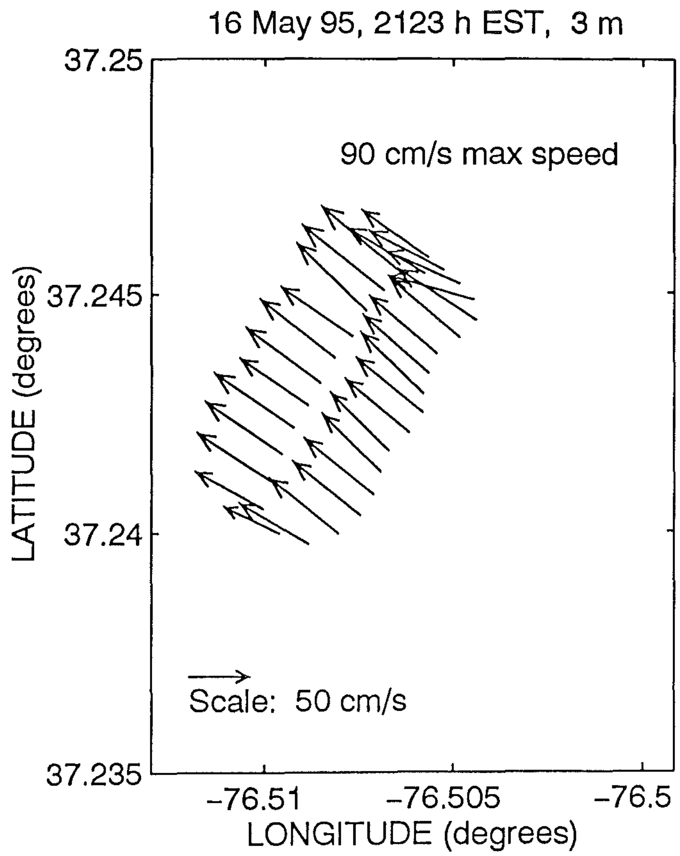
37.245
37.24
37.235
-76.51
-76.505
-76.5
LONGITUDE (degrees)


16 May 95, 2123 h EST, 3 m
90 cm/s max speed
Scale: 50 cm/s
LATITUDE (degrees)
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37.245
37.24
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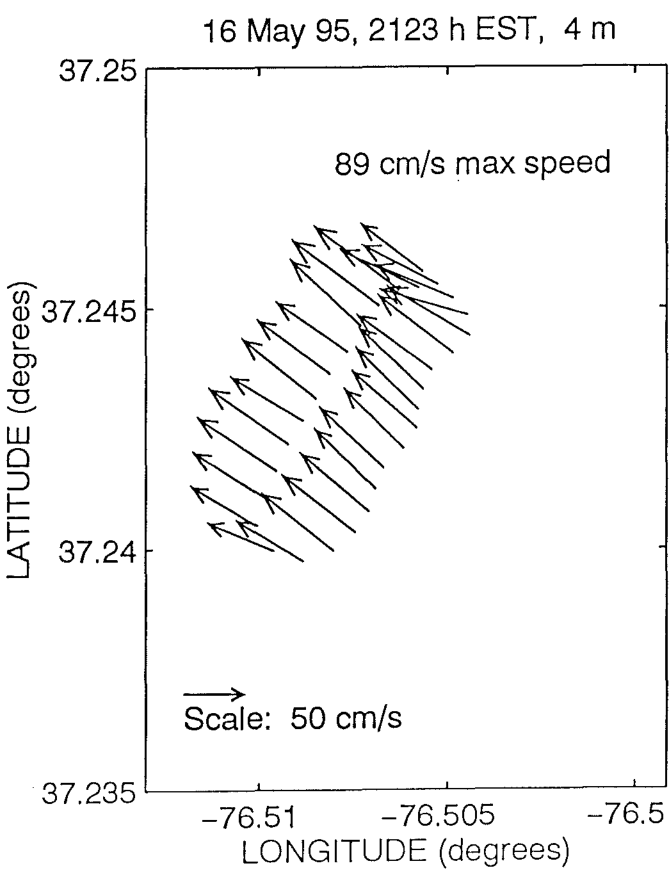
-76.51
-76.505
-76.5
LONGITUDE (degrees)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89 cm/s max speed
Scale: 50 cm/s
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37.25
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37.24
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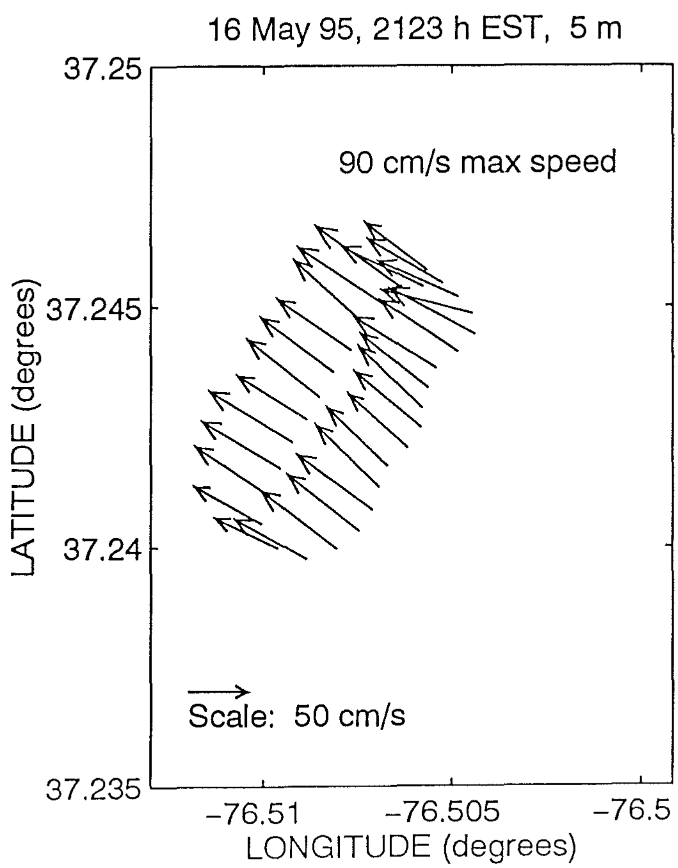
-76.51
-76.505
-76.5
LONGITUDE (degrees)


16 May 95, 2123 h EST, 5 m
90 cm/s max speed
Scale: 50 cm/s
LATITUDE (degrees)
37.25
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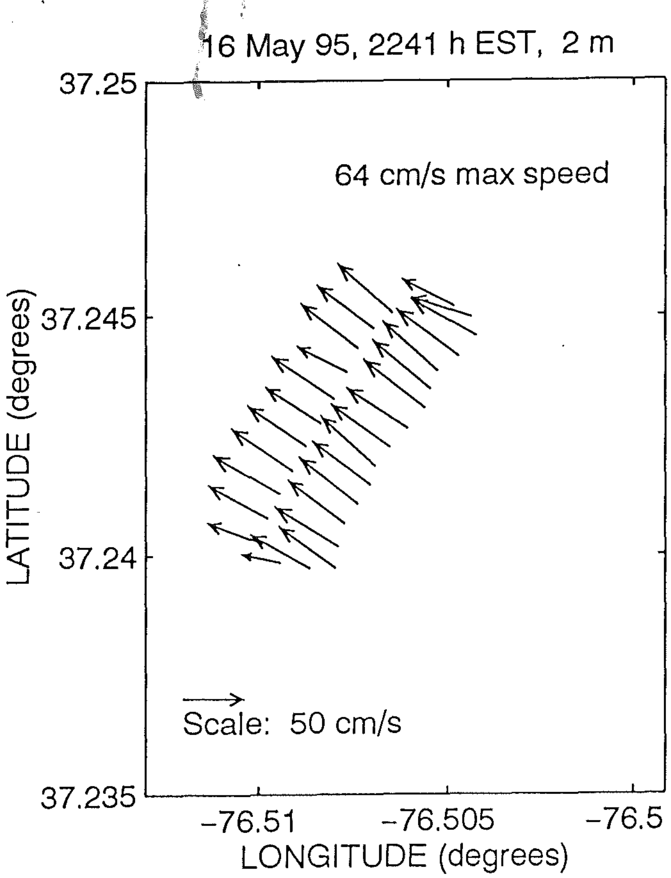
37.24
37.235
-76.51
-76.505
-76.5
LONGITUDE (degrees)


16 May 95, 2241 h EST, 2 m
64 cm/s max speed
Scale: 50 cm/s
37.25
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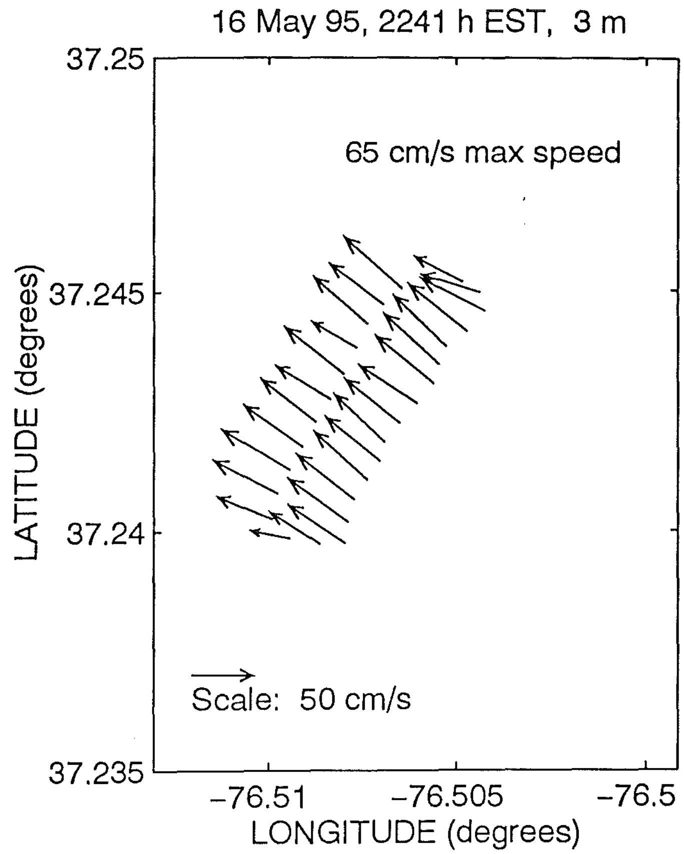
37.24
37.235
LATITUDE (degrees)
−76.51
−76.505
−76.5
LONGITUDE (degrees)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65 cm/s max speed
Scale: 50 cm/s
37.25
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37.24
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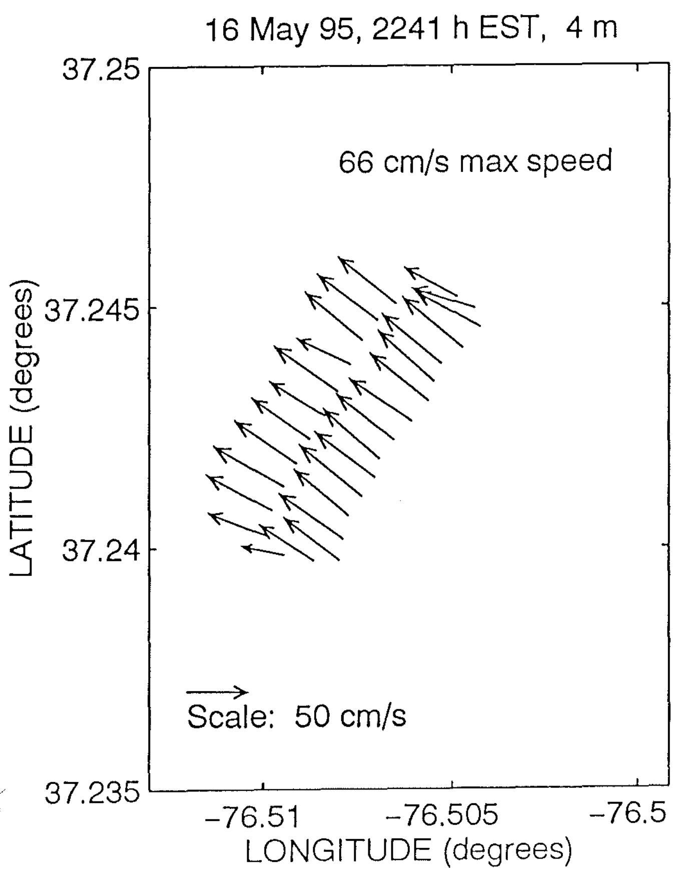
LATITUDE (degrees)
−76.51
−76.505
−76.5
LONGITUDE (degrees)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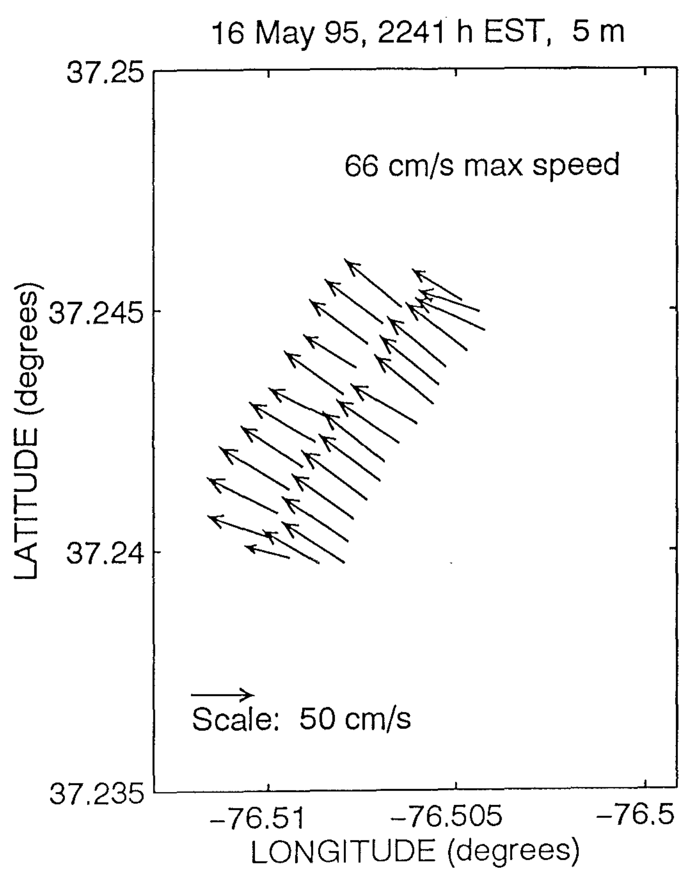
66 cm/s max speed
Scale: 50 cm/s
37.25
37.245
37.24
37.235
LATITUDE (degrees)
−76.51
−76.505
−76.5
LONGITUDE (degrees)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66 cm/s max speed
Scale: 50 cm/s
37.25
37.245
37.24
37.235
LATITUDE (degrees)
−76.51
−76.505
−76.5
LONGITUDE (degrees)