Tightly Integrated Inertially-Aided Post Processed Virtual Reference Station (PPVRS) Technique for Marine Hydrography

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PPVRS - Why is this Important?

- **Centimetric positioning for hydrographic surveying is of particular interest today due to the current trend towards using ellipsoidal altitude instead of heave and tidal reductions.**
- **Precise, sub-decimeter positioning can be accomplished on Marine surveys which were previously too far from shore.**
- **In many cases, it will not be necessary to mobilize GNSS reference stations. Existing public infrastructure can be used.**

The Problem

- **The challenge is provide differential GPS positioning based on GPS carrier phase data in kinematic mode.**
- **To have a high degree of confidence and reliability in positioning in a wider range of environments then is currently possible.**
- **To achieve optimum quality from integrated inertial and satellite positioning**

Today

- **Strict limitations are necessary to achieve a high position and orientation accuracy for Marine operation:**
  - Inertially Aided Kinematic Ambiguity Resolution (IAKAR) Maximum distance to base stations: 25 km

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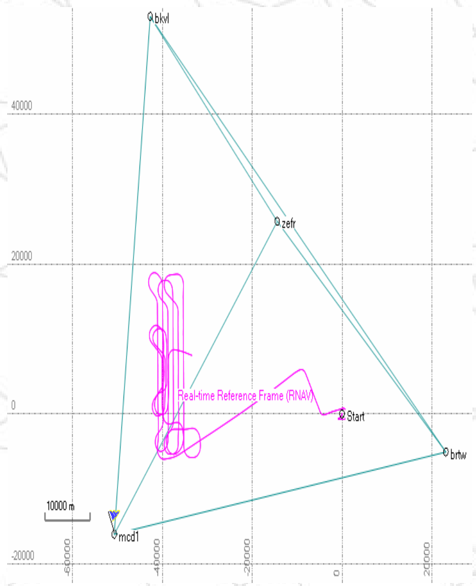
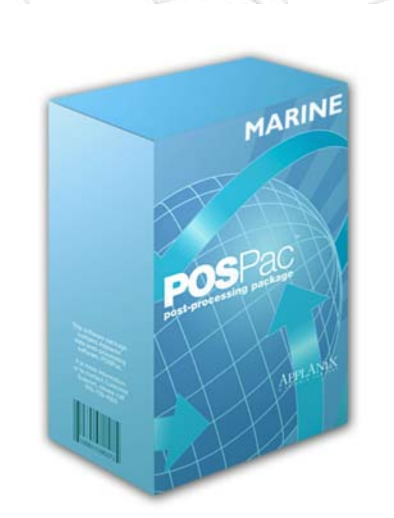
Solution

Tightly Integrated Inertially Aided Post Processed Kinematic (IAPPK) with post processed VRS (PPVRS) technology

Data Acquisition



GPS Network - VRS



Post Processing

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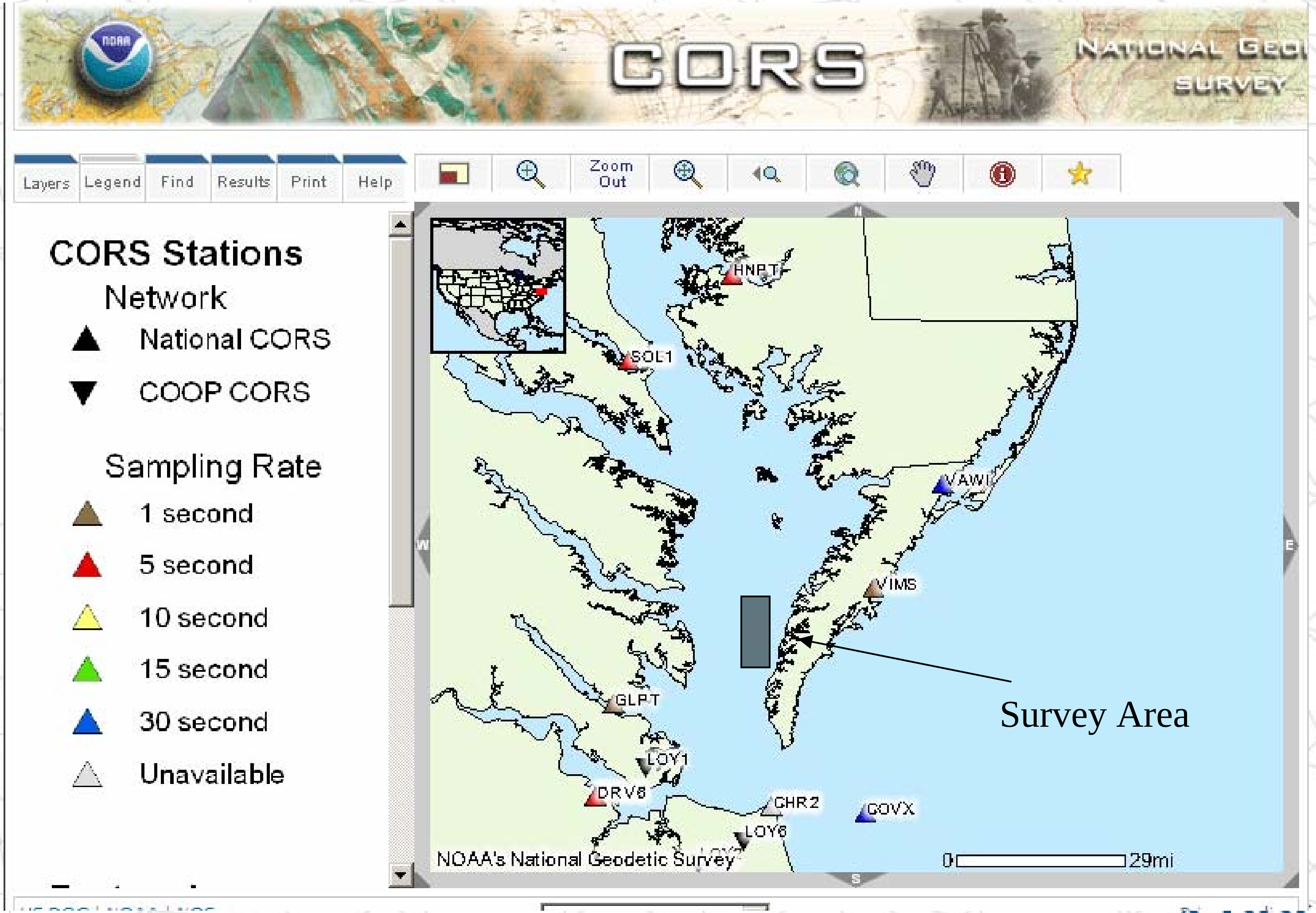
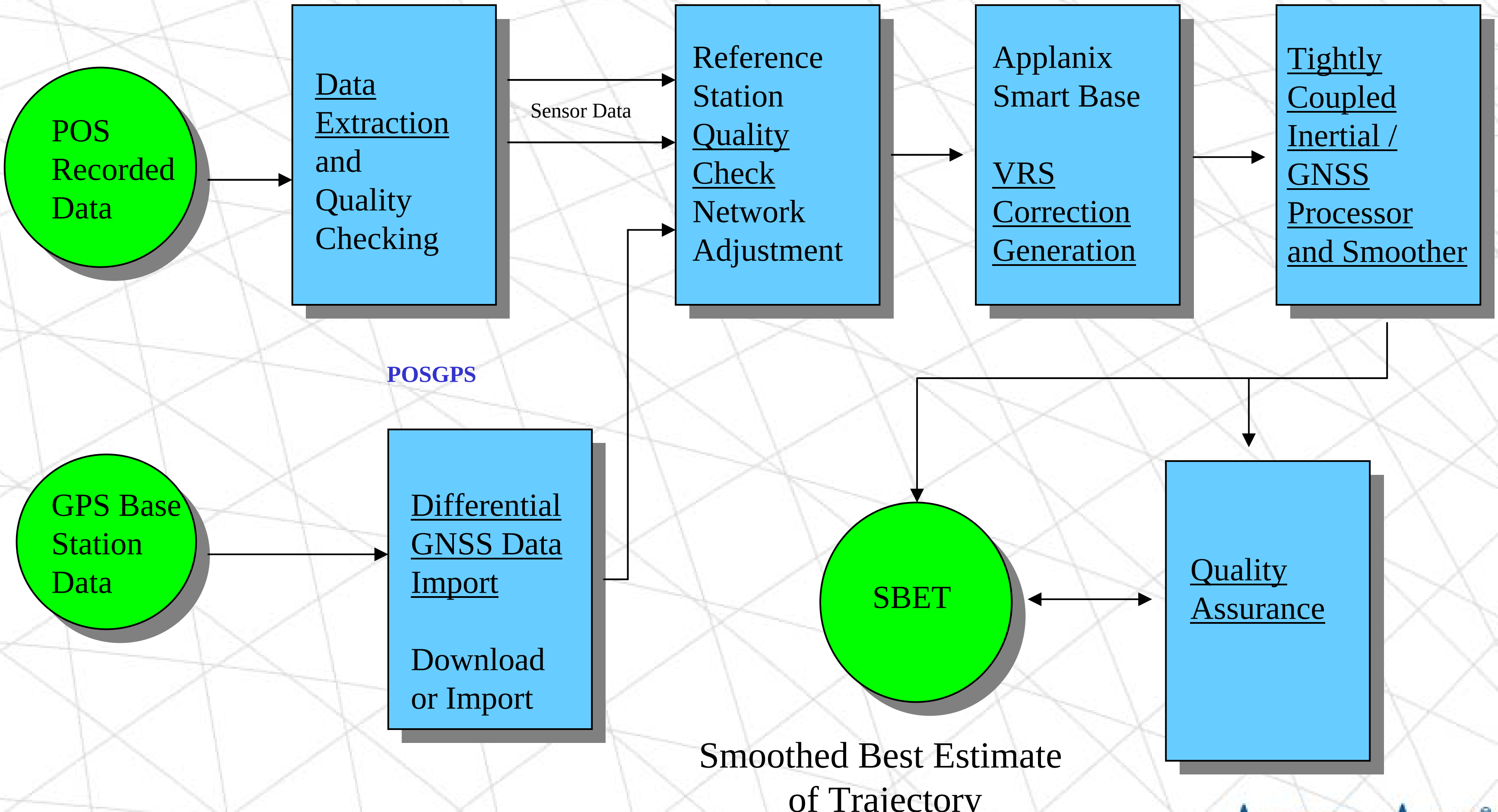
Case Study – NOAA RUDE in the Chesapeake



PPVRS Marine – Data Flow



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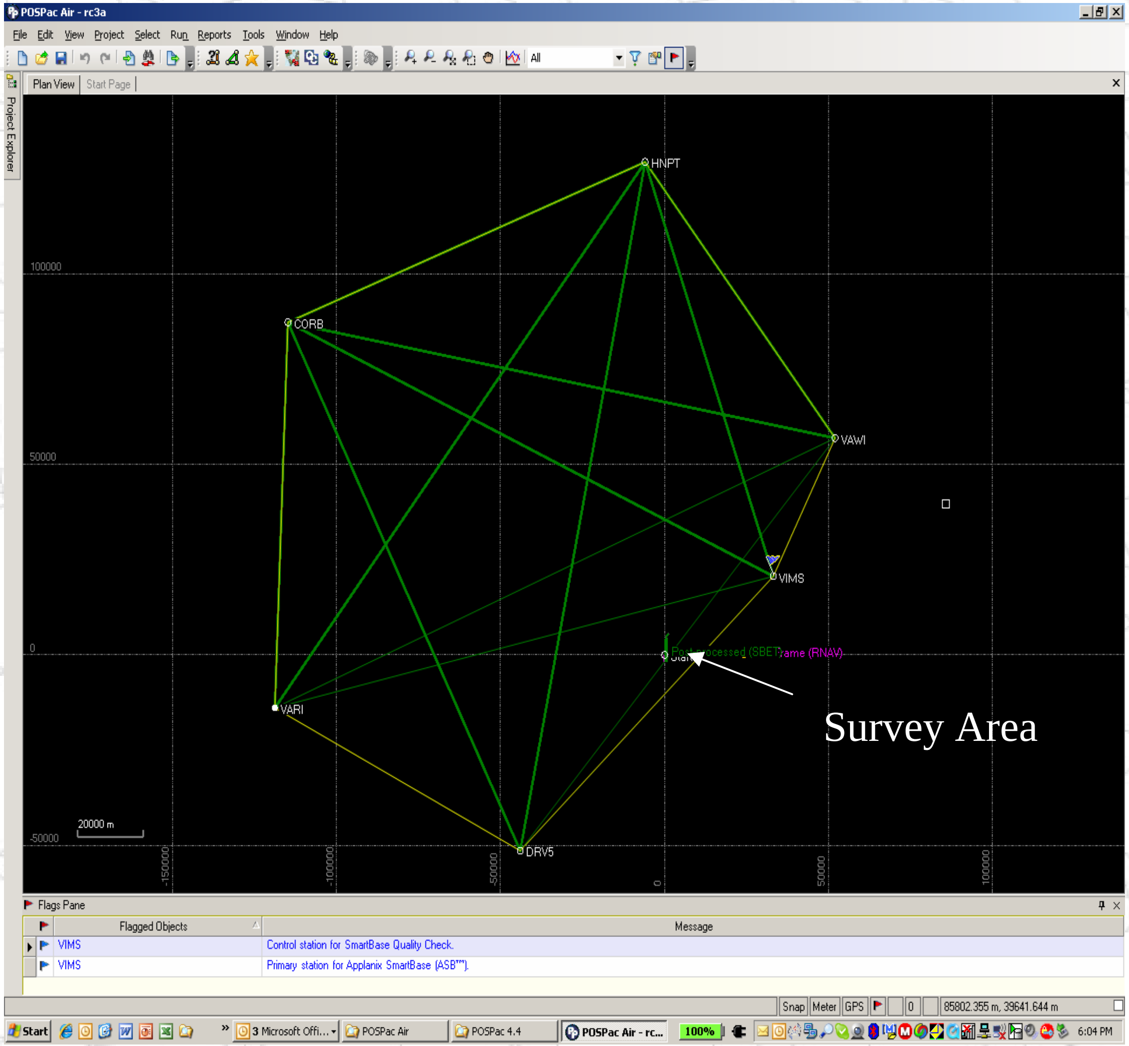
Case Study – Final PPVRS Network



GPS Network

6 Public Reference Stations

The Maximum distance from the survey to the nearest base station is 38 kms**

The Maximum distance between reference stations is 143 kms

An automated tool for internet download makes getting the reference station correction data very easy

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POSPac PPVRS Quality Check/ Network Adjustment

```
--------------------------------------------------------------------------------
Termination status : Normal
--------------------------------------------------------------------------------
```

Station	Input Coords	Status	Horizontal	Vertical	Total	Time Span	Output Coords
VIMS	Control	Control	0.000 m	0.000 m	0.000 m	23.88 h	Control
VAWI	Original	OK	0.008 m	0.044 m	0.045 m	23.88 h	Original
VARI	Original	OK	0.008 m	0.007 m	0.010 m	23.88 h	Original
HNPT	Original	OK	0.008 m	0.030 m	0.031 m	23.88 h	Original
DRV5	Original	OK	0.006 m	0.022 m	0.023 m	23.88 h	Original
COVX	Original	Bad Estimate	0.006 m	0.015 m	0.016 m	9.38 h	Disabled
CORB	Original	OK	0.019 m	0.024 m	0.031 m	23.88 h	Original

The network adjustment uses GPS measurements, input base station coordinates, and computed baselines in a least squares adjustment.

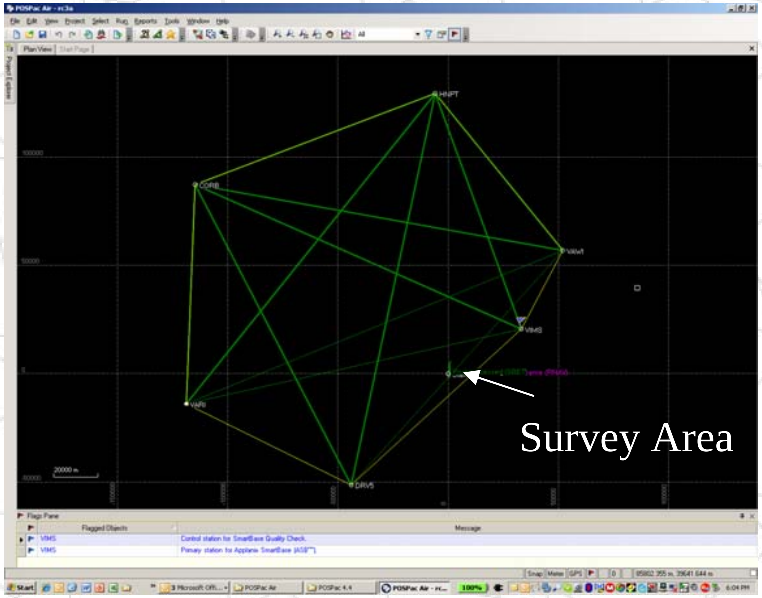
A control station is selected as fixed in the adjustment.

24 hours of reference station data are required for this quality check in order to ensure the most accurate validation of base station coordinates.

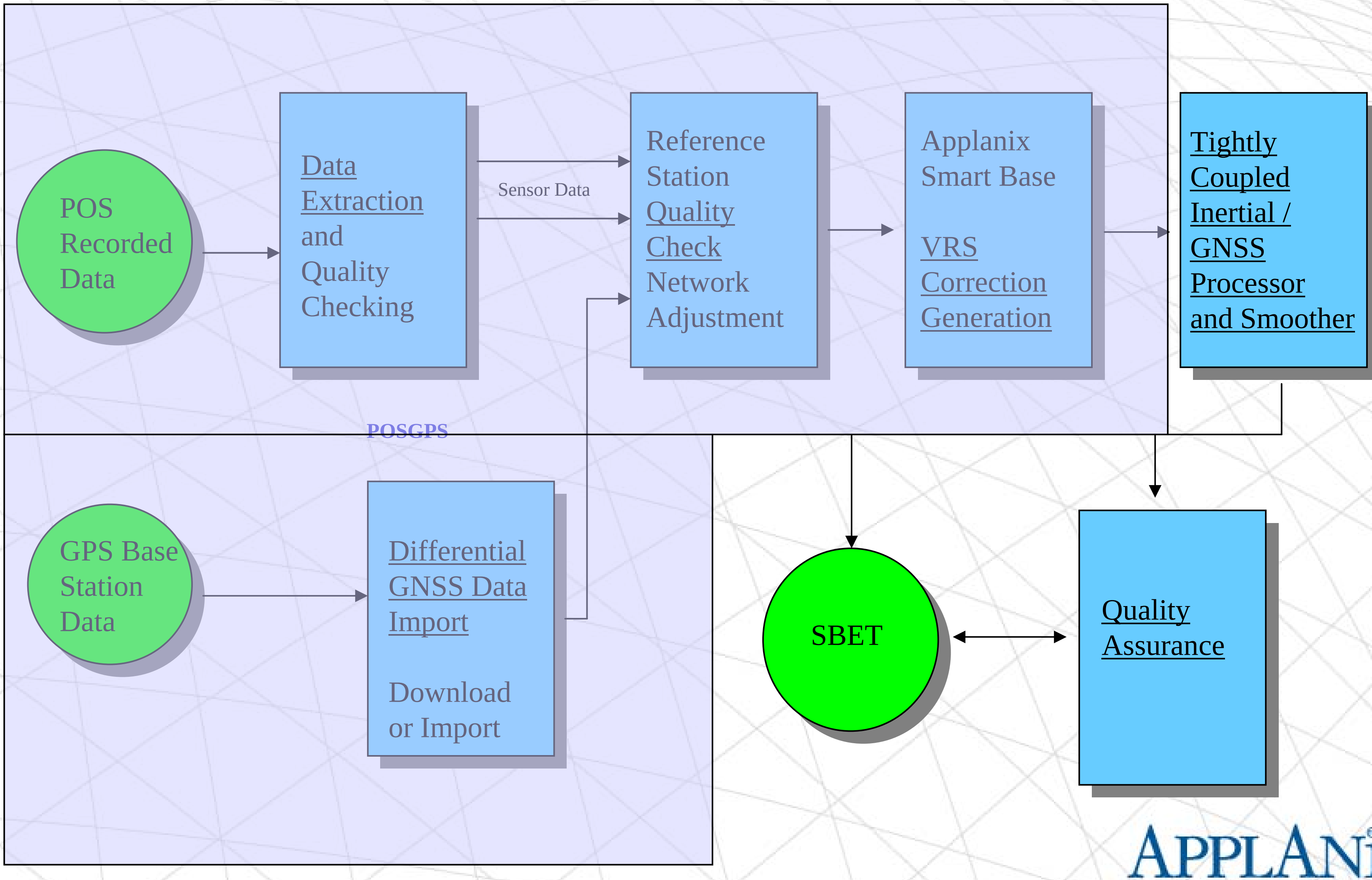
If a shorter time period is used, centimetric accuracy in the final rover position cannot be guaranteed.

POSPac PPVRS Correction Generation

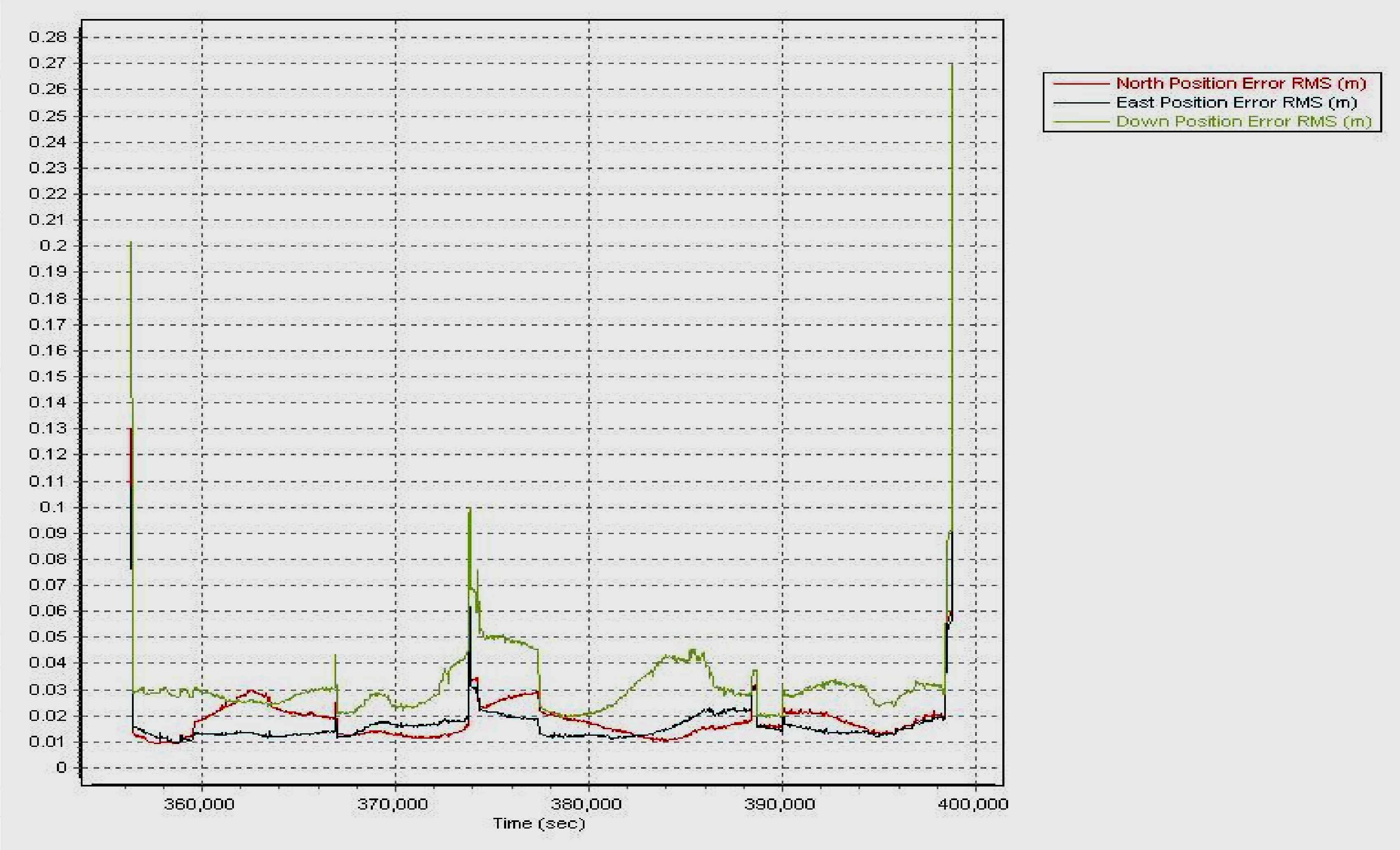
```
-------------------------------------------------------------------------------
        Reference Station Raw Data Analysis
-------------------------------------------------------------------------------

Station_ID | Total_Gap | Max_Gap | Min_Gap | Unrepaired_CS | Simul_unrepaired_CS | REF2Traj_Centre(km)
    VIMS      240.0       180.0      60.0        195                 8                  37.0
    VAWI        0.0         0.0       0.0        501                 0                  75.0
    VARI        0.0         0.0       0.0        105                 0                 121.4
    HNPT        0.0         0.0       0.0        104                 0                 128.3
    DRV5        0.0         0.0       0.0         69                 0                  69.8
    COVX     5460.0      3630.0    1830.0        564                 4                  65.8
    CORB        0.0         0.0       0.0        103                 0                 144.7

-------------------------------------------------------------------------------
              SmartBase Statistics
-------------------------------------------------------------------------------
SmartBase Status: PROC_STATUS_OK
Primary Station ID: DRV5
Number of Reference Stations: 7
Percentage of Primary Station Measurement Usage: 94.9%
Average Number of satellites per epoch:  8.5
Total full data gap: 0 s
Total individual satellite data gap: 19800 s
-------------------------------------------------------------------------------
```



POSPac 5 Marine – Data Flow



Tightly Integrated Post Processed Solution using GPS Network Technology



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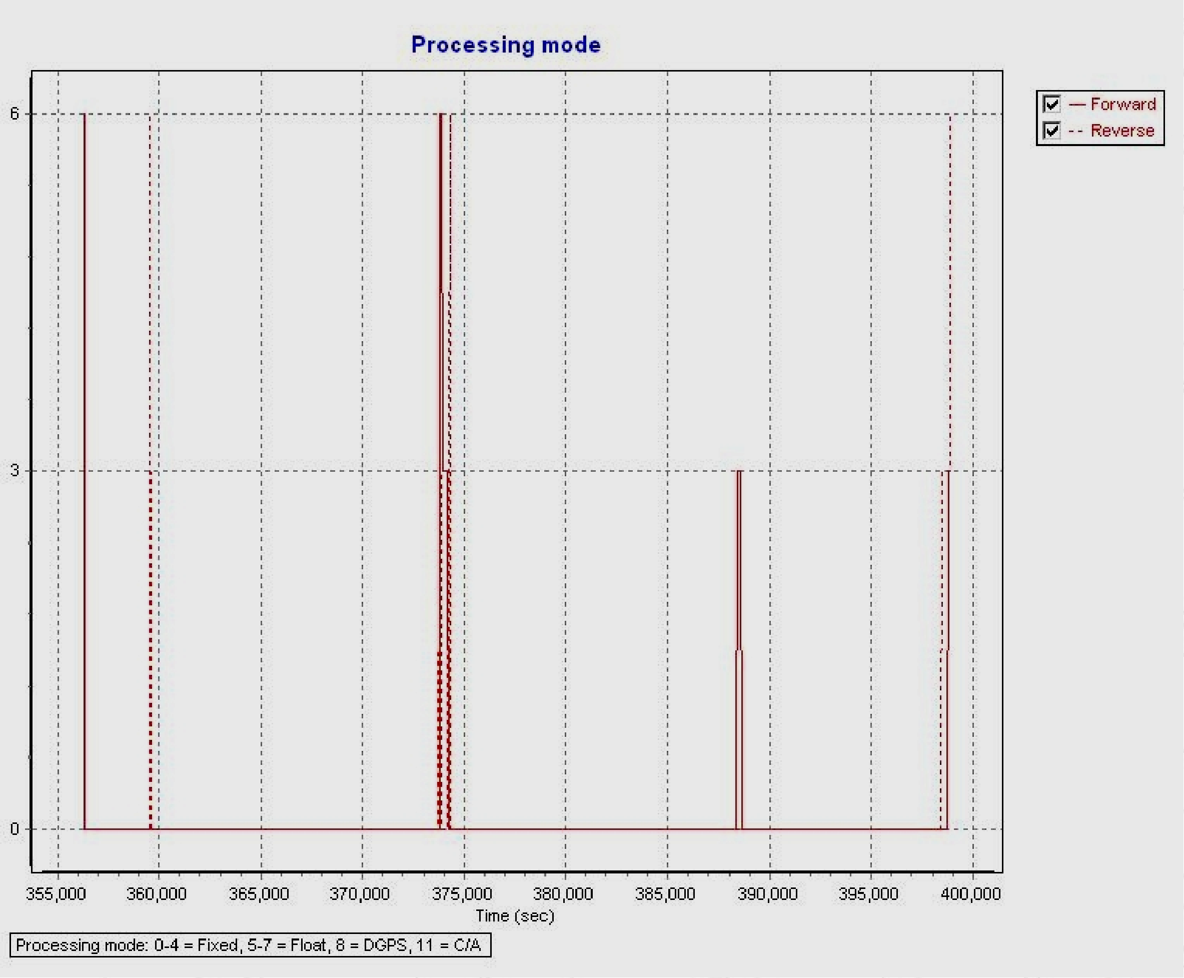
Tightly Integrated GPS Processing Mode



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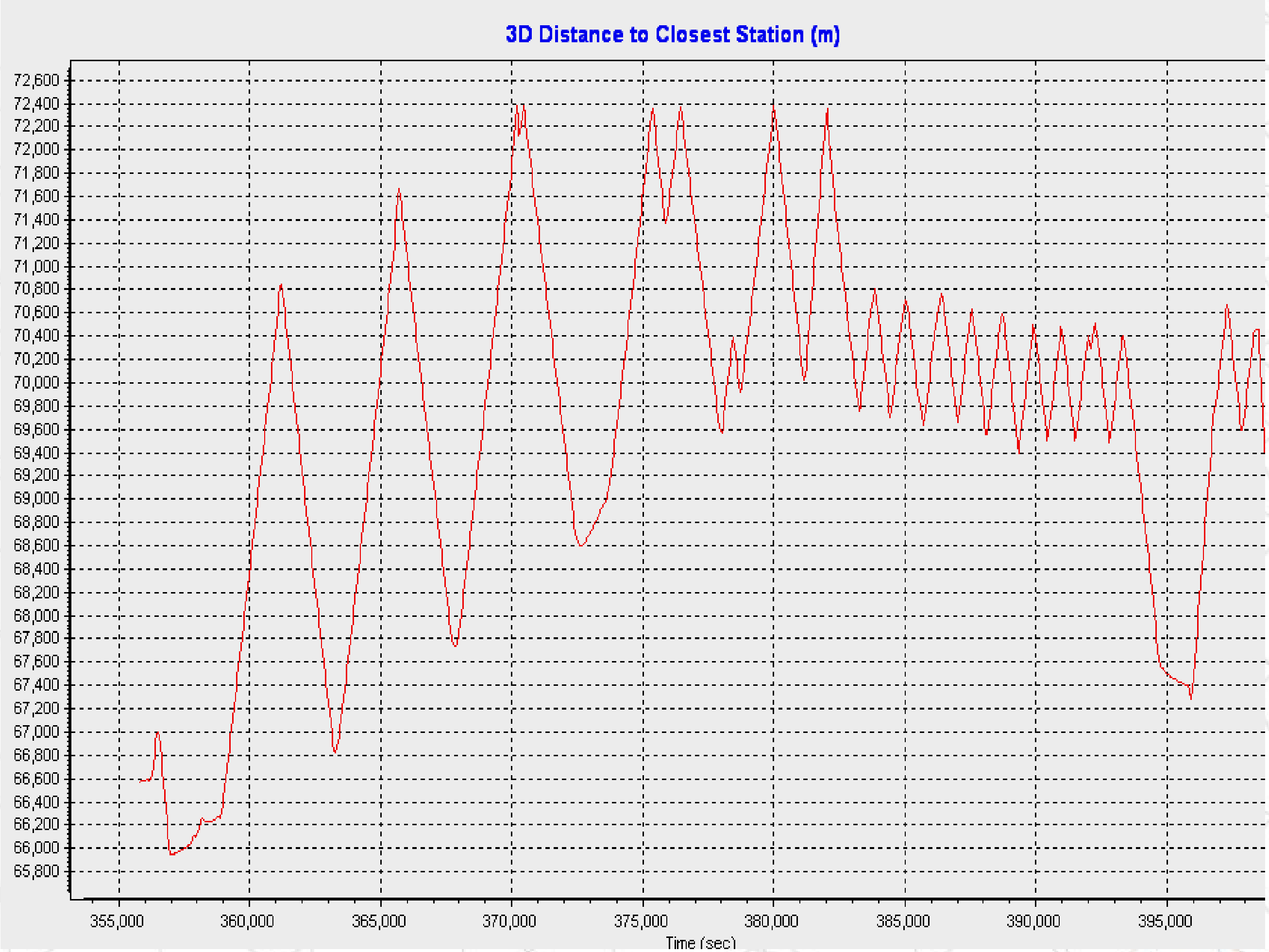
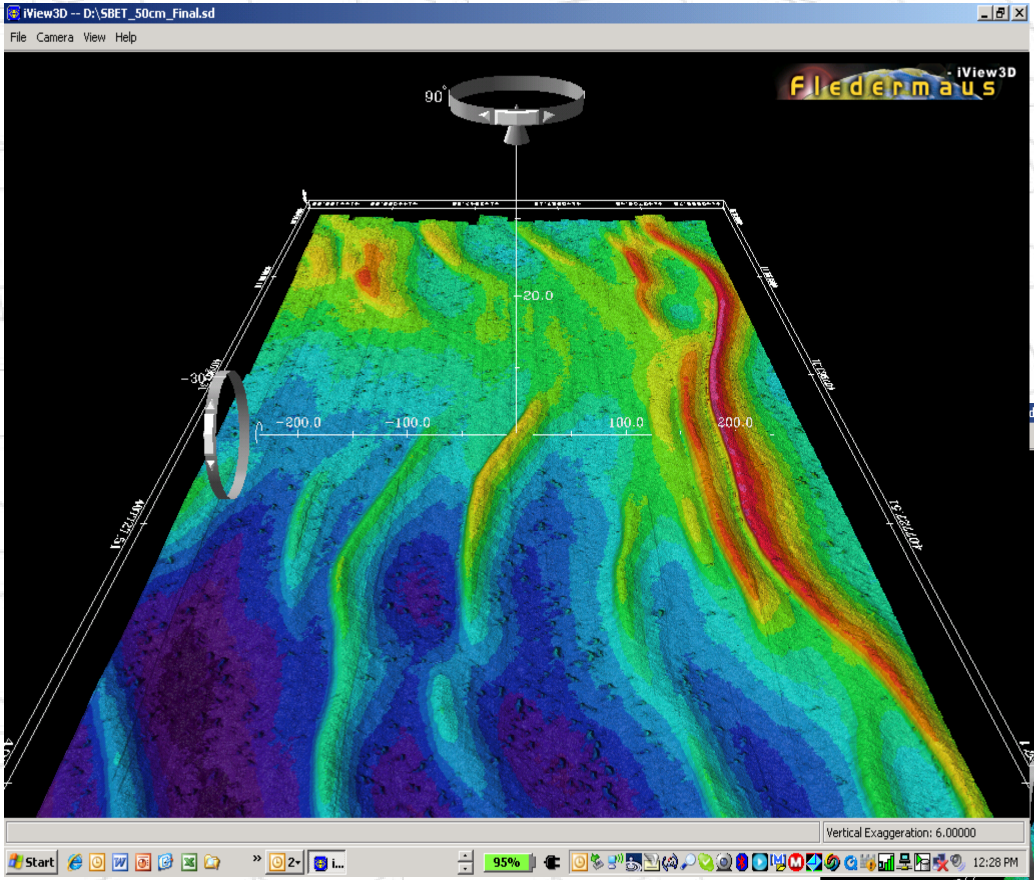
Closest Station

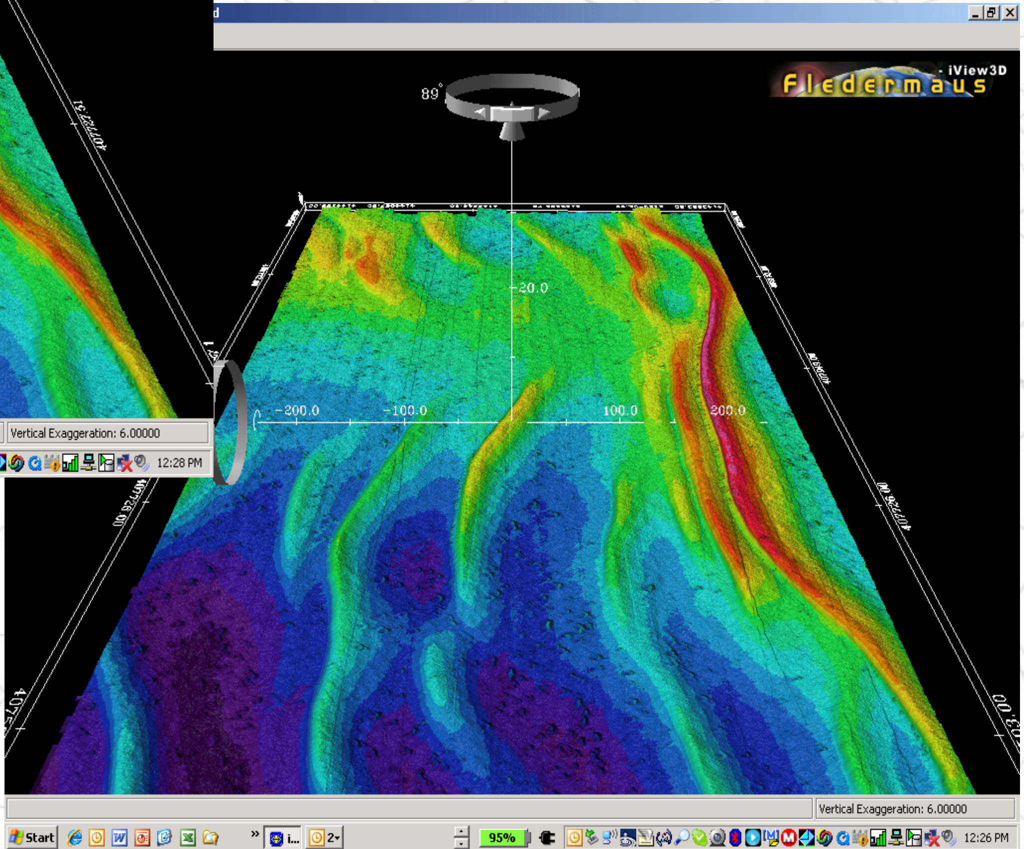


SBET Altitude VDatum Derived



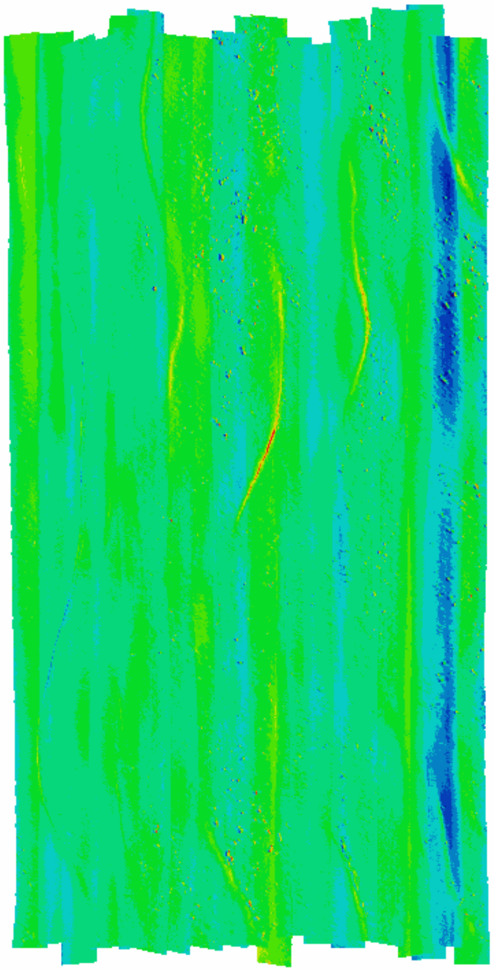
Sea Floor Images

MLLW Heave Tidal Zoning Derived



~1kms x .5kms

Difference Plot of Vertical



Difference range -.29 to .-74

Differences are mostly systematic
and attributed to datum

There is a lever arm issue in this data which
explains the striping
-Post processing to find lever
arms is a powerful tool

Conclusions

- The PPVRS process provides a logistically simple method, when compared with the traditional IAKAR mechanization, for achieving sub-decimeter accuracy without the need to install and maintain dedicated base stations.
- This is particularly true in locations with dense Continuously Operating Reference Stations such as the east coast of the continental United States where baselines of less than 100 km may be obtained.
- The overall process is simple and can be easily added to existing hydrographic data processing workflows without a significant decrease in processing productivity.
- Much of Europe and North America, including the entire continental U.S. inland waters and near-shore areas, can now obtain centimetric positioning accuracy more efficiently by utilizing the existing reference station networks as we have described.

Acknowledgments

- LCDR Rick Brennan earned a B.S. degree in Civil Engineering from the Citadel in Charleston, South Carolina and a M.S. in Ocean Mapping at NOAA's Joint Hydrographic Center. LCDR Brennan started his NOAA career in 1992 and has had various assignments on NOAA vessels. LCDR Brennan served as the Chief of NOAA's Hydrographic Systems and Technology Program and as the Commanding Officer aboard the NOAA Ship RUDE.
- LCDR E.J. Van Den Ameele is the Chief of NOAA's Hydrographic Systems and Technology Programs of the Coast Survey Development Laboratory in Silver Spring, Maryland, USA. He has been working in NOAA hydrography for 14 years and has held positions at sea aboard NOAA Ships MT MITCHELL, RAINIER, and most recently FAIRWEATHER, and in the Office of Coast Survey at the Atlantic and Pacific Hydrographic Branches.

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