

GPS Best Practices For Moving-Boat ADCP Measurements

OSW Webinar March 2013

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Overview

- **Why use GPS**
- **GPS Requirements**
- **Typical Setup**
- **Potential Issues**
- **Questions**

Why Use GPS

- **GPS is the preferred reference for ADCP measurements where moving bed is detected**
- **GPS can be used a reference when the ADCP can NOT bottom track**
- **The additional GPS data can help QA bottom track even when there is no moving bed.**

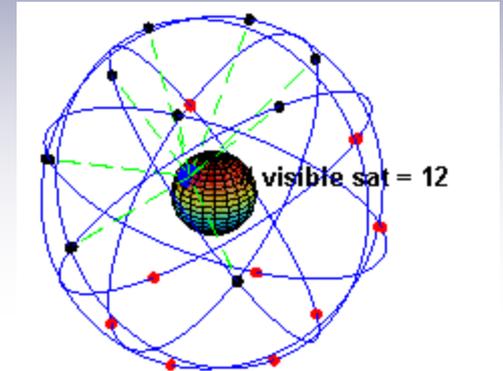
Moving-Bed Test Still Required

- ❑ It is USGS policy to collect a moving bed test for every measurement
- ❑ The need for a correction or using GPS is based on percent potential error (moving-bed velocity / mean velocity for the test).

| Moving Bed Detection Method | Detection Threshold | Minimum Duration |
|---|--|--------------------|
| Stationary (Stable location or GPS reference) | Moving bed velocity > 1% of mean water velocity | 5 minutes (300 s) |
| Stationary (Manned Boat no anchor) | Moving bed velocity > 2% of mean water velocity | 10 minutes (600 s) |
| Loop | Moving bed velocity > .04 ft/s and > 1% of Mean Water Velocity | >3 minutes (180 s) |

GPS Hardware

- **Differential Capable**
 - Corps or Coast Guard Beacons
 - OmniSTAR (Annual cost)
 - WAAS (Most common)
- **NMEA 0183 Output**
 - GGA string – at least 5 decimal minute precision
 - VTG string – 2 decimal precision for speed
- **Output rate of at least 2 Hz is preferred**
- **Minimal positional filters**
- **Handheld GPS units do not meet the above requirements**



Common GPS Hardware

- Trimble Ag132



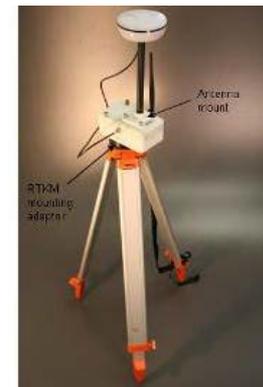
- Hemisphere A-100



- Hemisphere A-101



- SonTek Supplied with M9/S5

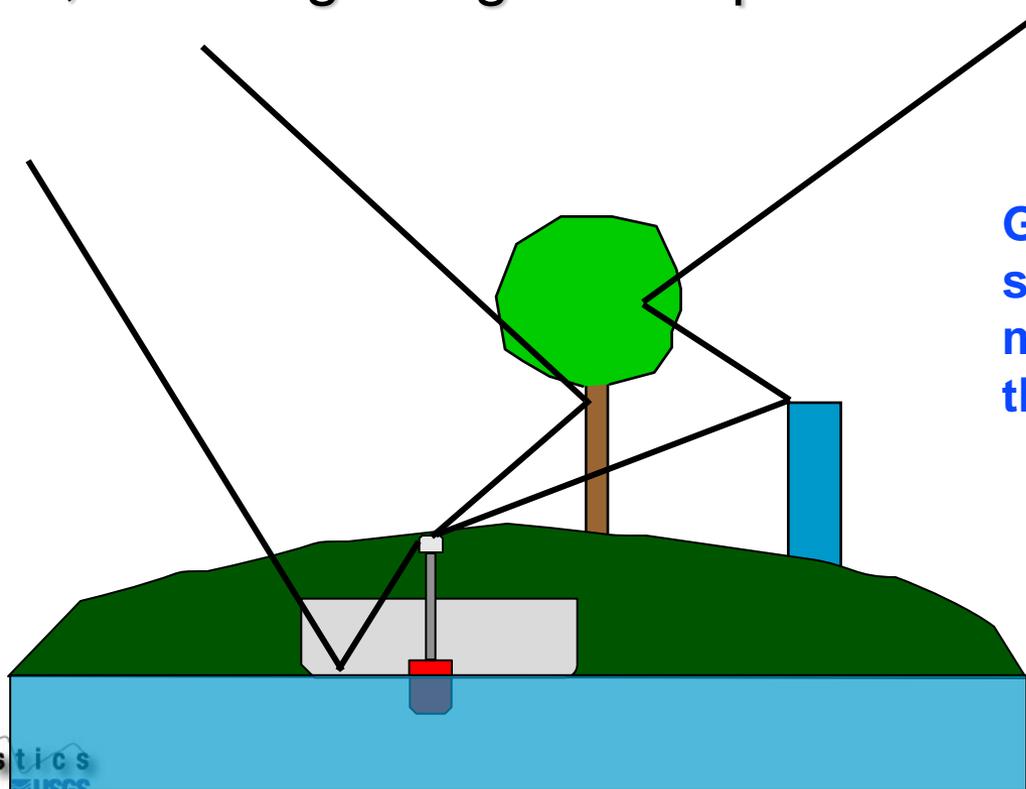


GGA GPS Reference

- Provides position but no velocity
- Velocity is computed from two consecutive GGA sentences by computing the distance travelled and dividing by the time between
- Requires differential correction for acceptable accuracy
- Can be affect by multipath errors
- Errors tend to be easy to spot

Multi-Path Errors

Multi-path is a reception of a reflected signal in lieu of a direct signal. Trees, bridges, steep banks, buildings, water, and other obstructions can cause the GPS signal to reflect, resulting in significant position errors.



GGA is more susceptible to multipath errors than VTG

Sites with High Multi-Path Potential



VTG GPS Reference

- Provides velocity only
- Based on Doppler-shift from the satellite signals to the receiver
- Not affected by multipath errors
- Does not require differential correction
- Can be a valid alternative to GGA
- More difficult to detect errors
- Can have issues with boat speeds less than .8 ft/sec

Selecting GPS Update and Baud Rates

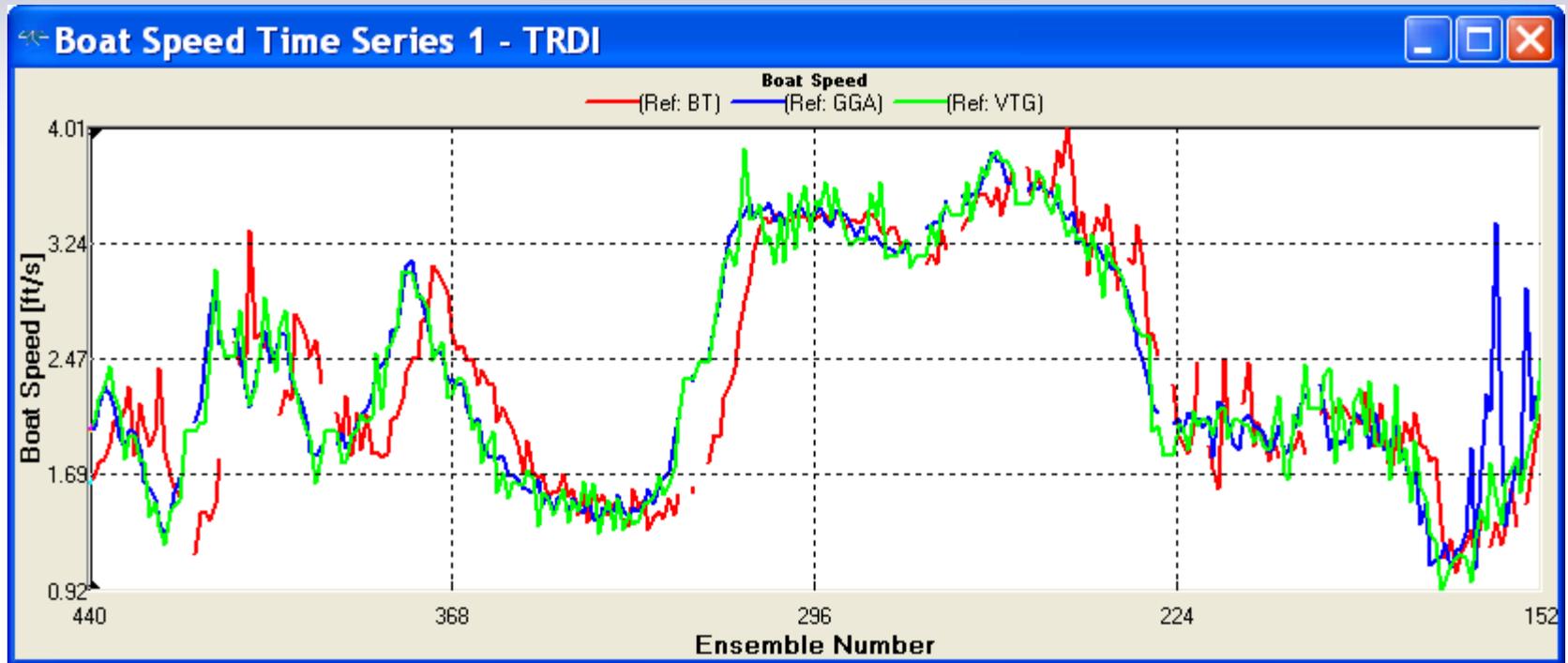
Update Rate: At least one GPS position and/or velocity string per ensemble. This translates to an update rate of at least 2 Hz with a preferred update rate of 5 or higher. Rates of 10 Hz and higher may cause problems with some computers and software.

Baud Rate: Must be sufficient to handle the data throughput. This table provides some reasonable estimates.

| GPS Update Rate | Baud Rate |
|-----------------|-----------------|
| 1 Hz | 4800 or higher |
| 5 Hz | 19.2k or higher |
| 10 Hz | 38.4 or higher |

If update rate is too high for Baud rate, GPS data may be buffered resulting in GPS data lagging behind ADCP data.

Example of GPS Lagging Bottom Track



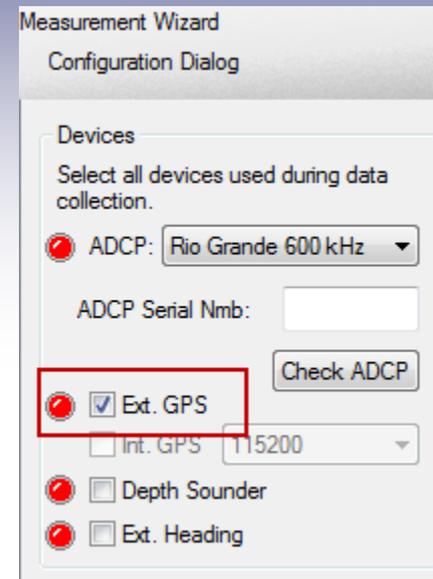
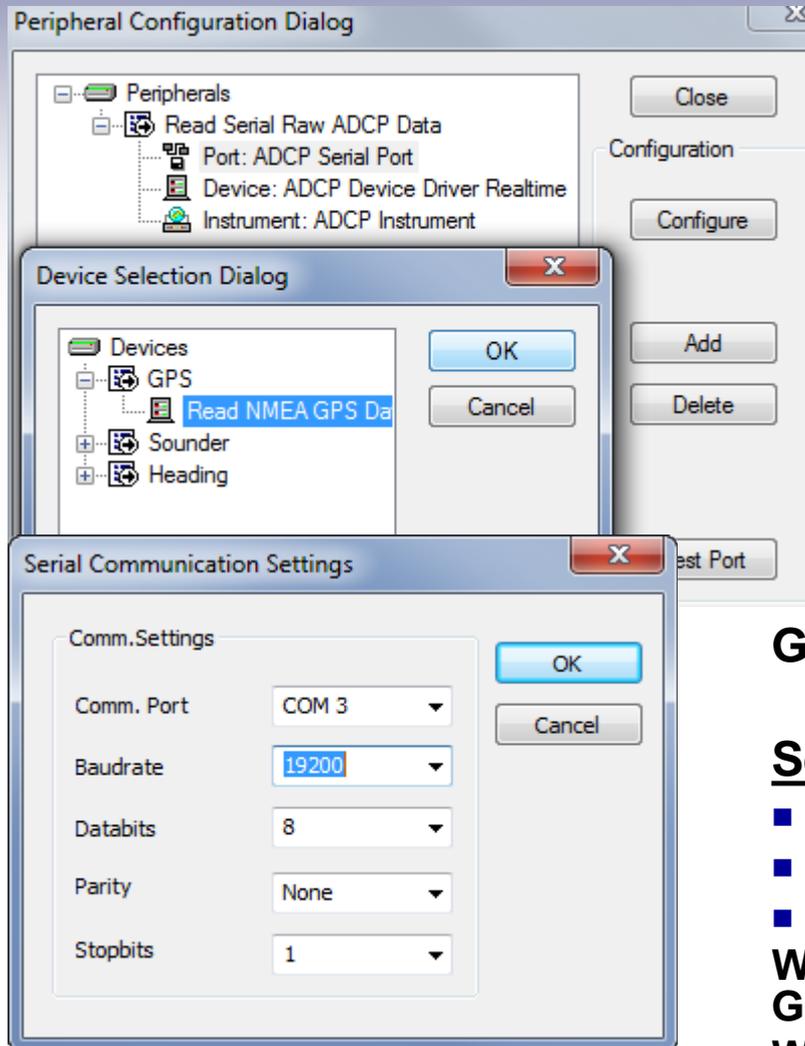
←
Increasing Ensemble Number

GPS Antenna Placement

- Over the ADCP
- Higher than the rest of the deployment
- Clear view of sky



Typical GPS Setup in WinRiver



GPS coming in over separate serial port

Set the communications for GPA

- Select **Peripherals** then **Add**
- Set Serial port and baud rate
- In Configuration Wizard **Check** Ext GPS

While collecting AcquireControl should display GPS status: valid

Will create GPS log files for each transect

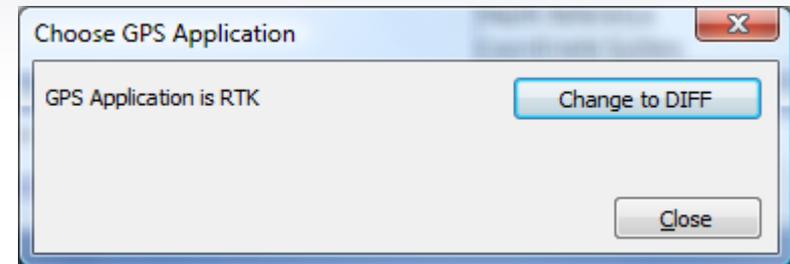
RiverRay Direct GPS Connection

- If GPS is connected to RiverRay (y-cable)
 - Check Int. GPS
 - Select baud rate GPS is using
 - GPS status in AcquireControl: No data
 - No GPS log files
 - Look for lat/long in composite tabular

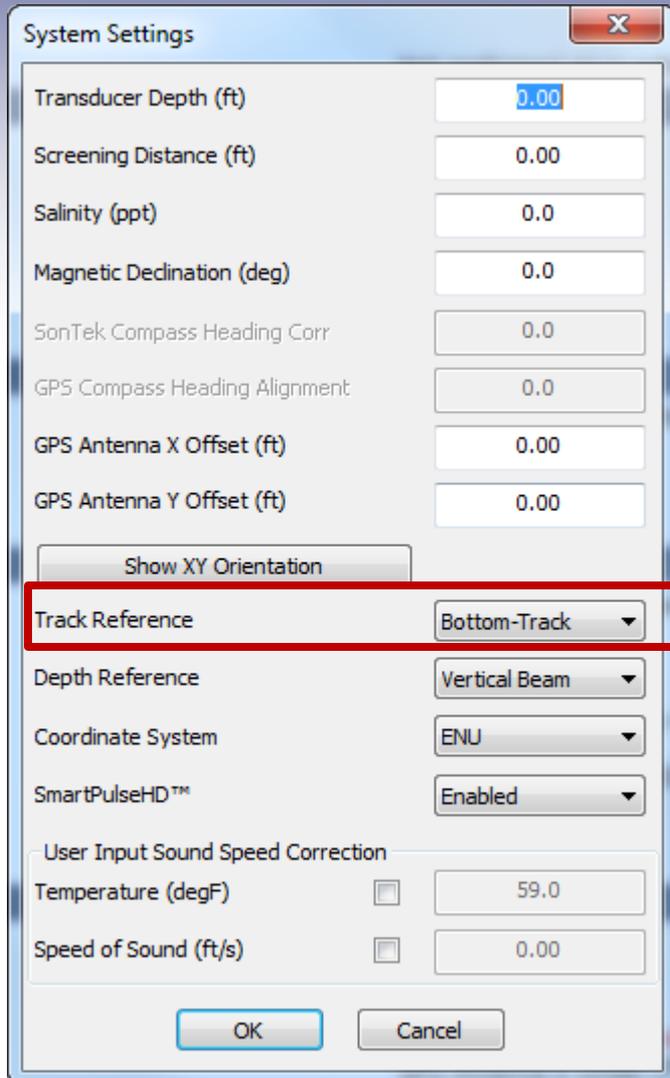
The screenshot shows the RiverRay software configuration window. The 'Devices' section is active, showing 'ADC: RiverRay' selected. Below it, 'ADC Serial Nmb:' is empty, and a 'Check ADCP' button is present. The 'Int. GPS' checkbox is checked, with a baud rate of '57600' selected. Other options like 'Ext. GPS', 'Depth Sounder', and 'Ext. Heading' are unchecked. A red arrow points from the 'Int. GPS' checkbox to the 'GPS status in AcquireControl: No data' bullet point in the text on the left. The 'ADCP Wizard Configuration' section includes fields for 'Max. Water Depth [ft]: 16.40', 'Secondary Depth [ft]: 0.00', 'Max. Water Speed [ft/s]: 1.64', and 'Max. Boat Speed [ft/s]: 1.64'. It also has dropdown menus for 'Streambed: Sand', 'Bottom Mode: Auto', 'Water Mode: Auto', and 'Update Rate: Auto'. The 'Offsets' section shows 'Transducer Depth [ft]: 0.32' and 'Mag Variation [deg]: 0'. The 'Discharge' section includes 'Top Method: Power', 'Bottom Method: Power', 'Power Curve Coeff: 0.1667', 'Left Bank Coeff: Triangle 0.35', 'Right Bank Coeff: Triangle 0.35', and 'Shore Pings: 10'.

RiverSurveyor Live

- GPS data is combined on ADCP
- GPS Option must be set correctly prior to data collection
 - DIFF no RTK base station
 - RTK – when using RTK base station
- If using RTK, place base station in clear view of sky, then turn on (5-10 min to acquire)



RS Live Track Reference



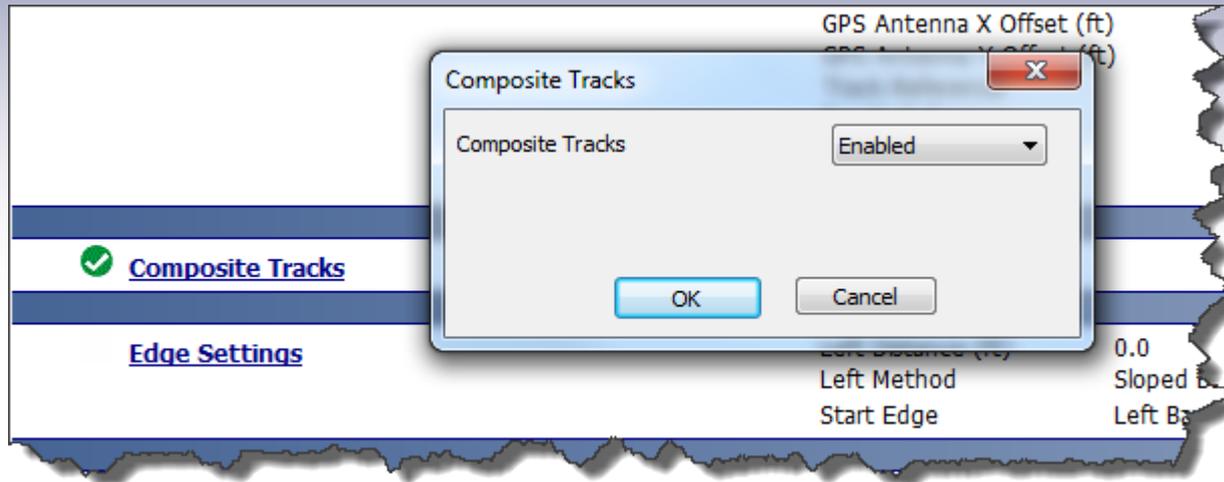
System Settings

| | |
|-----------------------------------|-------------------------------|
| Transducer Depth (ft) | 0.00 |
| Screening Distance (ft) | 0.00 |
| Salinity (ppt) | 0.0 |
| Magnetic Declination (deg) | 0.0 |
| SonTek Compass Heading Corr | 0.0 |
| GPS Compass Heading Alignment | 0.0 |
| GPS Antenna X Offset (ft) | 0.00 |
| GPS Antenna Y Offset (ft) | 0.00 |
| Show XY Orientation | |
| Track Reference | Bottom-Track |
| Depth Reference | Vertical Beam |
| Coordinate System | ENU |
| SmartPulseHD™ | Enabled |
| User Input Sound Speed Correction | |
| Temperature (degF) | <input type="checkbox"/> 59.0 |
| Speed of Sound (ft/s) | <input type="checkbox"/> 0.00 |

OK Cancel

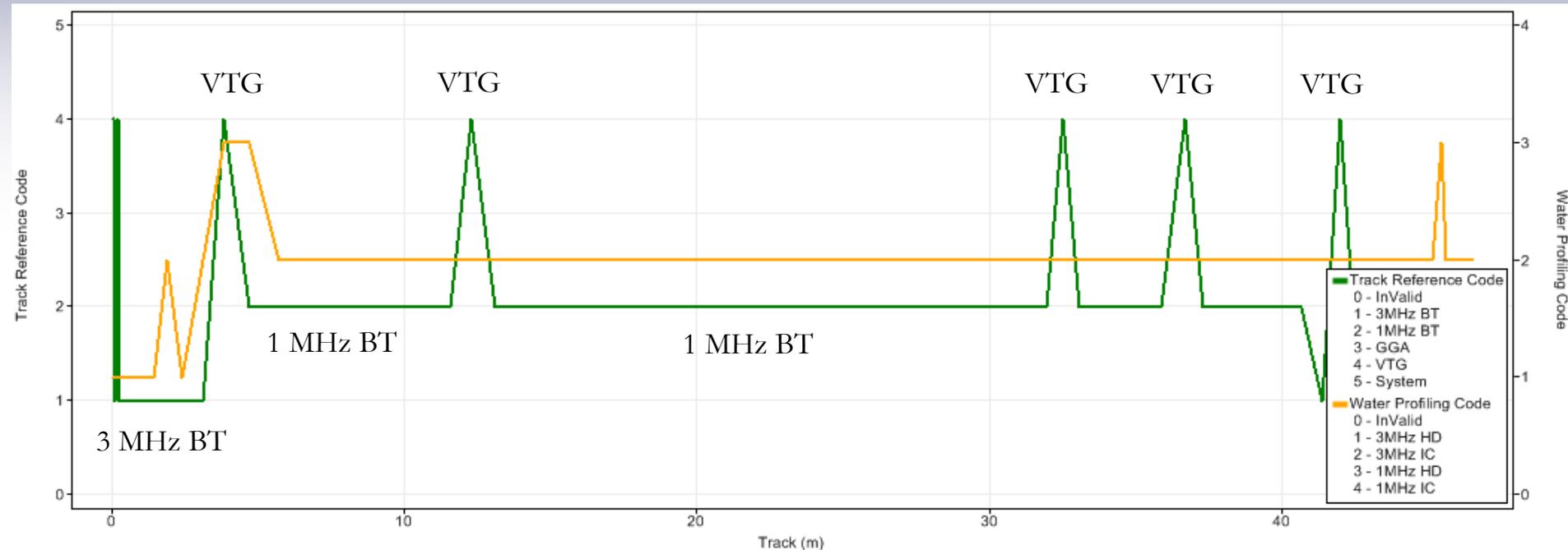
- Usually leave as bottom track when collecting data, unless a moving bed are bad bottom track are likely for the measurement
- Can be adjusted when reprocessing
- If GPS might be used as reference watch for compass calibration issues during data collection and recalibrate if found

Composite Track



- When enabled – will substitute bad reference with other available reference (VTG for BT, etc)

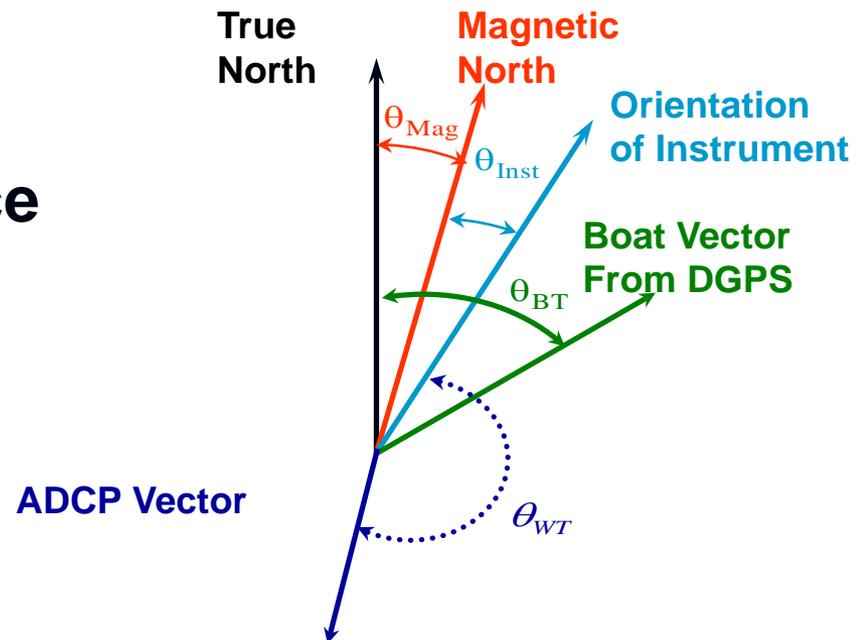
RS Live – Track Reference Time Series



- View if/when track references are being substituted
- Area for any samples with track reference “0-Invalid” for more than 9 samples will not have a measured discharge

Aligning ADCP and GPS

- compass heading used to align GPS boat speed with ADCP water speeds. Errors in heading will cause errors in discharge
 - Correct magnetic variation for site
 - Relatively free of magnetic interference
 - Properly calibrated compass



Affecting Compass Accuracy

- Structures having local magnetic fields relatively large compared to Earth's magnetic field: steel truss bridges, bridge piers (steel or concrete full of rebar)
 - If their orientation changes during transect, the affect can not be calibrated out
- Rapid/sudden acceleration and/or deceleration
- Ferrous materials and electromagnetic field interference near ADCP (ferrous parts on mount, steel toolbox on boat, etc)



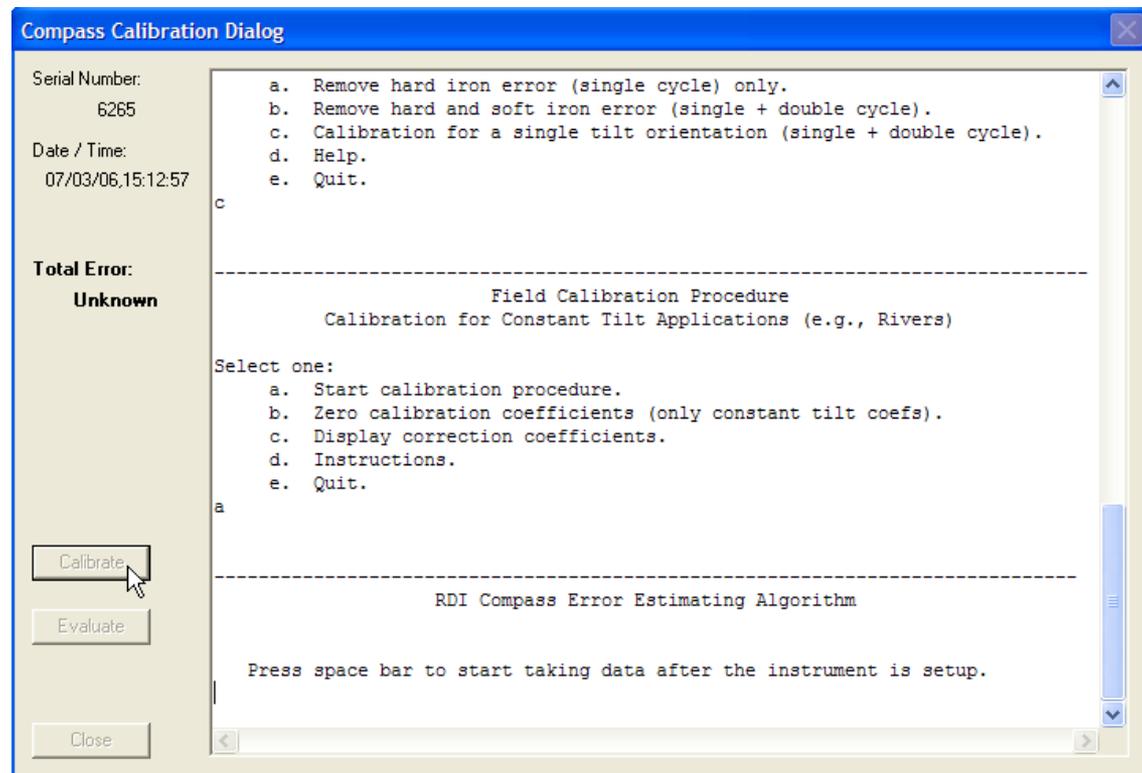
Calibrate the Deployment

- Compass calibrations are an attempt to calibrate out heading errors caused by sources near the ADCP and the local area
- Minimize deployments exposure to potential interference (truck, cell phones, bridge deck, etc)
- Entire deployment should be moved through the calibration routine when practical
- Do not simply rotate the ADCP



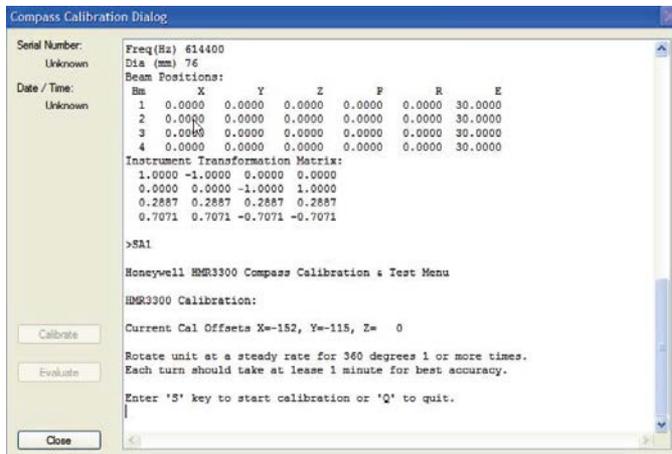
Rio Grande Compass Calibration

- Slowly rotate (1 to 2 min) one complete circle (360 degrees) with minimal pitch and roll
- An evaluation must always be completed after calibration. Total error reported should typically be less than 1 degree and always less than 2 degrees



RiverRay – Honeywell Compass

- Original RiverRay compass (Honeywell) seems more sensitive to sources of interference than previous ADCP's
- No feedback to evaluate the accuracy of the compass calibration
- TRDI offers an upgrade to compass similar to StreamPro. This compass is all new RiverRays
- Smoothly complete 2-3 rotations taking 2 to 3 minutes (> 40 – 50 data points on screen)



Enter: 'A' to Accept new X and Y CAL offsets and zero Z Cal Offset.
Recommended for flat calibration.
'P' to Accept new X, Y and Z CAL offsets.
Use only if pitch and roll varied during calibration.
'R' to Restore previous offsets, X=784, Y=-392, Z=0
'F' to set Factory default CAL offsets, X=0, Y=0, Z=0
New X and Y Cal Offsets accepted.
Clearing Z offset.
Cal complete. Offsets: X=-217, Y=-434, Z=0

StreamPro and NEW RiverRay Single Tilt Calibration

- Recommend Single tilt calibration - Pitch/Roll *No (Simple on PDA)*
- Using pitch and roll (advanced on PDA) not practical in field
- Place deployment in calm water or on flat surface so it can be rotated without any pitch/roll
- Slowly rotate the boat 360
- There are 12 squares that change colors as you rotate
- The more Green = Good
- Go slower if they are yellow or red
- Evaluation immediately after calibration

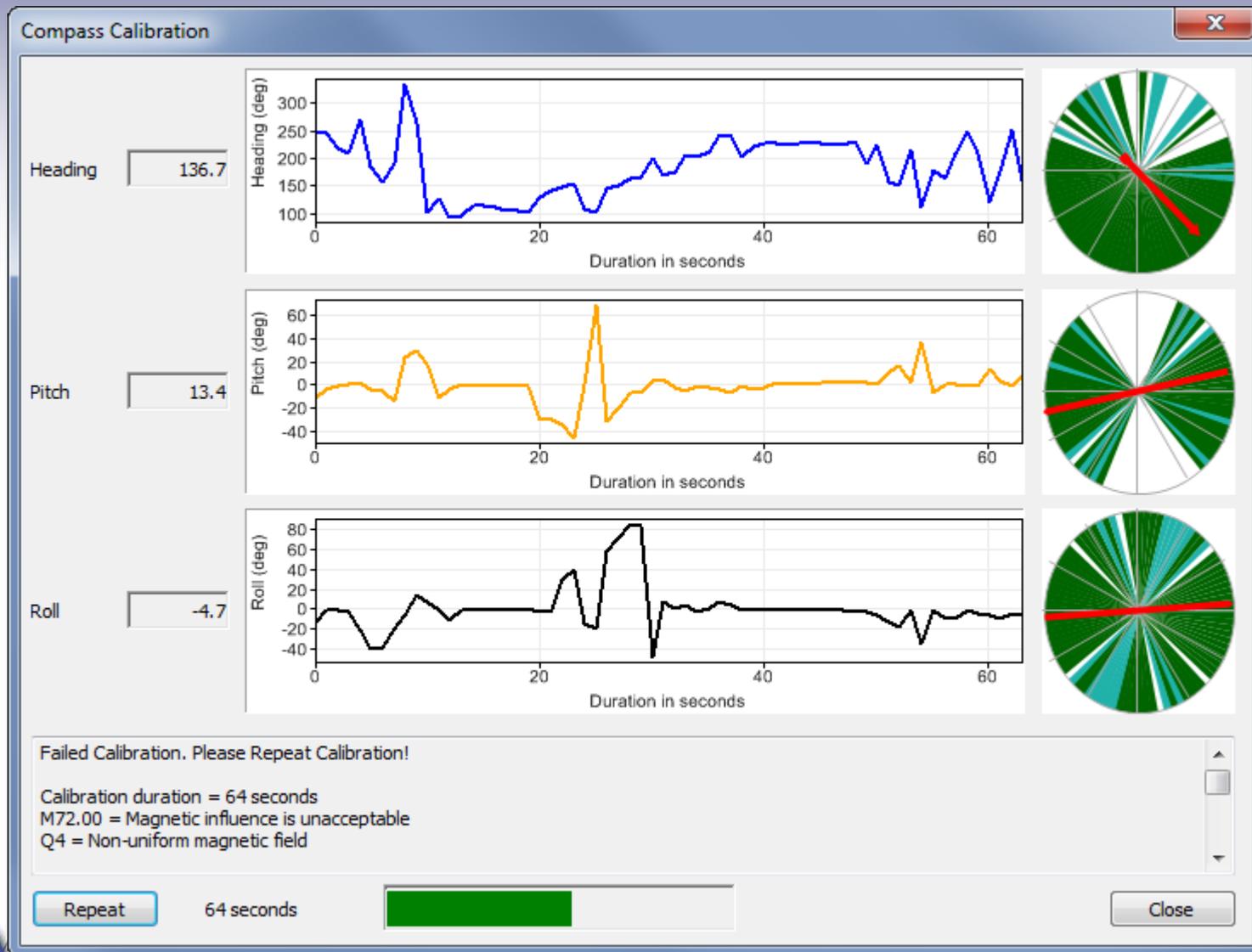


- Green – Good
- Light Green – Acceptable
- Yellow – within parameters (one or two yellow bars for the entire rotation is OK)
- Orange – unacceptable (slower rotation required)

SonTek M9/S5 Compass Current Best Practices

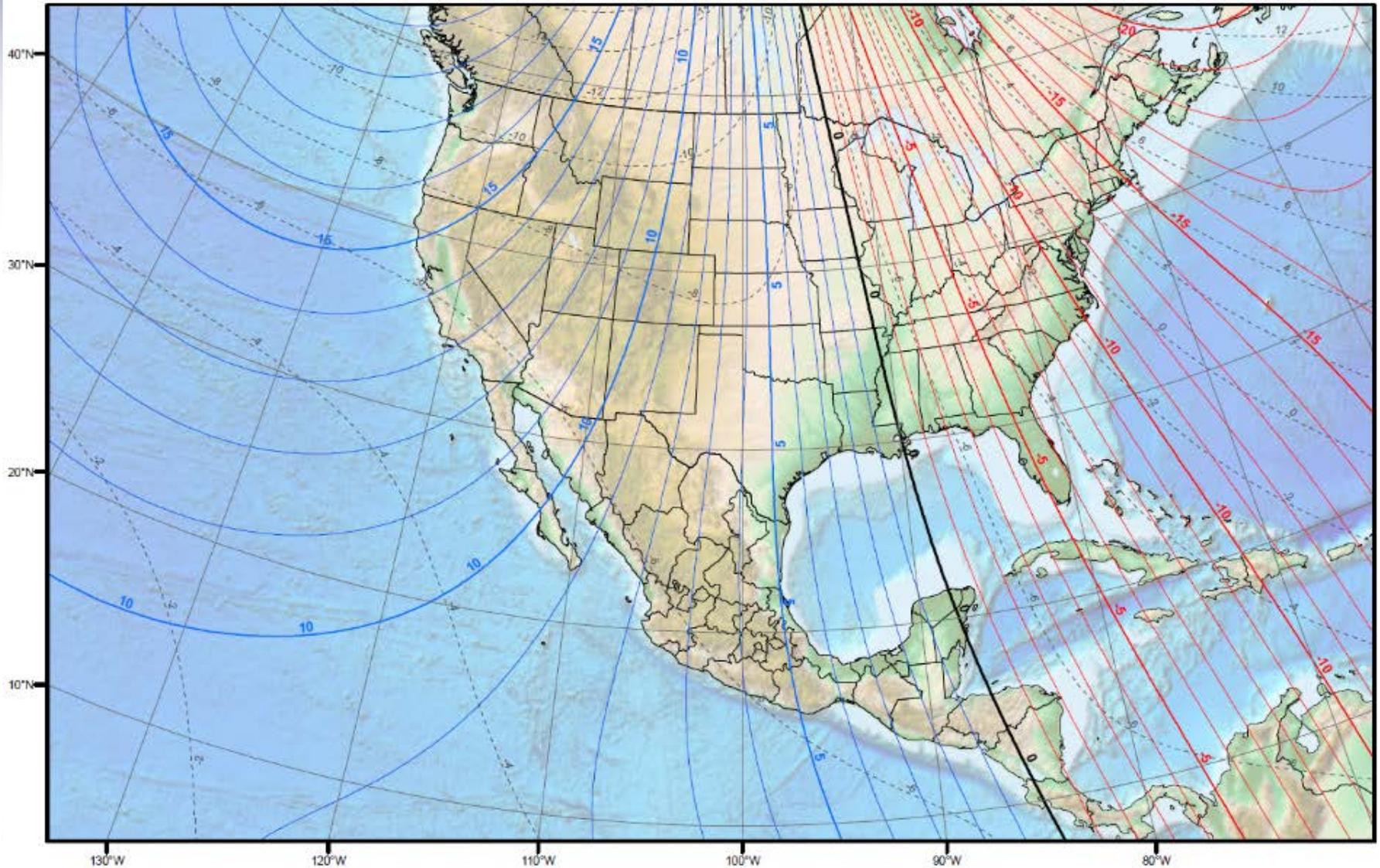
- Calibration should be at least 1 minute and less than 2 minutes in duration
- Try covering all pitch/rolls unit will might see during measurement. If pitch or roll encountered during measurement exceeds those during calibration, large errors may result – on manned boat, do not pitch/roll adcp independent of boat
- Watch for issues in measurement data...
Calibration scores NOT always indicative of a properly calibrated compass!

Compass Calibration



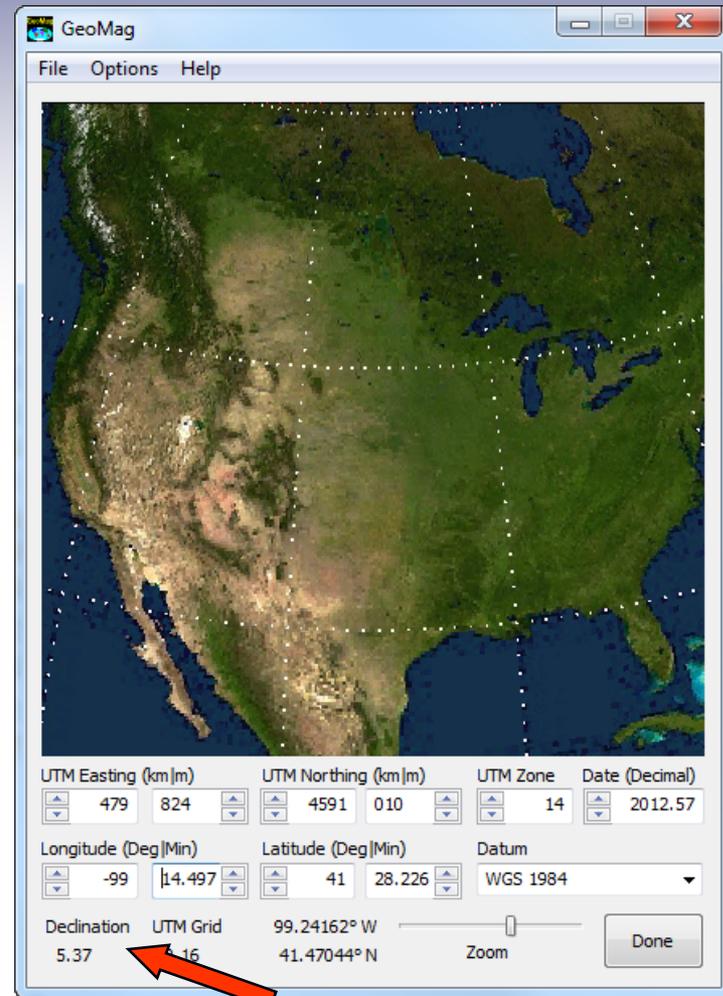
Magnetic Declination/Variation

Magnetic Declination Map of North America for the year 2010



Sources of Magnetic Variation

- Common way to determine mag var:
 - GeoMag (Win)
 - WMM software (Win)
 - Smart Phone Apps
- Enter latitude and longitude for the measurement site and date (Datum=WGS84)
- The value labeled declination is what should be entered as the mag var in the ADCP software

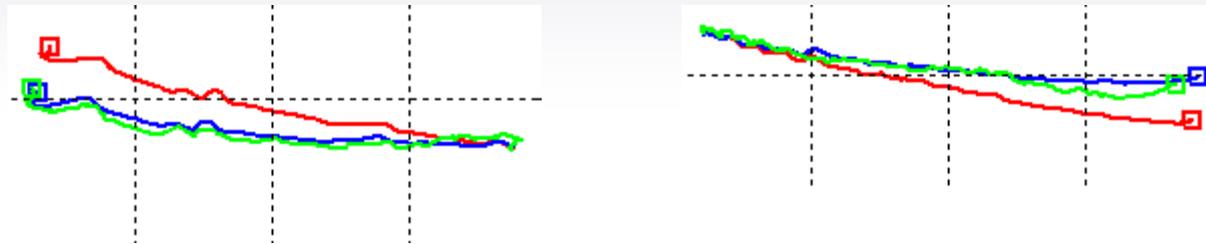


[Web alternative:](http://www.ngdc.noaa.gov/geomag-web/?id=declinationFormId#declination)

<http://www.ngdc.noaa.gov/geomag-web/?id=declinationFormId#declination>

Errors in Magnetic Variation

- When compared to Bottom Track, BT US of GPS when starting at one bank and DS starting at other



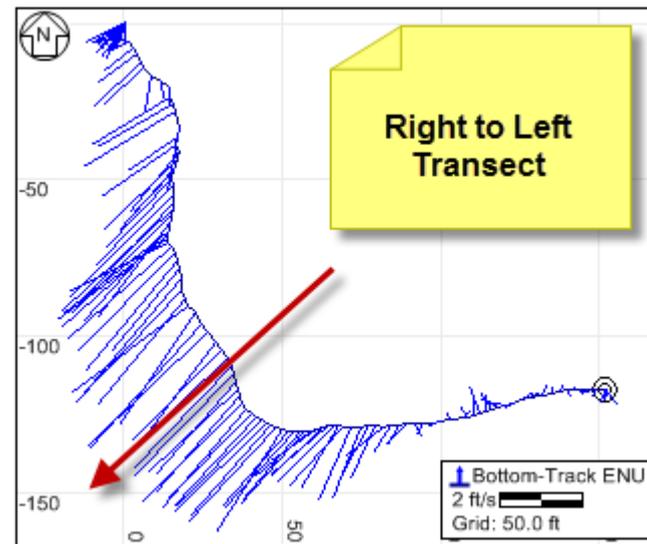
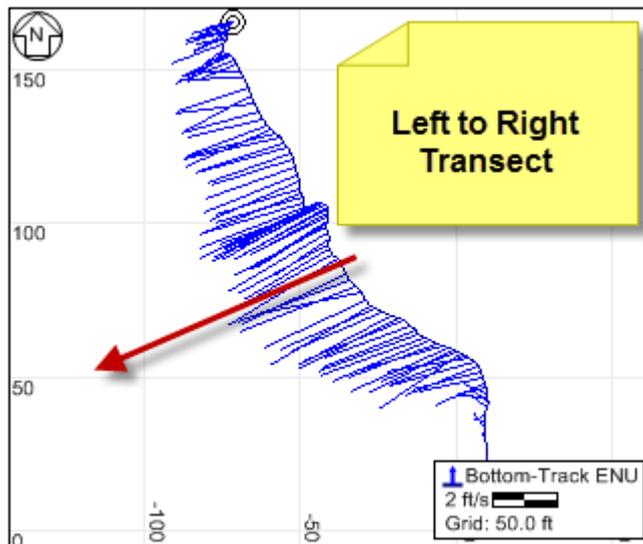
- Directional Bias in Discharge

| Start Bank | # Ens. | Start Time | Total Q ft ³ /s | Delta Q % |
|------------|--------|------------|-------------------------------|--------------|
| Left | 358 | 15:06:53 | 919.035 | 2.28 |
| Right | 434 | 15:11:53 | 873.250 | -2.81 |
| Left | 247 | 15:17:45 | 934.729 | 4.03 |
| Right | 241 | 15:21:55 | 867.108 | -3.50 |

- Could adjust mag. Var. a couple of degrees for all transect to minimize bias, do NOT adjust differently for each transect (Tends to not greatly affect avg Q)

Watch for Compass Issues

- Differences in flow direction in reciprocal transects / flow direction seems to depend on orientation of instrument



- If found recalibrate compass (especially when GPS required for reference)

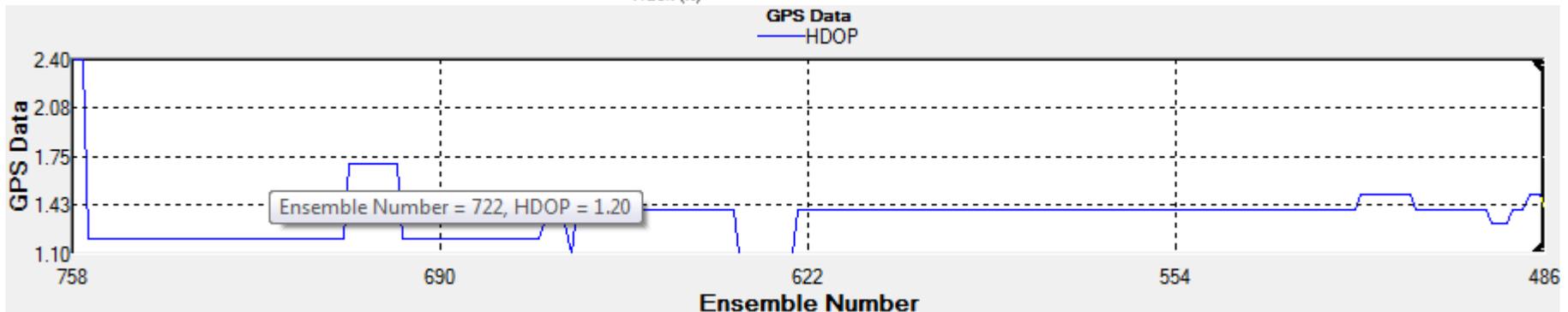
Viewing GPS Quality Indicators

■ Tabular Data

| GPS | |
|-----------------|----------------|
| Satellites | 8 |
| GPS Quality | 2 |
| GC-BC | 2.3 |
| D(BT)/D(GPS) | 1.006 |
| Latitude (deg) | 65° 49' 39.17" |
| Longitude (deg) | 21° 37' 14.52" |
| HDOP | 1.00 |

| GPS Tabular 1 - TRDI | |
|----------------------|------------------|
| Latitude | 30° 20.722851' N |
| Longitude | 94° 4.986109' W |
| Number Invalid | 0 |
| Number of Sats | 6 |
| Sats Changes | 0 |
| Altitude | 3.6 [ft] |
| Delta Altitude | 0.0 [ft] |
| HDOP | 1.4 |
| Delta HDOP | 0.0 |
| Delta Time | 0.0 [s] |
| DGPS Status | DGPS |
| DGPS Corr. Age | 6.0 [s] |
| DGPS Stn. ID | 133 |

■ Time Series Plots



Other Indicators of GPS Quality

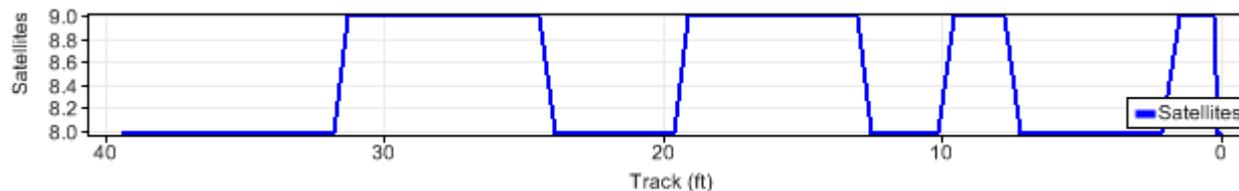
■ Number of Satellites

- At least 4 satellites required (> 7 satellites preferred) greater # = more accurate

| GPS | |
|-----------------|-----------------|
| Satellites | 8 |
| GPS Quality | 2 |
| GC-BC | 3.2 |
| D(BT)/D(GPS) | 1.003 |
| Latitude (deg) | 30° 6' 37.49" |
| Longitude (deg) | -95° 26' 15.59" |
| HDOP | 1.20 |
| Altitude (ft) | 56.43 |

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- **Satellite Changes** - if the # satellites changes it may cause a jump in the position (large # = data could be suspect)

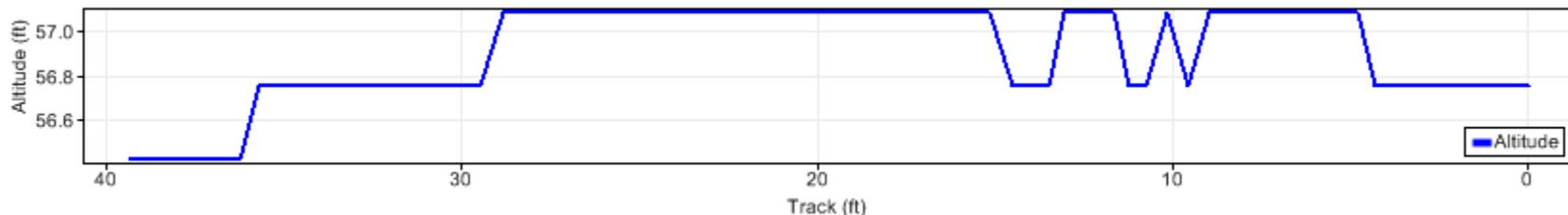


Other Indicators of GPS Quality

- **Altitude (delta altitude)**
 - **Change in altitude should be minimal (typically < 11.5 ft)**

| GPS | |
|-----------------|-----------------|
| Satellites | 8 |
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| D(BT)/D(GPS) | 1.003 |
| Latitude (deg) | 30° 6' 37.49" |
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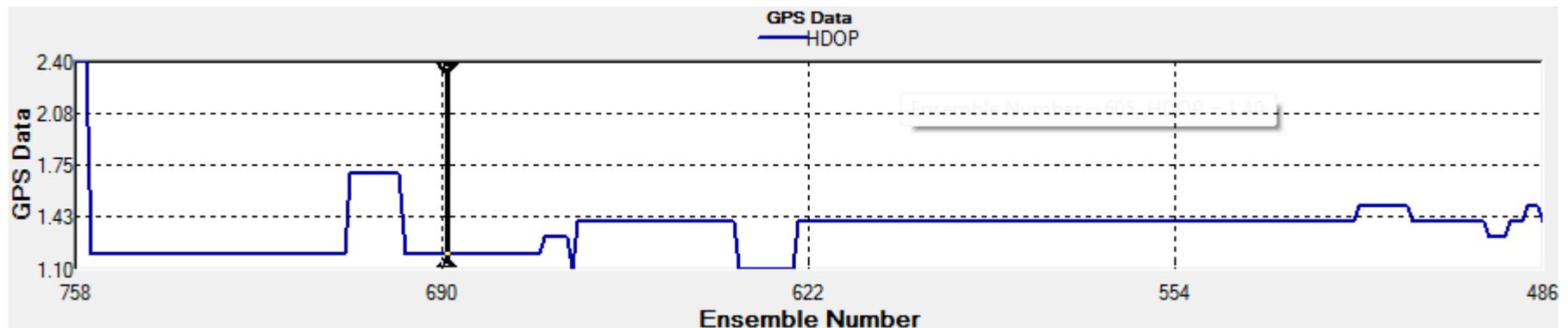


Other Indicators of GPS Quality

- **HDOP – Horizontal Dilution of Precision**
 - **Measure of possible error (GPS accuracy) due to the geometry of the satellites visible to the GPS receiver (lower is better, < 2 preferred)**

| GPS | |
|-----------------|-----------------|
| Satellites | 8 |
| GPS Quality | 2 |
| GC-BC | 3.2 |
| D(BT)/D(GPS) | 1.003 |
| Latitude (deg) | 30° 6' 37.49" |
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| Delta Altitude | 0.0 [ft] |
| HDOP | 1.4 |





RSLive Status Bar

- Indicates Quality of GGA and VTG Data

- GGA data

| | | | | |
|---|---|---|---|---|
|  |  |  |  |  |
| 4 | 2 | 1 | 0 | |
| RTK Quality Position | Differential Quality Position | Uncorrected Position | Invalid or no data | Disabled /Inactive |

- VTG data

| | | | |
|---|--|---|---|
|  |  |  |  |
| Valid Velocity | Valid Velocity* (Limited Satellite Coverage) | Invalid or no data | Disabled /Inactive |

- If **RED** stop and resolve issue (check antenna cables and make sure clear view of sky)

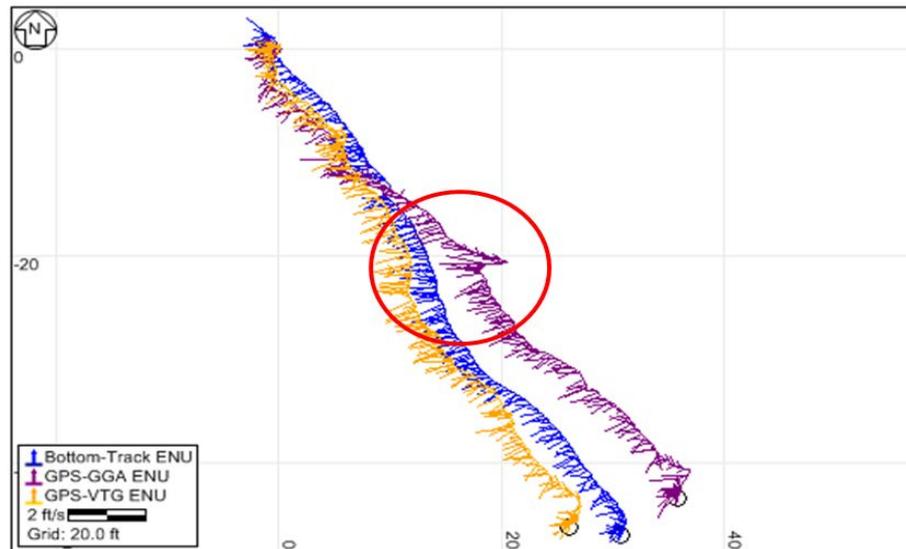
Maintaining Speed and Direction

- Avoid abrupt changes in heading and speed
- When using GPS, it is even more important to maintain a consistent speed and direction



Selecting Reference to Compute Q

- If no moving bed or few invalid BT, Bottom track should be used as reference
- When deciding between GGA and VTG, select the reference that looks the most uniform and consistent for all transects



GPS Summary

- Use of DGPS is preferred in moving bed conditions
- Requires:
 - Clear line of sight to satellites
 - Accurate compass headings
 - Magnetic variation (declination) for site
- Watch for errors in the field,
- Go smooth, steady and slow
- Select best reference available that can be applied to all transects

Questions?

