SVC Summary Report:
Mapping, Navigation, & Sub Data
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1. Mapping

Our evaluation of Alvin's mapping capabilities is incomplete, as the mapping sonar (Reson 7200K) is not installed on the submarine. Key to integrating the sonar with Alvin will be the inclusion of new hardware components including a timing switch to ensure that the DVL and sonar don't interfere with each other and a sound velocity profiler (SVP) that continuously feeds data to the sonar to correct for sound speed variations. The Alvin group does not currently have either of these components. During the cruise we will attempt to evaluate the capability of the sub to run survey patterns using closed loop control, evaluate the limits of the DVL for maintaining bottom lock at altitude, and assess the position and attitude data collected by the sub.

1.1 DVL performance

The ideal altitude for mapping surveys with the Reson multibeam sonar is ~65 m based on experience with Sentry. It was necessary to determine whether the DVL, which provides point-to-point Alvin positions, can operate at this altitude. To test this, we ascended to 50 m, 65 m, and 80 m above the seafloor and held position for a period of approximately five minutes (**Figure 1**). During this test, the DVL maintained bottom lock for the entire time. Given that the seafloor in this region is muddy, this performance indicates that DVL can provide excellent navigation, a necessity for processing multibeam sonar data.

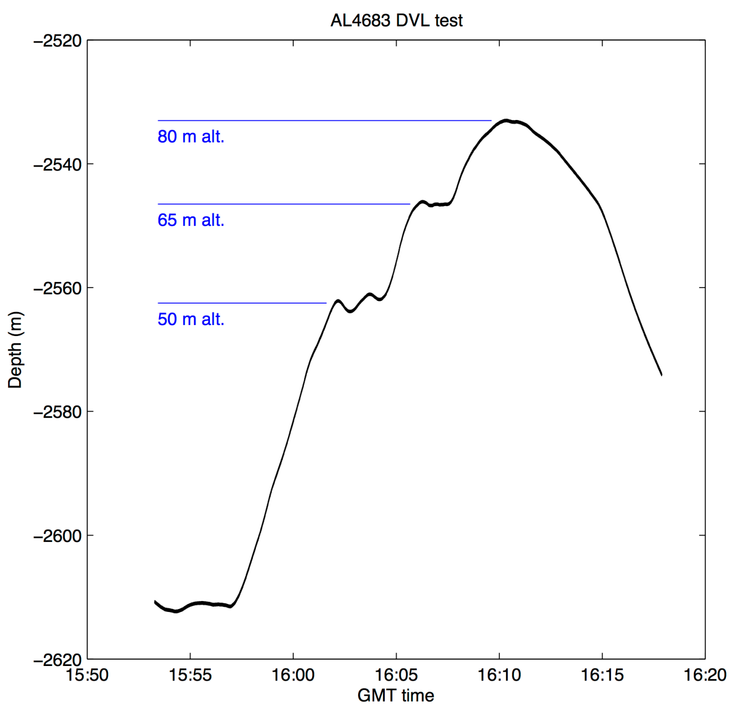
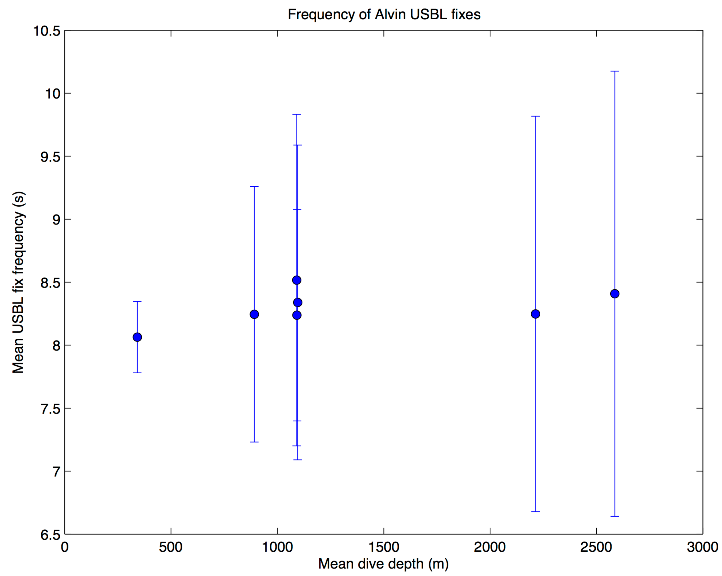


Figure 1. Test of the Alvin DVL system consisted of ~5 minutes of holding position at a variety of altitudes encompassing the ideal Reson survey altitude of 65 m. The DVL maintained bottom lock throughout the test.

1.2 USBL performance

USBL fixes of Alvin occur every 8-8.5 seconds. The frequency of the fixes is somewhat dependent on the depth of the sub, with greater depths leading to greater variability in frequency although the mean remains close to 8 s (**Figure 2**).

Figure X. Comparison of the mean and standard deviation of times between USBL fixes at a range of mean dive depths. The mean period between fixes remains constant at 8-8.5 s, but the variability in period increases with increasing dive depth.



The precision of the fixes is evaluated by looking the variability in position when Alvin remains in a fixed location on the seafloor. Examples from a shallow and deep dive indicate that USBL positions have overall greater accuracy, but lower precision than Doppler-derived positions (**Figure 3**). As the Doppler-derived location will accumulate small point-to-point errors that result in significant position drift through time, the precision of the Doppler-derived positions depends on how recently the Alvin position was reset to a USBL fix. On shallow dives (300 m), USBL precision is better (±2m) than on deeper dives (>2000 m) (±10m). In all cases, Alvin-derived depth is both more precise and more accurate than USBL-derived depths.

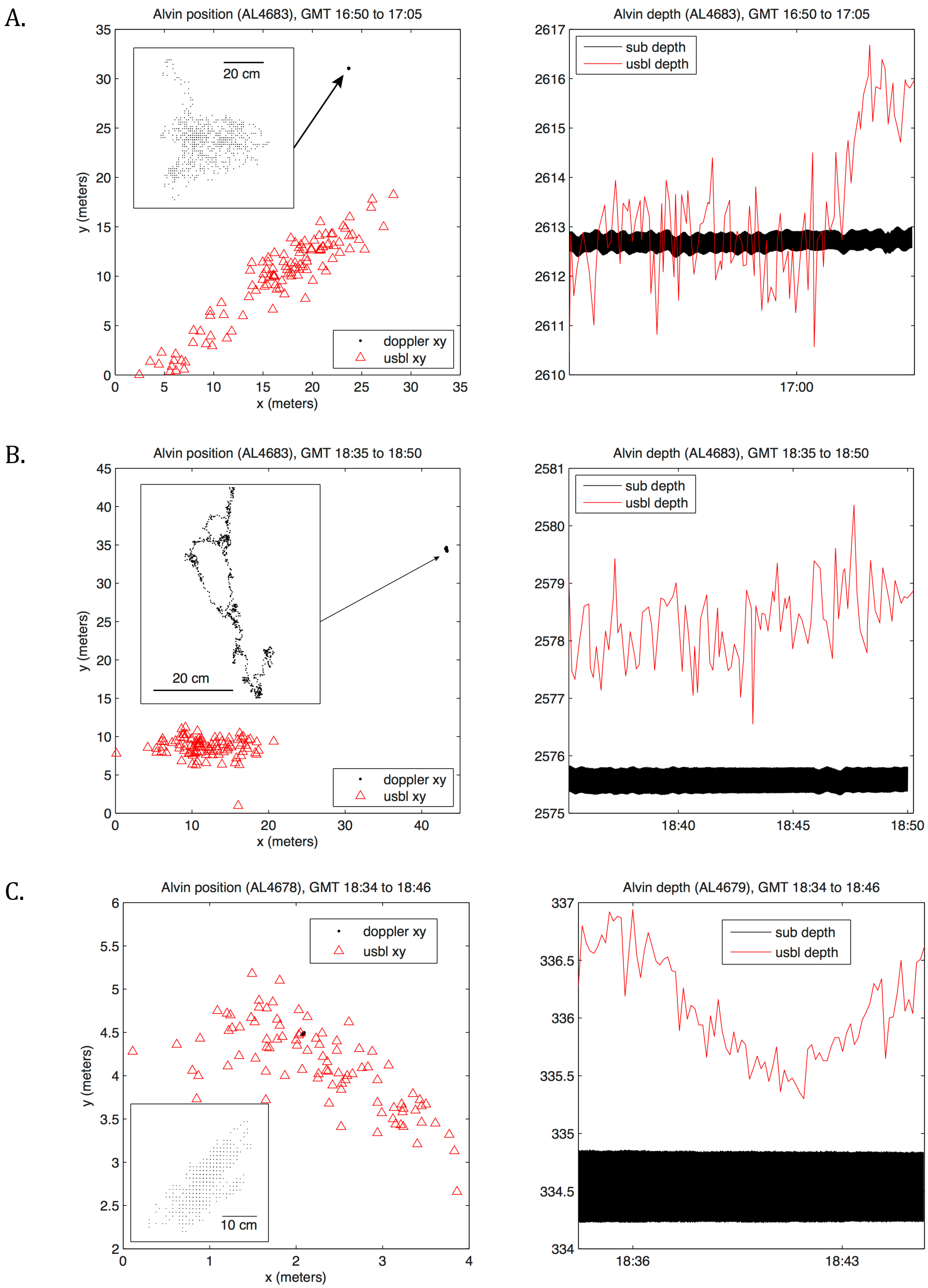


Figure 3. Alvin Doppler- and USBL-derived position (*left*) and depth (*right*) over a period of 15 minutes in which Alvin was stationary on a deep dive (A&B) and over a period of 12 minutes on a shallow dive (C).

1.3 Survey line performance

We tested Alvin's capabilities of running typical survey tracklines (Fig. Xa) using the new command-and-control software, including auto-heading, auto-altitude, and auto-xy. These features will be familiar to ROV Jason users. The intial survey line was run in auto-heading (315˚), auto-altitude (30 m) and auto-xy (250 m step size and 0.4 m/s max speed). The choice not to run the survey-line test at the ideal survey altitude of 65 m was made based on the evaluation that DVL performance was more than adequate to maintain bottom lock and to save dive time for ascent/descent from survey altitudes.

The start of the survey produced some oscillatory behavior in heading resulting in a 'wavy' trackline (**Figure 4b**). The heading variations settled out within 10-15 m. We infer this heading issue a related to the gain settings in the auto-features. The initial trackline was started at 0.4 m/s. At the end of the first trackline, the sub overshot the end of the line and the thrusters oscillated between full-reverse and full-forward. Again, the gain settings could have a significant impact on how the thrusters are utilized as the end of the line is approached. We used auto head to make a 90˚ turn to port for the transit to the next survey line (~150 m). Minor oscillations in heading were again observed. This line was run at 0.4 m/s again, but we decreased max speed to 0.2 m/s ~3/4 through the line in order to limit thruster oscillations and overshooting the end point. Immediately upon lowering the max speed (during transiting), thrusters went to full reverse. This again was another indication that modifying gain would facilitate smoother transitions in speed and reduce overusing the thrusters. At 0.2 m/s, stopping at the endpoint was more efficient, and heading changes during another 90˚ turn to port was smoother. The final track was run at 0.4 m/s and did not show any oscillations of thrusters or heading.

During these tests, we found power consumption to be higher than typical especially at speeds of 0.4 m/s and during thruster use. From our experience, the Reson multibeam sonar also uses significant power resources. It is possible that mapping dives may not last as long as typical dives (e.g., sampling), although we caution that this cannot be verified until the Reson is installed and used. We also note that power consumption by Alvin and/or battery performance appears to be improved over the previous sub. We recommend that during mapping operations all systems that are not in use (e.g., lights, hydraulics for manipulators) be turned off.

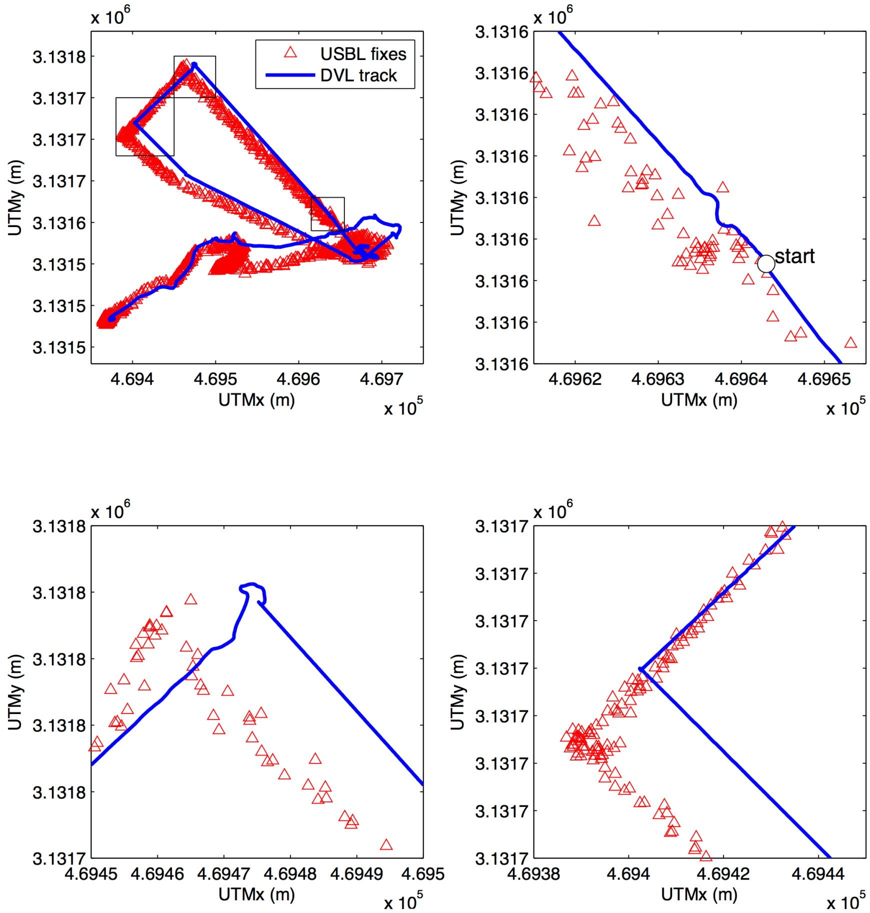


Figure 4. Alvin performance during test survey operations. Doppler dive track is blue and USBL fixes are red. The start of the first survey line resulted in some wiggling along the track as the heading settled in (upper right). At the end of the first survey line, the sub overshot the point and had difficulty obtaining a stable heading after a 90˚ turn to port (lower left). Towards the end of the second line, we slowed speed to 0.2 m/s and the sub did a much more controlled turn and maintained solid heading after 90˚ turn to port (lower right).

1.4 Mapping Assessment and Recommendations

We are pleased with Alvin's performance in tests of it's mapping capabilities and hopeful that further testing, after installation of the Reson multibeam sonar, will show Alvin to be a capable and facile mapping vehicle. The quality of multibeam seafloor mapping by Alvin will be dependent on three things: 1) the ability of Alvin to maneuver in typical survey patterns at altitude above the seafloor; 2) the ability to recover accurate sub position and attitude data during the survey; and 3) the quality of acoustic data from the sensor. In summary, our current testing has shown that Alvin can navigate survey patterns, does not yet have the ability to provide the science user with accurate position data – although the necessary components to produce such data are in place, and the quality of acoustic data remains untested until the sonar is installed on the sub.

2.0 Alvin Data Streams

Our evaluation of Alvin data streams will include an assessment of what is provided to the science user post-dive and the ease of access to the data. We recognize that, unlike other NDSF vehicles, the Alvin at-sea operations group does not include a data manager. Thus, our assessment will assume that the science party will be required to conduct any data stream manipulation and offer some instructions for doing so.

2.1 Data structures

Data comes off the sub in an array of image and text, some of which are parsed into more manageable subsets of the same data (**Figure 5**). Video data is treated separately. Below we provide a description of the data files and what they contain:

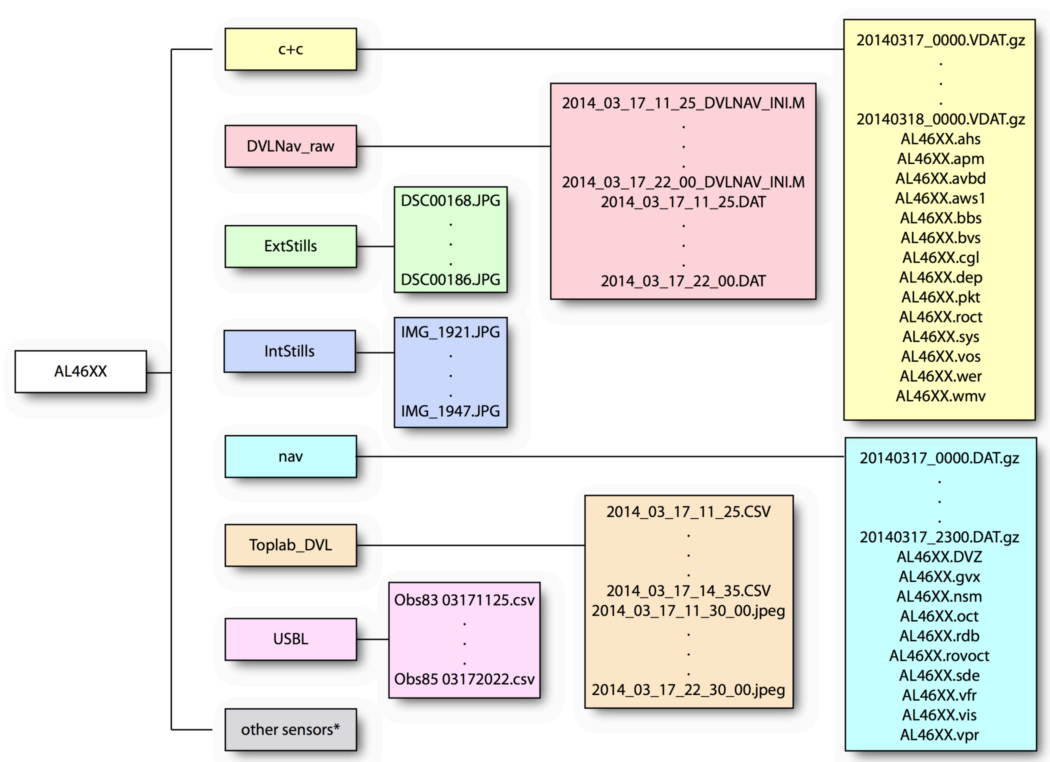


Figure 5. File structure for a typical Alvin dive. Other sensors* might include data from a magnetometer, CTD, or mapping sonar.

c+c: This directory contains data recorded by the command and control software. All the data is contained in GMT date and time stamped VDAT files, which are zipped (e.g., 20140321_1400.VDAT.gz). A new file is started every ~1 hr. These files are parsed into a series of ascii text files by vehicle subsystem that are named with the dive number and a file-ending indicating the data type. Refer to NDSF support documents for more details on files and included data. File sizes depend on bottom time and sensors used.

ALXXXX.ahs: Contains records of Alvin power usage (Alvin hotel status). AHS1 records give detailed information for each BUS and powerboard. AHS2 records give ascii messages. Data rate is variable.

ALXXXX.apm: Contains records of Alvin hydraulic pressure Data rate is ~1 Hz.

ALXXXX.avbd:	Contains records of Alvin variable ballast system pressure and temperature. Data rate is ~1 Hz.
ALXXXX.aws1:	Contains records of Alvin sphere environmental conditions including temperature, humidity, pressure, and any alarms. Data rate is ~0.3 Hz.
ALXXXX.bbs:	Contains records of Alvin battery status including current and voltage for stbd and port battery bays. temperature, humidity, pressure, and any alarms. Data rate is ~2 Hz.
ALXXXX.bvs:	Contains records of Alvin battery low voltage situations. Data rate is variable.
ALXXXX.cgl:	Contains records of Alvin gains navigation control. Data rate is ~0.1 Hz.
ALXXXX.dep:	Contains depth records from Alvin sensors (raw sensor, processed). Data rate is ~1 Hz.
ALXXXX.oct:	see nav directory.
ALXXXX.pkt:	Contains parameters used in closed-loop navigation control system (e.g., velocity, acceleration, pitch/head/roll). Data rate is ~2 Hz.
ALXXXX.roct:	Contains log of raw strings from Octans or PHINS attitude sensor. Data rate is ~10 Hz.
ALXXXX.vos:	Contains log of data used in dead-reckoning positional calculations by DVL. Data rate is ~10 Hz.
ALXXXX.wer:	Contains log of magnetic variation reset from magnetic sensor. Data rate depends on sensor.
ALXXXX.wmv:	Contains log of magnetic declination reset from magnetic sensor. Data rate depends on sensor.

DVLNav_raw: This directory contains date and time stamped initialization files (INI.M) and data files (.DAT) from the DVLNav software that are generated in TopLab during the dive. INI files contain an array of parameters used by the DVLNav software (e.g., orgin, target locations). DAT files contain position information for the ship, Alvin, and any other USBL tracked objects used during the dive. The .DAT files are the primary source for recovering USBL position of the sub during the dive.

ExtStills: This directory contains sequentially numbered digital photographs collected by the Alvin external still camera (e.g., 'science cam').

IntStills: This directory contains sequentially numbered digital photographs collected by the Alvin internal still camera.

nav: This directory contains Alvin position data recorded by the nav computer. The data is contained within GMT date and time stamped DAT files, which are zipped (e.g., 20140321_1600.DAT.gz). A new file is started every ~1 hr. These files are parsed into a series of ascii text files that are named with the dive number and a file-ending indicating data type.

AL4683.DVZ:	Contains data transmitted to the C+C system including vehicle position and DVL fix quality and local origin information. Data rate is ~5 Hz.
AL4683.gvx:	Contains data from Alvin gyro. Data rate is ~10 Hz.
AL4683.nsm:	????? No Data ?????
AL4683.oct:	Contains reports of vehicle attitude from octans or PHINS sensor. Data rate is ~10 Hz.
AL4683.rdb:	Contains log of raw Doppler data. Data rate is ~5 Hz.
AL4683.rovoct:	????? No Data ??????
AL4683.sde:	Contains log of informational threads from sensors. Data rate is variable.
AL4683.vfr:	Contains log of navigation fixes from dead-reckoning and usbl (Alvin) or GPS (Atlantis). Data rate is variable.
AL4683.vis:	Contains log of data used in dead-reckoning positional calculations by DVL. Data rate is ~10 Hz.
AL4683.vpr:	Contains log vehicle position reports, including Doppler-derived position in geographic coordinates. Data rate is ~1 Hz.

TopLabDVL: This directory contains sequentially numbered digital screen grabs of the TopLab DVLNav screen and time-stamped .CSV files containing USBL-derived position data recorded on the TopLab computer.

USBL: This directory contains raw data from the Sonardyne USBL. File numbering and data structures are defined by Sonardyne and are not recommended for use by the science party.

Other_sensors: An array of sensors may be used by Alvin and data from each will be transferred in their raw format.

2.2 Navigation data

Navigation data is generated on the surface (USBL) and in the sub (DVL). As a result, it is advisable that USBL data be recovered from TopLab sources (e.g., DVLNav_raw) and DVL data from sub sources (e.g., nav). Although USBL fixes are recorded in the sub, the time-stamp of those fixes will be delayed from their actual time as they are transmitted through the water column. Ultimately, a data product for sub x, y, z, time will require merging of the DVL and USBL data. That is not currently done by the Alvin operations group. In the short-term, we have supplied instructions for obtaining and processing these data separately (cf., Best Practices: Navigation data).

2.3 Data stream assessment and recommendations

At present, the data produced by Alvin recorded by the command and control software is, for the most part, difficult to impossible to comprehend. It is recommended that a description of the data streams that are parsed from the raw files and handed over to the science party be generated. The volume of data produced during a dive (excluding video data) will depend on bottom time, active sensors, and how the sub is used (**Figure 6**). On average, users can expect 2-6 GB per hour of bottom time.

Navigation data is perhaps the most important product produced during an Alvin dive as it is critical to know where samples, imagery, and observations were collected on the seafloor. Data generated in Alvin and TopLab computers can provide pre-processed navigation data that likely has sufficient accuracy for dive planning, cruise reports, but may be insufficient for publication or analysis of sub-collected samples, observations, and measurements. We recommend that the Alvin operations group develop a protocol for generating a navigation product at sea for the science users. This data product should be similar to those produced by Jason and Sentry and take advantage of both USBL and DVL data streams. We recognize that the vehicles and their operations groups are not directly comparable, and that Alvin requires specialized personnel that, at present, may not be well suited for generating navigation data products.

Some expertise in programming, geospatial data analysis, and signal processing will be required in the development of any processing scheme for generating navigation data. In addition, some human intervention will likely be necessary in applying the processing scheme due to unique complications that may arise on any dive. One possibility is for on-shore personnel be tasked with taking raw data products generated by Alvin and producing navigation data. After reaching a stage where navigation data processing is routine and requires little intervention, those duties could be transferred back to on-board personnel (e.g., Alvin operations group or SSSG).

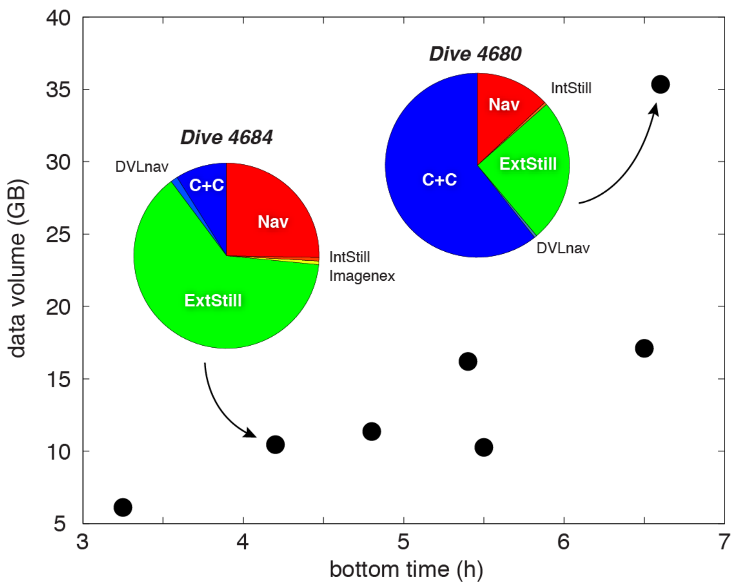
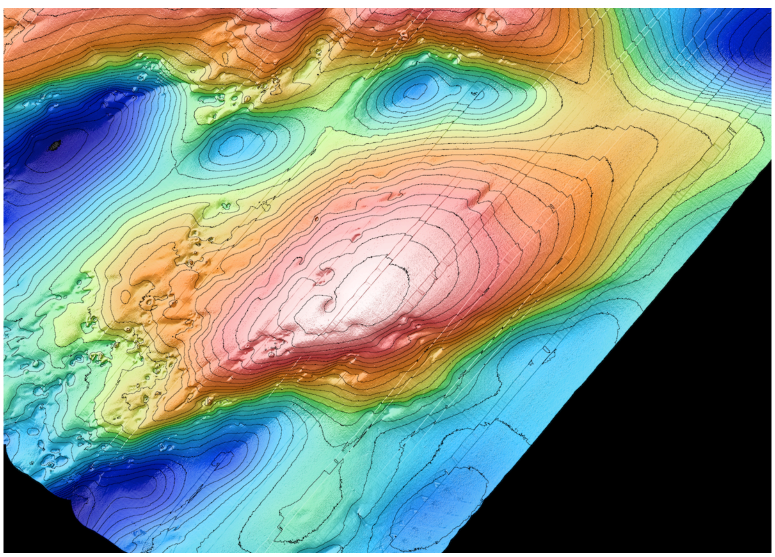


Figure 6: Total data volume (excluding video) is correlated with bottom time for the SVC dive series. The breakdown within each dive depends on the sensors used. For ALV4684, the External Still camera makes up the bulk of the total whereas for ALV4680 C+C data is the largest contributor.

Best Practices: Underlays

Science users can provide underlays for Alvin's onboard navigation system. A number of image file formats can be used (.png, .tif, .jpg, .bmp). It is recommended that image files are constructed at high resolution (e.g., 500 dpi), while ensuring that file sizes remain in a reasonable range (<30 MB). Image files should contain a bathymetric map or some other representation of the seafloor (e.g., sidescan sonar) in geographic coordinate system (e.g., WGS1984). On bathymetric data, contour lines at an interval of 5 m or less will typically be beneficial to seafloor navigation. Bathymetric maps with larger grid resolutions (e.g., from ship-based multibeam, >20 m) will definitely benefit from inclusion of contour lines. Multiple images may be displayed at the same time, varying the opacity of each. Images need to be accompanied by a 'world' file that provides the minimum and maximum longitude and latitude in decimal degrees. Below is an example underlay and associated 'world' file.



The world file is an ascii file with the following format:

```
[CORNERS]
LL_LAT=28.933333333
LL_LON=-88.205000000
UL_LAT=28.941666667
UL_LON=-88.205000000
UR_LAT=28.941666667
UR_LON=-88.191666667
LR_LAT=28.933333333
LR_LON=-88.191666667
```

In addition, a target text file can be supplied. Targets will appear as points (i.e. crosses) on the map with a label and can be toggled on/off by the pilot. Target files should be text files of comma-separated values for target_name, lon(dd), lat(dd). Although any name can be supplied for a target, a naming convention of Tgt1, Tgt2, … TgtN is beneficial as it keeps the in-sub nav screen from getting cluttered. An example is as follows:

Tgt1, -88.20384905, 28.93597022
Tgt2, -88.20167410, 28.93770155
Tgt3, -88.2015, 28.93829167
Tgt4, -88.1980833, 28.94083
Tgt5, -88.19625, 28.9420833
Tgt6, -88.19375, 28.944875

Targets supplied to TopLab should be in degrees-decimal-minutes as follows:

Tgt1 -88 12.2309 28 56.1582

Launch coordinates should be provided to the Alvin group and bridge (e.g., through the POD) in the same degrees decimal-minutes-formation

Best Pracitices: Getting sub navigation data

As of July 2015, there is no NDSF-provided solution for processing and delivering navigation data in a form that most science users will be familiar with. Science users have constructed some Matlab tools for parsing useful navigation data from the NDSF-supplied data files and these are described below. It should be noted that these are temporary solutions and they do not merge the USBL and DVL nav data into a single navigation data product.

Option A: Matlab scripts written by A. Soule reside on a desktop computer in the main science lab that will parse navigation data. There are two navigation records of interest. First, TopLab is recording USBL fixes for the sub. The frequency and quality of these positions depend on the dive depth. Second, there is the doppler position recorded in the sub. This is recorded at very high frequency and has good accuracy point-to-point, but will jump around as you reset the sub position to the USBL fix (due to drift in the doppler record).

Processing Alvin Nav Data on NICKEL in Computer Lab:
1. Make a directory for the dive on Nickel and copy data from data_on_alvin for that dive. You only need to copy three directories: c+c, nav, DVLNav_raw

Change the permissions on each directory to read+write for sci0. Right click on folder, select get info, at the bottom, click on read only for sci0 and change to read & write.

2. Open Matlab and change the current directory to the location you copied the Alvin data. There are three ways to do this…

- at the command line, use 'cd' and the path to the directory.
- in the upper right of the Matlab window, click the button '…' next to the current directory indicator and navigate there by pointing-and-clicking.
- drag the folder with the data into the matlab window.

3. To run toplab_usbl_parse.m, cd to DVLNav_raw (e.g., >> cd DVLNav_raw/), type toplab_usbl_parse at the command line. It produces three files AL4XXX_depth_usbl.eps, AL4XXX_track_usbl.eps, AL4XXXusbl.txt, all of them in DVLNav_raw.

The only human intervention needed in this script is to enter the dive number (e.g., AL4683) and to click on the on-bottom and off-bottom points on a plot of sub depth versus time. Once you have done that the code will produce a plot of the dive track, depth vs. time, and a comma-delimited text file of date, time, lon, lat, utmx, utmy, depth. USBL data is noisy, so the code will do a low-pass filter of the data to remove some noise. Filtering would happen in any nav processing algorithm, but just be aware that this is going on (you can see it in the plots). An example of the dive track and depth plots and csv file are attached.

4. To run vpr_parse.m, cd to nav directory (e.g., >> cd ../nav/), type vpr_parse at the command line to run. It produces four files AL4XXX_depth_sub.eps, AL4XXX_track_doppler.eps, AL4XXXsubdepth.txt, AL4XXXsubnav.txt, in the nav

directory.

Again, you will need to pick on- and off-bottom times. This time they will come from the sub record of depth. The code will then produce a plot of the sub track from the doppler (replete with position shifts due to resetting sub position to USBL fix). It will also produce two text files...sub postion: date, time, lon, lat, utmx, utmy and sub depth: date, time, depth.

Option B: A GUI was developed for these codes by E. Cole (Duke). It uses the same scripts, but provides a potentially simpler interface for executing the codes (see below).