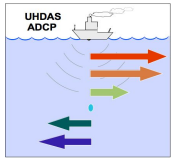


UHDAS ADCP Fundamentals

2023 NOAA Survey Tech Training
Newport, OR

Andrew Frambach, NOAA Affiliate

UHDAS 101 - Administrivia

What is UHDAS?

the **U**niversity of **H**awaii **D**ata **A**cquisition **S**ystem (...associated with ADCPs)

- "UHDAS" is:

  …the name of our group.
  …the collection of software that we provide and maintain.

- UHDAS is:
  - focused on both acquisition AND processing *(not your normal DAS)*.
  - specifically designed for the acquisition, quality control, processing, monitoring, and near real-time presentation of data related to shipboard ADCPs.
  - not affiliated with ADCP manufacturers.

UHDAS 101 - Administrivia

Who are UHDAS?

- The UHDAS team is a subset of the Currents group at the University of Hawaii, School of Ocean and
- Earth Science and Technology (SOEST).

- UHDAS Team: People and history
  https://currents.soest.hawaii.edu/home/people/

- We are a supplement to the on-board ship's technical personnel, we work **with** you.

UHDAS 101 - Administrivia

What services does UHDAS provide?

The UHDAS Team:

- installs and maintains software to acquire ADCP and ancillary sensor data;
- provides automated, near real-time, on-ship ADCP data analysis and displays;
  - Ex.: speedlog, maypole plot, ADCP contours (updated every new profile - 2 to 5 minutes)
- monitors the daily quality of ADCP and ancillary data;
  - 2 rotating team members read 35-50 emails per day, notify and engage with you concerning issues with your ADCPs, ancillary devices and feeds, NTP servers, etc.
  - A “second set of eyes” on your devices (eyes that open once every 24 hours…)
- facilitates the transport of the ADCP and ancillary data to an appropriate archive;
  - N2N development - a pipeline for ADCP data from ship to NCEI.

UHDAS 101 - Administrivia

Who does the ADCP data belong to?

The data collected are the property of **the sponsoring science agency.** With specific exceptions, ADCP data are neither final processed nor published by the UHDAS team.

Where does the ADCP data go?

The ADCP and ancillary data are usually distributed to:

- interested on-board science teams;
- an appropriate archive (R2R, NCEI, JASADCP,...);

UHDAS 101 - Administrivia

Where is UHDAS being used?

UHDAS is currently installed and running on 44 research vessels (with several more on the way) in the fleets of:

- **UNOLS** (University-National Oceanographic Laboratory System) **ARF**; *(17 ships)*
- **NOAA** (National Oceanic and Atmospheric Administration); *(11 ships)*
- **CSIRO** (Commonwealth Scientific and Industrial Research Organisation, Australian Government); *(1 ship)*
- **IMR** (Norwegian Institute of Marine Research); *(2 ships)*
- **NOC** (British National Oceanography Centre); *(2 ships)*
- **RCCL** (Royal Carribean Cruise Lines); *(2 ships)*
- **NSF** (National Science Foundation) Polar Programs; *(2 ships)*
- **SOI** (Schmidt Ocean Institute); *(1 ship)*
- **U.S. Coast Guard**; *(1 ship)*
- and various voluntary observing ships *(3 ships)*

UHDAS 102 - ADCP Basics

Acoustic **D**oppler **C**urrent **P**rofilers

- Measures a vertical profile of ocean currents in Earth-relative coordinates down to some depth below the ship.

Who makes ADCPs?

- Teledyne RDI - supported by UHDAS since the beginning.
- Kongsberg - now (mostly) supported by UHDAS.
- Nortek - not supported by UHDAS.

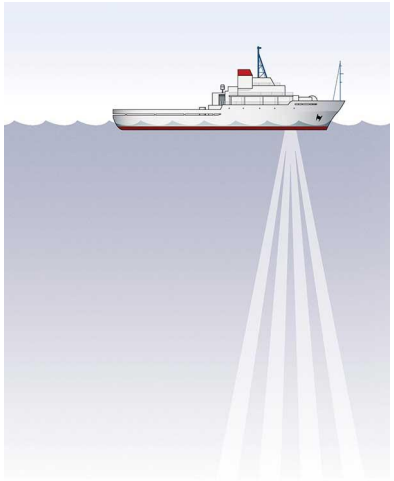
UHDAS 102 - ADCP Basics

Acoustic Sonars

- ADCPs are sensors that use sound to measure the aquatic environment by transmitting acoustic signals and listening for the returns (echoes) of the reflected transmissions.

Types of ADCPs

- Lowered ADCP
  - like on a CTD.
- Moored ADCP
  - to the side of a pier, oil platform, fishing trawl, etc.
  - bottom-mounted, on a platform facing up.
- **Shipboard ADCP**
  - in the hull of a ship, facing down.



UHDAS 102 - ADCP Basics

Doppler Effect

- The frequency shifts coming and going: like a train or motorcycle.
- The shift in frequency (Doppler shift) of a returning signal gives the relative speed and direction, along the beam (1 dimension), of the object that reflected the signal.

Underwater

- We know the frequency (pitch) of sound that we transmitted. We measure the difference in the returned signal.
- Positive difference = current is moving away from us.
- Negative difference = current is moving towards us.
- Speed of sound in water
    - Affected by temperature, salinity, pressure, but those are functions of depth.

UHDAS 102 - ADCP Basics

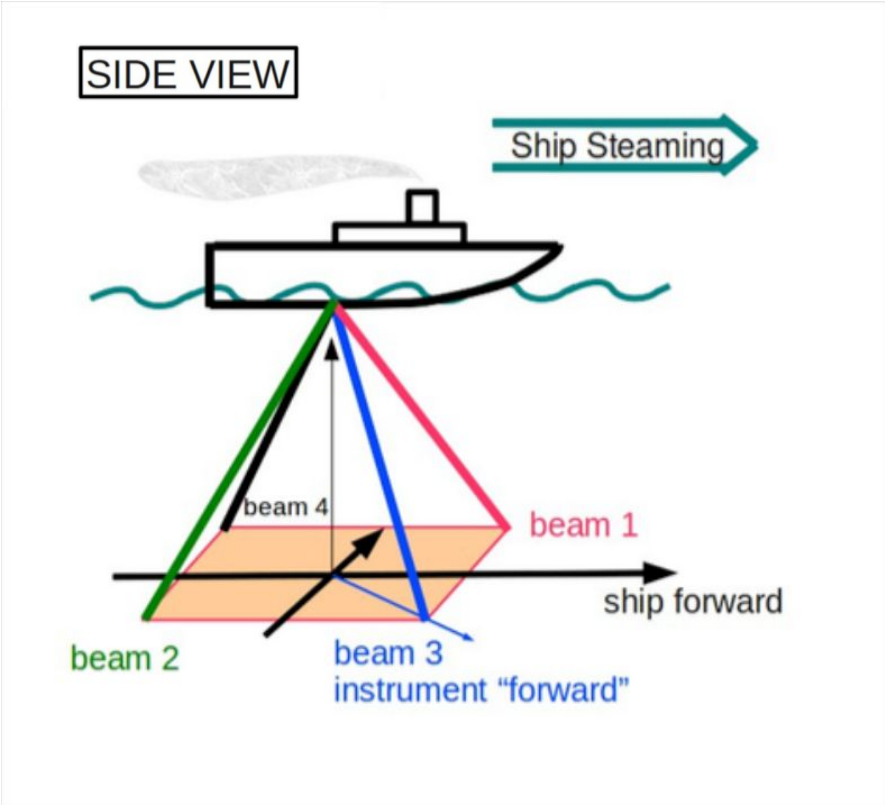
Current

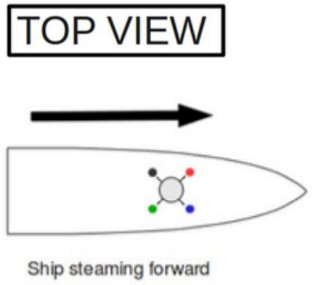
- The flow of the water, speed and direction, Earth-relative.
- The ADCP measures current relative to ship, we use accurate headings from some other device to rotate to Earth-relative coordinates.

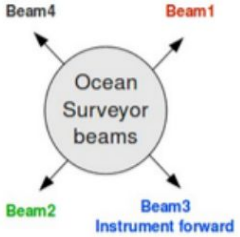
Basic ADCP Operation

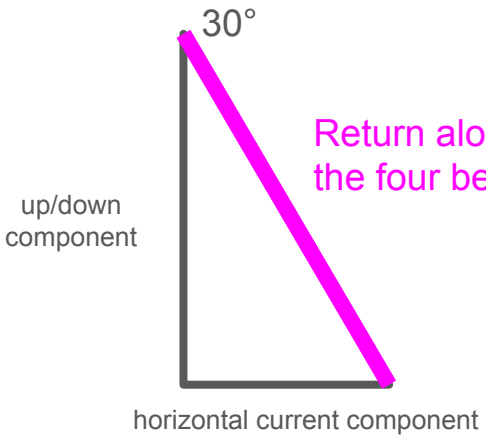
- ADCPs simultaneously transmit along 4 (usually) beams oriented 20 deg or 30 deg up from the vertical, in a crosshair.
- Each beam can be separated into components (up/down is vertical velocity, out/in is current).
- By combining the Doppler returns from all 4 beams, the relative horizontal speed and direction (in 2 dimensions) of the scatterer can be determined (which is equal to the current of the water that it is in).

UHDAS 102 - ADCP Basics



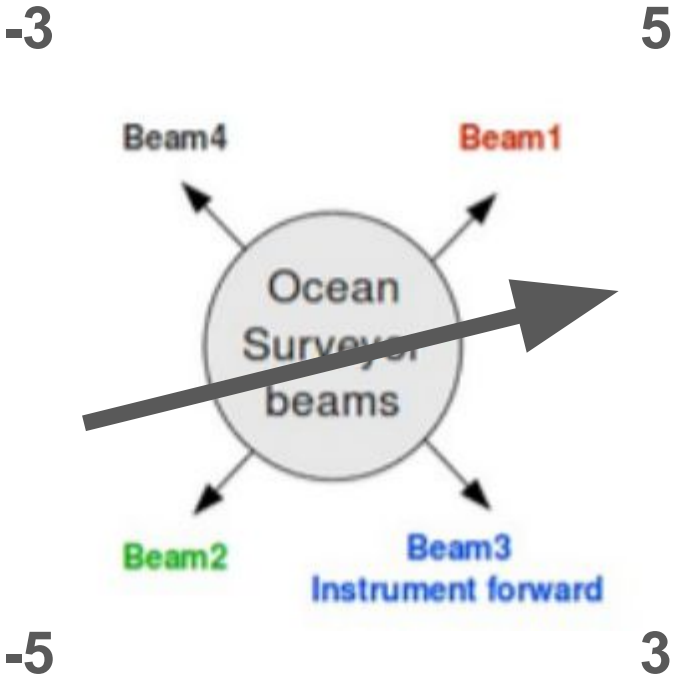






Return along just one of the four beams

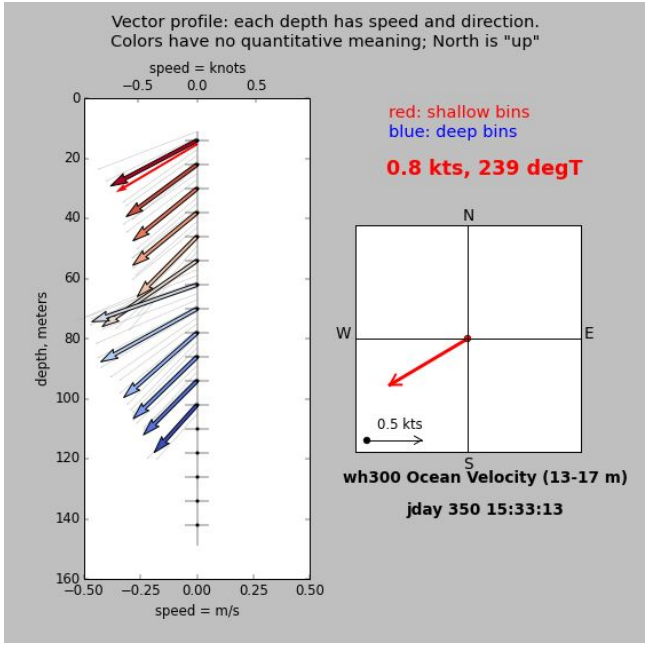
UHDAS 102 - ADCP Basics



UHDAS 102 - ADCP Basics

Profiler

- Returns from multiple reflectors are combined to build a vertical profile of the speed and direction of the water at various depths below the ship.



Slicing the Water Column into Bins

- The elapsed travel time (duration between transmission and return) of one ping return divided by two gives us the distance (depth, 3rd dimension) of the reflector, given the speed of sound in water at that depth.
- The water column is then divided into uniform bins of depth, we call this the vertical profile.
- The size of the bin is determined by the user up to a point…
  - there is a relationship between ADCP frequency and the finest vertical resolution needed to adequately sample the water column.

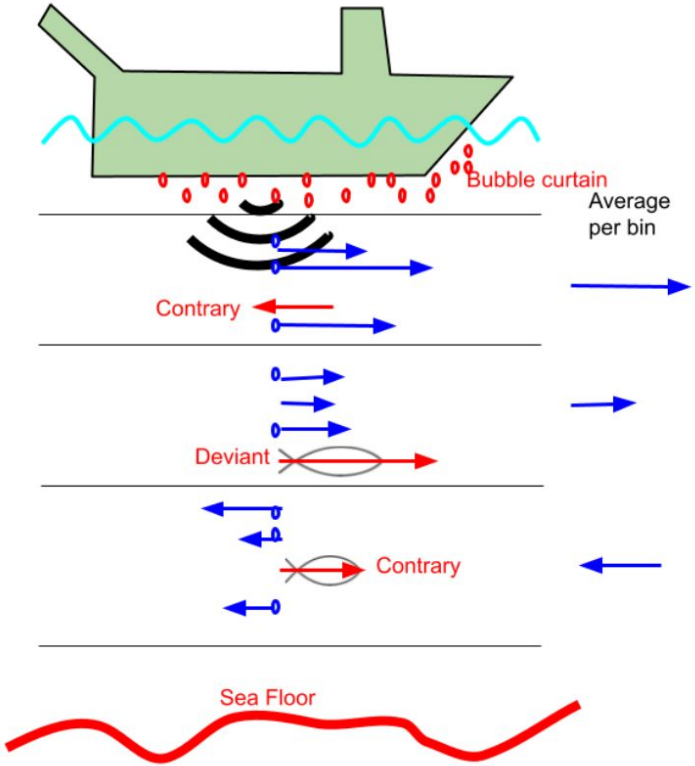
UHDAS 102 - ADCP Basics

Types of Reflectors/Scatterers

- The ADCP is an active sensor, meaning that it transmits a pulse of energy and then listens for a return.
- The sound waves reflect off objects in the water, rather than the water itself.
- Some types of reflectors have a deleterious effect on the overall ADCP data.

The Good:

- Anything small, floating passively in the water.
  - Ex. phytoplankton, tiny bubbles, detritus, suspended sediments, etc



UHDAS 102 - ADCP Basics

Types of Reflectors/Scatterers

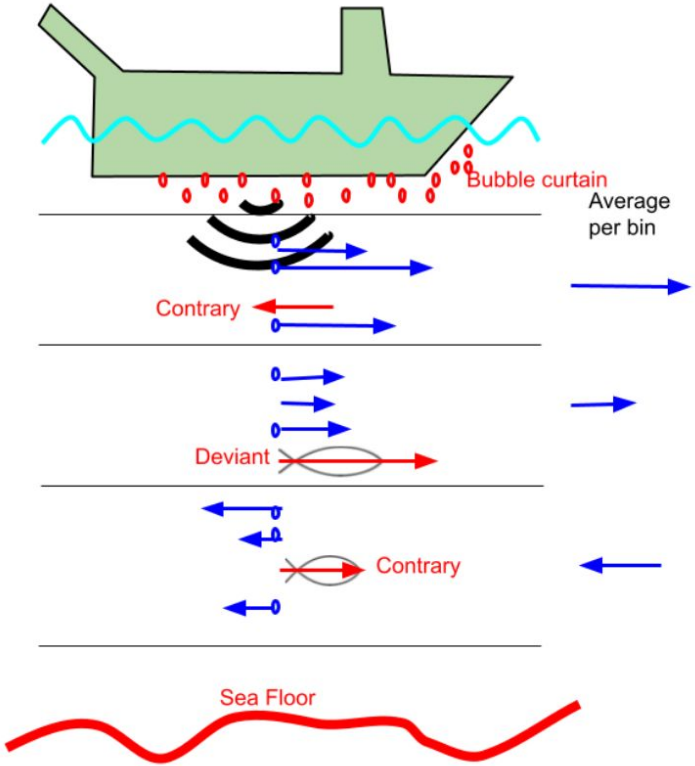
- The ADCP is an active sensor, meaning that it transmits a pulse of energy and then listens for a return.
- The sound waves reflect off objects in the water, rather than the water itself.
- Some types of reflectors have a deleterious effect on the overall ADCP data.

The Bad:

- Anything moving and loud.
  - Ex. fish, density gradients

The Ugly:

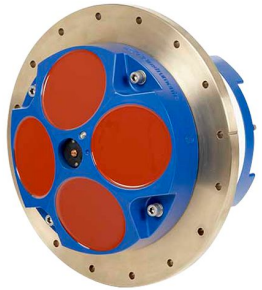
- Anything that actively blocks all the sound.
  - Ex. bubble sheets under the ship, the sea floor, whales?



UHDAS 102 - ADCP Basics

ADCPs - RDI Default/Typical Depth Ranges and Resolutions

ADCP Frequency (kHz)	Vertical resolution (bin size), meters	Default Ringing Distance (meters)	Bin #1 Center (meters) (eg. 5m hull)	Typical Maximum Depth Range (meters)	Shallowest ocean depth for valid Bin #1 Center
os38nb os38bb	12 24	12 12	41 29	1100 900	61 40
os75nb os75bb	16 8	6 6	27 19	700 600	40 26
os150nb os150bb	8 4	5 5	18 14	300 200	25 19
wh300, sv300	2	2	9	80	11
wh600	1	1	7	30	8



UHDAS 102 - ADCP Basics

Ping Modes

- **Narrowband:** robust, 10-20% deeper nominal maximum depth, half the vertical resolution as broadband, narrower and longer pulse;

- **Broadband:** fragile, 10-20% shallower nominal maximum depth, twice the vertical resolution as narrowband, coded pulse;

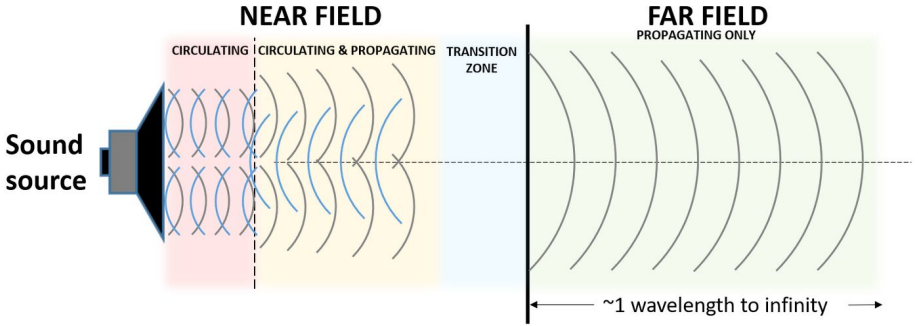
- **Bottom-tracking:** only listening for the bottom, useful ONLY for transducer alignment or loss of accurate heading device (POS MV, Seapath, ABX-Two, …), noisy;

Ringing

- Ringing is the swamping of the return signal due to the energy of the reverberation of the transducer elements in the near field, immediately after a fresh pulse is sent.

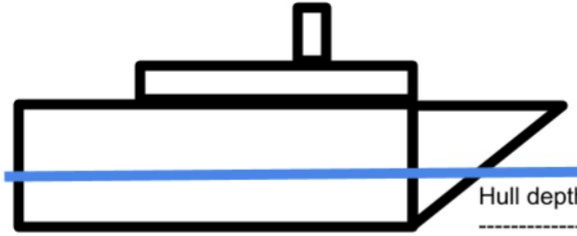
Vibrating Transducer Elements

- …don't immediately stop vibrating when the electricity is turned off, they are dampened with time instead.
- Effect can be enhanced by bubble curtains, ship pitch/roll (weather), near transducer turbidity, mounting of the transducer.



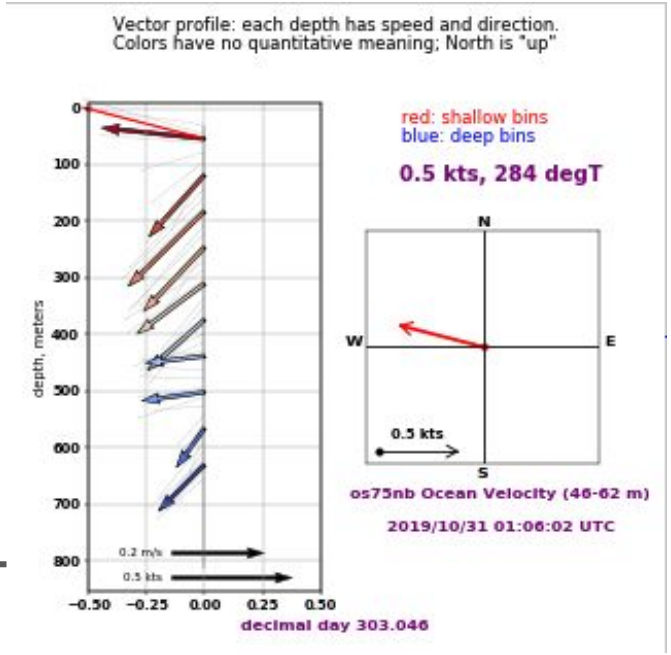
UHDAS 102 - ADCP Basics

Minimum Working Depth

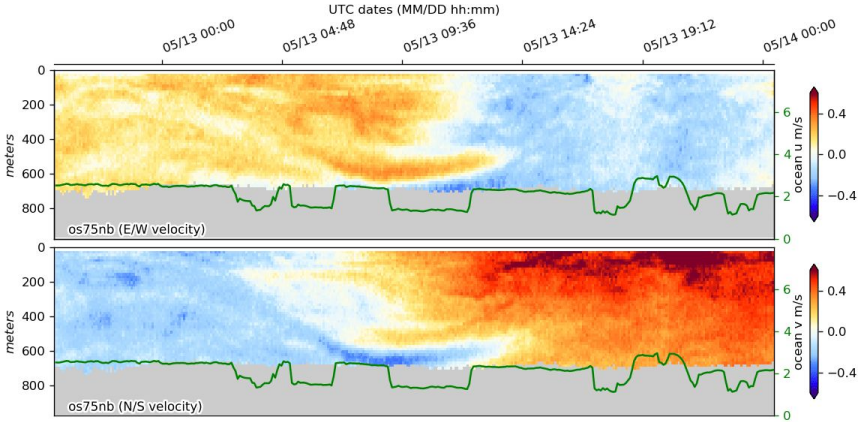


Massively oversimplified calculation of minimum water depth necessary to resolve valid currents.

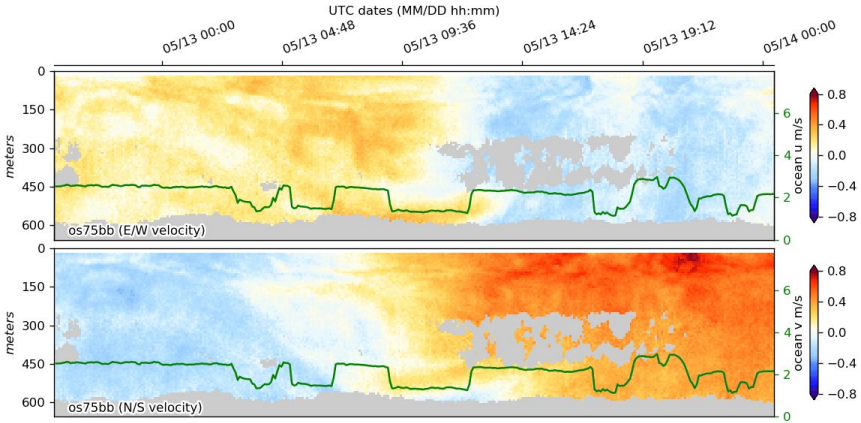
os150bb		depth	os150nb
	4 m bins		8 m bins
Hull depth	5 m		5 m
		5 m	
ringing / blanking	6 m		6 m
		11 m	
gap (math)	2 m		
		13 m	gap 4 m
		15 m	
Bin 1	4 m		
		17 m	
Bin 2	4 m		Bin 1 8 m
		21 m	
Side lobe (15% of 24) = 3 m		23 m	
		24 m	
			Bin 2 8 m
		31 m	
		Side lobe (15% of 35 m) = 5 m	
		36 m	



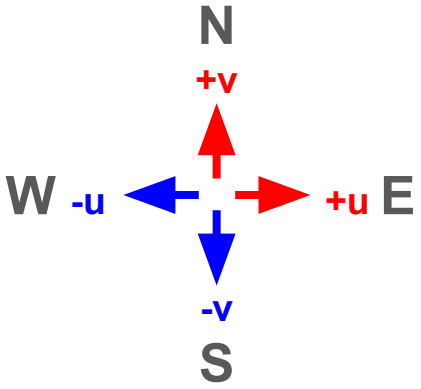
UHDAS 102 - ADCP Basics



Narrowband



Broadband



UHDAS 103 - UHDAS Processing and Operations

UHDAS…

– is a collection of programs, procedures, and configurations installed on Linux for use with multiple ADCPs;
– has a nested directory structure;
– stores raw (*.raw), intermediate components (*.rbin files);
– transforms, edits, averages, and stores the data products;
– leverages **CODAS** processing

CODAS

Core processing algorithms

GUI and command line tools for post-processing

Free and open source software

https://currents.soest.hawaii.edu/docs/adcp_doc/index.html

When is processing done?

- **At Sea:** processing is done in real time while recording, provides users with 5-min plots, data analysis, near-real time currents for operations.
- **At Home:** using free and open source CODAS software, the raw data may be processed again to fix errors, switch out ancillary devices, etc; any processed dataset may be post-processed by data users for greater data quality (manually remove bad data, adjust calibrations, etc).

UHDAS 103 - UHDAS Processing and Operations

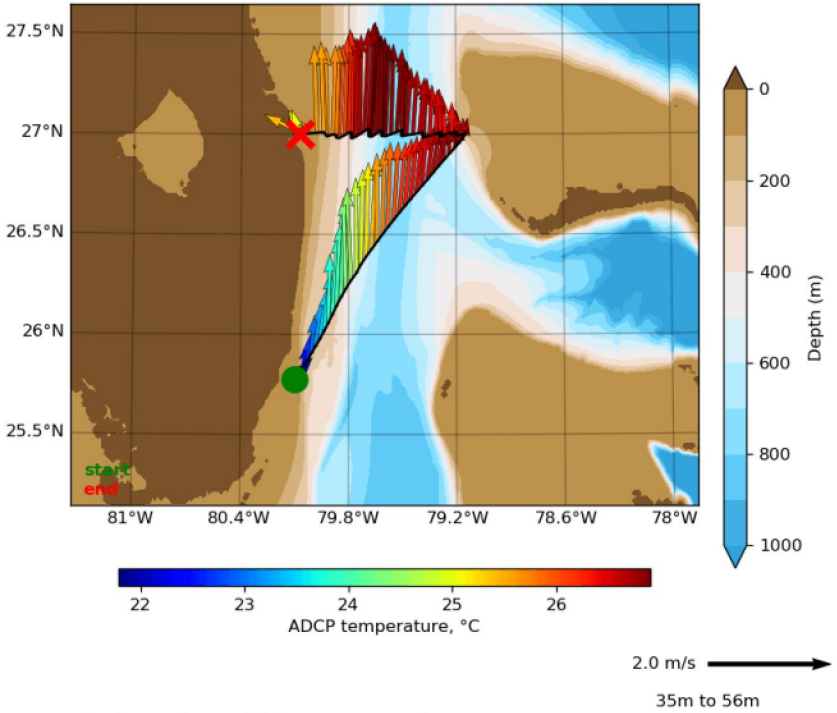
ADCP Data → Ocean Currents

ADCP single-ping data

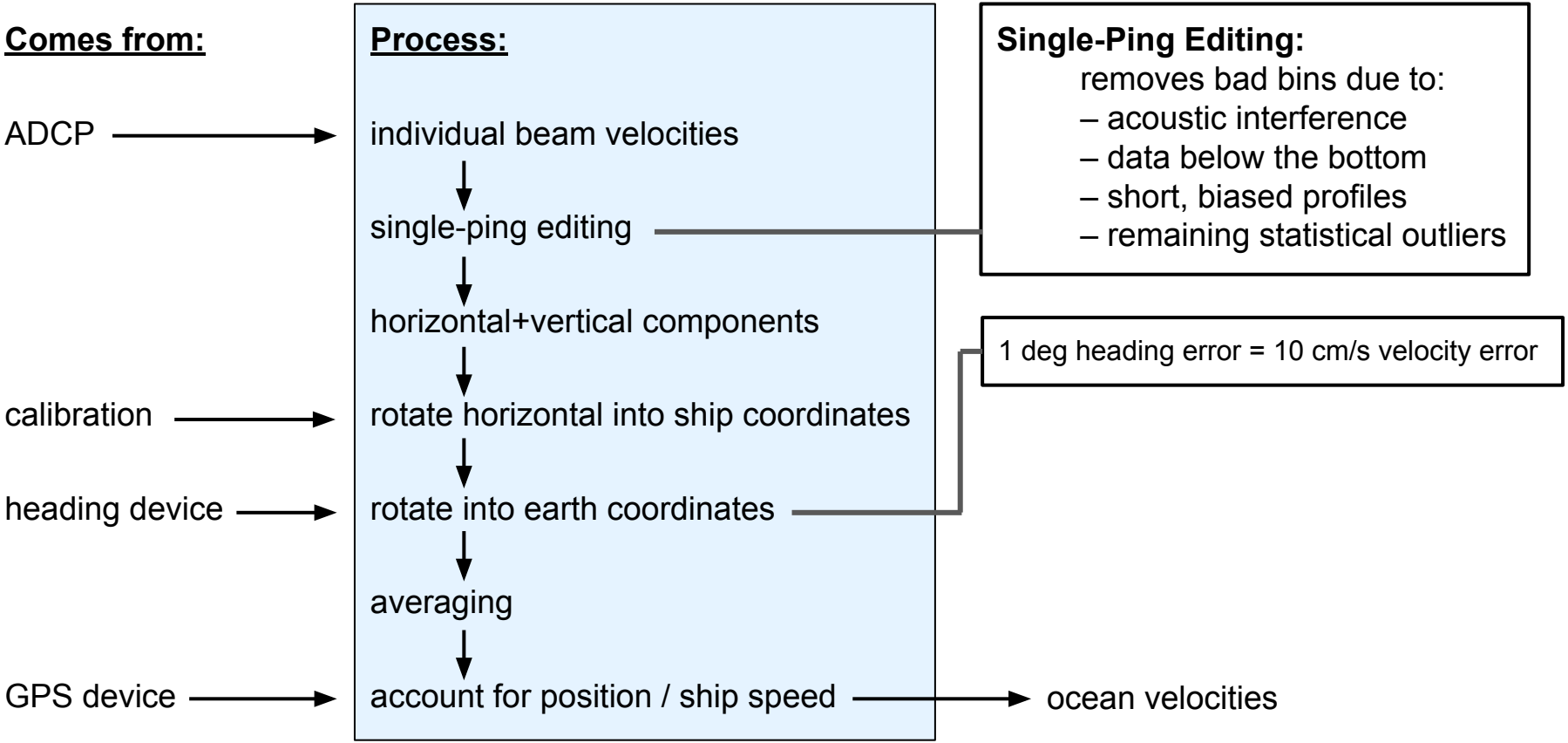
Time

GPS position

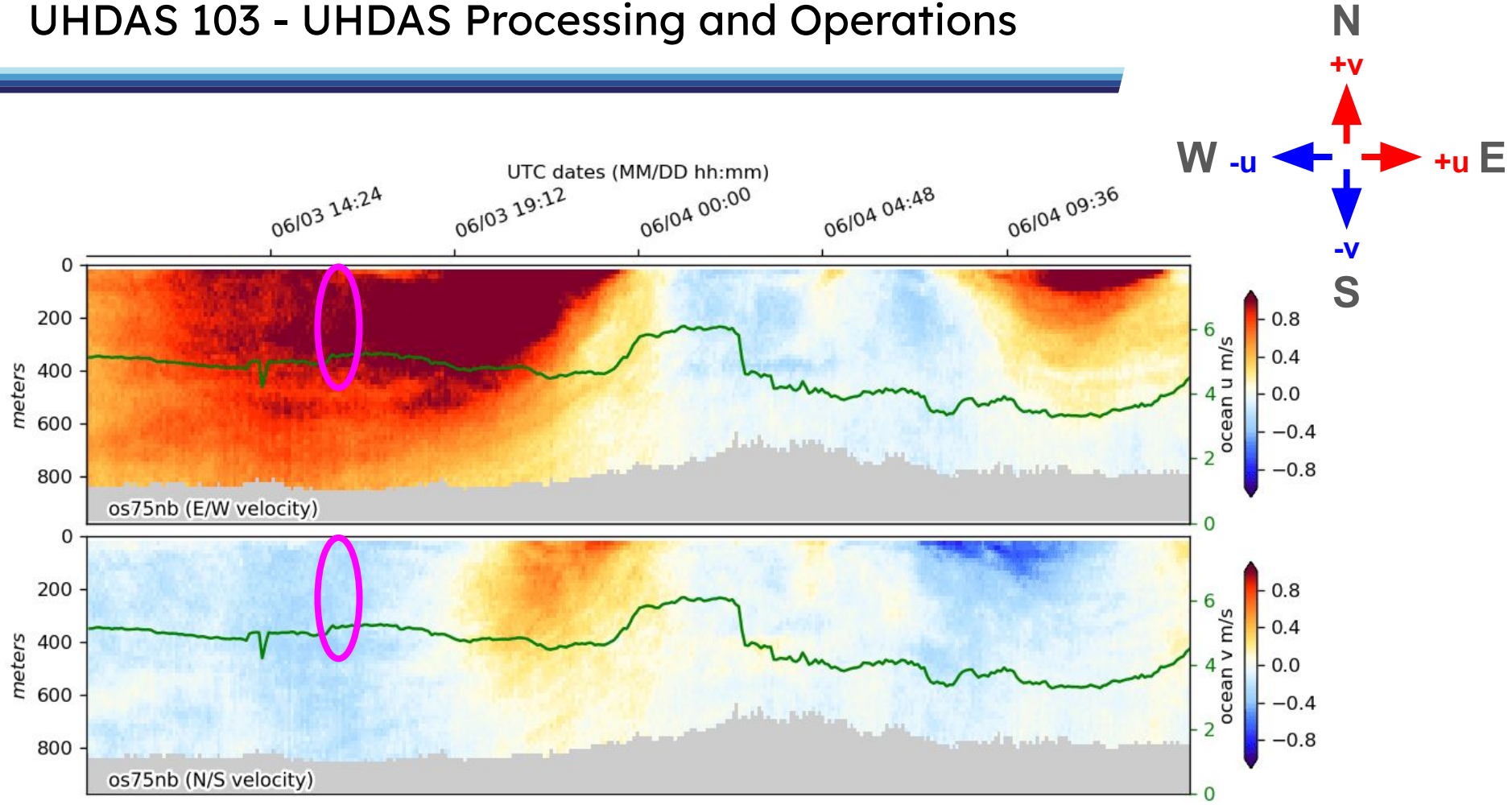
Heading



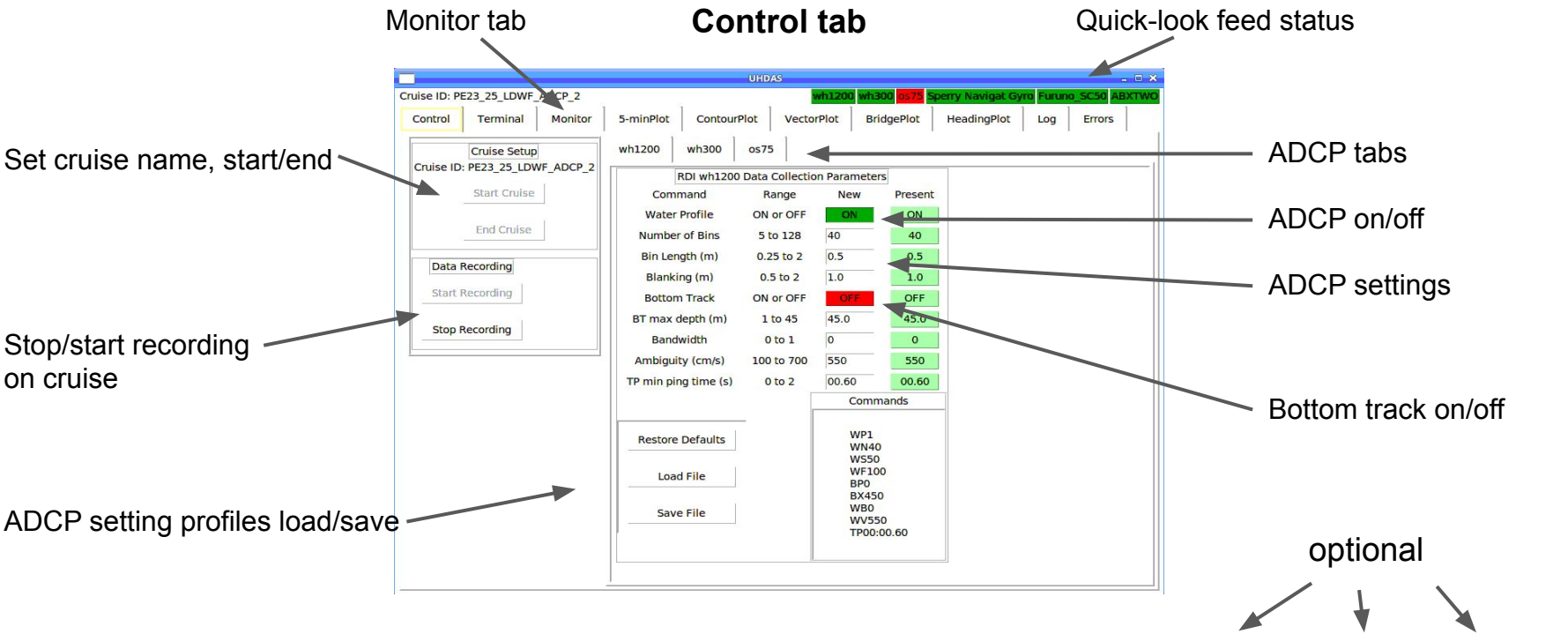
UHDAS 103 - UHDAS Processing and Operations



UHDAS 103 - UHDAS Processing and Operations



UHDAS 103 - UHDAS Processing and Operations

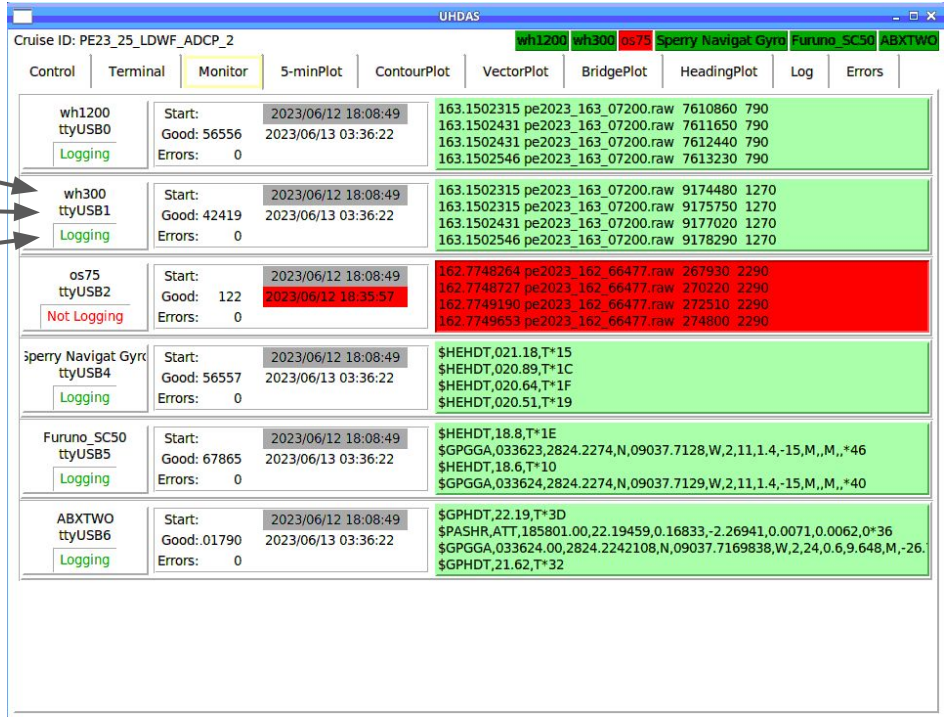


NOAA Cruise Naming: <ship letters><fiscal year><cruise number>_<cruise name>_Leg#_<extra>

Example: SE2303_HICEAS_Leg5

UHDAS 103 - UHDAS Processing and Operations

Monitor tab



Device

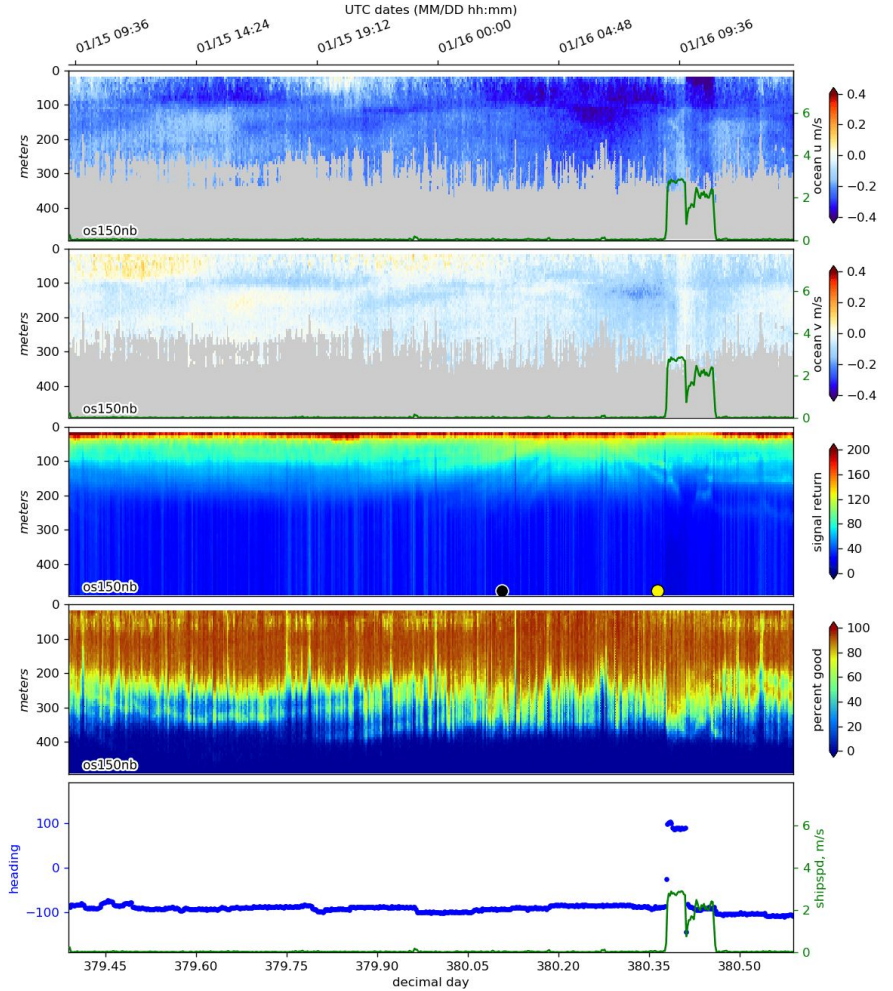
Port

Status

Real-time feed monitoring
GREEN = logging
RED = not logging, maybe something wrong

UHDAS 104 - Common Data Artifacts

What's Wrong?



379.39 to 380.59 (1.20 days)

2023/01/15 09:23 to 2023/01/16 14:11

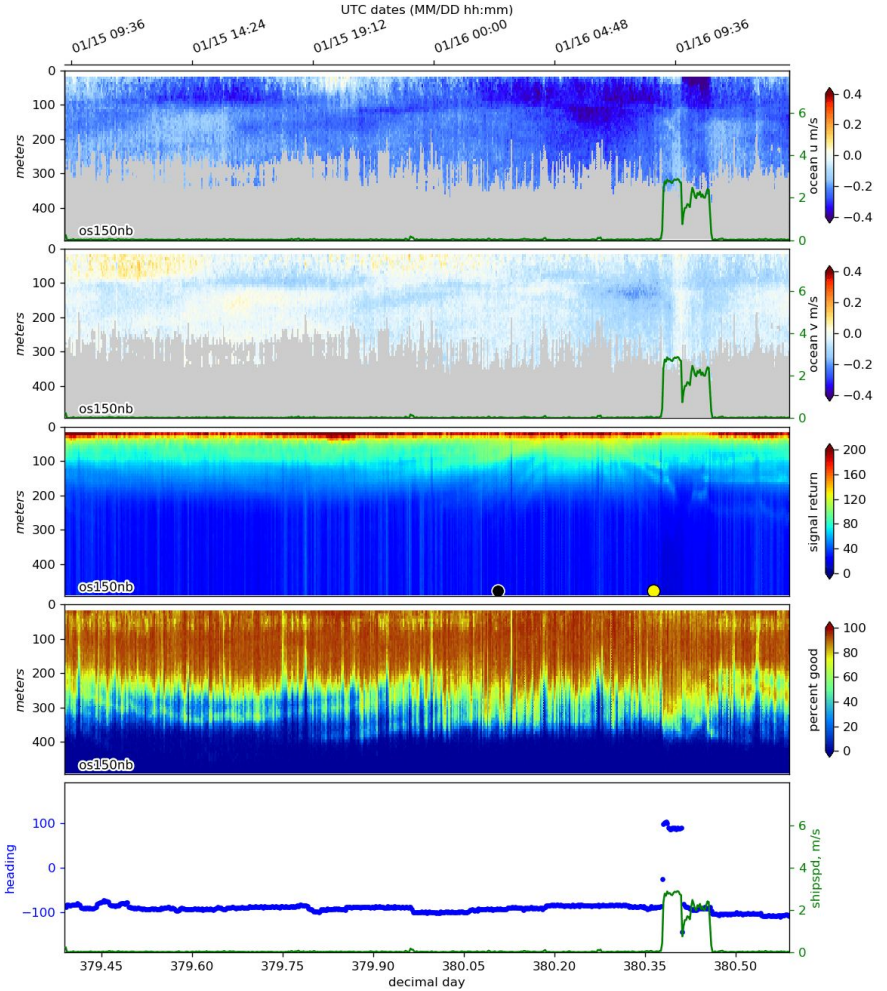
UHDAS 104 - Common Data Artifacts

What's Wrong? Bubbles

Severity: **Moderate**

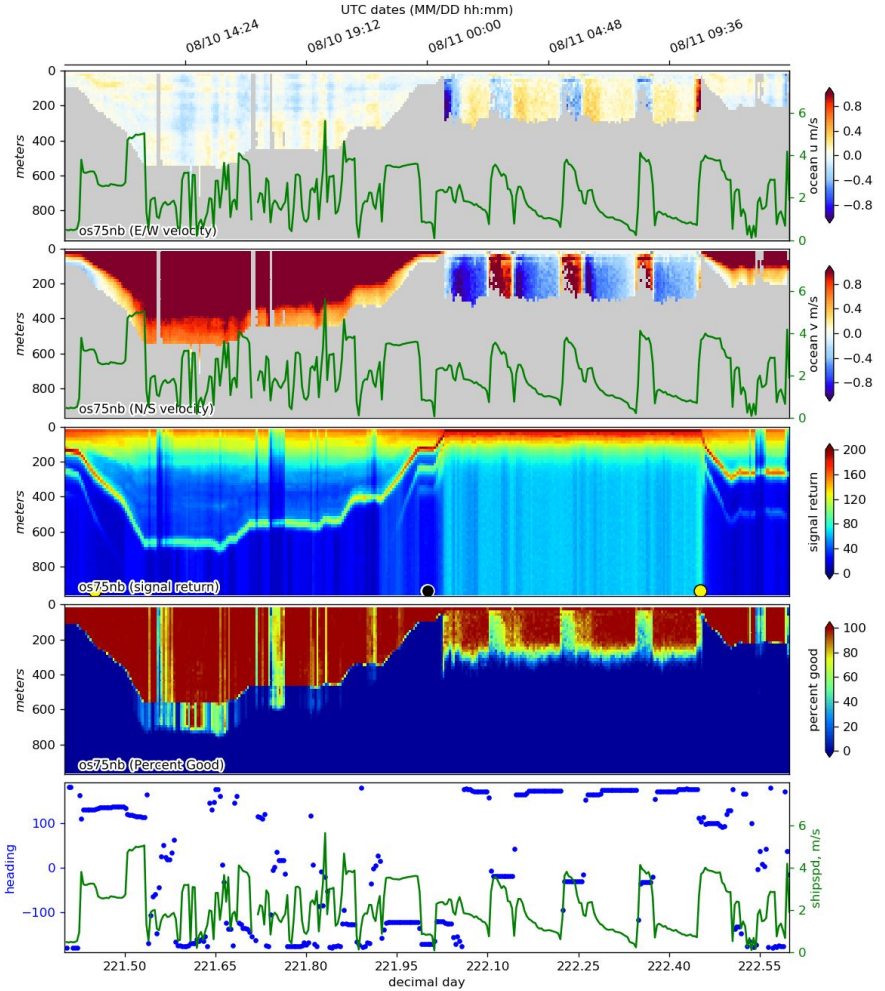
Details:

- Cause:
  1. bubbles under the ADCP transducer block the sound from being transmitted very far.
- Related causes:
  1. inclement weather and/or ship rolling;
  2. ship design / travelling at high speeds;
  3. bow thruster, maneuvering to maintain position.
- Solution:
  - Narrow-band mode.
  - If ADCP data is particularly important on this cruise, avoid the above where possible.
  - Cannot be mitigated in post-processing.



UHDAS 104 - Common Data Artifacts

What's Wrong?



221.4 to 222.6 (1.20 days)

2023/08/10 09:41 to 2023/08/11 14:27

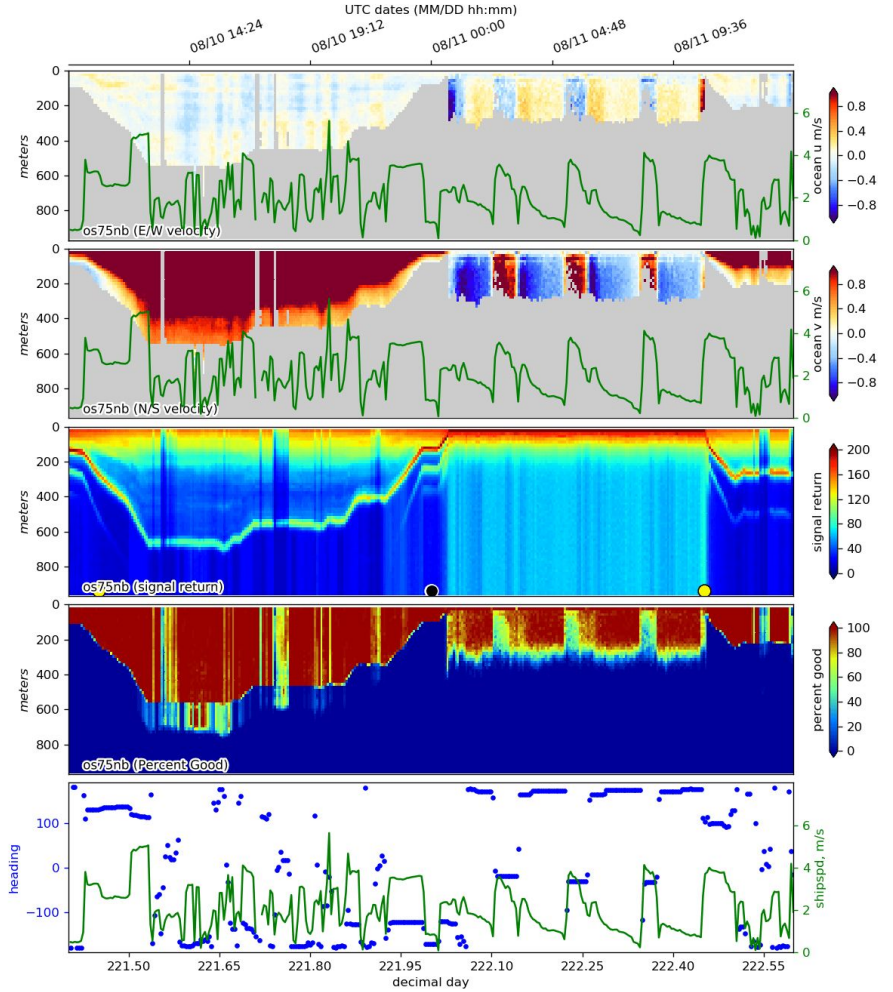
UHDAS 104 - Common Data Artifacts

What's Wrong? Bottom Interference

Severity: **Non-Issue**

Details:

- Cause:
  1. if the seafloor is close enough to the ADCP, bottom detection no longer works and the sound reverberates between the bottom and the hull of the ship.
- Solution:
  - Can be edited out in post-processing.

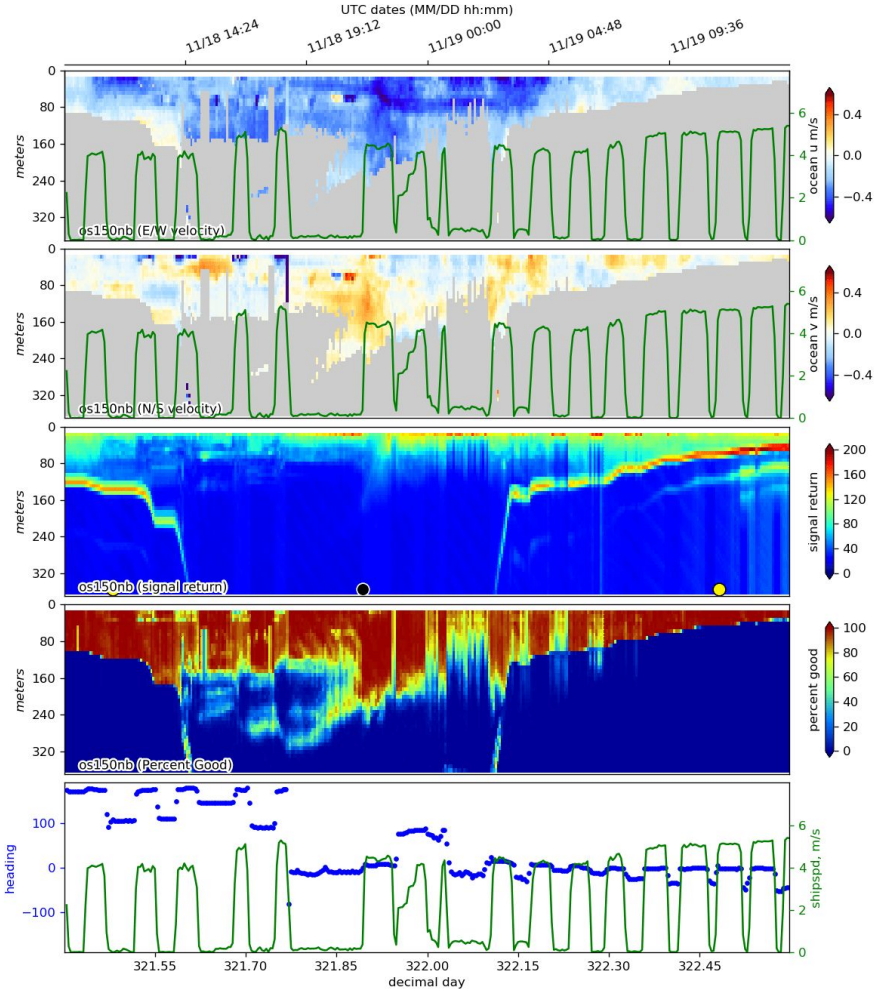


221.4 to 222.6 (1.20 days)

2023/08/10 09:41 to 2023/08/11 14:27

UHDAS 104 - Common Data Artifacts

What's Wrong?



321.4 to 322.6 (1.20 days)

2023/11/18 09:41 to 2023/11/19 14:25

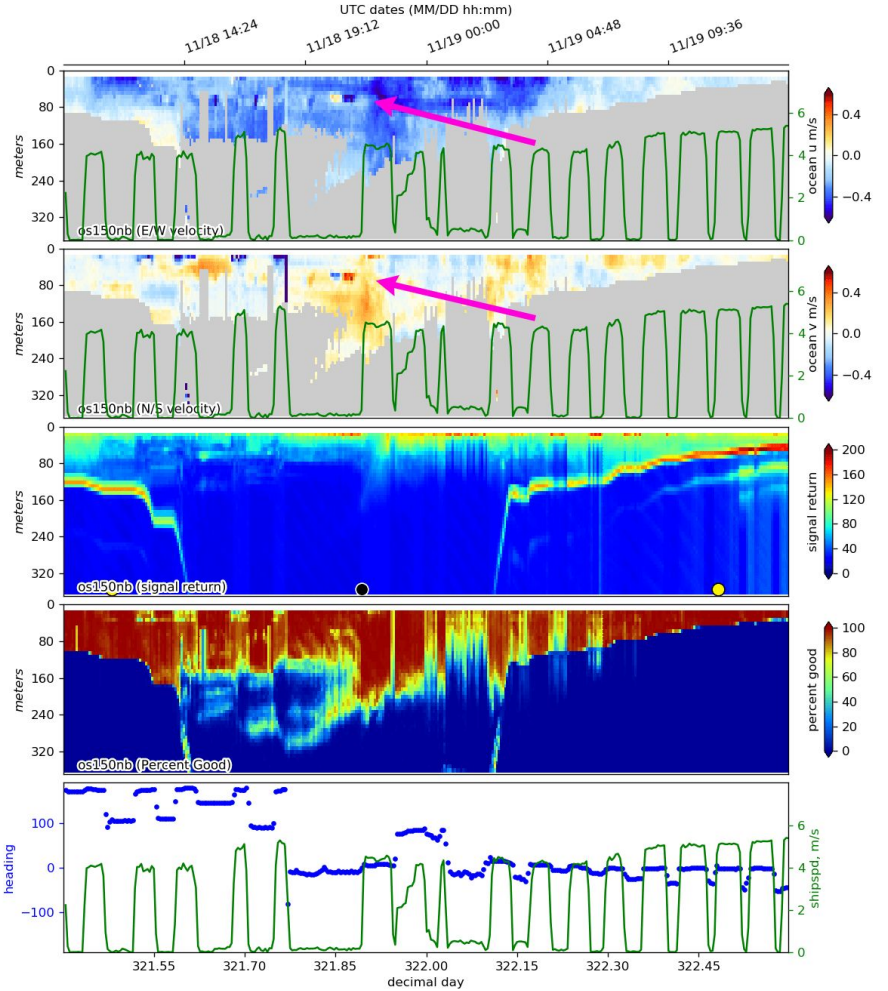
UHDAS 104 - Common Data Artifacts

What's Wrong? CTD Wire Interference

Severity: **Low**

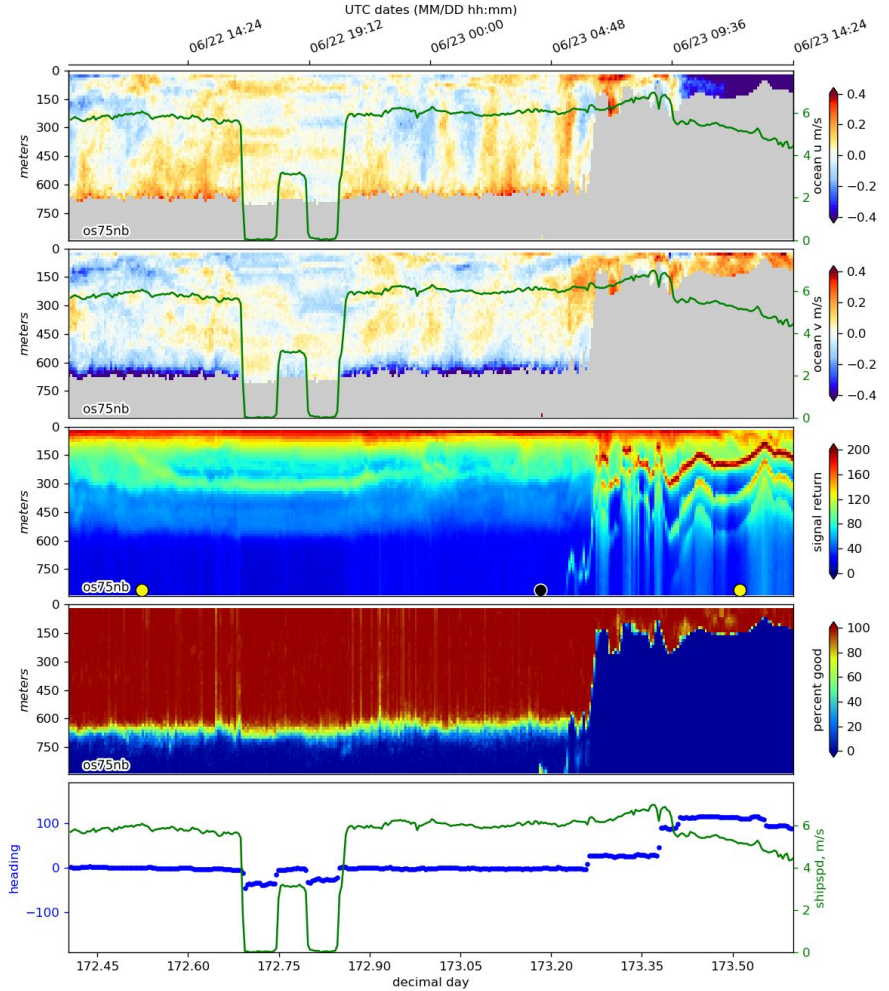
Details:

- Cause:
  1. the CTD is being dropped directly in the path of an ADCP beam, and the beam is detecting the wire that is hanging the package.
- Solution:
  - If at all possible, consider dropping the CTD from another part of the ship.
  - Change the rotation of the ADCP in the hull during the next overhaul.
  - Can be edited out in post-processing, though the data in that one area is lost.



UHDAS 104 - Common Data Artifacts

What's Wrong?



172.41 to 173.6 (1.20 days)

2021/06/22 09:44 to 2021/06/23 14:29

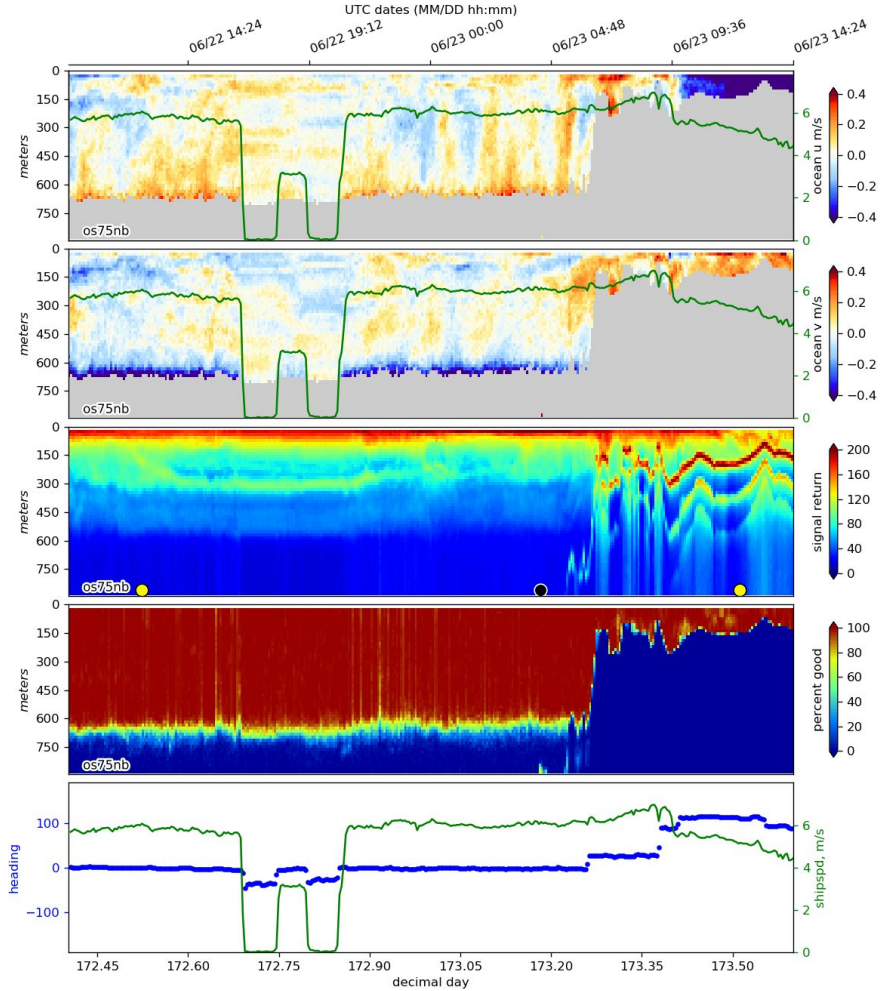
UHDAS 104 - Common Data Artifacts

What's Wrong? Electrical Interference

Severity: **High**

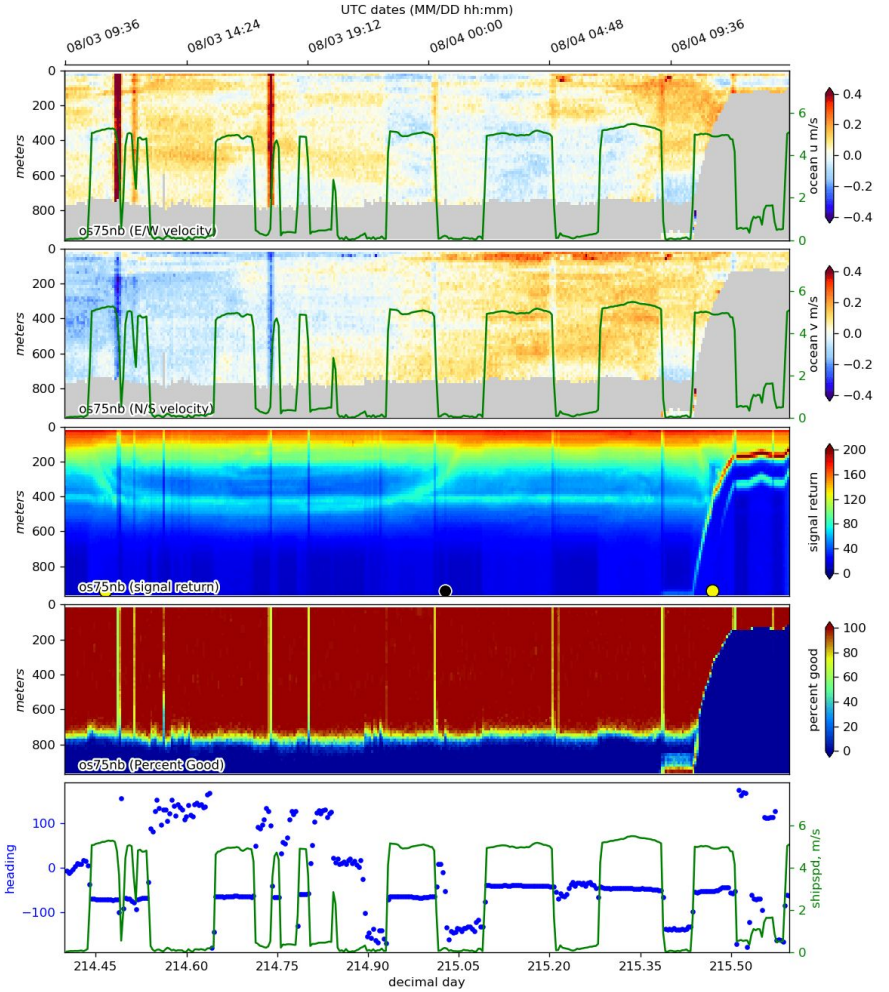
Details:

- Cause:
  1. the cable running from the ADCP to the deck box of an Ocean Surveyor is being impacted somewhere along the line by a strong enough EM field to disrupt the data signal.
- Affects Ocean Surveyors, but not typically Workhorses.
- When it happens, it's usually after some sort of overhaul period (think back, what has been changed?)
- Solution:
  1. Identify the source of the interference, and secure it if possible.
  2. Mitigation algorithm (a partial solution).
  3. Move the deck unit closer to the transducer.
  4. Keep cables separate wherever possible.



UHDAS 104 - Common Data Artifacts

What's Wrong?



214.4 to 215.6 (1.20 days)

2023/08/03 09:38 to 2023/08/04 14:23

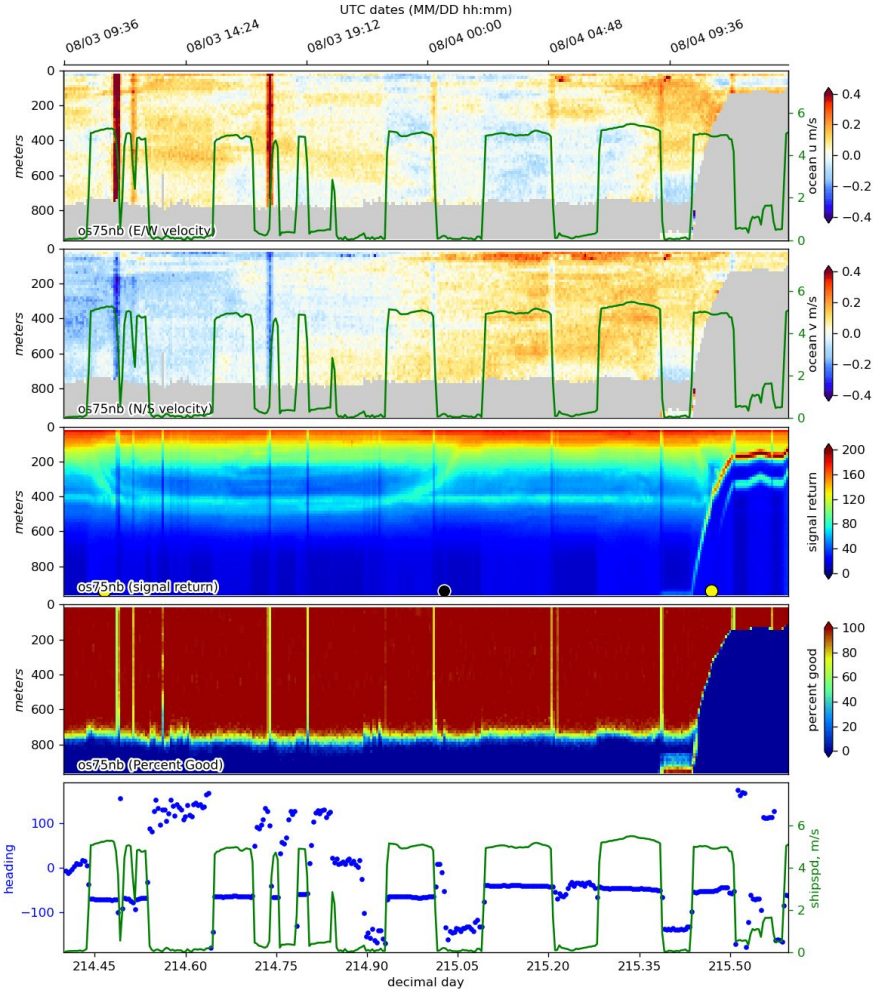
UHDAS 104 - Common Data Artifacts

What's Wrong? Calibration Error - GPS

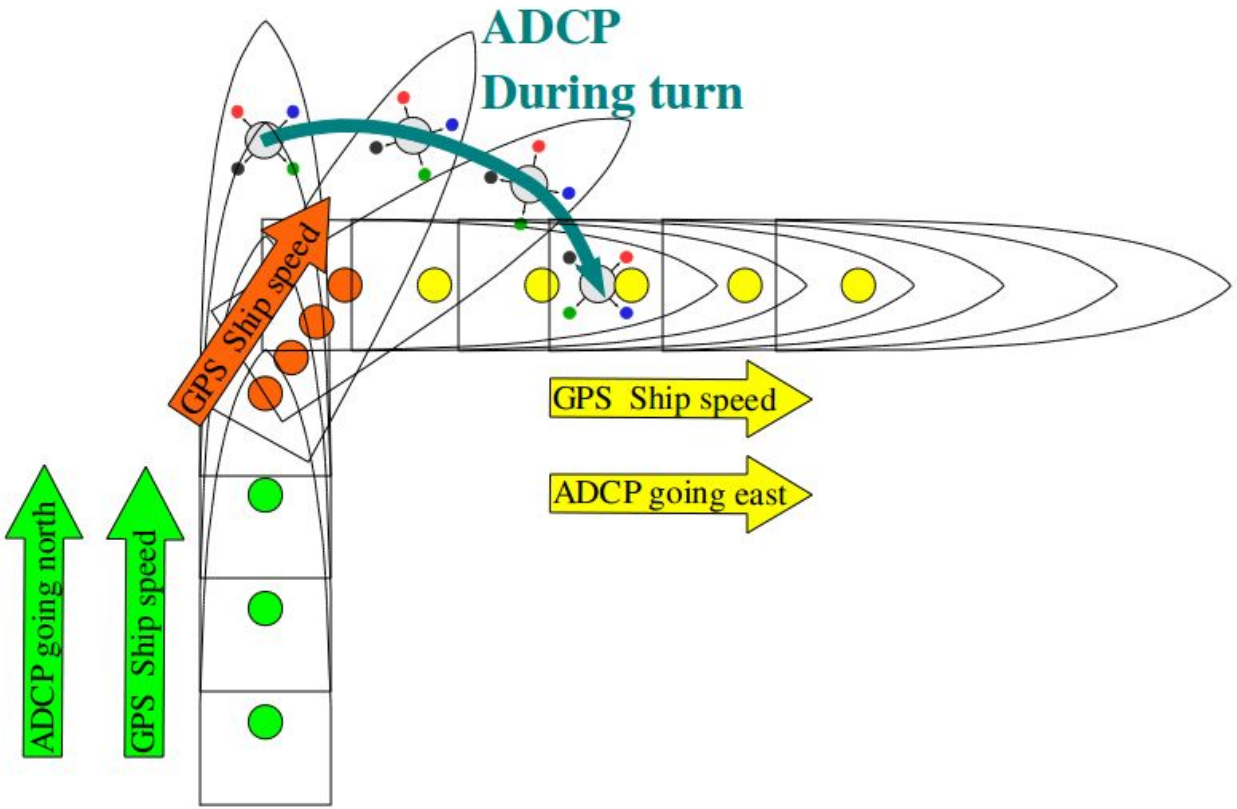
Severity: **Moderate**

Details:

- Cause:
  1. the calibration value that defines the horizontal overhead distance between the GPS transceiver and the ADCP transducer needs adjusting.
- Related causes:
  1. an antenna has been moved;
  2. the primary GPS position device for the ADCP was switched to another whose antenna is in another part of the ship.
- Solution:
  - UHDAS staff will adjust the calibration after this cruise, if the calibration estimation numbers gathered during this cruise are sound.
  - This cruise may be reprocessed with different calibration values.

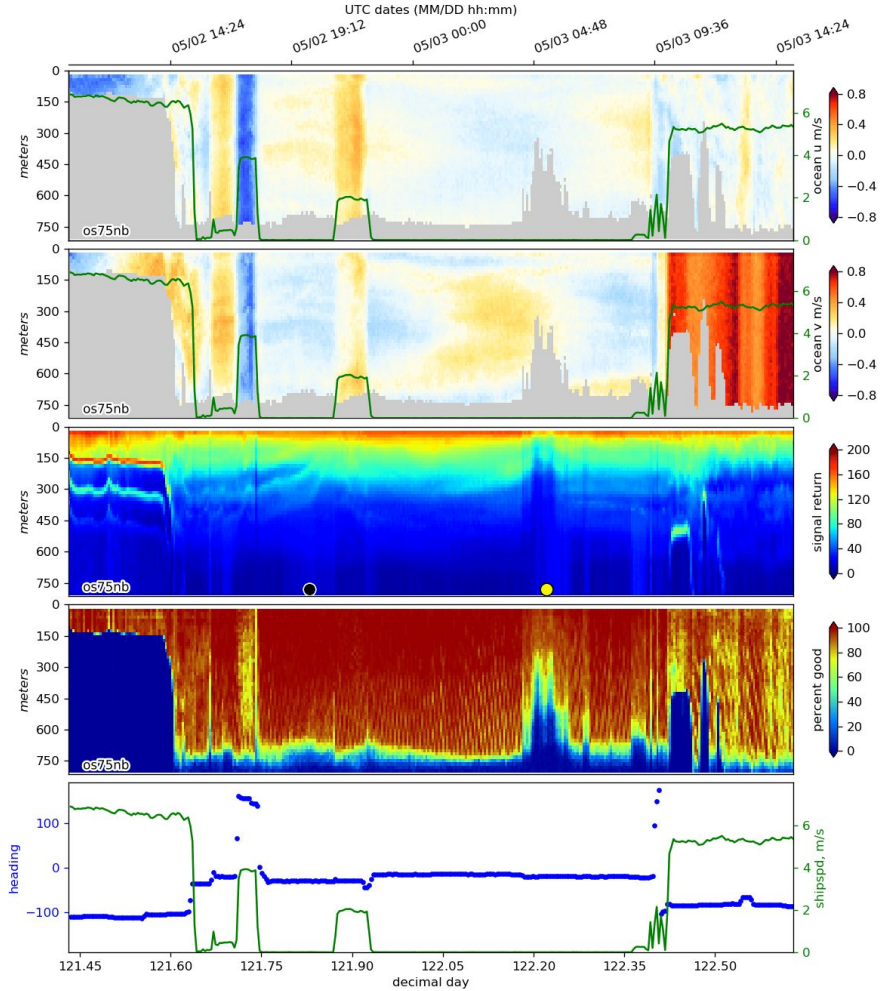


UHDAS 104 - Common Data Artifacts



UHDAS 104 - Common Data Artifacts

What's Wrong?



121.43 to 122.63 (1.20 days)

2022/05/02 10:26 to 2022/05/03 15:11

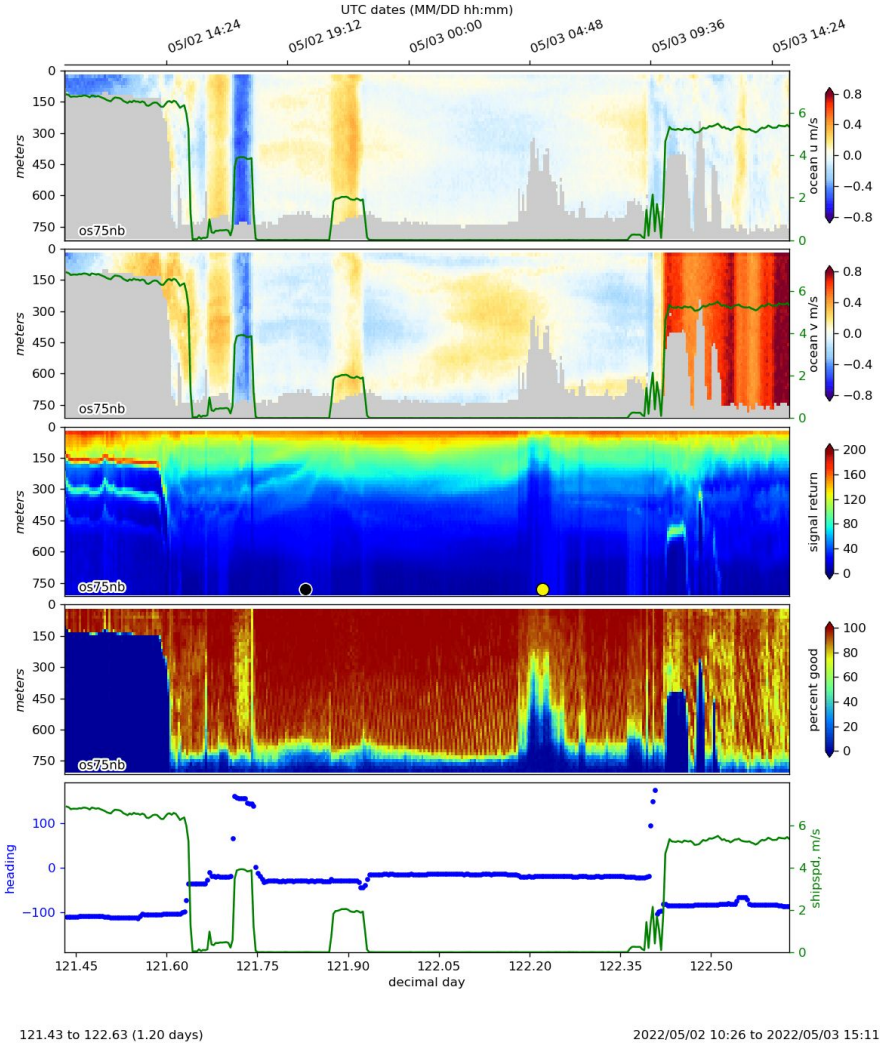
UHDAS 104 - Common Data Artifacts

What's Wrong? Calibration Error - Phase

Severity: **Moderate**

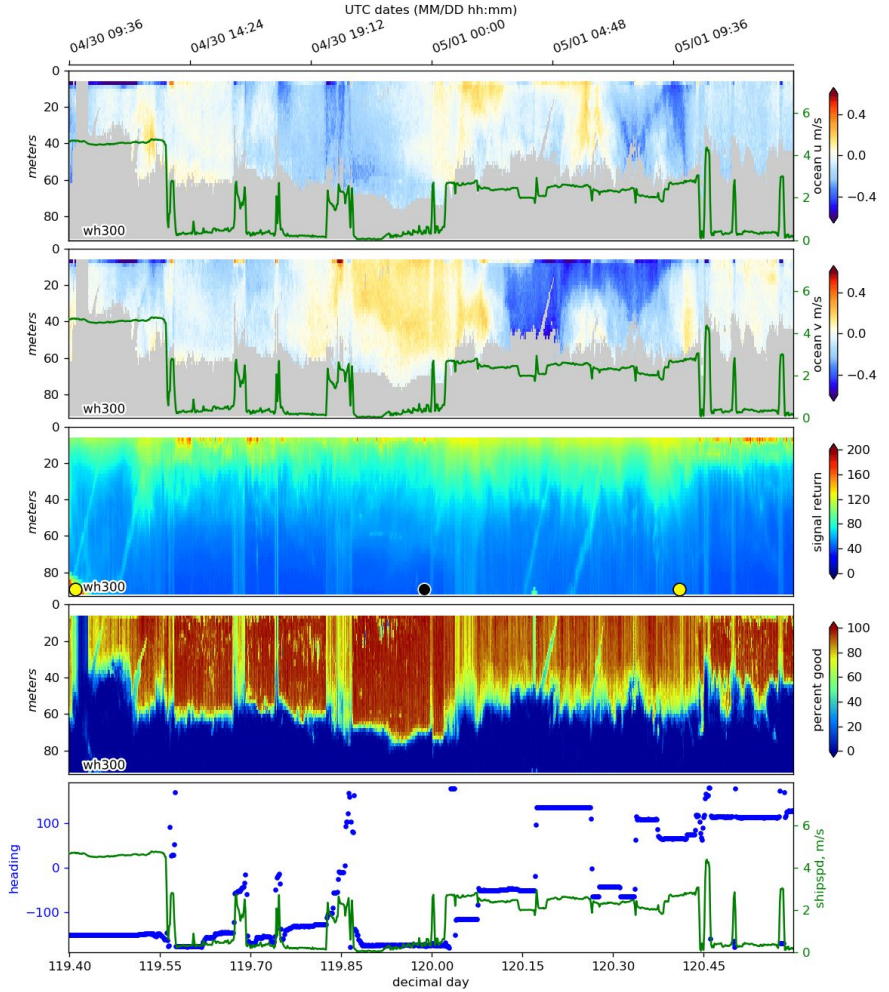
Details:

- Cause:
  1. the calibration value that defines the rotation of the ADCP transducer in the hull with respect to the ship needs adjusting.
- Related causes:
  1. the ADCP was taken out and put back in during a shipyard overhaul.
- Solution:
  - UHDAS staff will adjust the calibration after this cruise, if the calibration estimation numbers gathered during this cruise are sound.
  - This cruise may be reprocessed with different calibration values.



UHDAS 104 - Common Data Artifacts

What's Wrong?



119.4 to 120.6 (1.20 days)

2022/04/30 09:36 to 2022/05/01 14:24

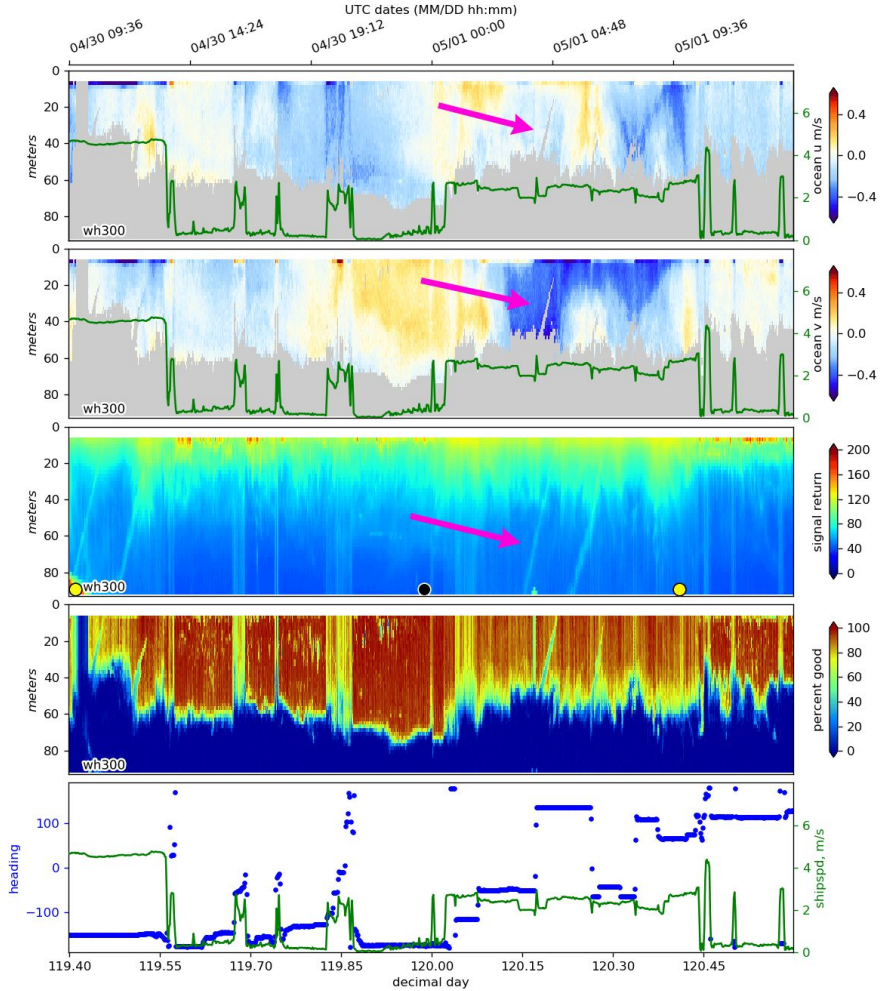
UHDAS 104 - Common Data Artifacts

What's Wrong? Acoustic Interference

Severity: **Moderate**

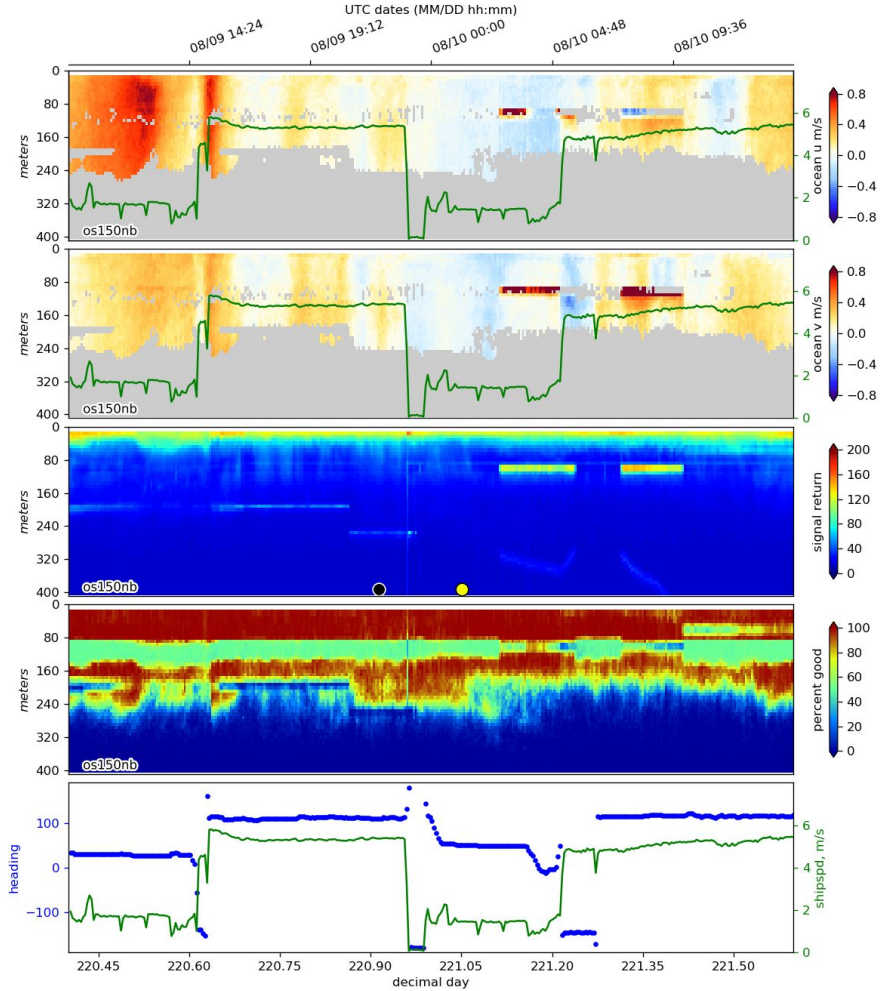
Details:

- Cause:
  1. the return ping from another sonar is being detected by the ADCP. At least one of the two units is not being triggered.
- Solution:
  - If ADCP data is particularly important on this cruise, secure the other device.
  - Enable triggering on both devices.



UHDAS 104 - Common Data Artifacts

What's Wrong?



220.4 to 221.6 (1.20 days)

2022/08/09 09:42 to 2022/08/10 14:27

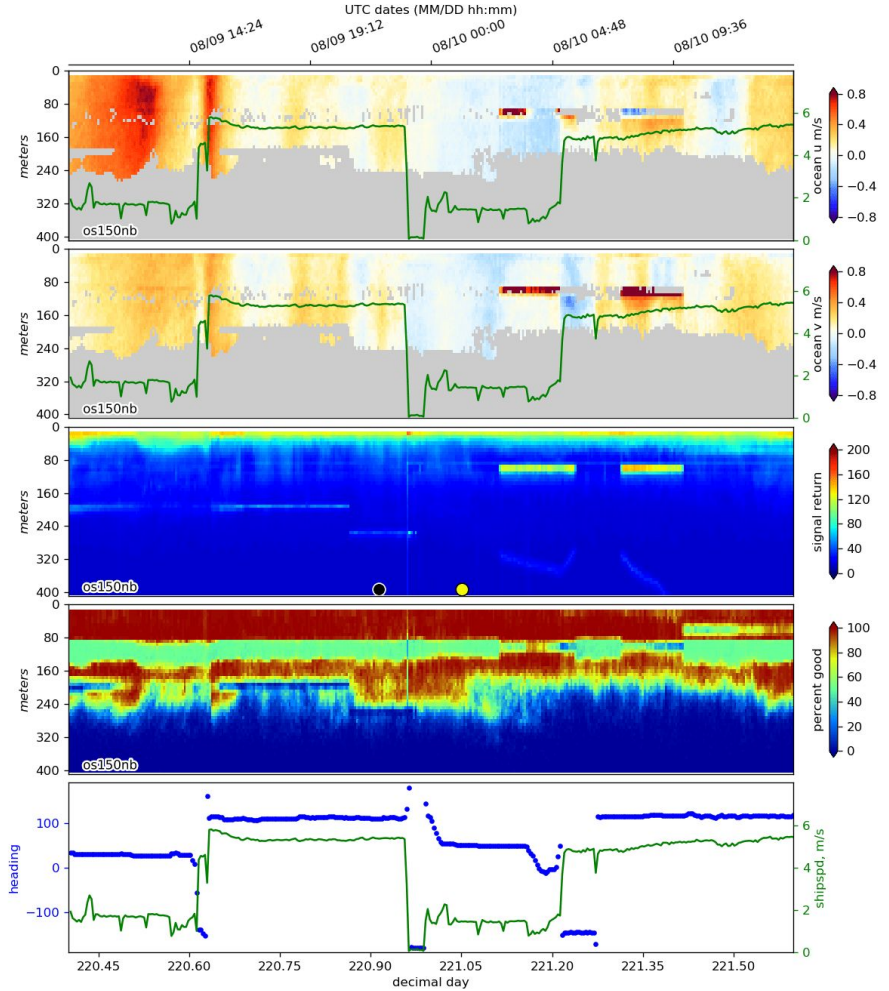
UHDAS 104 - Common Data Artifacts

What's Wrong? Acoustic Interference - Triggered

Severity: **High**

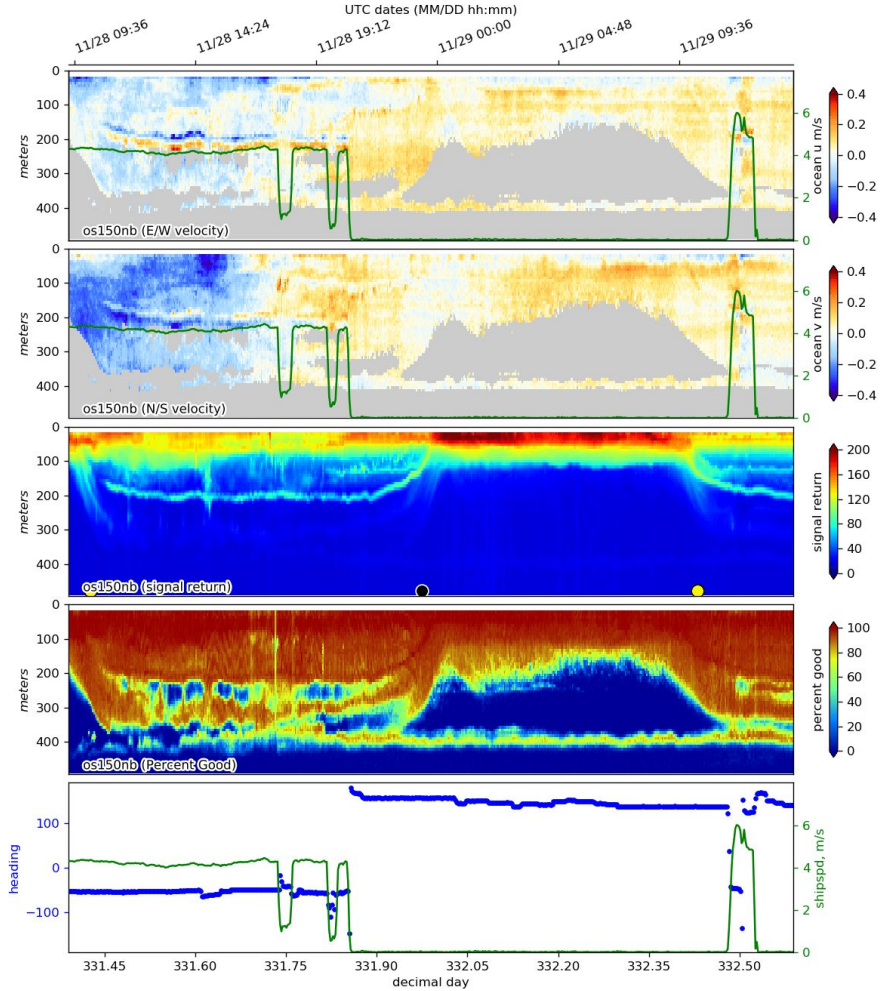
Details:

- Cause:
  1. The ADCP and the other sonars are being triggered, but the triggering settings are allowing pings to interfere with each other.
- Solution:
  - If ADCP data is particularly important on this mission, consider different triggering settings.
  - The currents data in the area of the horizontal scarring is lost.



UHDAS 104 - Common Data Artifacts

What's Wrong?



331.39 to 332.59 (1.20 days)

2023/11/28 09:24 to 2023/11/29 14:11

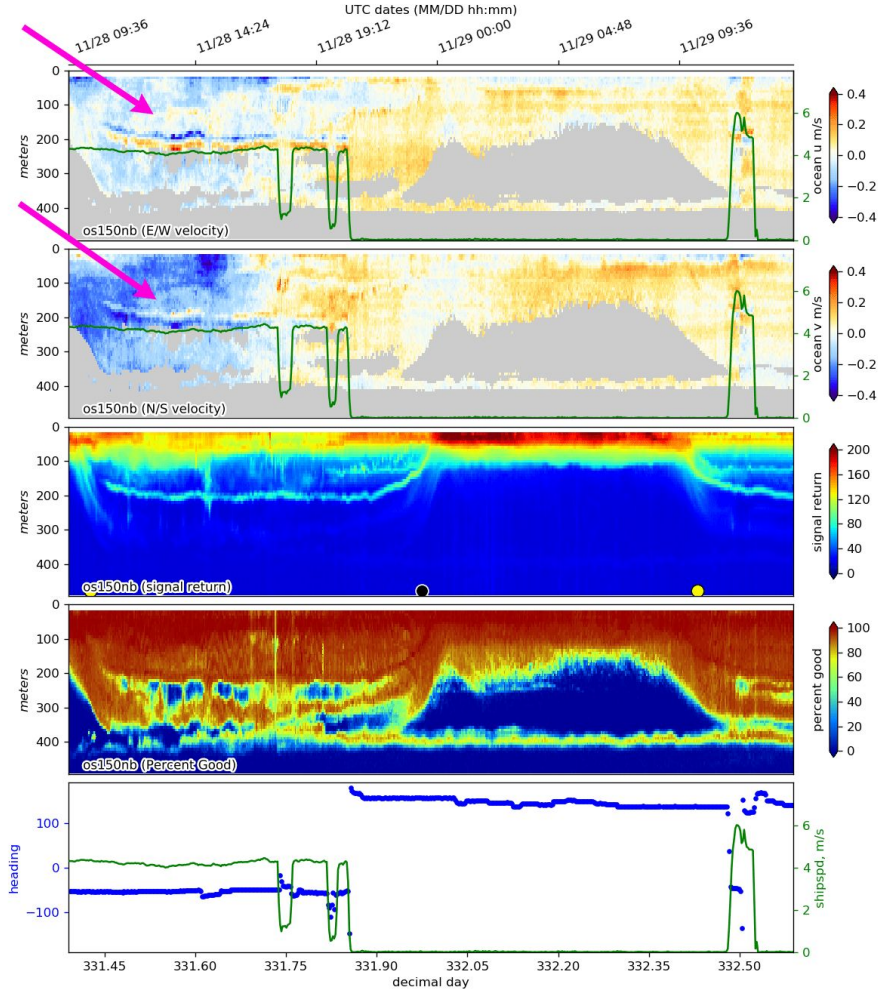
UHDAS 104 - Common Data Artifacts

What's Wrong? Strong Scattering Layer

Severity: **Moderate**

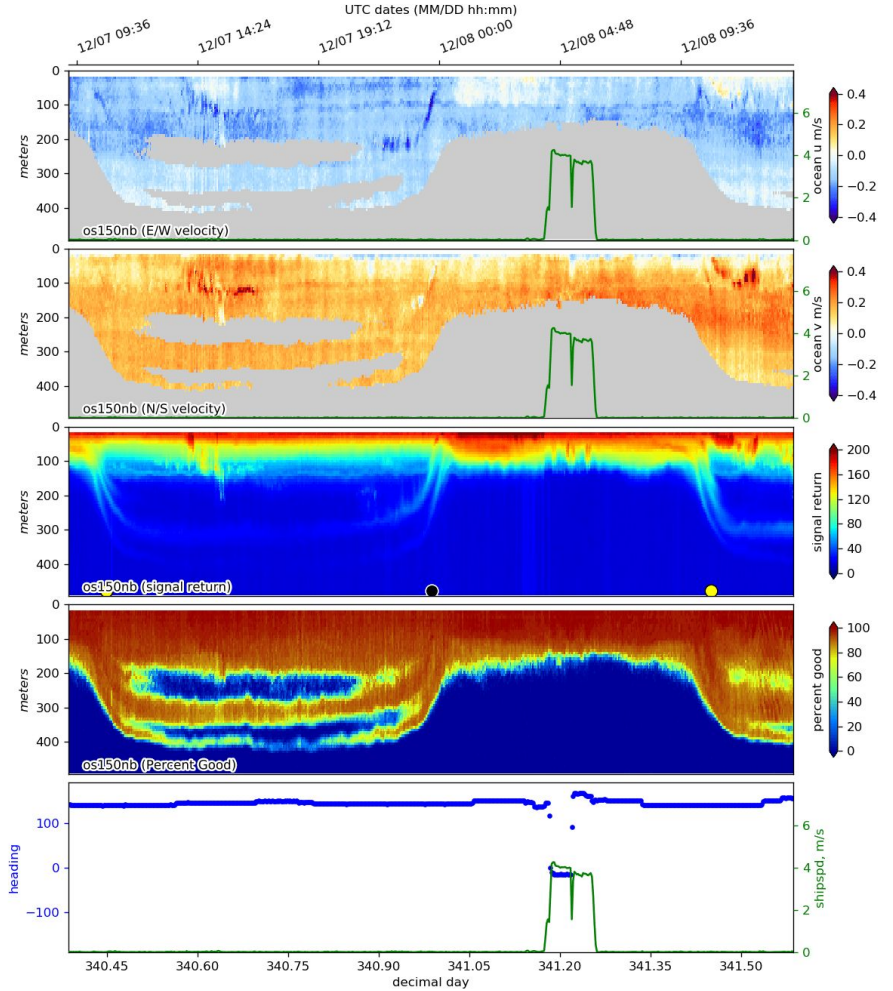
Details:

- Cause:
  1. a scattering layer is so strong that it is impacting the ADCP data.
- Solution:
  - Edit out in post-processing, though the current data in that region is lost.



UHDAS 104 - Common Data Artifacts

What's Wrong?



340.39 to 341.59 (1.20 days)

2023/12/07 09:20 to 2023/12/08 14:08

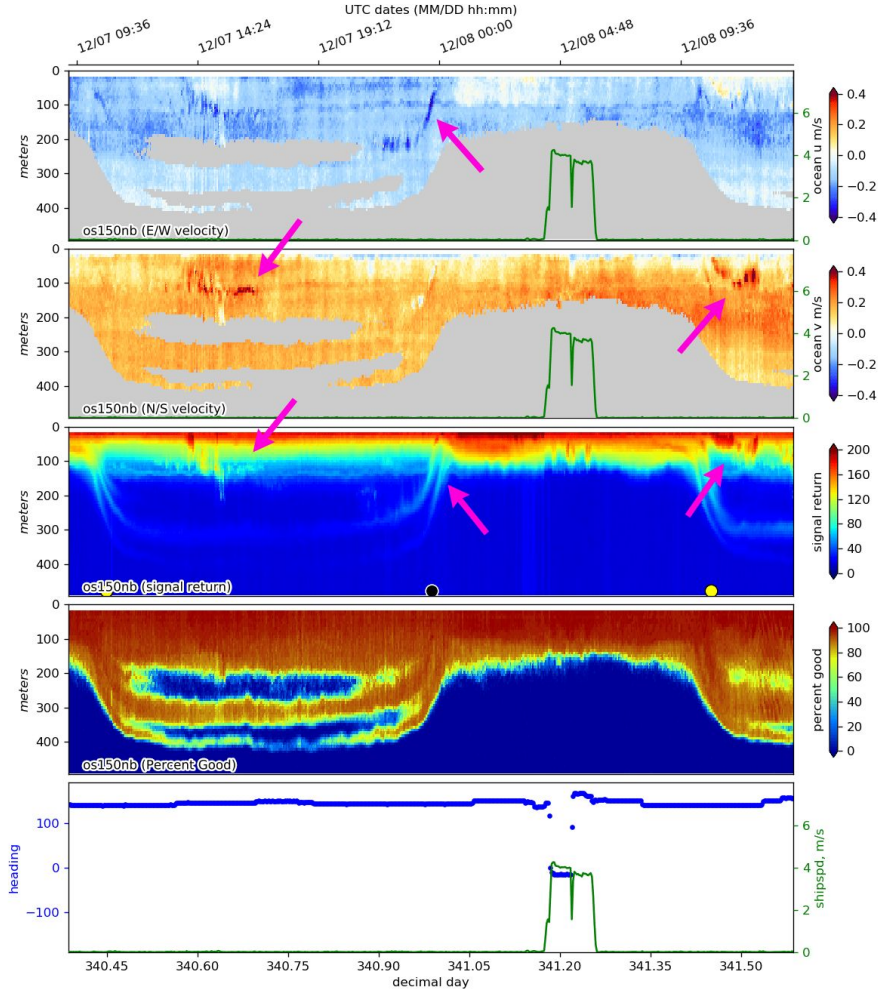
UHDAS 104 - Common Data Artifacts

What's Wrong? Weak Scattering

Severity: **Low**

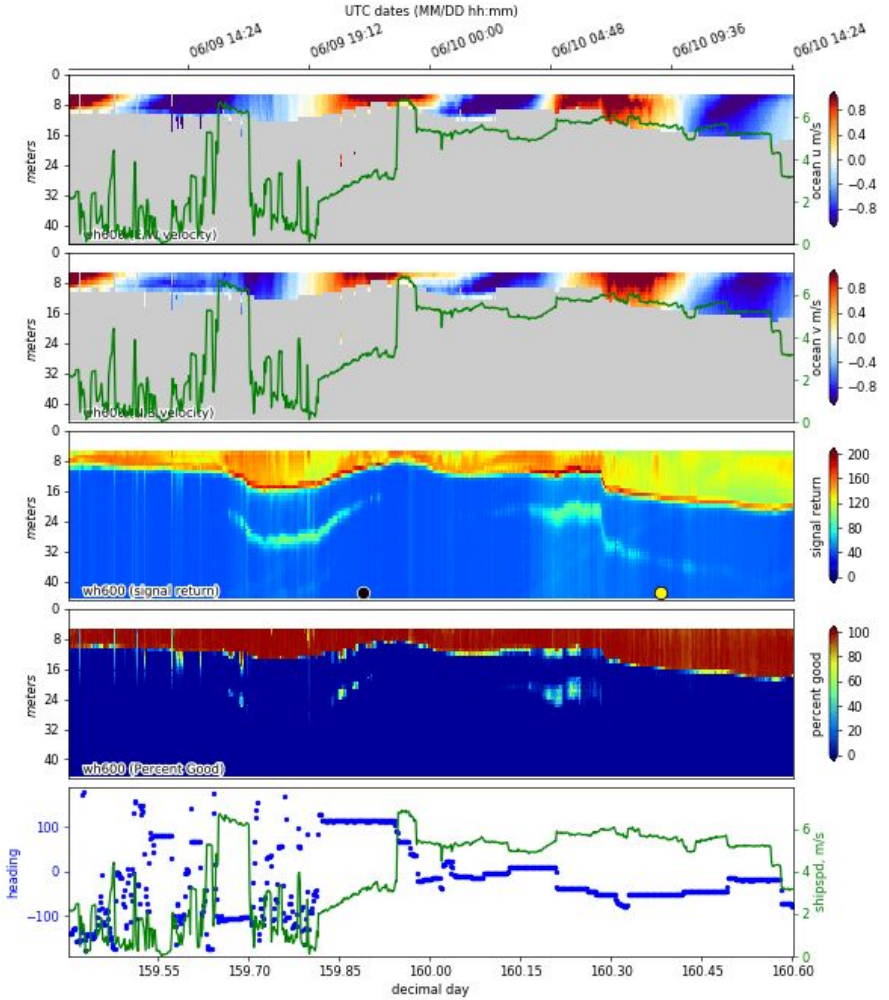
Details:

- Cause:
  1. scattering from large schools of fish, whales or large phytoplankton blooms.
- Sometimes, related to the diurnal phytoplankton migration to and from the surface.
- Solution:
  - Edit out in post-processing, though the current data in that region is lost.



UHDAS 104 - Common Data Artifacts

What's Wrong?



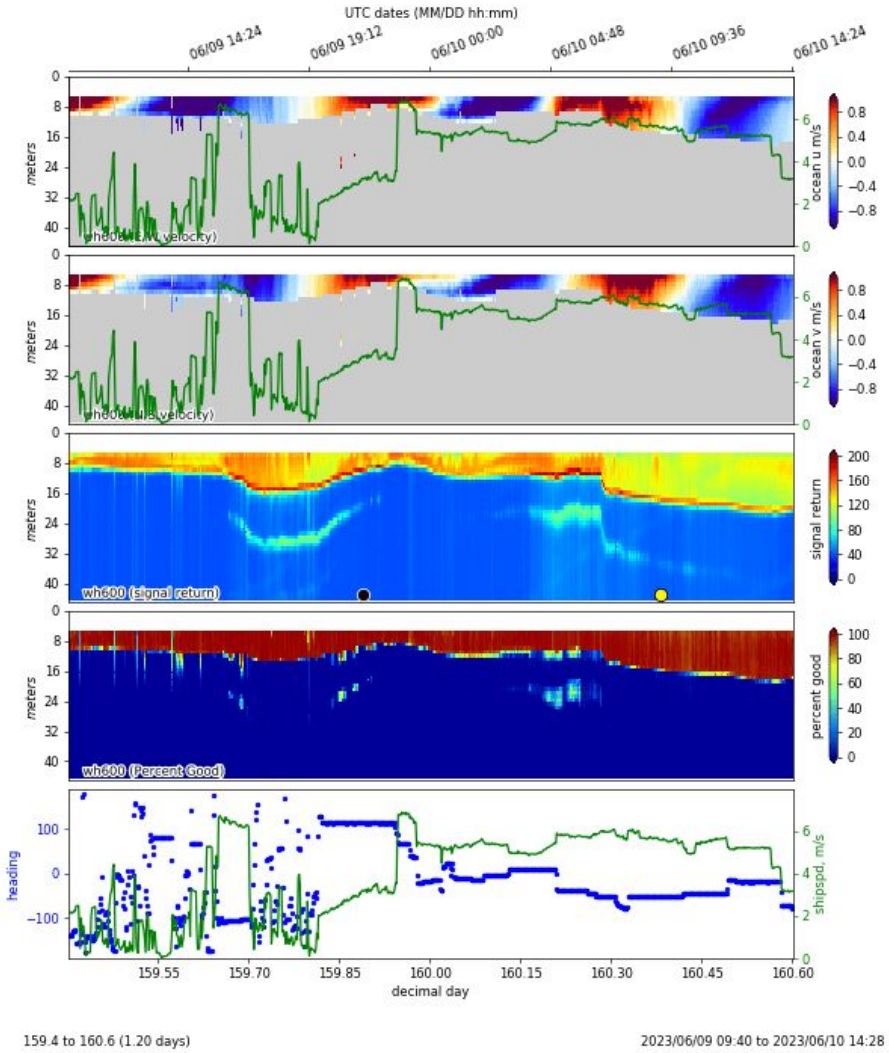
UHDAS 104 - Common Data Artifacts

What's Wrong? Nothing! Just tides.

Severity: **Non-Issue**

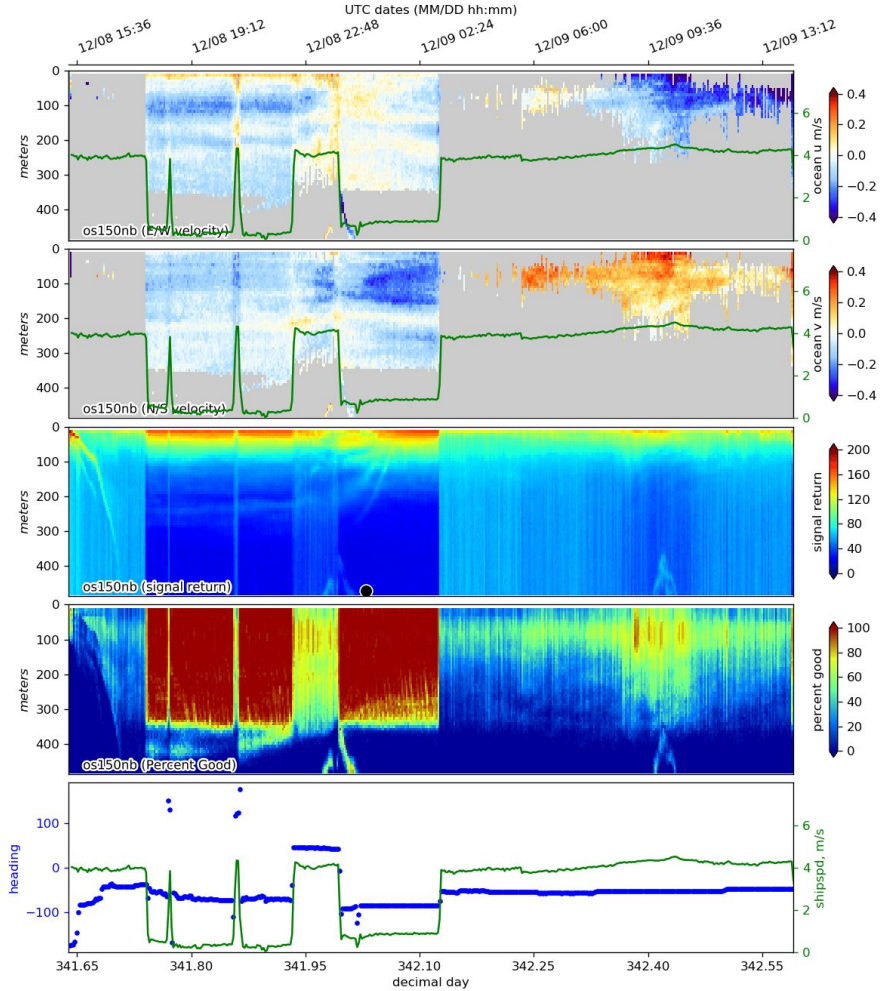
Details:

- Cause:
  1. in some shallow areas, tides play a dominant role in determining currents.
- Solution:
  - Nothing to do, good data.



UHDAS 104 - Common Data Artifacts

What's Wrong?



341.64 to 342.59 (0.95 days)

2023/12/08 15:22 to 2023/12/09 14:13

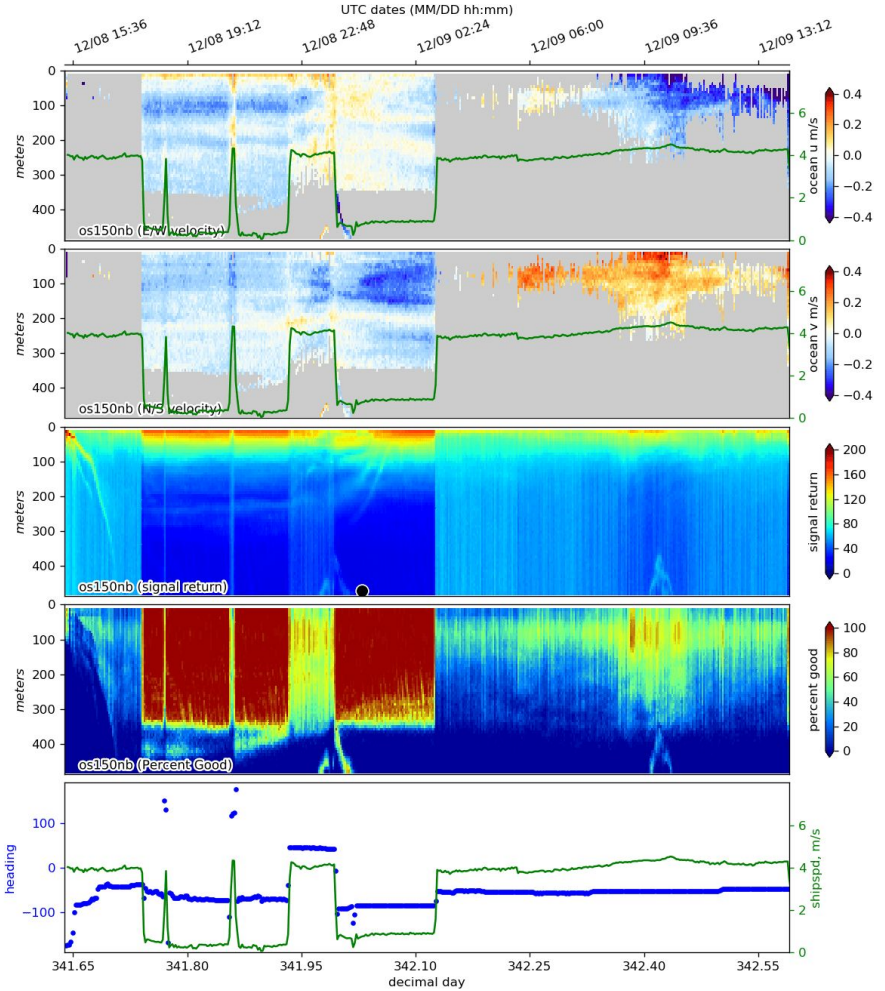
UHDAS 104 - Common Data Artifacts

What's Wrong? Too fast!

Severity: **High**

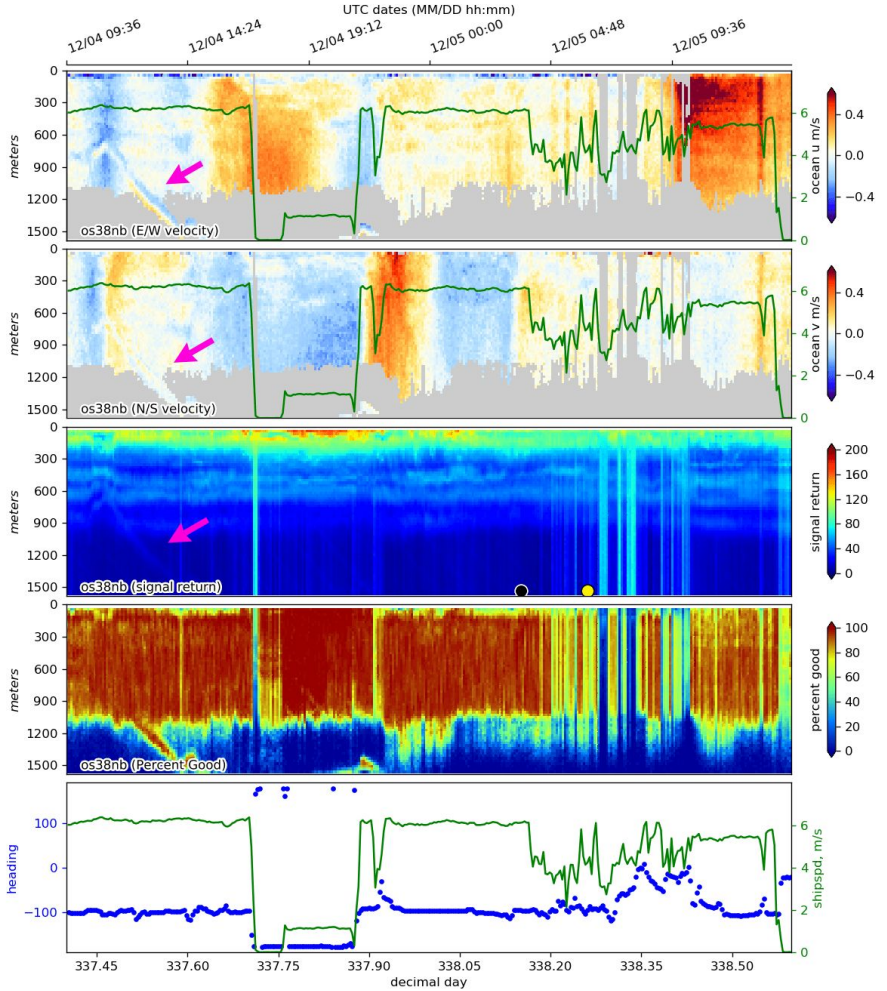
Details:

- Cause:
  1. the ship is going too fast, bubbles are getting under the ADCP transducer.
- Related Causes:
  1. small ships have this worse than larger ships.
  2. hull design / ADCP placement in the hull.
- Solution:
  - If ADCP data is important while transiting, advise the bridge that they need to slow down to improve data quality.
  - Can't be fixed in post-processing.



UHDAS 104 - Common Data Artifacts

What's Wrong?



337.4 to 338.6 (1.20 days)

2023/12/04 09:40 to 2023/12/05 14:25

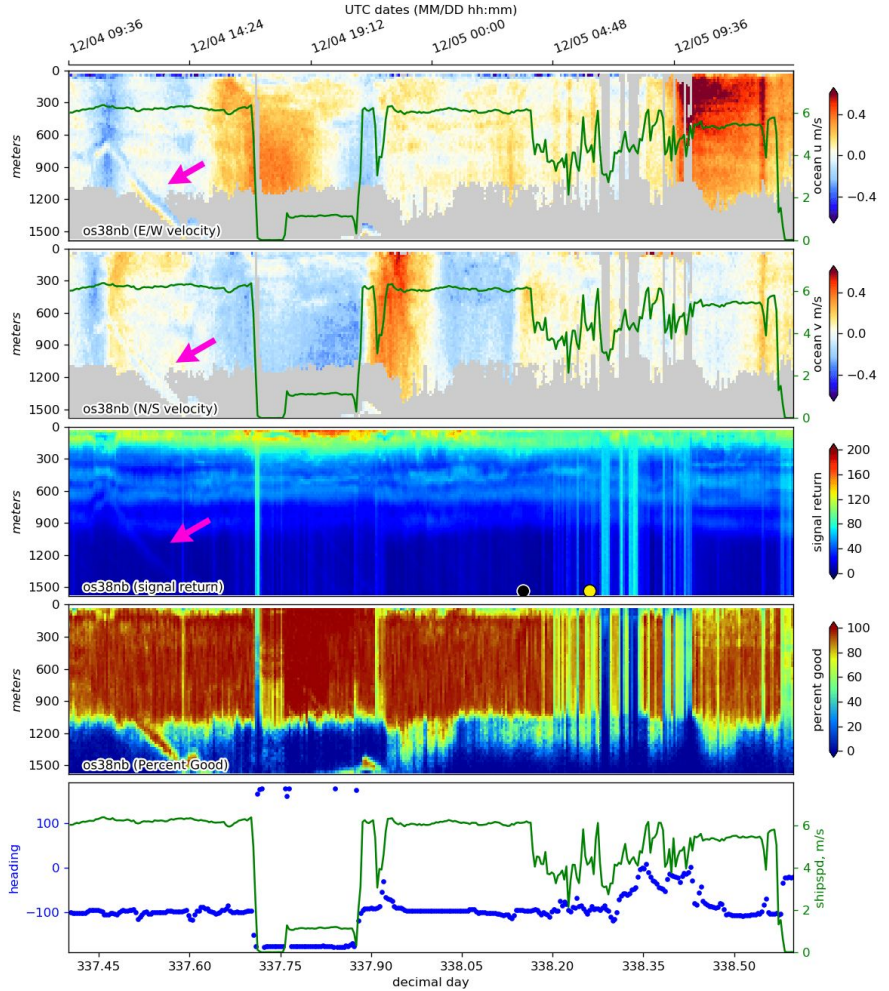
UHDAS 104 - Common Data Artifacts

What's Wrong? Previous Ping Interference

Severity: **Low**

Details:

- Cause:
  1. The return echo from a ping that hit the bottom is received during the next ping cycle, so the ADCP detects it at a lesser depth.
- Solution:
  - Edit out in post-processing, though the current data in that region is lost.



UHDAS 104 - Common Data Artifacts

List of Common ADCP Ailments

- installation: recessed, flush, window (fresh water, glycol) bleeder valve
- pings per ensemble
- biofouling and noise
- weather
- hull depth: 5-ish meters
- ringing: 4-8 meters
- bubble curtains
- acoustic interference
- electrical interference
- side lobe interference - 15%-ish closest to bottom, multipathing
- vertically uneven bottom
- bin overlap (about 15%)
- heading accuracy: 1 degree of error = 10 cm/s for a ship underway at 10 kts (10 cm/s is about 0.2 knots)
    - 50% of average open ocean velocity
    - UHDAS targets < 0.1 degree

Light Reading

- ***ADCP Principles of Operation A Practical Primer***

  The practical Primer is my primary reference for the operational principles of ADCPs. It is available on every UHDAS server at:

  rdi_docs/sci_tech/Broadband_Primer.pdf

  A few particularly fascinating sections:

  page 03, section 2: The Doppler Effect and Radial Current Velocity

  page 16, The Relationship of Range Gates and Depth Cells

  page 17, The Weight Function for a Depth Cell 15% overlap

- CODAS+UHDAS Documentation

  (on shore) https://currents.soest.hawaii.edu/docs/adcp_doc

  (on-ship) available on the UHDAS server

Light Reading

- Siemens Digital Industries Software, Knowledge base
  Sound Fields: Free versus Diffuse Field, Near versus Far Field
  https://community.sw.siemens.com/s/article/sound-fields-free-versus-diffuse-field-near-versus-far-field

- Navy Manuals and Documents Online
  https://www.maritime.org/doc/index.htm
  Hundreds, maybe thousands, of old and only slightly out-of-date Navy manuals and training guides, for example:
  - ***Sperry Mark 15 gyrocompass manual***
    https://maritime.org/doc/gyromk14/index.htm
  - Navy Electricity and Electronics Training Series
  - Antennas and Wave Propagation
    https://maritime.org/doc/pdf/et7.pdf