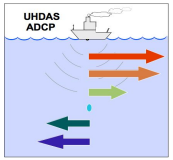


Shipboard ADCP Acquisition, Processing and Monitoring with UHDAS

Andrew Frambach
Jules Hummon
University of Hawai'i at Manoa

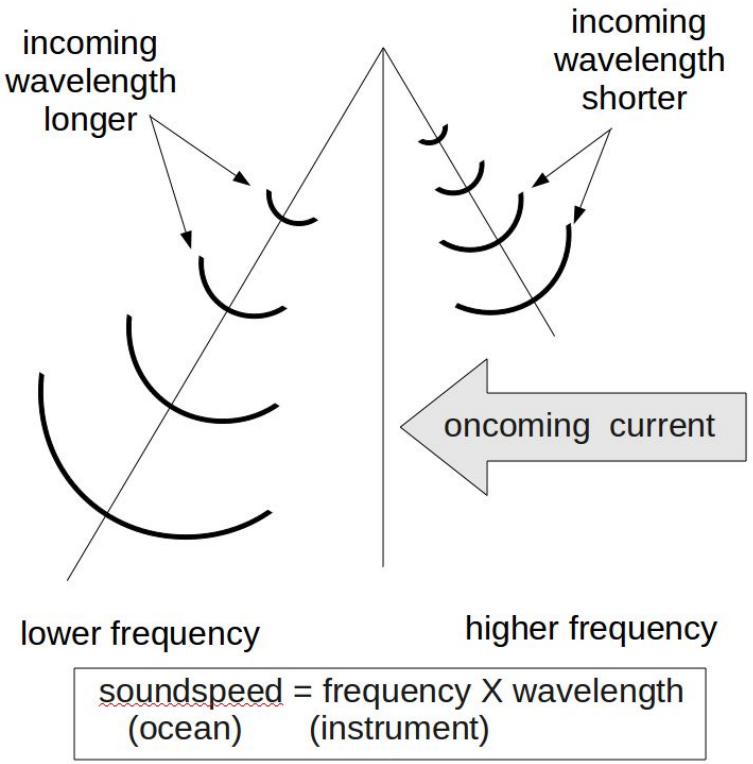
ADCP: Ocean Velocity from Sound Waves

Acoustic - ping at a frequency along a beam and wait for the return

Doppler - measure the frequency shift along a beam to get the velocity

Current - integrate GPS position and heading to get ocean velocity

Profiler - water column depth bins ~ sound speed x time bins

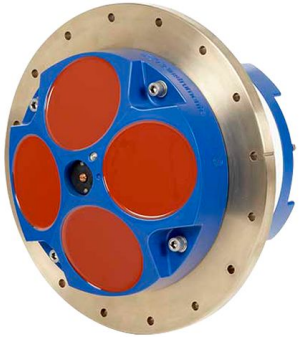


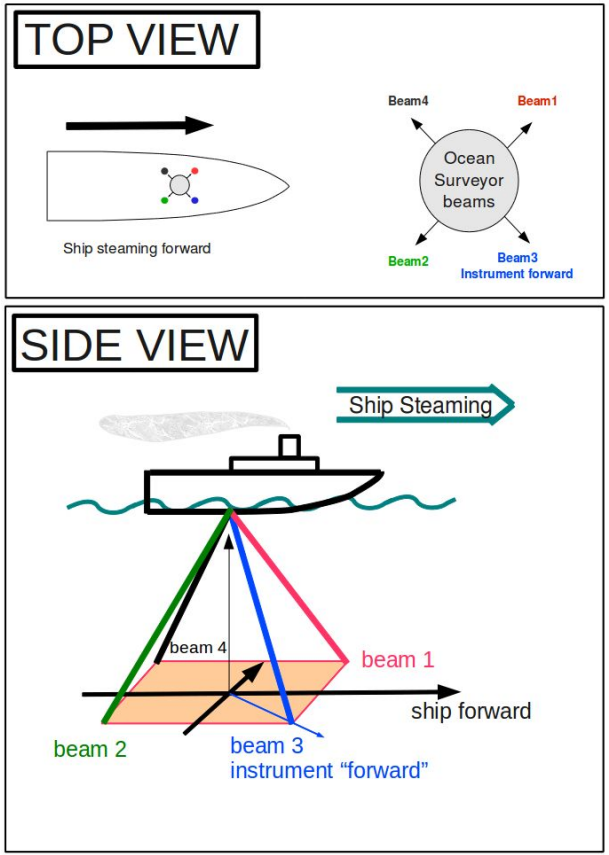
Acoustic **D**oppler **C**urrent **P**rofilers

- Shipboard (**SADCP**)
- Typically 1-3 instruments per ship

Teledyne RDI: Workhorse Mariner, Sentinel V, Ocean Surveyor, etc
Kongsberg: Simrad EC150

- Come in many frequencies:
  - on ships: 38 kHz - 1200 kHz
  - lower frequency = greater depth = longer time period between pings
- 4 beams:
  - offset at an angle relative to ship forward





	shallowest bin	typical max range	bin size	beam angle	transducer depth
wh1200	4m	12-15m	0.5m	20deg	3m
wh600	4m	30-35m	1m	20deg	3m
wh300	7m	50-80m	2m	20deg	5m
sv300	7m	50-80m	2m	20deg	5m
nb150	11m	300-400m	8m	30deg	5m
os150bb	8m	150-300m	4m	30deg	5m
os150nb	11m	250-350m	8m	30deg	5m
os75bb	11m	400-550m	8m	30deg	5m
os75nb	18m	600-750m	16m	30deg	5m
os38bb	15m	600-1000m	12m	30deg	5m
os38nb	25m	800-1400m	24m	30deg	5m

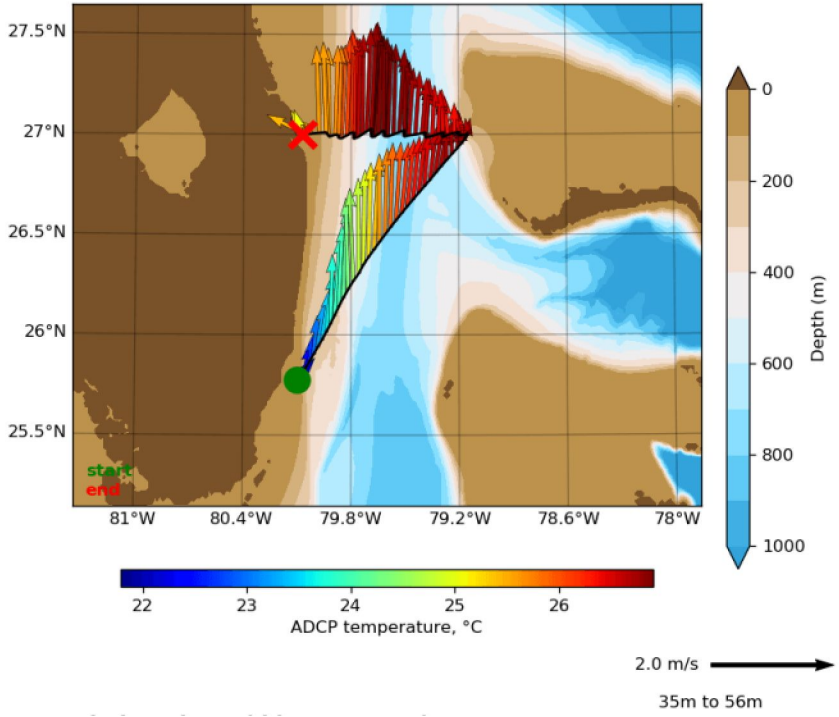
ADCP Data → Ocean Currents

ADCP single-ping data

Time

GPS position

Attitude



How is SADCP data used?

Operations:

– targeted biological sampling (fisheries, etc)
– over-the-side work (CTDs, moorings, etc)
– ROV deployments

Questions: What are the currents right now?

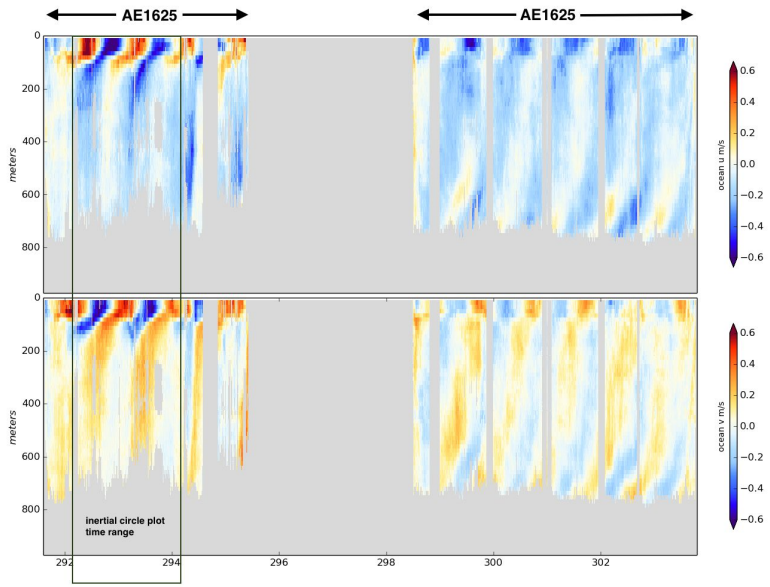
Dynamic Sampling:

– where is the front, when did we cross it?

Questions: How will my mooring drift?

Process Studies:

– near-inertial motion (wind-driven forcing)
– internal wave energy (energy down, phase up)
– high-frequency internal waves (on station)
– deep eddies
– context for small-scale mixing studies



Time Series:

– dedicated, on station (HOT, BATS)
– transects (Drake Passage, Gulf Stream, etc)
– after-the-fact (equatorial crossings)

Comparison with Satellites

Backscatter (even if uncalibrated)

What makes for good ADCP data?

Collect High-quality Data:

– thoughtful ADCP installation (free of bubbles, shorter cable runs for lower chance of electrical interference)

– heading and position from reliable and accurate devices **(1° heading err ~ 10 cm/s vel err)**

– good timestamps and acquisition practices

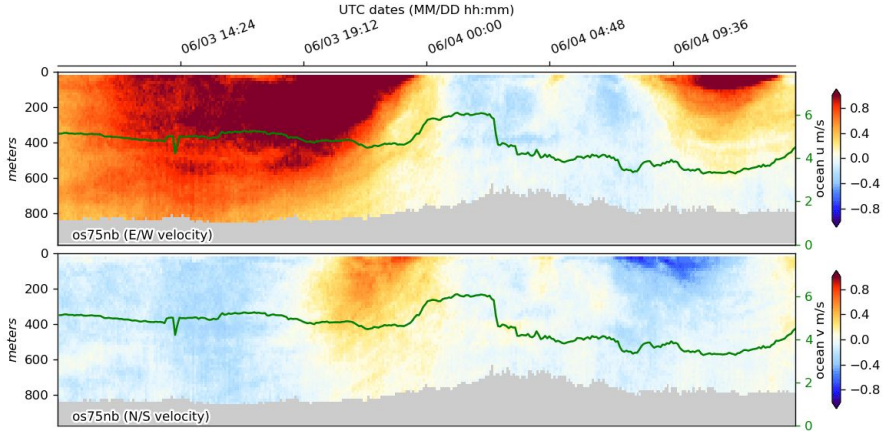
– ingest multiple feeds (including spares),

– record QA messages (POS MV, Seapath, etc)

Processing:

– single-ping editing (filter, mask outliers and weak profiles, bottom detection, etc)

– provide data products at sea (and for future use)



Monitoring:

– watch data feeds (from both ADCP and ancillary devices), make sure everything is okay

After the Cruise:

– be able to re-process with different inputs

What makes for a good Data Acquisition System (DAS)?

Basic →

Basic Functions:

– interface with ADCP, control settings
– acquire ADCP data
– acquire ancillary data (position, attitude)
– timestamp everything

Better →

Processing:

– deliver ocean velocity products from raw ADCP/ancillary data

Best →

Monitoring:

– watch the feeds as they're being recorded, fix problems in the field

What currently exists?

VmDAS: (**V**essel **M**ount **D**ata **A**cquisition **S**ystem)
- – Windows program for use with Teledyne RDI ADCPs
- – all files go into a single directory
- – stores raw (ENR, N1R, N2R), intermediate components (ENS, ENX)
- – transforms and averages the data (makes LTA, STA files)

Provided with purchase of ADCP

UHDAS: (**U**niversity of **H**awaii **D**ata **A**cquisition **S**ystem)
- – collection of programs, procedures, and configurations installed on Linux for use with multiple ADCPs
- – nested directory structure
- – stores raw (*.raw), intermediate components (*.rbin files)
- – transforms, edits, averages, and stores the data products
- – leverages **CODAS** processing

Subscription based - requires UHDAS personnel to install

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

UHDAS: What are our goals?

1. Enhance the utility and visibility of SADCP data
2. Provide viable ocean currents at sea:
   – data should be useful for science and operations
   – data should be as close to final as possible (for an automated system)
   – require minimal post-processing for science
3. Make available re-processing tools on multiple operating systems
   – can be run on Linux, Mac, Windows – **CODAS**

But most of all…


Happy Scientists

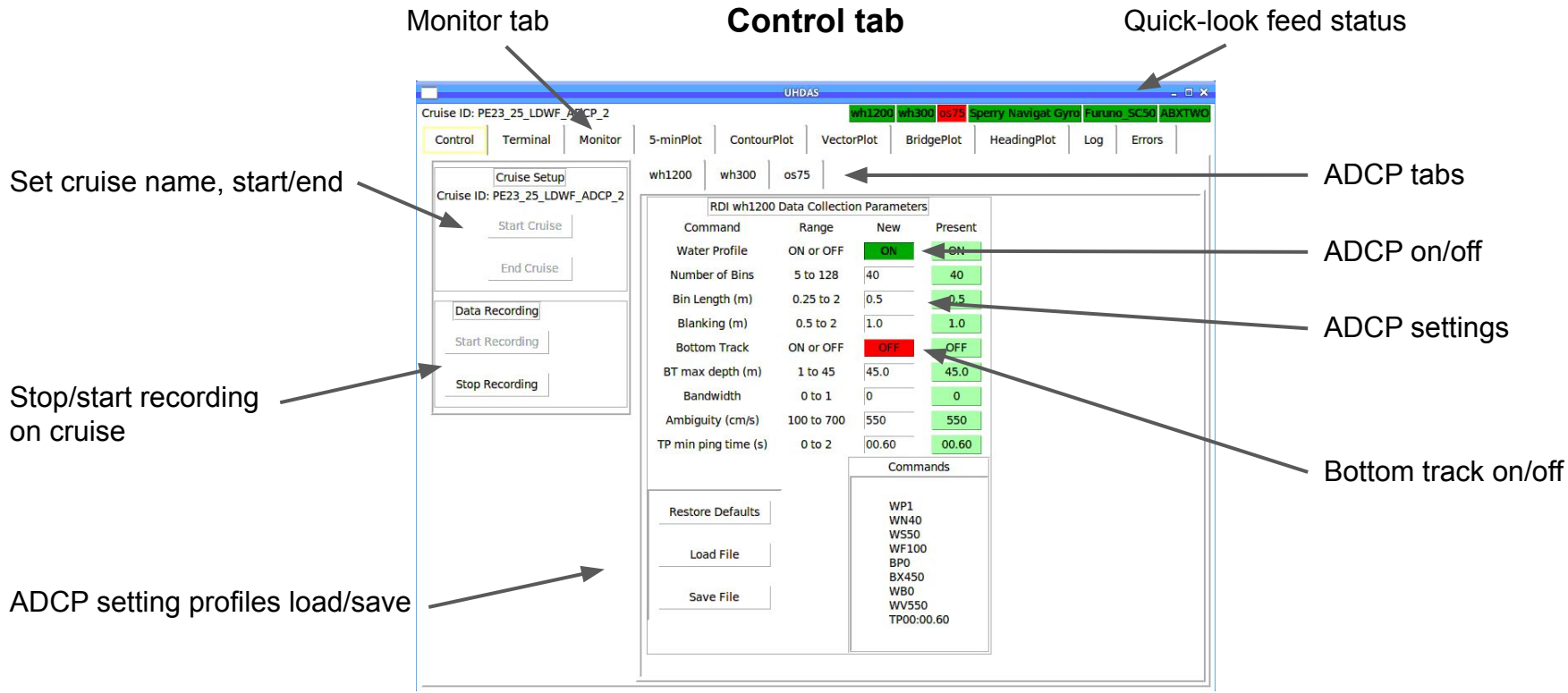

Happy Techs


Happy Managers

How does UHDAS achieve these goals?

1. **Acquisition** (ADCP, position, heading)
   – easy-to-use, intuitive GUI interface
   – can easily return to known working settings, can save settings profiles for later
2. **Automated Processing**
   – “preliminary processing” is done at sea in real-time, can also be re-processed later
3. **Data and Products**
   – for use in both operations and science at sea
   – **CODAS** tools for ease of post-processing after the cruise (can switch in different feeds, new QC algorithms)
   – data products (NetCDF, Matlab) and visualization (Python plots)
   – discovery/evaluation in the future
4. **Monitoring**
   – by techs and crew on the ship
   – by UHDAS staff on land

UHDAS: Acquisition



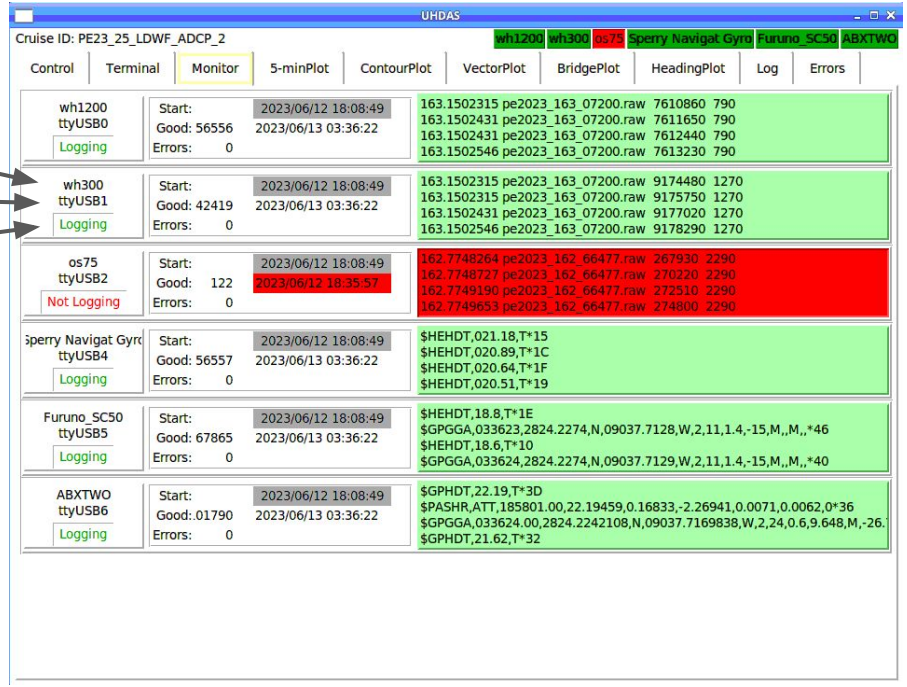
UHDAS: Acquisition

Monitor tab

Device

Port

Status



Real-time feed monitoring
GREEN = logging
RED = not logging

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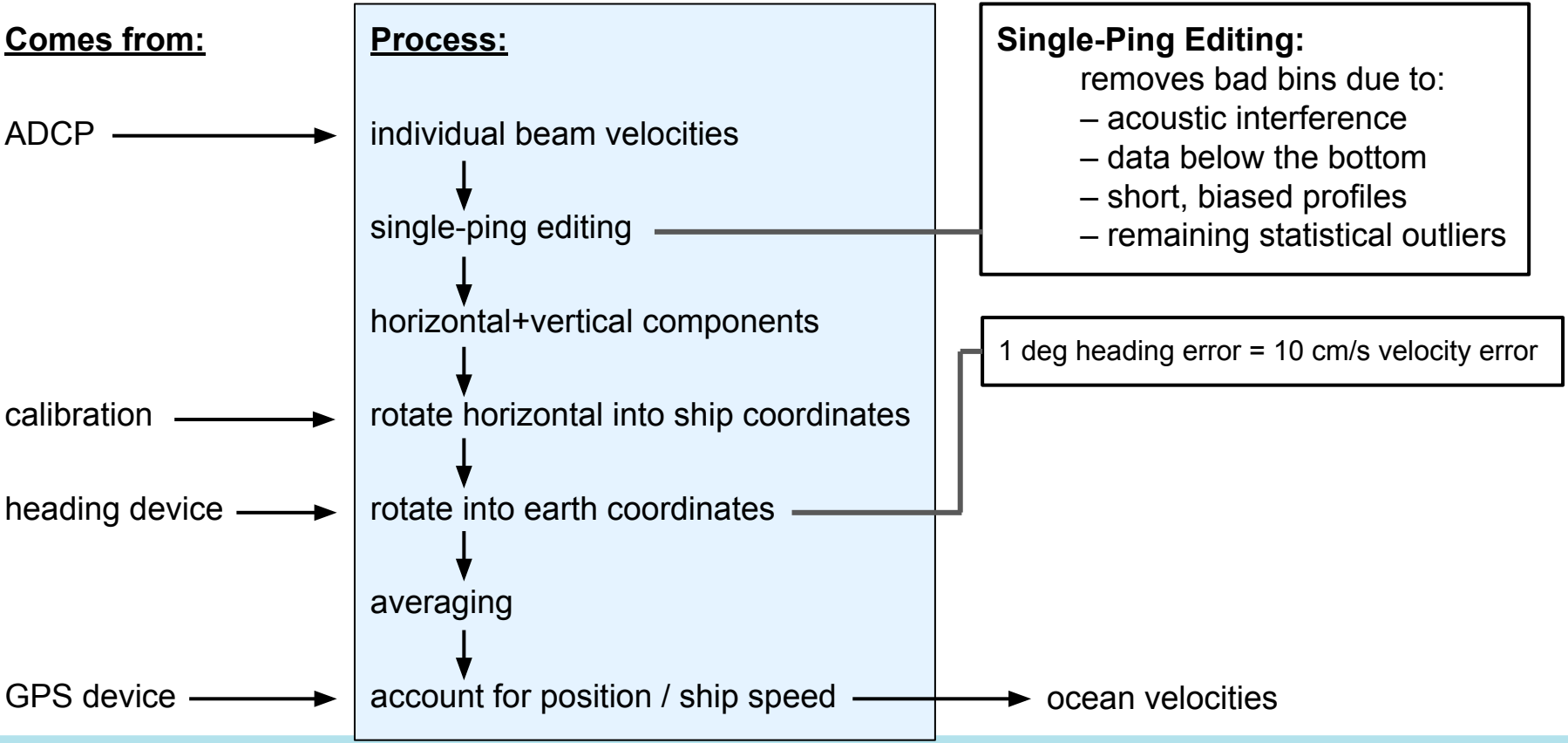
UHDAS: Processing



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   – data products (NetCDF, Matlab) and visualization (Python plots)
   – useful for evaluation in the future
4. **Monitoring**
   – by techs and crew on the ship
   – by UHDAS staff on land

UHDAS: Data and Products

	at sea	on land
At-Sea UHDAS Website		
• operational / scientific figures	yes	no
CODAS Data Products		
• NetCDF files for science	yes	yes
• Matlab data files	yes	yes
• Daily figure archive	yes	yes
• Estimated calibration from processing results and figures	yes	yes
• Settings used during processing	yes	yes
Complete CODAS+UHDAS documentation	yes	yes

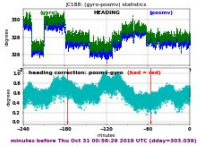
UHDAS: At Sea Monitoring by Techs and Crew

HOME

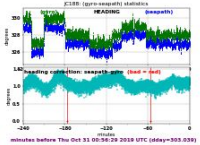
Monitoring: click opens a new figure

Attitude Devices

- posmv-gyro comparison (thumbnail)



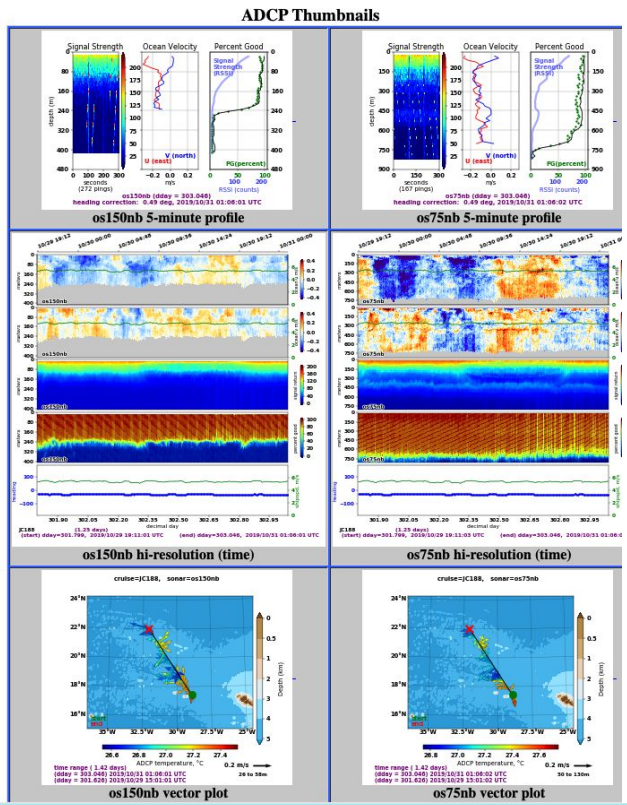
- seapath-gyro comparison (thumbnail)



Bridge plots:

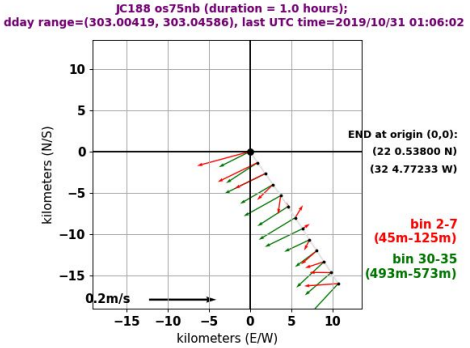
- surface vector :
  - day
  - night
- kts and direction profile:
  - day
  - night

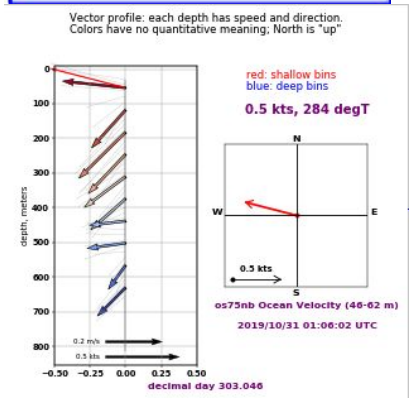
Diagnostics



Science

Operations





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UHDAS: On land Monitoring by UHDAS Staff

Staff provide troubleshooting and feedback for:

– problems with ADCP instrument or computer

Ex.: bad beams, electrical noise, RDI tech support

– problems with ancillary data acquisition

Ex.: bad timestamps, glitchy or failing serial (or UDP) feeds, reduced quality data, dropped feeds, etc, etc.

– preliminary processing

Ex.: change in calibrations, sensor configuration swap

How?

– staff monitoring of daily status emails from ships (7 days a week, 365 days a year)
– complex issue flagging system with 60 unique parsers
– email ticketing system for easy issue tracking and conversation with techs, crew, or anyone of interest.

The End

Who’s that smiling face at the other end of the email thread?

Jules Hummon

Andrew (Drew) Frambach

Jamie Ash

David Vadnais

CODAS Shipboard ADCP processing

Marine Technology Unit,
Spanish Research Council
June 21, 2023

Dr Julia Hummon
University of Hawaii
http://uhdas.org

UHDAS + CODAS Documentation

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

- CODAS processing introduction
  - show 10 slides of this ~40-slide presentation
- Switch to the “live” demo
  - slides for the demo are here

CODAS Documentation is here

- section for adcp_database_maker.py VmDAS LTA

DATA ACQUISITION

Time, ADCP, Position, Attitude

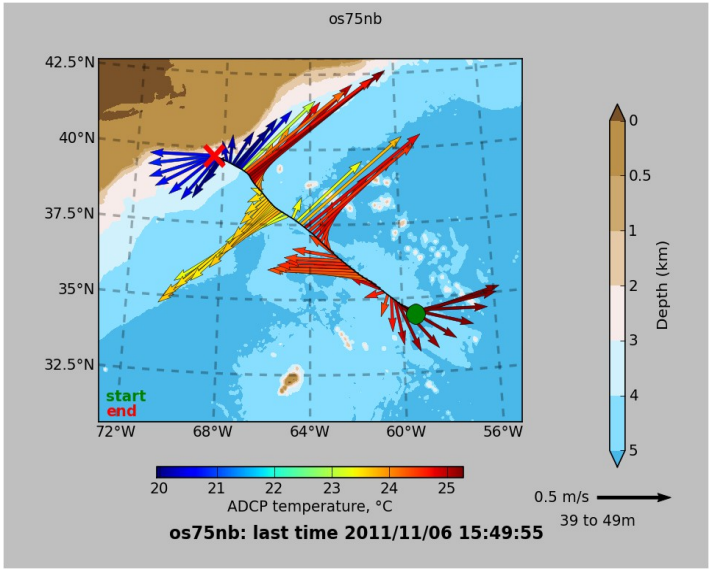
primitive (raw) data

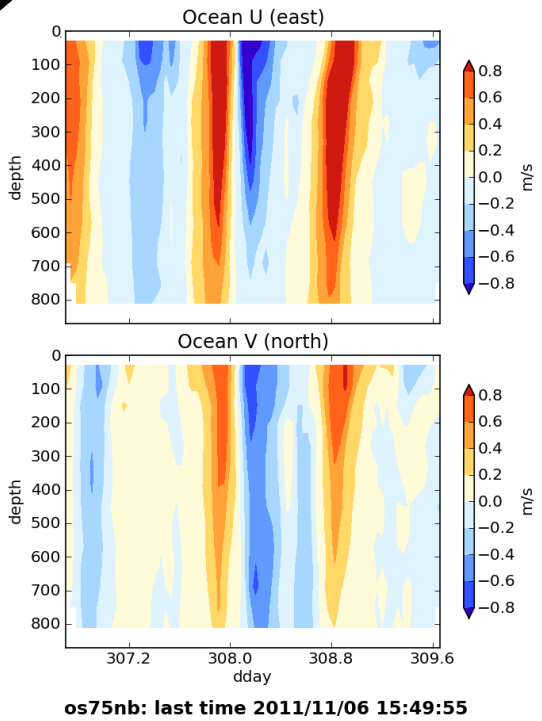
Time
ADCP
Position
Heading

Timestamp, Write to disk

DATA PROCESSING

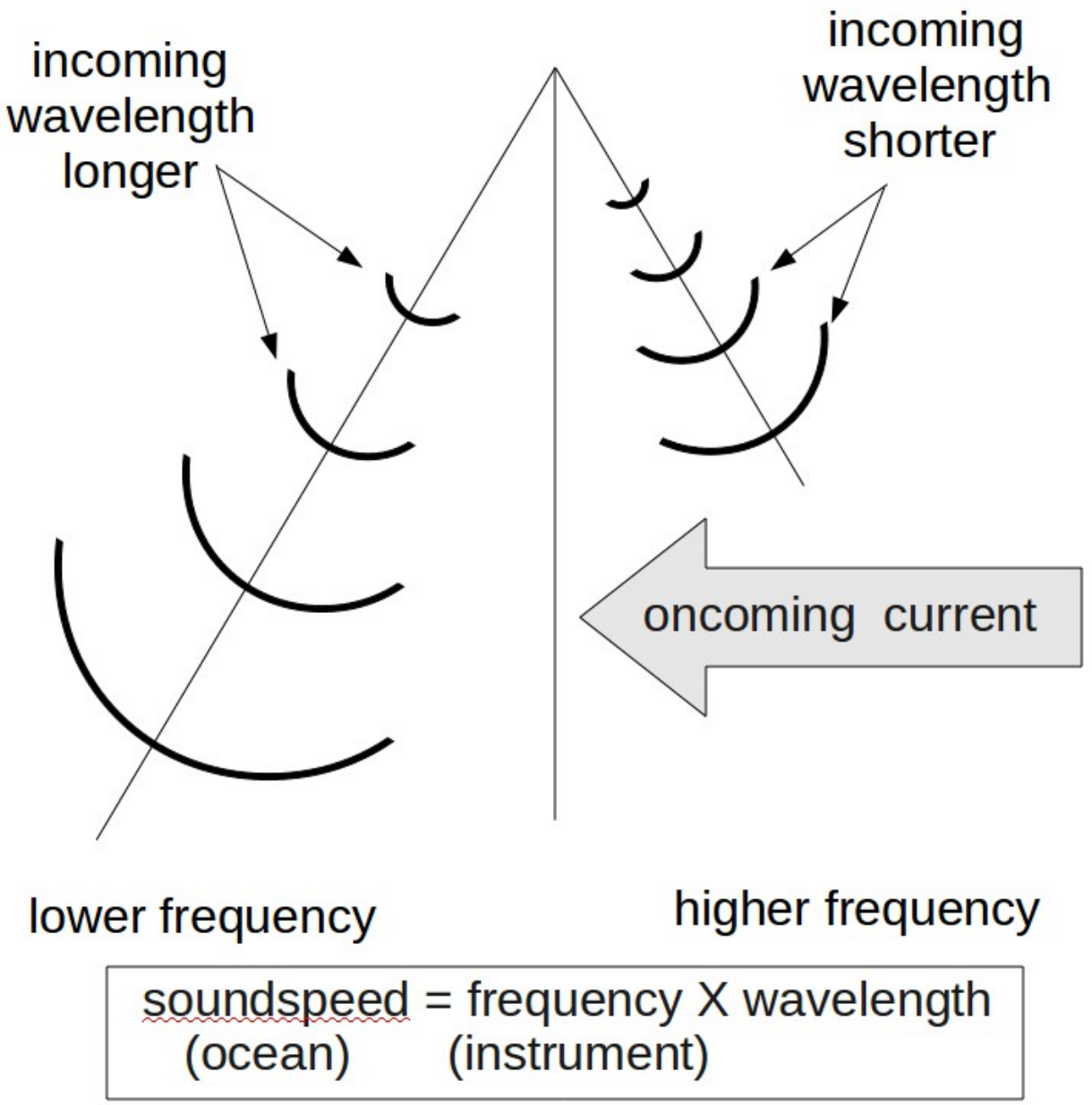
(Data Products)
(Visualization)





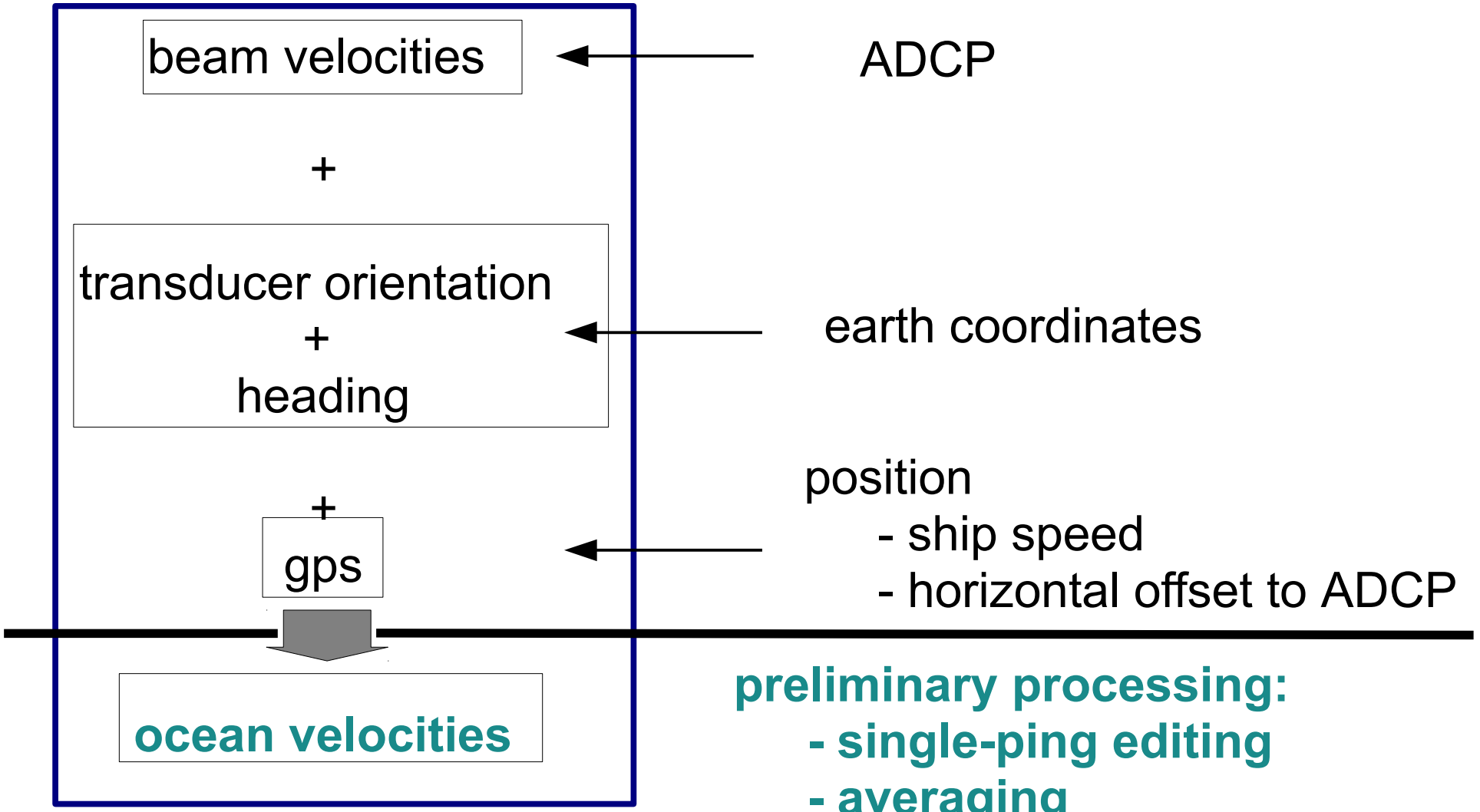
ADCP

Acoustic
Doppler
Current
Profiler



more details: Calculating ocean currents from ADCP

ADCP: Acquisition, Processing



ADCP: Getting Ocean Currents

Collect Data

ADCP

heading

position

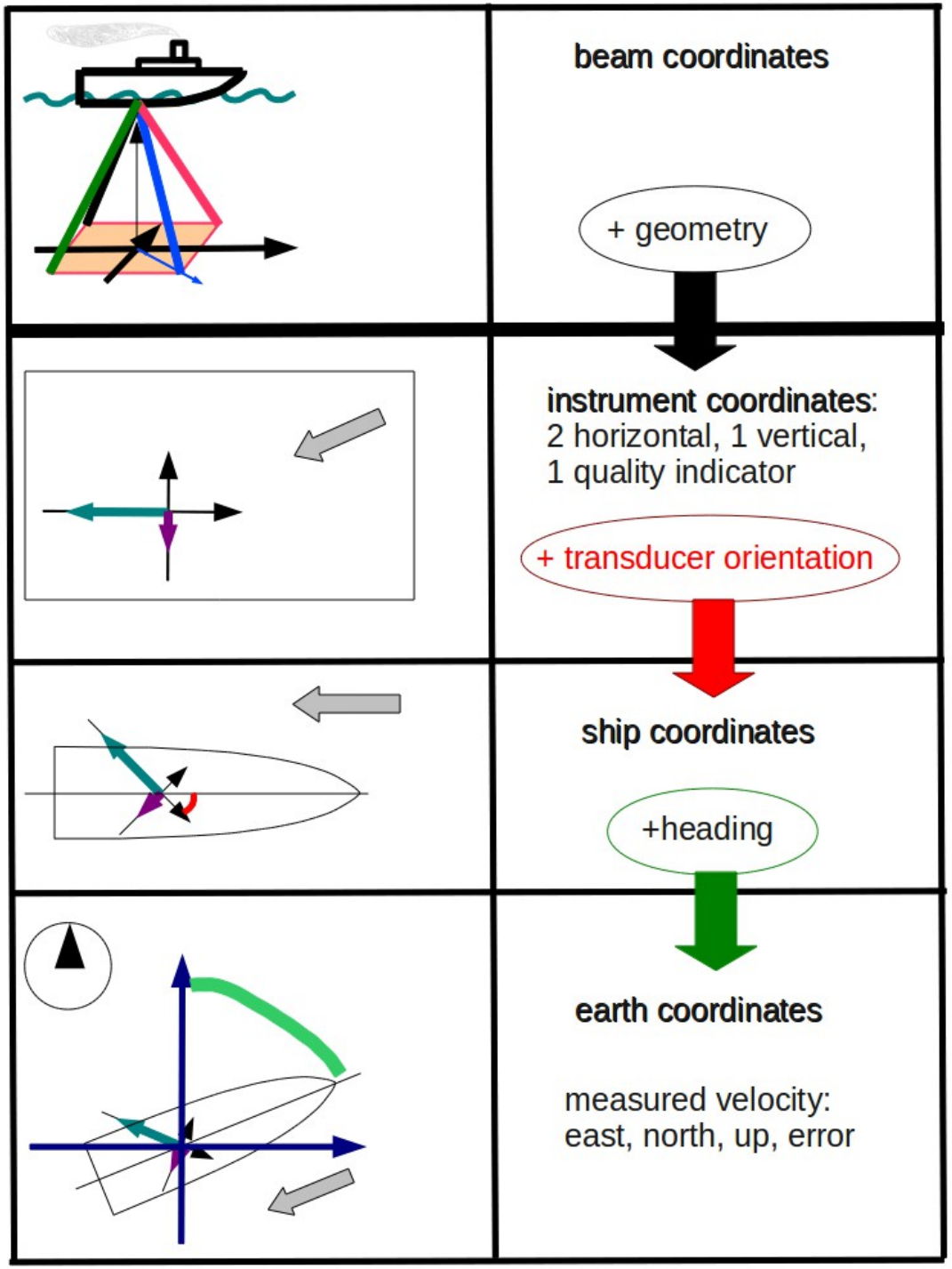
Transformations

Doppler to beam
(occurs in the ADCP)

- beam to instrument
- instrument to ship
- ship to earth

Preliminary Processing

- single-ping editing
- averaging
- remove ship's speed



“CODAS” ADCP Processing

Goals

- Run on multiple operating systems
  - (Windows,(*) OSX, Linux)
- Open source, free (Python)

(*) via VirtualBox pre-configured Linux computer

Processing

- Written for ADCP data; Works with most RDI ADCPs (link)
- Balance real-time product with recoverable dataset
- Single-ping (automated) and manual editing
- Calibration diagnostics and visualization tools
- Export in matlab or netCDF format

- UHDAS + CODAS Documentation

CODAS preliminary processing: 2 flavors

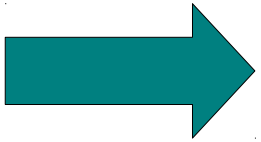
(1) **Preliminary processing single-ping data**

- beam-to-earth coordinates
- single-ping editing (acoustic interference, bottom)
- create averages; save to disk
- format averages into CODAS database

(2) **reformat pre-averaged data** into CODAS database

- 1980's PINGDATA
- VmDAS: *.LTA, *.STA

} (no single-ping editing)



Next: "post-processing steps"

CODAS Processing Overview

UHDAS single-ping data

single-ping processing

CODAS averages after single-ping editing

VmDAS data

***.LTA, *.STA**

reformat LTA averages to CODAS averages

CODAS Averages

***.ENR**
***.N1R, *.N2R**

***.VMO**

uhdas-style single-ping data

single-ping processing

CODAS averages after single-ping editing

CODAS post-processing:

(1) View figures and logfiles

(2) Fix heading:

- patch gappy but accurate heading correction (if relevant)
- apply time-dependent heading correction

(3) Determine corrections/calibrations, then apply

- remaining transducer angle offset
- scale factor (if relevant)
- transducer-GPS offset (in meters)

(4) Manually edit out bad data (dataviewer.py)

- use thresholds for bulk editing
- graphically select bins or profiles; use Seabed Selector for bottom

(5) check calibrations (angle, scale factor, gps-ADCP offset)

(6) make figures (web page) export data (matlab, netCDF)

VmDAS Demonstration

- Point Sur data
  - LTA
  - ENR
  - compare: effect of
    - single-ping editing
    - heading correction
    - transducer angle (calibration)
- Knorr Norwegian Sea
  - compare LTA vs/ ENR
  - show effect of GPS-ADCP offset

The rest of this presentation will be “live”.

- running adcp_database_maker.py, showing
  - work flow
  - how to find and apply calibration values
    - transducer angle
    - scale factor
    - ADCP-GPS horizontal offset
  - where this is all documented
  - information about the dataset
  - how to view the data
  - how to process
    - LTA
    - ENR
- how to make a little web site with figures
- how to compare LTA and ENR

Slides for adcp_database_maker.py are here

CODAS preliminary processing

- Editing (single-ping)
  - Acoustic interference
  - Bubbles
  - Below bottom
- Averaging

} Automated at-sea processing

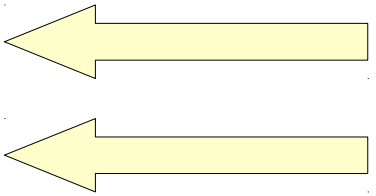
- Fix time-dependent heading correction (eg. if gaps)
- Apply calibrations
  - Rotation
  - Scale factor
  - Horizontal offset between GPS and ADCP (new)
- Manually edit CODAS database averages

post-processing = Manually, AFTER AVERAGING

ADCP Single-ping Editing

The most common causes of error
(addressed by single-ping editing)

- Acoustic Interference
- Bubbles
- Below bottom



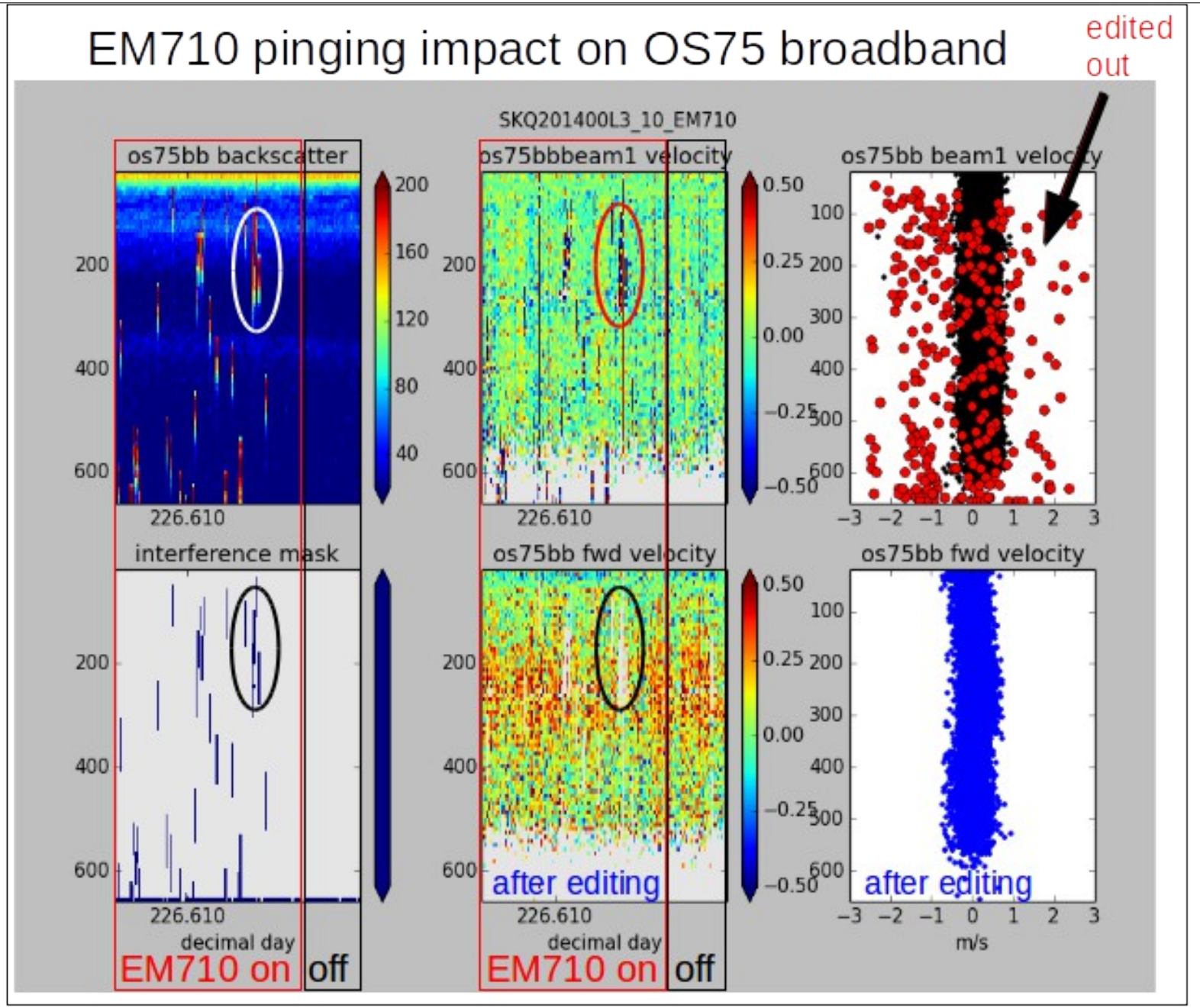
Both tend to cause bias towards zero
in measured velocity

ADCP Single-ping Editing

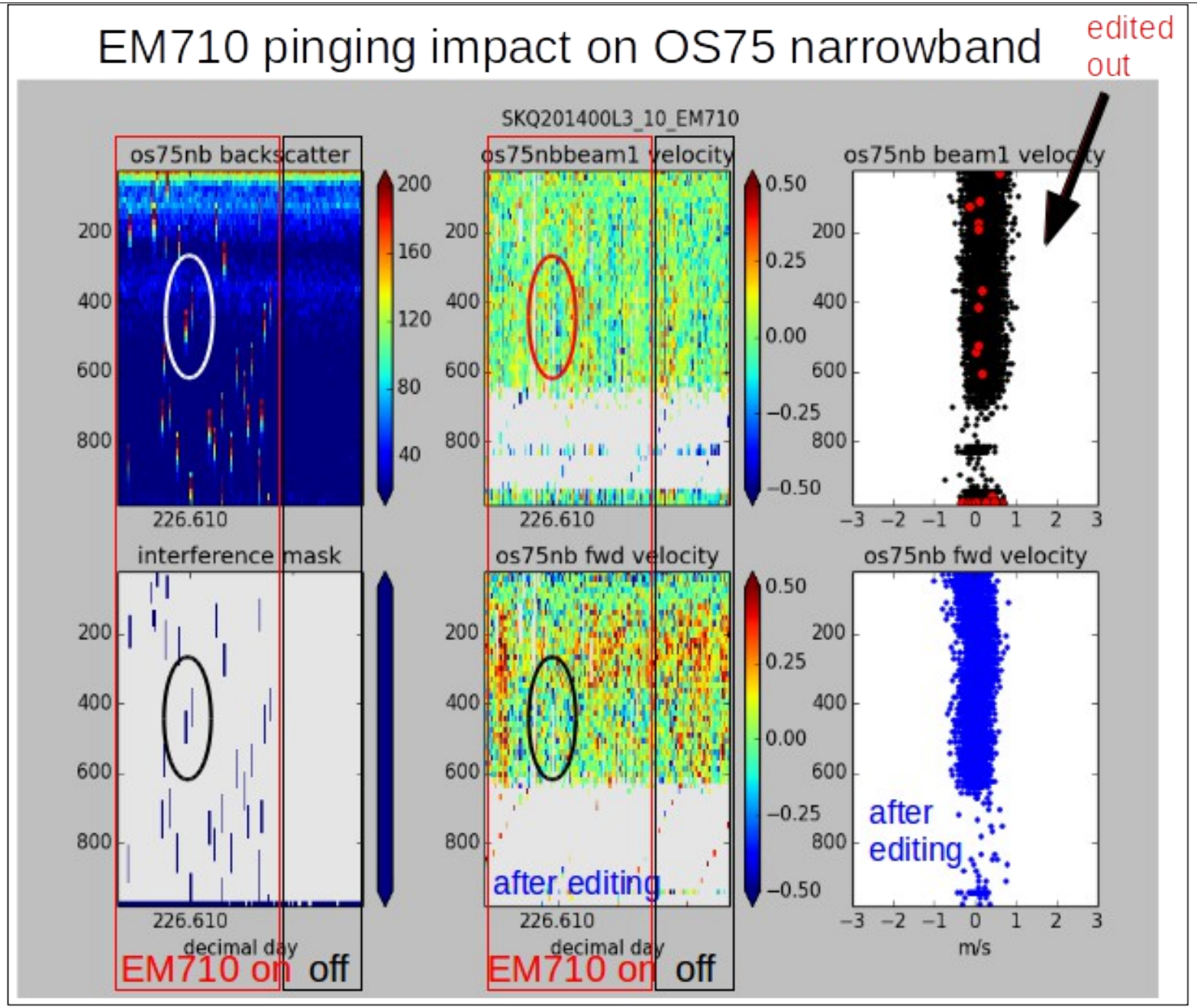
The most common causes of error (addressed by single-ping editing)

- Acoustic Interference
- Bubbles
- Below bottom

ADCP Processing: editing out interference

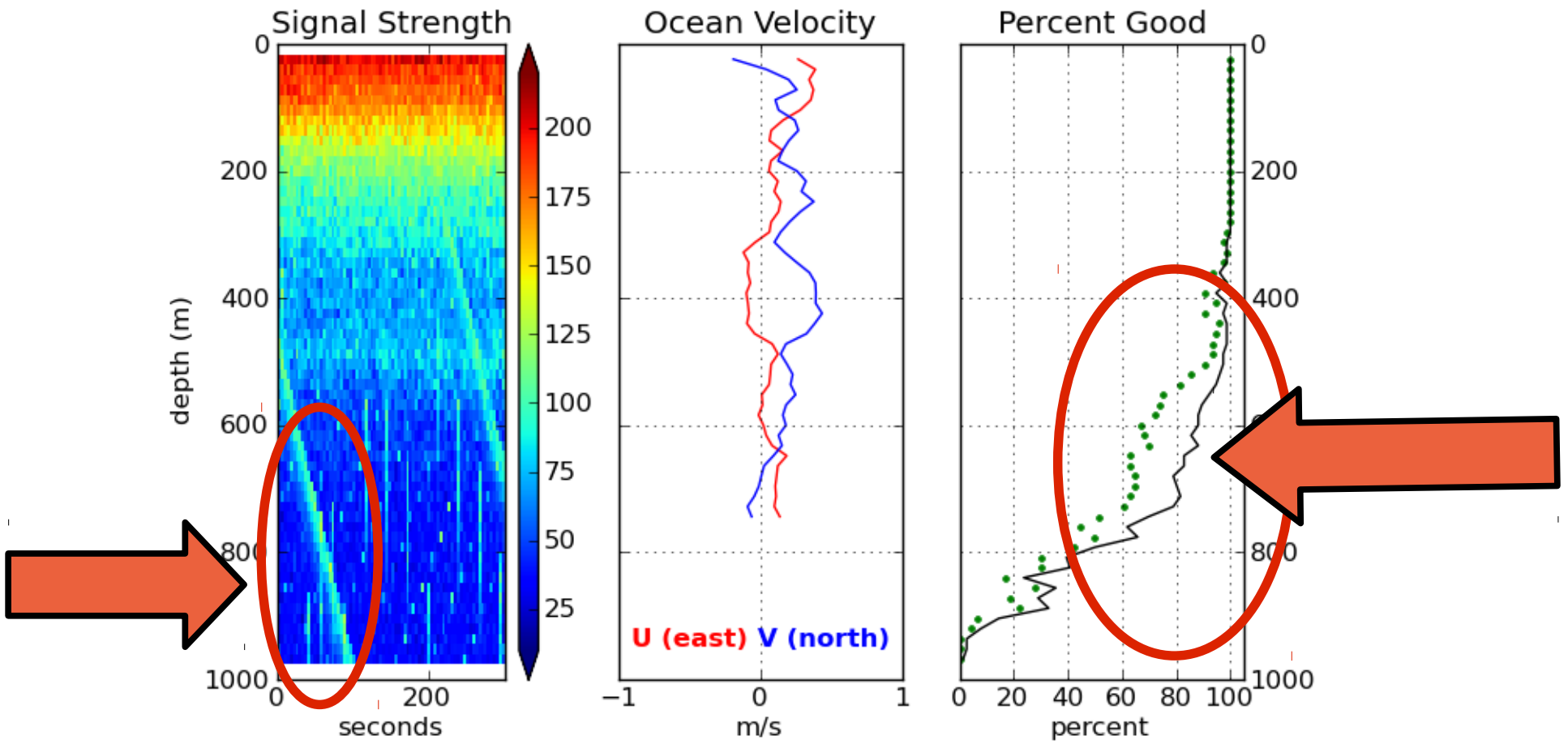


ADCP Processing: editing out interference



ADCP Processing

Singleping editing: acoustic interference



ADCP Single-ping Editing

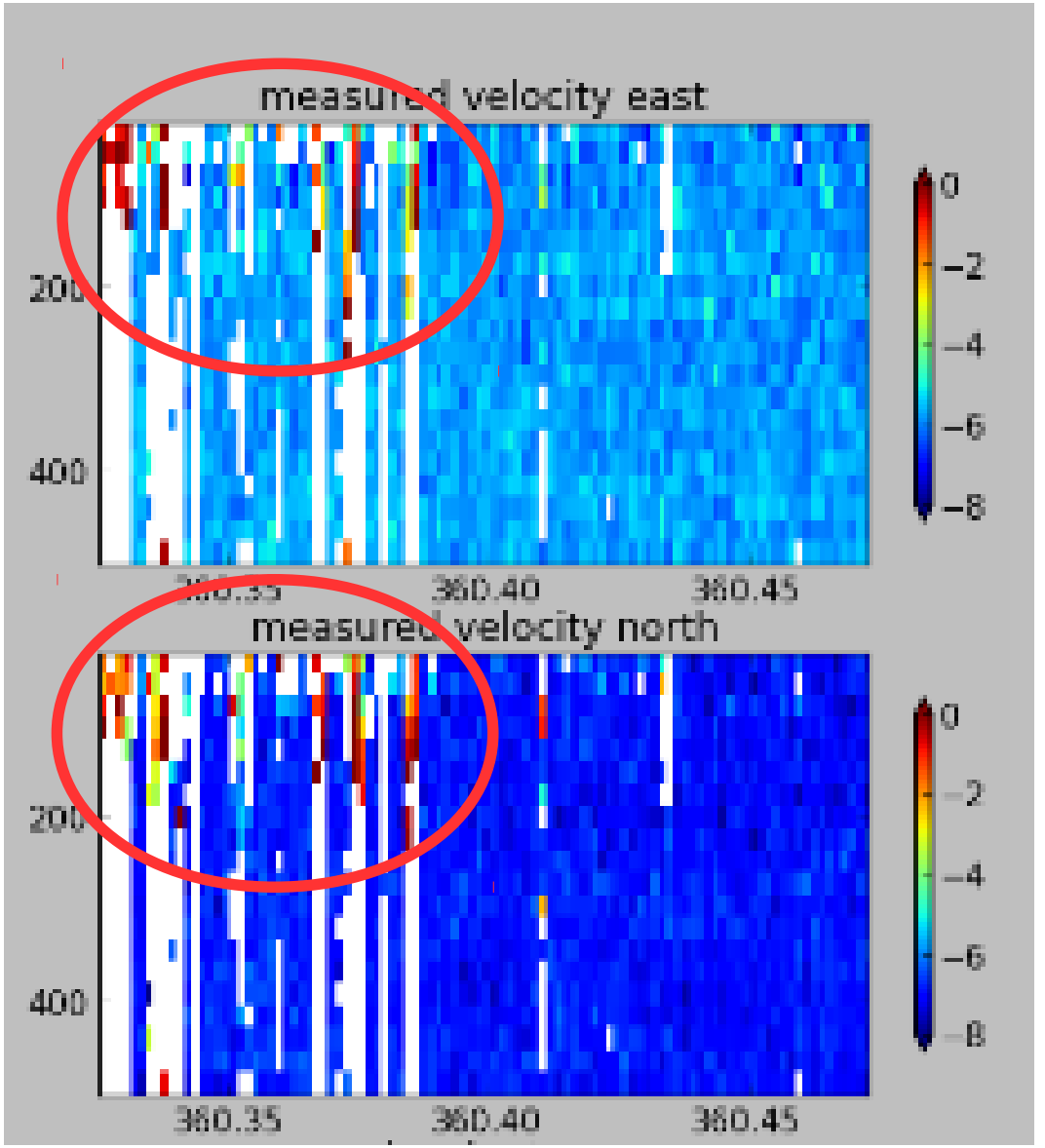
The most common causes of error (addressed by single-ping editing)

- Acoustic Interference
- Bubbles
- Below bottom

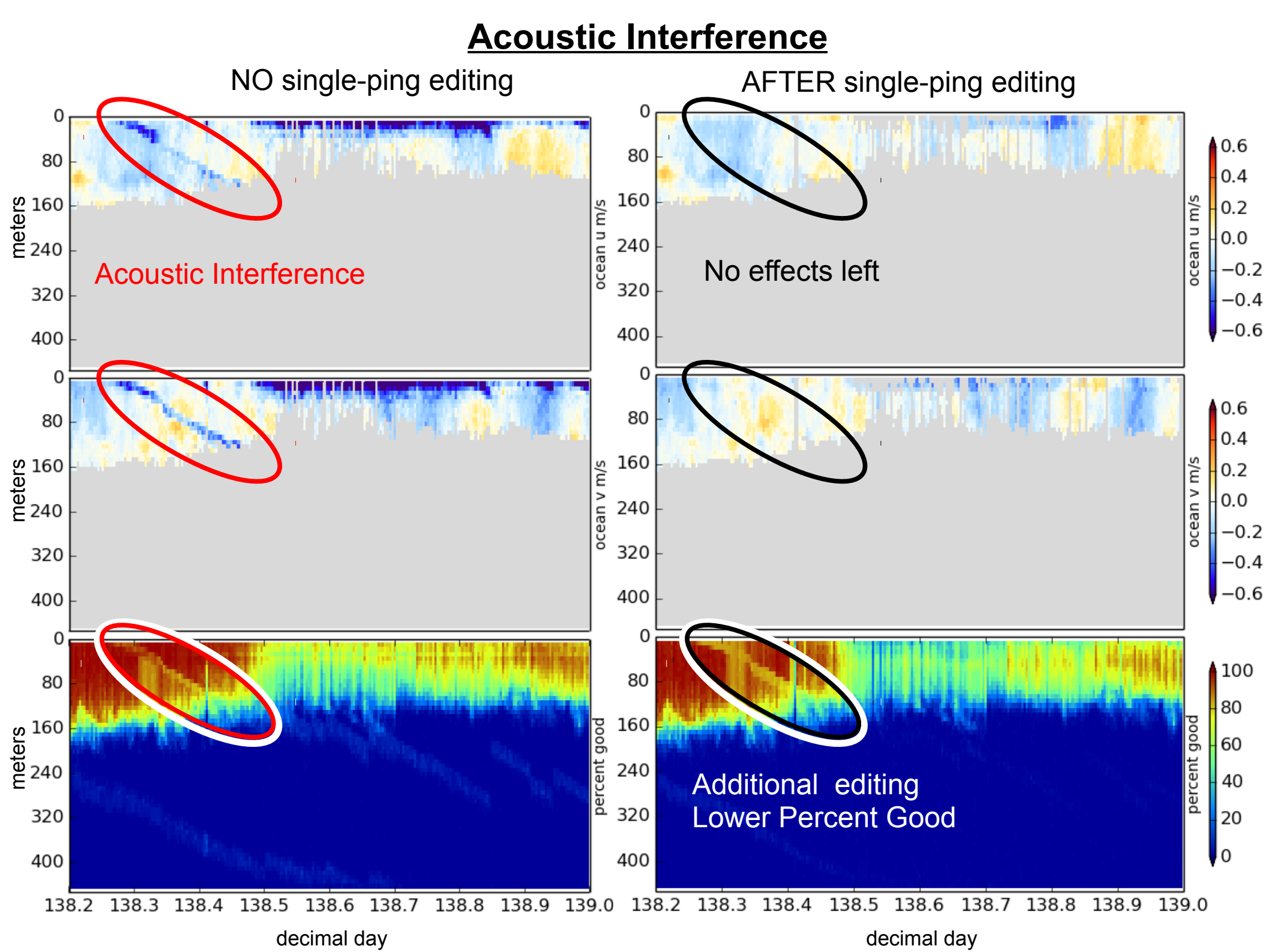
ADCP Data: effect of bubbles

Bubbles:
- short profiles
- strongly biased towards zero

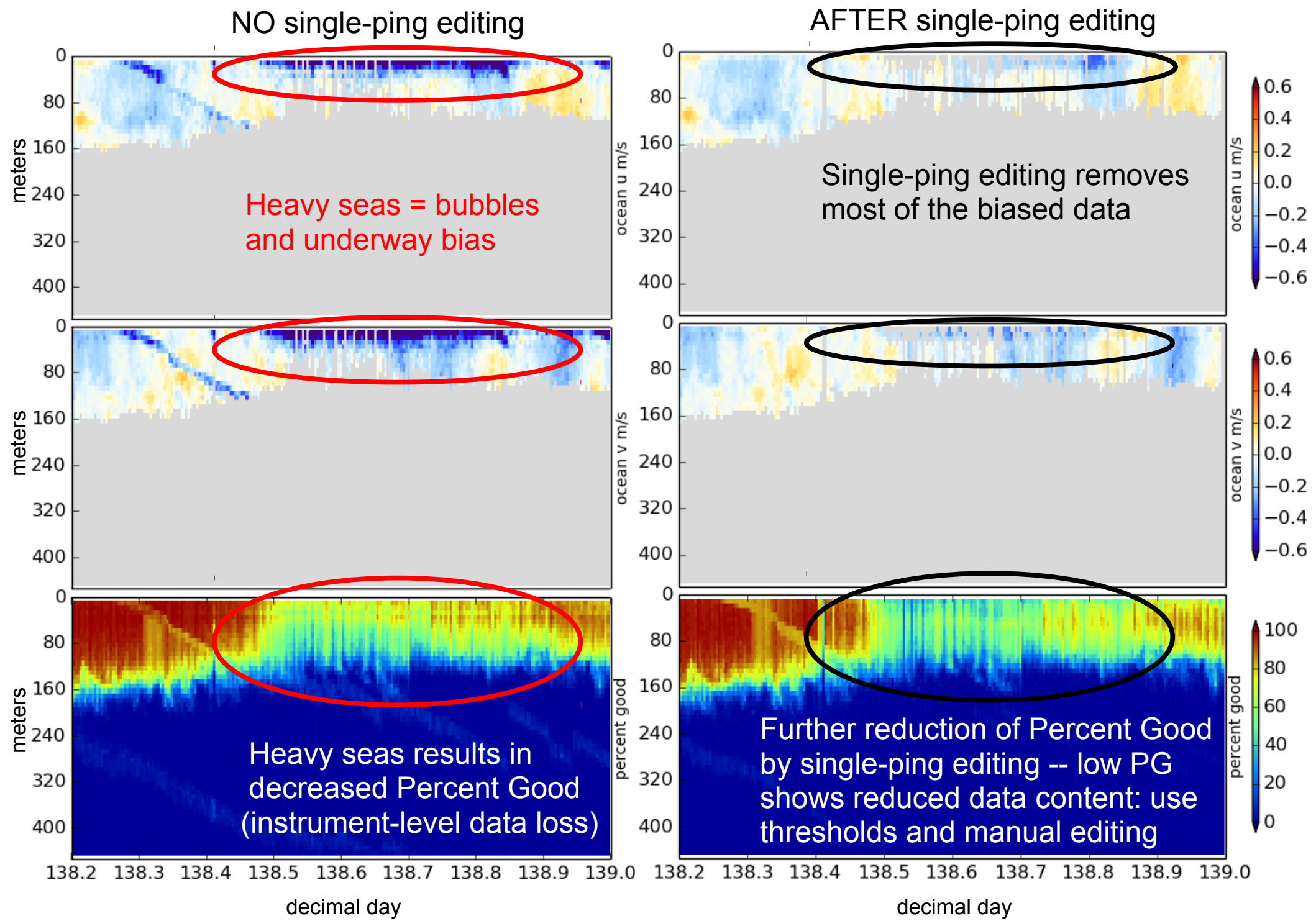
Untreated:
- biased ocean velocities



Acoustic Interference



Bubbles and alongtrack bias



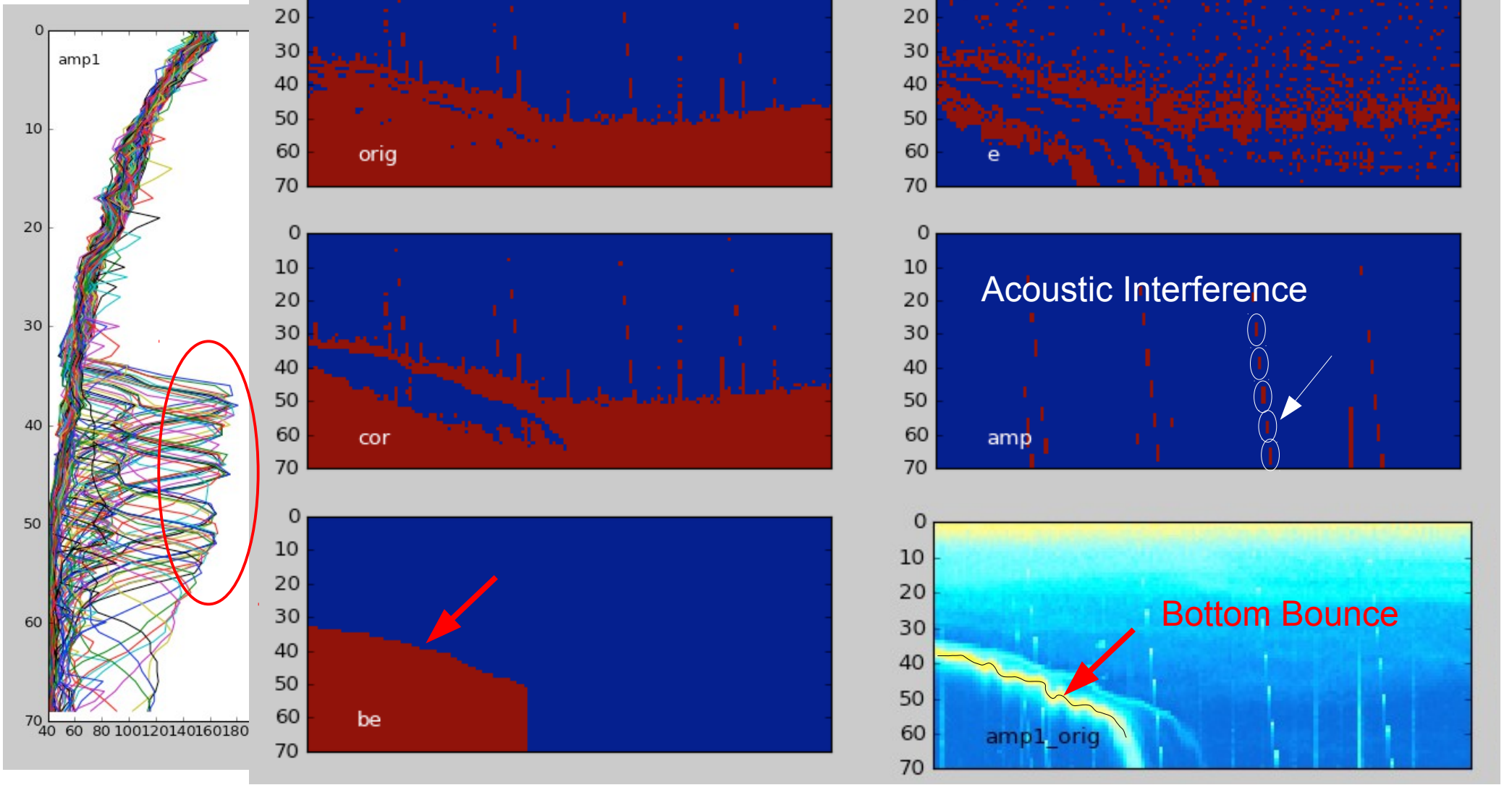
ADCP Single-ping Editing

The most common causes of error (addressed by single-ping editing)

- Acoustic Interference
- Bubbles
- Below bottom

Bottom Editing:

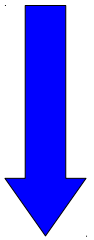
- remove acoustic interference, identify maximum amplitude
- calculate region of side-lobe interference
- flag as BAD all data below the bottom or with side-lobe interference



CODAS Post-processing

- Editing (single-ping)
  - Acoustic interference
  - Bubbles
  - Below bottom

AFTER AVERAGING



- Fix time-dependent heading correction (eg. if gaps)
- Apply calibrations
  - Rotation
  - Scale factor
  - Horizontal offset between GPS and ADCP (new)
- Manually edit CODAS database averages

CODAS post-processing:

(1) View figures and logfiles

(2) Fix heading:

- patch gappy but accurate heading correction (if relevant)
- apply time-dependent heading correction

(3) Determine corrections/calibrations, then apply

- remaining transducer angle offset
- scale factor (if relevant)
- transducer-GPS offset (in meters)

(4) Manually edit out bad data (dataviewer.py)

- use thresholds for bulk editing
- graphically select bins or profiles; use Seabed Selector for bottom

(5) check calibrations (angle, scale factor, gps-ADCP offset)

(6) make figures (web page) export data (matlab, netCDF)

Manual Editing

- Bottom interference
- Wire interference
- Scattering layers
- Ringing
- Bad shallow PG and underway bias

(see dataviewer.py documentation)

Post-Processing: Calibration of Averaged Data

(1) Cross-track error (angle error)

- Inaccurate heading (time-varying)
- Incorrect transducer angle (constant)

(2) Alongtrack bias (scale factor)

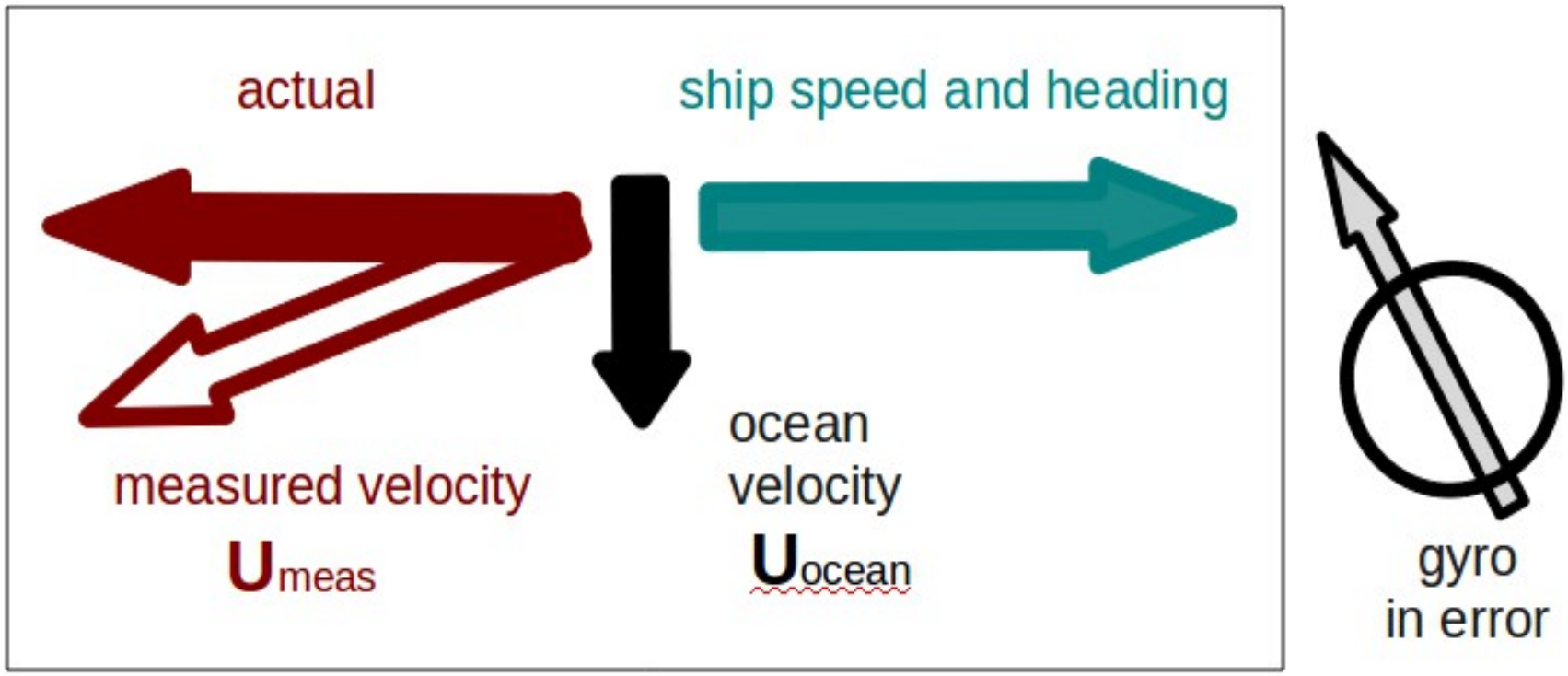
- Soundspeed (single-ceramic transducers only)

(3) Transition Error

- Horizontal offset between GPS and ADCP

Calibration: Angle Error

Cross-track bias in ocean velocity from angle error:
(heading + transducer angle)



Symptom = Cross-Track Error
Cause = incorrect **angle applied**

Angle applied comes from

- Transducer angle (beam “3” clockwise from bow)
- Heading of ship
  - **VmDAS**,
    - “Primary” heading, often no QC message
    - If “Primary” fails, replace with “Secondary”
  - **UHDAS**,
    - Reliable heading for each ping (eg gyro)
    - Heading correction for each averaging period
    - Calculated relative to devices such as Ashtech, POSMV, Seapath, Mahrs, Phins (hopefully w/ QC fields)

Symptom = Cross-Track Error
Cause = incorrect **angle applied**

Angle applied comes from

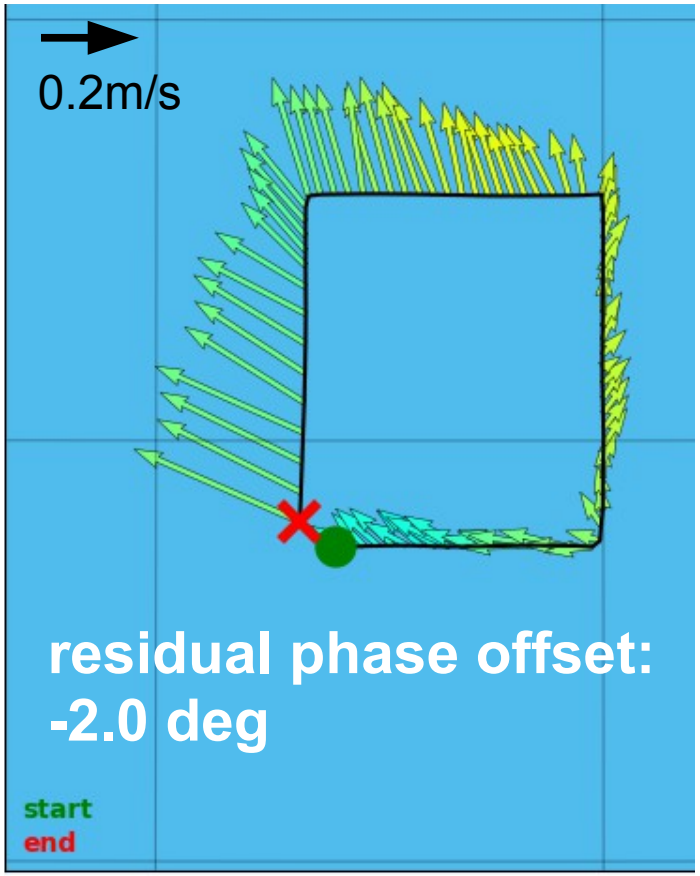
- Transducer angle (beam “3” clockwise from bow)

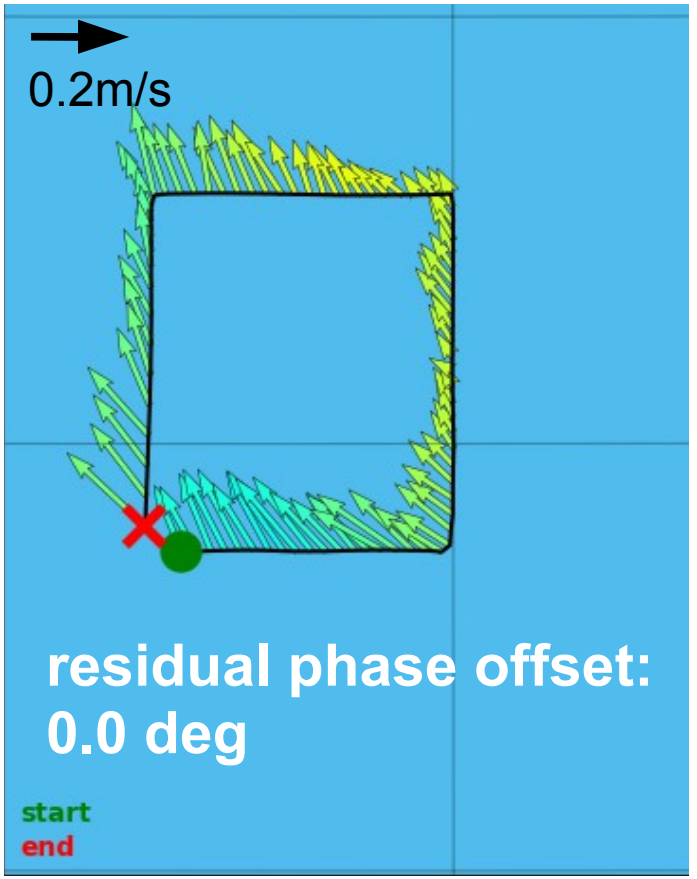
This is a **constant value** for the whole cruise

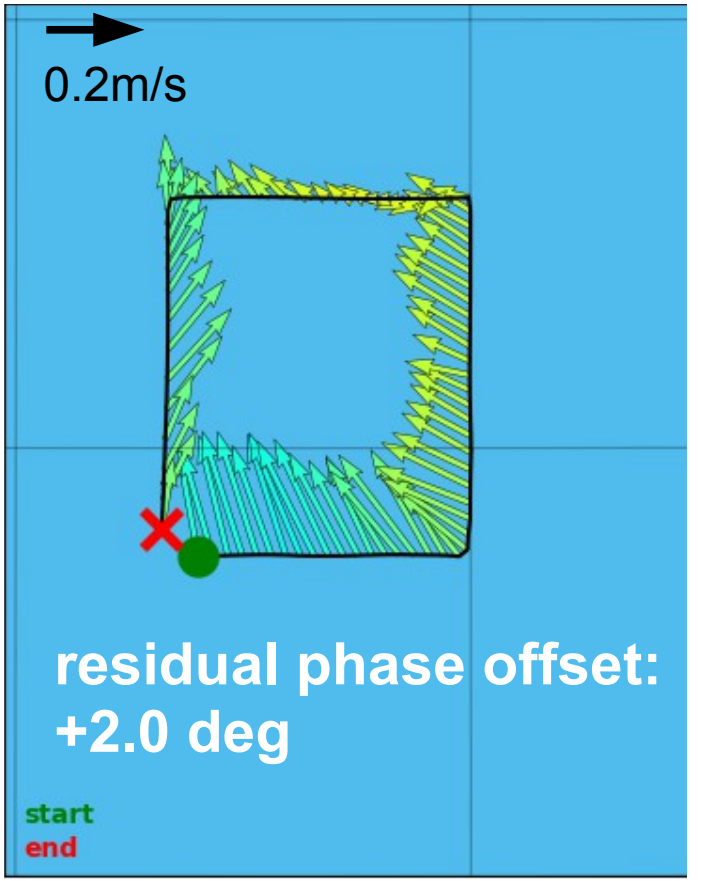
Examples of error in transducer angle follow...

water track phase calibration

1 deg. error = 10cm/s crosstrack error at 10kts







median	mean	std
-0.0085	**-0.0261**	0.3742

Goal: get within +/- 0.1deg

median	mean	std
-2.0020	**-2.0186**	0.3762

median	mean	std
1.9925	**1.9798**	0.3757

Examples of along-track error

Remove during single-ping editing

- Acoustic interference
- Bubbles (underway bias)

Correct after averaging:

- Scale factor (NB150 soundspeed correction)

Calibration: scale factor (alongtrack bias)

Ocean U (original)

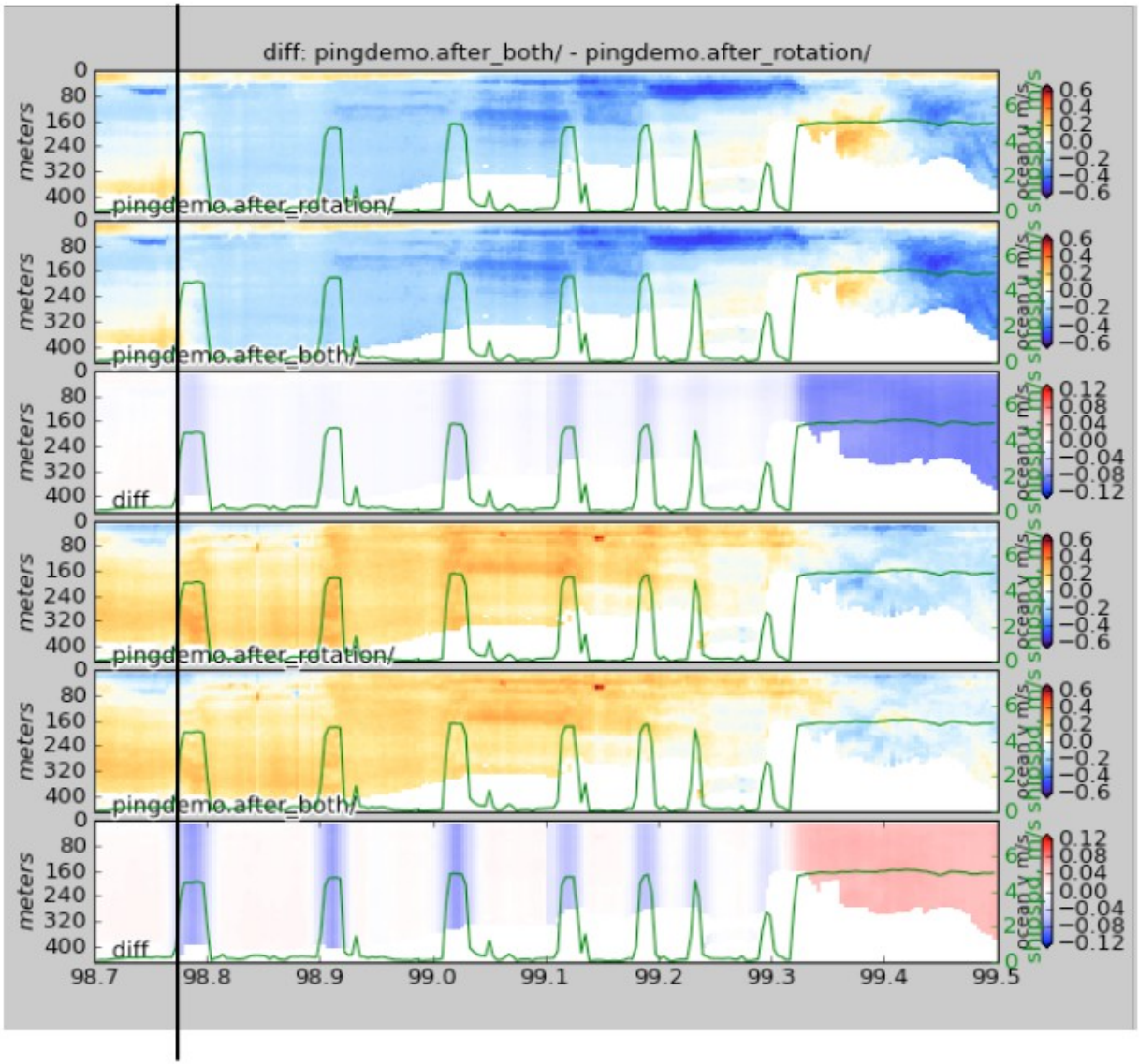
Ocean U (after scalefactor)

Diff: after-before

Ocean V (original)

Ocean V (after scalefactor)

Diff: after-before



Calibration: ADCP-GPS offset

(1) Cross-track error:

- recovery requires accurate heading

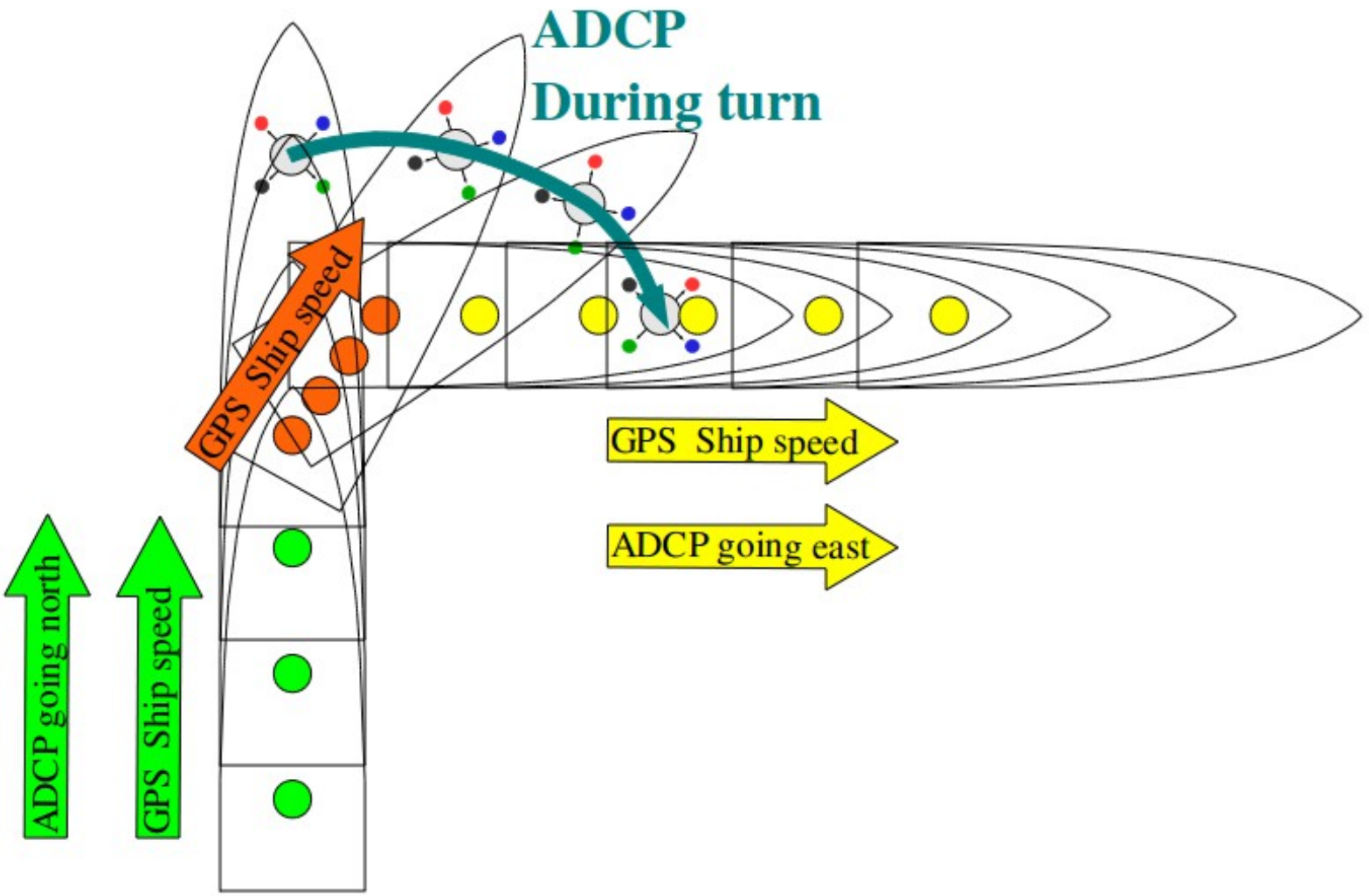
(2) Along-track error:

- may indicate a serious problem
- recovery may be possible, incomplete, ambiguous

(3) Transition/maneuvering error

- Lag or offset in time or space

Example: offset between ADCP and GPS creates an artifact during maneuvering

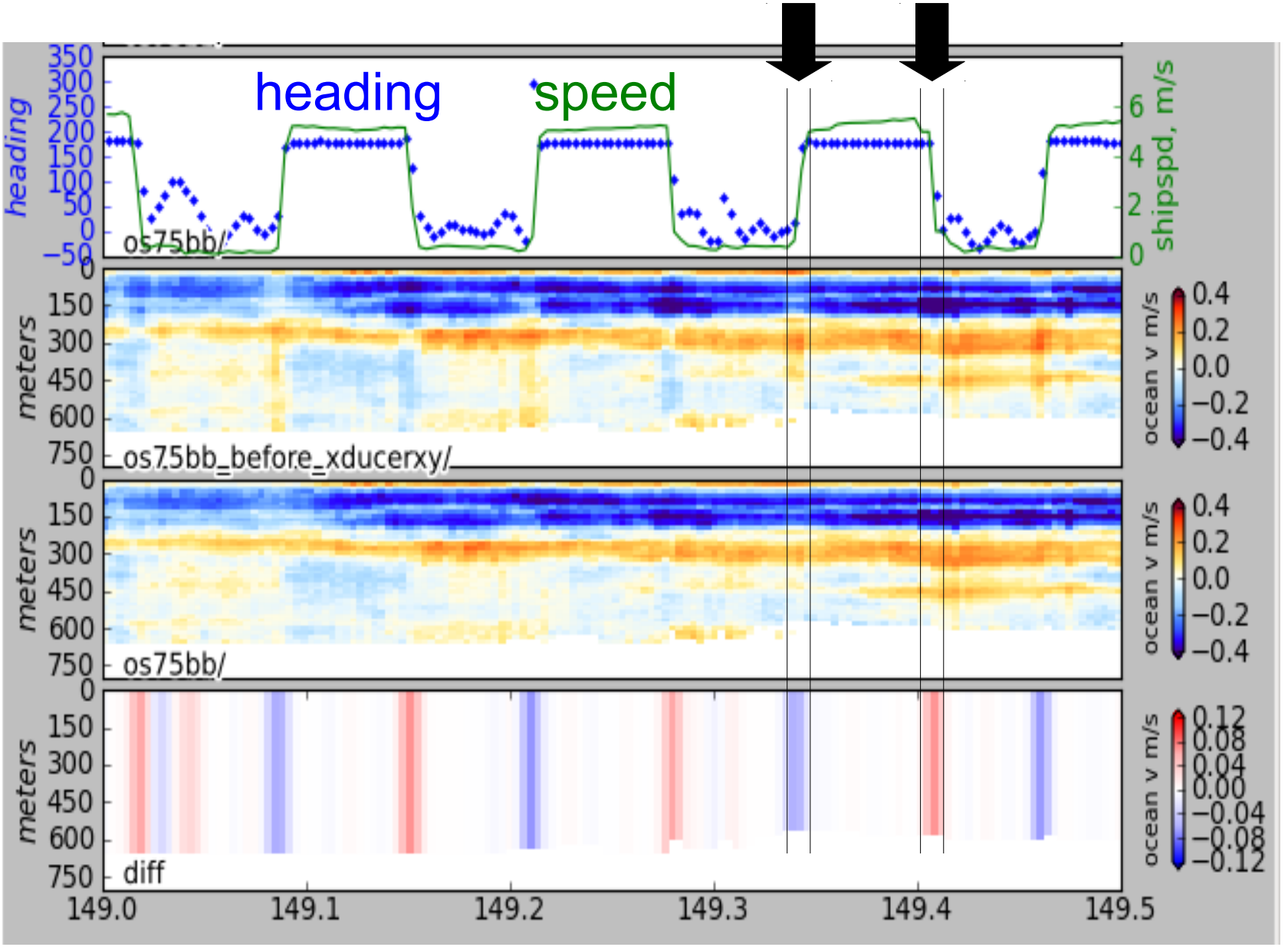


Transducer offset from GPS--error occurs: **transition** between on-station and underway

...using actual location

...using shifted GPS location

difference



Then go do science!