# ADCP System: what can go wrong

Viewed from the Perspective of:

- ADCP systems (components)
  - Computer
  - ADCP
  - Ancillary: GPS, Heading
- Data flow (where does the problem occur)
- Manifestation in ocean velocities – examples
  - Cross-track error (transducer angle)
  - Along-track error (scale factor)
  - Transition/maneuvering errors (lags in time or space)
  - depth-dependent bias (electrical noise)
  - surface bias (ringing)

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# What can go wrong: system=computer

- PC clock is erratic
- PC clock is set to local time
- Poor quality serial feed
  - Too many messages
  - Low baud rate
  - Multiple unbuffered devices

**Partial loss, Garbled messages**

---

Solution: FIX IT

•Clock set to UTC, do not use bad timeserver

•ONLY send serial data from the original instrument

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---

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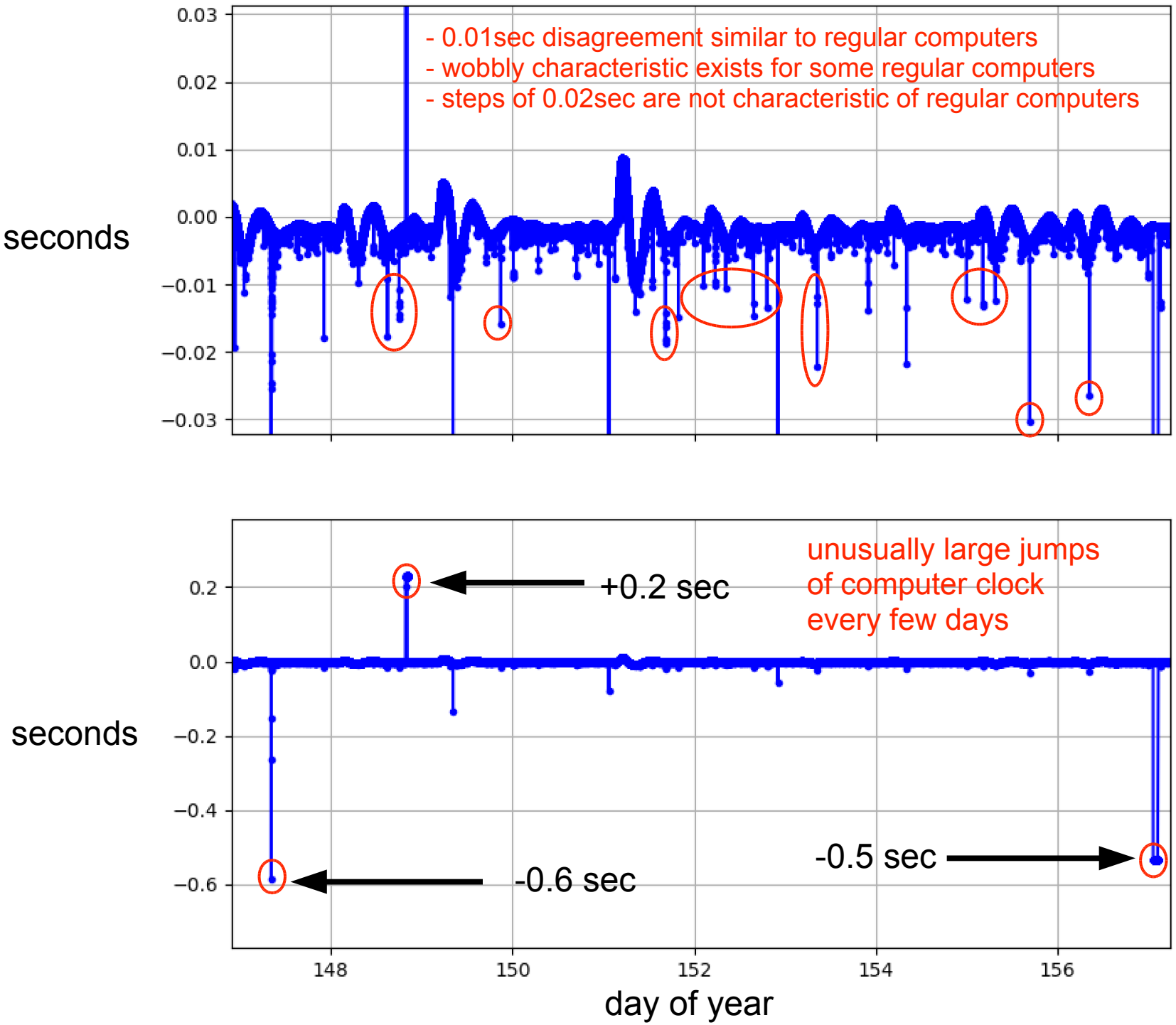
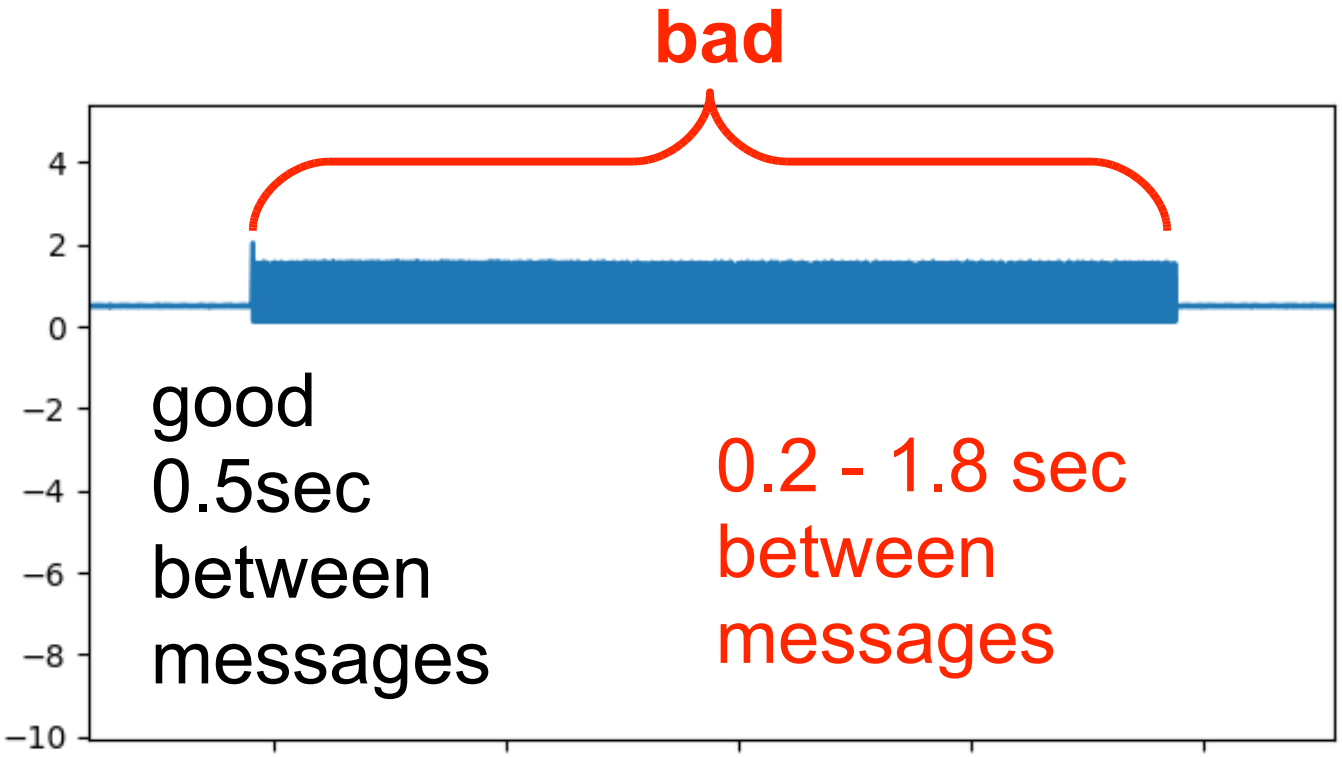
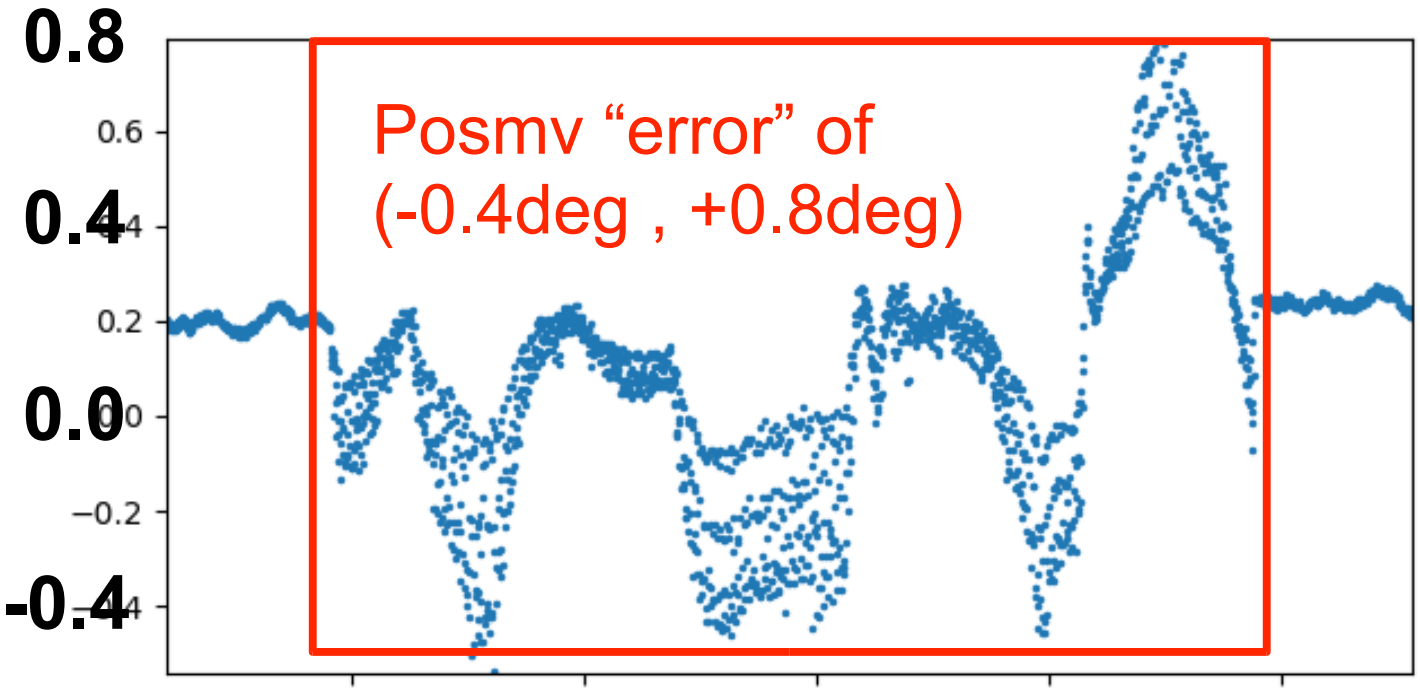
# Virtual Computer: Computer clock (on ntp) compared to GGA message timestamp






NMEA messages:
- none missing
- timing delayed
- buffer cleared

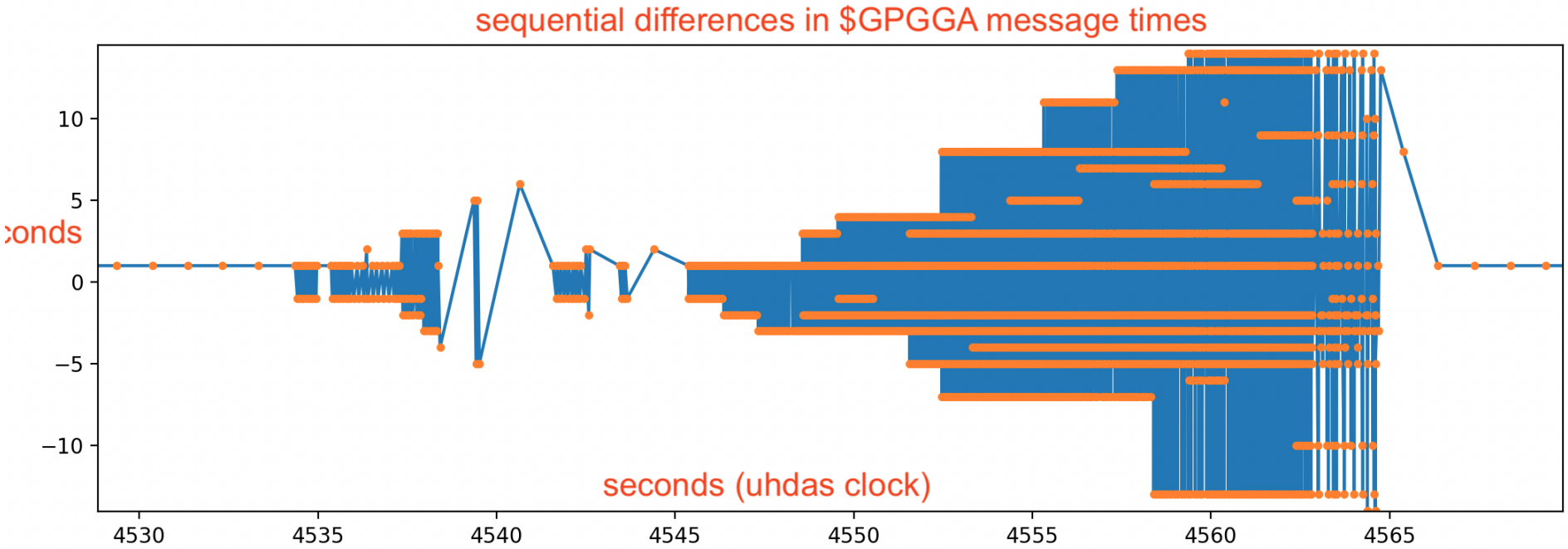



Comparison of Seapath to Posmv:
- both work
- errors created by variable (bad) arrival times

# What can go wrong: system=computer

Networking: UDP feeds

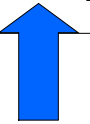
- multiple feeds coming in the same port
- UDP-to-serial over network: subject to network saturation
- network loops lead to UDP “storm”



# What can go wrong: system=ADCP

- ADCP loss or degradation
  - Loss of range (loud while underway; weak beam)
  - Loss of one beam (failure; blocked by object)
  - Loss of multiple beams
  - Acoustic interference (another pinger) see processing
  - Triggering (reduced ping rate, damage to pings)
  - Ice
  - Bubbles
  - Electrical noise

multiple examples (link)



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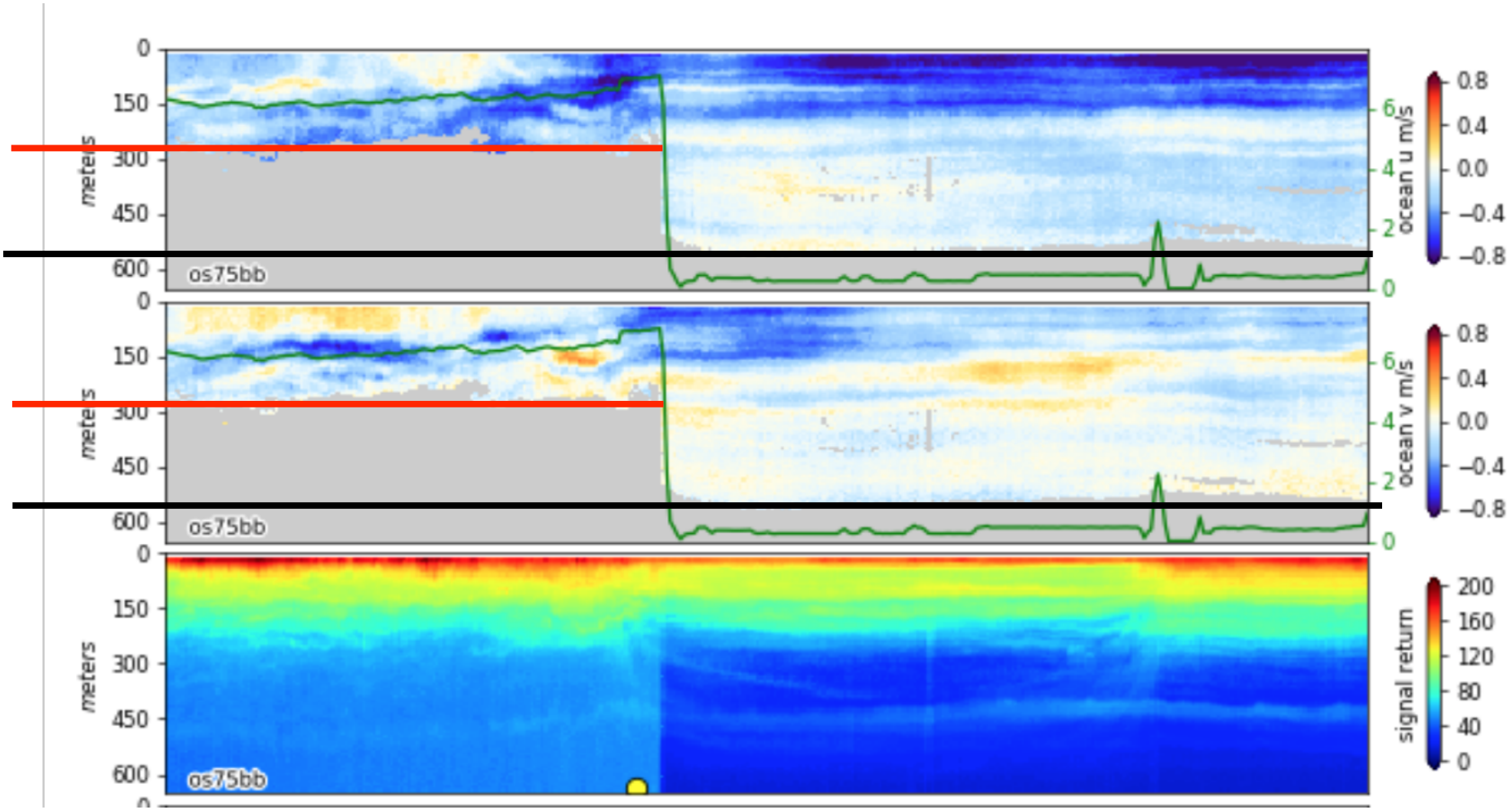
# Loss of range when ship is underway

- Symptom: range decreases when ship is underway
- Solution: Short term:
  - switch to narrowband mode
  - slow down
- Solution: Long Term:
  - scrub barnacles off hull and propellor
  - identify what is loud, remove it
  - redesign the hull to be quieter

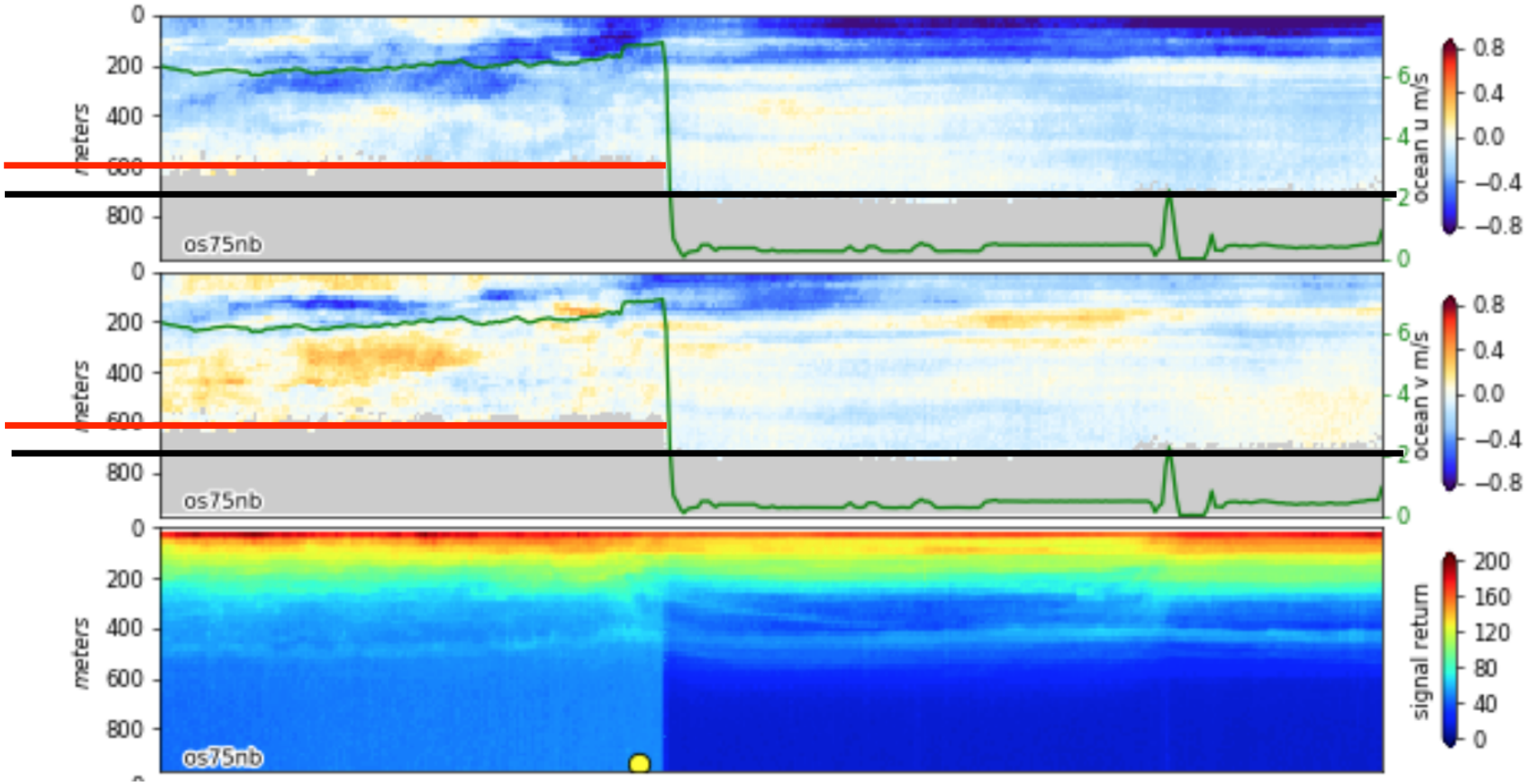
# broadband mode more susceptible to loss of range (loud ship or low scattering)




~300m range when underway

~600m range when on station

# narrowband mode less susceptible to loss of range (loud ship or low scattering)




~600m range when underway

~700m range when on station

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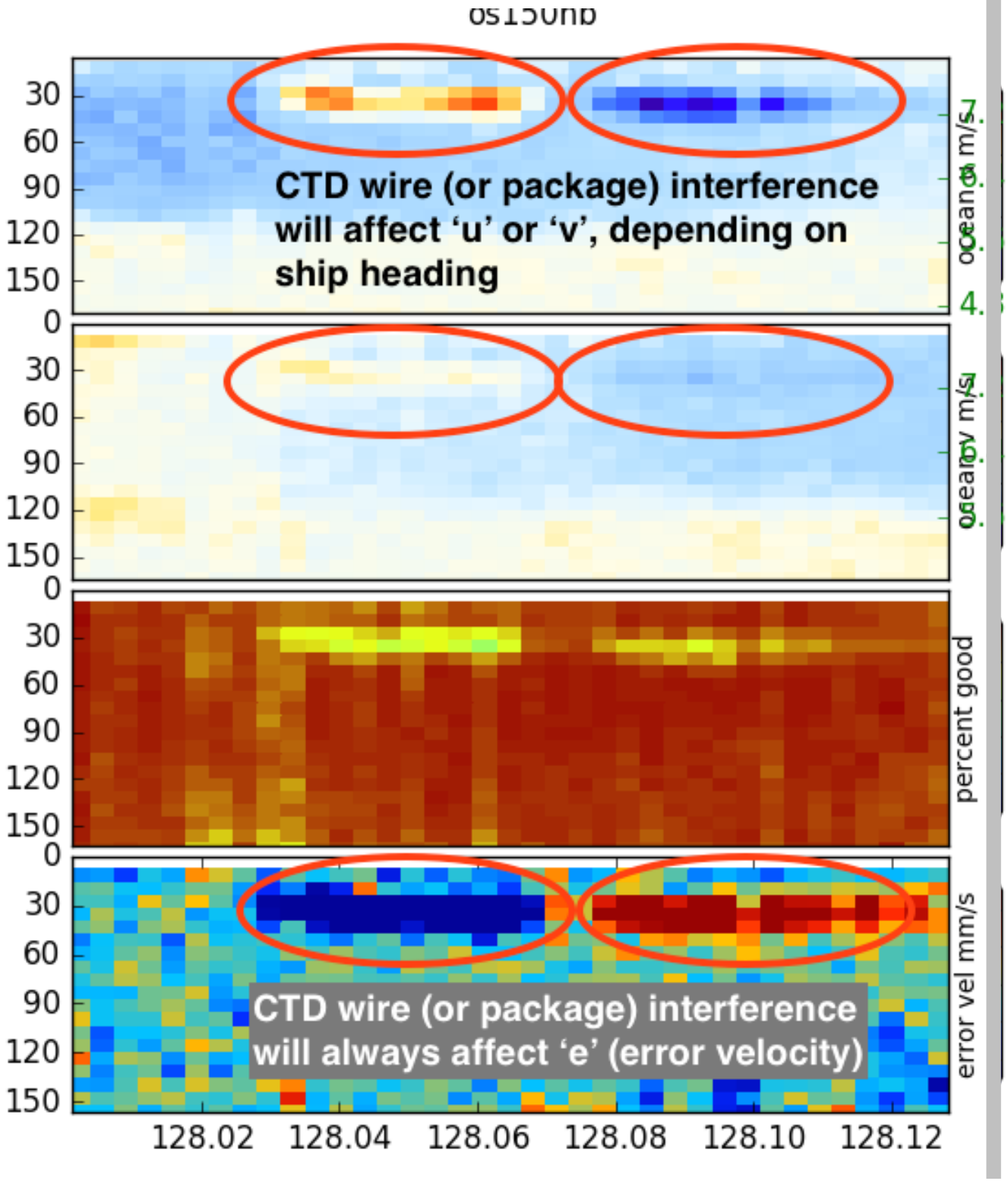
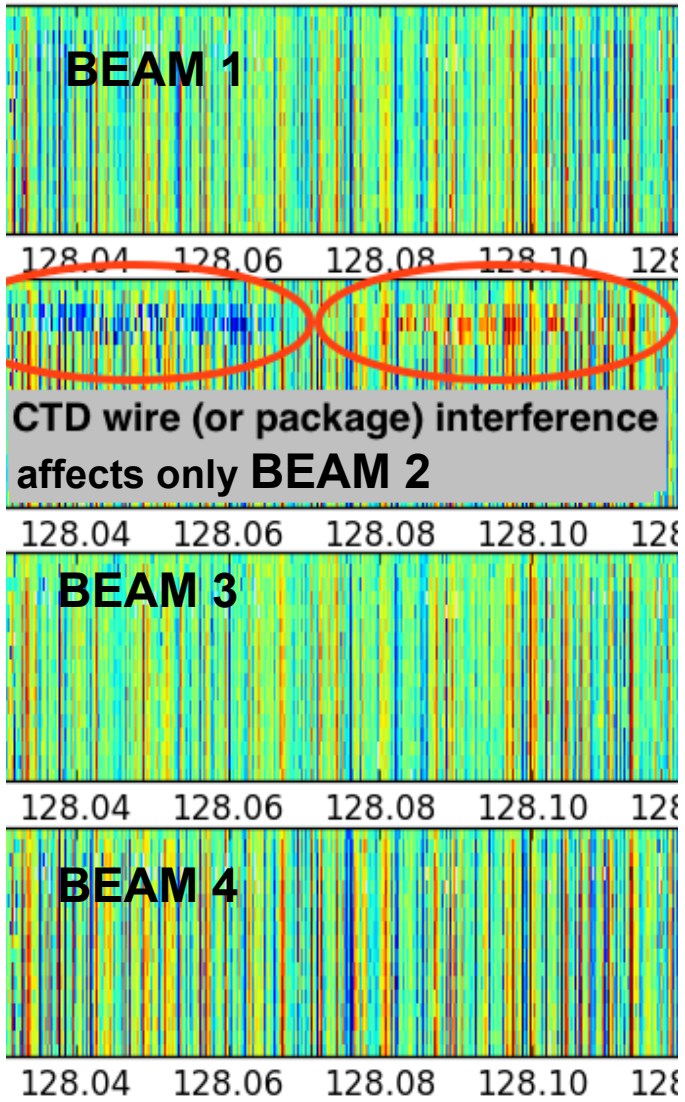
# CTD wire interference



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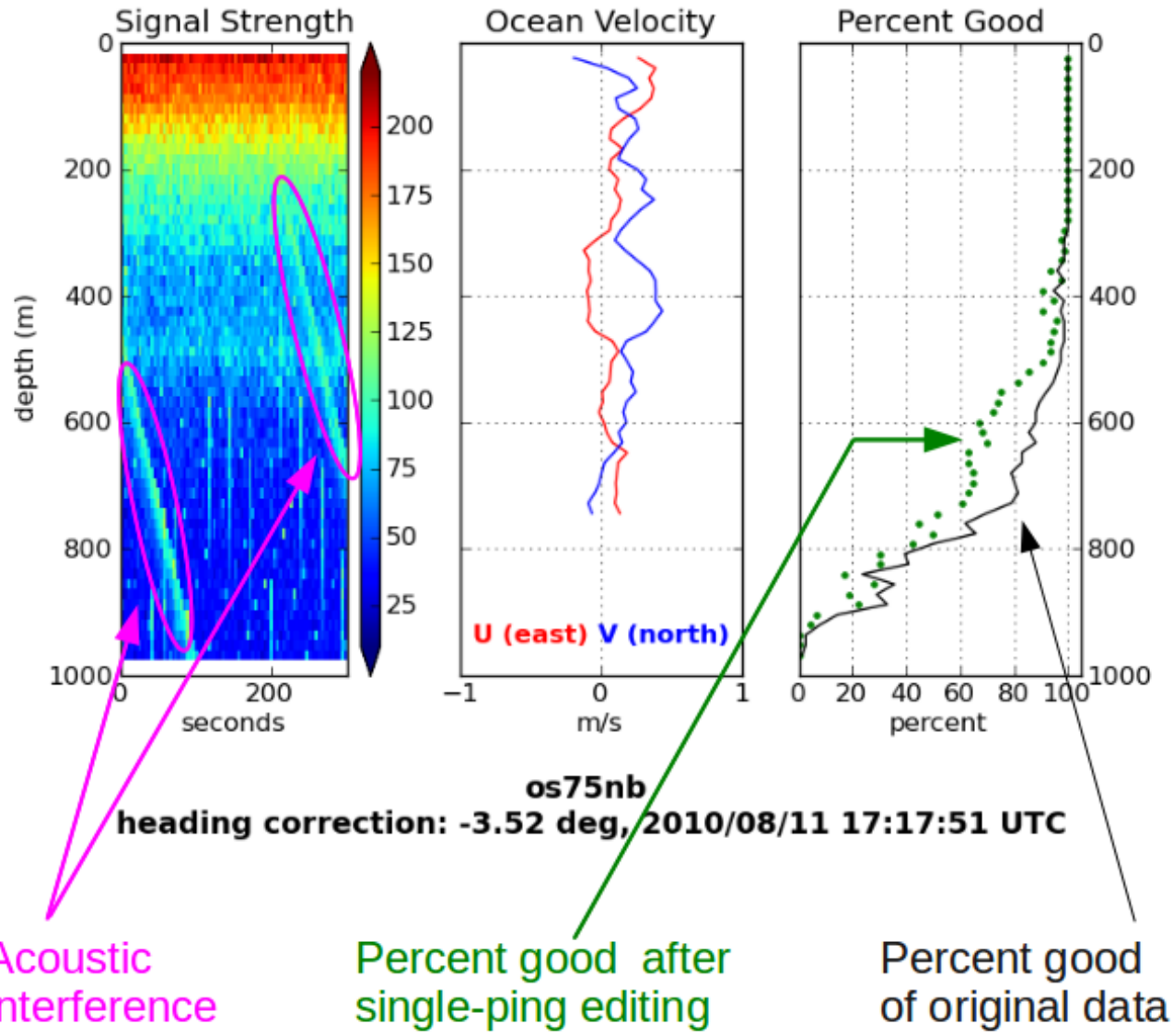
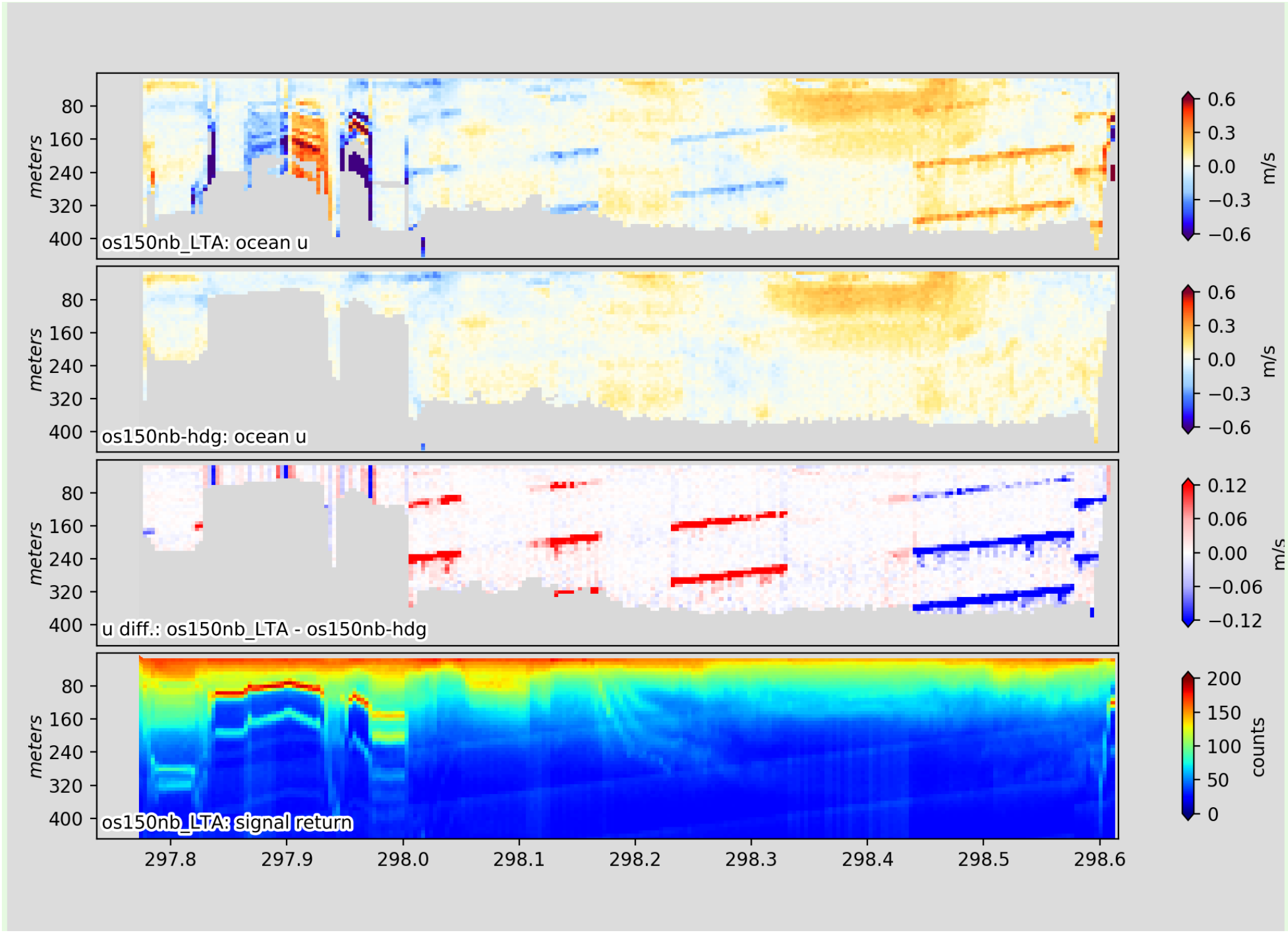
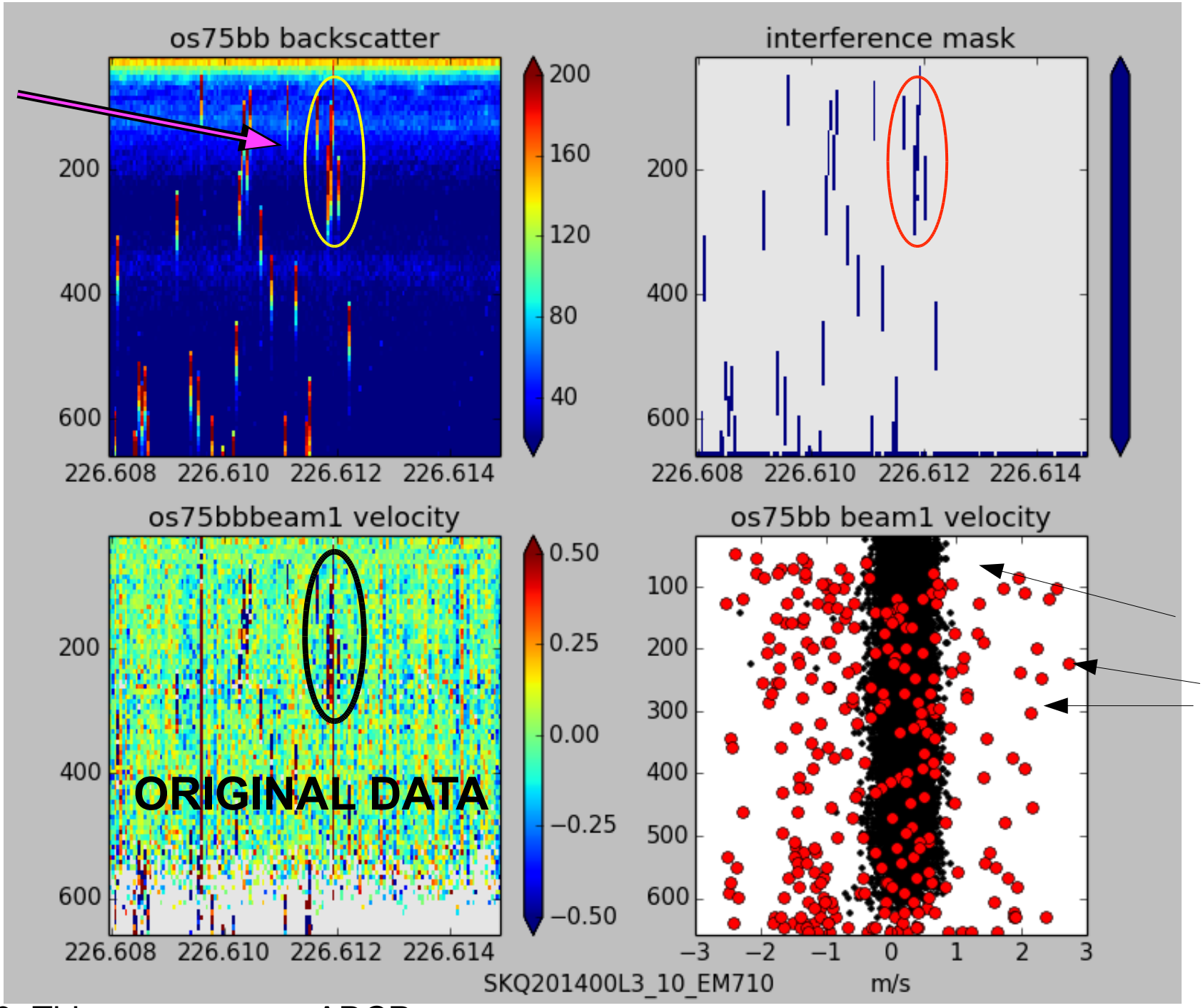
# Acoustic interference after editing



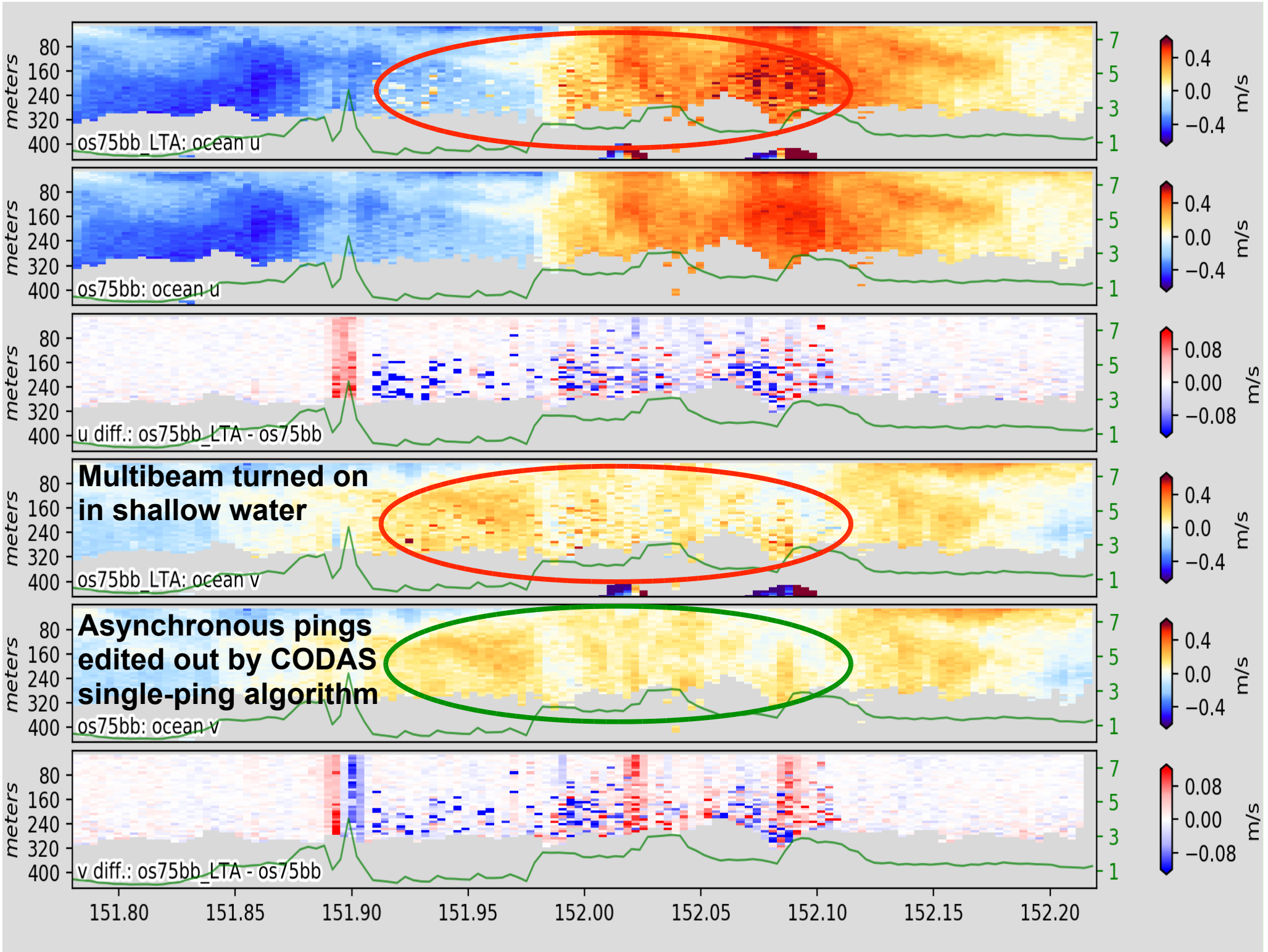

meters
80
160
240
320
400
os150nb_LTA: ocean u
os150nb-hdg: ocean u
u diff.: os150nb_LTA - os150nb-hdg
os150nb_LTA: signal return
0.6
0.3
0.0
−0.3
−0.6
m/s
0.12
0.06
0.00
−0.06
−0.12
200
150
100
50
0
counts
297.8
297.9
298.0
298.1
298.2
298.3
298.4
298.5
298.6

# Acoustic interference (single-ping editing)




**IDENTIFY acoustic interference using backscatter**

**FLAG and remove before averaging**


meters
80
160
240
320
400
os75bb_LTA: ocean u
os75bb: ocean u
u diff.: os75bb_LTA - os75bb
Multibeam turned on
in shallow water
os75bb_LTA: ocean v
Asynchronous pings
edited out by CODAS
single-ping algorithm
os75bb: ocean v
v diff.: os75bb_LTA - os75bb
7
5
3
1
0.4
0.0
−0.4
0.08
0.00
−0.08
m/s
151.80
151.85
151.90
151.95
152.00
152.05
152.10
152.15
152.20

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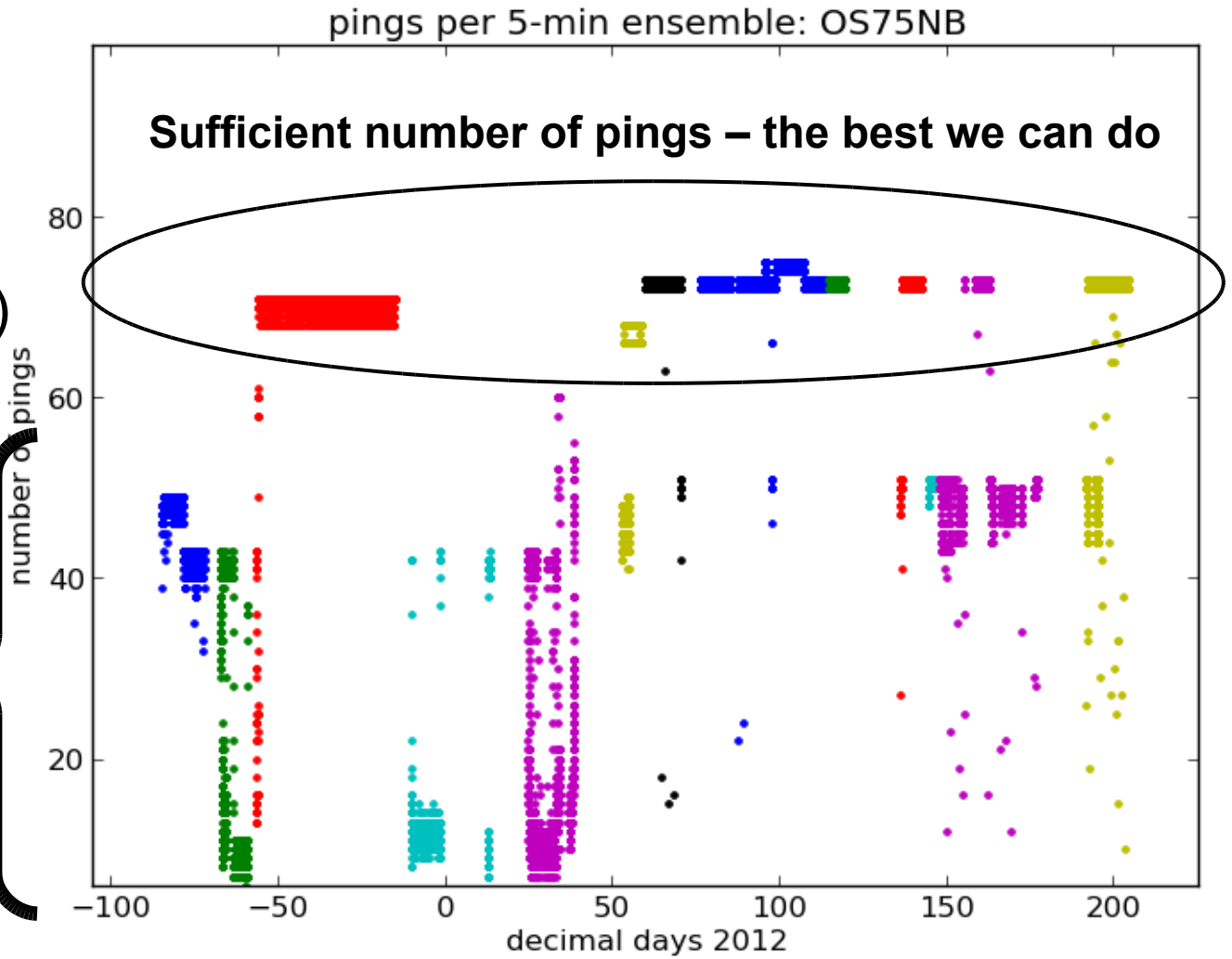
# Triggering: reduced ping rate

- 300-sec averages
- 2-second ping rate
- interleaved (BB+NB)
- expecting 70 pings

REDUCED number of pings due to triggering



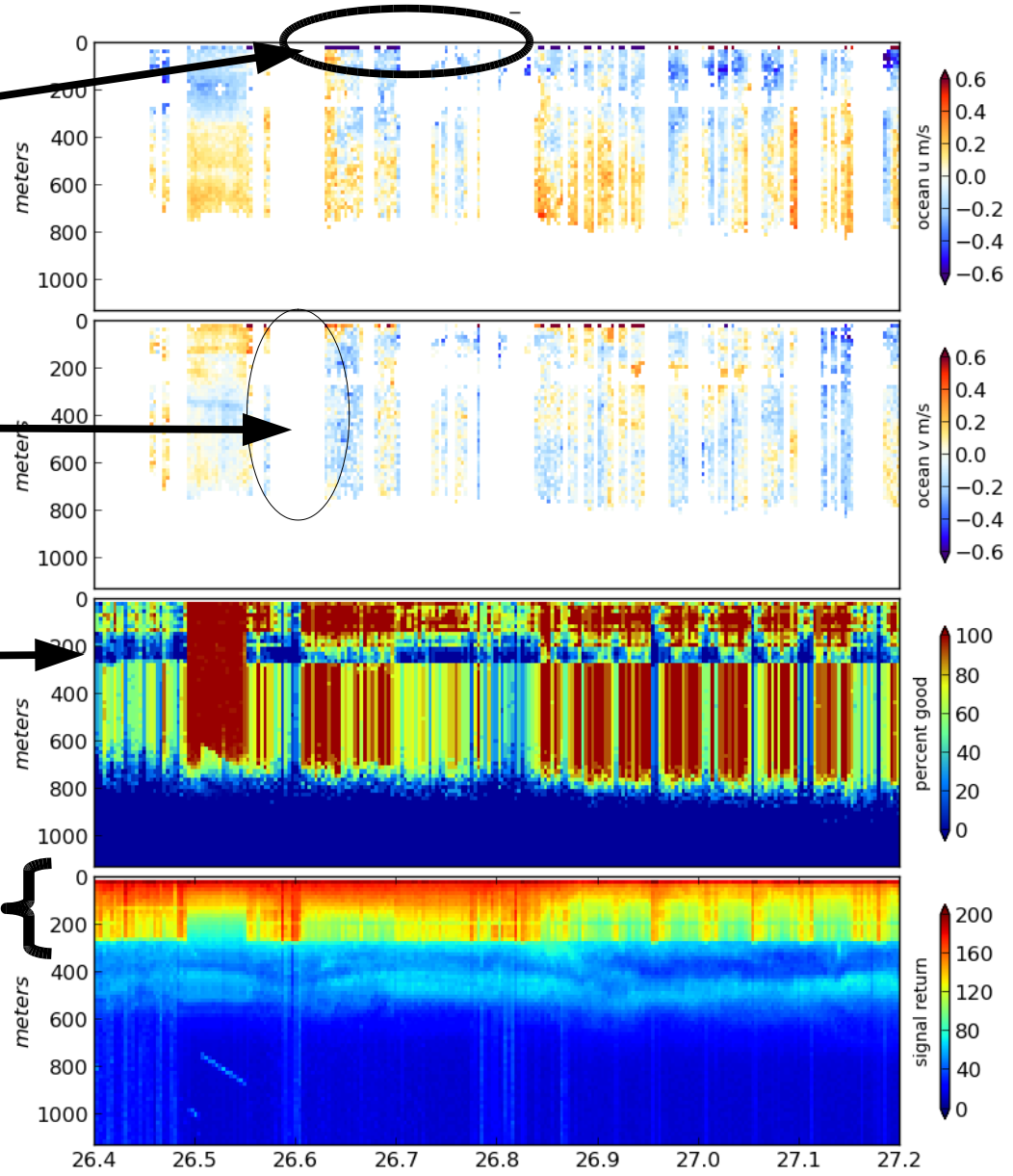
# Triggering: damage to pings

- bias in top bin(s)

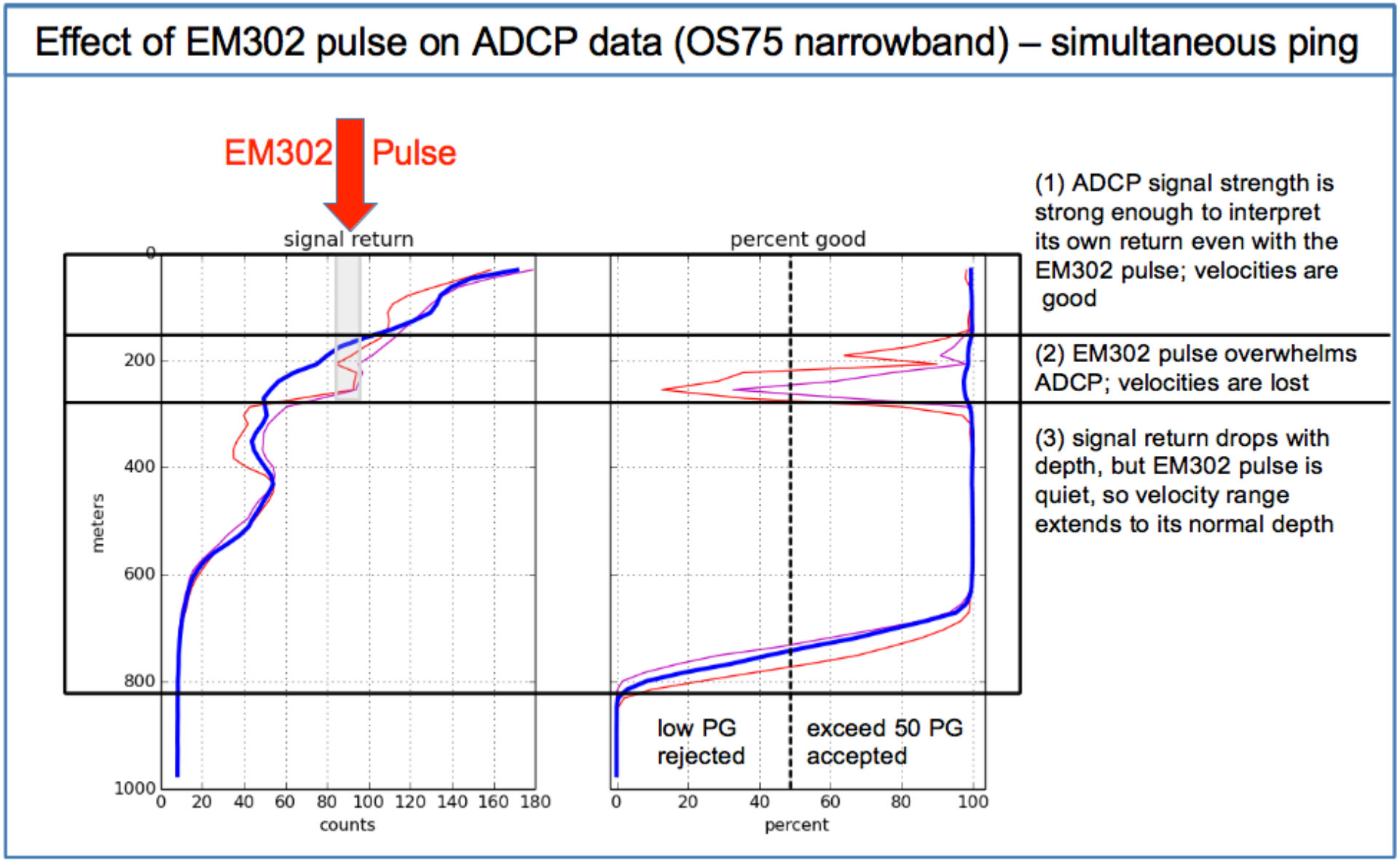
- gaps due to decreased ping rate

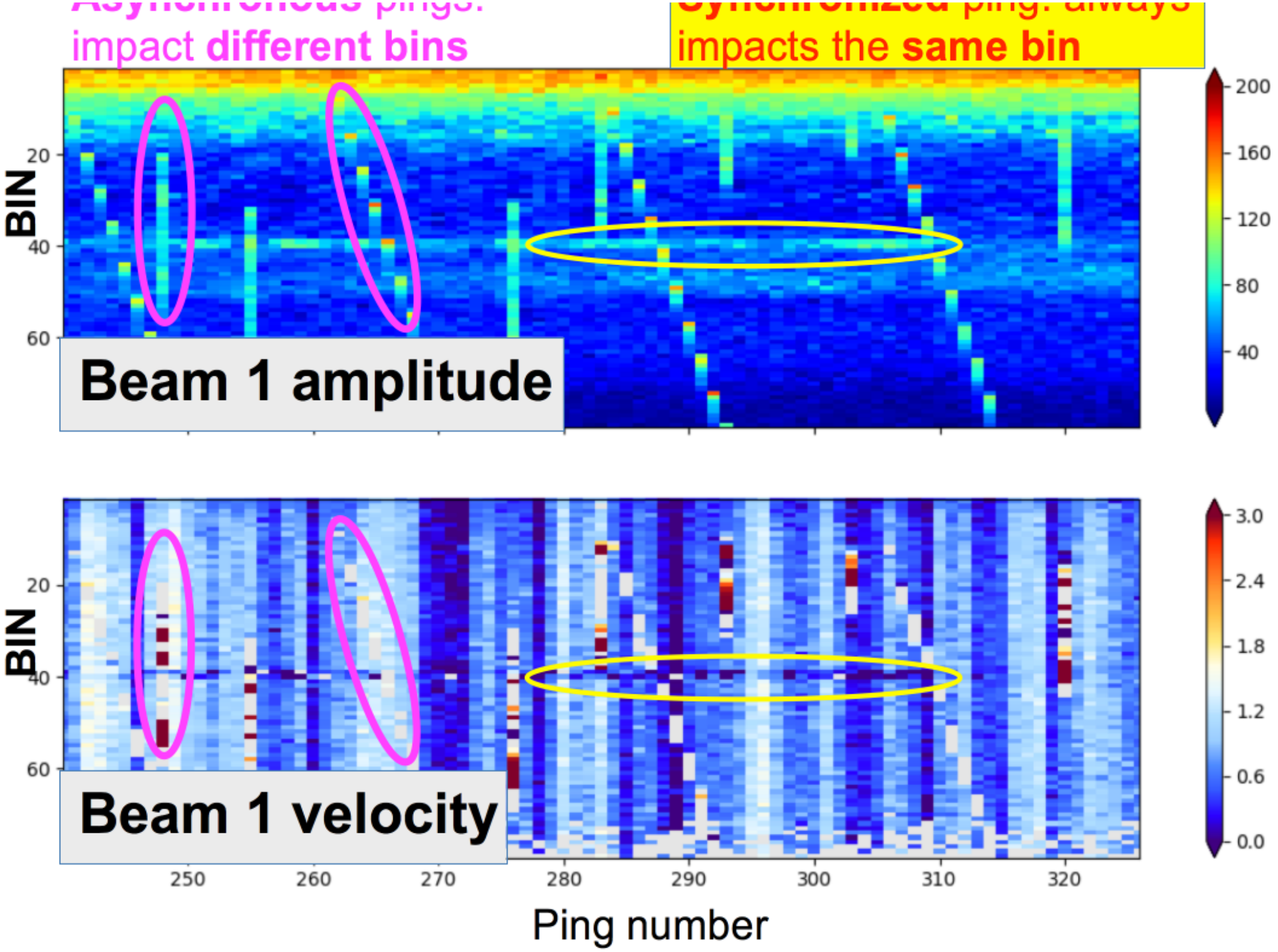
- Scarring where the master's pulse kills the ADCP signal

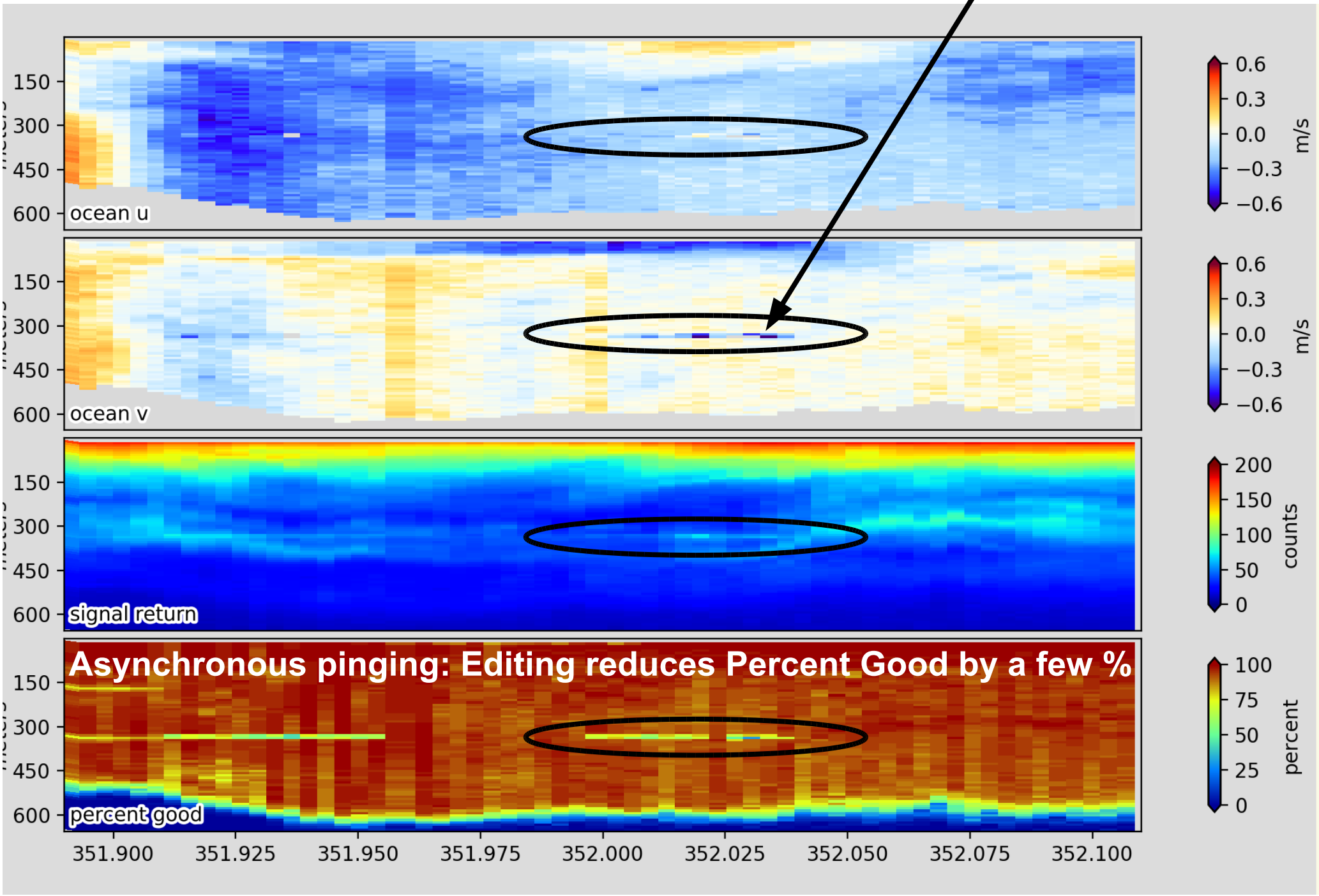
- Long pulse damages the top 250m of ADCP data



# Triggering: damage to data




impact different bins
impacts the same bin
BIN
20
40
60
200
160
120
80
40
Beam 1 amplitude
BIN
20
40
60
3.0
2.4
1.8
1.2
0.6
0.0
Beam 1 velocity
250
260
270
280
290
300
310
320
Ping number


Asynchronous pinging:
Editing is successful
Synchronized pinging: incomplete editing
leaves contaminated velocities in averages
ocean u
ocean v
signal return
percent good
Asynchronous pinging: Editing reduces Percent Good by a few %
150
300
450
600
0.6
0.3
0.0
−0.3
−0.6
m/s
200
150
100
50
0
counts
100
75
50
25
0
percent
351.900
351.925
351.950
351.975
352.000
352.025
352.050
352.075
352.100

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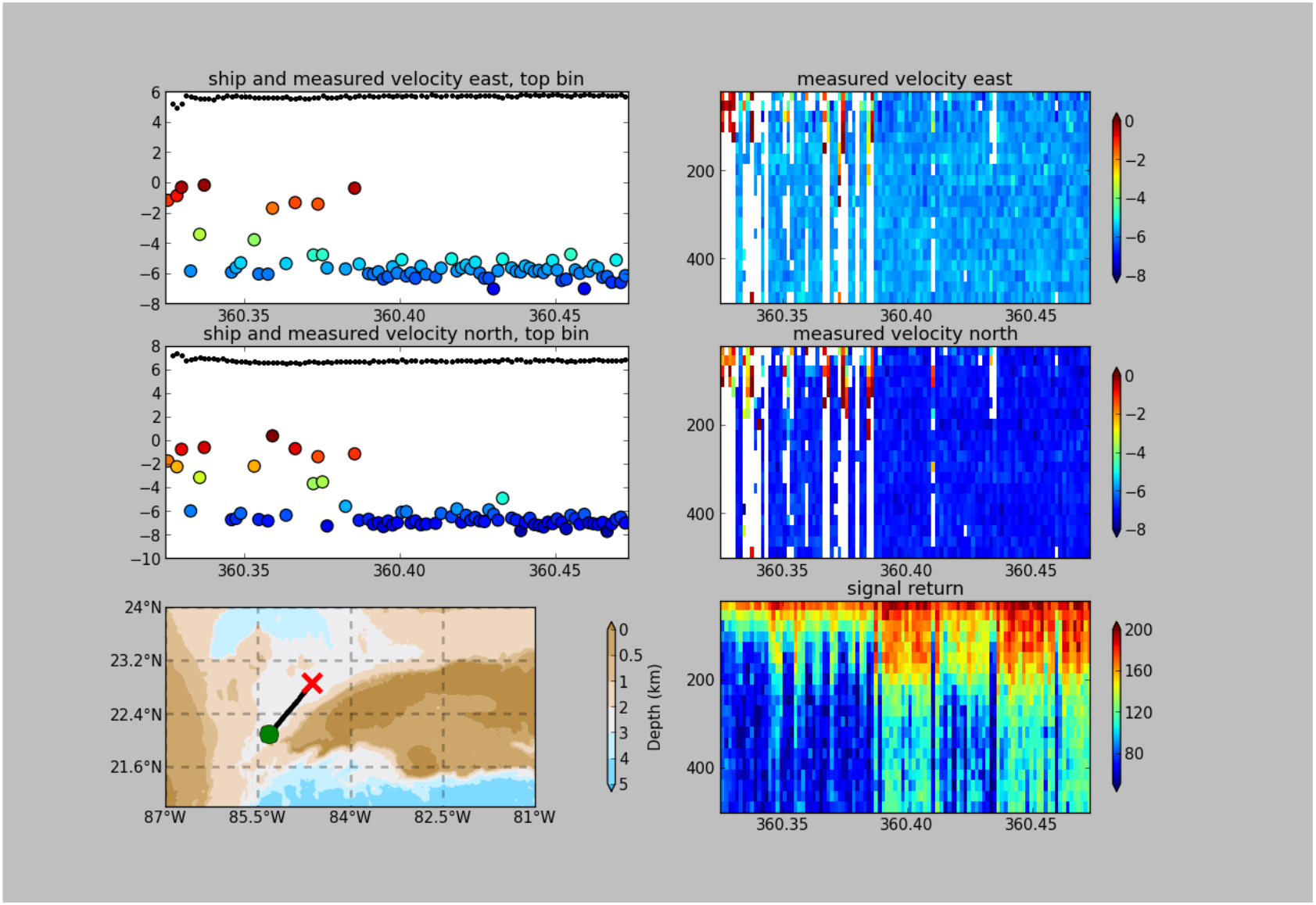
# Bubbles block sound, distort shallow bins

- Symptom:
  - Beam velocities biased towards zero near the surface
  - Ocean velocity biased in the direction of ship's motion
  - range is less, Percent Good is reduced near surface
- Solution: Short term:
  - slow down (if at sea), edit out bad data, be brutal
  - Do preliminary processing with single-ping data (editing)
- Solution: Long Term:
  - change the installation or hull; install a faring?

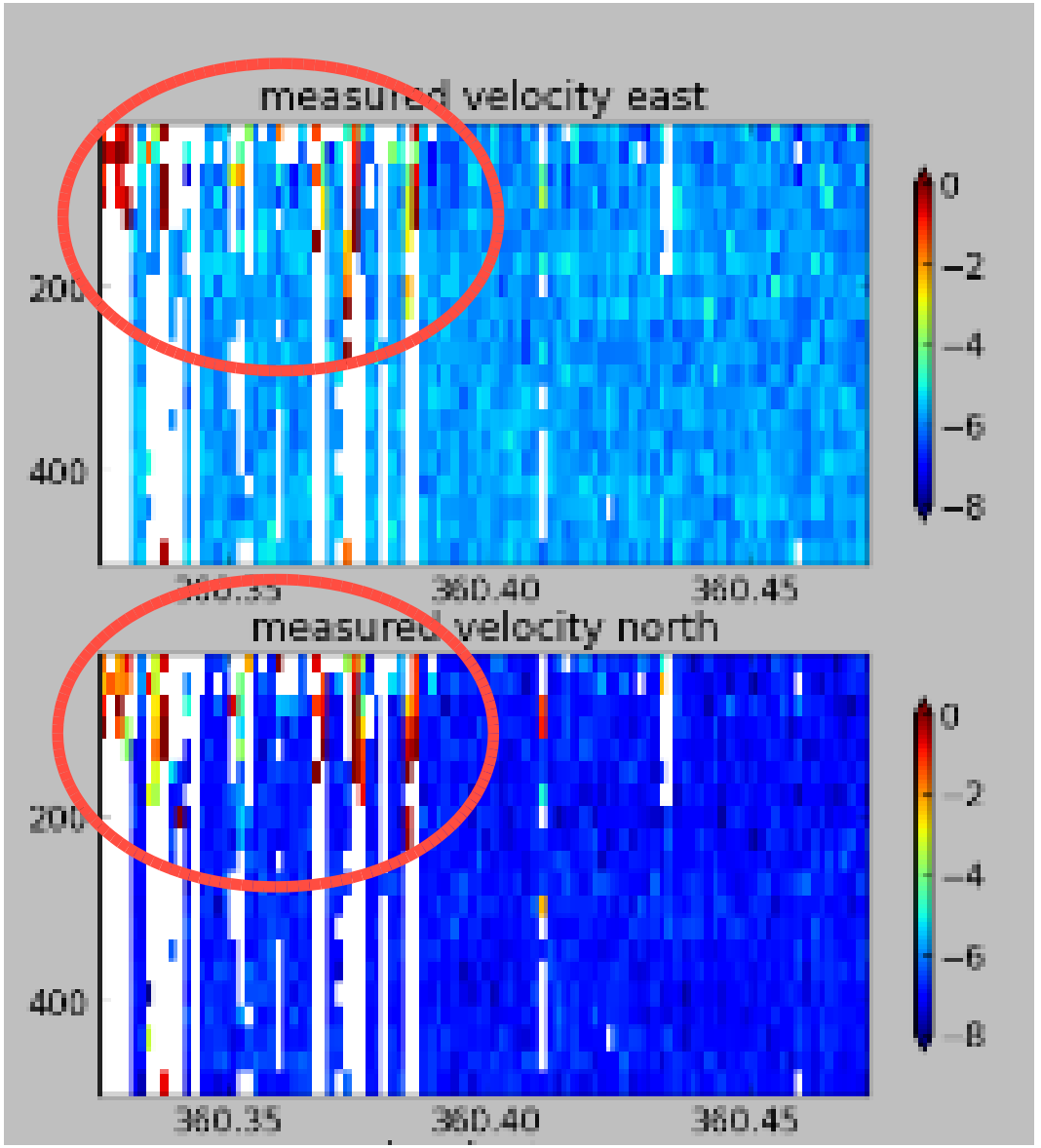
# single-ping editing:underway bias



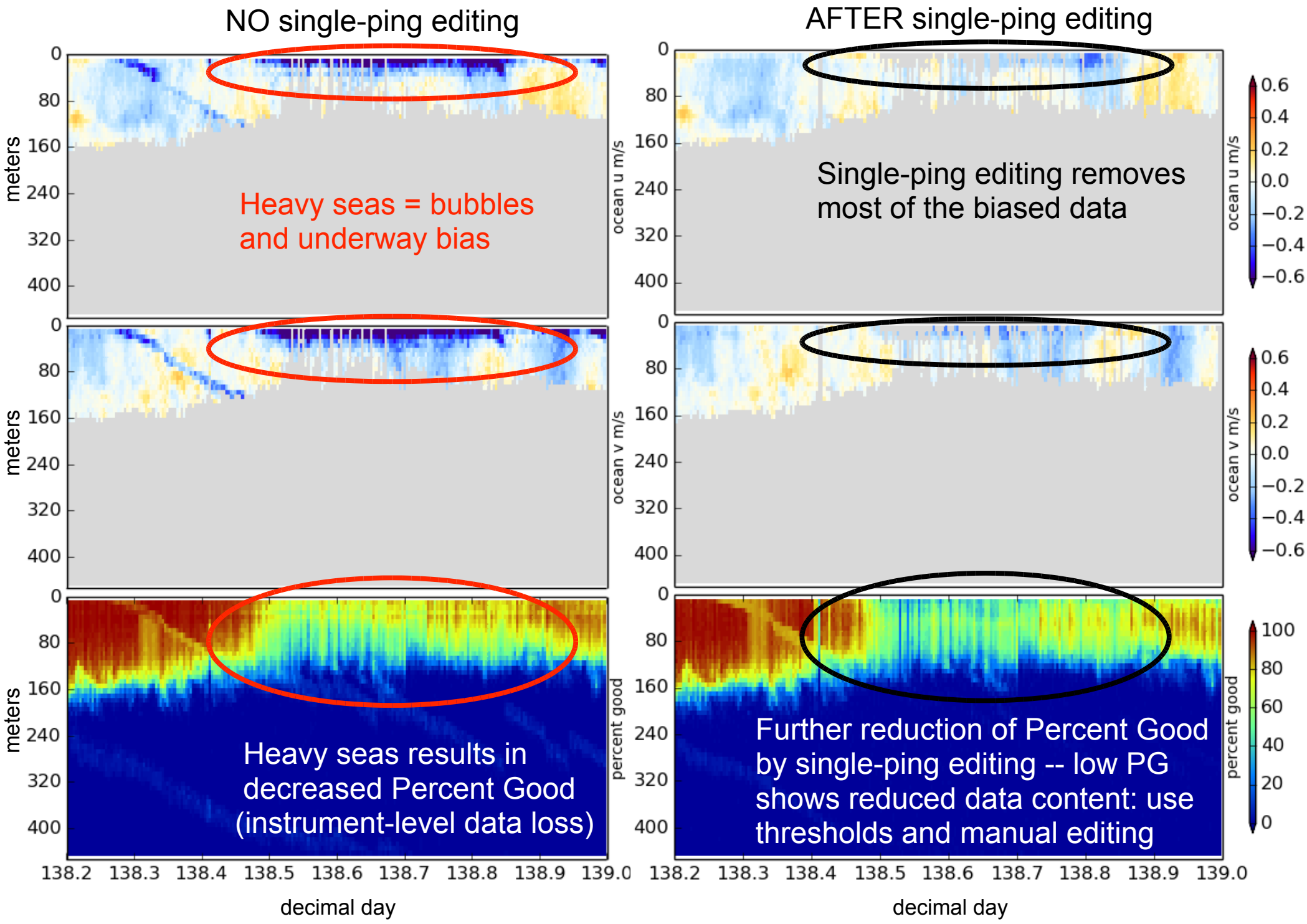
# ADCP Data: effect of bubbles

Bubbles:
- short profiles
- strongly biased towards zero

Untreated:
- biased ocean velocities



# Bubbles and alongtrack bias



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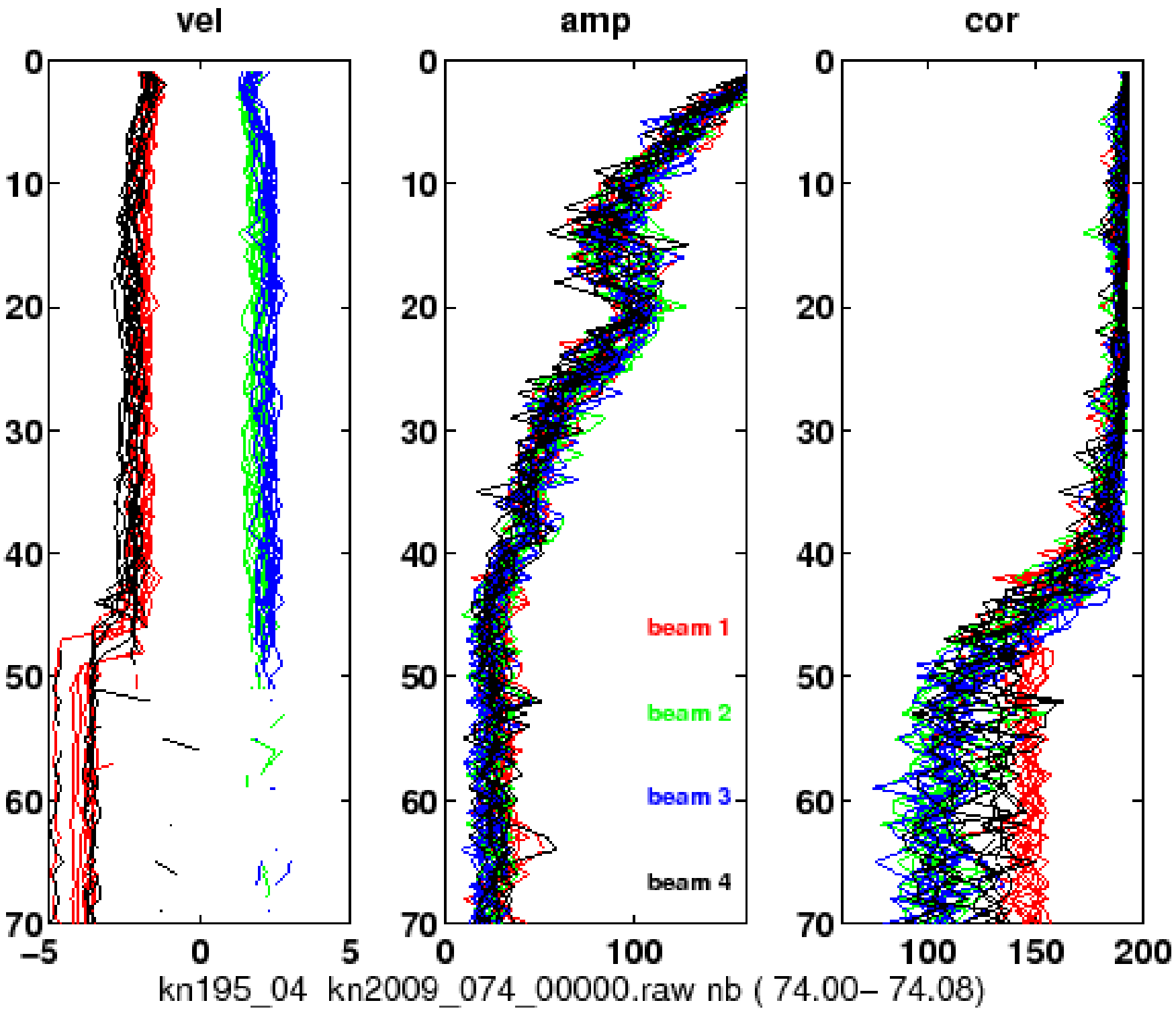
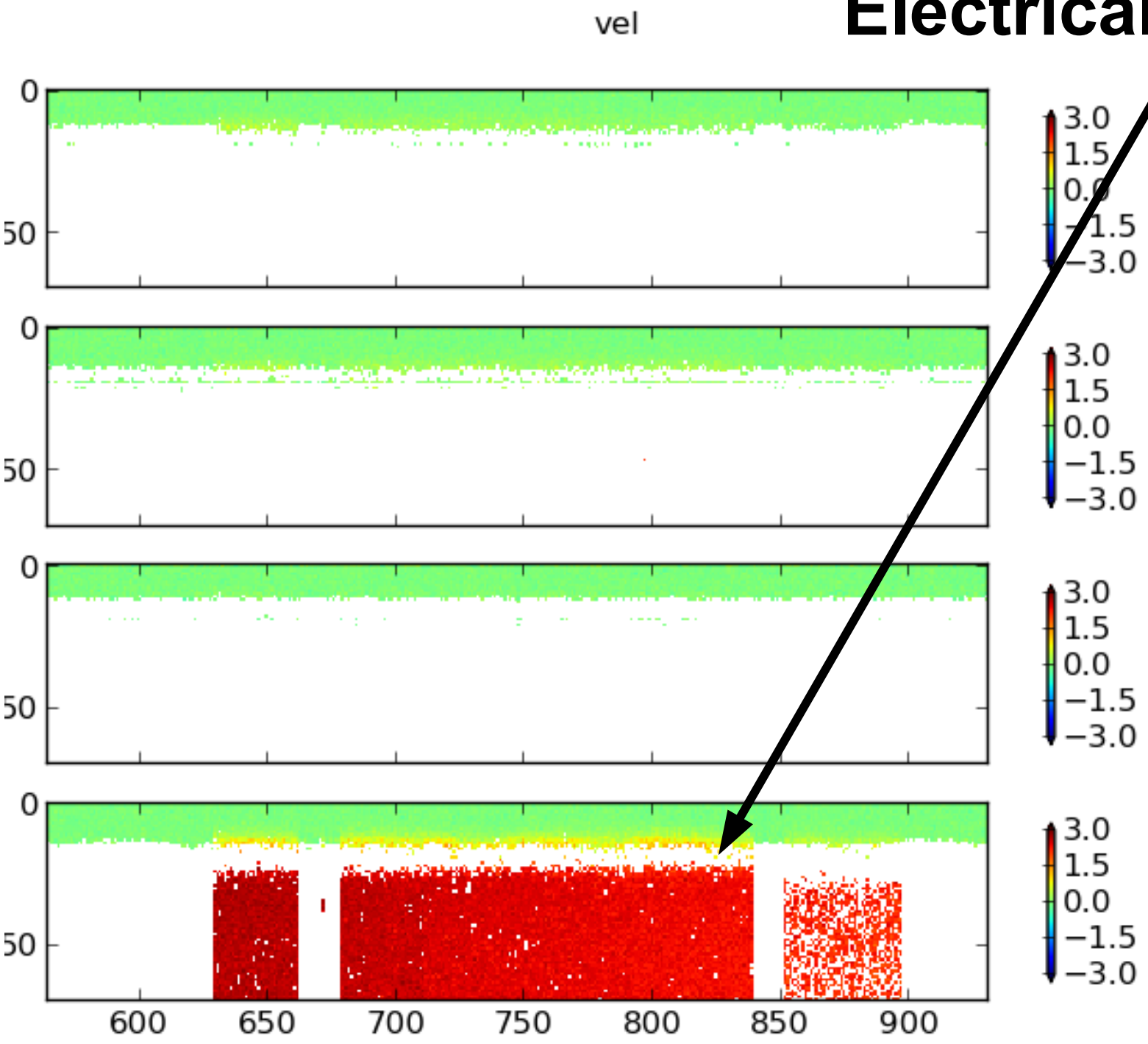

vel
amp
cor
0
10
20
30
40
50
60
70
−5
0
5
0
100
100
150
200
beam 1
beam 2
beam 3
beam 4
kn195_04 kn2009_074_00000.raw nb ( 74.00– 74.08)

# Electrical Noise

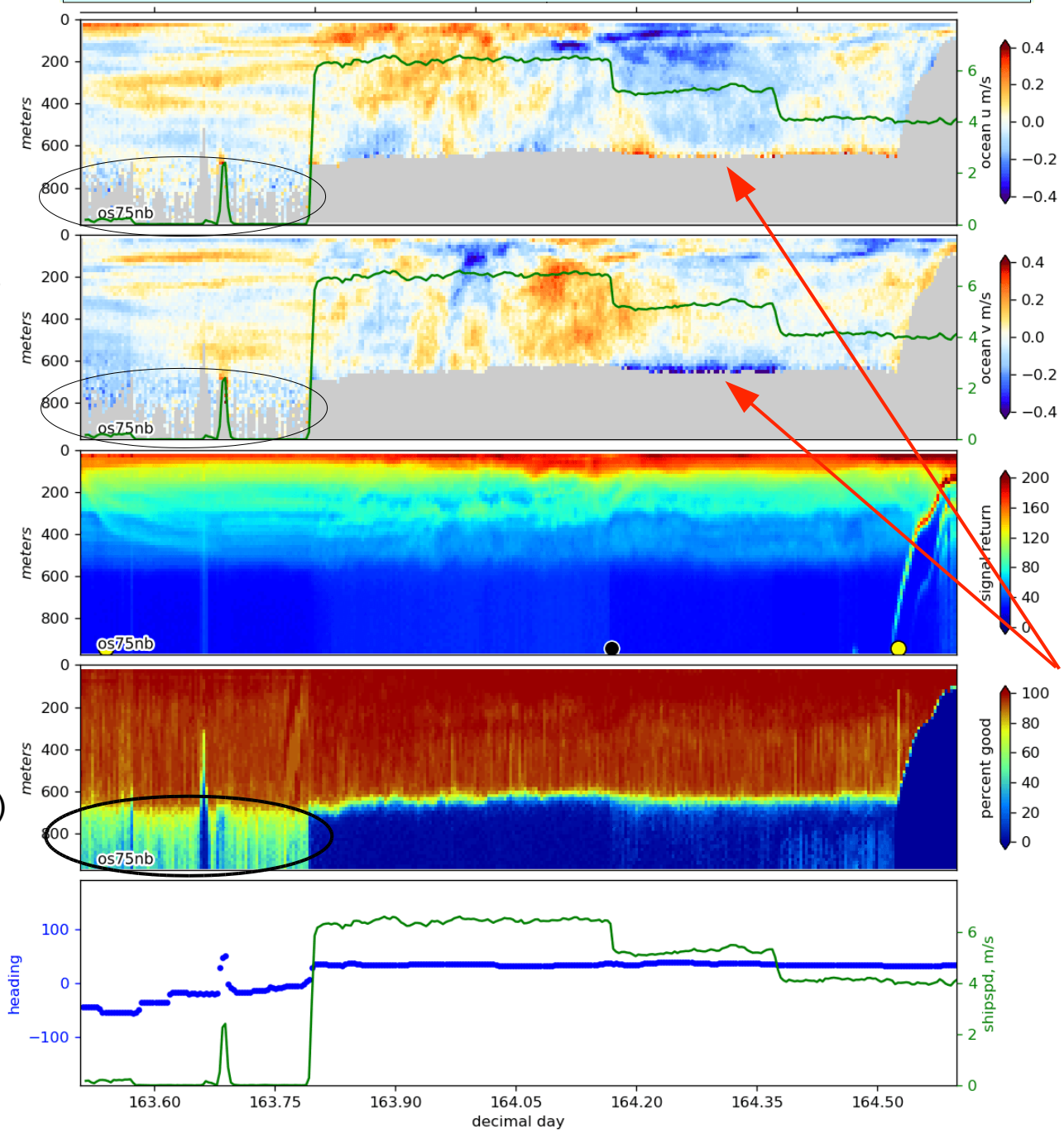



- strong signal in beam velocity
- deeper range than normal
- beams are often asymmetric (don't look like velocity)

# Electrical noise in averaged ADCP data

on-station “velocities” below the instrument's normal range

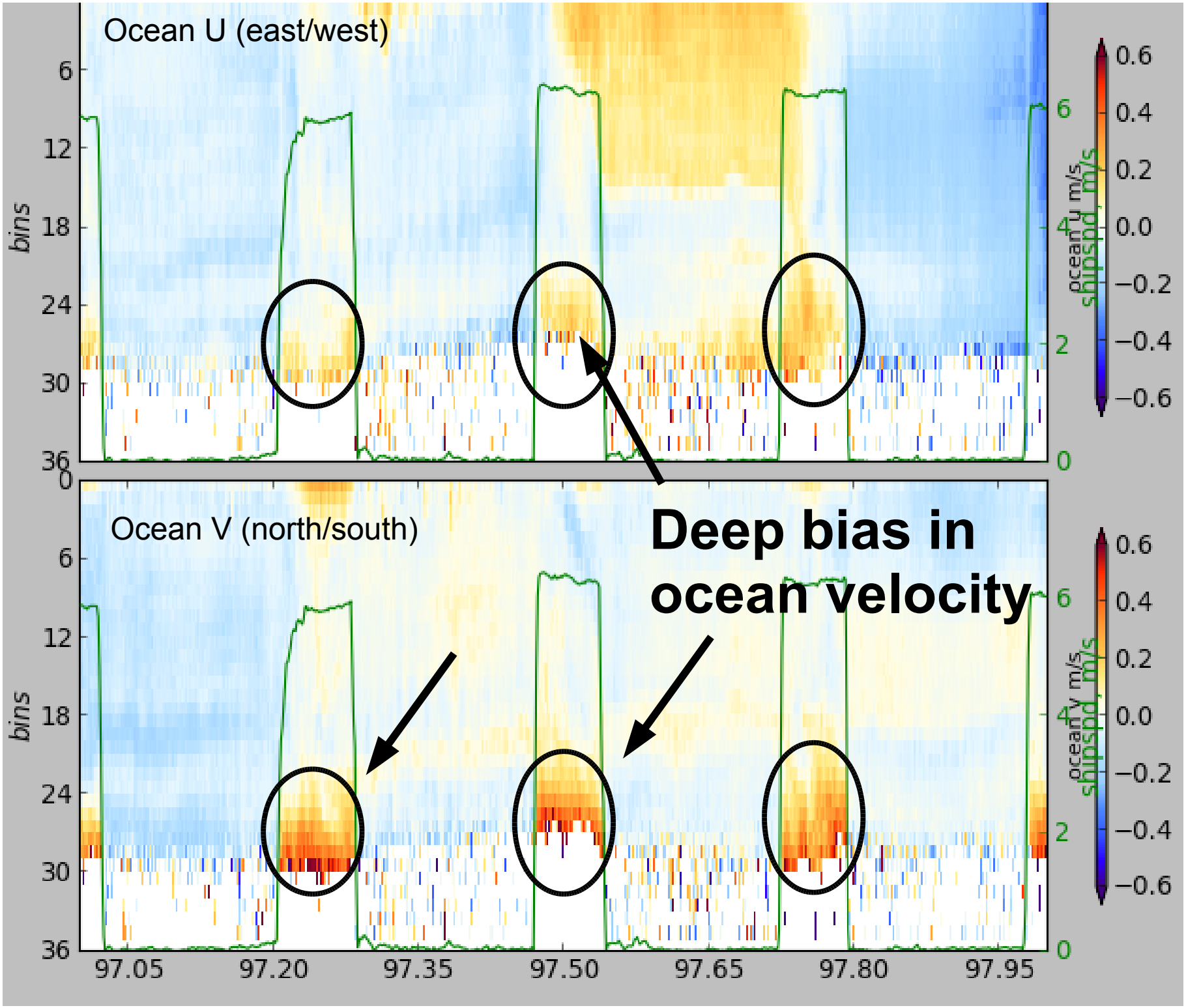
Percent Good is marginal (but not zero) below normal range




underway at slower speeds: strong bias at the bottom of the velocities

163.51 to 164.6 (1.09 days)

2022/06/13 12:16 to 2022/06/14 14:26


Ocean U (east/west)
Ocean V (north/south)
Deep bias in ocean velocity
bins
6
12
18
24
30
36
0
2
4
6
ocean U m/s
ocean V m/s
shipspd, m/s
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6
97.05
97.20
97.35
97.50
97.65
97.80
97.95

# More ways to go wrong: system=ADCP

- ADCP loss or degradation
  - Incorrect soundspeed at transducer face (only ceramic transducers: WH300, BB75, etc)
  - Fast ship, incorrect EA (ambiguity wrap)
  - ringing (shallow velocities biased towards zero)
  - mid-water biases due to strong scattering layer
    - strong scattering layer
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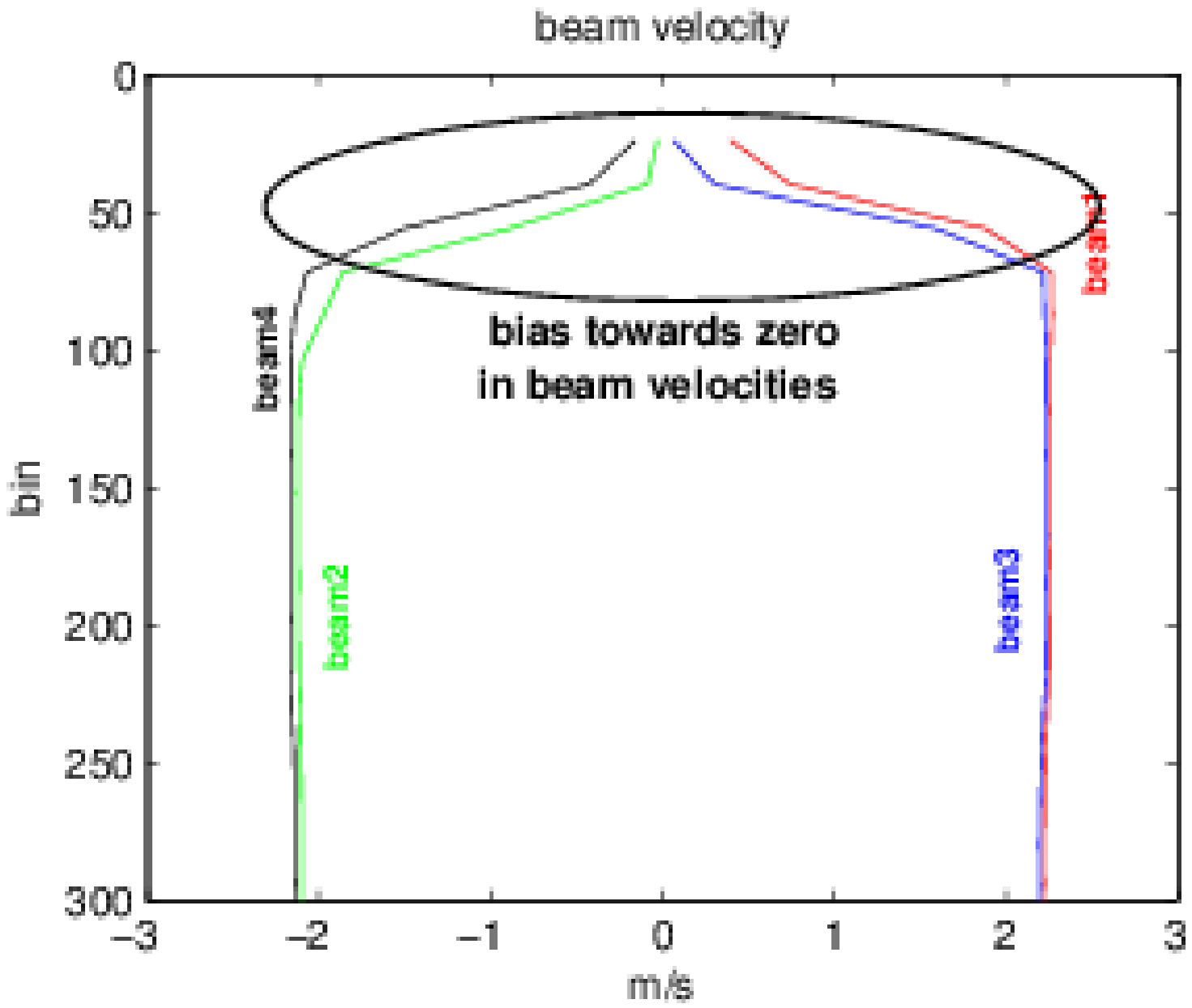
# Ringing: top bins biased towards zero



Ringing

Ringing usually contaminates the top bin or two, and is most obvious when the ship is moving. The bias in the ocean velocities is in the direction of motion, because the ringing contaminates the **top bins** towards zero.

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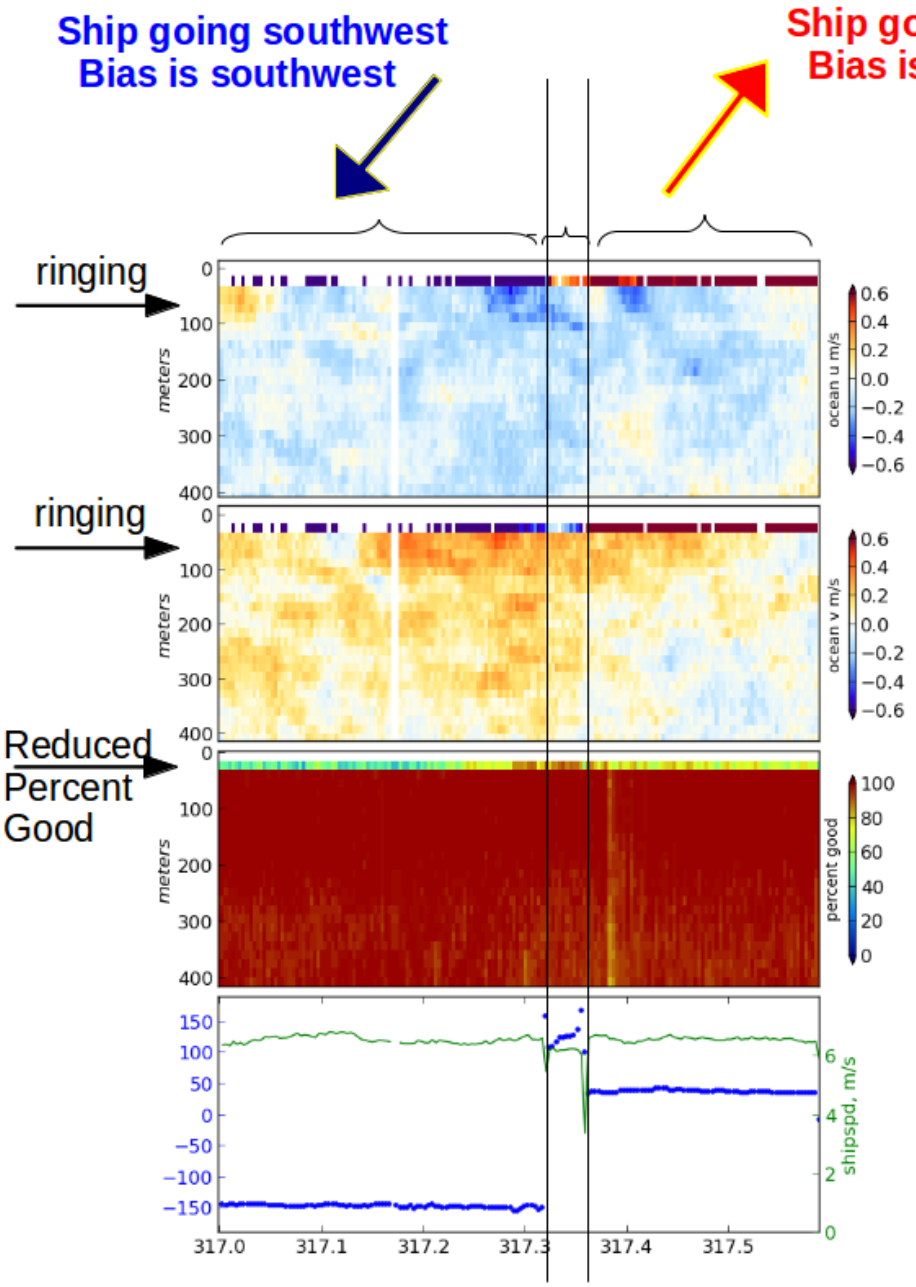


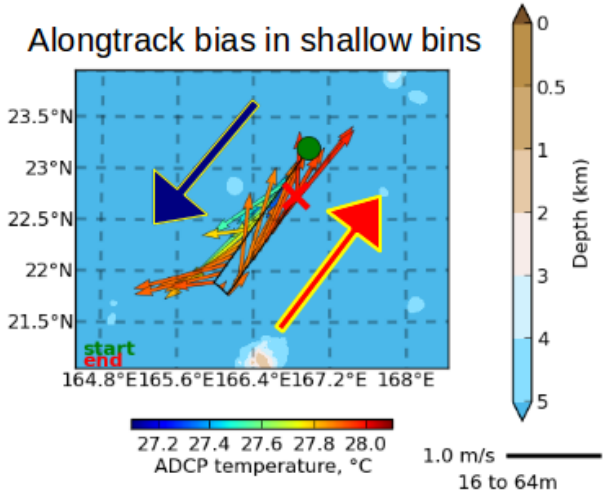


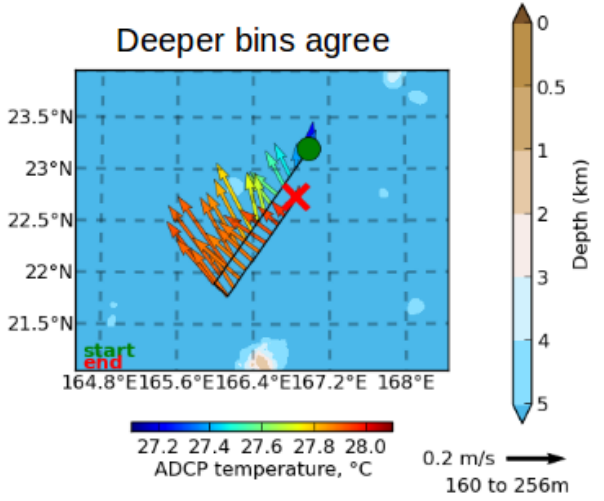

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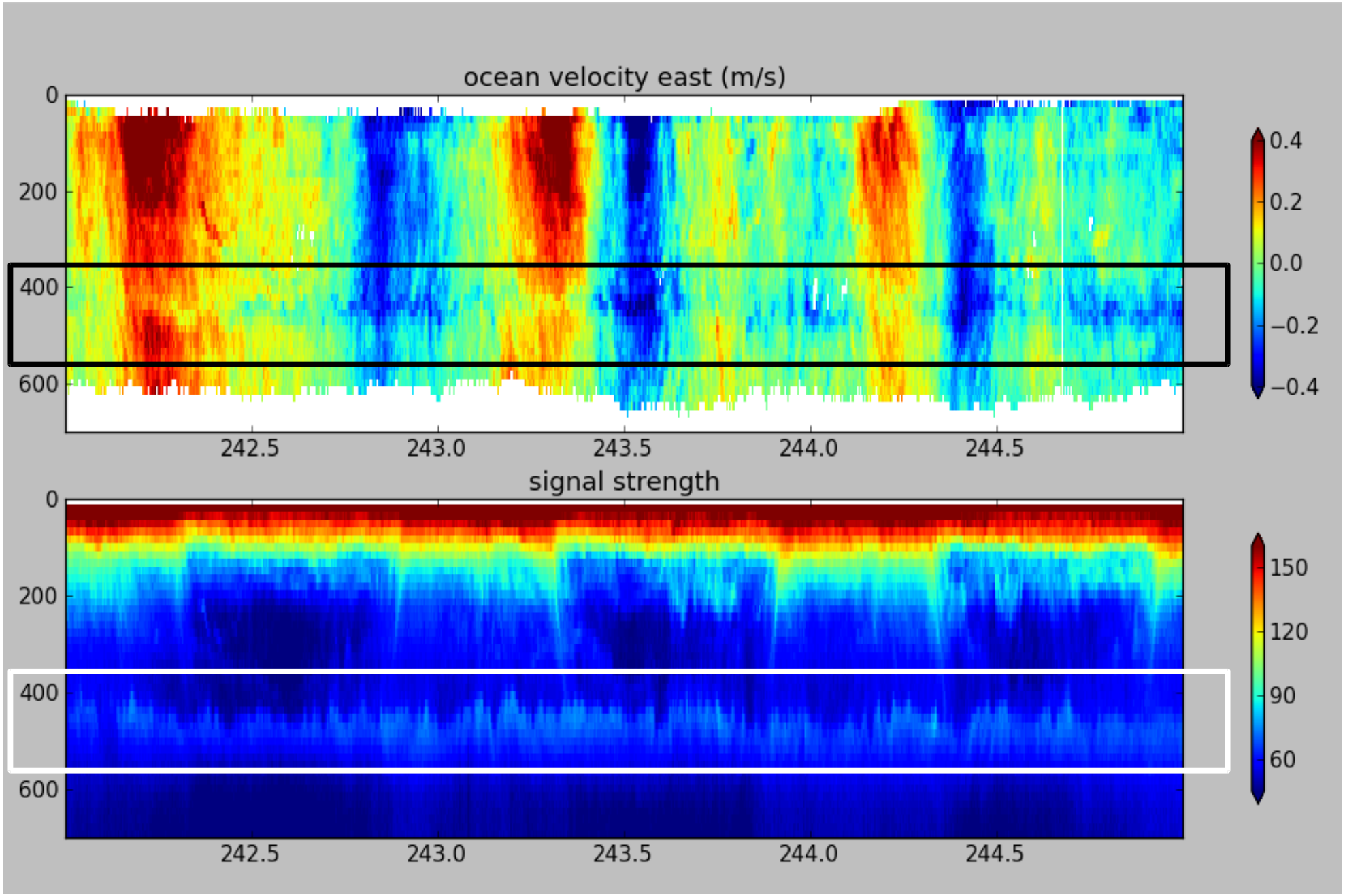
  - mid-water biases due to strong scattering layer
    - strong scattering layer
    - previous-ping interference

# Midwater bias due to scattering layer

- Symptom:
  - “S” shape in along-track direction
- Solution: Short term:
  - no solution.  Note in the logs; user beware
- Solution: Long Term:
  - related to transducer design; we're stuck with it

# Scattering Layer causes bias

**Ship was going WEST**
**Bias is to the WEST**



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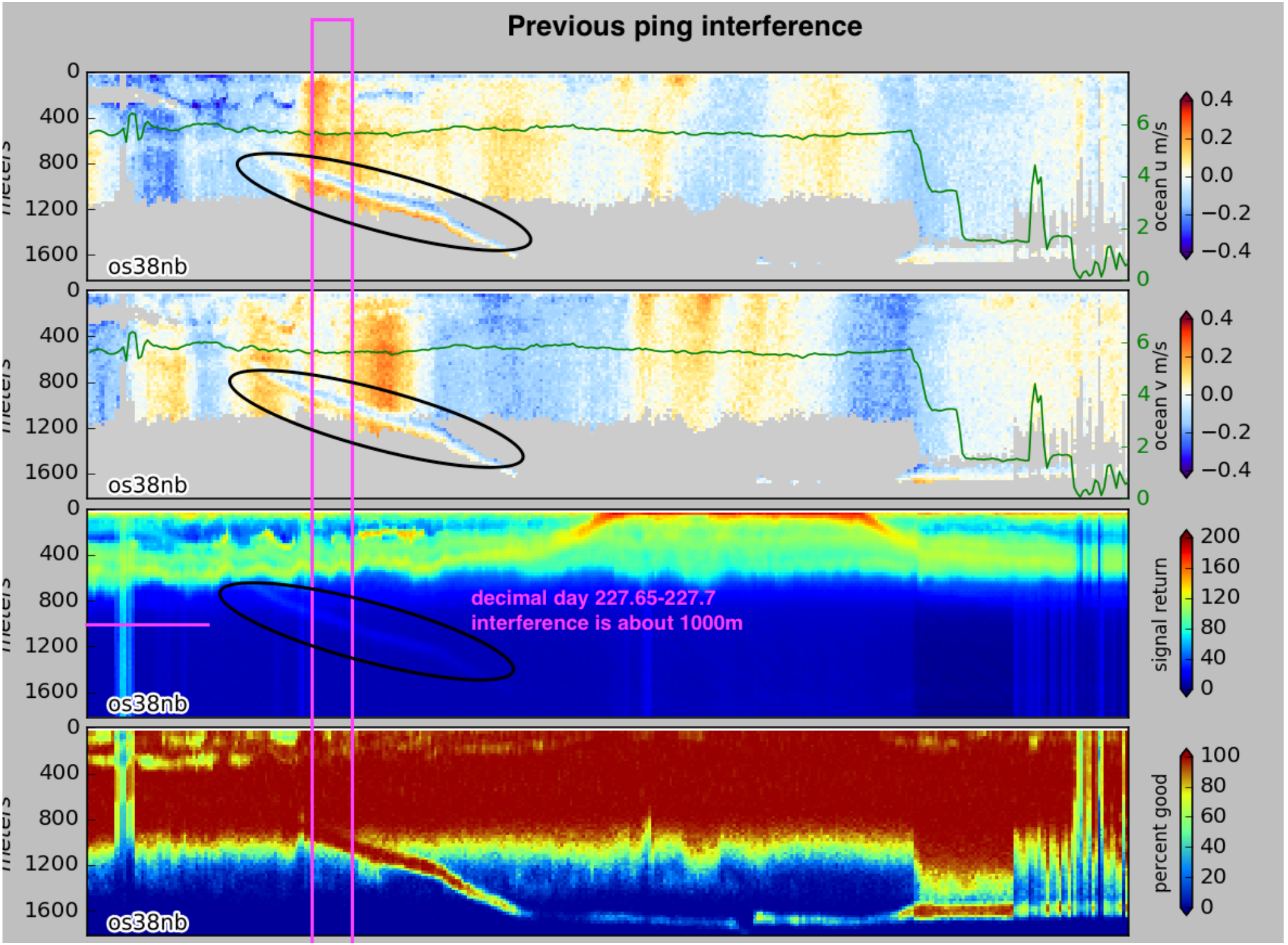
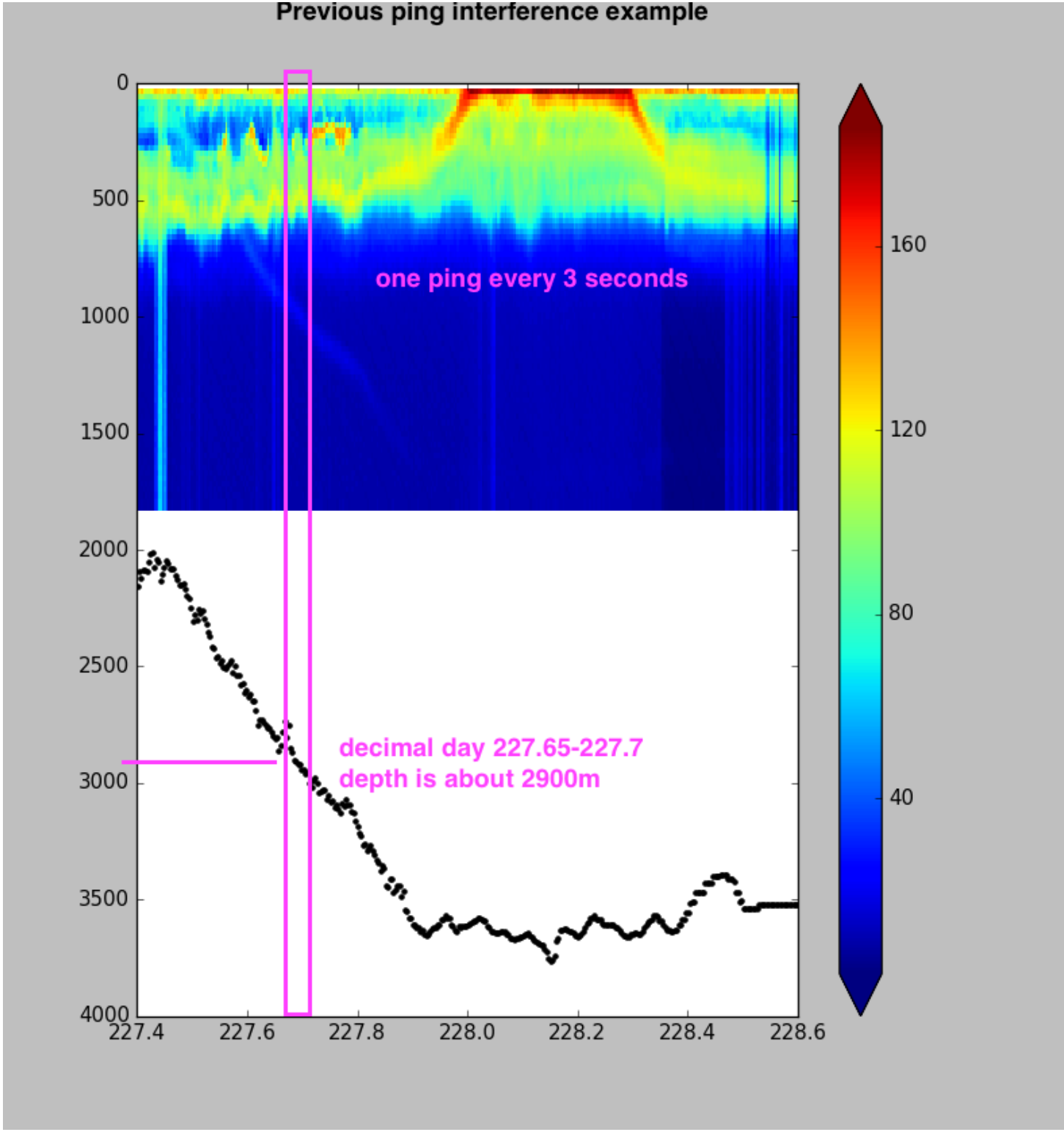

Previous ping interference
meters
0
400
800
1200
1600
os38nb
ocean u m/s
0.4
0.2
0.0
−0.2
−0.4
6
4
2
0
ocean v m/s
signal return
200
160
120
80
40
0
percent good
100
80
60
40
20
decimal day 227.65-227.7
interference is about 1000m

# Previous Ping Interference



# What can go wrong: system=ancillary

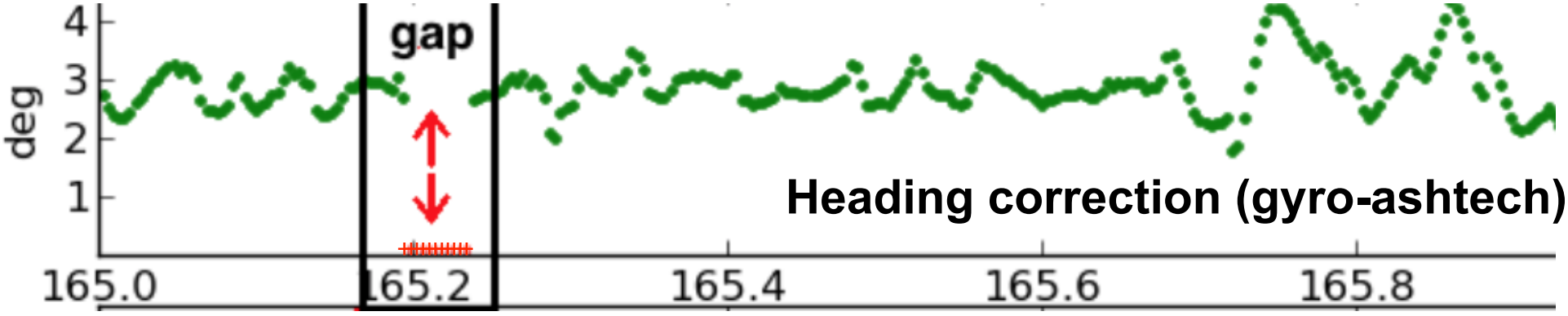
- Heading
  - Heading device fails
  - Inaccurate heading device (old mechanical gyro)
- Position
  - Position device fails; gappy
- Any: serial feed problems
  - Cable falls out
  - Instrument fails

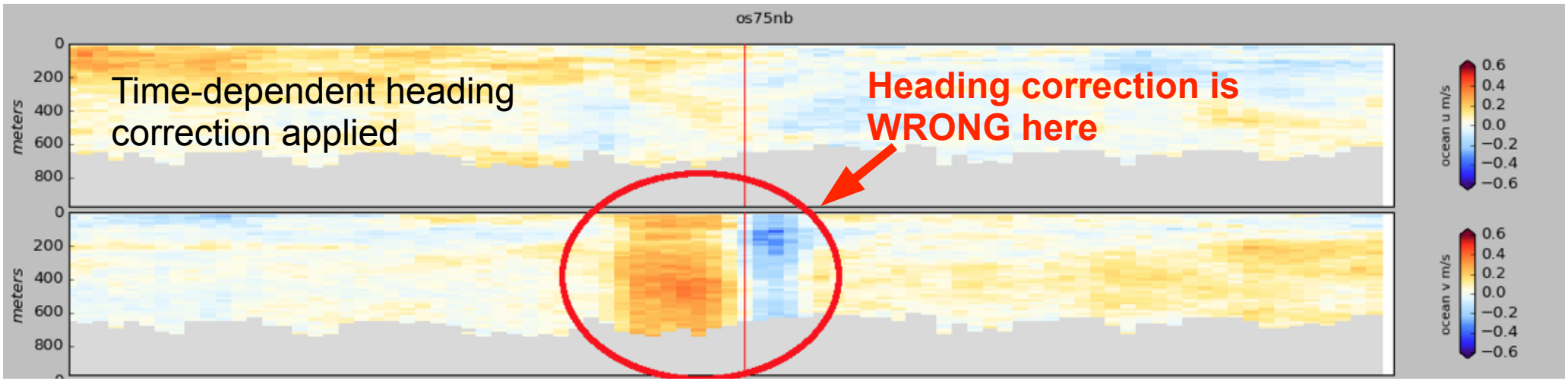
# What can go wrong: system=ancillary

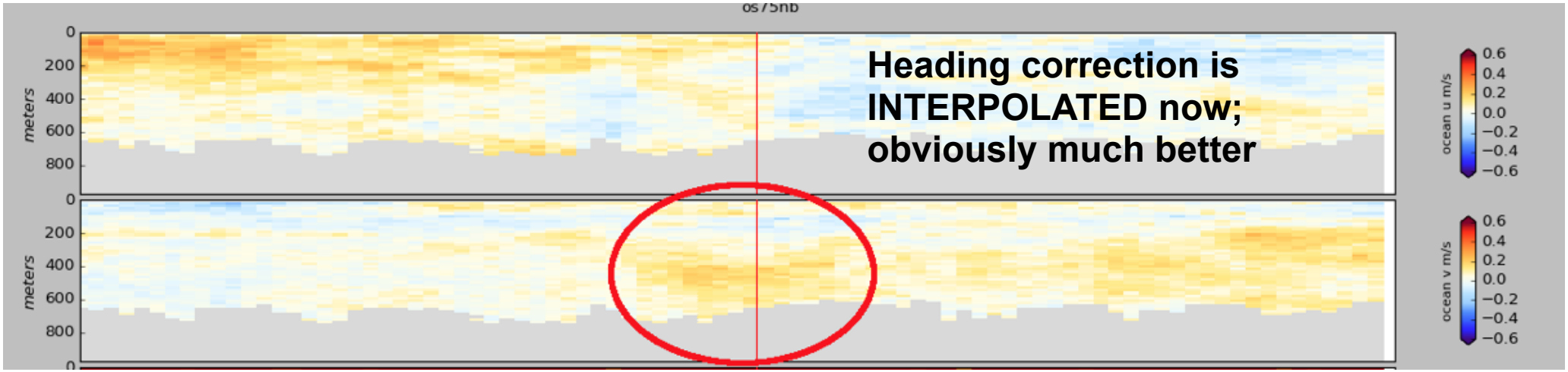
- Heading
  - Accurate heading device fails
  - Inaccurate heading device (old mechanical gyro)
- Position
  - Position device fails; gappy
- Any: serial feed problems
  - Cable falls out
  - Instrument fails

# Reliable and Accurate Heading

- log reliable (but inaccurate) heading, eg. gyro
- log accurate (but unreliable) heading, eg:
  - POSMV
  - Seapath
- correct inaccurate headings in the averages
- interpolate heading correction through small gaps


gap
deg
4
3
2
1
165.0
165.2
165.4
165.6
165.8
Heading correction (gyro-ashtech)

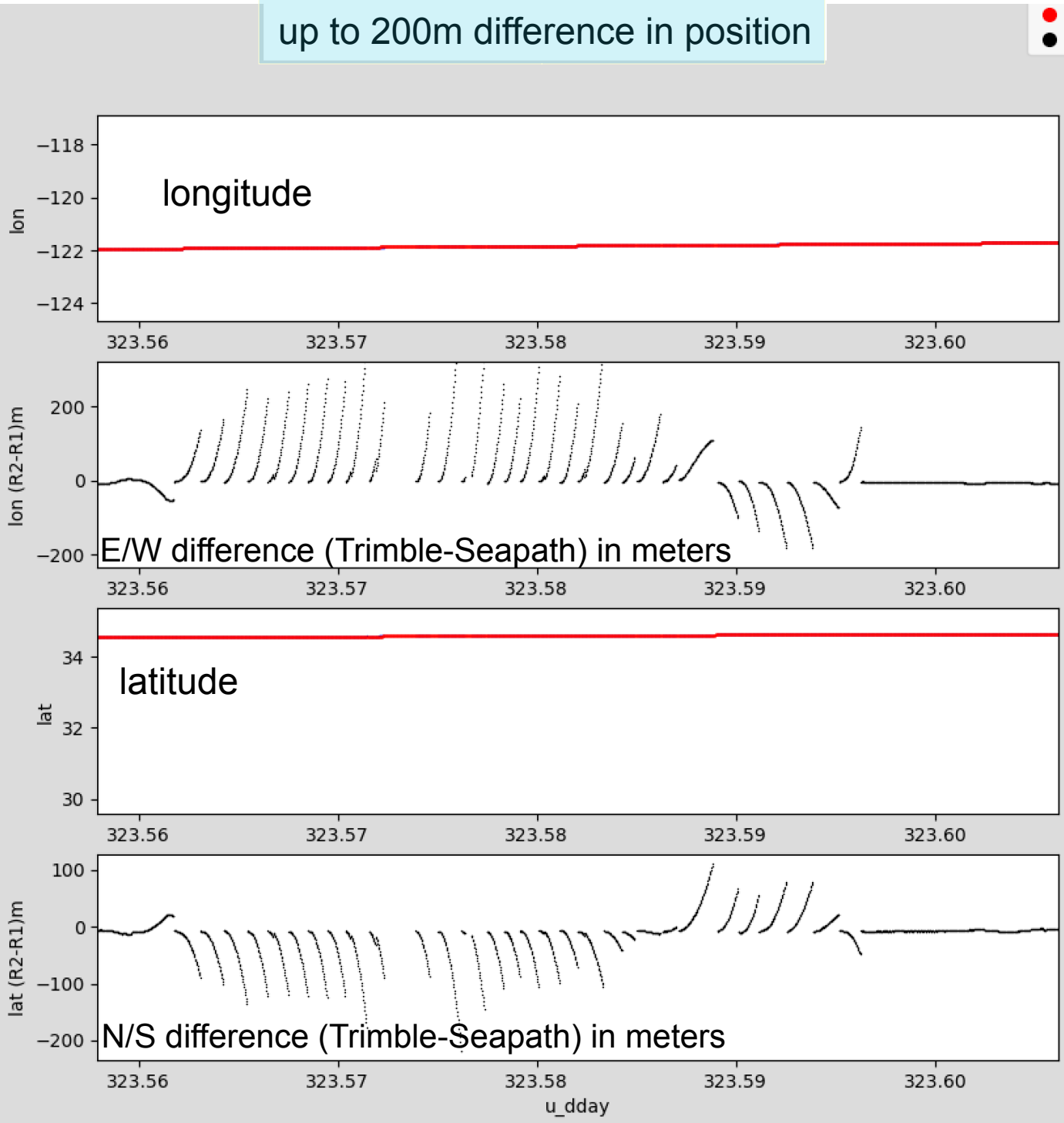

os75nb
meters
0
200
400
600
800
Time-dependent heading correction applied
Heading correction is WRONG here
ocean u m/s
ocean v m/s
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6


os75nb
meters
0
200
400
600
800
Heading correction is INTERPOLATED now; obviously much better
ocean u m/s
ocean v m/s
0.6
0.4
0.2
0.0
−0.2
−0.4
−0.6

# What can go wrong: system=ancillary

- Heading
  - Heading device fails
  - Inaccurate heading device (old mechanical gyro)
- Position
  - Position device fails; gappy
- Any: serial feed problems
  - Cable falls out
  - Instrument fails

up to 200m difference in position




Seapath position quality = 6: “free inertial” (dead reckoning)

dubious quality

must disregard for ADCP processing

# What can go wrong: system=computer

- PC clock is erratic
- PC clock is set to local time
- Poor quality serial feed
  - Too many messages
  - Low baud rate
  - Multiple unbuffered devices

**Partial loss, Garbled messages**

---

Solution: FIX IT

- Clock set to UTC, do not use bad timeserver
- ONLY send serial data from the original instrument

# VmDAS: Timestamping a serial feed

## (1) serial port

```
$PRDID,+000.68,-000.77,273.37
```

Message name | Heading | Pitch | Roll

```
$PRDID,+000.68,-000.77,273.37
$PRDID,+000.16,-000.49,273.48
$PRDID,-000.43,-000.54,273.85
$PRDID,-000.45,-000.72,274.12
$PRDID,+000.08,-000.67,274.13
$PRDID,+000.27,-000.45,274.12
$PRDID,-000.26,-000.46,274.35
$PRDID,-000.68,-000.49,274.65
$PRDID,-000.23,-000.25,274.88
```

$PADCP

## (2) VmDAS timestamp

```
$PADCP,1,20100620,223211.66
```

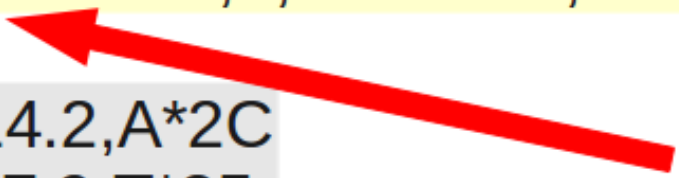
Message name | Ensemble number | YYYYMMDD | HHMMSS.SS

## Supposed to look like this:

```
$PRDID,+000.16,-000.49,273.48
$PRDID,-000.43,-000.54,273.85
$PADCP,1,20100620,223211.66
$PRDID,-000.45,-000.72,274.12
$PRDID,+000.08,-000.67,274.13
$PRDID,+000.27,-000.45,274.12
$PRDID,-000.26,-000.46,274.35
$PRDID,-000.68,-000.49,274.65
$PRDID,-000.23,-000.25,274.88
$PADCP,2,20100620,223218.16
$PRDID,+000.56,+000.05,275.00
$PRDID,+000.84,-000.15,275.05
$PRDID,+000.48,-001.15,275.15
$PRDID,+000.07,-002.38,275.28
$PRDID,-000.01,-002.76,275.33
$PRDID,-000.02,-001.75,275.43
$PADCP,3,20100620,223223.64
$PRDID,-000.26,+000.05,275.72
$PRDID,-000.51,+001.37,276.10
$PRDID,-000.35,+001.45,276.35
```

# VmDAS serial feed: a common problem

```
$HEROT,010.9,A*23
$HEHDT,157.4,T*28
$HEROT,011.0,A*2B
$HEHDT,1$PADCP,1,20111111,154915.01,0.00
57.7,T*2B
$HEROT,014.2,A*2C
$HEHDT,157.9,T*25
$HEROT,014.0,A*2E
$HEHDT,158.2,T*21
$PADCP,2,20111111,154917.04,0.00
$HEROT,015.6,A*29
$HEHDT,158.4,T*27
$HEROT,016.7,A*2B
$HEHDT,158.7,T*24
$HEROT,015.5,A*2A
$HEHDT,159.0,T*22
$PADCP,3,20111111,154920.06,0.00
$HEROT,015.0,A*2F
```



**Rudely inserted**

Mangled N1R file: cannot be used

$GTG,A,054,35,27209.679,N7.5500.C
8,01HDT,354.5,-2.4,M8685.4,8507.0,03,W*6D
$GPM,0,356,13358,M
$H.4,N,3543,K*
$
$GPG,350545357272 7.5,5,N,.6,00.45
$GW,2,,0501.0,272$PADCP,4910,20110507,054659.19,70.00
5,M,94,.4,M,00.0,01,W,65
,01HDT,354.3,-2
$GPM,0,355,13358,M
$H.3,N,3542,K*
$
$GPG,350545358272 7..4,1,N,.5,00.45
$GW,2,,0501.0,2726,M,20,.4,M,00.0,01,W,64
,01HDT,354,M,T
$GPVTG,354,T,356,M,09.3,N,17.2,KT

Partial $GPGGA position messages

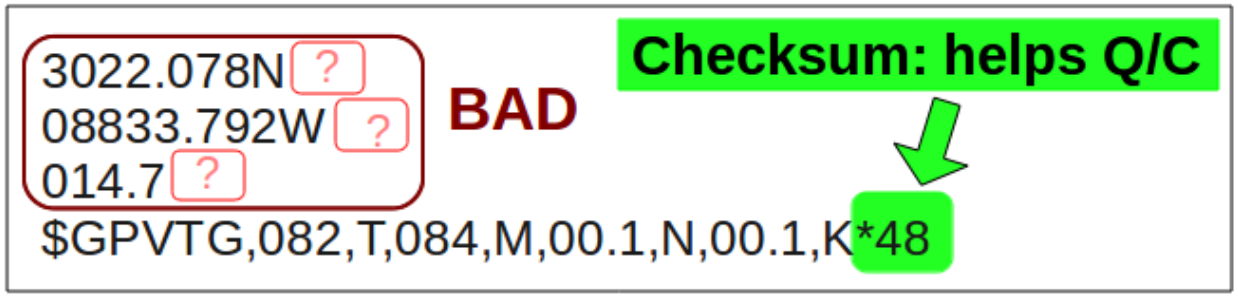
Partial $HEHDT heading messages

# Serial Data Logging Rules

(1) DO NOT
- push multiple sources into one port
- use long RS232 cables
- send too many extra messages

(2) DO
- get data directly from the instrument
  - NOT a computer-generated message
  - NOT a switched feed (eg. Various GPS)

(3) IF POSSIBLE
- avoid unnecessarily high repetition rate
- choose a higher baud rate
- use feeds with a checksum



Time for a break?

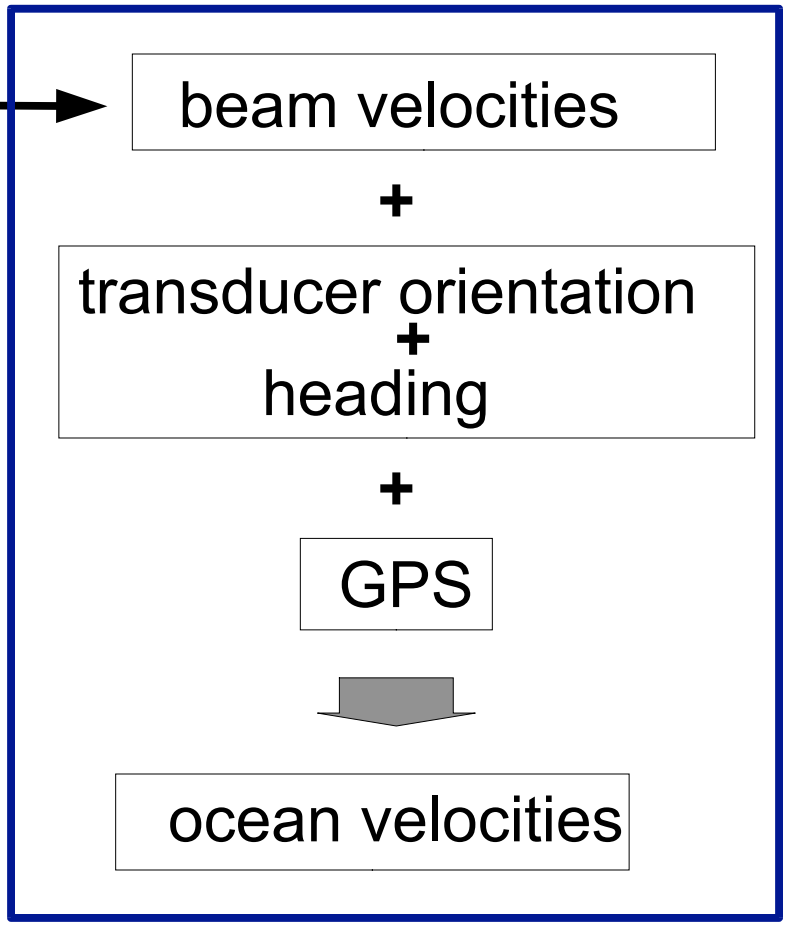
# ADCP: what can go wrong

Viewed from the Perspective of:

- ADCP systems (components)
  - Computer
  - ADCP
  - Ancillary: GPS, Heading
- Data flow (where does the problem occur)
- Manifestation in ocean velocities – examples
  - Cross-track error (transducer angle)
  - Along-track error (scale factor)
  - Transition/maneuvering errors (lags in time or space)
  - depth-dependent bias (electrical noise)
  - surface bias (ringing)

# ADCP: data loss, degradation
## degraded range and coverage....

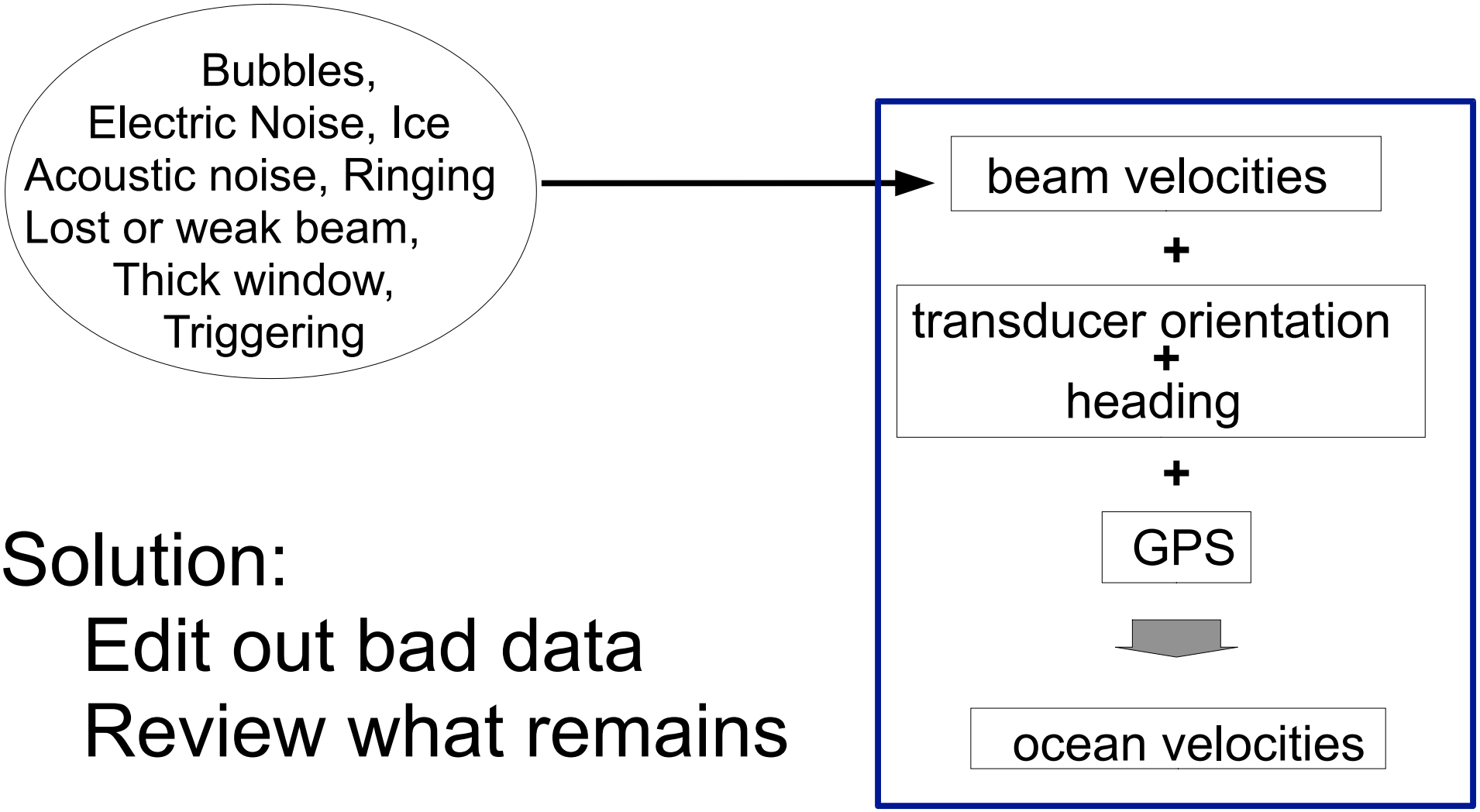
Bubbles,
Electric Noise, Ice
Acoustic noise, Ringing
Lost or weak beam,
Thick window,
Triggering




Solution:

Improve the installation

# ADCP: data loss, degradation
## .... remaining data compromised




Solution:

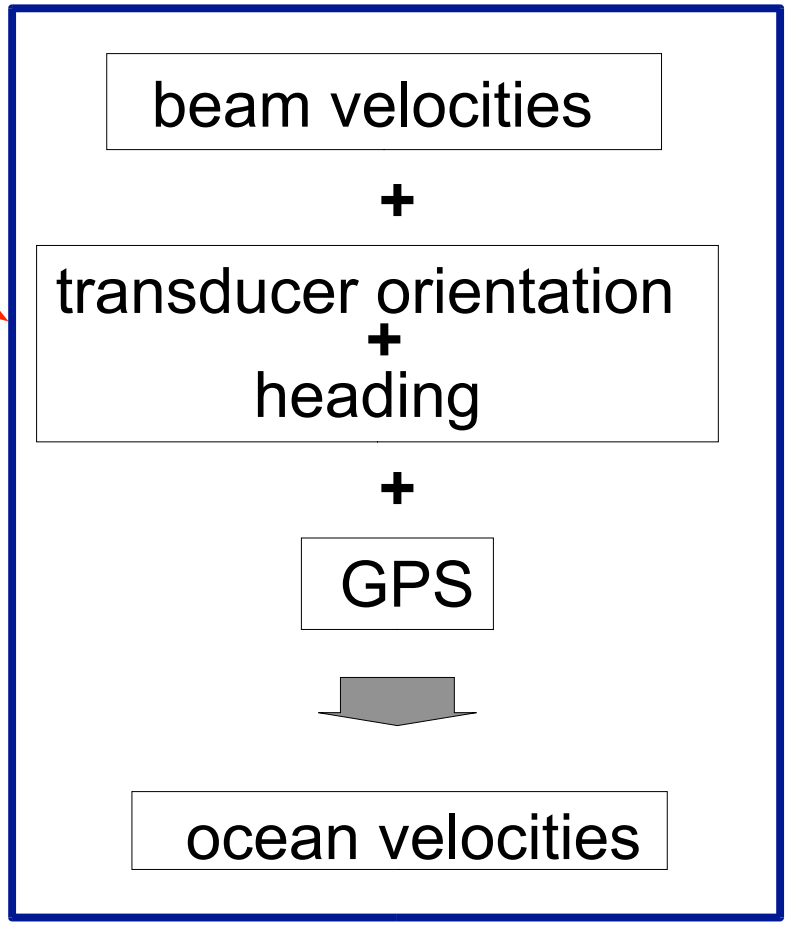
- Edit out bad data
- Review what remains

# Transducer misalignment

1deg error in heading

⇕

10cm/s error in ocean velocity
(cross-track direction)



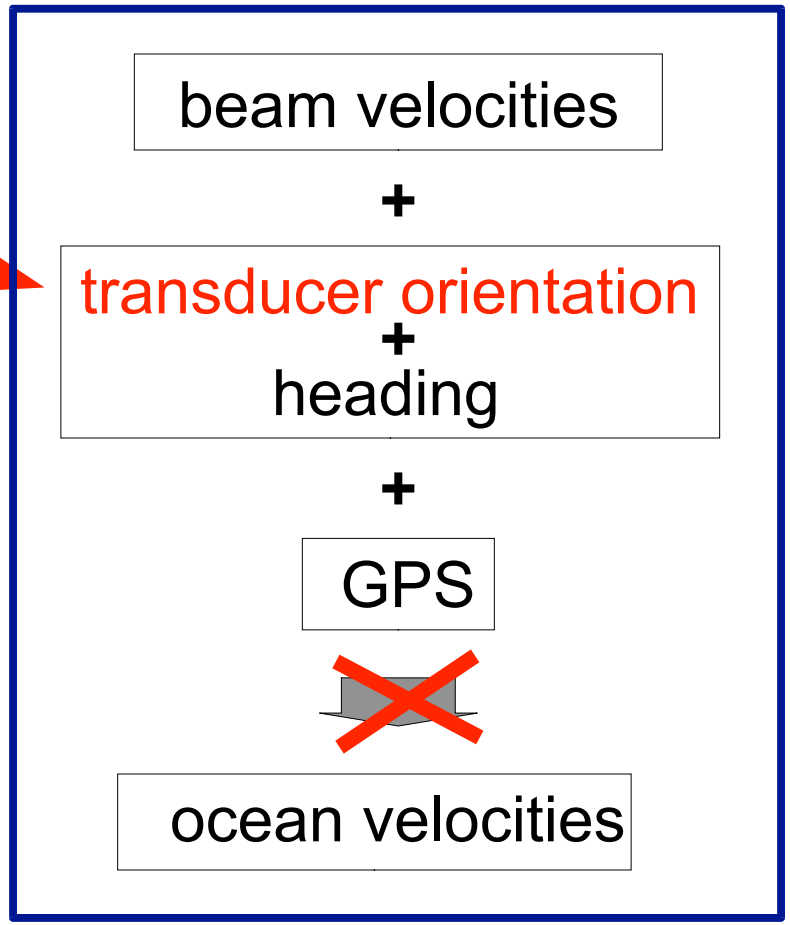

Diagnostic:

Cross-track error looks different on-station vs/ underway

# Transducer misalignment

## ..... angle off by >90deg (*)

Ocean Surveyor acquires data using **EA** in the calculation of BEAM VELOCITIES. Gross error could irrevocably ruin the data




Diagnostic:

beam velocities corrupted (wrap)

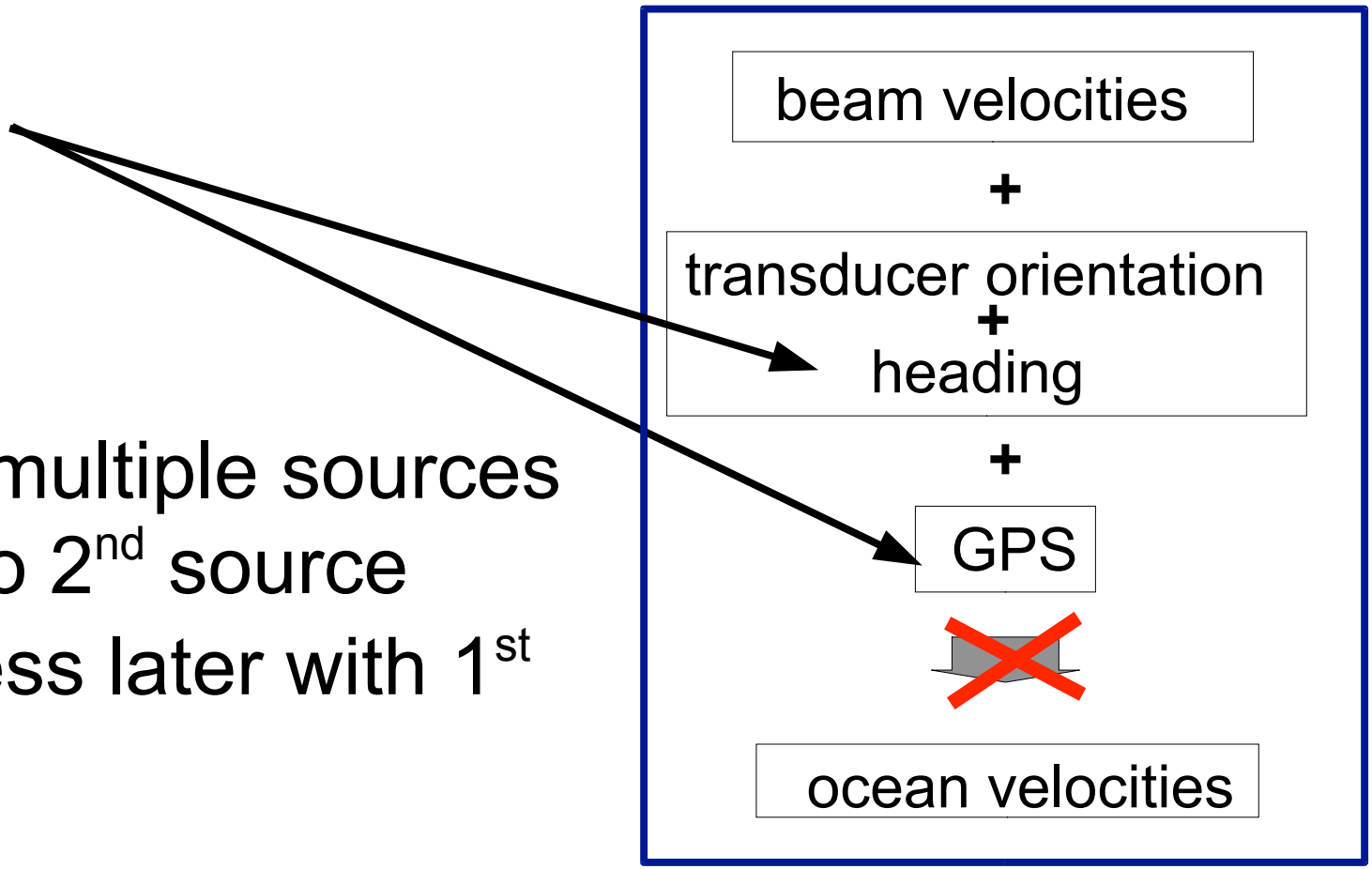


(*) actual value varies with ship

# Failure of ancillary (heading, gps)

Solution:

- Record multiple sources
- Switch to 2nd source
- Reprocess later with 1st



# ADCP: what can go wrong

Viewed from the Perspective of:

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  - Cross-track error (transducer angle)
  - Along-track error (scale factor)
  - Transition/maneuvering errors (lags in time or space)
  - Depth-dependent bias (electrical noise or ringing)

# What can go wrong: in the ocean velocities

## (1) Cross-track error:

- recovery requires accurate heading
- could be related to bad transducer angle

## (2) Along-track error:

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

## (3) Transition/maneuvering error

- Lag or offset in time or space.
- might need to input the GPS-ADCP offset

## (4) Depth-dependent bias

- Surface along-track bias: ringing
- Surface? Deep? Could be electrical noise, could be acoustic

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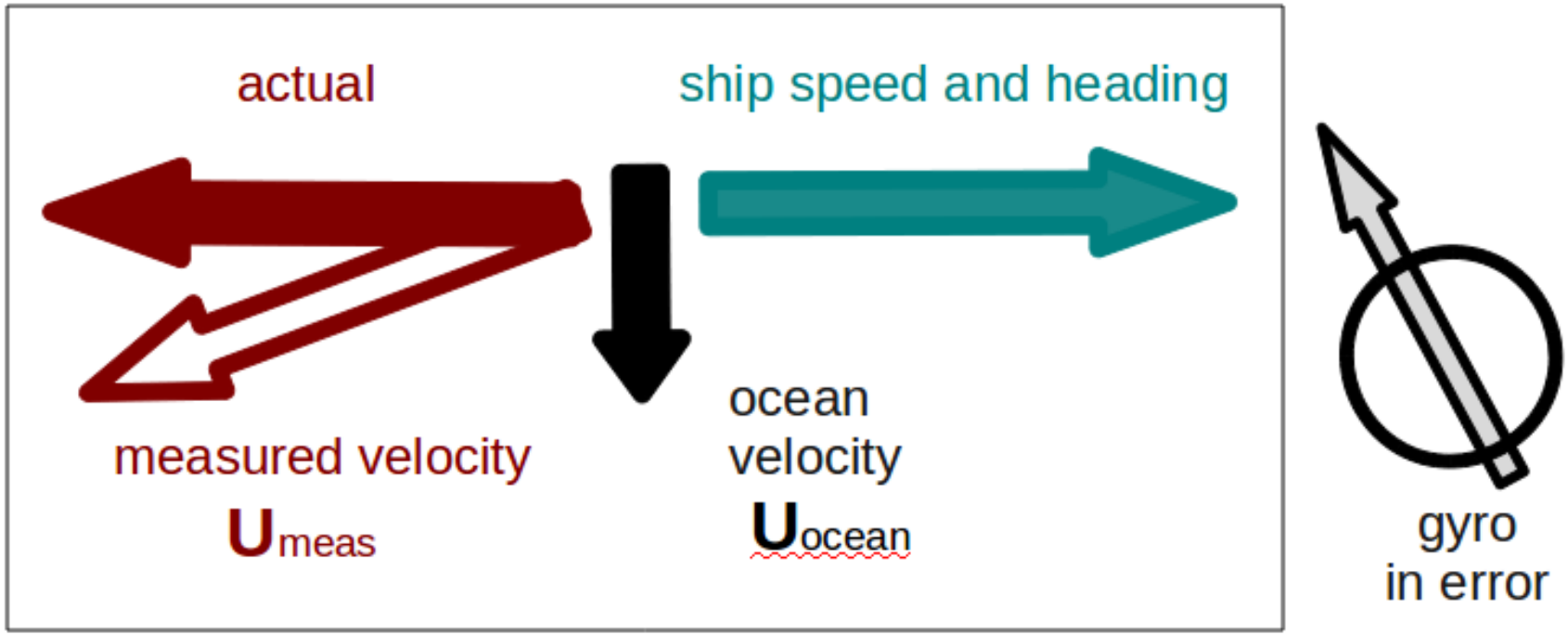
(4) Depth-dependent bias

- Surface along-track bias: ringing
- Surface? Deep? Could be electrical noise, could be acoustic

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

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
- If 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

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

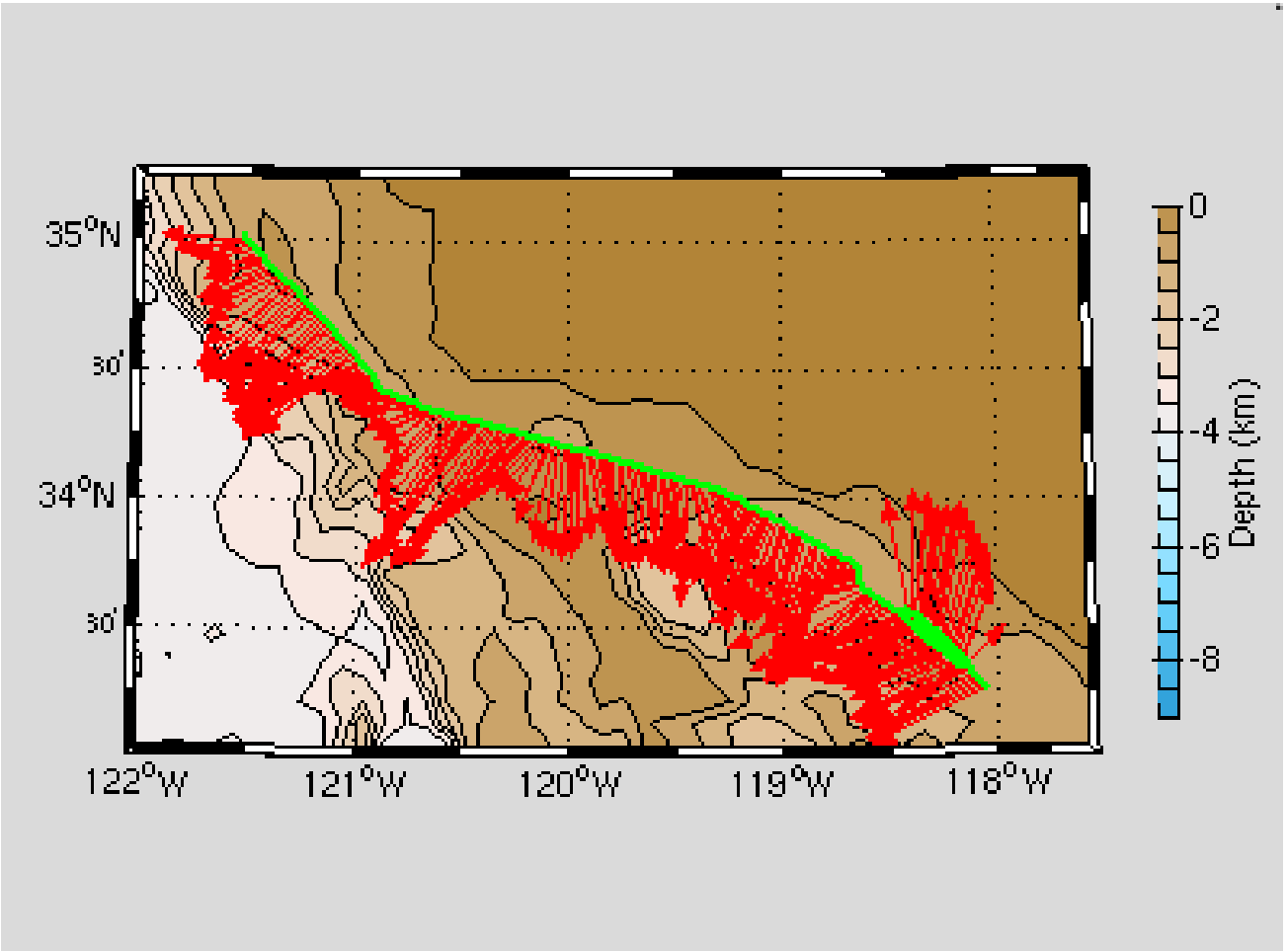
Angle applied comes from

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

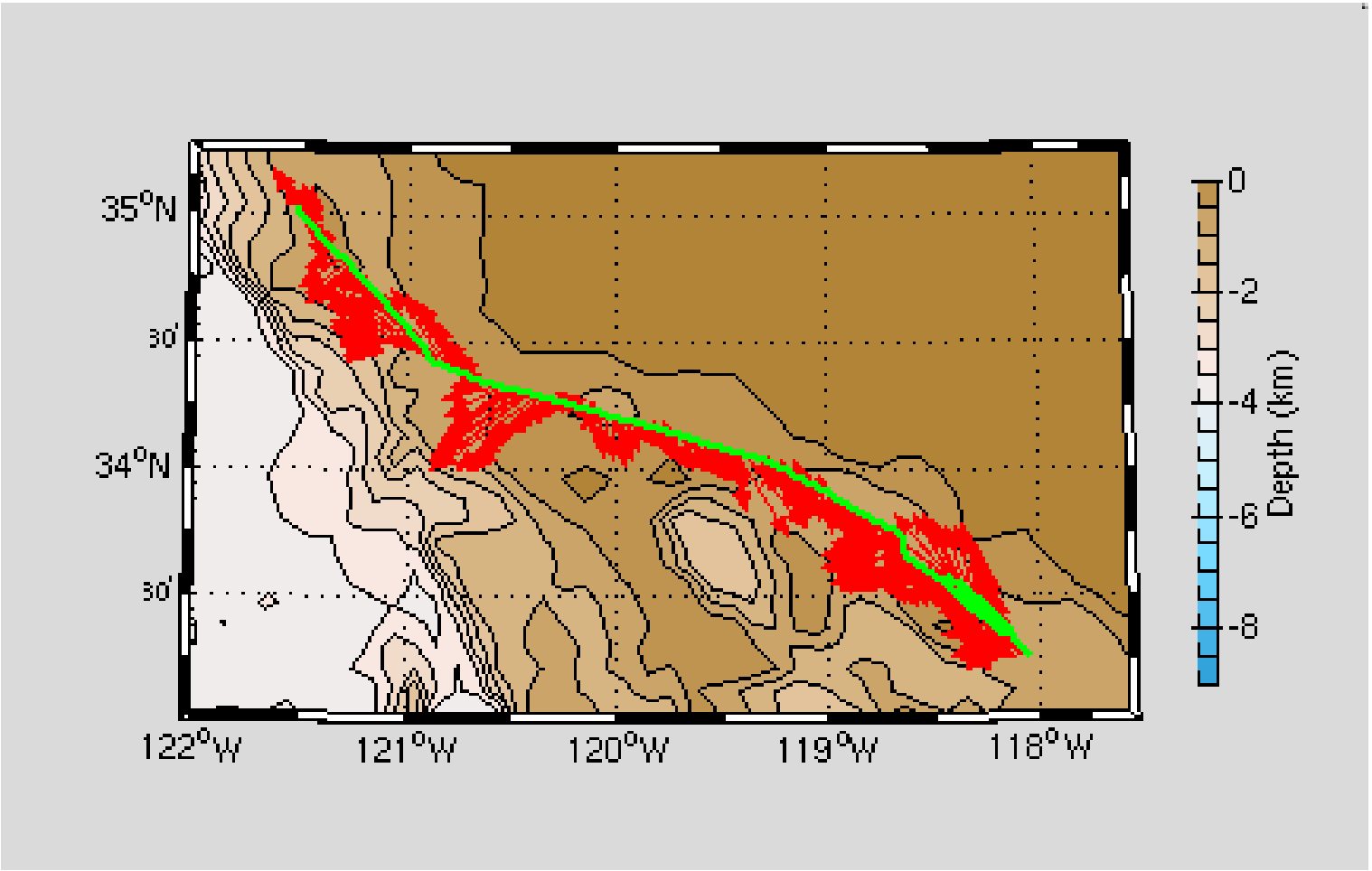
This is a **constant value** for the whole cruise

Examples of error in transducer angle follow...

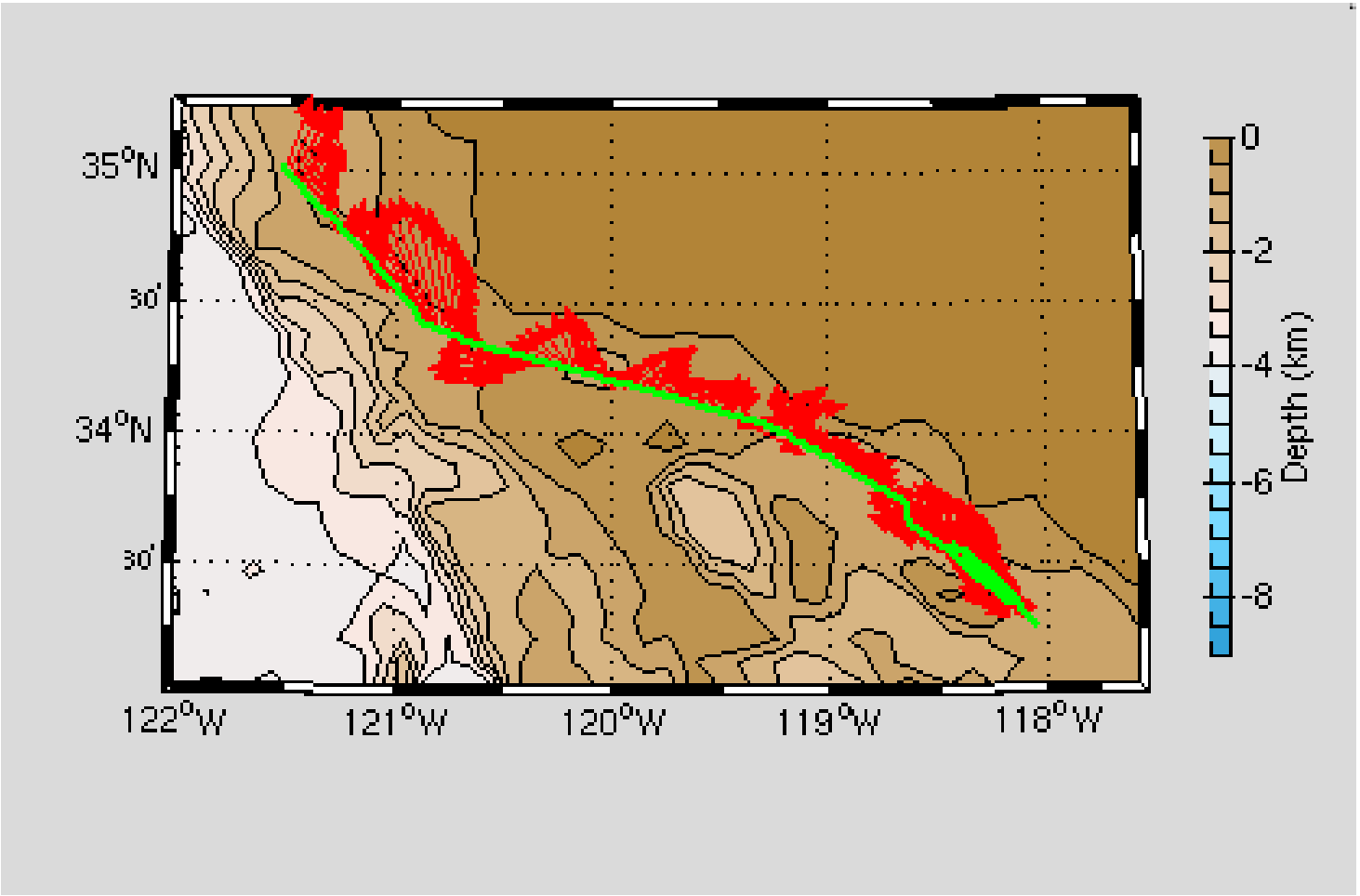
# Calibration: angle error -3.6deg



# Calibration: angle error -1.6



# Calibration: angle error 0.4



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

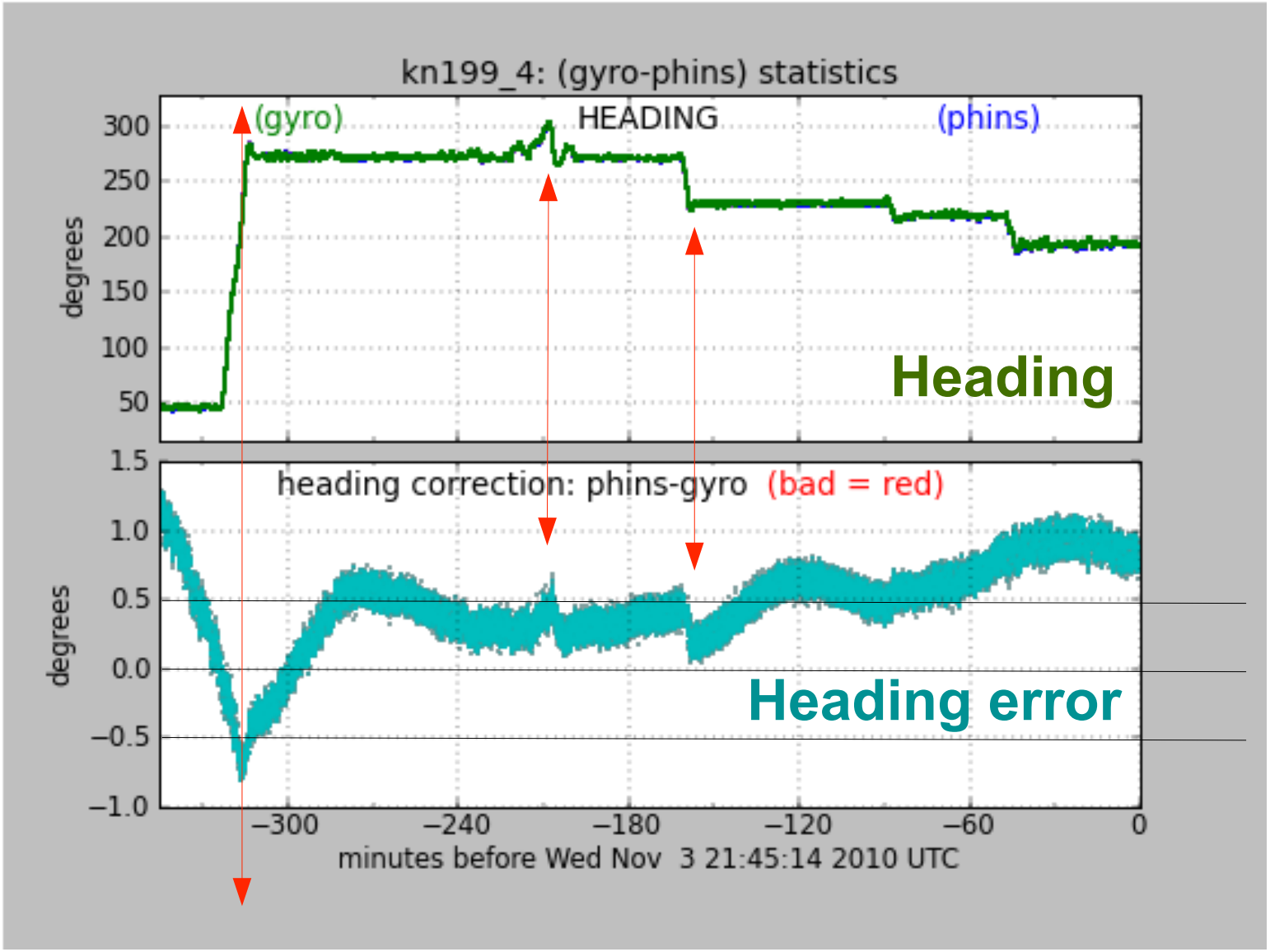
Angle applied comes from

Heading, which may be in error by

- A constant offset
- A **time-dependent offset**

Example follows ...

# Phins-Gyro difference varies with time

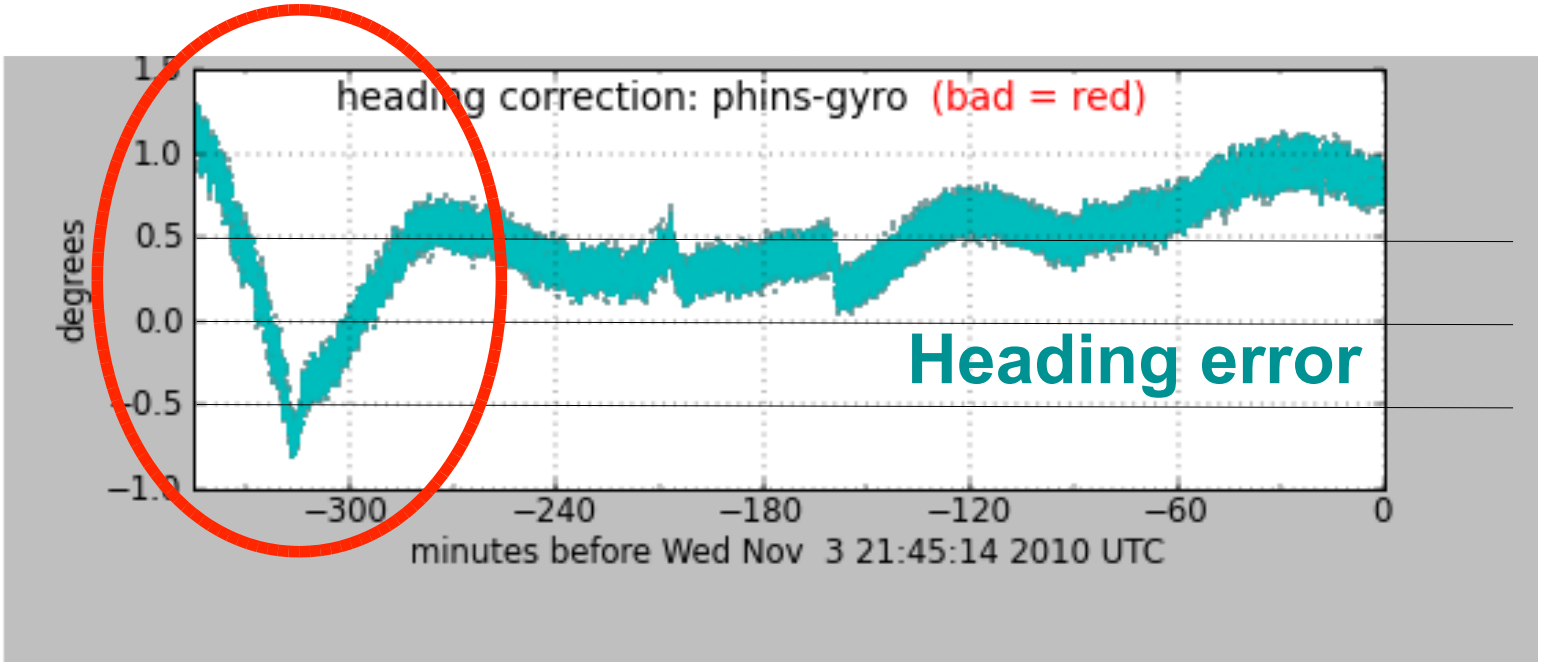



Changes in ship's heading affect heading error

# Effect of Time-Dependent Heading Error on Ocean Velocties

1 degree error in heading means:

- 0.1m/s error in ocean velocity
- in the cross-track direction

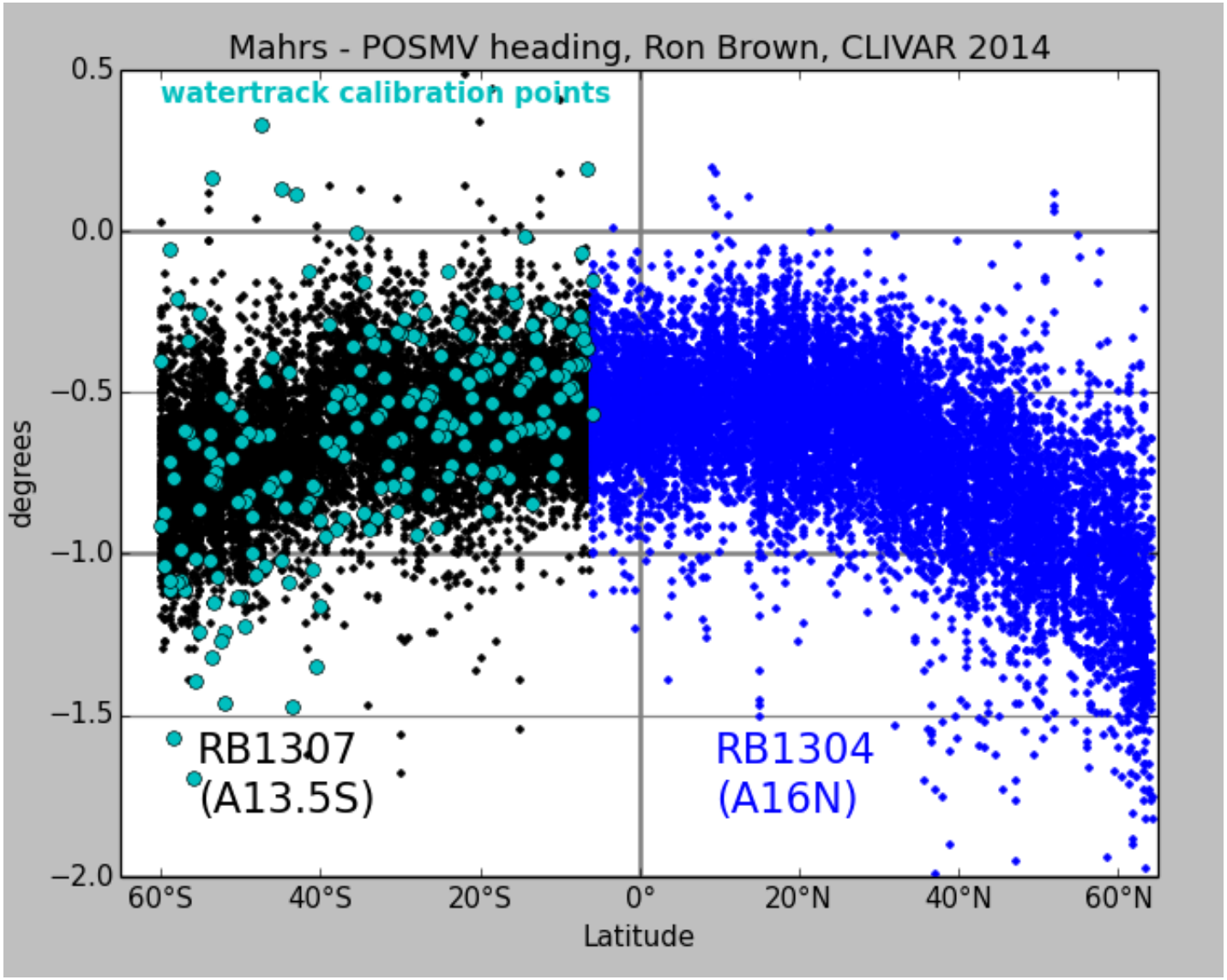



Changes in ship's heading affect heading error

# Heading error with latitude

MAHRS
- reliable
- not accurate

POSMV
- should be accurate
- but has glitches
- still good enough to show the error in MAHRS over latitude



# What can go wrong in the ocean velocities

(1) Cross-track error:

- recovery requires accurate heading
- could be related to bad transducer angle

(2) Along-track error:

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

(3) Transition/maneuvering error

- Lag or offset in time or space.
- might need to input the GPS-ADCP offset

(4) Depth-dependent bias

- Surface along-track bias: ringing
- Surface? Deep? Could be electrical noise, could be acoustic

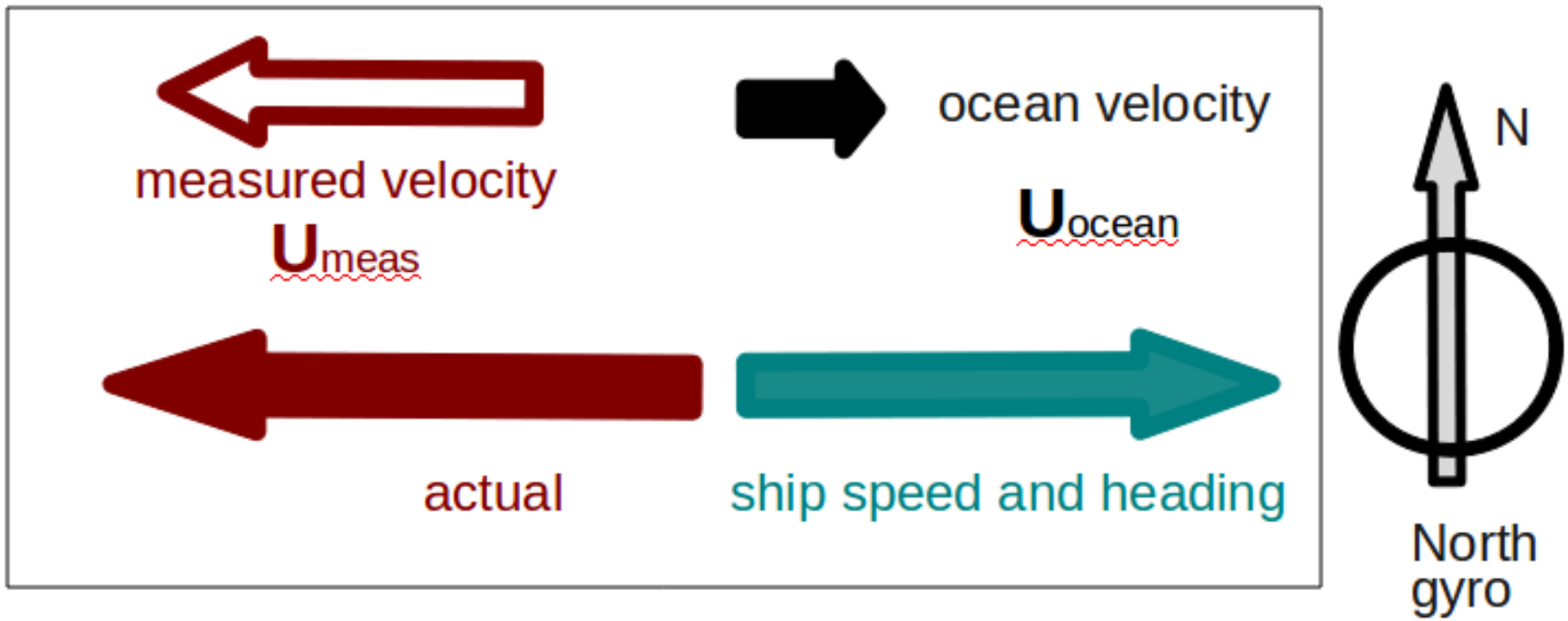
# Examples of along-track error

- Acoustic interference
- Underway bias (bad weather)
- Scale factor (WH300 soundspeed correction)

# Along-track Error

Bias towards zero in measured velocity

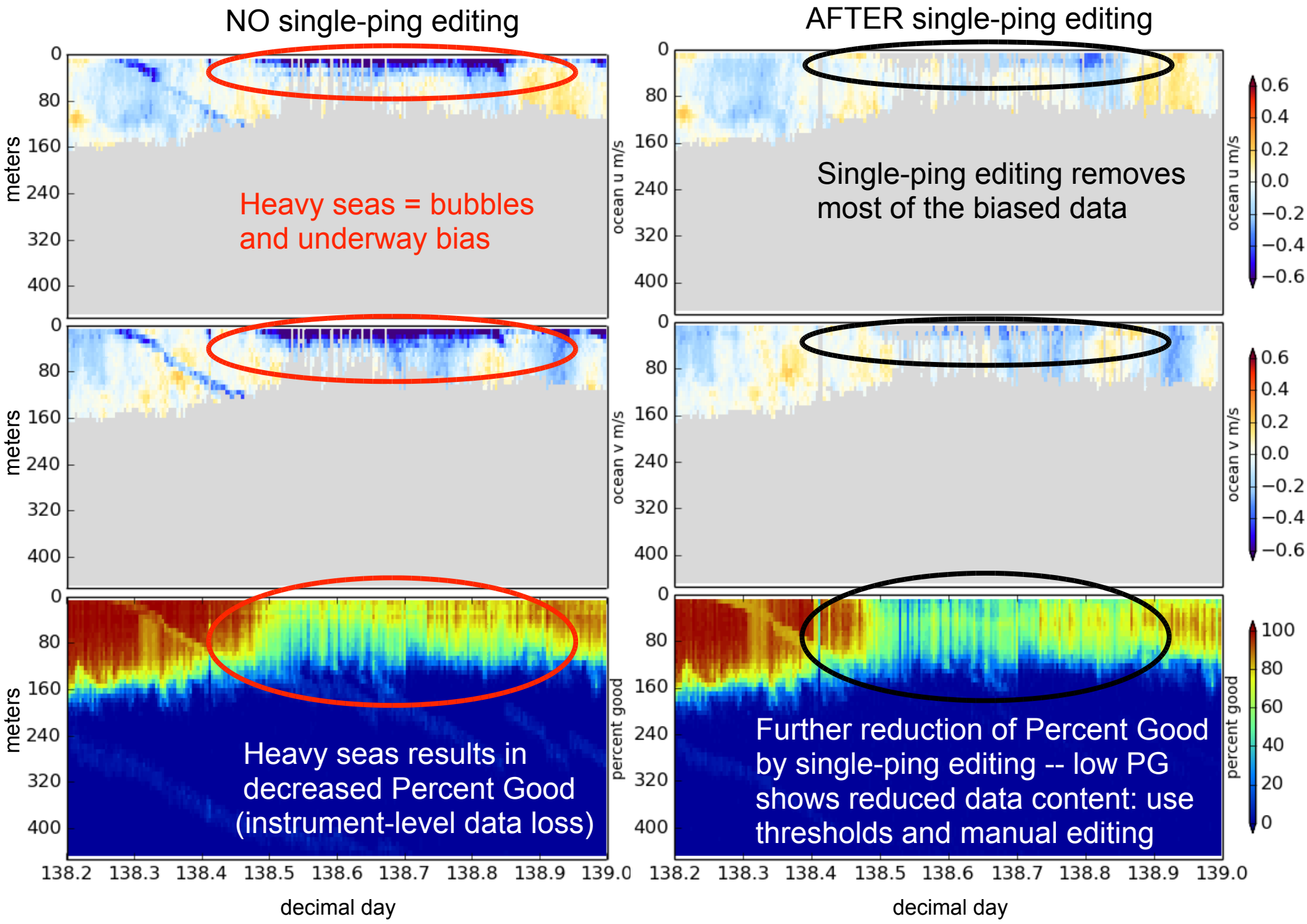
Alongtrack bias in ocean velocity



# Examples of along-track error

- Acoustic interference
- Underway bias (bad weather)
- Scale factor (NB150 soundspeed correction)

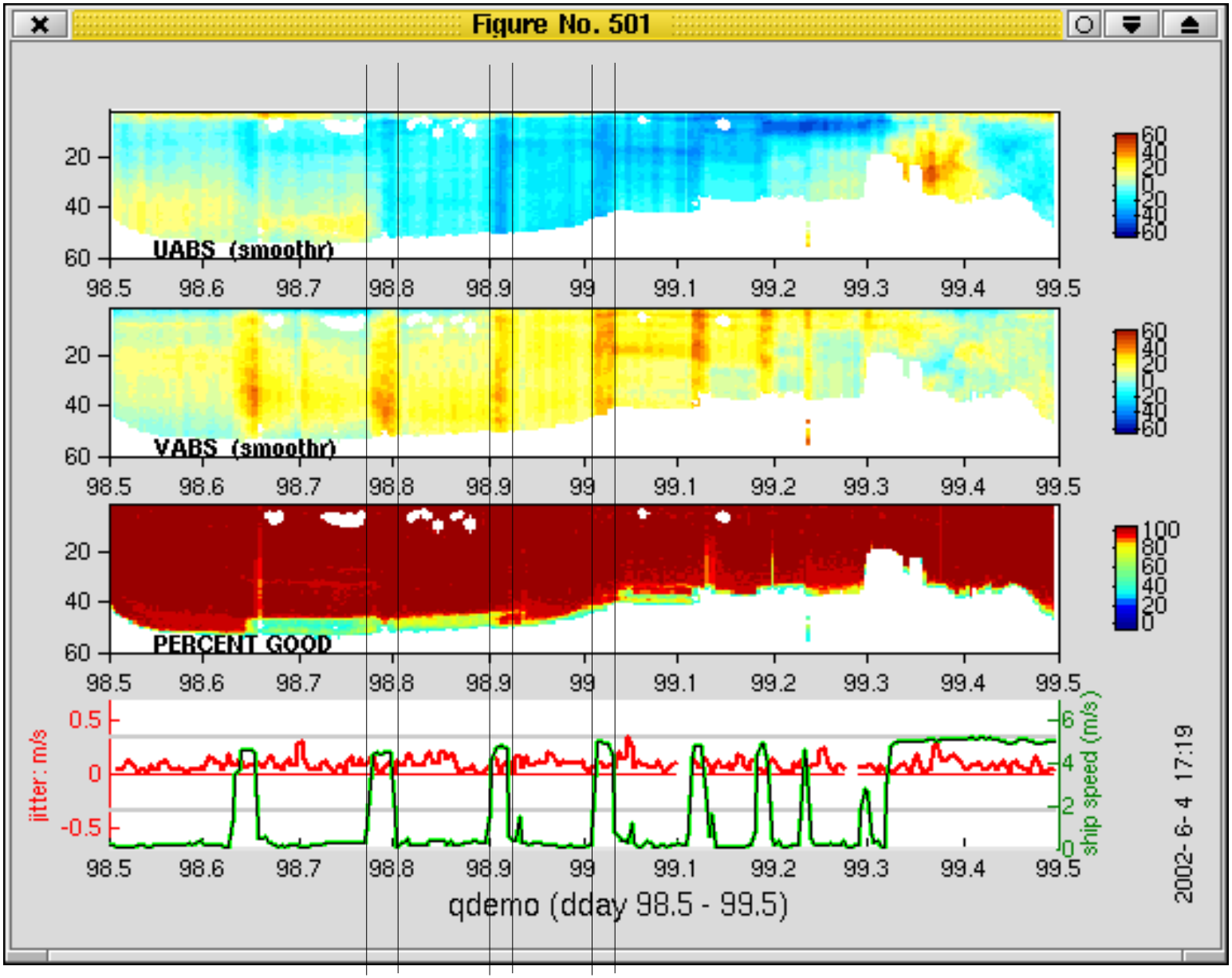
# Bubbles and alongtrack bias



# Examples of along-track error

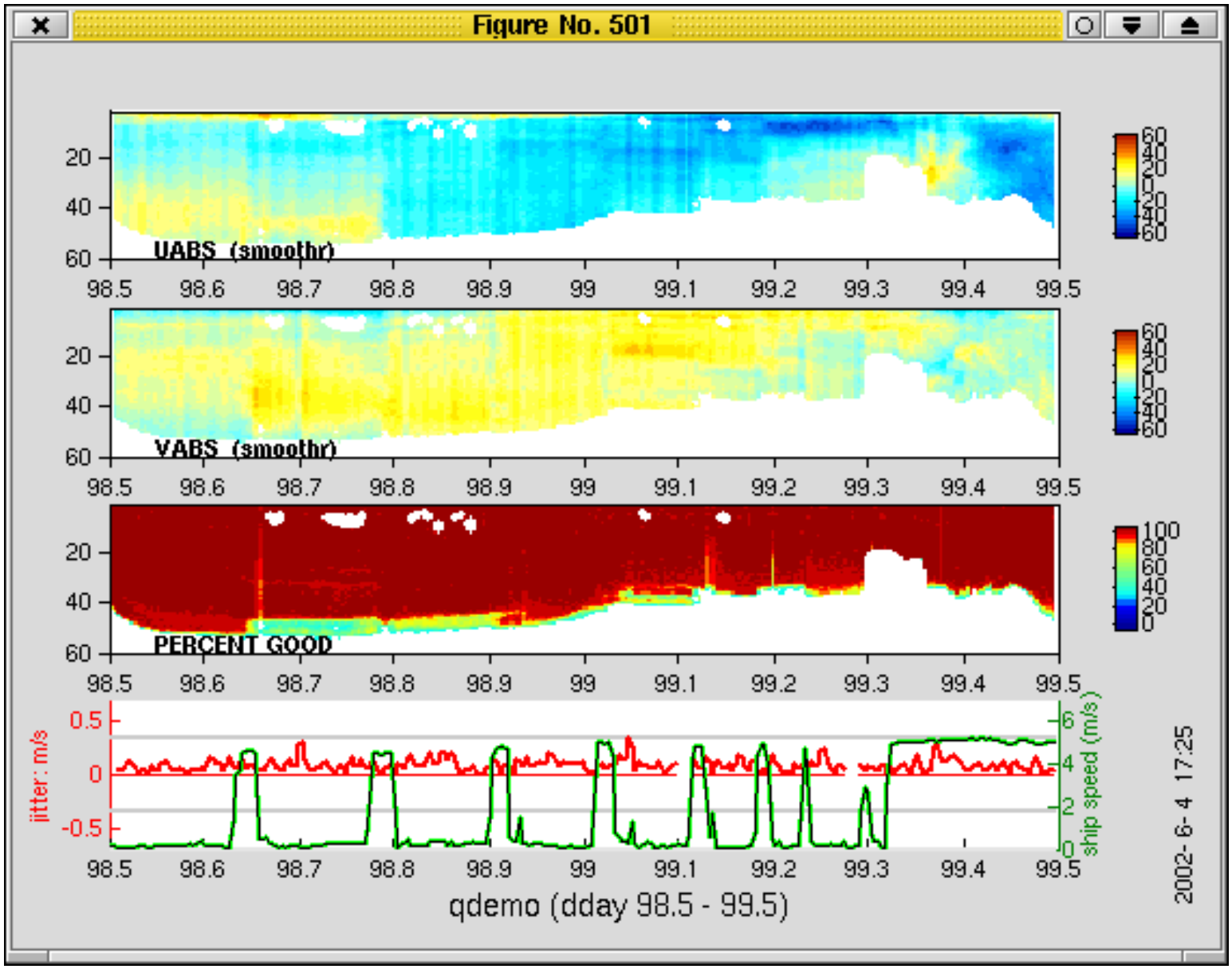
- Acoustic interference
- Underway bias (bad weather)
- Scale factor (NB150 soundspeed correction)

# scale factor: alongtrack bias




84: Things go wrong (scale factor, before)

# After scale factor applied




85: Things go wrong (scale factor, after)

# What can go wrong in the data product

(1) Cross-track error:

- recovery requires accurate heading
- could be related to bad transducer angle

(2) Along-track error:

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

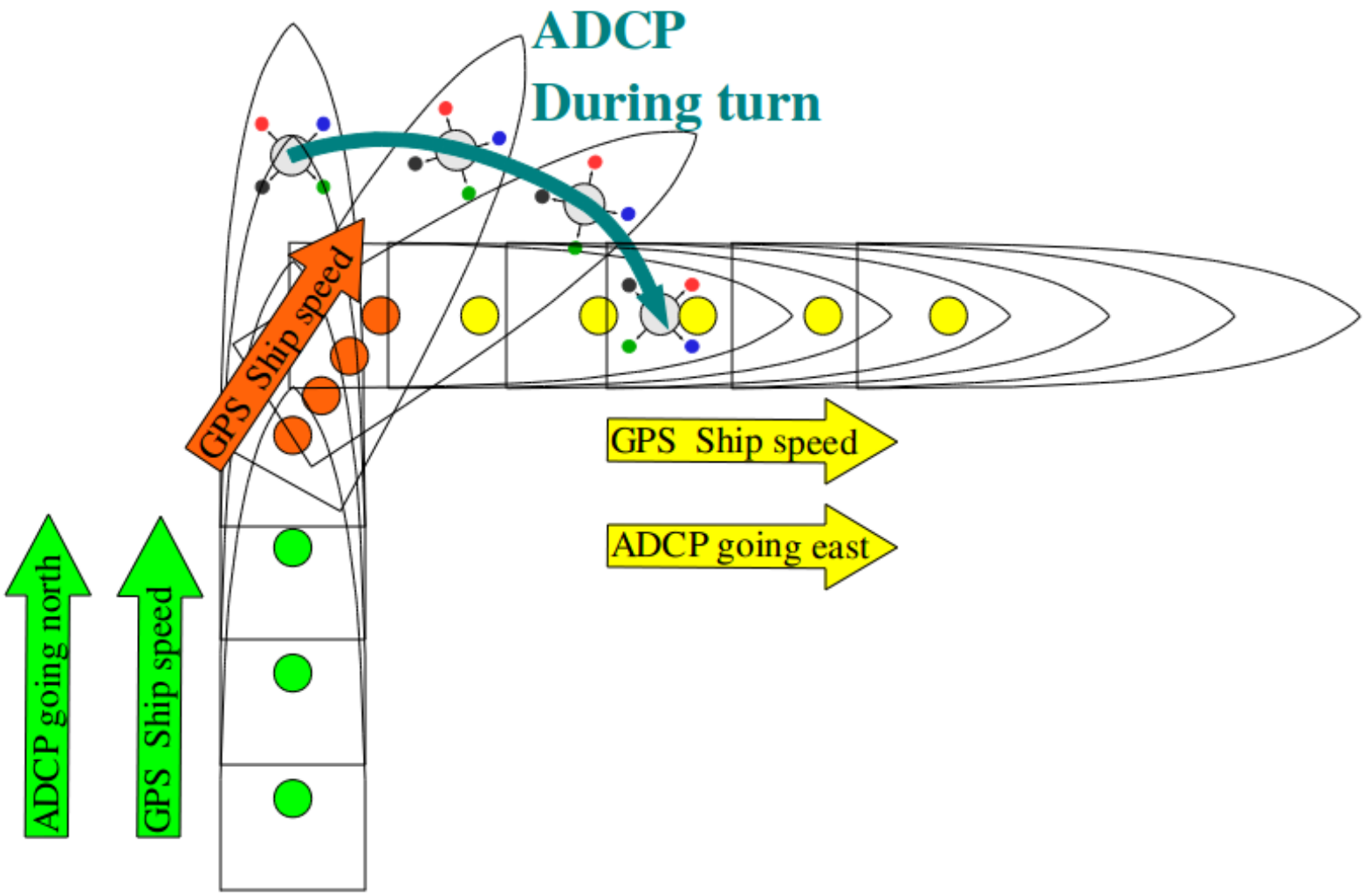
(3) Transition/maneuvering error

- Lag or offset in time or space.
- might need to input the GPS-ADCP offset

(4) Depth-dependent bias

- Surface along-track bias: ringing
- Surface? Deep? Could be electrical noise, could be acoustic

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

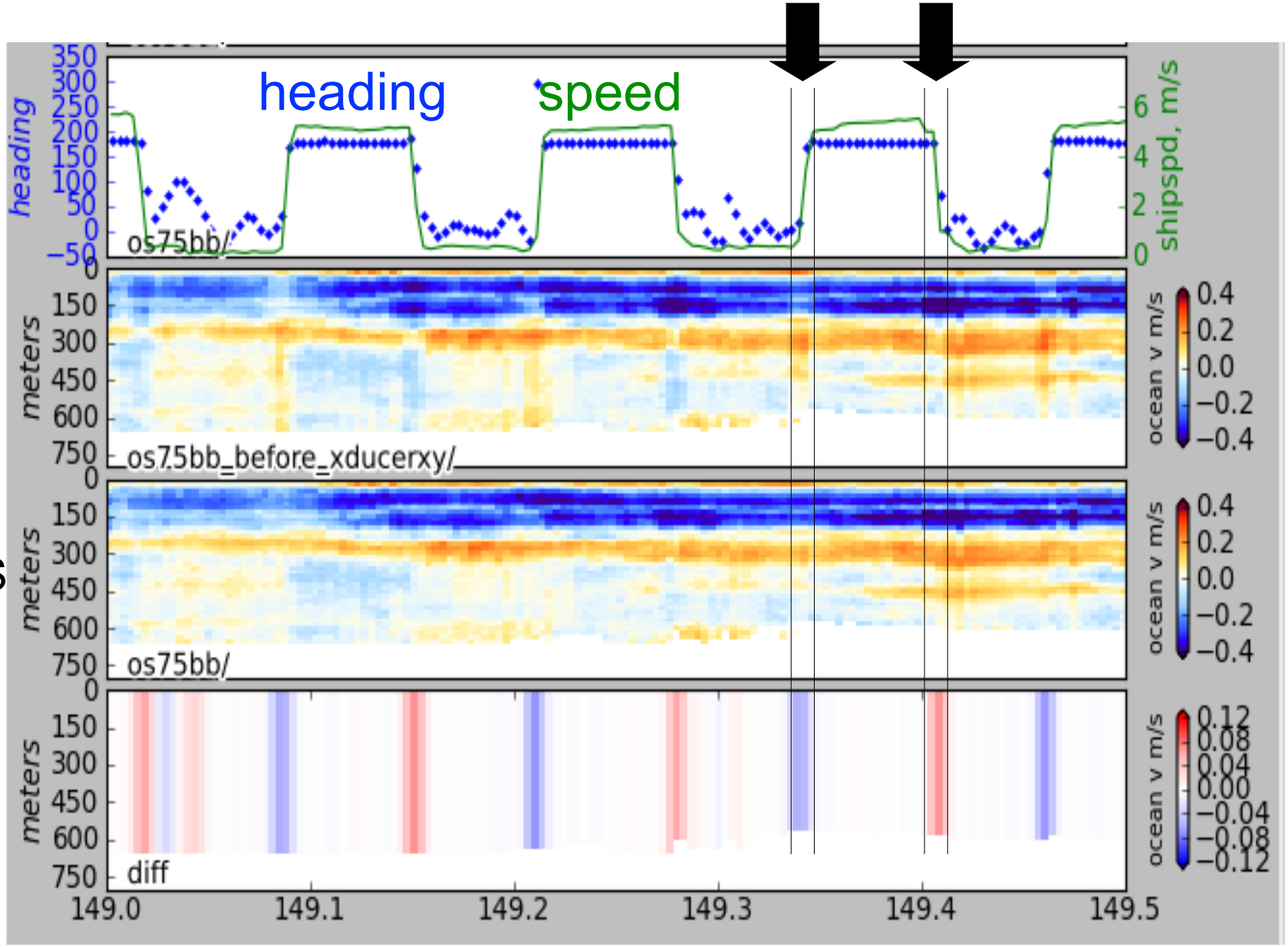


# Transducer offset from GPS--error occurs: **transition** between on-station and underway

...using actual location

...using shifted GPS location

difference



# Summary

## (1) Cross-track error:

- 1deg angle error → 10cm/s crosstrack velocity

## (2) Along-track error:

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

## (3) Transition/maneuvering error

- Lag or offset in time or space.
- correct the GPS-ADCP offset

## (4) Depth-dependent bias

- Surface along-track bias: ringing
- Surface? Deep? Could be electrical noise, could be acoustic