Scripps Institute of Oceanography ADCP processing workshop May 18-20, 2015

UHDAS ADCP data Acquisition and CODAS processing

UHDAS + CODAS Documentation

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

Outline

Day 1: Morning: Presentation

1. ADCP
2. ADCP Data Acquisition
3. CODAS Processing
4. Evaluation

After: Practice

Outline

1. ADCP
2. ADCP Data Acquisition
3. CODAS Processing
4. Evaluation

(I) ADCP: Getting Ocean Velocity

ADCP :

Acoustic (it pings along beams at a frequency)

Doppler (uses frequency shift to get velocity along the beam)

Current (include many more steps to get ocean velocity)

Profiler (listen for the return in small chunks of time to create a vertical profile)

(I) ADCP: Getting Ocean Velocity

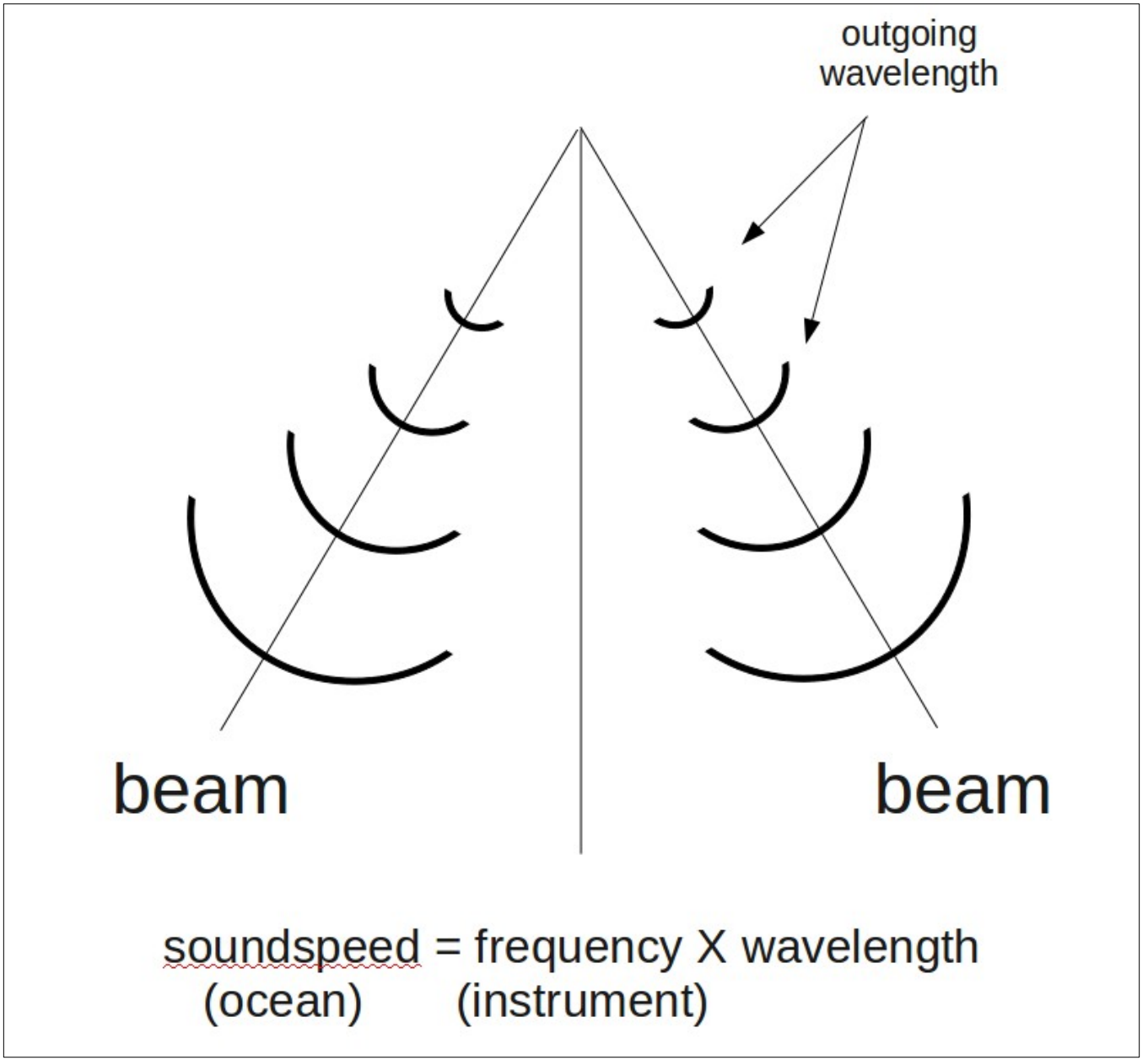
ADCP :

Acoustic

Doppler

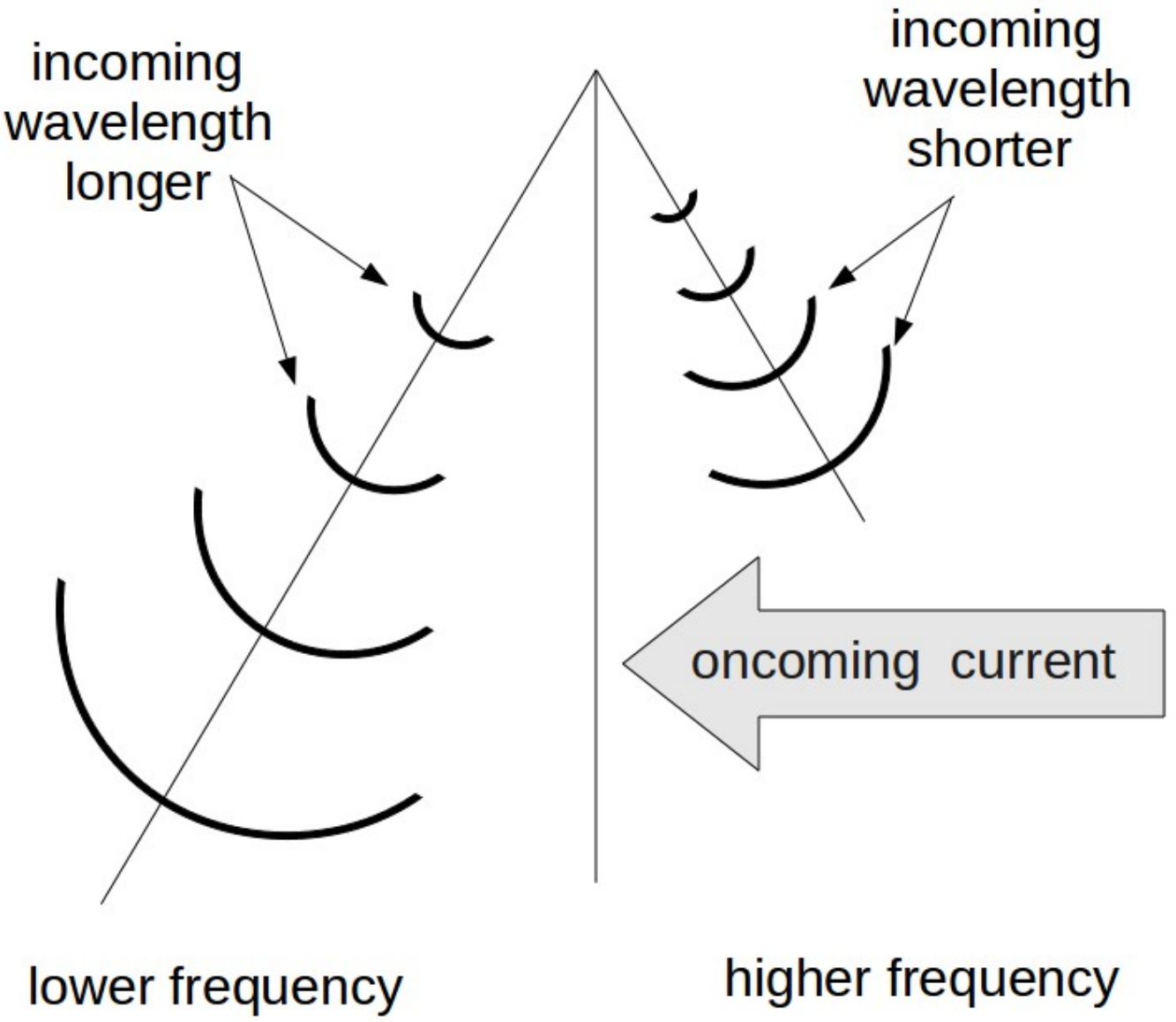
Current

Profiler



ADCP :

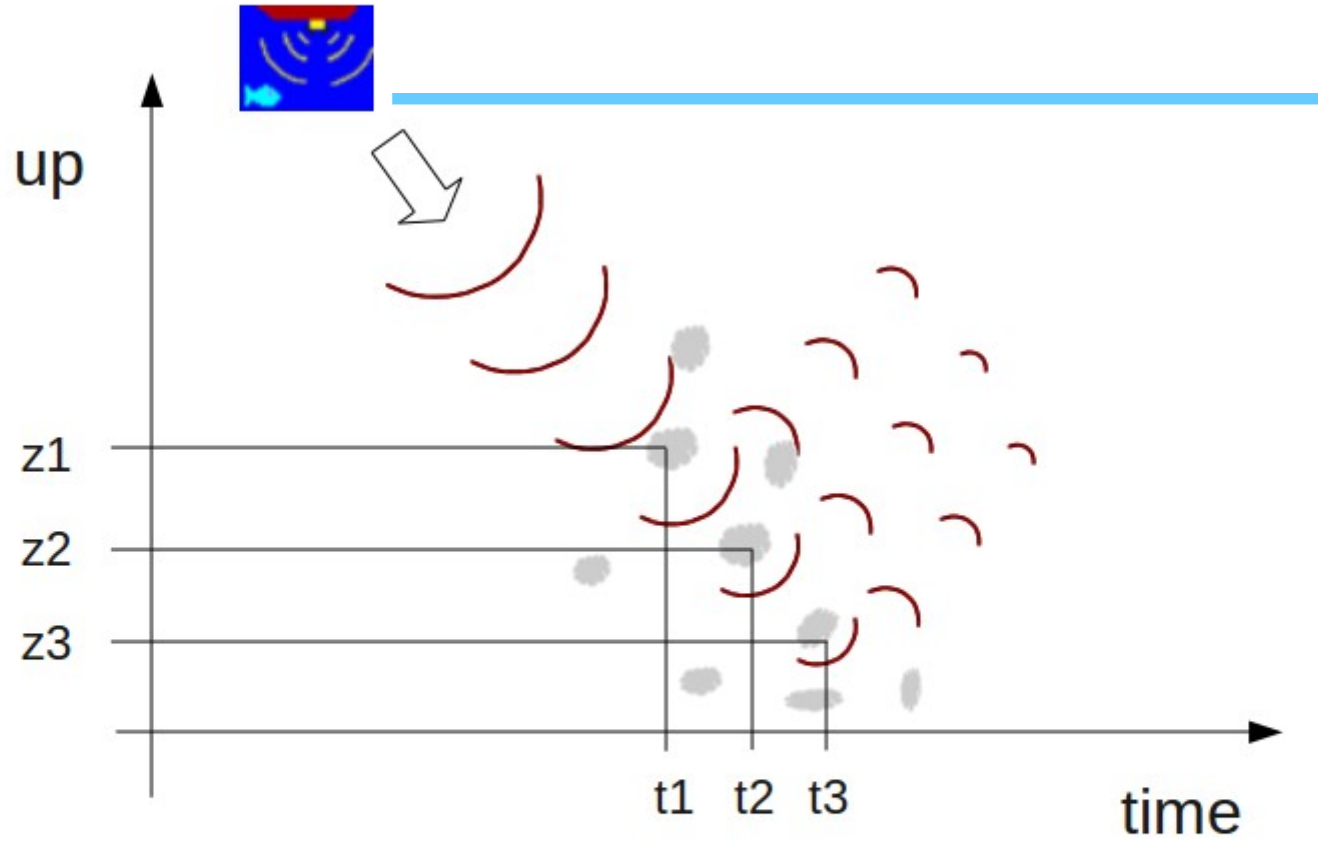
Acoustic
Doppler
Current
Profiler



soundspeed = frequency X wavelength
(ocean) (instrument)

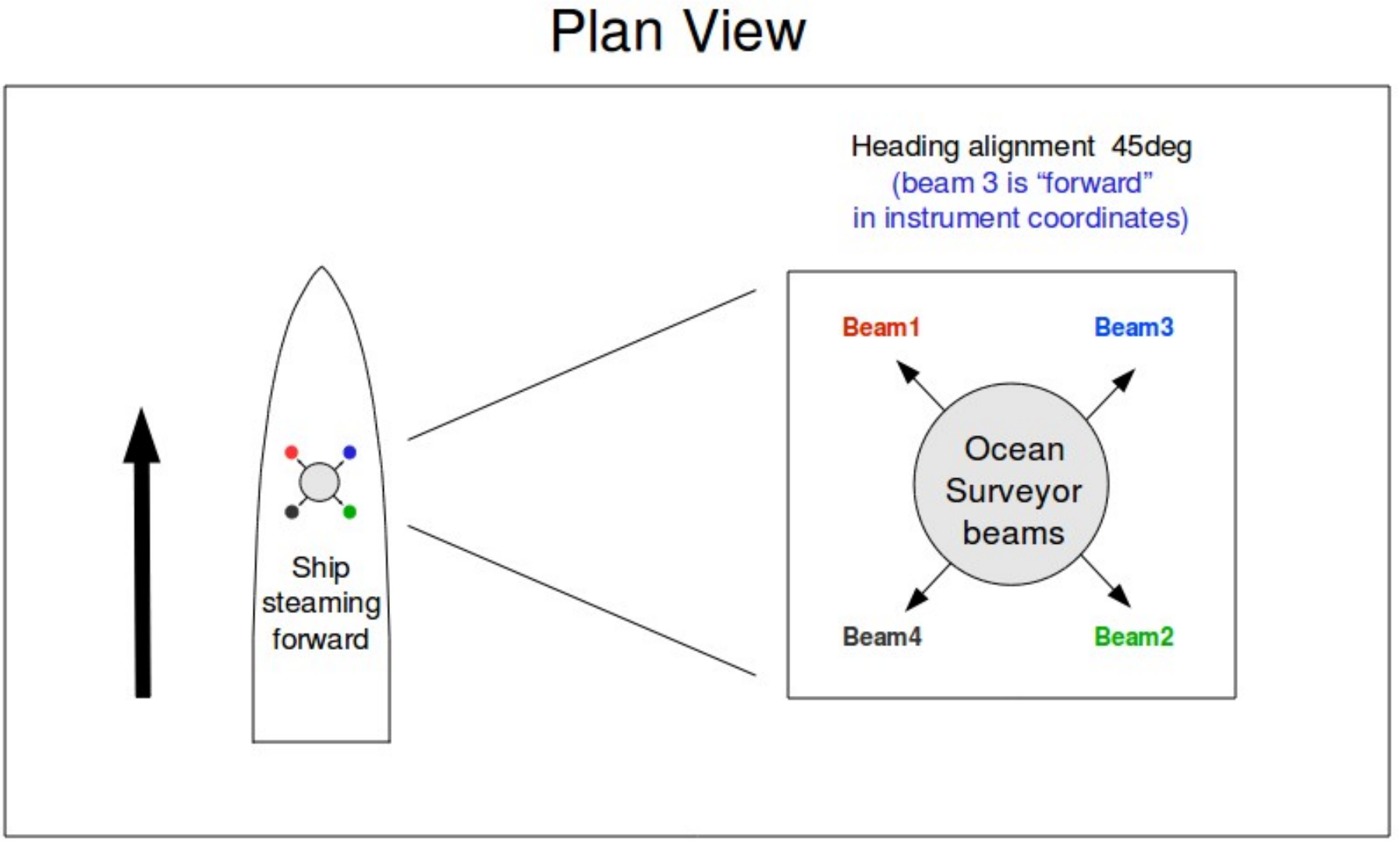
ADC**P**:

Acoustic
Doppler
Current
Profiler

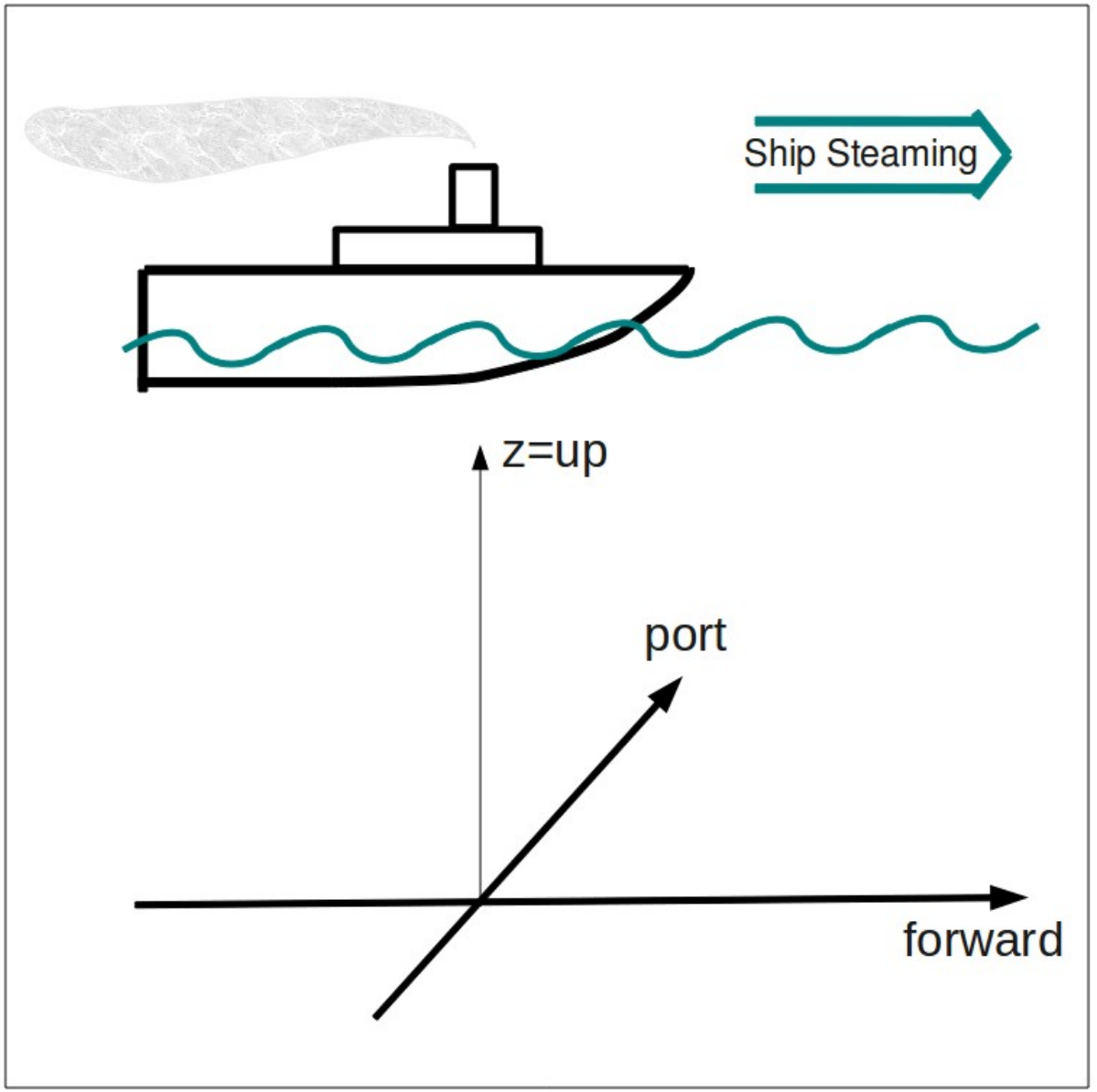


"Gating" the return over time results in "bins" in the vertical, creating a profile of information

ADCP : Getting Ocean Currents



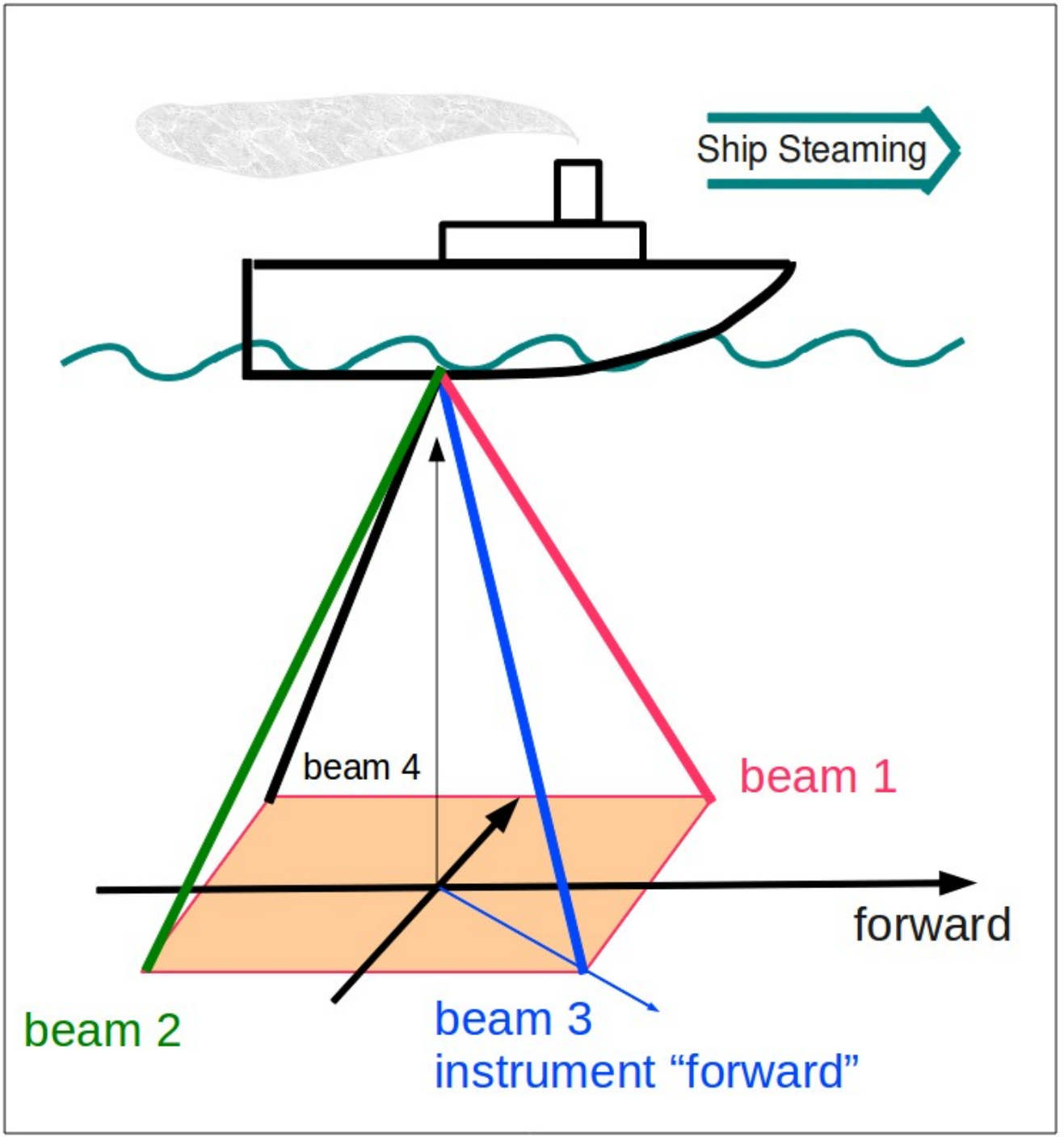
ADCP : Getting Ocean Currents



ADCP

Getting Ocean Currents

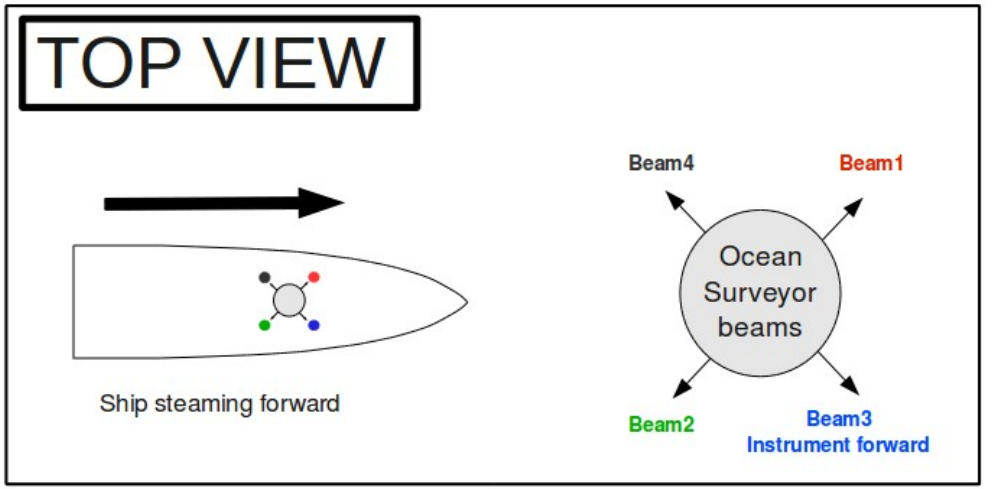
Four beams
- 90deg apart
- 30 (or 20)deg up from vertical
- “forward beam” is #3
- usually 45deg starboard of forward

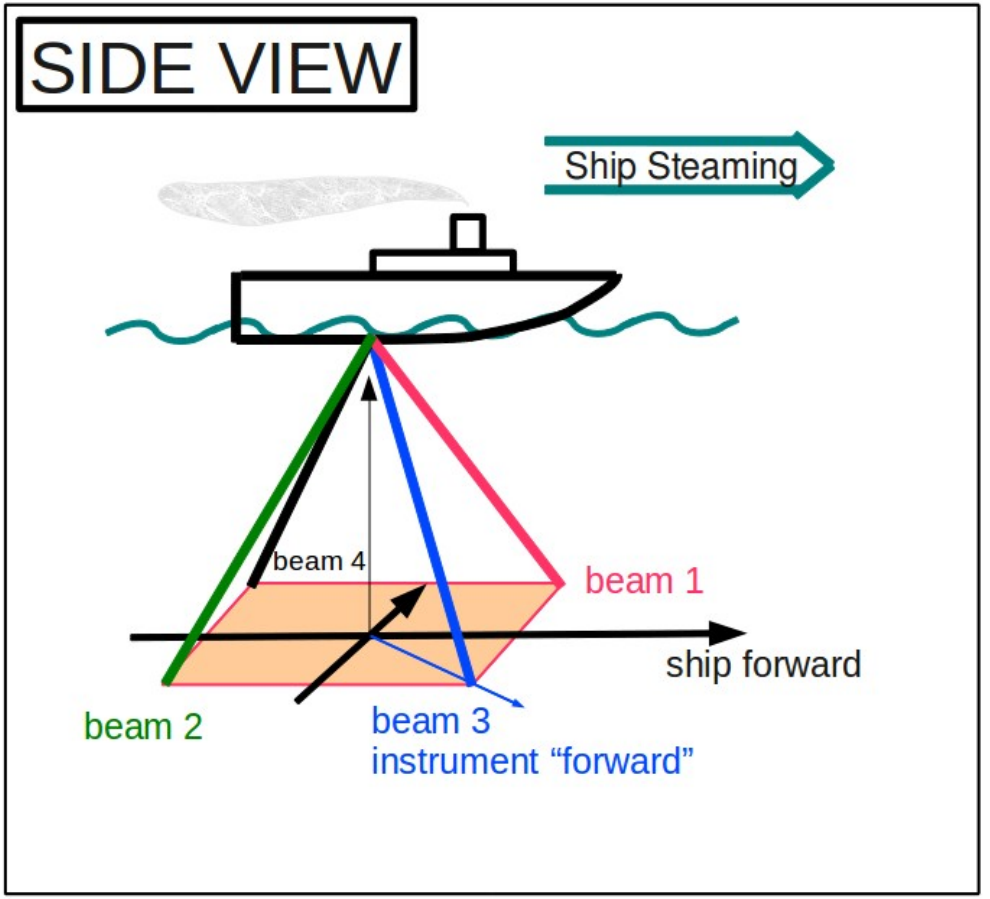


ADCP

Getting Ocean Currents

Four beams
- 90deg apart
- 30 (or 20)deg up from vertical
- “forward beam” is #3
- usually 45deg starboard of forward

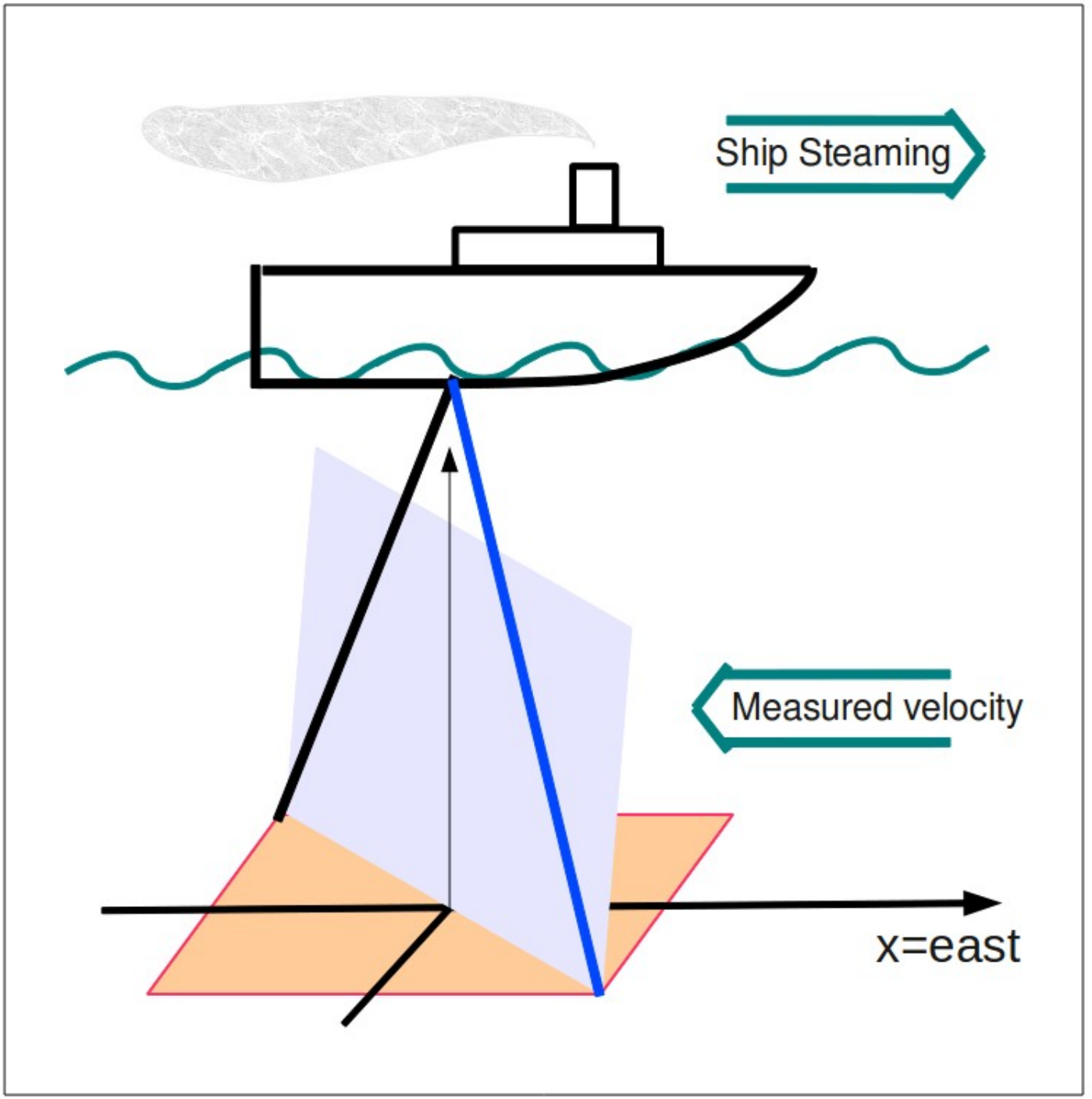




ADCP

Getting Ocean Currents

Two opposite beams make a vertical plane



ADCP

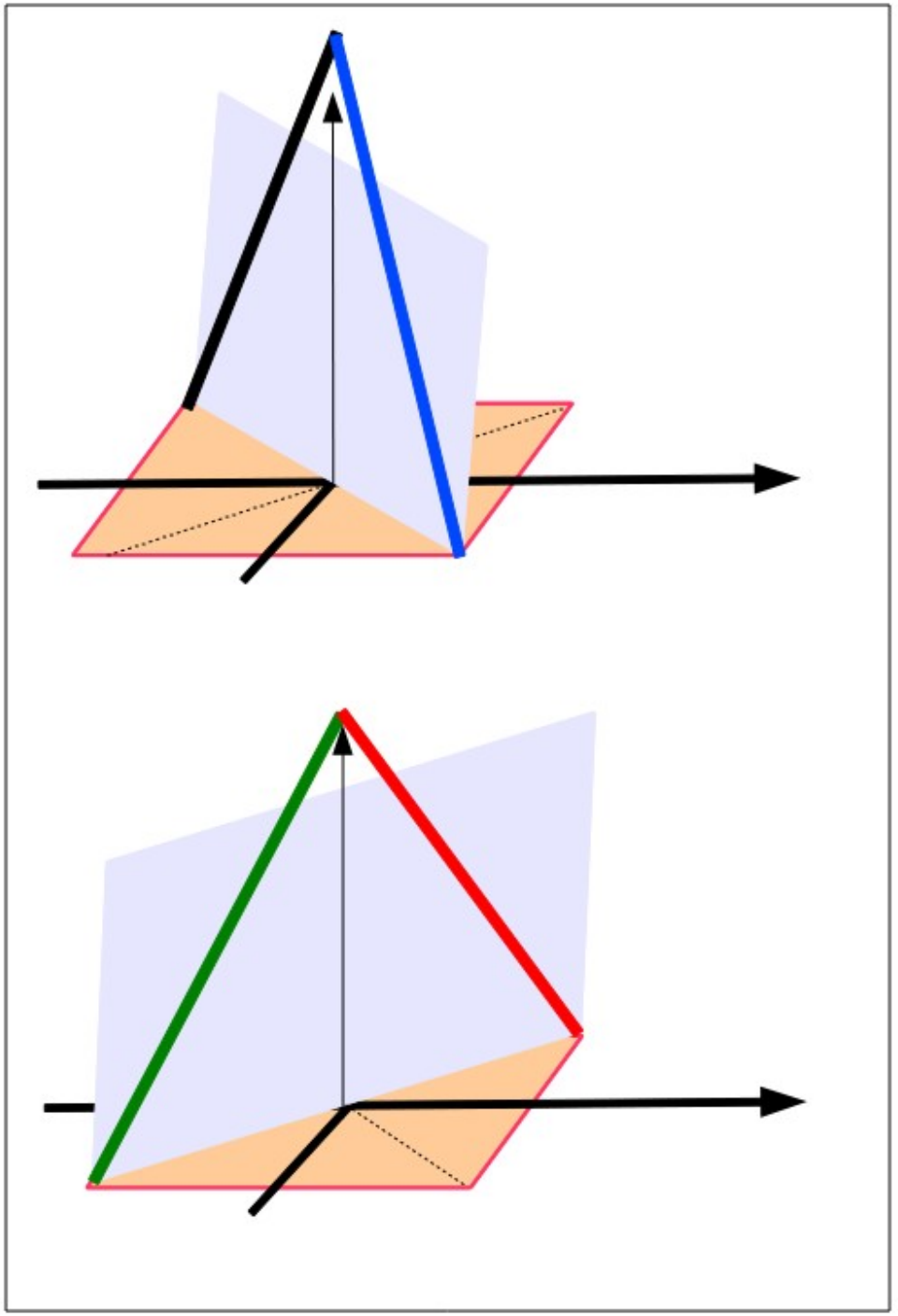
Getting Ocean Currents

Now we have two vertical planes at 90deg to each other

These are the basis of the horizontal and vertical velocities

Horizontal velocities will be used to get ocean velocities

Vertical velocities will be used for error-checking



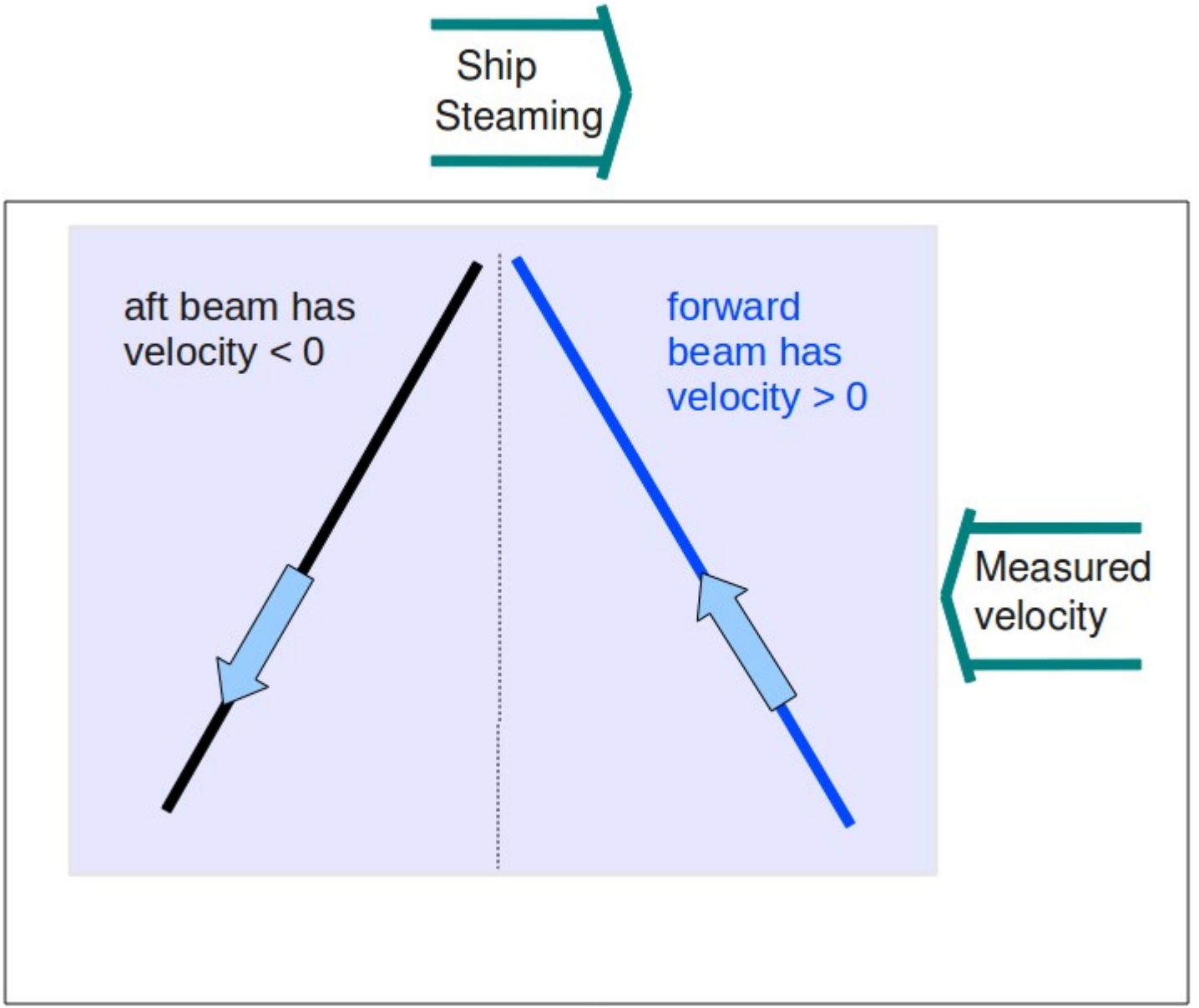
ADCP

Getting Ocean Currents

Two beams make one vertical plan

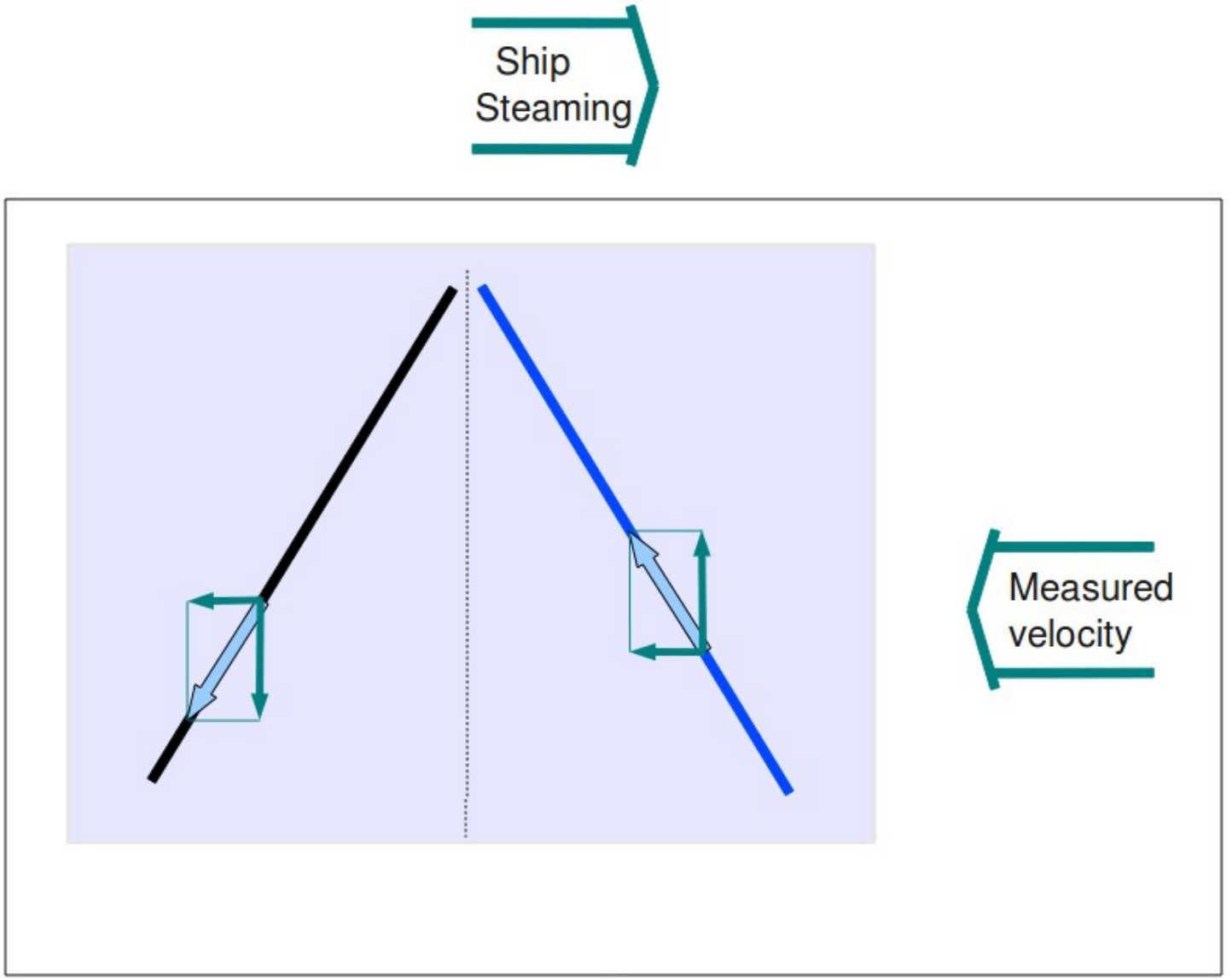
This shows the velocities determined by the Doppler shift;

“beam velocities”



ADCP: Getting Ocean Currents

Interpret the two beam velocities one horizontal and one vertical velocity

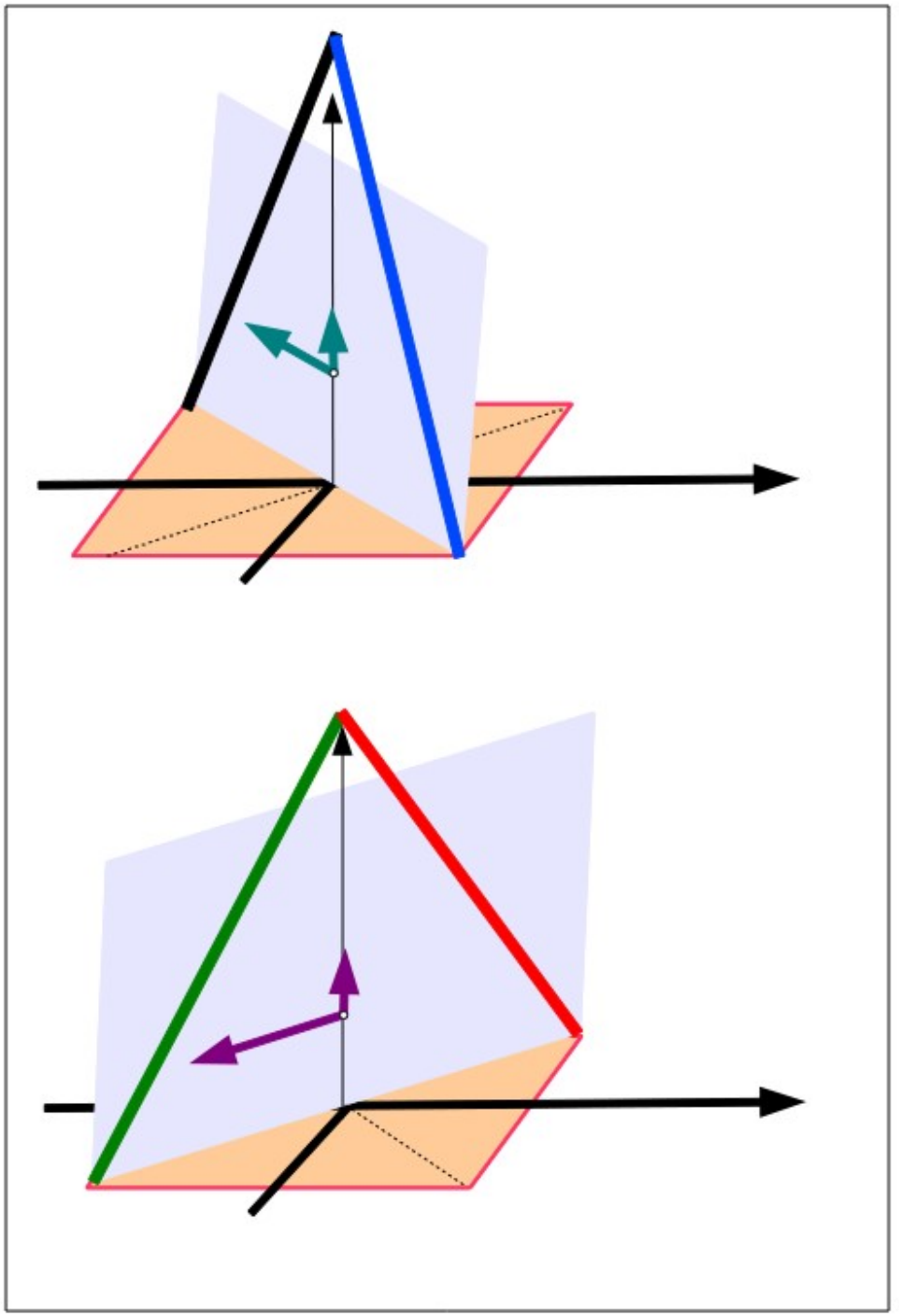


ADCP:

Getting Ocean Currents

Now we see the horizontal and vertical velocities on the two planes

Use the horizontal velocities for determining ocean velocities requires more steps.

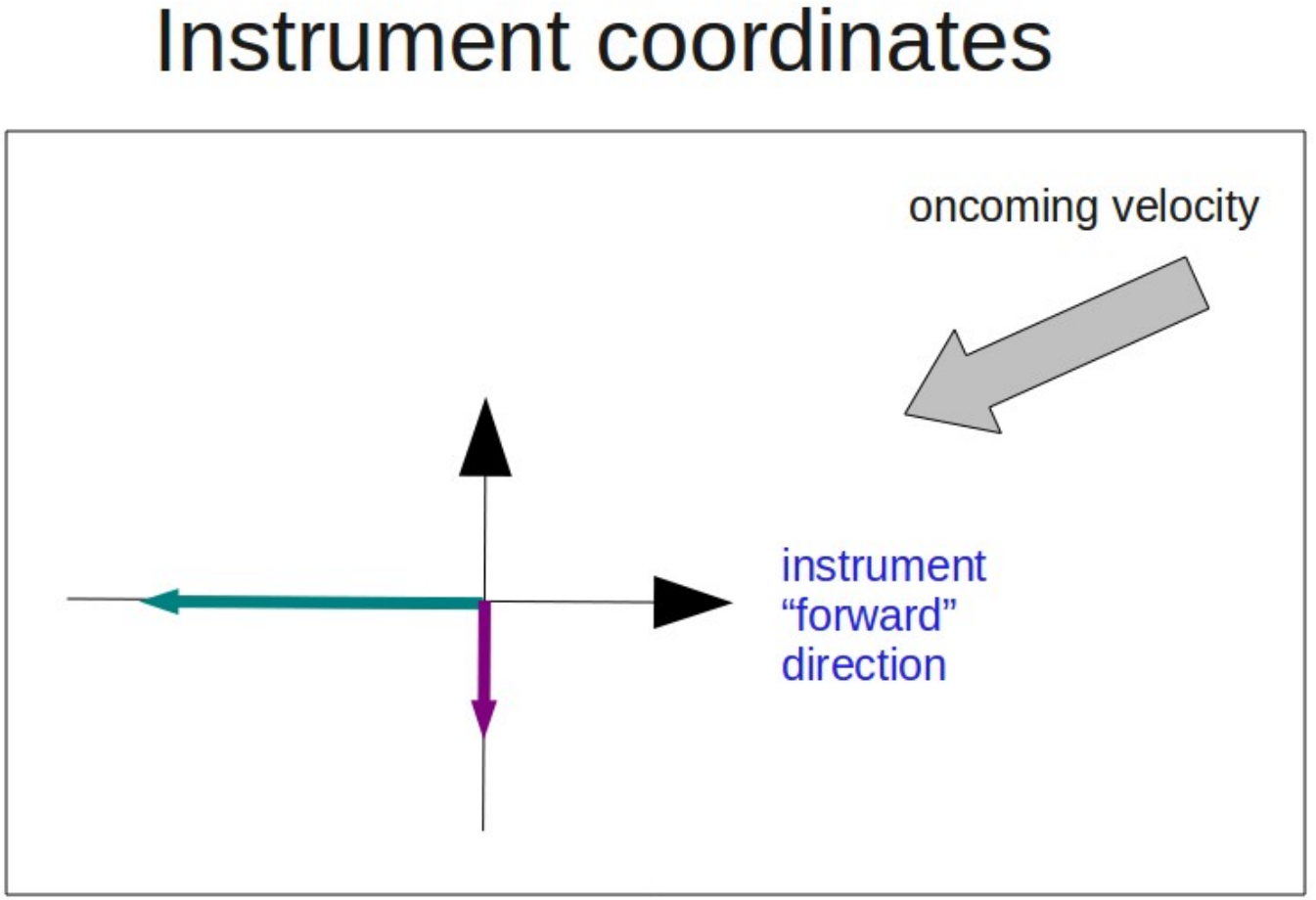


ADCP:

Getting Ocean Currents

This is a top-down view of the measured horizontal velocity in **instrument coordinates** (from the two planes made by the beams)

(determining ocean velocities requires more steps)



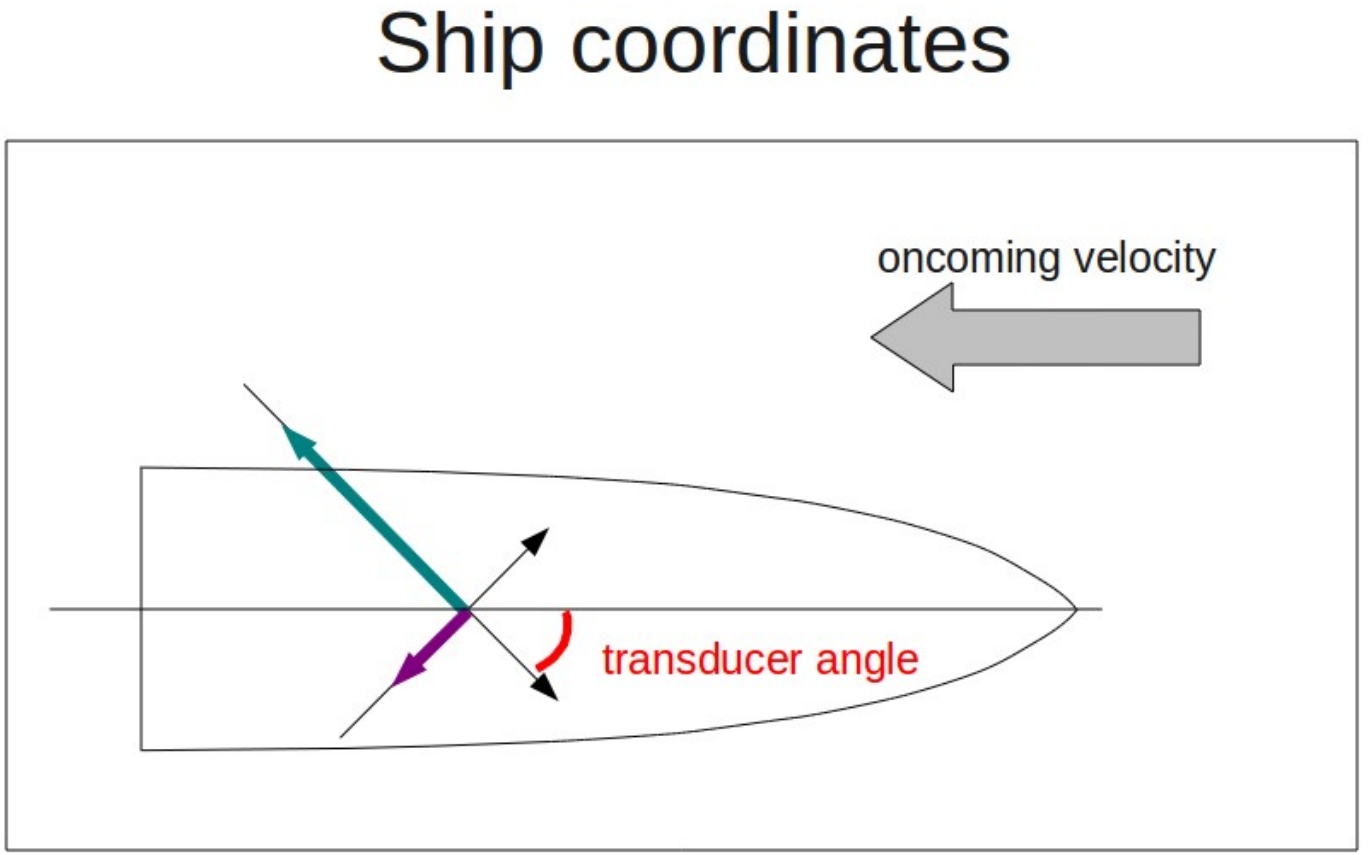
ADCP:

Getting Ocean Currents

This is a top-down view of the measured horizontal velocity in ship coordinates.

The instrument coordinates values are rotated by the **transducer angle**.

(determining ocean velocities requires more steps)



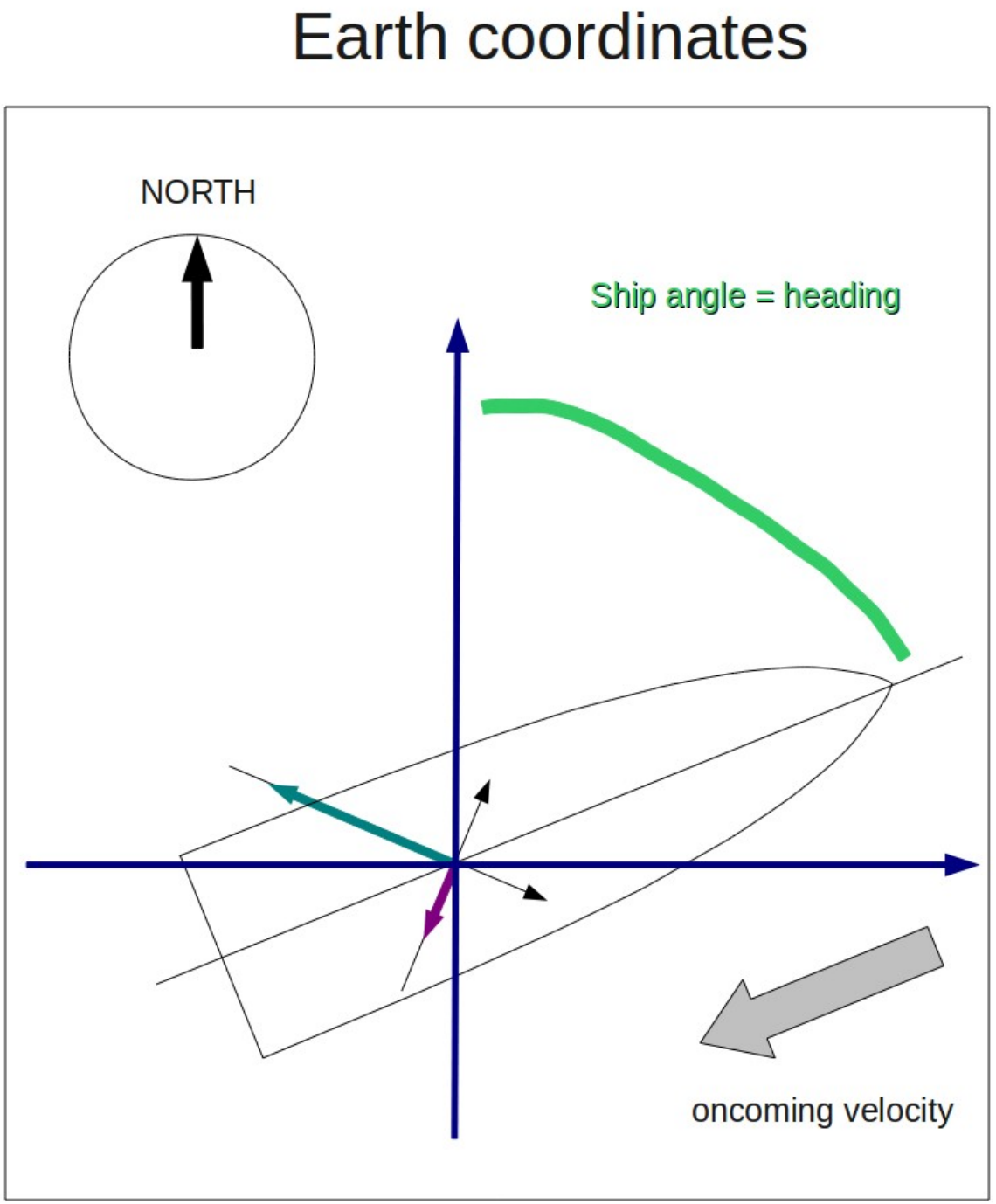
ADCP:

Getting Ocean Currents

This is a top-down view of the measured horizontal velocity in earth coordinates.

The instrument coordinates values are rotated by the **ship's heading**.

(determining ocean velocities requires more steps)



ADCP:

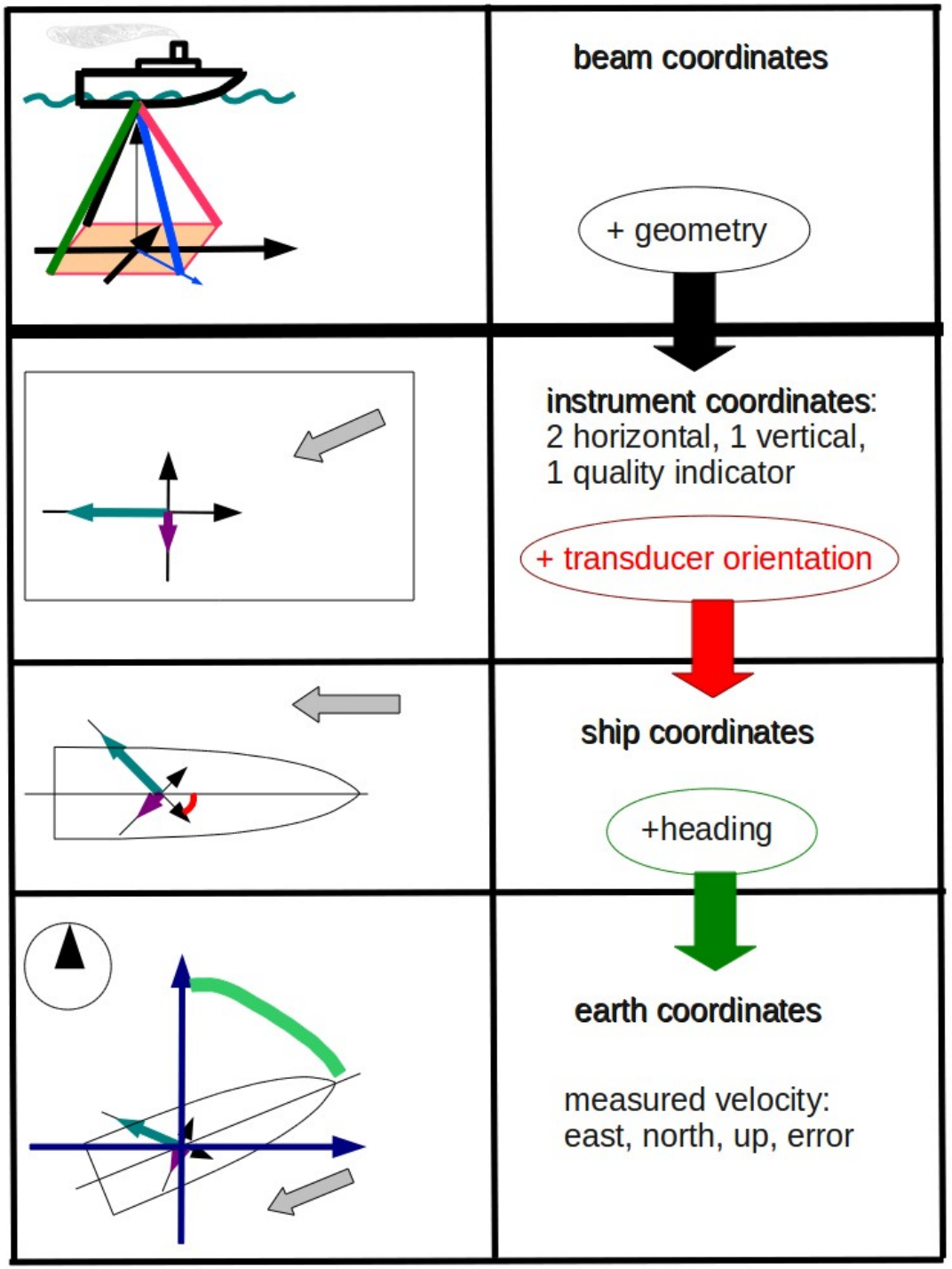
Getting Ocean Currents

Summary of steps:

Doppler to beam
(not shown)

<u>below here: horizontal+vertical</u>

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



ADCP:

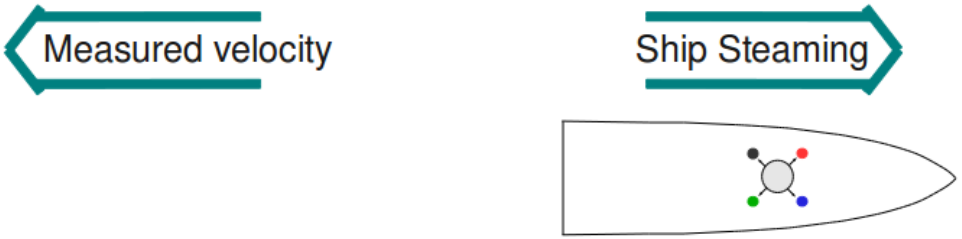
Getting Ocean Currents

Earth coordinates + **GPS** gives ship speed

add ship speed to measured velocity to get ocean velocity

Earth coordinates

If no ocean currents:



$U_{meas} = -U_{ship}$

With Ocean current

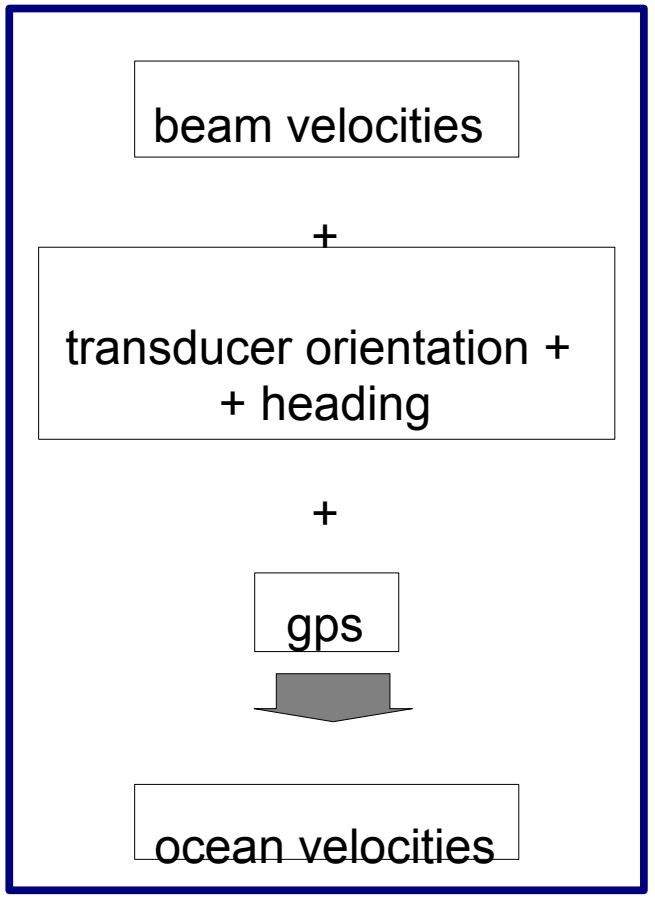
$U_{meas} = -U_{ship} + U_{ocean}$

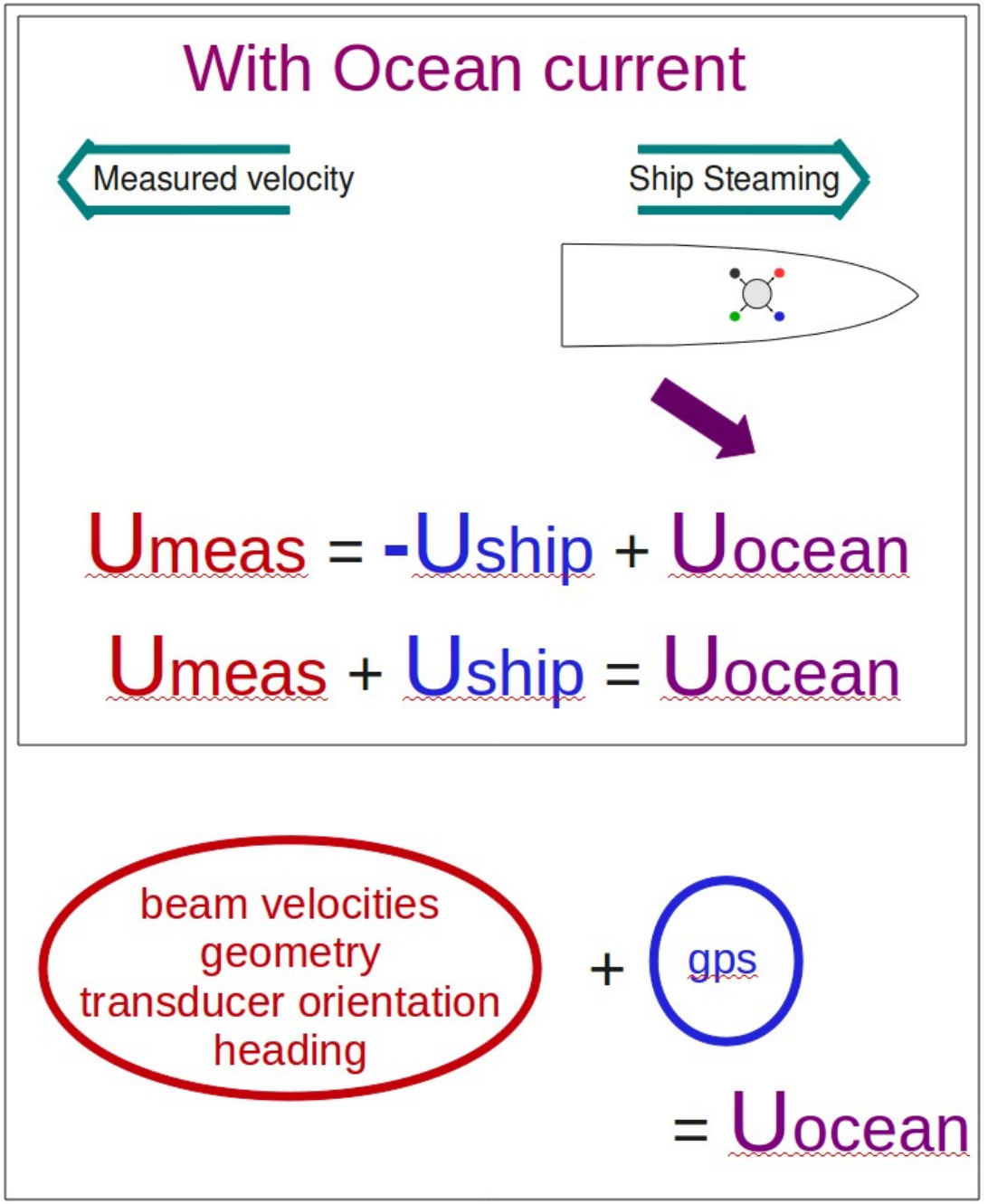
$U_{meas} + U_{ship} = U_{ocean}$

ADCP:

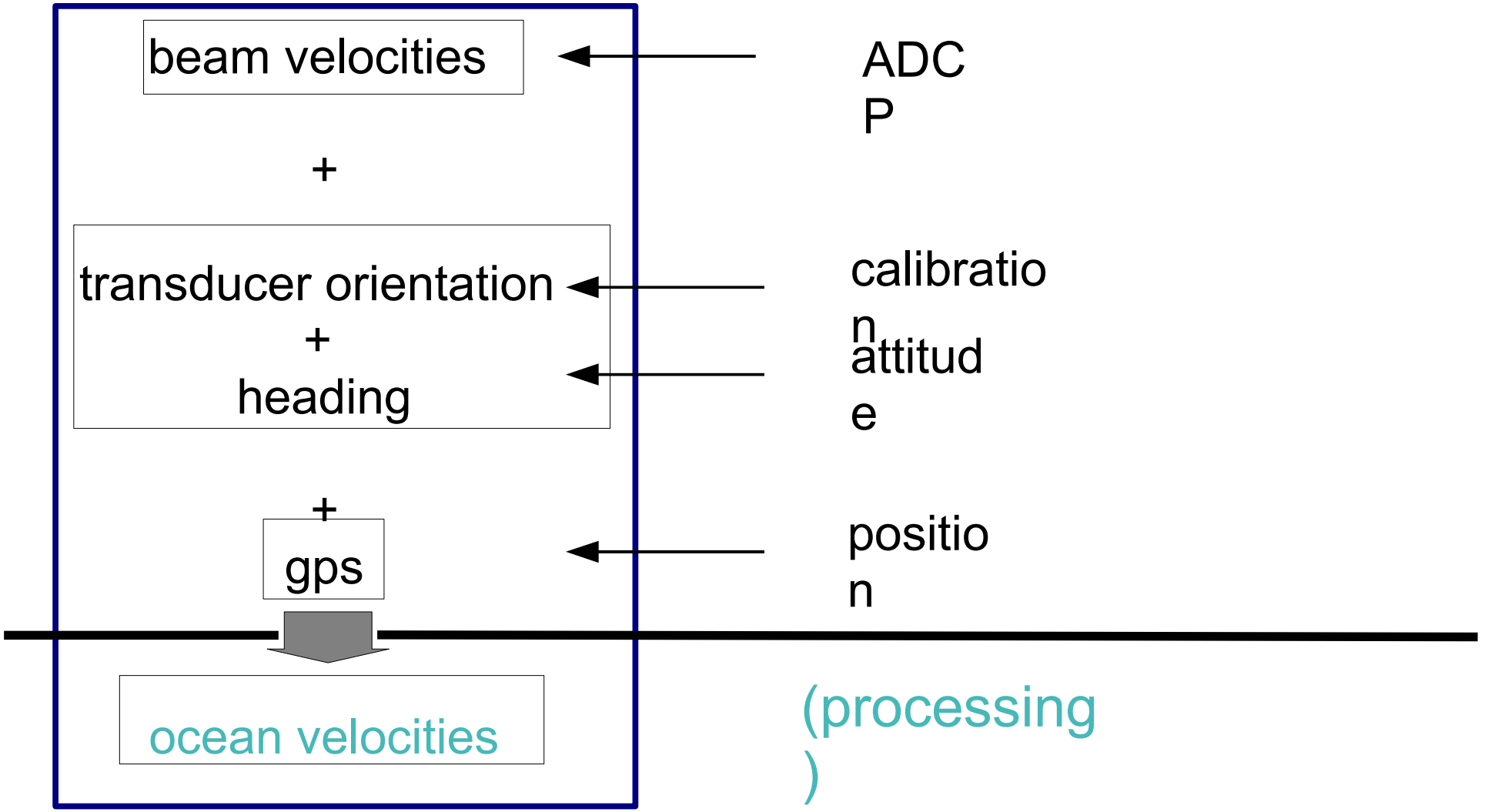
Getting Ocean Currents

Complete summary:





ADCP: Data components



Outline

1. ADCP
2. ADCP Data Acquisition
3. CODAS Processing
4. Evaluation

ADCP Acquisition Systems

There are two acquisition systems for vessel-mounted ADCPs:

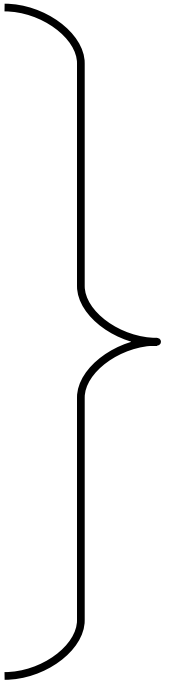
- VmDAS (provided with purchase)
- UHDAS (developed at Univ Hawaii)
  - Installed on UNOLS ships, rolling out to NOAA ships
  - Link to **Table of ships**

Components – Overview:

- Basic requirements
- Processing
- Monitoring

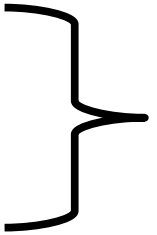
ADCP Acquisition Systems: Overview

- Basic requirements:
  - Control ADCP settings
  - Acquire ADCP data
  - Acquire ancillary data
    - Position
    - Attitude (heading)
  - Timestamp all



Core

- Processing
- Monitoring



Extra

ADCP Acquisition Systems: Overview

- Basic requirements
- Processing
  - Coordinate transformation
  - Editing
  - Averaging
  - Graphical Displays
- Monitoring

ADCP Acquisition Systems: Overview

- Basic requirements
- Processing

- Monitoring
  - Computer system
  - Data acquisition
  - Processing
  - Access to data

ADCP Acquisition systems: Details

- Basic requirements:
  - Overview
  - Serial setup
  - Data logging

Comparison (UHDAS/VmDAS)

- Processing
- Monitoring

ADCP Acquisition Systems- Overview

	UHDAS	VmDAS
developer	Univ Hawaii	TRDI
style	linux system	windows application
source	open source	executable
purpose	seagoing oceanographers	all-purpose
goals	maximize - usefulness at sea - long-term value for research	off-the-shelf
evolution	continuous	incremental
setup	complex	confusing

ADCP Acquisition: Serial Setup

	UHDAS	VmDAS
ADCPs	multiple	one (per computer)
feeds	any number	3 (older version=2)
messages	many types can add more subsample feed choose messages	fewer types record all record all
GUI controls	 instrument settings	 everything
operation	simple	simple/confusing
protected	serial processing	nothing protected

Acquisition: Data Logging

	UHDAS	VmDAS
data logging	separate processes	one big program
time tagging	buffered tag every line	unbuffered tag ensemble
data formats	multiple	TRDI ADCP
data directory	heirarchical	flat
time range	match per file	match for one logging period
filenames sort (time=ascii)	always	one logging period
metadata	stored with data	text file elsewhere

ADCP Acquisition Systems: Comparison

- Basic requirements
  - Overview
  - Serial setup
  - Data logging
- Processing
  - Processing components
  - Accessing data products
- Monitoring

Processing: Comparison

	UHDAS	VmDAS
editing	CODAS	minimal
heading	reliable	primary
secondary heading	corrected to accurate	replaced by fallback
pings	interleaved	first
configure plots??	no	yes
plots	oceanographic: - profiles (E,N) - vector (+topo) - contour - bridge (mariner)	profile (speed, dir) vector WinADCP?

Accessing Data Products

	UHDAS	VmDAS
access plots	ship's web console	console only
data formats	TRDI Matlab netCDF	TRDI
access data	ship's web windows share NFS	acquisition PC windows share
documentation	ship's web www	acquisition PC www
speedlog out	NB150 only	yes

ADCP Acquisition Systems: Comparison

- Basic requirements
  - Overview
  - Serial setup
  - Data logging
- Processing
  - Processing components
  - Accessing data products
- Monitoring

Monitoring

monitor	**UHDAS**	**VmDAS**
computer	daily report	?
serial	daily_report	LOG and console messages configure tables
ADCP	beam plots	configure plots
Processing	daily_report	configure plots
	plots	
	calibration	no
	ping rate	?
	bottom track	no
remotely	email to anyone	no

UHDAS: what it does

- Data acquisition
- Data processing
- Data access (for scientist at sea)
- Monitoring tools
  - at sea
  - from shore

(link in documentation – UHDAS overview)

UHDAS cruise directory structure

Data for scientists:

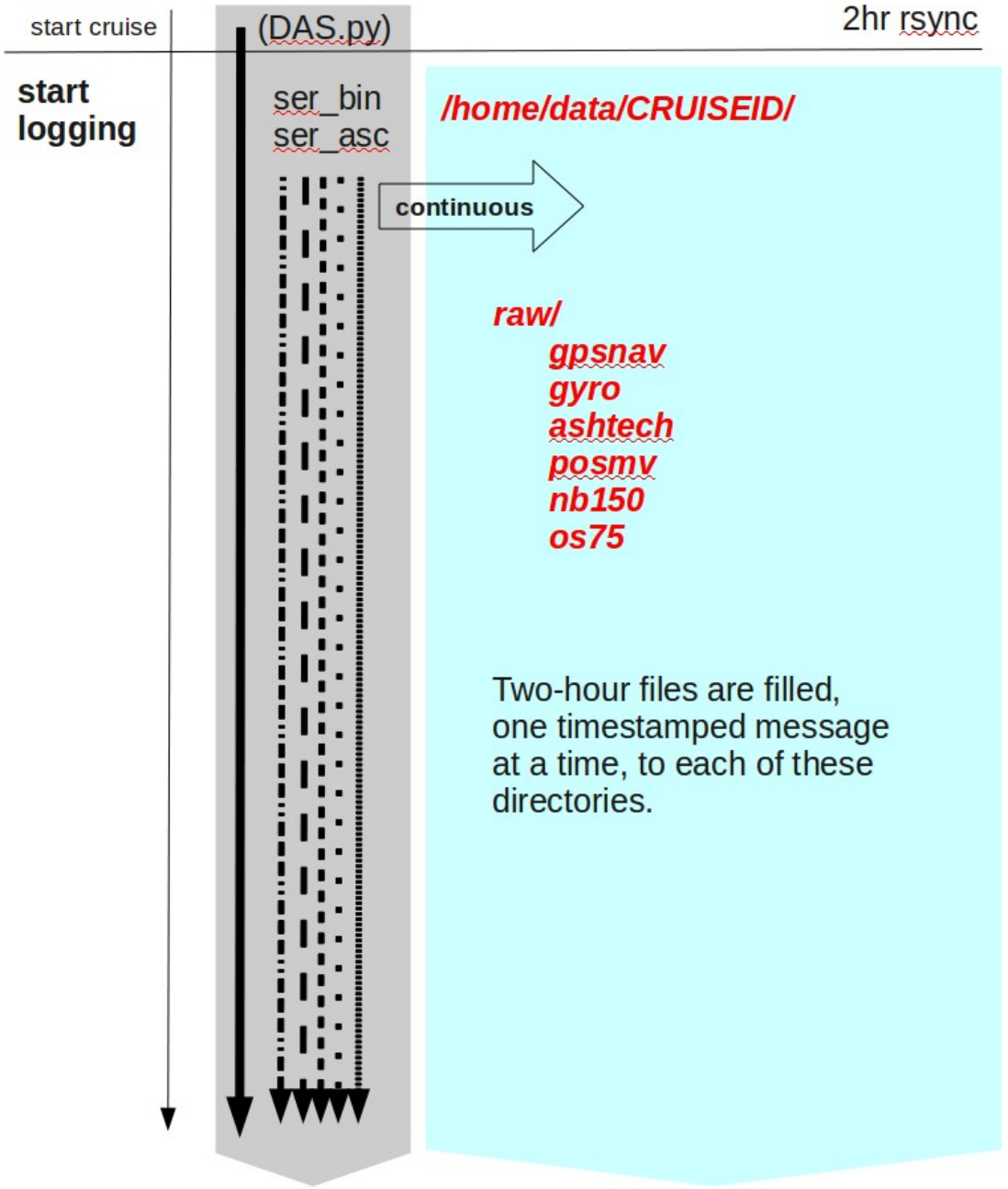
There are three categories of data, all located in the logging directory, /home/data/[CRUISEID]:

ADCP logging directories

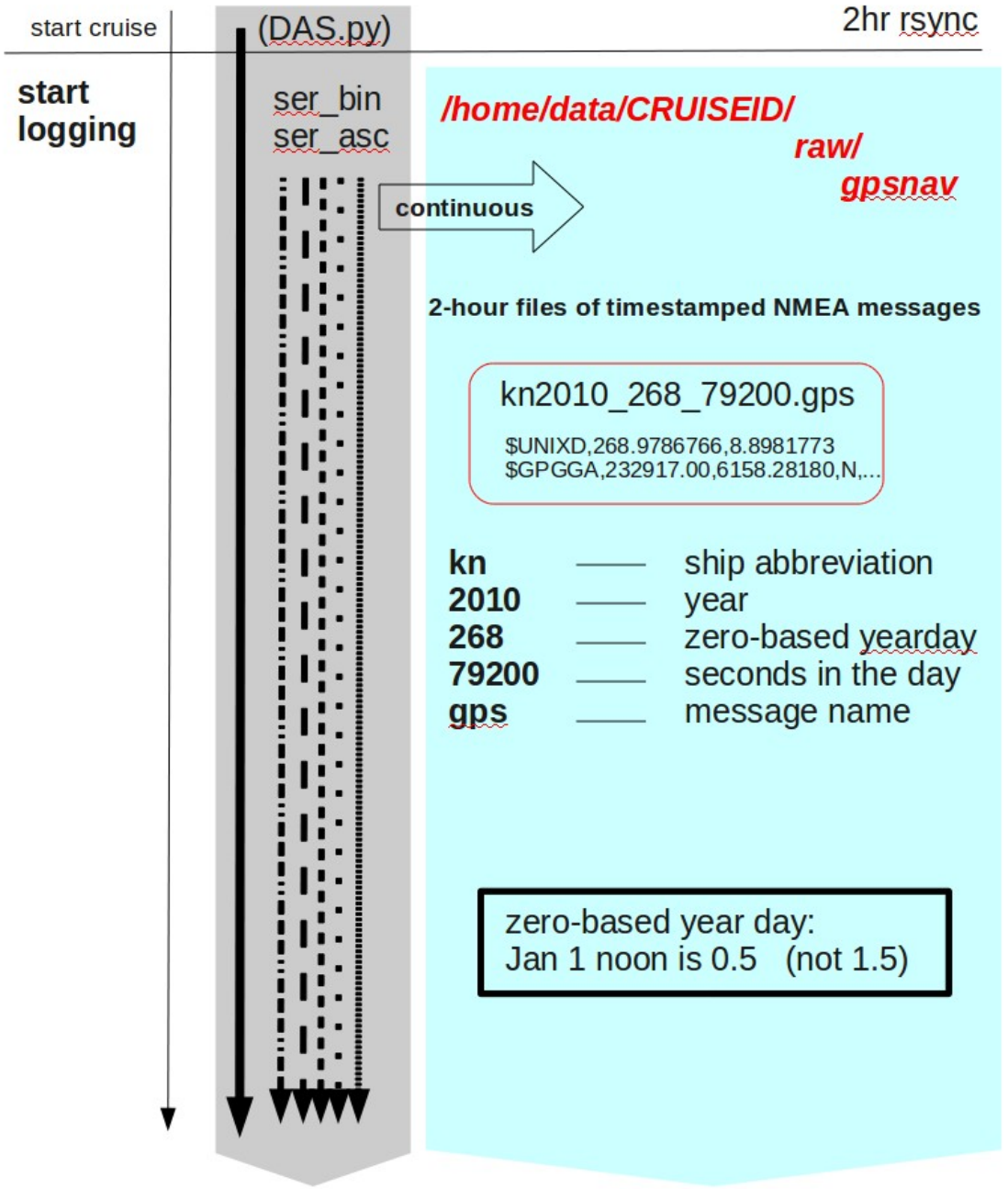
subdirectory	contents	importance	back up for...
raw	all raw data	critical	◦ archiving ◦ scientists who ask for it
rbin	intermediate files	nice to have	anyone who gets **raw**
gbin	intermediate files	nice to have	anyone who gets **raw**
proc	◦ final processing ◦ codas database ◦ underway figure archive ◦ matlab files	final product	science CDs after cruise

(link in documentation – [raw+rbin+gbin])

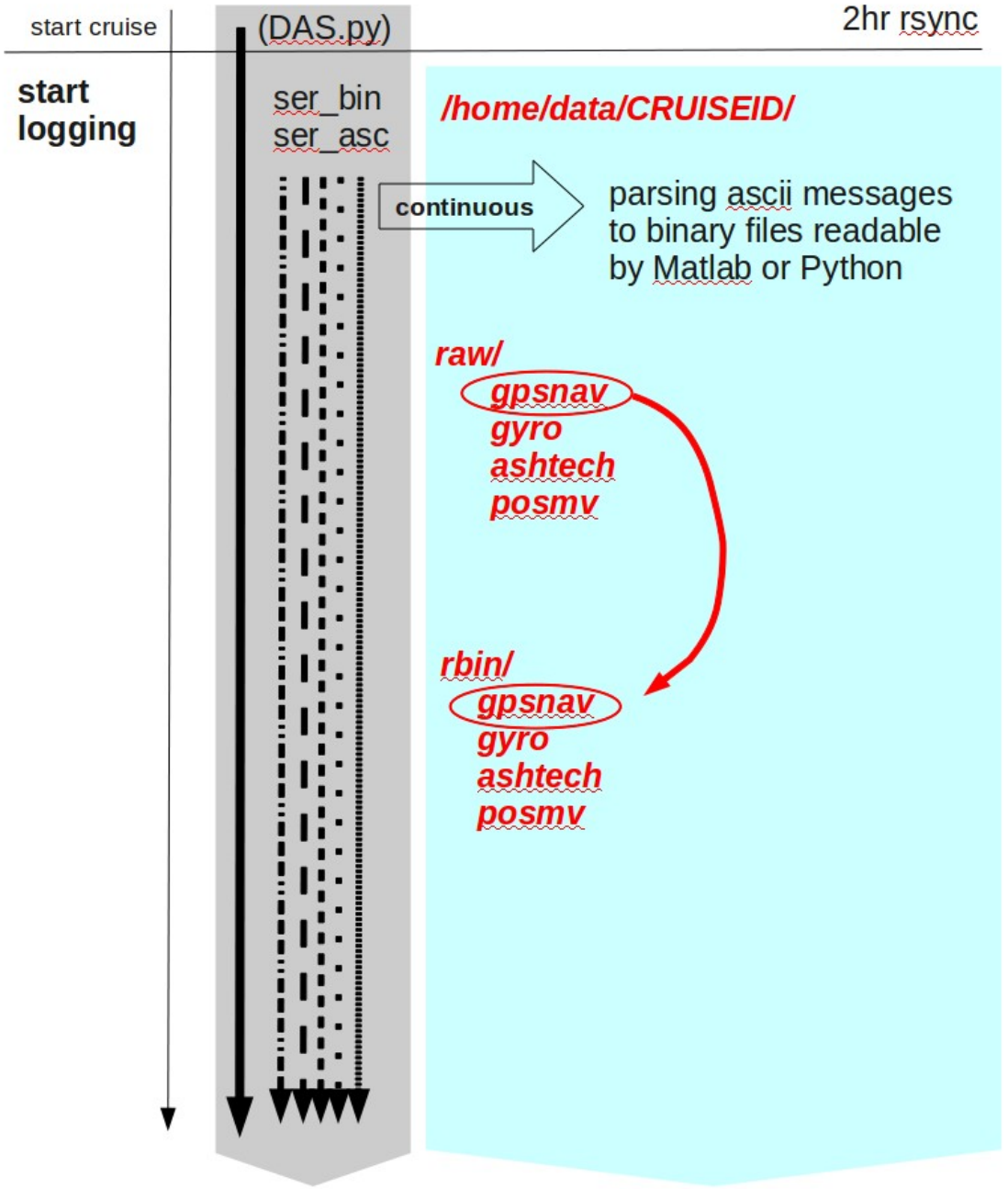
serial logging (raw files)



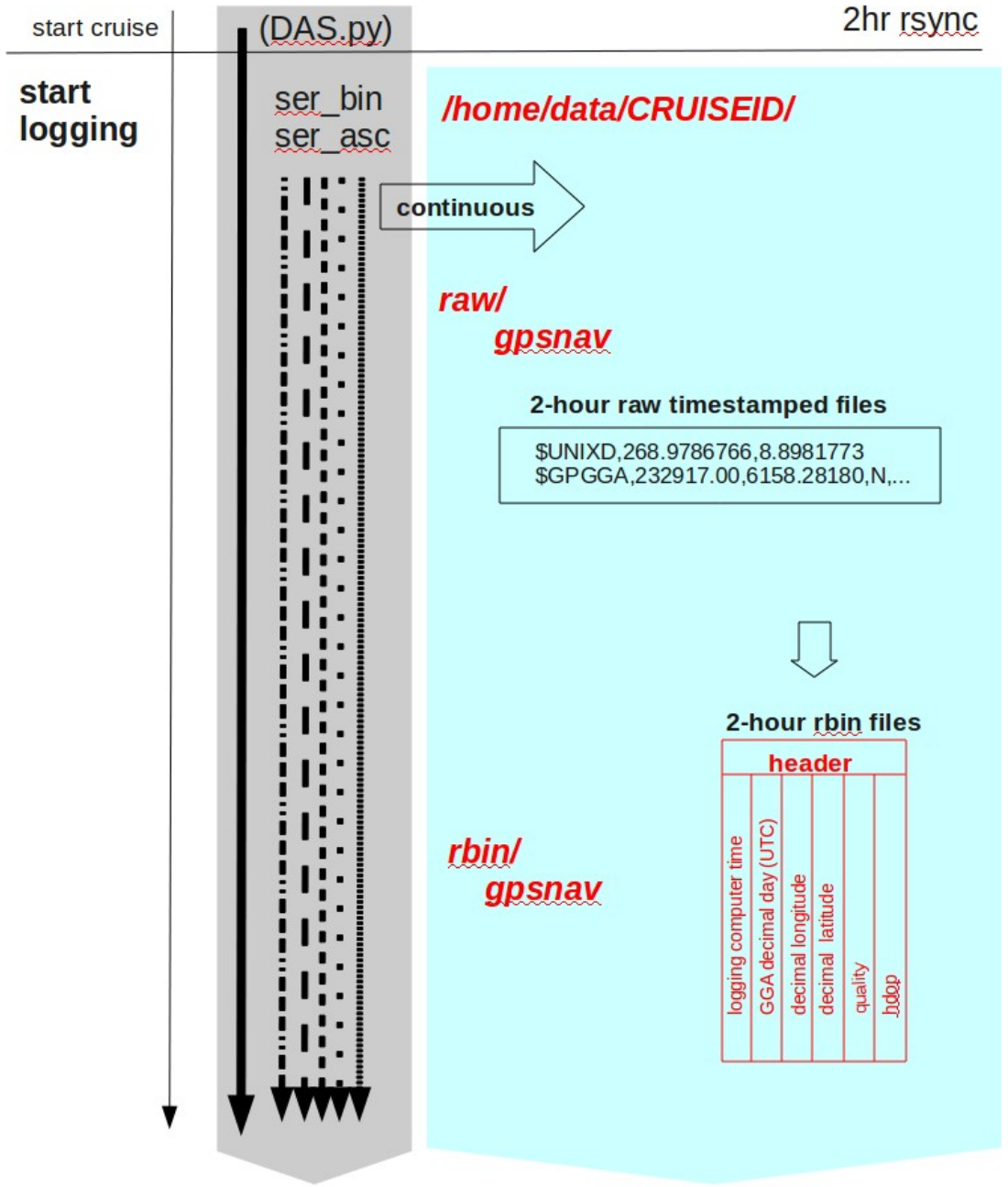
serial logging (write raw file)



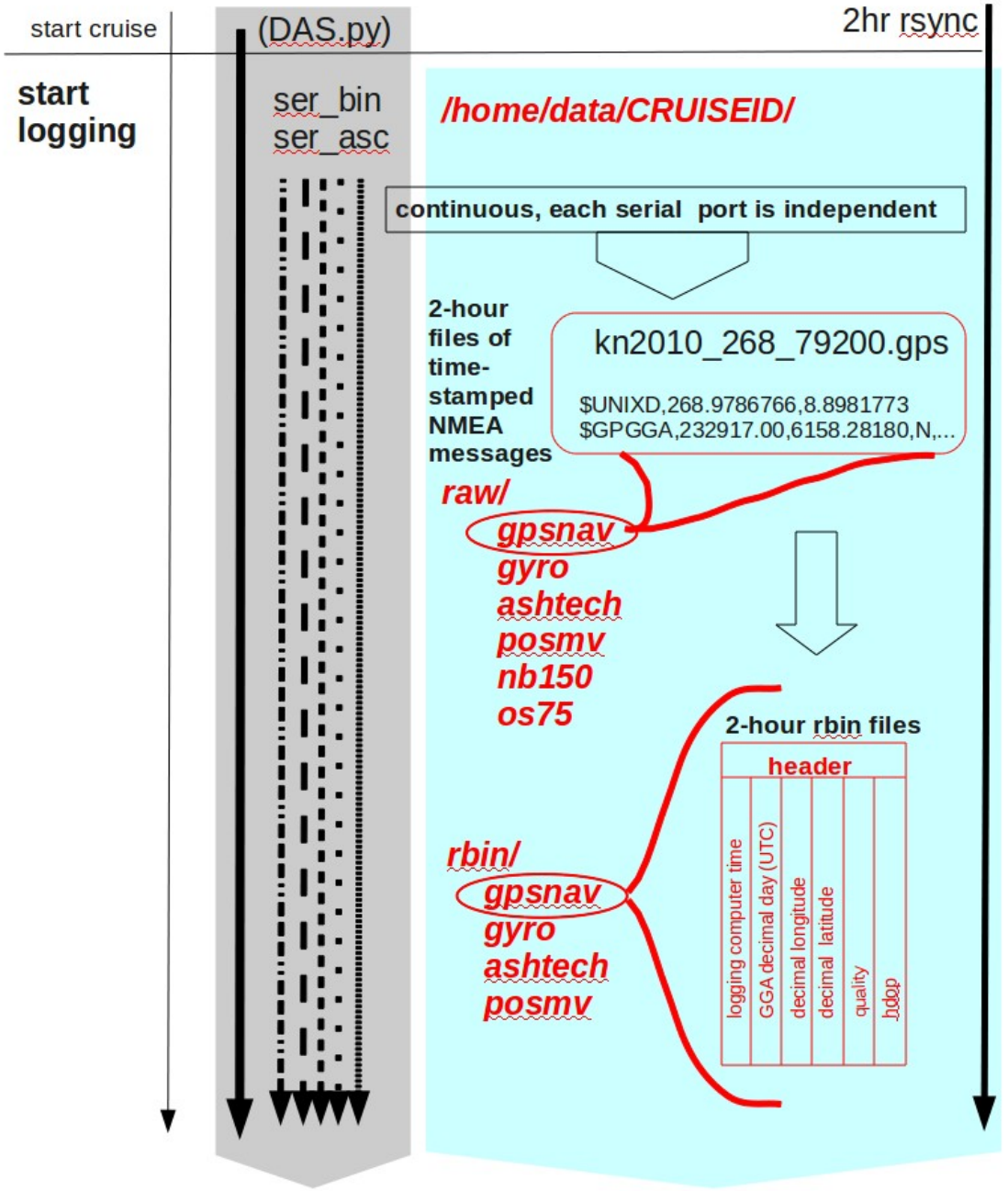
serial logging (raw ➡ rbin)



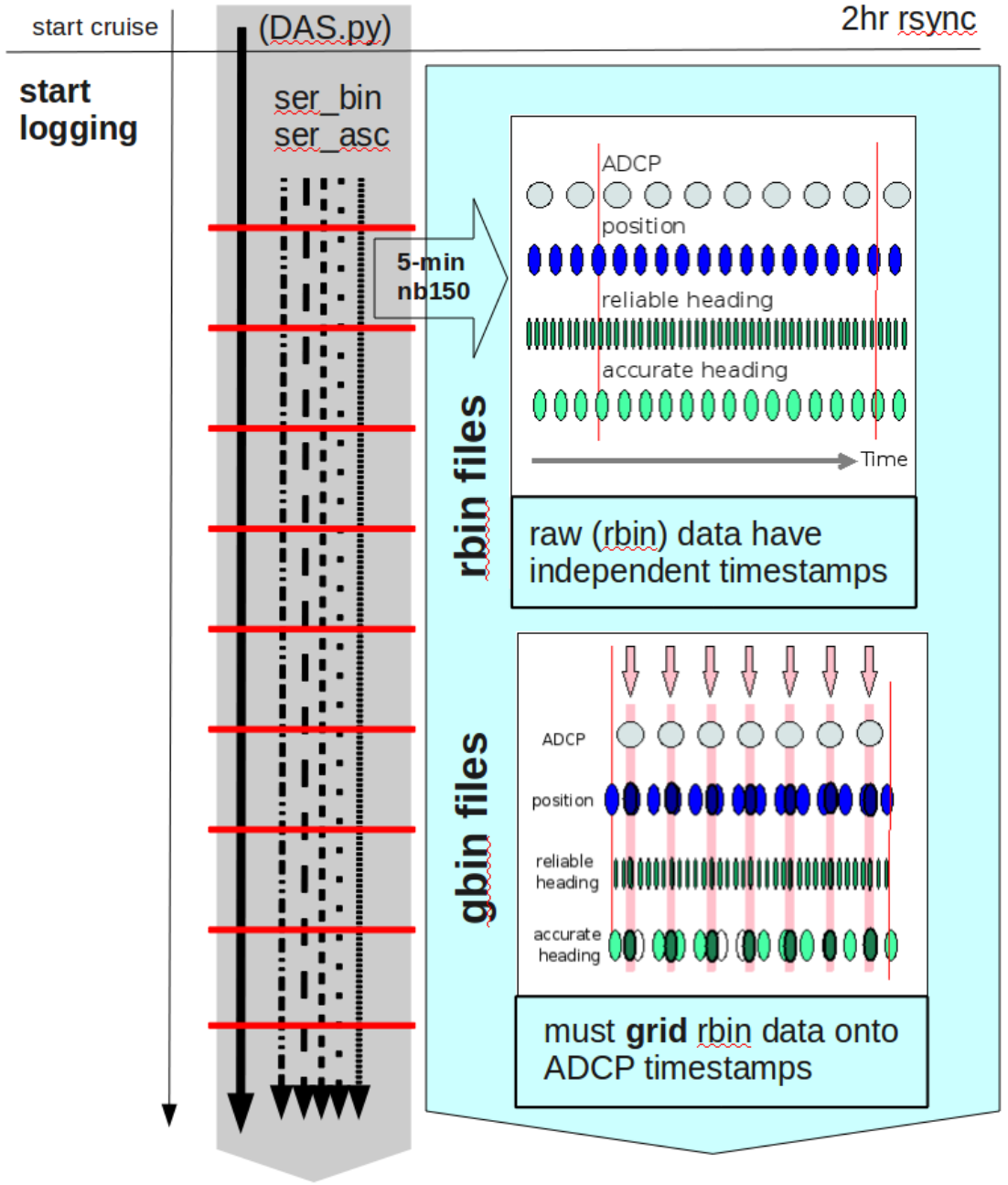
serial logging (rbin file contents)



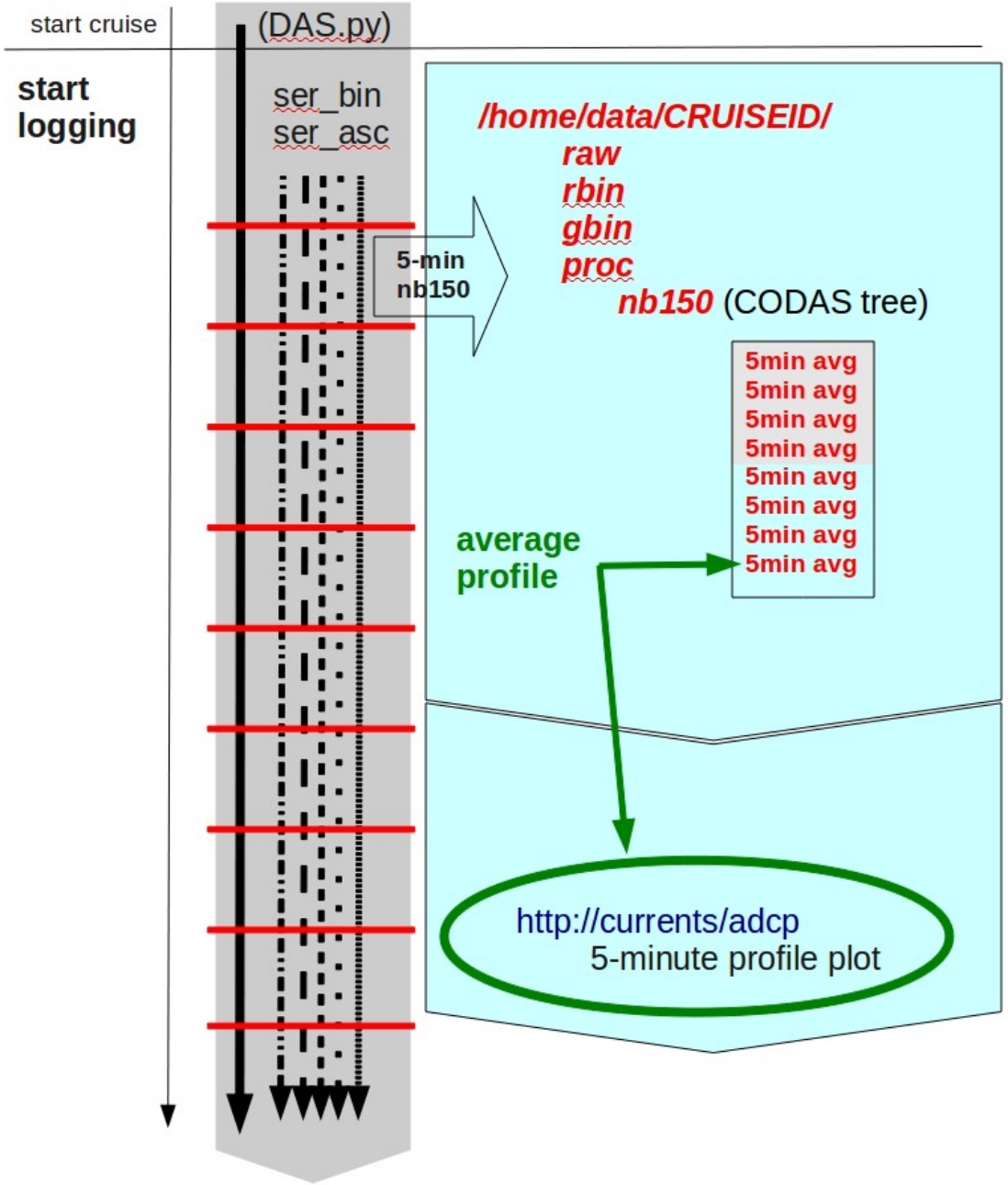
serial logging (raw, rbin)



UHDAS: 5min timer (make gbins)



UHDAS 5-minute timer: make profile



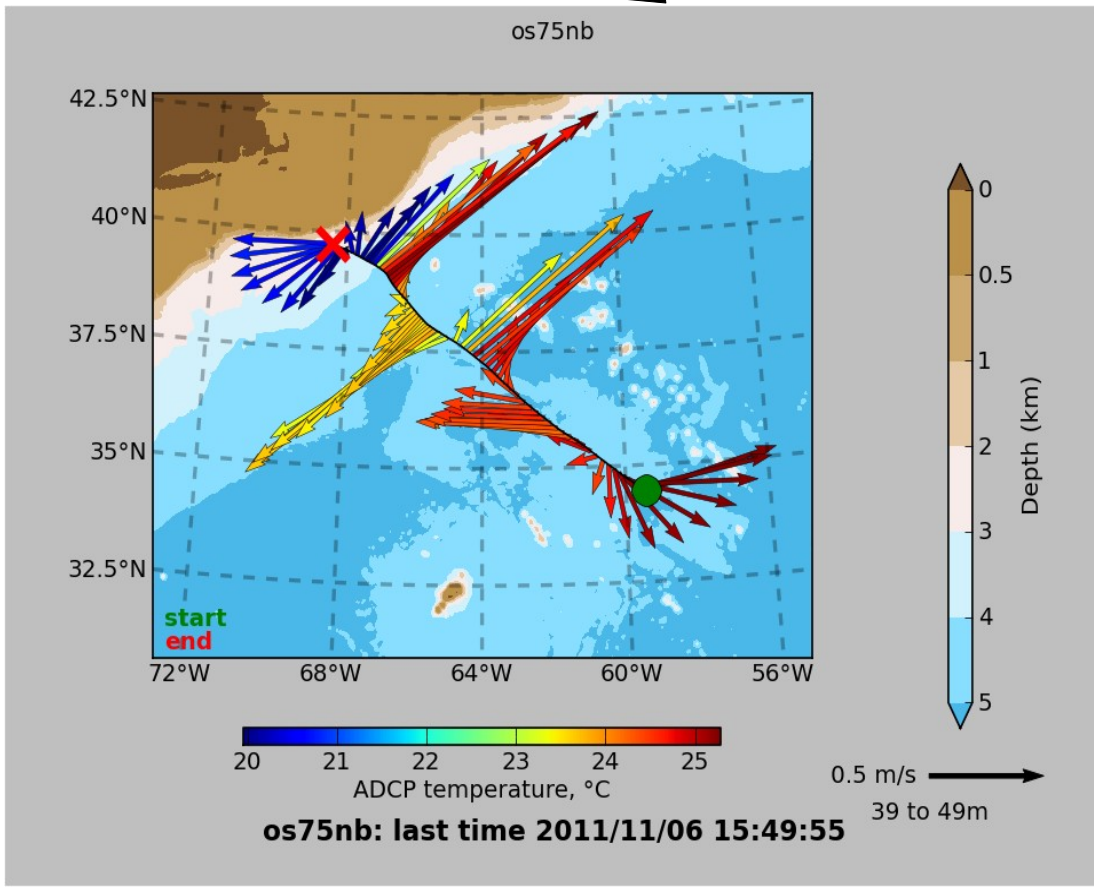
Outline

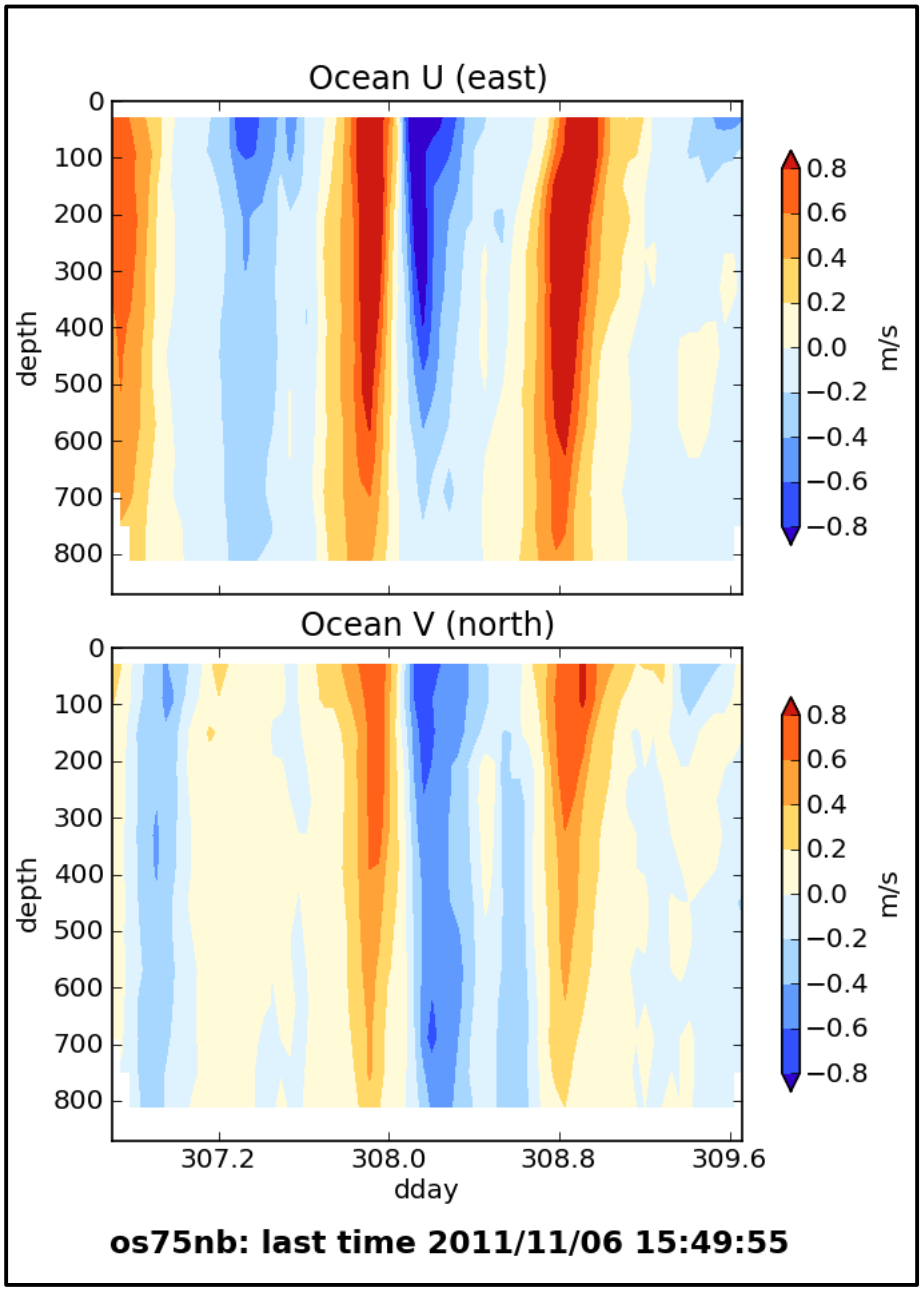
1. ADCP
2. ADCP Data Acquisition
3. CODAS Processing
4. Evaluation

CODAS Processing

Time, ADCP, Position, Attitude

primitive (raw) data





CODAS Processing Overview

CODAS: Common Ocean Data Access System

- Portable
- Self-descriptive
- aggregated files (vs/ netCDF which is one file)
- designed for ADCP data

"**CODAS Processing**" → produce ocean velocities

- tools to access and modify CODAS files

“CODAS” ADCP Processing

Goals

- run on multiple operating systems (Windows, OSX, linux)
- open source
- now free (Python)

Processing

- written for ADCP data
- works on most ADCP data acquisition systems (link)
- balance real-time product with recoverable dataset
- single-ping (automated) and manual editing
- calibration

CODAS = “**C**ommon **O**cean **D**ata **A**ccess **S**ystem”

CODAS Processing Supports...

Python CODAS support

Acquisition program	instrument	ping type	file type (suffix)	Averaged? or raw?
DAS2.48	Narrowband	nb	pingdata	avg
VmDAS	Broadband/ or Workhorse	bb	LTA, STA	avg
			ENR	raw
	Ocean Surveyor	nb	LTA, STA	avg
			ENR(N1R,N2R)	raw
		bb	LTA, STA	avg
			ENR(N1R,N2R)	raw
		nb bb	ENR(N1R,N2R)	raw
UHDAS	NB150,NB300	nb	raw	raw
	Ocean Surveyor	nb	raw	raw
		bb	raw	raw
		nb bb	raw	raw
	WH300	bb	raw	raw

CODAS Processing Steps

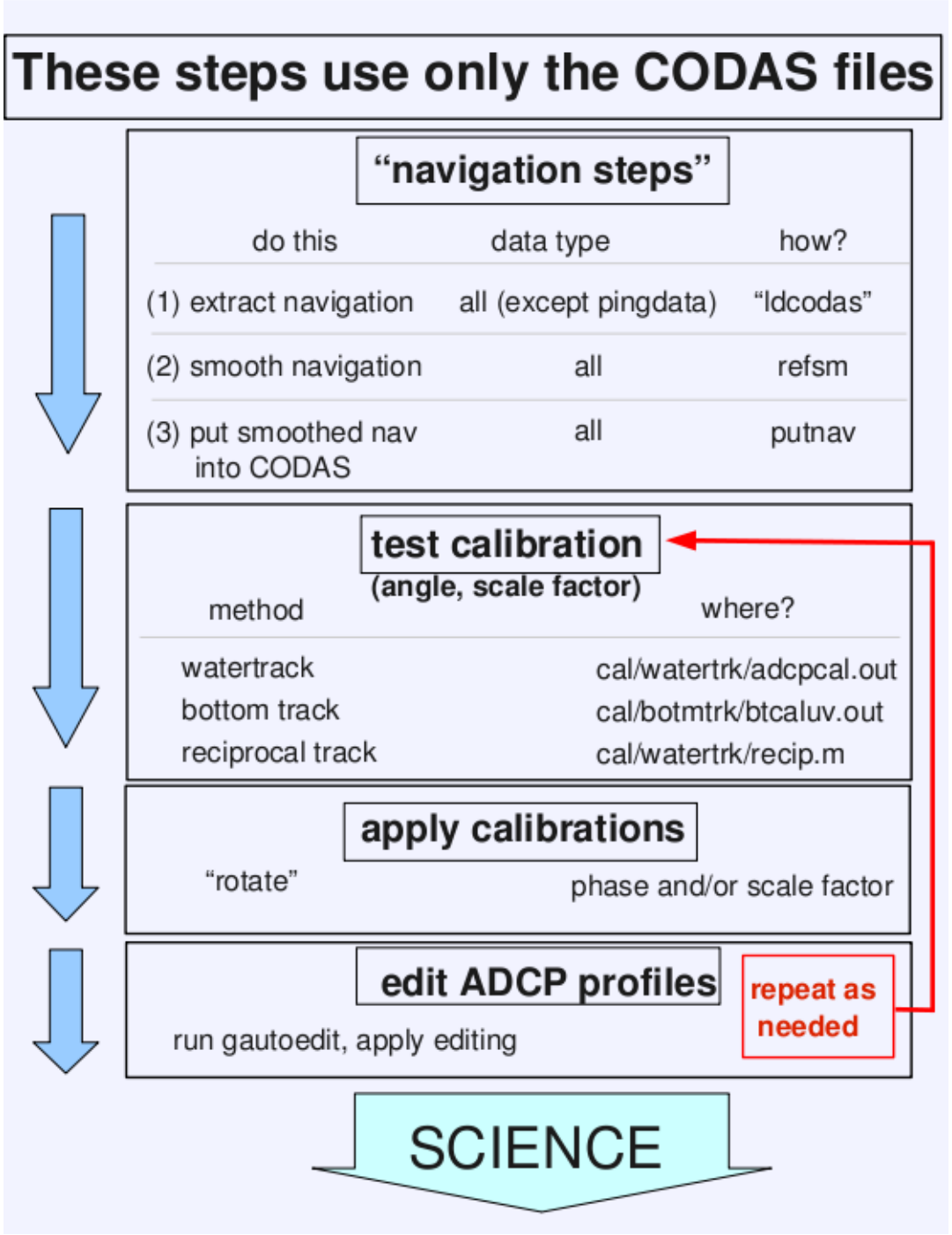
- read ADCP + ancillary data
- [transform, edit single-pings, average]
- load into CODAS database

- nudge positions to get smooth reference layer
- apply heading corrections (calculated from difference between gyro and accurate heading)
- determine calibration values (angle, scale factor), - apply angle and scale factor
- edit out bad profiles of averaged data

Acquire the data, write to disk → **Fill the CODAS database**

acquisition	data stored to disk		load the database	
program name	averaged	singleping	translate to *.bin + *.cmd	executable (to load)
DAS2.48	pingdata.*		(no)	loadping
VmDAS	*.STA *.LTA		load_lta.m	ldcodas
VmDAS		*.ENR *.ENS *.ENX	load_ens.m	ldcodas
UHDAS		*.raw	load_uhblk	ldcodas
HDSS		50K*, 140K*	load_hrdata.m	ldcodas

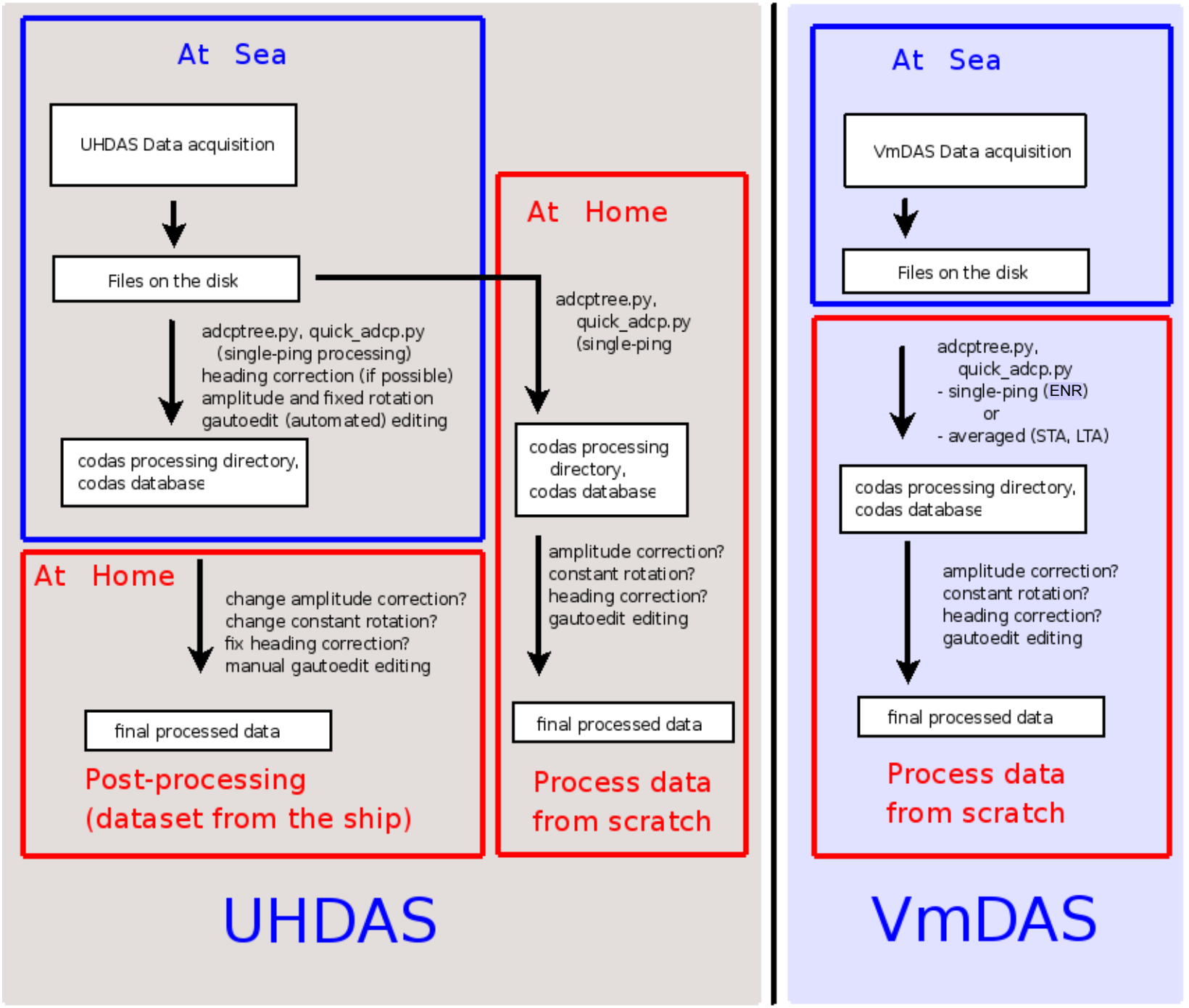
53: CODAS processing



54: CODAS processing

At Sea

At Home



CODAS Processing

- Editing (single-ping)
  - Acoustic interference
  - Bubbles
  - Below bottom
- Editing CODAS database averages "gee-autoedit"
- Interpolate missing heading correction
- Apply calibrations
  - Scale factor
  - Rotation
  - Transducer offset (new/experimental)

CODAS Processing

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

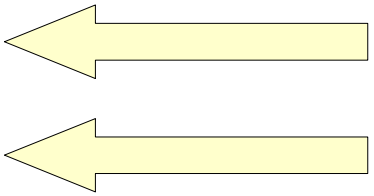
BEFORE AVERAGING

- Editing CODAS database averages "gee-autoedit"
- Interpolate missing heading correction
- Apply calibrations
  - Scale factor
  - Rotation
  - Transducer offset (uncommon/experimental)

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

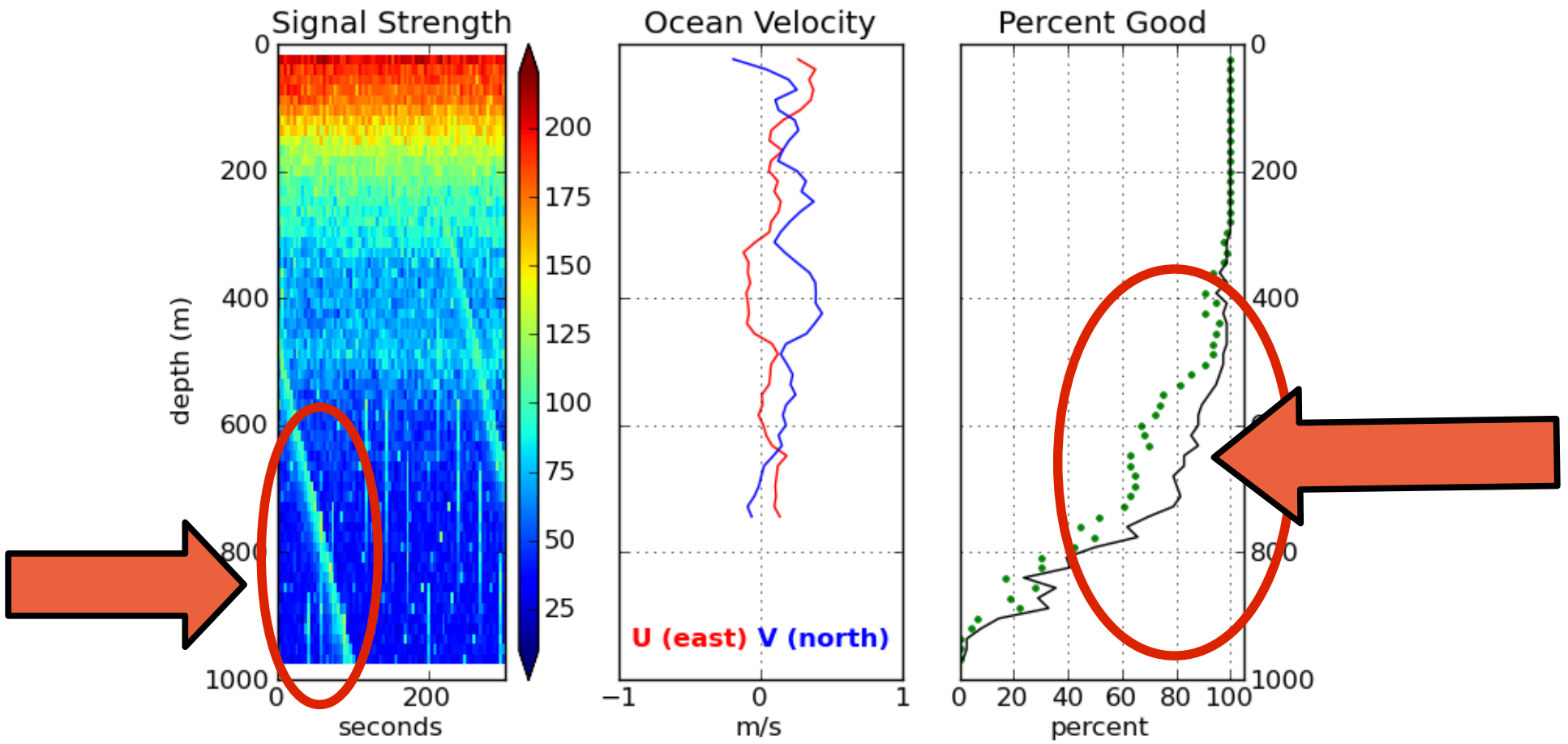
ADCP Single-ping Editing

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

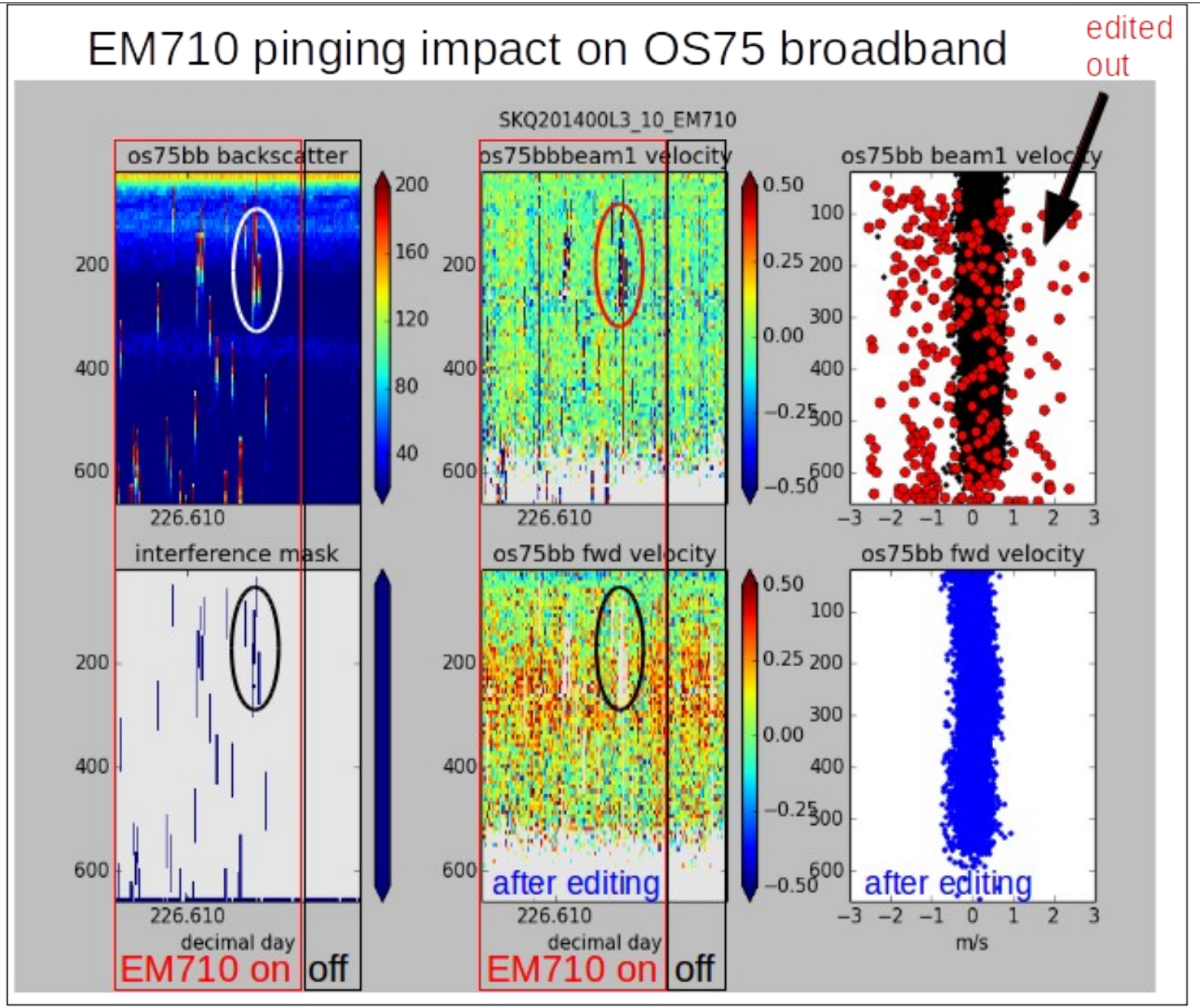
- Acoustic Interference
- Bubbles
- Below bottom

ADCP Processing

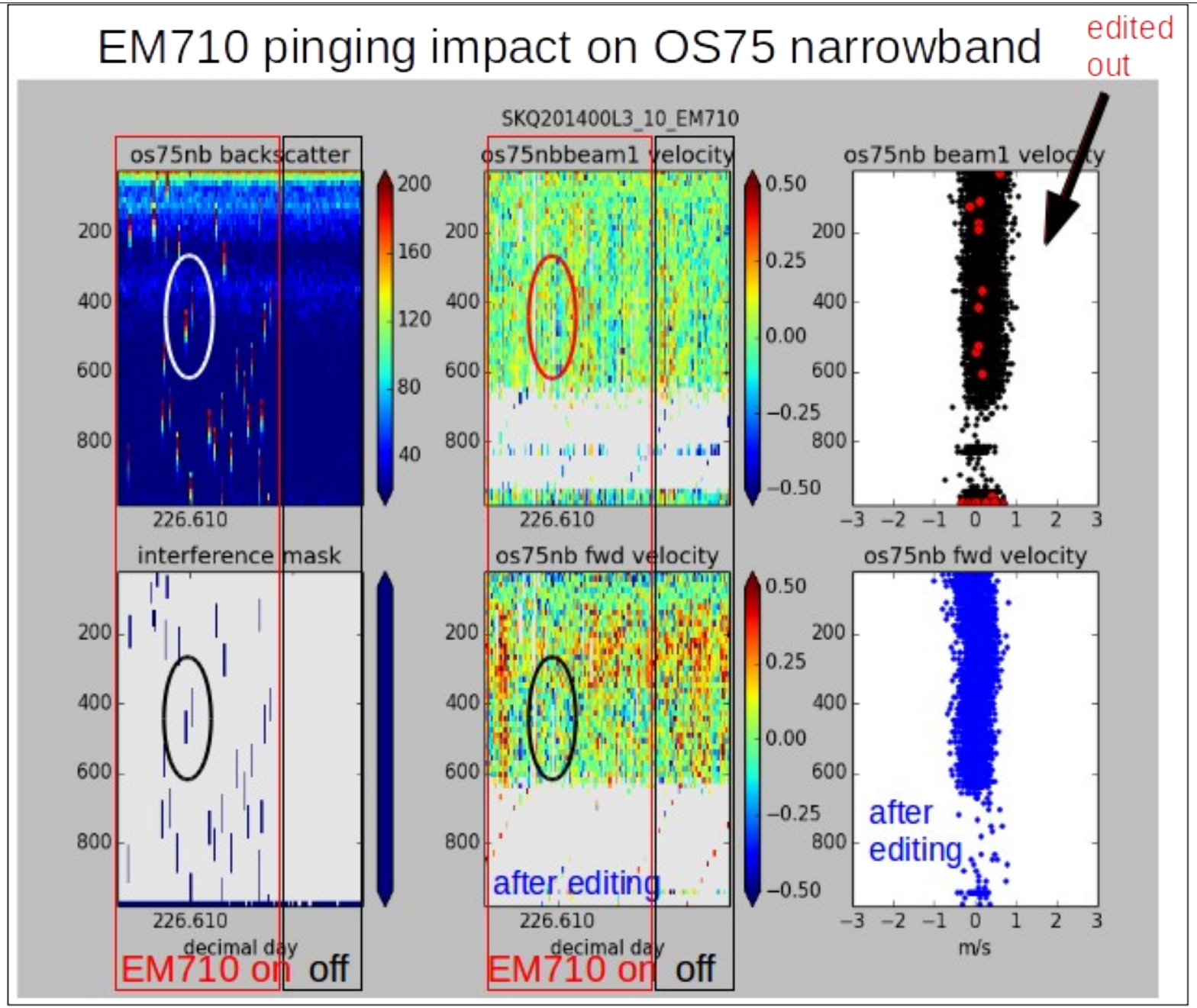
Singleping editing: acoustic interference



ADCP Processing: editing out interference



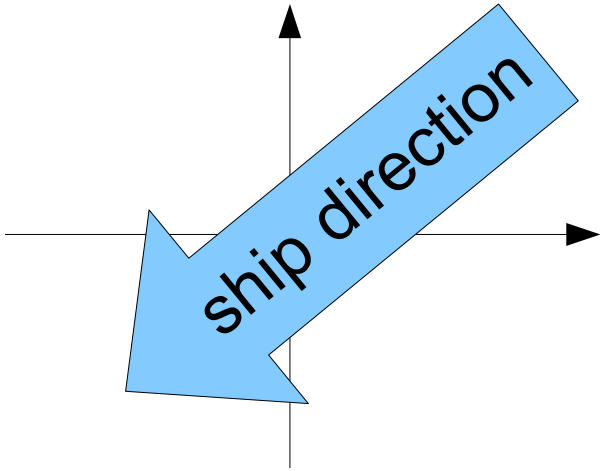
ADCP Processing: editing out interference

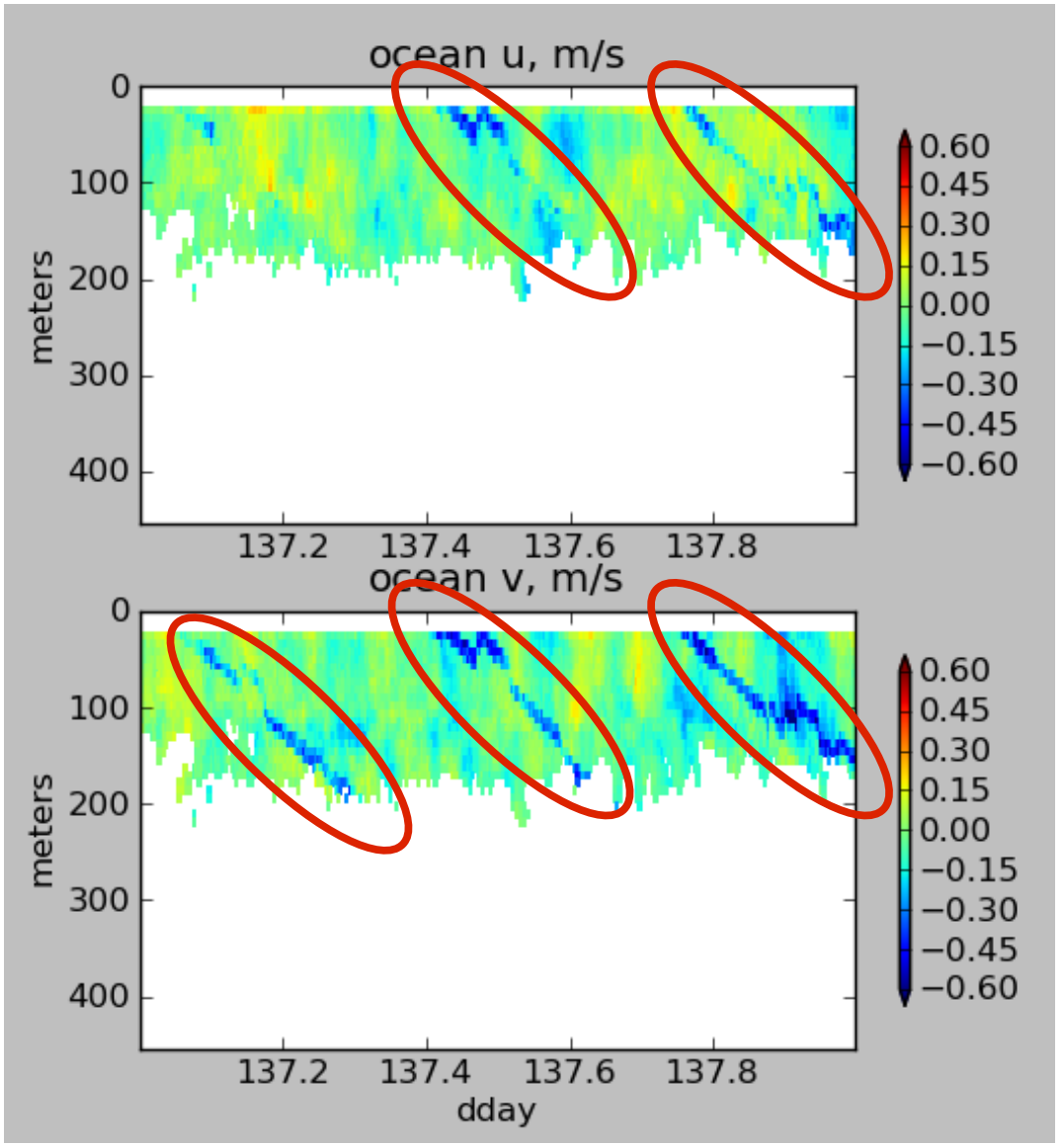


ADCP Processing **without** singleping editing

Averaged
ocean velocities

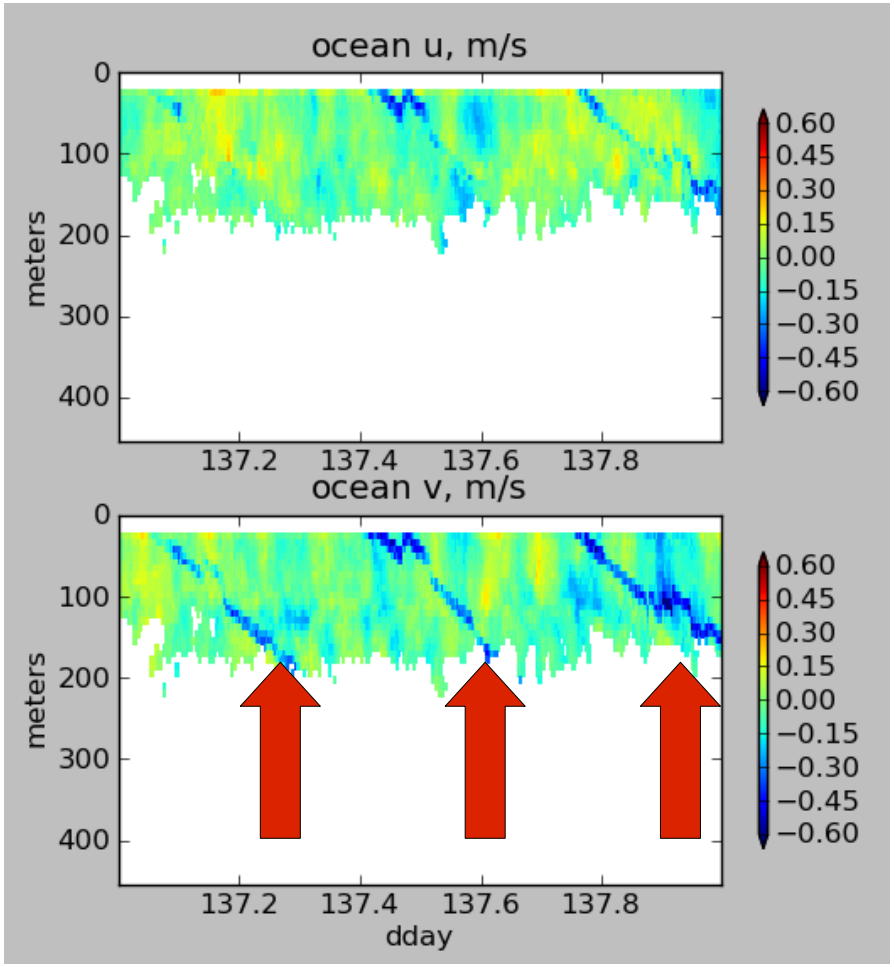
NOTE: along-track
direction bias



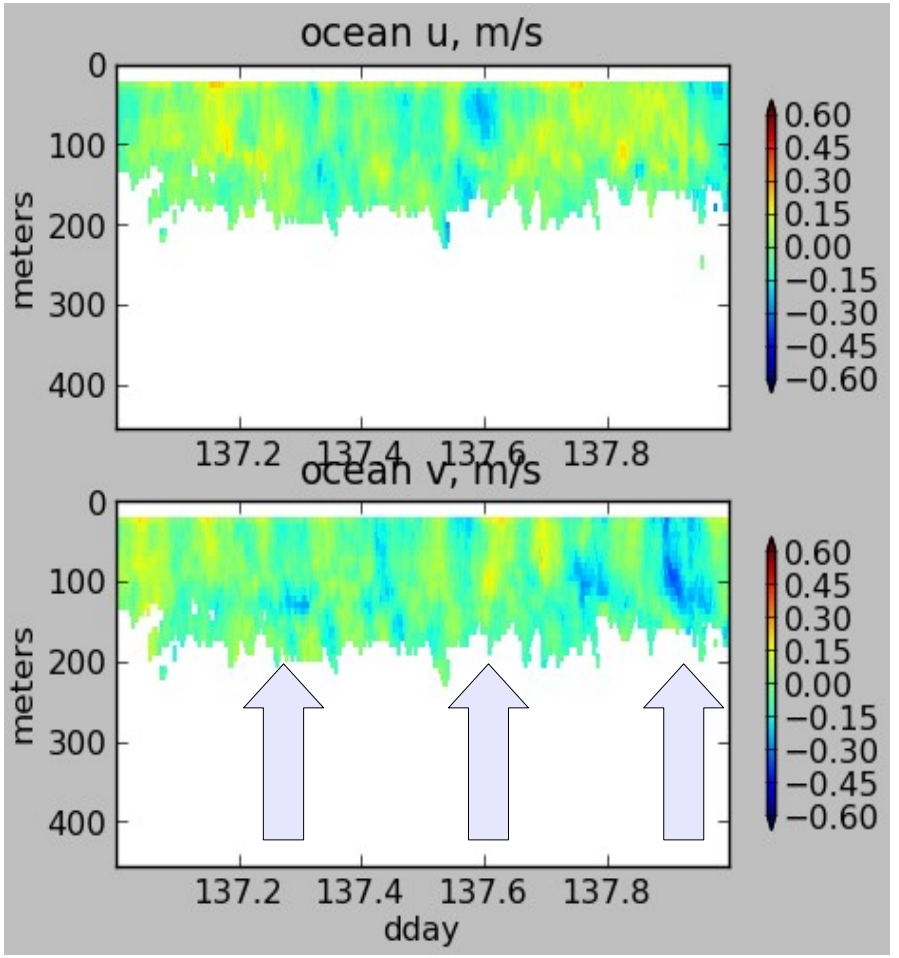


ADCP Processing: acoustic interference

WITHOUT
singleping editing



USING
singleping editing

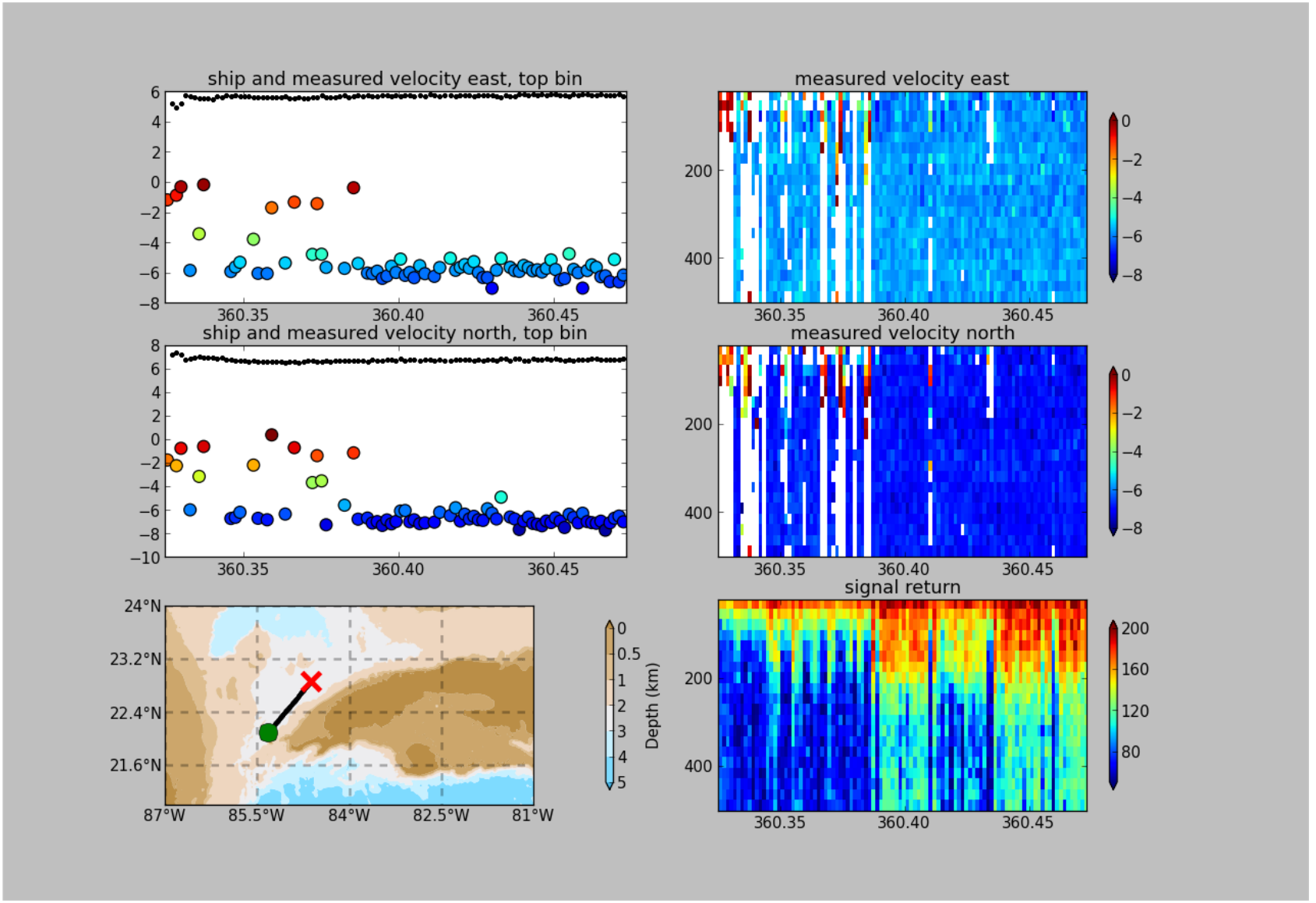


ADCP Single-ping Editing

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

- Acoustic Interference
- Bubbles
- Below bottom

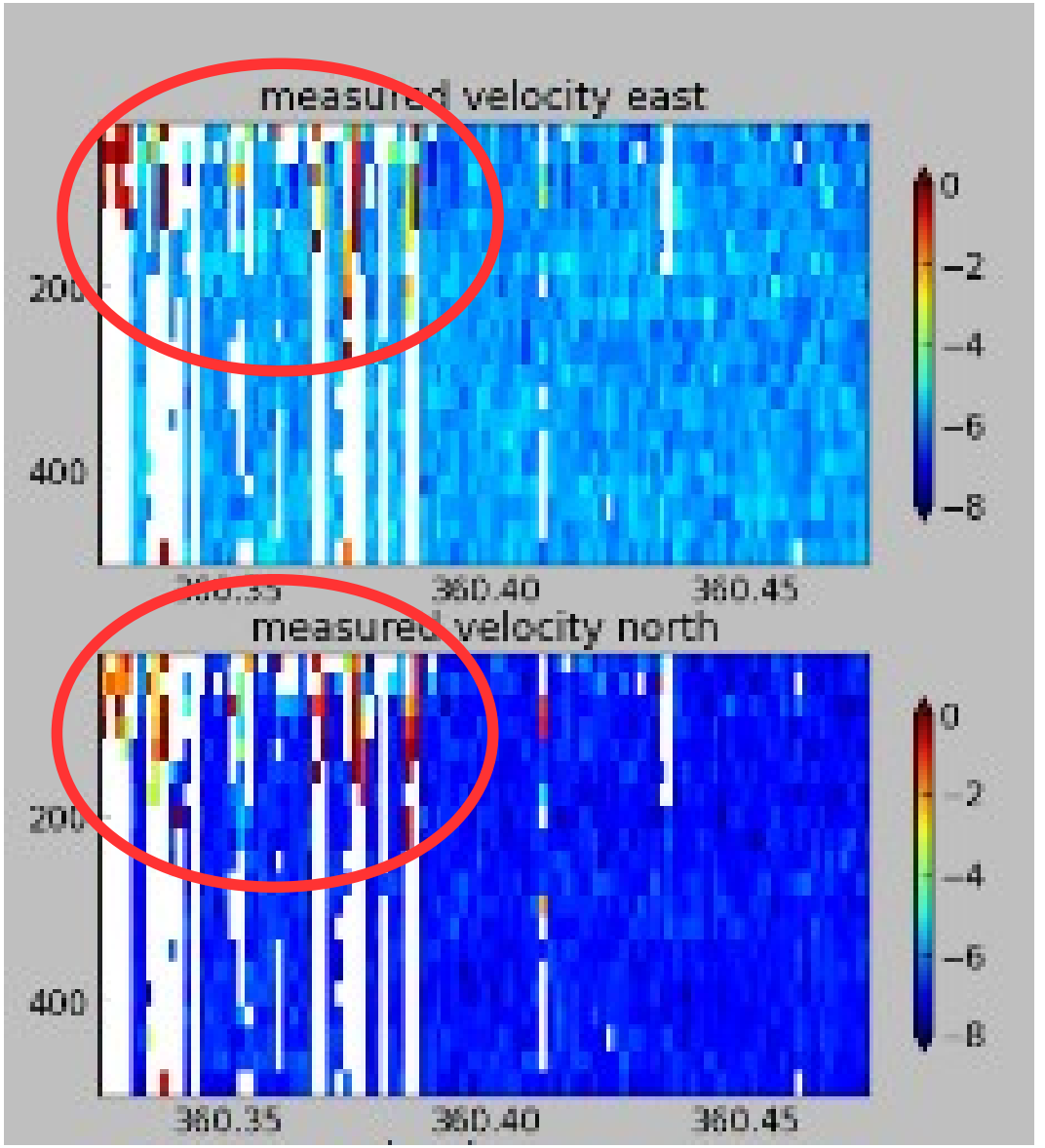
single-ping editing:underway bias



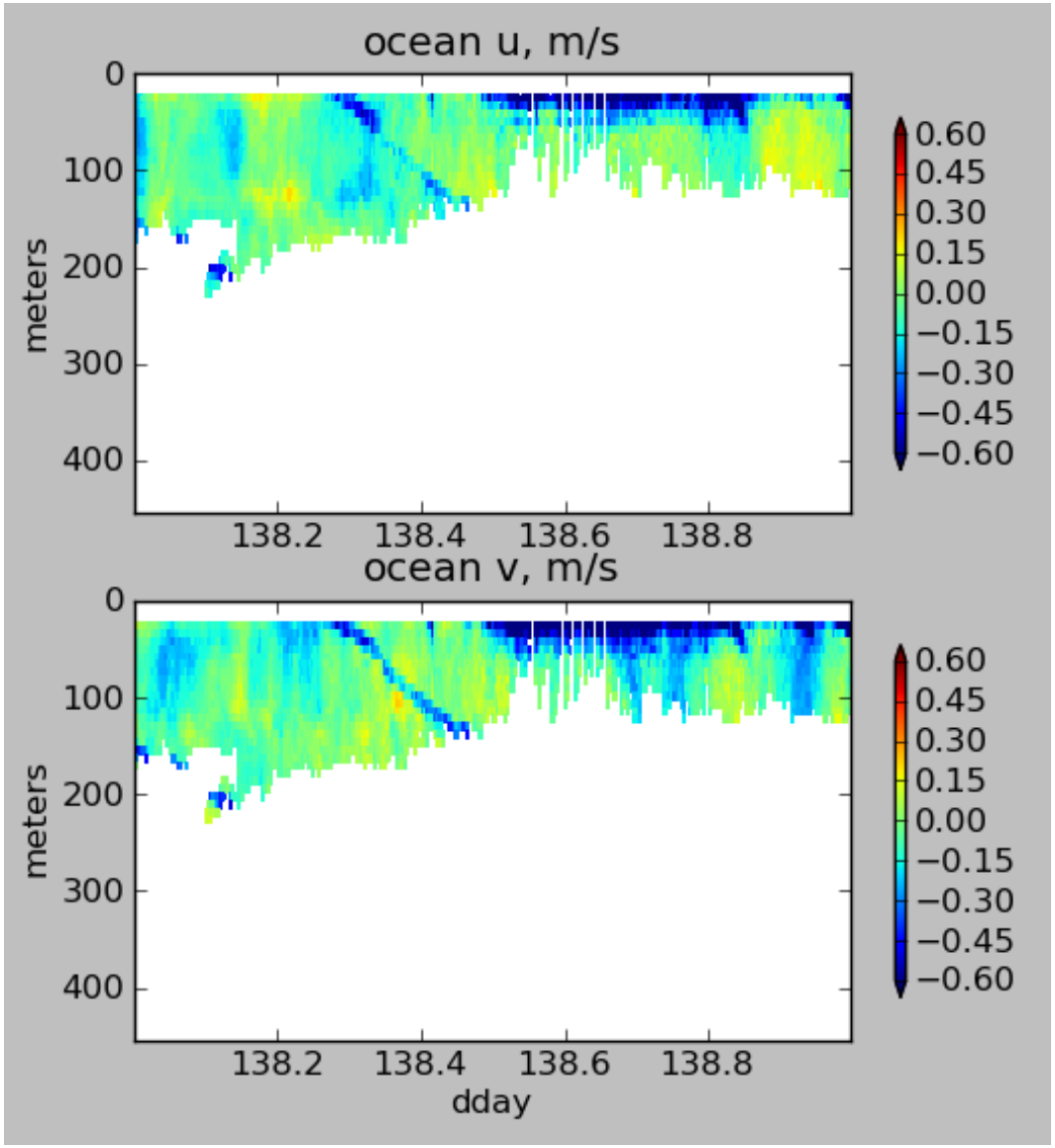
ADCP Data: effect of bubbles

Bubbles:
- short profiles
- strongly biased towards zero

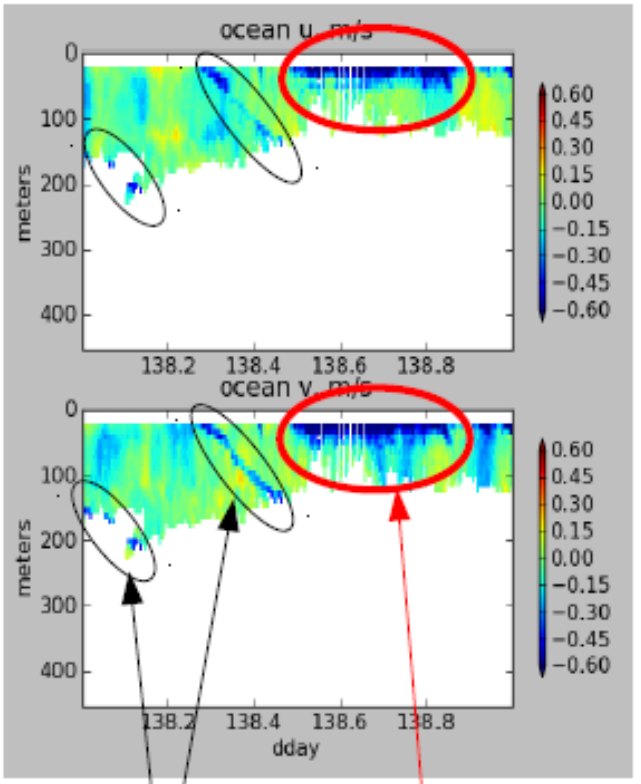
Untreated:
- biased ocean velocities

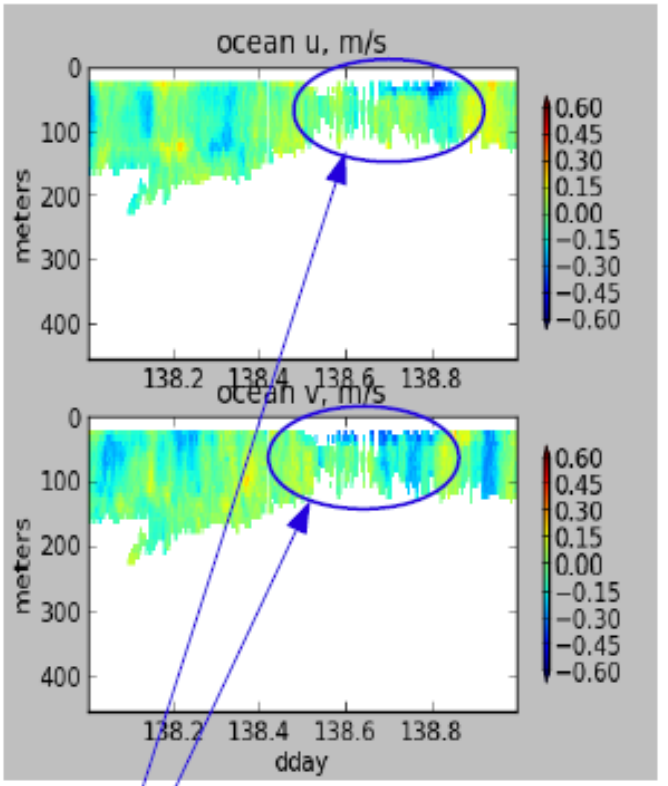


Averaged (unedited) data:
Acoustic interference and underway bias (bubbles)



OS150 underway bias due to poor weather conditions





acoustic Interference from OS75 on OS150

Biased pings mostly edited out, but manual post-processing is required

Biased pings, due to bad weather
- bias towards zero in measured velocities
- bias in direction of motion in ocean velocities
- shorter profiles (degraded quality)

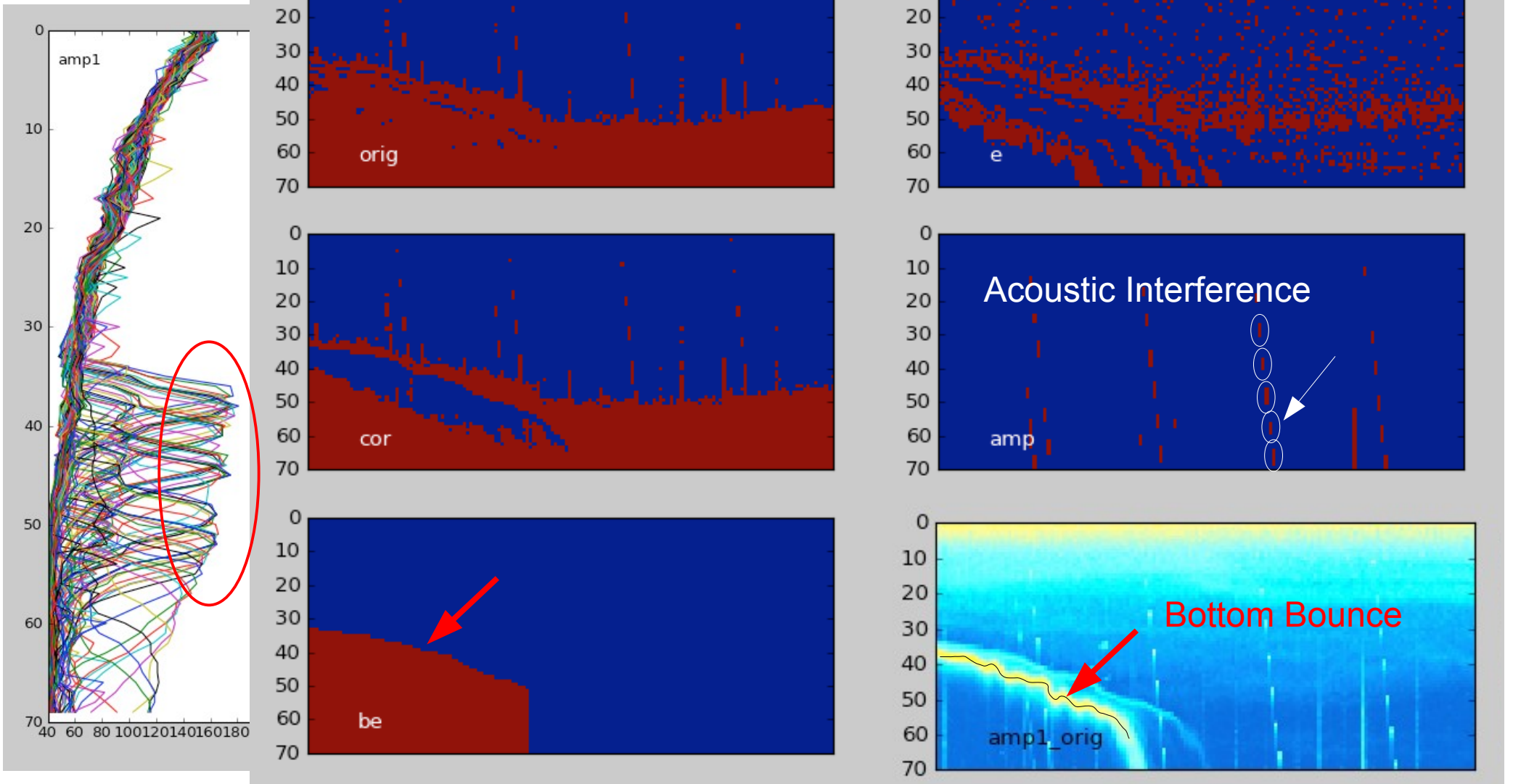
ADCP Single-ping Editing

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

- Acoustic Interference
- Bubbles
- Below bottom

Bottom Editing:

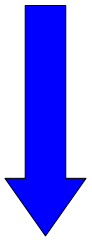
- remove acoustic interference, identify maximum amplitude
- calculate region of side-lobe interference
- flag as BAD all data below the bottom or with side-lobe interference



CODAS Postprocessing

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

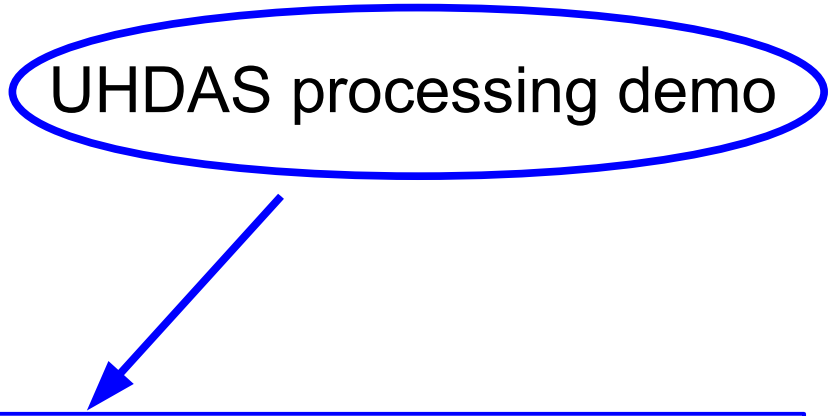
AFTER AVERAGING



- Interpolate missing heading correction
- Apply calibrations
  - Rotation
  - Scale factor
  - Transducer offset (new)
- Manually edit CODAS database averages “gee-autoedit”

CODAS Postprocessing

- Editing (single-ping)
  - Acoustic interference
  - Bubbles
  - Below bottom
- Interpolate missing heading correction
- Apply calibrations
  - Rotation
  - Scale factor
  - Transducer offset (new)
- Manually edit CODAS database averages "gee-autoedit"



CODAS Postprocessing

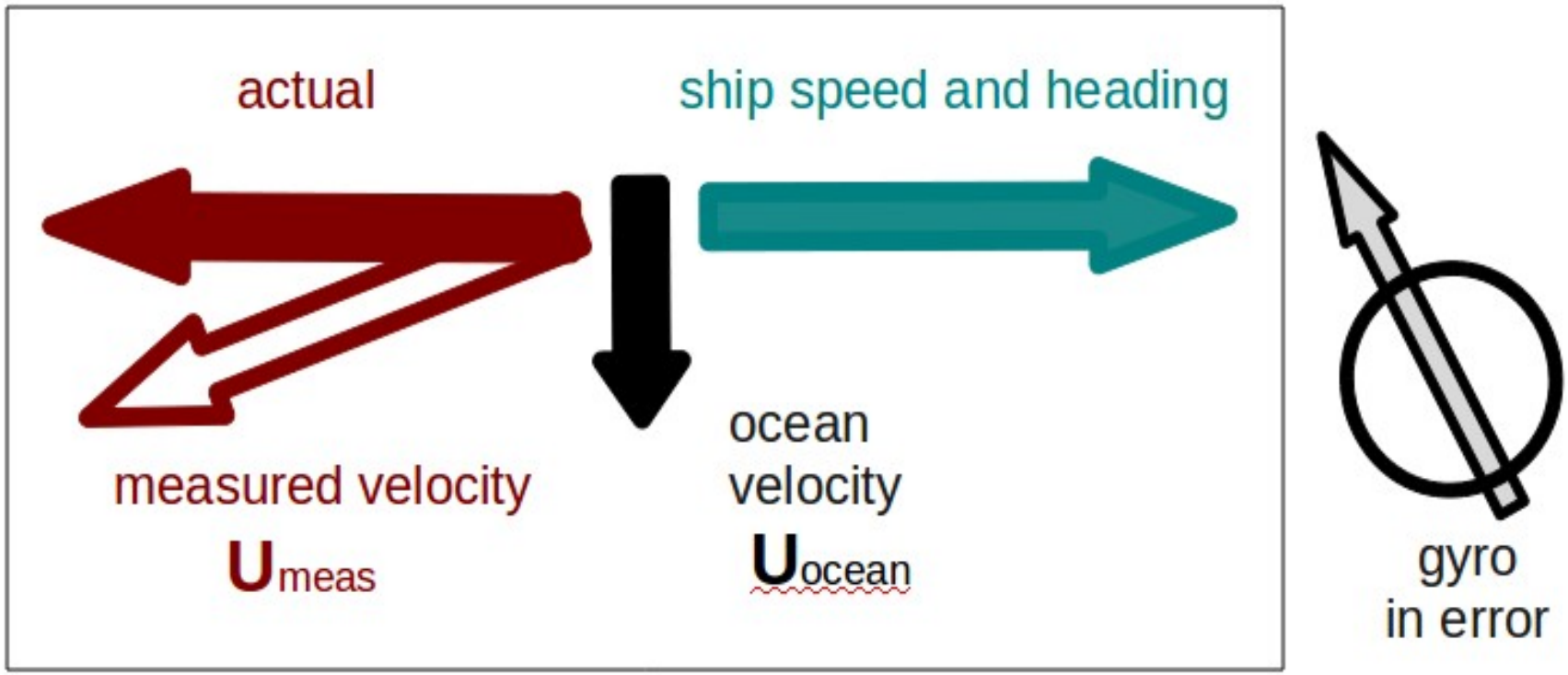
- Editing (single-ping)
  - Acoustic interference
  - Bubbles
  - Below bottom
- Interpolate missing heading correction
- Apply calibrations
  - Rotation
  - Scale factor
  - Transducer offset (new)
- Manually edit CODAS database averages “gee-autoedit”

CODAS Processing: Calibration

- Calibration of averaged data:
  - Cross-track error (angle error)
    - Incorrect transducer angle (constant)
    - Inaccurate heading (time-varying)
  - Alongtrack bias (scale factor)
    - Soundspeed (single-ceramic transducers only)
  - Transition Error
    - 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
  - If VmDAS,
    - “Primary” heading, often no QC message
    - If “Primary” fails, replace with “Secondary”
  - 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 (hopefully with QC fields)

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

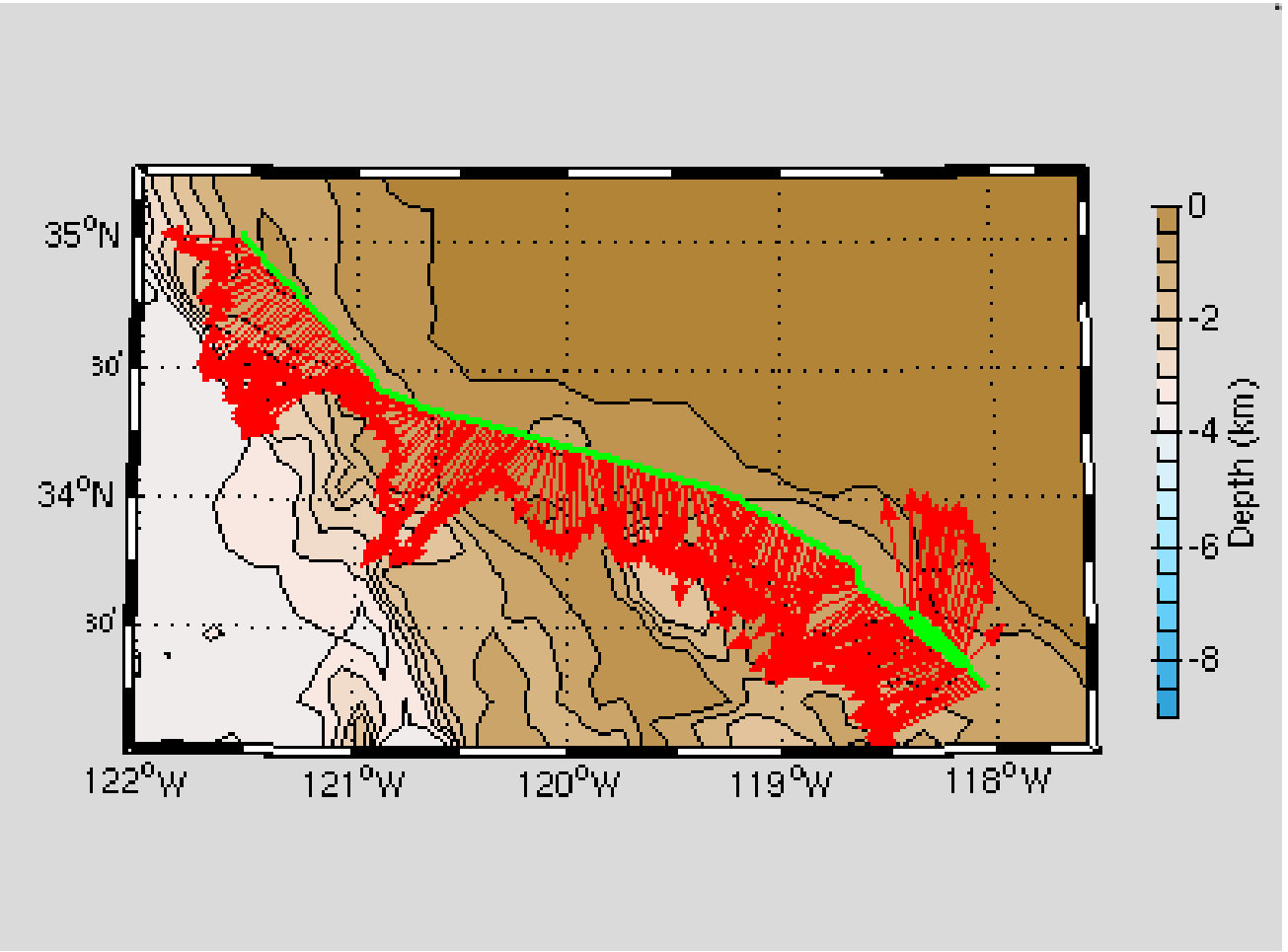
Angle applied comes from

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

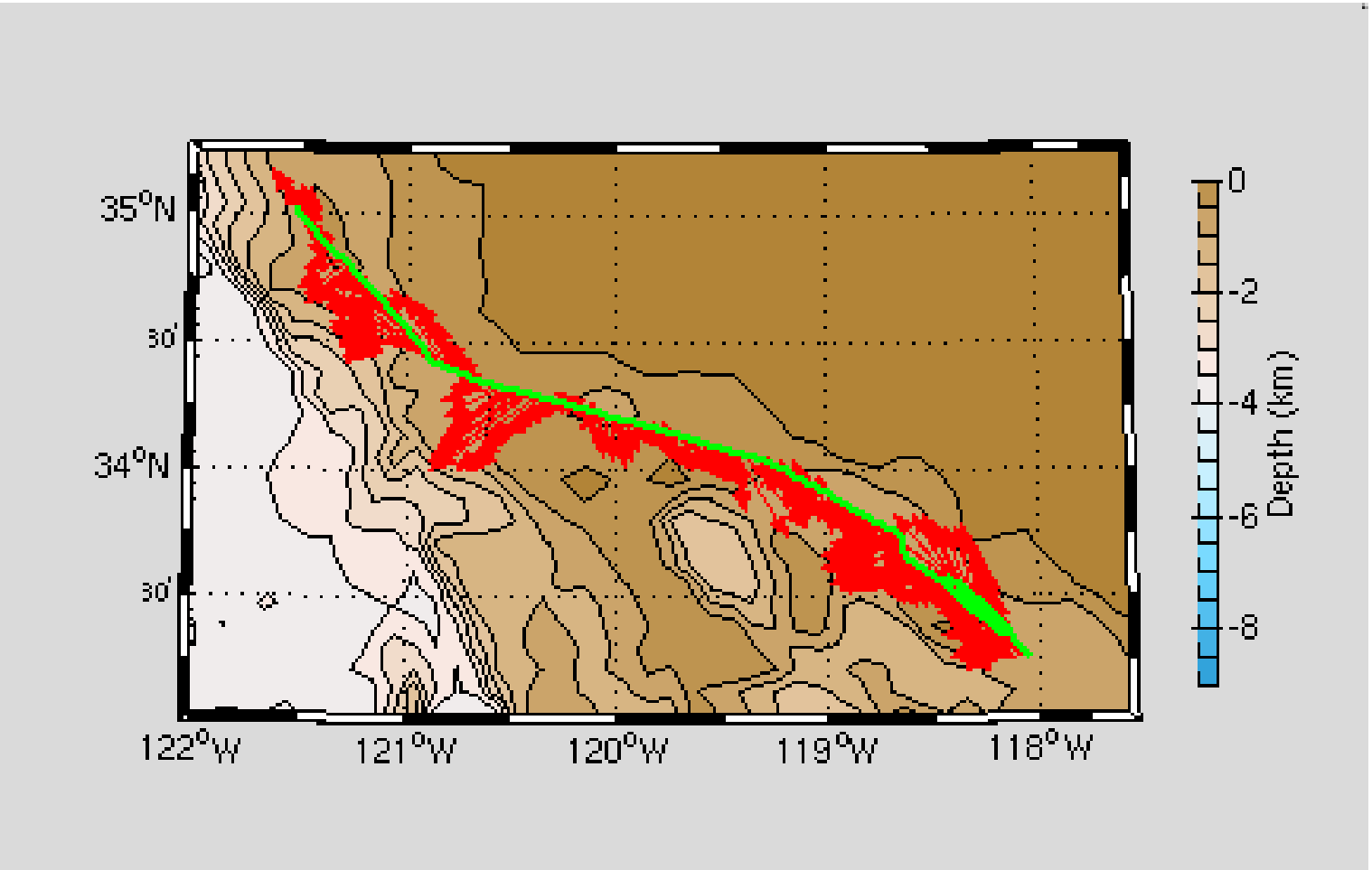
This is a **constant value** for the whole cruise

Examples of error in transducer angle follow...

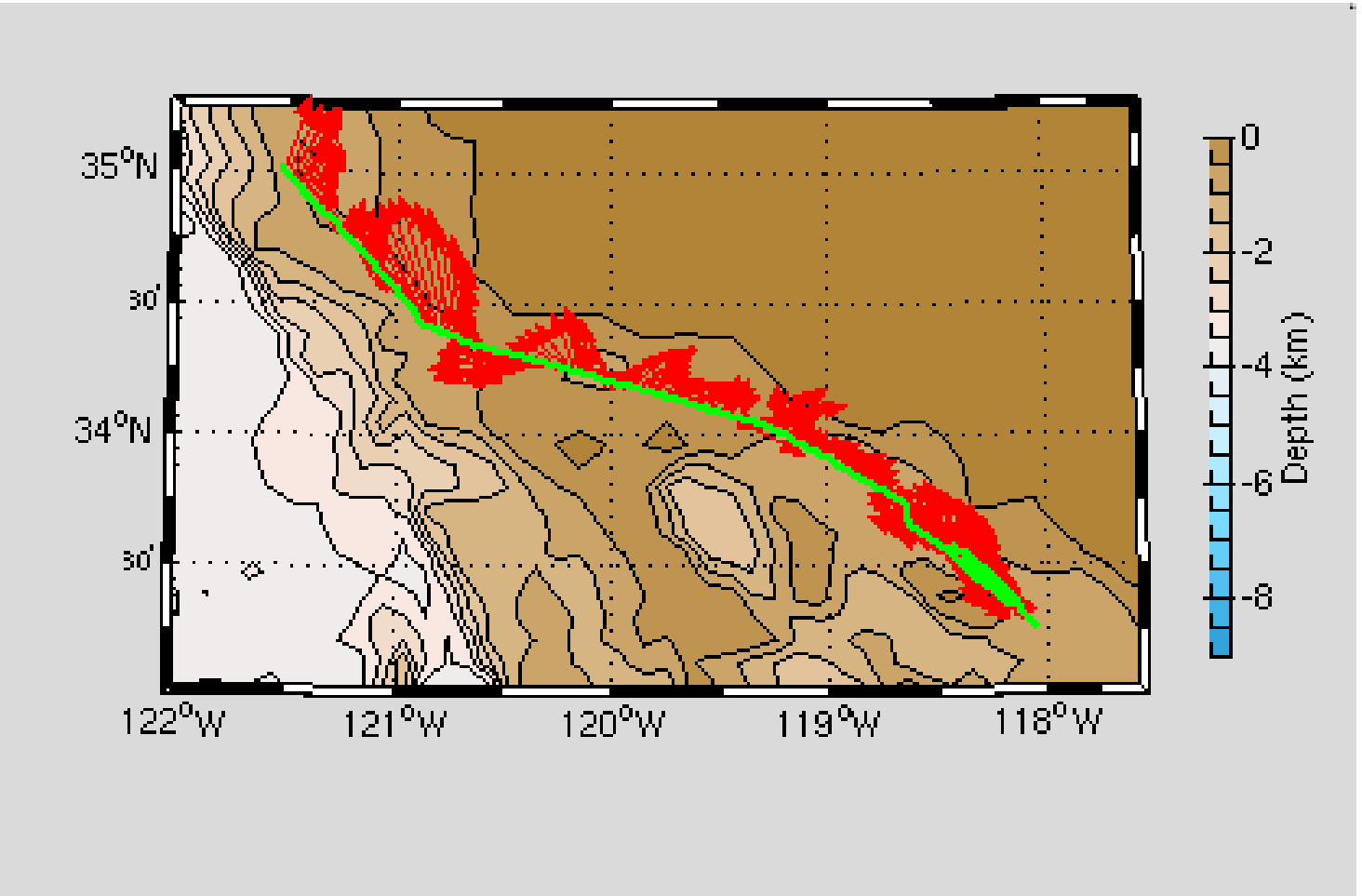
Calibration: angle error -3.6deg



Calibration: angle error -1.6



Calibration: angle error 0.4



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

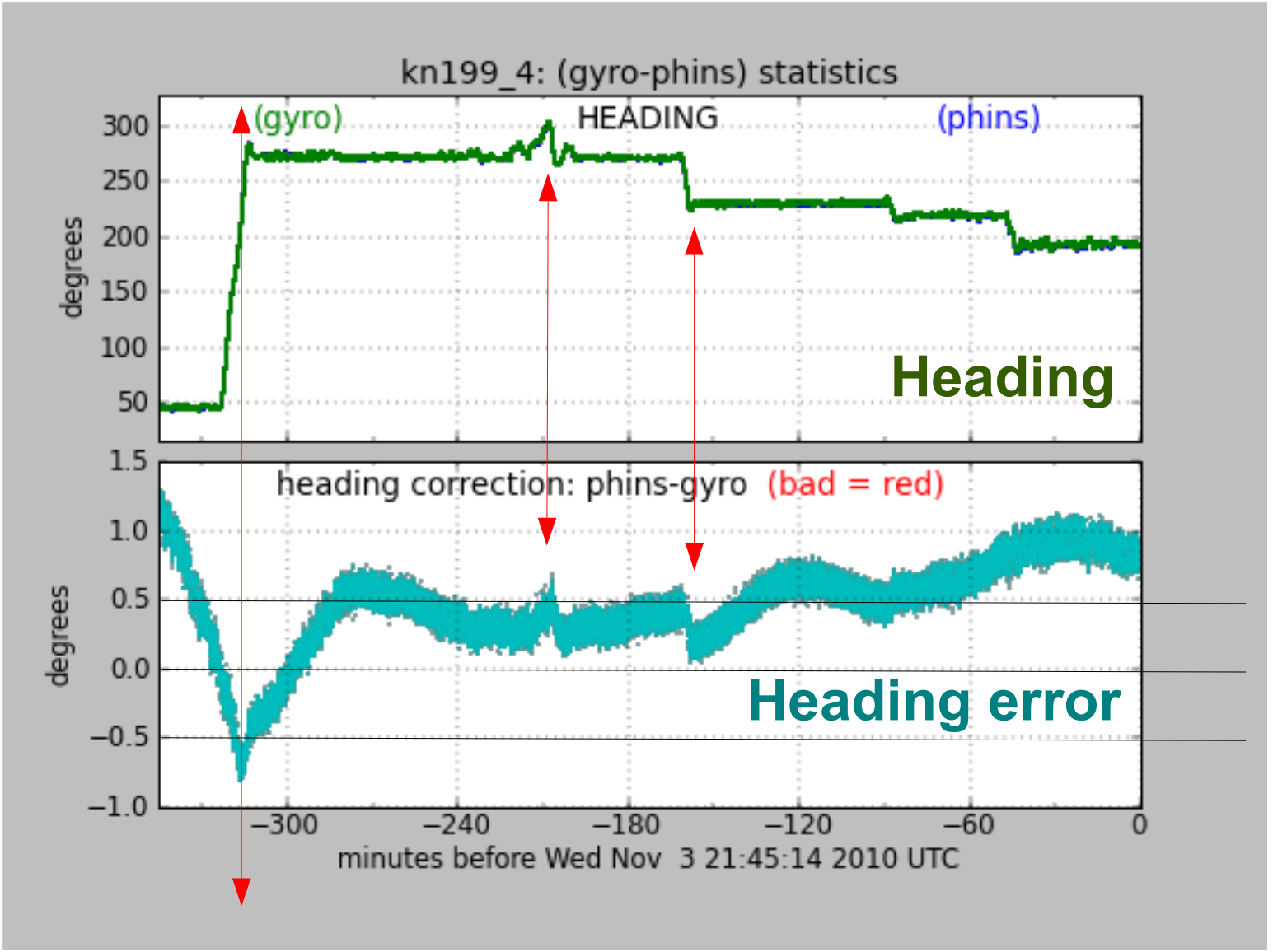
Angle applied comes from

Heading, which may be in error by

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

Example follows ...

Phins-Gyro difference varies with time

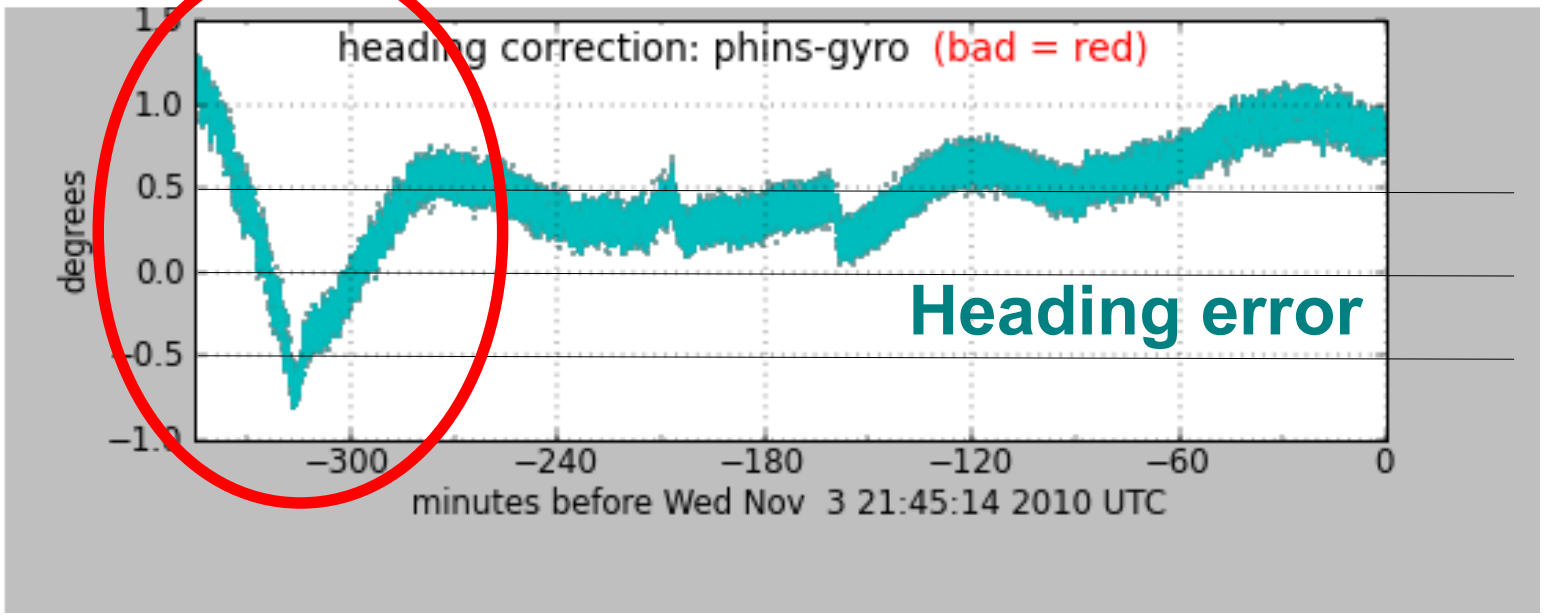


Changes in ship's heading affect heading error

Effect of Time-Dependent Heading Error on Ocean Velocties

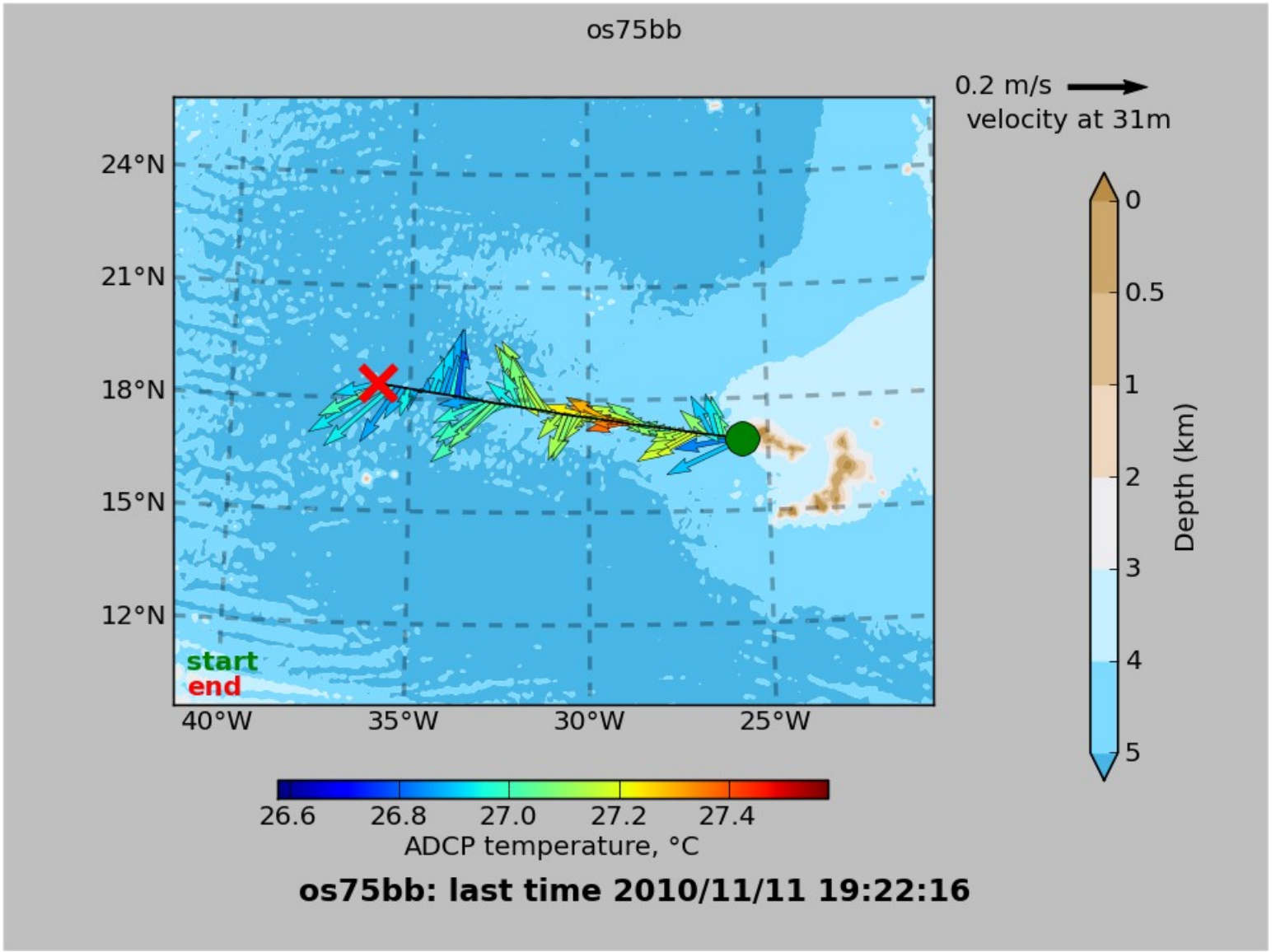
1 degree error in heading means:

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



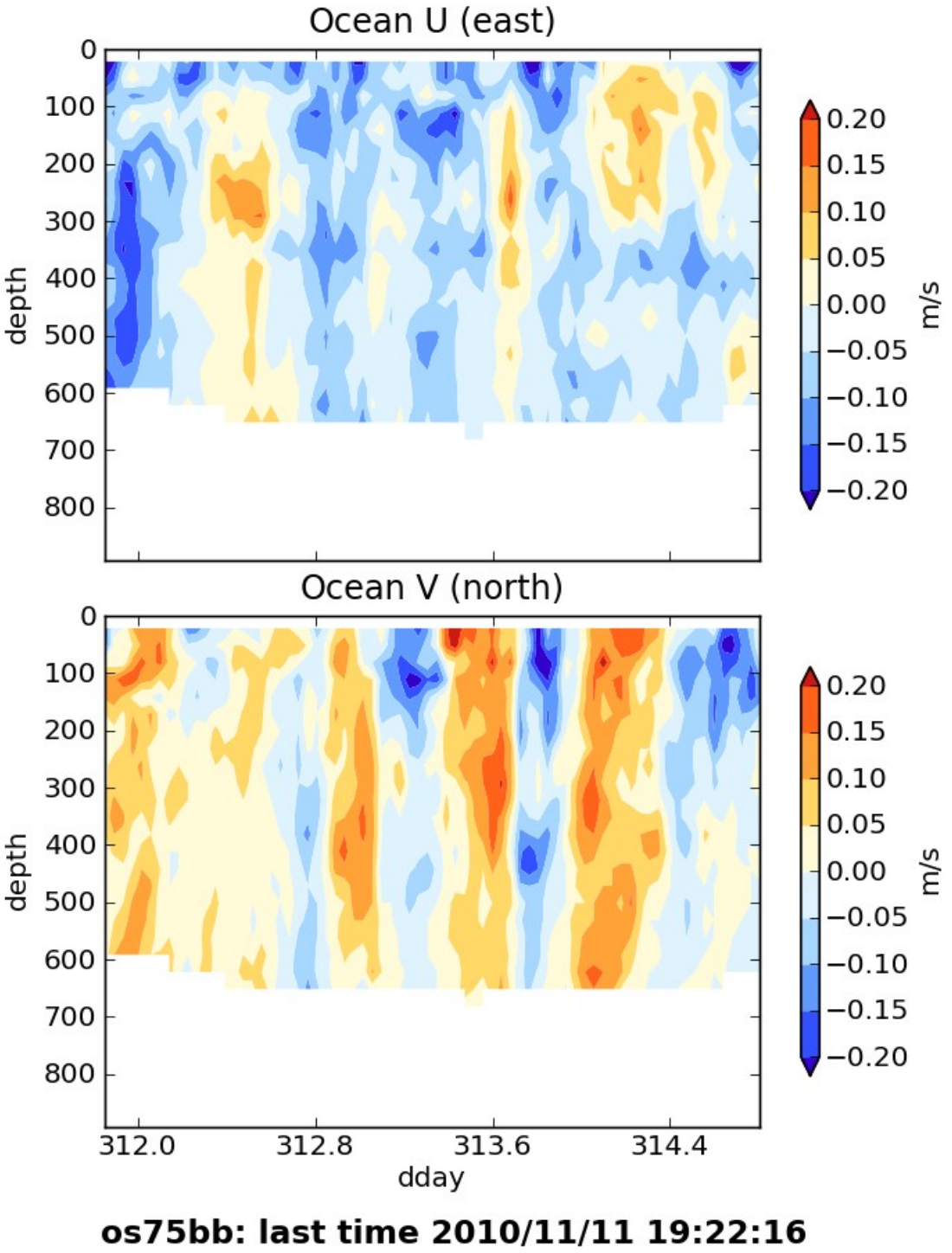
Changes in ship's heading affect heading error

Is this a heading error?



Contour plot:

Is this cross-track signal (stripes in N/S ocean velocity) due to a heading error?



Answer

Actually, it's really the ocean, but
we can't tell without knowing
the quality of the accurate
heading device.

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)

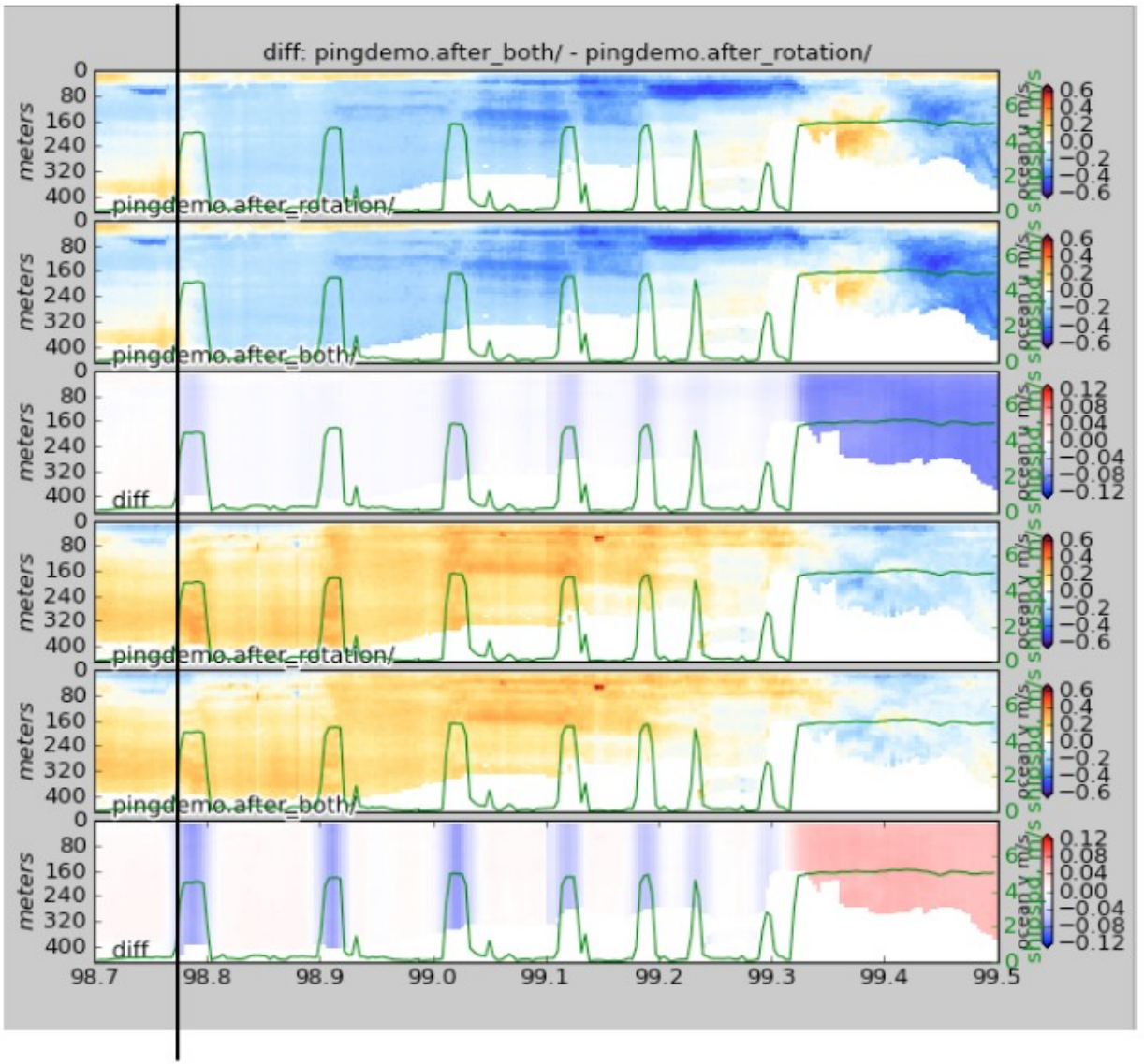
Ocean U (after scalefactor)

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

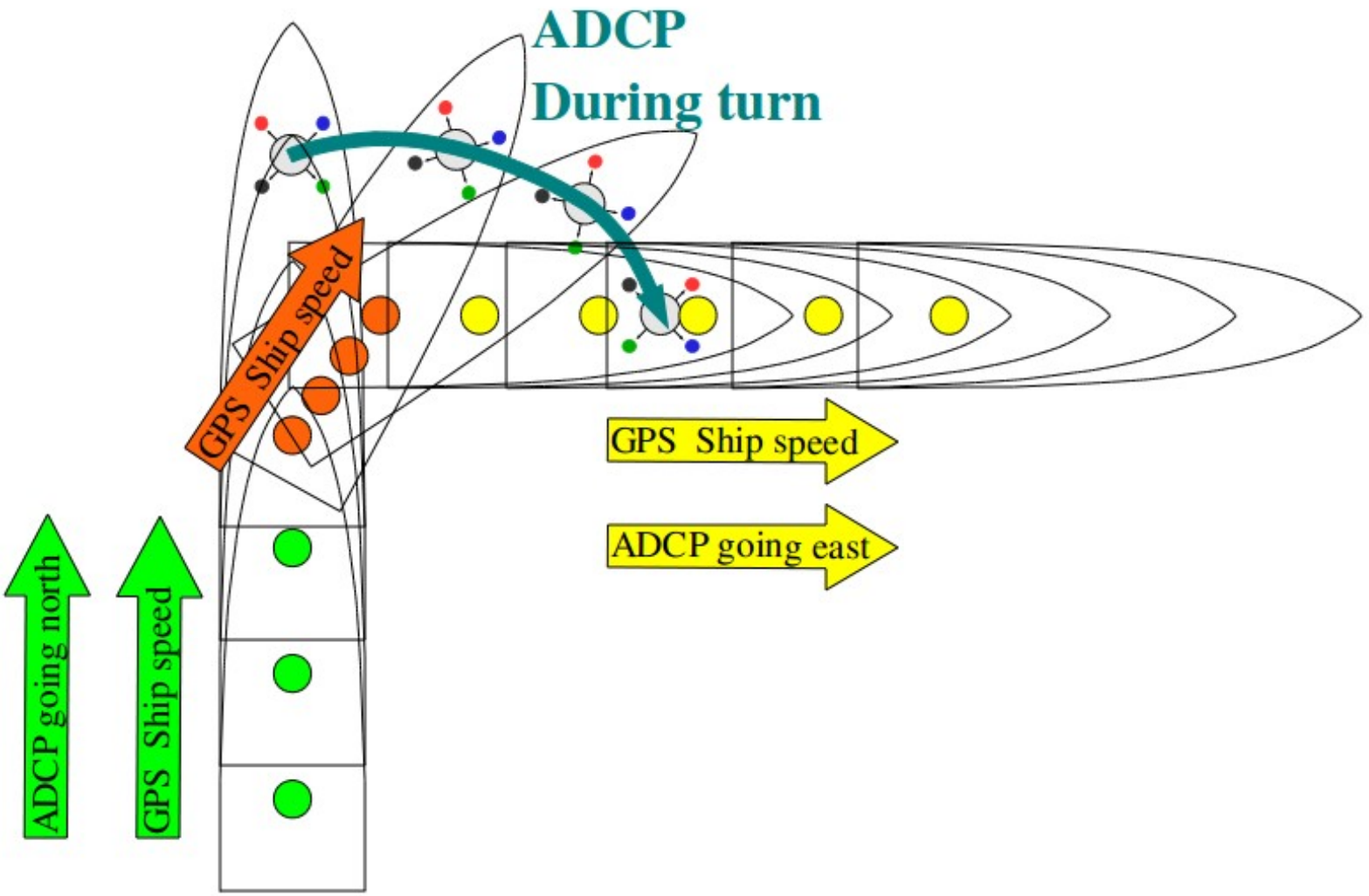
(2) Along-track error:

- 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

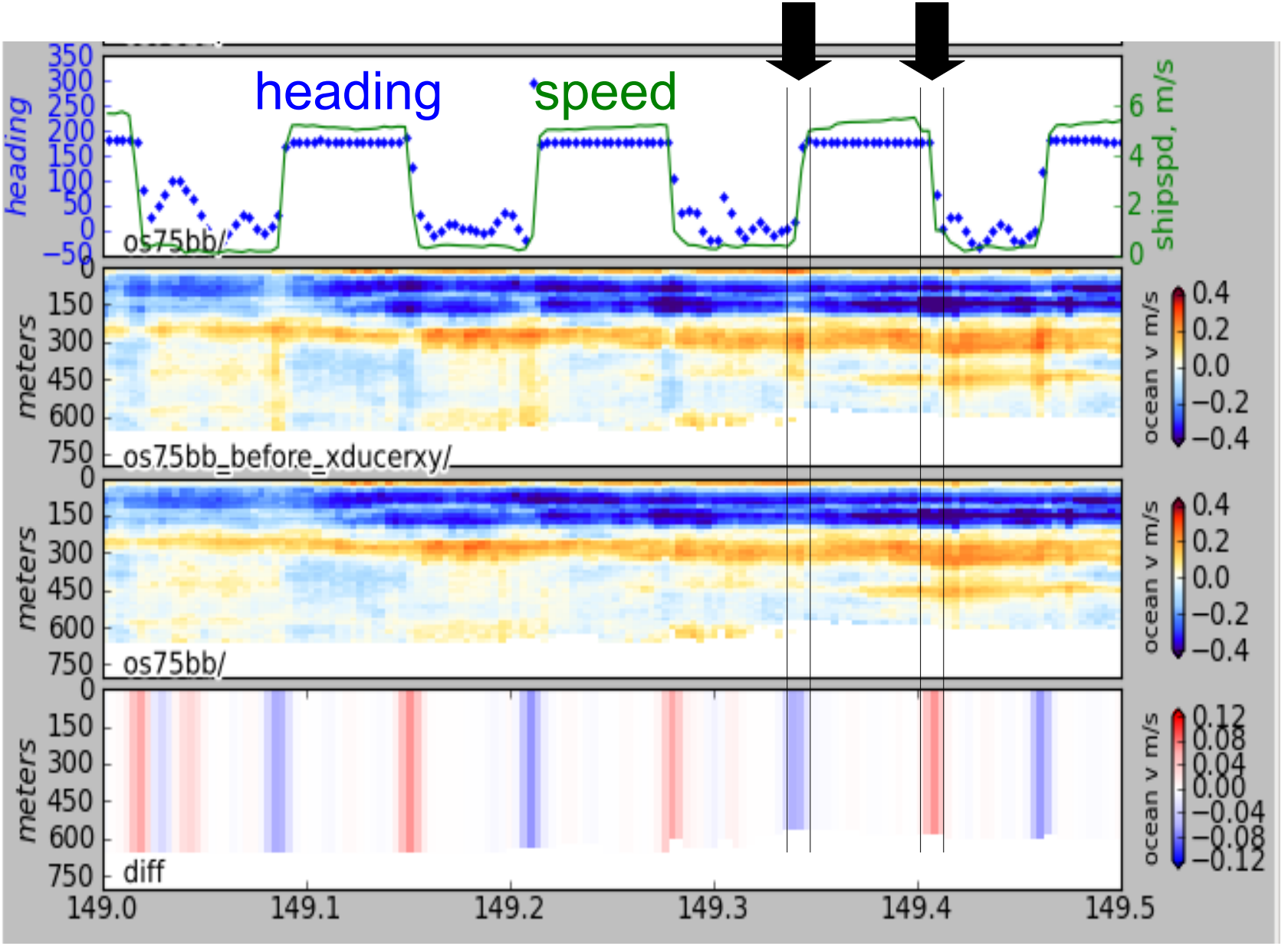


Transducer offset from GPS--error occurs: **transition** between on-station and underway

...using actual location

...using shifted GPS location

difference



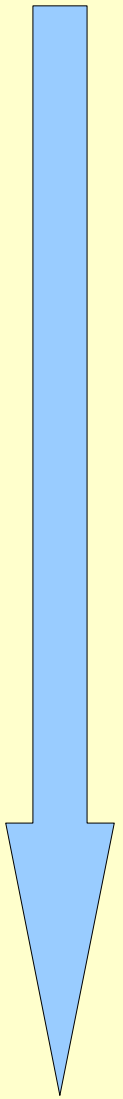
Manual Editing

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

(see GeeAutoedit documentation)

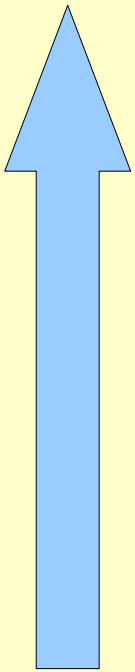
Summary: What We Did

1. ADCP instrument
   - What it is; getting ocean velocities
2. ADCP Data Acquisition
   - Acquisition, processing, monitoring
   - Comparison: UHDAS vs/ VmDAS
   - UHDAS data details
3. CODAS Processing
   - Single-ping editing
   - Postprocessing
     - Calibration
     - Editing



Workshop: What Will Do

1. ADCP instrument
   - What it is; getting ocean velocities
2. ADCP Data Acquisition
   - Acquisition, processing, monitoring
   - Comparison: UHDAS vs/ VmDAS
   - UHDAS data details
3. CODAS Processing
   - Single-ping editing
   - Postprocessing
     - Calibration
     - Editing



Day 3

Day 2

Day 1 afternoon