Shipboard ADCP processing workshop
Nov 11-13, 2019
National Oceanography Centre, UK

UHDAS ADCP data Acquisition and CODAS processing

UHDAS + CODAS Documentation

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

Outline

Day 1: Morning:

- Seminar: Maximizing the Scientific Value of Ocean Current data from Shipboard ADCP
- 2. ADCP Data Acquisition
  - compare: VmDAS UHDAS
  3. CODAS Processing
  4. Data Stewardship

After: Practice

Maximizing the Scientific Value of Ocean Current data from Shipboard ADCP

Monday November 11, 2019
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Southampton, UK

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https://currents.soest.hawaii.edu

Overview

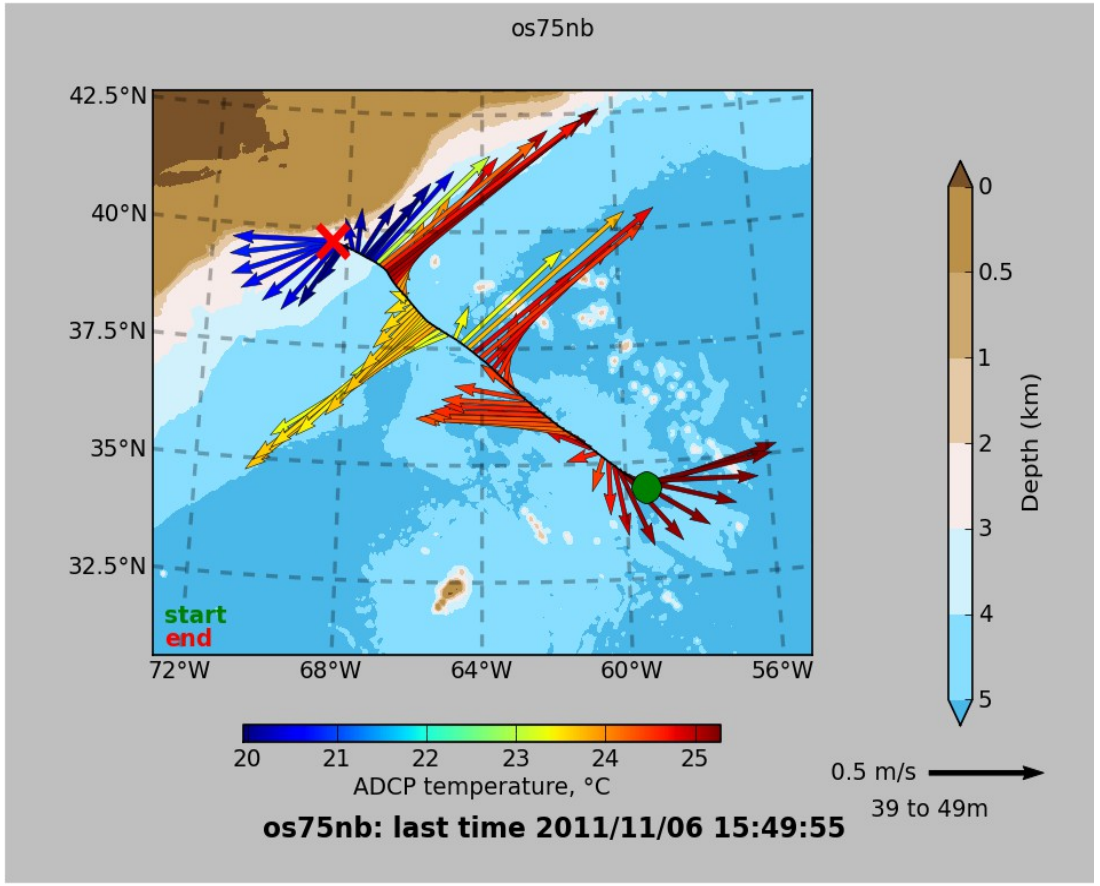
- what is shipboard ADCP? who uses the data?
- where are SADCPs installed?
  - introduction to U.S. Academic Research Fleet; NOAA
- data flow (part 1):
  - acquisition, data on the ship
- maximizing scientific value of shipboard ADCP
  - make it work well; keep it working well
  - make it available immediately and in the future
  - be able to reprocess after the cruise
- data flow (part 2):
  - roles of processing, scientists, national archive

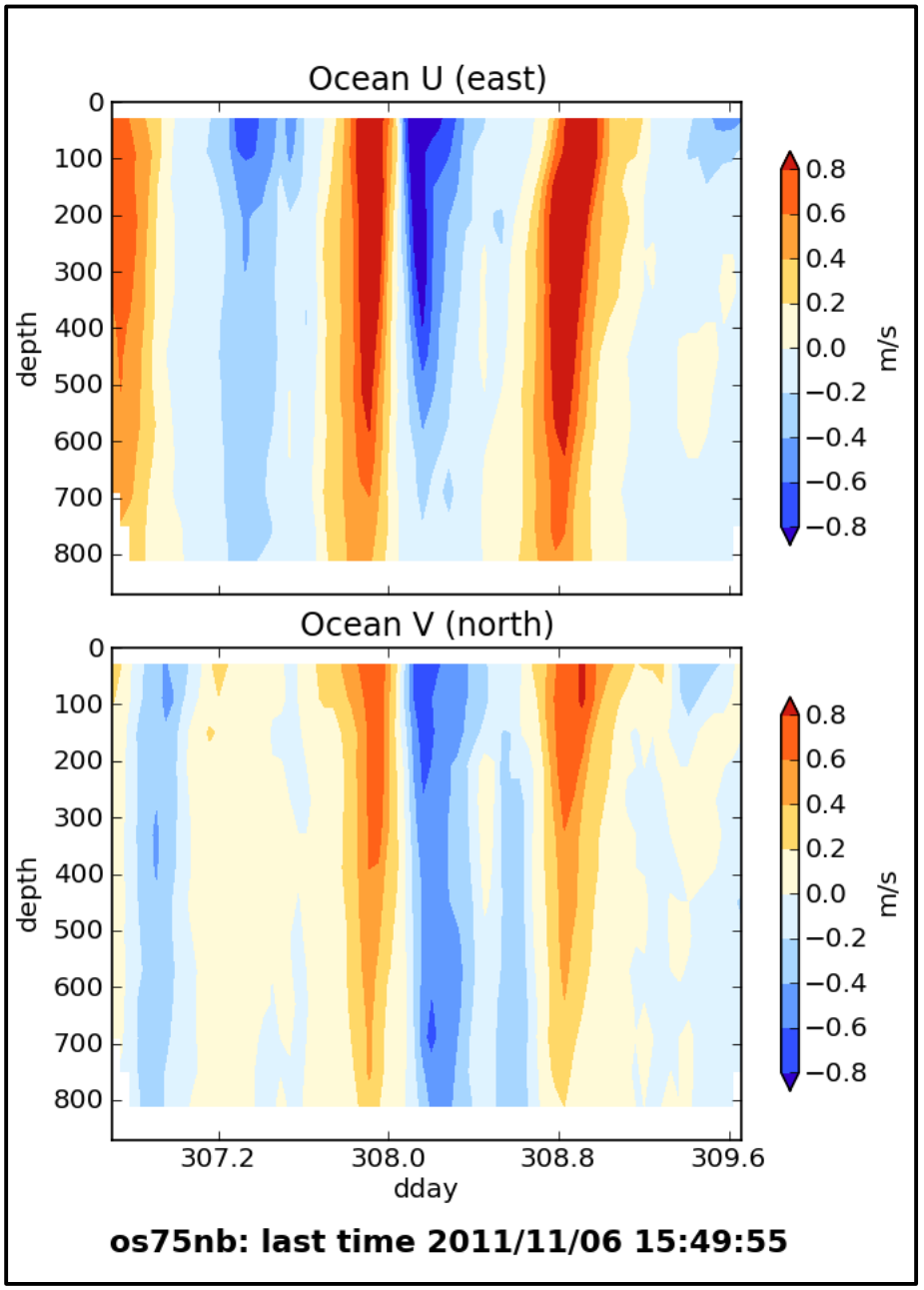
Time, ADCP, Position, Attitude

primitive (raw) data

After Processing

AfterProcessing





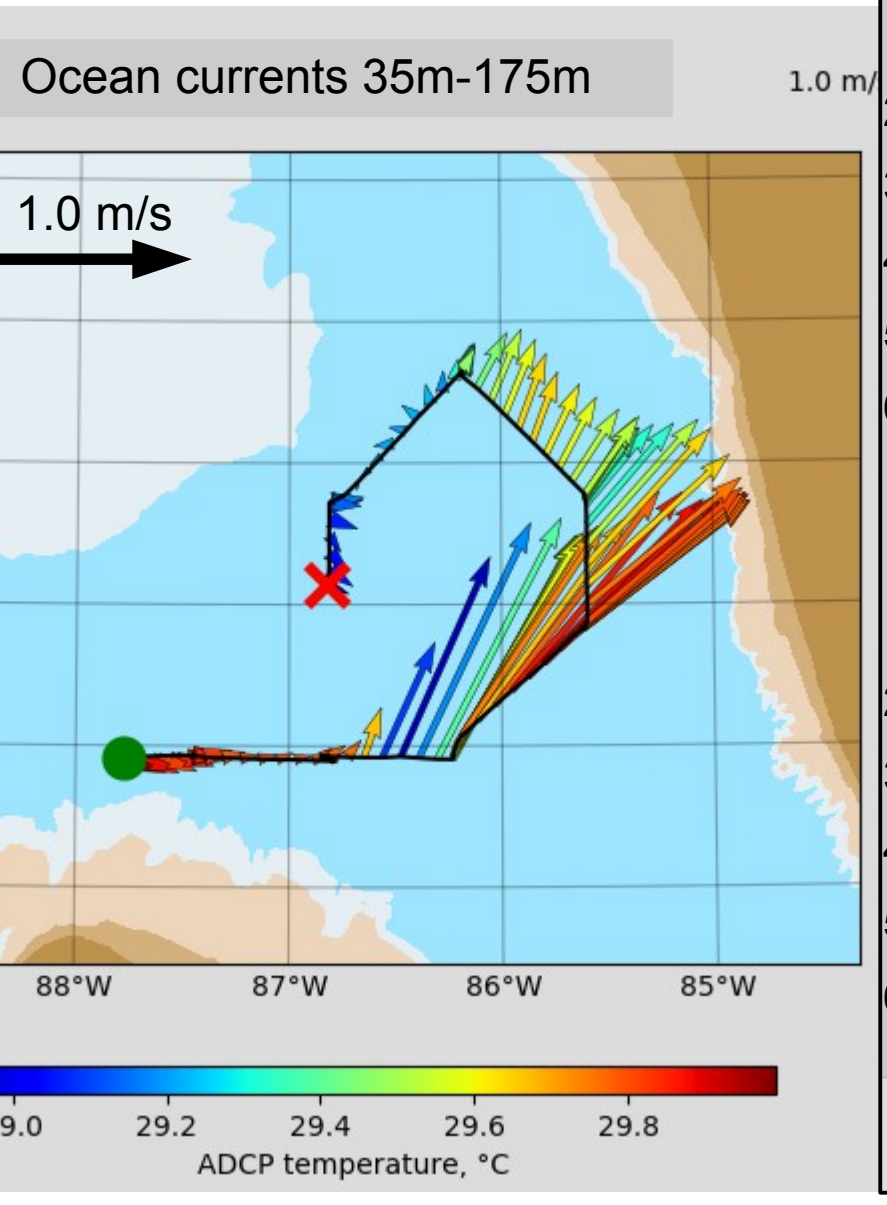
Who uses the data? What is it good for?

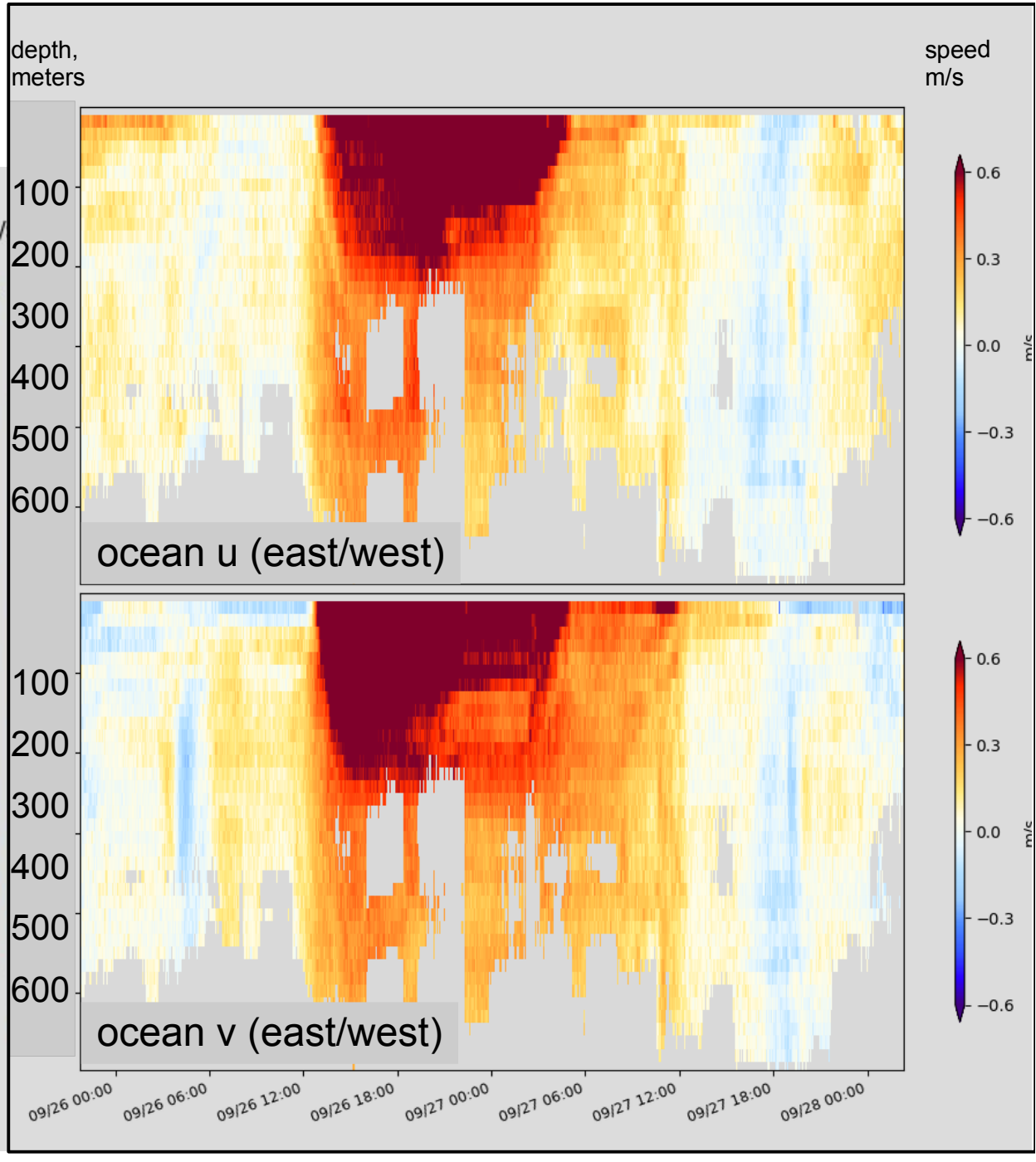
at sea:

- operations, eg:
  - currents for over-the-side work (moorings, CTD)
  - backscatter levels for targeted biological sampling
  - currents for ROV operators
- dynamic sampling, eg:
  - where is the front?
  - when did we cross the front?
  - which direction will the instrument drift after deployment?

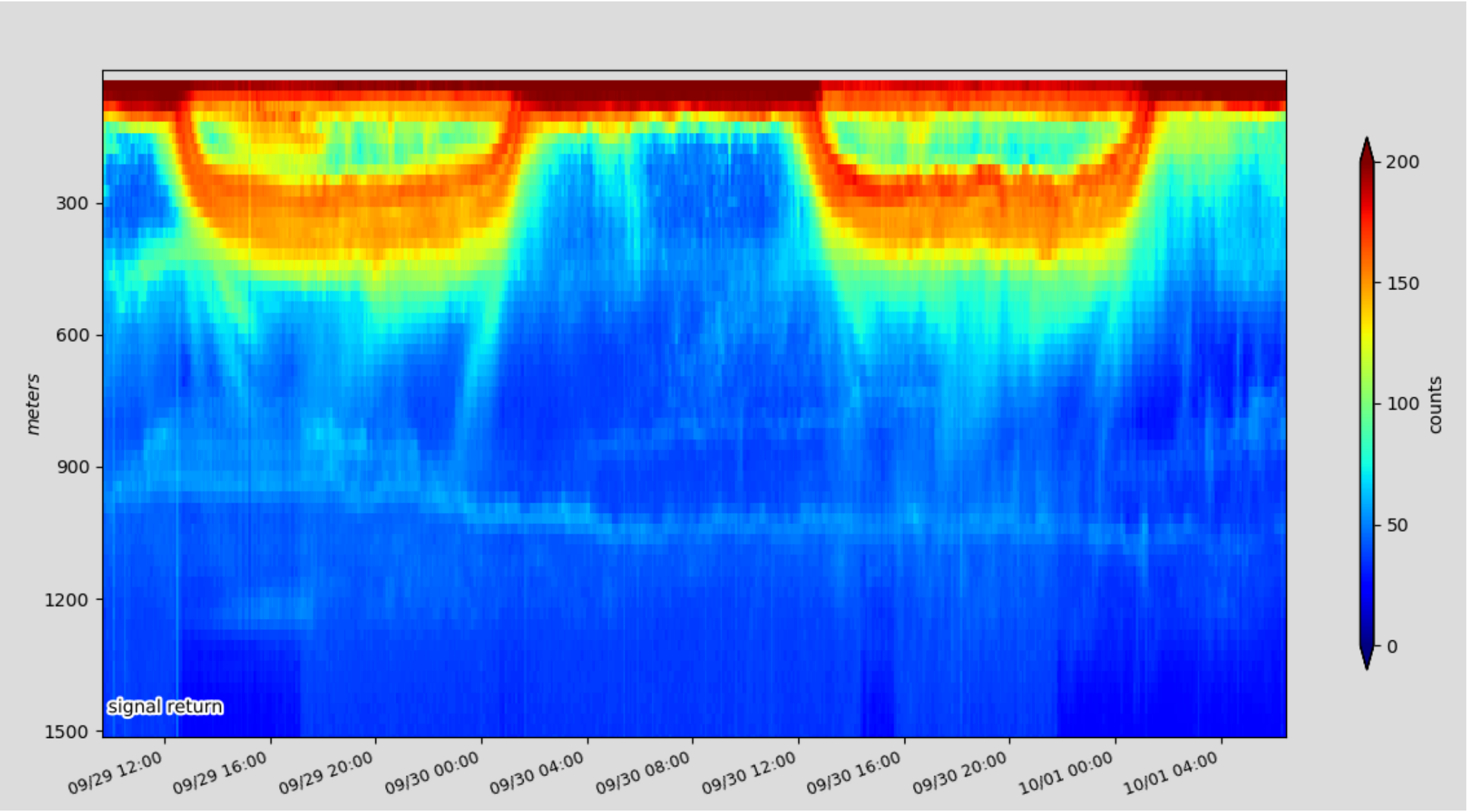
R/V Pelican Mooring cruise, Gulf of Mexico

Donohue, PE20-06





Kilo Moana: 38kHz ADCP backscatter (tropical eastern pacific)



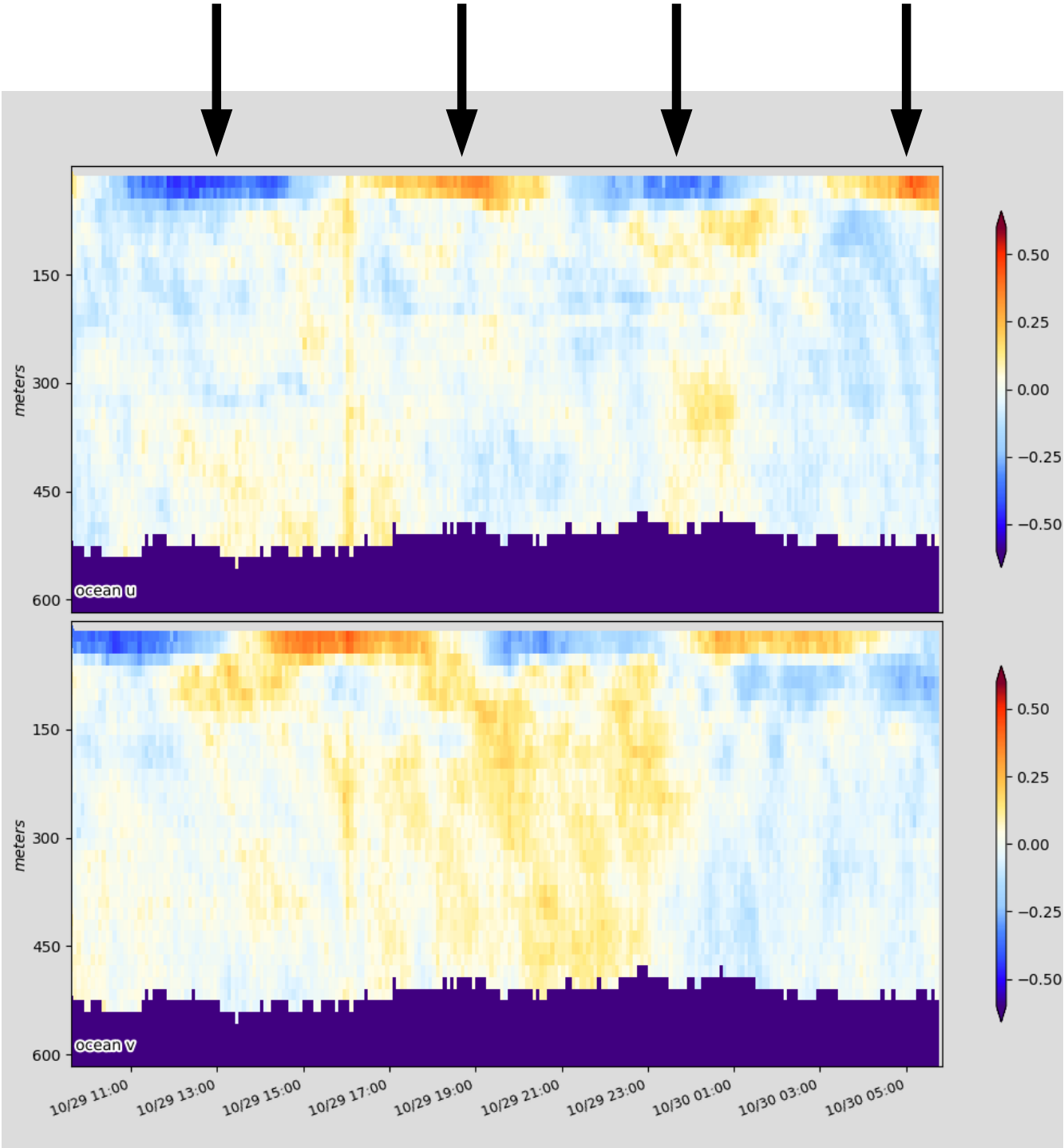
Scientific relevance of shipboard ADCP data

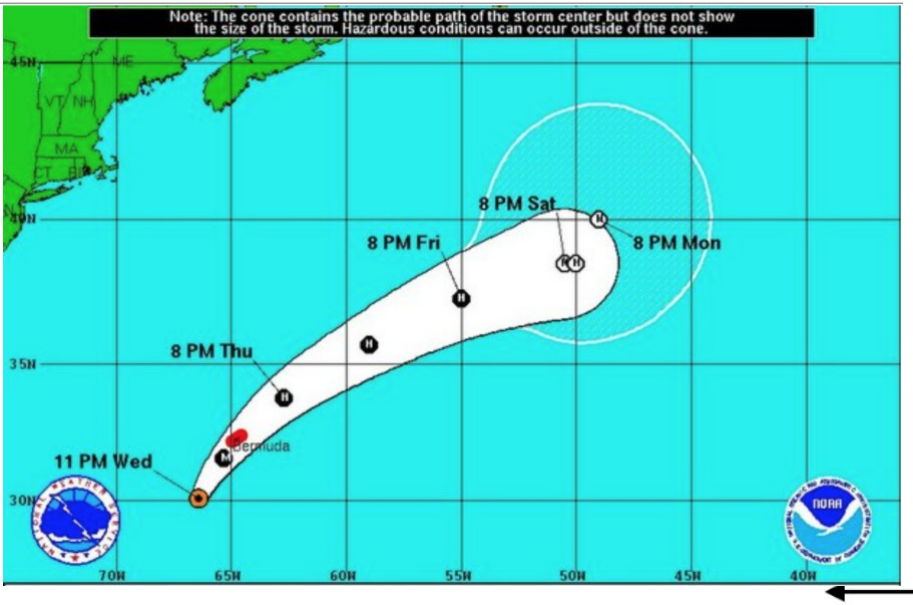
- process studies:
  - near-inertial motion
  - internal wave energy (upward propagation of phase)
  - high-frequency internal waves (on station)
  - context for small-scale mixing studies
- time series
  - dedicated, on station (HOT, BATS)
  - transects: Drake Passage, Oleander
  - after the fact: equatorial Pacific
- comparison with satellites
- backscatter (even if uncalibrated)

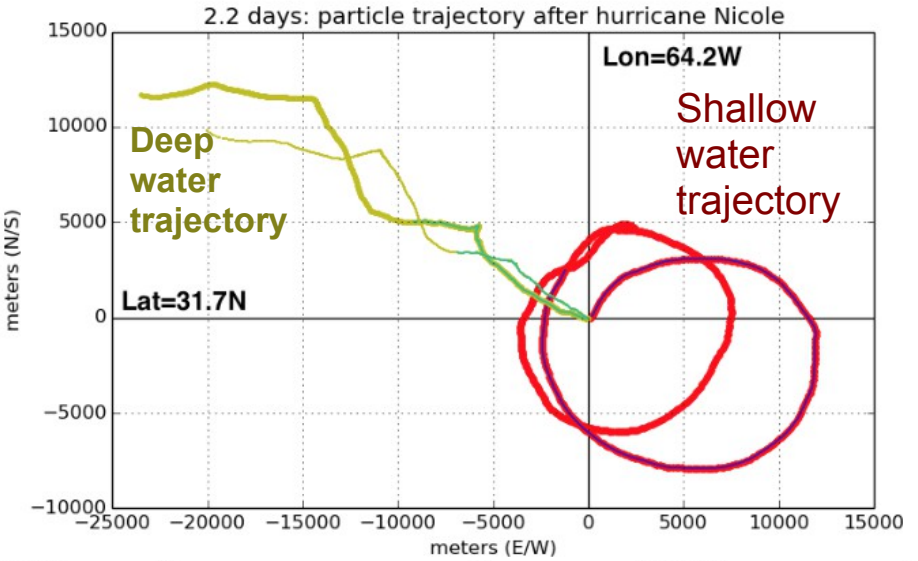
examples follow...

Near-inertial motion caused by strong winds;

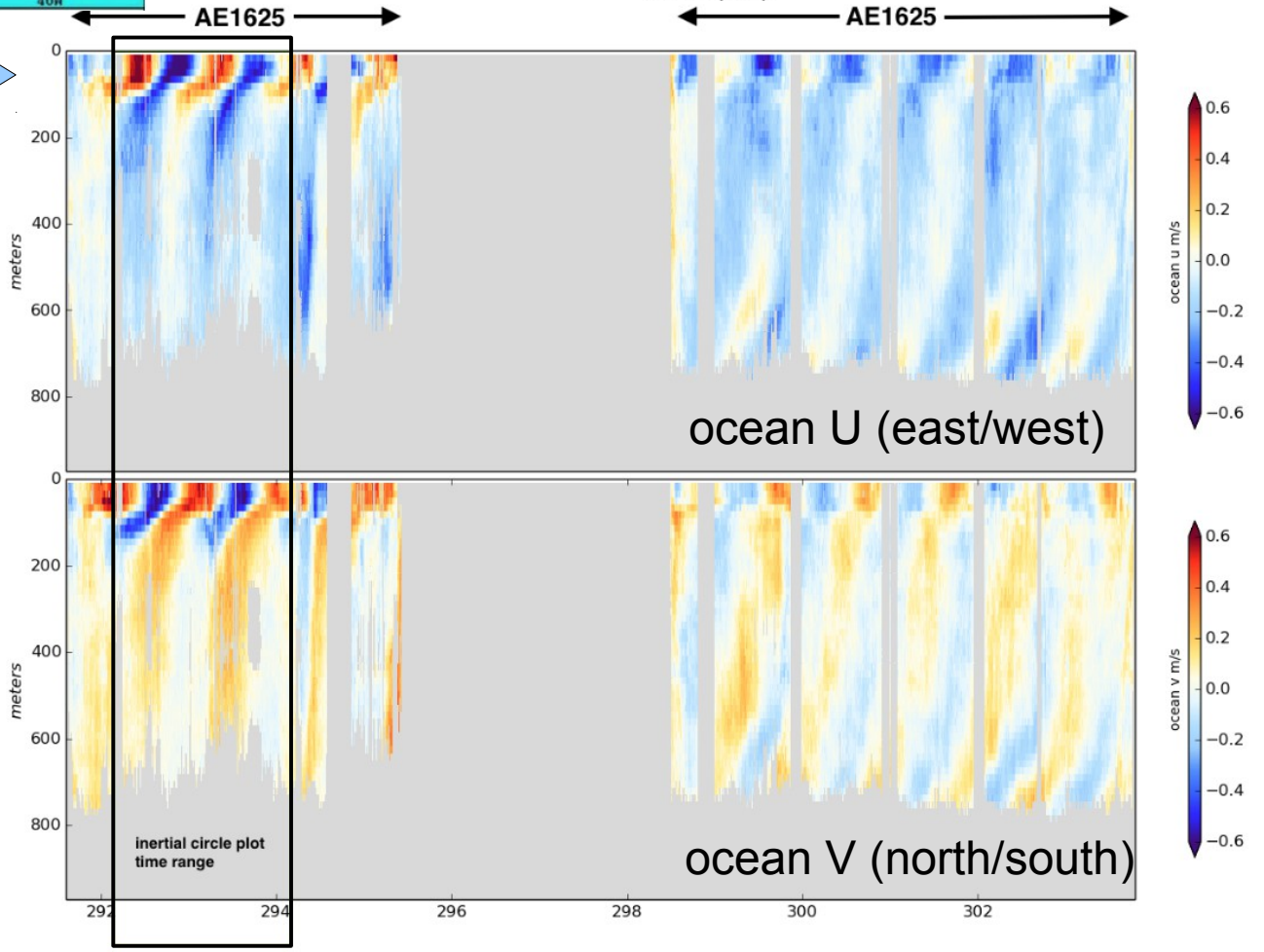
stratified ocean keeps the energy at the surface







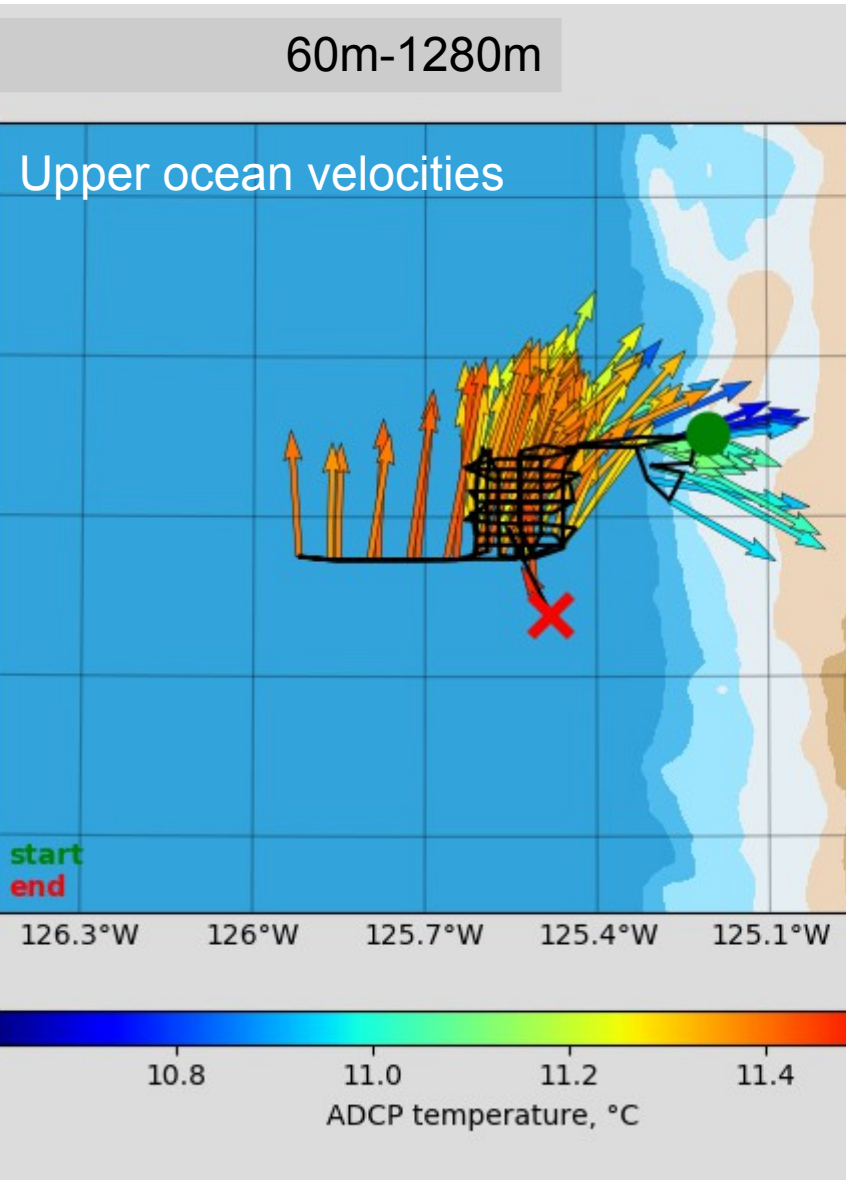
shallow inertial signal

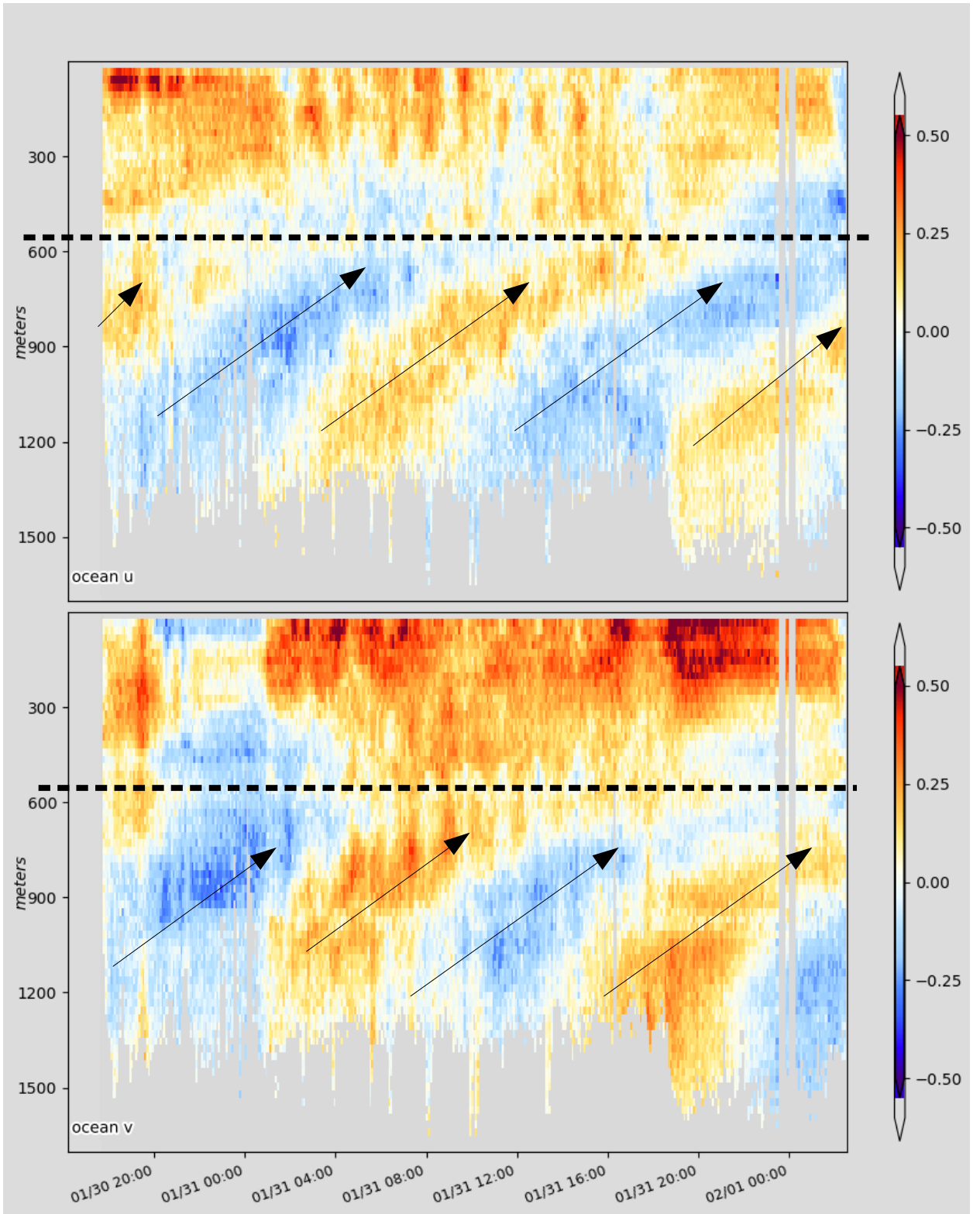


Hurricane Nicole
Oct 12, 2016

deep inertial signal later

Kilo Moana (45N) off the Oregon Coast: internal tide beam, energy downward (phase upward) below 600m

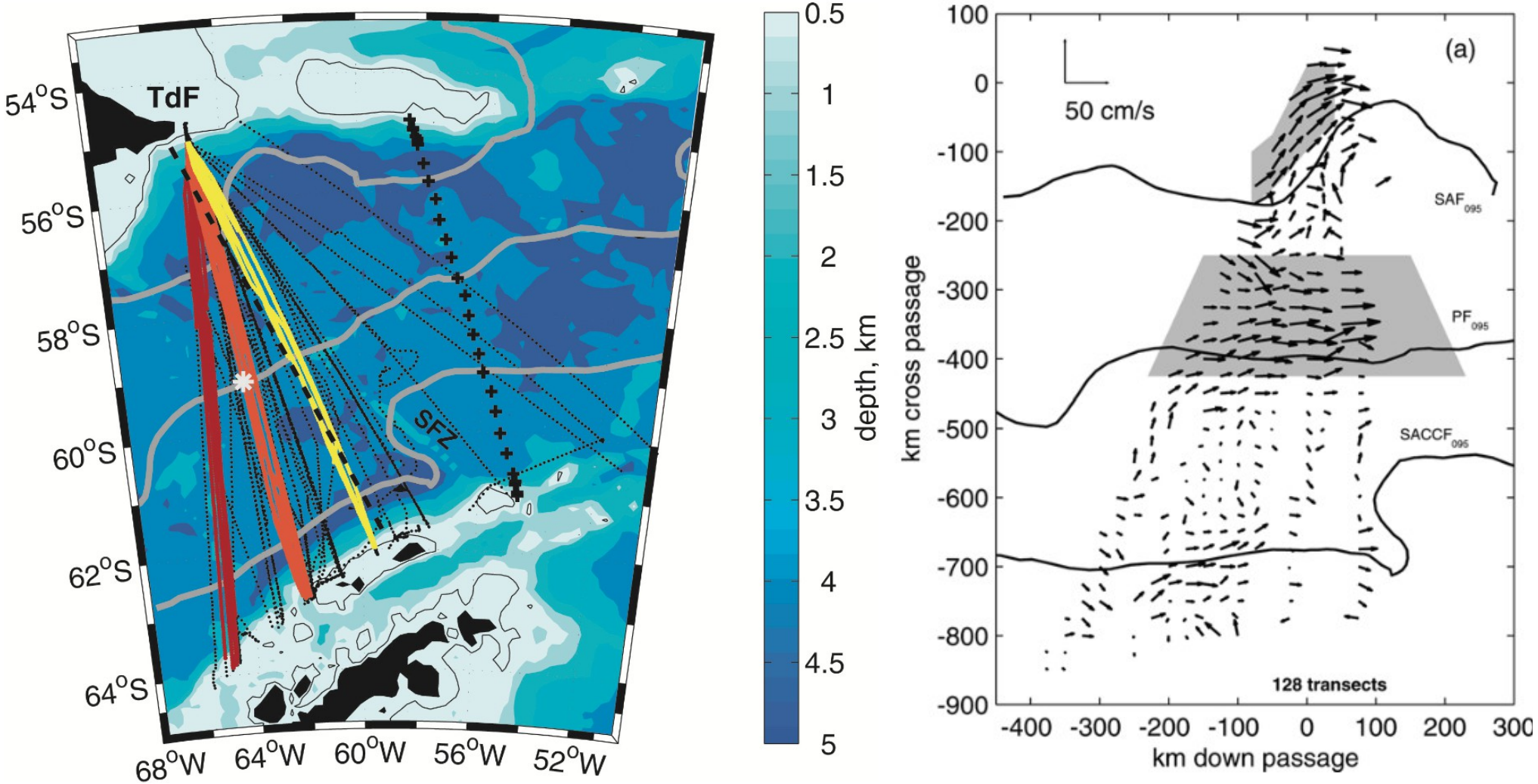




Time Series Examples

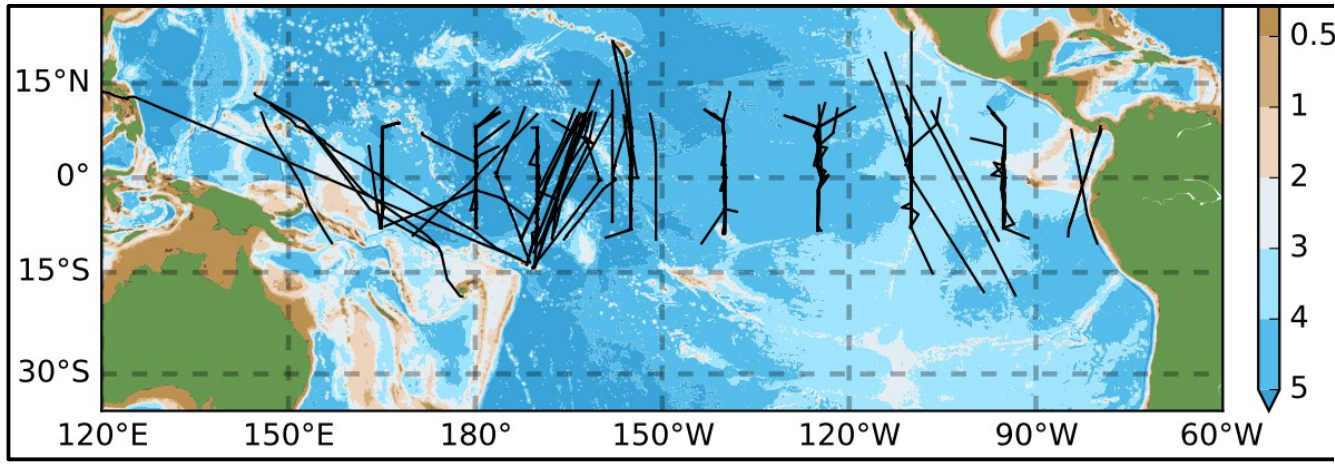
Laurence M. Gould: Drake Passage

Lenn et all, JMR, 2007



Time Series: Equatorial Pacific

SADCP from TAO sections
Crevatte et al, JMR 2017



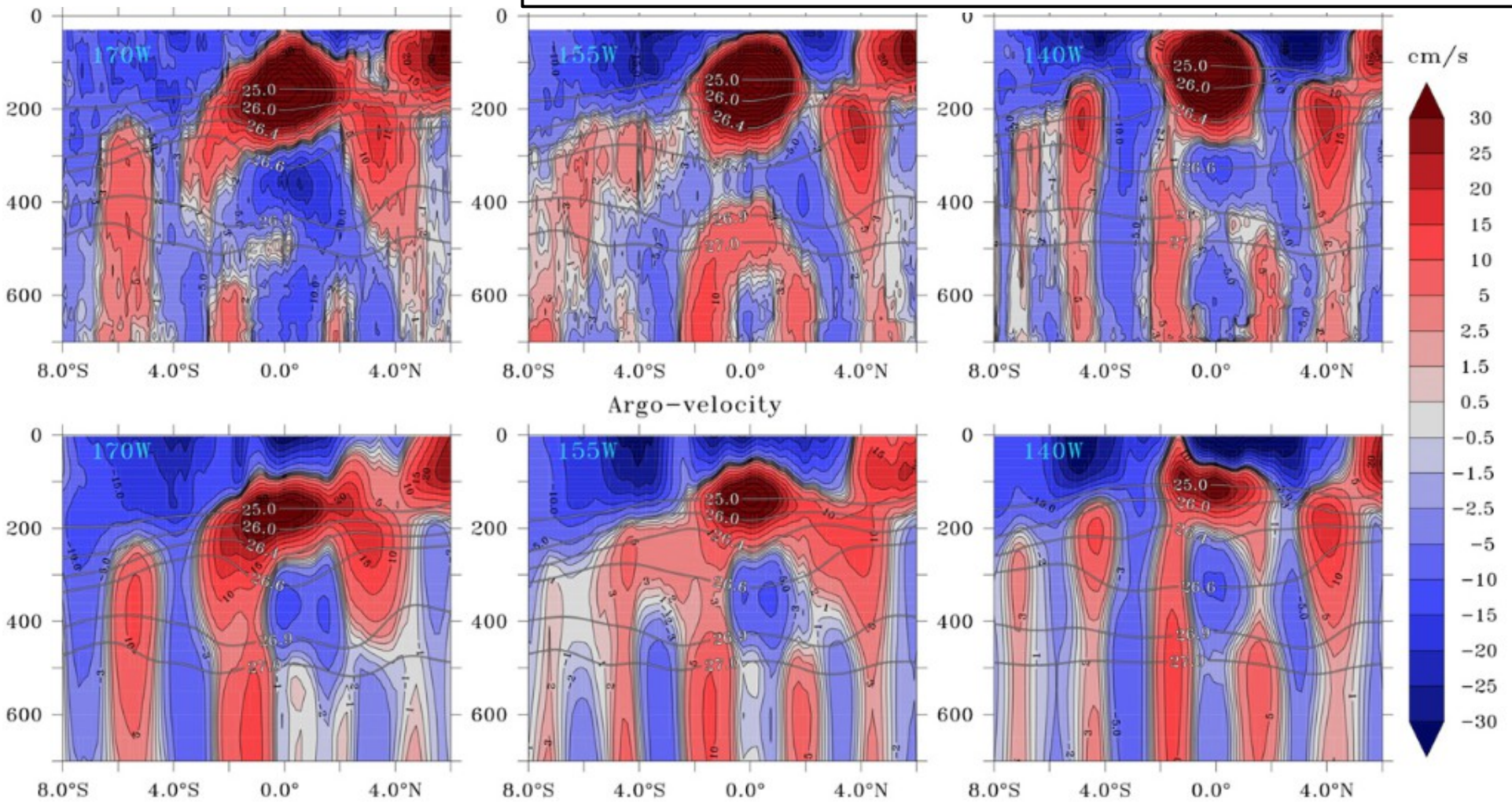


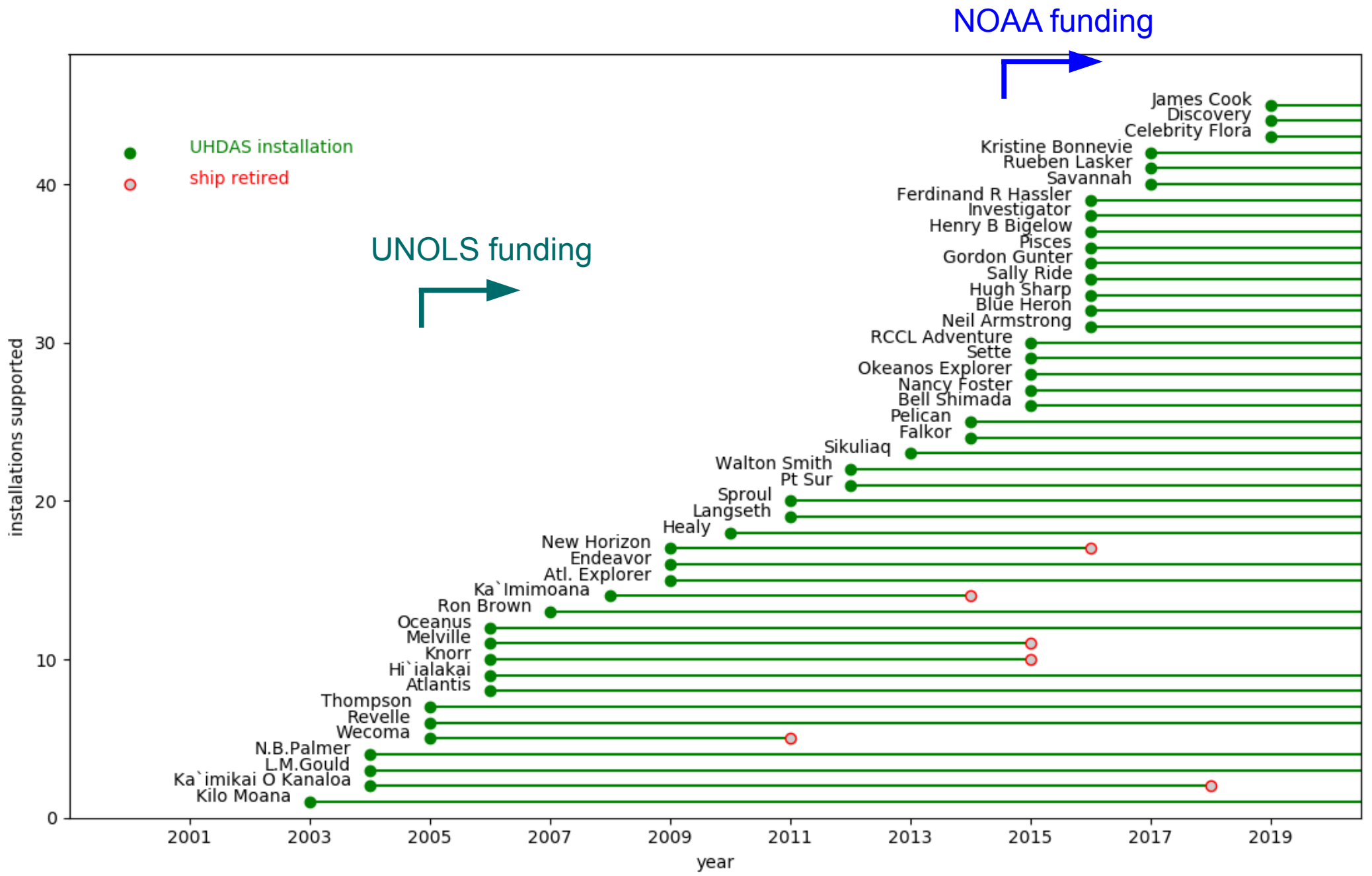
FIG. 12. Mean zonal velocity from (top) SADCP data and (bottom) Argo velocity product at (left) 170°W, (center) 155°W, and (right) 140°W in cm s^{-1}. Superimposed are some selected isopycnals.

Where are scientific shipboard ADCPs installed?

- Internationally:
  - oceanographic research vessels
  - smaller science vessels
  - Navy ships

- In the United States:
  - Academic Research Fleet ("**UNOLS**" = ~20 ships)
    - general oceanography: 30m-85m, polar: 70m-130m
    - operated by 12 different institutions
    - each ship sails with 1-6 techs (depending on ship size)
  - Nat'l Oceanographic and Atmospheric Admin (**NOAA**=11 ships)
    - each ship sails with 2 techs
  - smaller science vessels

UHDAS Installations supported: by year



Data flow: from ship to science

- acquisition, data on the ship
  - VmDAS (available from RDI, windows)
  - UHDAS (from University of Hawaii, linux)
- roles of processing
  - On the ship?
  - Does the scientist process the data?
  - Is there a “processing facility” cleaning the data?
- U.S. national archive
  - JASADCP (for processed science-ready SADCP)
  - NCEI (via R2R) “as collected” UHDAS SADCP

Maximizing the Scientific Value of Shipboard ADCP

- make it work well; keep it working well
- make it available immediately and in the future
- be able to reprocess it in the future

links:

UHDAS Operations

Comparison between UHDAS and VmDAS

ADCP:

Getting Ocean Currents

Summary of steps:

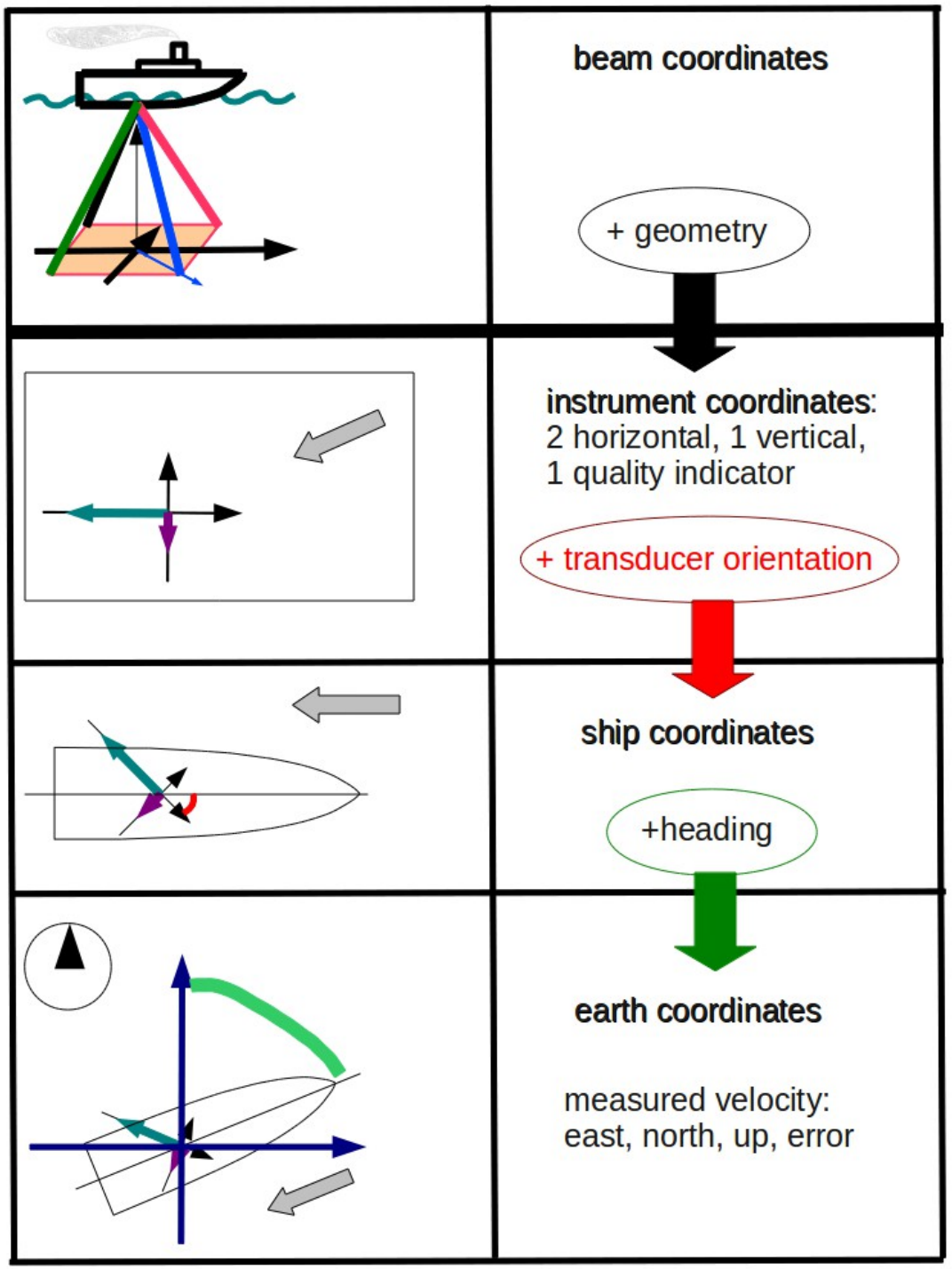
Doppler to beam
(not shown)

<u>below here: measured velocity</u>
(coordinate transformations)

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

<u>below here: ocean velocities</u>

- remove ship's speed



ADCP preliminary Processing

"processing" requires (at minimum)

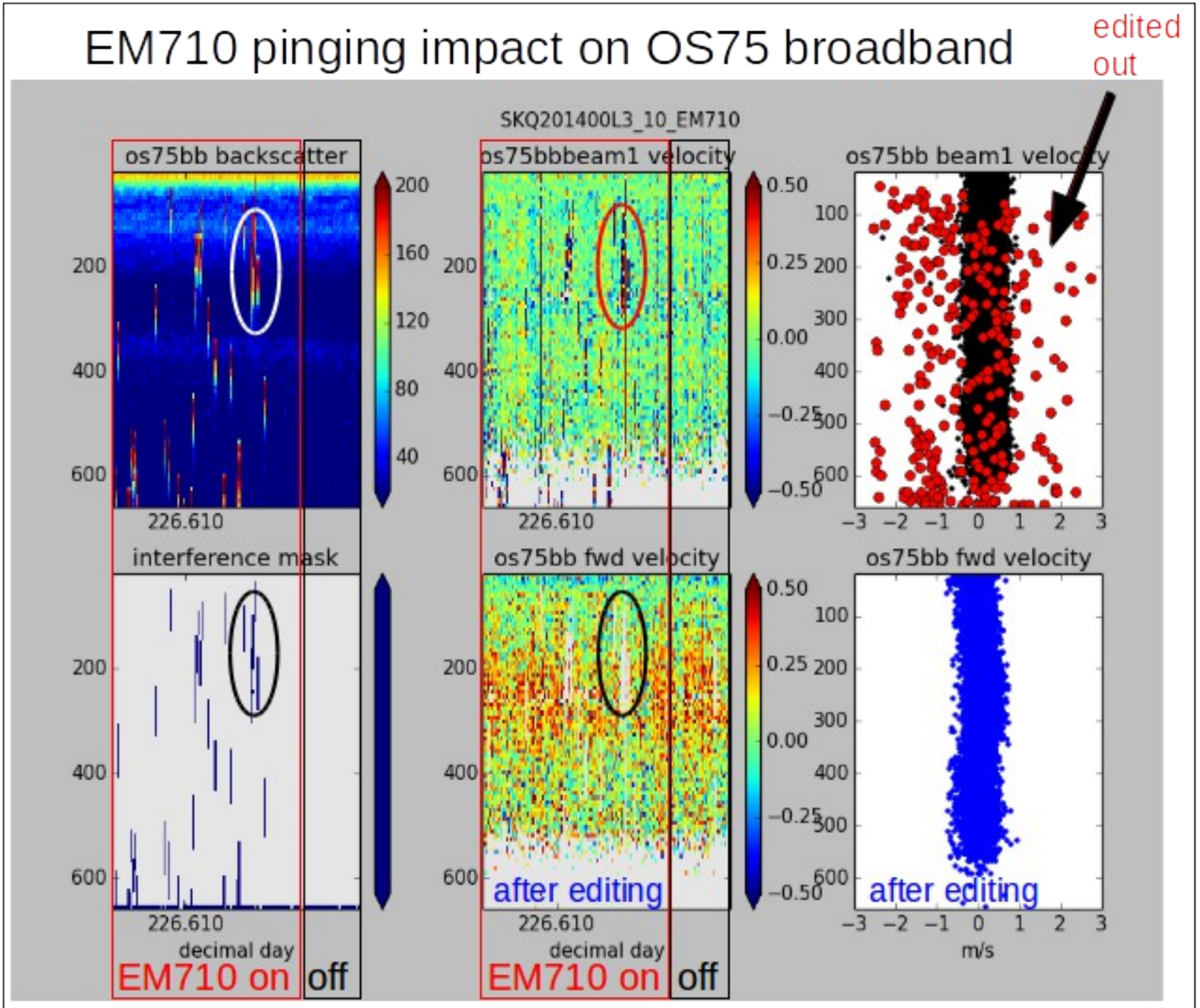
- transform from beam coordinates to horizontal
- rotation into ship coordinates
- further rotation based on heading
- removal of ship's speed

CODAS processing also has single-ping editing:

- **velocity editing based on acoustic interference**
- **removal of data below the bottom (and side-lobe)**
- **weak (short), biased profiles**
- **remaining statistical outliers**

- averaging
  - **CODAS directory is staged for post-processing**
  - **5Gb cruise directory distilled down to 50Mb-100Mb**

CODAS single-ping editing based on acoustic interference



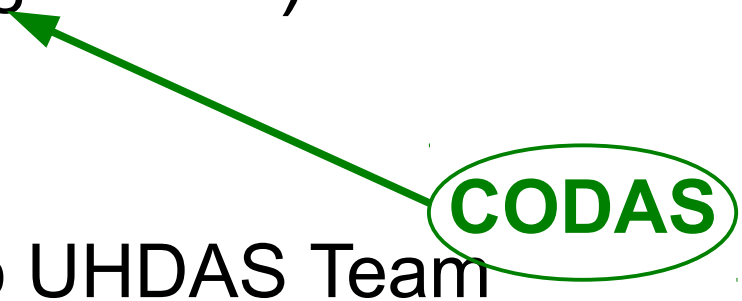
CODAS processing overview

- built from scratch for shipboard ADCP
- data are stored in a CODAS database; routines for manipulation
- open source (Python3, C)
- runs natively on Mac, Linux
- fully functional virtual linux computer available (Virtual Box)
- modular, configurable
- pairs well with UHDAS data, (can be used for VmDAS data)
- visualization tools, calibration tools
- documented and freely available

link: CODAS+UHDAS documentation
https://currents.soest.hawaii.edu/docs/adcp_doc/index.html

How UHDAS improves the quality of shipboard ADCP data

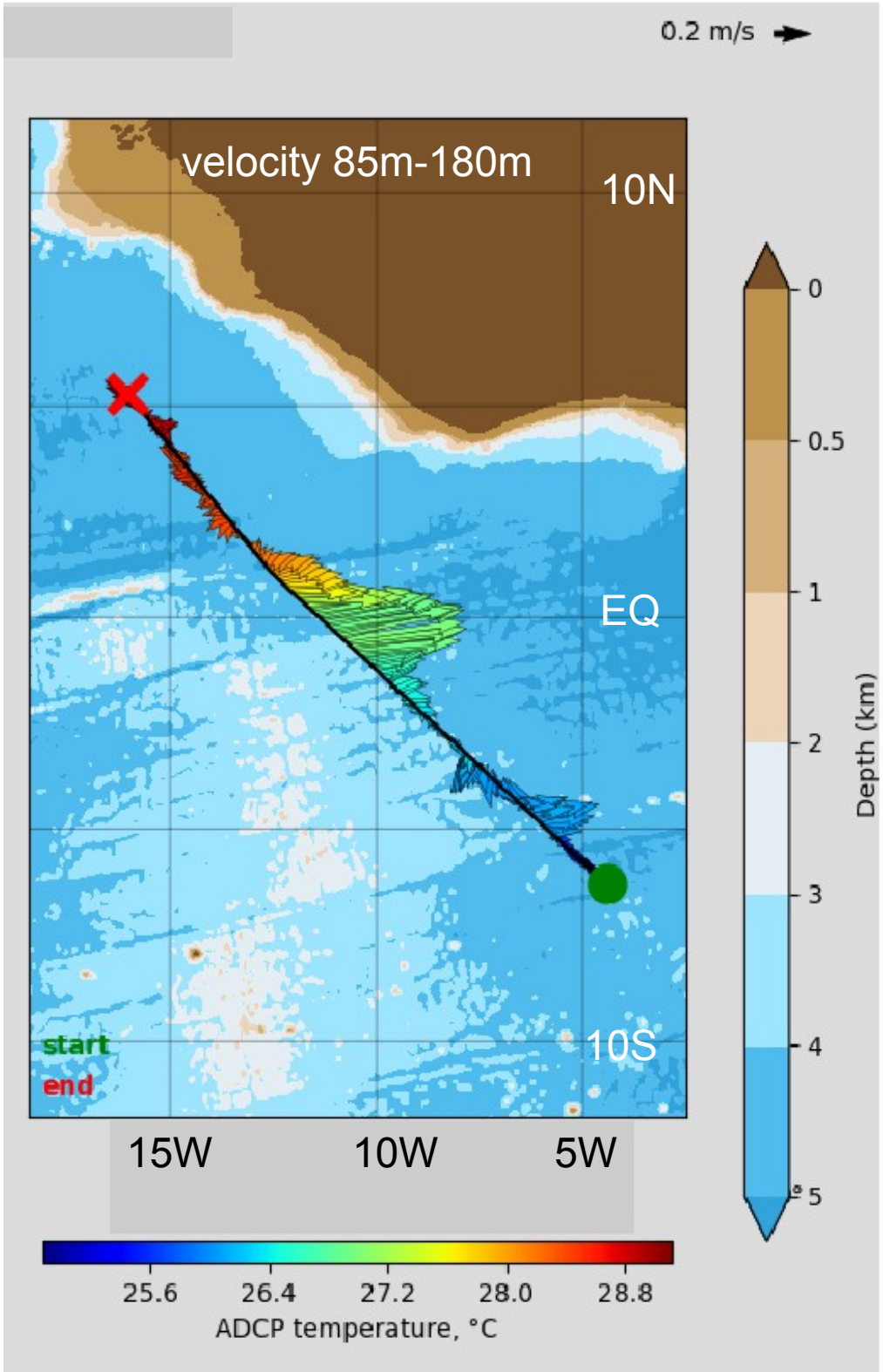
- **acquisition** (ADCP, position, heading)
  - easy to use; can return to known-working settings
- **automated processing** ("pre-processing" at sea)
- **monitoring**
  - on ship: via at-sea web site
  - on land: automated daily emails to UHDAS Team
  - feedback to technicians on the ship
- **data and products** for
  - operations and science at sea
  - ease of post-processing after the cruise
  - discovery/evaluation in the future

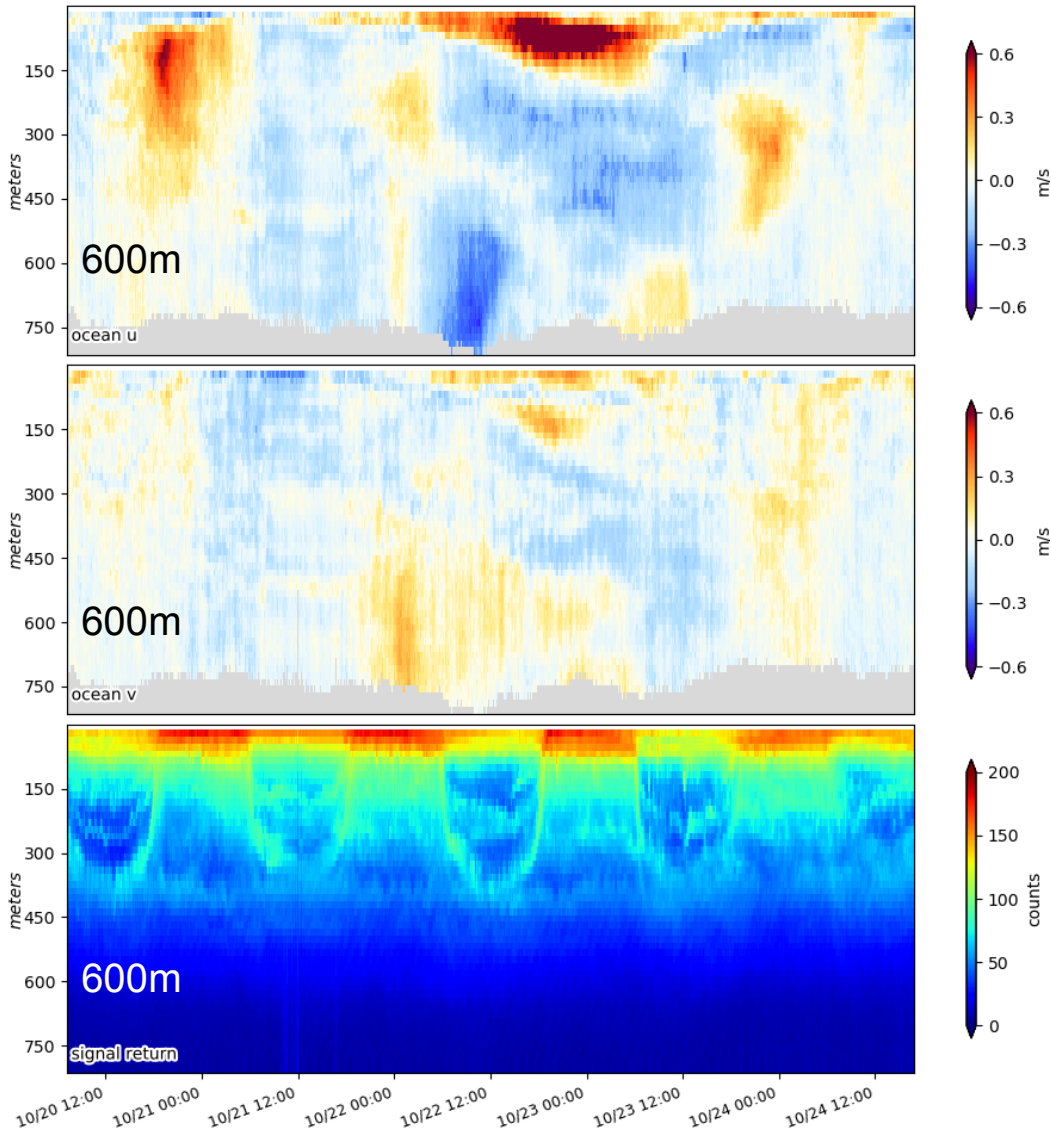


Monitoring

- on ship:
  - via at-sea web site
- on land
  - automated daily emails to UHDAS Team
  - Dashboard with cruise status, figs, diagnostics
  - ticketing system: first pass at identifying problems:
    - notifies the team of a problem
    - mechanism for tracking problems (eg, cruise, ship, instrument)
    - has guidance for common problems
- Team provides feedback to technicians on the ship

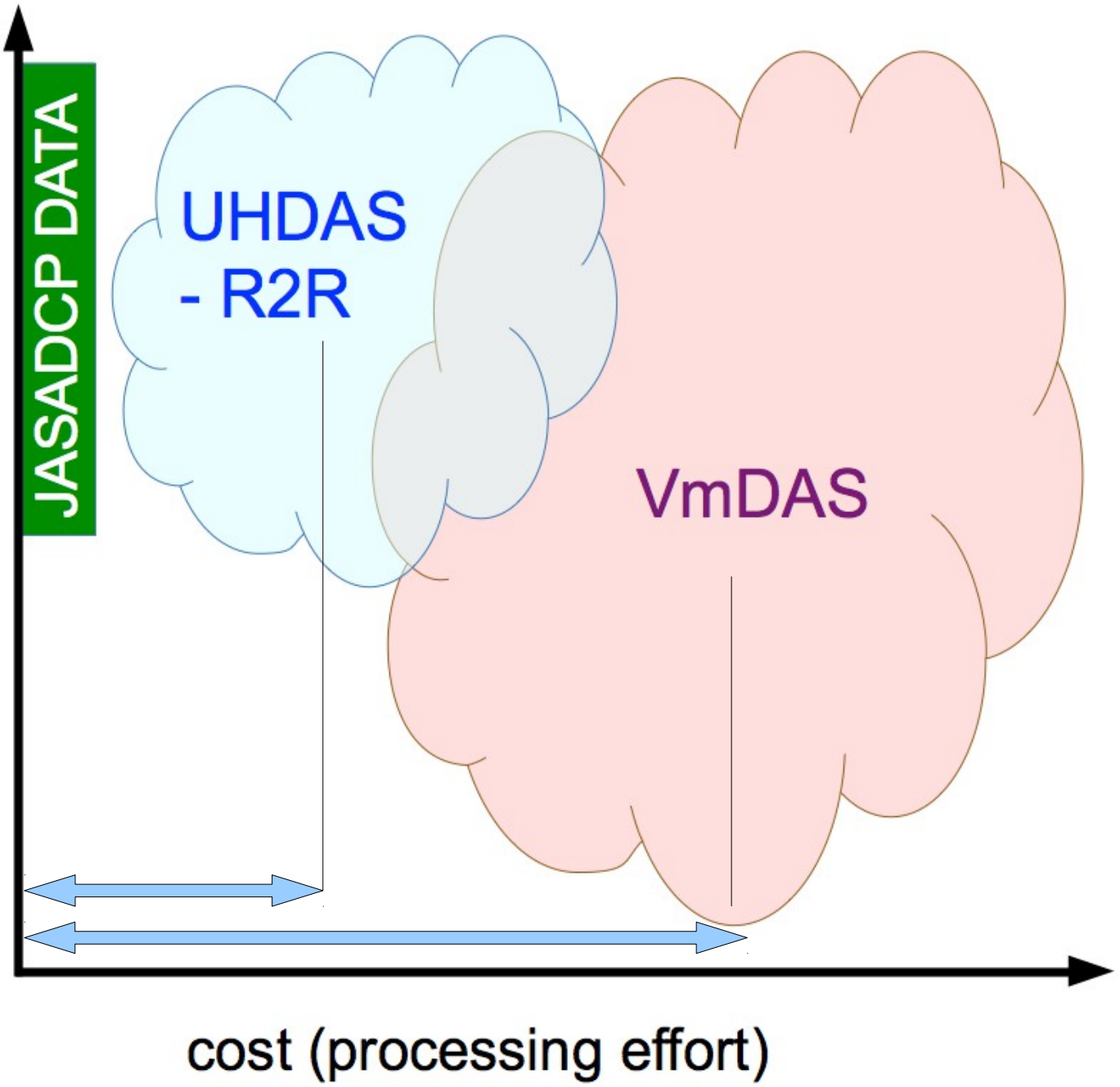
Equatorial Cross-section
R/V James Cook
Oct 21-24, 2019





UHDAS vs/ VmDAS data quality and processing effort

JASADCP:
science-ready
shipboard ADCP
ocean currents



UHDAS designed to:
- maximize raw data quality
- reduce total processing effort

CODAS data and products

At sea:

- **example web page at sea** (James Cook Oct 31,2019)
  - figures for operations and science at sea
  - netCDF data files for science
  - complete CODAS+UHDAS documentation
- access to data+processing directories
  - matlab data files
  - archive of daily figures

CODAS data and data products, cont

After the cruise:

For immediate use, cruise directory has

- processing directories
  - matlab data files
  - netCDF file
  - archive of daily figures
  - ready for post-processing
- raw data directories
  - evaluate quality of the ADCP or ancillary data
  - reprocess with different inputs
  - reprocess with different averaging duration

CODAS data and data products, cont

After the cruise:

For future use, cruise directory has

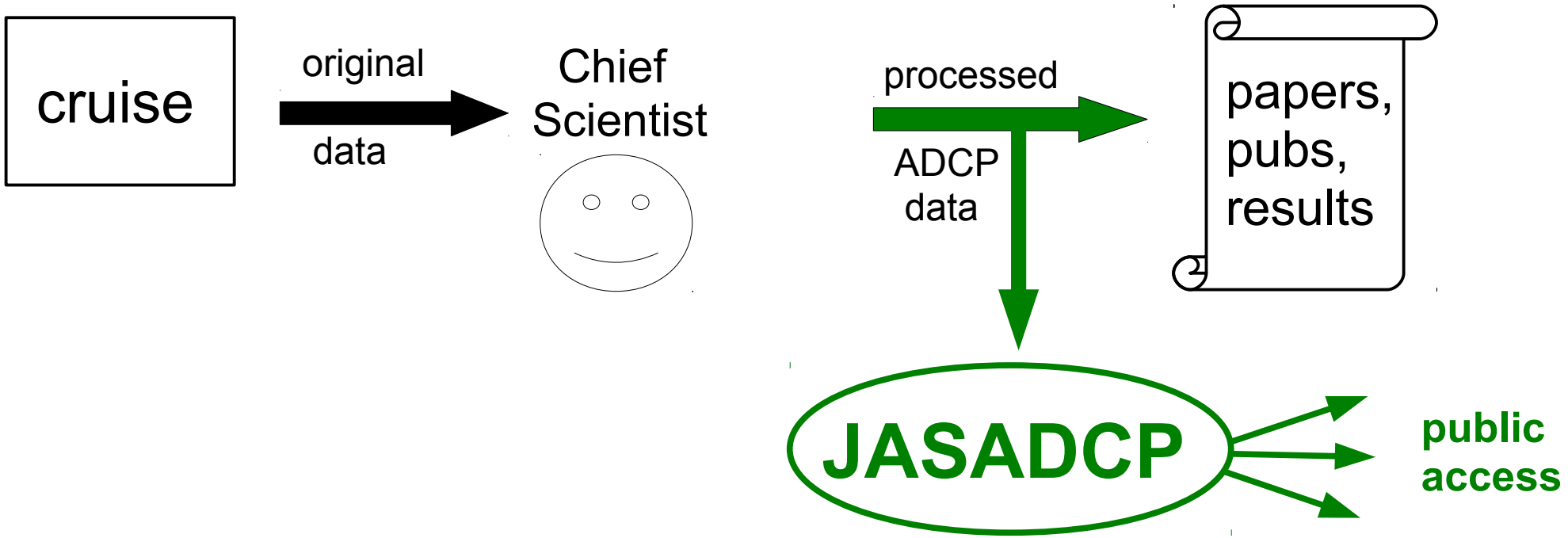
- "reports" directory, with summaries of
  - calibration
  - settings used
  - figures from the cruise
- This is suitable for showing on a web site, to allow exploration of older datasets, and to find "low-hanging fruit"

  example (Atlantis)

Archiving and long-term use ... 

Historically in the U.S.

Past and Present



Joint Archive for Shipboard ADCP

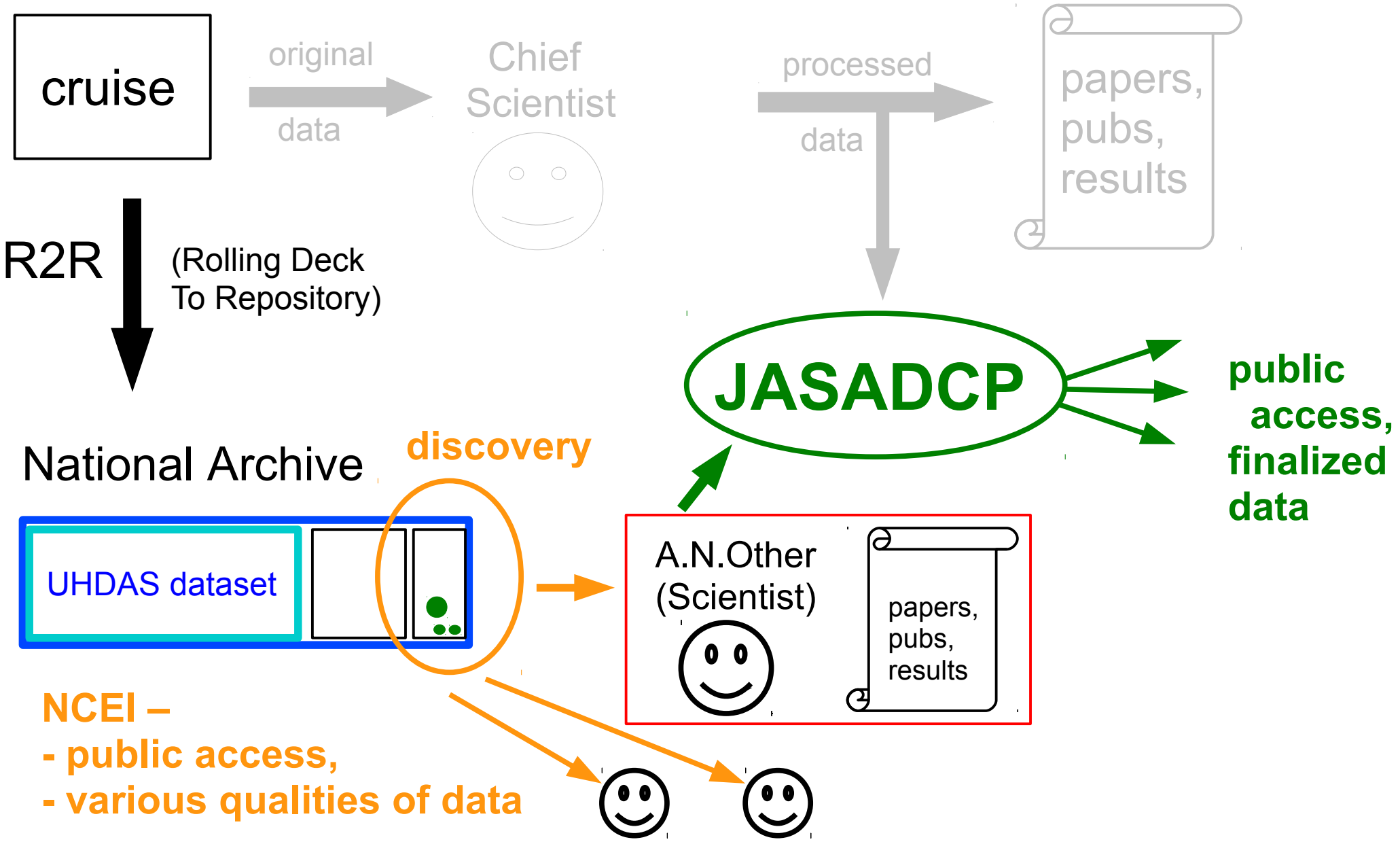
Part of NCEI

Serving science-ready data since 1992.

Over 800 cruises so far...

Present and Future:

- two paths to finalized public data
- more opportunities for original data to be used



References

Drake Passage

- ***Vertical structure and transport of the Antarctic Circumpolar Current in Drake Passage from direct velocity observations***

  Journal of Geophysical Research, 116, C08015; 2011; Y. Firing, T. Chereskin, M. Masloff

- ***Mean jets, mesoscale variability and eddy momentum fluxes in the surface layer of the Antarctic Circumpolar Current in Drake Passage***

  Journal of Marine Research, 65, 27–58, 2007; Y.-D. Lenn,T. K. Chereskin, J. Sprintall, E. Firing

Equatorial Pacific

- ***Subthermocline and Intermediate Zonal Currents in the Tropical Pacific Ocean: Paths and Vertical Structure***

  Journal of Physical Oceanography, 47, 2305-2324,2017; S. Cravatte, E. Kestenare, F. Marin, P. Dutrieux, E. Firing

- ***Annual Reversal of the Equatorial Intermediate Current in the Pacific: Observations and Model Diagnostics***

  Journal of Physical Oceanography, 40, 915-933, 2010; F. Marin, E. Kestenare, T. Delcroix, F.Durand, S. Cravatte, G. Eldin

Equatorial Cross-section
R/V James Cook
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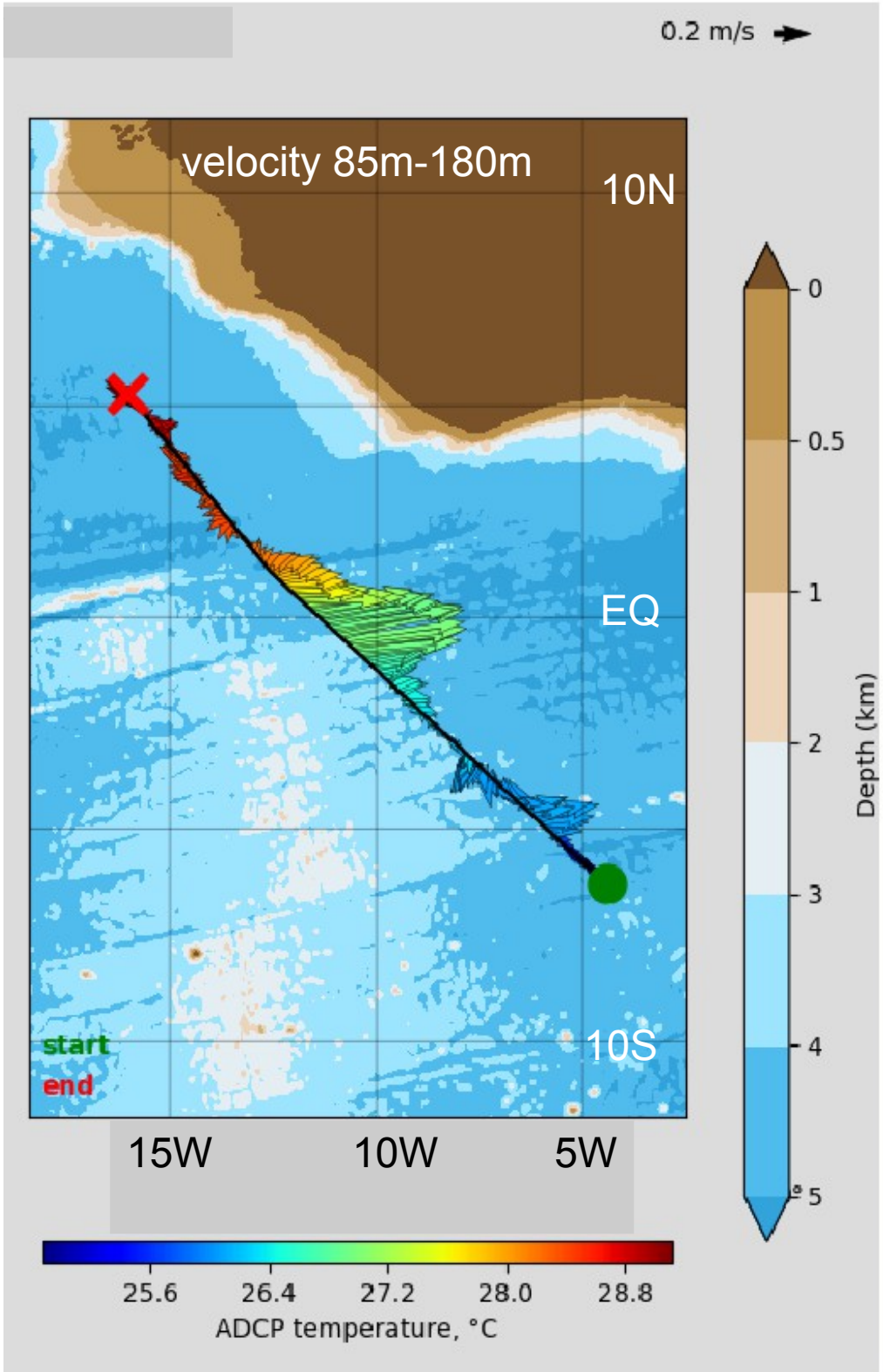
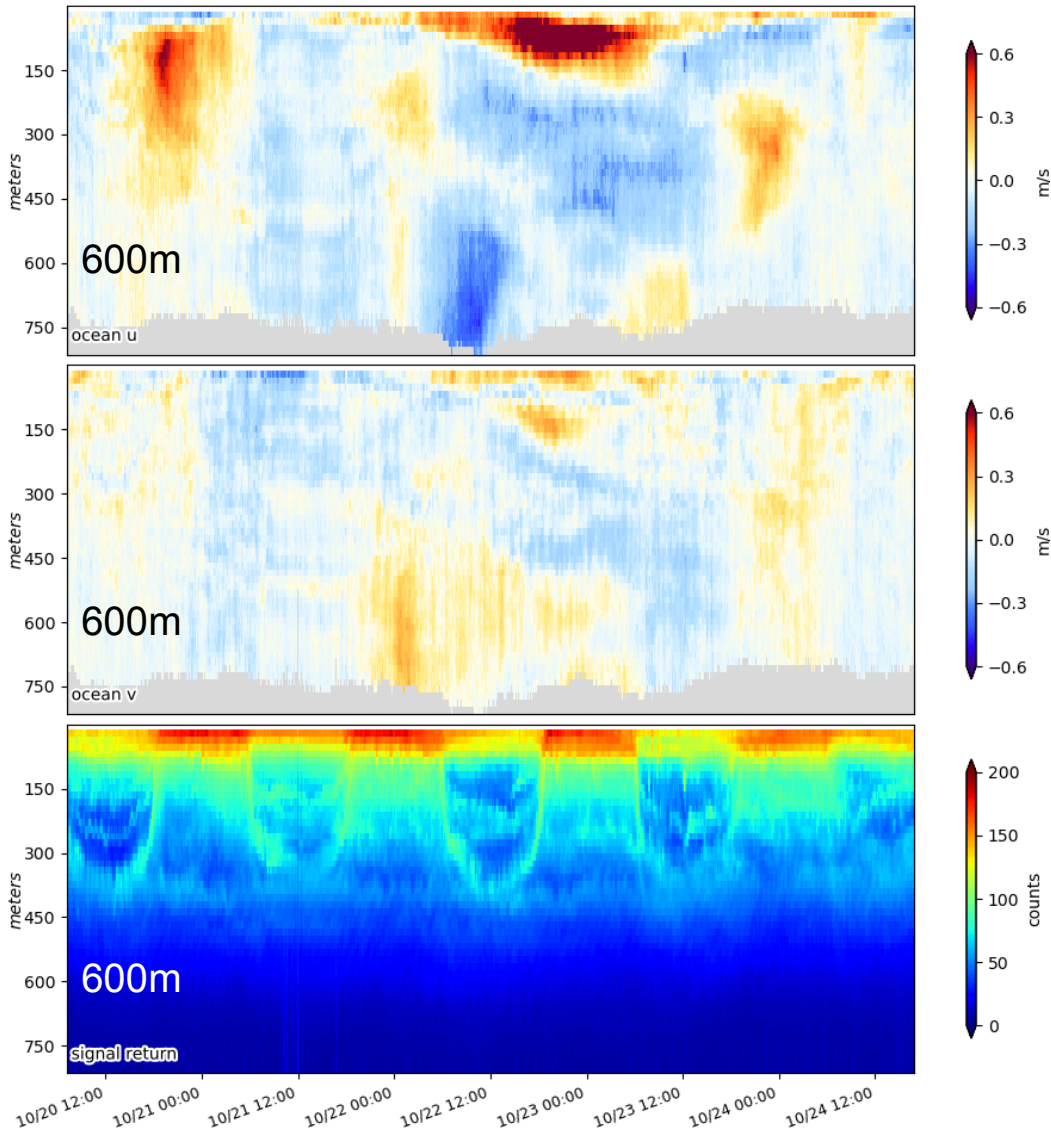




break for tea

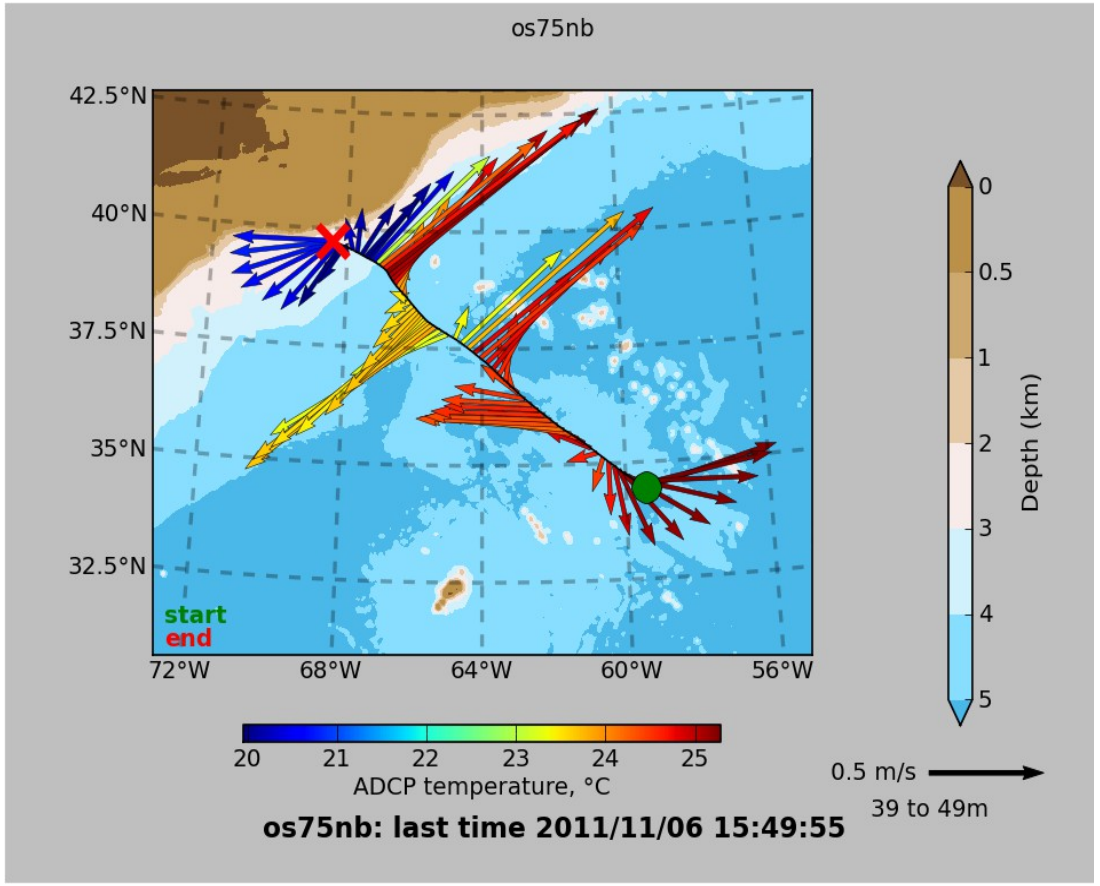
Part 2:

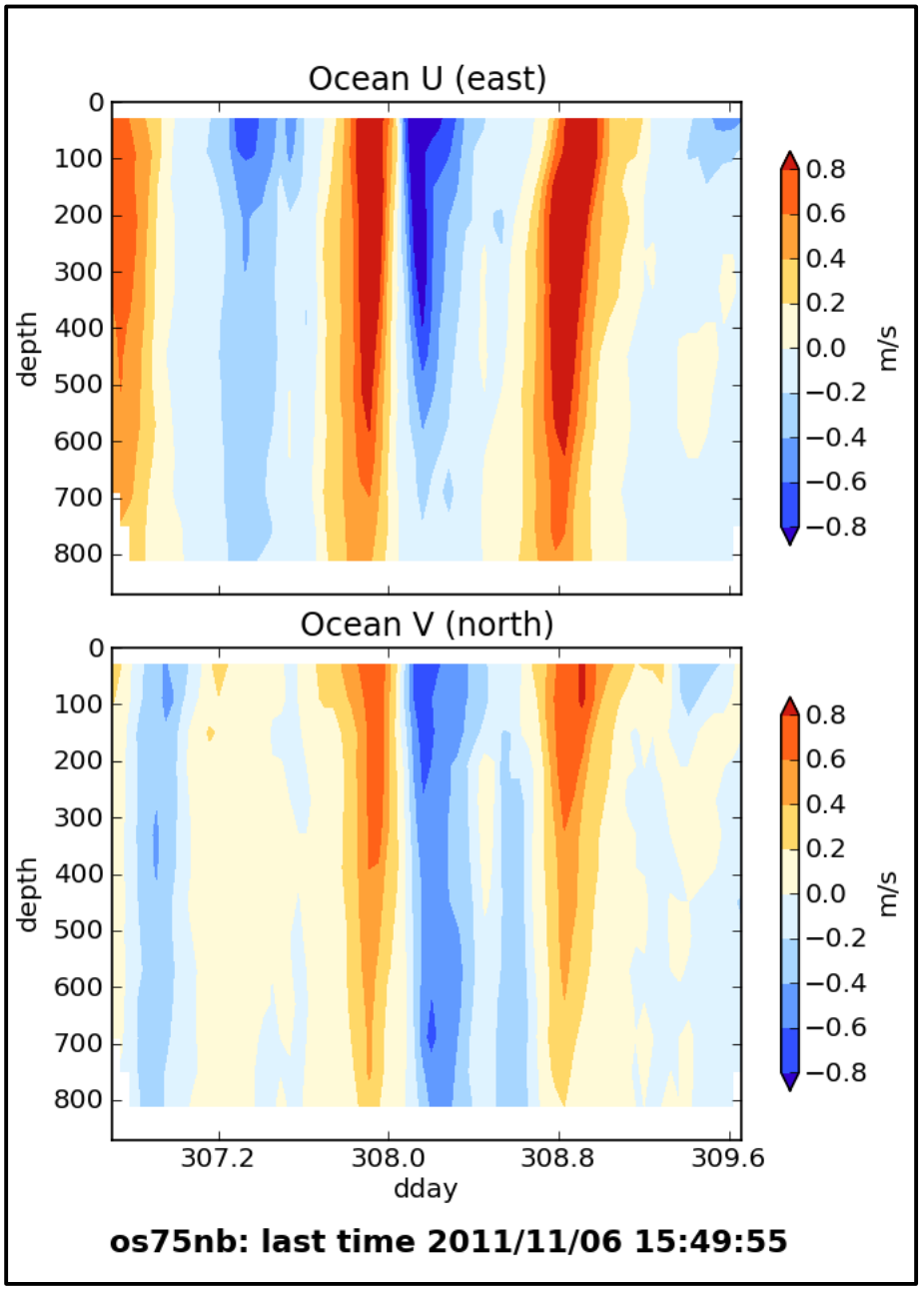
- CODAS processing
- diagnosing errors in ADCP datasets

CODAS Processing

Time, ADCP, Position, Attitude

primitive (raw) data





CODAS Processing Overview

CODAS: **C**ommon **O**cean **D**ata **A**ccess **S**ystem

- Portable (multiple operating systems)
- Self-descriptive (like netCDF)
- Aggregated files (multiple files)
- 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, free (Python)
- Flexible (tweak, tune, patch, augment)

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 routines
- Documented

(*) via VirtualBox pre-configured Linux computer

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: 2 modes

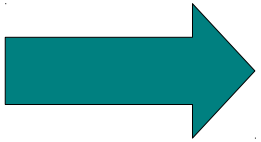
(1) **process single-ping data**

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

(2) **load averaged data** into CODAS database

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

} (no single-ping editing)



Next: "post-processing steps"

CODAS post-processing:

- View figures and logfiles
- Fix heading:
  - patch gappy but accurate heading correction (if relevant)
  - apply time-dependent heading correction
- Determine corrections/calibrations, then apply
  - remaining transducer offset
  - scale factor (if relevant)
  - transducer-GPS offset (in meters)
- Manually edit out bad data (dataviewer.py tutorial)
  - graphically select bins, profiles
  - using thresholds
- check calibrations
- make figures (web page); export data (matlab, netCDF)

CODAS software tools:

- **Tools for or raw (single-ping) ADCP data**:
- visualization of beam values
  - RSSI (signal return)
  - beam velocity
- estimate EA (transducer angle)

RDI ADCPs

- conversion of NMEA strings to “rbin” data files
  - N1R, N2R, N3R (from VmDAS)
  - UHDAS raw serial data
- tools to plot rbin data:
  - plot POSMV quality
  - plot navigation over topography
  - plot one (or compare two) rbin data streams

UHDAS data products

CODAS Processing

- Editing (single-ping)
  - Acoustic interference
  - Bubbles
  - Below bottom
- Editing CODAS database averages (dataviewer.py)
- Interpolate missing heading correction (patch_hcorr.py)
- Apply calibrations
  - Scale factor
  - Rotation
  - Transducer offset (new)

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)

(I) ADCP: Getting Ocean Velocity

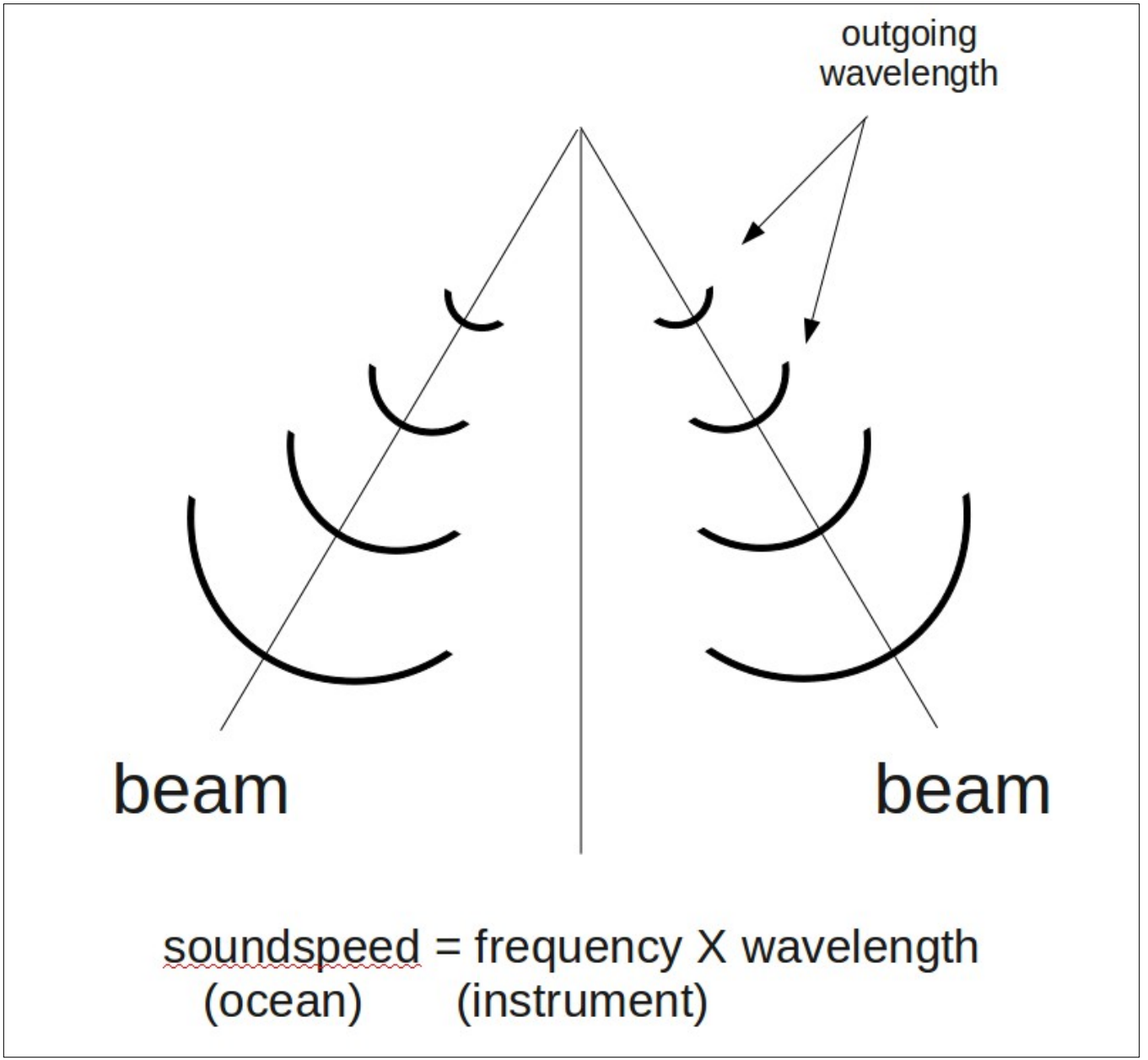
ADCP :

Acoustic

Doppler

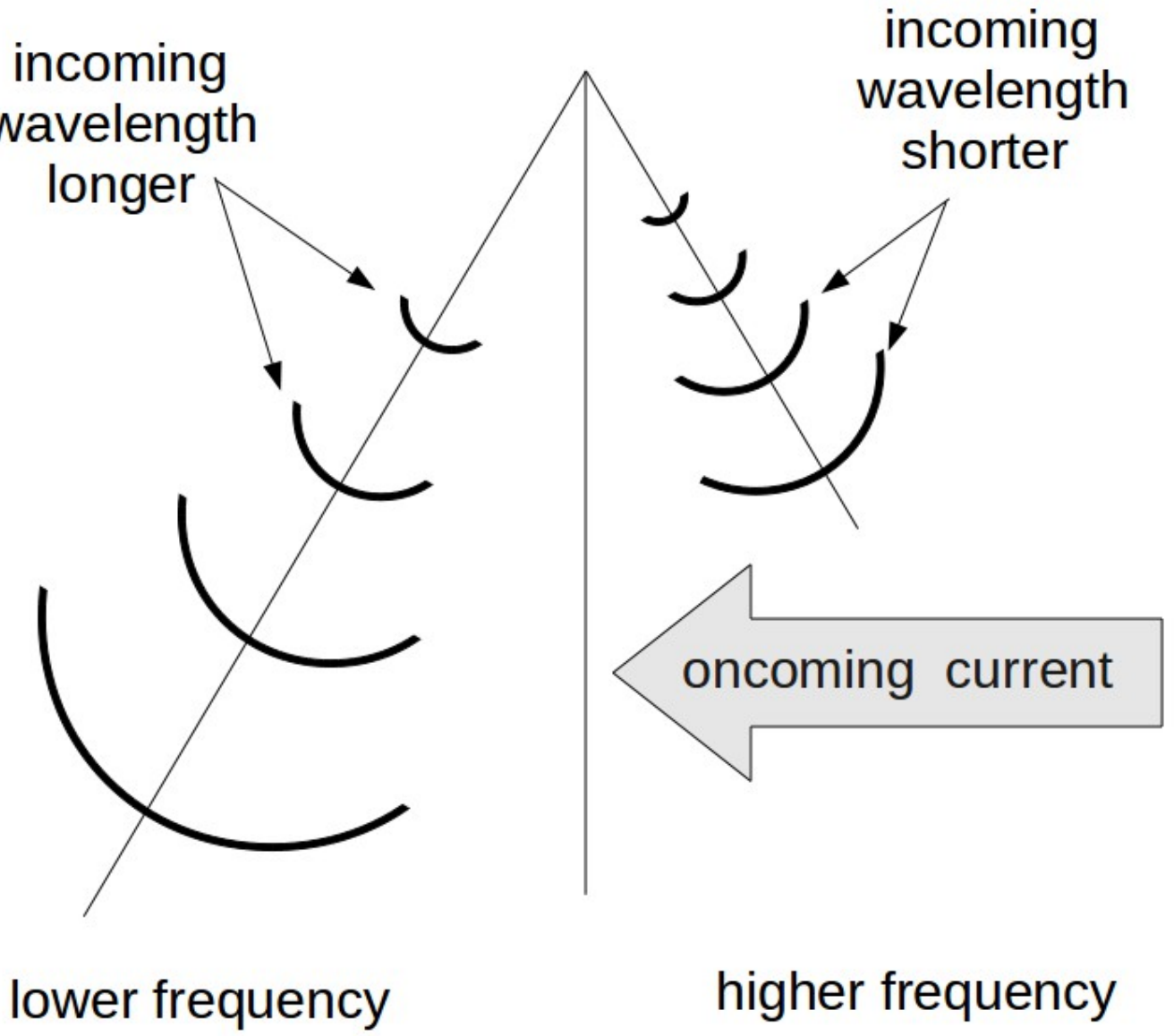
Current

Profiler



ADCP :

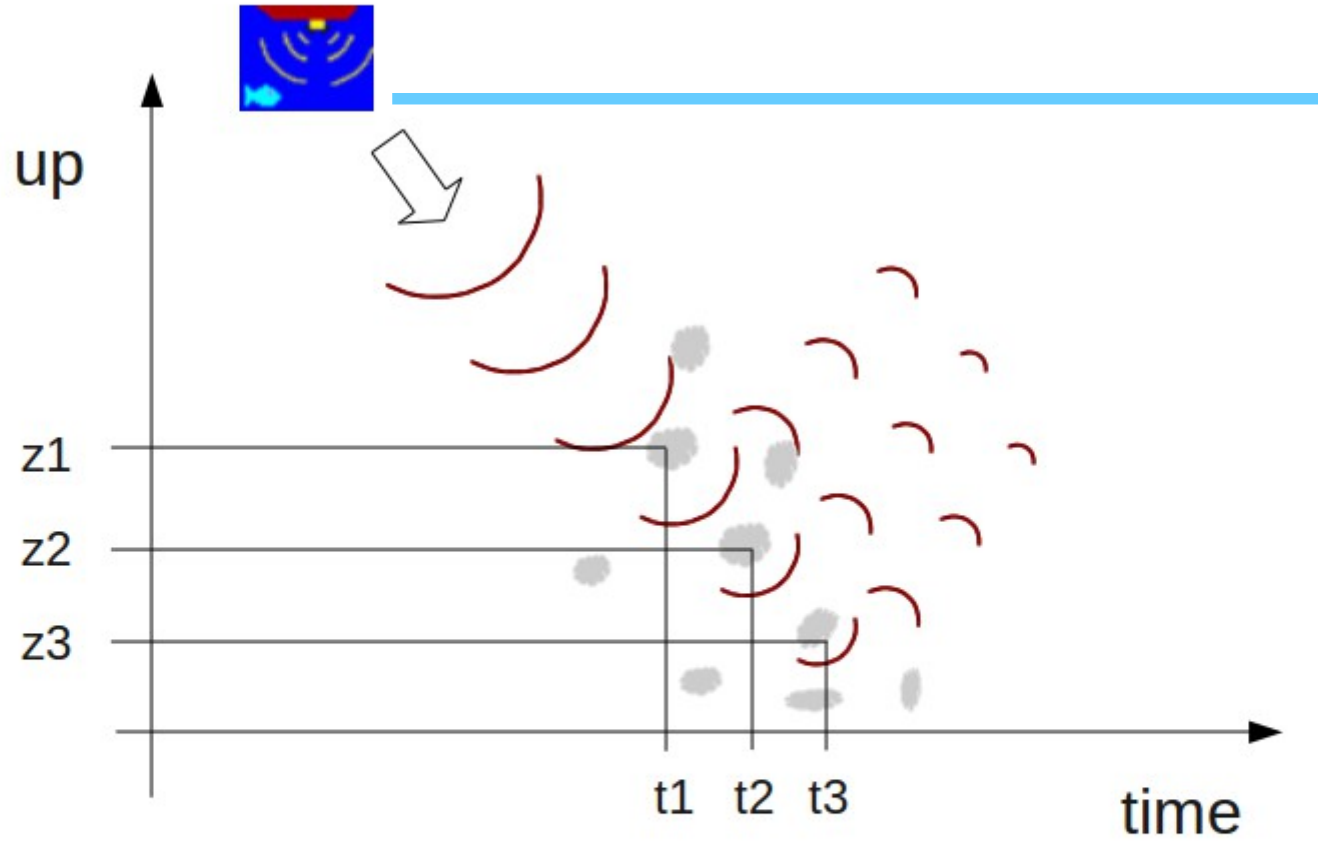
Acoustic
Doppler
Current
Profiler



soundspeed = frequency X wavelength
(ocean) (instrument)

ADCP:

Acoustic
Doppler
Current
Profiler

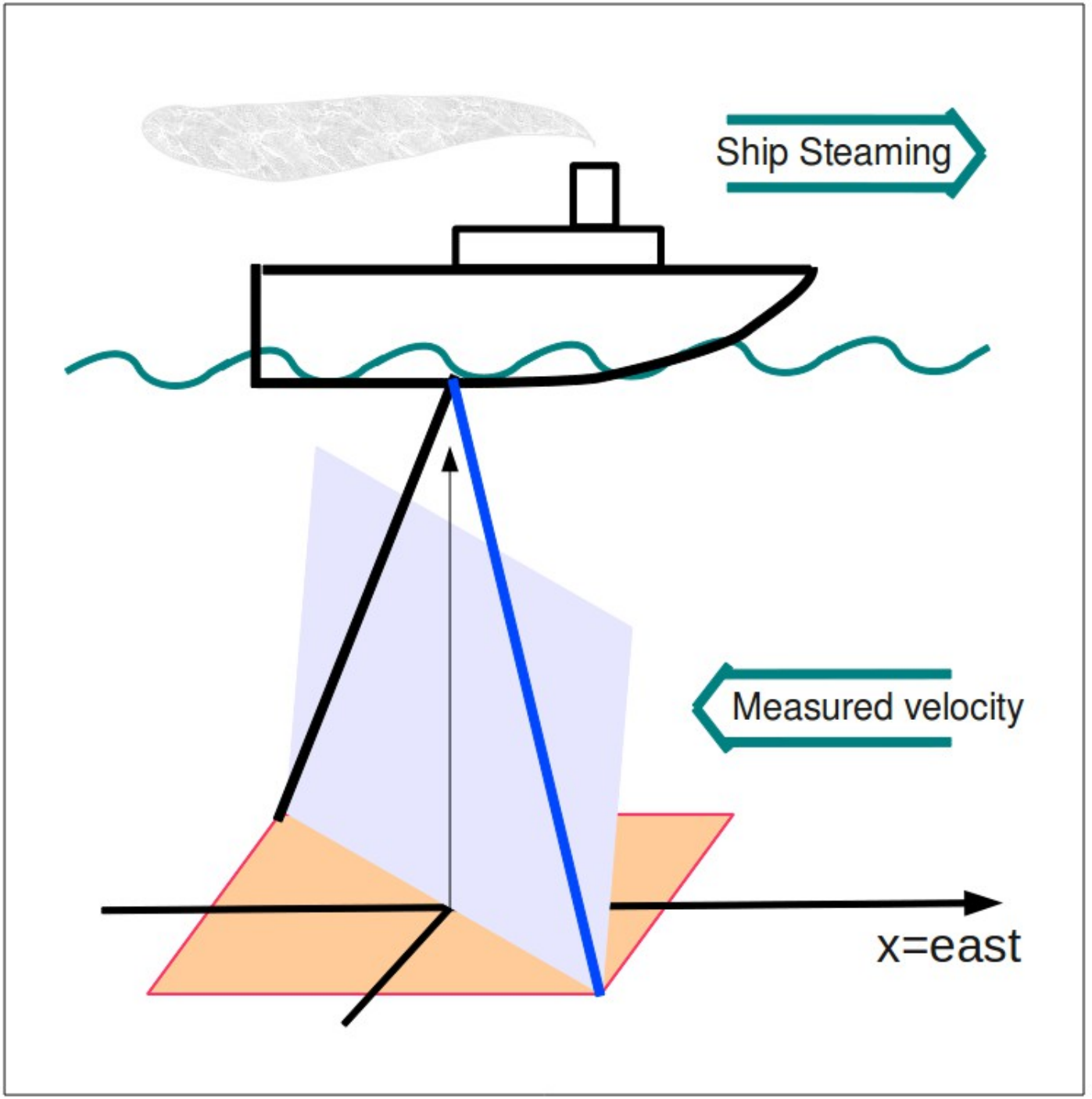


"Gating" the return over time results in "bins" in the vertical, creating a profile of information

ADCP

Getting Ocean Currents

Two opposite beams make a vertical plane

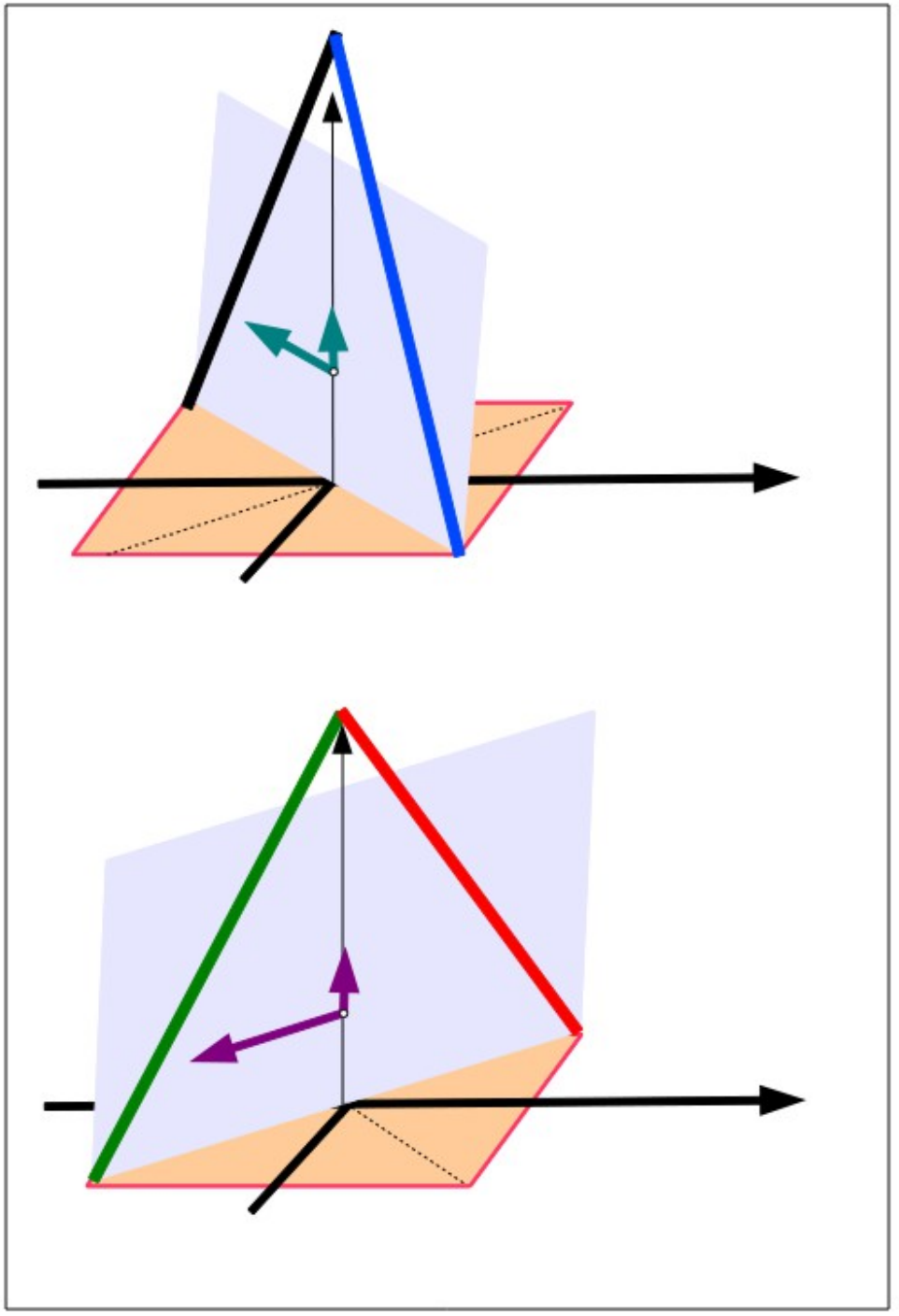


ADCP:

Getting Ocean Currents

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

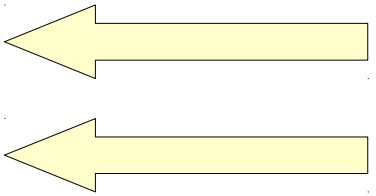
Use the horizontal velocities for determining ocean velocities requires more steps.



ADCP 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

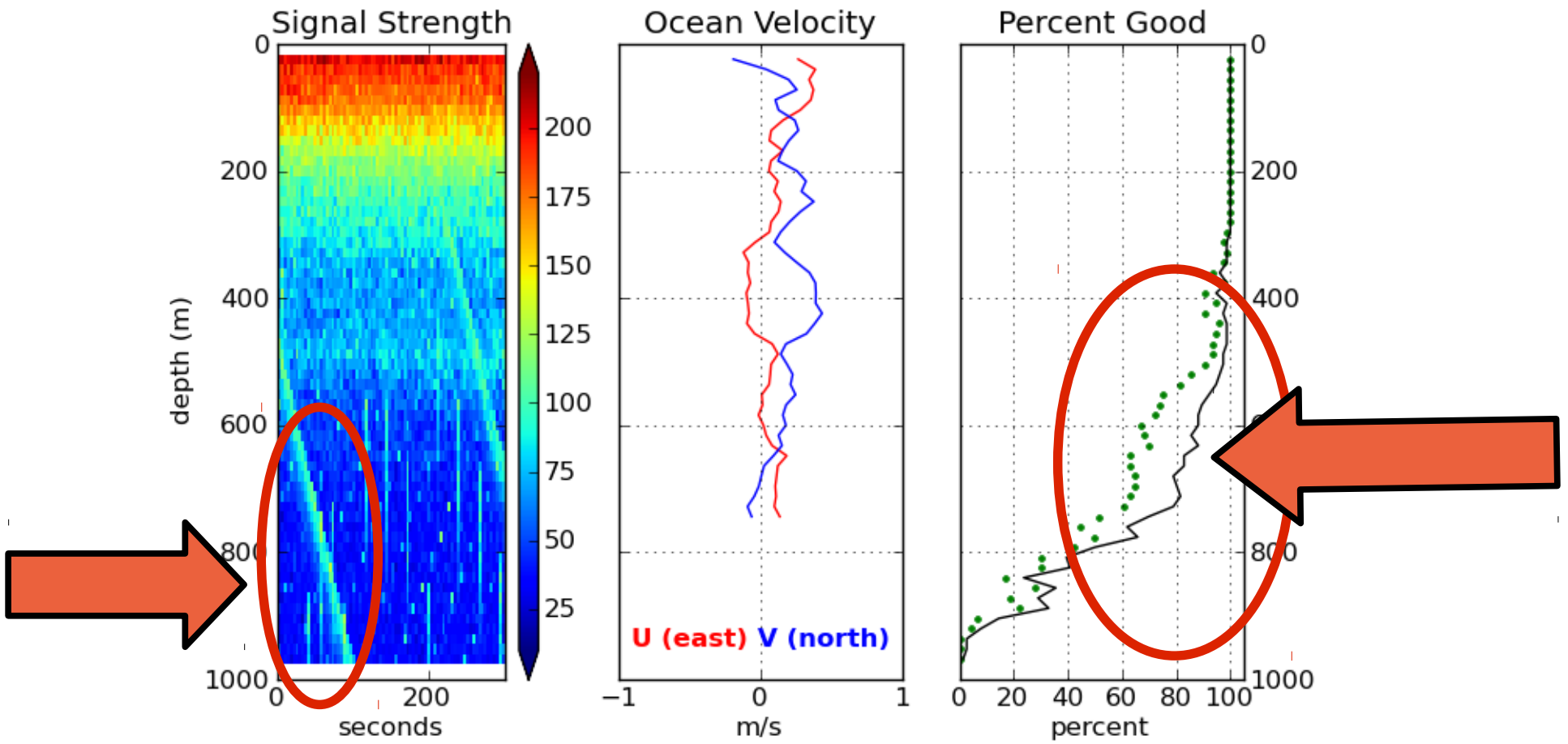
ADCP Single-ping Editing

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

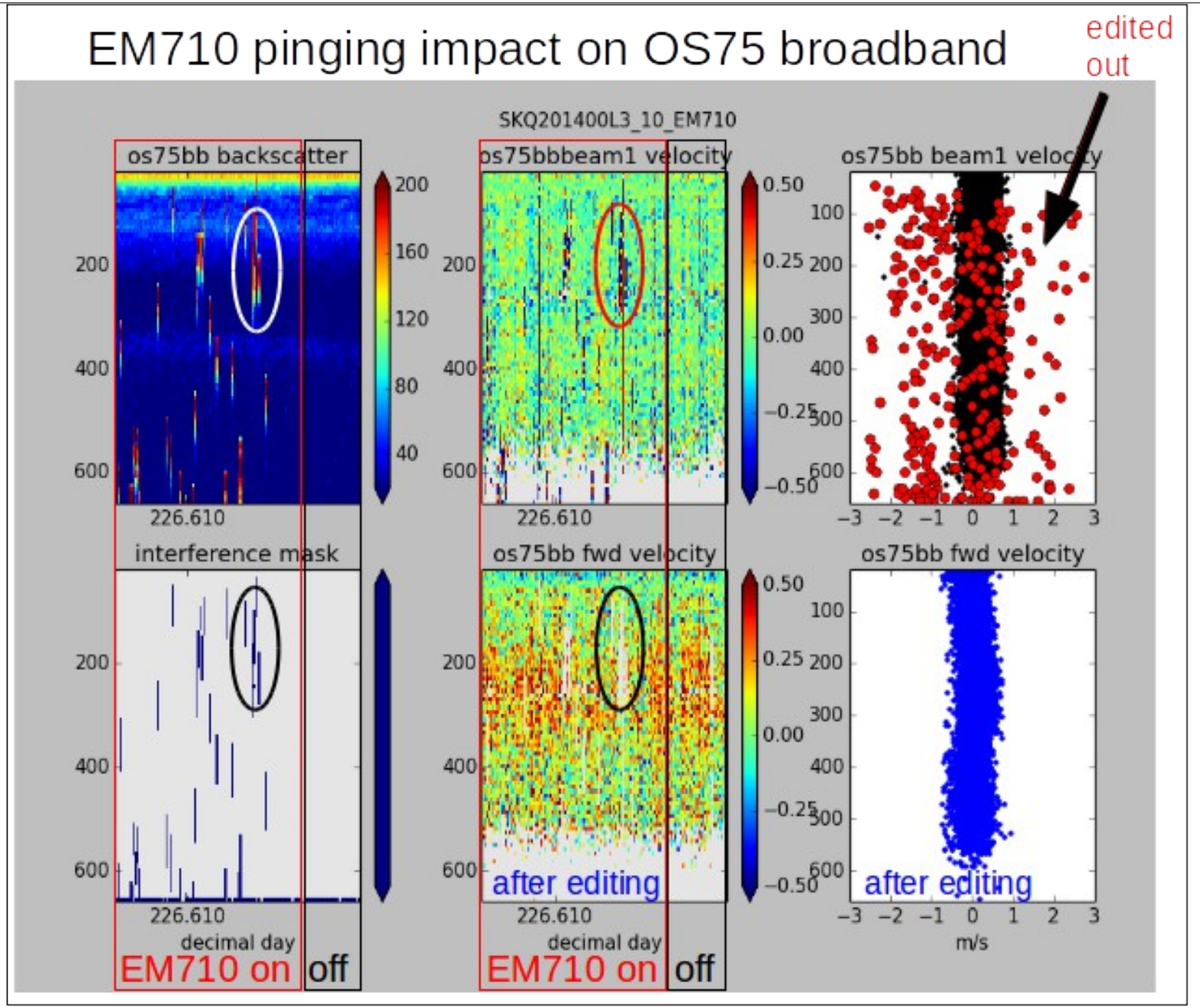
- Acoustic Interference
- Bubbles
- Below bottom

ADCP Processing

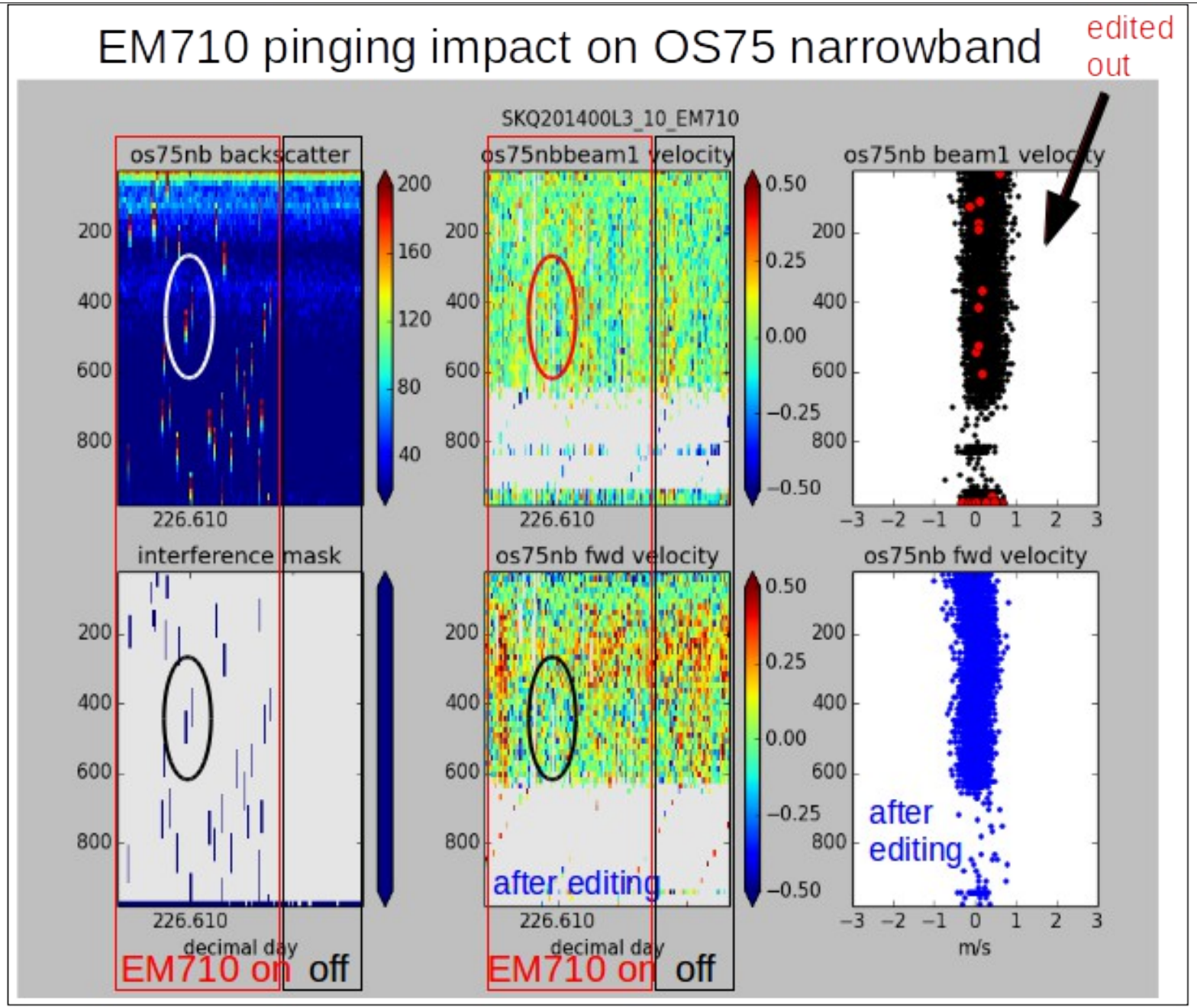
Singleping editing: acoustic interference



ADCP Processing: editing out interference



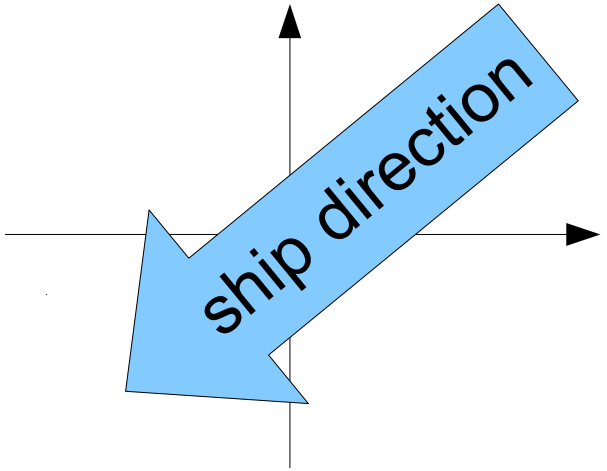
ADCP Processing: editing out interference

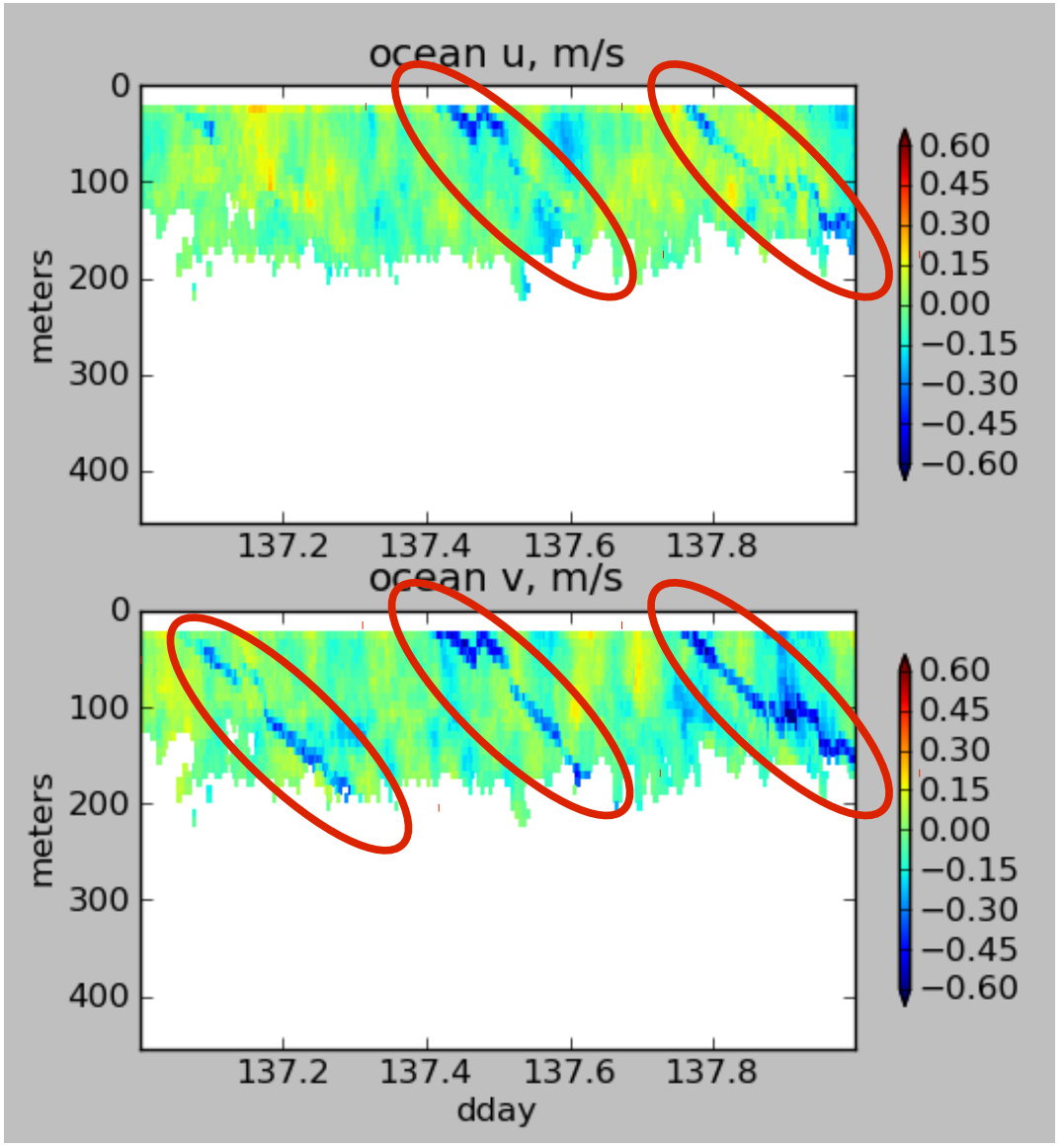


ADCP Processing **without** singleping editing

Averaged
ocean velocities

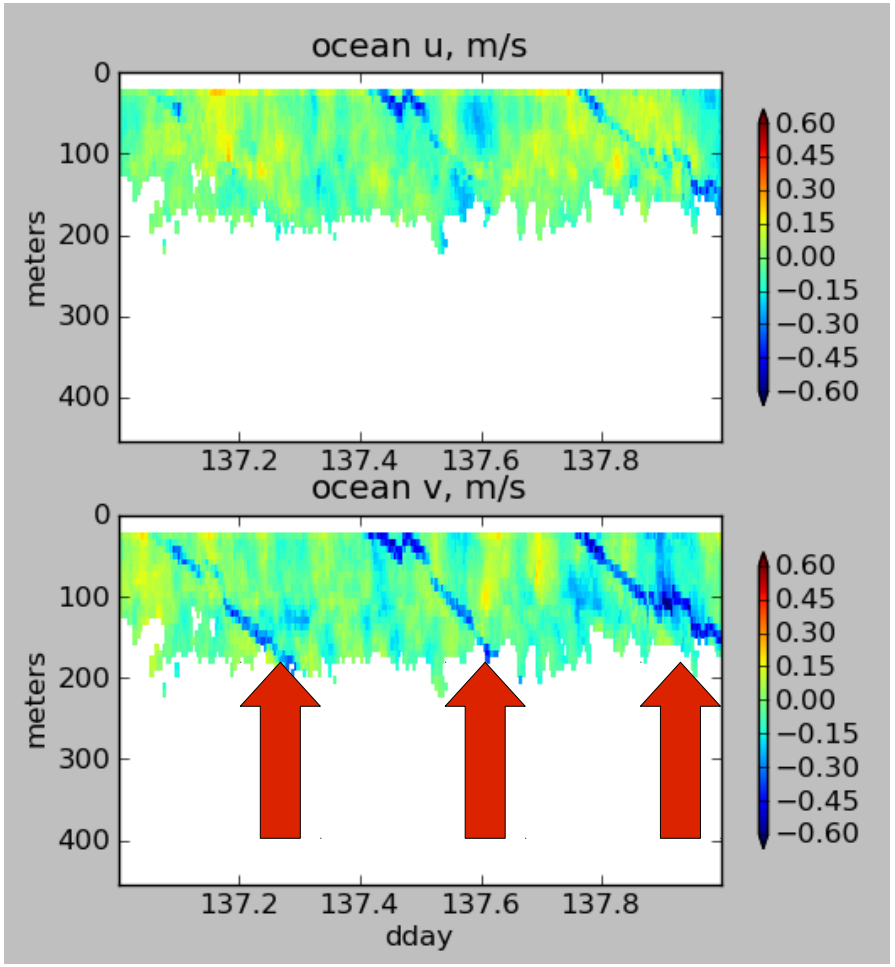
NOTE: along-track
direction bias



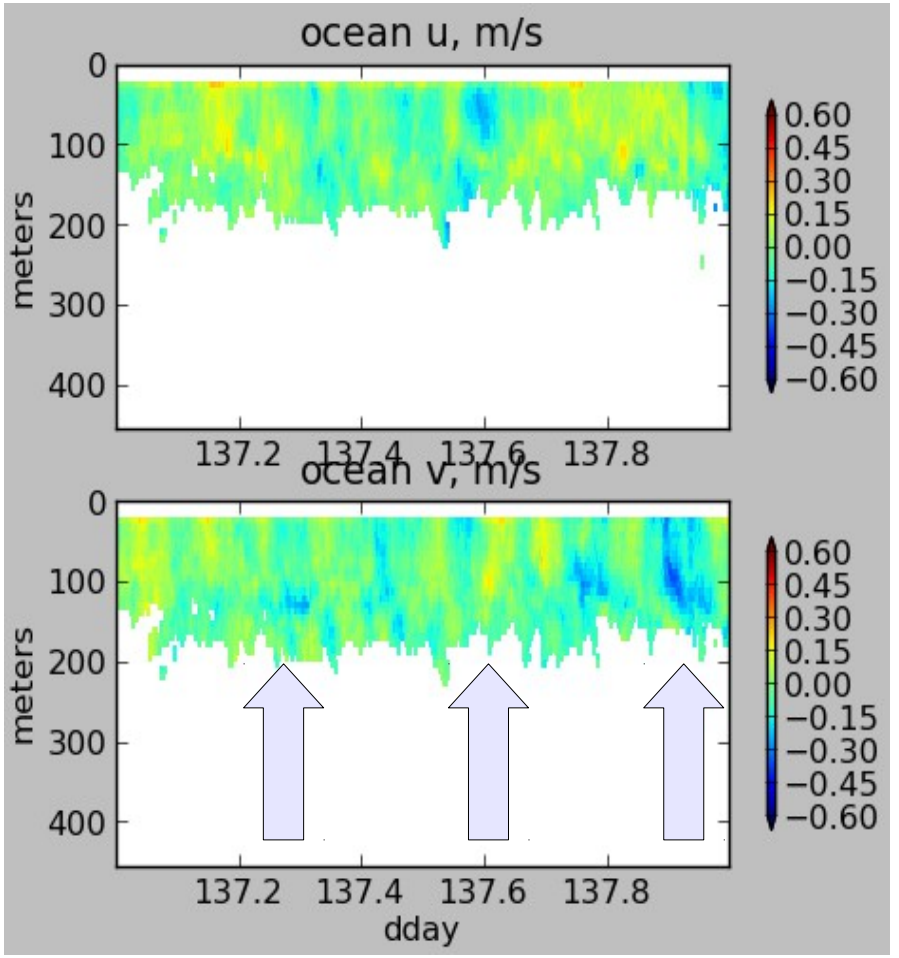


ADCP Processing: acoustic interference

WITHOUT
singleping editing



USING
singleping editing

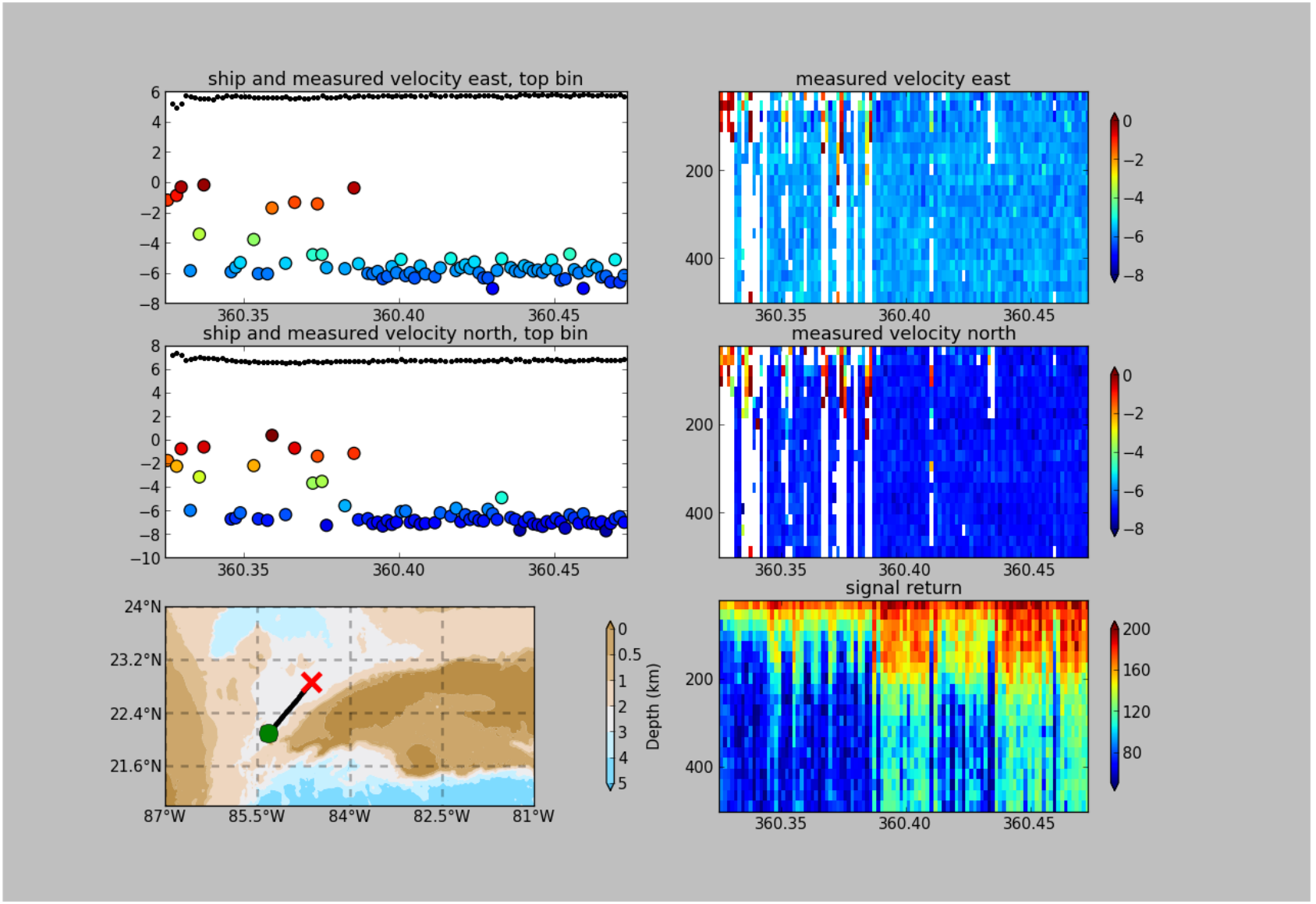


ADCP Single-ping Editing

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

- Acoustic Interference
- Bubbles
- Below bottom

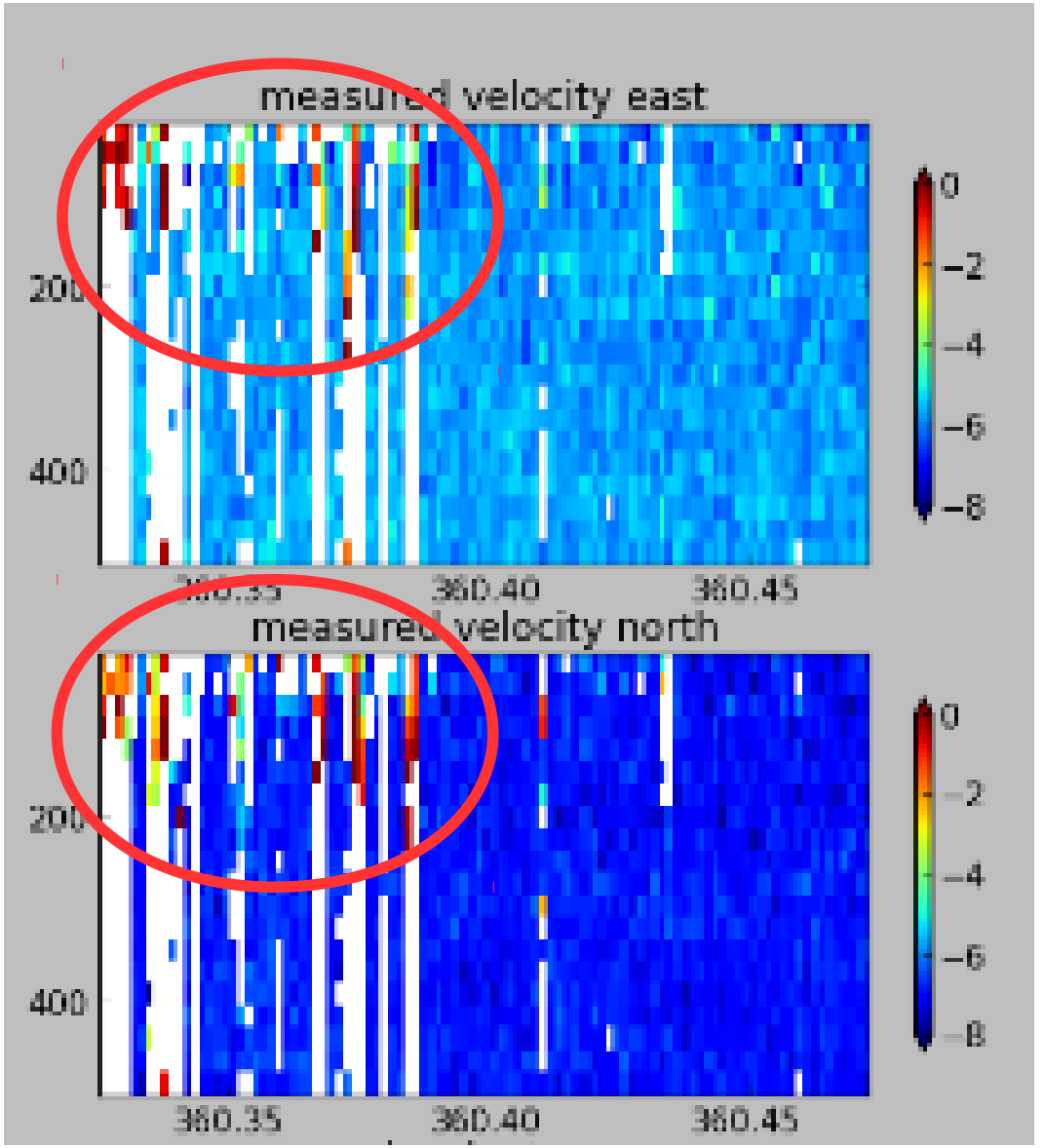
single-ping editing:underway bias



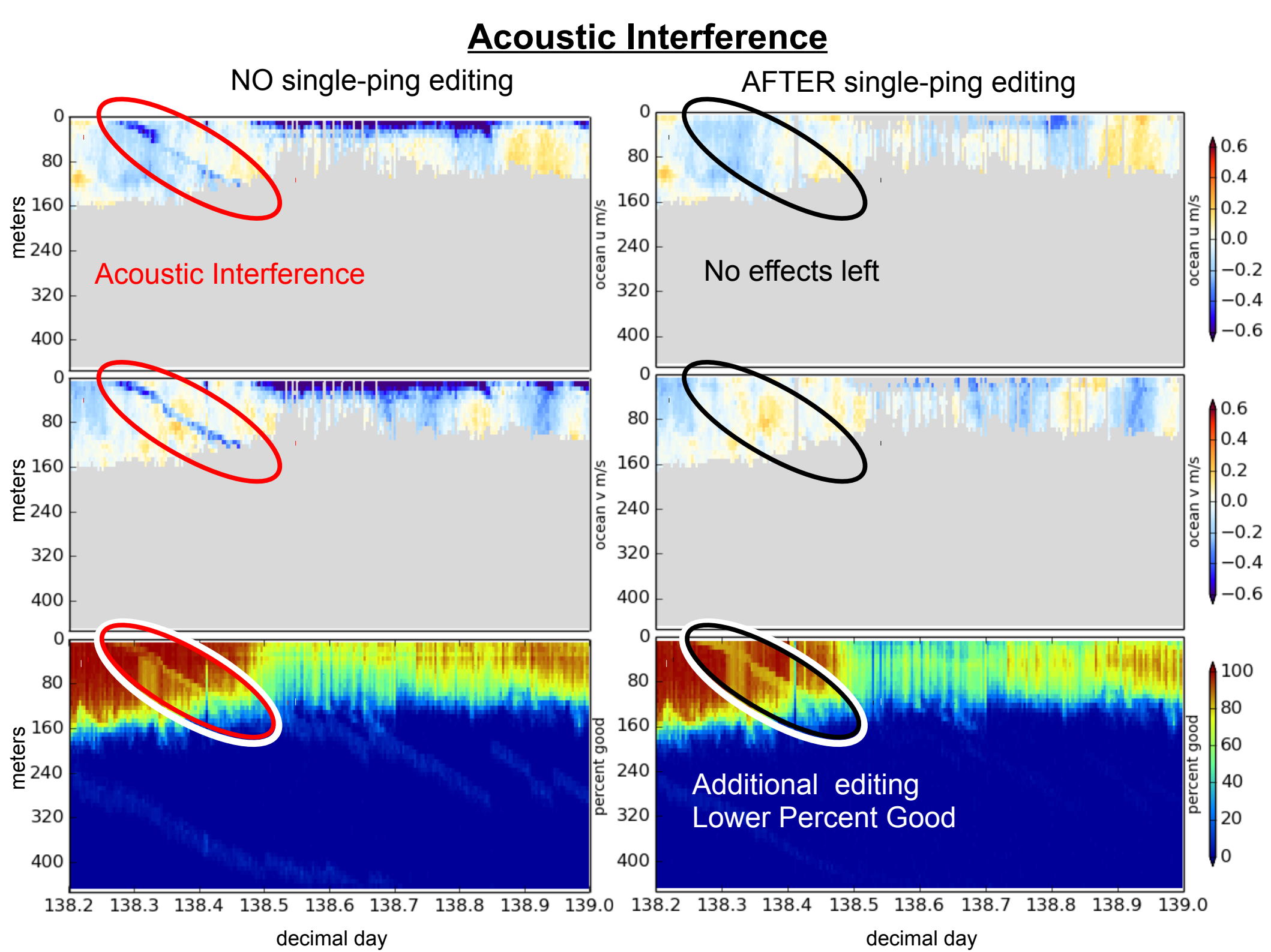
ADCP Data: effect of bubbles

Bubbles:
- short profiles
- strongly biased towards zero

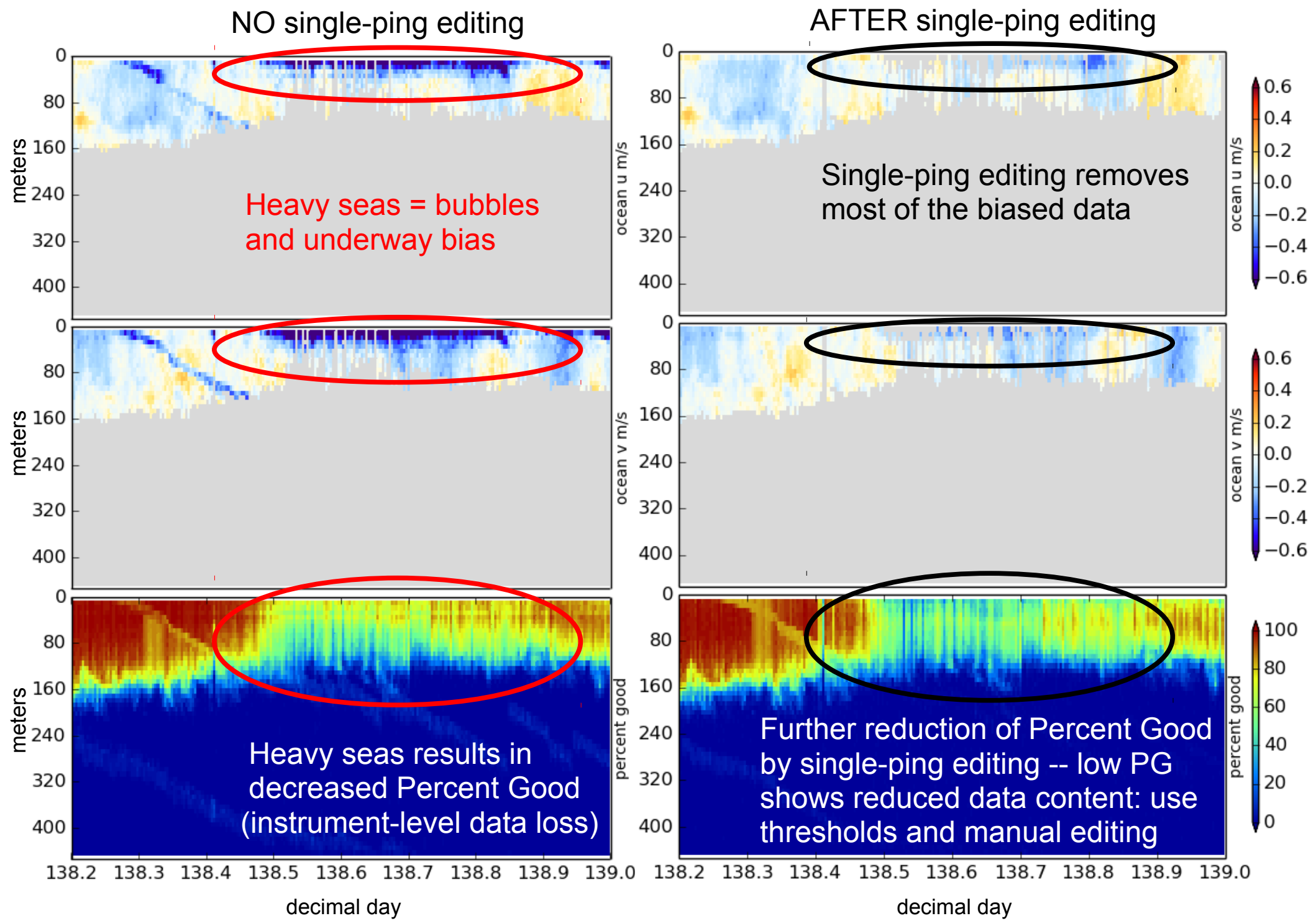
Untreated:
- biased ocean velocities



Acoustic Interference



Bubbles and alongtrack bias



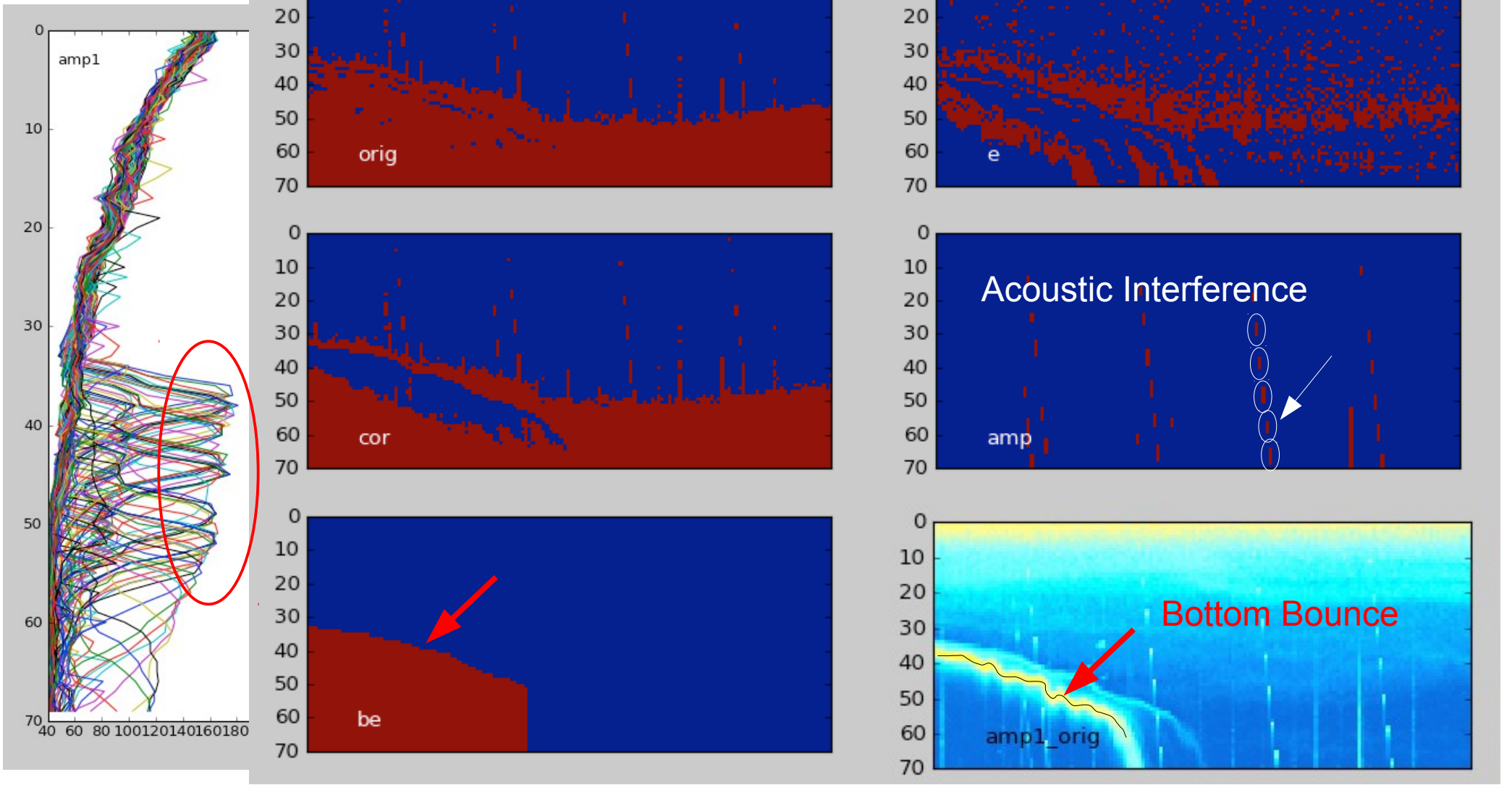
ADCP Single-ping Editing

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

- Acoustic Interference
- Bubbles
- Below bottom

Bottom Editing:

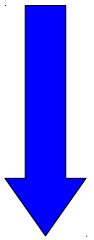
- remove acoustic interference, identify maximum amplitude
- calculate region of side-lobe interference
- flag as BAD all data below the bottom or with side-lobe interference



CODAS 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
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  - Transducer offset (new)
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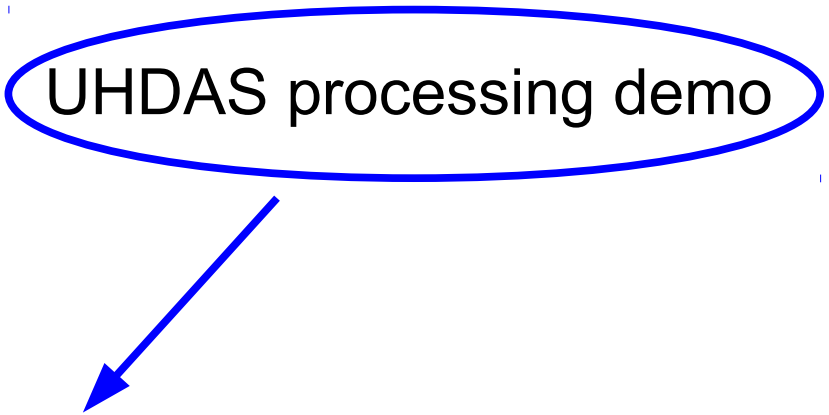


CODAS Postprocessing

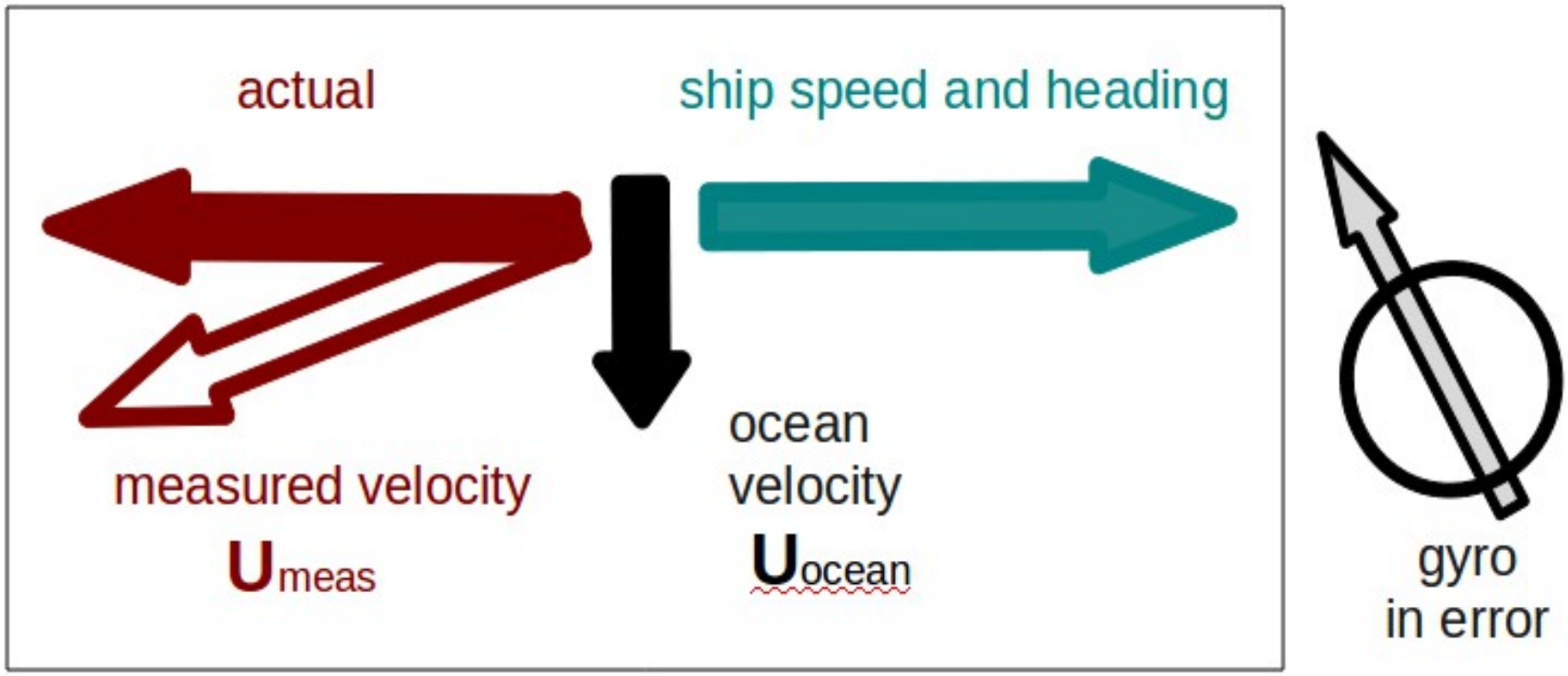
- Editing (single-ping)
  - Acoustic interference
  - Bubbles
  - Below bottom
- Interpolate missing heading correction
- Apply calibrations
  - Rotation
  - Scale factor
  - Transducer offset (new)
- Manually edit CODAS database averages “gee-autoedit”

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
    - 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 with QC fields)

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

Angle applied comes from

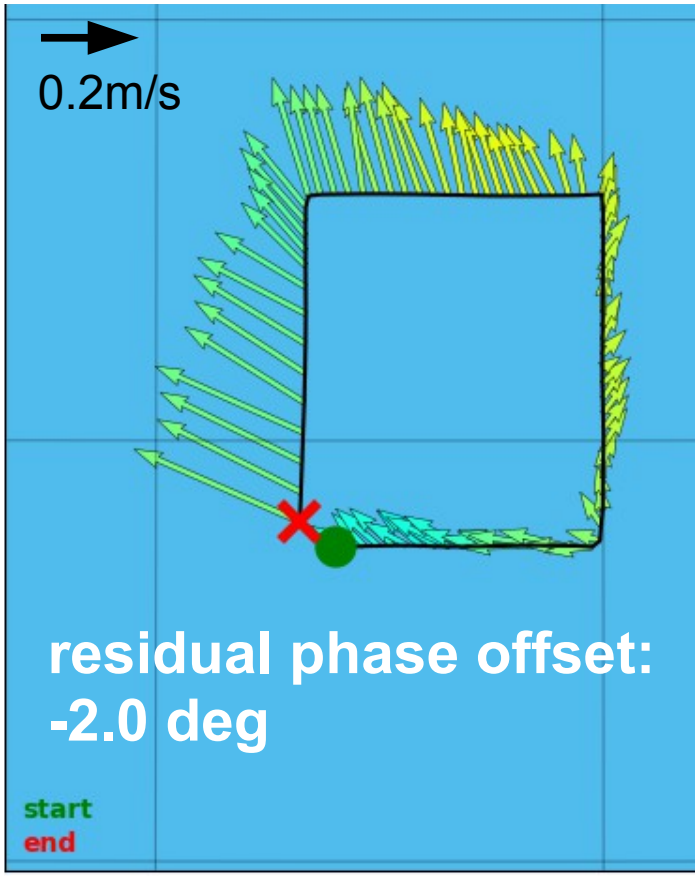
- Transducer angle (beam “3” clockwise from bow)

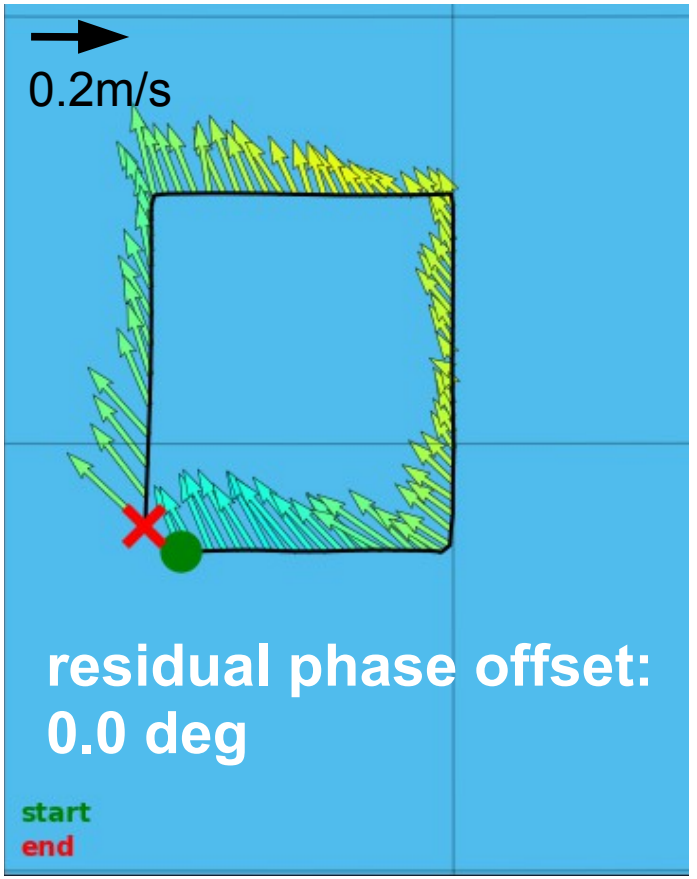
This is a **constant value** for the whole cruise

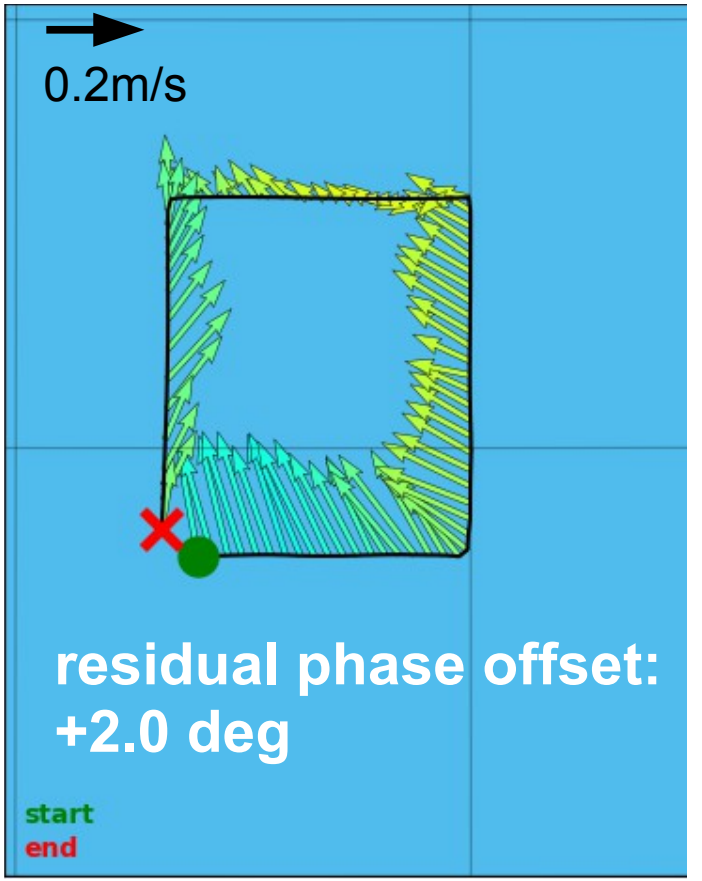
Examples of error in transducer angle follow...

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)

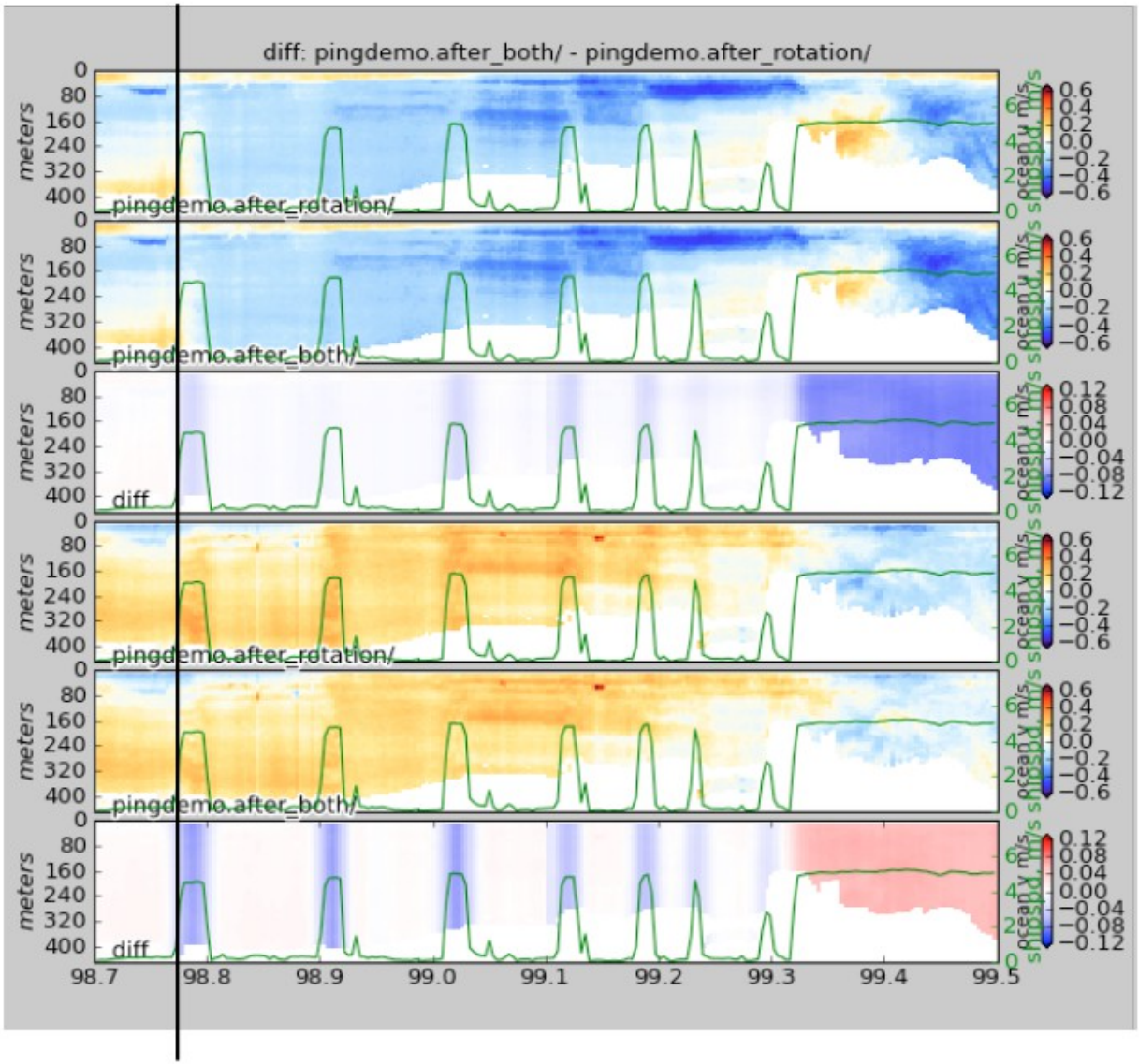
Ocean U (after scalefactor)

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

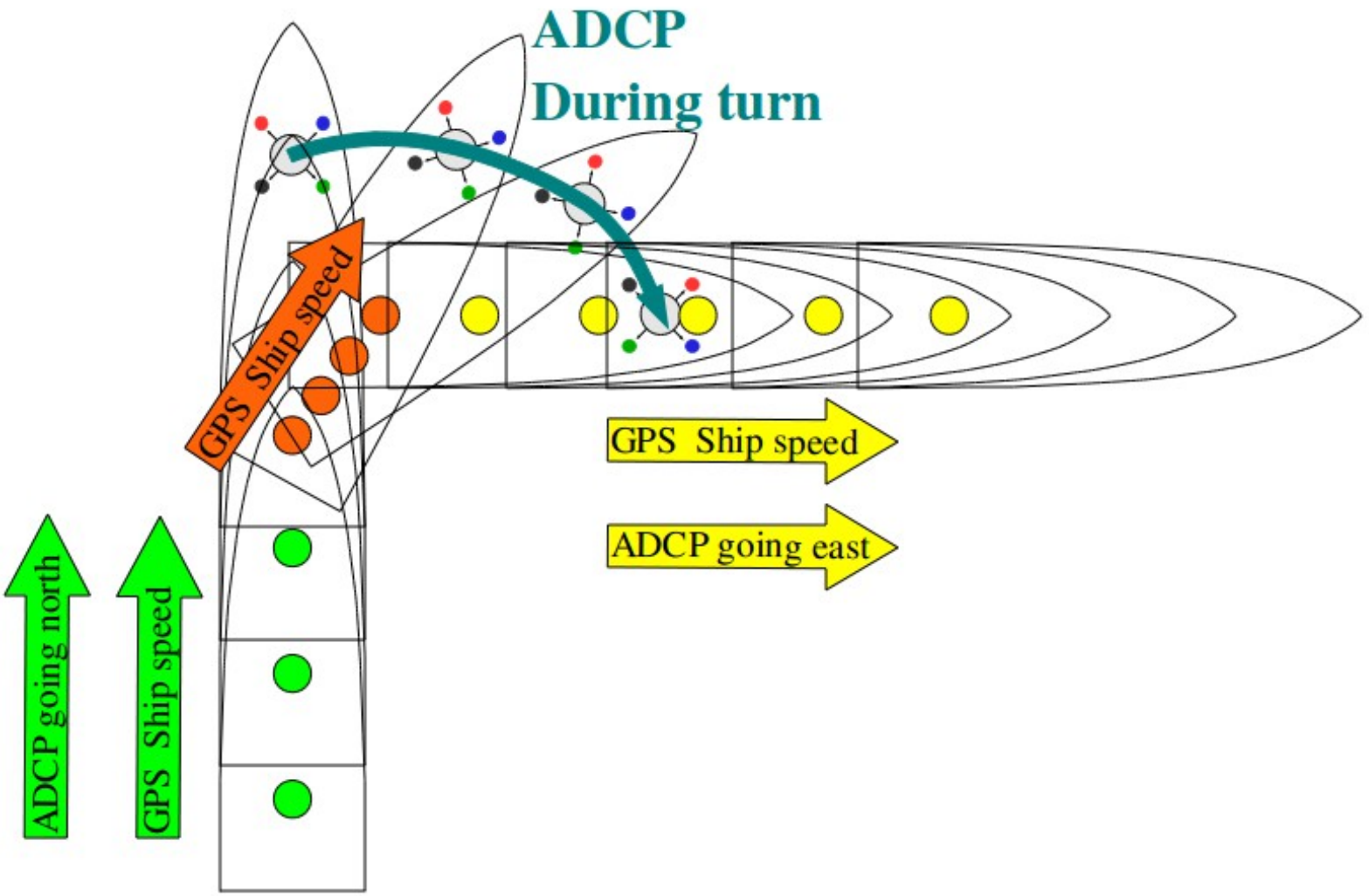
(2) Along-track error:

- 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

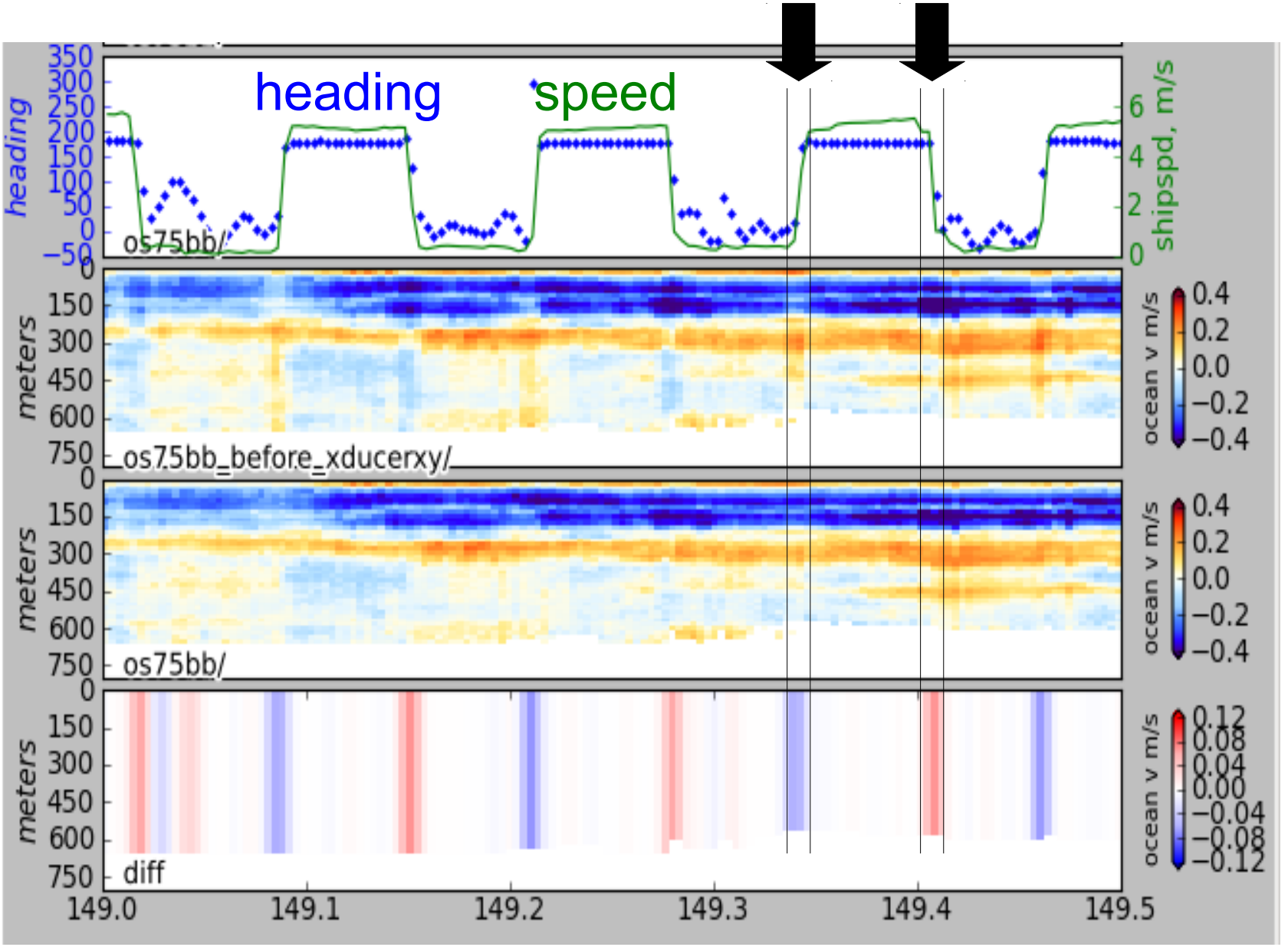


Transducer offset from GPS--error occurs: **transition** between on-station and underway

...using actual location

...using shifted GPS location

difference



lunch break

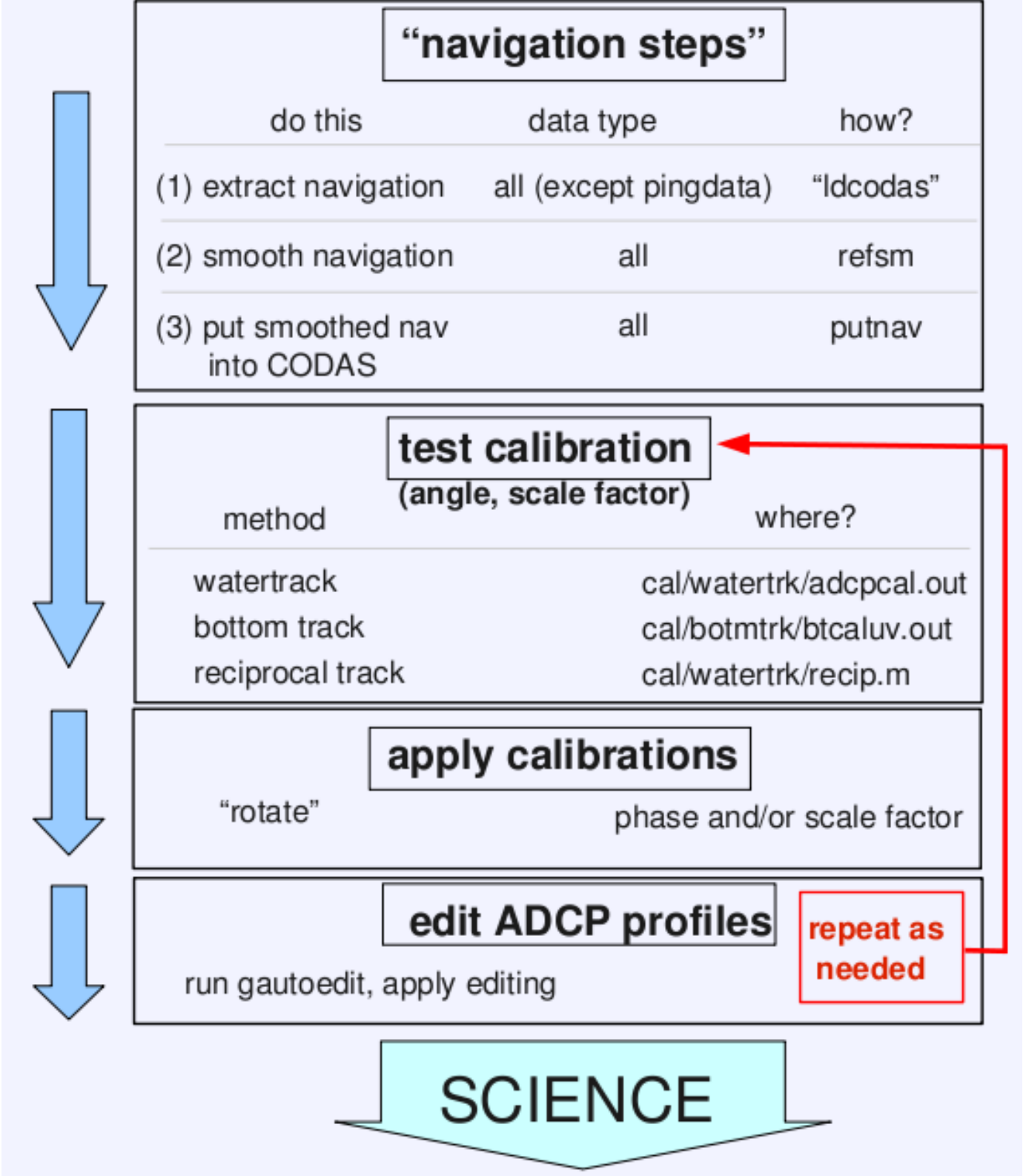
CODAS Processing

- practical matters

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

These steps
use only the
CODAS files
so work on
any averaged
data, regardless
of the source
- single-ping editing
- LTA/STA
- PINGDATA



UHDAS cruise directory structure

subdirectory	contents	importance	back up for ...
raw	all raw data	critical	archiving
rbin	intermediate files	nice to have	anyone who gets 'raw'
gbin	intermediate files	nice to have	anyone who gets 'raw'
proc	processed data • codas database • underway figure archive • matlab files	final at-sea product CODAS PROCESSING	science CD after cruise
reports	mini-webpage with metadata and overview of processed data	nice to have (only in modern cruise directories)	science CD after cruise

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

VmDAS vs/ UHDAS

- Wed AM

Overview: Matching UHDAS and VmDAS Components

Category	UHDAS	VMDAS
Acquisition	see	next
Logfiles Settings		page
Transformations Averaging	see	2nd
Preliminary processing Monitoring		page

Data flow: acquisition

task	UHDAS	VmDAS
• talk to instrument	DAS.py	vmdas.exe
• timestamps + write to disk:		
- ADCP(s)	raw/adcp/*.raw	*.ENR
- NMEA (serial, udp)	raw/serial/*.msg	*N1R, N2R, N3R
• write intermediate files	rbin/serial/*.rbin	
• correct the timestamps:		
- write lookup table	gbin /ztimefit.txt :	
- write ADCP data again		*ENS
• write logfiles	raw/log/*	*.LOG
• note settings	raw/config	*.VMO

Data flow: editing + averaging + calibration = preliminary processing

task	UHDAS	VmDAS
• transform to earth:	(in memory)	*.ENX
• create averages:		
- **edit single-ping earth data**:	(in memory)	--
- average, write averages	CODAS database	*STA, *LTA
• **preliminary processing:**		
- assess calibration:	**watertrack**	
	bottomtrack	
	ADCP-GPS offset	--
• monitoring, access		
- make plots	web site on ship	PC monitor
- store plots	**- web site on ship**	--
	- processing dir	--