Shipboard ADCP in the US Academic Research Fleet: UHDAS Acquisition and CODAS processing
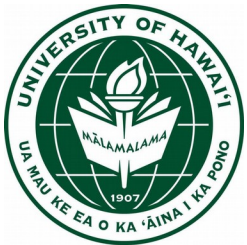
AUF Marine Center, Seward Alaska
June 5, 2023

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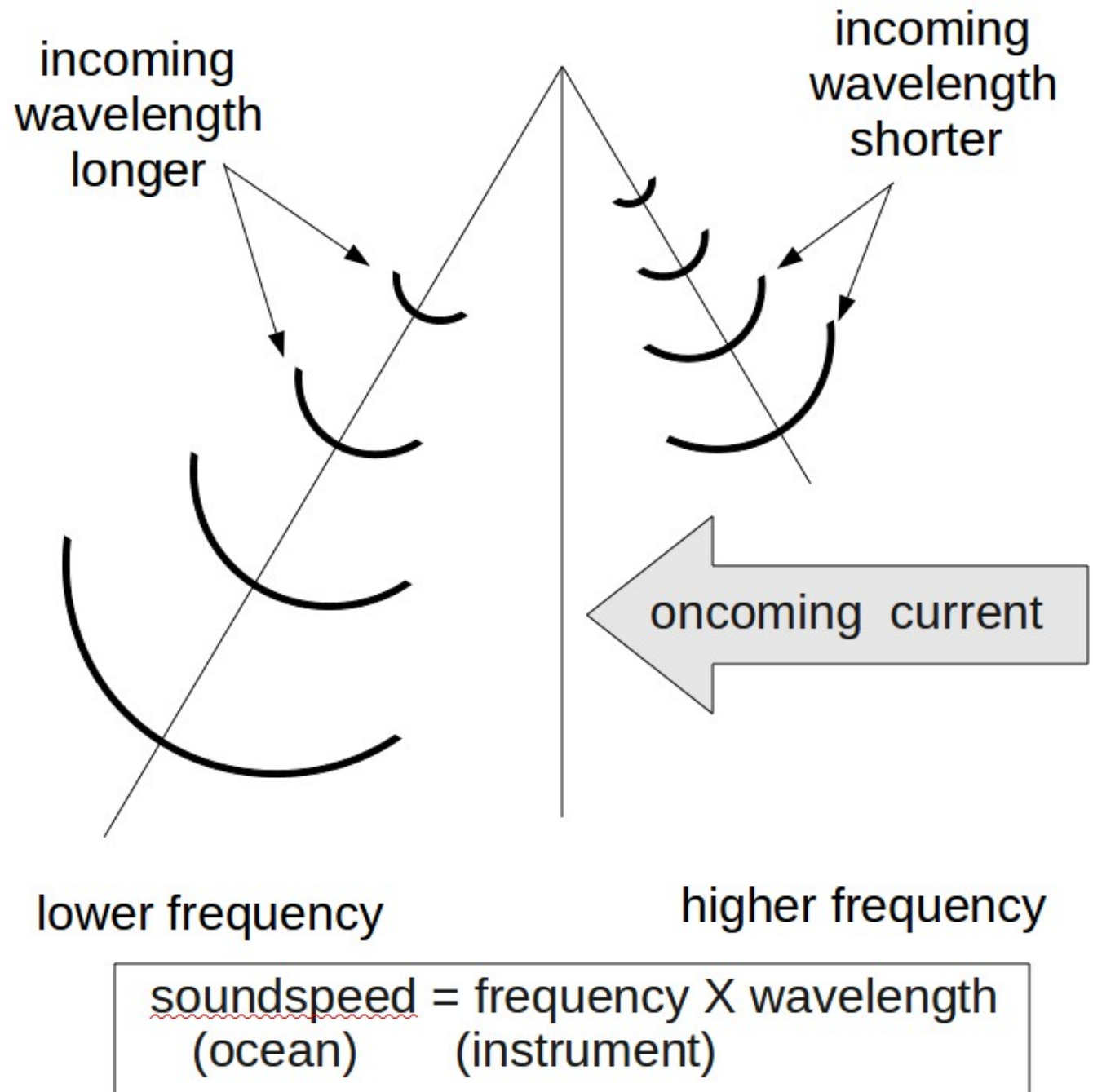https://currents.soest.hawaii.edu
https://uhdas.org

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

ADCP

Acoustic
Doppler
Current
Profiler

incoming
wavelength
longer

incoming
wavelength
shorter

oncoming current

lower frequency

higher frequency

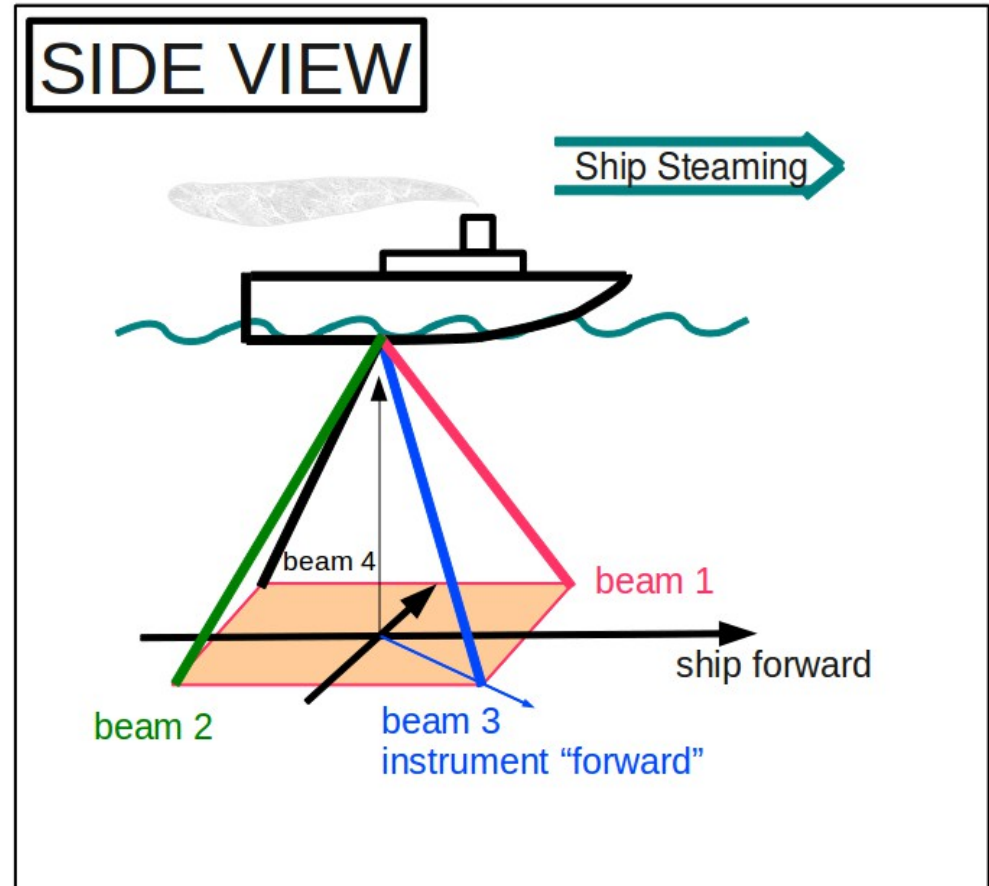soundspeed = frequency X wavelength
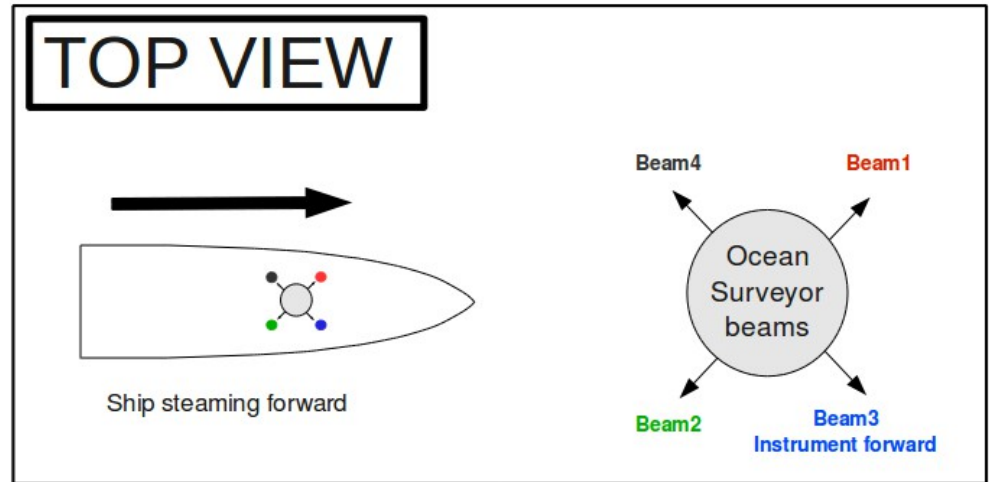(ocean)   (instrument)

ADCP
Getting Ocean Currents

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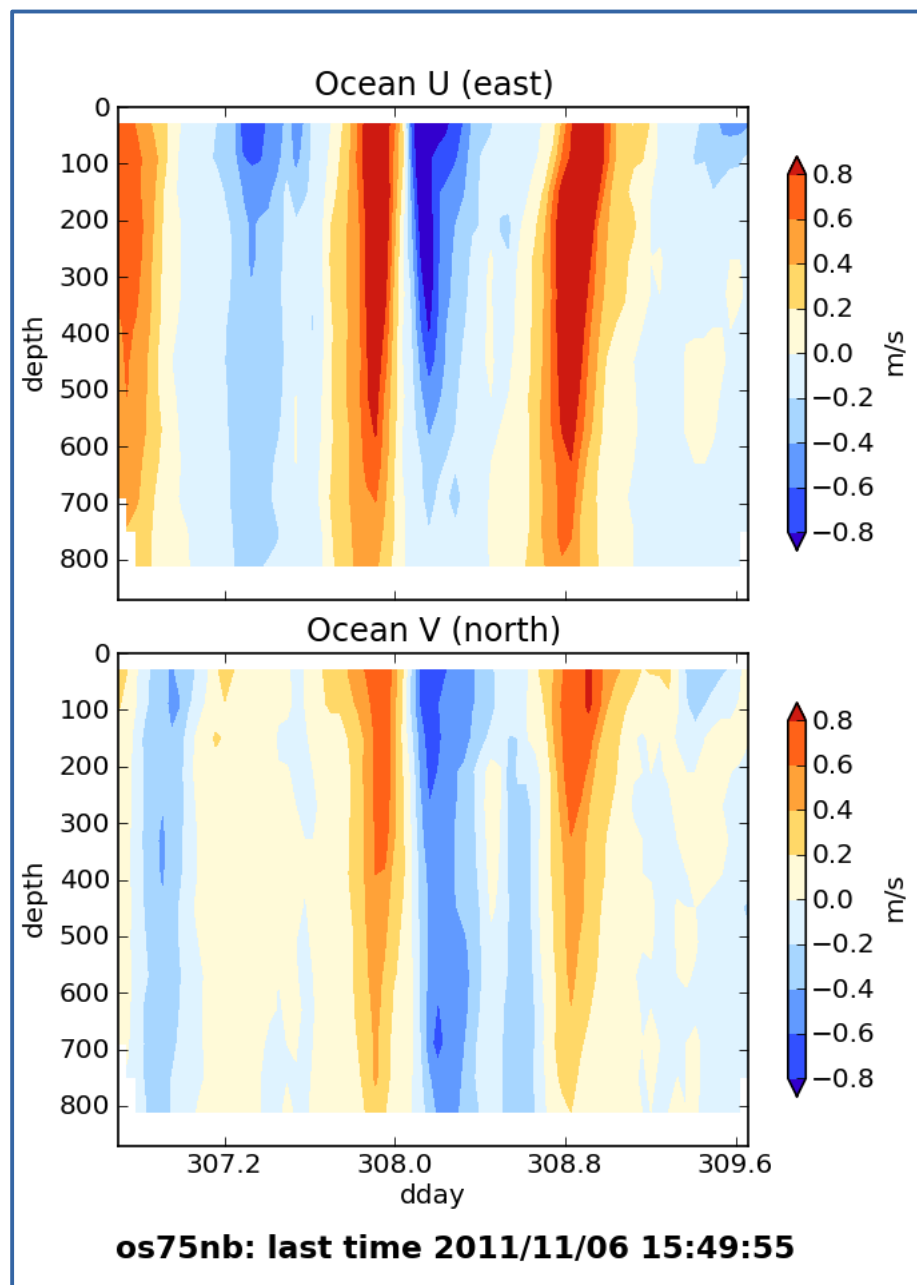- usually 45deg starboard of forward

TOP VIEW

Ship steaming forward

Ocean Surveyor beams

Beam4 Beam1
Beam2 Beam3 Instrument forward

SIDE VIEW

Ship Steaming

beam 4

beam 1

beam 2

beam 3 instrument "forward"

ship forward

Time, ADCP, Position, Attitude

primitive (raw) data

After Processing

AfterProcessing

os75nb

start
end

0.5 m/s
39 to 49m

os75nb: last time 2011/11/06 15:49:55

Ocean U (east)

Ocean V (north)

os75nb: last time 2011/11/06 15:49:55
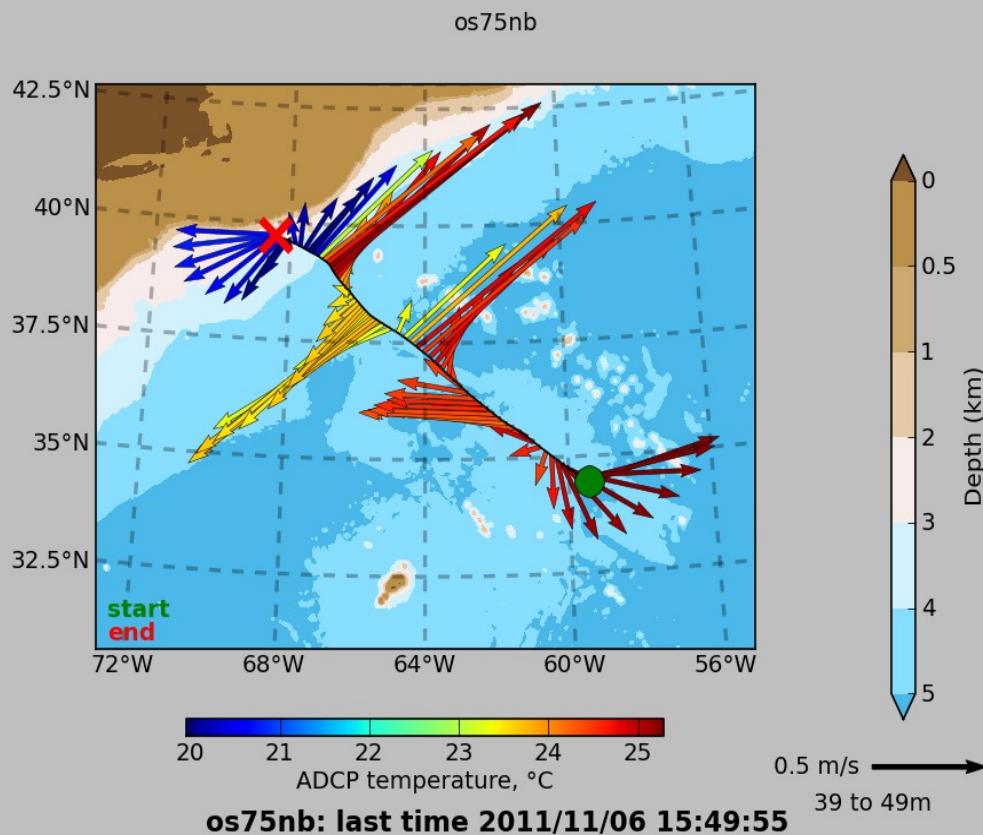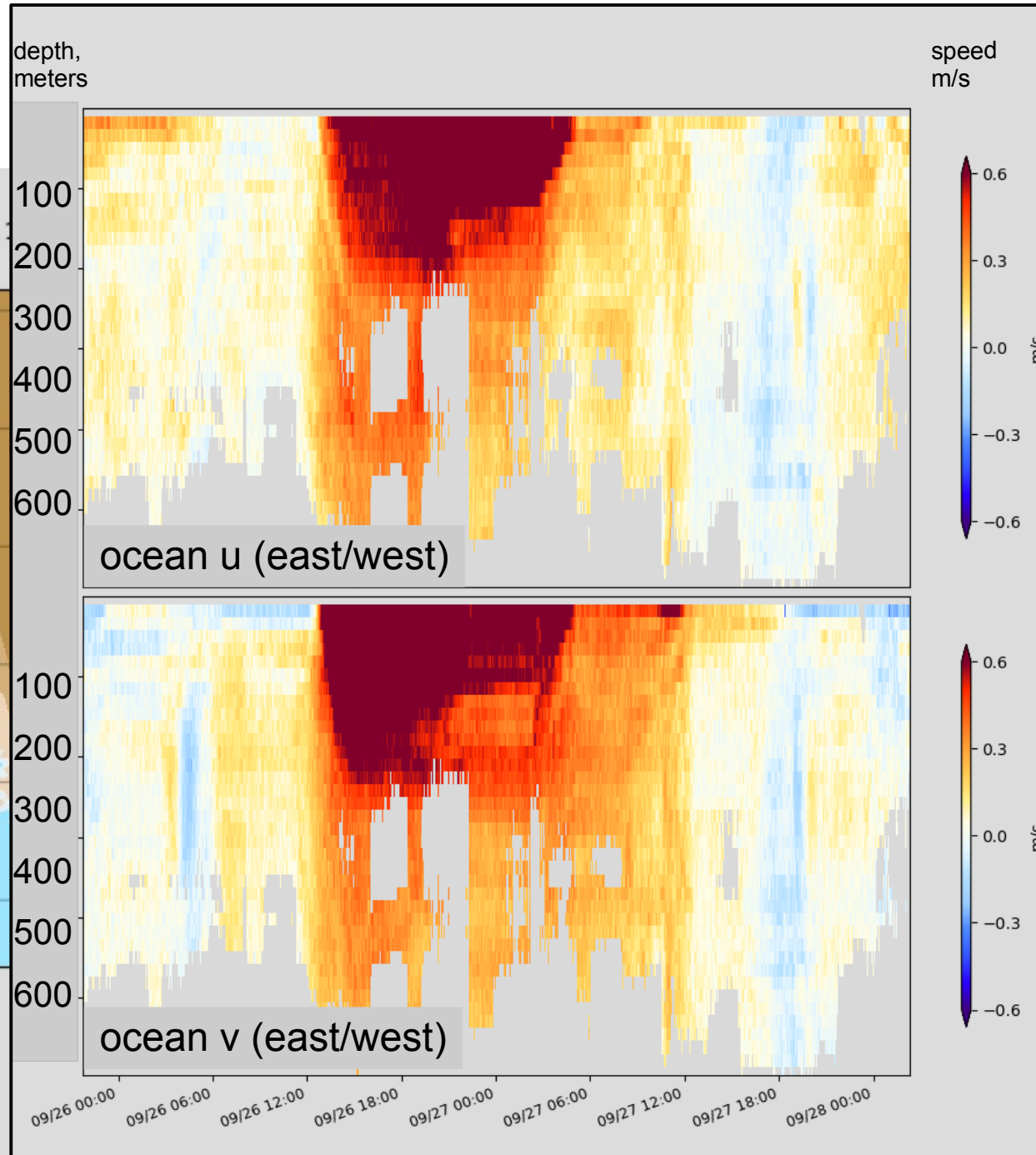
Who uses the data? What is it good for?
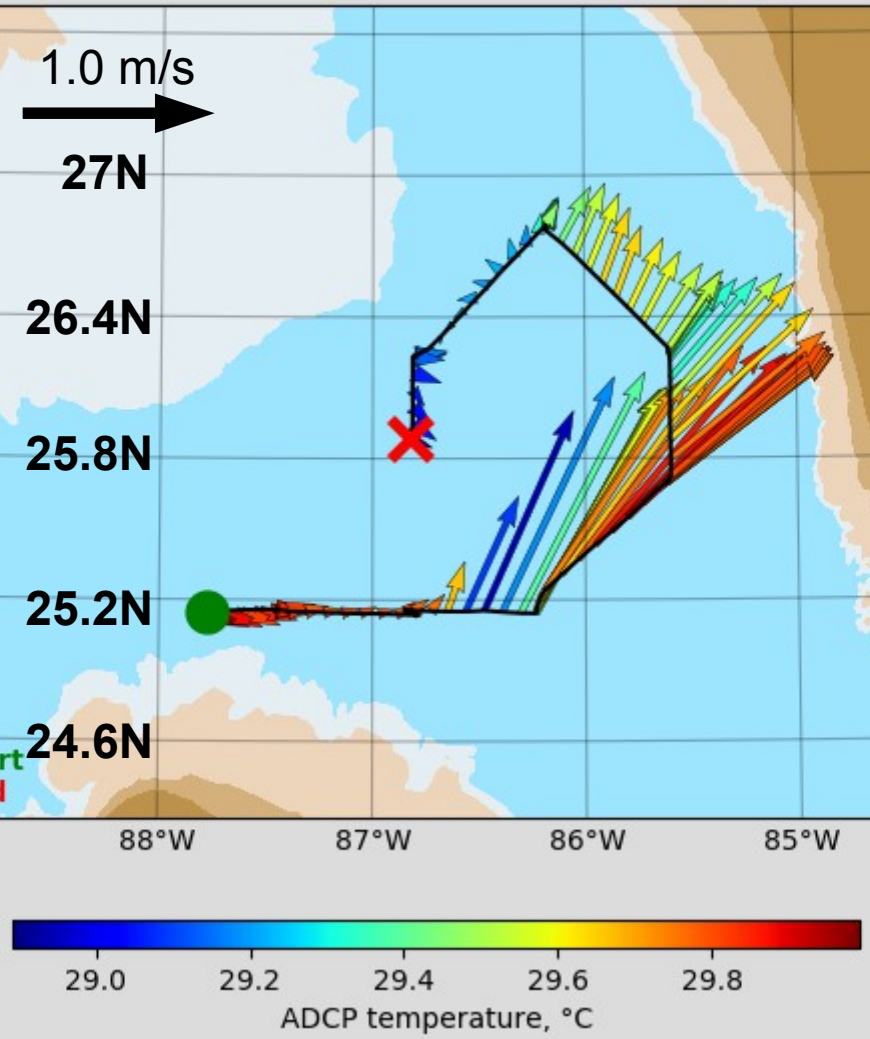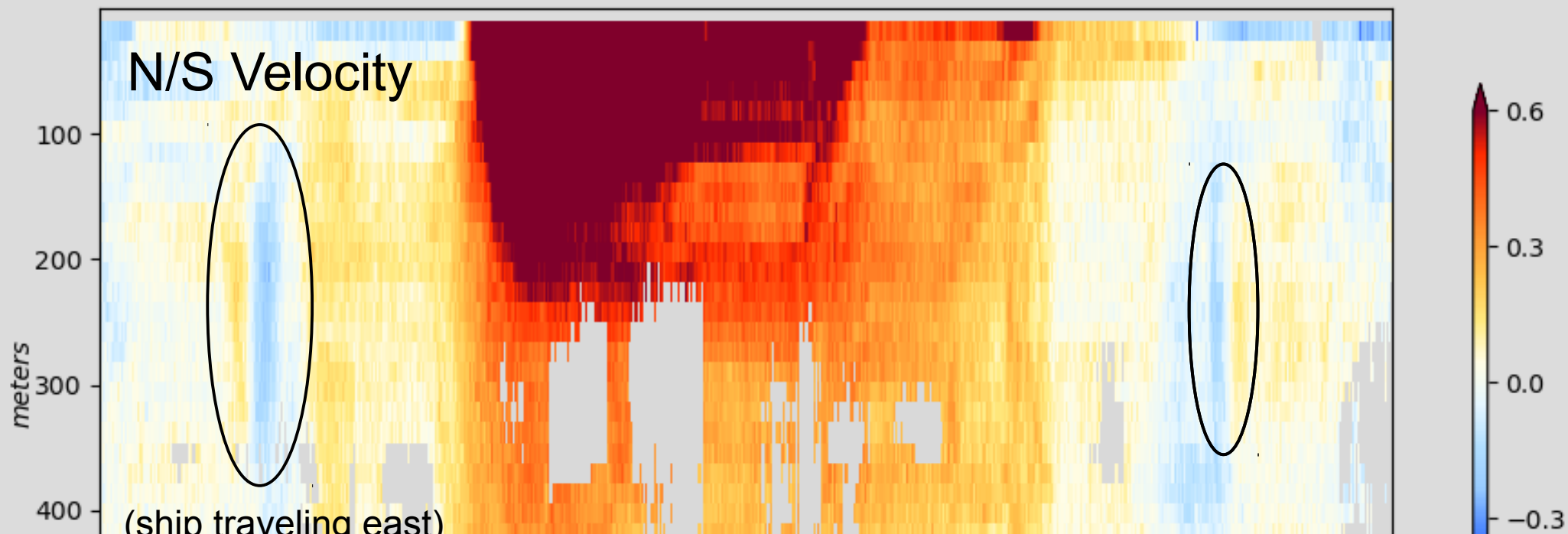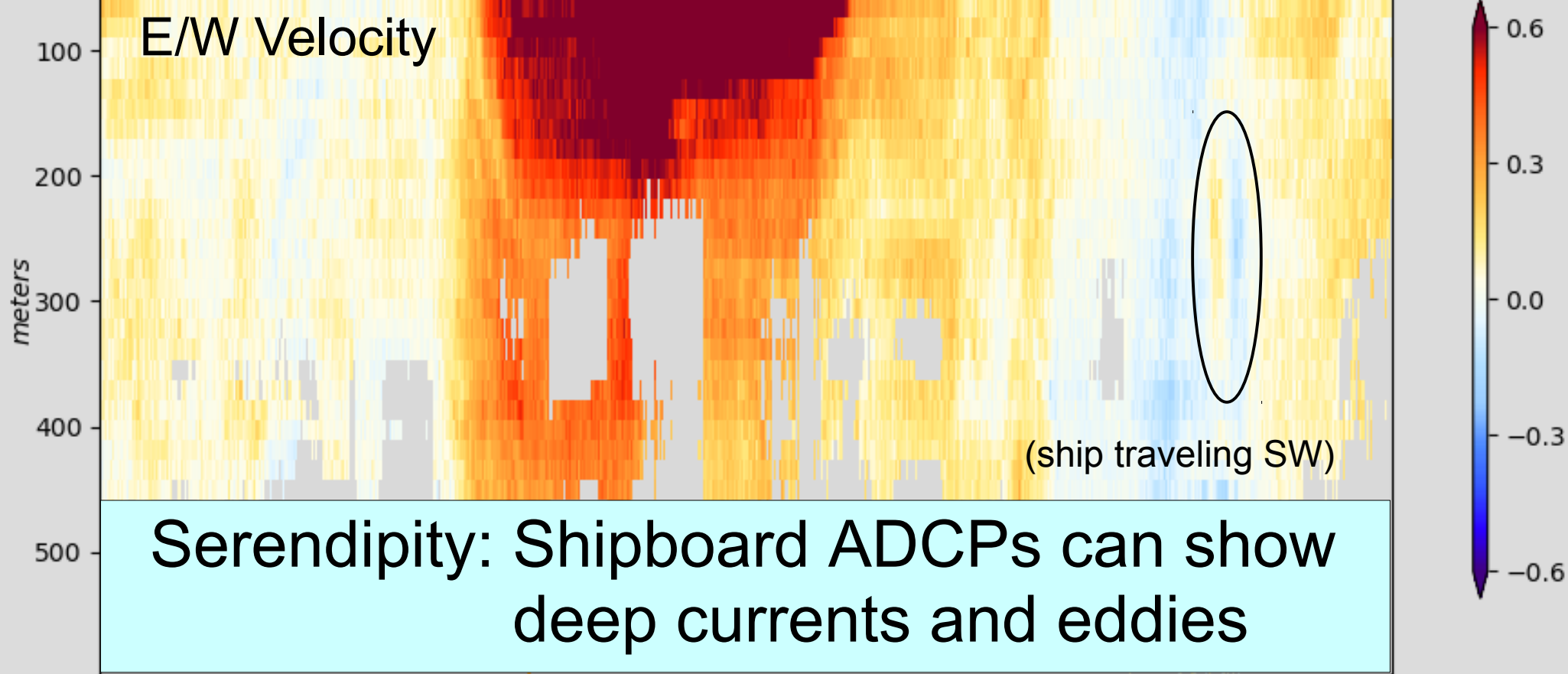
at sea:

- 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

E/W Velocity

(ship traveling SW)

Serendipity: Shipboard ADCPs can show deep currents and eddies

N/S Velocity

(ship traveling east)

Scientific relevance of shipboard ADCP data

- backscatter (even if uncalibrated)

- 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
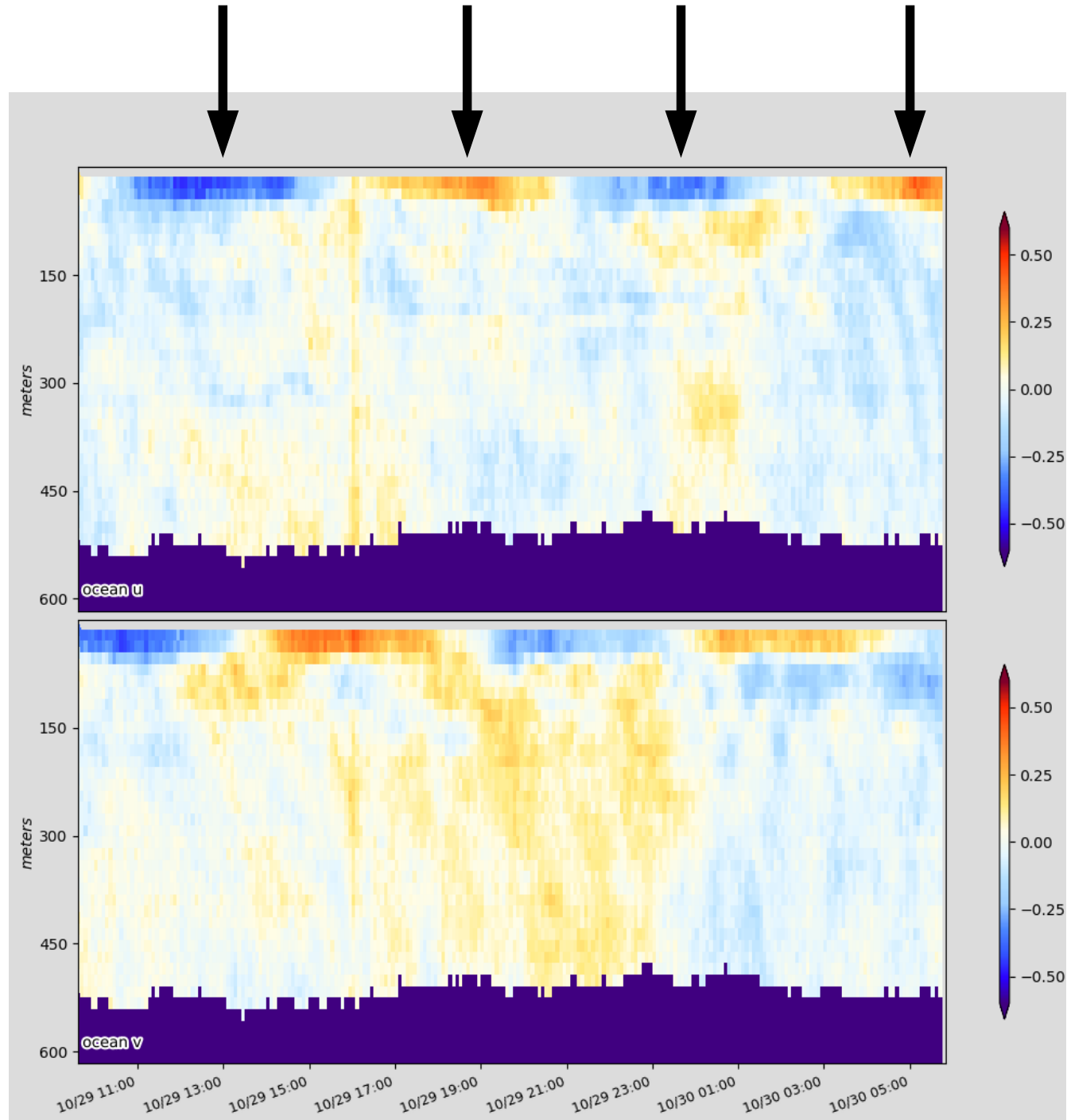
- comparison with satellites

examples
follow...

Kilo Moana: 38kHz ADCP backscatter (tropical eastern pacific)
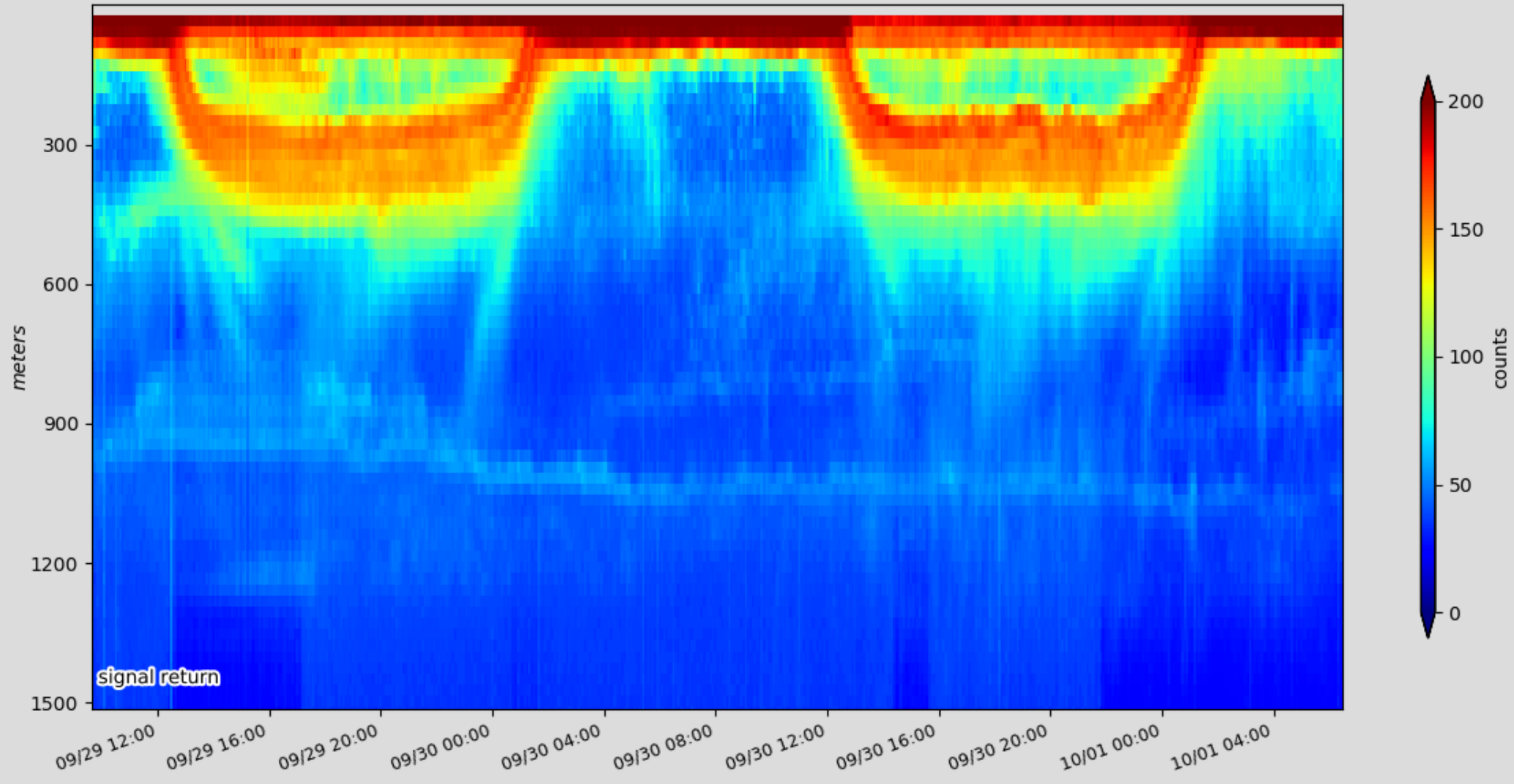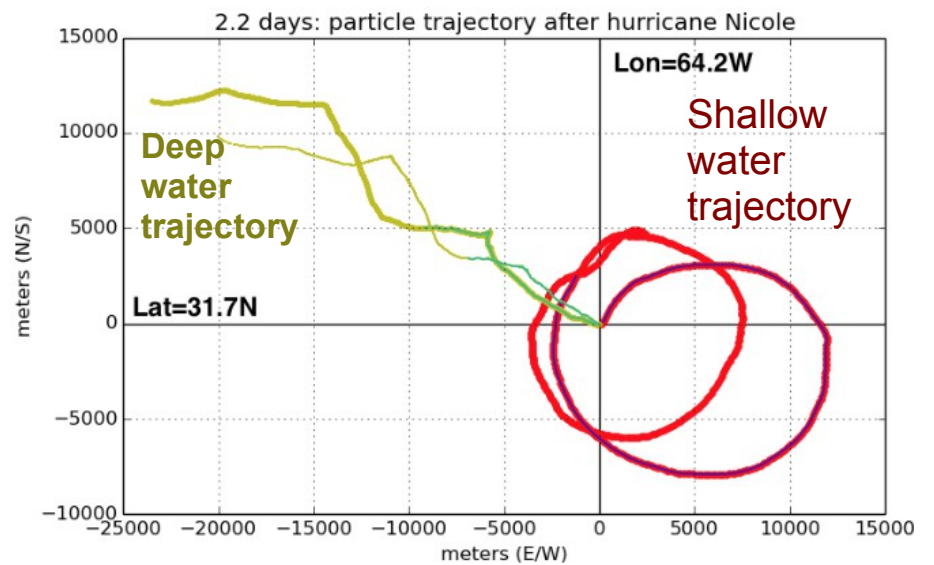
Near-inertial
motion caused
by strong winds;

stratified ocean
keeps the energy
at the surface

Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.

2.2 days: particle trajectory after hurricane Nicole

Lon=64.2W

Deep water trajectory

Shallow water trajectory

Lat=31.7N

meters (N/S)

meters (E/W)

AE1625

AE1625
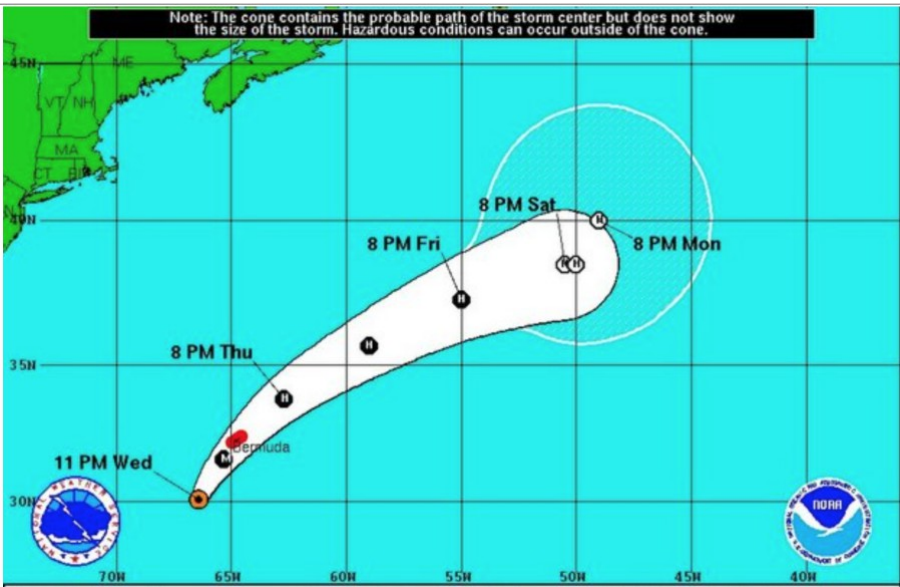
shallow inertial signal

Hurricane Nicole
Oct 12, 2016

ocean U (east/west)

deep inertial signal later

inertial circle plot time range

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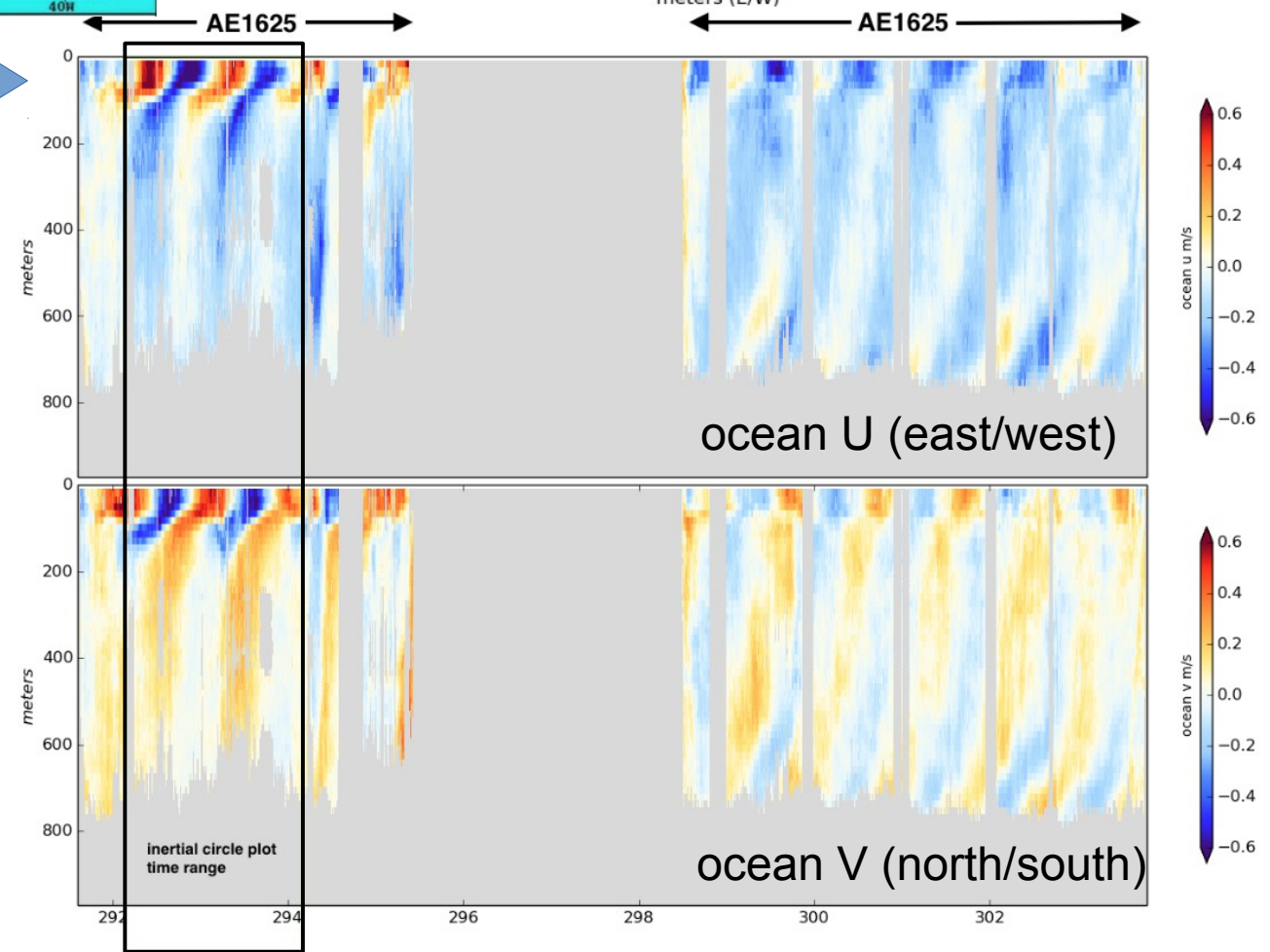
Kilo Moana (45N)
off the Oregon Coast:
internal tide beam,
energy downward
(phase upward) below 600m

60m-1280m

Upper ocean velocities

start
end

126.3°W   126°W   125.7°W   125.4°W   125.1°W

ADCP temperature, °C

ocean u

ocean v
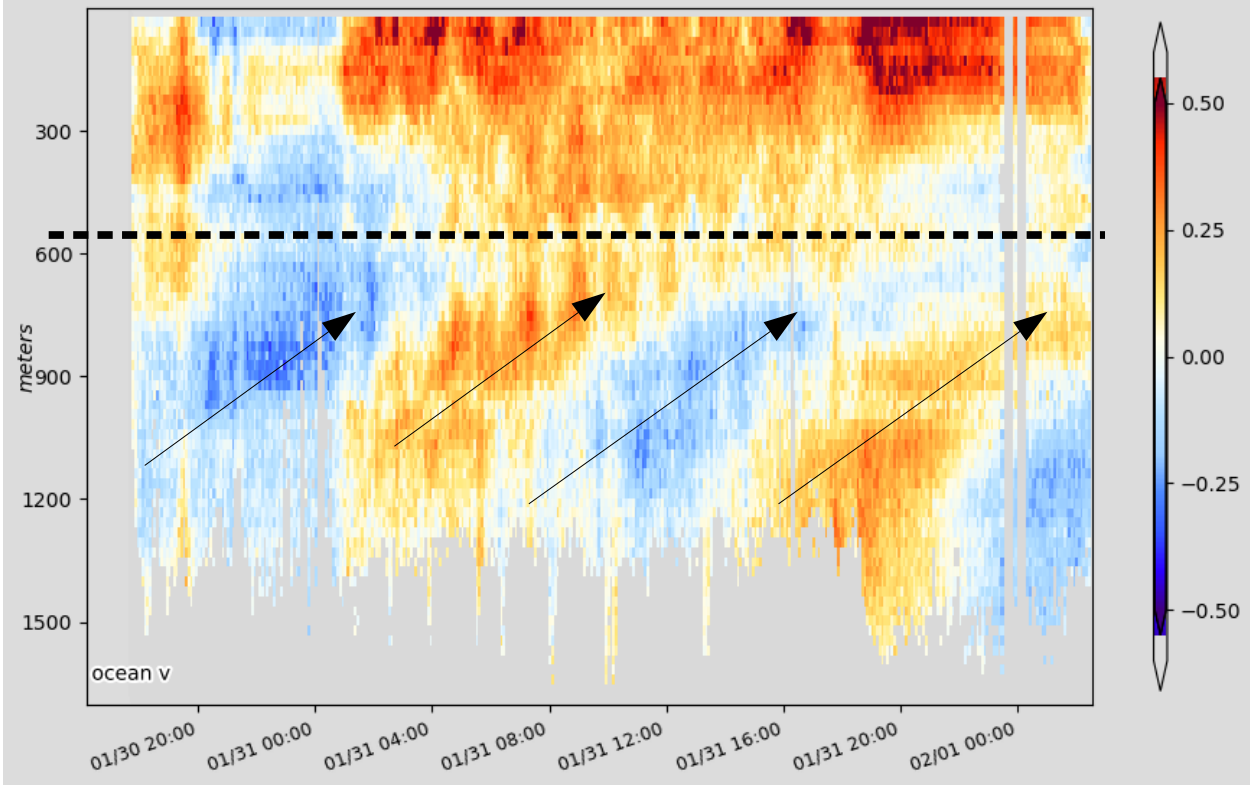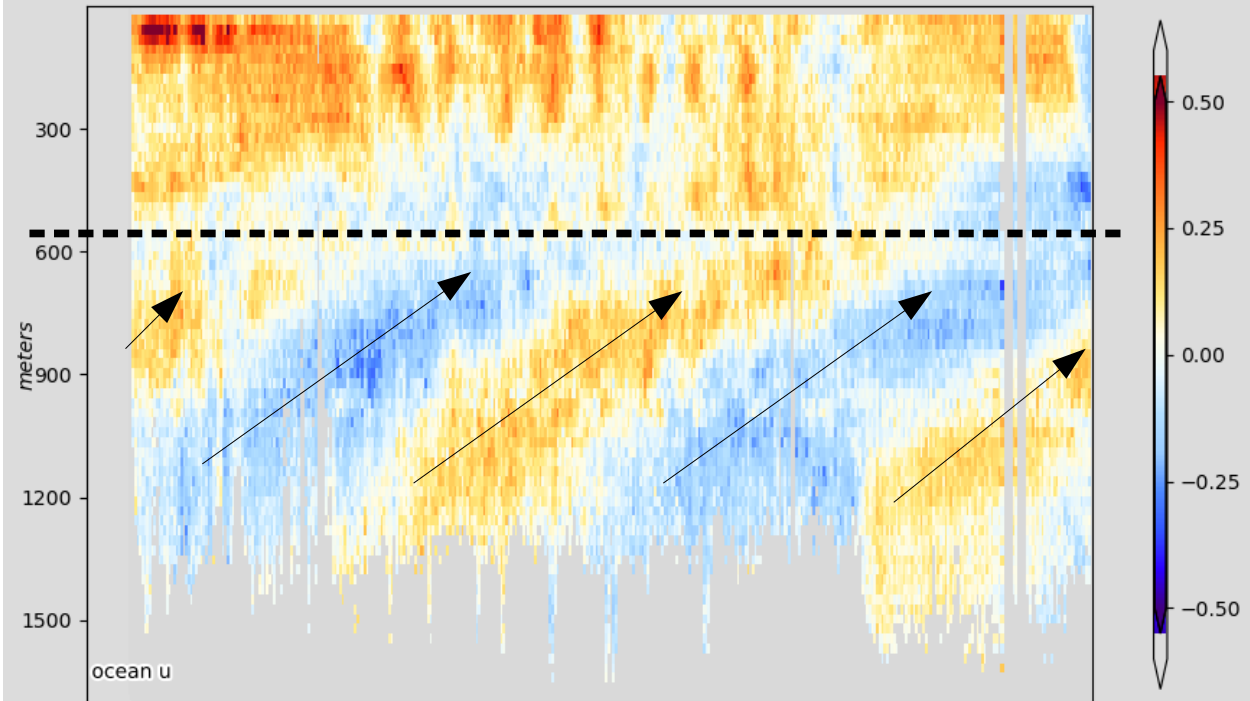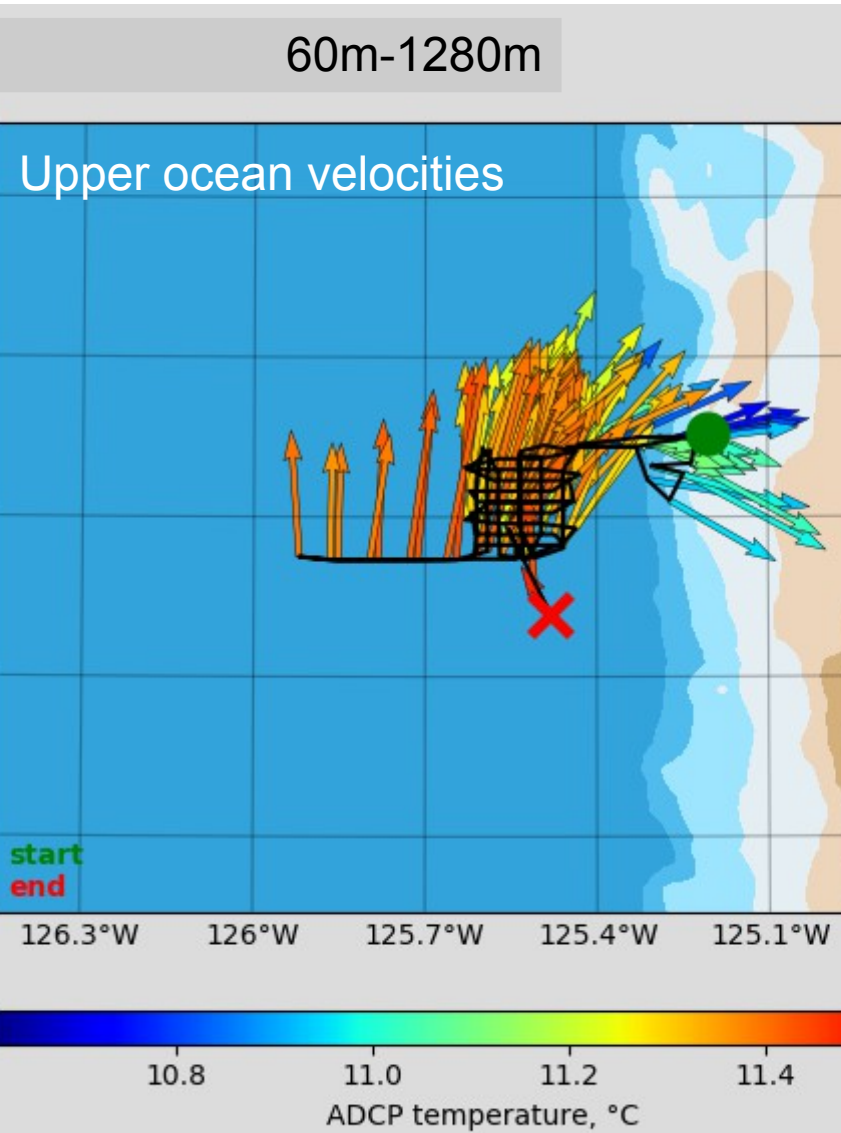
Time Series Examples

Laurence M. Gould: Drake Passage

Lenn et all, JMR, 2007
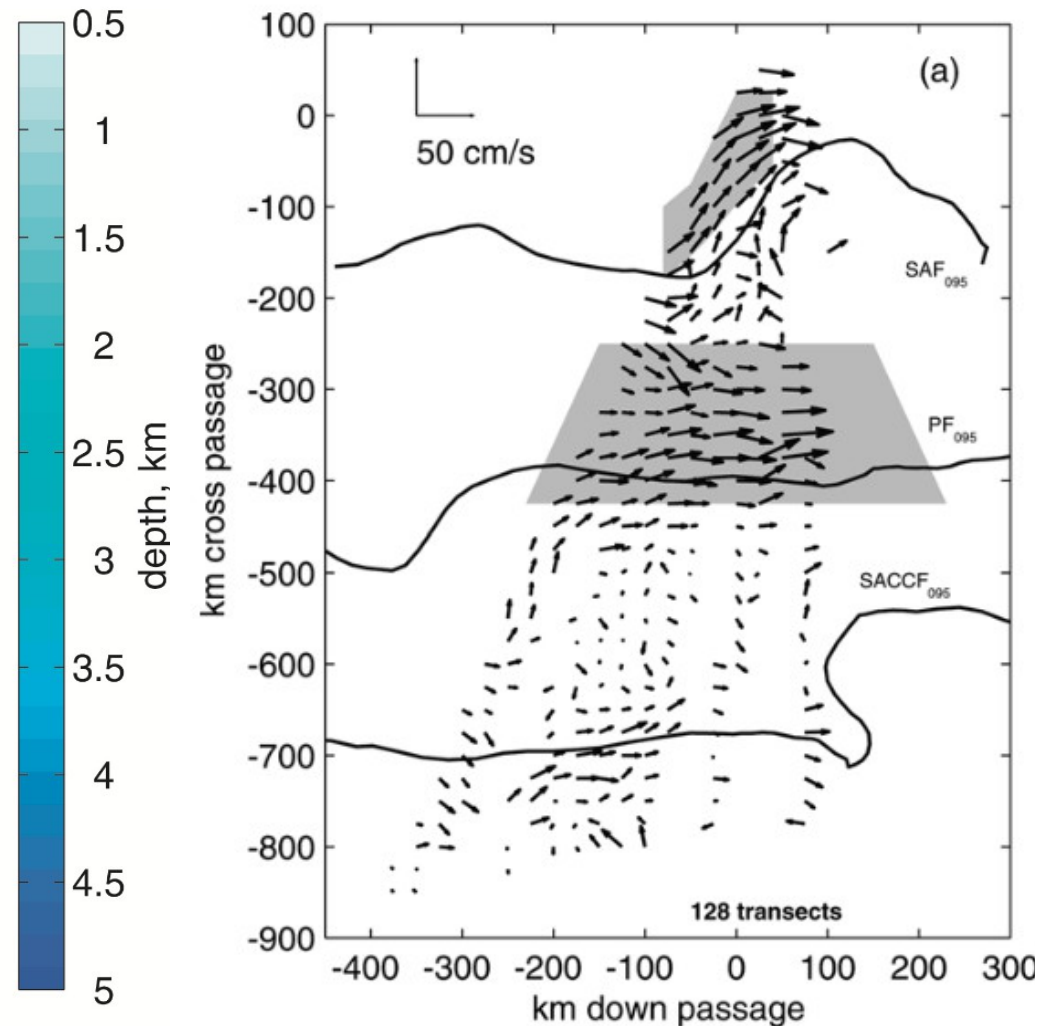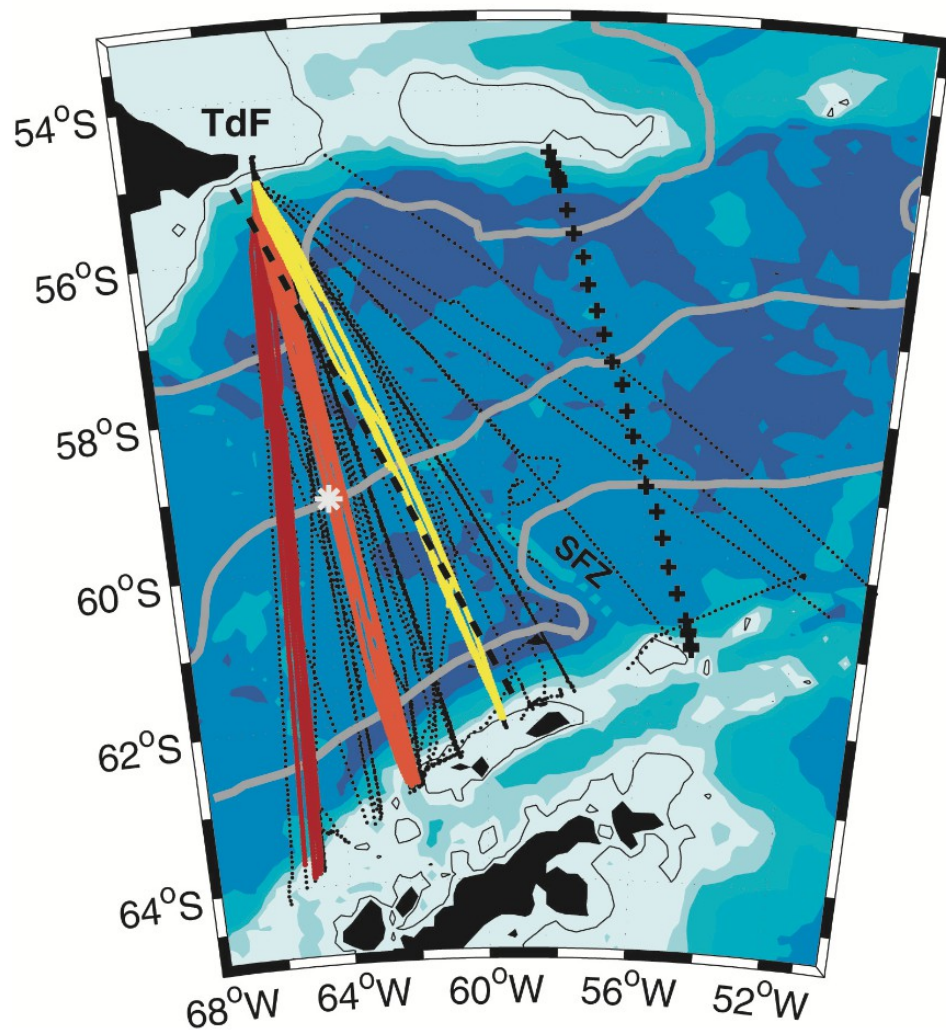
Time Series: Equatorial Pacific

SADCP from TAO sections
Crevatte et al, JMR 2017
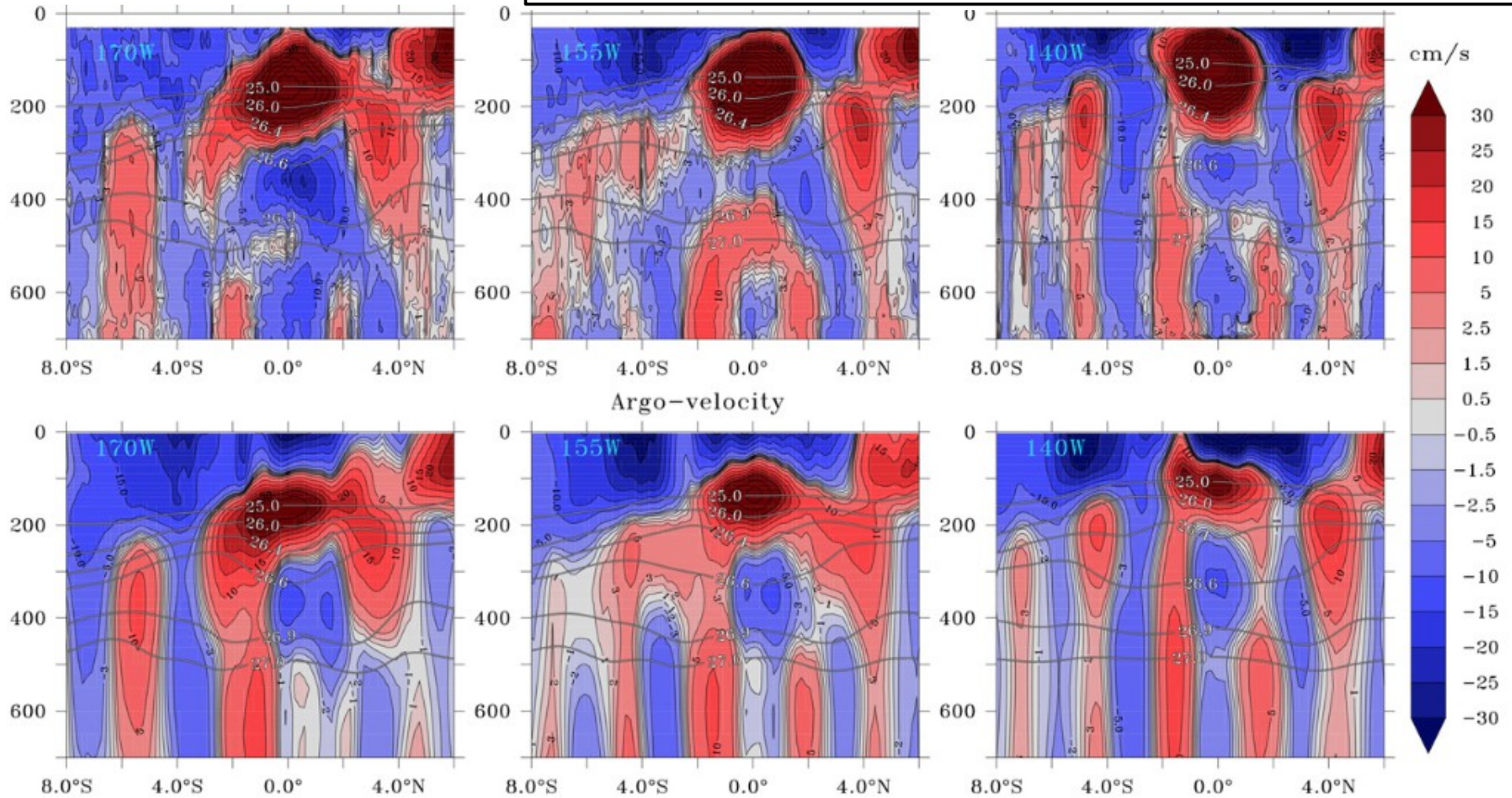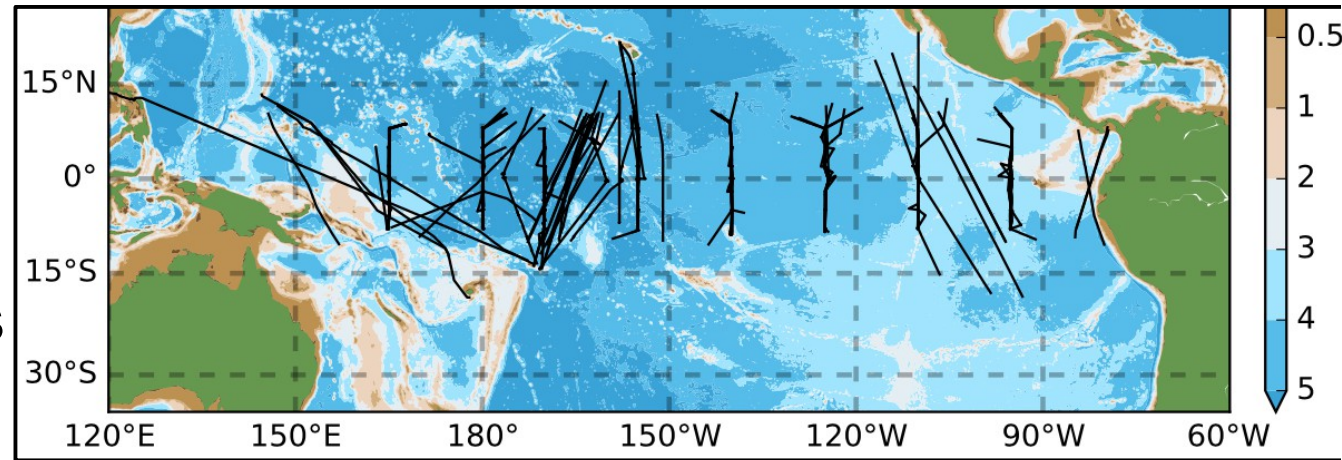
FIG. 12. Mean zonal velocity from (top) SADCP data and (bottom) Argo velocity product at (left) 170°W, (center) 155°W, and (right) 140°W in cm s^{-1}. Superimposed are some selected isopycnals.

References

<u>Drake Passage</u>

- ***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

<u>Equatorial Pacific</u>

- ***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

Where are scientific shipboard ADCPs installed?

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

- ## Internationally:

- oceanographic research vessels
- smaller science vessels
- Navy ships

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

One vetted ADCP manufacturer for vessel-mounted use:
(T.R.D.Instruments)
- ADCP ships with VmDAS (Windows acquisition program)
- U.H. Currents Group developed UHDAS as an alternative

links:

UHDAS Operations
Comparison between UHDAS and VmDAS

UHDAS - What it does (follow the data)

(1) Acquisition
(2) Processing
(3) Data Access
     - At Sea
     - On Land (after the cruise)
(4) Monitoring
     At Sea
     On Land

UHDAS components

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

CODAS

ADCP: Getting Ocean Currents

Collect Data

ADCP

heading

position

Transformations

Doppler to beam
 (occurs in the ADCP)

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

Preliminary Processing

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

beam coordinates

+ geometry

instrument coordinates:
2 horizontal, 1 vertical,
1 quality indicator

+ transducer orientation

ship coordinates
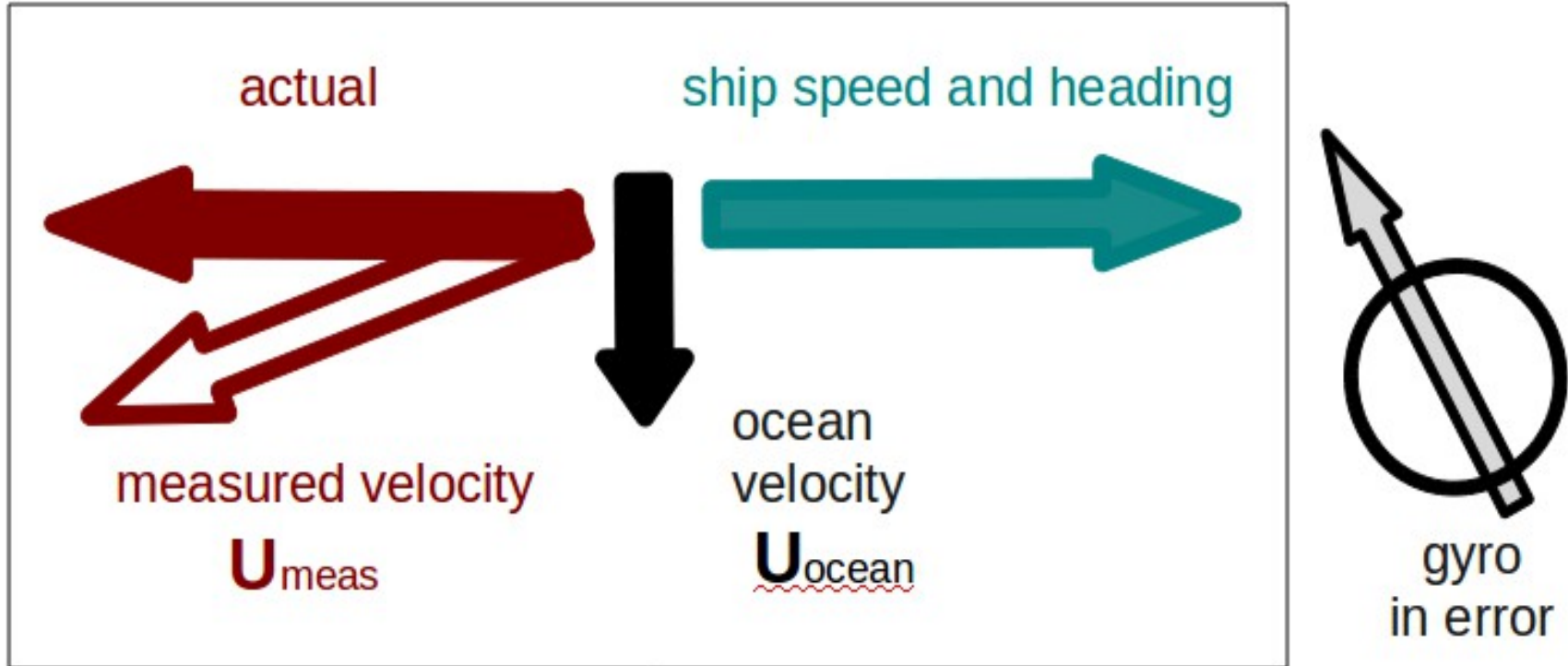
+heading

earth coordinates

measured velocity:
east, north, up, error
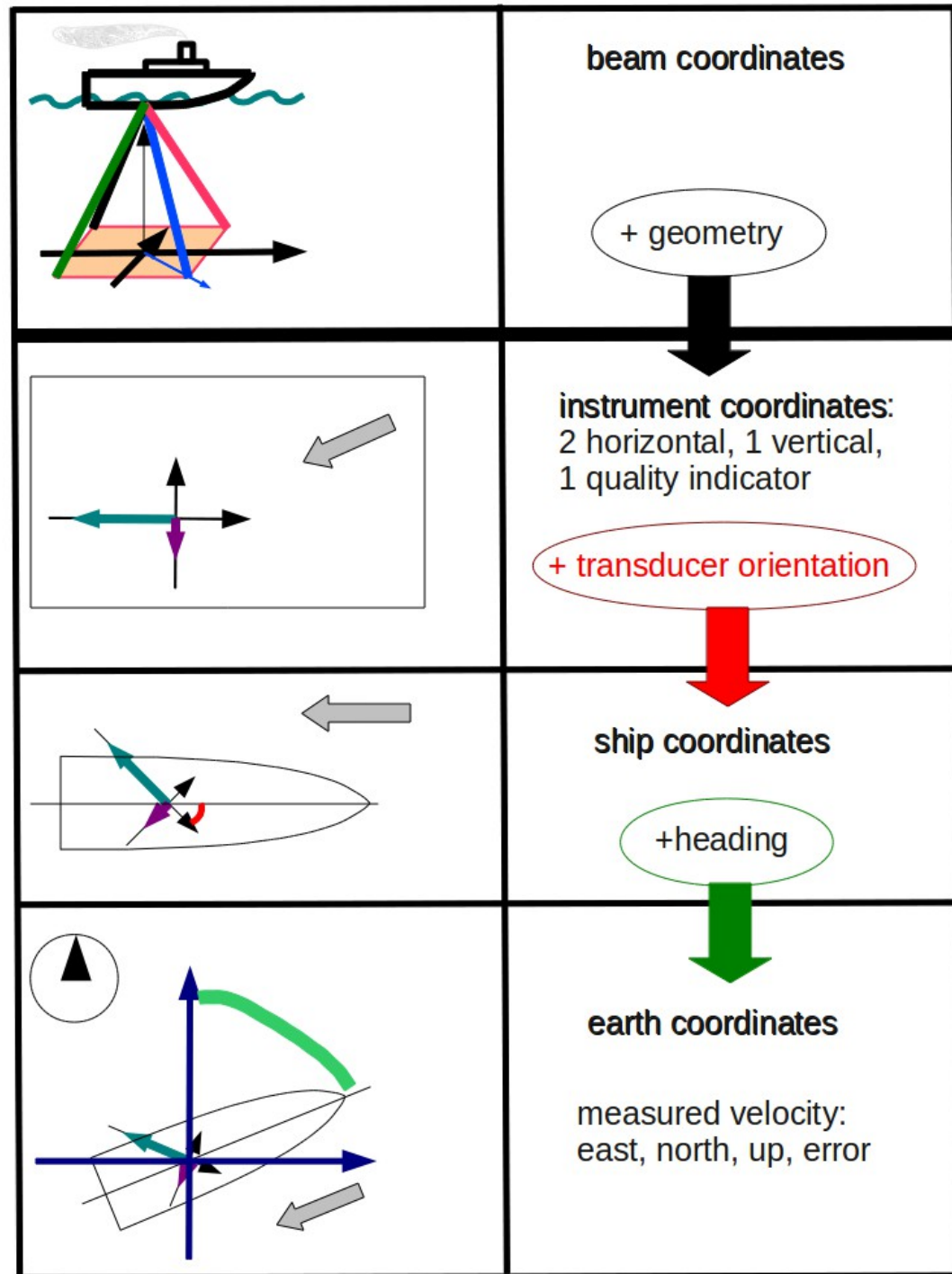
Calibration: Angle Error

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

1deg heading error ➡️ 10cm/s cross-track velocity error

ADCP preliminary Processing

"processing" requires (at minimum)

- transform from beam coordinates to horizontal

- rotation into ship coordinates

- further rotation based on heading

- account for ship's speed

  - acoustic interference
  - data below the bottom
  - short, biased profiles (bubbles)
  - remaining statistical outliers
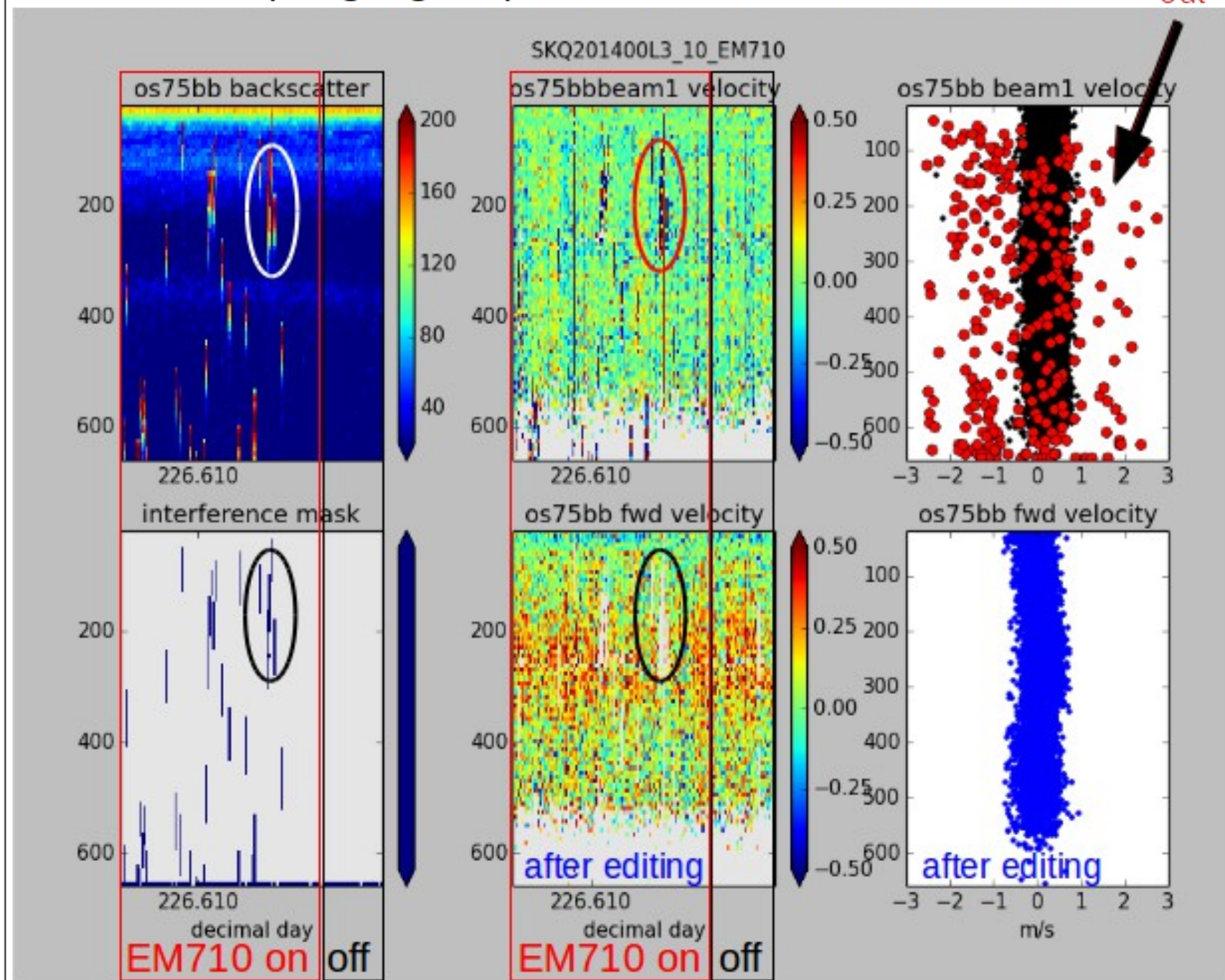
  CODAS
  single-ping editing:
  remove bins due to...

- 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 software details

- built from scratch for shipboard ADCP

- data are stored in a <u>CODAS database</u>; 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
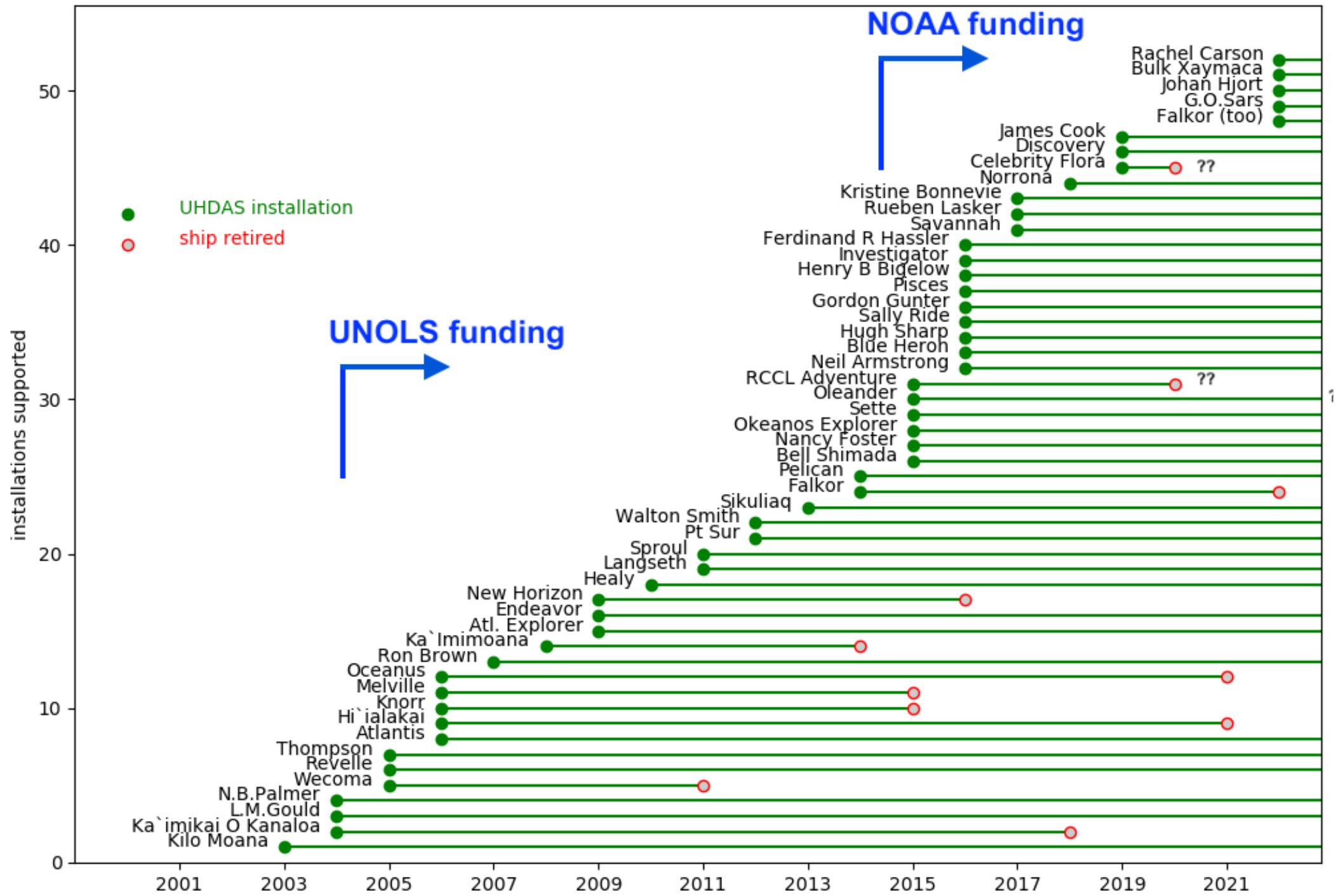https://currents.soest.hawaii.edu/docs/adcp_doc/index.html

UHDAS components

- **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**
  - operations and science at sea
  - ease of post-processing after the cruise
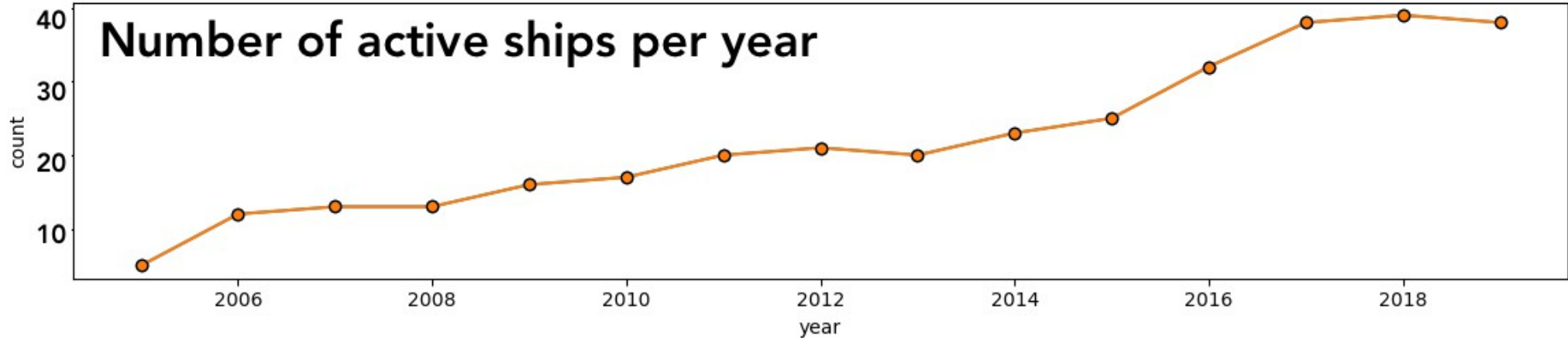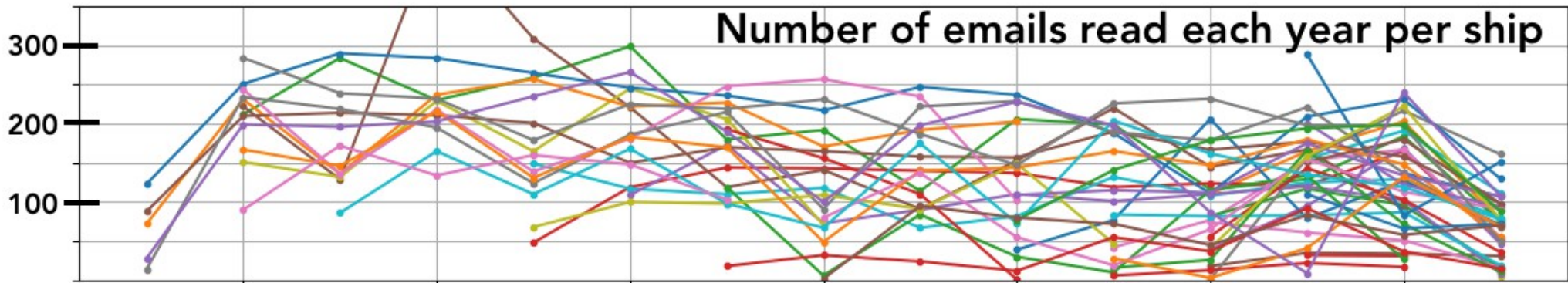 - discovery/evaluation in the future

Monitoring

- on ship:
  - via web site on ship (science and diagnostic figs)
- on land
  - automated daily emails to UHDAS Team
  - dashboard with
    - cruise status
    - links to figures, diagnostic files
  - 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

UHDAS Installations supported: by year

UHDAS ship and email metrics

Total number of emails read by year
while the ship was collecting data

Number of emails read each year per ship

Number of active ships per year

UHDAS components

- **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
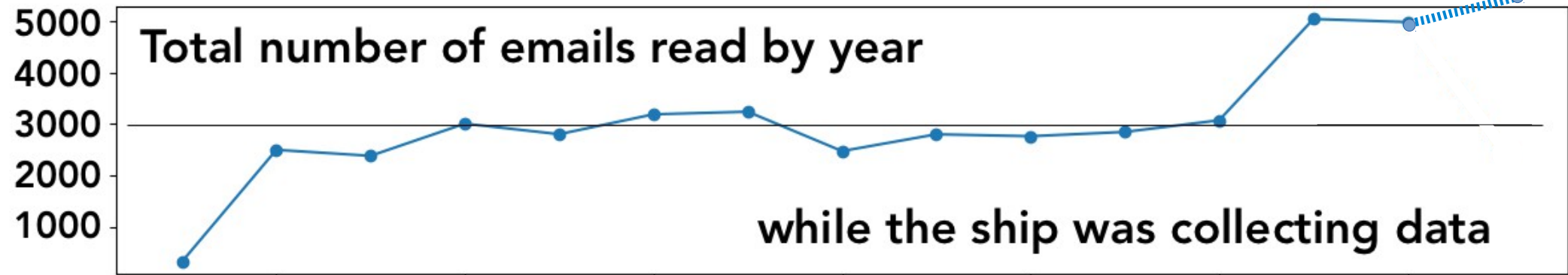 - ease of post-processing after the cruise
  - discovery/evaluation in the future

CODAS data and products

At sea:

- **example at-sea web site**   (James Cook Oct 31,2019)
  - figures for operations and science at sea
  - netCDF data files for science
  - matlab data files
  - archive of daily figures
  - calibration from processing
  - settings used during processing
- complete CODAS+UHDAS documentation

- **After the cruise**:
  - processing directories
    - matlab data files
    - netCDF file
    - archive of daily figures
    - ready for post-processing
    - calibration from processing
    - settings used for processing
  - raw data directories
    - evaluate quality of the ADCP or ancillary data
    - reprocess with different inputs
    - reprocess with different averaging duration

After the cruise:

For <u>future use</u>, 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 ...

Data flow: from ship to science

- acquisition, data on the ship
  - VmDAS (available from RDI, windows)
  - **UHDAS** (from University of Hawaii, linux)

- U.S. national archive
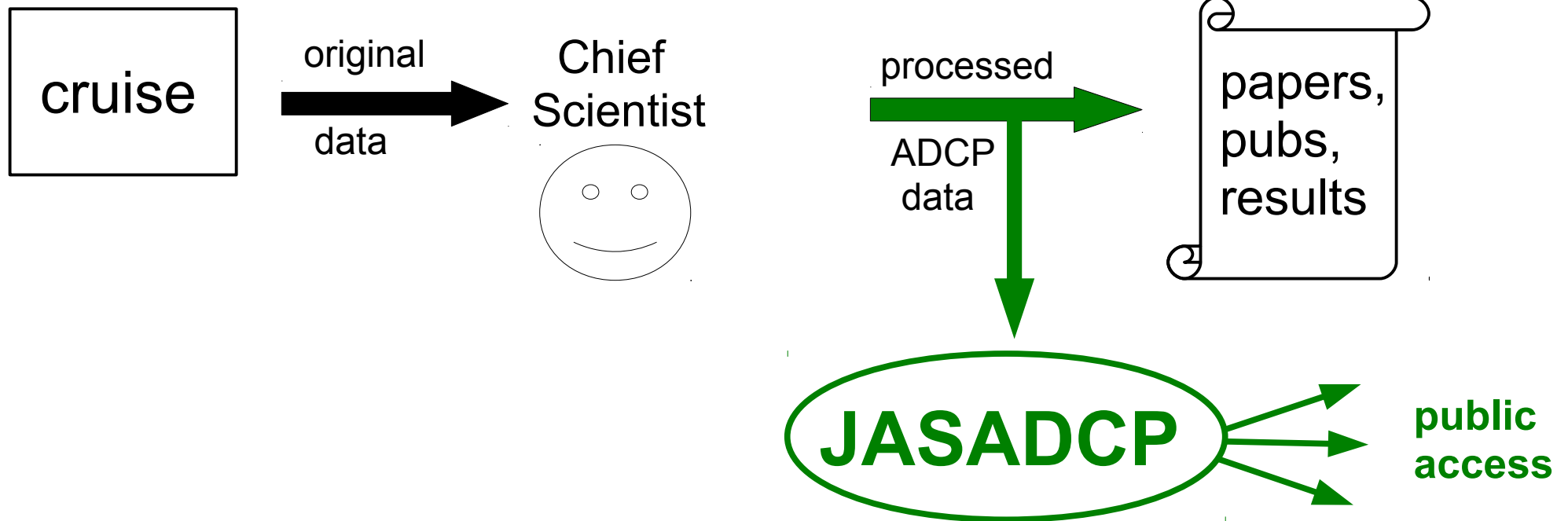 - NCEI: UHDAS data via R2R "as collected" (*)

  - after a human does the final processing:
  - JASADCP (for processed science-ready SADCP)

(*) in the Global Ocean Current Database

Historically in the U.S.

Past and Present

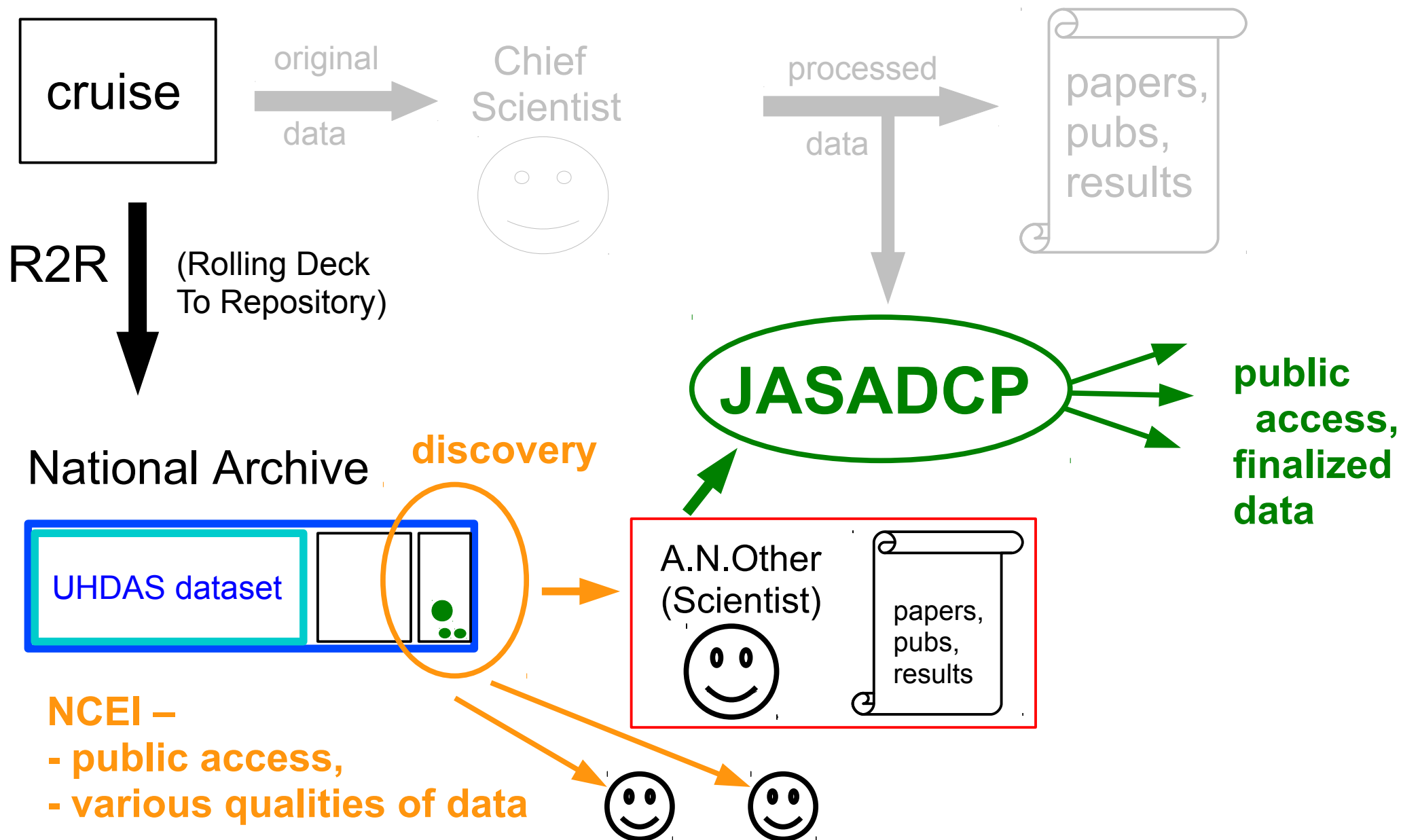
Joint **A**rchive for **S**hipboard **ADCP**
Part of NCEI
Serving science-ready data since 1992.
Over 800 cruises so far...

Present and Future:
   - two paths to finalized public data
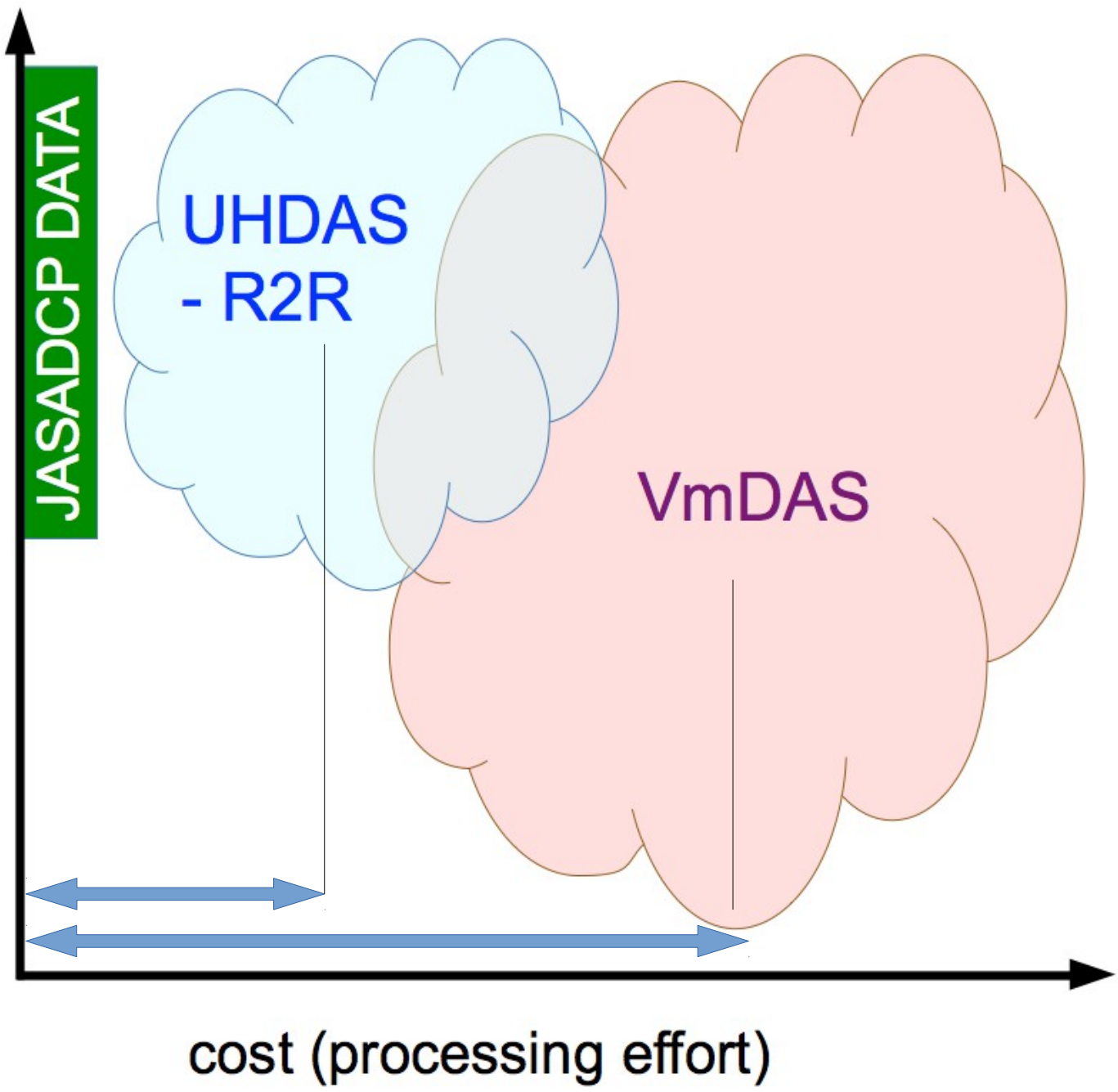   - more opportunities for original data to be used

UHDAS vs/ VmDAS data quality and processing effort

JASADCP:
science-ready
shipboard ADCP
ocean currents

JASADCP DATA

potential
benefit
to
science

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

UHDAS - R2R

VmDAS

cost (processing effort)

Science by Serendipity

HLY1102 (390m-530m)