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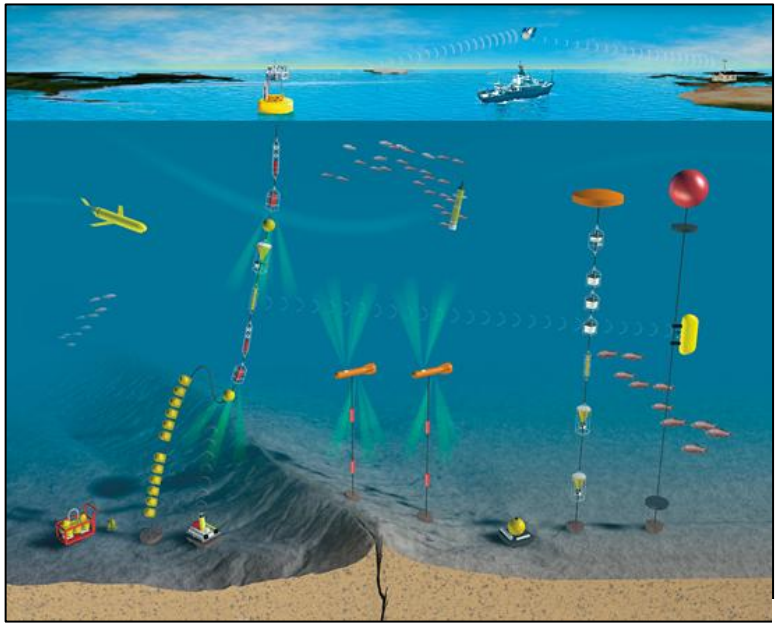
COAS
Centre for Ocean and Atmospheric Sciences

UEA
University of East Anglia

Beyond Argo:
ocean gliders and sensors on seals

Seal photos from Lars Boehme



RMetS
Royal Meteorological Society

The Challenger Society for Marine Science

Argo plan was for one float on average in every 3x3º square, so ~3000 active floats

Sparseness map shows % of target coverage

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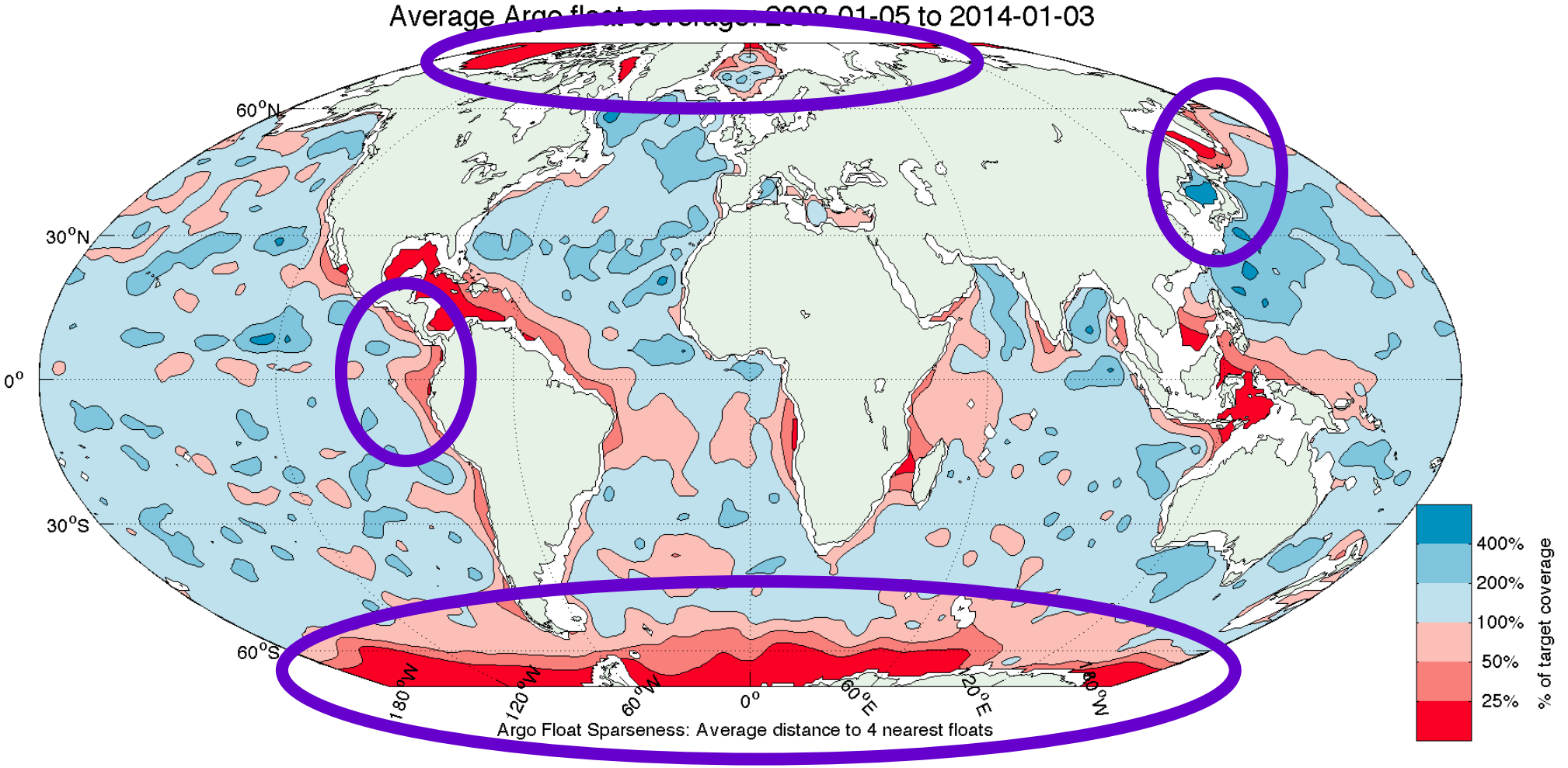

How do we get data from Argo floats in areas of sea ice?

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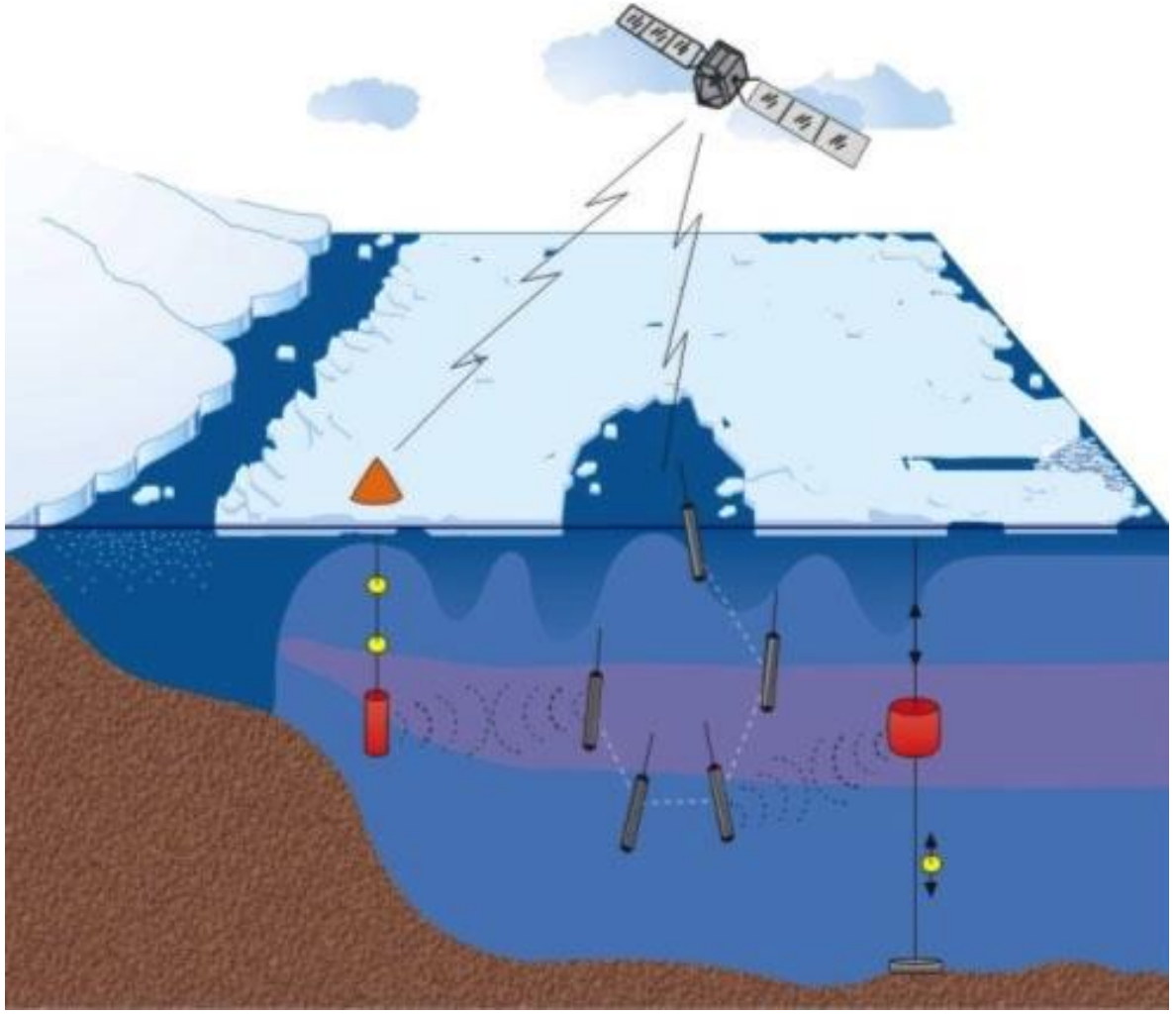

- Algorithms to detect ice above the float so it doesn't get damaged
- Acoustic navigation to track where the float is
- Storage of profiles until the float emerges into open water
- Transmission of profiles over iridium in spring

An Argo float with a mind of its own….

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- Small sensors (“tags”) designed to be glued to the heads of marine mammals
- Temperature, salinity and depth are standard; dissolved oxygen, chlorophyll fluorescence etc are available
- Profile transmitted when the seal hauls out
- Tag falls off when the seal moults in summer
- Used by biologists to understand the environment of the seals
- A bonus for climate scientists!

An Argo float with a mind of its own….

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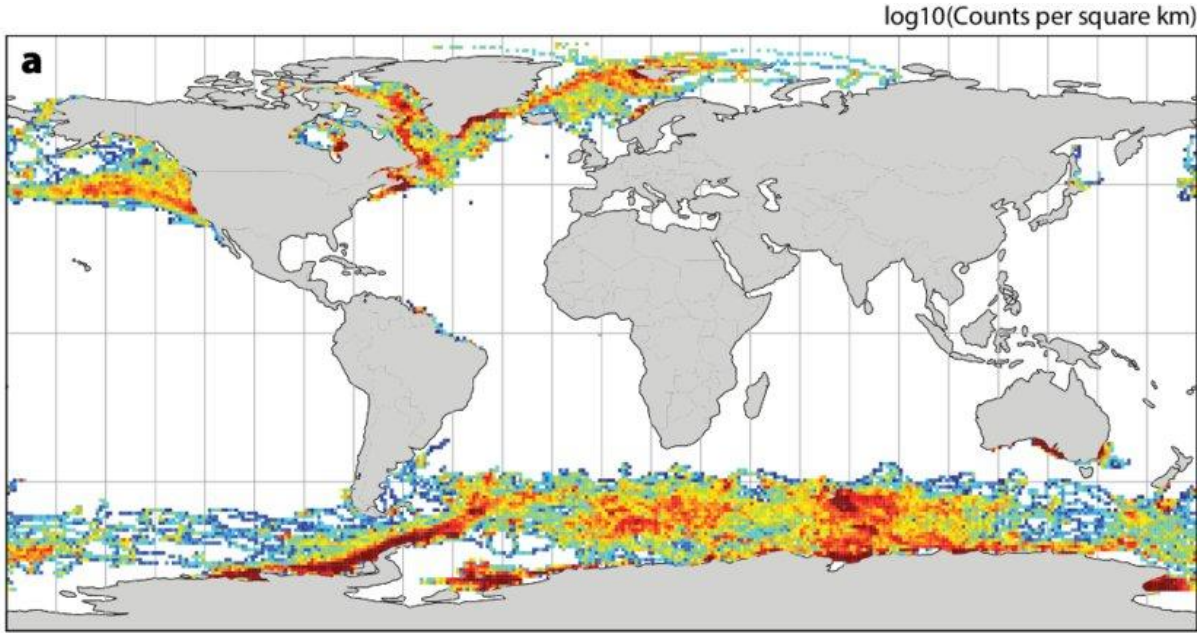
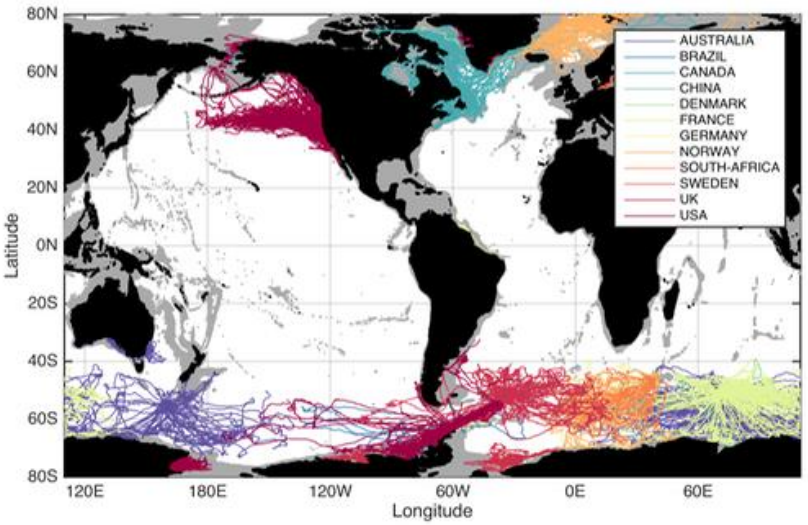
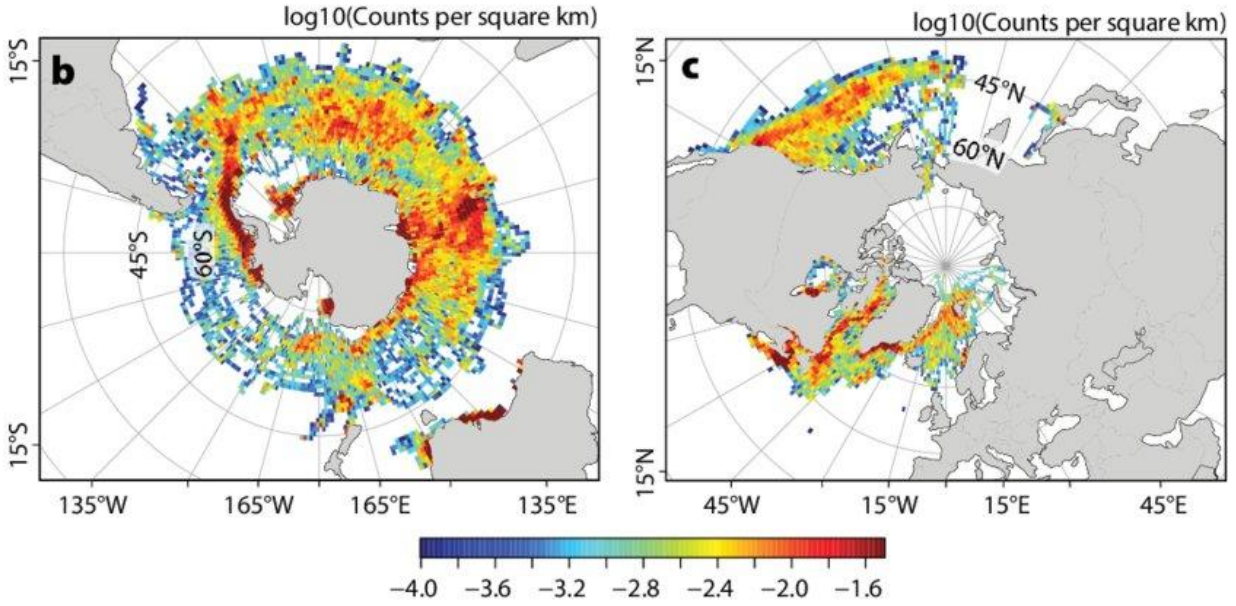
- Advantages:
  - Profiles throughout the year in sea ice regions
  - Sensors and Argos signal transmissions are cheap
- Disadvantages:
  - Only about 18 points in the vertical
  - Accuracy is an issue
  - Only last a year







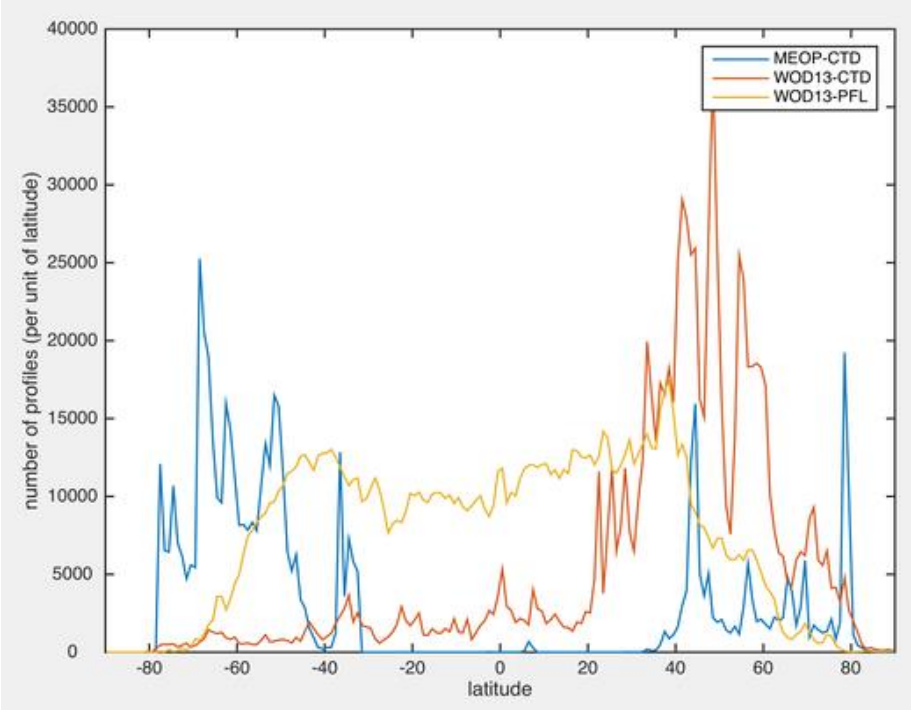
Treasure et al., 2017, *Oceanography*

Marine mammals Exploring the Oceans Pole to Pole

www.meop.net

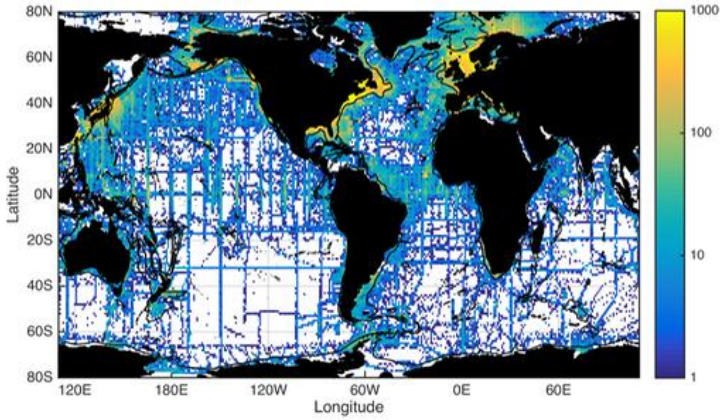
Data available

Number of profiles per 1º square

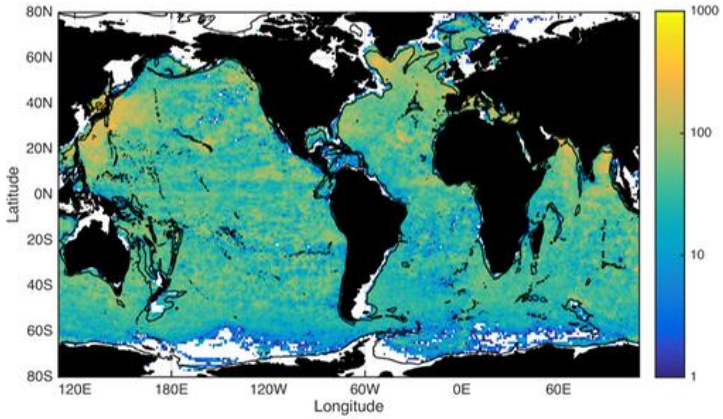


Treasure et al., 2017, *Oceanography*

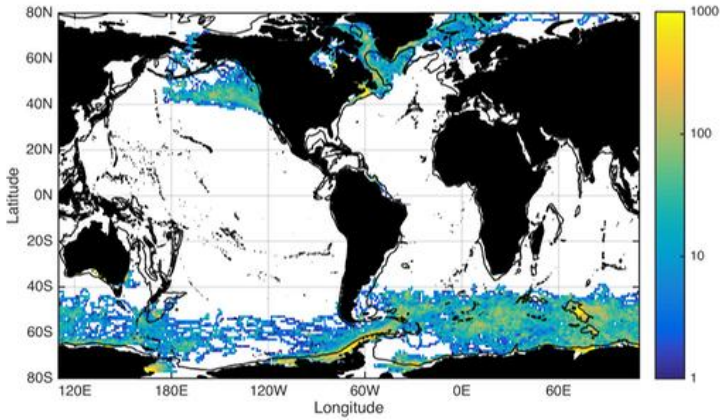
WOD13-CTD hydrographic profiles from ships 93058 profiles



WOD13 Profiling floats (Argo) 1318582 profiles

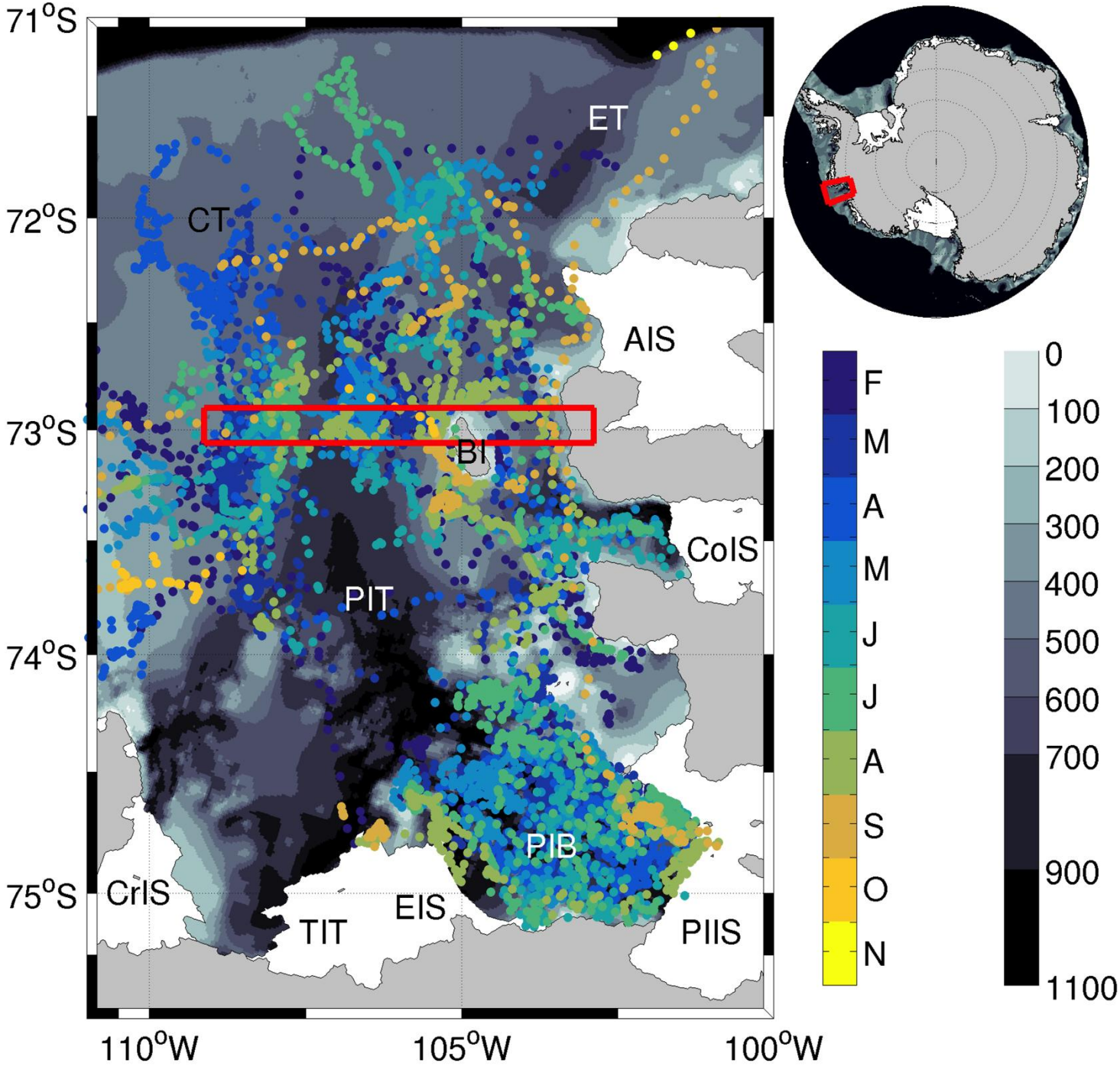


MEOP-CTD profiles from seals 517429 profiles 1197 seals



Amundsen Sea, 2014

> 10000 profiles of temperature and salinity from seal tags



Temperature in summer (FMA)

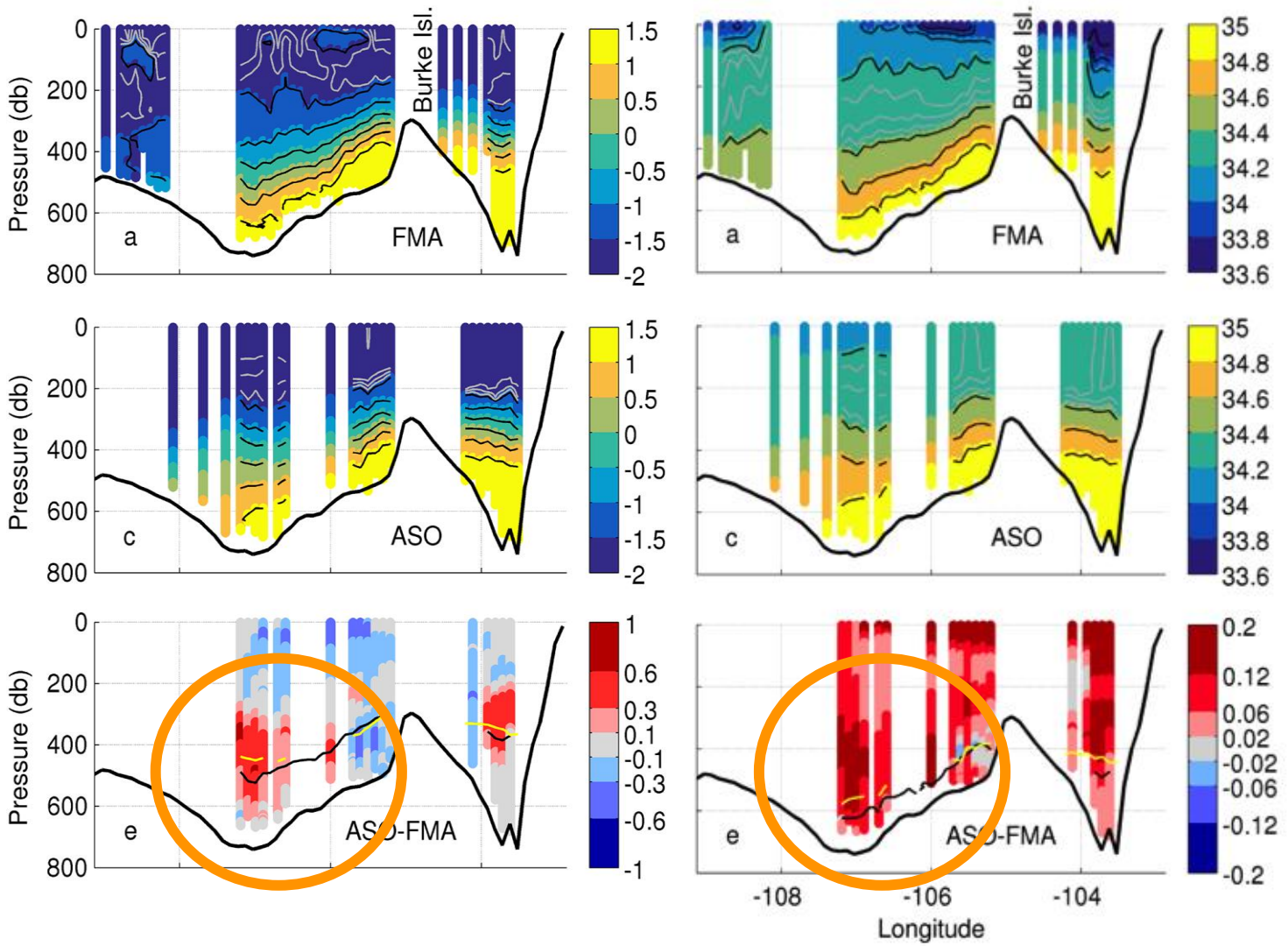
Salinity in summer (FMA)

Temperature in winter (ASO)

Salinity in winter (ASO)

Winter minus summer

Winter minus summer



Dense, warm water heading for Pine Island Glacier is warmer, saltier and thicker in winter

Mallett et al., 2018, *GRL*

Argo plan was for one float on average in every 3x3º square, so ~3000 active floats

Sparseness map shows % of target coverage

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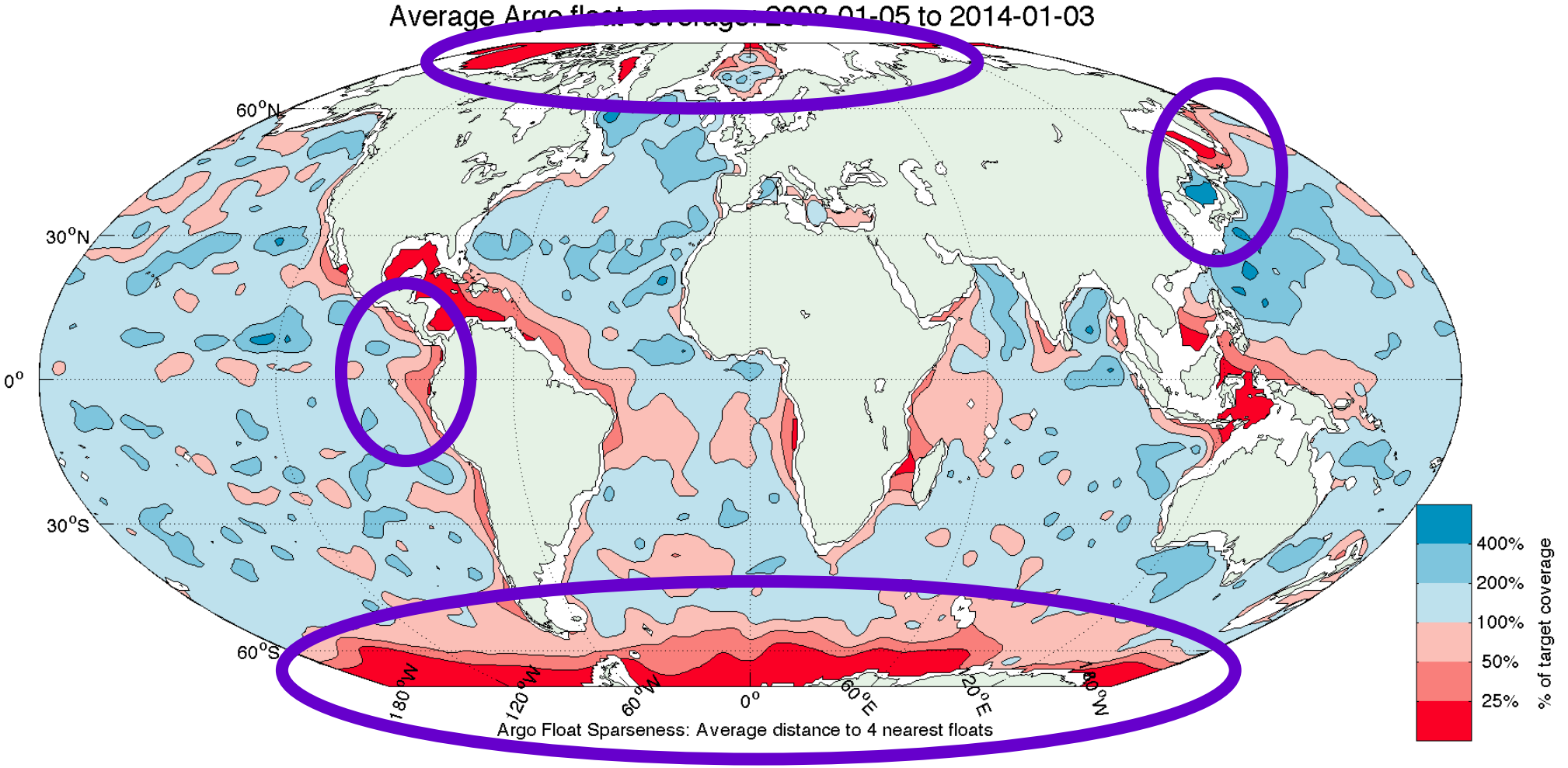

Ocean Gliders

Like Argo floats, but you tell them where to go

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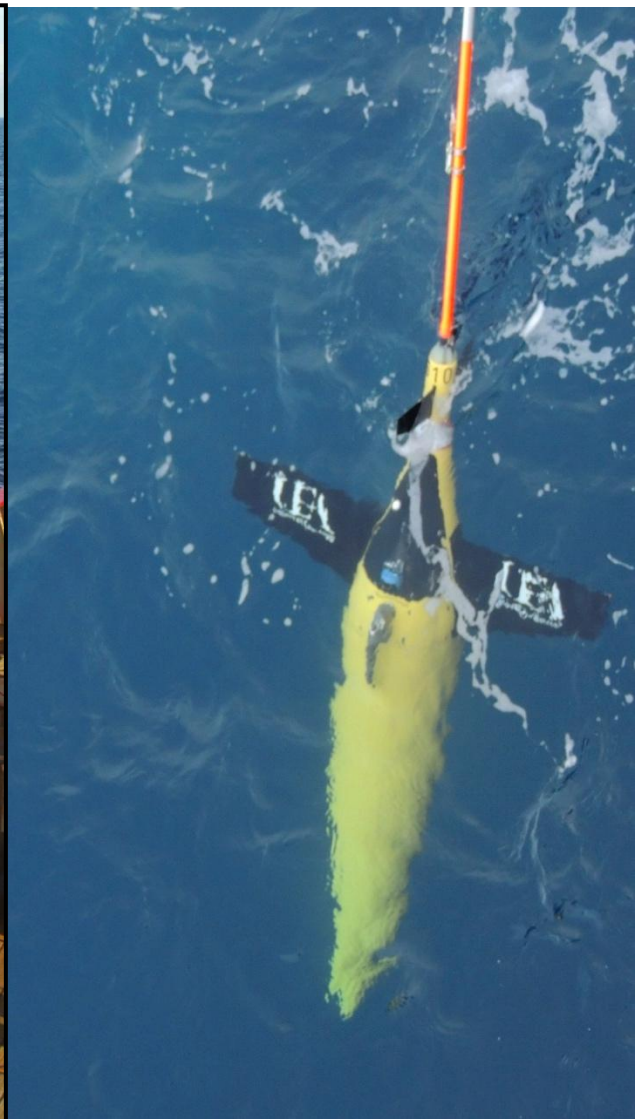


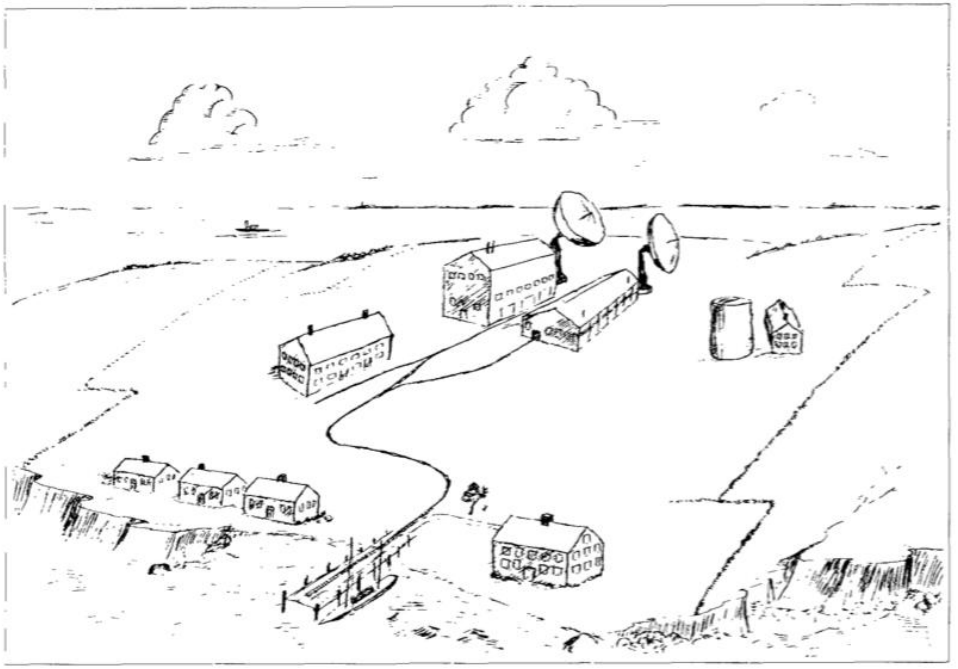
FEATURE

THE SLOCUM MISSION

Narrative and Illustration
By Henry Stommel

IT IS DIFFICULT to realize that twenty-five years have passed since I first came to the Slocum Mission Control Center on Nonamesset Island, one of the Elizabeth Islands, in 1996. I was a post-doc in physical oceanography, and the Department of the Environment had just acquired the island from the descendants of a sea captain prominent in the China trade of the early nineteenth century. The government acquired Nonamesset to establish the World Ocean Observing System [WOOS], a facility capable of monitoring the global ocean, using a fleet of small neutrally-buoyant floats called Slocums that draw their power from the temperature stratification of the ocean. Nonamesset Island was chosen partly because it is isolated from the mainland of Cape Cod, but mostly because it is close to the Woods Hole Oceanographic Institution, the Marine Biological Laboratory, and a thriving scientific community.

Henry Stommel's vision of the future in *Oceanography* magazine in 1989.... leading to ocean gliders



The Slocum Mission Control Center on Nonamesset Island.

Each Slocum reports into Mission Control via satellite about six times a day.

Ocean gliders : a new component of the ocean observing system

www.ego-network.org

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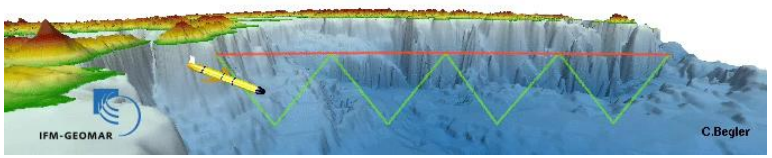

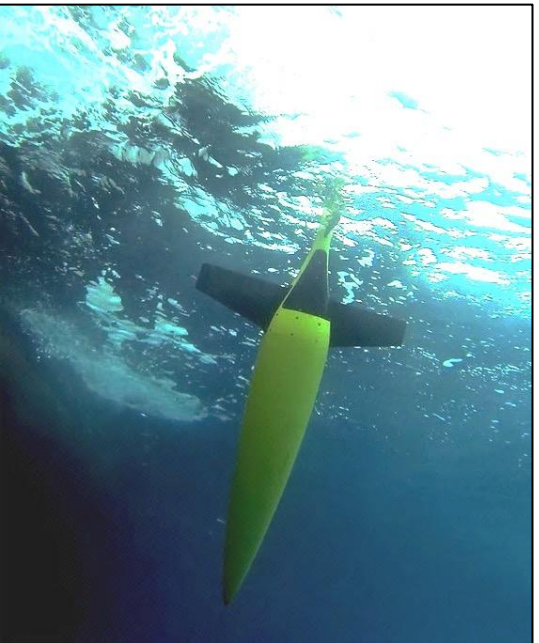

- They yoyo up and down in the top 1000 m
- Take ~ 4 hours for 1000 m dive
- Use buoyancy changes to descend or ascend like Argo floats, but they have wings and can be steered
- Horizontal speed ~25 -50 cm/s, ~20 km/day
- At the surface, they transmit data back via iridium satellite phone and receive new instructions
- Missions of ~ 6 months' duration
- Temperature and salinity data are sent to met agencies in real time
- Ideal for:
  - Monitoring currents that Argo floats escape from
  - Submesoscale information
  - Rapidly varying processes, e.g. diurnal cycle.

Gliders can carry many sensors – ideal for multidisciplinary studies

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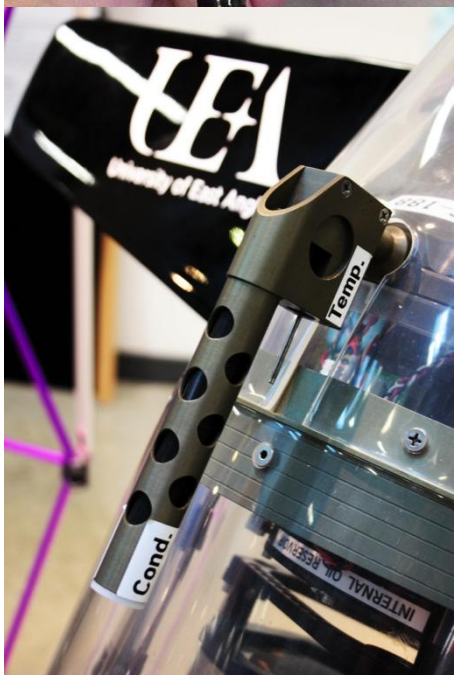
- Temperature and salinity (Seabird)
- Dissolved oxygen (Aanderaa optode)
- Chlorophyll fluorescence (Wetlabs triplet puck)
- Optical backscatter for particulates
- CDOM fluorescence
- PAR for underwater light levels
- Echo sounder for zooplankton biomasss
- Turbulent shear and temperature microstructure
- Dive-average current velocity
- Marine noise levels
- pH, pCO2 (in development)



Buoyancy-driven autonomous underwater vehicles

Ocean gliders offer new opportunities

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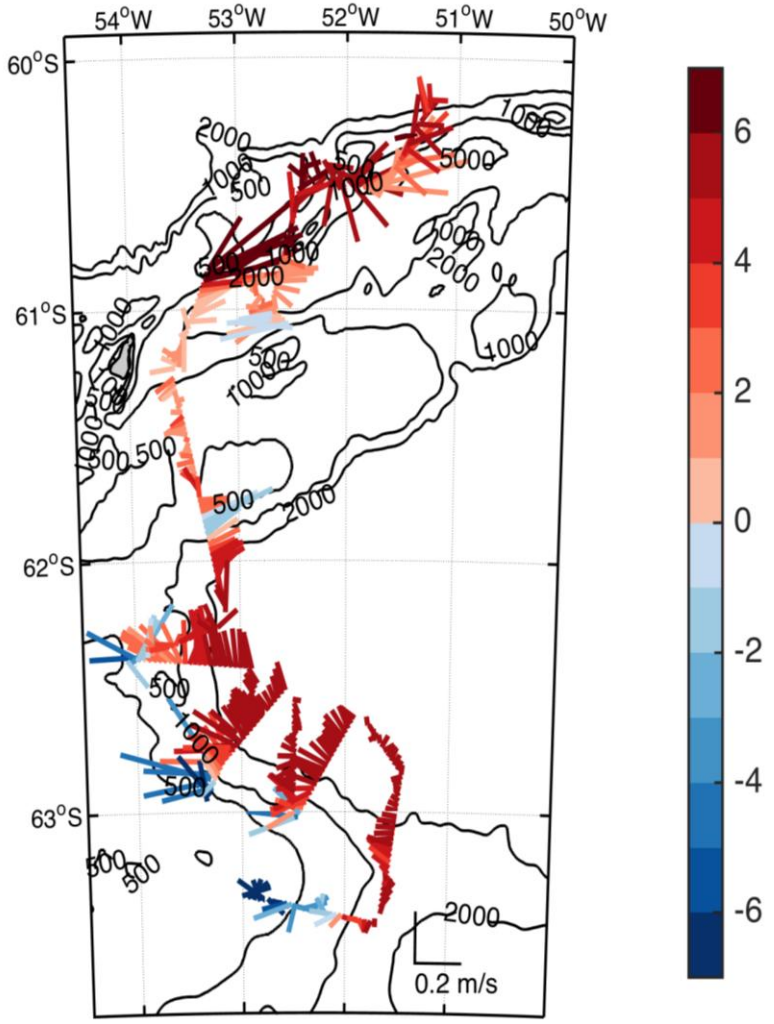
- Glider surveys can be designed to:
  - follow eddies
  - follow Lagrangian floats
  - occupy repeat sections
  - be a virtual mooring….



Glider dive average current coloured by warmest temperature below 300 m
Azaneu et al. (2017)

A whole year of glider measurements in the North Atlantic

Virtual mooring at Porcupine Abyssal Plain time series site

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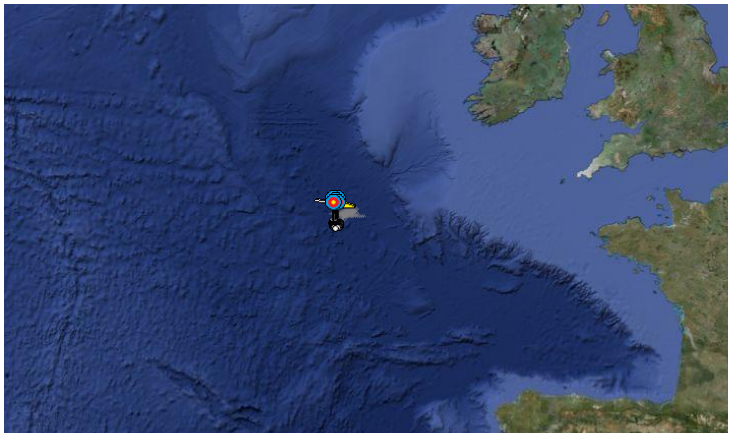
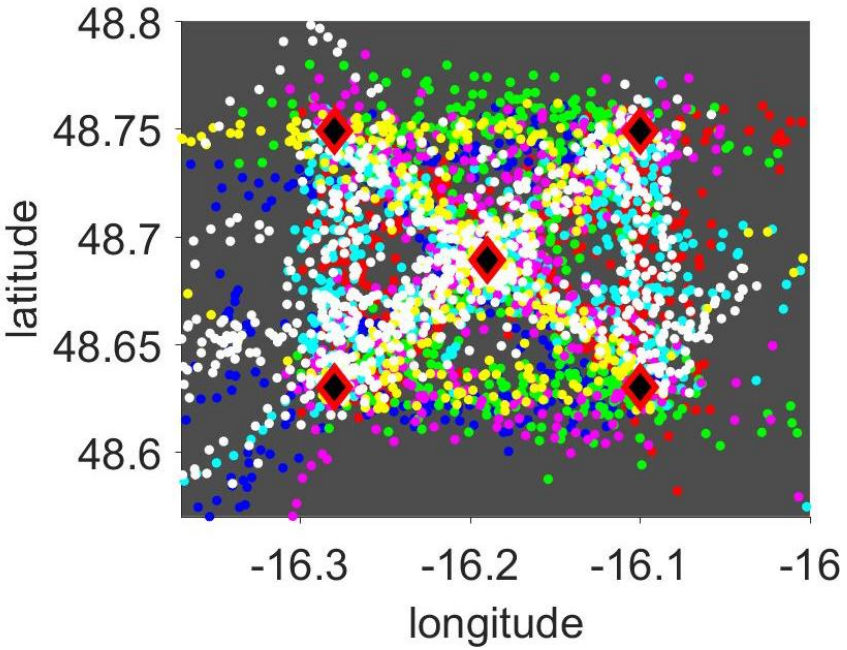


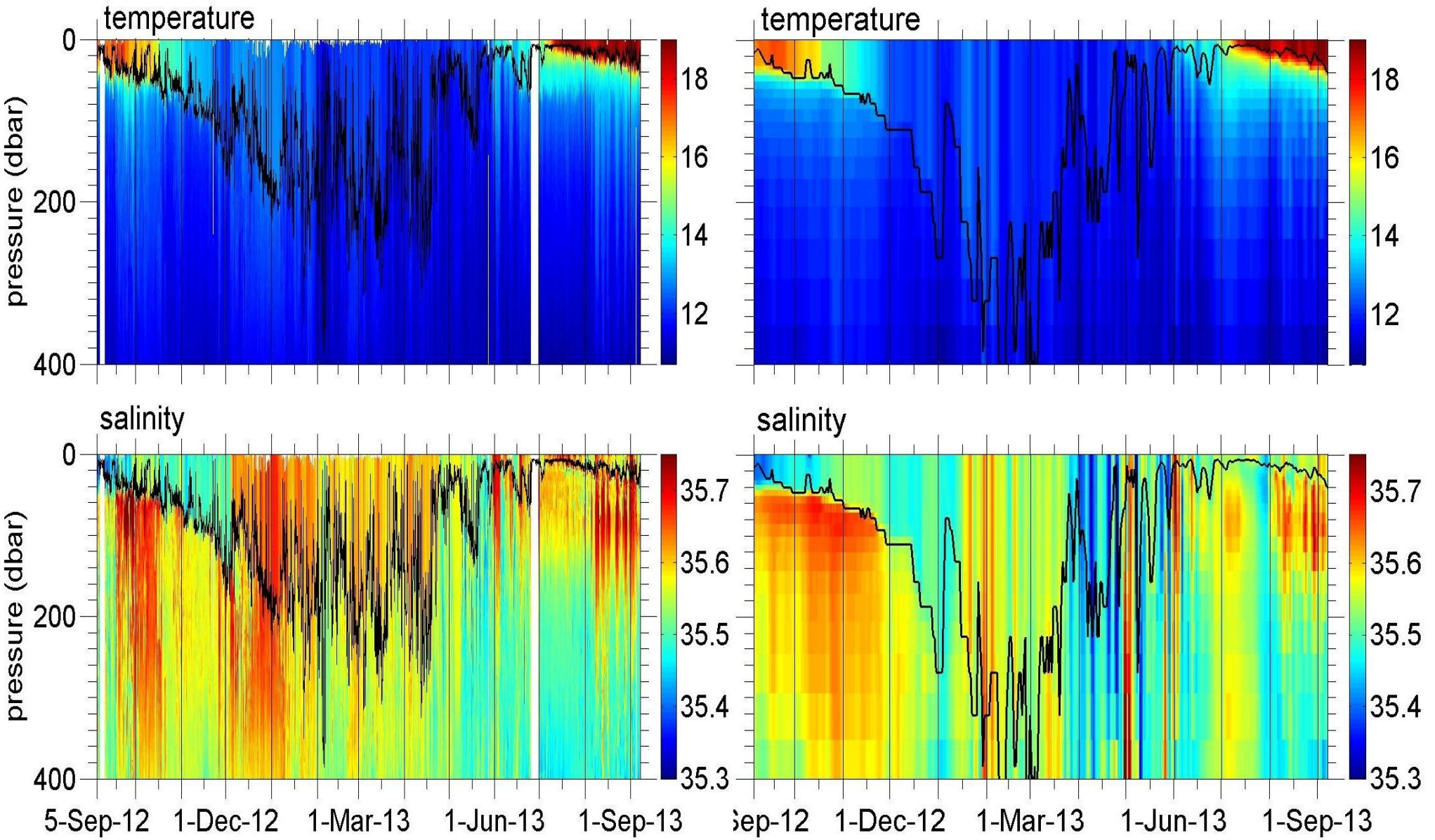


- OSMOSIS project with UK Met Office for improved weather and climate forecasting
- Aimed to better parameterise upper ocean wind-driven mixing and restratification
- Deployment September 2012 - September 2013, 2 gliders at a time continuously
- Turnaround every ~4 months; 4069 dives to 1000 m
- CTD, oxygen, chlorophyll & CDOM fluorescence, optical backscatter & PAR

Damerell et al. *(2016) J. Geophys. Res. Oceans.*
Thompson et al. *(2016) J. Phys. Oceanogr.*

Glider observations as a time series

FOAM Operational model



Damerell et al. (2016) The Vertical Structure of Upper Ocean Variability at the Porcupine Abyssal Plain during 2012-2013, Journal of Geophysical Research Oceans.

Seaglider deployment in the Indian Ocean
Equatorial dynamics

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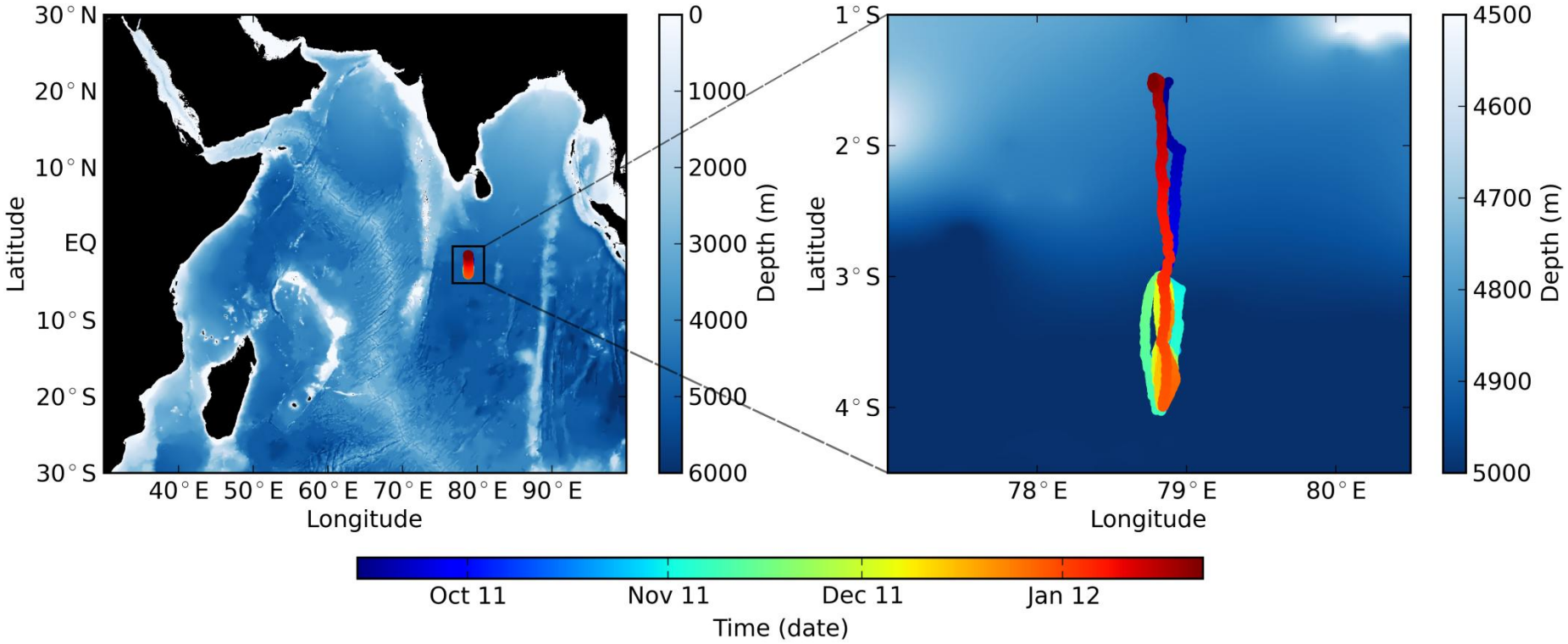

- Role of the ocean in the Madden Julian Oscillation
- Rectification of the diurnal cycle

CINDY/DYNAMO 2011/12 study area

Climate and Madden Julian Oscillation (MJO) variability

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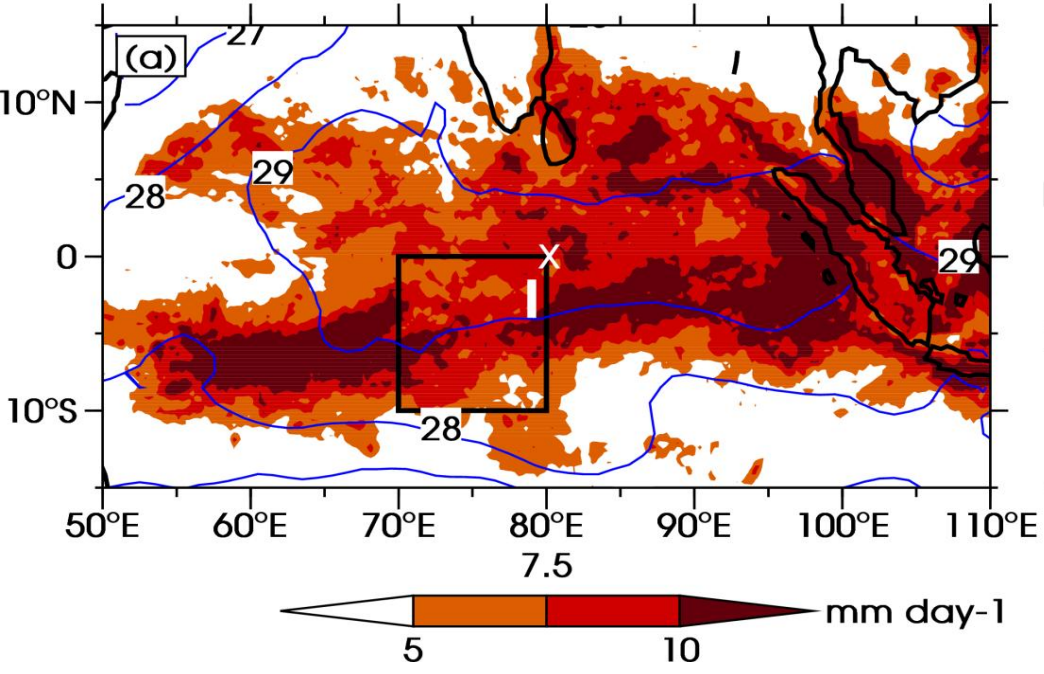
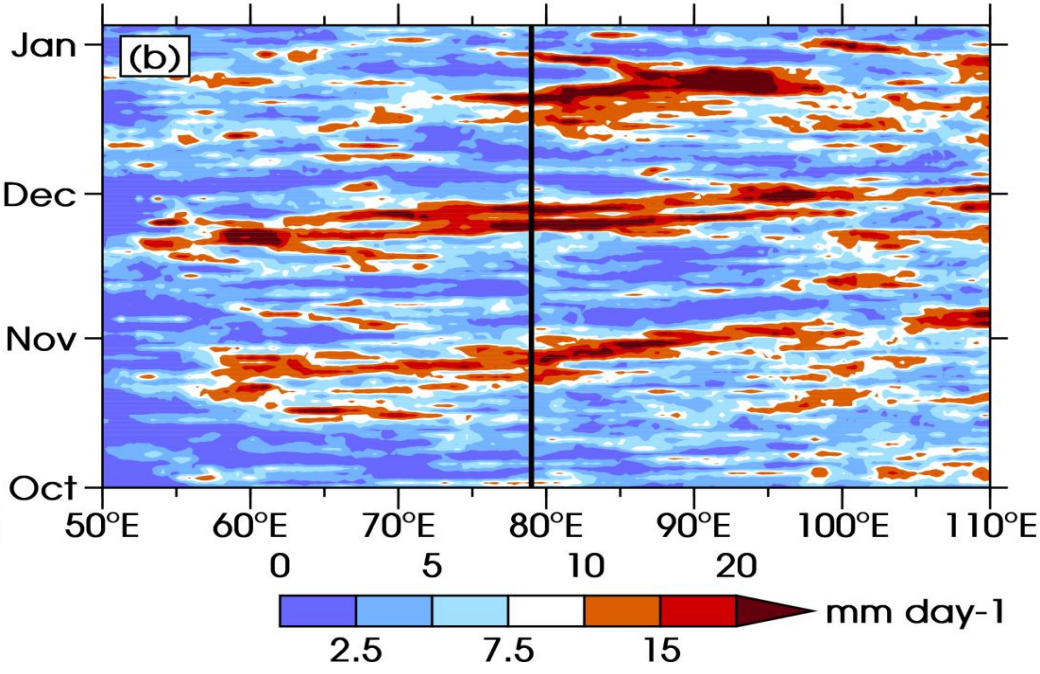
- Glider deployed at heart of tropical warm pool in the Indian Ocean
- ~100 days measurements
- 3 MJO events in study period
  - Different regimes in which diurnal cycle develops





Temporal variability

Sample month: November 2011

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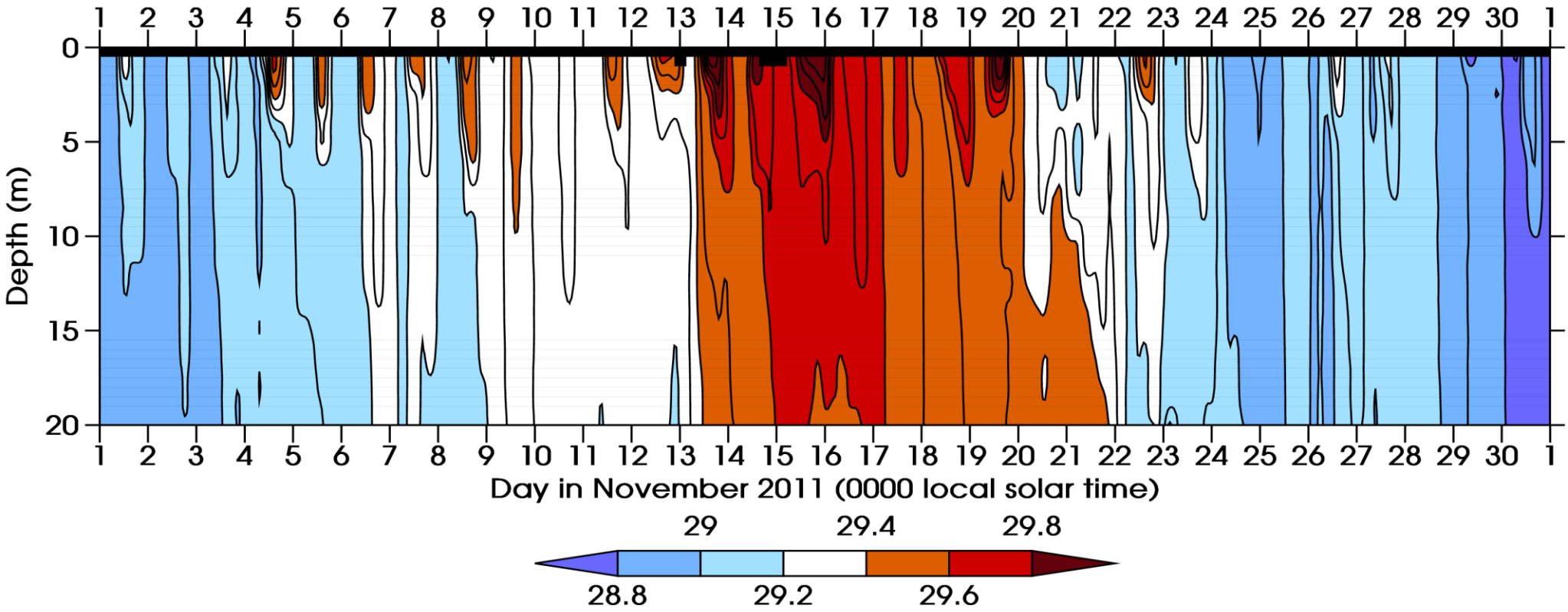
- Intraseasonal variability, Madden Julian Oscillation
- Ubiquitous diurnal variability



Glider profiles and optimal interpolation
Diurnal warm layer definition
Sample day: 3 December 2011

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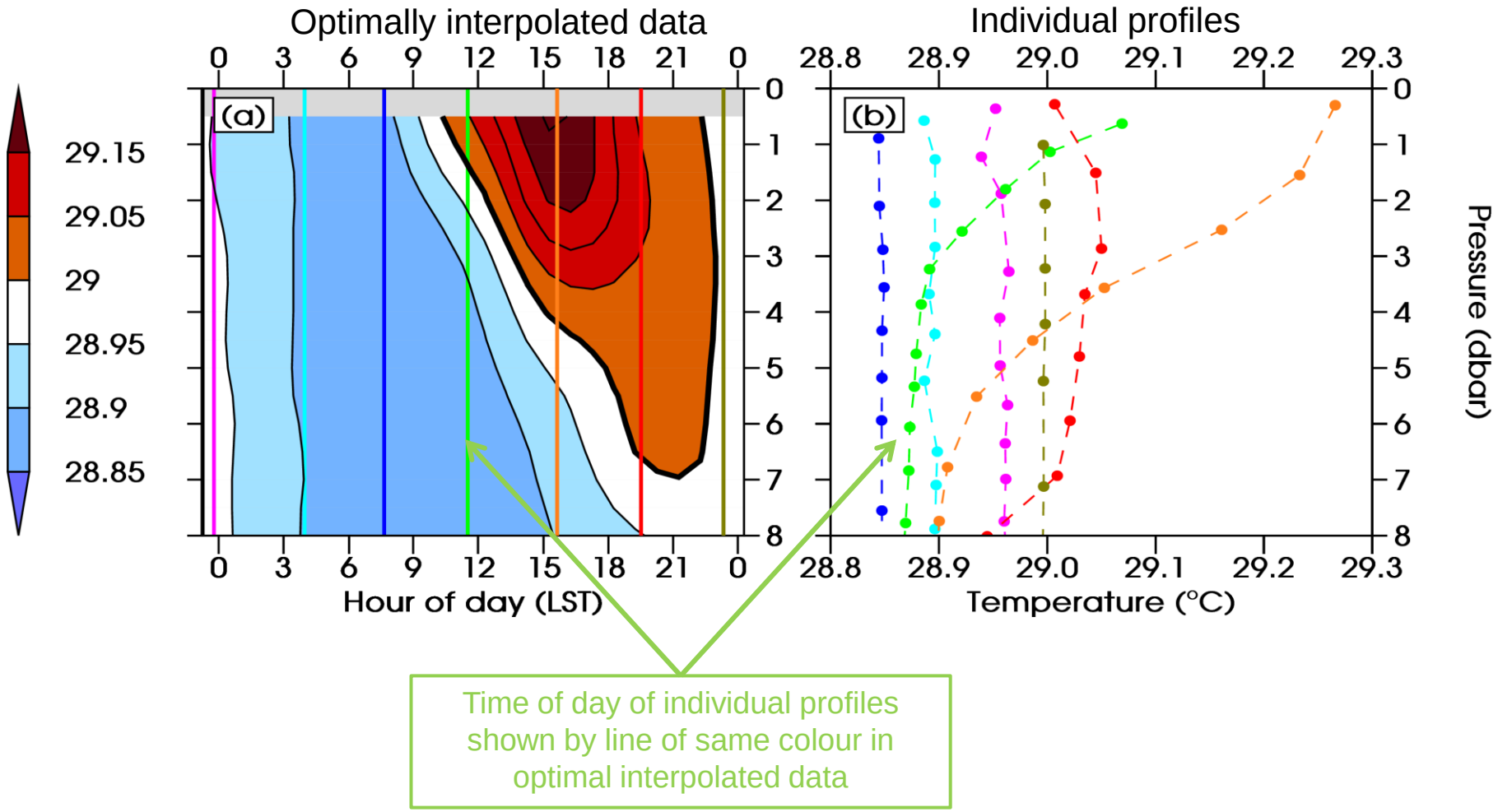

Argo floats and gliders make measurements in the top 10 m

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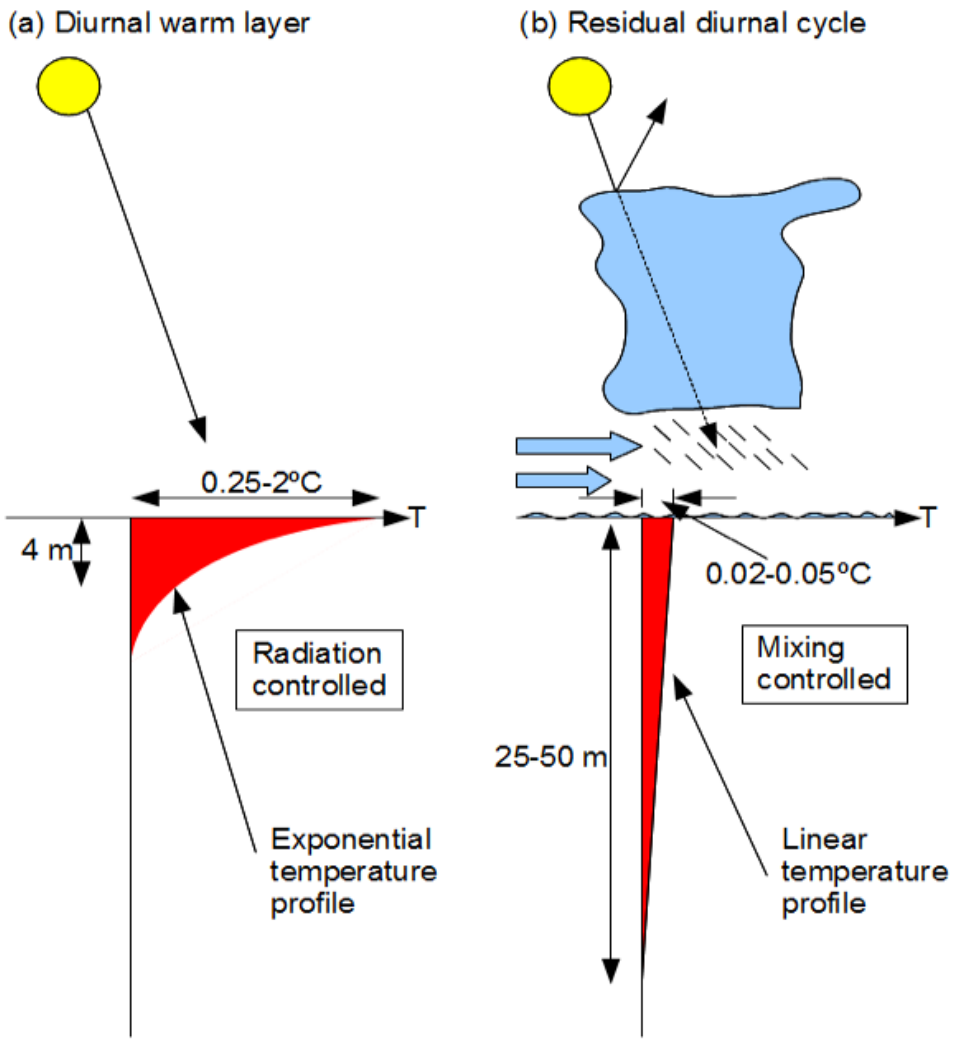
- Two regimes of diurnal cycle of ocean surface boundary layer
- Diurnal surface warm layer leads to cooling of ocean (~4 W m^{-2})
- Missing process in many climate models

Matthews et al. (2014) The surface diurnal warm layer in the Indian Ocean during CINDY/DYNAMO, *Journal of Climate*



ERC funded project COMPASS

Devising a way to deliver a profiling ocean glider to remote locations

- Using wave-powered autonomous surface vehicle AutoNaut
- Currently being designed for delivery and trials in 2019
- Caravela's first science mission in 2020
- Provide simultaneous atmospheric and oceanographic measurements

UEA & AutoNaut joint PhD studentship using Caravela now advertised! www.aries-dtp.ac.uk

Vision of the global ocean observing system

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