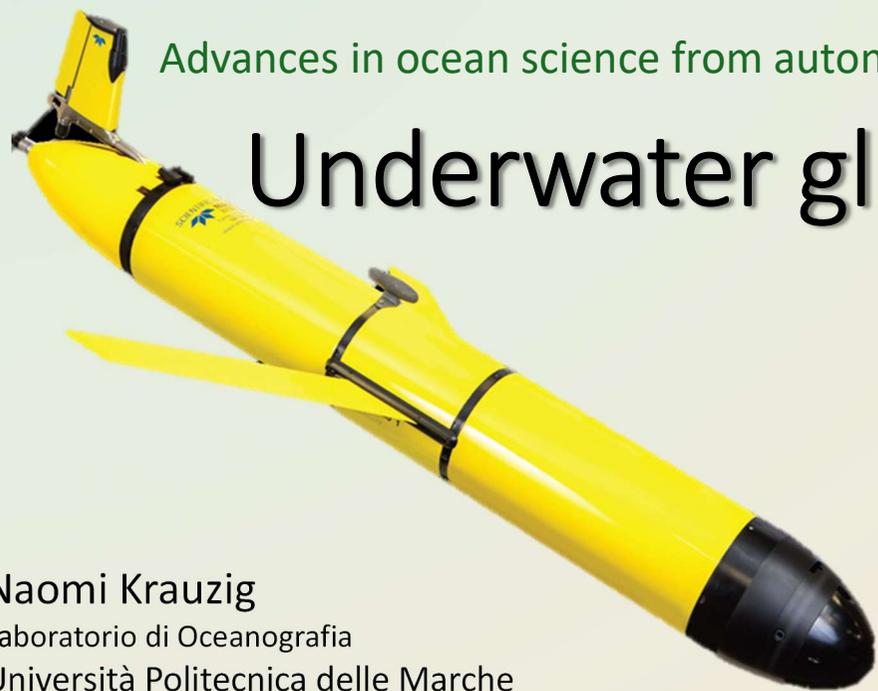




Advances in ocean science from autonomous gliders



# Underwater gliders

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Laboratorio di Oceanografia

Università Politecnica delle Marche

Autonomous Instruments in Oceanography

Università degli Studi di Napoli Parthenope

10-14 February 2025

**IR0000032 – ITINERIS, Italian Integrated Environmental Research Infrastructures System**

(D.D. n. 130/2022 - CUP B53C22002150006) Funded by EU - Next Generation EU PNRR-  
Mission 4 "Education and Research" - Component 2: "From research to business" - Investment  
3.1: "Fund for the realisation of an integrated system of research and innovation infrastructures"



## Contents

### **1) Introduction to underwater gliders**

*Overview, history, design  
Principles of operation*

### **2) Technical aspects and instrumentation**

*Energy efficiency, communication & navigation system and scientific sensors*

### **3) Real-life applications and usages in different disciplines**

*Capabilities and insight into diverse glider operations  
Exercise on realistic mission planning with the GLIMPSE simulation software*

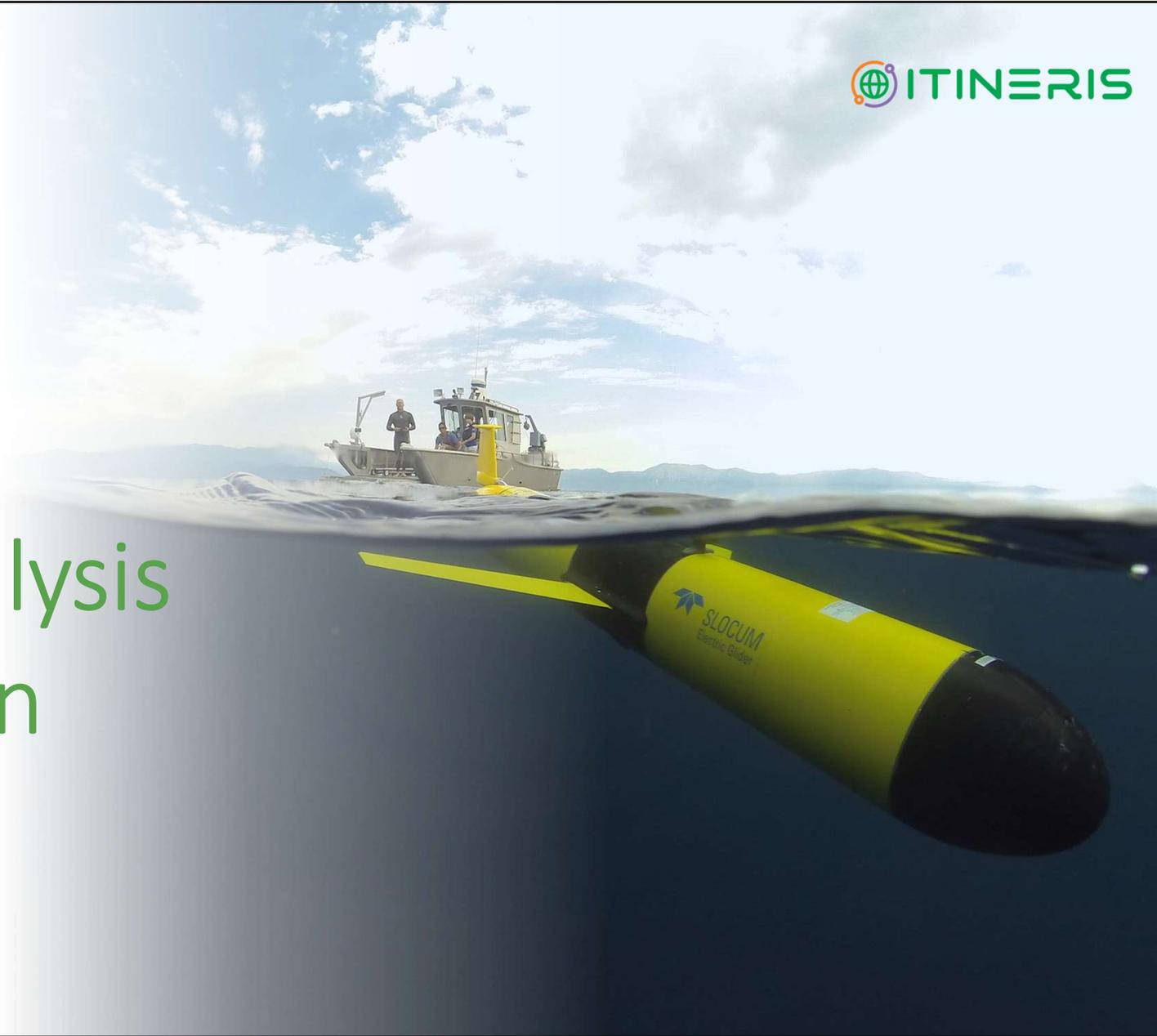
### **4) Glider data analysis and interpretation**

*Data output, existing processing tools and community efforts  
Practical session with sample data from recent missions*

### **5) Challenges, innovations and future perspectives**

*Current limitations and challenges, tips and tricks  
Ongoing innovations and future directions in glider technology*

# Glider data analysis & interpretation



Glider operation ends...

**Yay, the mission went well!**



**Safely recovered & tucked in “bed”**



Next steps

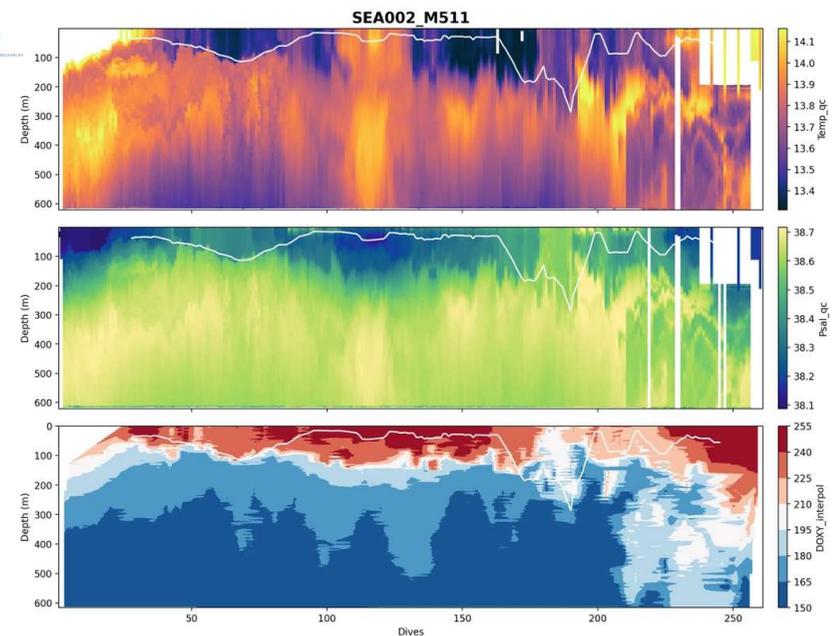
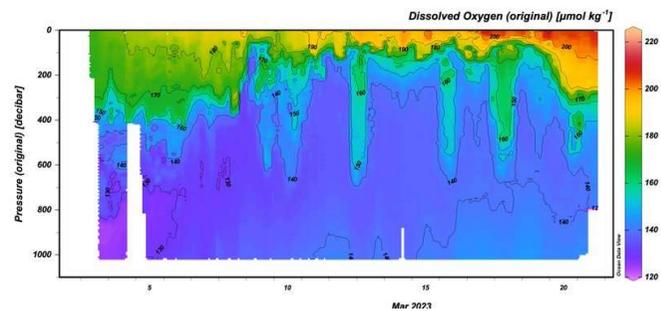
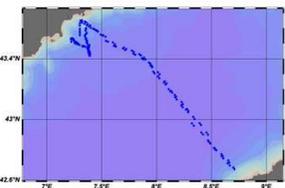
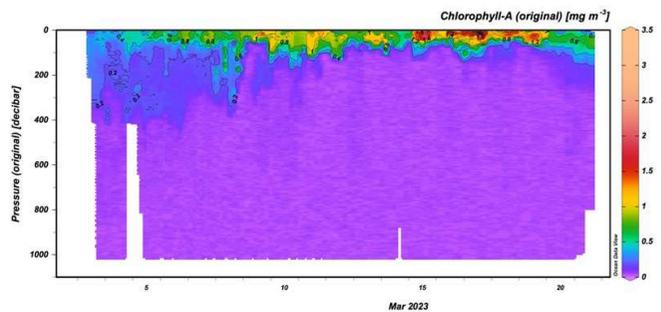
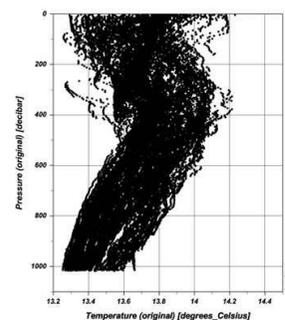
**Yay, the mission went well!**



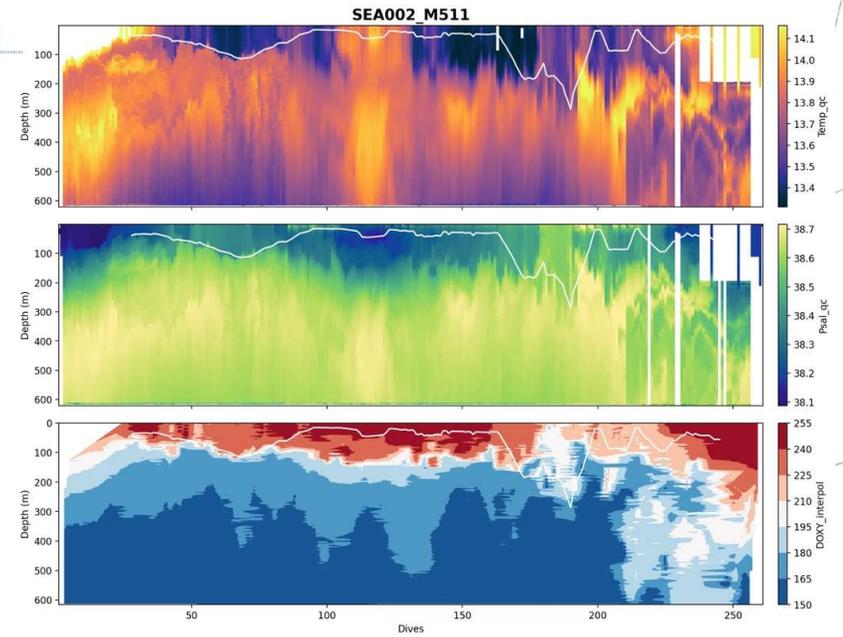
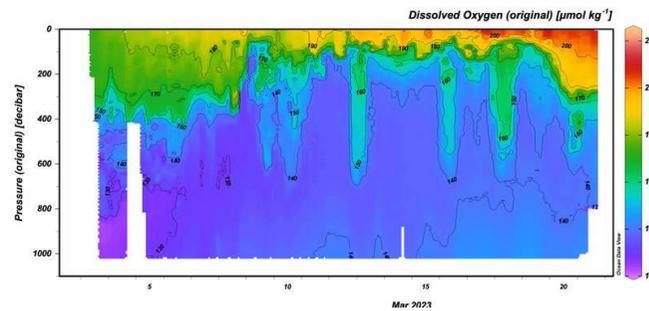
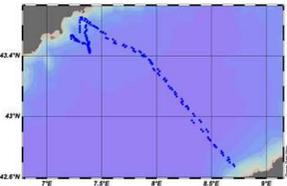
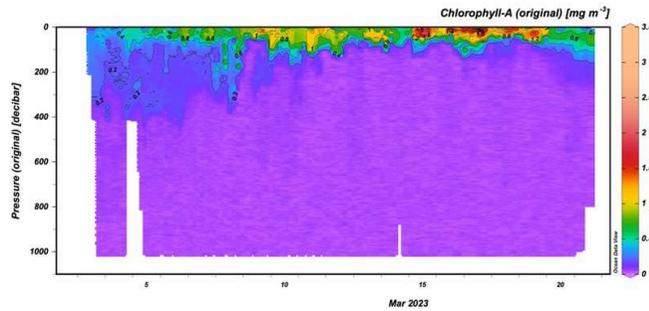
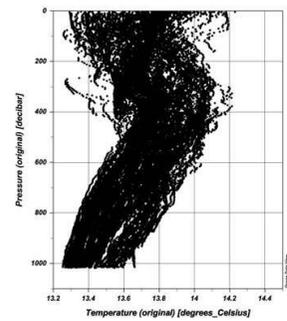
**Safely recovered & tucked in “bed”**



# Glider observations: raw data and outcomes

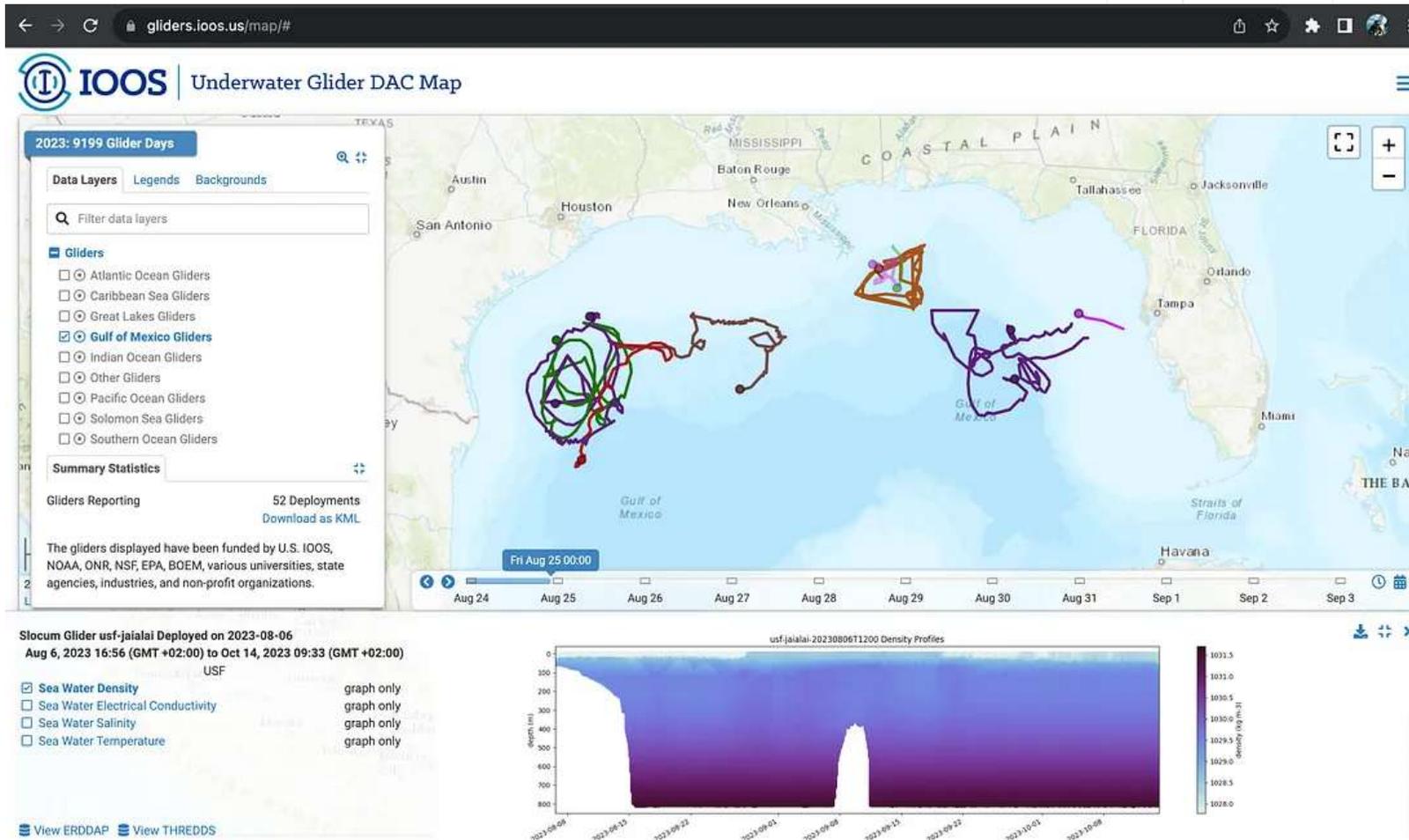


# Glider observations: raw data and outcomes



## Why do we collect data ?

# Direct data dissemination



## Data analysis, process studies, new insights and publication



### | DATA ACQUISITION

Continued development of smart sensors for automated sampling and data processing as well as more efficient data transfer, so more ocean data can be collected by machines rather than humans.



### | DATA HANDLING AND MANAGEMENT

Develop community standards and well-designed data management plans ensuring Findable, Accessible, Interoperable and Reusable (FAIR) data.



### | COMPUTING INFRASTRUCTURE AND INTEROPERABILITY

Marine data services need to be interoperable and incorporate cloud-computing, cloud-storage, and analytical tools.



### | DATA SHARING

Data need to be open and data sharing should be incentivized between scientists, industry and governments.



### | BIG DATA ANALYTICS AND DATA VALIDATION

Develop standardized algorithms and community maintained data sets that can be used for model training and calibration.

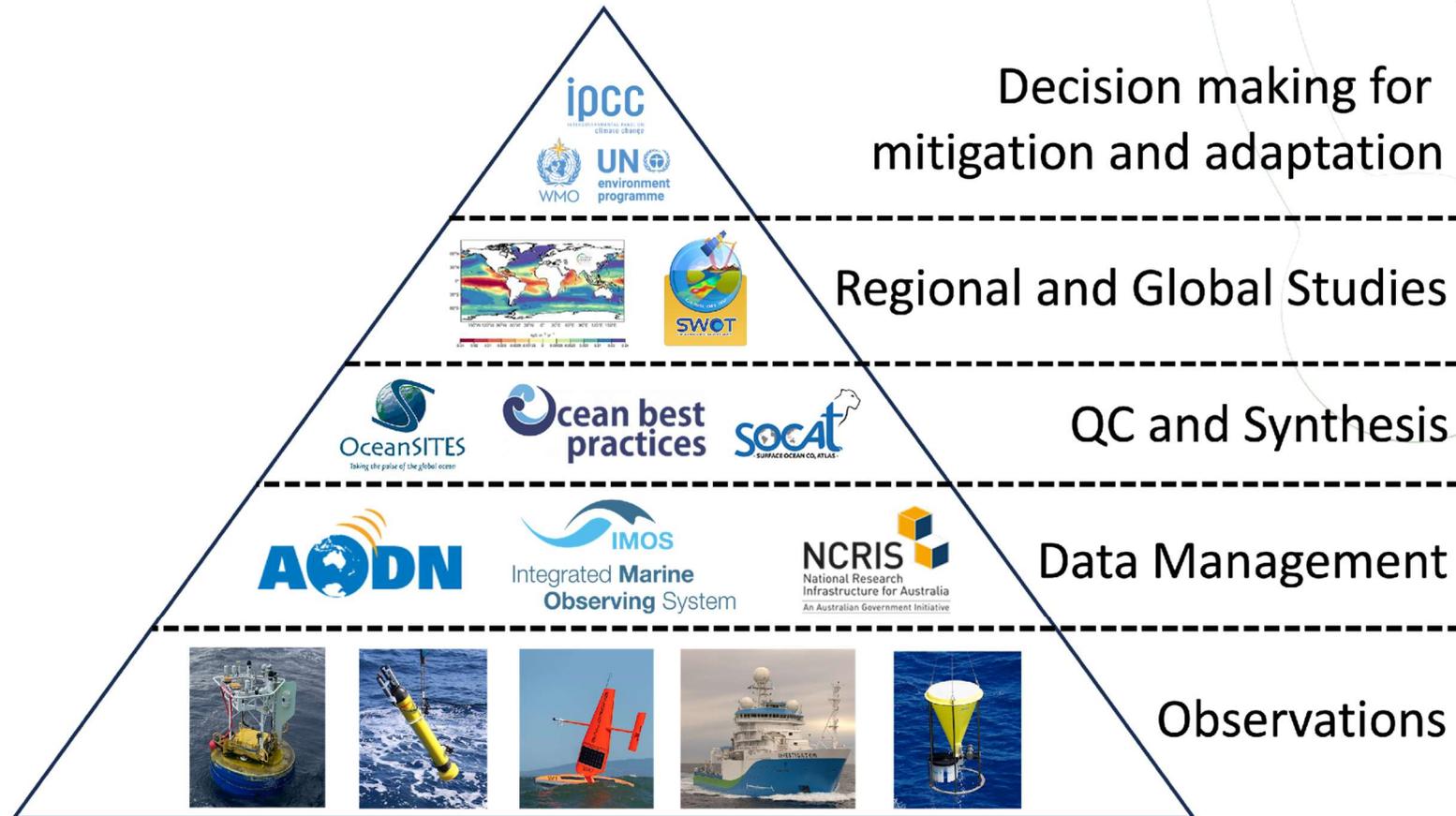


### | TRAINING AND COLLABORATION

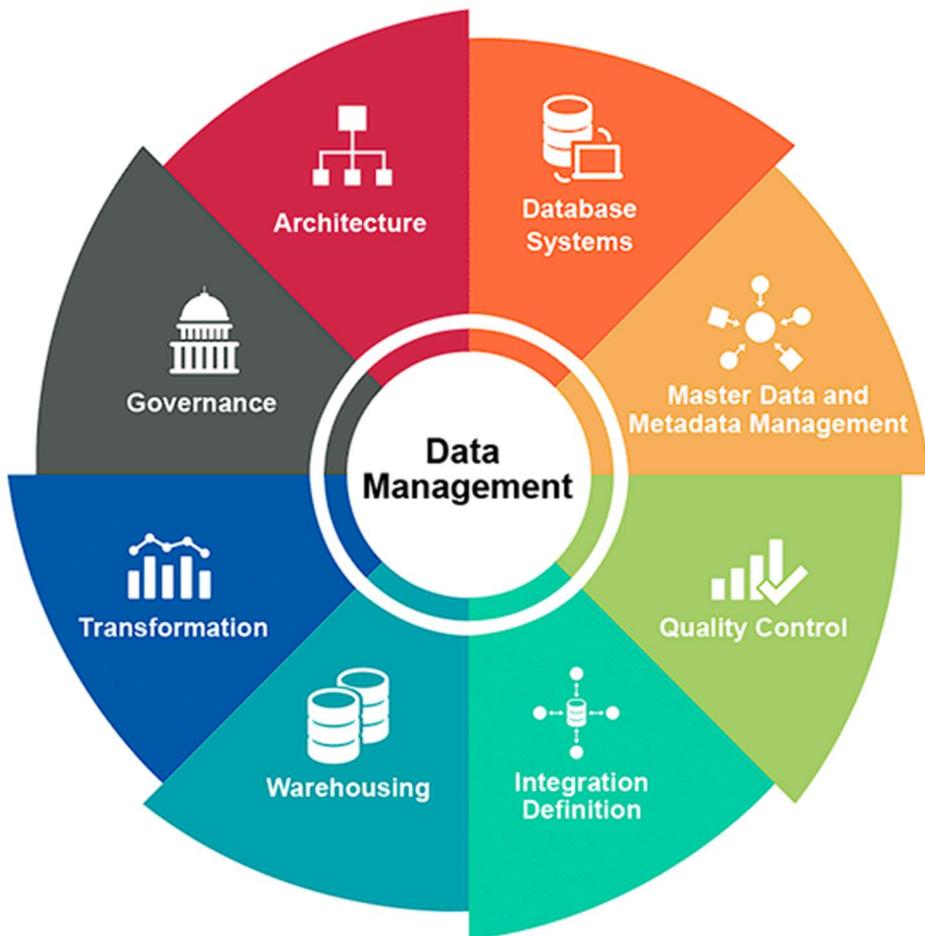
Develop specialized training for marine scientists to adopt the use of artificial intelligence. Collaborations are needed between marine scientists and computer scientists.

Guidi et al., 2020 (<https://doi.org/10.5281/zenodo.3755793>)

# Data chain, usage and impact



Best available quality



### Delayed Mode Quality Control

- Physics
- Biogeochemistry



<https://github.com/OceanGlidersCommunity>

# Quality Control



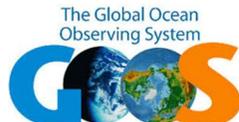
## Delayed Mode Quality Control

### Physics

- Depth
- Temperature
- Salinity
- Ocean currents
  - Depth-average currents
  - Depth-dependent horizontal currents
- Turbulence

### Biogeochemistry

- Dissolved oxygen
- Nitrate
- Chlorophyll a concentration
- Carbon variables
  - Particulate matter
  - CO<sub>2</sub>
  - pH
  - Hydrocarbons



<https://oceangliderscommunity.github.io/OG-format-user-manual/vocabularyCollection/tableOfControlledVocab.html>

## A KEY EMERGING GLOBAL NETWORK FOR IMPROVING STORM FORECASTS

### Why storm forecasts?

- Storms effect billions of people that live and work near the coast, causing 100's of billions of dollars in damage annually
- Many storms originate at sea, and are affected by specific Ocean Features such as boundary currents and eddies, subsurface thermal structure, and major river plumes
- Some of the world's best weather forecasts are produced by coupled atmosphere-ocean models that assimilate real-time data from a vast global observation network

### How do gliders improve hurricane forecasts?

- OceanGliders operate unhindered by storms in a broad range of water depths
- All OceanGliders provide critical data for assimilation well ahead of the storms to better define Essential Ocean Features impacting storm intensity
- OceanGliders encountering storms improve scientific understanding of Essential Ocean Processes and their atmospheric feedbacks
- Uncertainties in forecast models provide guidance on where and when to deploy OceanGliders to maximize value

### Next Steps - Increasing the availability of glider data globally

- **Enable any glider deployed at sea to contribute to improved storm forecasts**
- **Develop increased capacity to operate gliders in regions with severe storms**
- **Expand use of glider sensors that foster collaborations beyond tropical storms**

### OceanGliders: our task teams aim to enhance the global ocean observing system\*

- **Boundary Current** › Sustained glider observations in the ocean boundaries
- **Storms** › Improve extreme weather forecasts with unique ocean observations
- **Water Transformation** › Monitor shelf/open sea water formations & variability
- **Ocean Health & Ecosystems** › Observe variability, change and stress in habitats
- **Data Management** › Harmonise globally and support implementation
- **Best Practices** › Guide implementation of gliders capabilities for all

\*Ocean OPS Observation Coordination Group (OCG) adopted OceanGliders as an "emerging" network in 2016.

Powered by

See OceanGliders sponsors on: [www.oceangliders.org/taskteams/storm/](http://www.oceangliders.org/taskteams/storm/)

**Can we help you contribute to global Storm Forecasting?**  
[contact@oceangliders.org](mailto:contact@oceangliders.org)

The Global Ocean Observing System

# Ocean observations: fundamental to society



Climate action

Forecasts & early warnings

Blue economy

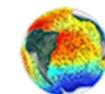
Community adaptation

Ocean health

Carbon strategies



No one country can observe the ocean effectively on its own.



## Best available quality

Delayed Mode Quality Control (DMQC) for salinity:

### •Correction for Dynamic Errors:

- Address spatial offsets, timestamp misalignments, and thermal-inertia effects in conductivity and thermistor measurements.
- Apply thermal mass correction using methods like Garau et al. (2011) for pumped and unpumped CTDs.

### •Sensor Offset and Drift Correction:

- Compare salinity and temperature measurements with co-located reference CTD casts to detect and correct sensor drifts.
- Report correction details and reference data used.

### •Secondary Cleaning and Despiking:

- Remove residual spikes using median filters or rolling medians in regions with strong thermoclines.
- Improve error correction for salinity in areas with rapid temperature changes.

### •Inter-comparison:

- Perform inter-calibration with data from different platforms (e.g., shipboard CTDs, Argo floats).
- Ensure salinity consistency across platforms using  $\theta/S$  diagrams and historical data comparisons.
- Use semi-automatic tools (e.g., SOCIB's salinity correction toolbox) for field corrections.



# OceanGliders



We are an open community! If you want to join the effort just browse through the different repositories, raise issues or start a discussion. A good start is also to [introduce you](#).

## Ongoing community efforts

- [GitHub training](#) 🤖 🏆
- [Meeting notes](#)
- Access and discuss the OceanGliders format - [OG1.0](#).
- OceanGlider's BUFR format is defined in [WMO's manual on Code Vol 1.2](#) in table D by descriptor 3-15-012. Provisional version of next release is available [here](#) (see page #658). The archived proposal and related discussions can be found at: [wmo-im/BUFR4#16](#)
- SOPs for Data Assembly Centers are available [here](#).
- Join the [Oxygen SOP](#). v1.0.0 released on June 1 2022, [doi](#)
- Join the [Salinity SOP](#) community review: Open until June 30 2022.
- Join the [Nitrate SOP](#) community review: Open until June 30 2022.
- Join the [Depth Average Currents \(DACs\) SOP](#).
- Join the [Chla SOP](#).
- Join the [Vertical Velocities SOP](#)
- Join the [BOON task team repository](#).
- Join the [Glidertest repository](#).

If you wish to contribute to the SOP development just let us know [here](#).



## Data processing: Quality Control



### 1) Response Time Lag

Sensors might be slightly out of sync due to:

**1. Sensor Placement:** If one sensor (e.g., temperature) is positioned slightly **ahead** or **behind** the conductivity sensor on the instrument, it will sense the same water at a different moment.

**2. Water Flow:** If water takes **different paths** to reach each sensor (like through tubing or plumbing), there's a delay in when they sense the same water.

This delay (or **lag**) can lead to **incorrect salinity values** and make the data look like it has sharp jumps (spikes), especially in density profiles.

### How is this fixed?



[https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data\\_05\\_09\\_16.pdf](https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data_05_09_16.pdf)

## Data processing: Quality Control

### 1) Response Time Lag Correction

The method solves this problem by:

- **Shifting one data set in time** to align the temperature and conductivity measurements correctly.
- The amount of shift depends on how fast the water is flowing (either due to the glider's speed or a pump system) and the **sampling rate** of the instrument.

By aligning the temperature and conductivity values, you ensure the salinity calculation is based on measurements from the **same parcel of water**, resulting in more accurate and stable data.

[https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data\\_05\\_09\\_16.pdf](https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data_05_09_16.pdf)



# Data processing: Quality Control

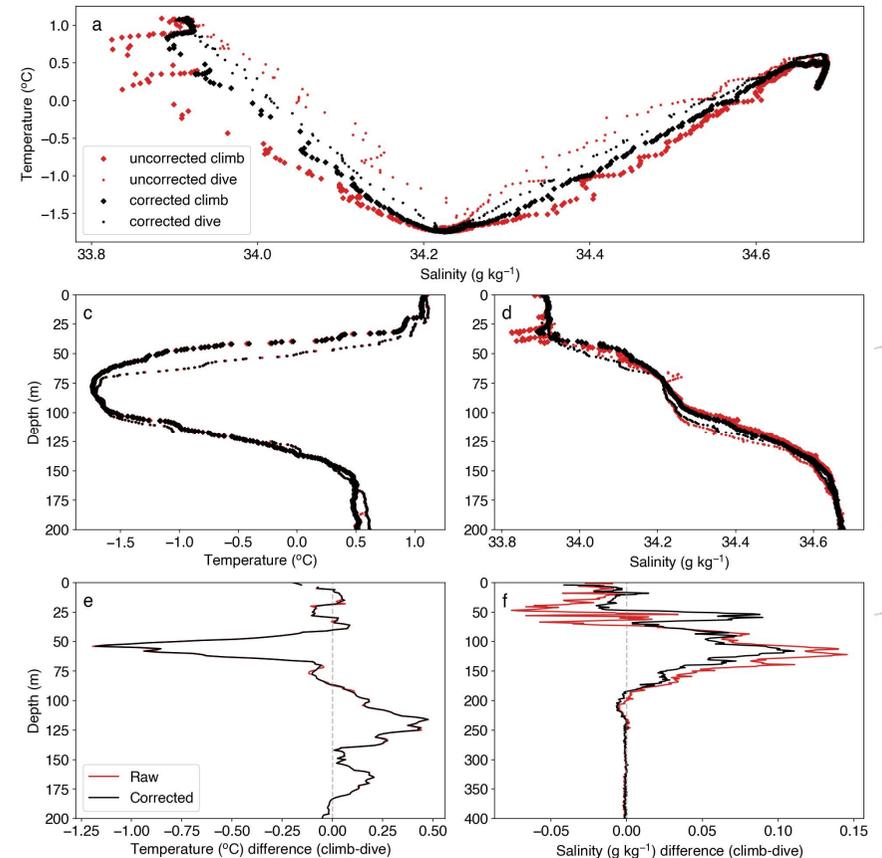
## 2) Thermal Lag

When a glider moves from **warm water into cooler water** (or vice versa), the **conductivity sensor** takes some time to adjust to the new temperature.

This creates **artificial spikes or offsets** in the data, making it hard to interpret what's really happening in the ocean.



[https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data\\_05\\_09\\_16.pdf](https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data_05_09_16.pdf)



### 2) Thermal Lag Correction

The **method** accounts for this by adjusting the conductivity data to remove the effect of the sensor's heating or cooling.

It works like this:

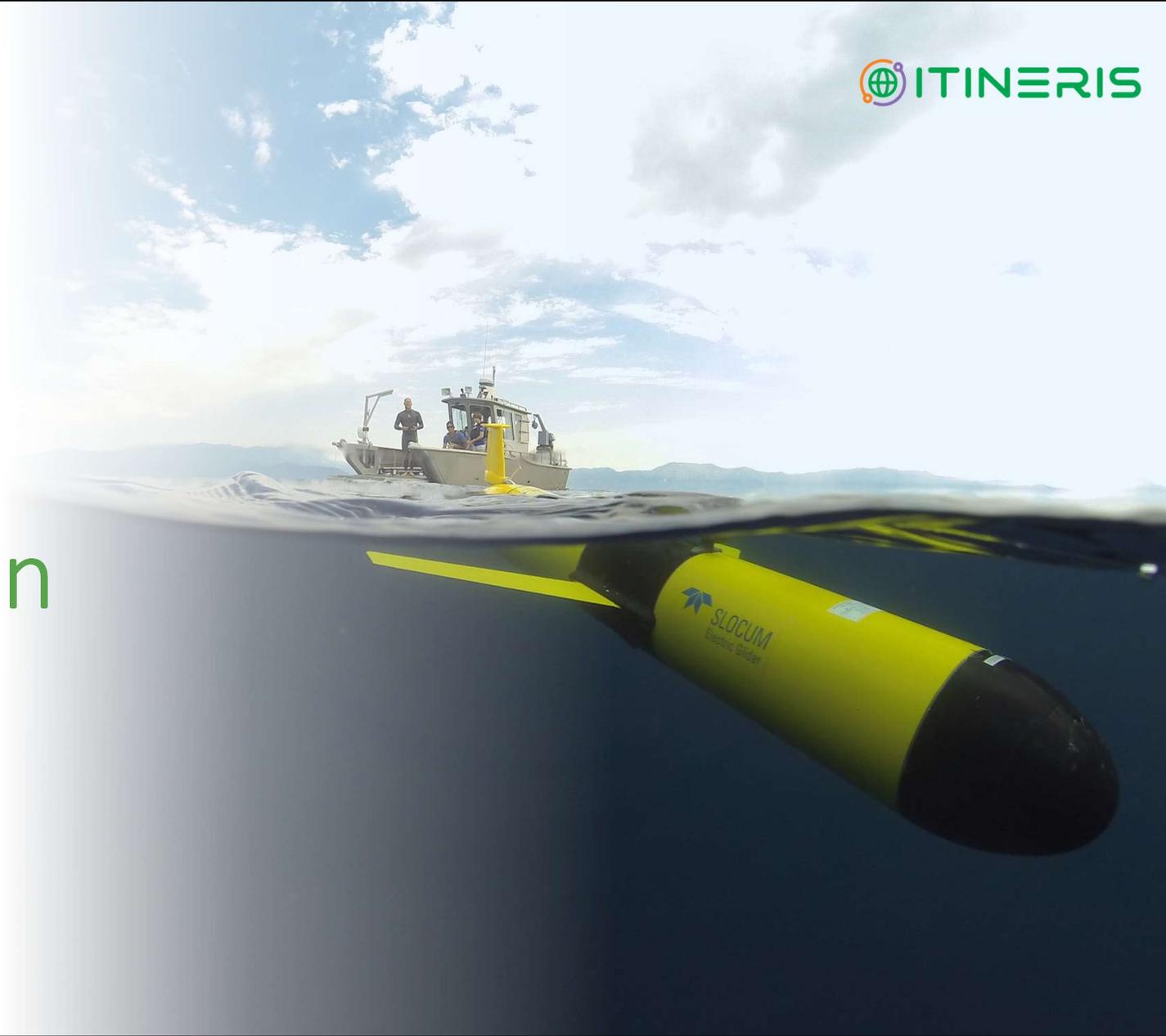
**1. Estimate how much the sensor heats or cools the water** based on the sensor's thermal properties and the rate of temperature change.

**2. Correct the conductivity readings** by compensating for this small temperature change inside the sensor.



[https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data\\_05\\_09\\_16.pdf](https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data_05_09_16.pdf)

# Practical session



## Data source

### Rutgers University RU29 Challenger glider

From Ubatuba, Brazil on June 23, 2015 to travel across the Atlantic Ocean.

After 282 days at sea, the Challenger was picked up off the coast of South Africa, on March 31, 2016



# Requirements

## 1) Anaconda

### Free Download\*

Register to get everything you need to get started on your workstation including Cloud Notebooks, Navigator, AI Assistant, Learning and more.

- ✓ Easily search and install thousands of data science, machine learning, and AI packages
- ✓ Manage packages and environments from a desktop application or work from the command line
- ✓ Deploy across hardware and software platforms
- ✓ Distribution installation on Windows, MacOS, or Linux

\*Use of Anaconda's Offerings at an organization of more than 200 employees requires a Business or Enterprise license. [See Pricing](#)

<https://anaconda.cloud/>

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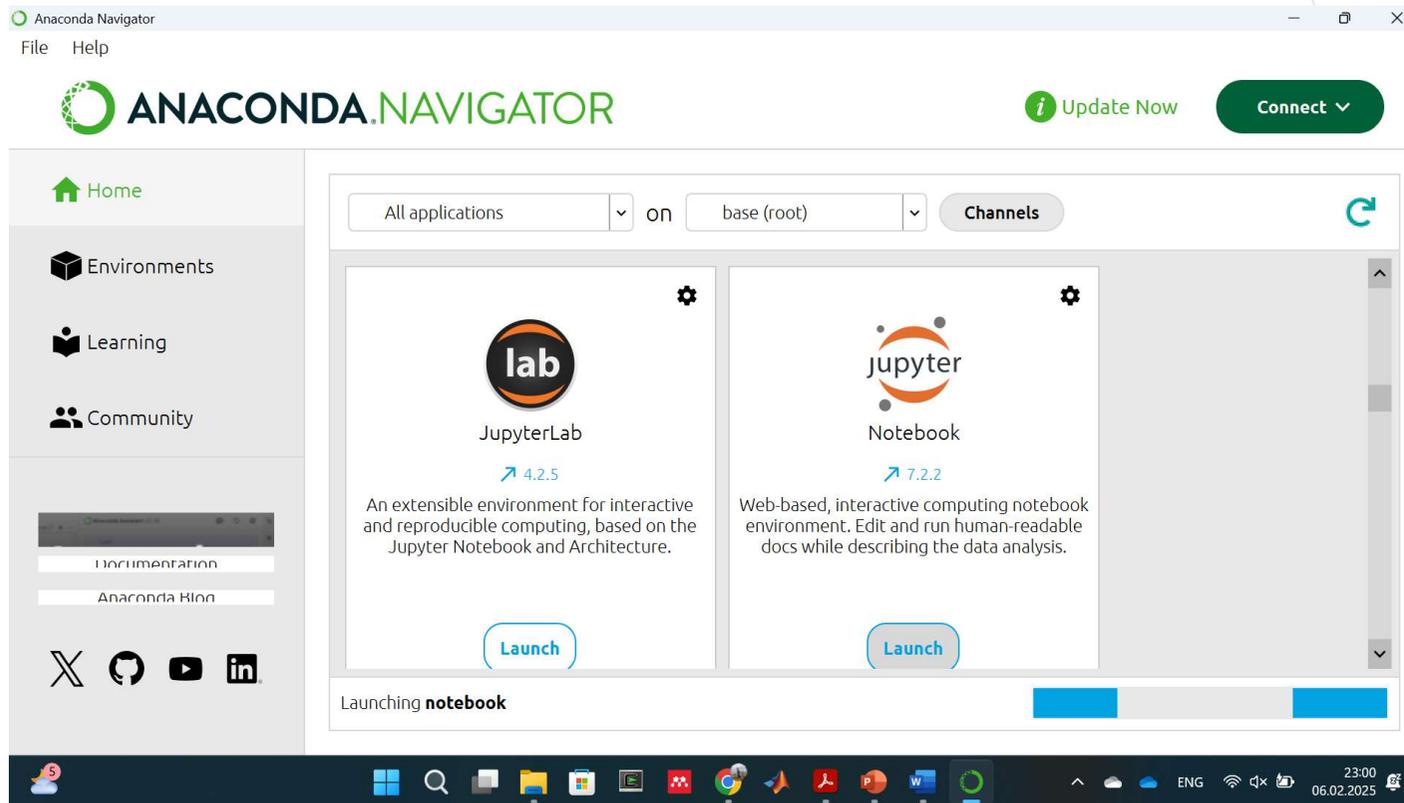
[Skip registration](#)



<https://www.anaconda.com/download>

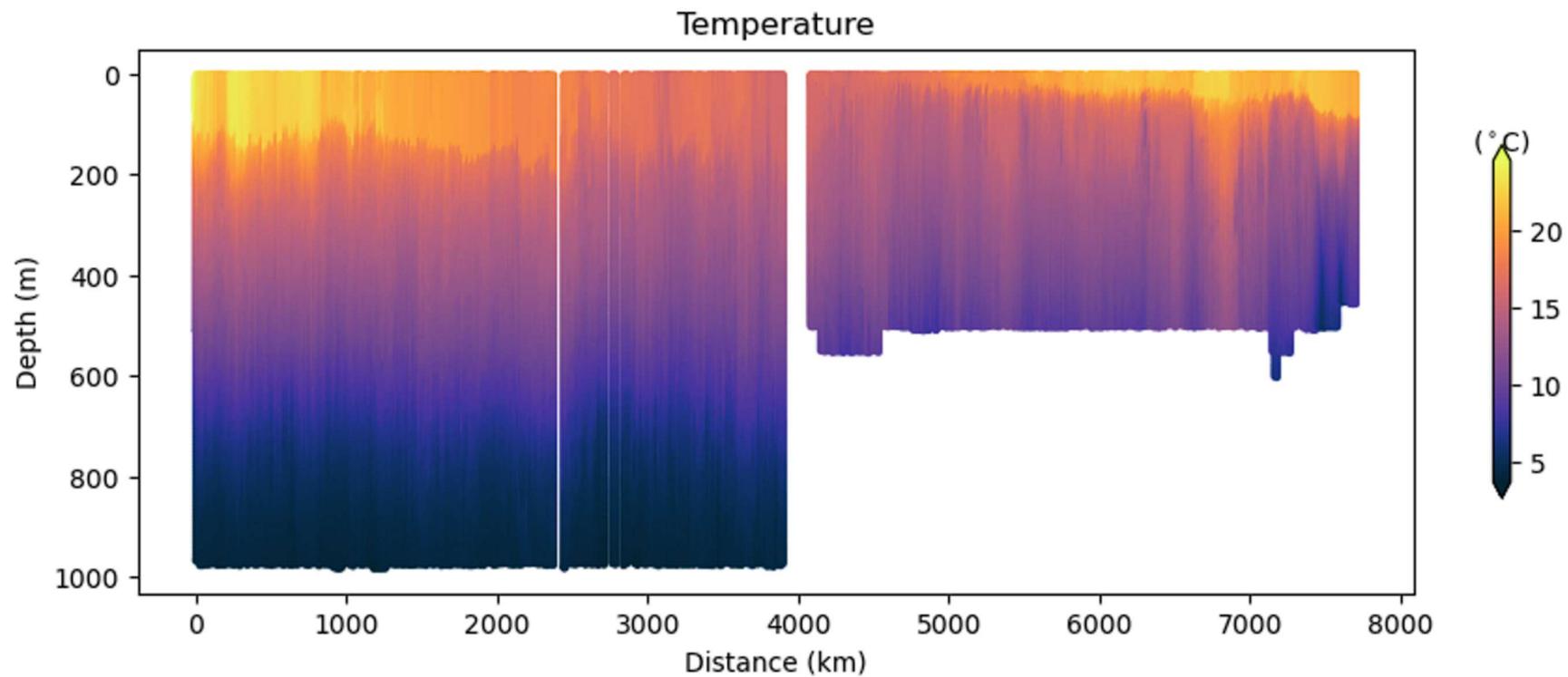
# Requirements

## 2) Anaconda Navigator → Jupyter Notebook



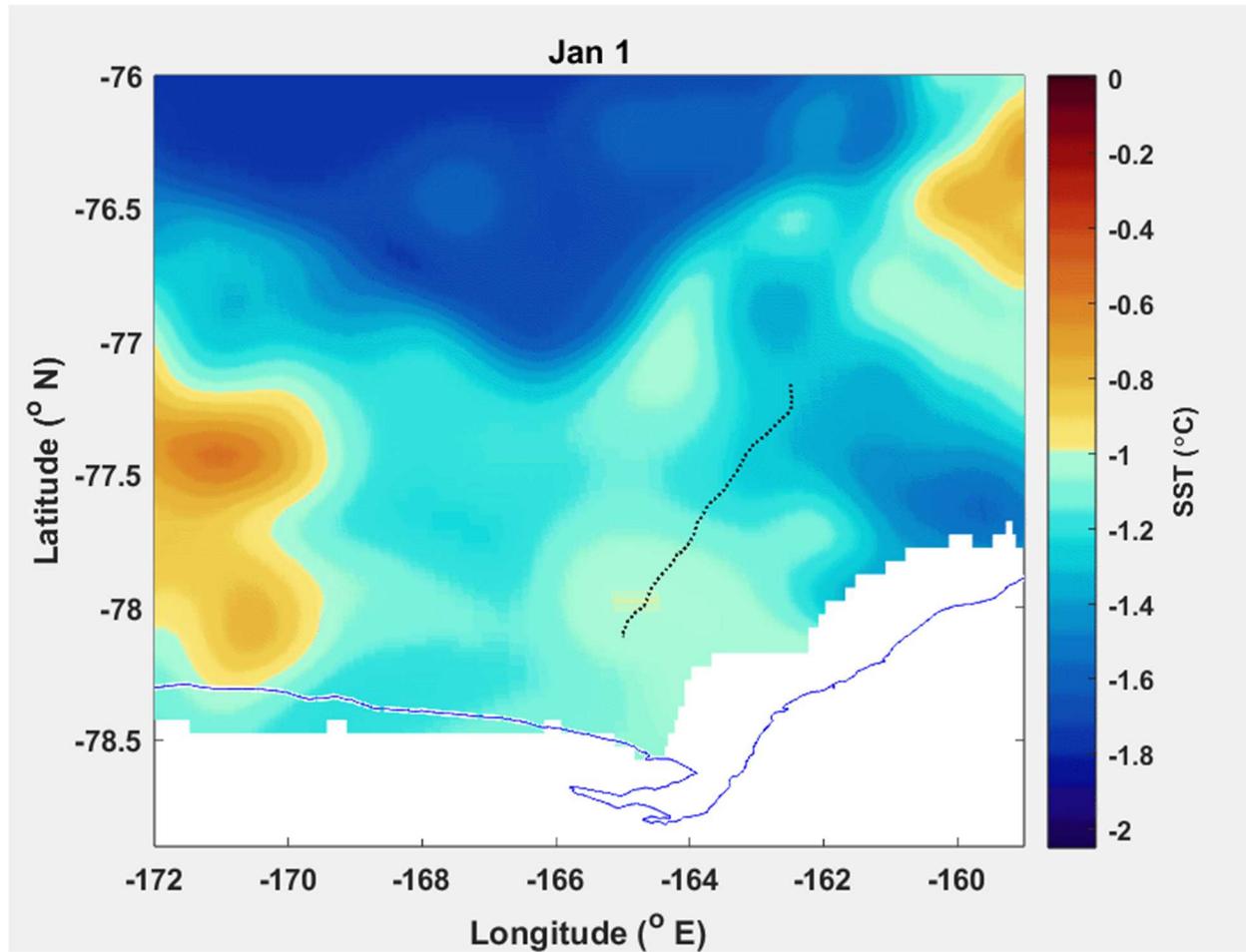
# Requirements

## 3) Glider data

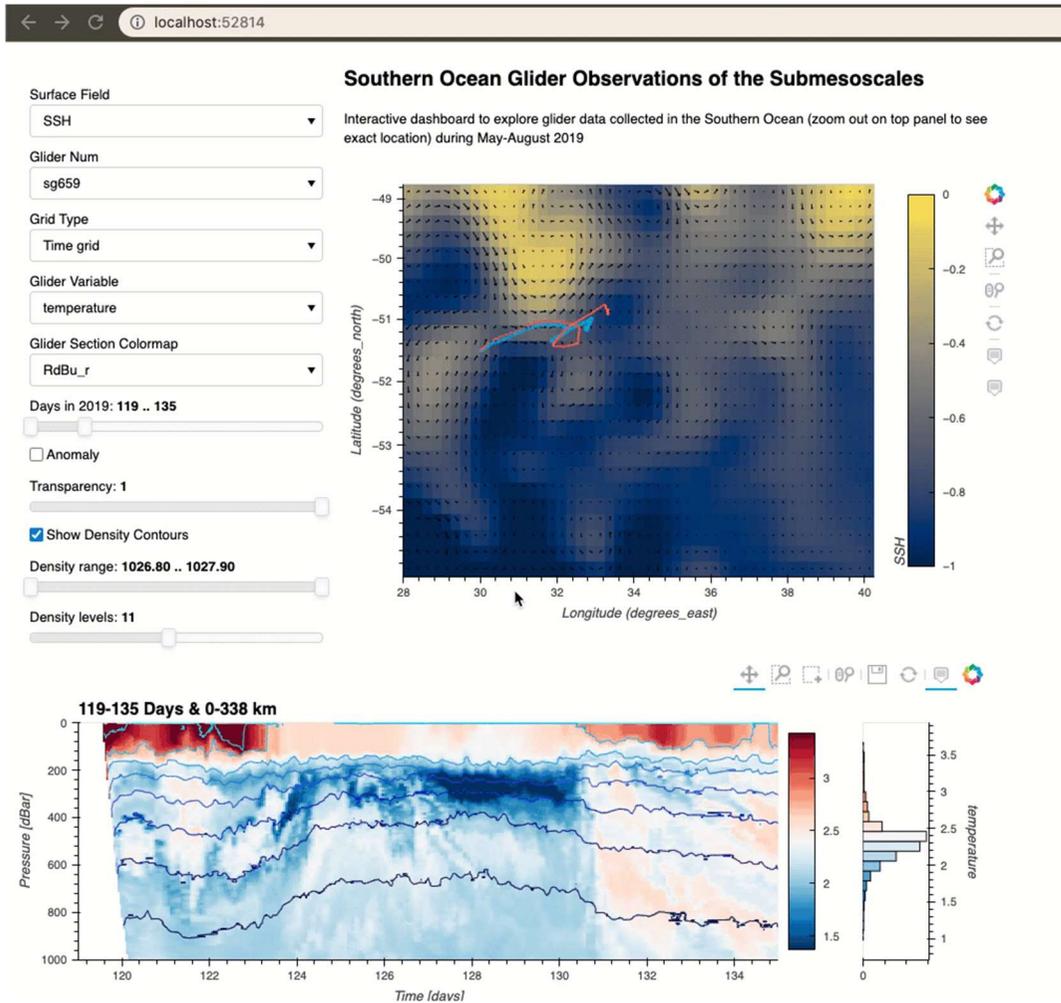


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# Assessing environmental conditions



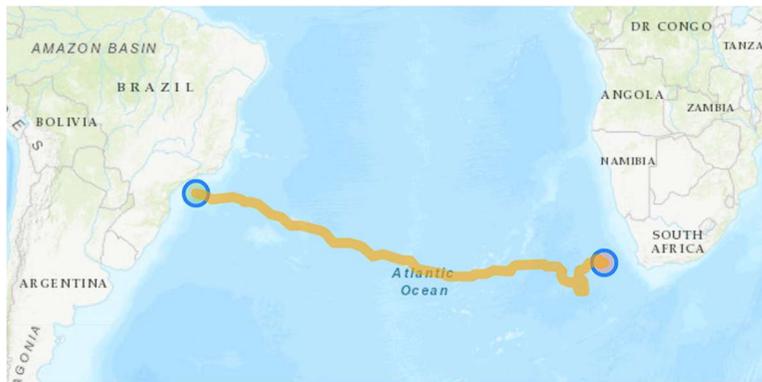
# Assessing environmental conditions



# Dissemination of glider data



Dissemination of glider data in global databases (like [Coriolis Data Center](#)) in real-time and delayed mode for a wider community.



<https://www.coriolis.eu.org/>

<https://github.com/OceanGlidersCommunity>

Questions?



## Quiz 4



Are You QRious?



<https://www.menti.com/al2pkzjuc8vg>

**Which of the following statements about data quality control in glider measurements are correct?**

Select all correct answers.

- a) Response time lag correction aligns temperature and conductivity to prevent salinity errors.
- b) Thermal lag correction adjusts for cell temperature differences affecting salinity.
- c) Misaligned measurements cause incorrect density profiles.
- d) Thermal lag correction isn't needed without temperature gradients.
- e) Response time lag correction only applies to pumped CTDs.

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