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Advances in ocean science from autonomous gliders

Underwater gliders

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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”

Finanziato dall'Unione europea NextGenerationEU
Ministero dell'Università e della Ricerca
Italiadomani

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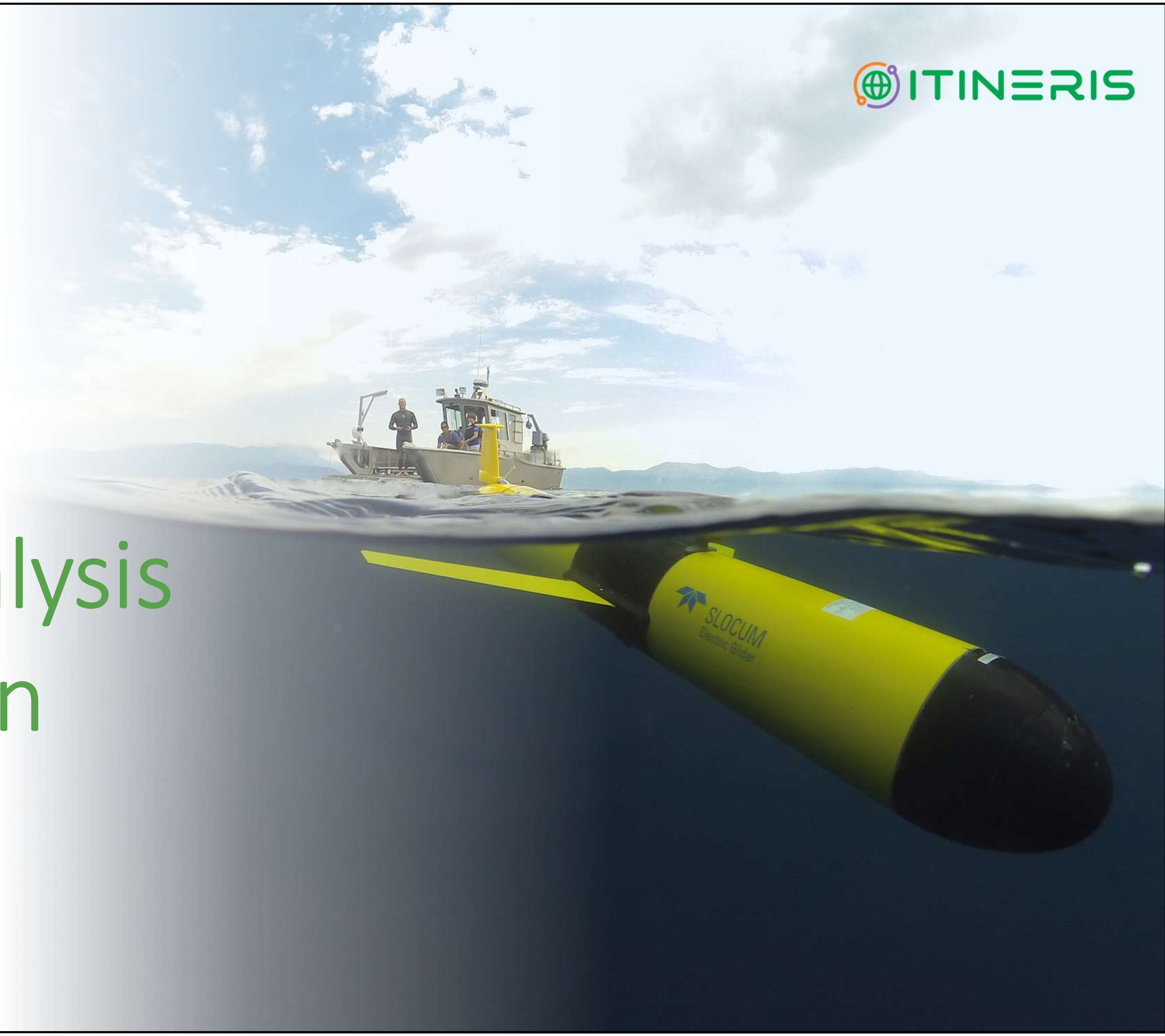
Glider data analysis & interpretation



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Yay, the mission went well!

Safely recovered & tucked in "bed"

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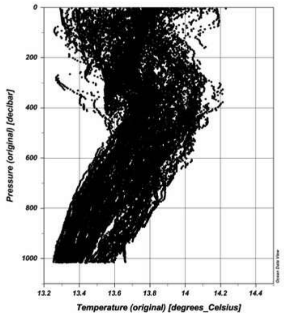
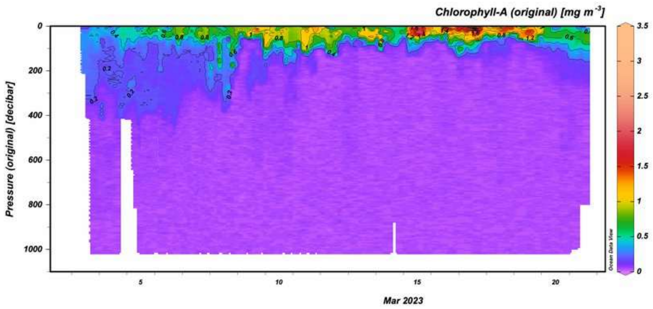
Yay, the mission went well!

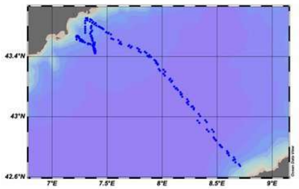
Safely recovered & tucked in “bed”

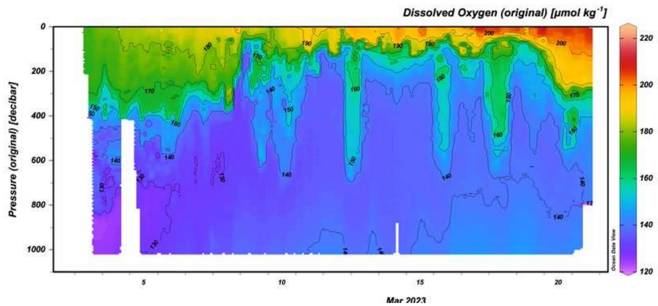
Now what ?

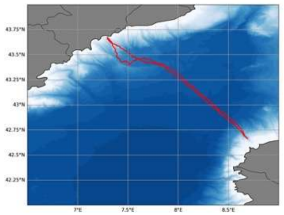
Glider observations: raw data and outcomes

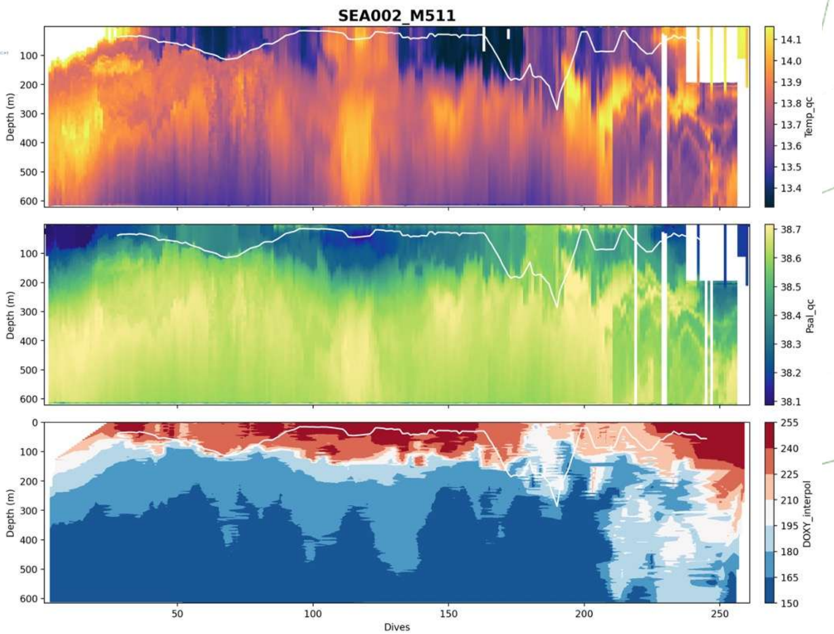




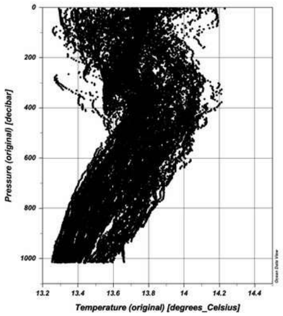


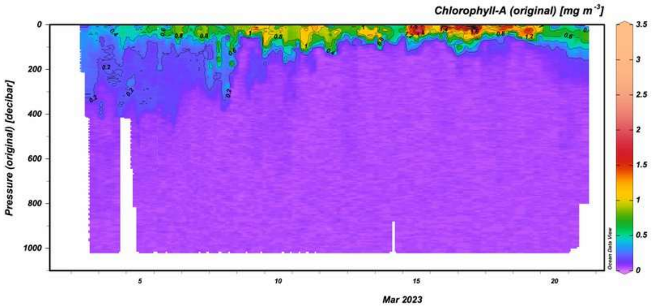


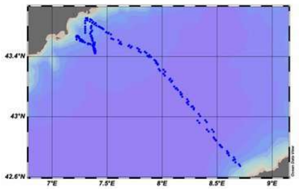


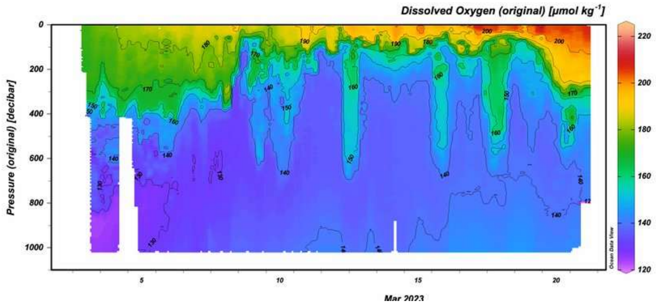


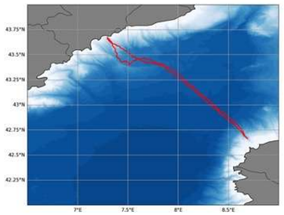
Glider observations: raw data and outcomes

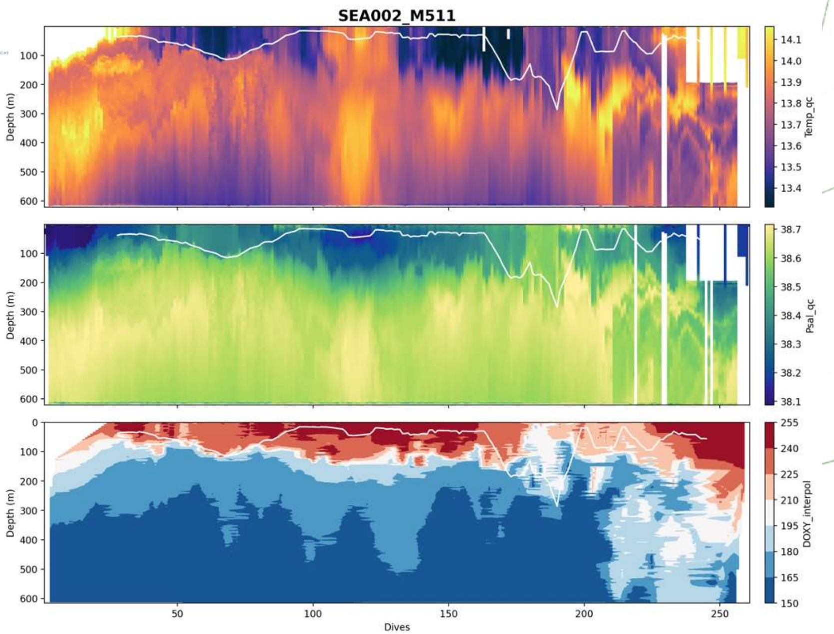






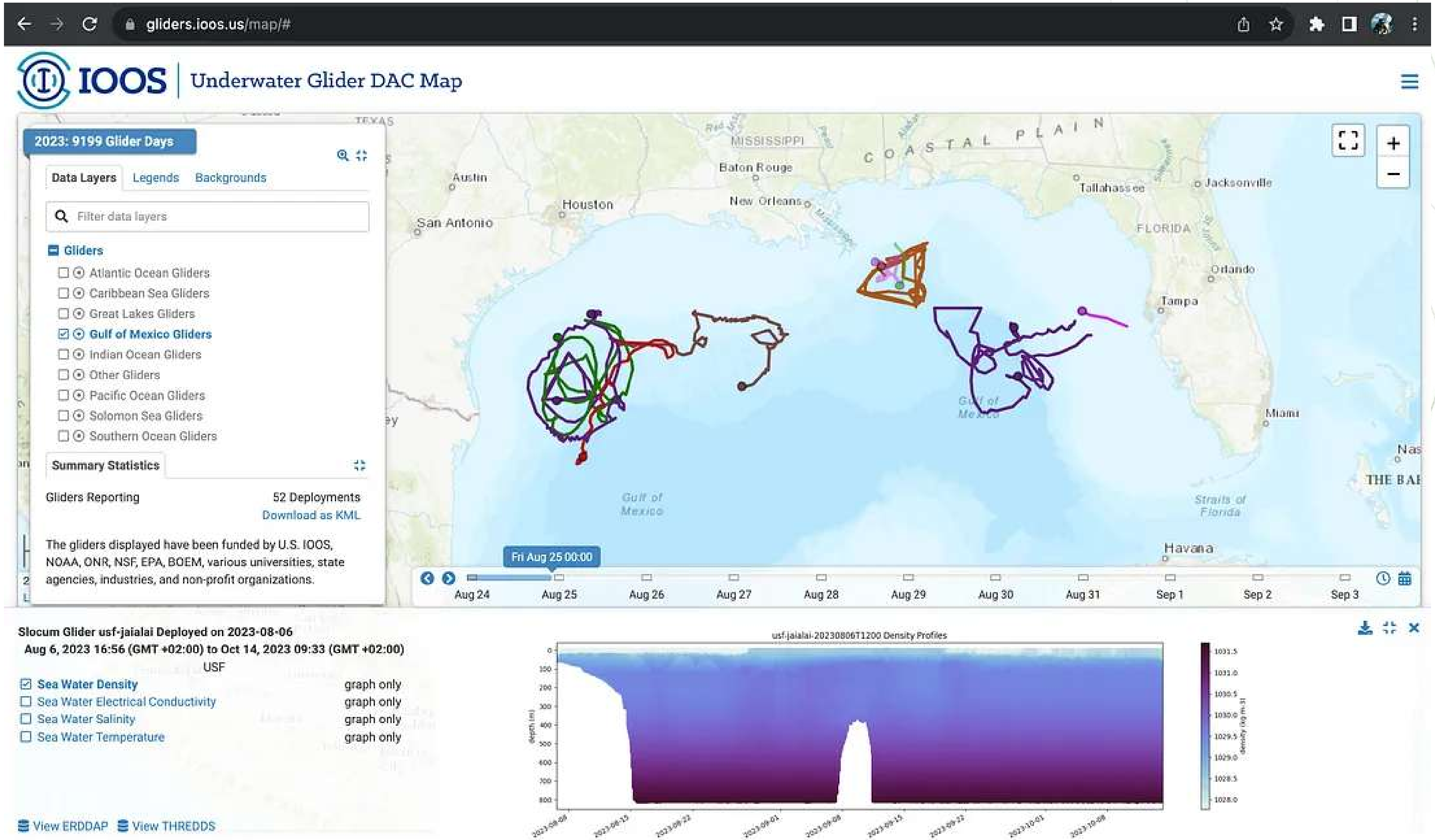




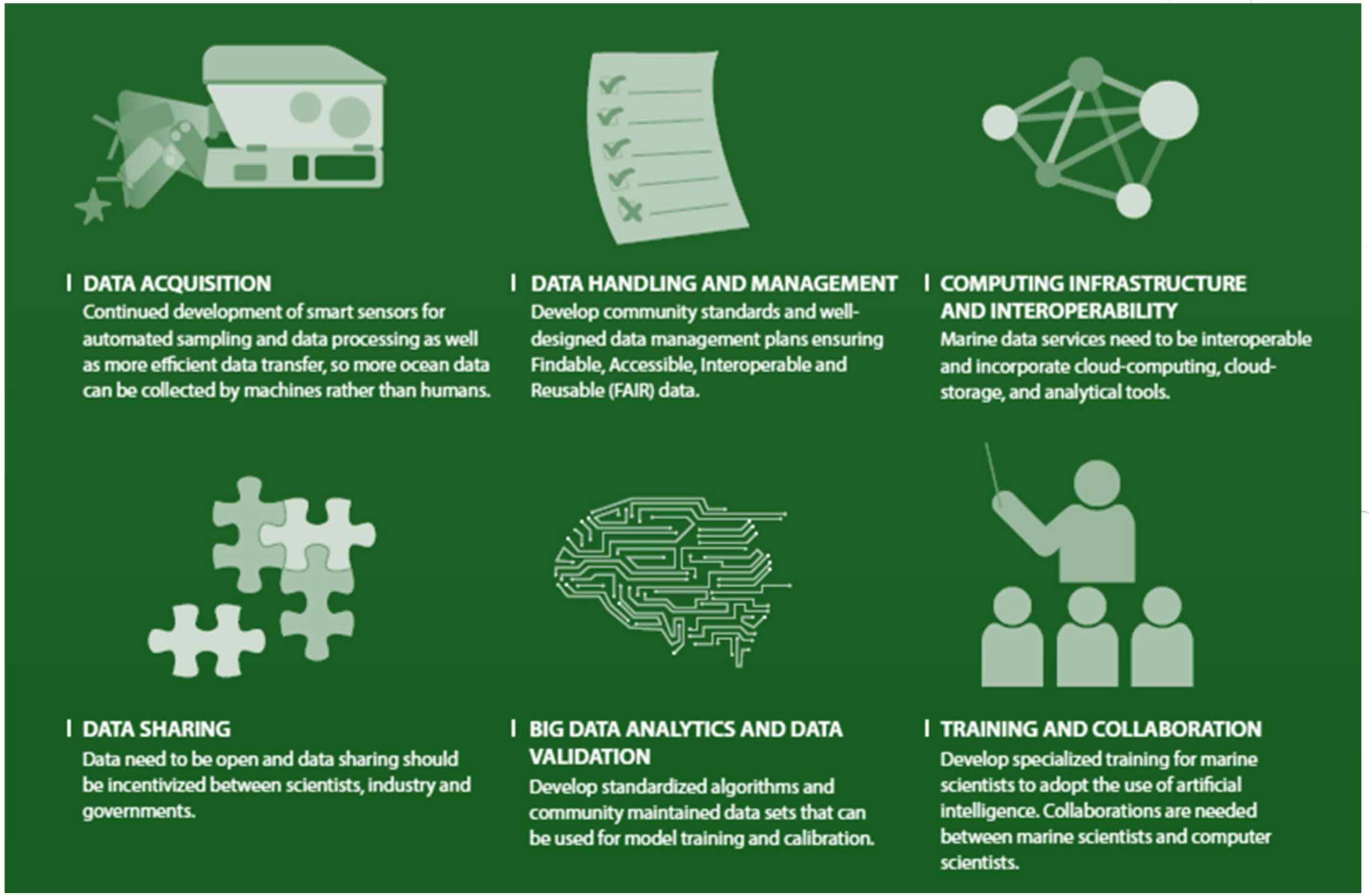


Why do we collect data ?

Direct data dissemination



Data analysis, process studies, new insights and publication



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

Data chain, usage and impact

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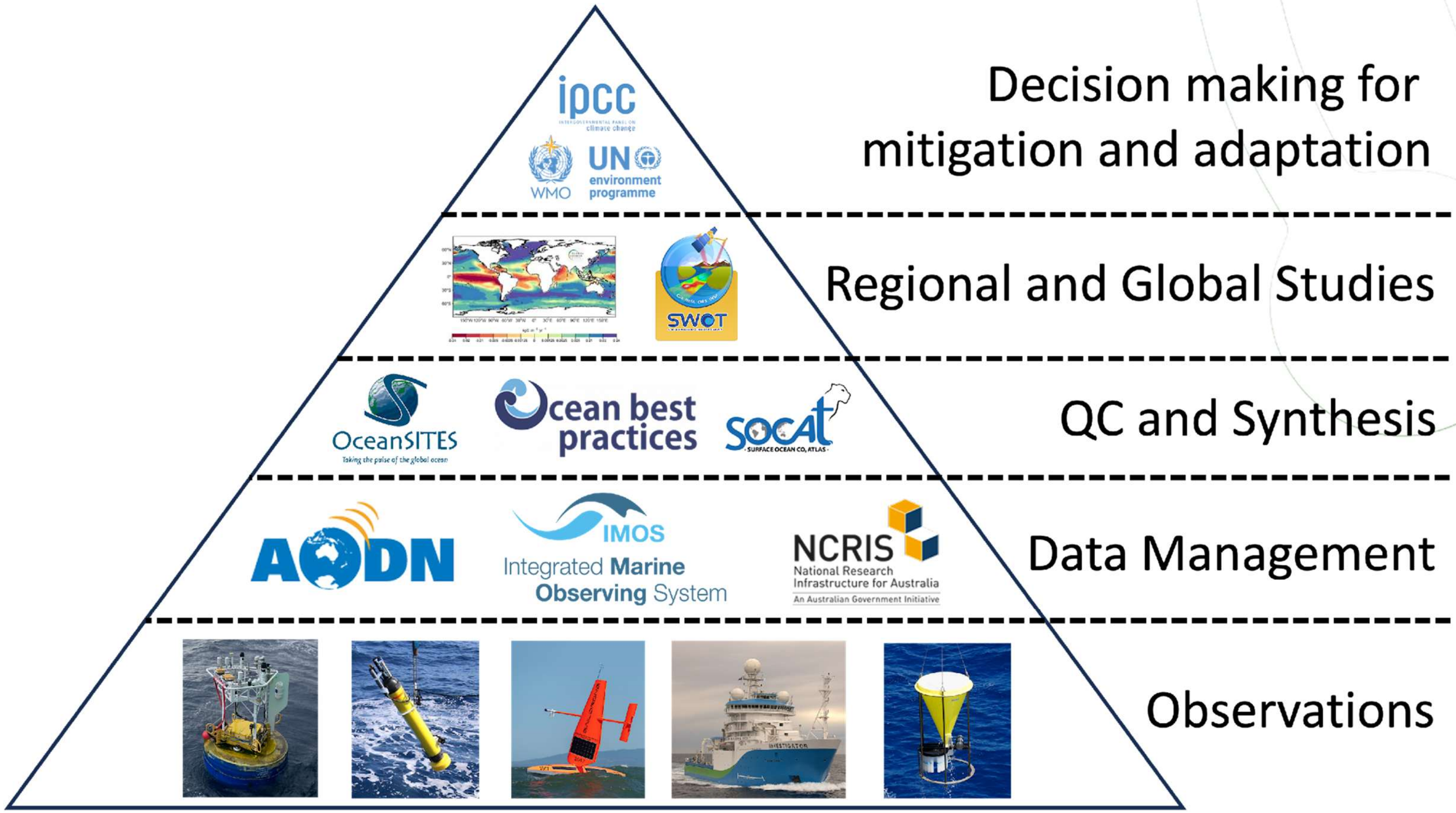
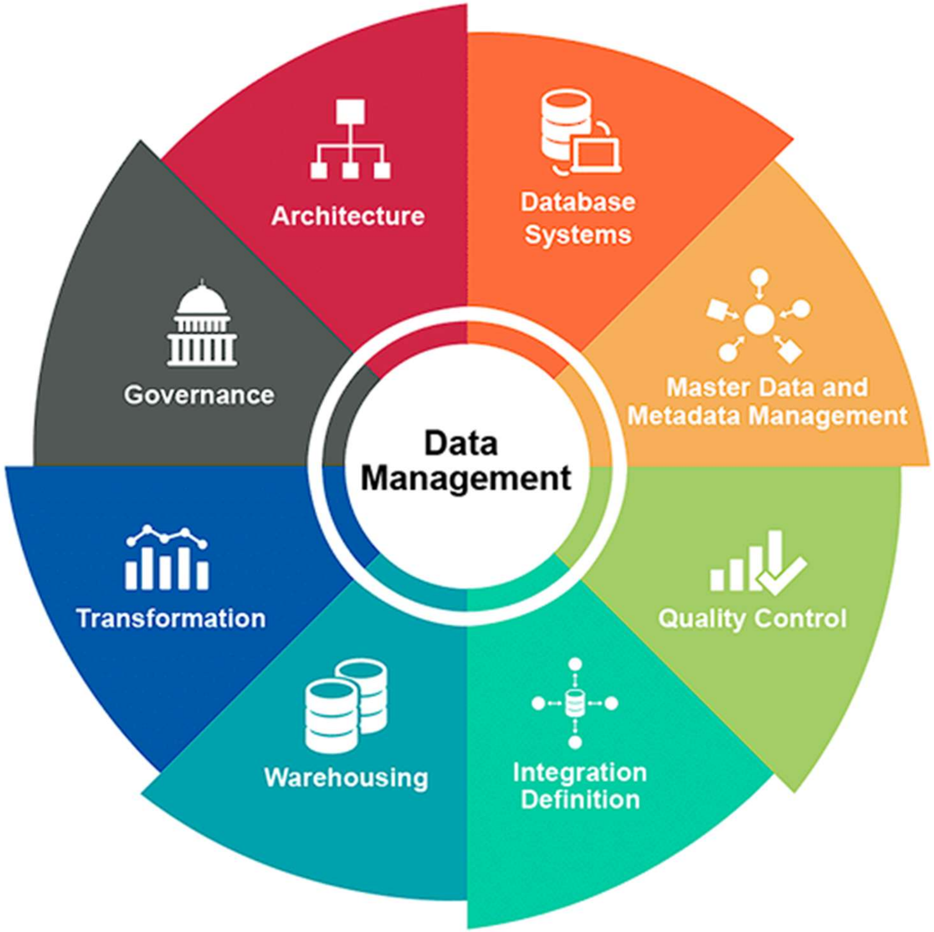


Best available quality



Delayed Mode Quality Control

- **Physics**
- **Biogeochemistry**

https://github.com/OceanGlidersCommunity

Quality Control

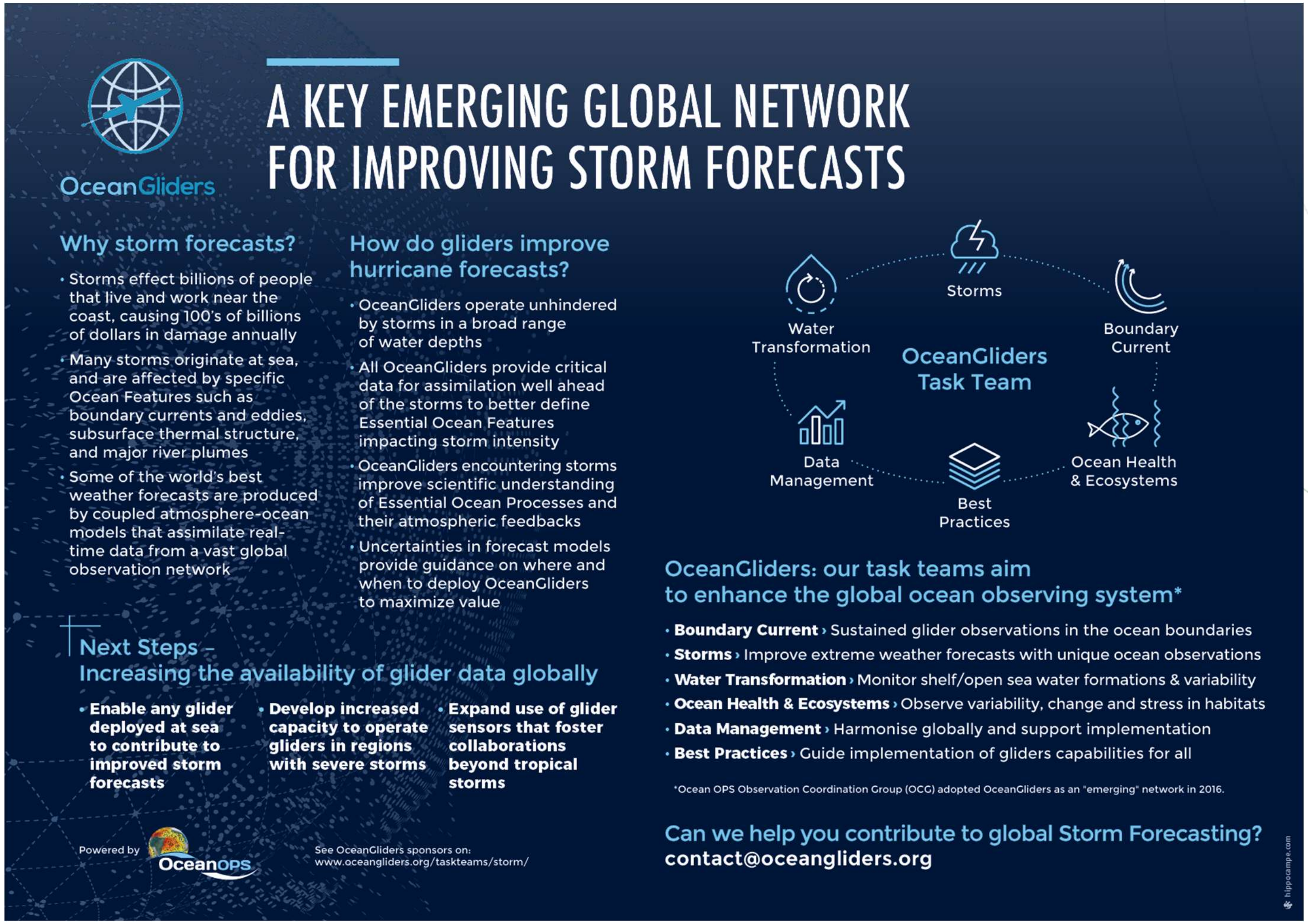
Delayed Mode Quality Control

- **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
    - CO2
    - pH
    - Hydrocarbons

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

Community efforts



The Global Ocean Observing System

Community efforts

Ocean observations: fundamental to society

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

3

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 θ/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

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.

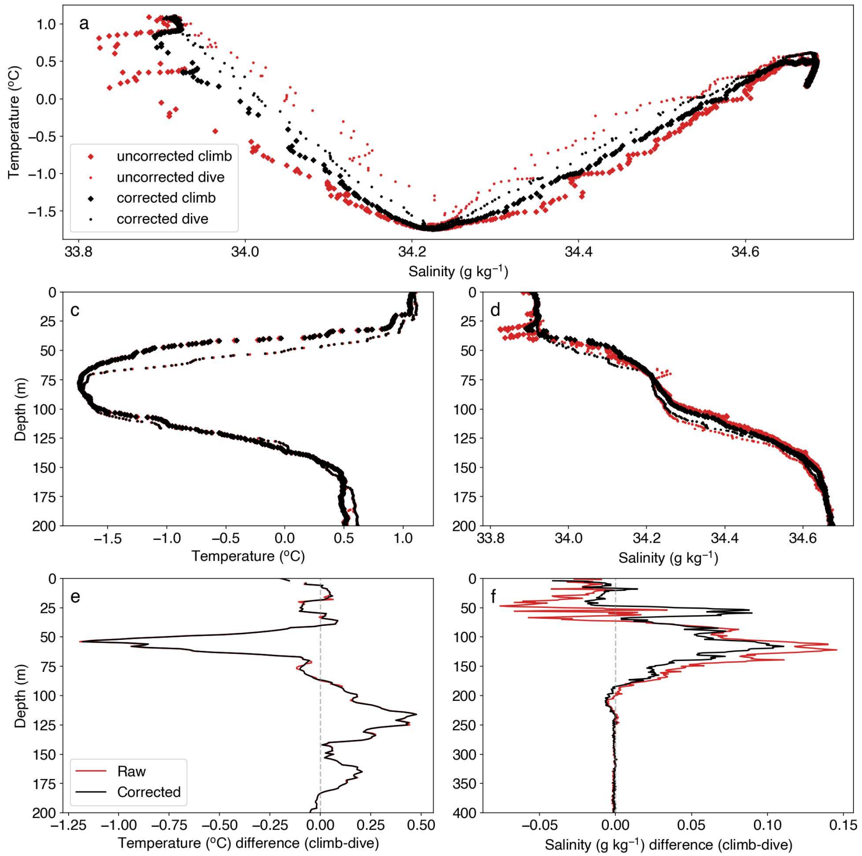
https://cdn.ioos.noaa.gov/media/2017/12/Manual-for-QC-of-Glider-Data_05_09_16.pdf

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

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

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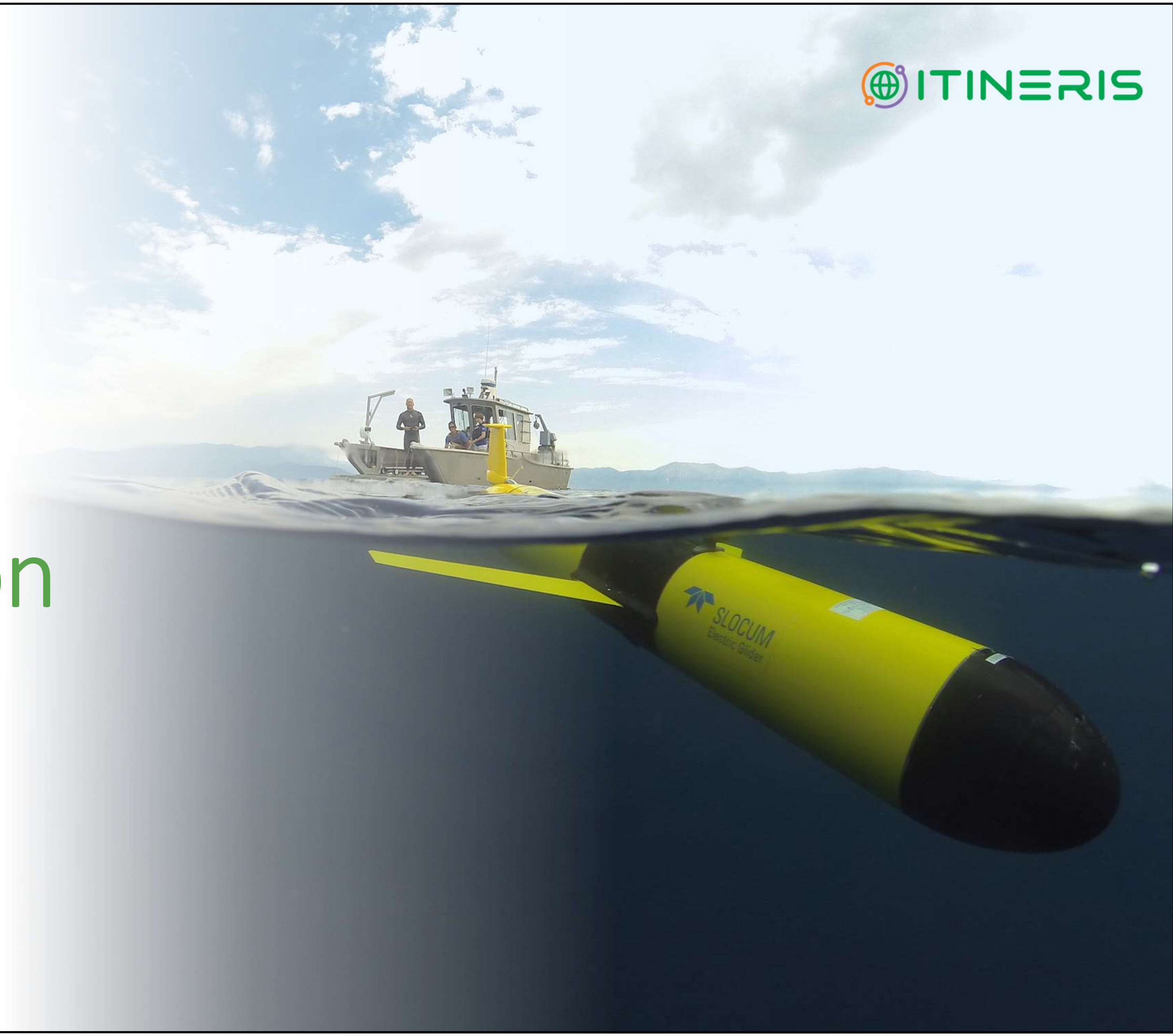
Practical session



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

IOOS | Integrated Ocean Observing System

Requirements

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1) Anaconda

https://anaconda.cloud/

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
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- 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

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Requirements

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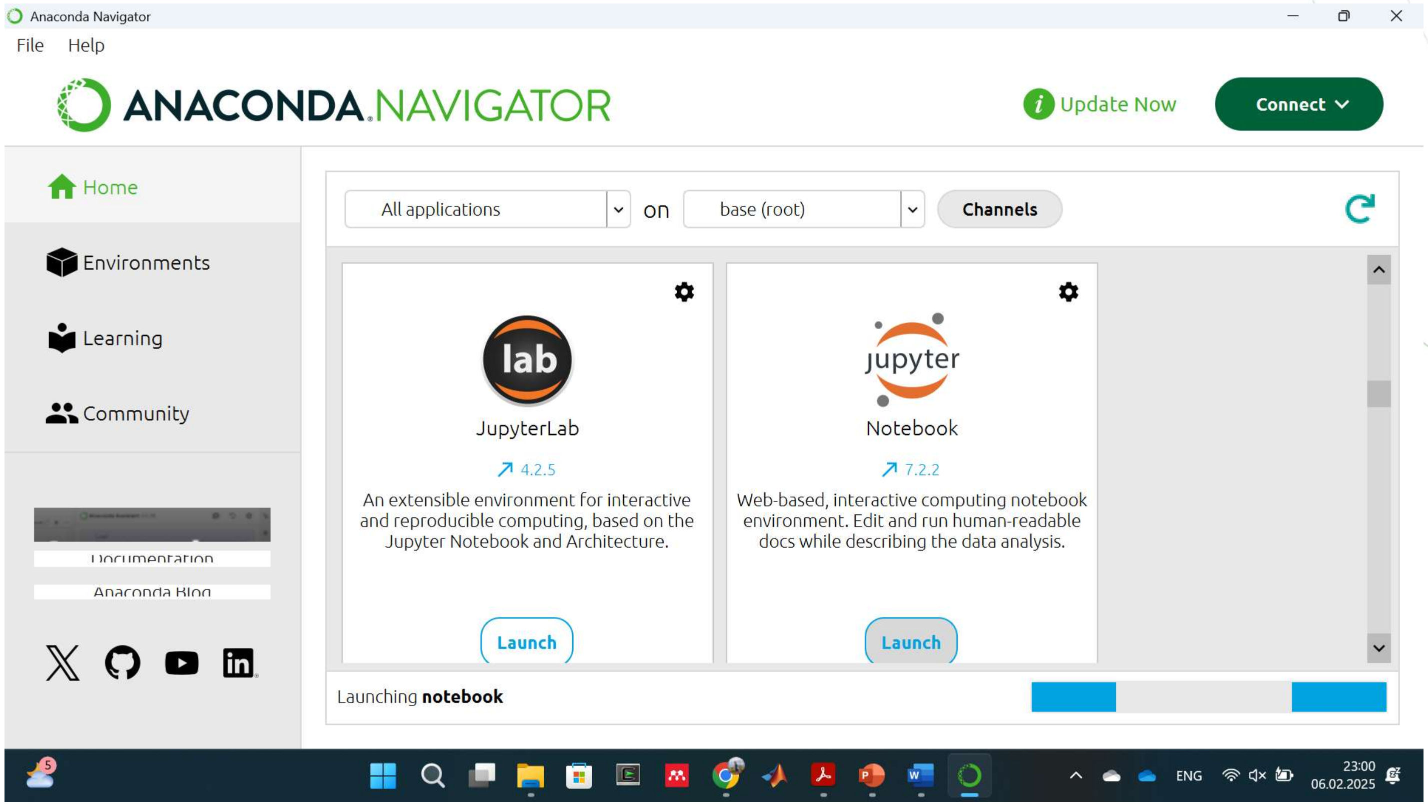
2) Anaconda Navigator → Jupyter Notebook



Requirements

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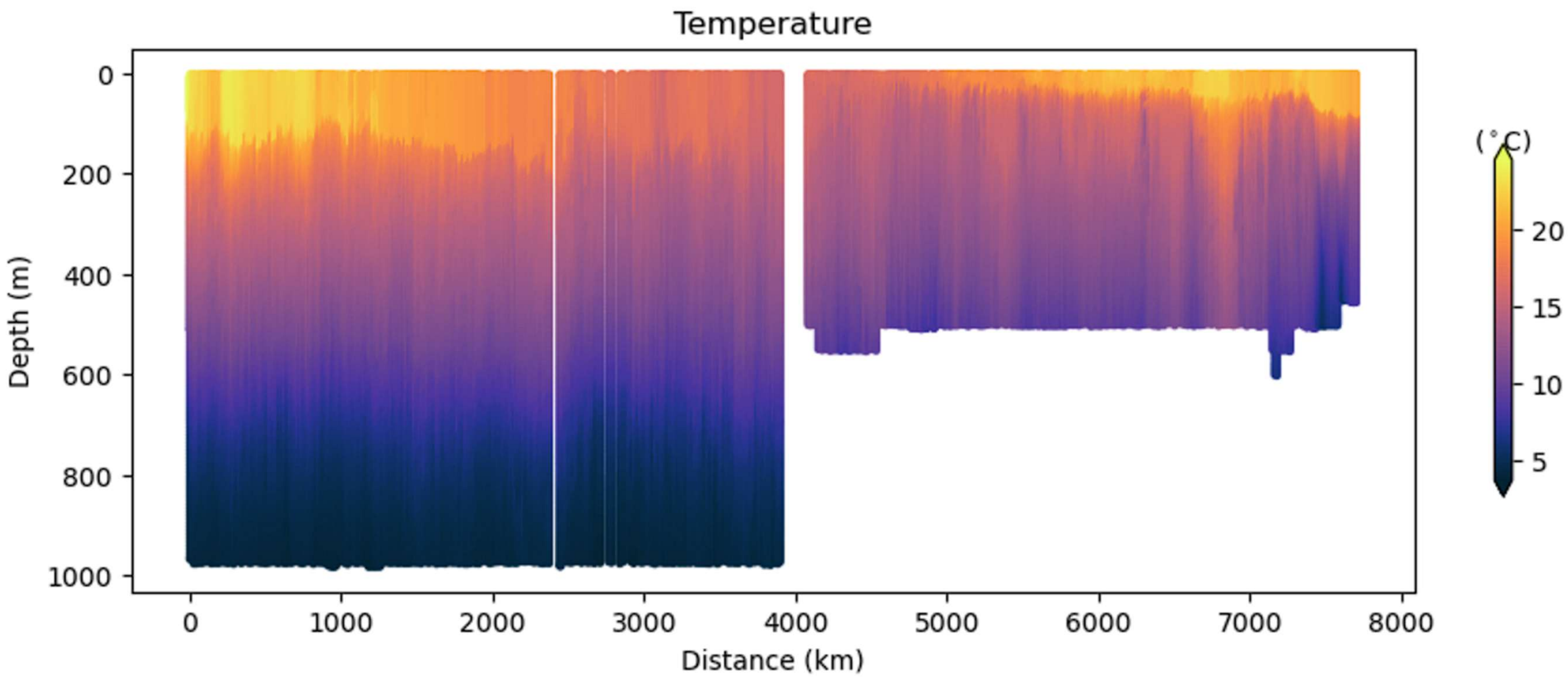
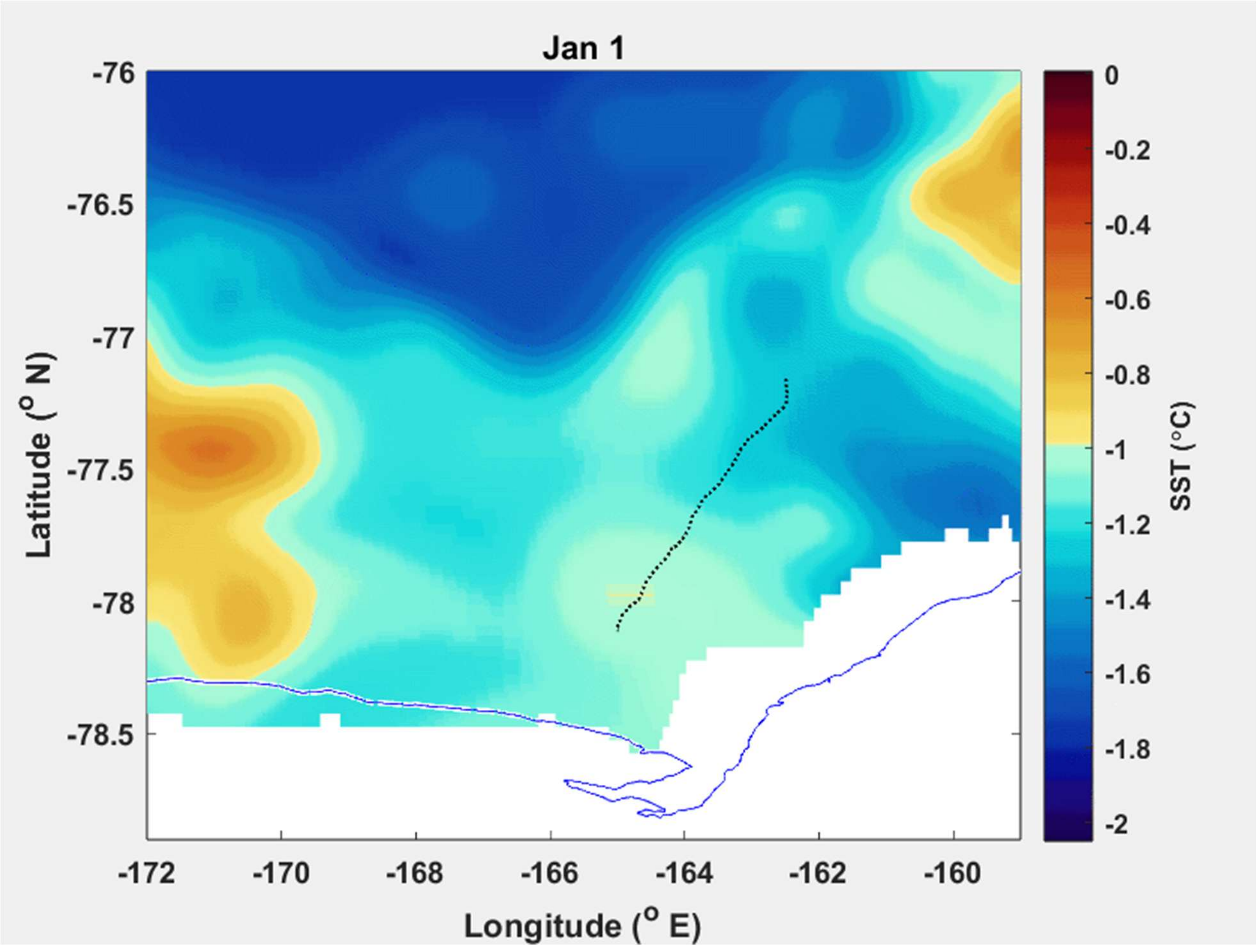
3) Glider data

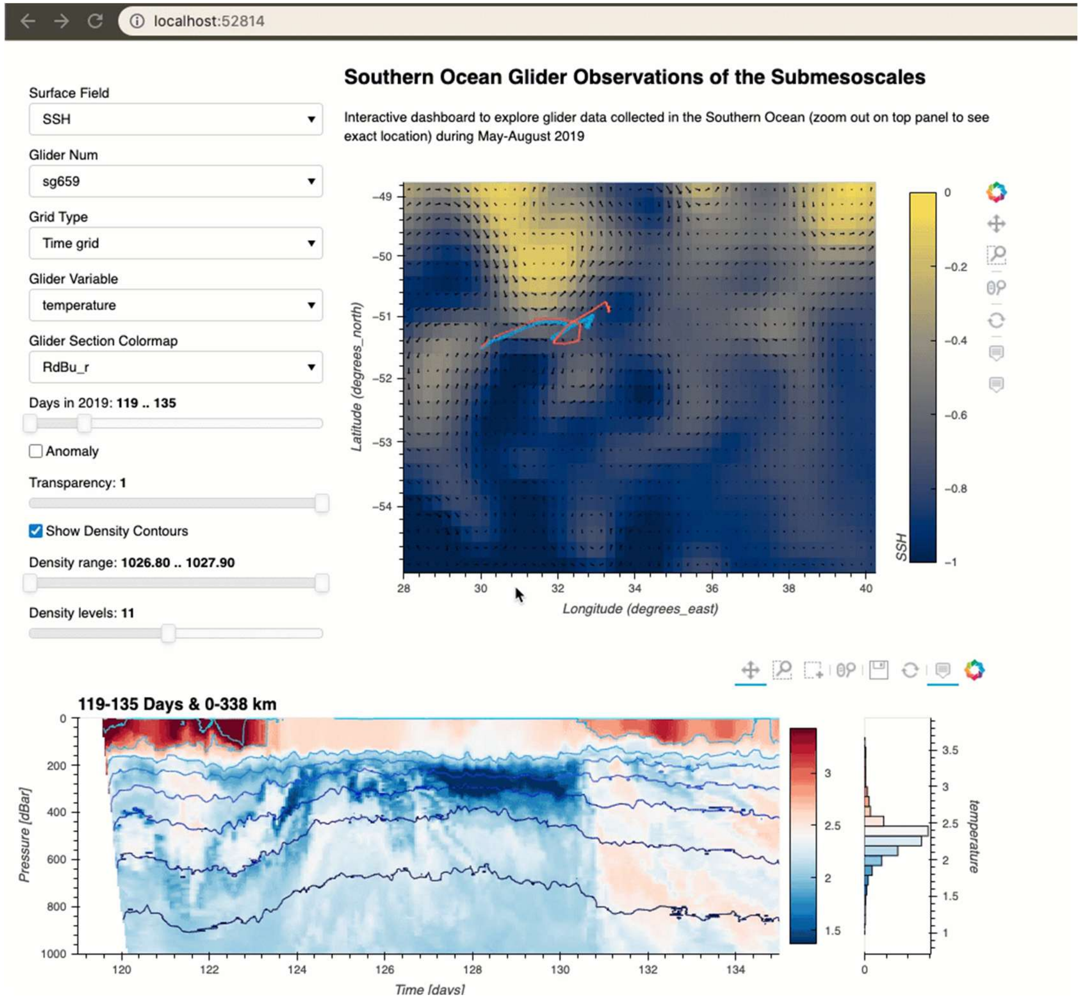


https://drive.google.com/drive/folders/1wI2oBqq2sD81eHiSVWh8peozDQY4eFAN?zx=avlgu68vc27l

Assessing environmental conditions



Assessing environmental conditions



Dissemination of glider data

Dissemination of glider data in global databases (like [Coriolis Data Center](https://www.coriolis.eu.org/)) in real-time and delayed mode for a wider community.

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

https://github.com/OceanGlidersCommunity

Questions?

Quiz 4

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Are You QRious?

https://www.menti.com/al2pkzjuc8vg

Offline quiz

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.

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. ❌