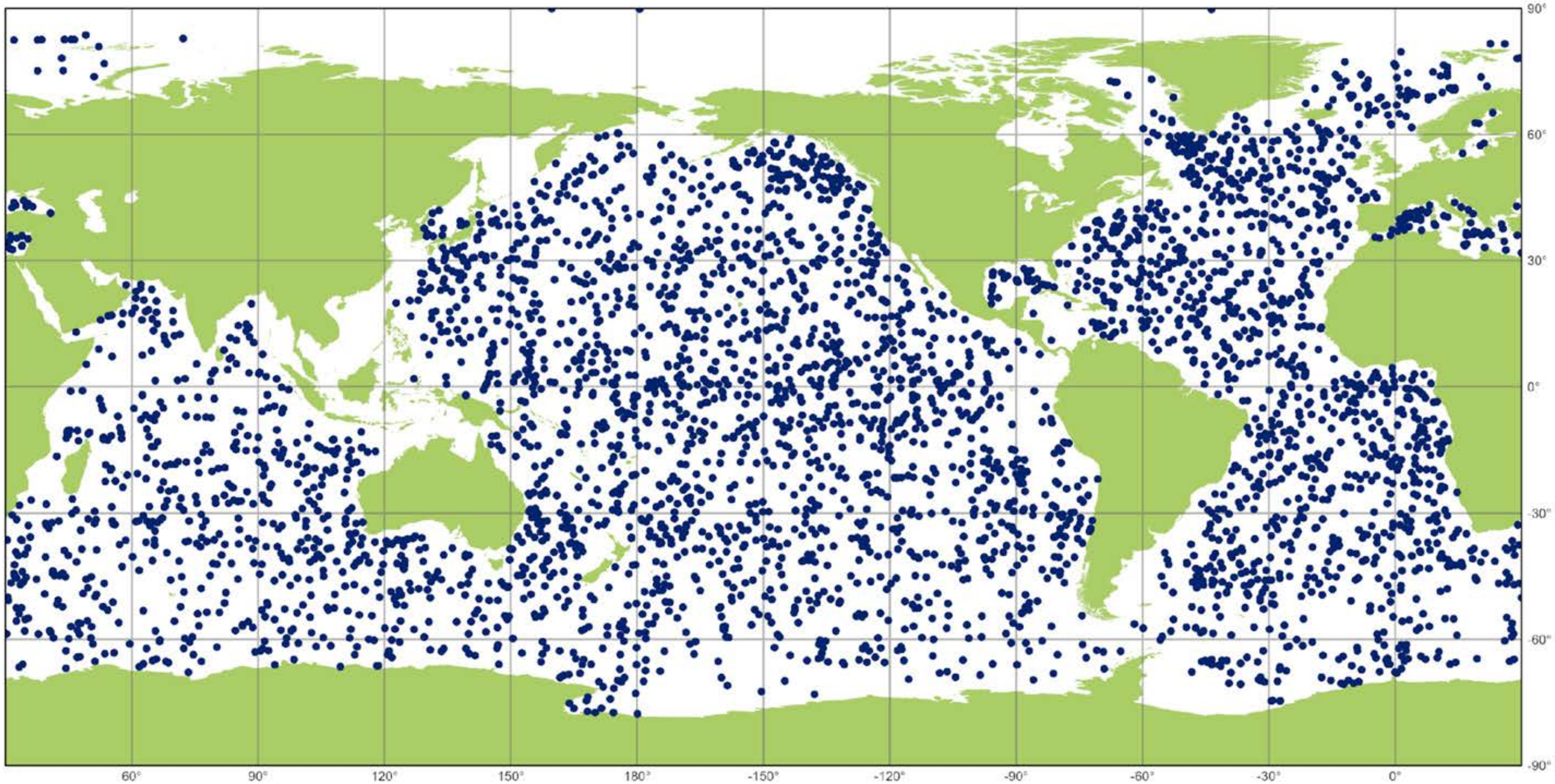
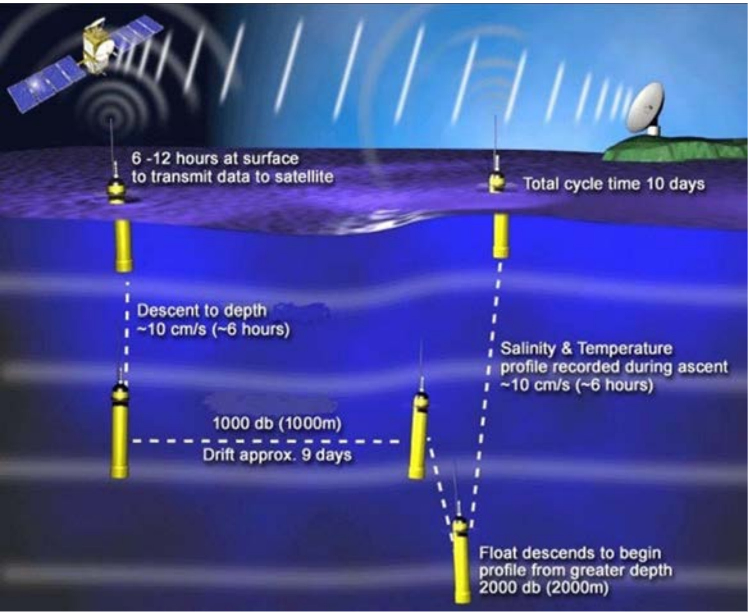


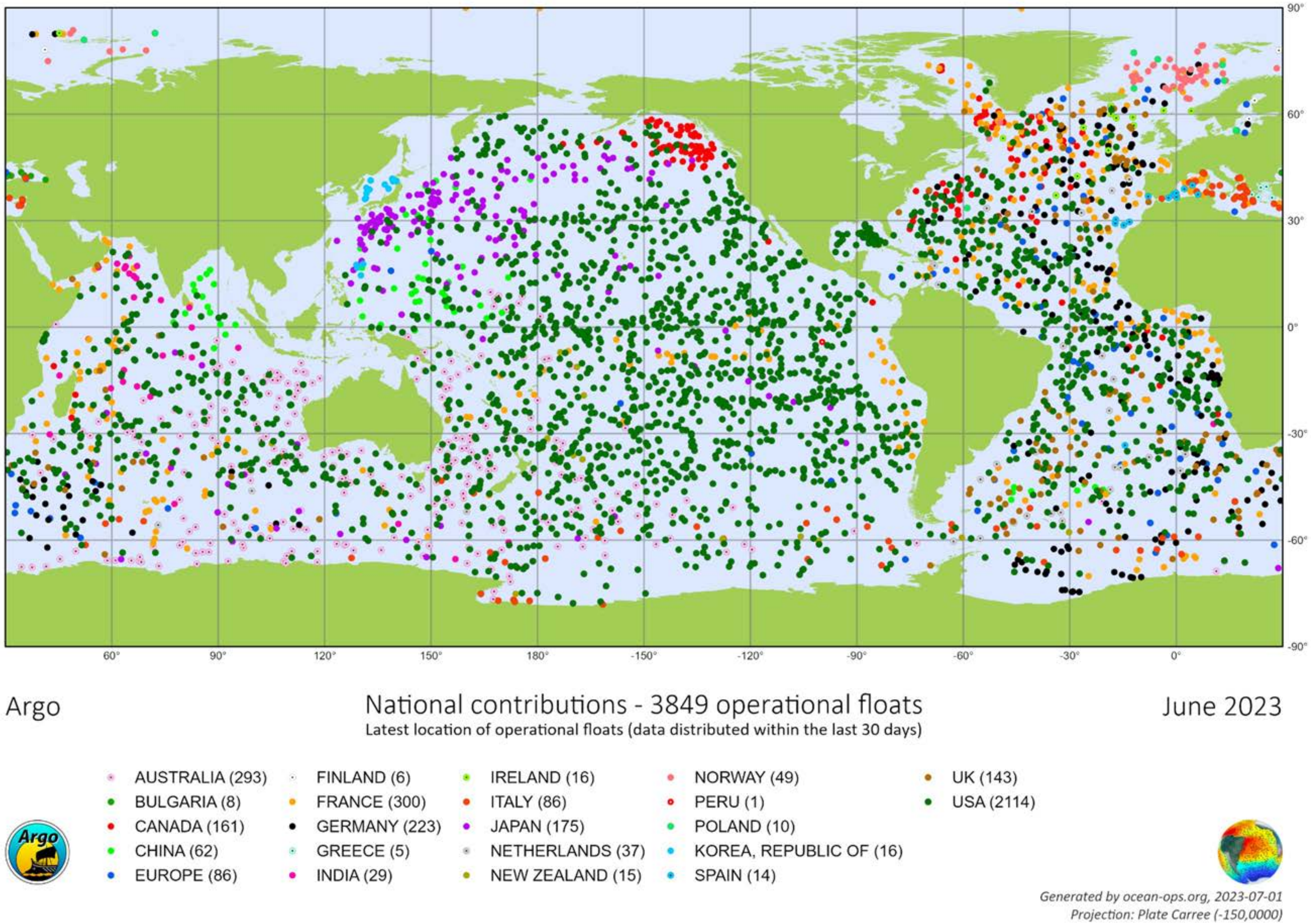
Argo:
Present and Future Challenges

Stephen Riser, Susan Wijffels, Brian King, Breck Owens, Megan Scanderbeg and the Argo Steering Team

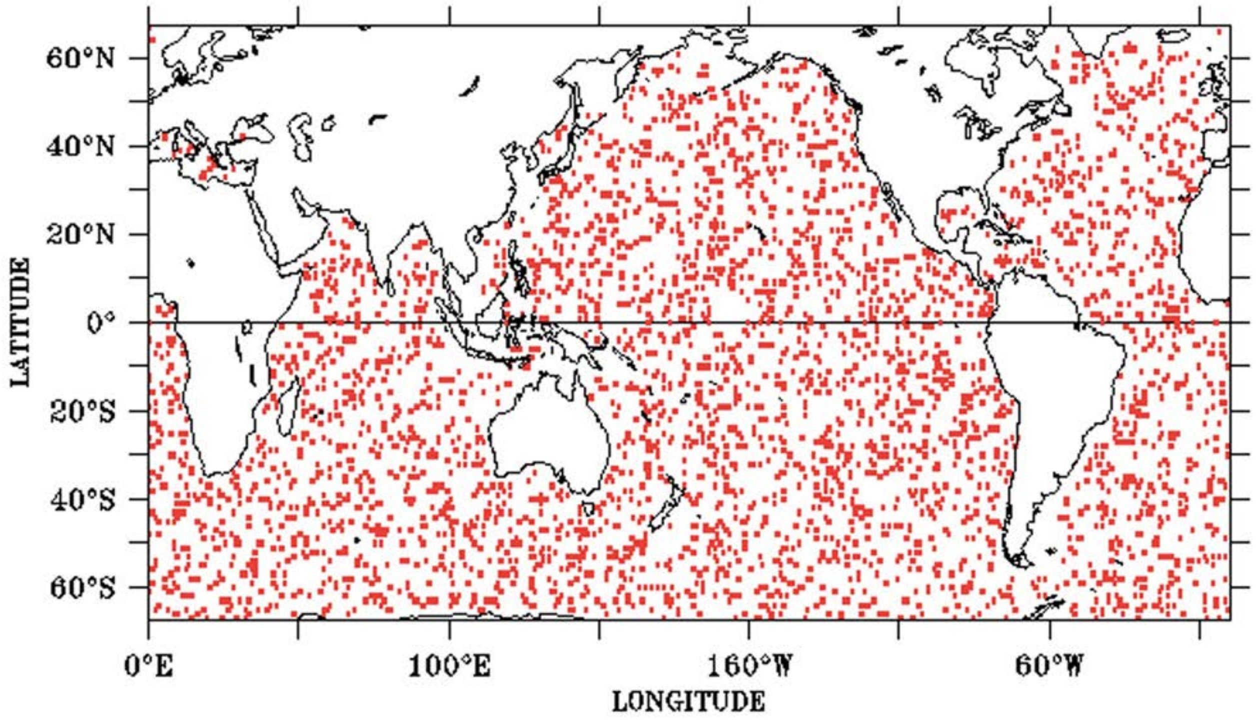
Argo's original design: implemented 2006-2023

- ~3000 floats uniformly sampling the offshore oceans
- 30 nations
- spans 0-2000m
- 10,000 profiles/month
- mostly T/S measured
- data shared globally in real-time
- > 6000 research papers

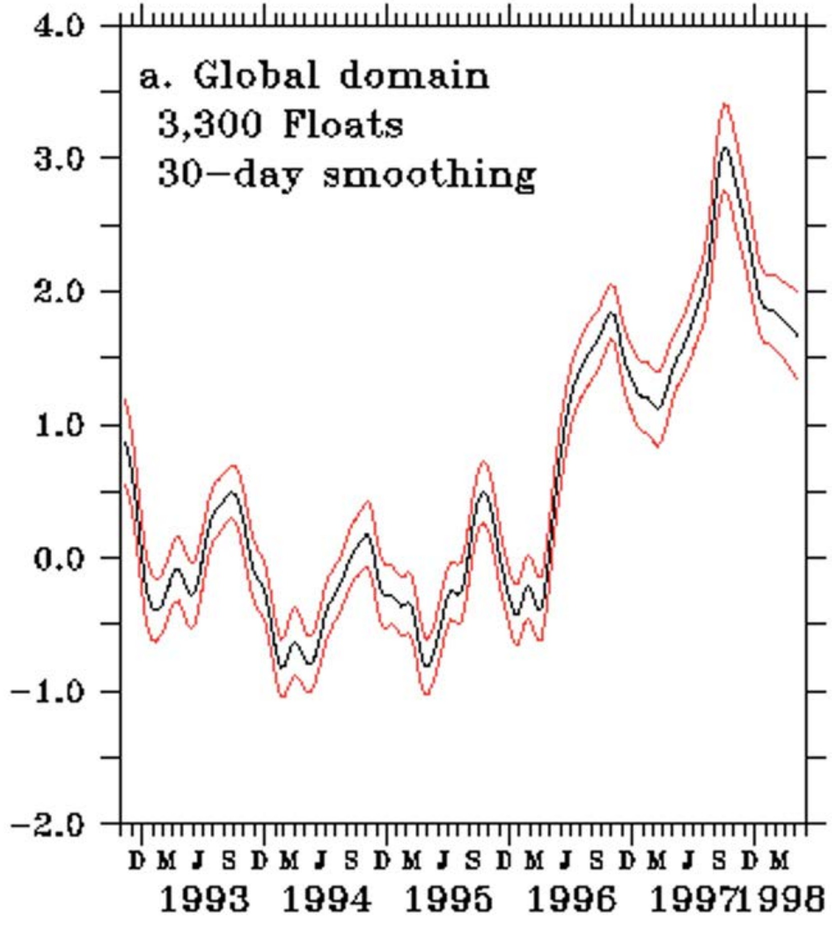




Argo's design was informed by satellite altimetry



Global average sea-level 'reconstructed' from sub-sampled altimetry sea level anomaly maps

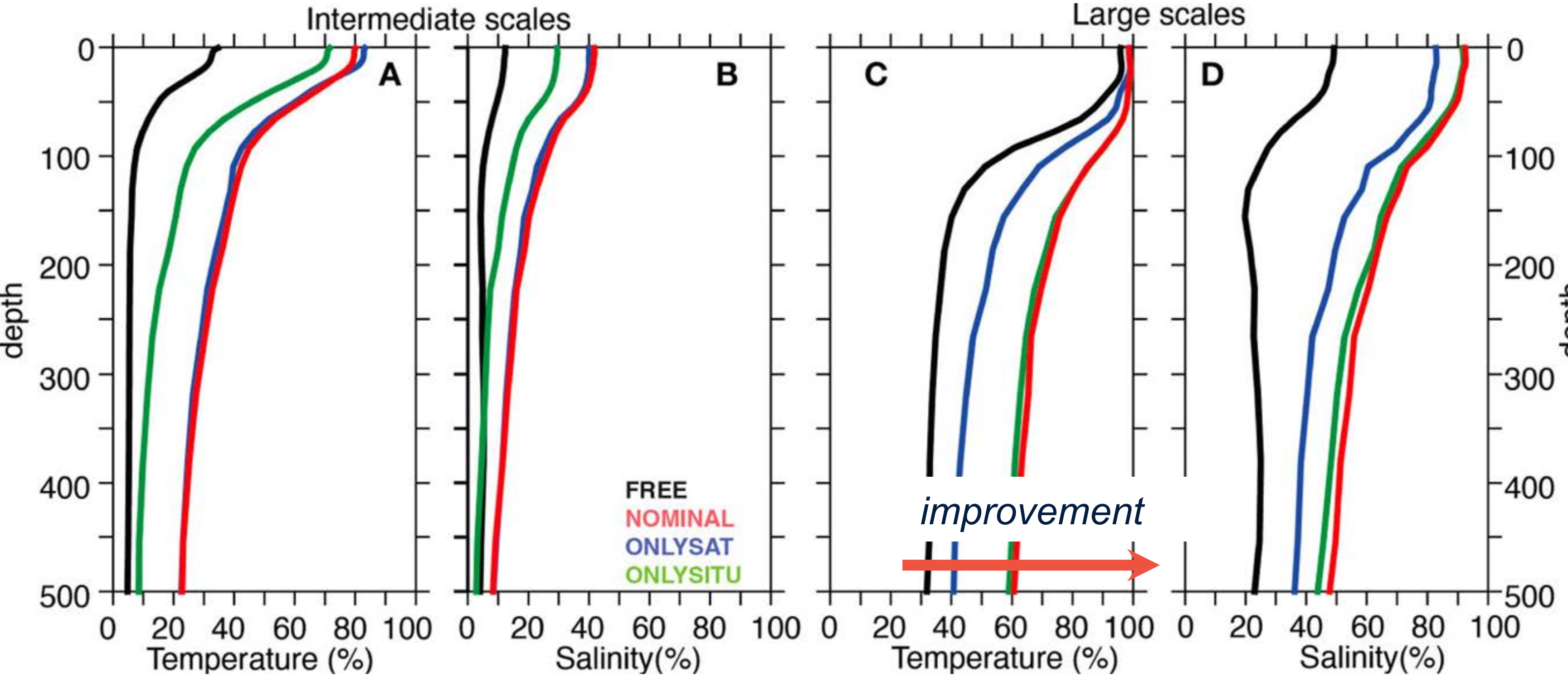


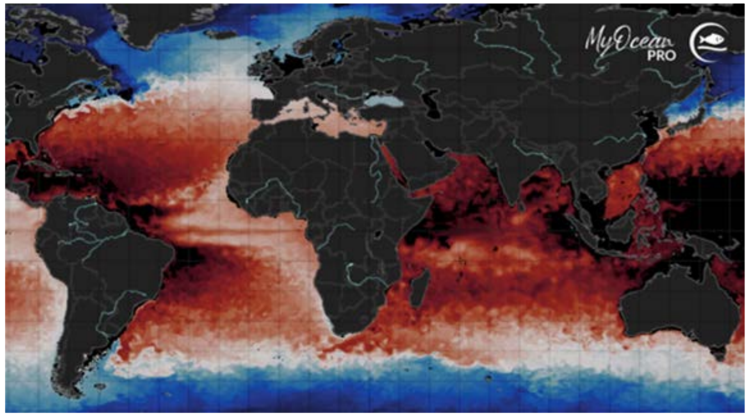
SLA plots from T/P were used to develop the original design and ensure the global change signal could be recovered.
Similar tests were done regionally.

Roemmich & AST, 1998

Impacts on ocean state-estimates

*Globally averaged % of **reconstructed Nature Run variance** for temperature and salinity for the OSSEs: FREE, NOMINAL (ALL), ONLYSAT, and ONLY INSITU*

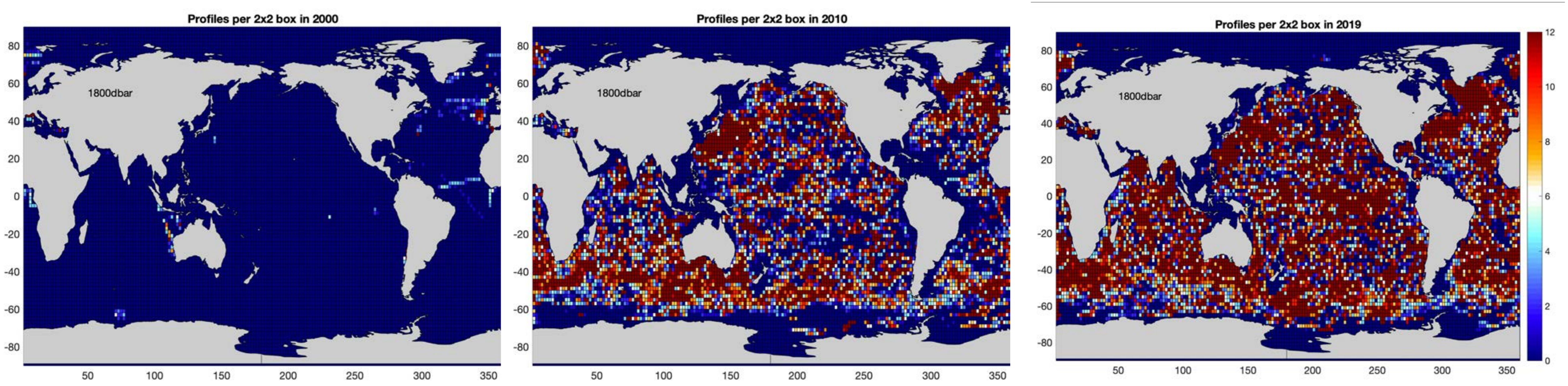




Argo constrains the 'slow manifold', satellites constrain the fast features and meso-scales: a strong synergy is realized

Gasparin et al, Frontiers Mar. Sci. (2023)

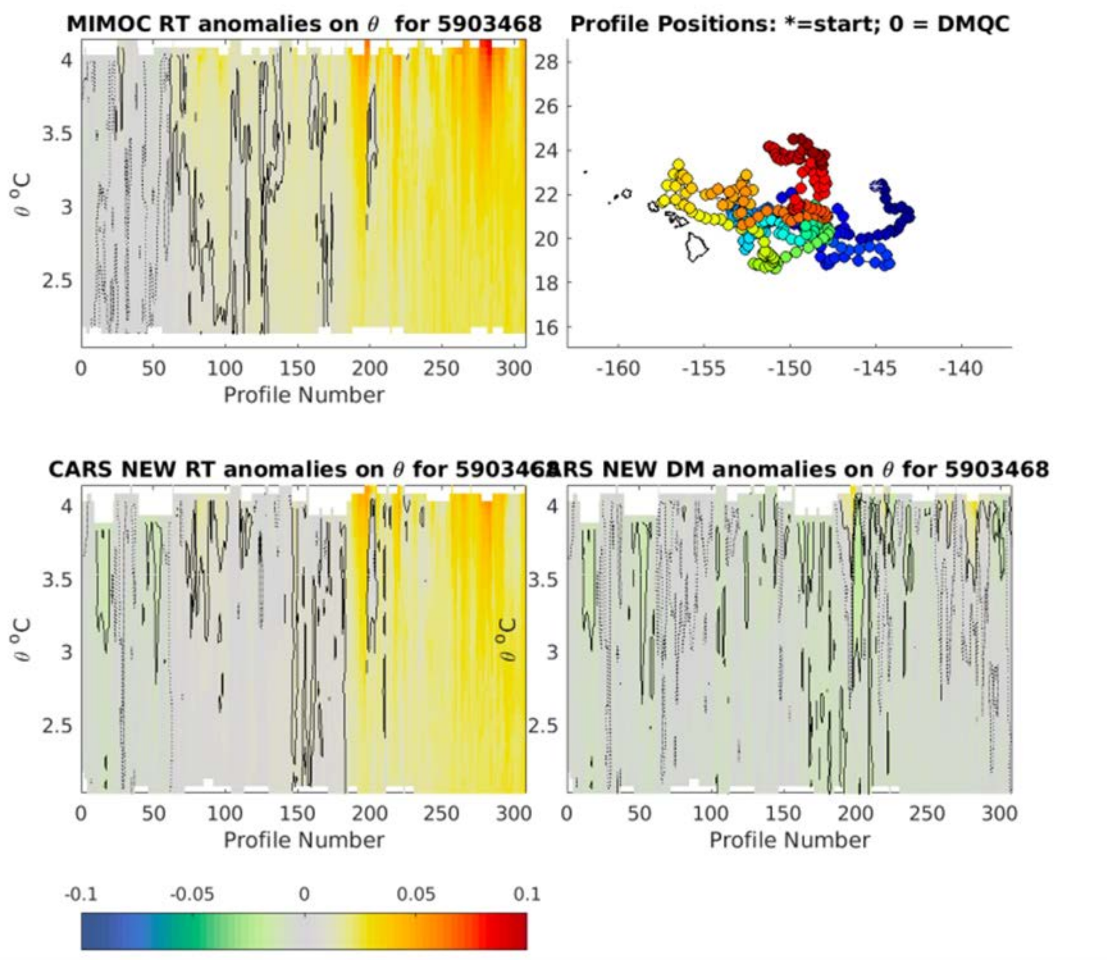
Data coverage: 1800dbar



- **2000-2010: drastic improvement with implementation of core Argo**
- **Float engineering improvements 2010's -> reach 2000dbar in tropics**
- **Better float ice-avoidance algorithms – more polar profiles > 2015**

Challenges: salinity remains problematic to measure

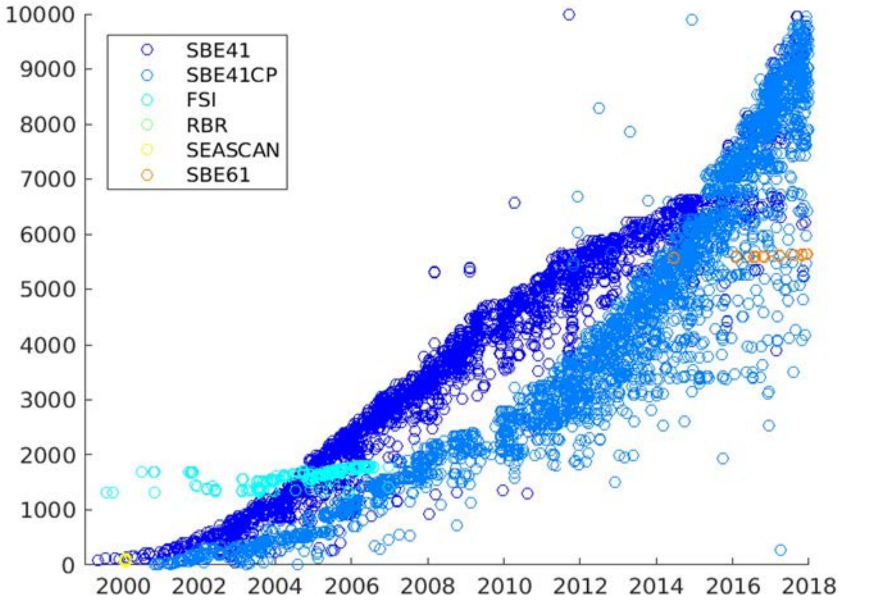
- Pre-2017 only **around 15%** of salinity sensors drifted saltier over 3-6 years
- **Corrections** could be **well-defined** and DMQC teams corrected for drift
- The physical cause of this slow salty drift was **never understood**
- Biofouling causes cells to drift fresh. This is **not seen** much in Argo.

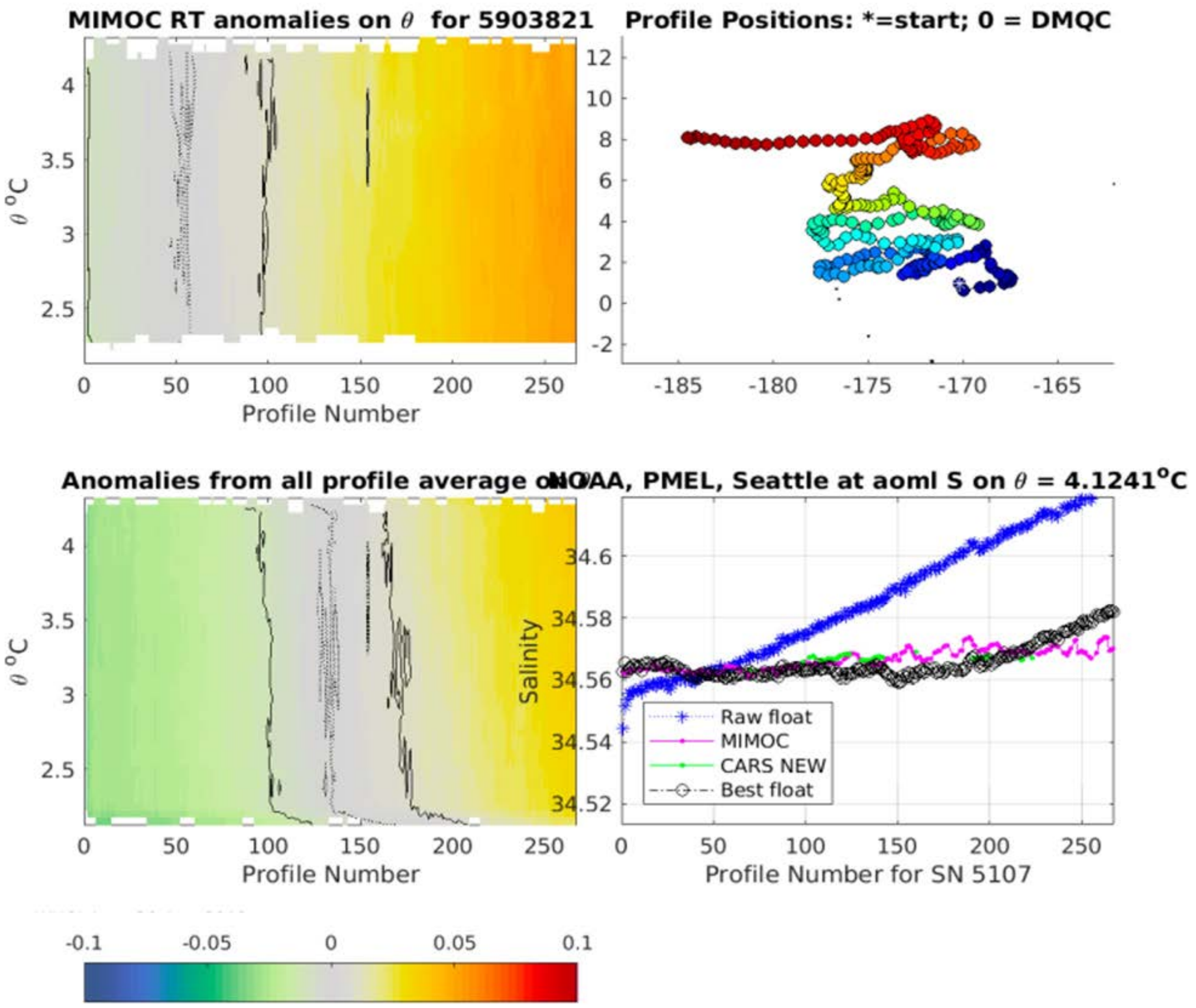


Float-climatology salinity differences (on theta levels)

Challenges: salinity remains problematic to measure

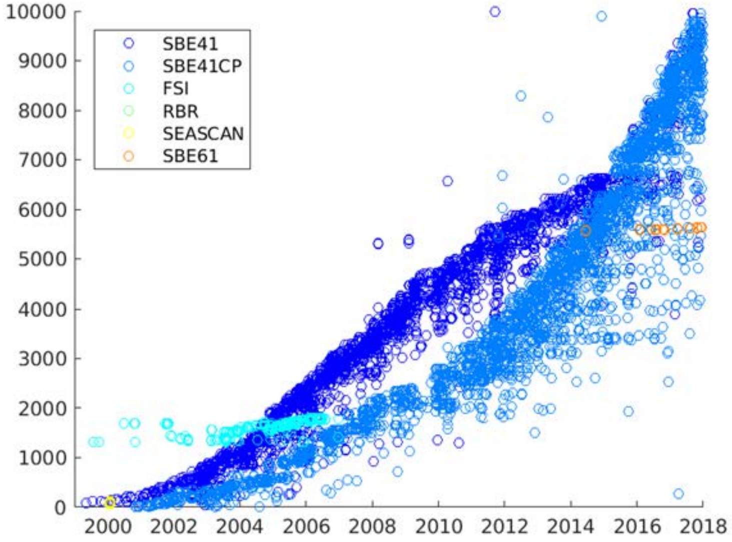
- In 2017, DMQC teams noted more frequent and fast drifts in some float CTDs
- Drift turned up < 2 years and was rapid and sometime catastrophic
- This triggered a **global census** by Argo

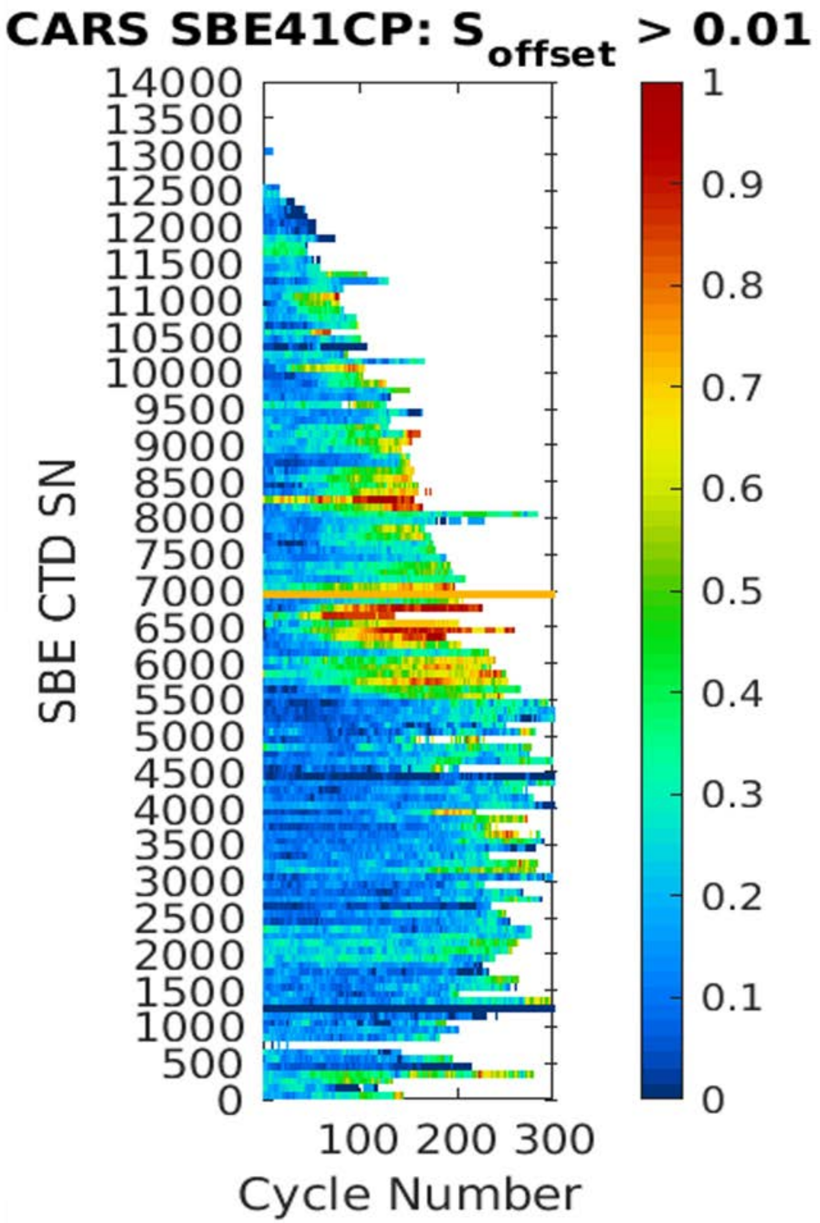




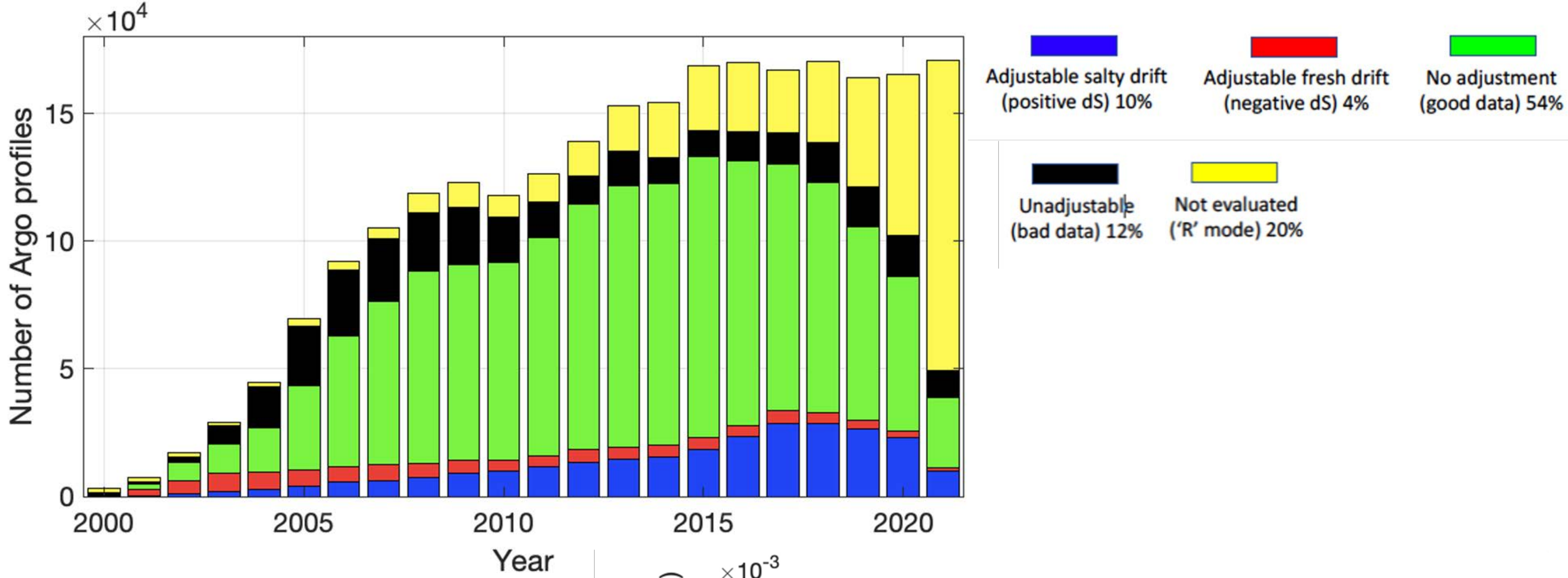
Challenges: CTD Manufacturing Issues

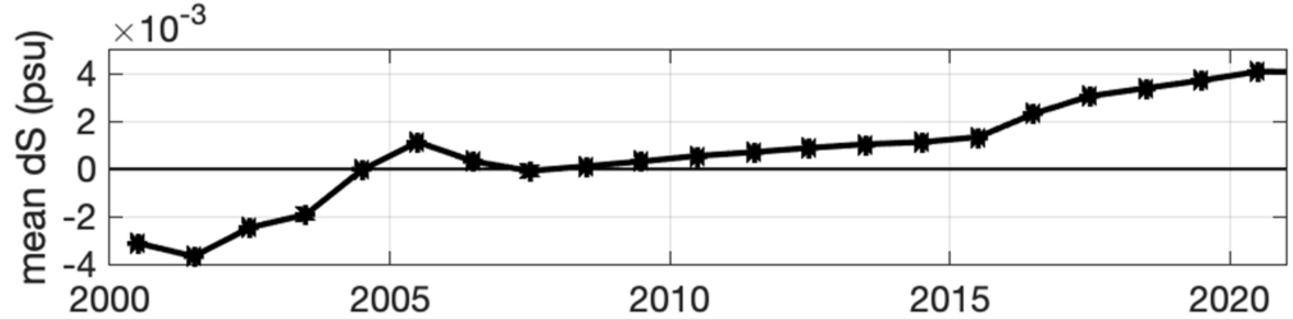
- Global analysis revealed a clear **batch behaviour** in frequency of fast drifters
- Engaged with manufacturer (SBE) to find the cause
- After many tests and analysis of retrieved floats, they eventually discovered and confirmed it was due to changes in the **encapsulant used in C-cell construction**
- Likely source of both fast and slow drift - breakdown of the encapsulant allows **water ingress into the cell**
- SBE made changes CTD SN > 11250.
- Drift in subsequent CTD is **greatly diminished** but these are still 'young'





Argo data teams got to work: flagging/adjusting

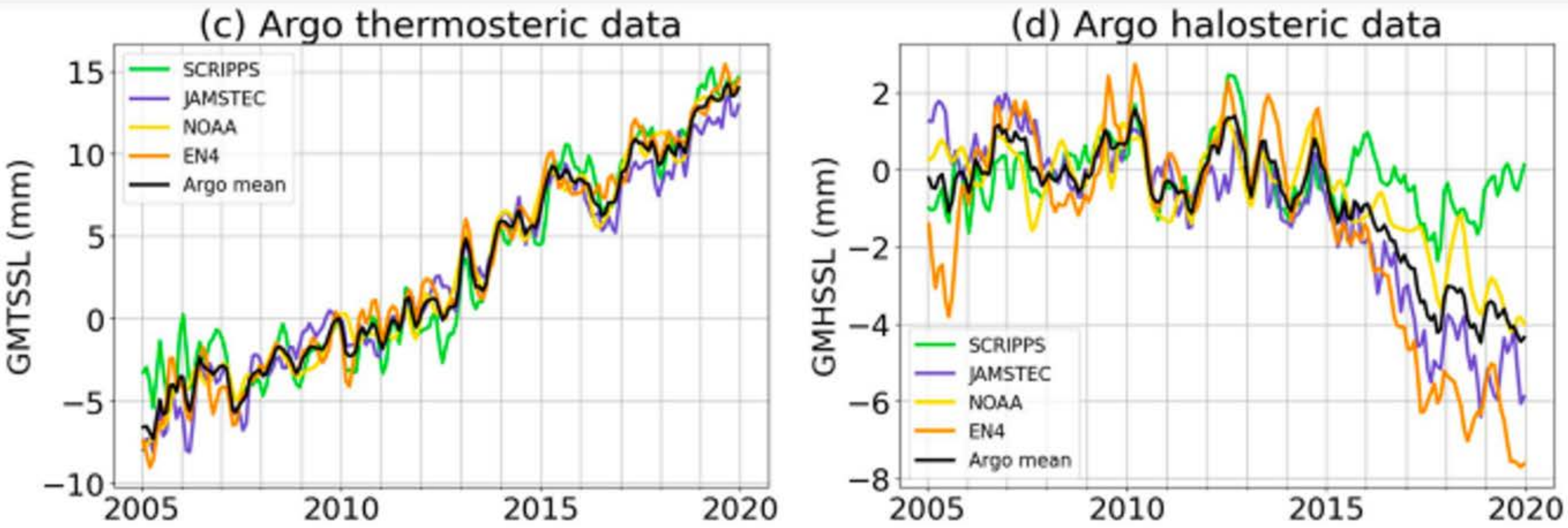




Problem solved?

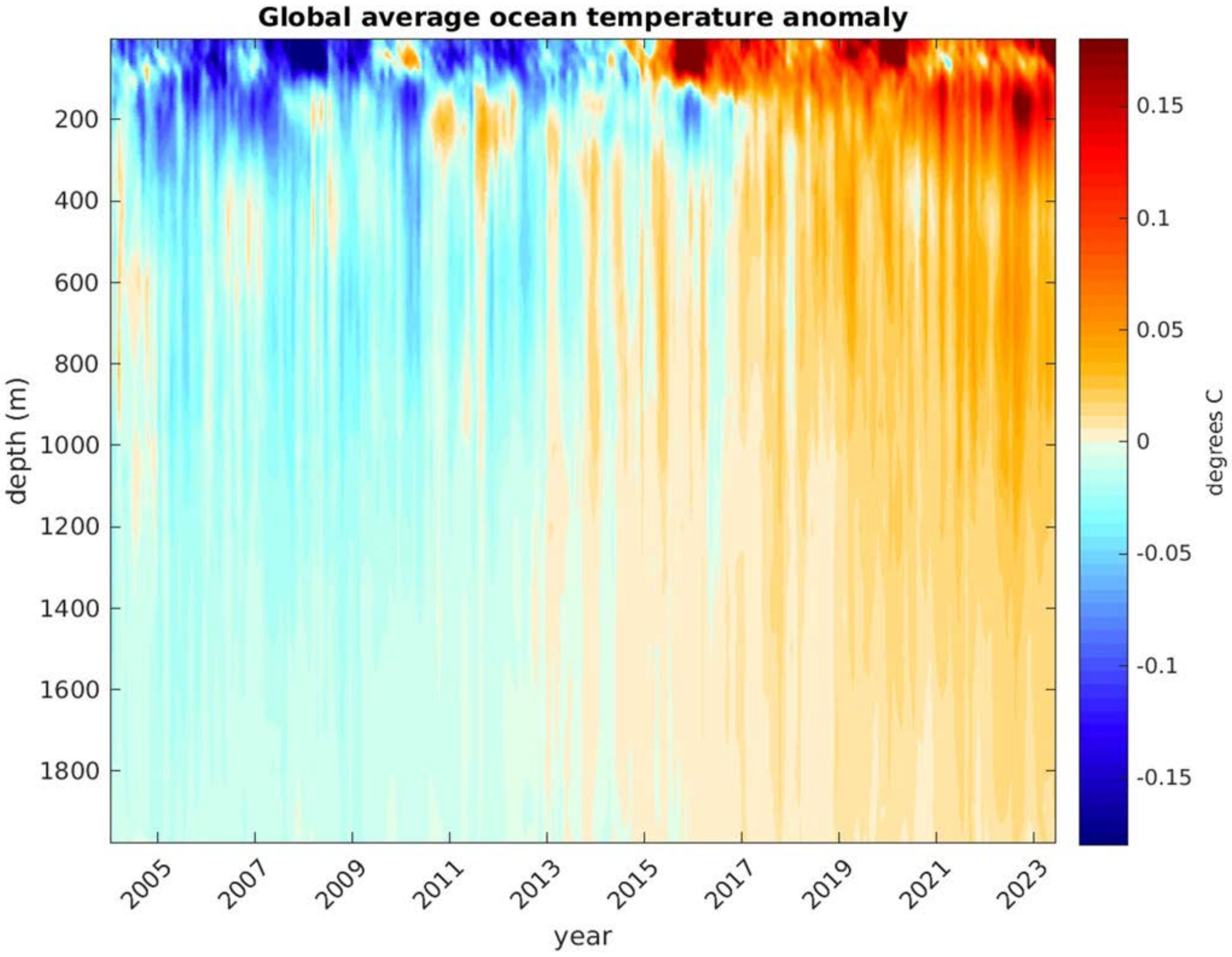
- Biased real-time data has clearly impacted the **closure of global sea level budget** using certain products

- Many global reanalysis groups are **not refreshing** their analysis **archives** with DMQC'd Argo data -> analyses with large and unrealistic halosteric sea level contraction

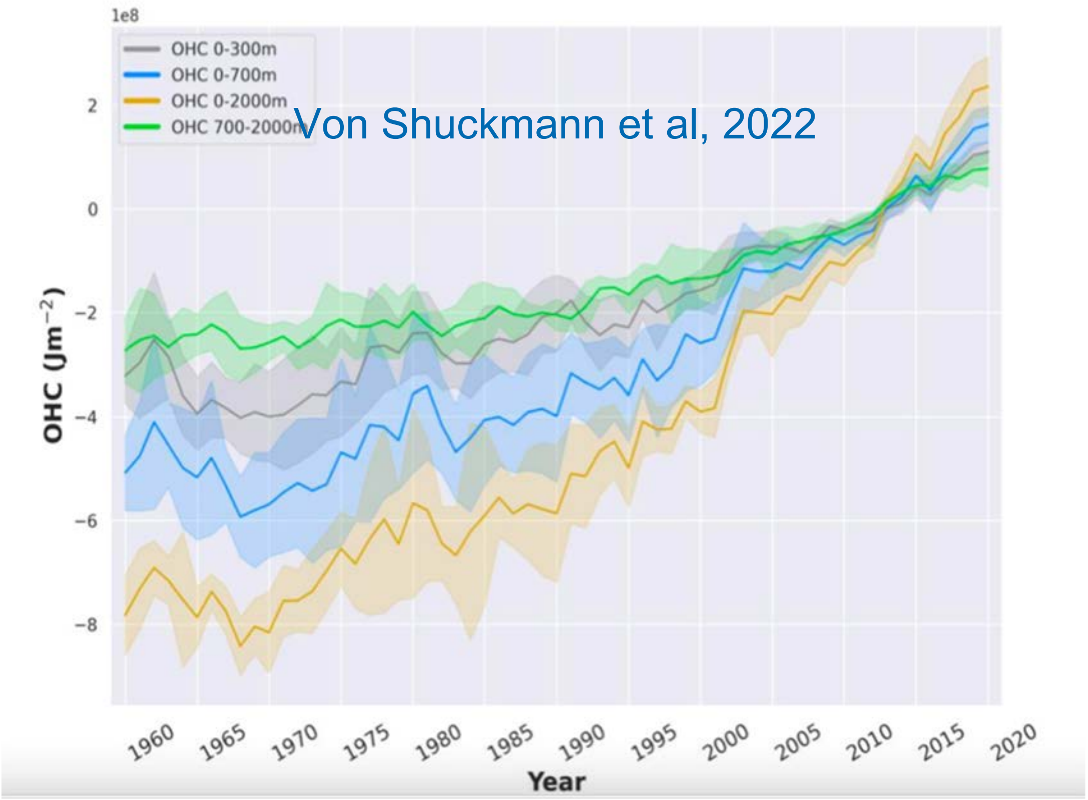


Barnoud, A., Pfeffer, J., Guérou, A., Frery, M.-L., Siméon, M., Cazenave, A., et al. (2021). GRL, 48, e2021GL092824.
https://doi. org/10.1029/2021GL092824

We have enabled routine assessments of Earth's energy budget



Roemmich and Gilson, 2009.



Von Shuckmann et al, 2022

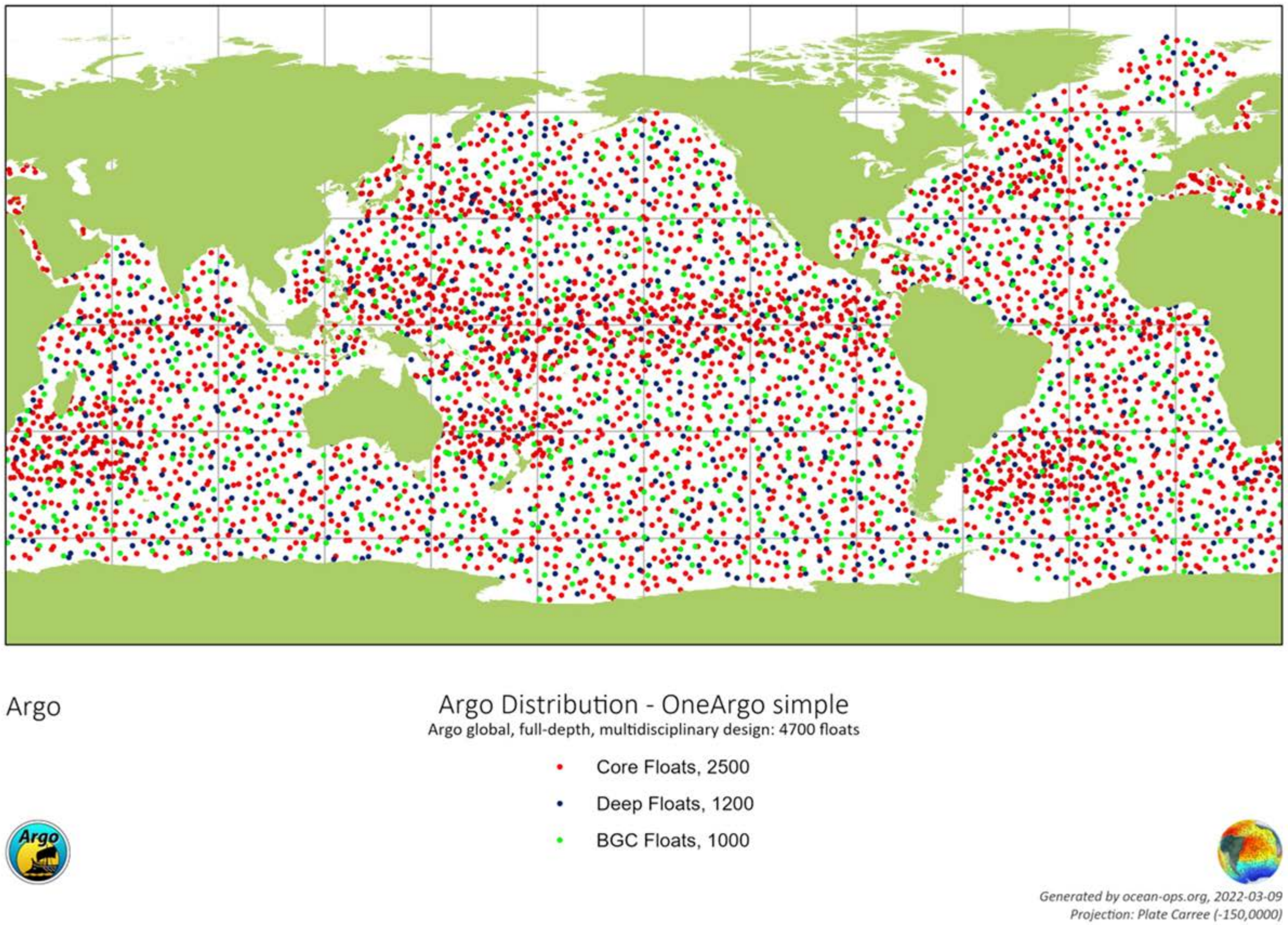
- How do we extend this to the sea floor?
- How do we extend this to carbon and oxygen?

Pathway to improvement: OneArgo

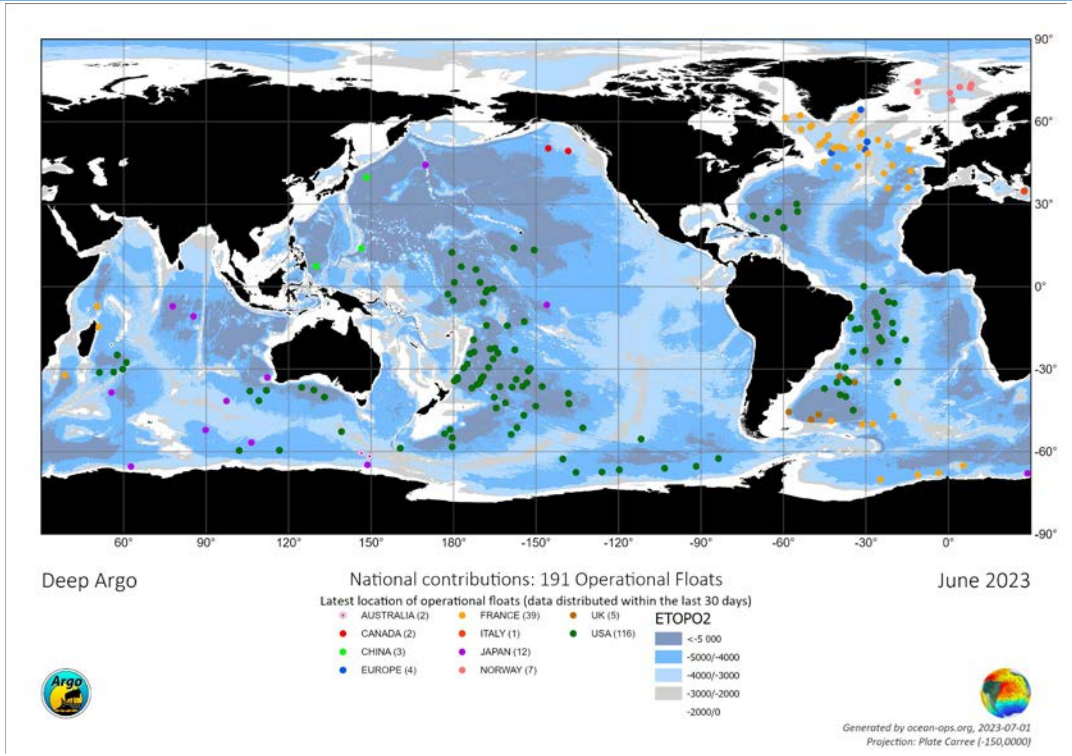
An **ambitious** but urgently needed expansion of the Argo array

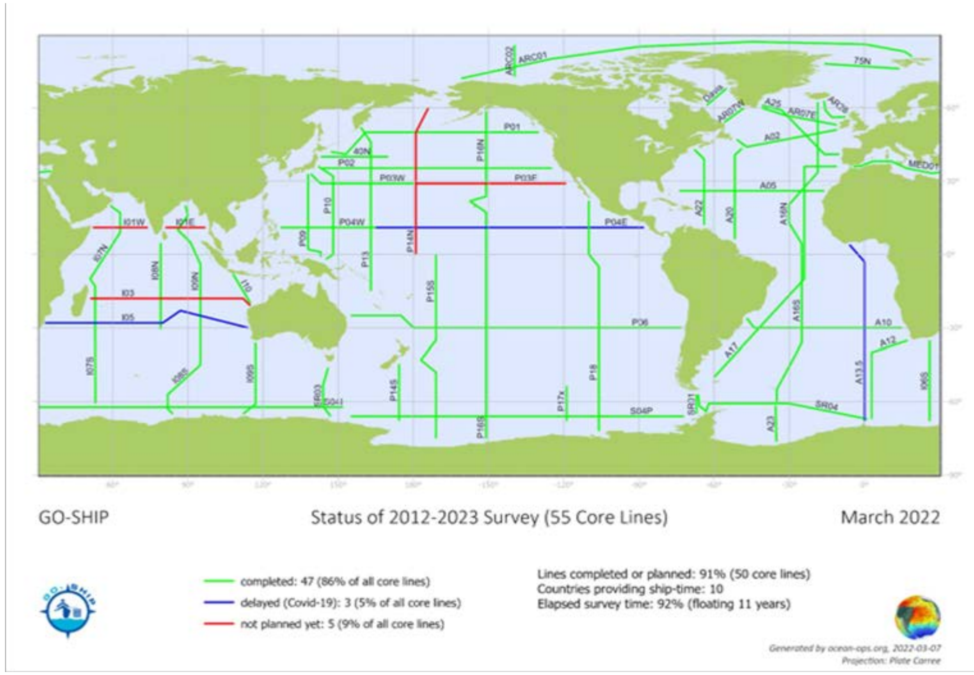
Comprises 4700 floats including:

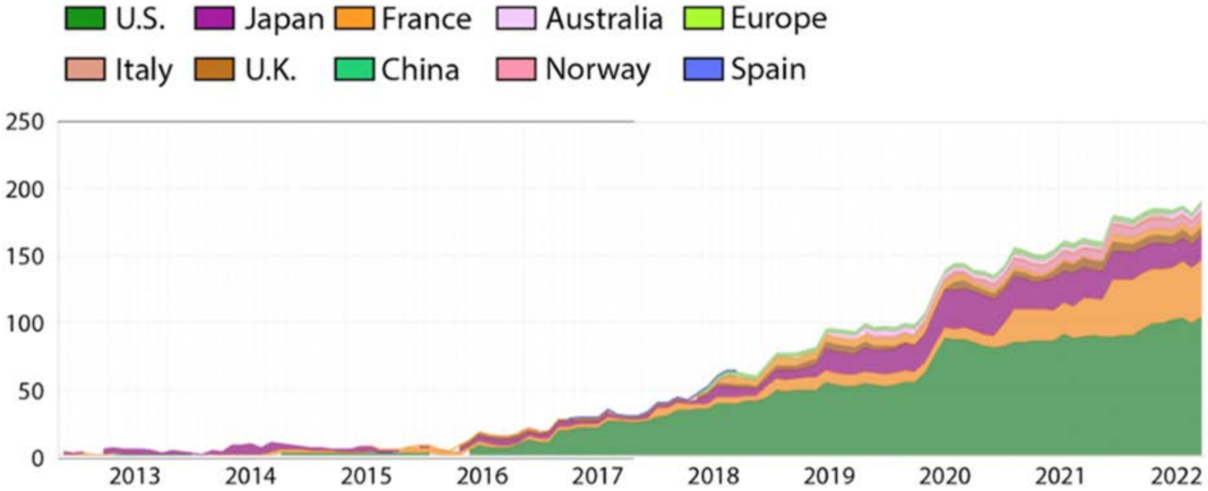
- 1200 deep floats
- 1000 biogeochemical floats
- Expansion into seasonal ice zones
- Enhanced sampling in the equatorial and western boundary regions



Challenges: Gaps in the Deep, Polar Oceans and Marginal Seas

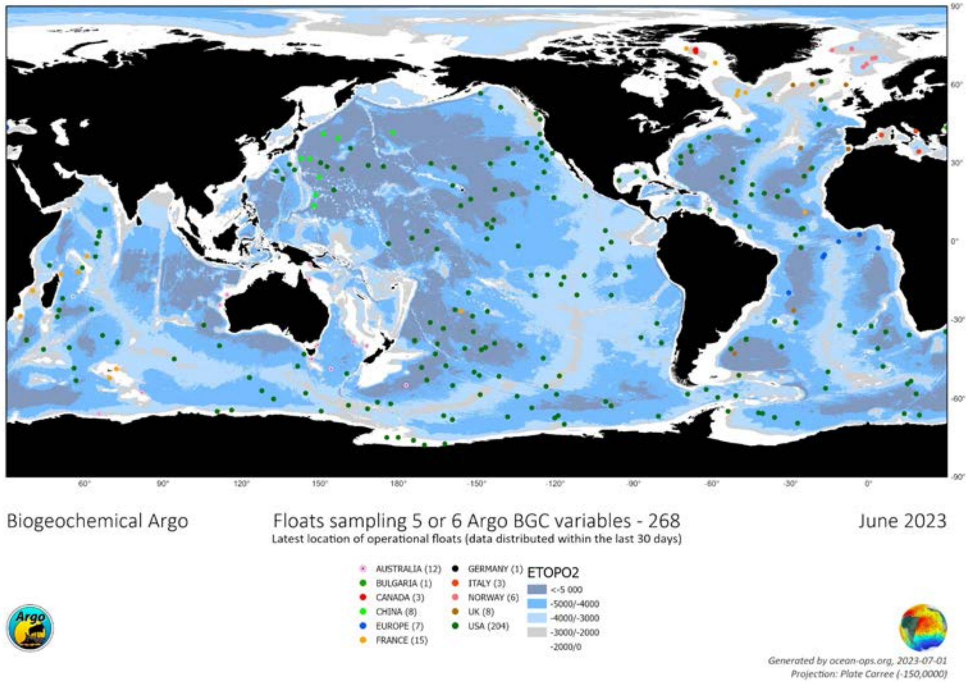


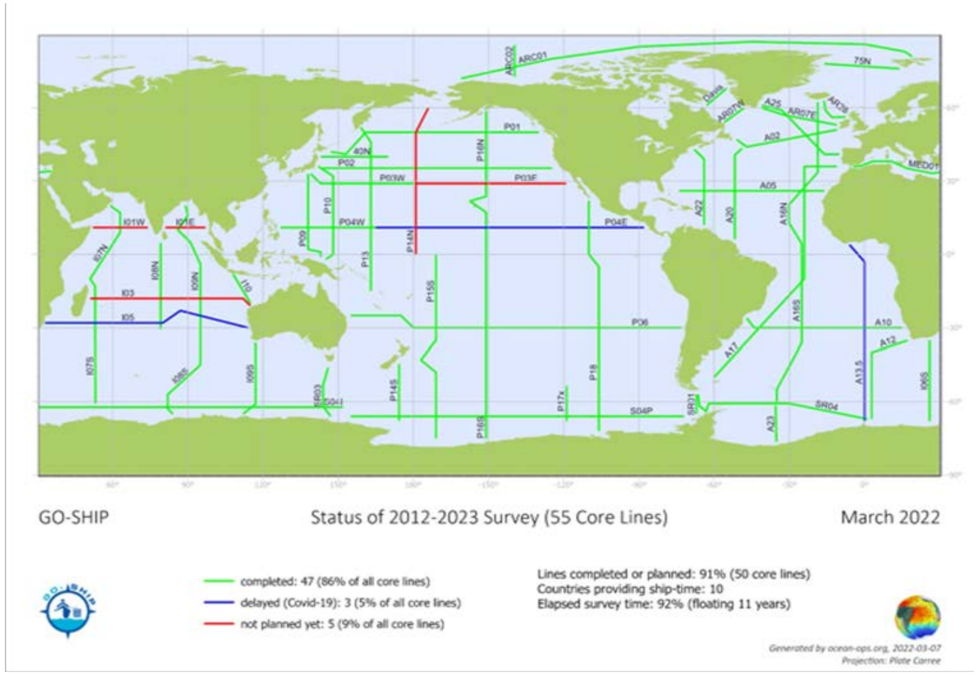


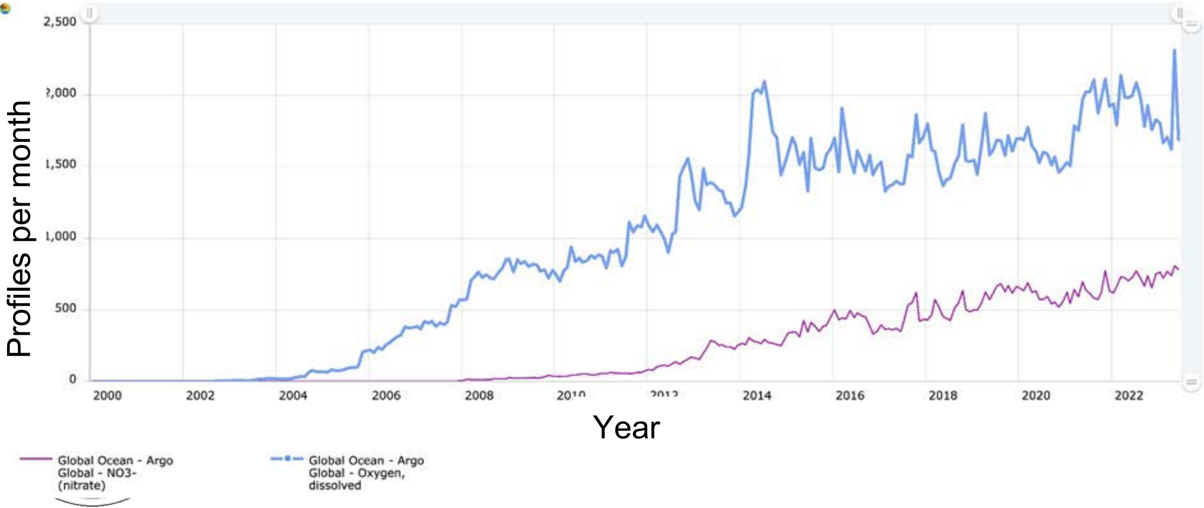


- GO-SHIP decadal surveys
- Deep Argo regional pilots
- Polar oceans remain poorly sampled

Challenges: Carbon, biogeochemistry

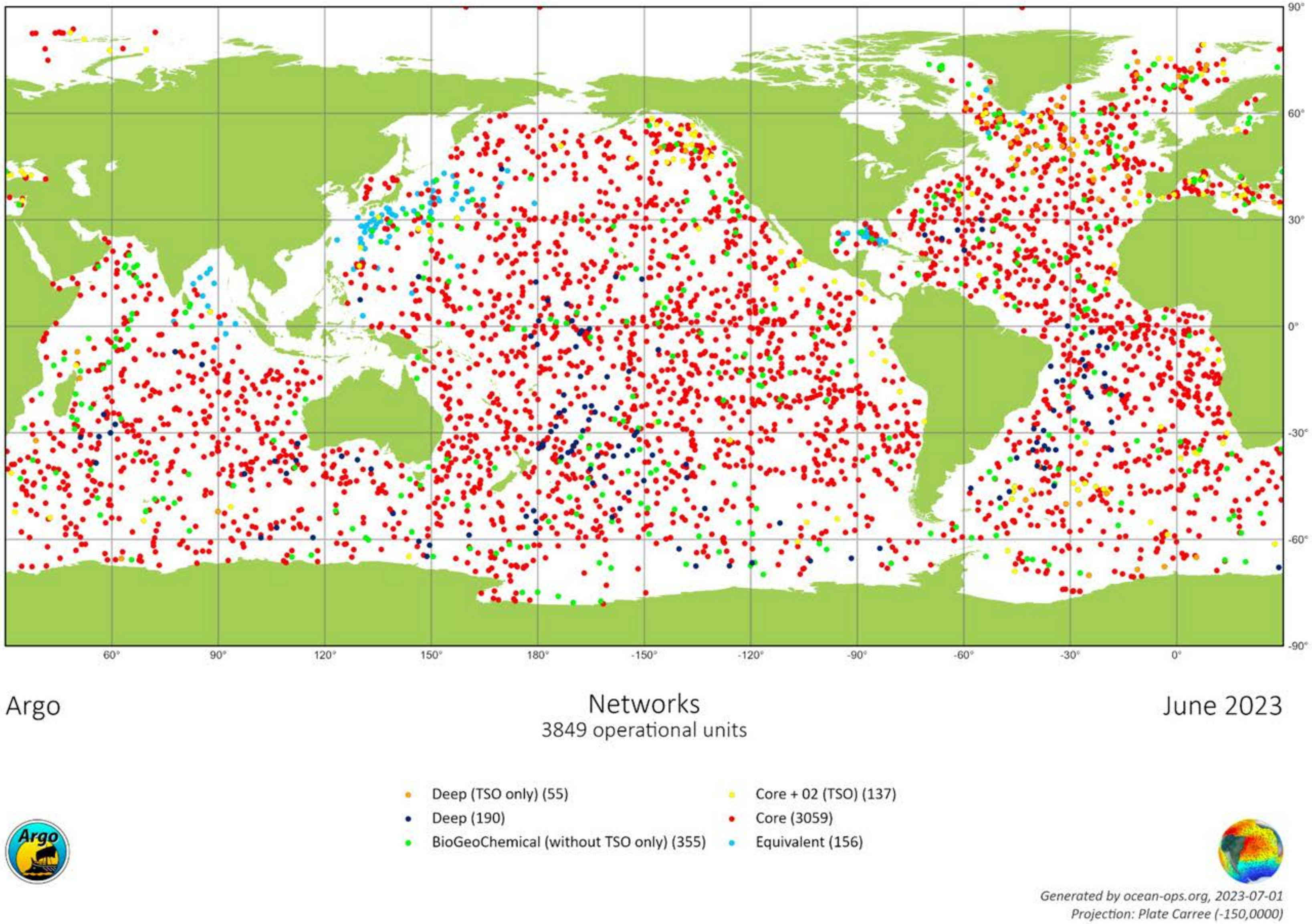






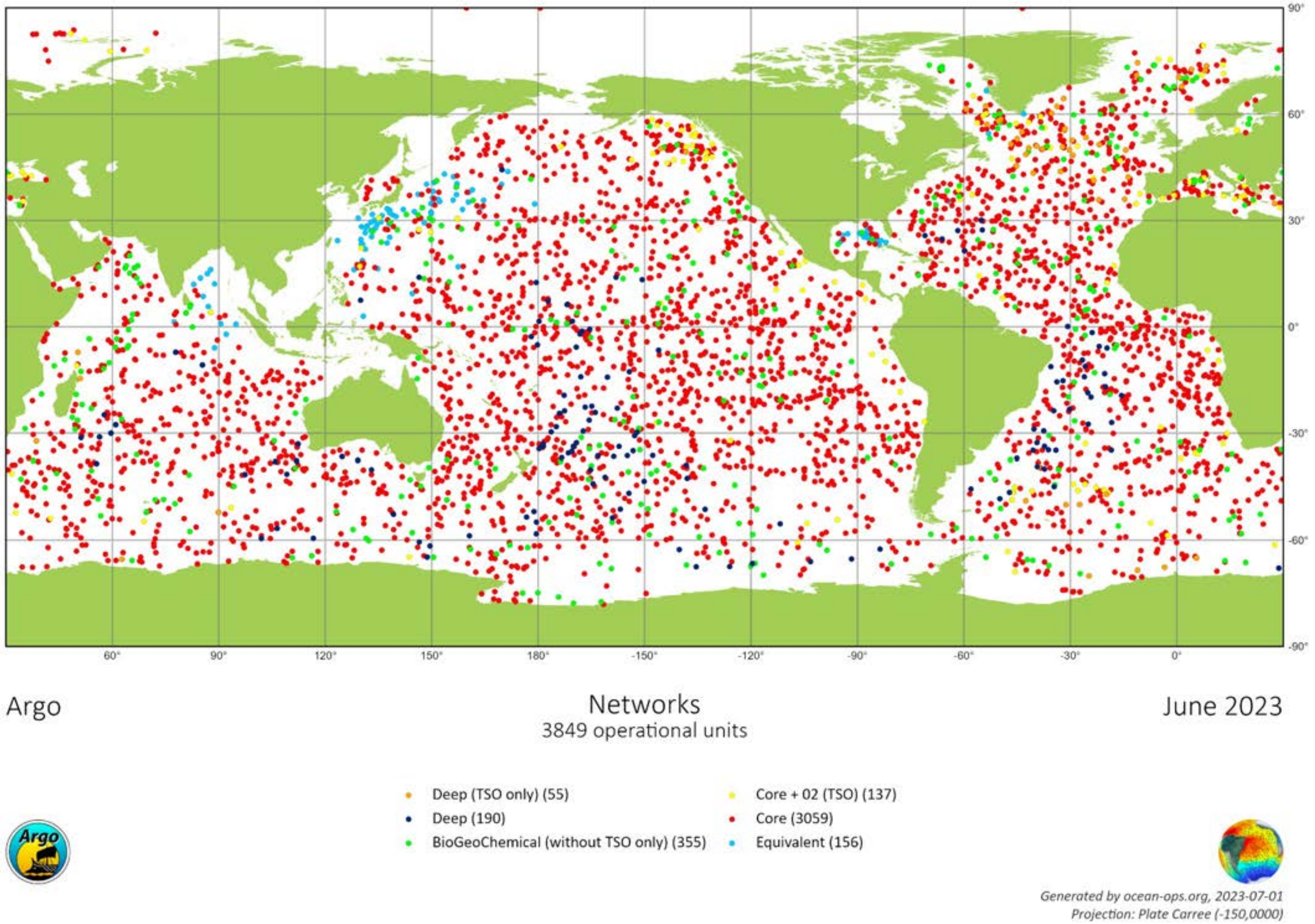
- Good initial progress
- Capacity building in data system, national programs and at manufacturers
- **Implementation stalling - high dependence on short-term research funds**

OneArgo – Achieved High Technical Readiness Level



- 2019: OneArgo design articulated at OceanObs'19, approved by GCOS/GOOS
- 2015-23: successful deep pilot arrays and deep CTD technical developments
- 2015-23: BGC pilot arrays progress sensor and platforms
- 20XX: OneArgo design implemented?

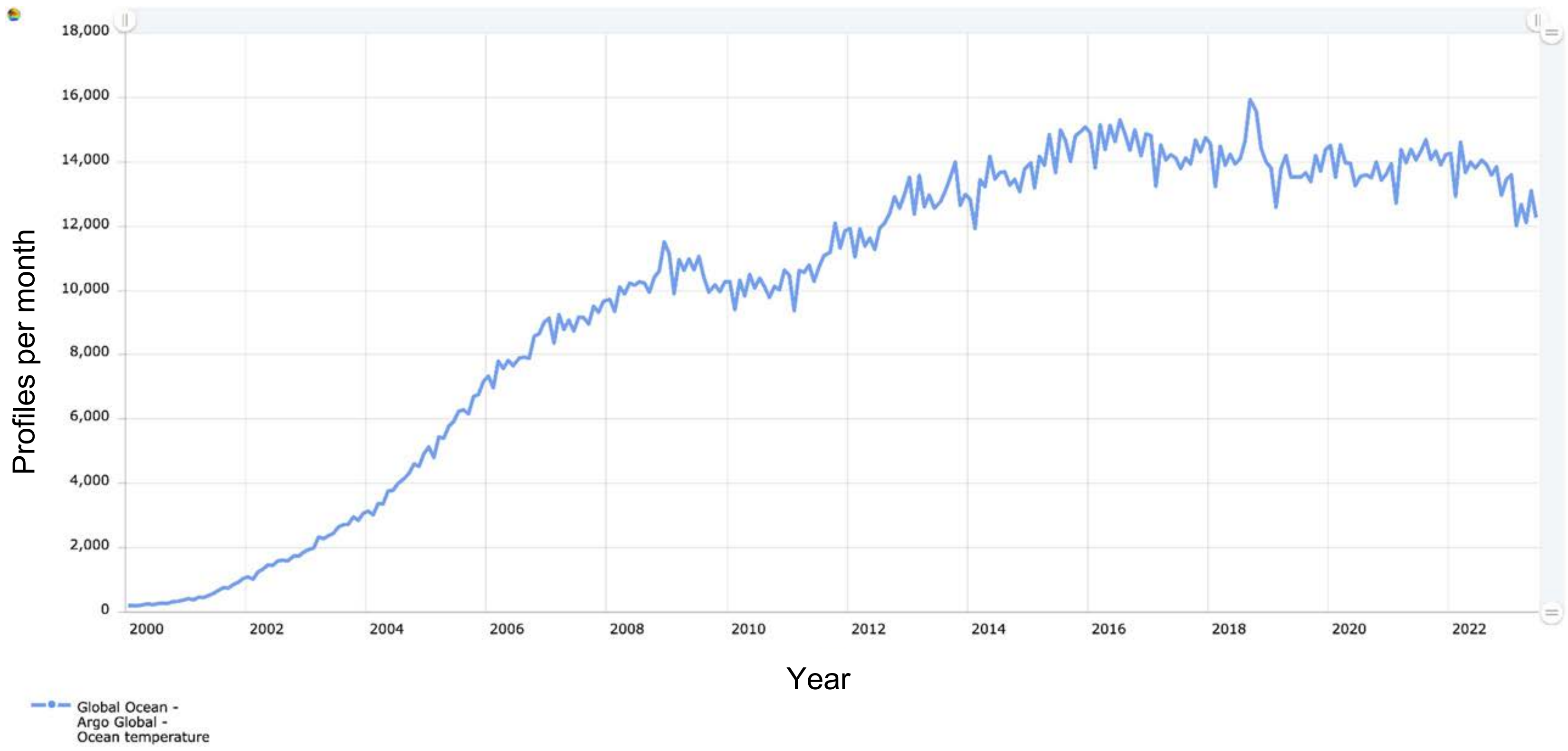
OneArgo – successful pilots arrays, stalled global implementation



- Total = 3849/4700 (83%)
- Deep = 190/1250 (14%)
- Biogeochemical (>=5 params) = 355/1000 (28%)

Presently the Argo system is in net decline

OneArgo – beginnings of decline in total profile returns



Presently the Argo system is in <u>net decline</u>

Flat budgets while developing new capabilities and facing COVID inflation

Conclusions

- Argo and observations from space are **a powerful observing system combination**
- **Major gaps remain** in the deep and polar oceans, and for biogeochemical sampling.
- **OneArgo** –is a new design that targets these gaps
- We welcome ongoing discussion and **refinement of the design** – Task Team on oxygen in Argo
- It requires ~ **$100M/year funding globally**, similar in cost to a single sensor Earth Observing Satellite
- National Argo programs and our industrial partners have **successfully developed the capacity** to operate the OneArgo array
- Without strong support to **implement OneArgo** (and maintain core Argo), **past successes** will be under **threat** and **future gains not realized**
- We need **strong community support** to drive the required investment in this new observing revolution