Intersections of need and opportunity in Observing System evolution – some reflections

Susan Wijffels

WOODS HOLE OCEANOGRAPHIC INSTITUTION

Some personal reflections

- **Opportunity**: Weigh up **needs** (co-design) and technological **developments** (including cost)
- **Value:** Prioritise systems that are **synergistic** with other elements of the GOOS and that meet **multiple needs** (forecasting, science, climate assessment, etc)
- **Rigor in design** should be pursued, and revisited with new tools
- Be clear about **design goals** and **track success** against these to help guide implementation teams
- A **well-resourced and fit for purpose data management** system is crucial

Argo Design (late 1990s’): intersection of need and opportunity

- **OPPORTUNITY: Technological developments** - long lived autonomous profiling platforms that can host a CTD, and the satellite network to position the platform and bring the data home affordably

- **NEED: Climate science and prediction** - seasonal forecasting saw the need for measuring beyond the tropical Pacific (e.g. IOD), climate change assessments needed global data for Earth’s energy imbalance and drivers of sea level rise; nascent ocean forecasting was desperate for more subsurface data

- **VALUE:** more is realised in serving **many needs**: operational forecasting wants fast data and lots of it; climate prediction, assessment and science want global and accurate data, but can tolerate a slower delivery time.

Observing systems serve multiple goals – Argo(1998)

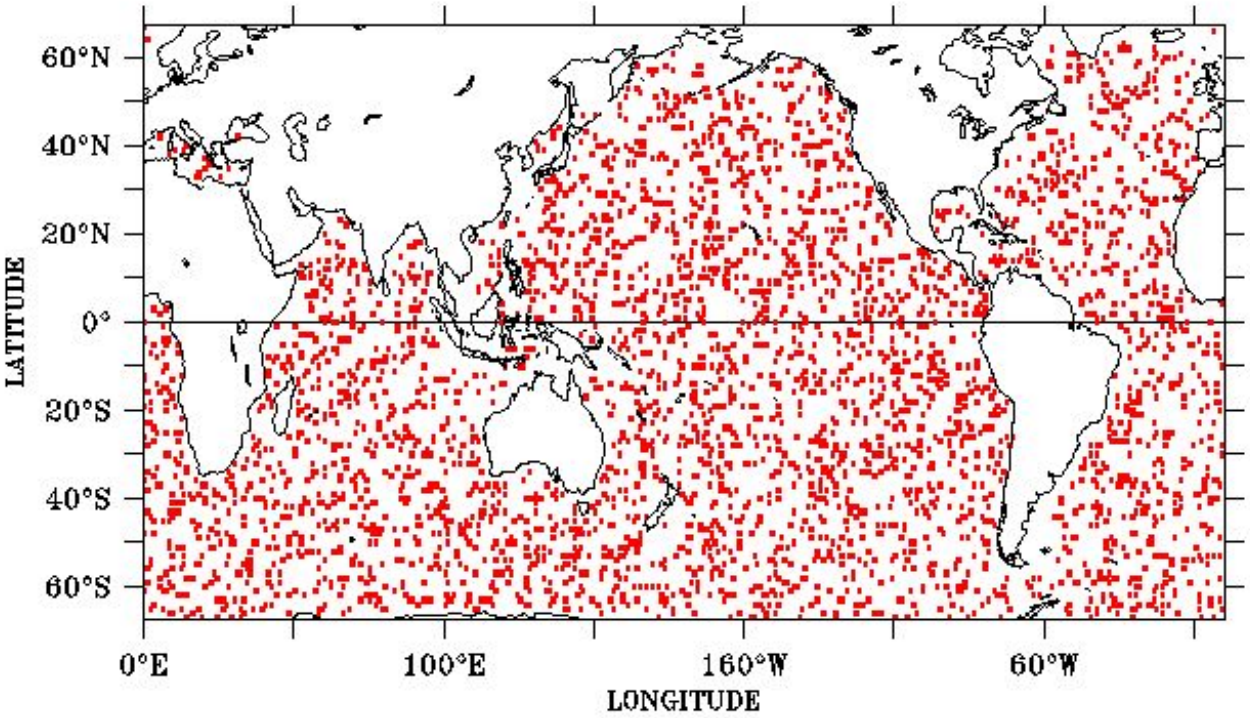
The network should be **integrated with other elements of the climate observing system**,

- to detect climate variability on seasonal to decadal time-scales. The targeted variability includes changes in the large-scale distribution of temperature and salinity and in the transport of these properties by large-scale ocean circulation.
- to deliver information needed for calibration/interpretation of satellite measurements, and
- to provide data for initialization and constraint of climate models. [ocean prediction was still nascent]

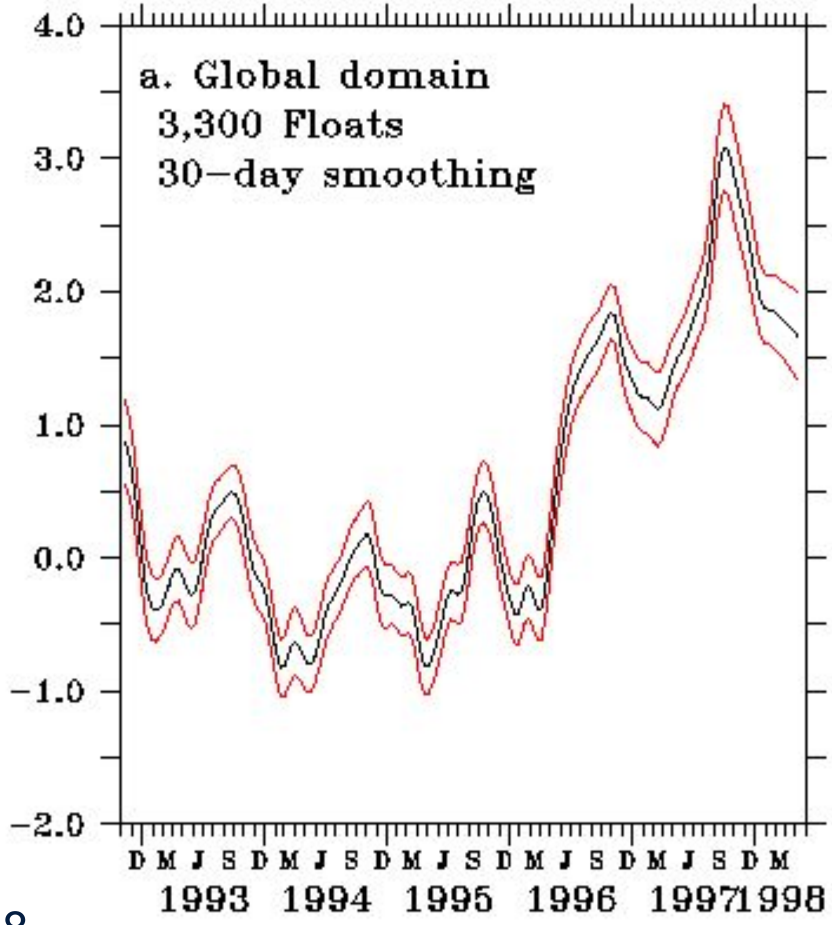
The most serious defects in present networks are the lack of global span in thermal data and the lack of any systematic subsurface salinity data. These are major weaknesses, in effect limiting scientific progress in climate studies.

Argo is also needed to **accelerate the development of ocean models and data assimilation**, providing key data for testing and constraining ocean and coupled ocean-atmosphere climate models. Lack of adequate subsurface temperature and salinity data is a severe barrier to developing useful and reliable estimates of the ocean physical state, even in the presence of satellite data from altimetry, radiometers (sea surface temperature) and scatterometry (surface wind stress)

Argo's design was informed by satellite altimetry



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



- SLA track data from T/P were used to develop the original design and ensure the large-scale signal could be recovered.
- Similar tests were done regionally
- Core Argo is designed to track **the slow manifold**: 3 months/1000km ocean variability

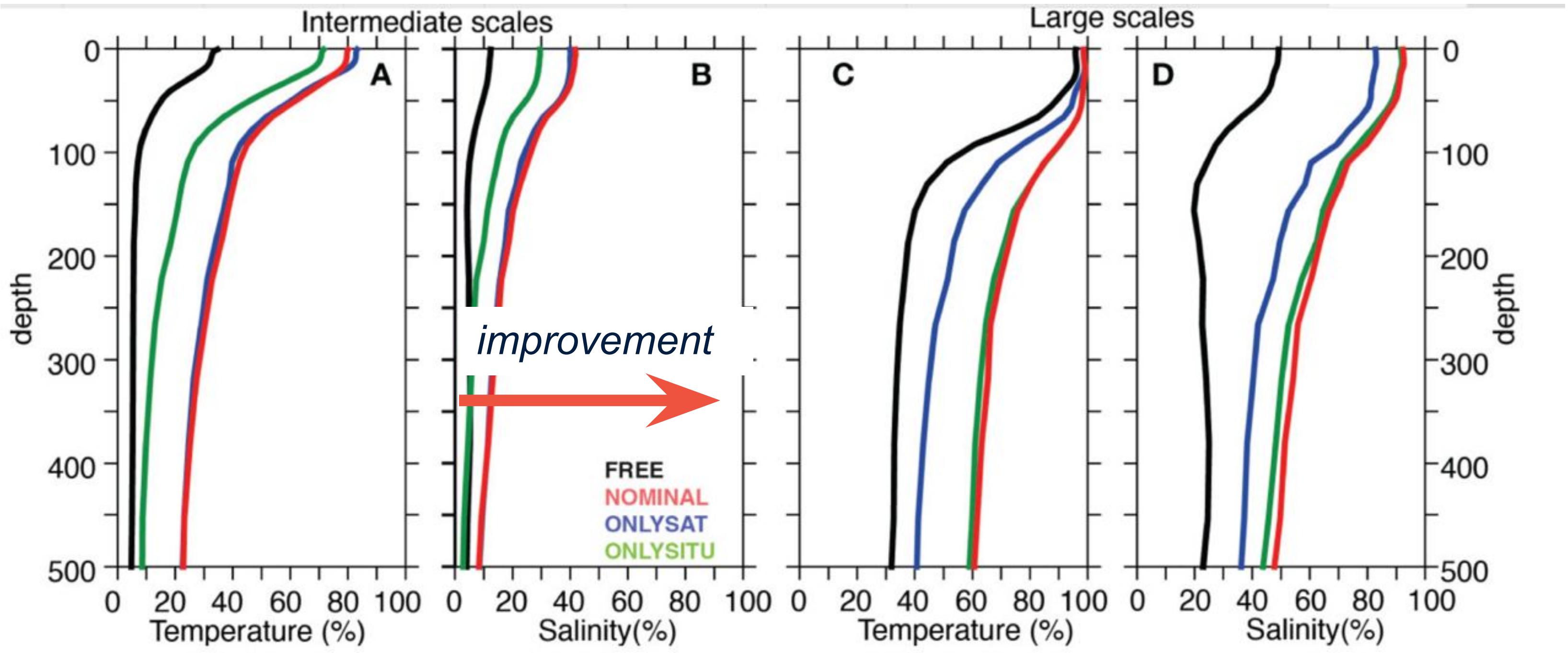
Roemmich & AST, 1998

This concept has been verified using modern DA/OSSE

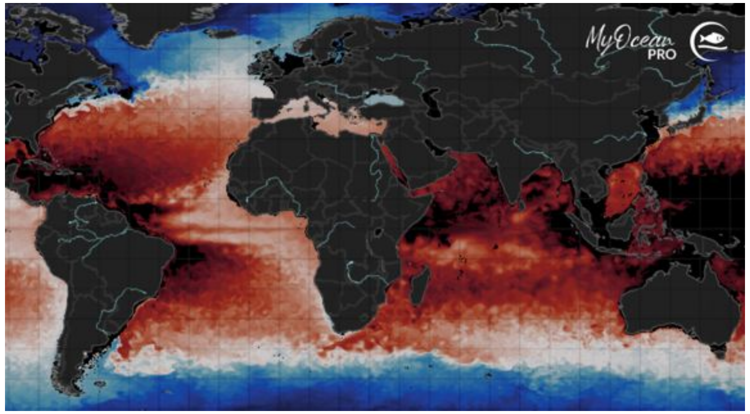
*Globally averaged % variance recovered from an **1/12º Nature Run** for temperature and salinity for the OSSEs: FREE, NOMINAL (ALL), ONLYSAT, and ONLY INSITU*

Intermediate scales (100-1000 km/ 20-100 days)

Large scale



Percent variance captured

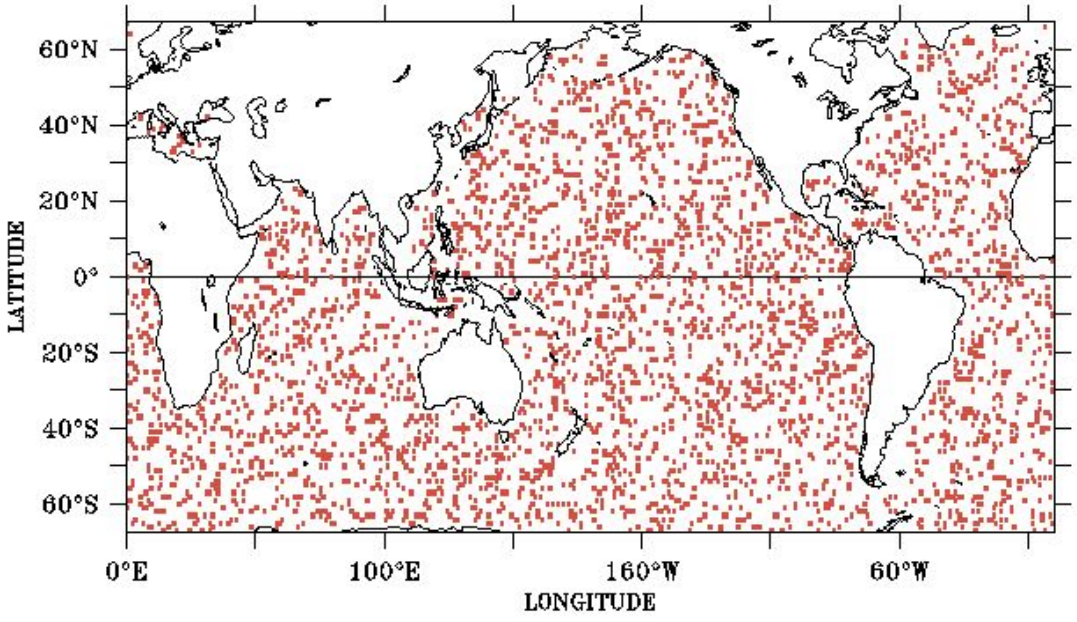


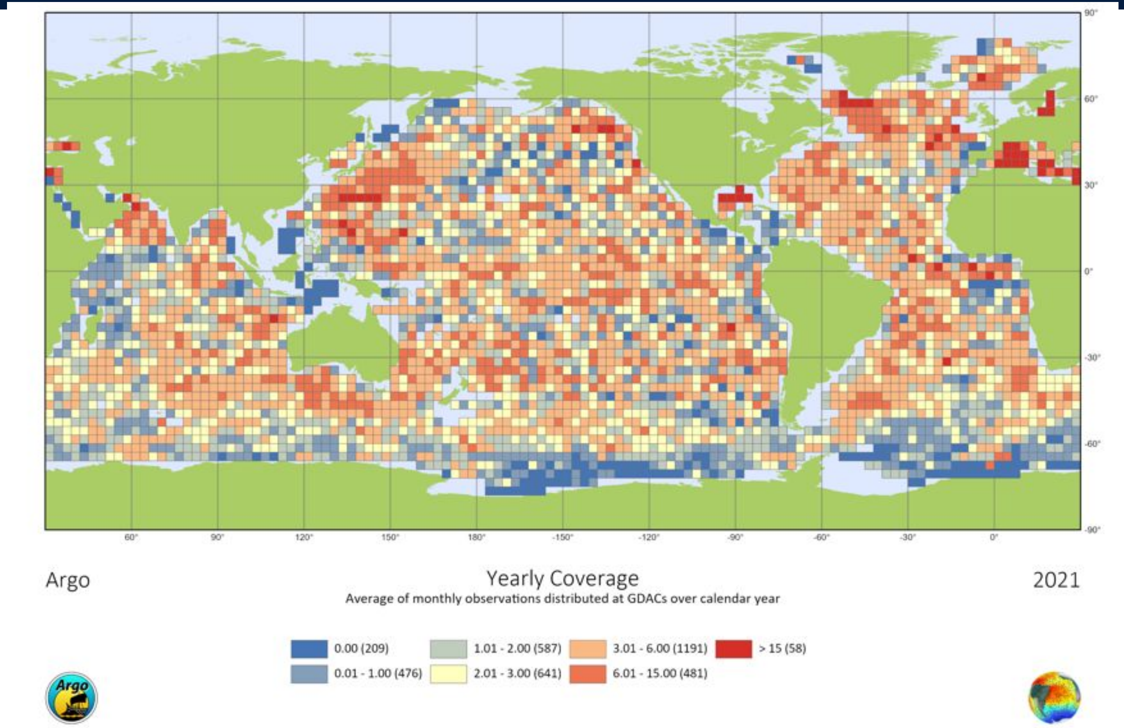
Argo constrains the 'largescale slow manifold', satellites SLA constrains the fast features and small spatial scales - a strong synergy is realized

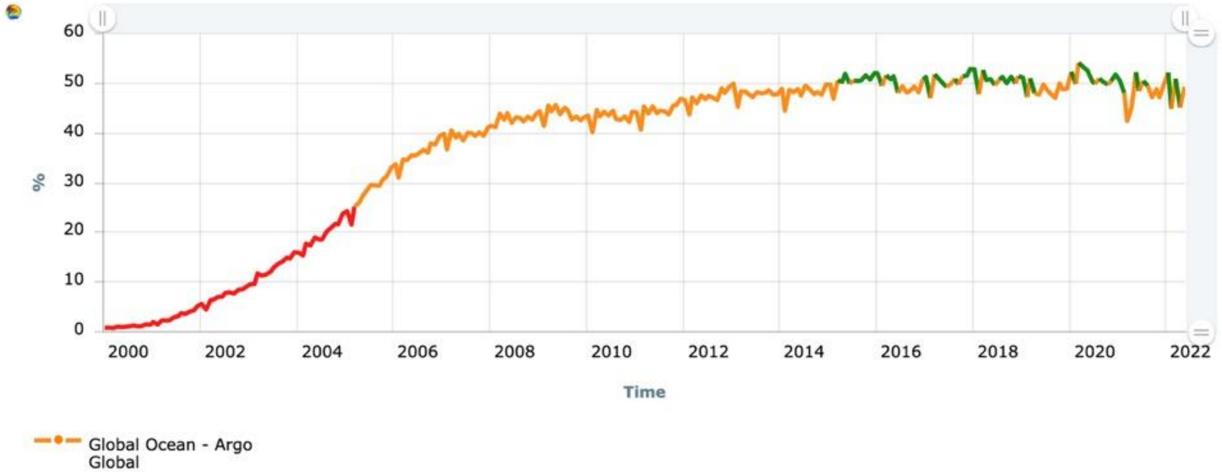
Gasparin et al. (2023), Frontiers MS

Key Ingredient for success

Clear design and performance metrics





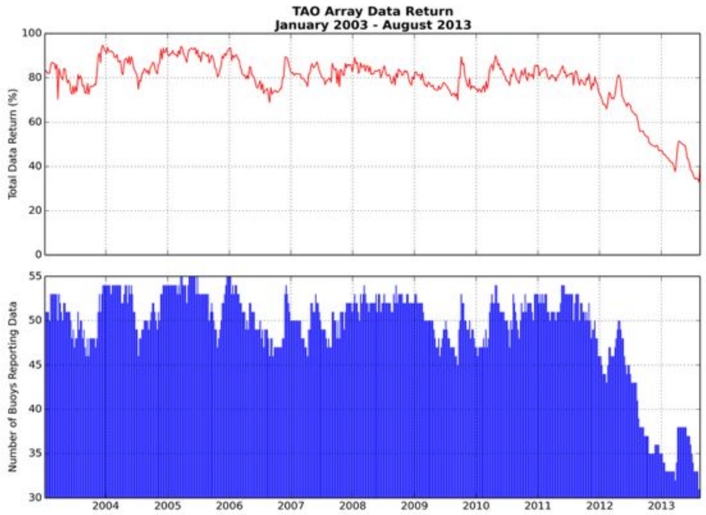


WOODS HOLE **OCEANOGRAPHIC** INSTITUTION

Observing systems serve multiple goals – TPOS (2015)

The TPOS backbone has five key functions (from the Resource Forum):

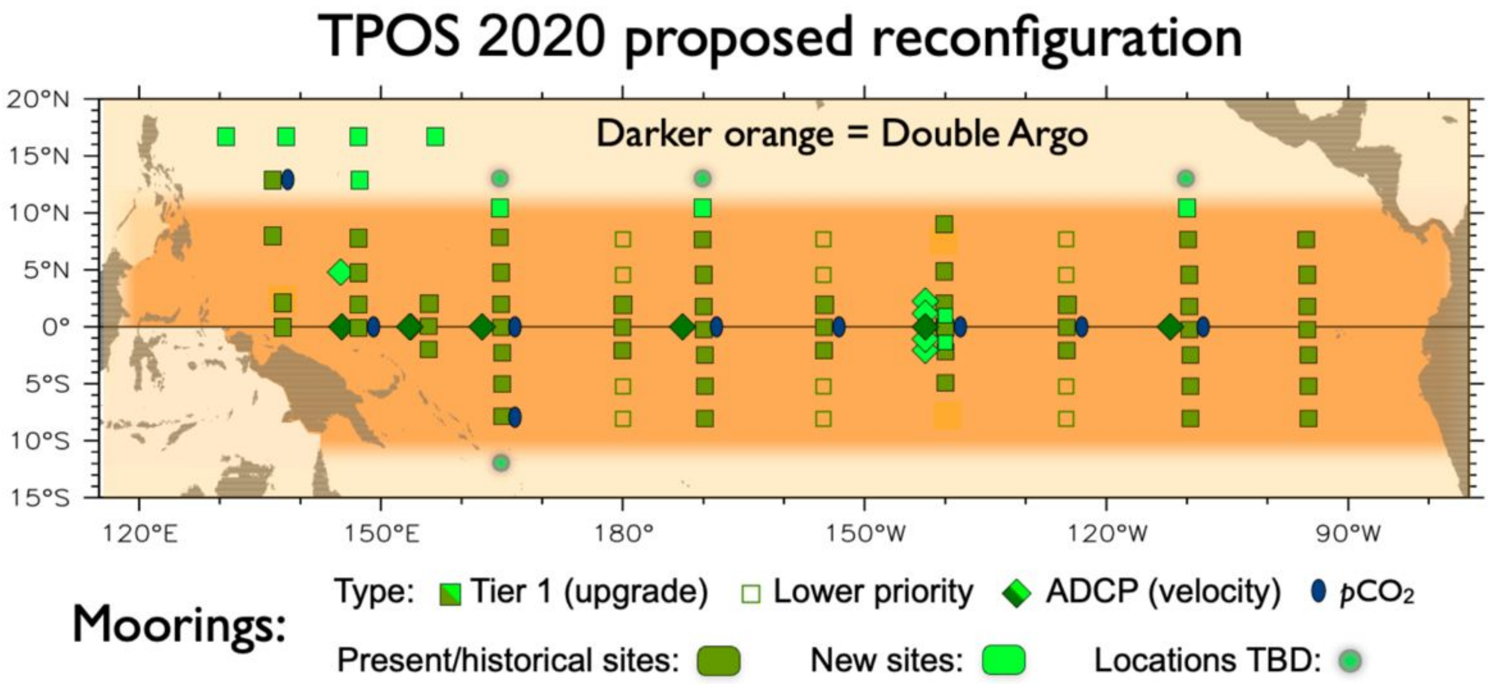
- Observe and quantify the **state of the ocean**, on time scales from weekly to interannual/decadal;
- Provide data in support of, and to validate and improve, **forecast**ing systems;
- Support integration of **satellite measurements** into the system including calibration and validation;
- **Advance understanding** of the climate system in the tropical Pacific, including through the provision of observing system infrastructure for process studies; and
- Maintenance and, as appropriate, extension of the tropical Pacific **climate record**

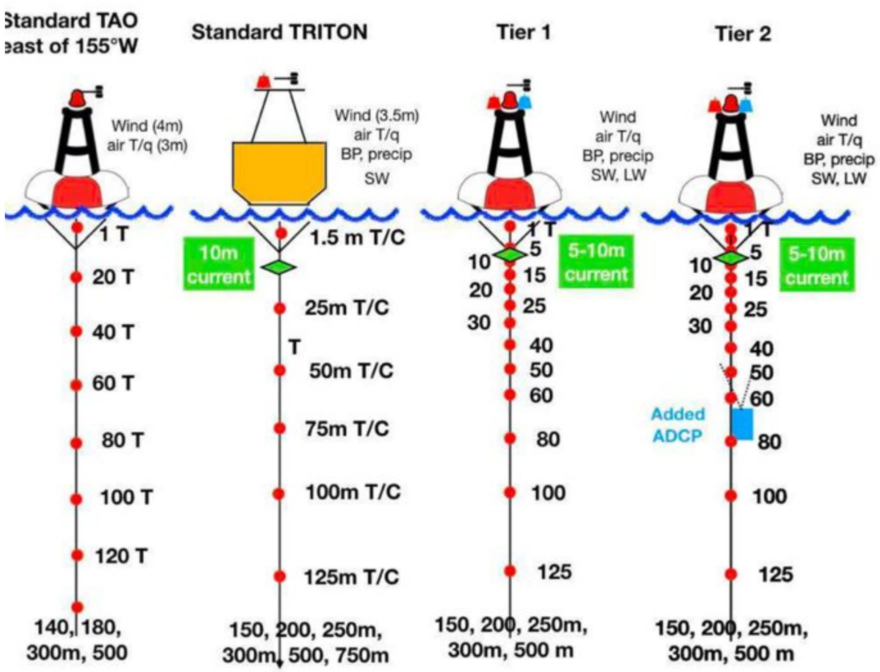


Approach of the BB Task Team: to more highly value observing elements that serve multiple goals

Evolution of TPOS Backbone

- Focus moored array on near surface resolution and more complete air/sea flux observations
- Broadscale state tracking function relies more on satellite and other broad-scale *in situ* observing systems e.g. Argo/XBT etc
- Maintain some 'broadscale' capability in the TMA as a form of redundancy





Challenging ourselves

- Revisit assumptions: e.g. are moorings the only way to maintain a wind climate record or tracking the broadscale subsurface?

- Be aware of and test the critical dependencies we have in the system e. g. to anchor/validate satellite SST or sea level or winds?

- Keep track of emerging technological advances – SWOT, BGC and biological sensors, ASVs, etc. When will profiling floats be replaced by something better/cheaper, more pilotable etc?

- What goals can be accomplished by a limited duration process study (e.g. WOCE) vs those that need long-term sustained observing. Our community often conflates these two types of needs.

Some reflections

- **Opportunity**: Weigh up **needs** and technological **developments** (including cost/realities e. g. global class ship time is becoming a scarce commodity)

- **Value:** Prioritise systems that are **synergistic** with other elements of the GOOS and that meet **multiple needs** (science, climate assessment, forecasting etc)

- **Rigour in design** should be pursued and revisited with new tools. Formally analysing skill by space/time scale is needed. Statistical and/or model/DA both useful. Prediction skill impact is harder but should be assessed (humbling).

- Be clear about **design goals** and **track success** against these to help guide implementation teams

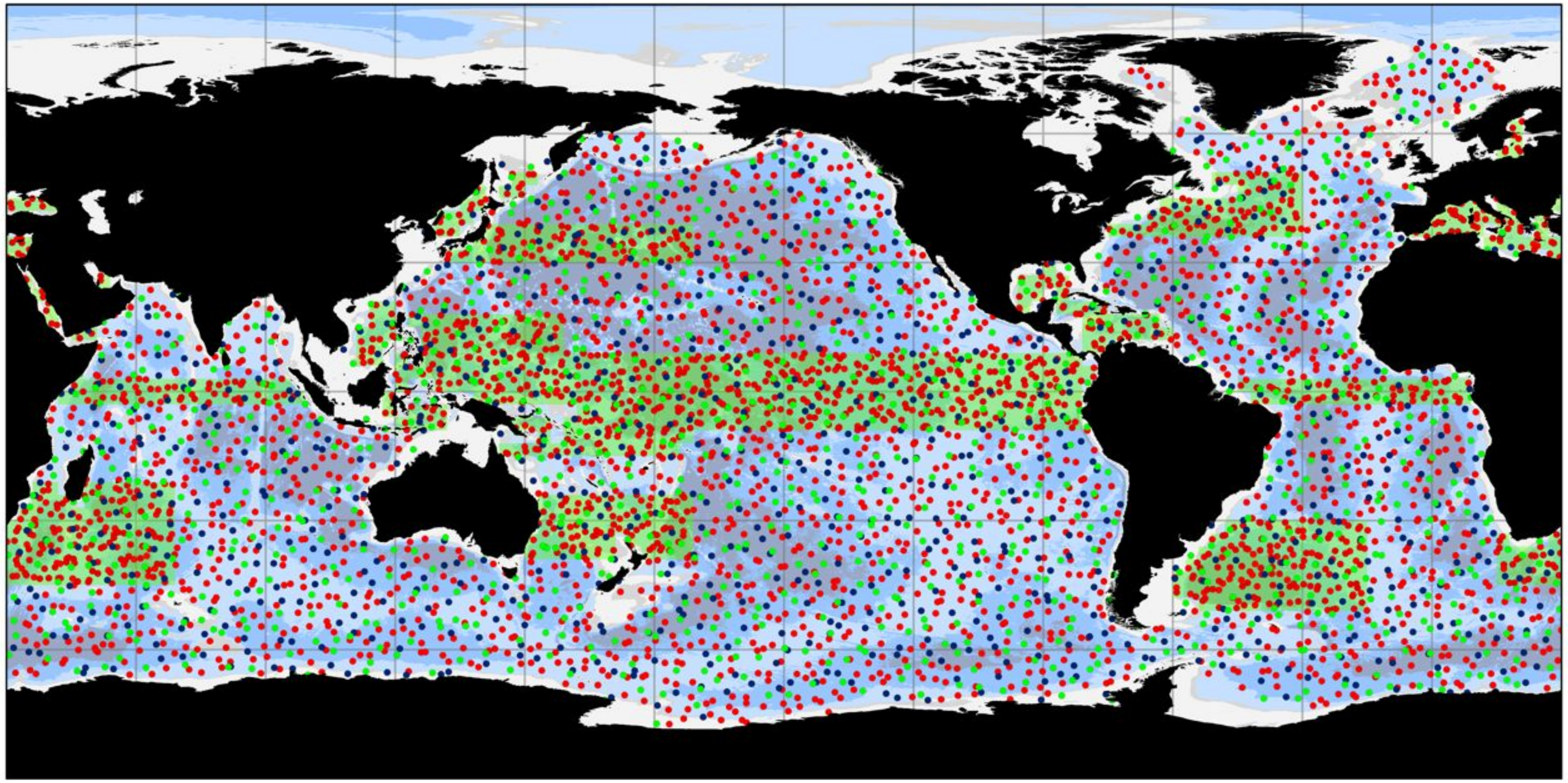
- A **well-resourced and fit for purpose data management** system is crucial - specify accuracy and timeliness

Thank you

swijffels@whoi.edu

WOODS HOLE
OCEANOGRAPHIC
INSTITUTION

| Responding to new opportunities/needs



Argo

Argo Distribution - OneArgo

Argo global, full-depth, multidisciplinary design: 4700 floats

- Core Floats, 2500
- Target density doubled
- Deep Floats, 1200
- BGC Floats, 1000

OceanObs '09 –
go deeper,
go multi-disciplinary

OneArgo Design

- 1000 BGC floats (Nitrate/oxygen/pH /Chla/CDOM/Irradiance)
- 1250 Deep float
- 2500 core floats

- 5-8 years of technological development
- Ready for global implementation

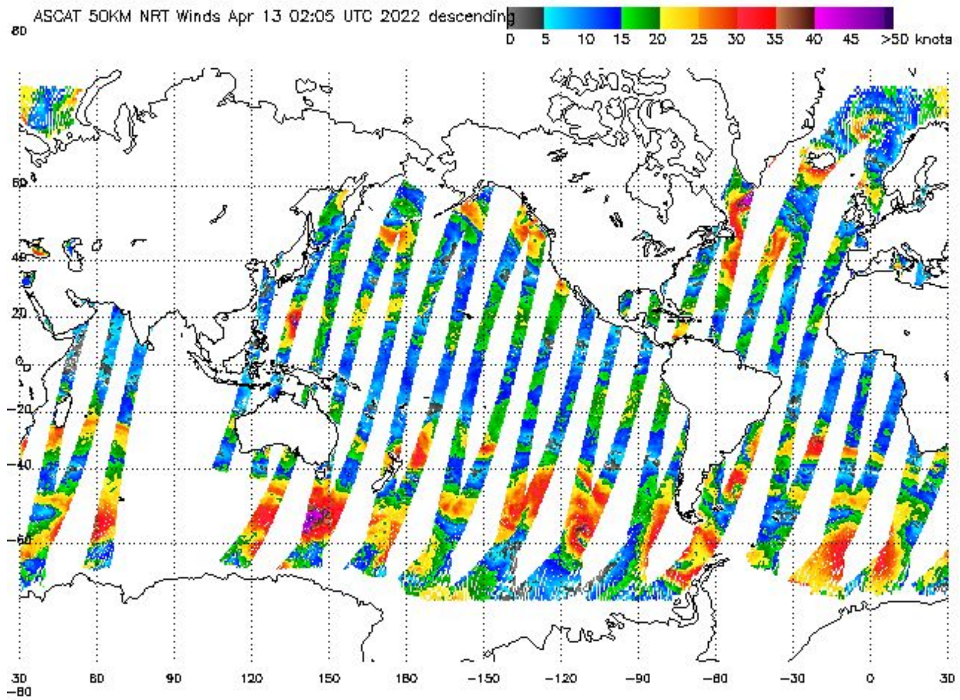
Bigger context? Exploit critical satellite missions

Earth Observing Satellite programs coordinated by the CEOS

- Ocean colour radiometry
- Surface Topography
- Vector Winds
- Precipitation
- Sea Surface Temperature
- Sea surface Salinity

Networks should be designed to be synergistic to deliver an **Integrated System**

- **surface topography/Argo**
- **vector winds/Moored Surface Buoy Arrays**
- **Satellite SST/Surface Drifters + SOOP TSG …**
- **Ocean color/BGC Argo + …**
- **Surface waves from space/ drifters+moorings**
- **Space-based SSS/Argo and SOOP TSG**



Synergies:

- Cal/val
- Product development
- Retrieval algorithms
- Scale and sampling trade-offs

Argo Data System

Provides near **real-time** and **climate-quality delayed mode** data.

Consistent meta- and technical data.

All Argo data are **freely available** via the internet and GTS

Uniform format – enforced at GDACs