The Tropical Atlantic Observing System

Greg Foltz, NOAA/AOML

Significant input from Sabrina Speich and the TAOS review committee, and coauthors of OceanObs19 white paper

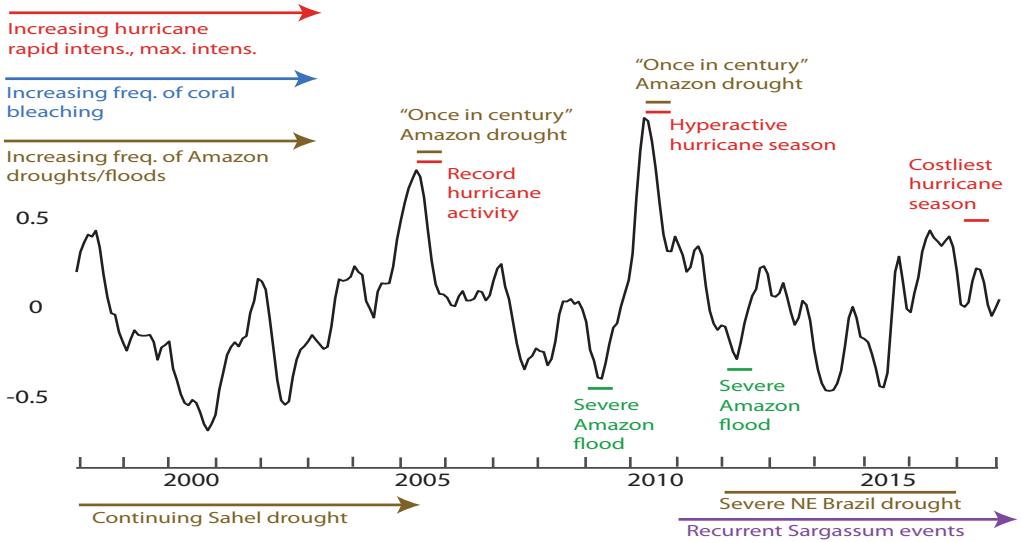
Tropical Atlantic Observing System Review

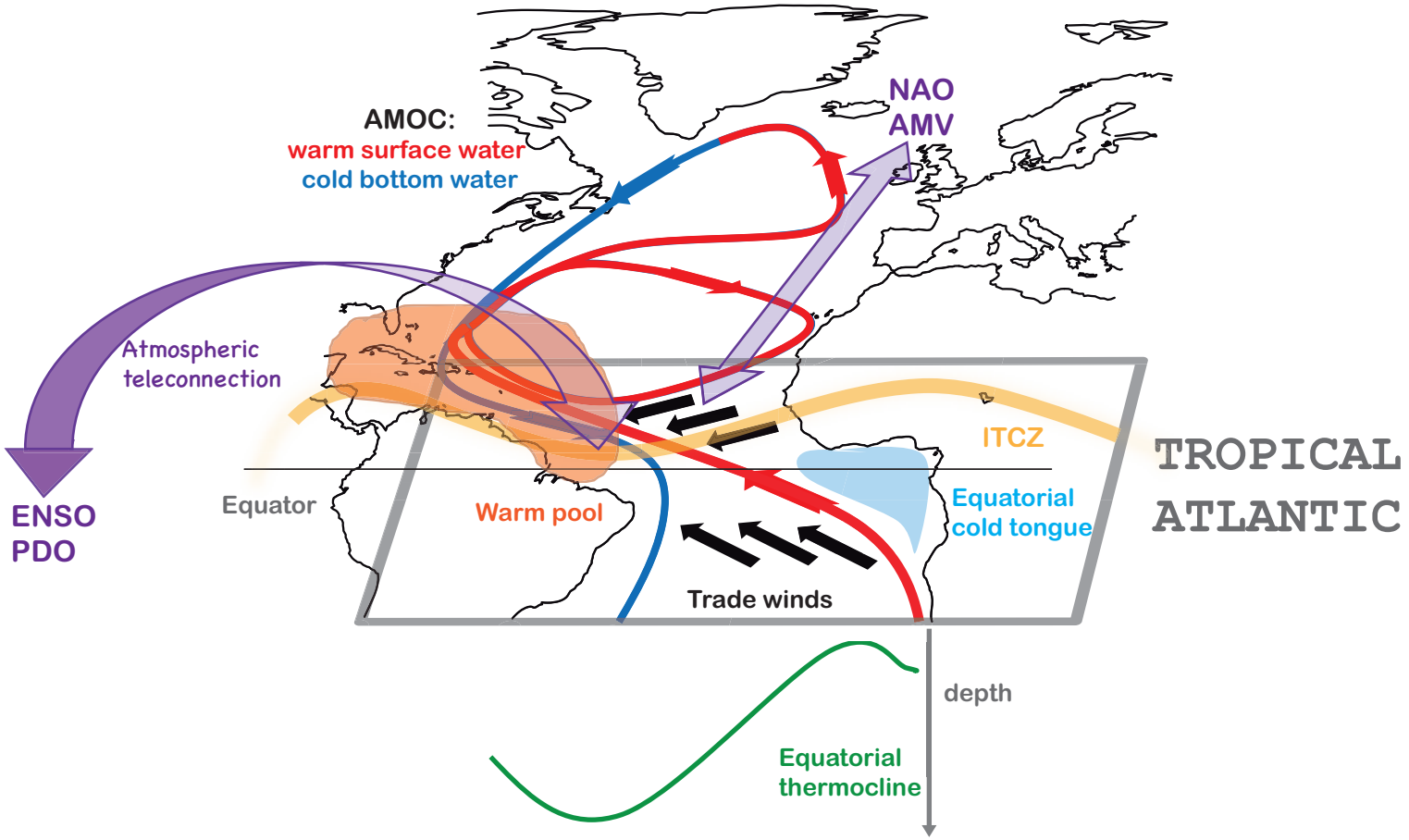
Why a Review ?

- Last review in **2006** by **CLIVAR** and **OOPC**
- Primary focus was on **PIRATA** (now **PIRATA** is 22 years old)
- Since then **CLIVAR TACE** & **PREFACE** have been completed.
- Evolution of scientific priorities and observational technologies (Argo, new sensors, new moorings)
- PIRATA has also expanded (new sites, higher vertical resolution in ML, new variables implemented - CO_2 and O_2)

The sociopolitical background

- Climate is changing rapidly, positive trends in extreme events
- Anthropogenic pressure on fisheries, pollution
- Reviews underway in other basins (TPOS2020 and IndOOS)
- A favorable and rapidly evolving political framework (OO'09 & FOO, Galway and Belém Accords, AtlantOS)





ENSO: El Niño-Southern Oscillation
PDO:Pacific Decadal Oscillation

NAO: North Atlantic Oscillation
AMV: Atlantic Multidecadal Variability

ITCZ: Inter Tropical Convergence Zone
AMOC: Atlantic Meridional Overturning circulation

Who ?

- Organised by the CLIVAR Atlantic Region Panel (ARP) in close cooperation with the PIRATA consortium.
- ARP will seek OOPC's endorsement for the review.
- It has tried to involve the IOCCP, IMBeR, SOLAS, among others.
- The review will complement other reviews of the Atlantic observing system (RAPID-AMOC, OSNAP).
- It is benefitting from TPOS 2020 and IndOOS reviews.
- Results of the TAOS review are also feeding into the AtlantOS design strategy & OceanObs'19 conference.

Terms of Reference

- Review and articulate the **existing and anticipated future drivers for TAOS**.
- Evaluate (review/assess/prioritize) existing and potential **requirements for sustained observations of essential (ocean) variables**
- Evaluate the **adequacy of existing observing strategies** to deliver requirements for variables, and characterize their impacts
- Provide **recommendations on the current suite and configuration of observing systems** to enhance their resilience and robustness in order to produce data in the most cost-efficient and sustainable manner

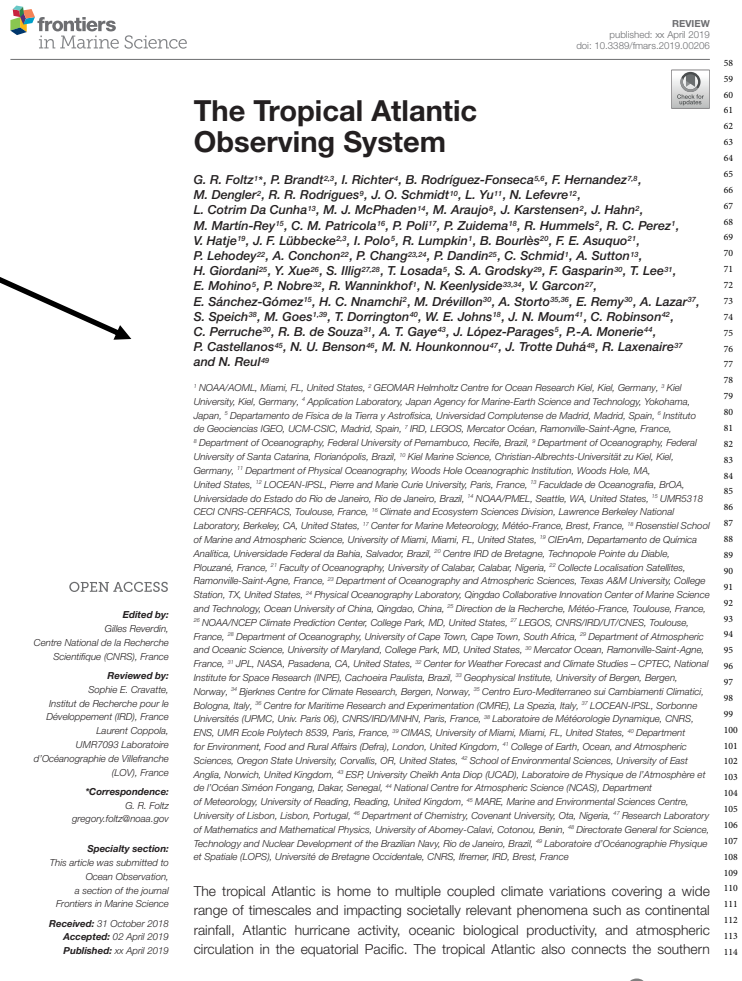
- Identify potential **enhancement or reconfiguration of the sustained observing system** suite to address gaps and new requirements
- Evaluate requirements for **delivery of data, and derived products and information,** in real time and delayed mode
- Assess **readiness of new technologies**, their potential impact and feasibility in addressing requirements, and their potential to contribute towards addressing gaps, improving robustness/resilience, and/or lowering costs per observation
- Highlight the **impacts of TAOS on the delivery of information/services** of societal importance and relevance

Anticipated deliverables

- **A white paper for OO19** documenting the actual state of TAOS and requirements expressed by the TA community (Foltz et al., in press).

- **A Review Report** to provide the scientific guidelines on TAOS future development, setting priorities as well as mindful resource trade-offs.

- **Articles to highlight the major outcomes of the review** could be prepared for Eos, Bulletin of the American Meteorological Society, CLIVAR Exchanges, and/or US CLIVAR Variations, etc.



frontiers in Marine Science

REVIEW
published: xx April 2019
doi: 10.3389/fmars.2019.00206

The Tropical Atlantic Observing System

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Specialty section:
This article was submitted to Ocean Observation, a section of the journal Frontiers in Marine Science

Received: *31 October 2018*
Accepted: *02 April 2019*
Published: *xx April 2019*

The tropical Atlantic is home to multiple coupled climate variations covering a wide range of timescales and impacting societally relevant phenomena such as continental rainfall, Atlantic hurricane activity, oceanic biological productivity, and atmospheric circulation in the equatorial Pacific. The tropical Atlantic also connects the southern

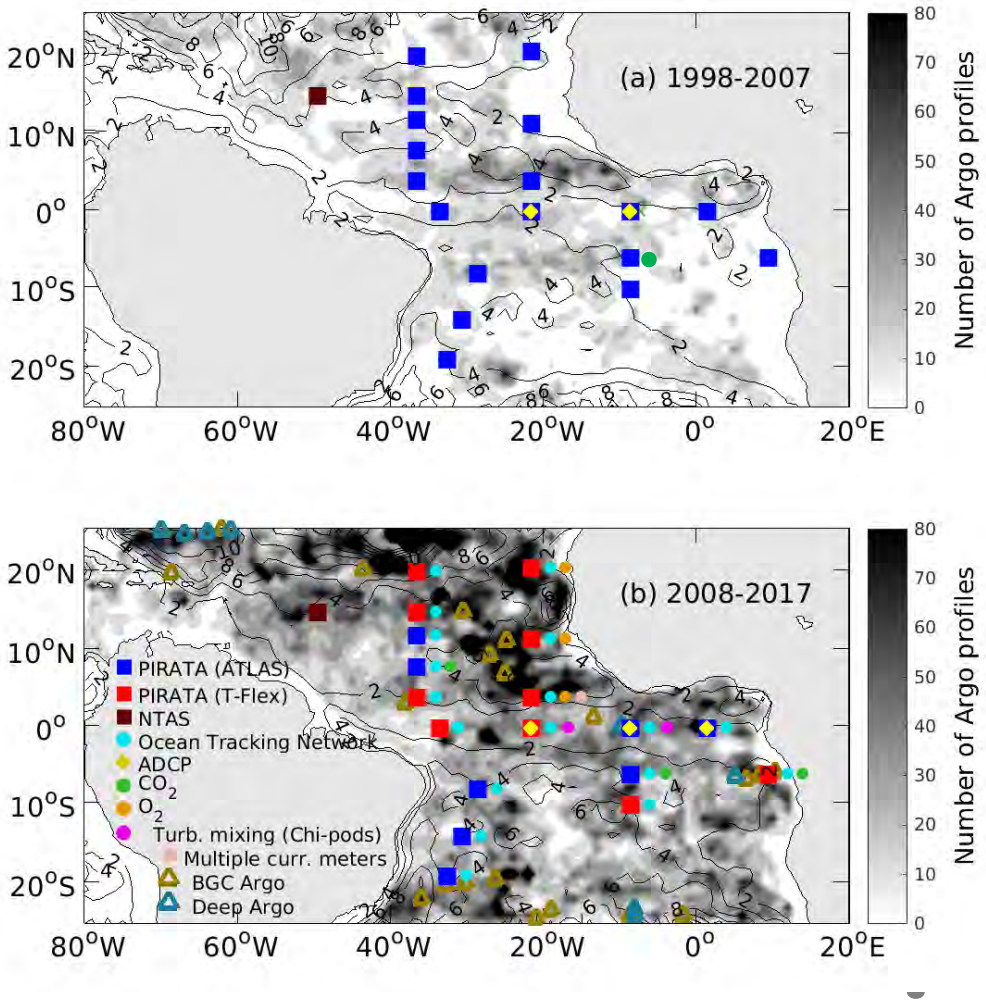
TAOS Review Timeline

- **Feb 2018** Kick-off, 1st TAOS Review workshop, Portland, OR
- **Oct 2018** TAOS CWP for OO19 submitted to Frontiers
- **Oct 2018** 2nd TAOS Review Workshop, Marseille, France

- **May 2019** Complete draft report
- **Jun 2019** Send out for "expert" review and agency comments
- **Aug 2019** Deliver final report to CLIVAR ARP

Evolution of TAOS

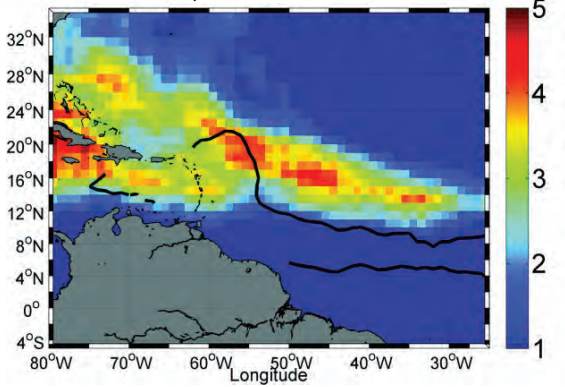
- Significant progress over 20 years, but gaps remain.



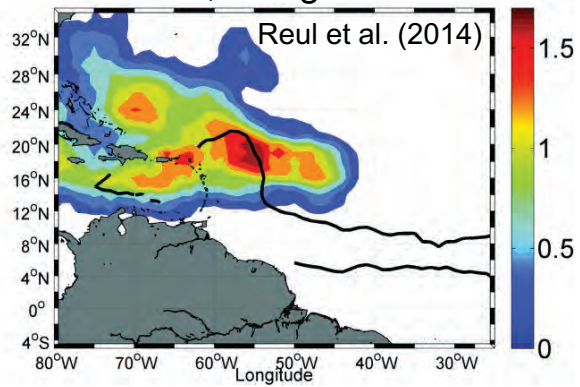
Hurricanes

- Ocean observations are sparse in the western Atl., a region with strong salinity stratification and eddies.

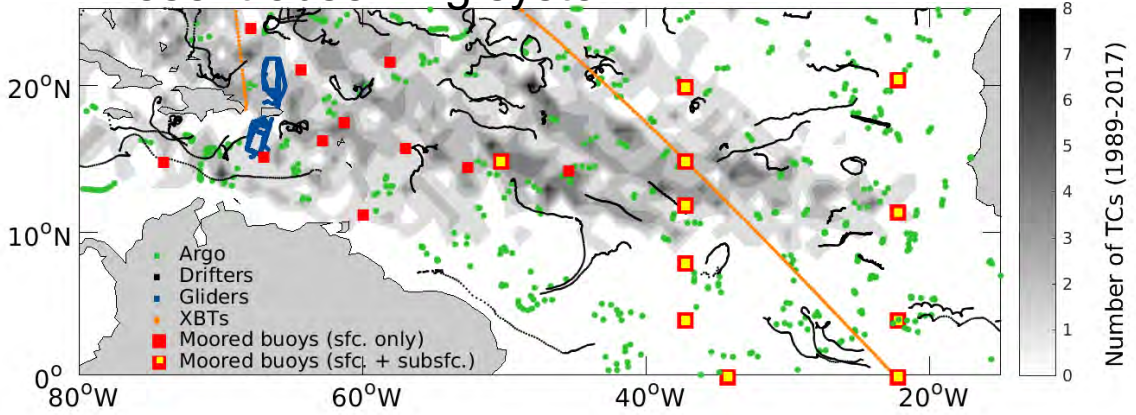
Number of TCs that strengthen to Cat. 4, 5 somewhere



Number of TCs that strengthen to Cat. 4, 5 at given location

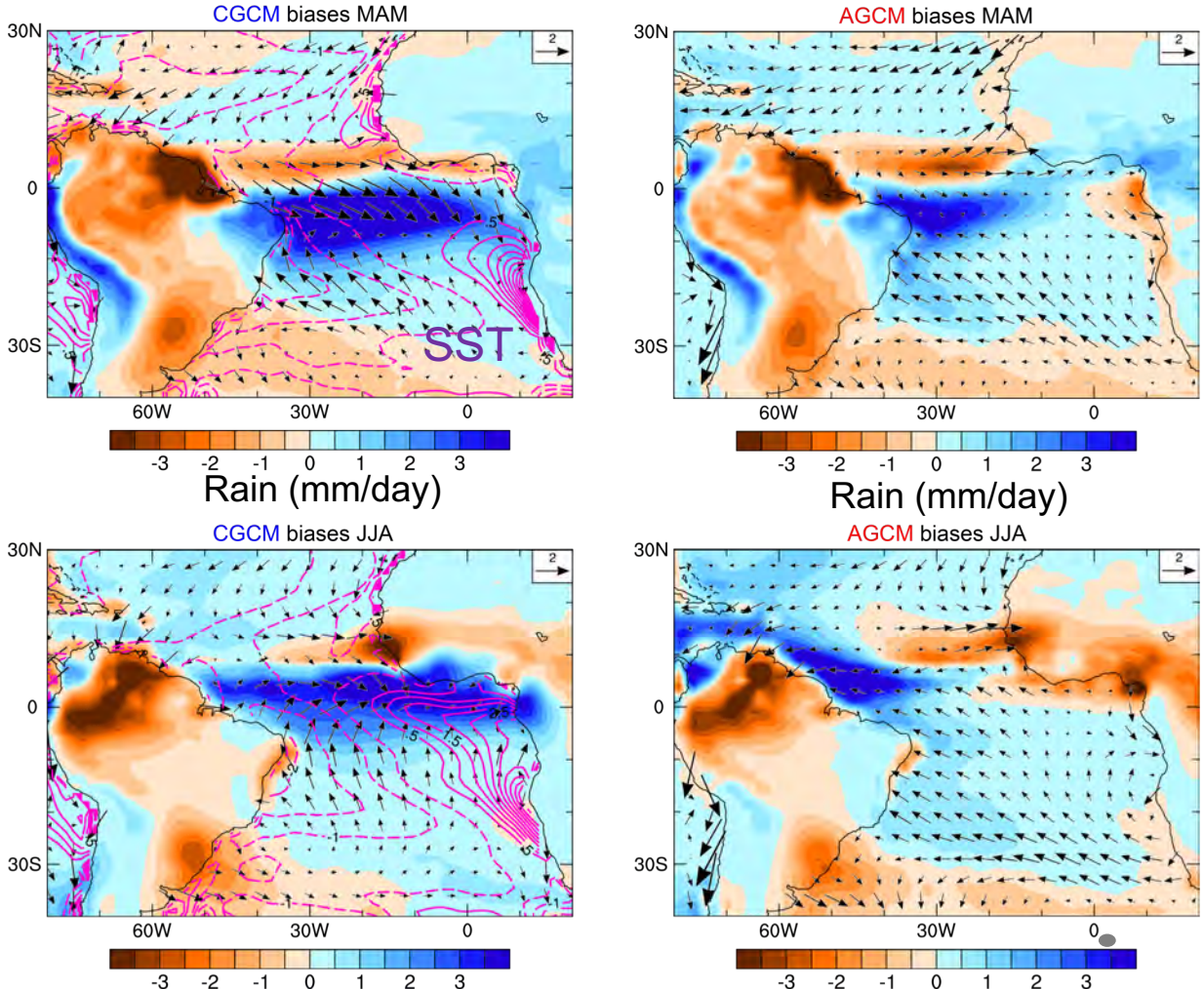


Present observing system



Coupled model biases

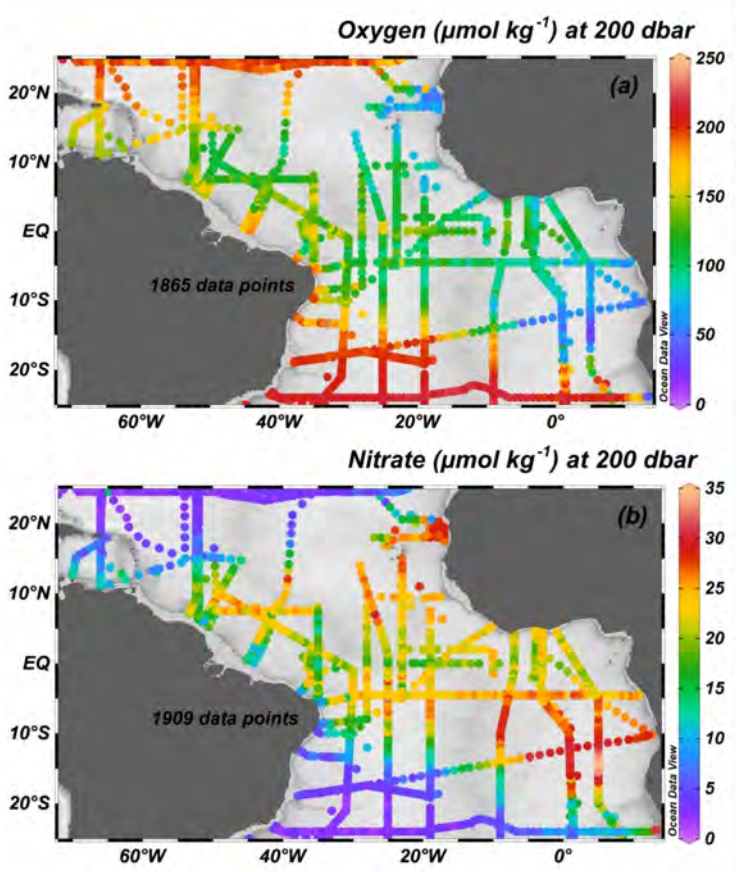
- Obs. system must evolve to address biases (ocean and atmosphere).



BGC and fisheries

- Severely undersampled.
- Need to integrate fisheries surveys into larger obs. system that considers needs of society, private sector, science.

Number of historical measurements



Quantifying observing system needs

- Ocean and coupled models and assimilating techniques are diverse and not able to produce robust OSSE assessments. There should be more work to improve the reliability of OSSEs, including more dialogue between the observing and modelling communities.

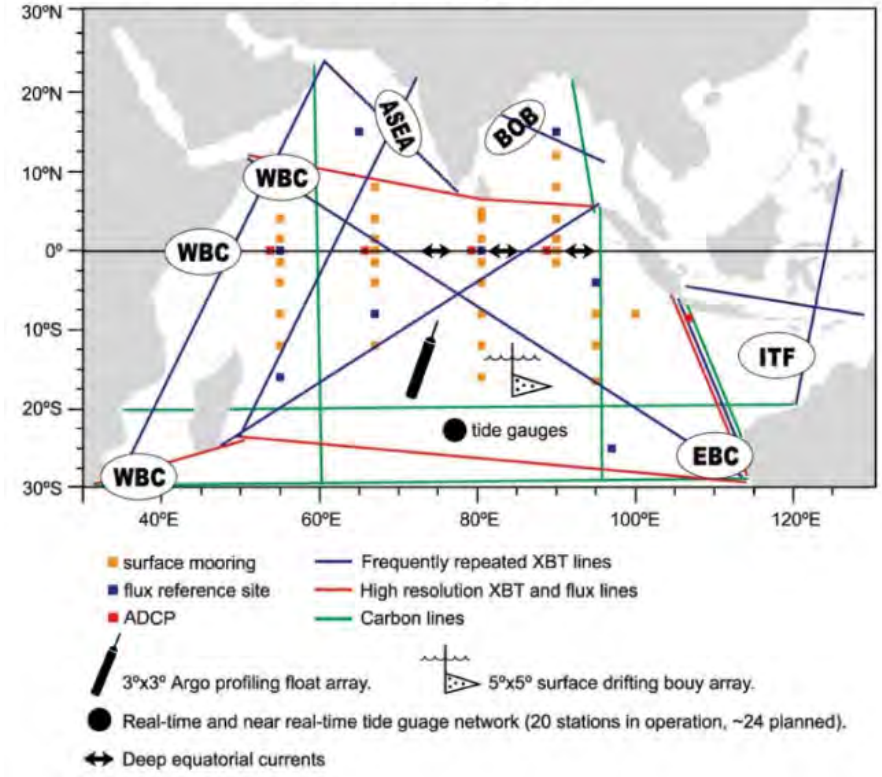
CLIVAR IORP: IndOOS Decadal Review — Sponsors

1. IndOOS Decadal Review: Processes & Timeline

Dates	Event
31 Jan – 2 Feb 2017	**1st IndOOS Review Workshop (Perth, Australia)** ToRs, scope, outline
Feb – Mar 2017	Formulation of writing team, guidelines, timeline
Jun 2017	Formulation of IndOOS Review Board
Apr – Sep 2017	First draft of 25 IndOOS Review chapters
Oct – Nov 2017	Cross-chapter review by lead authors, IORP, and SIBER
Dec 2017	First draft of Executive Summary
Jan – Mar 2018	Reviews of first draft from Review Board and broader community
22 – 23 Mar 2018	**2nd IndOOS Review Workshop (Jakarta, Indonesia)** Chapter presentations and discussion, reviews, formulation of rubric for prioritization
Aug 2018	Comments and reviews collated and sent to lead authors with guidelines for final chapter revision (Editors: Lisa, Jerome, and Roxy)
Aug – Nov 2018	Second draft of 25 IndOOS Review chapters
Nov 2018 – Feb 2019	Editing of all chapters, prioritization of Actionable Recommendations, Second draft of Executive Summary, first draft of Introduction and Synthesis
Feb – Apr 2019	Final reviews and comments on complete second draft
14 – 15 Mar 2019	**Final IndOOS Review Workshop (Port Elizabeth, South Africa)** Outcomes and implementation
Aug 2019	Final version disseminated

The 1st IndOOS Science Plan, 2006

Indian Ocean Integrated Observation Systems

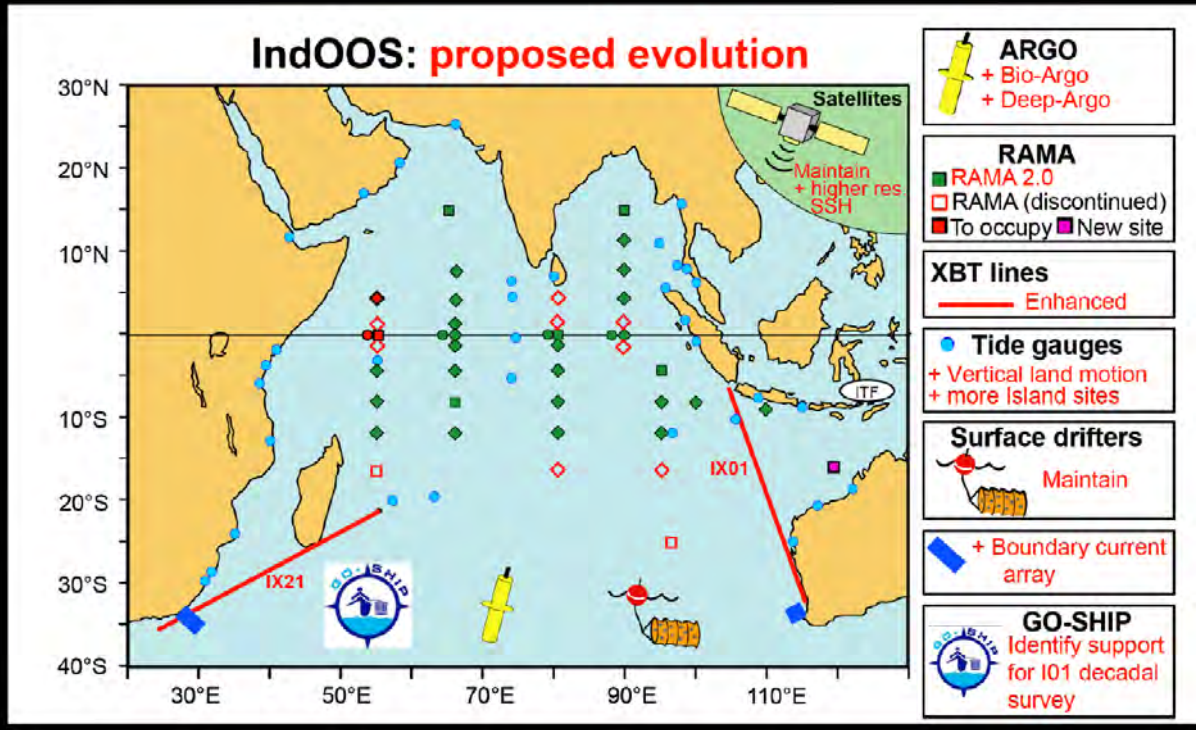


Since then, the societal and scientific priorities and measurement technologies have evolved, and practicalities of implementation have been learned

2. Current & future planned IndOOS maps

Prioritized actionable recommendations

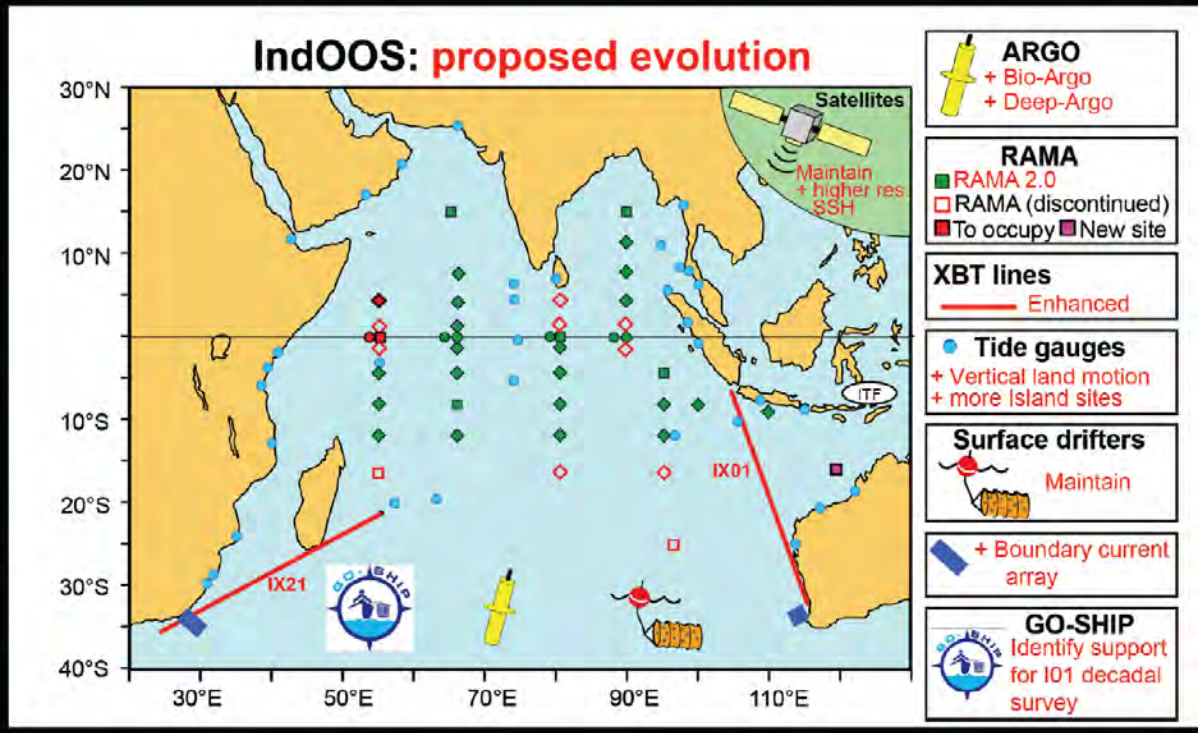
- **Argo**: Maintain the core 3° x 3° array, add 200 BGC-Argo floats, develop a Deep-Argo program.
- **RAMA**: Consolidate to RAMA-2.0 (13 less sites), increase resolution of upper-ocean measurements and add BGC measurements to flux reference sites, add new site off NW Australia. (46-33)
- **XBT**: Maintain IX01 (ITF) and IX21 (pCO2) lines. Install auto-launchers and increase near-coastal resolution on IX01.
- **Tide gauges**: Add colocated measurements of land motion, add sites in SW Indian Ocean and on islands.



2. Current & future planned IndOOS maps

Prioritized actionable recommendations

- **Surface drifters**: Maintain core 5° x 5° array, evaluate addition of barometric pressure.
- **Boundary current arrays**: Add measurements of mass, heat, and freshwater fluxes of the Agulhas and Leeuwin Currents, including hydrographic end-point moorings to capture basin-scale overturning.
- **GO-SHIP**: Find national commitment for section I01, add measurements of phytoplankton community structure.
- **Satellites**: Maintain overlapping, inter-calibrated missions, enhance spatial resolution of SSH.



CLIVAR IMBeR GOOS•GOOS•WCRP OOPC WCRP World Climate Research Programme IOGOOS United Nations Educational, Scientific and Cultural Organization Intergovernmental Oceanographic Commission NOAA IUGG IAPSO International Association for the Physical Sciences of the Oceans

3. Implementation challenges & timeline

Multi-national & multi-program coordination & interaction;
Some coastal systems within EEZ

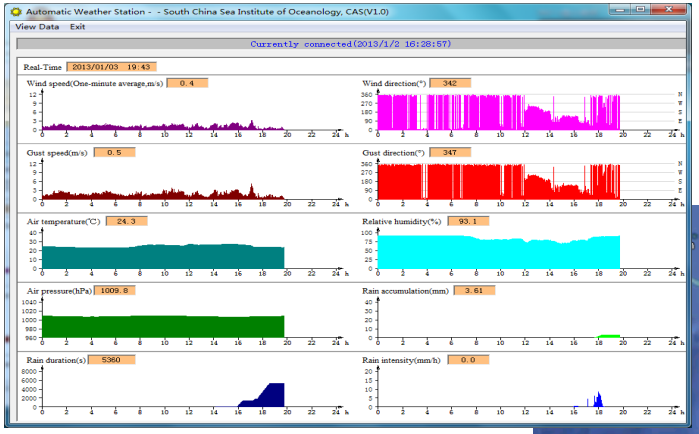
RAMA: 13 reduced sites due to current implementation challenges (new sites: specific implementation plan was proposed)

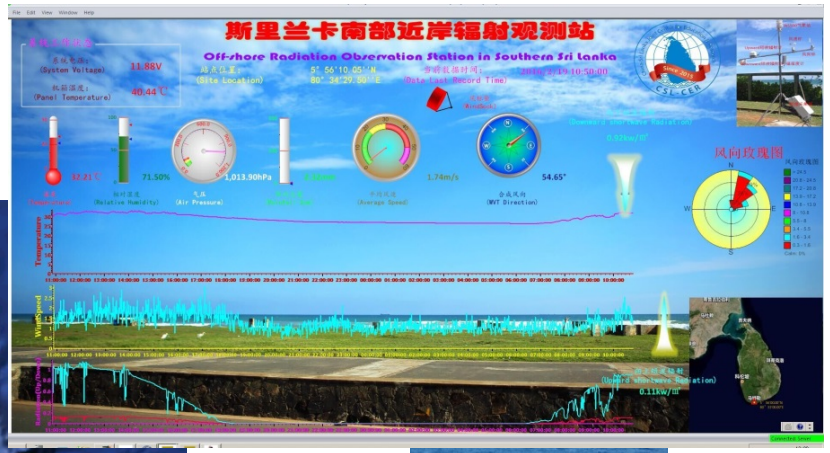
ARGO: 200 BGC Argo – part of global BGC-Argo Program (>1000 BGC Argo) Implementation plan (Johnson and Claustre, 2016).

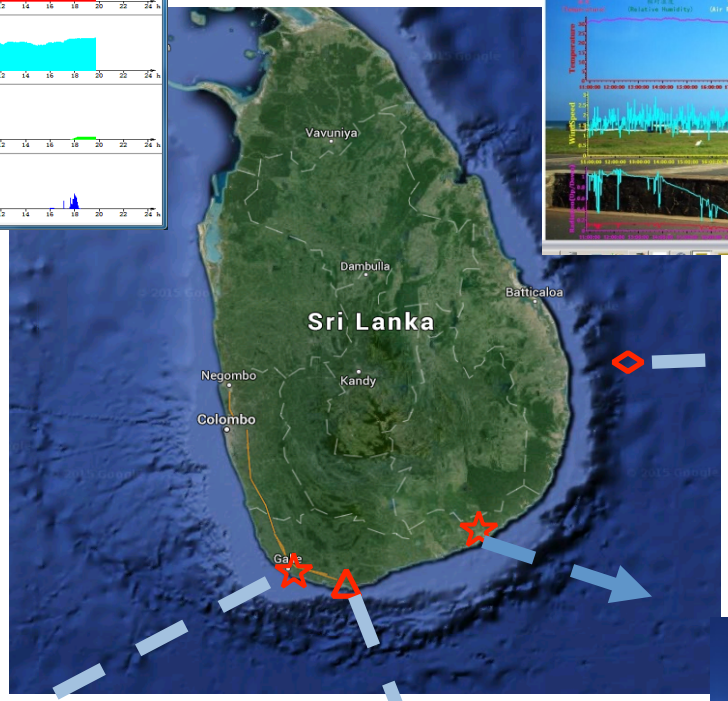
RAMA cruises provide opportunities for Argo deployments, a synergetic interaction in the implementation of these two IndOOS programs.

Timeline

D. Wang: China activities: Marine Environmental Observation Network

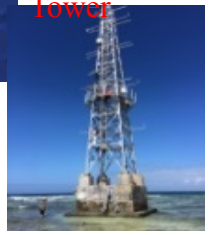






Air-Sea Flux Tower

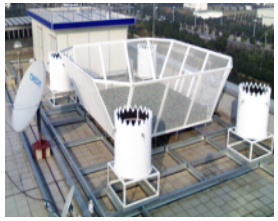
Surface Data Buoy



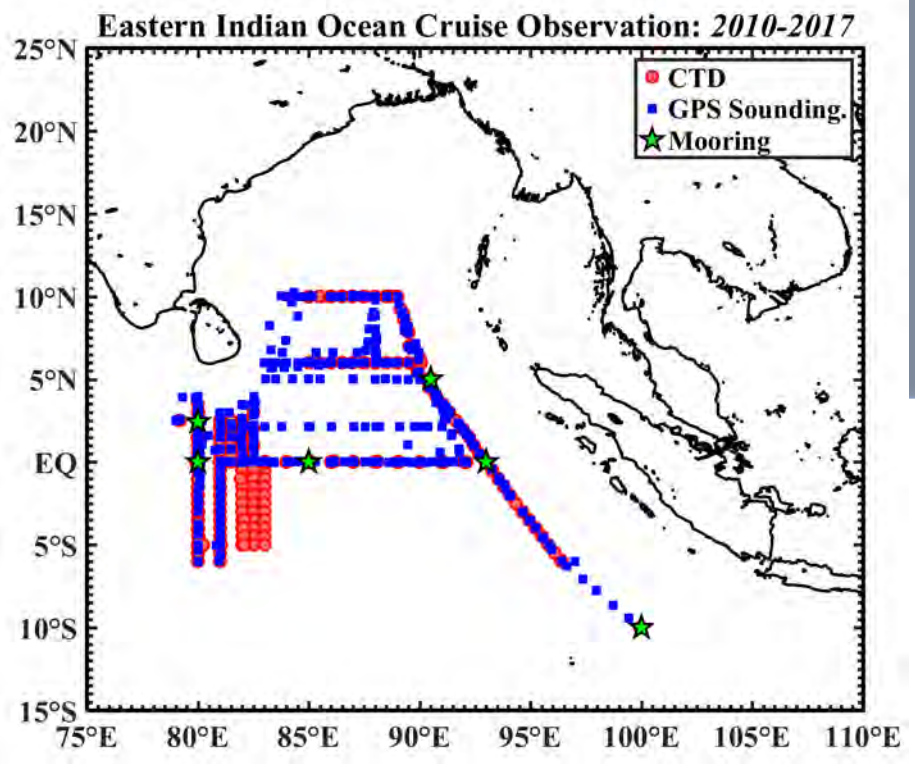
Air-Sea Flux Tower

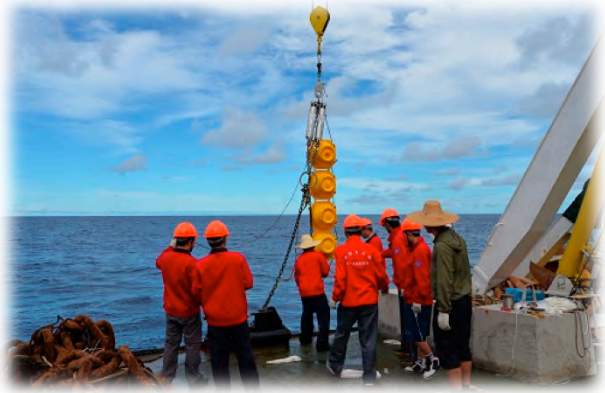
Air sampler

Wind Profiler Radar



D. Wang: East Indian Ocean Research Cruise (2010 - 2019)





Year	Mileage(NM)	Duration(day)
2010	7900	48
2011	7710	65
2012	9000	59
2013	10470	65
2014	9916	61
2015	8920	51
2016	10070	70
2017	9884	55
2018	11300	61
合计	85170	535

TPOS 2020 update

Meghan Cronin (NOAA PMEL)

Co-chair TPOS 2020 Planetary Boundary Layer Task Team

Contributing author to First and Second TPOS 2020 Reports

Science Steering Committee Meetings

2018 Backbone Task Team Face-to-Face Meeting

Others involved in TPOS2020 who are here: **Tom Farrar, Yolande Serra, Carol Anne Clayson,…**

tpos2020.org

TPOS 2020 Tropical Pacific Observing System

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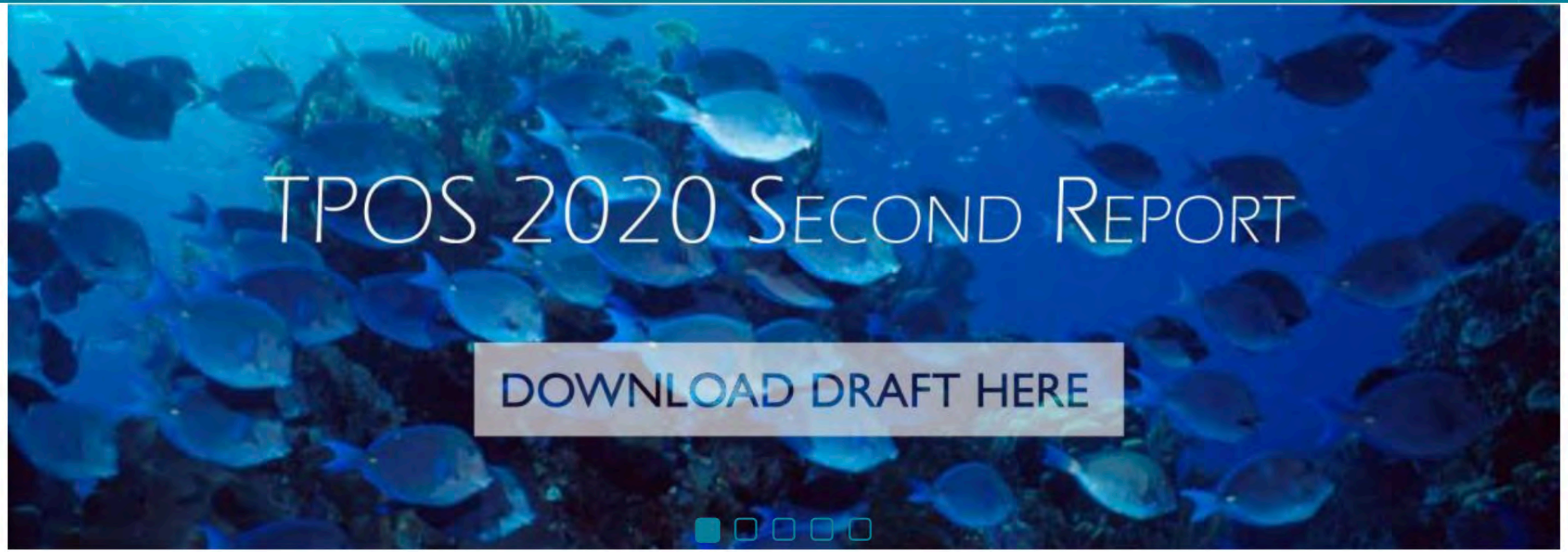


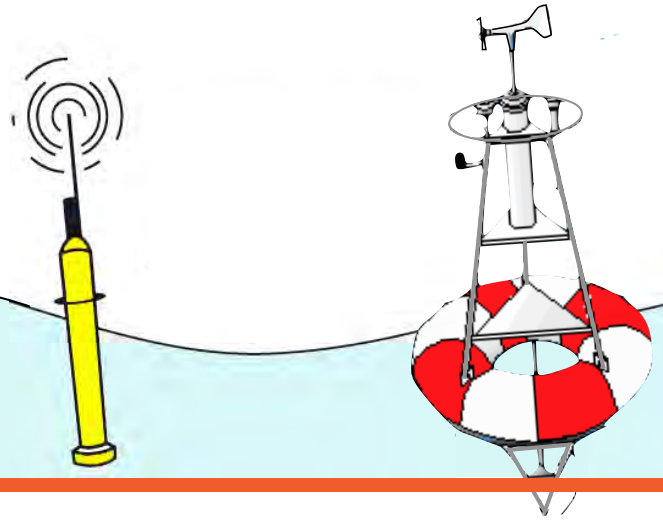
An integrated vision

Complementary "backbone" technologies:

- Satellites give global coverage, horizontal detail
- Moorings sample across timescales, allow co-located ocean-atmosphere observations, velocity sampling
- Argo resolves fine vertical structure, adds salinity, maps subsurface T and S, connects to subtropics

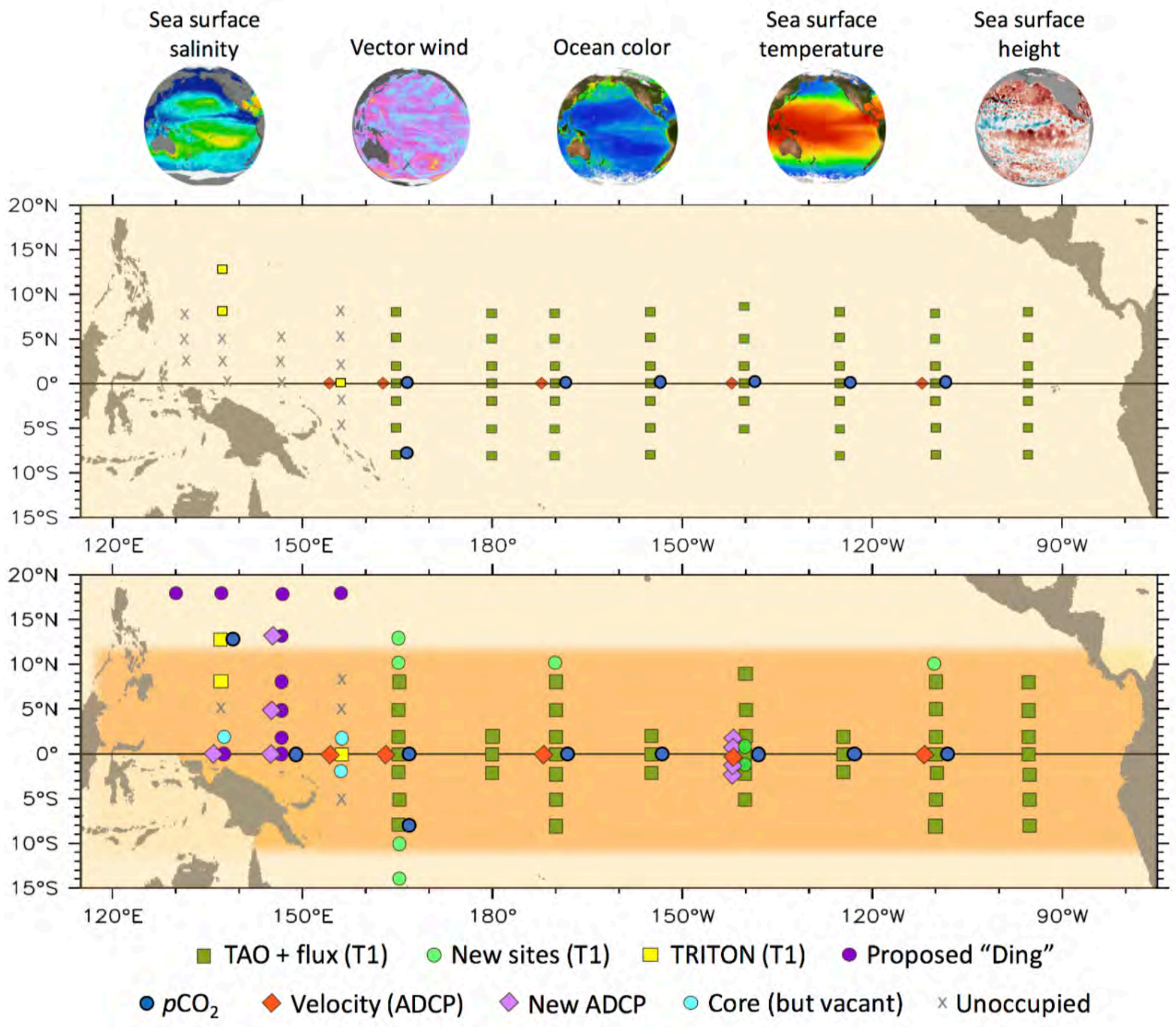
Assimilating models integrate diverse observations

TPOS data reaches our stakeholders primarily as the output of an assimilation



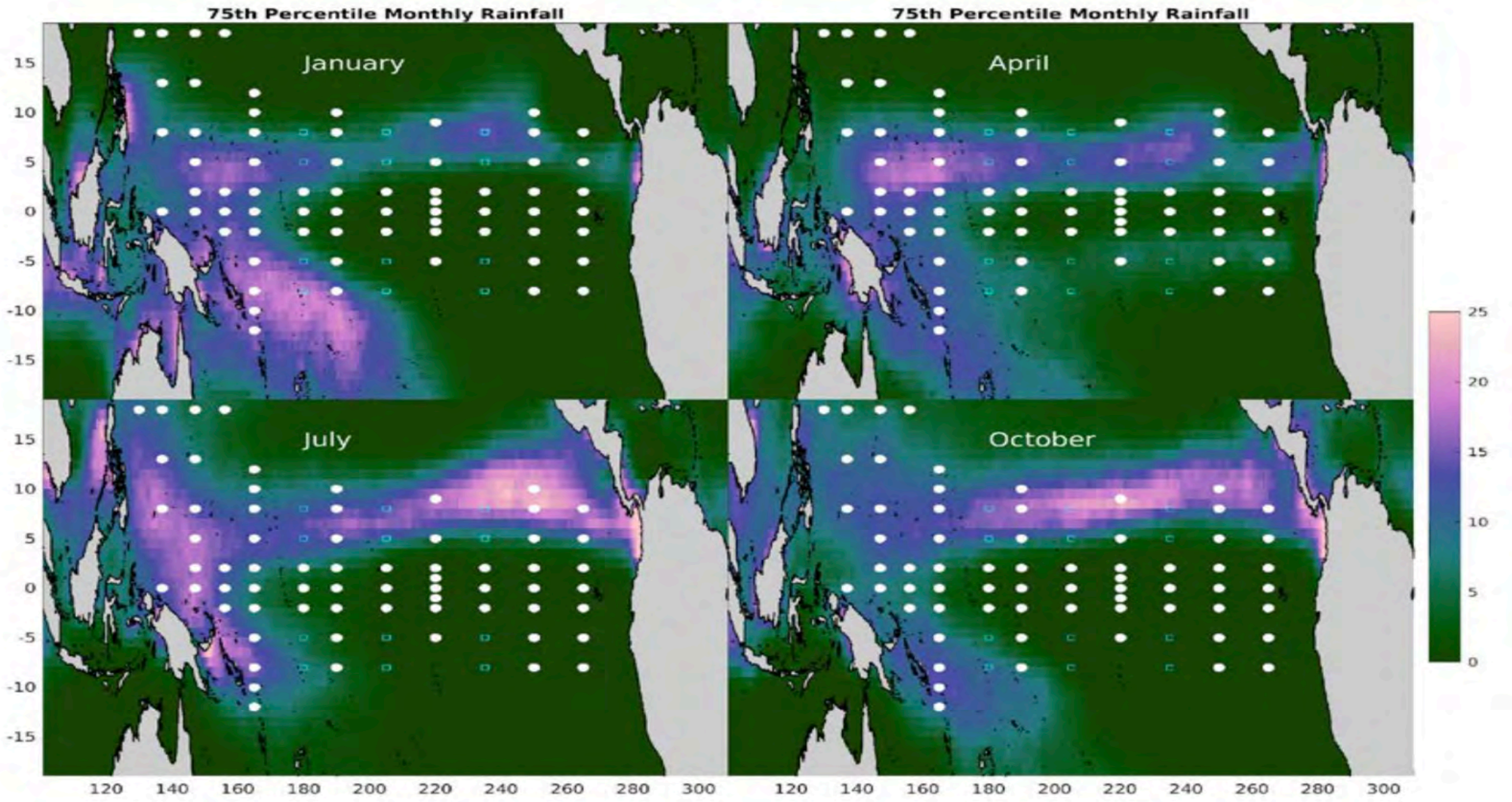
Present Tropical Moored Array (TMA)

Proposed TPOS TMA high priority sites and double Argo region (dark orange)



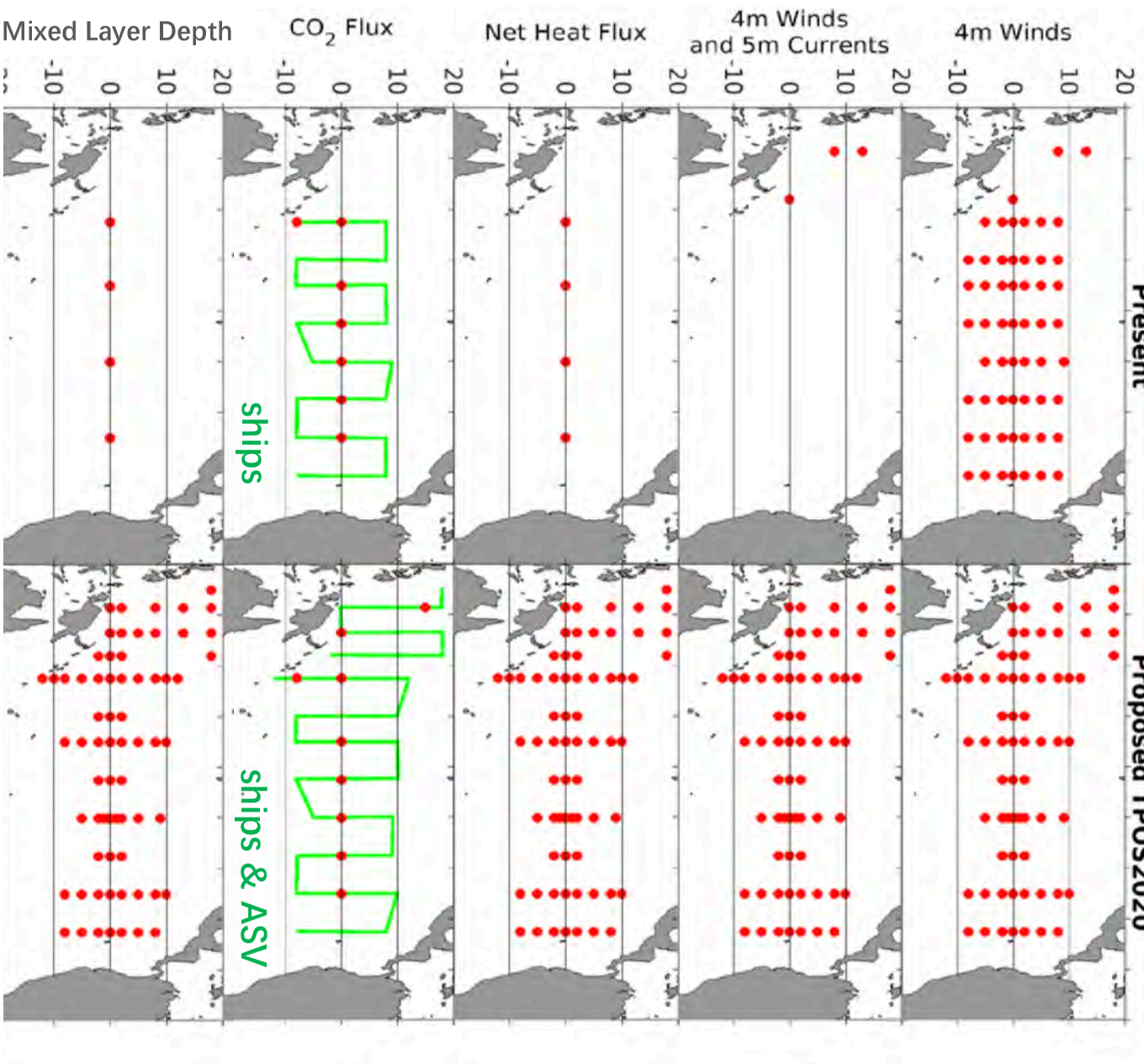
Better support the satellite products

---- better coverage for high rain regions



What are the differences?

--Better air-sea interaction



What are the differences?

--Better air-sea interaction

How will it be done?

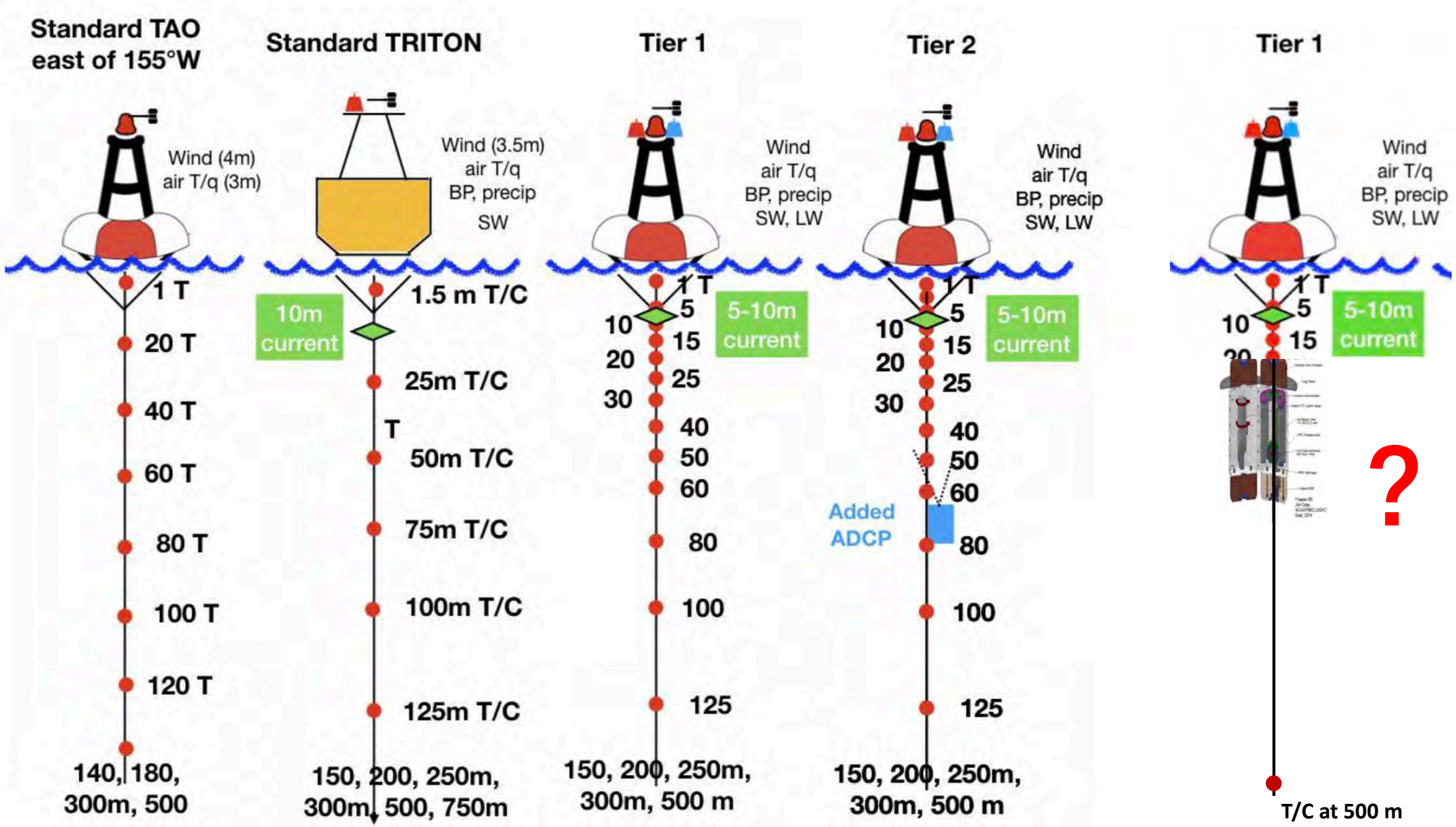
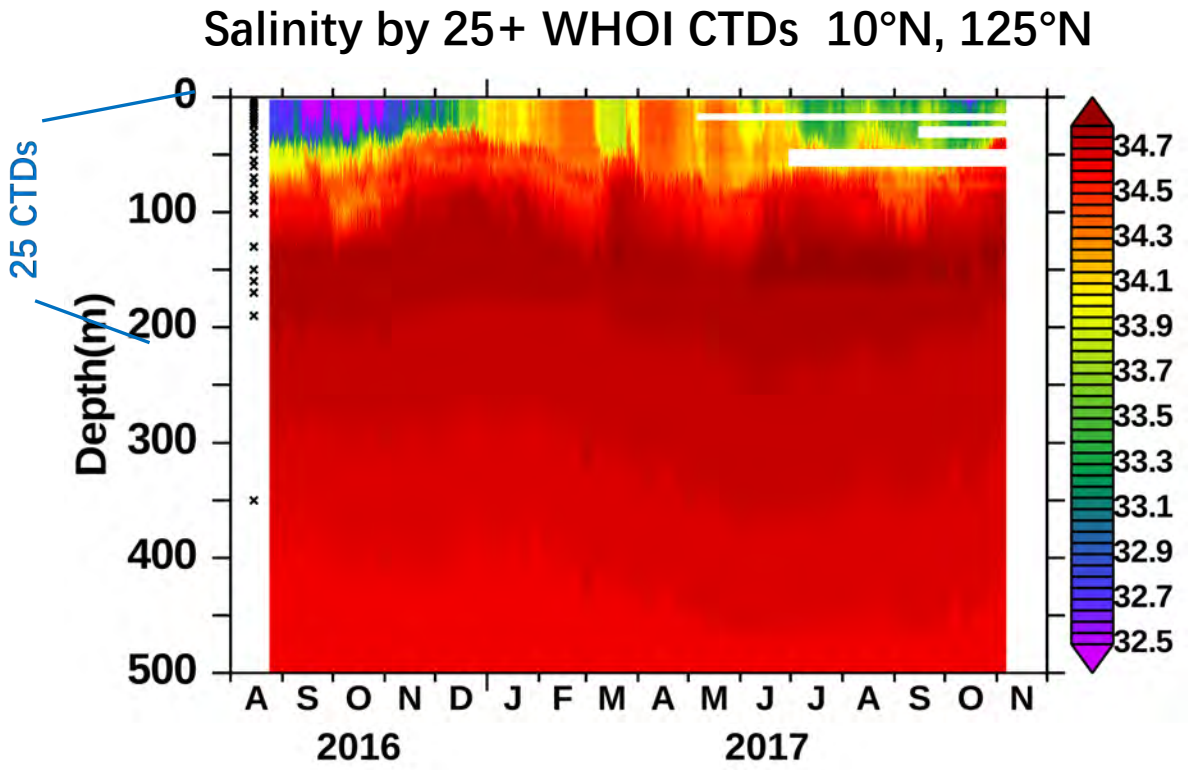
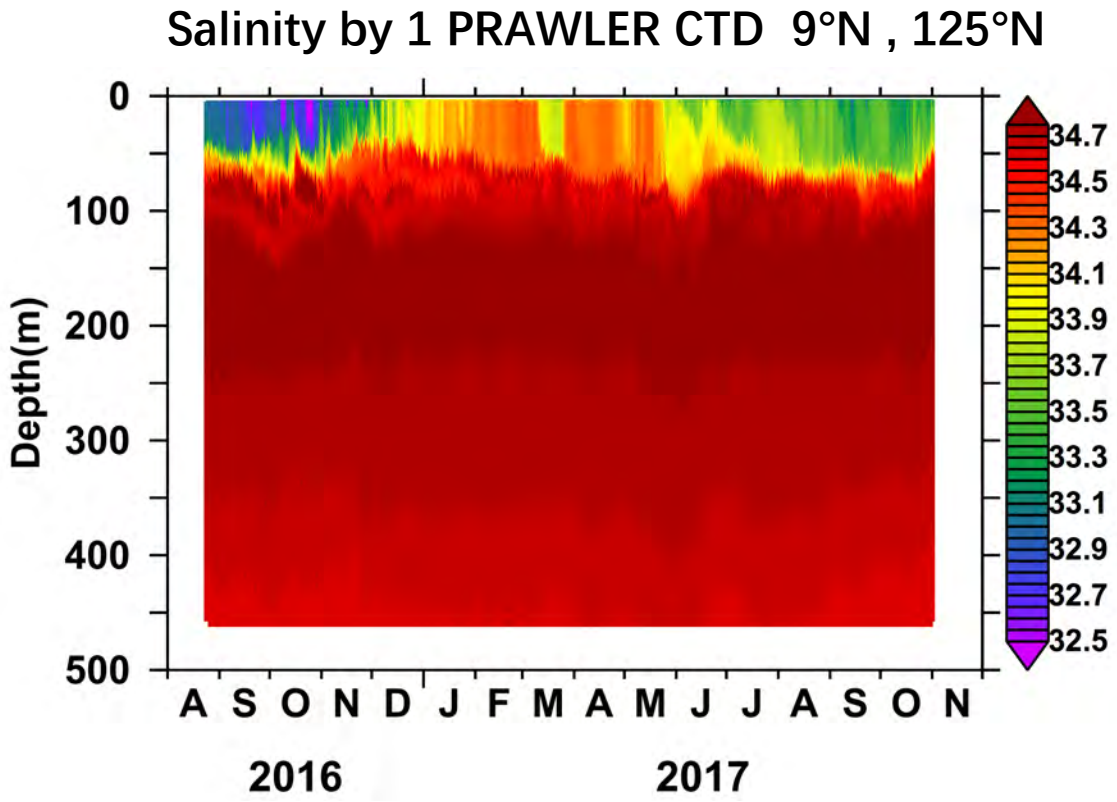


Figure 7.3: Schematics comparing the instrumentation of the current TAO and TRITON moorings- on the left, with those of the new enhanced TMA Tier 1 and Tier 2 - on the right. In the subsurface red dots and black text indicate the depths of temperature and salinity measurements, and green diamonds velocity measurements. Tier 2 moorings will have an upward looking current profiler (blue rectangle). Above the surface, parameters are noted as: Wind = wind speed, air T/q = air temperature and specific humidity, BP = barometric pressure, precip = rainfall, downwelling SW and LW = shortwave and longwave radiation respectively.

PMEL PRAWLER 14-month High Quality Measurements During SPURS-2





- High temporal resolution, every 5 minutes
- Available commercially
- **Lower Risk (failure → data gap at single depth), higher cost**

- Near-realtime telemetry, 2-way communication
- High vertical resolution; Settable 8-24 profiles/day, 20-30 minutes/profile (limited by battery: 8 profiles/day lasts ~ 14+ months)
- Available commercially
- **Higher risk (failure → loss of profile), lower cost**

NOAA OOMD funded 4 pilot studies of emerging technologies that may eventually be used in TPOS.

Saildrone TPOS pilot study will have another mission to the equator summer of 2019.