The TPOS 2020 project

(T.P.O.S. is the observing system, TPOS 2020 the project)

The Tropical Pacific Observing System 2020 (TPOS 2020) is an international project to rethink the T.P.O.S., which was designed in the 1980s, based on 1980s science issues, and largely on techniques from that era.

We now have new tools and new issues ...

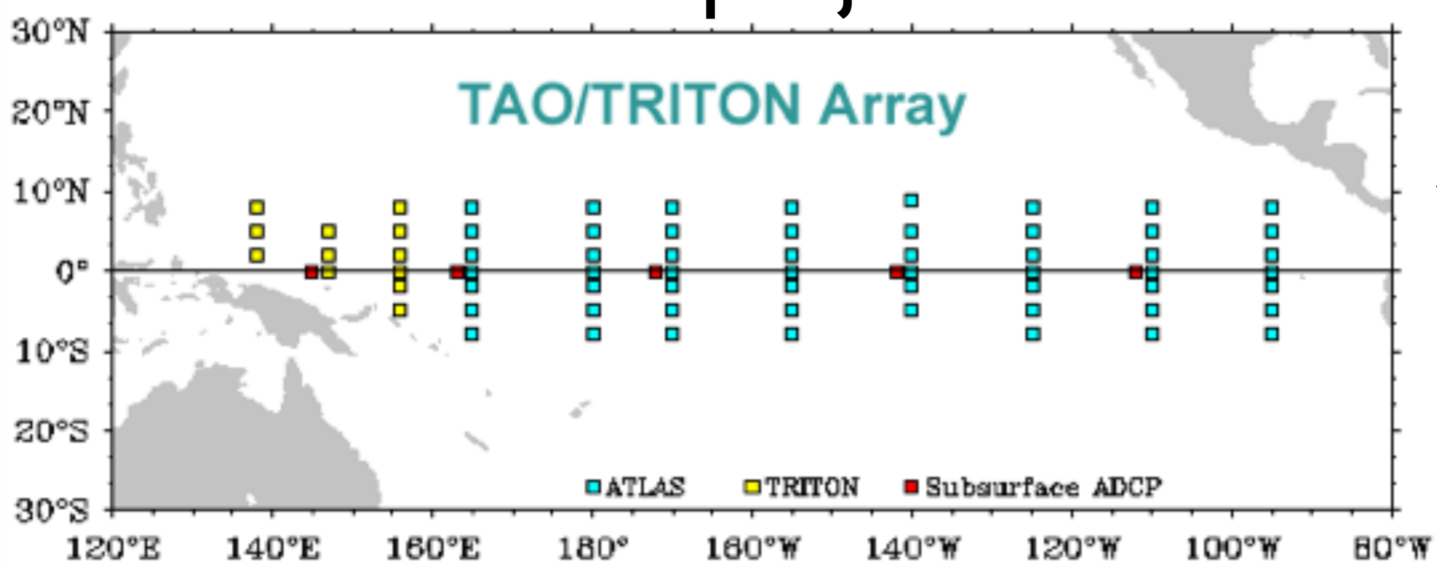
TPOS 2020 was defined by an international workshop in January 2014

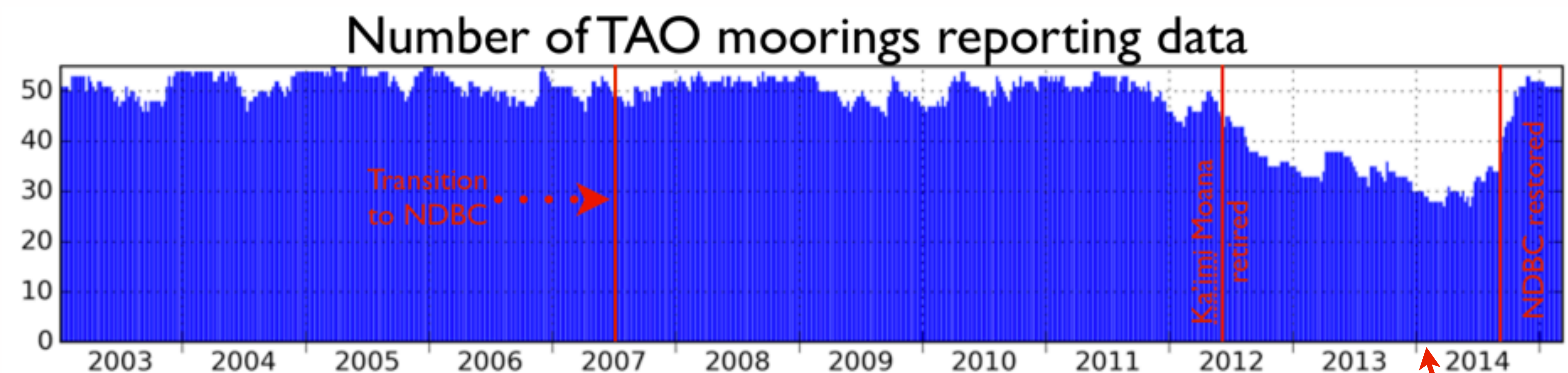
TPOS 2020 Tropical Pacific Observing System

Making an opportunity from a crisis:

Can we build a more effective, modern, robust system?

The TPOS 2020 project arose from the 2012-14 crisis of TAO, and JAMSTEC's eventual withdrawal from TRITON, but the time is ripe to reexamine the whole system.



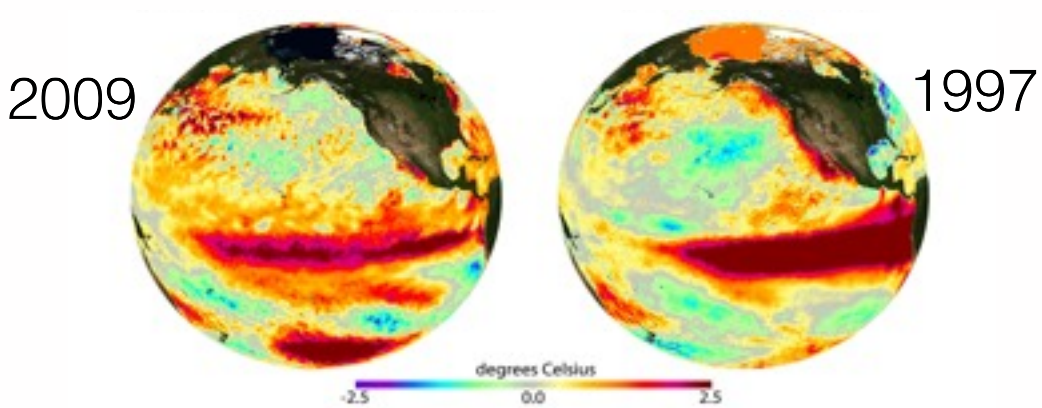


NOAA / JAMSTEC workshop, January 2014

ENSO drove the original TPOS

- El Niño of 1982-83
  – and the failure to recognize it until very late –
  was the impetus for the TOGA observing system.
- Original TAO designed to detect equatorial waves, then the key issue for ENSO diagnosis and prediction.
- Now, those issues are well understood, and we face a different set of scientific challenges. The observing and forecast systems must adapt to today's issues.

The lesson of the past 3 decades is ENSO diversity, the ongoing succession of surprises in these events. The potential for future surprises is high.



Our foremost goal remains to improve ENSO understanding and predictability.

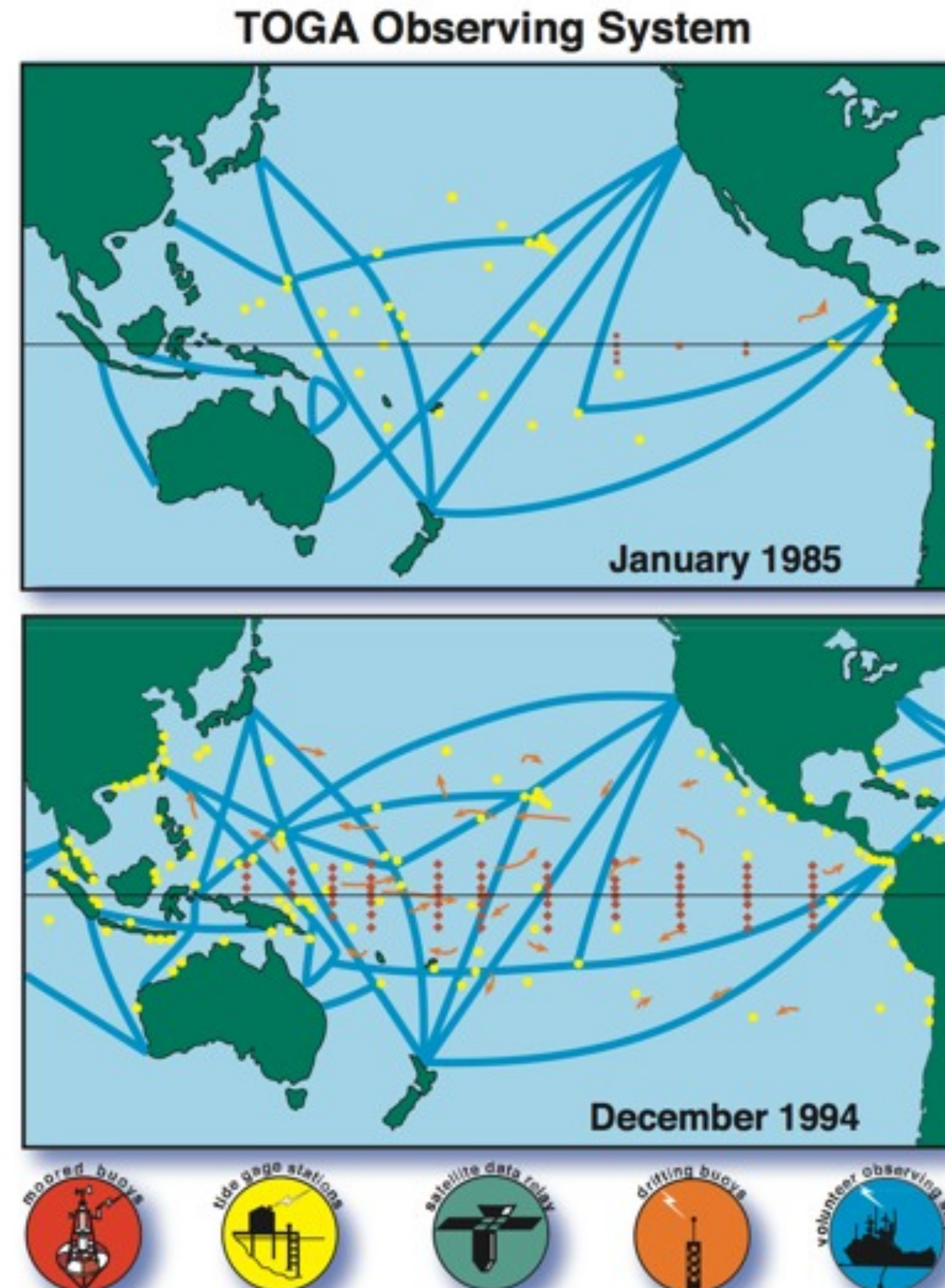
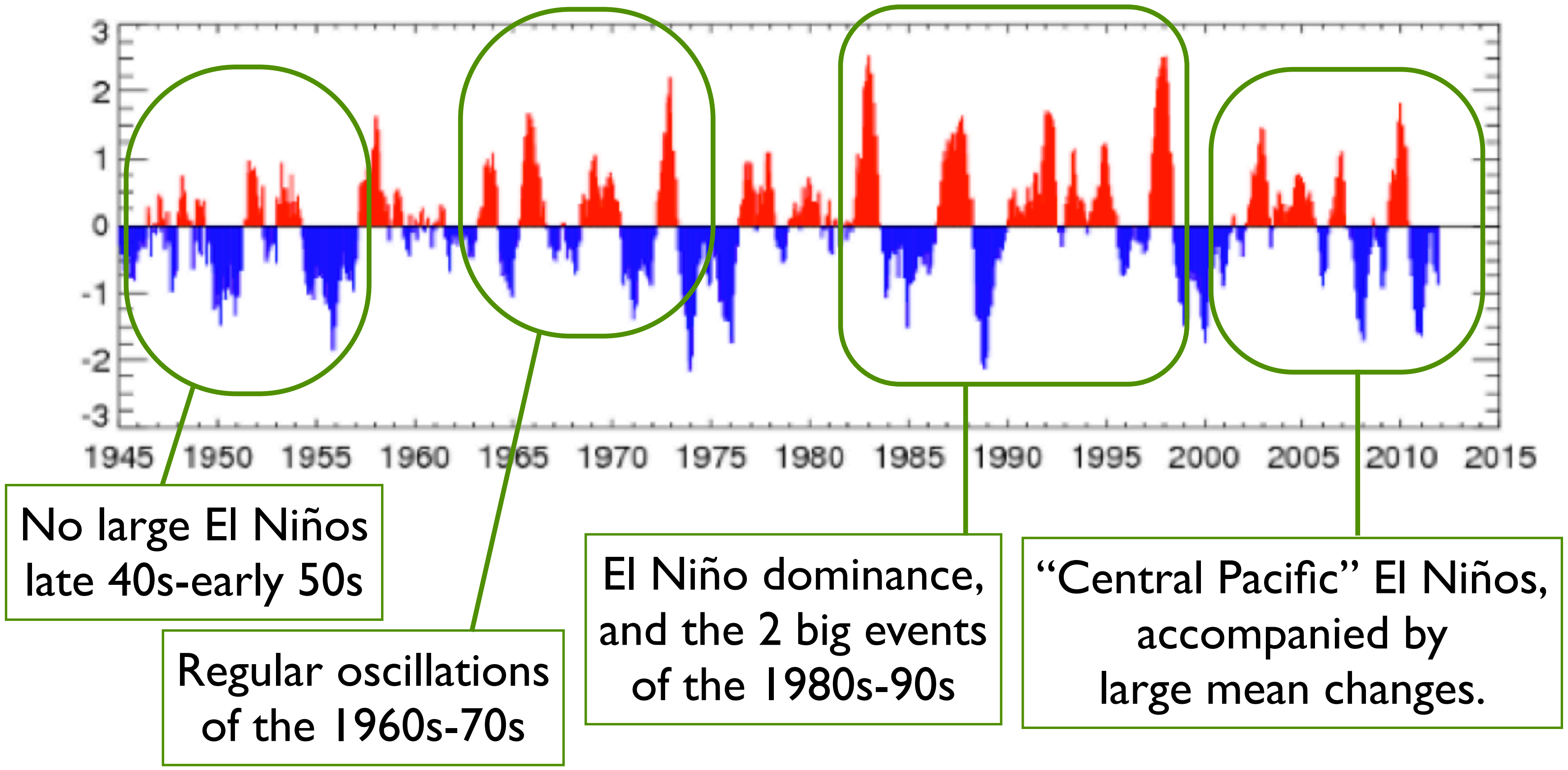


Figure 2. In situ components of the Tropical Ocean Global Atmosphere (TOGA) observing system at (top) the start of TOGA in January 1985 and (bottom) the end of TOGA in December 1994. Color coding indicates the moorings (red symbols), drifting buoys (orange arrows, one for approximately every 10 drifters), ship-of-opportunity lines (blue), and tide gauges (yellow). *After McPhaden et al., 1998*

ENSO is irregular ... and full of surprises

Niño 3.4 (Central Pacific) SST (red = El Niño)



- The overall story is diversity and surprises. Expect more ...
- These event changes have been accompanied by changes to the background (e.g., trade wind increase since 1998).

The lessons we take from this are:

Build a resilient T.P.O.S.

Do not focus only on the challenges/issues of today; tomorrow's will be different:
Looking back from 2030, what will we wish we had started sampling in 2016?

Describe the physical processes that drive the tropical climate.

Integrate this understanding into models.

Maintain and build long time series:

High-quality data, detect weak trends
(Three examples ....)

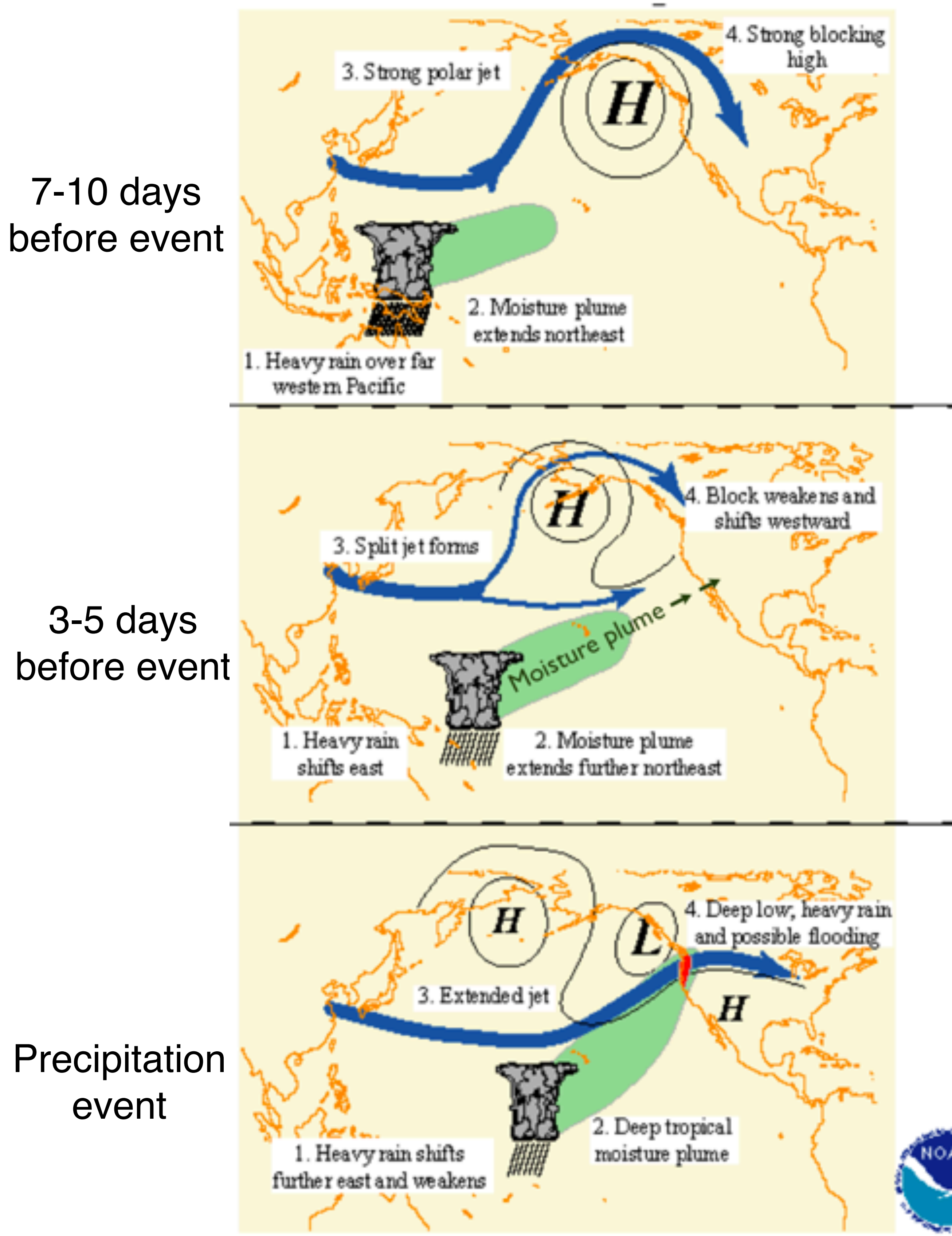
It's not just El Niño ...

Because the atmosphere is so sensitive to changes tropical heating, many kinds of tropical disturbances radiate to North America.

An example is the MJO, that powers heavy rain events on the west coast ("Pineapple Express").

Radiating phenomena like this are common to all the tropical oceans.

Typical winter tropical Pacific anomalies preceding heavy West Coast precipitation events



Climate Prediction Center/NCEP/NWS

TPOS 2020 Tropical Pacific Observing System

TPOS 2020 Goals

- To redesign and refine the T.P.O.S. to observe ENSO and advance understanding of its causes,
- To determine the most efficient and effective observational solutions to support prediction systems for ocean, weather and climate services,
- To advance understanding of tropical Pacific physical and biogeochemical variability and predictability.

TPOS 2020 will provide evidence-based, vetted advice pointing to an intelligent evolution of the observing system.

Evolution is essential ...
for both practical and scientific reasons:

- The ENSO observing system was designed in the 1980s-90s:
  - based largely on technology from that era,
  - and also on the scientific challenges of that era,
  - it is an ad hoc collection of pieces.
- The crisis of TAO in 2012-14 showed the risk to this system that underpins our seasonal forecasting and tropical research.
- We are now in a position to improve the system by taking full advantage of present tech (Argo, robotics, satellites), and recent scientific understanding, in a thought-through system.

As with TAO, we will live with what we design for many years, so we will move slowly and carefully (no crisis now).

TPOS 2020 organization

TPOS 2020 is an international project under GOOS,
but in fact is effectively appointed by the 2014 workshop.

Steering Committee:

15 members from 6 nations (5 U.S., 2 NOAA)
Co-chairs: Billy Kessler (NOAA) and Neville Smith (BOM, Australia)

Task Teams:

- Planetary Boundary Layers
- Models and data assimilation
- Biogeochemistry
- Eastern Pacific

} Recommendations due early 2016, to feed the design of the Backbone

- Backbone ⟶ Plan due July 2016

Strawmen ideas being developed by TTs, done by late summer.

Our first customers are the operational centers
but we will design an array to serve both research and operations

Although TPOS 2020 is mostly about observations,
we consider the role of observations in the entire system:

Observations • Analyses • Forecasts

Current-generation assimilation/forecast systems do not make effective-enough use of observations. Thus we aim to:

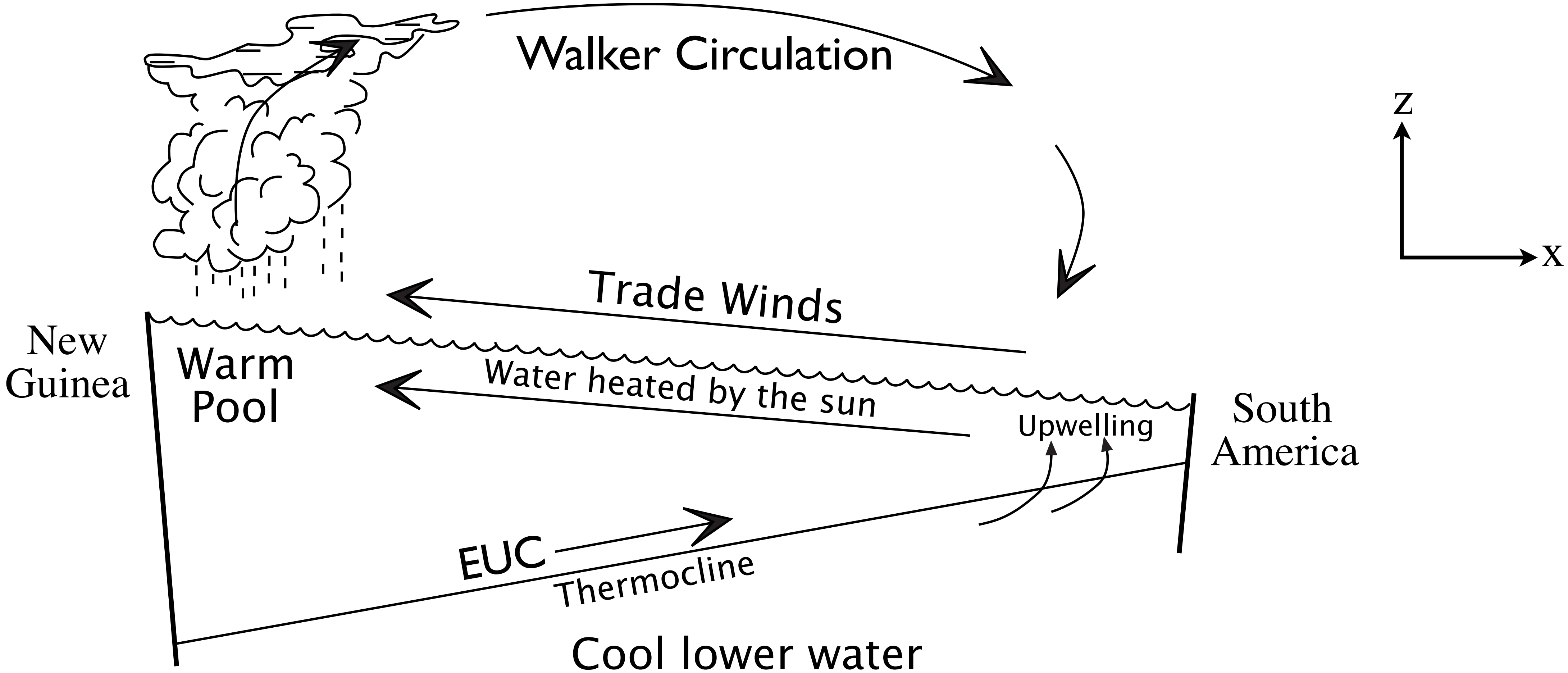
→ Target sampling where the models and data assimilation systems need guidance for improvements,

→ Improve knowledge and model representation of unresolved processes,

→ Evolve the T.P.O.S. in concert with advances in the forecast and data assimilation systems,

→ The operational array must provide infrastructure for research to improve the models

The Bjerknes feedback: Fundamental coupling



Positive feedbacks couple thermocline slope, SST, zonal winds.

The coupling depends on communication links:
- between the thermocline and the surface
- between the free atmosphere and the surface stress/fluxes

(The above is glib and vague about how these links operate ... and so are models)

How does the thermocline communicate with the atmosphere?

The diurnal cycle is surprisingly important ... and its effect depends on background conditions.

Can we teach this to models?

Diurnal cycle composite at 2°N,140°W: Winds, current shear.

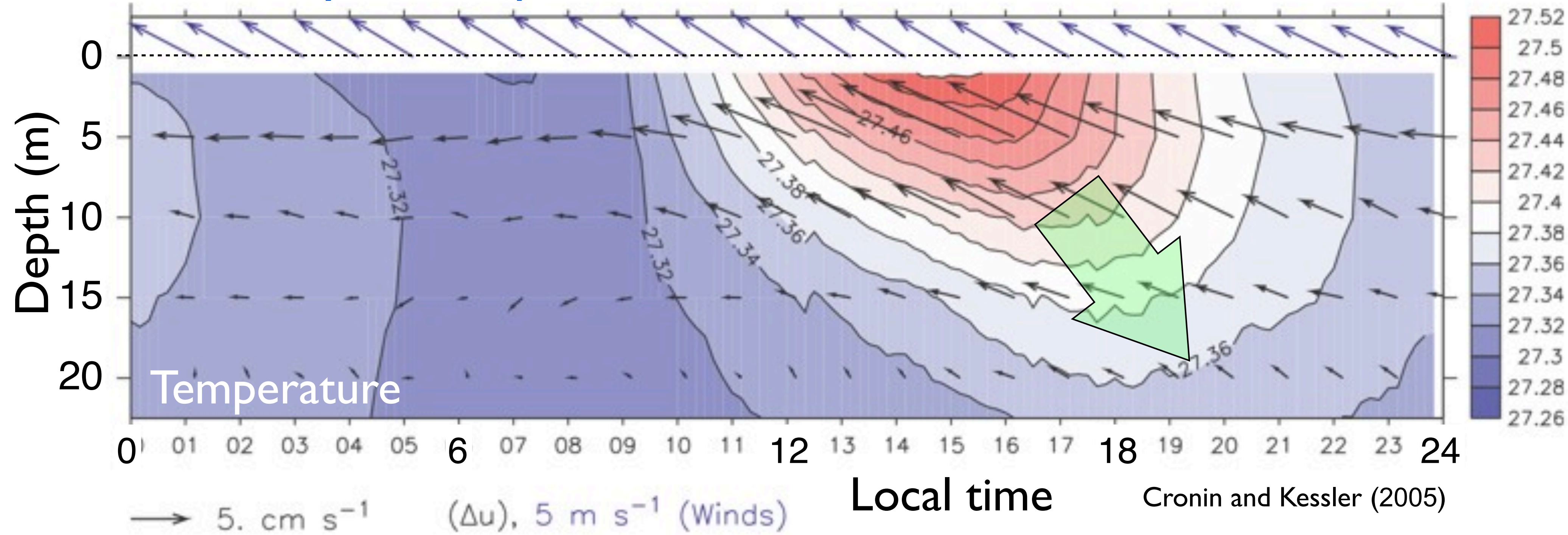
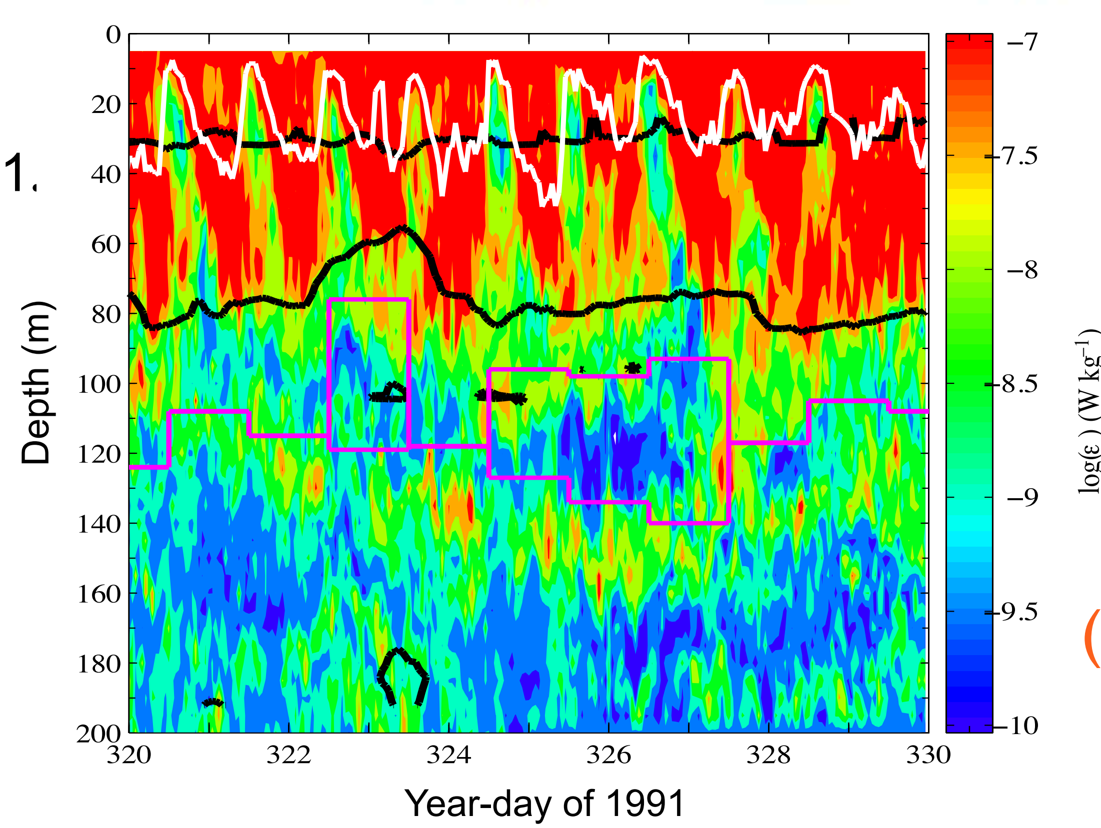


FIG. 5. Mean diurnal composite (24 May 2004–7 Oct 2004) of wind (blue vectors), temperature (color shading), and currents relative to 25 m (black vectors). The vector scale is shown at the bottom.

Turbulent dissipation during 10 days of 1991.
White = Mixed layer
Red = Turbulent ϵ

TIWE (Lien)



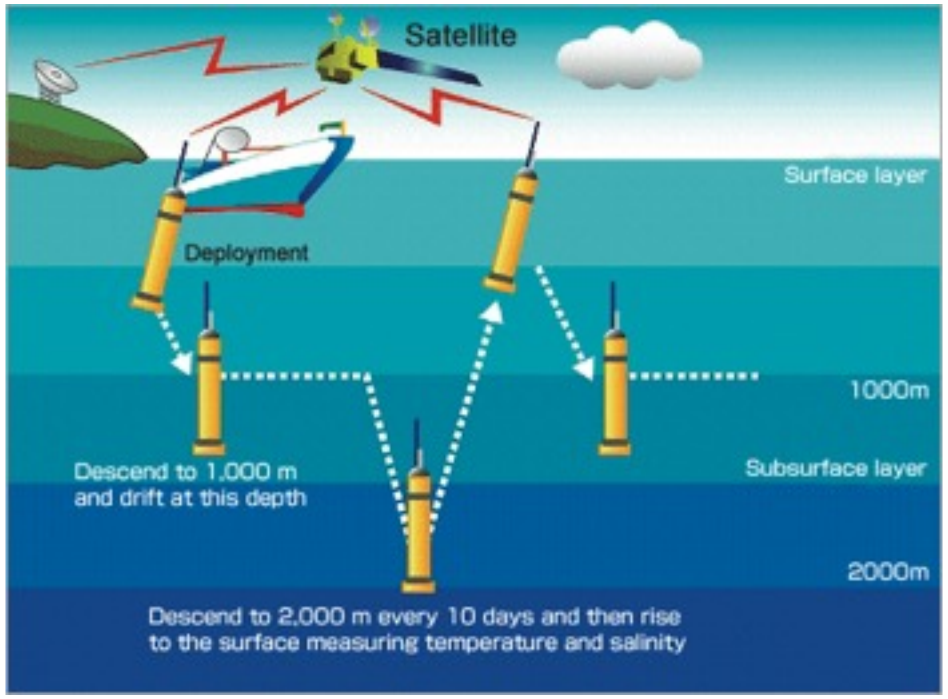
Much of the work of heat and momentum transmission to the thermocline is accomplished by the diurnal cycle.

(Planetary Boundary Layer Task Team)

TPOS 2020 Tropical Pacific Observing System

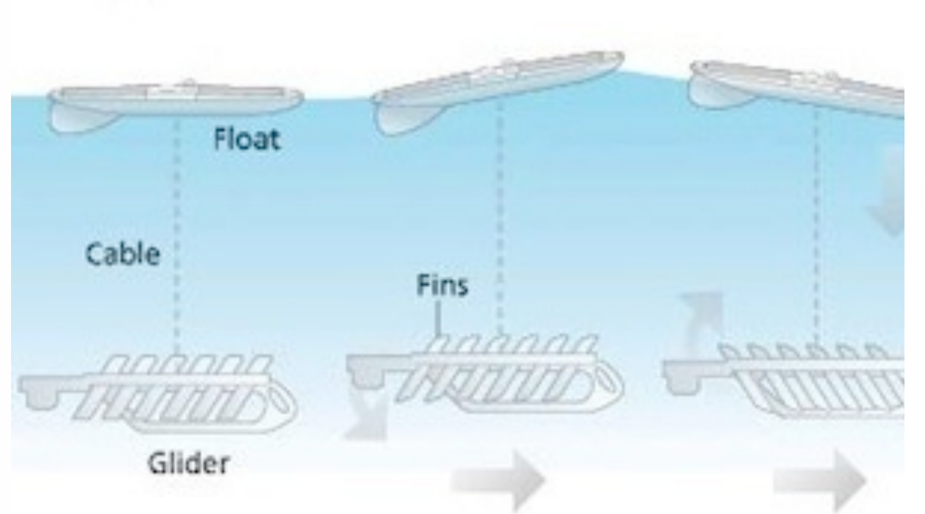
Take advantage of developing ocean technology

Argo floats make a profile every 10 days
Measure temperature and salinity

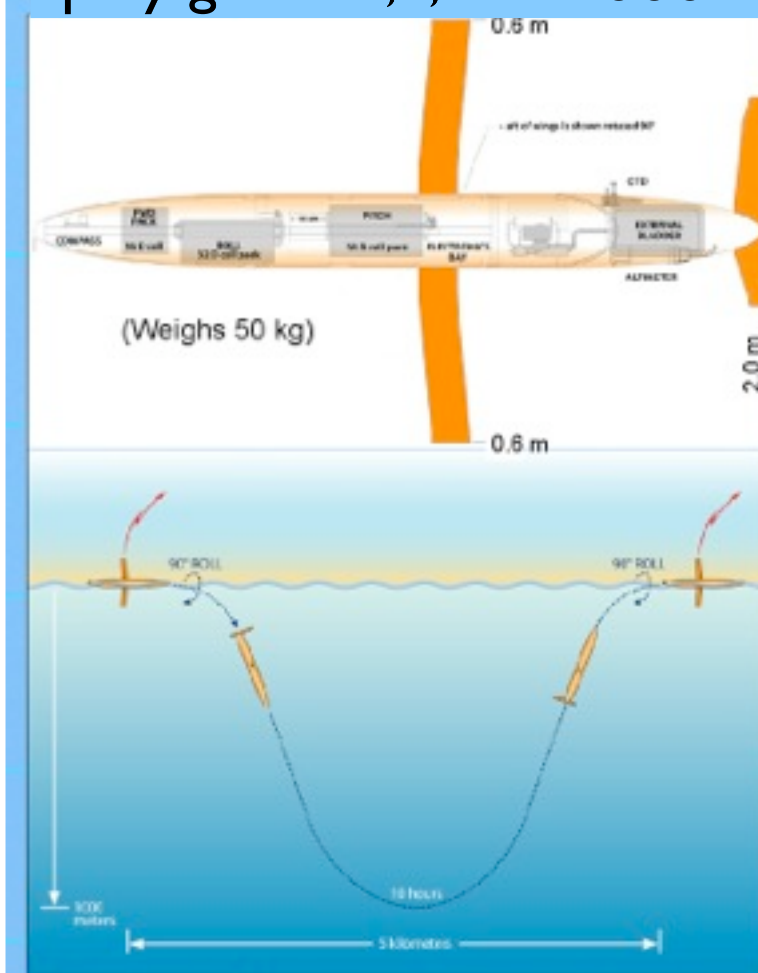


Argo float array:
More than 3800 (~2000 US = Green)

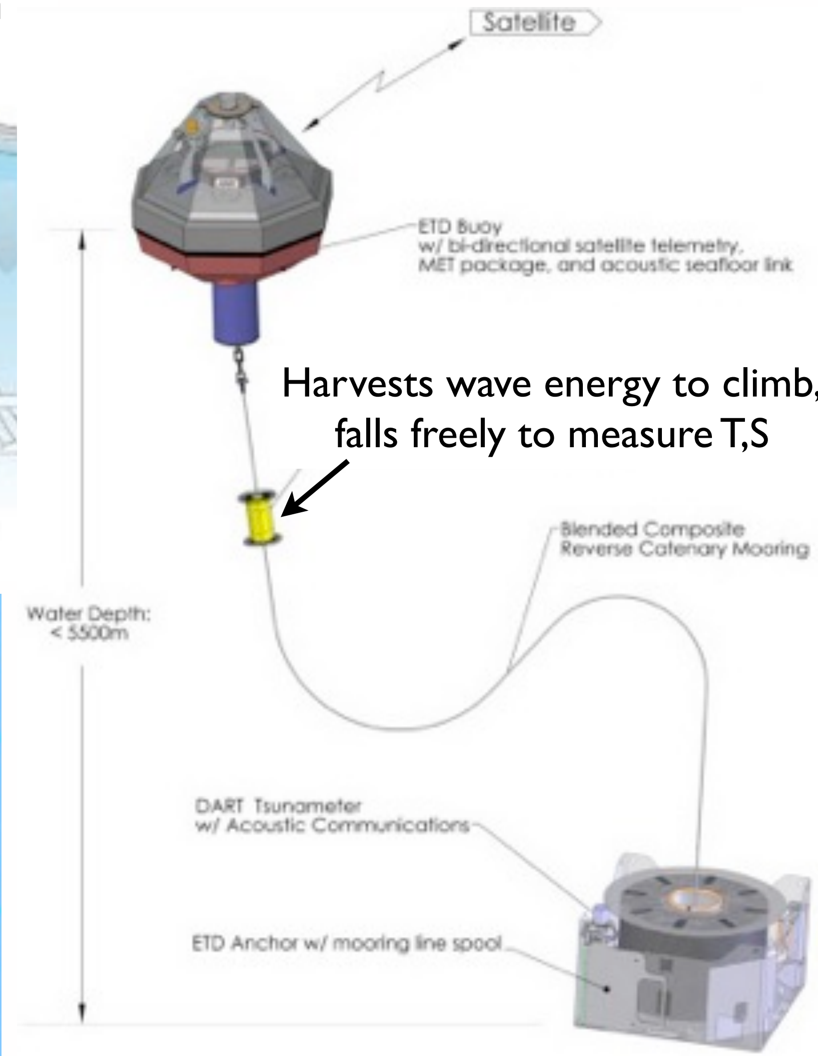
Wave glider: near-surface to 6m



Spray glider: T,S,u to 1000m



Prawler mooring:
T,S, etc to 600m



Harvests wave energy to climb,
falls freely to measure T,S

Saildrone
Surface met

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Changes? (premature to say, but …) 1:TAO evolution

It's likely that a <u>moored array</u> will continue to be necessary:

- TAO time series calibrate satellite winds, SST, …
- Near-equatorial current measurements are vital.
- The long records from TAO are a key climate indicator.
- High-frequency sampling for interpretation of coarser measurements.
- Co-located ocean-atmosphere sampling to diagnose the (poorly-modeled) interaction of the two boundary layers.

A fresh view <u>might</u> point to fewer, but more-capable moorings, especially for better sampling of the ocean mixed layer and surface meteorology.

Because of the great cost of ship time, we will explore how the above requirements can be met with a more compact array.

Changes? (premature to say, but …) 2: new tools

We have tools that did not exist when TAO was designed:
Argo floats, extensive satellite sampling, other autonomous vehicles.

Argo is improving and complementing existing subsurface sampling:
Argo has better vertical resolution, better zonal spacing, salinity ...
It is a major part of the TPOS 2020 vision.
But Argo can't do the diurnal mixed layer, or the surface met obs.

Satellites should complement in situ sampling, but we are just learning how to integrate the two kinds of measurements.

Learning how to incorporate other new technology (previous slide)

We anticipate that a more-useful, more-resilient data set can be collected at similar cost to today's system.

(Backbone Task Team)

Questions for discussion

1) We've heard from CPC and other centers that TAO buoy humidity sampling and ability to estimate evaporation and latent heat fluxes from the buoys is valuable, especially for subseasonal forecasts and analyses. How is this information used? How does it complement satellite moisture soundings?

2) What other surface met sampling would be useful? (e.g. BP, SW / LW radiation, precip, ...).

3) Another set of questions concerns the geographical shape of the array.
Is the present TAO grid appropriate? Any changes to suggest?
Examples: Contract TAO to denser spacing near the equator; Or, extend a few lines across the ITCZ or SPCZ.
Would a few highly-instrumented sites (e.g. for direct surface flux measurements) be useful?
Where should those be? How would they be used? (for realtime assimilation or delayed-mode validation?)

4) What about the near-surface ocean?
We can now make profiles of T,S,velocity at much higher vertical resolution than present TAO for the upper 50m, thus can resolve the diurnal warm layer, its formation and nighttime dissipation. Is this a valuable target?

5) TAO now makes delayed-mode velocity profiles at 4 sites along the equator.
CPC said those were important as independent validation. Agree? If we measured velocity at more sites, would that be useful? For example, we are considering adding velocity sampling for two additional targets: the ocean mixed layer everywhere (could be realtime), and delayed-mode full-depth profiles at near-equatorial sites which would describe the meridional structure of the EUC and velocity gradients.

6) How do you see the combination of TAO and Argo being used?
One strawman idea would refocus TAO:
(a) towards the near-surface (where Argo is less useful because its sampling is so slow), and
(b) away from the thermocline and subthermocline (where Argo gives salinity and better vertical resolution)?
Would a rearrangement like this make sense for your work?

7) Since whatever system we design will be in place for decades, we need to think ahead to what future models/ forecasts will need. Looking back from 2030, what will we wish we had started measuring in 2016? What observations would guide model improvement?

Extra slides below

Guiding principles

0. Do not repeat the mistake of changing observing systems without adequate overlap and evaluation!

1. Advance by observing the mechanisms connecting the equatorial thermocline and the free atmosphere. Challenge and guide model improvement.

2. Foster a diverse-platform observing system to adequately sample ENSO's rich multi-scale variability. Integrate tools that did not exist when TAO was designed:
   Satellites, Argo, new autonomous samplers, …

3. Beyond its monitoring capability, TPOS should serve as the backbone for essential ancillary and process studies (allowing others to propose and participate).

Advance the data assimilation systems, and use those systems to assess array configurations.

1. OSEs: "Many lives of an observation"
   - Calibration of satellite retrievals
   - Model development, tuning, initialization, verification
   - Trend detection
   - Underpin evolving climatologies
   - Process diagnosis

A typical OSE that tests only the initialization step is not a full evaluation, and the results depend on the particular model and its biases.

How can TPOS 2020 use OSEs to assess array configurations?

2. Operational centers agree that present systems do not make effective use of observations: Much of the "information content" of an observation is "used up" in correcting biases.

   Climate Process Teams?

What does TPOS 2020 offer NOAA?

- Tested, vetted redesign of a modernized and sustainable system, explicitly planned to serve and advance our forecast and research mandates, taking full advantage of new technologies.
- Enhanced effectiveness, less risk for our observing investment.
- Testbed for observing strategies:
  new science objectives, potentially less shiptime.
- Identification, testing and implementation of improvements to the models and data assimilation systems.
- Better sampling responsive to new needs (near-surface, CO_2 ,…).
- Maintain, build capability to assess climate change signatures.
- Path to gain committed agency / international contributions.

What does TPOS 2020 need from NOAA?

- Support for research to develop and test new technology, new system configurations, and new observational targets
- Maintain TAO as the new T.P.O.S. is developed and built
- Maximize use of TAO cruises: Ancillary sampling
- Shiptime for testing and evaluation of new systems
- Advance the models and data assimilation systems, and use those systems to assess array configurations

A "strawman" is a simple draft proposal intended to generate discussion of its advantages and disadvantages, thus to provoke evolution of new and better proposals.

Key words: → "generate discussion" "provoke evolution" ←

Strawman ≠ What we will eventually propose

Example strawman ideas (more coming soon):

1. Move all the 8°S/N moorings to 1°S/N.
2. Refocus TAO to the near-surface (short timescales [diurnal↑], co-located ocean-atmosphere obs [enhance these]).
   Rely on Argo in the thermocline and below (salinity, vertical resolution, timescales well-matched to phenomena).
3. Rearrange TAO to fewer longitudes, but extend lines across the ITCZ and SPCZ.
4. Shift towards regime-based sampling, with highly-capable sites.

Suggestions wanted! Think big, but:

- Must meet the needs of operational forecast systems!
- Backbone technology must be mature or nearly so!
- Must not cost (much) more than the present system!
- Must maintain an adequate climate record!