The TPOS 2020 Project
A redesigned Observing System in the Tropical Pacific

S. Cravatte, W.S. Kessler, N. Smith, S. Wijffels

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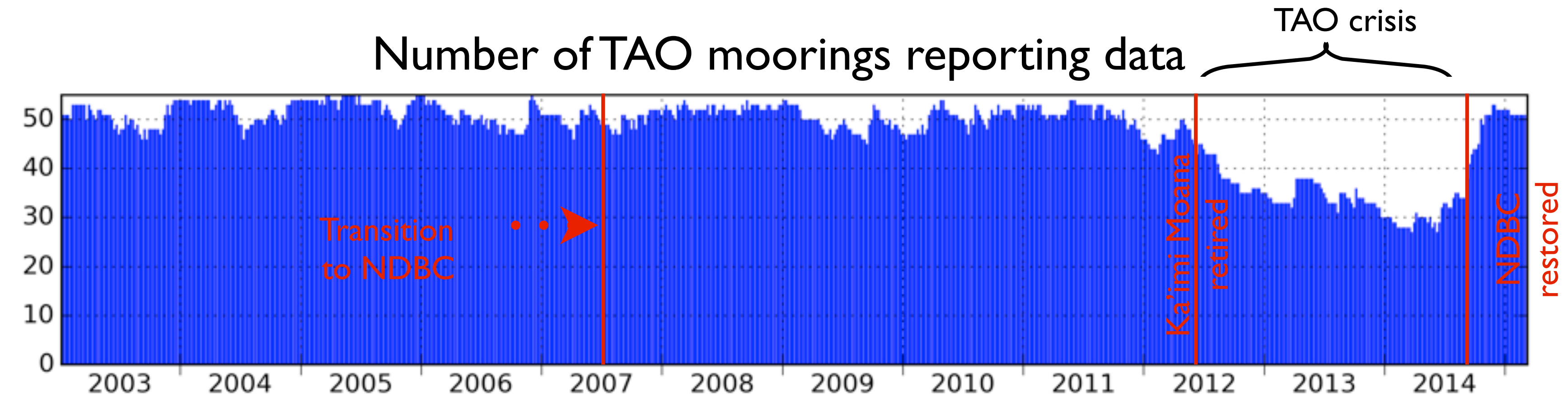
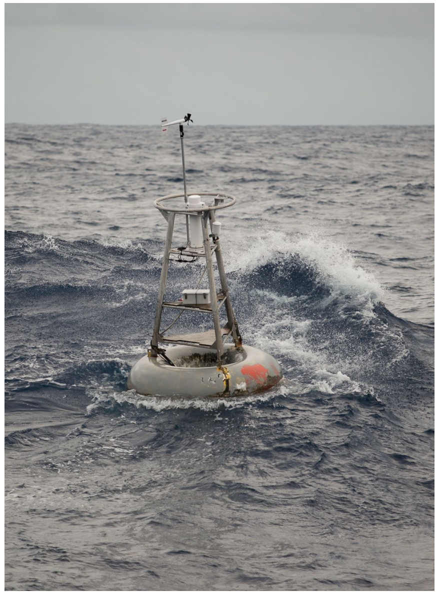
French National Research Institute for Sustainable Development

ECMWF Workshop
Tropical modelling, observations and assimilation
7-10 November 2016

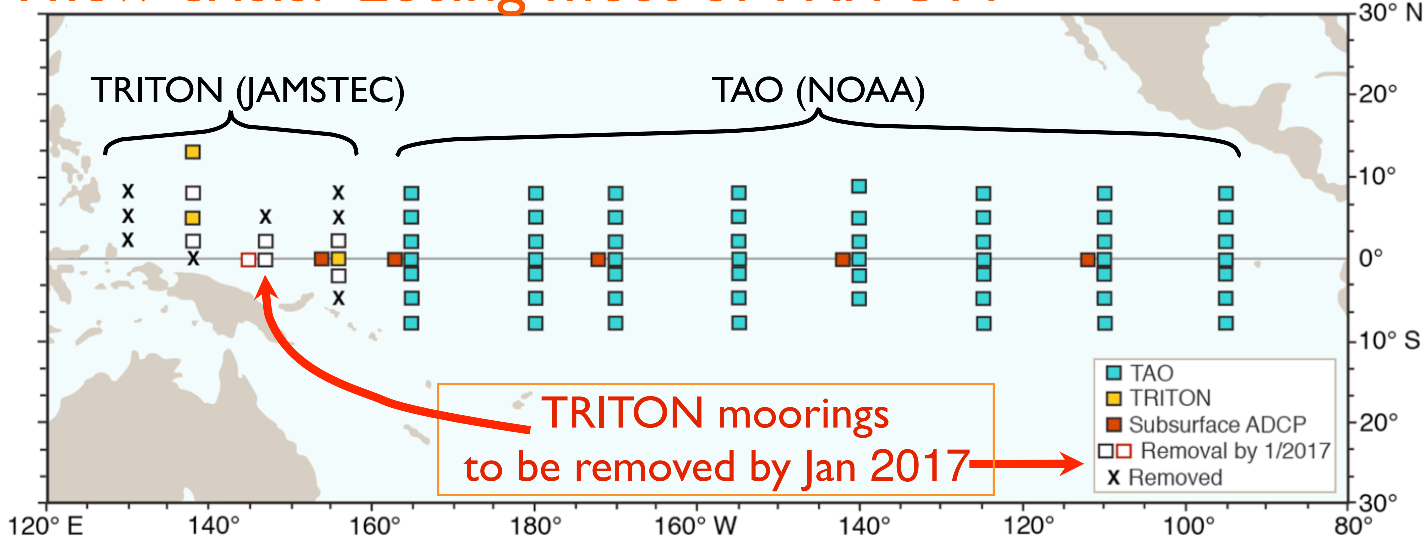
TPOS 2020 started in crisis of the TAO/TRITON array.

mid 80s (start)
-> 91 (complet)
-> 98 (Japan)





A new crisis: Losing most of TRITON



Serious risk to ENSO predictions

Need international cooperation over the long term

Tropical Pacific Observing System

Timely for re-examination

Since the arrays were designed:

- New technical possibilities:
  - Satellite sampling (especially scatterometers)
  - Argo floats, more capable moorings, gliders…
- New model and DA systems developments
  - Operational centers have (and will have) different observational needs
- New scientific understanding and issues:
  - ENSO diversity
  - Focus on the coupled boundary layers, role of the diurnal cycle
  - Biogeochemistry, air-sea carbon fluxes

What are the needs for the coming decades?

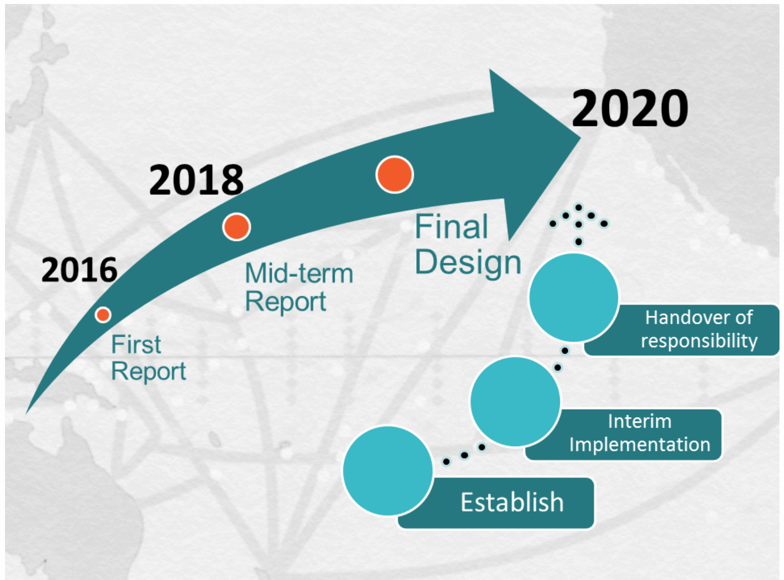
The TPOS 2020 project

TPOS 2020 is an international project under GOOS
Steering Committee:
15 members from 7 nations
Co-chairs: Billy Kessler (NOAA) and Neville Smith (BOM, Australia)
Task Teams

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

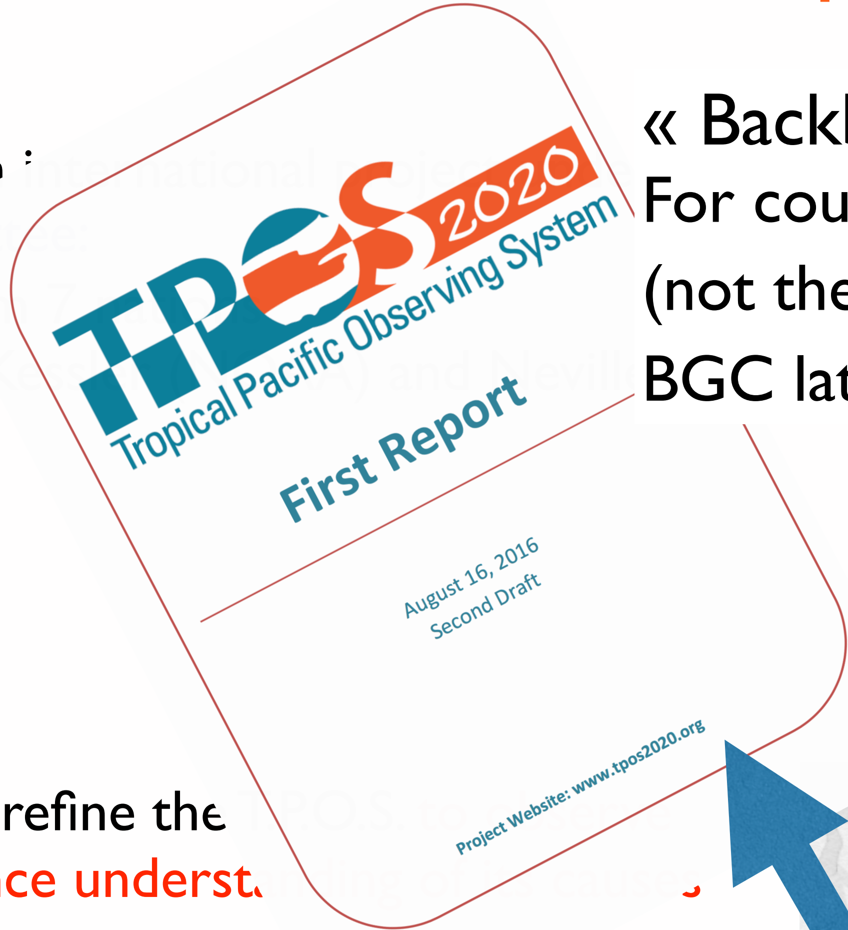
Timeline



2020 Tropical Pacific Observing System

The TPOS 2020 project

TPOS 2020 is an i
Steering Com
15 members fr
Co-chairs: Billy
Task Teams:



« Backbone »
For coupled ocean/atm
(not the free atmosphere)
BGC later

Goals

- To redesign and refine the
ENSO and advance underst
- To determine the most efficie ... effective observational solutions to support prediction systems for ocean, weather and climate services
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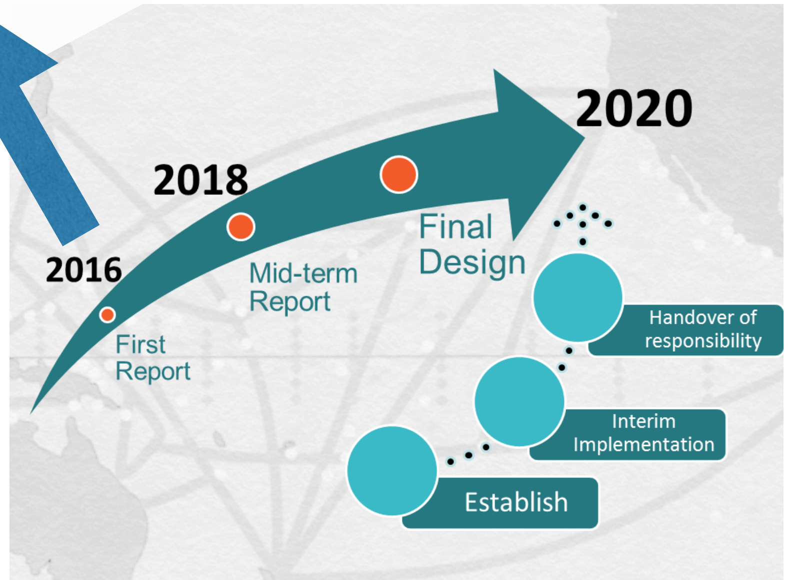
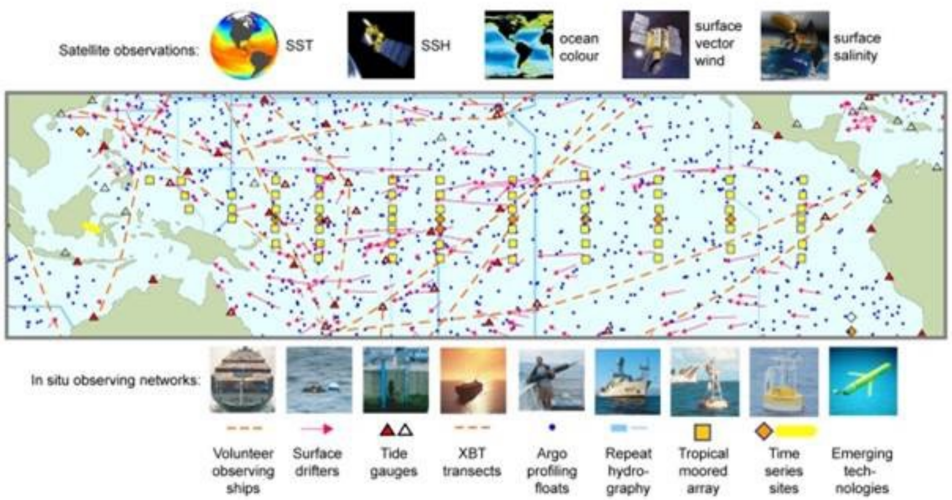
Timeline



TPOS 2020 Tropical Pacific Observing System

Philosophy and design principles

Integrated design:
satellites and in situ capabilities



Users will increasingly rely on gridded products

- Success depends on advances in the models and data assimilation systems.

TPOS 2020 should provide data to advance these systems:

1. To meet forecasts requirements (initialization, verification, validation)
   To improve satellite retrievals (calibration, validation)

2. To challenge the models and guide parameterizations

An integrated design

Satellites give global coverage and fine spatial detail;

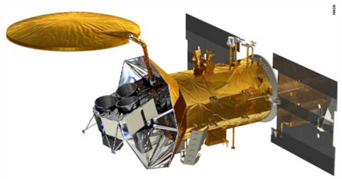
but… need very high quality in situ data

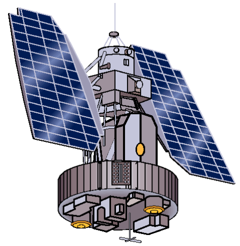
Argo is global, resolves fine vertical structure to 2000m, gives salinity.

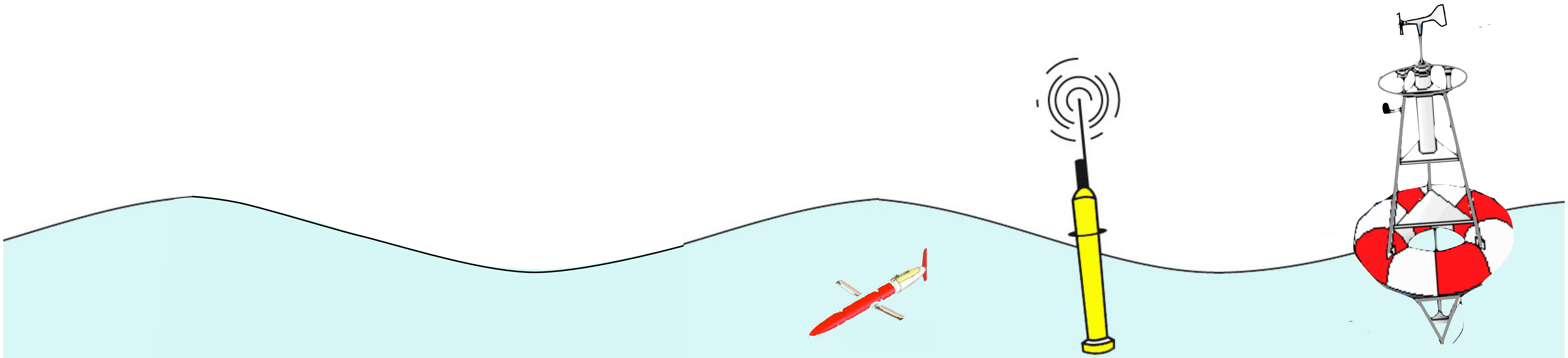
but… not for short timescales, not surface met

Moorings measure high frequencies, allow co-located ocean-atmos observations, direct velocity;

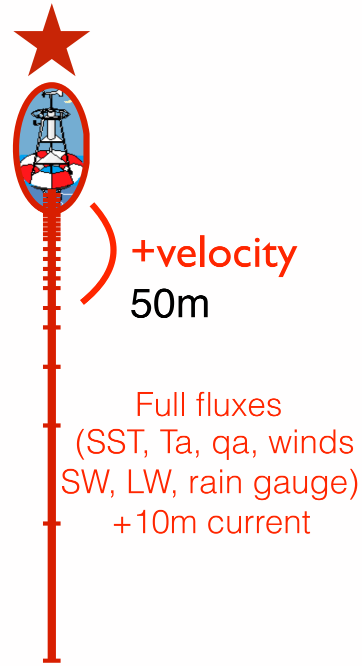
but… wide spatial spacing







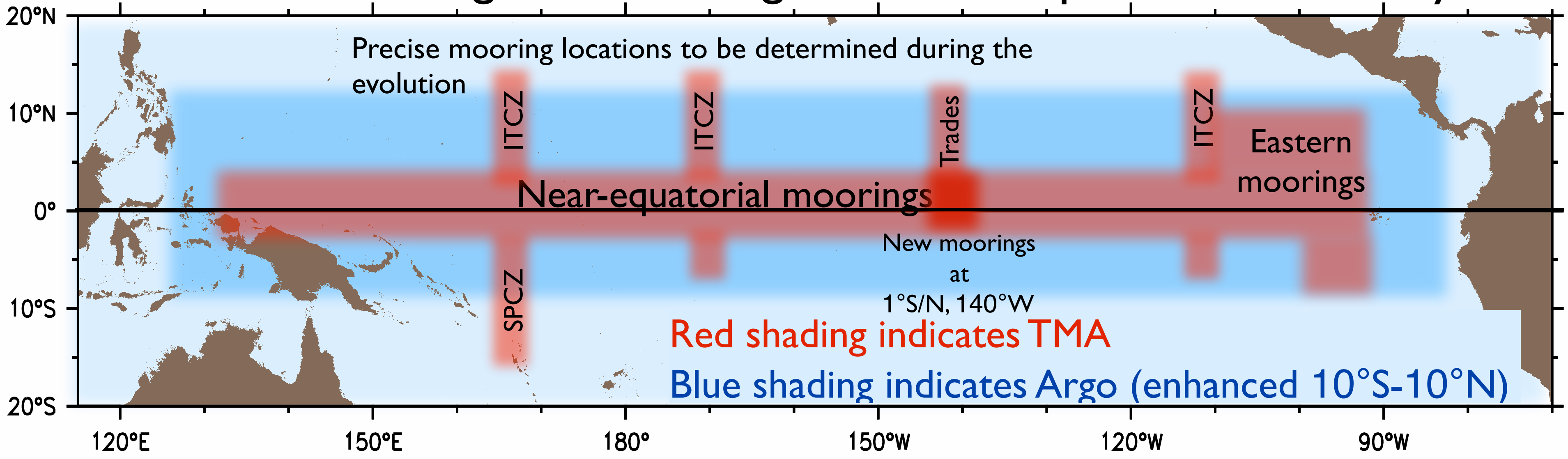
Proposed eventual in situ T.P.O.S.



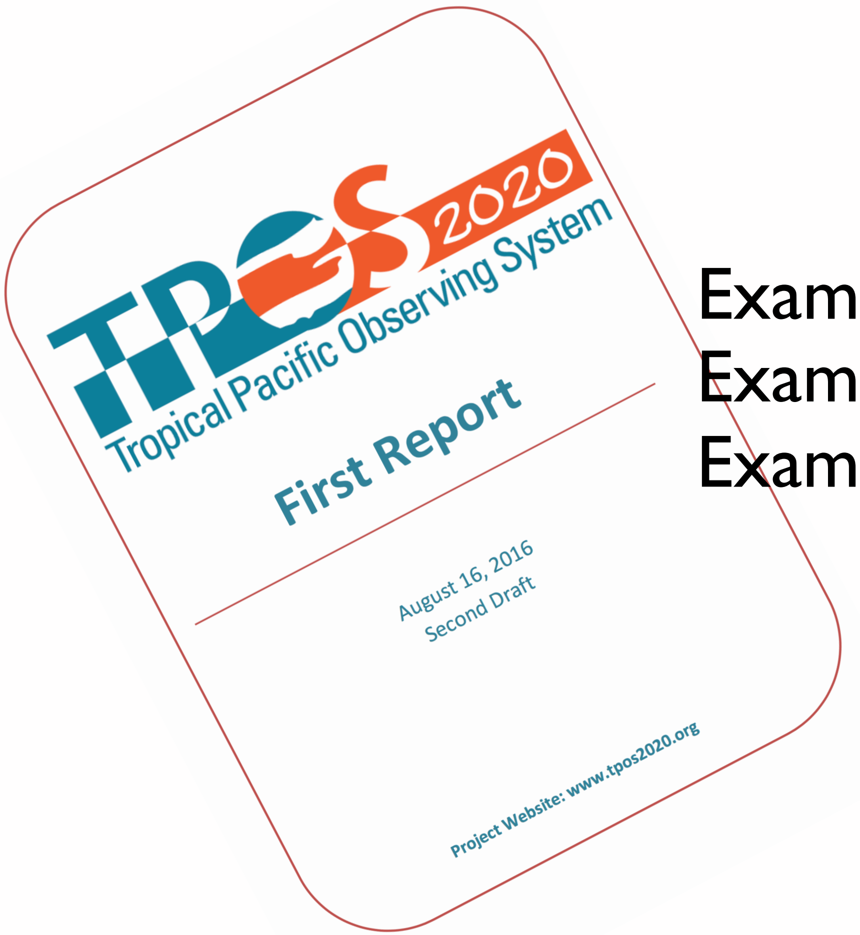
—> Grid-sampling to regime sampling strategy

Refocus more capable moorings on specific targets
(near-equator, near-surface)
and key regimes (warm pool, cold tongue, convergence zones)

Eventual configuration of Argo and the Tropical Moored Array



How did we arrive to this design?



Example 1: the surface winds
Example 2: the subsurface ocean
Example 3: Air temperature, humidity, fluxes

Example 1: surface winds

The moored array: originally designed to comprehensively sample tropical winds, before scatterometry.

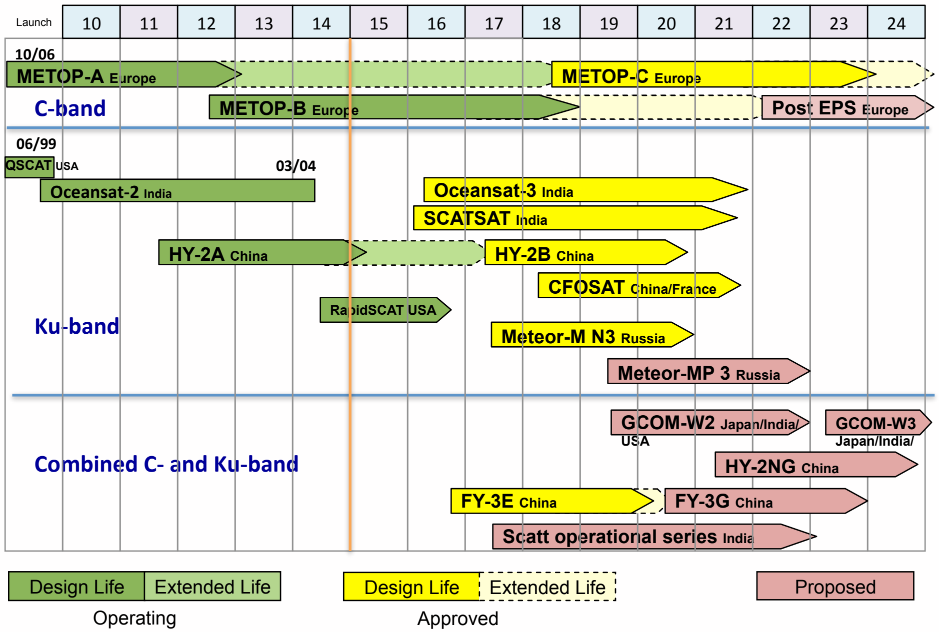
Strategy: rely on scatterometers winds (with sufficient coverage), and maintain in situ time series for correction/calibration and validation

Example 1: the surface winds

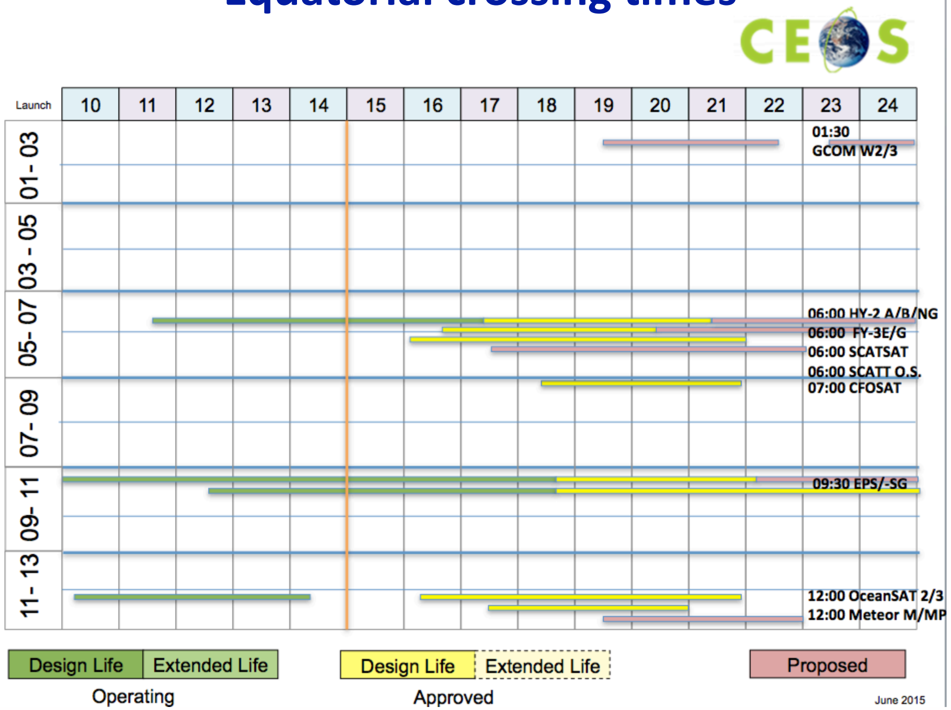
Recommendation 1 A constellation of multi-frequency scatterometer missions and complementary wind speed measurements from microwave sensors to ensure broad-scale all-weather wind retrievals over 90% of the oceans 6 hourly for the next decade and beyond, with different equatorial crossing times to capture the diurnal cycle.

CEOS constellation for measuring ocean surface wind

Courtesy of Mark Bourassa (FSU), Paul Chang (NOAA), and Ad Stoffelen (KNMI)



Equatorial crossing times



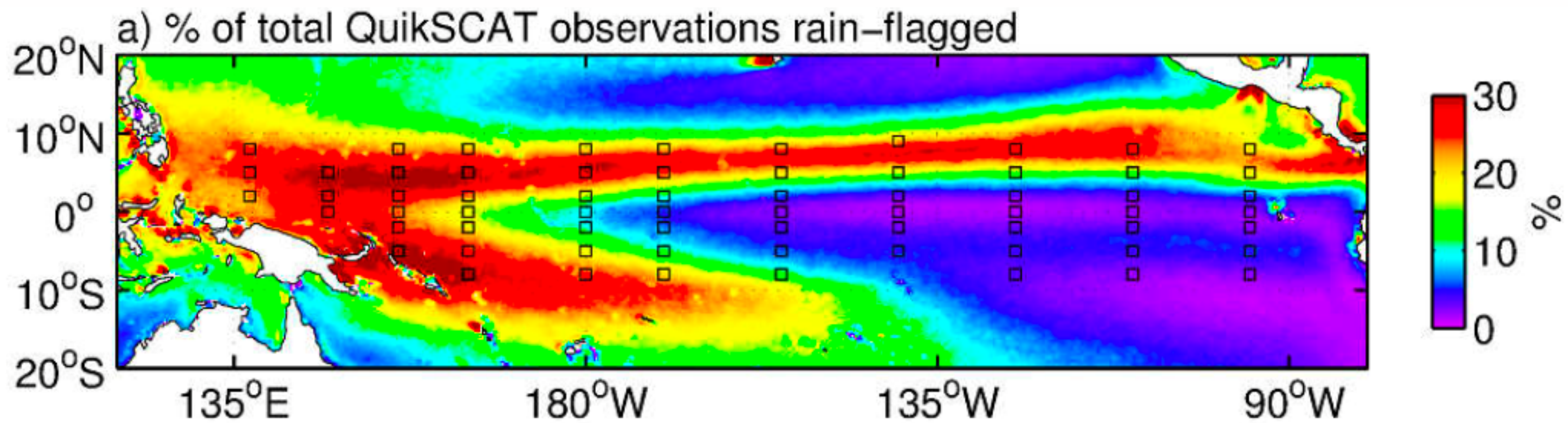
TPOS 2020 Tropical Pacific Observing System

Example 1: the surface winds

Where and how many in situ observations are needed?

Recommendation 2 In situ vector wind measurements, with particular emphasis on extending the in situ based climate records, and inter-calibrating different satellite wind sensors especially in the equatorial Pacific and in tropical rainy areas.

subtle: global climate
very sensitive to Eq zonal winds



Courtesy of L. O'Neill

Example 1: the surface winds

We need credible gridded wind fields

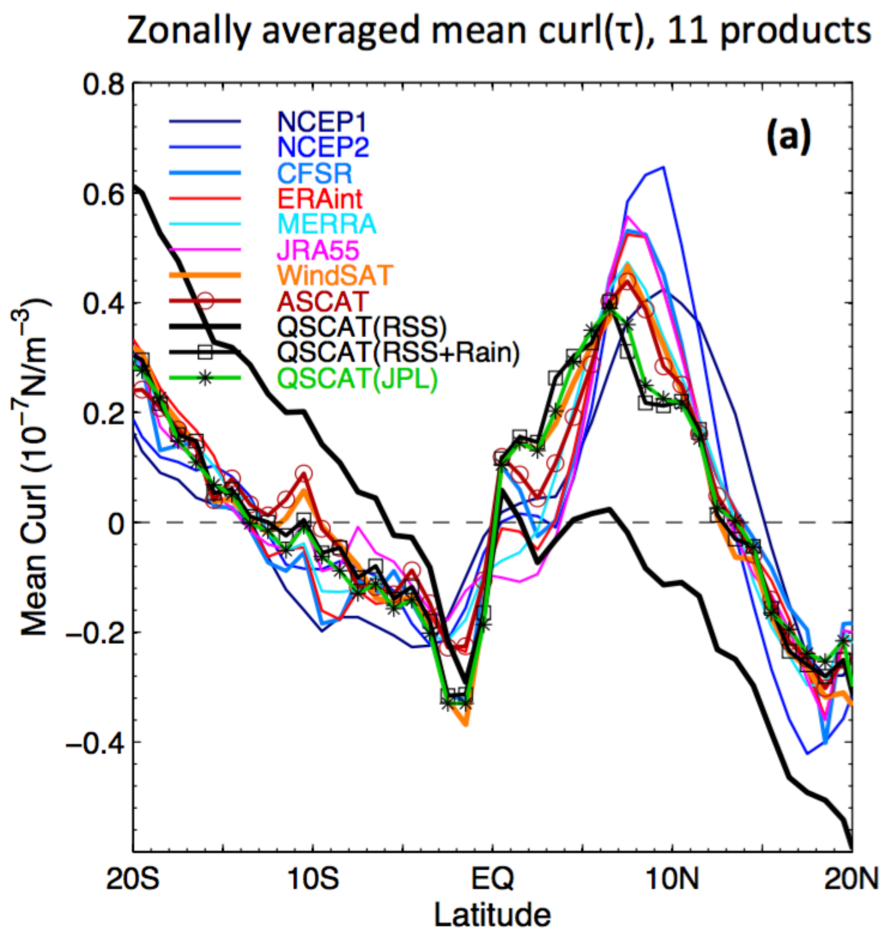
-Significant differences in surface wind reanalyses; (mean, spurious trends, the curl)

—> large ocean response

-Satellite-based synthesis products: (sampling errors: background= ERAi)

11/2007– 10/2009

ASCAT/QuikSCAT overlapping period



courtesy of Lisan Yu

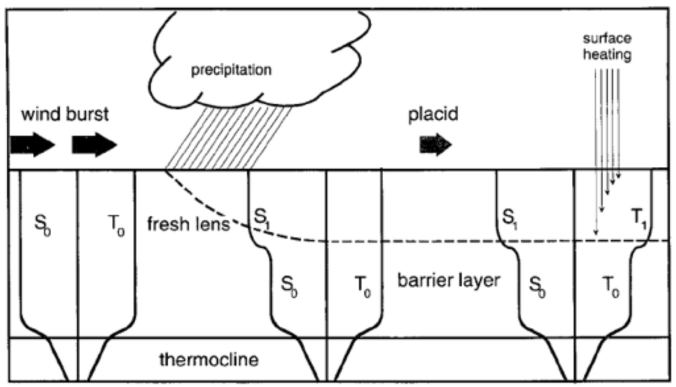
Improved gridded surface wind products is a TPOS priority

(E. Guilyardi's talk)

Example 2: the ocean subsurface

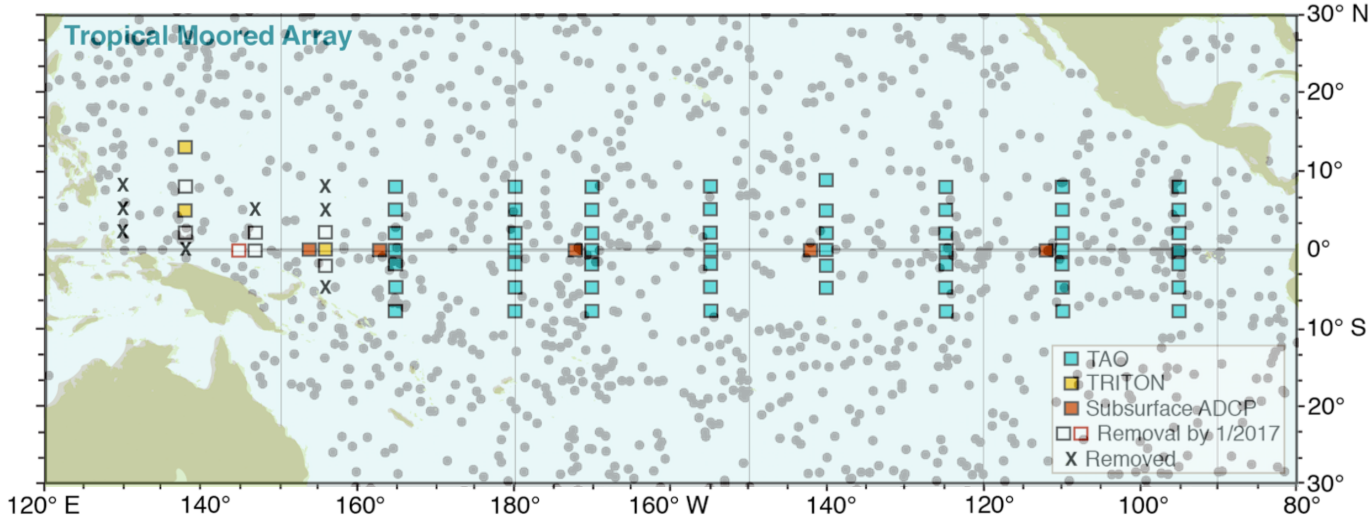
Requirements for sustaining forecasts and monitoring the state of the ocean:
- broad scale sampling of T and S (2°x2°x 10 days) in the tropics
- increased vertical resolution and meridional sampling in the eq. region
- enhanced near-surface salinity sampling (Warm Pool, rainy regions)

Barrier Layers



Barrier layers in the west Pacific warm pool affect the penetration of momentum fluxes.

Current status: TMA +Argo



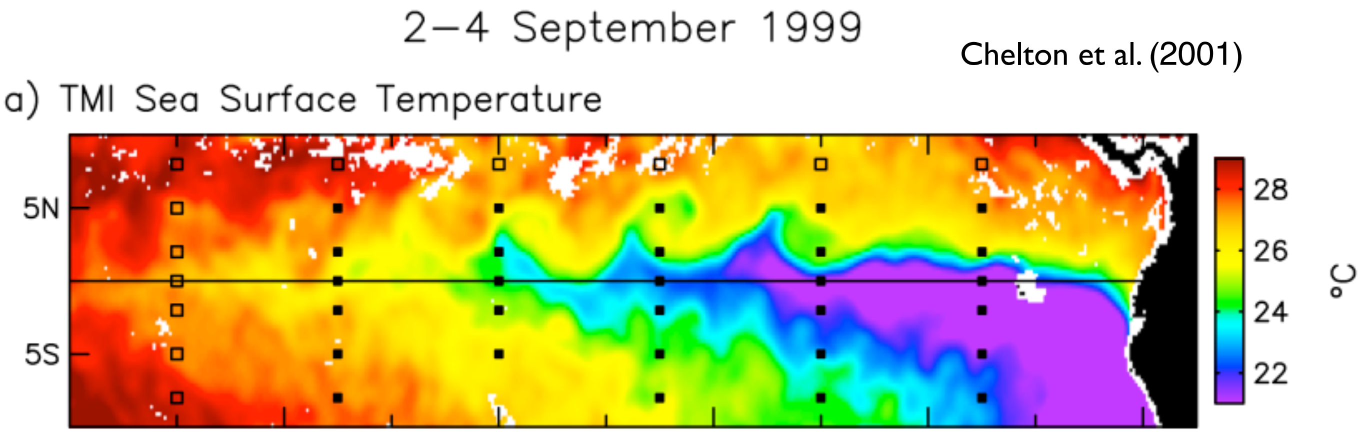
Recommendation
- doubling Argo in (10°S-10°N)
- targeting first the western and the eq region, and use 1m resolution (0-100m)

Example 2: the ocean subsurface

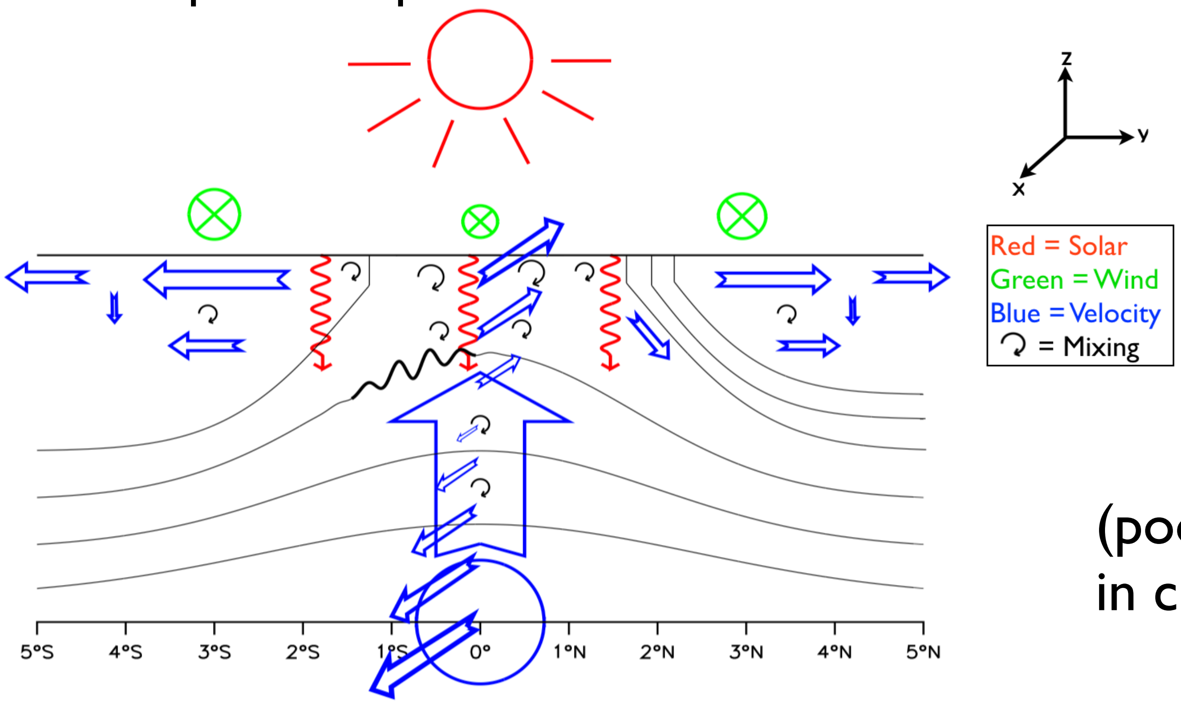
Requirements for understanding key processes:

- upwelling and mixing in the near-equatorial region

Chelton et al. (2001)



balance between upwelling, mixing and horizontal advection
the atmosphere responds to SST on short timescales!



(poorly constrained in climate models)

Example 2: the ocean subsurface

Requirements for understanding key processes:
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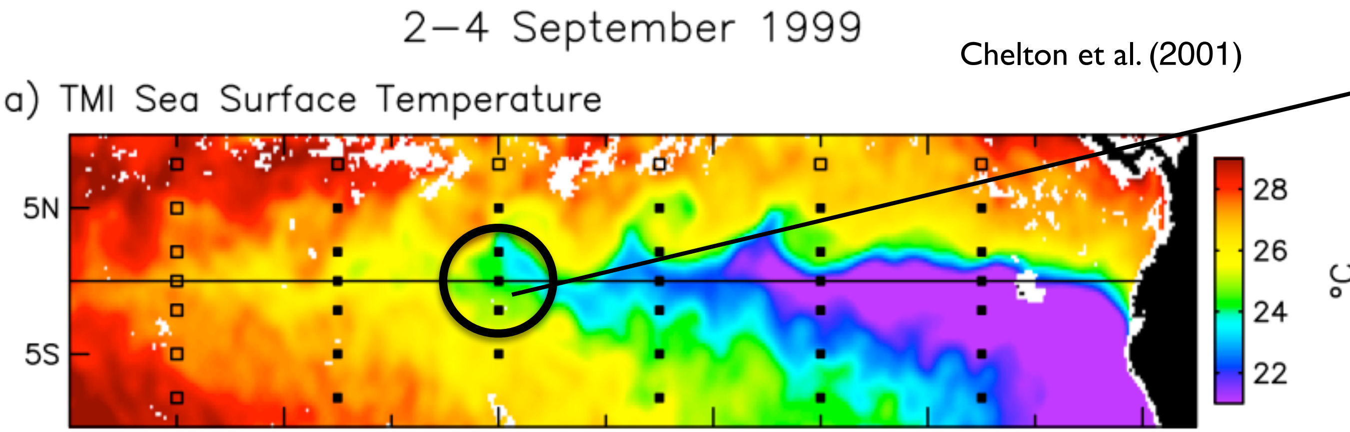
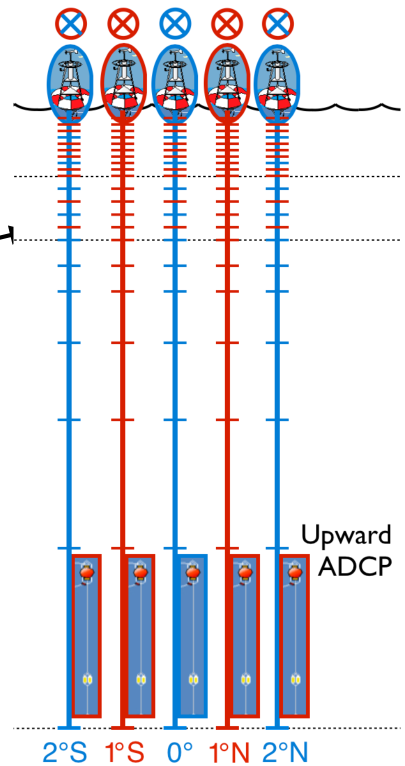




balance between upwelling, mixing and horizontal advection
the atmosphere responds to SST on short timescales!

We want to describe the full structure of the equatorial system

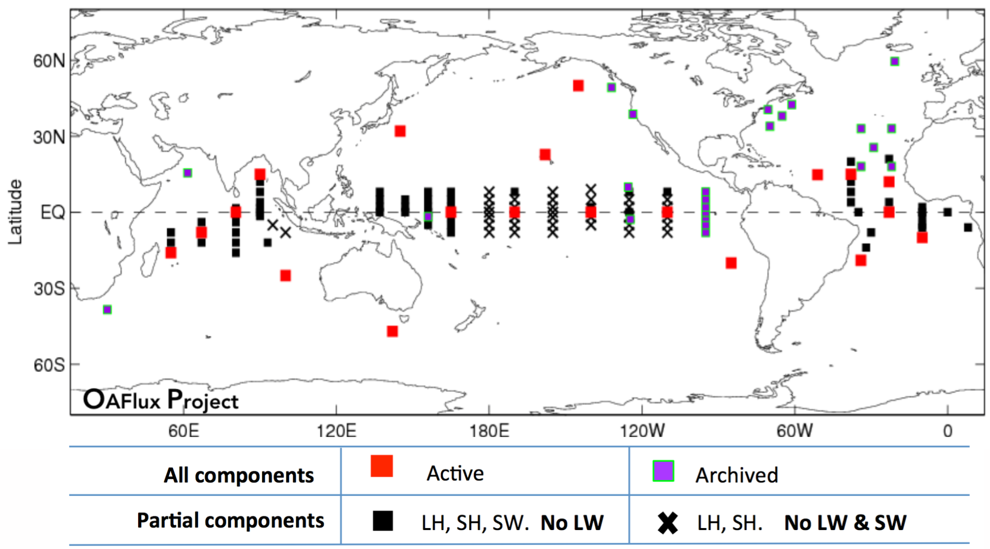
Recommendation: additional moorings near the equator with T, S and V and near-surface measurements, resolving the diurnal cycle

Hope it will challenge ocean models!

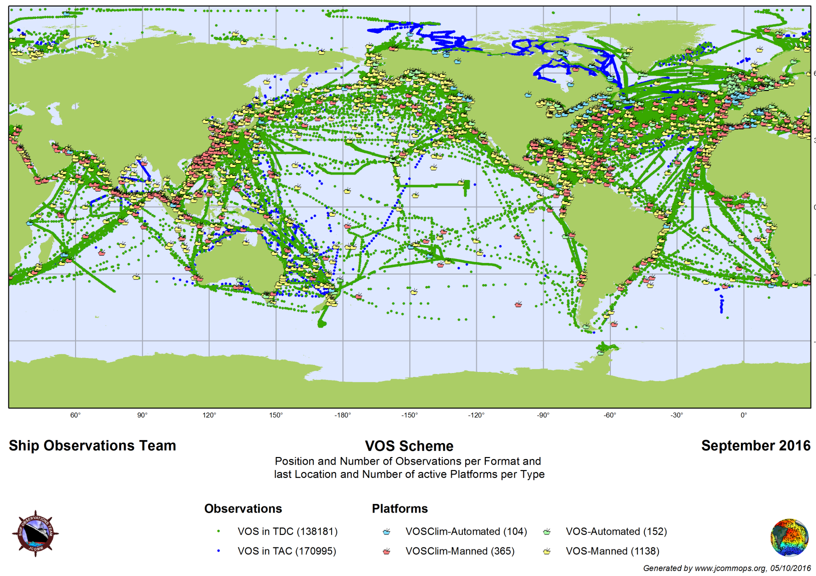
Example 3: air temperature and humidity, Fluxes

Hard problem!

Current status for in situ: Flux reference stations and VOS



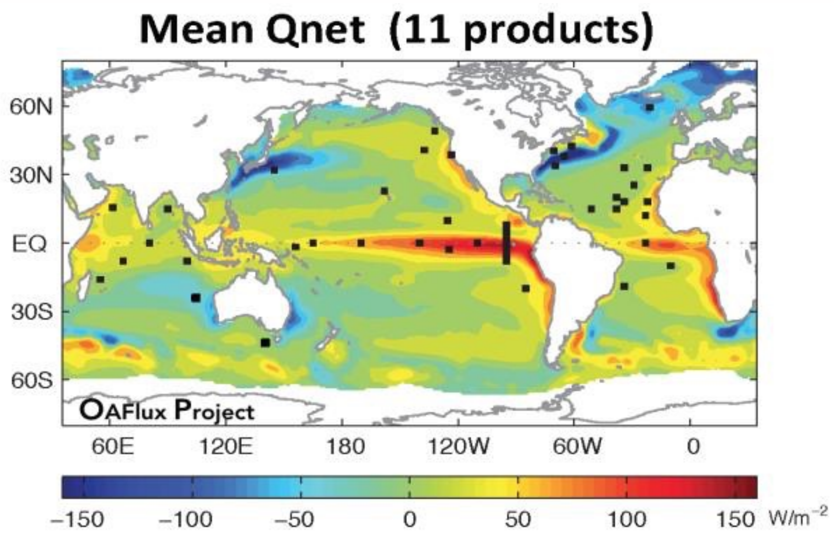
Courtesy L. Yu

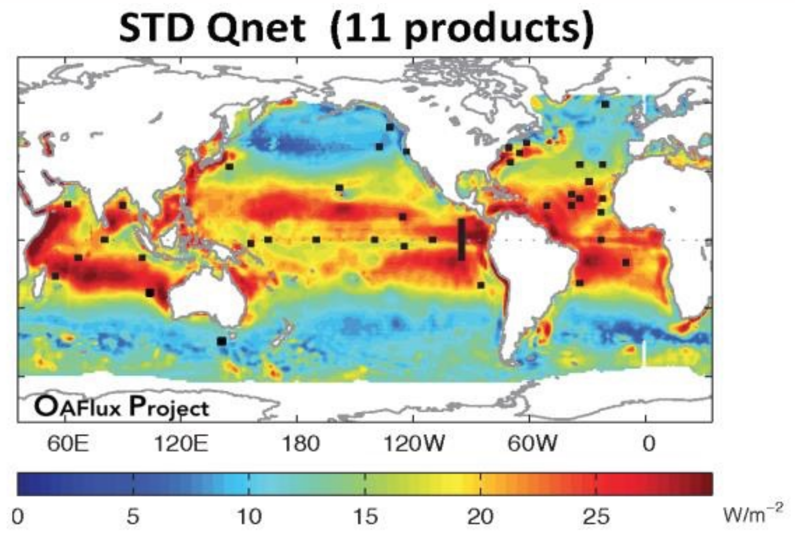


- satellite estimates have large errors (blind to some state variables)

Example 3: air temperature and humidity, Fluxes

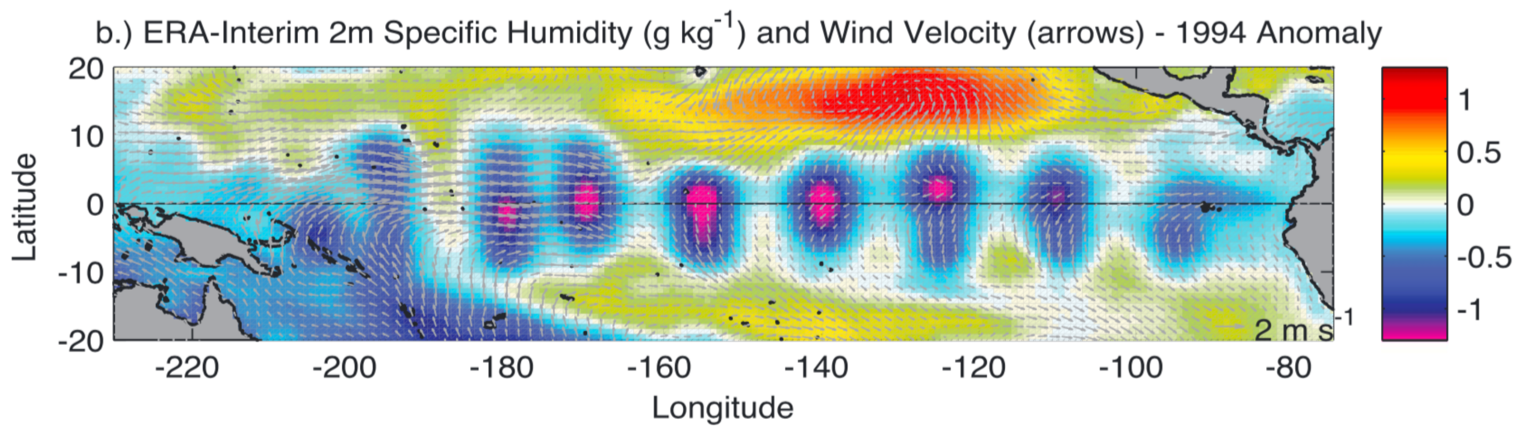
- NWP products and RA: large biases also





Products: OAFlux, NOC2, ERAinterim, MERRA, CFSR, ERA40, NCEP1, NCEP2, CORE2, ISCCP, NASA/SRB, CERES

(Cronin et al., 2014)



(Josey et al., 2014)

- Point data have limited value for data assimilation
- BUT crucial for model validation and improvement

OK, but where? How many sites?

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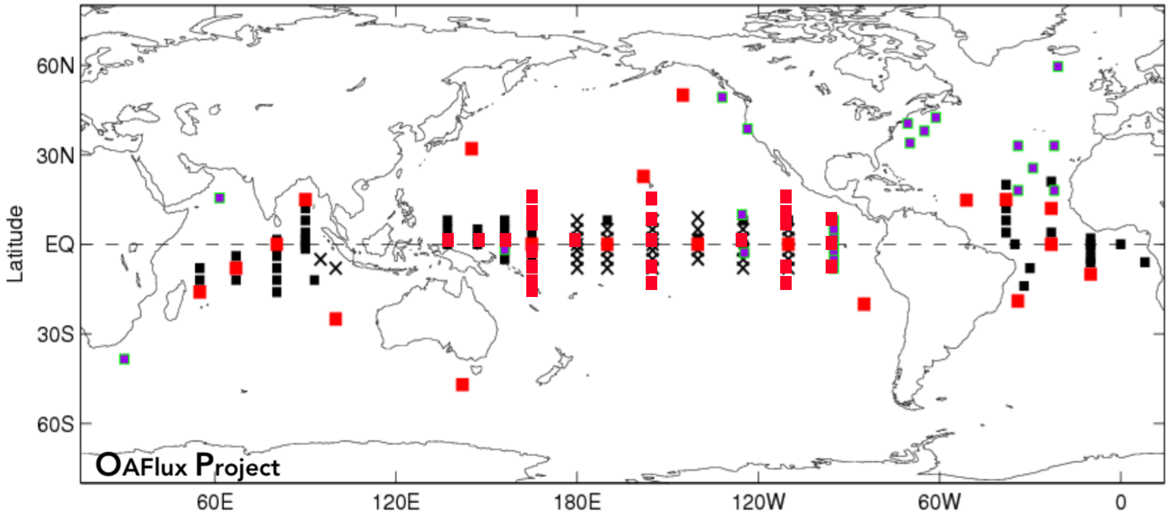
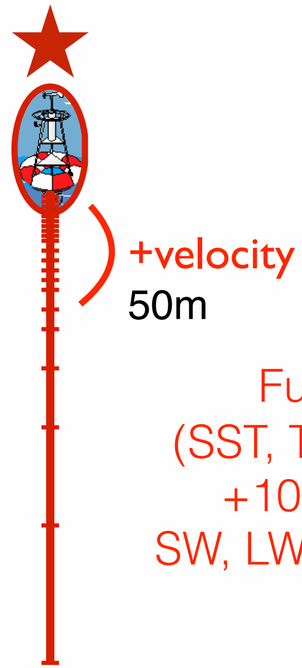
Example 3: air temperature and humidity, Fluxes

Future T.P.O.S: more flux reference stations



All components	■ Active	■ Archived
Partial components	■ LH, SH, SW. **No LW**	✖ LH, SH. **No LW & SW**

Courtesy L. Yu



Full fluxes
(SST, Ta, qa, winds
+10m current
SW, LW, rain gauge)

Recommendation: Comprehensive sampling both of the state variables for turbulent ***heat fluxes*** (SST, Ta, qa, wind and surface currents), and of the ***radiative fluxes*** (SW, LW, emissivity) in the full range of climatic/weather regimes and key oceanic regimes

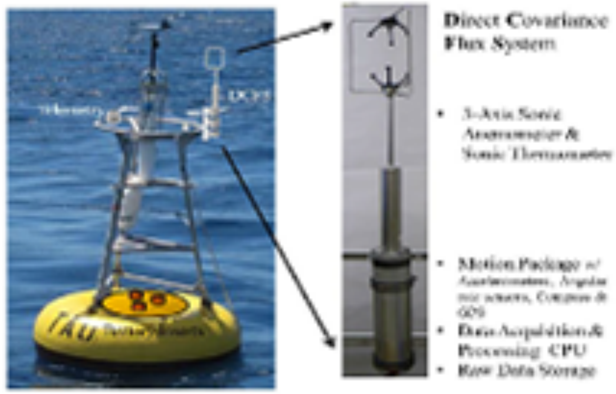
Pathway to help improving atmospheric reanalyses and satellites based estimates

Is it a good strategy?

TPOS 2020 Tropical Pacific Observing System

Example 3: air temperature and humidity, Fluxes

direct covariance flux system

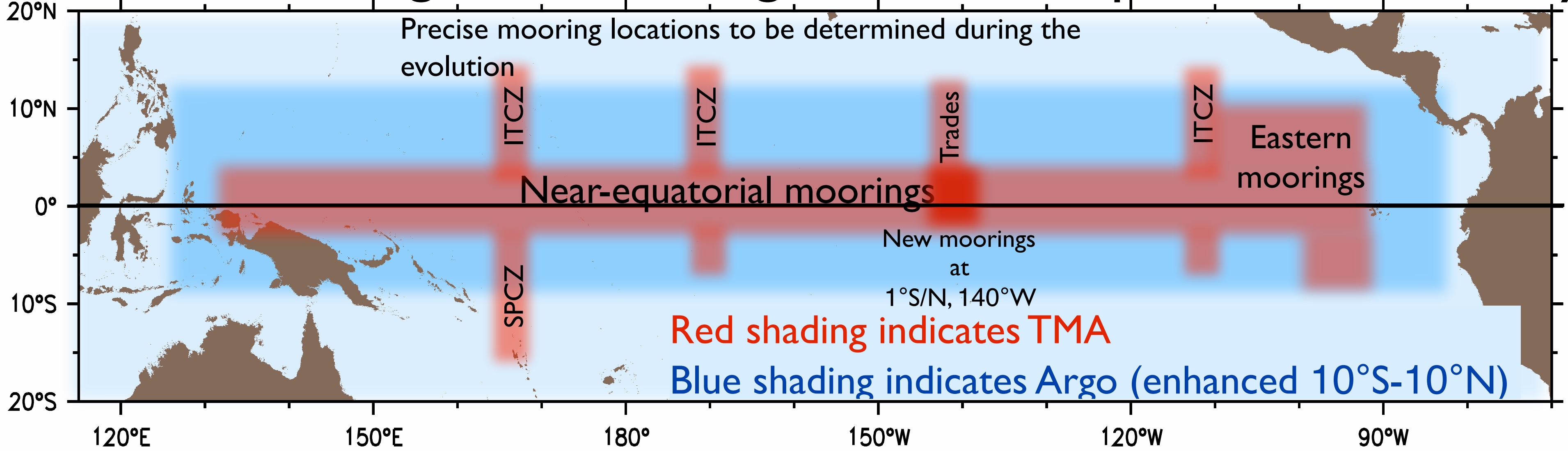


Action: seeks (b) support for new technology developments (c) encourages further development in flux products, including through grand ensembles and corrections based on in situ reference data

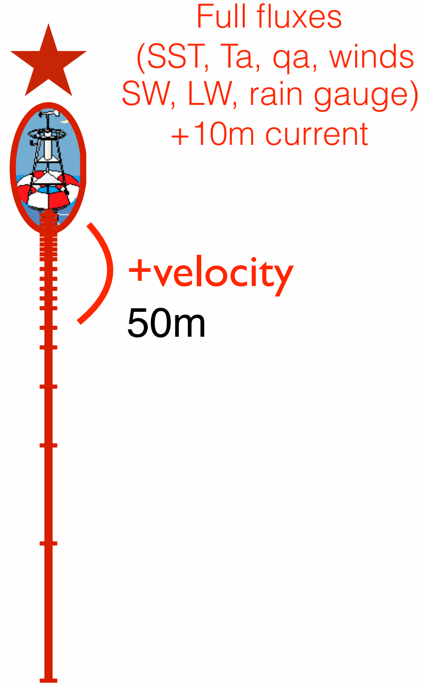
Action: Efforts to understand the sensitivity and diagnose the impact of TMA air-sea flux variables in weather prediction, atmospheric reanalyses and coupled models should be renewed and coordinated, including through existing activities focused on the impact of observations

Proposed eventual in situ T.P.O.S.

Eventual configuration of Argo and the Tropical Moored Array

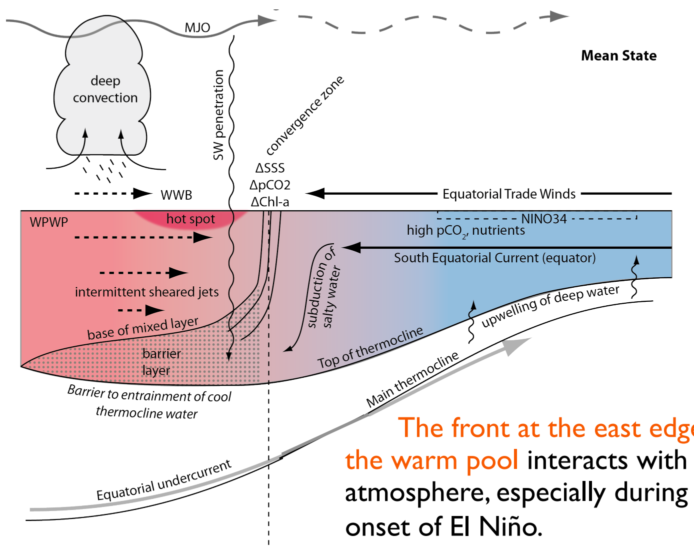


- Restore 6 moorings in the West (for ENSO Forecasts)
- More capable moorings (mixed layer full flux)
- Extend moorings lines across the ITCZ and SPCZ
- Increase Argo (doubling), 1m to 100m
- Increase near-equatorial meridional moorings spacing

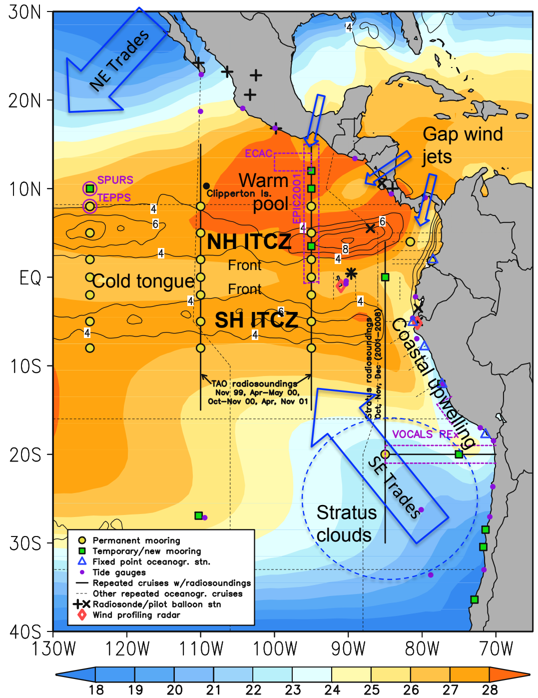


Next steps

- Pilot studies enhance TPOS capability
- Process studies to understand phenomena
- Modeling studies on impact and uptake

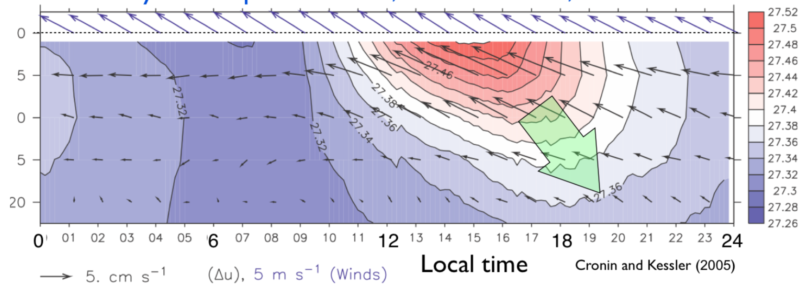


The front at the east edge of the warm pool interacts with the atmosphere, especially during the onset of El Niño.

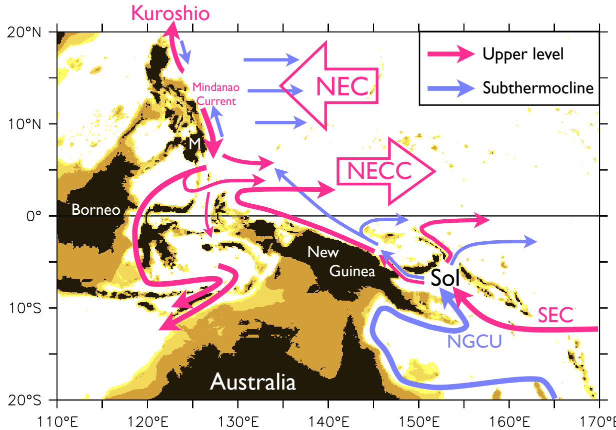


Critical processes in the east include the stratus/cold tongue front/ITCZ system and coastal upwelling.

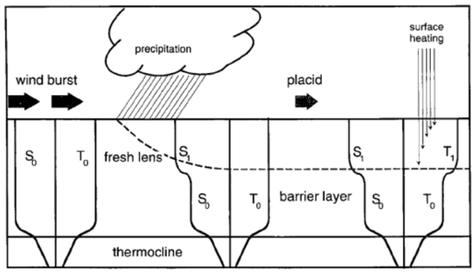
Diurnal cycle composite at 2°N,140°W: Winds, current shear.



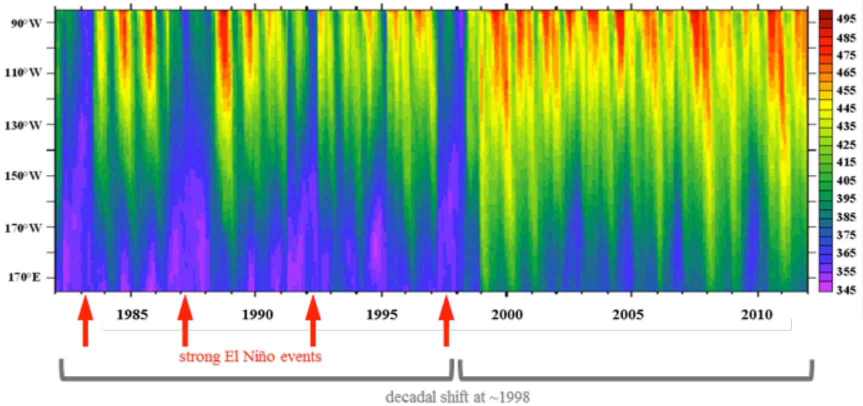
The diurnal cycle can be an important mechanism allowing downward propagation of heat and momentum fluxes.



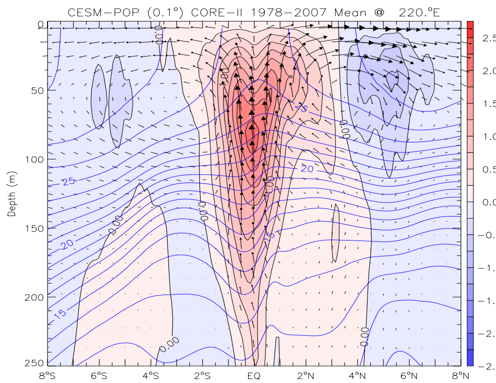
Low-latitude western boundary currents and the Indonesian Throughflow are principal conduits of tropical-subtropical interaction.



Barrier layers in the west Pacific warm pool affect the penetration of momentum fluxes.



The 30-year record of surface pCO_2 shows strong annual, interannual and decadal variability of CO2 fluxes in the east Pacific cold tongue.



Equatorial upwelling is fundamental but poorly known; its modeling is uncertain.

TPOS 2020 Tropical Pacific Observing System

Summary

Integrated design: satellites and in situ capabilities

Users will increasingly rely on gridded products

- Success depends on advances in the models and data assimilation systems.

Strategy: rely on broadscale observations as possible (satellites, Argo)

use complementary in situ obs

- for calibration, validation or verification
- for illuminating key processes

Moored array: from a grid sampling to a regime sampling strategy

Trade-offs and risks: not able to « map » from moorings

Actions to be undertaken:

-further development in surface wind and air-sea fluxes gridded products

What we need from centers like ECMWF

We need more information on the impact of observations in NWP and RA
-Paucity of studies on the impact of TMA surface met data
How is used the information content?
Guidance from DFS studies?

-How can TPOS 2020 use OSEs or OSSEs to assess array configurations?

We need guidance for the future
-Is our strategy relevant? Enough in situ data?
-What will the models and DA systems need in 2030?
for coupled DA systems?
for the next step of model development?

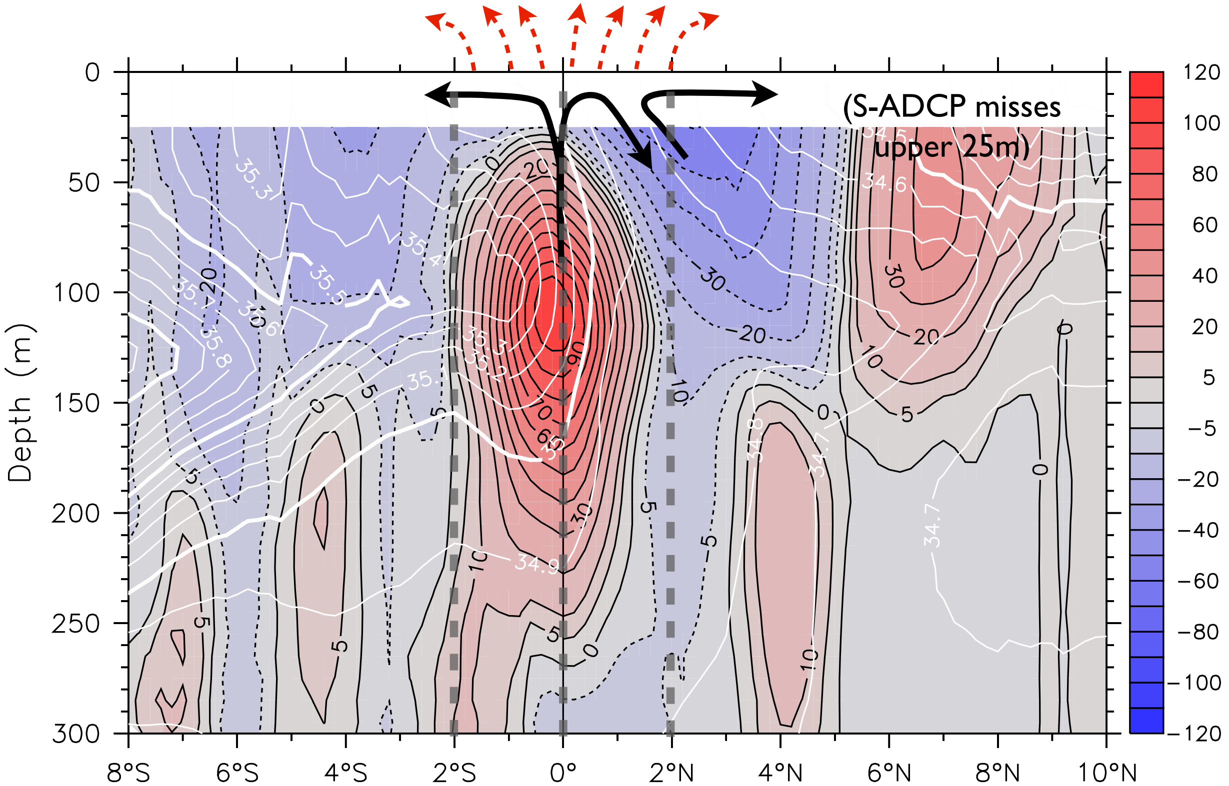
We wish to challenge models and guide parameterizations:
- Which other observations are needed?

Download pdf: www.tpos2020.org/first-report

Extra slides

Example 2: the ocean subsurface

- monitor near-equatorial physics

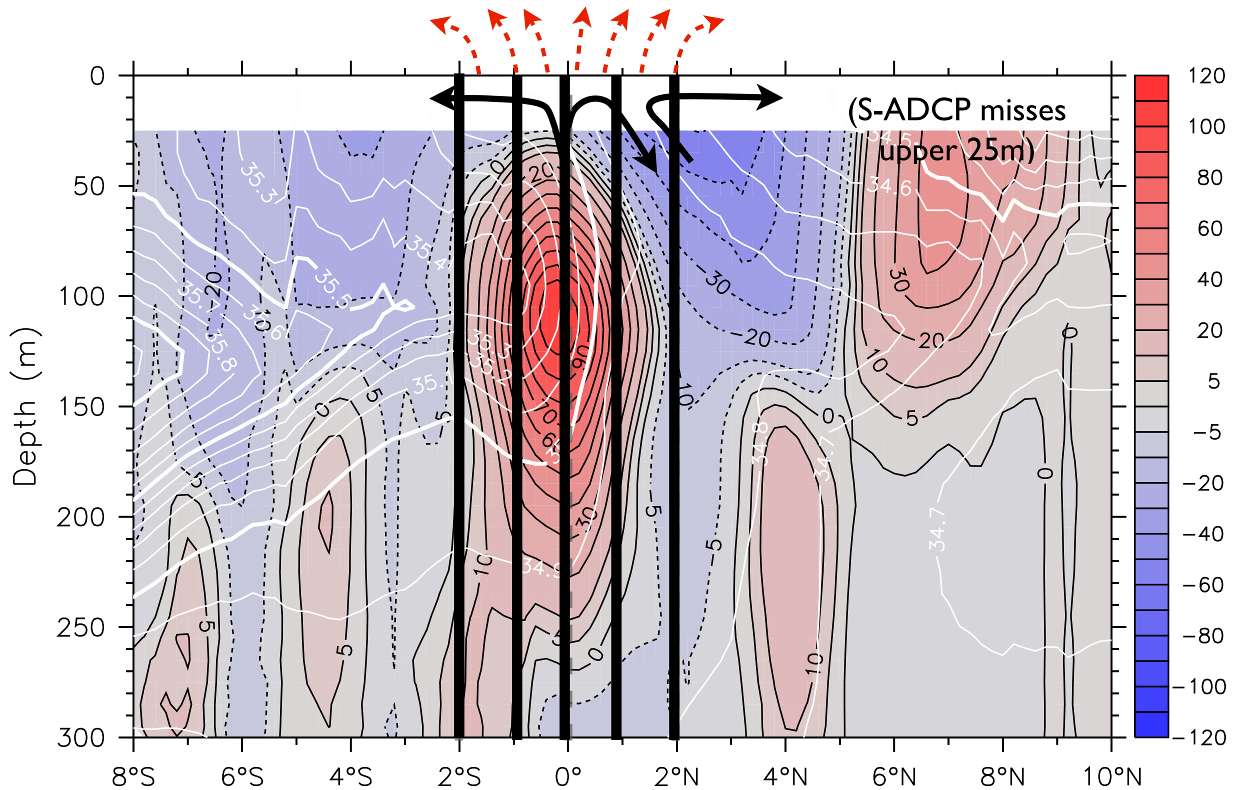


Johnson et al 2001
(Shipboard ADCP)

Mean u (colors) and Salinity at 140°W (10-yr mean)

Example 2: the ocean subsurface

- describing the full structure of the equatorial system



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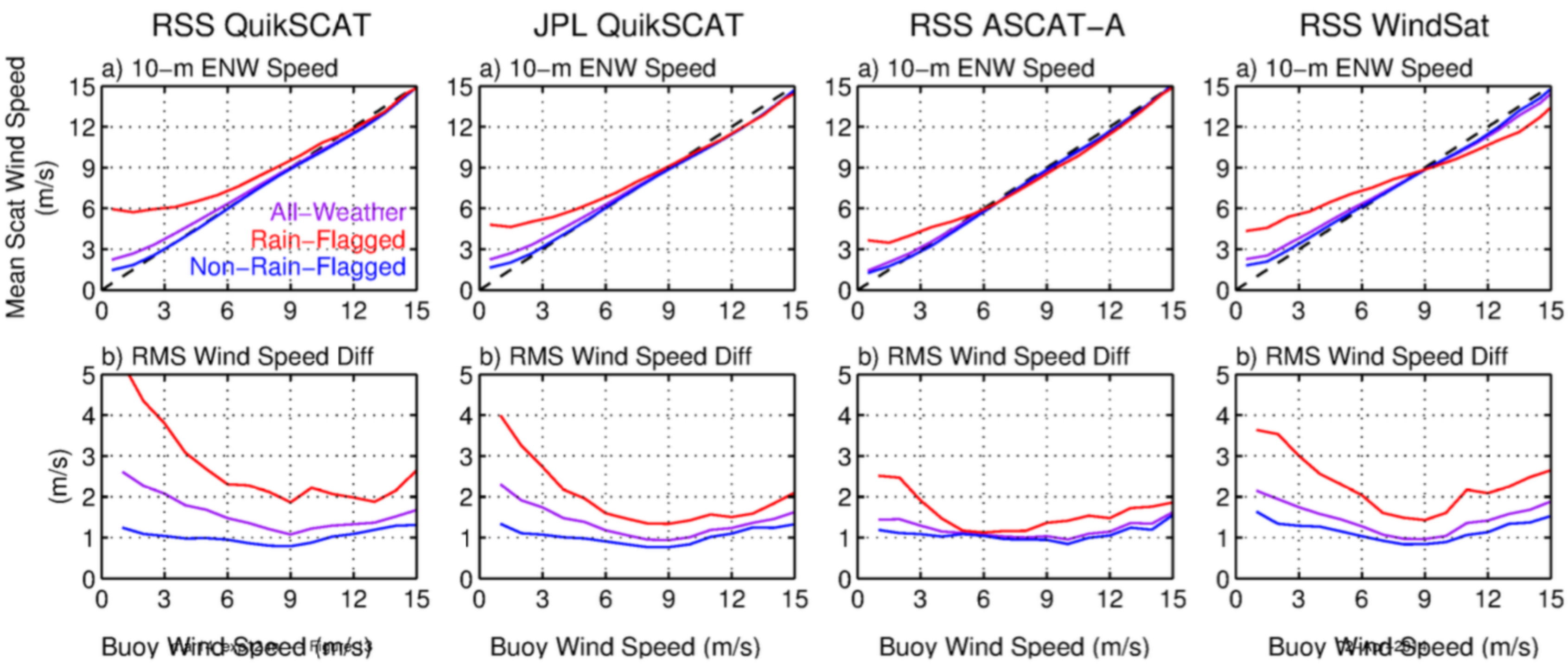

Courtesy of L. O'Neill

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