US and International CLIVAR Sponsored workshop on

Organizing committee

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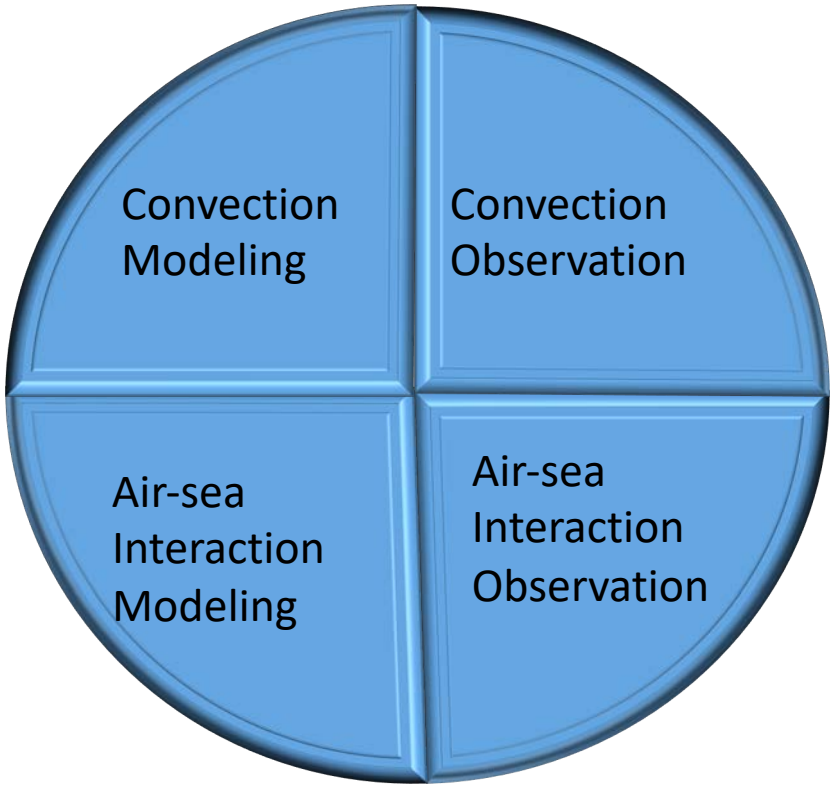
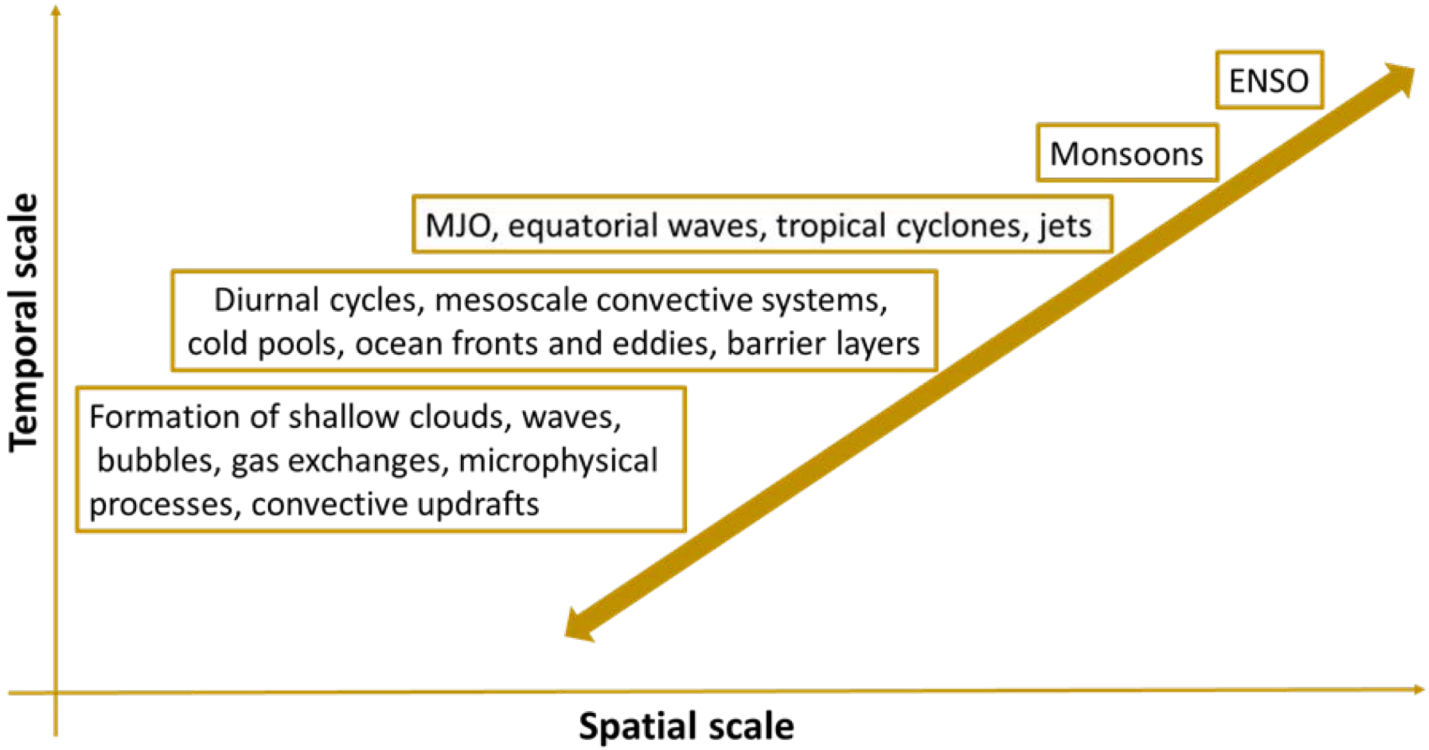
Objectives

- Review and document progress in atmospheric convection and air-sea interaction research in the tropics over the last 30 years.
- Identify outstanding issues and propose approaches for potential integrated process studies in the future that effectively use advanced technologies.
- Identify strategies for leveraging and contributing to ongoing and future broader community activities.



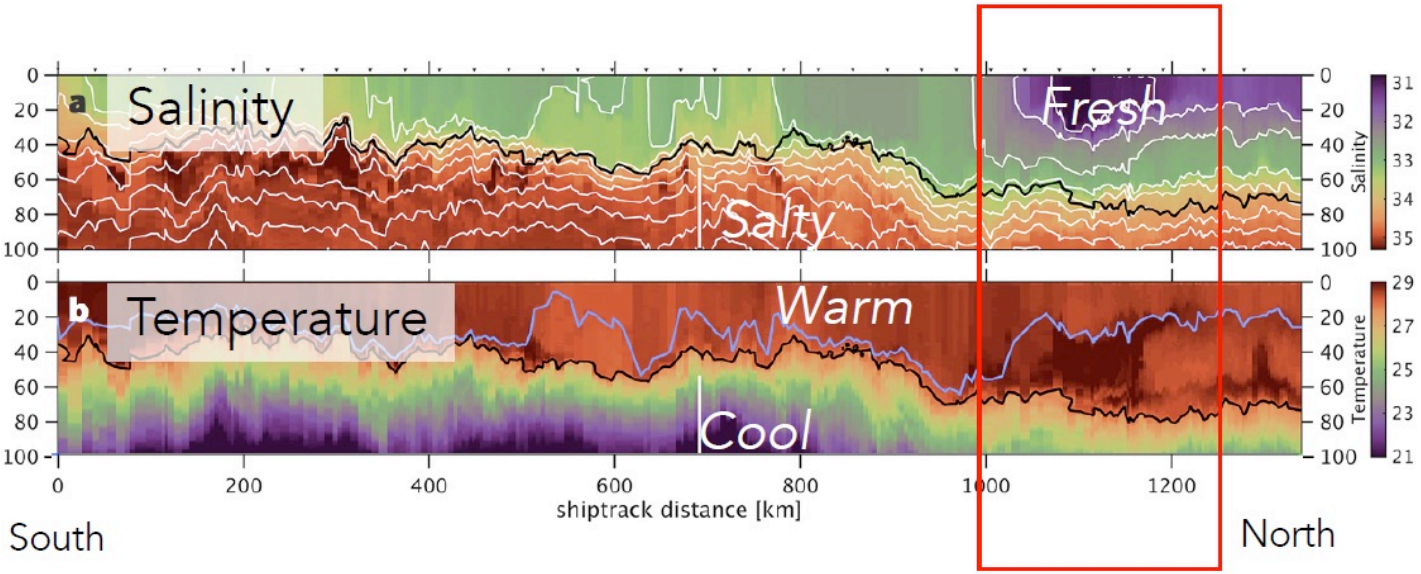
The overarching science problem:

The multi-scale nature of atmospheric convection and air-sea interaction processes



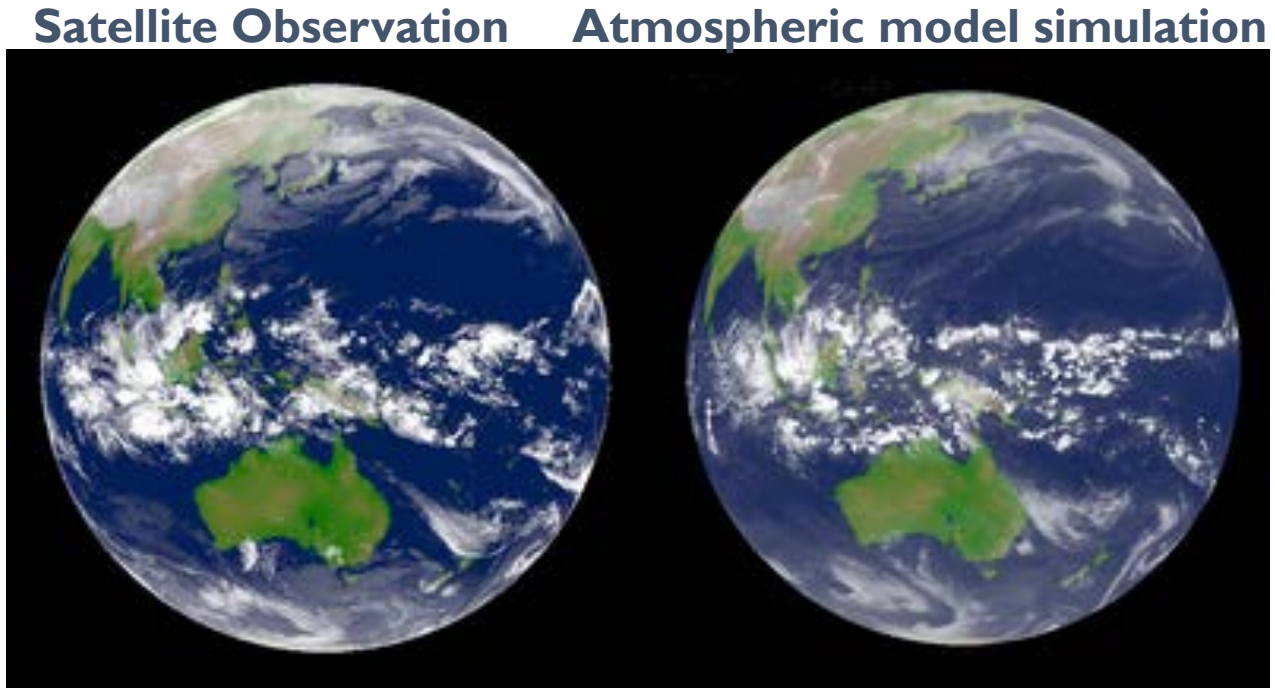
Progress is scientific understanding

- The propagation mechanisms of the MJO
- The relationship between precipitation and precipitable water at a broad range of scales.
- Improved understanding of the vertical distributions of salinity and temperature in the upper ocean and their roles in air-sea interaction were also noted as important areas of progress.



Methodological innovations in modeling/parameterization

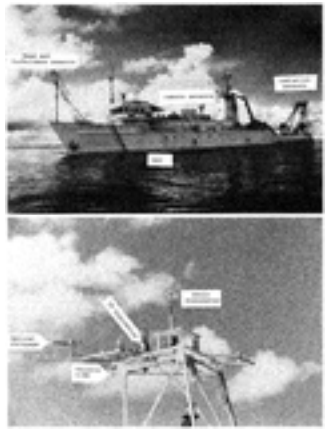
- On the modeling front, innovations include convection- and eddy-resolving models, superparameterization, bulk representation of fluxes, stochastic perturbation ensembles, stochastic cloud population models.



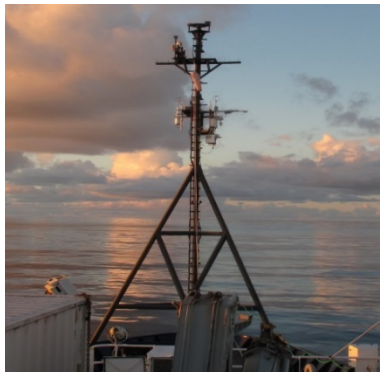
A global cloud-resolving model simulation. (Miura et al. 2007)

Observational Technological innovations

- Modern technology has enabled measurements of the vertical structure of the ocean mixed layer, the atmospheric boundary layer, and the troposphere as a whole.
- Ground and space-borne dual polarization radars, lidars, and millimeter cloud radars.
- Autonomous sea-surface platforms (e.g., wavegliders, Saildrones, drifters) and unmanned aerial vehicles (UAVs) equipped with various kinds of sensors.
- They can perform adaptive sampling to augment, and potentially replace, measurements from research ships, sometimes at a fraction of the cost.



1992 TOGA COARE

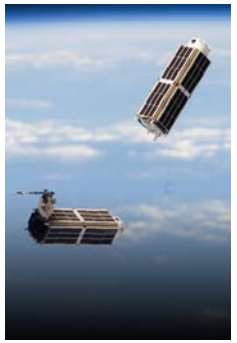


2017 NASA SPURS

Air-Sea Interaction Spar (ASIS)

UAV

AEOLUS satellite



CubeSat

Specific Scientific Problems:

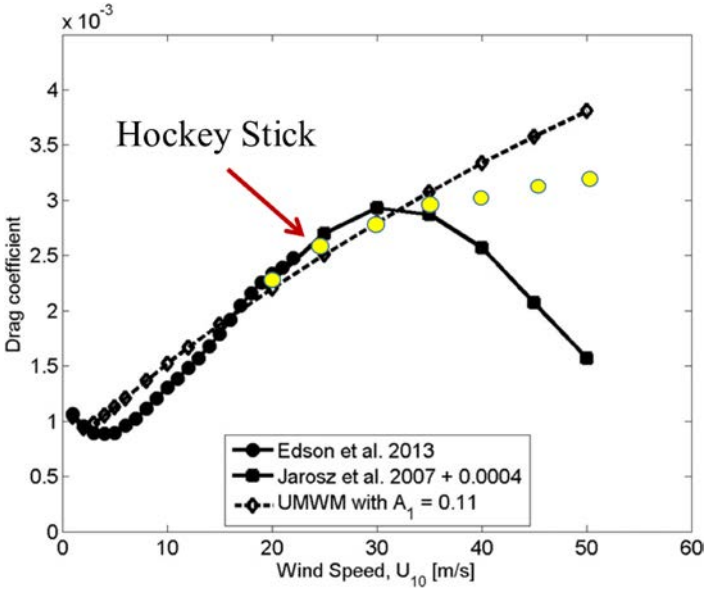
- The roles of momentum and thermodynamic feedbacks in the zonal movement of the western Pacific Ocean warm and fresh pool and their implications for the **onset of El Nino**.
- The multi-scale processes affecting the **variability and predictability of the MJO** such as its seasonality and relationships with ENSO, the Quasi-biennial Oscillation (QBO), local air-sea coupling, and the diurnal cycle over the Indo-Pacific Maritime Continent.
- The net effect of small-scale phenomena (e.g., SST fronts, atmospheric cold pools, precipitation- or river-induced surface freshening,
- The coupled atmosphere-wave boundary layer in the **presence of swell and high wind**.
- The formation and evolution of **ocean barrier layers** and their potential effects on air-sea interactions at large or long time scales as well as under extreme conditions (high winds and rain).

Observational issues

- Satellites still have limitations in **observing the near-surface variables** (e.g., temperature and humidity) that are required for accurate estimate of surface turbulent fluxes.
- The **vertical and temporal resolutions of Argo floats** are not sufficient to reveal key details of stratification and variability near the ocean surface.
- Current measurements of the atmospheric boundary layer structure are mainly from towers that are **extremely limited in spatial coverage and from ships that are expensive and allow only short-duration sampling**, leaving much of the tropical ocean unsampled.

Modeling issues

- Entrainment of environmental air into convection
- Parameterization need to capture the **full range of variability including extremes** not just relationships between mean values.
- A coupled boundary layer problem with a permeable layer between them the effect wave dynamics should be built in the parameterization.
- Ocean model representation of barrier layers, mixing.

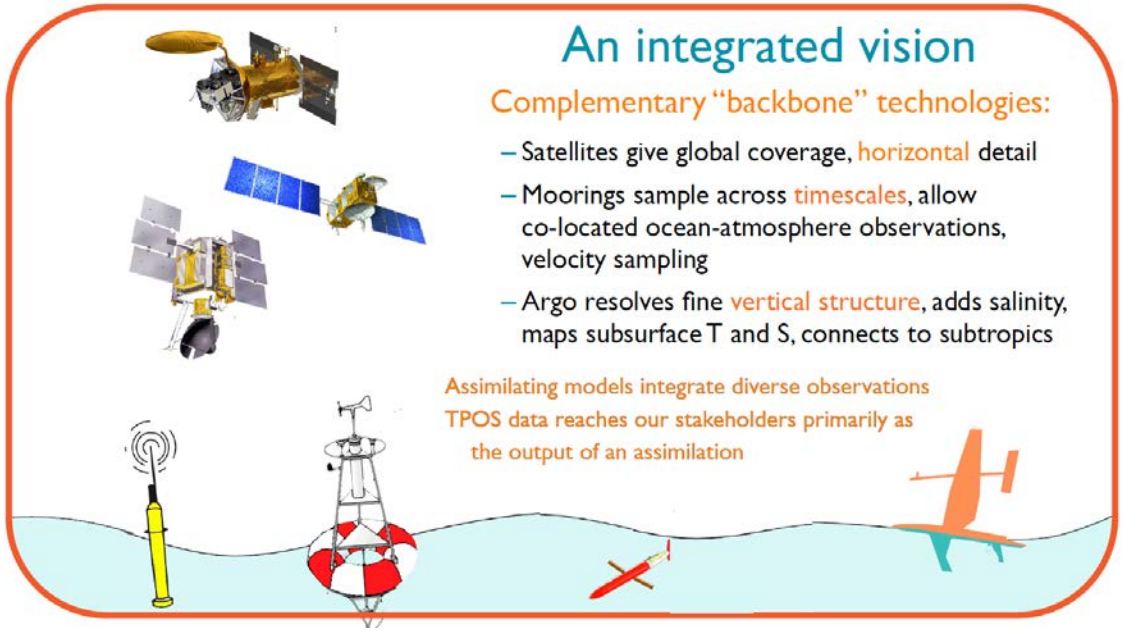


Recommendations:

Recommendation 1: A tropical supersite for a multi-scale integration of modeling and observations and for process studies

A tropical observational and modeling "supersite" was proposed to facilitate multi-scale integrated modeling and observational studies.

1. **Application:** high resolution coupled data assimilation systems and forecast models but also for process studies as well as model validation and improvement.
2. **Strategy:** Co-location of field campaign and pilot study instrumentation with the sustained observing system.



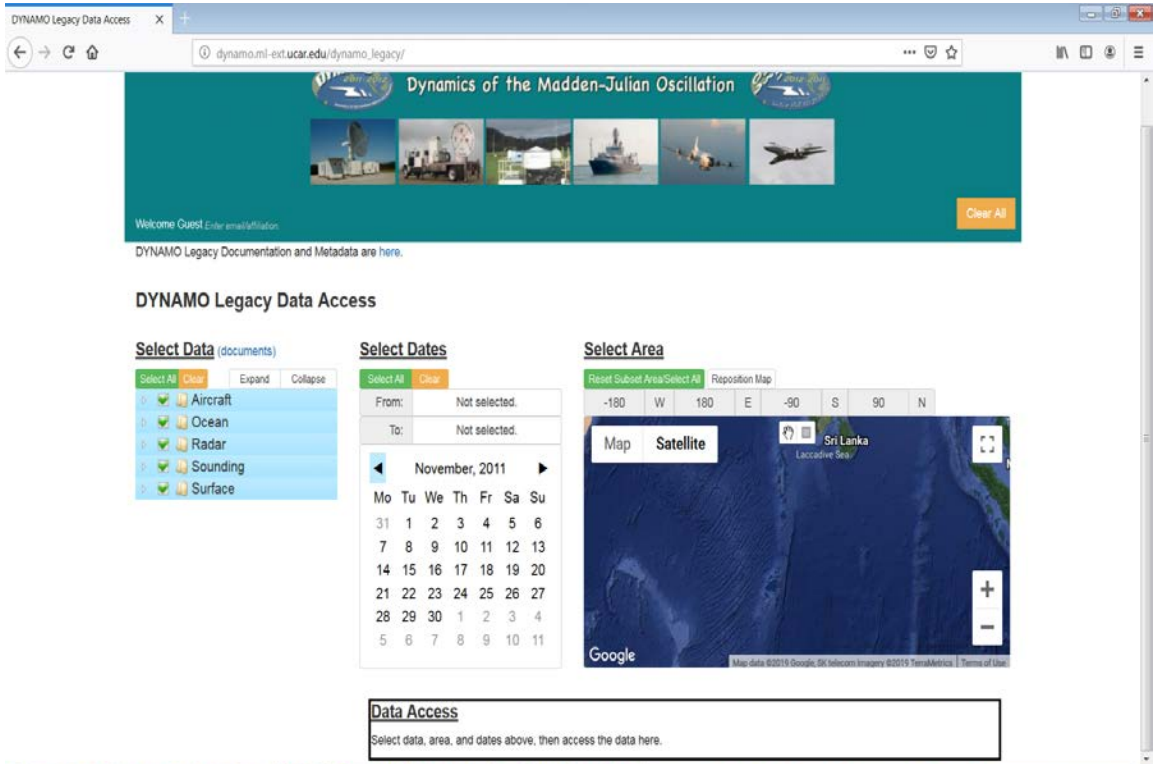
Recommendation 2

- Investment in the development of properly equipped aerial and oceanic autonomous vehicles is critical for observations over remote tropical oceans.
- Deployment of such autonomous platform can be optimized by virtual field campaigns that simulate sampling strategies through existing gridded numerical model and satellite products.

The Saildrone is an autonomous sailing drone currently being explored as a tool to provide high quality oceanic and atmospheric observations

Recommendation 3

- Significant national and international coordination and investment are required to maintain and curate the collected observational and coupled assimilation datasets.
- A fully supported center or organization would create and maintain a searchable database of measurements.
- As applications of machine learning and artificial intelligence, the availability of easily accessible and comprehensible high quality data-sets for training and validation of algorithms will be critical.



Recommendation 5: Outreach

- Societal value of understanding atmospheric convection and air-sea interaction over the tropical oceans needs to be articulated in a way that is easily understandable by the general public and policy makers.
- The researchers' engagement with the local communities where the measurements are to take place, and consideration for the communities' need for education and capacity development

AMIE/DYNAMO (Maldives)

Recommendation 5

- The interactions between convection and air-sea interaction communities need to be sustained by holding "**atmospheric convection and air-sea interactions over the tropical oceans**" sessions and workshops during regular meetings of the scientific societies such as **American Geophysical Union, European Geosciences Union, and Asia-Oceania Geosciences Society**.

Acknowledgements

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