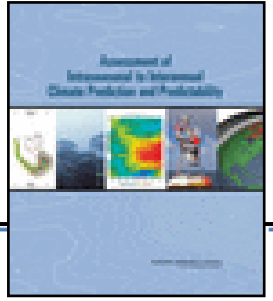
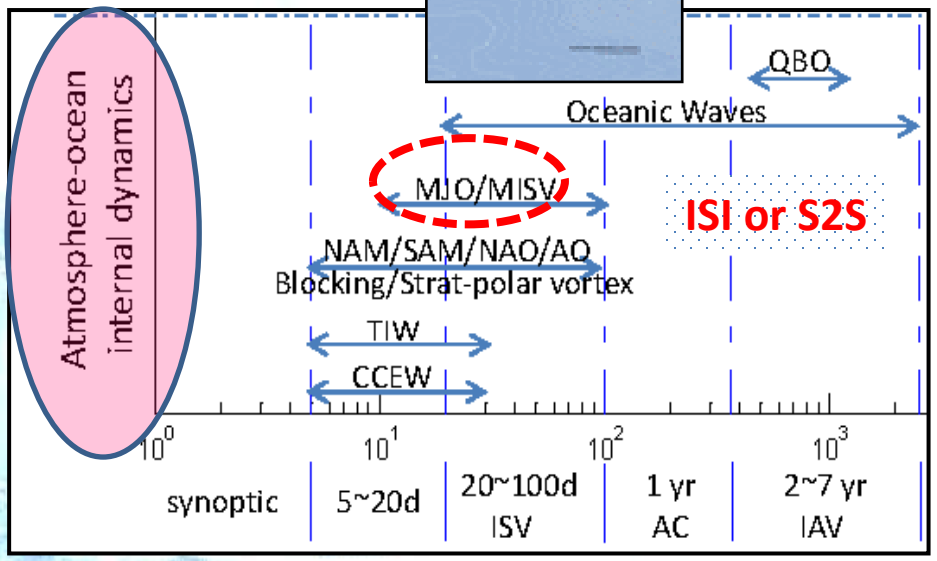
Is the MJO an atmospheric internal phenomenon or an atmosphere-ocean coupled system?

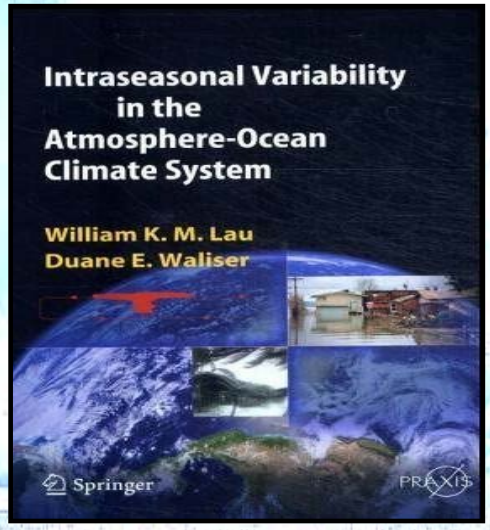




(1), Atmospheric Internal Phenomenon
(Lau and Peng 1987; Chang and Lim 1988; ..... ; NAS 2010).

(2), Atmosphere-Ocean Coupled System
(Krishnamurti et al. 1988, ...
Lau and Waliser 2011).

(3), ??



Courtesy to Owen Shieh for the photo

The Effects of Air-Sea Coupling on the MJO Vary Event-by-Event: A New Perspective Revealed from the DYNAMO/CINDY Field Campaign

Joshua Xiouhua Fu

University of Hawai'i Mānoa | soest university of hawai'i | iprc International Pacific Research Center

K. Kikuchi, J. Y. Lee, J.-W. Xu, J. Li, B. Wang, W. Q. Wang, & S. Weaver

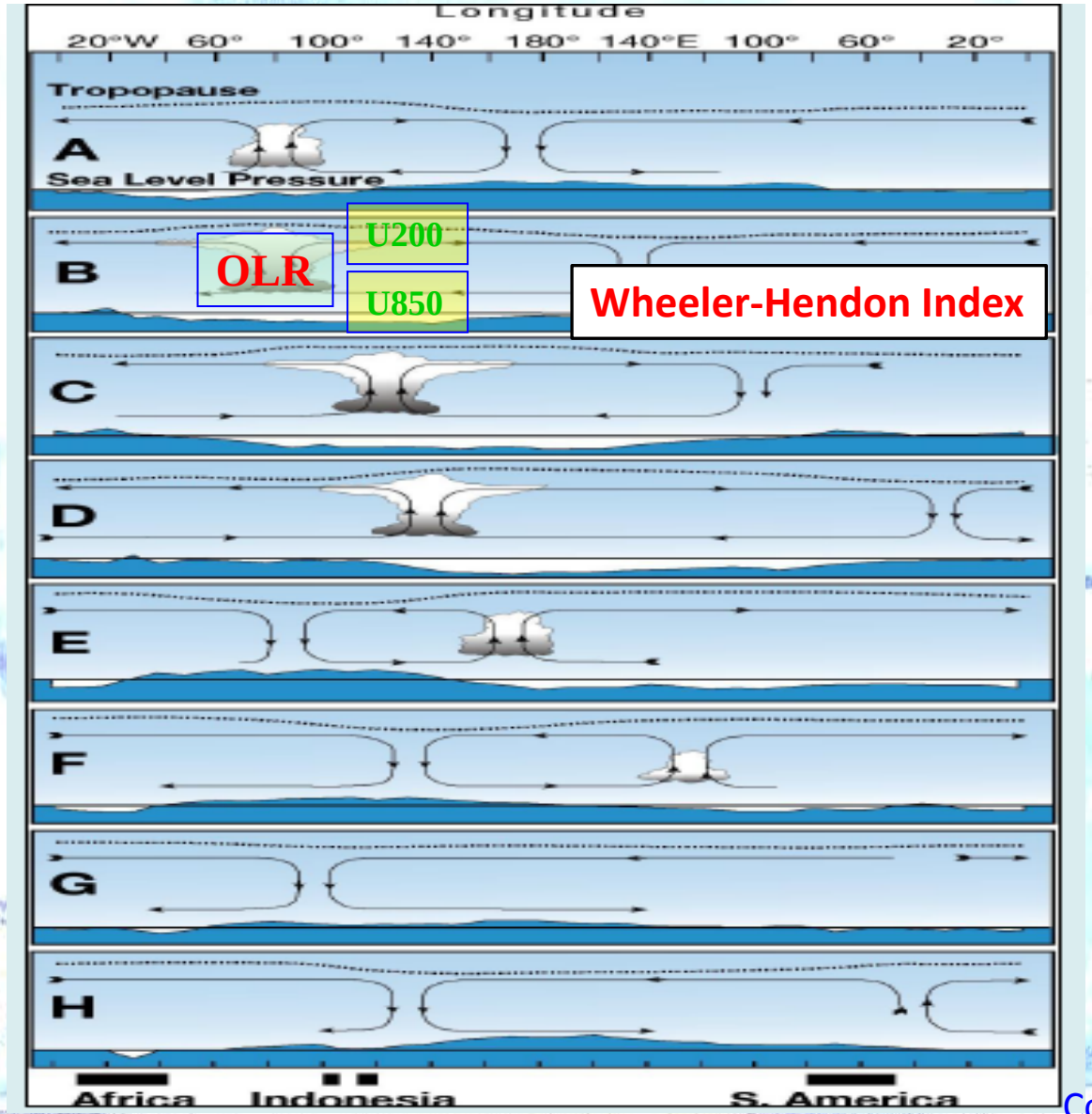
Madden-Julian Oscillation

Courtesy of Duane Waliser

R. Swinbank, T. N. Palmer, and M. K. Davey, 1988: Numerical Simulations of the **Madden and Julian Oscillation**. *J. Atmos. Sci.*, **45**, 774-788

N.-C. Lau, I. M. Held, and J. D. Neelin, 1988: The **Madden-Julian Oscillation** in an Idealized General Circulation Model. *J. Atmos. Sci.*, **45**, 3810-3832

2-D Schematics of The MJO



0 day

5 day

11 day

16 day

22 day

28 day

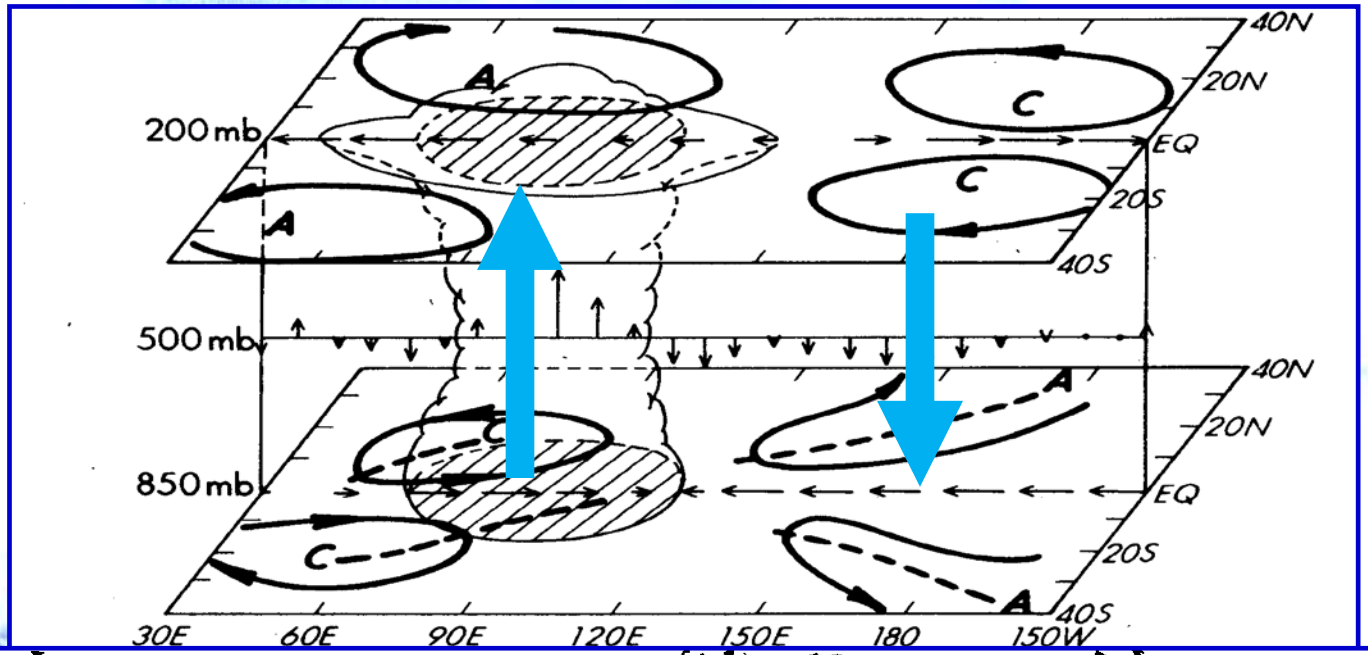
34 day

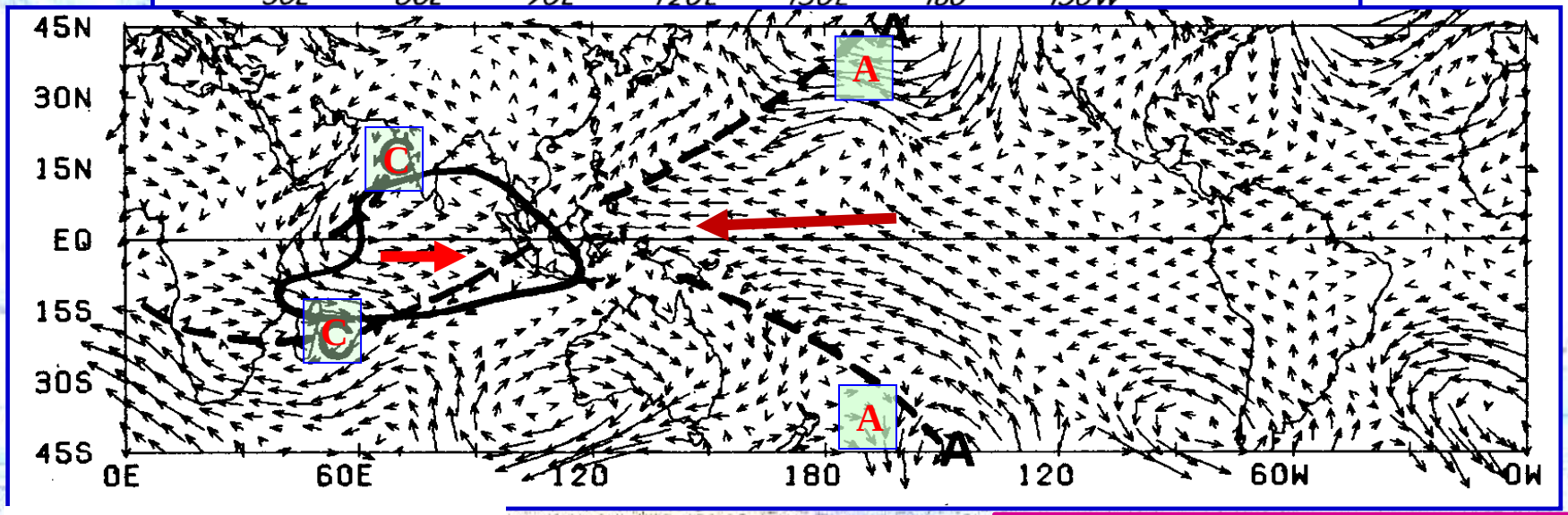
40 day

Courtesy of Michael McPhaden

Madden and Julian (1971, 1972, 1994)

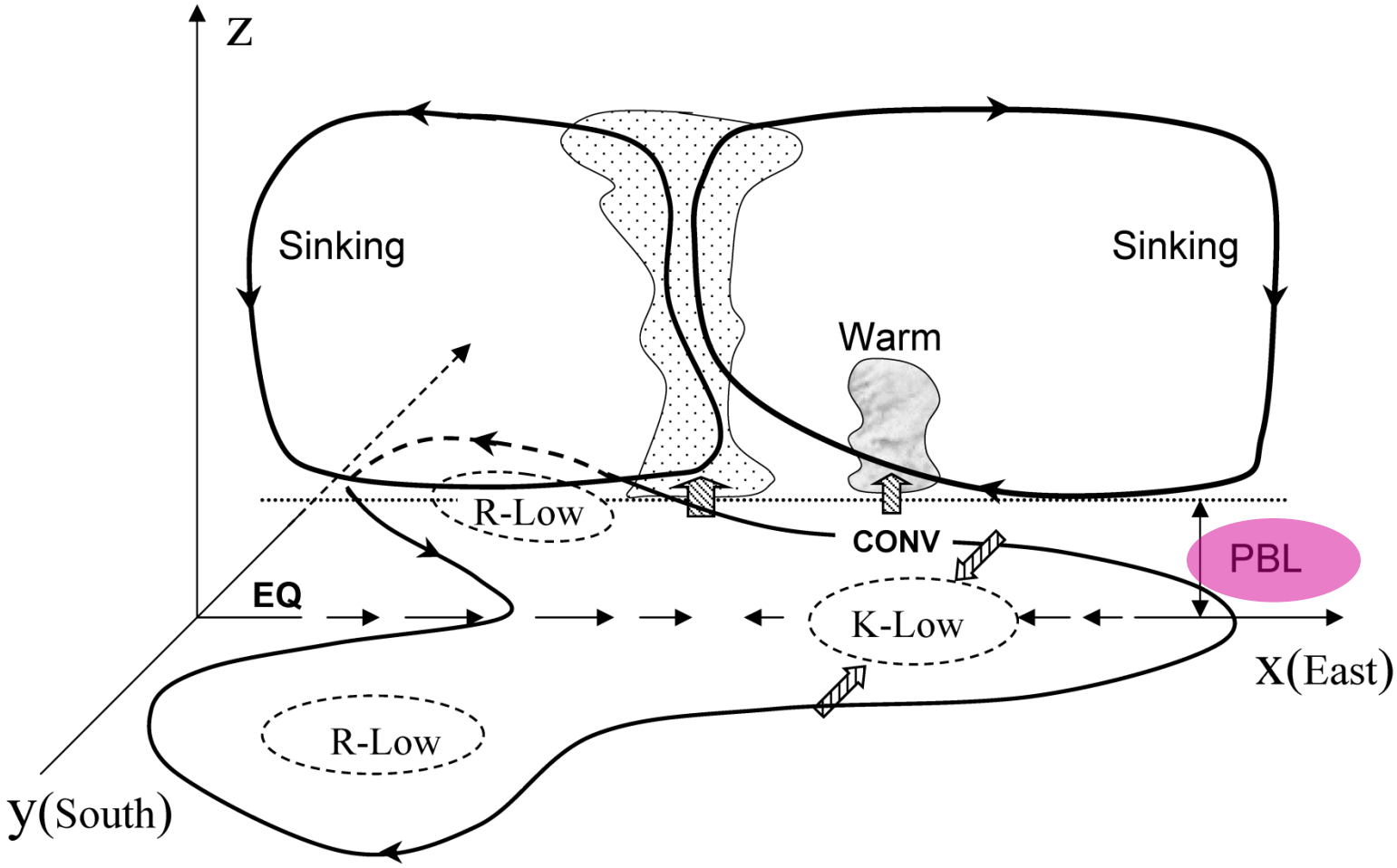
3-D Circulations of the MJO





Rui and Wang (1990)

Frictional Wave-CISK Theory for the MJO

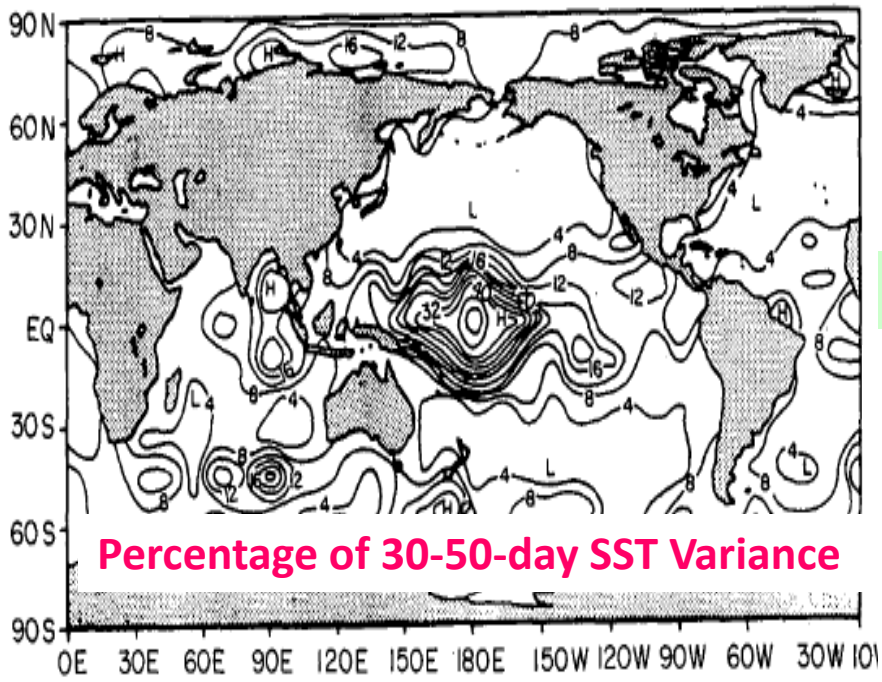


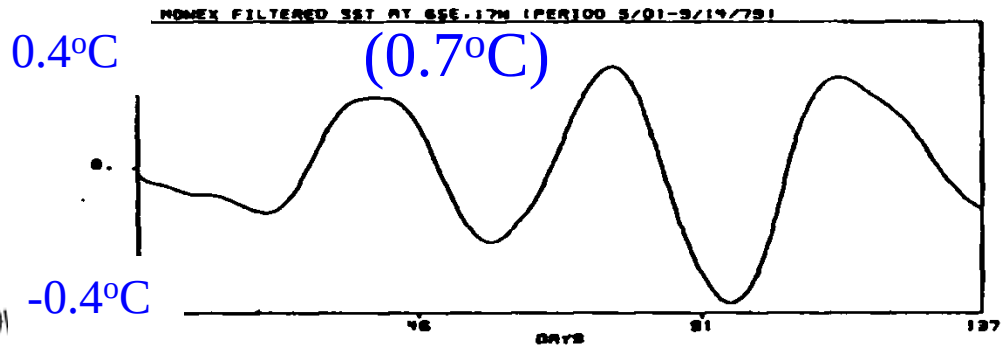
Wang (1988)

What have we learned from the TOGA-COARE field campaign and follow-up modeling studies?

"Air-sea interaction on the time scale of 30 to 50 days"

Krishnamurti et al. (1988)





It is conceivable that a combination of internal instabilities and external SST forcing on the intraseasonal time scale (generated by atmosphere-ocean coupling) may enhance the atmospheric response towards an eventual satisfactory simulation of intraseasonal oscillation (e.g., MJO).

MJO-Ocean Interaction Observed during TOGA-COARE

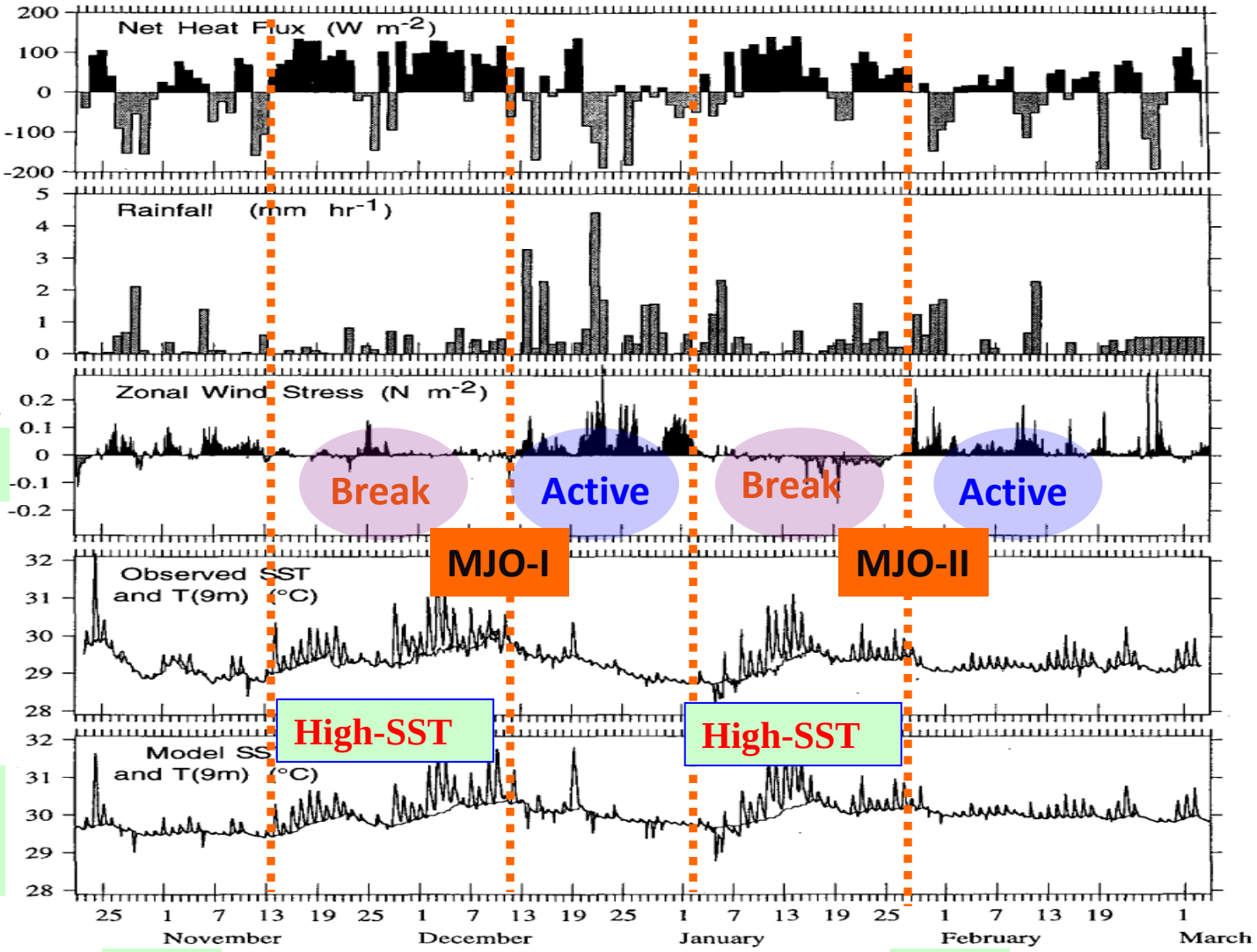
Net surface heat flux

Rainfall

Zonal wind stress

Observed SST

1-D ocean model simulation



Anderson et al. (1996)

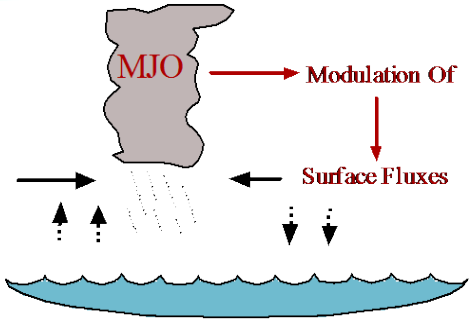
Location: (1°45′S, 156°E)

Coupled Modeling Studies

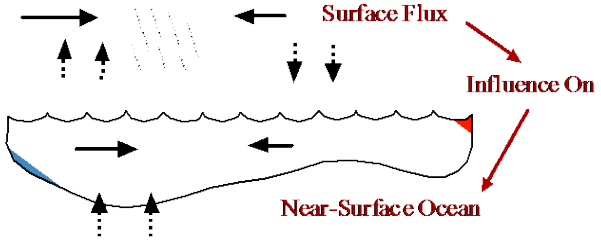
Flatau, Flatau, Phoebus and Niiler1997
Waliser, Lau, and Kim, 1999
Kemball-Cook, Wang and Fu, 2002
Hendon, 2000
Fu, Wang, Li and McCreary, 2003
Inness and Slingo, 2003
Fu and Wang, 2004
Zheng, Waliser, Stern and Jones, 2004
Maloney and Sobel, 2004

MAY - IMPORTANT TO COHERENCE, PHASE SPEED, AND/OR STRENGTH

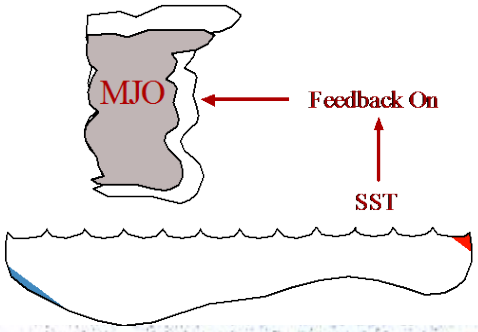
I.



II.

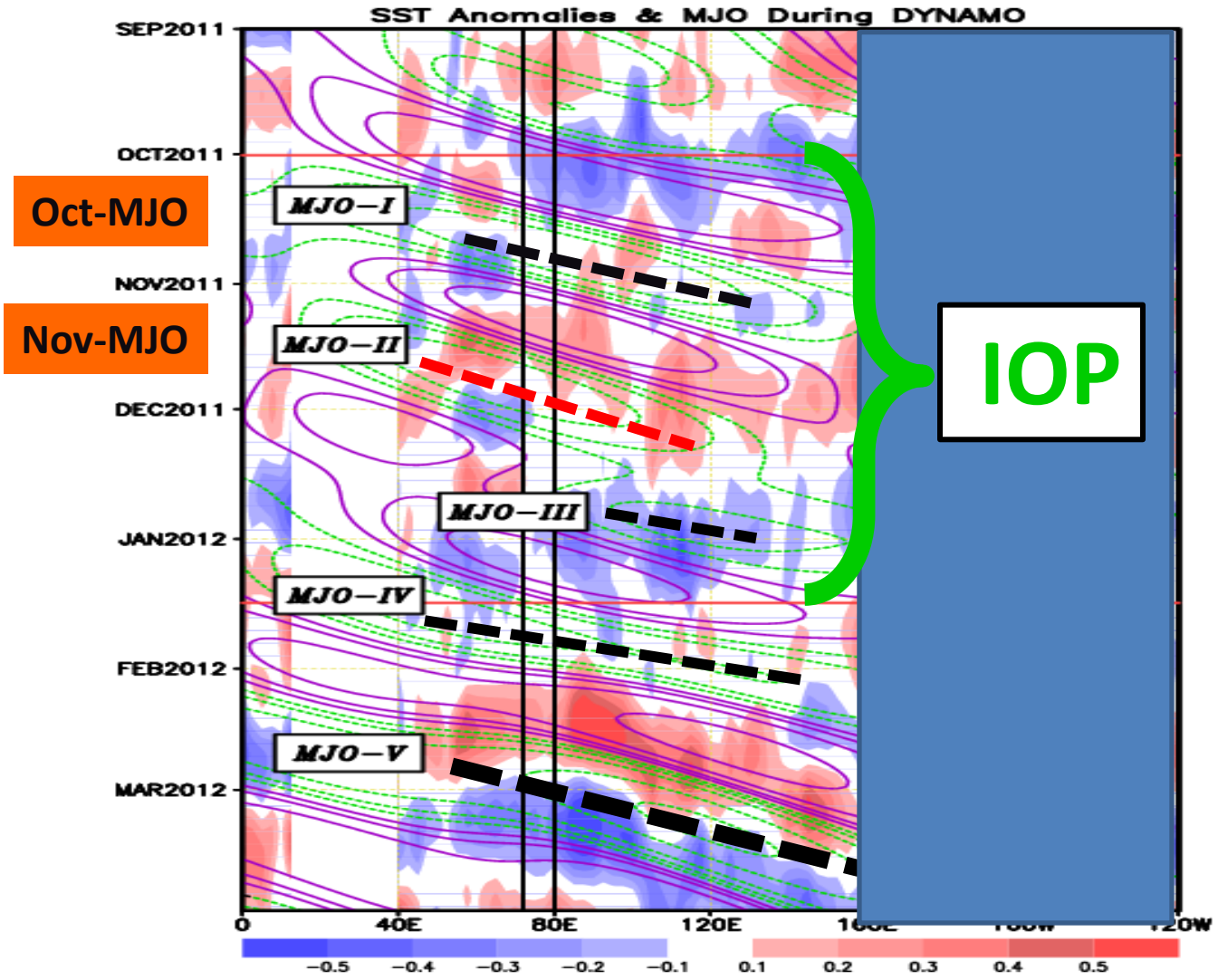


III.



Courtesy of Duane Waliser

SST and MJO-filtered OLR Anomalies in DYNAMO/CINDY Period

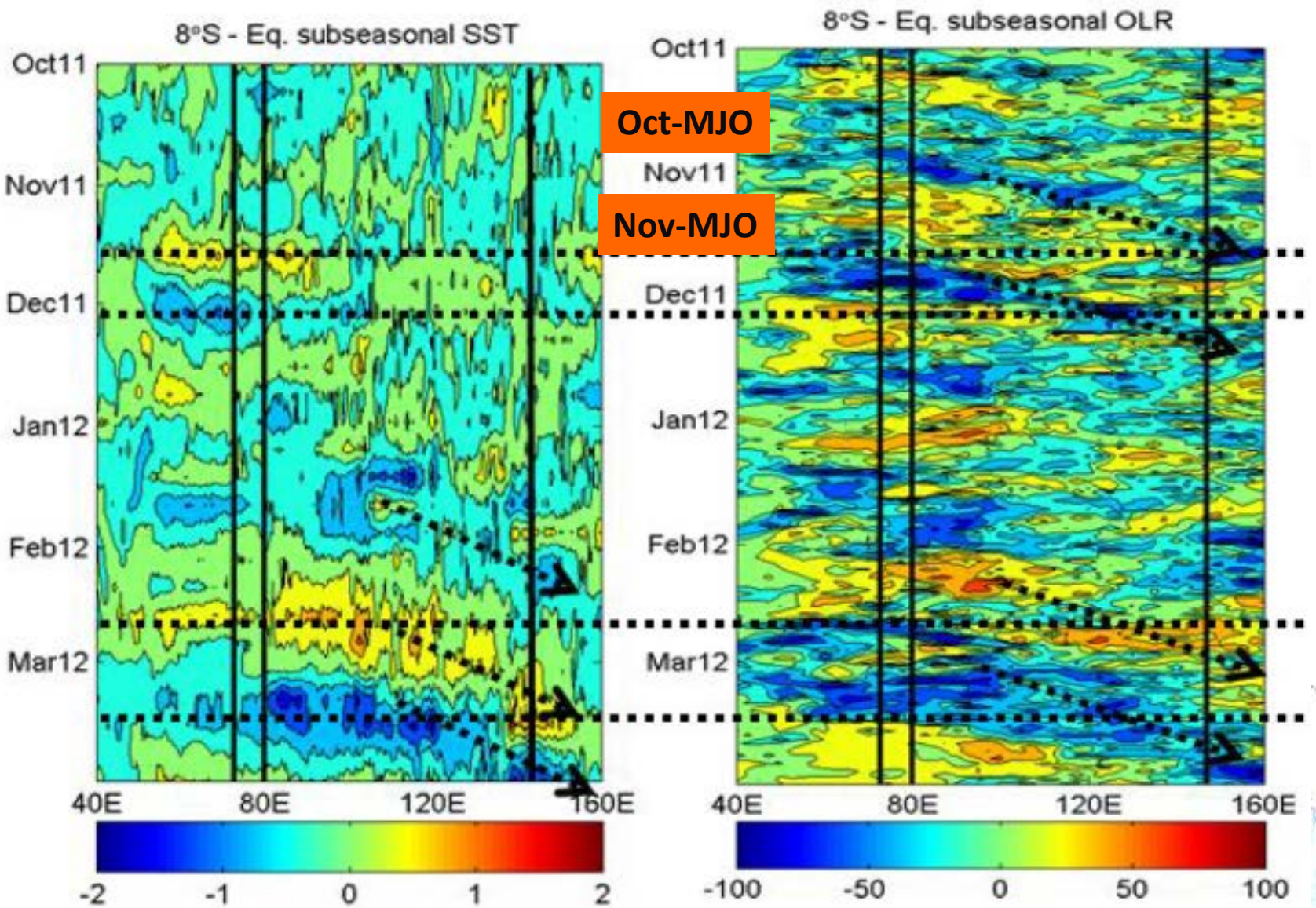


SSTA (shading); OLRA (contours)

Fu et al. (2014)

SSTA

OLRA



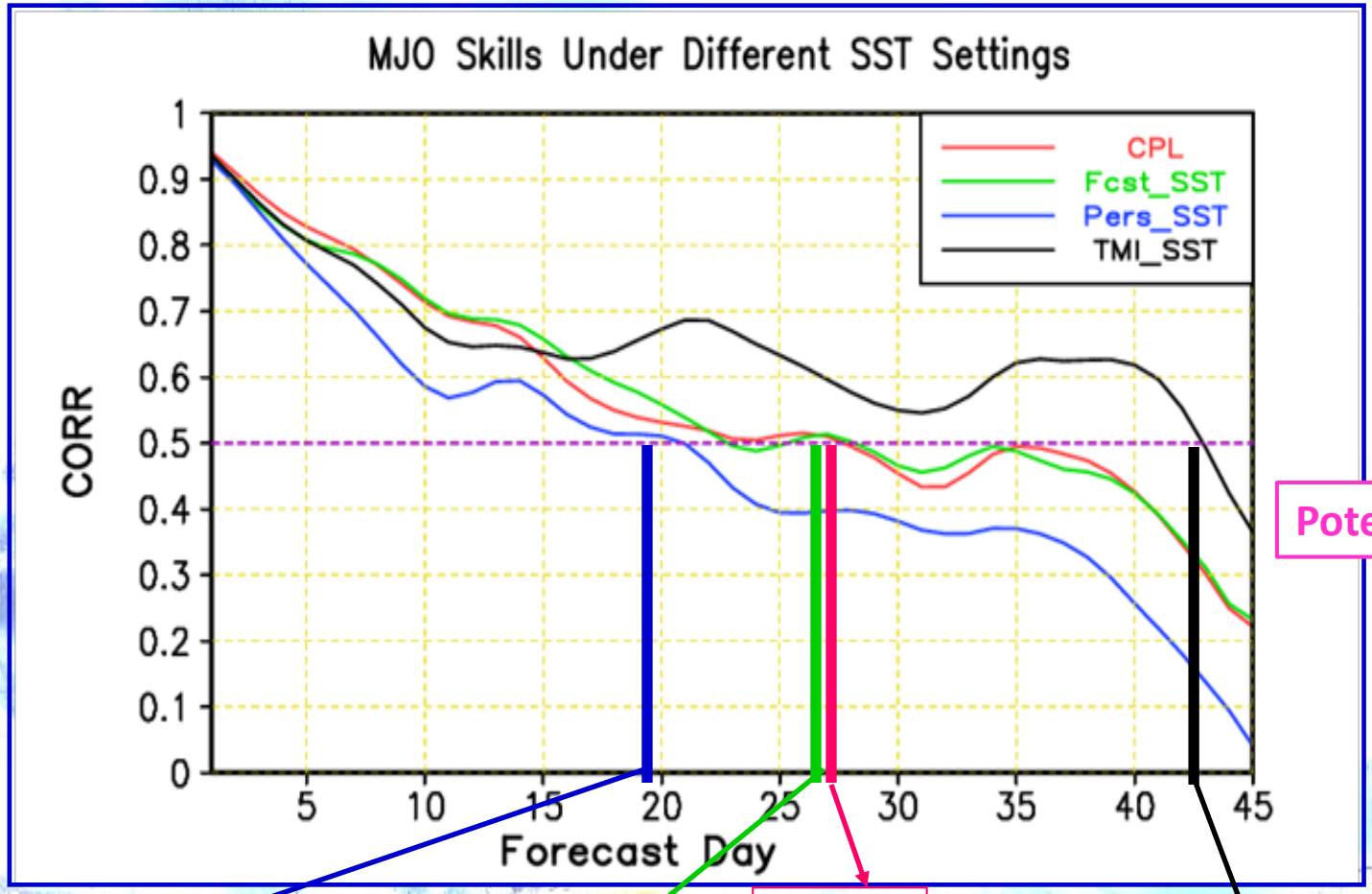
Gottschalck et al. (2013)

To assess the impact of atmosphere-ocean coupling on MJO prediction skill with "coupled" and "uncoupled" GCM experiments.

Numerical Experiments with Different SST Settings

Names of Experiments	SST Settings
CPL	Atmosphere-ocean "coupled" forecasts.
Fcst_SST (or fsst)	"uncoupled" forecasts driven by daily SST derived from the 'cpl' forecasts.
Pers_SST (or psst)	"uncoupled" forecasts driven by persistent SST.
TMI_SST (or osst)	"uncoupled" forecasts driven by observed daily TMI SST.

SST-Feedback Significantly Extends MJO Prediction Skill



Potential

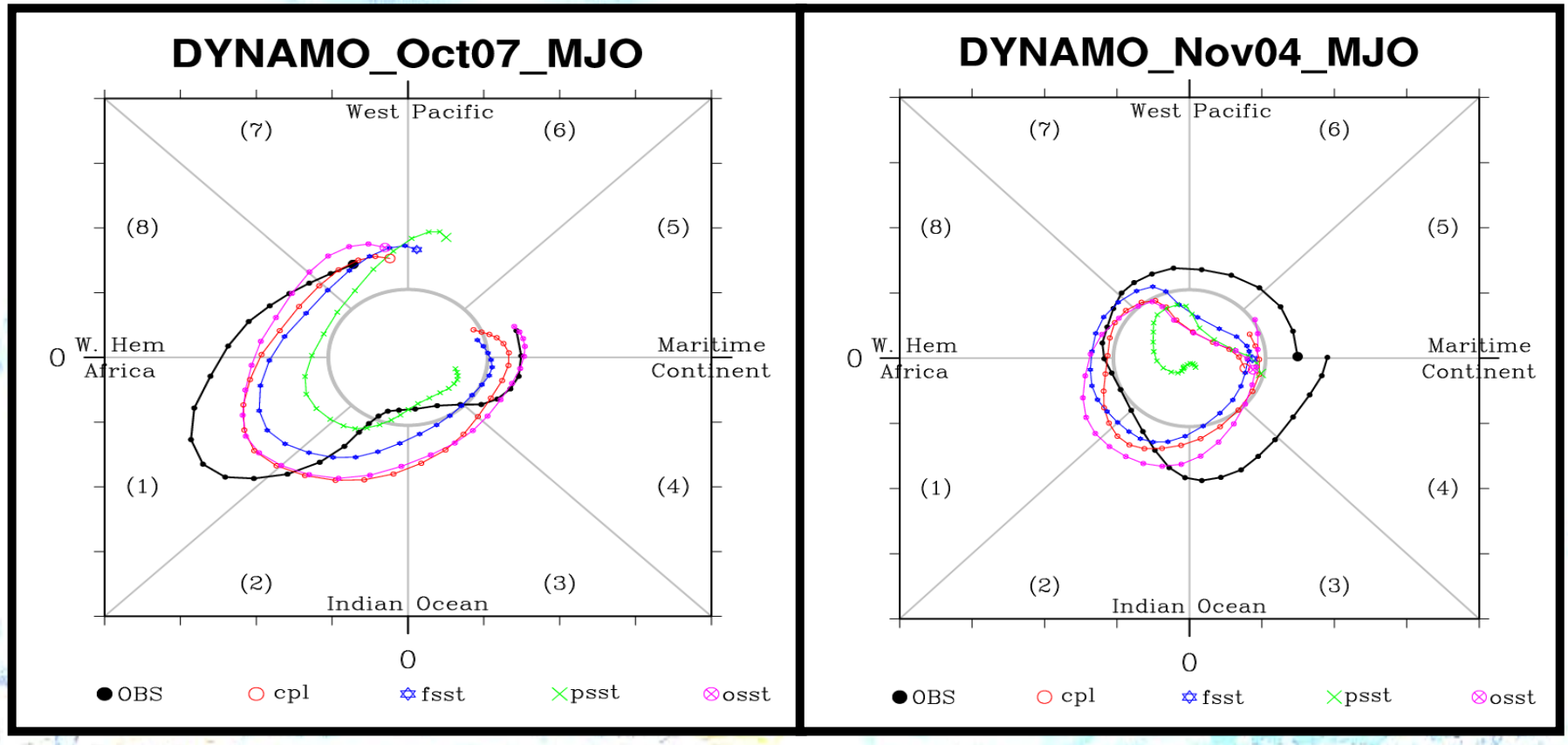
Persistent SST

CPL

Observed Daily SST

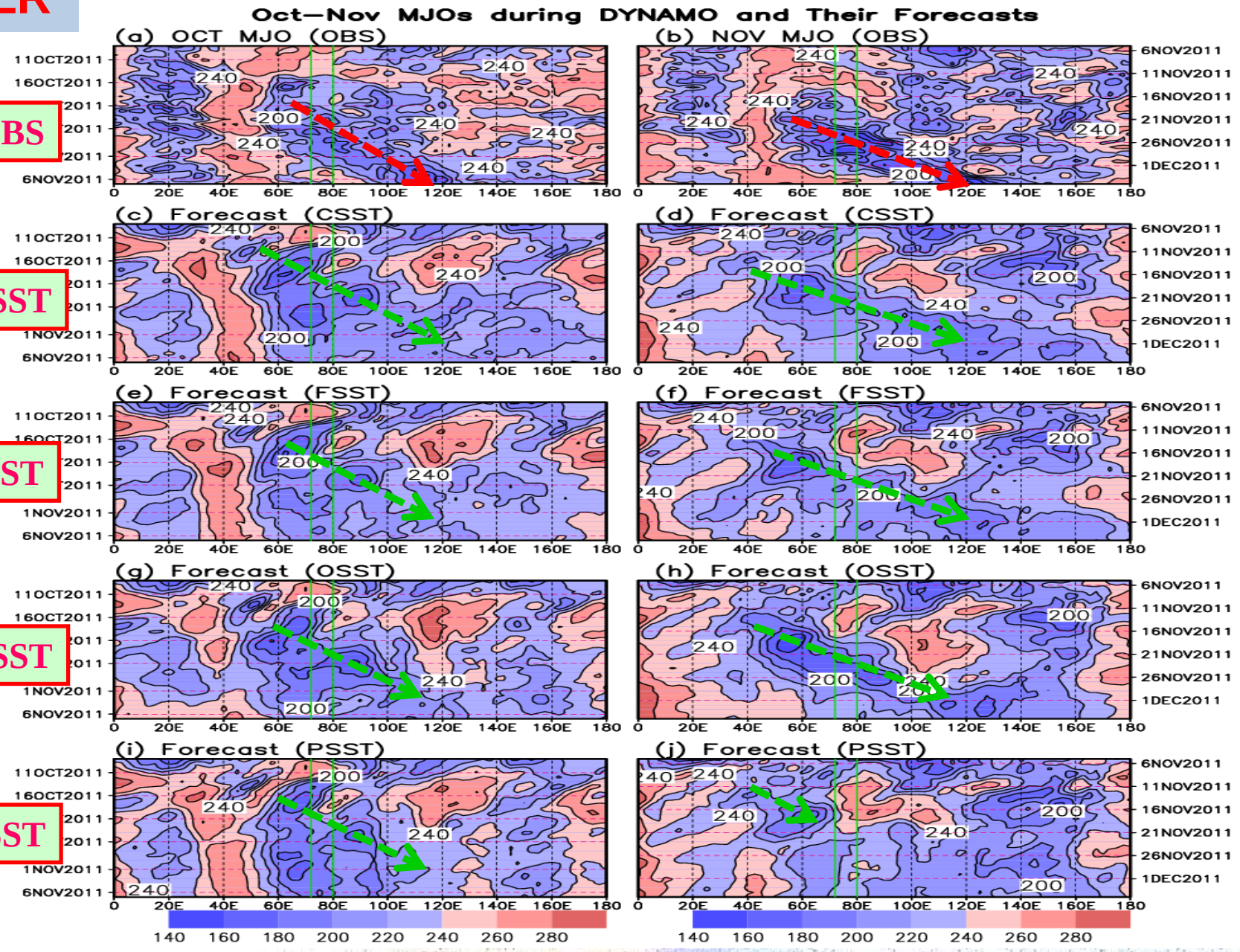
Forecasted Daily SST

Different Impacts of Air-sea Coupling on the October and November MJO Events



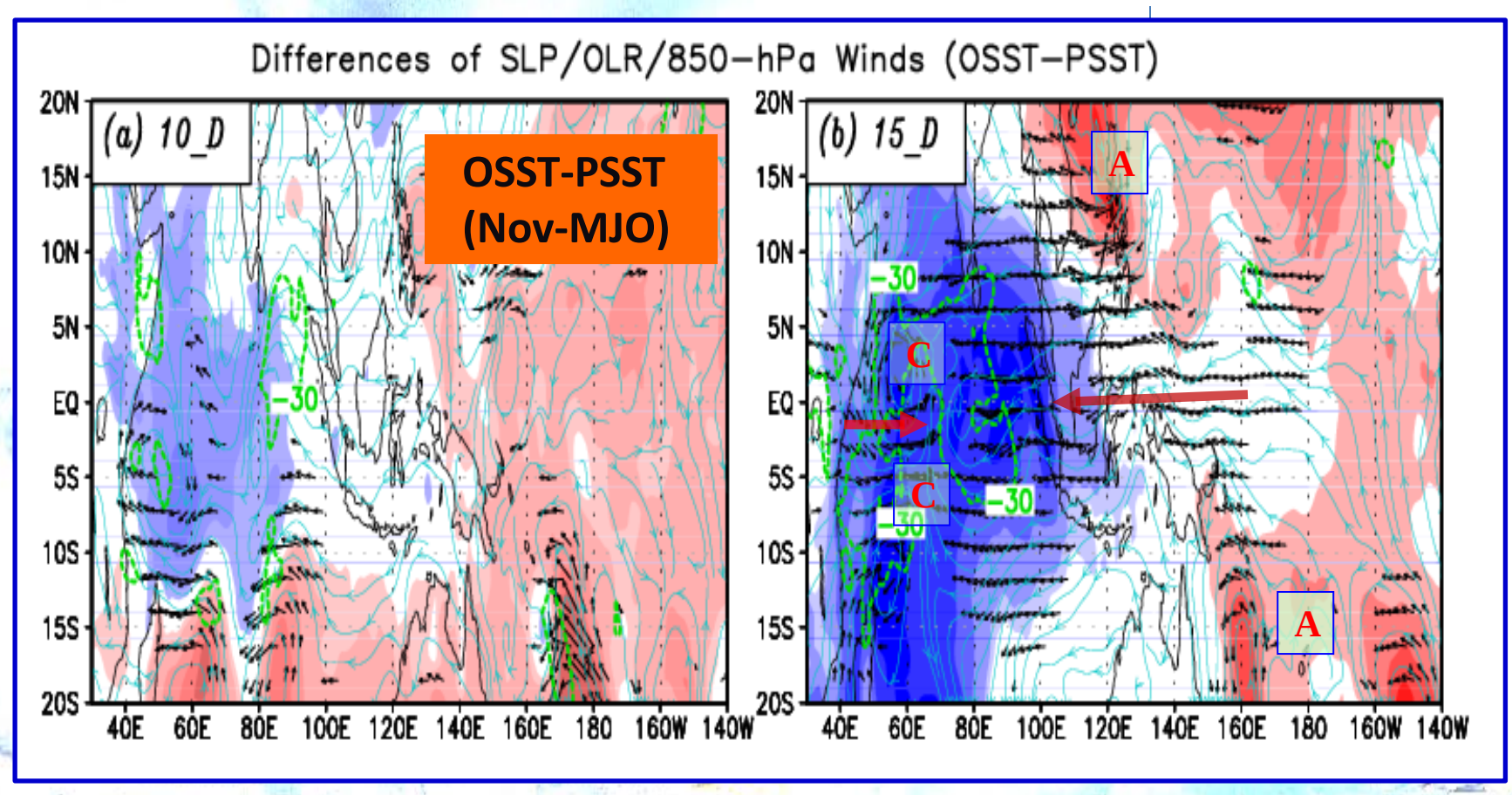
Fu et al. (2014)

OLR



Fu et al. (2014)

SST Feedback Enhances Kelvin-Rossby-wave Couplet



SLP (shading); Convection (dashed green lines)

Fu et al. (2014)

Summary

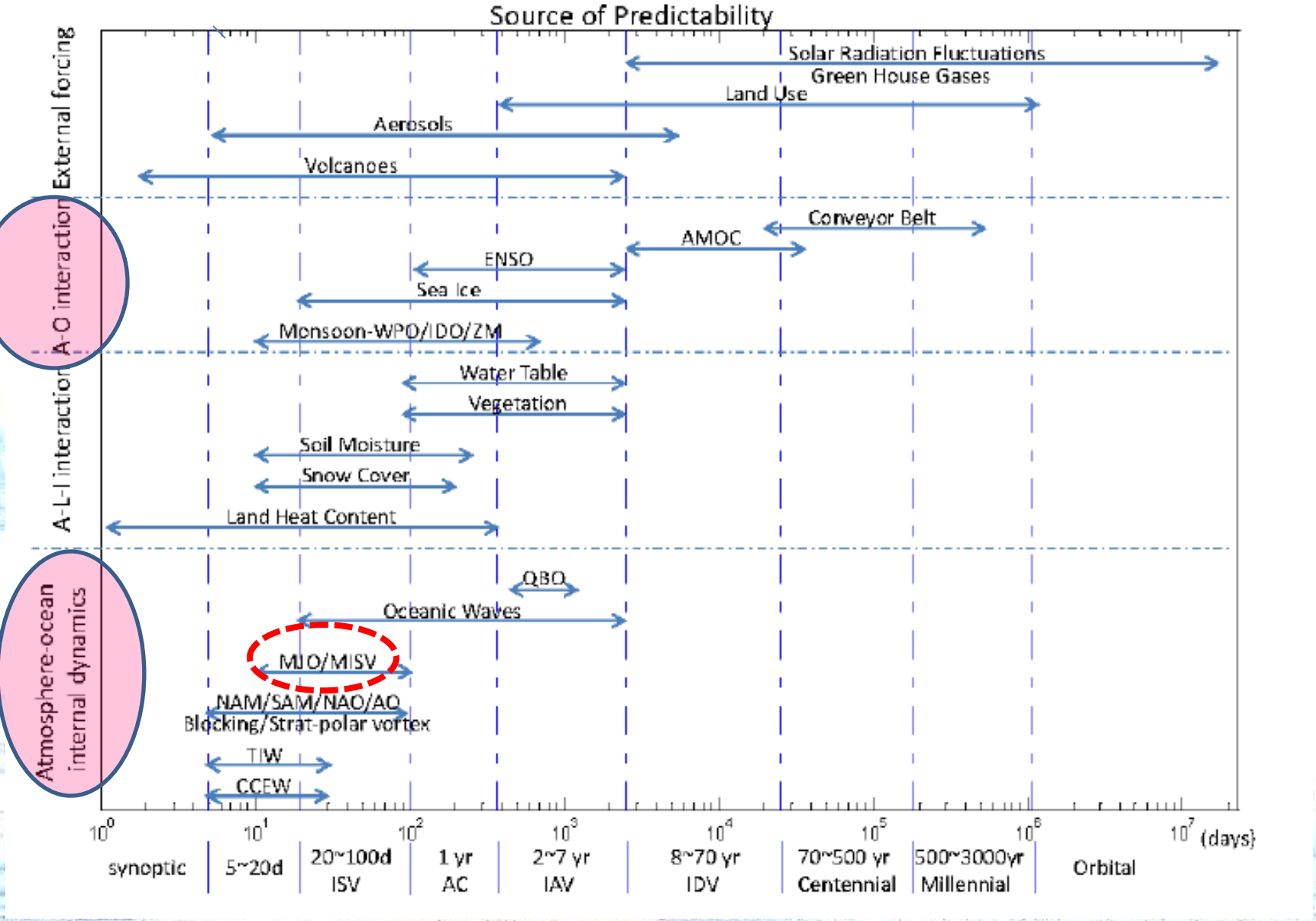
- The MJO primarily manifests as an atmospheric system with large-scale convective envelope coupling to planetary-scale baroclinic circulations.
- Coherent SST variations are observed in association with two MJO events during TOGA-COARE field campaign. Many modeling studies support that atmosphere-ocean coupling improves the simulation of MJO in terms of its intensity, propagation, and coherence; and extends its prediction skill.
- The DYNAMO/CINDY field campaign, however, reveals that coherent SST variations are associated with only two (Nov & Mar) of five (or four) MJOs occurred during this period, which suggests that some MJOs are basically controlled by atmospheric internal dynamics. Numerical experiments targeting two contrasting MJO events (Oct & Nov) supports this hypothesis.

Future Study

- Why are some MJO events largely controlled by atmospheric internal dynamics and others are strongly coupled to underlying ocean?
- What are the major physics governing these two-types of MJOs?
- Which type of them is more predictable and why?

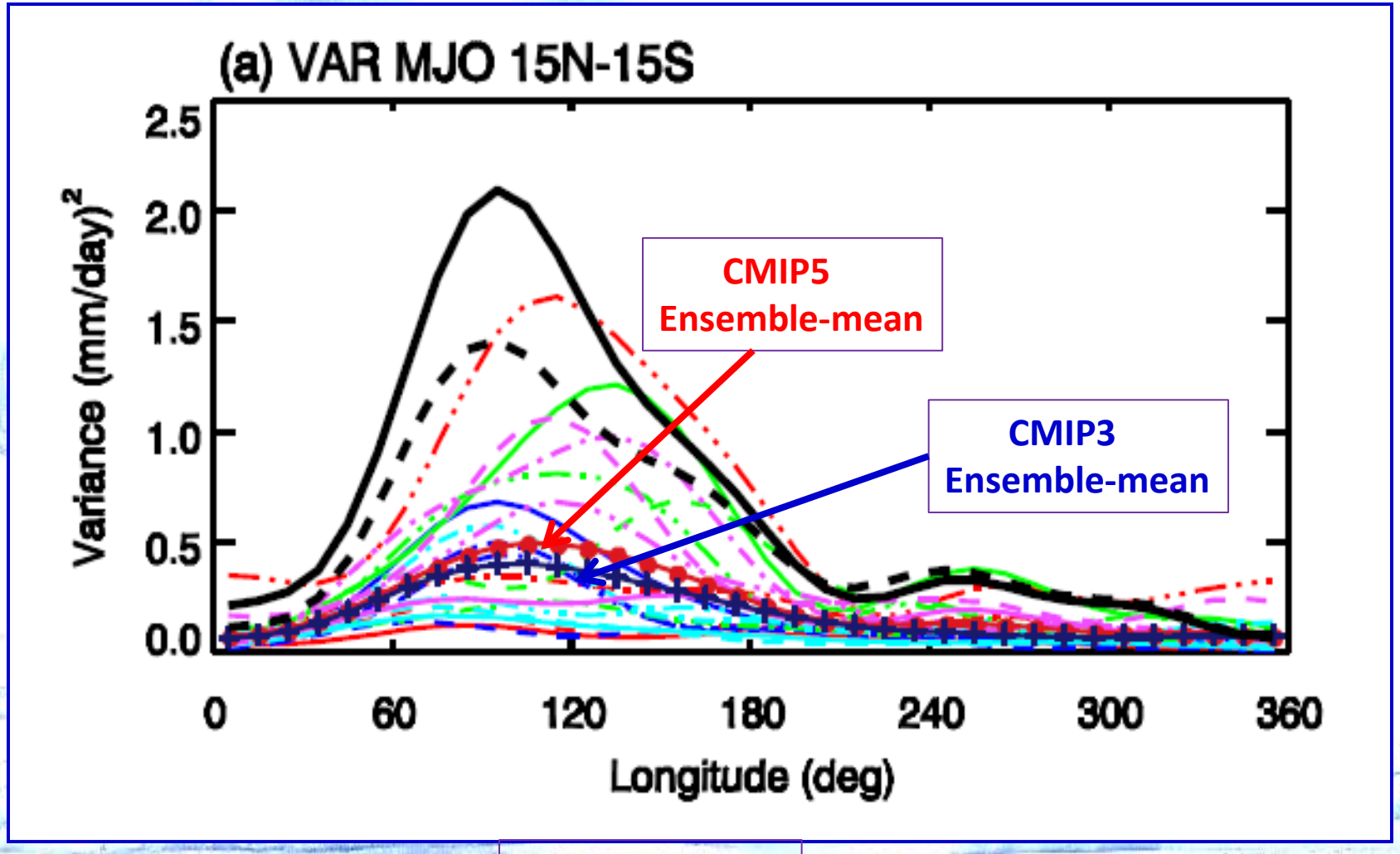

Thank You Very Much!
Courtesy to Owen Shieh for the photo
TD and the MJO, Jan. 14-16, 2014

National Academy of Sciences (2010)



Challenges Ahead

Many atmosphere-ocean coupled models still have difficulties to simulate the MJO

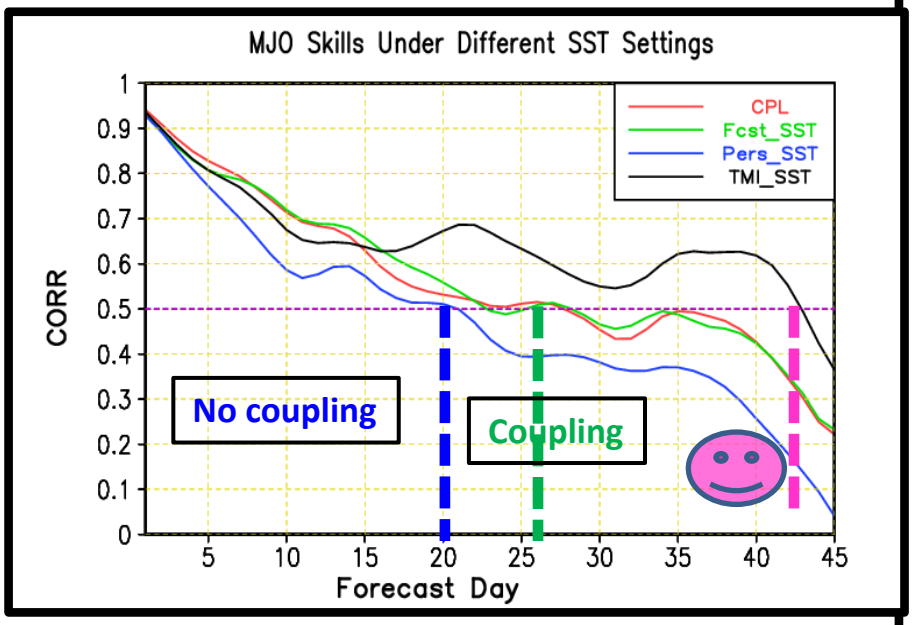


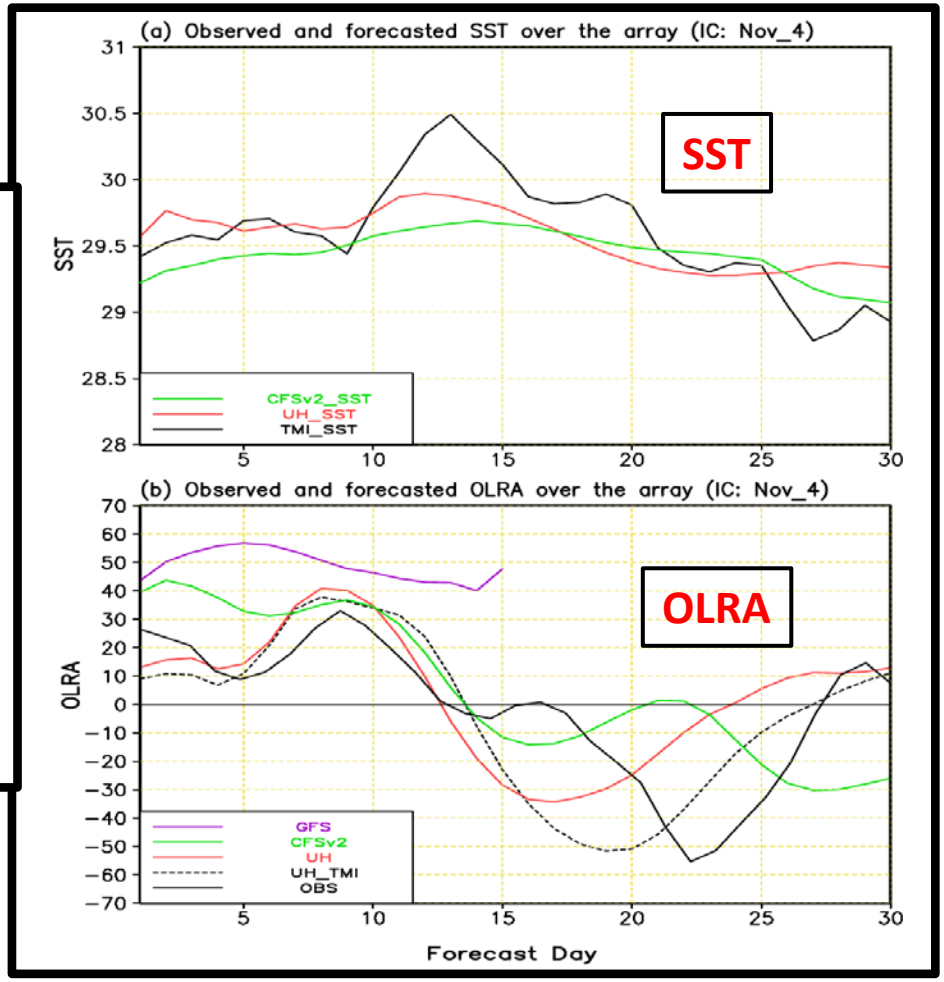
CMIP5
Coupled Models

(Hung et al. 2013)

Better Representation of Air-Sea Coupling is Needed to Advance MJO Forecasting

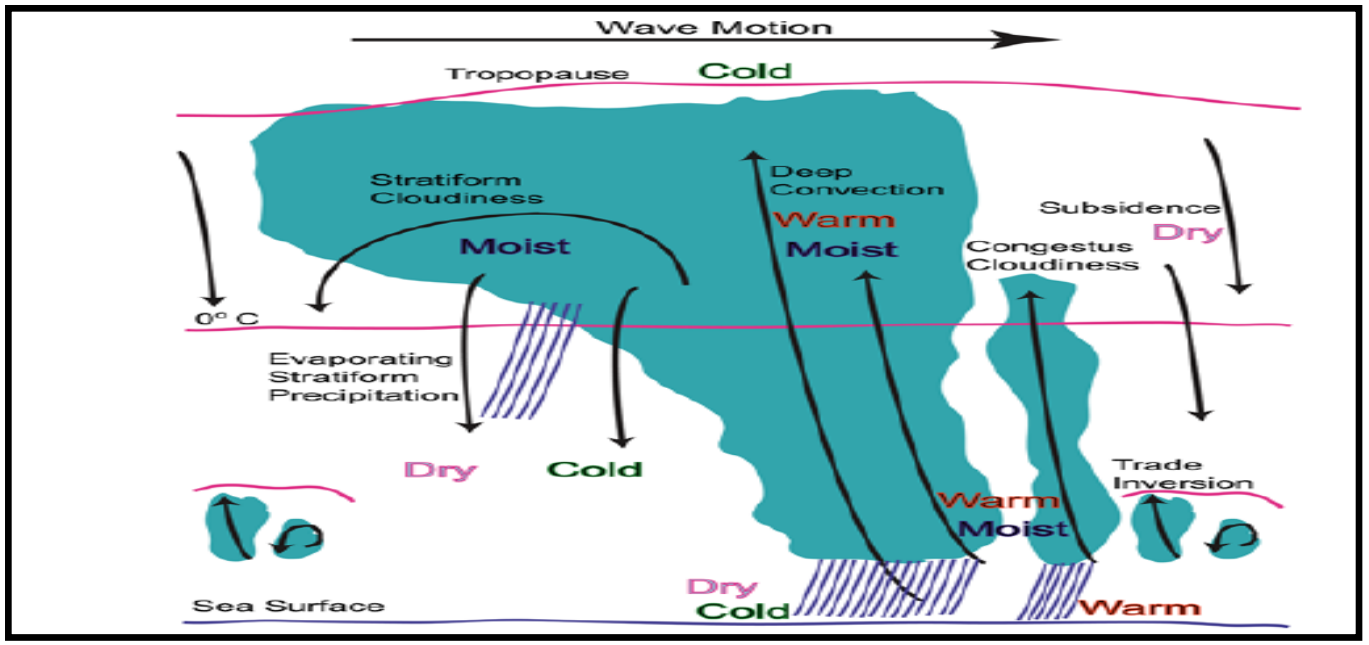
Joshua Xiouhua Fu et al (IPRC/SOEST/University of Hawaii at Manoa)



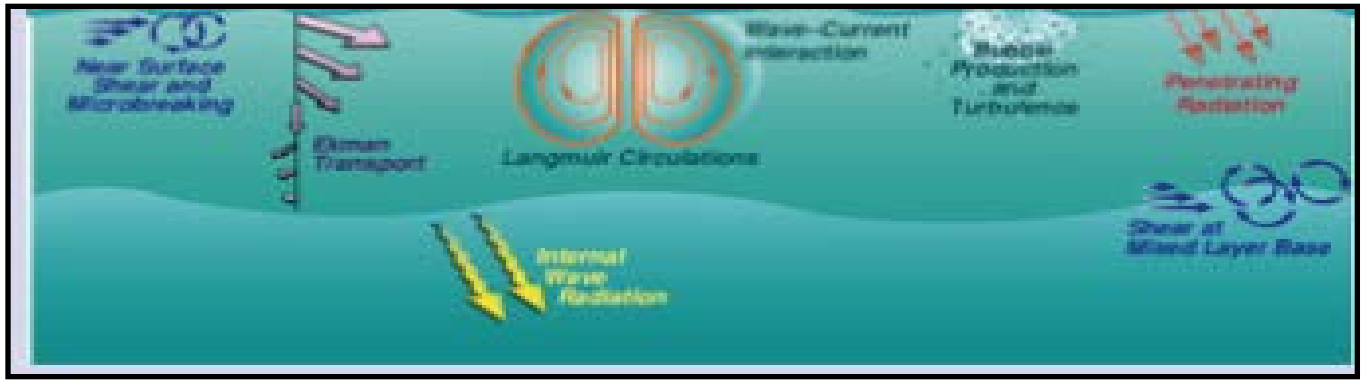


Potential

Better Representation of Air-Sea Coupling is Needed to Advance MJO Forecasting



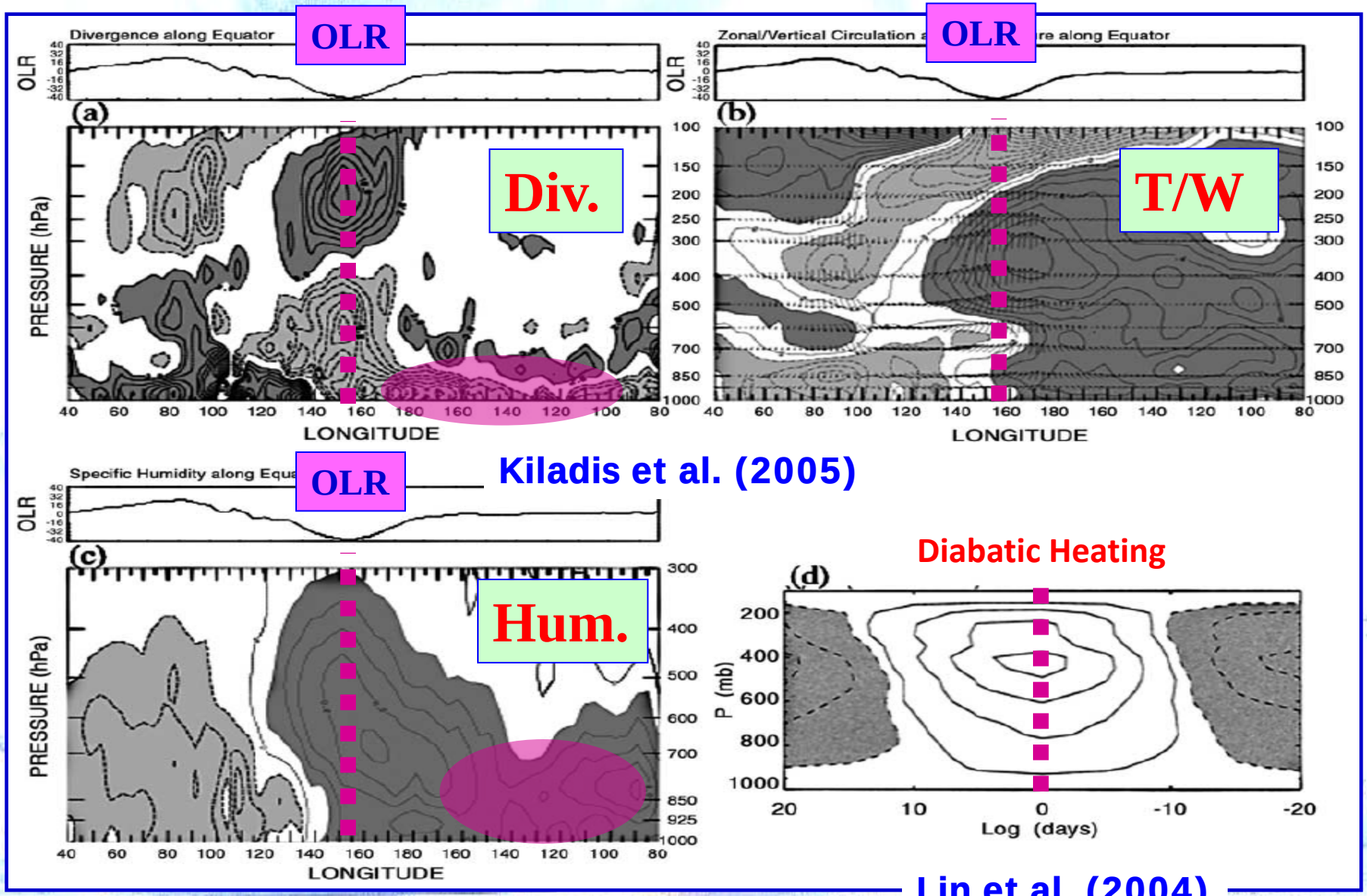
SST



To-do list:

- Validation of **surface fluxes**: solar radiation, latent heat flux, and wind stress.
- Validation of **oceanic mixed-layer depth and heat budget**.
- Explore the ways to **improve the misrepresented processes**.

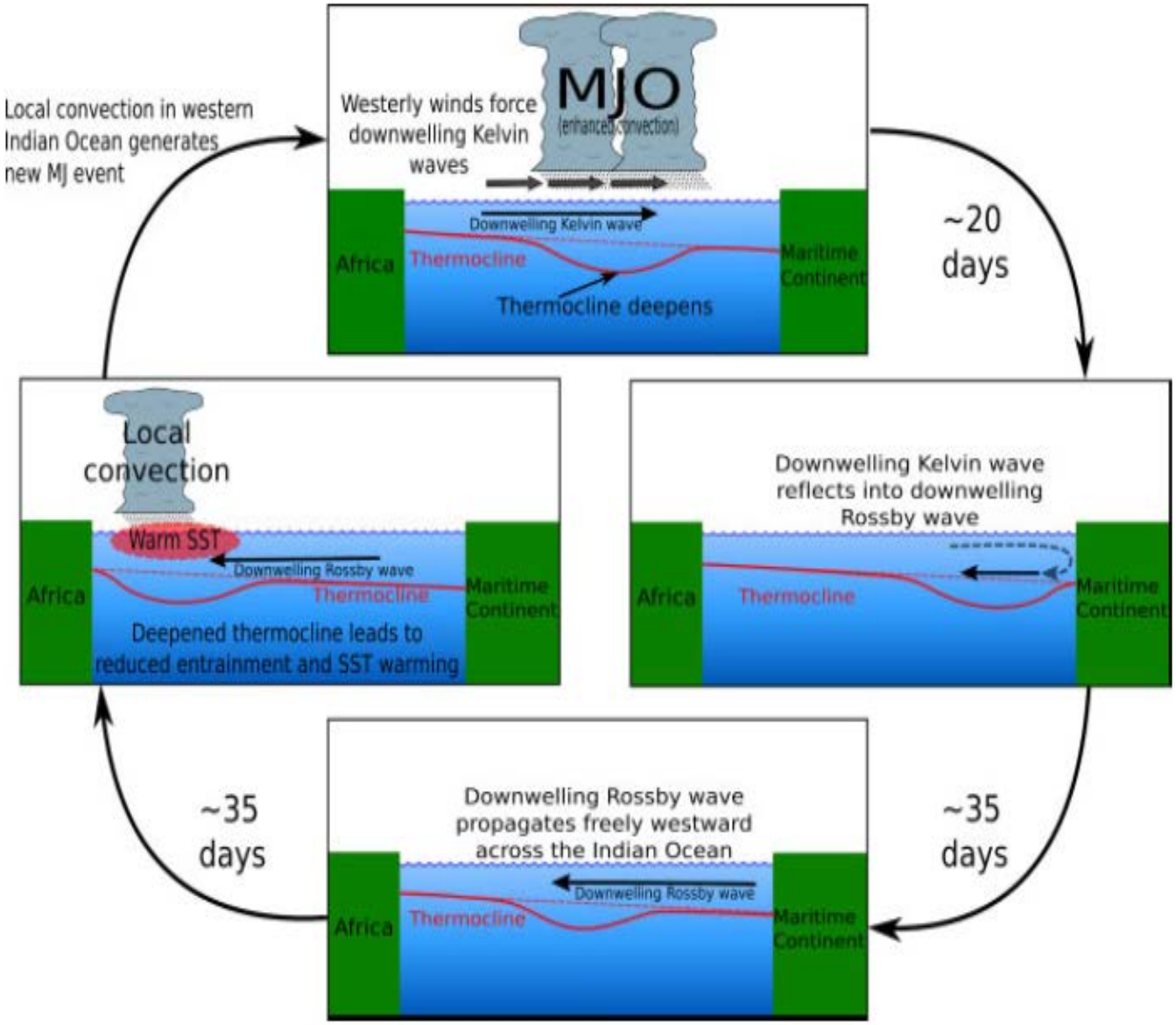
Vertical Structures of the MJO



Kiladis et al. (2005)

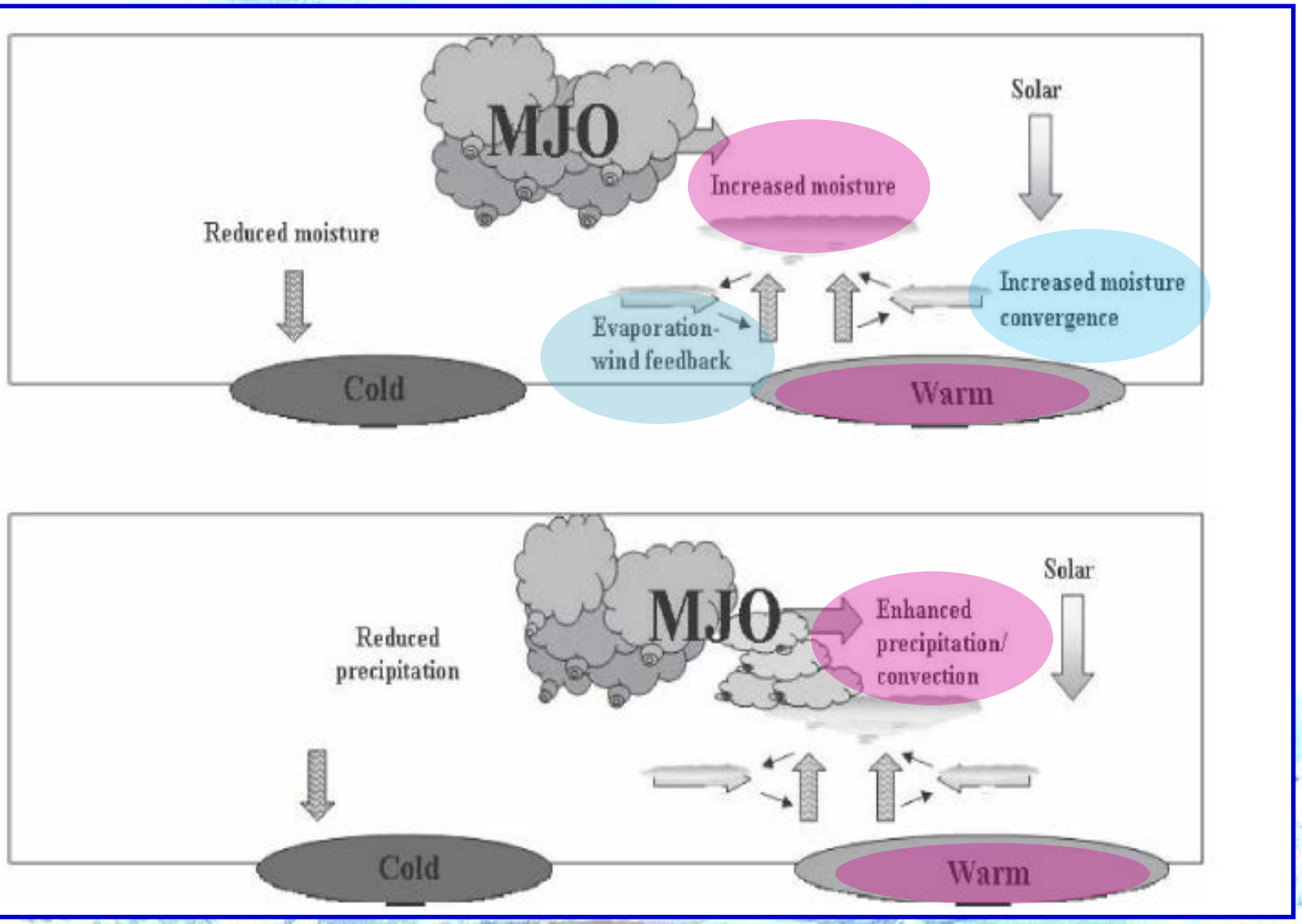
Lin et al. (2004)

Oceanic Kelvin-Rossby Waves can trigger MJO



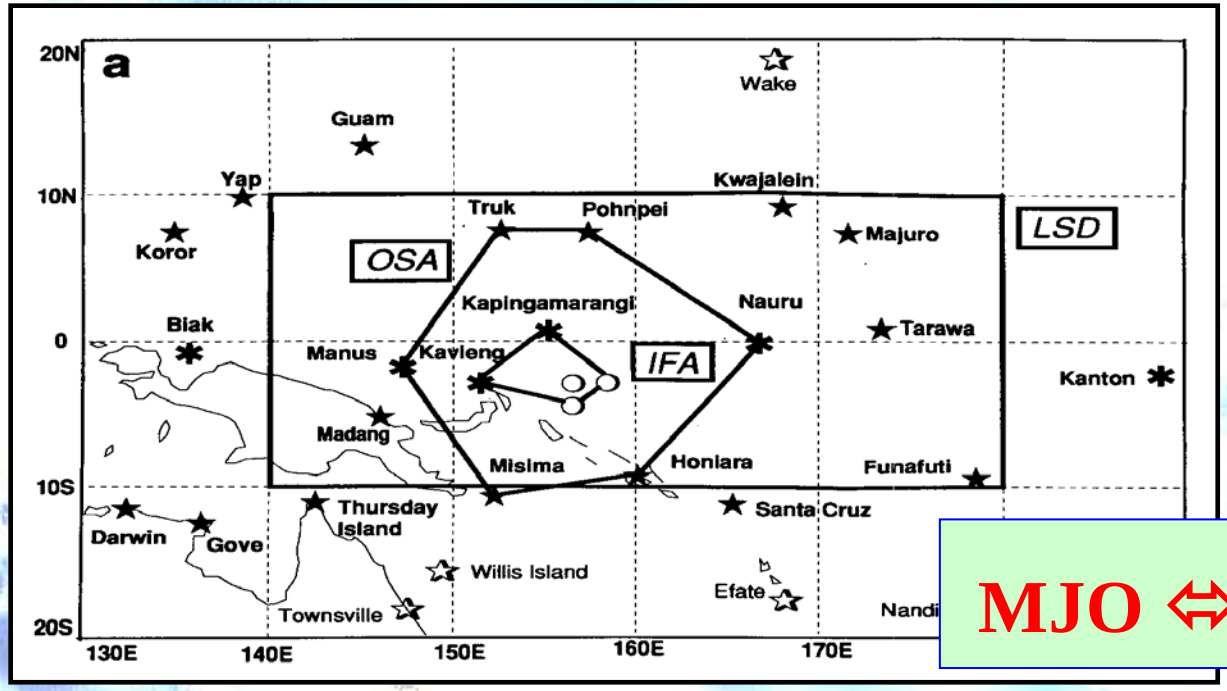
Webber and Matthews (2010, 2012)

Enhanced Evaporation-Convergence Feedback



Marshall et al. (2008)

TOGA-COARE Field Campaign (Nov. 1992-Feb. 1993)



MJO ⇔ ENSO

"The ultimate goal is to model *coupled ocean-atmosphere* phenomena more realistically, so the goal is not to have an oceanographer produce only an oceanographic dataset and a meteorologist produce only an atmospheric dataset." Richard Chinman (TOGA-COARE IPO)

Webster and Lukas (1992)

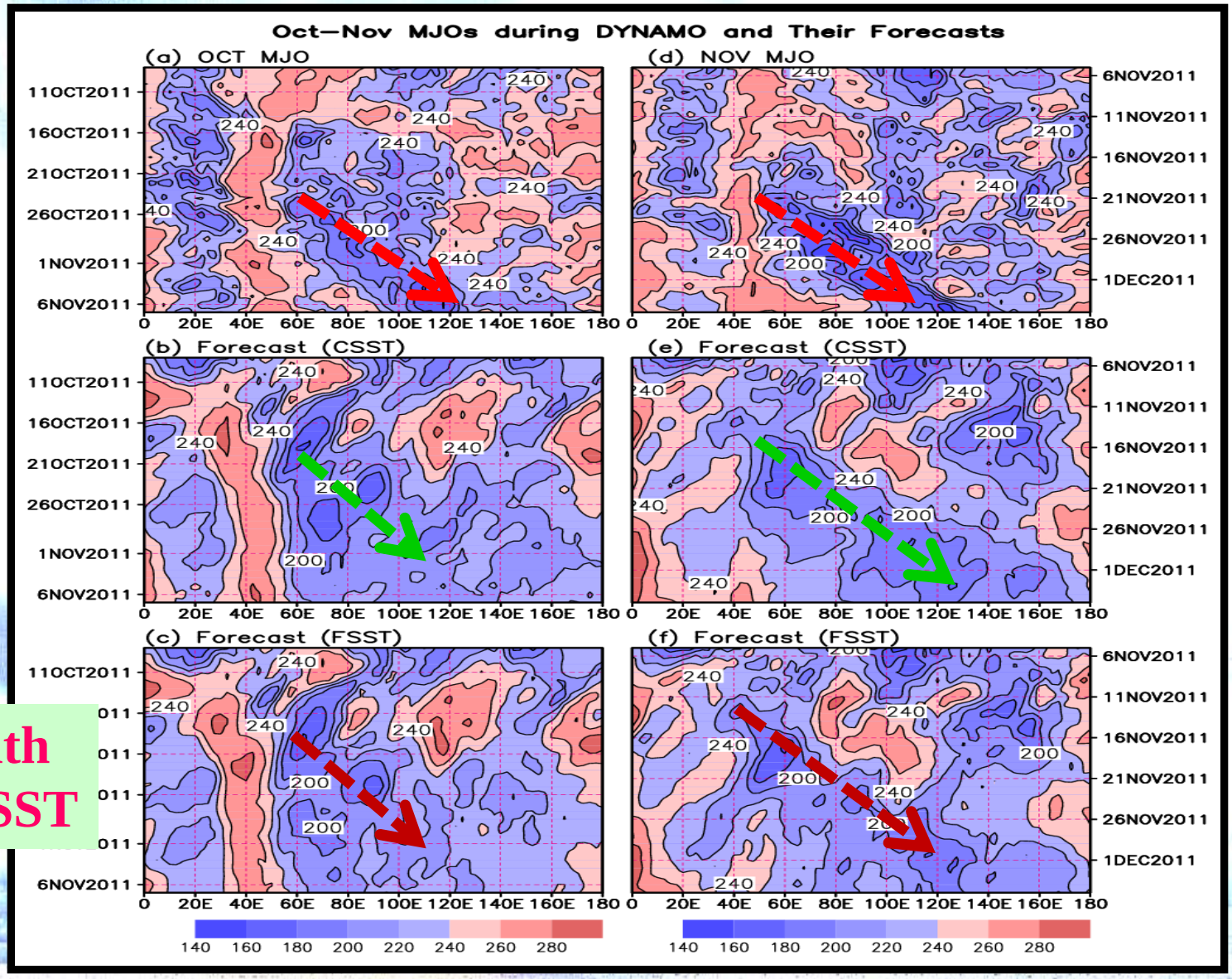
Forecasted Oct/Nov MJOs under Different SST Settings

OBS

Coupled

Forced with forecasted SST

OLR



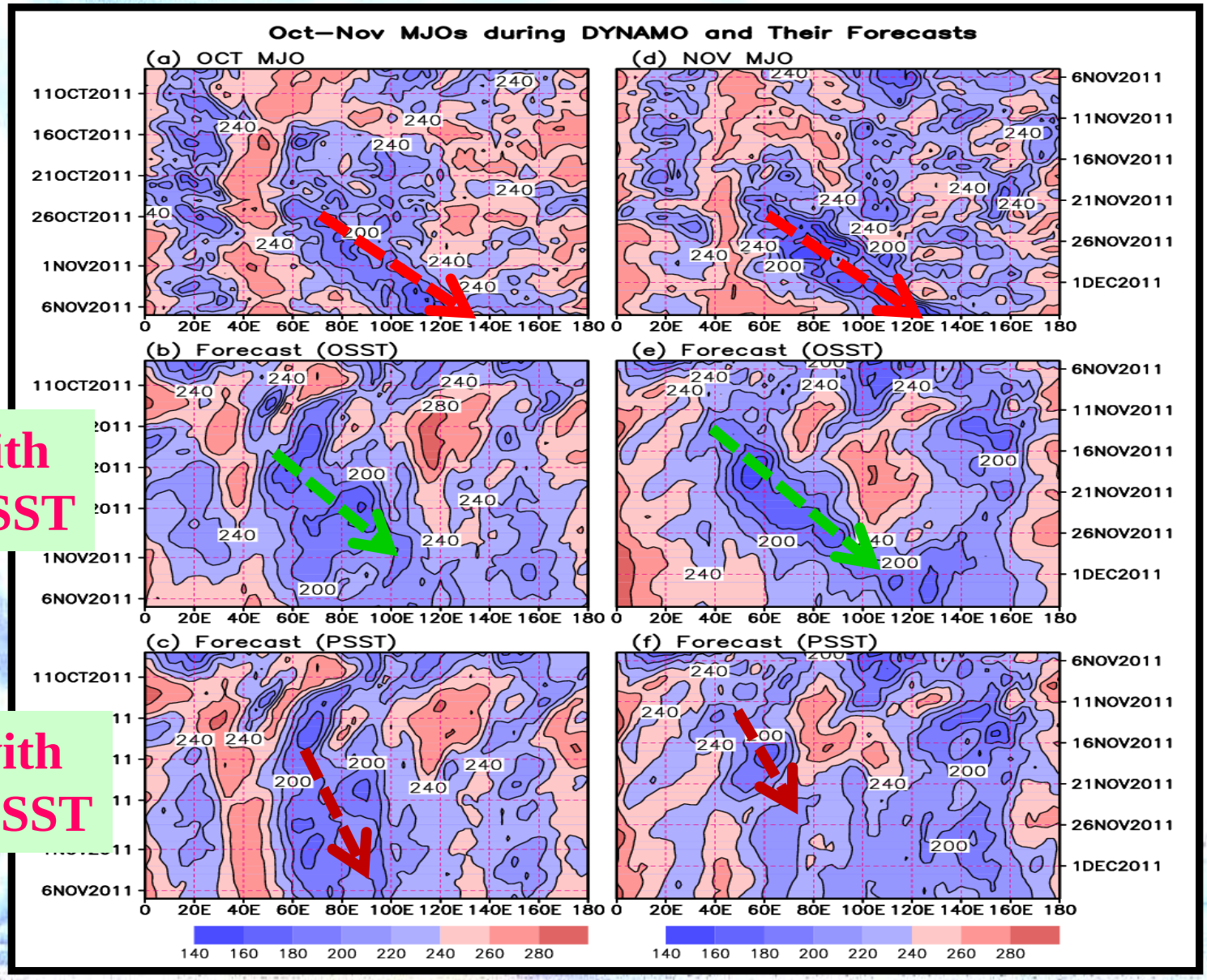
Forecasted Oct/Nov MJOs under Different SST Settings

OBS

Forced with observed SST

Forced with persistent SST

OLR



Extended-range Forecasts of Nov. MJO Initiation

---------- Forwarded message ----------
From: **Xiouhua Fu** <xfu@hawaii.edu>
Date: Sat, Nov 5, 2011 at 2:25 PM
Subject: Re: Re:DYNAMO - update from the field!
To: Hisayuki Kubota <kubota@jamstec.go.jp>
Cc: Owen Shieh <oshieh@hawaii.edu>, xfu@hawaii.edu

Hi, Owen and Hisayuki:
Nice to know that your guys are taking or will take observations at DYNAMO array. MJO is transitioning into dry phase now. It is likely another event (wet phase of MJO) will reach your site around late second week/early third week from now (Nov.16-21) :(.
Best Regards!
Xiouhua

c----------c
Dr. Joshua Xiouhua Fu
International Pacific Research Center (IPRC)
SOEST, University of Hawaii at Manoa
1680 East West Rd., POST Bldg., 4th Floor
Honolulu, HI 96822
Tel: (808) 956-2629, Fax: (808) 956-9425
Web: <http://www.soest.hawaii.edu/~xfu>

==========

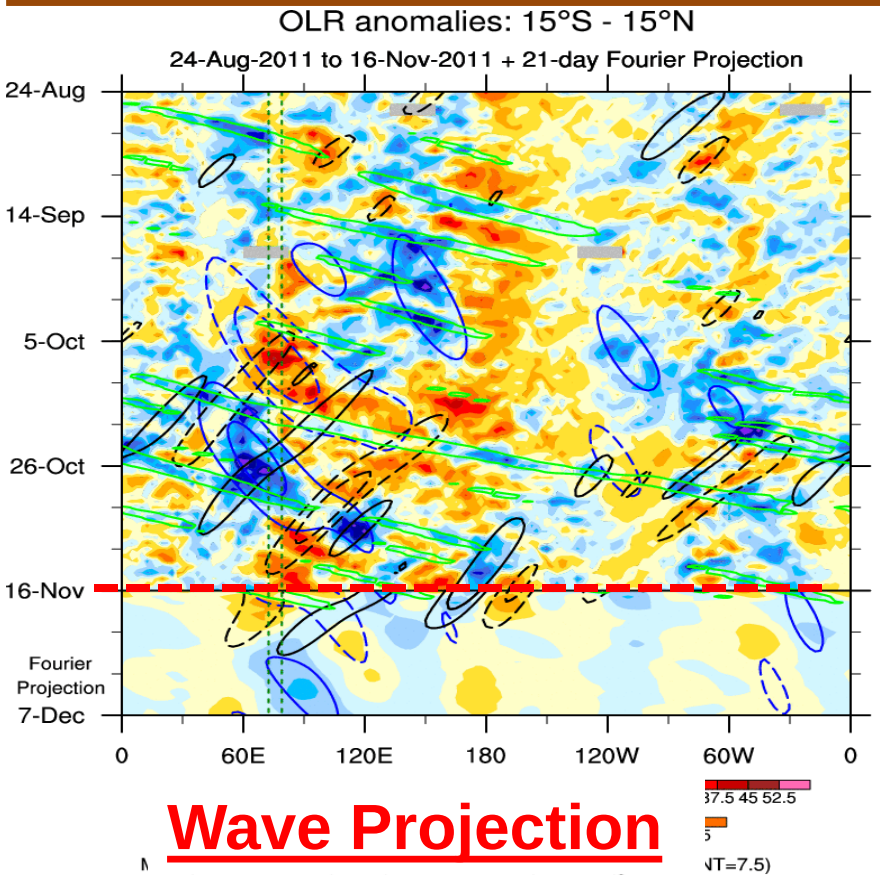
Kelvin Wave vs. Madden and Julian Oscillation?

Madden-Julian Conversation (http://maddenjulianconversation.blogspot.com)

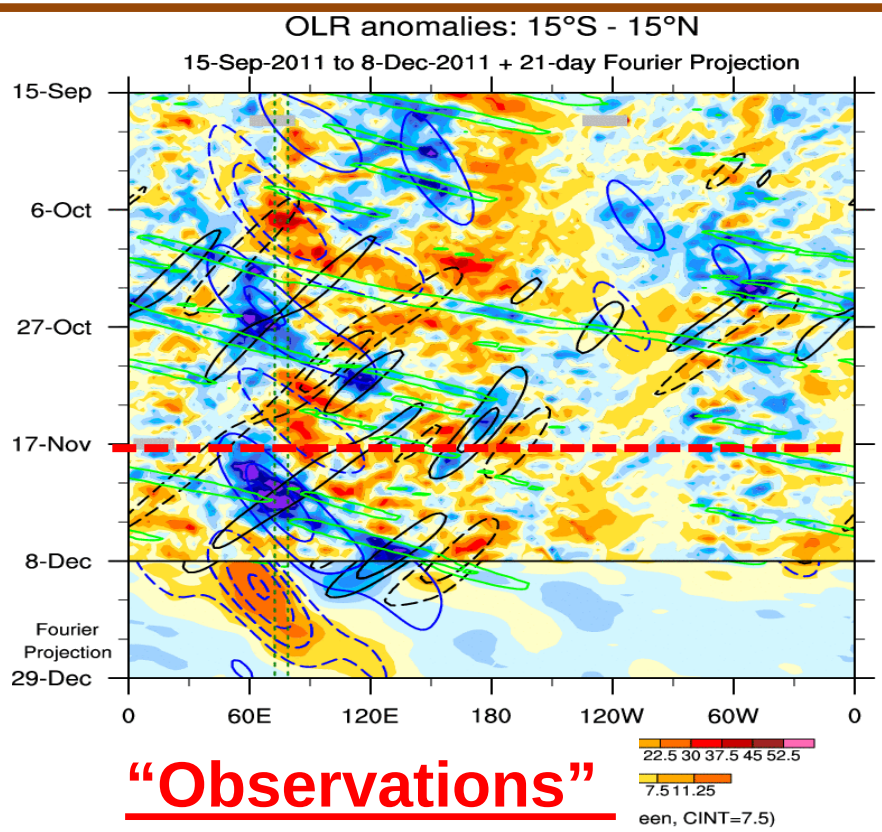
A blog by a small group of climate scientists about the Madden-Julian Oscillation and the DYNAMO field campaign in the Indian Ocean.

Friday, November 18, 2011

Kelvin vs. Madden and Julian ?



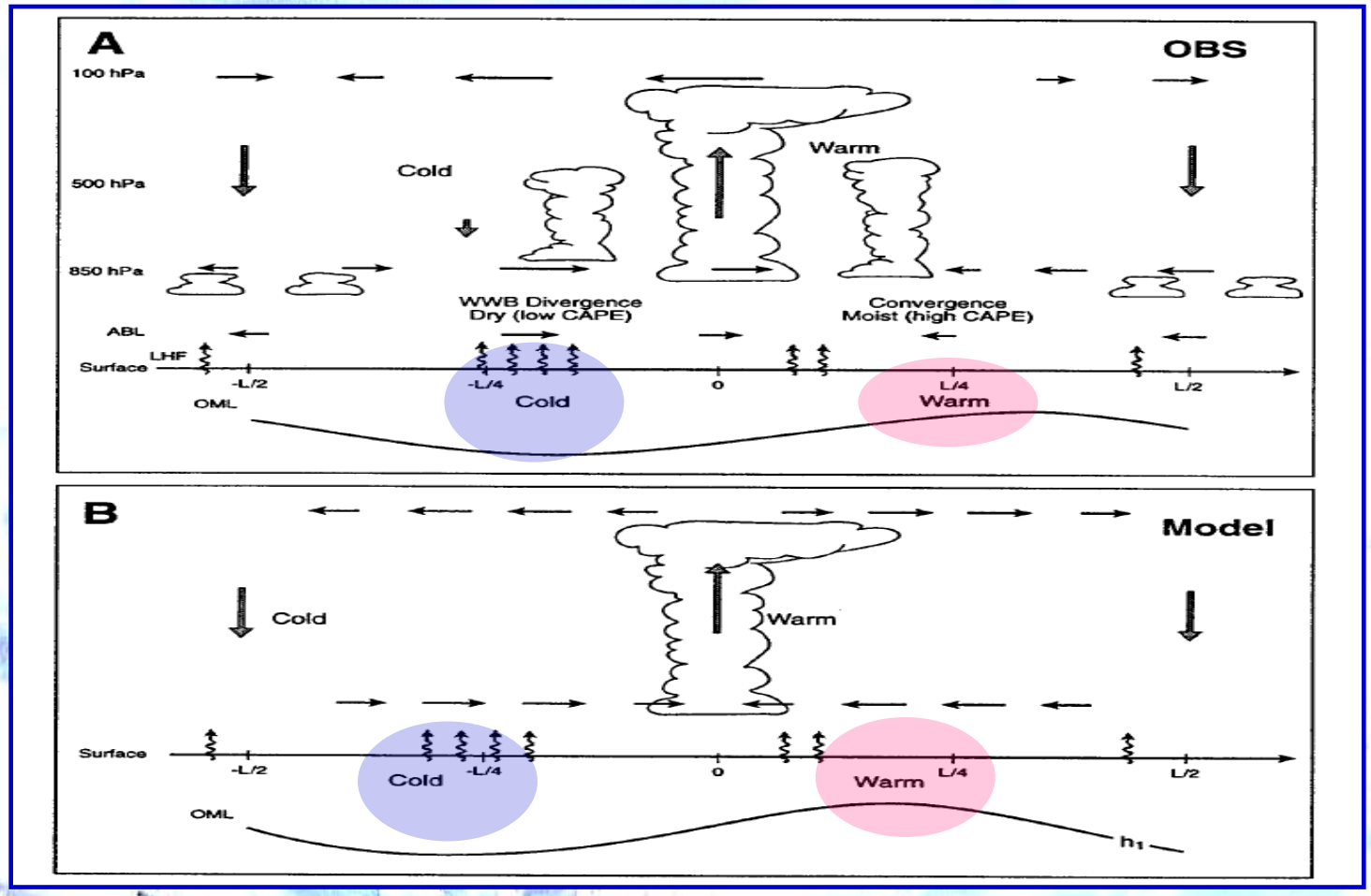
Wave Projection



"Observations"

TD and the MJO, Jan. 14-16, 2014

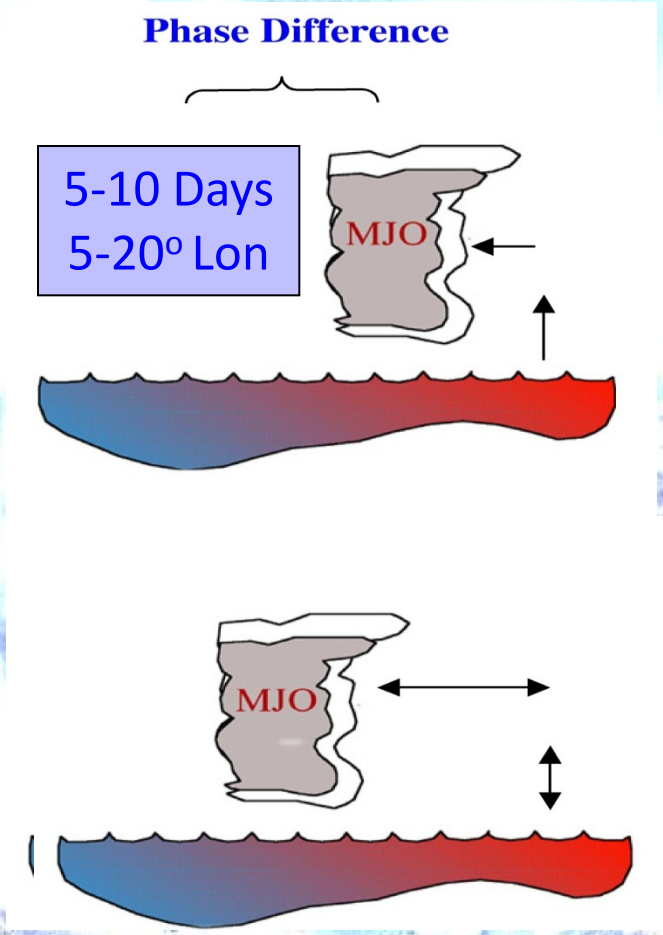
Air-sea Coupling Destabilizes Kelvin-Rossby-wave Couplet



Positive SST anomaly → Enhanced moisture convergence → Enhanced eddy available potential energy

Wang and Xie (1998); Lau and Shen (1988); Hirst and Lau (1990)

"Coupled" vs. "Uncoupled"



Specified SST -> AGCM

MJO/ISO feels impact from SST - tends to move over warmest water.

One-way interaction.

Two-Tier Prediction Inadequate?

Coupled GCM

SST anomaly a product of MJO/ISO. As convection moves towards warm SST anomaly, it cools it and moves the warm anomaly eastward.

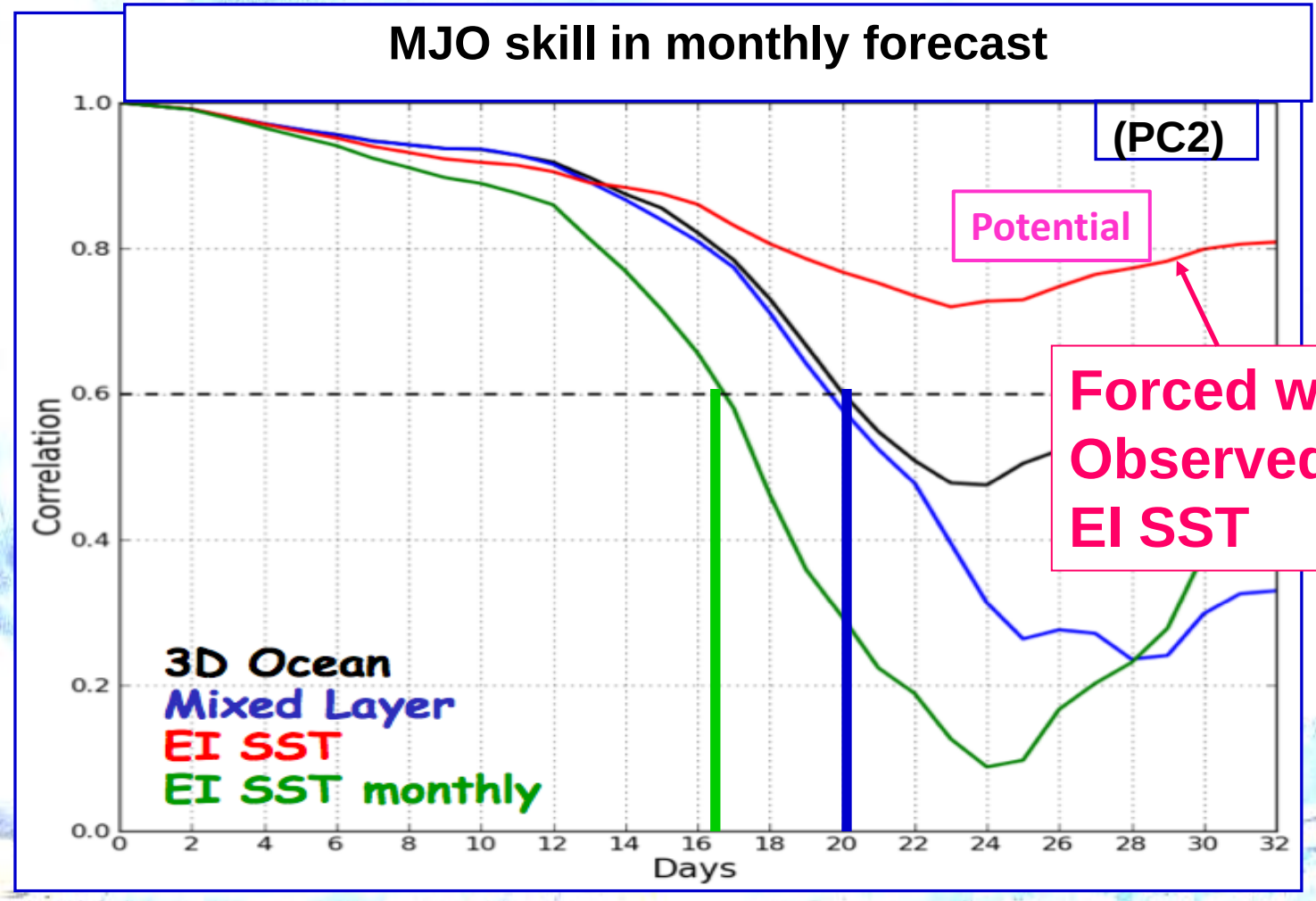
Two-way interaction.

Matches Observations.

Fu, Wang, Li and McCreary, 2003
Inness and Slingo, 2003
Fu and Wang, 2004
Zheng, Waliser, Stern and Jones, 2004

Courtesy of Duane Waliser

SST-Feedback Significantly Extends MJO Prediction Skill

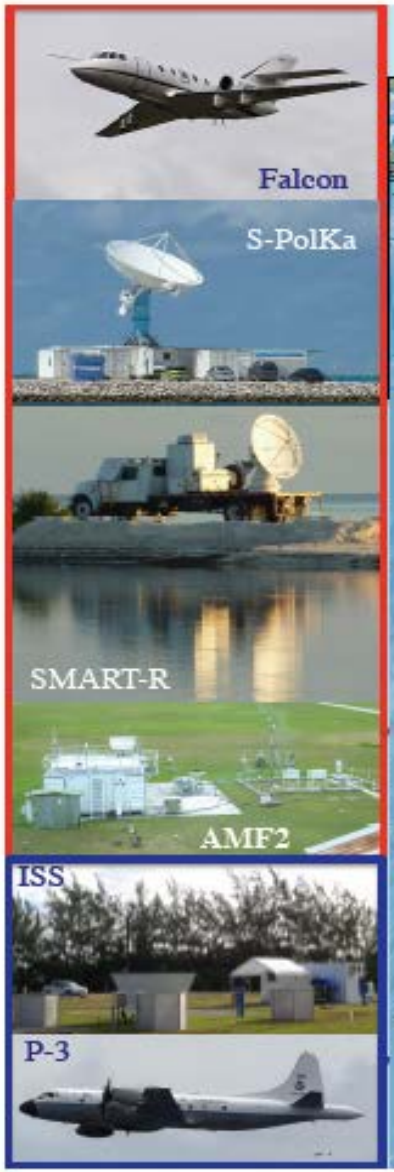


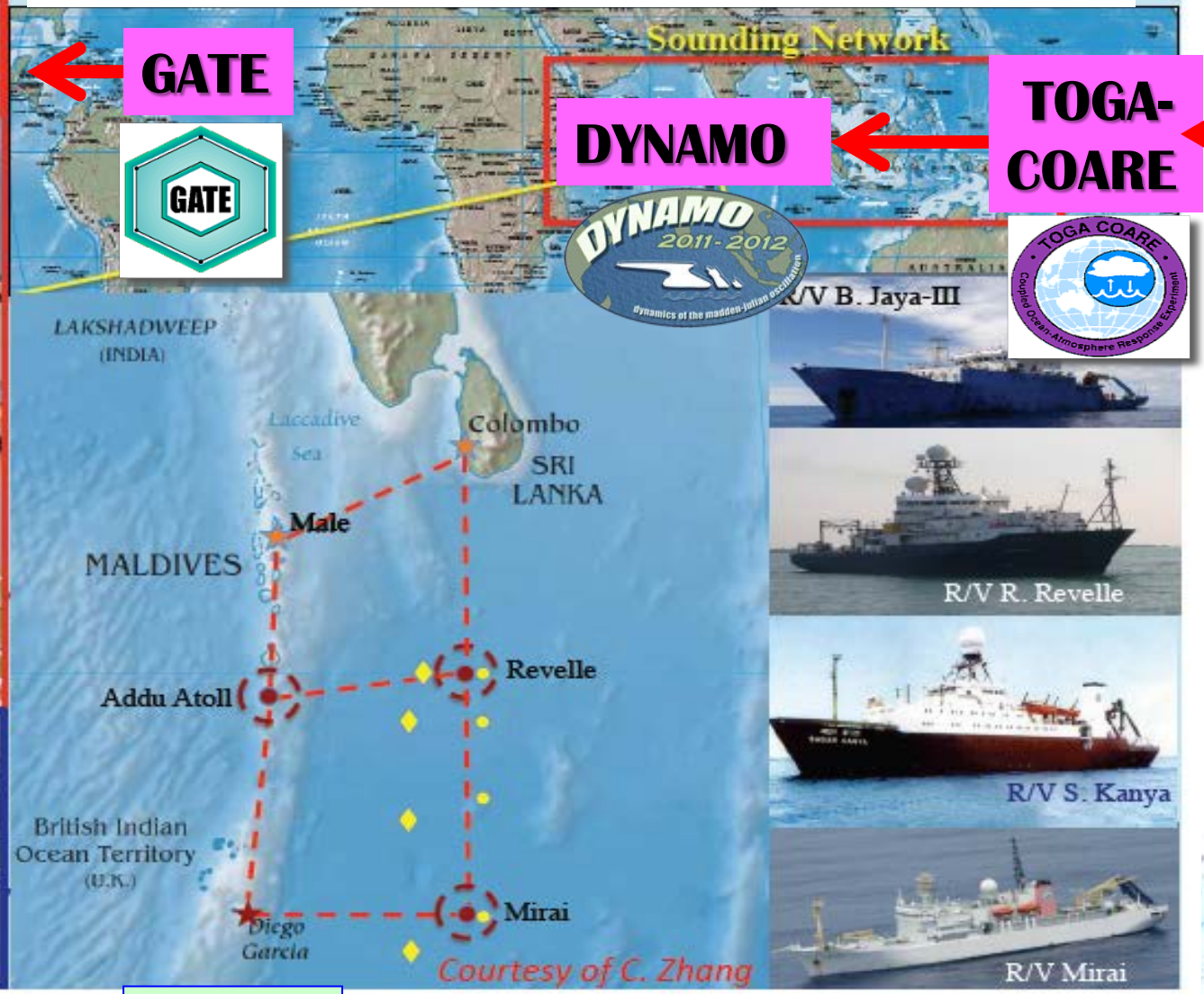
(Toga-Coare 92/93) ECMWF 5 mem. Ens. E. De Boisseson et al 2012

Courtesy of Martin Miller

DYNAMO/CINDY Field Campaign (Oct. 2011-Mar. 2012)

http://www.eol.ucar.edu/projects/dynamo/





(Zhang et al. 2013)

MJO