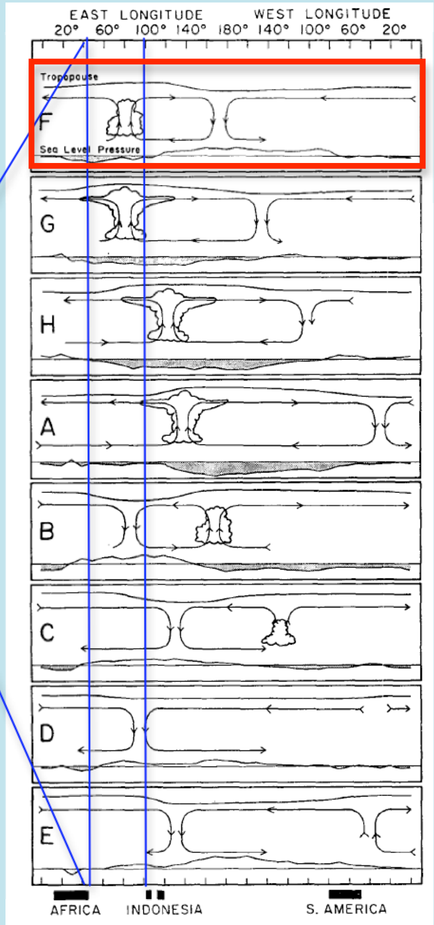
DYNAMO
(Dynamics of the MJO)

The US Participation in CINDY2011

(Cooperative Indian Ocean Experiment on Intraseasonal Variability in Year 2011)

US IAG briefing September 30, 2009

Indian Ocean



Madden and Julian 1972

Main Objectives of this Presentation:

- **Demonstrate the progress made in DYNAMO planning**
- **Highlights the facility needs**

Outline

1. Background

2. Scientific Program

3. **Experimental Design**

4. **Issues and Concerns**

The Rationale for a Field Experiment in the Indian Ocean for the MJO Initiation Study in 2011

- A unique prediction and modeling problem
- A unique climate environment
- In situ observations in a poorly sampled region needed for testing new hypotheses
- New observing technology for unprecedented data
- A rare opportunity for multi-nation, multi-program synergy

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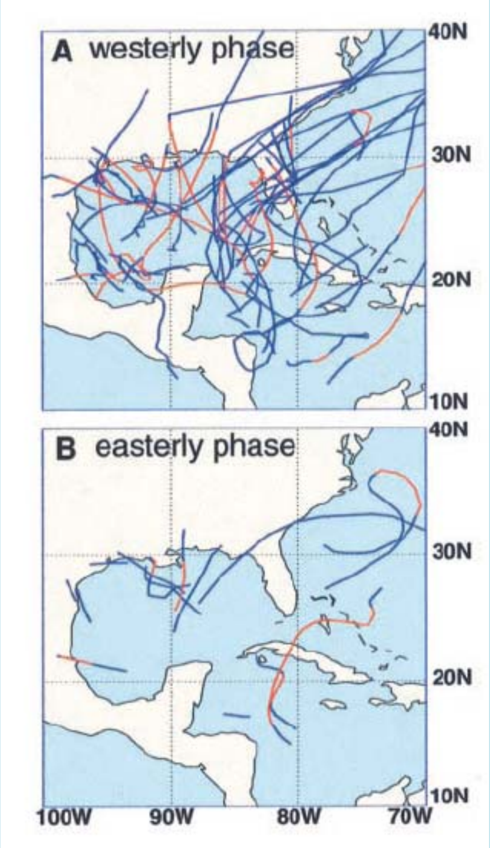
Importance of the MJO: Bridging Weather and Climate

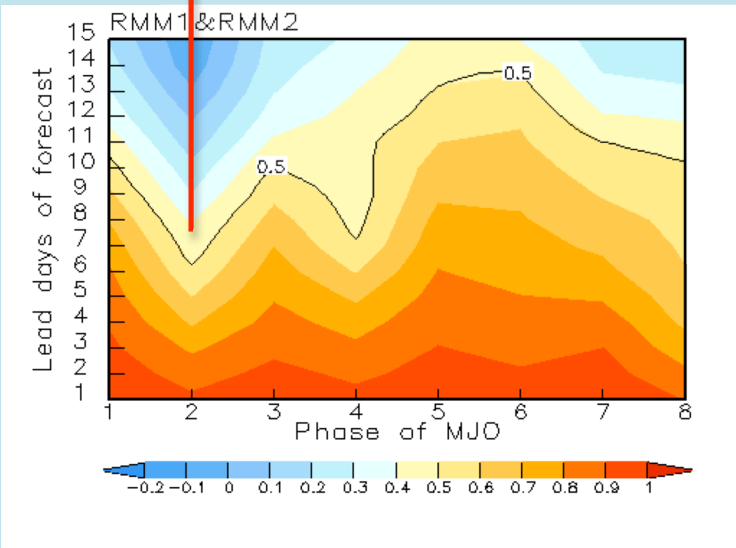
- Monsoons, ENSO
- Extreme events (flood, tropical storm/cyclones)
- Indian Ocean Dipole and Indonesian Throughflow
- Teleconnections, extratropical circulation/weather
- North Atlantic Oscillation, Arctic Oscillation, Antarctic Oscillation
- Atmospheric and oceanic chemistry and biosystem (ozone, CO_2, aerosols, chlorophyll)
- Global angular momentum, Earth’s rotation rate, length of the day

1947 - 1997

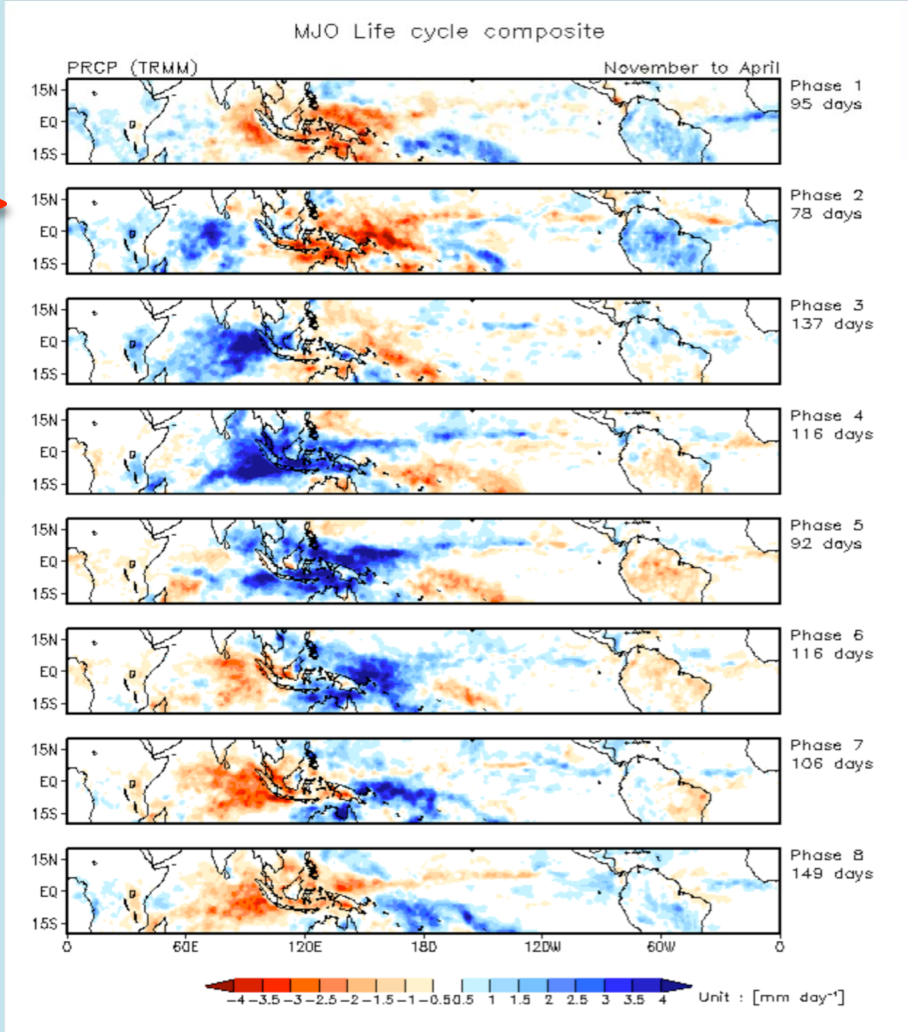


(Maloney and Hartmann 2000)

Limited intraseasonal prediction skill (< 15 days) – particularly low during the initiation of the MJO in the Indian Ocean and during the passage of the MJO over the Maritime Continent.



Correlation between predicted (by CFS) and observed MJO indices (Courtesy of Jon Gottschalck and Qin Zhang)



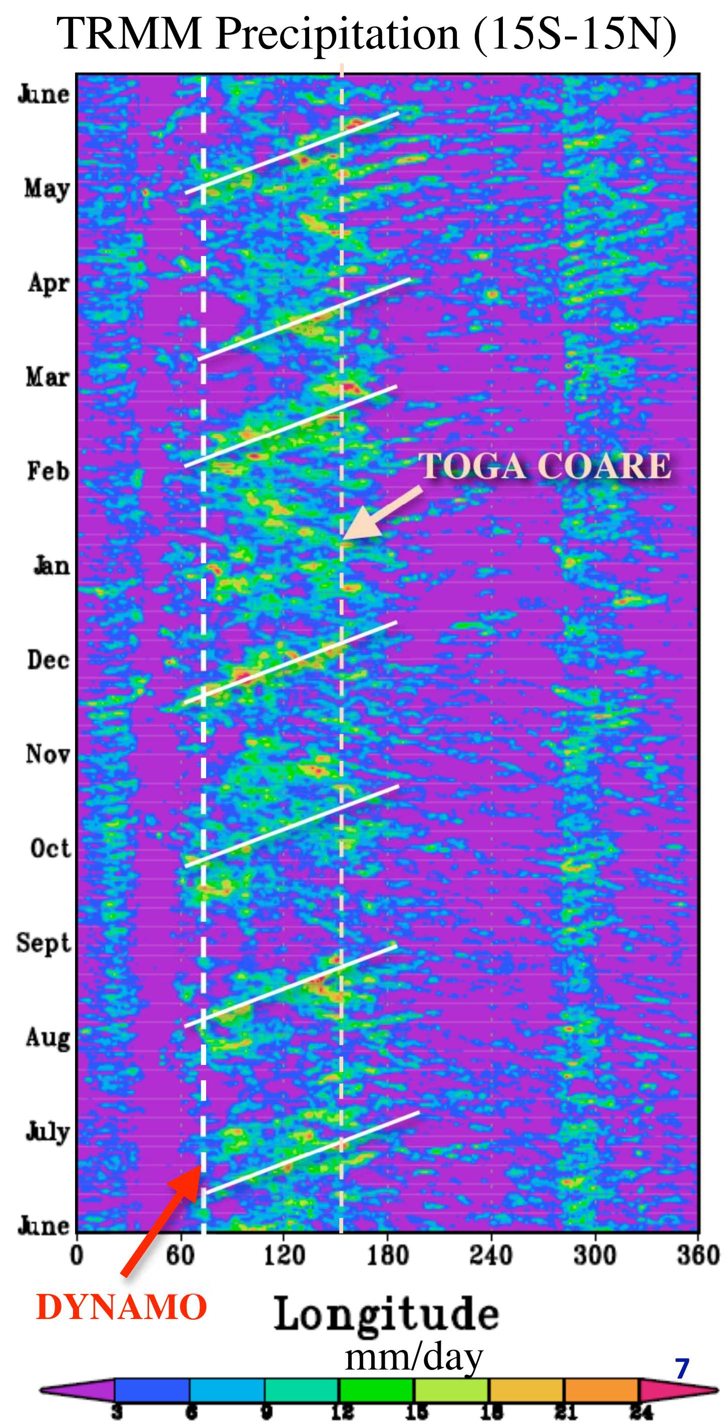
Main Problems of MJO Initiation:

Determining factors for

(1)The maintenance of inactive phases (dominated by *shallow convection*)

(2) The transition between inactive phase to active phase (dominated by *deep convection*)

(3) The local termination of active phase and its commencement of eastward propagation



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Major Progress since the CLIVAR Summit (July 2009)

- Hypotheses reorganized
- Satellite element included
- Modeling component adjusted
- *More focused experimental design options*
- Critical timeline drawn
- Budget estimate updated (in progress)

DYNAMO Overall Goal:
Expedite our understanding of MJO initiation processes and thereby improve our ability to simulate and forecast the MJO

DYNAMO Scientific Objectives:

(1) *Collect in situ observations* from the equatorial Indian Ocean region urgently needed for testing hypotheses on MJO initiation processes based on recent advancement in the MJO study;

(2) *Identify and remedy critical deficiencies in current numerical models, especially their parameterization schemes,* that are responsible for the low prediction skill and poor simulations of MJO initiation;

(3) Provide guiding information to *enhance MJO monitoring and prediction capacities* that deliver climate prediction and assessment products on intraseasonal timescales for risk management and decision making over the global tropics

DYNAMO Milestones

2008

- June – DYNAMO white paper
- July – First presentation to the US CLIVAR Summit

2009

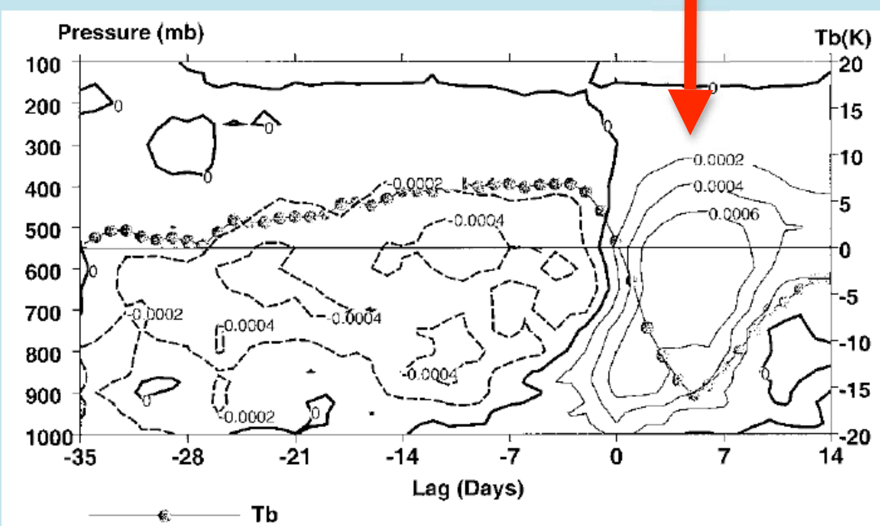
- January – Supporting feedback from the US CLIVAR PSMI Panel
- April – First planning workshop
- May – Science Steering Committee formed
- July – Second presentation to the US CLIVAR Summit
- August – updates to the IAG monthly meeting
- September – Endorsement from the International CLIVAR SSG
- (September – AMIE funded)
- *Today – IAG briefing*

DYNAMO Scientific Hypotheses:

(A) ***The depth of a "moist layer" is a critical factor determining MJO phases and their transitions.***

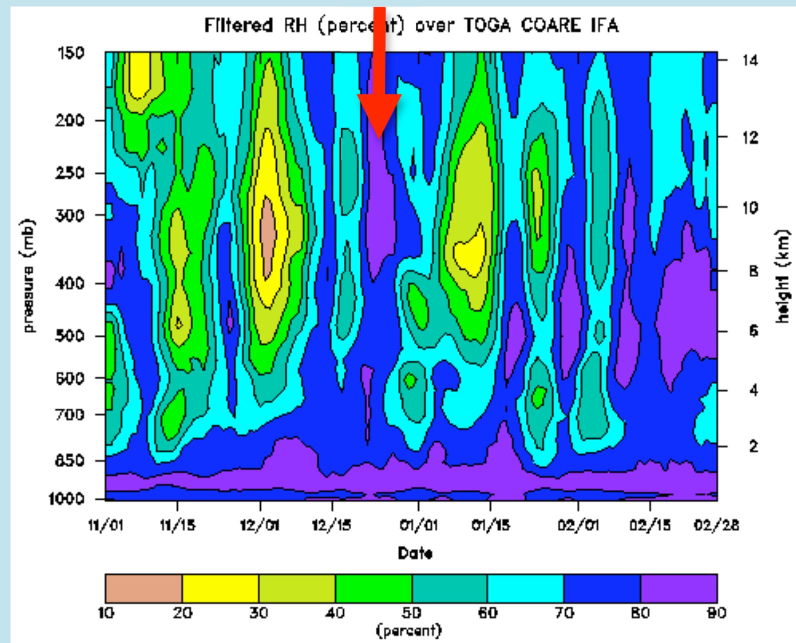
Active Phase

Δ q Composite



(Kemball-Cook and Weare 2001)

RH Time Series (TOGA COARE)

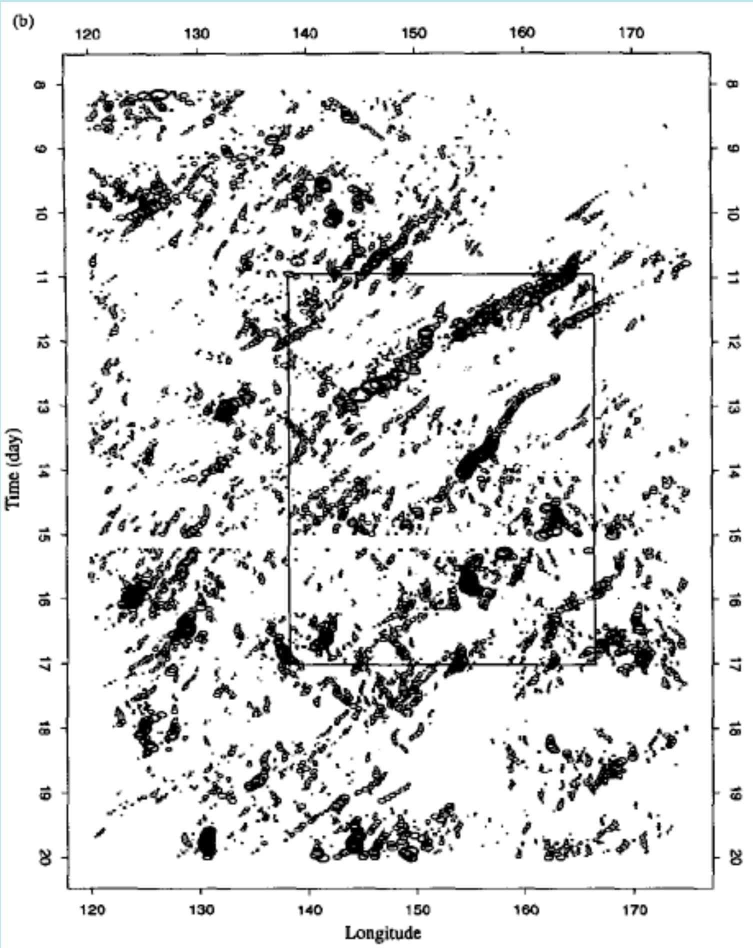


(Lin and Johnson 1996)

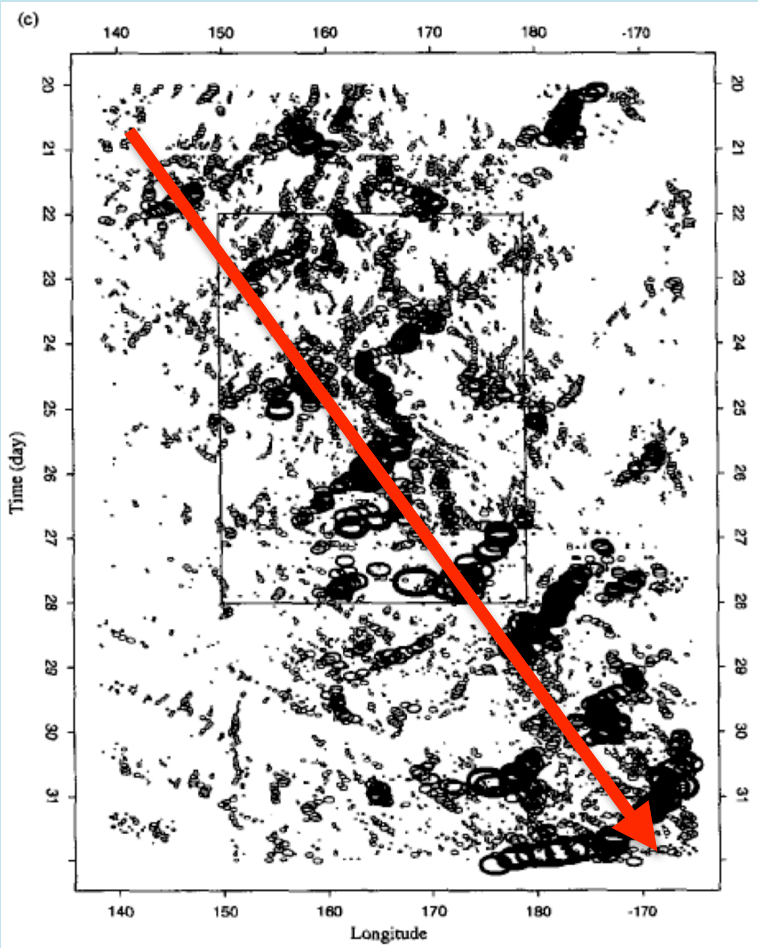
DYNAMO Scientific Hypotheses:

(B) ***Evolution in cloud population and its interaction with the environment is central to MJO initiation and life cycle.***

Inactive – Active Phase Transition



Active Phase

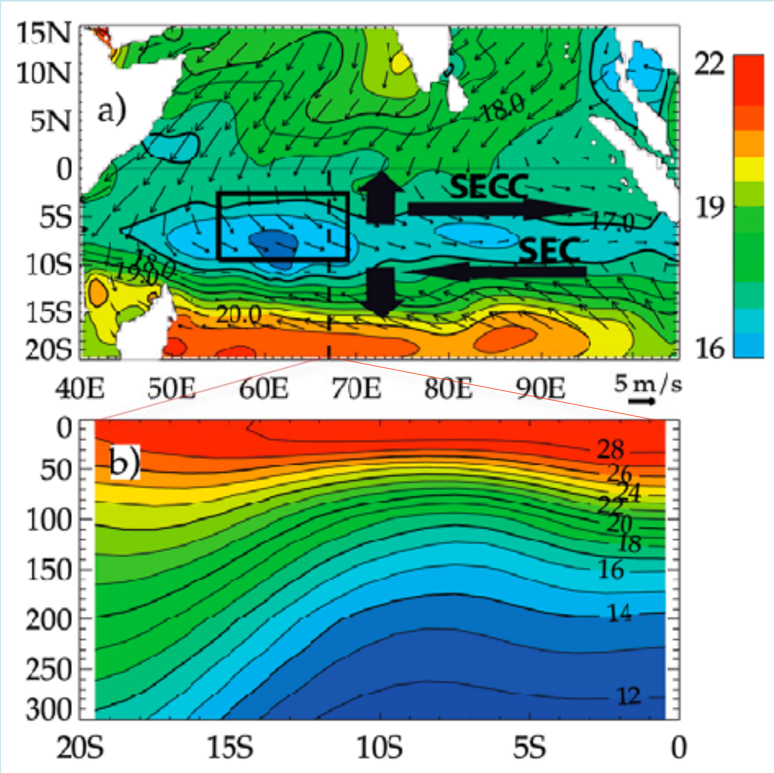


(Chen et al. 1996)

DYNAMO Scientific Hypotheses:

(C) ***Air-sea interaction associated with the MJO is unique in the Indian Ocean in comparison to the western and eastern Pacific.***

Seychelles-Chagos Thermocline Ridge (SCTR)

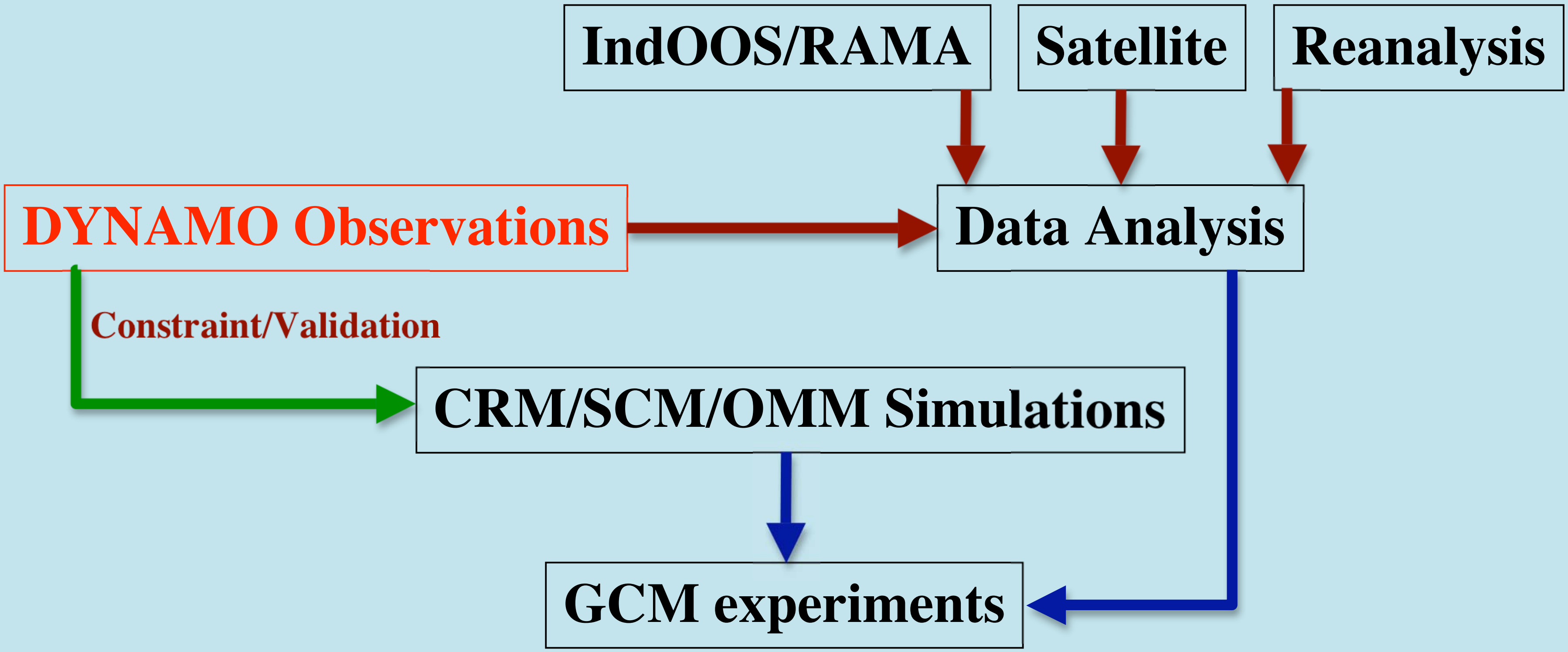


1 – 300 m mean temperature (˚C)

temperature (˚C)

(Vialiard et al. 2008)

DYNAMO Hypothesis Testing
General Strategy: Three Tiers



Observations Needed for Hypothesis Testing

Key Variables	DYNAMO in situ Observations	Auxiliary Data
Moist Layer, Atmospheric Profiles	Soundings, S-PolKa	AIRS, MEGHA-TROPIQUES
Cloud Population and Microphysics	Radars	CloudSat, TRMM MEGHA-TROPIQUES
Diabatic Heating	Soundings, Radars	TRMM
Surface Fluxes	Ships, Moorings	OAFlux
Rain	Rain Gauges, Radars	TRMM
SST	Ships, Moorings	TMI
Mixed Layer, Thermocline	Ships, Moorings	
Large-Scale Moisture Convergence, Vertical Motions	Soundings	Reanalyses
Extratropical/Upstream Influences		Reanalyses
MJO Phases	Soundings, Radars	Reanalyses, Satellite

DYNAMO Program Structure

Science Steering Committee

Simon Chang (NRL/MRY)

Chris Fairall (NOAA/ESRL)

Wayne Higgins (NOAA/NCEP/CPC)

Richard Johnson (CSU)

Chuck Long (PNNL)

Steve Lord (NOAA/NCEP/EMC)

Mike McPhaden (NOAA/PMEL)

Eric Maloney (CSU)

Mitch Moncrieff (NCAR)

Jim Moum (OSU)

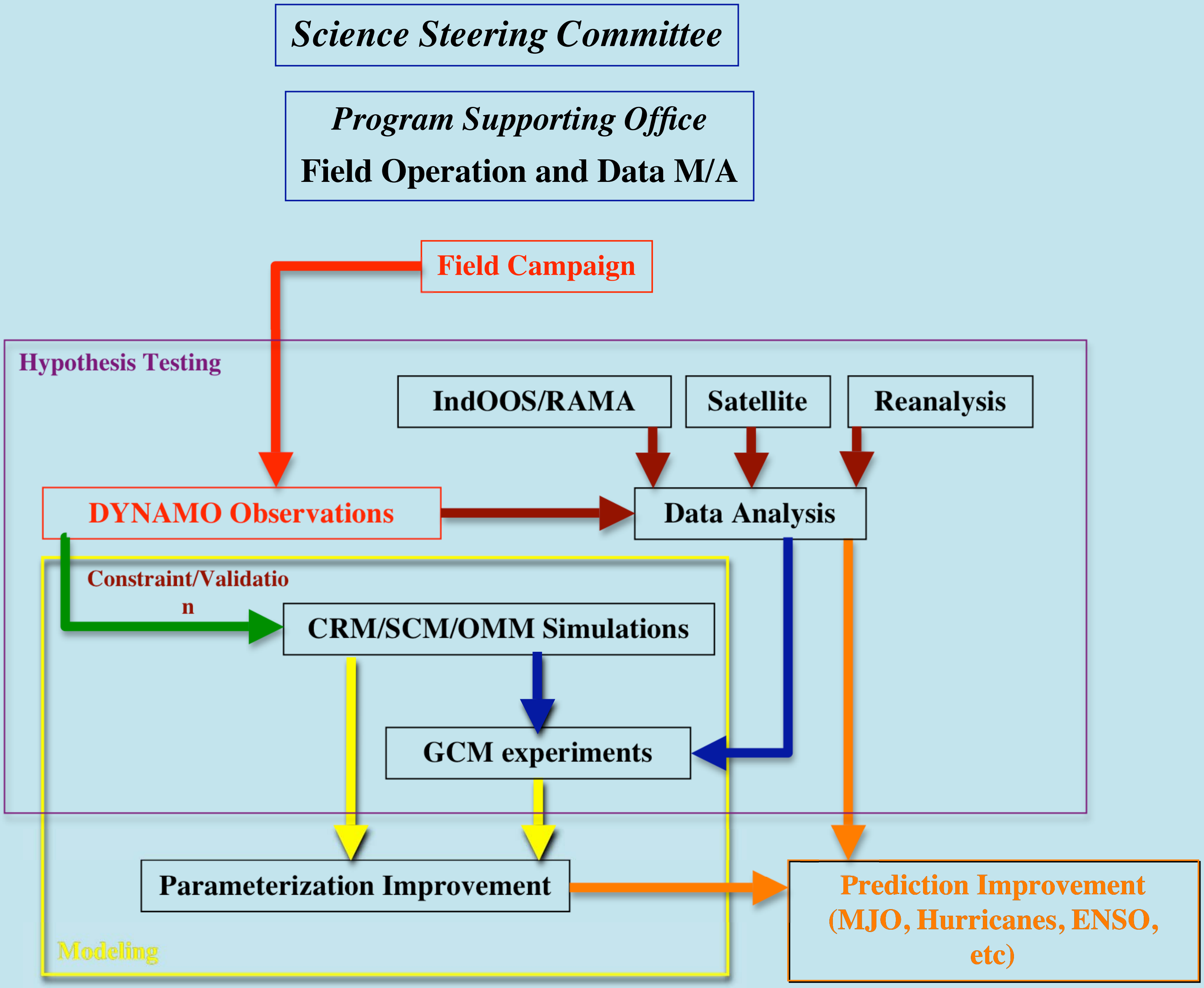
Steve Rutledge (CSU)

Augustin Vintzileos (NOAA/NCEP/EMC)

Duane Waliser (CalTech/JPL)

Chidong Zhang (UM)

DYNAMO Program Structure



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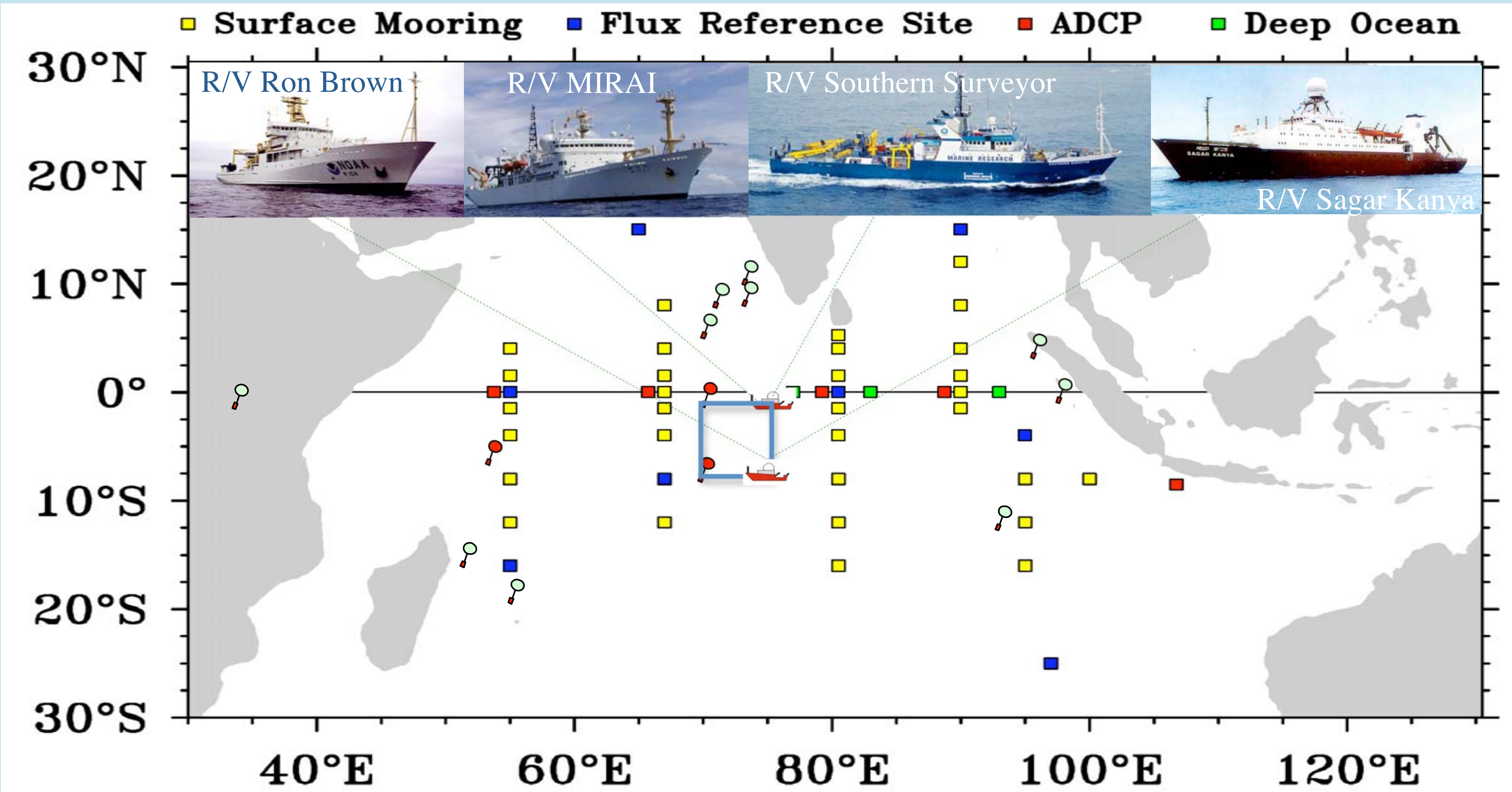
DYNAMO/CINDY2011 Field Campaign

- sounding-radar array
- ship-based measurement of air-sea flux, aerosol, and upper-ocean mixing
- addition mooring of surface meteorology and upper ocean measurement
- enhanced soundings at operational sites



Land-based operational sounding site   Land-based enhanced sounding site   RAMA

Program Synergy

CINDY2011/DYNAMO (September 2011 – January 2012): atmospheric heating and moistening profiles, cloud and precipitation, upper-ocean mixing and turbulence, aerosol

AMIE (October 2011 – March 2012): radiation, cloud, atmospheric profiles (pairing with DYNAMO SMART-R+AMF2 on Gan for EOP)

HARIMAU (2004 -): cloud, atmospheric boundary layer

PAC^{3}E-SA/7SEAS (2011): aerosol, convection

ONR Air-Sea (late 2011): meso-scale air-sea-wave interaction

DYNAMO/CINDY2011 Observation Periods

Long-Term Monitoring (LTM): IndOOS, RAMA

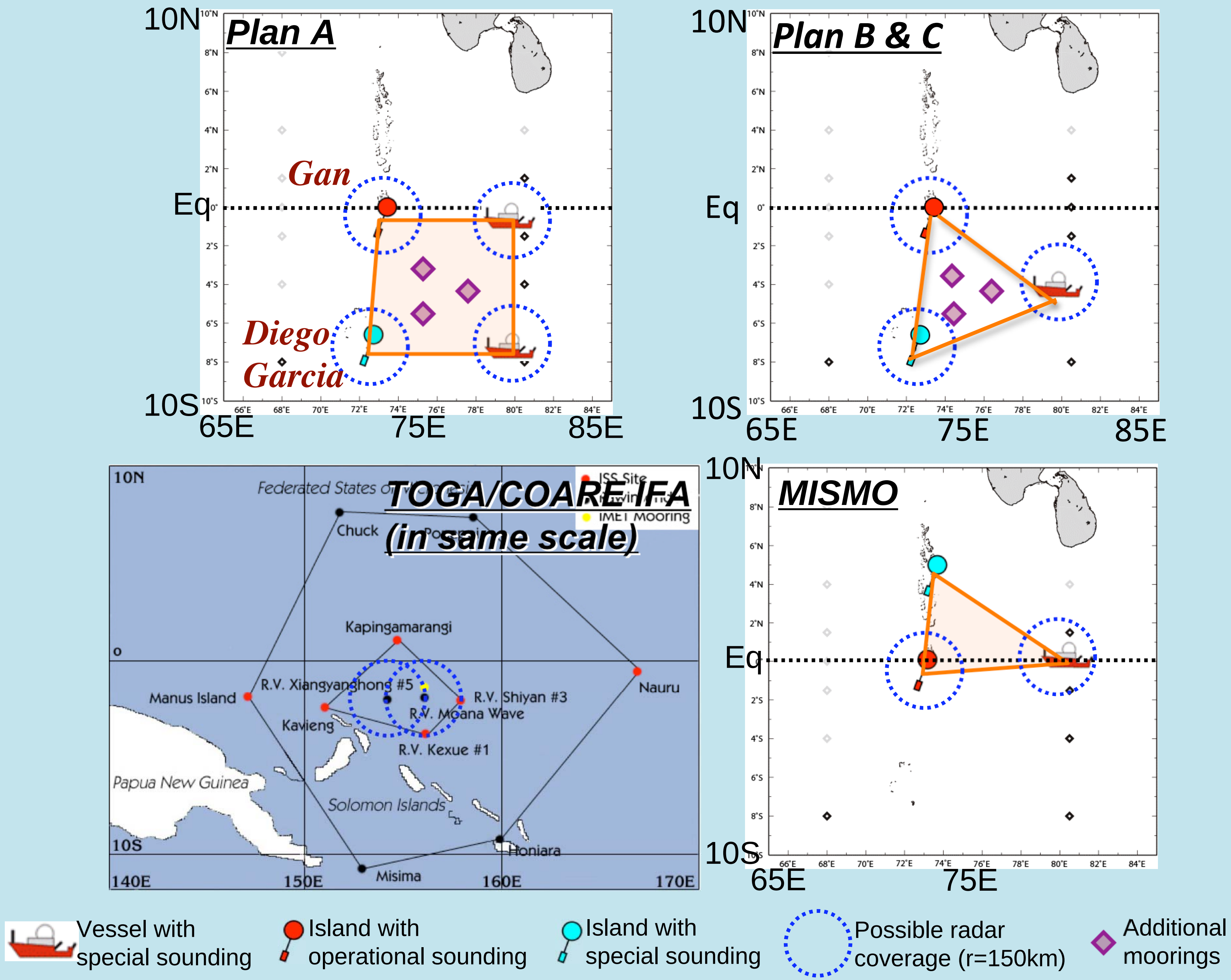
Extended Observing Period (EOP): island-based radar (SMART-R) and radiation package (AMF2), surface/upper-ocean moorings, drifters, enhanced RAMA moorings

Intensive Observing Period (IOP): sounding-radar array, ship-based measurement of air-sea fluxes, atmospheric boundary layer and upper-ocean mixing/turbulence profiles, aerosol

SOP: enhanced soundings

September	October	November	December	January	February
	2011			2012	

Proposed Sounding-Radar Array



Tentative Ship Schedules

OCT NOV DEC JAN Feb

Plan A: R-Array

NE: JPN (50) Oct 1 – Nov 20; US (40) Nov 20 – Dec 30

SE: US (40) Oct 1 – Nov 10; IND (30) Nov 10 – Dec 10; AUS (25) Dec 10 – Dec 30

SOP

Total IOP days: 91
Chance for a major MJO: 85%
Budget accuracy: high

Plan B: T-Array

JPN (50) Oct 1 – Nov 20; IND (30) Nov 20 – Dec 20; AUS (25) Dec 20 – Jan 15; US (40) Jan 15 – Feb 25

Total IOP days: 148
Chance for a major MJO: >95%
Budget accuracy: medium

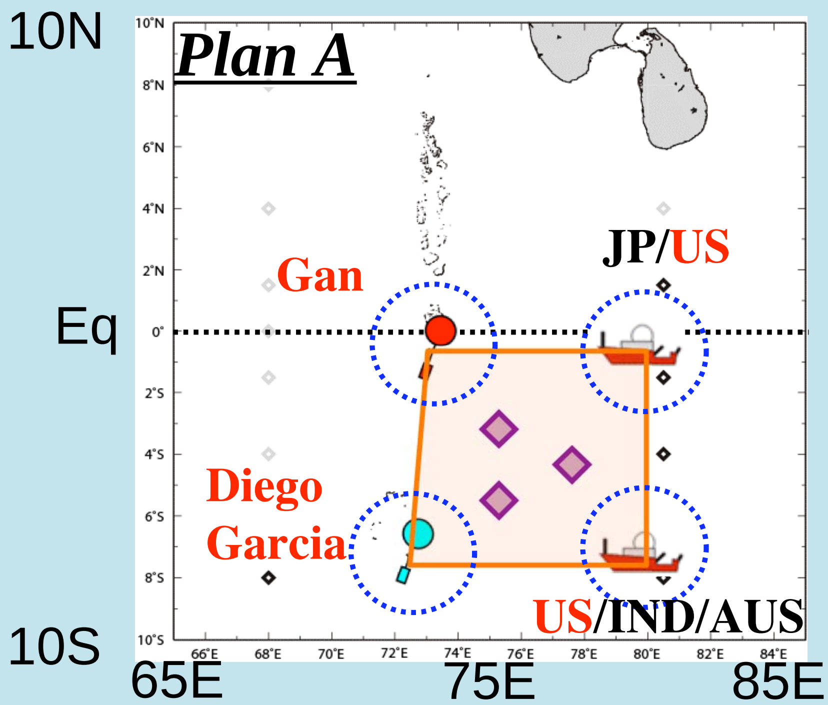
Plan C: T-Array

JPN (50) Oct 1 – Nov 20; IND (30) Nov 20 – Dec 20; AUS (25) Dec 20 – Jan 15

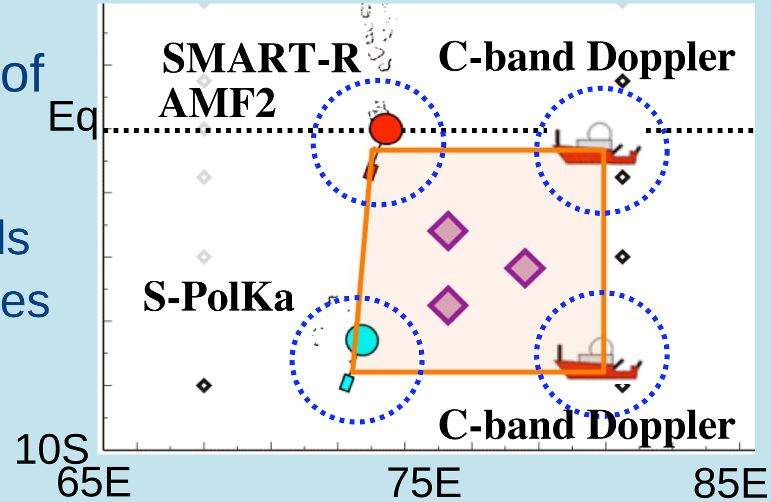
Total IOP days: 107
Chance for a major MJO: 90%
Budget accuracy: medium

DYNAMO Sounding Network
(4 per day for IOP; 8 per day for SOP)

- Convective environment (humidity, temperature and wind)
- Moisture divergence and vertical motions
- Diabatic heating and Moisture Sink profiles (Q1, Q2)



RADAR NETWORK AND ITS ROLE IN DYNAMO



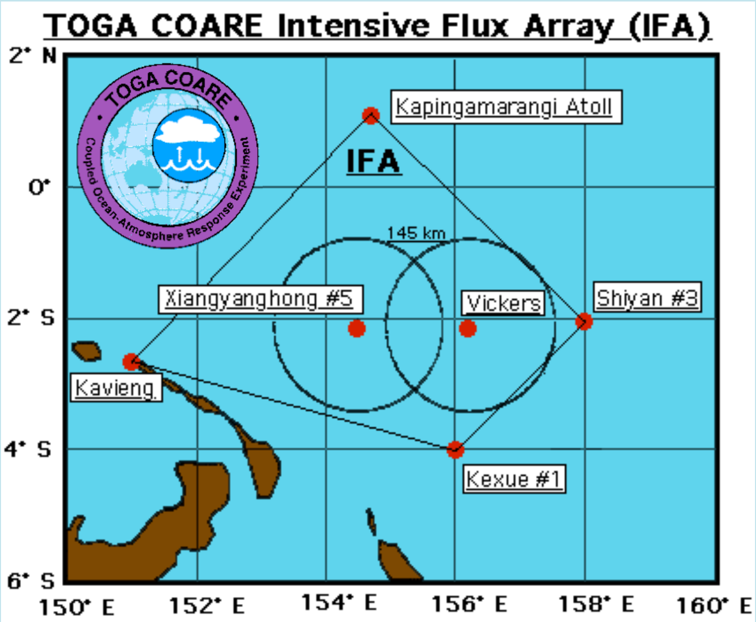
- Characterize moisture profile and spectrum of convection in suppressed phase
  - * Spectra of area, height, lifetime, motion, LWC of non-precipitating and raining clouds
  - * Tendency of small clouds to organize in lines or random cells in relation to boundary layer winds
  - * Profile of boundary layer humidity
- Make measurements to assess how precipitation efficiency changes during MJO transitions
  - Vertical structure of reflectivity
  - Single Doppler representation of storm circulations
  - * Polarimetric documentation of microphysical mechanisms
- Determine structure of heating and momentum feedbacks as a function of MJO phases
  - Convective/stratiform separation of precipitation
  - Single Doppler representation of storm circulations
  - * Rain estimation

S-Polka will contribute uniquely to items marked with *

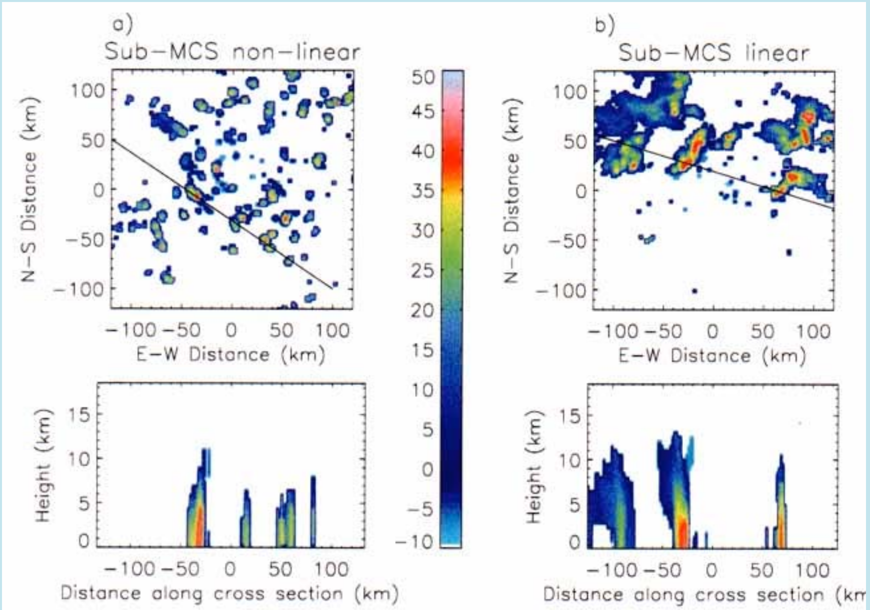
TOGA Radar

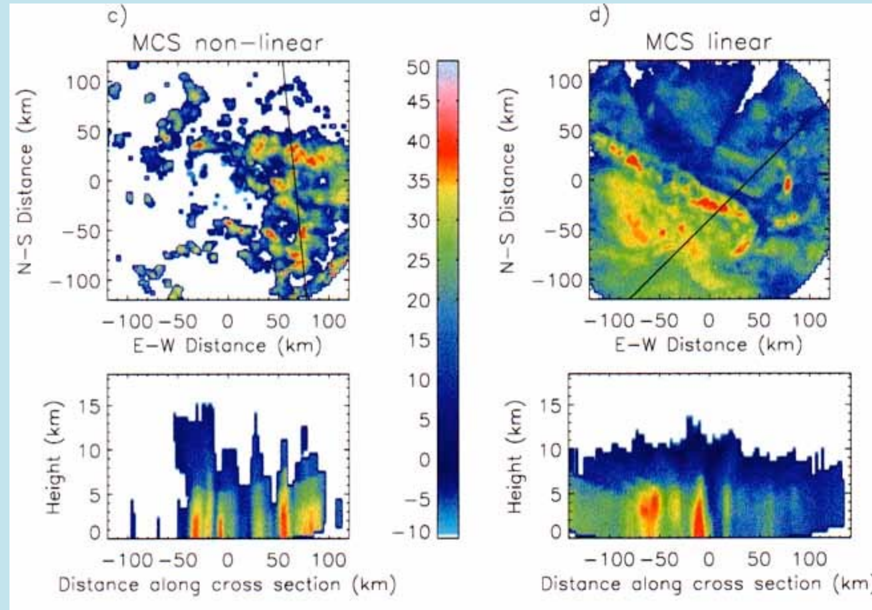
- Used successfully in TOGA COARE and elsewhere
- 5 cm Doppler radar, single polarization
- State of the art signal processor upgrade to be done before field campaign
- To be installed on a UNOLS ship (Revelle?)
- Deployment costs about $400K (installation and operation)
- PI, S. Rutledge, Colorado State University

TOGA COARE: Dec 92-Feb 93

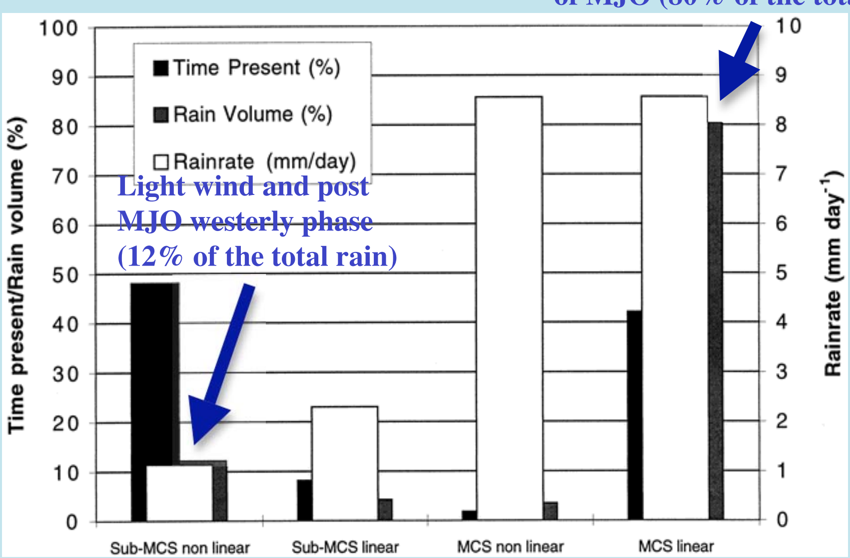


Classification of convective systems by mesoscale vs. sub mesoscale definitions





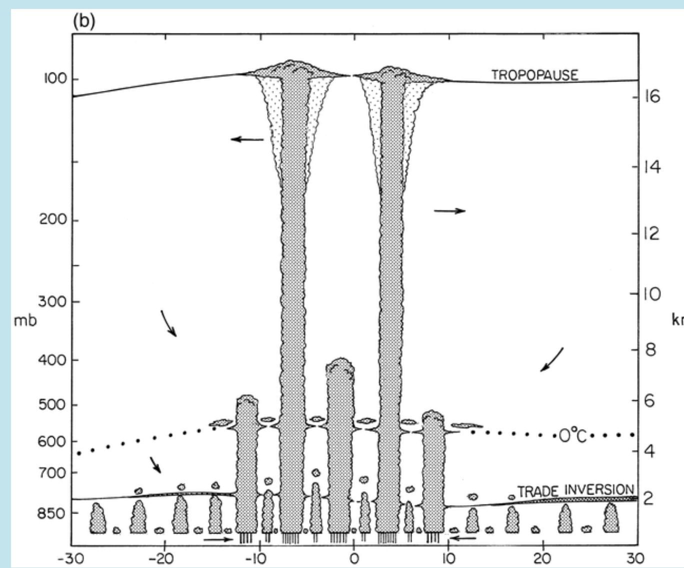
Pre-MJO and at leading portion of MJO (80% of the total rain)



Light wind and post MJO westerly phase (12% of the total rain)

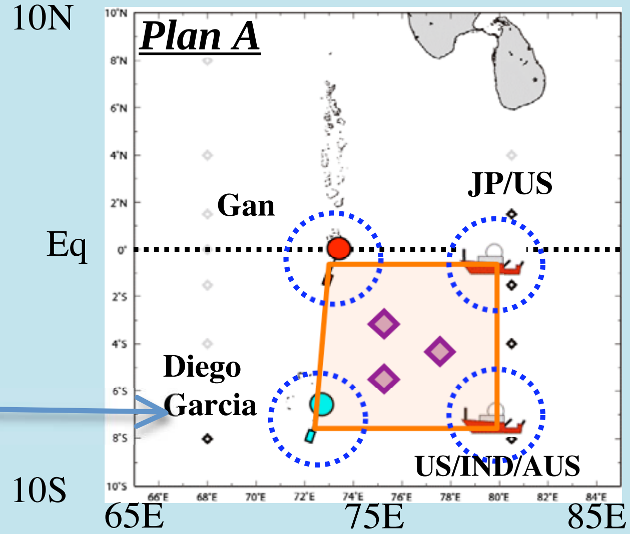
Rickenbach and Rutledge (1998)

Trimodal cloud structure



Johnson et al. 2000

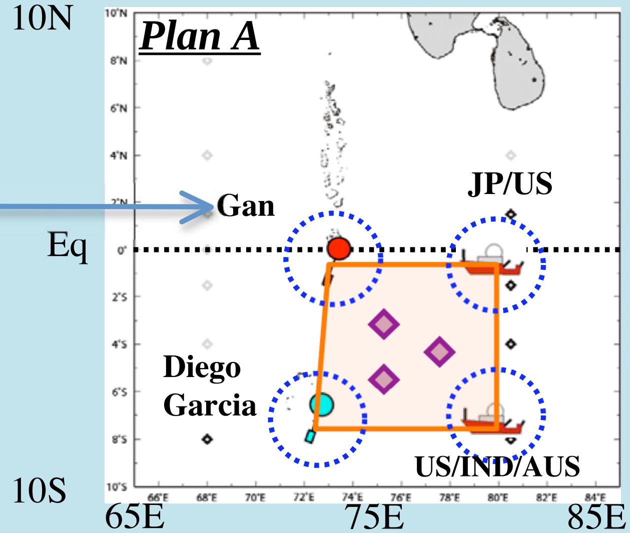
NCAR S-PolKa Radar



- S-band (10 cm) – convection spectrum, organization, and evolution through the MJO life cycle
- Single Doppler – convective storm circulations
- *Ka-band (8 mm) – 3D structure of shallow non-precipitating clouds
- * Dual wavelength (Ka- and S-band) – vertical profile of boundary layer specific humidity
- Dual polarimetric – microphysics of oceanic tropical convection
- Proposed to be deployed on Diego Garcia (budget being estimated)
- PIs, Socorro Medina and Robert Houze, University of Washington

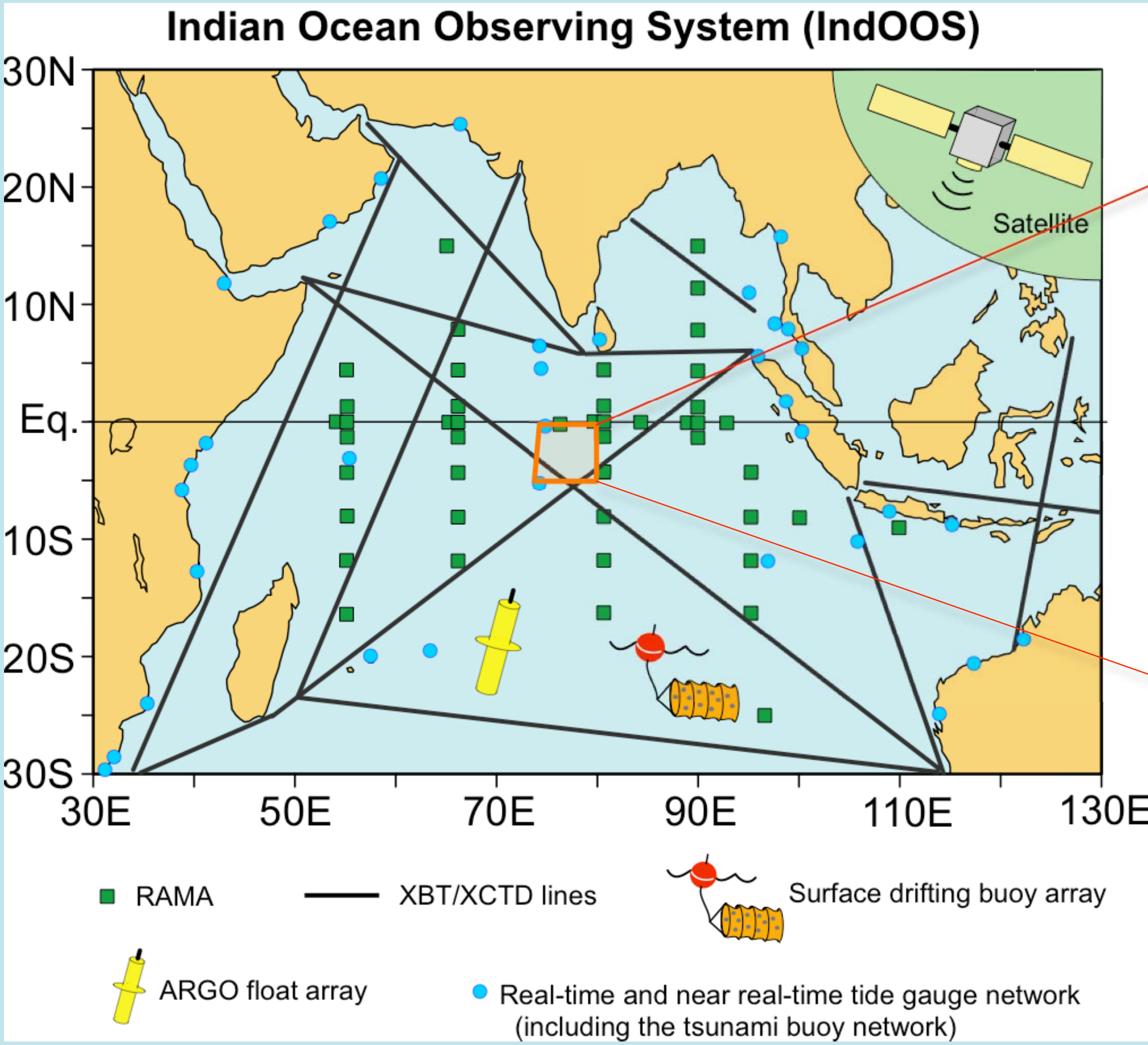
* Need upgrade

SMART Radar

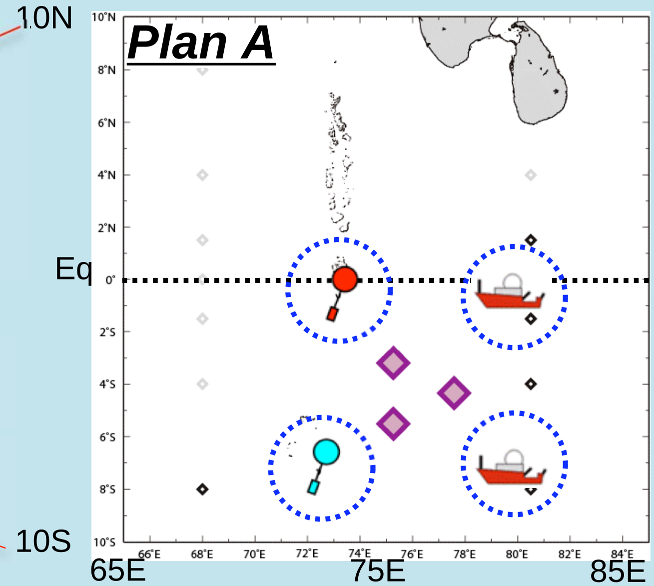


- C-band (5.5 cm), Doppler radar jointly owned by Texas A&M and University of Oklahoma
- 2.54 m antenna, ~1.5° beamwidth (circular)
- International 4700 dual-cab diesel truck (~2.6 m wide, ~10 m long, ~4.1 m tall, ~11,800 kg) with 10-kW diesel generator
- Reflectivity, radial velocity, and spectrum width measured out to 150 km radius
- PI, Courtney Schumacher, Texas A&M
- *Deployment cost: $300K (JAMSTEC agrees to share $150K)*

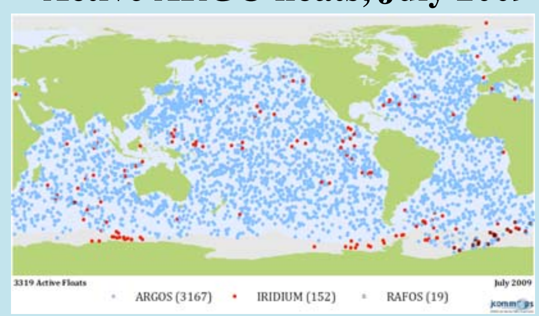
DYNAMO Air-Sea Network



RAMA is fully instrumented in the MJO initiation region

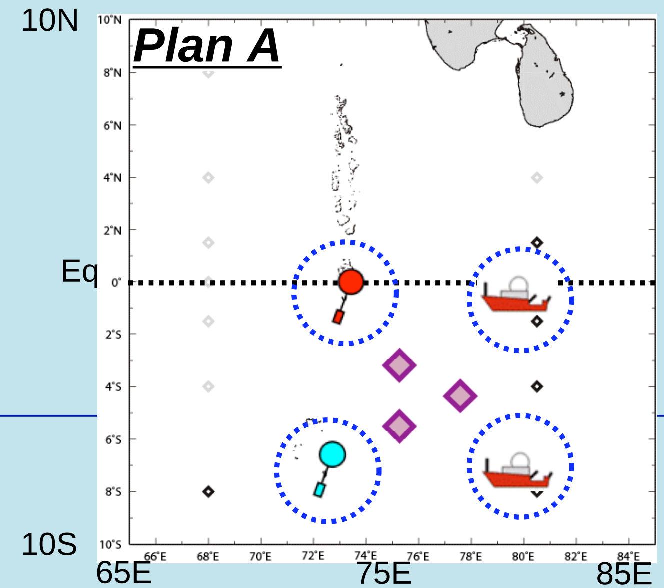


Active ARGO floats, July 2009



DYNAMO Air-Sea Network

Ship-borne measurements:
– surface turbulent and bulk fluxes, radiation fluxes, rain (US, JP, AU, IN)
– multiple-ADCP (2 1200-kHz 30m, 300-kHz 100m, 75-kHz 500-600m) (US)
– 120 kHz echosounder (150m) (US)
– Chameleon turbulence profiler (200m) (US)
– CTD (JP, AU, IN)
– ACDP (US, JP, AU, IN)
– TSG (JP, AU)
– SST (JP, AU)
– SeaSoar (AU)



Mooring-enhancements: primarily on RAMA moorings
– surface bulk fluxes, radiation flux, rain
– subsurface fluxes (*χpod)*
- ADCPs

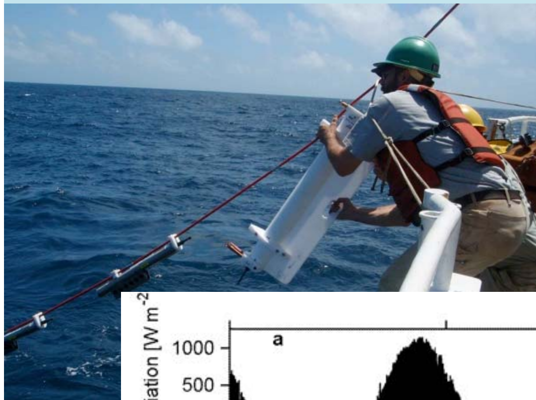
shipboard profiling flux measurements

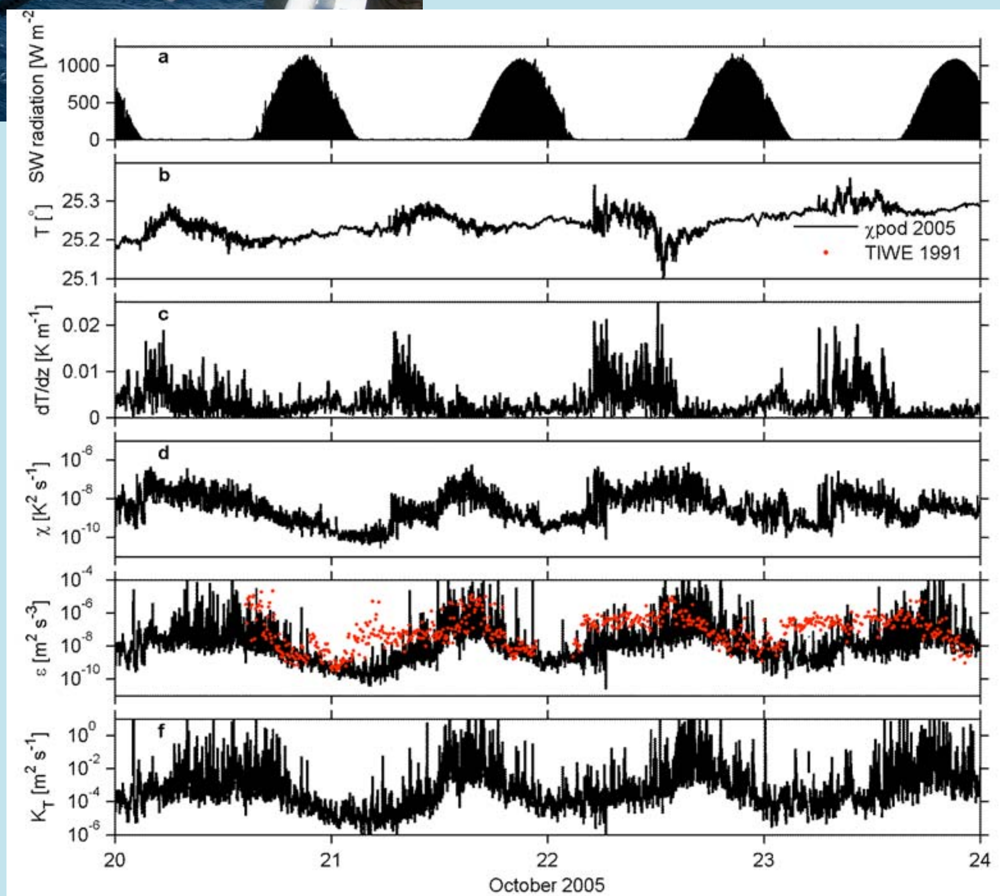
multiple high-res modern ***ADCP***s
sampled rapidly
Hull 300 kHz
75 kHz
Over-the-side
150 kHz

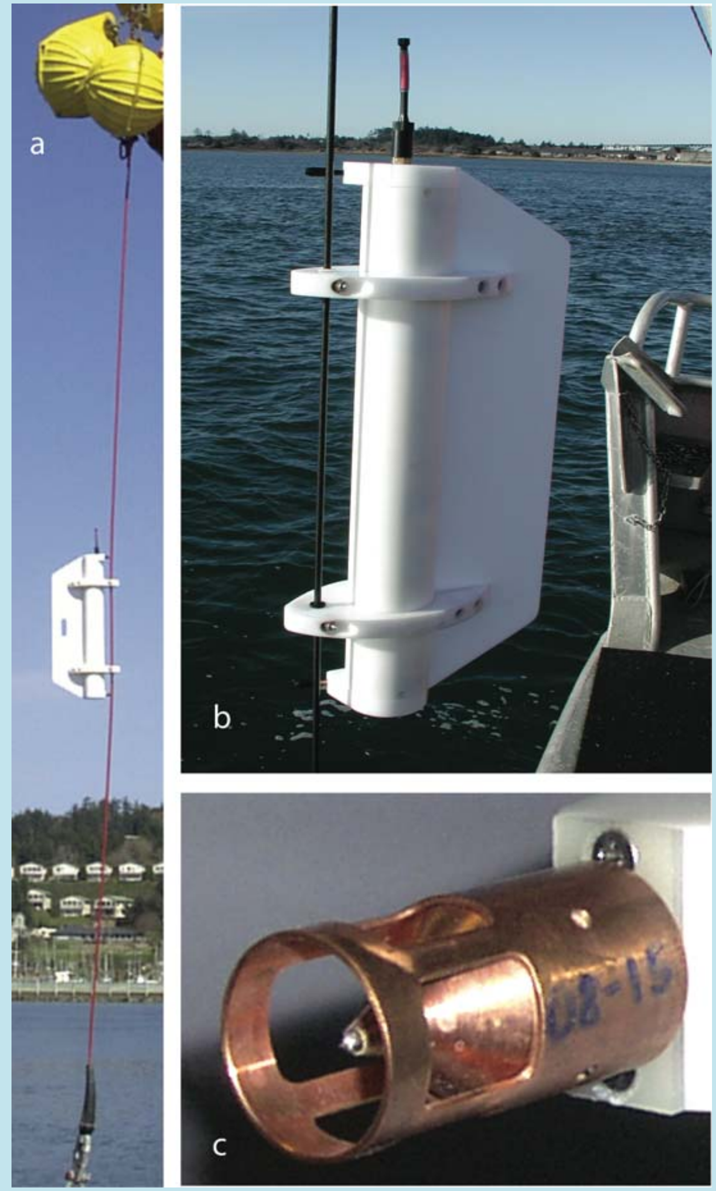
Chameleon turbulence profiler

χpod

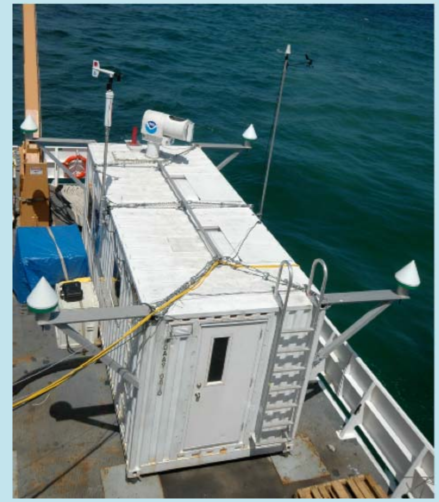
- moored subsurface flux measurement
- analogous to a subsurface flux tower



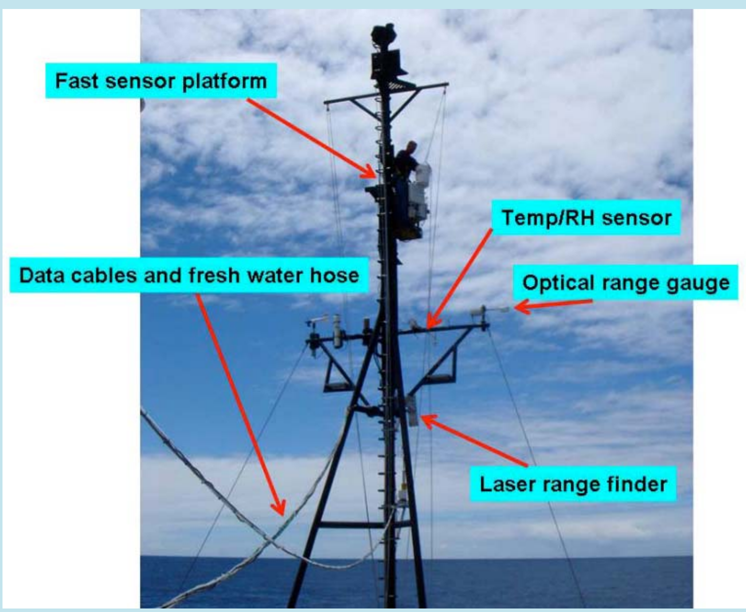


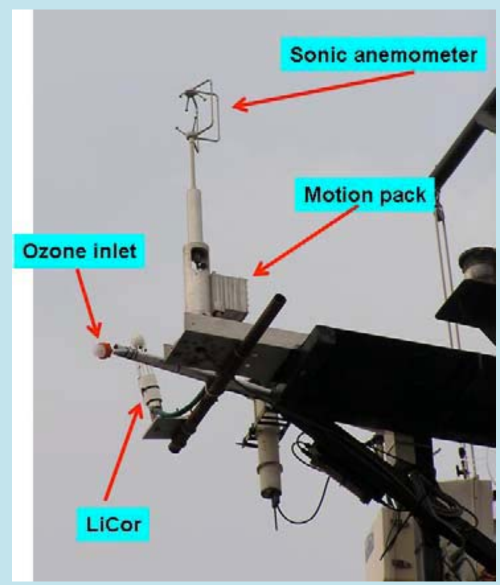


Flux, Boundary Layer, Cloud Observing Systems

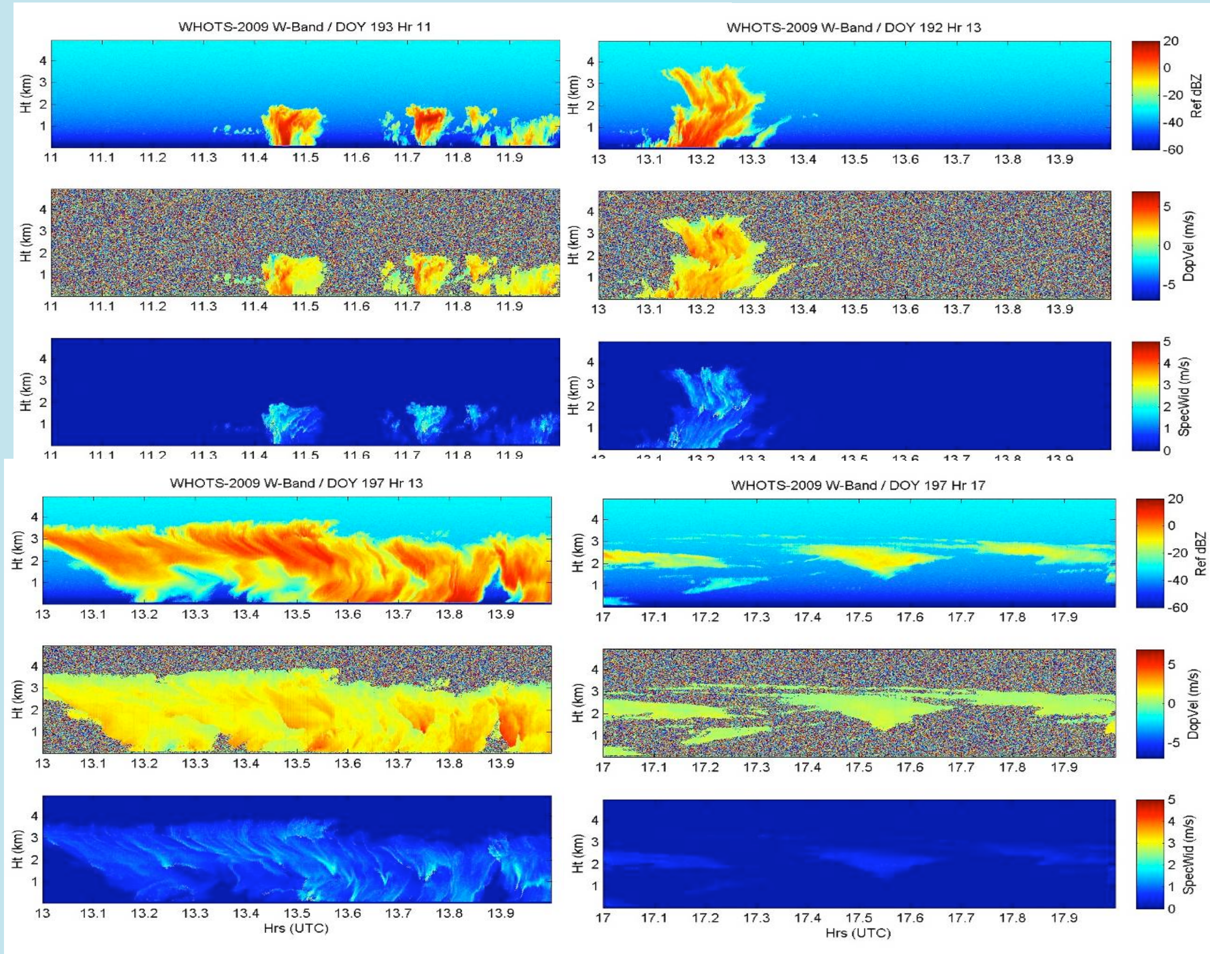


The picture on the left shows the ESRL Doppler Lidar (right), the W-band radar (left), the air/sea flux system (on the jack staff) and the elevated inlet for an in-situ aerosol sampling system operated by PMEL located on the O2 deck of the RV Ron Brown during the VOCALS_REx study in 2008. The picture on the right shows the HRDL seatainer mounted on the Fantail of the same ship during TEXAQS study in 2006.



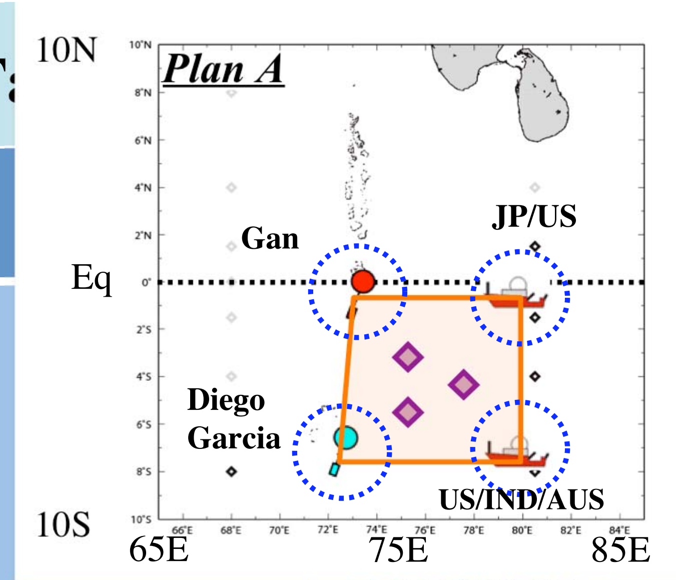


Shallow Convection Life Cycle



Four time-height cross section panel sets, each from 1 hour of data from ESRL/PSD W-band cloud radar. Each individual panel set shows: radar reflectivity (dBZ), top; mean Doppler velocity (m/s, positive down), middle; Doppler width (m/s) of the return, bottom. Panel sets are examples of: weak convection, upper left; strong convective cell, upper right; strong cell complex, lower left; decaying cloud remnants, lower right.

Summary of DYNAMO Major F



Facility	Plan A (91 days)	Plan B (148 days)		
Ship	80 days	40 days		
TOGA Radar	10/1/2011 – 12/30/2011	1/15/2011 – 2/25/2012		
Soundings		[11/20/2011 – 2/25/2012]		Deployment
Air-Sea Interaction				NSF OCE, ONR, NOAA
S-Polka/Soundings (Diego Garcia)	10/1/2011 – 12/30/2011	10/1/2011 – 2/25/2012	10/1/2011 – 1/15/2012	NSF Deployment
SMART-R (Gan)	10/1/2011 – 3/31/2012 (EOP)	10/1/2011 – 3/31/2012 (EOP)	10/1/2011 – 3/31/2012(EOP)	NSF ATM JAMSTEC
AMF2 (Gan)				DOE
Moorings	10/1/2011 – 3/31/2012 (EOP)	10/1/2011 – 3/31/2012 (EOP)	10/1/2011 – 3/31/2012 (EOP)	NSF OCE, ONR, NOAA

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Major Issues to be Resolved

- **Ship time: Ron Brown vs. Revelle (need to install the TOGA radar)**
- **S-PolKa Ka-band upgrading schedule**
- **NSF-JAMSTEC contact on SMART-R deployment**

- **NSF OCE-ATM proposal coordination**
- **NSF/NOAA proposal coordination**
- **DYNAMO – ONR IO Exp coordination**
- **Modeling "early engagement" and funding procedures**

- DYNAMO – IAG coordination √
- Sounding operation at Diego Garcia √
- ~~DYNAMO – CPT connection~~

TOGA Radar Issue: Installation and Ship Schedules

Plan A: Install at a domestic port

October 2011 - DYNAMO field campaign starts

May 2011 - ship leaves port

April 2011 – install and test radar

March 2011 – truck radar from lab to installation port

February 2011 – assess/order/build parts for deck mounting requirements

January – February 2011 – visit ship to evaluate installation requirements

Plan B: Install at a foreign port

October 2011 - DYNAMO field campaign starts

September 2011 - ship leaves foreign port

August 2011 – install and test radar

July 2011 – clear customs

April – May 2011 – ship radar from domestic to foreign port

March 2011 – truck radar from lab to domestic port

February 2011 - assess/order/build parts for deck mounting requirements

January – March 2011 – visit foreign port for site survey, establish local contact, estimate shipping cost and storage cost at foreign port

January – February 2011 – visit ship to evaluate installation requirements

DYNAMO Timeline
(proposed deadline in blue)