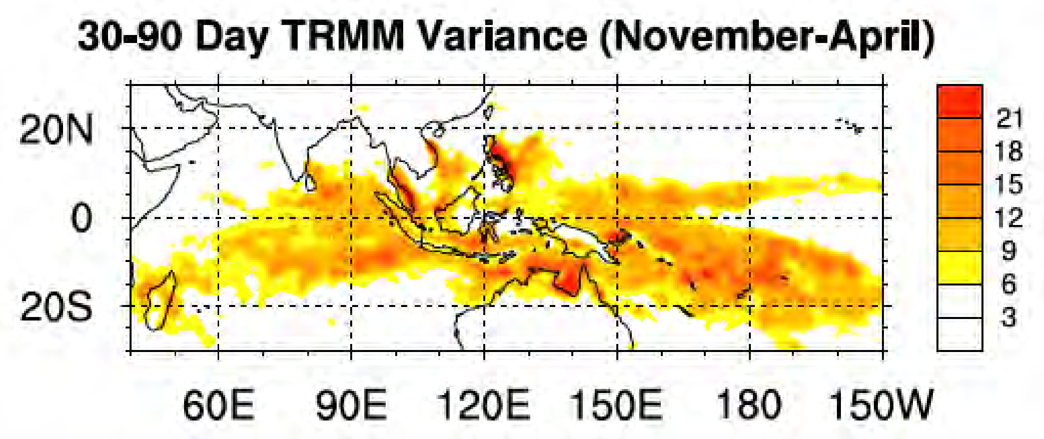
MJO and Diurnal Cycle Experiment (MODEX): The proposed YMC-NCAR aircraft and ground deployment

Courtney Schumacher (Texas A&M),

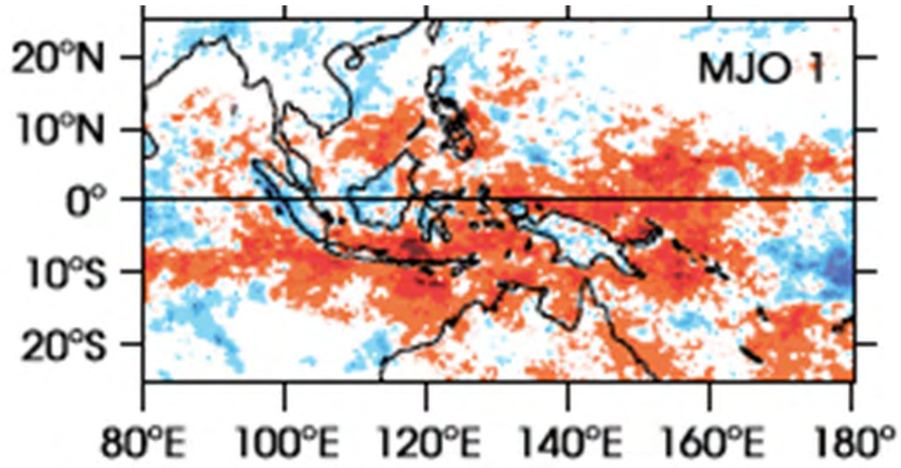
Shuyi Chen and Chidong Zhang (U. Miami)

MJO in the MC

- Weakens over islands
- Jumps ahead, so out of phase over islands vs surrounding ocean
- In models, has trouble propagating through from Indian to Pacific



Sobel et al. (2008)



Peatman et al. (2013)

Table I. Percentage of MJO events moving from one MJO phase to another for reanalysis and model hindcasts.

Phase	1 ⇒ 2	2 ⇒ 3	3 ⇒ 4	4 ⇒ 5	5 ⇒ 6	6 ⇒ 7	7 ⇒ 8	8 ⇒ 1
Reana	71%	81%	81%	80%	86%	79%	68%	55%
Model	71%	81%	80%	71%	72%	78%	65%	87%

Vitart and Molteni (2010)

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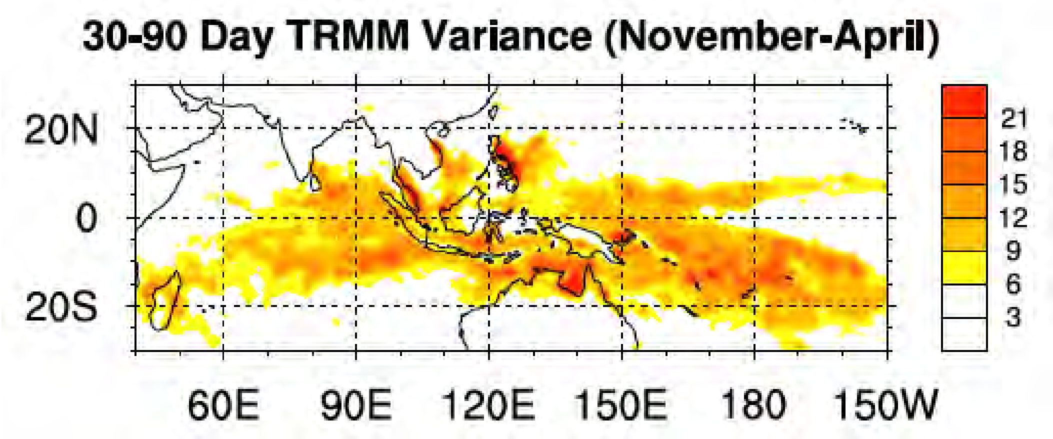

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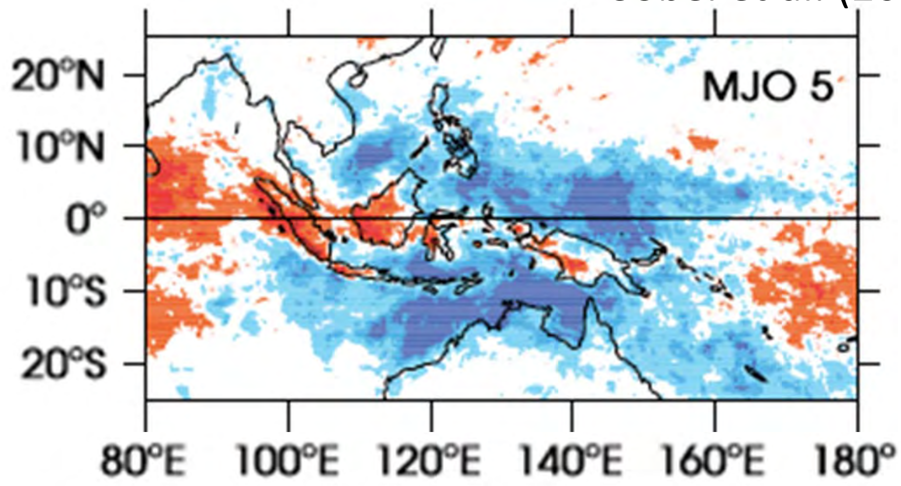

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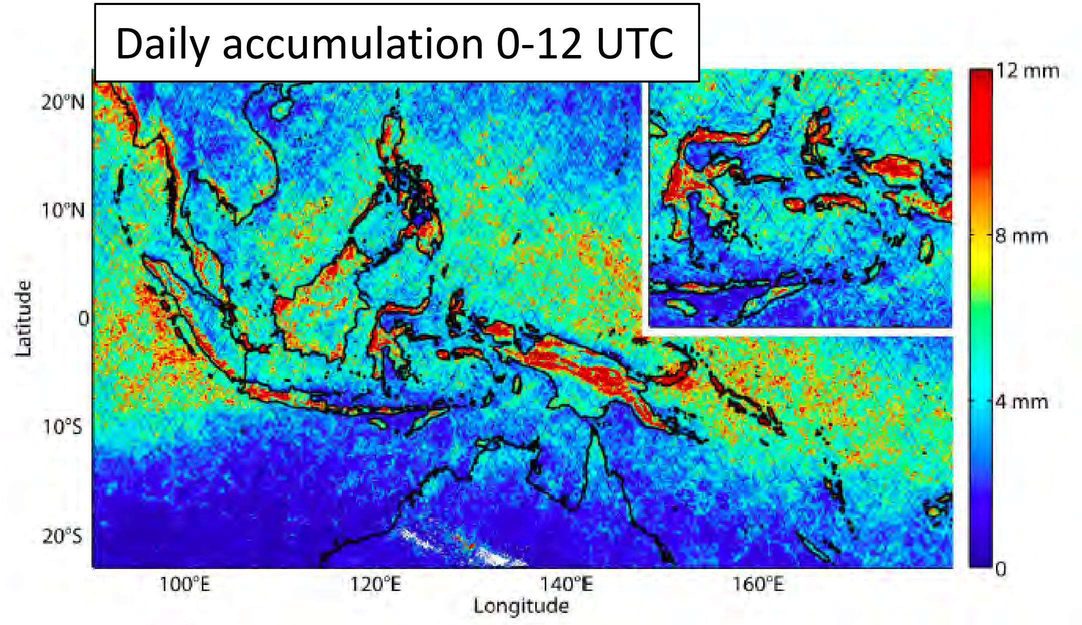
Diurnal cycle in the MC

- Strongly controlled by mountains & coastlines
- Interacts with MJO and other low-frequency variability
- Mesoscale systems form over land in day, move over ocean at night
- Role of orography in deep tropics not fully understood



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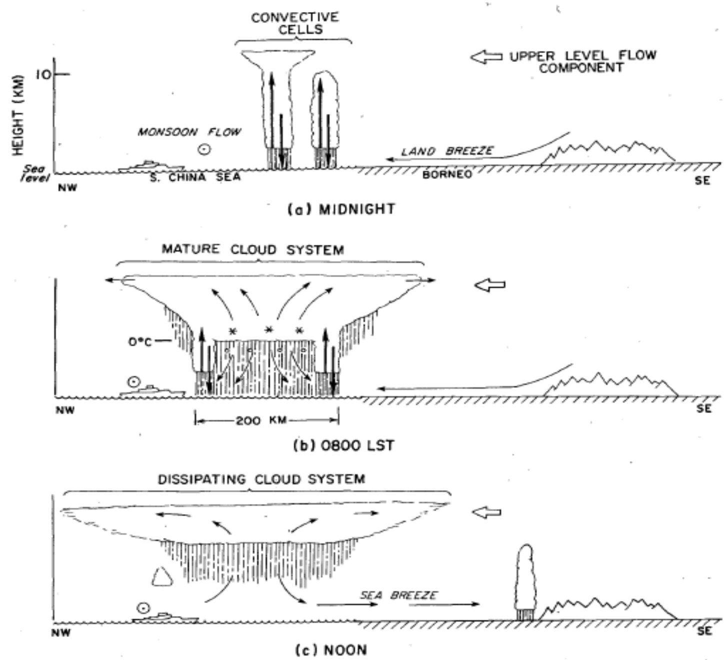

Houze et al. (1981)

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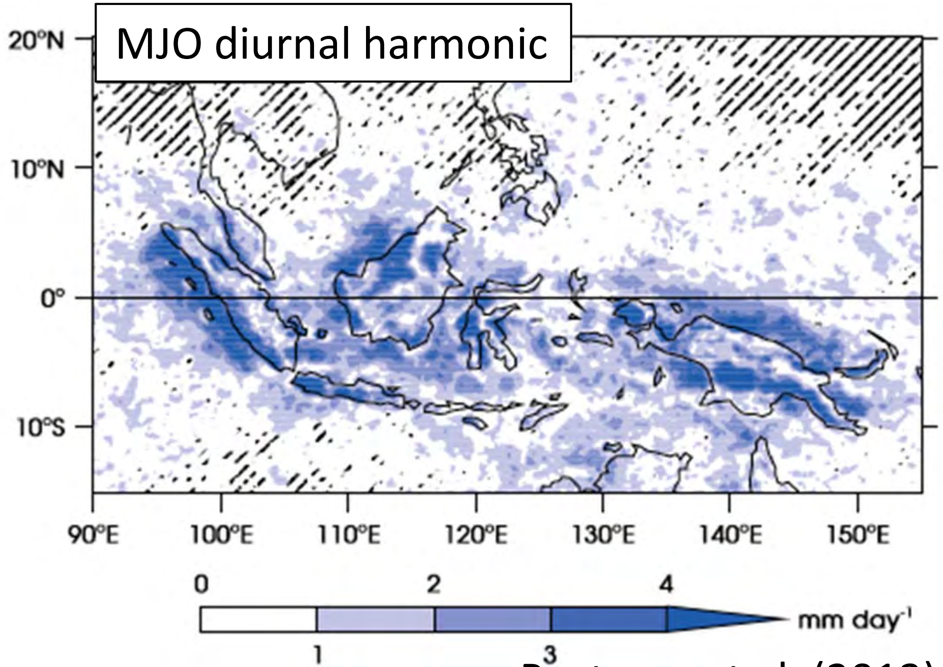
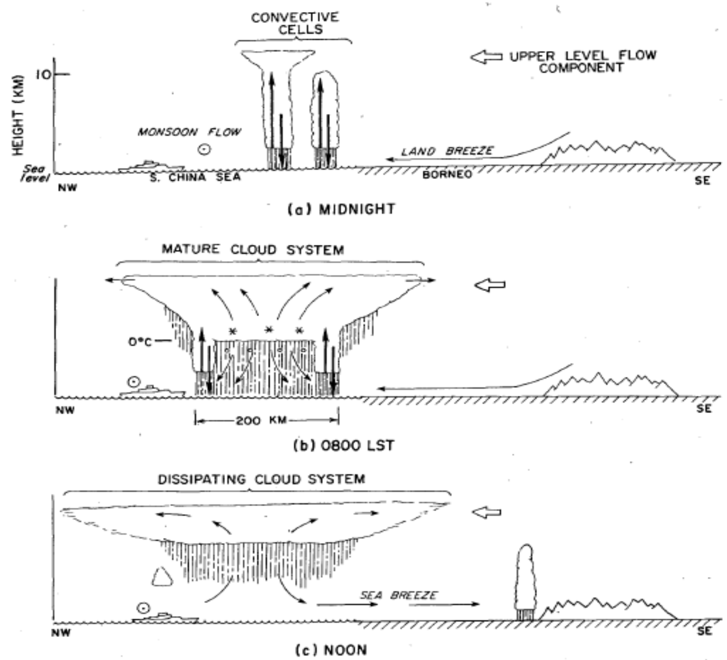


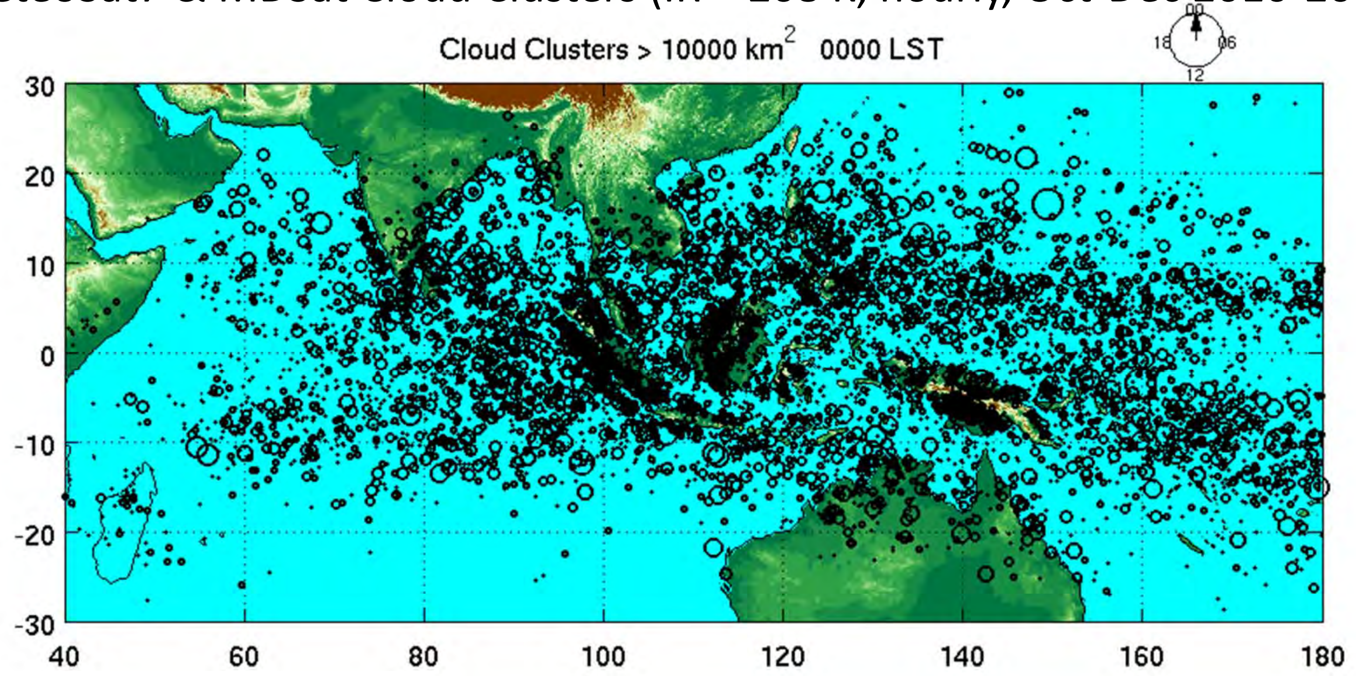
Peatman et al. (2013)

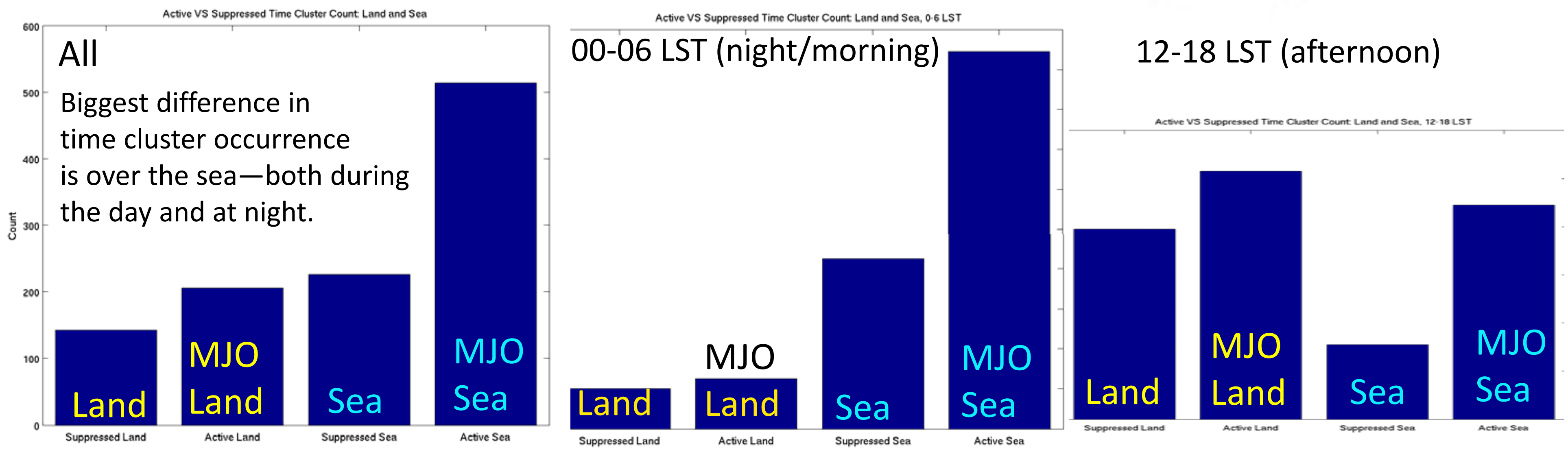


Houze et al. (1981)

Diurnal Cycle of Convective Systems and MJO

MeteoSat7 & MDSat Cloud Clusters (IR < 208 K, hourly, Oct-Dec 2010-2012)

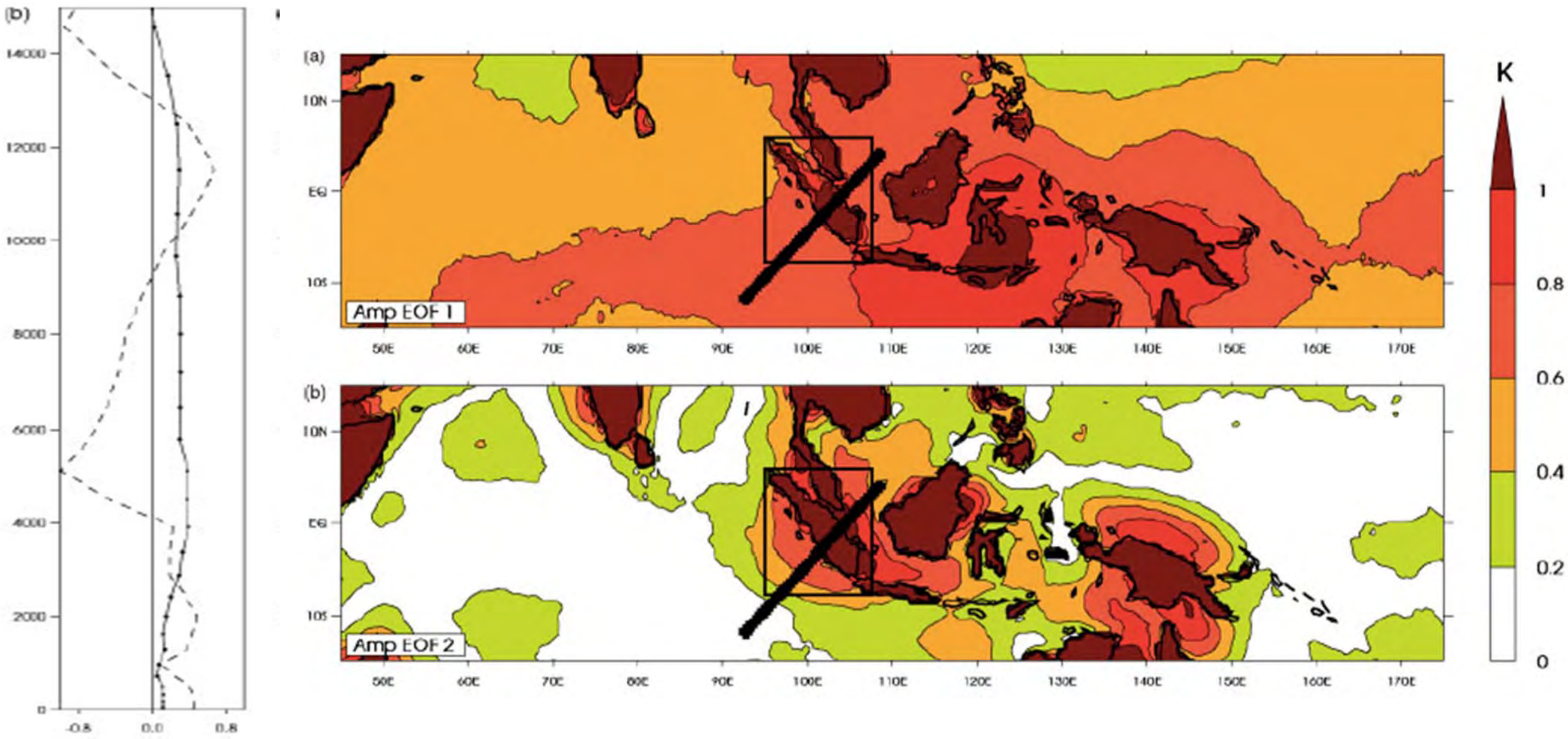




MODEX Science Questions

- Diurnal precipitation: What are the prime diurnal cycle mechanisms of convection over the MC (e.g., land/sea contrasts, topography, or convective dynamics/microphysics/organization)? How important is representing the diurnal cycle in model simulations to obtain correct large-scale precipitation?
- MJO propagation: How does the character of MJO convection change as the MJO goes across the MC? What is the interaction with the diurnal cycle? Why do some models fail to propagate the MJO across this region?

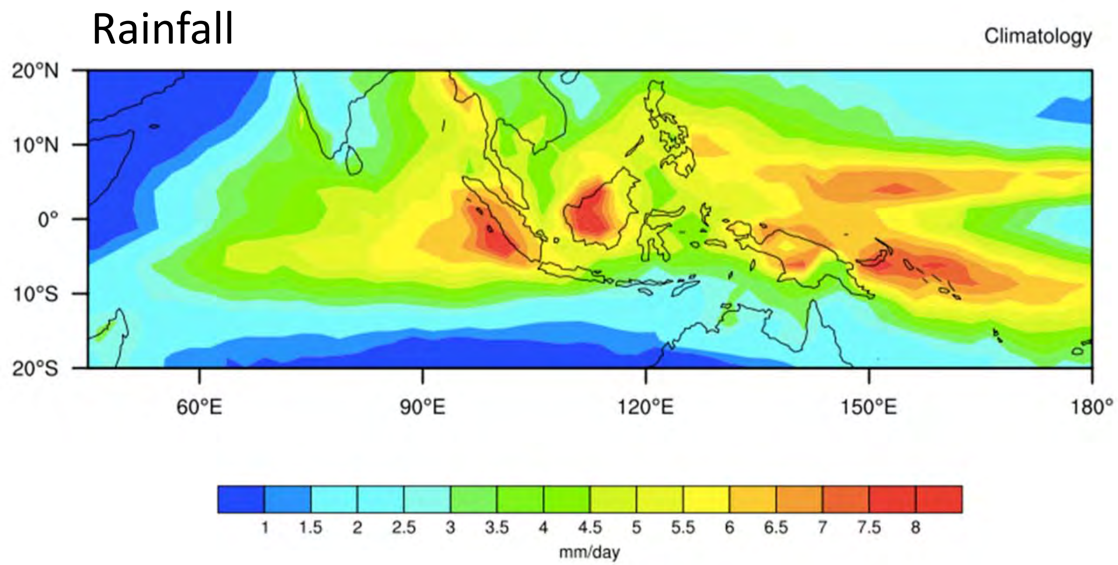
Convective and stratiform EOFs

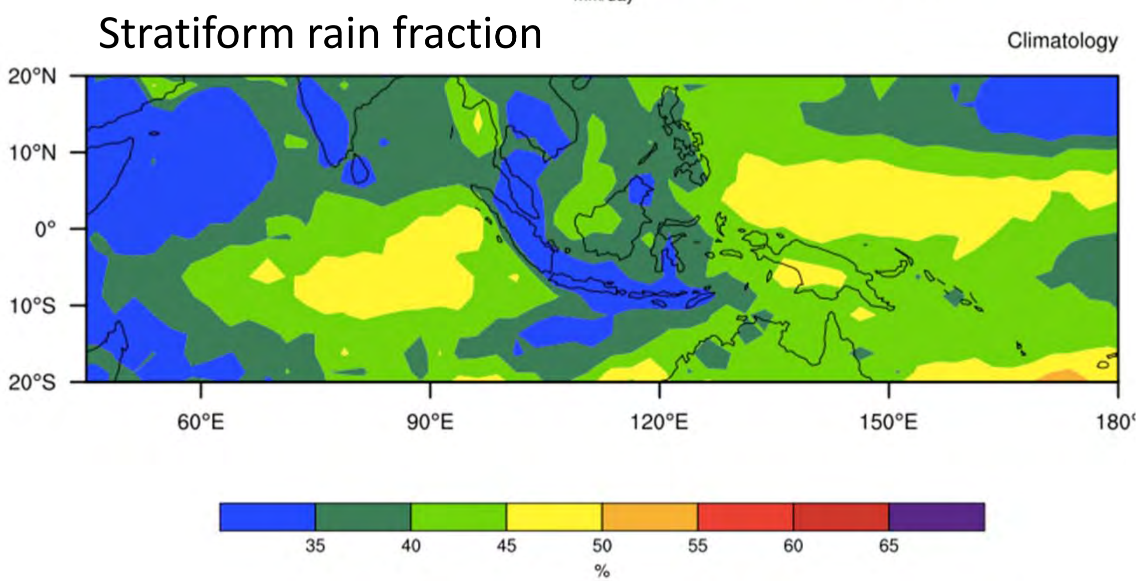


The stratiform EOF from a UK Met 40 km run describes the variability associated with offshore propagating systems ***across the MC***

Love et al. (2011)

TRMM PR 1998-2014

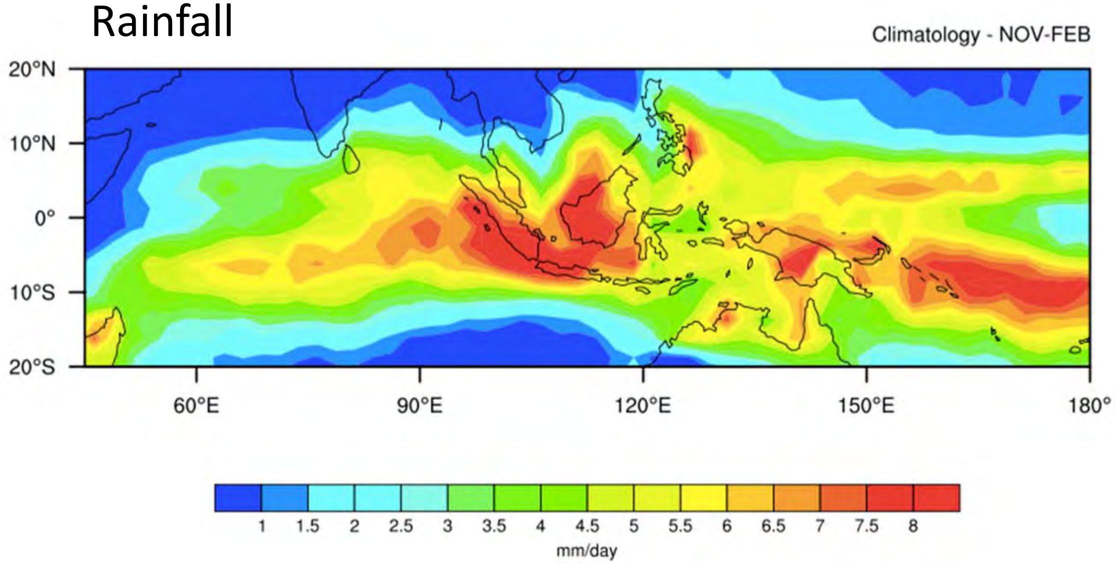




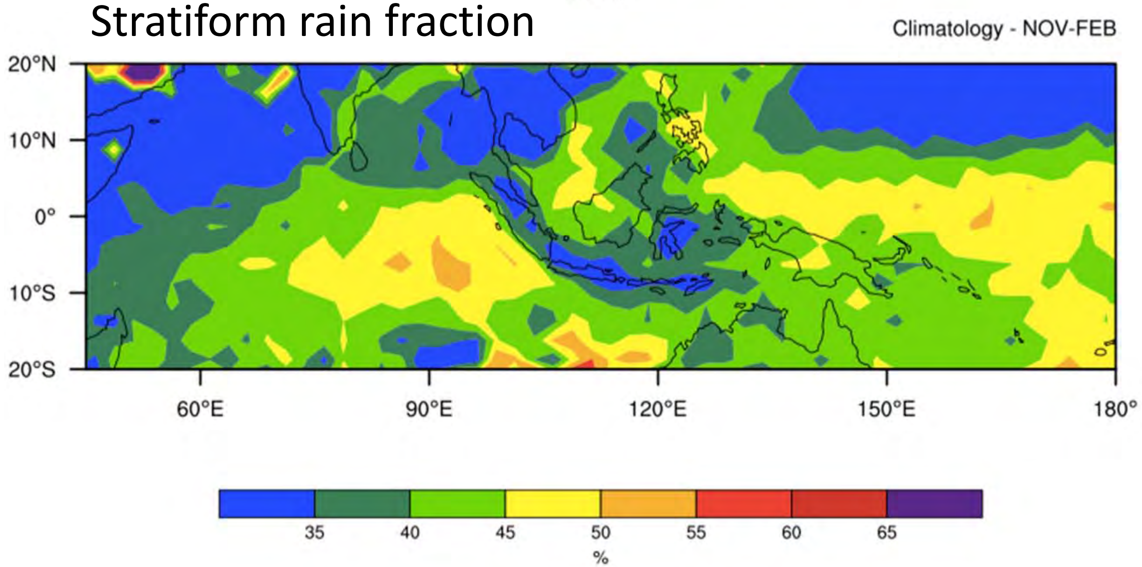
- TRMM PR climatology shows rain maxima over or just offshore of large MC islands (Sumatra, Borneo, and New Guinea)
- Lowest stratiform rain fractions exist over the farthest west islands in the MC

TRMM PR 1998-2014 Nov-Feb

Rainfall

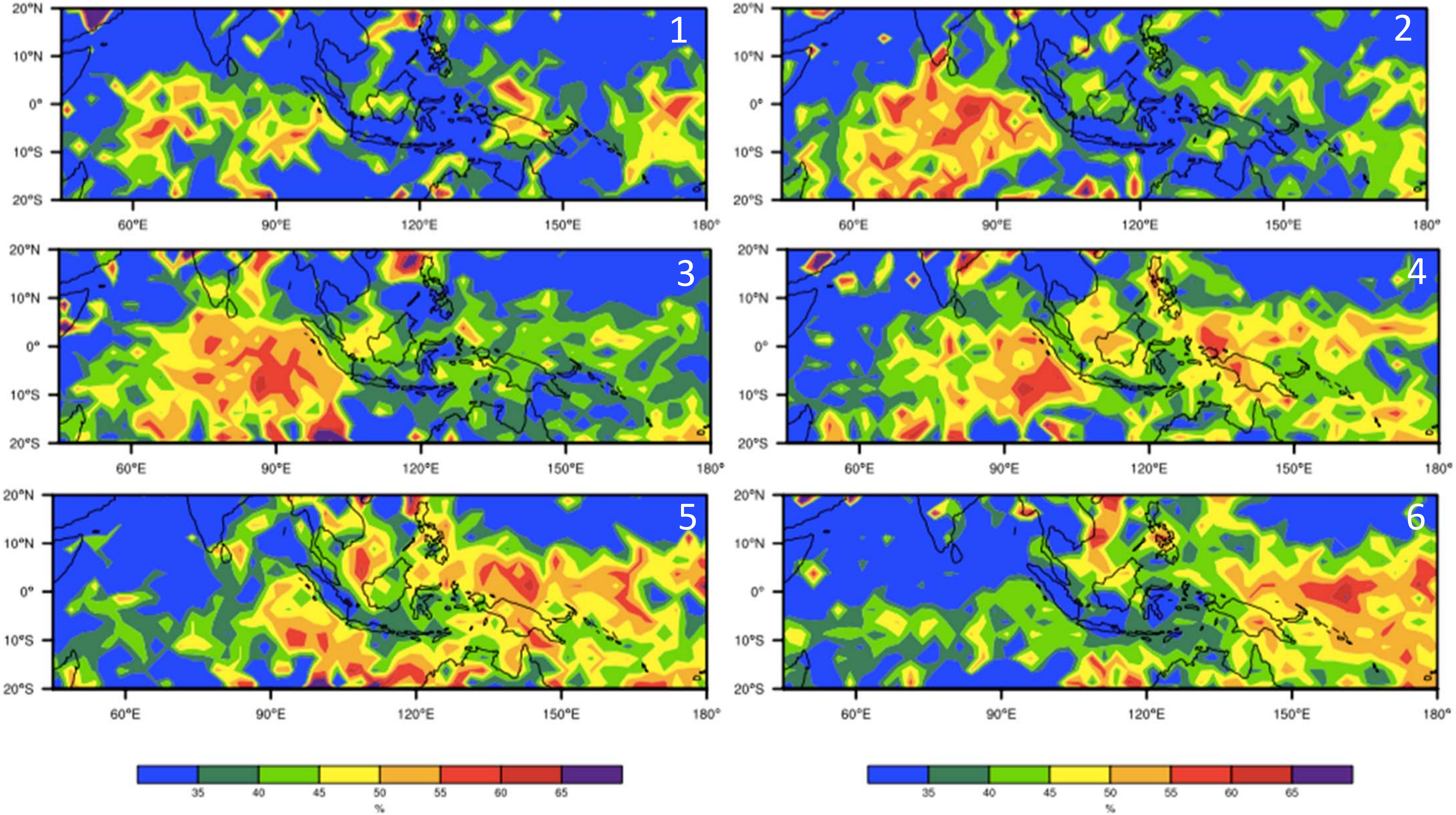


Stratiform rain fraction



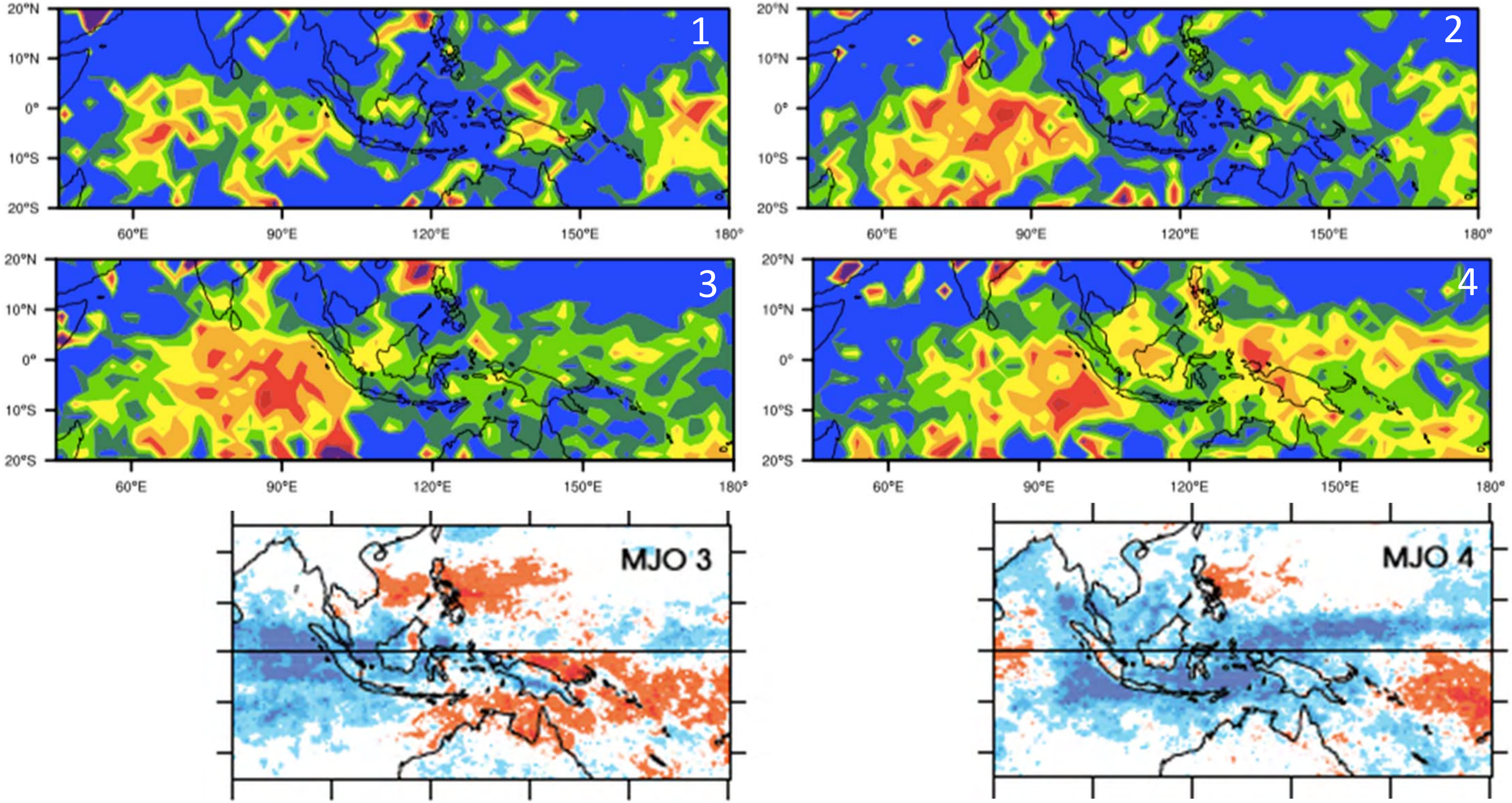
- The same mismatched patterns between rainfall and stratiform rain fraction exist in boreal winter
- Does Sumatra, Java, and the Malay Peninsula create a stratiform rain shadow?

Stratiform rain fraction by RMM phase 1-6



Stratiform rain fractions increase over Sumatra by about 10% during phases 3 and 4, but remain well below MJO mean values

Stratiform rain fraction by RMM phase 1-6



Stratiform rain fractions increase over Sumatra by about 10% during phases 3 and 4, but remain well below MJO mean values

A MODEX hypothesis

- The ability of the MJO to traverse the Maritime Continent is contingent on its ability to overcome the stratiform rain shadow created by the large MC islands. The MJO does this by providing a large-scale environment conducive to stratiform rain production over land during the day that then assists the offshore propagation of organized convective systems during the night; the enhanced rain and upper level heating provided by the islands and their coastal rain then feeds back onto the MJO convective envelope. Once the MJO convection is back over water, air-sea interactions help maintain its strength and organization.

MODEX-YMC ground deployment

S-Pol (S-band polarimetric radar): Mix of surveillance and RHI sector scans; **mesoscale organization, convective intensity, and microphysical properties**

DOW (X-band mobile radar): Sited within 30 km of S-Pol for multi-Doppler, multi-frequency retrievals; **storm kinematics and microphysical properties**

ISS (Integrated Sounding System): Sounding array with Indonesian/Malaysian operational sites; **environmental T, humidity, and winds**

ISFS (Integrated Surface Flux System): Network of 5-6 short towers; **surface meteorology and fluxes**

DOE MWR (Microwave radiometer): Co-located with ISS: **liquid water path**

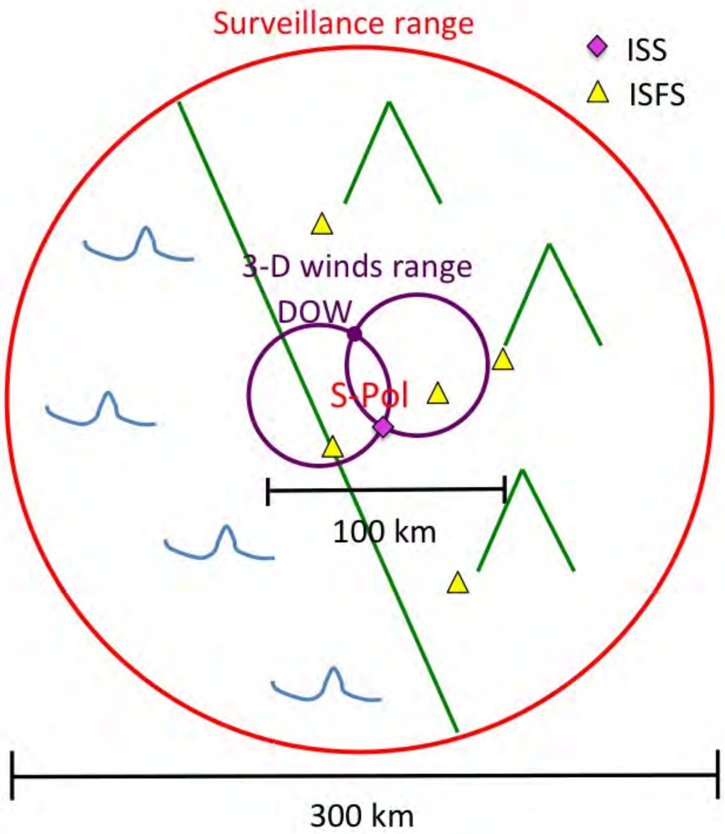
DOE KAZR (K_a-band ARM zenith radar): Co-located with ISS: **cloud and radiation properties**

NOAA SVPR (S-band profiler): Co-located with ISS: **precipitation properties, vertical velocity**

C-130 Aircraft Instruments

Flight Level *in situ* Sensors:	**Navigational parameters** **Pressure and thermodynamic parameters** **Mean winds and turbulence** **High-rate T, q, CO_2 perturbations**
Radar and Lidar:	**C-band Doppler radar (nose-mount)** **Wyoming Cloud Radar and Cloud Lidar, looking both upwards and downwards.**
Expendables:	**GPS dropwindsonde atmospheric profiling system** **Airborne eXpendable Bathythermographs (AXBT's), drifters**
Cloud Microphysics and Aerosol:	• Gas phase measurements (CO, CO2, CH4, Fast O3) for tracking air mass composition changes. • Basic aerosol size and number concentration measuring instruments (CN counter, PCASP wing-mounted) • Standard *in situ cloud particle probes (FSSP-100, FSSP-300, CDP, 2D-C,2D-S, and 2D-P)* •*CVI for condensed water and aerosol chemical properties* • *In situ instruments for high-resolution measurements of small ice and other hydrometeors (SID-2H) and for high-resolution* **Radiometric SST**

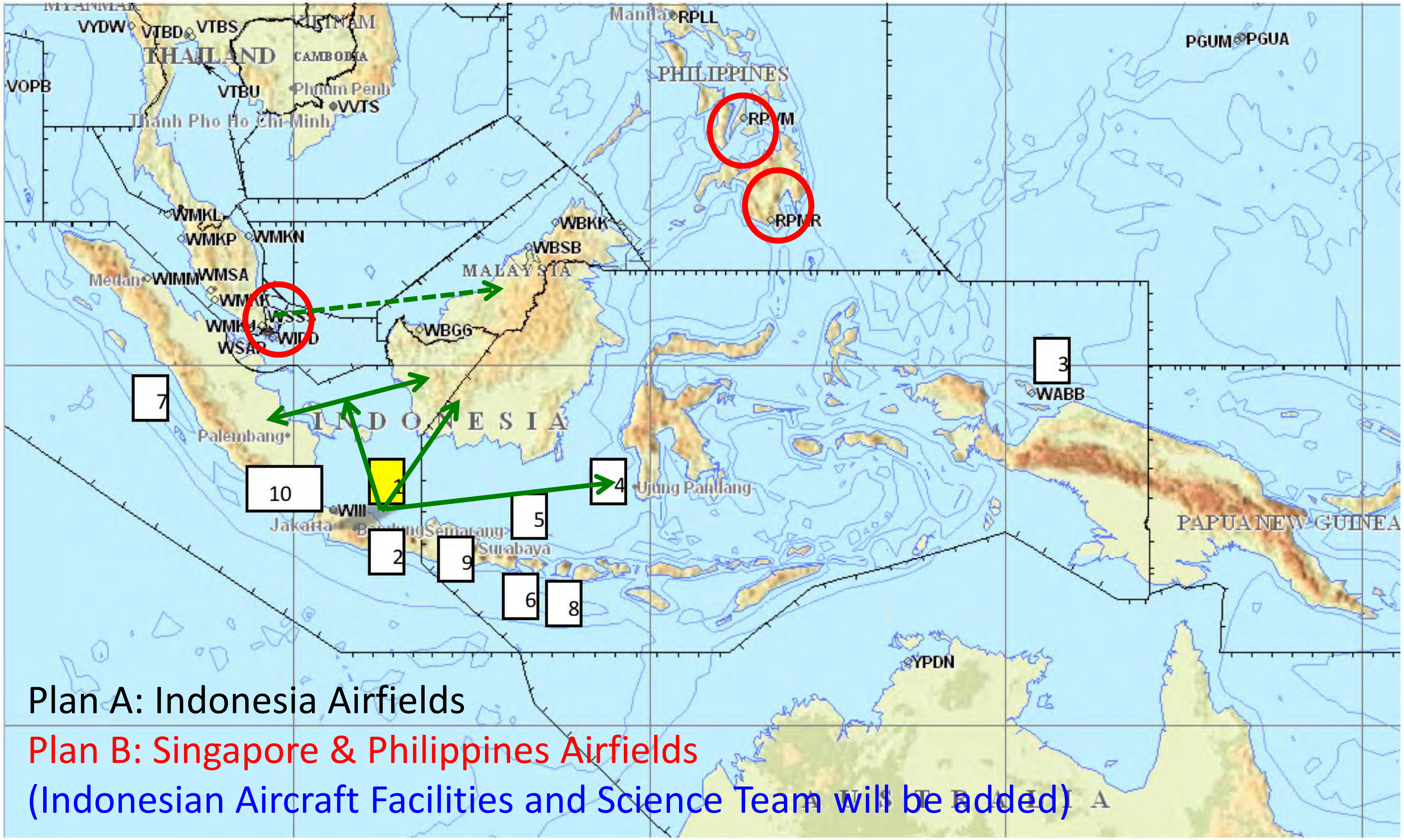
MODEX-YMC ground deployment



Deployment: November 2018-February 2019; preferred sites west coast of Sumatra; alternate is north coast of Borneo

Proposal submission to NSF: January 2015

MODEX-YMC aircraft deployment



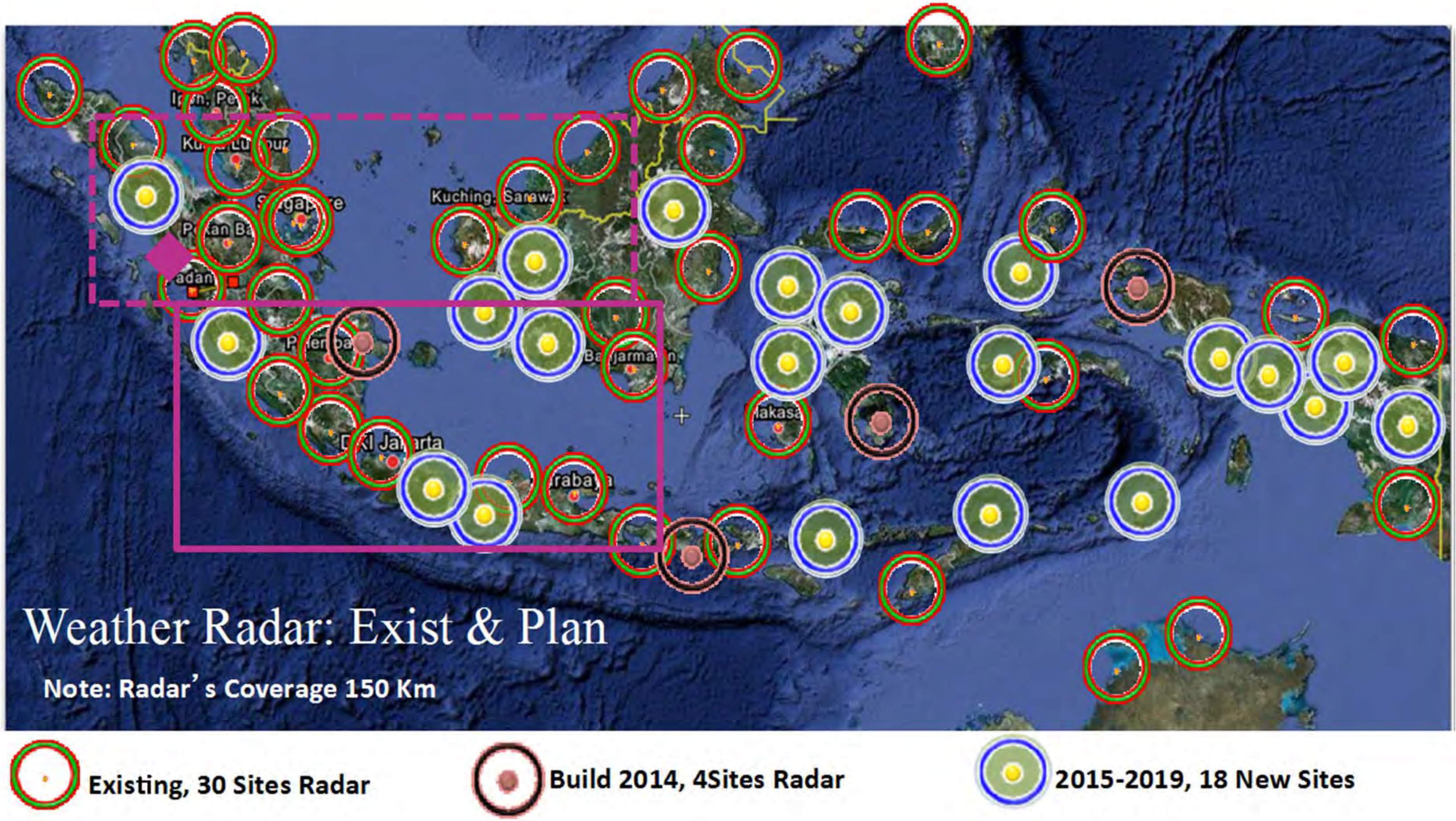
Plan A: Indonesia Airfields

Plan B: Singapore & Philippines Airfields

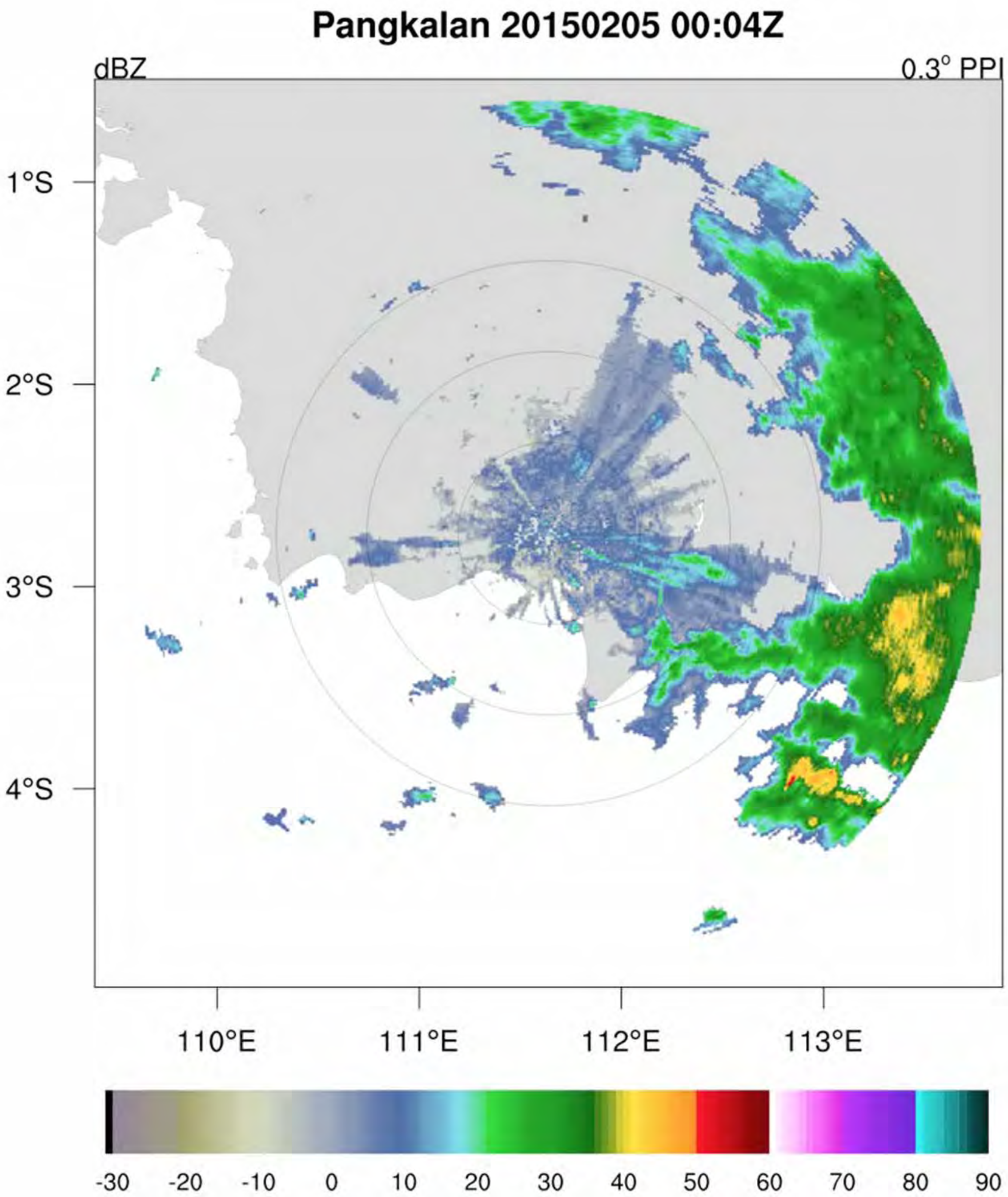
(Indonesian Aircraft Facilities and Science Team will be added)

Potential MODEX synergies with regional networks (and other YMC deployments)

Operational radars



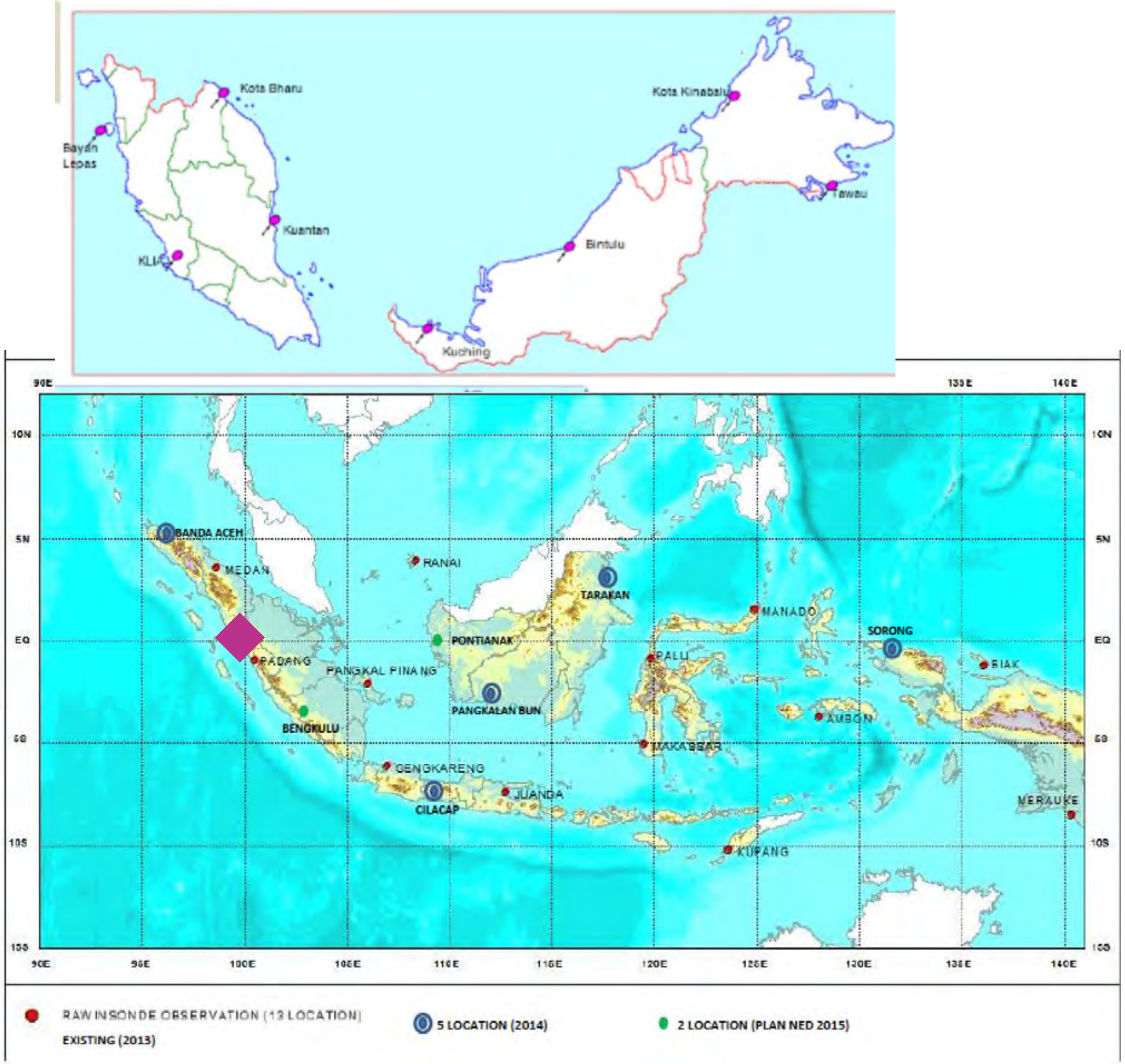
Can we create a climatology of operational radar data along a select E-W transect?



Operational radar issues to consider:

- Quality control (calibration, blockage, artifacts, etc.)
- Operational scan strategies
- Data availability
- Data quality

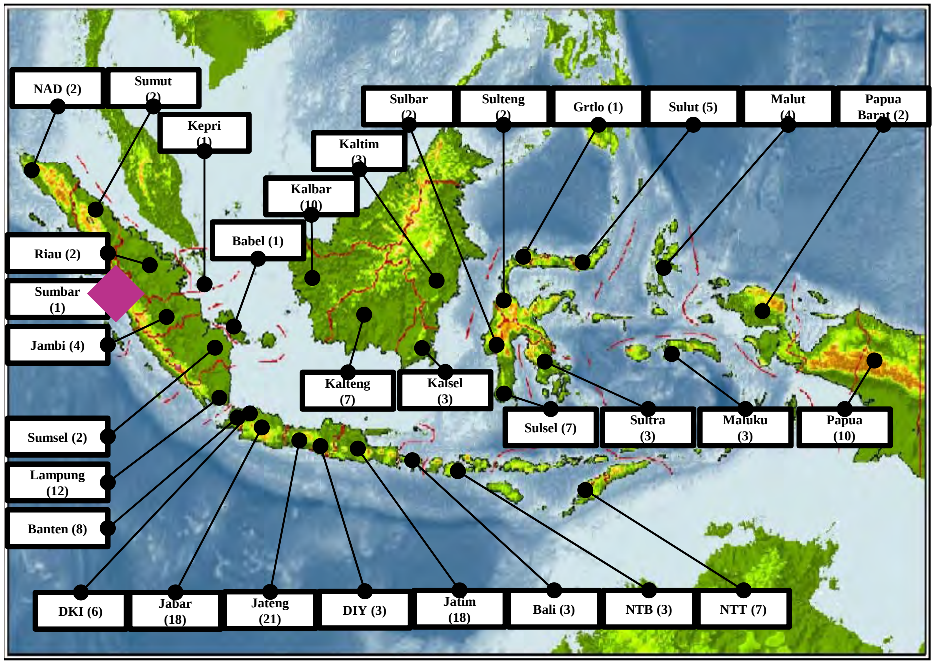
Upper air sites



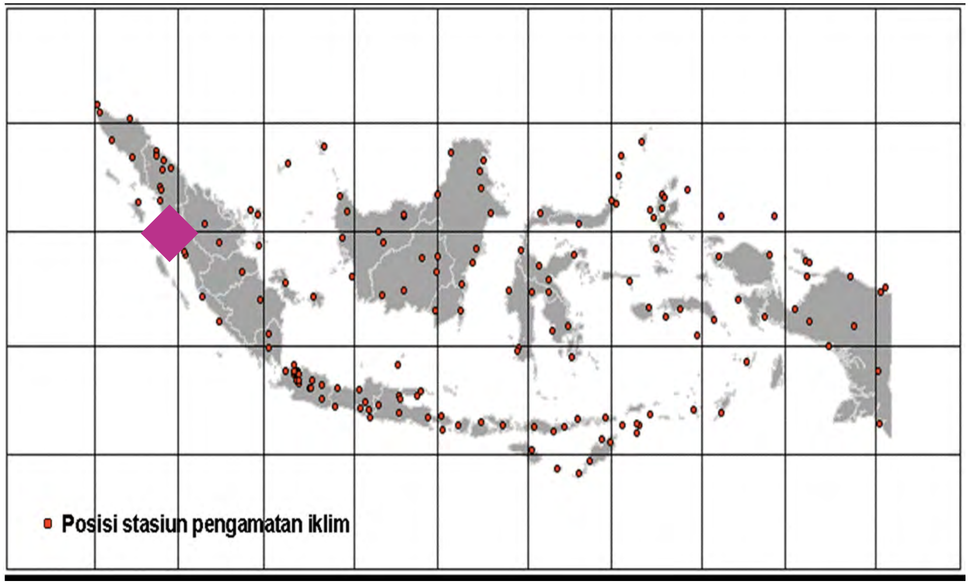
- Operational launches 2/day
- Requesting 8/day launches for diurnal cycle at ISS
- What is ideal network for enhanced operational launches?

Surface meteorology

Automatic Weather Station



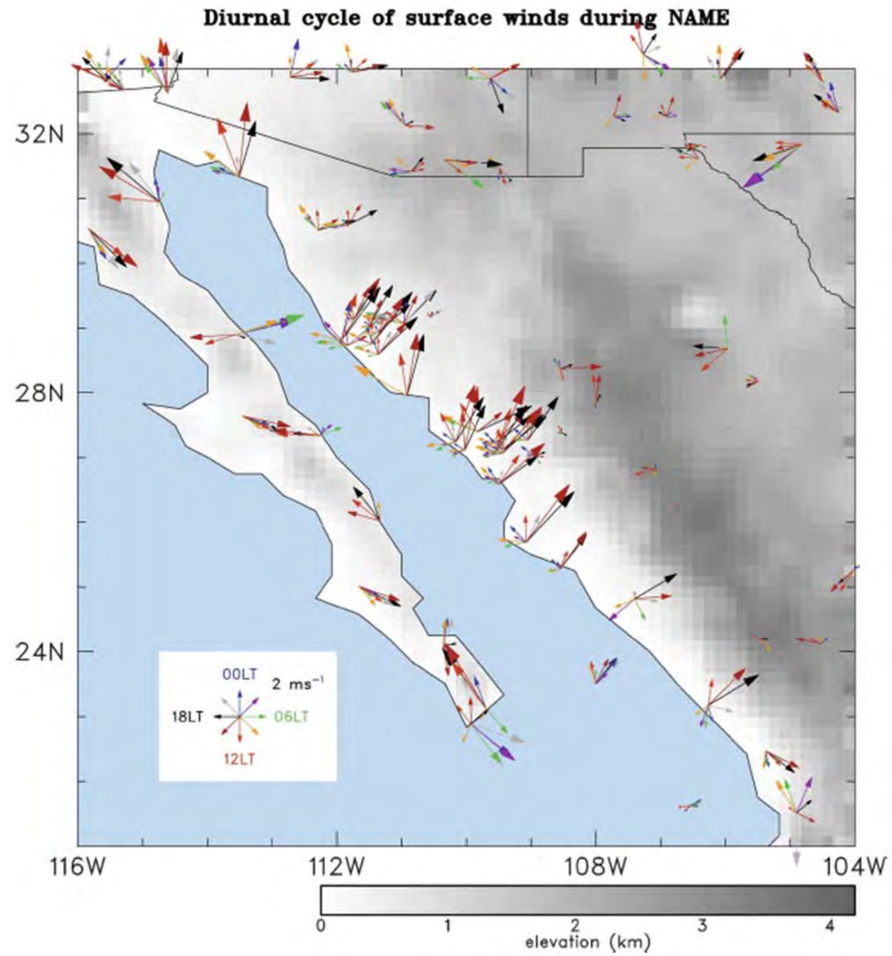
Rain Gauge Stations

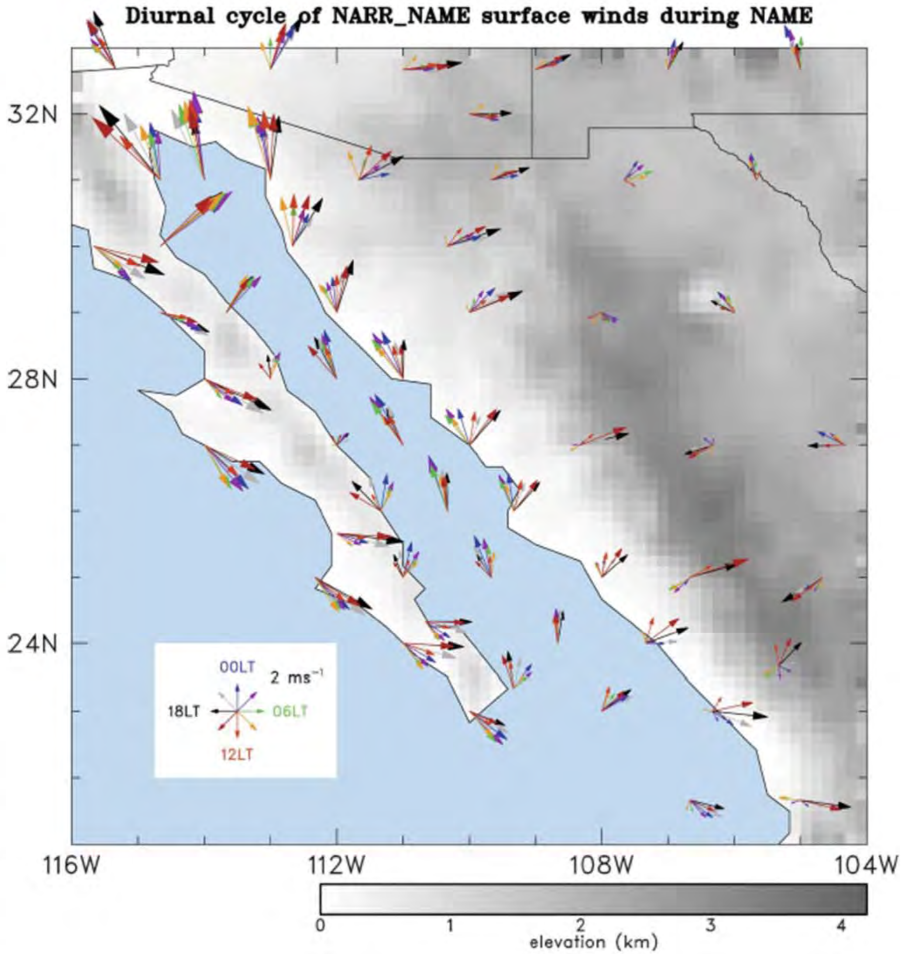


How can we best leverage operational surface systems with enhanced YMC surface sites?

Goal: Create regional ***observational*** analysis of T, humidity, winds, and precipitation to detail diurnal variations and assess model and satellite fields

NAME surface obs vs NARR_NAME



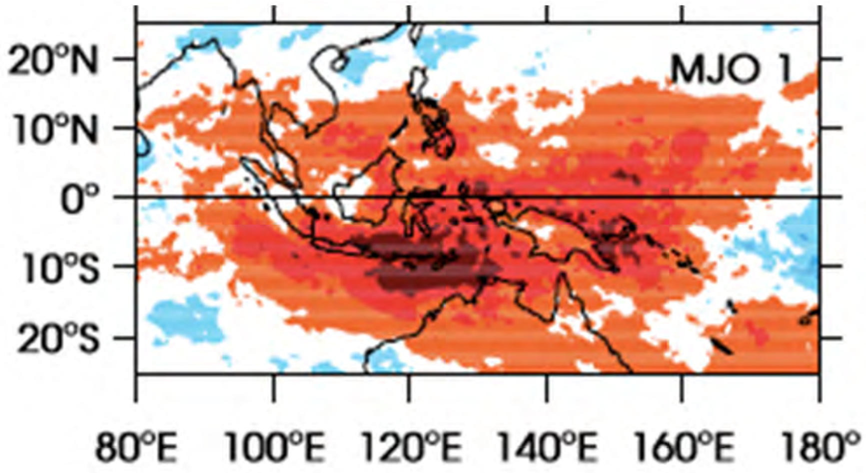


The special NARR analysis for NAME had a significant cool, dry bias along with diurnal wind biases

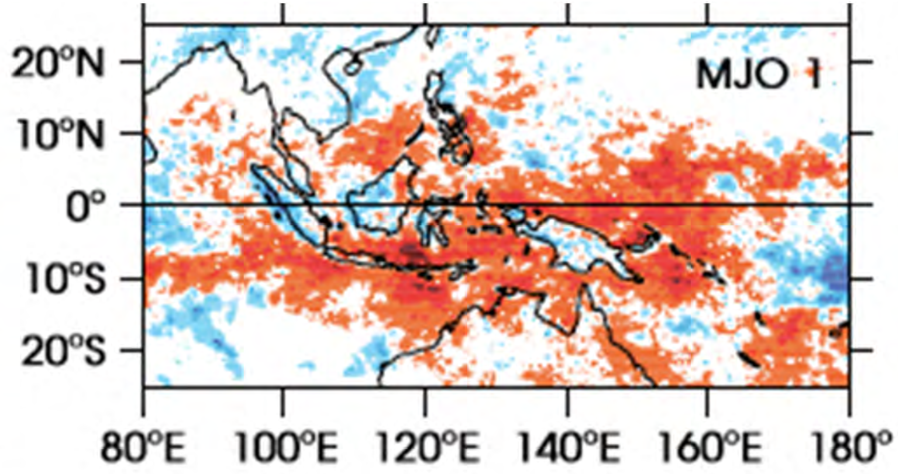
Ciesieselski and Johnson (2008)

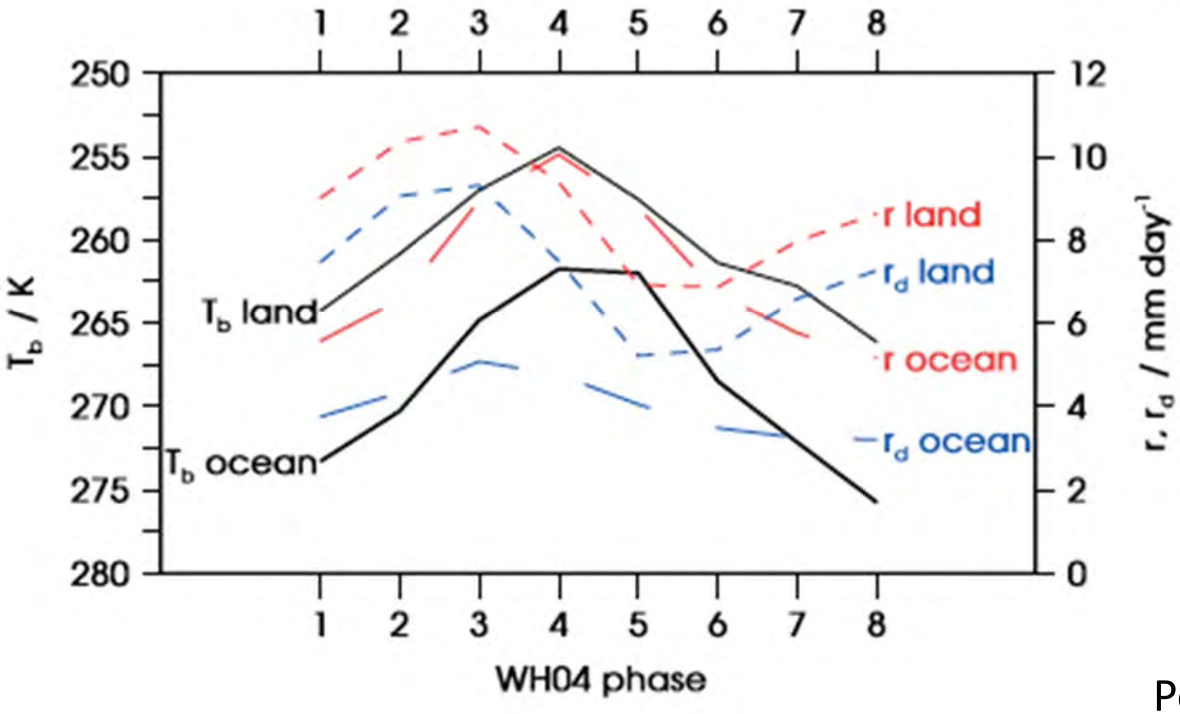
Satellite disparities

OLR



TRMM 3B42HQ

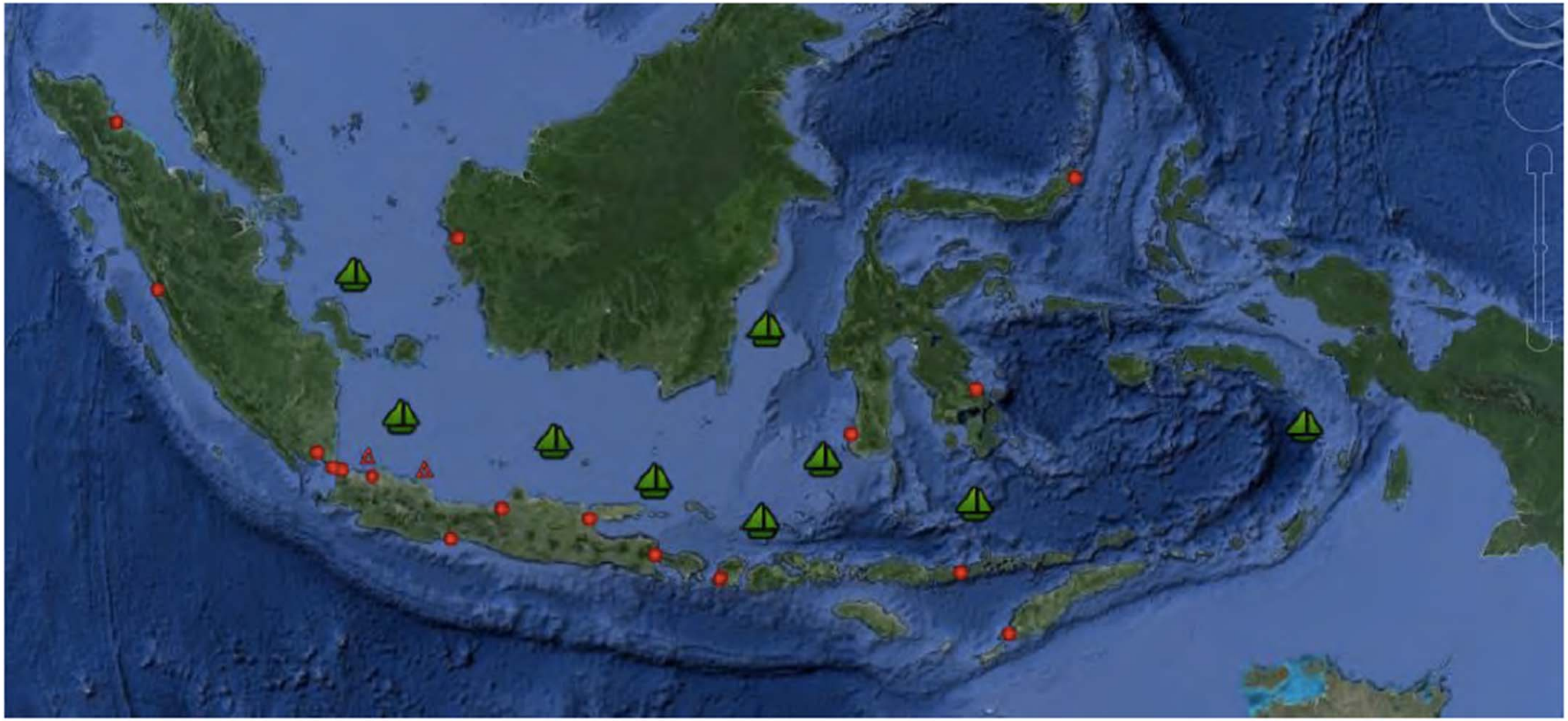




Peatman et al. (2013)

Indonesian Observing Network

Marine Observations



13 Marine Meteorology Stations Red dots

17 Harbor Automatic Weather Stations

10 Shipboard Automatic Weather Stations

2 Automatic Weather Stations on Platform (rig) Red triangles

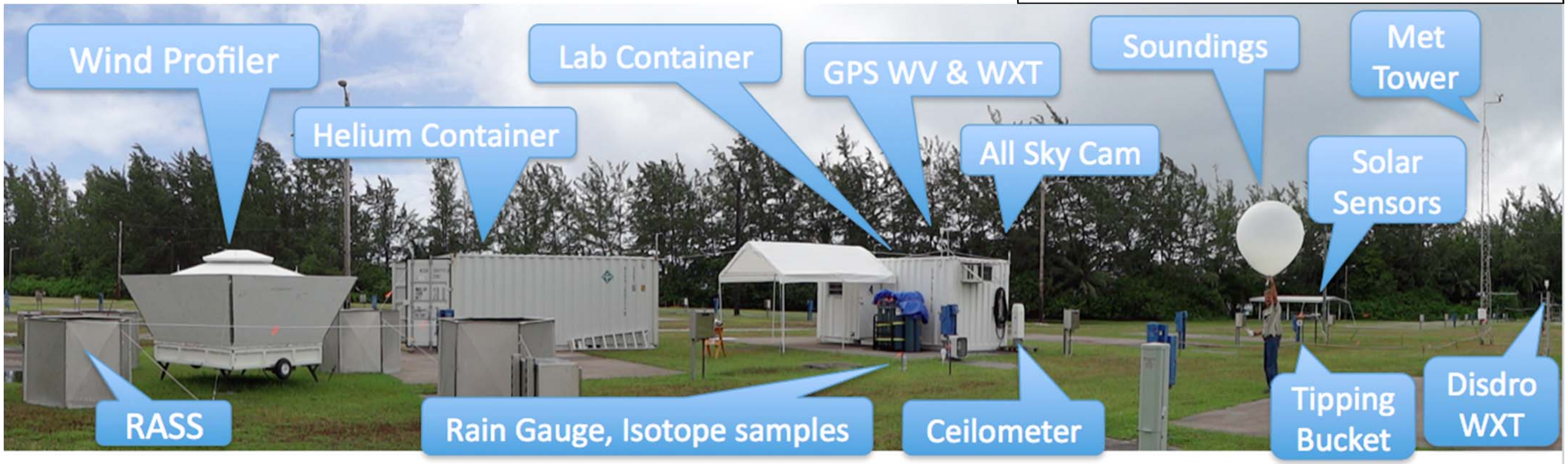
1 HF wave radar - InaTEWS

MODEX instruments

ISS : Integrated Sounding System

Flexible suite of instruments to profile the atmosphere
2 ISS in DYNAMO launched over 1300 soundings

DYNAMO – Diego Garcia



- 449 MHz 7-Module system for high coverage and rapid winds
- Likely winds to 4 – 6 km at least 75% of time

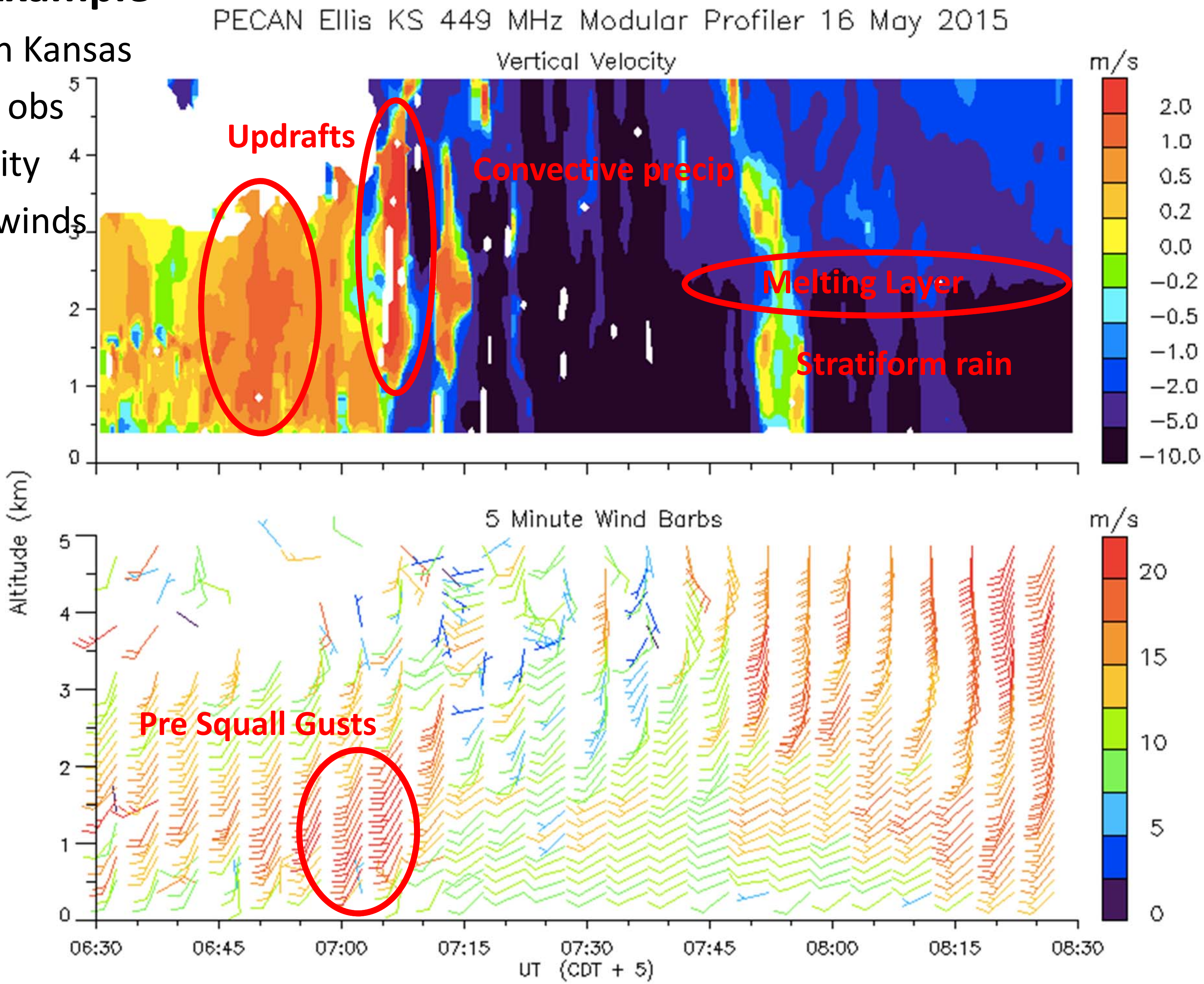
PECAN Example

Recently in Kansas

2 hours of obs

Vert Velocity

5-minute winds



Integrated Surface Flux System (ISFS)

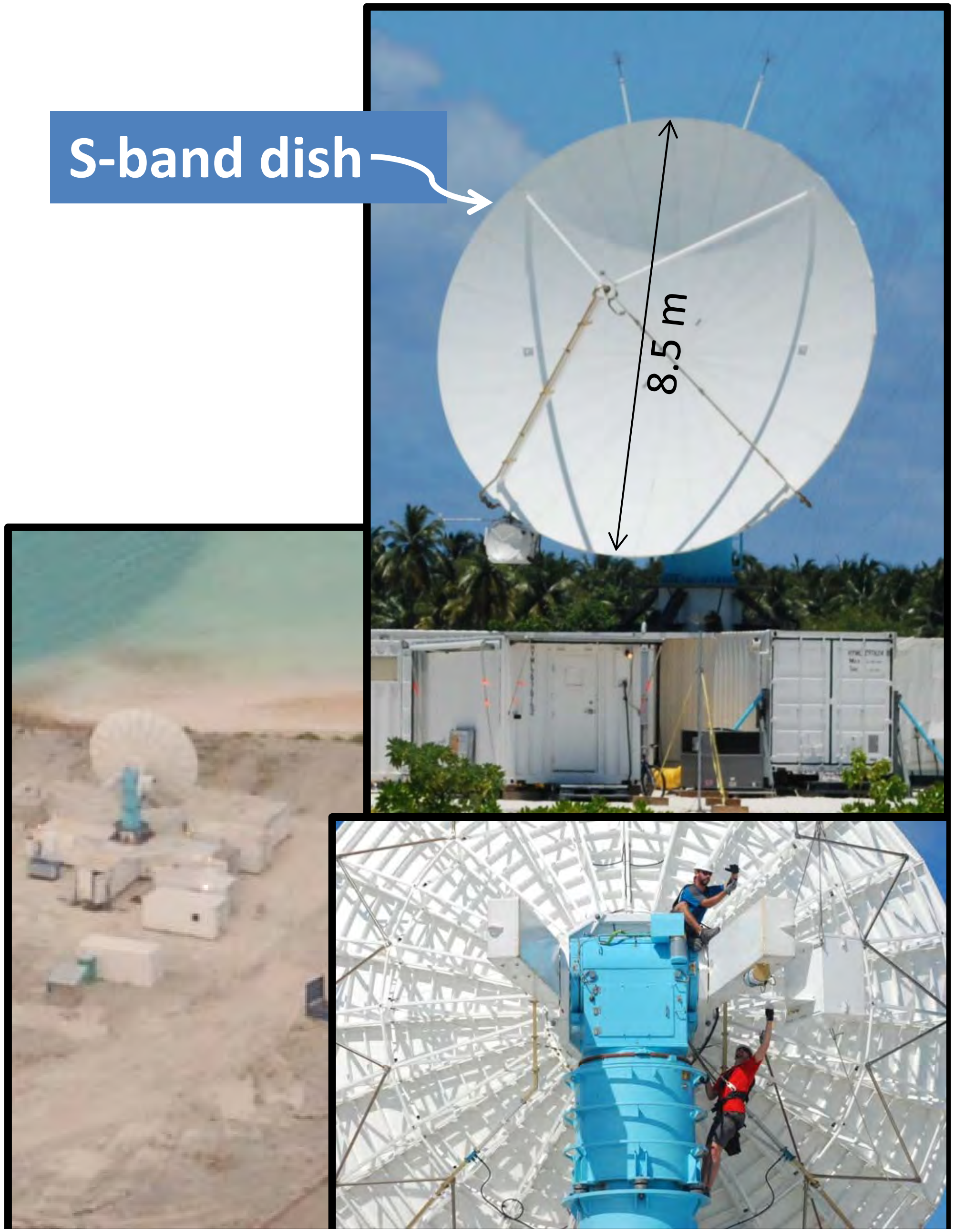
Can install tall towers (up to around ~50 m) or network of shorter towers (~10 m)

MODEX is requesting 5-6 short towers to form mesonet of surface meteorology

ISFS sites will also measure fluxes, surface energy budgets, turbulence and solar radiation

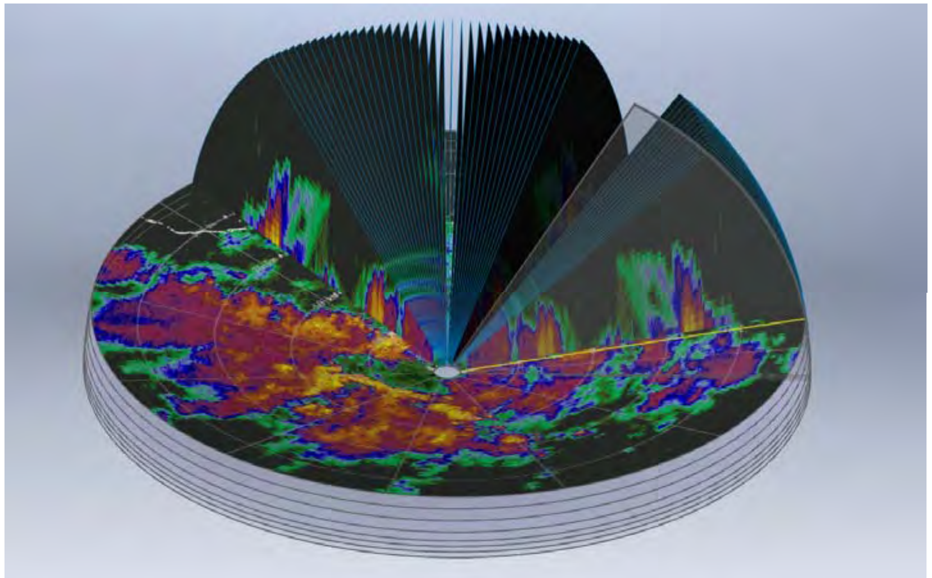
S-Pol

- S-band (10-cm wavelength), Doppler, dual-polarimetric scanning weather radar
- Precipitation, 3-D hydrometeor ID, radial winds
- Transportable
  - 8-9 20 ft seatainers
  - No radome
  - No concrete pad required
  - No power source required – need road access for fuel
  - ~ 14 days to setup
  - Numerous deployments worldwide



S-Pol Scanning

- Flexible scanning strategies
  - Horizontal Plan Position Indicator (PPI) scans (360 deg or sectors)
  - Vertical Range Height Indicator (RHI) scans
  - For MODEX: request alternating scan strategy for large-scale view of convective organization and detailed RHI sectors of cloud microphysics

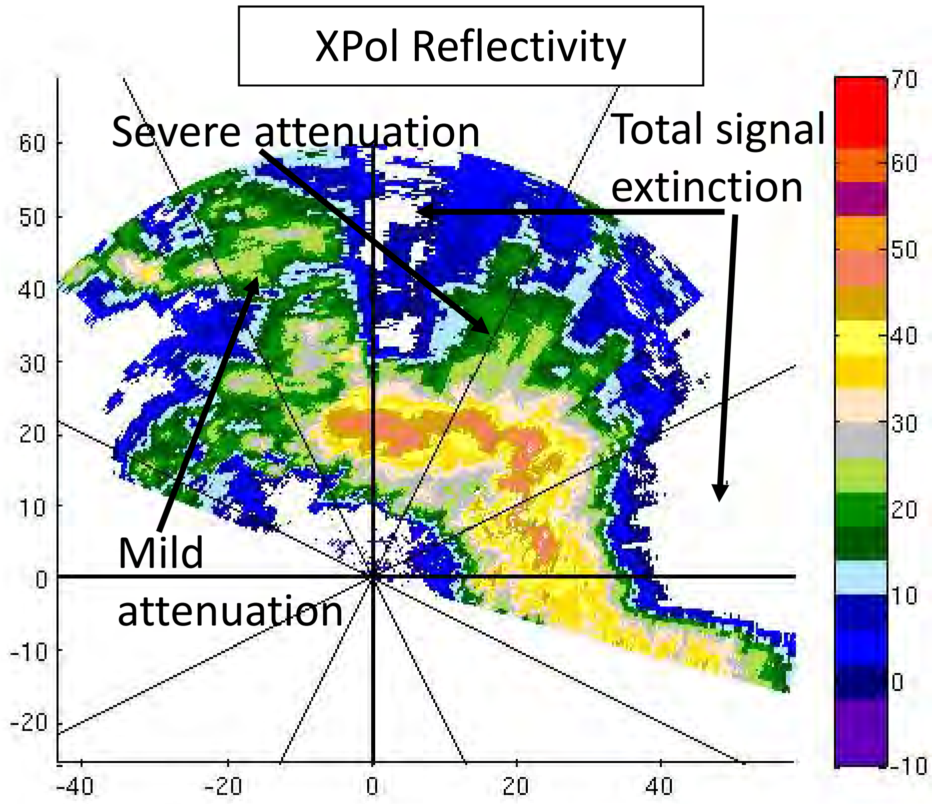


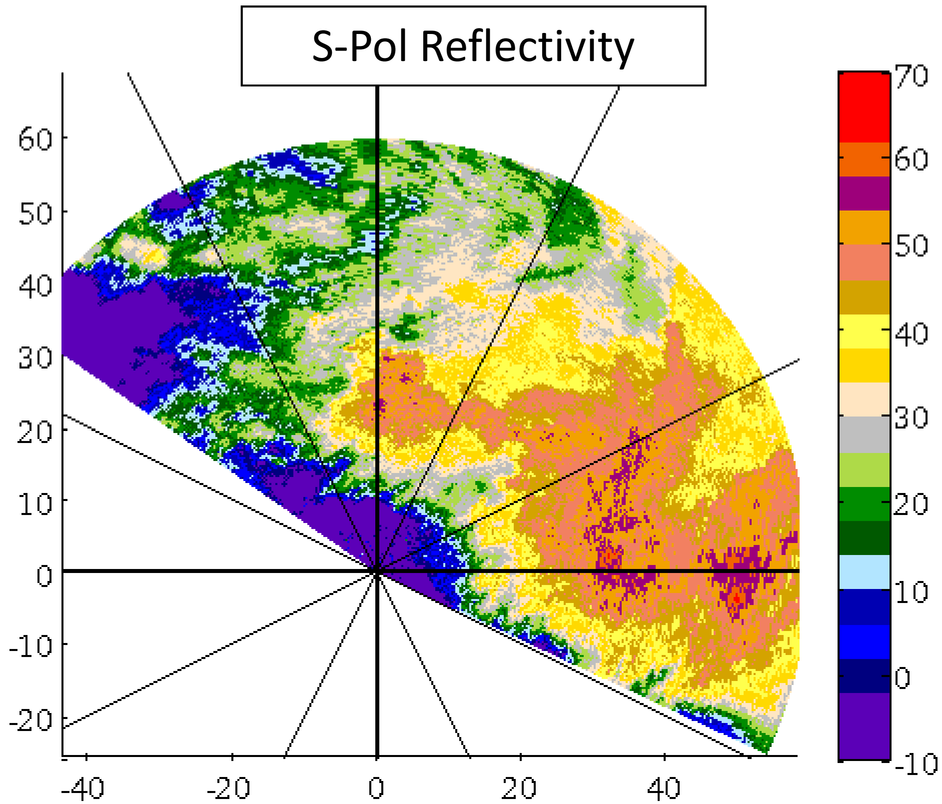
Doppler on Wheels (DOW)

- Dual-polarimetric, Doppler truck-mounted X-band (3-cm wavelength)
- Dual-Doppler 3-D wind retrieval
- MODEX request for DOW6 or DOW7

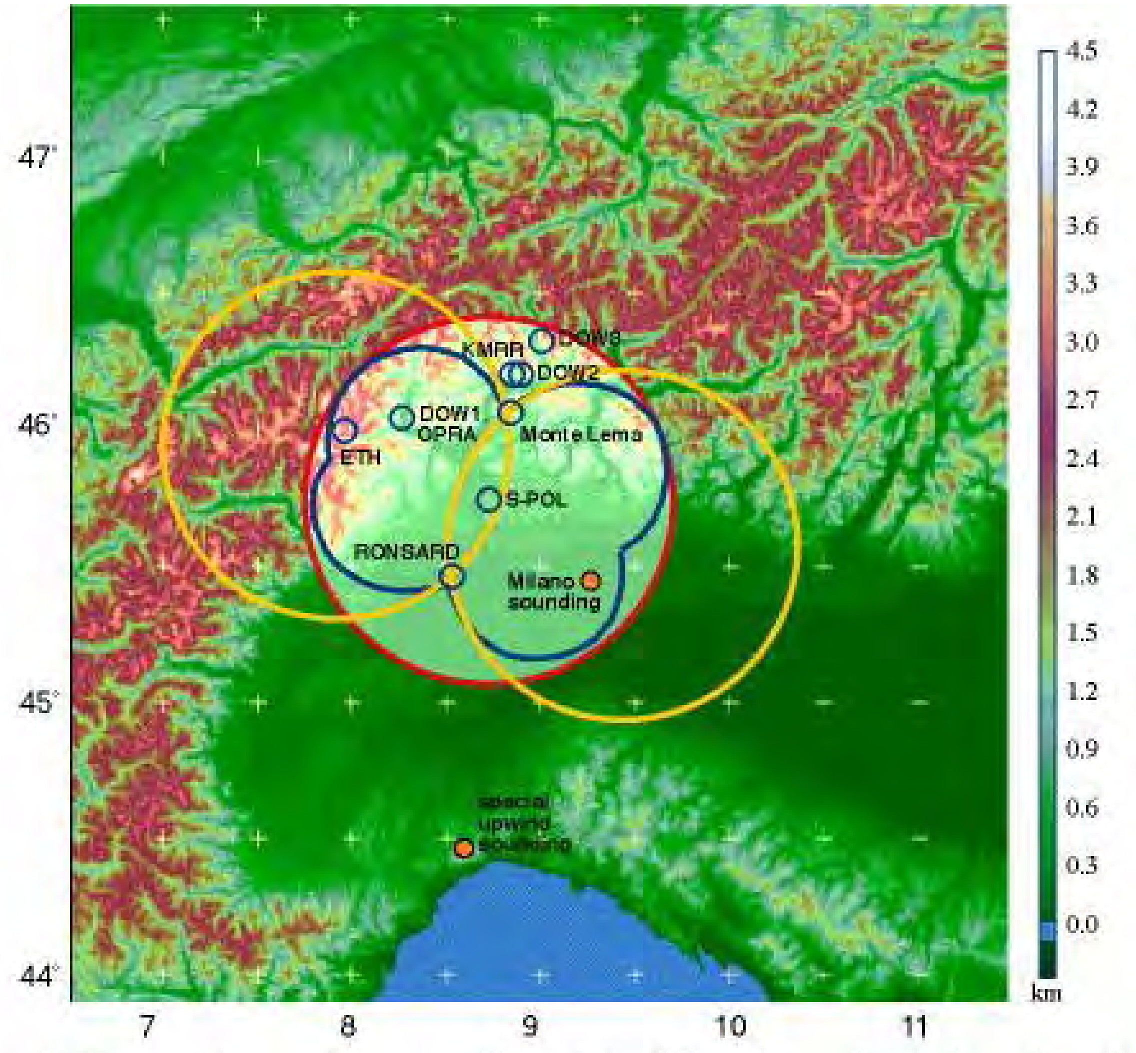
X-band vs S-band in deep convection

- **Collocated polarimetric National Observatory of Athens (NOA) X-band and NCAR S-band - 2002 International H2O Project (IHOP)**
  - Coordinated scans
  - ~6 hours on 2 days (May 15th and June 16/17th)





DOWs and S-Pol in MAP



Radar site considerations:

- Coastal (land/water) coverage by S-Pol desirable
- Proximity to orography (good for process studies, bad for blockage)
- Multi-Doppler baselines (heavily dependent on site)

Air-Sea Interaction and Aerosol-Cloud Interaction

Shuyi S. Chen (UM) and Andy Heymsfield (NCAR)

Air-Sea Interaction:

- Influence on the diurnal timescale in the MC stronger than in the open oceans because of strong tidal mixing and sea/land breezes of adjacent islands.
- Model biases in the diurnal cycle, propagation of the MJO, and mean precipitation in the MC are related to their poor representations and air-sea interaction processes in addition to other model deficiencies.

Aerosol-Cloud Interaction:

Distinct aerosols over land vs. sea that are important for precipitation efficiency and dynamics and microphysics of convection and precipitation in the MC.

- Land - Biomass burning aerosols develop a sulfate coating and become the dominant cloud condensation nuclei (CCN), removed near the surface by precipitation or transport to the upper troposphere.
- Sea - Sea salt mixed with particles of biological and other carbonaceous sources are the primary CCN and ice nuclei (IN).

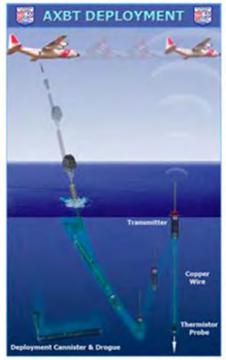
Science Objectives:

- To characterize deep convective processes and better understand the complex feedback processes among land-sea surface forcing, air-sea fluxes, aerosol-cloud microphysics-dynamics-thermodynamics, and large-scale environmental conditions
- To obtain a suite of observations suitable for coupled air-sea-land model evaluation, and coupled model data assimilation for improving model prediction

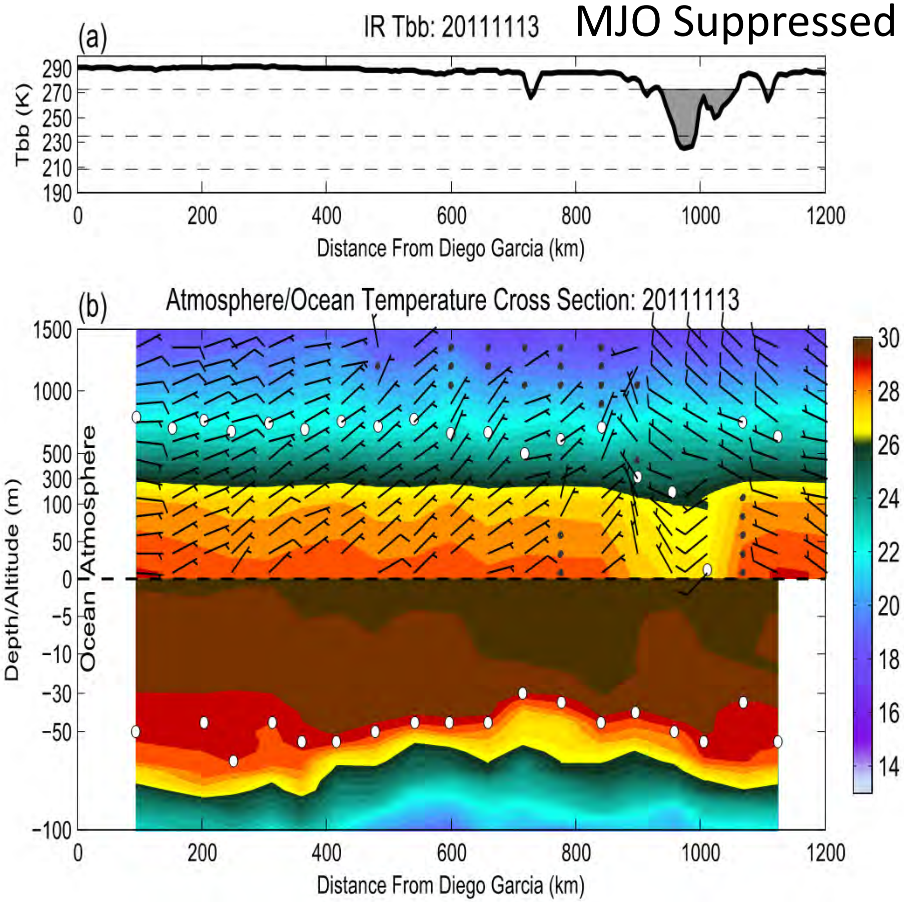
Air-Sea Interaction

Atmospheric and Upper Ocean Profiles

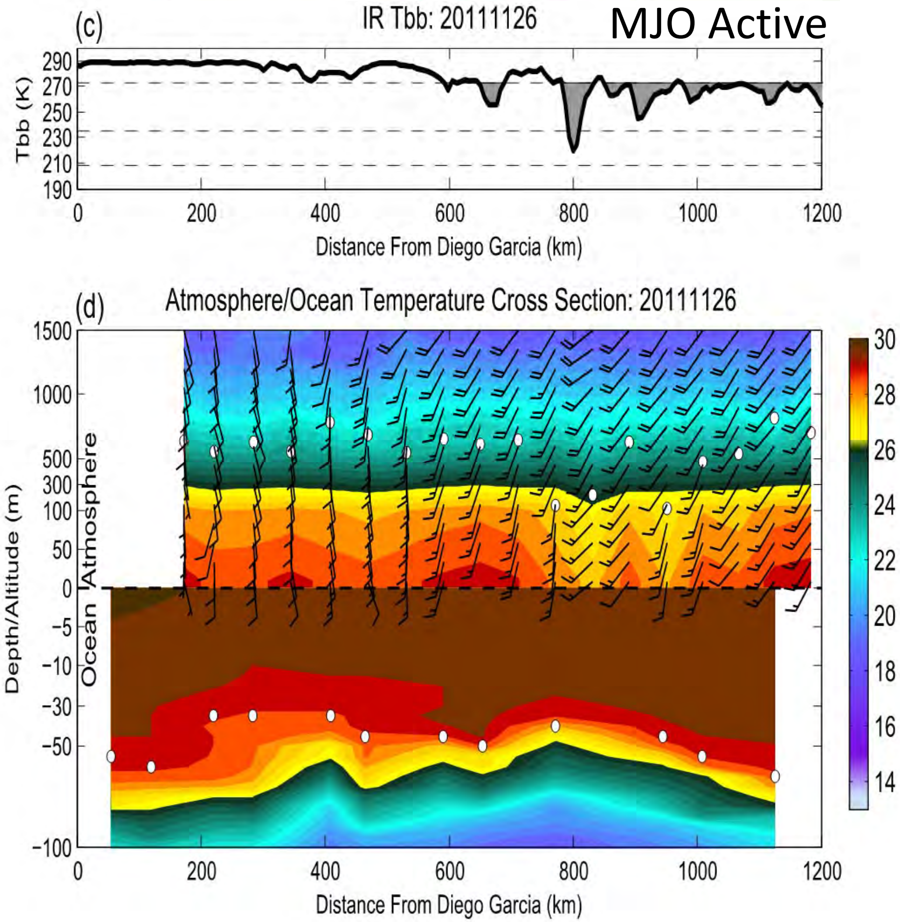
- Diurnal cycle
- MJO active/suppressed phases
- In cloud and environmental conditions



MJO Suppressed



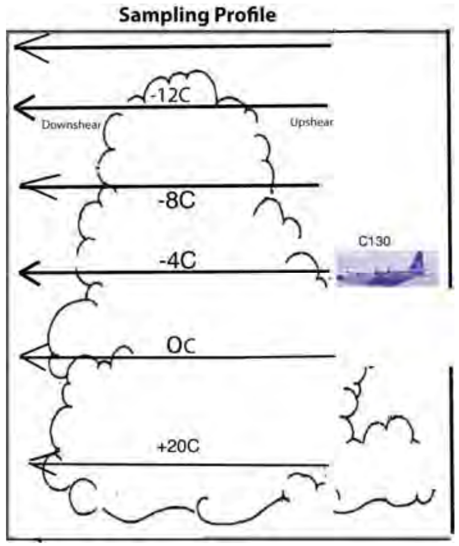
MJO Active



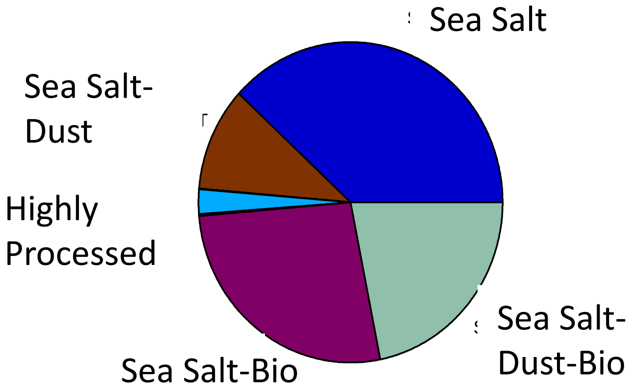
Aerosol-Cloud Interaction

Aerosol and Cloud Microphysics

- Evolution of aerosol size distribution as a function of cloud processing
- Aerosol, cloud microphysics, and cloud dynamic properties over land and sea



Expected Outcome: Statistics of Aerosols in the MC



Ice Nuclei Composition over Caribbean during ICE-T