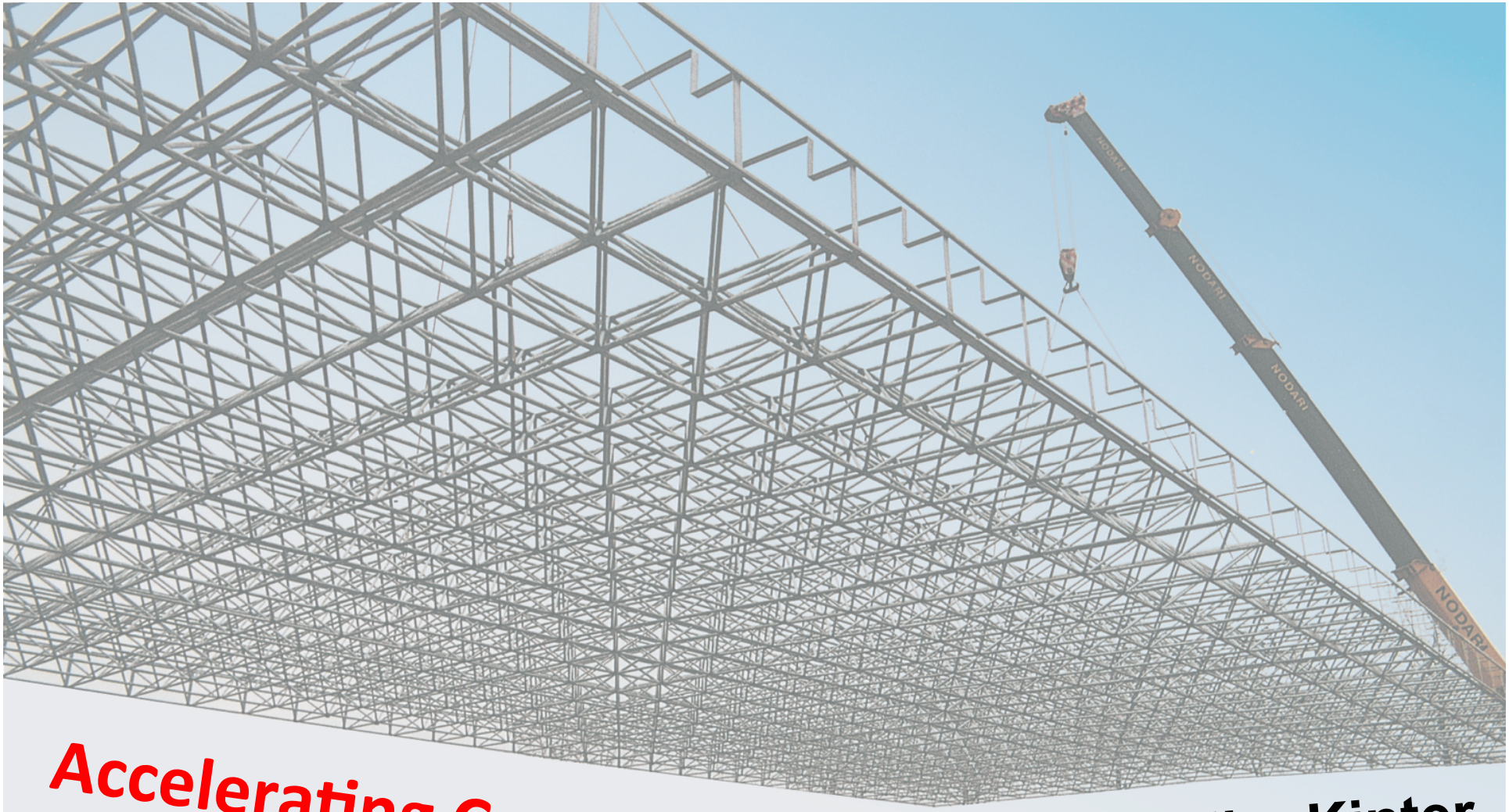


Accelerating Coupled NGGPS Development for Predicting Weeks 3 and 4

Jim Kinter

Center for Ocean-Land-Atmosphere Studies

George Mason University

Project Team

Center for Ocean-Land-Atmosphere Studies (COLA)
George Mason University (GMU)

- ***Principal Investigator:***
  - Jim Kinter
- ***Co-Principal Investigators*:**
  - Ben Cash
  - Tim DelSole
  - Bohua Huang
  - Kathy Pegion
  - Cristiana Stan

- ***Team Members:***
  - Rodrigo Bombardi
  - Larry Marx

Objective and Strategy

- Objective: Improve **3-4 week lead-time forecasts**, focusing on:
  - Weather statistics in North America, south Asia
  - Statistics of hurricane and typhoon formation
- Strategy:
  - Evaluate and correct **systematic biases in the tropics** to improve forecasts of weeks 3 and 4
  - Evaluate the **sensitivity of predictability to model resolution**, **coupling**, and **initial states** to identify best methods for utilizing potential skill at weeks 3 and 4.
  - Understand and correct **errors introduced by unrealistic representation of small-scale processes** in the climate system.

Why Do We Think We Can Make Forecasts for Weeks 3-4?

- There is **predictive power on all time scales**, including sub-seasonal (Hoskins 2013)
- Credible forecasts of PDF of future seasonal means are made possible by:
  - **El Niño and the Southern Oscillation** (ENSO)
  - Antecedent **soil moisture anomalies**
  - **Secular temperature trend** associated with global climate change
- Additionally, subseasonal predictability due to:
  - **Rossby wave dispersion**
  - **Persistent blocking states** in the atmosphere
  - **Tropical-extratropical interactions** at lag
  - **Persistent ocean anomalies** in both tropics and extratropics
- Despite progress in NWP and seasonal prediction, forecasts are not yet truly "seamless": lead-times of 3-4 weeks, beyond *deterministic* limit with large signal/noise, have received little attention

Proposed Work

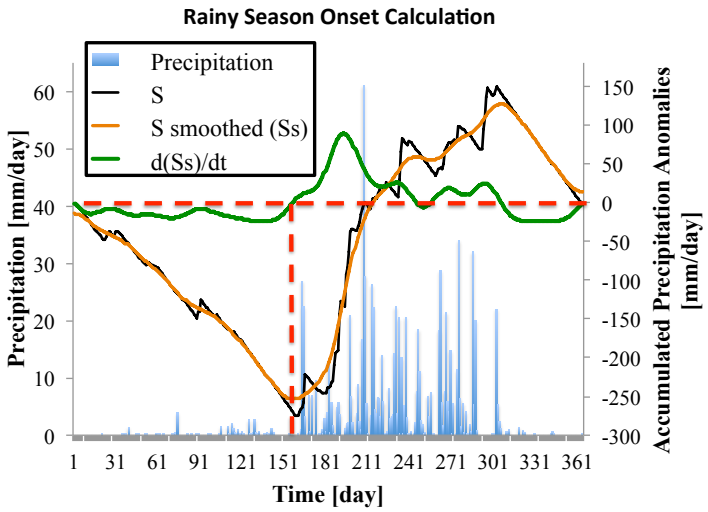
- C**ontribute to development of a new global, coupled weather prediction system**
- Adopt as development environment the **coupled NOAA Environmental Modeling System (NEMS) framework**
- Design experimental model versions and rigorous tests to:
  1. **Correct systematic biases**, especially deep convection in the tropics and extratropical fluxes between the ocean and the atmosphere
  2. **Quantify the predictability and skill** of weather forecasts for weeks 3-4, and their **sensitivity to spatial resolution**, factors in the **initial conditions** (e.g., state of the MJO, blocking conditions, etc.), and **coupling** between atmosphere and ocean.
- Use **statistical optimization** methods to comprehensively evaluate the predictability and skill at weeks 3-4.

Expected Outcomes

- Demonstrated capability to improve skill of NOAA operational 3-4 weeks weather forecasts.
- Recommendations for future research to be done collaboratively by NGGPS community.

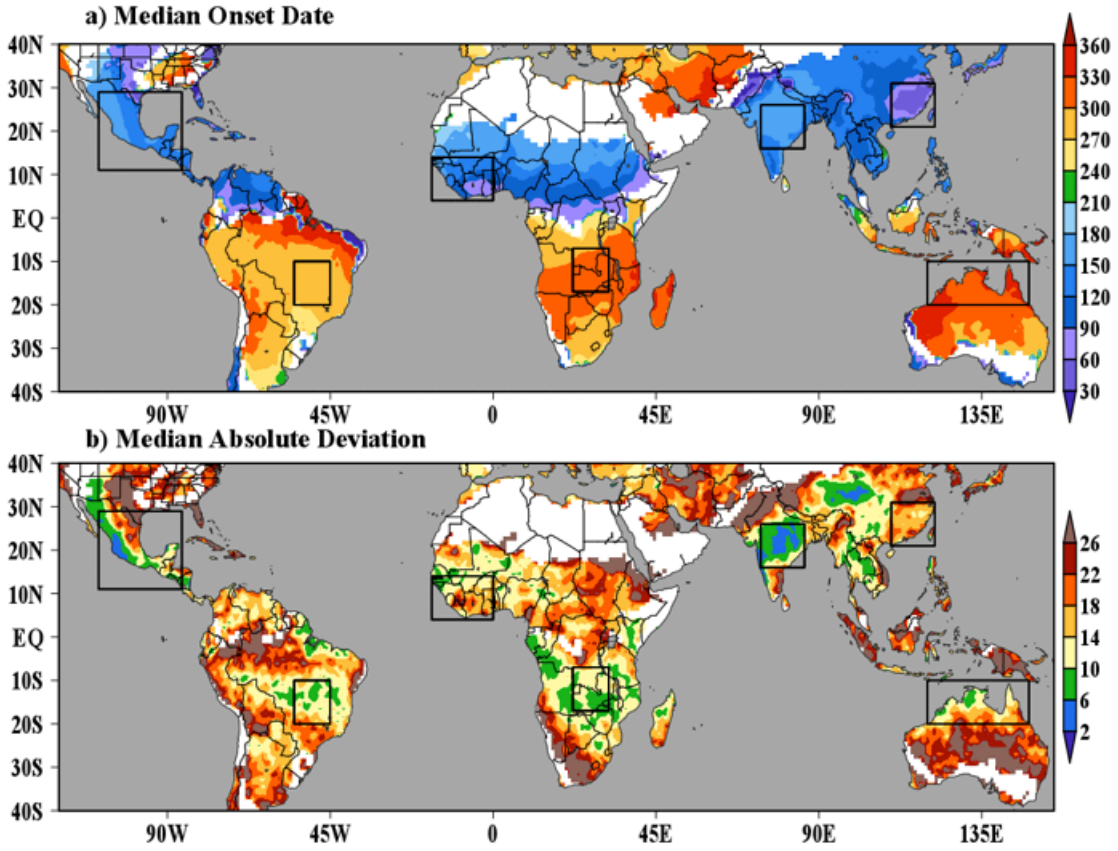
WEEKS 3-4: RAINY SEASON ONSET

Rainy Season Onset Calculation Method and Onset Date Climatology

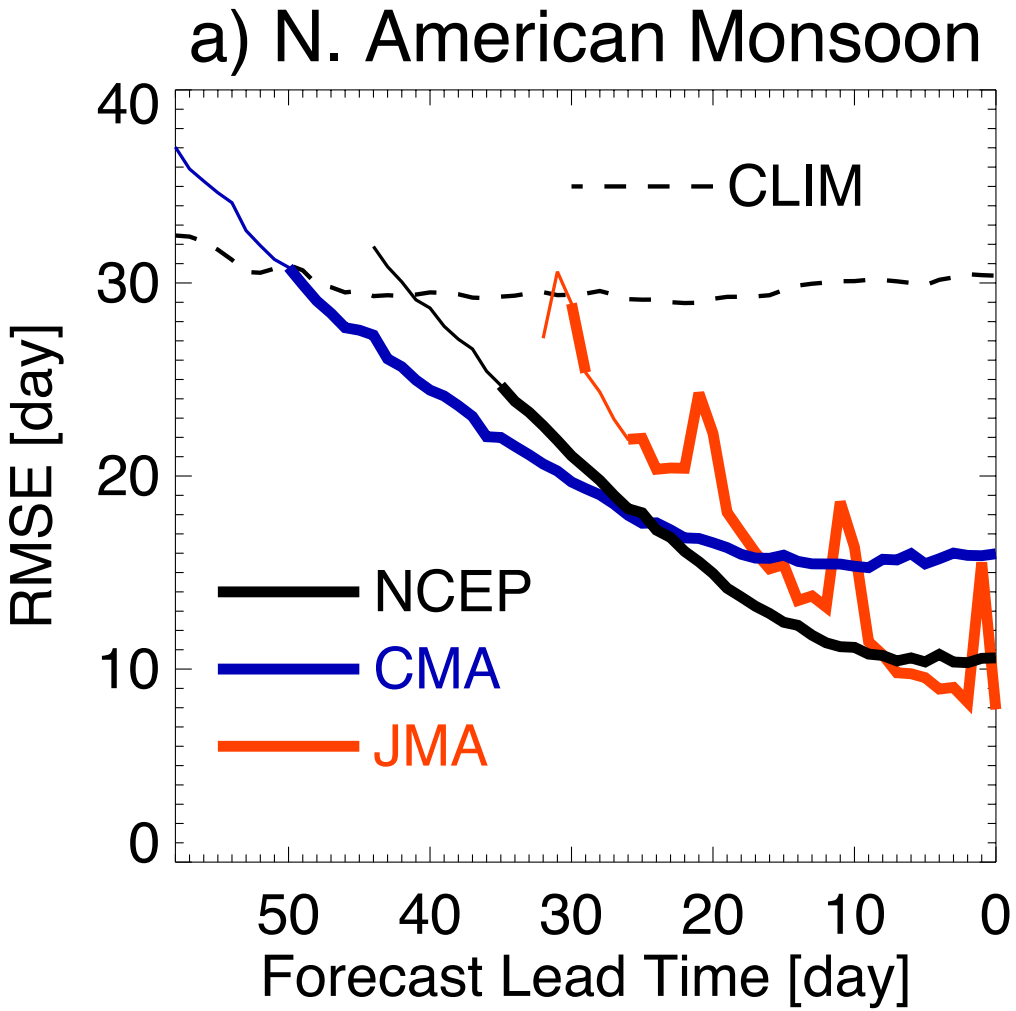


$$S = \sum_{i=t_0}^{N} (P_i - C)$$

Bombardi and Carvalho (2009)

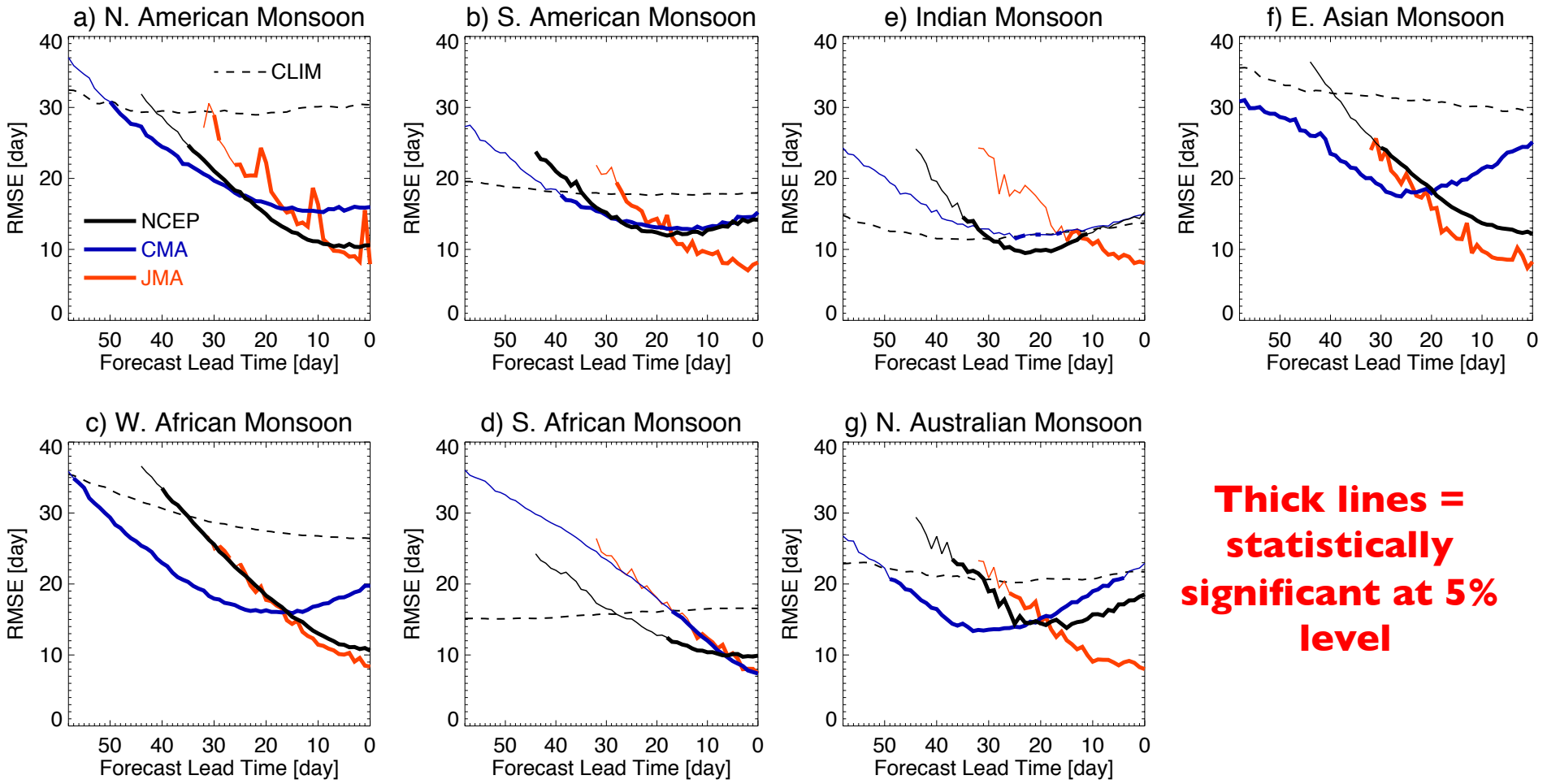


S2S Lead-time RMSE of Rainy Season Onset Date



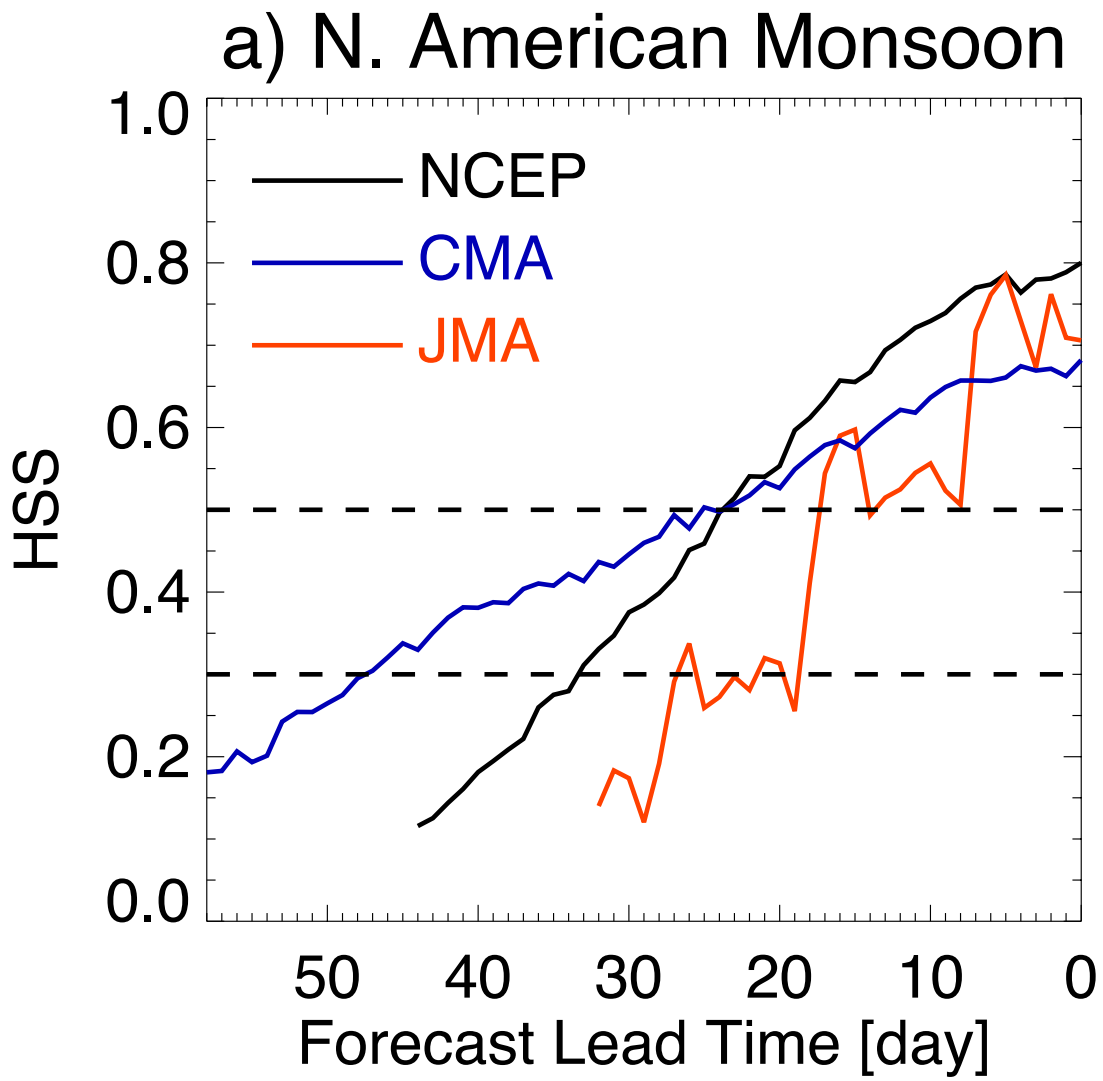
Thick lines = statistically significant at 5% level

S2S Lead-time RMSE of Rainy Season Onset Date



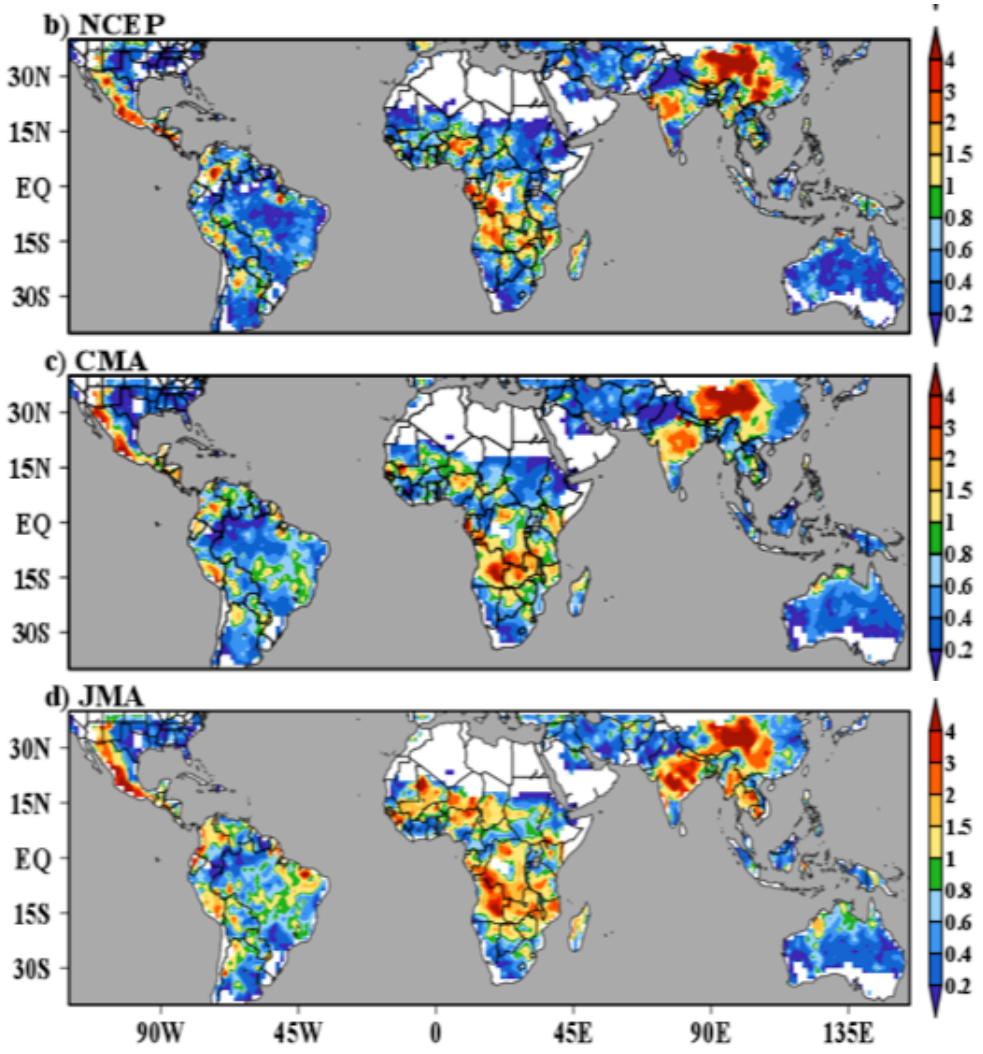
Thick lines = statistically significant at 5% level

S2S Heidke Skill Score for onset date hindcasts



Calculated using a 3 by 3 contingency table (A, N, B). HSS of 0.5 (dashed line) means that 2/3 of hindcasts fall in the correct tercile.

Ratio of simulated mean squared error (MSE) of onset dates for lead-times during **week 4** to MSE calculated using climatological values (blue indicates predictability)



Colors = Statistically significant at 5% level

Tawfik et al. 2015:

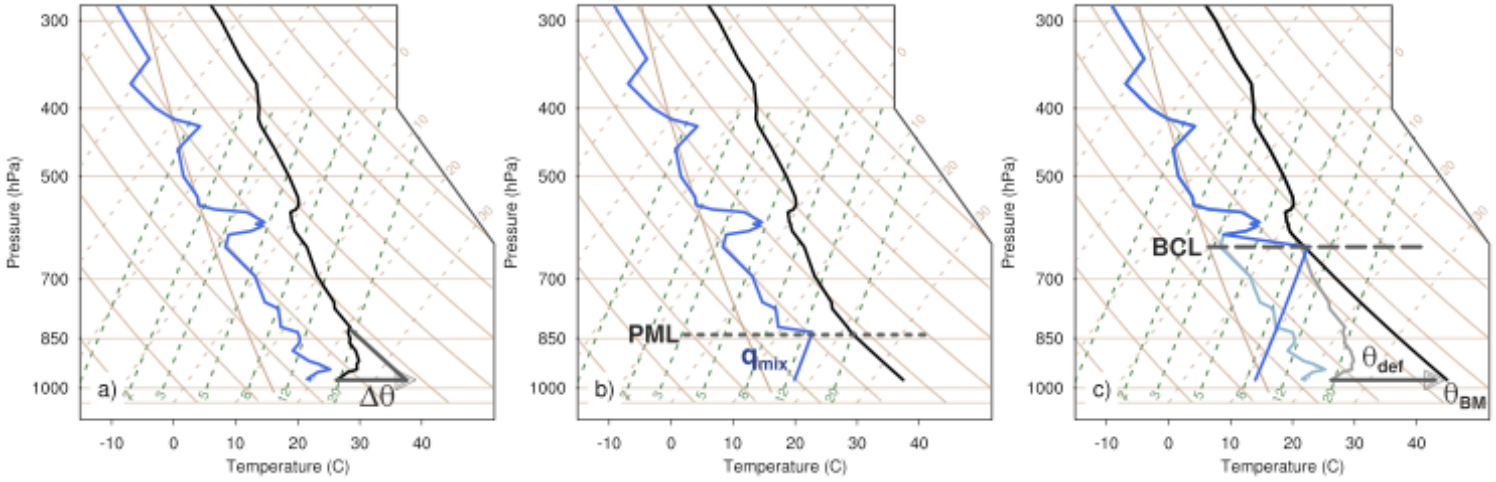
HEATED CONDENSATION FRAMEWORK

THE HCF TRIGGER

Tawfik and Dirmeyer (2014)

The HCF was designed to represent the atmospheric background state with respect to convection using standard profiles of temperature and specific humidity.

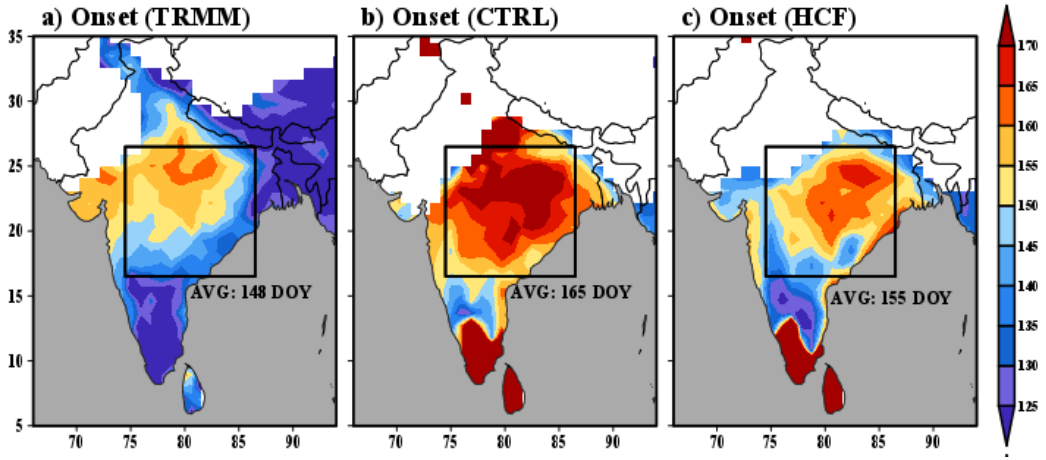
SkewT-LogP diagram of **temperature (black)** and **dew point (blue)** illustrating the steps to calculating the conditions for triggering convection.



Experiments

Expt.	Length (months)	Years	Period	Members/ Event/Year	Initialization Date	Spatial Resolution		Temporal Resolution	Model Physics
						ATM/LS	OCN/Sea ice		
CTRL	7	13	1998 - 2010	4	April 1,2,3,4	T126/ L64	0.5-degL40	Daily	Operational
HCF	7	12	1999 - 2010	4	April 1,2,3,4	T126/ L64	0.5-degL40	Daily	Operational + HCF trigger
CTRL2	7	10	2001 - 2010	4	April 1,2,3,4	T126/ L64	0.5-degL40	Daily	New SAS + Shallow Cu
HCFv2	7	9	2002 - 2010	4	April 1,2,3,4	T126/ L64	0.5-degL40	Daily	New SAS + Shallow Cu + HCF trigger
CTRL2	1	10	2001 - 2010	7	[Landfall, -1, …, -6]	T382/ L64	0.5-degL40	6-hourly	New SAS + Shallow Cu
HCFv2	1	9	2002 - 2010	7	[Landfall, -1, …, -6]	T382/ L64	0.5-degL40	6-hourly	New SAS + Shallow Cu + HCF trigger

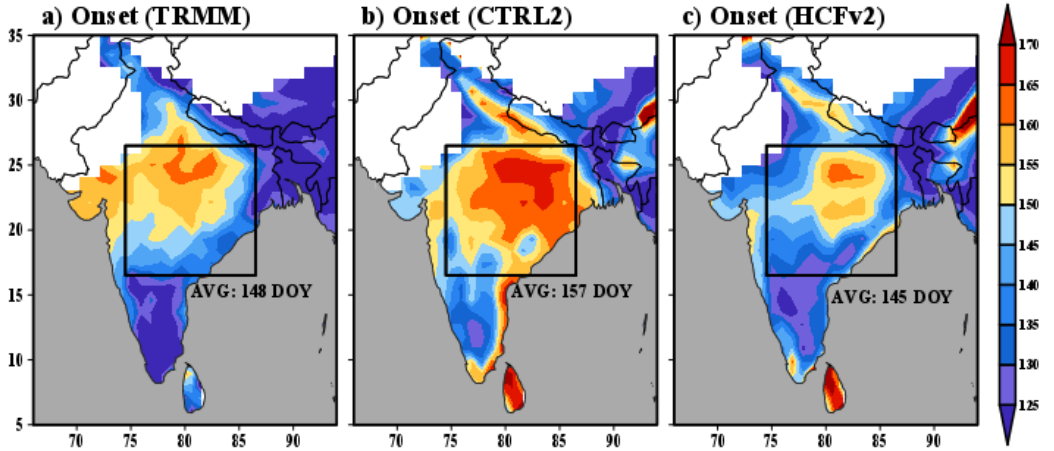
Bombardi et al. (2015)



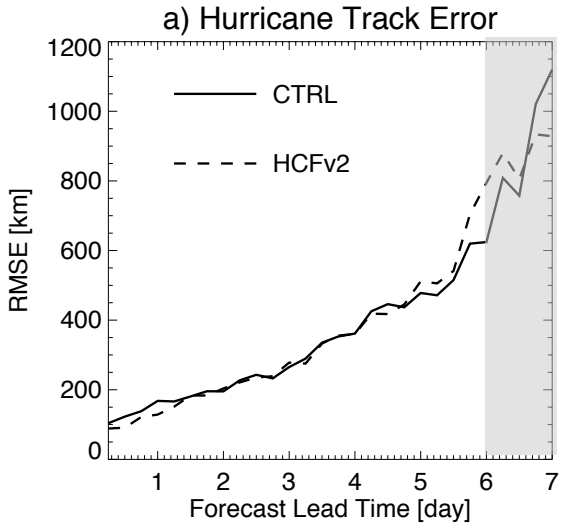
- **HCF trigger as alternative condition (in CFSv2 Oper.)**
- **Old SAS triggers more often → increase in the Summer Indian Monsoon Rainfall and improvement in rainy season onset date.**

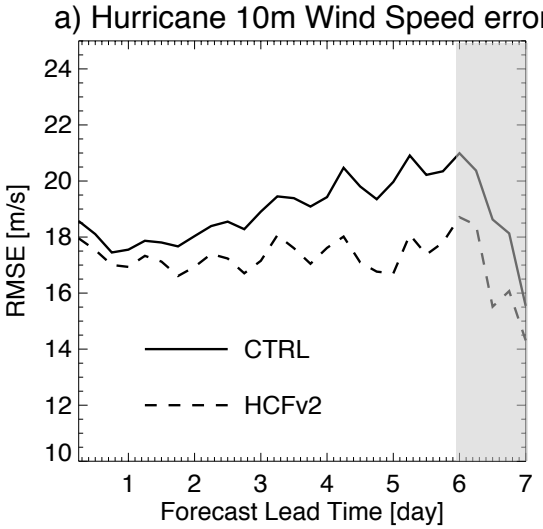
Bombardi et al. (2016)

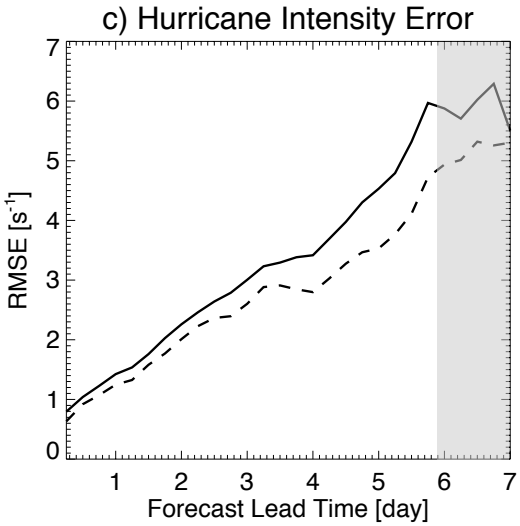
- **HCF trigger replaces original trigger (in exper. CFSv2)**
- **New SAS triggers less often: marginal change in Summer Indian Monsoon Rainfall but improves onset date.**

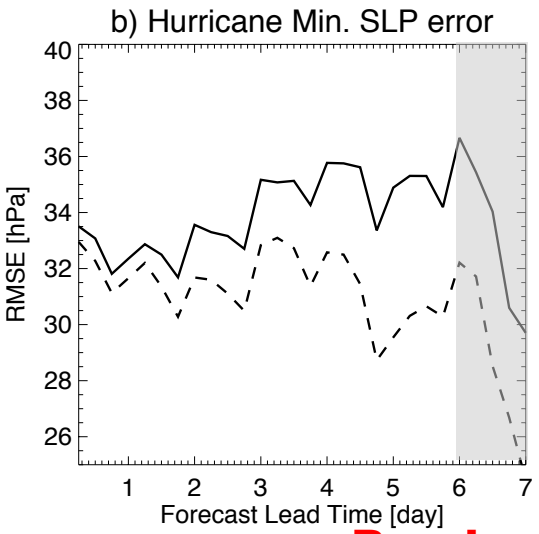


Simulating Hurricanes at T382









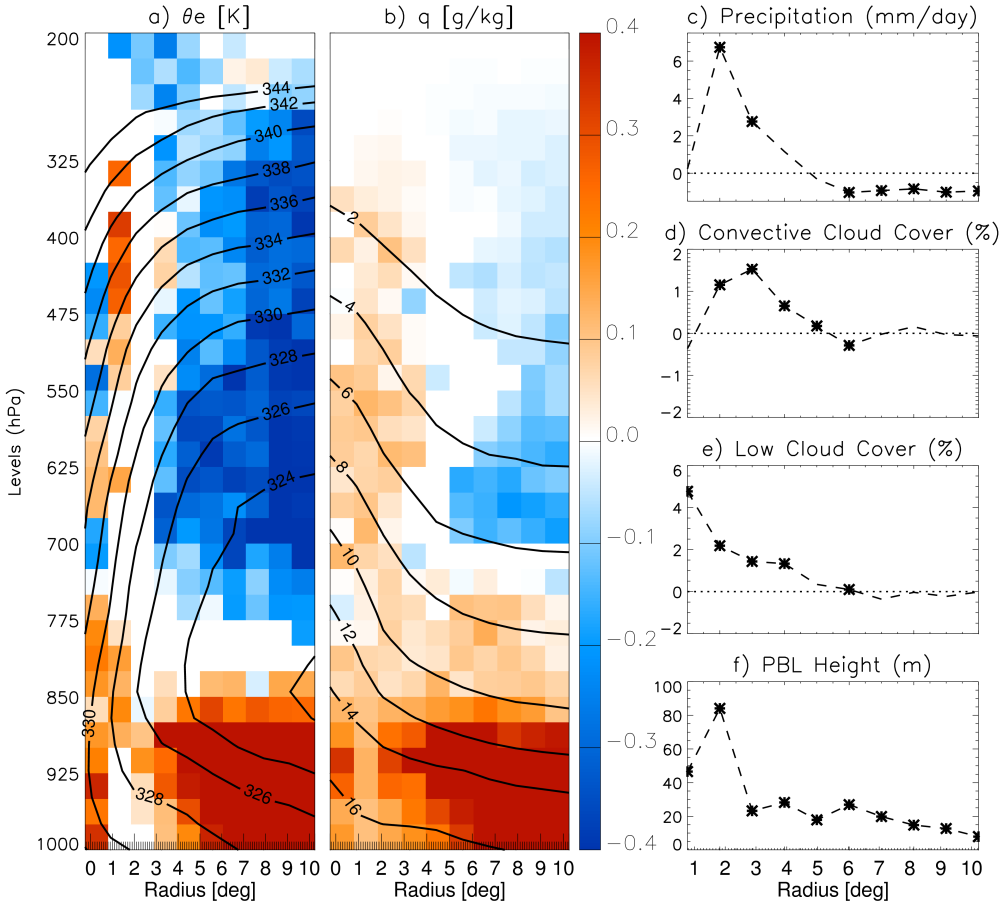
sample size too small

Bombardi et al. (2016)

Simulating Hurricanes at T382

The HCF trigger activated the convective schemes less frequently

- increasing convective instability
- allowing the PBL to moisten and grow higher
- Increasing precipitation, low and convective clouds
- releasing latent heat intensifying hurricanes



Shading or stars = statistically significant at 5% level

Bombardi et al. (2016)

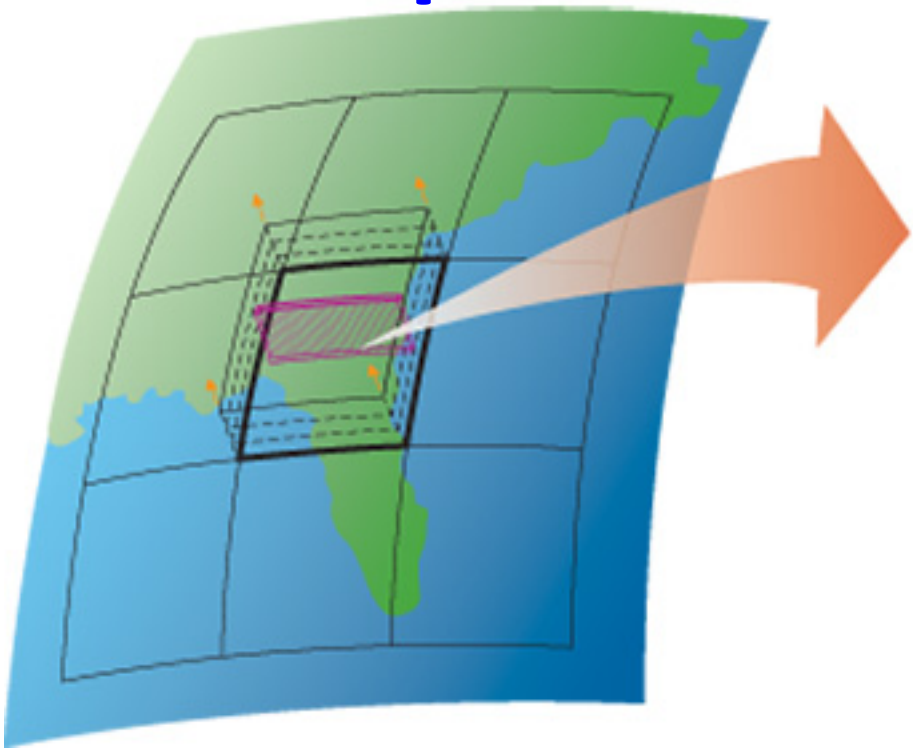
HCF - Summary

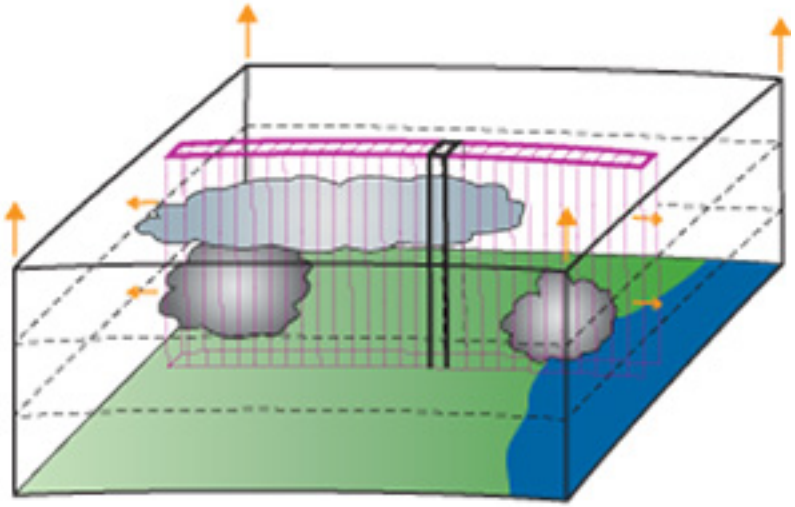
- The HCF trigger produces different results for the representation of convection in hurricanes vs. that during the Indian Summer Monsoon. That happens because these are different problems in CFSv2.
  - **The monsoon rainfall problem is too much light precipitation and too little intense precipitation**. By simply allowing the convective scheme to trigger more often, more precipitation is generated and the dry bias is reduced.
  - **The hurricane problem is too much convection**. By inhibiting activation of the convective scheme convective instability can build up, resulting in intensification of hurricanes.
- Additional work (not shown) with Eddy Diffusivity Mass Flux PBL scheme has so far resulted in little sensitivity in CFSv2

Khairoutdinov and Randall, 2001:

SUPER-PARAMETERIZATION

Super-Parameterization





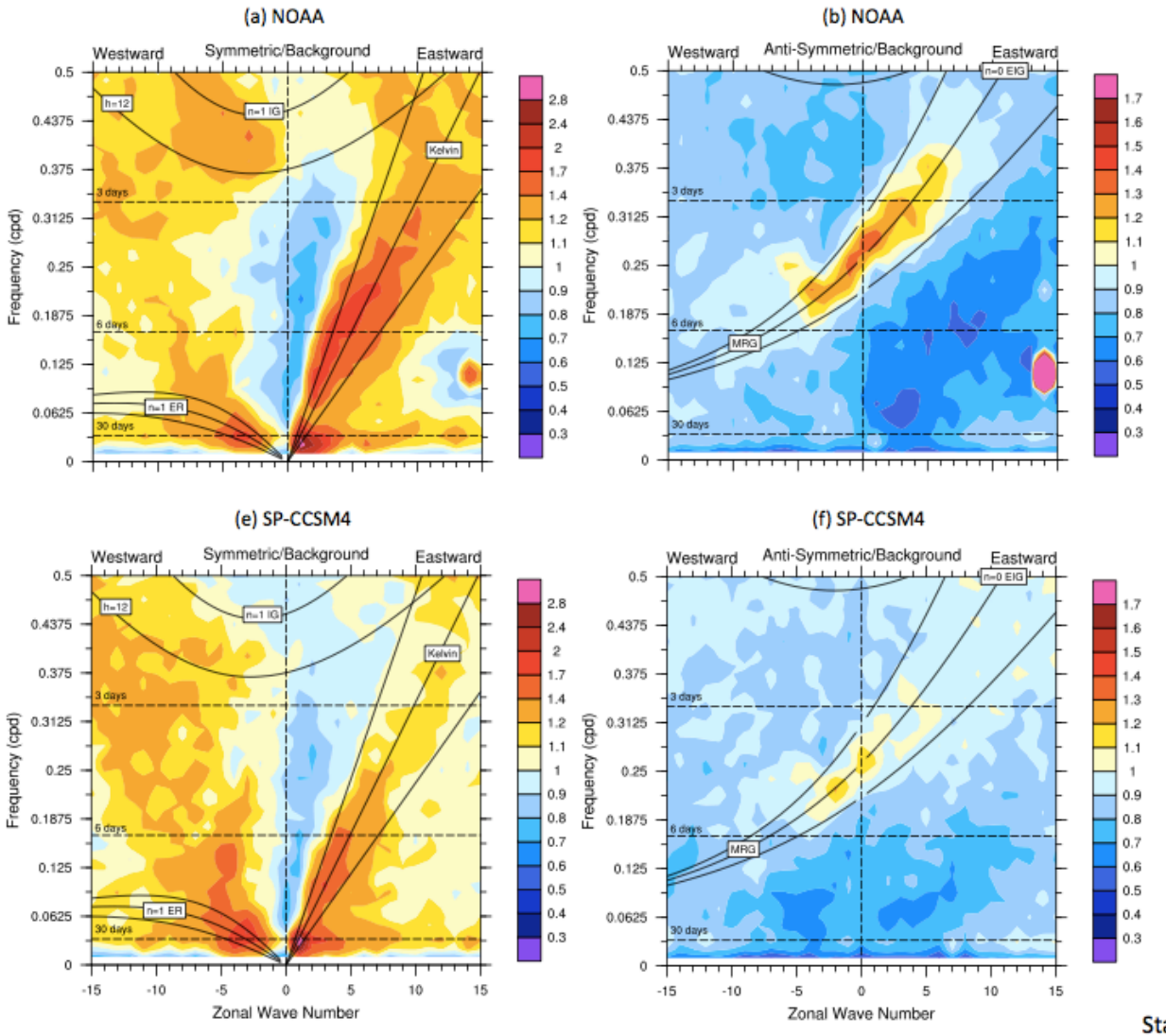
CRM

- 3-km clouds, aligned E-W
- Periodic domain
- Same vert. levels as host model

In a global climate model (left), each grid cell represents a large area of O(10^4) km^2. In the Multi-scale Modeling Framework, also called Super-Parameterization (SP), the clouds within each grid cell are represented with small cloud-system resolving models (CSRMs). A single cell might contain a row of 64 one-column CSRM models (right), each depicting clouds over a 3 x 3 km area. (Illustration by Mike Shibao, based on imagery from CMMAP.)

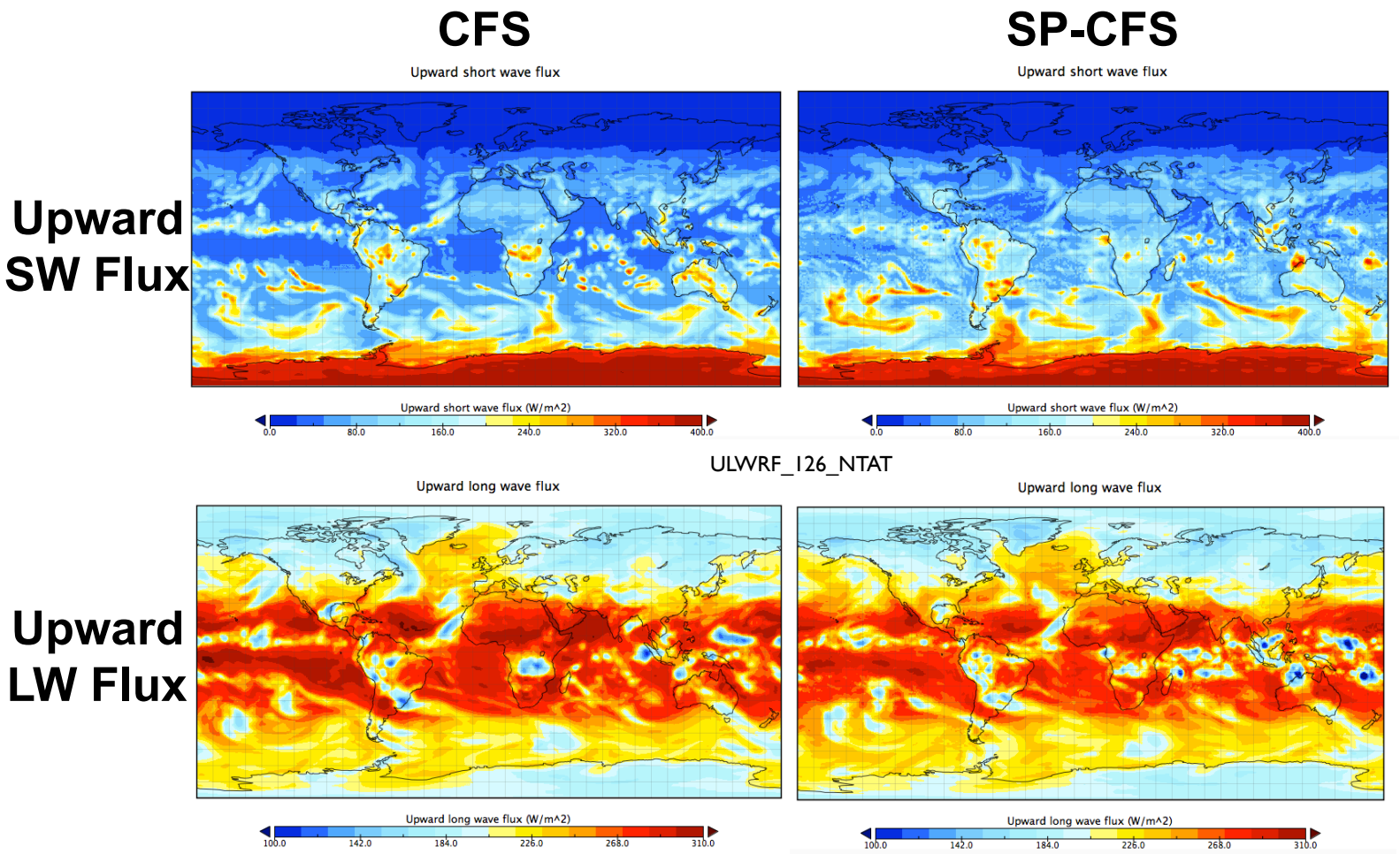
** Khairoutdinov and Randall, 2001*

SP-CCSM4 Simulation of MJO



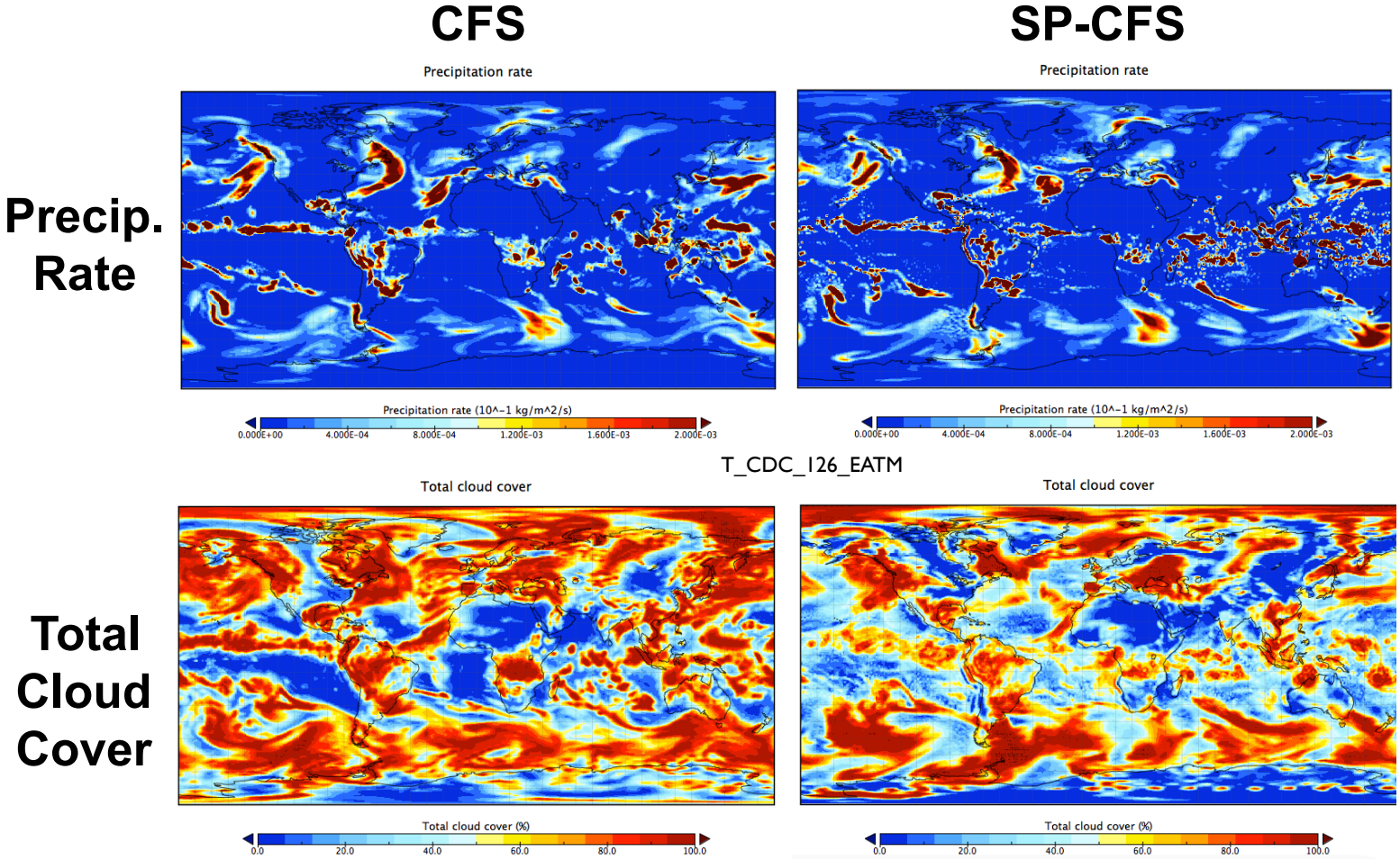
Stan and Xu, 2014

Initial 144-Hr. Test of SP-CFS (T126)



Thanks to Marat Khairoutdinov

Initial 144-Hr. Test of SP-CFS (T126)



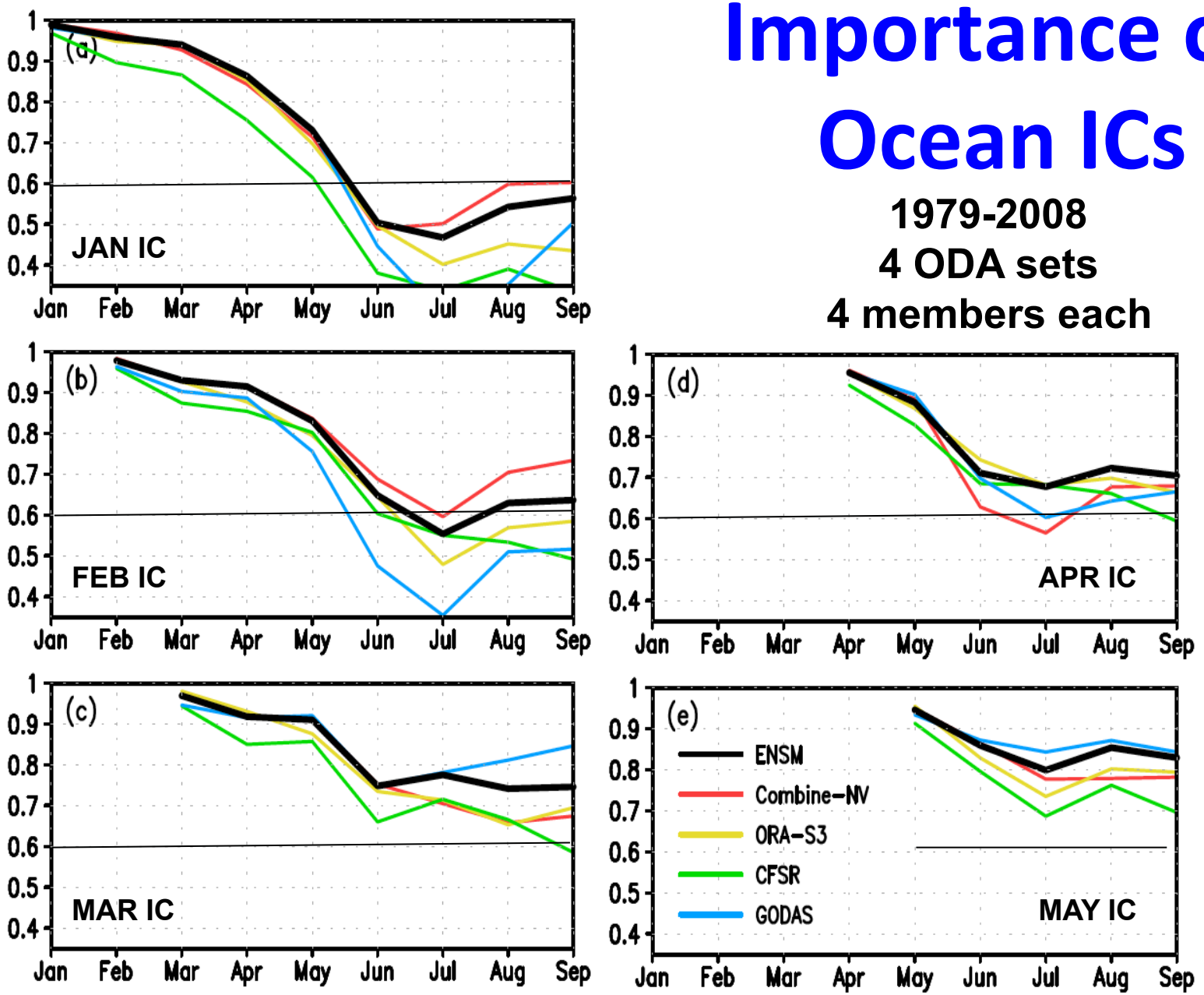
Thanks to Marat Khairoutdinov

Enhanced Ensembles

- Experiments with CFSv2 using ocean initial states from various ODA-based analyses of the global ocean (CFS-R, GODAS, COMBINE-NV, ORA-S3) confirm earlier result of Zhu et al. (2012) that MAE forecasts are superior to SAE forecasts
- Connection between ENSO and the Asian monsoon: predictability of monsoon rainfall is higher following an El Niño event that during the event

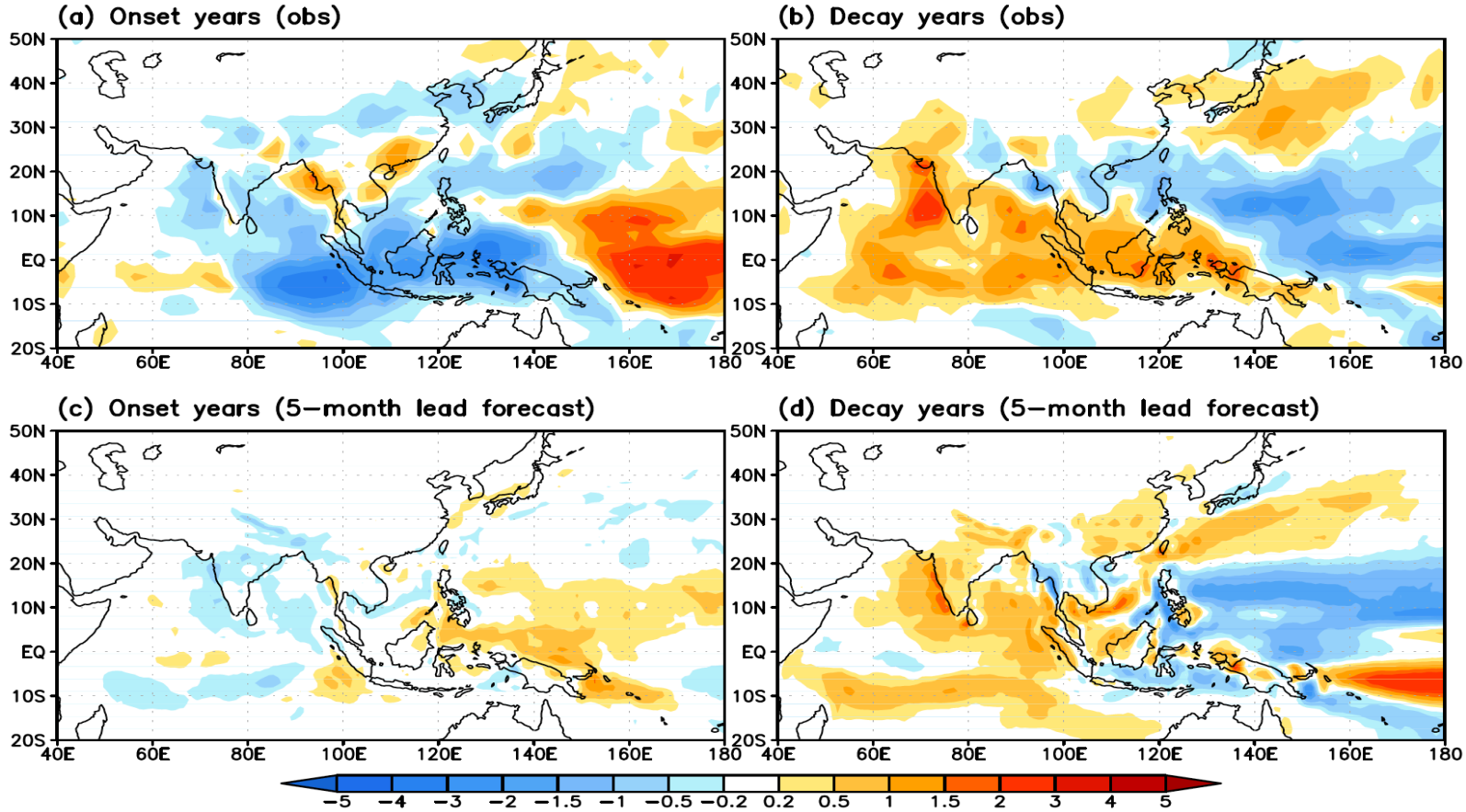
Importance of Ocean ICs

1979-2008
4 ODA sets
4 members each



Shin et al. 2016

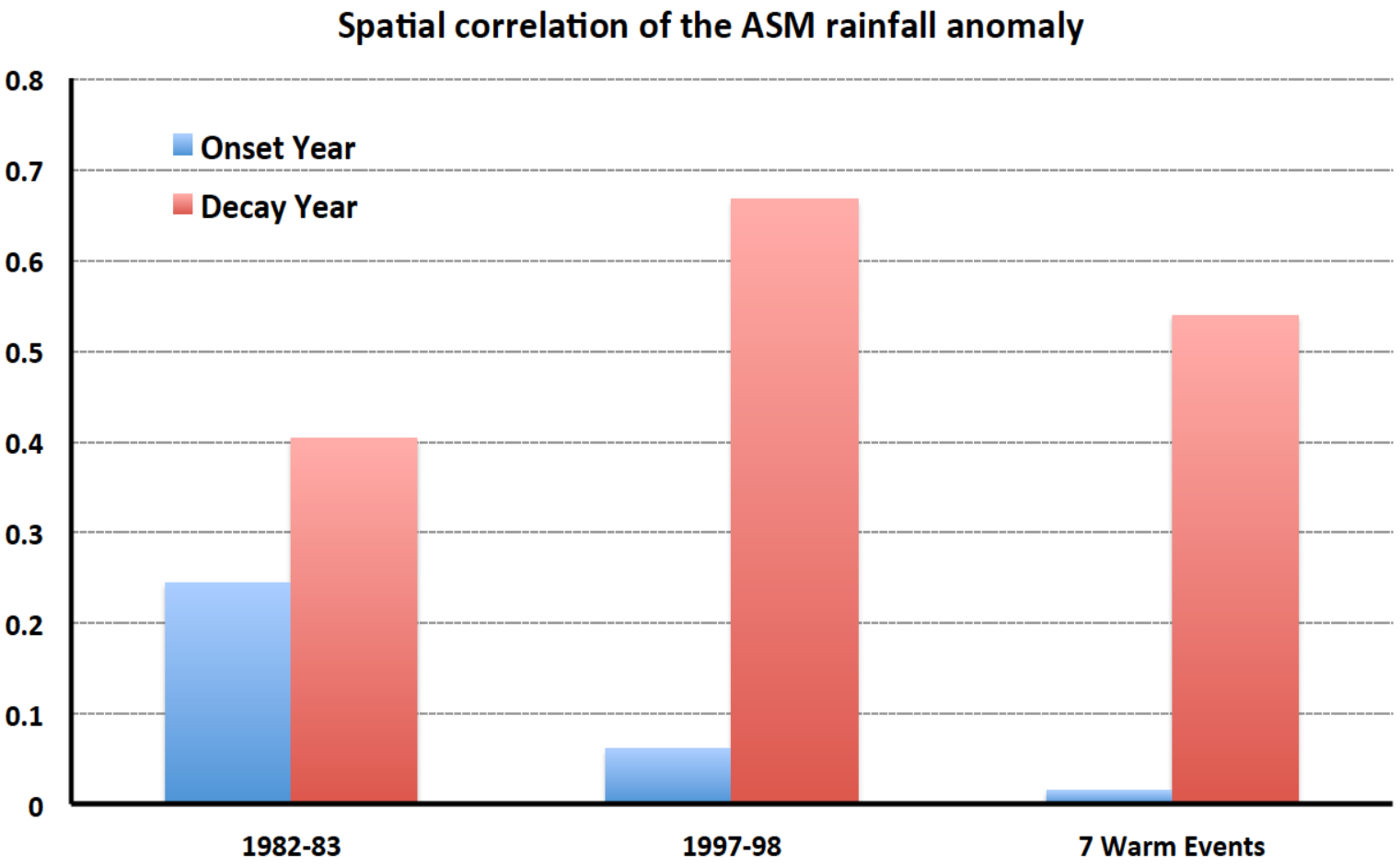
El Nino Onset vs. Decay → Rainfall Predictability



NOTE: These patterns are very similar to precip EOFs 1 and 2 for these domains

Shin et al. 2016

Forecast Skill @ 5-Months Lead



Contributions to UGCS

- Weekly telecons on NEMS implementation, sea ice, overarching system architecture
- Contributions to debugging sea ice coupling error
- Contributions to discussions and documents on diagnostics, documentation
- Developing design for more general coupling strategy

NGGPS COLA Team Summary

- **Major Accomplishment in FY16:**
  - Extensive reforecast analysis (S2S, CFSv2, modified CFSv2 with HCF, EDMF)
  - Tests with HCF convection trigger at ~100-km and ~35-km grids show positive impacts on forecast skill for rainy season onset, total monsoon accumulation and tropical cyclones
  - Installed SP in CFSv2
  - Tested multiple ocean analysis efficacy for coupled prediction
  - Contributed to UGCS design and development
- **Priority Focus for FY17**
  - Shift to UGCS for future development and testing
  - Apply advanced statistical methods to evaluate skill and predictability
- **Key Issue**
  - Readiness of UGCS for scientific evaluation
  - High-end computing resources