Modulation of TC Activity by the Tropical Intraseasonal Variability over the Eastern Pacific in a High Resolution GCM: Implications for Dynamically-based Intraseasonal TC Prediction

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1.Introduction

Tropical Cyclone Forecast (Dynamical/Statistical)

Operational

Short-Medium-range
~7 days
(Initial condition)

Operational

Seasonal Outlook
~Season
(SST, QBO, PDO, AMO, etc)

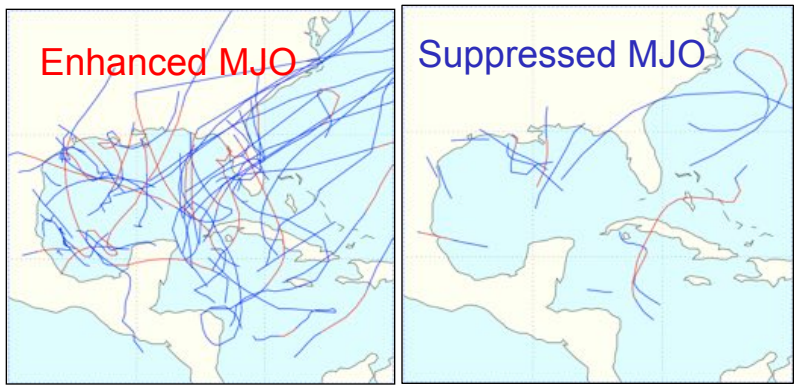
Research/Experimental

Intraseasonal Forecast
~ 7 days -weeks
(MJO, CCEWs, SST, etc)

Modulation of TCs by the ISV

- W. Pacific: Nakazawa (1988); Liebmann et al (1994); Wang & Zhou (2008)
- E. North Pacific: Molinari et al. (1997); Maloney & Harmann (2000)
- Gulf of Mexico: Maloney & Hartmann (2000); Mo (2002)
- S. Indian Ocean: Bessafi & Wheeler (2006); Ho et al (2006)
- N. Indian Ocean: Kukuchi & Wang (2010)
- Australian region: Hall et al (2001)

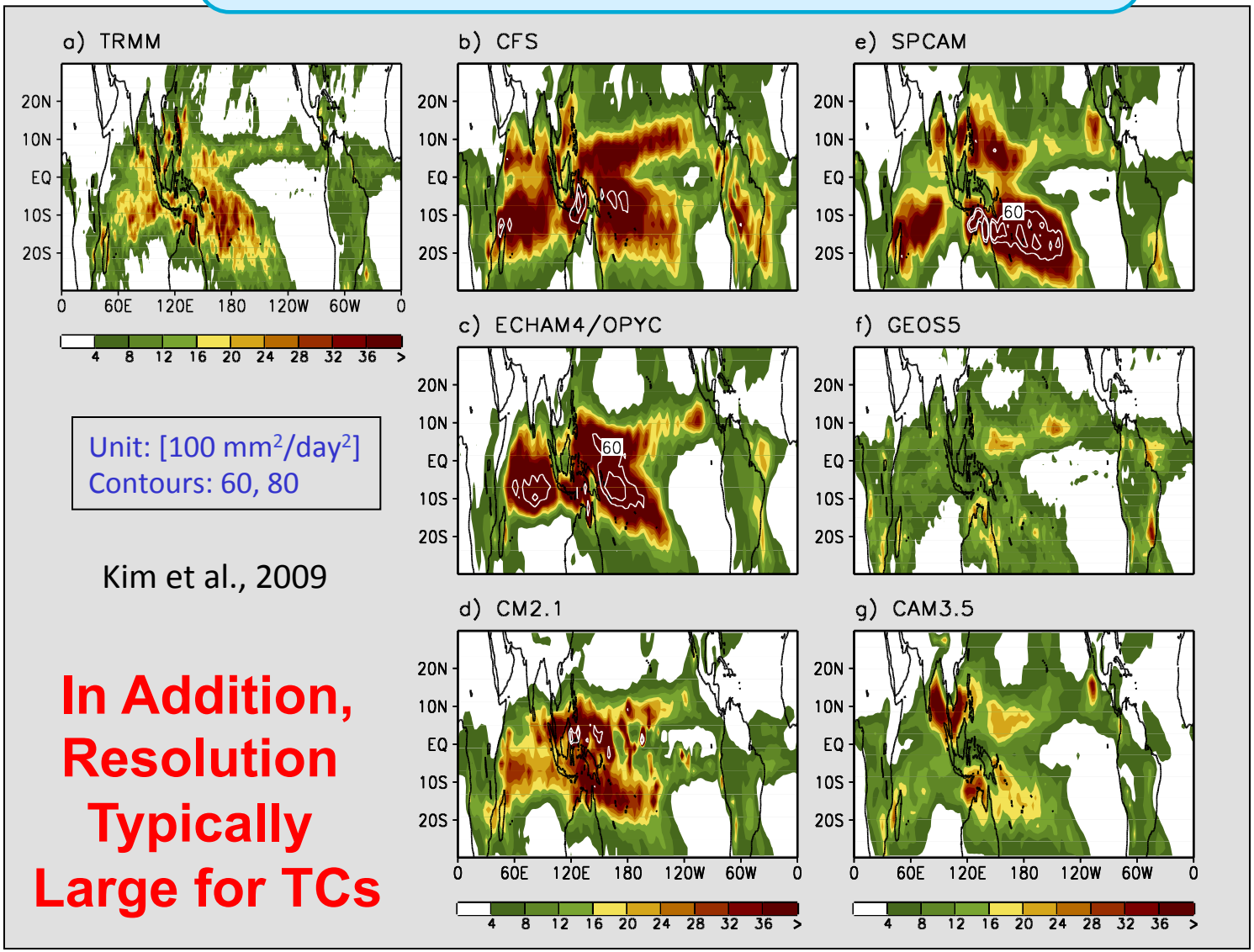
What about Forecasting?



Maloney and Hartmann (2000)

Simulations of the ISV in Climate Models

Variances of 20-100 day filtered rainfall (Nov-Apr)



Kim et al., 2009

In Addition, Resolution Typically Large for TCs

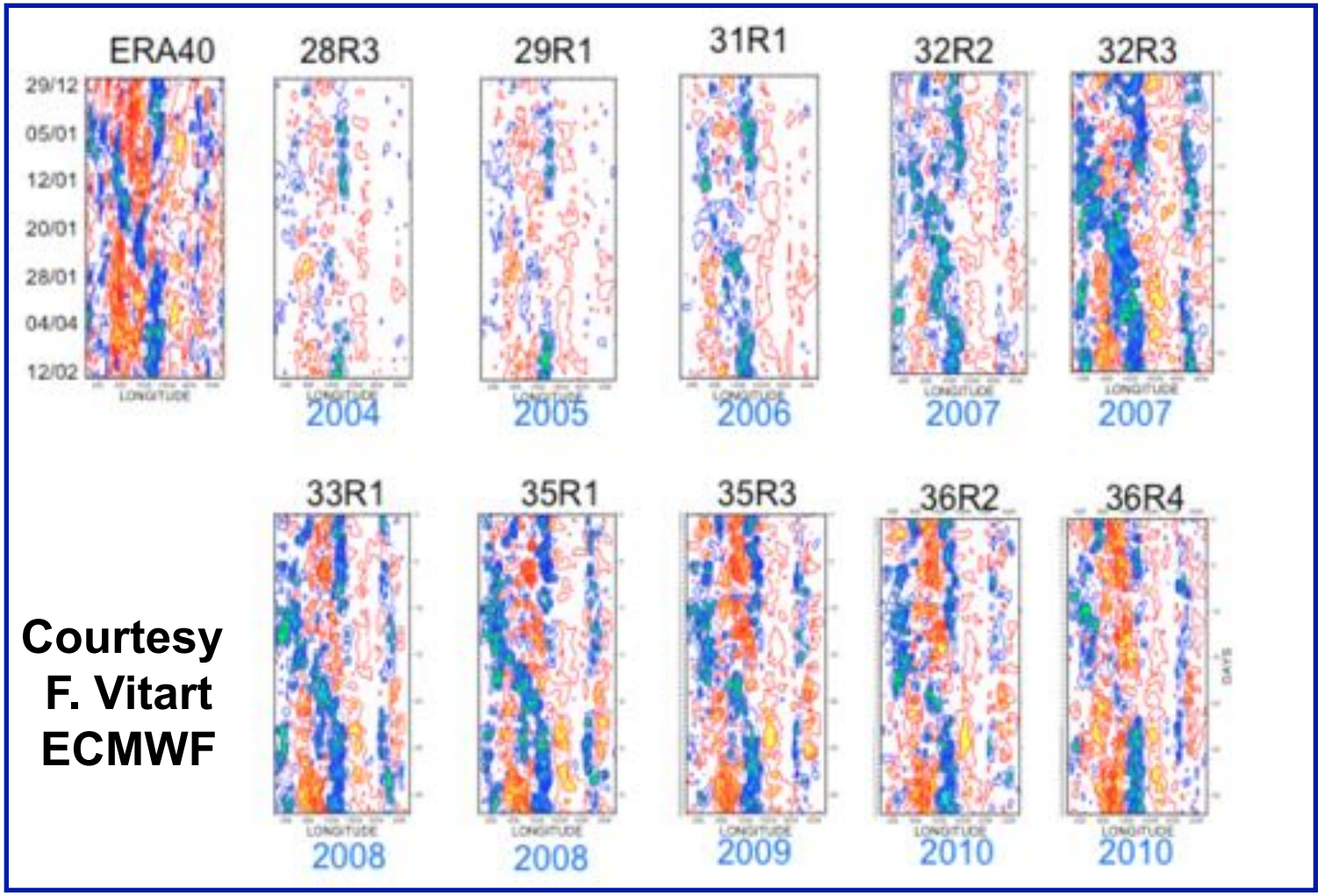
Statistical Intraseasonal TC-Activity Forecast

- Leroy et al (2004)
- Frank and Roundy (2006)
- Leroy and Wheeler (2008)
- Roundy (2008)
- Roundy and Schreck (2009)

Performance of these intraseasonal forecast are largely dependent on the forecast skill of the MJO

MJO Modeling and Forecasts from ECMWF

OLR; 15-day Lead Time; 10N-10S; TOGA COARE



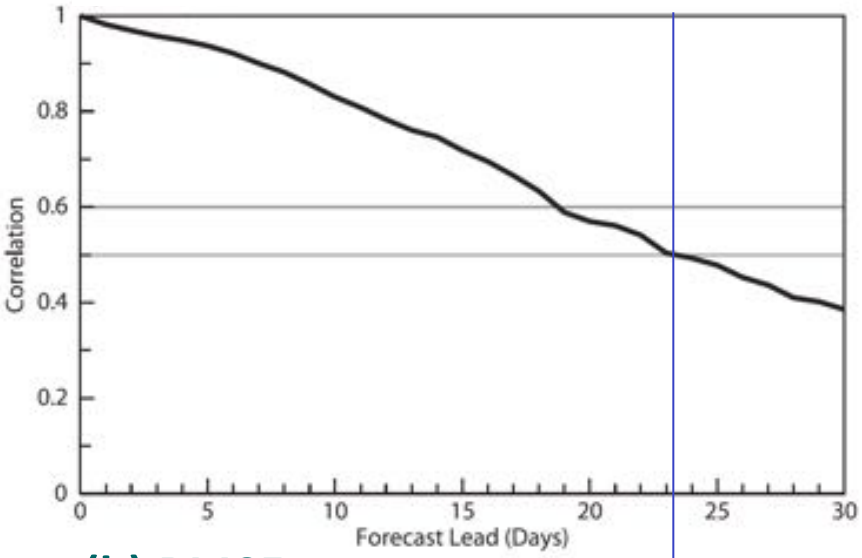
Courtesy F. Vitart ECMWF

Promising gains from continued model improvements

Resolution, Data Assimilation, Model Physics (Tomkins et al. 2007; Bechtold et al 2008) – M. Miller.

MJO Skills in ECMWF IFS (CY32R3) Hindcast

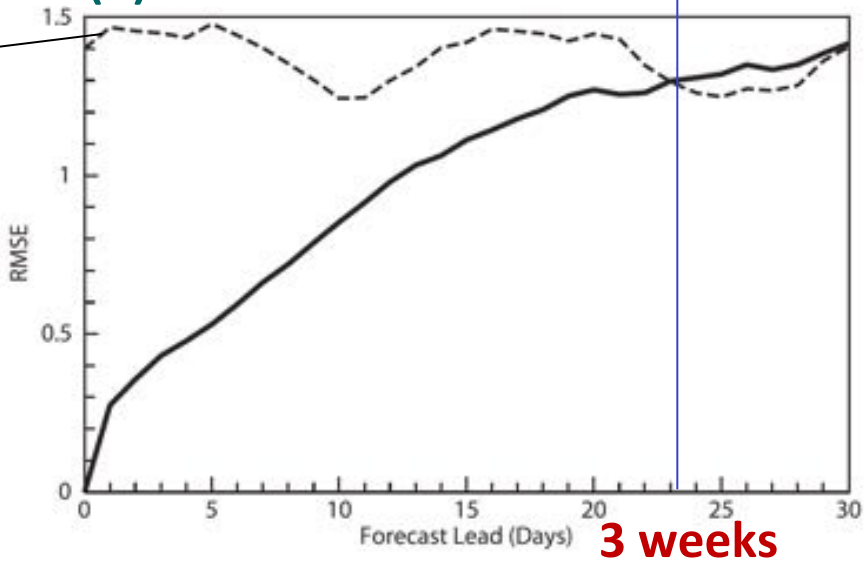
(a) Bivariate Correlation Skill



0.5

(b) RMSE

RMSE obtained with Climatology

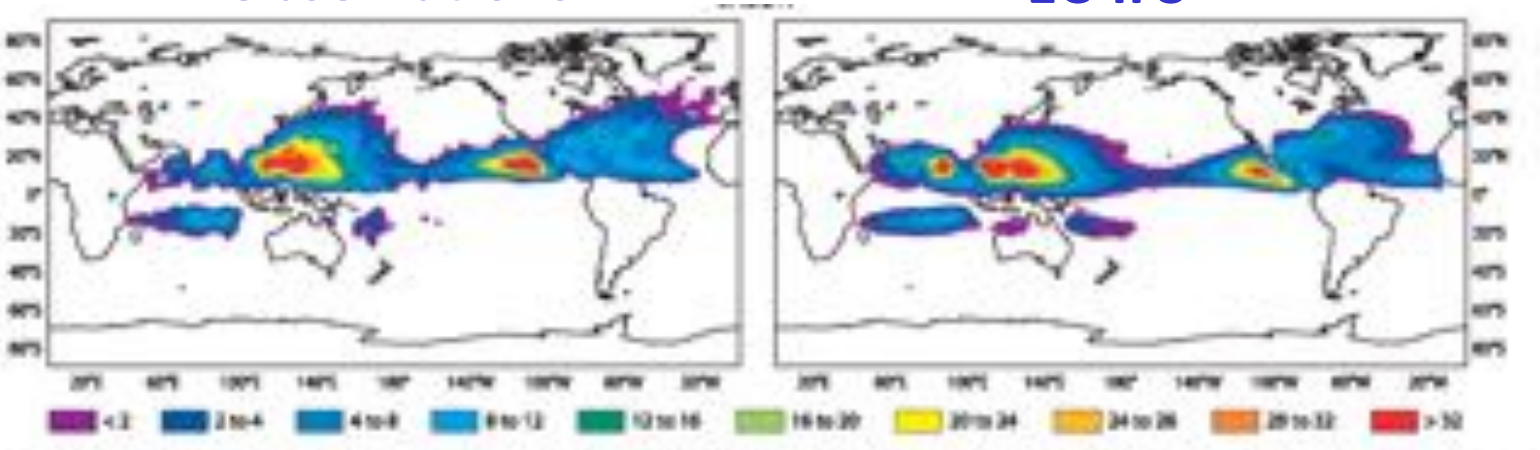


3 weeks

Vitart et al., 2010

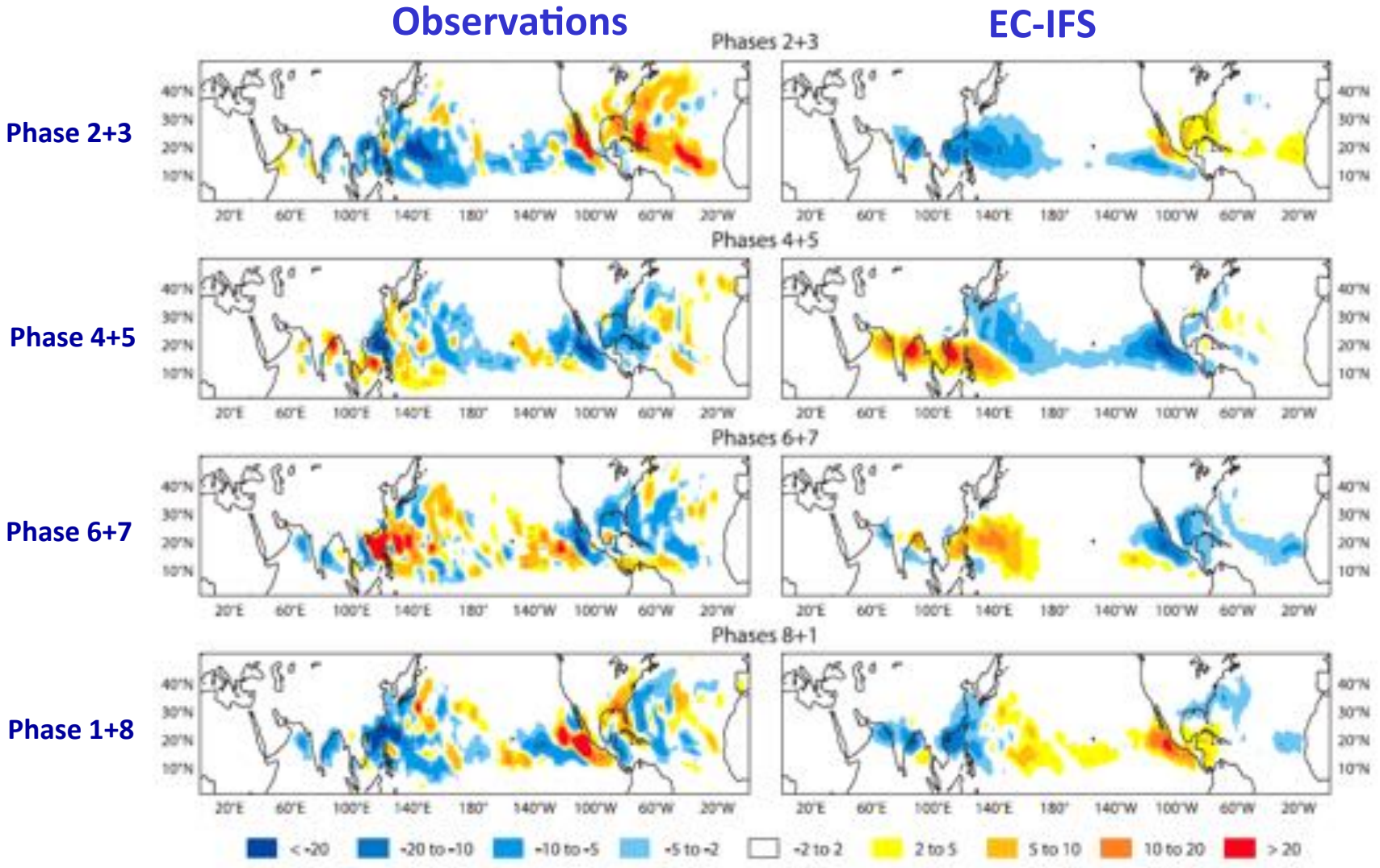
Climatological TC Density (*1000) in ECMWF-IFS
(Jun-Nov, 1989-2008)

Observations **EC-IFS**



Vitart 2009

MJO modulation of TC Density in ECMWF-IFS



Vitart et al., 2009

2. ISV and TC activity in GFDL High Resolution Atmospheric Model

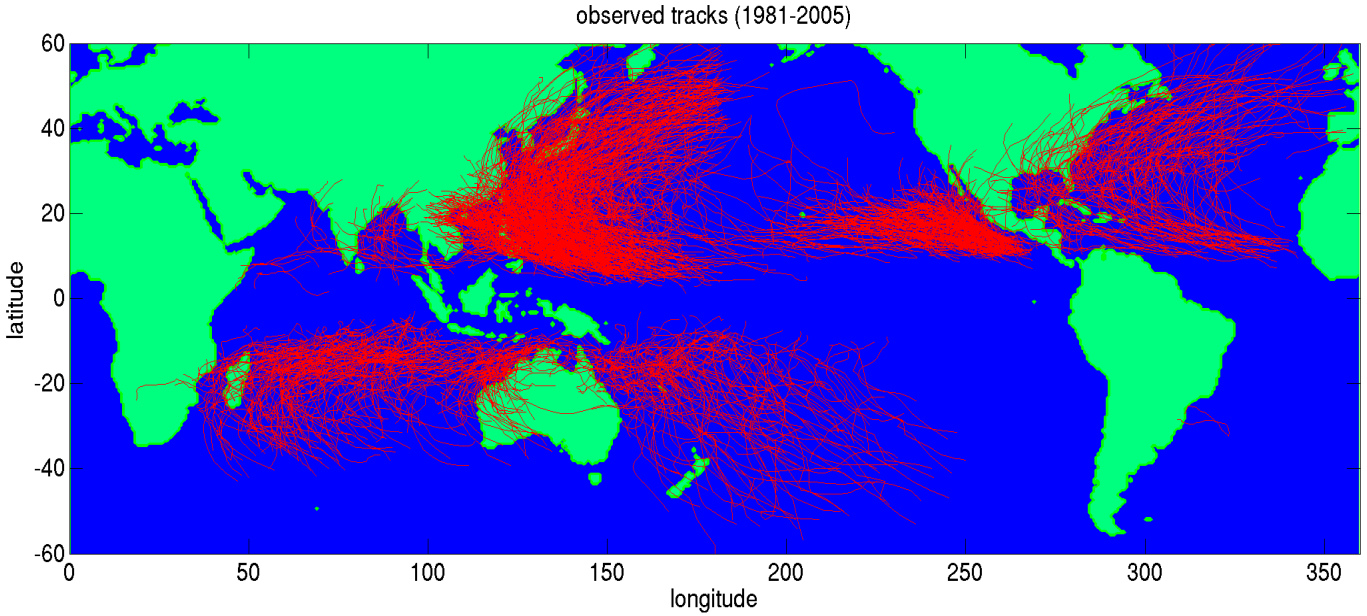
GFDL new High Resolution Atmospheric Model (HiRAM2.1)

- New **cubed-sphere dynamic core**
- Horizontal resolution: **50km** (C180)
- Vertical resolution: **32** levels
- **A moist convection scheme** based on shallow cumulus parameterization (Bretherton et.al 2004)
- A simple **statistical cloud fraction scheme**.

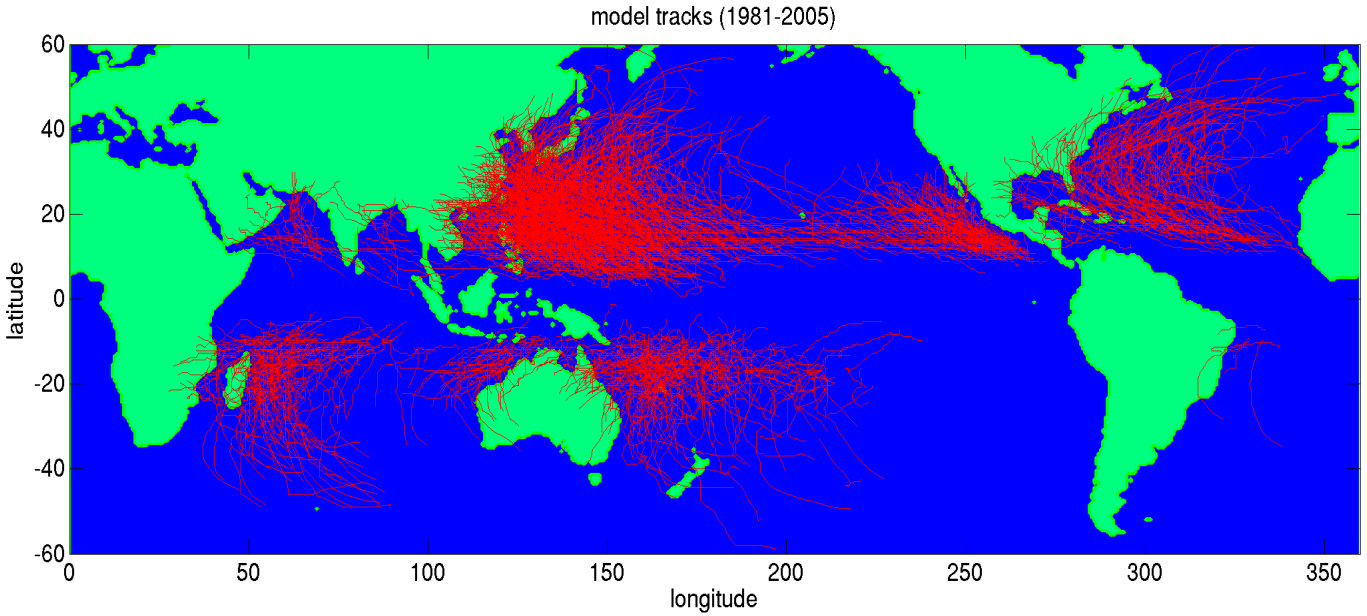
Captures TC activityand E.Pac ISV very well.

HiRAM2.1 captures geographical distribution of hurricane tracks (1981-2005)

Observation



HiRAM2.1



Zhao et al. (2009)

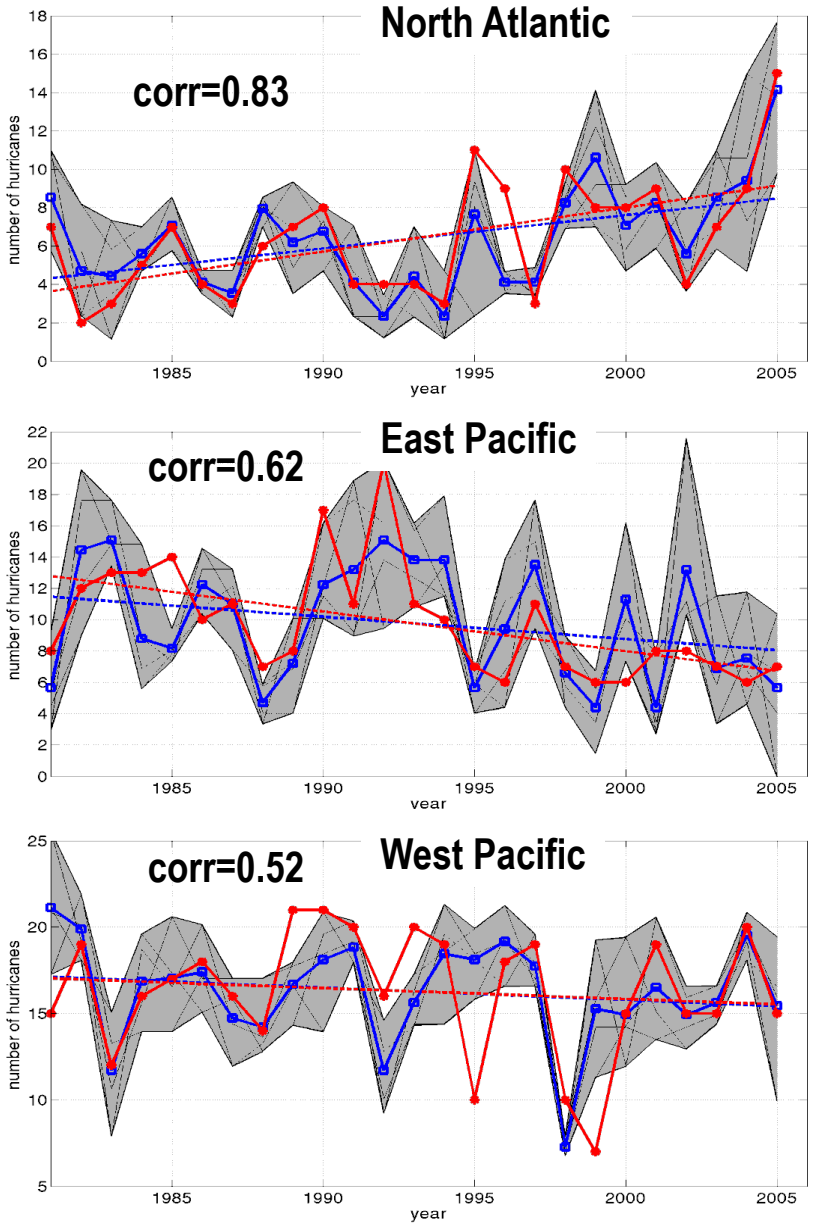
HiRAM2.1 captures both the inter-annual variability and decadal trend over the N. Atlantic, the E. and W. Pacific

Red: observations

Blue: HiRAM ensemble mean

Shading: model spread; N=4

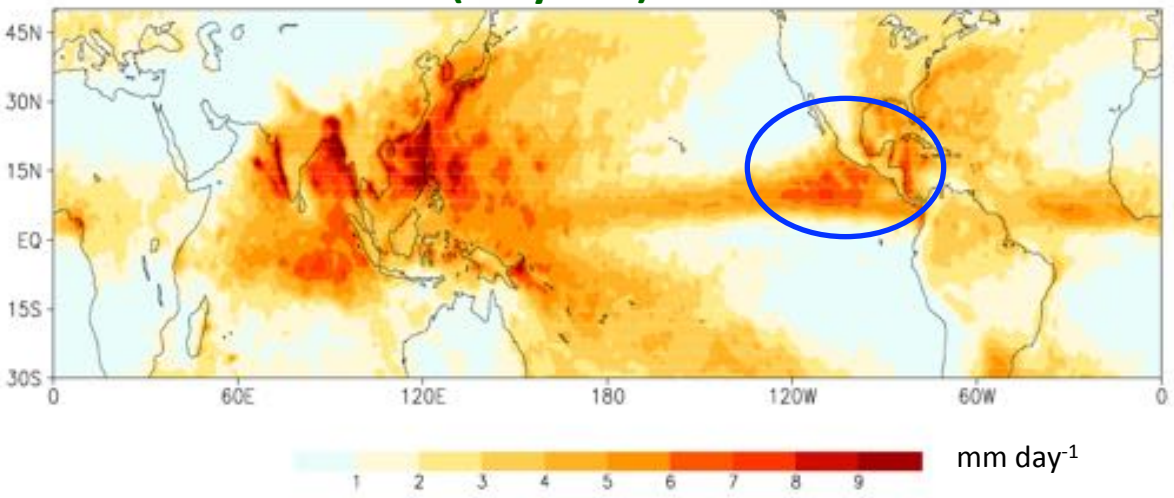
Model time-series are normalized to observed time-mean



Zhao et al. (2009)

Standard Deviation of Bandpass Filtered Rainfall

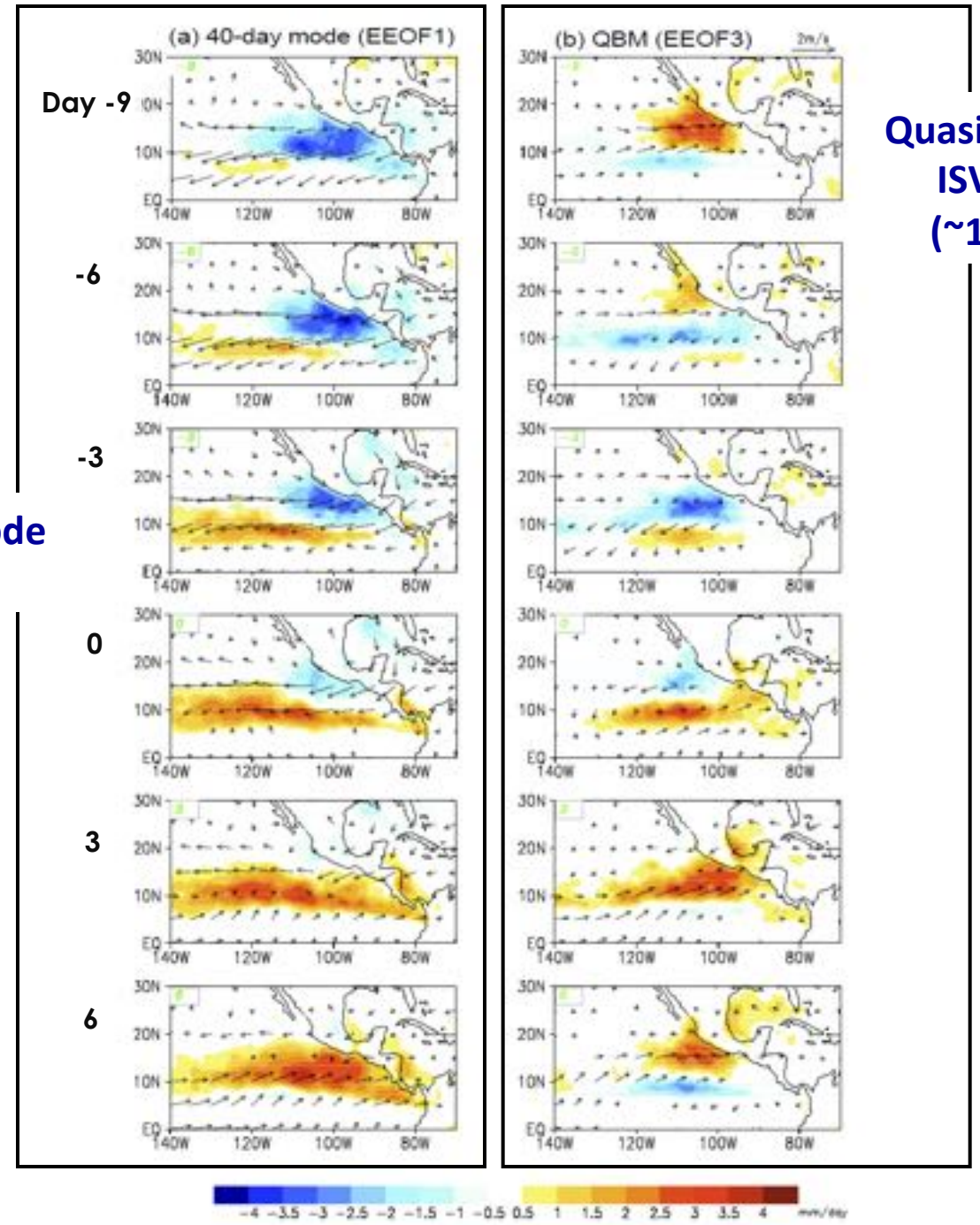
Northern Summer (May-Oct)



10-90 day filtered

Dominant ISV modes over the Eastern Pacific

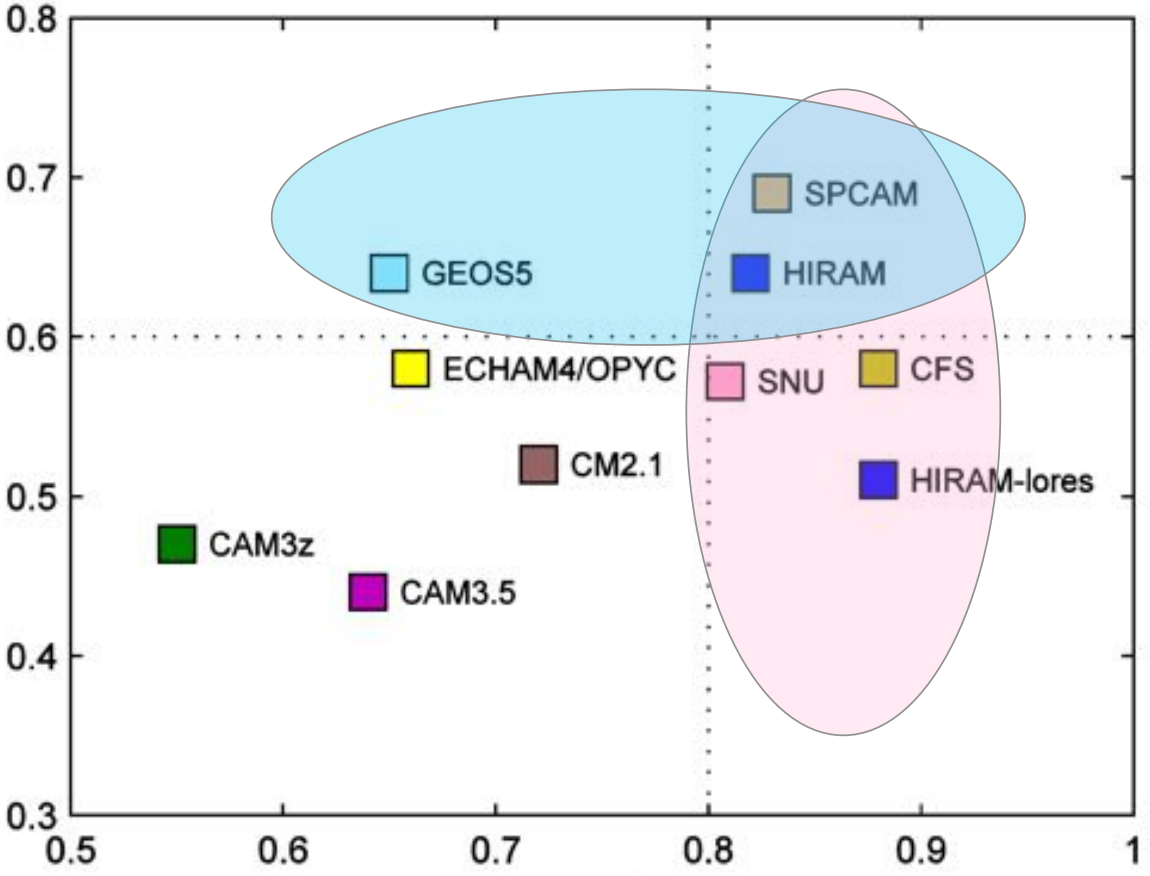
Jiang and Waliser 2008, 2009



40-day ISV mode (~ 40 days)

Quasi-biweekly ISV mode (~16 days)

Pattern correlations of the two dominant ISV modes between observations and GCM simulations



QBM

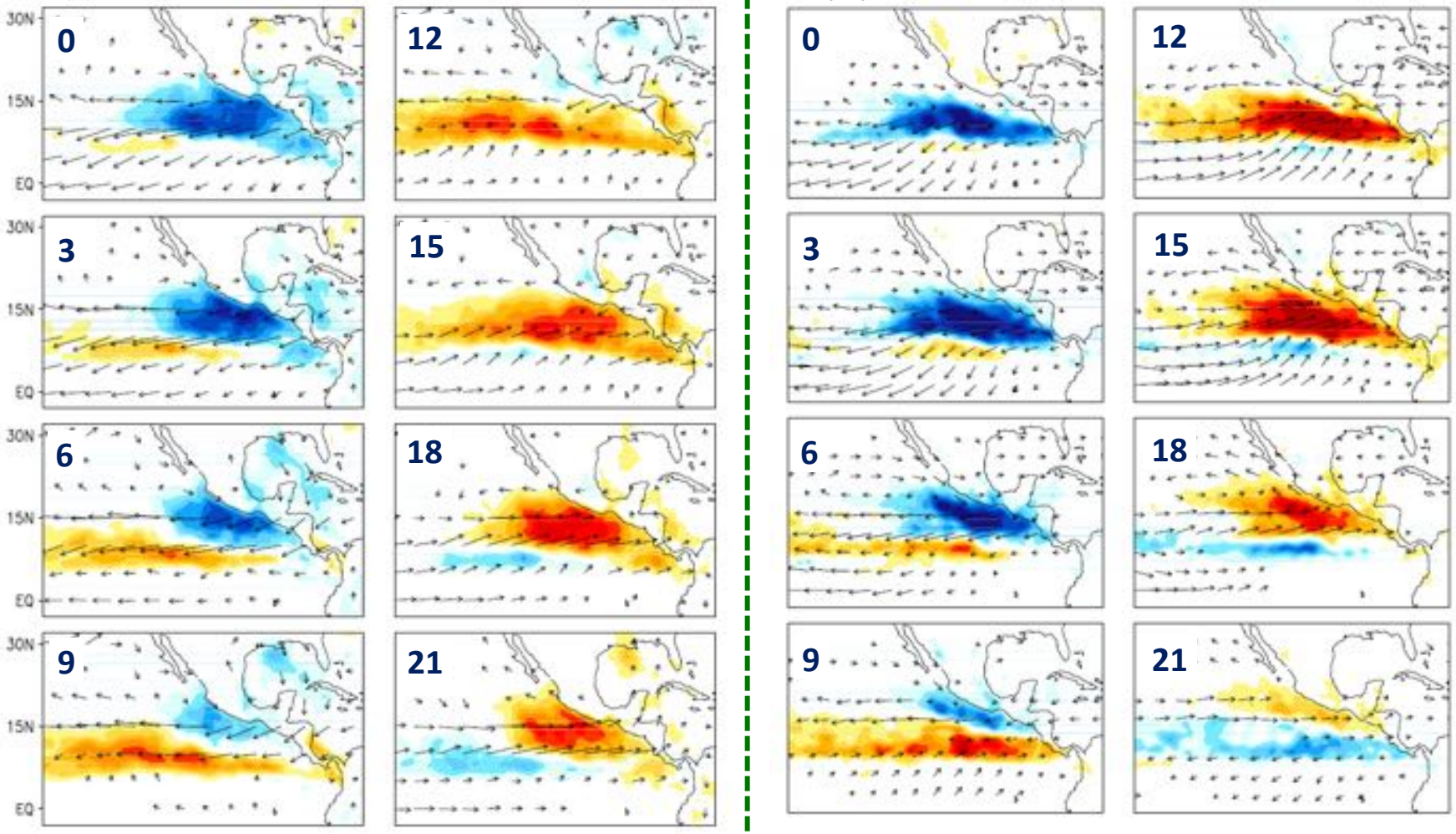
40-day mode

Jiang et al (2011a)

40-day ISV mode over the EPAC simulated by HiRAM

(a) Observations (TRMM/NCEP2)

(b) HiRAM



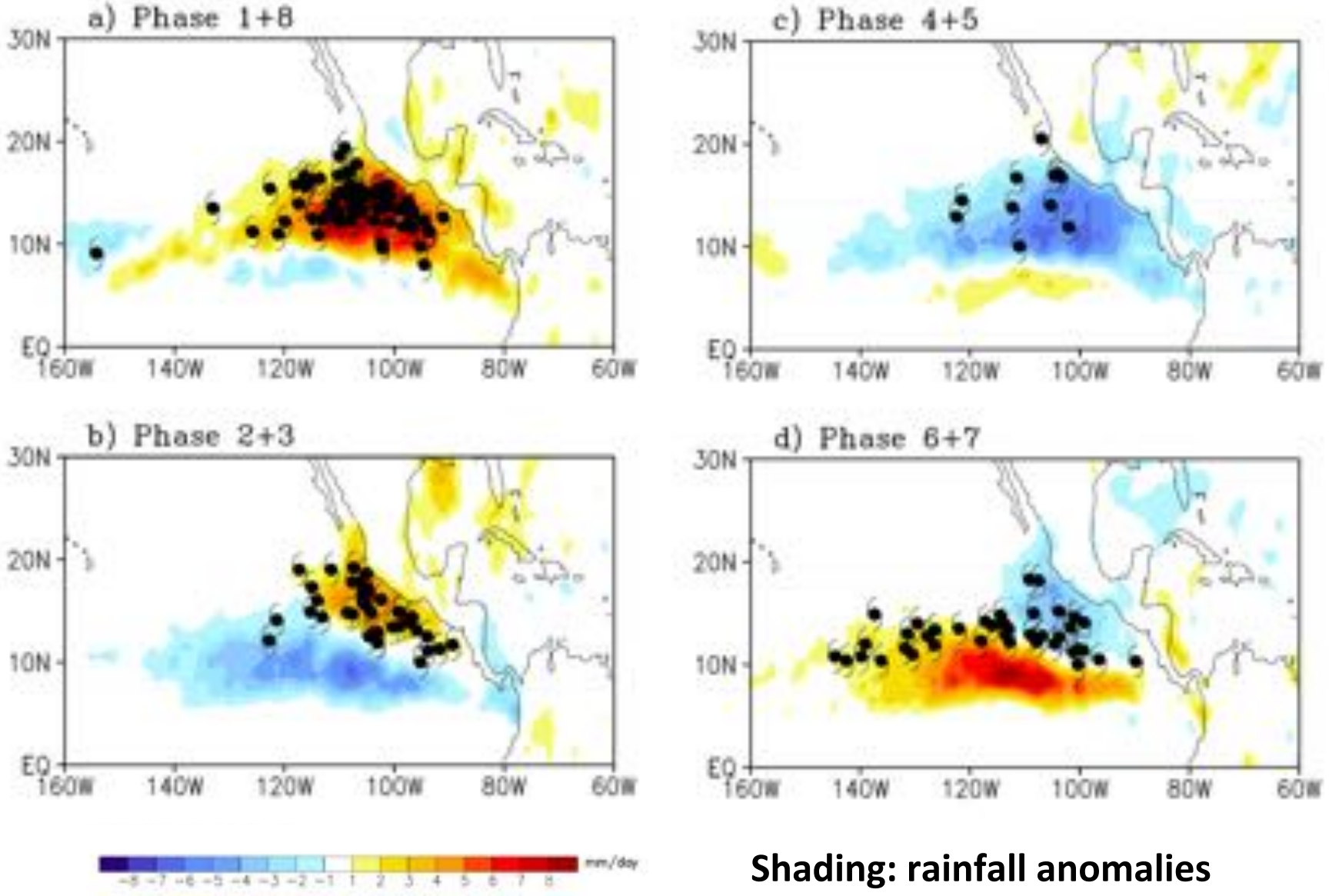
Shading: Rainfall

Vectors: 850mb wind

Jiang et al. (2011a)

ISV and TC genesis (1998-2008): OBS

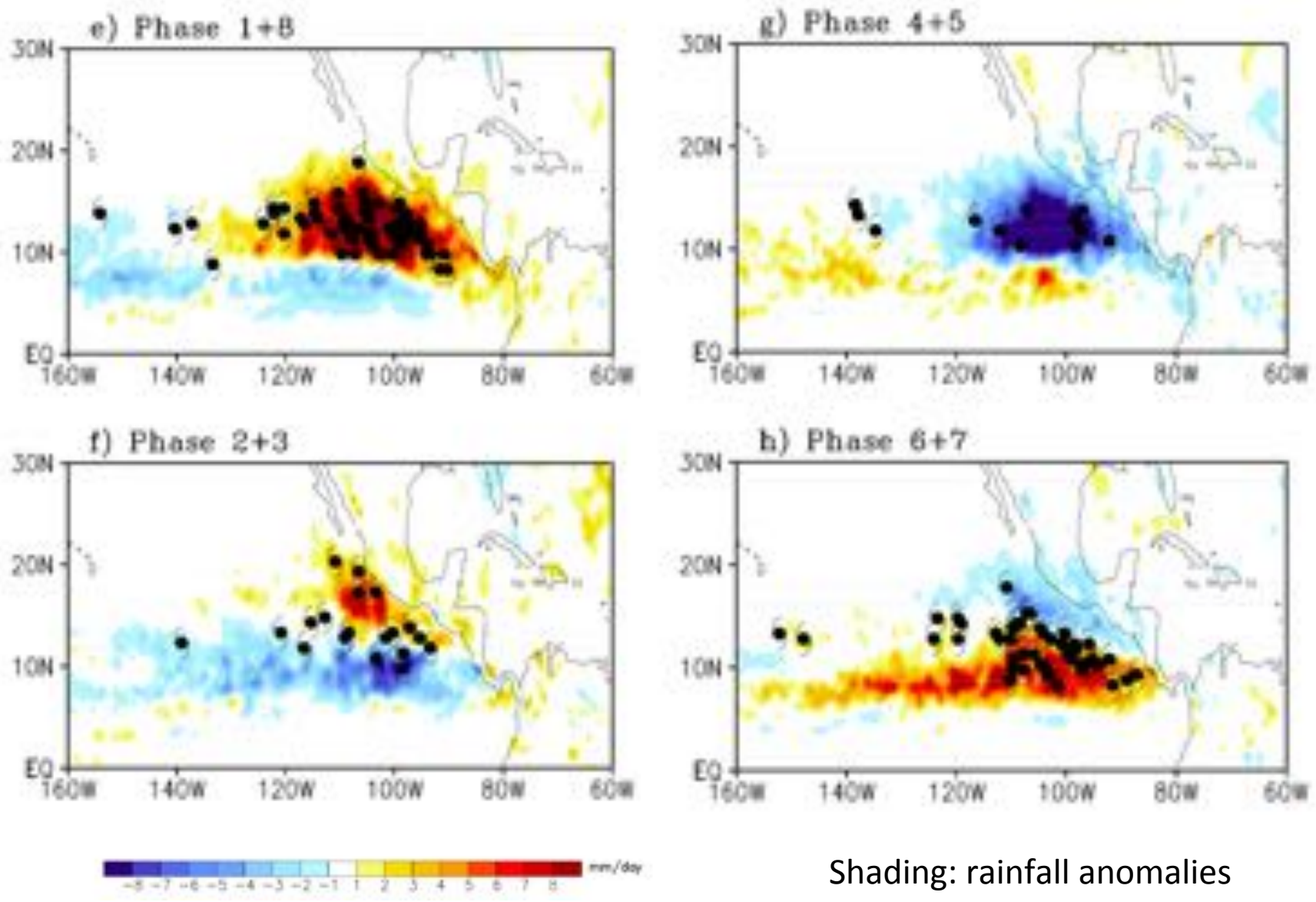
Jiang et al. (2011b)



Shading: rainfall anomalies

ISV and TC genesis (1998-2008): HiRAM

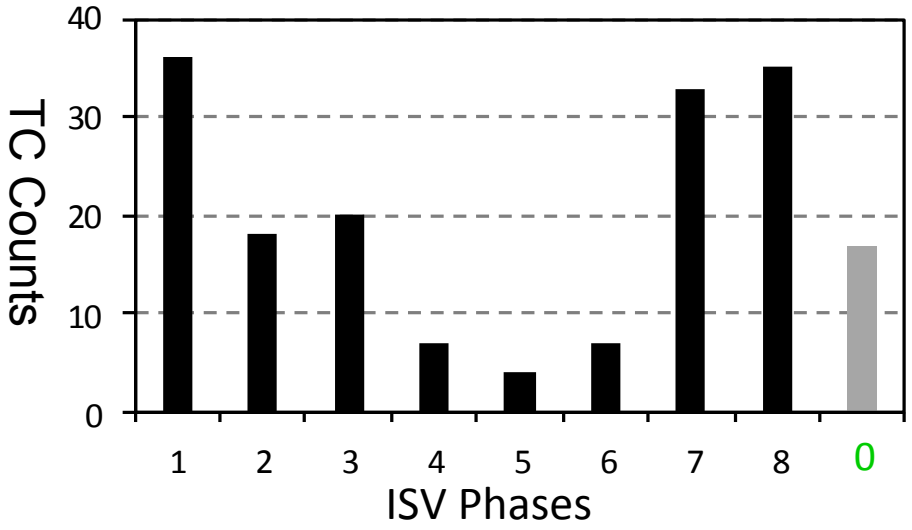
Jiang et al. (2011b)



Shading: rainfall anomalies

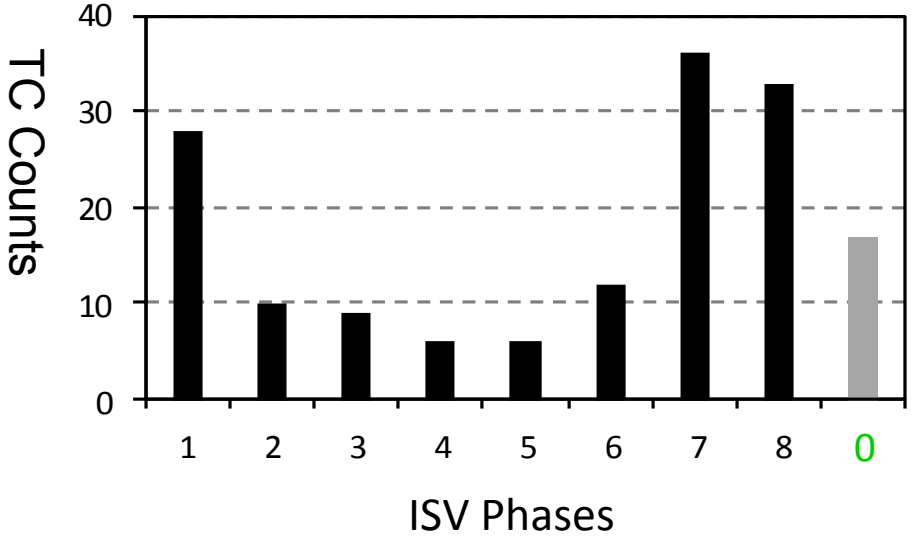
TC Genesis counts over the EPAC and ISV Phases

OBS



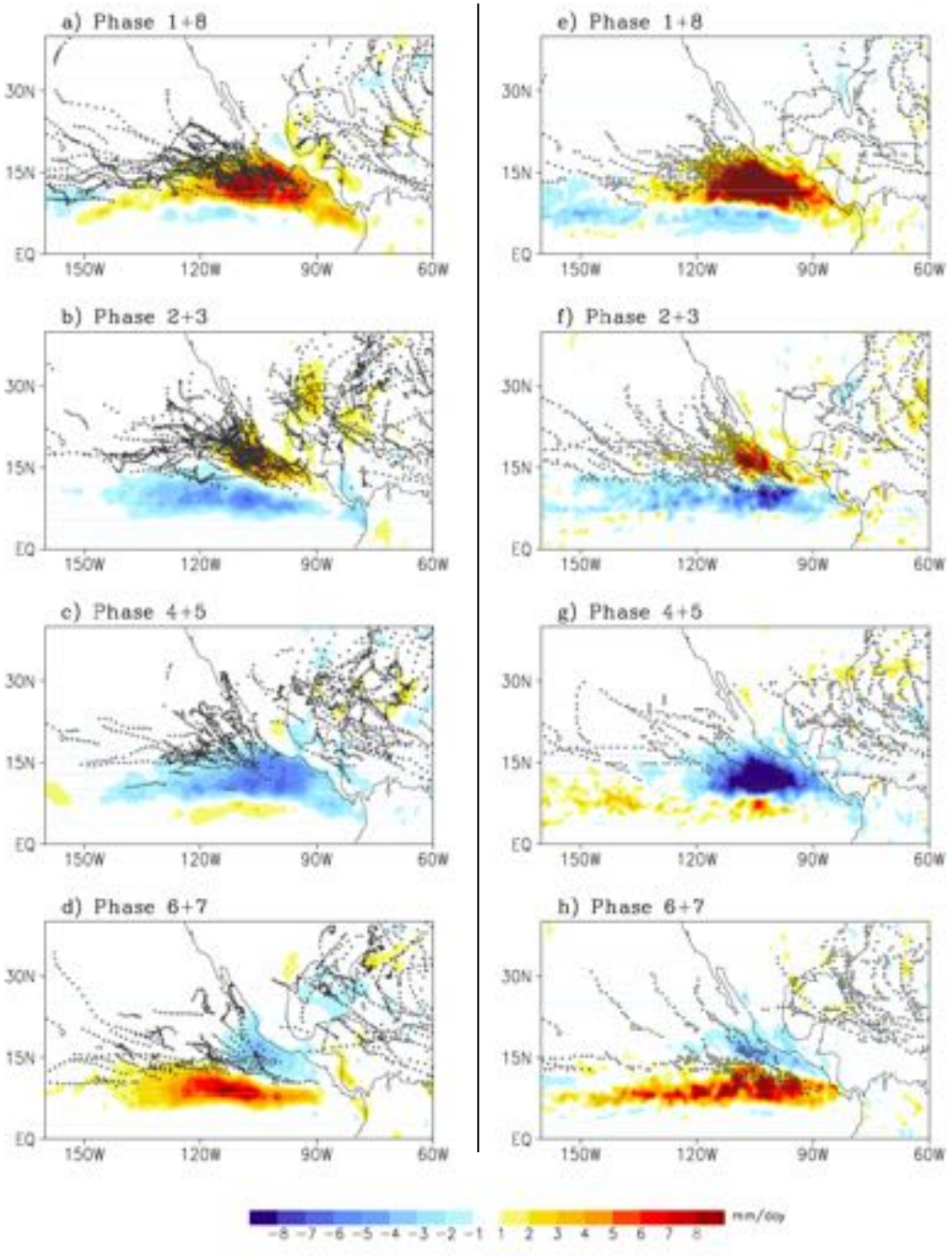
Phase 0 - Weak ISV

HiRAM



Modulation of TC movement by the ISV (1998-2008)

OBS



GFDL/HiRAM

Jiang et al. (2011b)

Genesis Potential Index (GPI)

Emanuel and Nolan (2004); Camargo et al. (2009)

$$GPI = \left|10^5 \eta\right|^{3/2} \left(\frac{\gamma}{50}\right)^3 \left(\frac{PI}{70}\right)^3 (1 + 0.1 \cdot V_{shear})^{-2}$$

η 850mb absolute vorticity (s^{-1})

γ 600mb relative humidity (%)

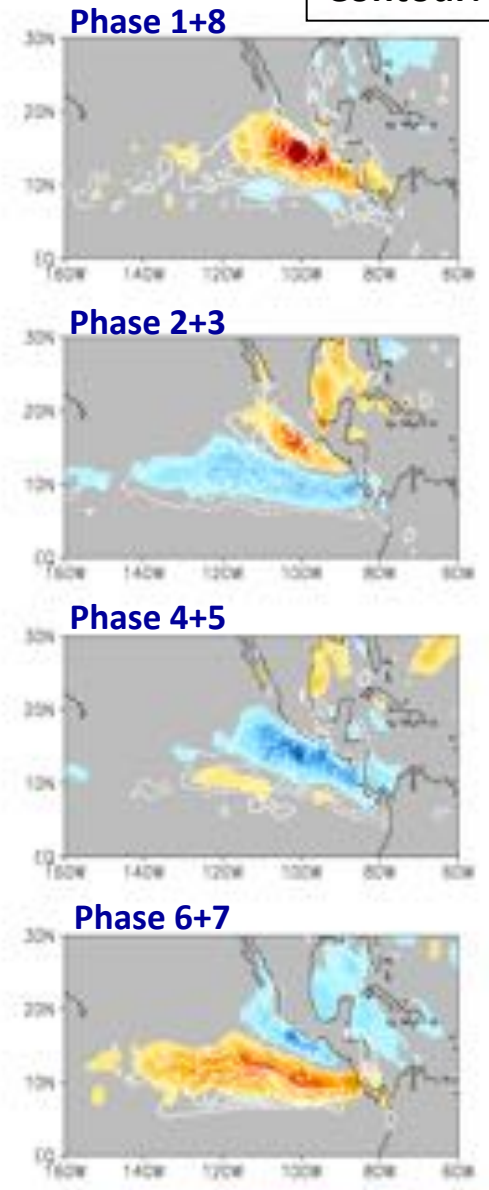
PI Maximum potential intensity (MPI) – SST, q, T, Ps

V_{shear} Vertical wind shear, 200mb-850mb (ms^{-1})

ERA-Interim 1998-2008

Jiang et al. (2011b)

Shading: GPI'
Contour: Rainfall'



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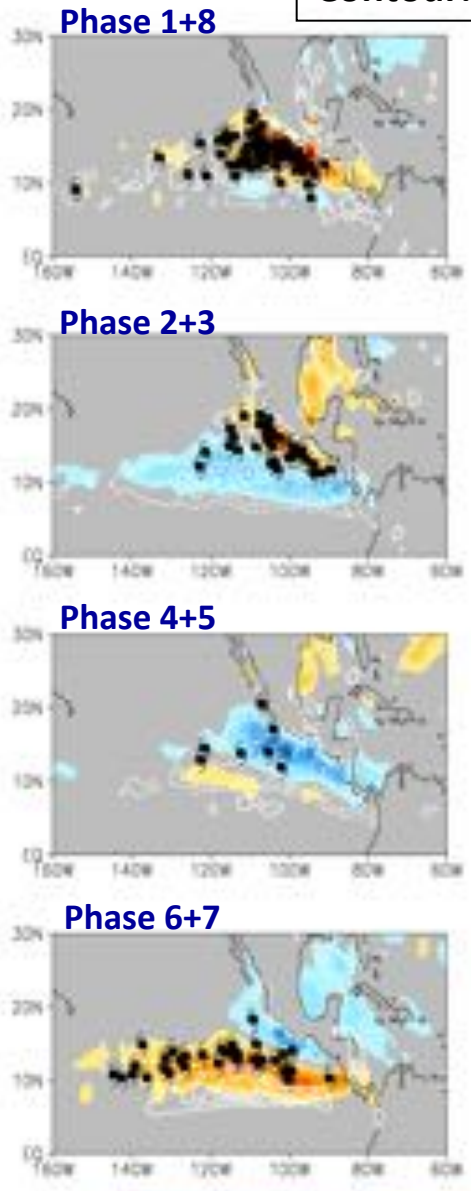
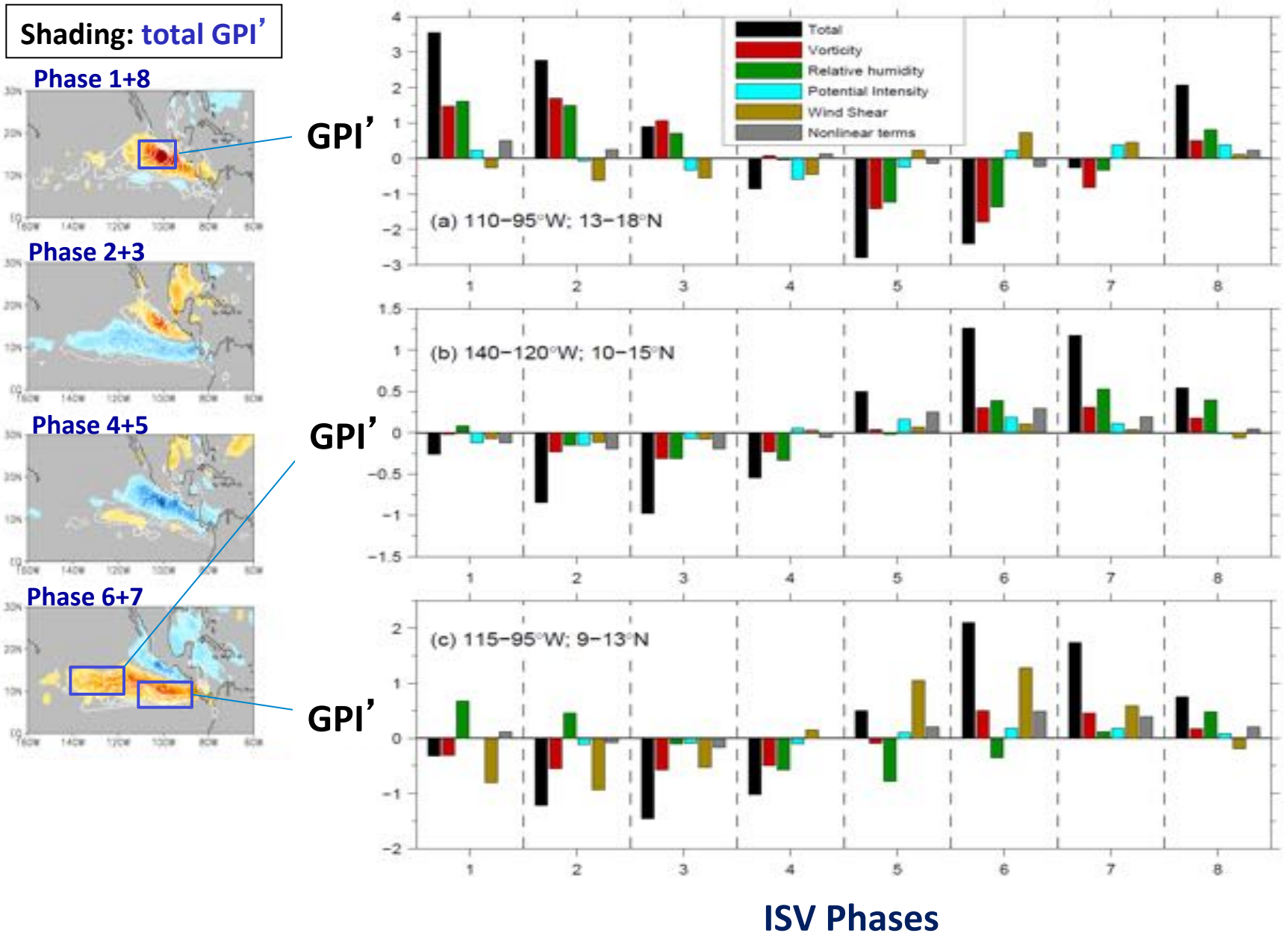


Contributing factors of total GPI'

Jiang et al. (2011b)



3. Summary

- The newly developed GFDL HiRAM GCM is able to well represent the observed modulations of TC activity over the EPAC by large-scale ISV.

- A budget analysis of the observed GPI anomalies during the ISV life cycle suggests that, relative roles of lower-level cyclonic vorticity, enhanced mid-level relative humidity, and reduced vertical wind shear in modulating TC formation over the EPAC are dependent on ISV phase and location. All of these factors can contribute to active TC genesis over the EPAC during particular ISV phases.

- The results presented in this study suggest great potential of intraseasonal TC forecasts based on high-resolution dynamical models with improved physics.

- Future Plan --- Use HiRAM to explore potential prediction skill and estimate predictability of TC-Activity on IS time scales.