Interannual and subseasonal prediction of tropical storms over the western North Paficic

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Outline

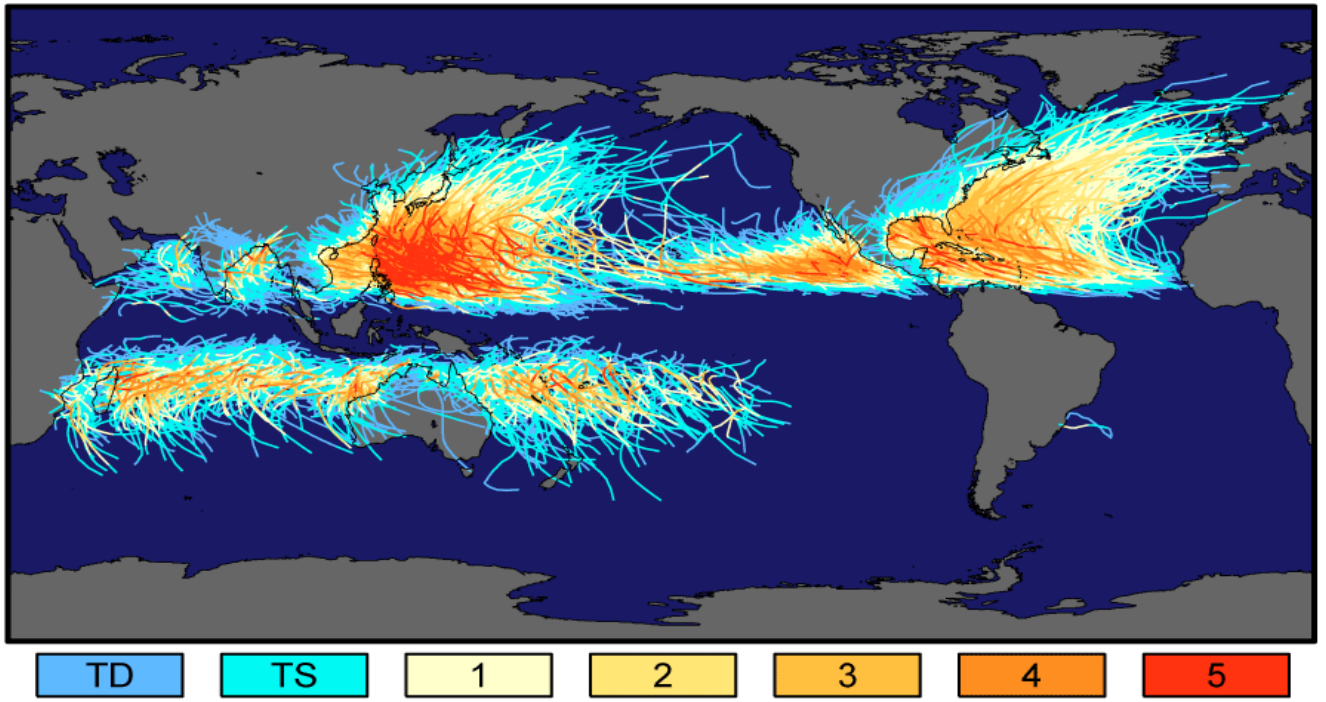
1. Tropical storm climatology

2. Impact of ENSO and MJO on tropical storms over WNP

3. Impact of ENSO and the MJO on model tropical storms

4. Tropical storm forecasting at ECMWF

Tropical cyclone climatology

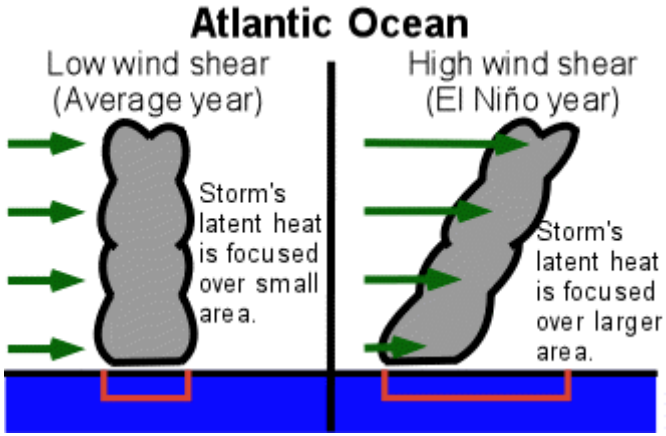


Saffir-Simpson Hurricane Intensity Scale

- **Why are tropical cyclones forming in specific locations?**
- **What explains their seasonality?**

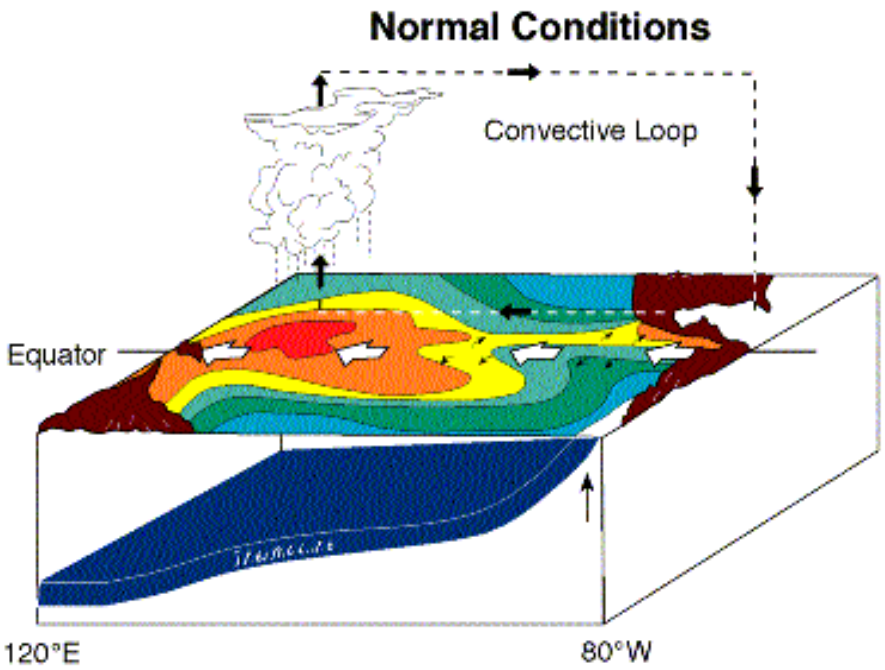
Main factors that affect tropical cyclone genesis

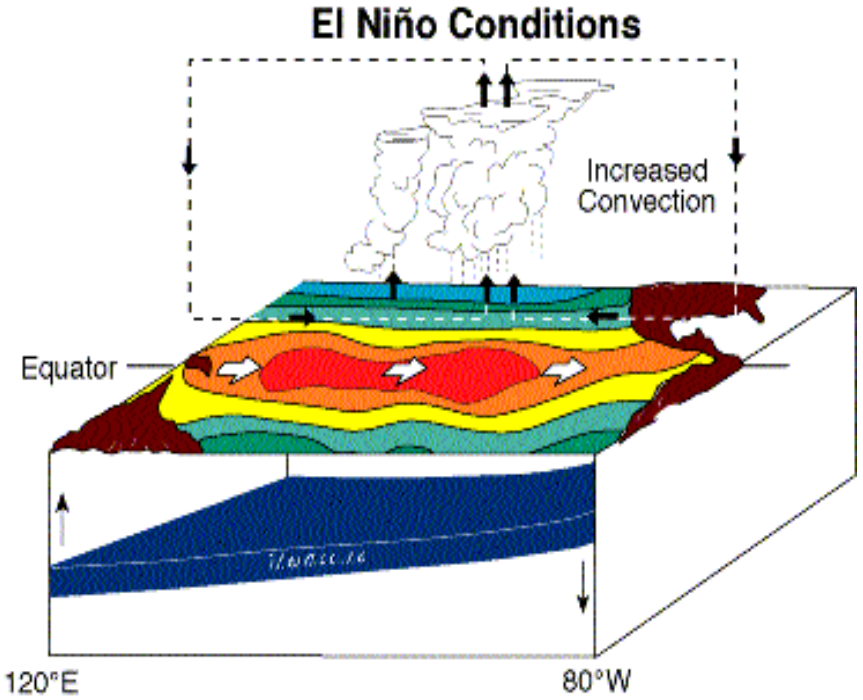
- **Sea Surface temperature** (main source of energy for tropical storms)
- **Coriolis force**
- **Vertical wind shear**



- **Low level absolute vorticity**
- **Mid-level relative humidity**

Impact of ENSO on tropical storms



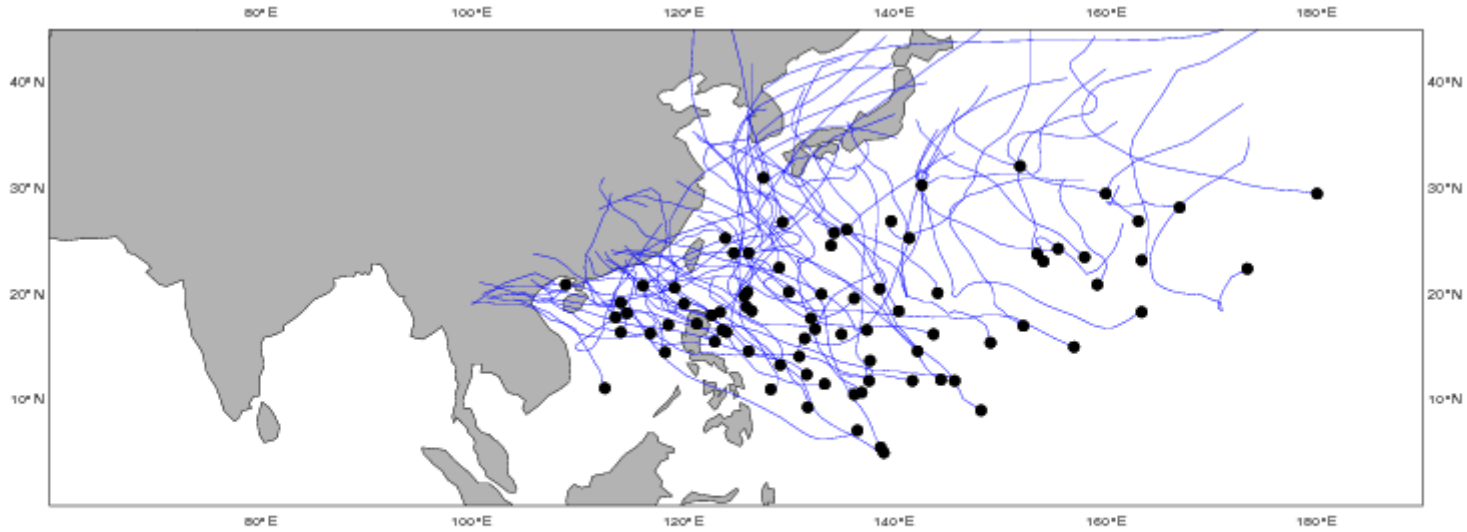


Impact of ENSO on tropical storms

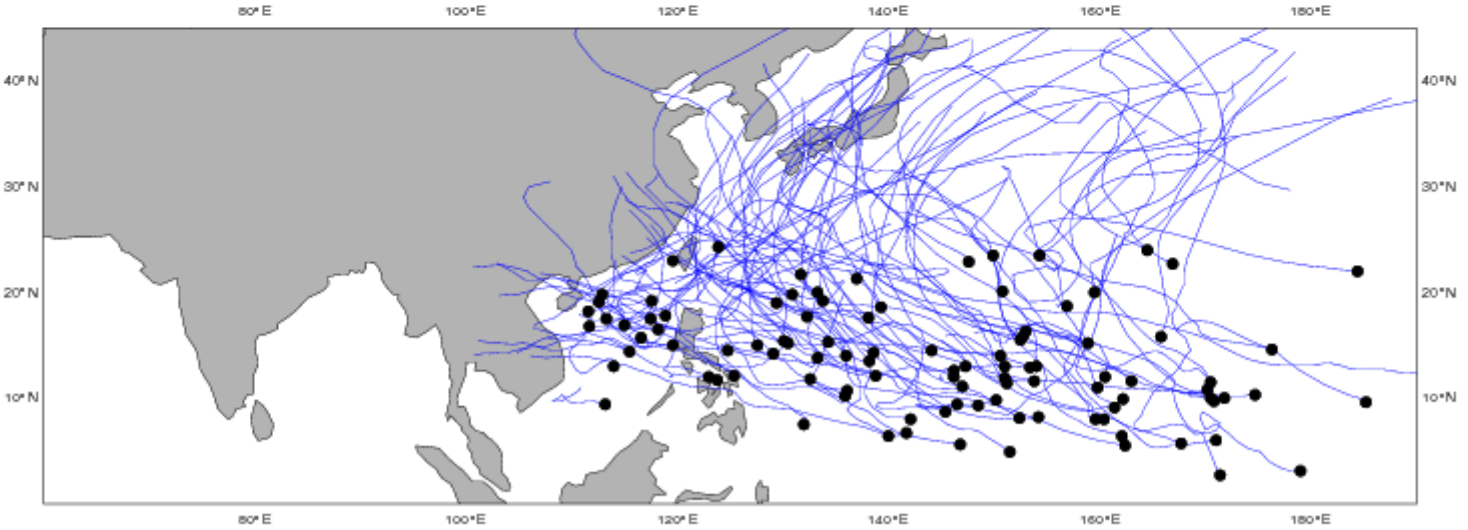
- No significant impact on the total number of WNP tropical storms
- Significant impact on the genesis location and the TC tracks
- Significant impact on tropical storm intensity

Impact of ENSO on TC genesis and tracks

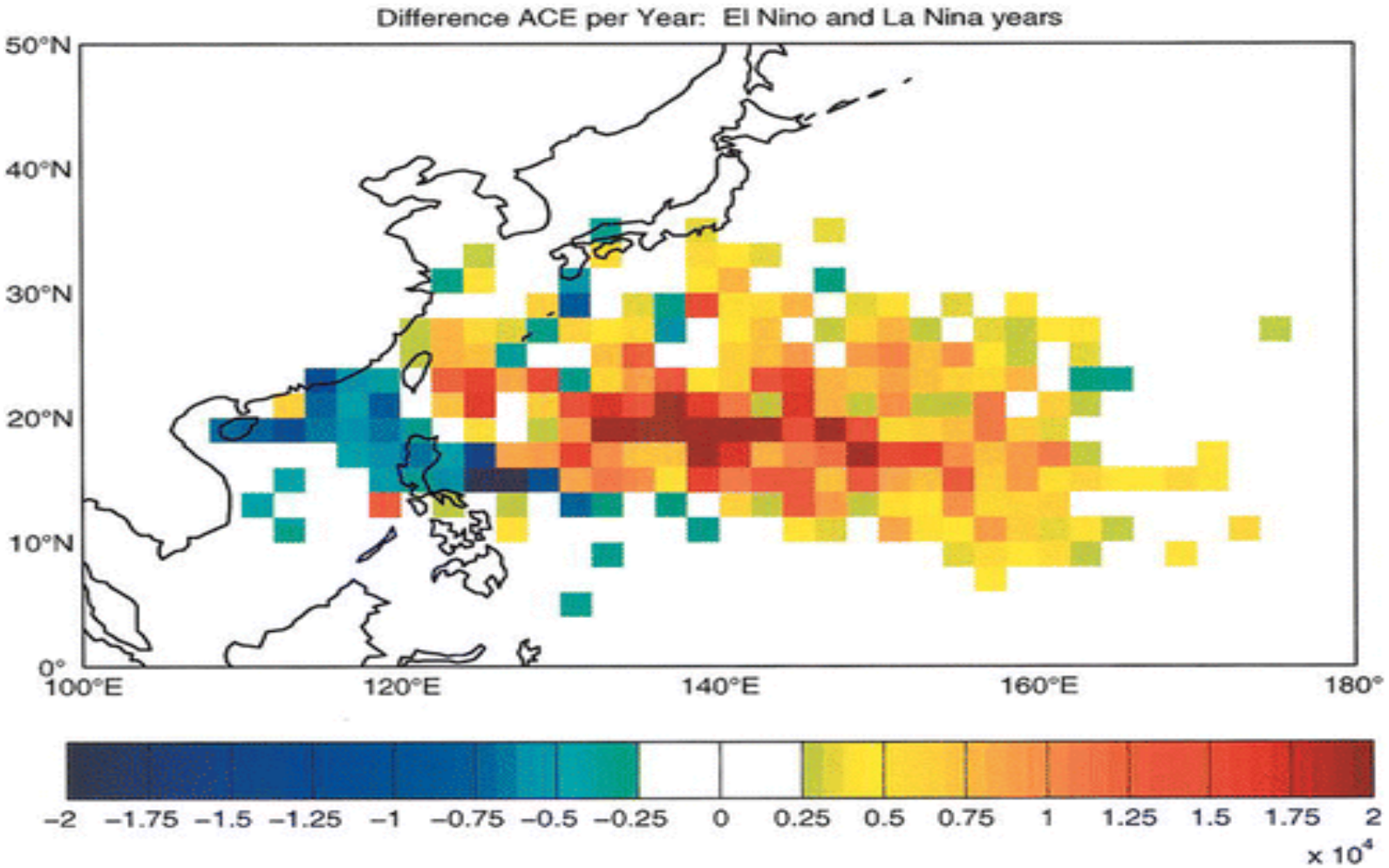
La-Niňa



El-Niño



Impact of ENSO on Accumulated Cyclone Energy



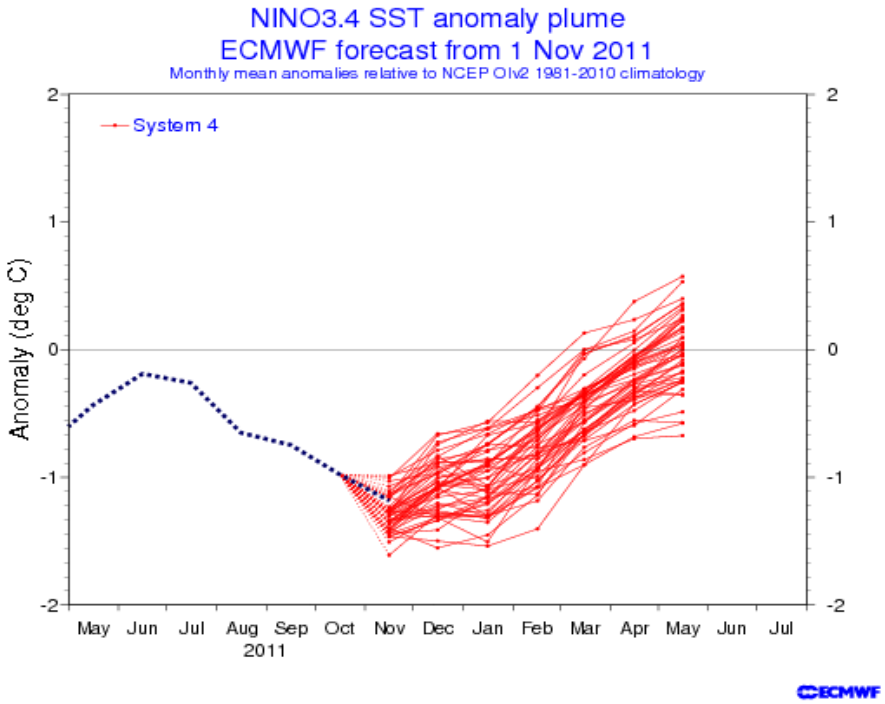
$$\mathrm{ACE} = 10^{-4} \sum v_{\max}^2$$

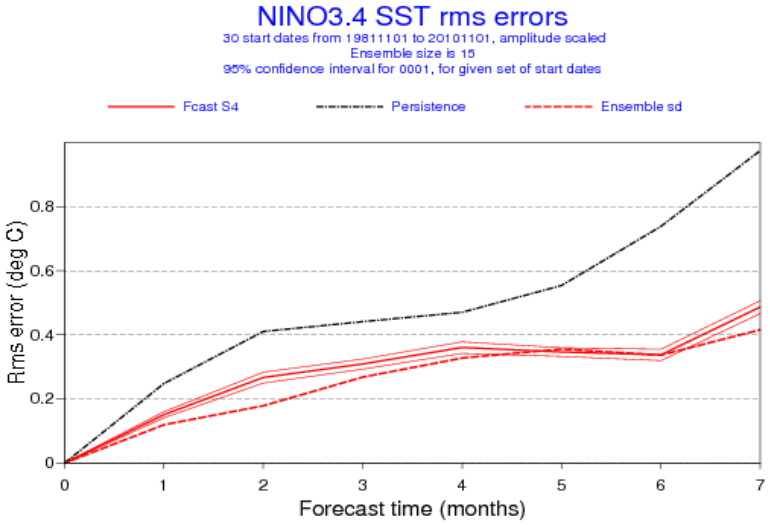
Camargo et al, 2005

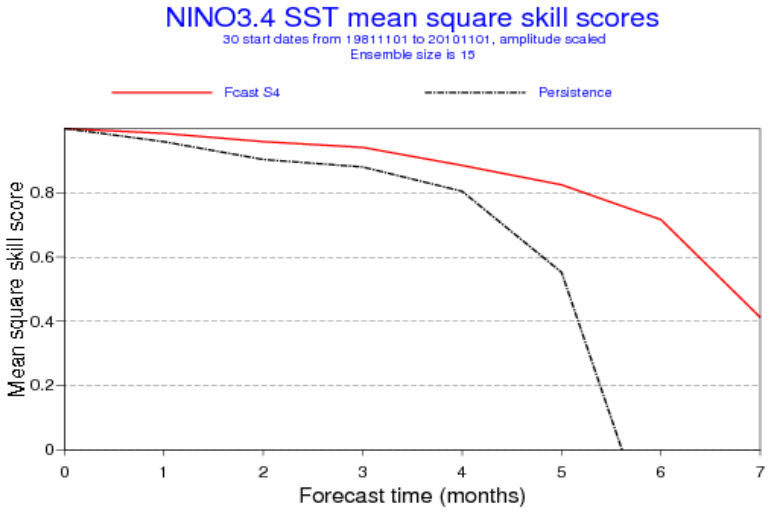
ECMWF System 4: main features

- **Operational forecasts**
  - 51-member ensemble from 1st day of the month
  - released on the 8th
  - 7-month integration
- **Re-forecast set**
  - 30 years, start dates from 1 Jan 1981 to 1 Dec 2010
  - 15-member ensembles, 7-month integrations
  - 13-month extension from 1st Feb/May/Aug/Nov
- Experimental ENSO outlook
  - 13-month extension from 1st Feb/May/Aug/Nov
  - 15-member ensemble

ENSO Prediction with SYSTEM 4





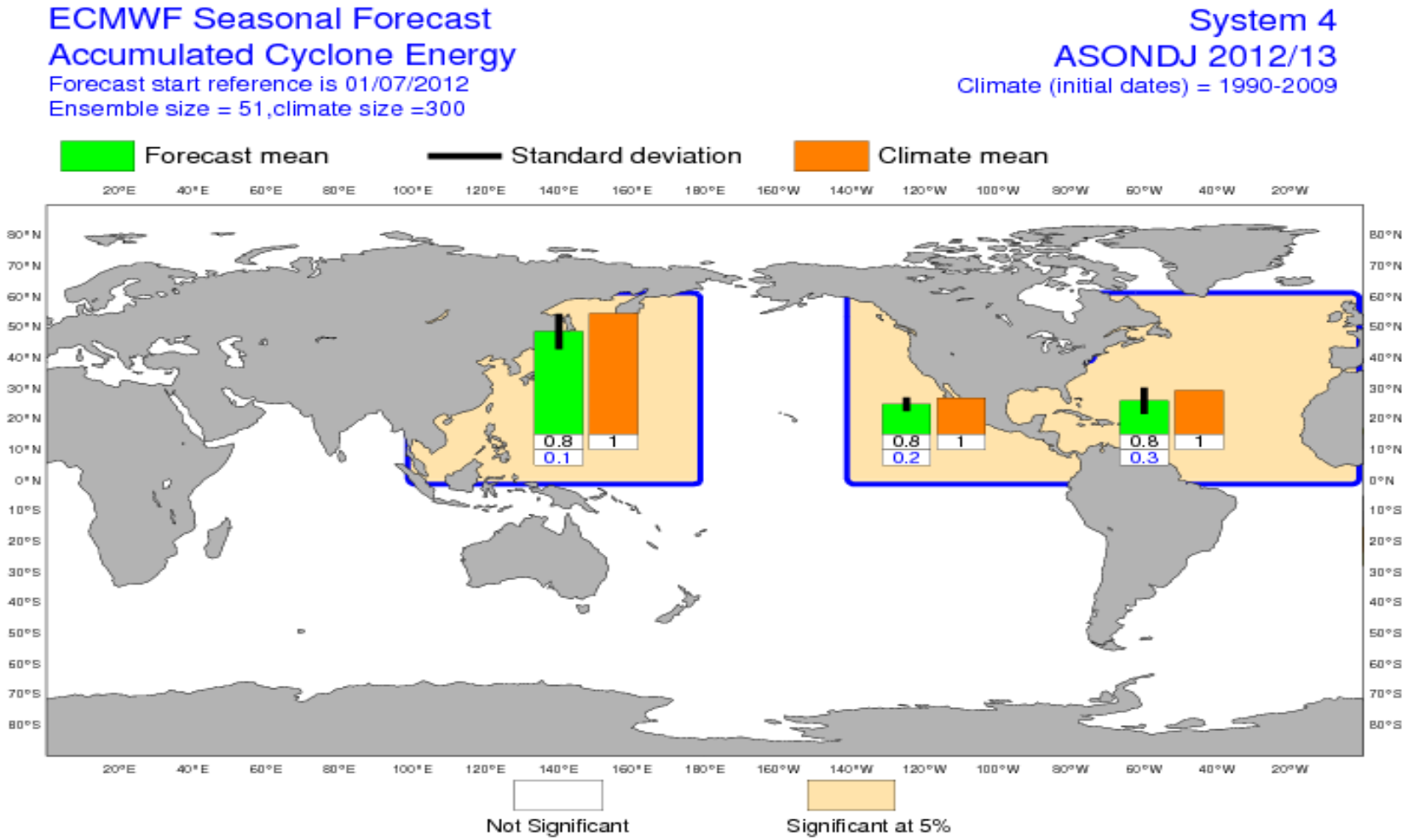


Tropical Cyclone Tracking (Vitart 1997, 2003)

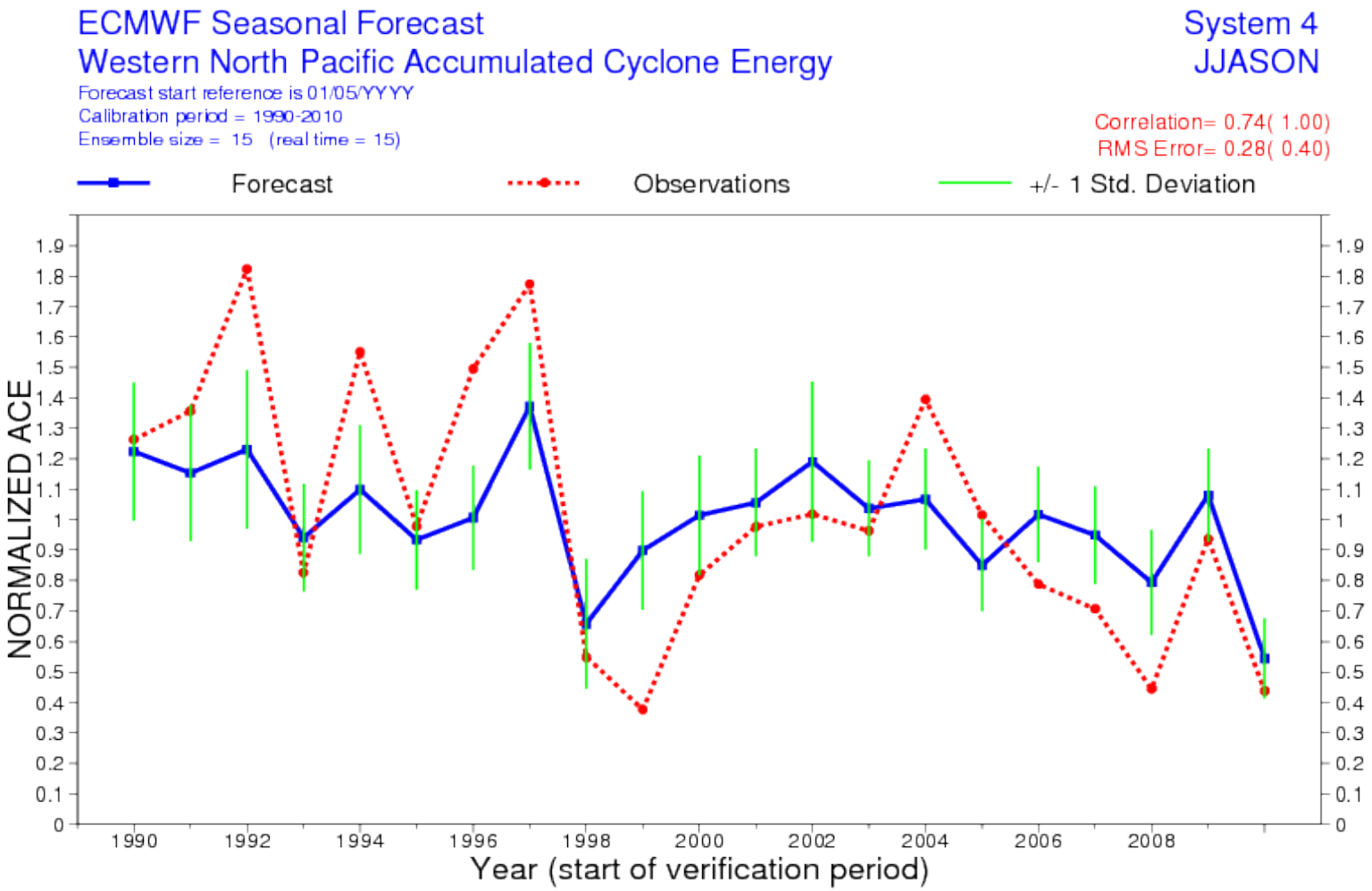
Step 1: Detection of intense vortices with a warm core for each time step:

- A local maximum of vorticity larger than 3.5 10^{-5} s^{-1} at 850 hPa is located
- The closest minumum of sea level pressure is located and defined as the centre of the storm
- Detection of a warm core above the centre of the storms by looking for a maximum of temperature averaged between 500 and 200 mb and a maximum thickness between 1000 and 200 mb.
- **Step 2: Connect the vortices into tracks:**
- The steering wind is used to compute a first guess of where the tropical storm should be located at the next time step.
- To be a tropical storm, the warm core criteria of step 1 have to be all verified at least twice. The maximum wind velocity at 10m should exceed 17 m/s. Criteria are resolution dependant.

Tropical Storm Seasonal Prediction



Tropical Storm Seasonal Prediction

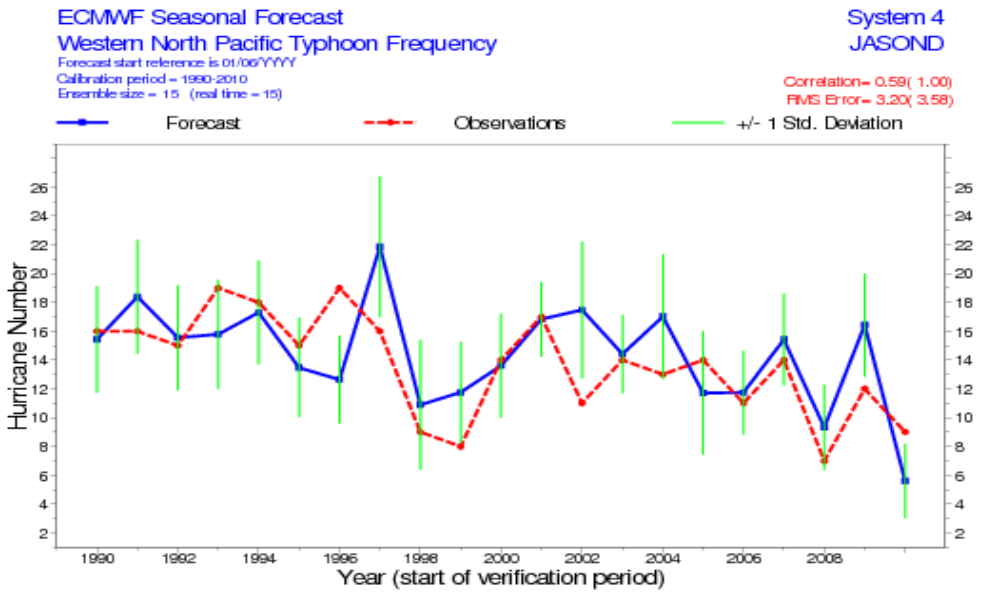


NINO 3.4 correlation:

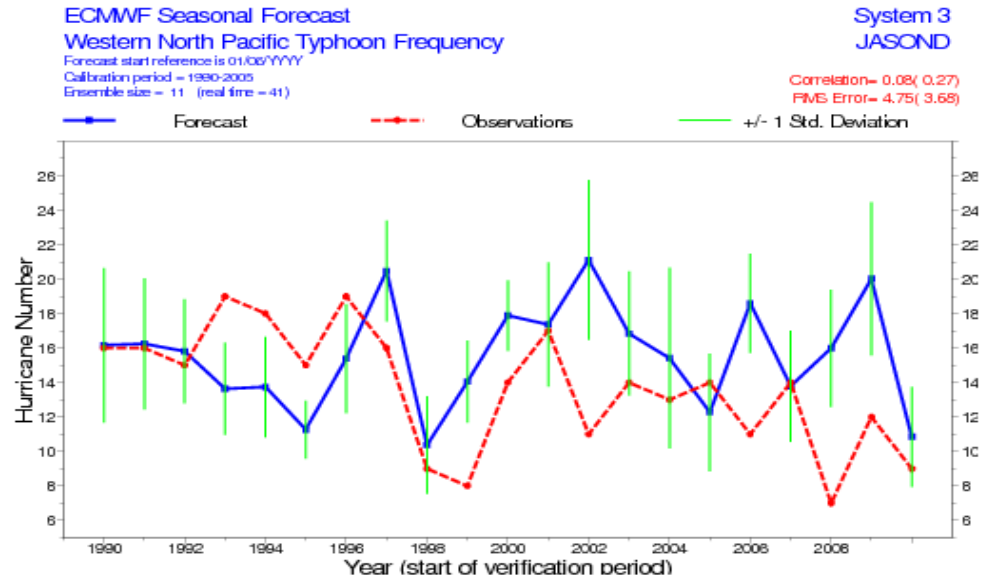
0.63

0.67

Prediction of tropical cyclone frequency: NW Pacific



System 4 vs. Obs.

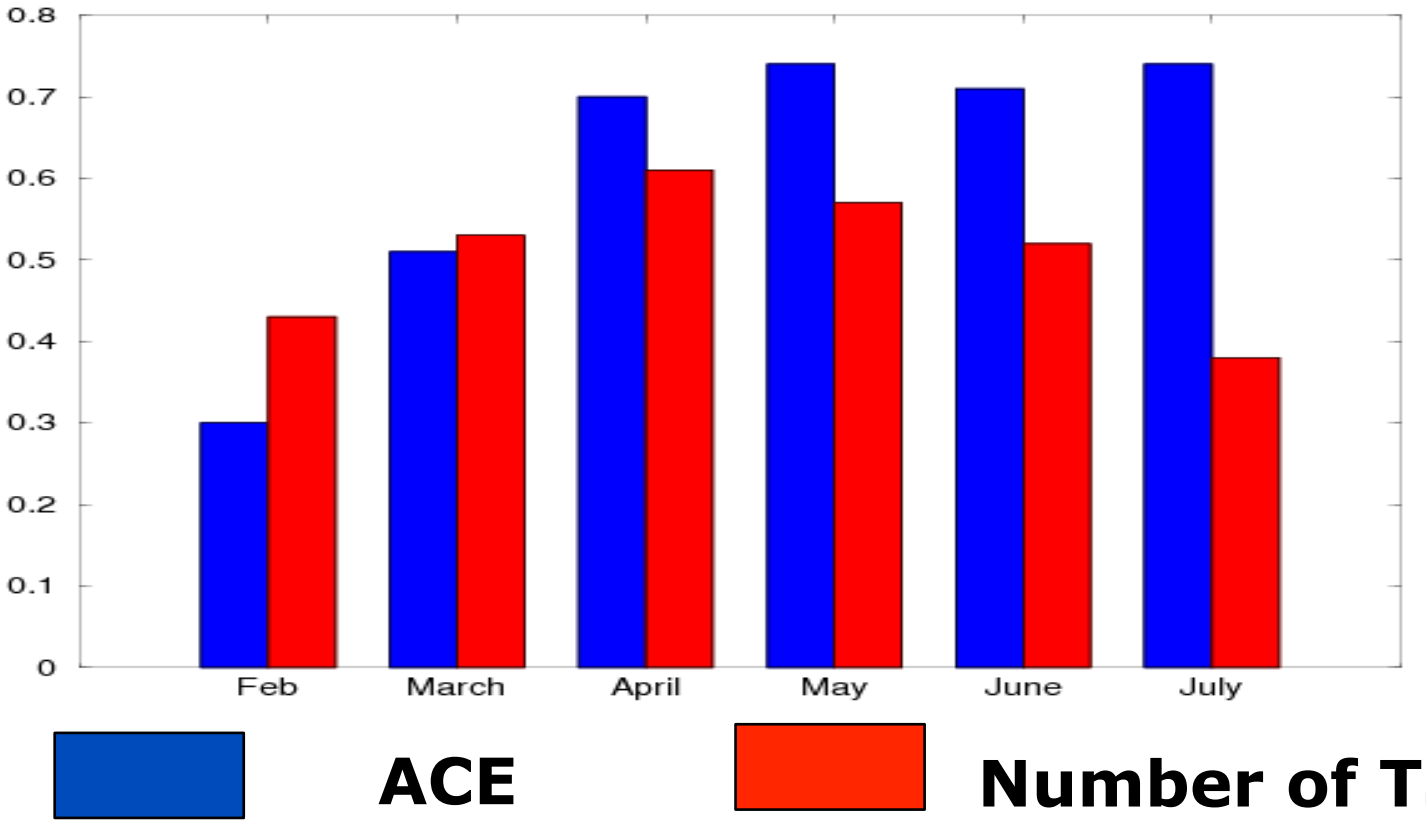


July-Dec. 1990-2010

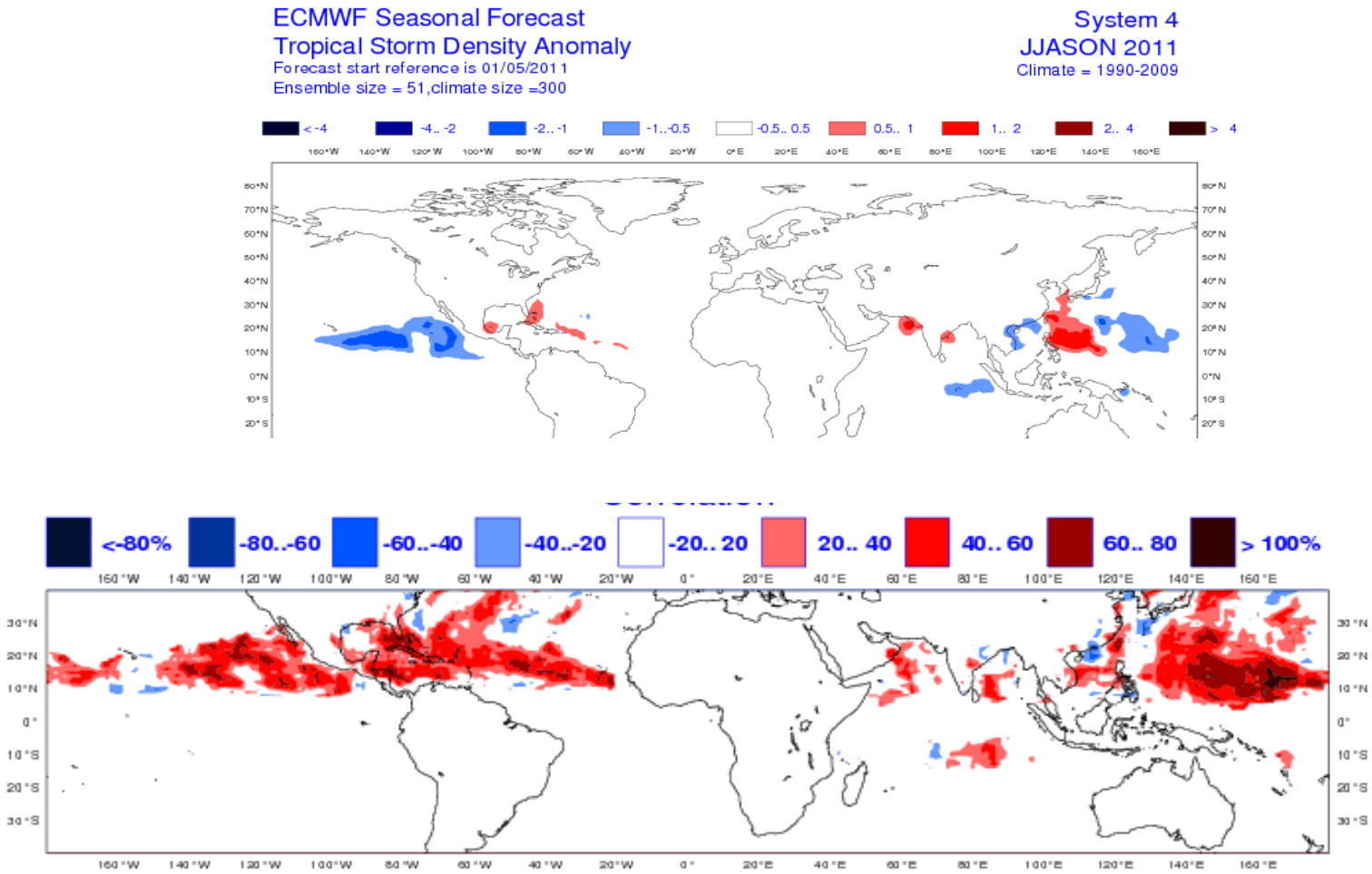
System 3 vs. Obs.

Tropical Storm Seasonal Prediction

Correlation between SYSTEM 4 and observed interannual variability
of ACE and nTS over the WNP
1990-2010
Forecast range: month2-7



Cyclone track density new product from S4 and its verificatior



Track density for the July-Dec. period from fc. started on 1 May 1990-2010

Impact of the MJO on Tropical cyclones

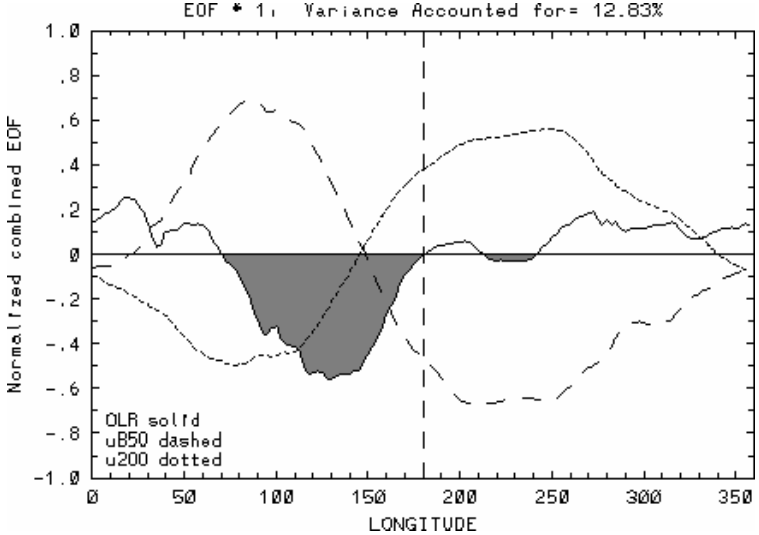
Observational studies

- **Western North Pacific**: Nakazawa (1988), Liebmann et al (1994)
- **Eastern North Pacific:** Molinari et al, (1997); Maloney and Hartmann (200)
- **Gulf of Mexico:** Maloney and Hartmann (2000< Mo (2002)
- **South Indian Ocean:** Bessafi and Wheeler (2006), Ho et al (2006)
- **Australian region:** Hall et al (2001)

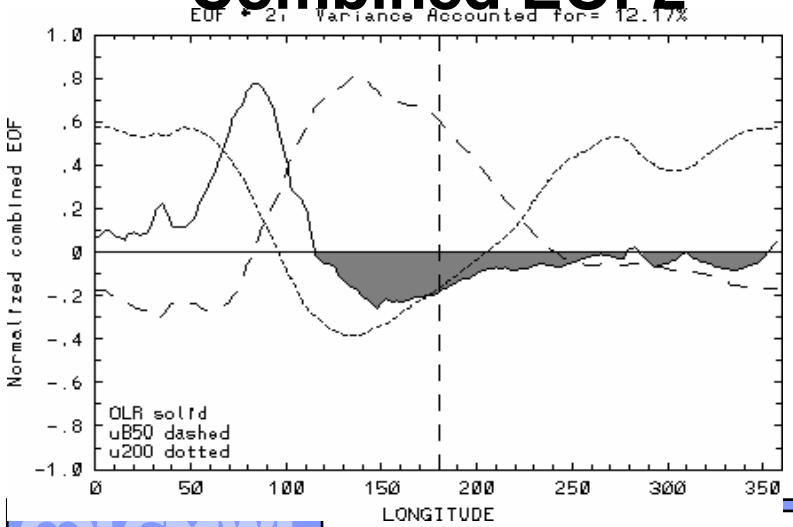
- Impact on tropical cyclone genesis index: Camargo et al (2009)

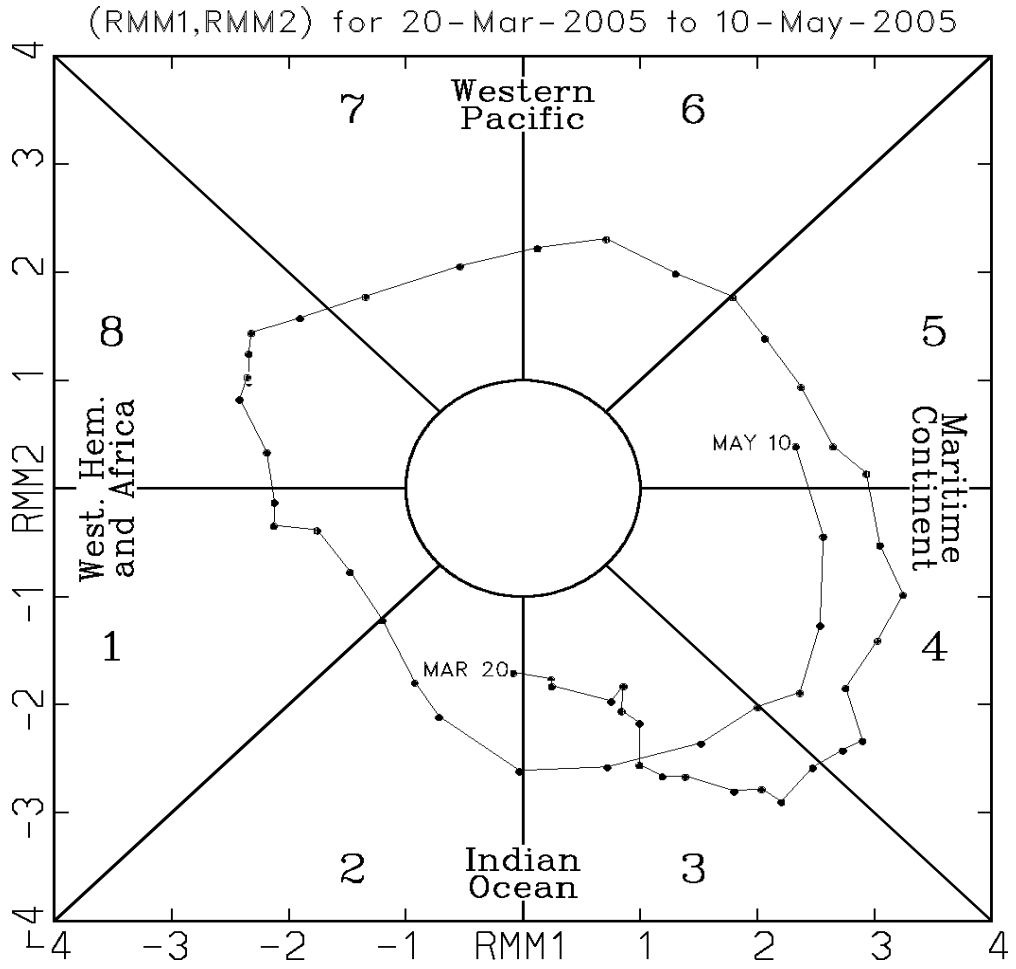
MJO Diagnostics
Wheeler and Hendon (2004) Index

Combined EOF1



Combined EOF2

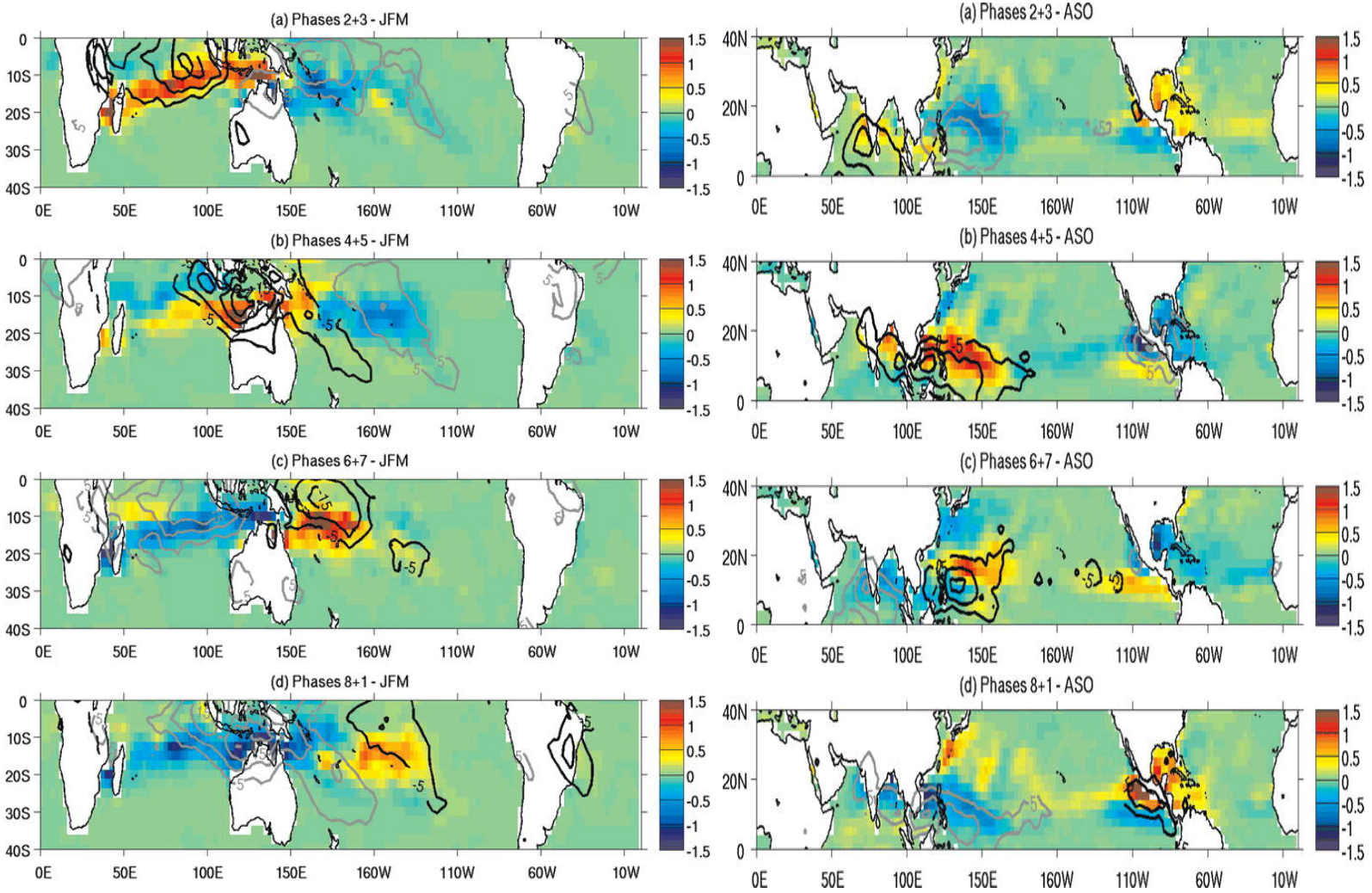




Wheeler and Hendon (2004

Impact of the MJO on TC activity

JFM **ASO**



Main contributions:

1) **Mid-level relative humidity**

2) **Low-level absolute vorticity**

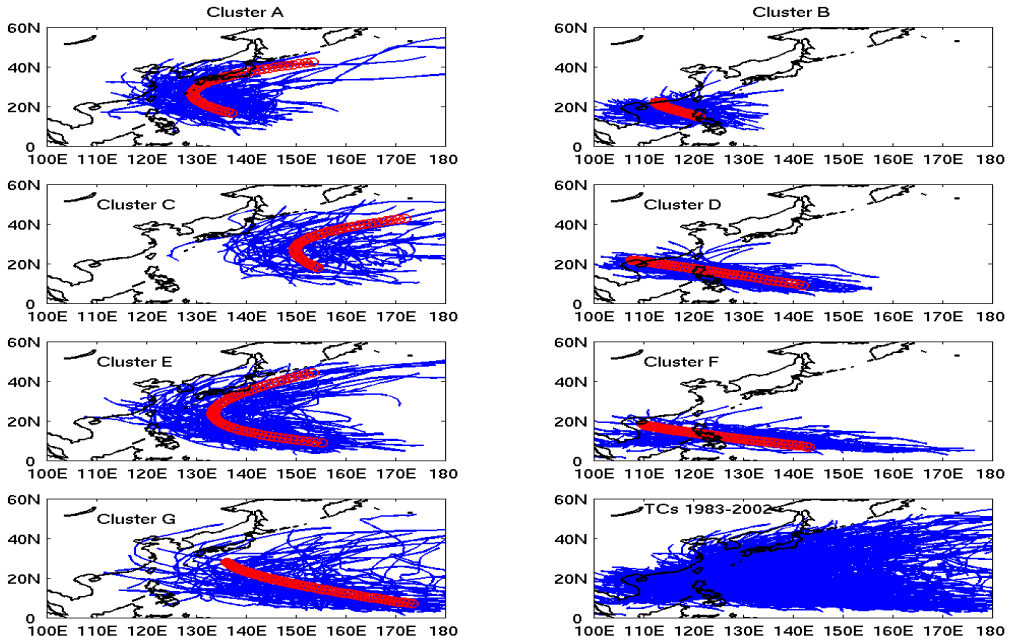
3) **Vertical wind shear and potential intensity**

Camargo, Wheeler, and Sobel, *J. Atmos. Sci.* (2009)

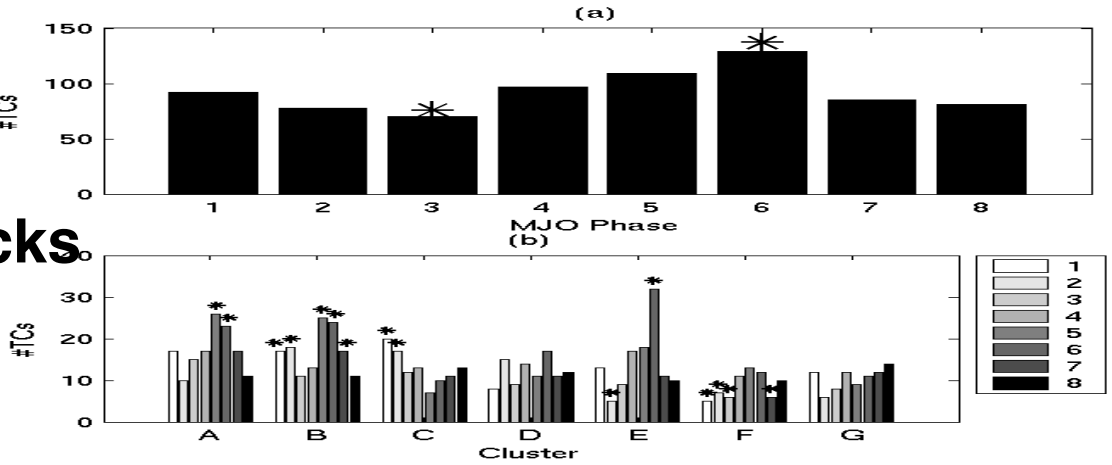
Impact of the MJO on TC tracks

Cluster Analysis of Western North Pacific Tropical cyclone tracks

Camargo, Robertson, Gaffney, Smyth and Ghil, Part I & Part II, J. Climate (2007)



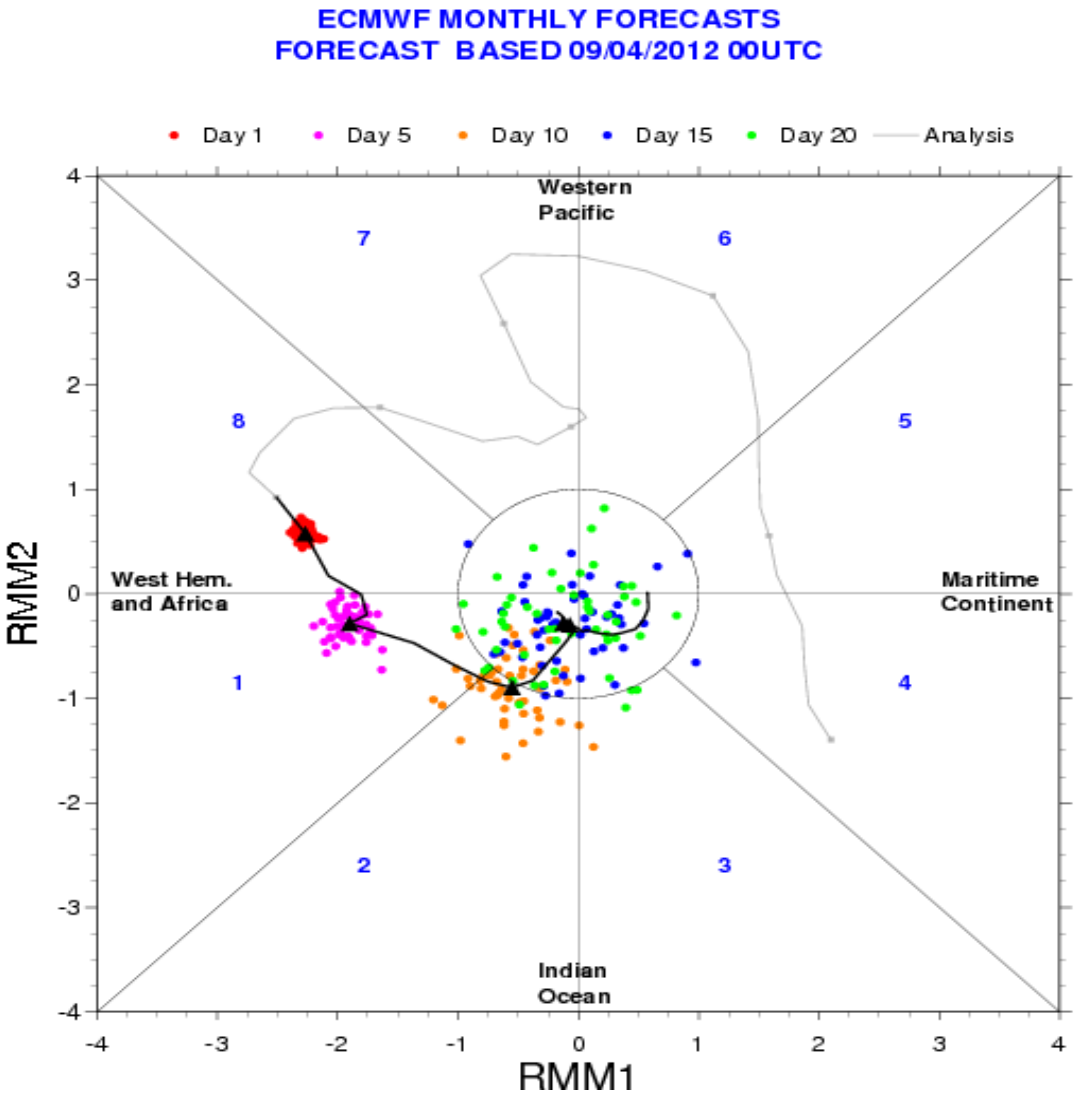
MJO modulation of TC tracks



The ECMWF monthly forecasting system

- A 51-member ensemble is integrated for 32 days twice a week (Mondays and Thursdays at 00Z)
- Atmospheric component: IFS with the latest operational cycle and with a T639L62 resolution till day 10 and T319L62 after day 10.
- Persisted SST anomalies till day 10 and ocean-atmosphere coupling from day 10 till day 32.
- Oceanic component: NEMO with a zonal resolution of 1 degree resolution
- Coupling: OASIS (CERFACS). Coupling every 3 hours.

MJO Forecasts

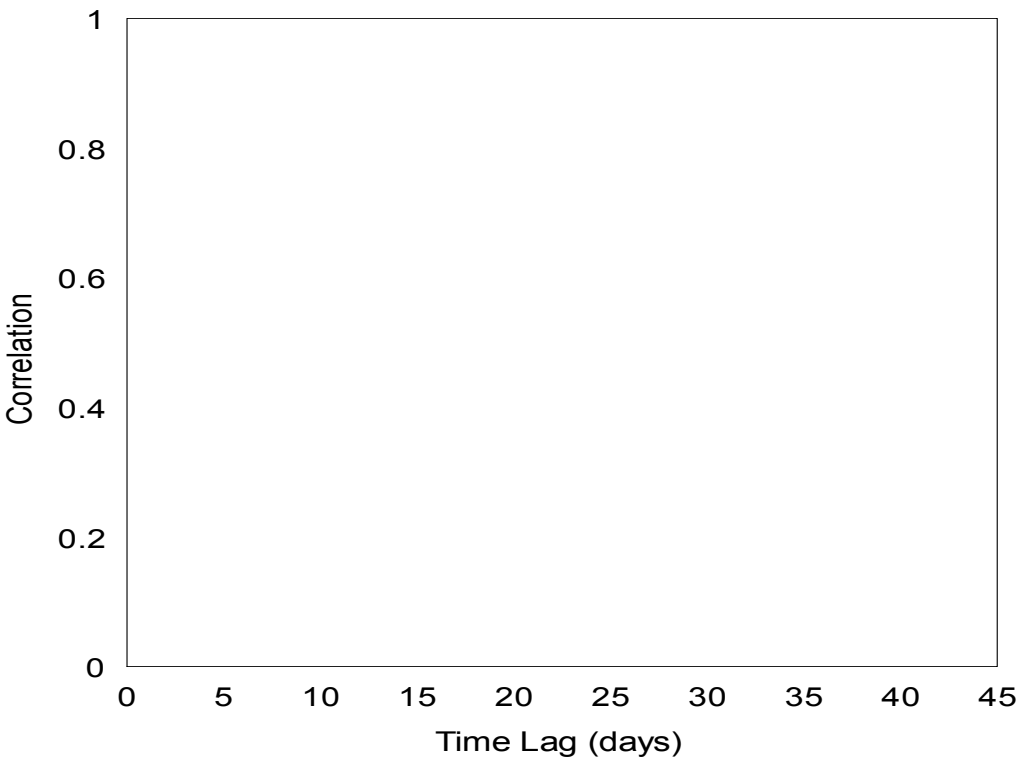


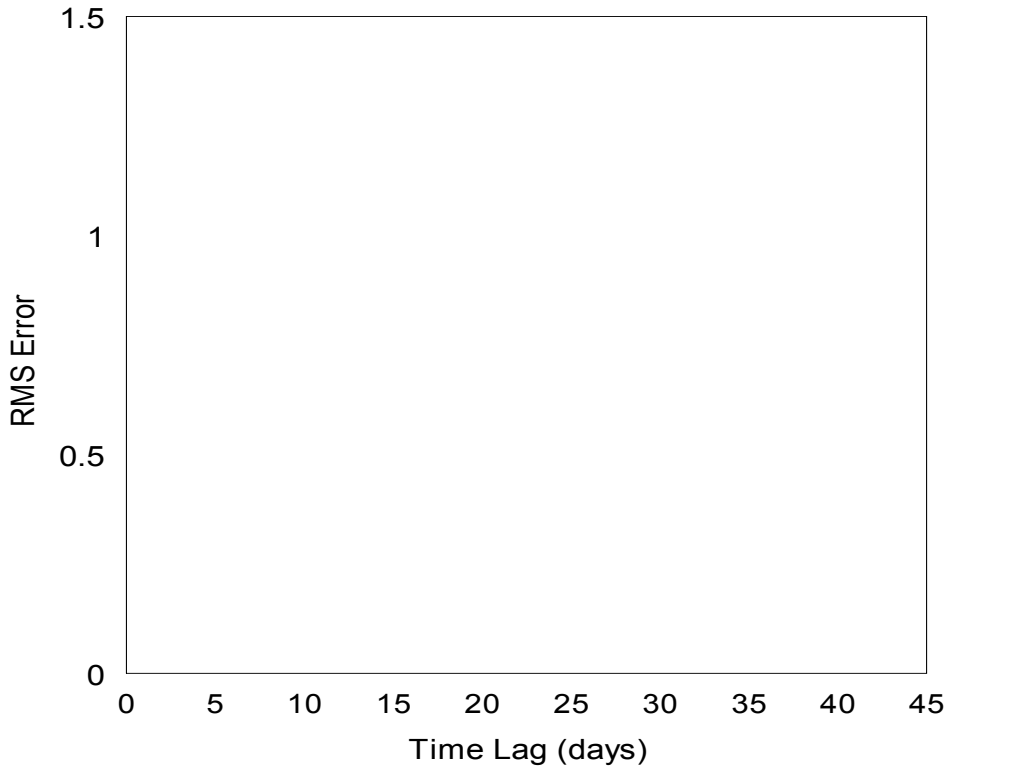
Subseasonal reforecast experiment

Experiment's setting:

- 46 day forecasts at T255L62 coupled to HOPE
- 15 members
- Starting dates: 15 Nov/Dec/Jan/Feb/Mar/Apr 1989-2008
- Model Cycle 32R3 (operational cycle from 11/07 to 06/08)

MJO Skill scores





Ensemble mean/ reanalysis

"Perfect Model"

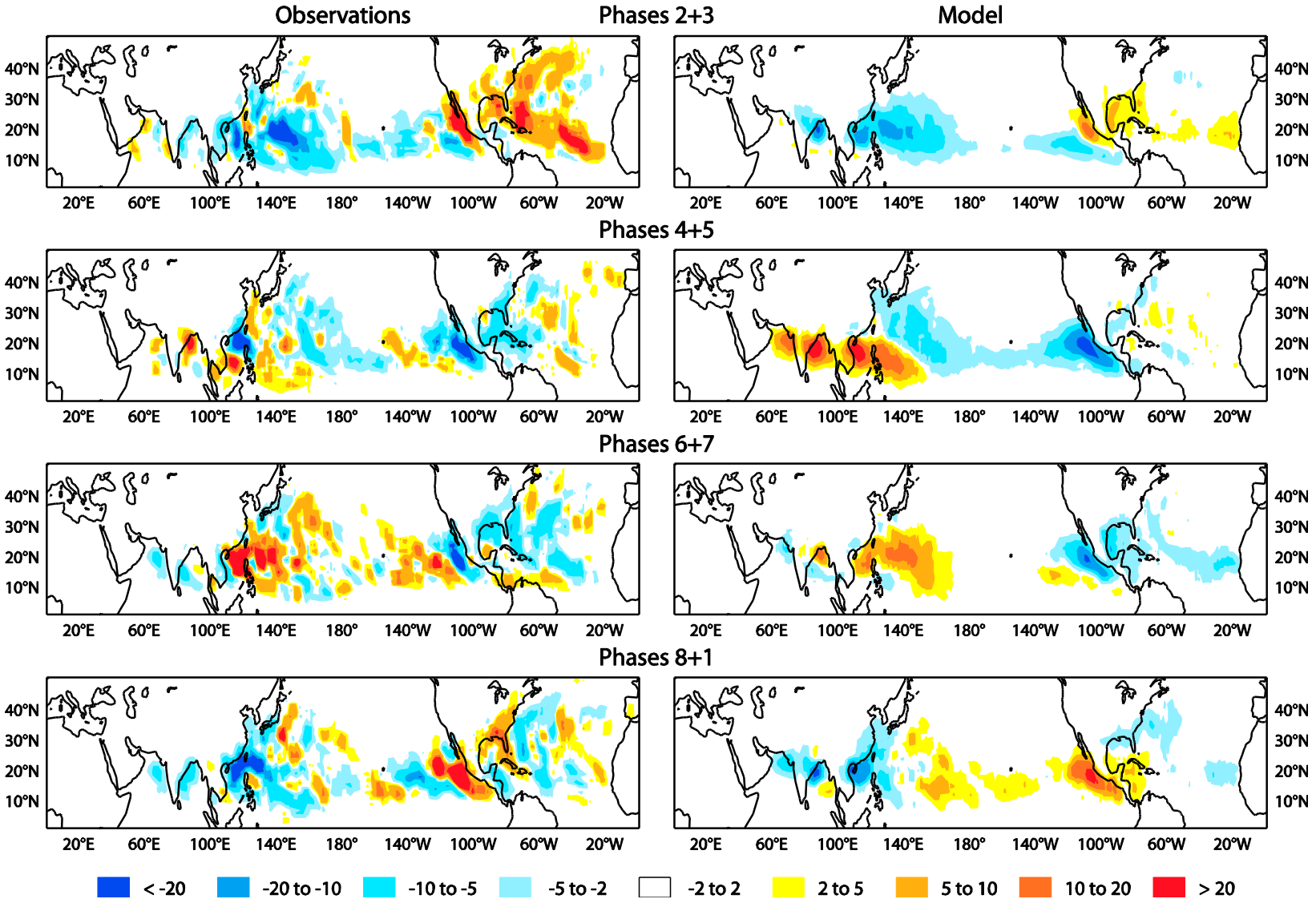
Ensemble mean/ reanalysis

Ensemble Spread

Climatology

MJO Composite- ASO

Tropical storm density anomaly

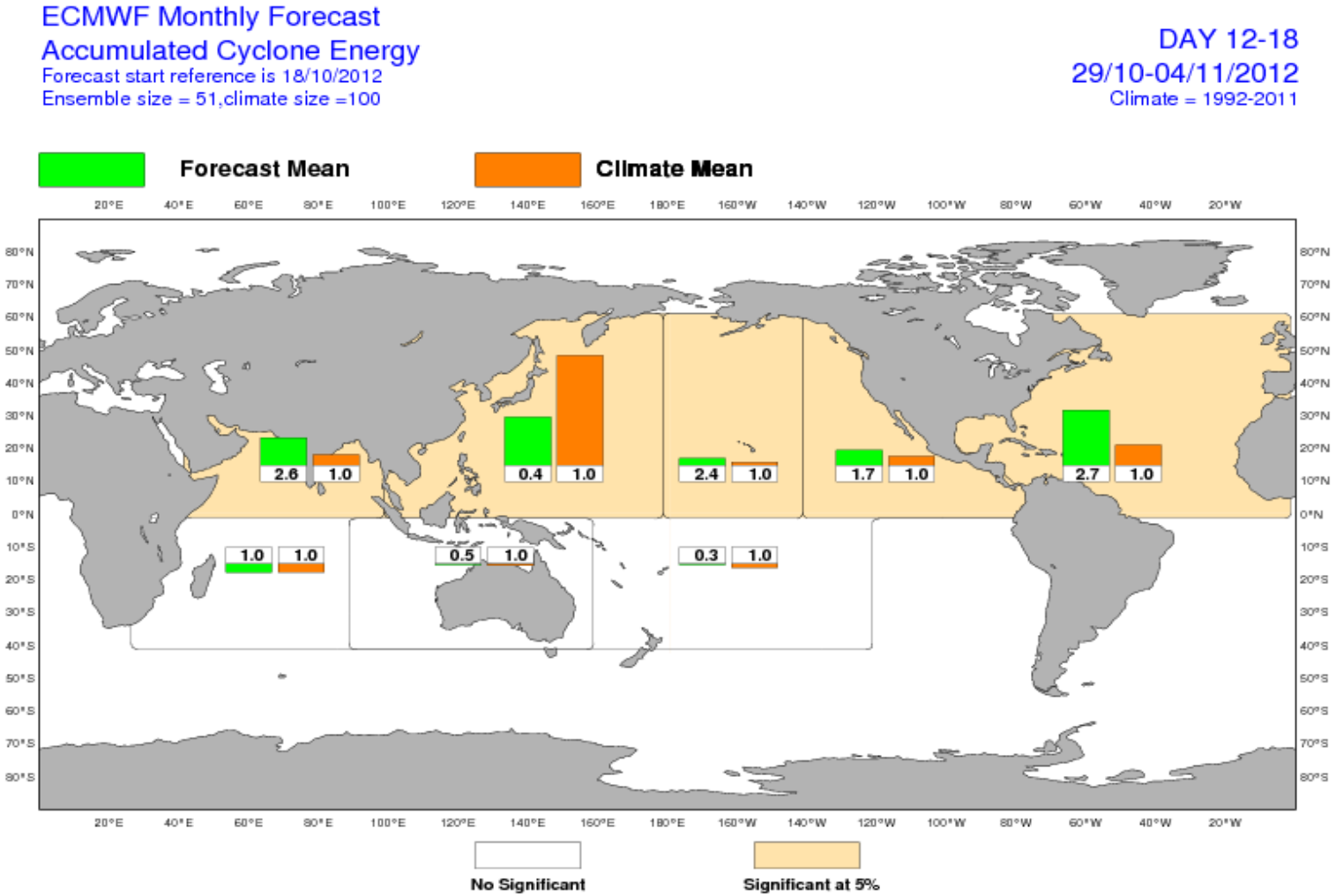


Impact of the MJO on ACE

Accumulated Cyclone Energy (ACE)

	ATL *ASO*	ENP *ASO*	WNP ASO	NIN *ASO*	SIN *NDJFMA*	AUS *NDJFMA*	SPC *NDJFMA*
Phase 2+3	**+25%**	-	-34%	-17%	**+31%**	-39%	-19%
Phase 4+5	-	-52%	-	**+43%**	**+53%**	**+30%**	-45%
Phase 6+7	-20%	-17%	**+37%**	-	-31%	**+44%**	**+22%**
Phase 8+1	-	**+58%**	-	-25%	-46%	-33%	**+39%**

Subseasonal prediction OF TC activity at ECMWF



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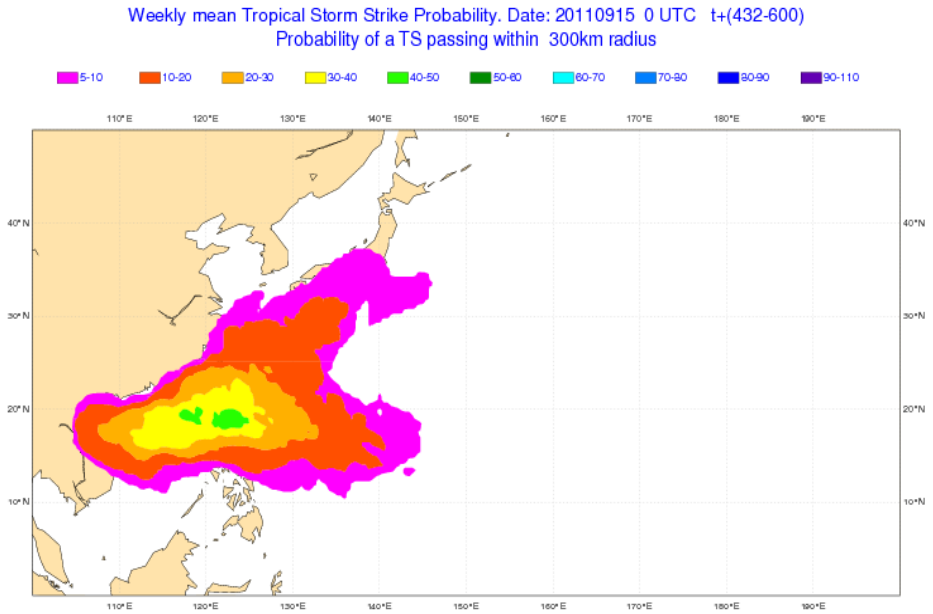
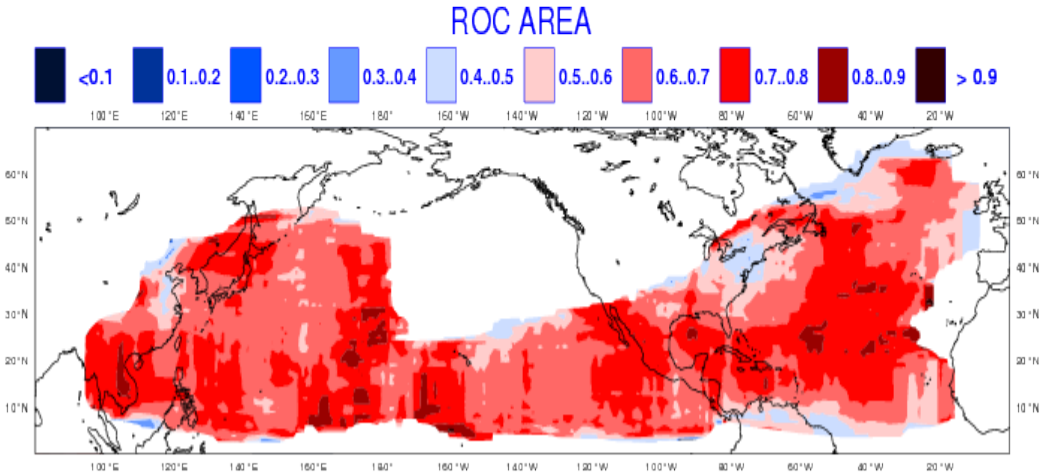


Verification – ASO
Day 12-18



Conclusion

- ENSO has a significant impact on tropical storm location, tracks and intensity, but not on the number of tropical cyclones.
- The MJO modulates the frequency and the tracks of tropical storms over the WNP.
- Sub-seasonal and seasonal forecasting systems display significant skill in predicting ENSO and the MJO.
- Sub-seasonal and seasonal predictions of tropical storm activity over WNP are currently operational at ECMWF.