

# **Application of a Hybrid Dynamical-Statistical Model for Week 3 and 4 Forecast of Atlantic/Pacific Tropical Storm and Hurricane Activity**

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# Project Objective

1. Develop a hybrid dynamical-statistical model for weeks 3 and 4 TS and hurricane activity forecast with the CFSv2 45-day hindcast data for 1999-2014.  
A hybrid prediction system for seasonal TS activity has been in operation at CPC since 2009 for the NOAA Hurricane Season Outlooks.
2. Test the hybrid model for real-time prediction for 2016 hurricane season.
3. Implement the model into operations at CPC in 2017.
4. Contribute towards CPC's effort for developing Week 3 and 4 forecast products.

# Project Accomplishments and Plan

- Year 1 Accomplishments
  1. Established a multiple regression relationship among TS activity, SST and atmospheric circulation variable indices.
  2. Developed the hybrid forecast model for weeks 3 and 4 TS activity prediction based on the CFSv2 45-day hindcast for 1999-2014, including the cross-validated evaluations.
- Year 2
  1. Real-time forecast test during the 2016 hurricane season
  2. Operational implementation at CPC for the 2017 season

# Hybrid Dynamical-Statistical Prediction System

- A Multiple regression relationship established between weekly tropical storm activity over the Atlantic/Pacific basins and predicted circulation variables.
- Tested Predictors:
  - Weekly wind shear (U200-U850), SST, mean sea level pressure, and two MJO indices
- Predictand:
  - Weekly total number of tropical storm days
- CFSv2 Hindcast data:
  - Period; 1999-2014
  - IC Months; April through November
- Hindcast evaluations performed in a cross-validation mode

Ref: Wang, H., J. E. Schemm, A. Kumar, W. Wang, L. Long, M. Chelliah, G. D. Bell, and P. Peng, 2009: A Statistical Forecast Model for Atlantic Seasonal Hurricane Activity Based on the NCEP Dynamical Seasonal Forecast., *J. Climate*, **22**, 4481–4500.

## 2. Data and methodology

### Data: 1999–2015

- CFSv2 45-day hindcasts (1999–2010) and forecasts (2011–15)
- CFSR for 1999 - 2015
- Best Track Data: Atlantic Hurricane Database, NE/NC Pacific Hurricane Database, RSMC Tokyo-Typhoon Best Track Data

### Methodology:

- The forecast model is based on the statistical relationships between observed tropical storm activity and model predicted large-scale circulation anomalies and linear regressions.
- Predictors: vertical wind shear (VWS;  $U_{200} - U_{850}$ ), sea level pressure (SLP), and two MJO indices.
- The forecast skill is cross-validated over the 1999–2014 period.

# Observational Analysis

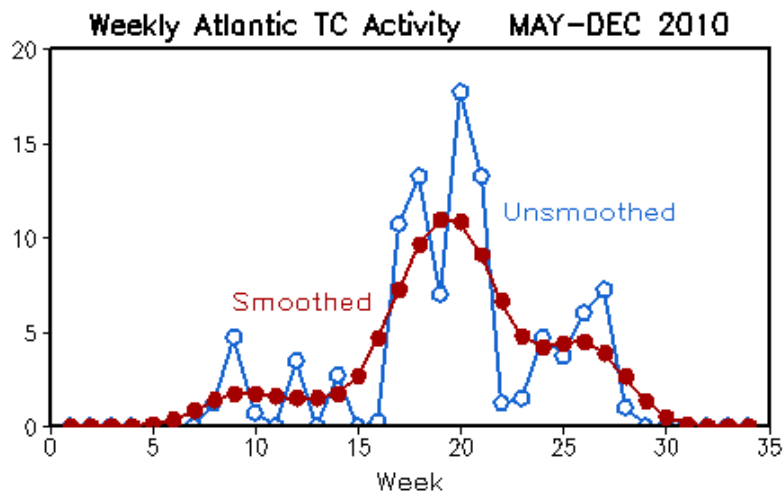
- Correlation between weekly TC activity and corresponding weekly SST/atmospheric circulation fields
- Weekly mean data: 7-day average from Sunday to Saturday
- Total 31 weeks from May to December
- Weekly SST: NOAA OISST v2
- Atmospheric fields (CFSR): vertical wind shear U200–U850, 500-mb height and relative humidity, sea level pressure
- Weekly TC activity: sum of the days of each TC over the 7-day period
- Relationship between Weekly TC activity and the MJO phase

A similar correlation analysis will be performed using the observed weekly TC activity and the SST/circulation from the CFSv2 45-day hindcasts. The regions of high correlations are used to make up for area-averaged indices as potential predictors.

# Correlation between Weekly SST and Weekly TC Activity

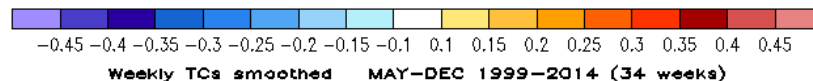
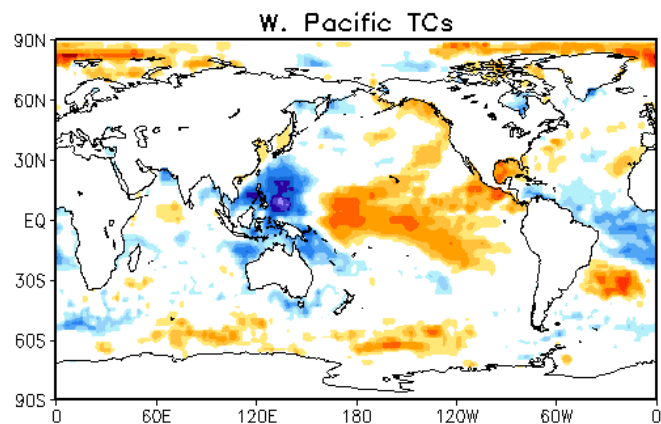
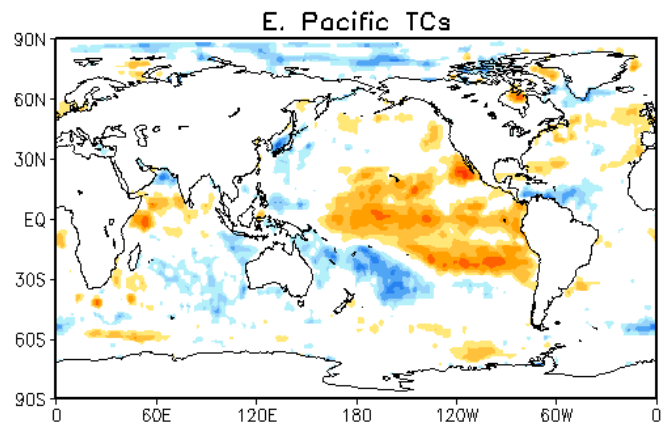
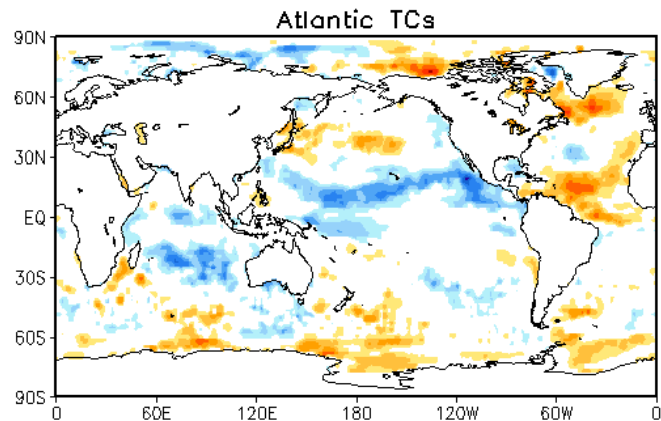
## Weekly TC activity smoothed

Example of Atlantic weekly TC activity  
**Smoothed** vs. **Unsmoothed**



Color shadings (correlation > 0.1):  
 Above the 95% significance level

Correlation (Weekly SST, Weekly TC Activity)



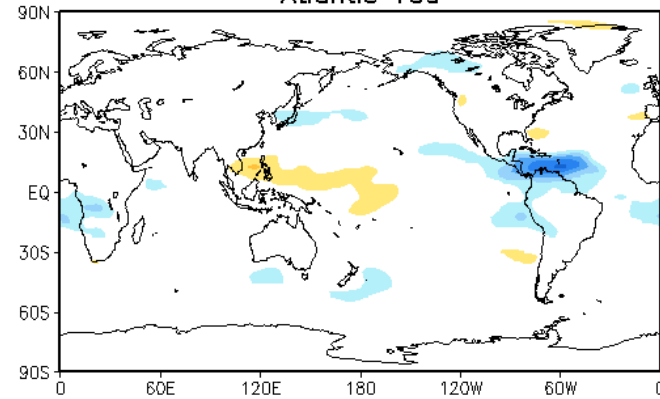
# Correlation between Weekly Wind Shear and Weekly TC Activity

Weekly TC activity unsmoothed

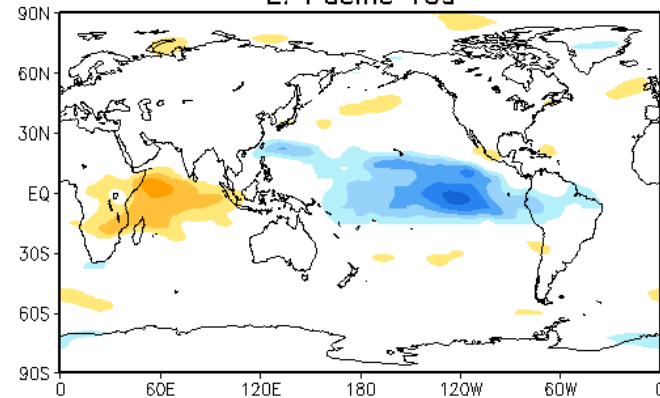
Unlike SST field, vertical  
wind shear is also highly  
correlated with the  
unsmoothed TC activity .

Correlation (Weekly U200–U850, Weekly TC Activity)

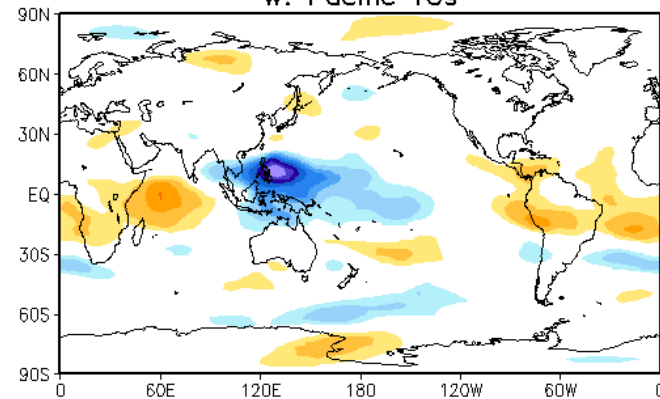
Atlantic TCs



E. Pacific TCs



W. Pacific TCs



Weekly TCs unsmoothed MAY–DEC 1999–2014 (34 weeks)



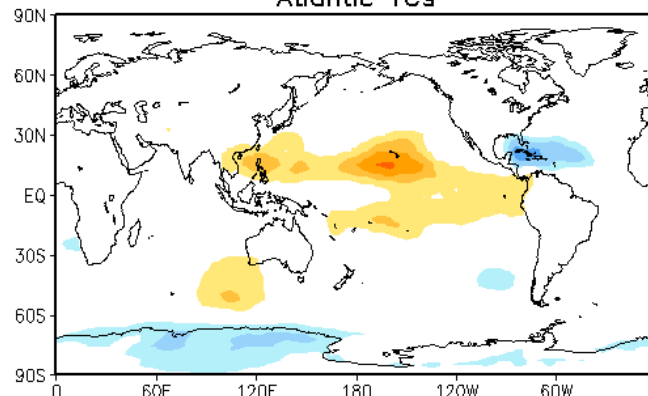
# Correlation between Weekly Sea Level Pressure and Weekly TC Activity

Weekly TC activity smoothed

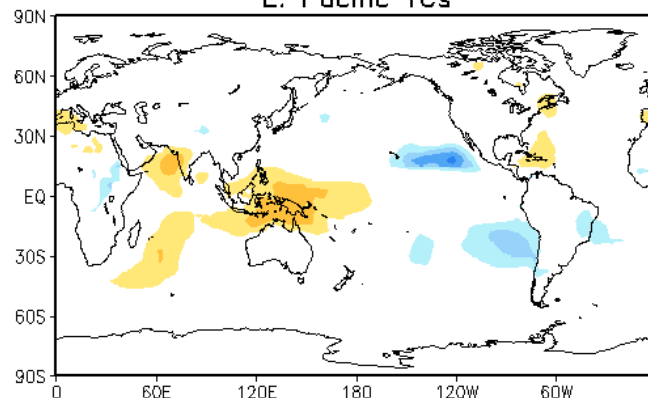
The weekly TC activity is  
negatively correlated with  
local SLP.

Correlation (Weekly SLP, Weekly TC Activity)

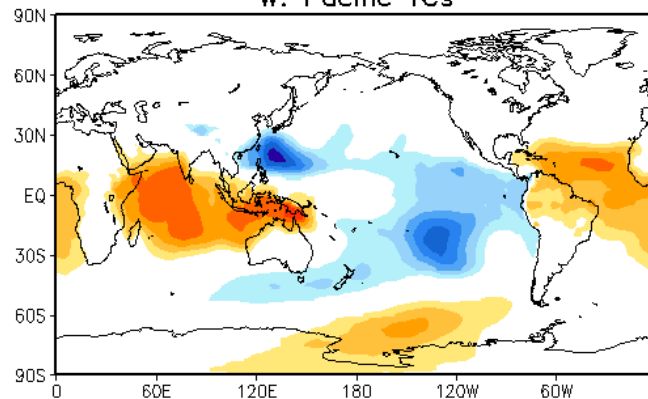
Atlantic TCs



E. Pacific TCs



W. Pacific TCs



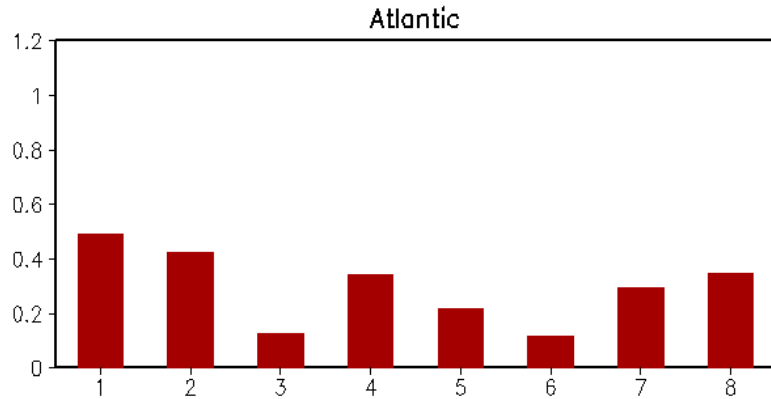
Weekly TCs smoothed MAY-DEC 1999-2014 (34 weeks)

## Effect of MJO on Weekly TS Activity

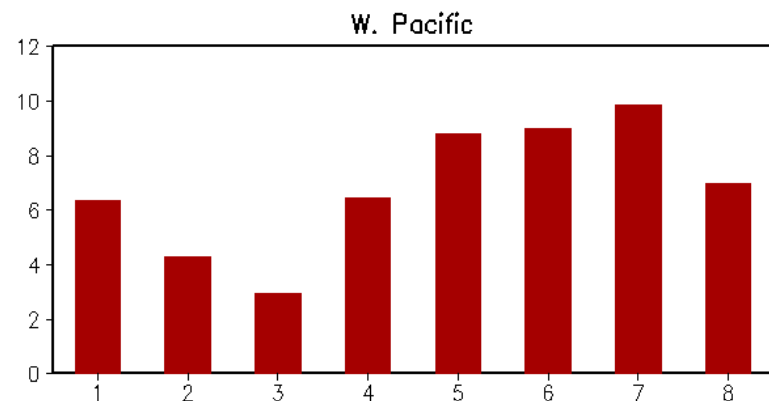
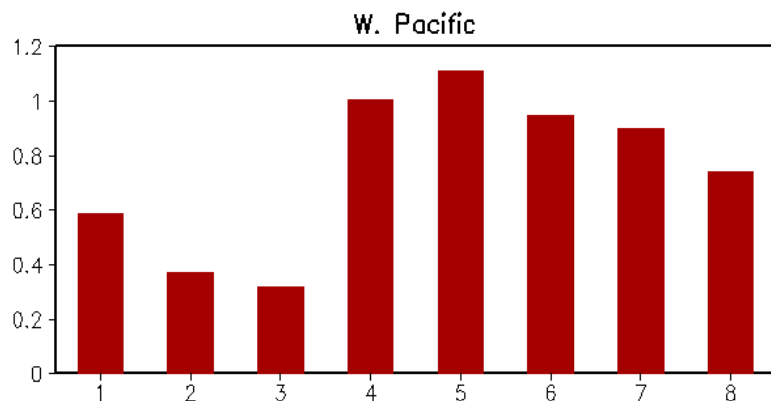
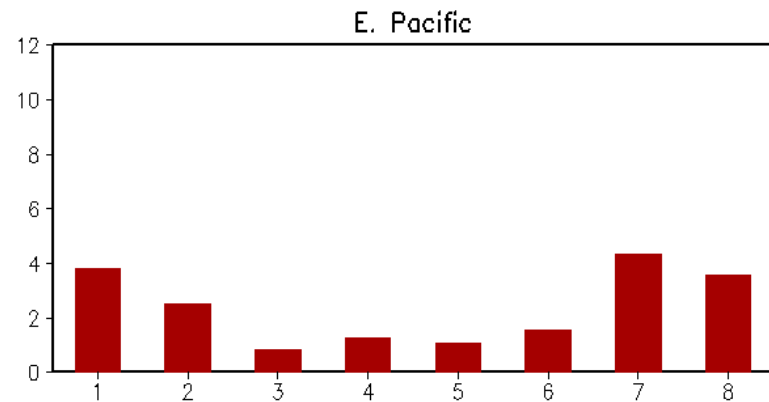
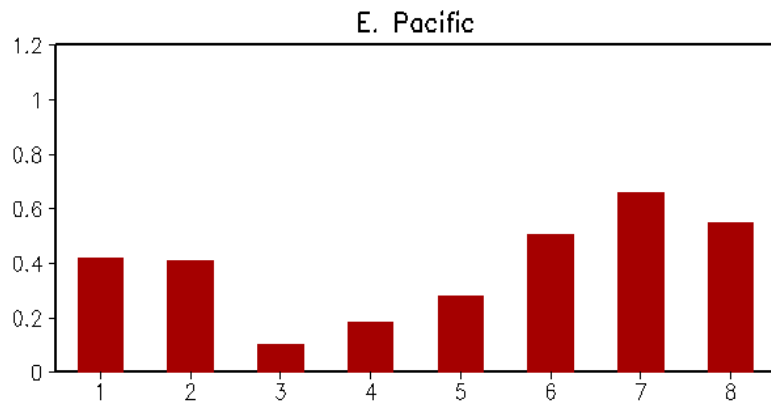
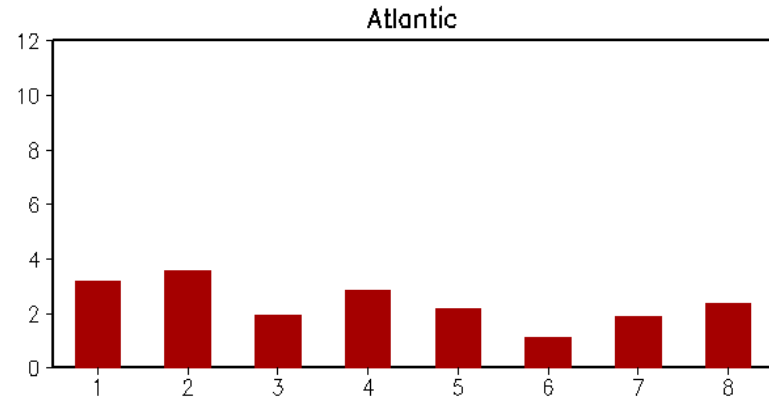
- Daily MJO index
- Weekly MJO index (7-day average of daily MJO index)
- Composite of weekly TCs based on 8 MJO phases

# Composites of TC Genesis and TC Activity Based on MJO Phase

Composite: TC Genesis/MJO Event May–Nov 7–day mean



Composite: TC Activity/MJO Event May–Nov 7–day mean



MJO Phase

MJO Phase

# CFSv2 45-day Hindcast Evaluation

## **Wind shear: U200 – U850**

- Anomaly correlation between CFSv2 45-day hindcasts and CFSR
- Weekly data: 7-day average from Sunday to Saturday
- May – November: 31 weeks
- 1999 – 2012
- Different leads: week 1 to week 4

## **Correlation between observed weekly TC activity and CFSv2 45-day hindcast wind shear**

- Atlantic, E. Pacific, W. Pacific TC activities
- OBS: CFSR
- CFSv2 45-day hindcasts: from week 1 to week 4
- Potential predictors: area-average over regions with high correlations

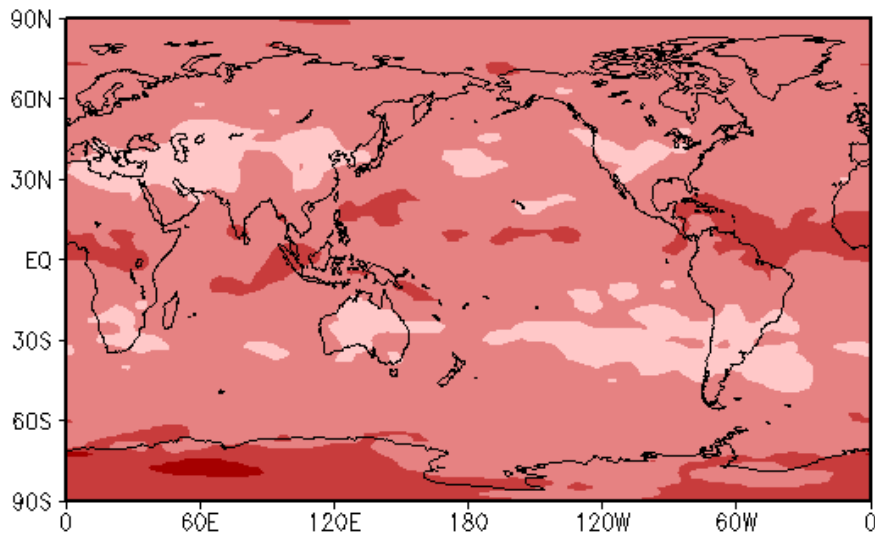
Anomaly Correlation: Weekly U200-U850

CFSv2 45-day Hindcast vs. CFSR

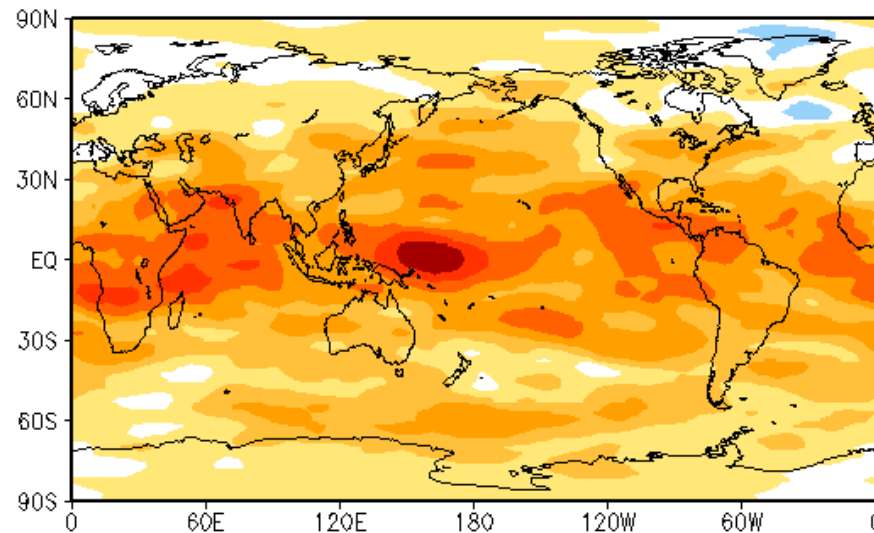
May-November (31 weeks)

1999-2012

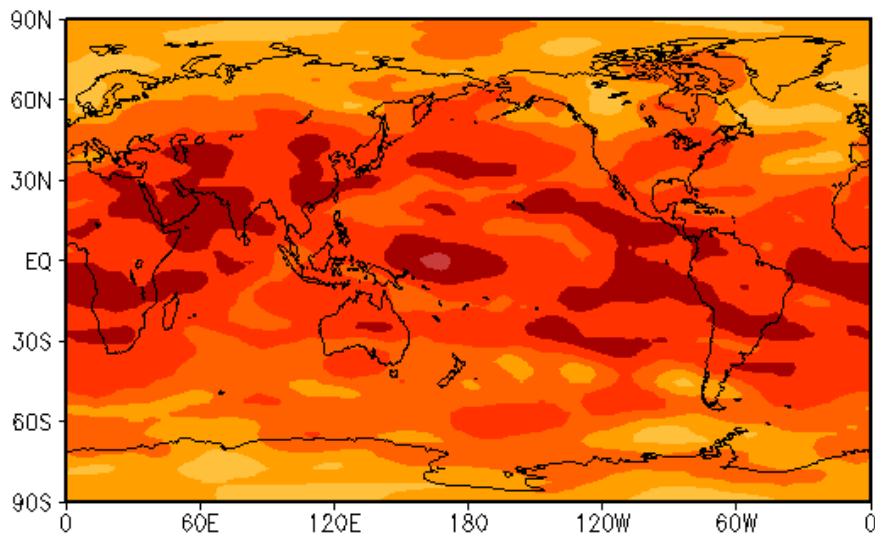
Week 1



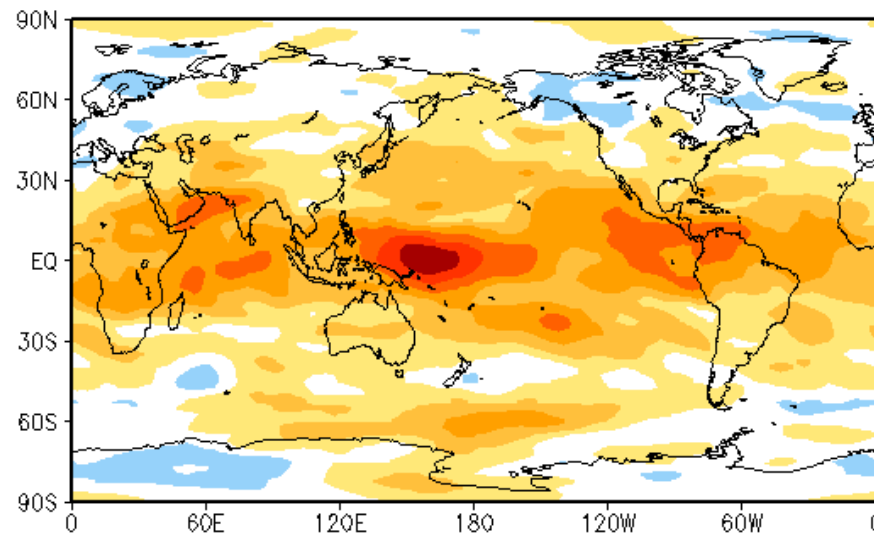
Week 3



Week 2

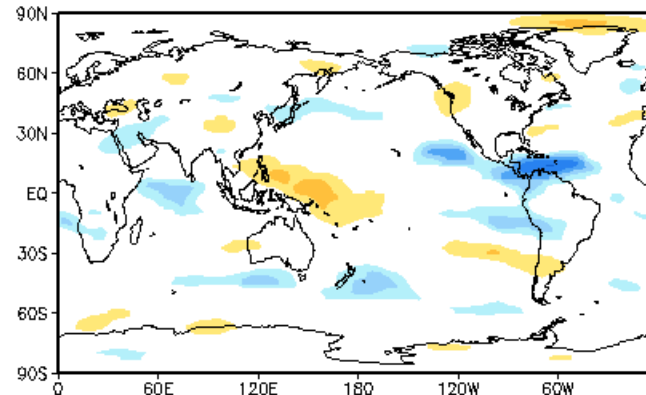


Week 4

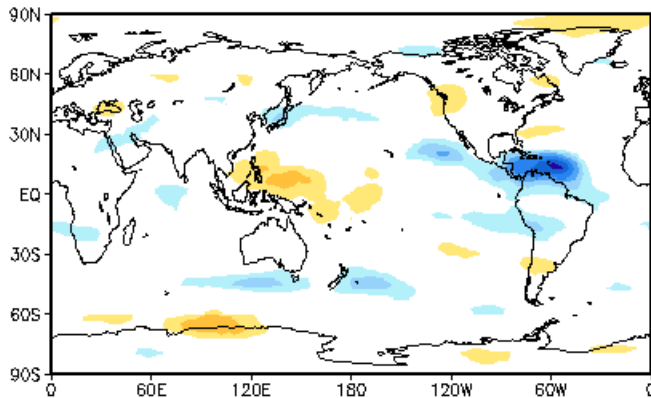


Atlantic TC  
Correlation  
TC Activity vs. U200-U850  
May–November (31 weeks)  
1999–2012  
TC Activity: Smoothed

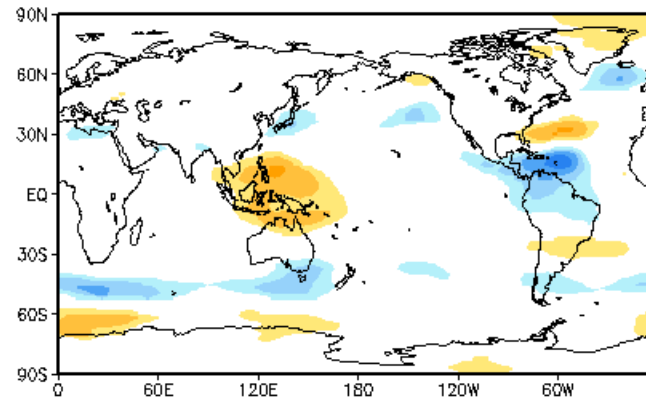
CFSR



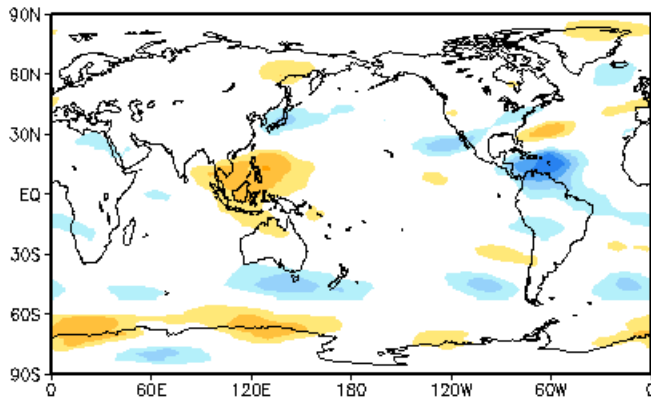
Week 1



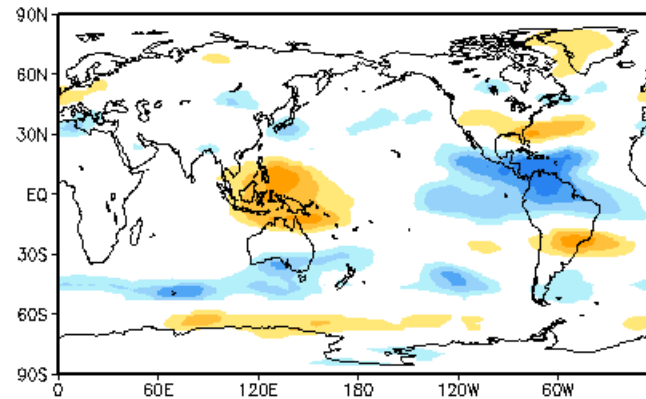
Week 3



Week 2

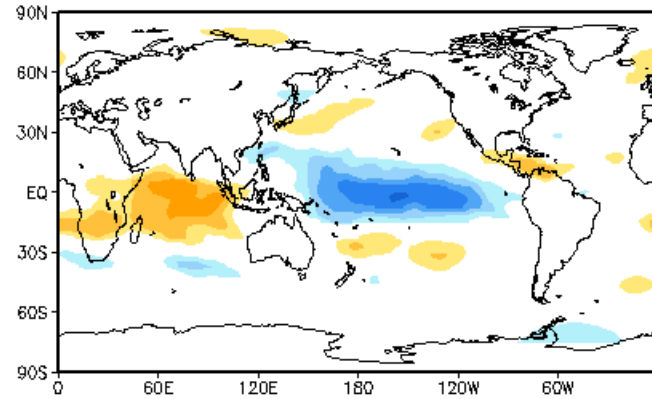


Week 4

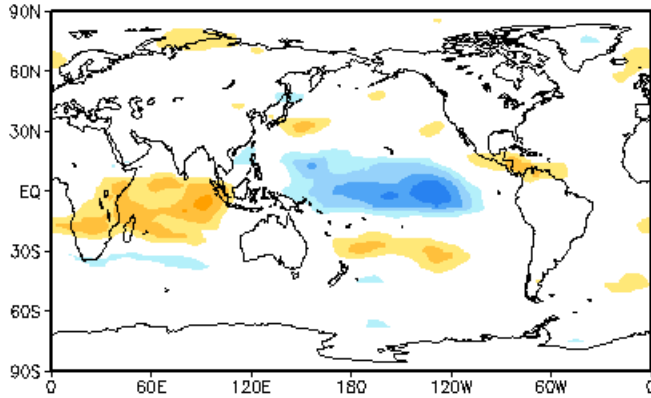


E. Pacific TC  
Correlation  
TC Activity vs. U200-U850  
May–November (31 weeks)  
1999–2012  
TC Activity: Smoothed

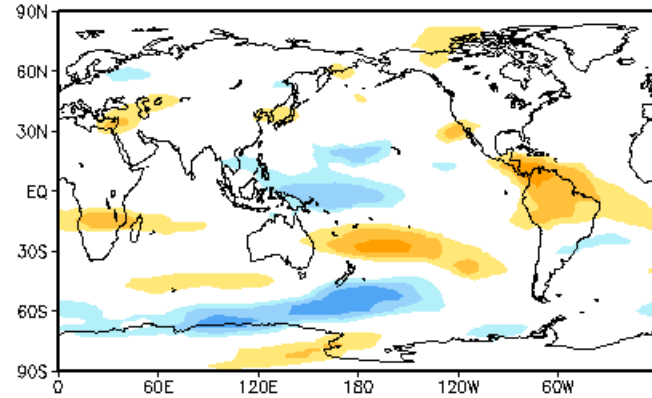
CFSR



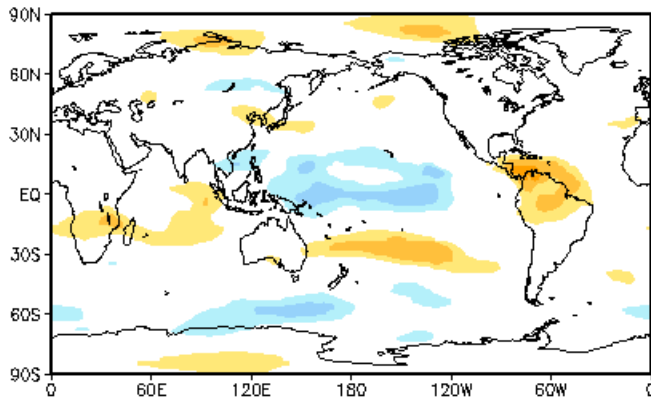
Week 1



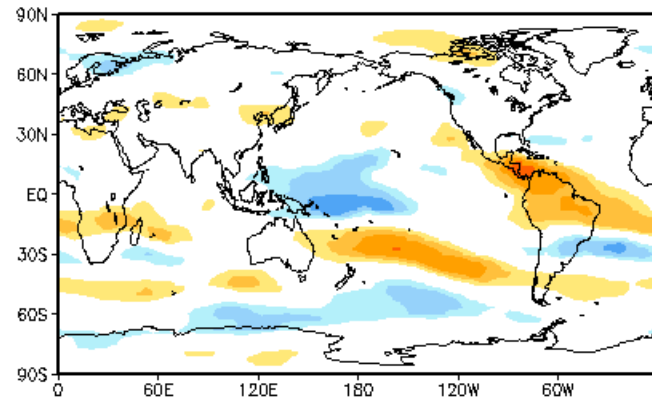
Week 3



Week 2



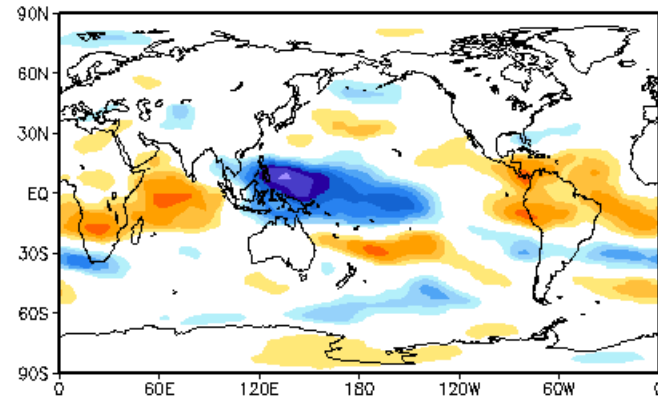
Week 4



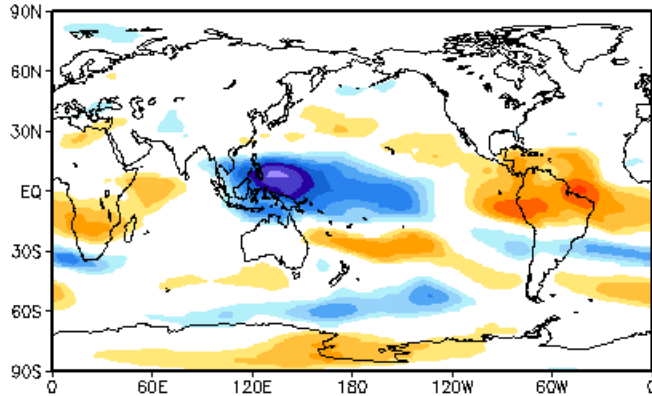


W. Pacific TC  
Correlation  
TC Activity vs. U200-U850  
May–November (31 weeks)  
1999–2012  
TC Activity: Smoothed

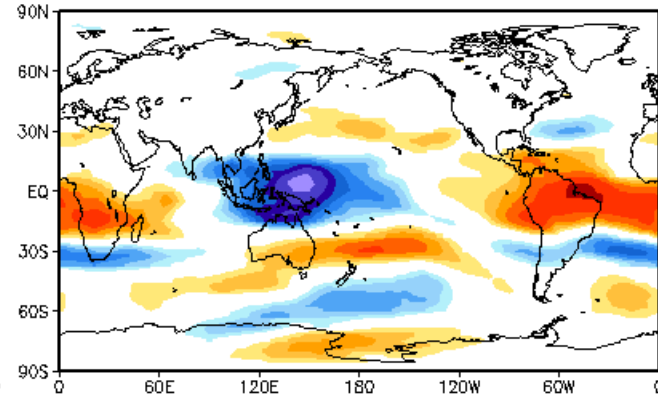
CFSR



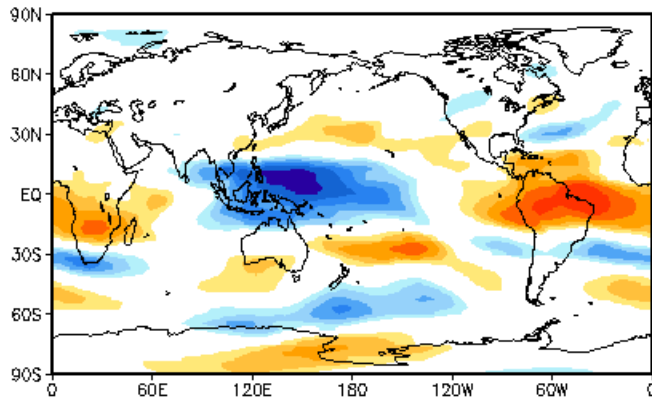
Week 1



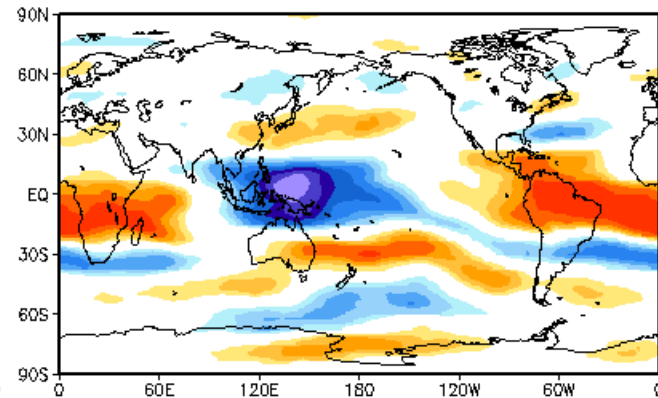
Week 3



Week 2



Week 4



## **Sea Level Pressure (SLP)**

- Anomaly correlation between CFSv2 45-day hindcasts and CFSR
- Weekly data: 7-day average from Sunday to Saturday
- May – November: 31 weeks
- 1999 – 2012
- Different leads: week 1 to week 4

## **Correlation between observed weekly TC activity and CFSv2 45-day hindcast SLP**

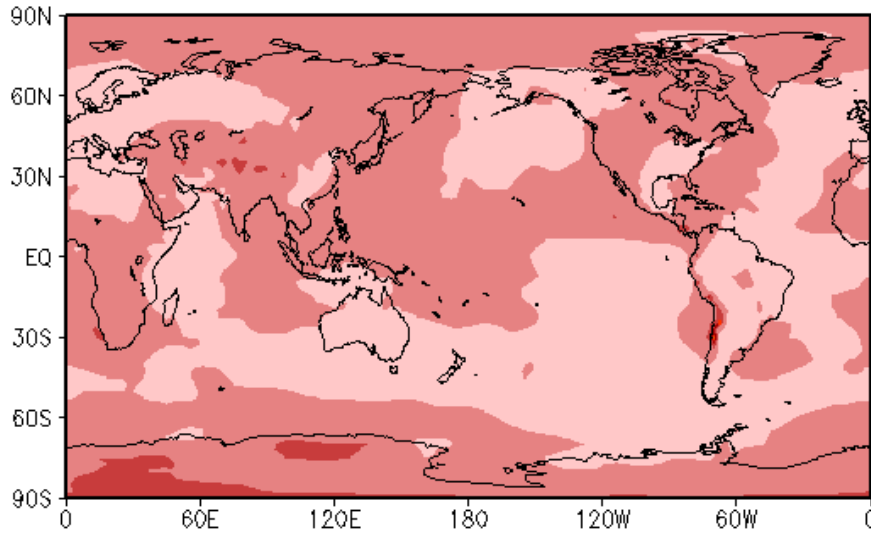
- Atlantic, E. Pacific, W. Pacific TC activities
- OBS: CFSR
- CFSv2 45-day hindcasts: from week 1 to week 4
- Potential predictors: area-average over regions with high correlations

# Anomaly Correlation: Weekly SLP

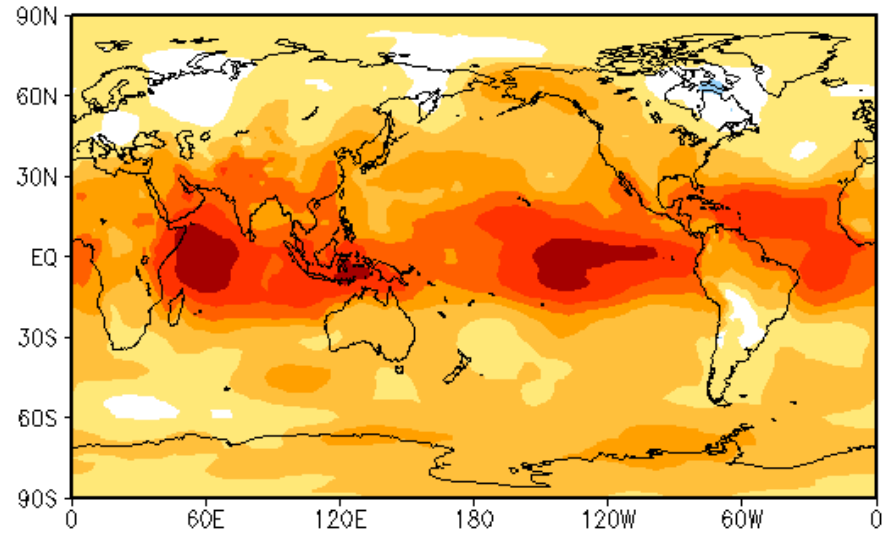
CFSv2 45-day Hindcast vs. CFSR

May–November (31 weeks) 1999–2012

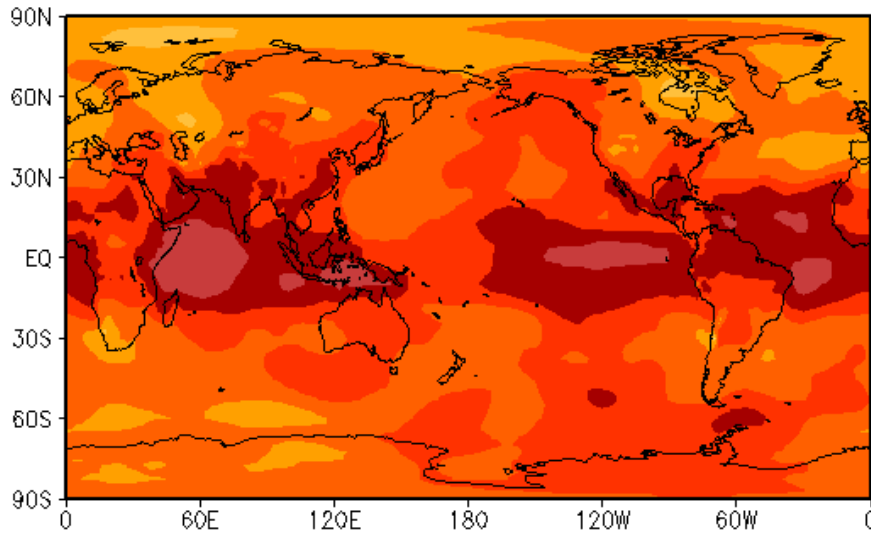
### Week 1



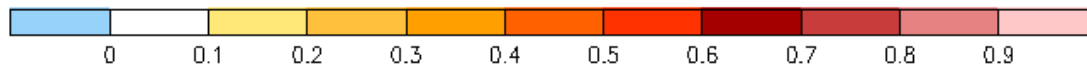
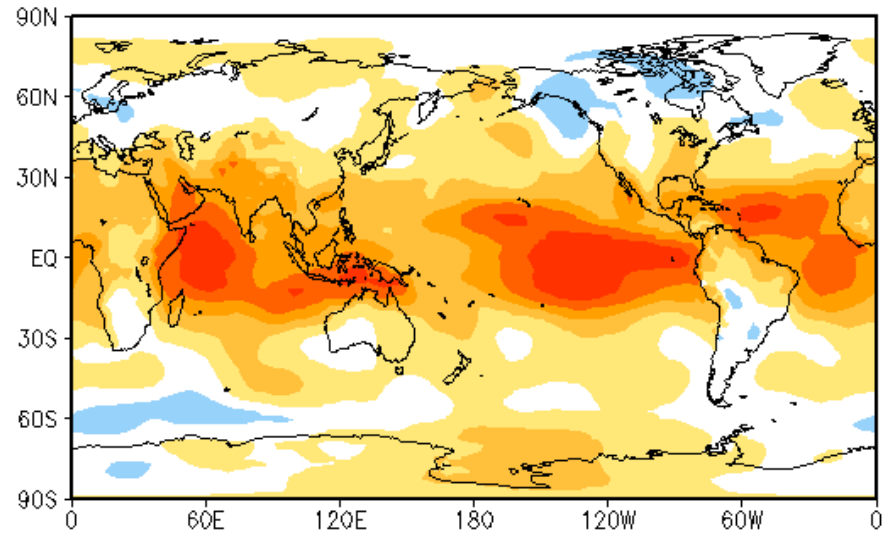
### Week 3



### Week 2

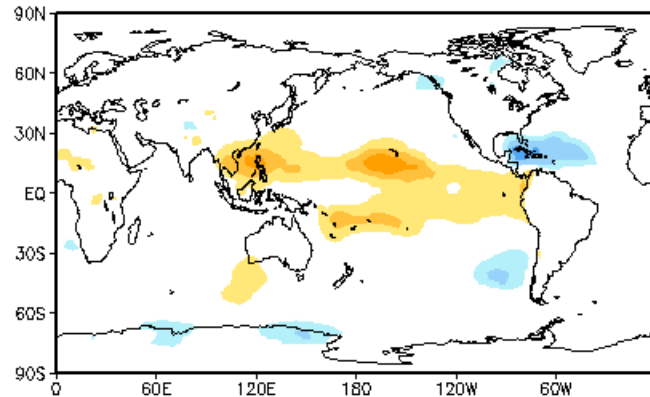


### Week 4

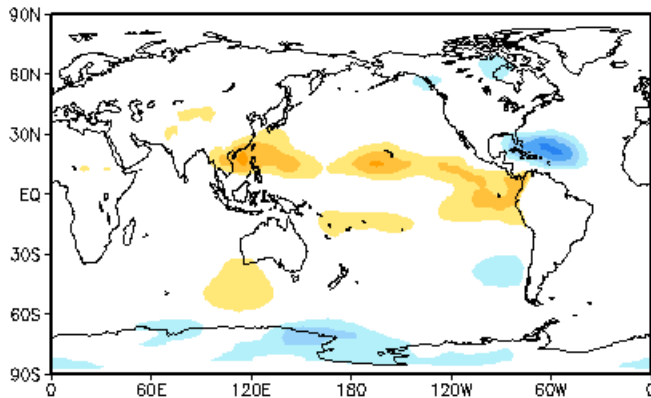


Atlantic TC  
Correlation  
TC Activity vs. SLP  
May–November (31 weeks)  
1999–2012  
TC Activity: Smoothed

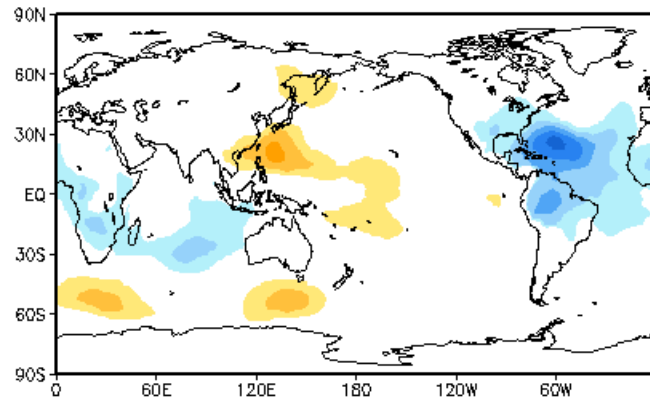
CFSR



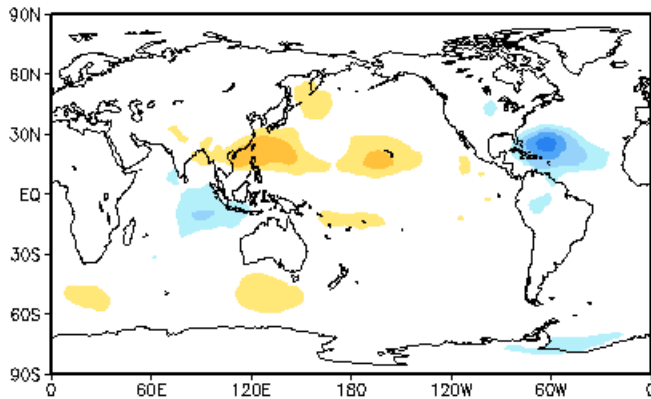
Week 1



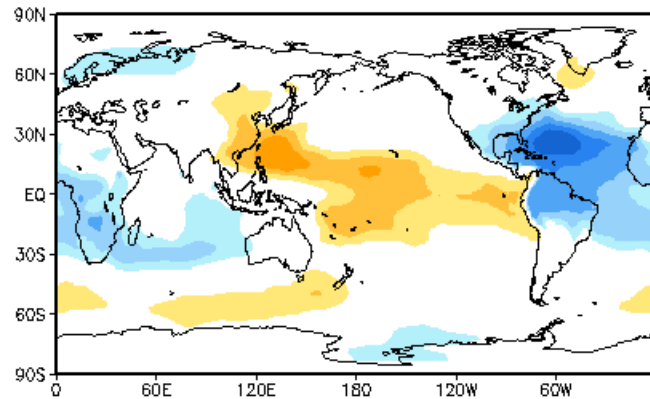
Week 3



Week 2

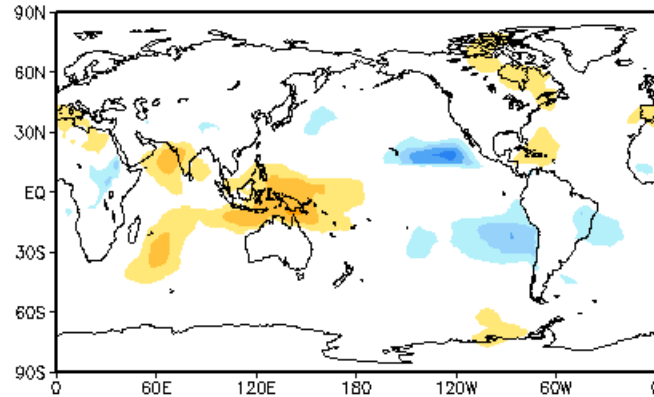


Week 4

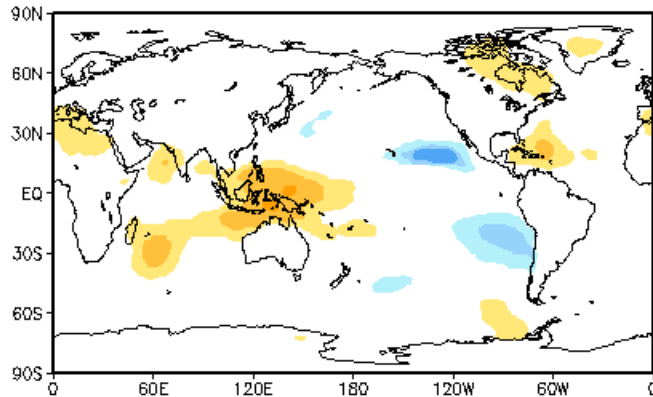


E. Pacific TC  
Correlation  
TC Activity vs. SLP  
May–November (31 weeks)  
1999–2012  
TC Activity: Smoothed

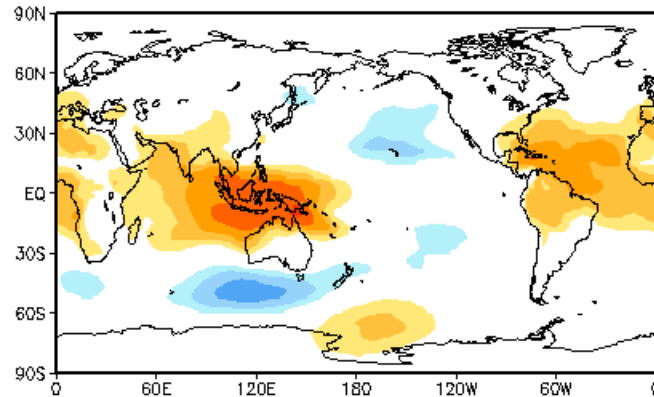
CFSR



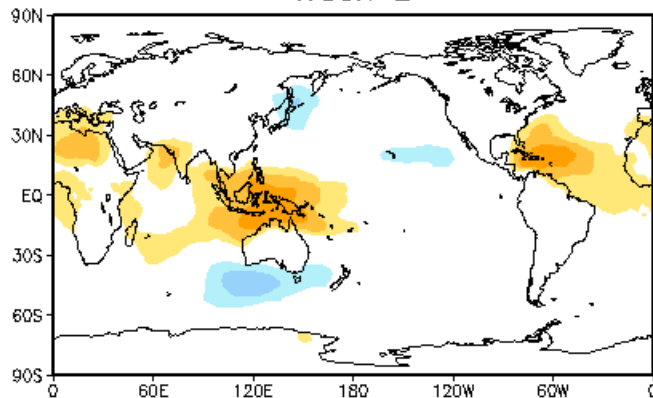
Week 1



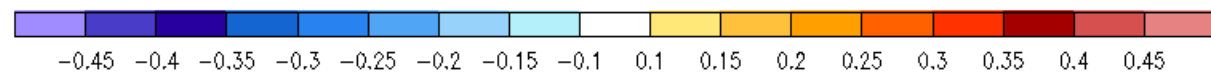
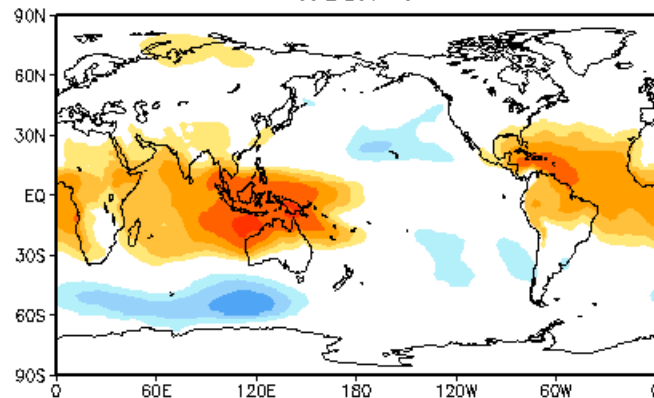
Week 3



Week 2

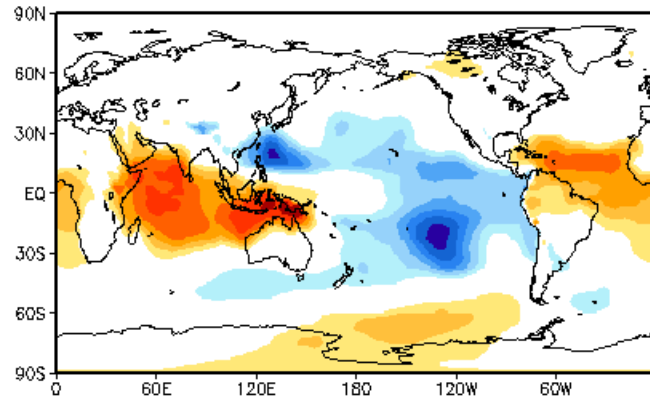


Week 4

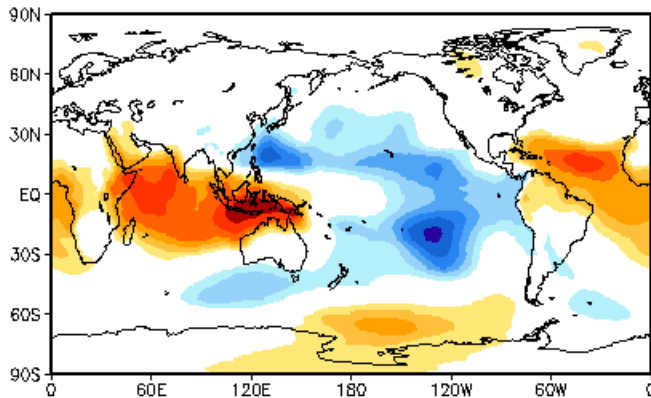


W. Pacific TC  
Correlation  
TC Activity vs. SLP  
May–November (31 weeks)  
1999–2012  
TC Activity: Smoothed

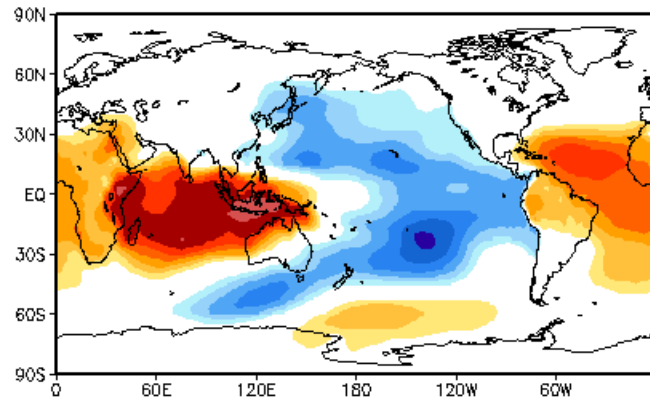
CFSR



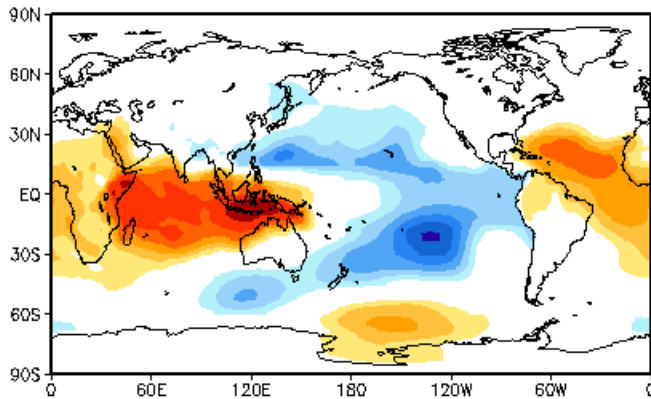
Week 1



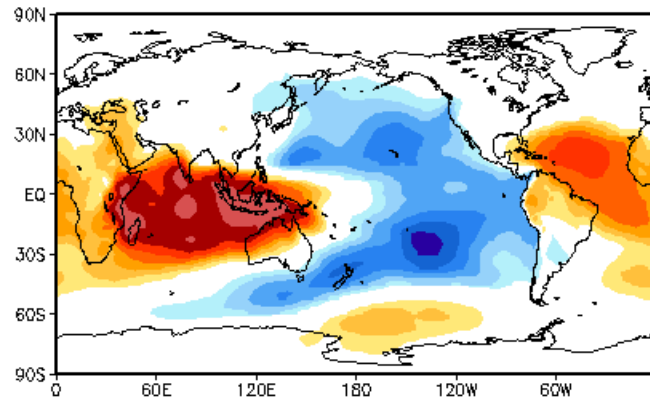
Week 3



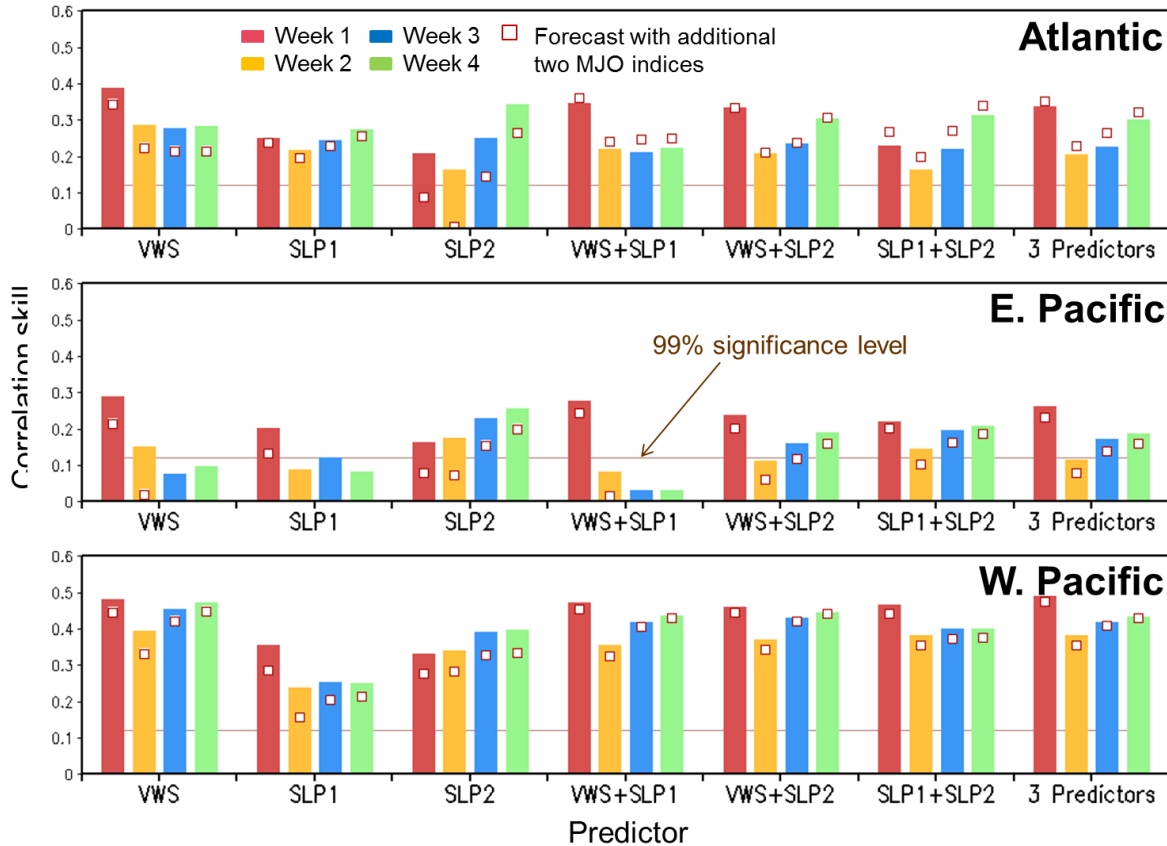
Week 2



Week 4



## Forecast skill for weekly TC activity (1999 – 2014)



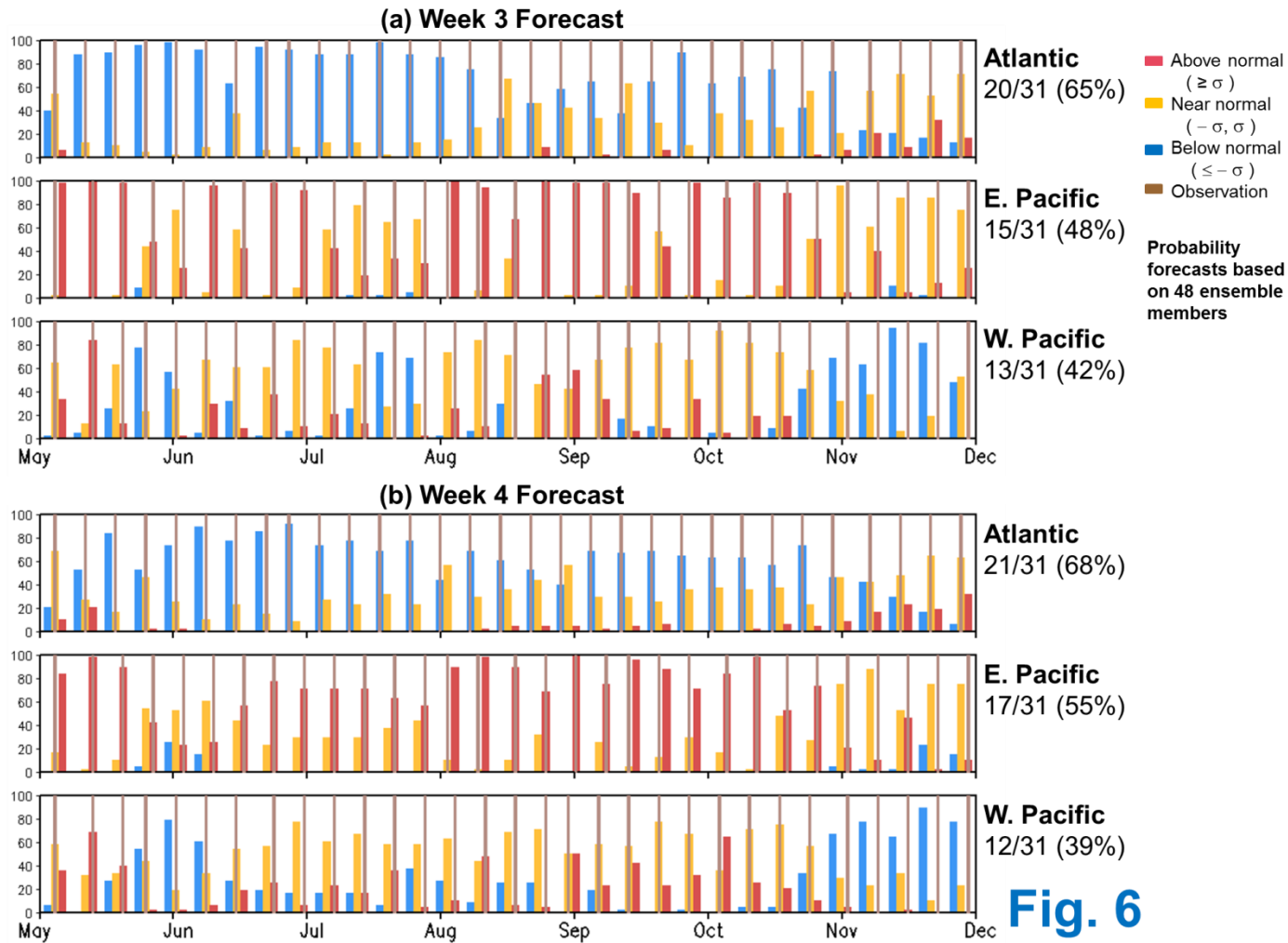
**Fig. 5.** Forecast skill for weekly TC activity using different predictors and based on the cross-validations.

**Fig. 5**

# **Experimental Prediction for 2015 – 2016 Seasons**

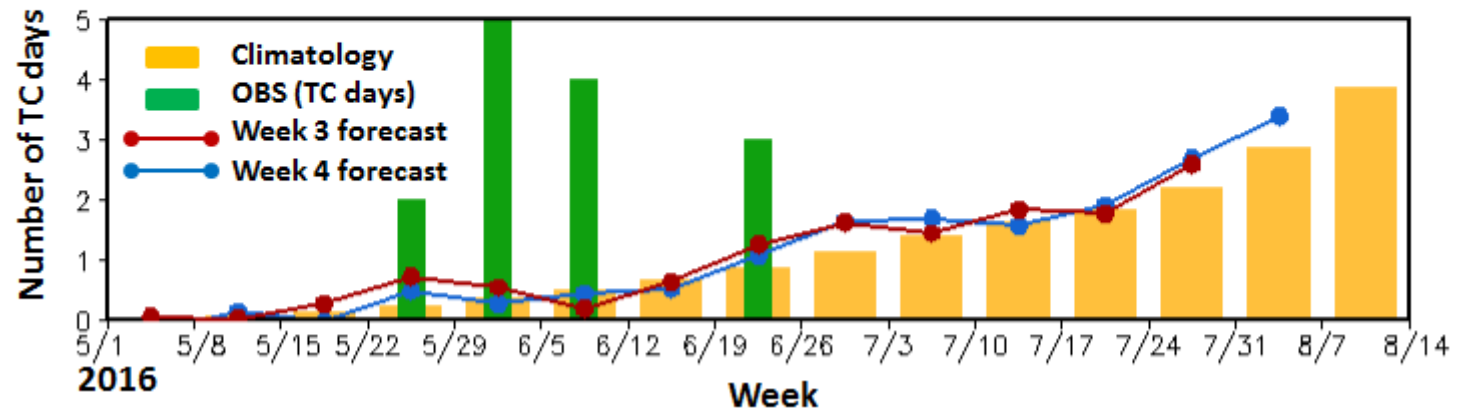
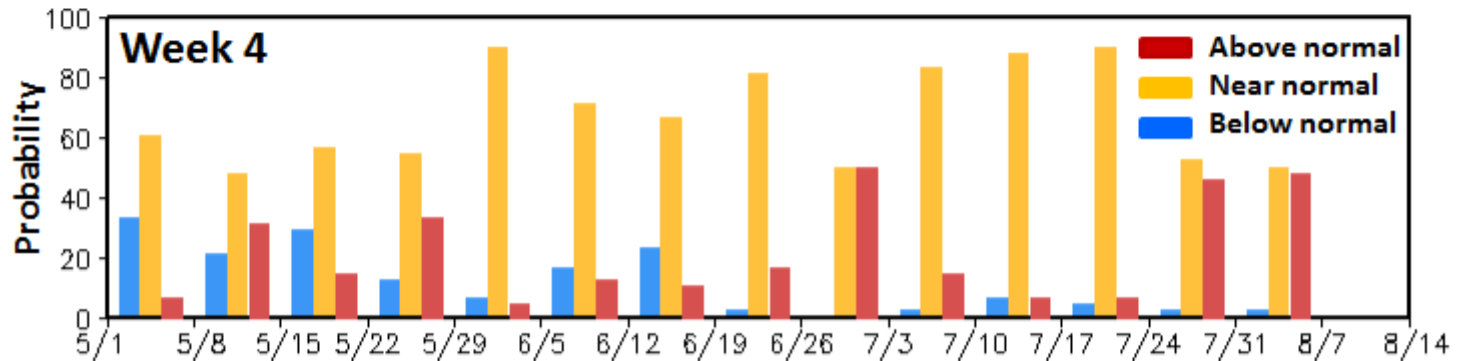
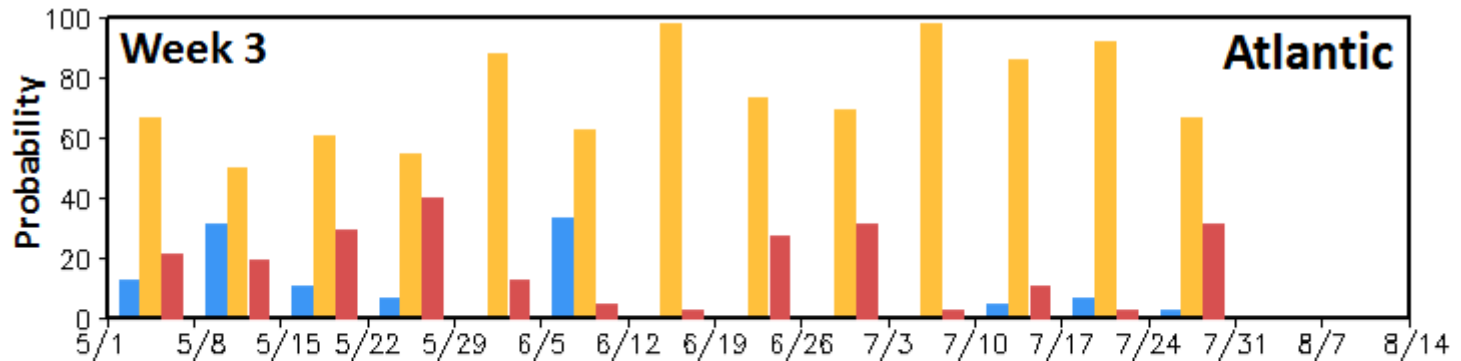


# Probability forecast for 2015



**Fig. 6**

**Fig. 6.** Probability forecasts of week 3 and 4 TC activity for 31 weeks from May to November 2015 using VWS as a predictor.



Week 3 and 4 forecasts for the Atlantic with vertical wind shear as a predictor.

# Summary

- **Evaluation of the CFSv2 45-day hindcasts for the hybrid model formulation for Weeks 1 – 4 TS activity prediction completed.**
- **Multiple regression relationship for the weekly TS activity established based on the CFSv2 hindcast data for 1999-2012. The hybrid model performance evaluated in cross-validation mode with the hindcast experiment, indicating fair level of forecast skills for weeks 3 and 4 TS activity.**
- **Real-time prediction experiment based on this hybrid system performed for 2015 season and continues in 2016. It is planned to implement operationally at CPC in 2017.**
- **This project contributes towards the NGGPS/R2O objective on the development of forecast products for Week 3 and 4.**