A Statistical-Dynamical Seasonal Forecast of US Landfalling TC Activity

Johnny Chan and Samson K S Chiu

Guy Carpenter Asia-Pacific Climate Impact Centre

City University of Hong Kong

Research sponsored by Risk Prediction Initiative, Bermuda Institute of Ocean Sciences

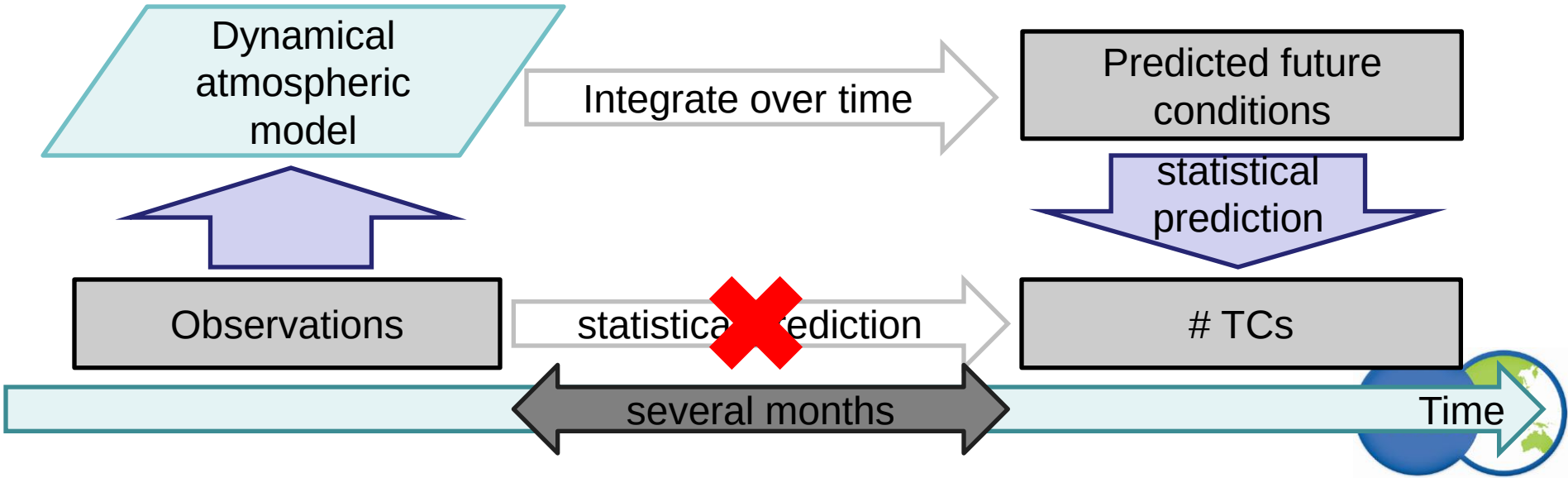
GCACIC

Outline

- Background
- Climatology of US landfall
- Data and methodology
- Results and interpretation
- Summary

Statistical vs. Statistical-dynamical Methods

- **Problem with the statistical method**
  - **Relate the past events and future conditions by statistics**
  - **Inherent problem**
    - **assumes the future would behave the same as the past, which may not be correct**
- **Statistical-dynamical method partly solves the inherent problem by**
  - **relating dynamical model predictions with future conditions**

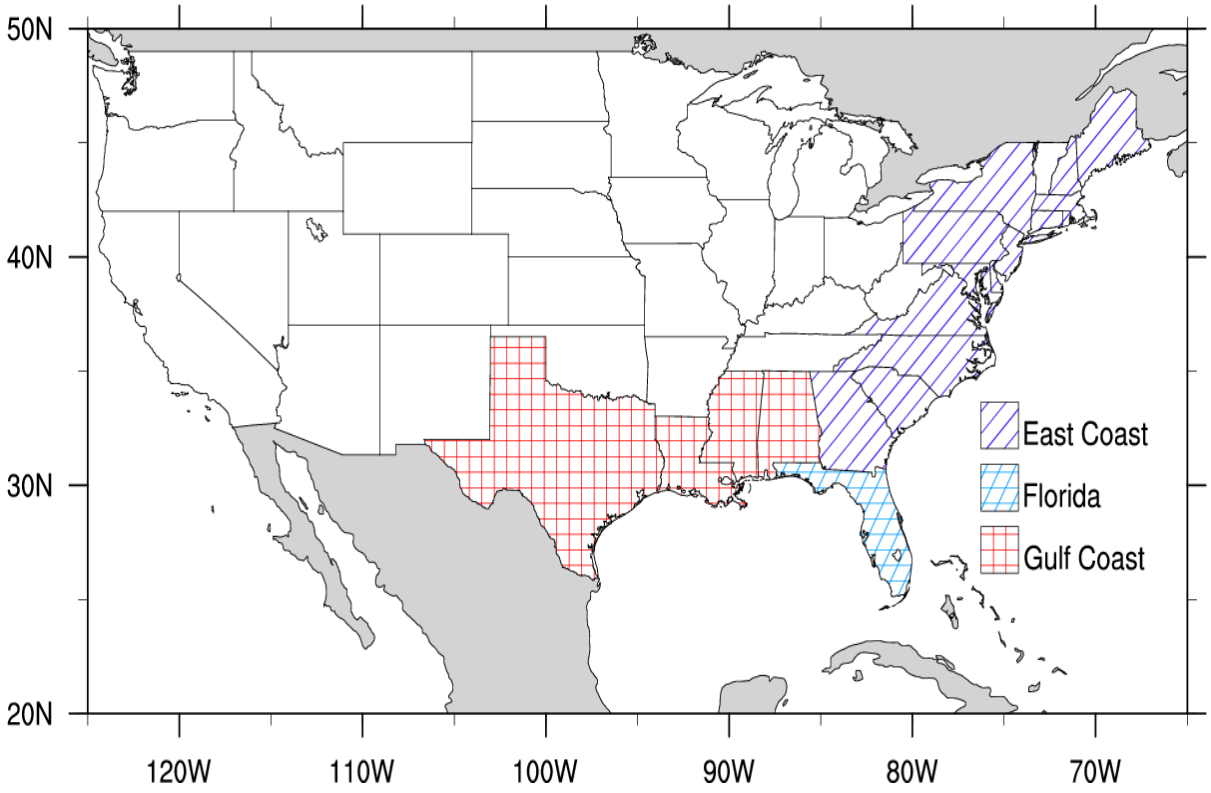


Objectives

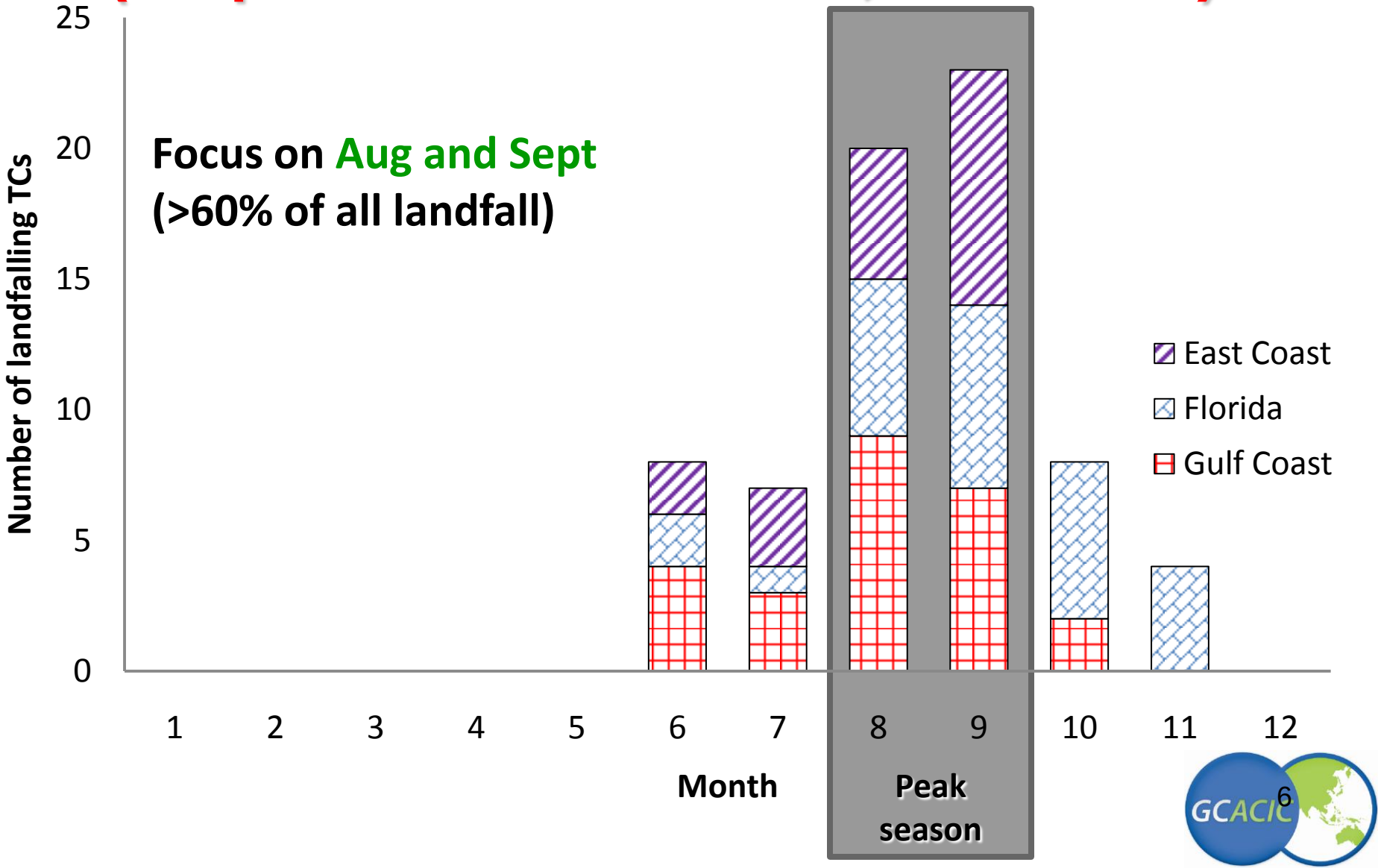
- To prove the feasibility of the statistical-dynamical prediction scheme
  - To develop a statistical-dynamical seasonal prediction scheme for U.S. landfalling tropical cyclones
  - To develop a multi-model statistical-dynamical seasonal prediction scheme
  - To evaluate the performance of the predictions

Tropical cyclones data – HURDAT

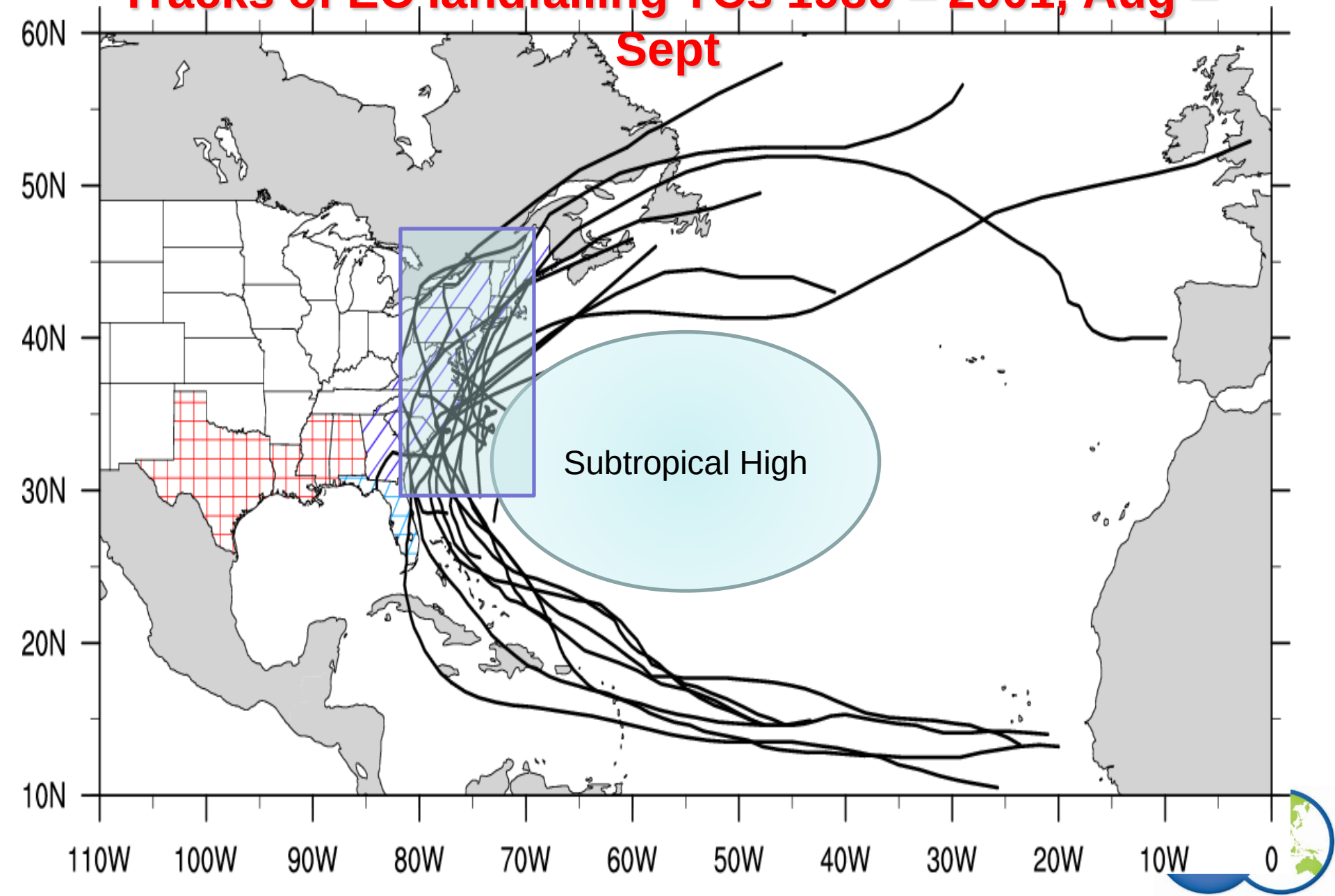
- National Hurricane Center Hurricane Best Tracks Files
  - 6-hourly position and intensity of TCs
- 3 regions of the U.S. Atlantic coast
  - East Coast (Maine to Georgia)
  - Gulf Coast (Alabama to Texas)
  - Florida



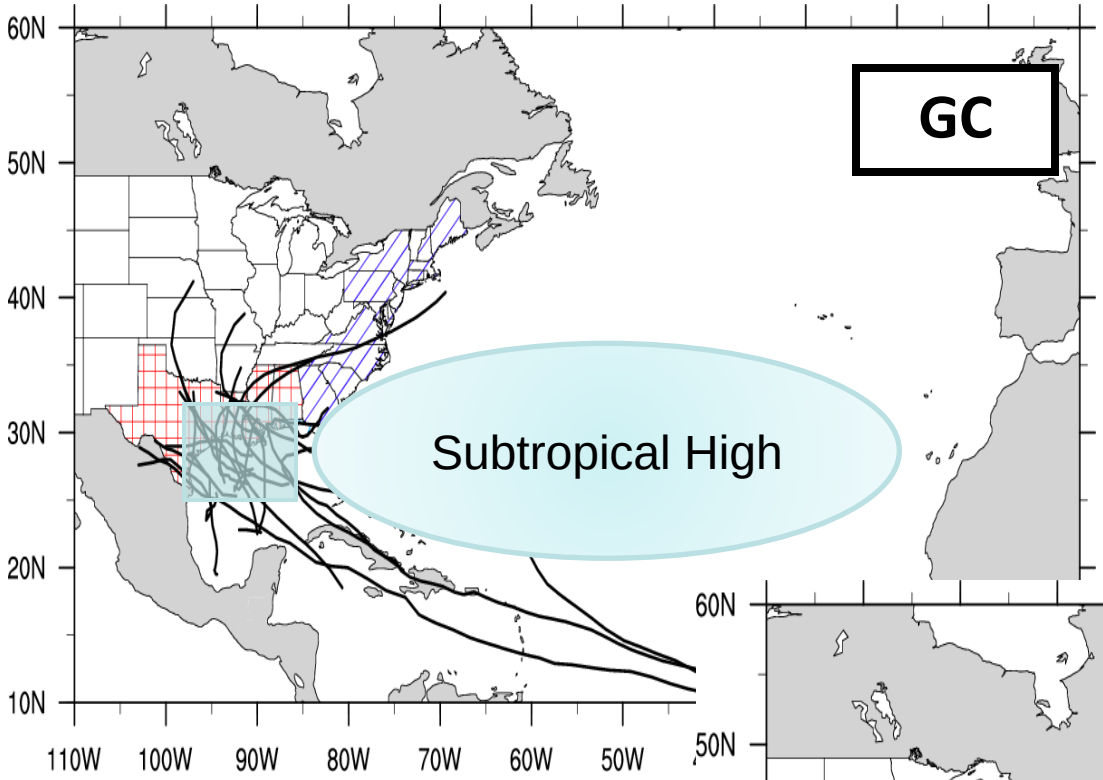
No. of US Atlantic landfalling TCs (Tropical Storm or above, 1980-2001)

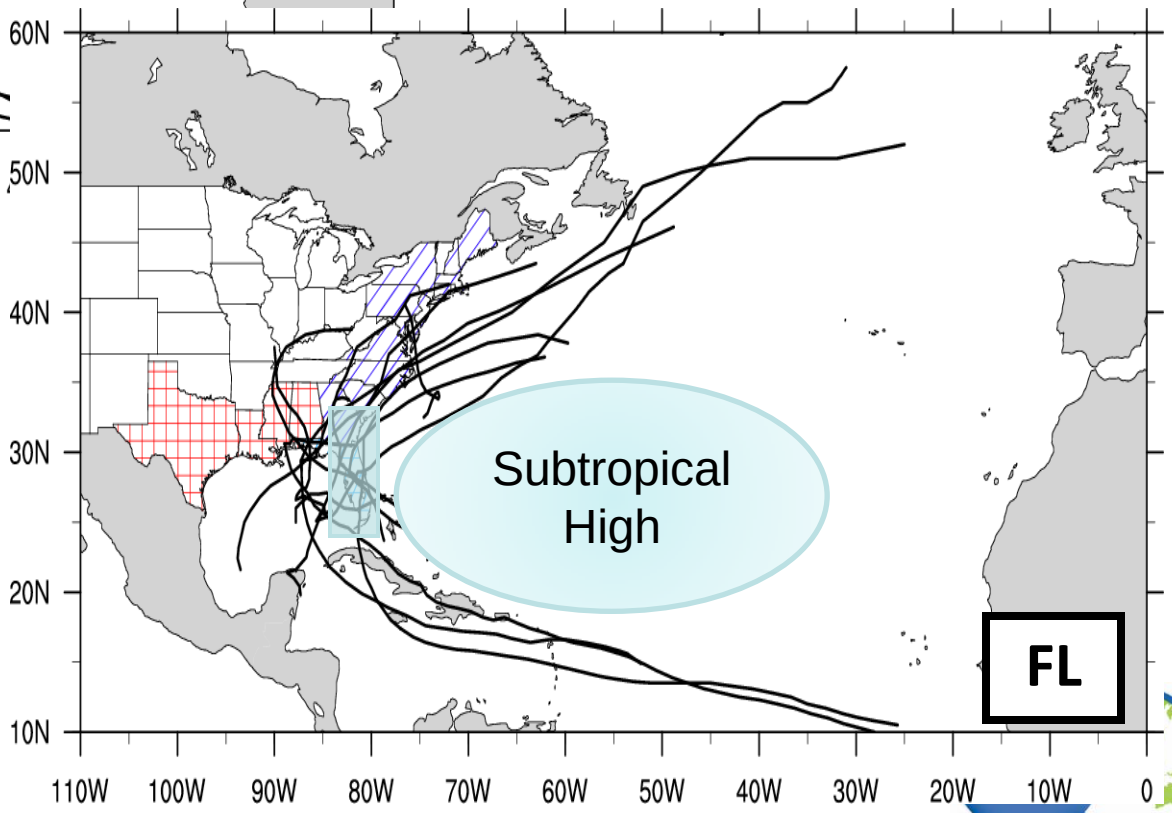


Tracks of EC landfalling TCs 1980 – 2001, Aug – Sept



Tracks of FL/GC landfalling TCs 1980 – 2001, Aug – Sept





Dynamical model data -DEMETER

- Development of a European multimodel ensemble system for seasonal to interannual prediction (from European Union)
  - 7 models (CERFACS, ECMWF, INGV, LODYC, Météo-France, MPI and UKMO)
  - 9 ensemble members each
  - 6 months forecasts available
  - Base time @ 1 Feb, May, Aug, Nov
  - 1980-2001 (22 years hindcast)
  - 2.5 x 2.5 degree resolution

Dynamical model data -DEMETER

Parameter	Physics
Geopotential (200-, 500-, 850-hPa)	subtropical high
Wind fields (200-, 500-, 850-hPa)	steering flow
SST	TC genesis
Sea-level pressure (SLP)	subtropical high, low for TC genesis

Methodology

- Compute the 9-member ensemble mean of each model-predicted atmospheric fields (Aug-Sept)
  - Geopotential, zonal and meridional winds (3 levels)
  - SST, SLP
- Extract the first 4 EOF modes of each predictor fields
  - 11 fields x 4 modes = 44 potential predictors from each DEMETER model
- Test the statistical significance of the relationship between the coefficient of each mode and the number of landfalling TCs

Methodology

- Fit a forecast equation for each regional # landfalling TCs
  - Poisson regression
  - Cross-validation (Jackknife method)
- 7 forecast equations, each from an individual model
- Multimodel equation derived from the 7 equations
  - Simple average
  - Agreement coefficient weighted-average

Regression

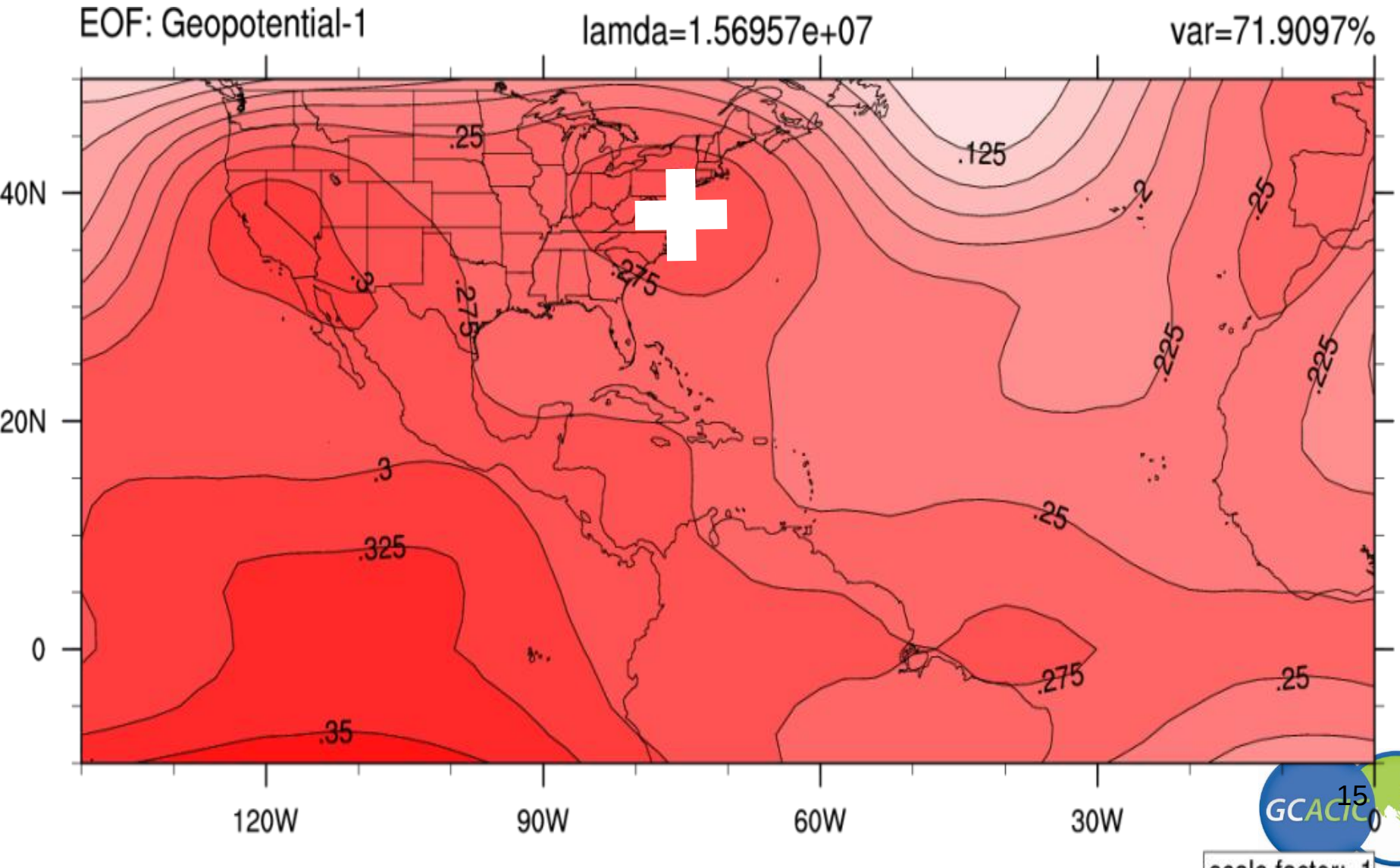
- **Linear regression is used in most previous studies**
  - **Normality assumption of predictors and predictand**
  - **Fails in # landfalling TCs (Discrete non-negative integers)**
- **Poisson regression**
  - **Discrete probability distribution**
  - **Zero probability for negative numbers**
- **Stepwise regression**

Factors affecting EC landfalling TCs

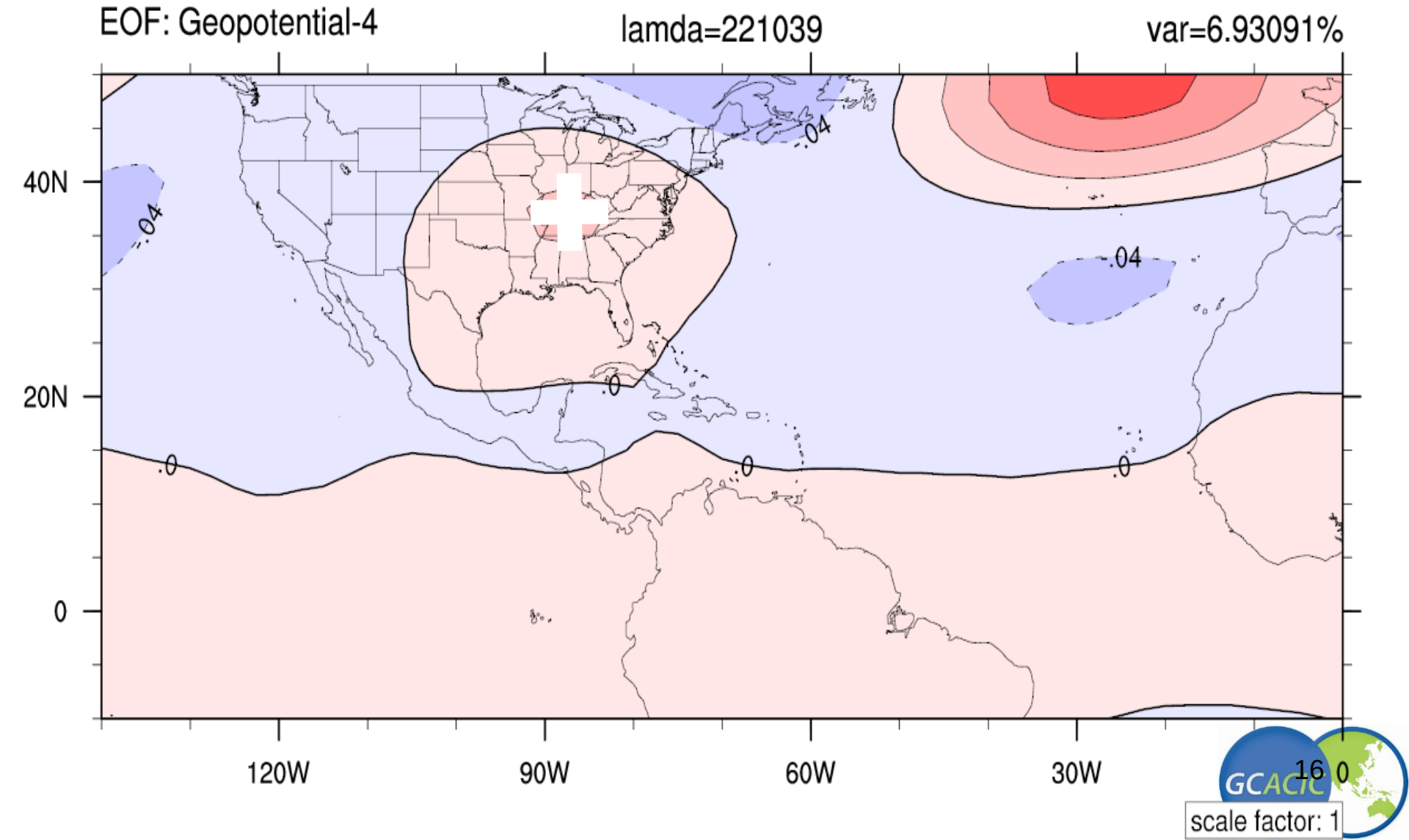
Model CERFACS

Level	Parameter	EOF mode
200 hPa	zonal wind	1
	zonal wind	3
	geopotential	1
500 hPa	zonal wind	1
	geopotential	1
	geopotential	4
850 hPa	meridional wind	1
surface	SST	1
	MSLP	1

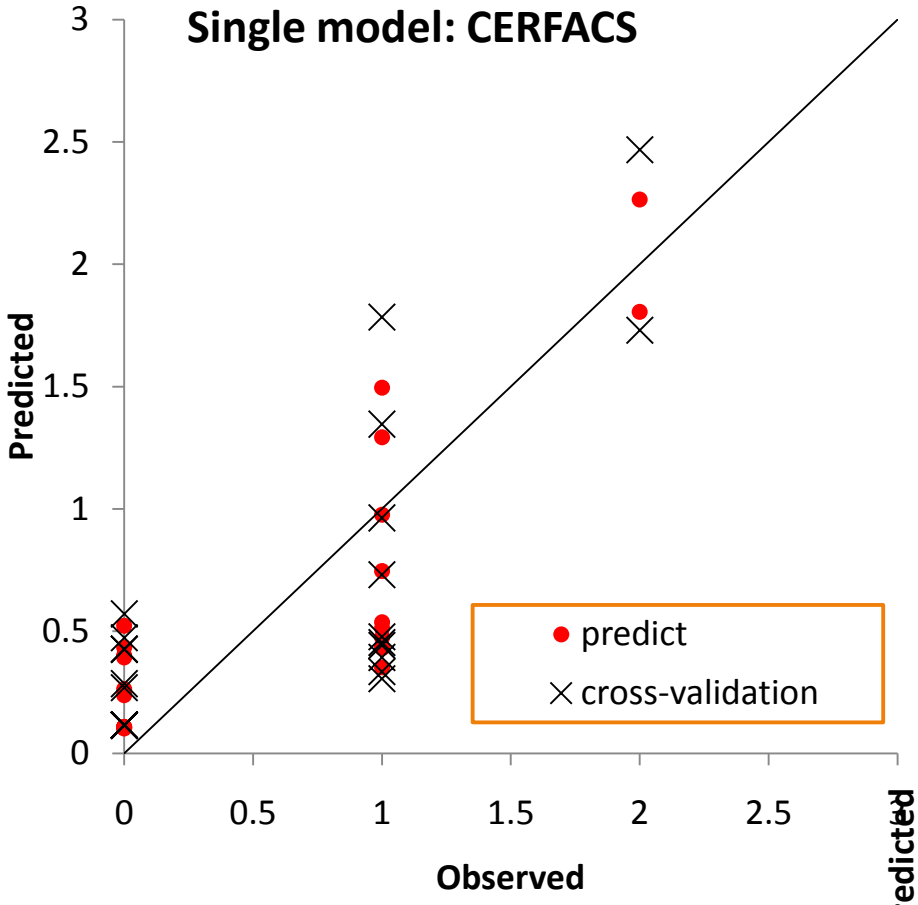
200-hPa geopotential EOF 1 (-vely correlated with EC landfall)

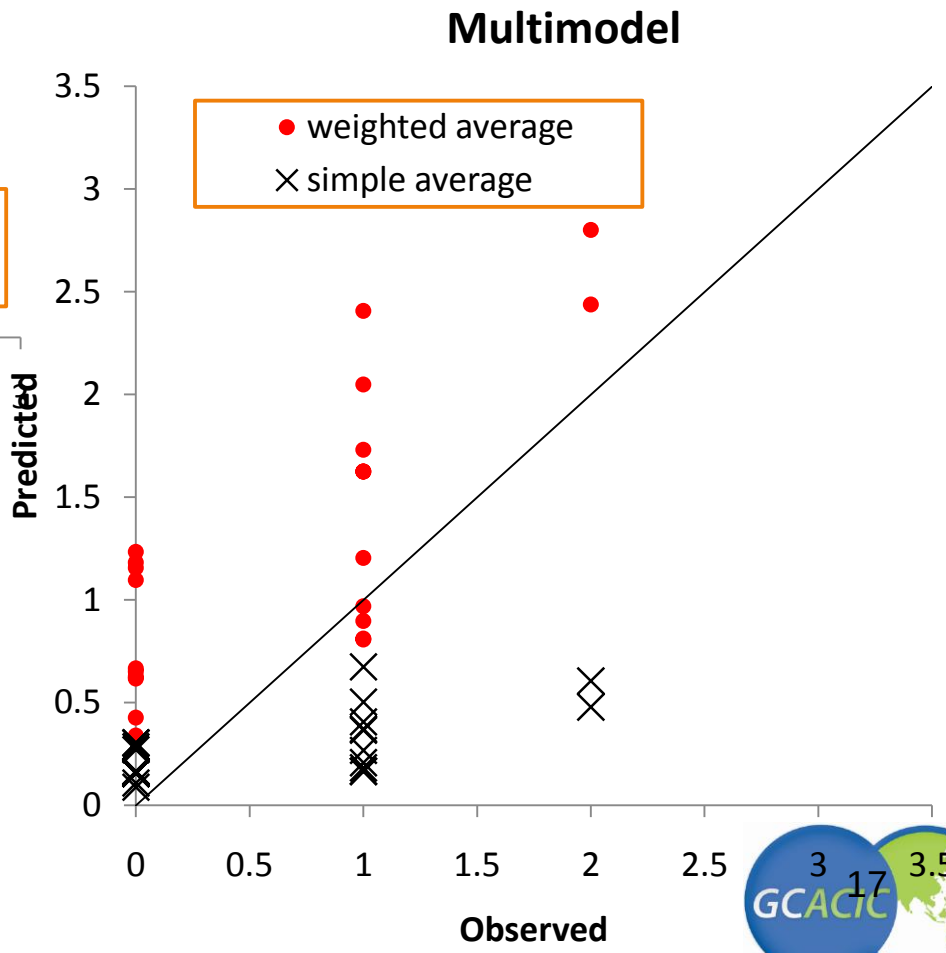


500-hPa geopotential EOF 4 (-vely correlated with EC landfall)



Observed vs. Predicted East Coast

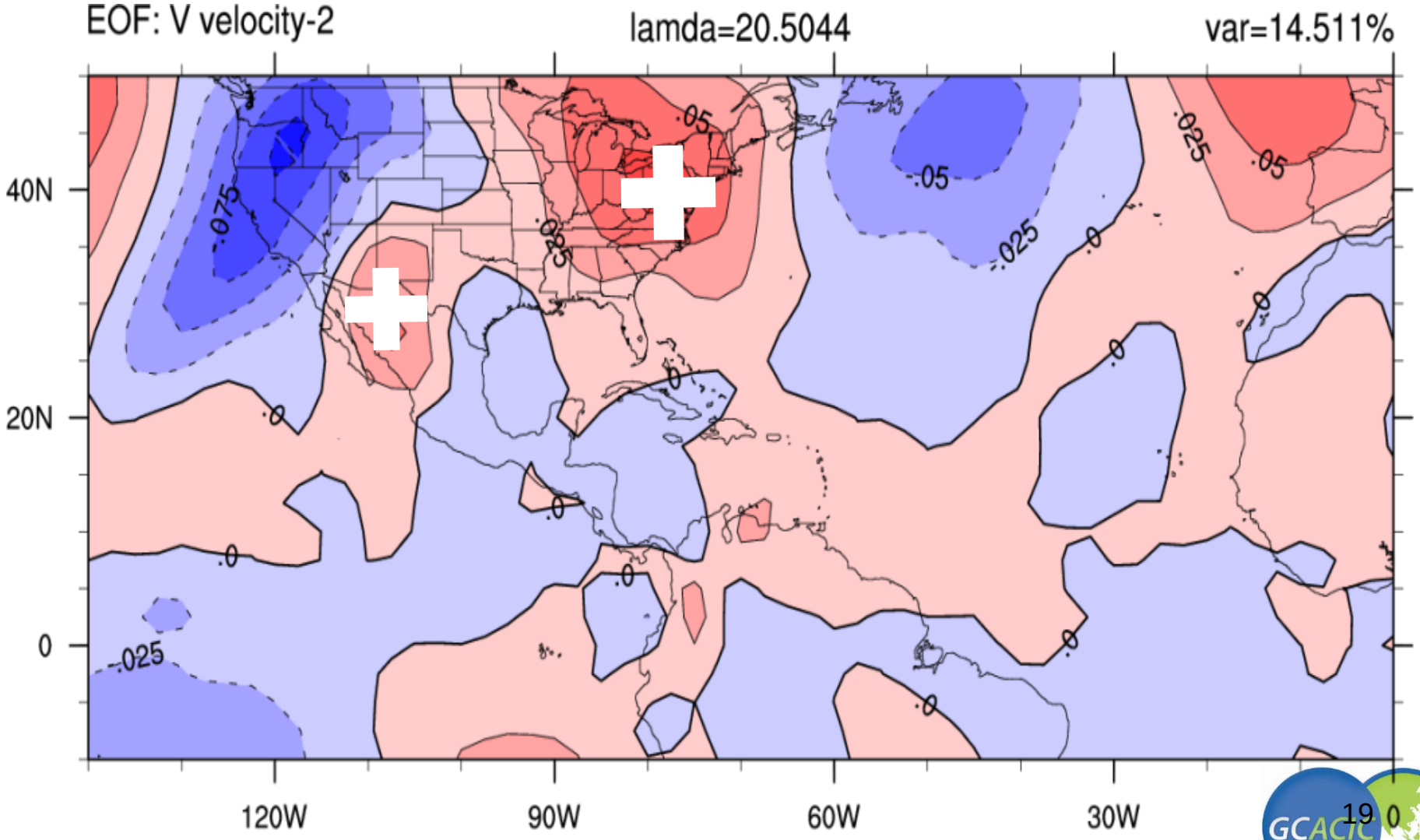




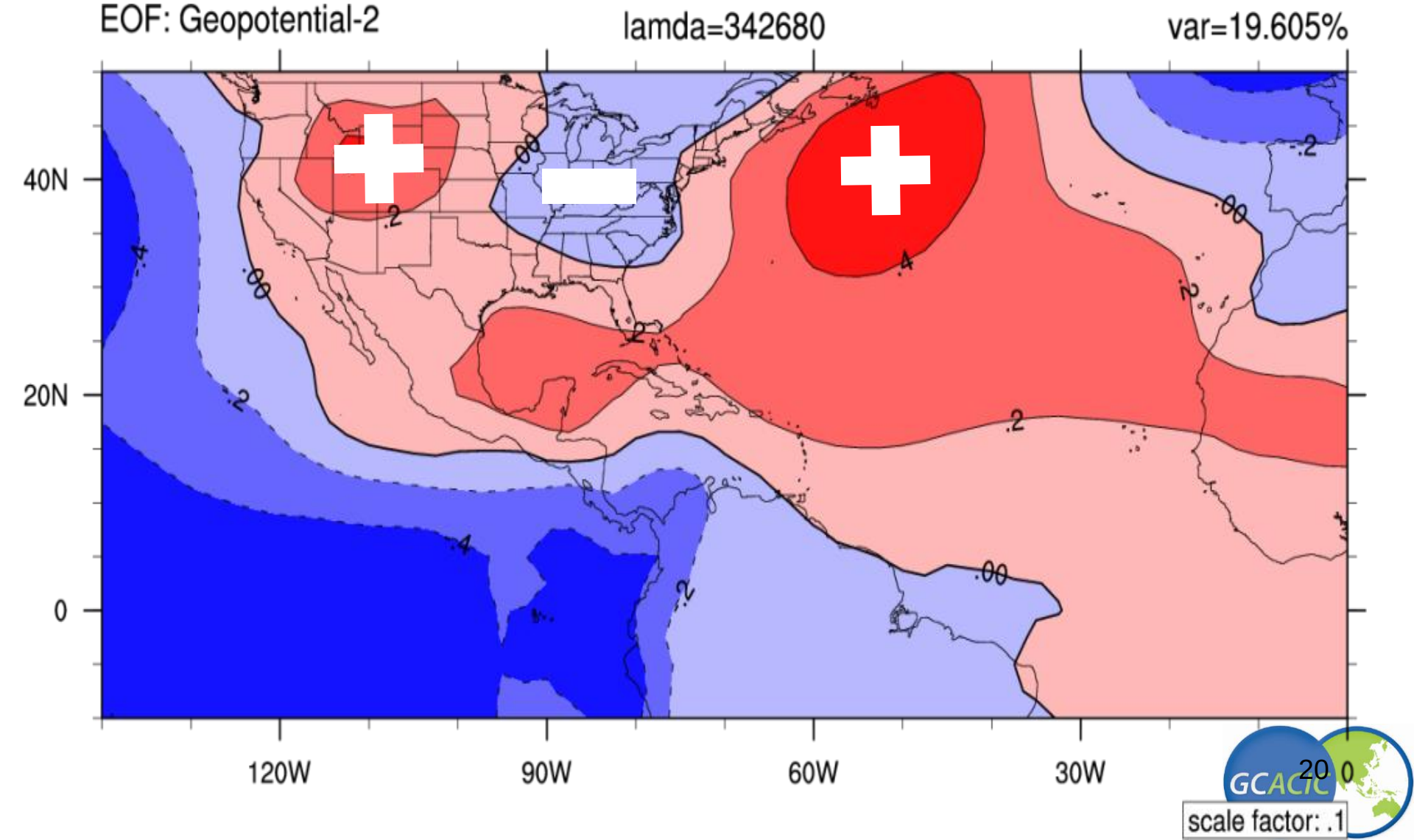
Factors affecting GC landfalling TCs

Level	Parameter	EOF mode
200 hPa	zonal wind	1
	meridional wind	2
	geopotential	2
500 hPa	zonal wind	2
	meridional wind	2
	geopotential	4
850 hPa	zonal wind	1
	meridional wind	1
	meridional wind	3
	geopotential	2
	geopotential	4
surface	SST	1
	MSLP	2

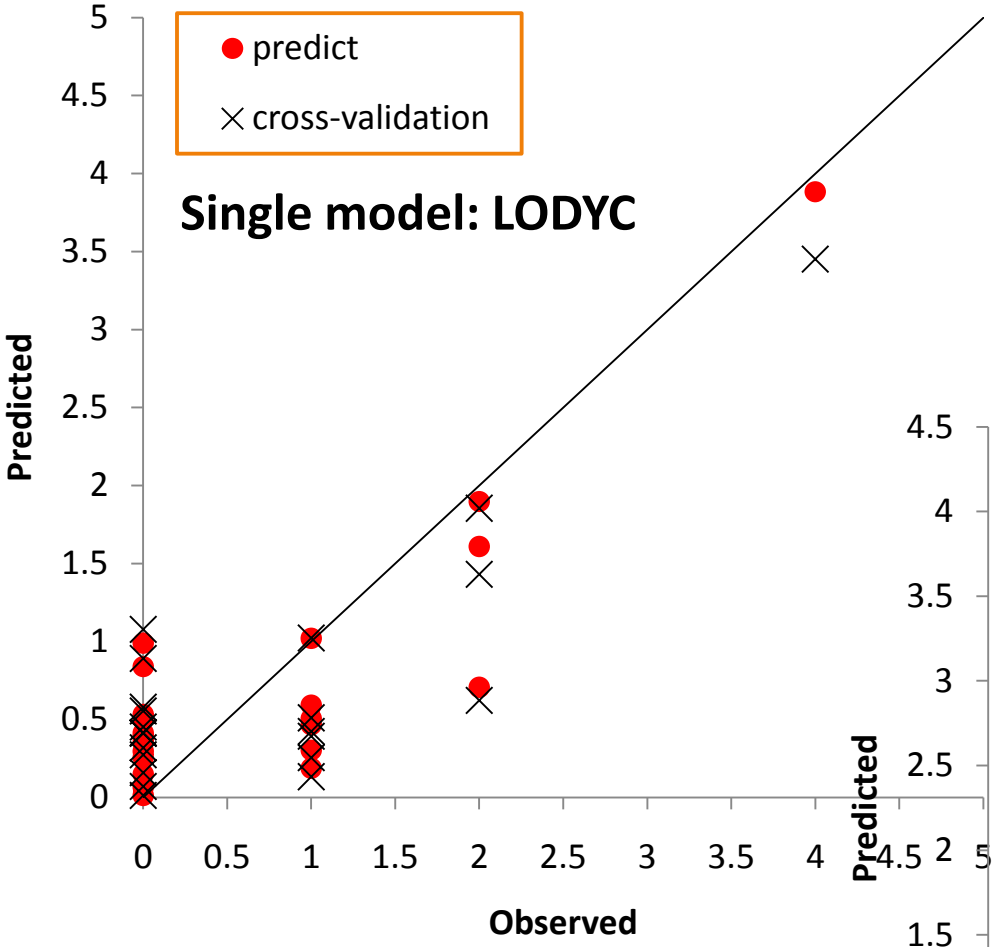
500-hPa meridional wind EOF 2
(-vely correlated with Gulf of Mexico landfall)

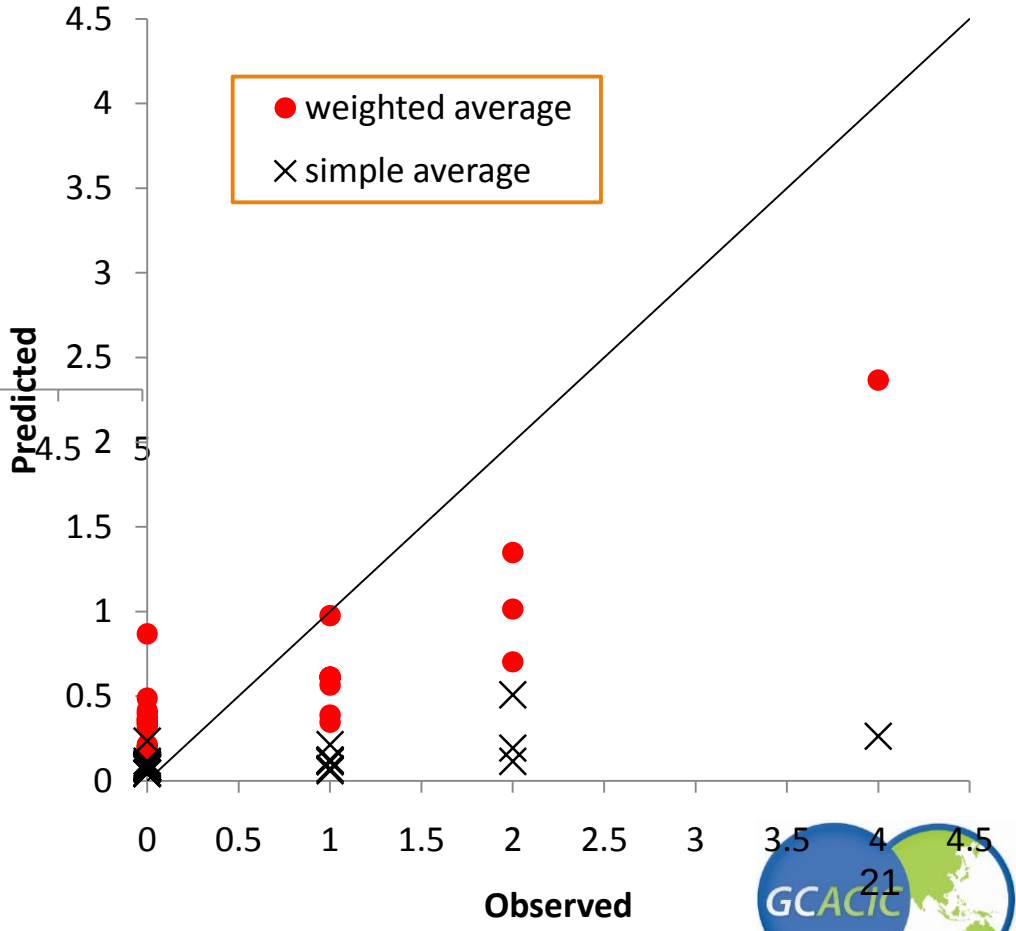


850-hPa geopotential EOF 2
(-vely correlated with Gulf of Mexico landfall)



Observed vs. Predicted Gulf Coast

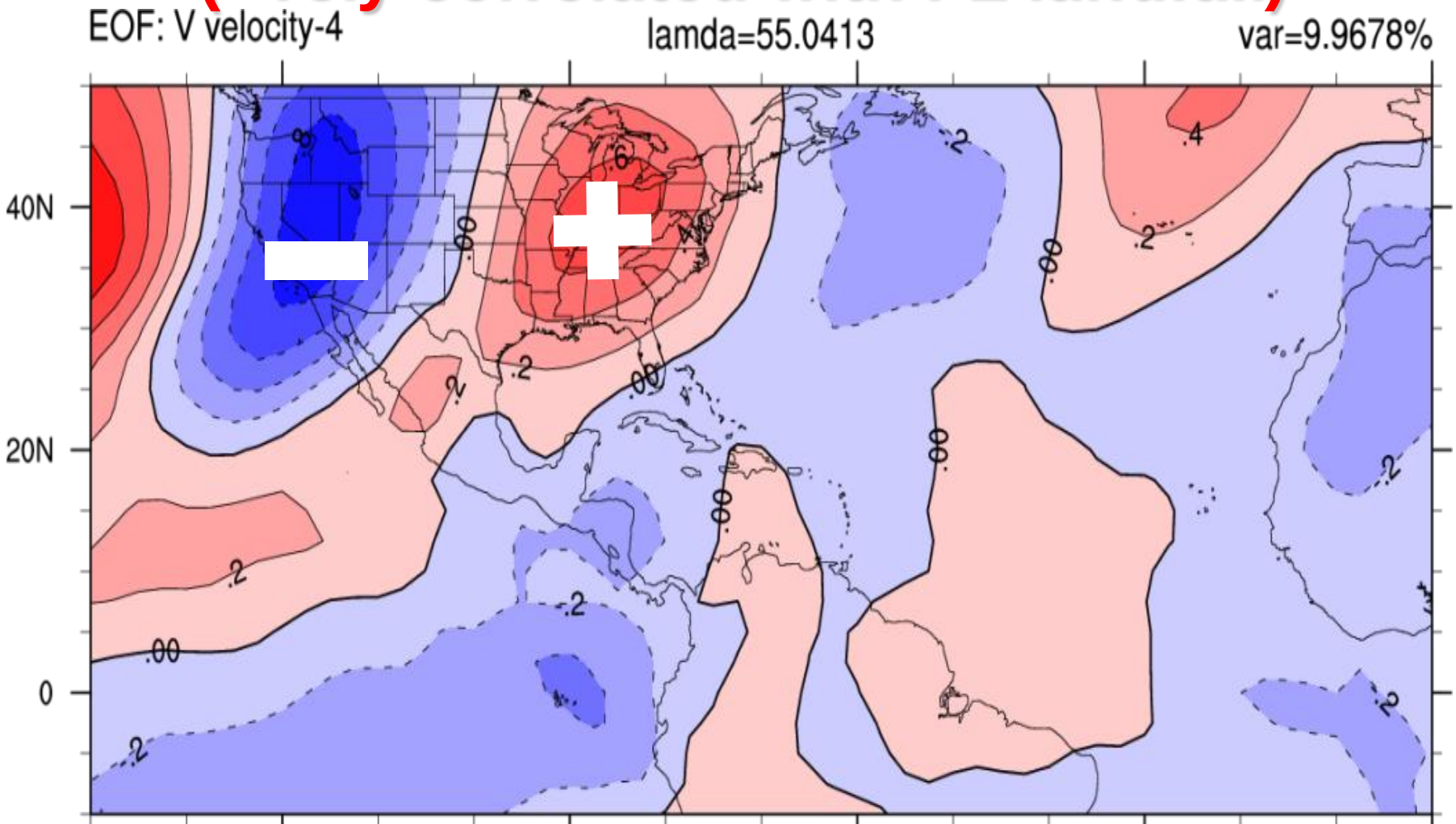




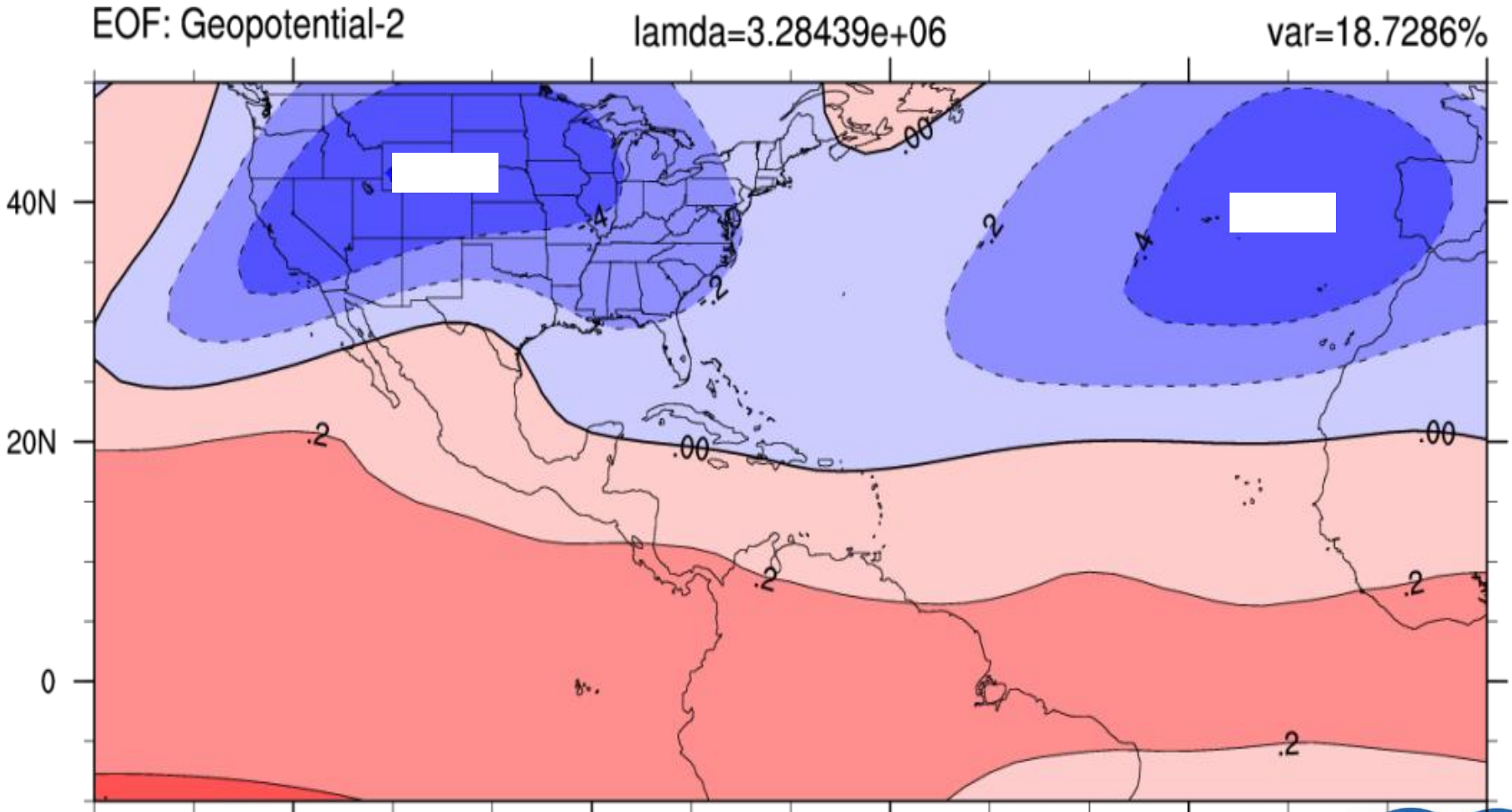
Factors affecting FL landfalling TCs

Level	Parameter	EOF mode
200 hPa	zonal wind	1
	meridional wind	2
	meridional wind	4
	geopotential	2
500 hPa	zonal wind	2
	meridional wind	3
850 hPa	zonal wind	1
	zonal wind	2
	geopotential	2
	geopotential	3
surface	SST	1
	SST	3
	MSLP	2

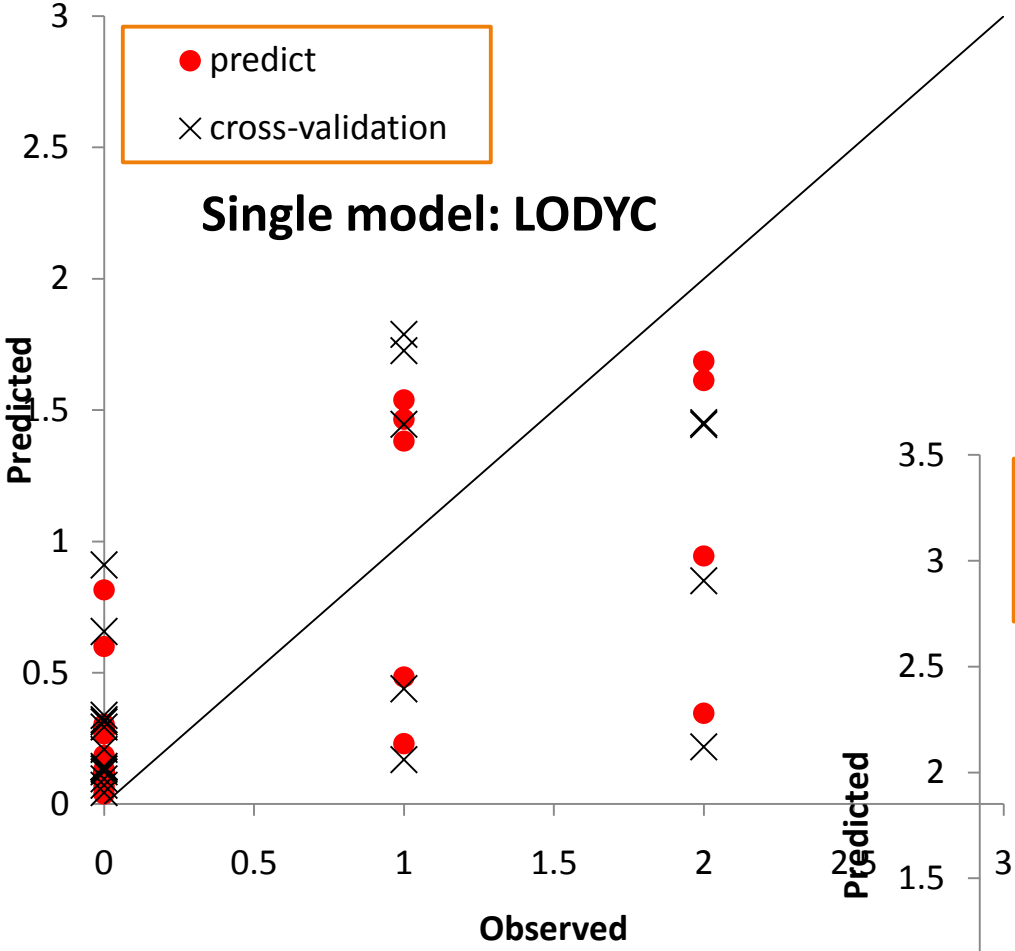
850-hPa meridional wind EOF 4 (+vely correlated with FL landfall)

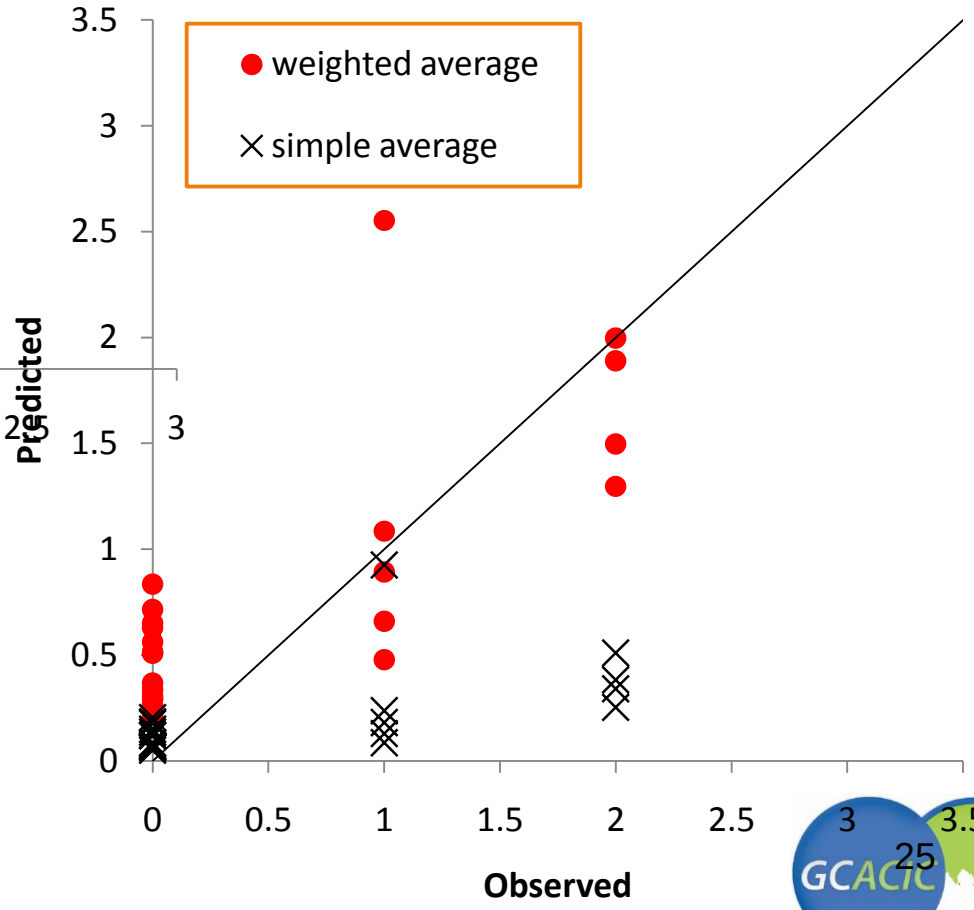


200-hPa geopotential EOF 2
(-vely correlated with FL landfall)



Observed vs. Predicted Florida





Summary

- A statistical-dynamical prediction scheme for U.S. landfalling TCs has been developed.
- Statistics
  - Significant skills over climatology:
    EC ~30%, GC ~40% and FL ~17%
  - Fair high agreement coefficient
    EC ~0.45, GC ~0.44 and FL ~0.34
- Most of the predictors are physically reasonable and are mostly related to the steering flow

Poission regression

Prob(# landfalling TC = y)

$$\Pr(y) = \frac{e_i^y \exp(-e_i)}{y!}$$

Expected # landfalling TCs

$$e_i = \exp\left(\beta_0 + \sum_j \beta_j x_{ij}\right)$$

Regression equation:

$$\ln(e_i) = \beta_0 + \sum_j \beta_j x_j + \varepsilon_i$$

Newton-Raphson iterative method (Wilks 2006)

$$\begin{pmatrix}\beta_0^{new}\\ \beta_1^{new}\end{pmatrix} = \begin{pmatrix}\beta_0\\ \beta_1\end{pmatrix} - \begin{pmatrix}-\sum_i e_i & -\sum_i x_i e_i\\ -\sum_i x_i e_i & -\sum_i x_i^2 e_i\end{pmatrix}^{-1} \begin{pmatrix}\sum_i (o_i - e_i)\\ \sum_i x_i (o_i - e_i)\end{pmatrix}$$

Residual deviance

$$D = 2\sum_i o_i \log\left(\frac{o_i}{e_i}\right)$$

Smaller the D, better the reg. eqt.

Skill over climatology

$$S = \left(1 - \frac{RMSE_{scheme}}{RMSE_{clim}}\right) \times 100\%$$

Agreement coefficient

$$A = 1 - \frac{\frac{1}{n}\sum_i |o_i - c_i|}{\frac{1}{n}\sum_i \frac{1}{n}\sum_k |o_i - c_k|}$$