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# Seasonal Tropical Cyclone Activity Prediction: Where We Stand & the Way Forward

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# Outline

- **Statistical methods – where we stand**
- **Statistical dynamical method**
- **Dynamical methods**
- **Summary**

# Statistical Method: Where We Stand

# Statistical method

- **Identify a list of variables relating to the atmospheric and oceanographic conditions prior to the season that significantly correlate with seasonal tropical cyclone activity**
- **Perform regressions to derive prediction equations**

# Examples of Predictors used in the CityU Forecasts

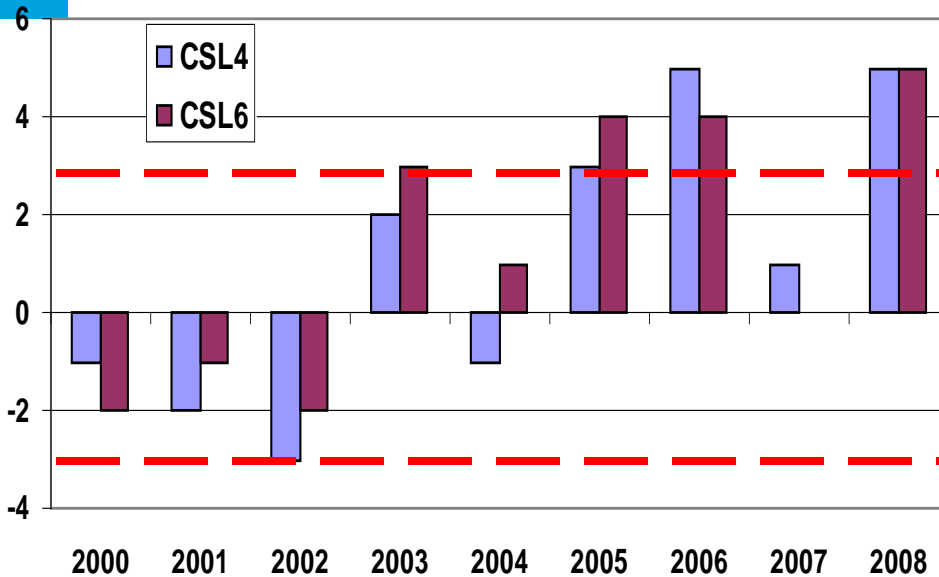
## large-scale atmospheric conditions

- **Index of the westward extent of the subtropical high over the western North Pacific**
- **Index of the strength of the India-Burma trough (15-20°N, 80-120°E)**
- **West Pacific index**

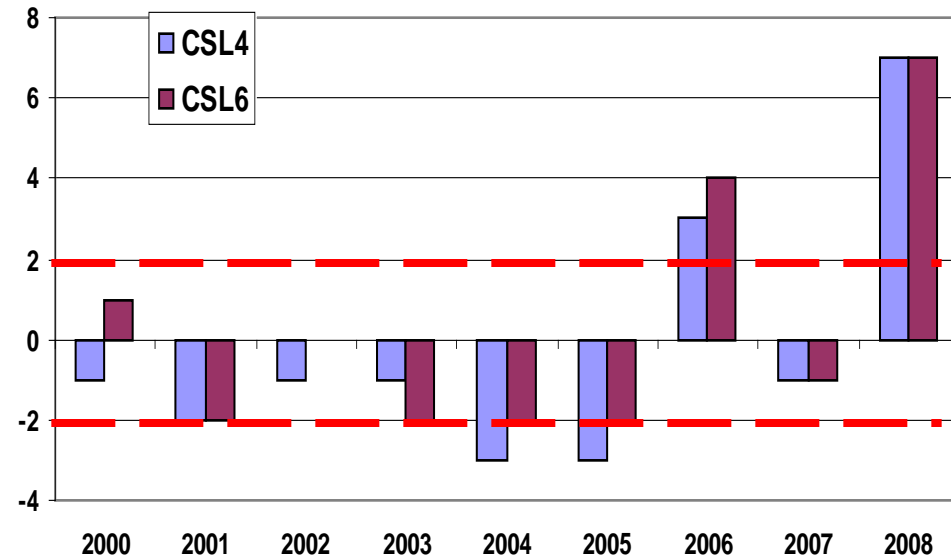
- **Sea surface temperature (SST) anomalies in the NINO3.4 region (5°S-5°N, 170-120°W)**
- **Sea surface temperature (SST) anomalies in the NINO4 region (5°S-5°N, 160°E-150°W)**
- **Equatorial Southern Oscillation Index (Equatorial SOI)**
- **Equatorial Eastern Pacific SLP - Indonesia SLP (standardized anomalies)**

## ENSO conditions

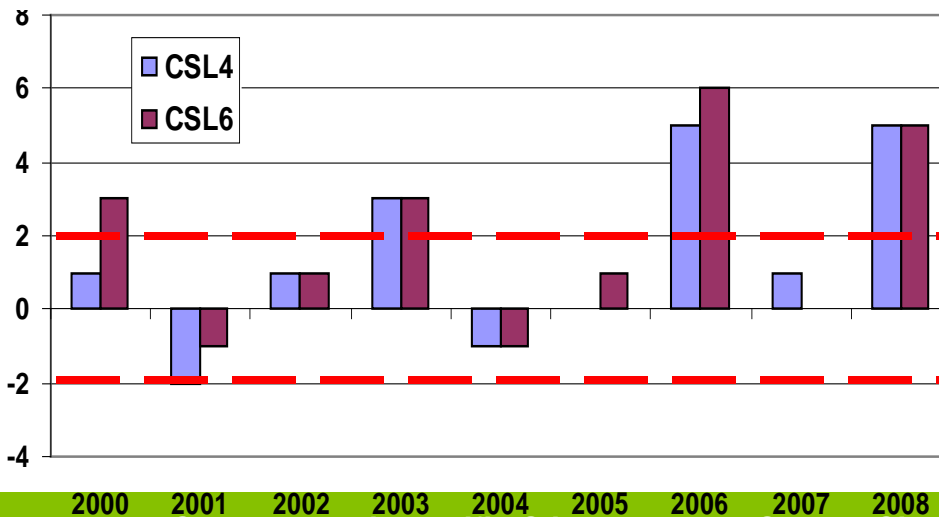
## All tropical cyclones



## Typhoons



## Tropical storms and typhoons



**Forecasts of Annual Tropical Cyclone Activity over the western North Pacific (Deviations from Observations)**

# Predictors used in the Tropical Storm Risk Forecasts

- **Tropical storm and typhoon (before May): Nino3 SST from prior September**
- **Tropical storm and typhoon (from May): April MSLP within (17.5-35°N, 160°E-175°W); forecast number of intense typhoons for that year**
- **Intense typhoons (before May): Mar and Apr MSLP within (10-20°N, 145-165°W);**
- **Intense typhoons (from May): Predicted SST for Aug and Sep within (5°S-5°N, 140-180°W)**

# Forecasts from Tropical Storm Risk

## NW Pacific ACE Index and System Numbers 2009

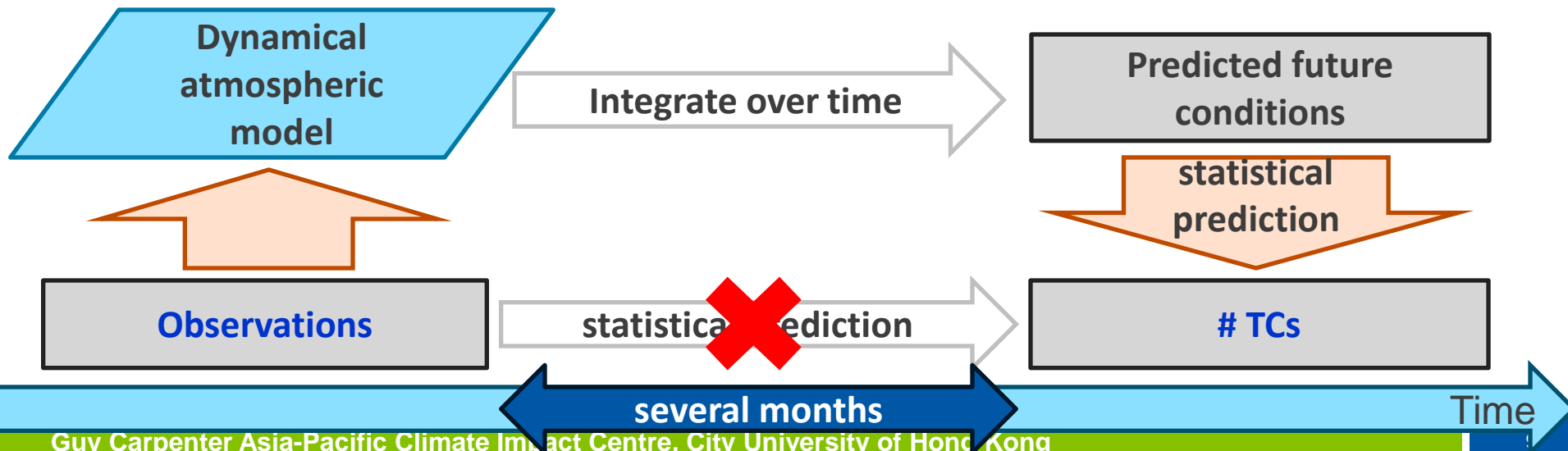
		ACE Index ( $\times 10^4$ knots <sup>2</sup> )	Intense Typhoons	Typhoons	Tropical Storms
Average Number ( $\pm$ SD) (1965-2008)		300 ( $\pm$ 98)	8.6 ( $\pm$ 3.0)	16.7 ( $\pm$ 3.6)	26.6 ( $\pm$ 4.3)
TSR Forecasts ( $\pm$ FE)	6th Jul 2009	359 ( $\pm$ 83)	10.3 ( $\pm$ 2.4)	18.1 ( $\pm$ 3.0)	28.0 ( $\pm$ 3.9)
	7th May 2009	319 ( $\pm$ 80)	9.1 ( $\pm$ 2.5)	17.6 ( $\pm$ 3.0)	27.5 ( $\pm$ 3.8)
	16th Mar 2009	247 ( $\pm$ 89)	6.7 ( $\pm$ 2.6)	16.0 ( $\pm$ 3.4)	25.6 ( $\pm$ 3.9)
Chan Forecasts	24th Jun 2009	-	-	19	27
	18th Apr 2009	-	-	18	27

An aerial photograph of a forest with a large tree stump in the center. The text "Statistical Dynamical Method" is overlaid in white on a semi-transparent grey background.

# Statistical Dynamical Method

# 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**



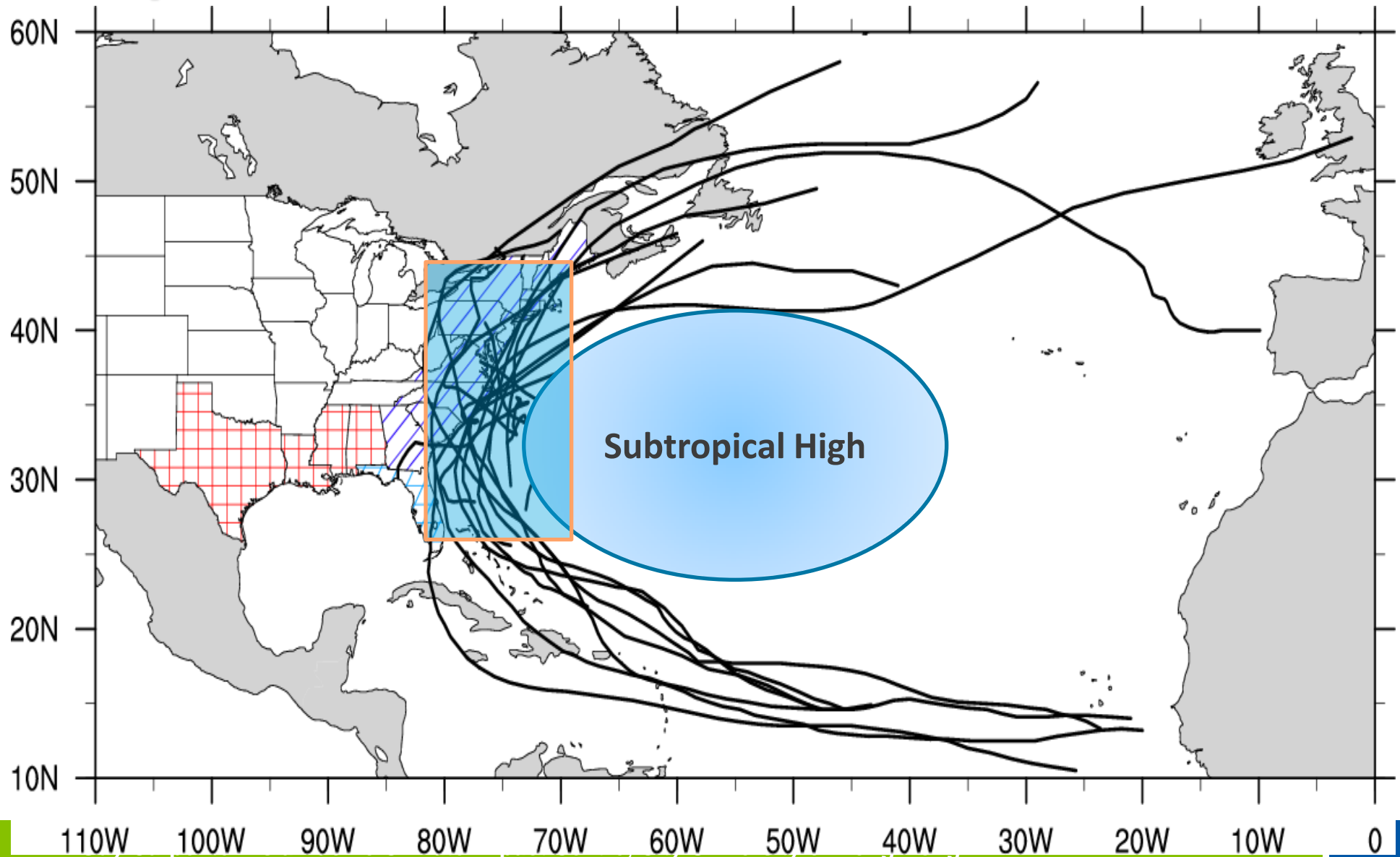
# Dynamical model data – DEMETER

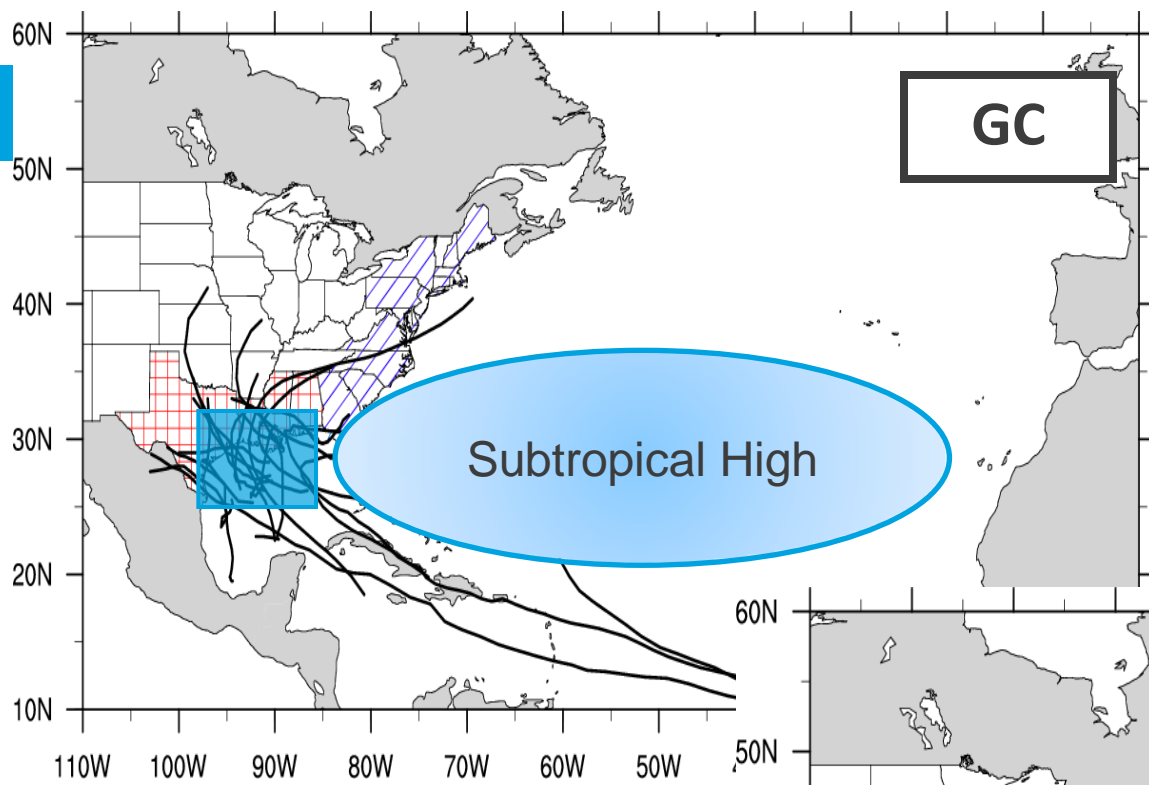
- **Development of a European multimodel ensemble system for seasonal to interannual prediction (from European Union)**
  - **7 models (CERFACS, ECMWF, INGV, LODYC, Météo-France, MPI and UKMO)**
  - **9 ensemble members each**
  - **6 months forecasts available**
  - **Base time @ 1 Feb, May, Aug, Nov**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

# Dynamical model data – DEMETER

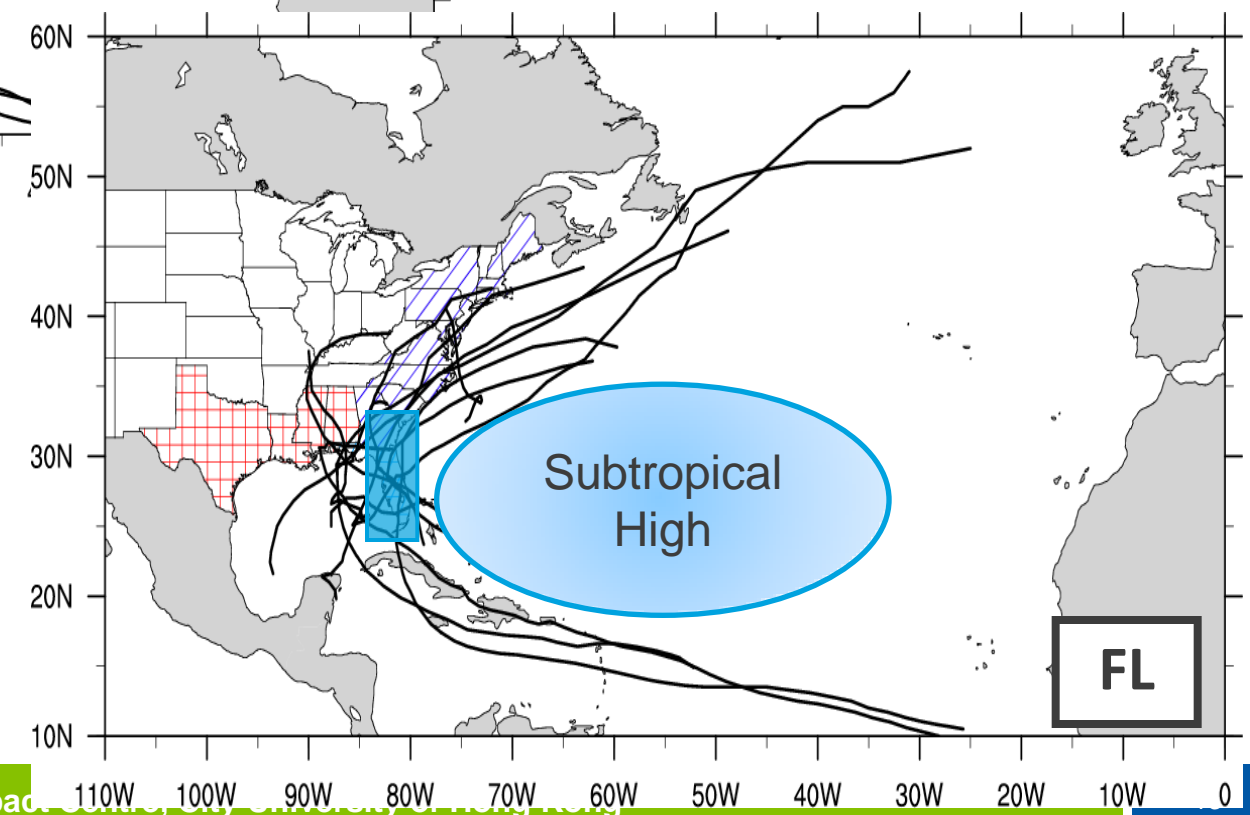
<b>Parameter</b>	<b>Physics</b>
<b>Geopotential (200-, 500-, 850-hPa)</b>	<b>subtropical high</b>
<b>Wind fields (200-, 500-, 850-hPa)</b>	<b>steering flow</b>
<b>SST</b>	<b>TC genesis</b>
<b>Sea-level pressure (SLP)</b>	<b>subtropical high, low for TC genesis</b>

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





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



# Methodology

- **Compute the 9-member ensemble mean of each model-predicted atmospheric fields (Aug-Sept)**
  - **geopotential, zonal and meridional winds (850, 500 and 200 hPa)**
  - **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 the number of landfalling TCs in each region**
  - **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**

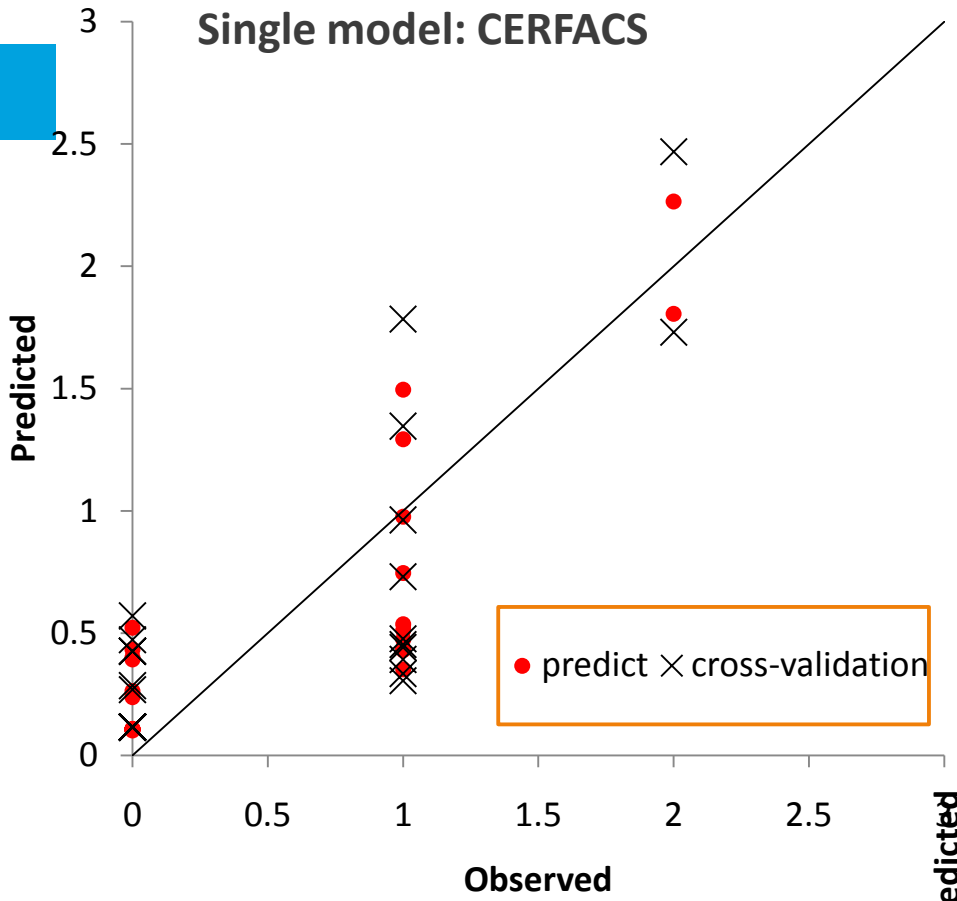
# Factors affecting EC landfalling TCs

## Model CERFACS

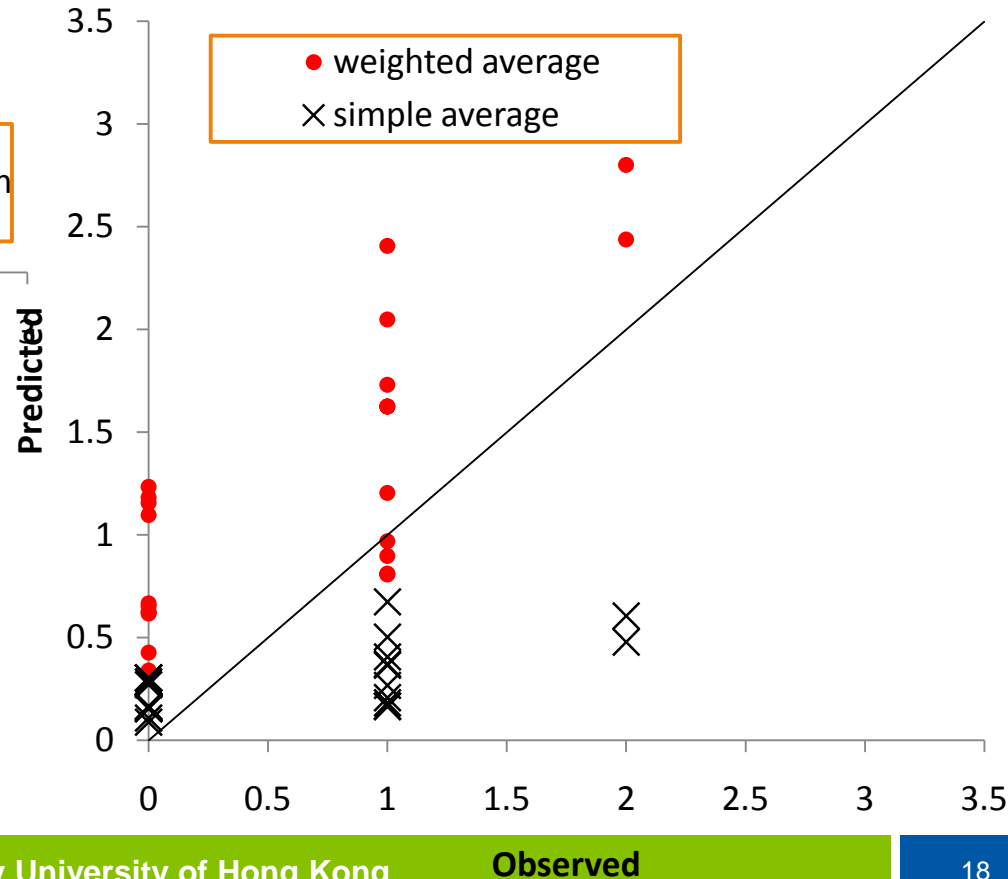
Level	Parameter	EOF mode
200 hPa	zonal wind	1
	zonal wind	3
	geopotential	1
500 hPa	zonal wind	1
	geopotential	1
	geopotential	4
850 hPa	meridional wind	1
surface	SST	1
	MSLP	1

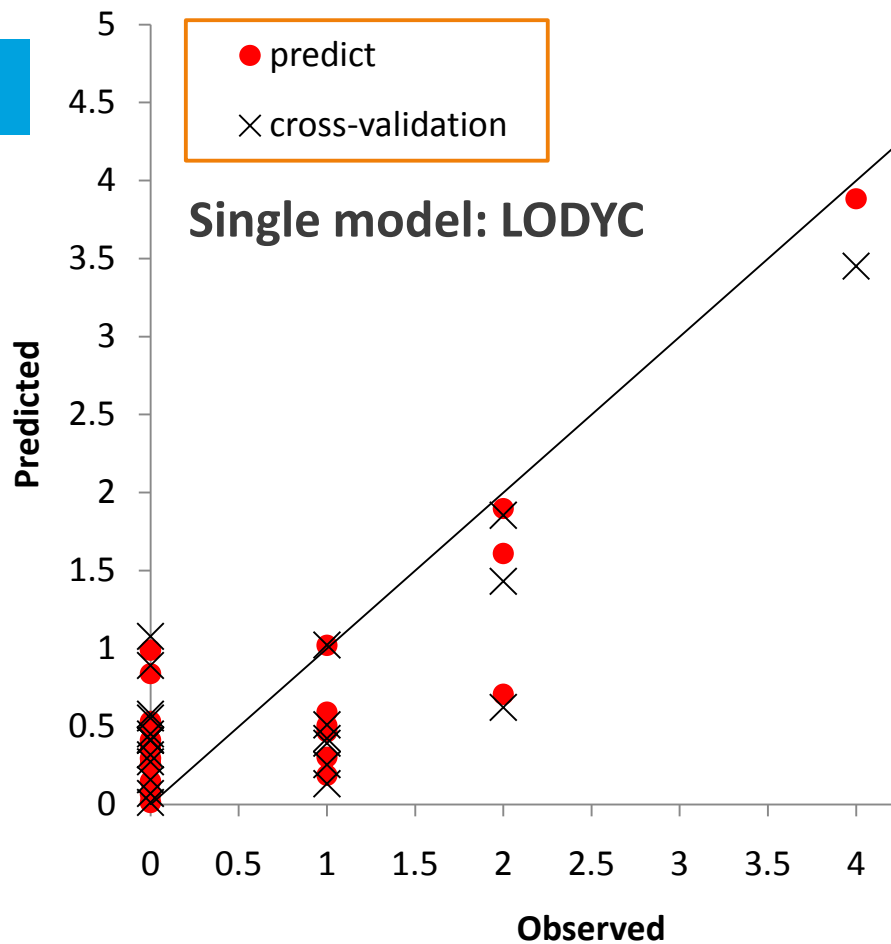
# Observed vs. Predicted East Coast

## Single model: CERFACS

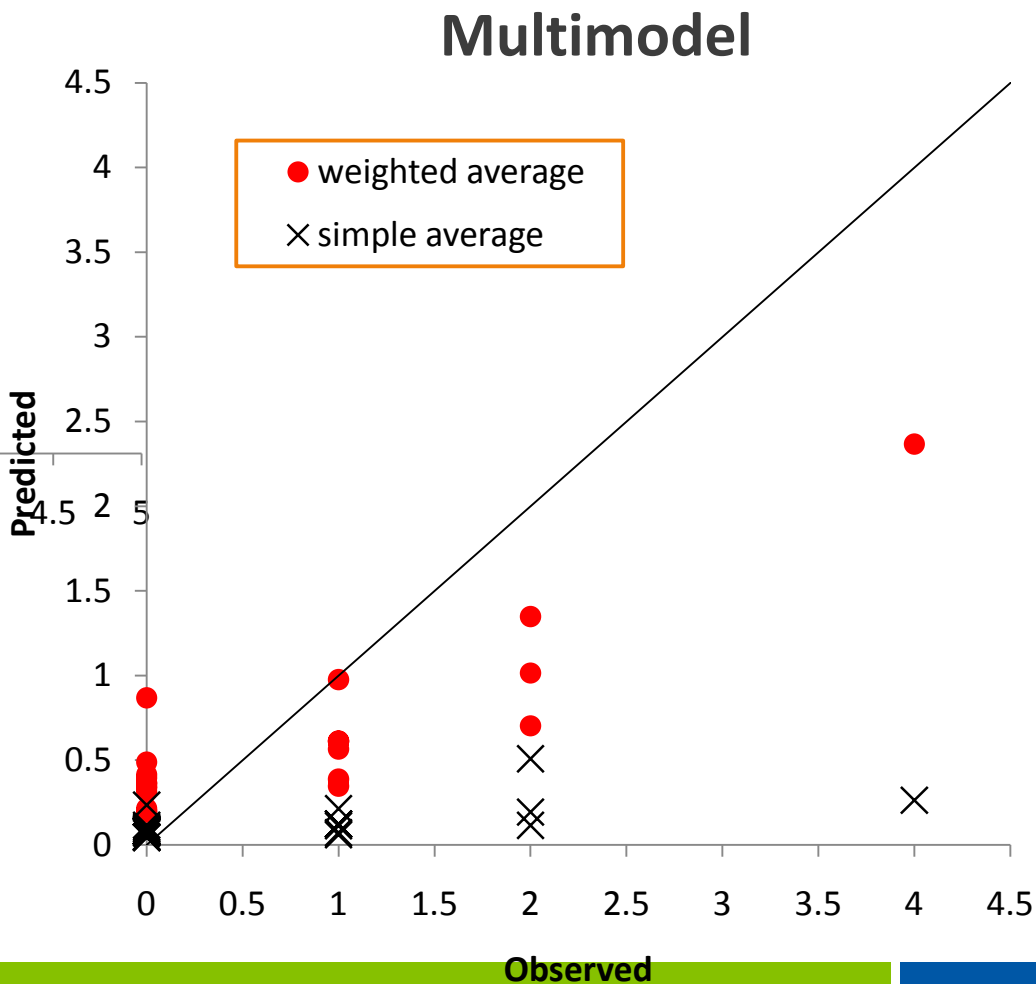


## Multimodel

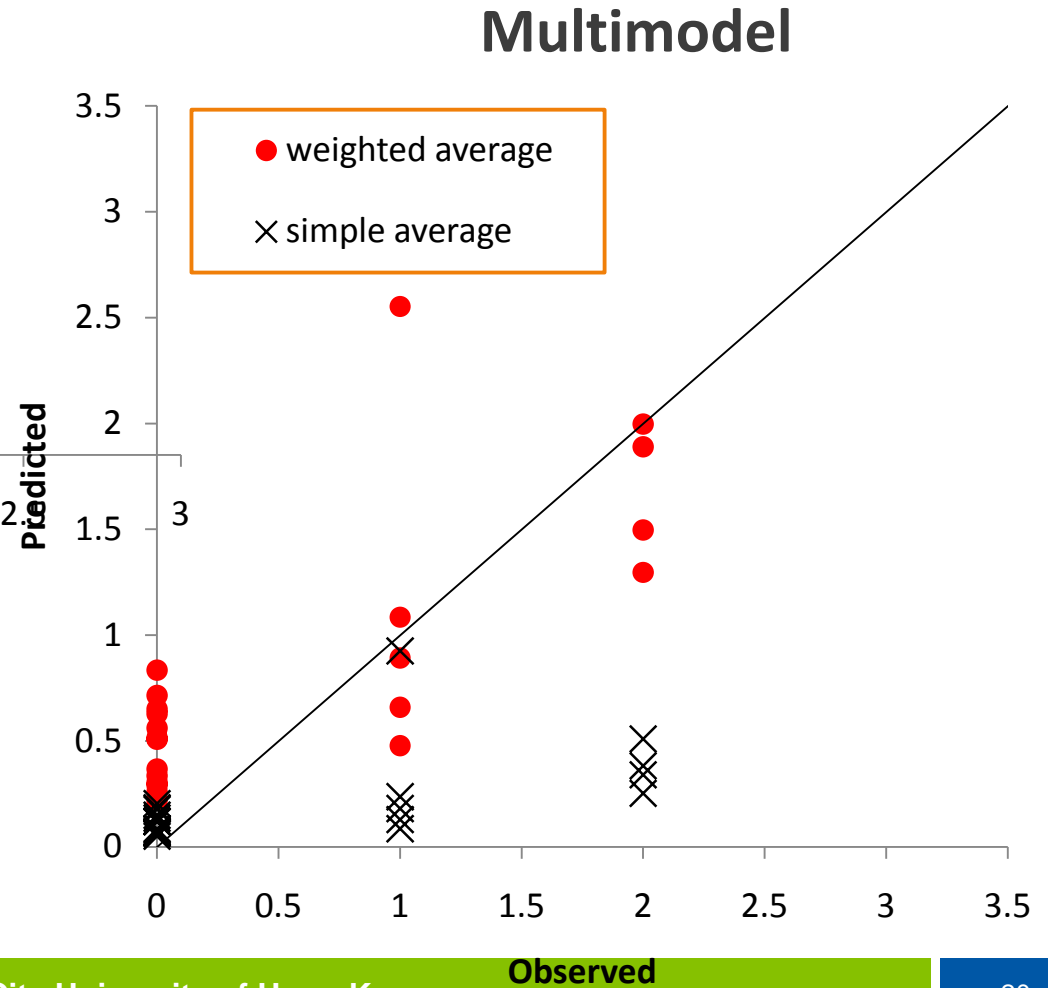
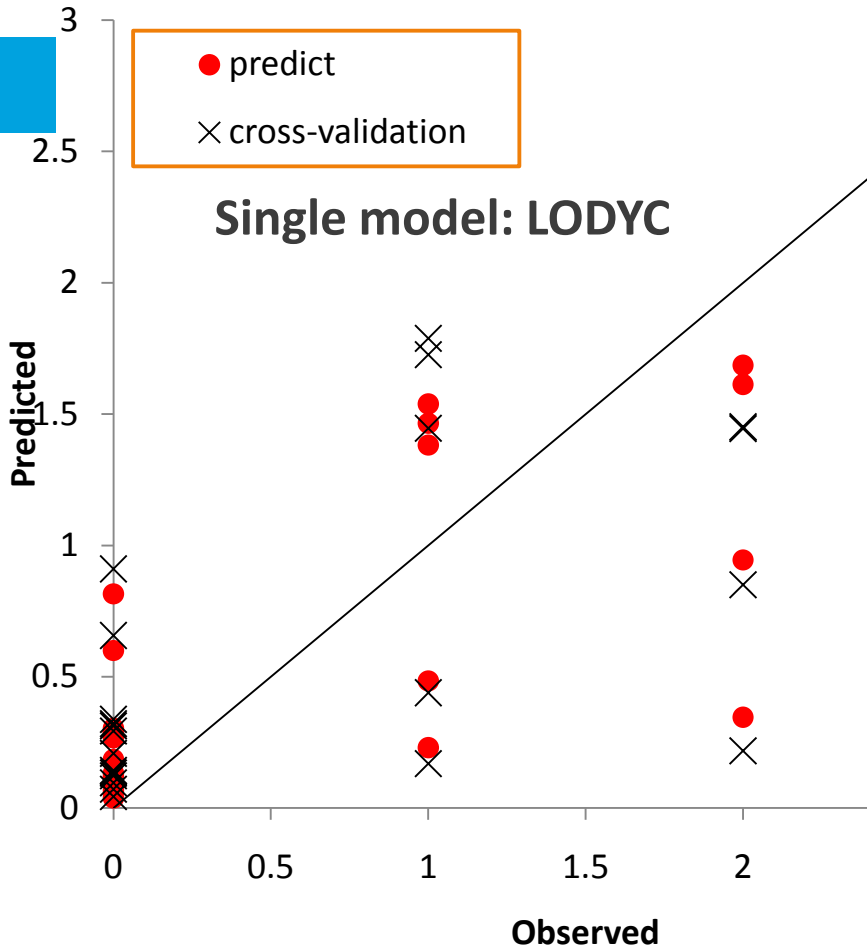




# Observed vs. Predicted Gulf Coast



# Observed vs. Predicted Florida



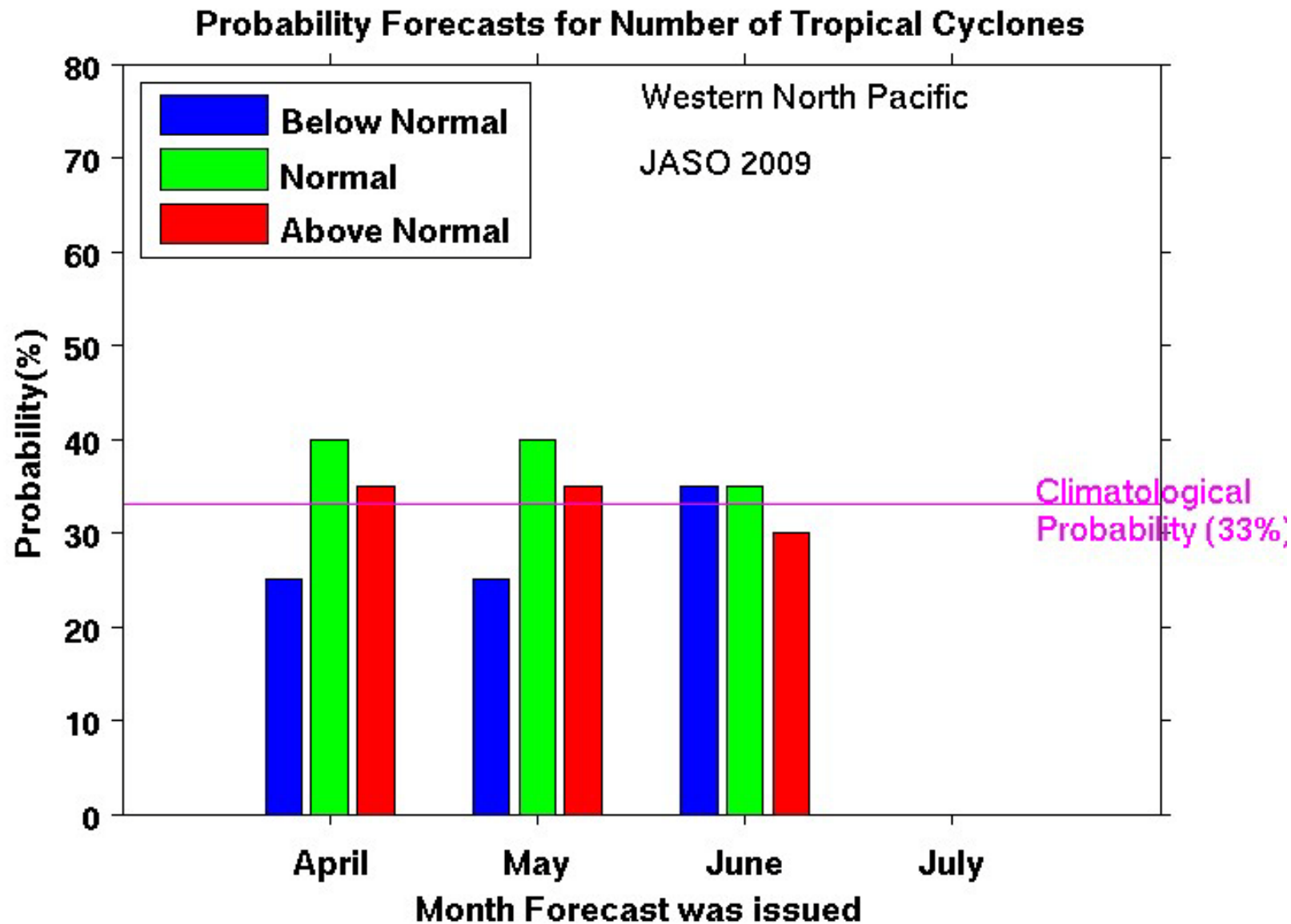
An aerial photograph of a desert landscape, showing a grid of lines overlaid on the terrain. The terrain is arid and rocky, with some small structures or features visible. The grid lines are thin and light-colored, creating a coordinate system over the landscape.

# Dynamical Methods

# Dynamical method (1)

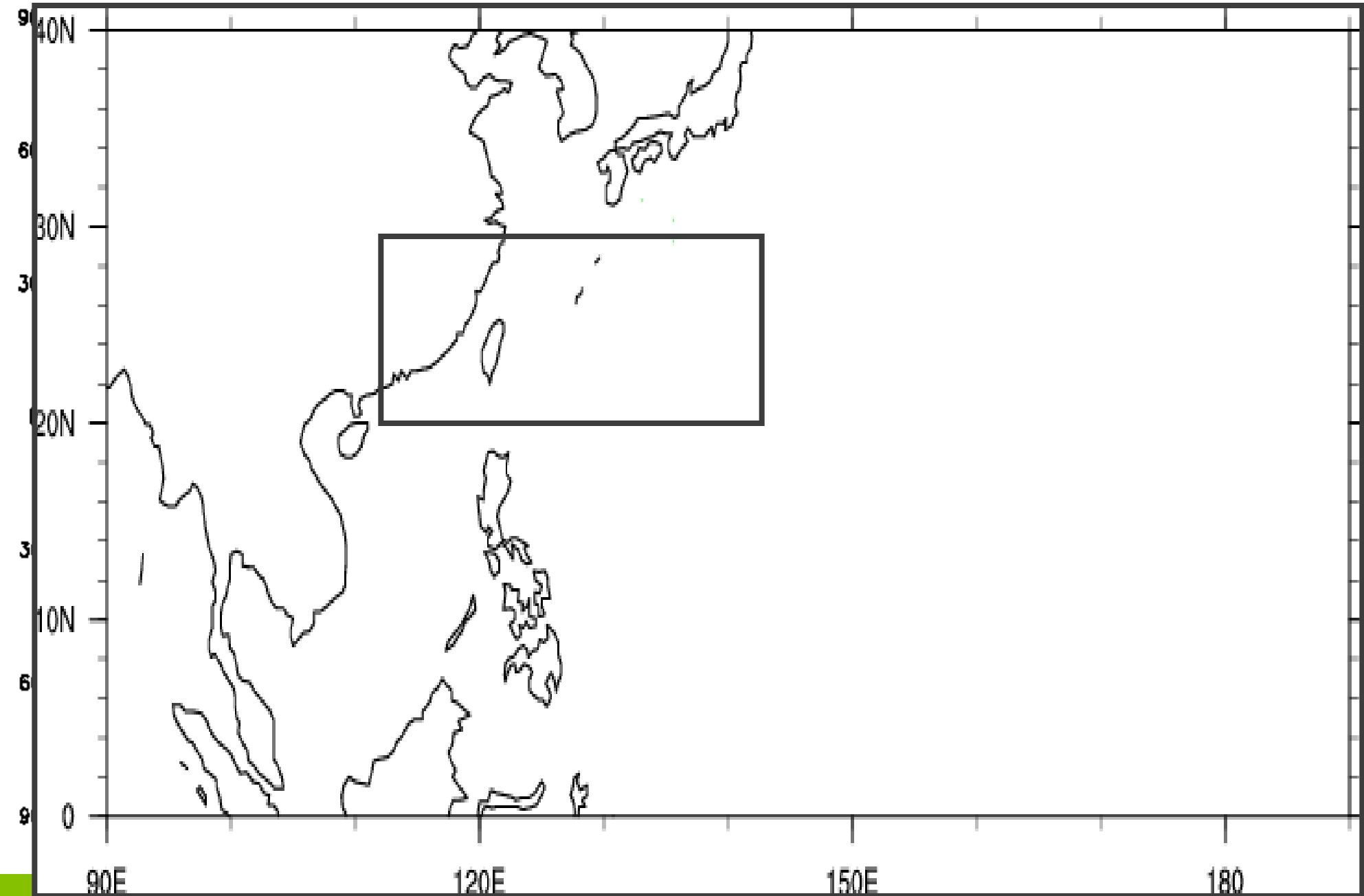
- **Run a global circulation model (GCM)**
- **Identify and count the number of vortices from the model integrations**

# IRI forecasts

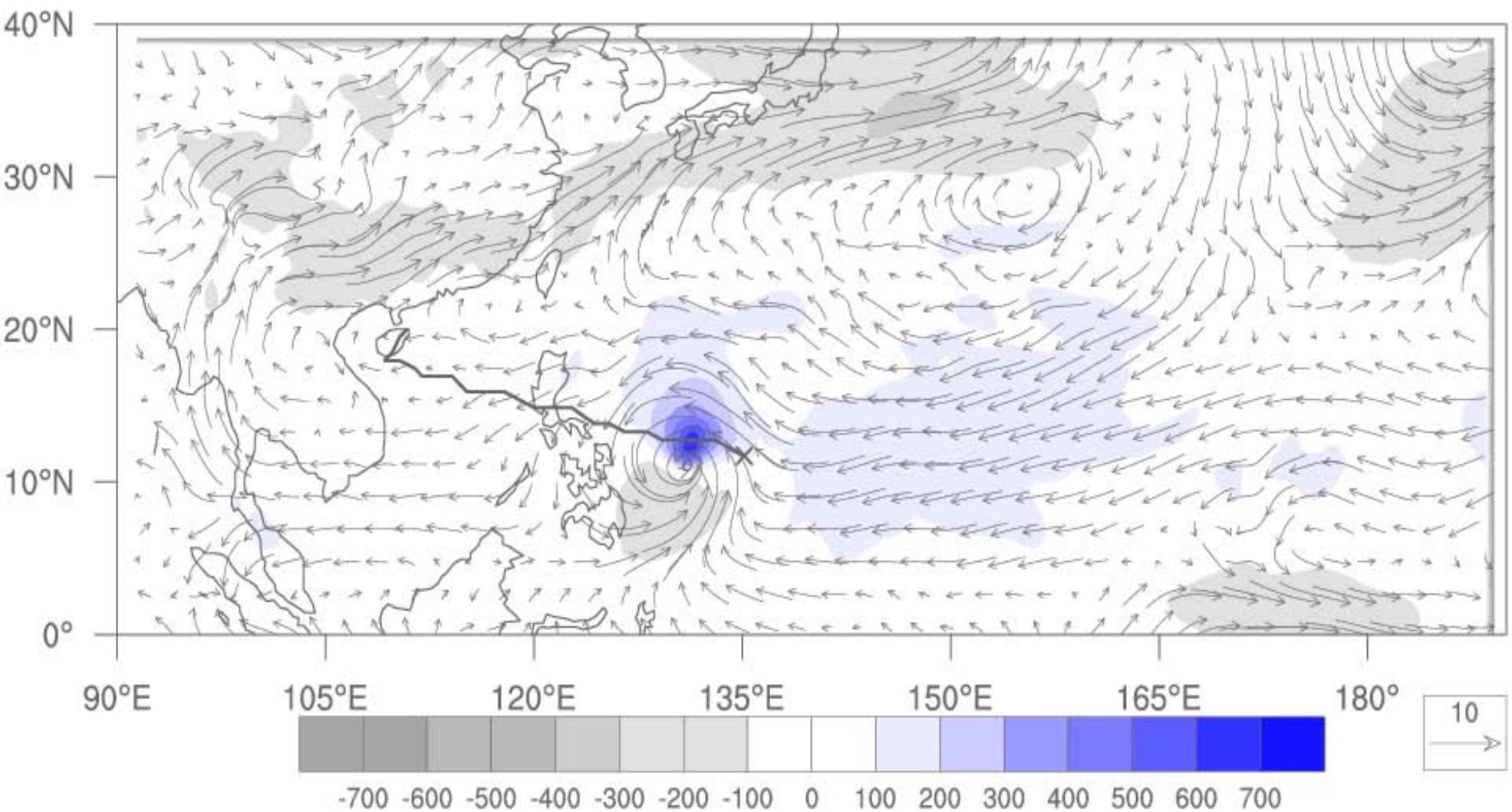


## **Dynamical method (2)**

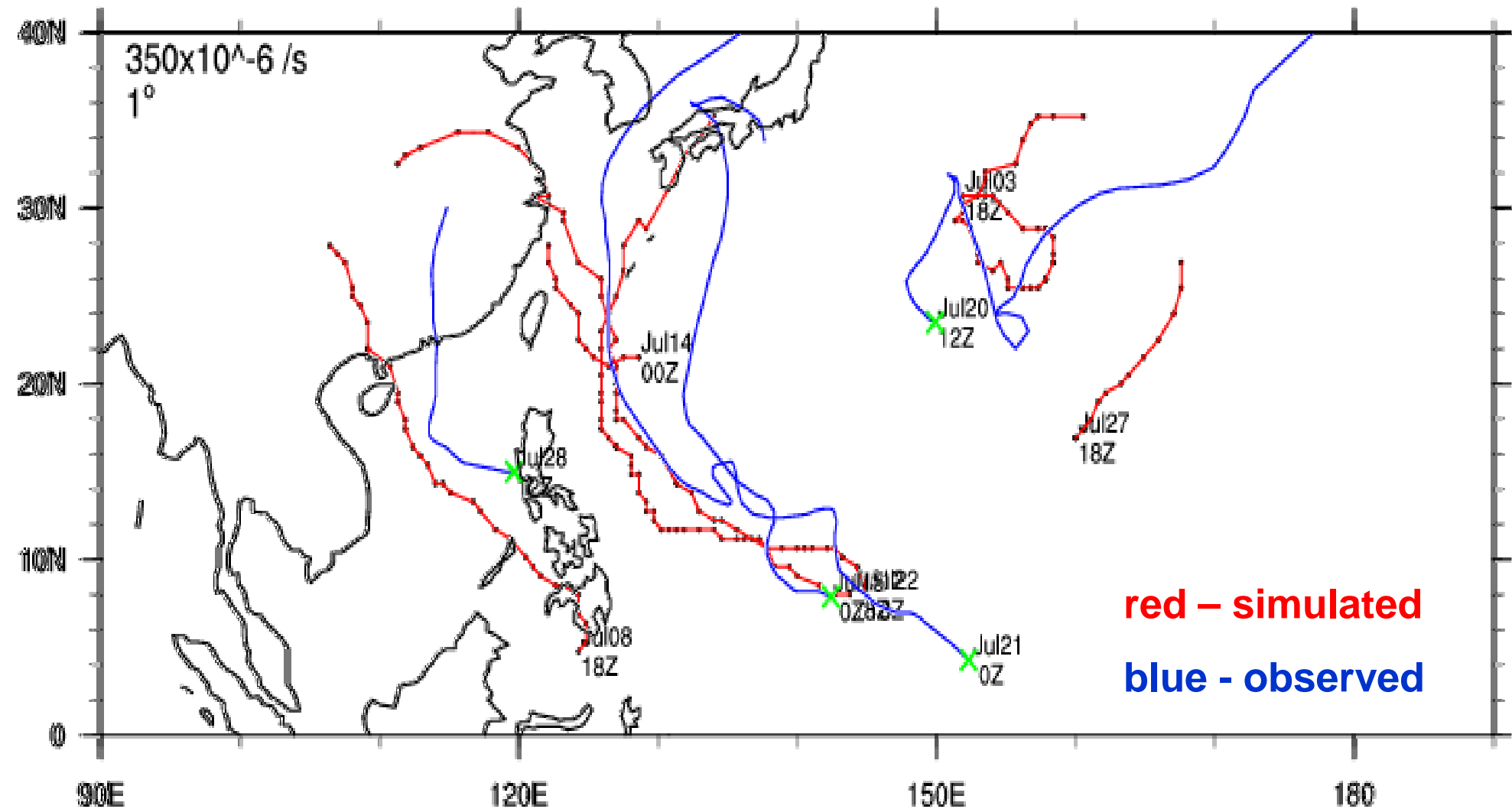
- **Run a global circulation model (GCM) with a relatively coarse resolution**
- **Solutions from the GCM are used as boundary conditions for a regional model with a higher resolution that can “resolve” a tropical cyclone**
- **Integrate the regional model to predict seasonal activity.**



# Example of 850-hPa flow and relative vorticity

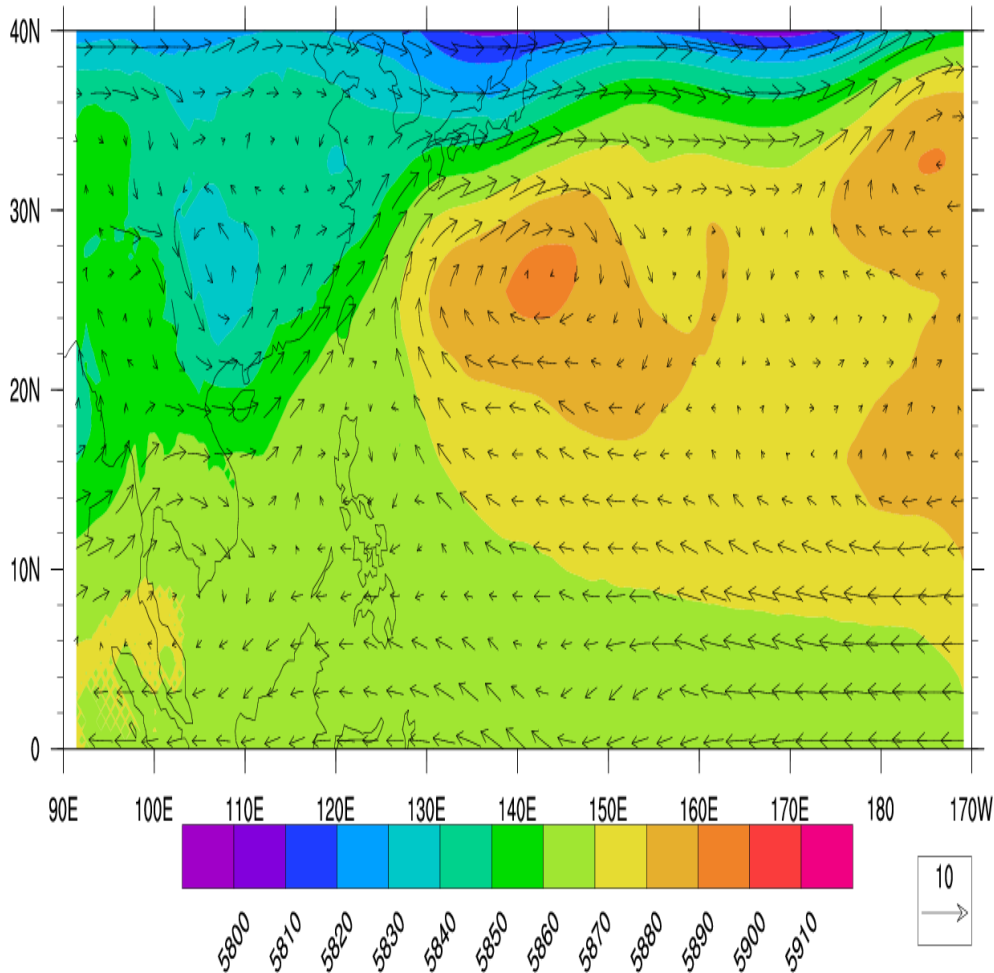


# Example of simulation of a 3-month forecast

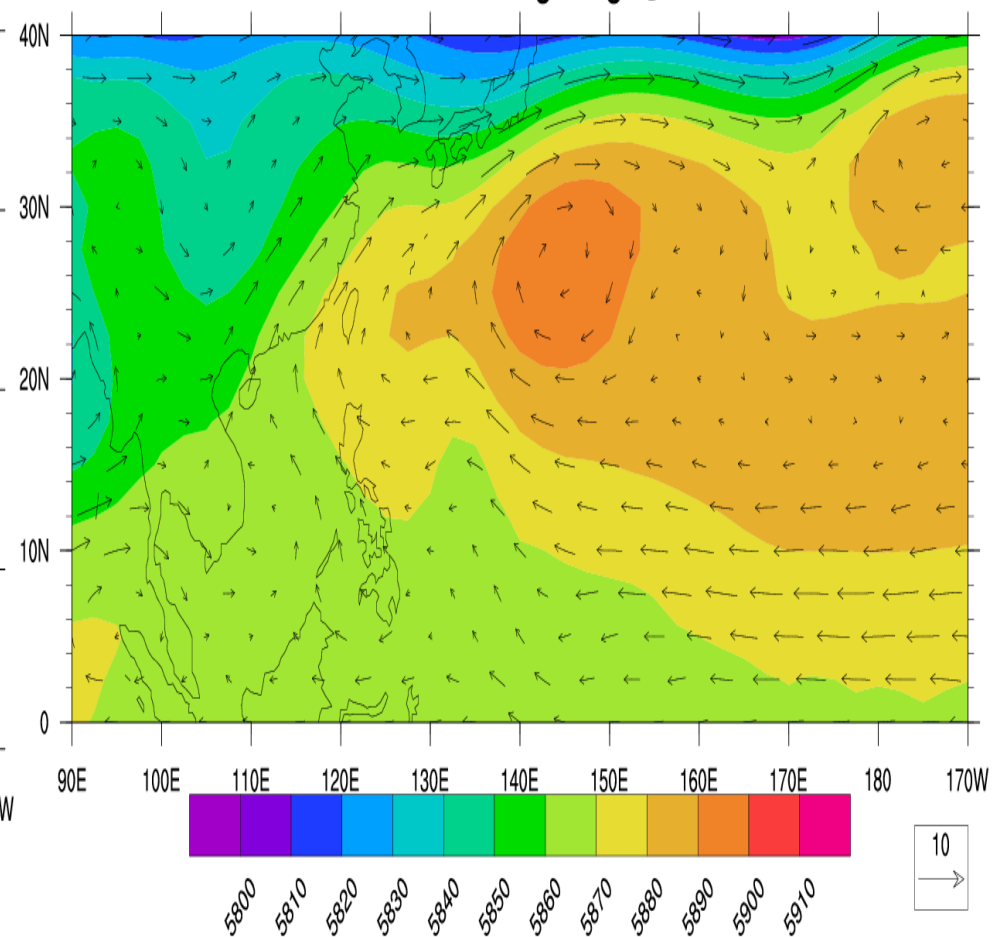


# 500-hPa simulated flow pattern

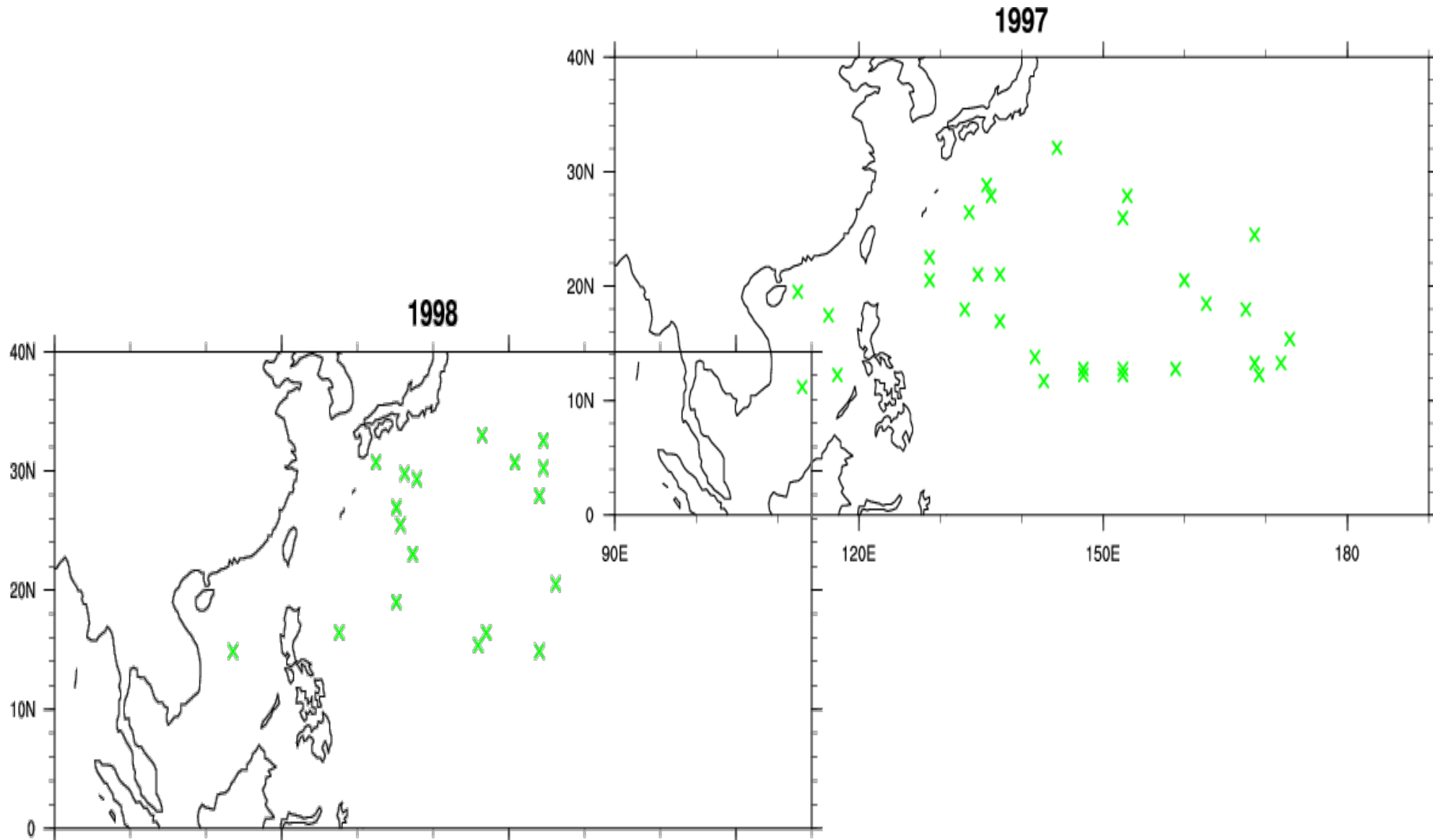
Run\_090616 1997Jul1500Z@500hPa



ERA40 1997JUL ave geo hgt @ 500hPa



# Regional Model Simulations of 1997 and 1998 TCs



# Summary

- **Statistical methods can provide some clues on tropical cyclone activity but suffers from an inherent problem of predicting future events based only on past conditions**
- **Statistical-dynamical methods can provide predictive information and therefore should give better results, but still suffers from the statistical nature of the method.**
- **Dynamical model forecasts should be the way forward to predict tropical cyclone risks although more research is still necessary on fine-tuning the regional model.**