

# Tropical Cyclone Genesis Ensemble Forecasts

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## Acknowledgements:

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# NOAA Seasonal Hurricane Outlook

## NOAA 2013 Atlantic Hurricane Season Outlooks

Activity Type	August Update	May 23 Outlook	NHC 1981-2010 Normals
Chance Above Normal	70%	70%	
Chance Near Normal	25%	25%	
Chance Below Normal	5%	5%	
Named Storms*	13-19	13-20	12
Hurricanes*	6-9	7-11	6
Major Hurricanes	3-5	3-6	3
ACE (% Median)	120-190	120-205	71-120**

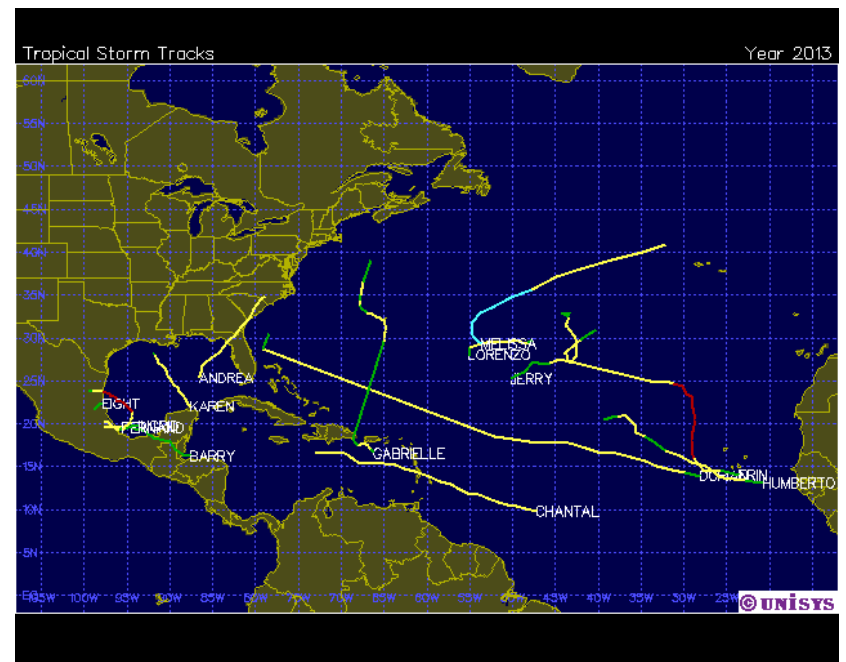
The outlooks indicate a 70% probability for each range of activity.

\* Includes all such storms regardless of strength

\*\*A near-normal season has ACE values of 71%-120% of the median.

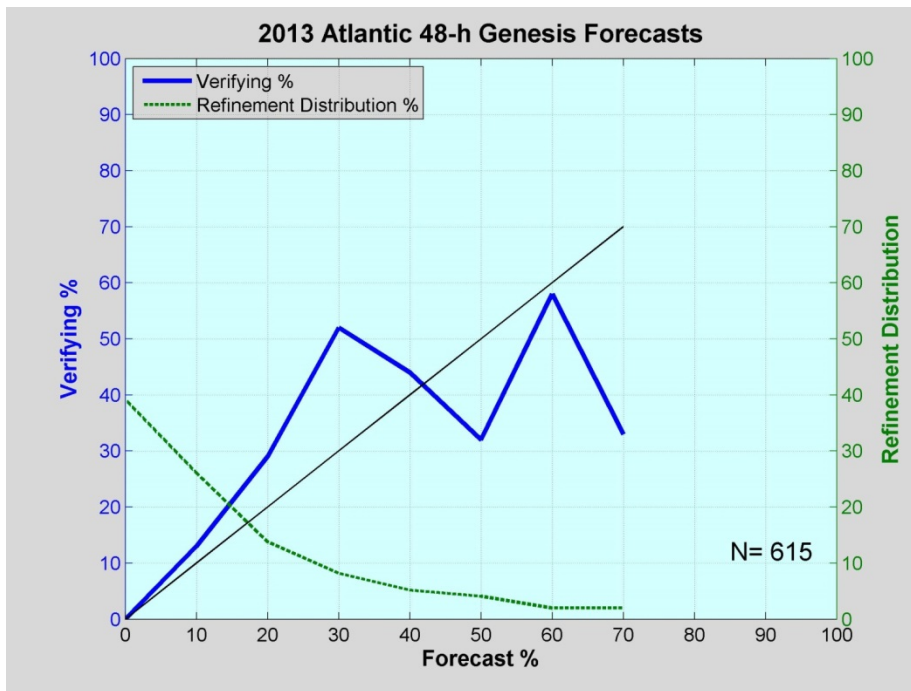
### Observed numbers:

Named storms: **13**  
 Hurricanes: **2**  
 Major Hurricanes: **0**  
 ACE: **36% of median**

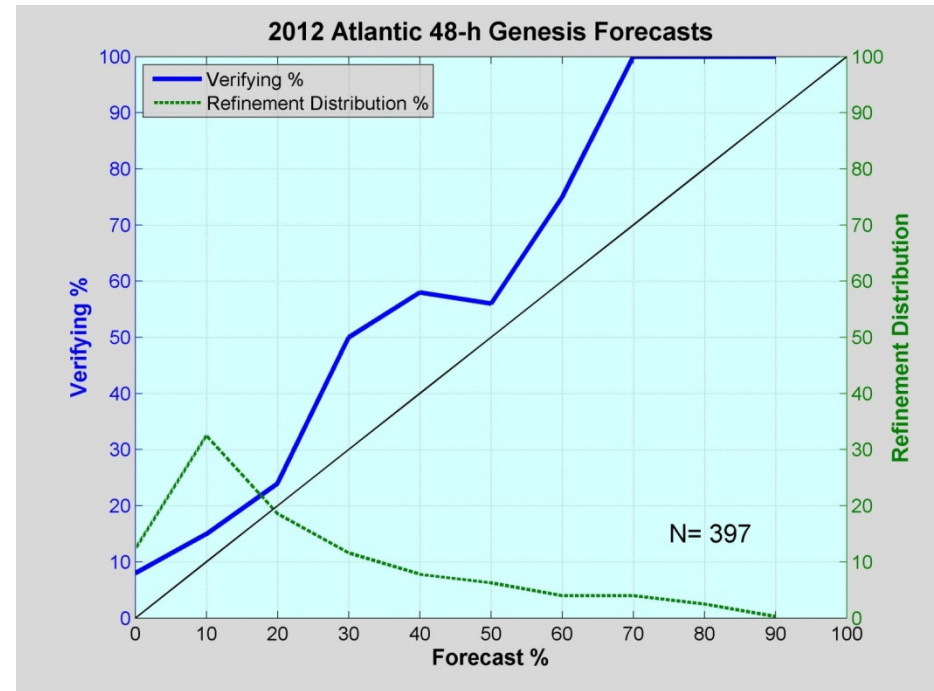


Courtesy of Jon Gottschalck, CPC

# Atlantic TC Genesis Verification(NHC,2013/2012)



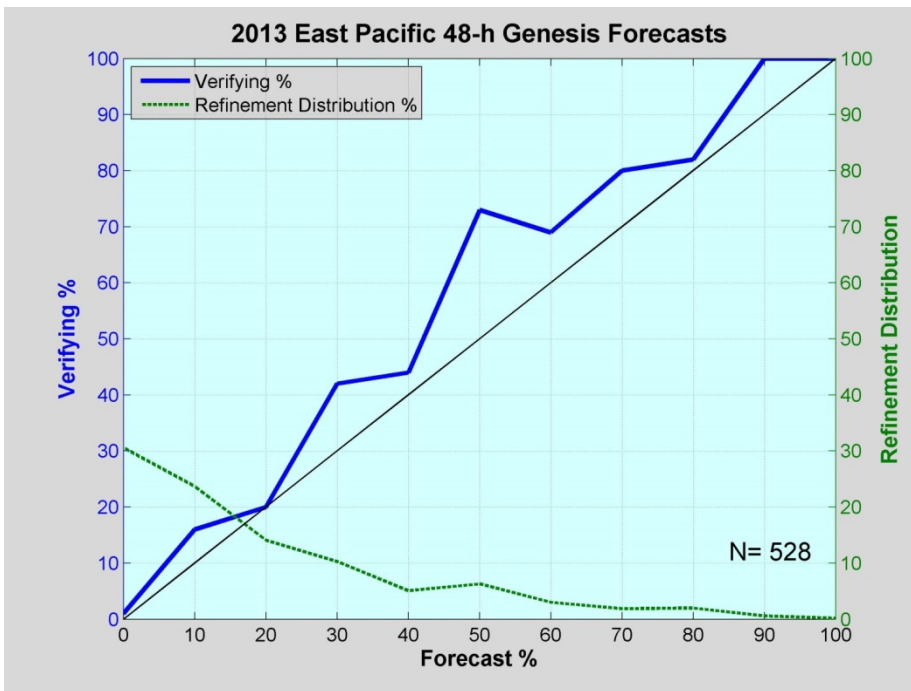
*2013: A slight under-forecast (low) bias was present at the low to medium probabilities. Sample is small at the high probabilities.*



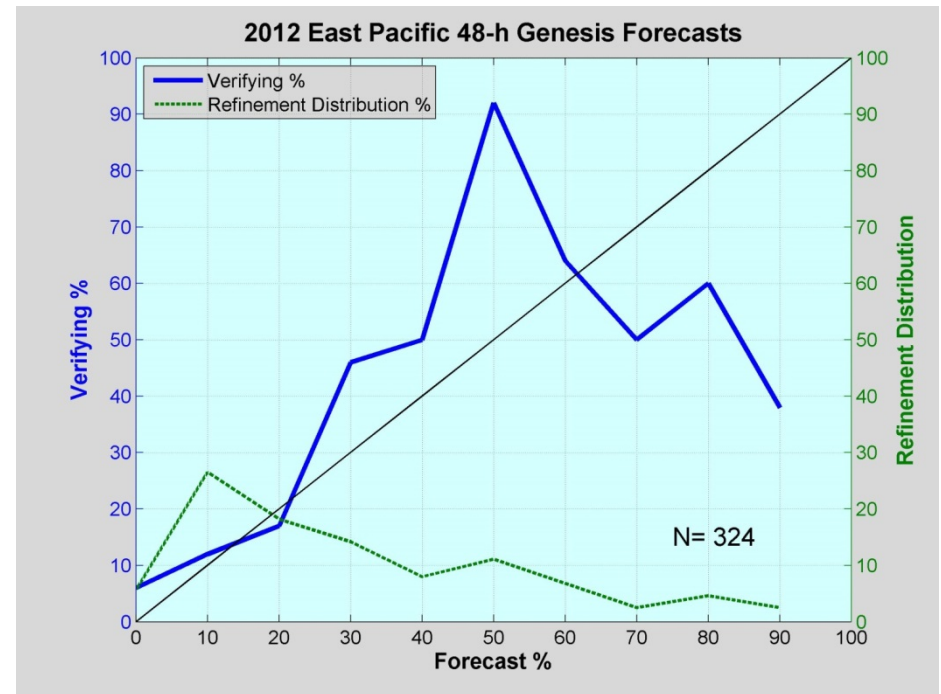
*A slight under-forecast (low) bias was present in 2012.*

Courtesy of James Franklin, NHC

# East Pacific TC Genesis Verification(NHC,2013/2012)



**2013:** A slight low bias at all probabilities, but overall fairly well-calibrated, and much improved from previous years.



**2012:** A low bias was present at the middle probabilities, and high bias at the high probabilities.

Courtesy of James Franklin, NHC

# Ensemble Models

<i>Models</i>	<i>Resolution</i>	<i>Members</i>	<i>Daily Frequency</i>	<i>Forecast Length</i>
NCEP ensemble	GFS T254L42 -55km (02/14/2012)	20+1	00, 06, 12, 18 UTC	16 days (384hrs)
CMC ensemble	GEM L72-66km (02/13/2013)	20+1	00, 12 UTC	16 days (384hrs)
ECMWF ensemble	IFS T639/319L62 -30/60km	50+1	00, 12 UTC	15 days (360hrs)
FNMOCC ensemble	NOGAPS T159L42-80km (09/14/2011)	20	00, 12 UTC	16 days (384hrs)

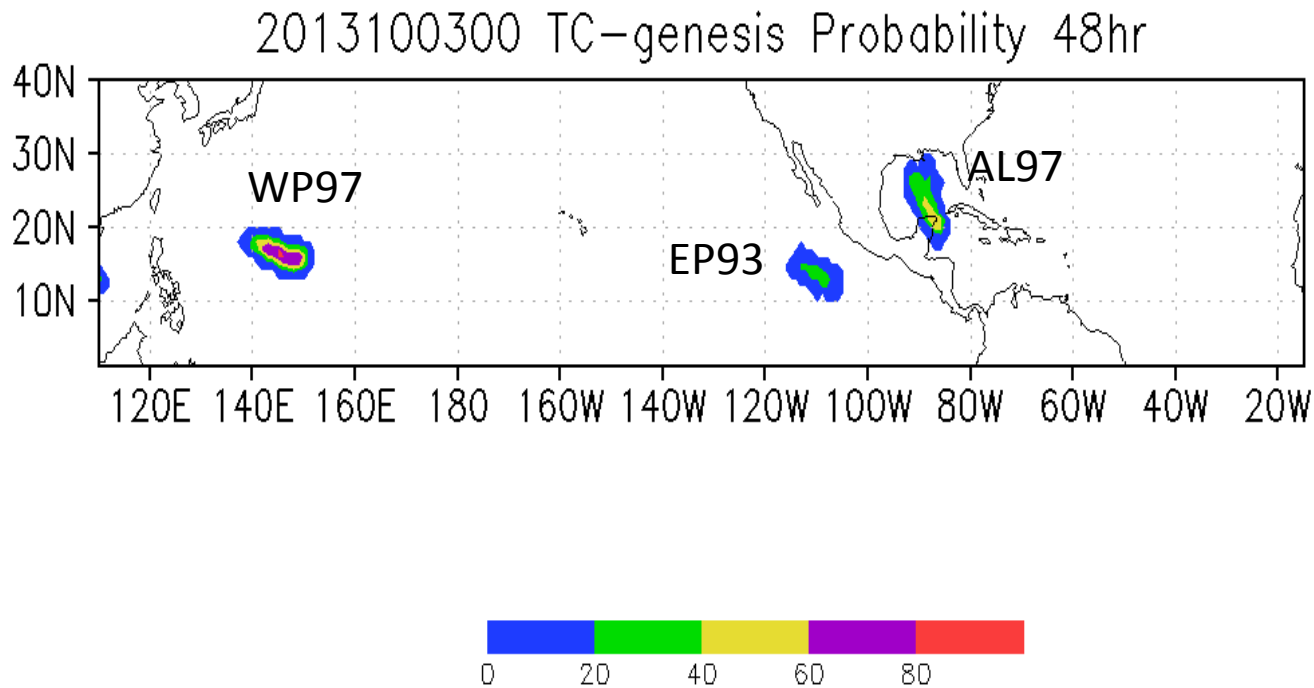
Our goal: Improve tropical-cyclone genesis prediction by using NCEP, CMC , FNMOCC and ECMWF global ensemble forecasts !



# TC Genesis Target Area: 0-40N, 110E-350E

## Forecast Time Window: 48-hour genesis

NCEP GEFS TC Genesis Probability Forecast Within 48 hours



WP97 will form "DANAS" (WP23, 10/03 06Z)  
EP93 will form "NARDA" (EP14, 10/06 18Z)  
AL97 will form "KAREN" (AL12, 10/03 06Z)

# Algorithms for TC genesis probabilistic forecast

## How to define global model TC genesis?

The prediction vortices in Global Ensemble Forecast Systems are very weak. (25kts ?)

Step No.1: (for GEFS, ECMWF, CMC, FNMOC ensembles)

We track every vortex by checking:

- 1)850/700hPa/surface relative vorticity (max)
- 2)850/700hPa geopotential height (min)
- 3)Sea level pressure (min)
- 4)850/700hPa/surface wind speed (min)
- 5)SLP gradient (0.0015mb/km), Wind speed at 850hPa ( $\geq 1.5\text{m/s}$ )
- 6)Closed SLP contour checked

Step No.2: (for GEFS and ECMWF ensemble)

We filter those vortices based on the following criteria:

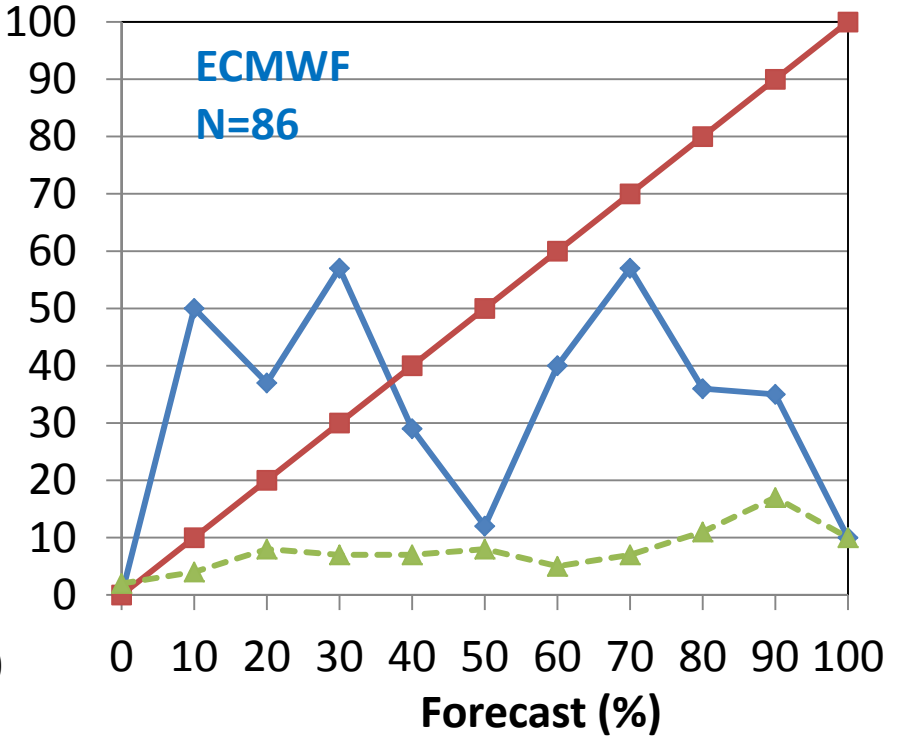
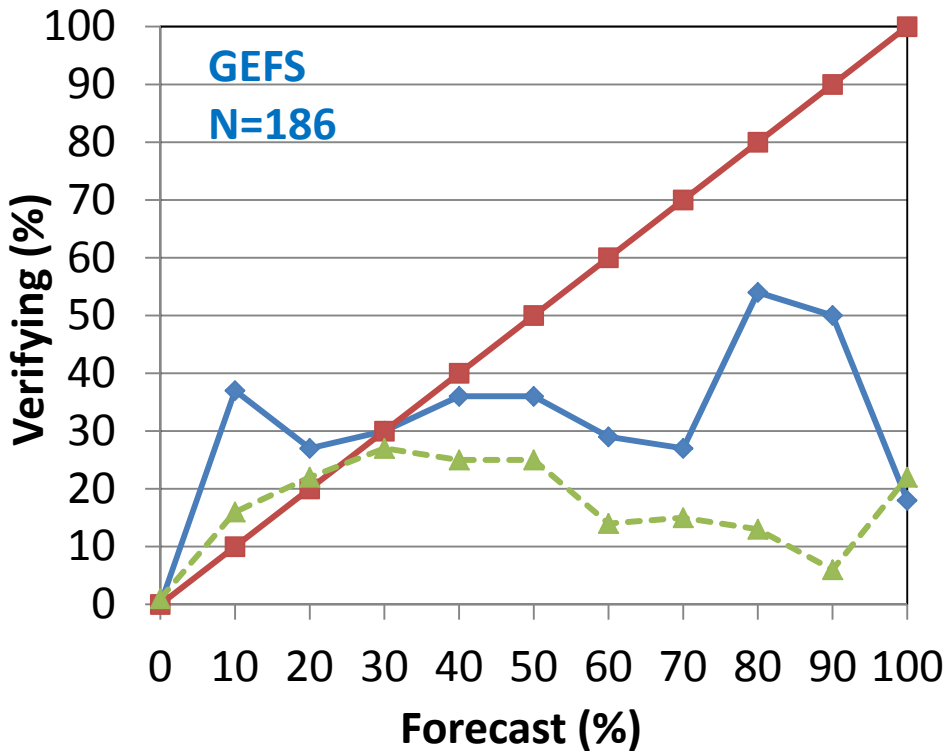
- 1)Surface maximum wind speed  $\geq 10\text{kts}$
- 2)850hPa maximum vorticity  $\geq 10^{*-4} \text{ 1/s}$
- 3)300-500hPa temperature anomaly  $\geq 0.5\text{c}$

## NHC Atlantic Basin Log: invest storm to TC genesis (June~November, 2013)

No.	INVEST	Date	TC	No.	INVEST	Date	TC
1	AL91	6/5	AL01	16	AL91	9/7,8	AL09
2	AL92	6/6-7		17	AL92	9/8-10	
3	AL93	6/16,17	AL02	18	AL93	9/11,12	AL10
4	AL95	7/6,7,8	AL03	19	AL94	9/14-16	
5	AL96	7/11,12		20	AL95	9/17-21	
6	AL98	7/22,23,24	AL04	21	AL96	9/28,29	AL11
7	AL99	7/24,25		22	AL97	9/30,10/1-3	AL12
8	AL91	7/28,29,8/1-3		23	AL98	10/7-13	
9	AL92	8/15-17		24	AL99	10/17	
10	AL93	8/14,15	AL05	25	AL90	10/21	AL13
11	AL95	8/24,25	AL06	26	AL98	11/17-18	AL14
12	AL96	8/30,31,9/1					
13	AL97	8/31,9/1-4	AL07				
14	AL98	9/2-3,5-8					
15	AL99	9/5,6	AL08				



## 2013 Atlantic TC Genesis Forecast Reliability Diagram



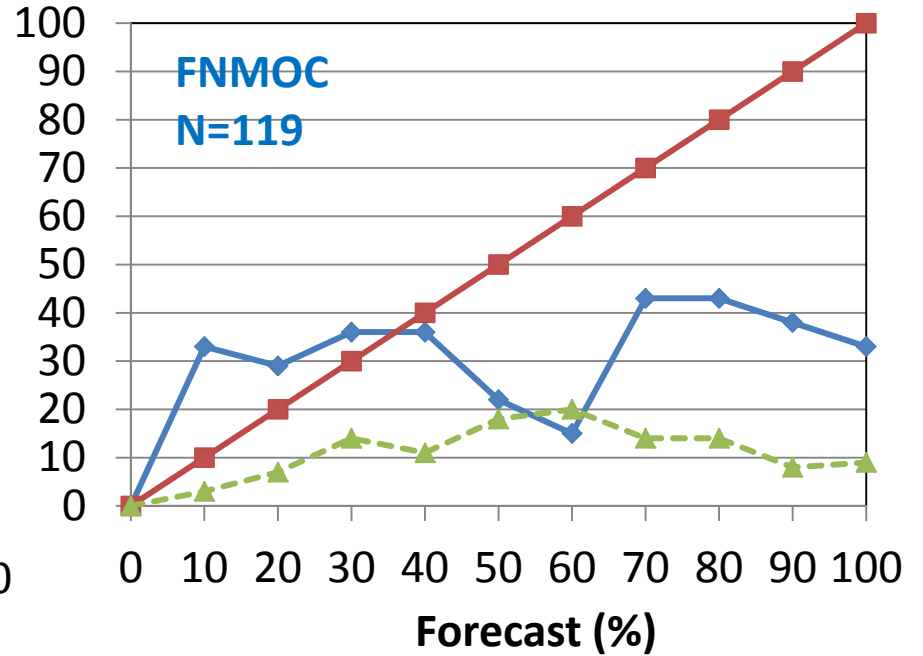
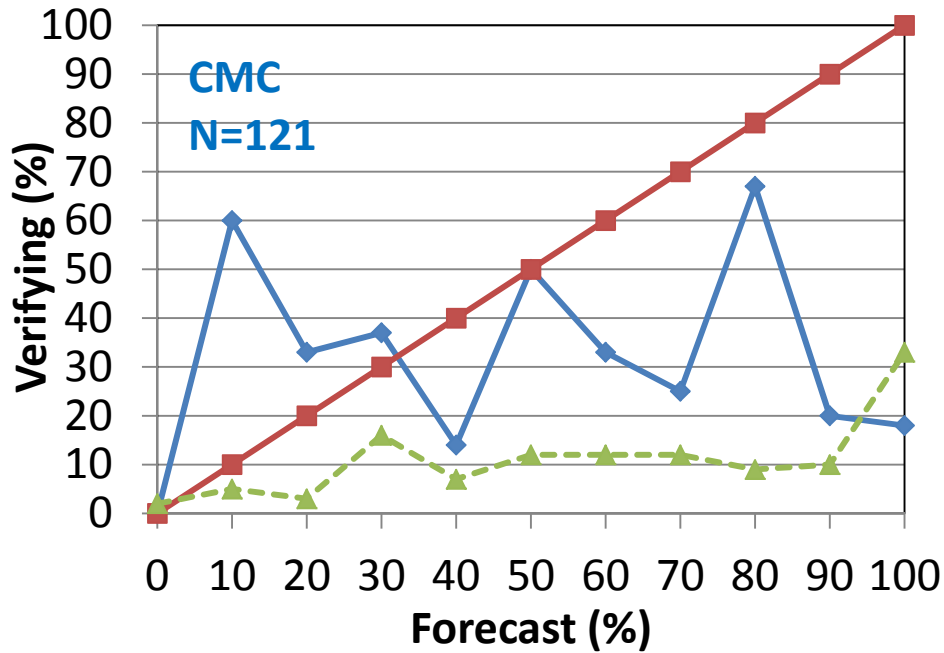
**Red line: perfect reliability**   **Green line: distribution of the forecast genesis probability**  
**Blue line: the relationship between the forecast and verifying genesis probability**

### Contingent Table

OBSERVATION		
FORECAST	YES	NO
YES	a=22	b=48
NO	c=38	d=78
Hit rate(POD)=a/(a+c)	37%	
Miss rate=c/(a+c)	63%	
False alarm rate=b/(b+d)	38%	
Correct rejection rate=d/(b+d)	62%	
Critical success index=a/(a+b+c)	0.2	

OBSERVATION		
FORECAST	YES	NO
YES	a=17	b=33
NO	c=12	d=24
Hit rate(POD)=a/(a+c)	59%	
Miss rate=c/(a+c)	41%	
False alarm rate=b/(b+d)	58%	
Correct rejection rate=d/(b+d)	42%	
Critical success index=a/(a+b+c)	0.27	

## 2013 Atlantic TC Genesis Forecast Reliability Diagram



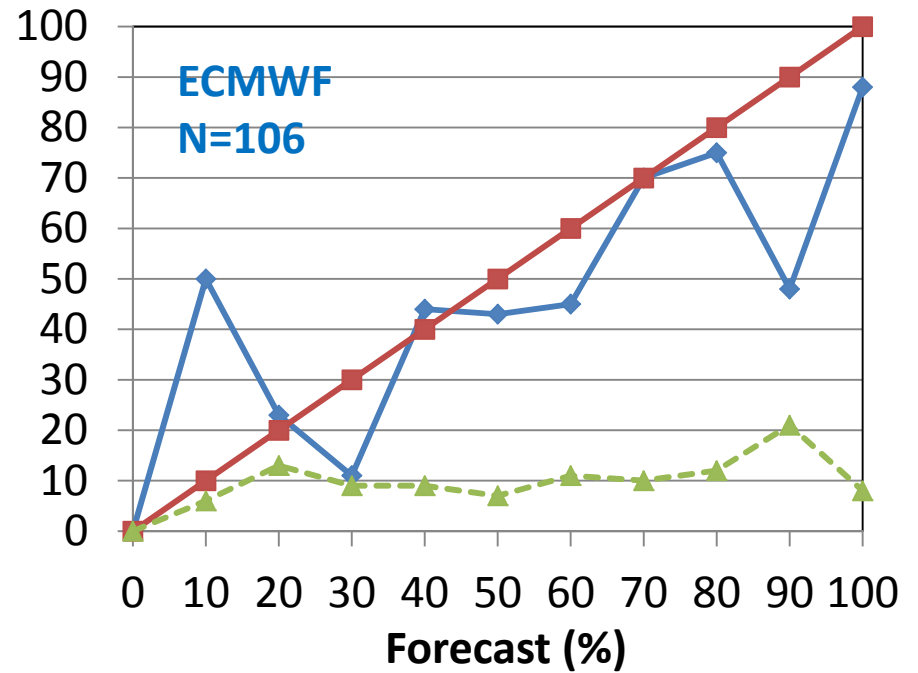
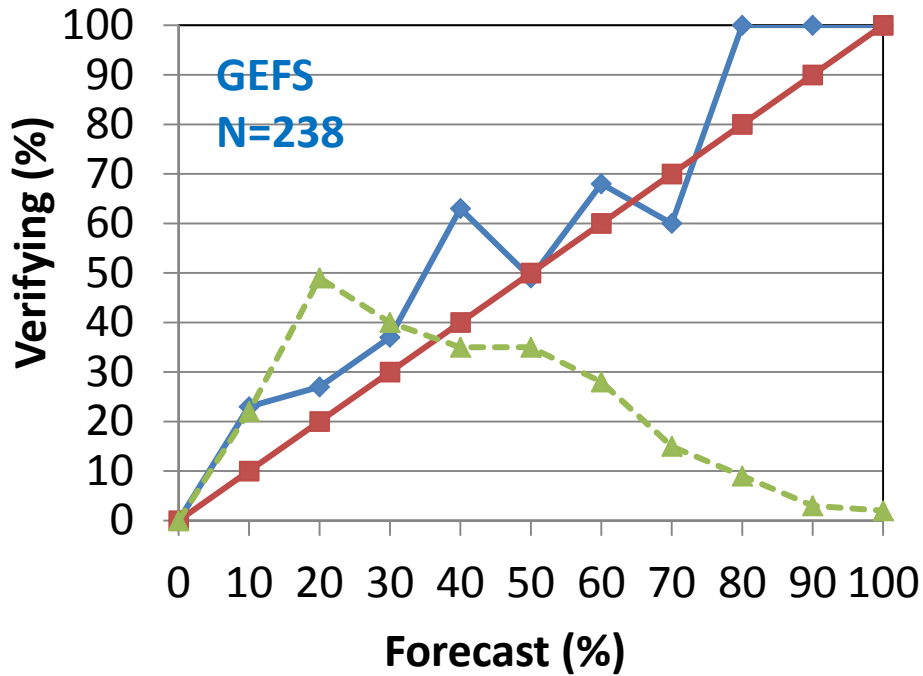
OBSERVATION		
FORECAST	YES	NO
YES	a=21	b=55
NO	c=17	d=28
Hit rate(POD)=a/(a+c)	55%	
Miss rate=c/(a+c)	45%	
False alarm rate=b/(b+d)	66%	
Correct rejection rate=d/(b+d)	34%	
Critical success index=a/(a+b+c)	0.23	

OBSERVATION		
FORECAST	YES	NO
YES	a=21	b=44
NO	c=16	d=37
Hit rate(POD)=a/(a+c)	57%	
Miss rate=c/(a+c)	43%	
False alarm rate=b/(b+d)	54%	
Correct rejection rate=d/(b+d)	46%	
Critical success index=a/(a+b+c)	0.26	

# NHC East Pacific Basin Log: invest storm to TC genesis (May~November, 2013)

No.	INVEST	Date	TC	No.	INVEST	Date	TC
0	EP90	5/13-15	EP01	15	EP96	8/27,28	EP10
1	EP91	5/23-30		16	EP97	8/28-30	
2	EP92	5/26-28	EP02	17	EP98	8/29-31	EP11
3	EP94	6/21-23	EP03	18	EP99	9/3,4	EP12
4	EP95	6/21-24		19	EP90	9/11-13	EP13
5	EP96	6/28-29	EP04	20	EP92	9/24-28	
6	EP97	7/2-4	EP05	21	EP93	10/2-6	EP14
7	EP98	7/21-24	EP06	22	EP94	10/9-13	EP15
8	EP99	7/29,30	EP07	23	EP95	10/12-14	EP16
9	EP90	7/30,8/2,3	EP08	24	EP96	10/18-20	EP17
10	EP91	8/2-3		25	EP97	10/30,31,11/1	EP18
11	EP92	8/8-15		26	EP98	11/14-16	
12	EP93	8/11					
13	EP94	8/19-22	EP09				
14	EP95	8/25-27					

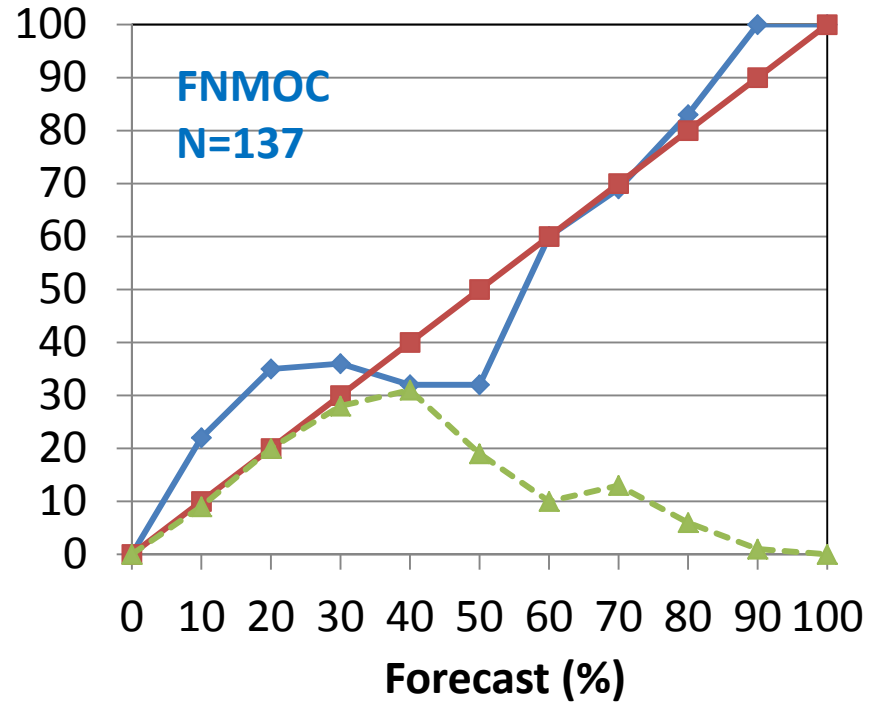
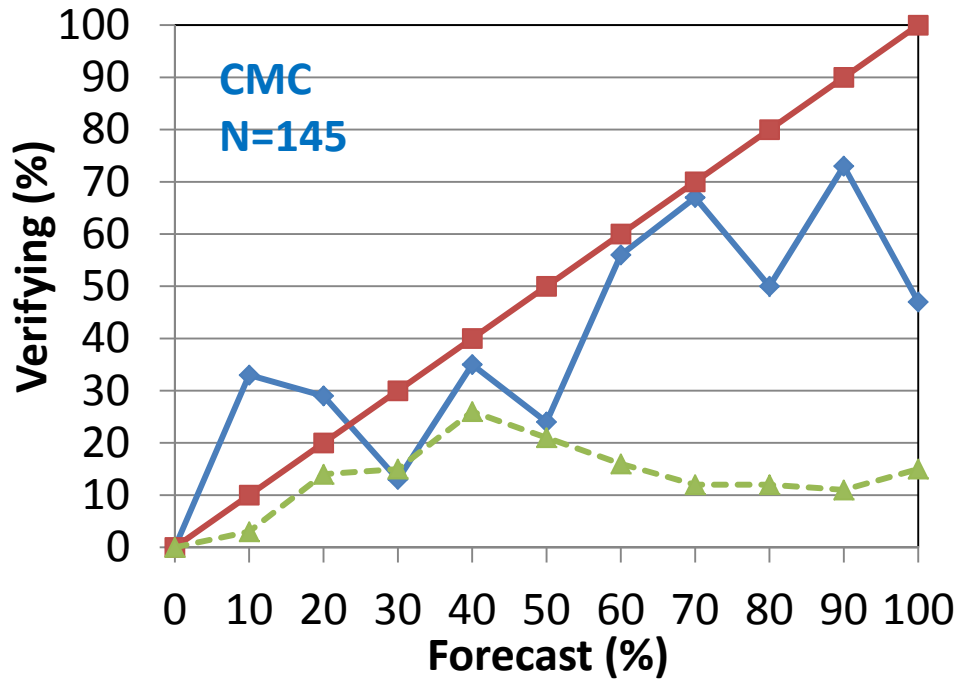
## 2013 East Pacific TC Genesis Forecast Reliability Diagram



OBSERVATION	FORECAST	
	YES	NO
YES	a=42	b=15
NO	c=72	d=109
Hit rate(POD)= $a/(a+c)$	37%	
Miss rate= $c/(a+c)$	63%	
False alarm rate= $b/(b+d)$	12%	
Correct rejection rate= $d/(b+d)$	88%	
Critical success index= $a/(a+b+c)$	0.33	

OBSERVATION	FORECAST	
	YES	NO
YES	a=38	b=24
NO	c=14	d=30
Hit rate(POD)= $a/(a+c)$	73%	
Miss rate= $c/(a+c)$	27%	
False alarm rate= $b/(b+d)$	44%	
Correct rejection rate= $d/(b+d)$	54%	
Critical success index= $a/(a+b+c)$	0.50	

## 2013 East Pacific TC Genesis Forecast Reliability Diagram



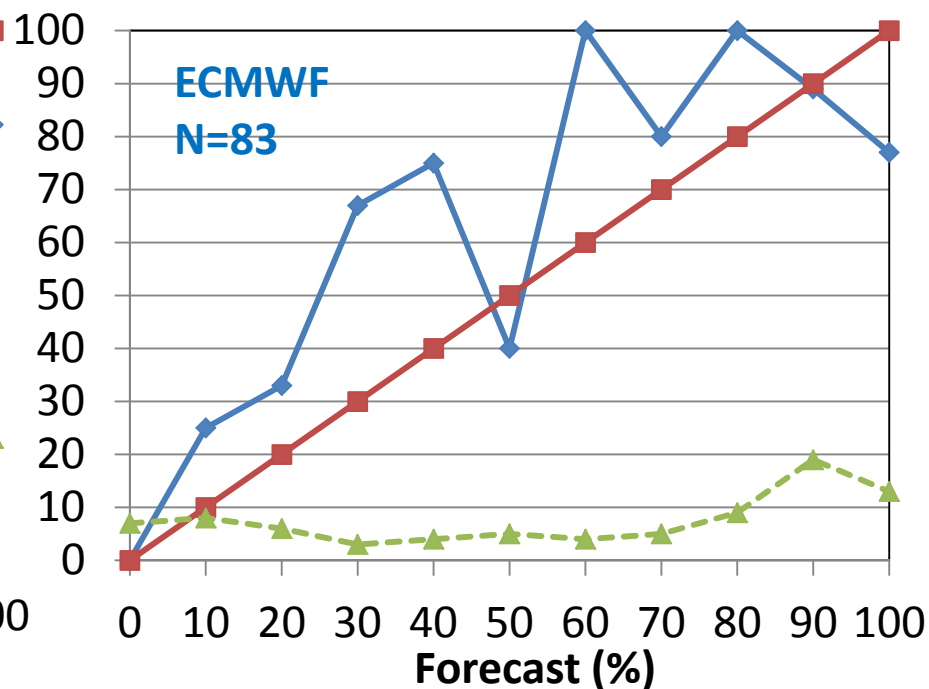
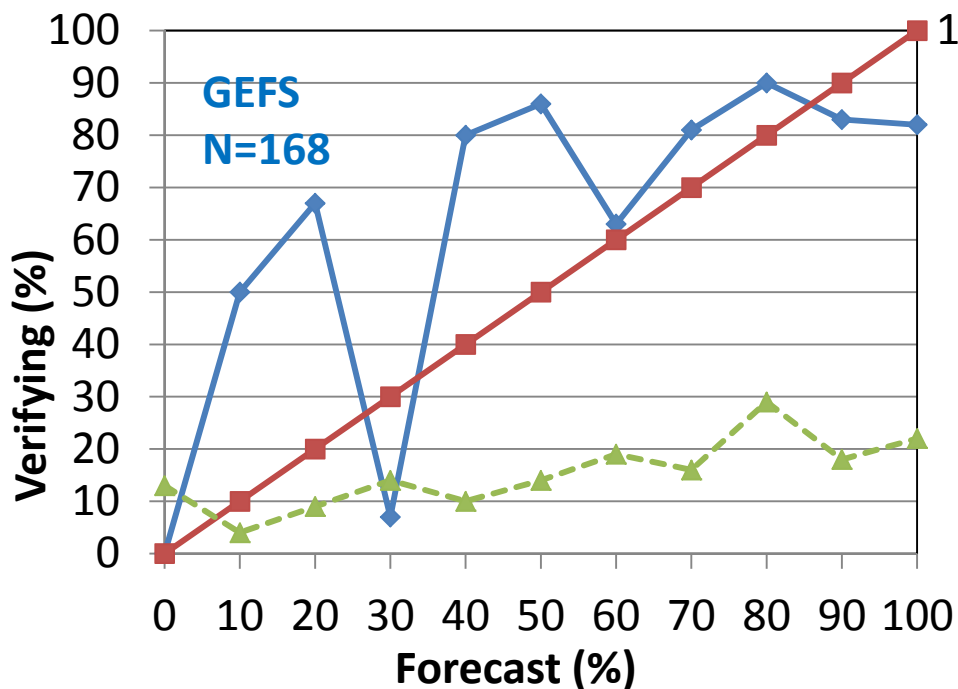
OBSERVATION	FORECAST	
	YES	NO
YES	a=38	b=28
NO	c=21	d=58
Hit rate(POD)= $a/(a+c)$	64%	
Miss rate= $c/(a+c)$	36%	
False alarm rate= $b/(b+d)$	33%	
Correct rejection rate= $d/(b+d)$	67%	
Critical success index= $a/(a+b+c)$	0.44	

OBSERVATION	FORECAST	
	YES	NO
YES	a=21	b=9
NO	c=35	d=72
Hit rate(POD)= $a/(a+c)$	38%	
Miss rate= $c/(a+c)$	62%	
False alarm rate= $b/(b+d)$	11%	
Correct rejection rate= $d/(b+d)$	89%	
Critical success index= $a/(a+b+c)$	0.32	

## West Pacific Basin Log: invest storm to TC genesis (June~December, 2013)

No.	INVEST	Date	TC	No.	INVEST	Date	TC
1	WP98	6/7,8	WP03	21	WP97	9/11,12	WP16
2	WP99	6/14,15		22	WP99	9/16	WP17
3	WP91	6/16,17	WP04	23	WP90	9/16,17,18	WP18
4	WP93	6/17		24	WP98	9/19,20,21	WP19
5	WP94	6/19,20	WP05	25	WP91	9/20	
6	WP99	6/27,28	WP06	26	WP93	9/25,26	WP20
7	WP92	7/7	WP07	27	WP96	9/29	WP21
8	WP93	7/14,15	WP08	28	WP95	9/27-30	WP22
9	WP94	7/18,19		29	WP97	10/2,3	WP23
10	WP91	7/30,31	WP09	30	WP90	10/7-9	
11	WP93	8/1		31	WP91	10/8	WP24
12	WP94	8/4,5	WP10	32	WP92	10/8,9,10	WP25
13	WP96	8/8	WP11	33	WP93	10/15,16	WP26
14	WP98	8/16,17	WP12	34	WP94	10/18,19	WP27
15	WP99	8/16,17	WP13	35	WP95	10/19,20	WP28
16	WP91	8/24,25	WP14	36	WP96	10/28,29	WP29
17	WP92	8/28		37	WP98	11/2,3	WP30
18	WP93	8/28-30		38	WP99	11/3	WP31
19	WP95	9/9,10		39	WP90	11/10-14	WP32
20	WP96	9/1	WP15	40	WP92	11/21-23	
				41	WP94	12/3	WP33

## 2013 West Pacific TC Genesis Forecast Reliability Diagram

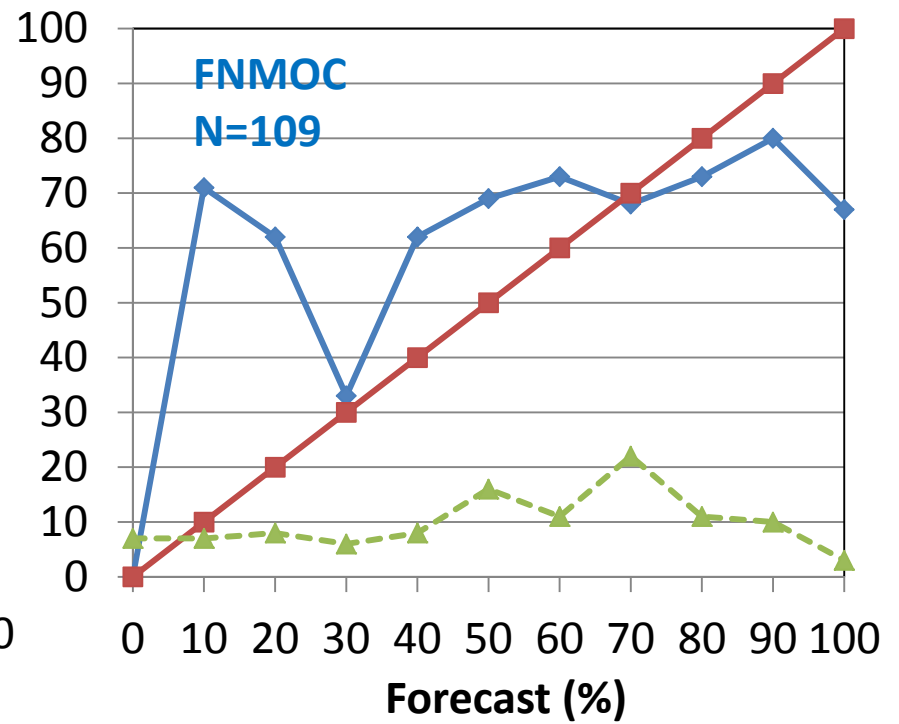
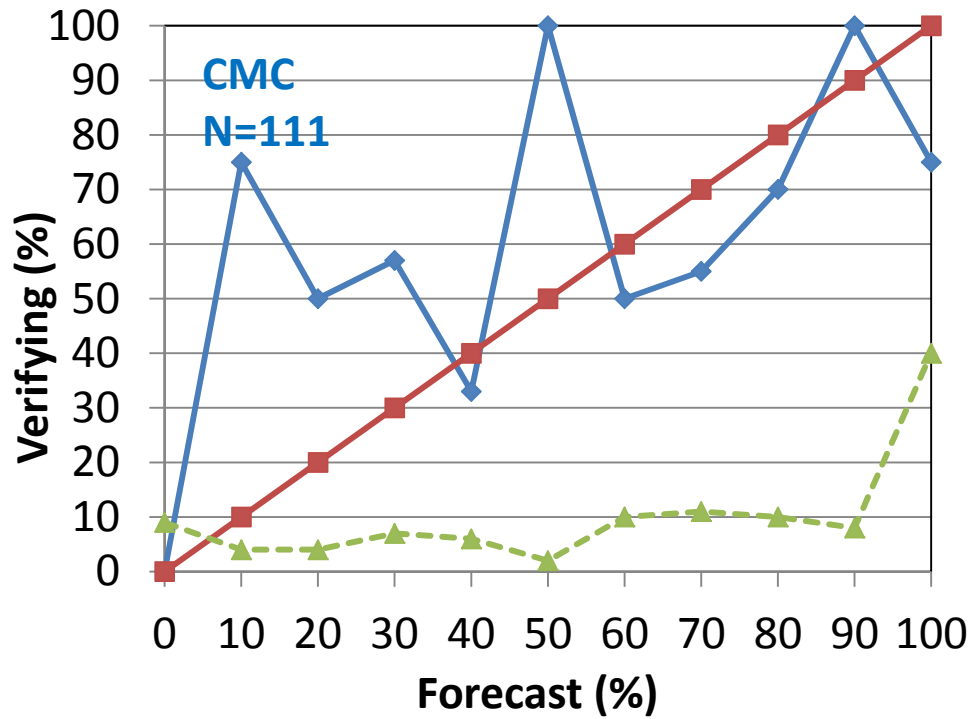


OBSERVATION	FORECAST	
	YES	NO
YES	a=84	b=20
NO	c=29	d=35
Hit rate(POD)=a/(a+c)	74%	
Miss rate=c/(a+c)	26%	
False alarm rate=b/(b+d)	36%	
Correct rejection rate=d/(b+d)	64%	
Critical success index=a/(a+b+c)	0.63	

OBSERVATION	FORECAST	
	YES	NO
YES	a=44	b=6
NO	c=11	d=22
Hit rate(POD)=a/(a+c)	80%	
Miss rate=c/(a+c)	20%	
False alarm rate=b/(b+d)	21%	
Correct rejection rate=d/(b+d)	79%	
Critical success index=a/(a+b+c)	0.72	



## 2013 West Pacific TC Genesis Forecast Reliability Diagram



OBSERVATION		
FORECAST	YES	NO
YES	a=56	b=23
NO	c=13	d=19
Hit rate(POD)=a/(a+c)	81%	
Miss rate=c/(a+c)	20%	
False alarm rate=b/(b+d)	55%	
Correct rejection rate=d/(b+d)	45%	
Critical success index=a/(a+b+c)	0.61	

OBSERVATION		
FORECAST	YES	NO
YES	a=41	b=16
NO	c=28	d=24
Hit rate(POD)=a/(a+c)	59%	
Miss rate=c/(a+c)	41%	
False alarm rate=b/(b+d)	40%	
Correct rejection rate=d/(b+d)	60%	
Critical success index=a/(a+b+c)	0.48	

# Next Ensemble (GEFS) Implementation

- Model
  - Current: GFS Euler model
  - Plan: GFS Semi-Lagrangian model
- Horizontal resolution
  - Current: T254 (55km for 0-192 hours), T190 (73km for 192-384 hours)
  - Plan: Variable resolution
    - T574 (T382 physics - 34km for 0-168 hours)
    - T382 (T254 physics – 55km for 168-384 hours)
- Vertical resolution
  - Current: L42 hybrid levels
  - Plan: L64 hybrid levels (will match with GFS and DA)
- Ensemble memberships:
  - The same as current operational – 21 members for each cycle (additional discussion)
- Computation cost:
  - Current: 84 nodes (+ post process) for 55 minutes
  - Plan: 252 nodes (+ post process) for peak time, within one hour for integration
- Initial perturbations:
  - Current: BV-ETR 6-hr cycling
  - Plan: EnKF f06 + 3DETR
- Stochastic perturbations:
  - Current: STTP
  - Plan: tuned STTP for new model, initial perturbations and higher resolution
- Output:
  - Current: every 6-hr for 1\*1 degree pgrb files
  - Plan: every 3-hr for 0.5\*0.5 degree pgrb files
- Challenge:
  - T574L64 configuration will need nearly 300 nodes in peak time
- Expectations:
  - Improving probabilistic forecast skills overall
  - Improving Tropical Storm track forecast errors, and intensity forecast

# Summary

- 1) Four ensembles over-predicted Atlantic TC genesis in 2013.
- 2) Four ensembles had reliable forecasts for East Pacific TC genesis, and higher hit rate in West Pacific TC genesis in 2012.
- 3) The new GEFS (GFS T574L64 Ensemble) implementation will provide more reliable TC genesis guidance for the coming hurricane season.

Please visit:

[http://www.emc.ncep.noaa.gov/gmb/jpeng/TC\\_ens\\_V1.html](http://www.emc.ncep.noaa.gov/gmb/jpeng/TC_ens_V1.html)

for 2014 real time TC track and genesis probabilistic forecasts.

## 2013 GFS TC Genesis Forecast Contingent Table

### Atlantic, N=110

OBSERVATION		
FORECAST	YES	NO
YES	a=19	b=41
NO	c=16	d=34
Hit rate(POD)=a/(a+c)	54%	
Miss rate=c/(a+c)	46%	
False alarm rate=b/(b+d)	55%	
Correct rejection rate=d/(b+d)	45%	
Critical success index=a/(a+b+c)	0.25	

### East Pacific, N=106

OBSERVATION		
FORECAST	YES	NO
YES	a=45	b=25
NO	c=16	d=20
Hit rate(POD)=a/(a+c)	74%	
Miss rate=c/(a+c)	26%	
False alarm rate=b/(b+d)	56%	
Correct rejection rate=d/(b+d)	44%	
Critical success index=a/(a+b+c)	0.52	

### West Pacific, N=133

OBSERVATION		
FORECAST	YES	NO
YES	a=86	b=23
NO	c=7	d=17
Hit rate(POD)=a/(a+c)	92%	
Miss rate=c/(a+c)	8%	
False alarm rate=b/(b+d)	58%	
Correct rejection rate=d/(b+d)	42%	
Critical success index=a/(a+b+c)	0.74	

GFS T574L64 -27km

Max wind speed >=25kts

## TC Genesis Tracker Code

Based on Tim Marchok's latest version for genesis track, we make the following changes:

- (1) Calculation for 300-500hPa temperature anomaly;
- (2) Calculation for 200-850hPa zonal wind shear;
- (3) Calculation for 500hPa mean relative humidity;
- (4) The AL90-99, EP90-99 and WP90-99 are those invest storms named by NHC and JTWC. In case of NHC and JTWC miss potential TC genesis, we create some interested storms based on GFS-T574 operational, Canadian, NOGAPS and ECMWF Deterministic Forecasts, named as HC01, HC02, etc.

# Algorithms for TC genesis probabilistic forecast

**TC Genesis:** maximum sustainable winds  $\geq 25$  kts (12.9 m/s)

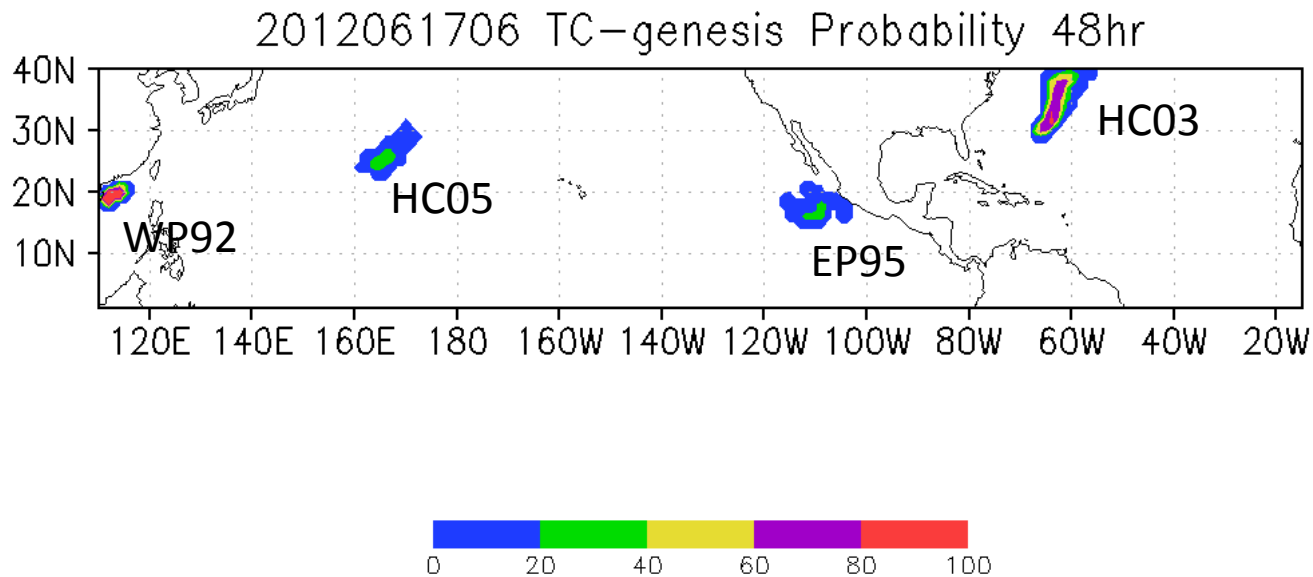
Criteria (Gray, 1968):

- 1) A positive relative vorticity in lower troposphere
- 2) Far away 5N/S from equator
- 3) Warm SST ( $\geq 79$ F or 26.1C for Atlantic)
- 4) Small vertical shear
- 5) Conditional instability in the lower to mid-troposphere
- 6) Large value of relative humidity in the middle troposphere

# TC Genesis Target Area: 0-40N, 110E-350E

## Forecast Time Window: 48-hour genesis

NCEP GEFS TC Genesis Probability Forecast Within 48 hours



WP92 will form “Talim” (WP06, 06/18 00Z)  
HC03 will form “Chris”(AL03, 06/18 18Z)