Hurricane Genesis Ensemble Forecasts

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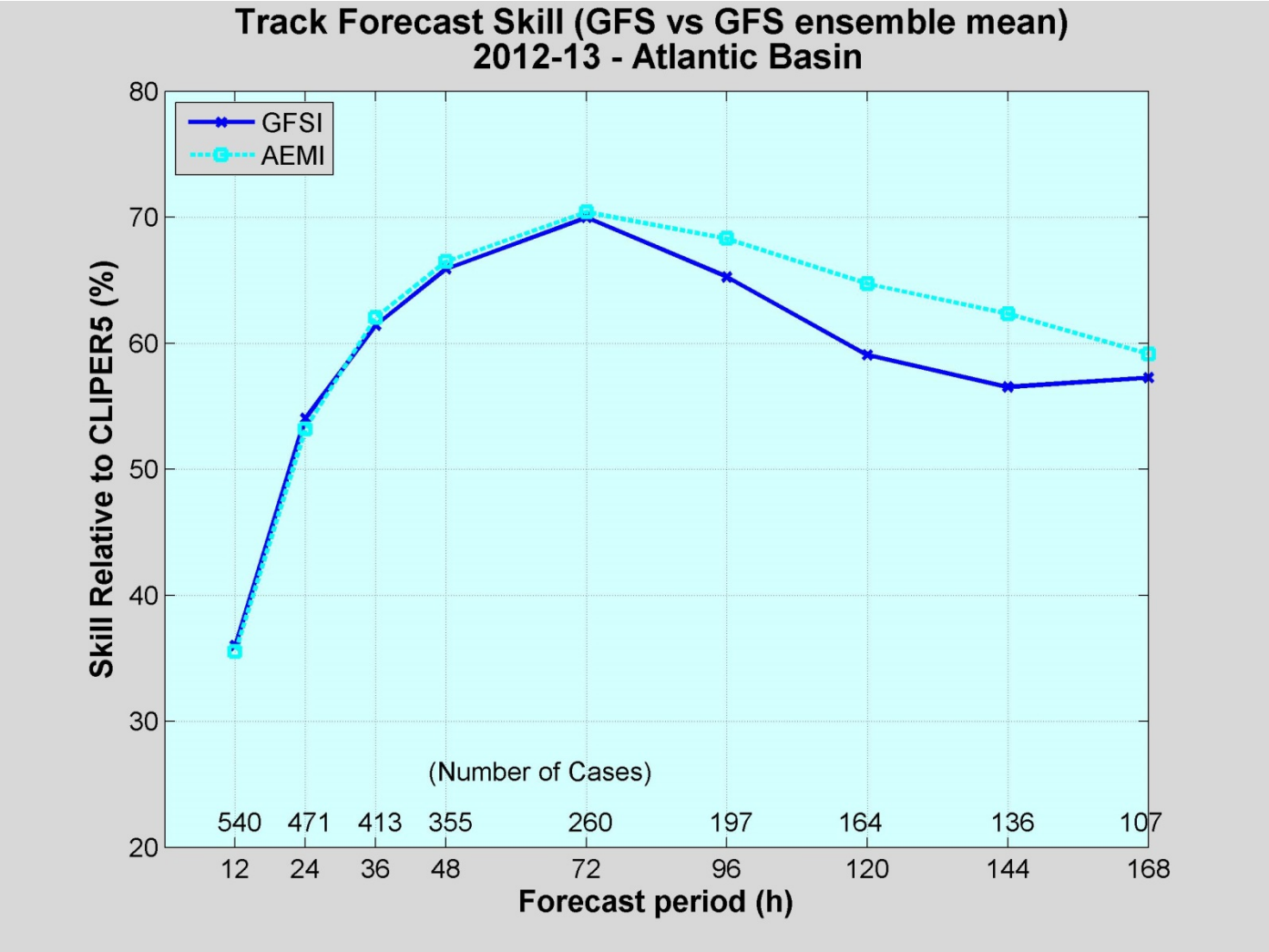
GEFS ensemble vs. GFS Forecast



- *This is a 2-yr sample (2012-13)*
- *The skill of GFS and AEMI are very similar through 72 h. After that, AEMI is more skillful.*

Courtesy of James Franklin, NHC

NOAA Seasonal Hurricane Outlook

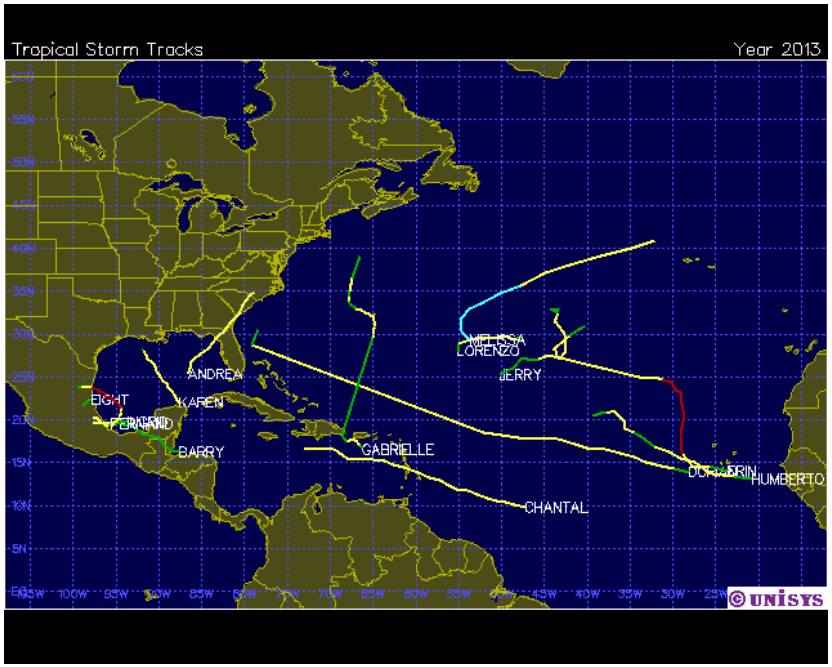
NOAA 2013 Atlantic Hurricane Season Outlooks

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.

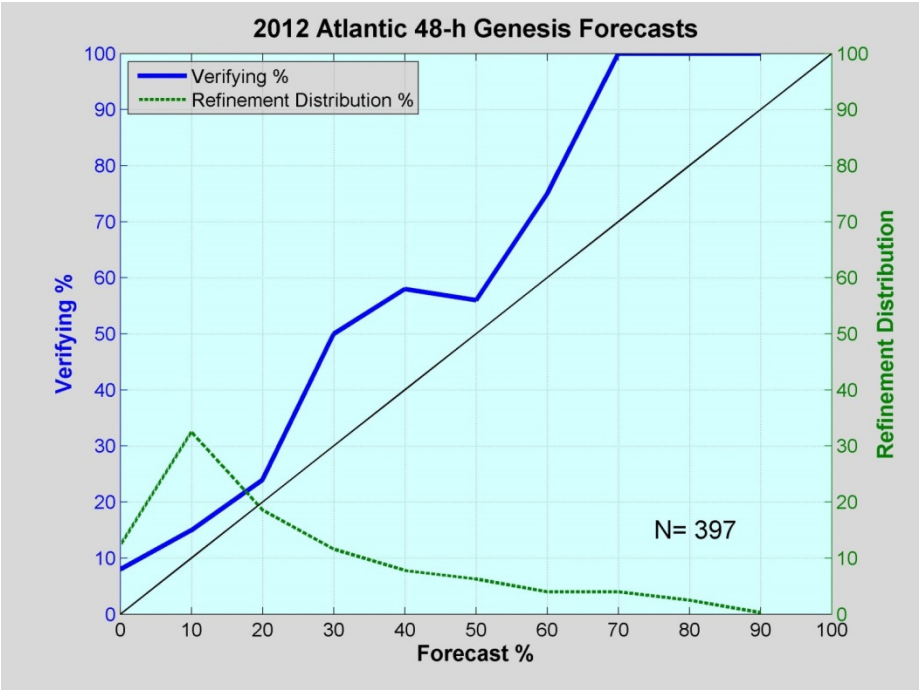
Observed numbers:

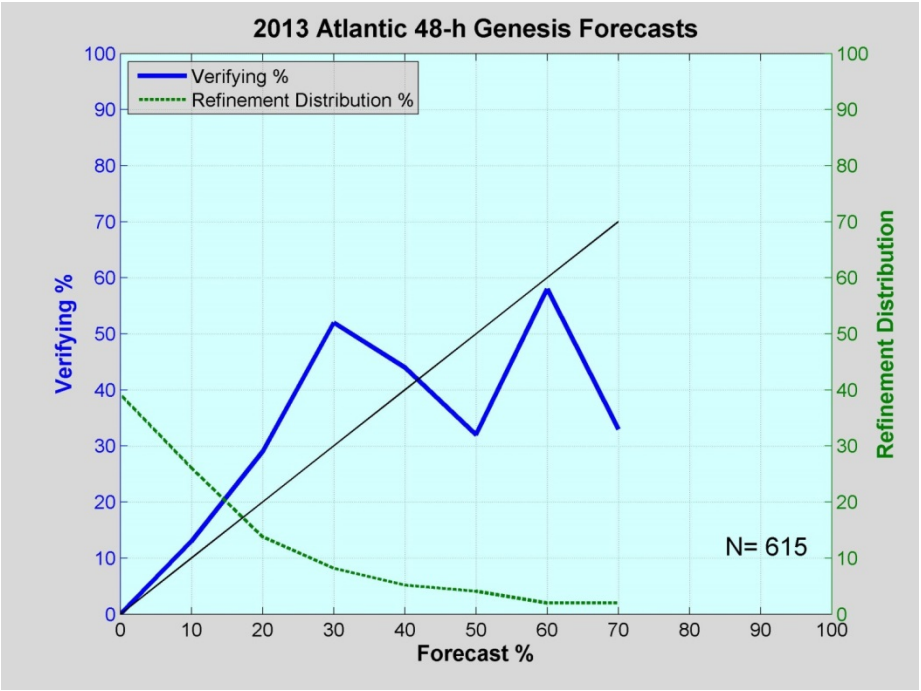
Named storms: **13**
Hurricanes: **2**
Major Hurricanes : **0**
ACE: **36% of median**



Courtesy of Jon Gottschalck, CPC

Atlantic TC Genesis Verification(NHC,2012/2013)



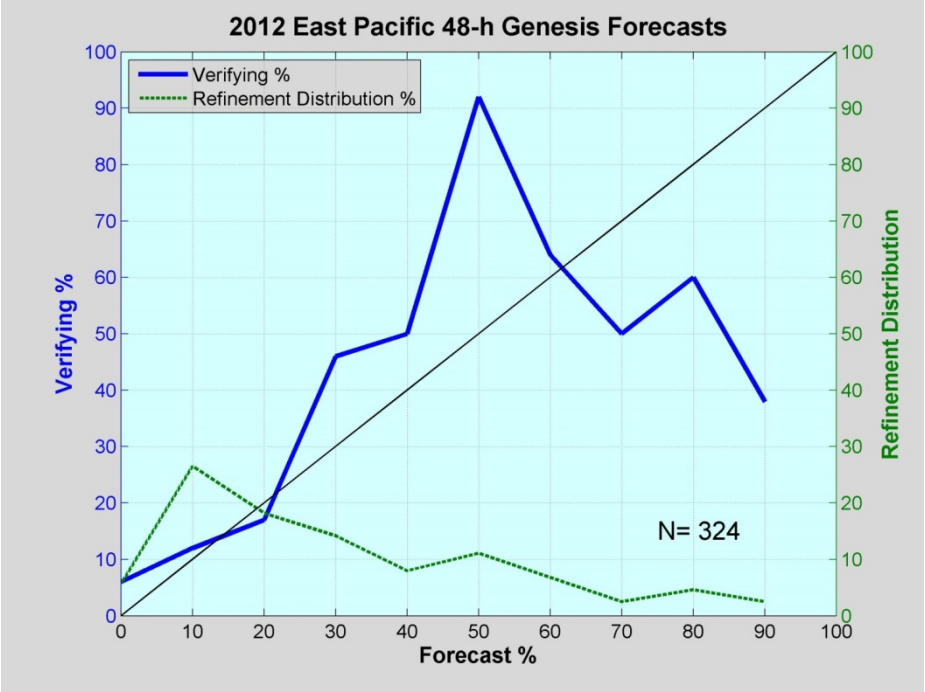


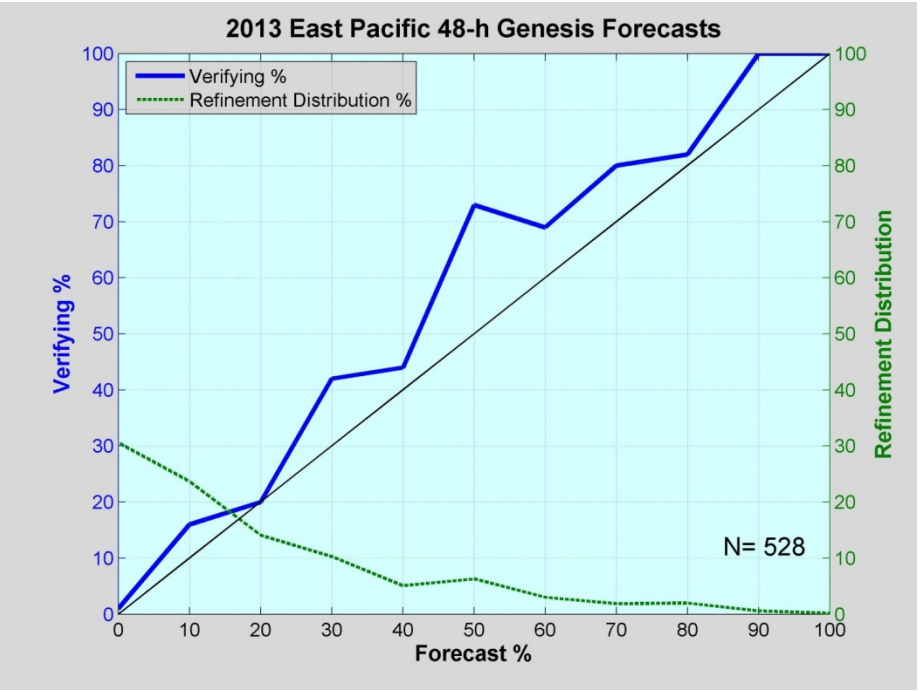
A slight under-forecast (low) bias was present in 2012.

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

Courtesy of James Franklin, NHC

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





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

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

Courtesy of James Franklin, NHC

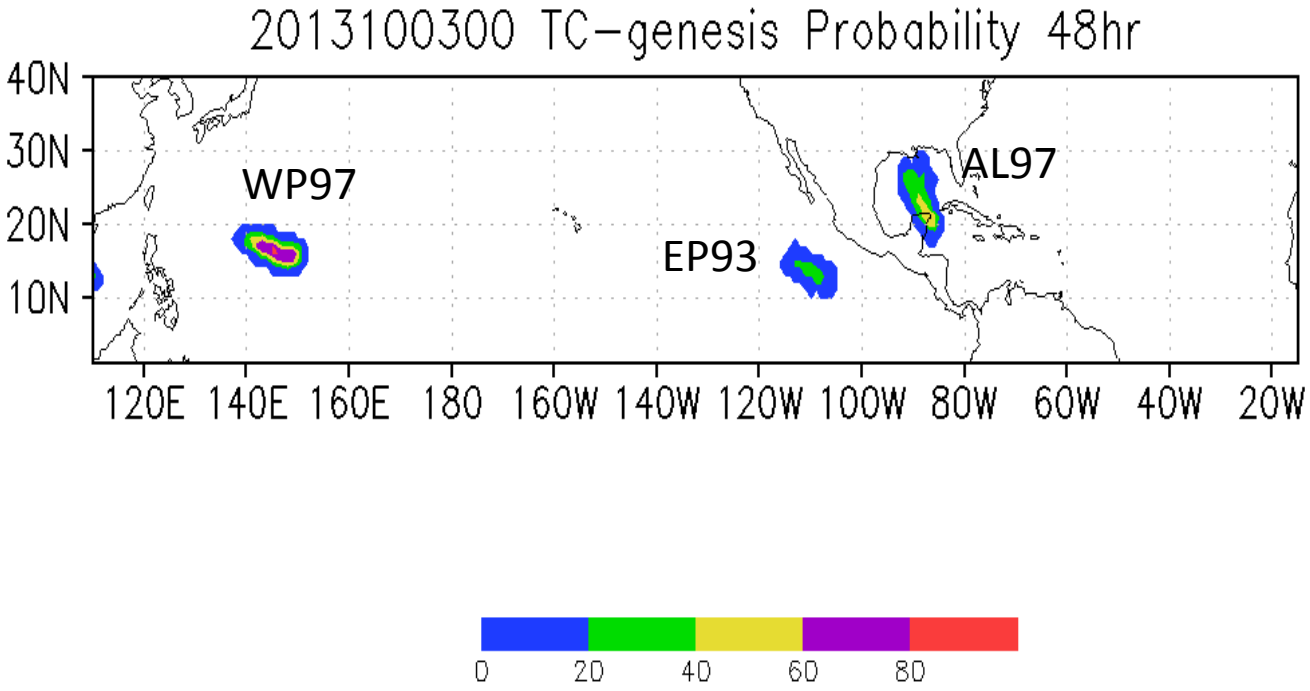
Ensemble Models

Models	*Resolution*	*Members*	*Daily Frequency*	*Forecast Length*
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)
FNMOC 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 , FNMOC and ECMWF global ensemble forecasts !

TC Genesis Target Area: 0-40N, 110E-350E
Forecast Leading Time: 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 (≥ 1.5m/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 ≥ 10kts

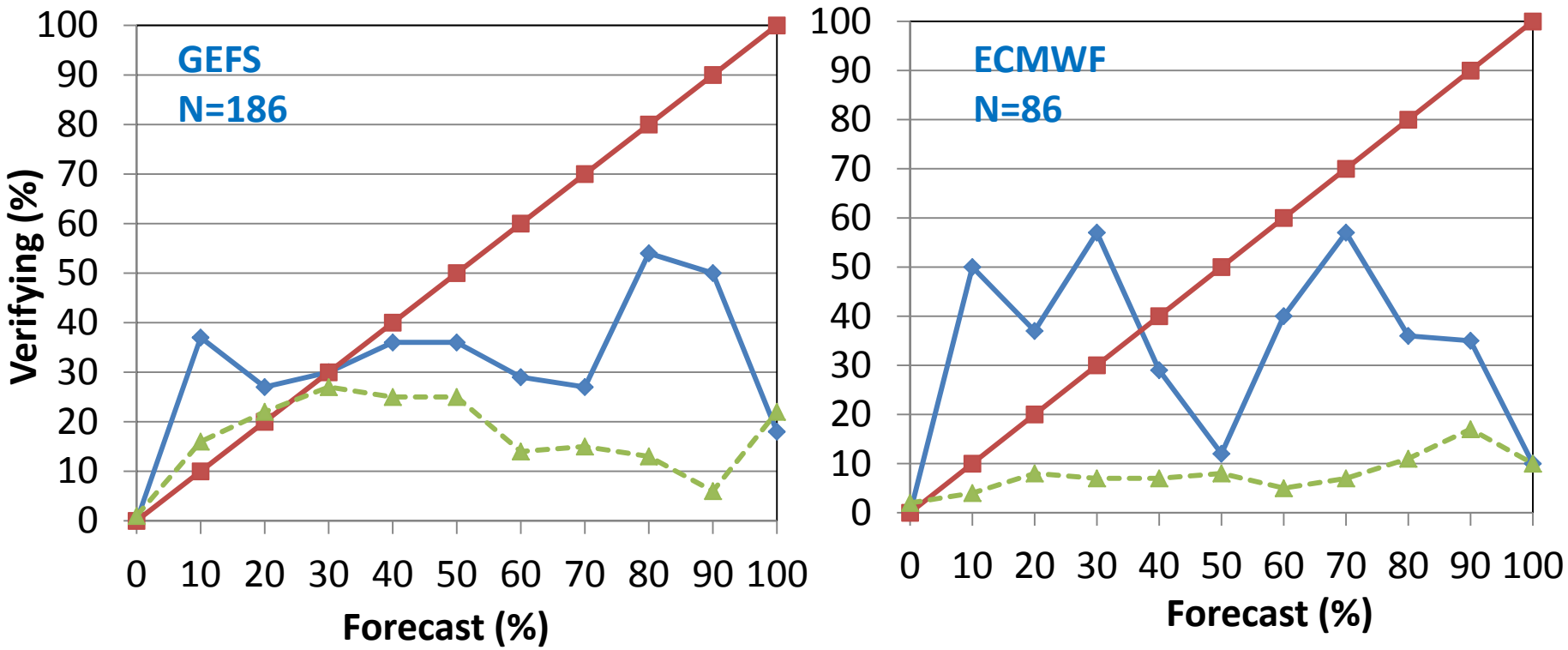
2)850hPa maximum vorticity ≥ 10**(-4) 1/s

3)300-500hPa temperature anomaly ≥ 0.5c

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**

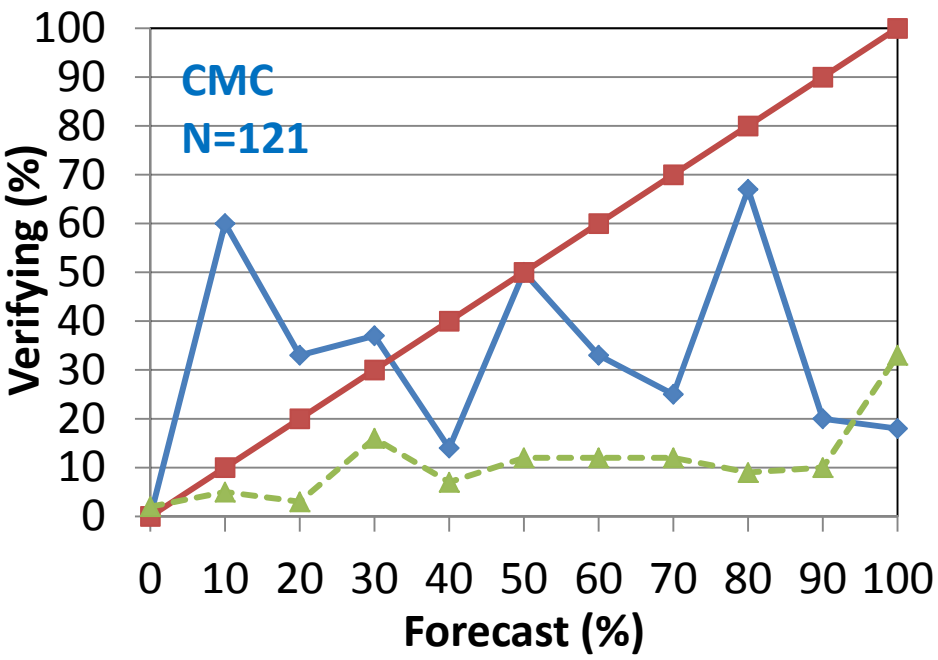
Blue line: the relationship between the forecast and verifying genesis probability

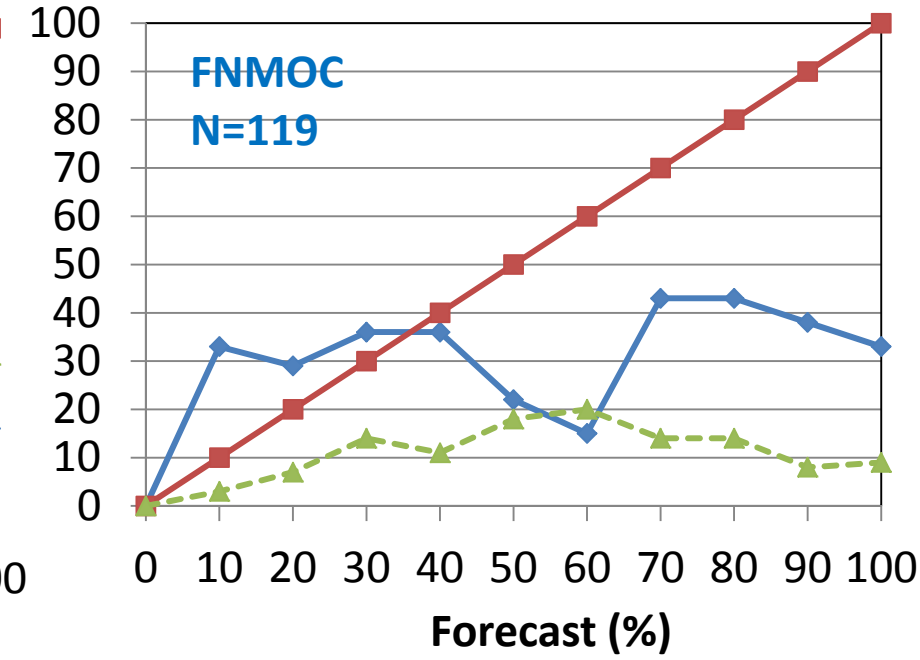
Contingent Table

OBSERVARTION		
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	

OBSERVARTION		
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





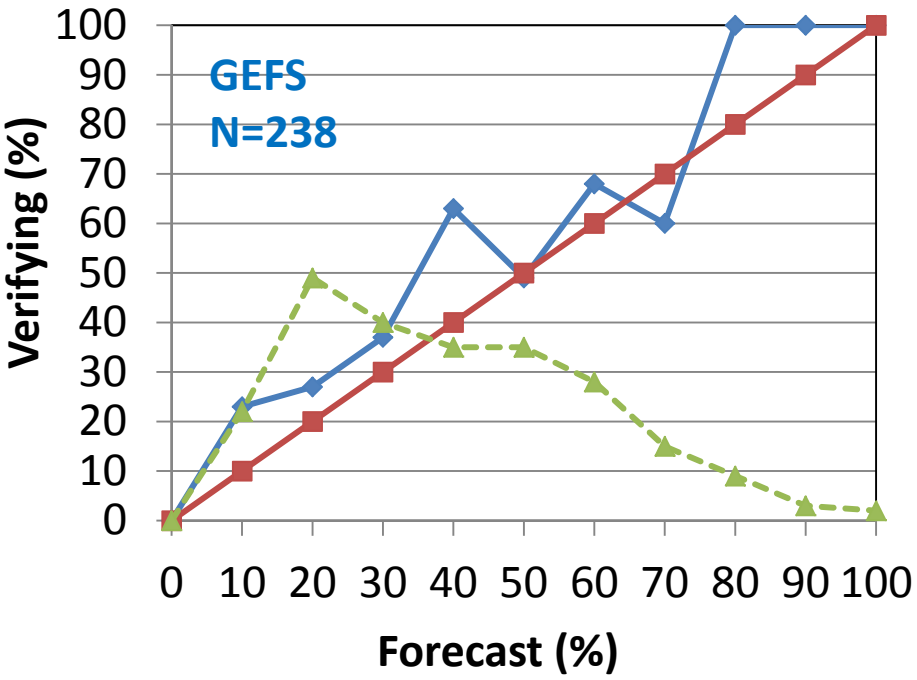
OBSERVARTION		
FORECAST	YES	NO
YES	a=21	b=55
NO	c=17	d=28
Hit rate(POD)=a/(a+c)	55%	
Miss rate=c/(a+c)	45%	
False alarm rate=b/(b+d)	66%	
Correct rejection rate=d/(b+d)	34%	
Critical success index=a/(a+b+c)	0.23	

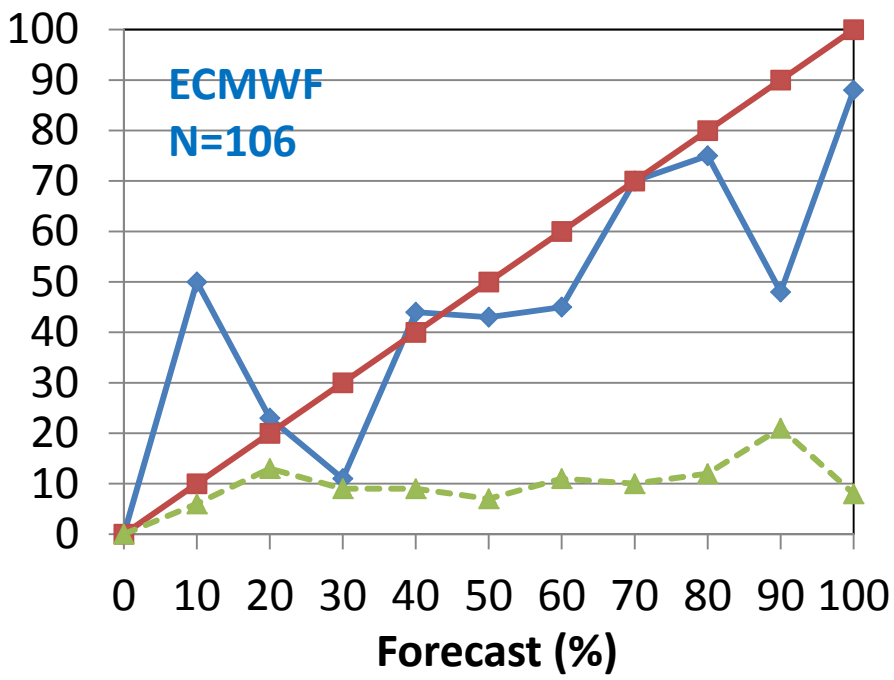
OBSERVARTION		
FORECAST	YES	NO
YES	a=21	b=44
NO	c=16	d=37
Hit rate(POD)=a/(a+c)	57%	
Miss rate=c/(a+c)	43%	
False alarm rate=b/(b+d)	54%	
Correct rejection rate=d/(b+d)	46%	
Critical success index=a/(a+b+c)	0.26	

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

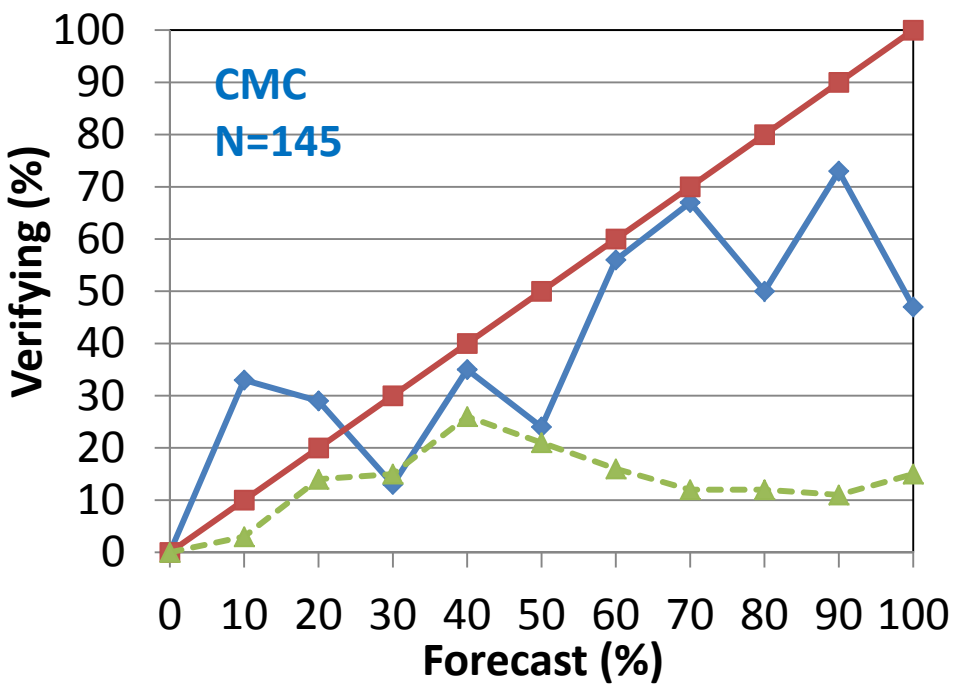


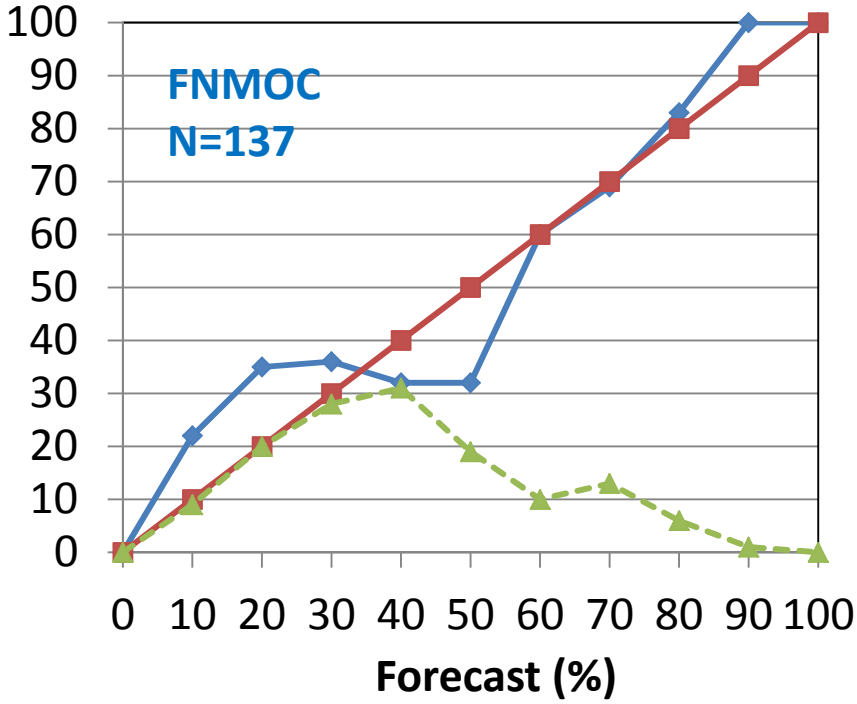


OBSERVARTION		
FORECAST	YES	NO
YES	a=42	b=15
NO	c=72	d=109
Hit rate(POD)=a/(a+c)	37%	
Miss rate=c/(a+c)	63%	
False alarm rate=b/(b+d)	12%	
Correct rejection rate=d/(b+d)	88%	
Critical success index=a/(a+b+c)	0.33	

OBSERVARTION		
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





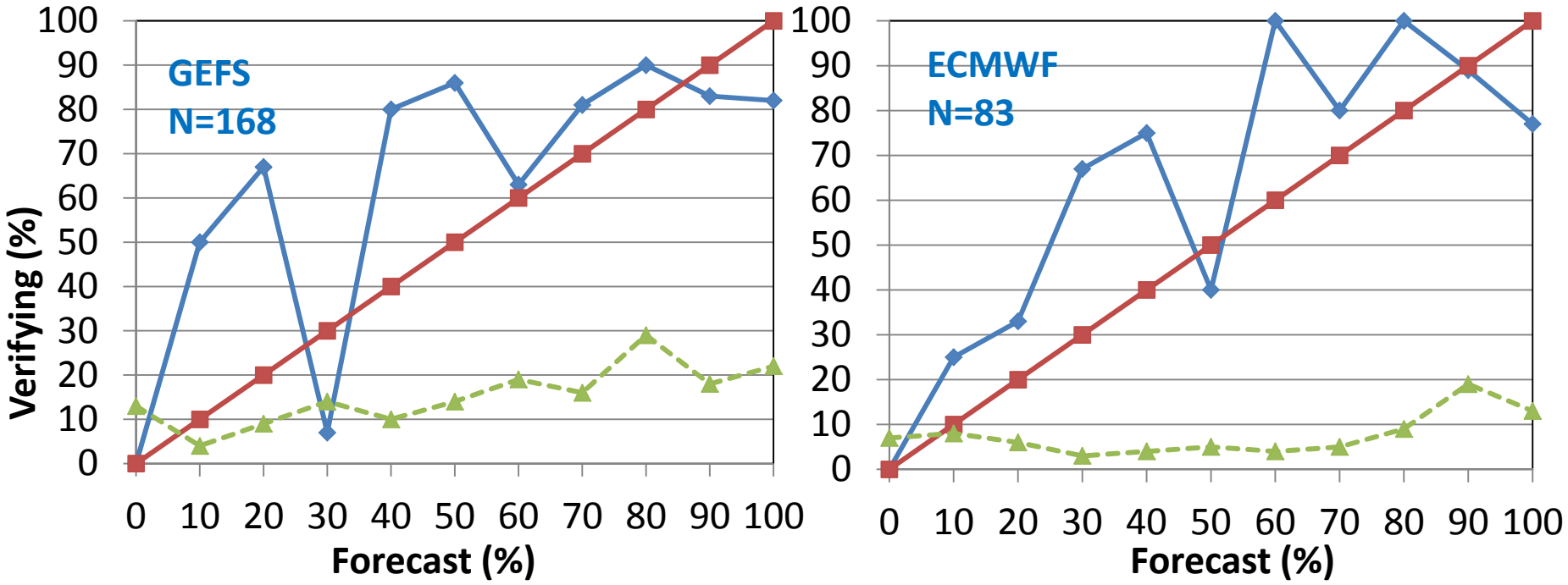
OBSERVARTION		
FORECAST	YES	NO
YES	a=38	b=28
NO	c=21	d=58
Hit rate(POD)=a/(a+c)	64%	
Miss rate=c/(a+c)	36%	
False alarm rate=b/(b+d)	33%	
Correct rejection rate=d/(b+d)	67%	
Critical success index=a/(a+b+c)	0.44	

OBSERVARTION		
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

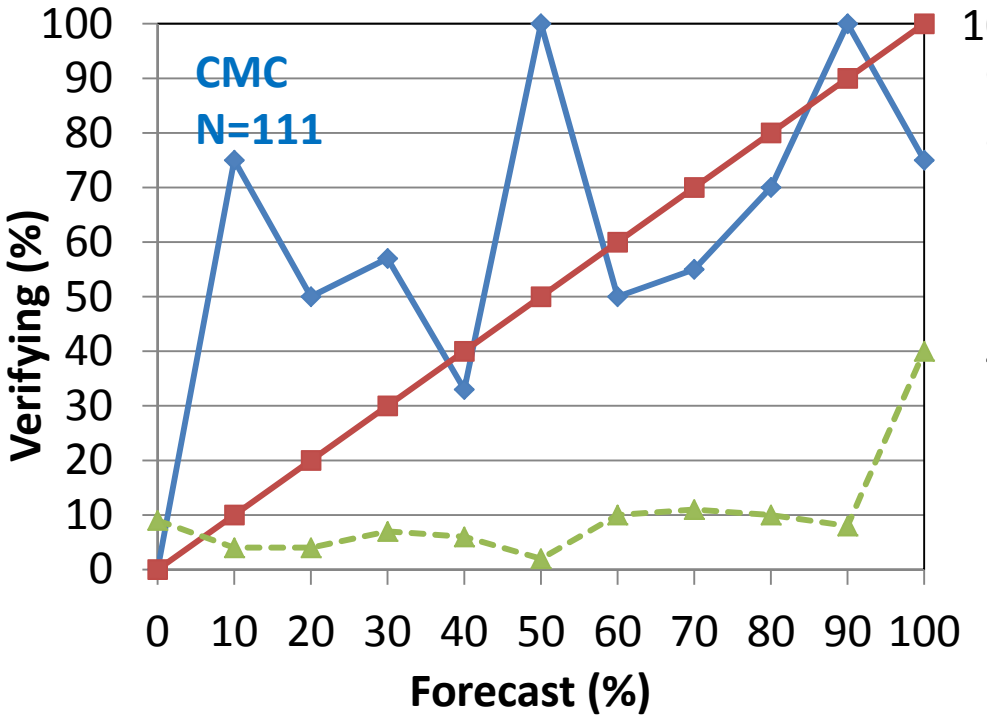
2013 West Pacific TC Genesis Forecast Reliability Diagram

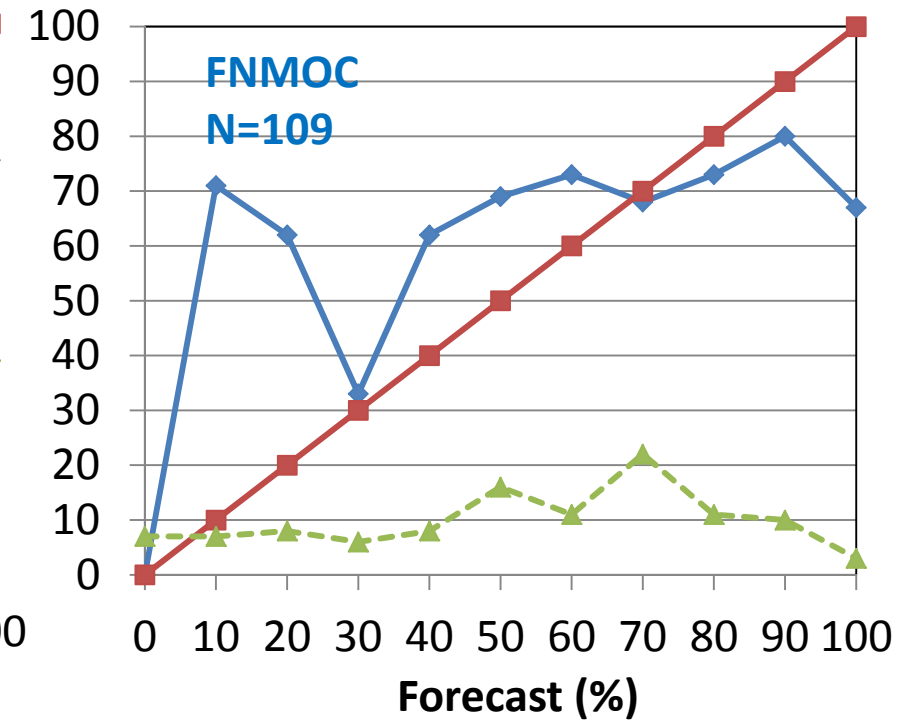


OBSERVARTION		
FORECAST	YES	NO
YES	a=84	b=20
NO	c=29	d=35
Hit rate(POD)=a/(a+c)	74%	
Miss rate=c/(a+c)	26%	
False alarm rate=b/(b+d)	36%	
Correct rejection rate=d/(b+d)	64%	
Critical success index=a/(a+b+c)	0.63	

OBSERVARTION		
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





OBSERVARTION		
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	

OBSERVARTION		
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 2013.
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
for 2014 real time TC track and genesis probabilistic forecasts.

2013 GFS TC Genesis Forecast Contingent Table

Atlantic, N=110

OBSERVARTION / 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

OBSERVARTION / 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

OBSERVARTION / 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

2012 GFS TC Genesis Forecast Contingent Table

Atlantic, N=108

OBSERVARTION / FORECAST	YES	NO
YES	a=47	b=21
NO	c=22	d=18
Hit rate(POD)=a/(a+c)	68%	
Miss rate=c/(a+c)	32%	
False alarm rate=b/(b+d)	54%	
Correct rejection rate=d/(b+d)	46%	
Critical success index=a/(a+b+c)	0.52	

East Pacific, N=82

OBSERVARTION / FORECAST	YES	NO
YES	a=30	b=18
NO	c=19	d=15
Hit rate(POD)=a/(a+c)	61%	
Miss rate=c/(a+c)	39%	
False alarm rate=b/(b+d)	55%	
Correct rejection rate=d/(b+d)	45%	
Critical success index=a/(a+b+c)	0.45	

West Pacific, N=120

OBSERVARTION / FORECAST	YES	NO
YES	a=74	b=24
NO	c=5	d=17
Hit rate(POD)=a/(a+c)	94%	
Miss rate=c/(a+c)	6%	
False alarm rate=b/(b+d)	59%	
Correct rejection rate=d/(b+d)	41%	
Critical success index=a/(a+b+c)	0.72	

GFS T574L64 -27km

Max wind speed>=25kts

TC Genesis Tracker Code

Based on GFDL 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 ≥25kts (12.9m/s)

Criteria (Gray,1968):

1)A positive relative vorticity in lower troposphere

2)Far away 5N/S from equator

3)Warm SST (≥79F or 26.1C for Atlantic)

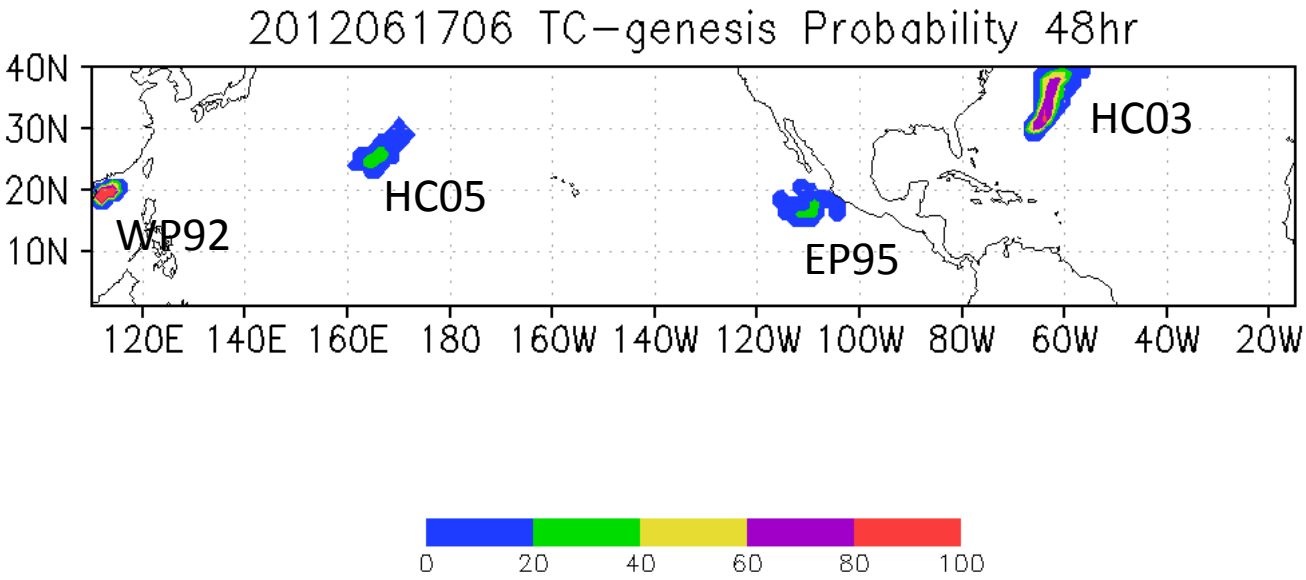
4)Small vertical shear

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)