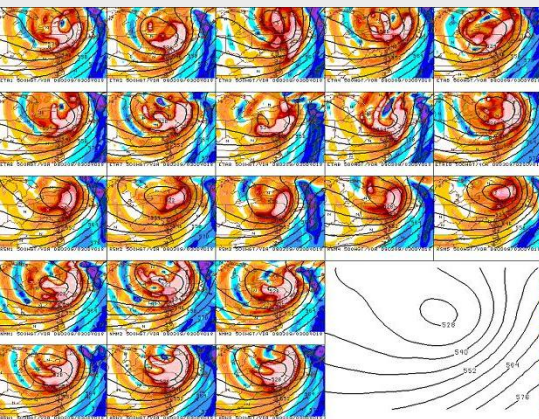


# Possible new ensemble applications for forecasters

Eric Blake and Todd Kimberlain  
Hurricane Specialists  
National Hurricane Center



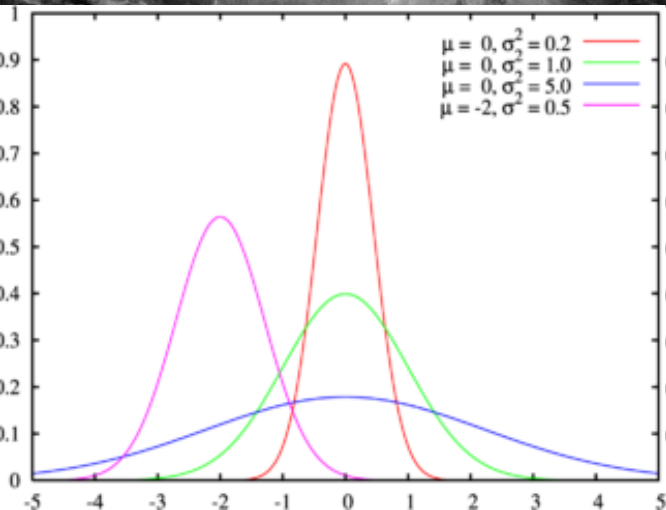
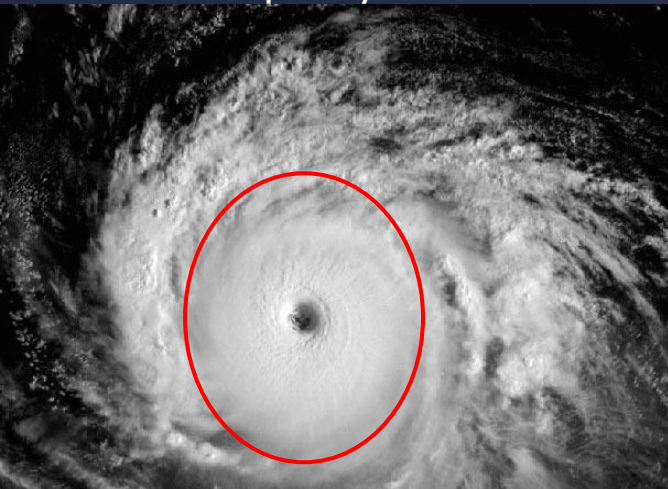
HFIP Ensemble Workshop

# Motivation

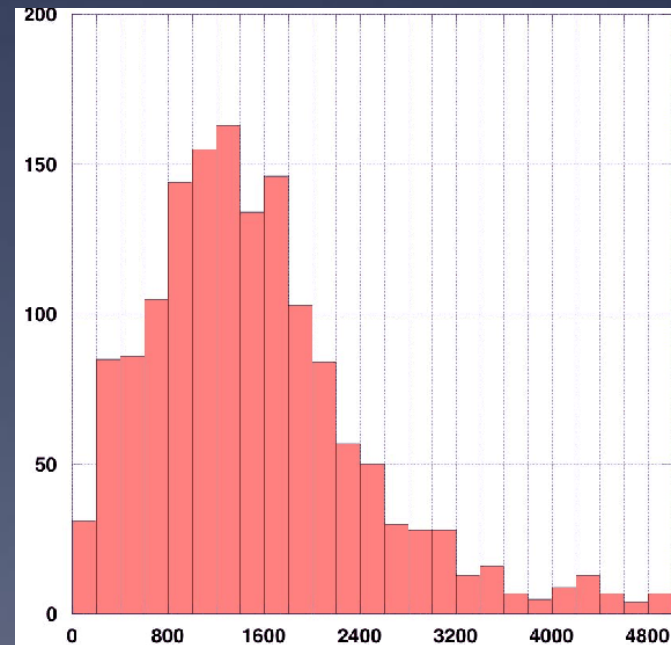
- \* Ensemble guidance is infrequently used in TC track forecasting at NHC
- \* Multi-model consensus methods have been shown to have more utility than single model ensemble methods
- \* Routine, user-friendly products based on ensembles not available
- \* Burden is on the forecaster to “interpret” ensemble output when time is scarce
- \* A greater effort is necessary to realize the benefits of ensemble forecasting

# Ensemble model storm graphics

- \* Ensemble probability density functions (PDFs) of important storm parameters for all members
- \* By tracking each ensemble member storm, could display shear, intensity change, mid-level moisture etc.



- \* Distribution and mean value of parameters important



# Ensemble SHIPS Rapid Intensity Index?

- Environmental parameters could be calculated for each large-scale model to obtain more realistic estimates
- Consensus of environmental fields from all global models may prove to be more useful than any given field (e.g. track forecasting)

```
** 2008 ATLANTIC RI INDEX AL172008 PALOMA 11/06/08 18 UTC **  
( 25 KT OR MORE MAX WIND INCREASE IN NEXT 24 HR)
```

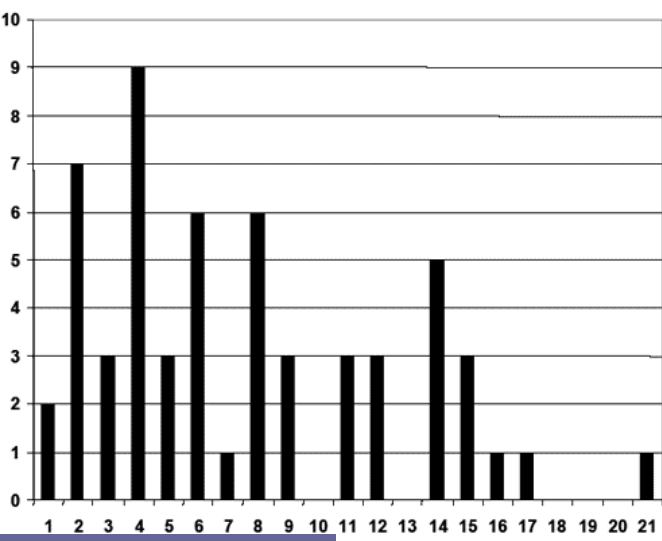
```
12 HR PERSISTENCE (KT) : 15.0 Range:-45.0 to 30.0 Scaled/Wgted Val: 0.8/ 1.4  
850-200 MB SHEAR (KT) : 4.4 Range: 35.1 to 3.2 Scaled/Wgted Val: 1.0/ 1.5  
D200 (10**7s-1) : 44.8 Range:-20.0 to 149.0 Scaled/Wgted Val: 0.4/ 0.6  
POT = MPI-VMAX (KT) : 87.4 Range: 25.1 to 130.7 Scaled/Wgted Val: 0.6/ 0.7  
850-700 MB REL HUM (%) : 71.6 Range: 56.0 to 88.0 Scaled/Wgted Val: 0.5/ 0.2  
% area w/pixels <-30 C: 74.0 Range: 17.0 to 100.0 Scaled/Wgted Val: 0.7/ 0.1  
STD DEV OF IR BR TEMP : 14.4 Range: 35.1 to 3.2 Scaled/Wgted Val: 0.6/ 0.8  
Heat content (KJ/cm2) : 51.2 Range: 0.0 to 132.0 Scaled/Wgted Val: 0.4/ 0.0
```

```
Prob of RI for 25 kt RI threshold= 44% is 3.6 times the sample mean(12.3%)  
Prob of RI for 30 kt RI threshold= 33% is 4.2 times the sample mean( 7.8%)  
Prob of RI for 35 kt RI threshold= 32% is 7.1 times the sample mean( 4.5%)
```

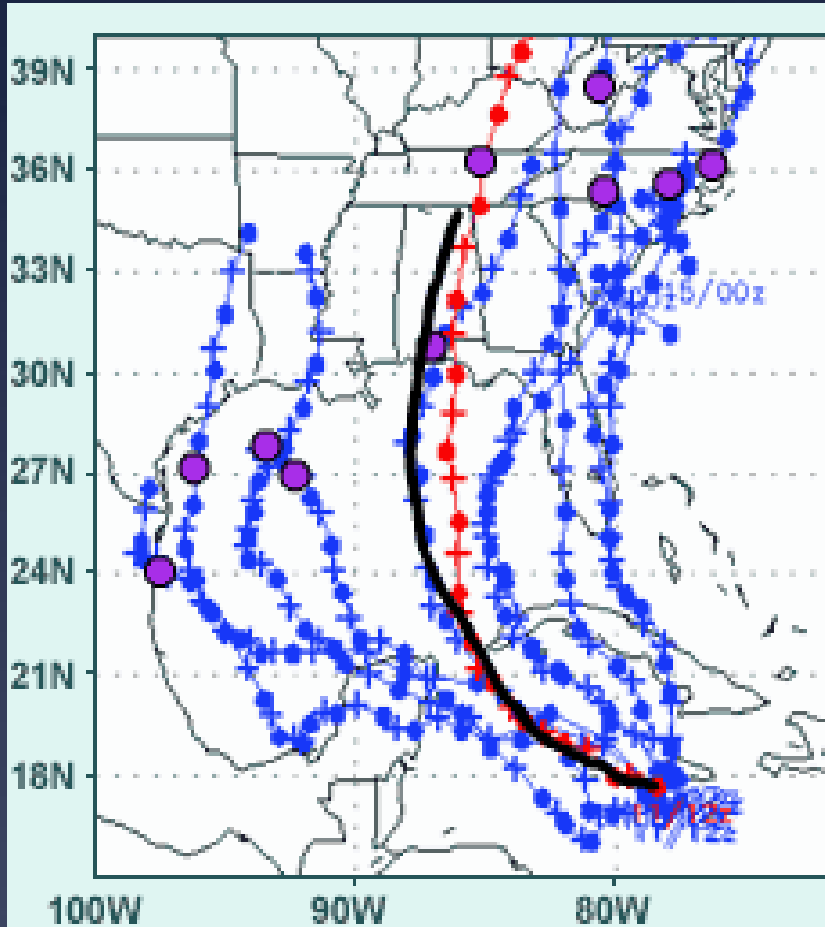
# Ensemble SHIPS/LGEM?

\* ATLANTIC SHIPS INTENSITY FORECAST \*  
 \* GOES/OHC INPUT INCLUDED \*  
 \* PALOMA AL172008 11/06/08 18 UTC \*

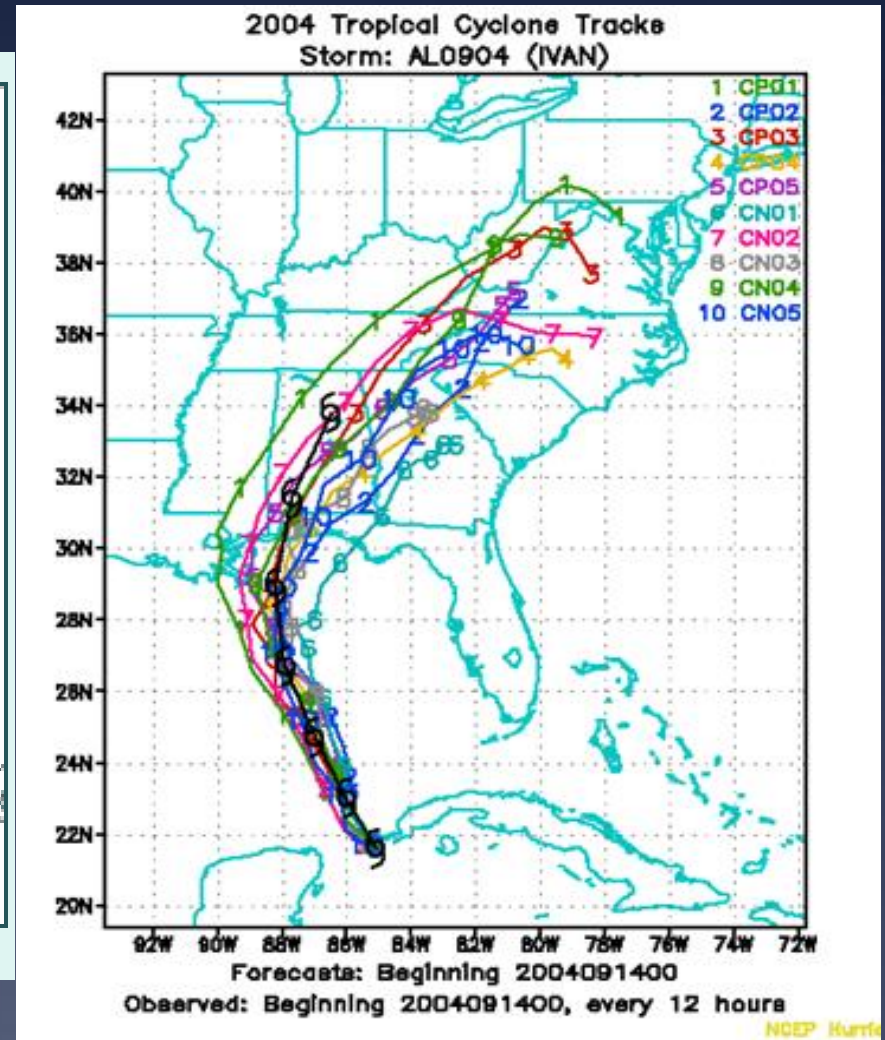
TIME (HR)	0	6	12	18	24	36	48	60	72	84	96	108	120
GFS (KT)	50	57	62	68	73	80	82	76	68	59	48	39	30
UKMET (KT)	50	57	62	68	73	80	82	76	68	52	41	32	23
ECMWF (KT)	50	56	62	67	71	78	81	79	71	54	45	37	30
GEFS (KT)	50	58	64	70	74	82	82	78	72	55	43	36	29
SHEAR (KTS)	3	6	7	6	1	12	14	33	35	41	37	50	47
SHEAR DIR	118	192	231	240	249	235	228	219	240	251	281	266	283
SST (C)	29.0	29.0	29.0	29.0	28.9	28.9	28.7	28.6	28.4	27.6	27.3	27.2	26.9
-----		149	149	149	148	148	145	143	141	132	128	126	122
		138	138	137	135	135	131	129	128	122	117	112	107
		3.4	-53.5	-53.8	-53.2	-53.5	-53.4	-53.4	-53.8	-54.5	-54.9	-55.2	-55.1
		8	7	6	8	7	8	8	8	7	7	7	8
		59	57	53	52	47	46	44	45	44	45	44	41
		13	14	16	15	17	16	13	10	9	6	6	4
		21	26	28	33	28	12	7	7	6	-1	1	-5
		54	26	20	46	50	23	25	29	21	22	-3	-33
		201	241	281	315	350	233	149	30	30	279	480	634
		6.4	16.9	17.4	17.9	18.9	19.8	20.3	20.8	21.8	23.4	24.6	25.6
		2.0	82.1	82.2	82.2	81.8	80.9	79.9	78.7	77.0	74.8	73.0	71.8
		5	5	5	5	6	6	6	7	11	12	9	7
		5	69	87	87	79	86	86	48	18	15	23	12



# Spread of ensembles as a confidence indicator?



Hurricane Ivan, 9/11/04 1200 UTC



Are both spreads really representative of the forecast uncertainty?

# Representativeness

- How do we know that a particular set of ensemble solutions is representative of the actual uncertainty?
- Forecasters tend to equate model spread with confidence. If the spread is not representative of the true confidence, what other measures are there?



# Realistic spreads?





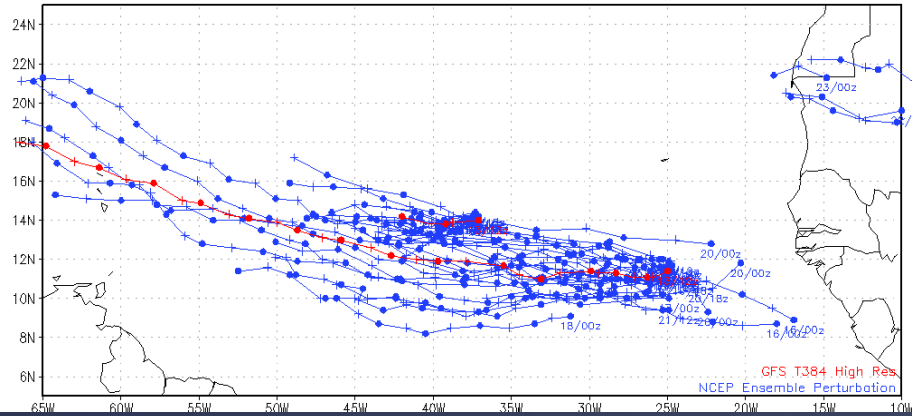
# Realistic spreads?



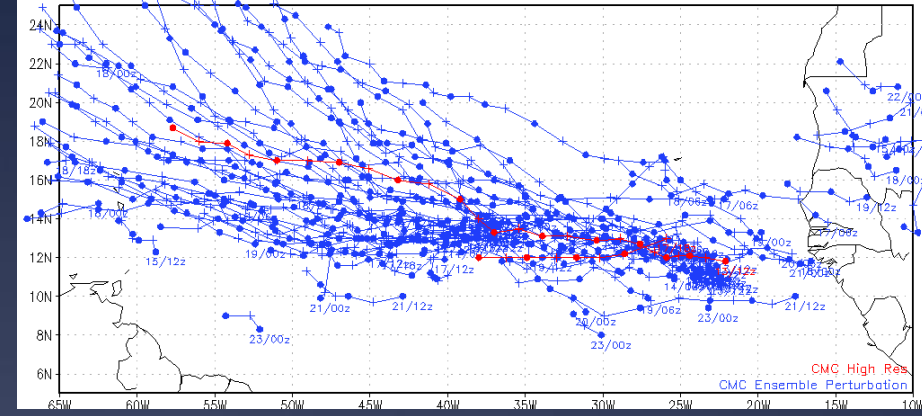
\*Forecasts may be biased and/or deficient in spread; need better tools to properly identify the full range of possibilities

# Genesis and track of current ensemble systems

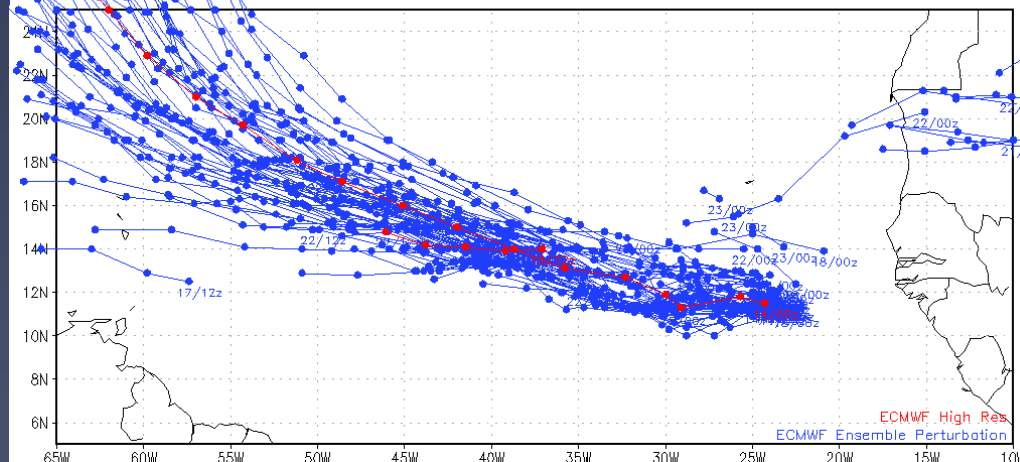
NCEP Ensemble Perturbation Forecast Storm Tracks  
For forecast with initial time = 2009081312



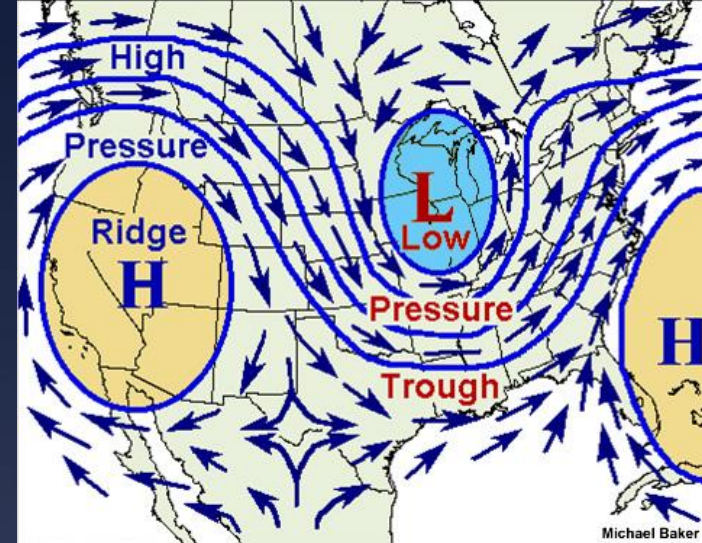
CMC Ensemble Perturbation Forecast Storm Tracks  
For forecast with initial time = 2009081312



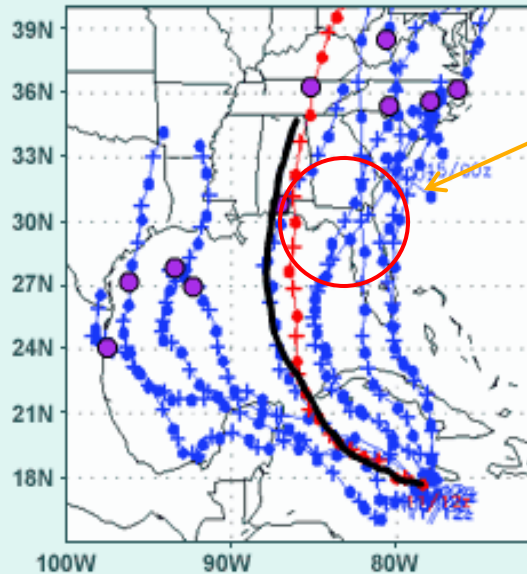
ECMWF Ensemble Perturbation Forecast Storm Tracks  
For forecast with initial time = 2009081312



# Other tools?



Hurricane Ivan Tracks from 1200 UTC 11 Sep 2004  
Ensemble Run and GFS Operational Model



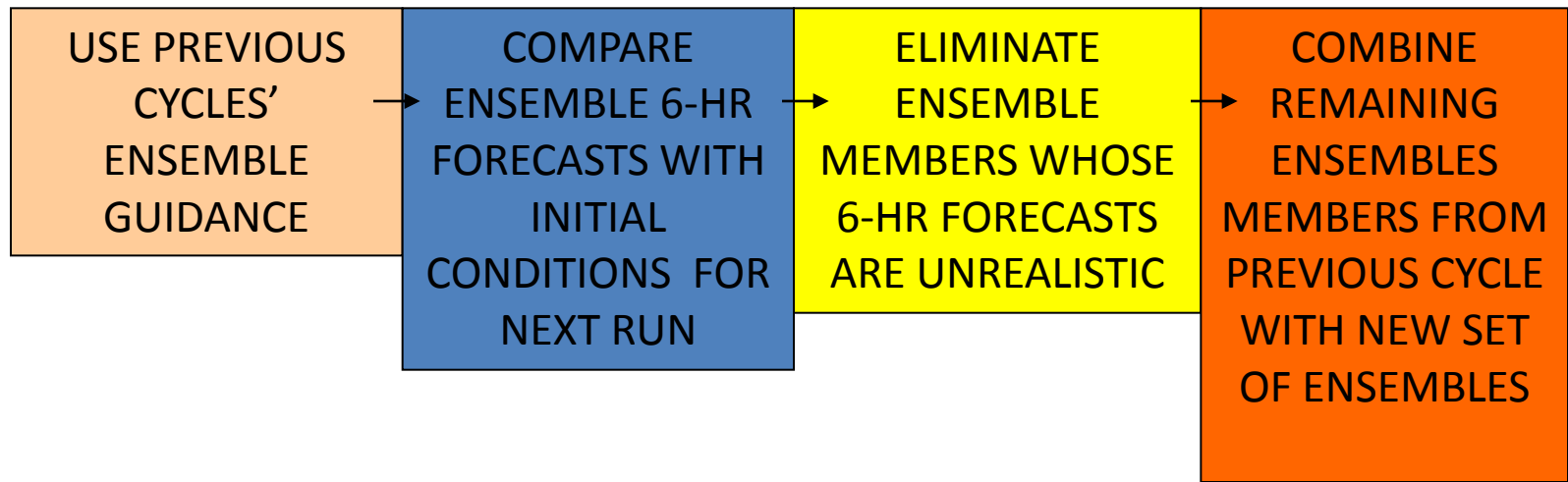
● - Indicates a position at 0000 or 1200 UTC  
+ - Indicates a position at 0600 or 1800 UTC

NOAA / GFDL

Ability to average model fields  
of associated tracks

Ability to difference ensemble model  
fields as well as those from other models

# Intelligent Use of Multi-Run Ensembles

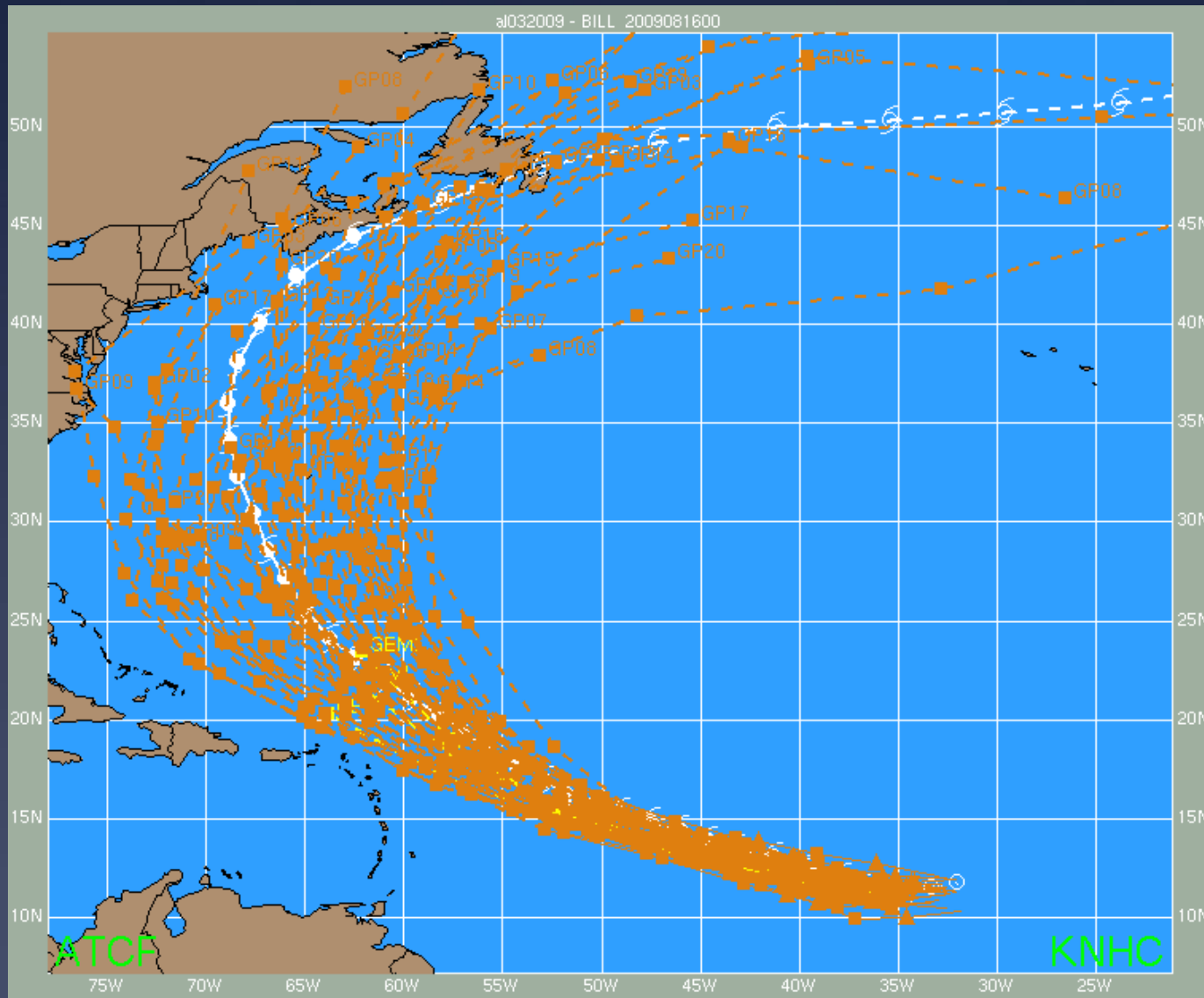


e.g., 50 ensembles (00z) + 27 ensembles (18z) + 7 ensembles (12z)

- Produce various PDFs for parameters of interest from various cycles
- Create interface to allow forecaster to choose which set of ensembles to use
- Have a tool that to allow forecasters to visualize which forecasts from previous sets of ensembles have been eliminated
- Repeat process

# Multi-run Single-model Ensemble

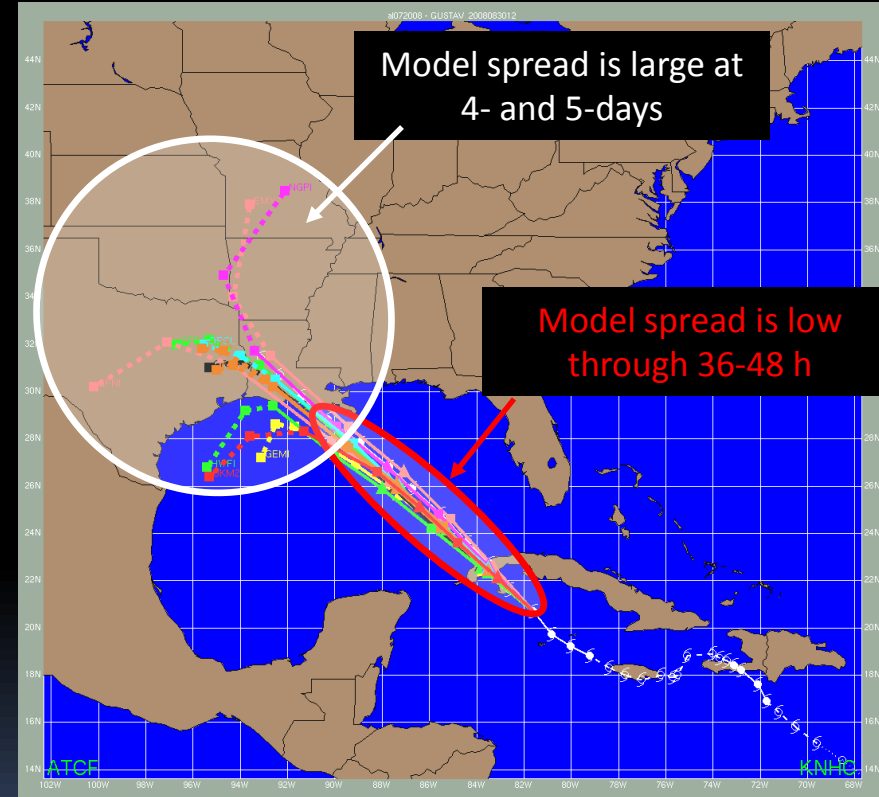
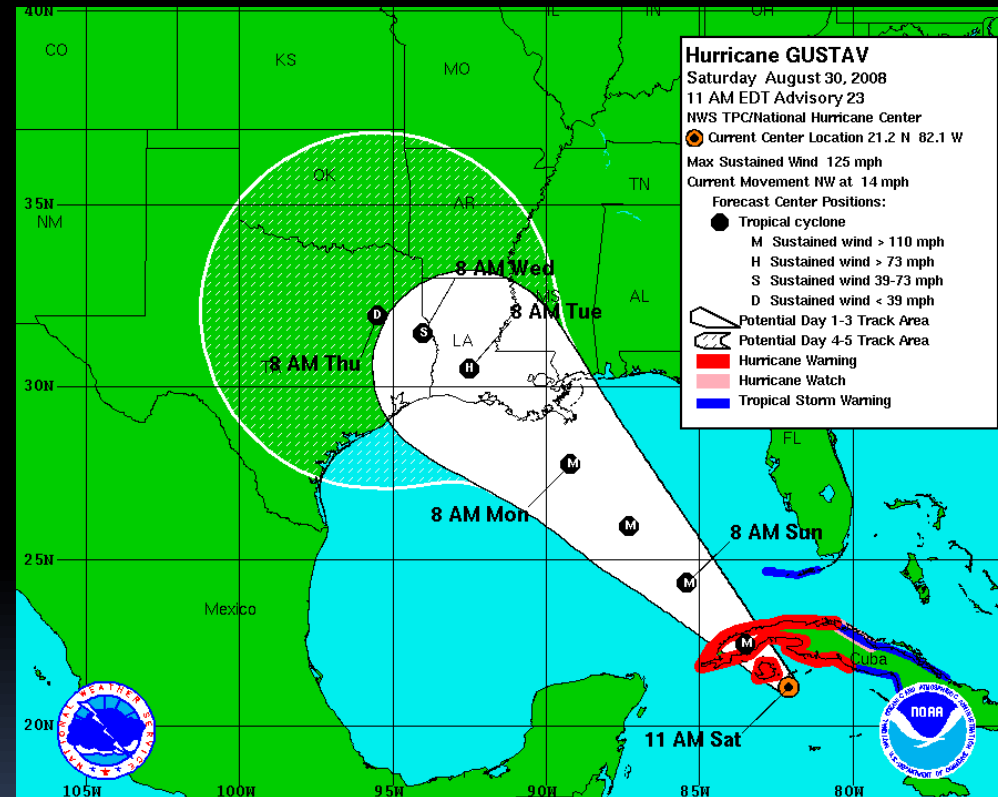
- \* GEFS from 3 consecutive runs, track in the center of the spread



# Example of Variable Cone Hurricane Gustav 2008

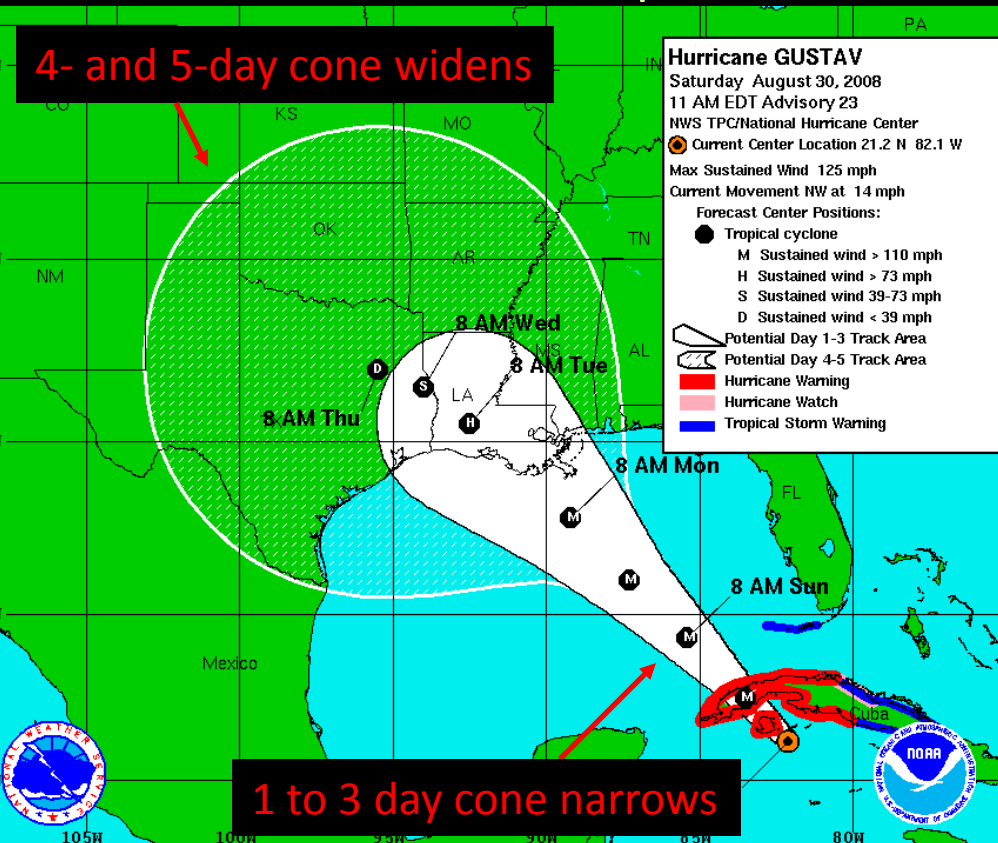
## Existing NHC Cone Graphic

## Corresponding Model Guidance

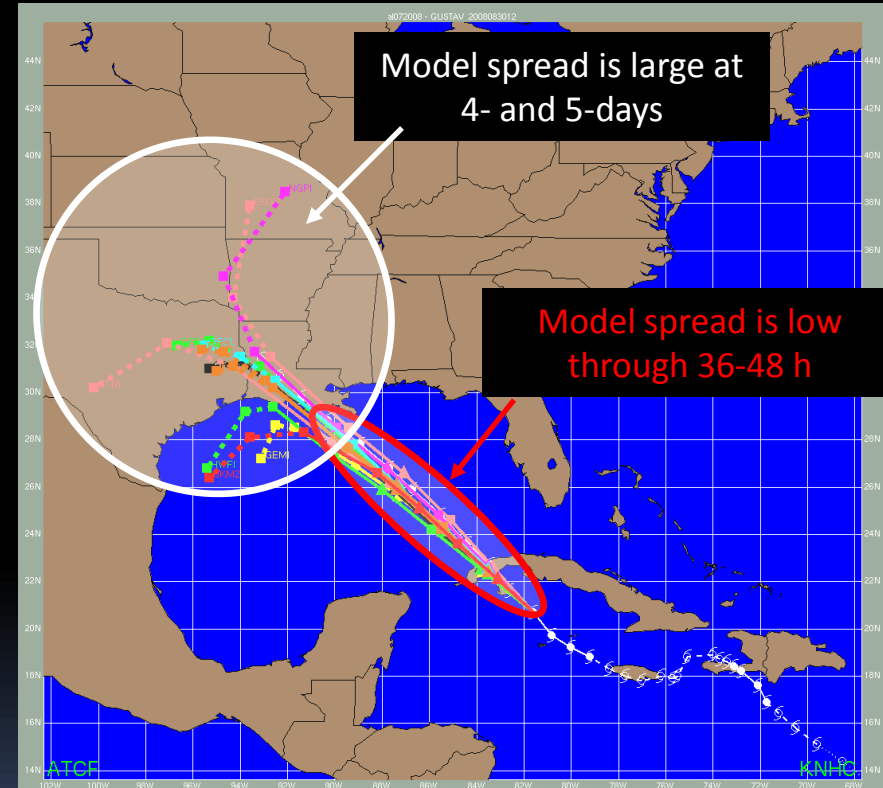


# Example of Variable Cone Hurricane Gustav 2008

## Variable Cone Graphic



## Corresponding Model Guidance

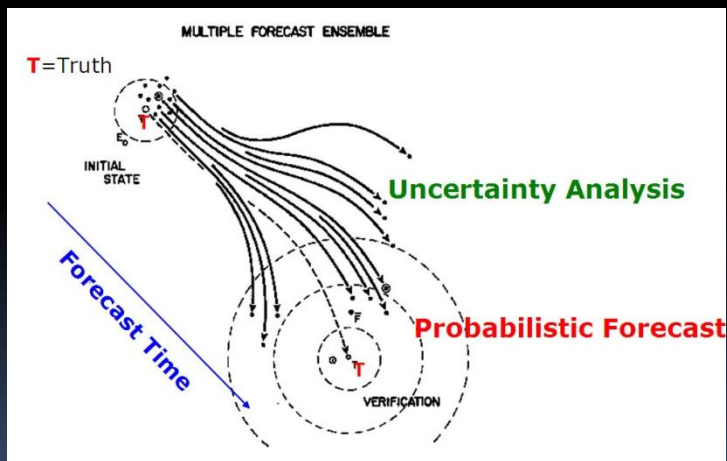


• Could ensemble spread be used to set cone width?

# Ensemble-derived size product

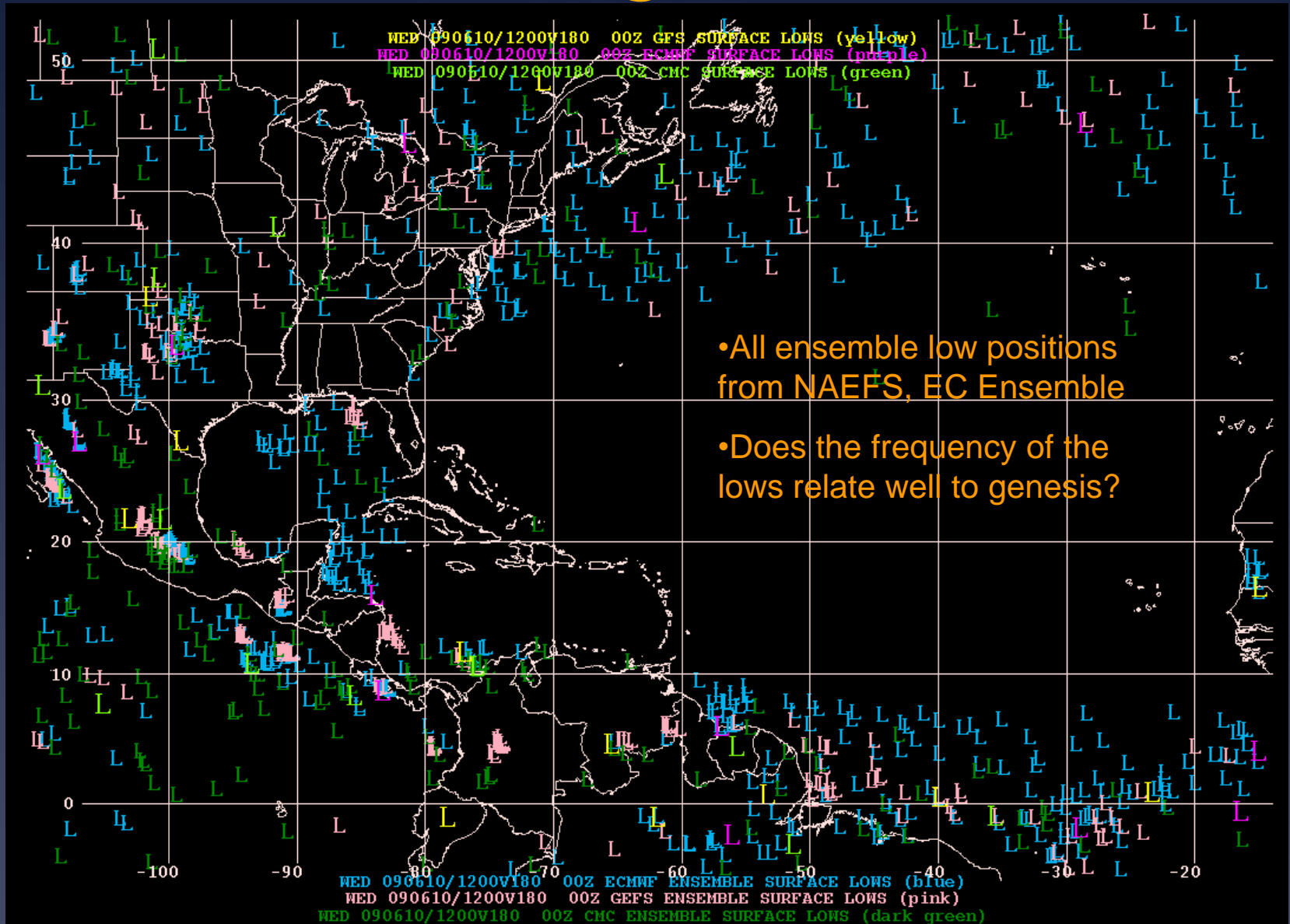


- Applications could include the development of derived products
- Size can currently be inferred from global dynamical models and skill, though currently limited, is increasing
- As model resolution gets finer, SREF/GEFS output could be used to determine an estimate of size
- Result could be a great improvement over current methods

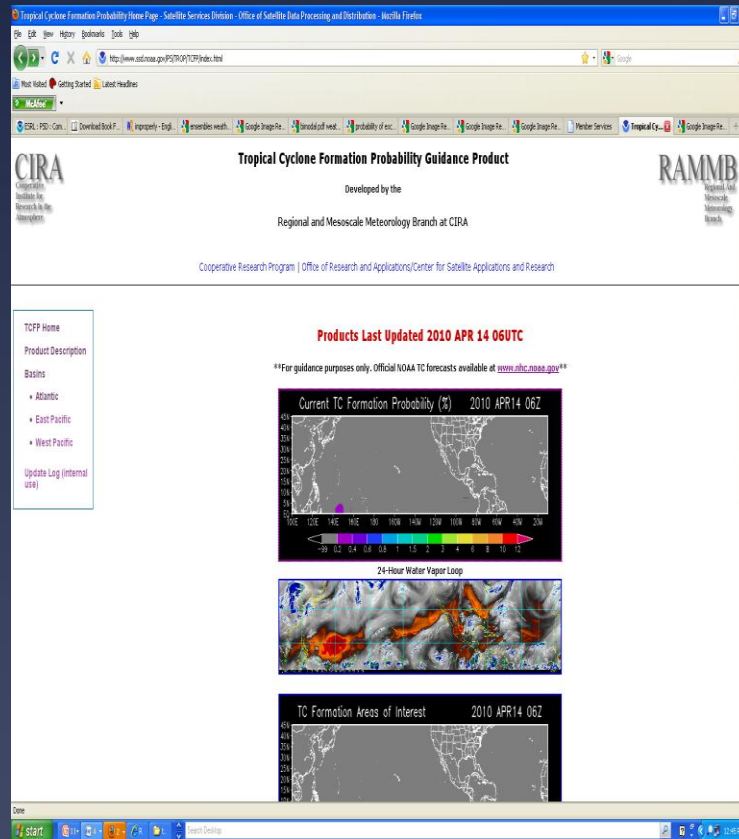




# TC Genesis guidance?

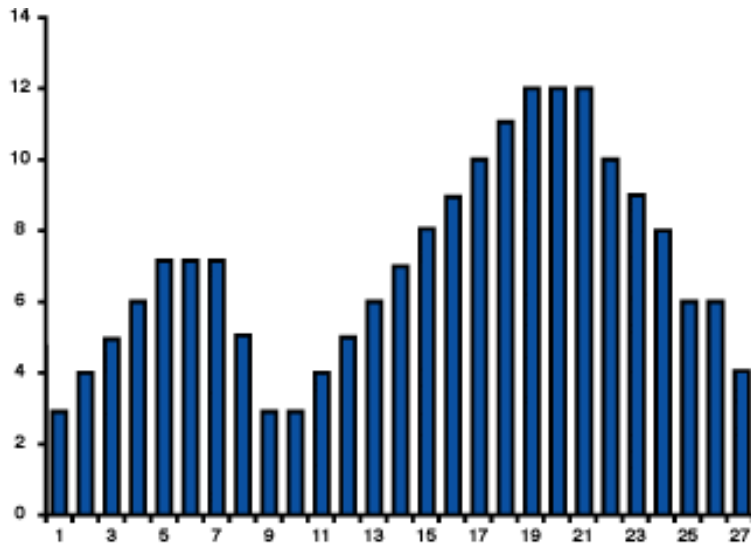


# Possible Ensemble Genesis Product



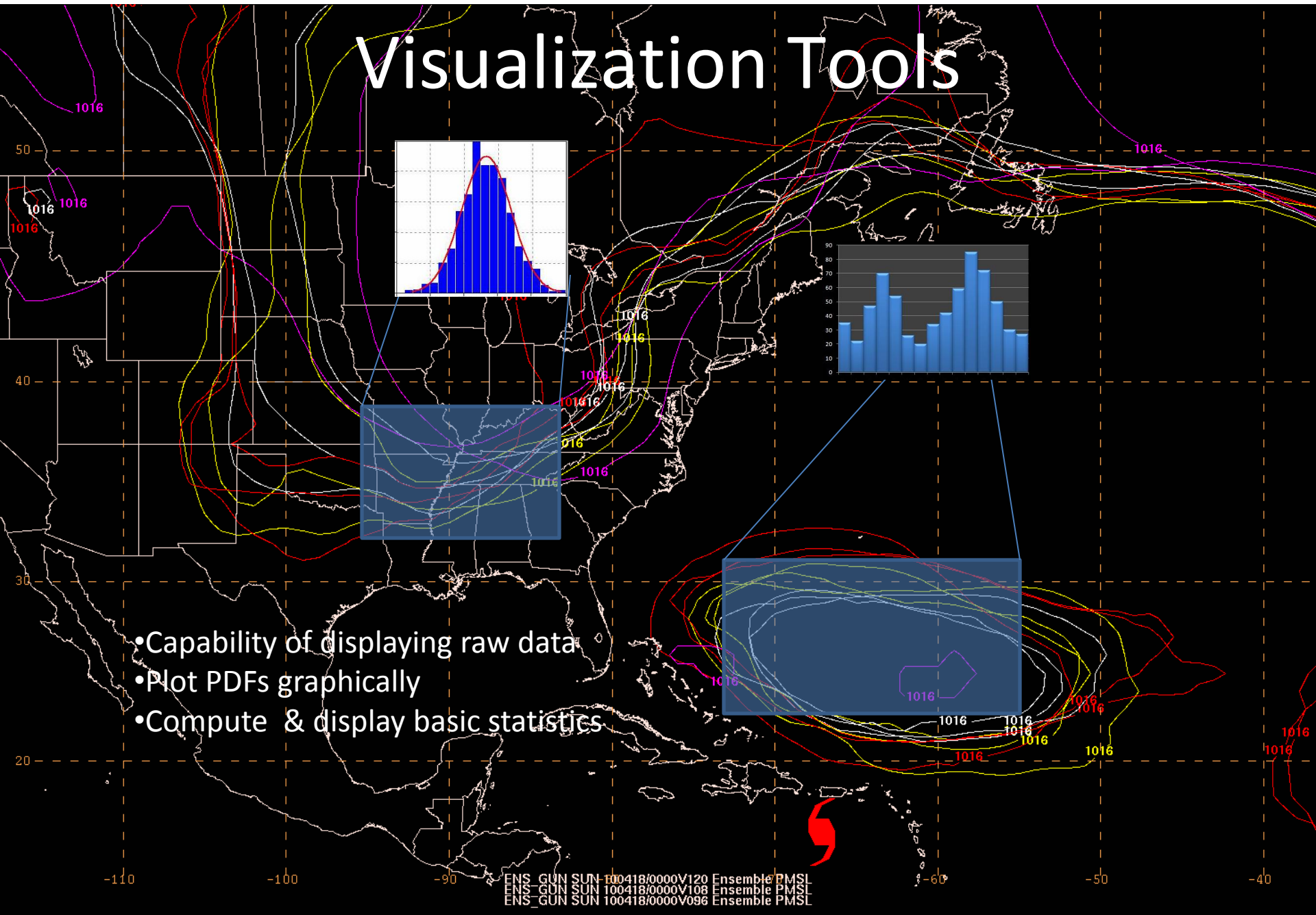
- \* CIRA TC Formation Probability Guidance Product is a diagnostic
- \* Supply input parameters using ensemble guidance and generate probabilities at various forecast times
- \* Input parameters include: vertical shear, 850mb circulation, vertical instability, 850mb horizontal divergence, how many members develop etc.
- \* Produce a PDF and show other statistical metrics for the ensemble-generated probabilities

# Multiple Outcomes



- Distribution of ensemble forecasts may be multi-modal (non-normal)
- How representative are the mean and median (in this case)?
- Problem: Ensemble forecasts may not have enough members to give an accurate estimate of the probabilities associated with forecast outcomes
- Could be indicative of multiple regimes
- Need to tools to determine maximum likelihood

# Visualization Tools

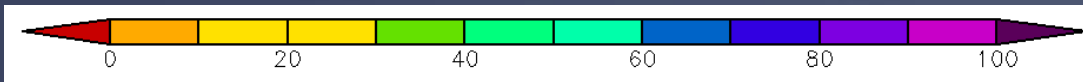
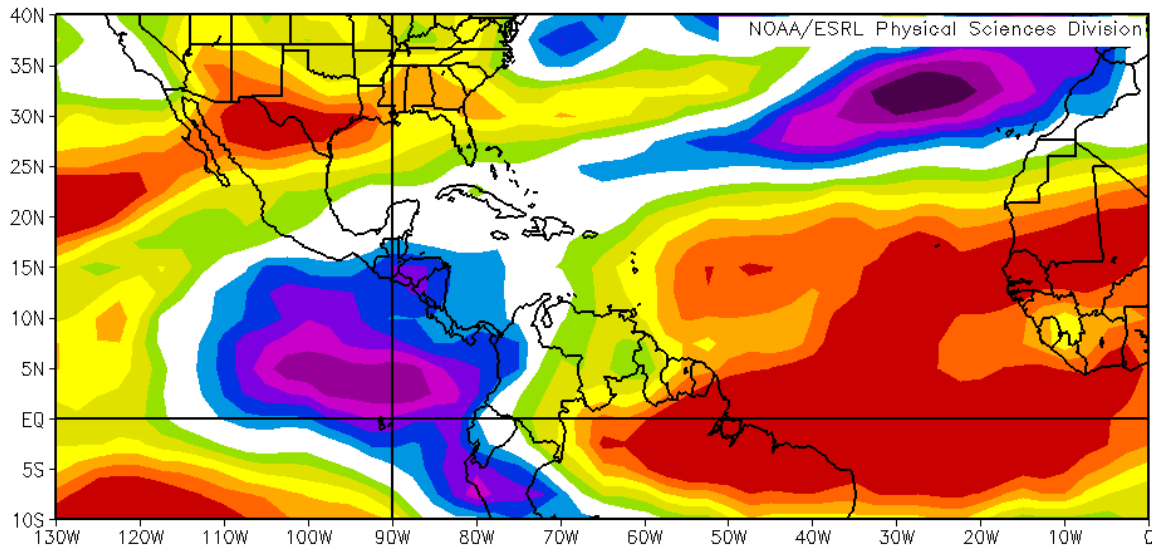


- Capability of displaying raw data
- Plot PDFs graphically
- Compute & display basic statistics

ENS\_GUN\_SUN\_100418/0000V120 Ensemble PMSL  
ENS\_GUN\_SUN\_100418/0000V108 Ensemble PMSL  
ENS\_GUN\_SUN\_100418/0000V096 Ensemble PMSL

# Probabilities of Exceedance

Probability of RH<30%

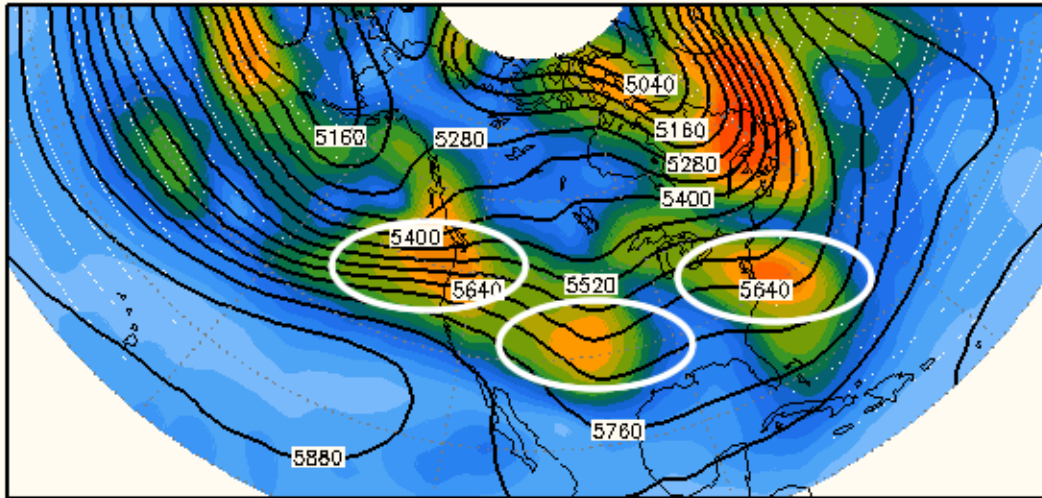


- Calculate the probability of certain parameters exceeding chosen critical values at grid points or over a domain

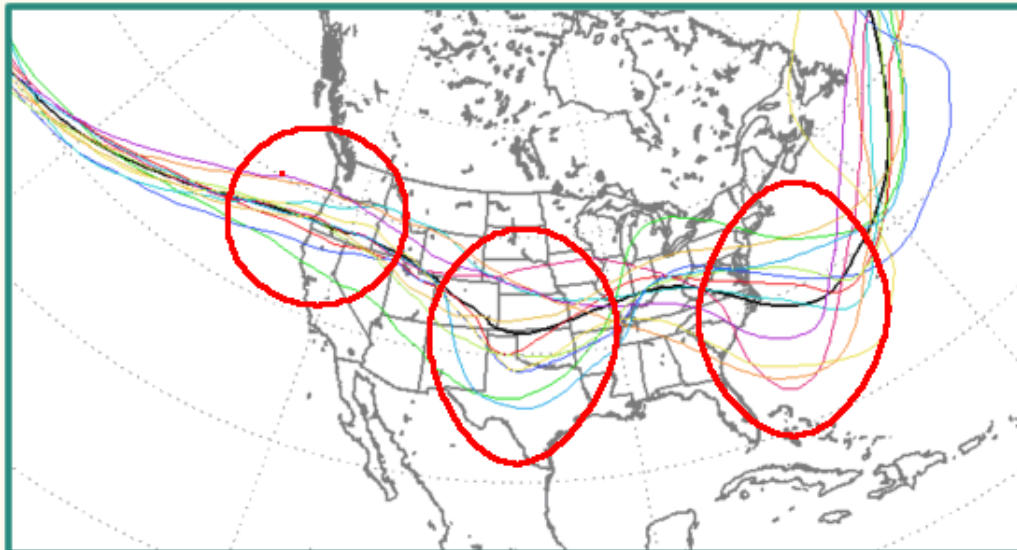
Pick thresholds for each parameters:

- Shear (10 kt or 15 kt)
- Dry air aloft (RH < 50% at 500 mb)
- Divergence/convergence
- Low-level vorticity
- Lapse rates

Ensemble mean, std. dev. for 500-hPa heights,  
forecast from 00z19Nov01 valid 12z22Nov01



Ensemble mean/members 564-dm 500-hPa height line,  
00z 19Nov01 forecast valid 12z22Nov01



## Mean/Spread and Spaghetti Plots

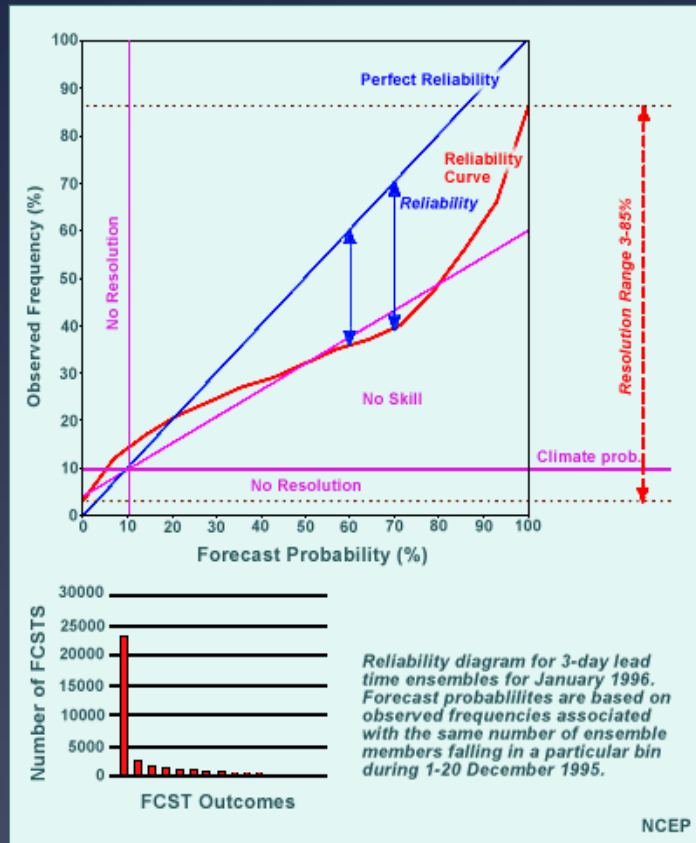
Motivation: Significant upstream weather features may play a key role in TC track and intensity

- Use mean/spread plot to choose a contour of interest

- Overlay forecasts of that contour on forecast spread

- Use combined plot to determine whether timing, amplitude, or existence of a feature contributes to overall uncertainty

# Useful Verification Tools for the Forecaster

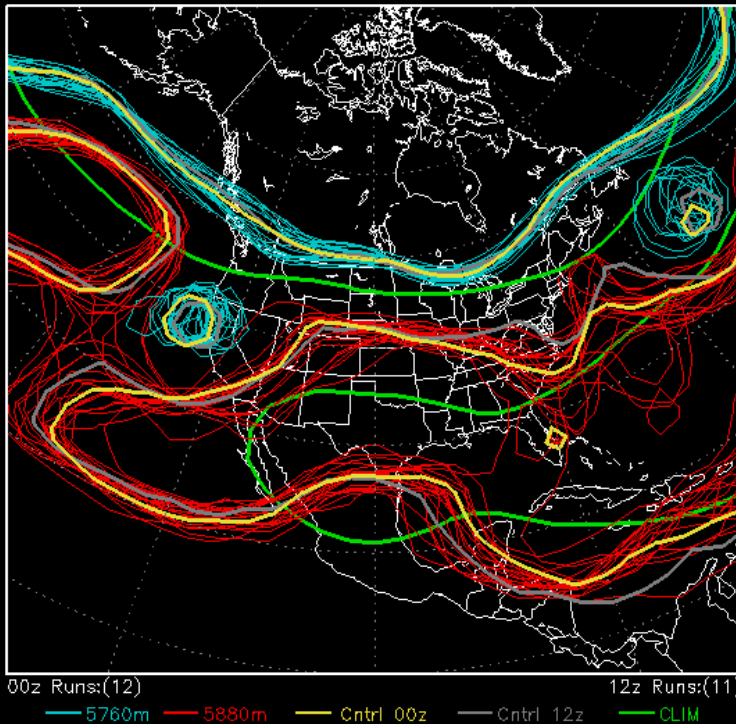


- \* Reliability diagrams – “guidance on guidance”
- \* Reliability diagrams for ensemble output could identify biases
- \* Ensemble forecast skill can be determined relative to climatology
- \* Results could help forecasters when interpreting ensemble guidance

# What isn't very helpful to the end forecaster...

## Spaghetti Diagram

NCEP ENSEMBLE 500mb Z  
048H Forecast from: 00Z Tue SEP,06 2005  
Valid time: 00Z Thu SEP,08 2005





# Summary of ideas for applications

- \* Ensemble approach to intensity and wind radii forecasting and confidence
- \* Realistic ensemble spreads relating to forecast confidence
- \* Improved ensemble mean accuracy
- \* New guidance on TC genesis formations
- \* More realistic initial condition perturbations for the tropics, TC structure
- \* Ensemble model physics
- \* Composite all ensemble members from all ensemble systems

# Summary

- \* Ensemble forecasts have been used more successively in mid-latitude meteorology than in the Tropics
- \* Ensemble TC-related applications are few in number and largely undeveloped
- \* We recommend several ensemble-based, storm-centric tools to better forecast genesis, track, and intensification
- \* Need improved methods/tools to identify full range of possible outcomes
- \* Production of visualization tools to facilitate the forecast process