August 15, 2013

Atlantic Basin Seasonal Hurricane Prediction

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Department of Atmospheric Science

Outline

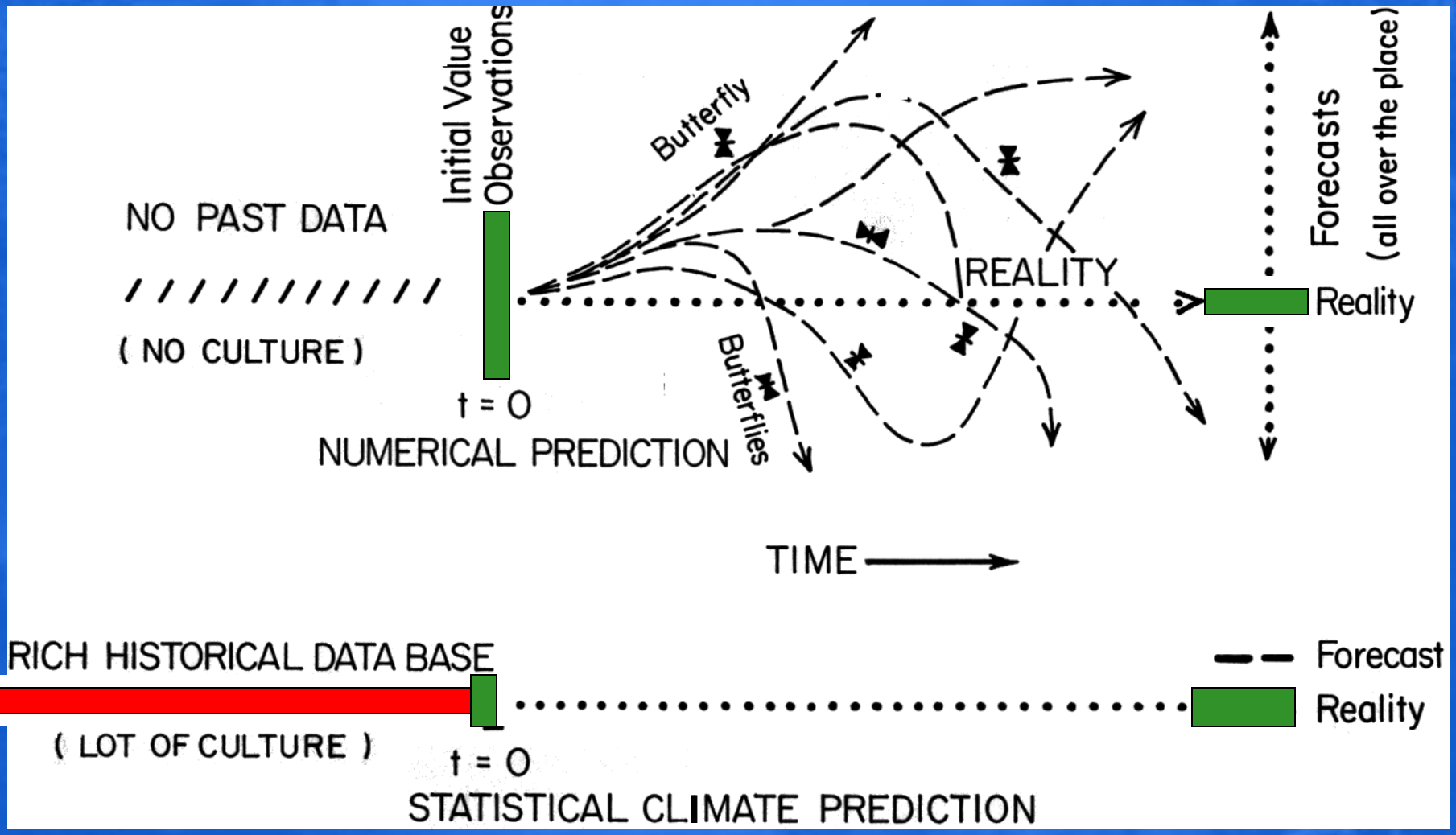
- Introduction
- Atlantic Basin Multi-Decadal Variability
- 2012 Atlantic Basin Seasonal Forecast Verification
- 2013 Atlantic Basin Seasonal Outlook
- Two-Week Forecasts

“It's tough to make predictions, especially about the future”

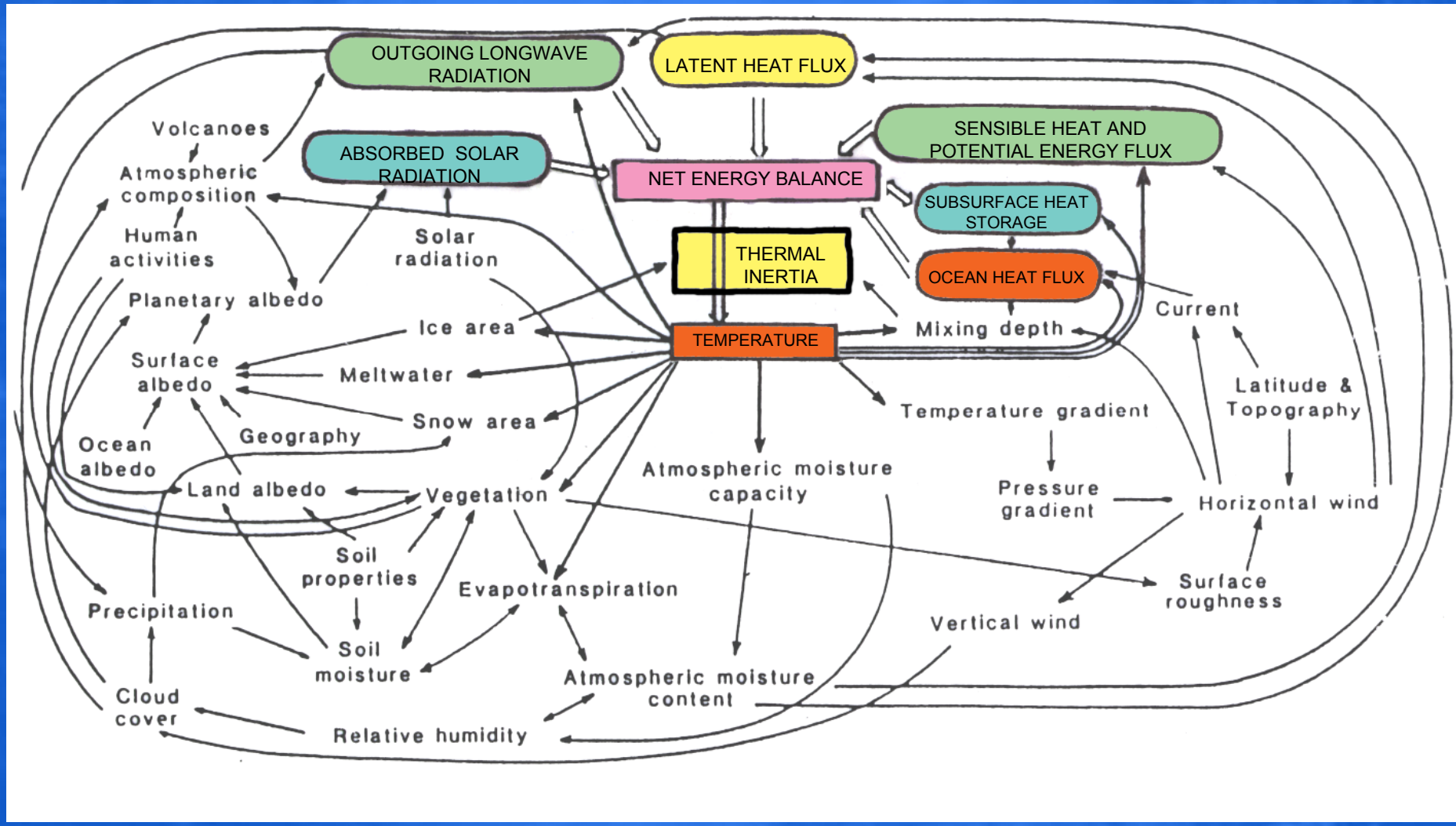
HOWEVER…

“You can see a lot by looking”

Yogi Berra


Initial Value
Observations
NO PAST DATA
(NO CULTURE)
t = 0
NUMERICAL PREDICTION
Butterfly
Butterflies
REALITY
Forecasts
(all over the place)
Reality
TIME
RICH HISTORICAL DATA BASE
(LOT OF CULTURE)
t = 0
STATISTICAL CLIMATE PREDICTION
Forecast
Reality

CLIMATE COMPLICATION



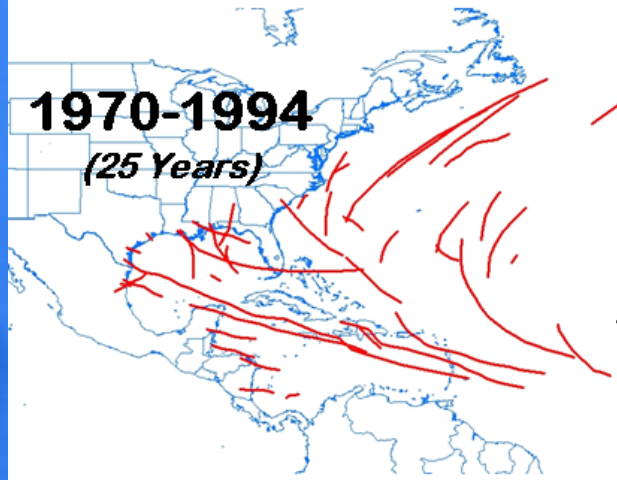
Flow diagram for climate modeling, showing feedback loops. From Robock (1985).

Multi-Decadal Variability – AMO (THC)

1945-1969
(25 Years)

ATLANTIC THC STRONG

80 MAJOR HURRICANES



1970-1994
(25 Years)

ATLANTIC THC WEAK

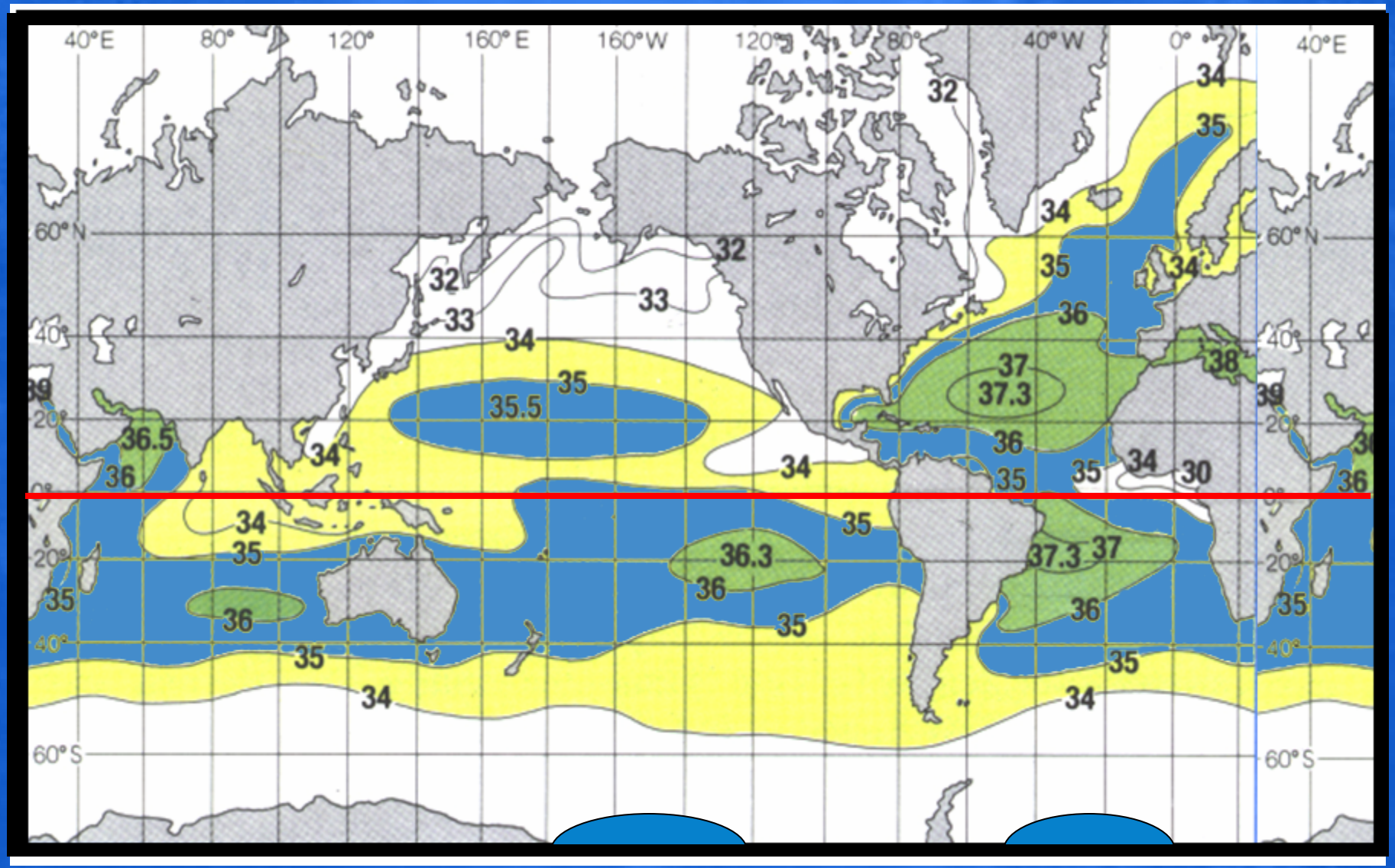
38 MAJOR HURRICANES

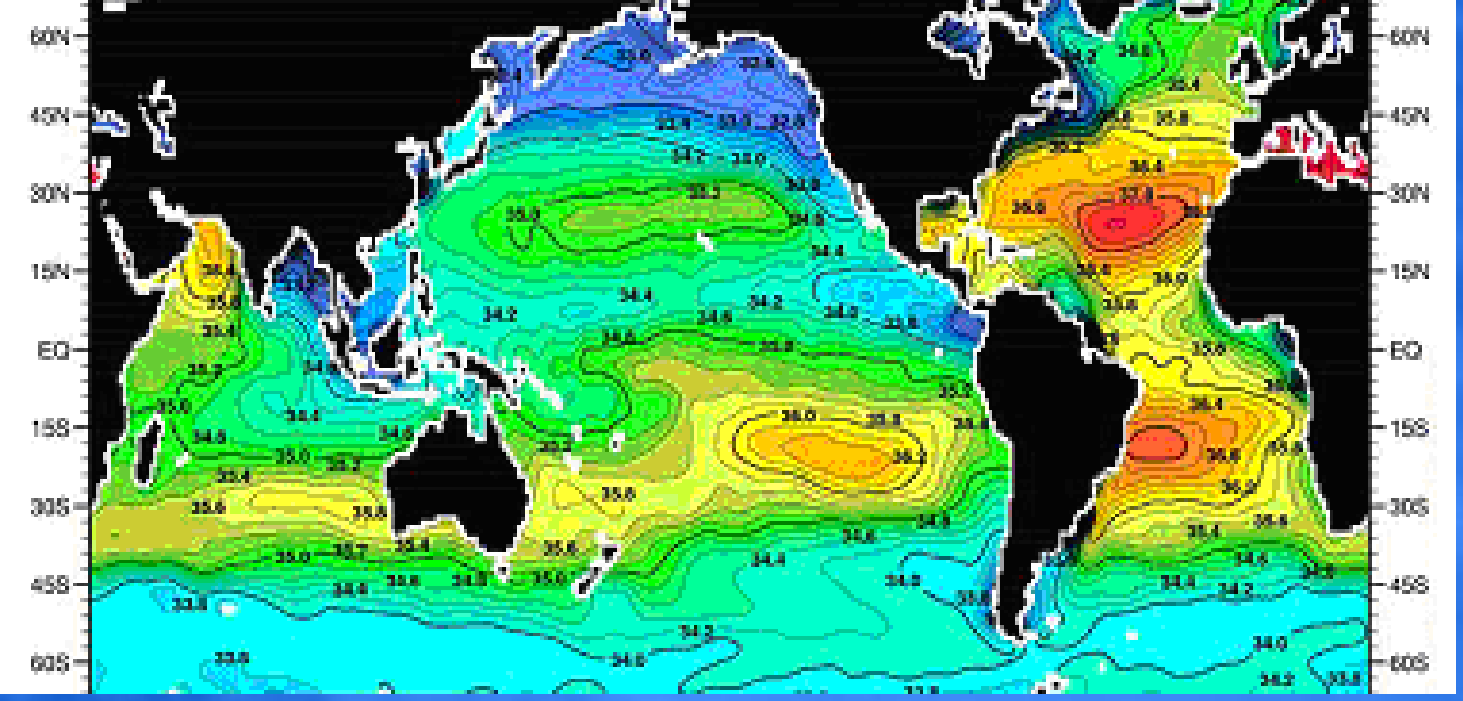
1995-2012
(18 Years)

ATLANTIC THC STRONG

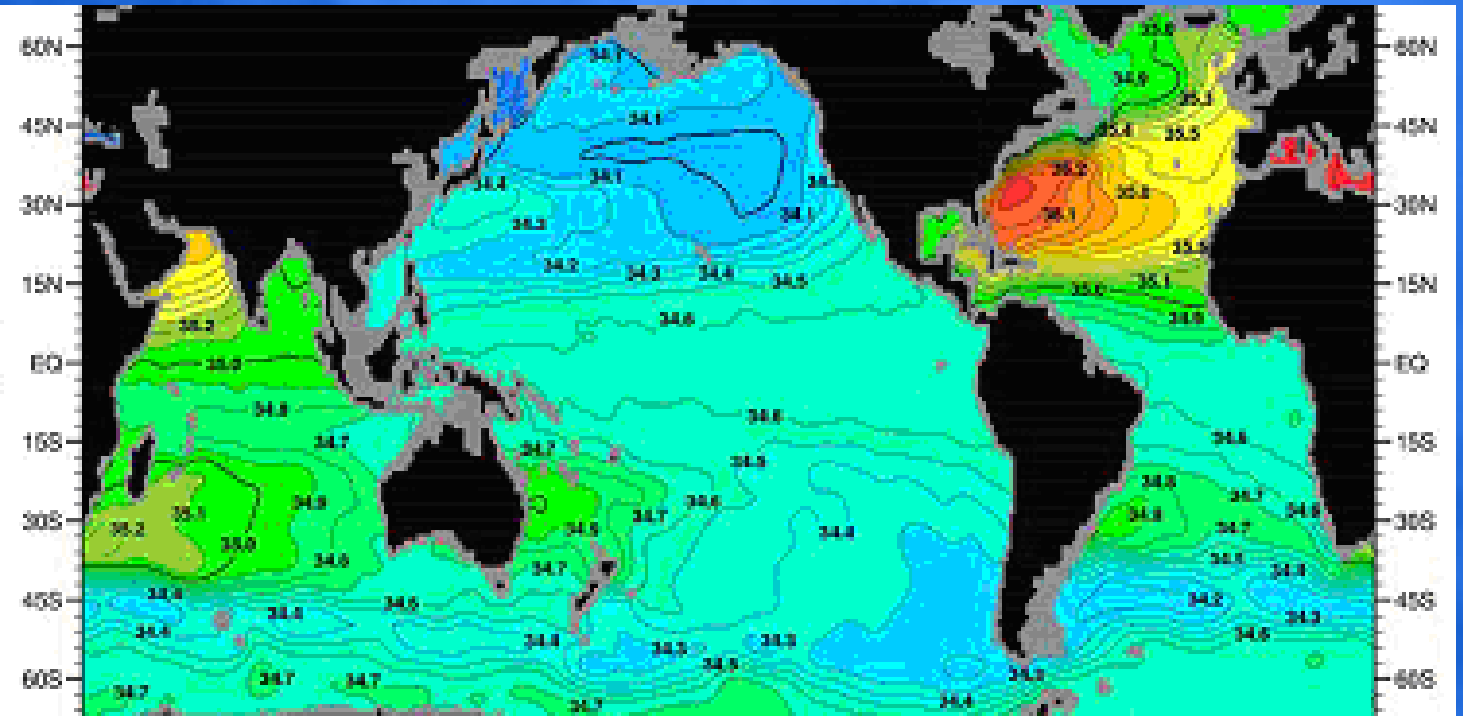
66 MAJOR HURRICANES or 92 Normalized to 25 Years

RATIO RELATIVE TO 1970-1994	
# MH	*# MHD*
2.1	*3.2*
1.0	*1.0*
2.4	*3.4*

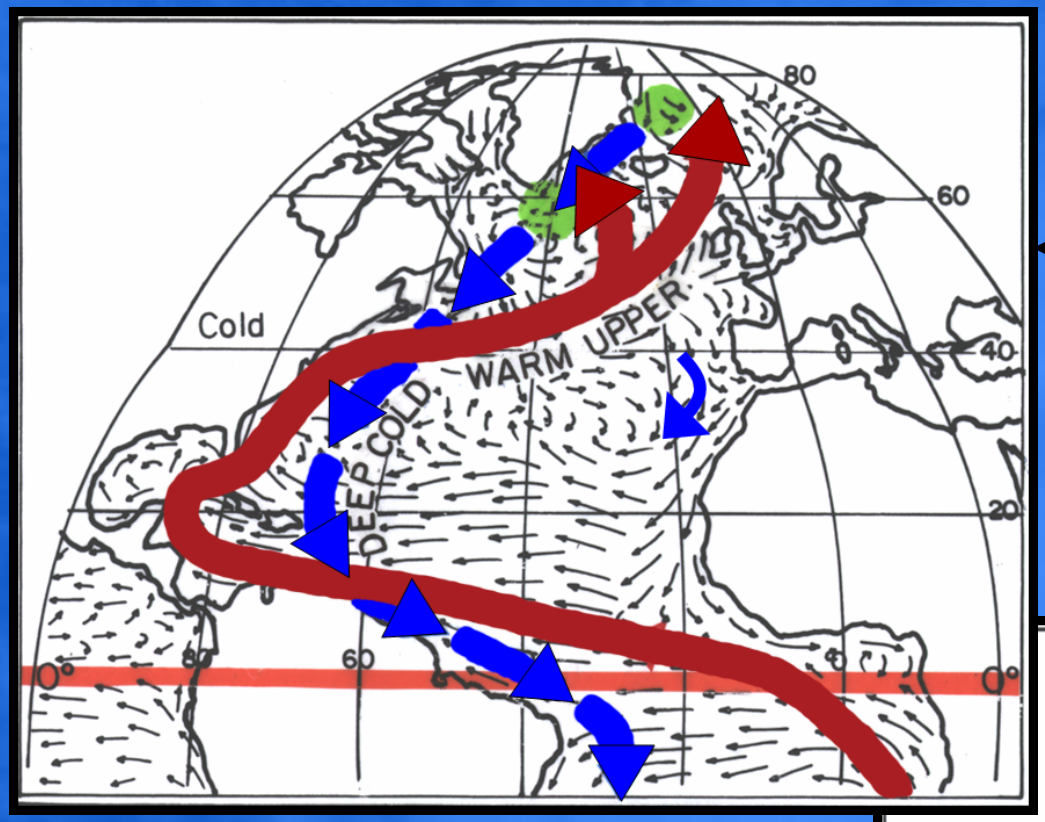

40°E
80°
120°
160°E
160°W
120°
80°
40°W
0°
40°E
60°N
40°
20°
0°
20°
40°
60°S
32
34
35
33
36
37
37.3
38
39
30
36.5
35.5
36.3



SALINITY SURFACE



SALINITY 500 METERS



THC *(or AMO)*

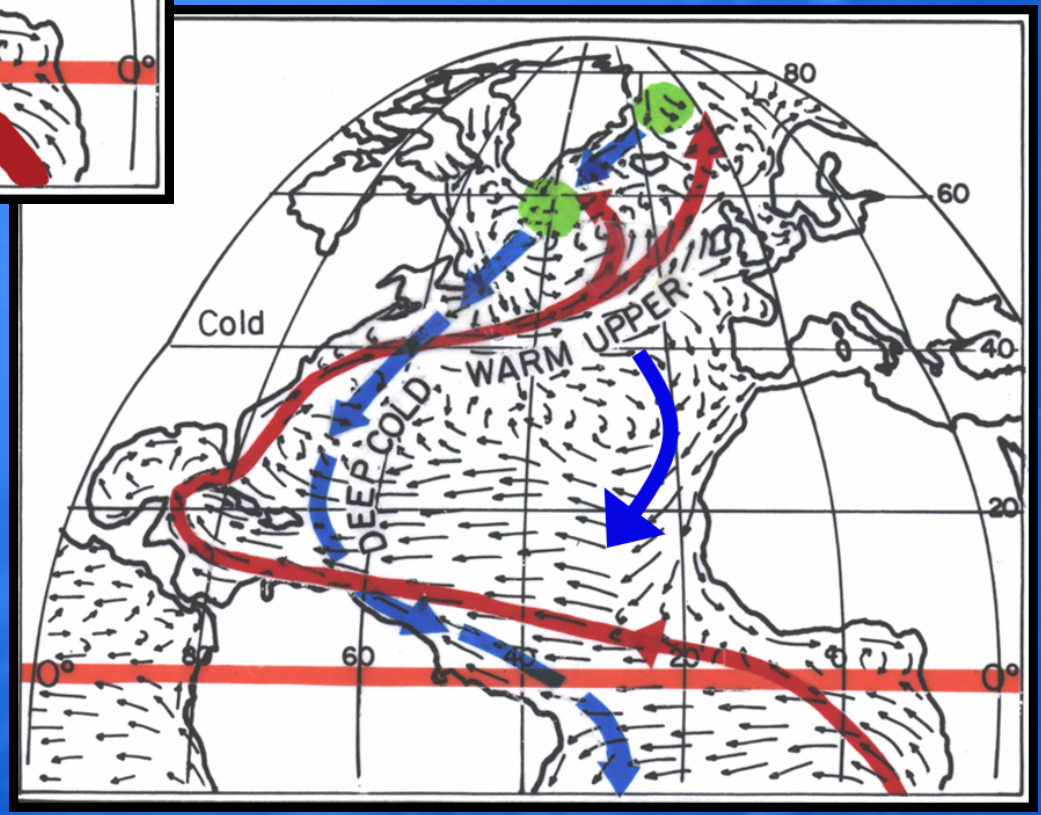
←

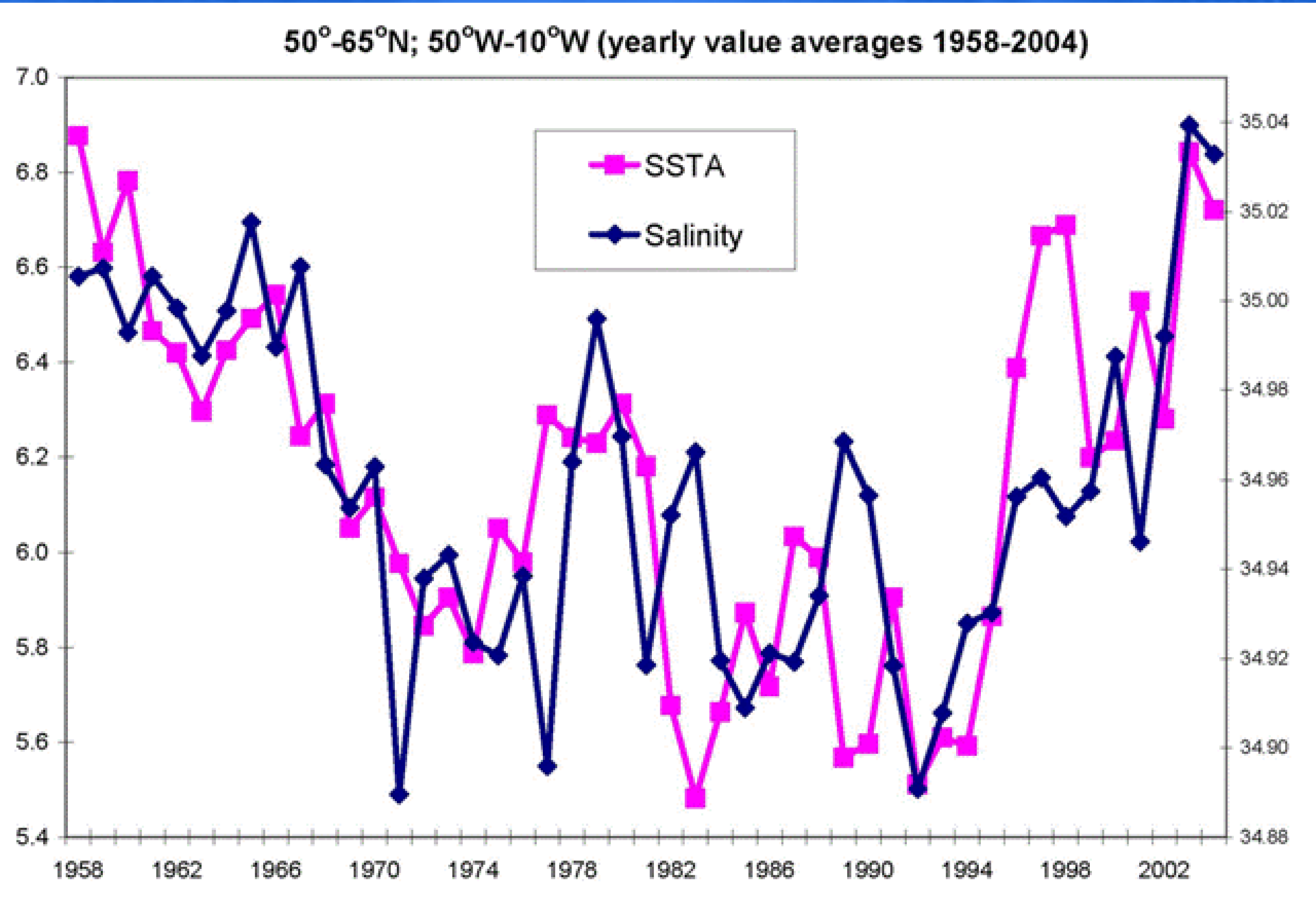
STRONG

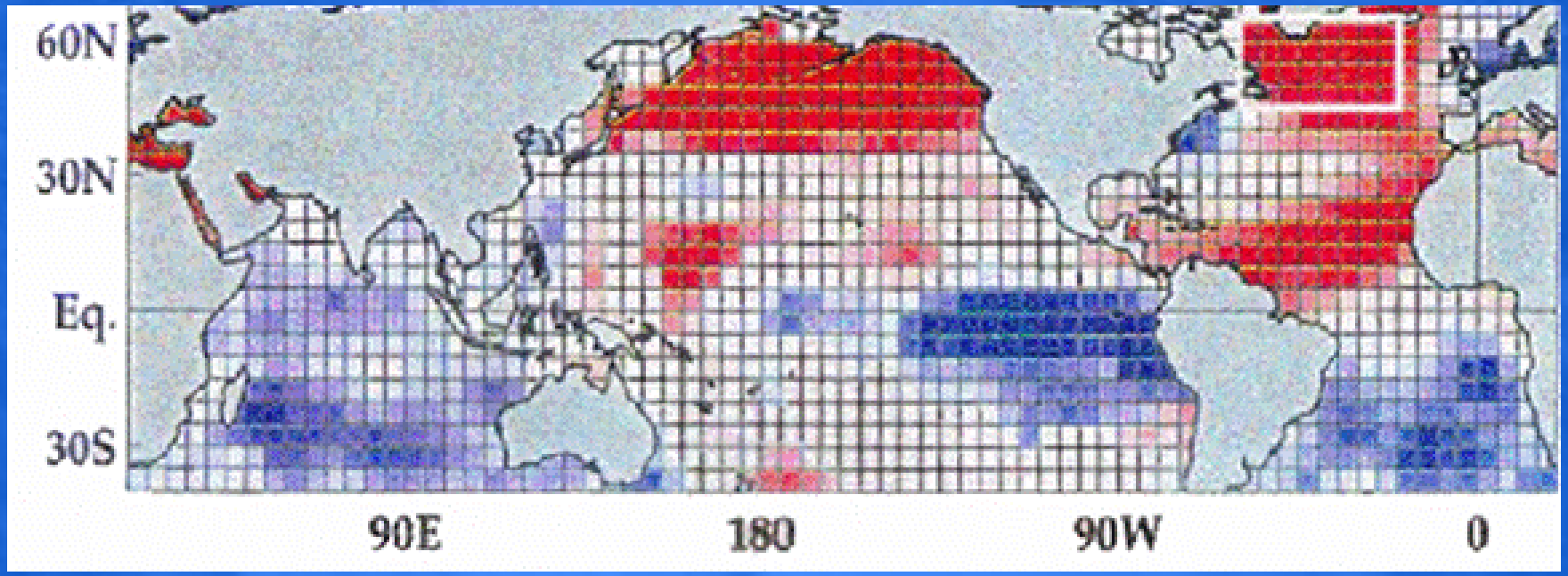
THC *(or AMO)*

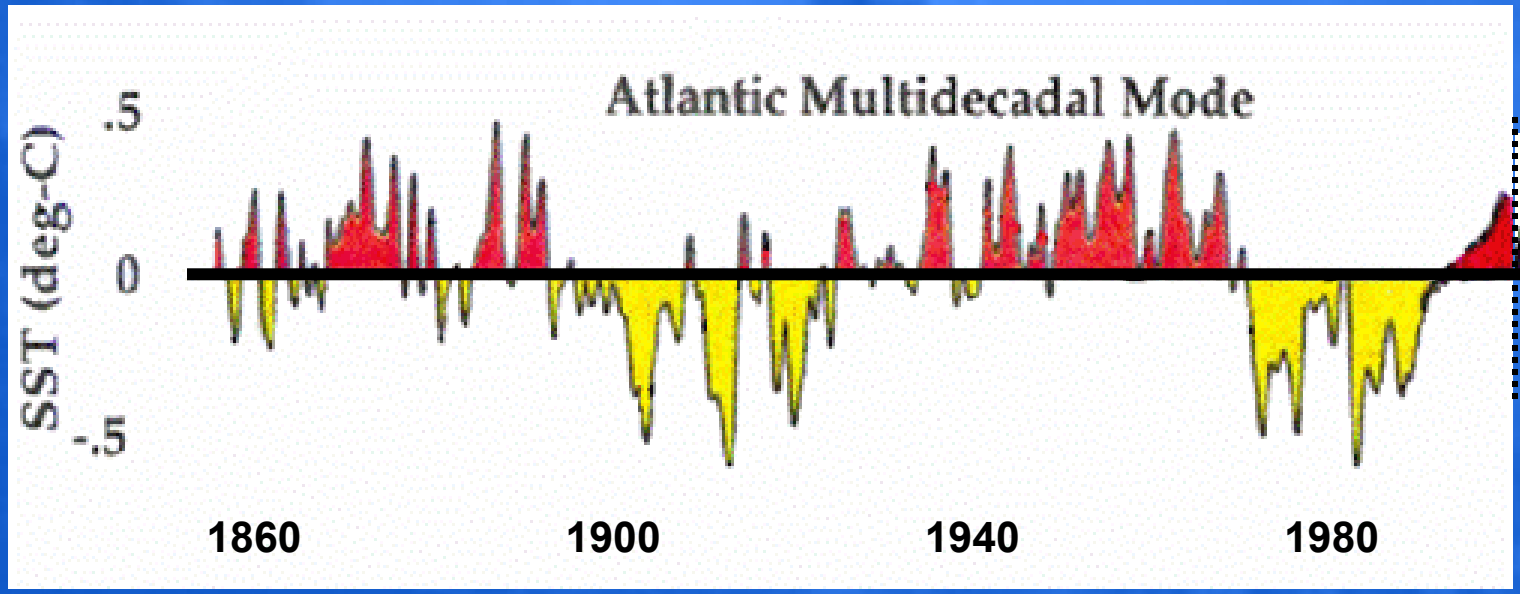
→

WEAK



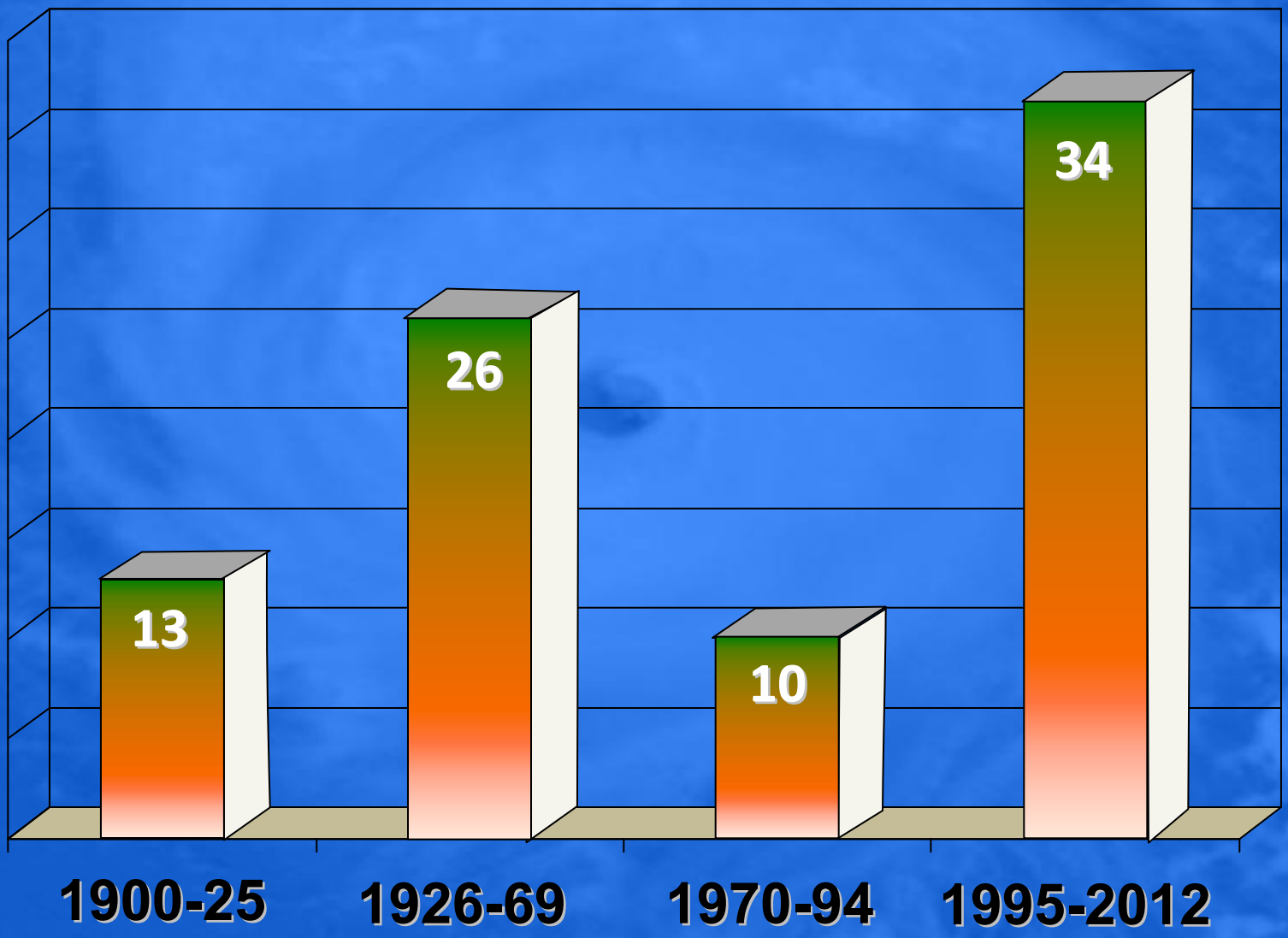

50°-65°N; 50°W-10°W (yearly value averages 1958-2004)
SSTA
Salinity
7.0
6.8
6.6
6.4
6.2
6.0
5.8
5.6
5.4
35.04
35.02
35.00
34.98
34.96
34.94
34.92
34.90
34.88
1958
1962
1966
1970
1974
1978
1982
1986
1990
1994
1998
2002

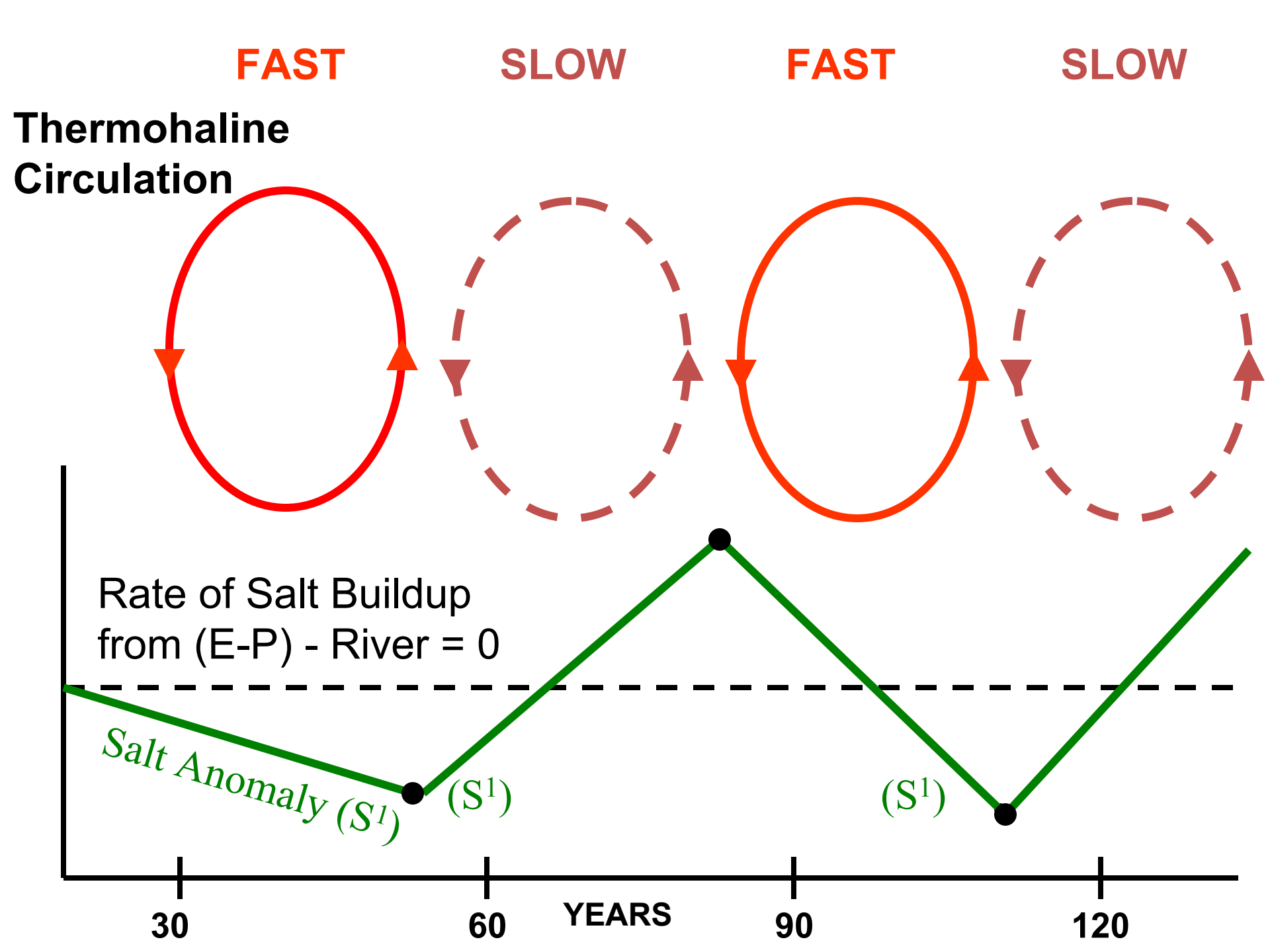




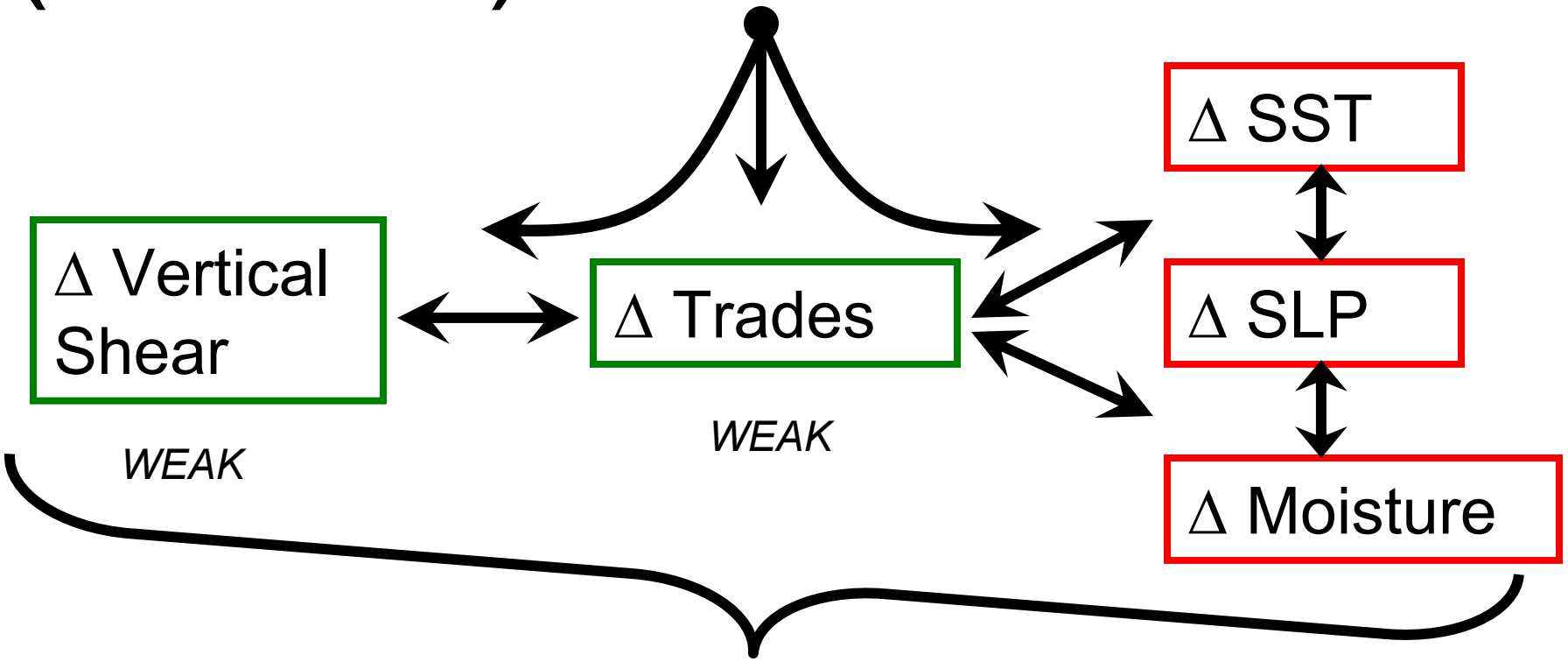
Goldenberg et al. (2001)

Annual Number of 6 Hour Periods for Cat. 3-4-5 Hurricanes in the Atlantic




FAST
SLOW
FAST
SLOW
Thermohaline Circulation
Rate of Salt Buildup from (E-P) - River = 0
Salt Anomaly (S^1)
(S^1)
(S^1)
30
60
YEARS
90
120

ATLANTIC OCEAN THC (or AMO) CHANGES



Change in hurricane frequency & intensity

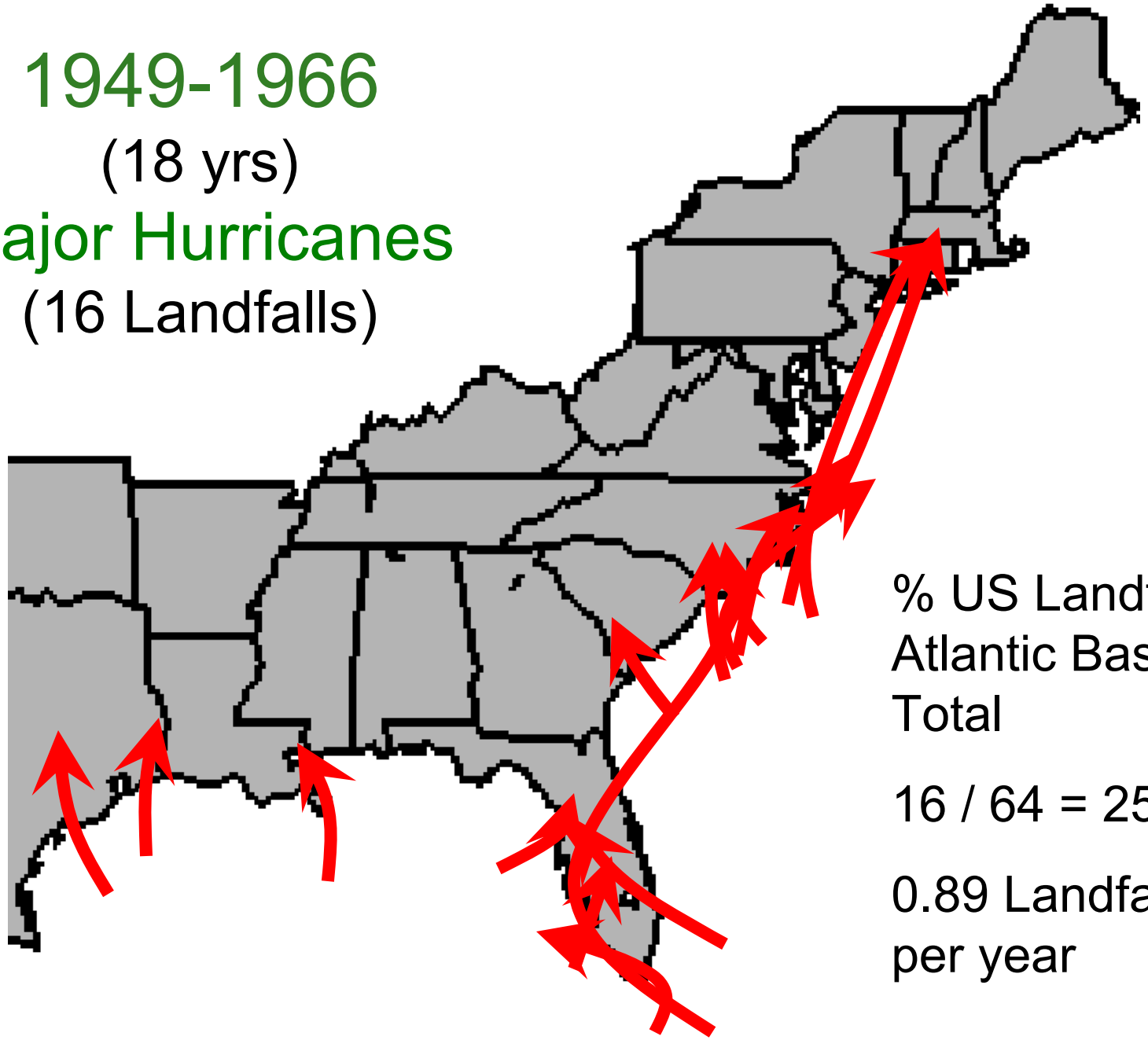
Lucky Recent Years Not Likely To Continue

1949-1966

(18 yrs)

Major Hurricanes

(16 Landfalls)



% US Landfall to Atlantic Basin Total

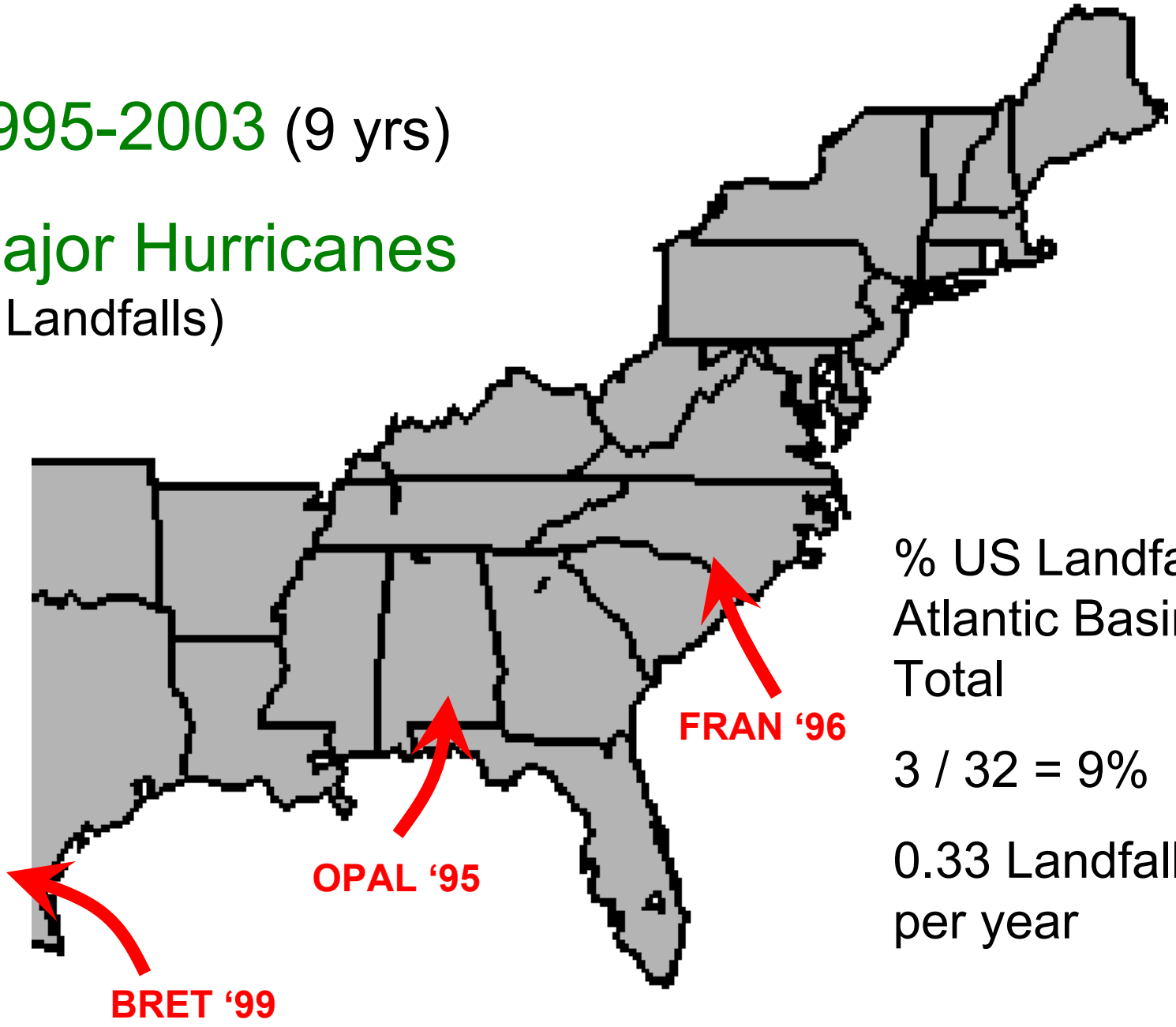
16 / 64 = 25%

0.89 Landfalls per year

1995-2003 (9 yrs)

Major Hurricanes

(3 Landfalls)



% US Landfall to Atlantic Basin Total

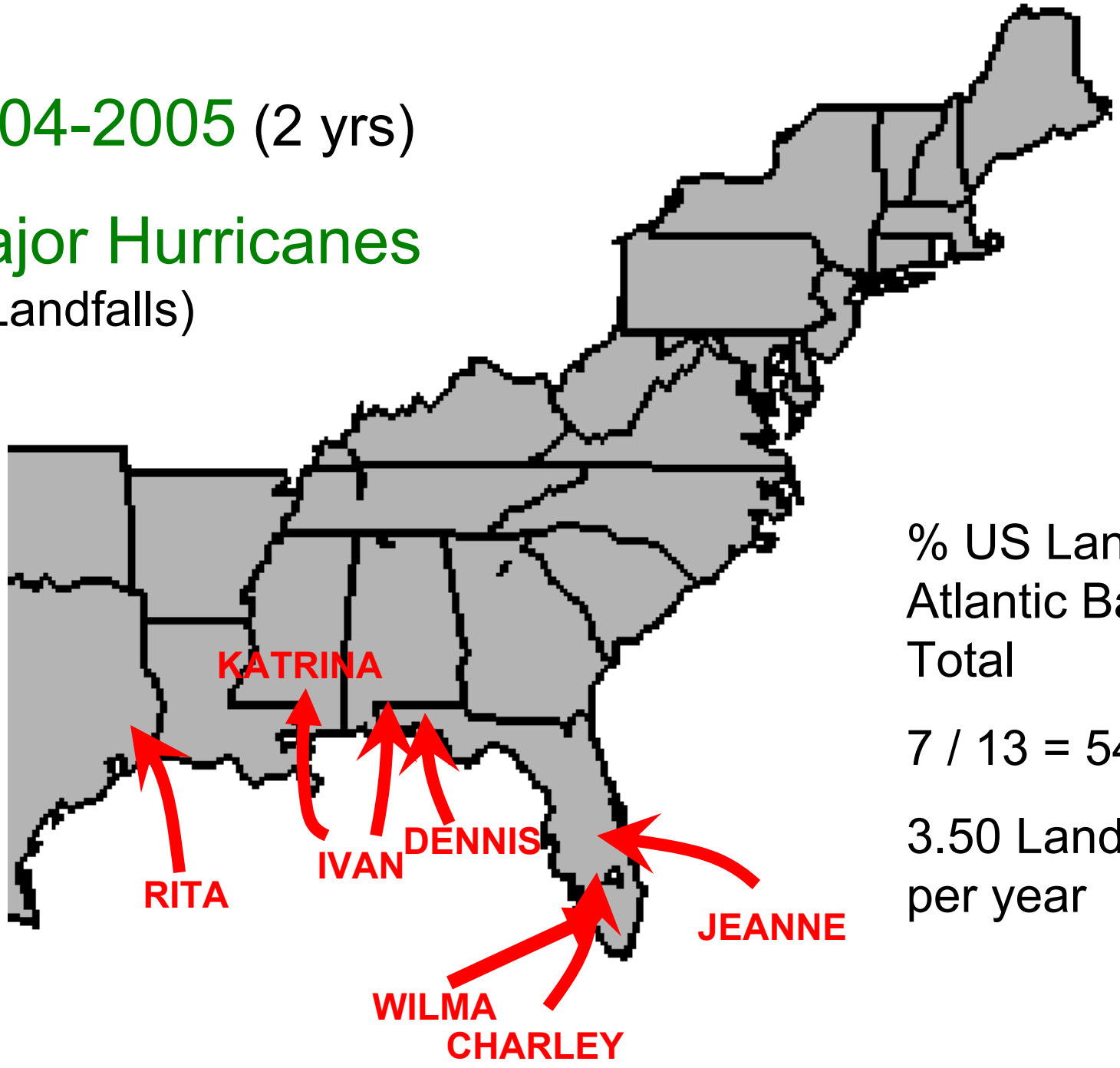
3 / 32 = 9%

0.33 Landfalls per year

2004-2005 (2 yrs)

Major Hurricanes

(7 Landfalls)



% US Landfall to Atlantic Basin Total

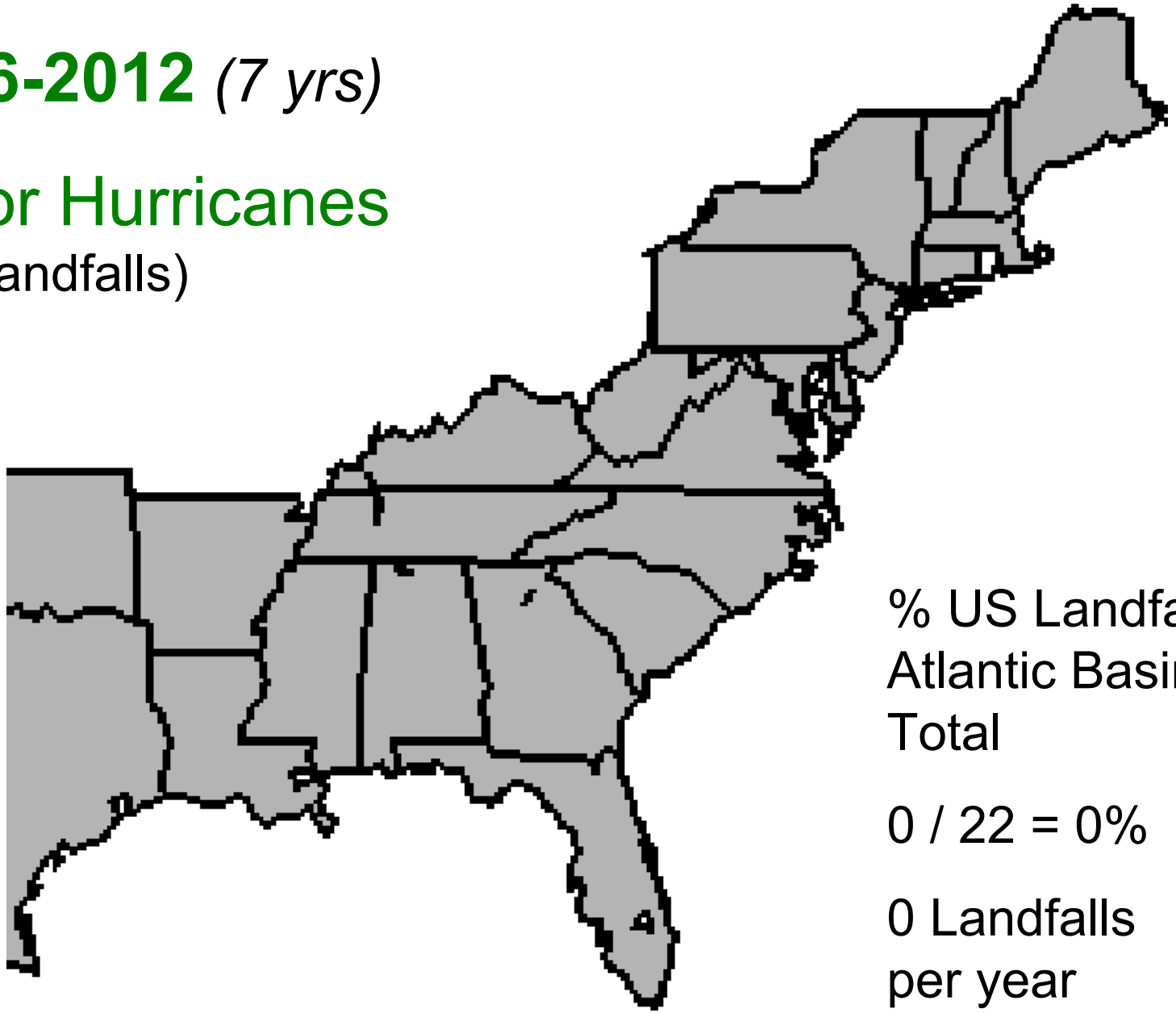
7 / 13 = 54%

3.50 Landfalls per year

2006-2012 *(7 yrs)*

Major Hurricanes

(No Landfalls)

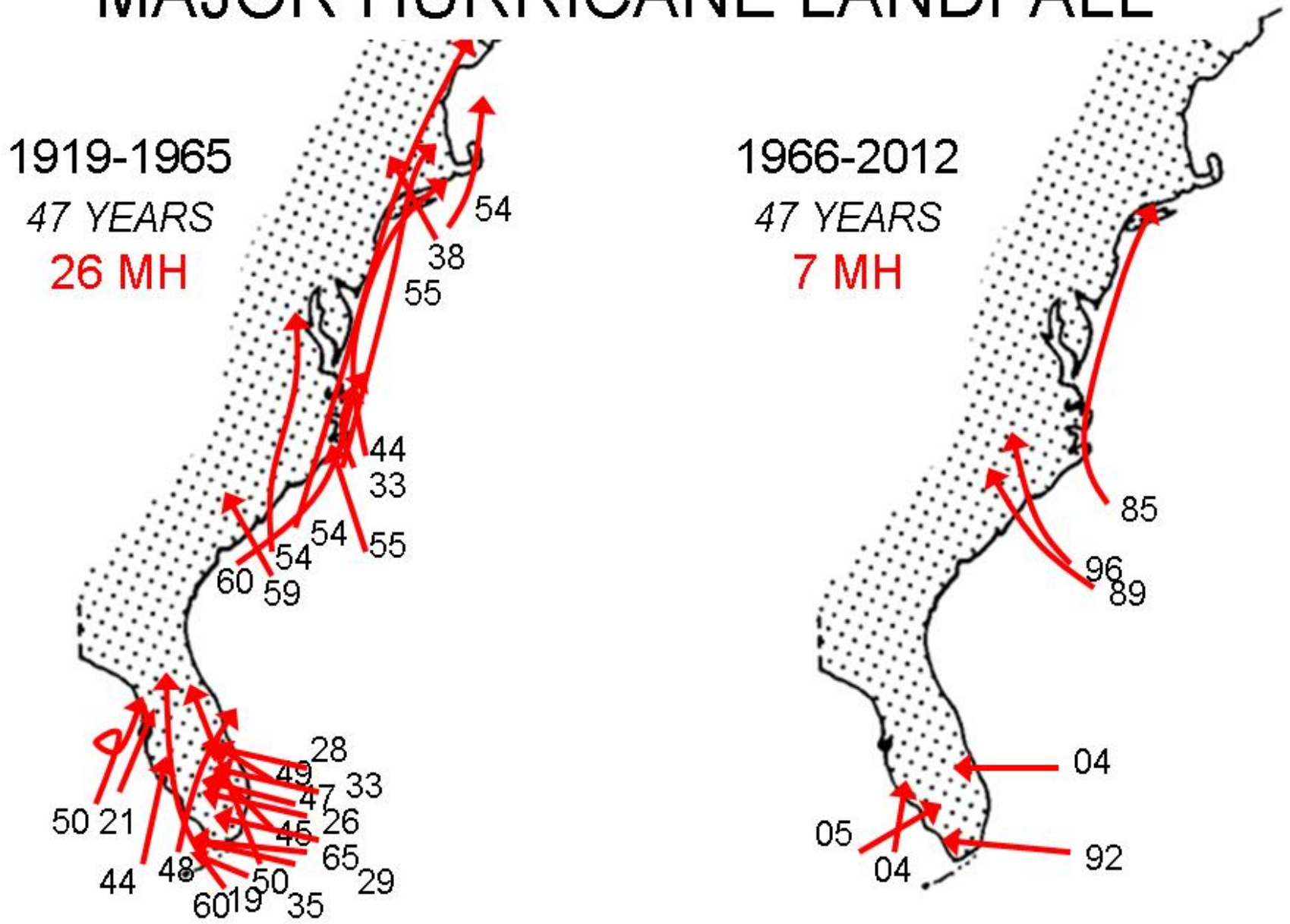


% US Landfall to Atlantic Basin Total

0 / 22 = 0%

0 Landfalls per year

MAJOR HURRICANE LANDFALL



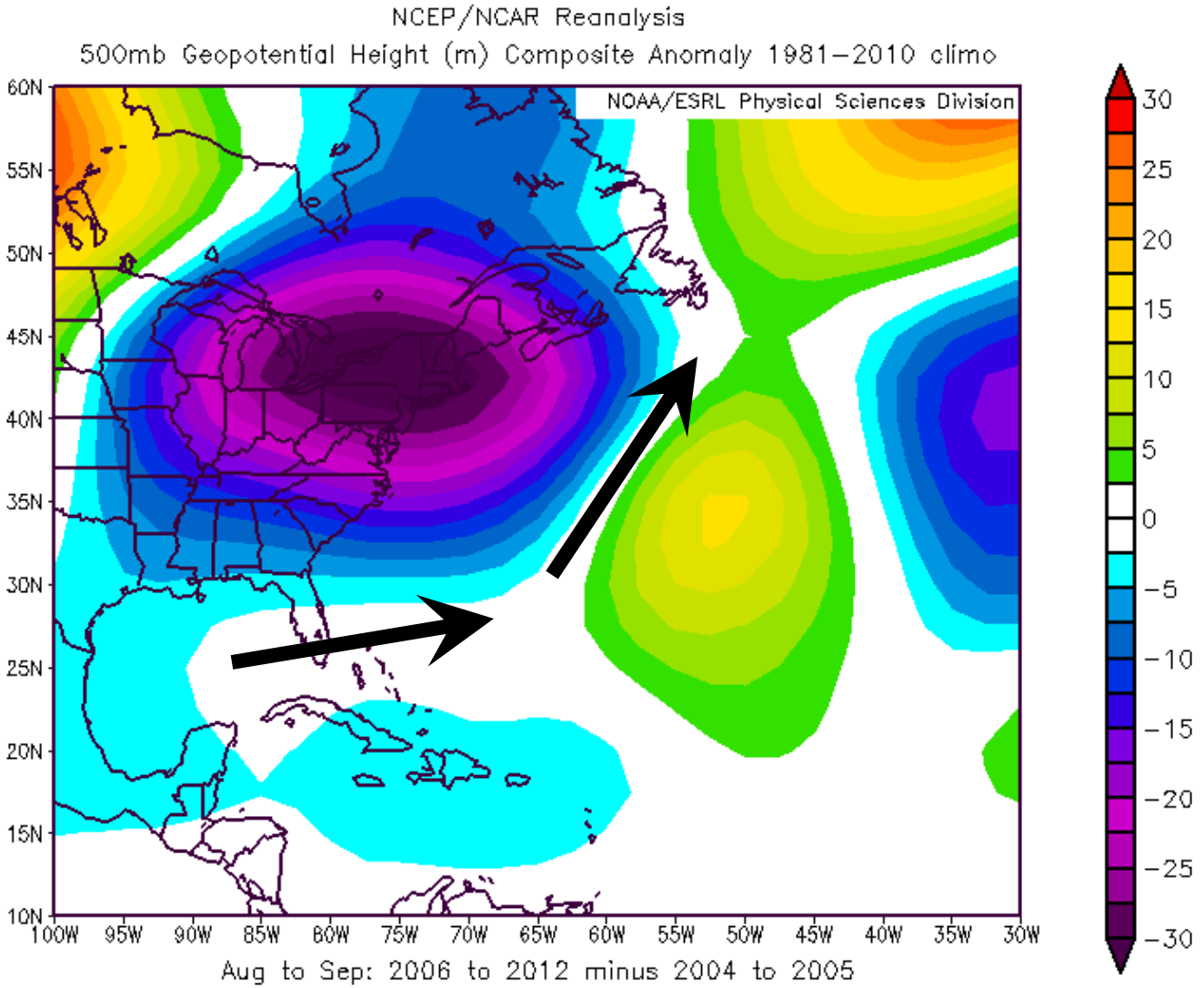


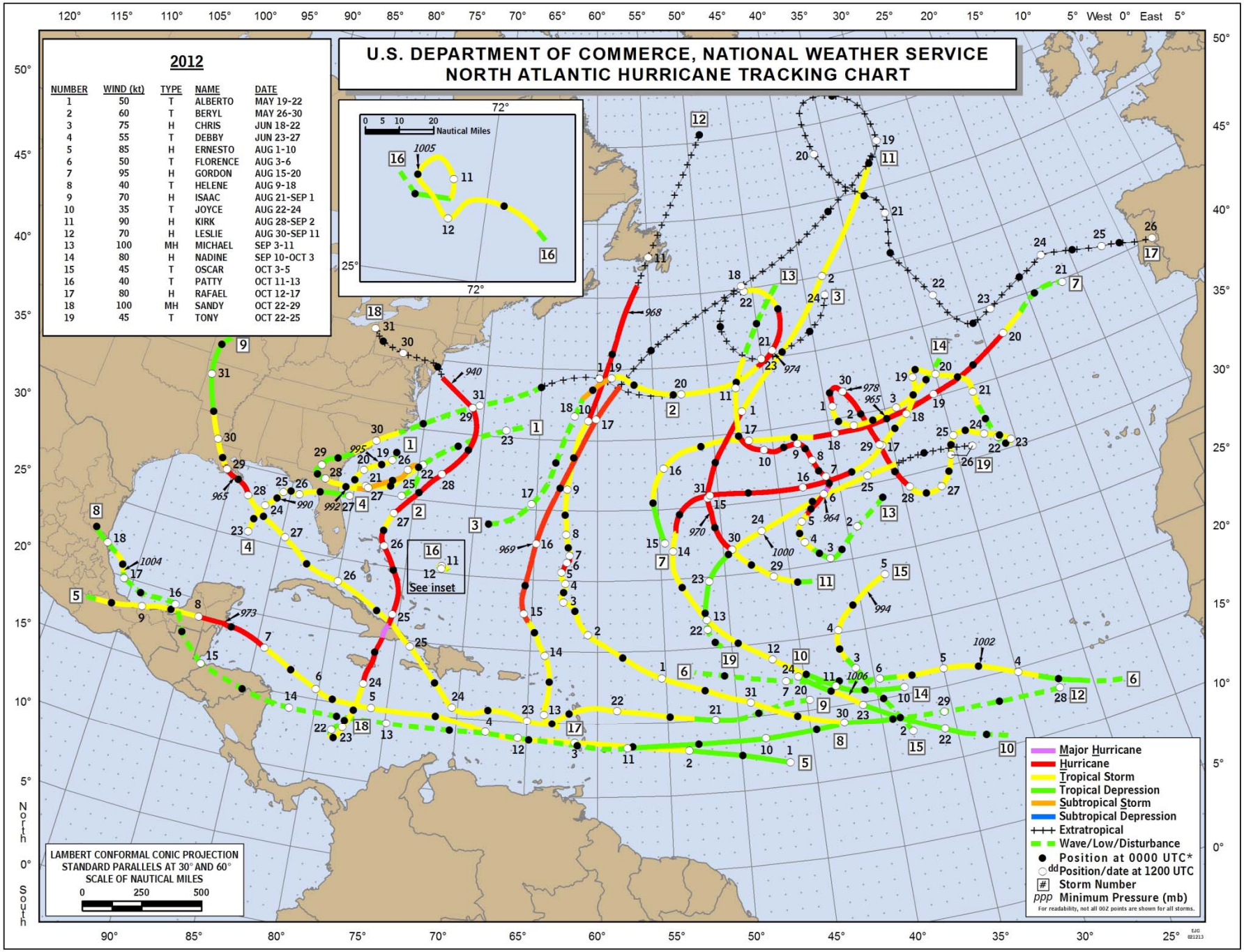
Figure 12: Average 500-mb height pattern difference of 2006-2012 minus 2004-2005. Note the anomalous troughing that has prevailed along the U.S. East Coast, causing systems to recurve before they could impact the U.S. mainland.

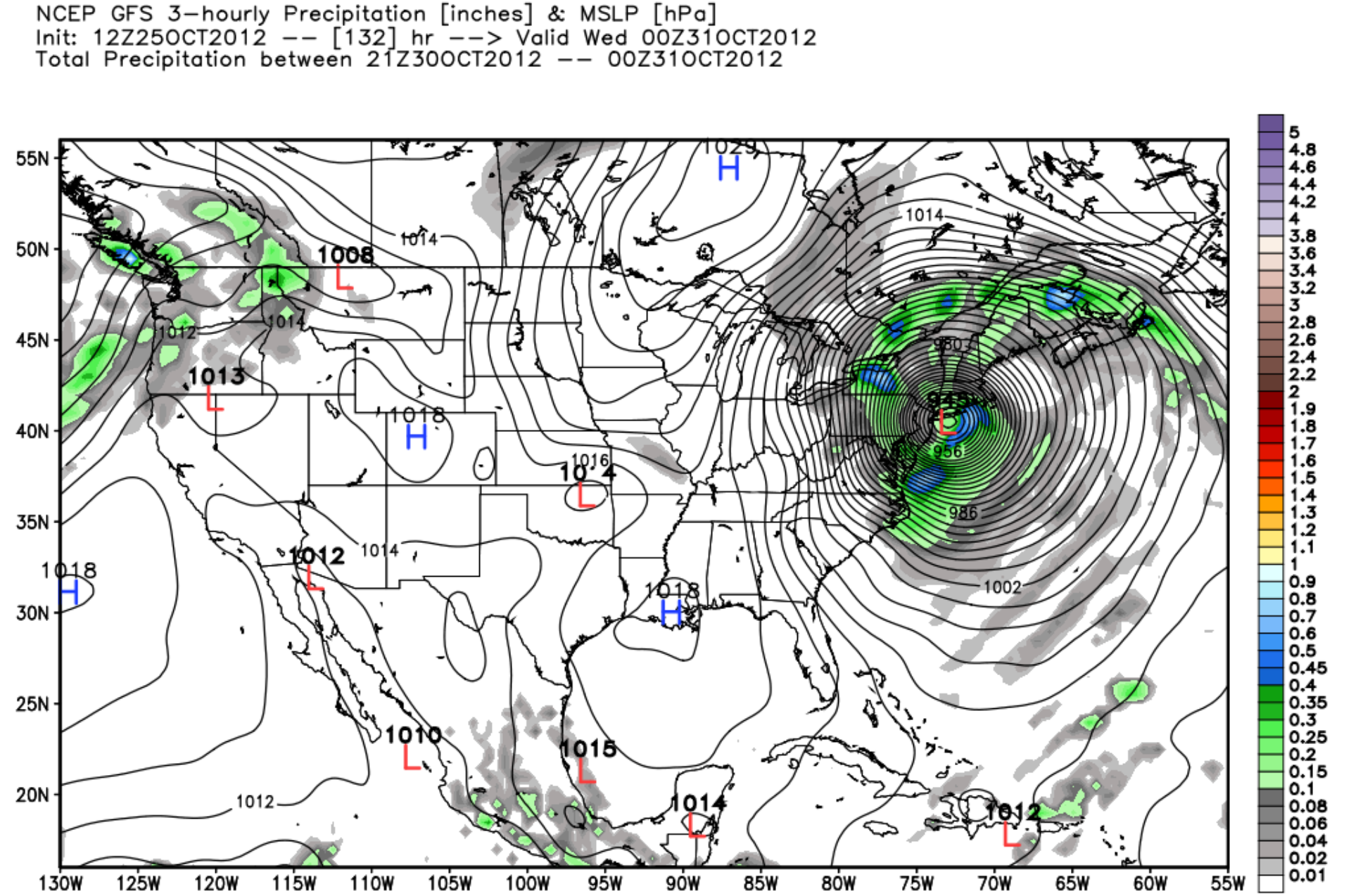
2012 Hurricane Season

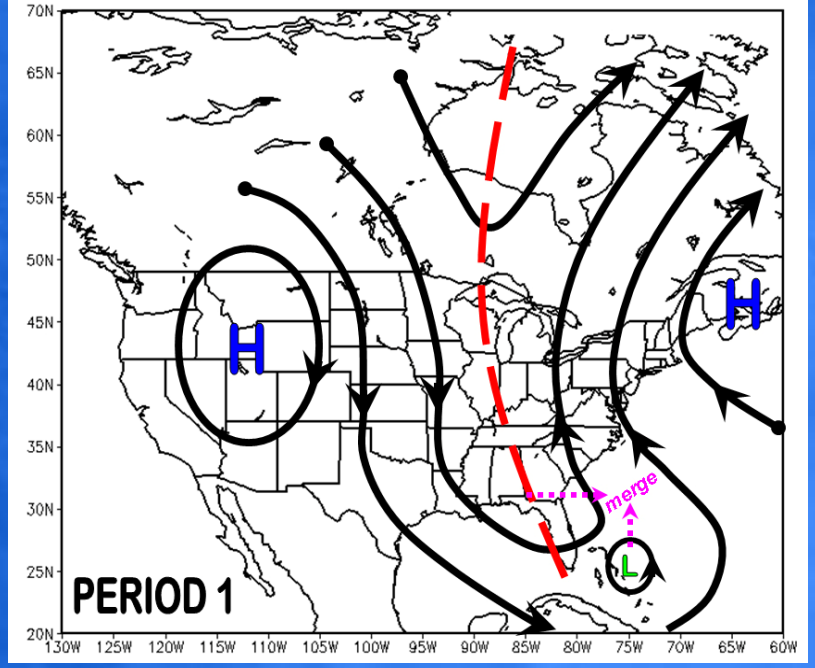
2012 Hurricane Forecasts and Verification

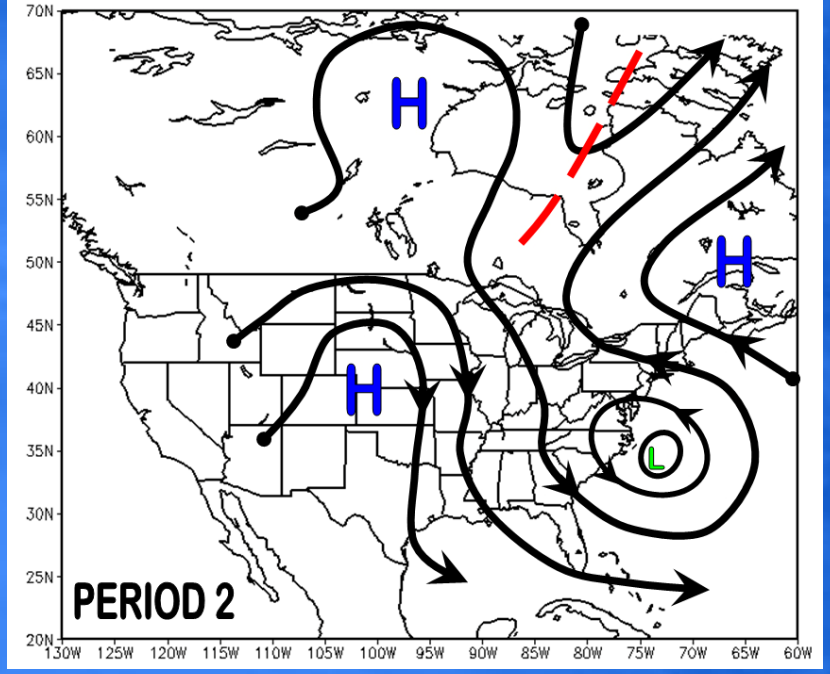
Forecast Parameter and 1981-2010 Median (in parentheses)	Update 4 April 2012	Update 1 June 2012	Update 3 Aug 2012	**Observed 2012 Total**
Named Storms (NS) (12.0)	10	13	14	**19**
Named Storm Days (NSD) (60.1)	40	50	52	**101**
Hurricanes (H) (6.5)	4	5	6	**10**
Hurricane Days (HD) (21.3)	16	18	20	**28.50**
Major Hurricanes (MH) (2.0)	2	2	2	**2**
Major Hurricane Days (MHD) (3.9)	3	4	5	**0.50**
Accumulated Cyclone Energy (ACE) (92)	70	80	99	**133**
Net Tropical Cyclone Activity (NTC) (103%)	75	90	105	**131**

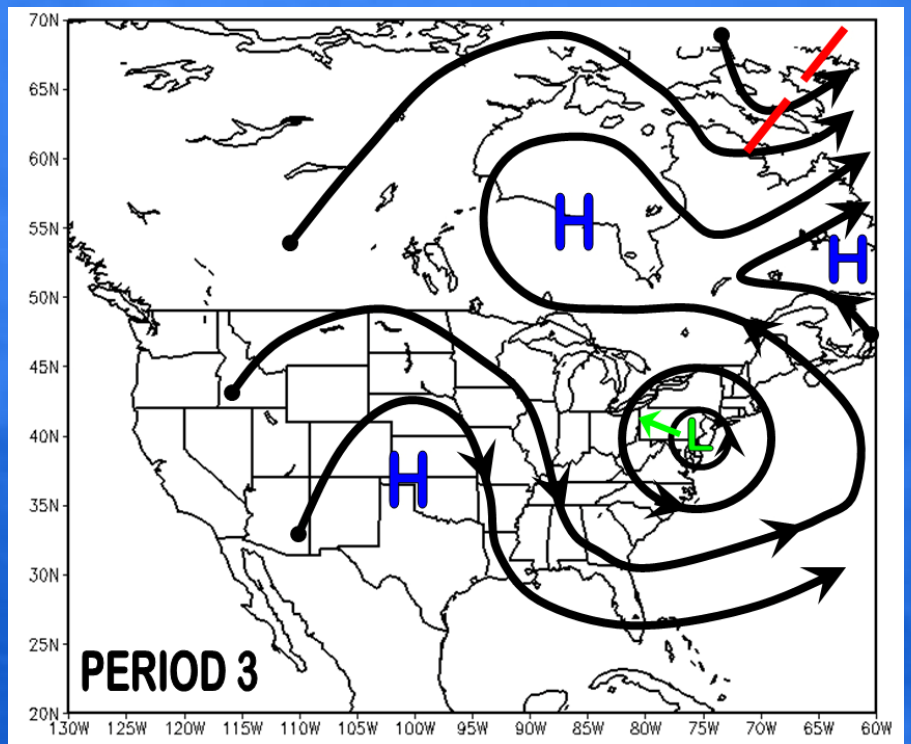
Characteristics of the 2012 Atlantic Hurricane Season

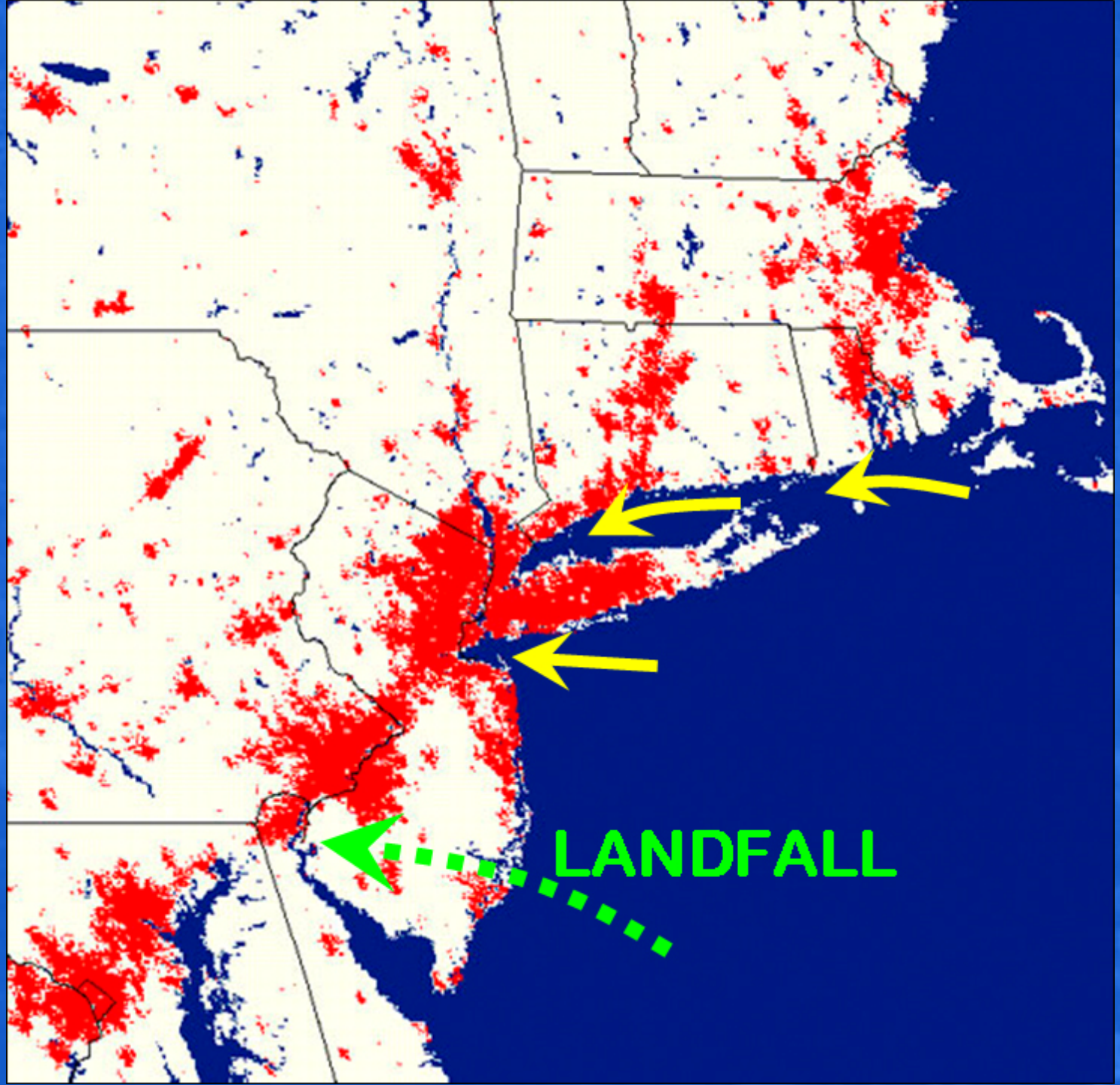

U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART
2012
NUMBER WIND (kt) TYPE NAME DATE
1 50 T ALBERTO MAY 19-22
2 60 T BERYL MAY 26-30
3 75 H CHRIS JUN 18-22
4 55 T DEBBY JUN 23-27
5 85 H ERNESTO AUG 1-10
6 50 T FLORENCE AUG 3-6
7 95 H GORDON AUG 15-20
8 40 T HELENE AUG 9-18
9 70 H ISAAC AUG 21-SEP 1
10 35 T JOYCE AUG 22-24
11 90 H KIRK AUG 28-SEP 2
12 70 H LESLIE AUG 30-SEP 11
13 100 MH MICHAEL SEP 3-11
14 80 H NADINE SEP 10-OCT 3
15 45 T OSCAR OCT 3-5
16 40 T PATTY OCT 11-13
17 80 H RAFAEL OCT 12-17
18 100 MH SANDY OCT 22-29
19 45 T TONY OCT 22-25
0 5 10 20 Nautical Miles
See inset
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 30° AND 60°
SCALE OF NAUTICAL MILES
0 250 500
Major Hurricane
Hurricane
Tropical Storm
Tropical Depression
Subtropical Storm
Subtropical Depression
Extratropical
Wave/Low/Disturbance
Position at 0000 UTC*
dd Position/date at 1200 UTC
Storm Number
ppp Minimum Pressure (mb)
For readability, not all 00Z points are shown for all storms.

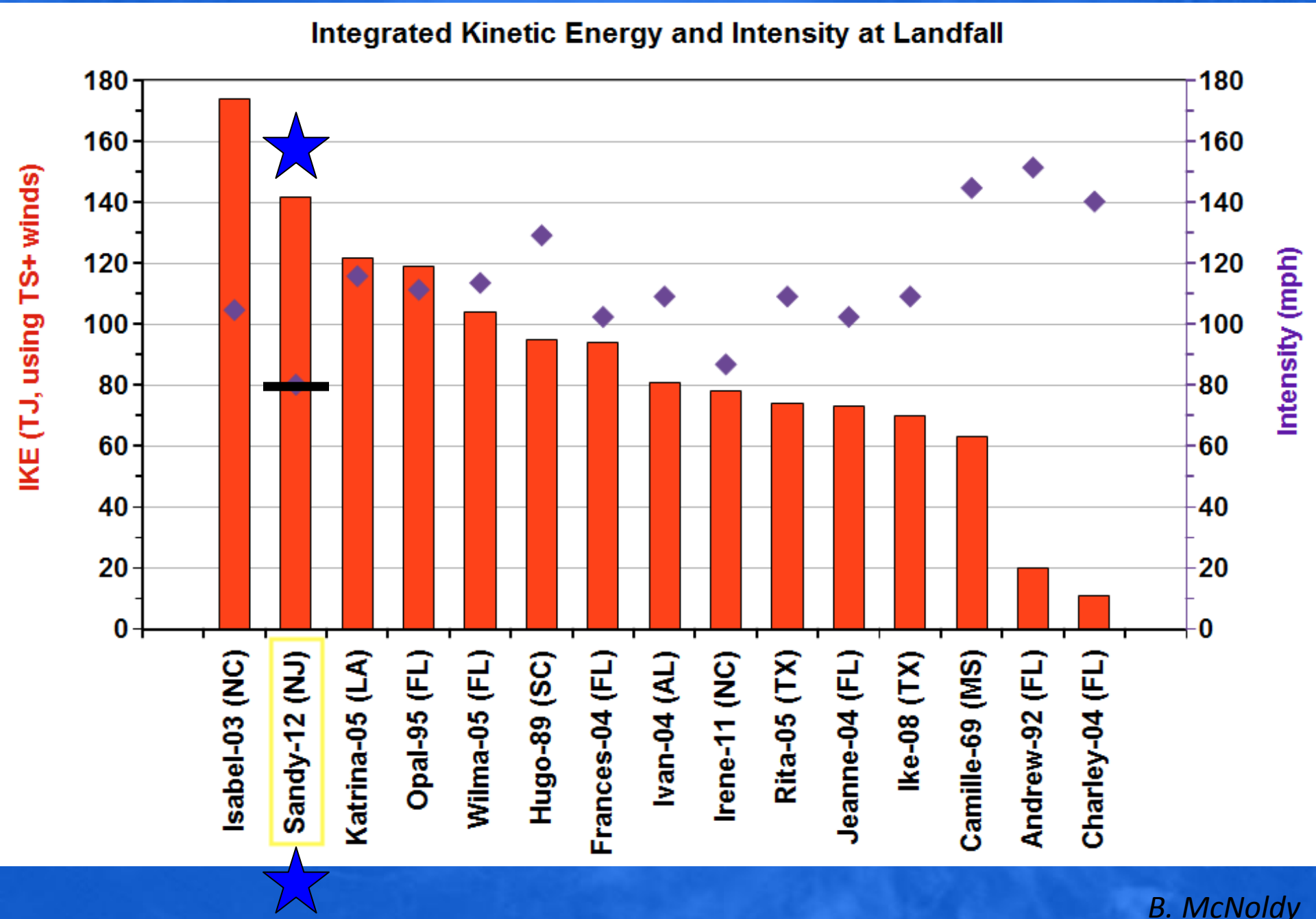

NCEP GFS 3-hourly Precipitation [inches] & MSLP [hPa]
Init: 12Z25OCT2012 -- [132] hr --> Valid Wed 00Z31OCT2012
Total Precipitation between 21Z30OCT2012 -- 00Z31OCT2012
55N
50N
45N
40N
35N
30N
25N
20N
130W
125W
120W
115W
110W
105W
100W
95W
90W
85W
80W
75W
70W
65W
60W
55W
1008
1013
1018
1012
1010
1015
1014
1012
1029
1018
1018
1014
1016
1014
1012
1014
1012
1014
1002
986
956
950
5
4.8
4.6
4.4
4.2
4
3.8
3.6
3.4
3.2
3
2.8
2.6
2.4
2.2
2
1.9
1.8
1.7
1.6
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.08
0.06
0.04
0.02
0.01
3-Hourly Precipitation (shaded) & MSLP contours
GFS 720x361 0.5°x0.5° Forecast Grid


70N
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
130W 125W 120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W 65W 60W
H
H
L
merge
PERIOD 1

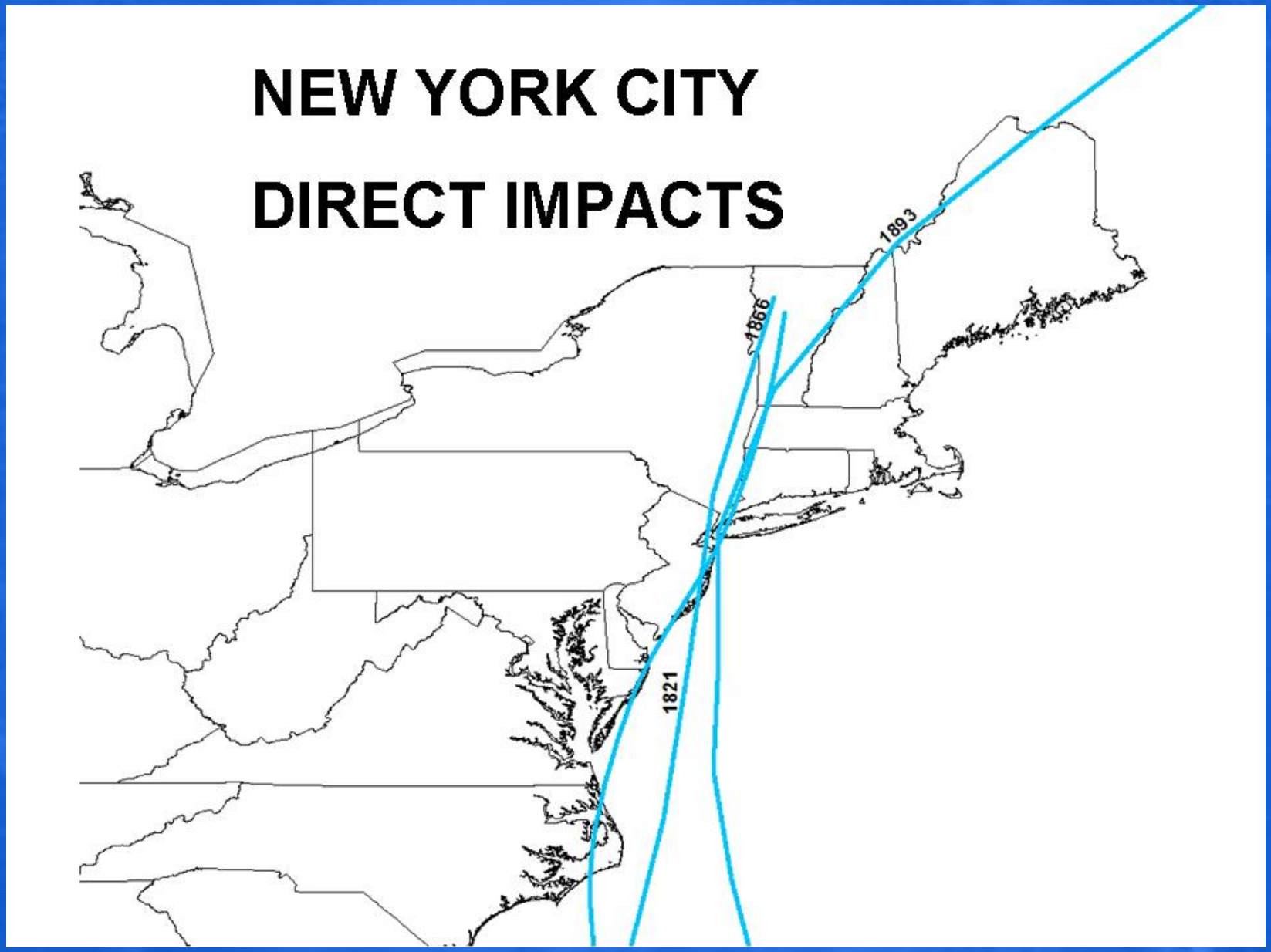

70N
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
130W 125W 120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W 65W 60W
H
H
H
L
PERIOD 2


70N
65N
60N
55N
50N
45N
40N
35N
30N
25N
20N
130W 125W 120W 115W 110W 105W 100W 95W 90W 85W 80W 75W 70W 65W 60W
H
H
H
L
PERIOD 3

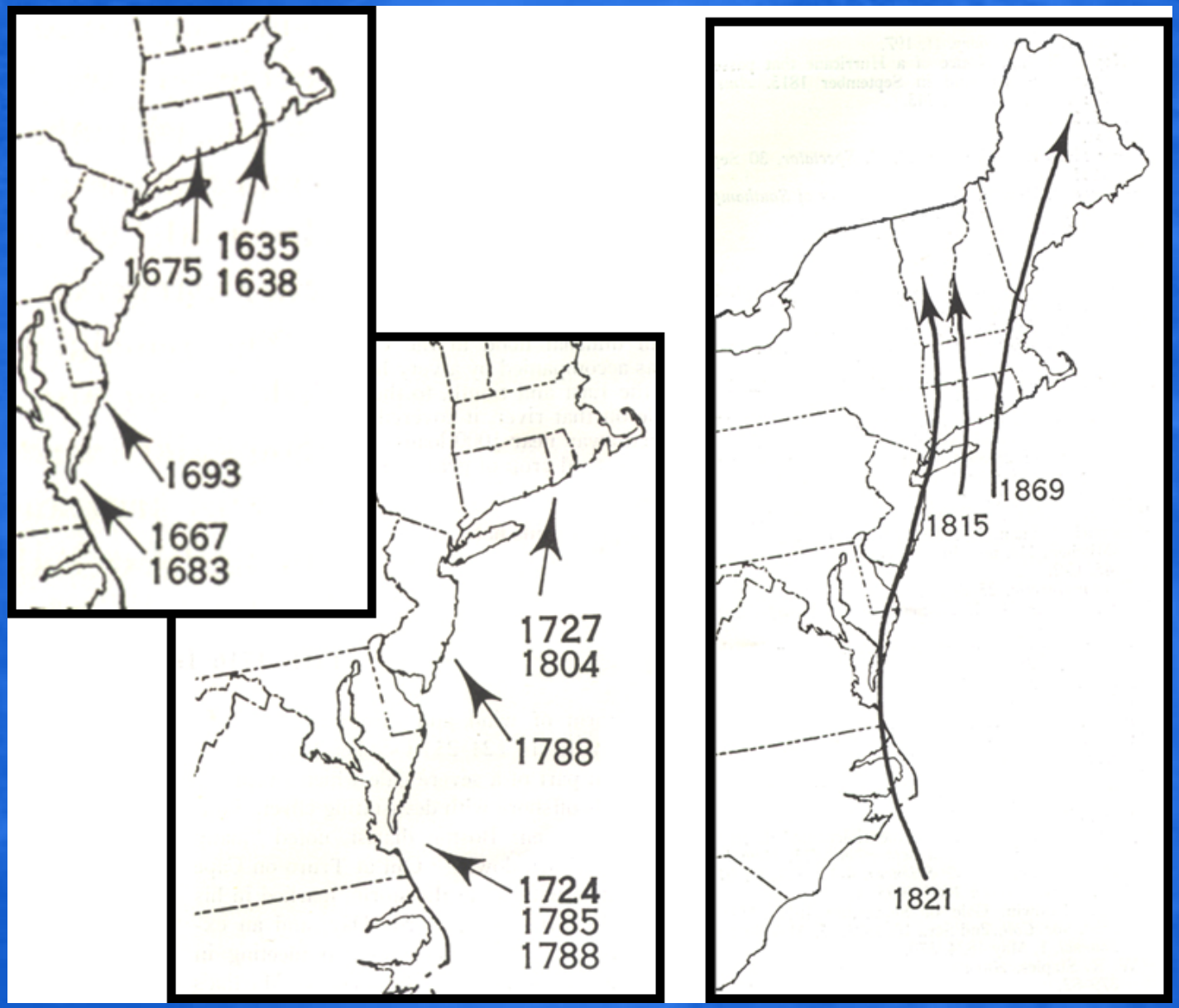

LANDFALL


Integrated Kinetic Energy and Intensity at Landfall
IKE (TJ, using TS+ winds)
Intensity (mph)
0
20
40
60
80
100
120
140
160
180
Isabel-03 (NC)
Sandy-12 (NJ)
Katrina-05 (LA)
Opal-95 (FL)
Wilma-05 (FL)
Hugo-89 (SC)
Frances-04 (FL)
Ivan-04 (AL)
Irene-11 (NC)
Rita-05 (TX)
Jeanne-04 (FL)
Ike-08 (TX)
Camille-69 (MS)
Andrew-92 (FL)
Charley-04 (FL)

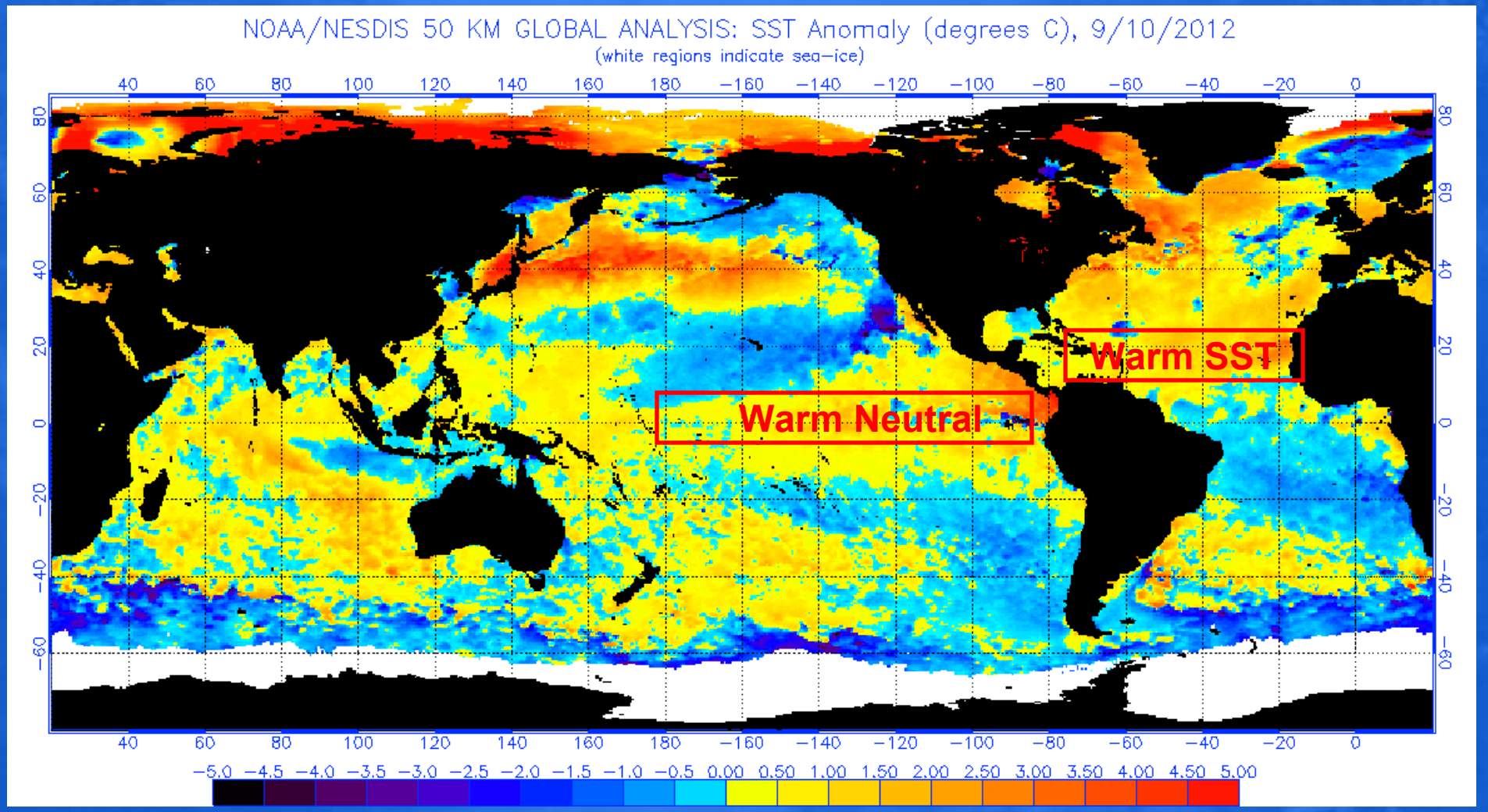
B. McNoldy



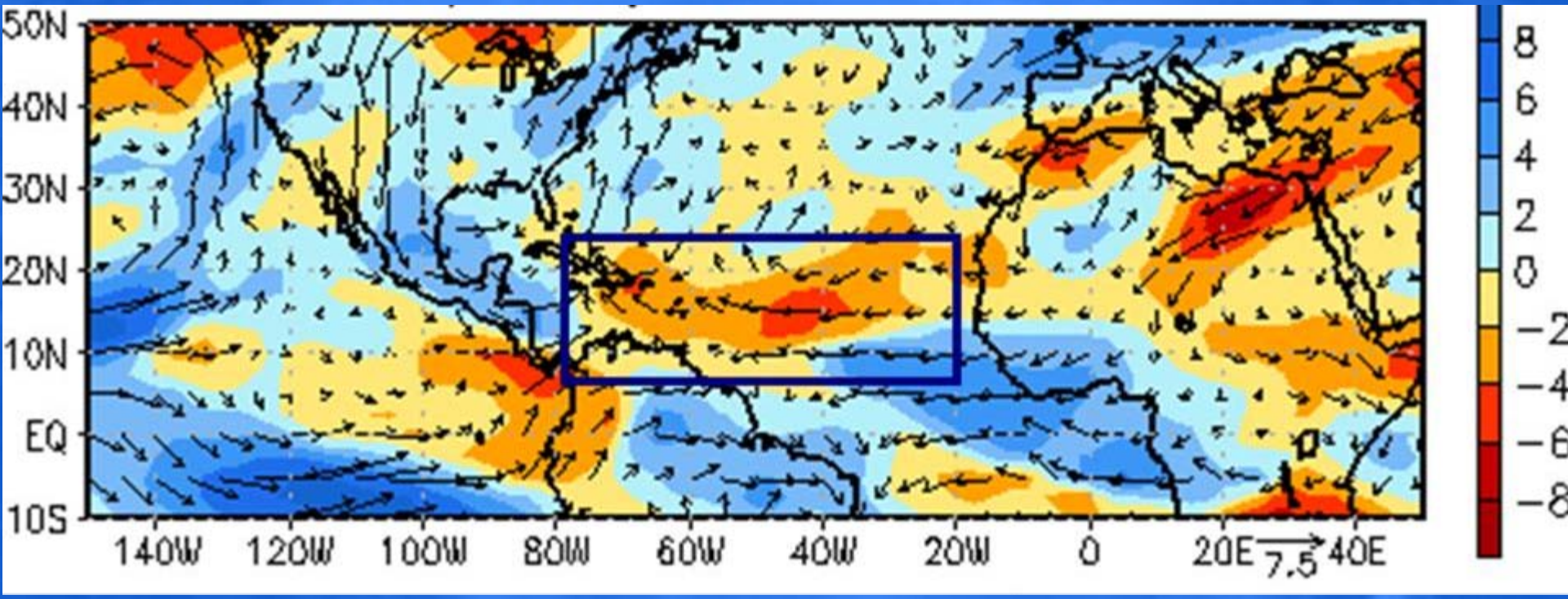
Notable cyclones with direct impacts on New York City.



Notable early American hurricanes that influenced the northeast US coastline as reported by D.M. Ludlum (1963).


NOAA/NESDIS 50 KM GLOBAL ANALYSIS: SST Anomaly (degrees C), 9/10/2012
(white regions indicate sea-ice)
Warm SST
Warm Neutral
40 60 80 100 120 140 160 180 −160 −140 −120 −100 −80 −60 −40 −20 0
80 60 40 20 0 −20 −40 −60
−5.0 −4.5 −4.0 −3.5 −3.0 −2.5 −2.0 −1.5 −1.0 −0.5 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00

200-850 hPa Anomalous Vertical Wind Shear Magnitude and Vector 60-Day Average 17 AUG-15 OCT 2012



200-850 hPa Vertical wind shear magnitude (shading, m x^{-1}) and vector: 60-Day average. (Top) Total and (Bottom) Anomalies. Vector scales are below plots. Anomalies are departures from the 1981-2010 period monthly means.

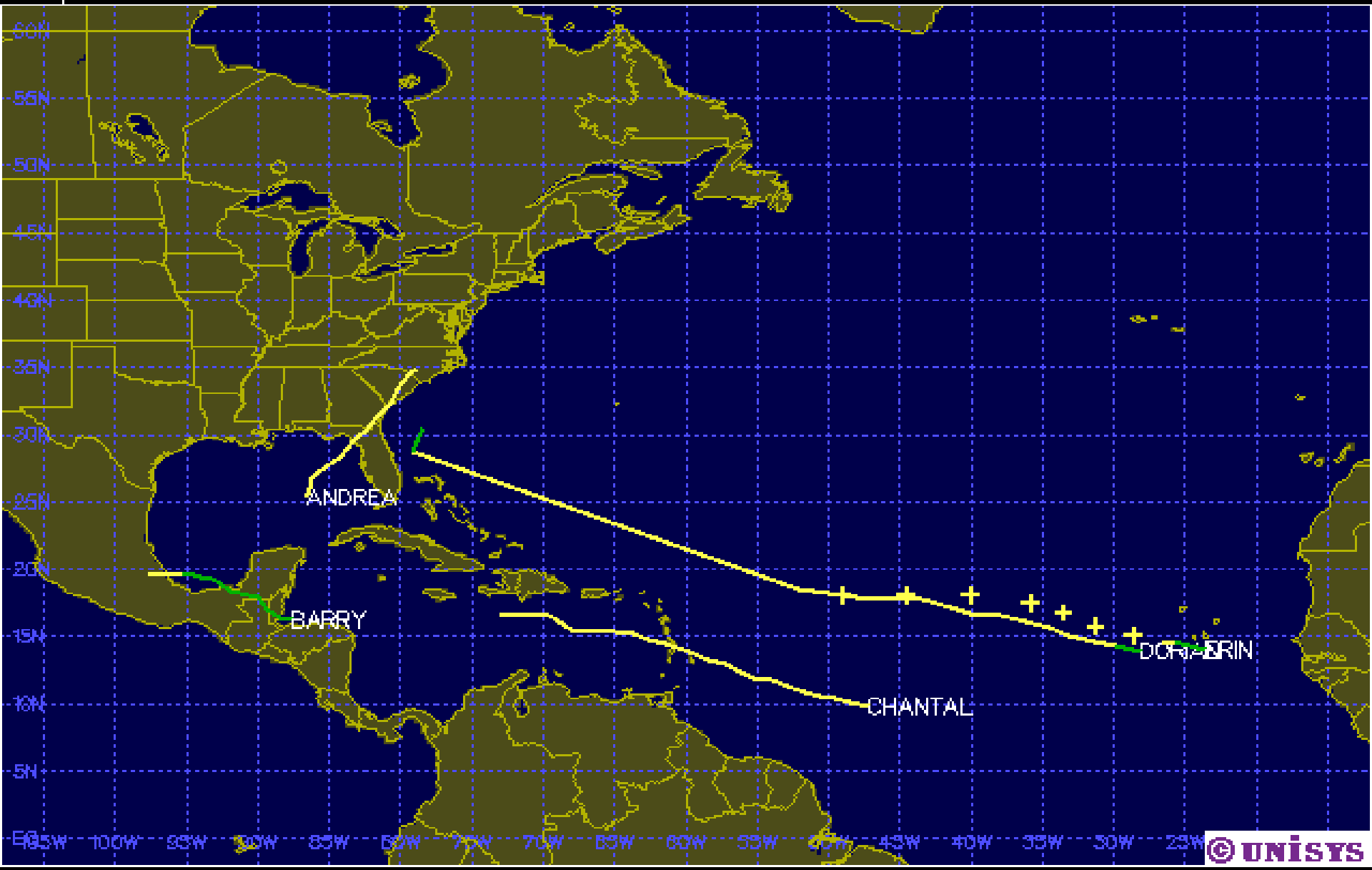
2013 Atlantic Basin Hurricane Outlook

All forecasts and verifications are available on our project's website:

http://tropical.atmos.colostate.edu

2013 FORECAST AS OF 2 AUGUST 2013

Forecast Parameter (1981-2010 Median in Parentheses)	Observed Activity Thru July 2013	Forecast Activity after 31 July	Total Seasonal Forecast
Named Storms (NS) (12.0)	4	14	18
Named Storm Days (NSD) (60.1)	9.25	75	84.25
Hurricanes (H) (6.5)	0	8	8
Hurricane Days (HD) (21.3)	0	35	35
Major Hurricanes (MH) (2.0)	0	3	3
Major Hurricane Days (MHD) (3.9)	0	7	7
Accumulated Cyclone Energy (ACE) (92)	7	135	142
Net Tropical Cyclone Activity (NTC) (103)	10	140	150


Tropical Storm Tracks
Year 2013
60N
55N
50N
45N
40N
35N
30N
25N
20N
15N
10N
5N
EQ
105W
100W
95W
90W
85W
80W
75W
70W
65W
60W
55W
50W
45W
40W
35W
30W
25W
ANDREA
BARRY
CHANTAL
DORIAN
ERIN
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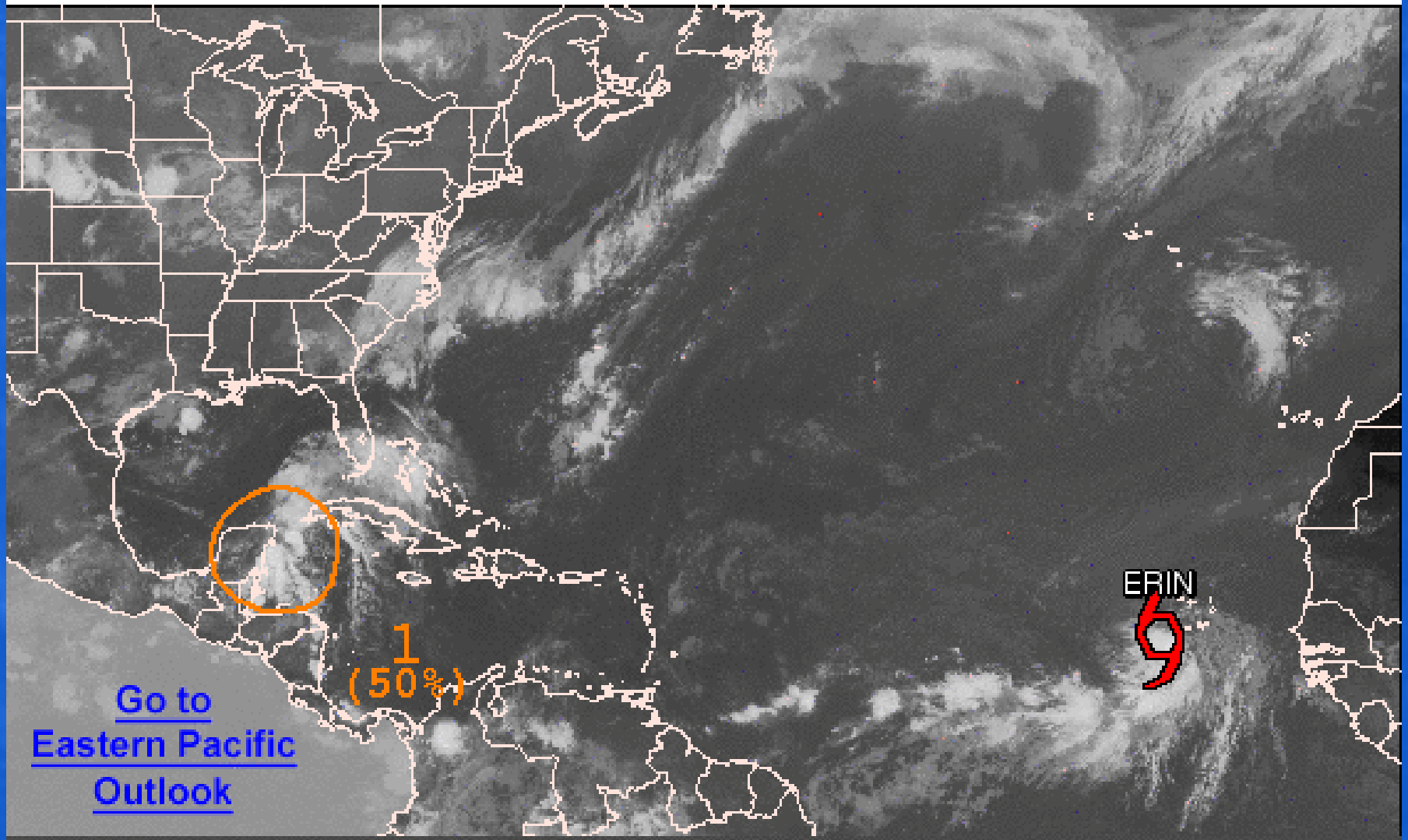
Graphical Tropical Weather Outlook

National Hurricane Center Miami, Florida



800 AM EDT THU AUG 15 2013 Satellite Image: 0722 AM EDT

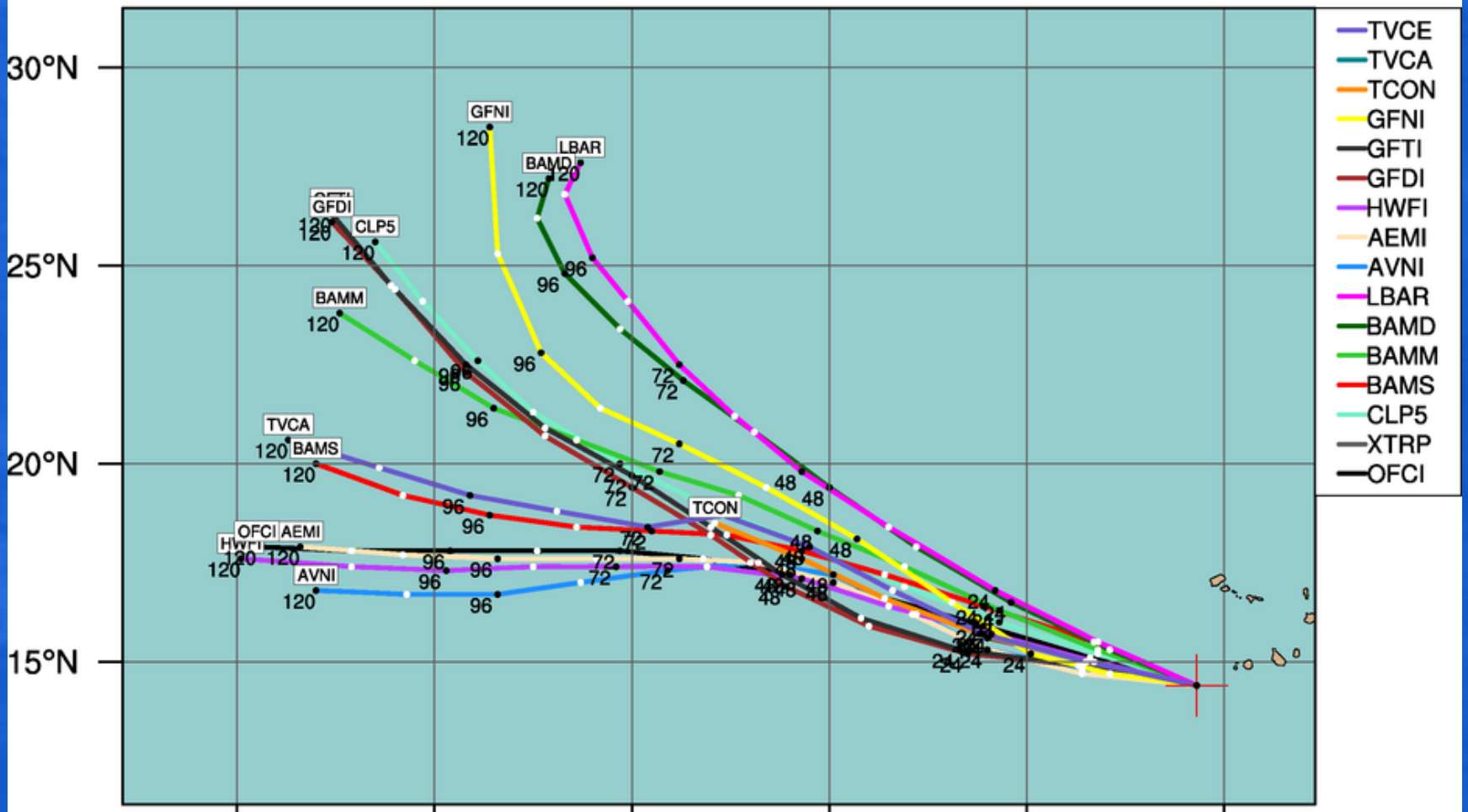
Outlined areas denote current position of systems discussed in the Tropical Weather Outlook. Color indicates probability of tropical cyclone formation within 48 hours.

Low <30% Medium 30-50% High >50%

TROPICAL STORM ERIN (AL05)

Early-cycle track guidance initialized at 1200 UTC, 15 August 2013

Current Intensity: 35 kt Current Basin: North Atlantic



By using this plot, the user agrees to the UCAR Terms of Use
which can be accessed at: http://www2.ucar.edu/terms-of-use

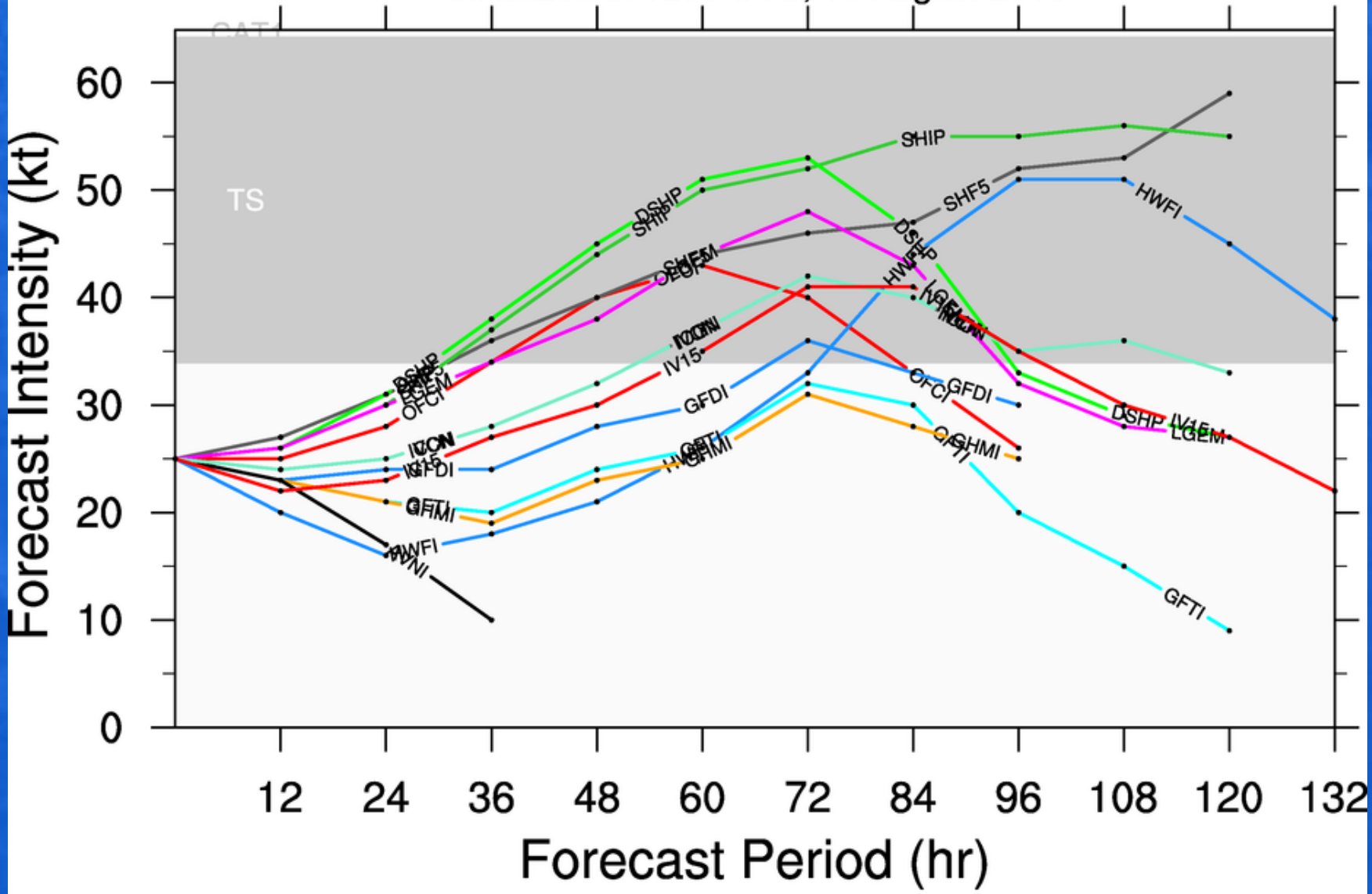
Plot generated at 1349 UTC 15 August 2013

NCAR

DISTURBANCE INVEST (AL92)

Early-cycle intensity guidance

initialized at 1200 UTC, 15 August 2013



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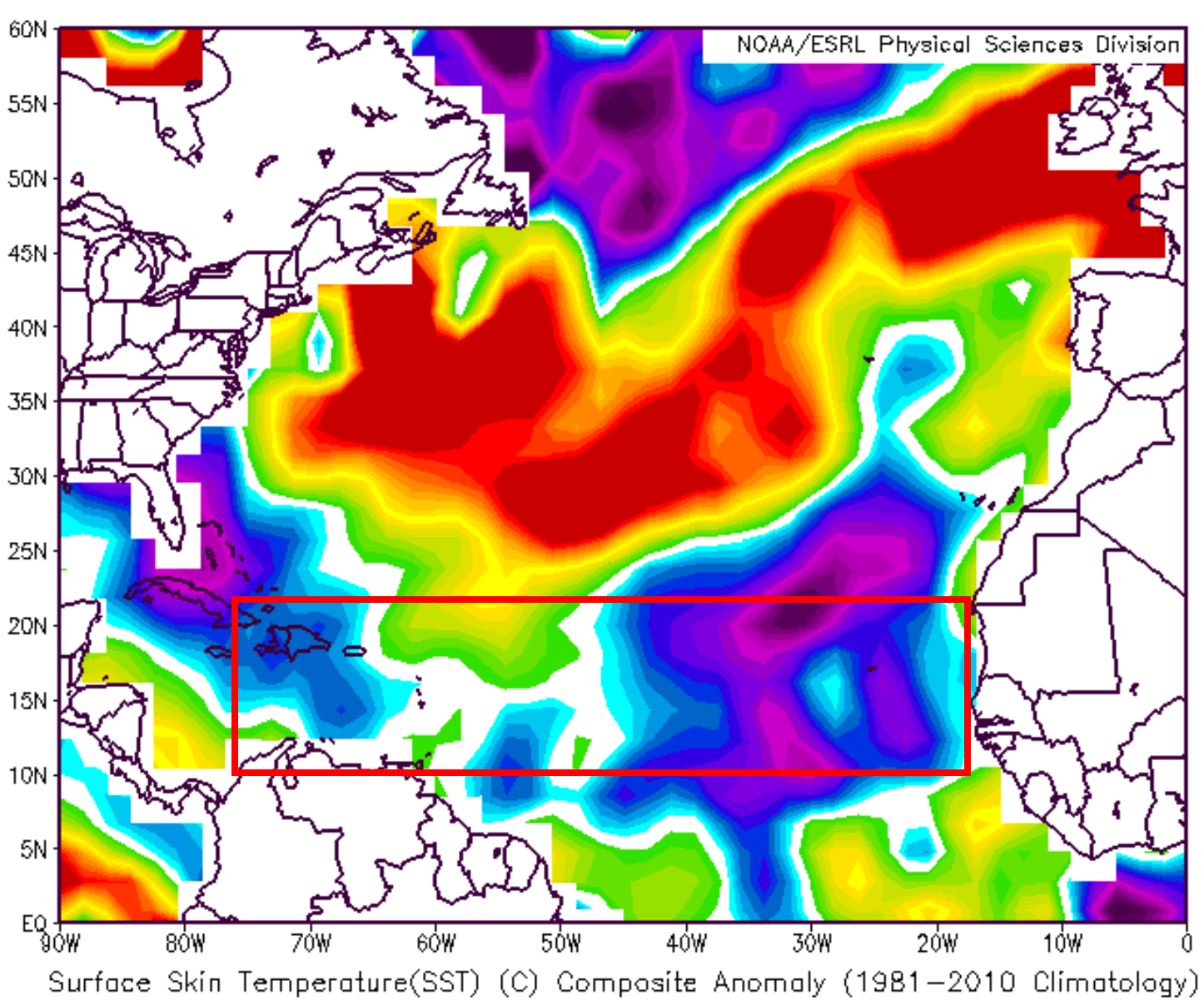
which can be accessed at: http://www2.ucar.edu/terms-of-use

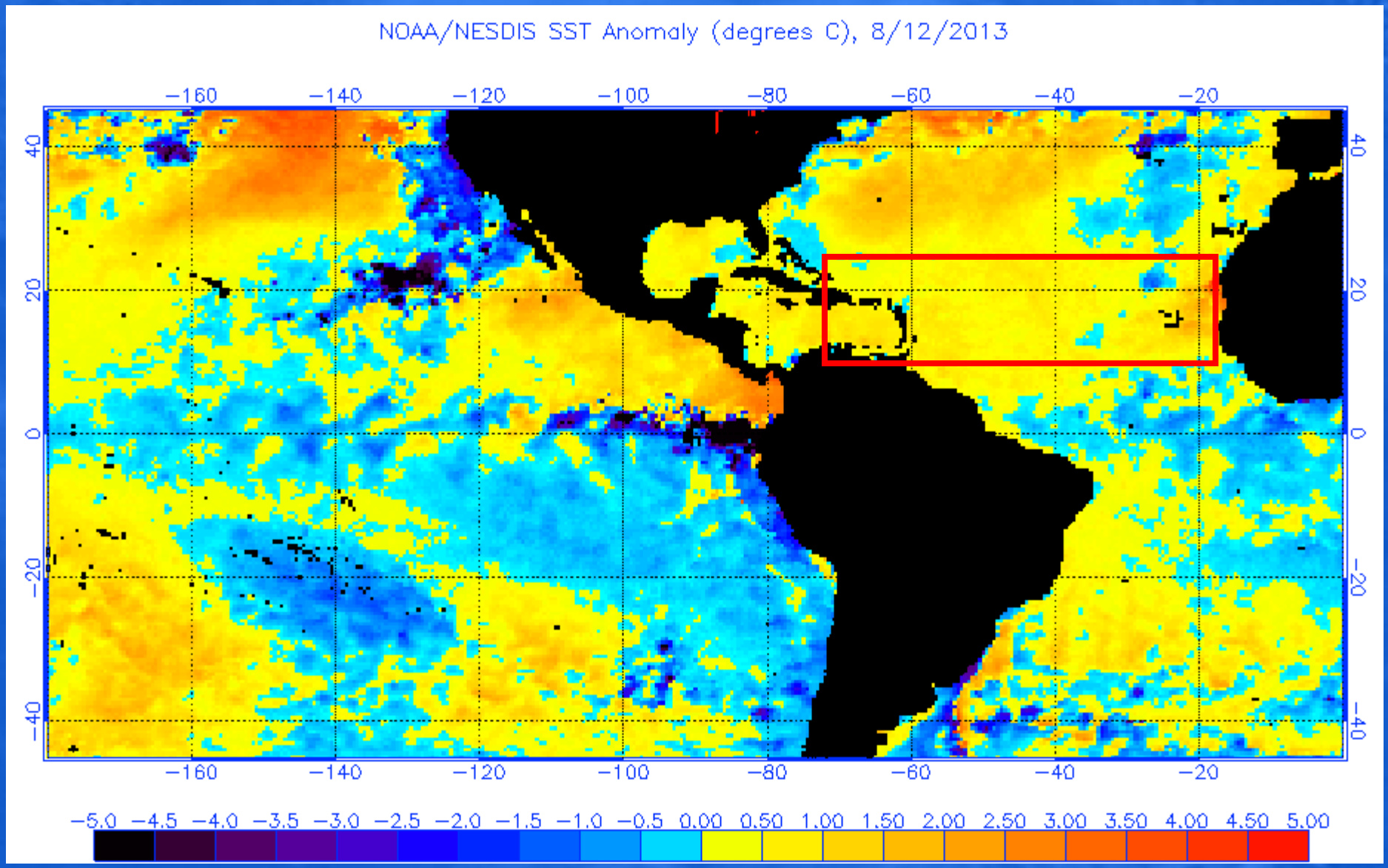
Plot generated at 1349 UTC 15 August 2013

NCAR

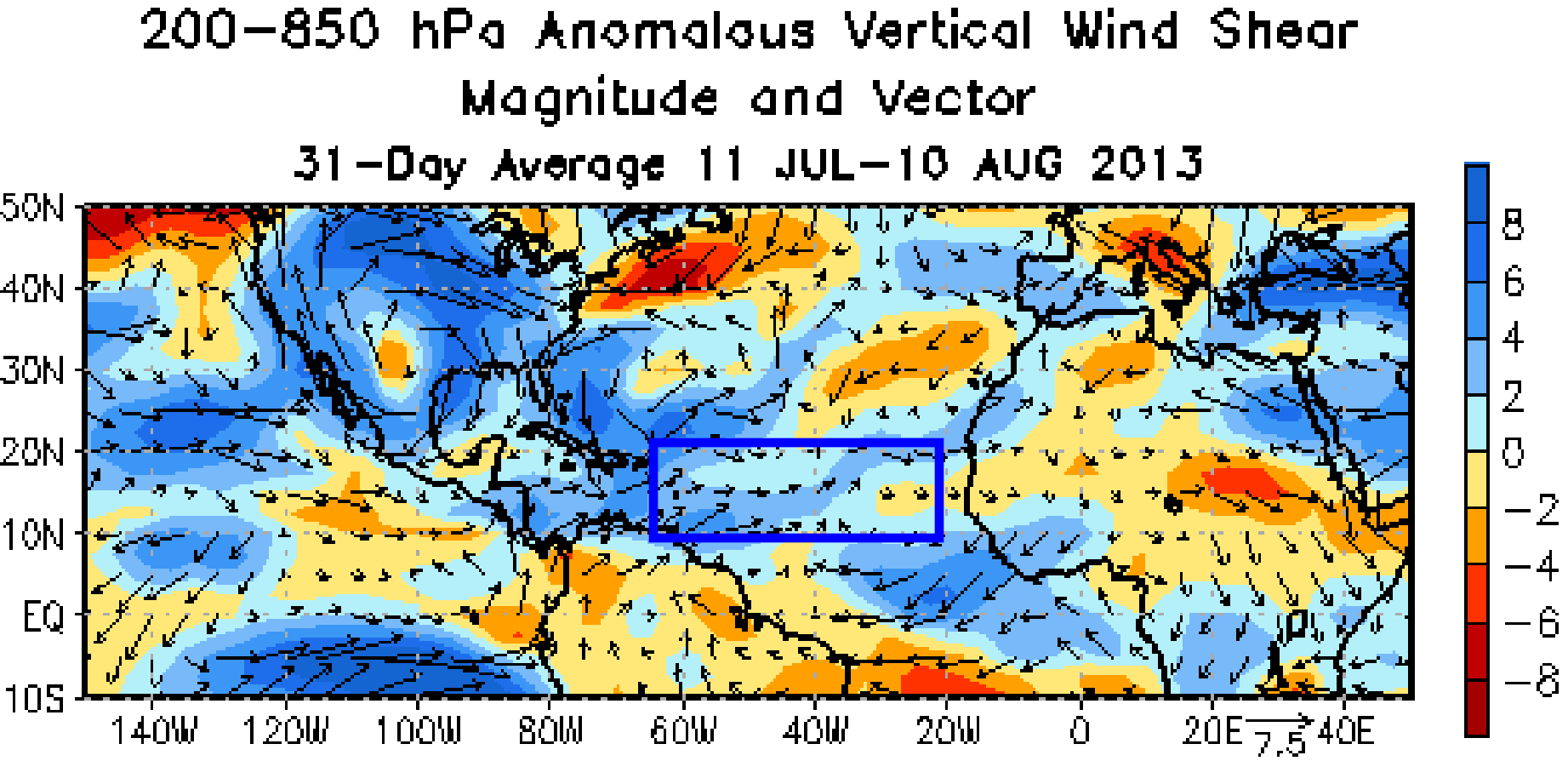


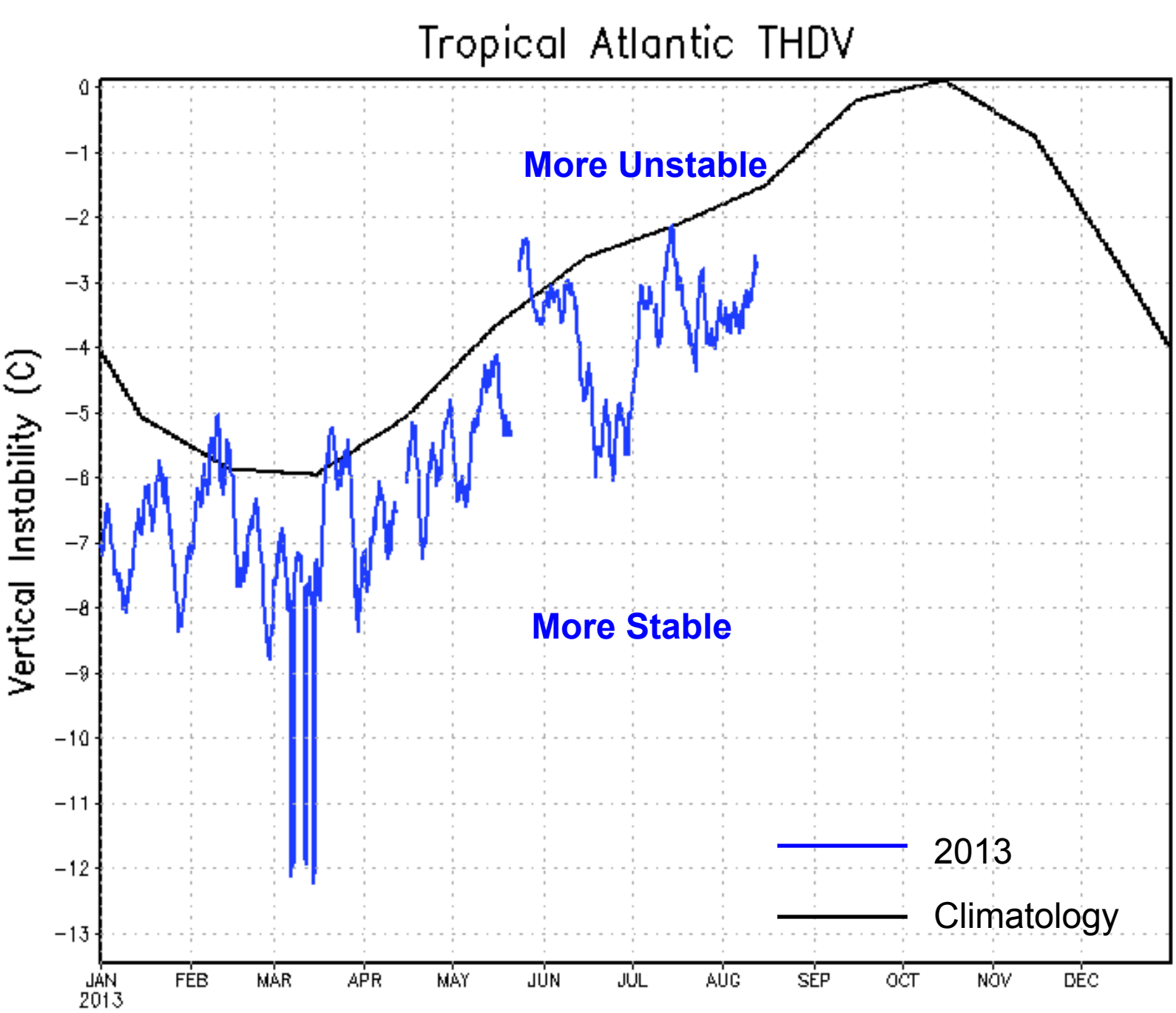
Surface Skin Temperature(SST) (C) Composite Anomaly (1981−2010 Climatology)
Late July 2013 − Late May 2013

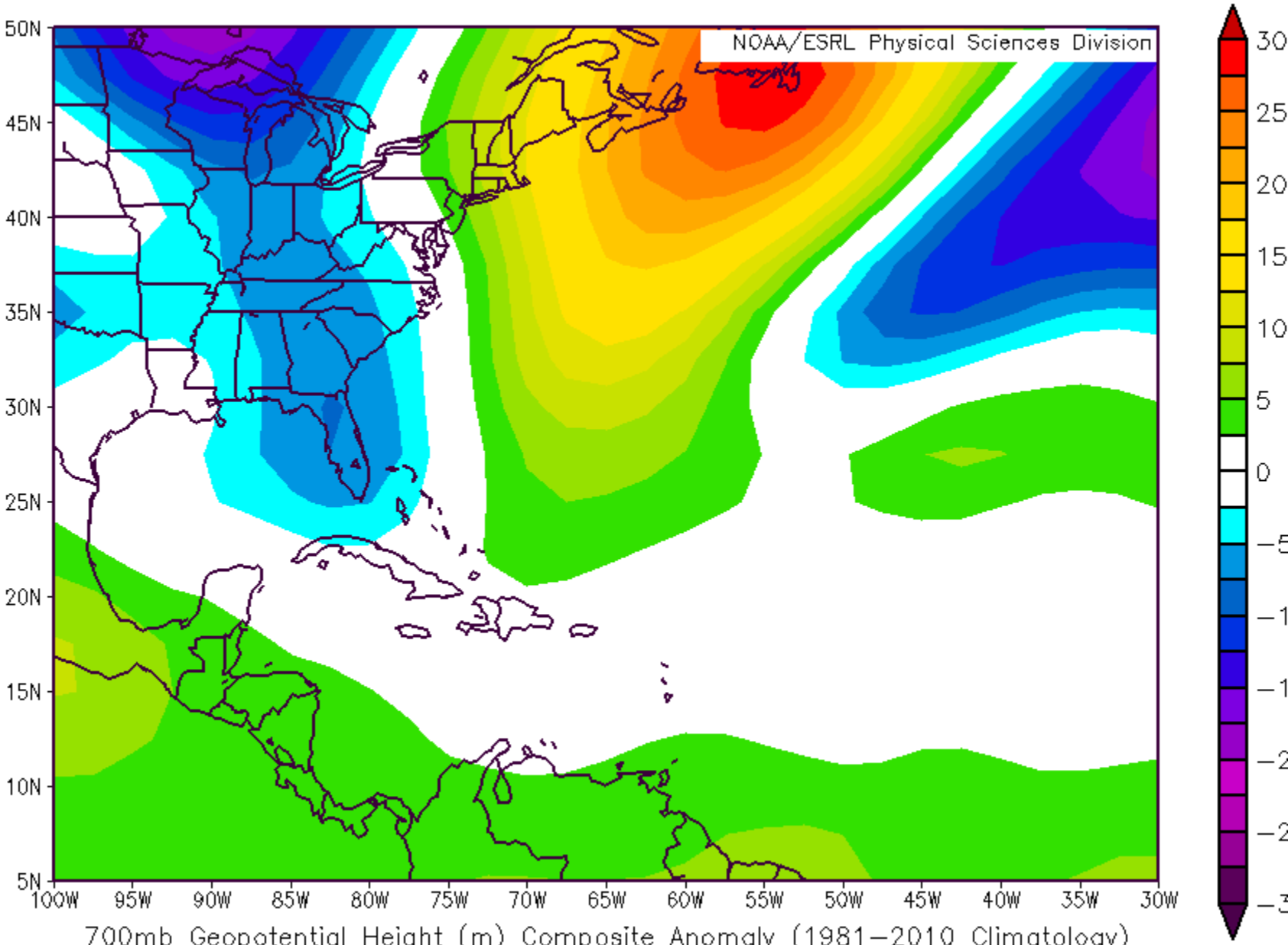
NCEP/NCAR Reanalysis


NOAA/NESDIS SST Anomaly (degrees C), 8/12/2013
−160 −140 −120 −100 −80 −60 −40 −20
40 20 0 −20 −40
−5.0 −4.5 −4.0 −3.5 −3.0 −2.5 −2.0 −1.5 −1.0 −0.5 0.00 0.50 1.00 1.50 2.00 2.50 3.00 3.50 4.00 4.50 5.00

Vertical Wind Shear Anomalies

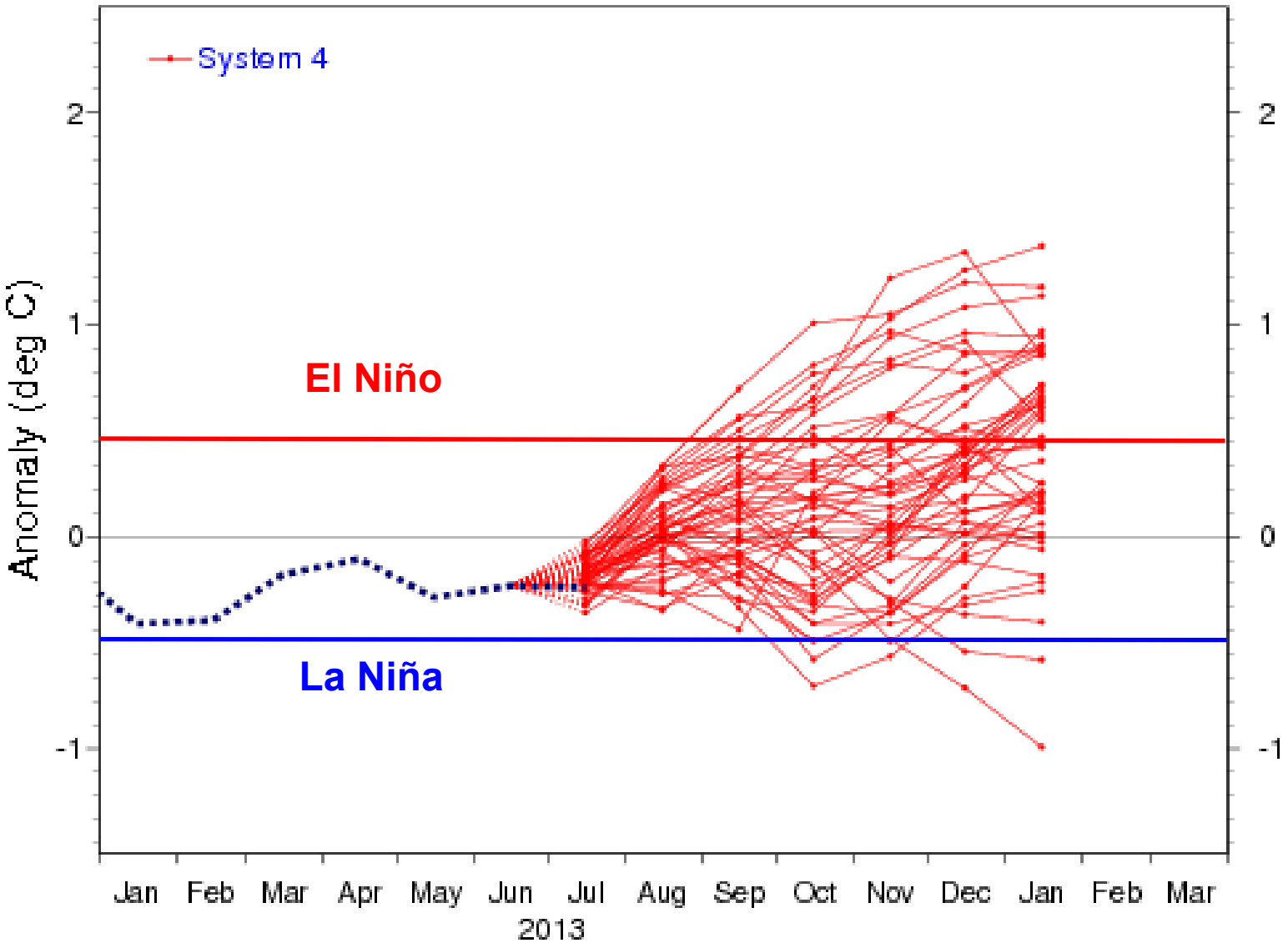



Tropical Atlantic THDV
Vertical Instability (C)
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
-11
-12
-13
More Unstable
More Stable
2013
Climatology
JAN
2013
FEB
MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC

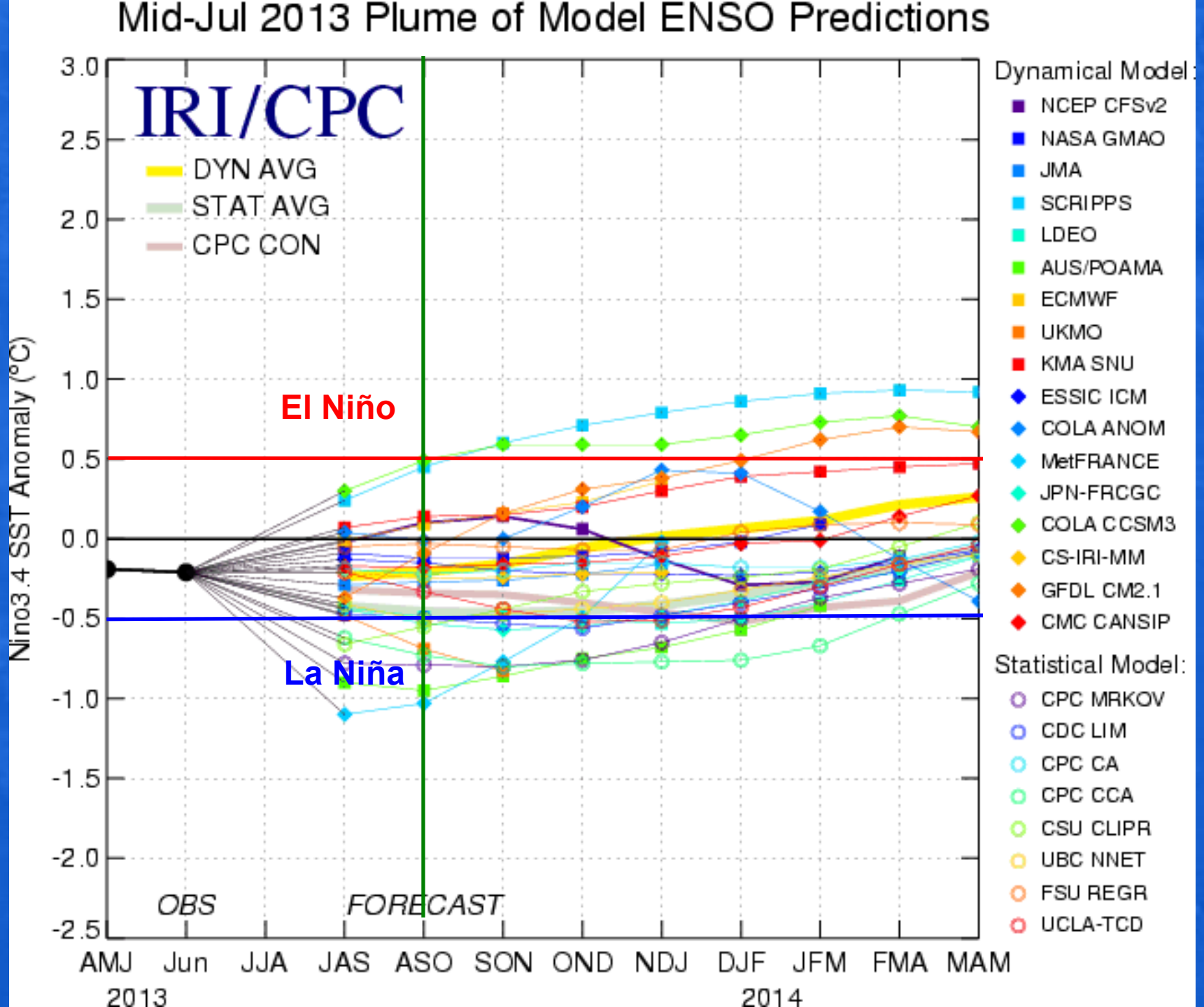


700mb Geopotential Height (m) Composite Anomaly (1981−2010 Climatology)
7/10/13 to 8/10/13

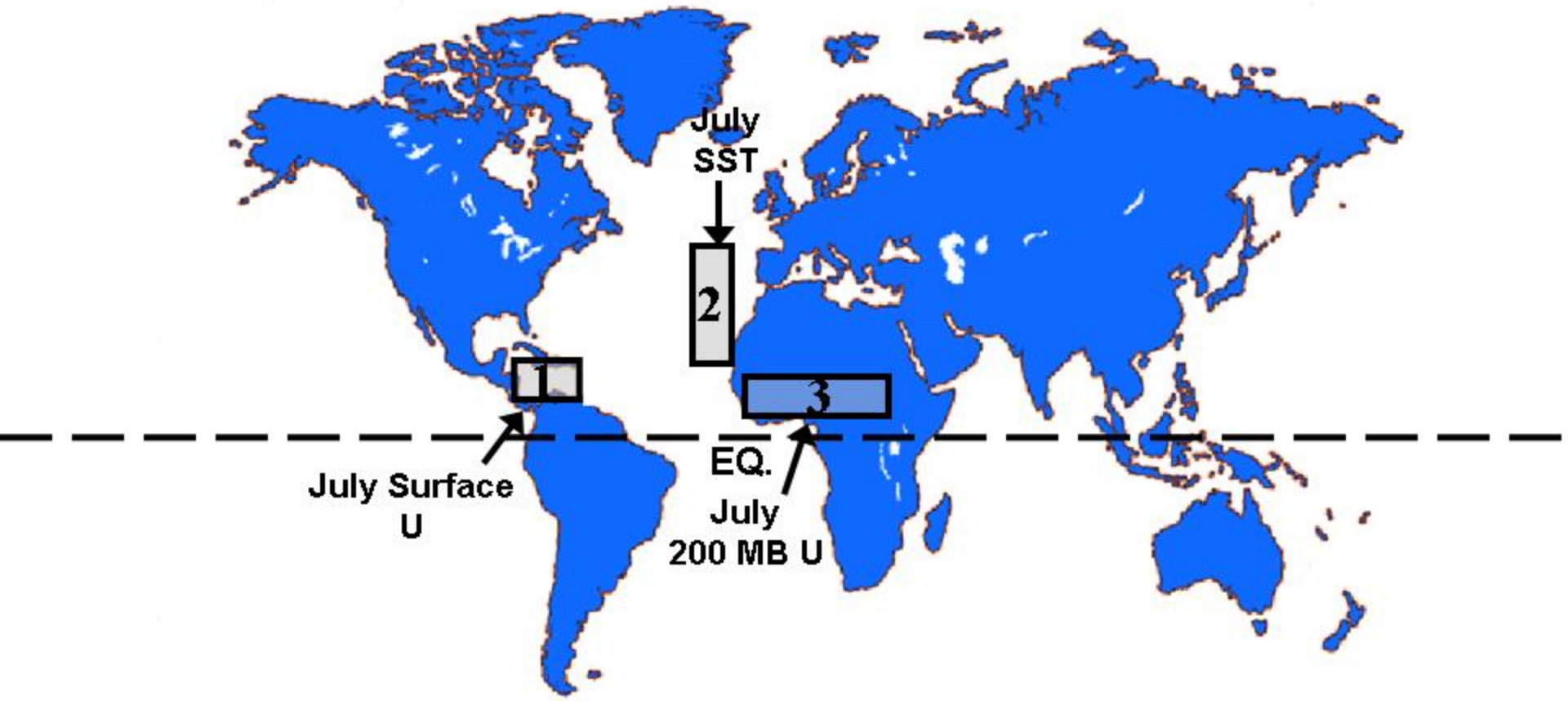
NCEP/NCAR Reanalysis

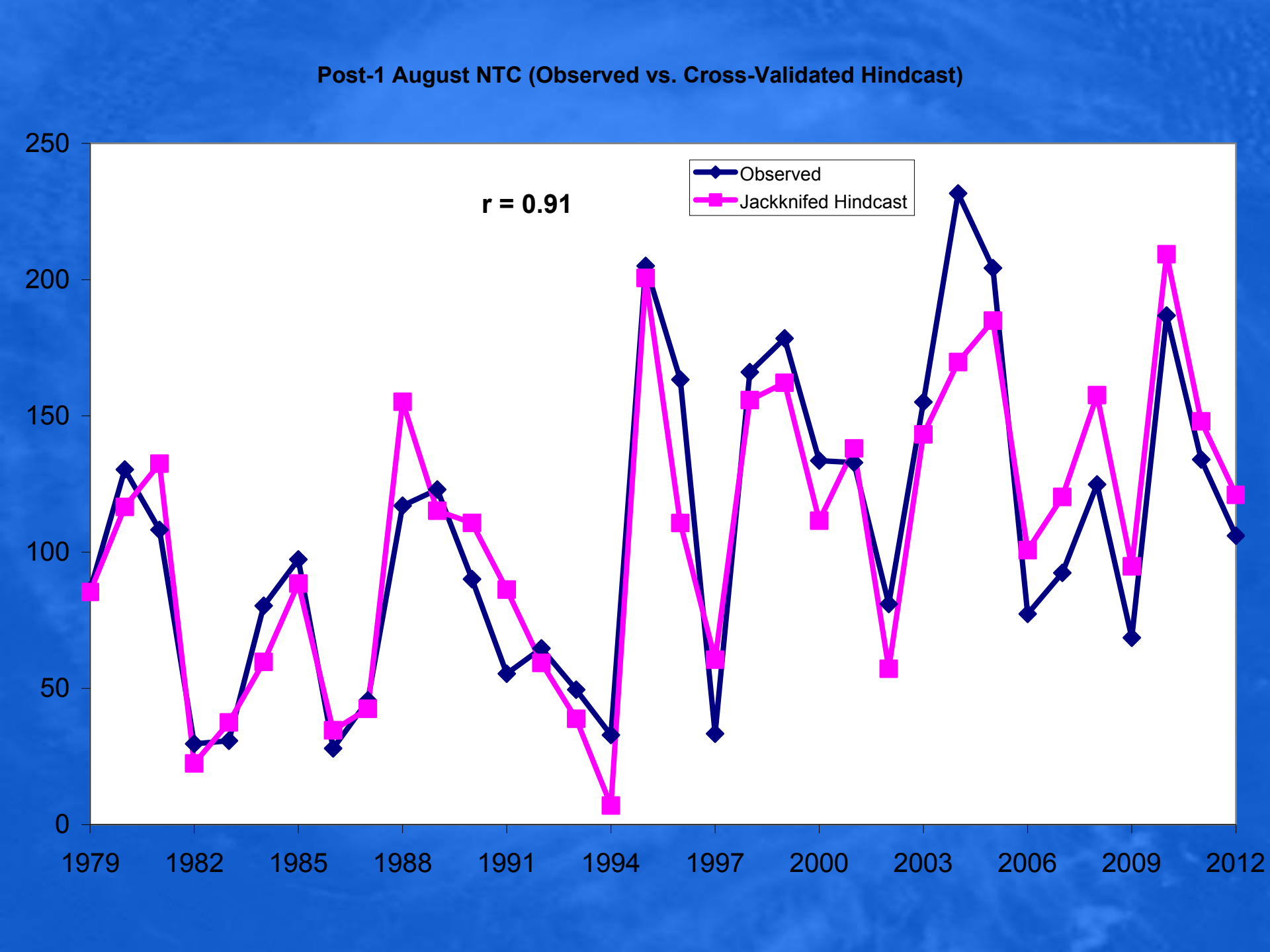

NINO3.4 SST anomaly plume
ECMWF forecast from 1 Jul 2013
Monthly mean anomalies relative to NCEP OIv2 1981-2010 climatology
System 4
El Niño
La Niña
Anomaly (deg C)
2
1
0
-1
Jan
Feb
Mar
Apr
May
Jun
Jul
Aug
Sep
Oct
Nov
Dec
Jan
Feb
Mar
2013

©ECMWF


Mid-Jul 2013 Plume of Model ENSO Predictions
IRI/CPC
DYN AVG
STAT AVG
CPC CON
El Niño
La Niña
OBS
FORECAST
Nino3.4 SST Anomaly (°C)
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-0.5
-1.0
-1.5
-2.0
-2.5
AMJ
Jun
JJA
JAS
ASO
SON
OND
NDJ
DJF
JFM
FMA
MAM
2013
2014
Dynamical Model:
NCEP CFSv2
NASA GMAO
JMA
SCRIPPS
LDEO
AUS/POAMA
ECMWF
UKMO
KMA SNU
ESSIC ICM
COLA ANOM
MetFRANCE
JPN-FRCGC
COLA CCSM3
CS-IRI-MM
GFDL CM2.1
CMC CANSIP
Statistical Model:
CPC MRKOV
CDC LIM
CPC CA
CPC CCA
CSU CLIPR
UBC NNET
FSU REGR
UCLA-TCD

Post-31 July Seasonal Forecast Predictors




Post-1 August NTC (Observed vs. Cross-Validated Hindcast)
r = 0.91
Observed
Jackknifed Hindcast
250
200
150
100
50
0
1979
1982
1985
1988
1991
1994
1997
2000
2003
2006
2009
2012

BEST ANALOG YEARS FOR 2013 (AUGUST FORECAST)

	NS	NSD	H	HD	MH	MHD	ACE	NTC
1952	7	39.75	6	22.75	3	7.00	87	103
1966	11	64.00	7	41.75	3	8.75	145	140
1996	13	79.00	9	45.00	6	13.00	166	192
2007	15	37.75	6	12.25	2	6.00	74	99
2008	16	88.25	8	30.50	5	7.50	146	162
MEAN	*12.4*	*61.8*	*7.2*	*30.5*	*3.8*	*8.5*	*124*	*139*
2013 Forecast	18	84.25	8	35	3	7	140	150

2013
Forecast Schedule

Date	7 Dec.	10 Apr.	3 June	2 Aug.
Seasonal Forecast	X	X	X	X

POST-31 JULY 2013 PROBABILITIES FOR AT LEAST ONE MAJOR (CATEGORY 3-4-5) HURRICANE LANDFALL IN EACH OF THE FOLLOWING AREAS (20th CENTURY PROBABILITIES IN PARENTHESES)

1) Entire U.S. coastline – 64% (52%)
2) U.S. East Coast including Peninsula Florida – 40% (31%)
3) Gulf Coast from the Florida Panhandle westward to Brownsville – 40% (30%)
4) Caribbean (10-20° N, 60-88° W) – 53% (42%)

Landfalling Hurricane Web Application

Currently Available at the following URL:

http://www.e-transit.org/hurricane

In partnership with the GeoGraphics Laboratory – Bridgewater State University, Bridgewater MA

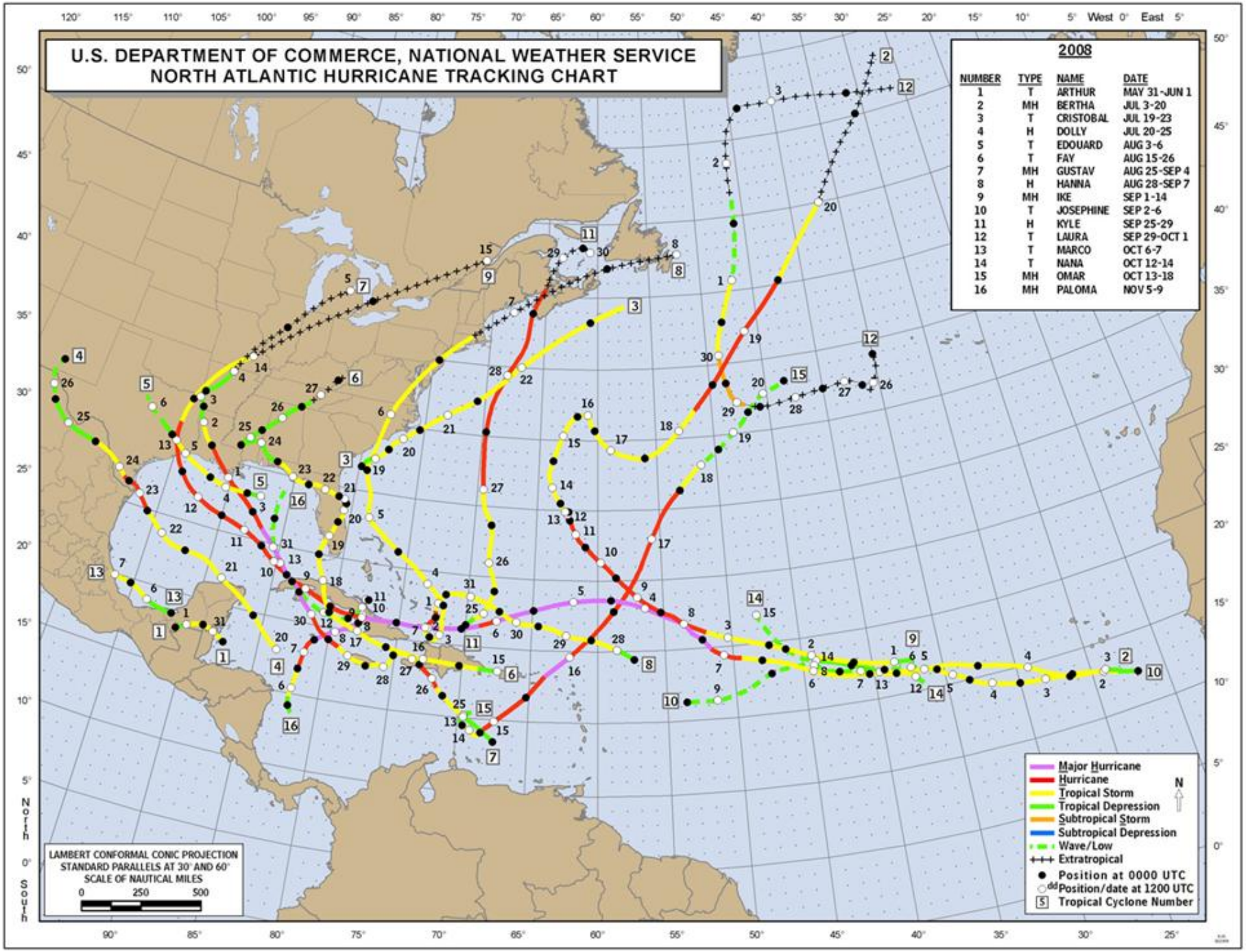
2013 Probabilities (20th Century Probabilities in Parentheses)

State	Hurricane Impact Prob.	MH Impact Prob.
Florida	63% (51%)	28% (21%)
Louisiana	40% (30%)	16% (12%)
Massachusetts	10% (7%)	3% (2%)
Mississippi	14% (11%)	6% (4%)
New York	10% (8%)	4% (3%)
North Carolina	37% (22%)	10% (8%)
Texas	43% (33%)	16% (12%)

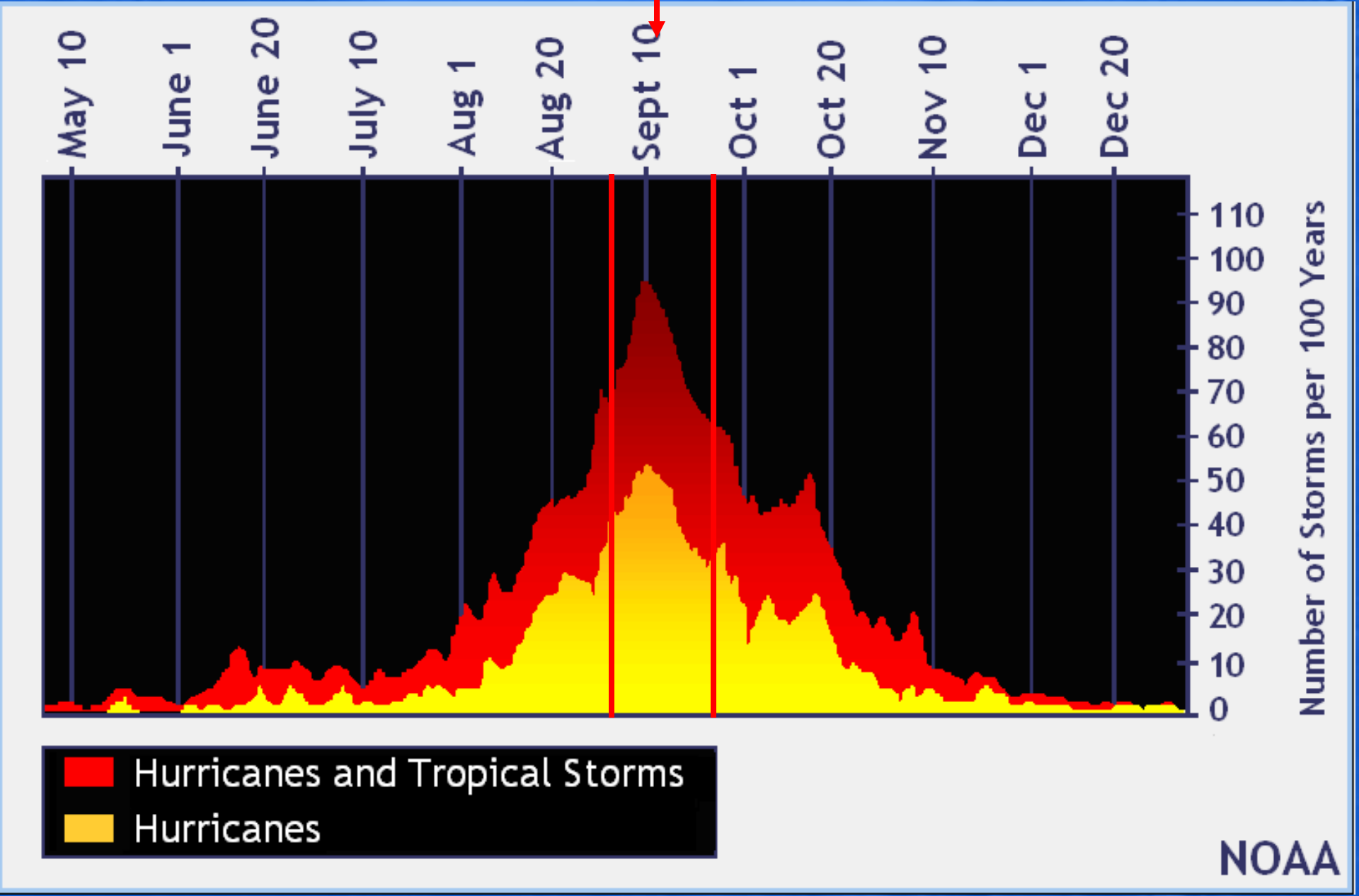
2013 Probabilities (20th Century Probabilities in Parentheses)

Country/Island	Hurricane within 100 Miles	MH within 100 Miles
The Bahamas	64% (51%)	39% (30%)
Cuba	64% (52%)	37% (28%)
Haiti	36% (27%)	18% (13%)
Jamaica	33% (25%)	15% (11%)
Mexico	70% (57%)	30% (23%)
Puerto Rico	38% (29%)	18% (13%)
US Virgin Islands	39% (30%)	16% (12%)

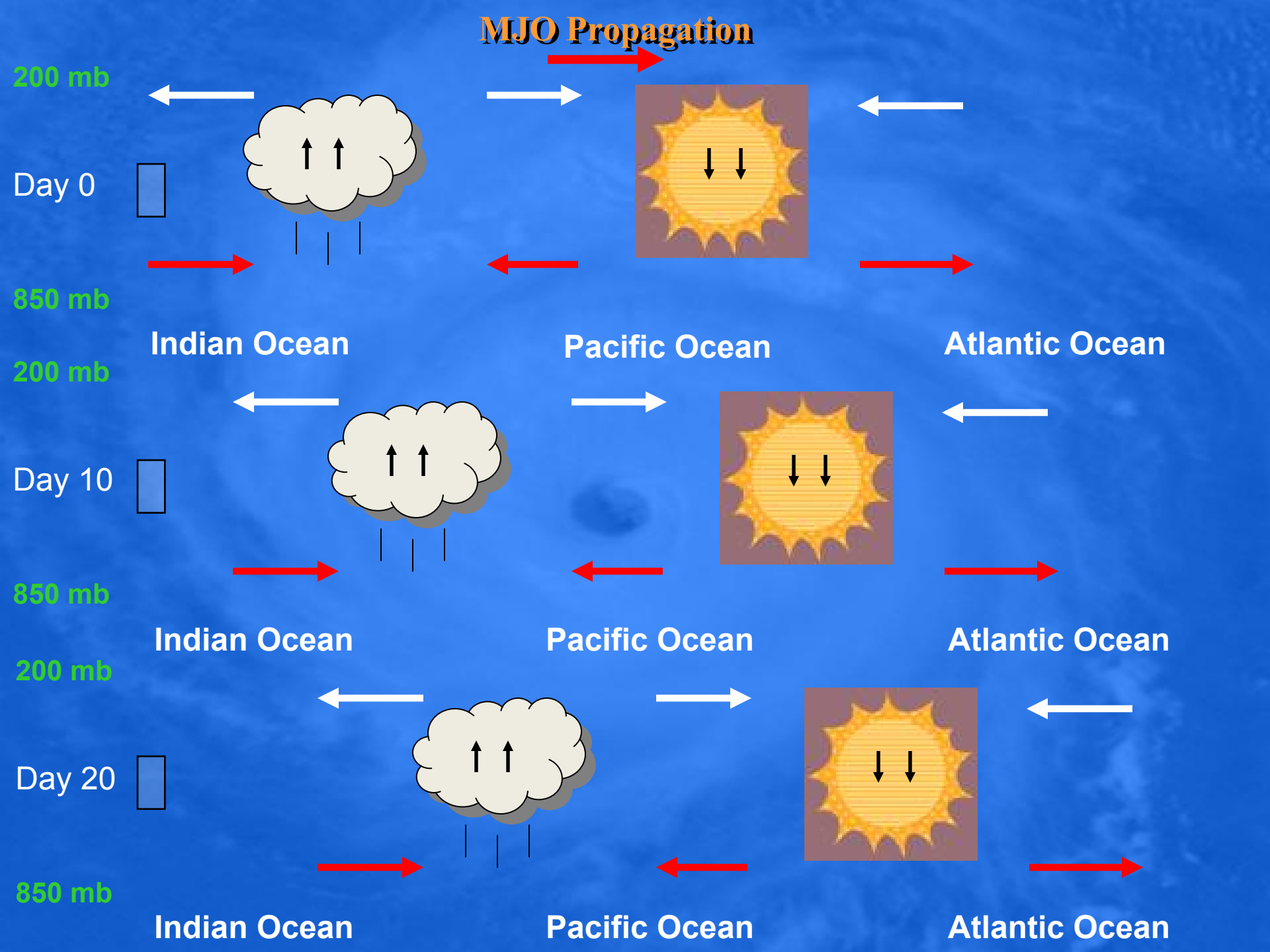
Two-Week Atlantic Basin Forecasts (available since 2009)

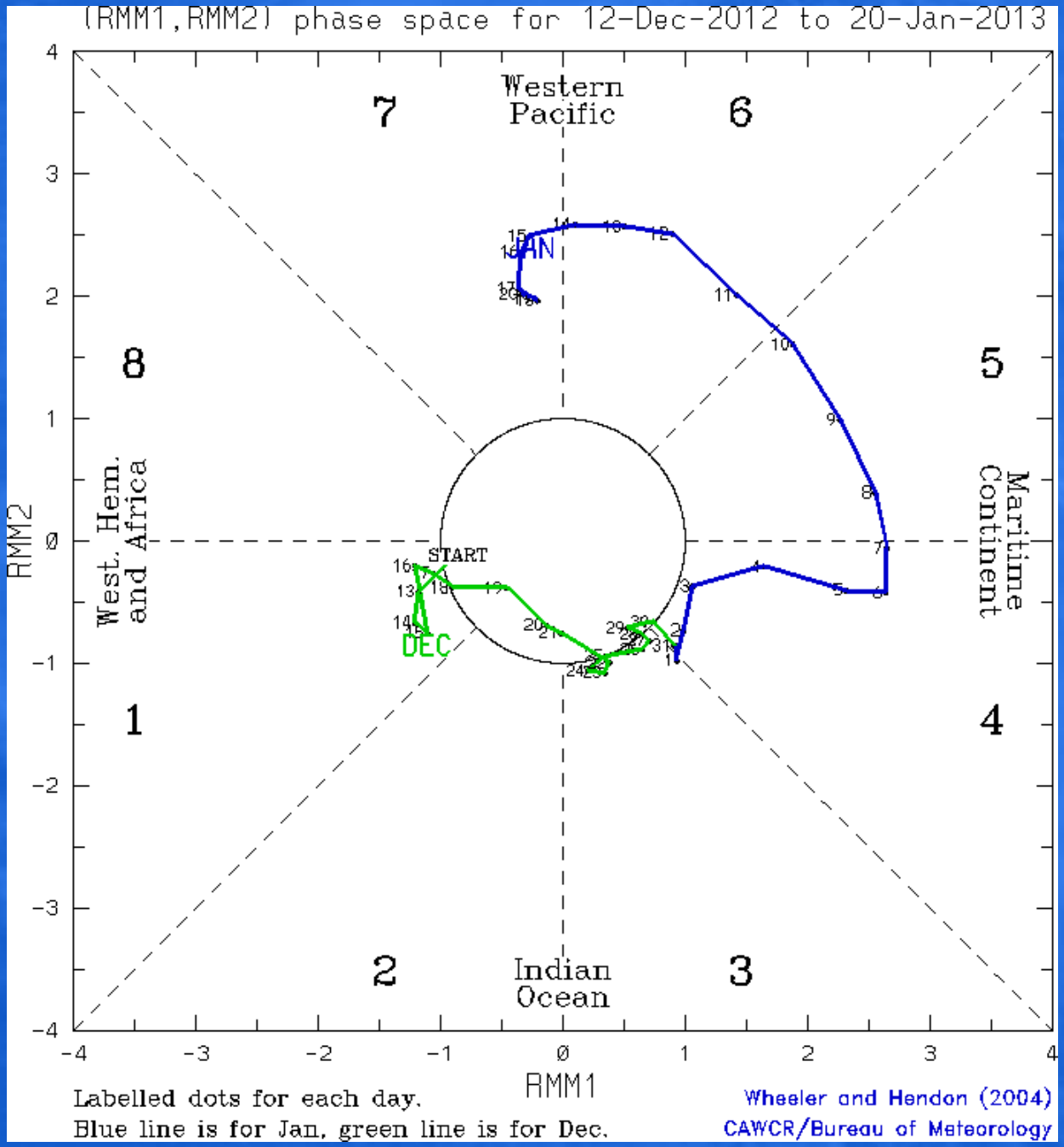

U.S. DEPARTMENT OF COMMERCE, NATIONAL WEATHER SERVICE
NORTH ATLANTIC HURRICANE TRACKING CHART
2008
NUMBER TYPE NAME DATE
1 T ARTHUR MAY 31-JUN 1
2 MH BERTHA JUL 3-20
3 T CRISTOBAL JUL 19-23
4 H DOLLY JUL 20-25
5 T EDOUARD AUG 3-6
6 T FAY AUG 15-26
7 MH GUSTAV AUG 25-SEP 4
8 H HANNA AUG 28-SEP 7
9 MH IKE SEP 1-14
10 T JOSEPHINE SEP 2-6
11 H KYLE SEP 25-29
12 T LAURA SEP 29-OCT 1
13 T MARCO OCT 6-7
14 T NANA OCT 12-14
15 MH OMAR OCT 13-18
16 MH PALOMA NOV 5-9
Major Hurricane
Hurricane
Tropical Storm
Tropical Depression
Subtropical Storm
Subtropical Depression
Wave/Low
Extratropical
Position at 0000 UTC
dd Position/date at 1200 UTC
5 Tropical Cyclone Number
N
LAMBERT CONFORMAL CONIC PROJECTION
STANDARD PARALLELS AT 30° AND 60°
SCALE OF NAUTICAL MILES
0 250 500
120° 115° 110° 105° 100° 95° 90° 85° 80° 75° 70° 65° 60° 55° 50° 45° 40° 35° 30° 25° 20° 15° 10° 5° West 0° East 5°
50° 45° 40° 35° 30° 25° 20° 15° 10° 5° North 0° South

No Storm Formations in 2008



MJO Propagation




(RMM1,RMM2) phase space for 12-Dec-2012 to 20-Jan-2013
Western Pacific
7
6
8
5
West. Hem. and Africa
Maritime Continent
1
4
2
Indian Ocean
3
RMM2
RMM1
START
DEC
JAN
Labelled dots for each day.
Blue line is for Jan, green line is for Dec.
Wheeler and Hendon (2004)
CAWCR/Bureau of Meteorology

Two-Week Forecast Verification for 2012

Forecast Day	Predicted ACE	Observed ACE
8/3/12	Above-Average (9 or More)	10
8/17/12	Above-Average (19 or More)	20
8/31/12	Average (20-37)	39
9/14/12	Below-Average (14 or Less)	14
9/28/12	Average (8-15)	11
10/12/12	Above-Average (9 or More)	15

Correct Category 1 Category Miss 2 Category Miss

Arago's Admonition:

"Never, no matter what may be the progress of science, will honest scientific men who have regard for their reputations venture to predict the weather."