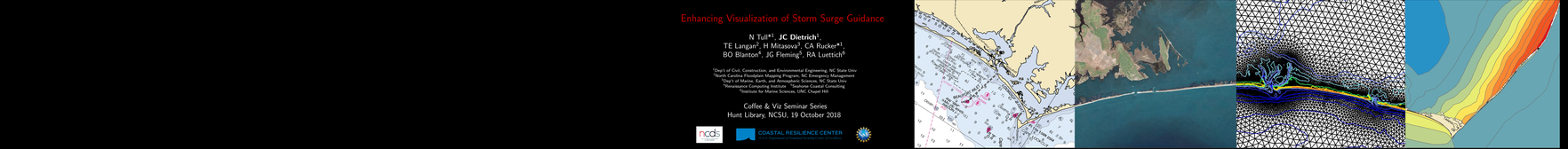
Enhancing Visualization of Storm Surge Guidance

N Tull*[1], **JC Dietrich**[1],
TE Langan[2], H Mitasova[3], CA Rucker*[4],
BO Blanton[4], JG Fleming[5], RA Luettich[6]

[1]Dept of Civil, Construction, and Environmental Engineering, NC State Univ
[2]North Carolina Floodplain Mapping Program, NC Emergency Management
[3]Dept of Marine, Earth, and Atmospheric Sciences, NC State Univ
[4]Renaissance Computing Institute, [5]Seahorse Coastal Consulting
[6]Institute for Marine Sciences, UNC Chapel Hill

Coffee & Viz Seminar Series
Hunt Library, NCSU, 19 October 2018

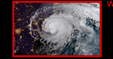


Enhancing Visualization of Storm Surge Guidance

N Tull*[1], **JC Dietrich**[1],
TE Langan[2], H Mitasova[3], CA Rucker*[4],
BO Blanton[4], JG Fleming[5], RA Luettich[6]

[1]Dept of Civil, Construction, and Environmental Engineering, NC State Univ
[2]North Carolina Floodplain Mapping Program, NC Emergency Management
[3]Dept of Marine, Earth, and Atmospheric Sciences, NC State Univ
[4]Renaissance Computing Institute, [5]Seahorse Coastal Consulting
[6]Institute for Marine Sciences, UNC Chapel Hill

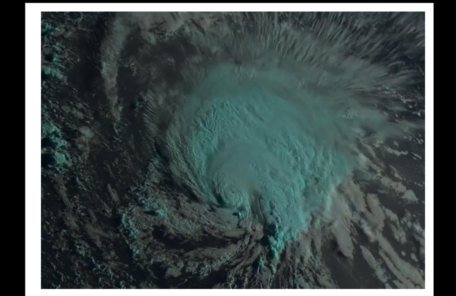
Coffee & Viz Seminar Series
Hunt Library, NCSU, 19 October 2018



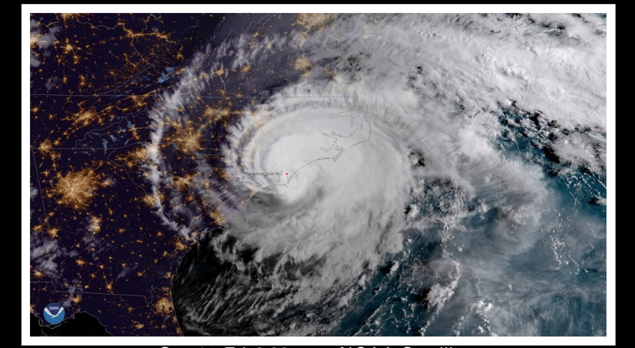
What Happened During Florence?

- Timeline of the Storm
- Predictions of Coastal Flooding

Sep 12 Wed 6:35am – Alex Gerst



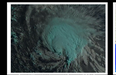
Sep 6 Thu 2:16pm – NOAA NESDIS



Sep 14 Fri 6:39am – NOAA Satellites

Sep 16 Sun 8:04am – NOAA Satellites

Sep 8 Sat 7:52pm – National Hurricane Center



Sep 9 Thu 3:16pm – NOAA NESDIS

Sep 9 Sun 8:15am – Central Emergency Risks Assessment

Sep 11 Tue 1:52pm – National Hurricane Center

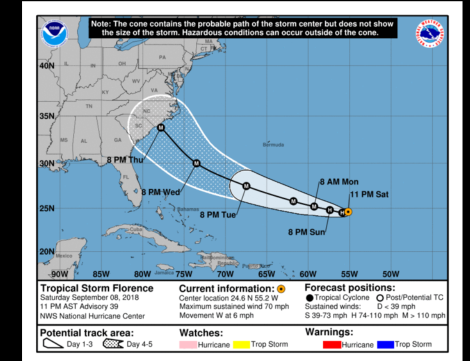
Sep 13 Wed 6:35am – Alex Gere

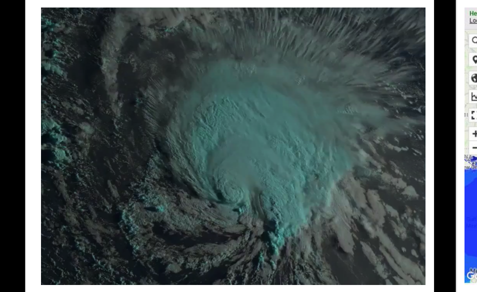
Sep 13 Wed 2:06pm – National Hurricane Center

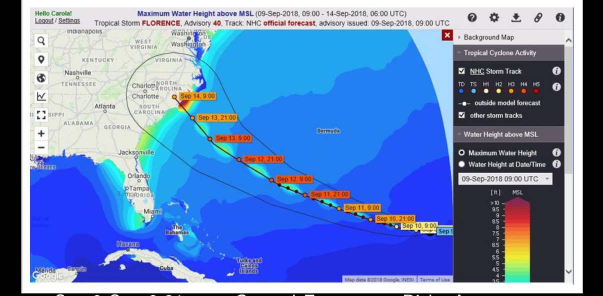
Sep 18 Fri 9:36am – NOAA Satellites

Sep 20 Sun 1:01am – NOAA Satellites

Sep 8 Sat 7:52pm – National Hurricane Center

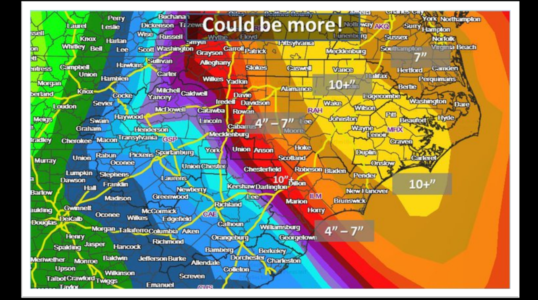


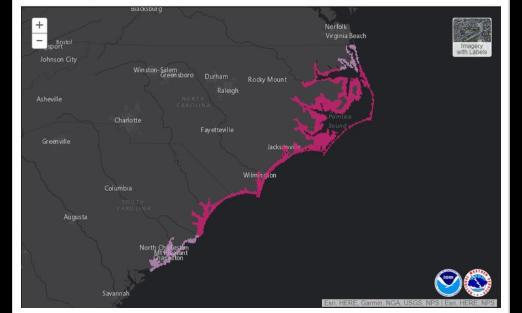

Sep 6 Thu 2:16pm – NOAA NESDIS



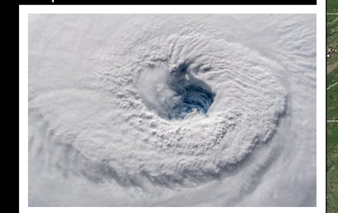
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment

Sep 10 Mon 3:40pm – NWS Raleigh

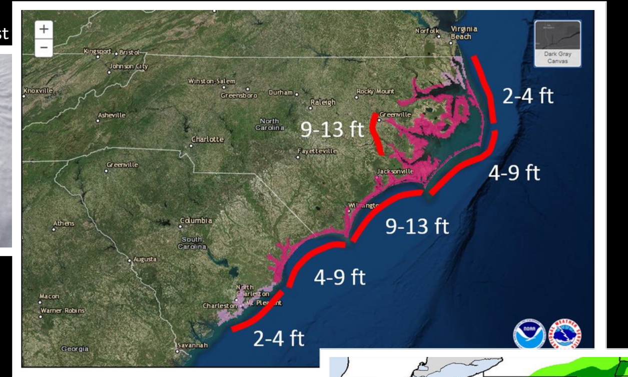


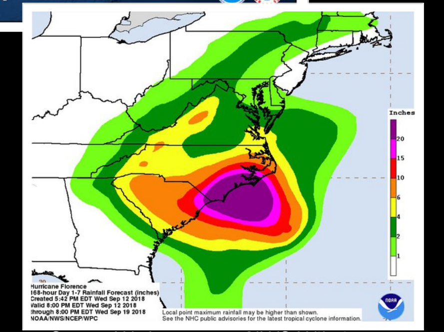

Sep 11 Tue 1:52pm – National Hurricane Center

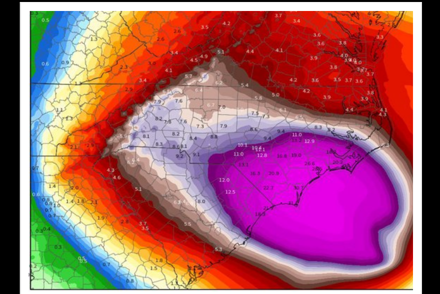
Sep 12 Wed 6:35am – Alex Gerst

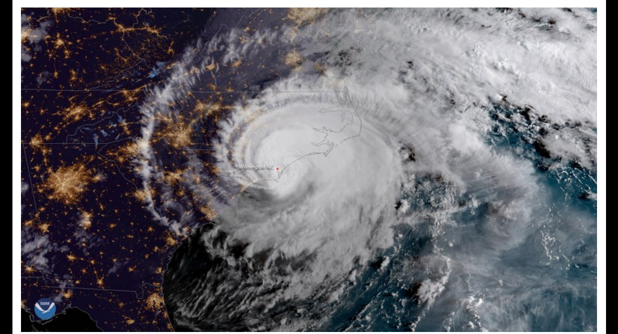


Sep 12 Wed 2:06pm – National Hurricane Center



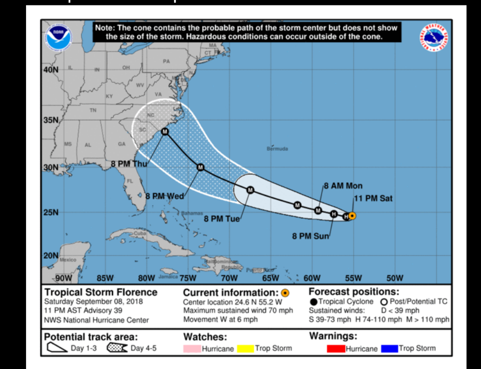

Sep 12 Wed 4:49pm – NWS Wilmington


Sep 13 Thu 4:29am – Eric Webb


Sep 14 Fri 6:39am – NOAA Satellites


Sep 16 Sun 8:04am – NOAA Satellites

Sep 8 Sat 7:52pm – National Hurricane Center



Sep 10 Mon 3:40pm – NWS Raleigh

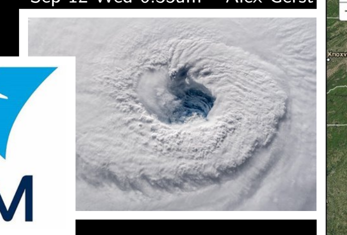
Sep 10 Mon 2:31pm

Sep 9 Sun 1:43pm

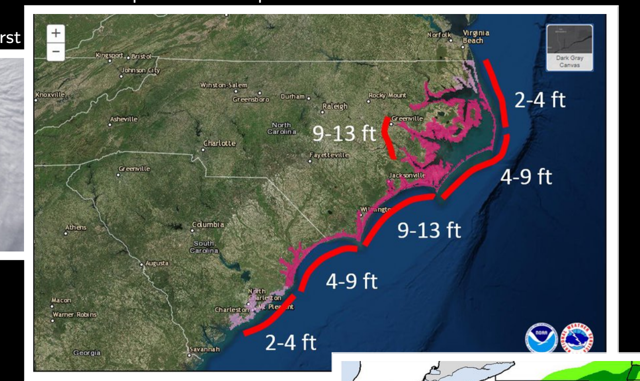
Sep 11 Tue 1:40pm

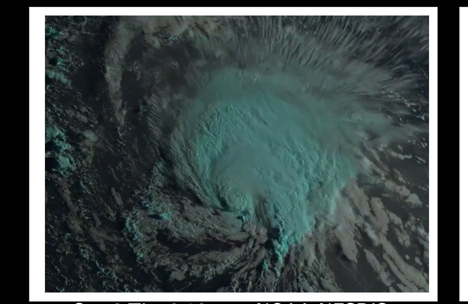
Sep 12 Wed 5:13am

Sep 12 Wed 6:35am – Alex Gerst

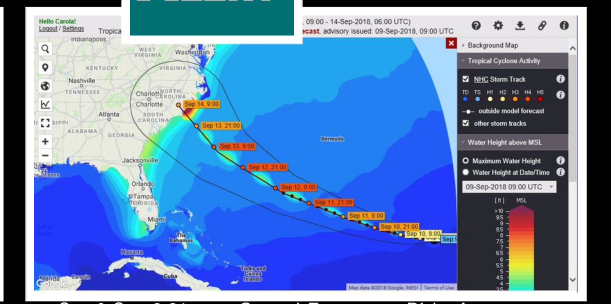


Sep 12 Wed 2:06pm – National Hurricane Center

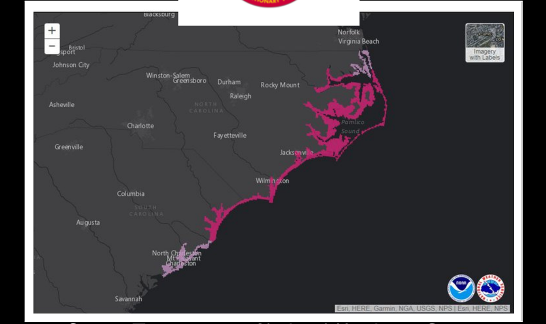




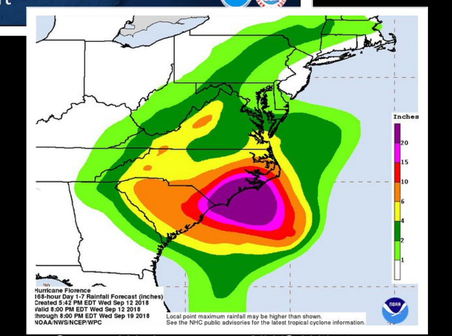
Sep 6 Thu 2:16pm – NOAA NESDIS



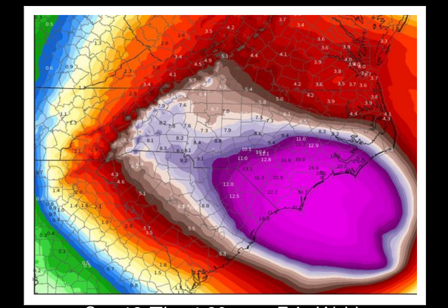
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment



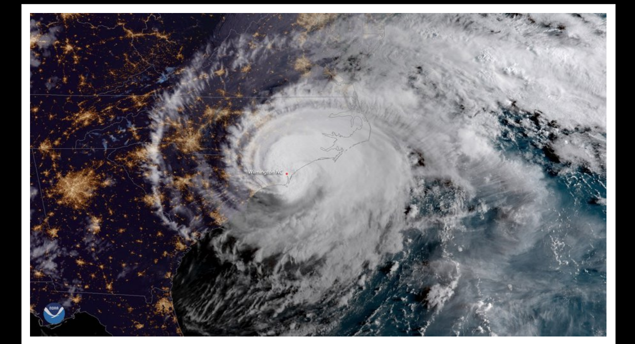
Sep 11 Tue 1:52pm – National Hurricane Center



Sep 12 Wed 4:49pm – NWS Wilmington

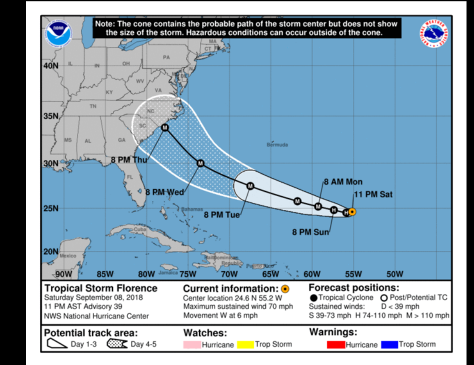


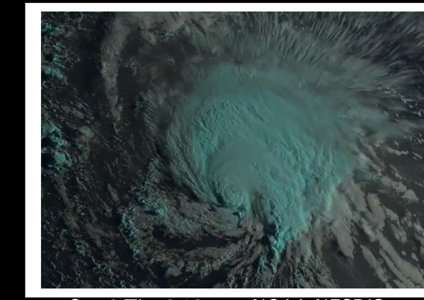
Sep 13 Thu 4:29am – Eric Webb

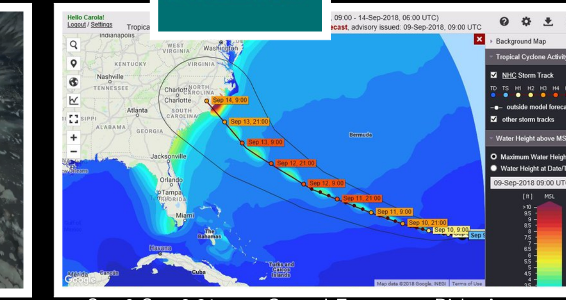


Sep 14 Fri 6:39am – NOAA Satellites

Sep 16 Sun 8:04am – NOAA Satellites

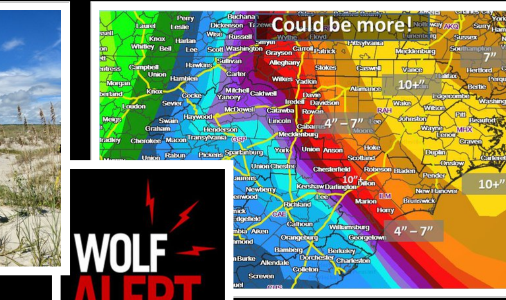

Sep 8 Sat 7:52pm – National Hurricane Center


Sep 6 Thu 2:16pm – NOAA NESDIS


Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment

Sep 9 Sun 1:43pm

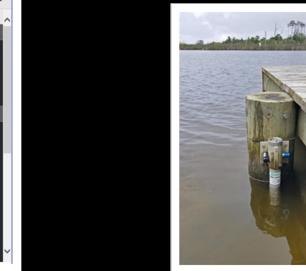

Sep 10 Mon 6:03pm

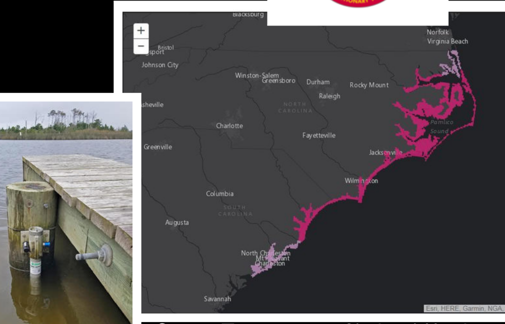


Sep 10 Mon 3:40pm – NWS Raleigh

Sep 10 Mon 2:31pm

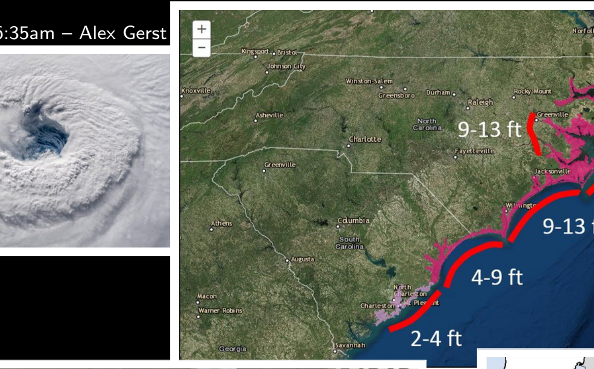
Sep 11 Tue 1:40pm


Sep 11 Tue 11:45am

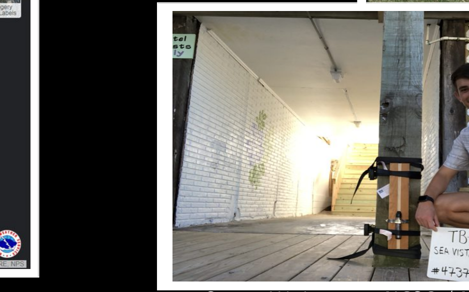

Sep 11 Tue 1:52pm – National Hurricane Center

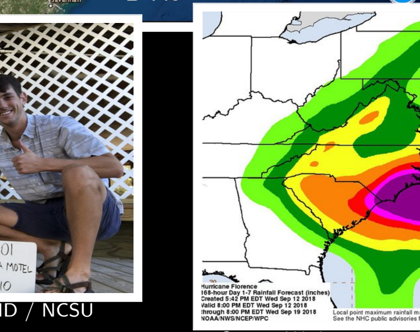
Sep 12 Wed 5:13am

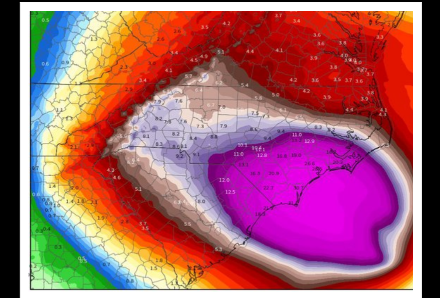

Sep 12 Wed 6:35am – Alex Gerst

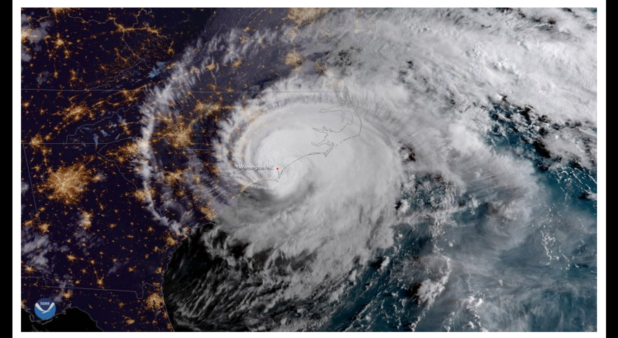


Sep 12 Wed 2:06pm – National Hurricane Center


Sep 12 Wed 10am – NCSG / ND / NCSU

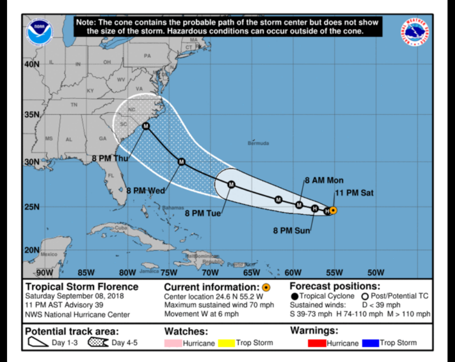

Sep 12 Wed 4:49pm – NWS Wilmington

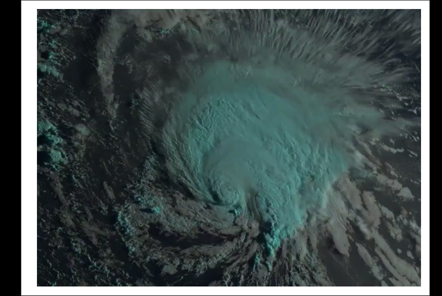

Sep 13 Thu 4:29am – Eric Webb


Sep 14 Fri 6:39am – NOAA Satellites


Sep 16 Sun 8:04am – NOAA Satellites

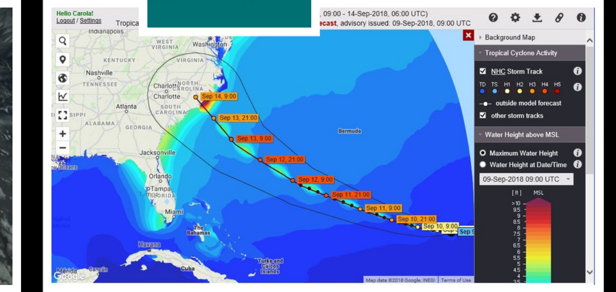
Sep 8 Sat 7:52pm – National Hurricane Center





Sep 6 Thu 2:16pm – NOAA NESDIS

Sep 9 Sun 1:43pm

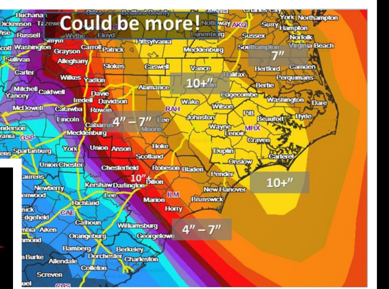


Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment

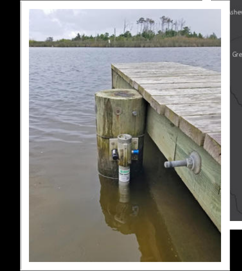
Sep 10 Mon 6:03pm

Sep 10 Mon 2:31pm

Sep 10 Mon 3:40pm – NWS Raleigh



Sep 11 Tue 1:40pm

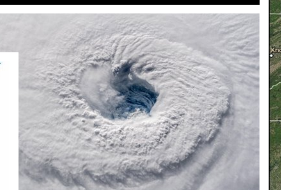


Sep 11 Tue 11:45am

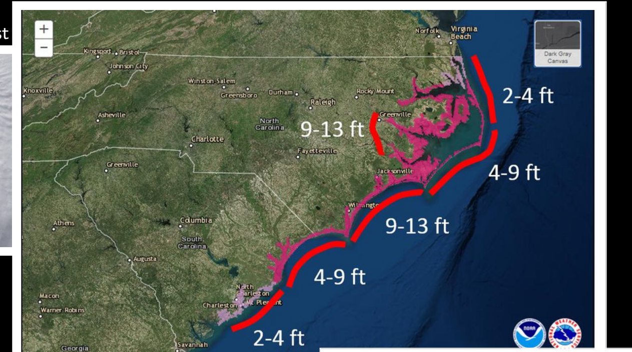
Sep 11 Tue 1:52pm – National Hurricane Center

Sep 12 Wed 5:13am

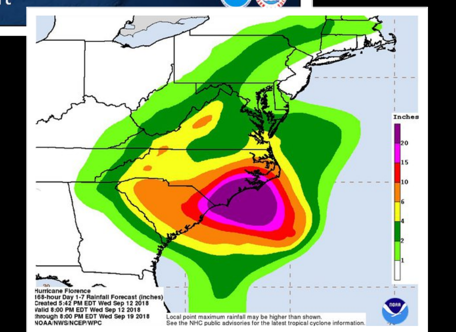
Sep 12 Wed 6:35am – Alex Gerst



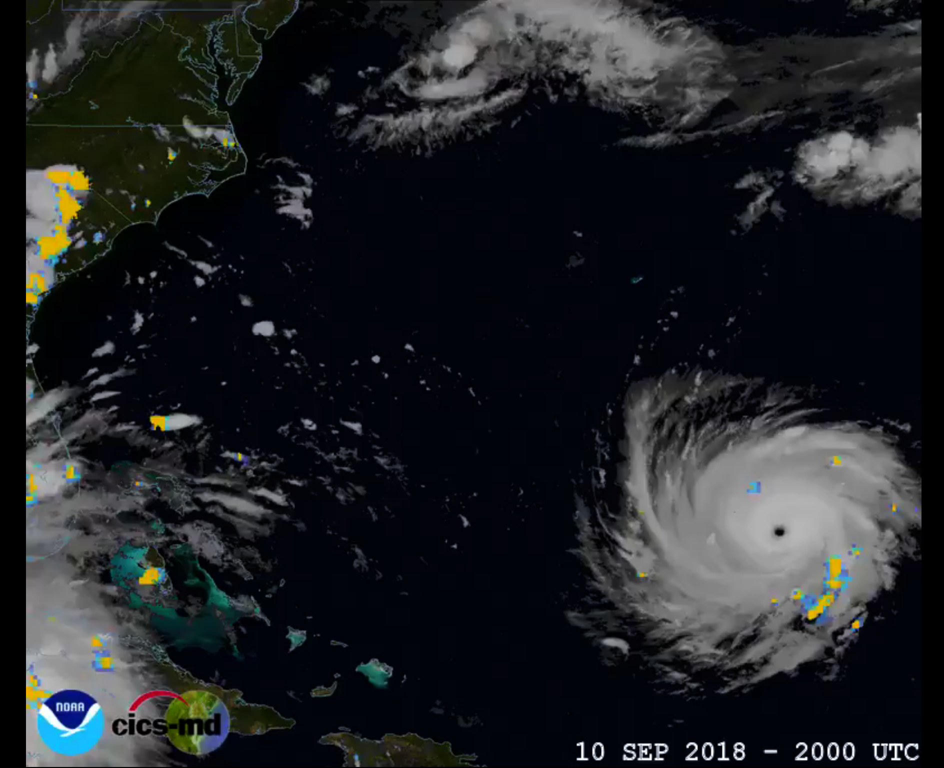
Sep 12 Wed 2:06pm – National Hurricane Center

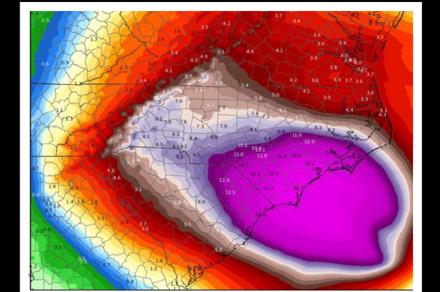


Sep 12 Wed 10am – NCSG / ND / NCSU

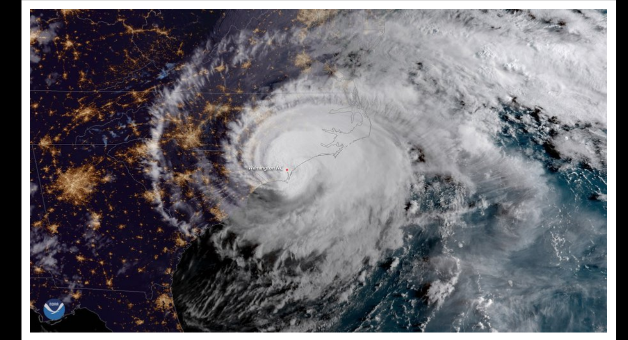


Sep 12 Wed 4:49pm – NWS Wilmington





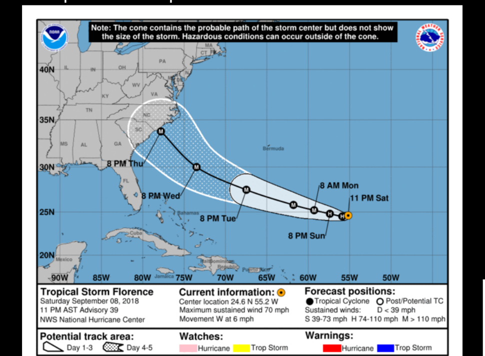
Sep 13 Thu 4:29am – Eric Webb

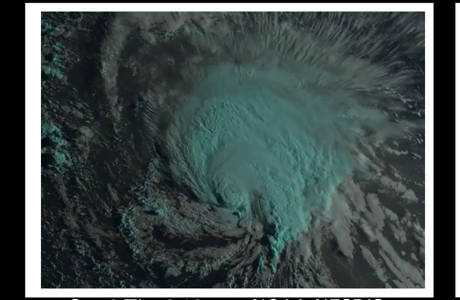


Sep 14 Fri 6:39am – NOAA Satellites

Sep 16 Sun 8:04am – NOAA Satellites

Sep 8 Sat 7:52pm – National Hurricane Center





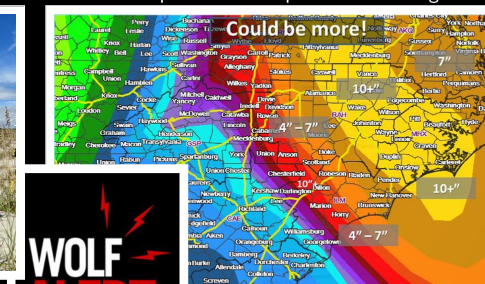
Sep 6 Thu 2:16pm – NOAA NESDIS

Sep 9 Sun 1:43pm

Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment

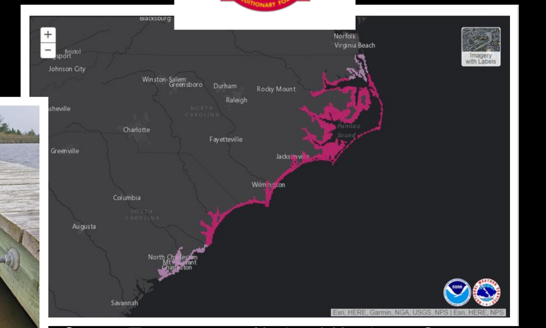
Sep 10 Mon 6:03pm

Sep 10 Mon 3:40pm – NWS Raleigh

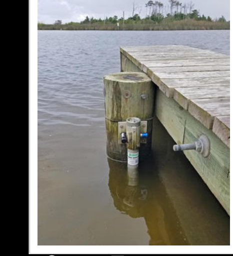


Sep 10 Mon 2:31pm

Sep 11 Tue 1:40pm



Sep 11 Tue 1:52pm – National Hurricane Center

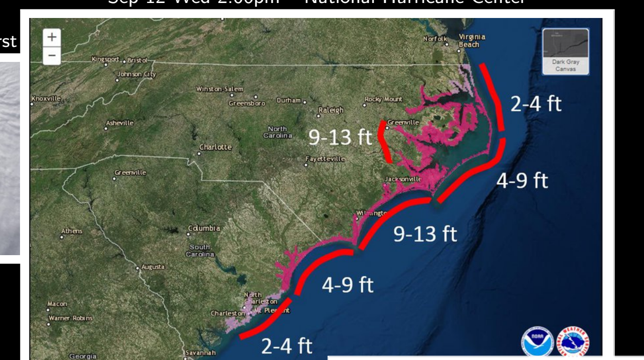


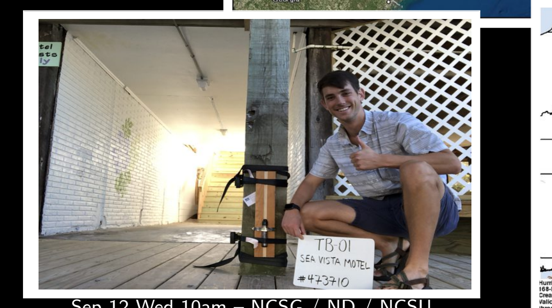
Sep 11 Tue 11:45am

Sep 12 Wed 5:13am

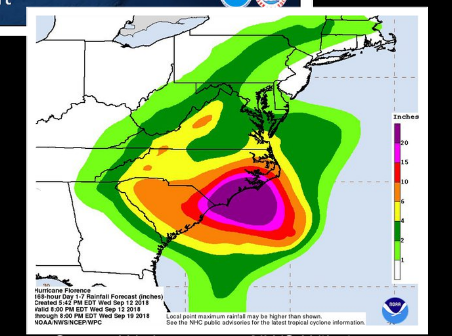
Sep 12 Wed 6:35am – Alex Gerst

Sep 12 Wed 2:06pm – National Hurricane Center

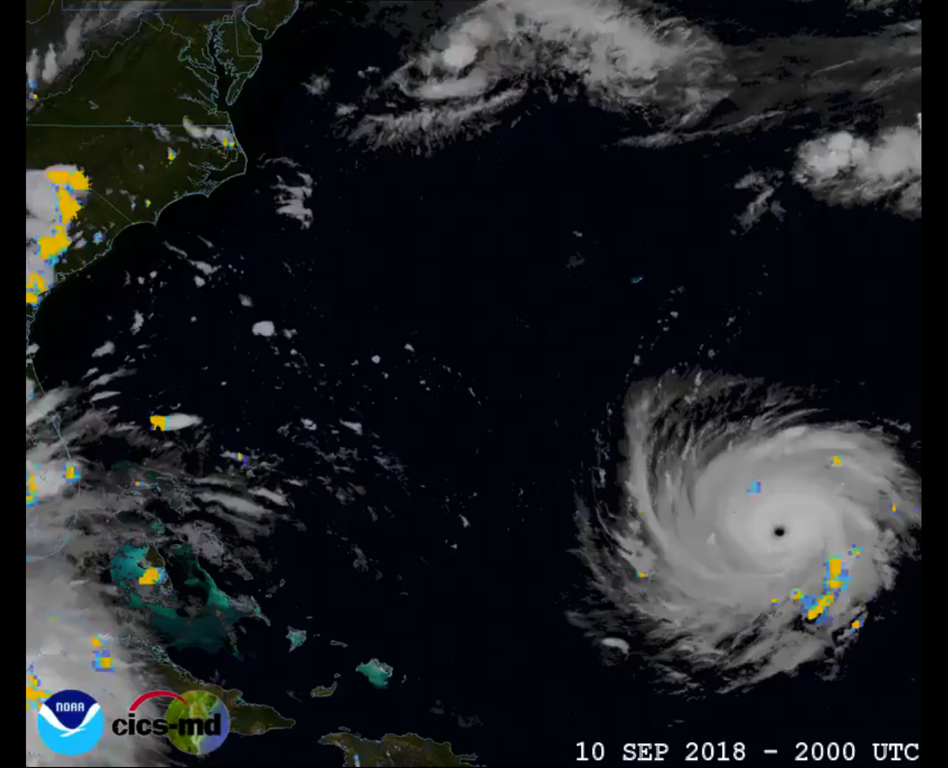




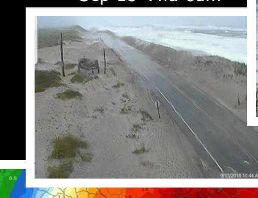
Sep 12 Wed 10am – NCSG / ND / NCSU



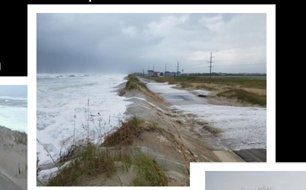
Sep 12 Wed 4:49pm – NWS Wilmington

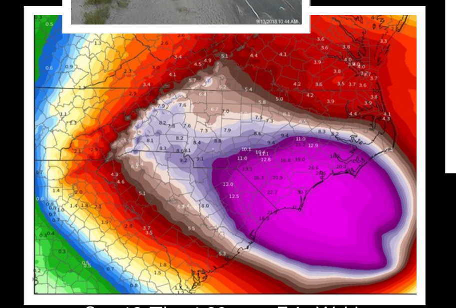


Sep 13 Thu 8am



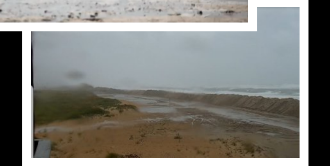
Sep 13 Thu 9:13am



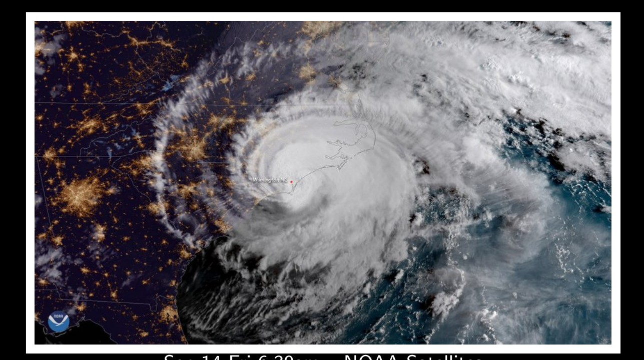


Sep 13 Thu 4:29am – Eric Webb

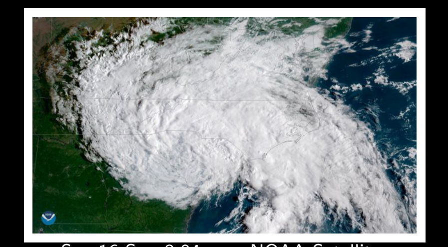
Sep 13 Thu



Sep 13 Thu 12:14pm

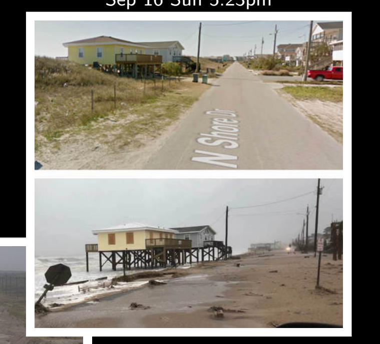


Sep 14 Fri 6:39am – NOAA Satellites



Sep 16 Sun 8:04am – NOAA Satellites

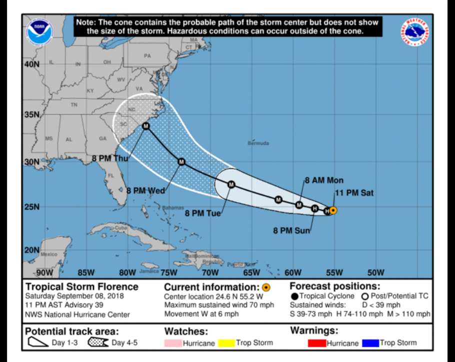
Sep 16 Sun 5:23pm

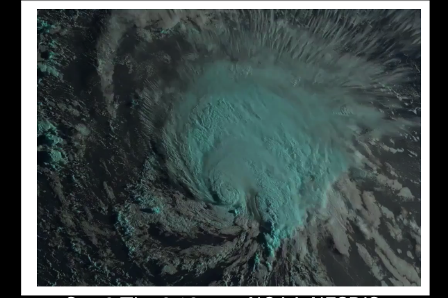


Sep 16 Sun 1:01pm – NC DA

Sep 26 Wed – NCSU

Sep 8 Sat 7:52pm – National Hurricane Center



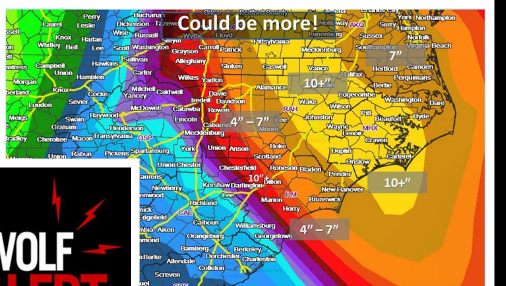


Sep 6 Thu 2:16pm – NOAA NESDIS

Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment

Sep 10 Mon 6:03pm

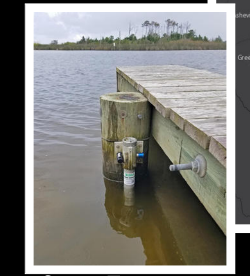
Sep 10 Mon 3:40pm – NWS Raleigh



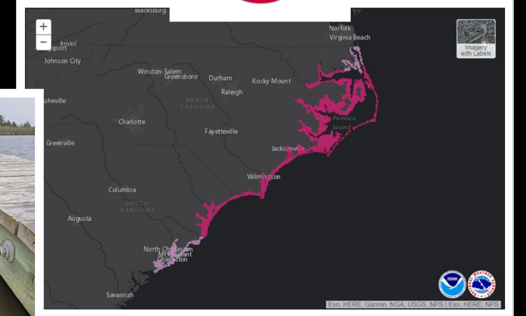
Sep 9 Sun 1:43pm

Sep 10 Mon 2:31pm

Sep 11 Tue 1:40pm

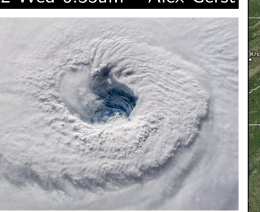


Sep 11 Tue 11:45am



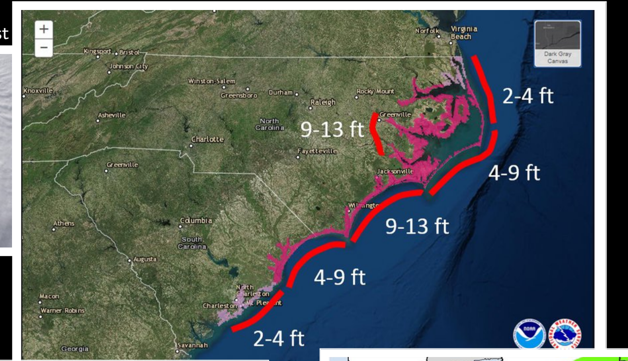
Sep 11 Tue 1:52pm – National Hurricane Center

Sep 12 Wed 6:35am – Alex Gerst

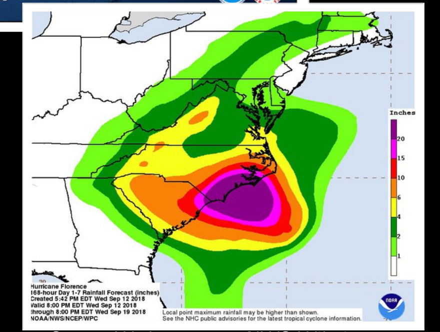


Sep 12 Wed 5:13am

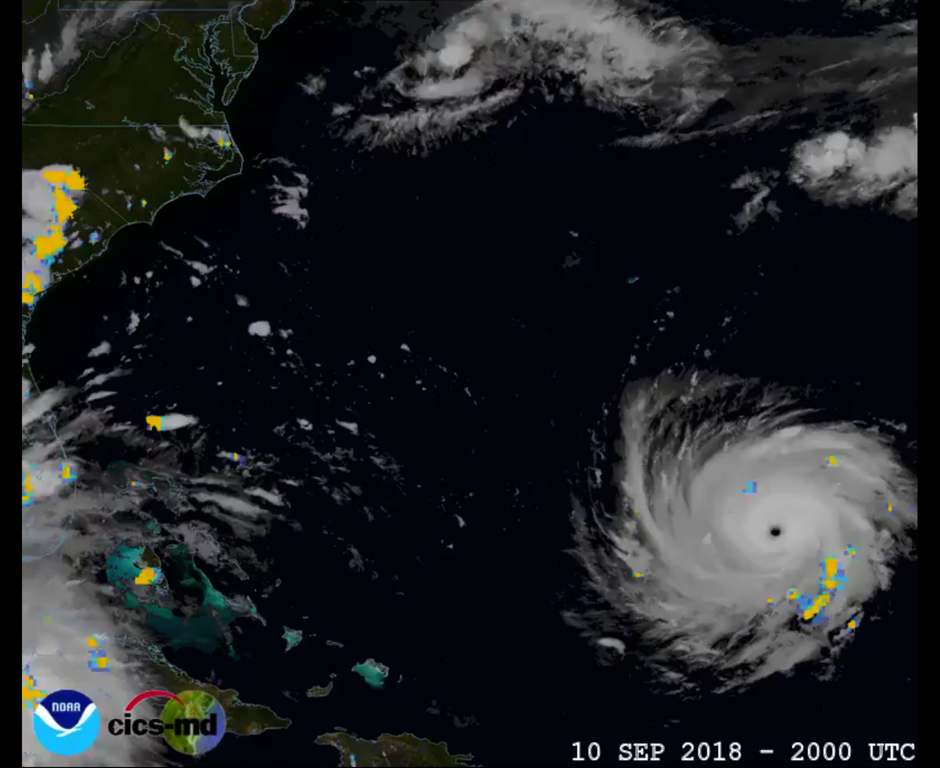
Sep 12 Wed 2:06pm – National Hurricane Center



Sep 12 Wed 10am – NCSG / ND / NCSU

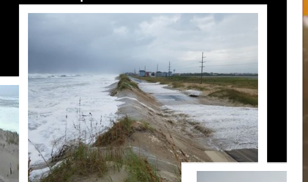


Sep 12 Wed 4:49pm – NWS Wilmington

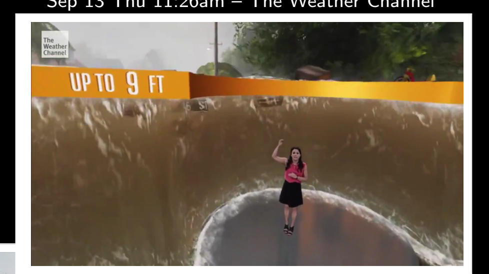


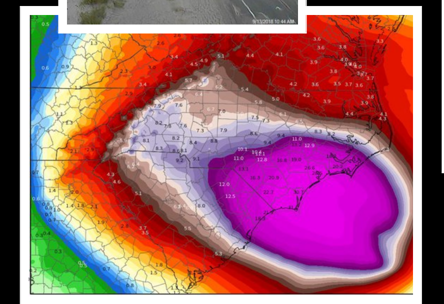
Sep 13 Thu 8am

Sep 13 Thu 9:13am

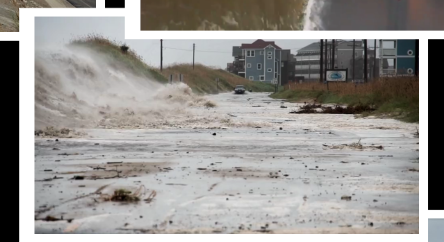


Sep 13 Thu 11:26am – The Weather Channel

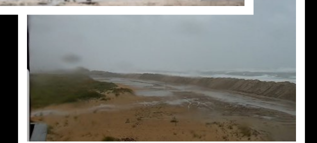




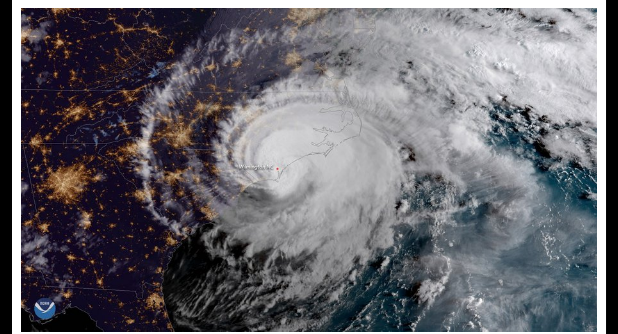
Sep 13 Thu 4:29am – Eric Webb



Sep 13 Thu



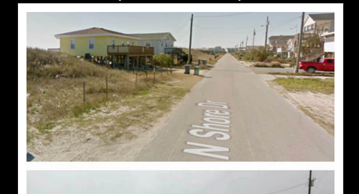
Sep 13 Thu 12:14pm

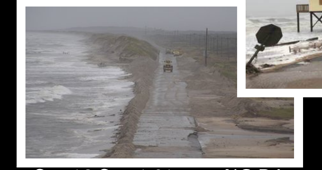


Sep 14 Fri 6:39am – NOAA Satellites

Sep 16 Sun 8:04am – NOAA Satellites

Sep 16 Sun 5:23pm



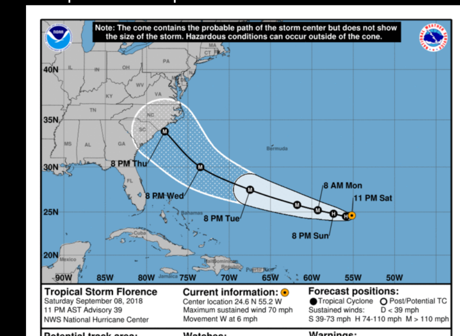


Sep 16 Sun 1:01pm – NC DA

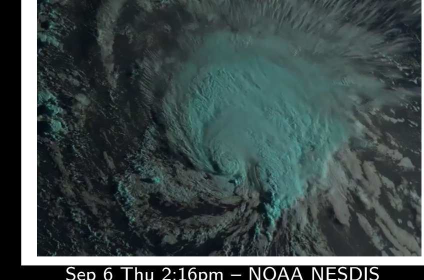
Sep 26 Wed – NCSU

Sep 8 Sat 7:52pm – National Hurricane Center
Tropical Storm Florence
Sep 6 Thu 2:16pm – NOAA NESDIS
Sep 9 Sun 1:43pm
UNCW ALERT
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment
Sep 10 Mon 6:03pm
Sep 10 Mon 3:40pm – NWS Raleigh
Could be more!
WOLF ALERT
Sep 10 Mon 2:31pm
Sep 11 Tue 1:40pm
Sep 11 Tue 11:45am
Sep 11 Tue 1:52pm – National Hurricane Center
ILM
Sep 12 Wed 5:13am
Sep 12 Wed 6:35am – Alex Gerst
Sep 12 Wed 2:06pm – National Hurricane Center
2-4 ft
9-13 ft
4-9 ft
9-13 ft
4-9 ft
2-4 ft
Sep 12 Wed 10am – NCSG / ND / NCSU
TB 01
SEA VISTA MOTEL
Sep 12 Wed 4:49pm – NWS Wilmington
10 SEP 2018 - 2000 UTC
Sep 13 Thu 8am
Sep 13 Thu 9:13am
Sep 13 Thu 11:26am – The Weather Channel
UP TO 9 FT
Sep 13 Thu 7:31pm
Sep 13 Thu 4:29am – Eric Webb
Sep 13 Thu
Sep 13 Thu 12:14pm
Sep 13 Thu 2:19pm – Mark Sudduth
Sep 14 Fri 6:39am – NOAA Satellites
Sep 16 Sun 8:04am – NOAA Satellites
Sep 16 Sun 5:23pm
Sep 16 Sun 1:01pm – NC DA
Sep 26 Wed – NCSU

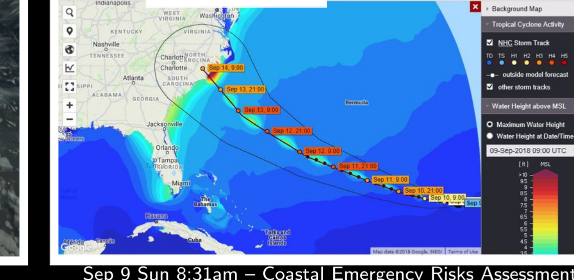
Sep 8 Sat 7:52pm – National Hurricane Center



Sep 9 Sun 1:43pm



Sep 6 Thu 2:16pm – NOAA NESDIS



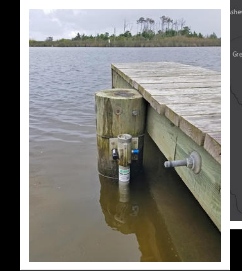
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment

Sep 10 Mon 6:03pm

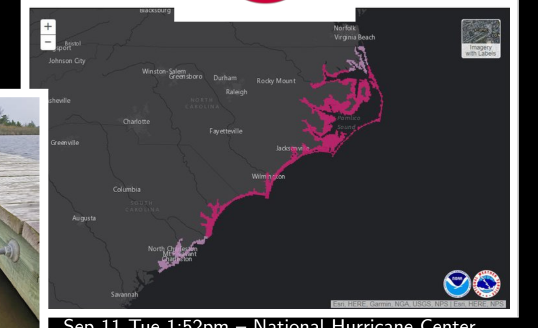
Sep 10 Mon 3:40pm – NWS Raleigh

Sep 10 Mon 2:31pm

Sep 11 Tue 1:40pm



Sep 11 Tue 11:45am

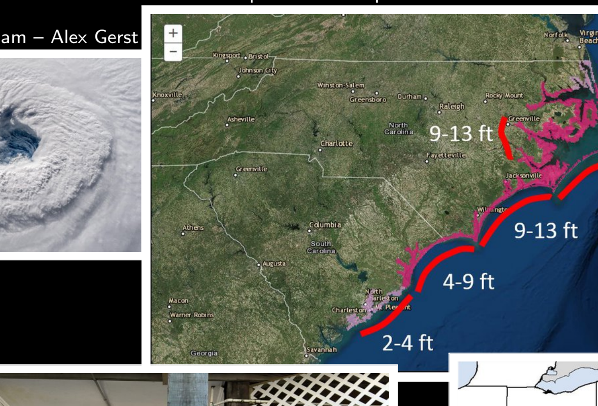


Sep 11 Tue 1:52pm – National Hurricane Center

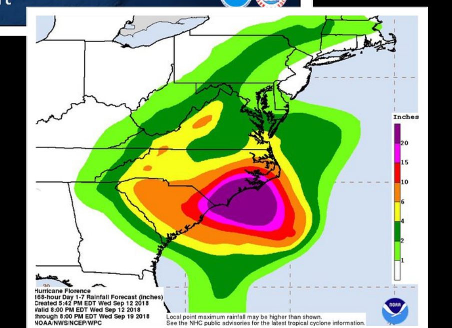
Sep 12 Wed 5:13am

Sep 12 Wed 6:35am – Alex Gerst

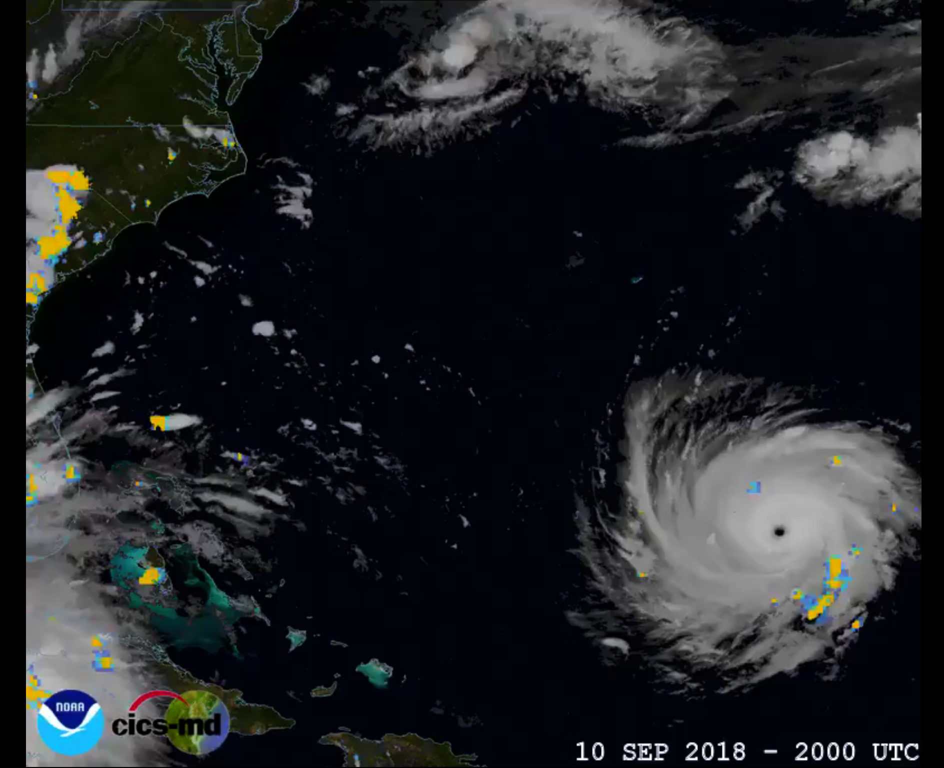
Sep 12 Wed 2:06pm – National Hurricane Center



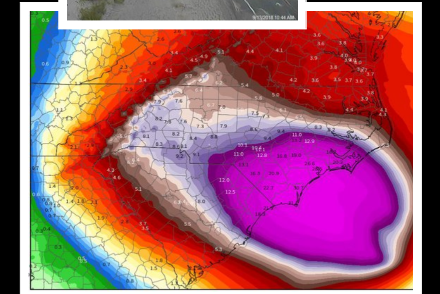
Sep 12 Wed 10am – NCSG / ND / NCSU



Sep 12 Wed 4:49pm – NWS Wilmington

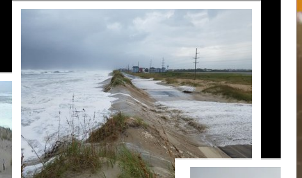


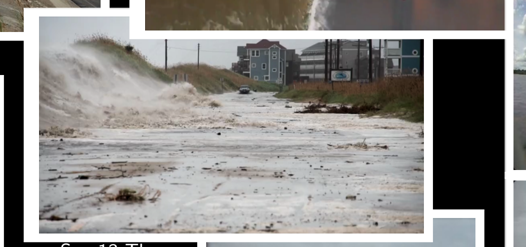
Sep 13 Thu 8am



Sep 13 Thu 4:29am – Eric Webb

Sep 13 Thu 9:13am

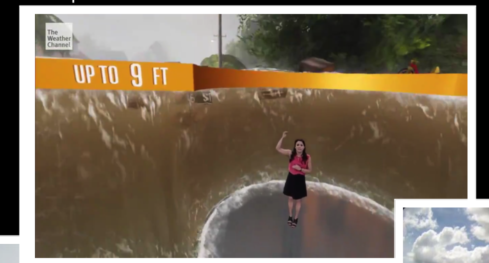




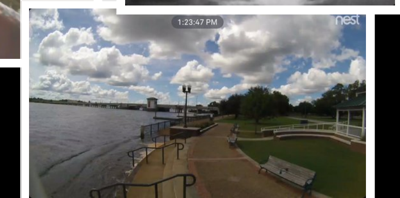
Sep 13 Thu

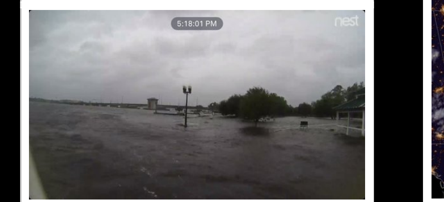
Sep 13 Thu 12:14pm

Sep 13 Thu 11:26am – The Weather Channel



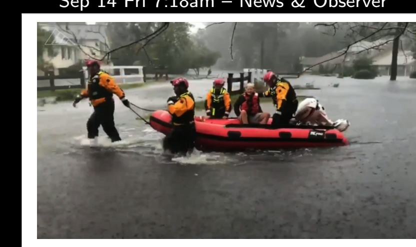
Sep 13 Thu 7:31pm

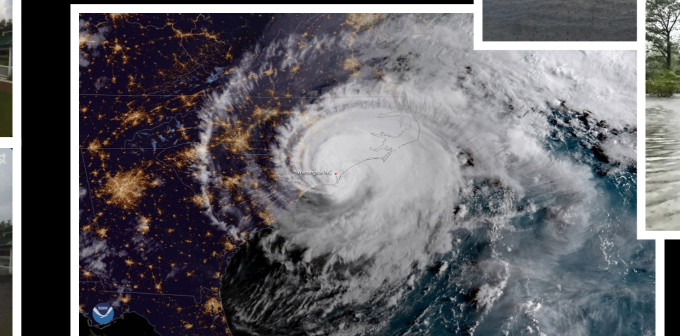




Sep 13 Thu 2:19pm – Mark Sudduth

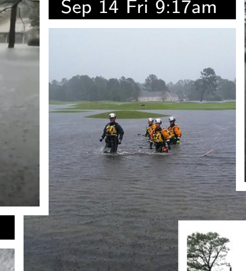
Sep 14 Fri 7:18am – News & Observer





Sep 14 Fri 6:39am – NOAA Satellites

Sep 14 Fri 9:17am



Sep 14 Fri – Getty Images

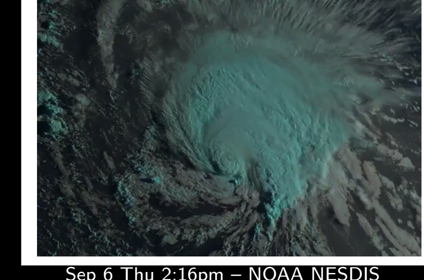
Sep 14 Fri 7:06pm – Andrew Carter

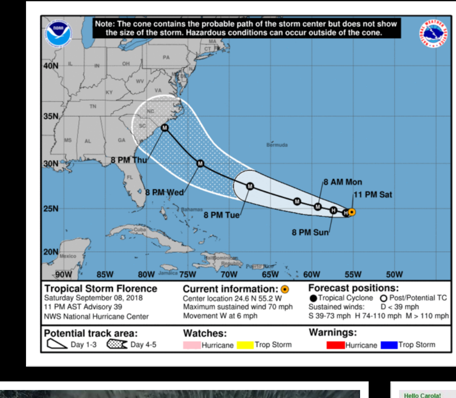
Sep 16 Sun 8:04am – NOAA Satellites

Sep 16 Sun 5:23pm

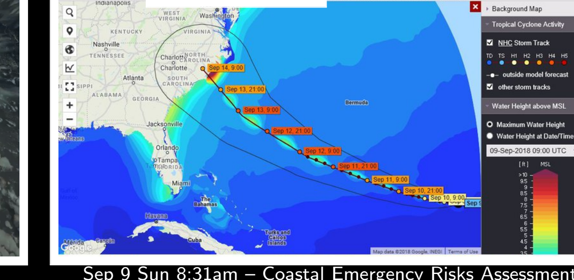
Sep 16 Sun 1:01pm – NC DA

Sep 26 Wed – NCSU

Sep 6 Thu 2:16pm – NOAA NESDIS


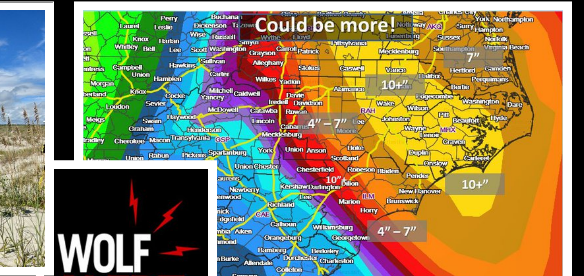
Sep 8 Sat 7:52pm – National Hurricane Center


Sep 9 Sun 1:43pm

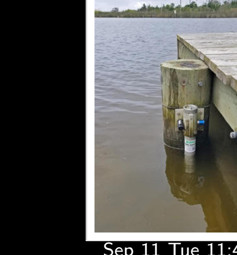
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment


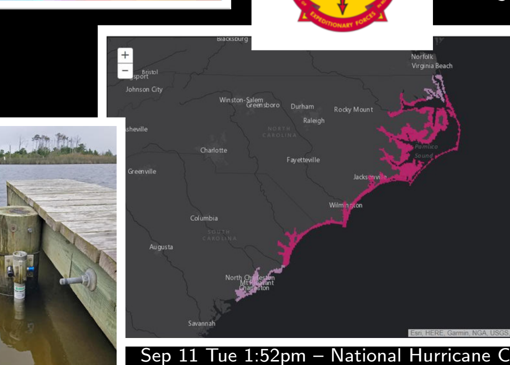
Sep 10 Mon 6:03pm


Sep 10 Mon 2:31pm

Sep 10 Mon 3:40pm – NWS Raleigh


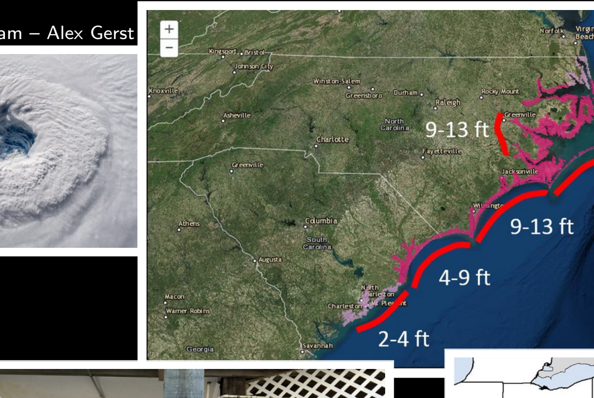
Sep 11 Tue 1:40pm

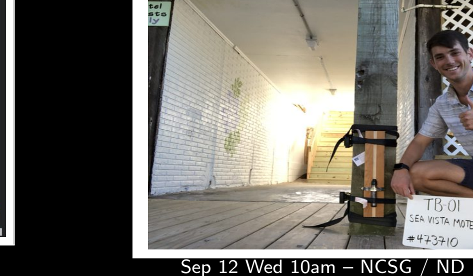
Sep 11 Tue 11:45am


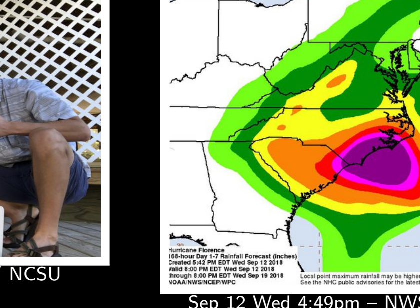

Sep 11 Tue 1:52pm – National Hurricane Center

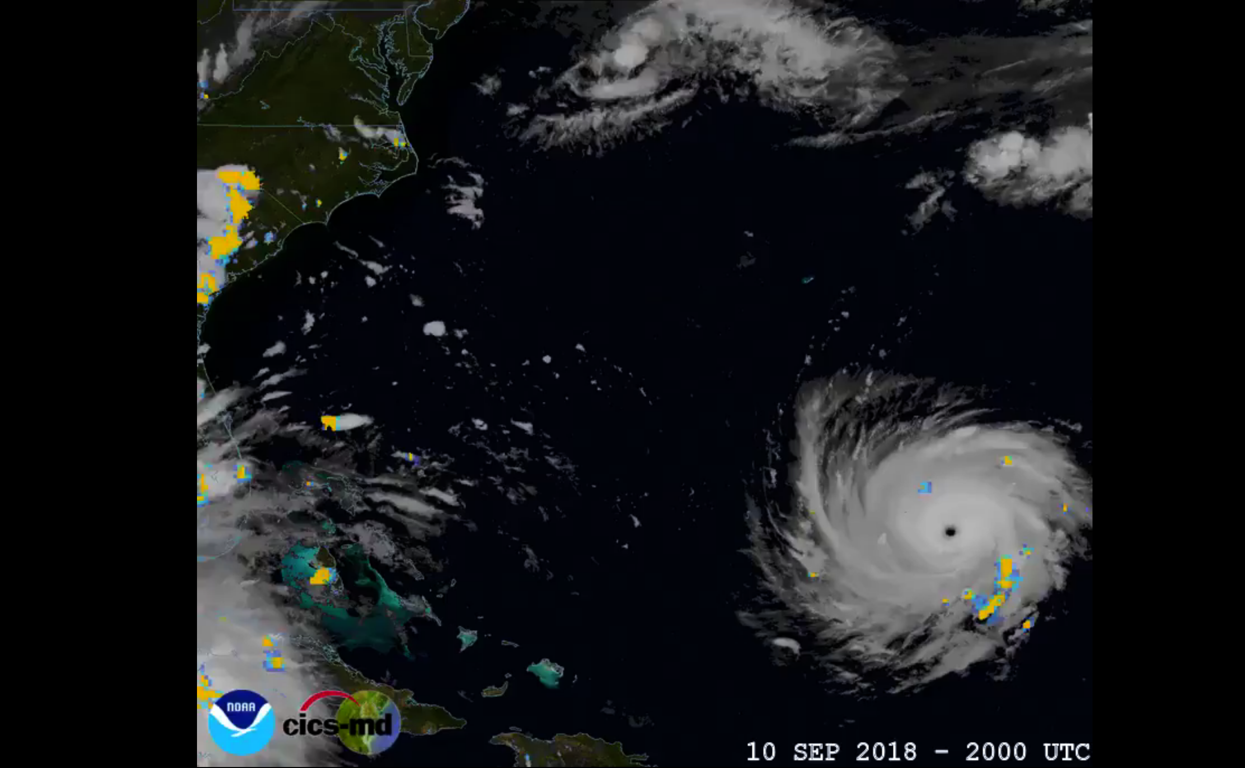
Sep 12 Wed 5:13am

Sep 12 Wed 6:35am – Alex Gerst

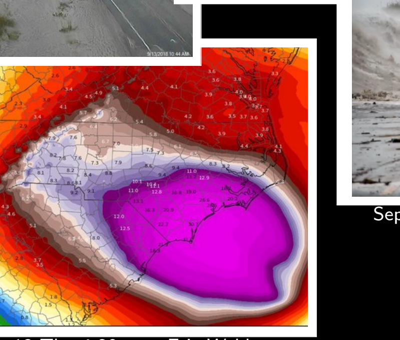

Sep 12 Wed 2:06pm – National Hurricane Center


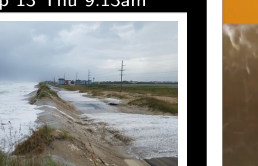

Sep 12 Wed 10am – NCSG / ND / NCSU

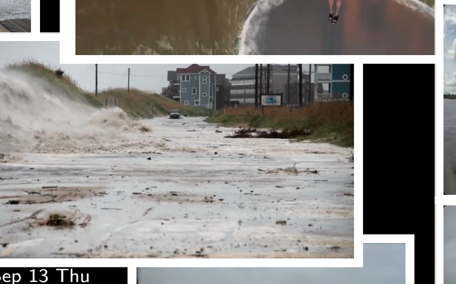

Sep 12 Wed 4:49pm – NWS Wilmington

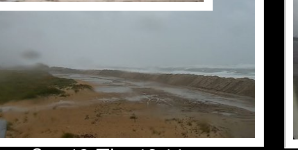


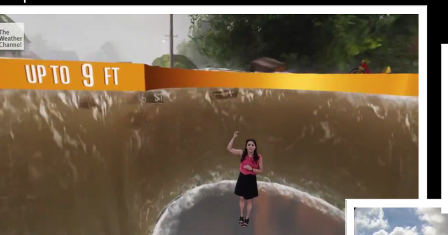
Sep 13 Thu 8am



Sep 13 Thu 4:29am – Eric Webb

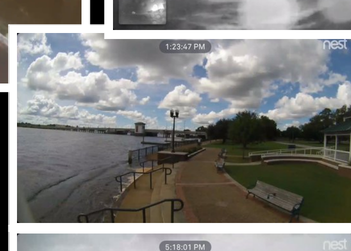
Sep 13 Thu 9:13am



Sep 13 Thu


Sep 13 Thu 12:14pm

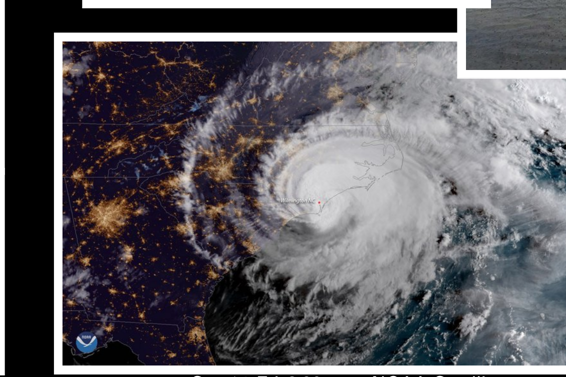
Sep 13 Thu 11:26am – The Weather Channel


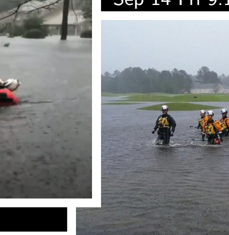
Sep 13 Thu 7:31pm

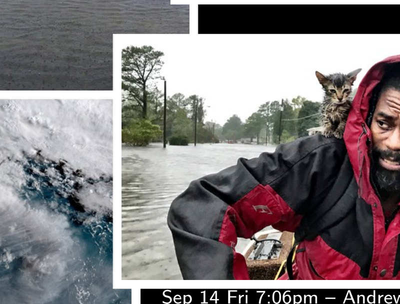

Sep 13 Thu 2:19pm – Mark Sudduth

Sep 14 Fri 7:18am – News & Observer



Sep 14 Fri 6:39am – NOAA Satellites

Sep 14 Fri 9:17am


Sep 14 Fri – Getty Images

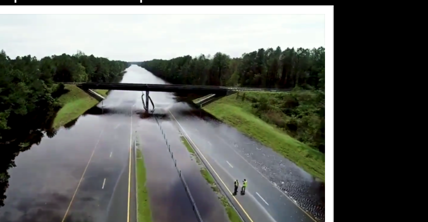


Sep 14 Fri 7:06pm – Andrew Carter

Sep 15 Sat 9:05pm – Allen Nosov

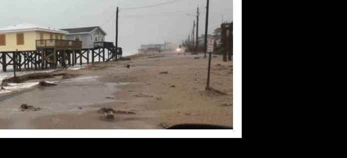


Sep 16 Sun 8:04am – NOAA Satellites

Sep 16 Sun 11:27am – Drew Brooks

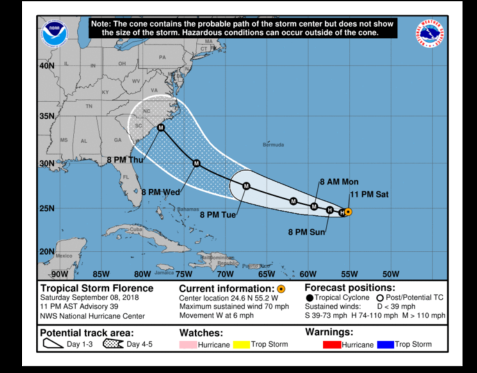

Sep 17 Mon 1:52pm – NCDOT


Sep 16 Sun 5:23pm


Sep 16 Sun 1:01pm – NC DA


Sep 26 Wed – NCSU



Sep 8 Sat 7:52pm – National Hurricane Center


Sep 10 Mon 6:03pm

Sep 10 Mon 3:40pm – NWS Raleigh

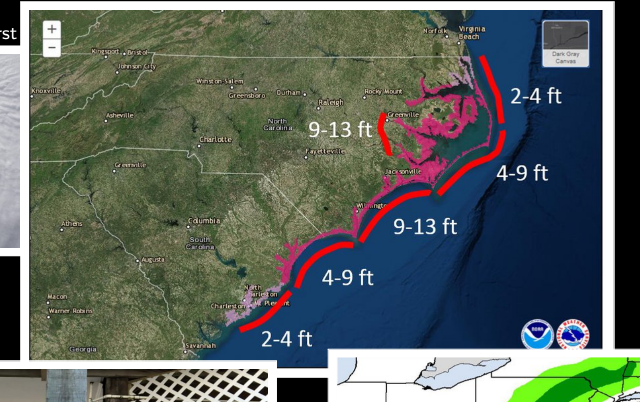
Sep 10 Mon 2:31pm

Sep 9 Sun 1:43pm

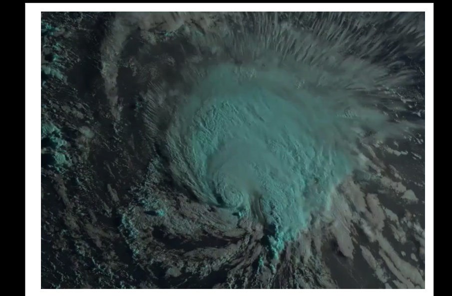
Sep 11 Tue 1:40pm

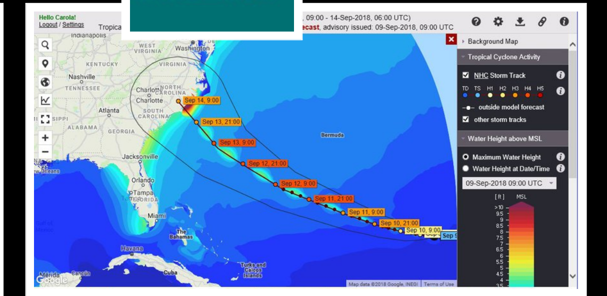
Sep 12 Wed 5:13am

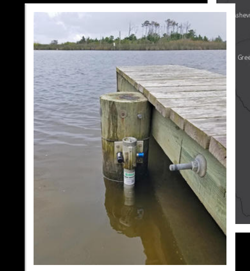

Sep 12 Wed 6:35am – Alex Gerst

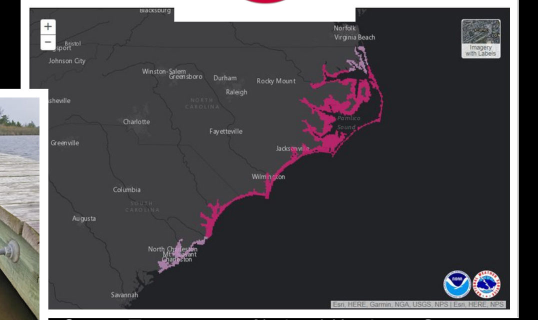


Sep 12 Wed 2:06pm – National Hurricane Center

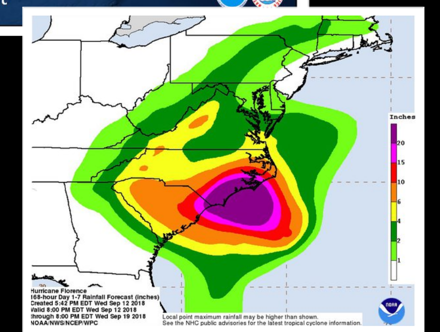

Sep 6 Thu 2:16pm – NOAA NESDIS

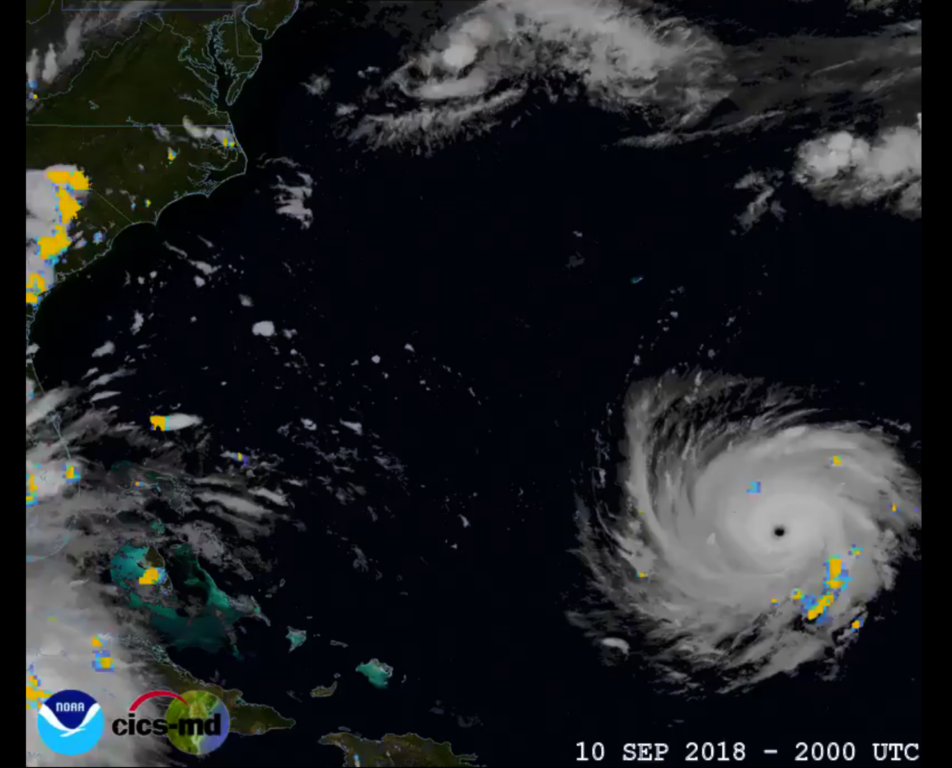

Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment


Sep 11 Tue 11:45am

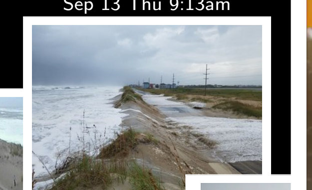

Sep 11 Tue 1:52pm – National Hurricane Center

Sep 12 Wed 10am – NCSG / ND / NCSU

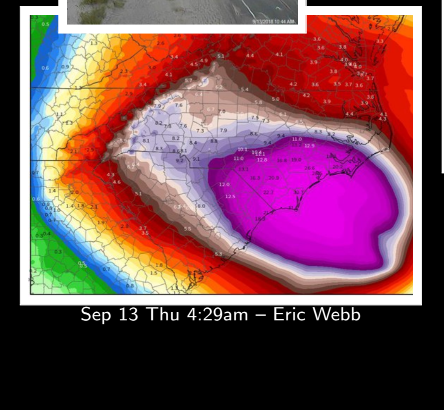

Sep 12 Wed 4:49pm – NWS Wilmington



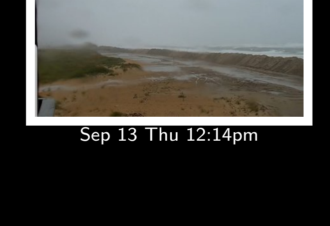

Sep 13 Thu 8am


Sep 13 Thu 9:13am

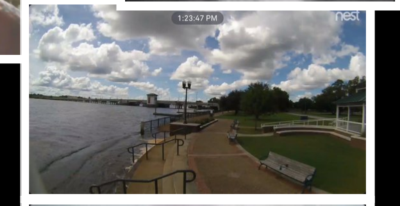
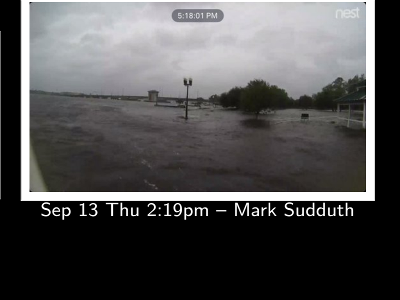
Sep 13 Thu 11:26am – The Weather Channel


Sep 13 Thu 4:29am – Eric Webb

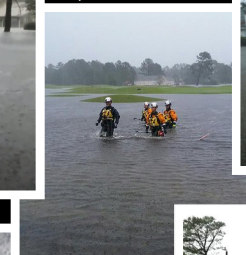

Sep 13 Thu


Sep 13 Thu 12:14pm

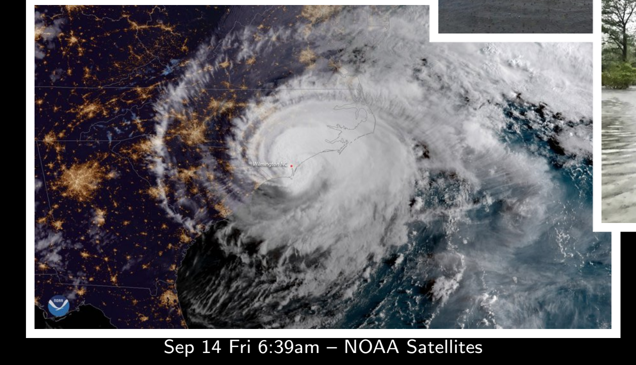

Sep 13 Thu 7:31pm



Sep 13 Thu 2:19pm – Mark Sudduth

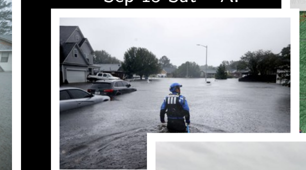

Sep 14 Fri 7:18am – News & Observer


Sep 14 Fri 9:17am

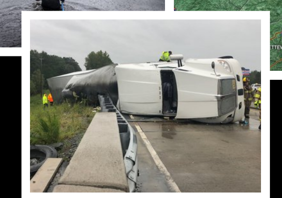

Sep 14 Fri – Getty Images

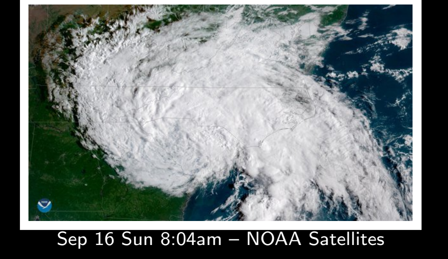

Sep 14 Fri 6:39am – NOAA Satellites

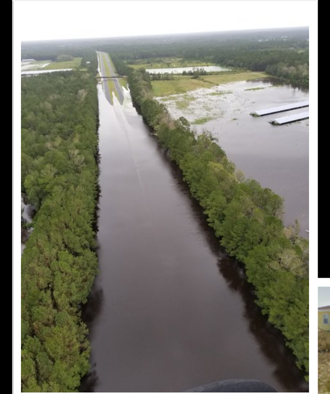

Sep 14 Fri 7:06pm – Andrew Carter


Sep 15 Sat – AP

Sep 15 Sat 9:05pm – Allen Nosov

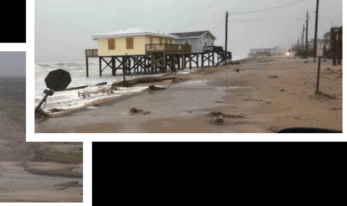

Sep 15 Sat 5:12pm


Sep 16 Sun 8:04am – NOAA Satellites


Sep 16 Sun 11:27am – Drew Brooks

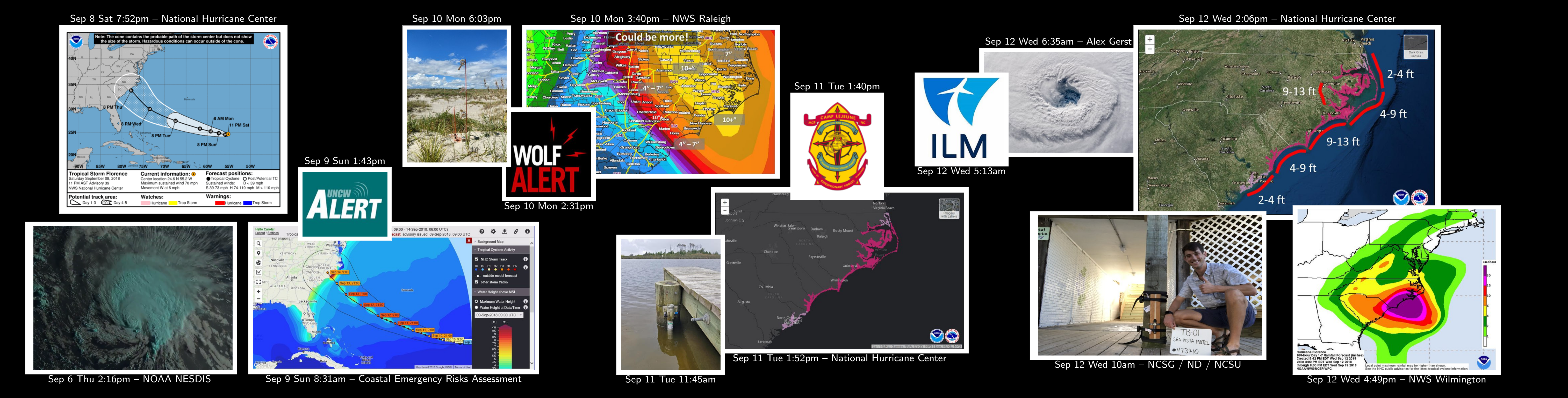

Sep 17 Mon 1:52pm – NCDOT

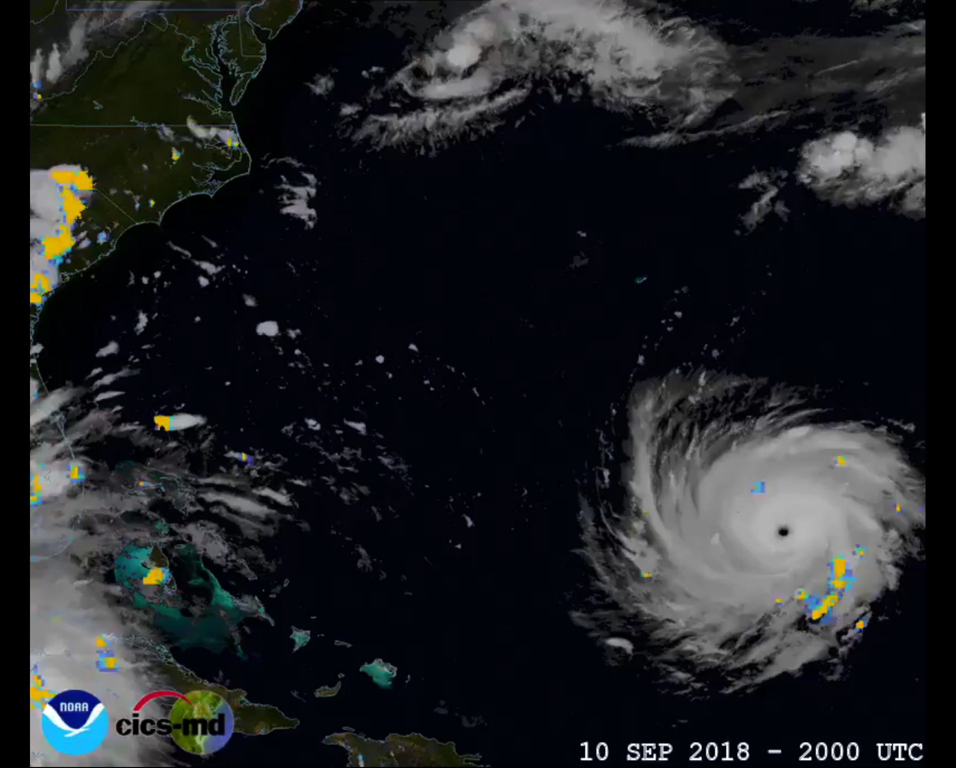

Sep 16 Sun 5:23pm

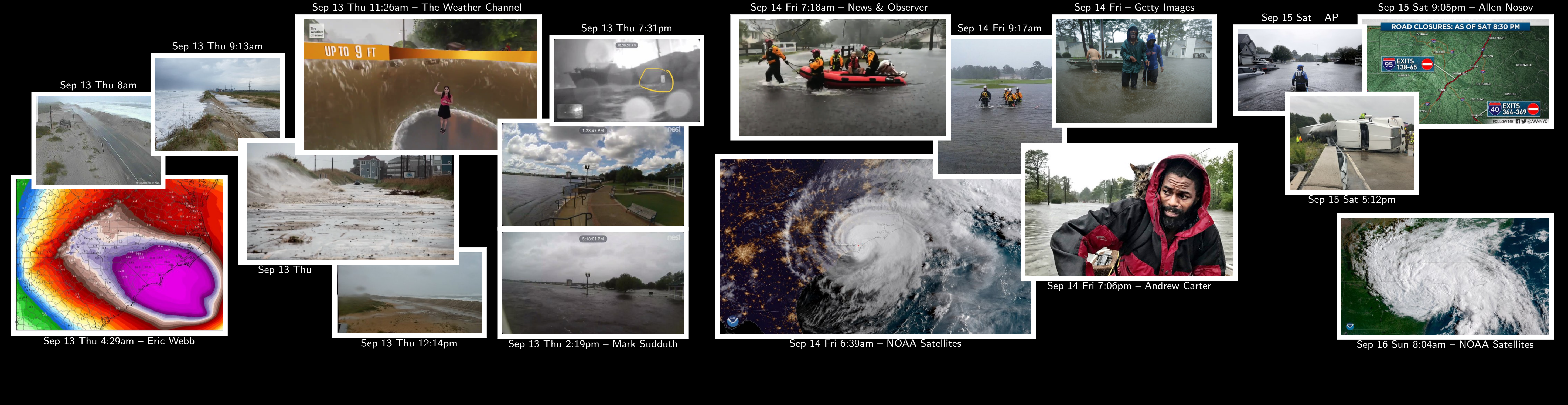


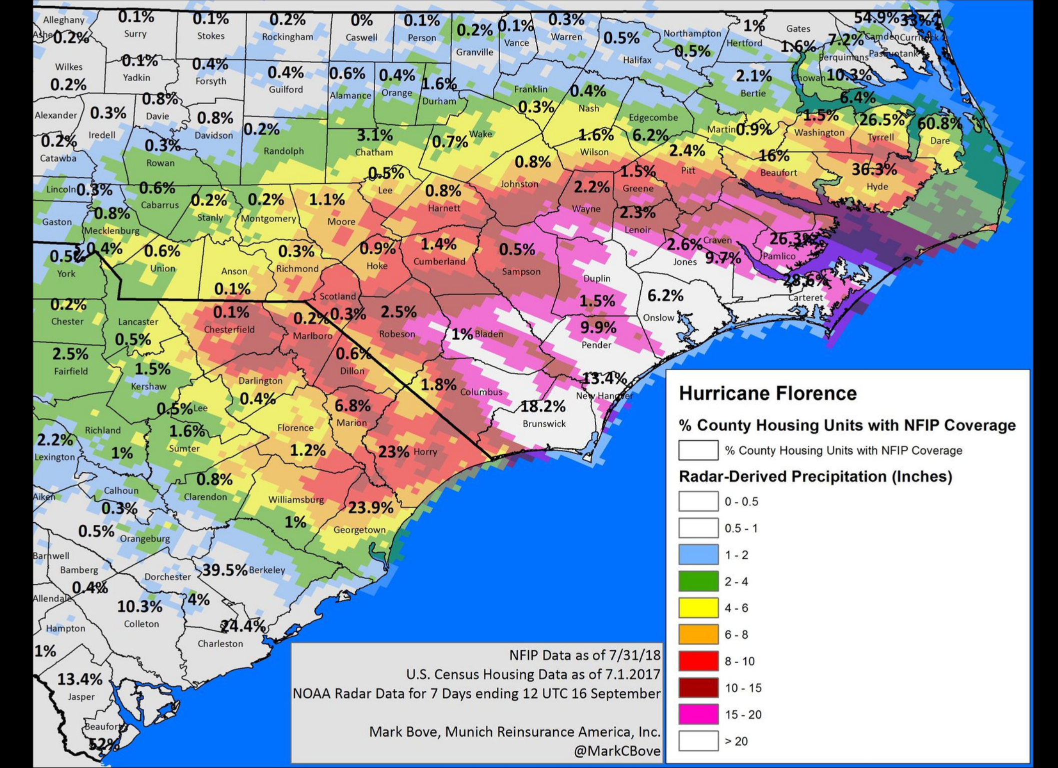
Sep 16 Sun 1:01pm – NC DA


Sep 26 Wed – NCSU


Sep 8 Sat 7:52pm – National Hurricane Center
Sep 10 Mon 6:03pm
Sep 10 Mon 3:40pm – NWS Raleigh
Could be more!
WOLF ALERT
Sep 10 Mon 2:31pm
Sep 9 Sun 1:43pm
UNCW ALERT
Sep 11 Tue 1:40pm
ILM
Sep 12 Wed 5:13am
Sep 12 Wed 6:35am – Alex Gerst
Sep 12 Wed 2:06pm – National Hurricane Center
2-4 ft
9-13 ft
4-9 ft
9-13 ft
4-9 ft
2-4 ft
Sep 6 Thu 2:16pm – NOAA NESDIS
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment
Sep 11 Tue 11:45am
Sep 11 Tue 1:52pm – National Hurricane Center
TB 01
SEA VISTA MOTEL
Sep 12 Wed 10am – NCSG / ND / NCSU
Sep 12 Wed 4:49pm – NWS Wilmington

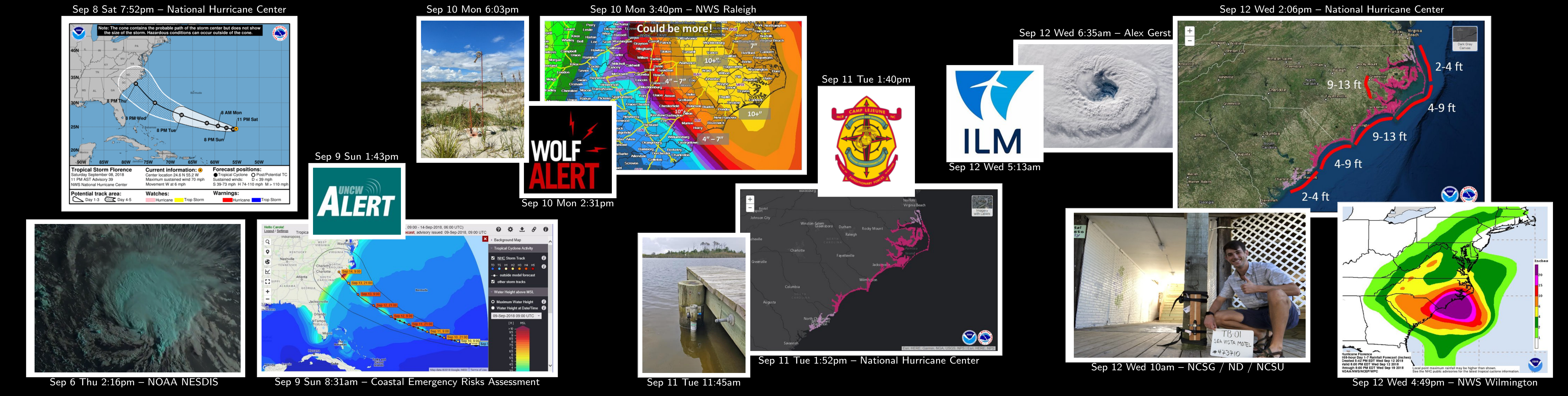

10 SEP 2018 – 2000 UTC


Sep 13 Thu 8am
Sep 13 Thu 9:13am
Sep 13 Thu 11:26am – The Weather Channel
UP TO 9 FT
Sep 13 Thu 7:31pm
Sep 13 Thu
Sep 13 Thu 4:29am – Eric Webb
Sep 13 Thu 12:14pm
Sep 13 Thu 2:19pm – Mark Sudduth
Sep 14 Fri 7:18am – News & Observer
Sep 14 Fri 9:17am
Sep 14 Fri – Getty Images
Sep 14 Fri 6:39am – NOAA Satellites
Sep 14 Fri 7:06pm – Andrew Carter
Sep 15 Sat – AP
Sep 15 Sat 9:05pm – Allen Nosov
ROAD CLOSURES: AS OF SAT 8:30 PM
95 EXITS 138-65
40 EXITS 364-369
Sep 15 Sat 5:12pm
Sep 16 Sun 8:04am – NOAA Satellites

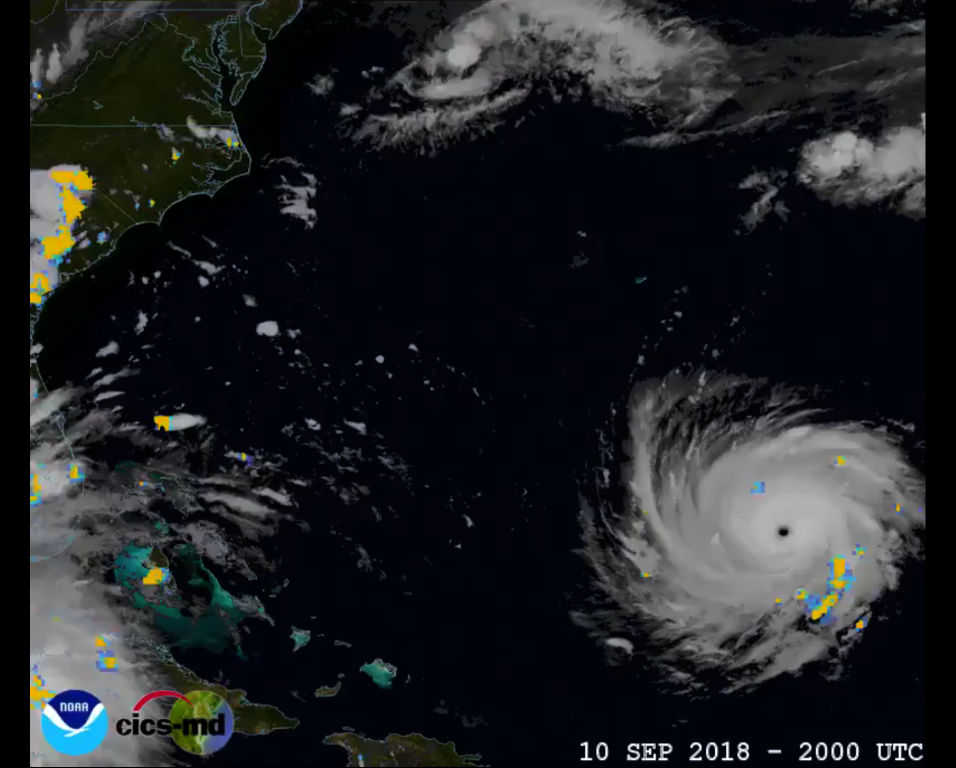

Hurricane Florence
% County Housing Units with NFIP Coverage
% County Housing Units with NFIP Coverage
Radar-Derived Precipitation (Inches)
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 15
15 - 20
> 20
NFIP Data as of 7/31/18
U.S. Census Housing Data as of 7.1.2017
NOAA Radar Data for 7 Days ending 12 UTC 16 September
Mark Bove, Munich Reinsurance America, Inc.
@MarkCBove


Sep 16 Sun 11:27am – Drew Brooks
Sep 17 Mon 1:52pm – NCDOT
Sep 16 Sun 5:23pm
Sep 16 Sun 1:01pm – NC DA


Sep 26 Wed – NCSU

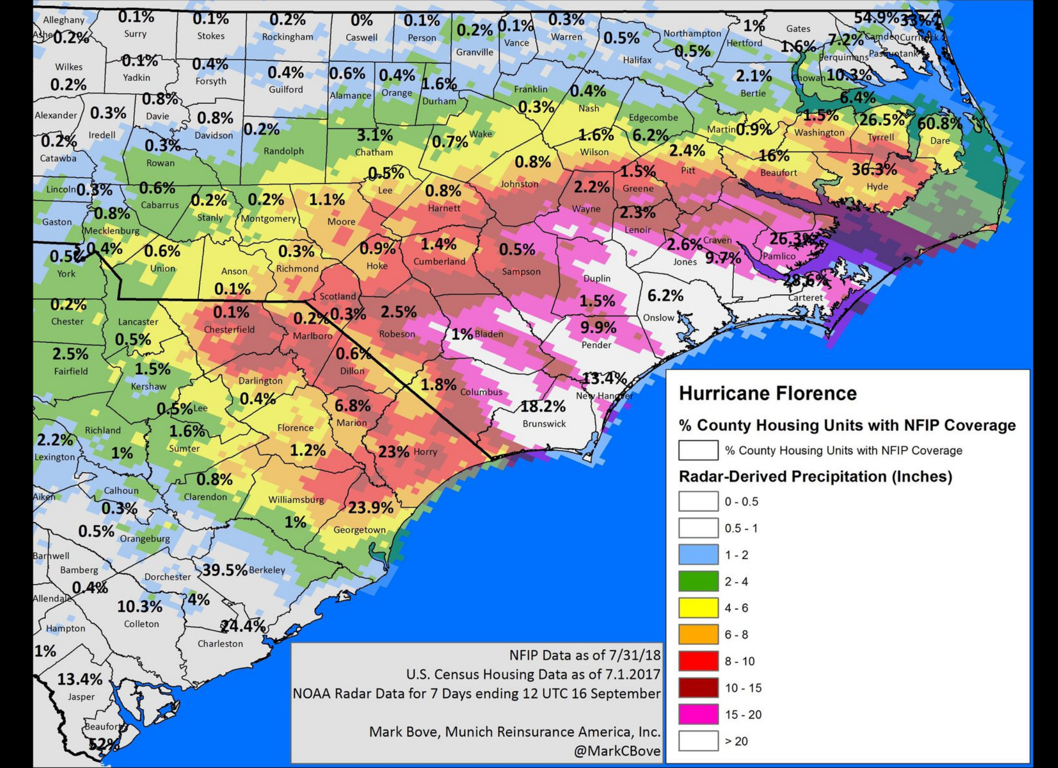


Sep 8 Sat 7:52pm – National Hurricane Center
Sep 10 Mon 6:03pm
Sep 10 Mon 3:40pm – NWS Raleigh
Could be more!
Sep 9 Sun 1:43pm
UNCW ALERT
WOLF ALERT
Sep 10 Mon 2:31pm
Sep 11 Tue 1:40pm
ILM
Sep 12 Wed 5:13am
Sep 12 Wed 6:35am – Alex Gerst
Sep 12 Wed 2:06pm – National Hurricane Center
2-4 ft
9-13 ft
4-9 ft
9-13 ft
4-9 ft
2-4 ft
Sep 6 Thu 2:16pm – NOAA NESDIS
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment
Sep 11 Tue 11:45am
Sep 11 Tue 1:52pm – National Hurricane Center
Sep 12 Wed 10am – NCSG / ND / NCSU
Sep 12 Wed 4:49pm – NWS Wilmington



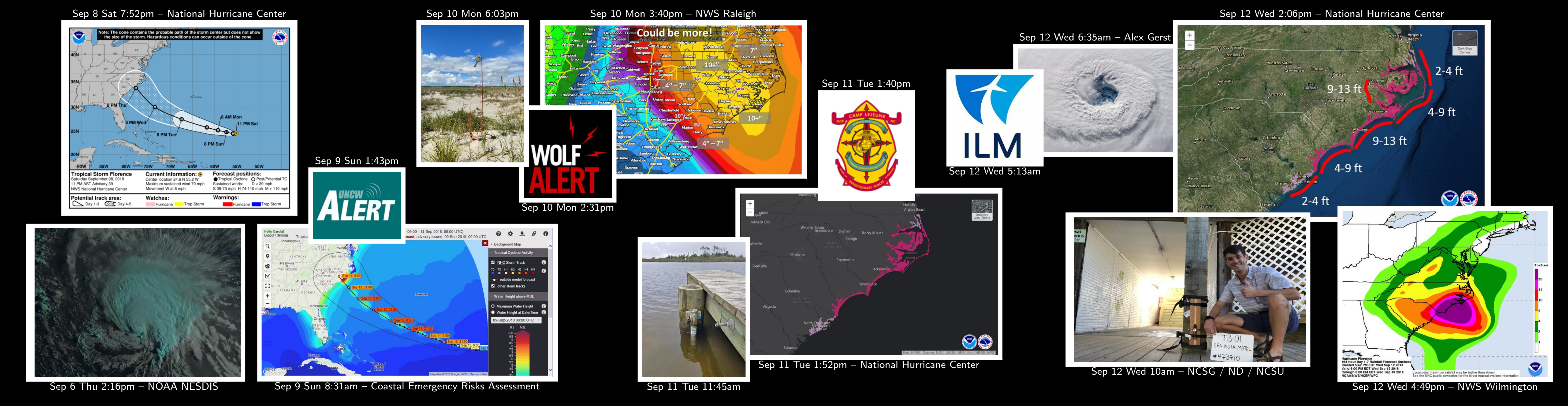
10 SEP 2018 – 2000 UTC

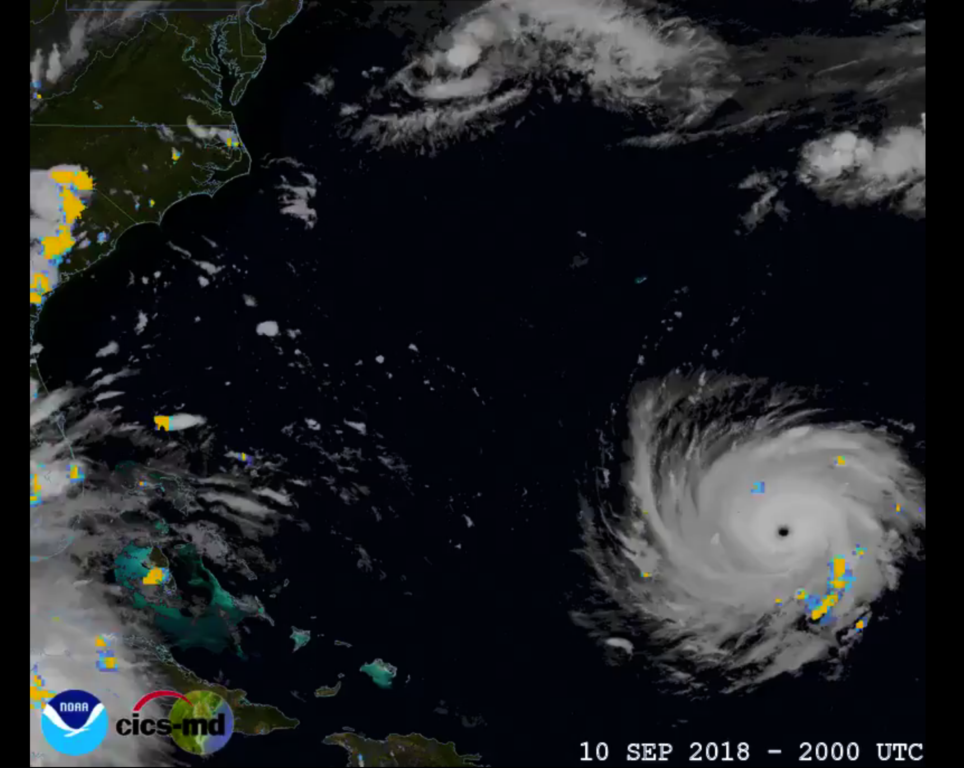
Sep 13 Thu 8am
Sep 13 Thu 9:13am
Sep 13 Thu 11:26am – The Weather Channel
UP TO 9 FT
Sep 13 Thu 7:31pm
Sep 14 Fri 7:18am – News & Observer
Sep 14 Fri 9:17am
Sep 14 Fri – Getty Images
Sep 15 Sat – AP
Sep 15 Sat 9:05pm – Allen Nosov
ROAD CLOSURES: AS OF SAT 8:30 PM
Sep 13 Thu
Sep 15 Sat 5:12pm
Sep 13 Thu 4:29am – Eric Webb
Sep 13 Thu 12:14pm
Sep 13 Thu 2:19pm – Mark Sudduth
Sep 14 Fri 6:39am – NOAA Satellites
Sep 14 Fri 7:06pm – Andrew Carter
Sep 16 Sun 8:04am – NOAA Satellites



Hurricane Florence
% County Housing Units with NFIP Coverage
% County Housing Units with NFIP Coverage
Radar-Derived Precipitation (Inches)
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 15
15 - 20
> 20
NFIP Data as of 7/31/18
U.S. Census Housing Data as of 7.1.2017
NOAA Radar Data for 7 Days ending 12 UTC 16 September
Mark Bove, Munich Reinsurance America, Inc.
@MarkCBove

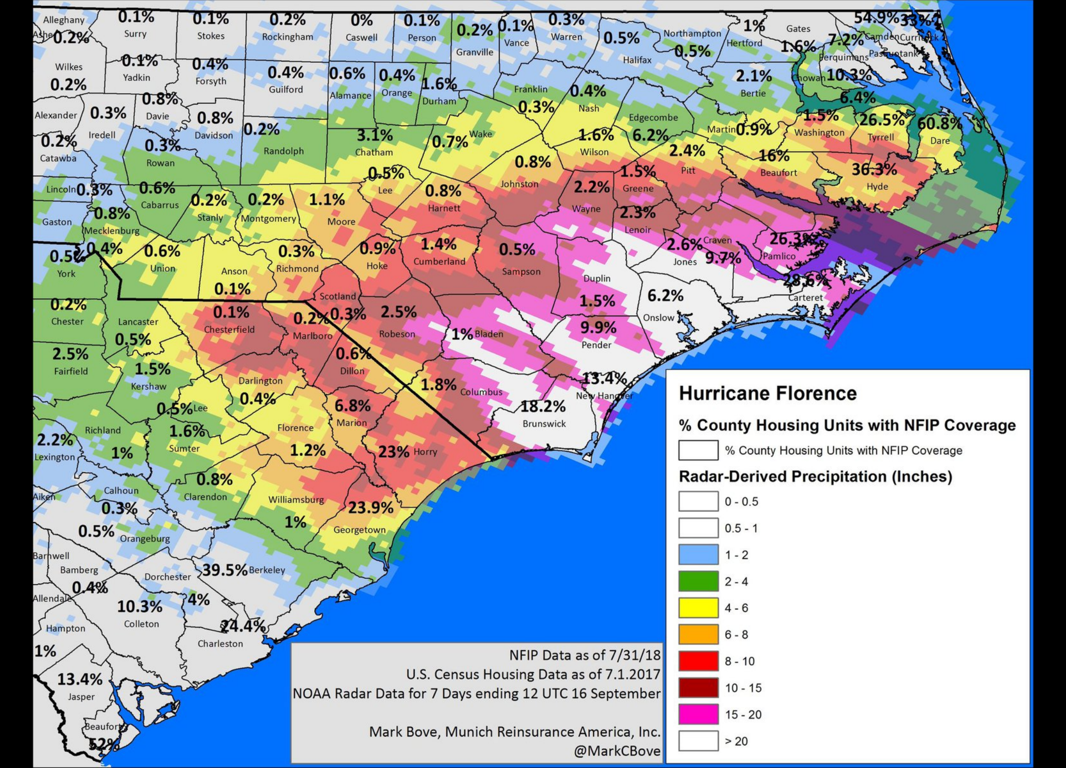
Sep 16 Sun 11:27am – Drew Brooks
Sep 17 Mon 1:52pm – NCDOT
Sep 16 Sun 5:23pm
Sep 17 Mon 5:12pm – NCEM
Sep 18 Tue 4:17am – Fayetteville PD
#FayPD
Sunday 9/16/18
Monday 9/17/18
Tuesday 9/18/18
Sep 18 Tue 7:57pm – Dakota Smith
Sep 16 Sun 1:01pm – NC DA
Sep 18 Tue 7:55pm
Sep 26 Wed – NCSU

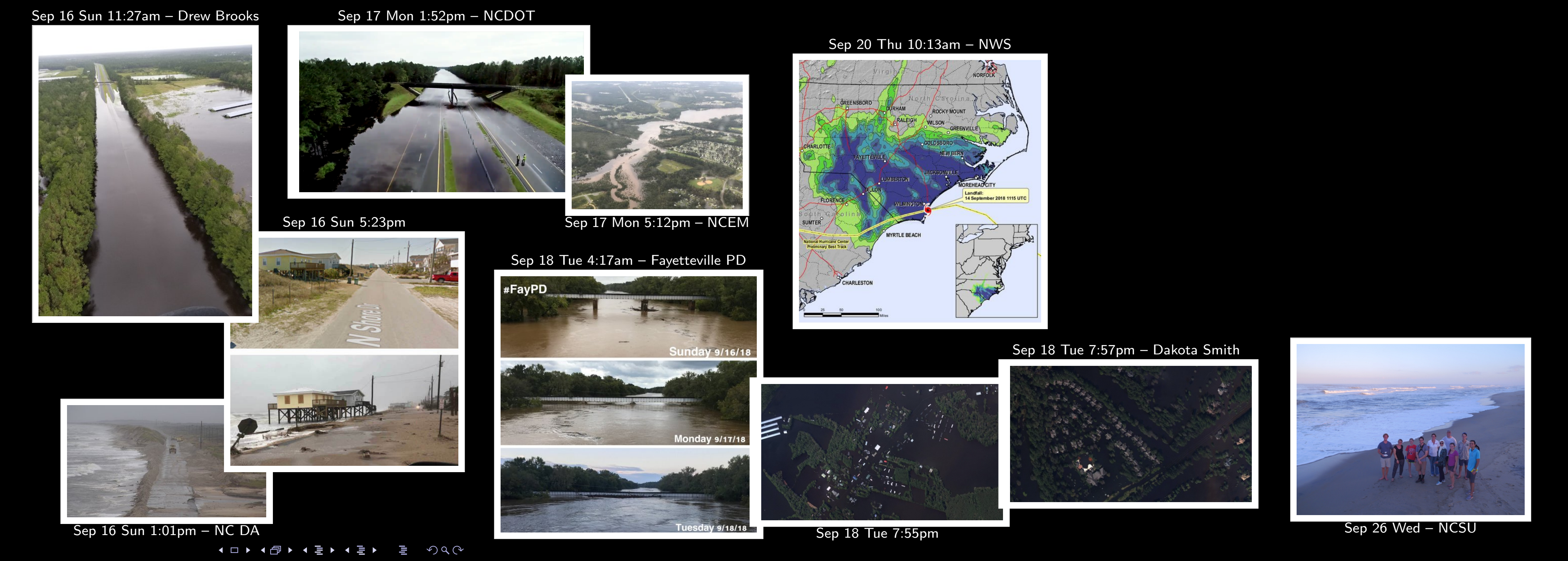

Sep 8 Sat 7:52pm – National Hurricane Center
Sep 10 Mon 6:03pm
Sep 10 Mon 3:40pm – NWS Raleigh
Could be more!
WOLF ALERT
Sep 10 Mon 2:31pm
Sep 9 Sun 1:43pm
UNCW ALERT
Sep 11 Tue 1:40pm
CAMP LEJEUNE
ILM
Sep 12 Wed 5:13am
Sep 12 Wed 6:35am – Alex Gerst
Sep 12 Wed 2:06pm – National Hurricane Center
2-4 ft
9-13 ft
4-9 ft
9-13 ft
4-9 ft
2-4 ft
Tropical Storm Florence
Sep 6 Thu 2:16pm – NOAA NESDIS
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment
Sep 11 Tue 11:45am
Sep 11 Tue 1:52pm – National Hurricane Center
TB 01
SEA VISTA MOTEL
#473710
Sep 12 Wed 10am – NCSG / ND / NCSU
Sep 12 Wed 4:49pm – NWS Wilmington

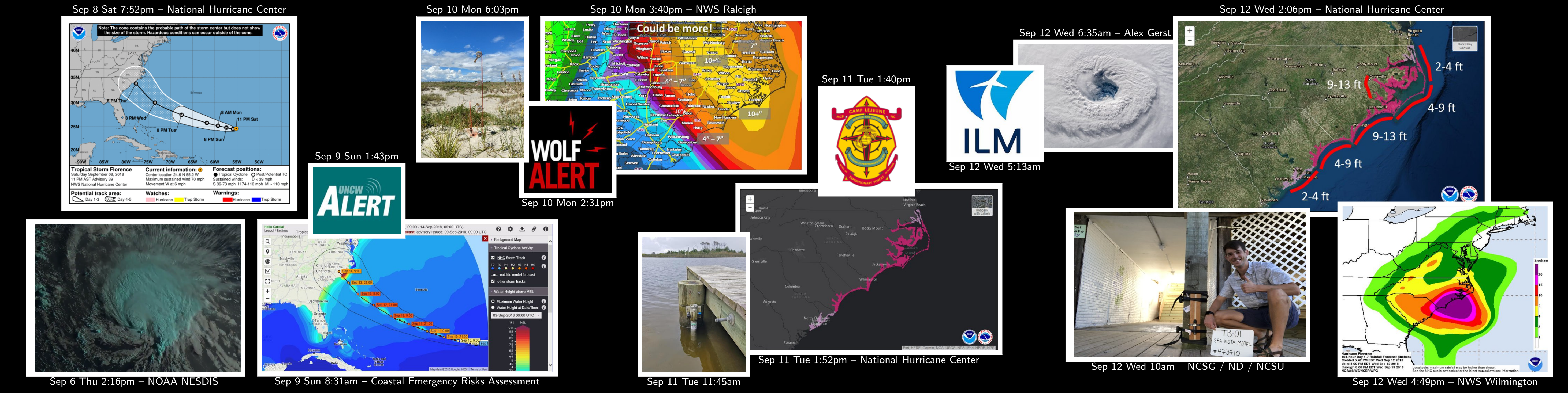

NOAA
cics-md
10 SEP 2018 - 2000 UTC


Sep 13 Thu 8am
Sep 13 Thu 9:13am
Sep 13 Thu 11:26am – The Weather Channel
The Weather Channel
UP TO 9 FT
Sep 13 Thu 7:31pm
Sep 13 Thu
Sep 13 Thu 4:29am – Eric Webb
Sep 13 Thu 12:14pm
Sep 13 Thu 2:19pm – Mark Sudduth


Sep 14 Fri 7:18am – News & Observer
Sep 14 Fri 9:17am
Sep 14 Fri – Getty Images
Sep 15 Sat – AP
Sep 15 Sat 9:05pm – Allen Nosov
ROAD CLOSURES: AS OF SAT 8:30 PM
95 EXITS 138-65
40 EXITS 364-369
Sep 15 Sat 5:12pm
Sep 14 Fri 6:39am – NOAA Satellites
Sep 14 Fri 7:06pm – Andrew Carter
Sep 16 Sun 8:04am – NOAA Satellites


Hurricane Florence
% County Housing Units with NFIP Coverage
% County Housing Units with NFIP Coverage
Radar-Derived Precipitation (Inches)
0 - 0.5
0.5 - 1
1 - 2
2 - 4
4 - 6
6 - 8
8 - 10
10 - 15
15 - 20
> 20
NFIP Data as of 7/31/18
U.S. Census Housing Data as of 7.1.2017
NOAA Radar Data for 7 Days ending 12 UTC 16 September
Mark Bove, Munich Reinsurance America, Inc.
@MarkCBove


Sep 16 Sun 11:27am – Drew Brooks
Sep 17 Mon 1:52pm – NCDOT
Sep 17 Mon 5:12pm – NCEM
Sep 20 Thu 10:13am – NWS
Sep 16 Sun 5:23pm
Sep 18 Tue 4:17am – Fayetteville PD
#FayPD
Sunday 9/16/18
Monday 9/17/18
Tuesday 9/18/18
Sep 16 Sun 1:01pm – NC DA
Sep 18 Tue 7:55pm
Sep 18 Tue 7:57pm – Dakota Smith
Sep 26 Wed – NCSU



Sep 8 Sat 7:52pm – National Hurricane Center

Sep 10 Mon 6:03pm

Sep 10 Mon 3:40pm – NWS Raleigh

Sep 9 Sun 1:43pm

Sep 10 Mon 2:31pm

Sep 11 Tue 1:40pm

Sep 12 Wed 5:13am

Sep 12 Wed 6:35am – Alex Gerst

Sep 12 Wed 2:06pm – National Hurricane Center

Sep 6 Thu 2:16pm – NOAA NESDIS

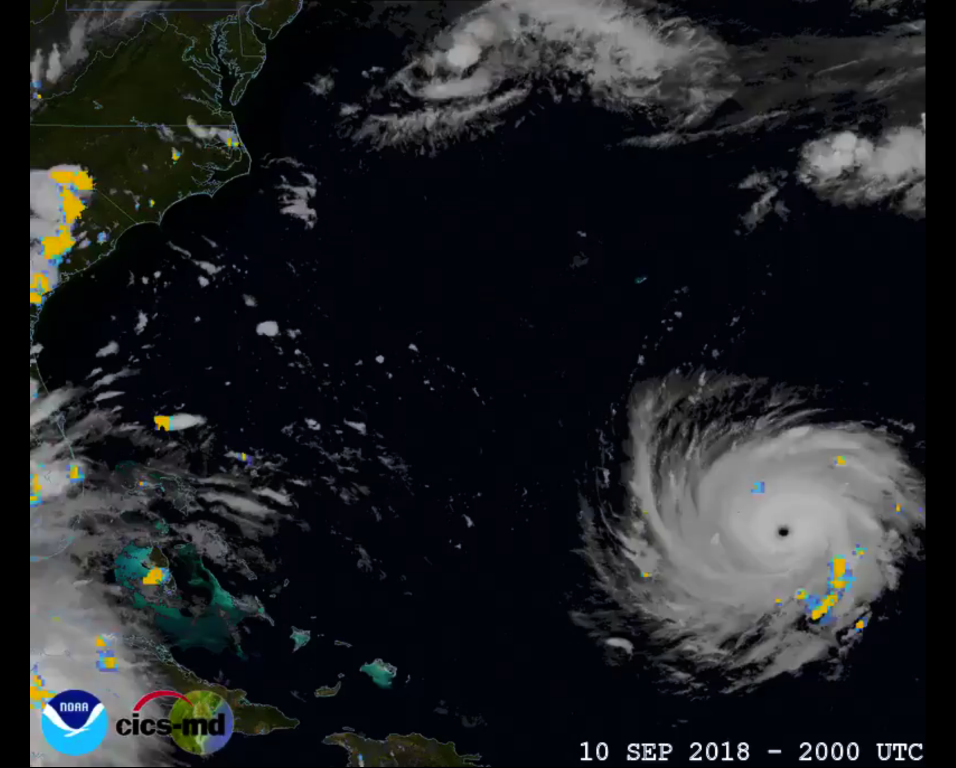
Sep 9 Sun 8:31am – Coastal Emergency Risks Assessment

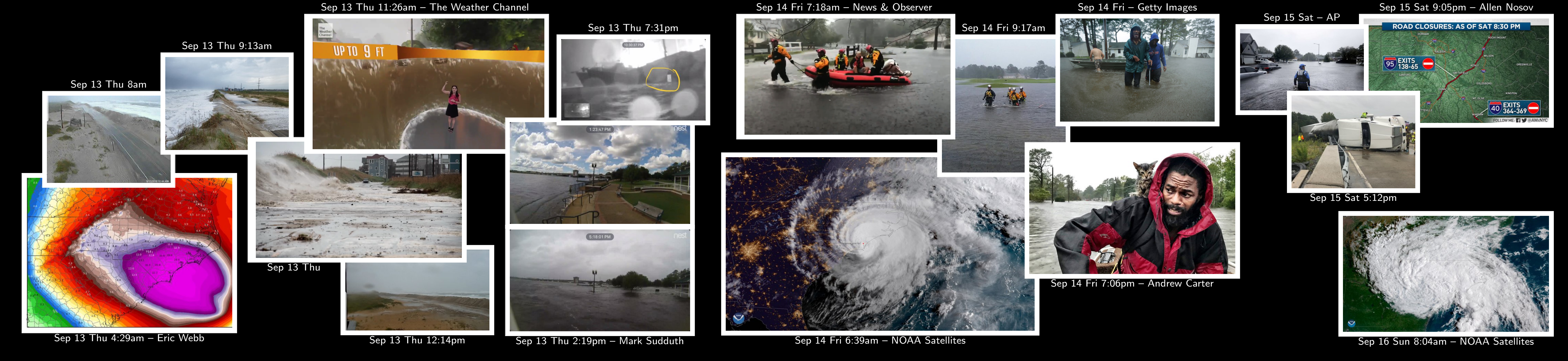
Sep 11 Tue 11:45am

Sep 11 Tue 1:52pm – National Hurricane Center

Sep 12 Wed 10am – NCSG / ND / NCSU

Sep 12 Wed 4:49pm – NWS Wilmington





Sep 13 Thu 8am

Sep 13 Thu 9:13am

Sep 13 Thu 11:26am – The Weather Channel

Sep 13 Thu 7:31pm

Sep 13 Thu 4:29am – Eric Webb

Sep 13 Thu

Sep 13 Thu 12:14pm

Sep 13 Thu 2:19pm – Mark Sudduth

Sep 14 Fri 7:18am – News & Observer

Sep 14 Fri 9:17am

Sep 14 Fri – Getty Images

Sep 15 Sat – AP

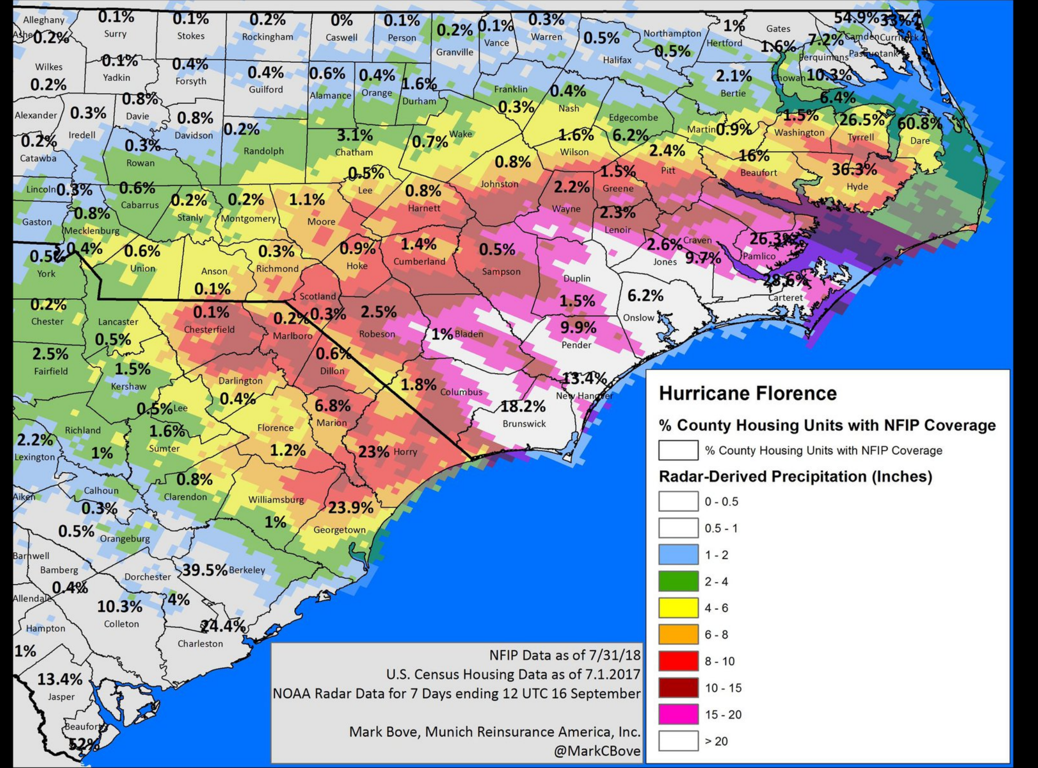
Sep 15 Sat 9:05pm – Allen Nosov

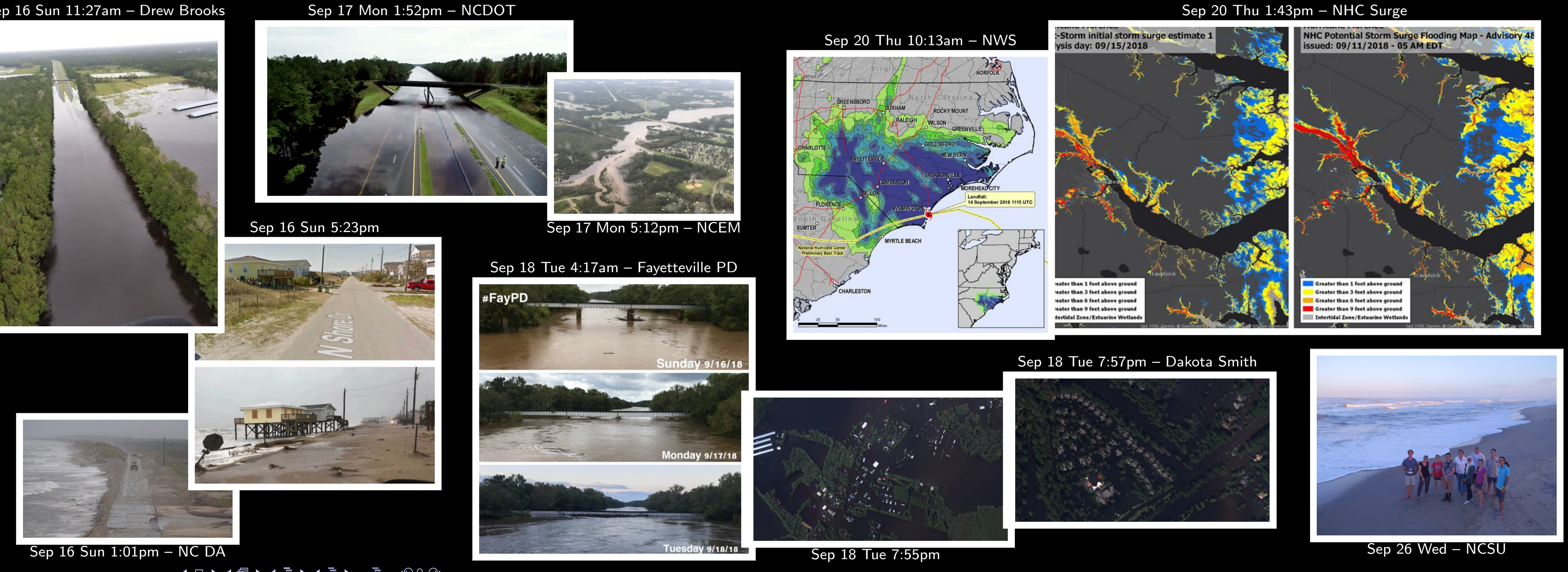
Sep 14 Fri 6:39am – NOAA Satellites

Sep 14 Fri 7:06pm – Andrew Carter

Sep 15 Sat 5:12pm

Sep 16 Sun 8:04am – NOAA Satellites





Sep 16 Sun 11:27am – Drew Brooks

Sep 17 Mon 1:52pm – NCDOT

Sep 17 Mon 5:12pm – NCEM

Sep 16 Sun 5:23pm

Sep 18 Tue 4:17am – Fayetteville PD

Sep 20 Thu 10:13am – NWS

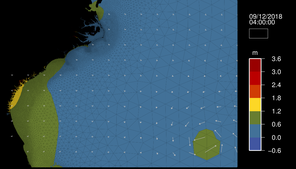
Sep 20 Thu 1:43pm – NHC Surge

Sep 16 Sun 1:01pm – NC DA

Sep 18 Tue 7:55pm

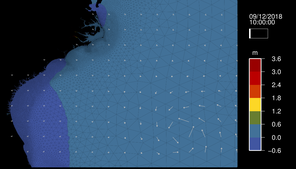
Sep 18 Tue 7:57pm – Dakota Smith

Sep 26 Wed – NCSU


09-12-2018
04:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/12/2018
06:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/12/2018
06:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/12/2018
10:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

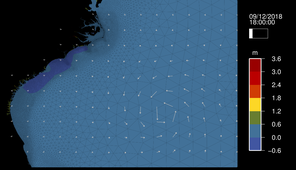
09/12/2018
12:00:00

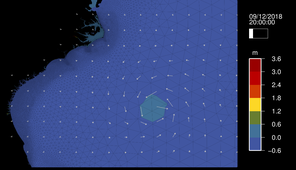
m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

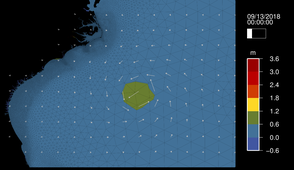
09/12/2018
14:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

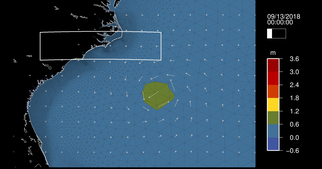
09/12/2018
16:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/12/2018
16:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

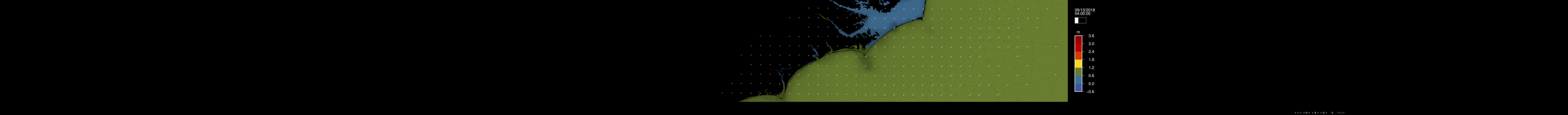

09/12/2018
20:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/12/2018
22:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/13/2018
00:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/13/2018
00:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
02:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/13/2018
04:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
06:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
08:00:00

m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
10:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
12:00:00

m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
14:00:00

m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
16:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
18:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
20:00:00

m

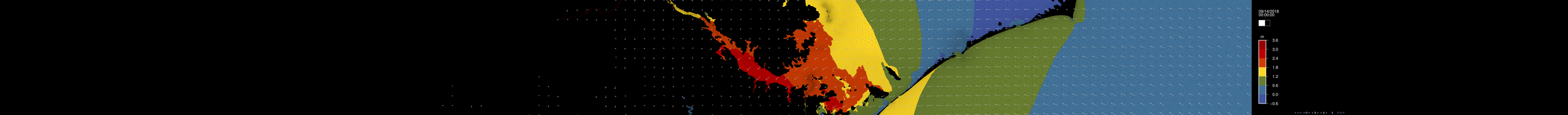
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
20:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/13/2018
22:00:00

m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/14/2018
00:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/14/2018
02:00:00

m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/14/2018
04:00:00

m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/14/2018
06:00:00

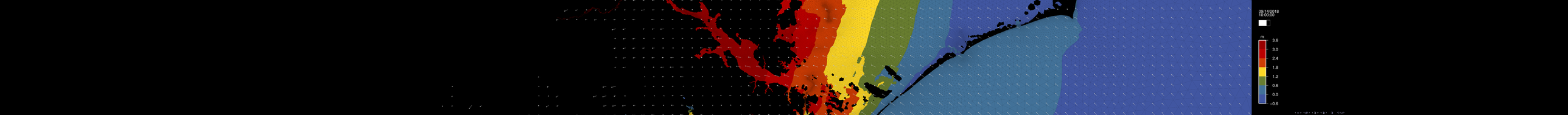
m

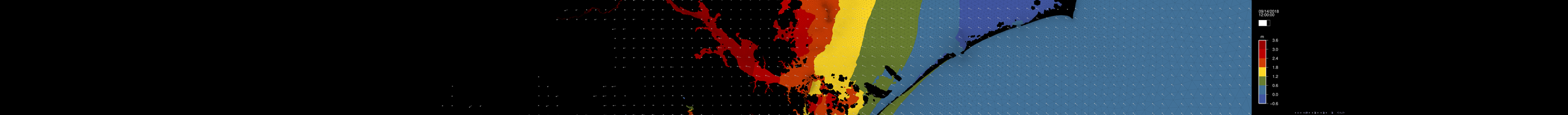
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

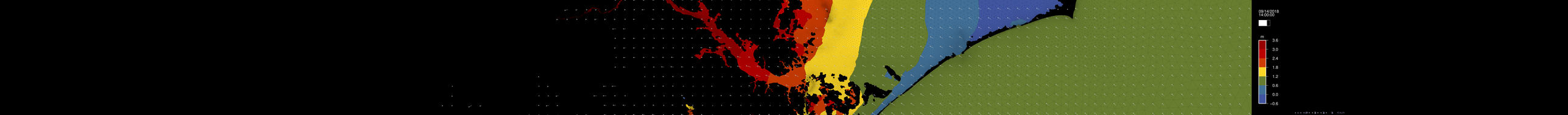
09/14/2018
06:00:00

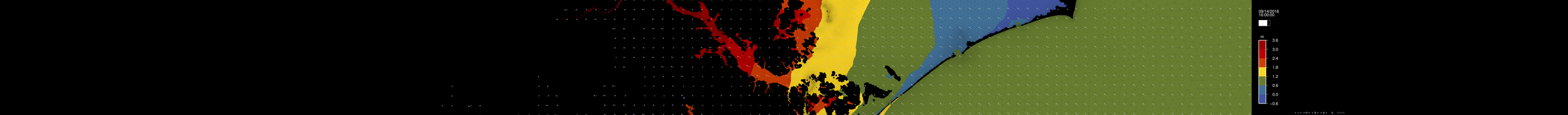
m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/14/2018
10:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/14/2018
12:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

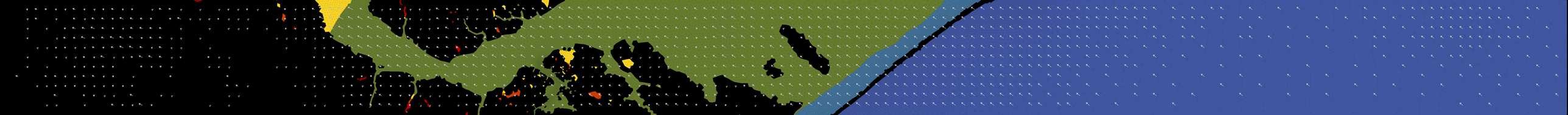

09/14/2018
14:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6


09/14/2018
16:00:00
m
3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6

09/14/2018
16:00:00

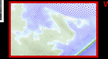
m

3.6
3.0
2.4
1.8
1.2
0.6
0.0
-0.6



What Happened During Florence?

- Timeline of the Storm
- Predictions of Coastal Flooding



What are the Components of Our Models?

- Equations for Ocean Circulation
- Unstructured Mesh for North Carolina

ADCIRC solves the shallow water equations

- These equations govern the conservation of fluid properties
- We must conserve MASS
  - Water cannot be created or destroyed
- We must conserve MOMENTUM
  - Forces and accelerations are linked
  - This is a form of Newton's second law of motion

ADCIRC solves the shallow water equations

- These equations govern the conservation of fluid properties
- We must conserve MASS
  - Water cannot be created or destroyed
- We must conserve MOMENTUM
  - Forces and accelerations are linked
  - This is a form of Newton's second law of motion

$$\frac{\partial \zeta}{\partial t} + \nabla \cdot (H\mathbf{V}) = 0$$

$$\frac{\partial \mathbf{V}}{\partial t} + \mathbf{V} \cdot \nabla \mathbf{U} + 2\boldsymbol{\Omega} \times \mathbf{V} = -g\nabla\left(\zeta + P_s/g\rho_0 - \alpha\eta\right) + \frac{\tau_s}{H\rho_0} - \frac{\tau_b}{H\rho_0} + \frac{\mathbf{M}}{H}$$

Note: We rewrite this equation to improve its numerical properties before solving in ADCIRC.

$$\frac{\partial \zeta}{\partial t} + \nabla \cdot (H\mathbf{V}) = 0$$

ADCIRC solves the shallow water equations
- These equations govern the conservation of fluid properties
- We must conserve MASS
  - Water cannot be created or destroyed
- We must conserve MOMENTUM
  - Forces and accelerations are linked
  - This is a form of Newton's second law of motion

There are only three unknowns in these equations
- Water surface elevation, ζ
- Horizontal water velocities, $\mathbf{V} = (U, V)$

These equations aren't so scary!

$$\frac{\partial \mathbf{V}}{\partial t} + \mathbf{V} \cdot \nabla \mathbf{U} + 2\mathbf{\Omega} \times \mathbf{V} = -g\nabla\left(\zeta + P_s/g\rho_0 - \alpha\eta\right) + \frac{\tau_s}{H\rho_0} - \frac{\tau_b}{H\rho_0} + \frac{\mathbf{M}}{H}$$

Note: We rewrite this equation to improve its numerical properties before solving in ADCIRC.

$$\frac{\partial \zeta}{\partial t} + \nabla \cdot (H\mathbf{V}) = 0$$

Local accumulation of water must be balanced by incoming and outgoing flows

Note: We rewrite this equation to improve its numerical properties before solving in ADCIRC.

ADCIRC solves the shallow water equations

- These equations govern the conservation of fluid properties
- We must conserve MASS
  - Water cannot be created or destroyed
- We must conserve MOMENTUM
  - Forces and accelerations are linked
  - This is a form of Newton's second law of motion

There are only three unknowns in these equations

- Water surface elevation, ζ
- Horizontal water velocities, $\mathbf{V} = (U, V)$

These equations aren't so scary!

$$\frac{\partial \mathbf{V}}{\partial t} + \mathbf{V} \cdot \nabla \mathbf{U} + 2\mathbf{\Omega} \times \mathbf{V} = -g\nabla\left(\zeta + P_s/g\rho_0 - \alpha\eta\right) + \frac{\tau_s}{H\rho_0} - \frac{\tau_b}{H\rho_0} + \frac{\mathbf{M}}{H}$$

$$\frac{\partial \zeta}{\partial t} + \nabla \cdot (H\mathbf{V}) = 0$$

Local accumulation of water must be balanced by incoming and outgoing flows

Note: We rewrite this equation to improve its numerical properties before solving in ADCIRC.

ADCIRC solves the shallow water equations
- These equations govern the conservation of fluid properties
- We must conserve MASS
  - Water cannot be created or destroyed
- We must conserve MOMENTUM
  - Forces and accelerations are linked
  - This is a form of Newton's second law of motion

There are only three unknowns in these equations
- Water surface elevation, ζ
- Horizontal water velocities, $\mathbf{V} = (U, V)$

These equations aren't so scary!

$$\frac{\partial \mathbf{V}}{\partial t} + \mathbf{V} \cdot \nabla \mathbf{U} + 2\boldsymbol{\Omega} \times \mathbf{V} = -g\nabla\left(\zeta + P_s/g\rho_0 - \alpha\eta\right) + \frac{\tau_s}{H\rho_0} - \frac{\tau_b}{H\rho_0} + \frac{\mathbf{M}}{H}$$

Water is accelerated (locally, horizontally, and rotationally)

$$\frac{\partial \zeta}{\partial t} + \nabla \cdot (H\mathbf{V}) = 0$$

Local accumulation of water must be balanced by incoming and outgoing flows

Note: We rewrite this equation to improve its numerical properties before solving in ADCIRC.

ADCIRC solves the shallow water equations

- These equations govern the conservation of fluid properties
- We must conserve MASS
  - Water cannot be created or destroyed
- We must conserve MOMENTUM
  - Forces and accelerations are linked
  - This is a form of Newton's second law of motion

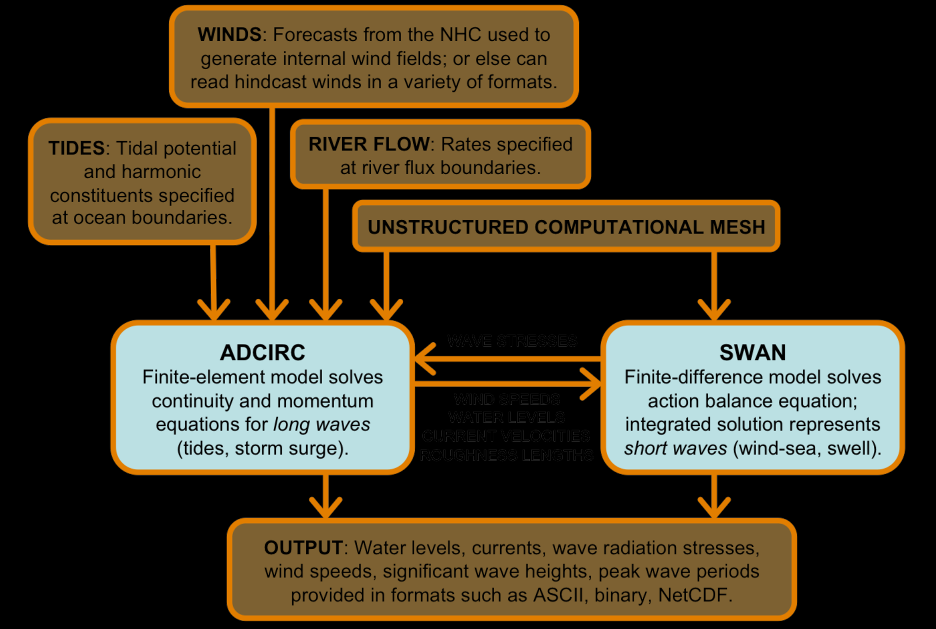
There are only three unknowns in these equations

- Water surface elevation, ζ
- Horizontal water velocities, $\mathbf{V} = (U, V)$

These equations aren't so scary!

$$\frac{\partial \mathbf{V}}{\partial t} + \mathbf{V} \cdot \nabla \mathbf{U} + 2\boldsymbol{\Omega} \times \mathbf{V} = -g\nabla\left(\zeta + P_s/g\rho_0 - \alpha\eta\right) + \frac{\tau_s}{H\rho_0} - \frac{\tau_b}{H\rho_0} + \frac{\mathbf{M}}{H}$$

Water is accelerated (locally, horizontally, and rotationally) due to external forces (pressures, tides, winds, bottom friction, and internal dissipation)



WINDS: Forecasts from the NHC used to generate internal wind fields; or else can read hindcast winds in a variety of formats.
TIDES: Tidal potential and harmonic constituents specified at ocean boundaries.
RIVER FLOW: Rates specified at river flux boundaries.
UNSTRUCTURED COMPUTATIONAL MESH
ADCIRC
Finite-element model solves continuity and momentum equations for long waves (tides, storm surge).
WAVE STRESSES
WIND SPEEDS
WATER LEVELS
CURRENT VELOCITIES
ROUGHNESS LENGTHS
SWAN
Finite-difference model solves action balance equation; integrated solution represents short waves (wind-sea, swell).
OUTPUT: Water levels, currents, wave radiation stresses, wind speeds, significant wave heights, peak wave periods provided in formats such as ASCII, binary, NetCDF.

What Happened During Florence?
- Timeline of the Storm
- Predictions of Coastal Flooding

What are the Components of Our Models?
- Equations for Ocean Circulation
- Unstructured Mesh for North Carolina

How Good are the Forecasts?
- Uncertainties Within and Across Advisories

SWAN+ADCIRC can be employed in real-time

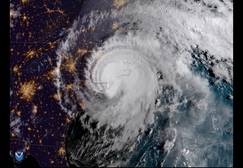
- **Everything happens automatically**
  - Models are initialized, run, and processed by Perl scripts

Wind fields from two sources:

- Under normal conditions:
  - Downloaded from NAM model output by NOAA/NCEP
  - Converted into format compatible with SWAN+ADCIRC
- Under storm conditions:
  - Download advisories from NOAA/NHC
  - Generate wind fields using parametric model (Holland, 1980)

Guidance can be shared in multiple formats:

- Send directly to stakeholders (NC Emergency Management)
- Share publicly via web service (`http://www.adcirc.org`)



SWAN+ADCIRC can be employed in real-time

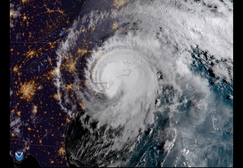
- **Everything happens automatically**
  - Models are initialized, run, and processed by Perl scripts

Wind fields from two sources:

- Under normal conditions:
  - Downloaded from NAM model output by NOAA/NCEP
  - Converted into format compatible with SWAN+ADCIRC
- Under storm conditions:
  - Download advisories from NOAA/NHC
  - Generate wind fields using parametric model (Holland, 1980)

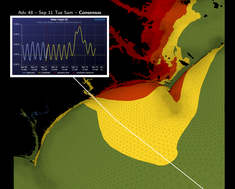
Guidance can be shared in multiple formats:

- Send directly to stakeholders (NC Emergency Management)
- Share publicly via web service (`http://www.adcirc.org`)



The larger ADCIRC team was forecasting Florence in real-time

- For 21 advisories (every 6 hr)
- For 3 ensemble members (consensus and track perturbations)
- On 3 high-performance computing systems

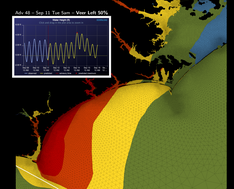


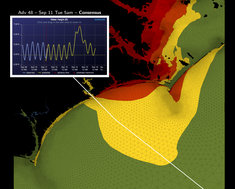
The larger ADCIRC team was forecasting Florence in real-time

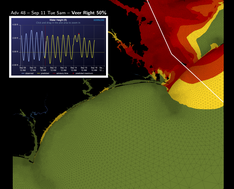
- For 21 advisories (every 6 hr)
- For 3 ensemble members (consensus and track perturbations)
- On 3 high-performance computing systems

What were the uncertainties within each advisory?

- Consider the forecast for advisory 48





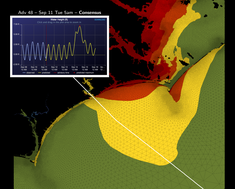


The larger ADCIRC team was forecasting Florence in real-time

- For 21 advisories (every 6 hr)
- For 3 ensemble members (consensus and track perturbations)
- On 3 high-performance computing systems

What were the uncertainties within each advisory?

- Consider the forecast for advisory 48
- Possible/likely for the storm to move west or east
- Different flooding scenarios near Wilmington and in estuaries

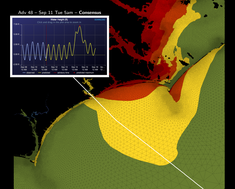


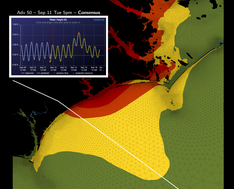
The larger ADCIRC team was forecasting Florence in real-time

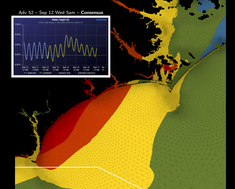
- For 21 advisories (every 6 hr)
- For 3 ensemble members (consensus and track perturbations)
- On 3 high-performance computing systems

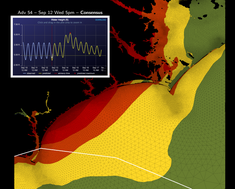
What were the uncertainties within each advisory?

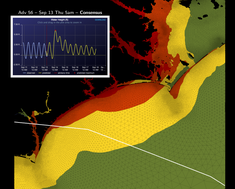
- Consider the forecast for advisory 48
- Possible/likely for the storm to move west or east
- Different flooding scenarios near Wilmington and in estuaries











The larger ADCIRC team was forecasting Florence in real-time

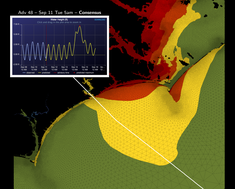
- For 21 advisories (every 6 hr)
- For 3 ensemble members (consensus and track perturbations)
- On 3 high-performance computing systems

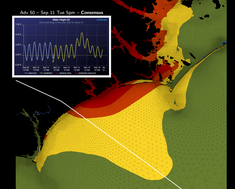
What were the uncertainties within each advisory?

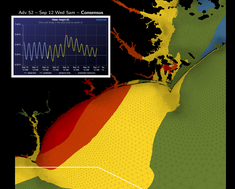
- Consider the forecast for advisory 48
- Possible/likely for the storm to move west or east
- Different flooding scenarios near Wilmington and in estuaries

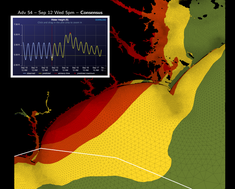
What were the uncertainties between advisories?

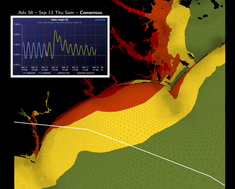
- Storm moved southward
- Storm slowed down
- At Beaufort gauge, very close to magnitude and timing of peak











The larger ADCIRC team was forecasting Florence in real-time

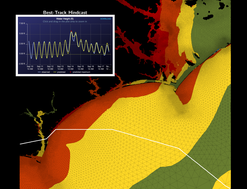
- For 21 advisories (every 6 hr)
- For 3 ensemble members (consensus and track perturbations)
- On 3 high-performance computing systems

What were the uncertainties within each advisory?

- Consider the forecast for advisory 48
- Possible/likely for the storm to move west or east
- Different flooding scenarios near Wilmington and in estuaries

What were the uncertainties between advisories?

- Storm moved southward
- Storm slowed down
- At Beaufort gauge, very close to magnitude and timing of peak



What Happened During Florence?
- Timeline of the Storm
- Predictions of Coastal Flooding

What are the Components of Our Models?
- Equations for Ocean Circulation
- Unstructured Mesh for North Carolina

How Good are the Forecasts?
- Uncertainties Within and Across Advisories

How Can We Improve Our Guidance?
- So ... What is the Problem?
- Downscaling and Extrapolation

We want to enhance the flooding guidance to NCEM

- Now we provide water levels at our model resolution
  - More than 600K points
  - Minimum spacing of about 50 to 100 m
- NCEM wants to combine with other datasets
  - More than 400M cells
  - High-resolution topography with equal spacings of 50 ft

Need to do two things:

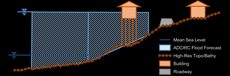
1. Downscale our resolution to high-resolution topography
2. Extrapolate our flooding into small-scale coastal regions

We want to enhance the flooding guidance to NCEM

- Now we provide water levels at our model resolution
  - More than 600K points
  - Minimum spacing of about 50 to 100 m
- NCEM wants to combine with other datasets
  - More than 400M cells
  - High-resolution topography with equal spacings of 50 ft

Need to do two things:

1. Downscale our resolution to high-resolution topography
2. Extrapolate our flooding into small-scale coastal regions

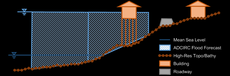


We want to enhance the flooding guidance to NCEM

- Now we provide water levels at our model resolution
  - More than 600K points
  - Minimum spacing of about 50 to 100 m
- NCEM wants to combine with other datasets
  - More than 400M cells
  - High-resolution topography with equal spacings of 50 ft

Need to do two things:

1. Downscale our resolution to high-resolution topography
2. Extrapolate our flooding into small-scale coastal regions



Goal:

- Enable data-driven decision-making for coastal communities during storm events

Objectives:

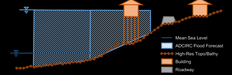
- Extrapolate ADCIRC results to intersect high-resolution DEM
- Create fully-automated process to be run during real-time
- Enable process to run in 10-20 minutes for each forecast
- Use open-source software for transferability
- Share enhanced guidance with NCEM

We want to enhance the flooding guidance to NCEM

- Now we provide water levels at our model resolution
  - More than 600K points
  - Minimum spacing of about 50 to 100 m
- NCEM wants to combine with other datasets
  - More than 400M cells
  - High-resolution topography with equal spacings of 50 ft

Need to do two things:

1. Downscale our resolution to high-resolution topography
2. Extrapolate our flooding into small-scale coastal regions

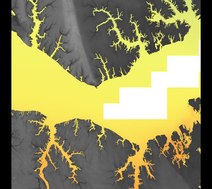


Goal:

- Enable data-driven decision-making for coastal communities during storm events

Objectives:

- Extrapolate ADCIRC results to intersect high-resolution DEM
- Create fully-automated process to be run during real-time
- Enable process to run in 10-20 minutes for each forecast
- Use open-source software for transferability
- Share enhanced guidance with NCEM



Use the Geographic Resources Analysis Support System (GRASS):

- Open-source software (https://grass.osgeo.org)
- Developed by Prof. Mitasova and researchers
  - Center for Geospatial Analytics
- Extremely fast for raster processing

Then the general steps were:

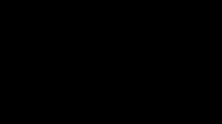
1. Interpolate ADCIRC points to raster at resolution of DEM
2. Extrapolate water levels into small-scale features
   a. Expand the raster outward only where the water levels are higher than the ground surface
   b. Remove isolated (not hydraulically-connected) cells
3. Convert the new "grown" raster to polygon format

Use the Geographic Resources Analysis Support System (GRASS):

- Open-source software (`https://grass.osgeo.org`)
- Developed by Prof. Mitasova and researchers
  - Center for Geospatial Analytics
- Extremely fast for raster processing

Then the general steps were:

1. Interpolate ADCIRC points to raster at resolution of DEM
2. Extrapolate water levels into small-scale features
   a. Expand the raster outward only where the water levels are higher than the ground surface
   b. Remove isolated (not hydraulically-connected) cells
3. Convert the new "grown" raster to polygon format

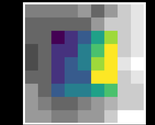


Use the Geographic Resources Analysis Support System (GRASS):

- Open-source software (`https://grass.osgeo.org`)
- Developed by Prof. Mitasova and researchers
  - Center for Geospatial Analytics
- Extremely fast for raster processing

Then the general steps were:

1. Interpolate ADCIRC points to raster at resolution of DEM
2. Extrapolate water levels into small-scale features
   a. Expand the raster outward only where the water levels are higher than the ground surface
   b. Remove isolated (not hydraulically-connected) cells
3. Convert the new "grown" raster to polygon format

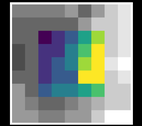


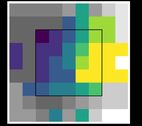
Use the Geographic Resources Analysis Support System (GRASS):

- Open-source software (`https://grass.osgeo.org`)
- Developed by Prof. Mitasova and researchers
  - Center for Geospatial Analytics
- Extremely fast for raster processing

Then the general steps were:

1. Interpolate ADCIRC points to raster at resolution of DEM
2. Extrapolate water levels into small-scale features
   a. Expand the raster outward only where the water levels are higher than the ground surface
   b. Remove isolated (not hydraulically-connected) cells
3. Convert the new "grown" raster to polygon format



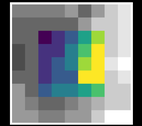


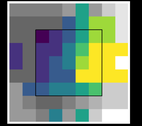
Use the Geographic Resources Analysis Support System (GRASS):

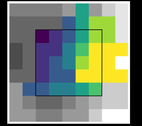
- Open-source software (`https://grass.osgeo.org`)
- Developed by Prof. Mitasova and researchers
  - Center for Geospatial Analytics
- Extremely fast for raster processing

Then the general steps were:

1. Interpolate ADCIRC points to raster at resolution of DEM
2. Extrapolate water levels into small-scale features
   a. Expand the raster outward only where the water levels are higher than the ground surface
   b. Remove isolated (not hydraulically-connected) cells
3. Convert the new "grown" raster to polygon format







The first interpolation step is costly

- Need to take water levels from the ADCIRC mesh vertices
  - About 600,000 vertices for NC
- And interpolate water levels onto 50-ft raster DEM
  - About 28 million cells for Carteret County
  - About 434 million cells for NC
- This process is slow
  - We use a file with pre-computed, inverse-distance weights
  - It still takes 5 min for each forecast

The new raster is imported into GRASS:

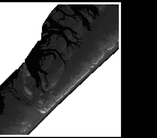
- Raster is extrapolated using a modified version of the module "r.grow"
- Only hydraulically-connected, flooded cells are retained

The first interpolation step is costly

- Need to take water levels from the ADCIRC mesh vertices
  - About 600,000 vertices for NC
- And interpolate water levels onto 50-ft raster DEM
  - About 28 million cells for Carteret County
  - About 434 million cells for NC
- This process is slow
  - We use a file with pre-computed, inverse-distance weights
  - It still takes 5 min for each forecast

The new raster is imported into GRASS:

- Raster is extrapolated using a modified version of the module "r.grow"
- Only hydraulically-connected, flooded cells are retained

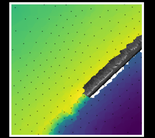


The first interpolation step is costly

- Need to take water levels from the ADCIRC mesh vertices
  - About 600,000 vertices for NC
- And interpolate water levels onto 50-ft raster DEM
  - About 28 million cells for Carteret County
  - About 434 million cells for NC
- This process is slow
  - We use a file with pre-computed, inverse-distance weights
  - It still takes 5 min for each forecast

The new raster is imported into GRASS:

- Raster is extrapolated using a modified version of the module "r.grow"
- Only hydraulically-connected, flooded cells are retained

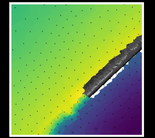


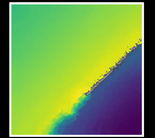
The first interpolation step is costly

- Need to take water levels from the ADCIRC mesh vertices
  - About 600,000 vertices for NC
- And interpolate water levels onto 50-ft raster DEM
  - About 28 million cells for Carteret County
  - About 434 million cells for NC
- This process is slow
  - We use a file with pre-computed, inverse-distance weights
  - It still takes 5 min for each forecast

The new raster is imported into GRASS:

- Raster is extrapolated using a modified version of the module "r.grow"
- Only hydraulically-connected, flooded cells are retained





We made some changes within the GRASS software:

- Normally, the r.grow function expands a raster outward
  - Fills surrounding cells with values taken from the outermost cells of the original raster
- Our modified version allows for expanding into null cells **only if** the ADCIRC cell value is greater than the value of the DEM
  - Water level must be higher than ground surface
- After "growing" by a sufficiently large radius, isolated cells are removed if they do not overlap with the original raster
  - Enforce a hydraulic connectivity

Then we convert back to polygons

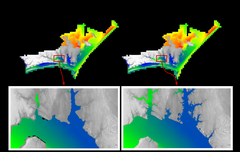
- Expanded water surface is binned into 0.5-ft intervals

We made some changes within the GRASS software:

- Normally, the r.grow function expands a raster outward
  - Fills surrounding cells with values taken from the outermost cells of the original raster
- Our modified version allows for expanding into null cells **only if** the ADCIRC cell value is greater than the value of the DEM
  - Water level must be higher than ground surface
- After "growing" by a sufficiently large radius, isolated cells are removed if they do not overlap with the original raster
  - Enforce a hydraulic connectivity

Then we convert back to polygons

- Expanded water surface is binned into 0.5-ft intervals

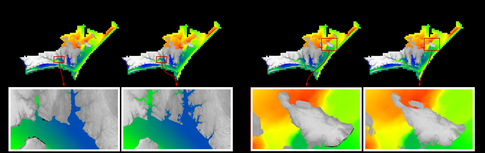


We made some changes within the GRASS software:

- Normally, the r.grow function expands a raster outward
  - Fills surrounding cells with values taken from the outermost cells of the original raster
- Our modified version allows for expanding into null cells **only if** the ADCIRC cell value is greater than the value of the DEM
  - Water level must be higher than ground surface
- After "growing" by a sufficiently large radius, isolated cells are removed if they do not overlap with the original raster
  - Enforce a hydraulic connectivity

Then we convert back to polygons

- Expanded water surface is binned into 0.5-ft intervals



We can intersect the flooding guidance with known buildings

- NCEM has compiled a database of infrastructure
- Building footprint, first floor elevation, etc.
- Used for their planning during and after storm events

We can analyze the number of buildings covered by our flooding prediction for a Hurricane Matthew hindcast

- Before enhancement: **2,435 buildings**
- After enhancement: **3,886 buildings**
- This is an increase of 60 percent

We can intersect the flooding guidance with known buildings

- NCEM has compiled a database of infrastructure
- Building footprint, first floor elevation, etc.
- Used for their planning during and after storm events

We can analyze the number of buildings covered by our flooding prediction for a Hurricane Matthew hindcast

- Before enhancement: **2,435 buildings**
- After enhancement: **3,886 buildings**
- This is an increase of 60 percent

We need the method to be *fast*:

- Interpolation of ADCIRC points to raster format is most time-consuming part, even with precomputed weights
- Entire process was taking **30-40 minutes** at first, and clearly needed to be parallelized:
  - Allow for parallel processing on up to 16 CPUs
  - DEM was divided into horizontal strips
- Some aspects cannot be parallelized
  - Final conversion into 0.5-ft polygons
- With parallelization, the entire process now takes **12-15 minutes** to run on the NCSU computing cluster

We can intersect the flooding guidance with known buildings

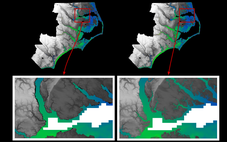
- NCEM has compiled a database of infrastructure
- Building footprint, first floor elevation, etc.
- Used for their planning during and after storm events

We can analyze the number of buildings covered by our flooding prediction for a Hurricane Matthew hindcast

- Before enhancement: **2,435 buildings**
- After enhancement: **3,886 buildings**
- This is an increase of 60 percent

We need the method to be *fast*:

- Interpolation of ADCIRC points to raster format is most time-consuming part, even with precomputed weights
- Entire process was taking **30-40 minutes** at first, and clearly needed to be parallelized:
  - Allow for parallel processing on up to 16 CPUs
  - DEM was divided into horizontal strips
- Some aspects cannot be parallelized
  - Final conversion into 0.5-ft polygons
- With parallelization, the entire process now takes **12-15 minutes** to run on the NCSU computing cluster



We can intersect the flooding guidance with known buildings

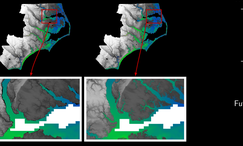
- NCEM has compiled a database of infrastructure
- Building footprint, first floor elevation, etc.
- Used for their planning during and after storm events

We can analyze the number of buildings covered by our flooding prediction for a Hurricane Matthew hindcast

- Before enhancement: **2,435 buildings**
- After enhancement: **3,886 buildings**
- This is an increase of 60 percent

We need the method to be *fast*:

- Interpolation of ADCIRC points to raster format is most time-consuming part, even with precomputed weights
- Entire process was taking **30-40 minutes** at first, and clearly needed to be parallelized:
  - Allow for parallel processing on up to 16 CPUs
  - DEM was divided into horizontal strips
- Some aspects cannot be parallelized
  - Final conversion into 0.5-ft polygons
- With parallelization, the entire process now takes **12-15 minutes** to run on the NCSU computing cluster

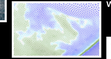


We are now providing the enhanced guidance to NCEM

- During hurricane season, we use an automated script on our cluster at NCSU:
  - Detects when ADCIRC results are posted to the archive
  - Downloads the maximum water levels
  - Runs the enhanced-resolution process
- Recent storms:
  - 2017 – Harvey & Irma
  - 2018 – Florence & Michael

Future work – Integrate this script into the forecasting system

What Happened During Florence?
- Timeline of the Storm
- Predictions of Coastal Flooding



What are the Components of Our Models?
- Equations for Ocean Circulation
- Unstructured Mesh for North Carolina

How Good are the Forecasts?
- Uncertainties Within and Across Advisories

How Can We Improve Our Guidance?
- So ... What is the Problem?
- Downscaling and Extrapolation