DOG & PUPPY

RIGBY   SADIE

BIRTH | 8 WEEKS

(PRESENT) 20 WEEKS | PROJECTED GROWTH BASED ON TREND

JESSIE ROBINSON
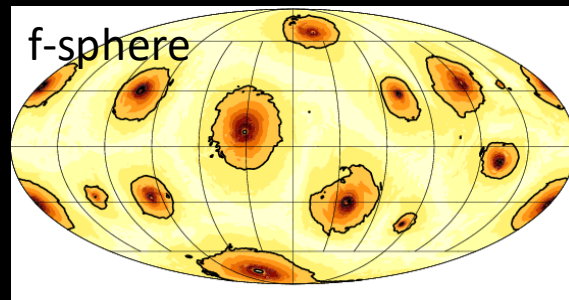
We want to predict the future

We have observational data from the recent past (sometimes)

But the world is warming – and we do not have data from the future

Physics can generalize – providing constraints on the future.

Integrate physics and observations → prediction

aquaplanet

real Earth

exoplanets too!

f-sphere
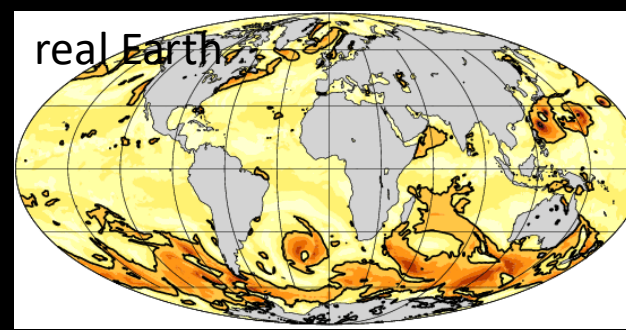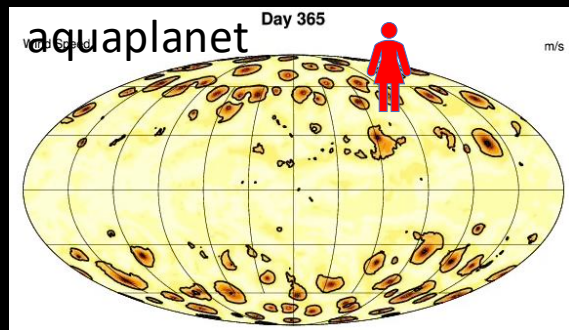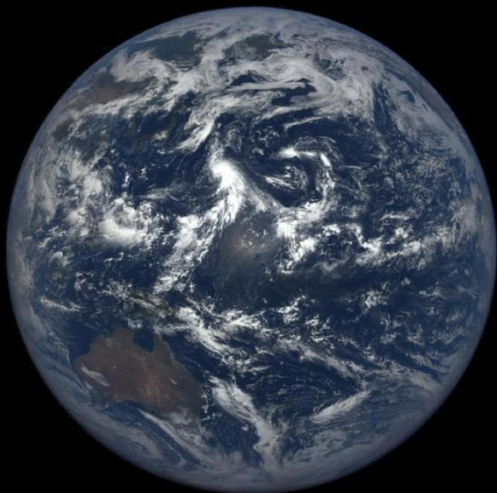
β -plane

f-plane

We use models as experimental laboratories
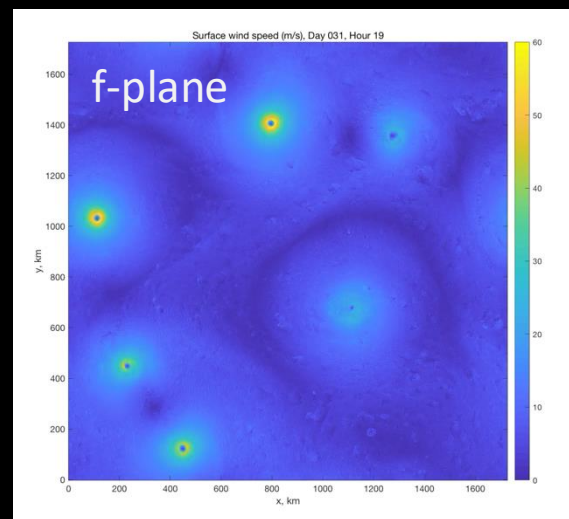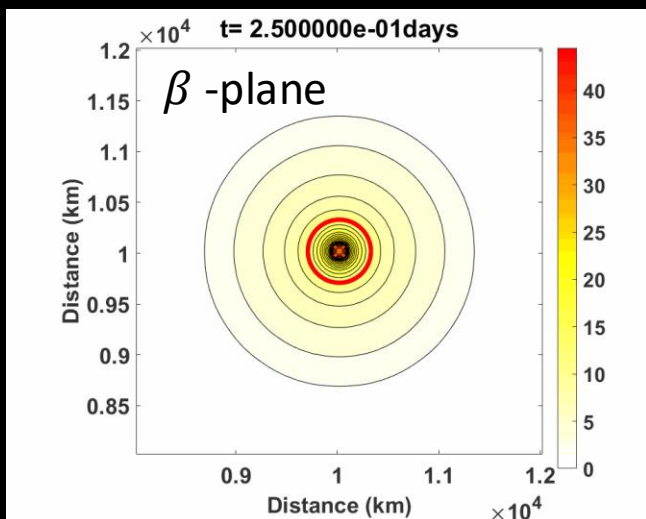
Imaginary worlds help us **better understand our own.**

Roadmap

0. Intro: two recent events
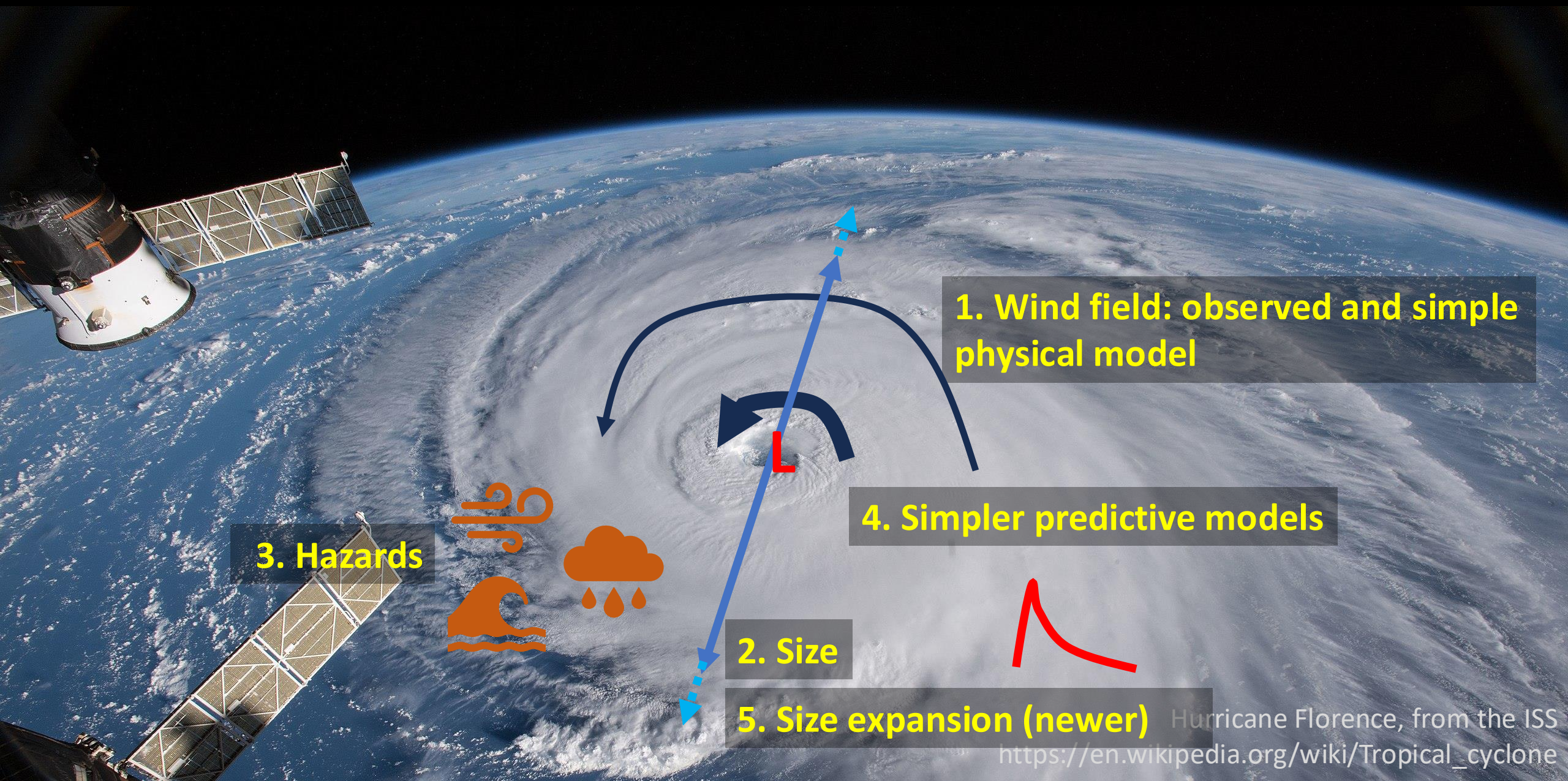
1. Wind field: observed and simple physical model

4. Simpler predictive models

3. Hazards

L

2. Size

5. Size expansion (newer)

Hurricane Florence, from the ISS
https://en.wikipedia.org/wiki/Tropical_cyclone

Recent events

2024
Milton: 11 deaths
Helene: 251 deaths

Tropical Storm Milton
39–73 mph
63–118 km/h

Milton https://www.youtube.com/watch?v=H_is9lbHP44

0 mi   400 mi

06 Oct 2024   1450

0 km   500 km

Everything about Milton was incredibly well forecast -- before the storm had even formed (4 days prior to landfall)

A product of **decades of advances** in:
1) Atmospheric obs (remote/in situ)
2) Numerical weather models

Note: The cone contains the probable path of the storm center but does not show the size of the storm. Hazardous conditions can occur outside of the cone.

X Actual landfall point

Tropical Depression Fourteen
Saturday October 05, 2024
10 AM CDT Advisory 1
NWS National Hurricane Center

Current information: ⊙
Center location 22.1 N 95.1 W
Maximum sustained wind 35 mph
Movement NNE at 3 mph

Forecast positions:
● Tropical Cyclone   ○ Post/Potential TC
Sustained winds: D < 39 mph
S 39-73 mph H 74-110 mph M > 110 mph

Potential track area:
Day 1-3   Day 4-5

Watches:
Hurricane   Trop Storm

Warnings:
Hurricane   Trop Storm

https://www.nhc.noaa.gov/archive/2024/MILTON_graphics.php?product=5day_cone_with_

Hazards: wind

Strongest near coast, as drag
weakens winds and storm
weakens rapidly after landfall

Milton dashcam

Power outages

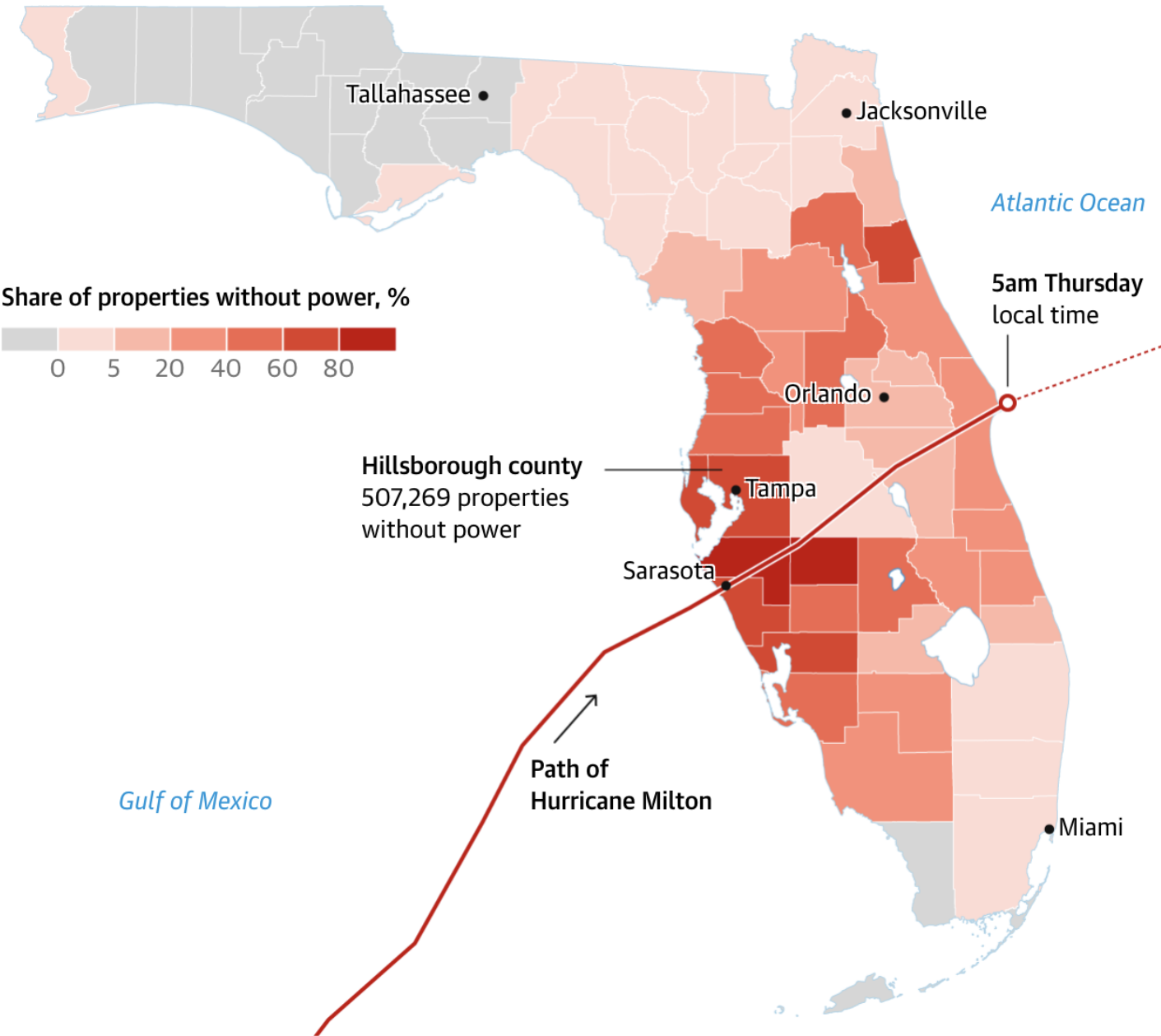## Hurricane Milton has cut power to millions of Florida homes

Tallahassee

Jacksonville

Atlantic Ocean

Share of properties without power, %

0 5 20 40 60 80

5am Thursday
local time

Orlando

Hillsborough county
507,269 properties
without power

Tampa

Sarasota

Gulf of Mexico

**Path of
Hurricane Milton**

Miami

Guardian graphic. Source: PowerOutage.US, data as of 10 Oct 2024, 3.26am local time

Note: even weaker storms (Cat 1) can
cause widespread power outages

Hazards: storm surge

ESTIMATED OBSERVED SURGE
MILTON
WEATHER ON THE 9S

TARPON SPRINGS
TAMPA
ST. PETERSBURG
LONGBOAT KEY
SARASOTA
VENICE

1-3 ft.
5-10 ft.
3-6 ft.

https://www.youtube.com/watch?v=IgflXCuiATQ

Hurricane winds

Storm surge

Mean sea level

Normal high tide

https://www.washingtonpost.com/weather/2022/09/26/what-is-storm-surge/
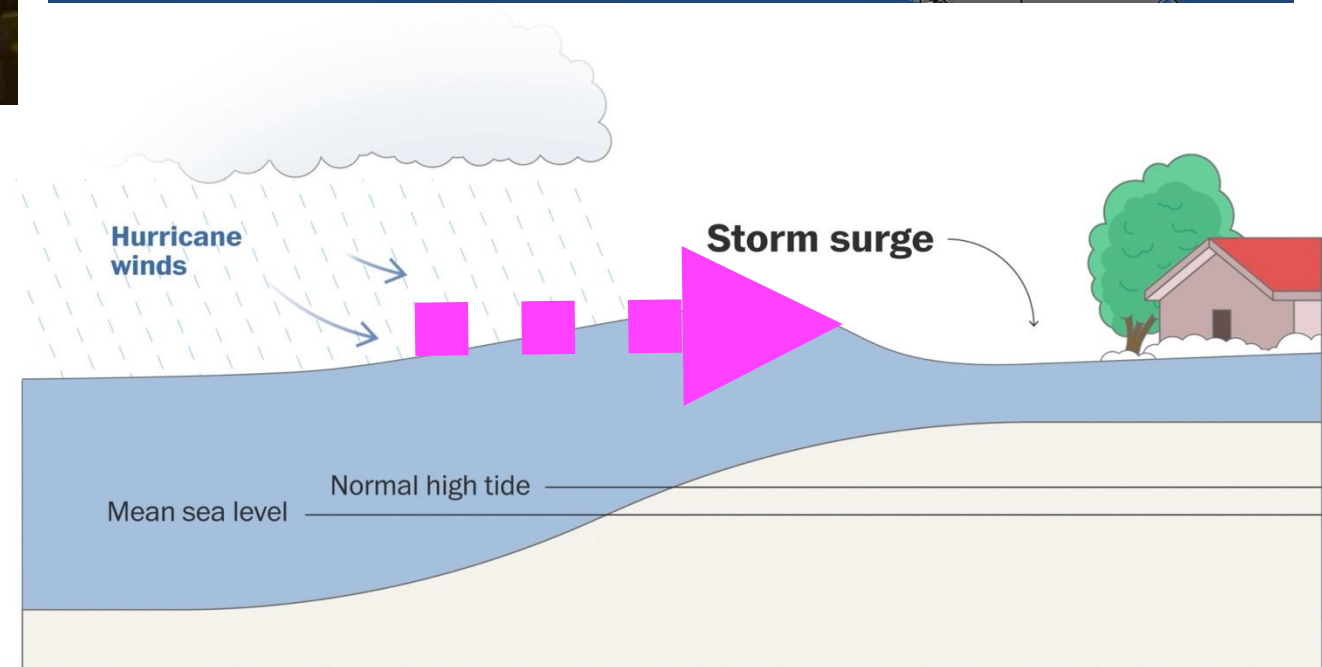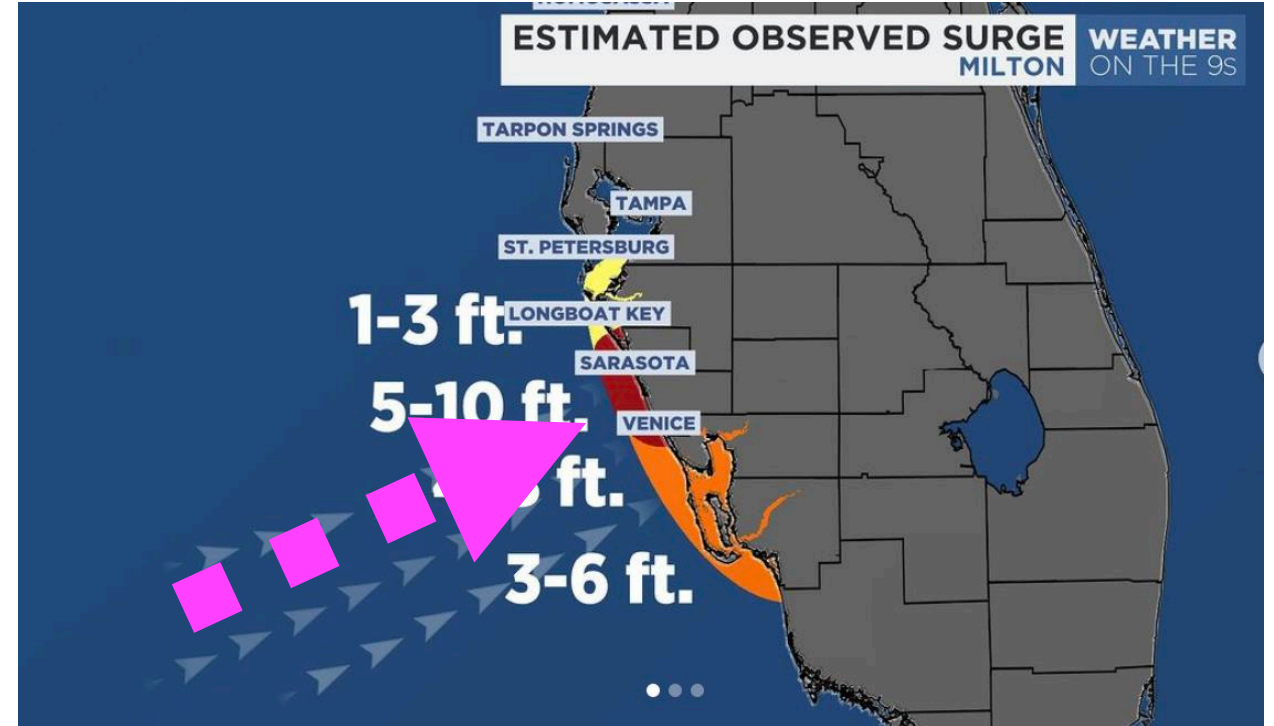
Hazards: rainfall

Rainfall from Hurricane Milton

Precipitation forecast from 6am to noon on Thursday*

Tallahassee

Jacksonville

Atlantic Ocean

Rainfall in inches, six-hour period

2   4   6   8   10   12

5am Thursday local time

Orlando

Tampa

Sarasota

Path of Hurricane Milton

Miami

Charleston

Savannah

Montgomery

Mobile

Tallahassee

Jacksonville

Orlando

Tampa Bay

Miami

Key West
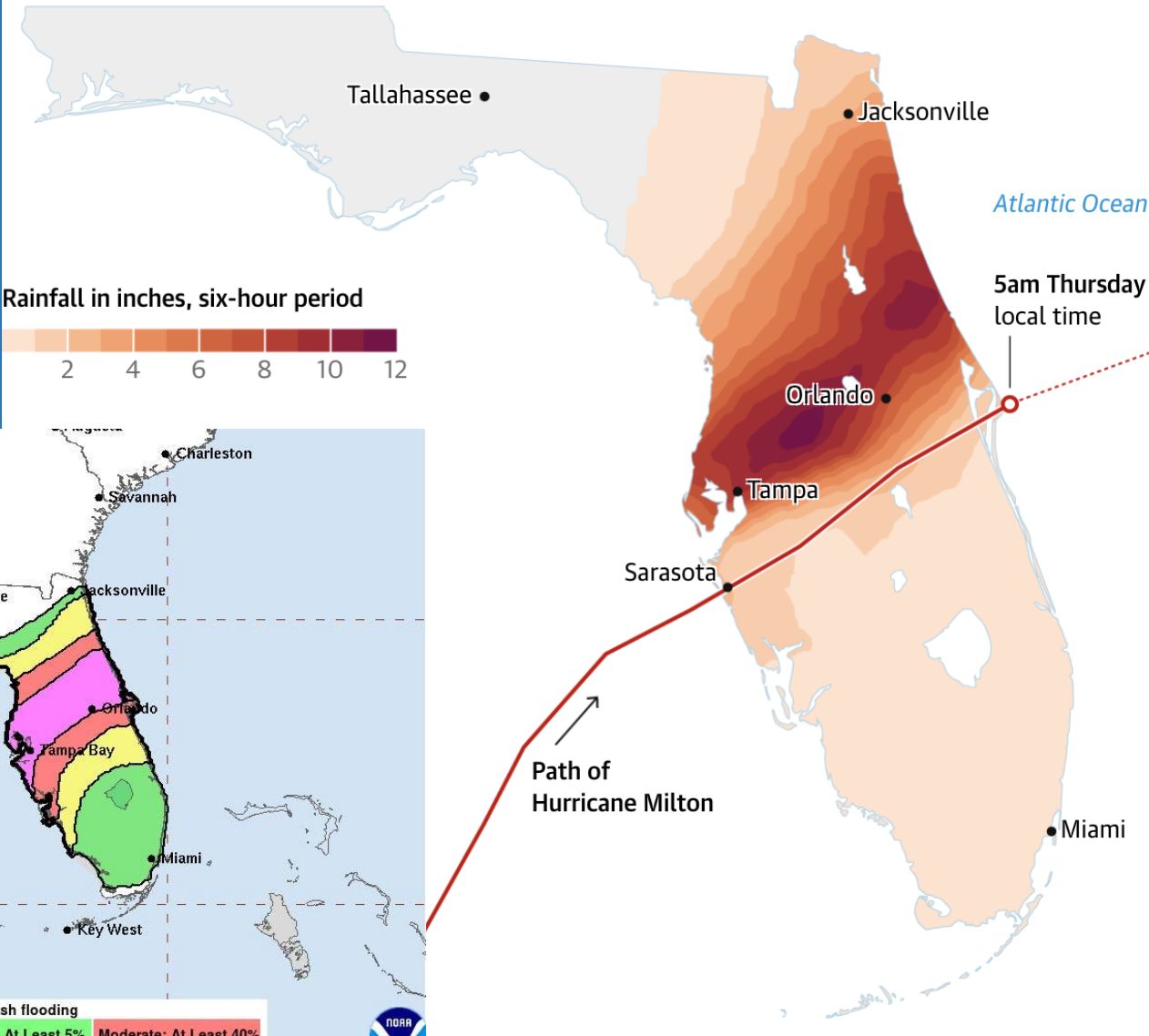
Hurricane Milton
Day 1-3 Excessive Rainfall Outlook
Created 4:20 AM EDT Wed Oct 9 2024
Valid 8:00 AM EDT Wed Oct 9 2024

Risk of flash flooding
Marginal: At Least 5%   Moderate: At Least 40%

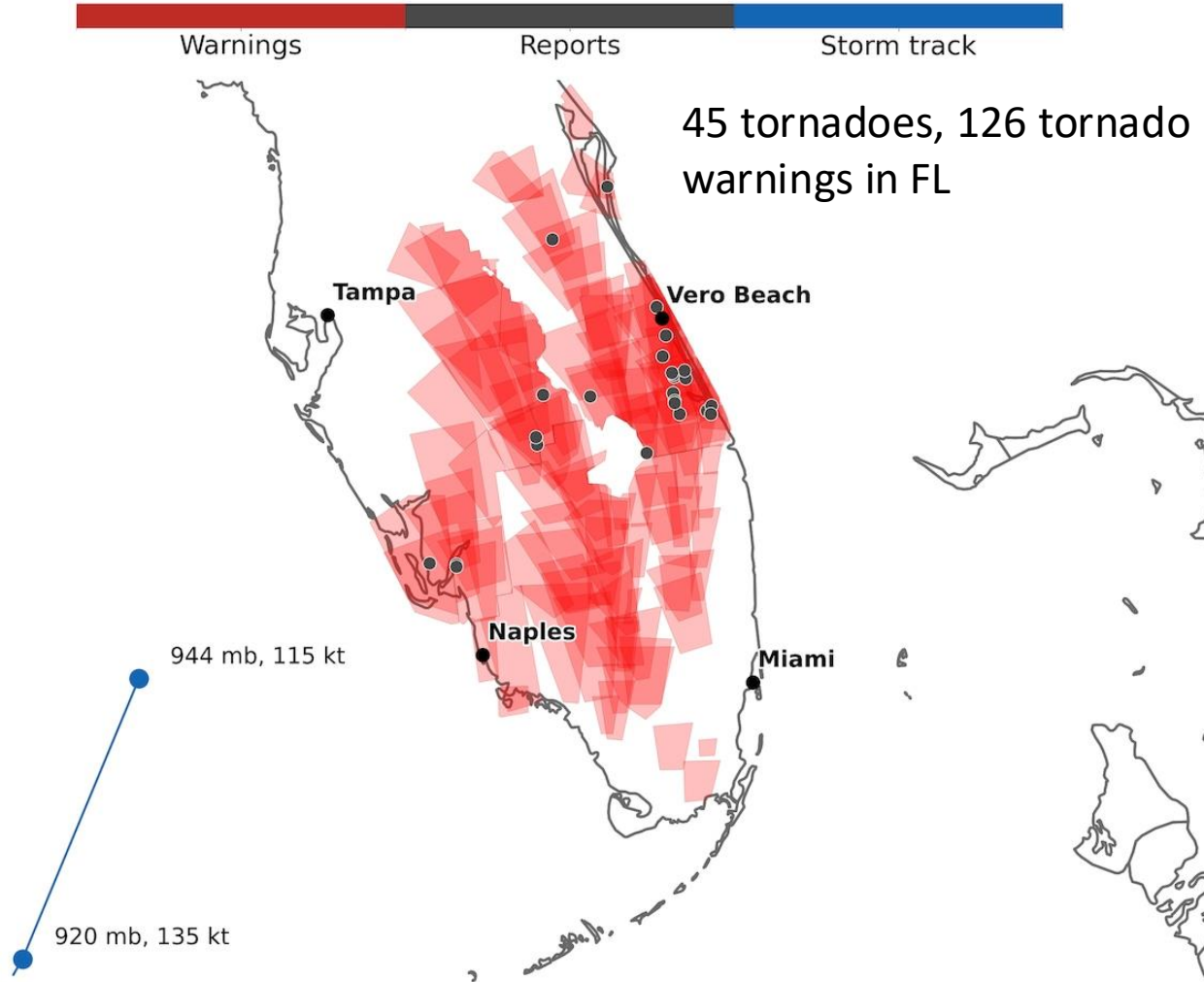Guardian graphic. Source: NOAA, forecast made at 6am ET.

Lightning Milton
https://www.youtube.com/watch?v=4f2xS4cEdNc

Milton notable 1: especially intense tornadoes (2 EF3s)

Tornado warnings and reports with Hurricane Milton

Warnings | Reports | Storm track

Tampa

Vero Beach

45 tornadoes, 126 tornado warnings in FL
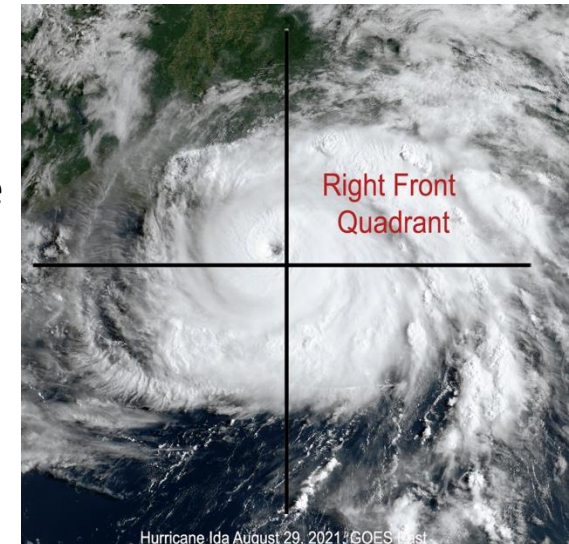
Naples

Miami

944 mb, 115 kt

920 mb, 135 kt

Source: National Weather Service, Iowa Environmental Mesonet

THE WASHINGTON POST

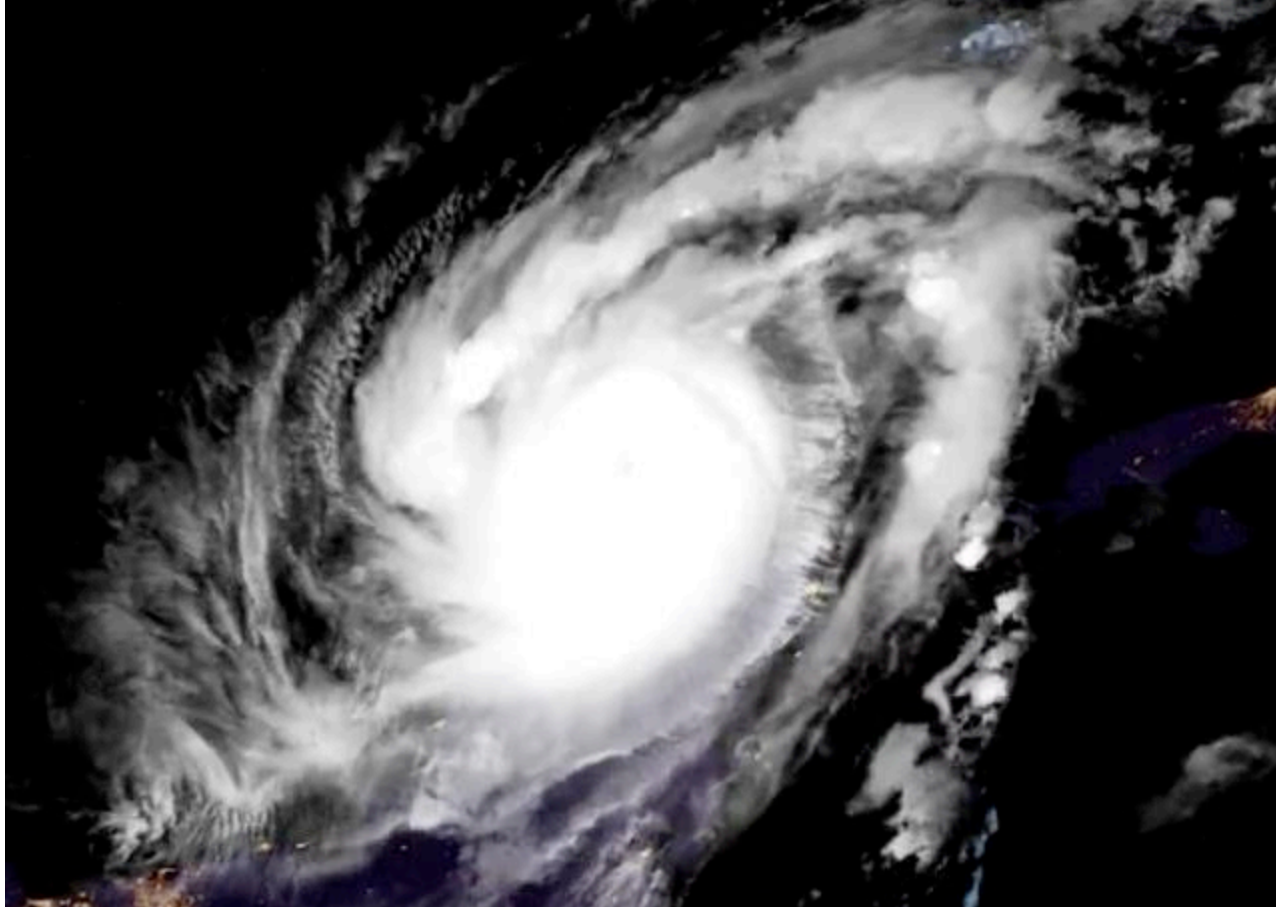https://www.washingtonpost.com/weather/2024/10/09/hurricane-milton-tornadoes-florida/

Morgan Guigon

The Guardian

https://www.theguardian.com/us-news/2024/oct/10/hurricane-milton-maps-charts-graphics-damage

Tornadoes common in right-front quadrant, but usually they are weak (EF0-1)

Right Front Quadrant

Hurricane Ida August 29, 2021, GOES East

https://wxguys.ssec.wisc.edu/2021/09/13/tornadoes-in-hurricanes/

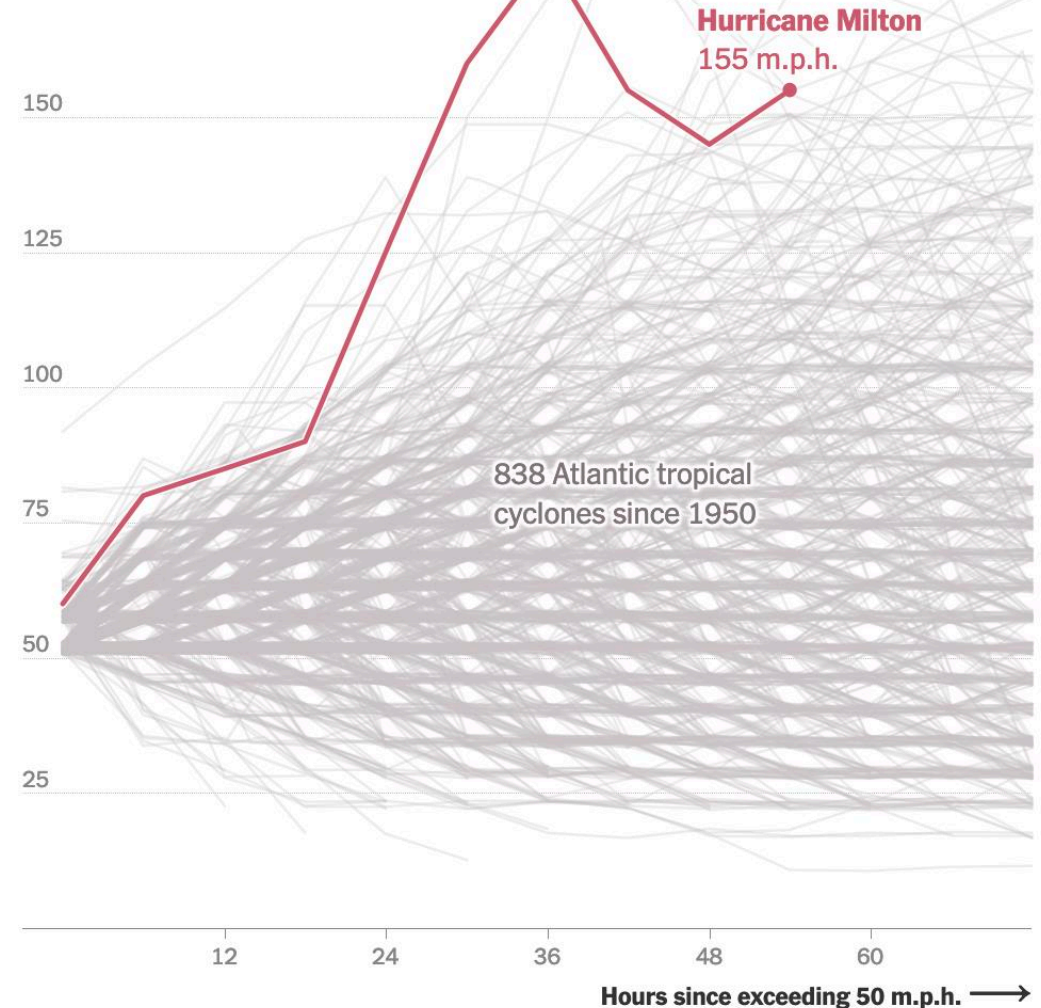# Milton notable 2: among the fastest intensifying storms on record

Hurricane Milton intensified rapidly

Hurricane Milton's wind speeds intensified from 60 m.p.h. to 180 m.p.h. in only 36 hours, among the fastest intensifications on record.

Maximum sustained winds

175 miles per hour

150

125

100

75

50

25

Hurricane Milton
155 m.p.h.

838 Atlantic tropical cyclones since 1950

12   24   36   48   60

Hours since exceeding 50 m.p.h. ⟶

https://www.nytimes.com/2024/10/07/weather/hurricane-milton-forecast-path.html

Source: National Hurricane Center hurricane database

Asheville, NC
09/28/2024
Hurricane Helene

Historic flooding in
Asheville, NC's
Biltmore Village

USA TODAY

https://www.youtube.com/watch?v=IIq3n8geXNk

Tropical Storm Helene
39–73 mph
63–118 km/h

Helene https://www.youtube.com/watch?v=egiZ URLe0E

24 Sep 2024 1650
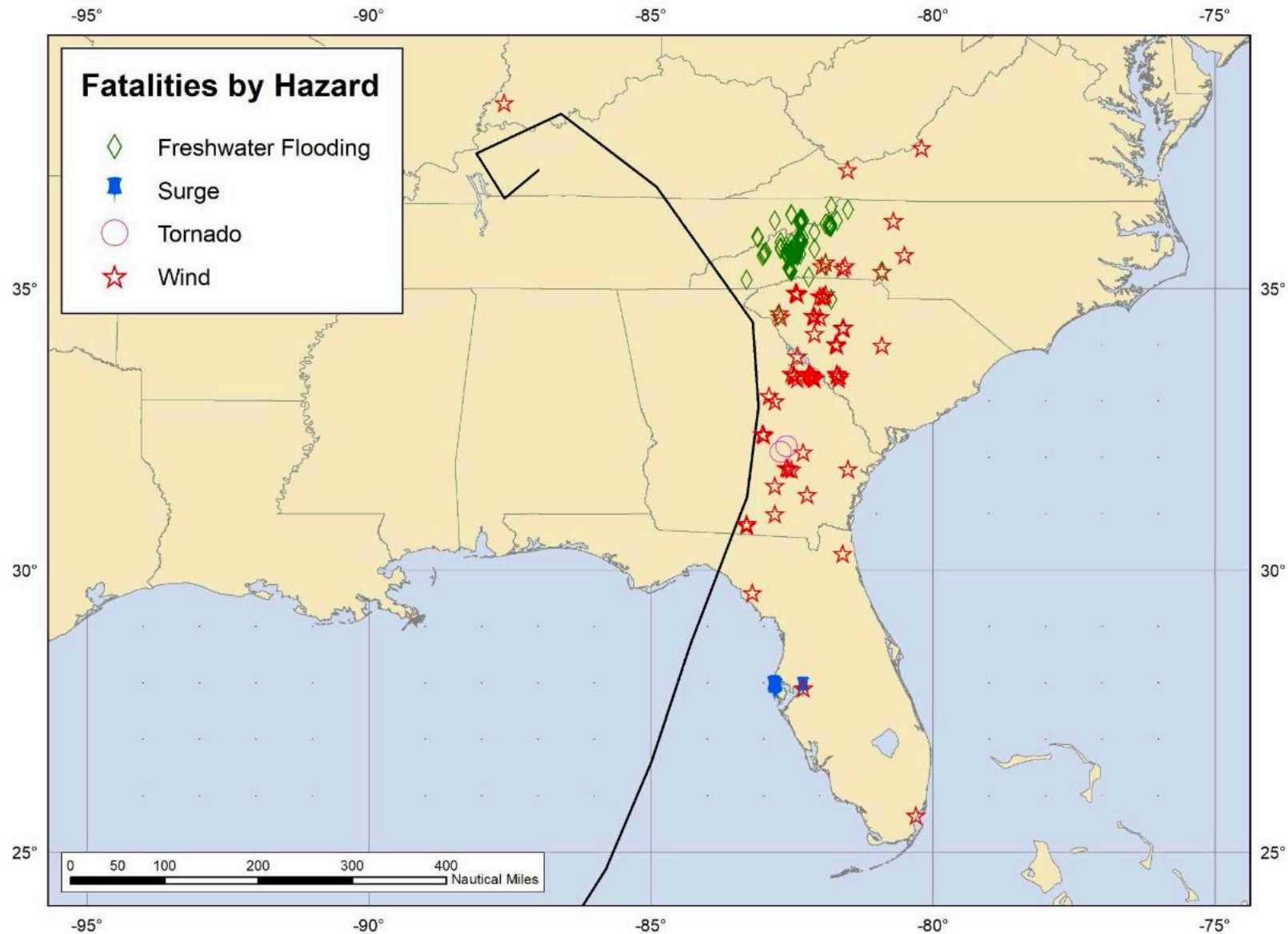
Note: 90% of wind deaths due to fallen trees – wind + wet soil

Rainfall (radar)

Map Center: -84.38, 35.71

Base Reflectivity

09/27/2024 05:08 UTC

dBZ
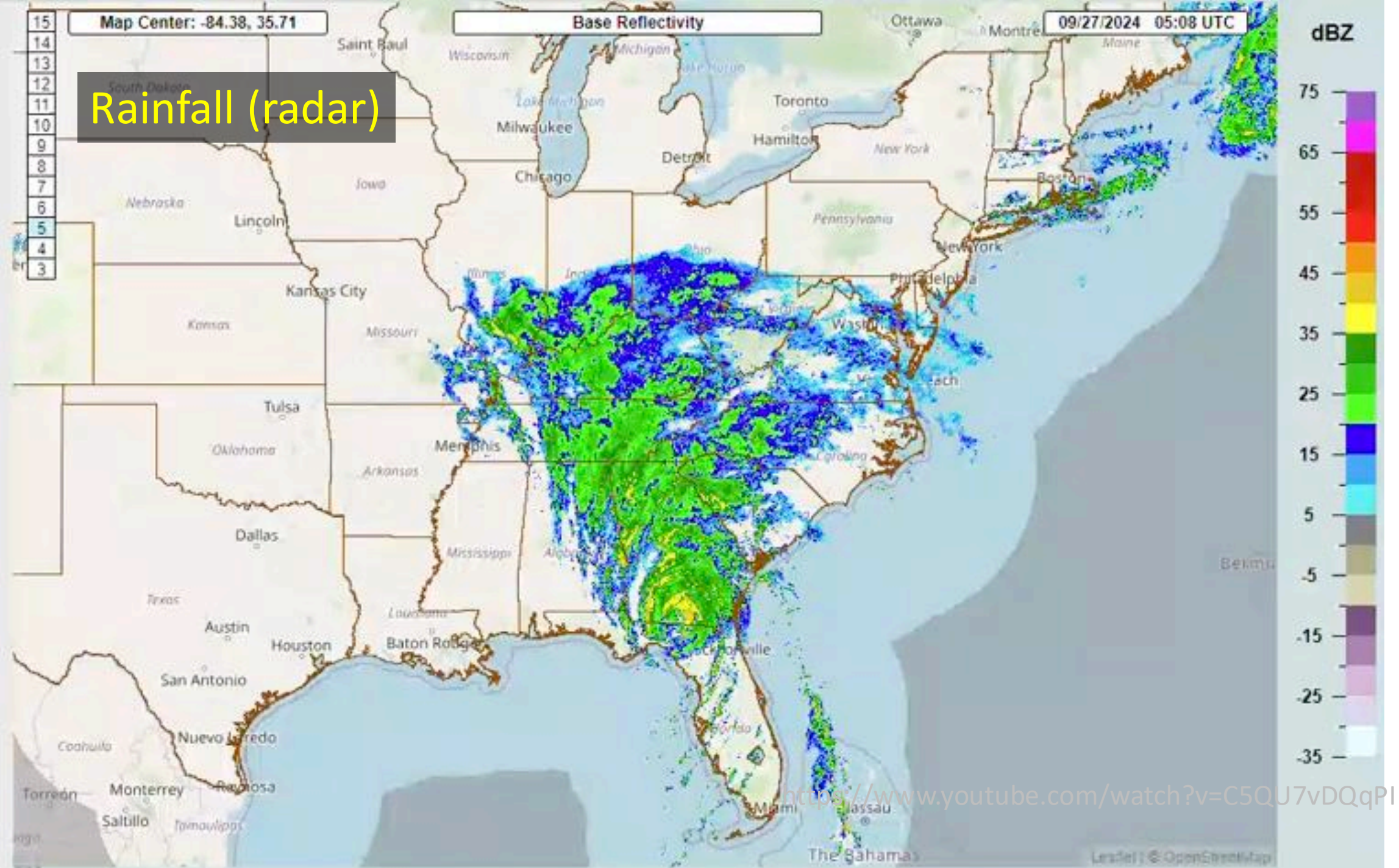
Everything about Helene was also incredibly well forecast -- before the storm had even formed (4 days prior to landfall)

Helene notable 1: rainfall/topography-induced flooding

3-day estimated rainfall
In inches as of Saturday 9 a.m. Eastern
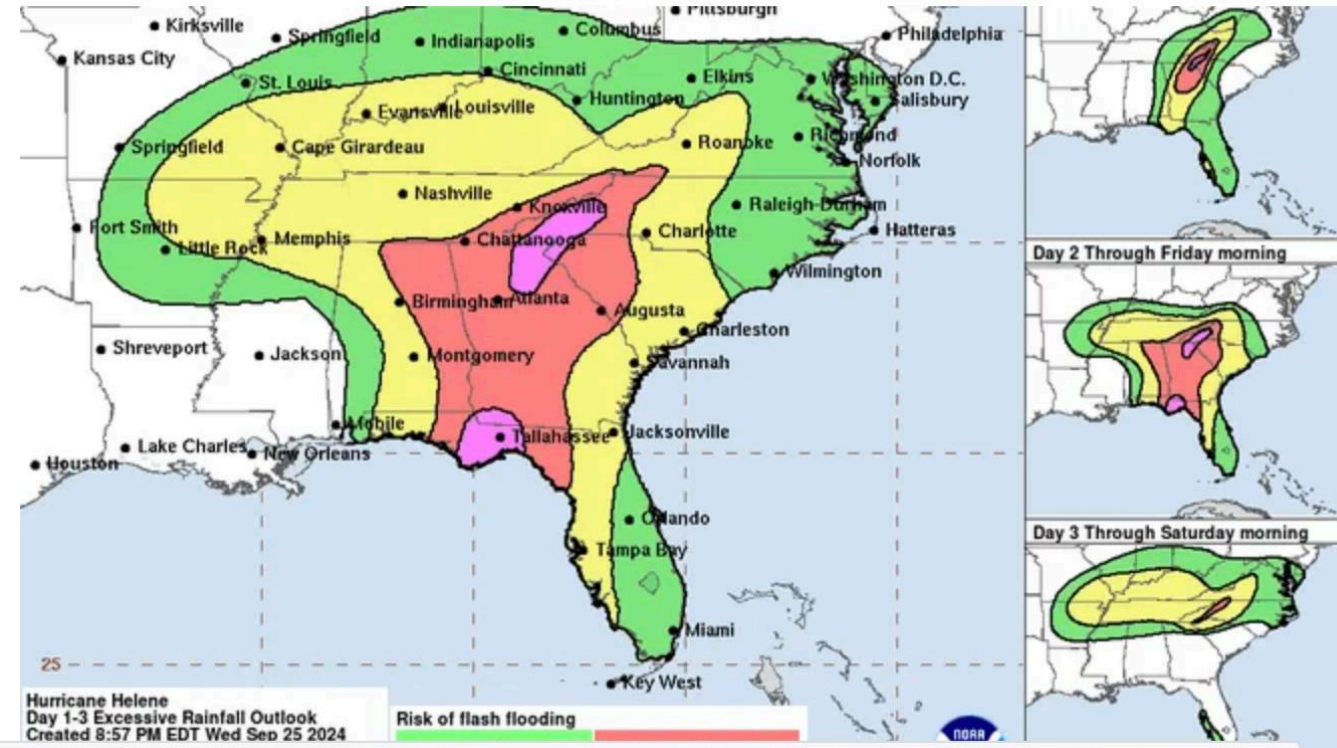
6   12   20 in. or more
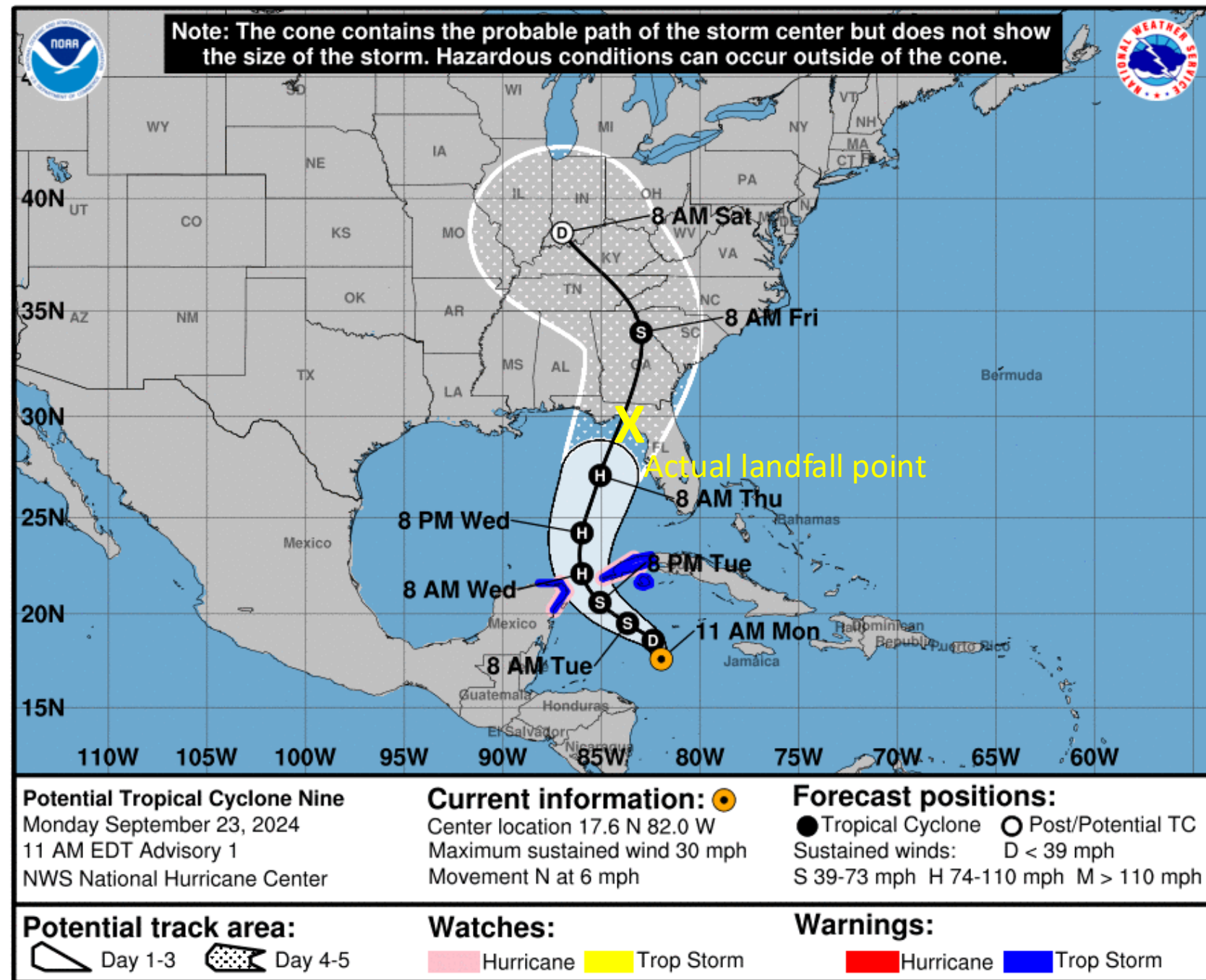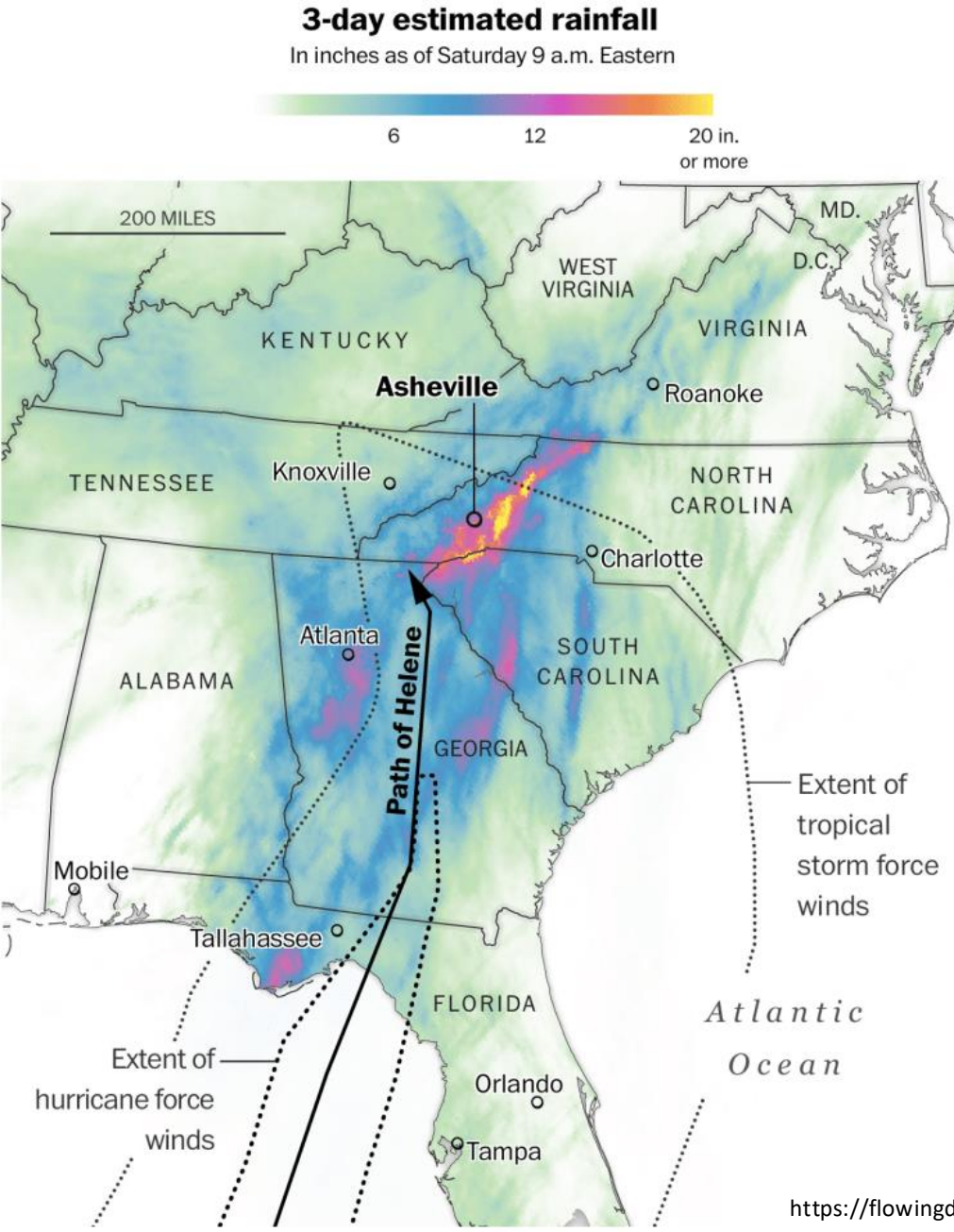
Hurricane Helene's forecast looks disastrous far beyond Florida

Jeanine Santucci
USA TODAY

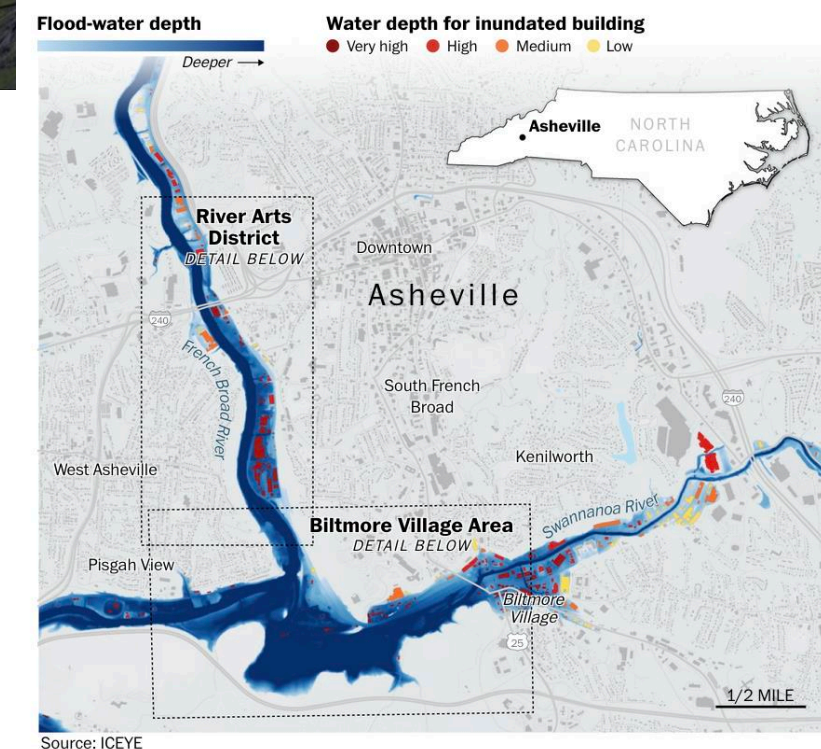Published 1:12 p.m. ET Sept. 26, 2024 | Updated 4:38 p.m. ET Sept. 26, 2024

Hurricane Helene
Day 1-3 Excessive Rainfall Outlook
Created 8:57 PM EDT Wed Sep 25 2024

Risk of flash flooding

Day 2 Through Friday morning

Day 3 Through Saturday morning

https://www.usatoday.com/story/news/nation/2024/09/26/hurricane-helene-flooding-risk-inland/75390418007/

https://flowingdata.com/2024/09/30/helene-rainfall/

Helene notable 1: rainfall/topography-induced flooding

Surrounded by mountains

Asheville

Persistent flow of very moist air pushed by Helene

UPSLOPE WINDS
Rising air cools; moisture is condensed into clouds and rain

HEAVY RAIN

Flood-water depth
Deeper →

Water depth for inundated building
Very high   High   Medium   Low

River Arts District
DETAIL BELOW

Downtown

Asheville

South French Broad

West Asheville

Kenilworth

Pisgah View

Biltmore Village Area
DETAIL BELOW

Biltmore Village

1/2 MILE

Source: ICEYE

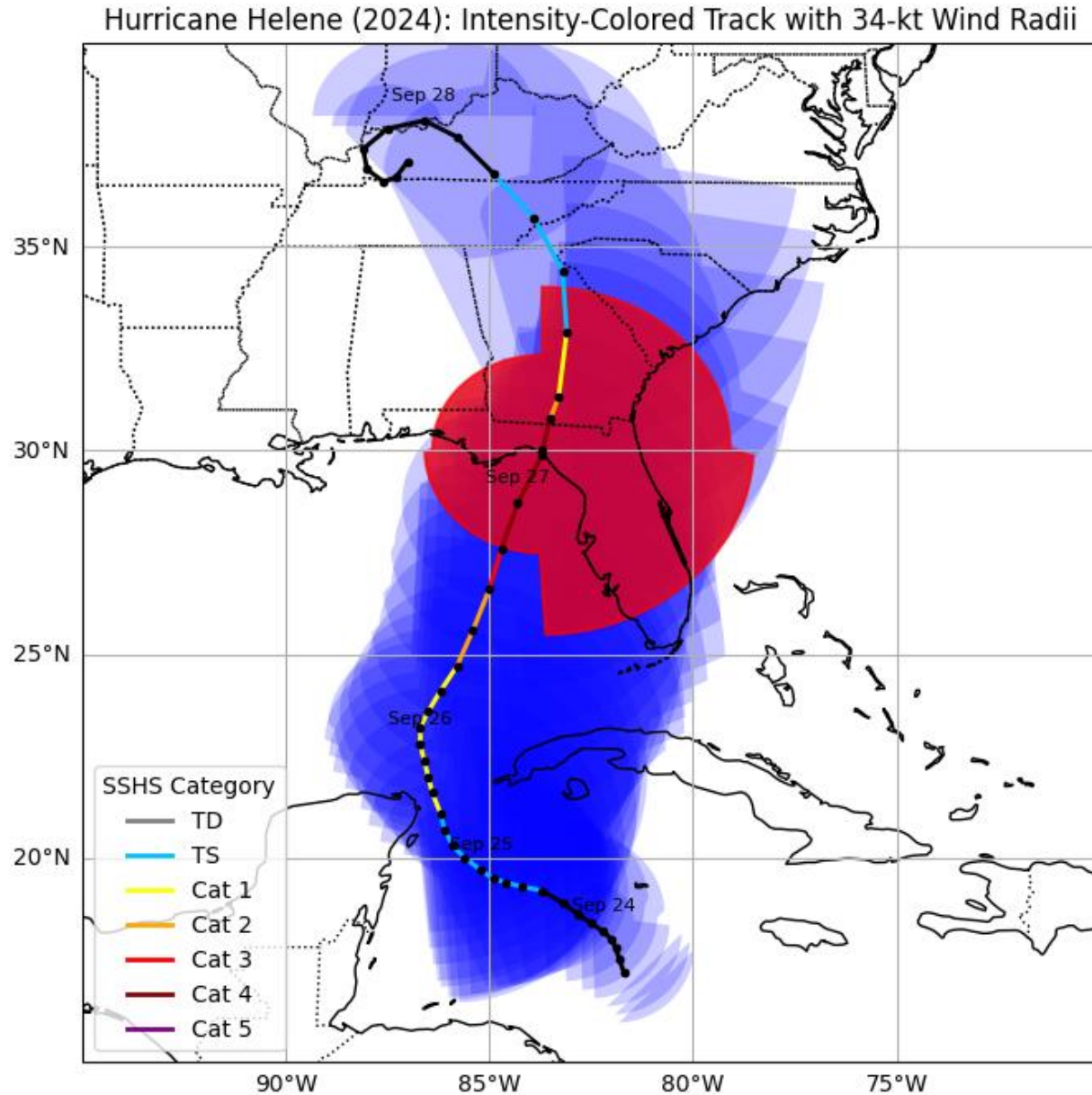# Helene notable 1: rainfall/topography-induced flooding

Not unprecedented -- Great Flood of 1916 in Asheville
Caused by two successive hurricanes

Total Precipitation on July 15-16, 1916
From Climatological Data for the United States by the US Weather Bureau

Precipitation values in inches

Altapass
22.22"

NORTH CAROLINA
CLIMATEOFFICE
@NCSCO

NC EXTREMES
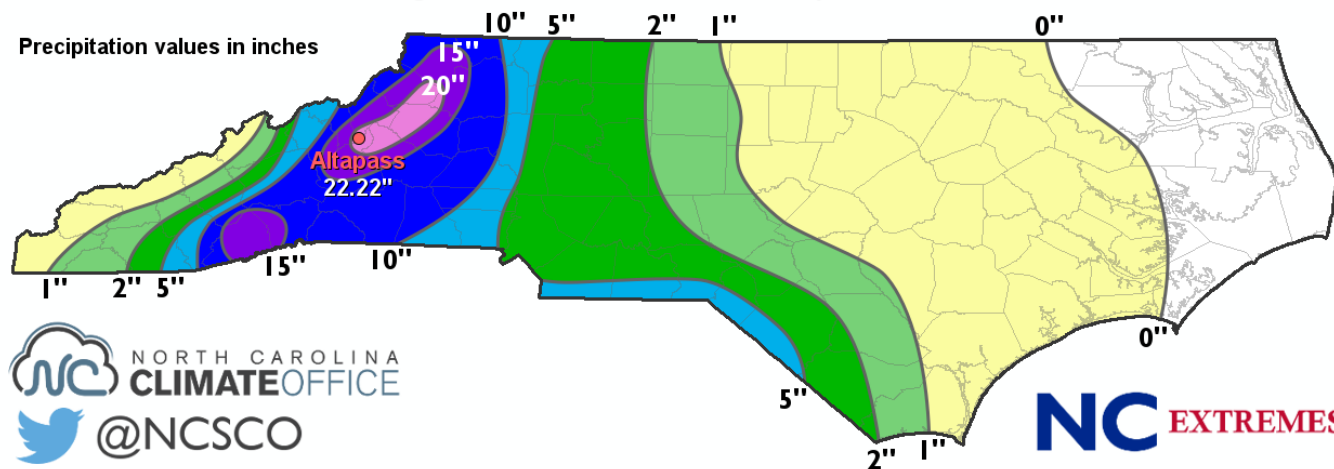
Helene notable 2: expanded rapidly in 1-2 days → very large at landfall

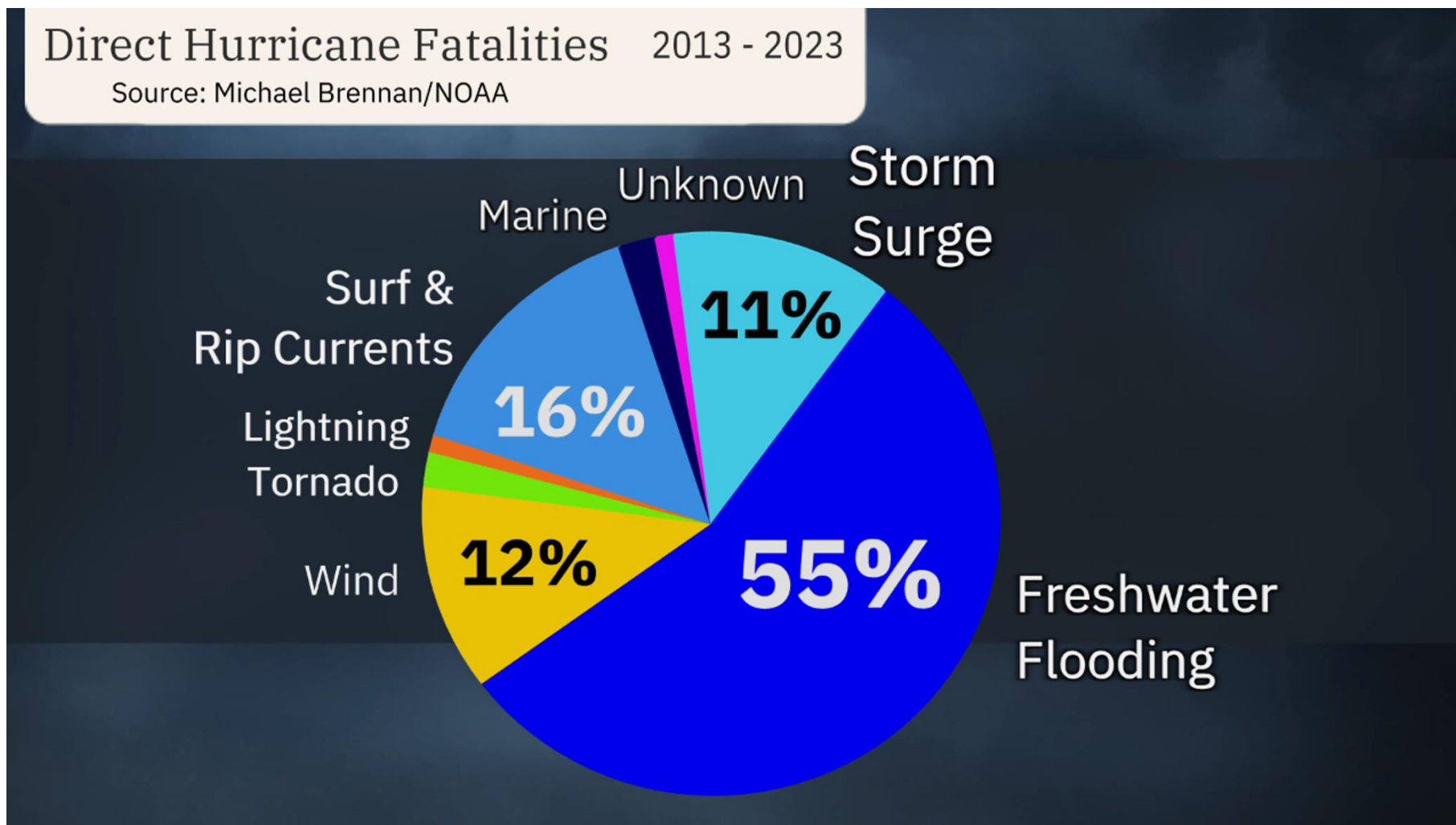Hurricane Helene (2024): Intensity-Colored Track with 34-kt Wind Radii

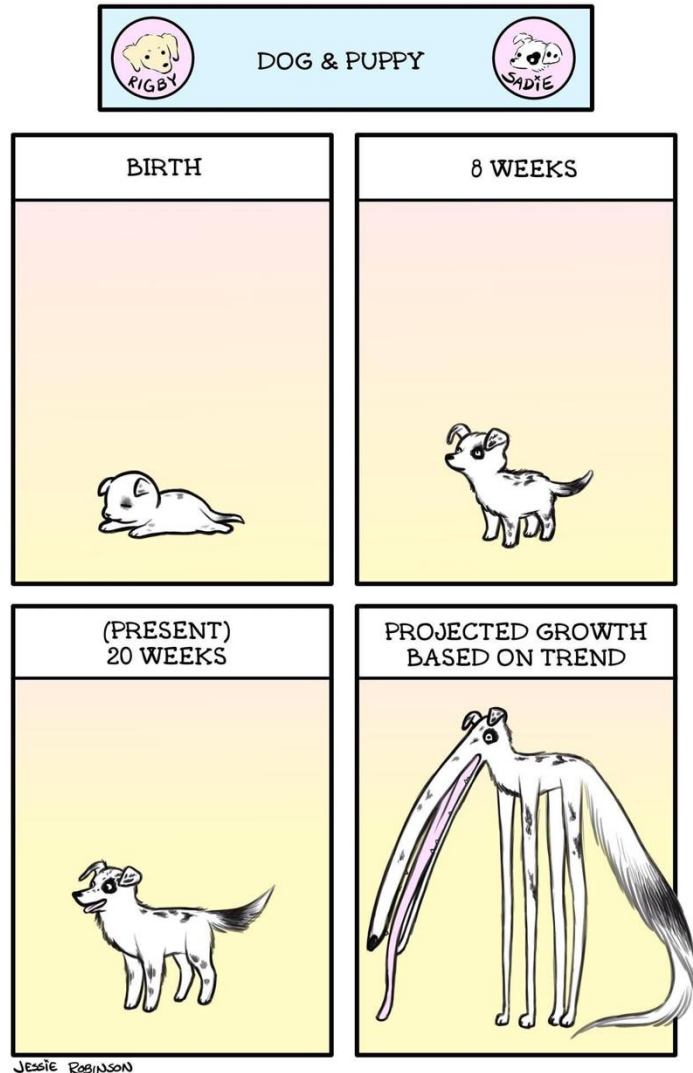This made Helene's wind, surge, and flooding dramatically worse

The near-surface wind field of the tropical cyclones drives its hazards: wind, surge, rain, tornadoes

If we want to model the hazards well, we need to model the wind field as best we can.

Recently inland rainfall has been the big killer

Direct Hurricane Fatalities 2013 - 2023
Source: Michael Brennan/NOAA

- Storm Surge: 11%
- Freshwater Flooding: 55%
- Wind: 12%
- Surf & Rip Currents: 16%
- Lightning
- Tornado
- Marine
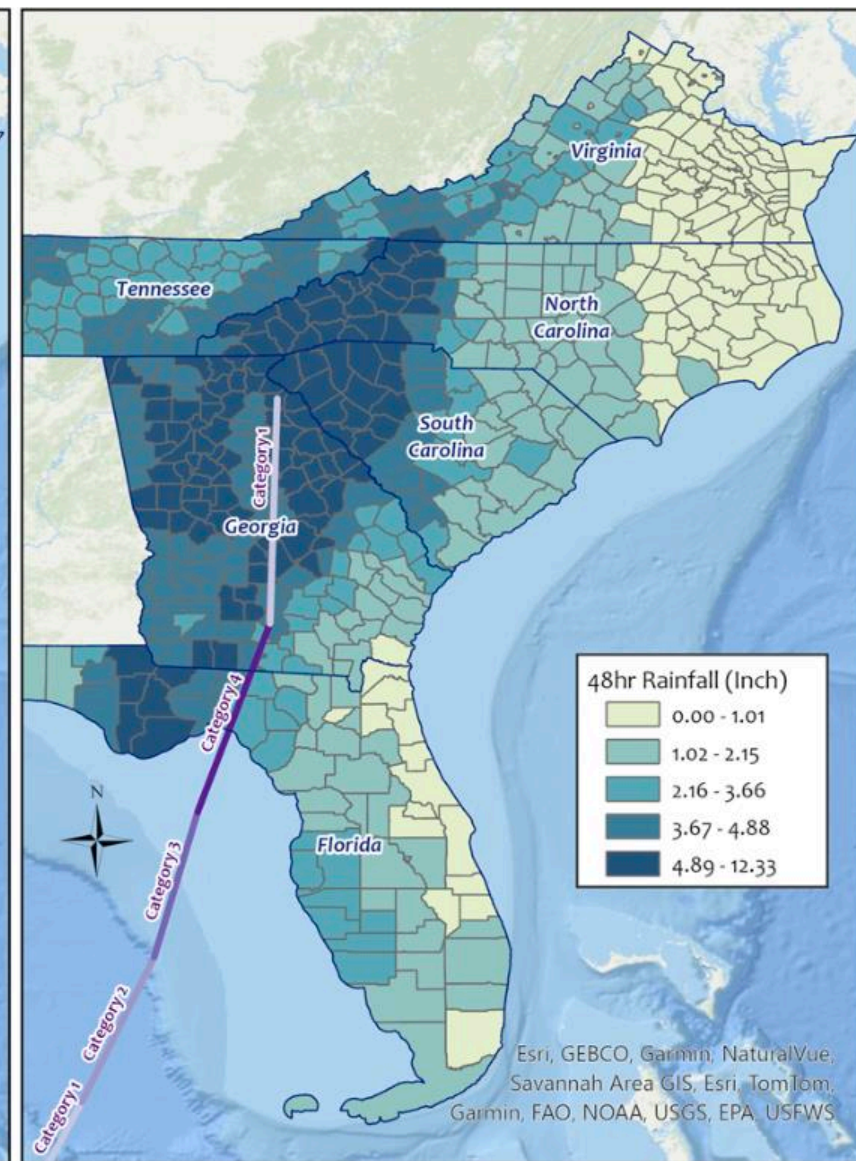- Unknown

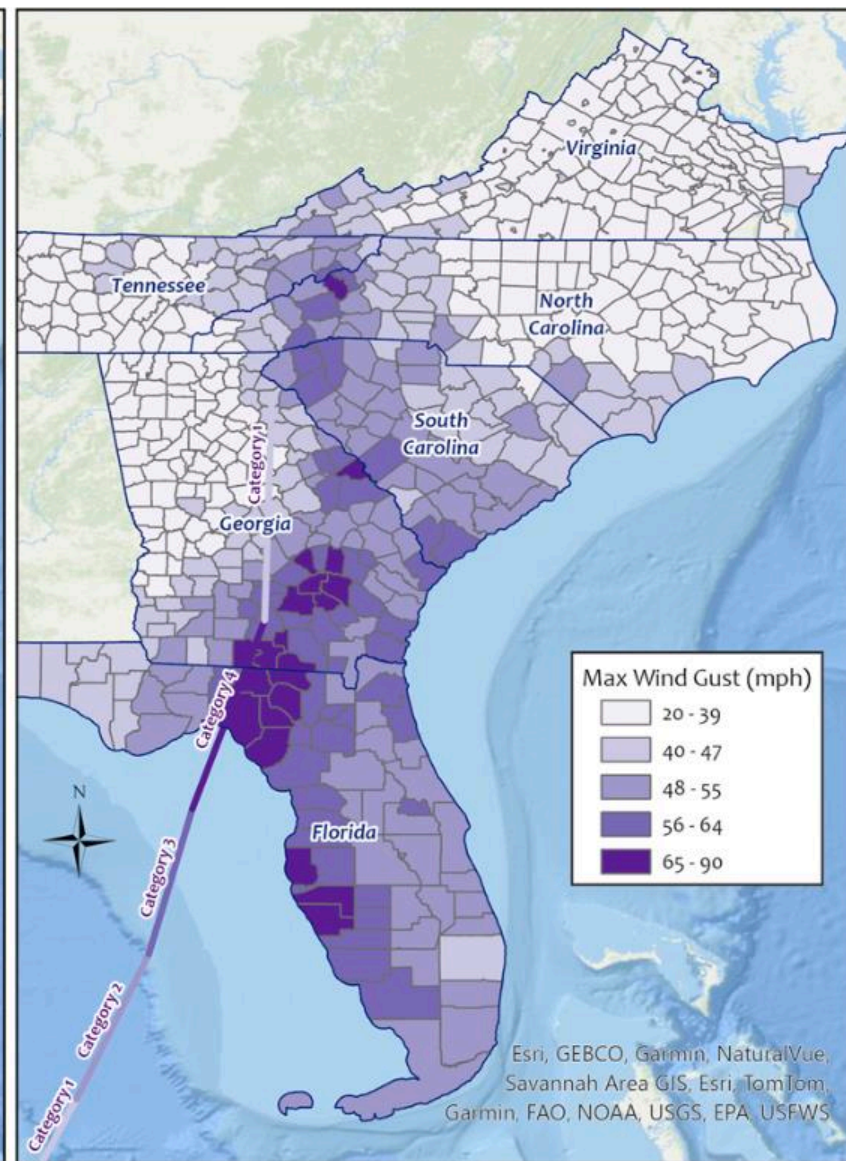# Physics can help us better model the wind field – and thus hazards/impacts
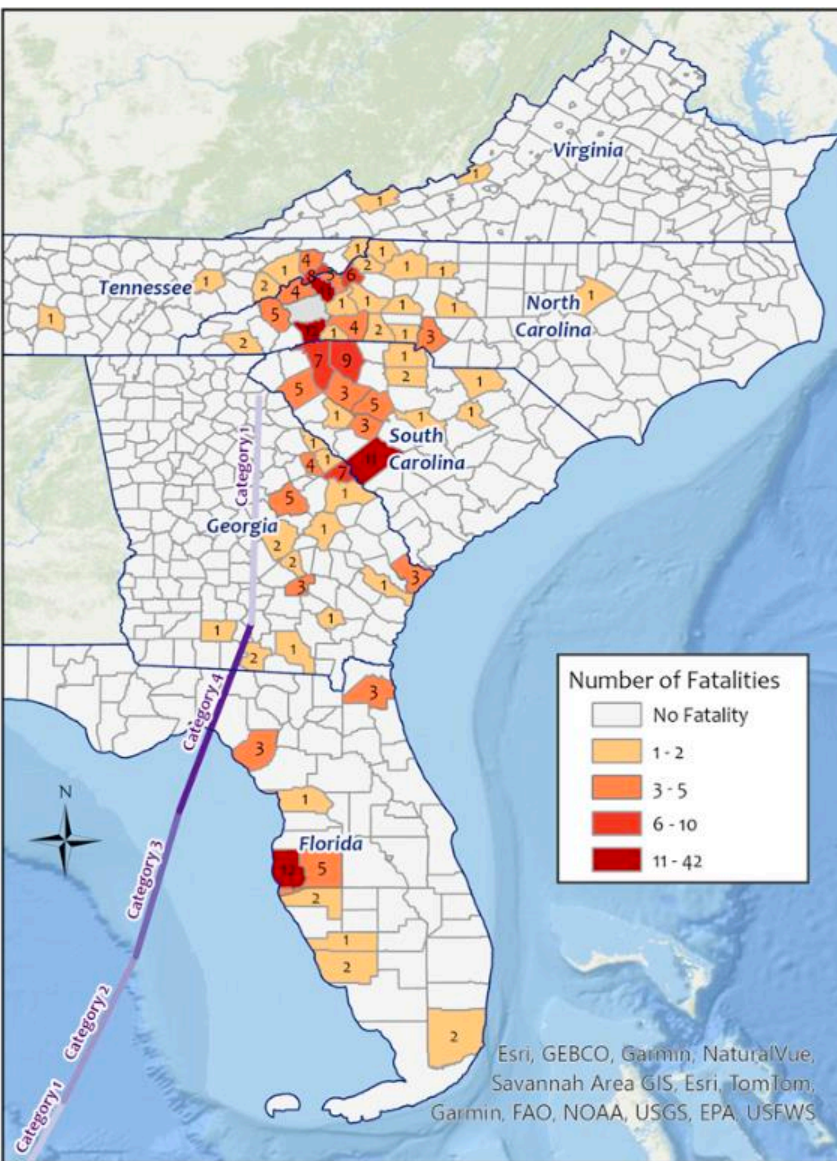

Integrate physics and observations → prediction

Next up: the tropical cyclone wind field

Questions?

EXTRA

Meng et al. (2025, *npj Nat. Haz.*)

Hurricane Helene
September 24-28, 2024
11418 sites

	1-2.99"
	3-4.99"
	5-6.99"
	7-9.99"
	10-14.99"
	15-19.99"
	20-24.99"
	25-29.99"
	30-30.78"

Maximum: 30.78"
Busick, NC

NHC Final Report Helene (2024)
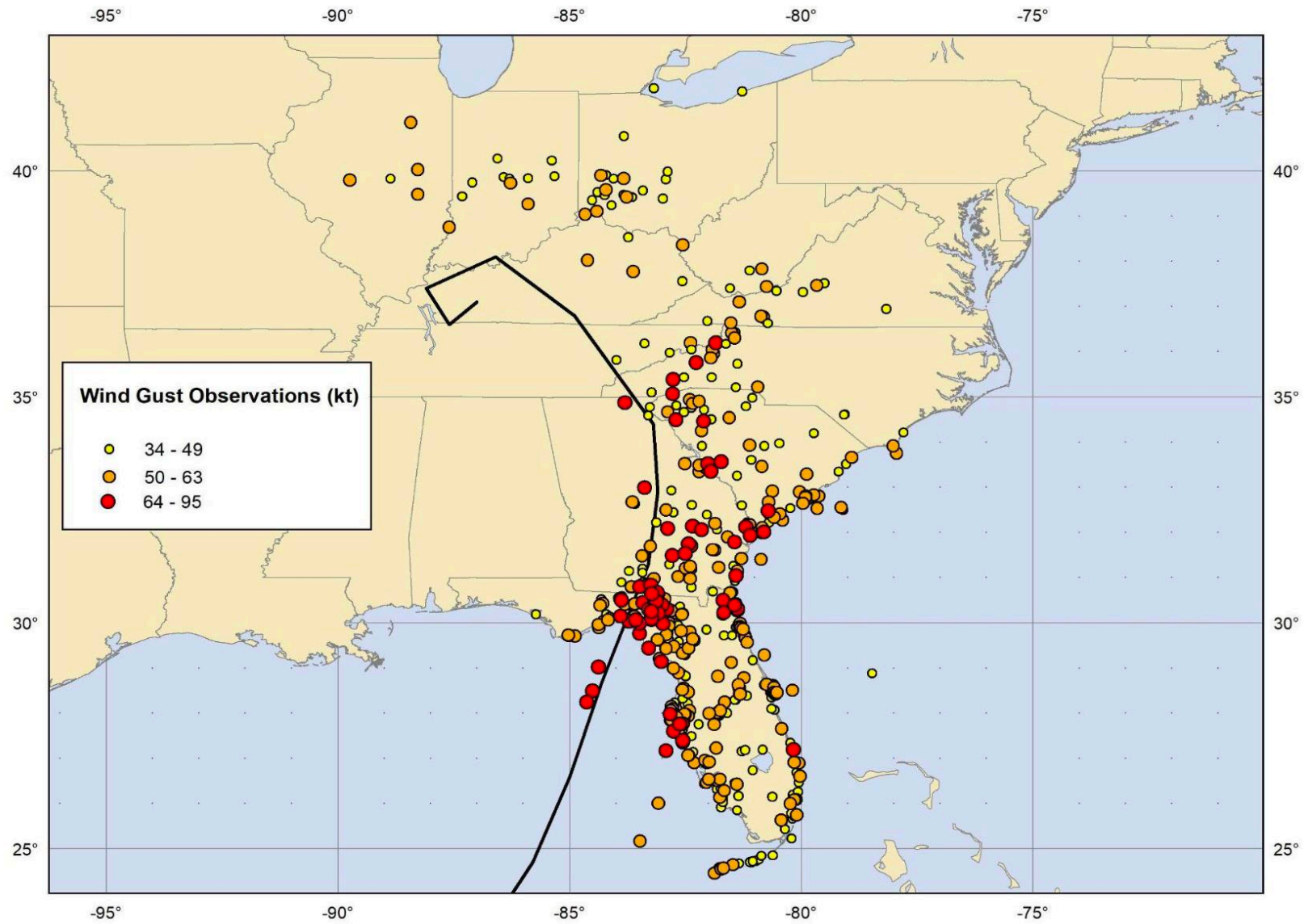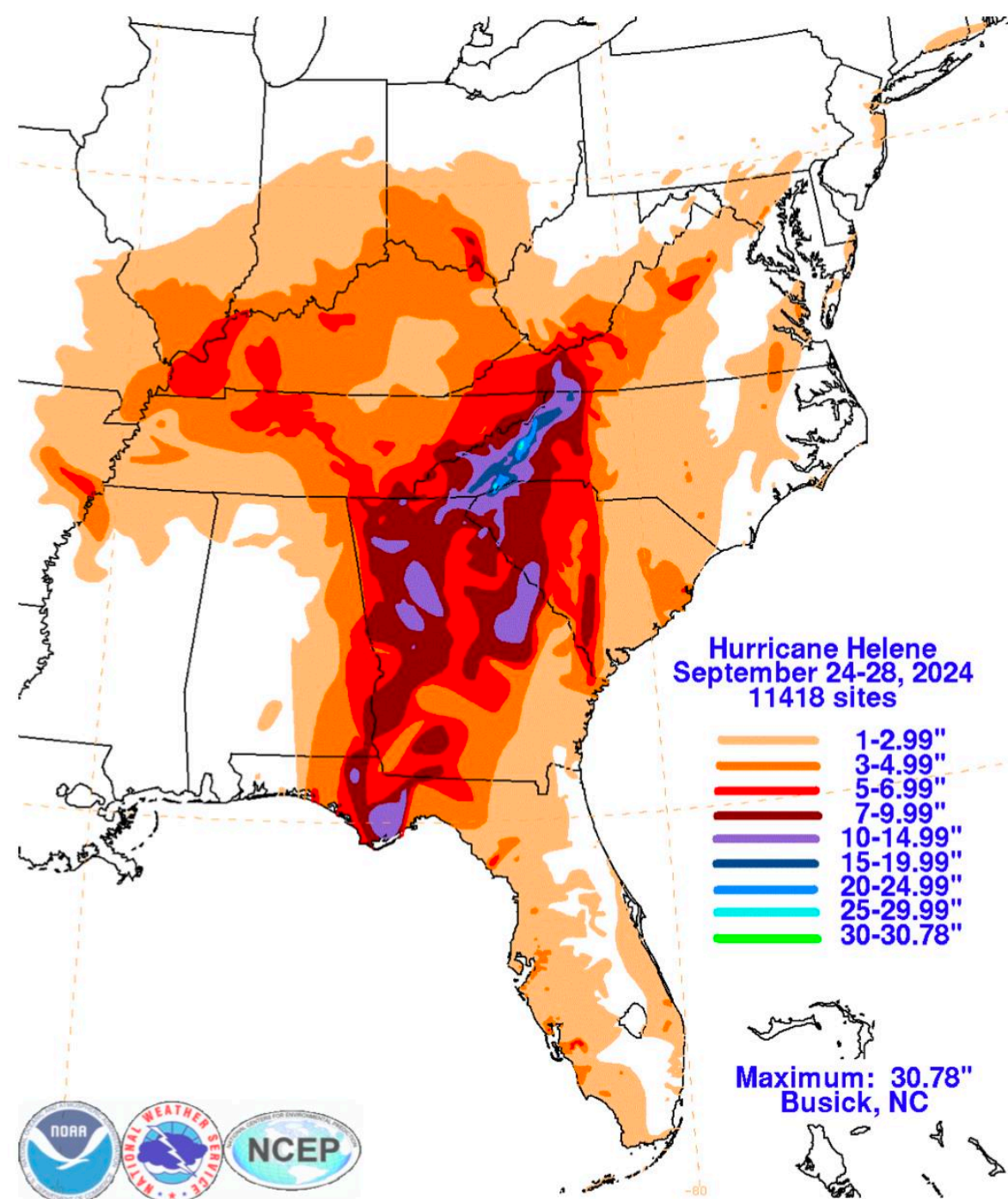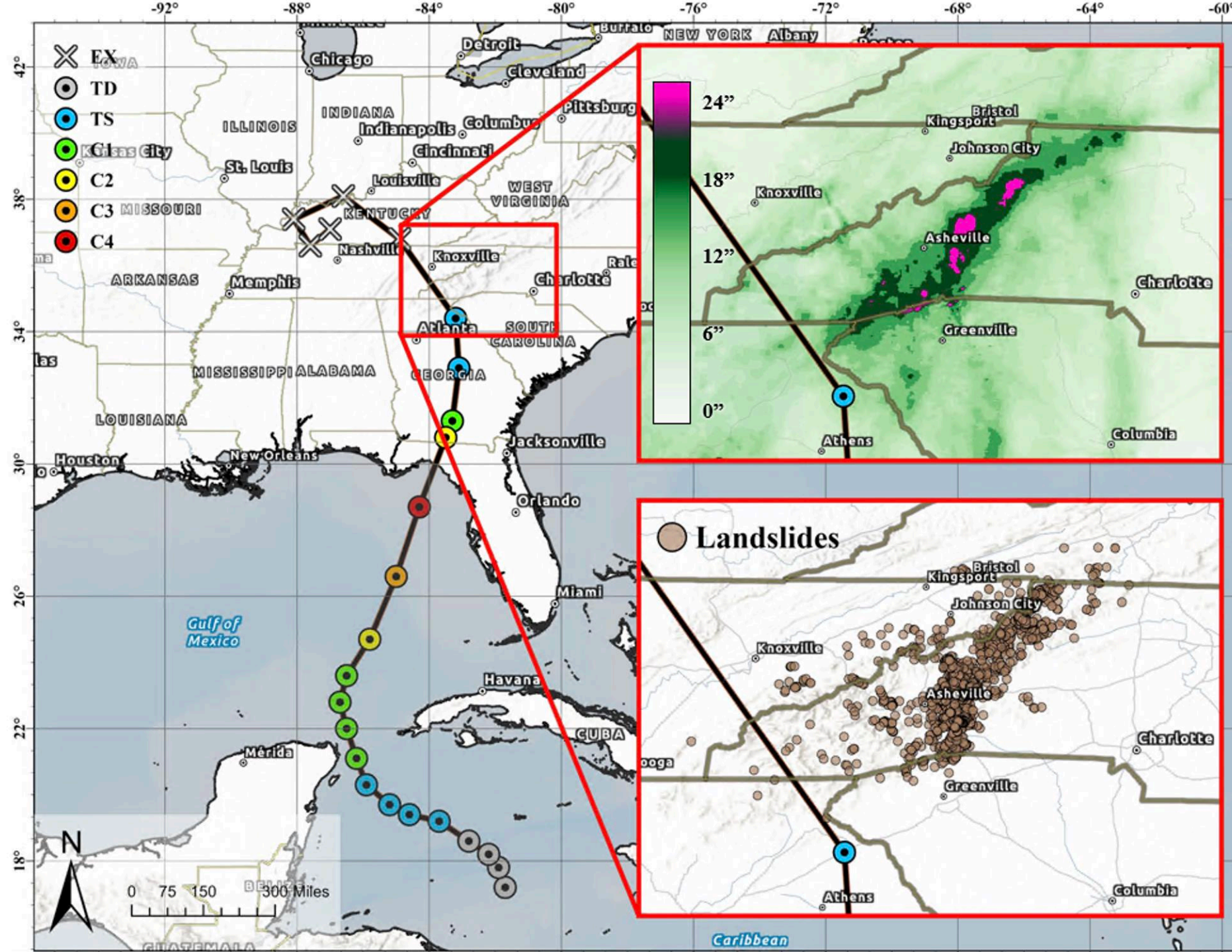
The costliest weather disasters in U.S. history are mostly caused by hurricanes

Ranked by CPI-adjusted economic damage

Also the two deadliest

Event	Type	Begin Date	End Date	CPI-Adjusted Estimated Cost (in Billions)	Deaths
Hurricane Katrina *August 2005*	Tropical Cyclone	Aug 25, 2005	Aug 30, 2005	$195.0	1,833
Hurricane Harvey *August 2017*	Tropical Cyclone	Aug 25, 2017	Aug 31, 2017	$155.0	89
Hurricane Ian *September 2022*	Tropical Cyclone	Sep 28, 2022	Sep 30, 2022	$116.3	152
Hurricane Maria *September 2017*	Tropical Cyclone	Sep 19, 2017	Sep 21, 2017	$111.6	2,981
Hurricane Sandy *October 2012*	Tropical Cyclone	Oct 30, 2012	Oct 31, 2012	$86.5	159
Hurricane Ida *August 2021*	Tropical Cyclone	Aug 29, 2021	Sep 1, 2021	$82.4	96
Hurricane Irma *September 2017*	Tropical Cyclone	Sep 6, 2017	Sep 12, 2017	$62.0	97
Hurricane Andrew *August 1992*	Tropical Cyclone	Aug 23, 1992	Aug 27, 1992	$58.9	61
U.S. Drought/Heat Wave *Summer 1988*	Drought	Jun 1, 1988	Aug 31, 1988	$53.0	454
Midwest Flooding *Summer 1993*	Flooding	Jun 27, 1993	Aug 15, 1993	$45.1	48
Hurricane Ike *September 2008*	Tropical Cyclone	Sep 12, 2008	Sep 14, 2008	$42.0	112
U.S. Drought/Heat Wave	Drought	Jan 1, 2012	Dec 31, 2012	$40.5	123

https://www.ncei.noaa.gov/access/billions/events/US/1980-2024?disasters[]=all-disasters

Hurricanes continue to kill people

U.S. hurricane deaths 2000-2024

Annual Hurricane Fatalities in the U.S. (2000–2024)

Katrina (>1400 deaths)

2024 (324 deaths)
Helene (251)
+ Beryl (44)
+ Debby (18)
+ Milton (11)