Weather Research and Forecasting model (WRF) simulation of the extreme rainfall event of April 12, 2023 in the Fort Lauderdale area

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Outline

- Overview of the April 12, 2023 event
- Overview of the Weather Research and Forecasting Model (WRF)
- WRF simulation of the April 12, 2023 event

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Overview of the April 12, 2023 event

- NOAA / National Weather Service website reviews the Fort Lauderdale event, April 12, 2023.

https://storymaps.arcgis.com/stories/55cf948a0bfe40509fb261203a160427

Fort Lauderdale Extreme Rainfall and Flooding Event

A review of the historic rainfall and flooding event that occurred around Fort Lauderdale beginning April 12, 2023.

National Weather Service Miami, FL
June 26, 2023

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A Deep Analysis Of The South Florida Floods And 4 Key Takeaways

Marshall Shepherd  Senior Contributor

Apr 14, 2023, 10:23am EDT

Listen to article  9 minutes

FORT LAUDERDALE, FLORIDA - APRIL 13: Planes sit at their gates after the Fort Lauderdale-Hollywood ... [+] GETTY IMAGES
Overview of the April 12, 2023 event

- Rainfall occurred in previous days
- Low pressure in northern Gulf of Mexico
- Warm front moving north across south Florida
  - provides initial lift for warm surface air
- Stationary supercell thunderstorms: rotating updraft
  - 2 tornadoes reported in Broward County (Hollywood, Dania Beach)
Supercell Thunderstorm

- Isolated from other thunderstorms
- Rotating updraft (wind shear)
  - “mesocyclone”
-Torrential rain
- Tornadoes
Weather stations and NEXRAD

- Ft. Lauderdale Beach
- WeatherSTEM
- FAWN 420
- Ft. Lauderdale airport
- S13_R
- NEXRAD Pixels
Weather stations and NEXRAD

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784

- 2-km east of airport
- East side of airport
- West side of airport

7 pm EST (00:00 UTC)
8 pm EST (01:00 UTC)
Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784 and WeatherSTEM

2-km east of airport

east side of airport

west side of airport

7 pm EST (00:00 UTC)

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Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784 and WeatherSTEM

2-km east of airport
- 7 pm EST (00:00 UTC)

East side of airport
- Sunset (6:43 pm EST)

West side of airport

Hourly rainfall, in inches

Date and Time (EST)

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Warm

Cool

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Dry air can enter into the cloud. Evaporation of water particles into the dry air further cools the cloud.
How quickly a cloud top cools is a proxy for strength of convection
Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784

Hourly rainfall, in inches

Date and Time (EST)

Preliminary Information - Subject to Revision. Not for Citation or Distribution.
GOES Cloud-top temperature at 7:36 pm EST
Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784

Sunset (6:43 pm EST)

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Warm front provides initial lift to start convection.
Weather Research and Forecasting Model

- NOAA/NWS weather forecasting tool
- Simulates the hydrodynamics and thermodynamics of the atmosphere
  - conservation of mass, heat, momentum
  - compressible gases
  - non-hydrostatic mode (convective-permitting)
- Simulates movement of water and heat between the land and atmosphere (Land Surface Model, LSM)

Preliminary Information - Subject to Revision. Not for Citation or Distribution.
Weather Research and Forecast Model

How is rainfall computed?

- “Microphysics scheme”: Thompson scheme
  - Developed for mid-latitude convective, orographic and snowfall conditions
  - Developed for “convective permitting” scales (small grid spacing)
  - Used operationally for weather forecasts

condensation and evaporation

updrafts and downdrafts

advection

drops grow (accretion)

rain
Weather Research and Forecast Model

- **Boundary and initial conditions from global scale model – general circulation model (GCM)**
  - European Centre for Medium-Range Weather Forecasts (ECMWF) Reanalysis Version 5 (ERA5, 30-km, hourly)
    - Wind speed ($u, v$)
    - Water vapor
    - Pressure
    - Air temperature
    - Sea-surface temperature
    - Greenhouse gas concentrations
Weather Research and Forecasting
Model Reanalysis

- Reanalysis of 1975-2020 underway
  - 1-km spatial scale, 1-hour temporal scale
  - Completion in Fall 2024
- January 1, 2022 through April 2023 underway
  - 2021, 2022 simulations completed
  - Will provide for a more in-depth analysis of the April 12, 2023 event --- MS Thesis for a student?
- Provisional WRF reanalysis spanning April 10-13
Fort Lauderdale rainfall, April 12, 2023

- Preliminary results

ERA5 30-km

WRF 4-km

WRF 1-km

- 3 inches per day
- 7 inches per day
- 15 inches per day

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Fort Lauderdale rainfall, April 12, 2023

- Preliminary results

ERA5 30-km

- 3 inches per day

WRF 4-km

- 7 inches per day

WRF 1-km

- 15 inches per day

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
10 pm EST

Hourly precipitation

Soil moisture

Air temperature (10 m)
10 pm EST

Daily total precipitation (7 am – 7 am)

Hourly precipitation

Air temperature (10 m)

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Timing of rainfall

NEXRAD Pixels 10048782, 10048783, 10048784

Hourly rainfall, in inches

Date and Time (EST)

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Timing of rainfall

NEXRAD Pixels 10048782, 10048783, 10048784

10-12 pm EST

Hourly rainfall, in inches

Date and Time (EST)

Preliminary Information - Subject to Revision. Not for Citation or Distribution.
Timing of rainfall

NEXRAD Pixels 10048782, 10048783, 10048784

10-11 pm EST

WRF event:
- 1-2 hours later
- one peak
- 15.1 inches
- 20 km north

Preliminary Information - Subject to Revision. Not for Citation or Distribution.
Surface analysis, 10:00 pm EST

WRF reanalysis for 4/12 at 10:00 pm EST
4/13 03:00 UTC

Surface temperature at Apr 13 03:00UTC in degrees F

Deerfield Beach
Fort Lauderdale
Hollywood
Miami

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Surface analysis, 10:00 pm EST

WRF reanalysis for 4/12 at 10:00 pm EST
4/13 03:00 UTC

Surface temperature at Apr 13 03:00UTC in degrees F

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Surface wind speed and direction

Vertical wind speed

Max windspeed 19.2 m/s

Max windspeed 9.0 m/s

Deerfield Beach

Fort Lauderdale

Hollywood

Miami

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Stronger easterly winds (blows from the east) offshore, compared to onshore.
Converging winds in area of the mesocyclone

Wind vectors converging
Front entered area to provide initial lift of warm surface air

Wind vectors converging

Max windspeed 19.2 m/s

Max windspeed 9.0 m/s

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Pressure:

- 1,013 mb (hPa) is about sea level (average)
- 800 mb is about 7,000 ft asl (2.1 km)
- 500 mb is about 19,000 ft asl (5.8 km)
- 300 mb is about 31,000 ft asl (9.4 km)

Wind speed and direction:

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<th>Speed</th>
<th>calm</th>
<th>5</th>
<th>10</th>
<th>15</th>
<th>20</th>
<th>25</th>
<th>50</th>
<th>55</th>
<th>60</th>
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<tr>
<td>Dir (from):</td>
<td>NA</td>
<td>All blowing from the North</td>
<td>or all towards the South</td>
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<td>Dir (from):</td>
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<td>NW</td>
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Varying wind direction promotes rotation and tornadoes

Preliminary Information-Subject to Revision. Not for Citation or Distribution.
Surface winds from E-NE
300 mb winds from W
800 mb winds from S

Varying wind direction promotes rotation and tornadoes

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Summary points

- April 12, 2023 was a supercell that was stationary over the Fort Lauderdale airport area
  - Two peaks of rainfall
  - Hypothesis: second peak due to cloud-top cooling as sun set
Summary points

- **Reanalysis for April 12 event using**
  - **ERA5 reanalysis**
    - 3 inches per day
  - **WRF at 4 km reanalysis**
    - 7 inches per day
  - **WRF at 1 km reanalysis**
    - 15 inches per day
    - 20 km (12 miles) north of observed
    - 1-2 hrs later than observed -- If timing of simulation changes, could trigger cloud-top cooling and more rain
Summary points

- **Simulating using longer “spin up”**
  - Allows soil moisture to equilibrate
  - MS Thesis: deep analysis of driving factors
- **Simulation of extreme rainfall event possible at 1-km resolution**
  - Increases confidence in possibility of high-resolution models simulating extreme events for future (projected) climate