



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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Caribbean-Florida Water Science Center

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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*

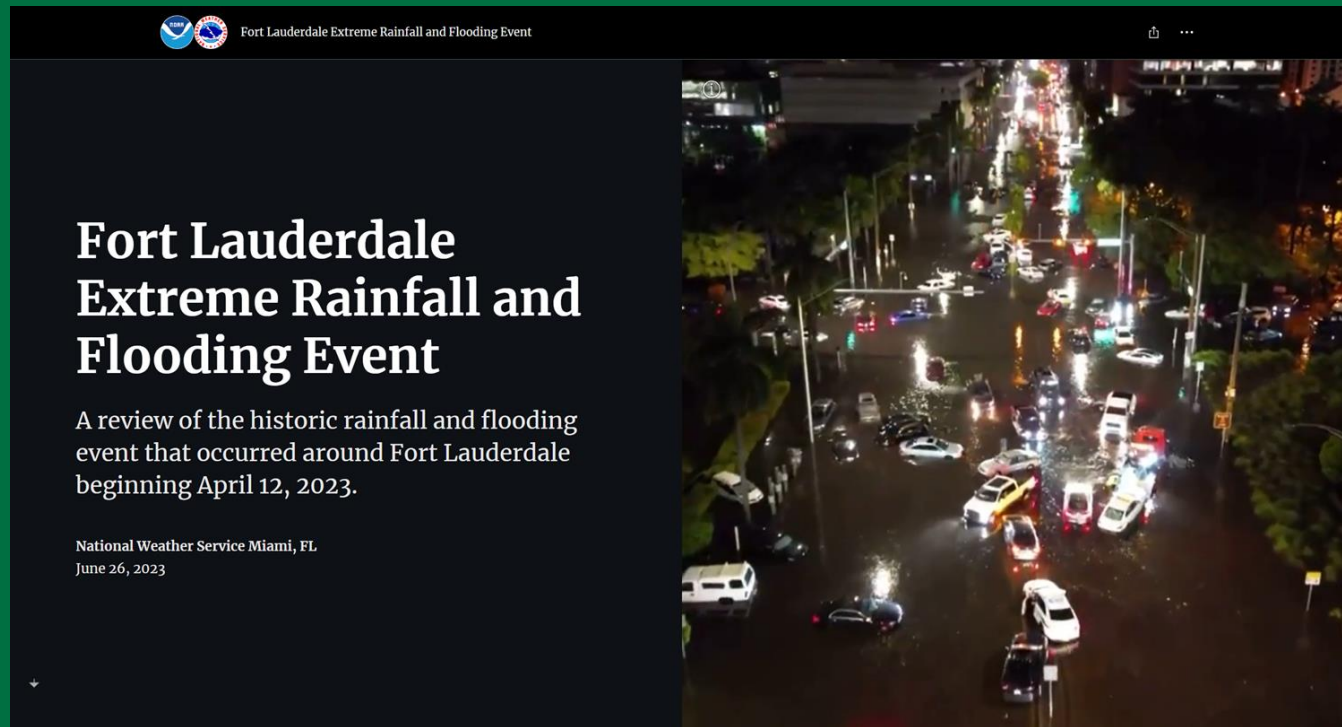


<https://www.forbes.com/sites/marshallshepherd/2023/04/14/a-deep-analysis-of-the-south-florida-floods-and-4-key-takeaways/?sh=7af119dc67ca>

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>



FORBES > INNOVATION > SCIENCE

EDITORS' PICK

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

Marshall Shepherd Senior Contributor 

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Apr 14, 2023, 10:23am EDT



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

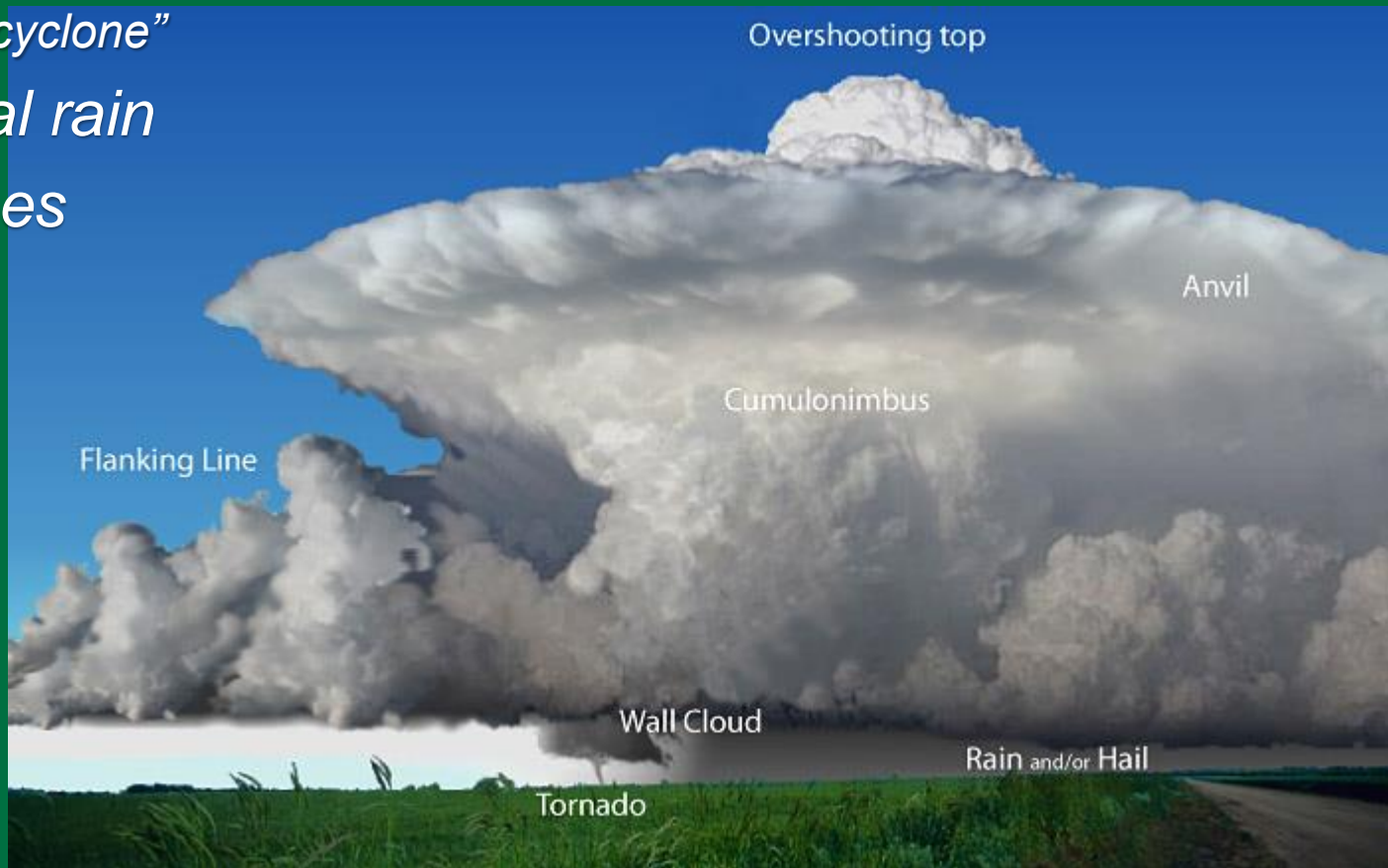


Overview of the April 12, 2023 event

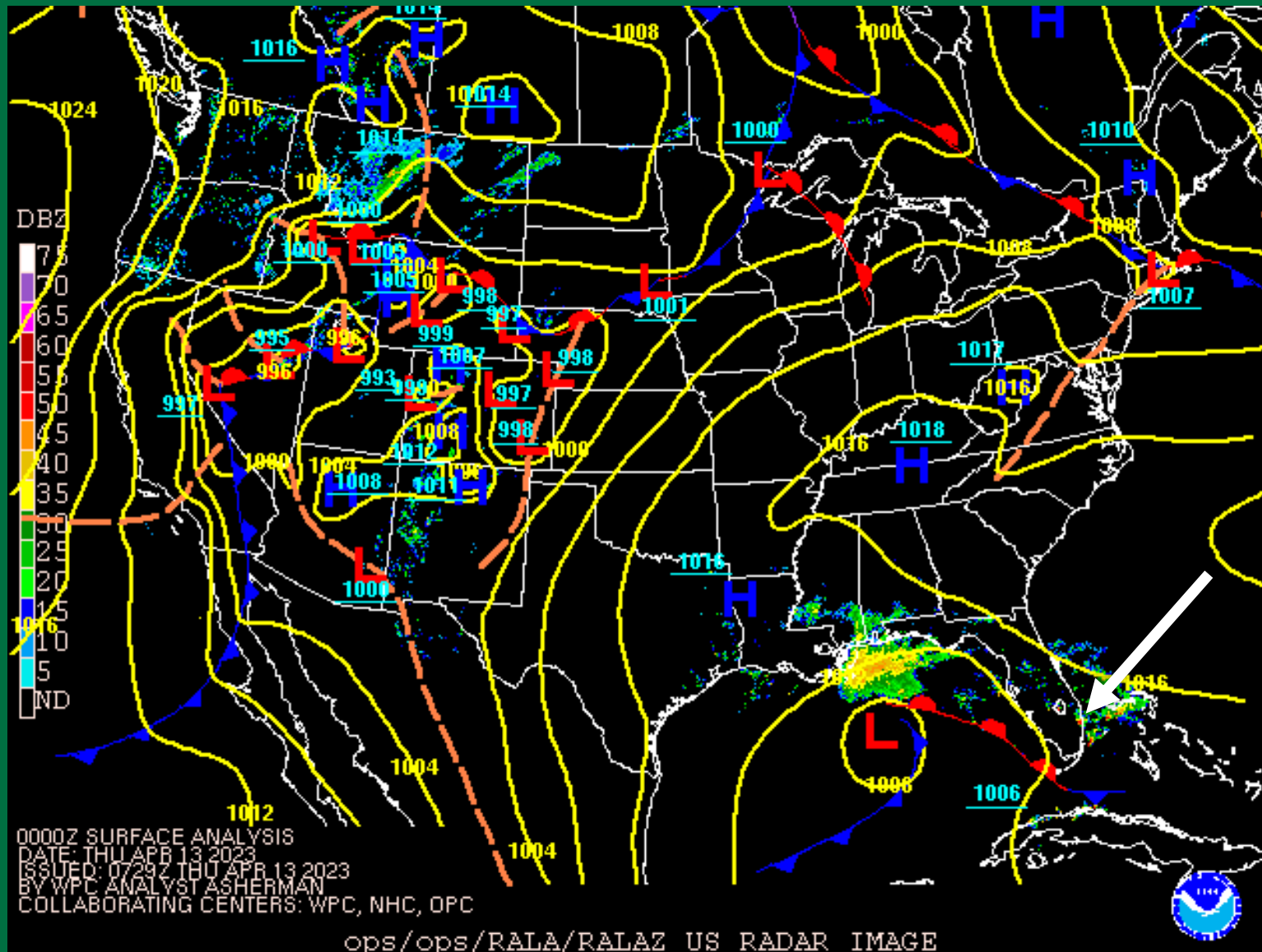
- *Rainfall occurred in previous days*
- *Low pressure in northern Gulf of Mexico*
- *Warm front moving north across south Florida*
 - *provides initial lift for warm surface air*
- *Stationary supercell thunderstorms: rotating updraft*
 - *2 tornadoes reported in Broward County (Hollywood, Dania Beach)*

Supercell Thunderstorm

- *Isolated from other thunderstorms*
- *Rotating updraft (wind shear)*
 - *“mesocyclone”*
- *Torrential rain*
- *Tornadoes*

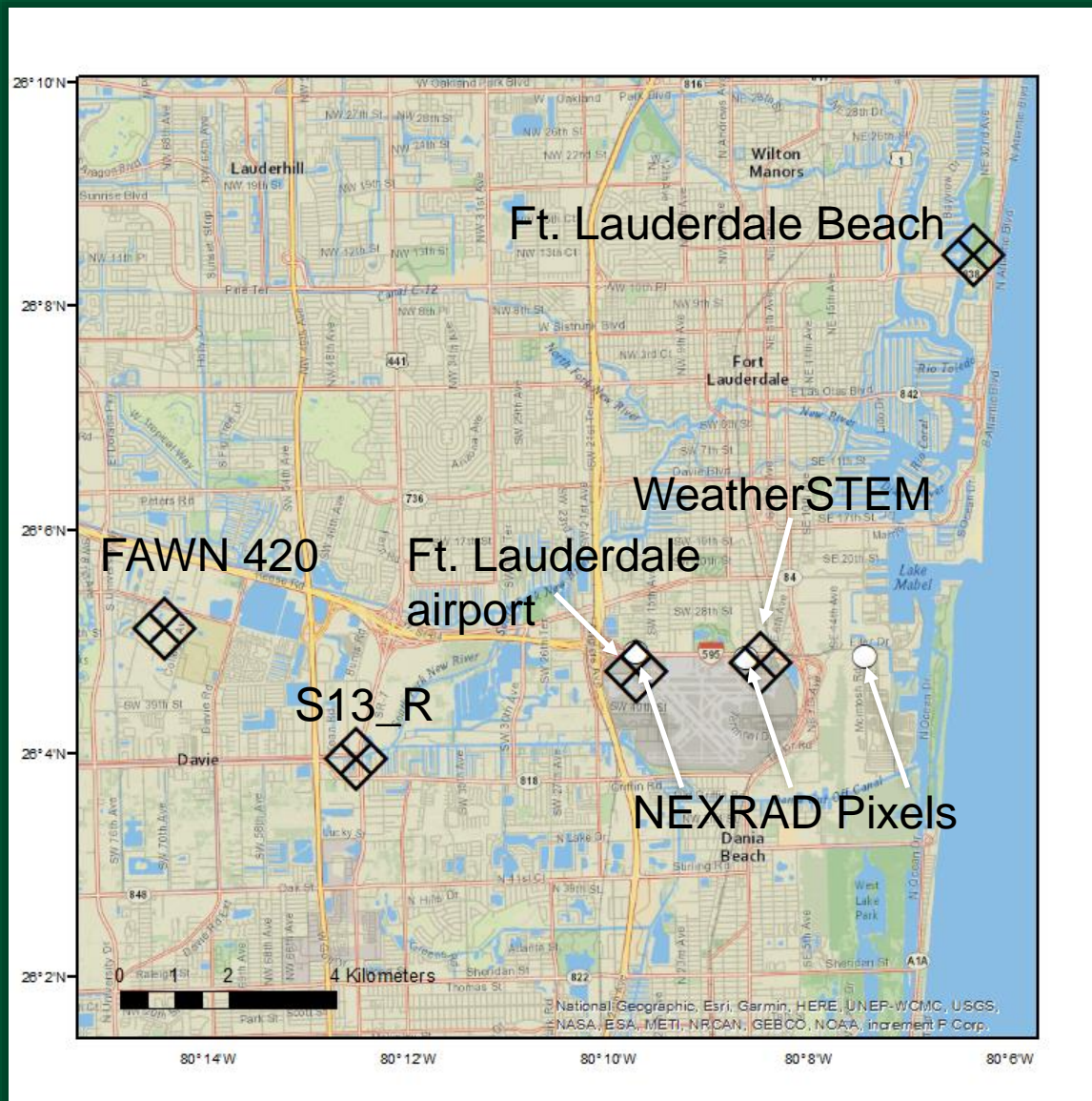


4/13/2023, 00:00 UTC (Zulu); 4/12 19:00 EST

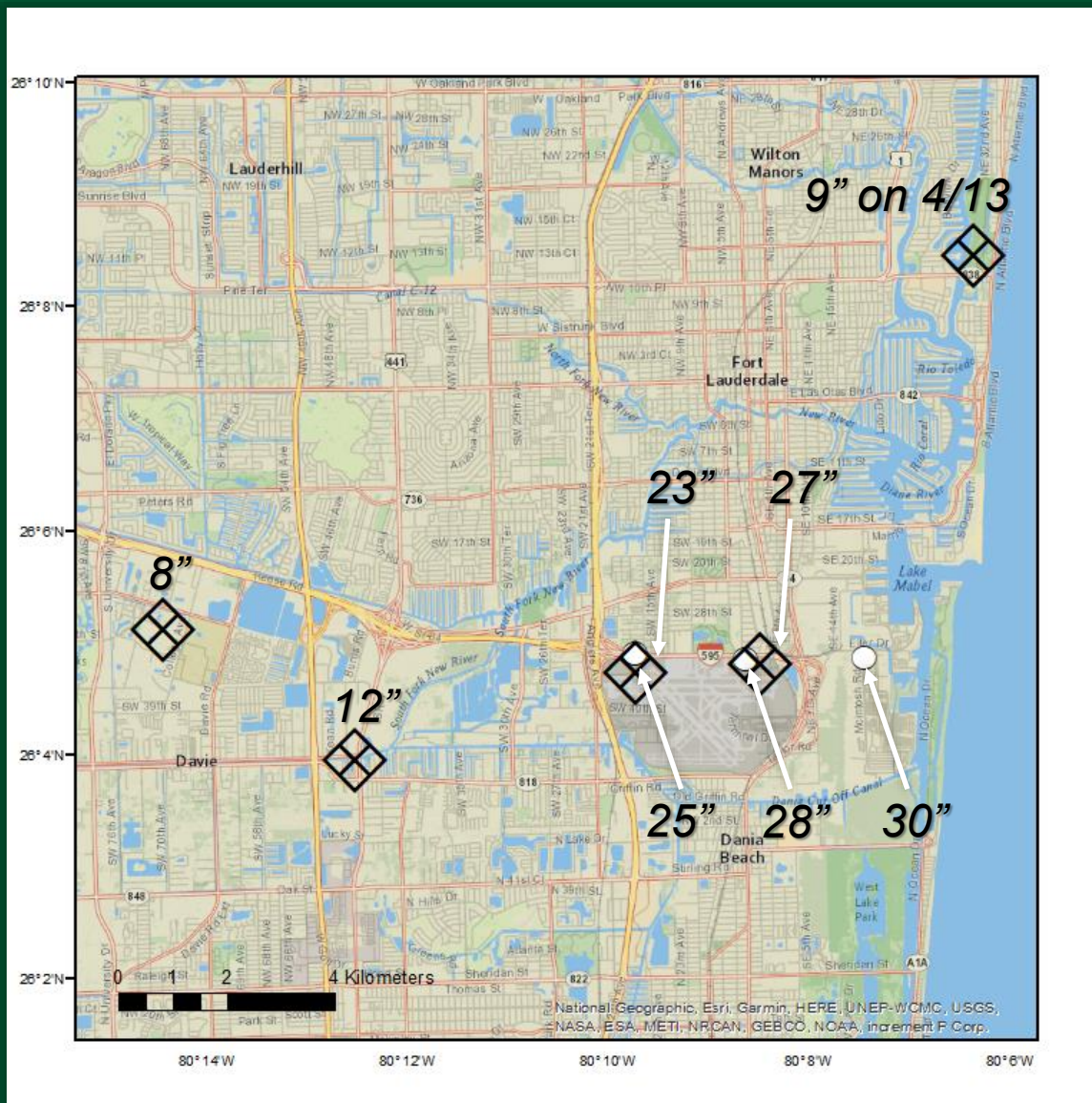


Preliminary Information-Subject to Revision. Not for Citation or Distribution.

Weather stations and NEXRAD

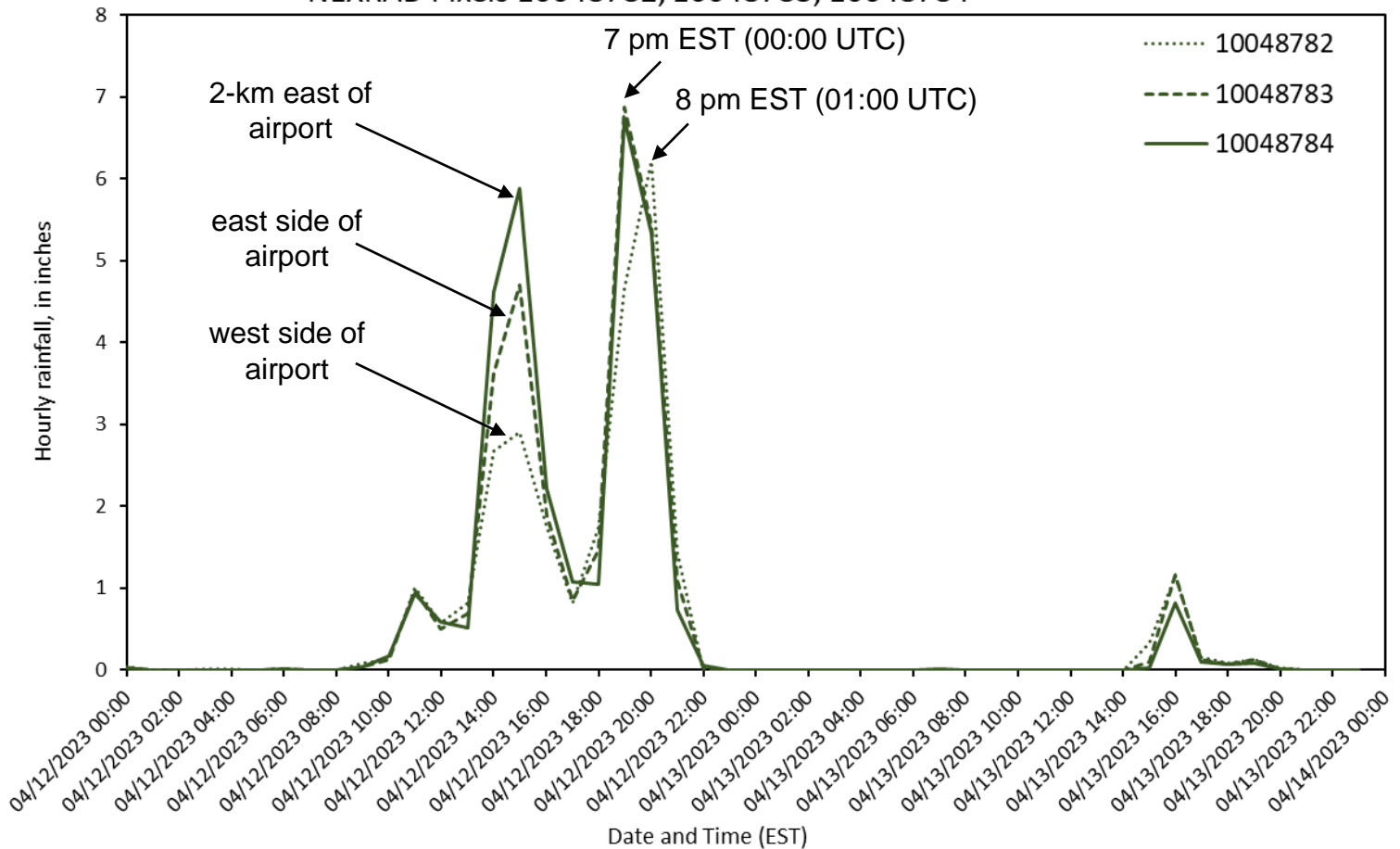


Weather stations and NEXRAD

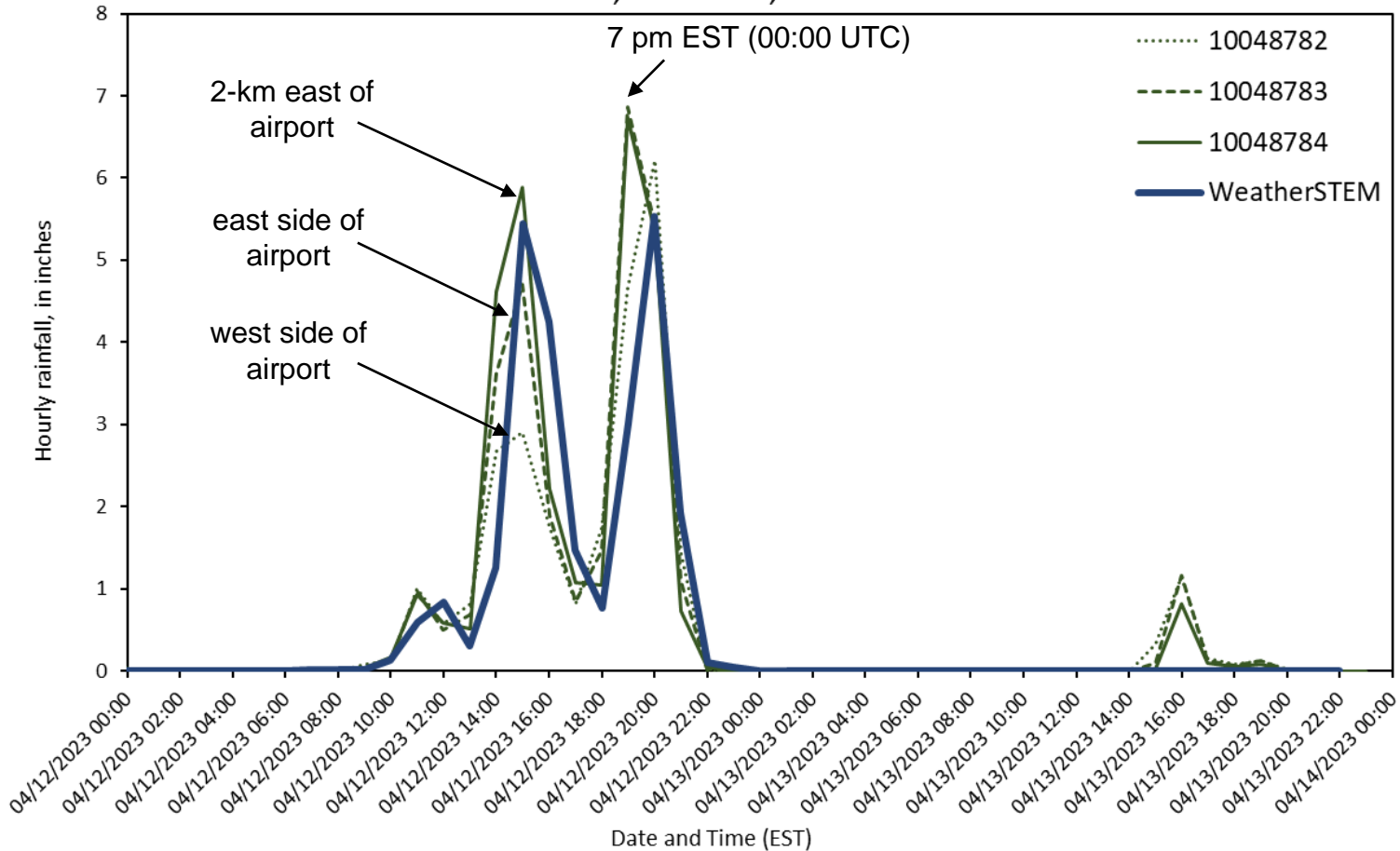


Preliminary Information-Subject to Revision. Not for Citation or Distribution.

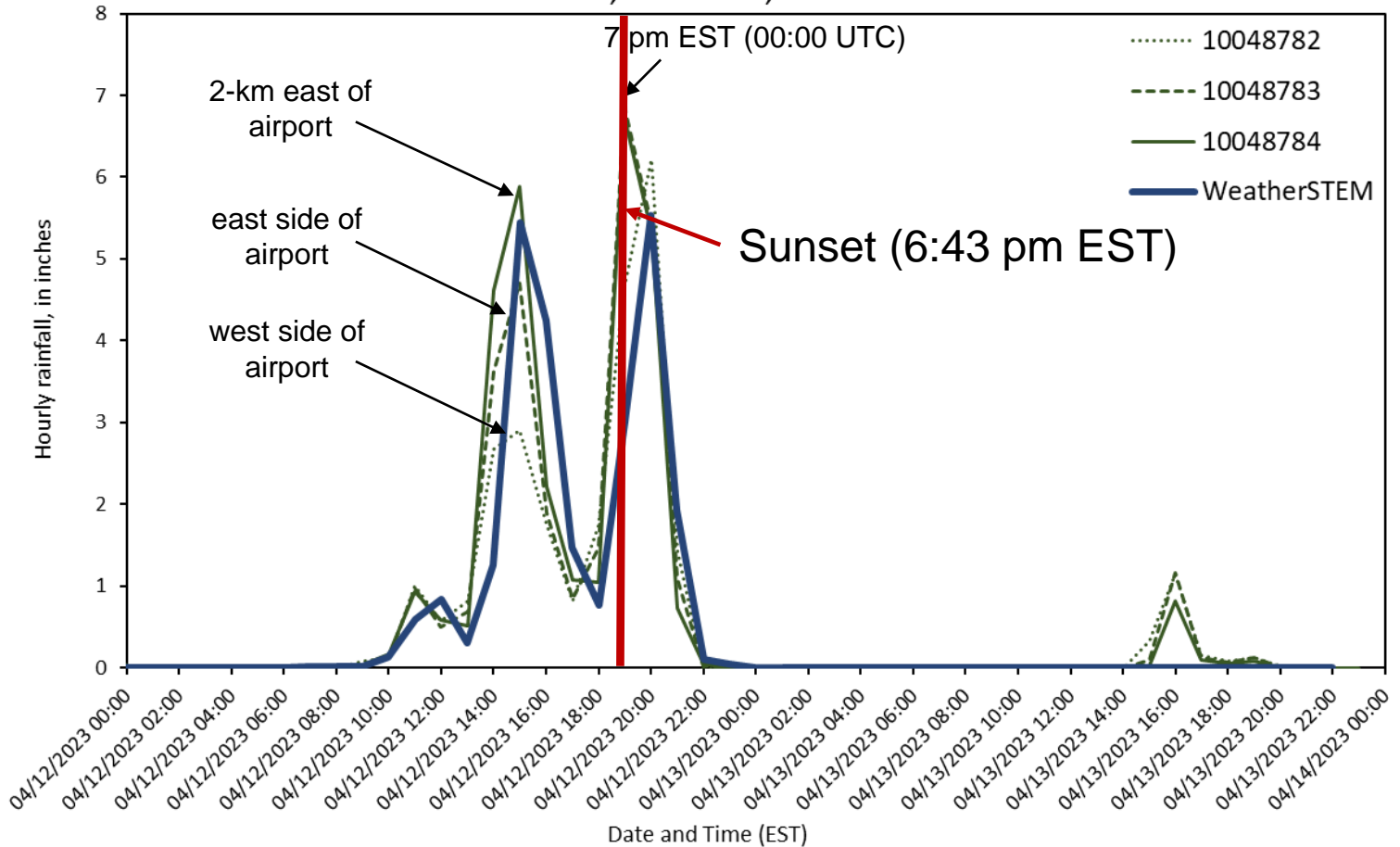
Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784

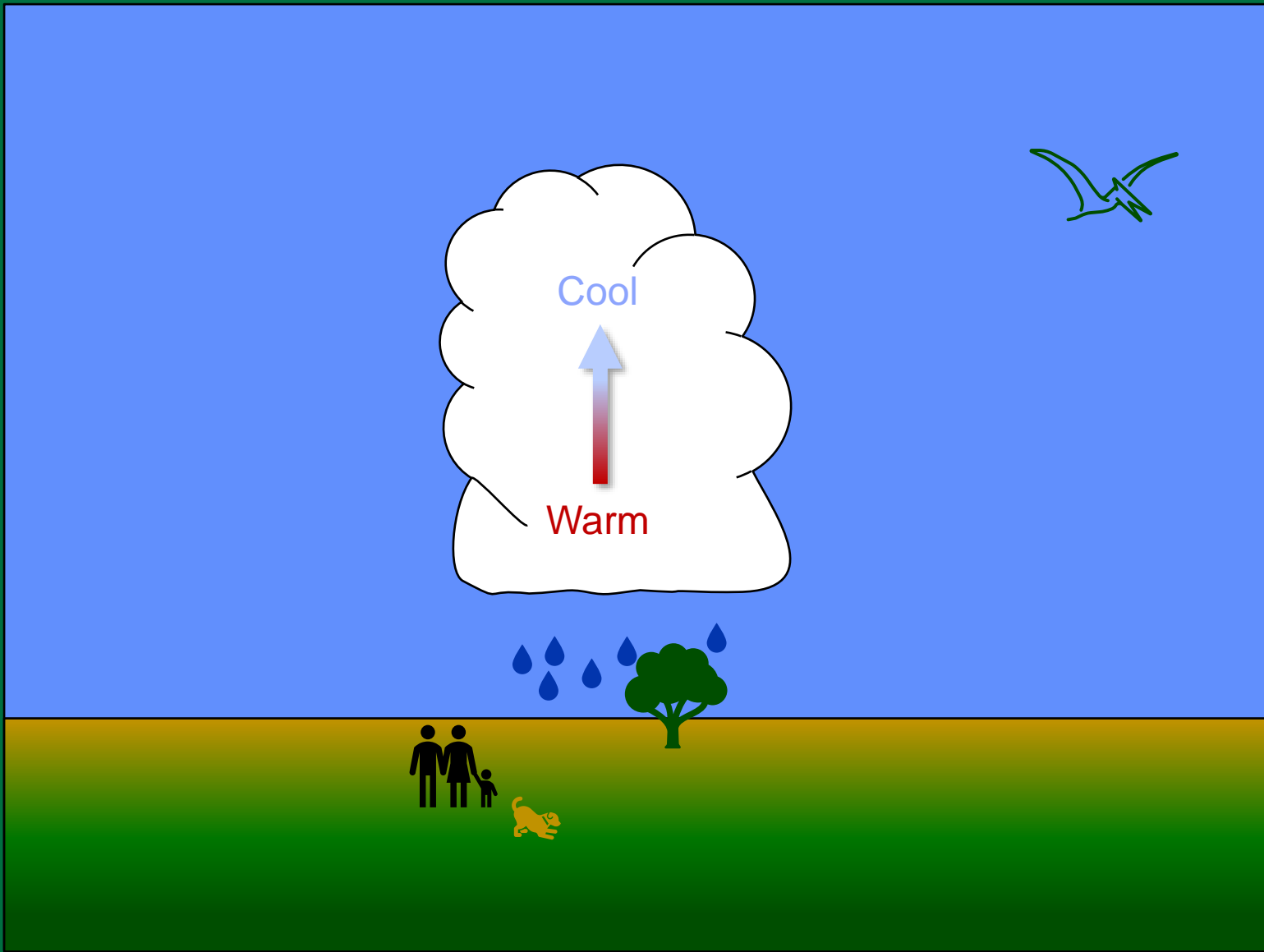


Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784 and WeatherSTEM

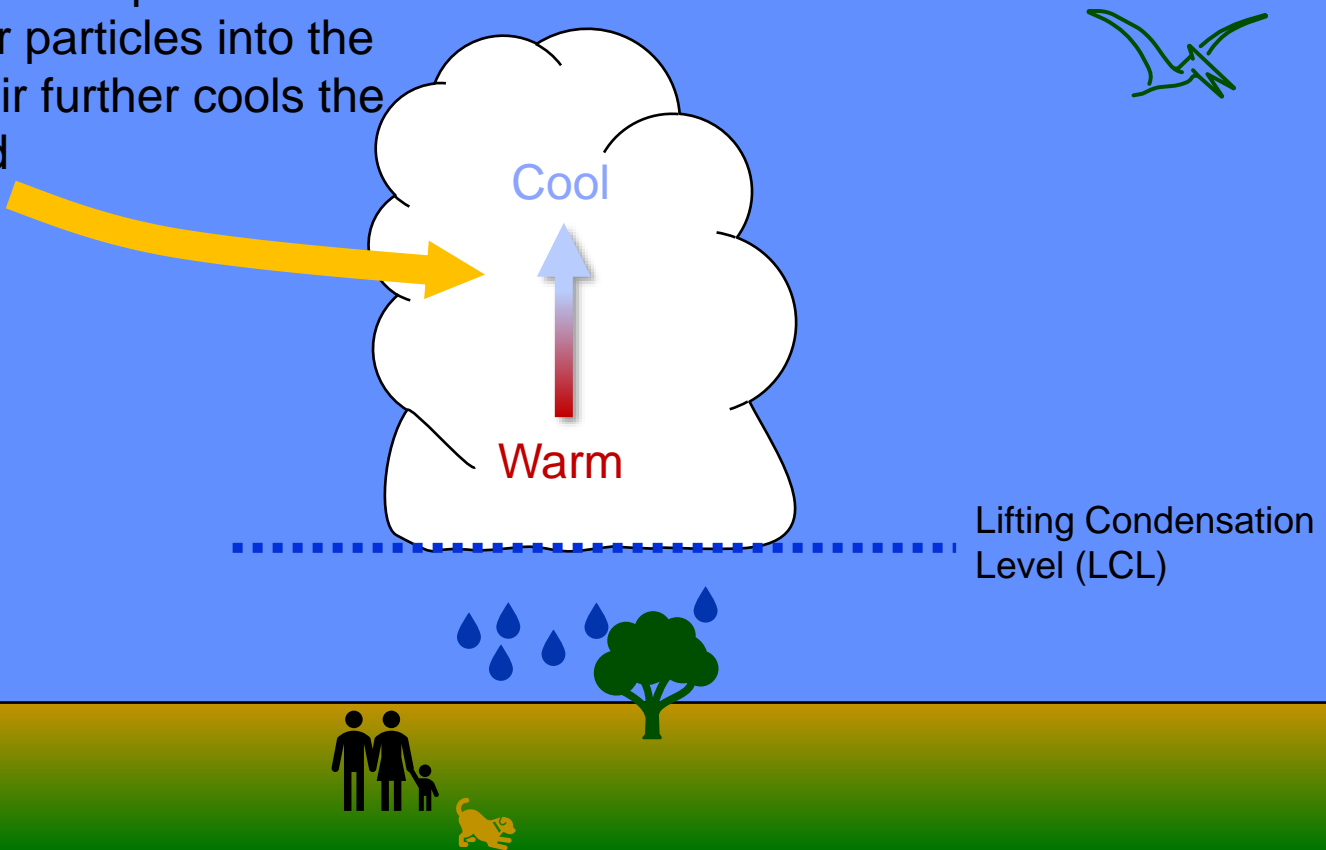


Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784 and WeatherSTEM

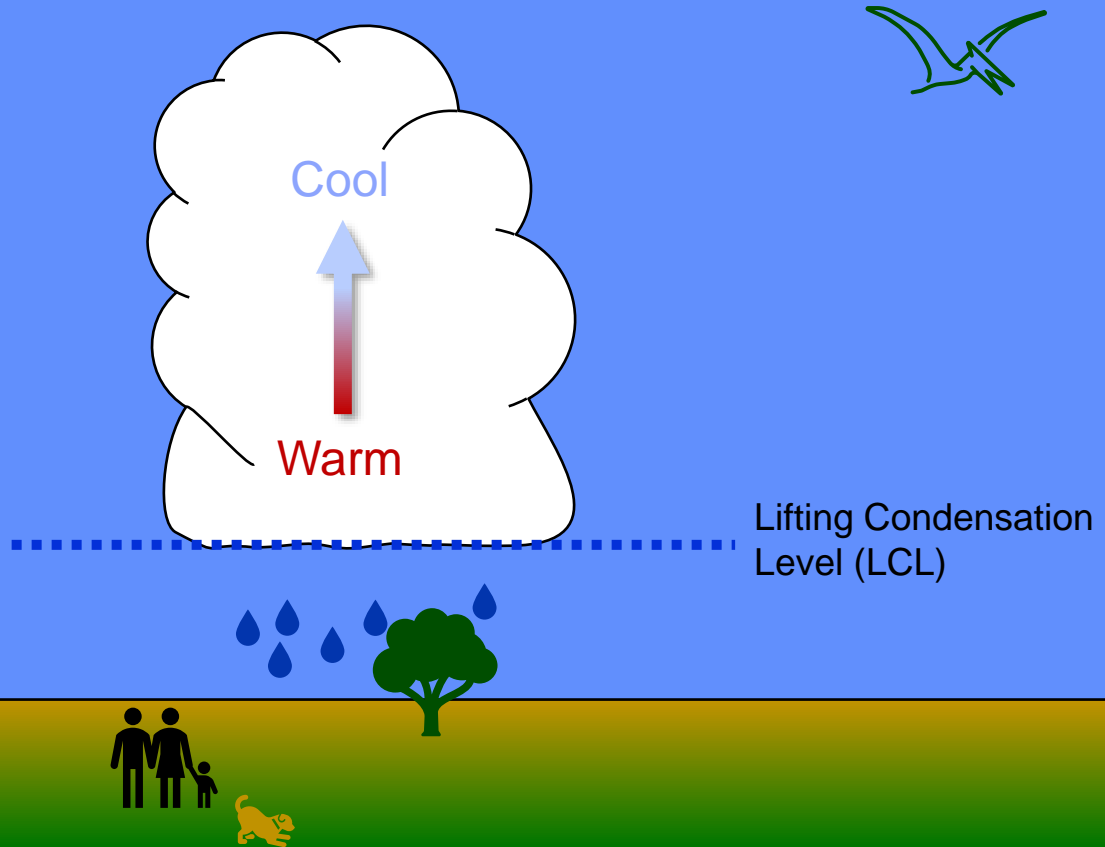


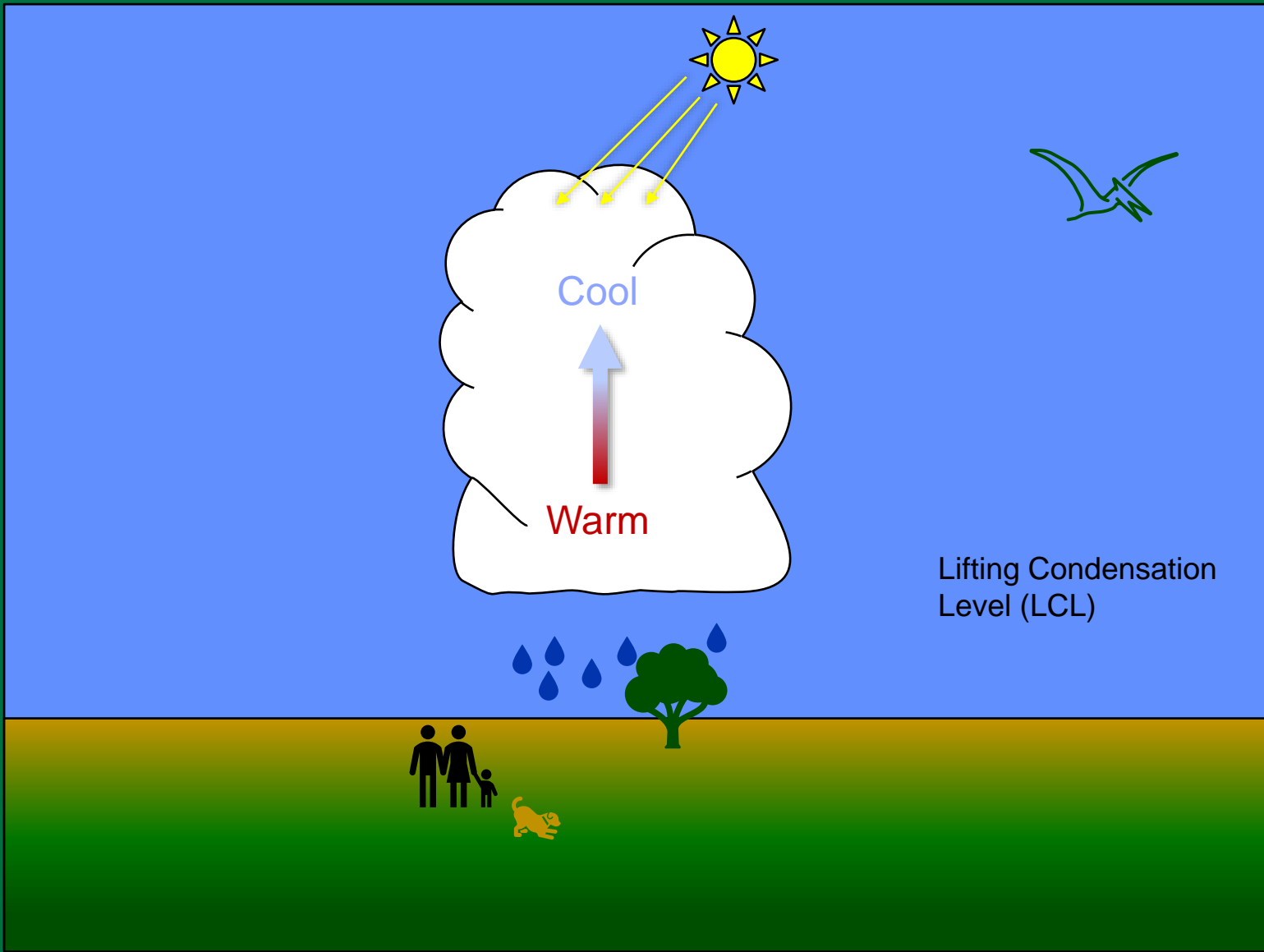


Dry air can enter into the cloud. Evaporation of water particles into the dry air further cools the cloud

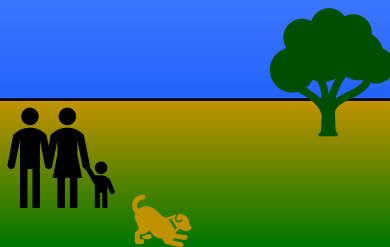
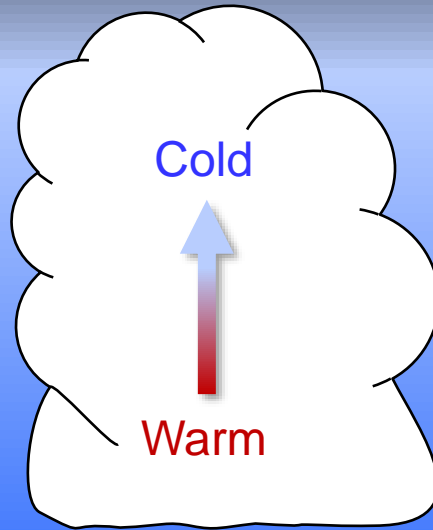


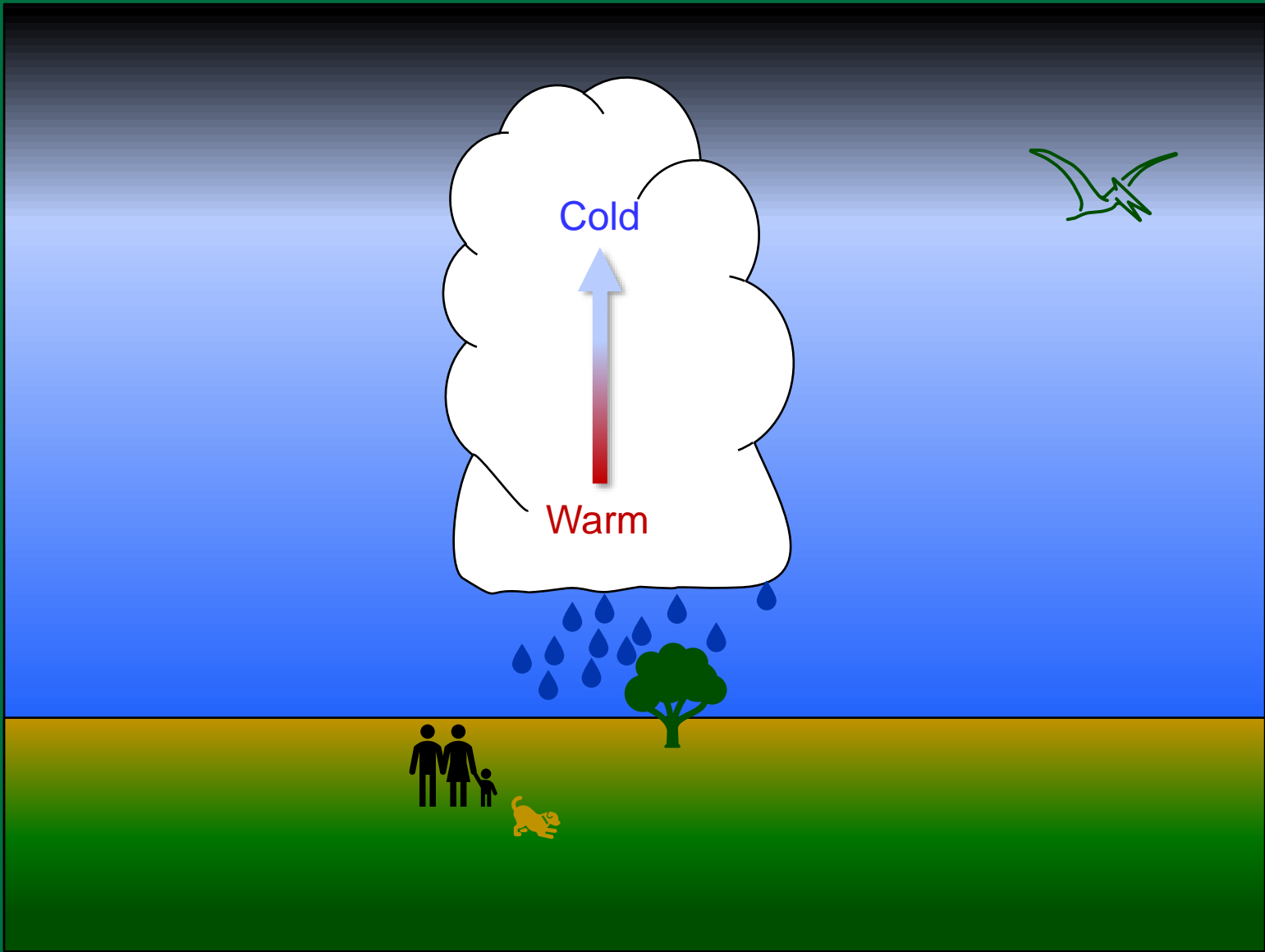
How quickly a cloud top cools is a proxy for strength of convection



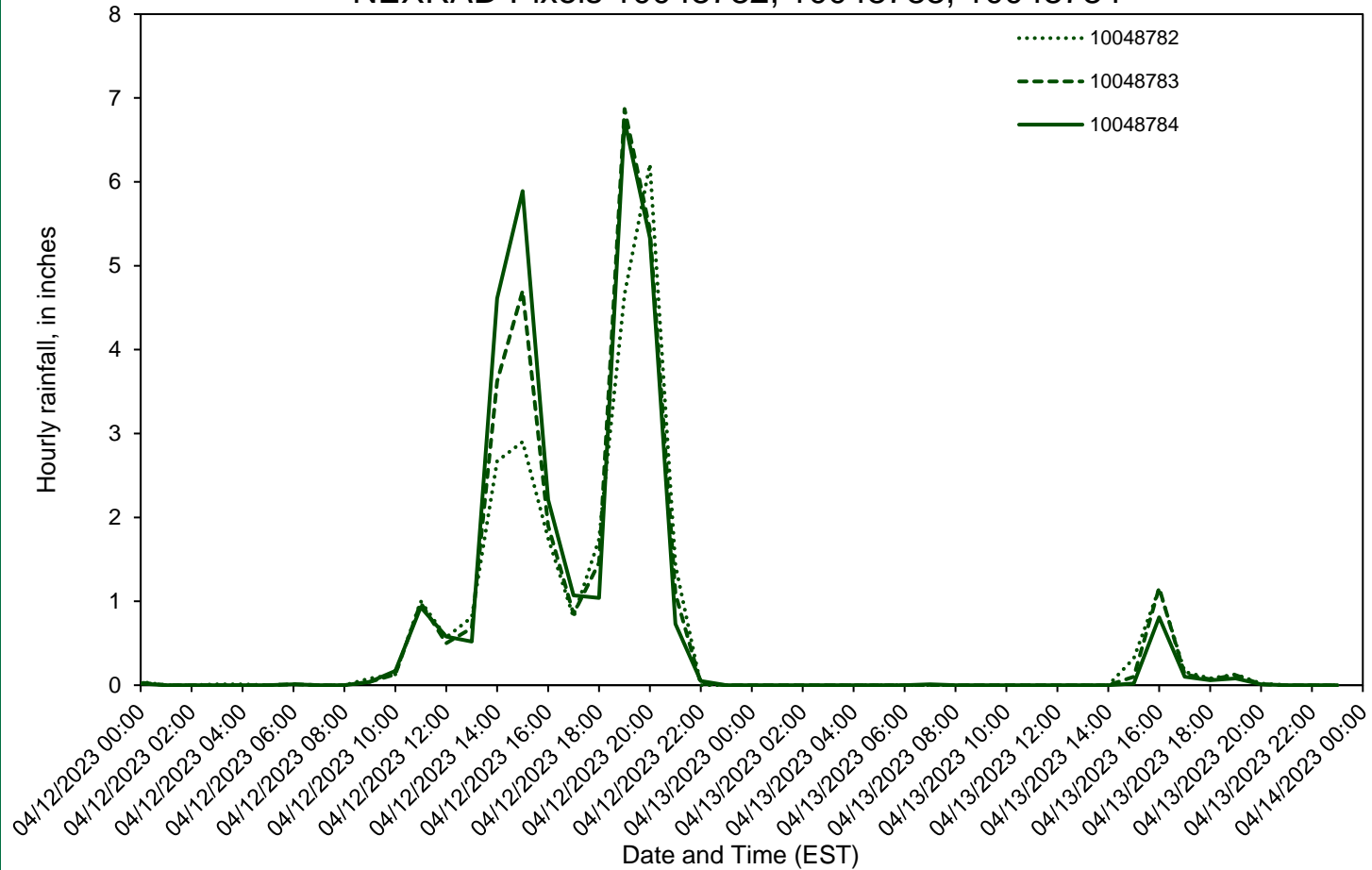


Cloud-top cooling

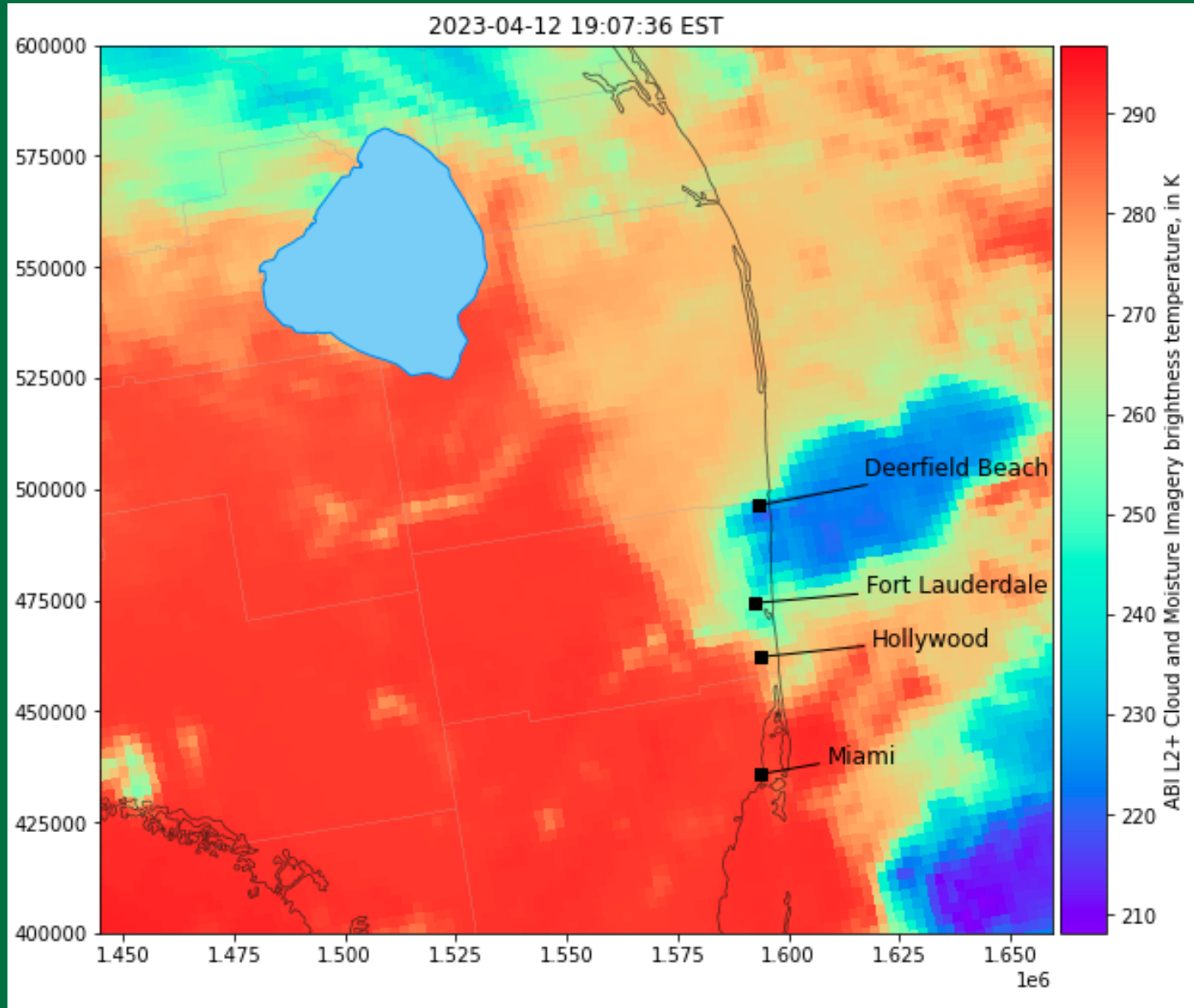




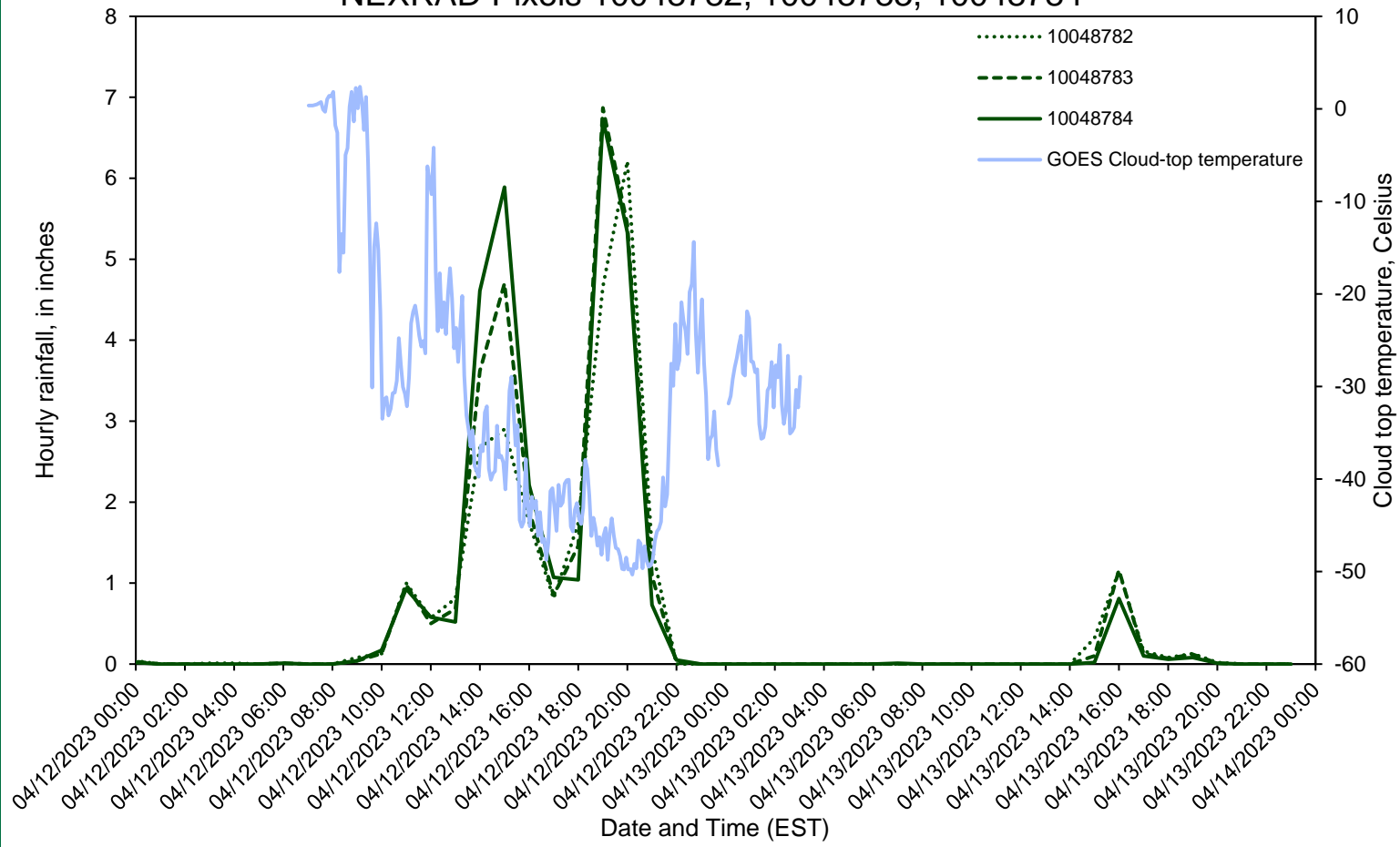
Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784



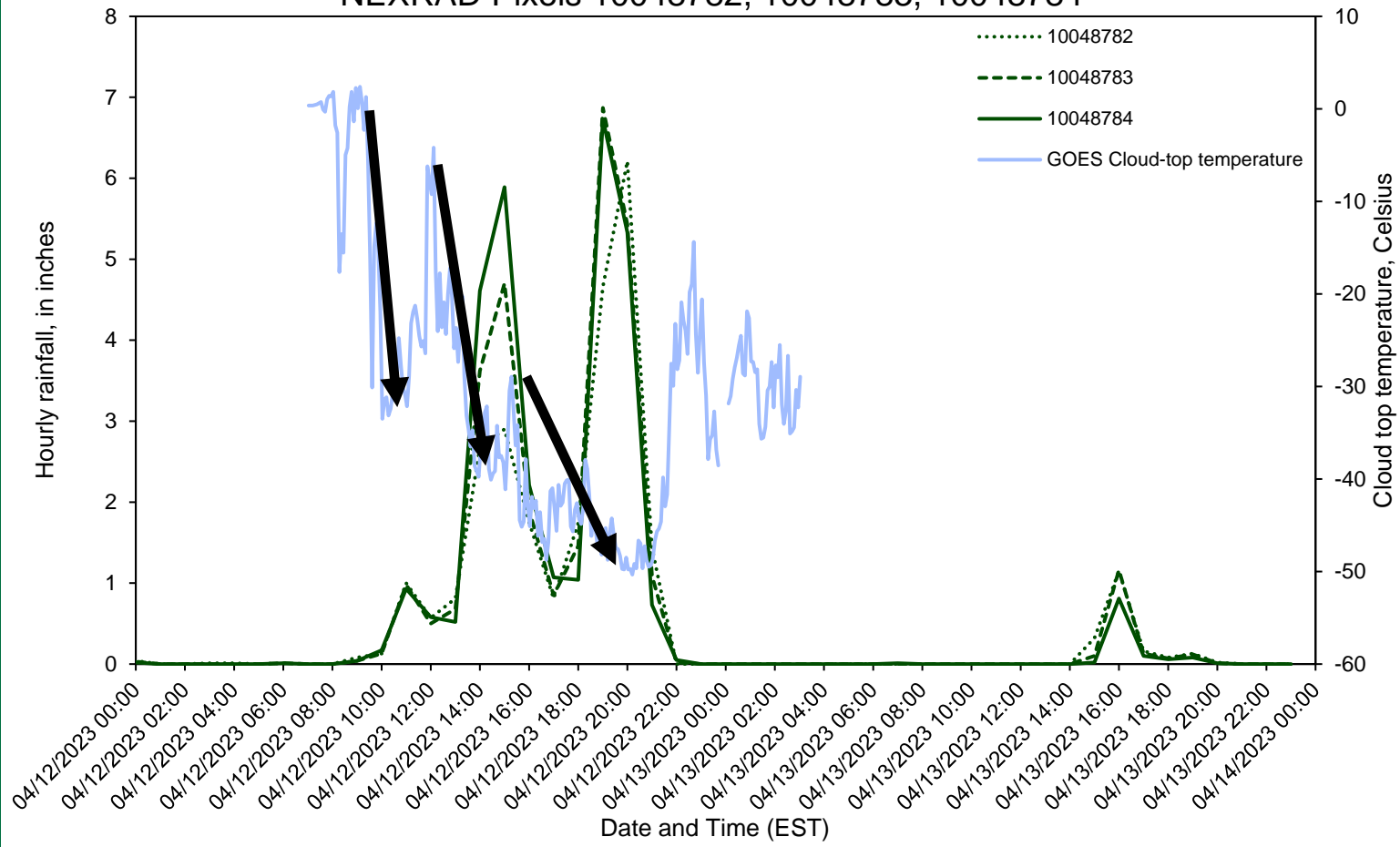
GOES Cloud-top temperature at 7:36 pm EST



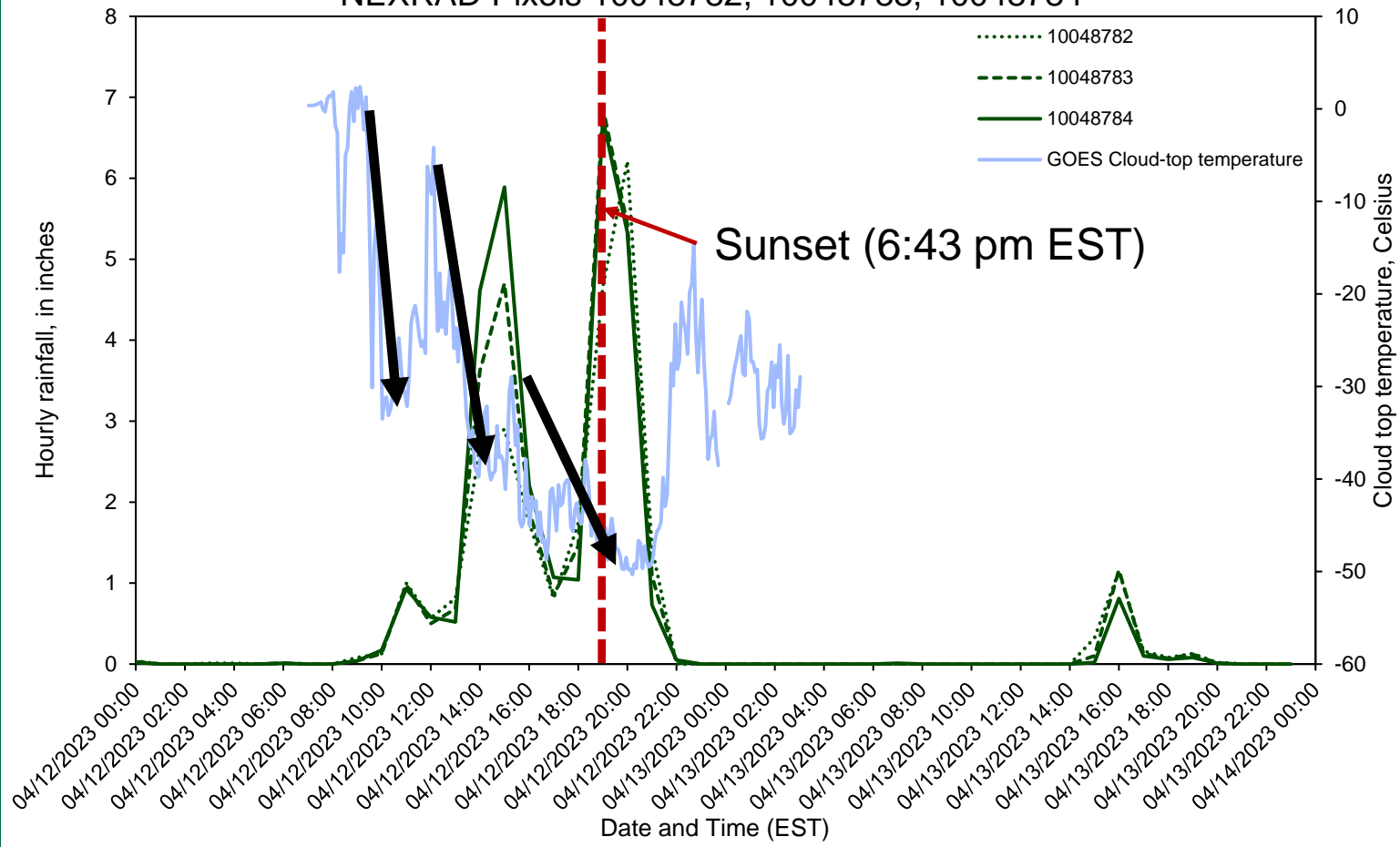
Fort Lauderdale - Hollywood International Airport area
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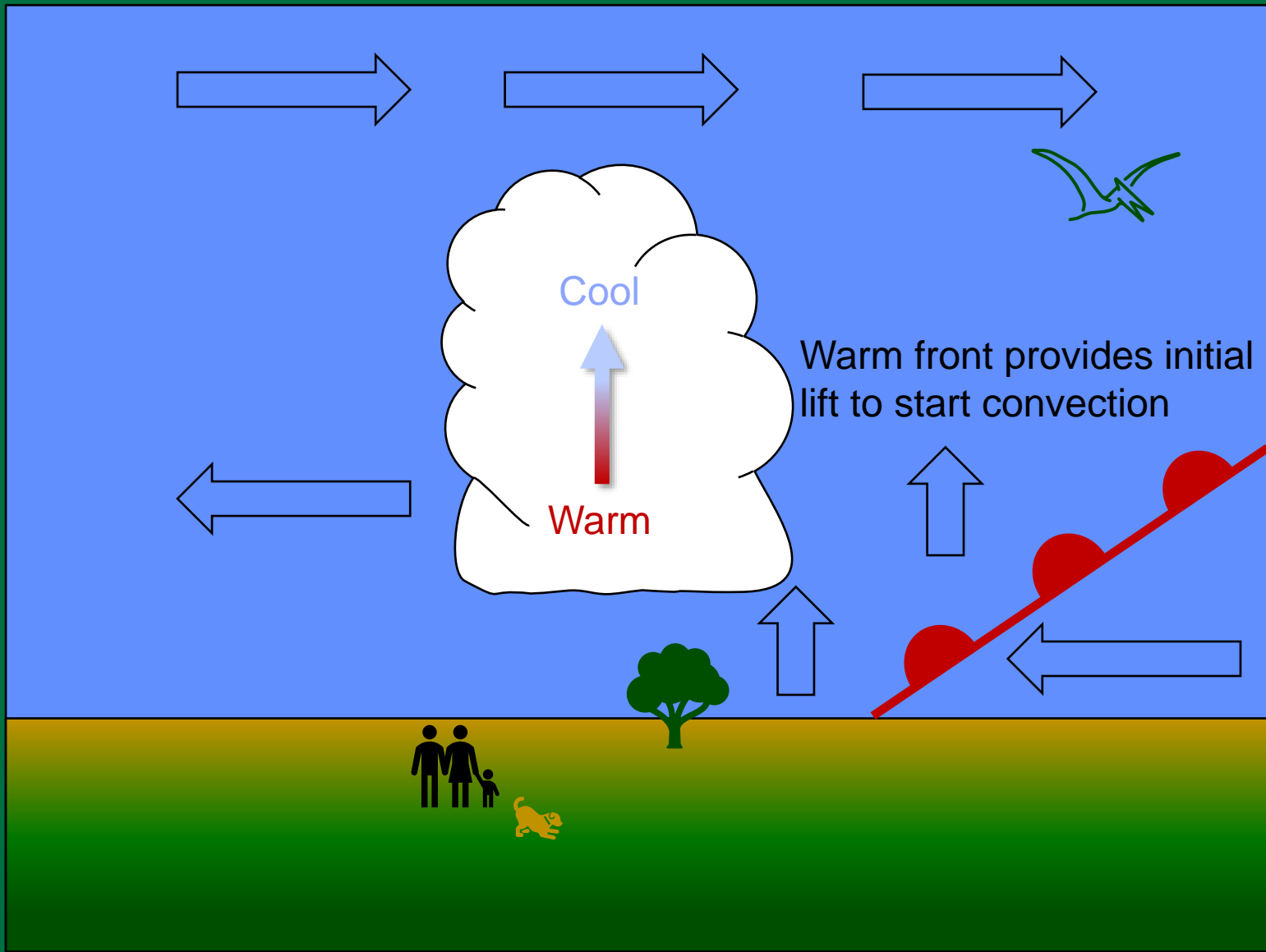


Fort Lauderdale - Hollywood International Airport area NEXRAD Pixels 10048782, 10048783, 10048784

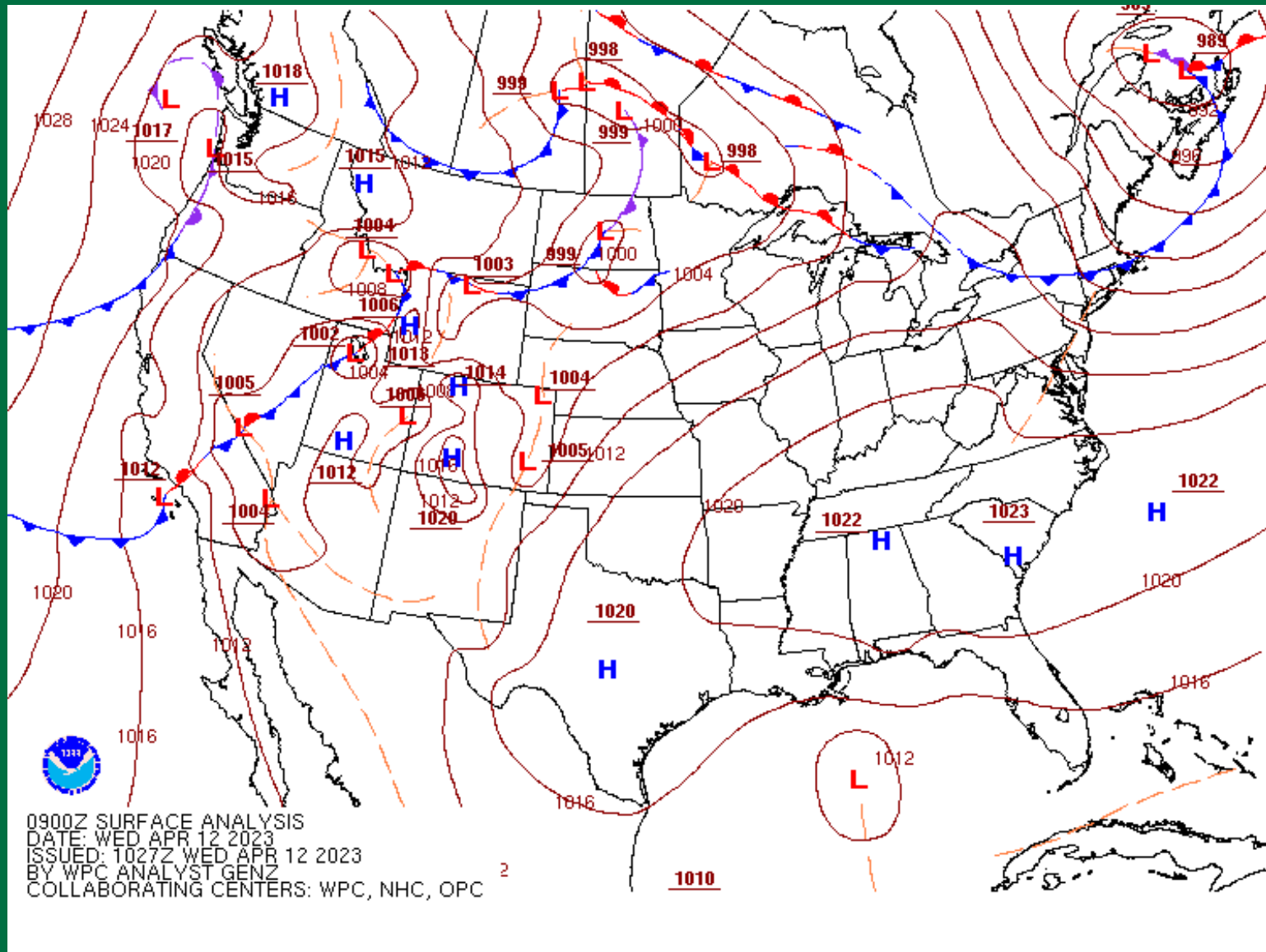


Fort Lauderdale - Hollywood International Airport area
NEXRAD Pixels 10048782, 10048783, 10048784



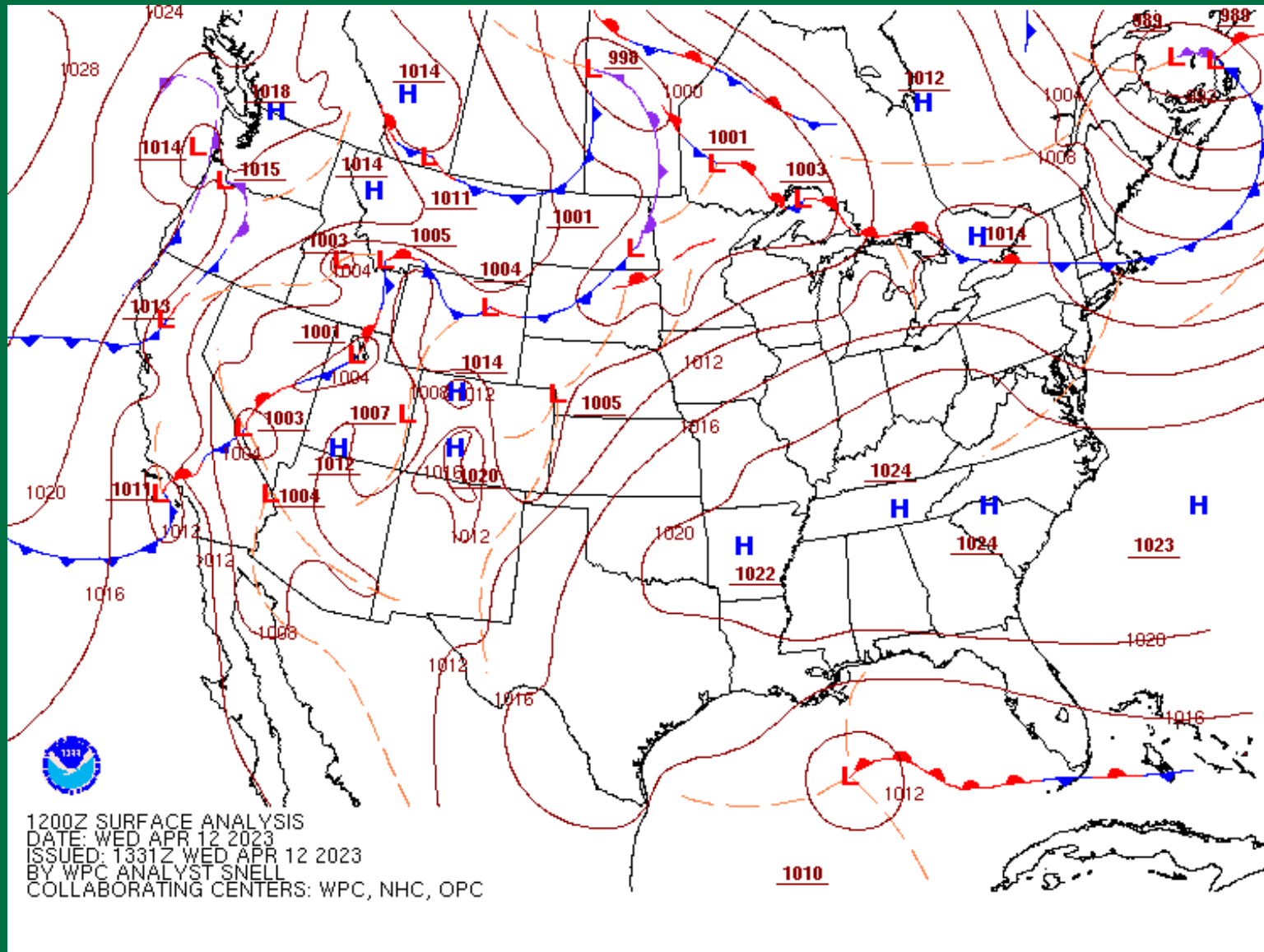


4/12/2023, 09:00 UTC (Zulu); 4/12 04:00 EST



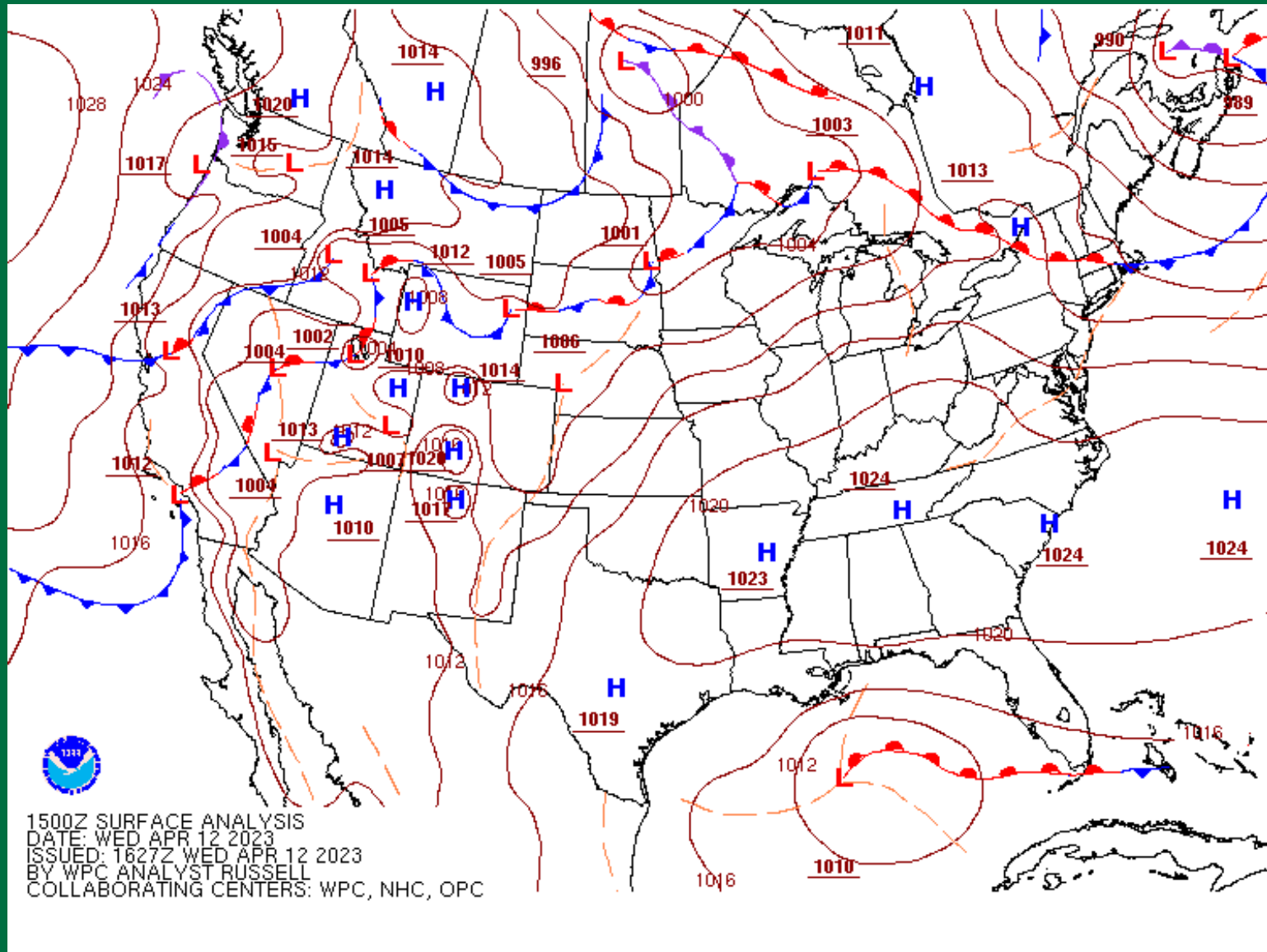
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4/12/2023, 12:00 UTC (Zulu); 4/12 07:00 EST



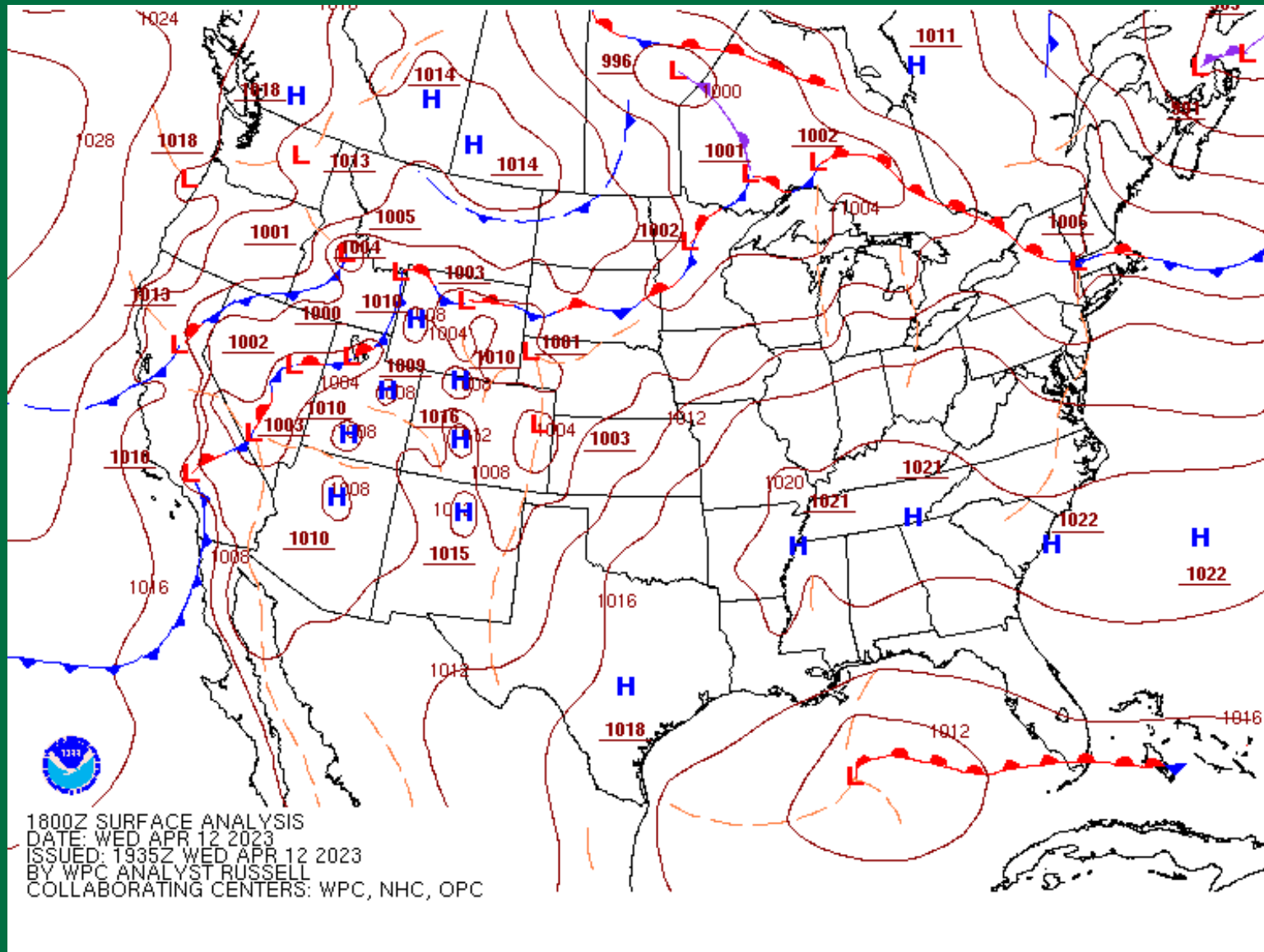
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4/12/2023, 15:00 UTC (Zulu); 4/12 10:00 EST



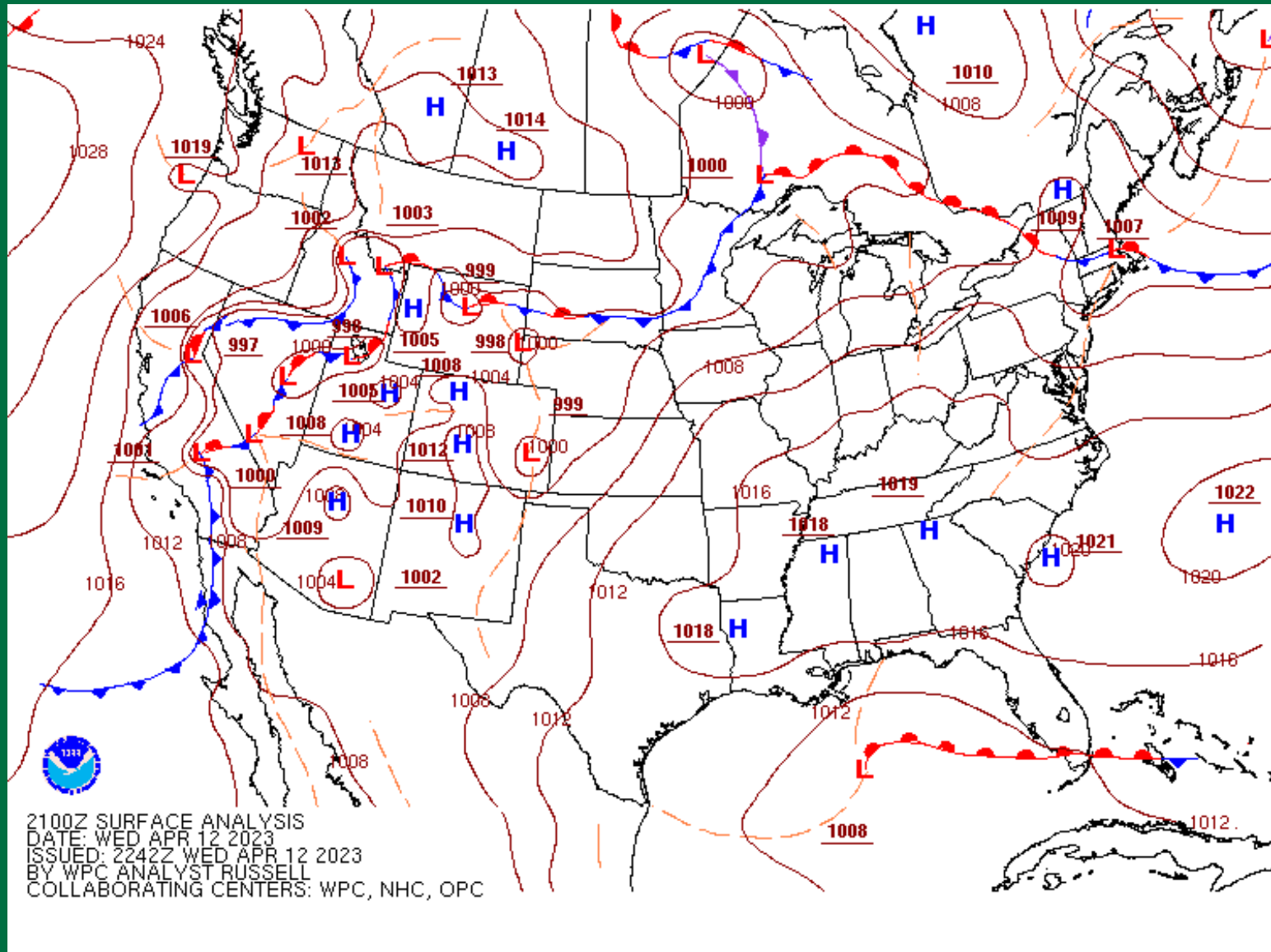
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

4/12/2023, 18:00 UTC (Zulu); 4/12 13:00 EST



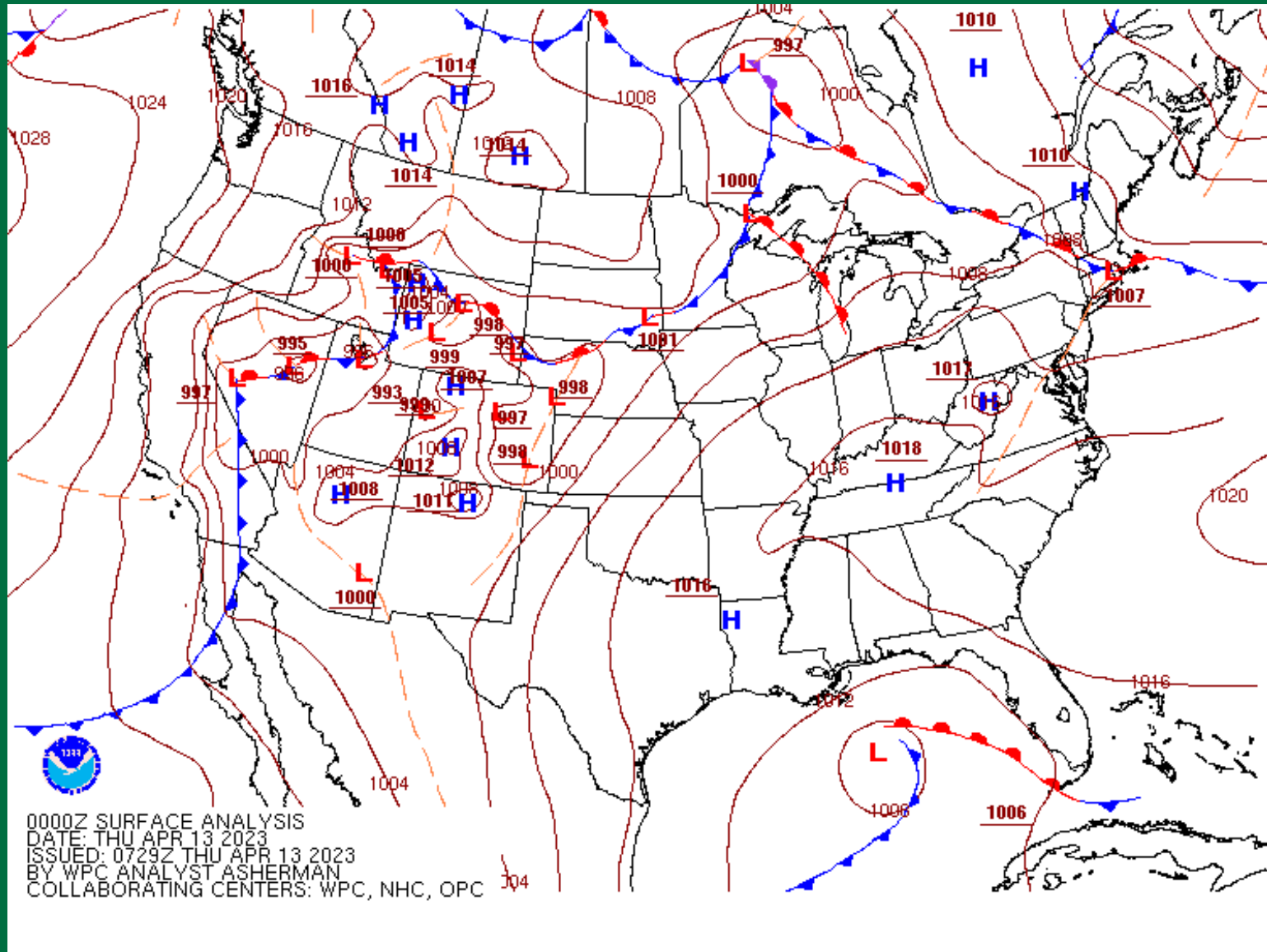
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

4/12/2023, 21:00 UTC (Zulu); 4/12 16:00 EST



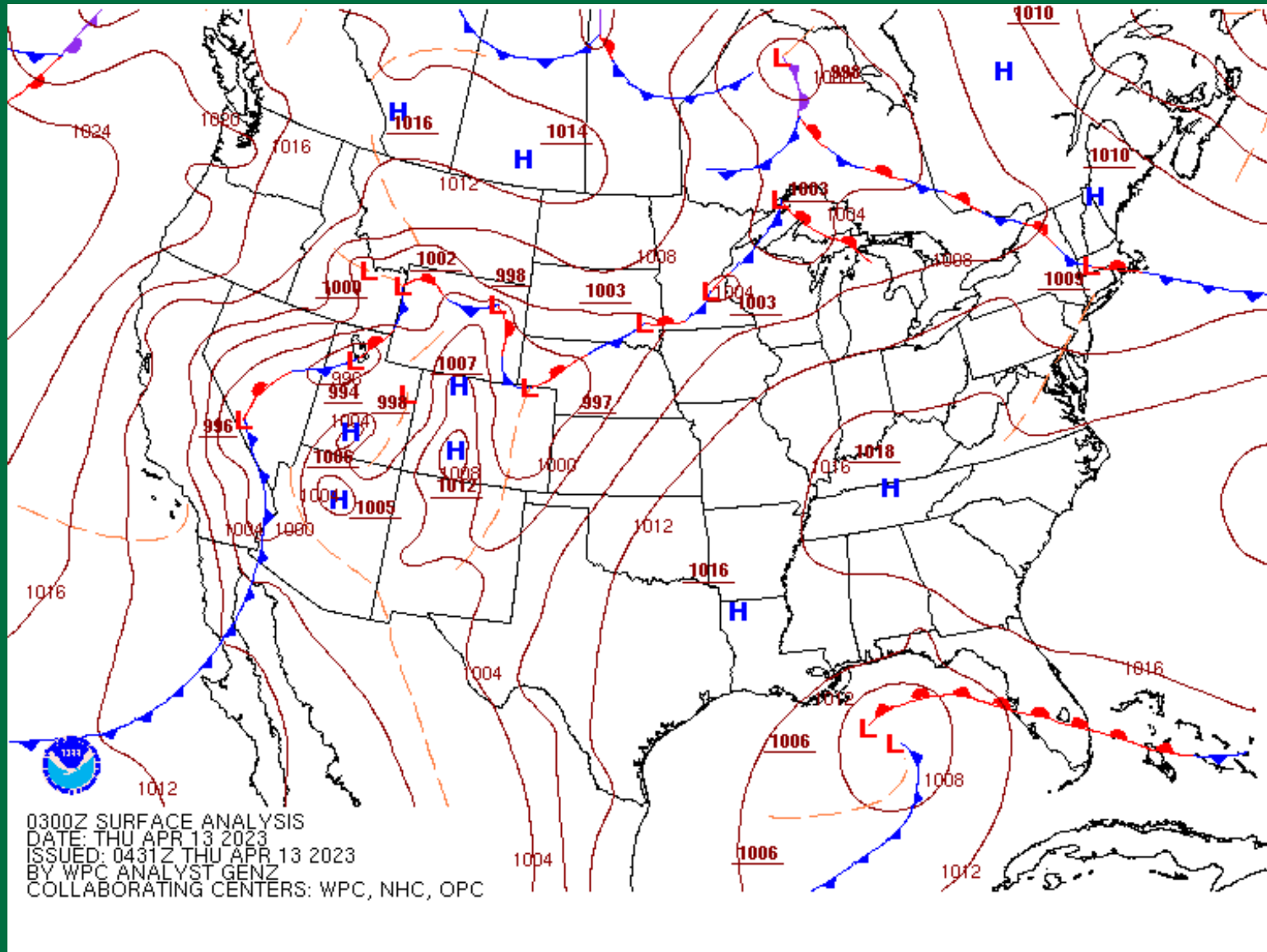
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

4/13/2023, 00:00 UTC (Zulu); 4/12 19:00 EST



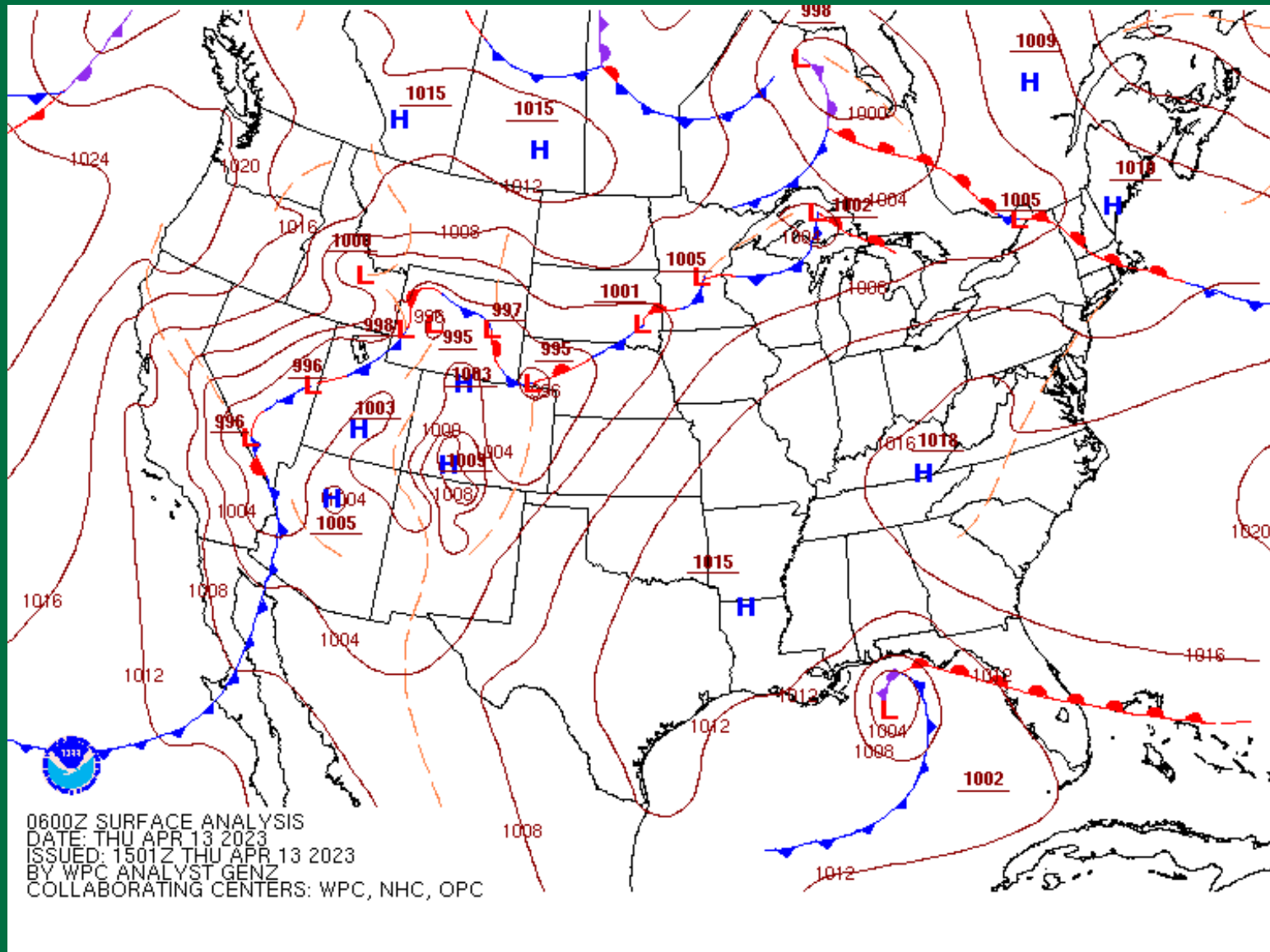
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4/13/2023, 03:00 UTC (Zulu); 4/12 22:00 EST



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

4/13/2023, 06:00 UTC (Zulu); 4/13 01:00 EST



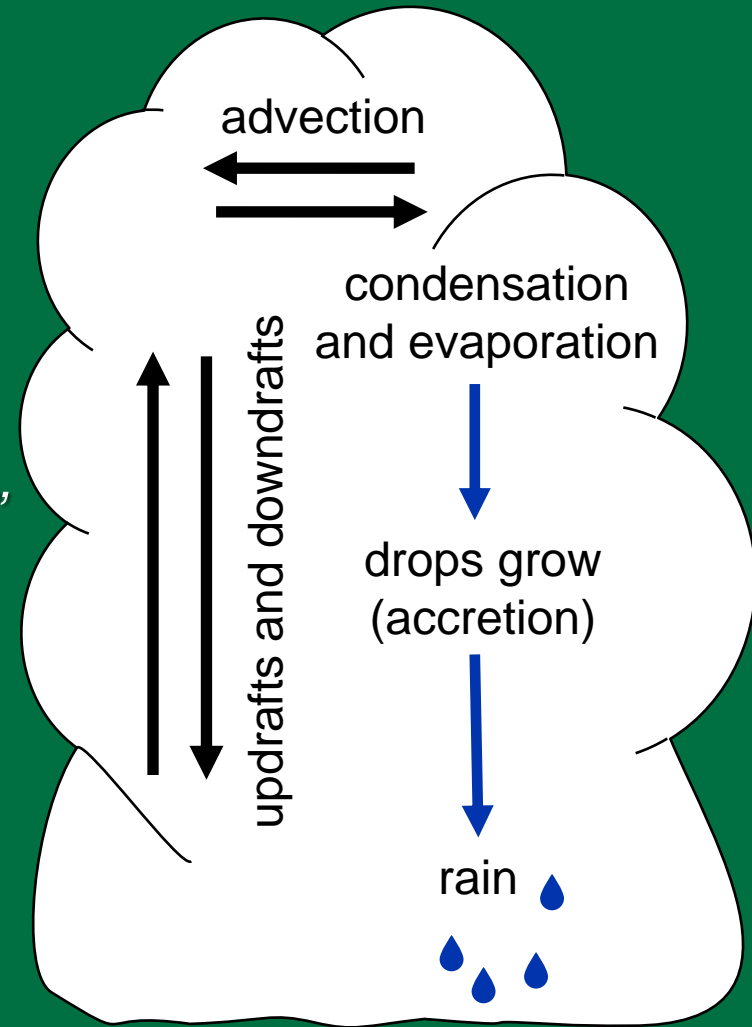
Preliminary Information-Subject to Revision. Not for Citation or Distribution.

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)*

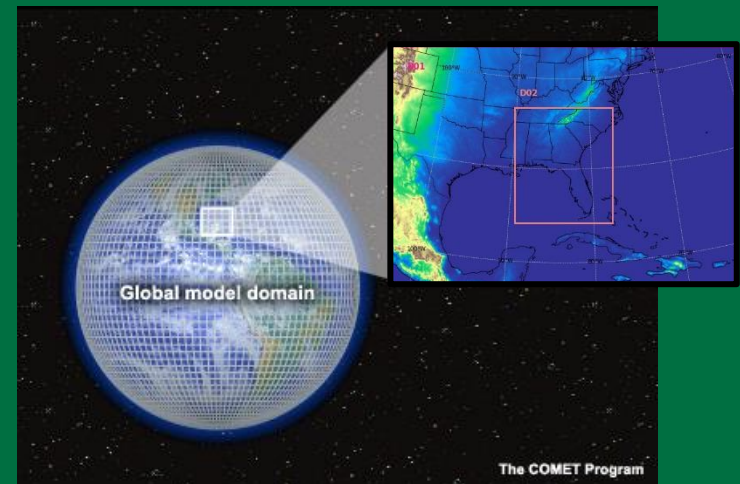
Weather Research and Forecast Model

- *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*



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*



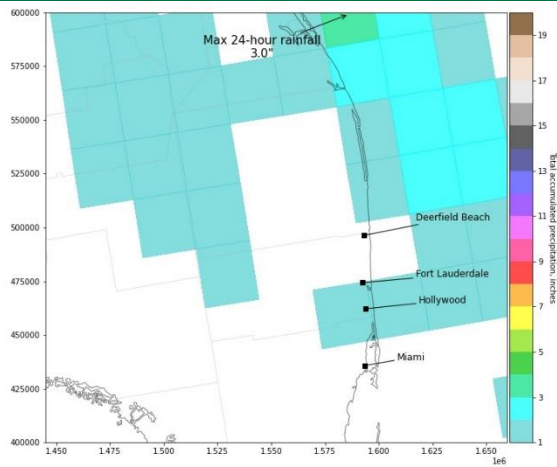
Weather Research and Forecasting Model Reanalysis

- *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

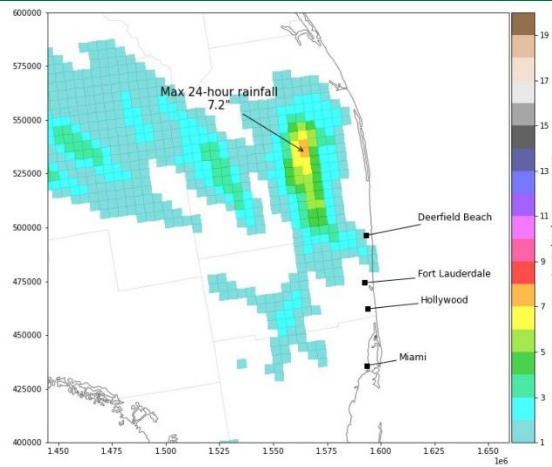
■ Preliminary results

ERA5 30-km



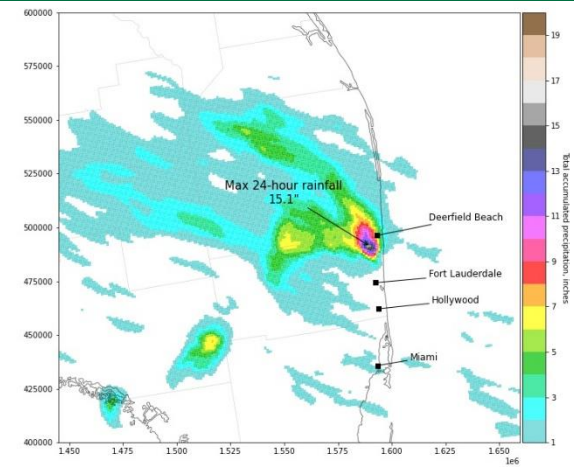
3 inches
per day

WRF 4-km



7 inches
per day

WRF 1-km



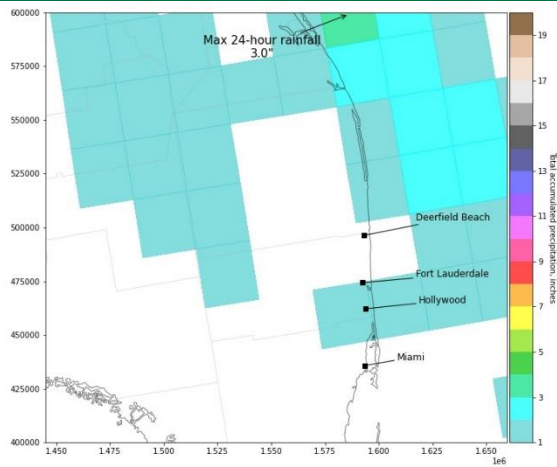
15 inches
per day



Fort Lauderdale rainfall, April 12, 2023

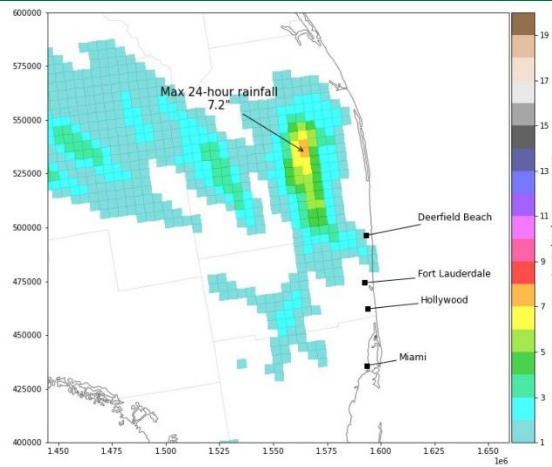
■ Preliminary results

ERA5 30-km



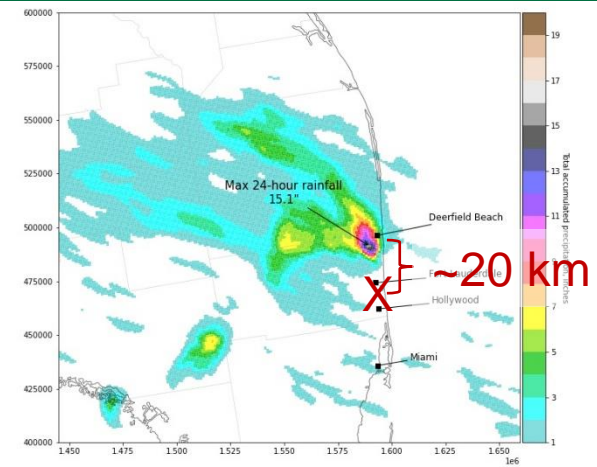
3 inches
per day

WRF 4-km



7 inches
per day

WRF 1-km



15 inches
per day

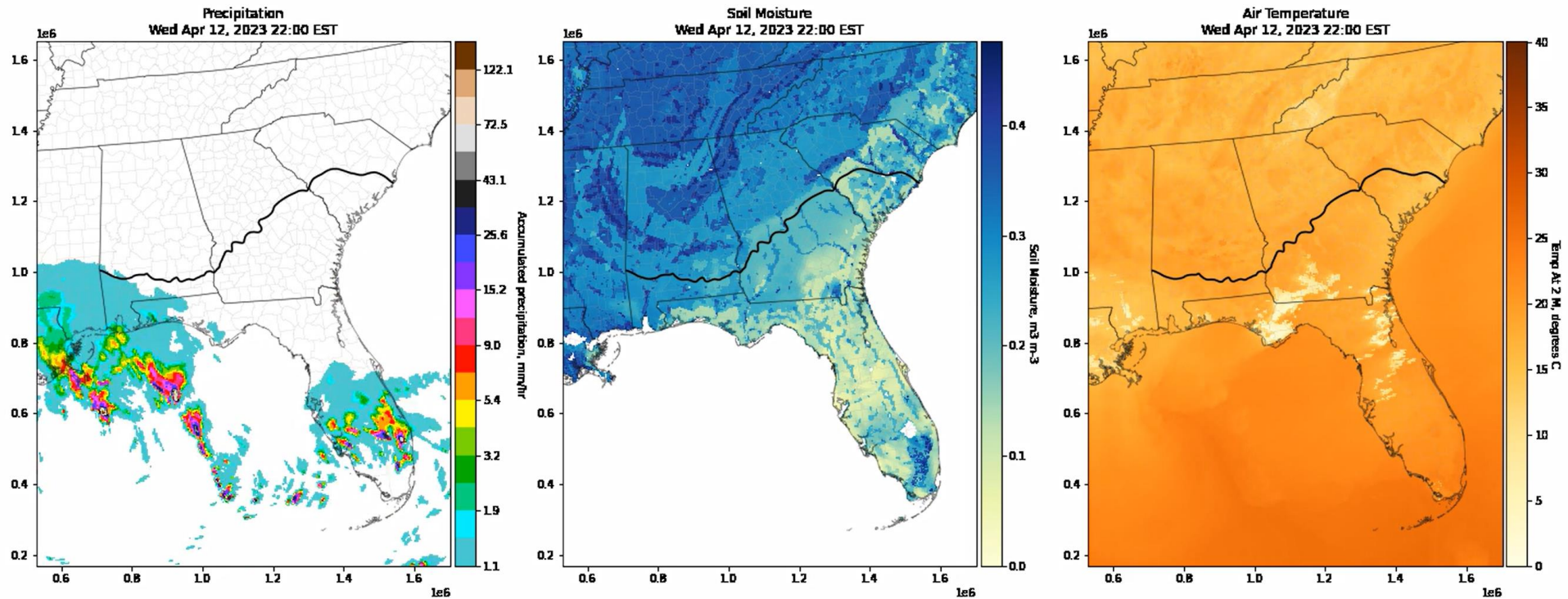


10 pm EST

Hourly precipitation

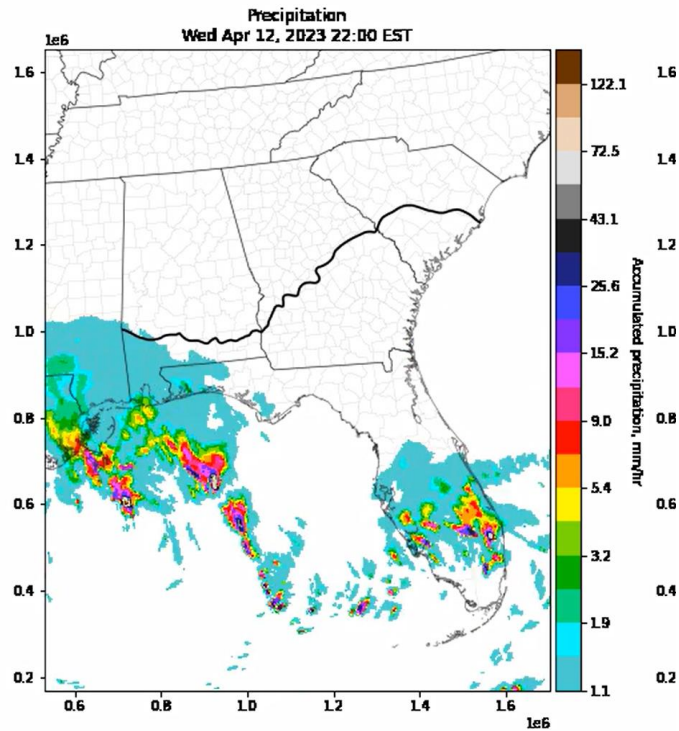
Soil moisture

Air temperature (10 m)



10 pm EST

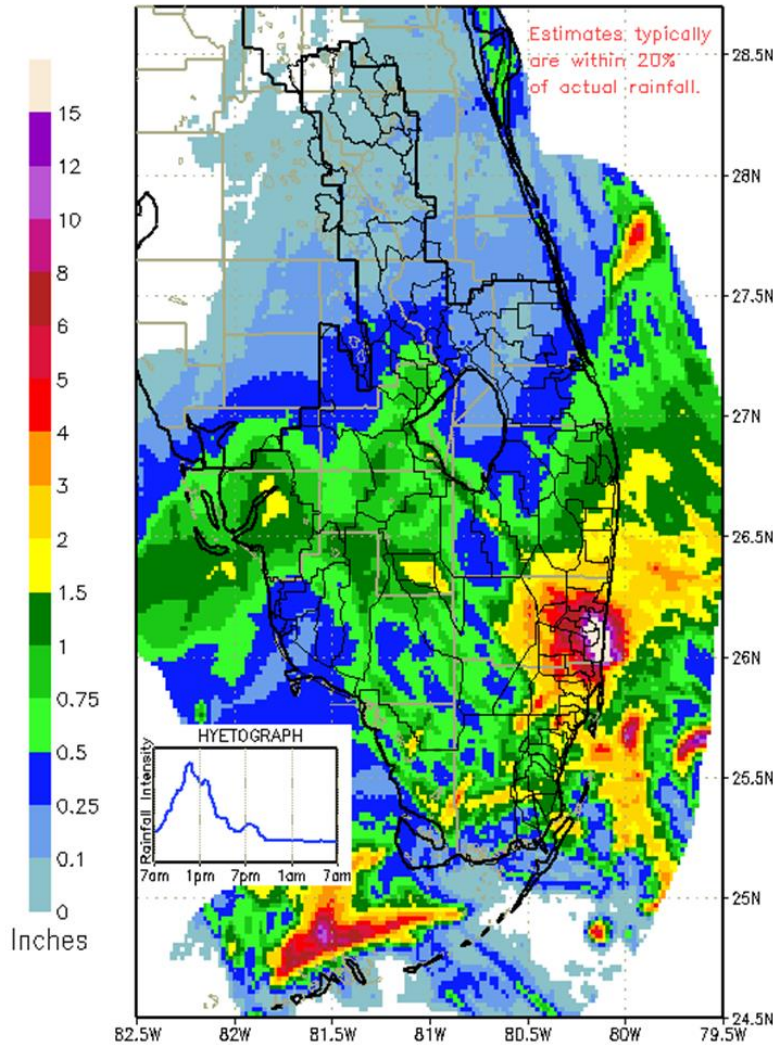
Hourly precipitation



Daily total precipitation (7 am – 7 am)

SFWM D PROVISIONAL RAINDAR EOD DAILY RAINFALL ESTIMATES

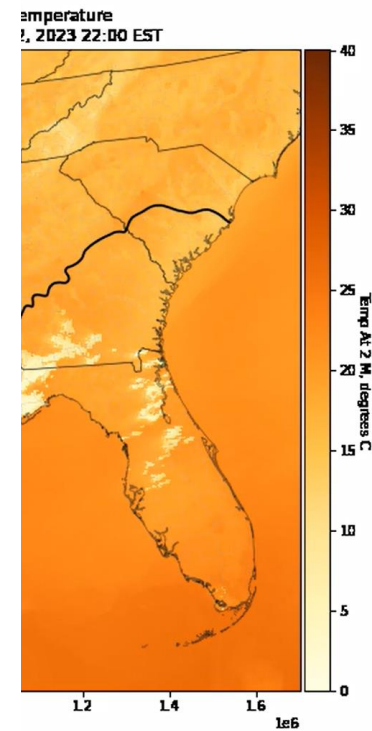
FROM: 0700 EST, 04/12/2023 THROUGH: 0700 EST, 04/13/2023



DISTRICT-WIDE RAINFALL ESTIMATE: 0.923"

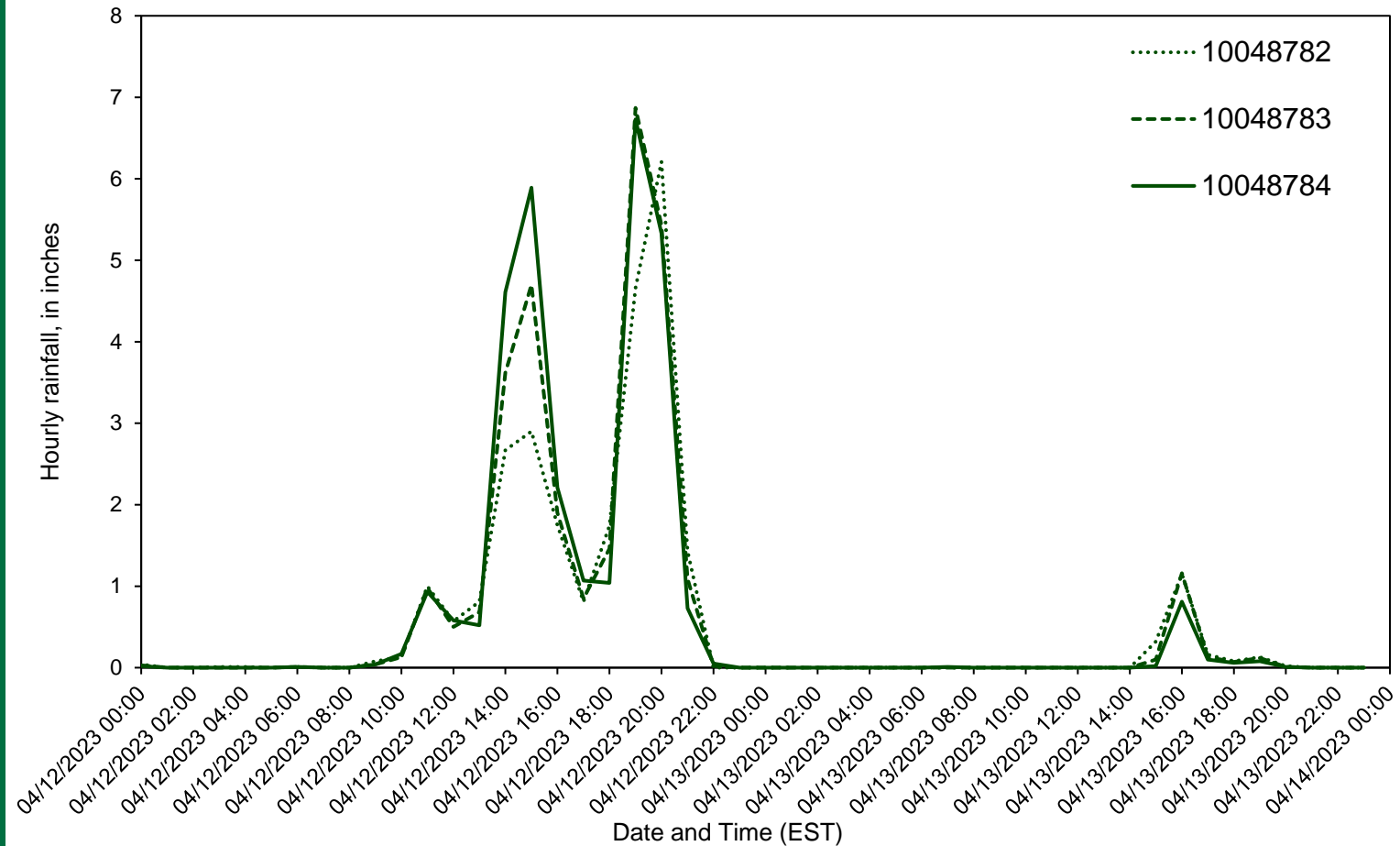
GrADS: COLA/IGES

Temperature (10 m)



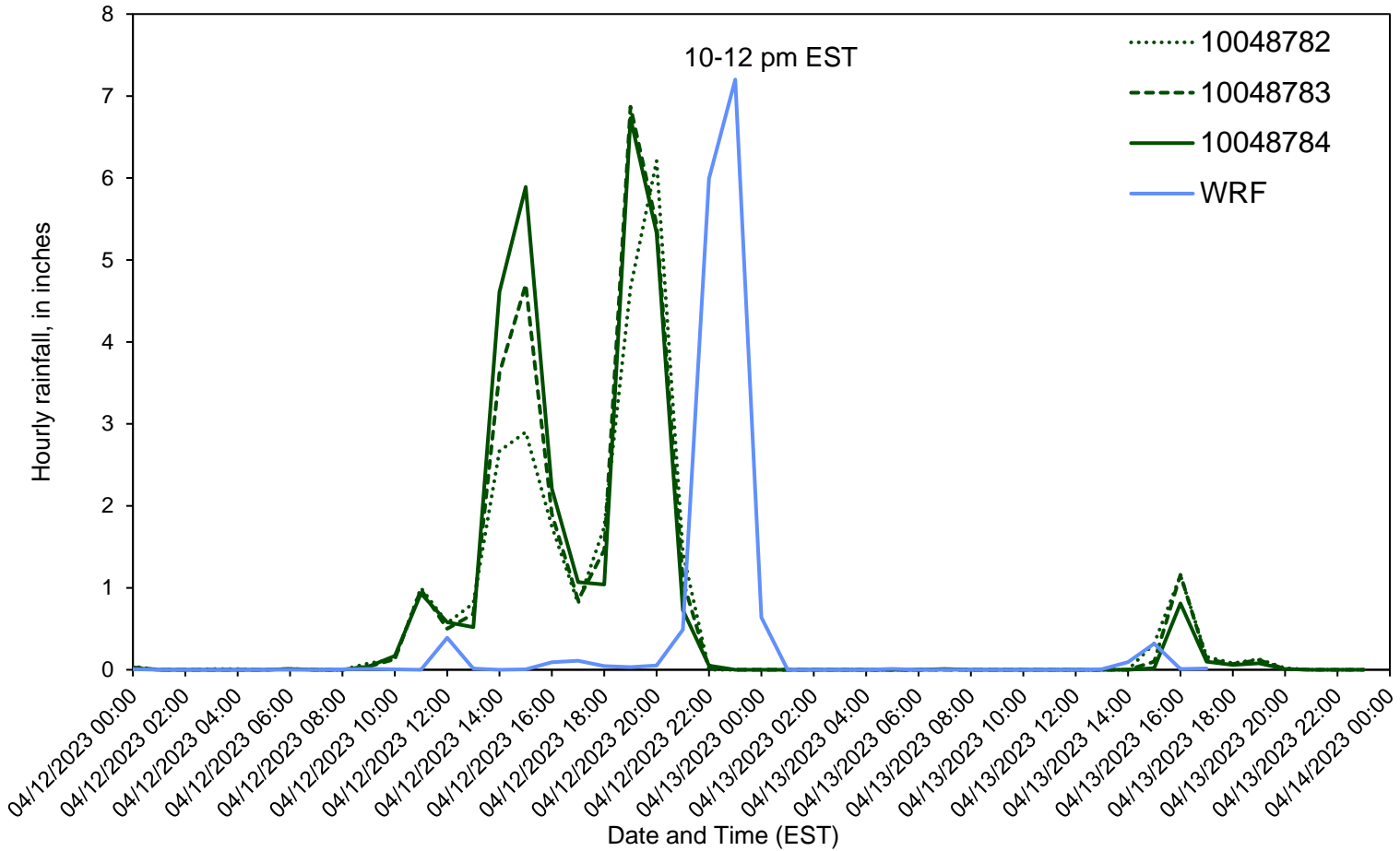
Timing of rainfall

NEXRAD Pixels 10048782, 10048783, 10048784



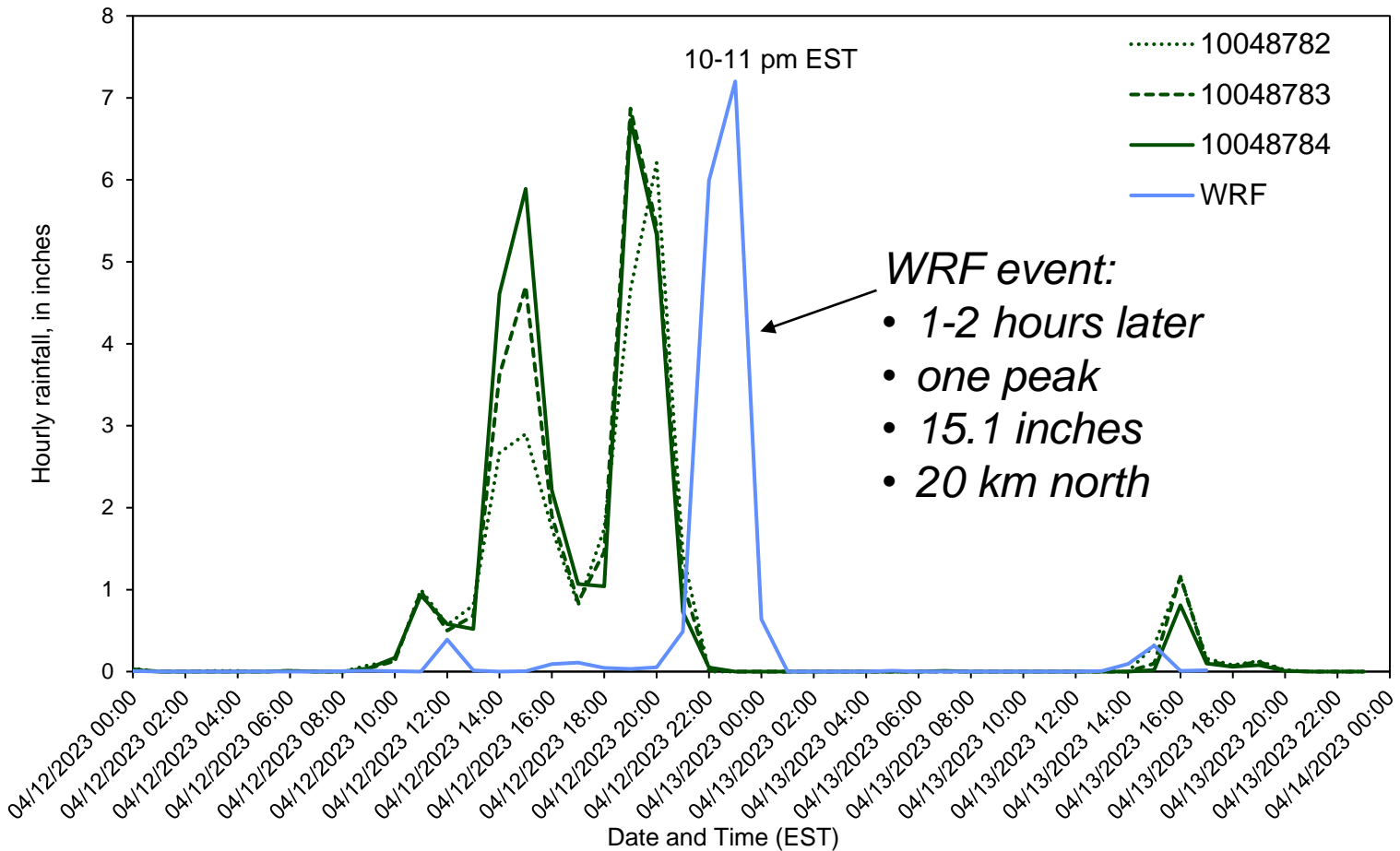
Timing of rainfall

NEXRAD Pixels 10048782, 10048783, 10048784

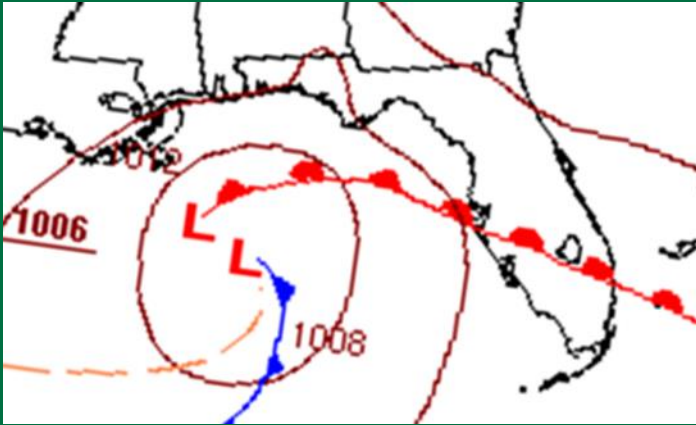


Timing of rainfall

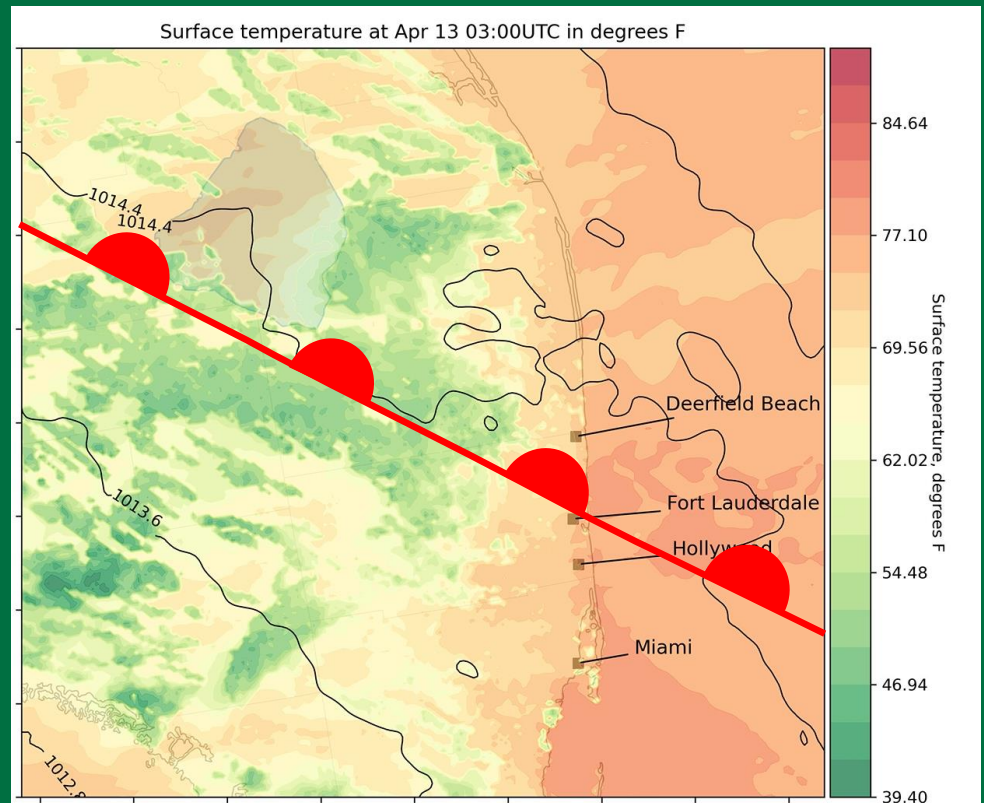
NEXRAD Pixels 10048782, 10048783, 10048784



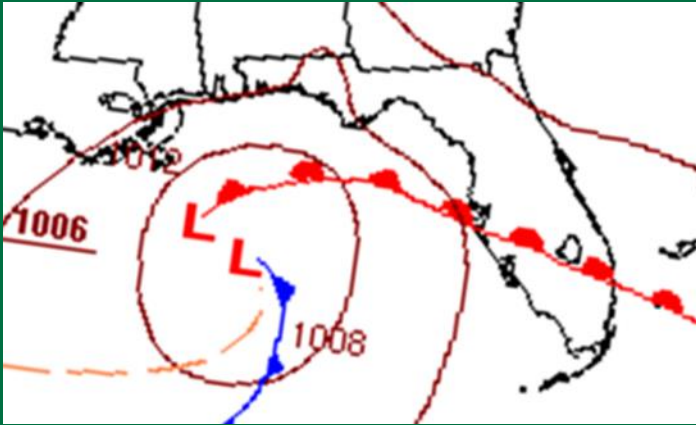
Surface analysis, 10:00 pm EST



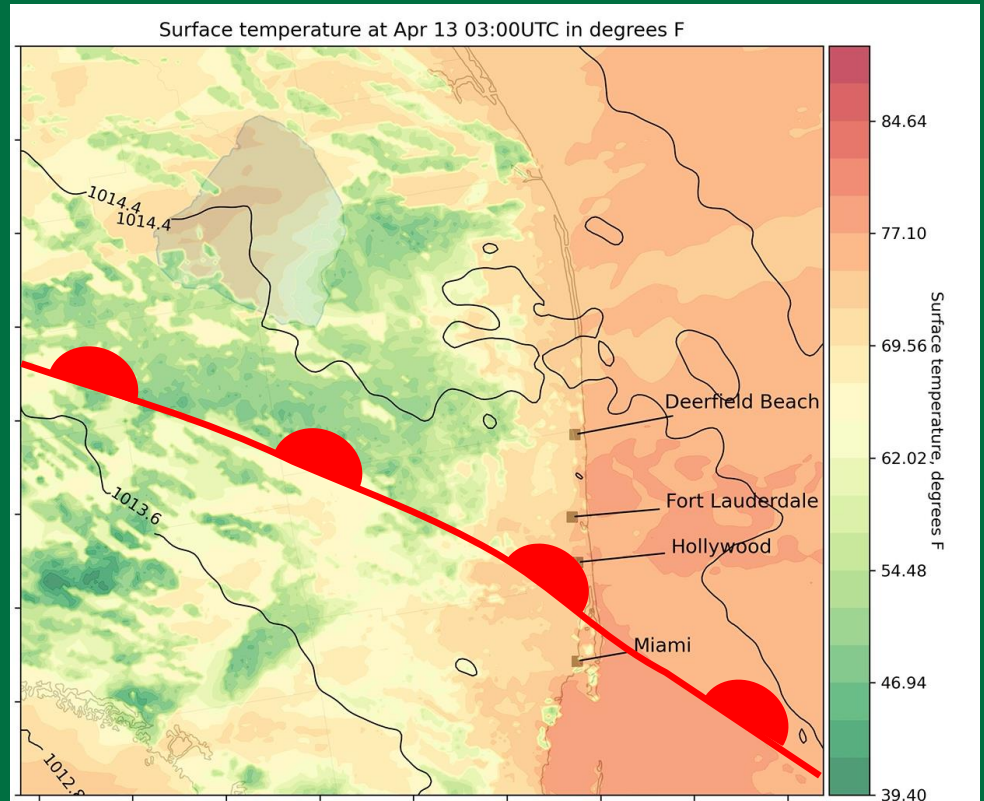
WRF reanalysis for 4/12 at 10:00 pm EST
4/13 03:00 UTC



Surface analysis, 10:00 pm EST



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

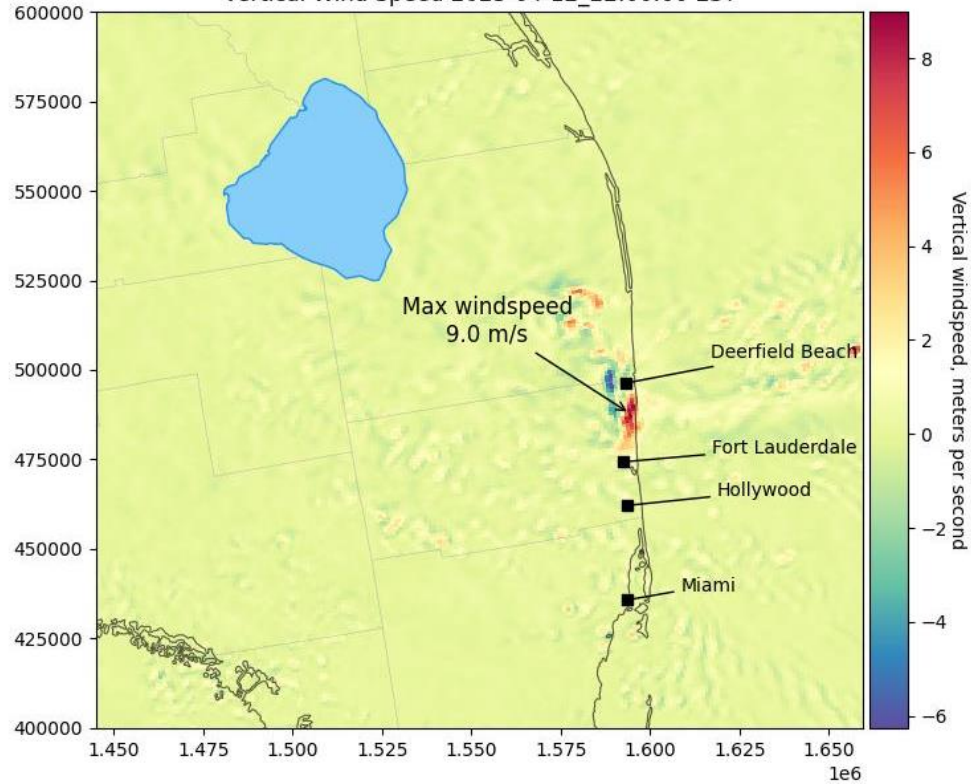
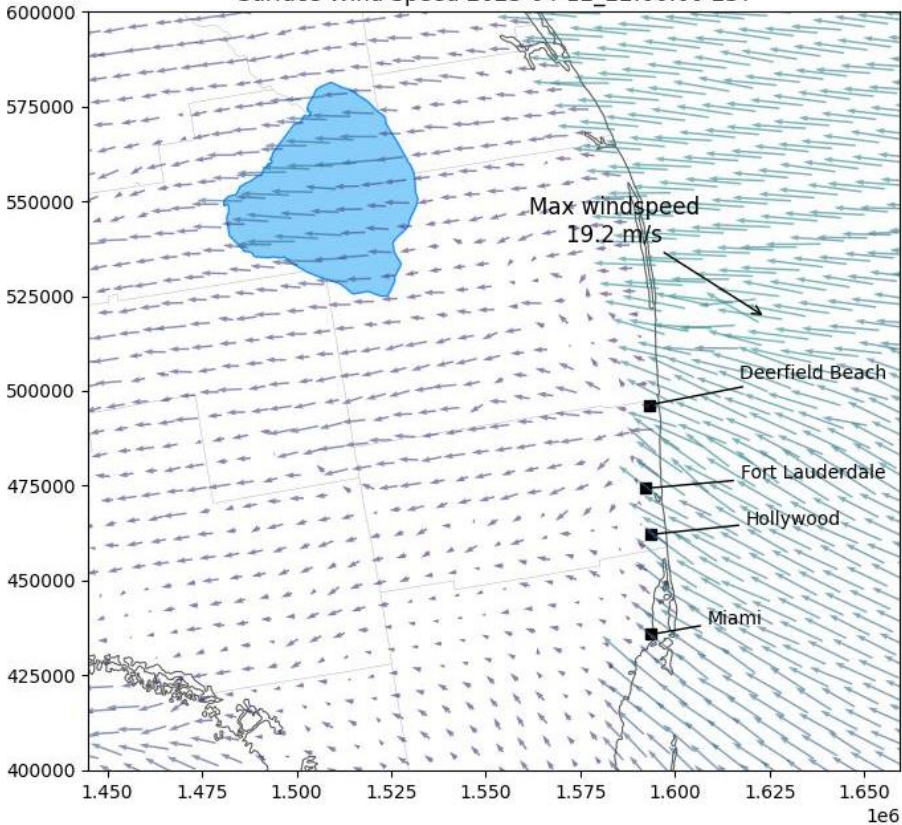


Surface wind speed and direction

Vertical wind speed

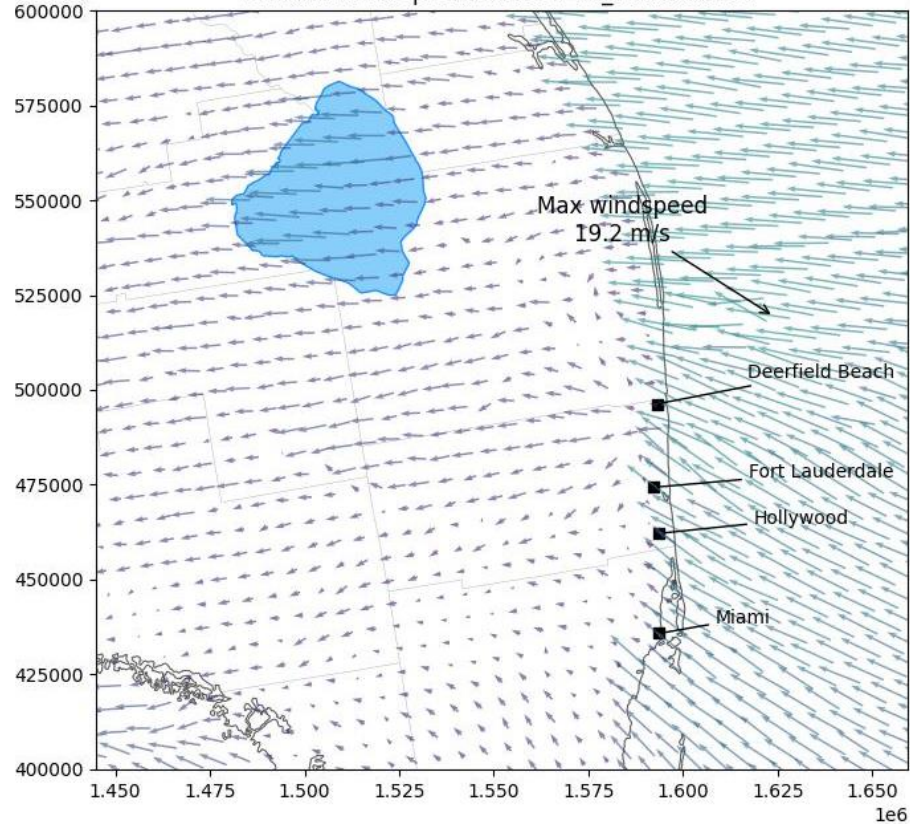
Surface Wind Speed 2023-04-12_22:00:00 EST

Vertical Wind Speed 2023-04-12_22:00:00 EST

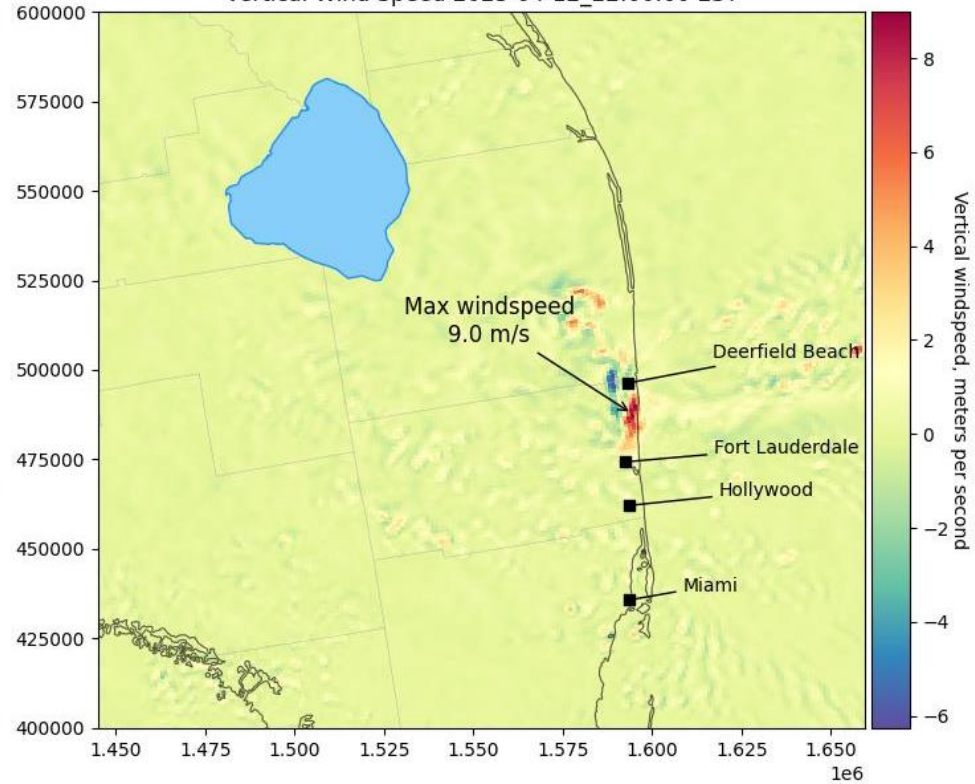


Stronger easterly winds (blows from the east) offshore, compared to onshore

Surface Wind Speed 2023-04-12_22:00:00 EST

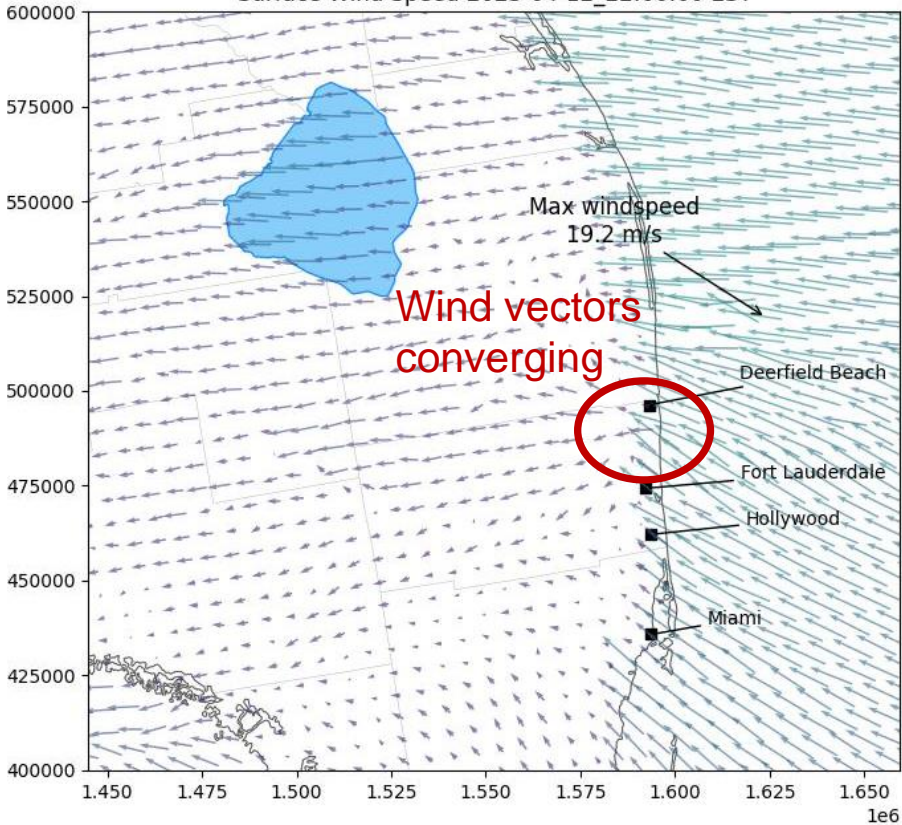


Vertical Wind Speed 2023-04-12_22:00:00 EST

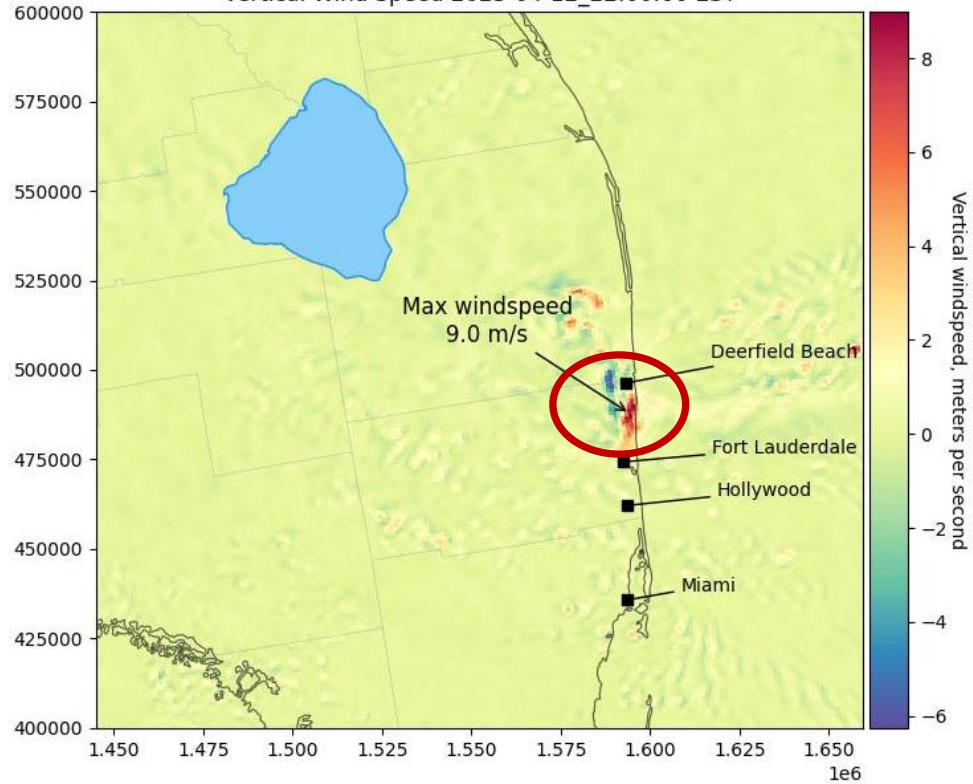


Converging winds in area of the mesocyclone

Surface Wind Speed 2023-04-12_22:00:00 EST

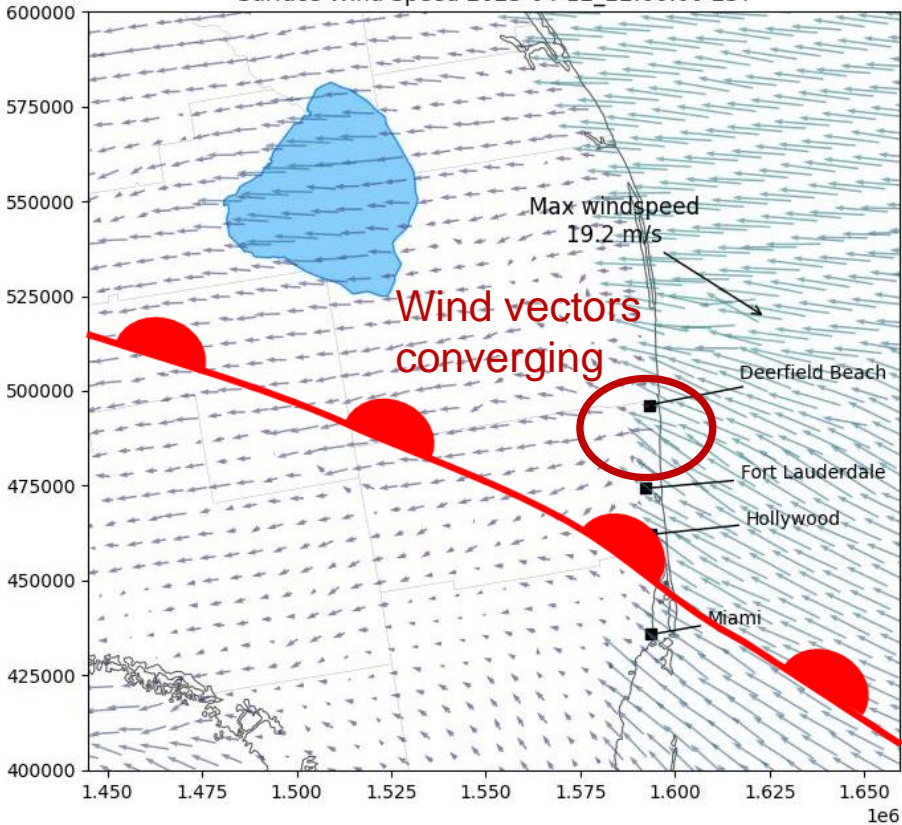


Vertical Wind Speed 2023-04-12_22:00:00 EST

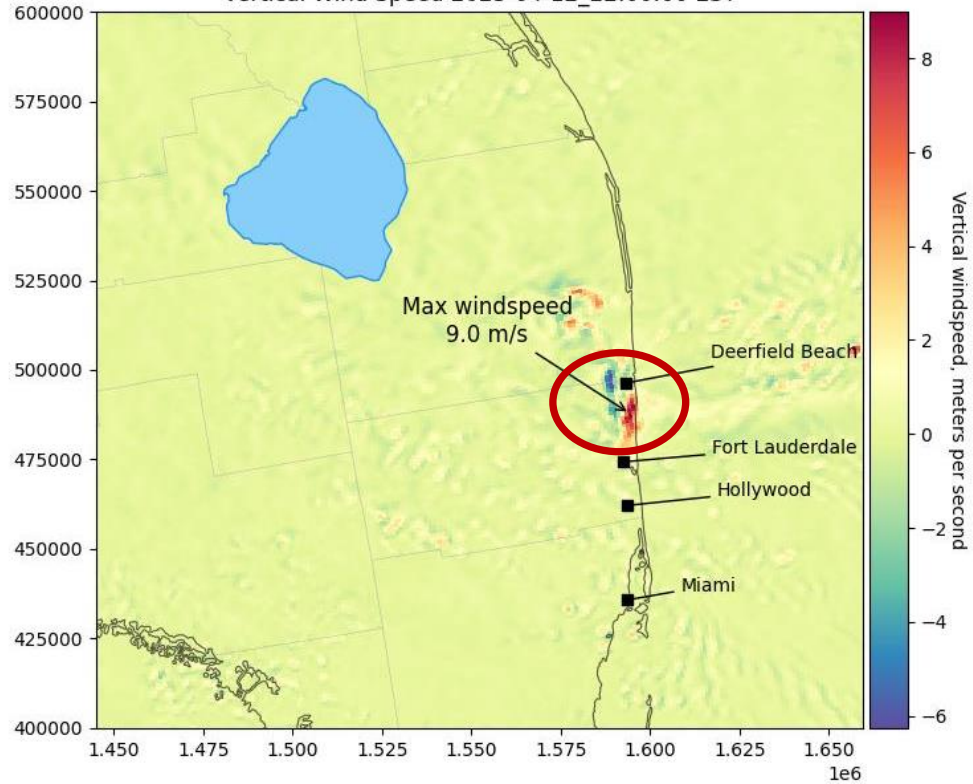


Front entered area to provide initial lift of warm surface air

Surface Wind Speed 2023-04-12_22:00:00 EST



Vertical Wind Speed 2023-04-12_22:00:00 EST

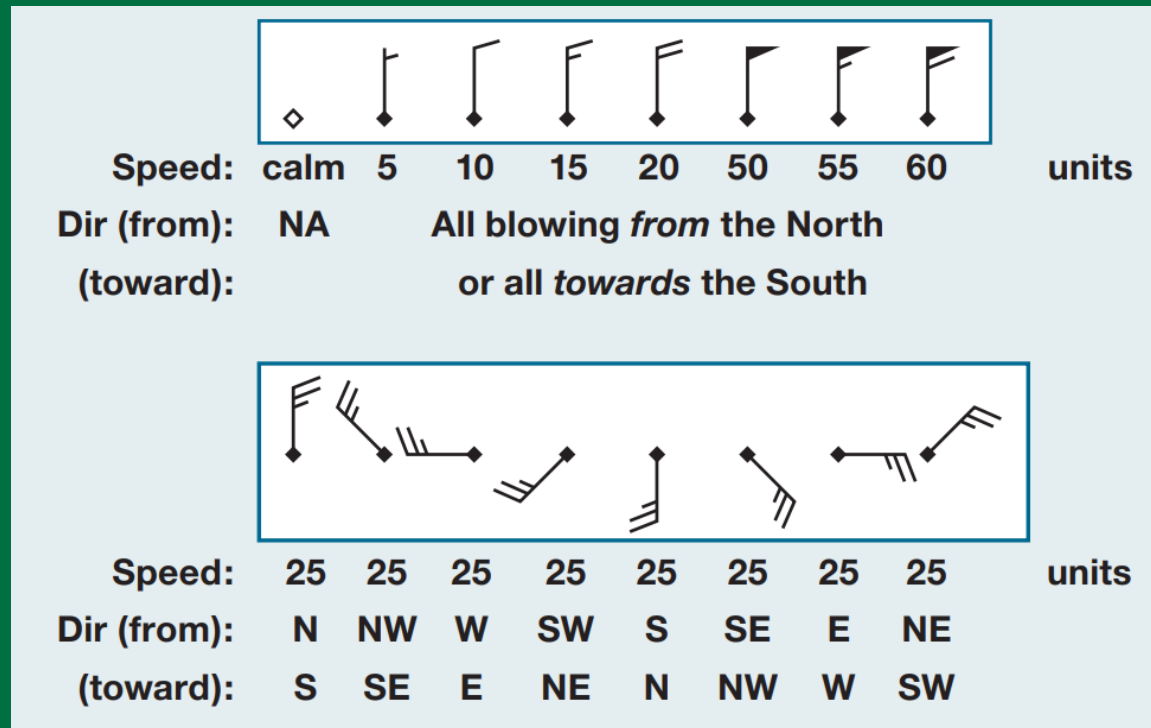


Background Information

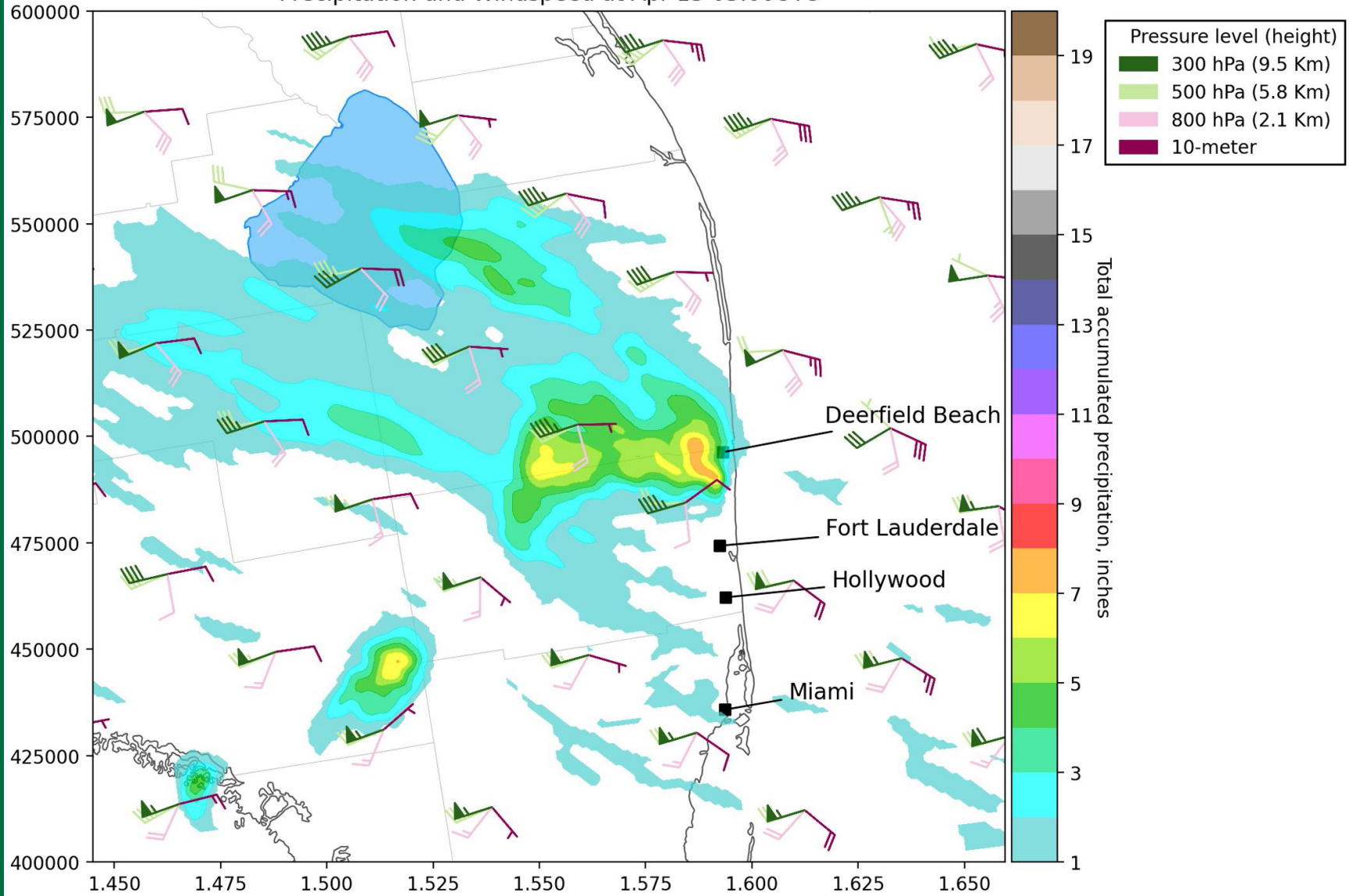
- **Pressure:**

- 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:**

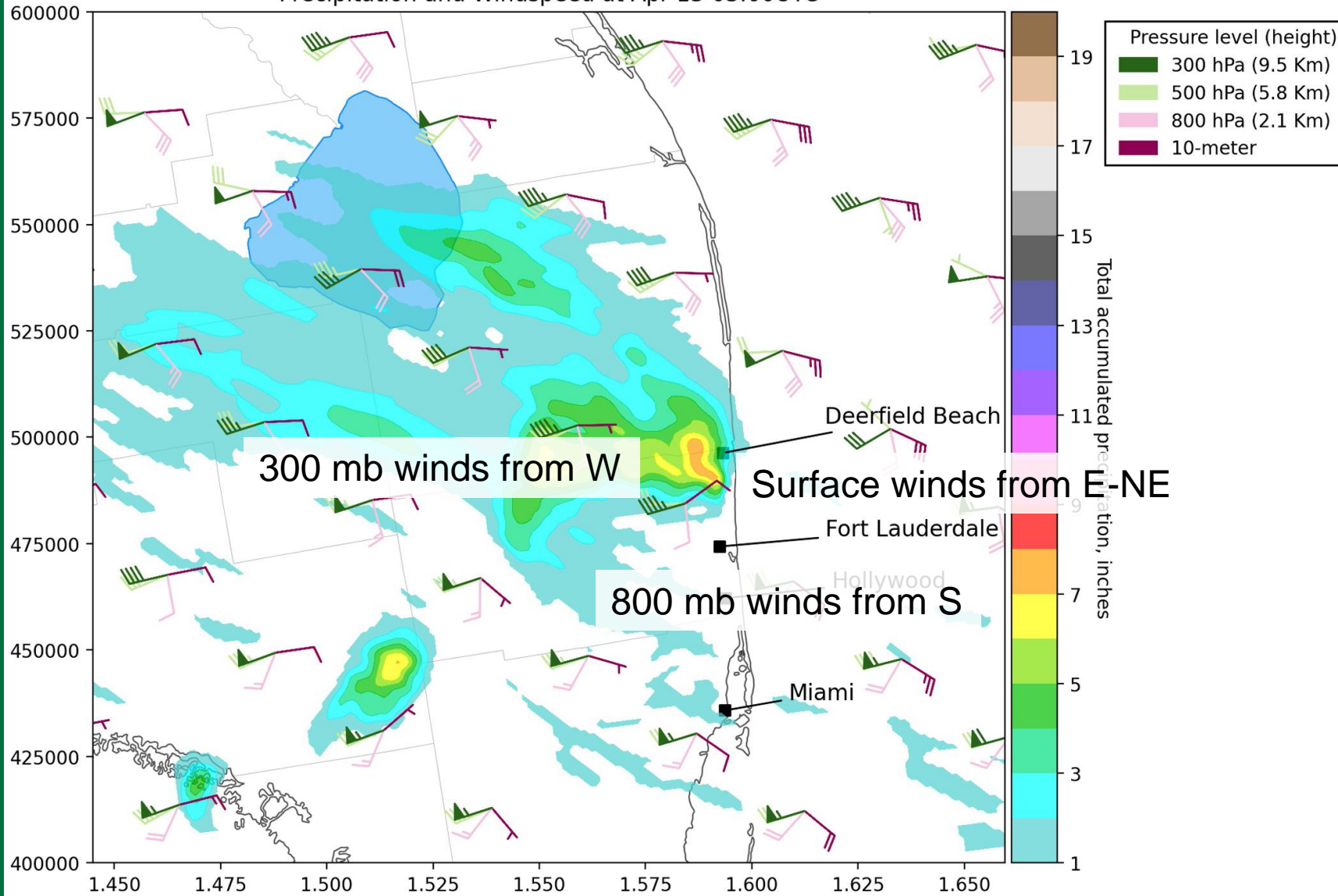


Precipitation and Windspeed at Apr 13 03:00UTC



Varying wind direction promotes rotation and tornadoes

Precipitation and Windspeed at Apr 13 03:00UTC



Varying wind direction promotes rotation and tornadoes

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*

