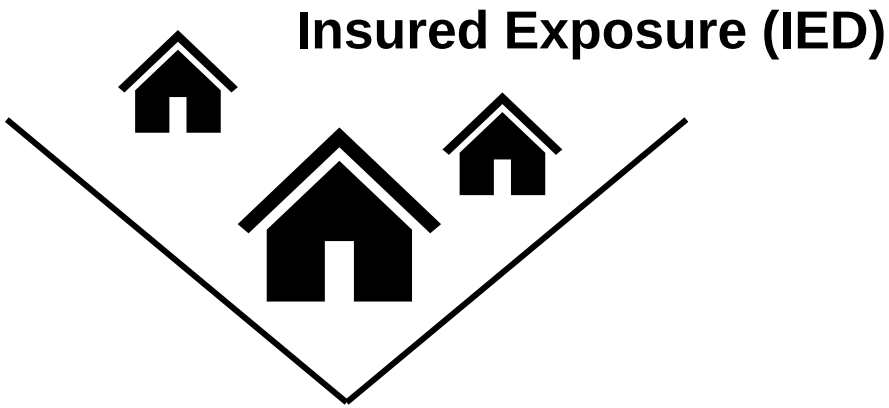
An Overview of RMS' Flood Event Response and Forecasting

Jose Salinas

24th April 2023 – Vienna, Austria
European Geosciences Union General Assembly

Event Response Workflow

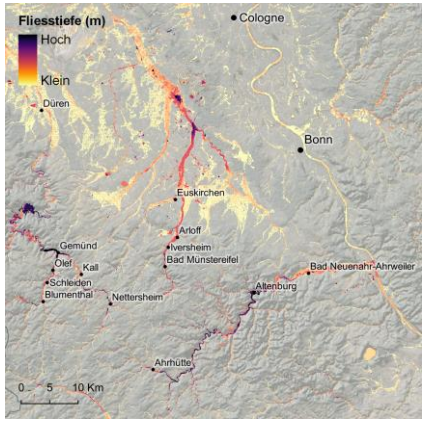
From Event to Industry Loss Estimate

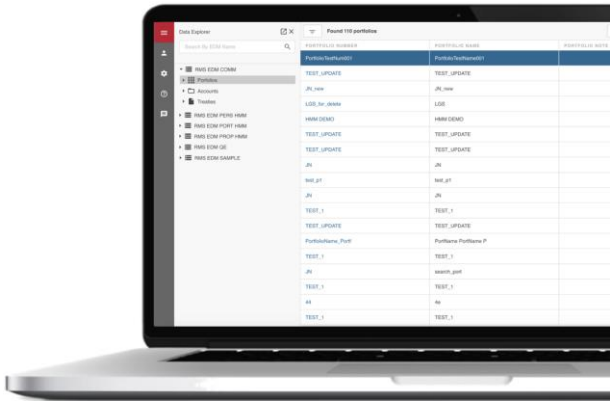


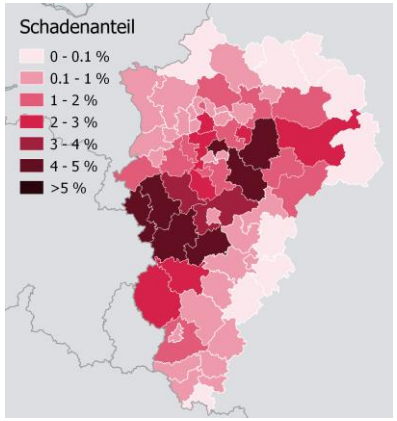
Event Reconstruction

Europe Inland / US Inland Flood models

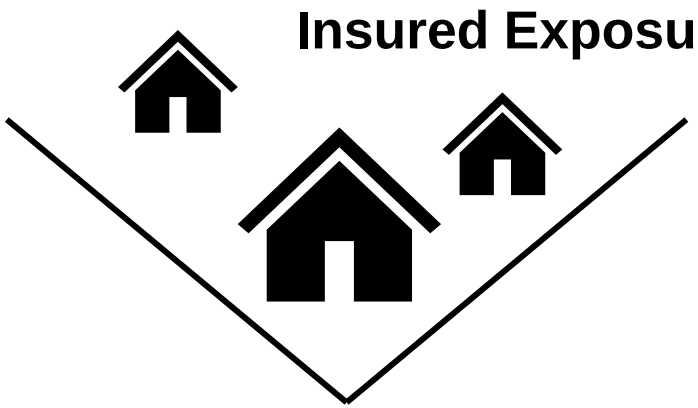
Loss Estimates





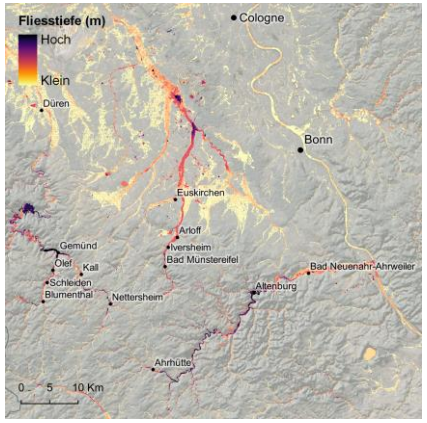


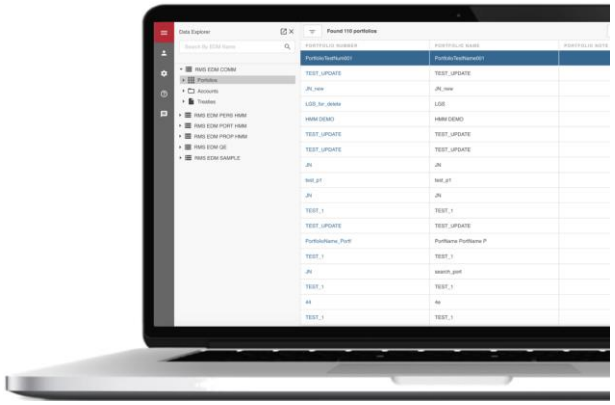
From Event to Industry Loss Estimate

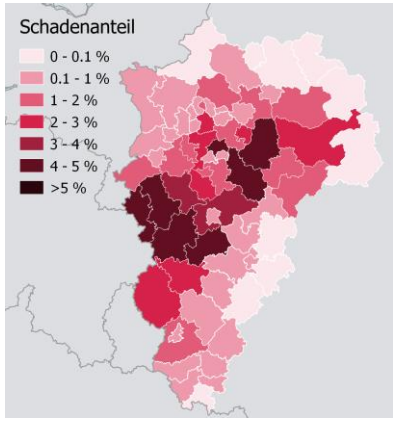


- **Workforce** transfer
- Capital allocation
- Insurance Claims **Reserve**
- ***1 week*** after the event

Event Reconstruction → Europe Inland / US Inland Flood models → Loss Estimates





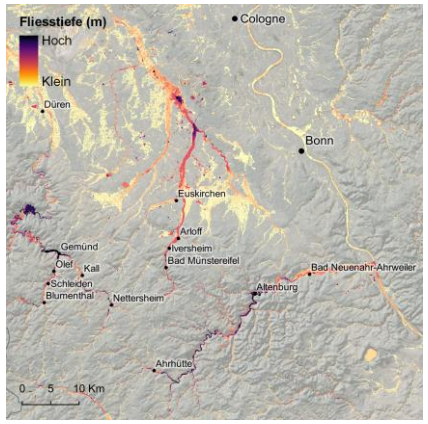


From Event to Industry Loss Estimate

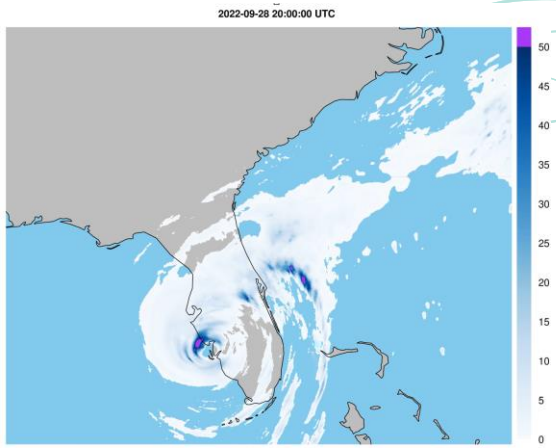
Event Reconstruction

Europe Inland / US Inland Flood models

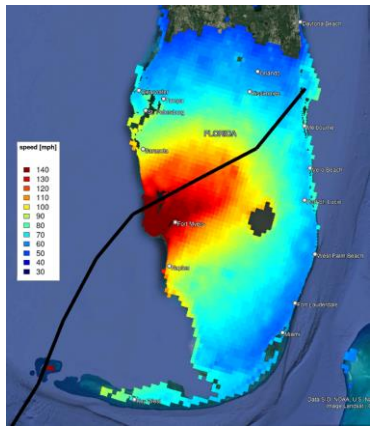
Loss Estimates

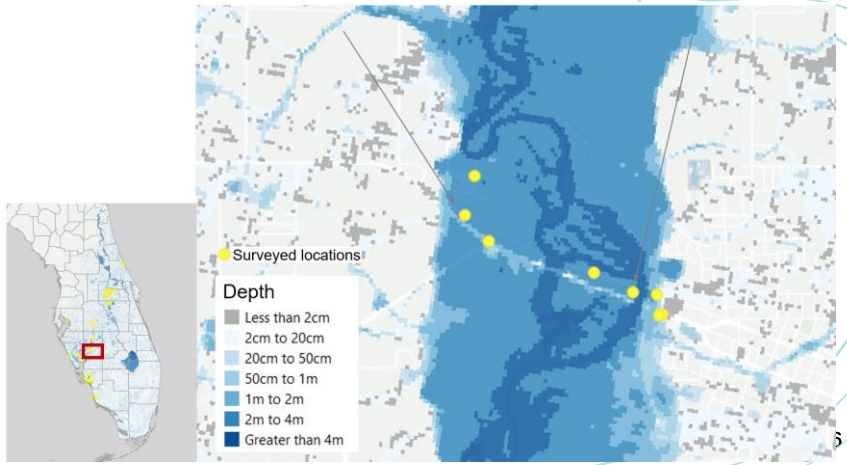


Timelines of RMS Event Response

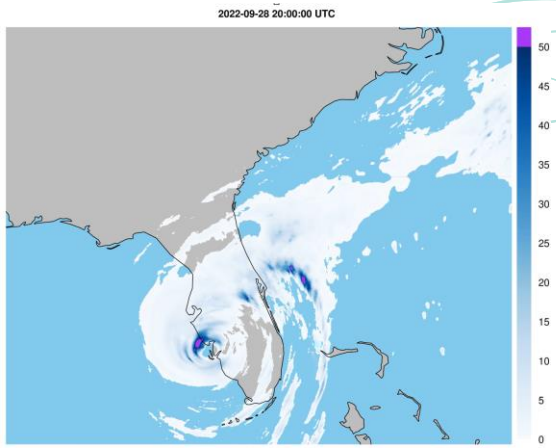


TC track and Precipitation Forecasts → Landfall Information → Quasi Real-Time high-resolution precipitation → Footprint Reconstruction & Validation



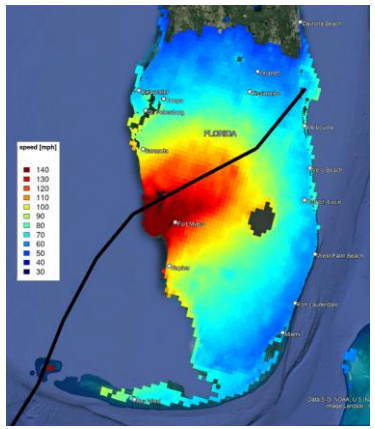


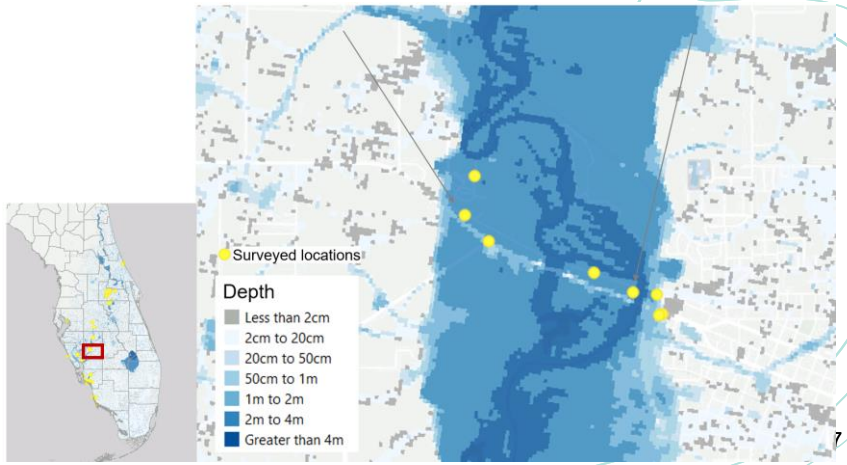
Timelines of RMS Event Response



TC track and Precipitation Forecasts → Landfall Information → Quasi Real-Time high-resolution precipitation → Footprint Reconstruction & Validation

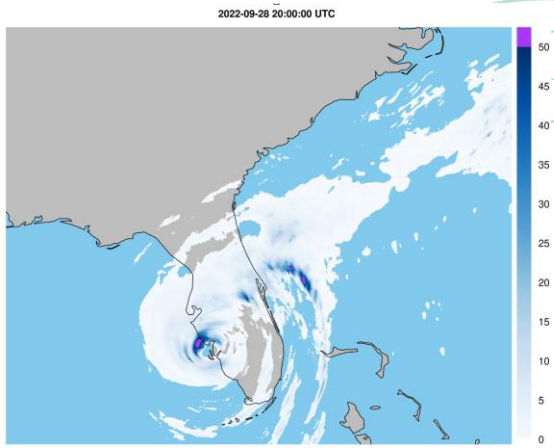
- **NCEP** precip forecast
- ~ 5-7 days before forecasted landfall
- Re-run the model with new forecast every 24hr





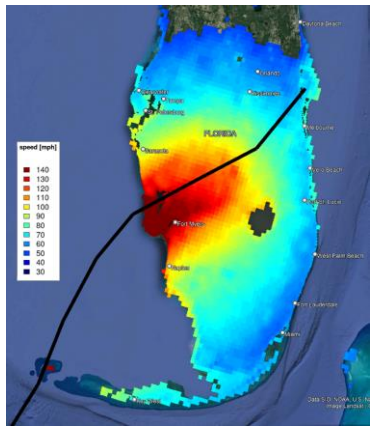
Timelines of RMS Event Response

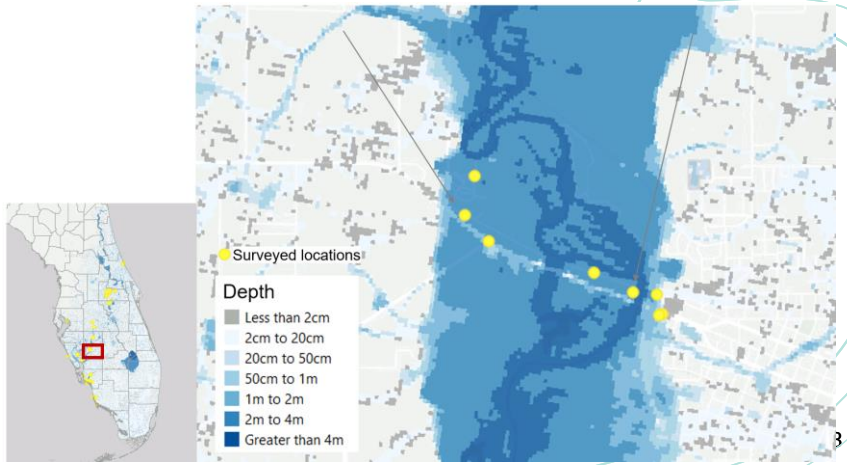
- First gage observations
- **CPC** rainfall data
- **MRMS** rainfall data



TC track and Precipitation Forecasts → Landfall Information → Quasi Real-Time high-resolution precipitation → Footprint Reconstruction & Validation

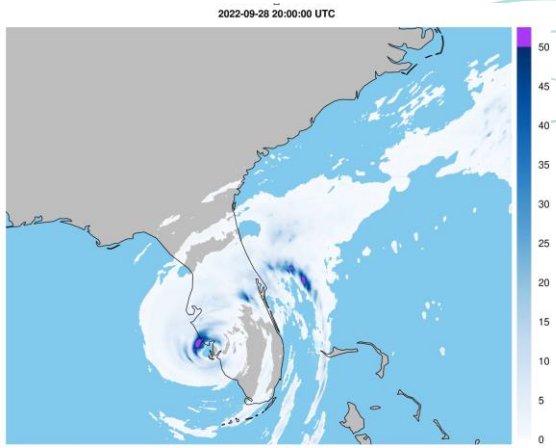
- **NCEP** precip forecast
- ~ 5-7 days before forecasted landfall
- Re-run the model with new forecast every 24hr





Timelines of RMS Event Response

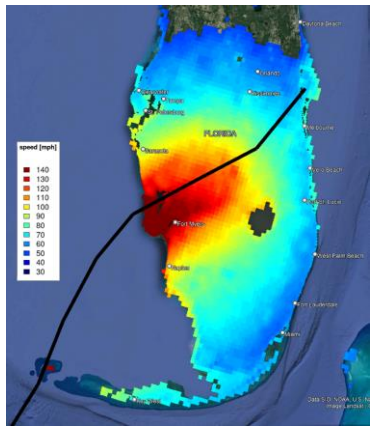
- First gage observations
- **CPC** rainfall data
- **MRMS** rainfall data

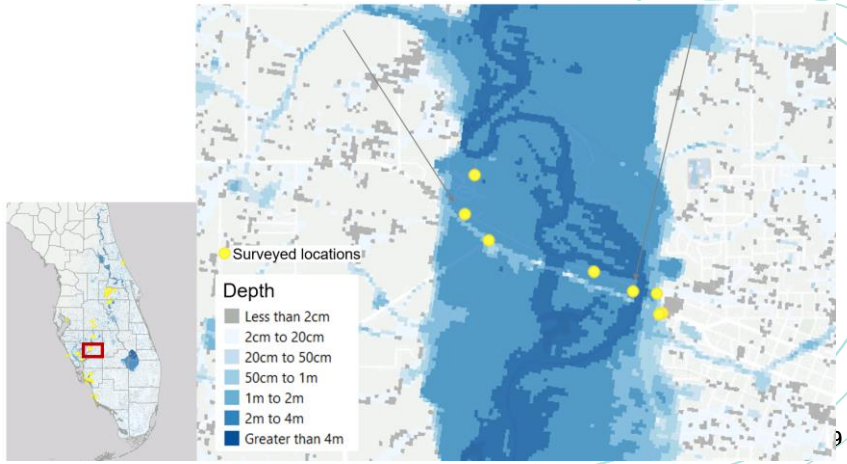


- 2yrs of **NLDAS** forcings pre-event
- Hydrological model
  - Rainfall Runoff
  - Routing
- 2D Inundation Model
  - Fluvial
  - Pluvial

TC track and Precipitation Forecasts → Landfall Information → Quasi Real-Time high-resolution precipitation → Footprint Reconstruction & Validation

- **NCEP** precip forecast
- ~ 5-7 days before forecasted landfall
- Re-run the model with new forecast every 24hr

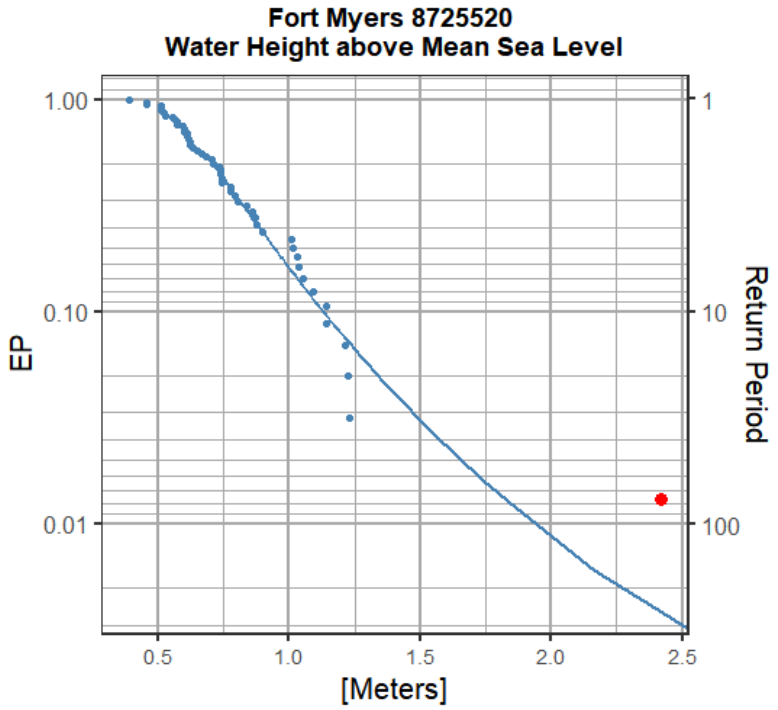




Hurricane Ian – September 2022

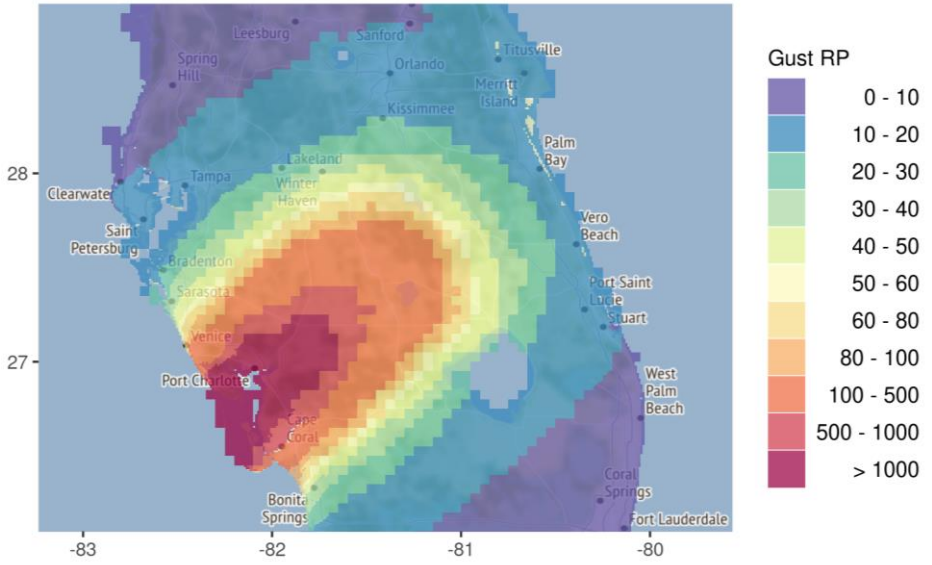
Hazard and Loss Return Periods

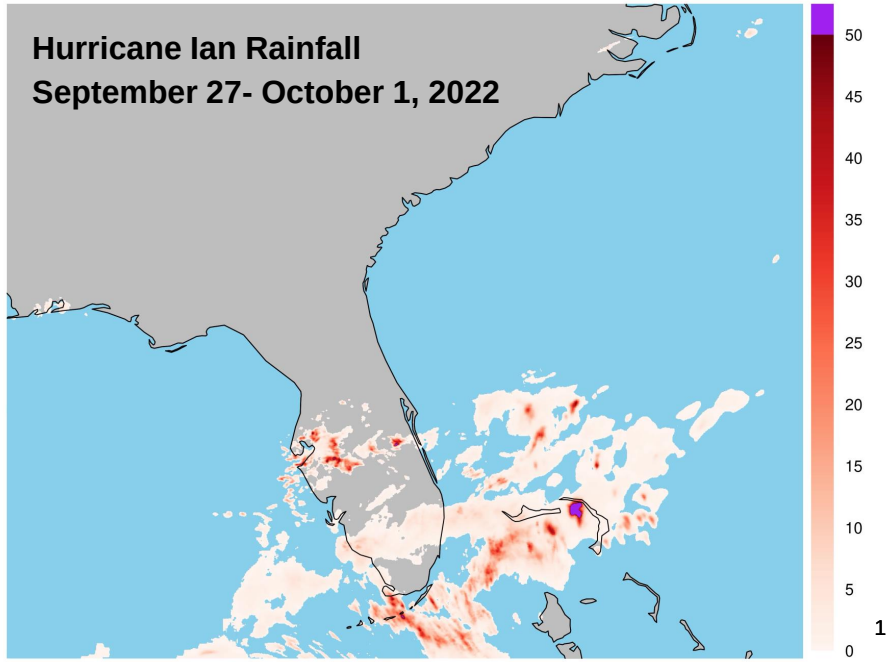
- ***Wind Hazard***
  - 100+ year RP from Venice to south of Cape Coral
  - 1000+ year RP around Port Charlotte
- ***Storm Surge Hazard***
  - 100+ year RP for Key West
  - 200+ years for Naples and Fort Myers
- ***Inland Flood***
  - 1000+ return period rainfall totals in DeSoto County



Wind Hazard (peak 3-sec gust) Return Period

RMS Best Footprint





Loss	All U.S.	Florida Only
Loss Return Period (incl. PLA, excl. NFIP and Non-Modeled Factors)	**OEP RP (All Lines)**	**OEP RP (All Lines)**
Wind + Surge + Inland Flood	10-15 years	15-30 years

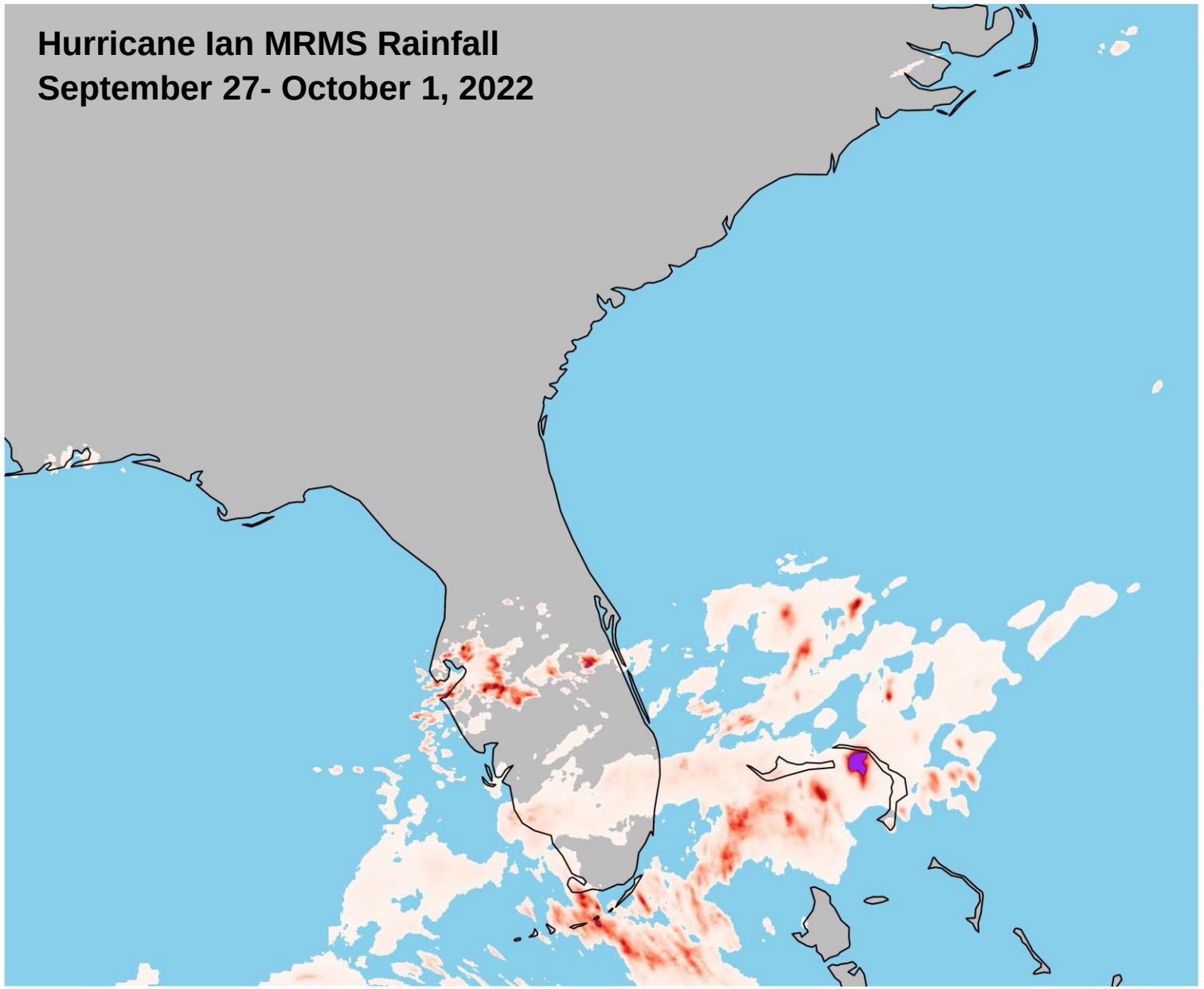
Sources: RMS

Hazard a

- *Wind Hazard*
  - 100+ year RP from Cape Coral
  - 1000+ year RP aro
- *Storm Surge Haza*
  - 100+ year RP for K
  - 200+ years for Nap
- *Inland Flood*
  - 1000+ return perioc DeSoto County

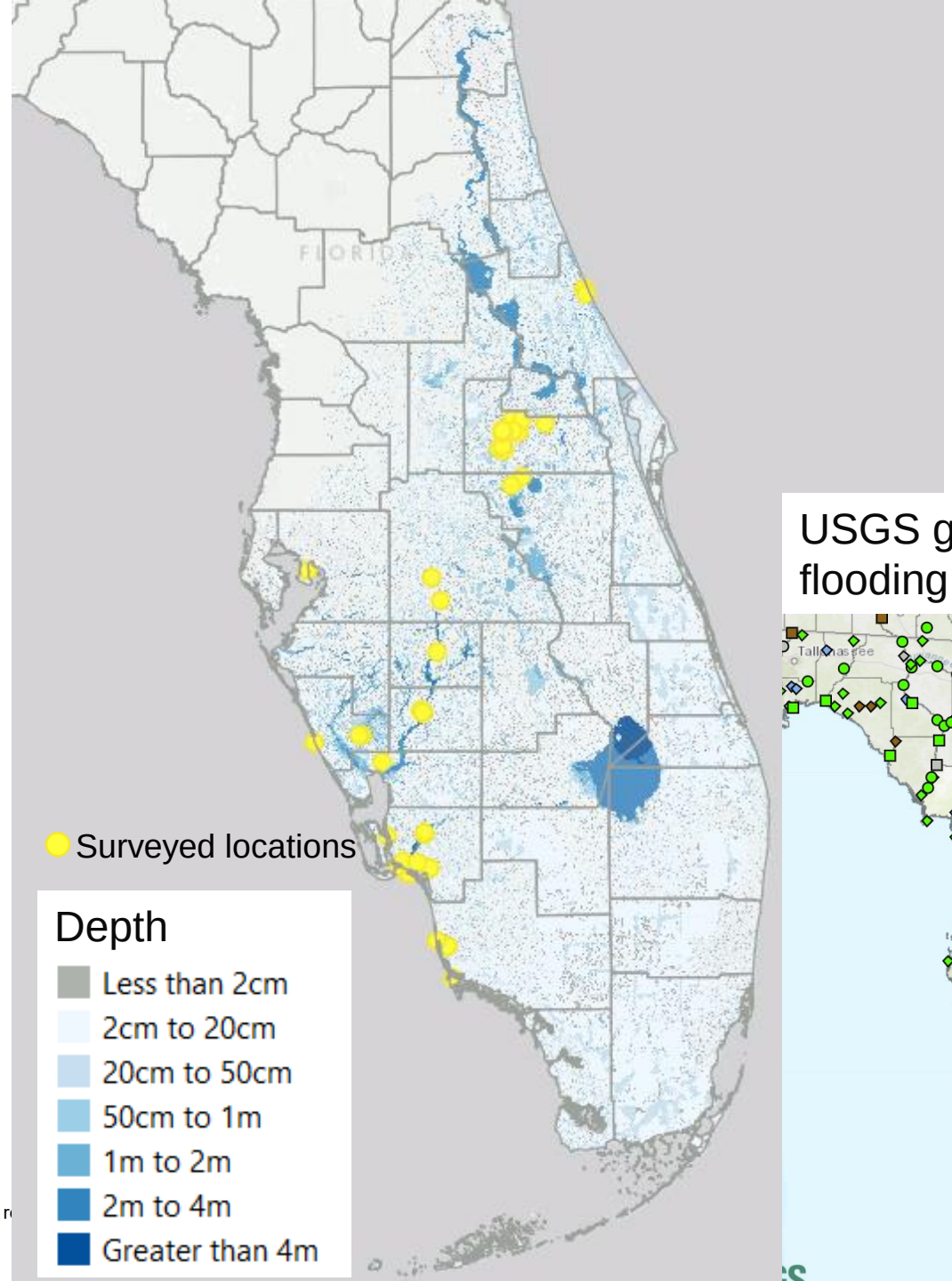
Loss R
(incl. PLA, excl. NFIP

Wind + Surge + Inland

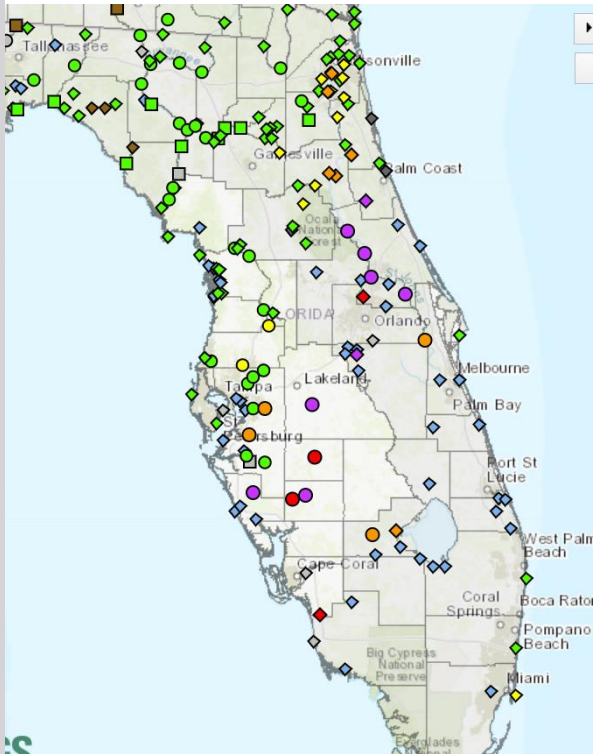


Inland Flood Validation

- RMS surveyed a number of points for evidence of inland flooding
- Survey methods included geolocated news reports and field survey
- High resolution **MRMS** Radar Rainfall showed the **best modelled results** when compared to **observations**
- Both **CPC** (quasi-real time) and **NCEP** forecasts **strongly underestimated** the flood extent and flood depths.



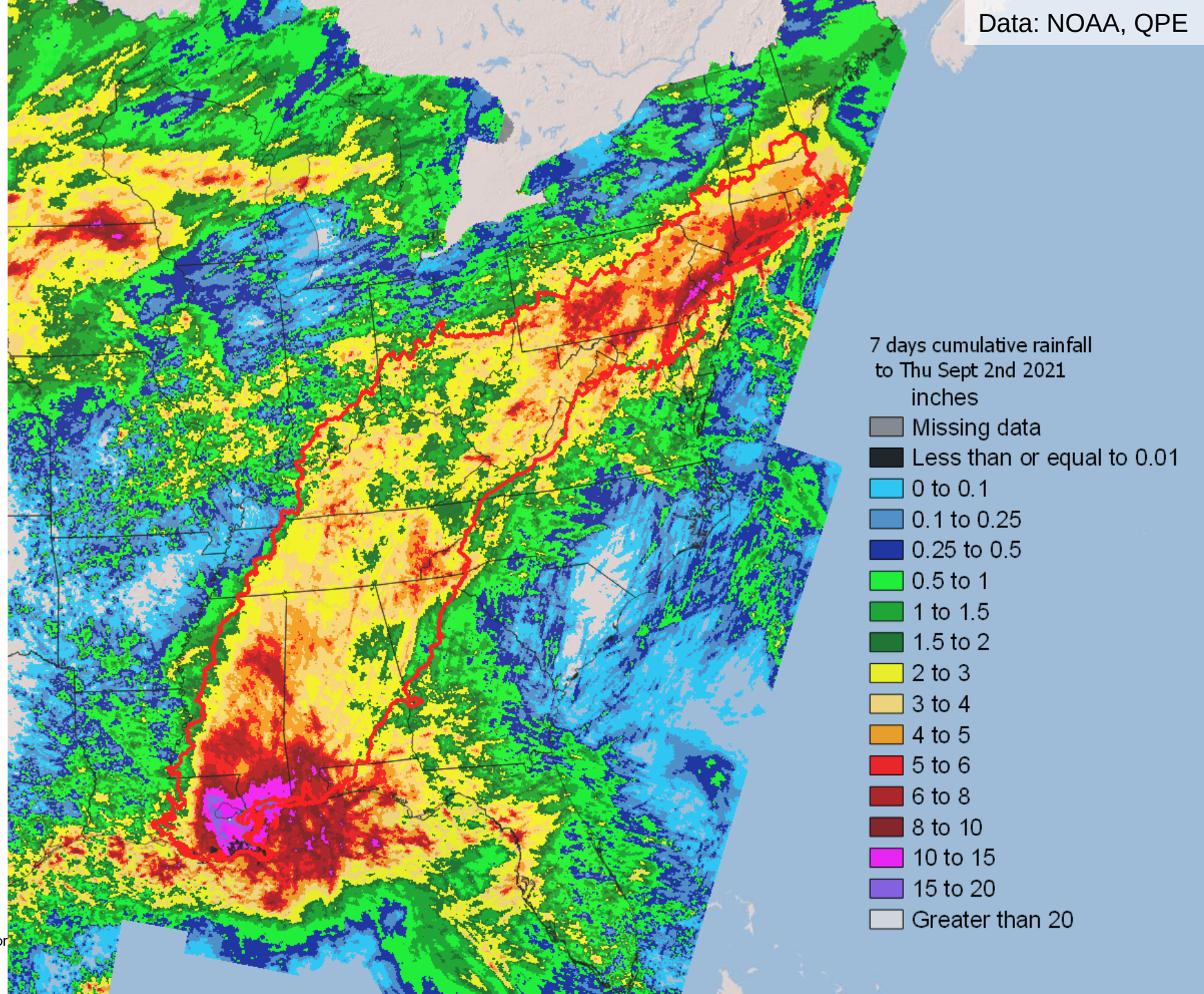
USGS gages in major flooding shown in purple



Hurricane Ida – August 2021

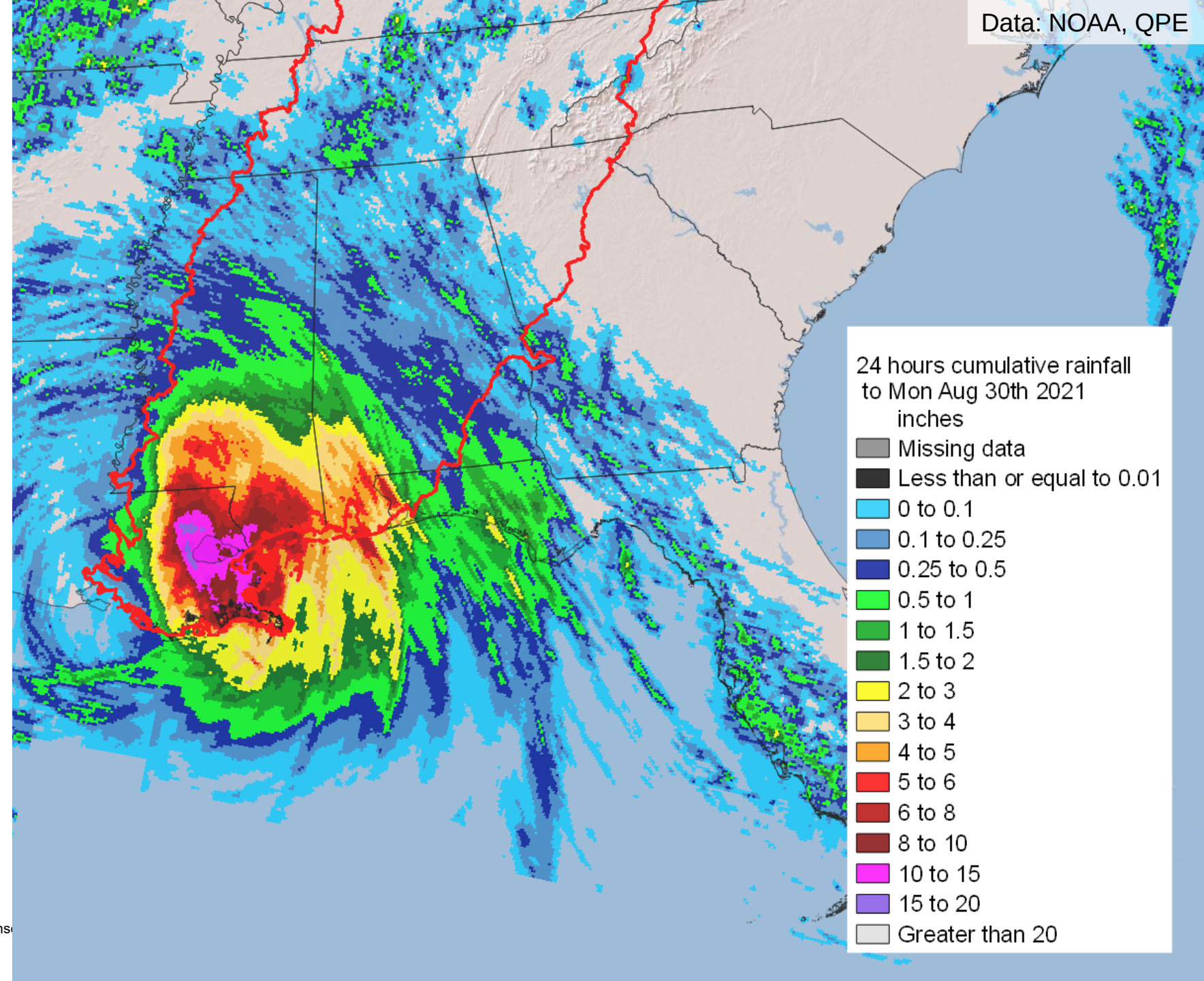
Ida Rainfall Pattern

- Extreme precipitation in landfall area
- Concentrated between 29th and 30th of August
- Storm moved north producing rainfall extremes along its path
- On September 1st unprecedented rainfall extremes over Mid-Atlantic and Northeast regions



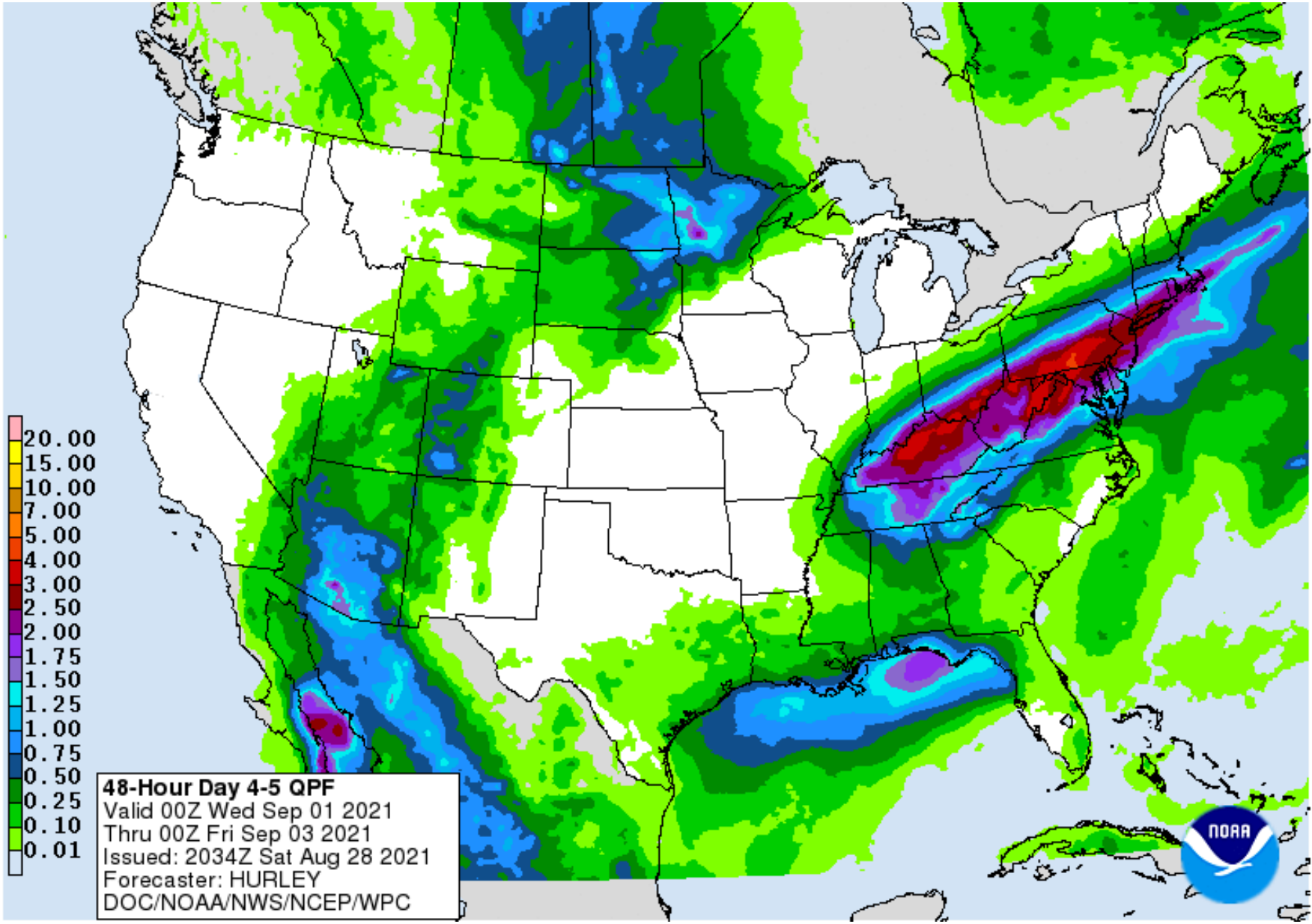
Landfall Area

- Extreme rainfall accumulation
- 9’’ rain registered at Lake Maurepas USGS gauge on Aug 29
- Evacuation and preparedness for the storm arrival
- **NLDAS**, **CPC**, and **MRMS** were very **similar** in magnitude for Louisiana



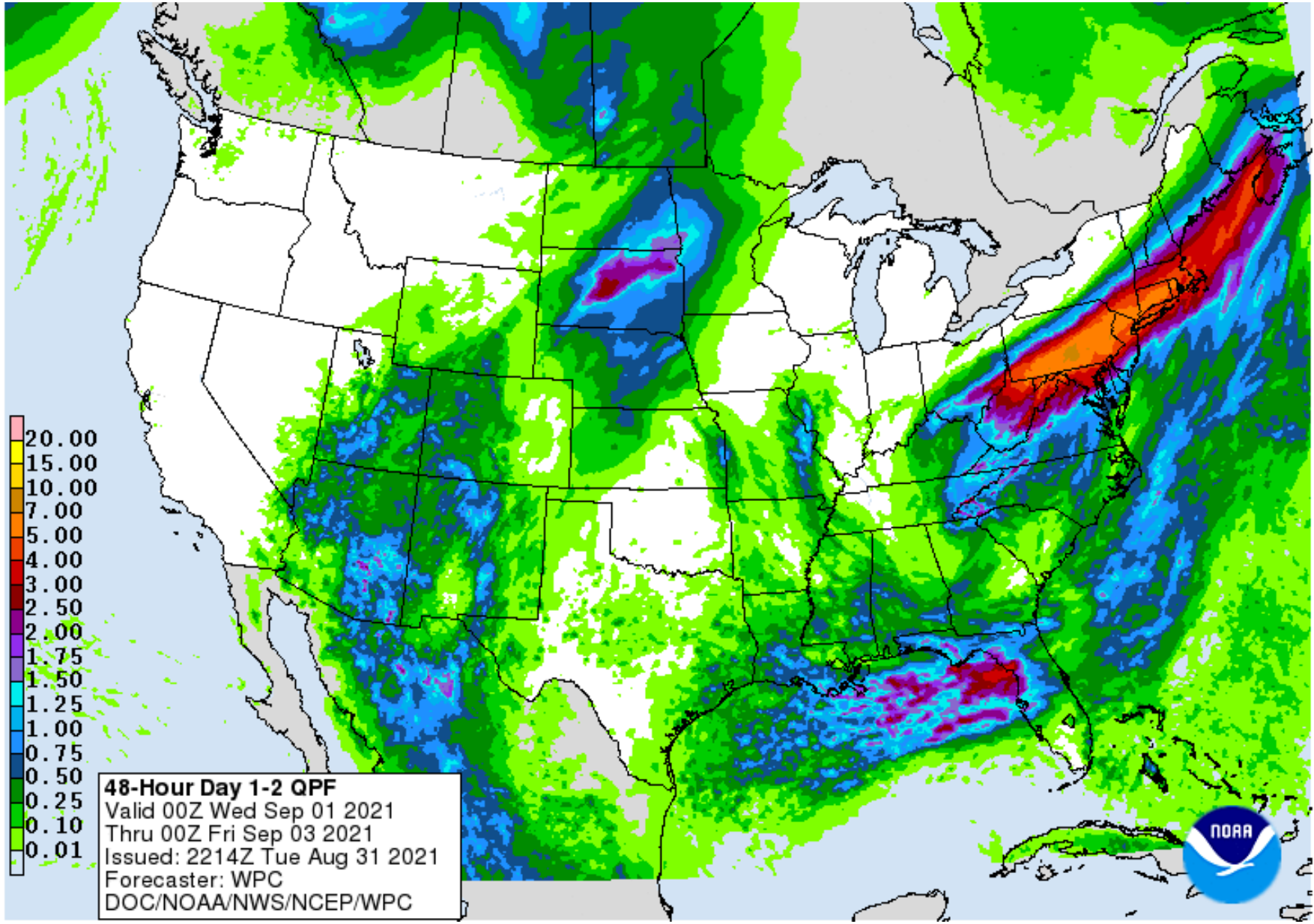
Rainfall Forecast

- Issued on 29th of August
- It started to become clear that the rainfall front would affect Northeast U.S.
- Forecast high rainfall over PA, 2-day totals of up to 5’’



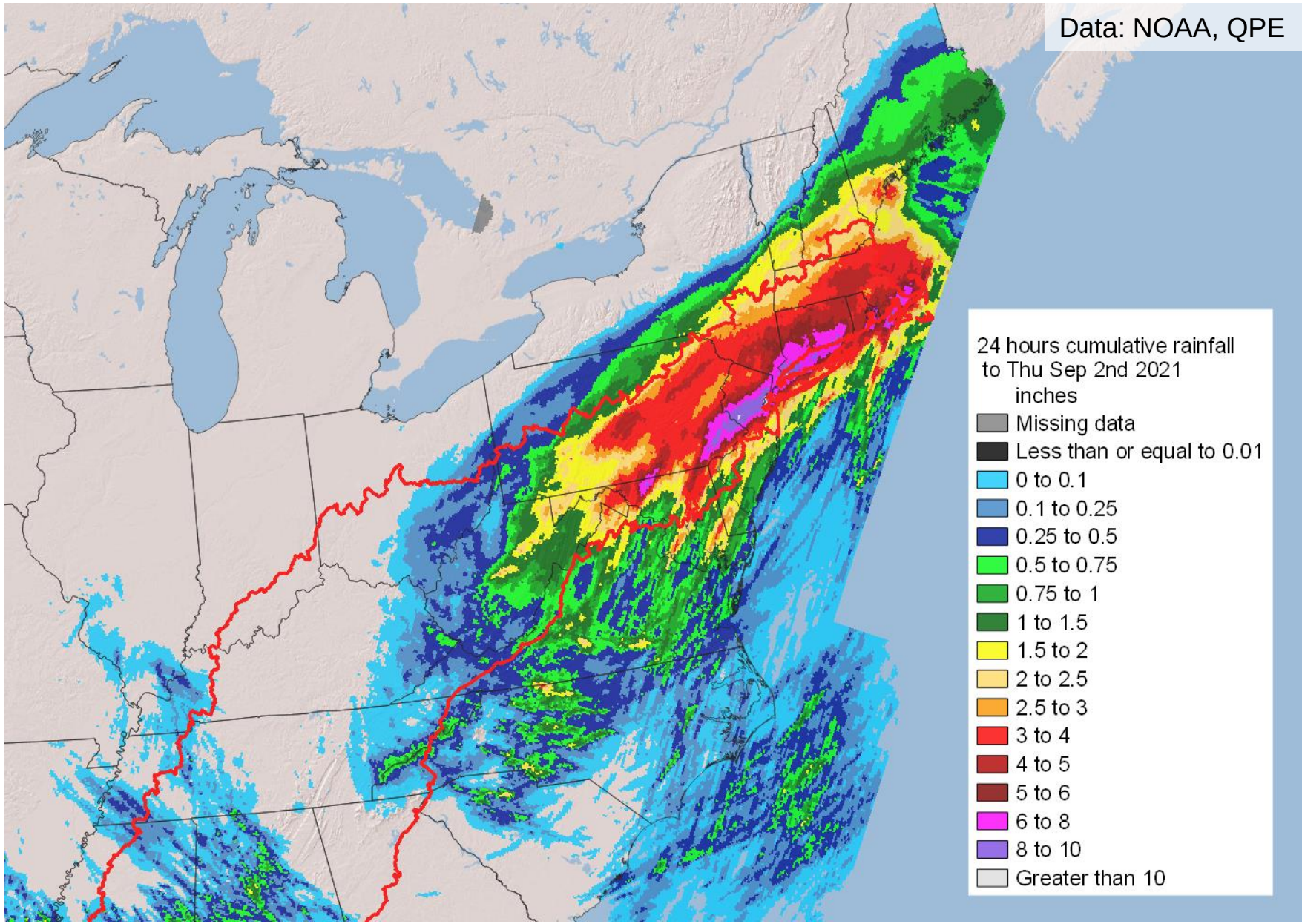
Forecast Evolution

- 2 days later
- Forecast issued 31st of Aug
- Up to 5-7’’ of rainfall
- Also affecting NJ, NY, CT



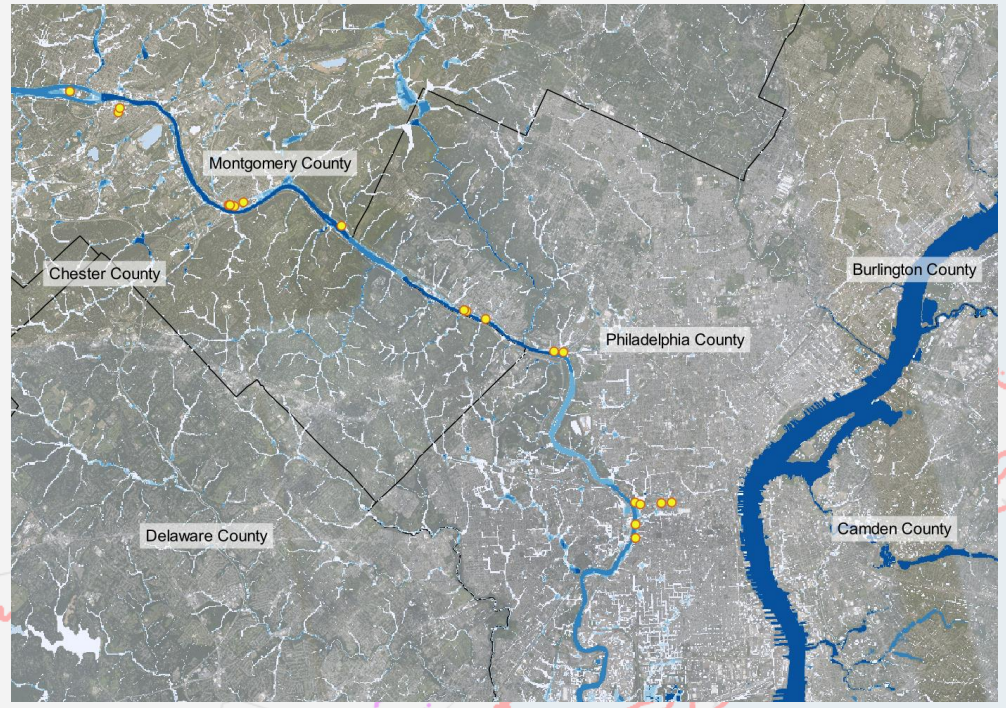
Then it started raining…

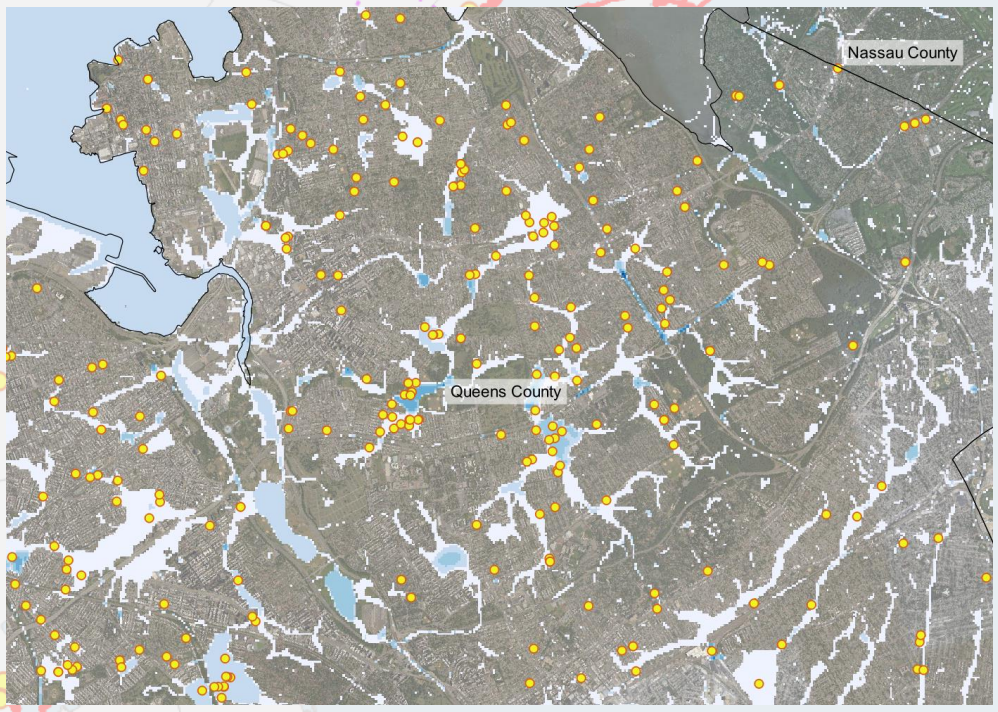
- Actual rainfall amounts largely exceeded **NCEP** forecasts
- Record-breaking rainfall over NJ, NY, PA, CT
- Several records broken for max hourly rainfall, max daily rainfall
- High resolution **MRMS** Radar Rainfall was **much higher** than **CPC**, **NLDAS** in the **Northeast**



Ida Flood Footprint Validation

- Flooding along Schuylkill River in Philadelphia
- Pluvial flooding in NYC
- ~70% of reported locations *within 100m* radius from modeled inundation in the map
- High resolution **MRMS** Radar Rainfall showed the **best modelled results** when compared to **observations**





Summary & Conclusions

Summary and Conclusions

- Using high resolution **MRMS** Radar Rainfall as model input produces the **best modelled results** when compared to **observations (flood extent and flood depths)**
  - **MRMS** tends to resolve well very localised, short duration high intensity rainfall events
  - Relevant when the main driver of loss is pluvial flooding in urban areas (or fluvial in small catchments)
- **NLDAS** rainfall works well for large areal estimates but tends to underestimate short duration high intensity rainfall events
  - Best product when the main driver of loss is fluvial flooding in middle to large sized catchments
- Both **CPC** (quasi-real time) and **NCEP** forecasts **strongly underestimated** the flood extent and flood depths.

- Other examples in the appendix: California Atmospheric Rivers (Jan 2023), Fort Lauderdale (April 2023), Low pressure front Bernd (July 2021, Germany and Belgium)

California – Atmospheric Rivers Jan 2023

Drivers of the flood: precipitation

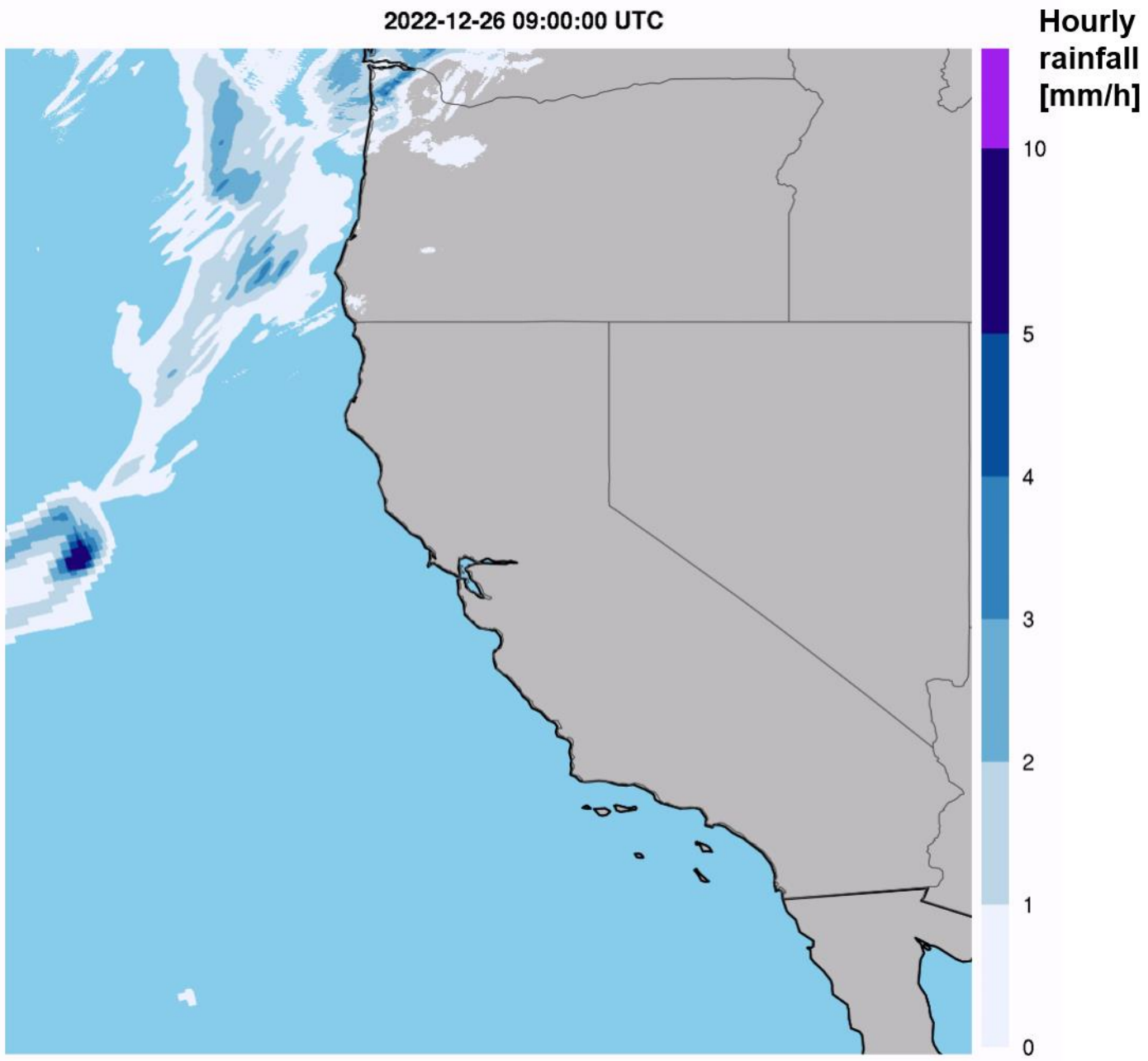
- One of the most distinguishing features of the recent California floods is the clustering pattern of ARs, **from December 25, 2022 to January 12**. The most heavily impacted areas include:

(1) San Francisco Bay Areas: **12+ inches** in San Francisco and Oakland between Dec 26 to Jan 9

(2) Sacramento Valley: **8+ inches** in Sacramento, and **4+ inches** in Los Angeles between Dec 26 to Jan 9,

(3) Southern California: **16+ inches** in Ventura and Santa Barbara counties.

(4) Central California



Source: RMS with rainfall data from *MRMS (Multi-Radar / Multi-sensor), NOAA*

Drivers of the flood: precipitation

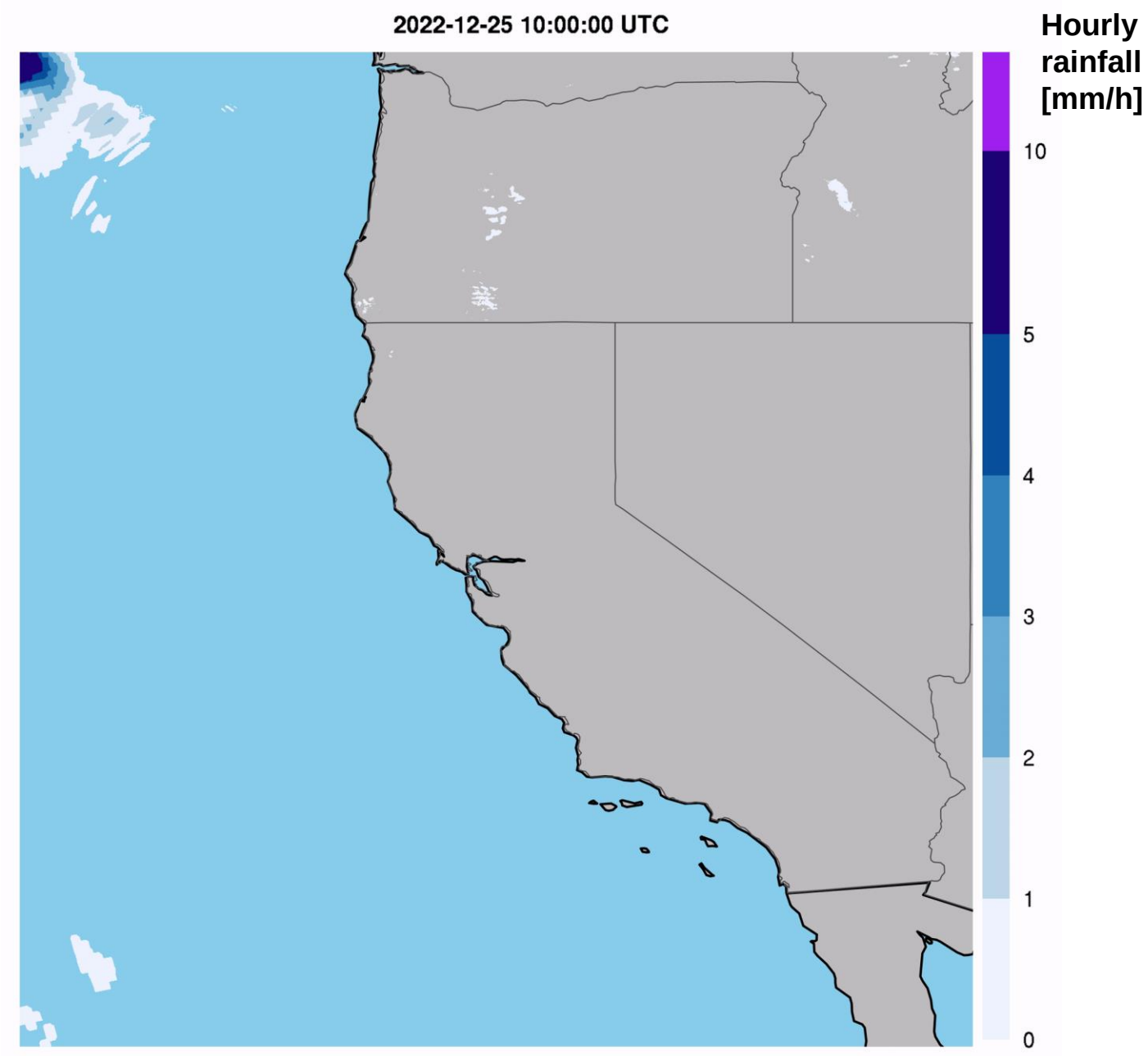
- One of the most distinguishing features of the recent California floods is the clustering pattern of ARs, **from December 25, 2022 to January 12**. The most heavily impacted areas include:

(1) San Francisco Bay Areas: **12+ inches** in San Francisco and Oakland between Dec 26 to Jan 9

(2) Sacramento Valley: **8+ inches** in Sacramento, and **4+ inches** in Los Angeles between Dec 26 to Jan 9,

(3) Southern California: **16+ inches** in Ventura and Santa Barbara counties.

(4) Central California



Source: RMS with rainfall data from *MRMS (Multi-Radar / Multi-sensor), NOAA*

Drivers of the flood: precipitation

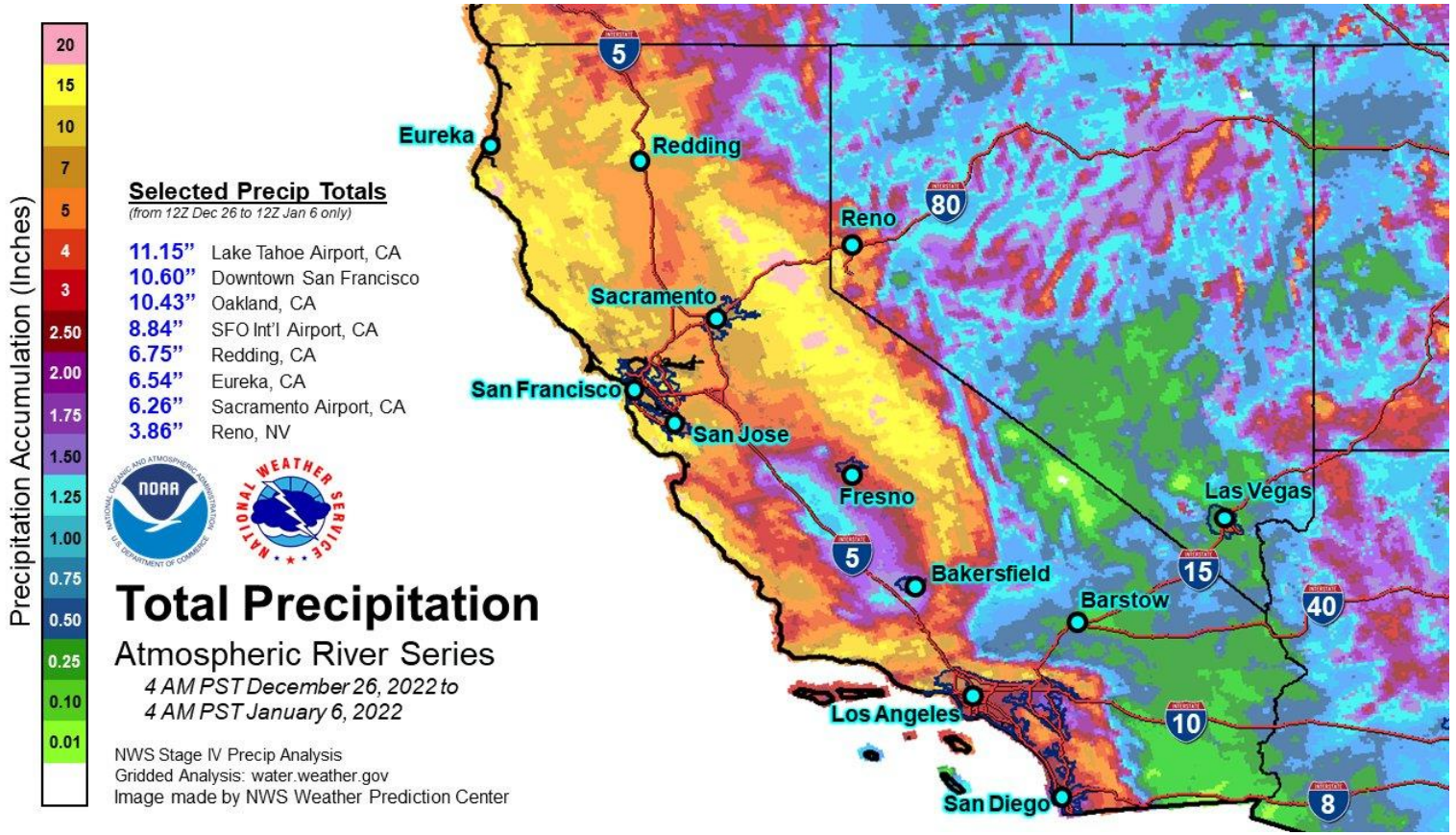
- One of the most distinguishing features of the recent California floods is the clustering pattern of ARs, **from December 25, 2022 to January 12**. The most heavily impacted areas include:

(1) San Francisco Bay Areas: **12+ inches** in San Francisco and Oakland between Dec 26 to Jan 9

(2) Sacramento Valley: **8+ inches** in Sacramento, and **4+ inches** in Los Angeles between Dec 26 to Jan 9,

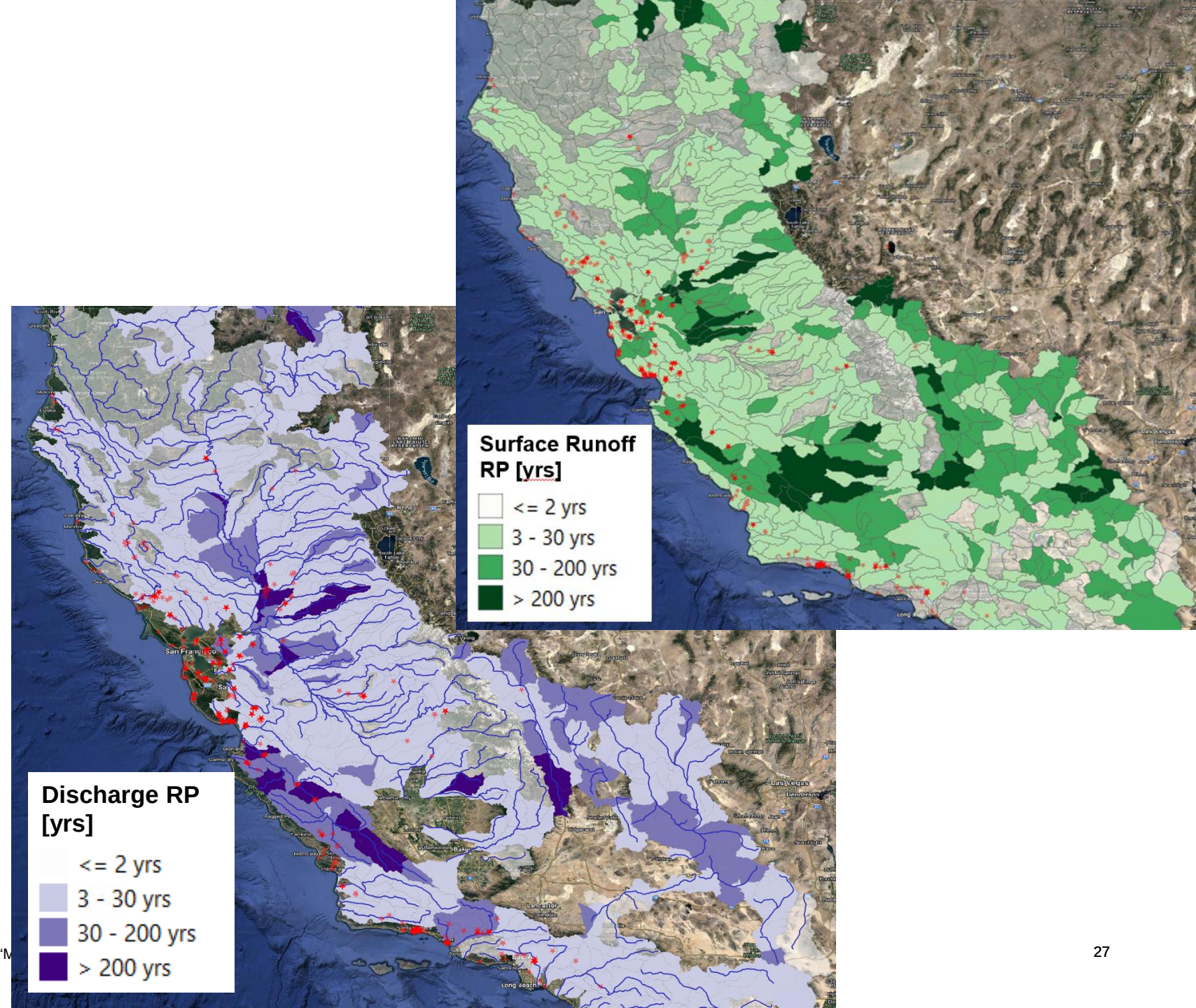
(3) Southern California: **16+ inches** in Ventura and Santa Barbara counties.

(4) Central California



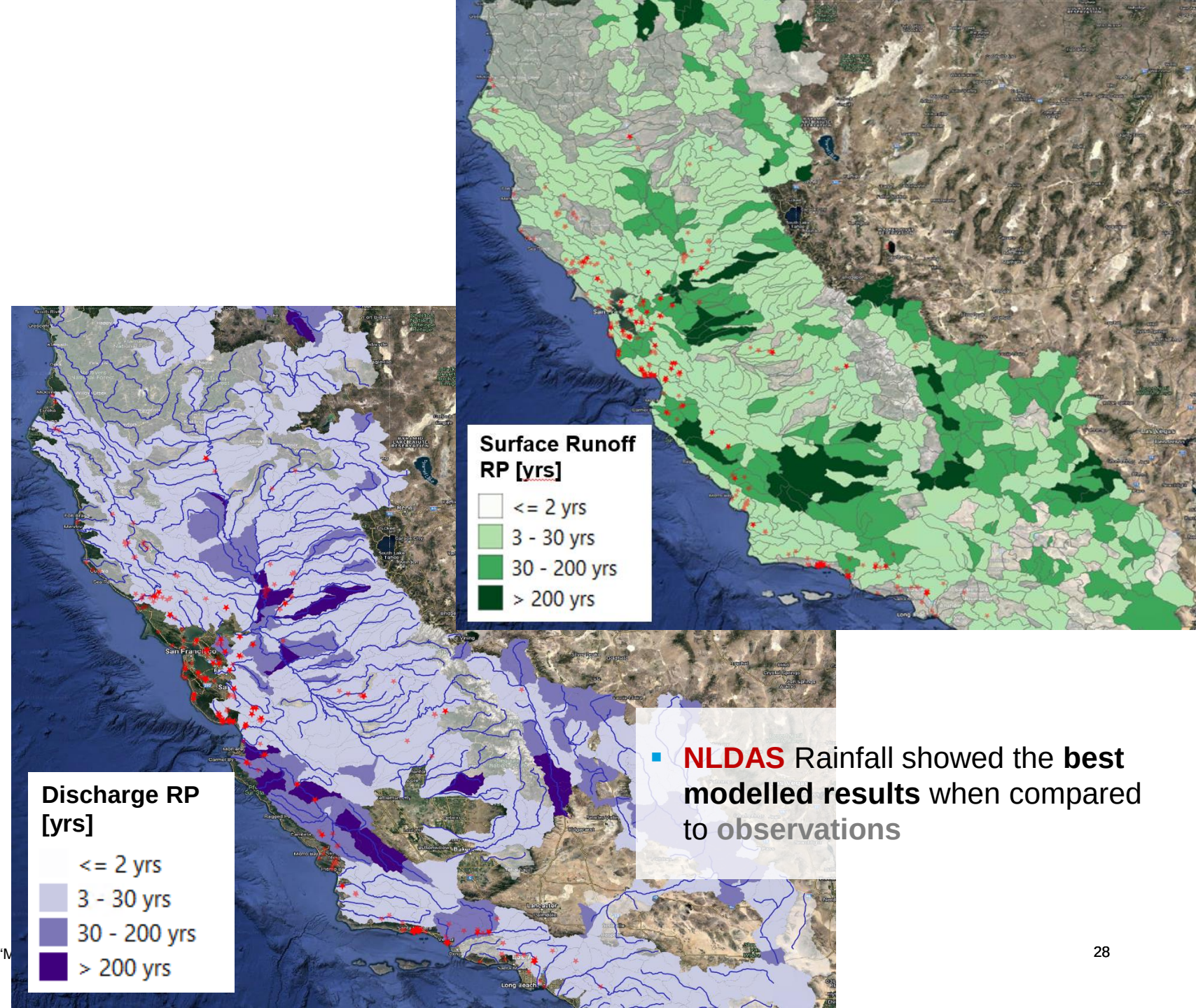
Hydrology

- Hydrological response after continuous rainfall: **saturated soils**
- Surface Runoff generation
  - RPs between *50-100yrs* in most affected areas
  - Locally exceeding *RP > 200yrs*
- Leads to flooding of smaller **streams and creeks**
- Riverine flooding in large rivers
  - Only locally RPs > 30yrs
  - ***Salinas River*** / Monterrey County
  - Eastern tributaries to the Sacramento River



Hydrology

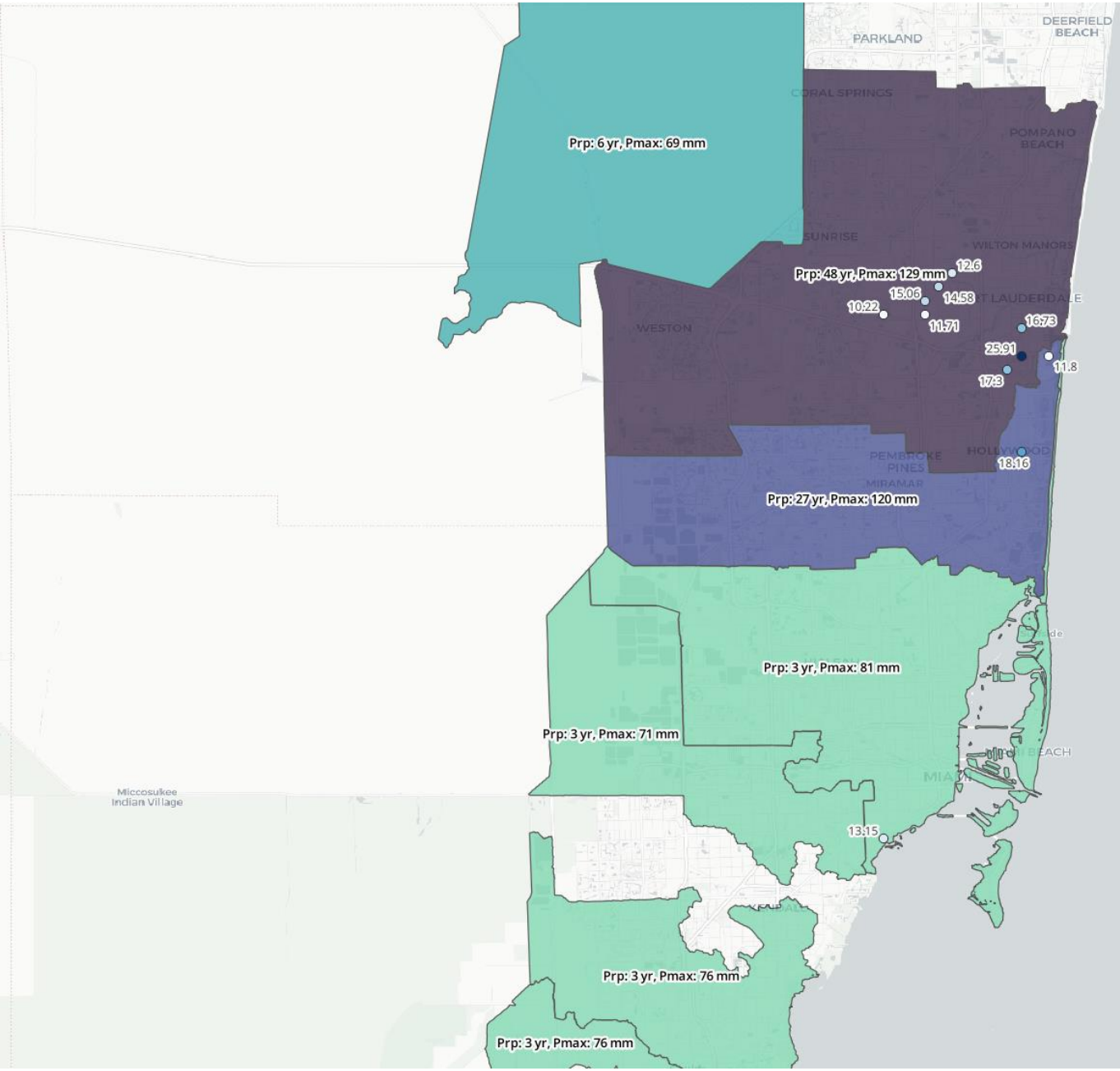
- Hydrological response after continuous rainfall: **saturated soils**
- Surface Runoff generation
  - RPs between *50-100yrs* in most affected areas
  - Locally exceeding *RP > 200yrs*
- Leads to flooding of smaller **streams and creeks**
- Riverine flooding in large rivers
  - Only locally RPs > 30yrs
  - ***Salinas River*** / Monterrey County
  - Eastern tributaries to the Sacramento River



- **NLDAS** Rainfall showed the **best modelled results** when compared to **observations**

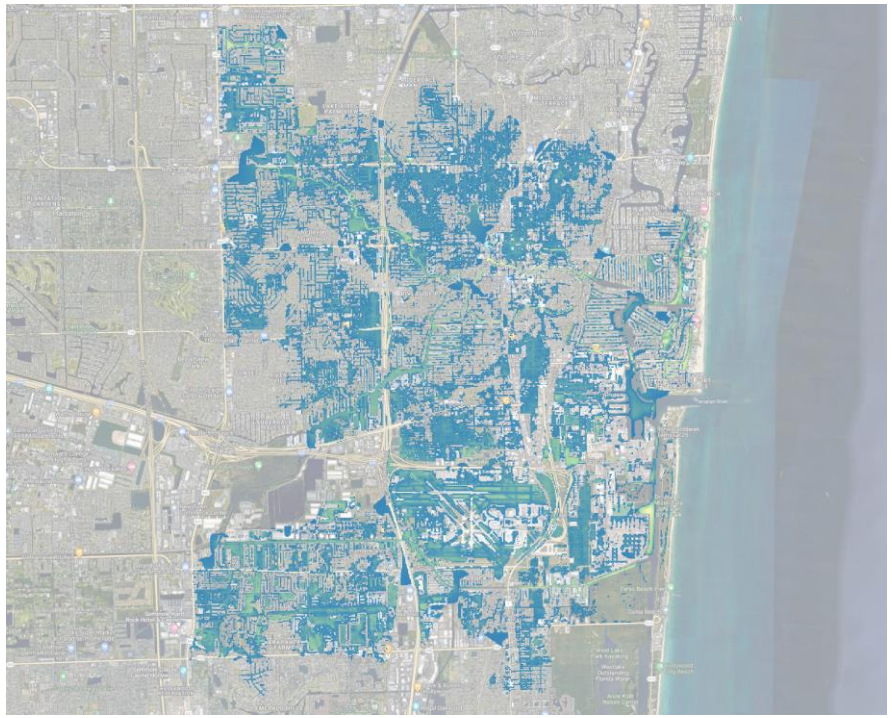
Fort Lauderdale – April 2023

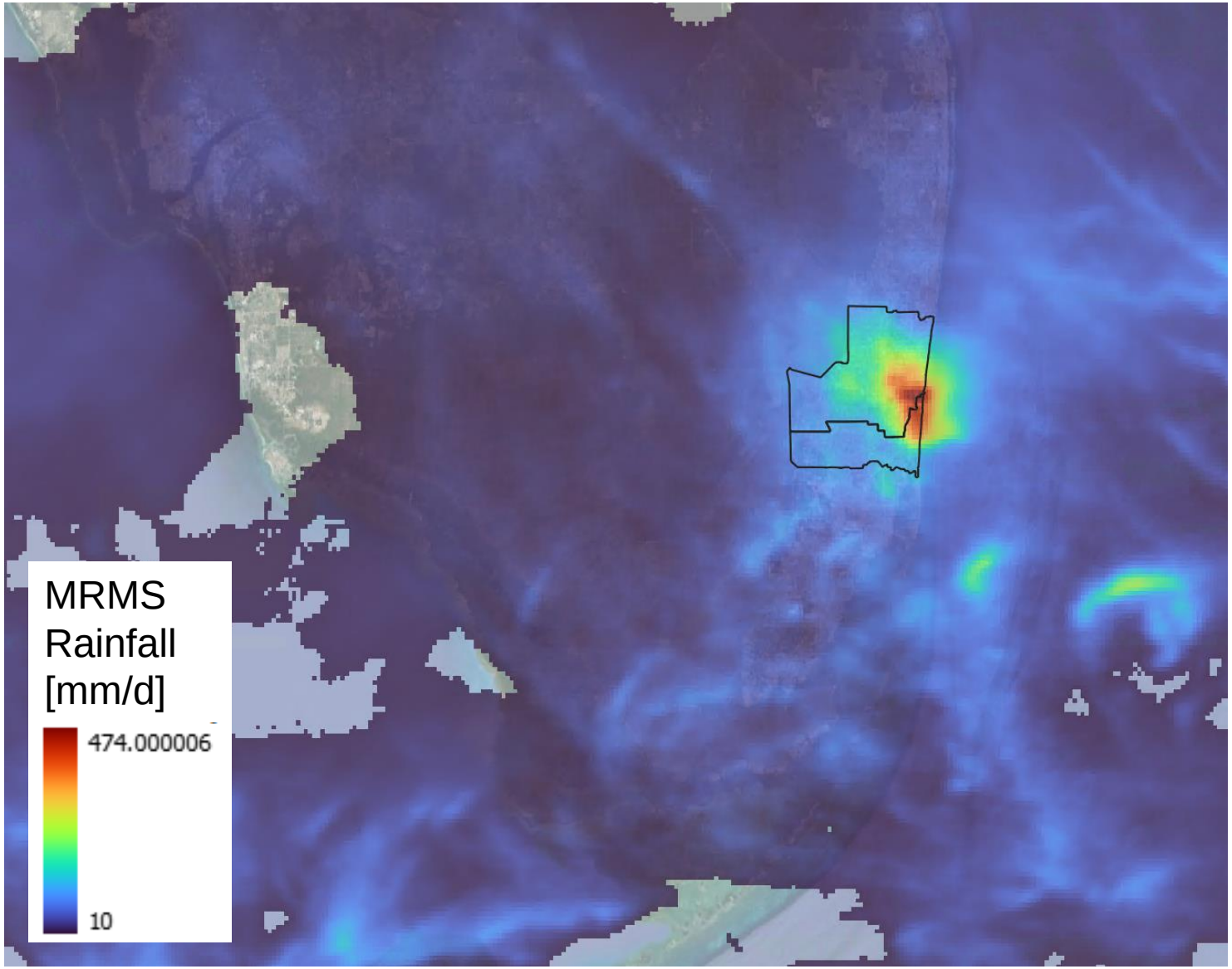
NWS Observations & Catchment P_{RP}



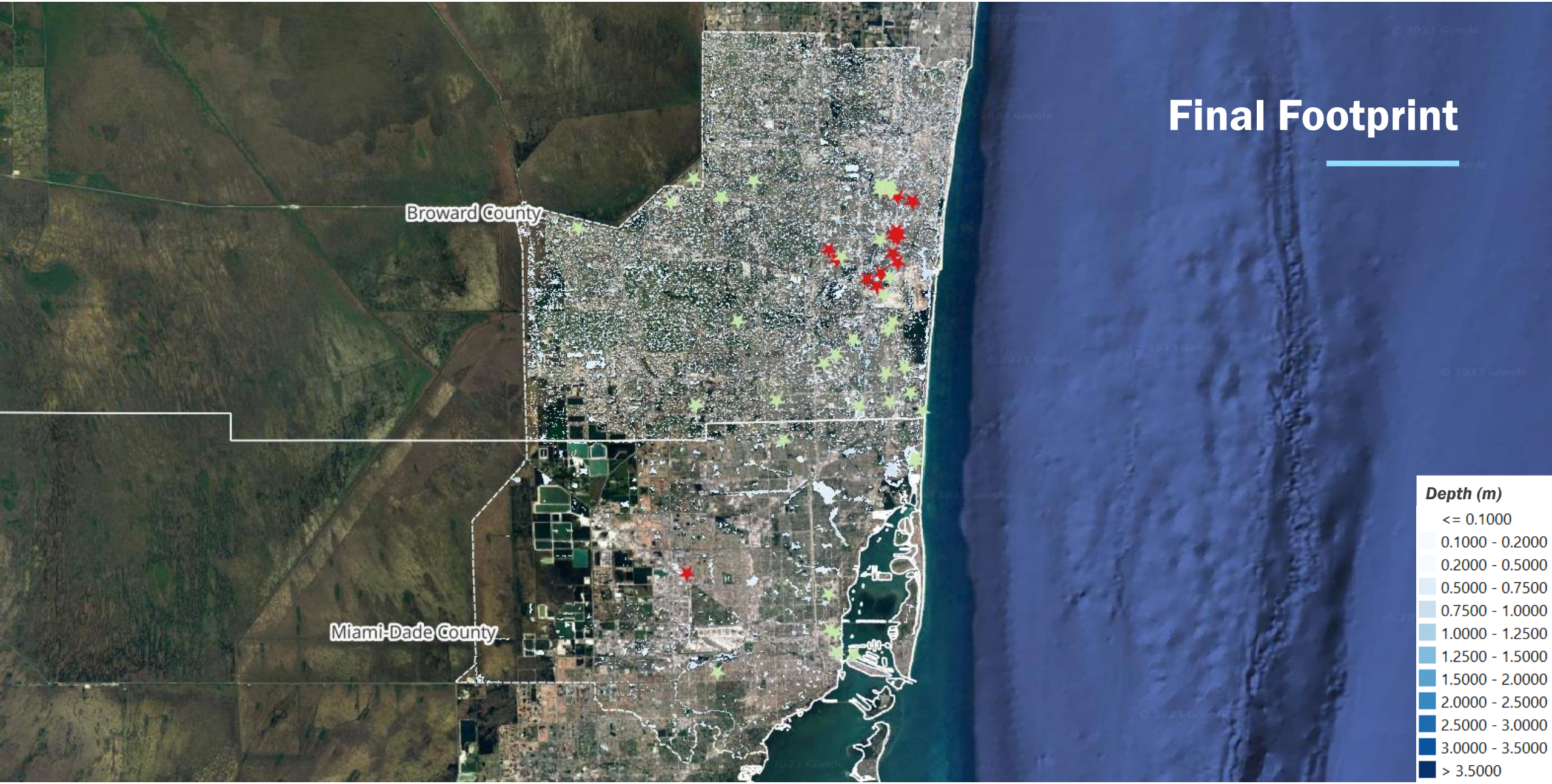
Fort Lauderdale

- ~ 500mm in 12hr
- Catchment aggregation makes the max Precip decrease to 180mm/d





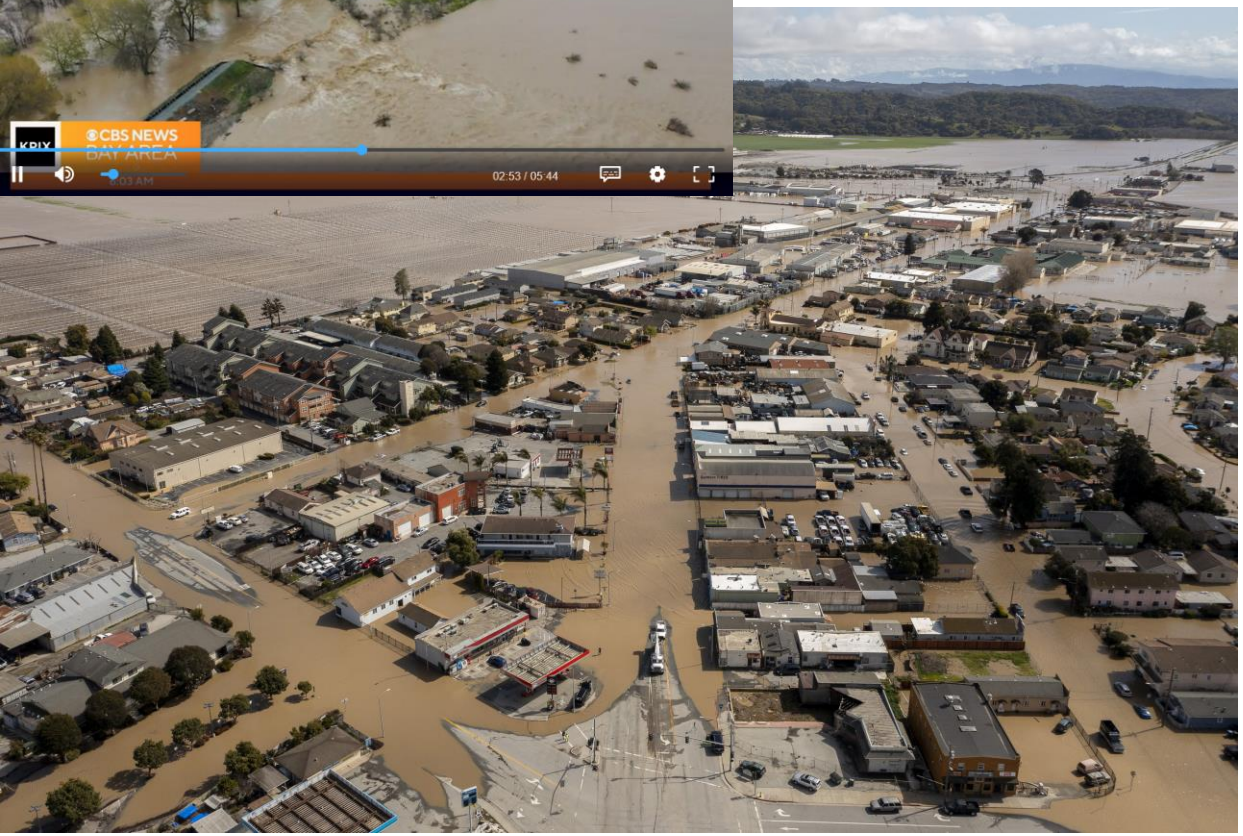
Final Footprint

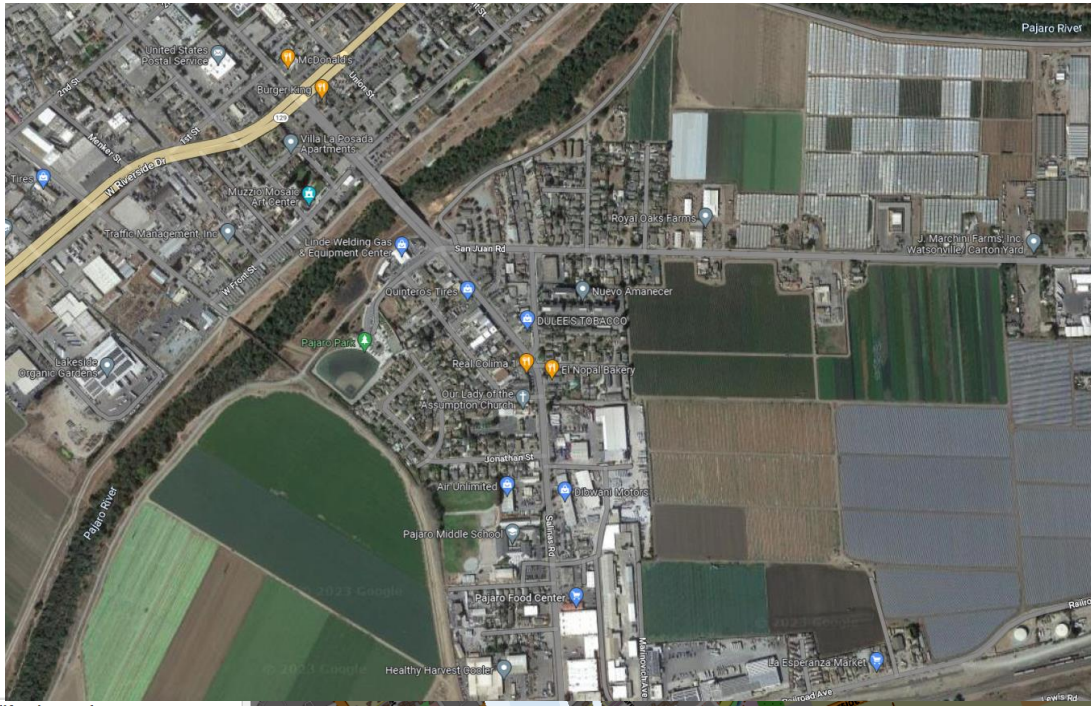


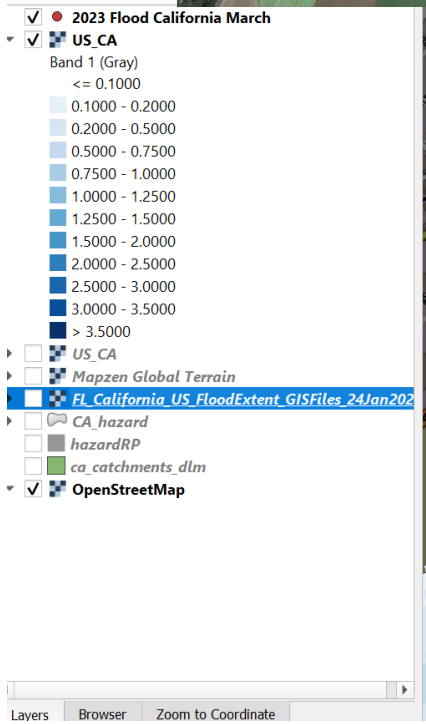
APPENDIX – FOOTPRINT VALIDATION

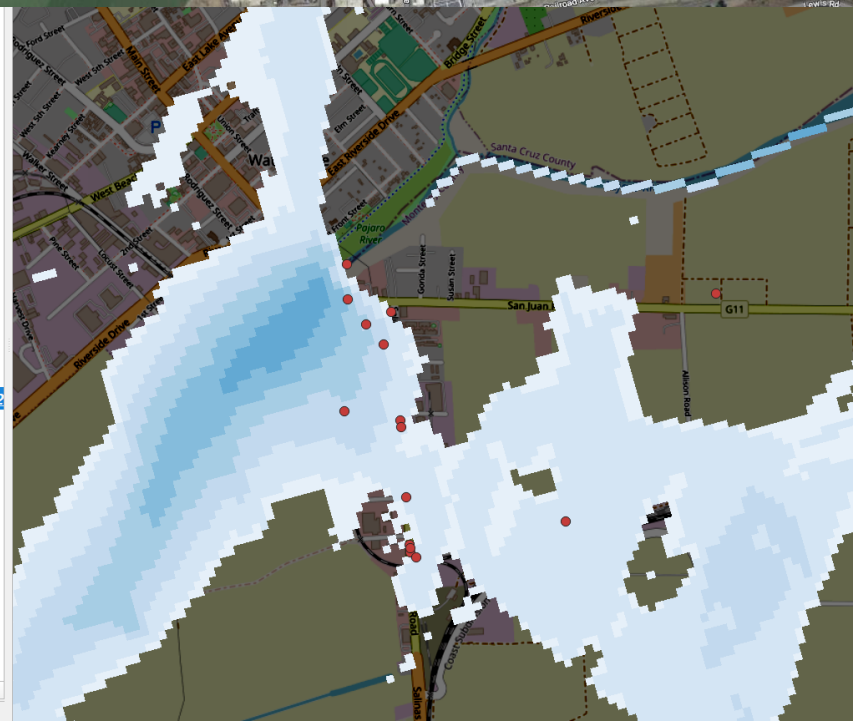
California – Atmospheric Rivers Jan 2023

Pajaro flood caused by levee breach



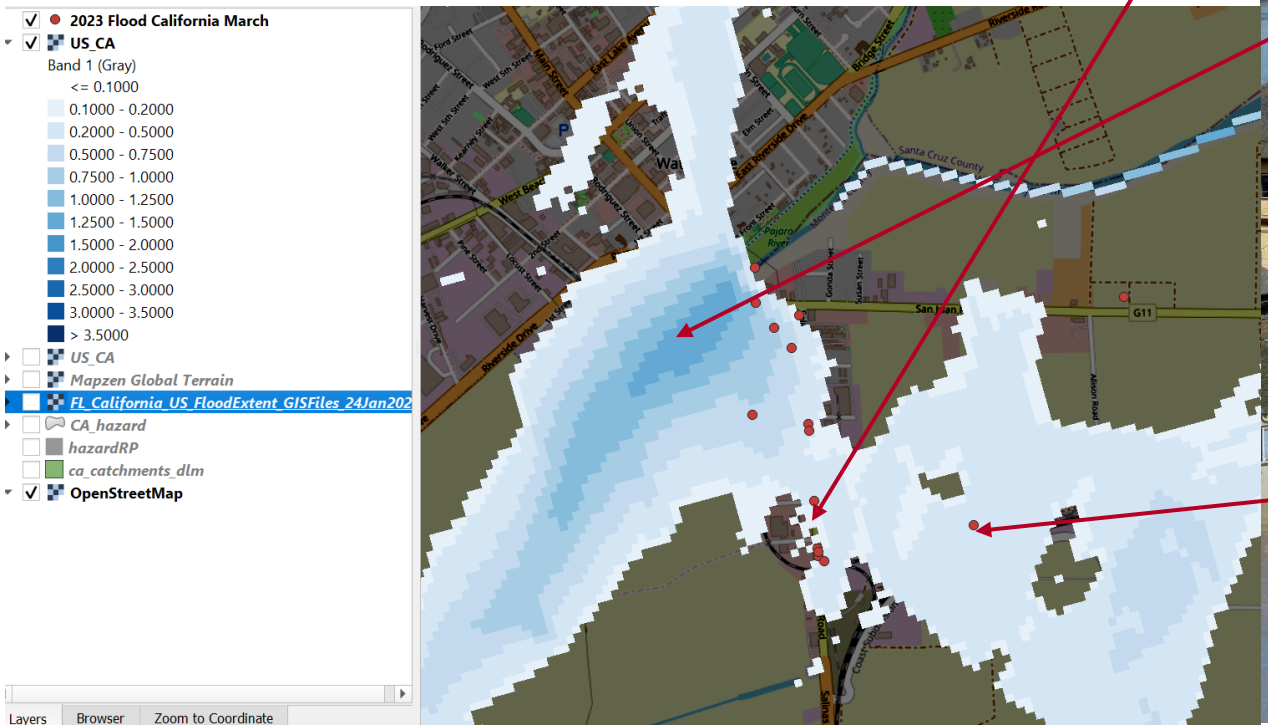




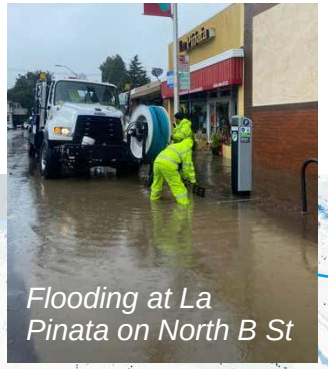


Pajaro flood caused by levee breach

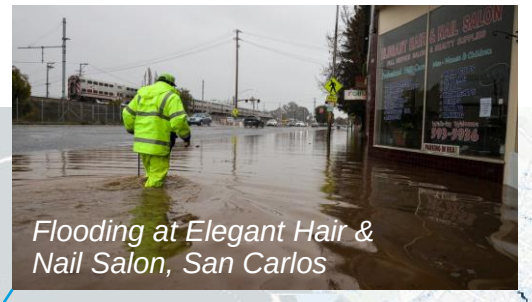
Photos from march 11



San Mateo



Flooding at La Pinata on North B St



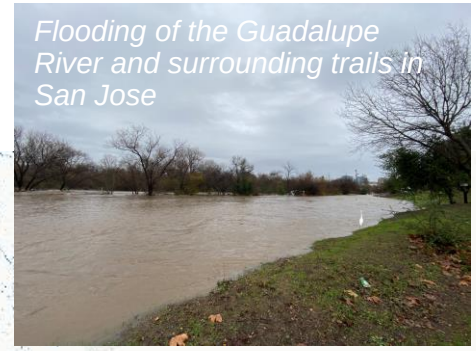
Flooding at Elegant Hair & Nail Salon, San Carlos

Cordilleras Creek in Redwood City

Flooding in Pescadero

A partial collapse of the 4100 block of Stage Road, Pescadero

Santa Clara



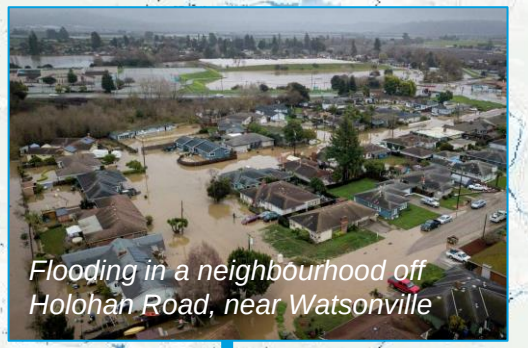
Santa Cruz

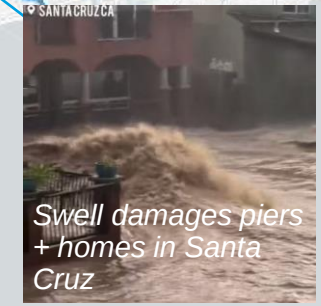

San Lorenzo River subemerged homes in the Santa Cruz Mountains


San Lorenzo River flooding in Felton Grove

Soquel


Aptos


Flooding in a neighbourhood off Holohan Road, near Watsonville

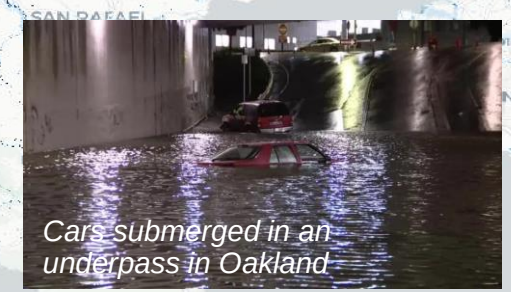


Swell damages piers + homes in Santa Cruz


Capitola Village

Alameda

"In Alameda County, there are 20 different sites where the storms caused serious road damage. The damage across the county will probably exceed $30 million to repair. Public Works hopes they'll be able to get funding from the state or federal government to cover a portion of that".



Cars submerged in an underpass in Oakland

Creek flooding near Temescal Regional Park

A Street in Castro Valley, Alameda County, where a portion of the road collapsed into San Lorenzo Creek when a retaining wall failed

Crosby St, Washington Manor-Bonaire neighborhood in San Leandro

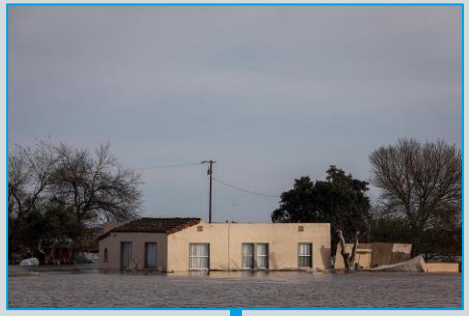
The area near Niles Canyon Rd and Kilkare Rd, Alameda has seen flooding and mudslides

Monterey

Flooding in Paso Hondo Road as the Carmel River floods in Carmel Valley

Flood waters inundate a home by the Salinas River near Chualar

Flooding on Villa Drive, King City



Flooding along the Salinas River

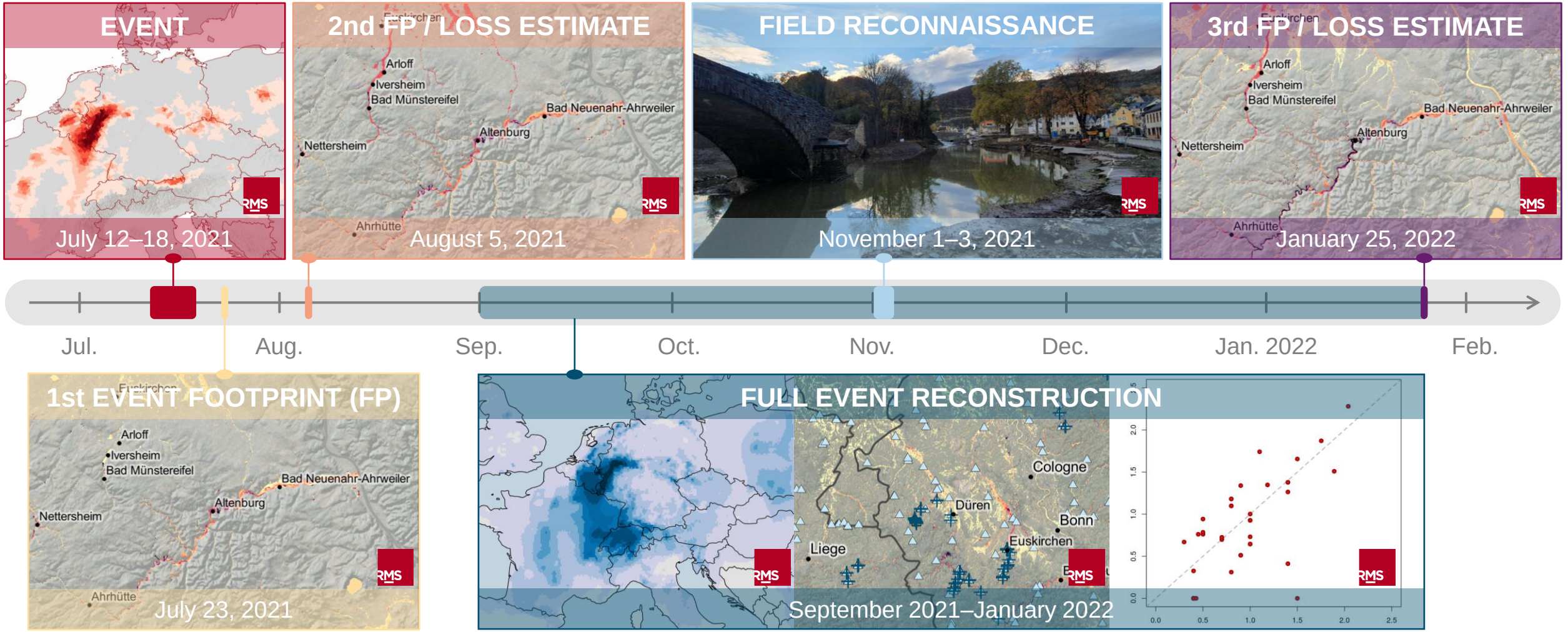
Flooding of farmland in Monterey

Flooded homes and vehicles in San Ardo

APPENDIX – Europe Inland Flood Event Response

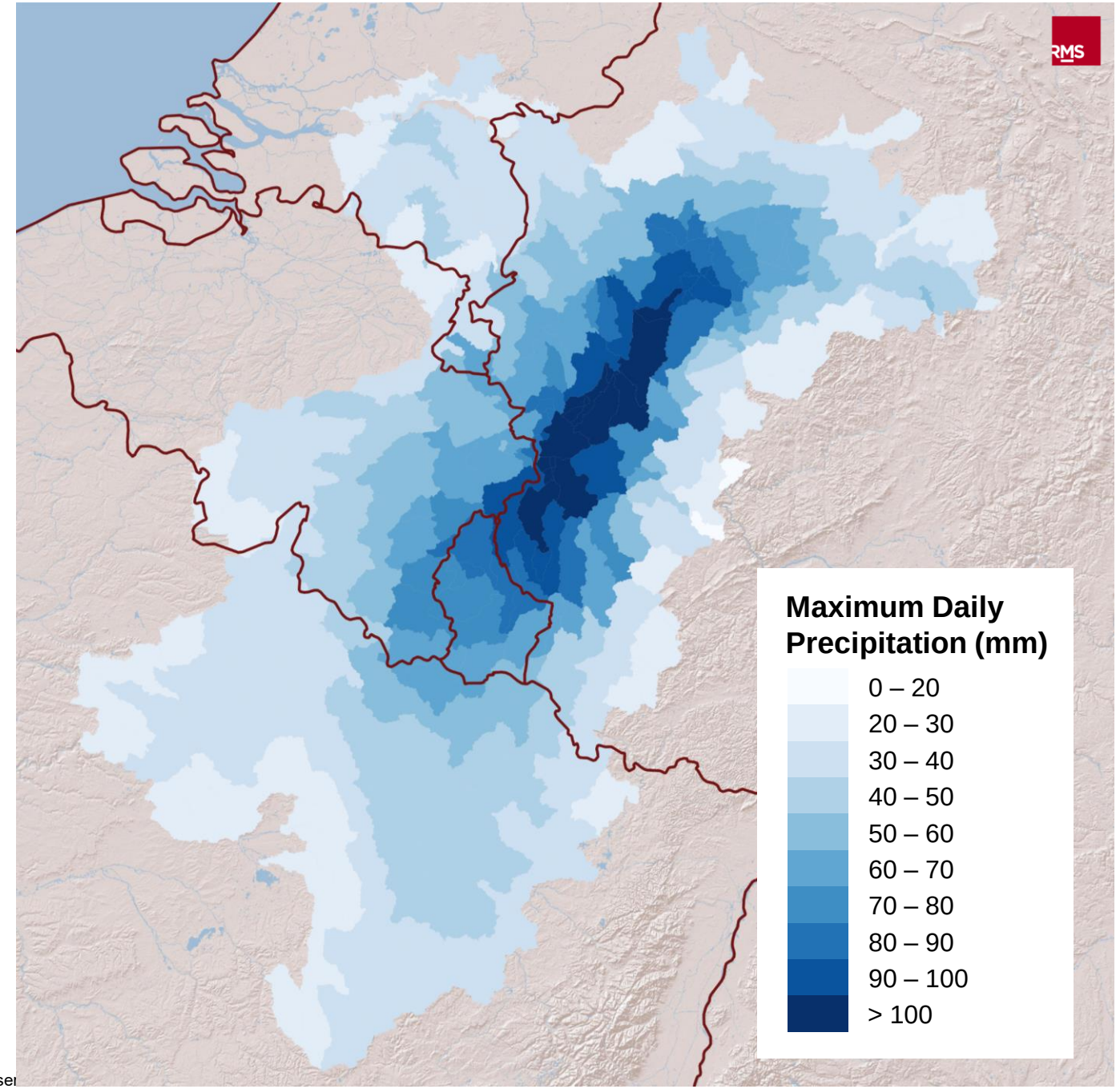
Low pressure front Bernd – July 2021

Timeline



Precipitation per Catchment

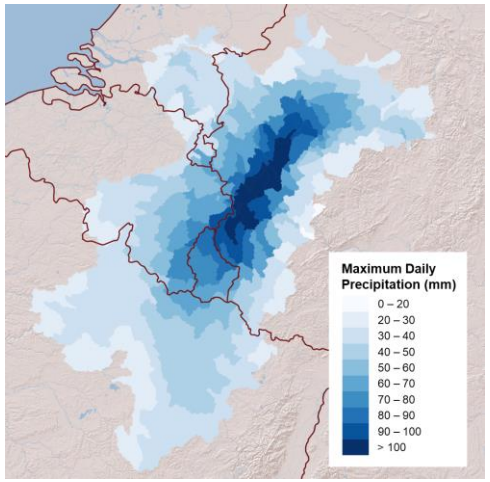
- E-OBS precipitation sums aggregated to the catchments of the RMS® Europe Inland Flood HD Models
- Maximum daily observed precipitation between July 13–15, 2021
- Data used as input for the full event reconstruction



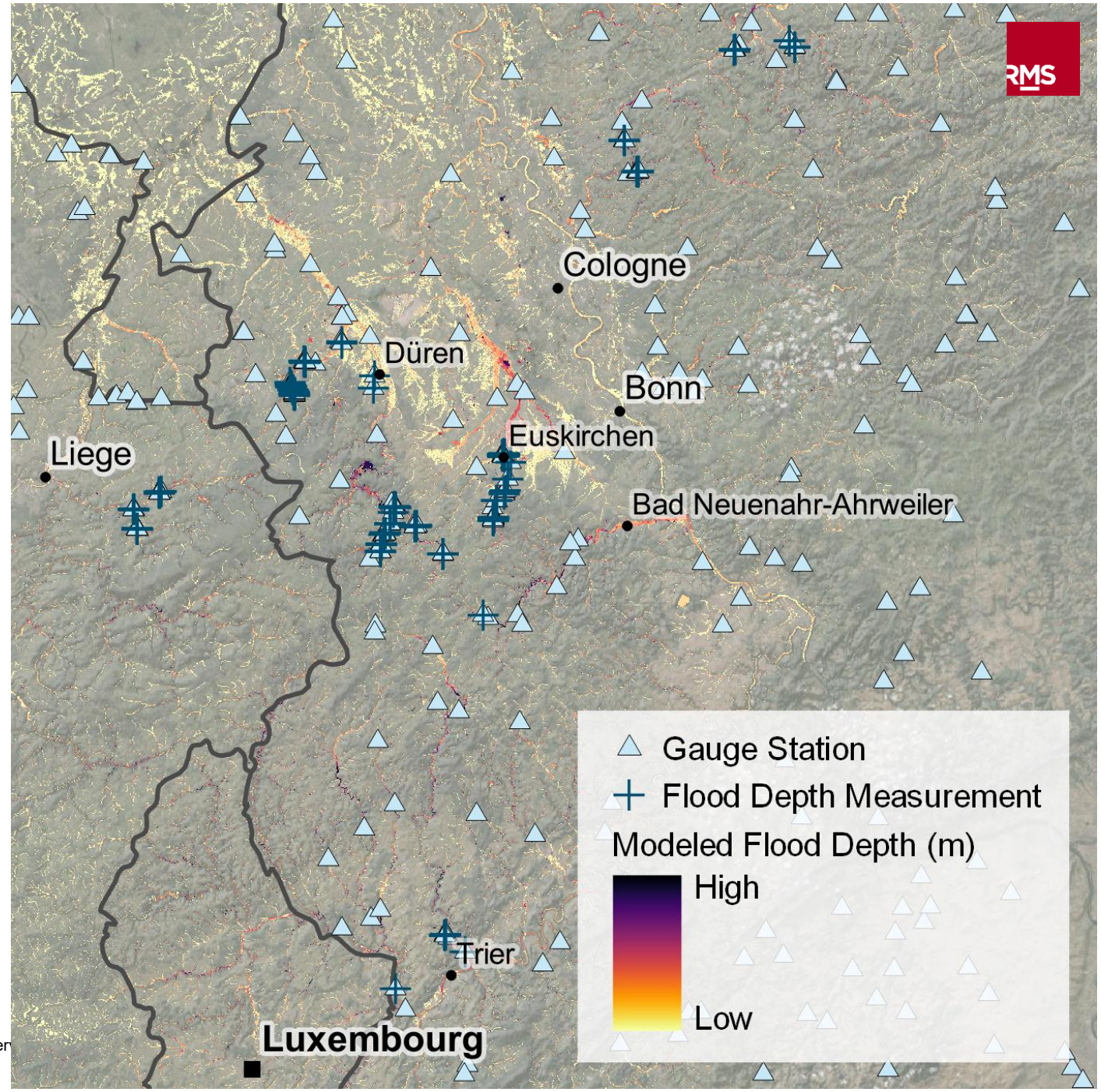
Source: E-OBS gridded dataset data

Full Event Reconstruction

- Focus on most affacted areas (e.g., Bavaria, Saxony excluded)
- Maximum precipitation from E-OBS dataset between July 13–15, 2021



- Leveraging components of the Europe Inland Flood HD Models
- Inclusion of data from roughly 700 gauge stations, mainly along small and medium rivers
- Incorporation of own ~200 flood depth measurements inferred from observed flood marks

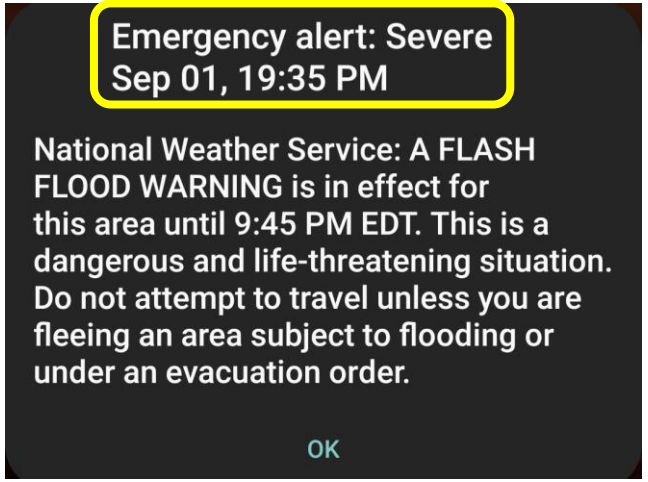


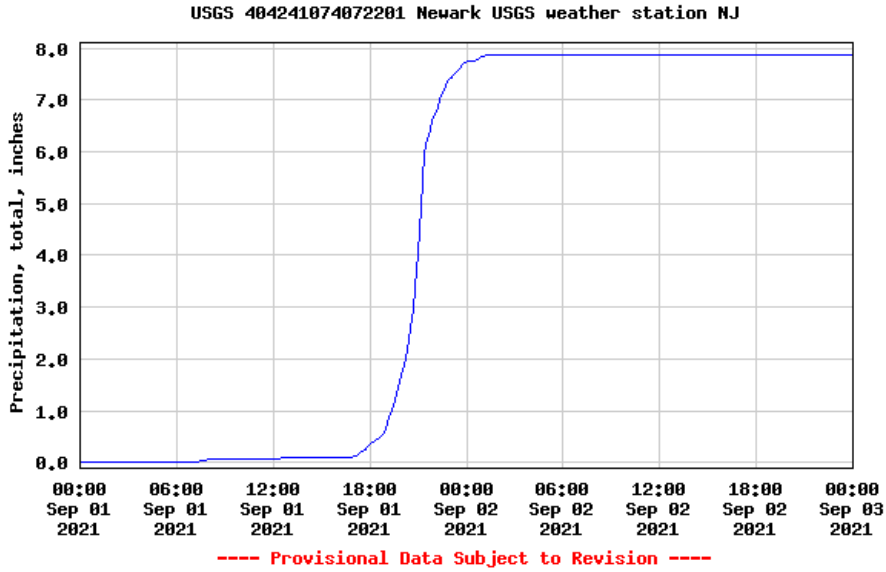
APPENDIX – EVENT RECONSTRUCTION

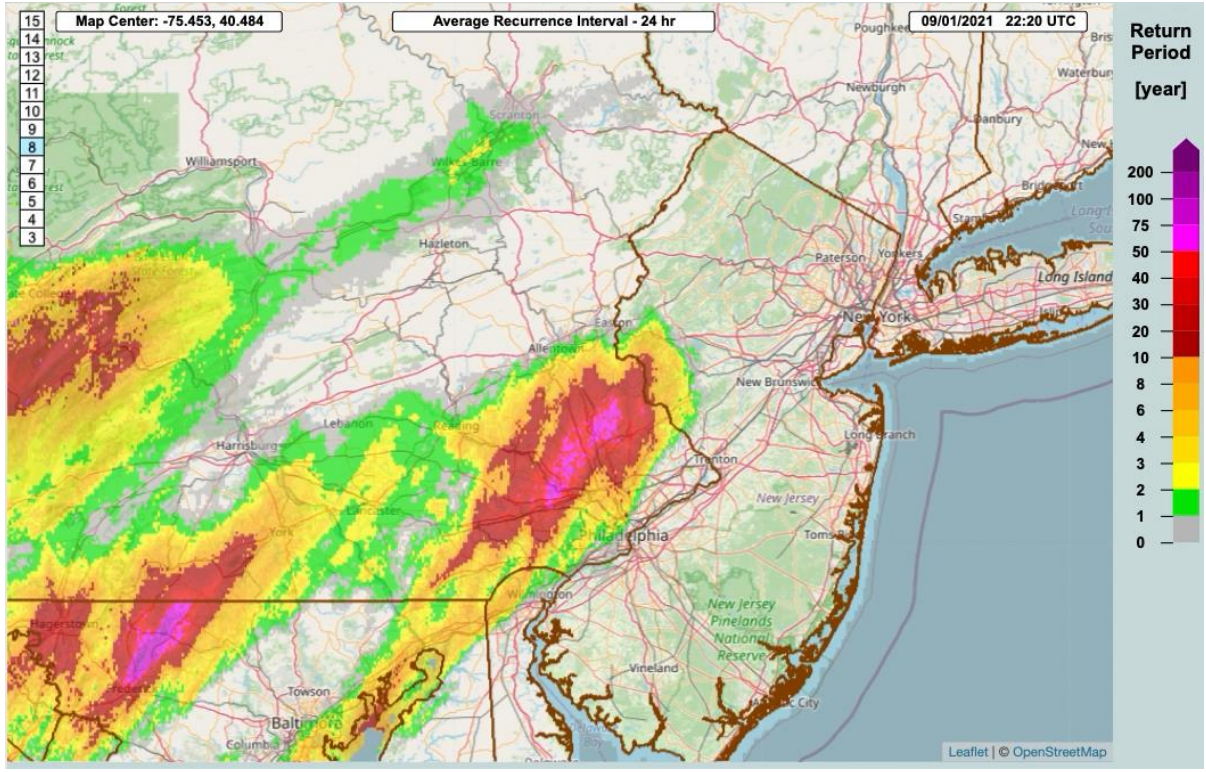
Hurricane Ida – Northeast US

Then it started raining…

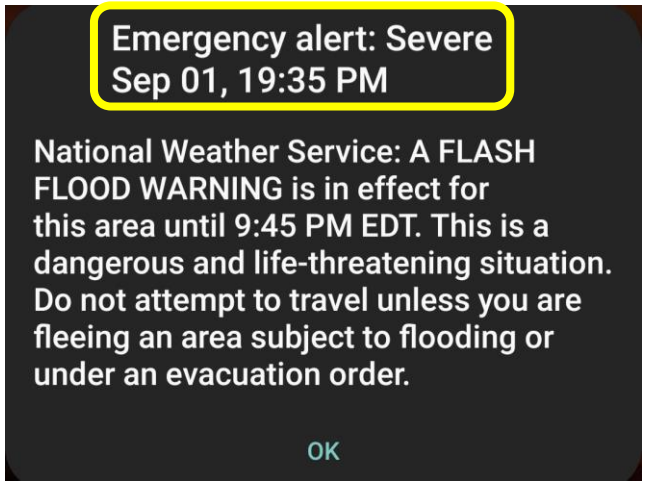
- Lack of warning made it harder to anticipate
- Record-breaking rainfall over NJ, NY, PA, CT
- Emergency alerts arrived when it was already raining
- Based on past events, **7.5” in 6h** represents **1,000-year RP** event

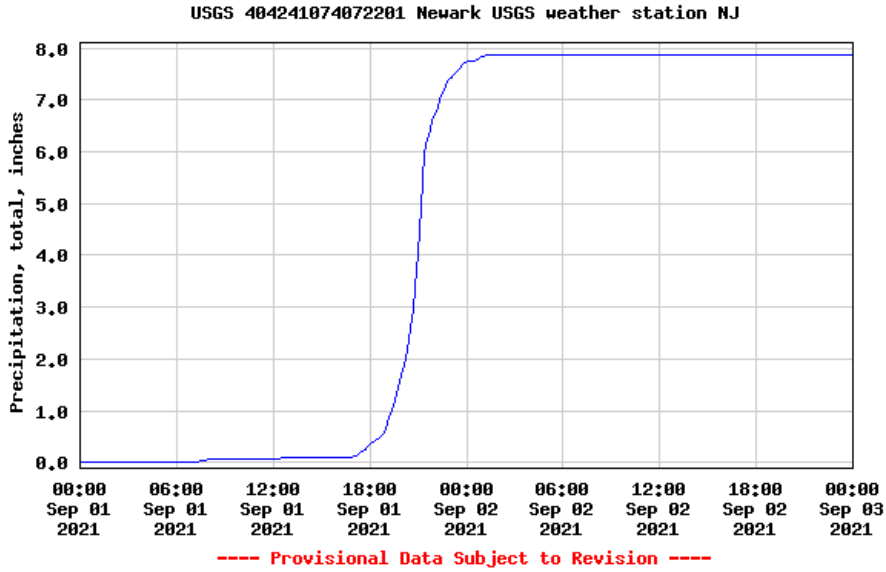




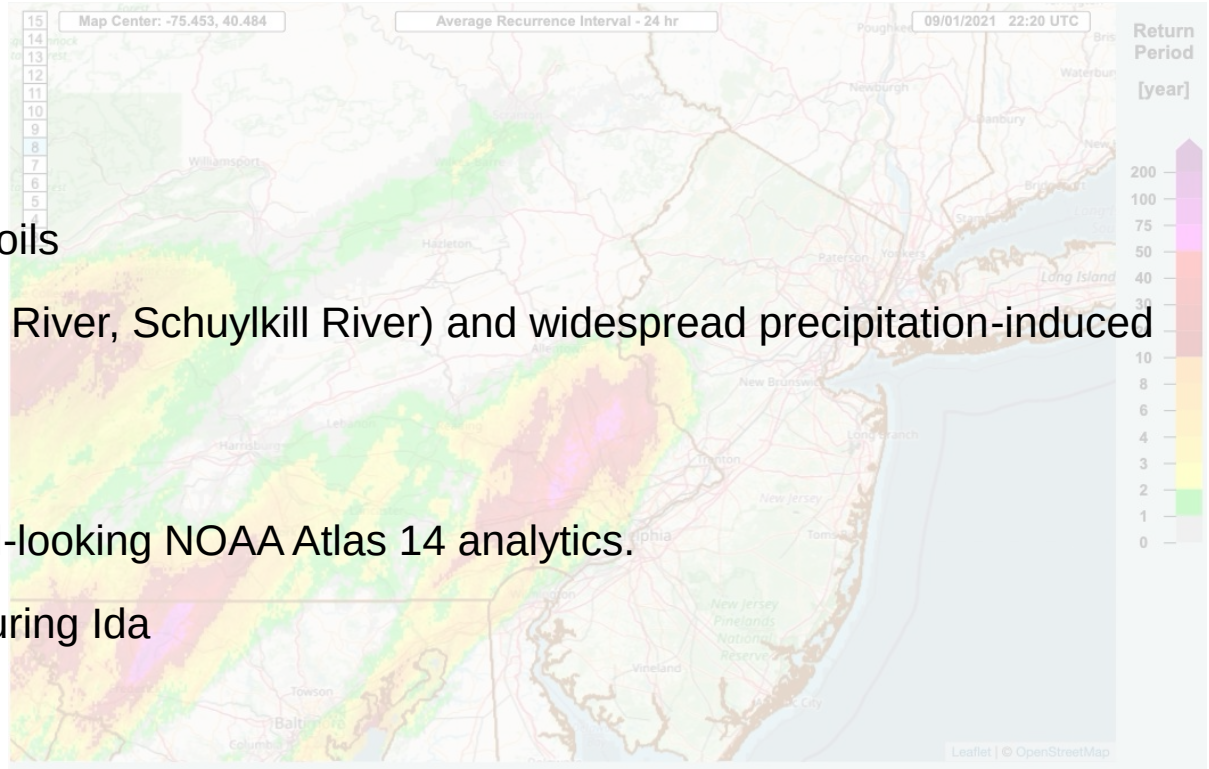


Then it started raining…





- Lack of warning made it harder to anticipate
- Record-breaking rainfall over NJ, NY, PA, CT
- Emergency alerts arrived when it was already raining
- Based on past events, **7.5” in 6h** represents **1,000-year RP** event
- High-intensity, short-duration precipitation over saturated soils
- Led to localized fluvial flooding (e.g. Raritan River, Passaic River, Schuylkill River) and widespread precipitation-induced flash floods
- Particularly severe in urban areas.
  - **NYC 100-year** hourly rainfall depth 2.87’’ from backward-looking NOAA Atlas 14 analytics.
  - **3.15” max hourly rainfall** measured at **Central Park** during Ida

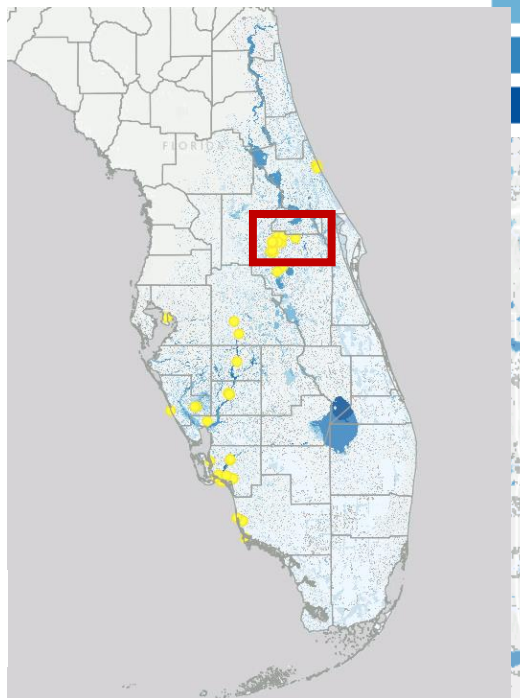


APPENDIX – FOOTPRINT VALIDATION

Hurricane Ian – Pluvial vs Fluvial

Pluvial flooding, Orlando

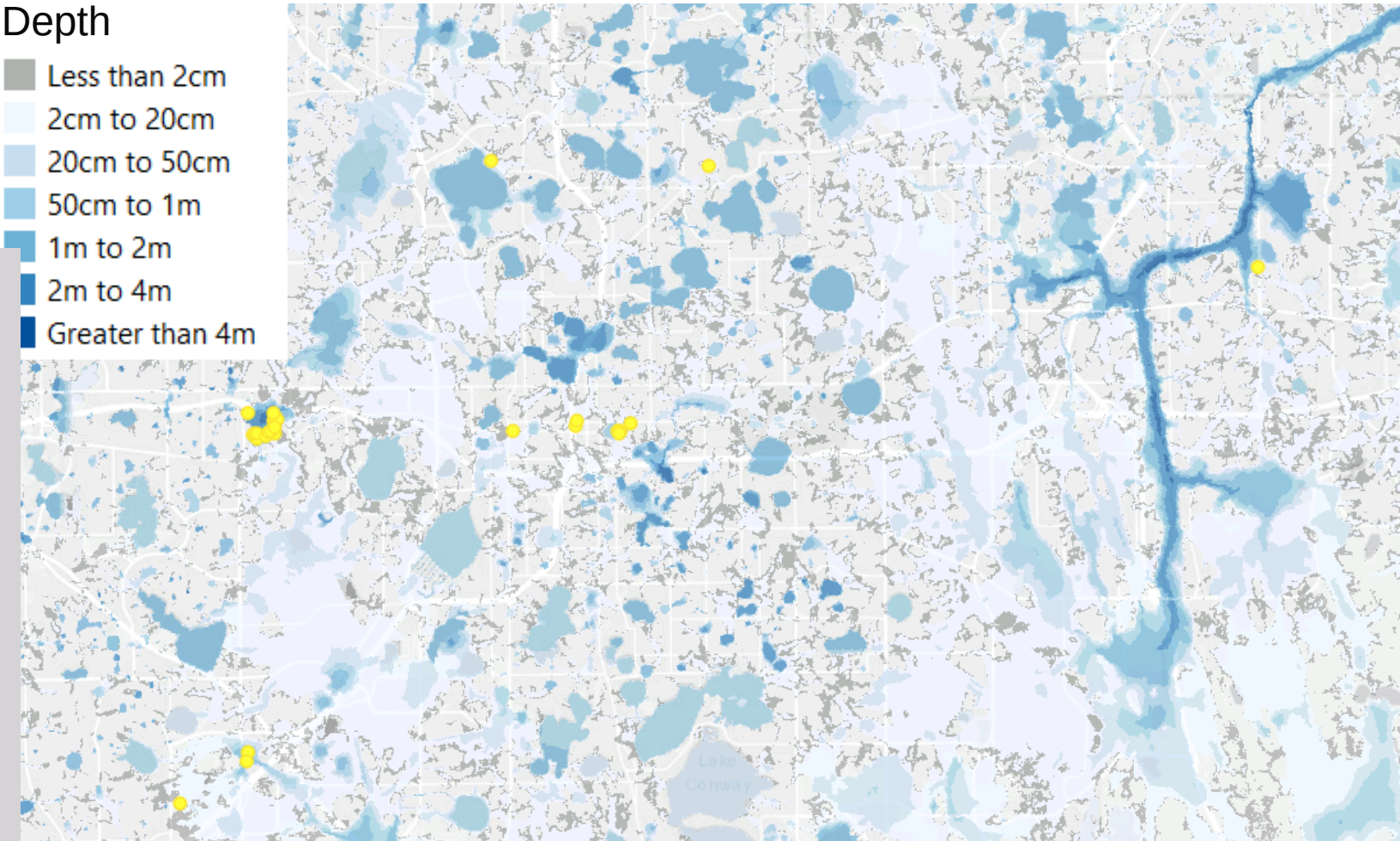
- Flat topography and shallow water table
- Requires detailed pluvial modeling to capture street level flooding and overflow of lakes



Surveyed locations

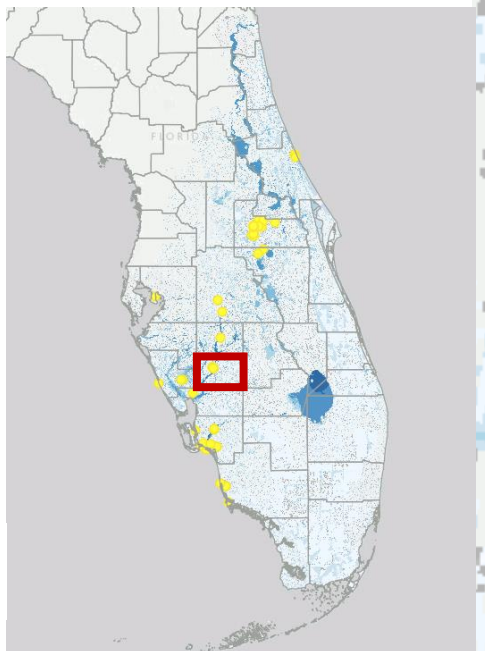
Depth

- Less than 2cm
- 2cm to 20cm
- 20cm to 50cm
- 50cm to 1m
- 1m to 2m
- 2m to 4m
- Greater than 4m



Fluvial flooding on the Peace River

- Major flooding stage on the Peace river lasted several days
- Surveyed damaged locations validated the extent of the fluvial inundation



Surveyed locations

Depth

- Less than 2cm
- 2cm to 20cm
- 20cm to 50cm
- 50cm to 1m
- 1m to 2m
- 2m to 4m
- Greater than 4m