

Improving Hail Hazard Intelligence: From MESH–LSR Validation to a High- Resolution Hail Size Return-Period Atlas

Logan Bundy* and Victor Gensini

Collaborators: Walker Ashley, Daniel Wright



Northern Illinois
University



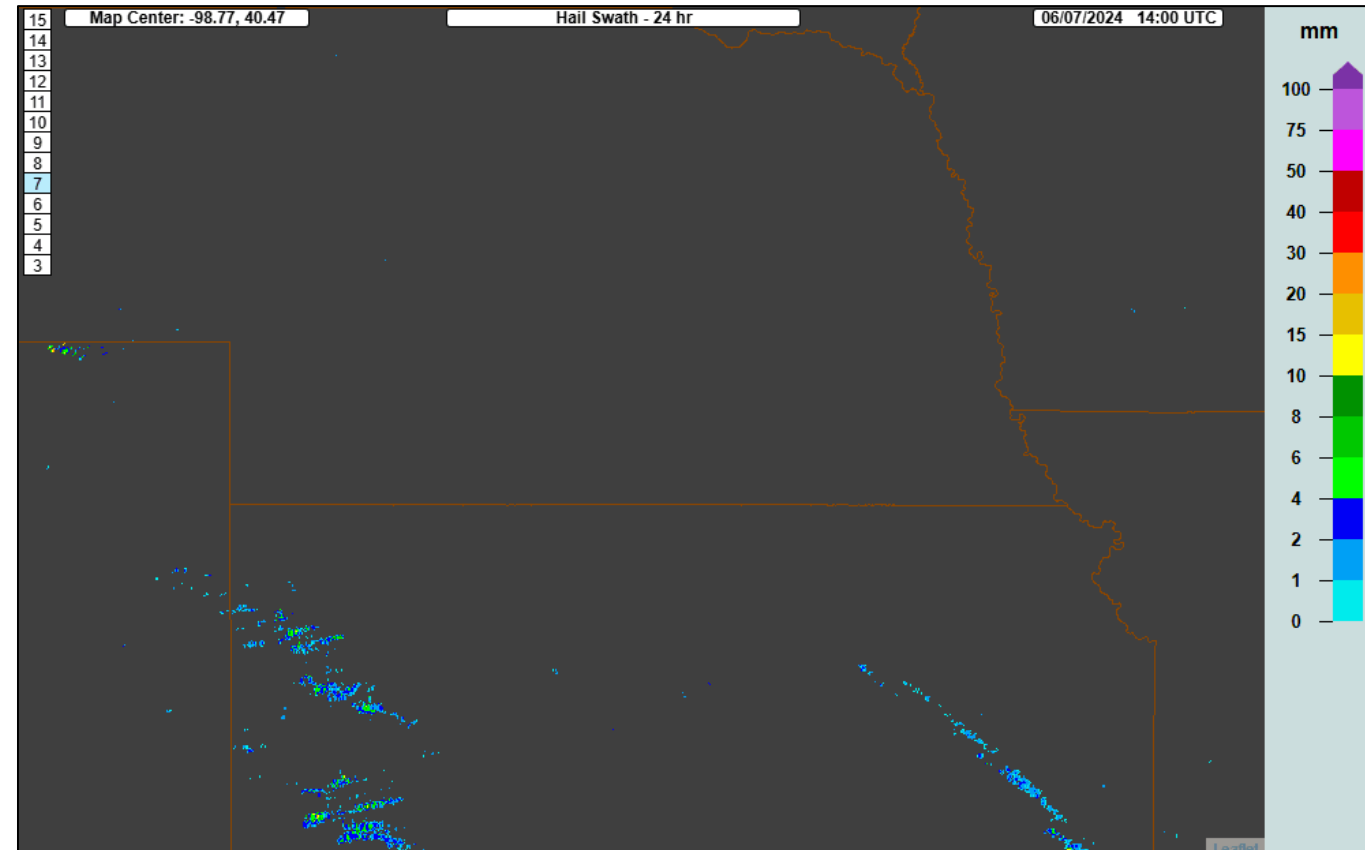
WISCONSIN
UNIVERSITY OF WISCONSIN-MADISON



What is MRMS MESH?

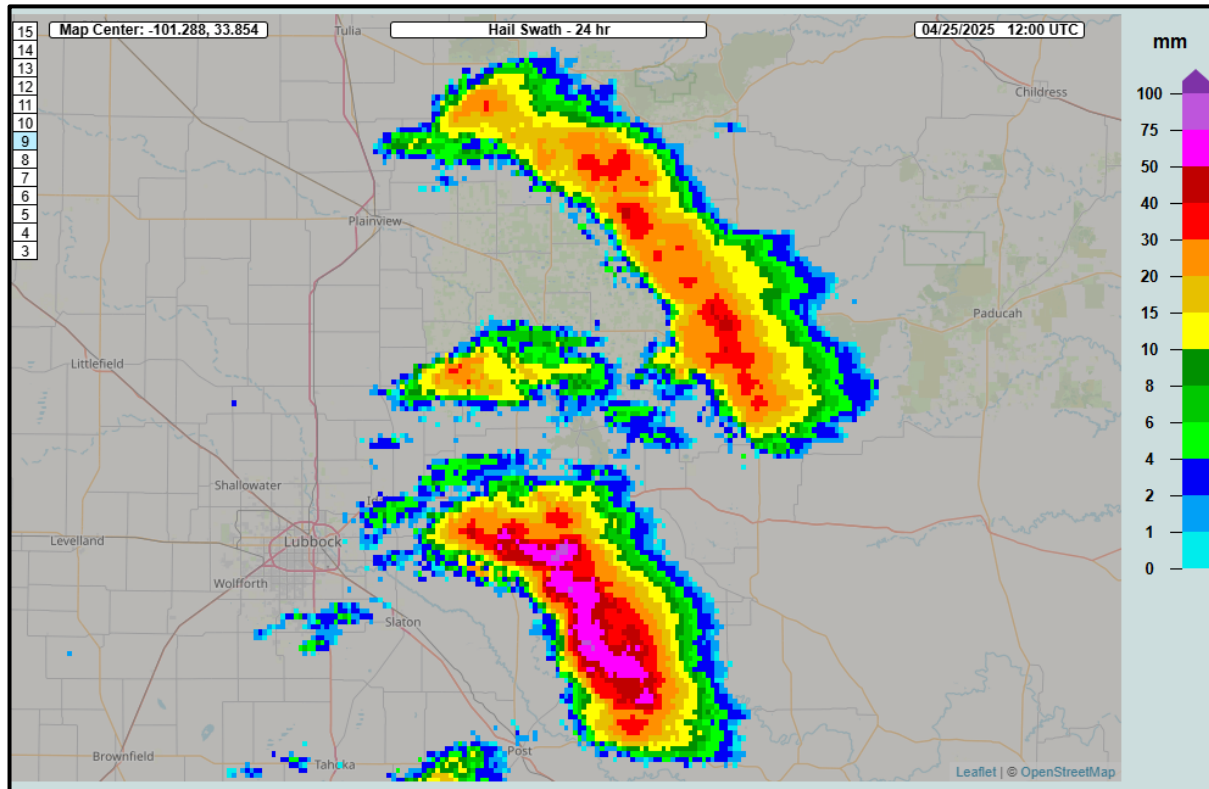
- **Objective**, multi-radar-derived hail swath data
- Temporal resolution: 2 minutes
- Spatial resolution: $\approx 1\text{km}$
- Enables **full coverage** and physical **consistency**
- Compensates for cone-of-silence, beam broadening at far ranges, and terrain blockage
- **Quality controlled**: non-hydrometeorological data removed

MRMS MESH Hail Swaths: 08 June 2024

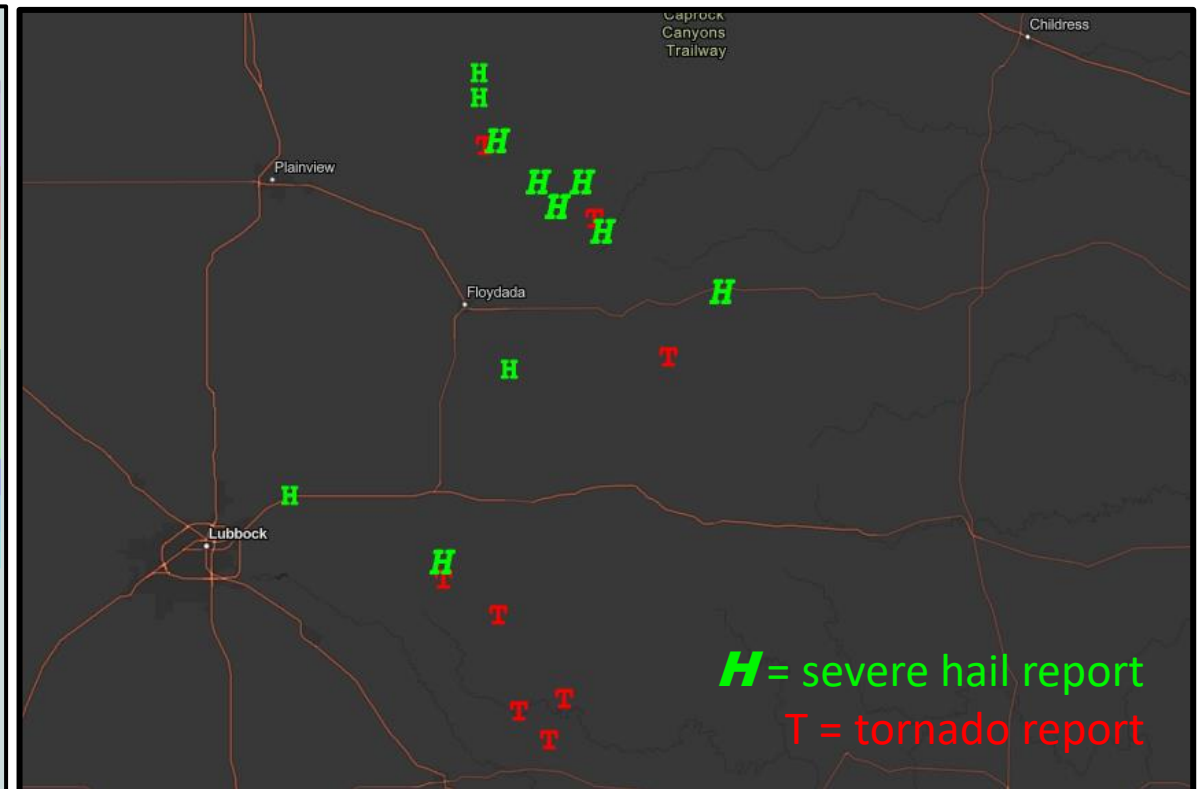


MESH vs Local Storm Reports (LSRs)

MRMS MESH Hail Swaths: 24 April 2025



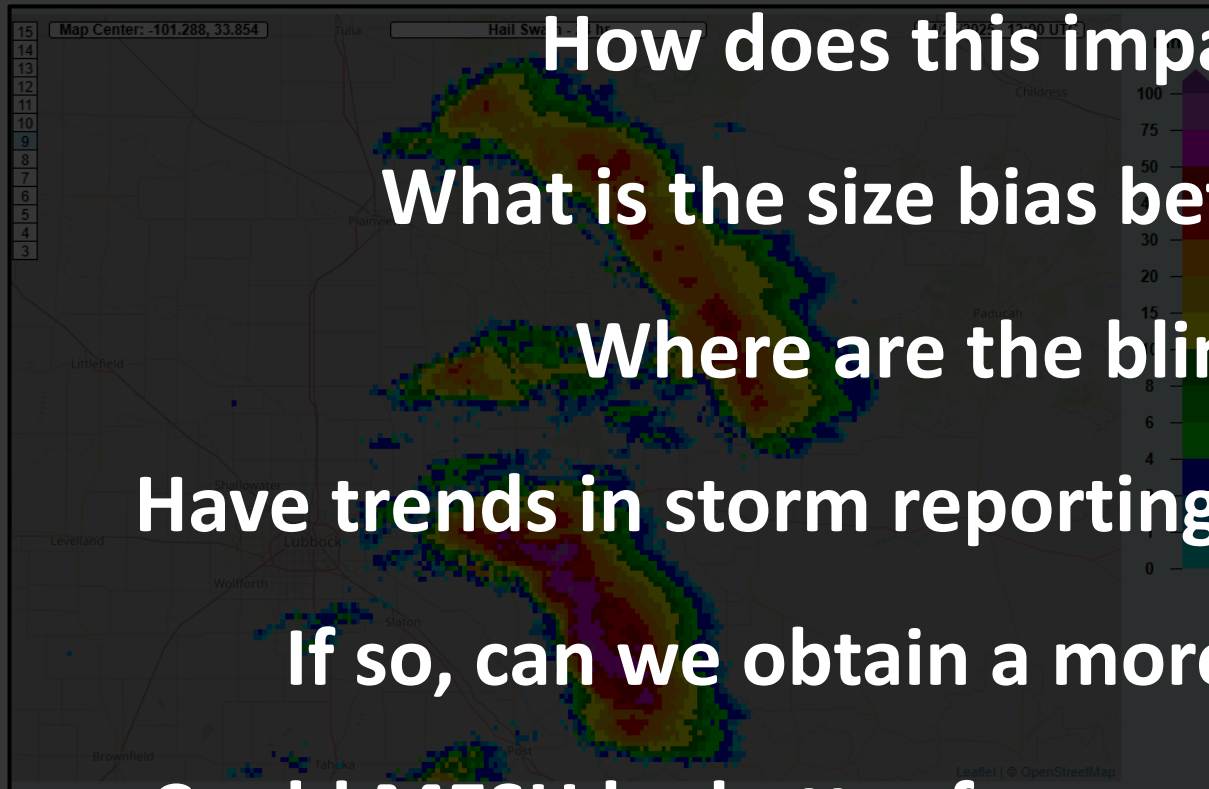
SPC Storm Reports: 24 April 2025



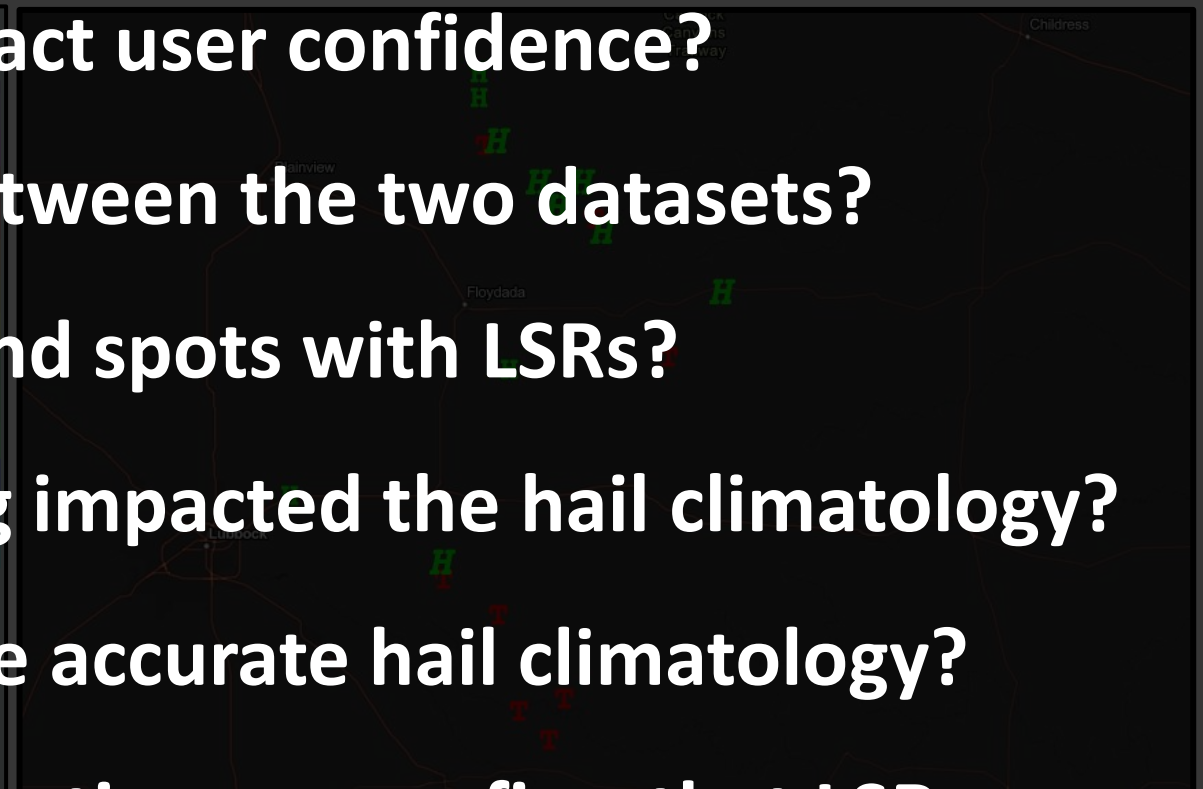
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MRMS MESH Hail Swaths: 24 April 2025



SPC Storm Reports: 24 April 2025



How does this impact user confidence?

What is the size bias between the two datasets?

Where are the blind spots with LSRs?

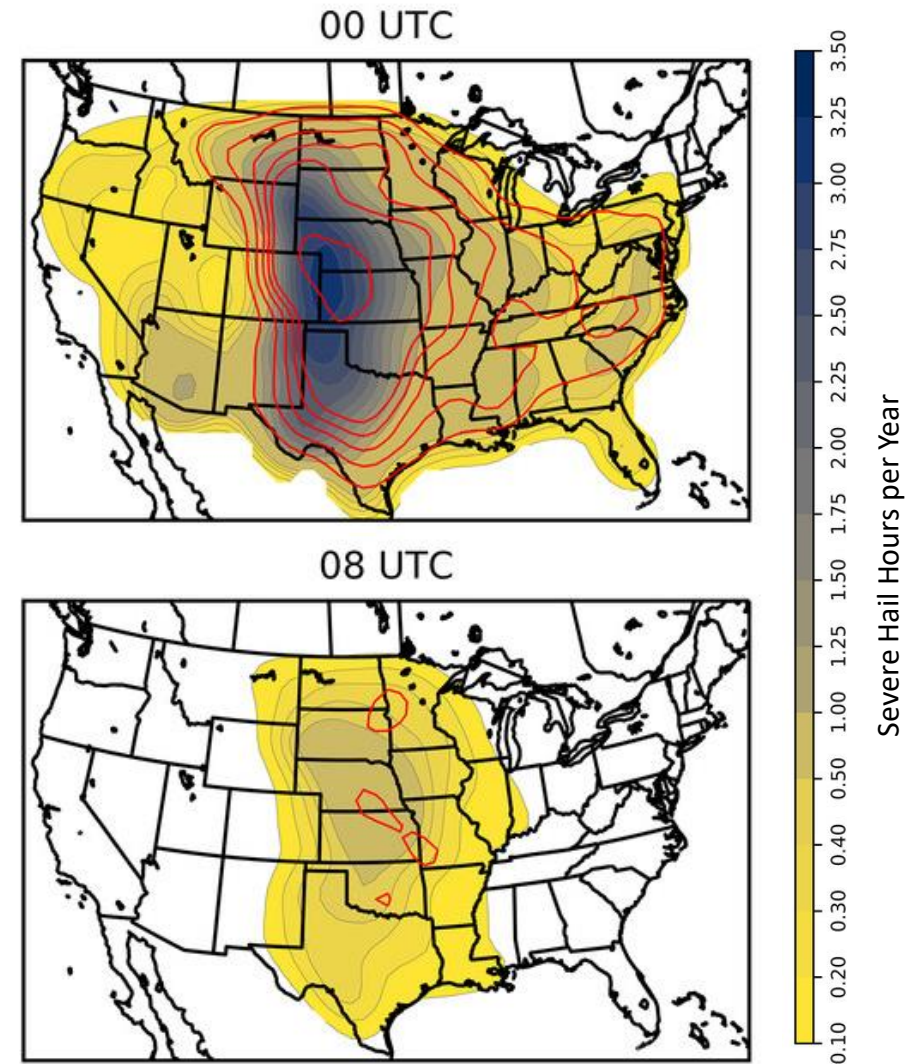
Have trends in storm reporting impacted the hail climatology?

If so, can we obtain a more accurate hail climatology?

Could MESH be better for operations or confirm that LSRs are good enough?

What's the problem?

1. **Limited research** on MRMS
MESH–LSR comparison
2. **Report clustering** and strong underreporting at night and in rural areas with LSRs
3. **Field estimates can vary** based on measuring method for LSRs



A comparison of average severe hail hours for 0000 and 0800 UTC between MESH (color fill) and *Storm Data* (red contours). Adopted from Wendt and Jirak (2021, WAF).

Project Vision



Main Goal

Validate radar-derived hail size estimates with observed hail reports to create a daily, real-time web interface of MESH, LSRs, and a high-resolution hail size return-period climatology.

Part 1

MESH–LSR Variance

Quantify the variance between 11 years of MRMS MESH-derived hail sizes (collected by Dr. Victor Gensini) and Local Storm Reports (LSRs).

Part 2

Hail Size Return-Periods

Statistical distribution of hail sizes at 5 km resolution, producing gridded maps of hail size return levels (2-, 5-, 10-, 25-, 50-, 100-, and 200-year events) and their uncertainty.

Approach

From validation → To application

MESH-LSR Analysis

1. **Data compilation:** Collect daily MRMS MESH composites (2015–2025) and SPC hail LSRs for the same period.
2. **Spatiotemporal matching:** Associate each LSR with the nearest MESH pixel within a set distance/time window (e.g., 5 km, ± 15 min).
3. **Feature extraction:** Derive local MESH maxima, neighborhood percentiles, distance to core, and potentially storm morphology descriptors.
4. **Model fitting:** Use regression to relate observed hail size to MESH metrics; compute bias.

Hail Size Return Intervals and Daily MESH Interface

1. **Annual maxima:** Compute annual maximum calibrated hail size per grid cell.
2. **GEV fitting:** Estimate location, scale, and shape parameters for each cell, calculate return sizes for 2–200 years.
3. **Bayesian-GPR smoothing:** Fit a Gaussian-Process to smooth and quantify uncertainty.
4. **Web Interface:** MESH return period intervals, MESH climatology layers, daily LSRs overlaid on daily MESH, variance statistics and errors.

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Expected Deliverables

1) Technical Report



- Includes validation statistics and MESH-LSR calibration function
- Also includes MESH hail climatology, return interval analysis, and web user guide

2) Hail Size Return-Period Atlas Data



- Gridded raster files of hail return sizes (2-200 years) at 5km resolution (monthly, annual)
- Gridded raster files of return periods for select hail sizes (1in, 2in, 3in, etc.)
- Gridded rasters of hail size threshold occurrence, max hail size, and mean hail size at annual level

3) Interactive Web Interface



- GIS-style viewer consisting of daily MESH swaths, LSRs, variance summaries and statistics, climatology MESH-LSR variance statistics, MESH climatologies, MESH hail size return levels

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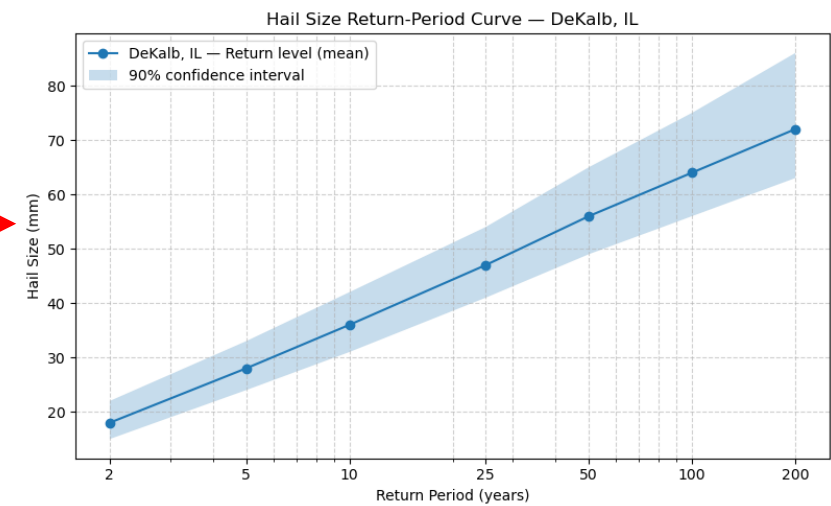
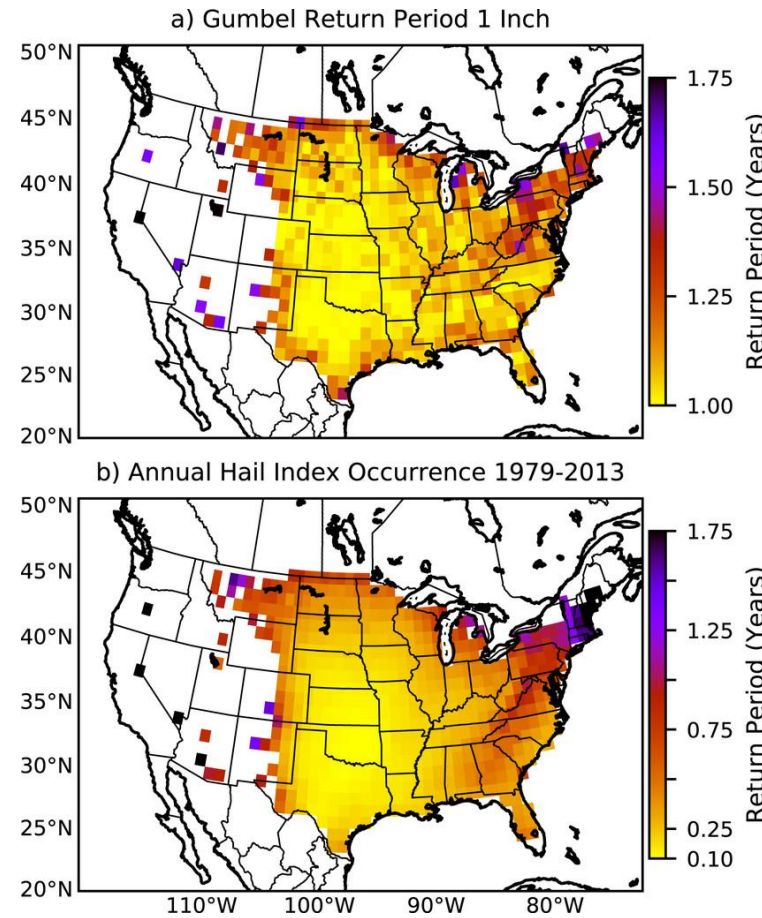
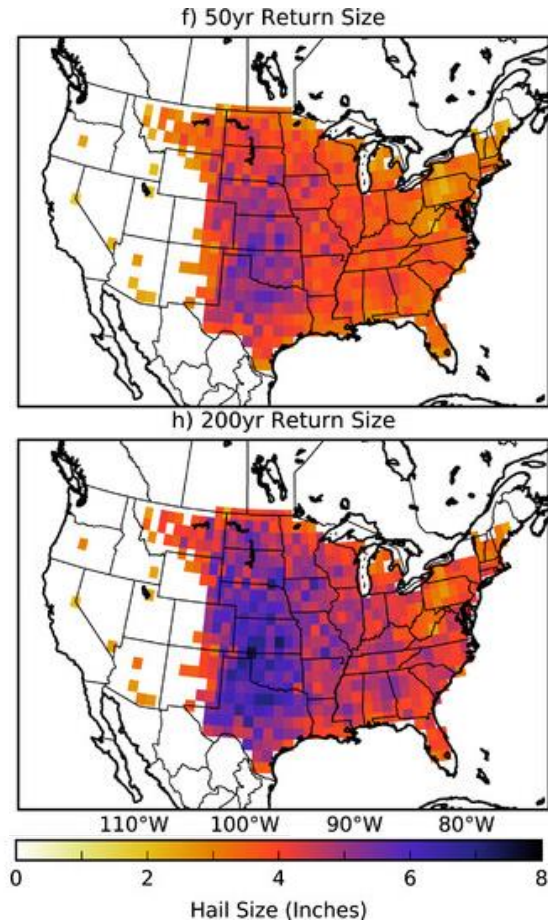
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Return Period Data Example

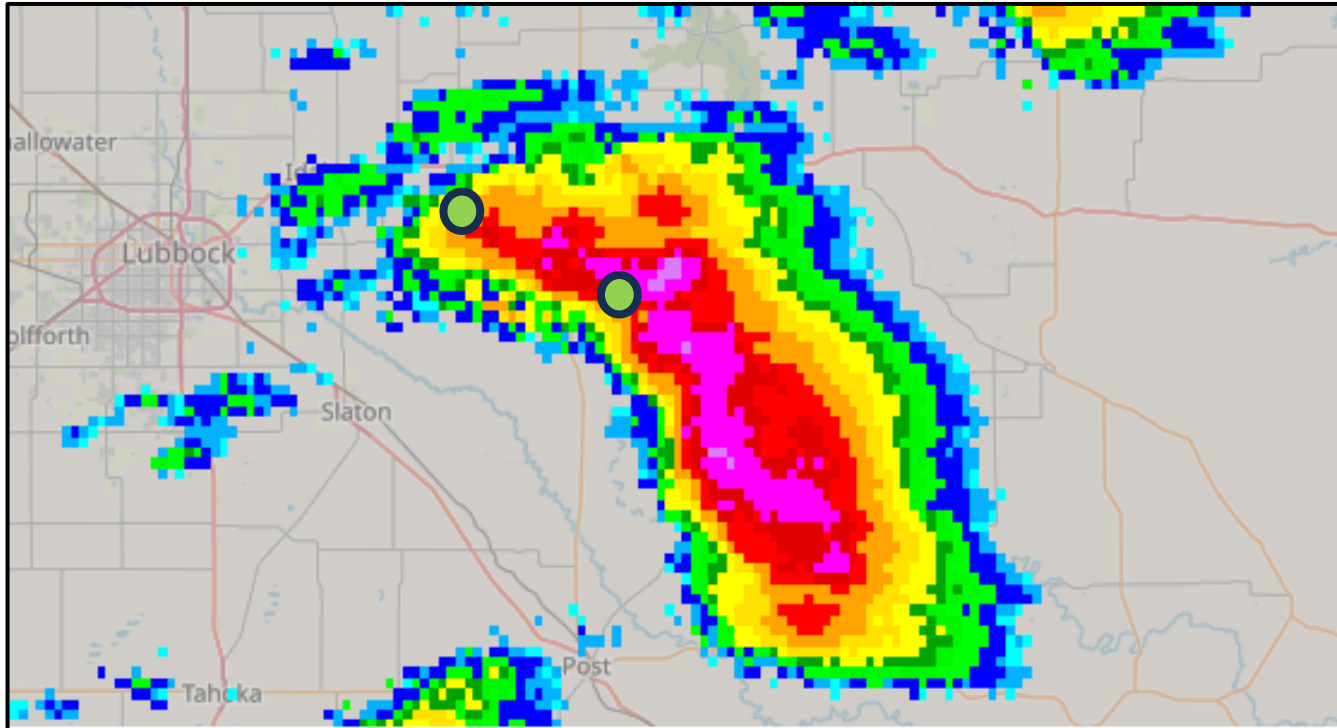


Fitted point dithered Gumbel estimated return hail sizes for the respective quantiles. Modeled return hail sizes are shown at the (f) 50- and (h) 200-yr intervals, for points with at least 30 annual maxima on the $1^\circ \times 1^\circ$ grid. Adopted from Allen et al. (2017, MWR).

Comparison of return periods over the climatology 1979–2013 from the (a) $1^\circ \times 1^\circ$ gridbox model for 25-mm (1 in.) hail with (b) inverse probability calculated using one on the mean annual hail occurrence above 25 mm (1 in.). Adopted from Allen et al. (2017, MWR).

MESH-LSR and Web Example

***Updated daily!** Will include daily MESH, LSRs, bias climatologies, MESH monthly and annual climatologies, MESH hail size return periods, variance stats, and export options.



Statistics

1. Size agreement
2. Bias score and match rate
3. Historical bias score at location
4. Areal coverage ratio
5. Uncertainty error bars between MESH and LSRs
6. National, daily statistics
7. Map overlay (bias climatology, MESH climatology, MESH return period)
8. Option to export county, state, national daily stats
9. Option to export MESH and LSRs for past week

Application of Results

Validated Data | Actionable Insights | Risk Intelligence | Decision Support | Confidence

MESH-LSR Validation

- ✓ Supports real-time application of MESH
- ✓ Facilitate cross-dataset harmonization
- ✓ Validate event footprints against MESH for claims
- ✓ Enhance due diligence
- ✓ Tune hazard-loss models
- ✓ Trigger-payout calibration (MESH → expected loss)
- ✓ Enables other CIRCS research and climate-risk research

Hail Size Return Intervals

- ✓ Portfolio % exposure in severe hail zones
- ✓ Underwriting caps
- ✓ Adjust cat models using radar-derived baselines
- ✓ Public hazard baselines for planning/risk communication
- ✓ Claims-surge early warning
- ✓ Event severity scoring for rapid loss models
- ✓ Trigger post-event if threshold is met

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Project Timeline



We anticipate this project will take **1 year** to complete:

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1. Data procurement	Yellow											
2. Data preprocessing		Yellow	Yellow									
3. <u>Data analysis:</u> MESH-LSR analysis				Yellow	Yellow	Yellow						
4. <u>Data analysis:</u> Return interval analysis							Yellow	Yellow	Yellow	Yellow		
5. Finalize products											Yellow	Yellow

Project Budget



- **Personnel: \$95k**
 - PI Time
 - Graduate student stipend
- **Materials and Supplies: \$8k**
 - Compute time
 - Data storage
- **Travel: \$4k**
 - Travel to CIRCS annual meeting
 - Conference attendance and presentation (SLS 2026)
- **Other: \$2k**

- **Total: \$109,000**

