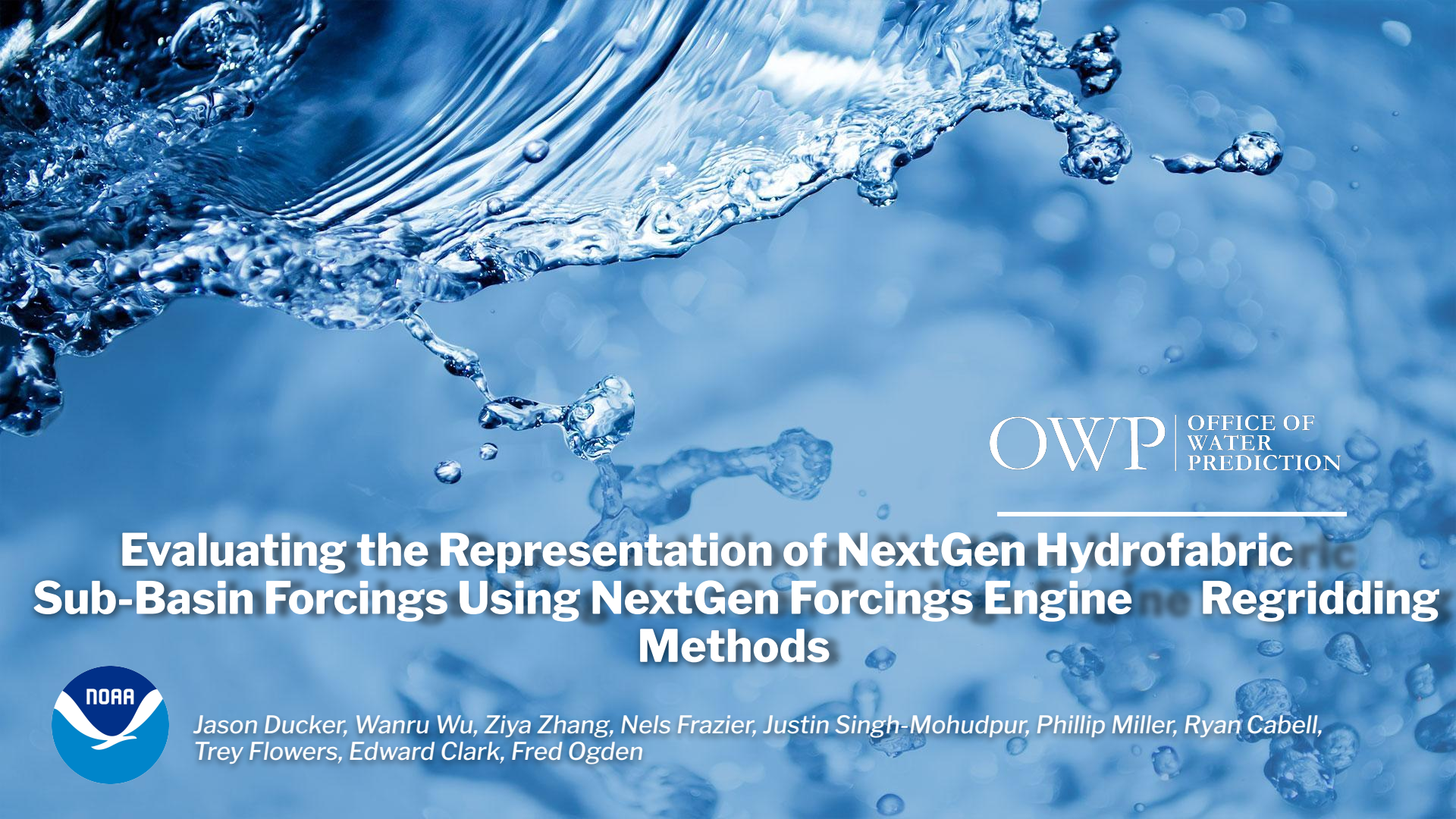

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Evaluating the Representation of NextGen Hydrofabric Sub-Basin Forcings Using NextGen Forcings Engine Regridding Methods

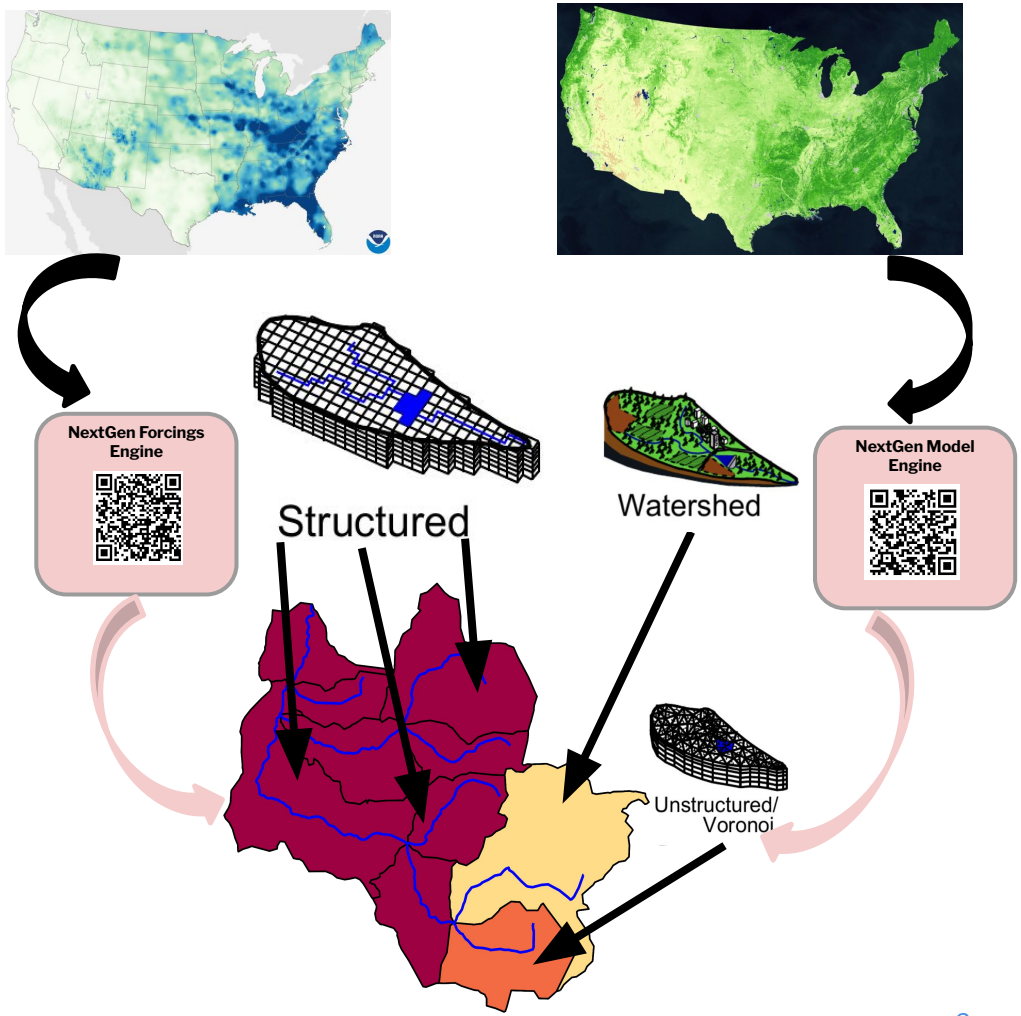
Jason Ducker, Wanru Wu, Ziya Zhang, Nels Frazier, Justin Singh-Mohudpur, Phillip Miller, Ryan Cabell, Trey Flowers, Edward Clark, Fred Ogden

Background

- NextGen supports multiple discritizations in a single model runtime, which requires forcing providers capable of rescaling global datasets across a variety of domain configurations.

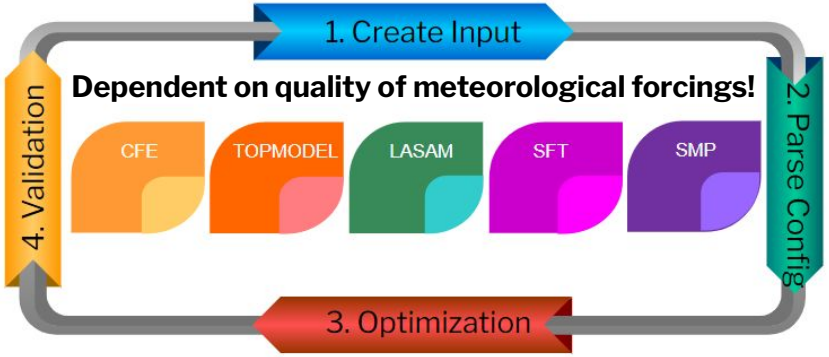
- The quality of a given forcing provider is a function of its weighting scheme (i.e. regridding method) targeted for a given forcing dataset.

- **The choice of regridding schemes (area vs. distance weighting) can greatly impact the rescaling of dynamical forcing datasets utilized in NextGen!**



Why Does the Choice of Regridding Methods Matter in NextGen?

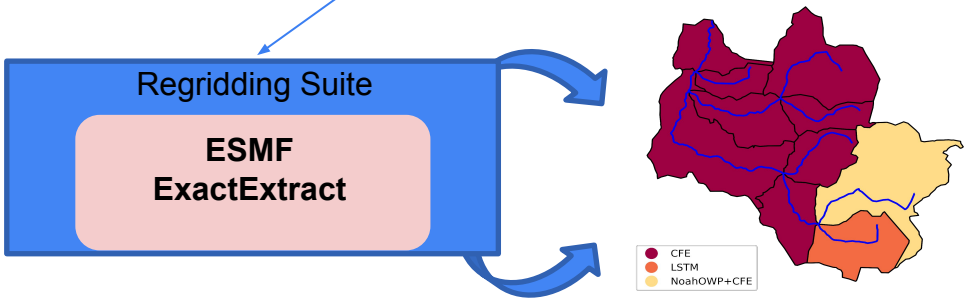
- NextGen allows flexible design of experiments to select performant models and module components over geographically varying regions.



- Calibration and model optimization for a suite of model formulations is a function of the quality of it's forcing inputs

- The focus of this regridding analysis here is concentrated on catchment polygon features representing a watershed.

Rainfall



ExactExtract Weighting Scheme

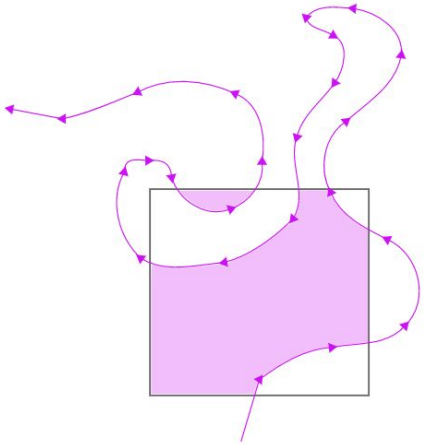
- ExactExtract provides a fast and accurate algorithm for summarizing values in the portion of a raster dataset that is covered by a polygon (e.g. zonal statistics).

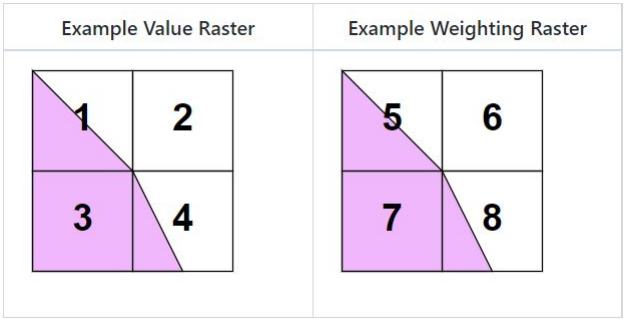
- Single threaded fast/efficient regridding technique

- ExactExtract calculates weighted averages based on the percent coverage each grid cell intersects the catchment polygon.

$$Weight(i,j) = \frac{V(i,j) * CF(i,j)}{\sum CF(i,j)}$$

$$y = \sum Weights(i,j)$$





Earth System Modeling Framework (ESMF) Bilinear Weighting Scheme

- The Earth System Modeling Framework (ESMF) is a suite of software tools for developing high-performance, multi-component Earth science modeling applications.

- Parallelized regridding approach for computational efficiency

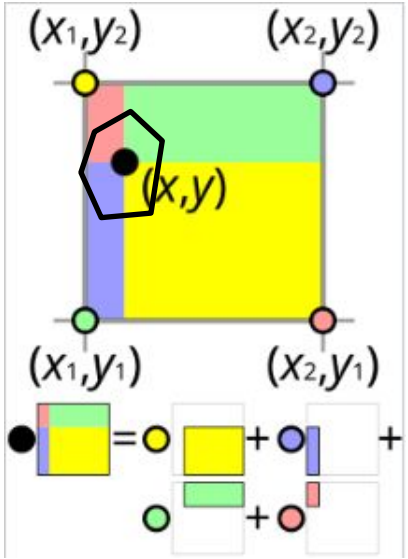
- ESMF provides a suite of regridding approaches (bilinear, patch, conservative) that will produce interpolation weight matrices for efficient communication of data fields between model components.

$$Weight(i,j) = V(i,j)\frac{(x - x_i)(y - y_j)}{(dx * dy)}$$

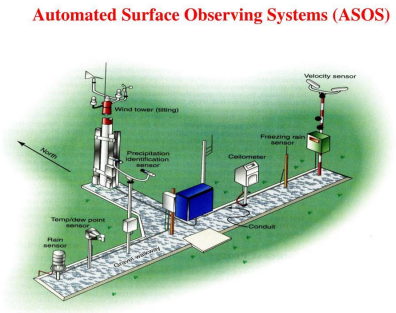
$$y = \sum Weights(i,j)$$

x,y = target coordinates; x(i),y(i) = source grid coordinates; dx,dy = grid spacings

Bilinear Weighting Scheme



Scope of the Statistical Analysis for Regridding Schemes



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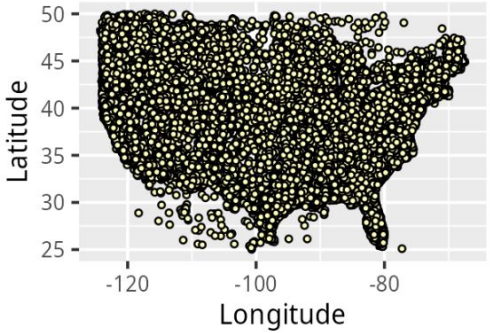


Dense observation network ~ 34,052 surface stations

- Applied quality control flags based on signal/noise filtering mechanisms to only extract best quality data available from surface stations.
- Analysis time period: 2023-08-30 12:00:00 until 2023-09-03 12:00:00 UTC.
- Grid cell/catchment centroid ≤ 10km from surface observation centroid.
- Observation station recorded variance in rainfall timeseries.

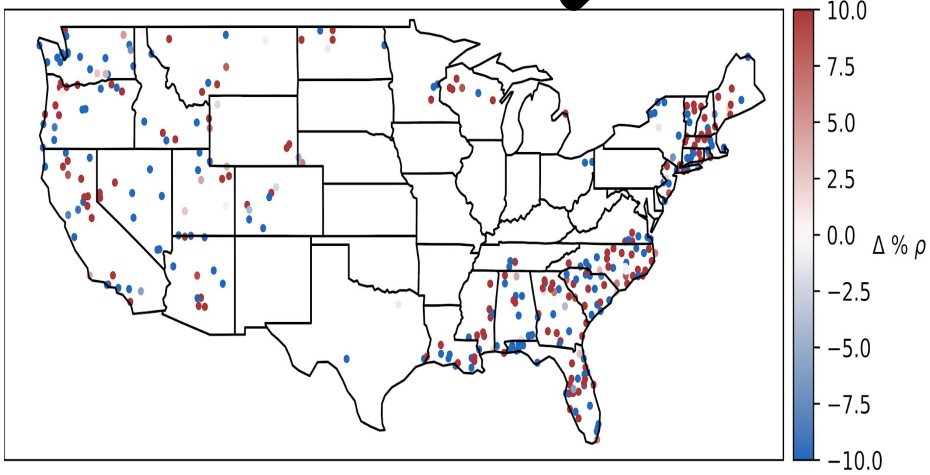
Reanalysis Datasets

Analysis of Record for Calibration (AORC) 1km
High Resolution Rapid Refresh (HRRR) 3km
ECMWF Reanalysis v5 (ERA5) 28km

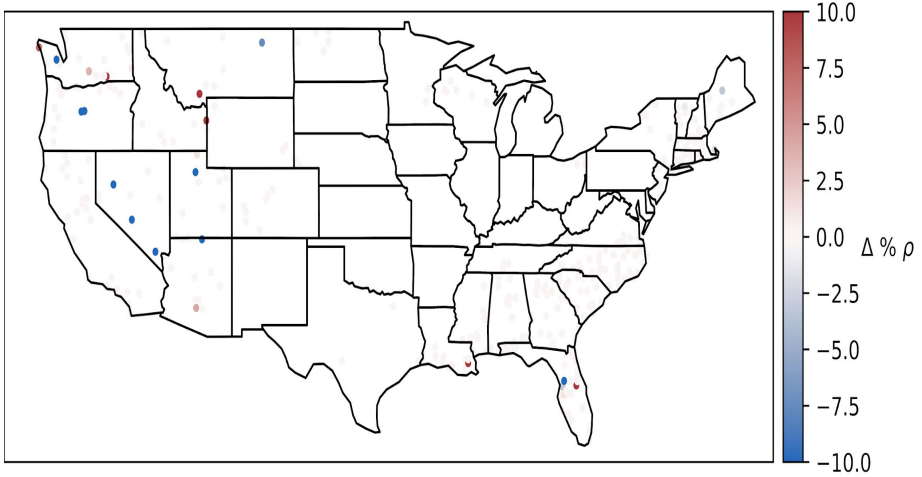
ERA5 28km Accumulated Hourly Rainfall: Spatial Variation Between Weighting Schemes

$$\Delta\%\rho = \frac{\rho_{ESMF,EE} - \rho_{ERA5}}{\rho_{ERA5}} * 100$$

ESMF Bilinear ✔



ExactExtract

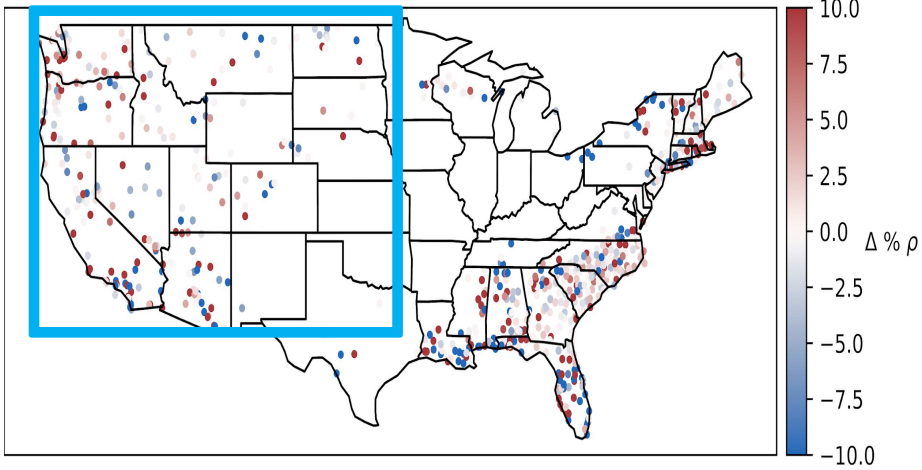


- ESMF Bilinear regridding showed net positive benefits for rescaling rainfall across CONUS
- ExactExtract showed no difference essentially from near neighbor approach

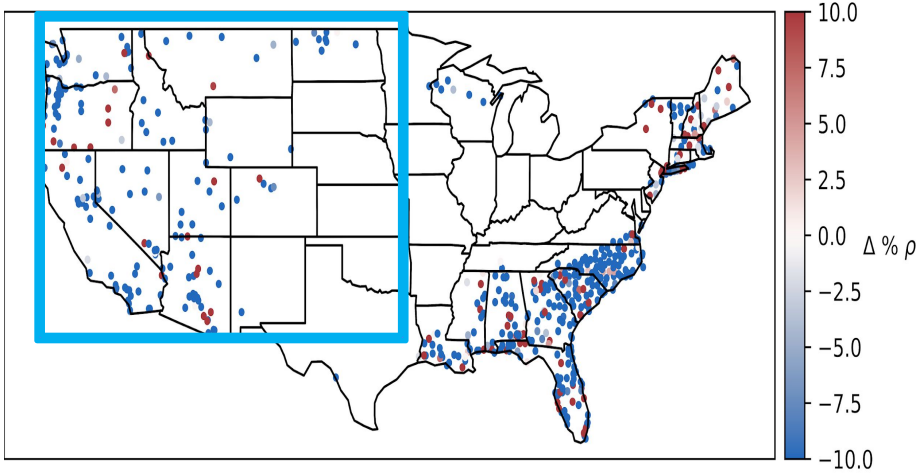
HRRR 3km Accumulated Hourly Rainfall: Spatial Variation Between Weighting Schemes

$$\Delta\%\rho = \frac{\rho_{ESMF,EE} - \rho_{HRRR}}{\rho_{HRRR}} * 100$$

ESMF Bilinear ✔



ExactExtract

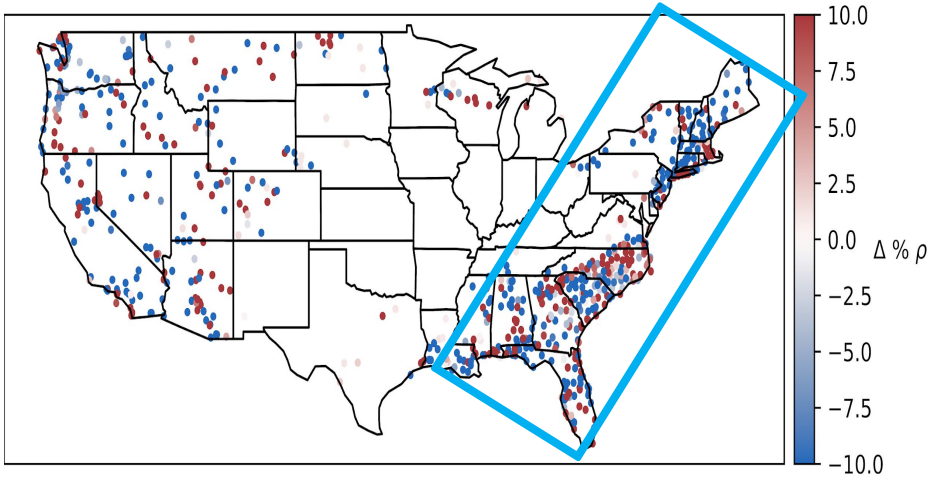


- Distance weighted regridding scheme performing well over sparse rainfall event features in Western US, slight benefit in rainfall features in Southeastern US.
- Across CONUS, ExactExtract showed an overall reduction in skill with rescaling rainfall

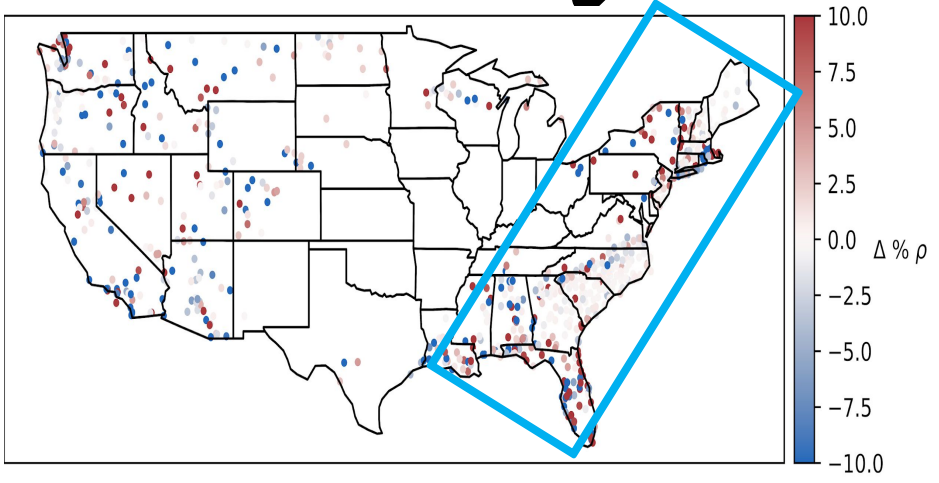
AORC 1km Accumulated Hourly Rainfall: Spatial Variation Between Weighting Schemes

$$\Delta\%\rho = \frac{\rho_{ESMF,EE} - \rho_{AORC}}{\rho_{AORC}} * 100$$

ESMF Bilinear



ExactExtract ✔

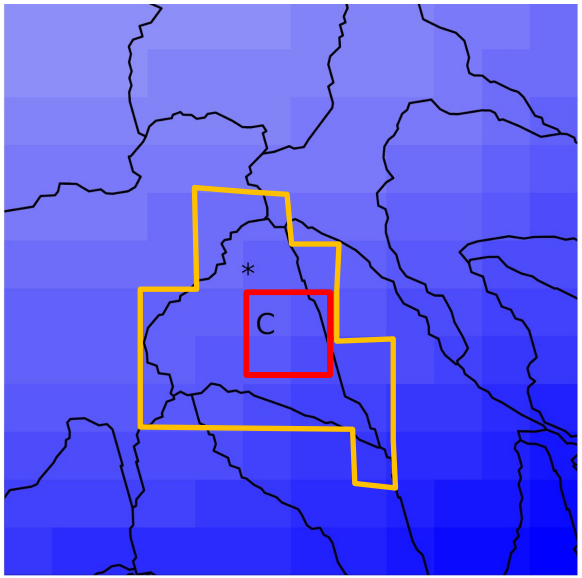


- Bilinear distance weighted approach shows a net reduction in statistical skill with rescaling high resolution rainfall data.
- ExactExtract area-weighted approach begins resoling dynamical rainfall gradients and shows a net benefit for rescaling high resolution rainfall fields.

Accumulated Hourly Rainfall: ExactExtract Weighting Scheme Advantage

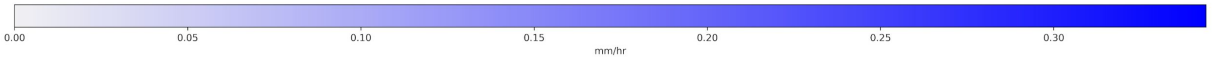
ESMF Bilinear

- Weighting 4 nearest grid cells from centroid of catchment.
- Cannot account for precipitation gradient covering entire catchment area.
- Estimate ~ 0.41 mm/hr



ExactExtract ✔

- Weighting coverage fraction of all interesting cells covering catchment polygon
- Captures precipitation gradient covering entire catchment area.
- Estimate ~ 0.74 mm



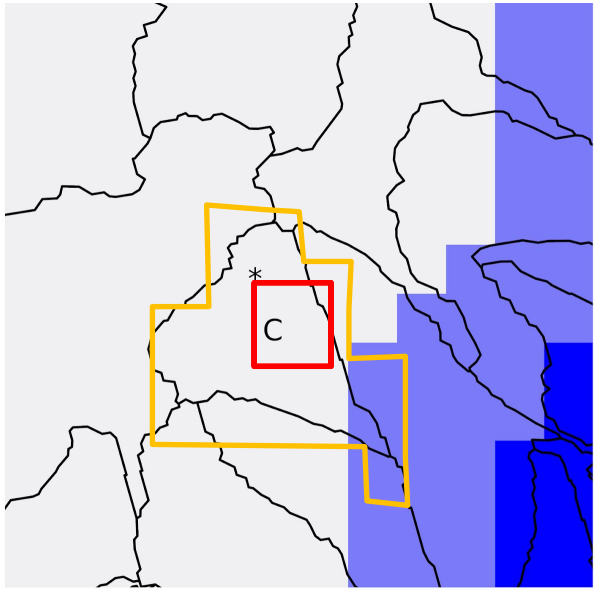
* ~ ASOS station location recording 1.17 mm/hr

C ~ centroid of the overlapping catchment

Accumulated Hourly Rainfall: ESMF Weighting Scheme Advantage

ESMF Bilinear

- Weighting 4 nearest grid cells from centroid of catchment.
- Represents the rainfall distribution
- Estimate ~ 0.00 mm/hr



ExactExtract

- Weighting coverage fraction of all interesting cells covering catchment polygon
- Weights rainfall amount on edges, where it may at times overestimate rainfall accumulated for catchment
- Estimate ~ 0.15 mm/hr

* ~ ASOS station location recording 0.0 mm/hr

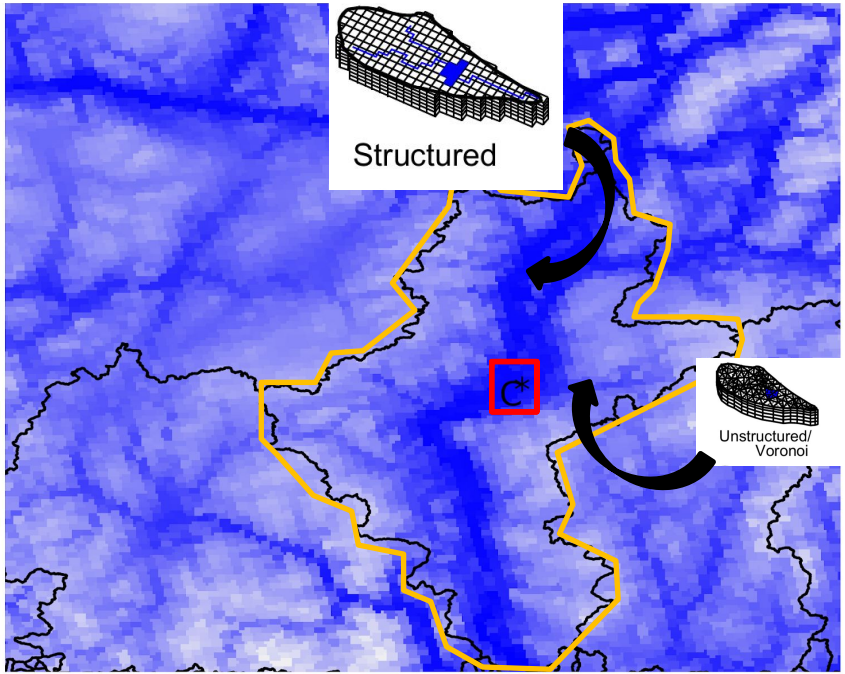
C ~ centroid of the overlapping catchment

Catchment Feature Sizing Also Impacts Rescaled Meteorological Forcing Inputs!

Observation ~ 965 mbs

Bilinear Lumped Estimate ~ 955 mbs

ExactExtract Lumped Estimate ~ 870 mbs



* ~ station location

C ~ centroid of the overlapping catchment

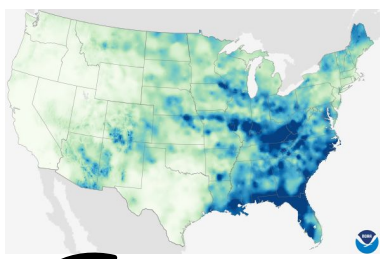
- Distance-weighted schemes better suited for lumped forcings of large catchments over heterogenous terrain
- Downscaled model formulations within this catchment will alleviate area-weighted regridding issues

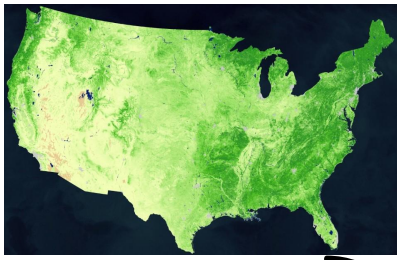
Key Takeaways

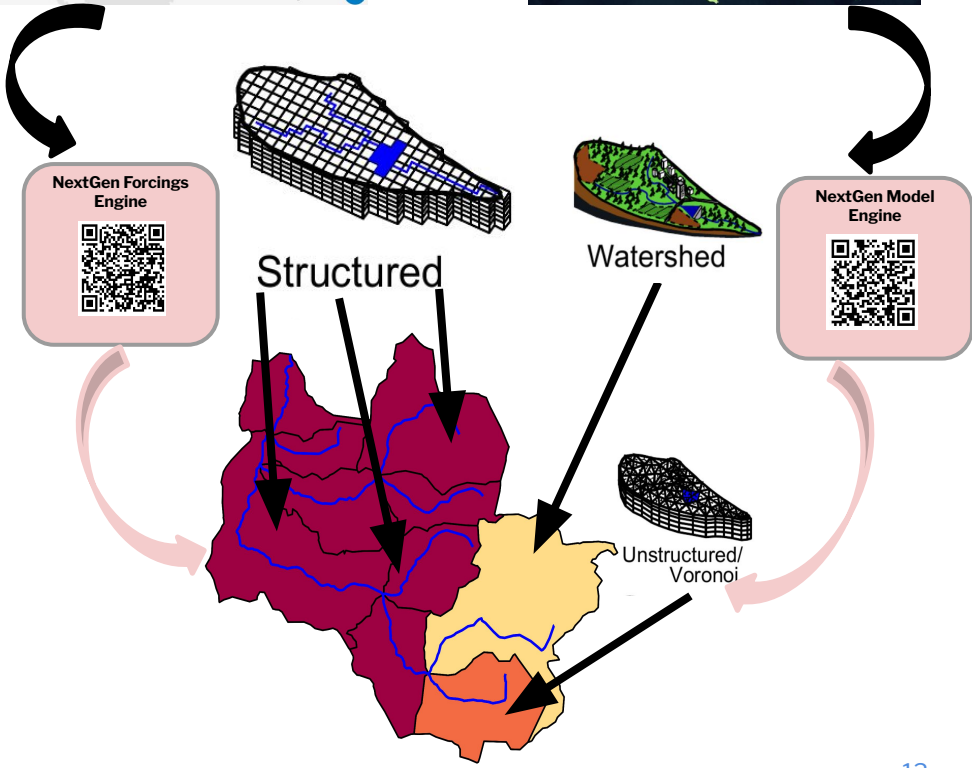
- The NextGen framework gives us the ability to refine forcing inputs for optimal rescaling given the knowledge leveraged in this analysis.

- Distance vs. area weighted regridding methods directly influence the rescaling of meteorological forcing data.
  - Coarse resolution, sparse rainfall -> ESMF Bilinear
  - High resolution, large-scale rainfall -> ExactExtract

- NextGen catchments encompassed in heterogenous terrain can directly impact the quality of rescaled meteorological forcings pending on weighting schemes.







Acknowledgments

Thank You!

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For More Information:

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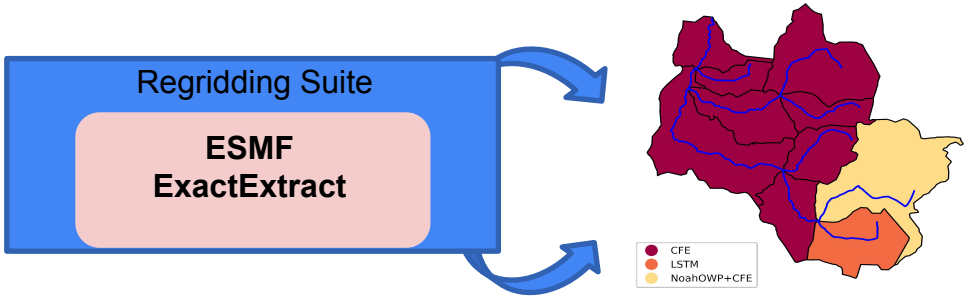
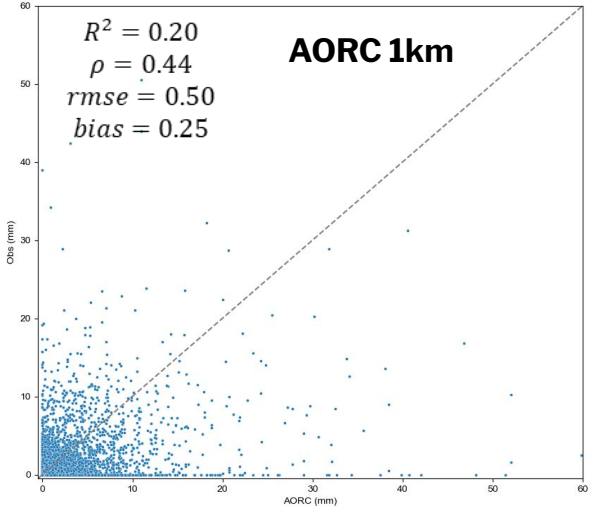
https://water.noaa.gov

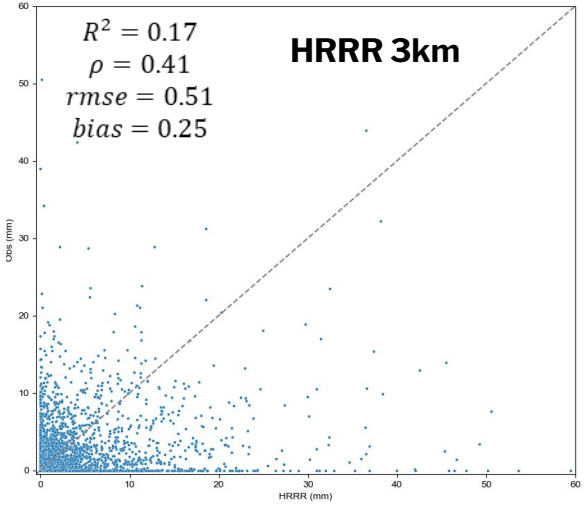
Future Developments

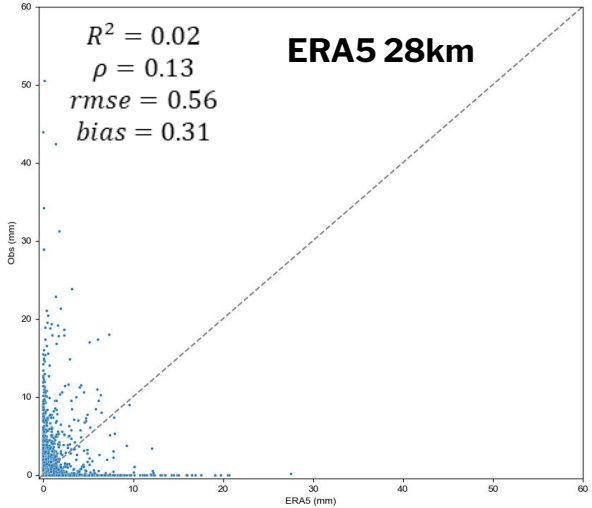
- Integrate the ExactExtract regridding method as a supplementary regridding approach to the NextGen Forcings Engine BMI tool.
- Potentially develop an area-weighted matrices as a secondary weighting factor for the ExactExtract regridding approach.
- Analyze ESMF area-weighted methods vs. ExactExtract area-weighted methods for flux-based variables for conservative regridding approaches.



Accumulated Hourly Rainfall: Observations vs. Reanalysis Datasets

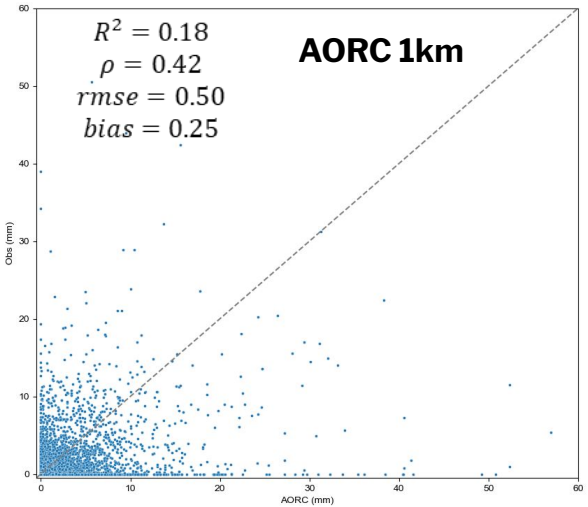


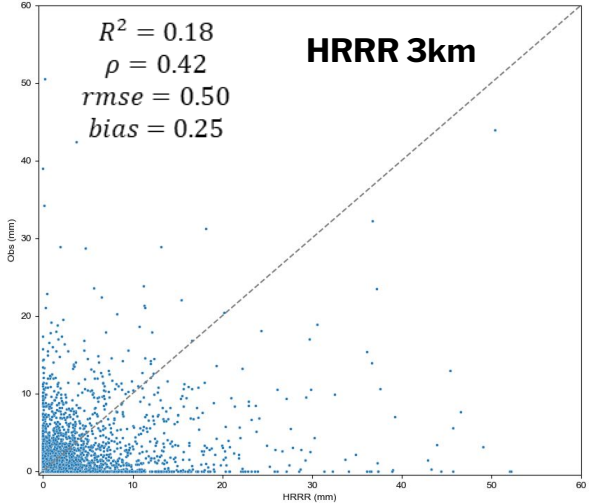


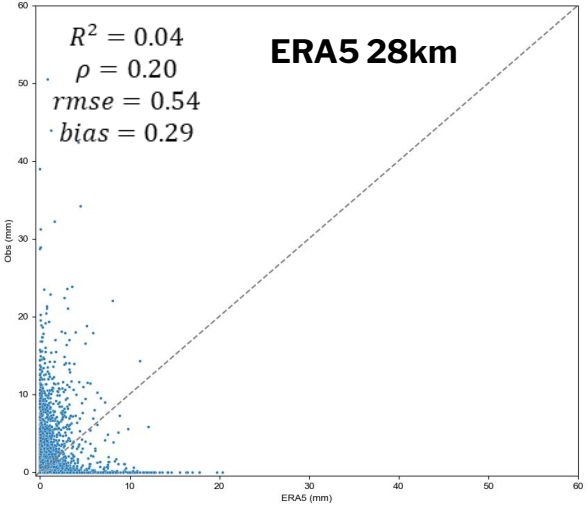


- Nearest neighbor regridding approach between reanalysis datasets vs. observations
- Skill improves with increasing resolution of reanalysis datasets
- Difficult to pick up spatial/temporal variability in rainfall across CONUS, with many false positives compared to surface observations

Accumulated Hourly Rainfall: Observations vs. ESMF Bilinear Weighting Scheme



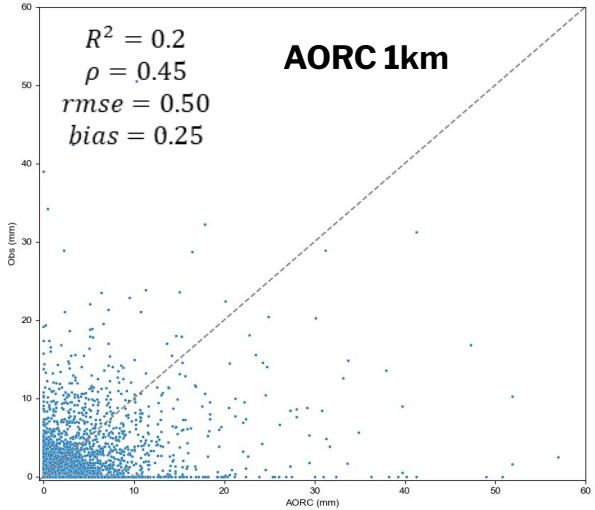


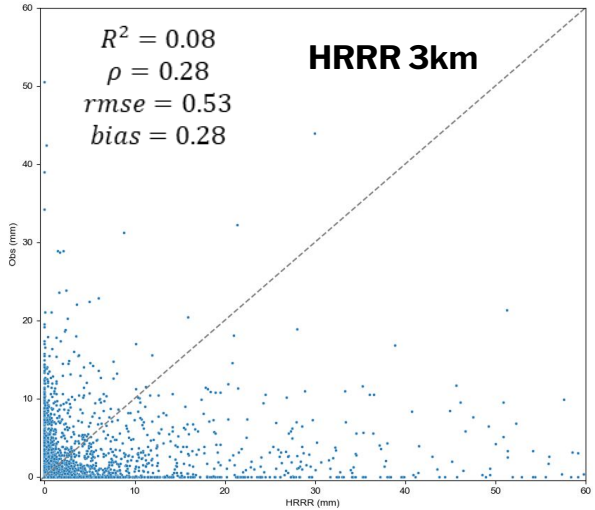


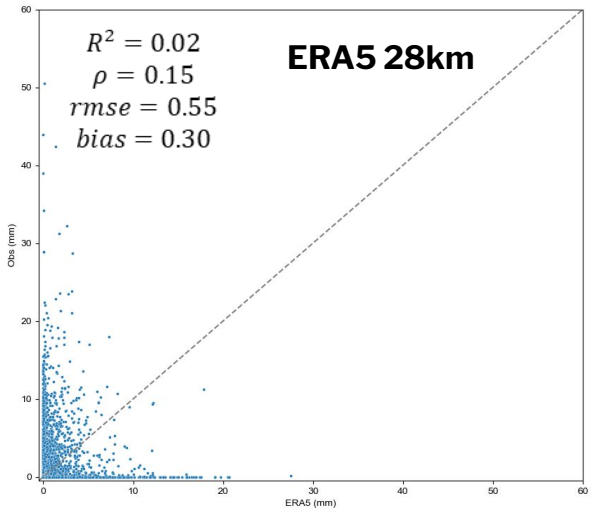
- Bilinear weighting scheme slightly worsened the statistical characteristics of the high resolution reanalysis datasets.

- Improved statistical distribution of coarser reanalysis dataset.

Accumulated Hourly Rainfall: Observations vs. ExactExtract Weighting Scheme



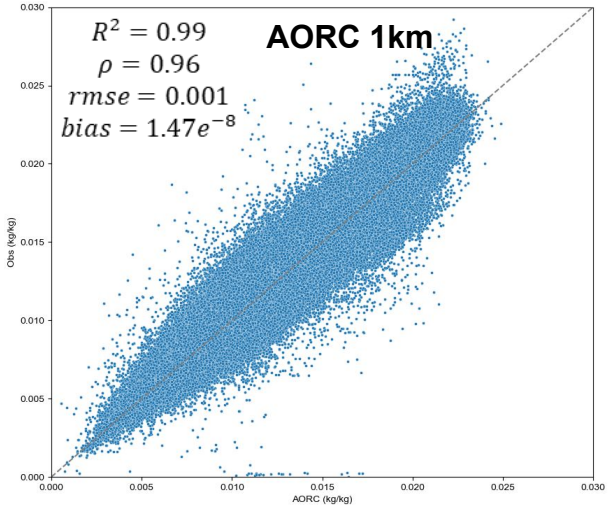


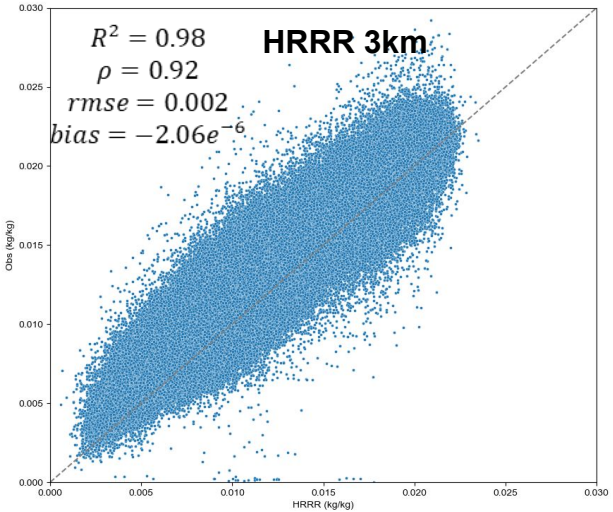


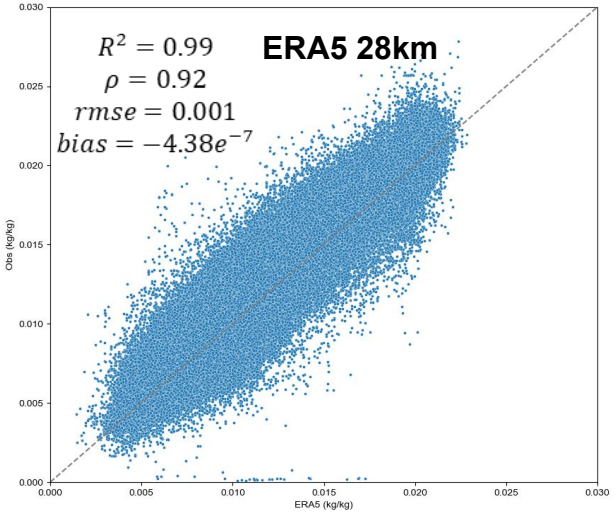
- ExactExtract weighting scheme slightly improves the statistical distribution in the highest resolution reanalysis dataset (AORC 1km).

- The area-based weighting scheme performance however worsens with decreasing resolution of reanalysis datasets for rainfall accumulation estimates.

Specific Humidity: Observations vs. Reanalysis Datasets

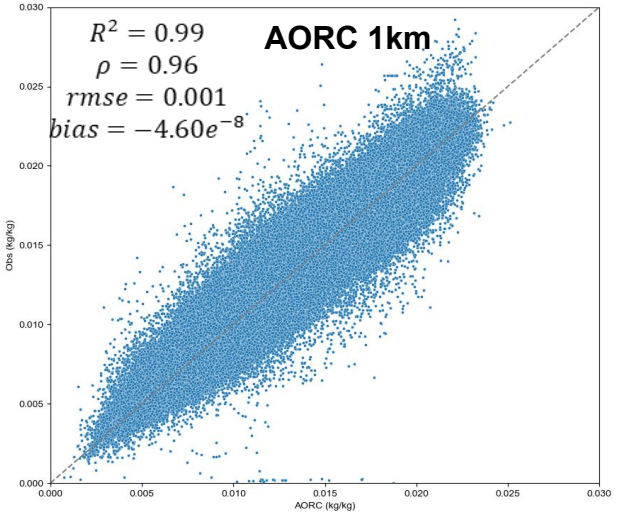


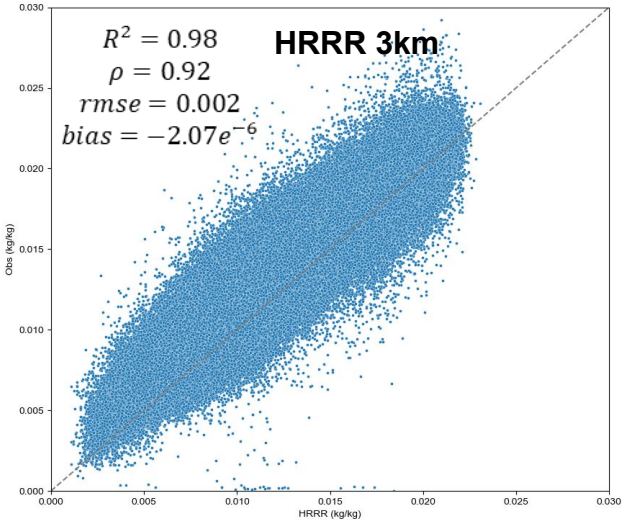


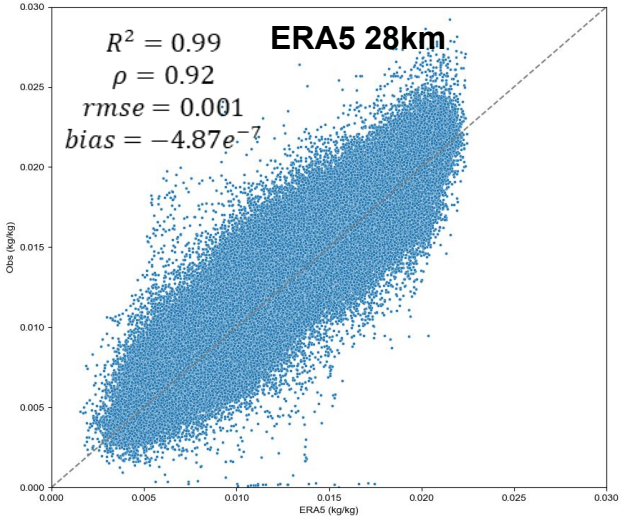


- Reanalysis datasets capture the variability in surface humidity levels across CONUS
- Increasing resolution reduces associated error in specific humidity estimates

Specific Humidity: Observations vs. ESMF Weighting Scheme

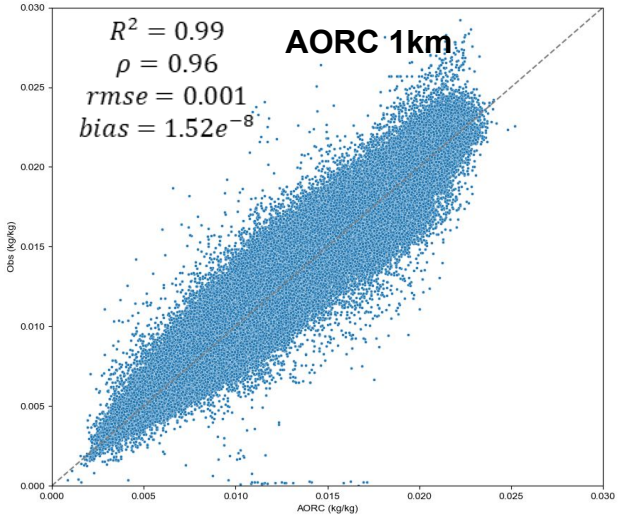


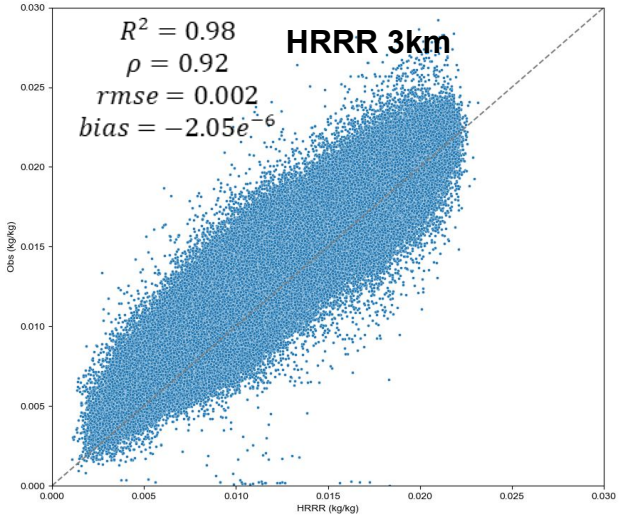


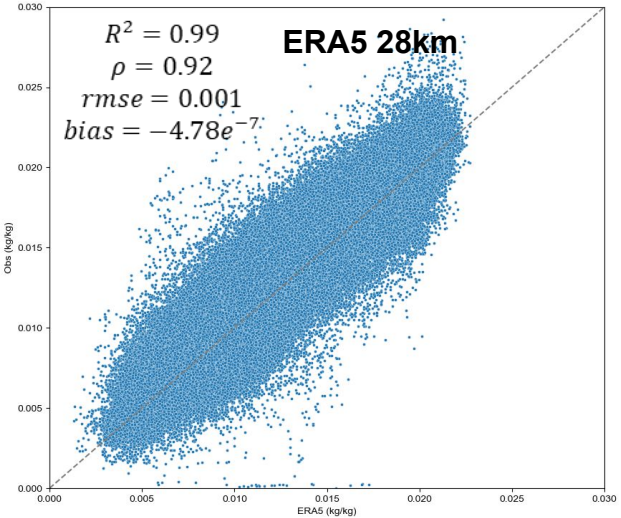


ESMF weighting scheme closely mimics the statistical distributions of the raw reanalysis datasets

Specific Humidity: Observations vs. ExactExtract Weighting Scheme

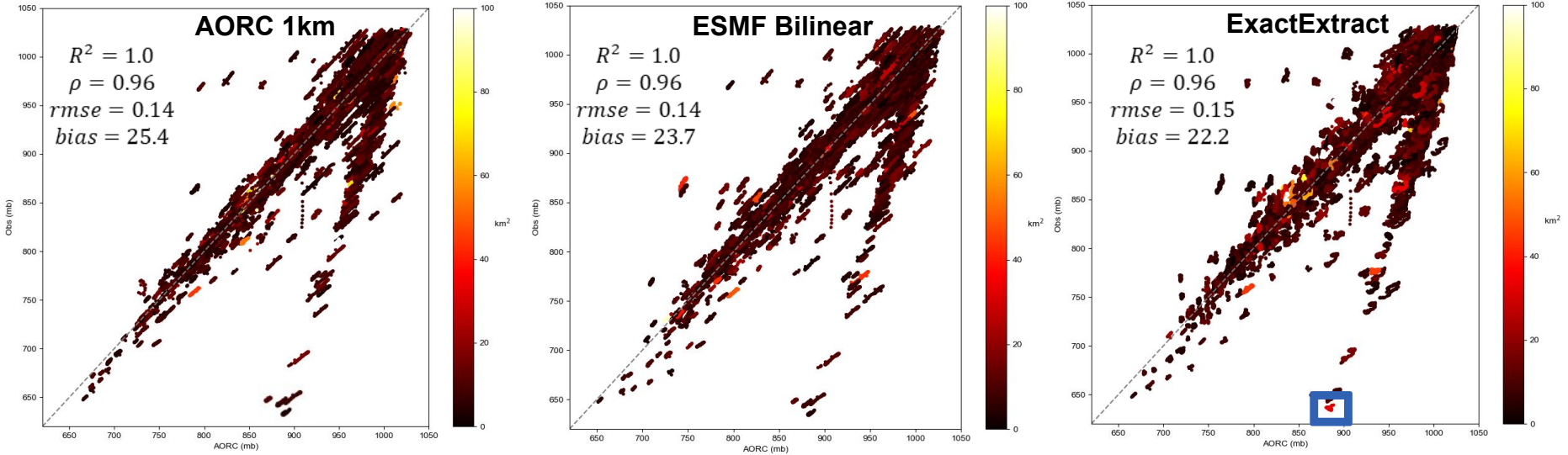






ExactExtract weighting scheme tends to overweight overlapping grid cell values over each catchment basin, thus weakening the representation of sharp humidity gradients across CONUS.

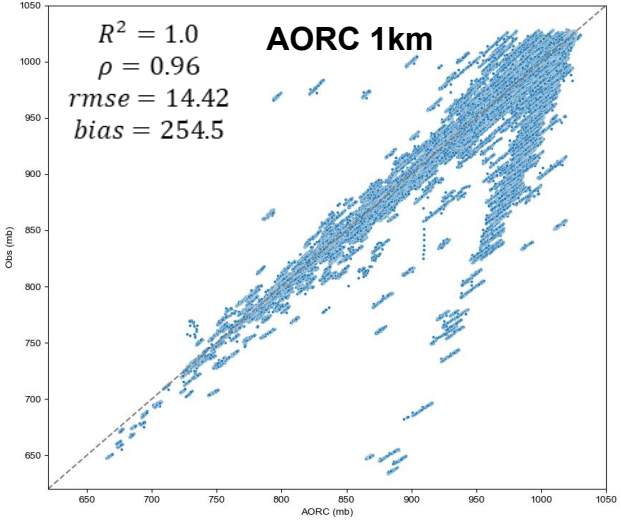
Surface Pressure: Observations vs. Reanalysis/Regridding Methods

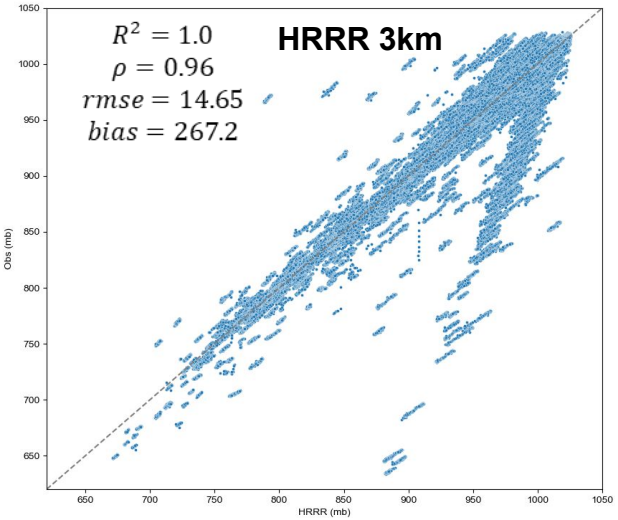


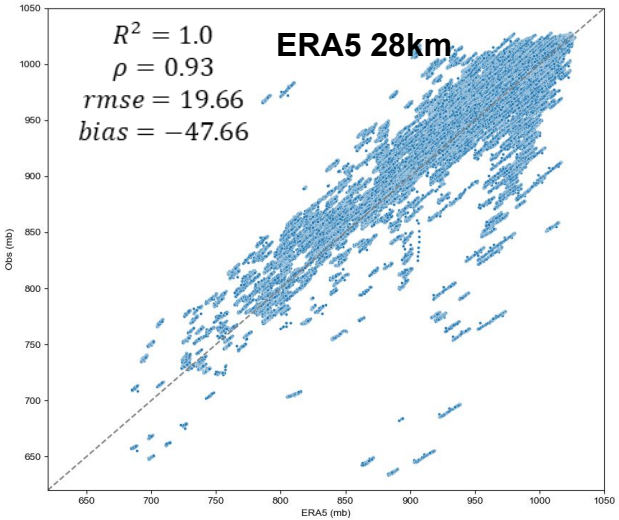
- Overestimations in surface pressure reanalysis data are mainly due to major topography differences within 10km of observation vs. model centroids

- Both, ESMF Bilinear and ExactExtract regridding methods slightly reduce the associated bias of surface pressure fields introduced by the 1km AORC dataset

Surface Pressure: Observations vs. Reanalysis Datasets

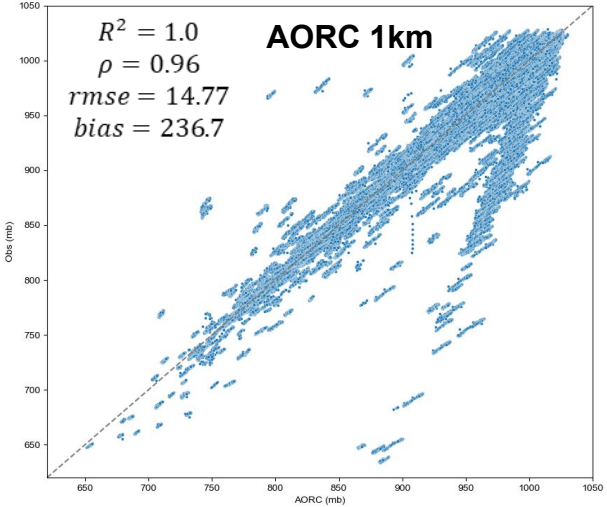


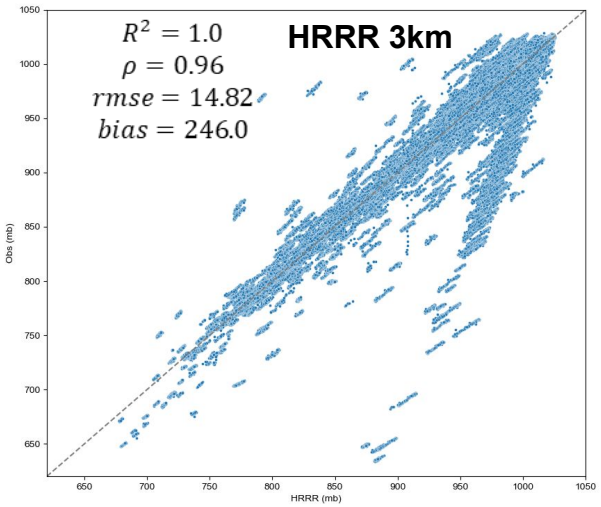


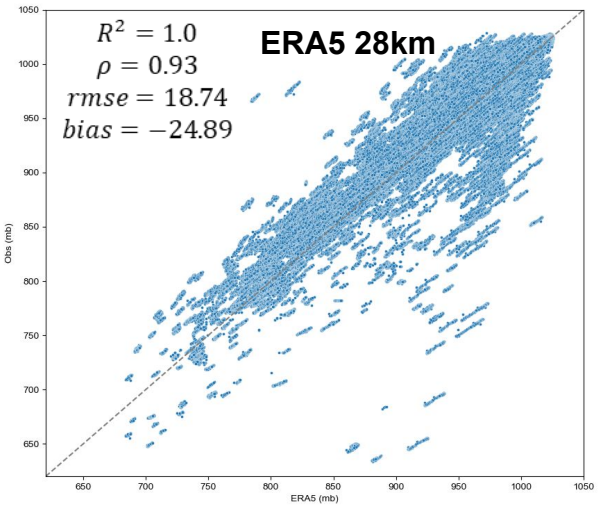


- Surface pressure estimates improve with increasing resolution.
- Overestimations in surface pressure reanalysis data are due to major topography differences within 10km of observation vs. model centroids.

Surface Pressure: Observations vs. ESMF Weighting Scheme

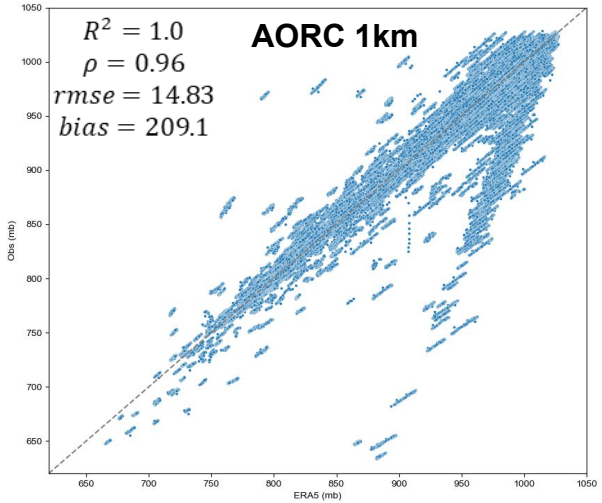


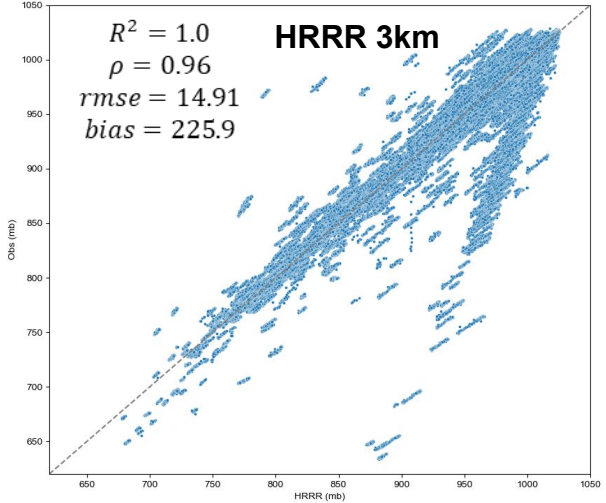


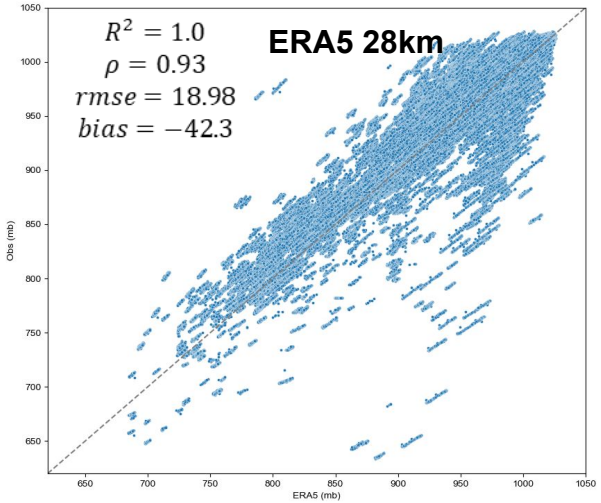


ESMF weighting scheme tend to reduce a small margin of error and bias for surface pressure estimates, particularly in areas with complex topographic features

Surface Pressure: Observations vs. ExactExtract Weighting Scheme







ExactExtract weighting scheme is covering too large of a weighting area across topographic regions with extreme gradients of surface pressure.