NOAA RESEARCH • ESRL • PHYSICAL SCIENCES DIVISION

High-Resolution Modeling to Understand Flood Risk and Hail Impacts in Future Climates

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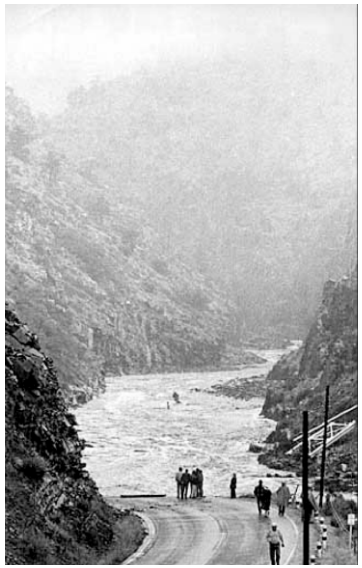
Flood risk and decision-making needs

- Will climate change affect flood risk for specific locations, civil/water infrastructure design, operations?
- Can elevation thresholds for storms, flooding, hail change in future?

1976: Big Thompson Canyon and washed out US 34 near Estes Park, CO (elevation: ~8000ft) 145 lives lost

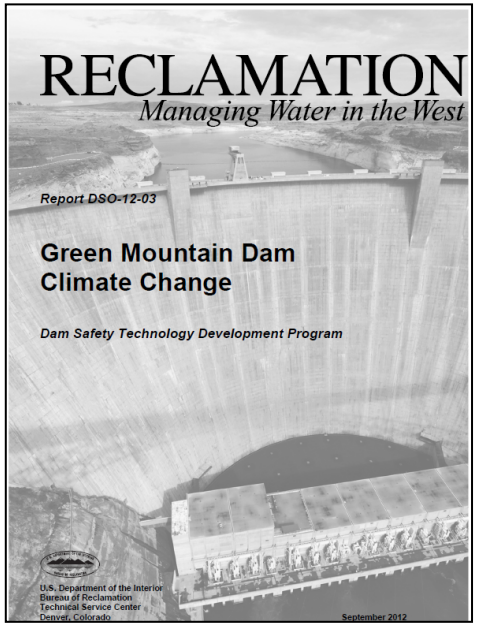


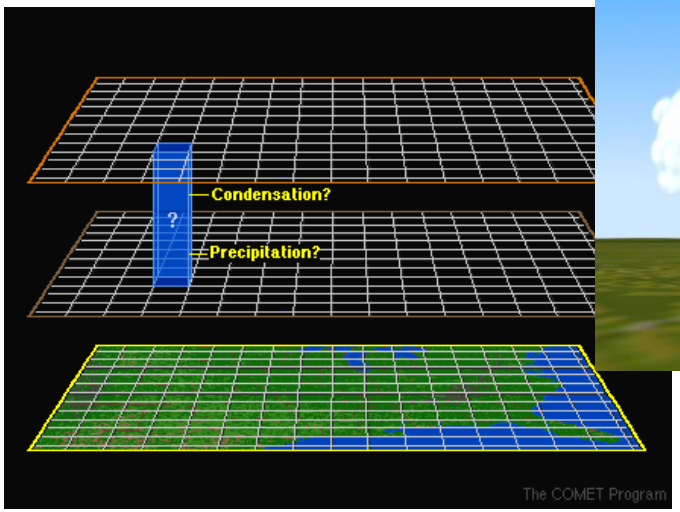
2013: Big Thompson Canyon and washed out US 34 near Estes Park, CO (elevation: ~8000ft) 10 lives lost

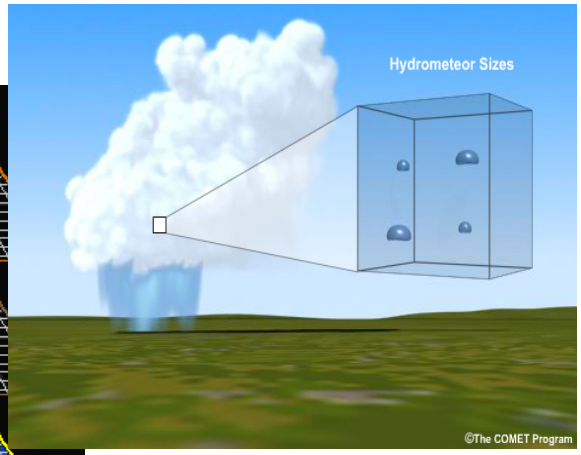
X2R: Needed: Climate change information at weather scales

Challenges:

- Users want high-resolution information to inform climate change planning
- Global climate models: Main tool for climate change info…but not designed for simulation of extreme precipitation (resolution, parameterizations)
- How to connect climate-scale questions with weather-scale answers?



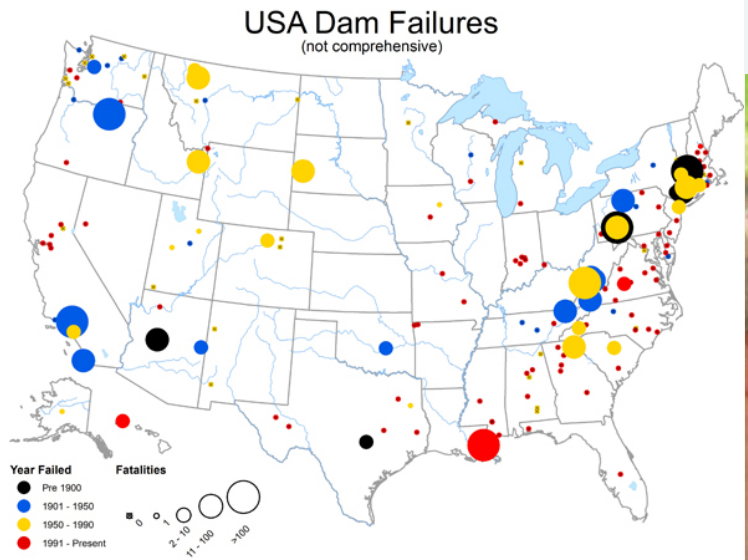




X2R: Needed: Climate change information at weather scales

Bureau of Reclamation Dam Safety/Flood Risk Study

- How will climate change affect extreme precipitation in the inter-mountain West?
- Can intense rainfall occur above 7500 ft?
- Common wisdom: all hail
- Current practice: Hail at high elevations → reduced flood risk → reduced dam safety criteria



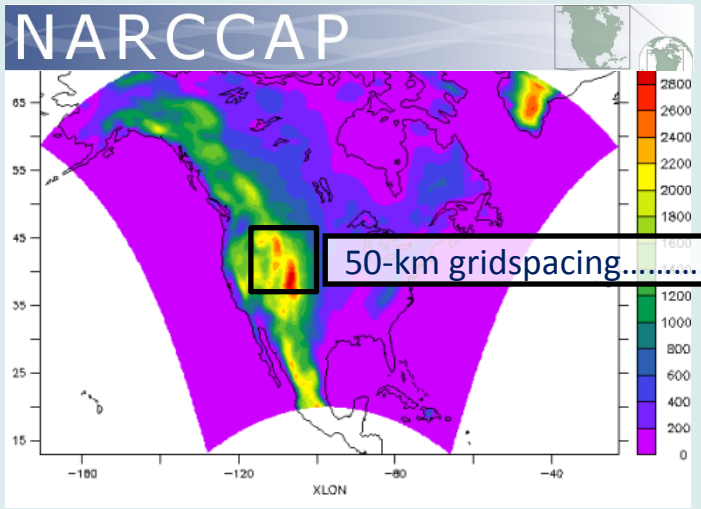
Select dam failures and fatalities
Map courtesy of James S. Halgren, Office of Hydrologic Development, NWS, NOAA

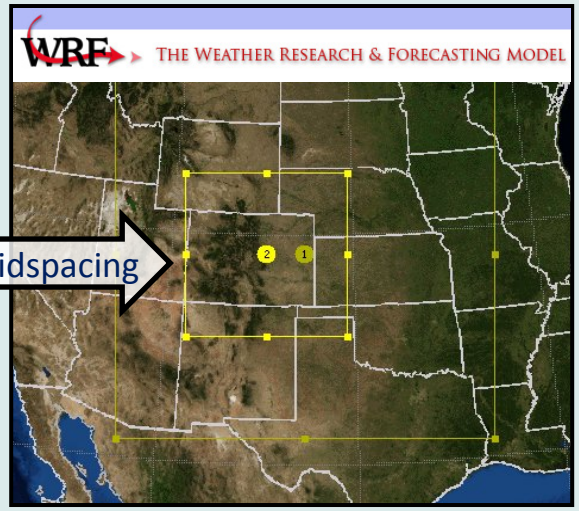
Small hail common in high terrain: Time to melt → slower flood response

X2R: Needed: Climate change information at weather scales

Downscaling method:

1. Select extreme cases from regional climate model data
2. Create initial conditions for weather model (WRF) simulations
3. Execute high-resolution simulations
4. Compare past, future high-resolution simulations



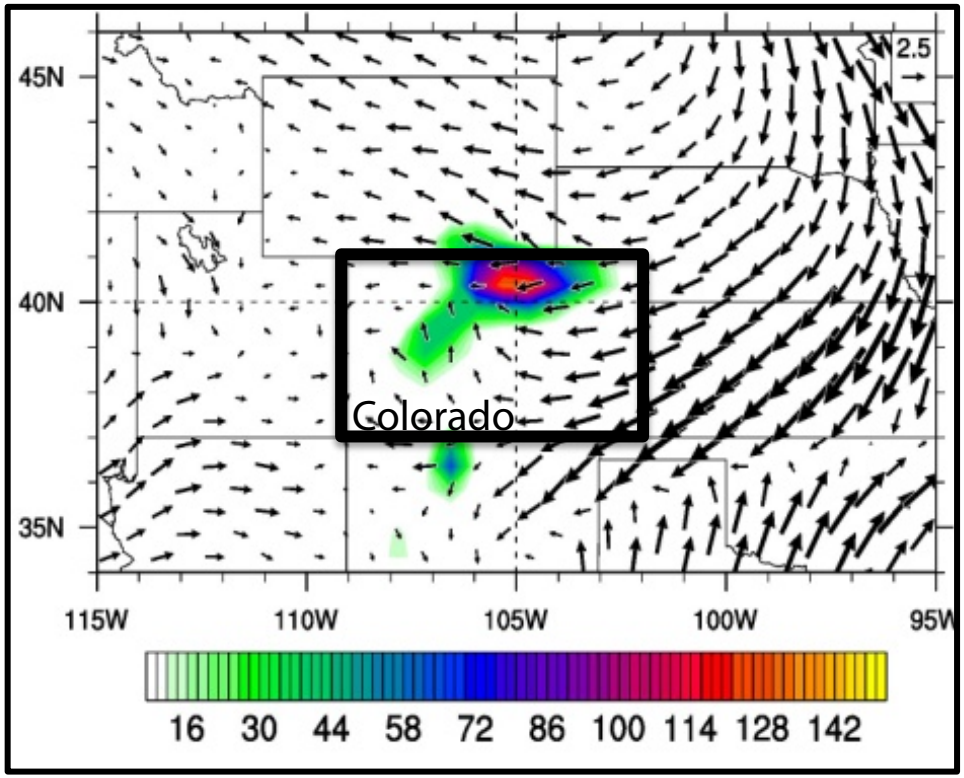


NCAR NARCCAP project:
- 3 regional climate model projections used
- Past (1971 – 2000) vs. Future (2041 – 2070)
- SRES-A2 scenario

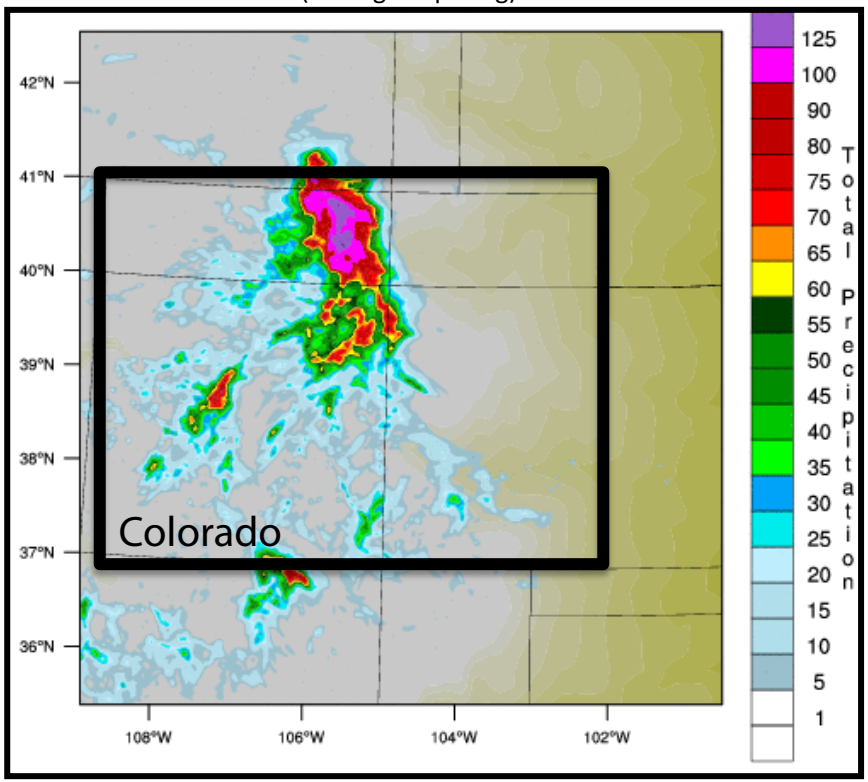
High resolution modeling:
- Storm-resolving
- No cumulus parameterization
- Microphysical detail

Connecting climate and weather scales

24-hour precipitation at regional climate model (RCM) scale
(50-km grid spacing)



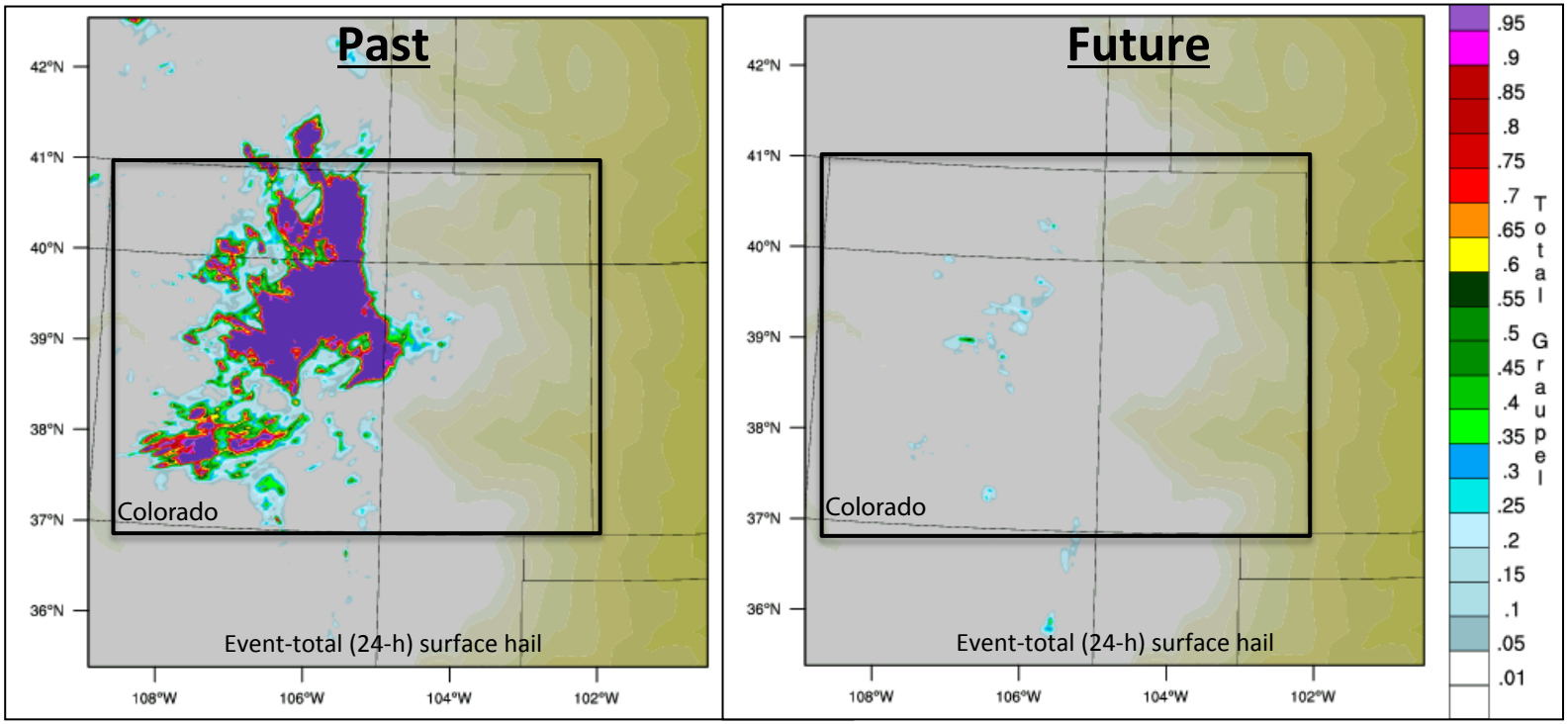
24-hour precipitation at weather model (WRF) scale
(1-km grid spacing)



- Simulated 60+ individual cases at 1-km grid spacing
- Precipitation trends varied across climate model inputs (Mahoney et al. (2013))
- High-resolution output: Can be used for **scenario planning, input into impact models (e.g., hydrologic models), to identify and explain climate model errors**

Mahoney, K., M.A. Alexander, J.D. Scott, and J.J. Barsugli (2013). High-resolution downscaled simulations of warm-season extreme precipitation events in the Colorado Front Range under past and future climates. *Journal of Climate*.

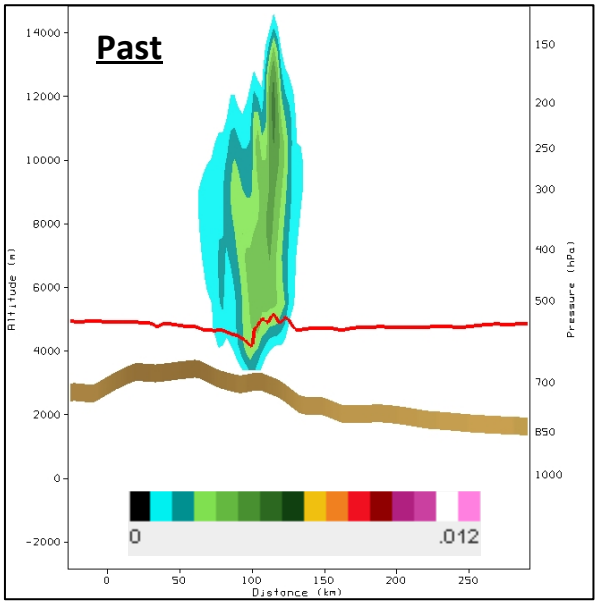
Beyond traditional climate model predictors: Hail?

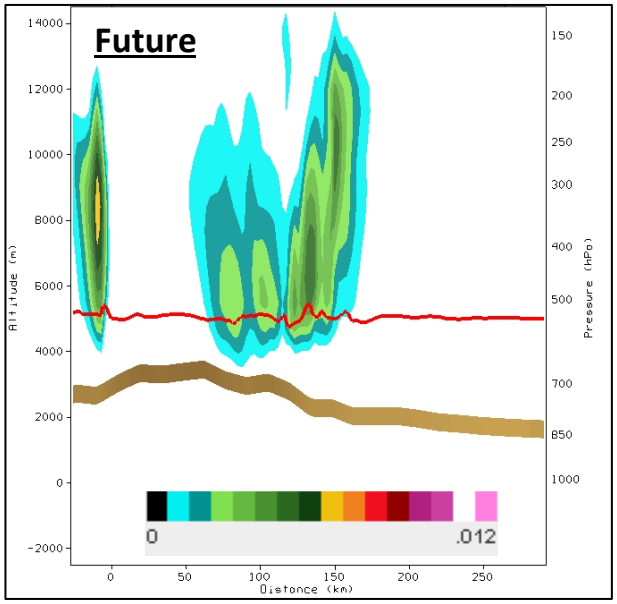


- Future storm simulations: Nearly no surface hail above 7500 ft
- If hail becomes rain, will flood risk increase?

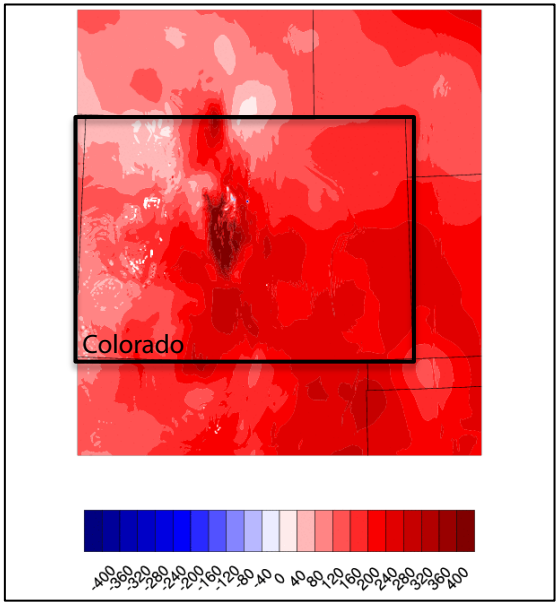
Mahoney, K. M., M. A. Alexander, G. Thompson, J. Barsugli, and J. Scott, 2012: Changes in hail and flood risk in high-resolution simulations over the Colorado Mountains. *Nature Climate Change*.

Beyond traditional climate model predictors: Hail?





Instantaneous vertical cross-sections of graupel/hail ($kgkg^{-1}$, shaded), Melting level (0°C-isotherm; red contour), Terrain height (m, thick brown contour)



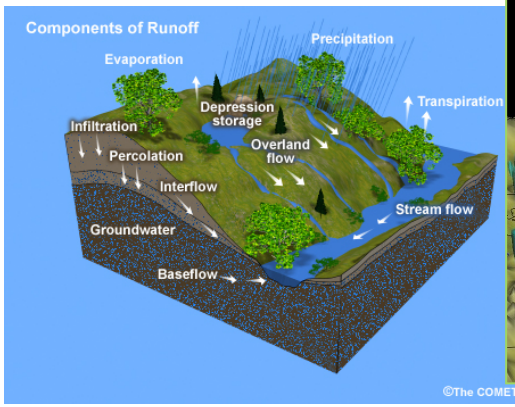
20-case average Δ melting level height (m)

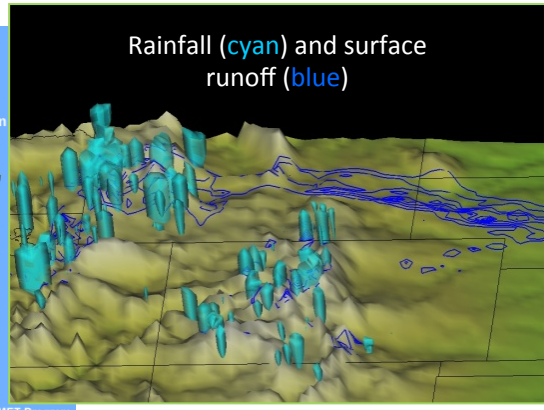
- "Future" storms still produce a lot of in-cloud hail
- Height of freezing level increases in future (~400 m difference)
- **Surface (small) hail accumulation decreases due to increased melting in warmer future environment**

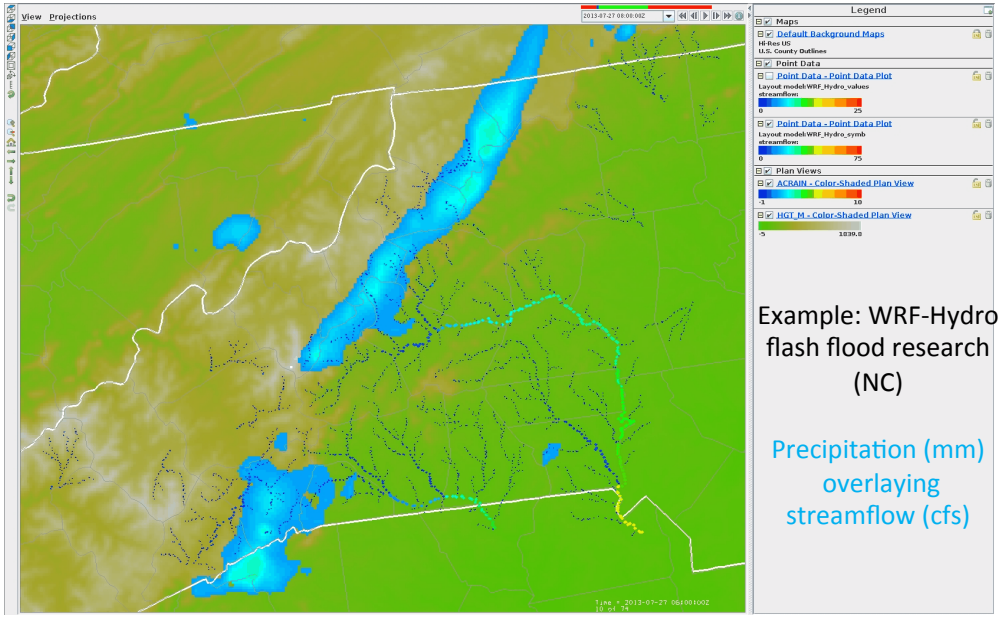
Mahoney, K. M., M. A. Alexander, G. Thompson, J. Barsugli, and J. Scott, 2012: Changes in hail and flood risk in high-resolution simulations over the Colorado Mountains. *Nature Climate Change.*

Hail, runoff, and flood risk

- Hydrologic impact of hail-turned-rain?
- Coupled atmospheric-hydrologic modeling framework: WRF-Hydro
- Flood risk/impacts sensitivity testing: hail vs. rain, land cover/ use changes, impact of climate changes
- Applications: Dam safety regulations (national standard?), flood risk evaluation in complex terrain



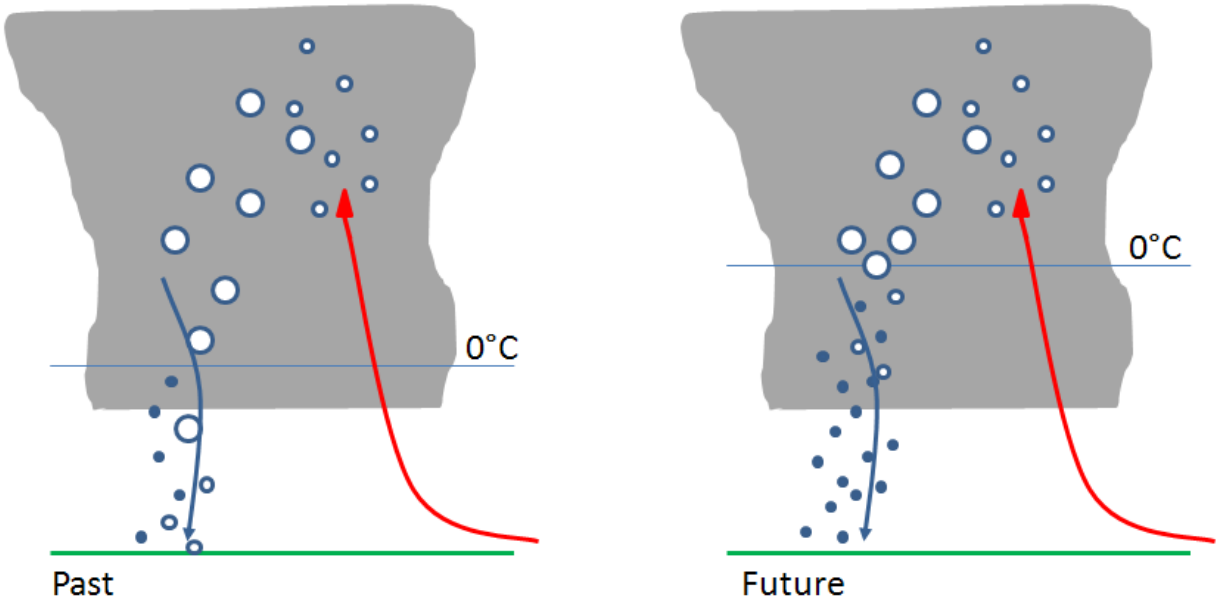




Example: WRF-Hydro flash flood research (NC)

Precipitation (mm) overlaying streamflow (cfs)

Summary and Conclusions



Schematic of hail melting and falling instead as rain in a warmer environment

- High-resolution modeling: **more realistic** treatment of physical processes critical to heavy rainfall, hail
- Climate downscaling experiments: **dramatic decrease of high-elevation surface hail**
- Present-day hail becoming future rain: **enhanced flood risk** → decision-maker, stakeholder considerations

Summary and Conclusions

- Future work
  - Rain vs. hail (or snow) at various **elevation thresholds**, additional climate scenarios
  - **Total flood risk**: combine traditional atmospheric fields with new coupled hydro-met (e.g., runoff, inundation)
  - Effectively communicate relative, combined flash flood **uncertainties** (atmospheric + hydrologic)