NATIONAL ACADEMIES Sciences Engineering Medicine

Extreme Rainfall in Mountainous Terrain:

Modeling and observational challenges for warm-season precipitation

Session 1: State of the Science: Extreme Warm Season Rainfall in Mountainous Terrain

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Session 2: Key mechanisms

- Major orographic precipitation events are usually due to **deep convective clouds** and **cyclonic storms of tropical origin**
- Importance of **synoptic-scale flow**:
  - Low-level moist unstable synoptic-scale flow **enhances pre-existing convection over mountains** (e.g., Thompson flood, Leh flood)
  - Strong **synoptic-scale unstable flows over mountains trigger convection** and heavy rainfall (e.g., Pakistan flood, Helene flood)
- **Small-scale terrain trigger very heavy rain** (e.g., Texas Hill Country flood, intense convection in the lee of the Andes)
- **Need accurate representation of basic type of storm, low-level moist flow and boundary layer fluxes, and details of sub-barrier scale terrain for triggering convection**

Session 2: Extreme convective rainfall

- **Ingredients for warm-season extreme convective rainfall modified by the terrain** – flow modification (blocking, barrier jet), terrain influence on shear, cold pools, and link to microphysics
- **Need improvement of remote sensing retrievals and high-resolution observations deployed along the terrain slope**
- **CONUS404 produces plenty of extreme short-duration convective rainfall, but more along the coasts than in regions of complex terrain**
- **Mesoscale-convective processes (and assimilation of mesoscale observations) are equally, if not more important than, the interactions with topography (which is important for flooding)**
- **Importance of sampling mesoscale variability for using simulations as a proxy for observations**

Session 2: Extreme tropical cyclone precipitation

- **Important TC processes**: TC intensification, landfall, post-landfall evolution, air-sea interactions, interaction with synoptic features
- **Key terrain-related meteorological factors**: strength of orographic ascent, mountain waves, orographic convection and static stability
- **TCs over land can impact areas far from the storm center**, with orography and predecessor rain events playing a major role in heavy rainfall and flooding
- **The distribution of extreme precipitation and flooding has a heavy tail** – need to move toward extremely low annual exceedance probabilities
- **Model-based approaches could produce events with extremely low annual exceedance probabilities, but need to overcome many challenges (e.g., ensemble strategy, data & verification)**