Mesoscale perspectives on extreme convective rainfall in mountainous terrain

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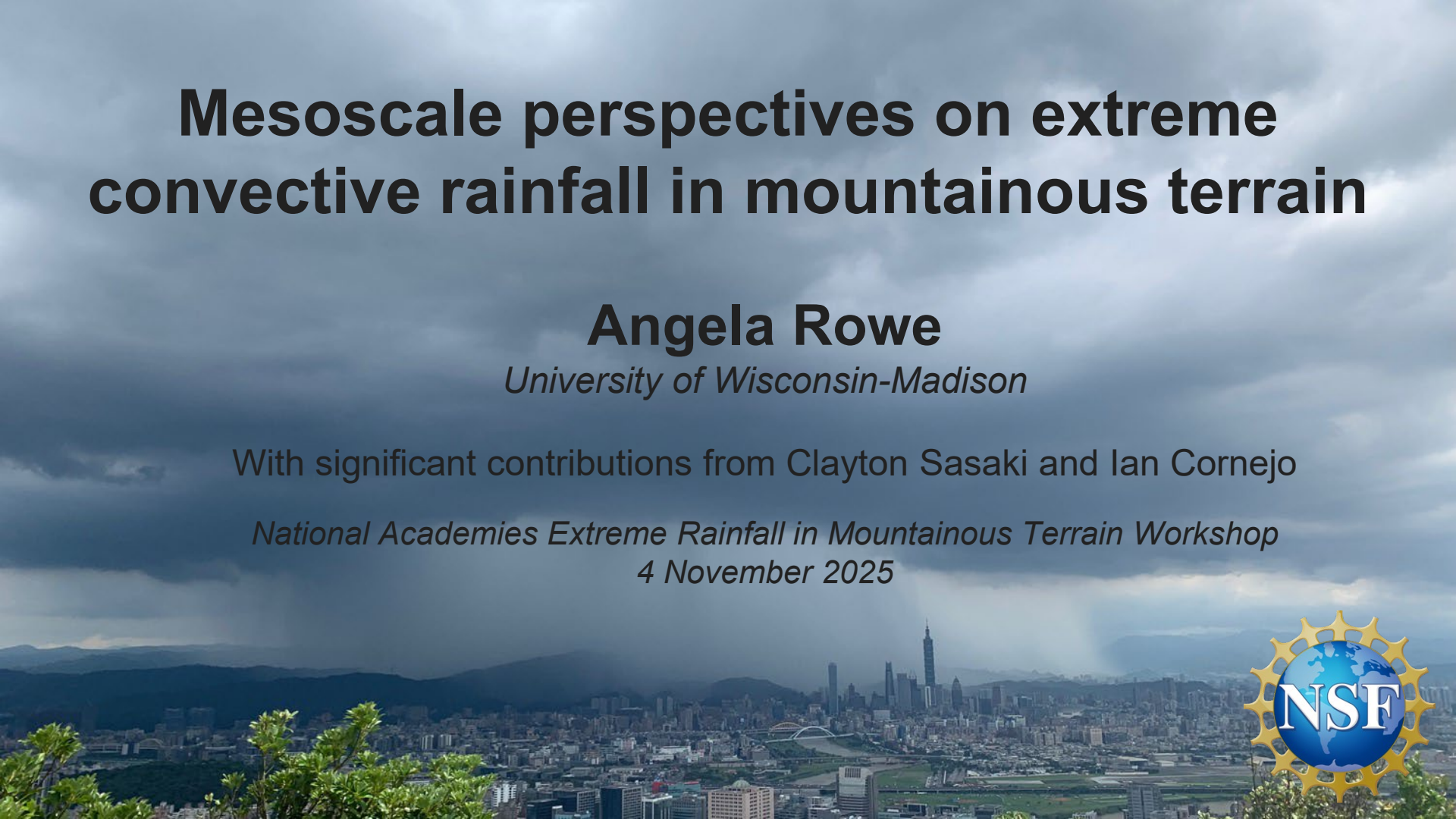
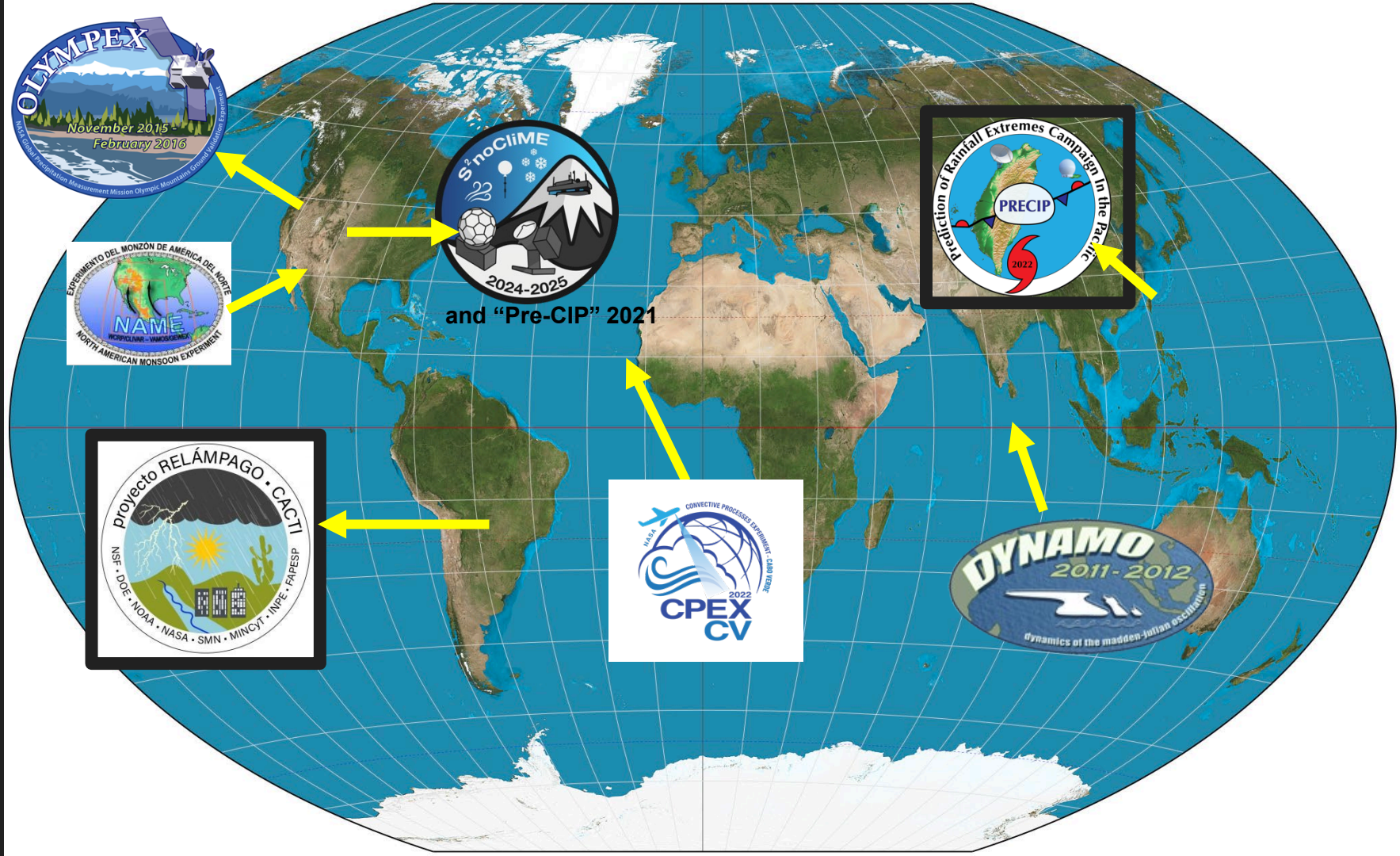
With significant contributions from Clayton Sasaki and Ian Cornejo

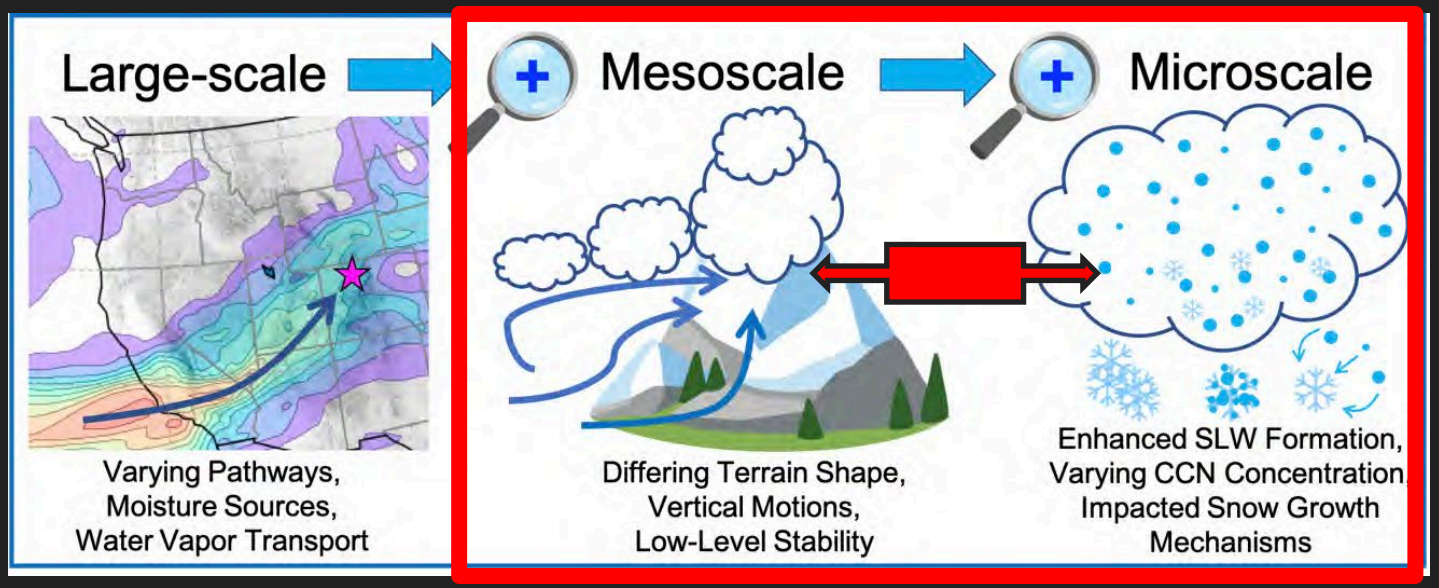
National Academies Extreme Rainfall in Mountainous Terrain Workshop
4 November 2025





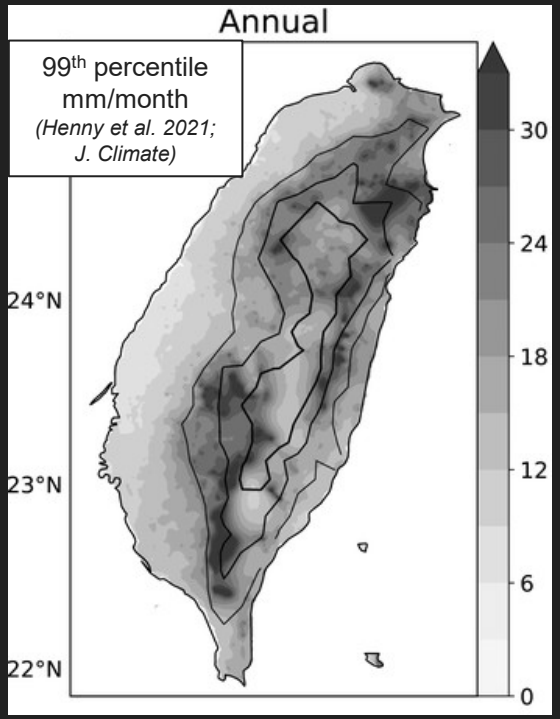
and "Pre-CIP" 2021

How does *mountainous terrain influence* ingredients and processes that control location, intensity, and duration of impactful precipitation?

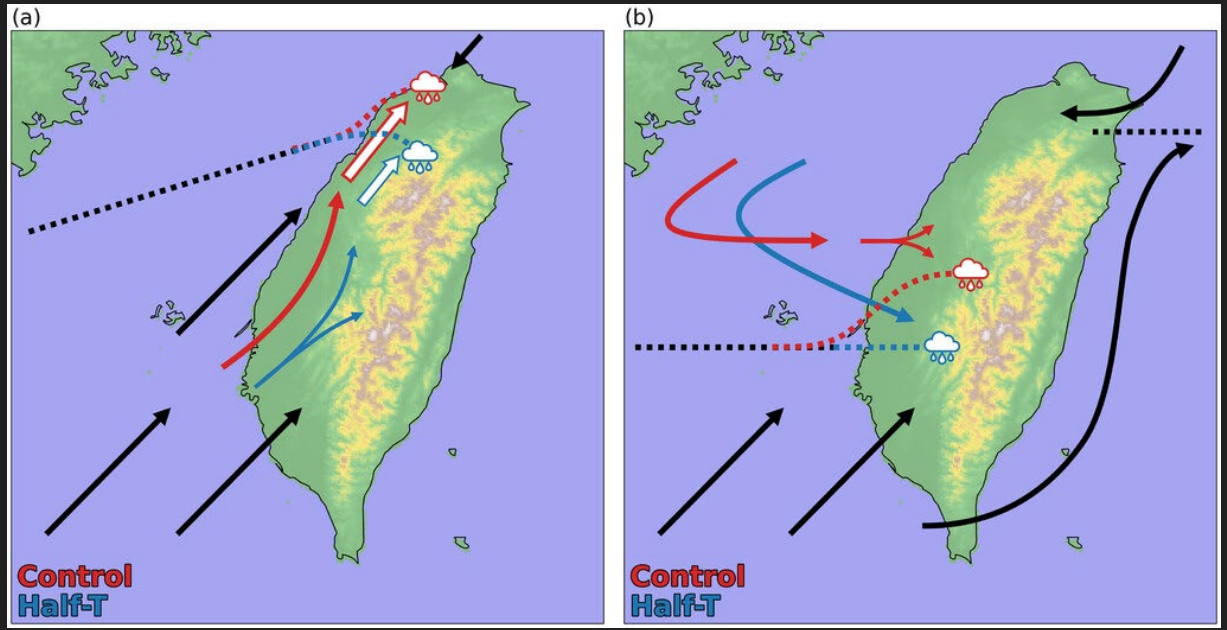


Credit: NSF S2noCLiME

Extreme rainfall in mountainous Taiwan



→ Frequent, extreme
(Typhoon Morakot, 4-day 2,965 mm)
→ Terrain and seasonal dependence



Modeled 2017 Mei-Yu event emphasizes terrain-blocking, barrier jet, flow modification *[Cornejo, Rowe, et al. 2024]*

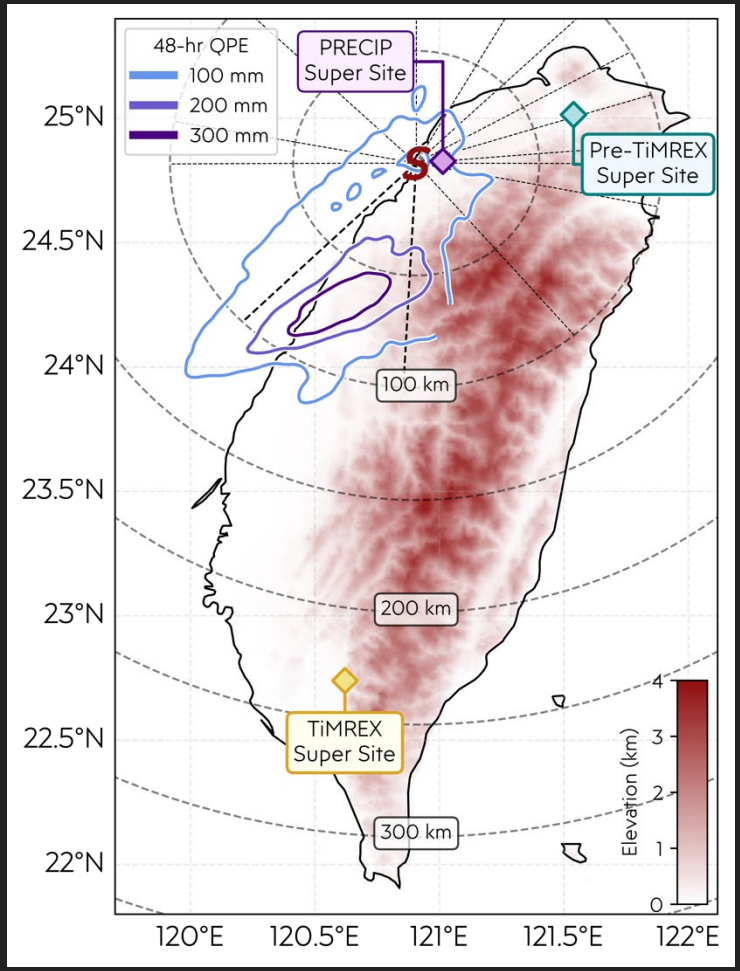
Opportunity: Moisture less of a limiting factor here!

PRECIP/TAHOPE 2022:

3 months of radar and environmental observations to improve understanding and predictability of extreme rainfall

- ✓ Mei-Yu frontal rainfall (coastal and mountainous maxima, variations in intensity-duration)
- ✓ Barrier jet, mesoscale vortices, convective outflow
- ✓ Afternoon storms over terrain (Move off? Merging, outflow)

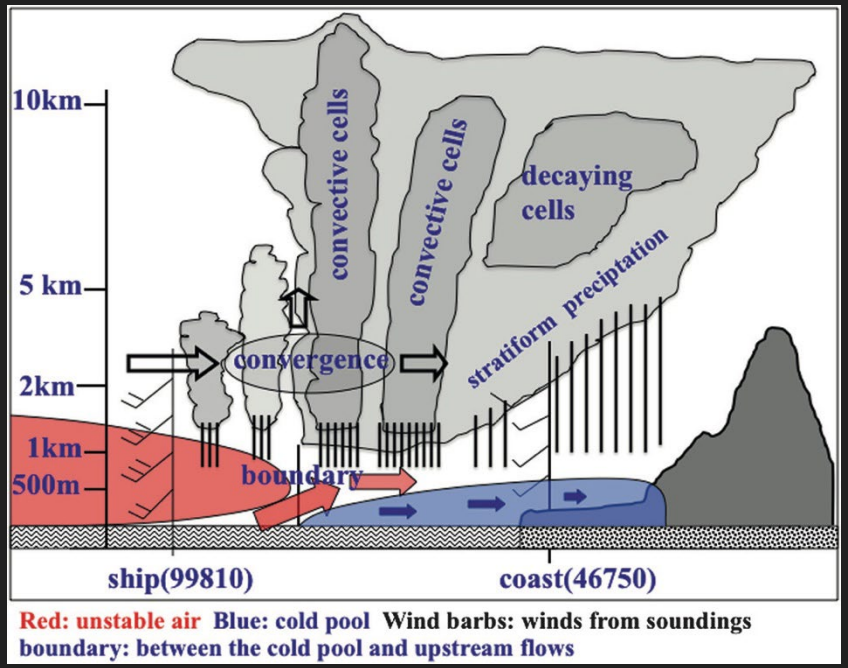
Key point: Intentional, long-lasting international partnerships that require time, understanding, and support



[Adapted from Cornejo, Rowe, et al. 2025b]

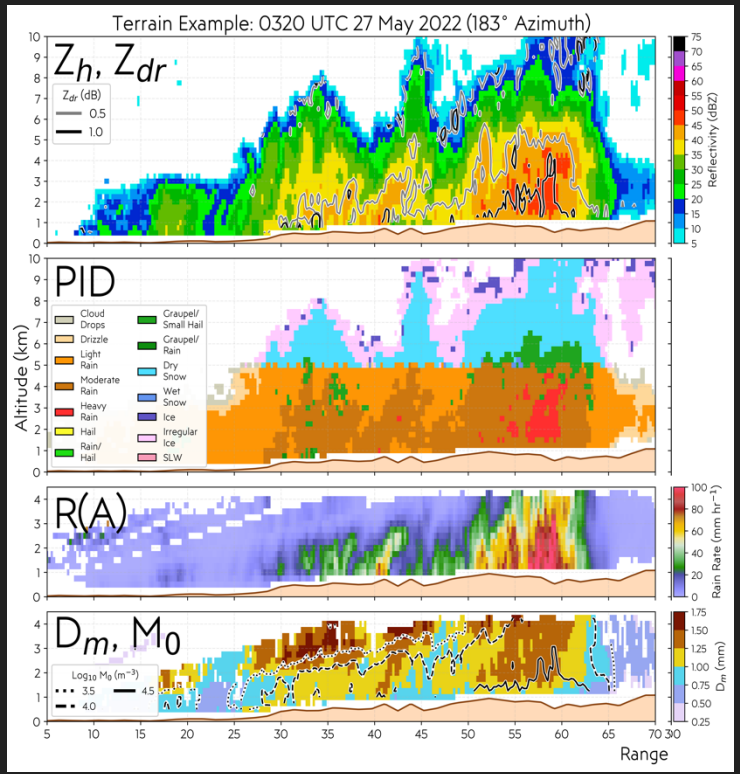
PRECIP/TAHOPE 2022 – SoWMEX/TiMREX 2008

Convective outflow → extension of mountain barrier effect (low-level convergence, backbuilding)



SoWMEX/TiMREX *[Xu et al. 2012]*

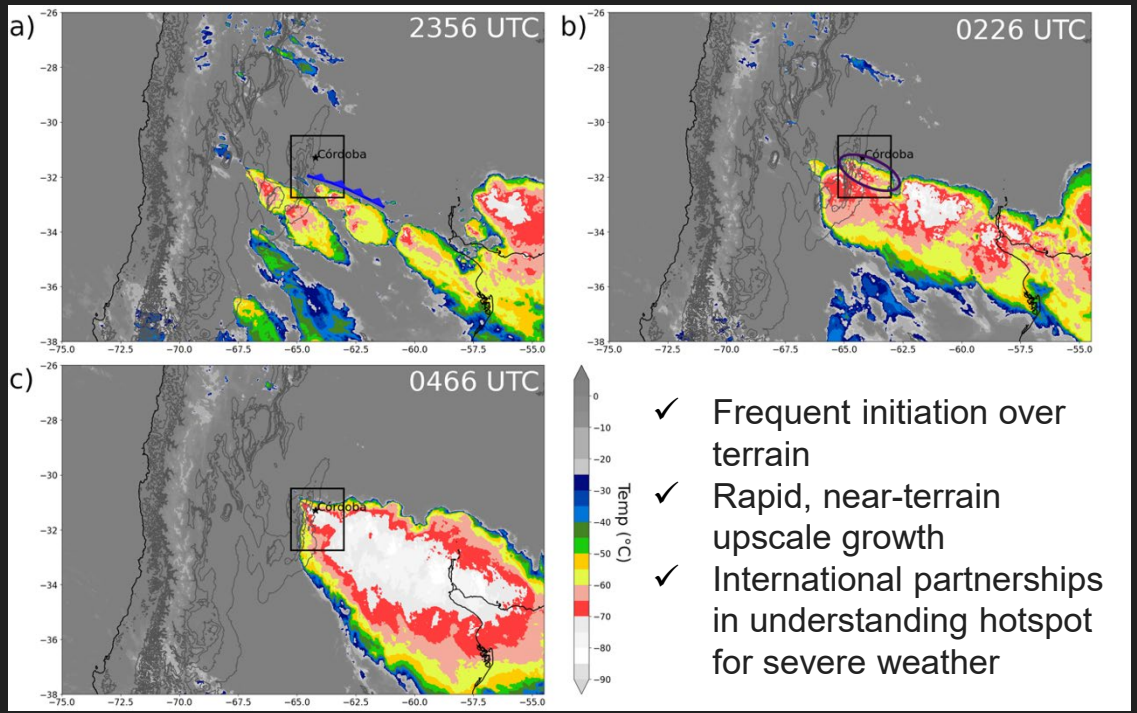
Tie to microphysical processes
→ **radar-based retrievals (challenge with terrain)**



[Adapted from Cornejo, Rowe, et al. 2025b]

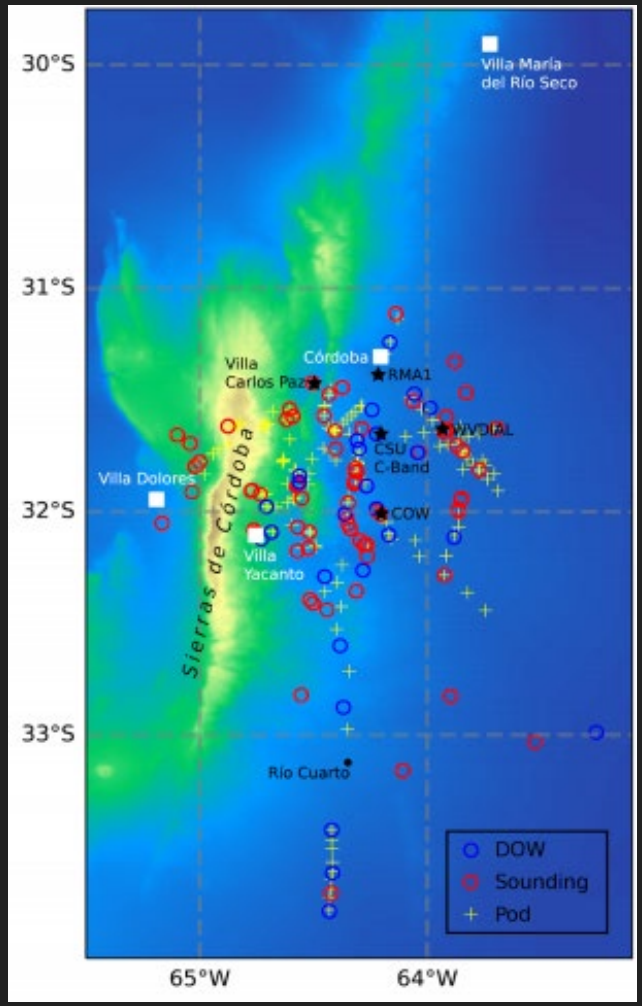
RELAMPAGO/CACTI 2018-19

Opportunities and challenges



- ✓ Frequent initiation over terrain
- ✓ Rapid, near-terrain upscale growth
- ✓ International partnerships in understanding hotspot for severe weather

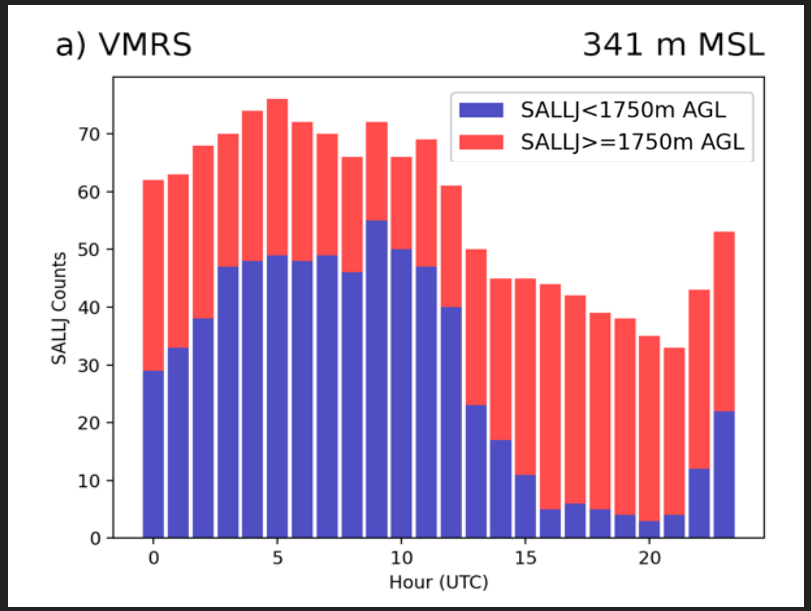
[Sasaki, Rowe, et al. 2025a]



Nesbitt,…Rowe, et al. 2021]

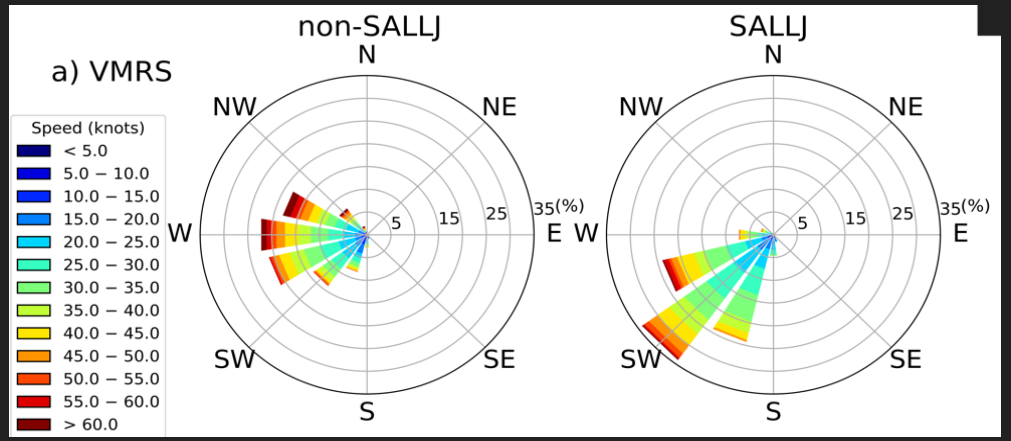
Impact and variations of the South American Low-Level Jet

Diurnal variations in presence/height, differs from U.S.



[Sasaki, Rowe, et al. 2024, 2025a]

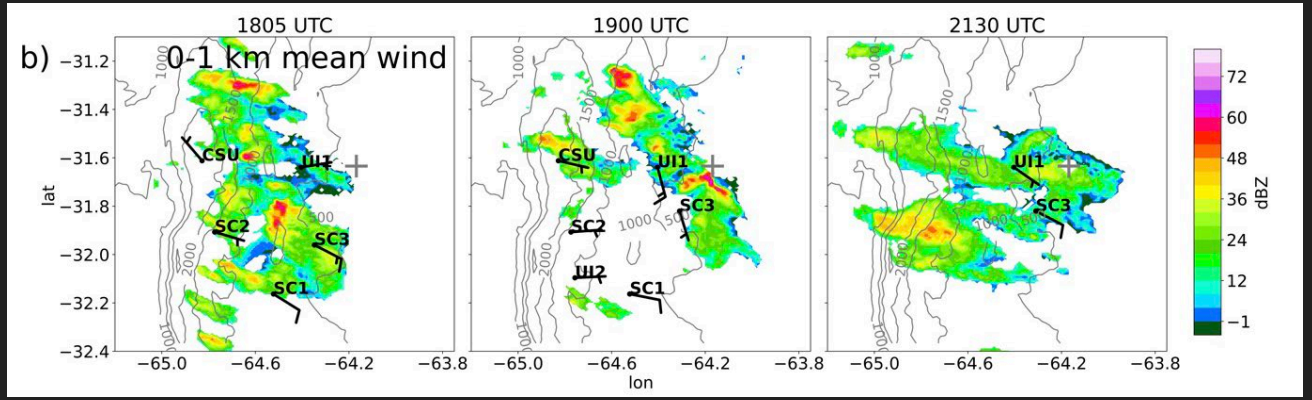
Impact on 2-6-km vertical wind shear



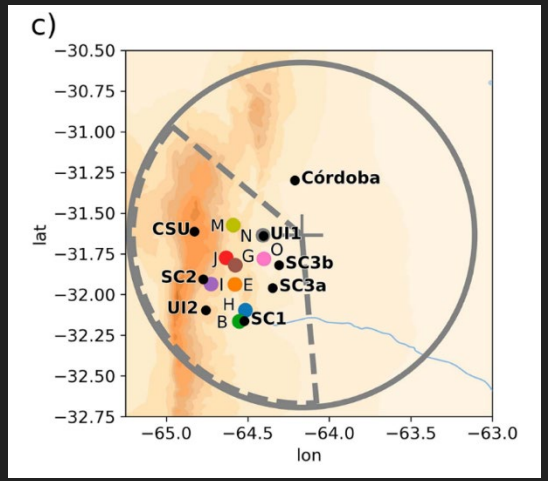
- Under strong synoptic forcing, rapid overnight upscale growth along frontal boundary with favorable wind shear from elevated SALLJ
- Challenge in recreating convective evolution in model owing to impact of terrain (local influences on shear, blocking cold pools)

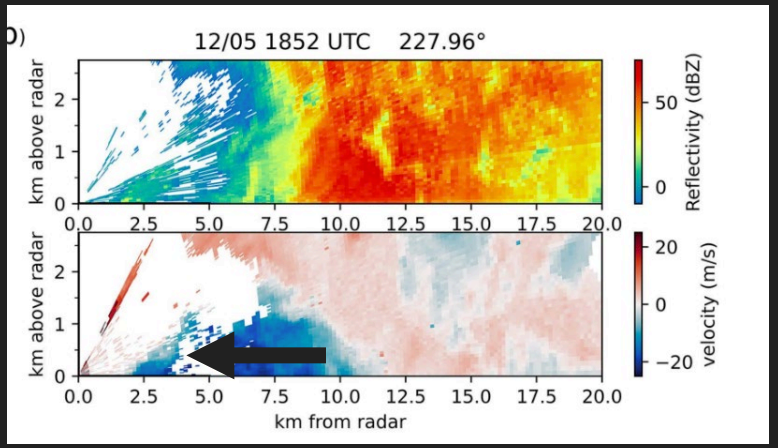
Convectively-generated cold pools in different upscale growth cases

SDC-initiated cells under weak synoptic forcing produced cold pools that influenced low-level winds and therefore shear
[Sasaki, Rowe, et al. 2025a]



But how does the terrain influence the cold pools?

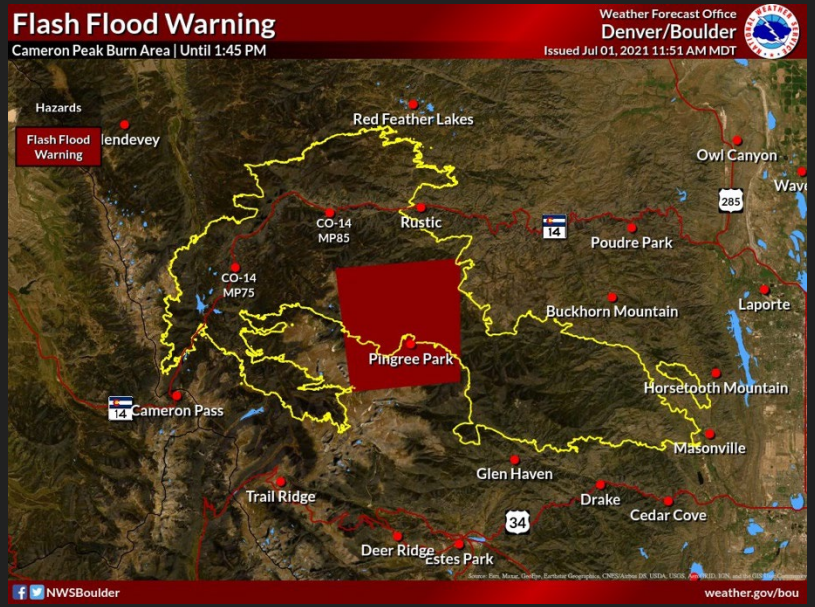




In Context of the U.S.

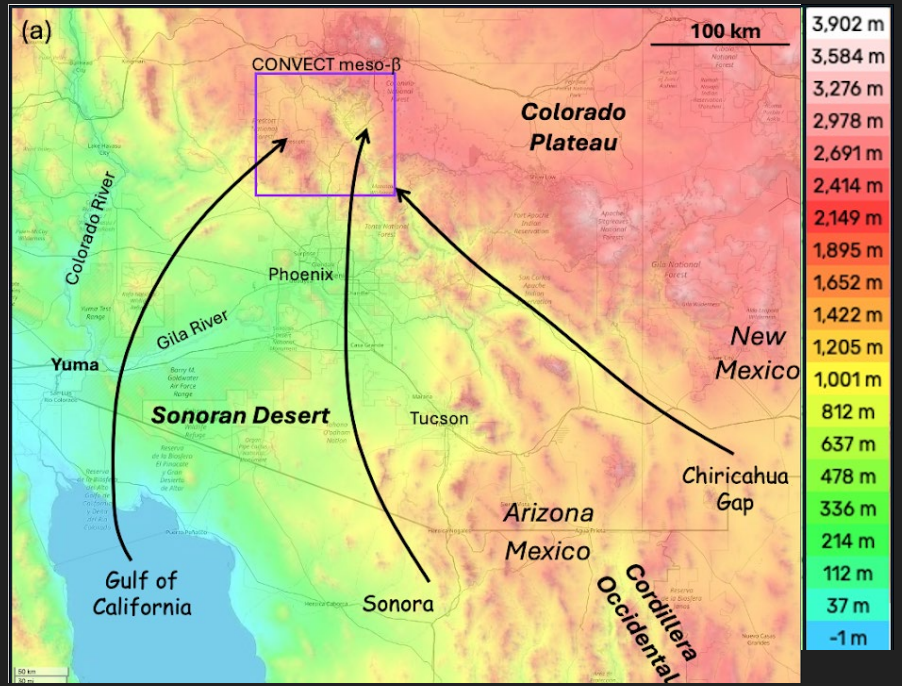
Pre-CIP 2021 Colorado

→ Similar obs and strategy to Taiwan in different environment/ terrain



North American Monsoon (CONVECT)

→ Link between vapor transport, land-atmosphere, PBL convective feedbacks (cold pools with terrain)



Credit: CONVECT Science Proposal

Key Messages

- Ingredients for warm-season extreme convective rainfall on multiple interacting scales that are modified by the terrain

- Need for continued improvement of remote sensing retrievals of key processes and QPE in challenging mountainous terrain

- Higher resolution observations deployed along terrain slope (how cold pools vary and their link to microphysics in different regimes)

- A global perspective is important → developing intentional relationships with international partners

Thank you to NSF for funding these efforts

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