Key mechanisms in understanding warm-season extreme convective rainfall in mountainous terrain

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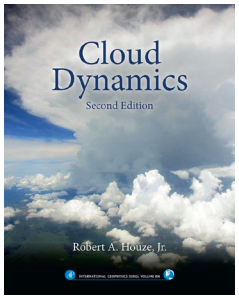
Starting points for this talk:

Houze, R. A., Jr., 2012: *Reviews of Geophysics*,

"Orographic Effects on Precipitating Clouds"

Houze, R. A., Jr., 2014: *Cloud Dynamics*, **2nd Ed**.

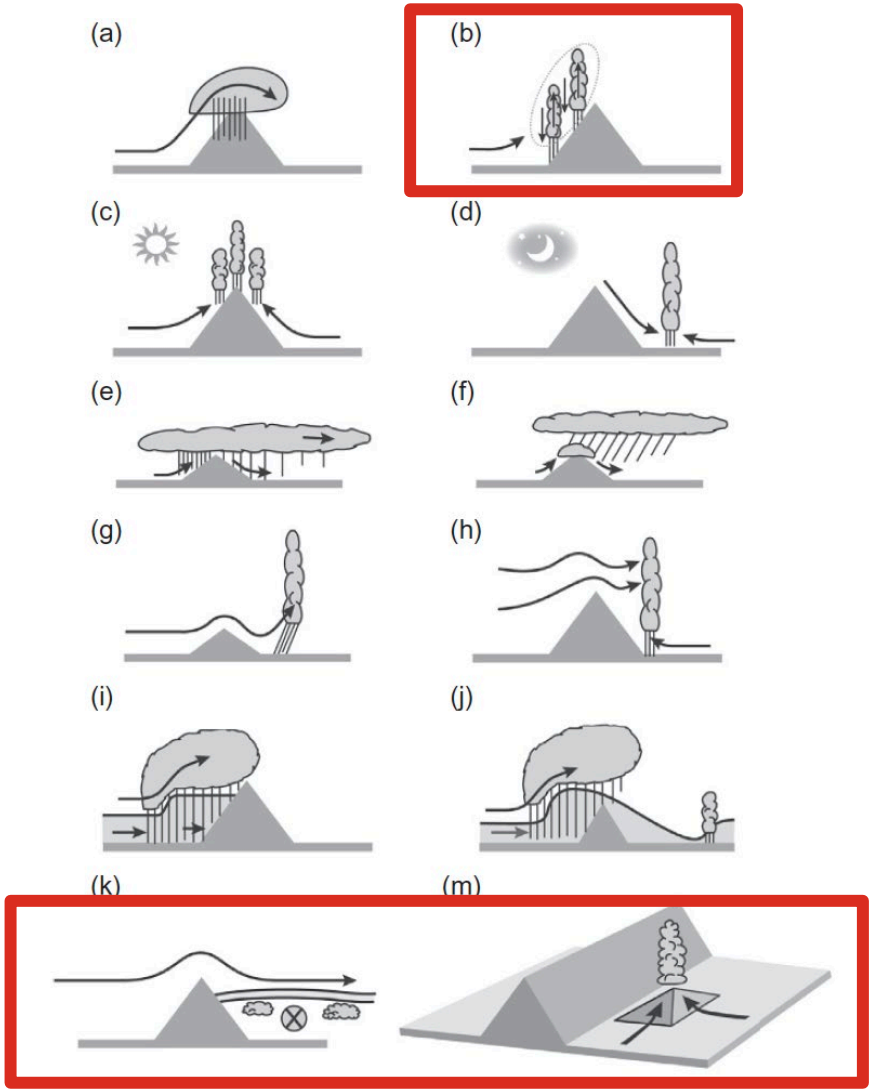


Chapter 12

"Clouds and Precipitation Associated with Hills and Mountains"

- Most “Orographic” Precipitation is due to the occurrence over or near mountains of
  - Deep convective clouds
  - Cyclonic storms of tropical origin
  - Frontal systems
- Simple cross barrier flow is seldom a cause of a major rain event
- Frontal systems have been studied in detail and are usually not a factor in warm seasons

Basic scenarios by which hills and mountains affect precipitating clouds

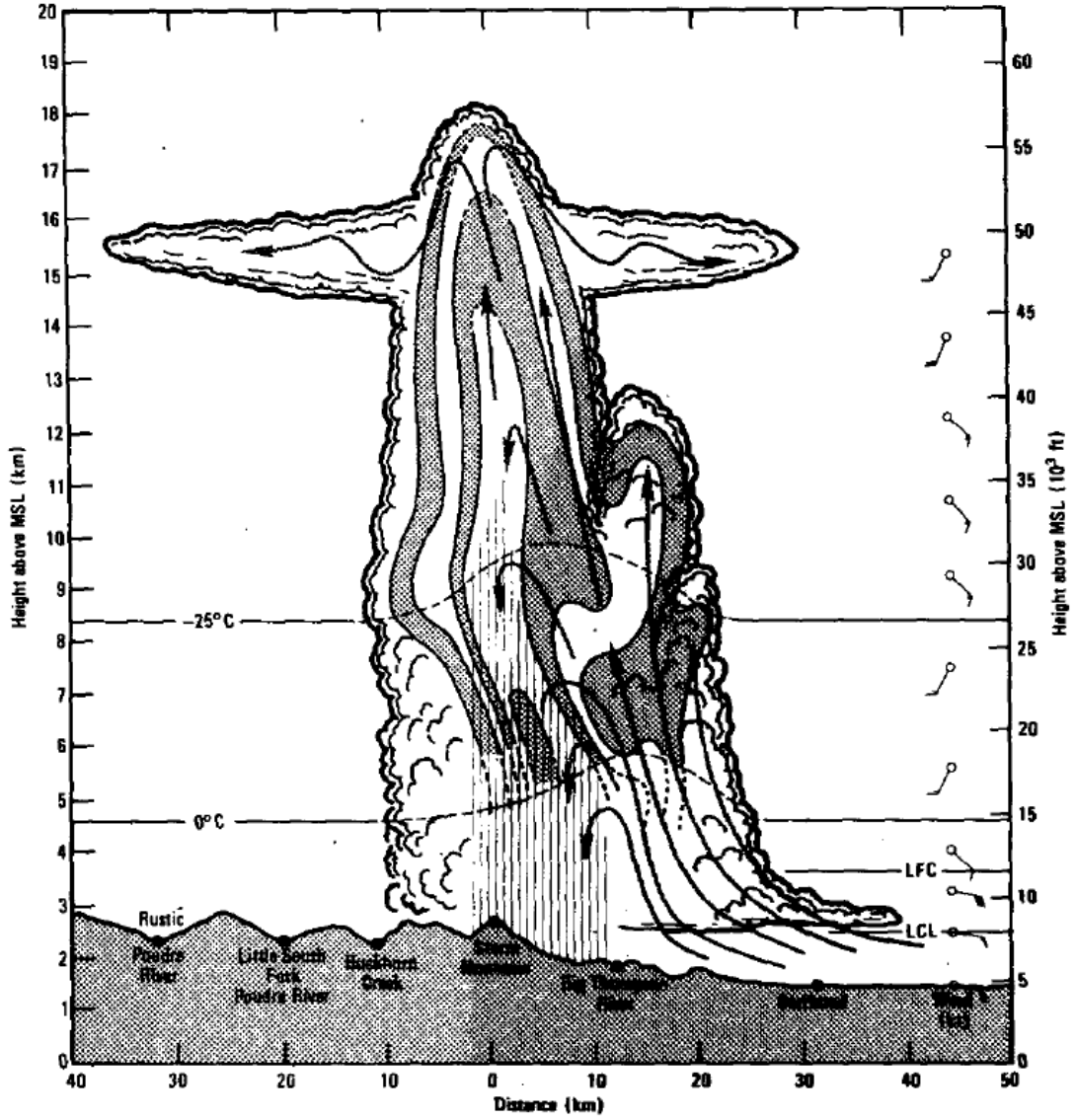


Upslope flow with moist unstable or neutral static stability

Leeside capping, moist jet, and small-scale triggering

Examples of convection over mountains fed by upslope moist potentially unstable flow driven by synoptic-scale conditions

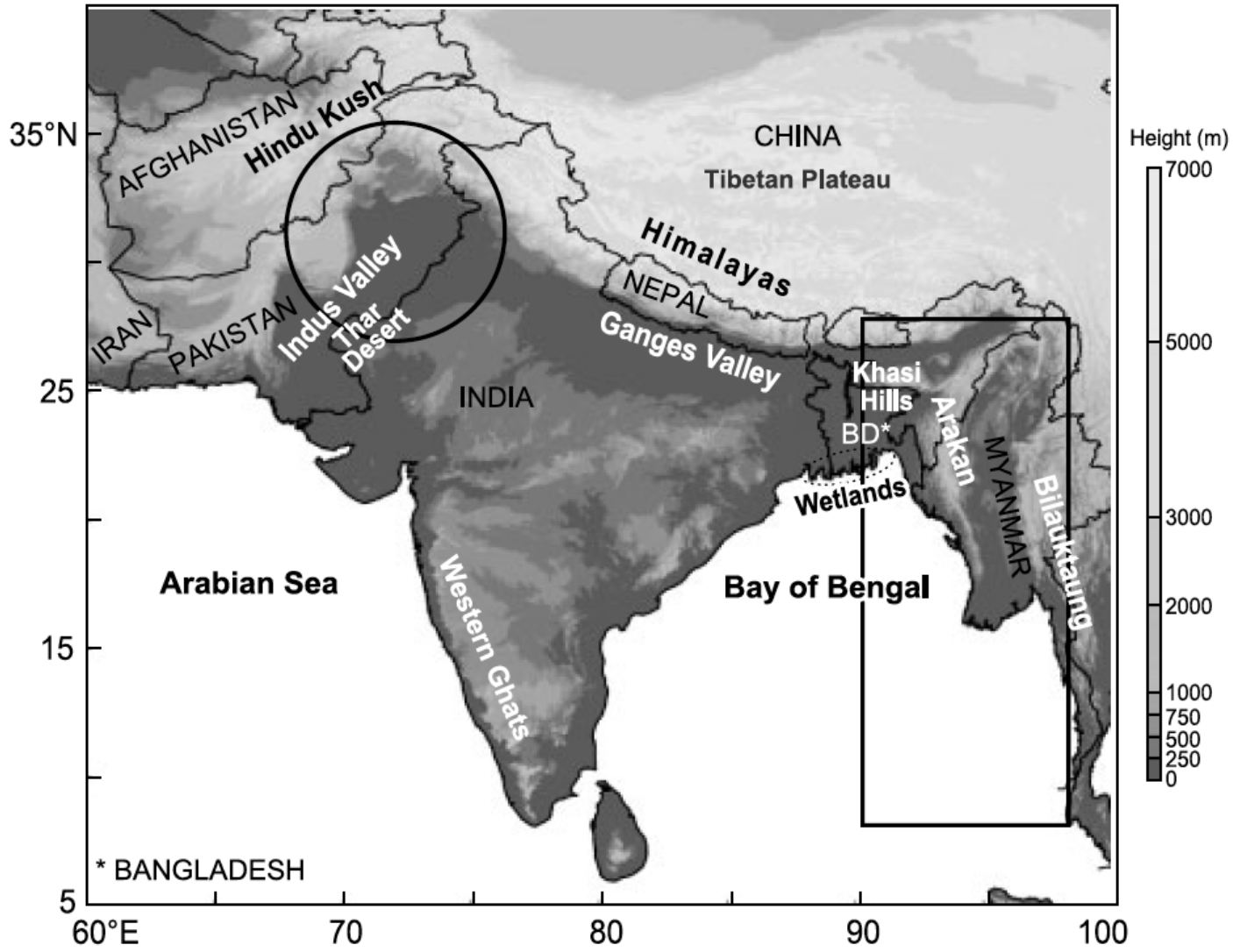
Colorado's Big Thompson Canyon flood, 1976, 139 fatalities (Caracena et al. 1979)



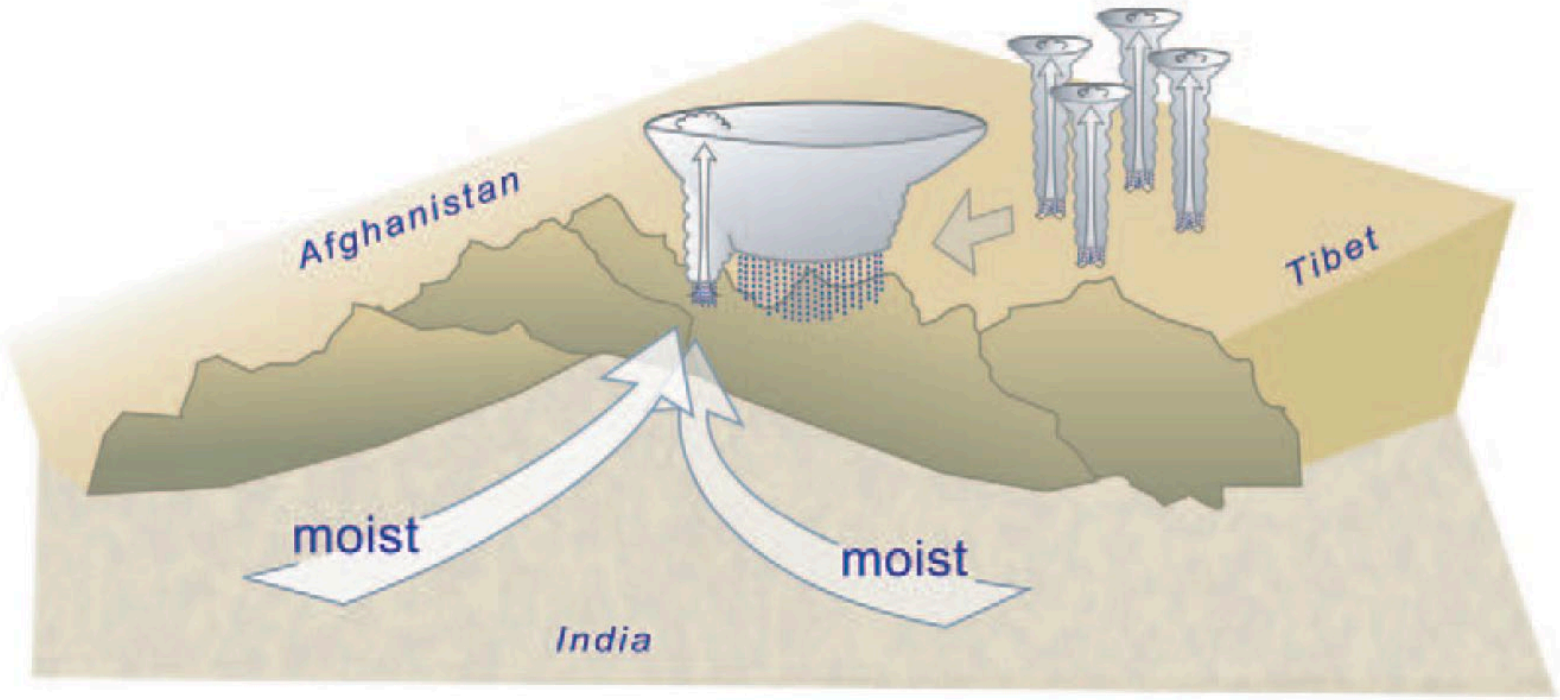
Deep moist potentially unstable synoptic-scale driven upslope flow

South Asia:

A region where the ingredients for orographic rain and flooding are extremely well-defined



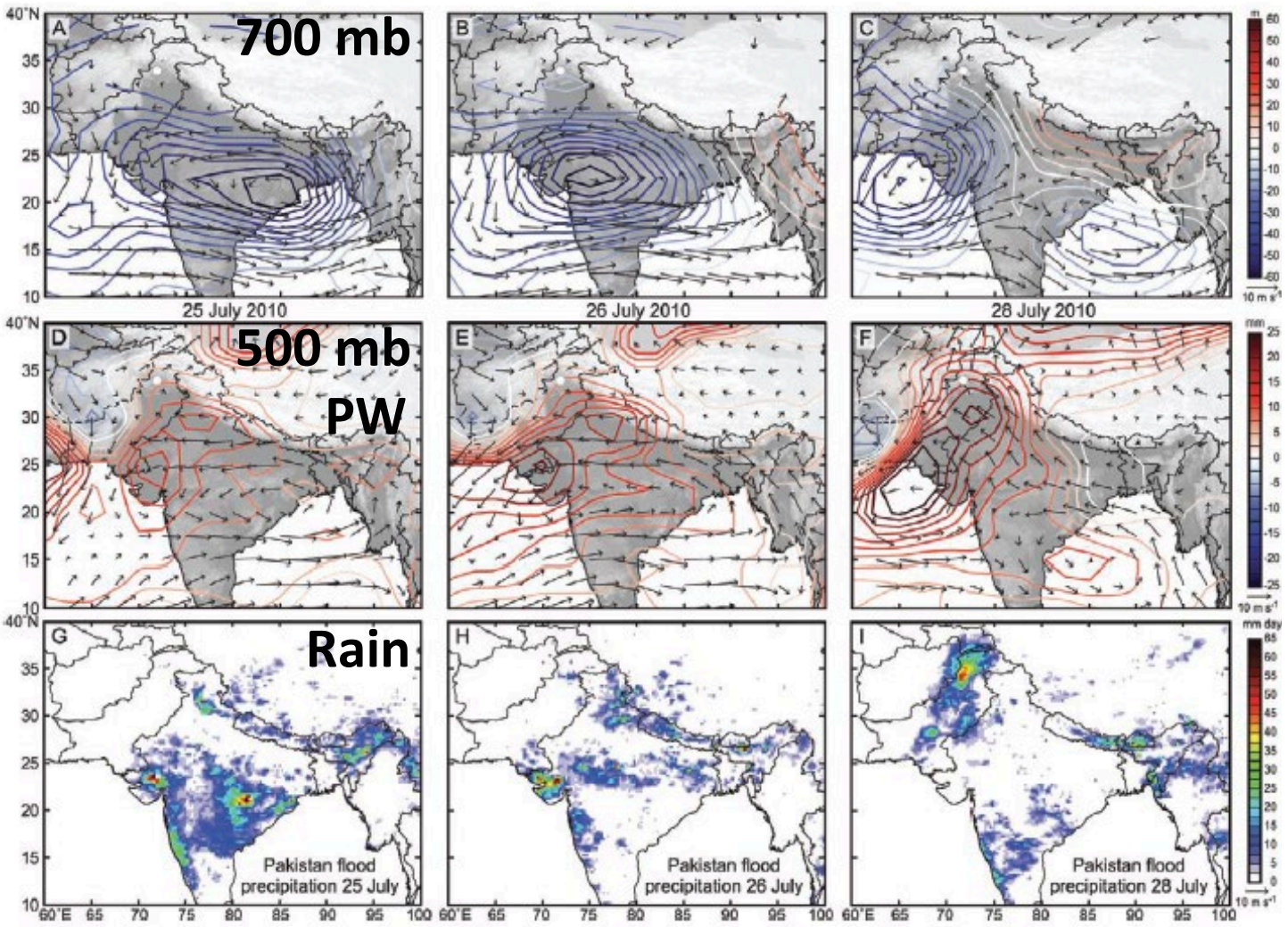
The Leh flood of 2010. A flash flooding storm at the steep edge of high terrain. 193 know fatalities, hundreds missing.
(Rasmussen and Houze, 2011



Low-level moist flow driven into the region by large-scale synoptic conditions.

Examples of flood events fed by upslope moist potentially unstable flow driven by synoptic-scale conditions without pre-existing convection over the mountains

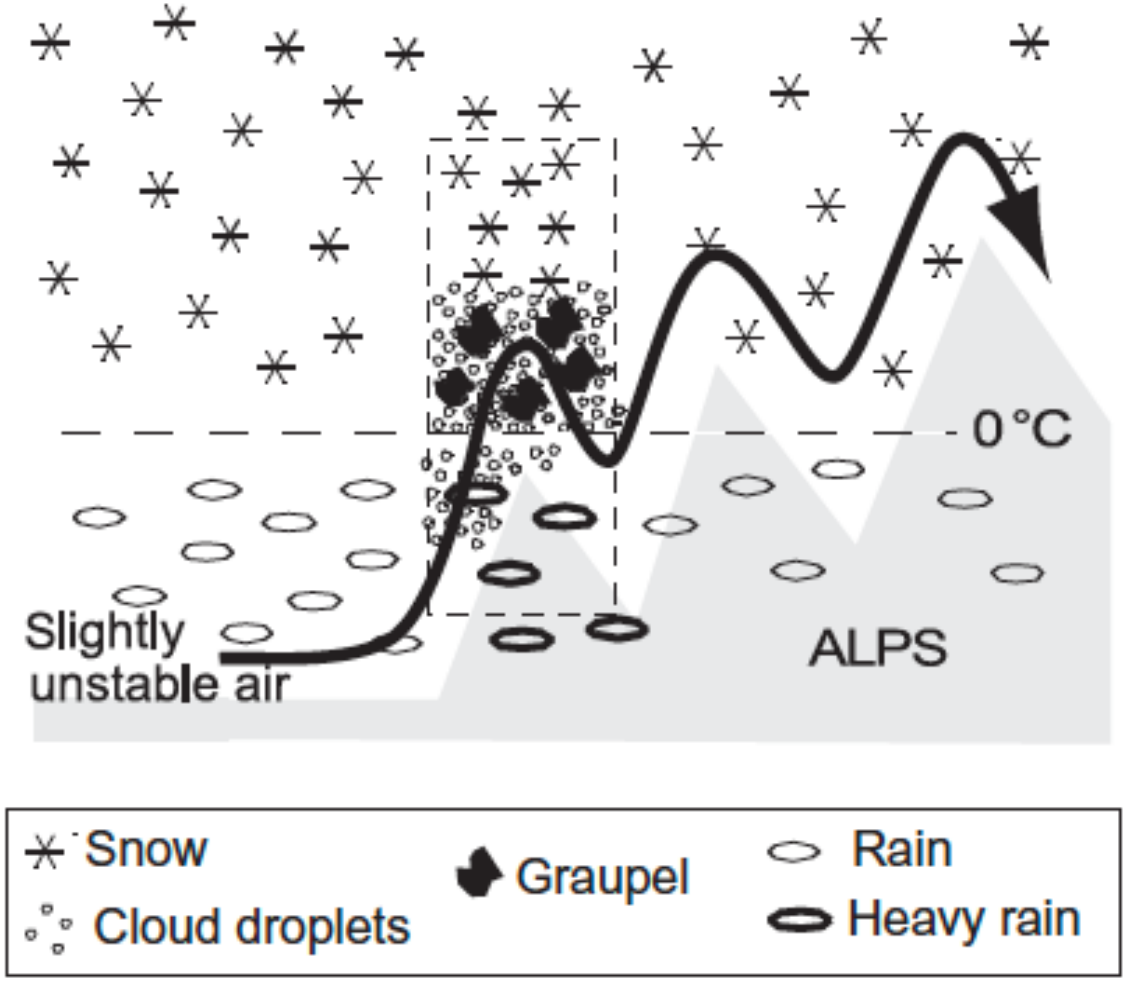
The Pakistan flood of the Indus River in 2010: 20M people affected, ~2000 died
One of the worst humanitarian disasters in history.
(Houze et al. 2011)



The monsoon low moved westward. Nearly saturated slightly moist unstable air was driven over the bare mountains of Pakistan, Afghanistan, and India. MCS precipitation was perpetuated for hours at the headwaters of the Indus river

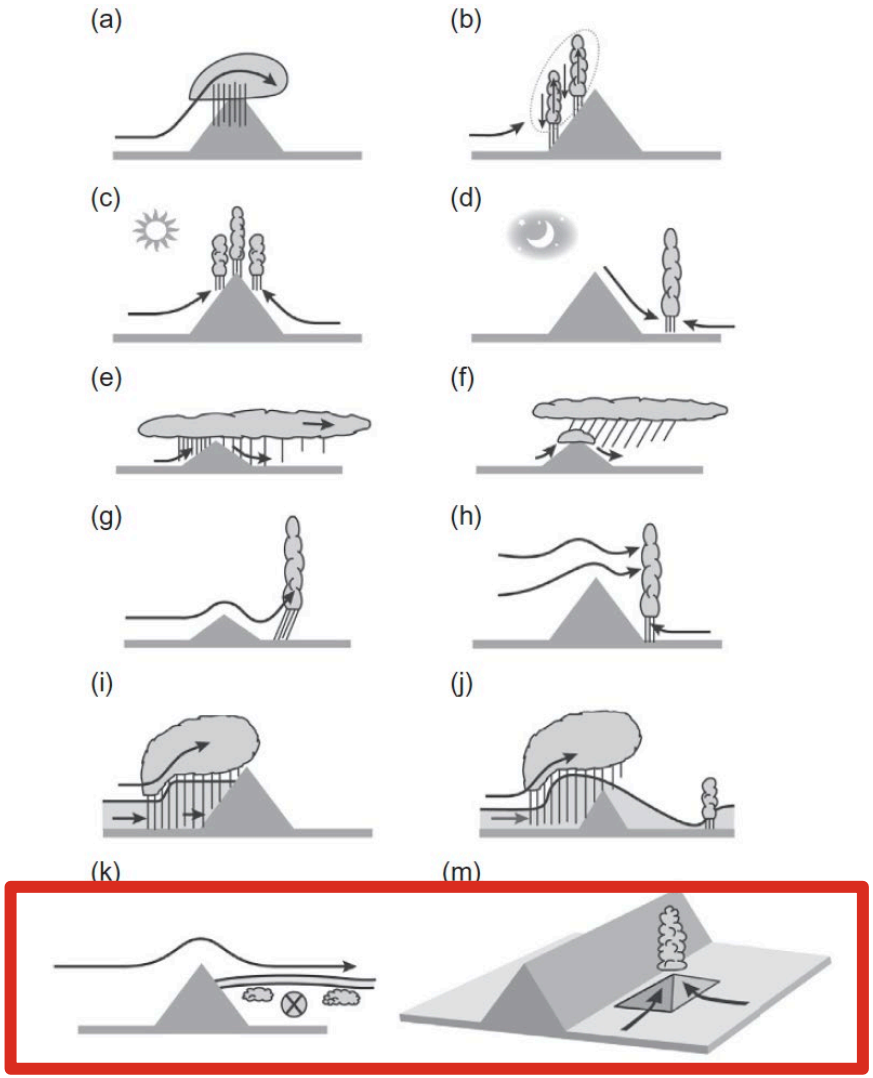
Details of the terrain

Heaviest rain-producing convection occurring over the first sharp peak



Medina and Houze 2003

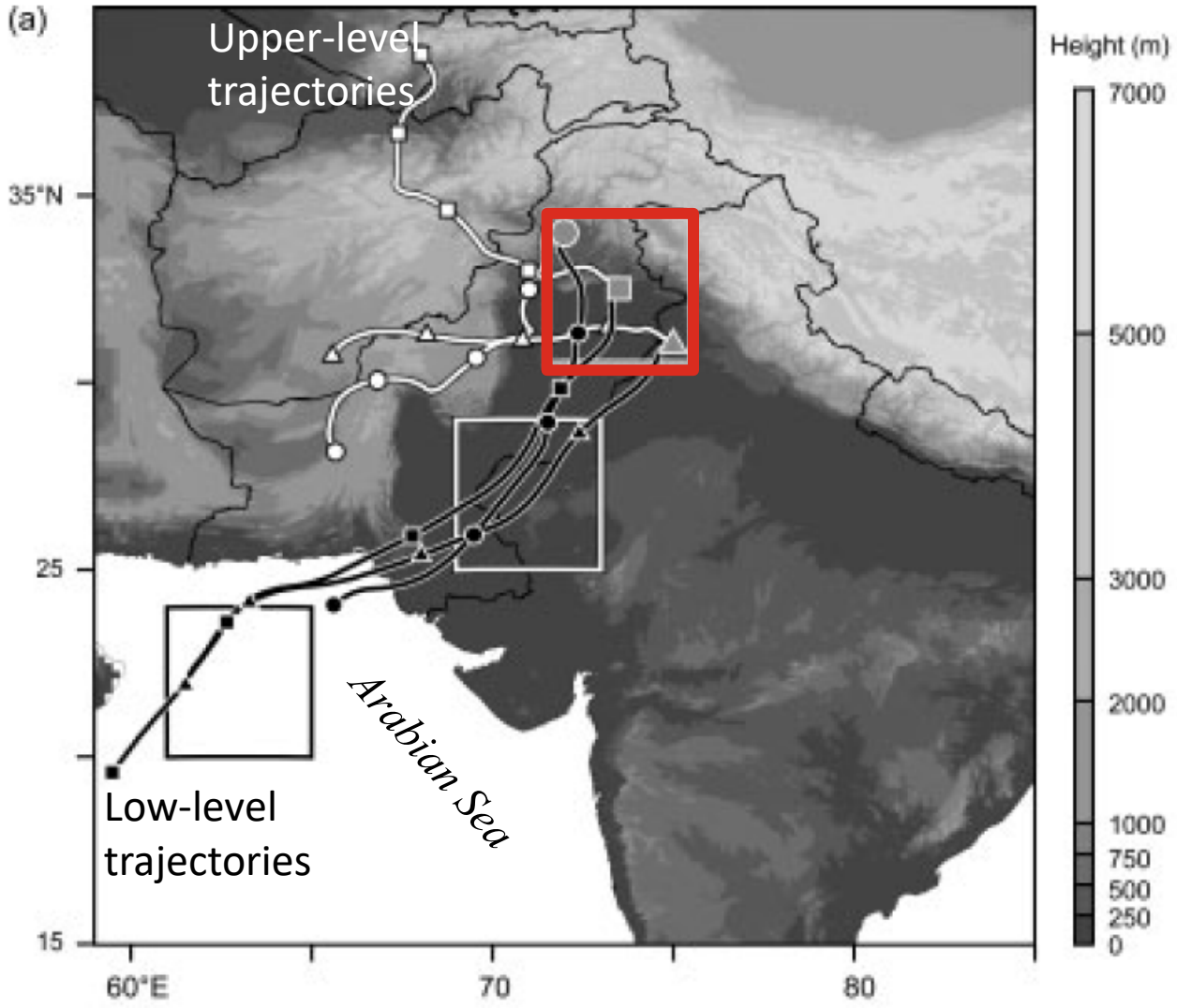
Other scenarios by which small-scale hills and mountains affect precipitating clouds



Upslope flow with moist unstable or neutral static stability

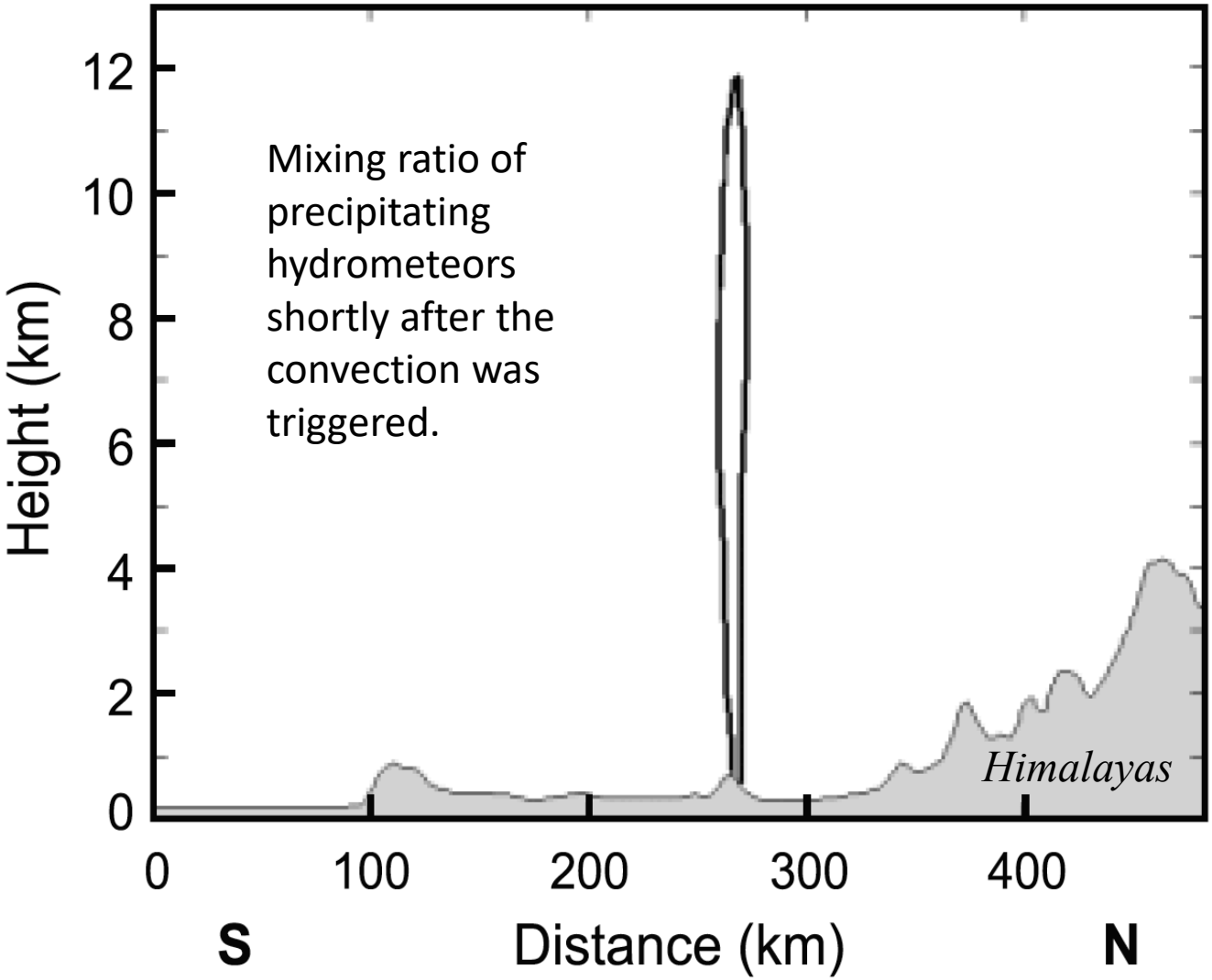
Leeside capping, moist jet, and small-scale triggering

From a WRF simulation of a major convective storm showed capping

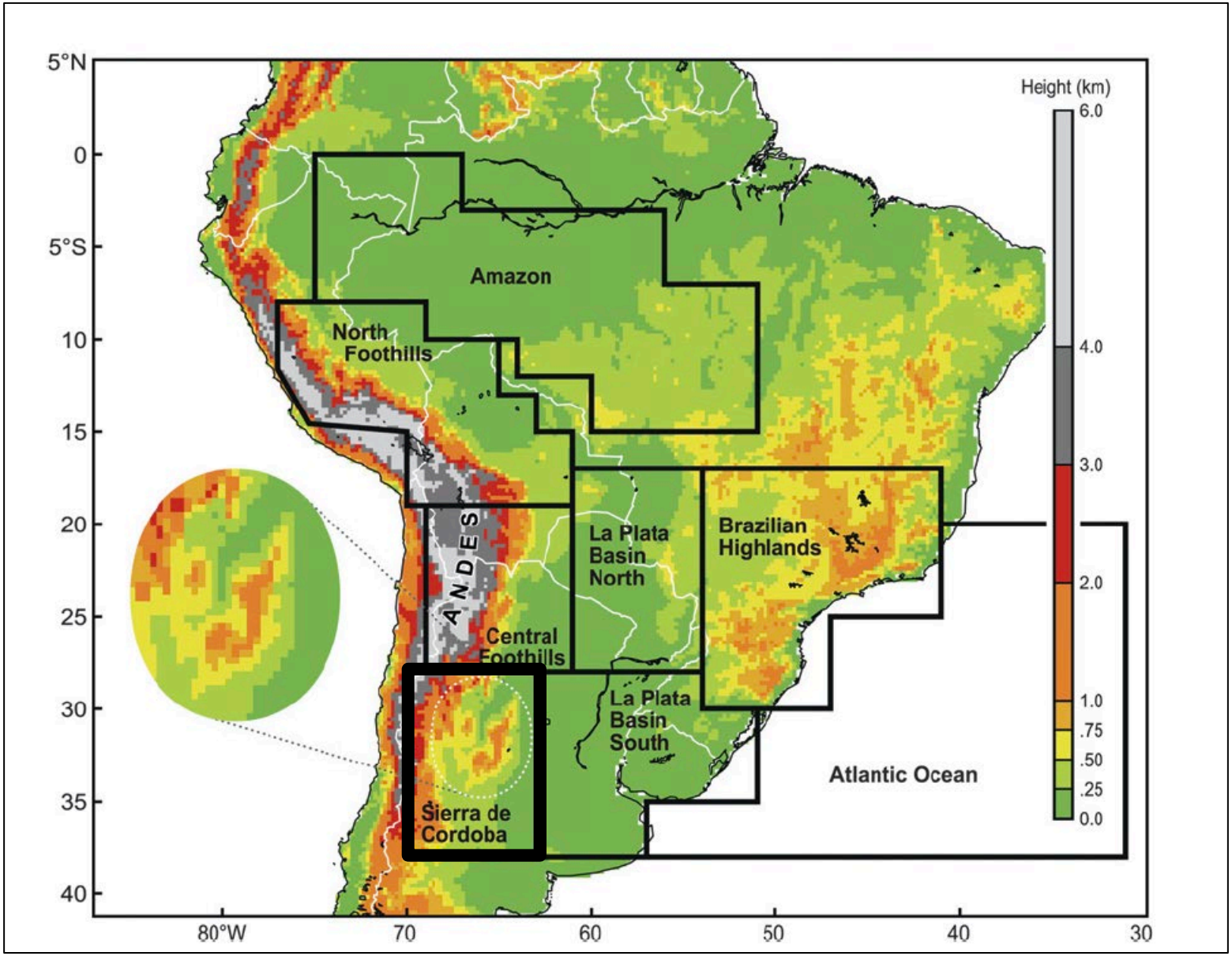


Medina et al. (2010)

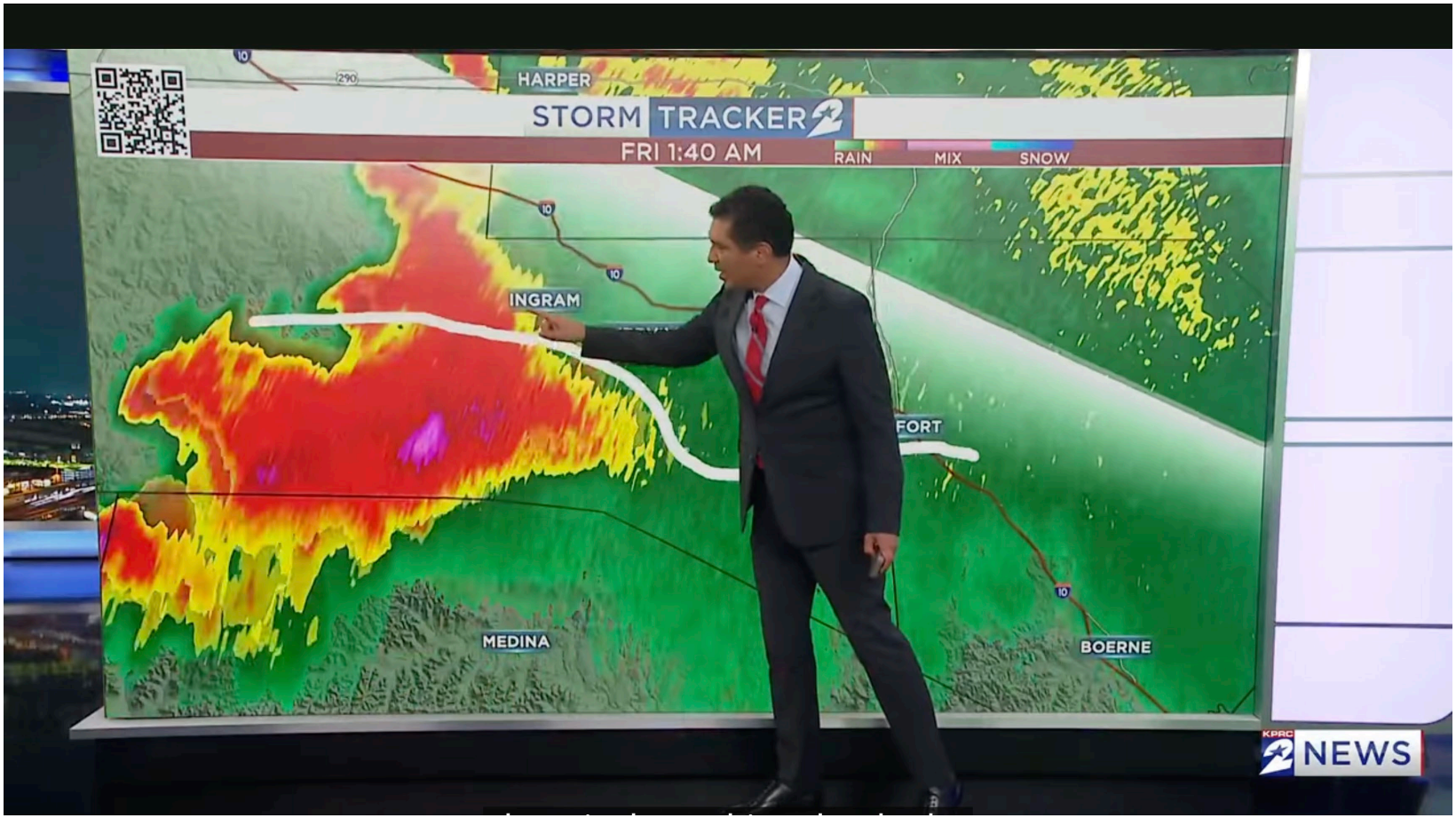
Convection triggered over a very low-level sharp ridge in the foothills



The relatively small Sierra de Cordoba range is the primary trigger spot in the lee of the Andes



Triggering in the Hill Country flood storm?



KPRC TV Houston

Summary

Predicting major precipitation events near a mountain range depend on accurate representation of:

- The type of rain-producing storm
  - Cyclone—especially of tropical origin
  - Convection—especially pre-existing storms over the high terrain
- Low-level moist flow in the vicinity of a mountain range
  - Including surface and boundary layer conditions affecting the low-level flow
- The multi-scale boundary conditions determined by the terrain
  - Barrier scale
  - Sub-barrier scale—important for triggering

End

Extra slides

Basic factors at play when hills and mountains affect precipitating clouds

- Microphysics
- Water Vapor
- Cross barrier flow speed and shear
- Static stability
- Height of the terrain
- Jaggedness of the terrain
- Triggering of convection