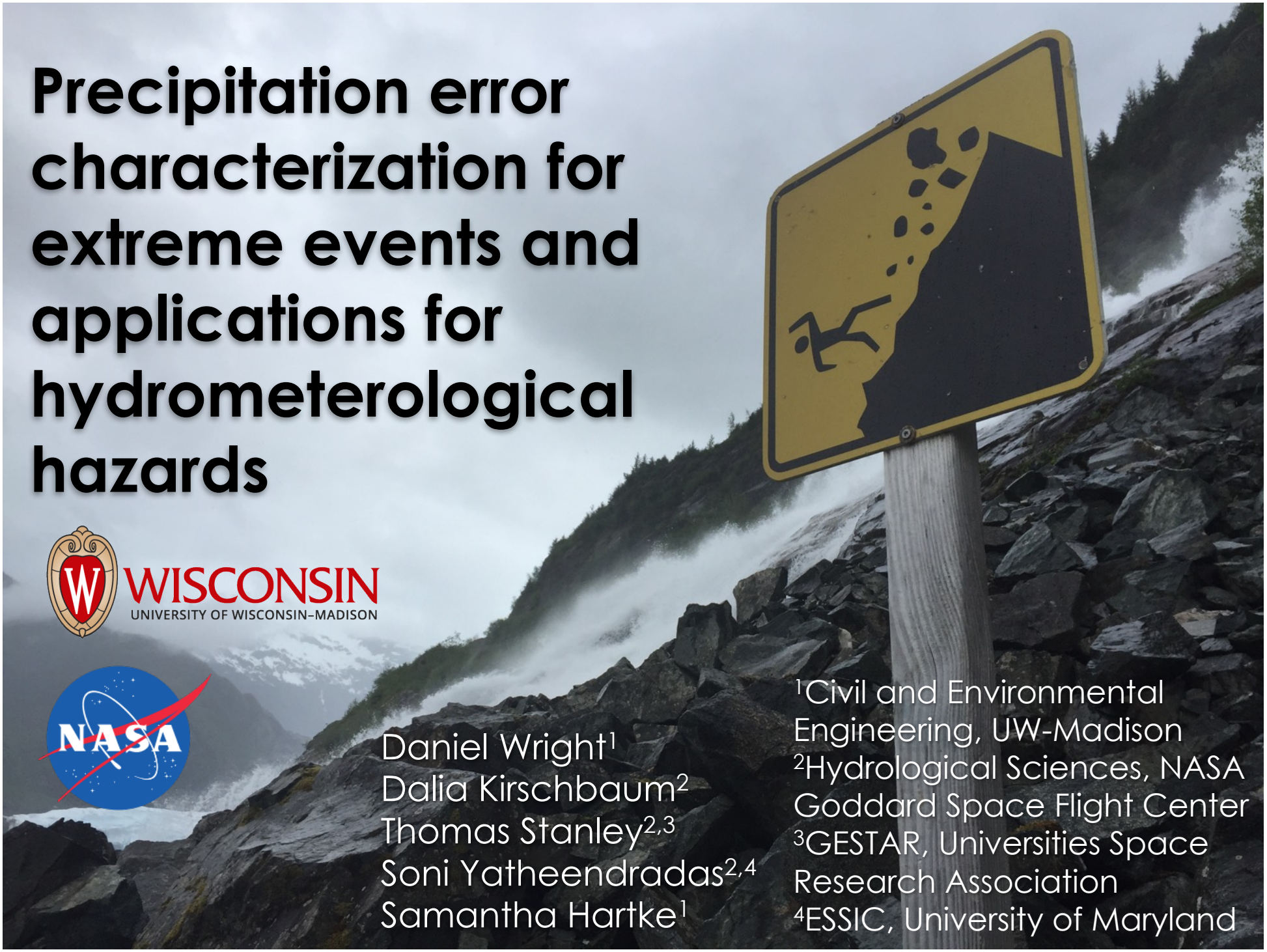
# Precipitation error characterization for extreme events and applications for hydrometerological hazards

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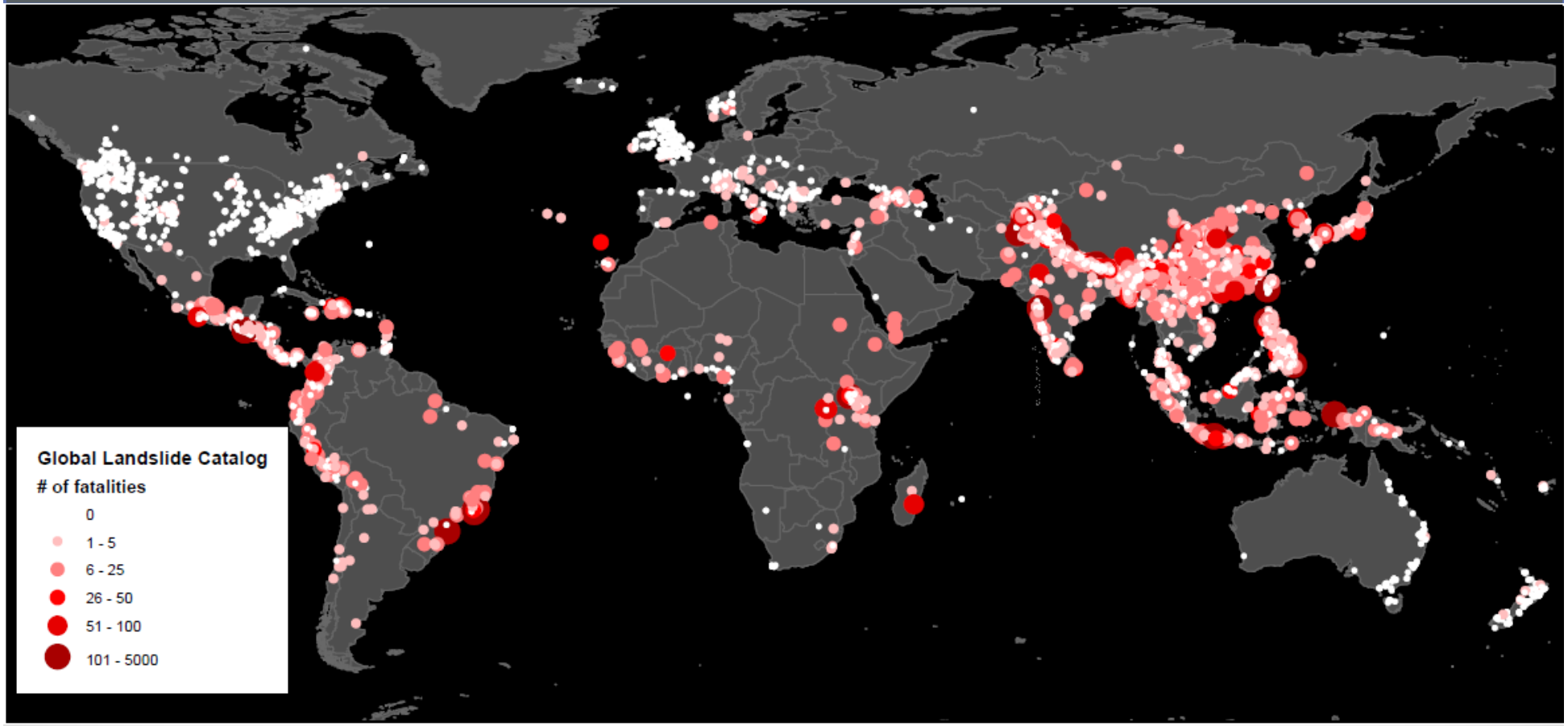
# GPM Applications

Precipitation error estimates are critical in GPM applications…

… coping with them is difficult and context-specific

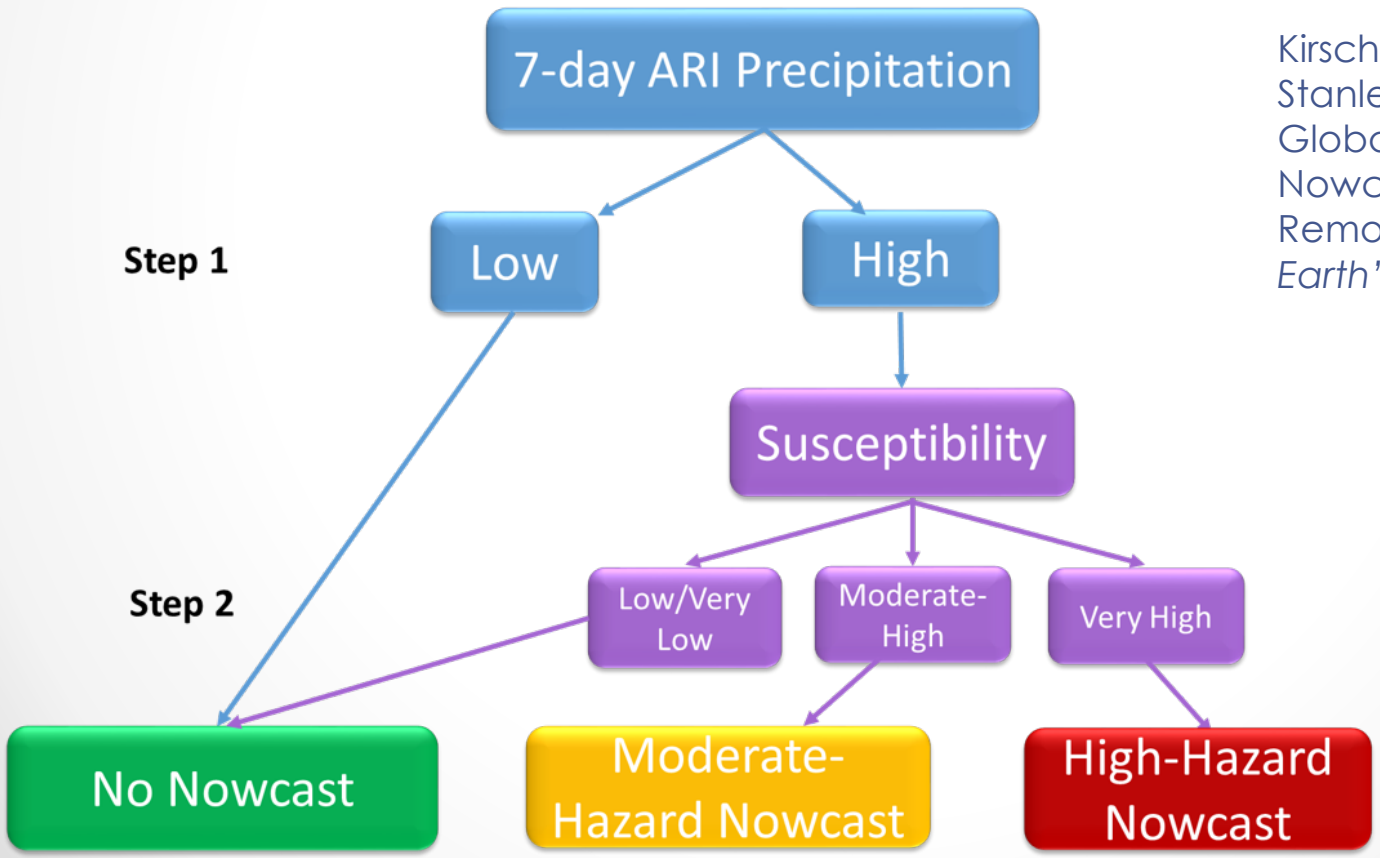
# Landslide Hazards




- Data accessible at: [https://data.nasa.gov/dataset/Global-Landslide-Catalog-Export/dd9e-wu2v](https://data.nasa.gov/dataset/Global-Landslide-Catalog-Export/dd9e-wu2v)

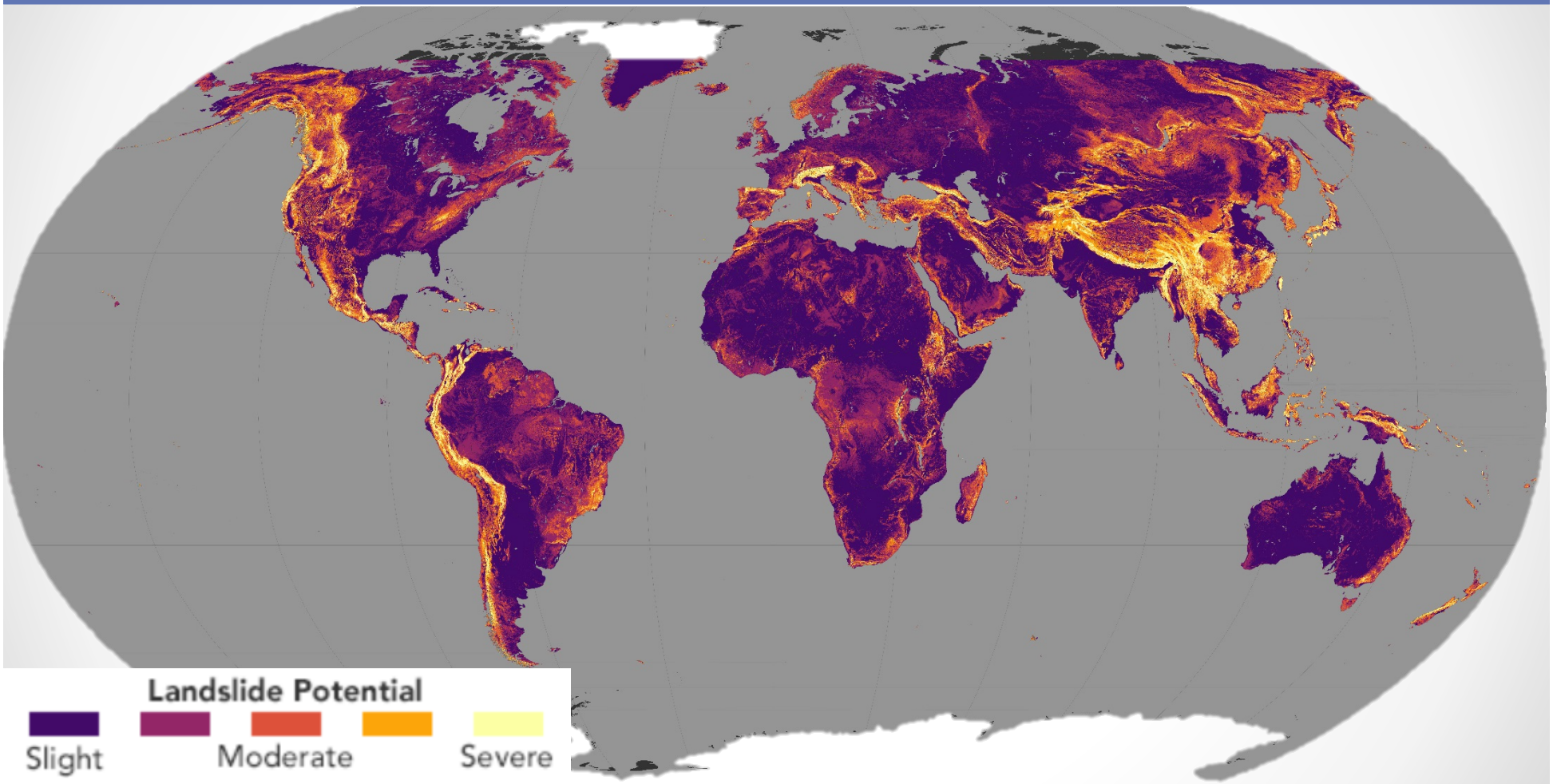
# Landslide Hazard Assessment for Situational Awareness (LHASA)

**Approach**: Merge landslide susceptibility map with satellite-based rainfall to represent potential hazard in near realtime ("nowcasts")




Kirschbaum, D., and T. Stanley (*in revision*), Global Landslide Nowcasting System using Remote Sensing Data, *Earth's Future*.

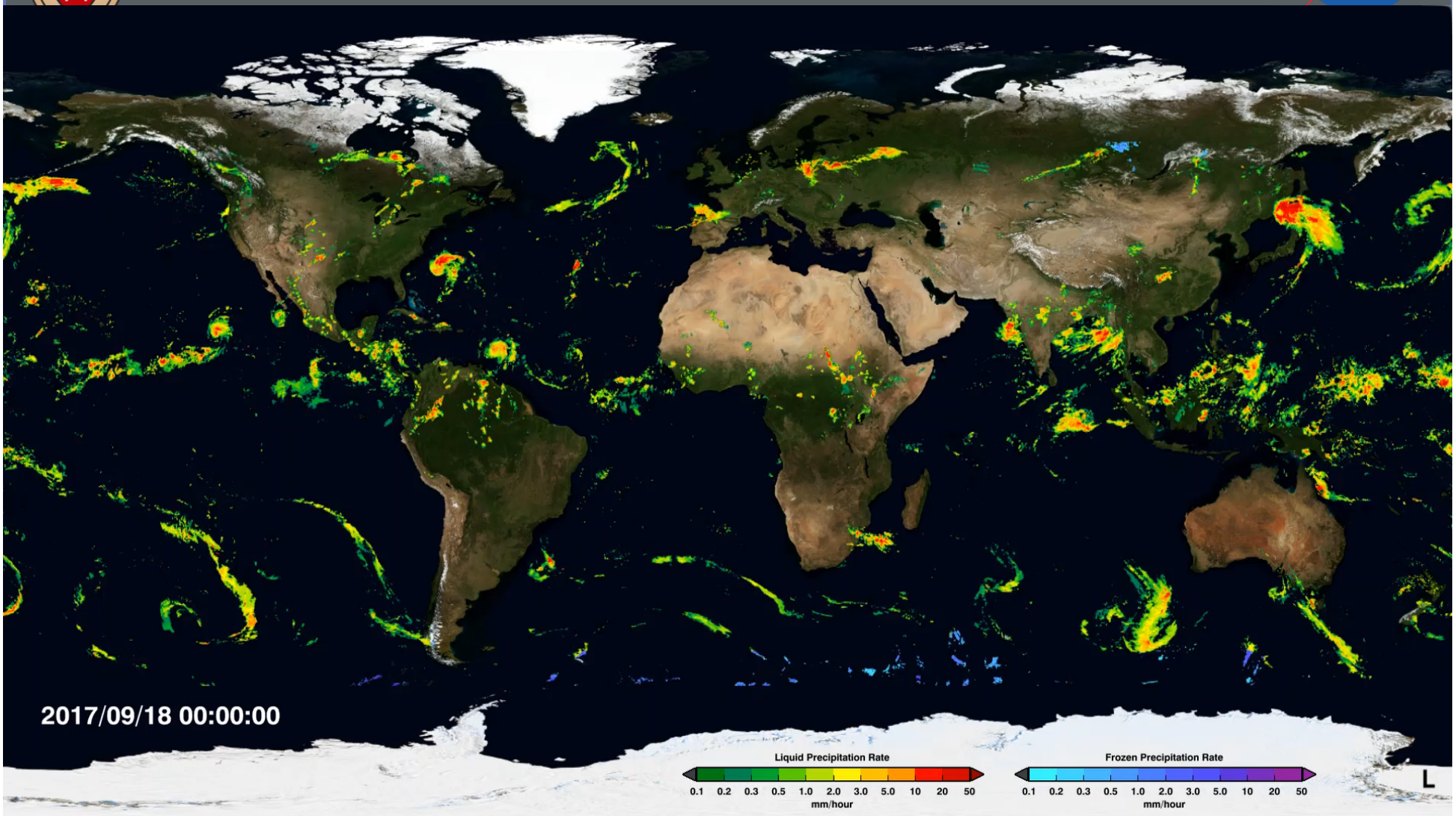
# “Static” Susceptibility

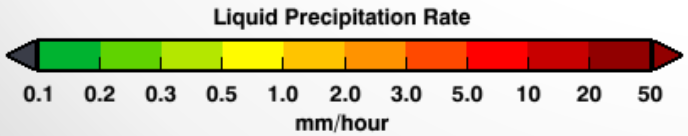


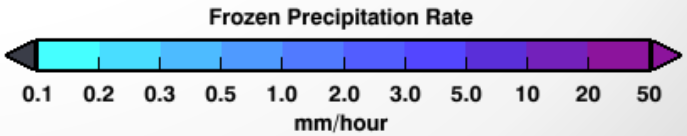

**Available for download at:**
https://pmm.nasa.gov/applications/global-landslide-model

Stanley and Kirschbaum 2017

# “Dynamic” Trigger: Precipitation



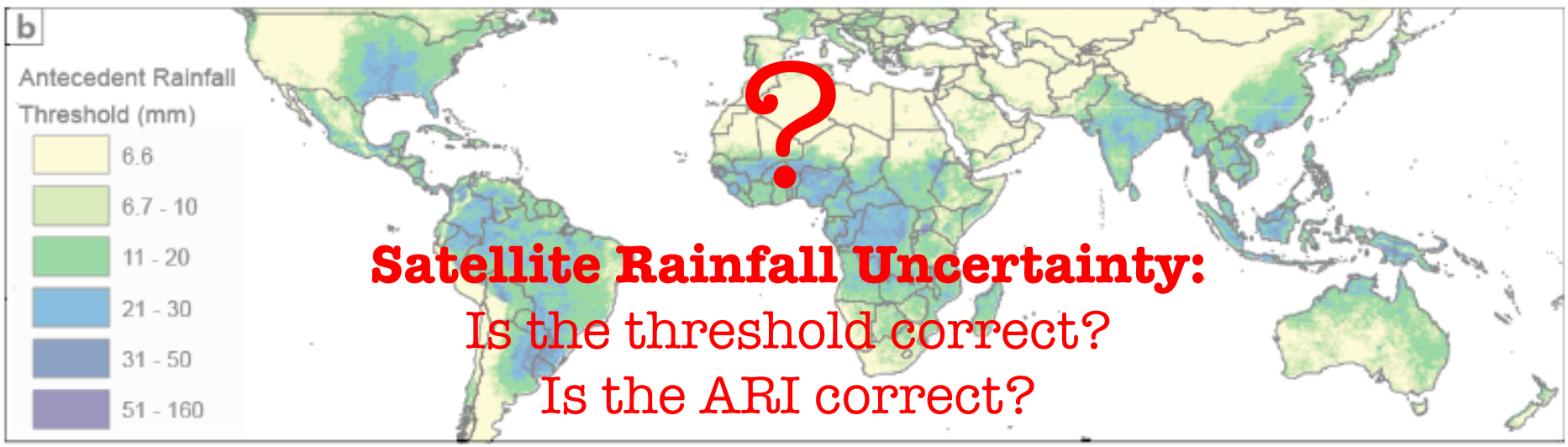



# **LHASA:** Antecedent Rainfall Index (ARI)

- Weighted average of the most recent 7 days of rainfall:

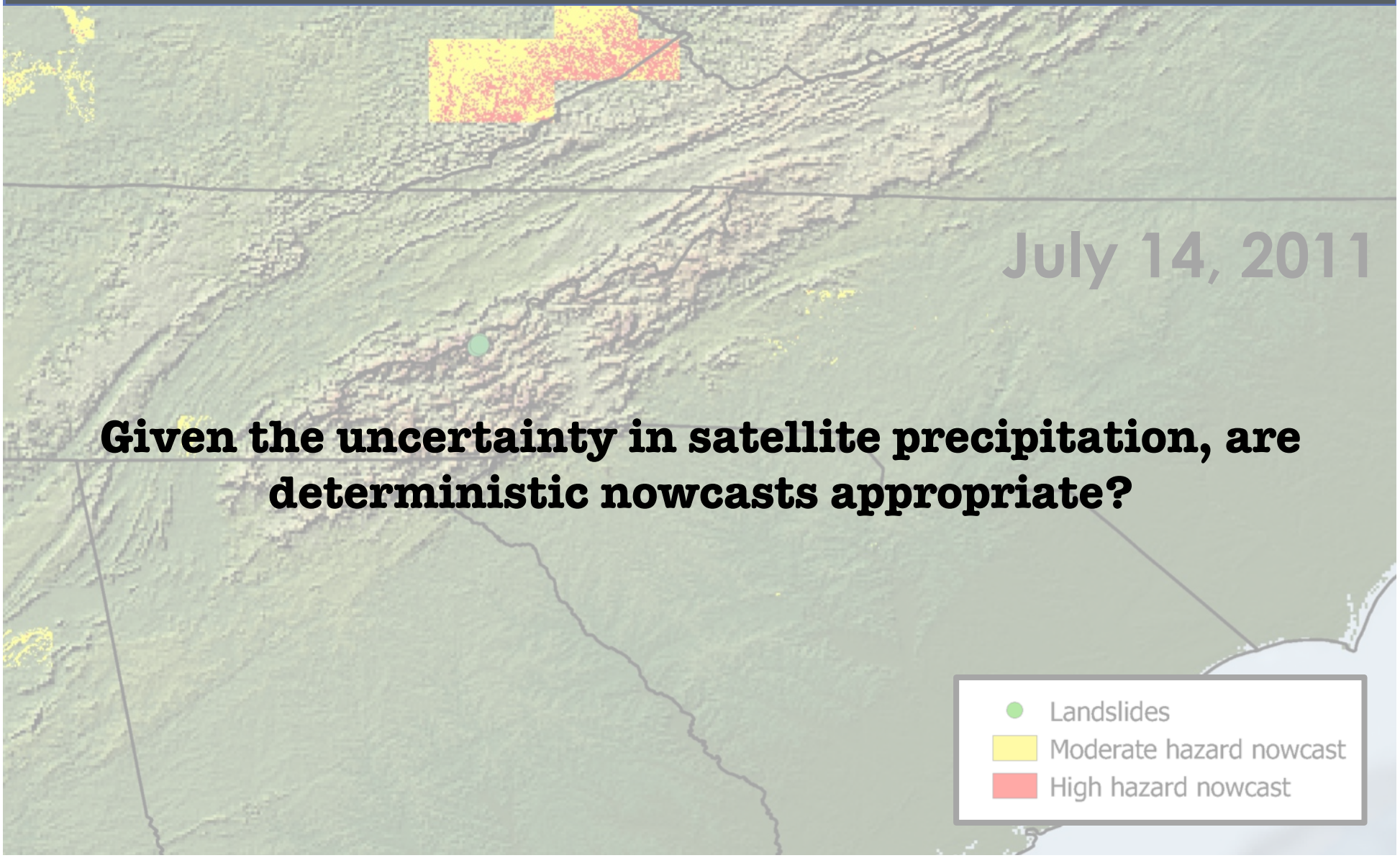
$$ARI = \frac{\sum_{t=0}^{6} p_t w_t}{\sum_{t=0}^{6} w_t}$$

We assume landslide potential begins when ARI exceeds 95th percentile:



# LHASA over IPHEX domain:

## Deterministic Landslide Nowcasts



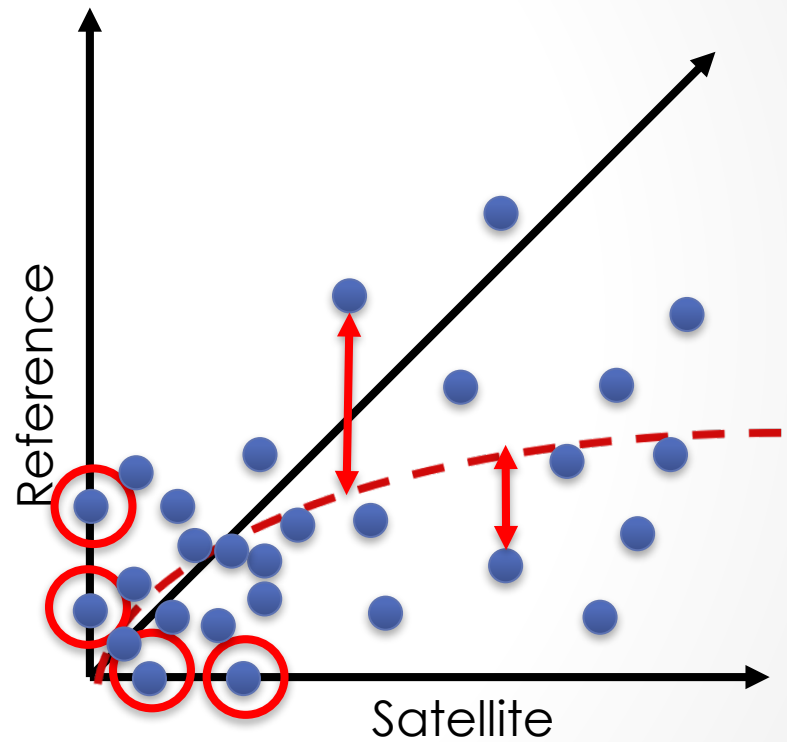

**Given the uncertainty in satellite precipitation, are deterministic nowcasts appropriate?**

# Precipitation Errors

**Satellite multisensor precipitation errors:**

- Occurrence
- Intensity

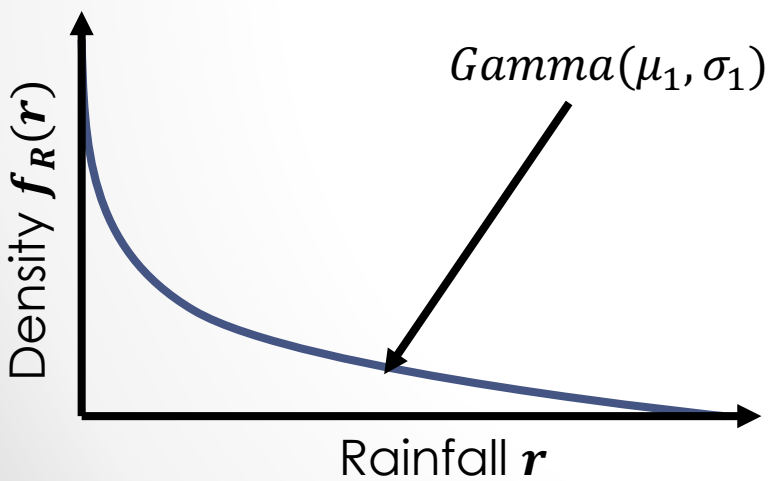
- Misses
- False alarms
- Hits
  - Bias may depend on observation magnitude: "conditional bias"/"systematic error"
  - Random error
  - Error grows with observation magnitude (heteroscedastic)

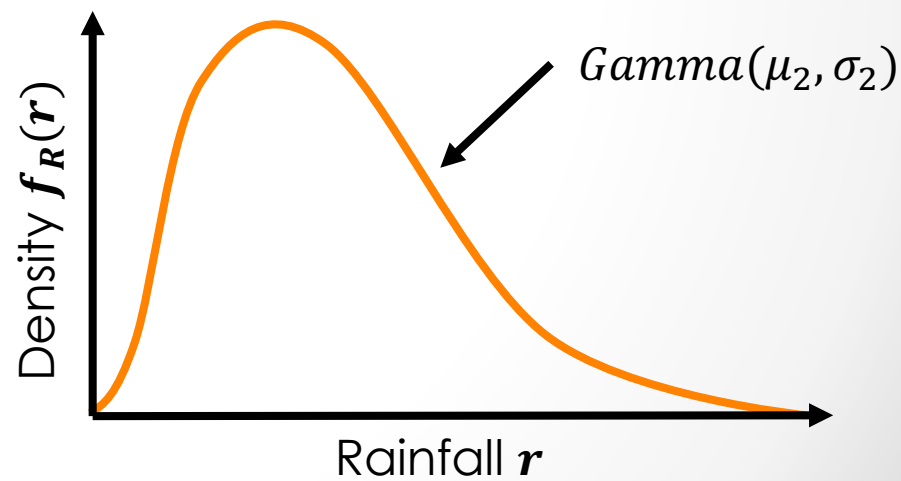


# Climatological Precipitation Characterization

**Typically a 2-step process:**

1. $p(r > 0)$: probability of nonzero rainfall (Bernoulli trial)
2. if $r > 0$; $f_R(r)$: Gamma distribution with parameters $\mu, \sigma$



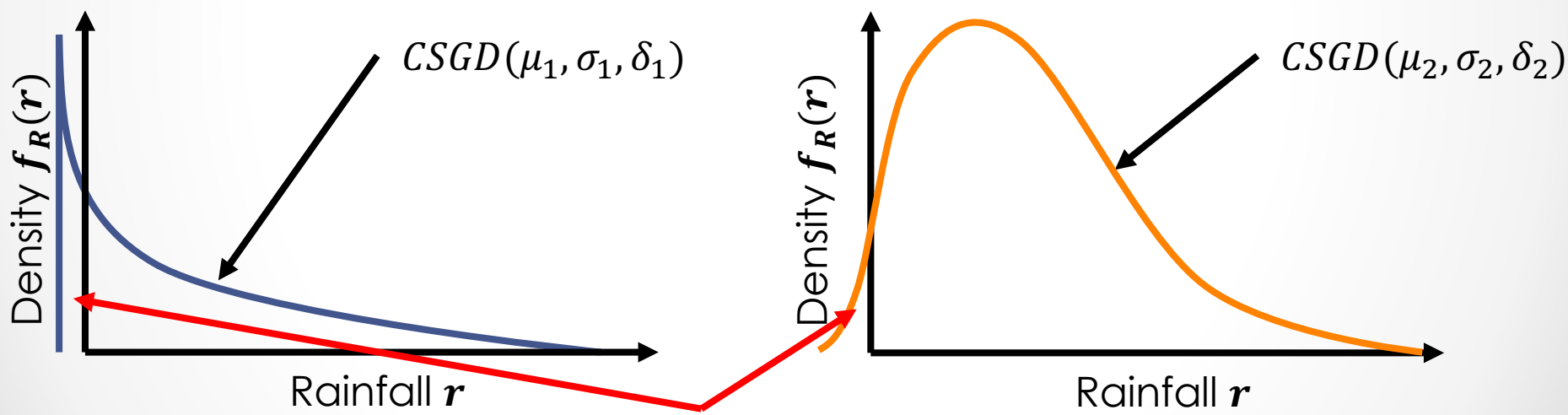



# Climatological Precipitation Characterization

**Censored Shifted Gamma Distribution *** (CSGD):**

1-step alternative:

- Left-censor "negative" precipitation to 0 using "shift" parameter $\delta \rightarrow$ CSGD with parameters $\mu, \sigma, \delta$




$$p(r = 0) = \int_{-\infty}^{0} f_R(r)dr$$

***Note: could be some other distribution (Weibull, etc.)

# Satellite Precipitation Error Modeling

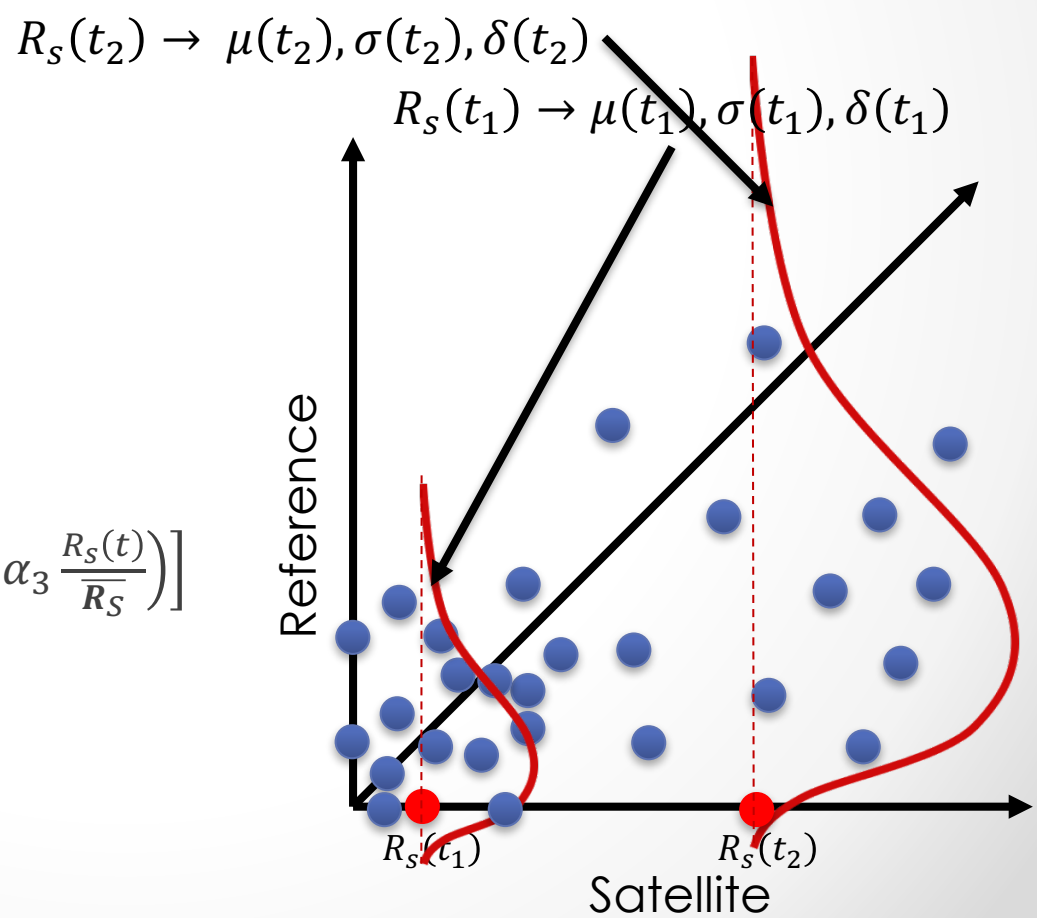
**CSGD Error Model:** For climatological $CSGD(\mu, \sigma, \delta)$ and satellite rainfall observation $R_s(t)$, obtain "conditional parameters" $\mu(t), \sigma(t), \delta(t)$ that best describe the distribution of "true" rainfall at time $t$:

**Linear systematic error:**

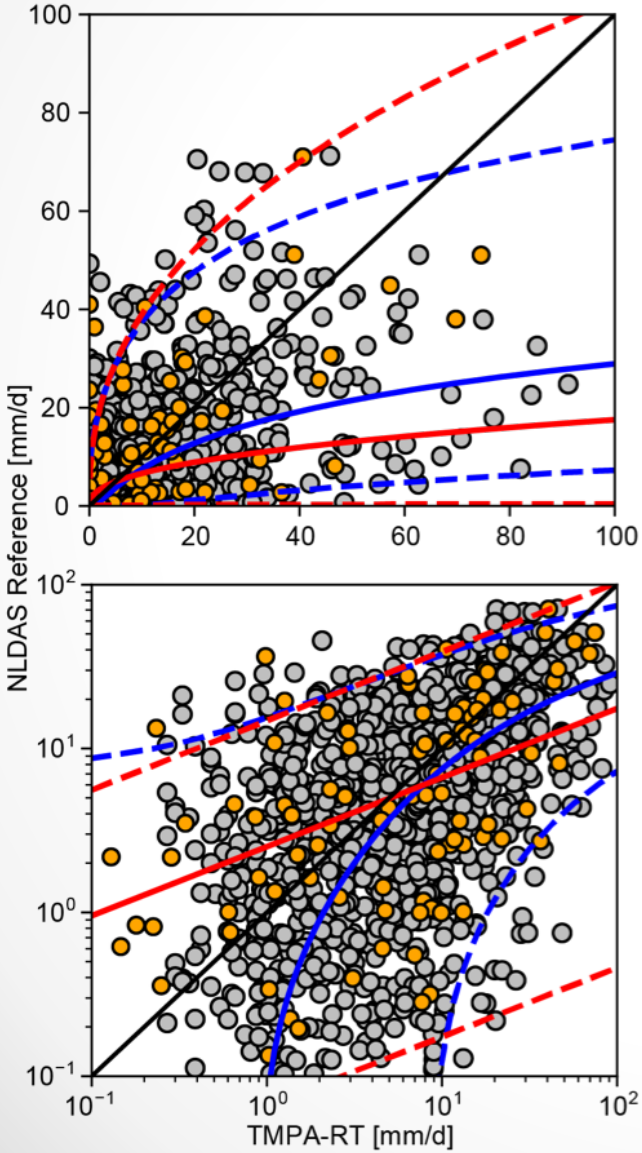
- $\mu(t) = \mu\left(\alpha_1 + \alpha_2 \frac{R_S(t)}{\overline{R_S}}\right)$
- $\sigma(t) = \alpha_3 \sigma \sqrt{\frac{\mu(t)}{\mu}}$
- $\delta(t) = \delta$

**Nonlinear systematic error:**

- $\mu(t) = \frac{\mu}{\alpha_1} log1p\left[expm1(\alpha_1)\left(\alpha_2 + \alpha_3 \frac{R_S(t)}{\overline{R_S}}\right)\right]$
- $\sigma(t) = \alpha_4 \sigma \sqrt{\frac{\mu(t)}{\mu}}$
- $\delta(t) = \delta$



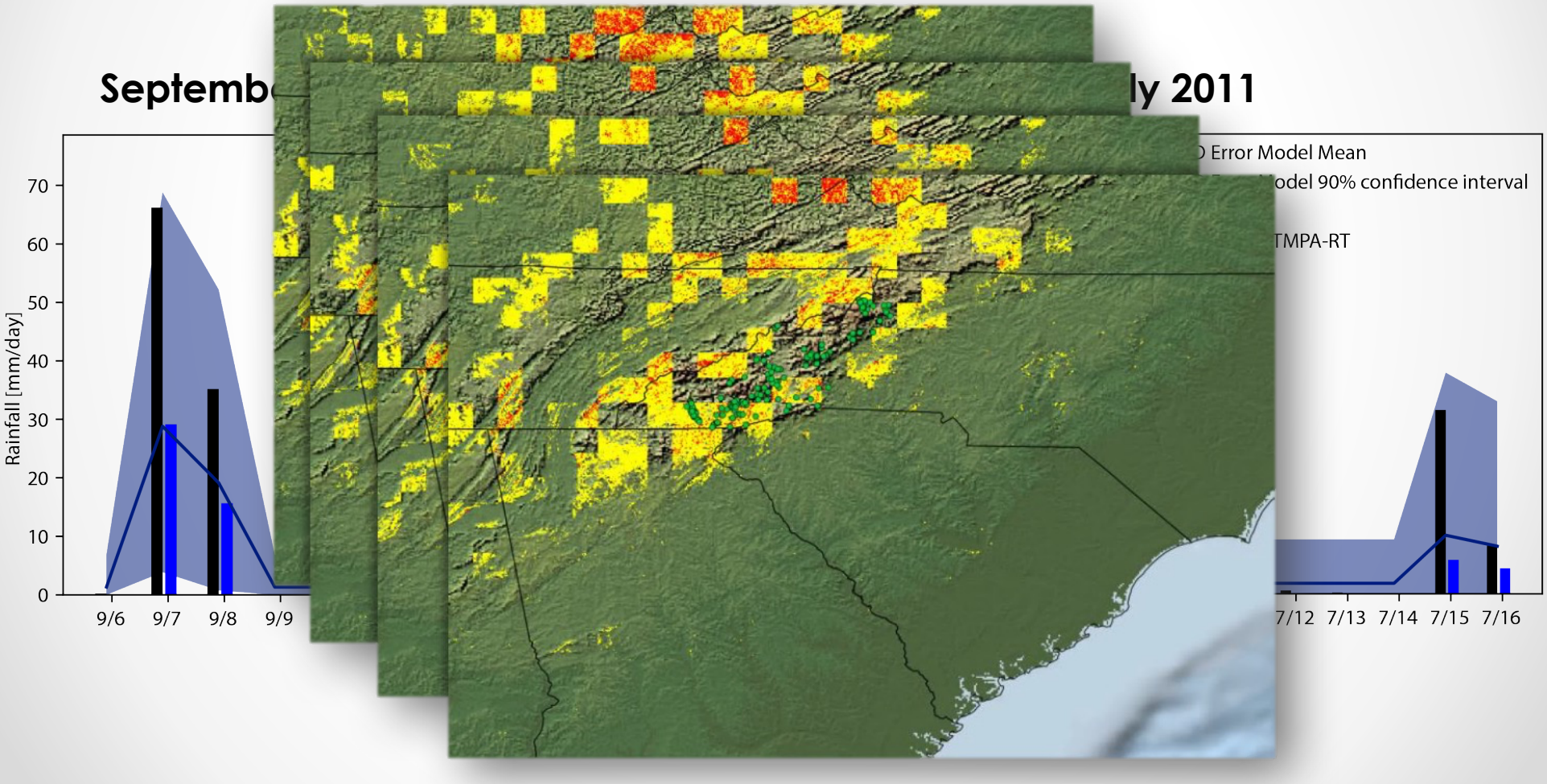
# Satellite Precipitation Error Modeling



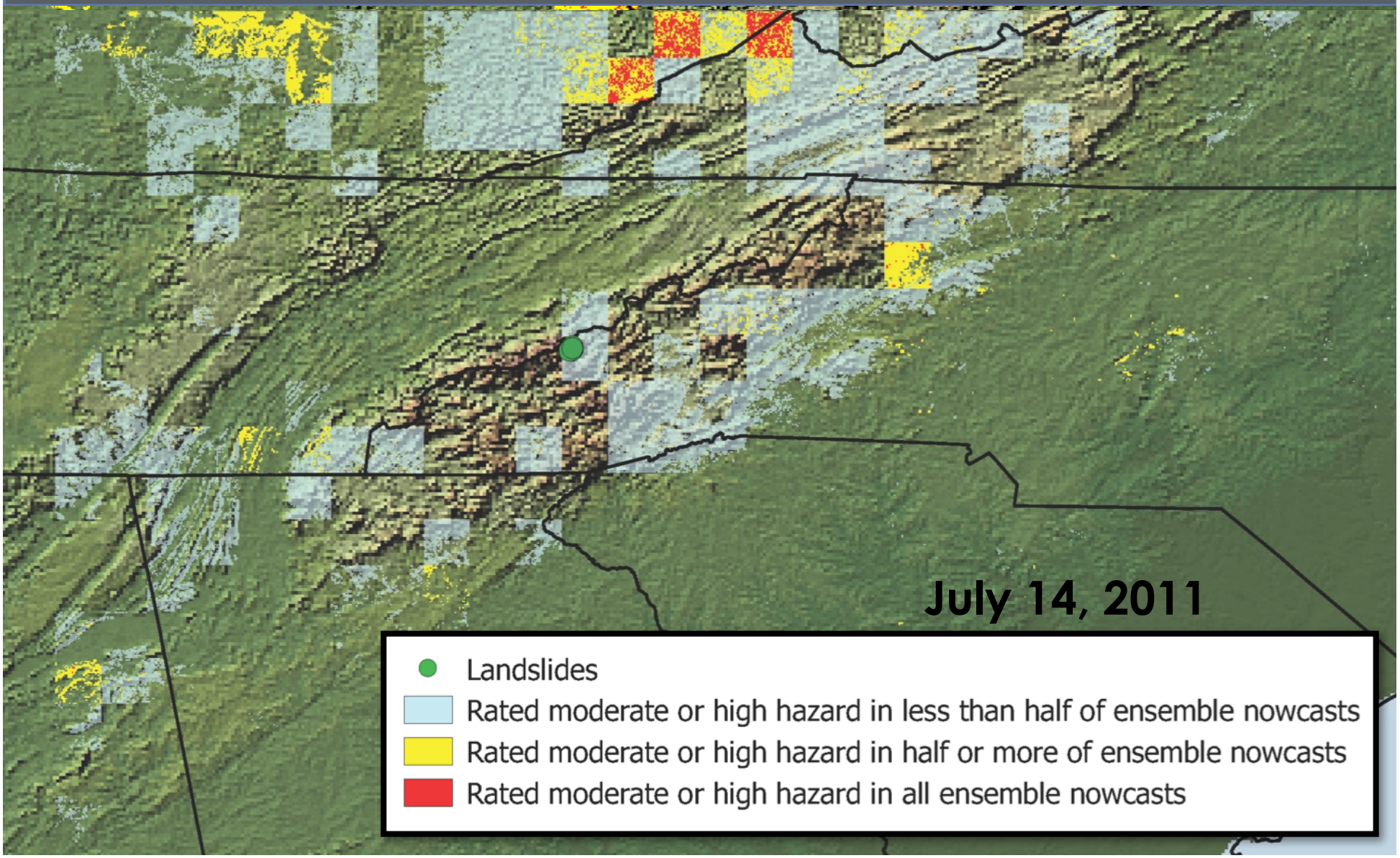

**CSGD:** Wright, D., D. Kirschbaum, S. Yatheendradas: Satellite Precipitation Characterization, Error Modeling, and Error Correction Using Censored Shifted Gamma Distributions. *J. Hydromet.*, 2017

**PUSH:** Maggioni, V., M. Sapiano, R. Adler, Y. Tian, G. Huffman: An Error Model for Uncertainty Quantification in High-Time-Resolution Precipitation Products. *J. Hydromet.*, 2014

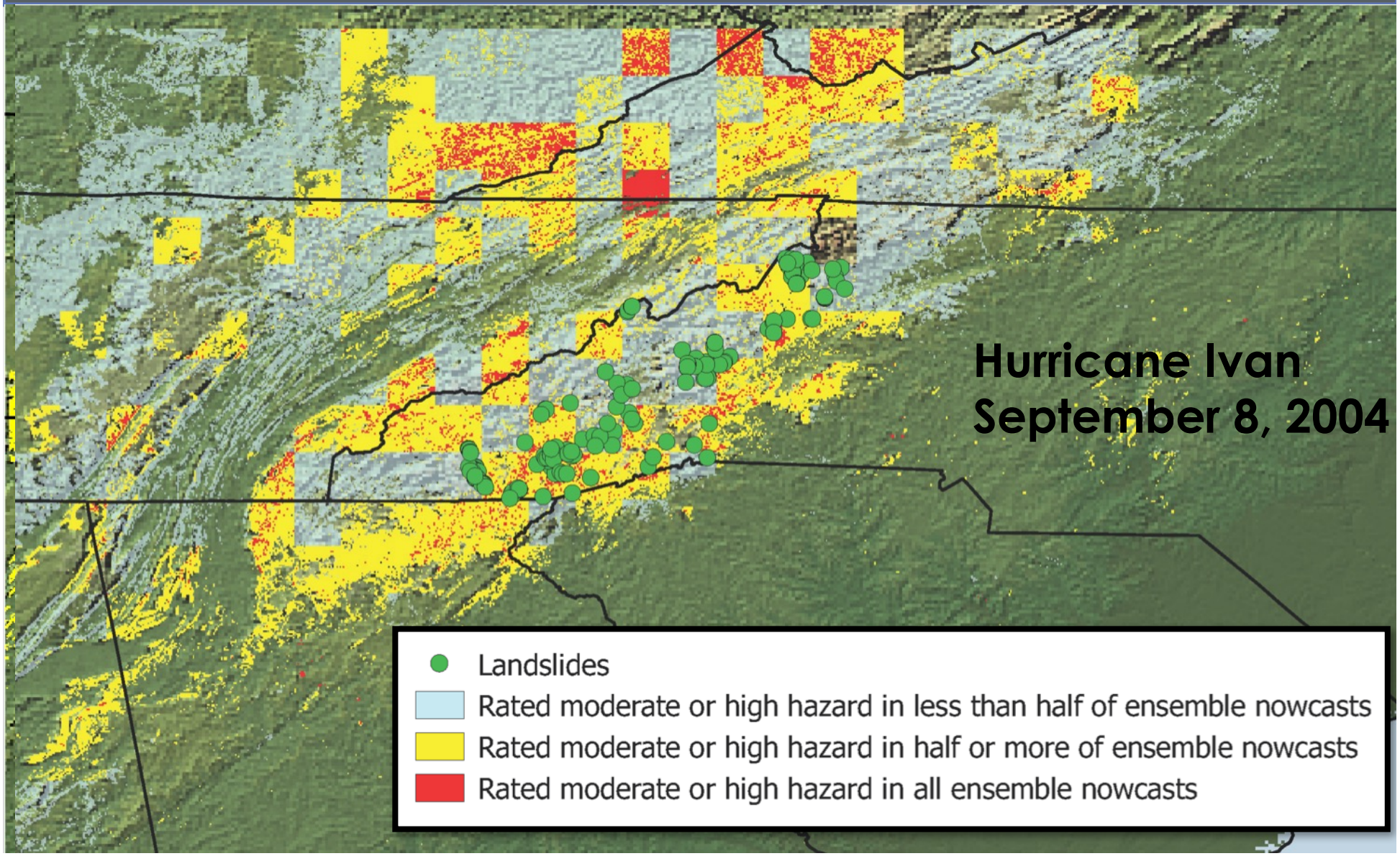
# Extreme Precipitation Characterization



# Ensemble Nowcasting in LHASA



# Ensemble Nowcasting in LHASA



# Next Steps

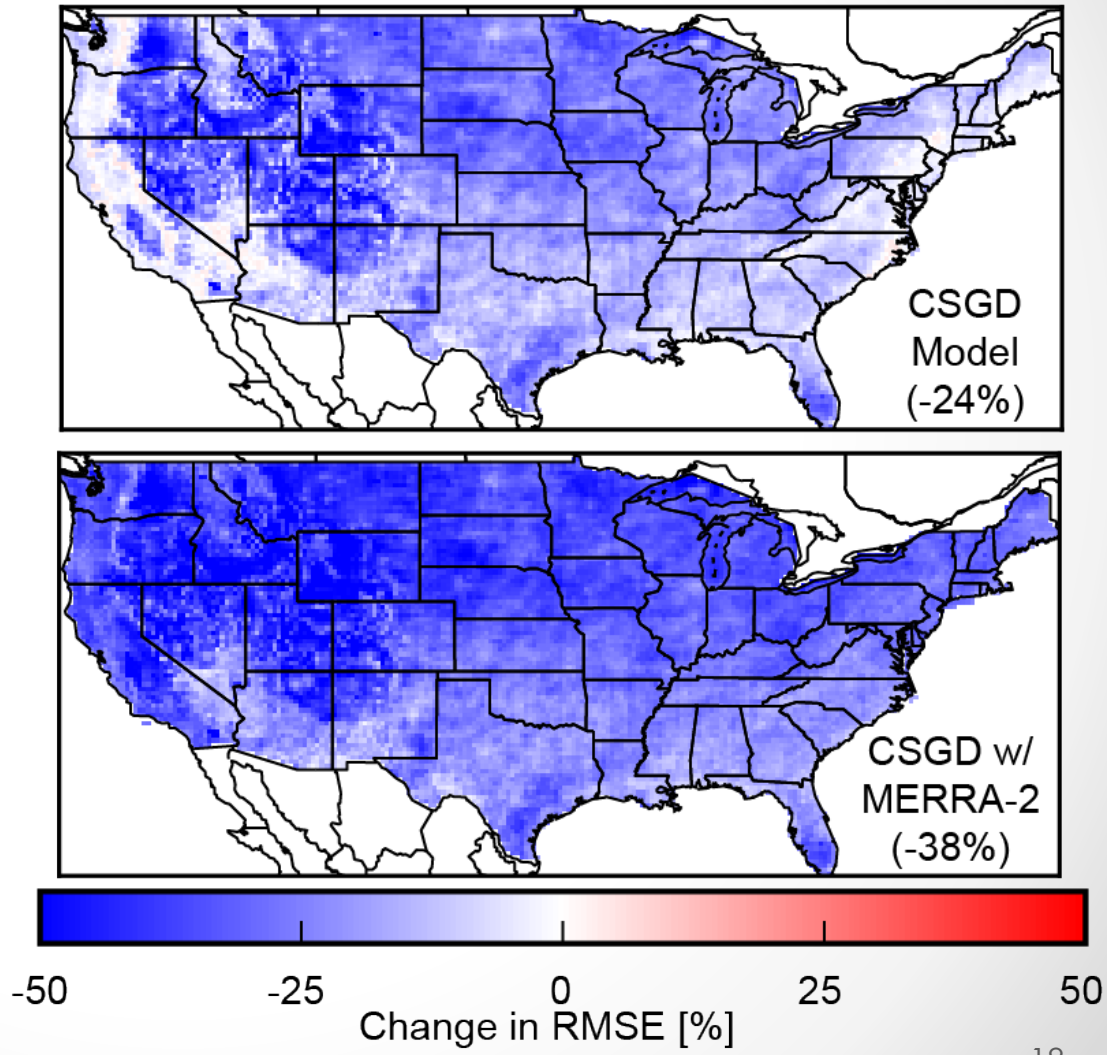
- Develop simple but probabilistic nowcast communication
- Use CSGD error model to downscale error estimates to "hillslope scale" using IPHEX rain gage records
- Explore relative importance of precipitation errors vs. "static susceptibility"-DEM, model parameters, etc.
- Longer-term project: global error estimates

# Merging NWP and Satellite Precipitation Estimates

CSGD error model can accommodate "additional information" such as NWP precipitation, precipitable water, etc.:

- $\mu(t) = \mu\left(\alpha_1 + \alpha_2 \frac{R_S(t)}{\overline{R_S}} + \alpha_5 \frac{R_{MERRA-2}(t)}{\overline{R_{MERRA-2}}}\right)$

- Potential to reduce random error component, which is otherwise irreducible



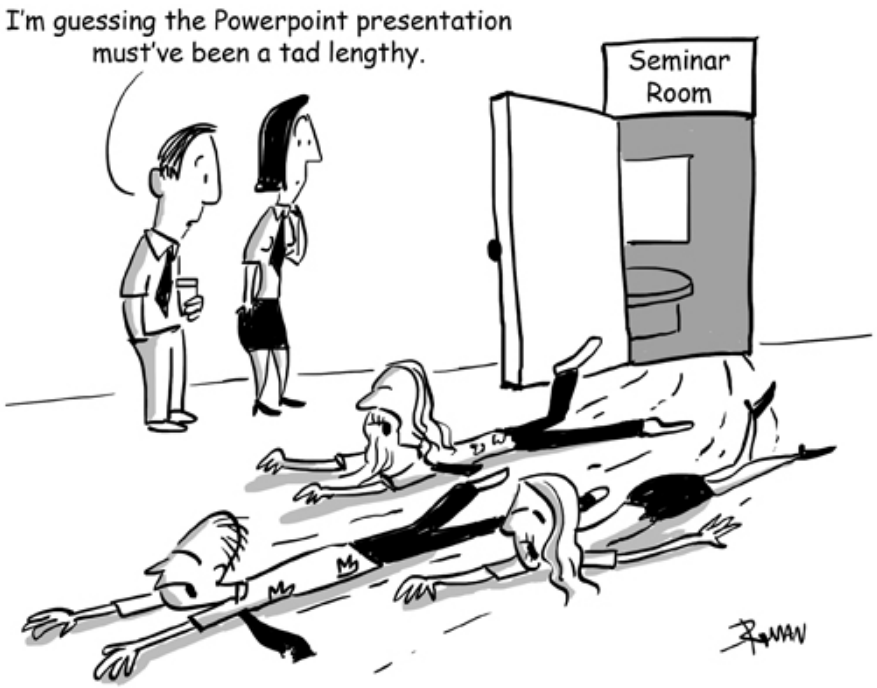
# Summary

- Error estimates/probabilistic precipitation estimates are necessary for applications, but are no substitute for higher accuracy

- Context matters (for example, error requirements for floods and landslides are very different)

- We need to rethink the way we interpret and communicate model outputs:

  Deterministic → Probabilistic



# Recent Publications

- Wright, D. B., D. B. Kirschbaum, and Soni Yatheendradas. "Satellite Precipitation Characterization, Error Modeling, and Error Correction Using Censored Shifted Gamma Distributions." *Journal of Hydrometeorology*, September 1, 2017. doi:10.1175/JHM-D-17-0060.1.

- Kirschbaum, D., and T. Stanley (*in revision*), Global Landslide Nowcasting System using Remote Sensing Data, *Earth's Future*.

- Stanley, T., and D. B. Kirschbaum (2017), A heuristic approach to global landslide susceptibility mapping, *Nat. Hazards*, *87*(1), 145–164, doi:10.1007/s11069-017-2757-y.

- Stanley, T., D. B. Kirschbaum, G. J. Huffman, and R. F. Adler (2017), Approximating long-term statistics early in the Global Precipitation Measurement era, *Earth Interact.*, *21*(3), 1–10, doi:10.1175/EI-D-16-0025.1

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