Extreme Rainfall in a Multi-scale Modeling Framework

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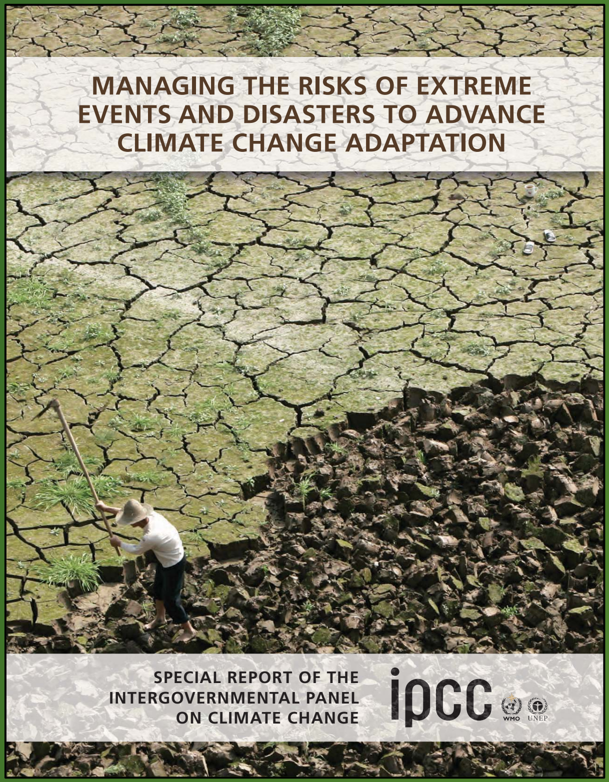
Extreme Precipitation: Why do we care?

- Extreme rainfall: Occurrence of rainfall near the upper ends of observed values
  - Damage to assets and infrastructure, loss of life
  - Physical interaction of rainfall with land surface

How might extremes in precipitation behave under changing climate?



Extreme Precipitation: Scale Dependence

10 mm/hr

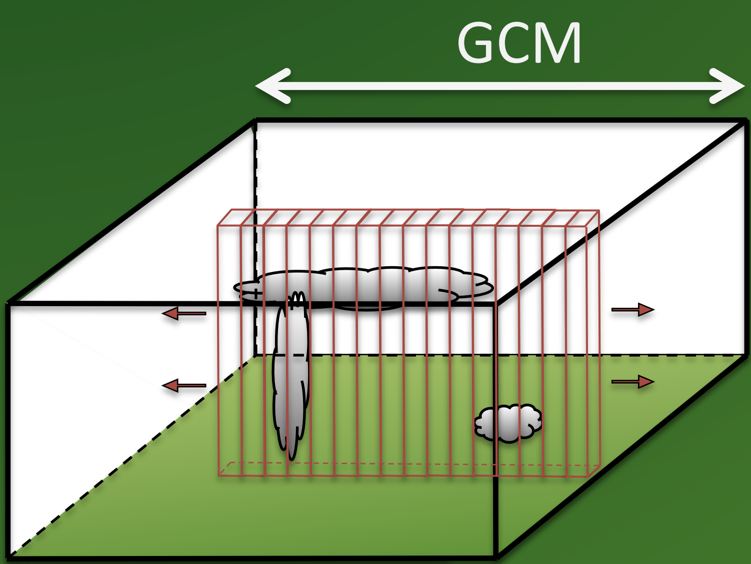
2 mm/hr

Precipitation intensity is function of spatial resolution

Introduction: Downscaling

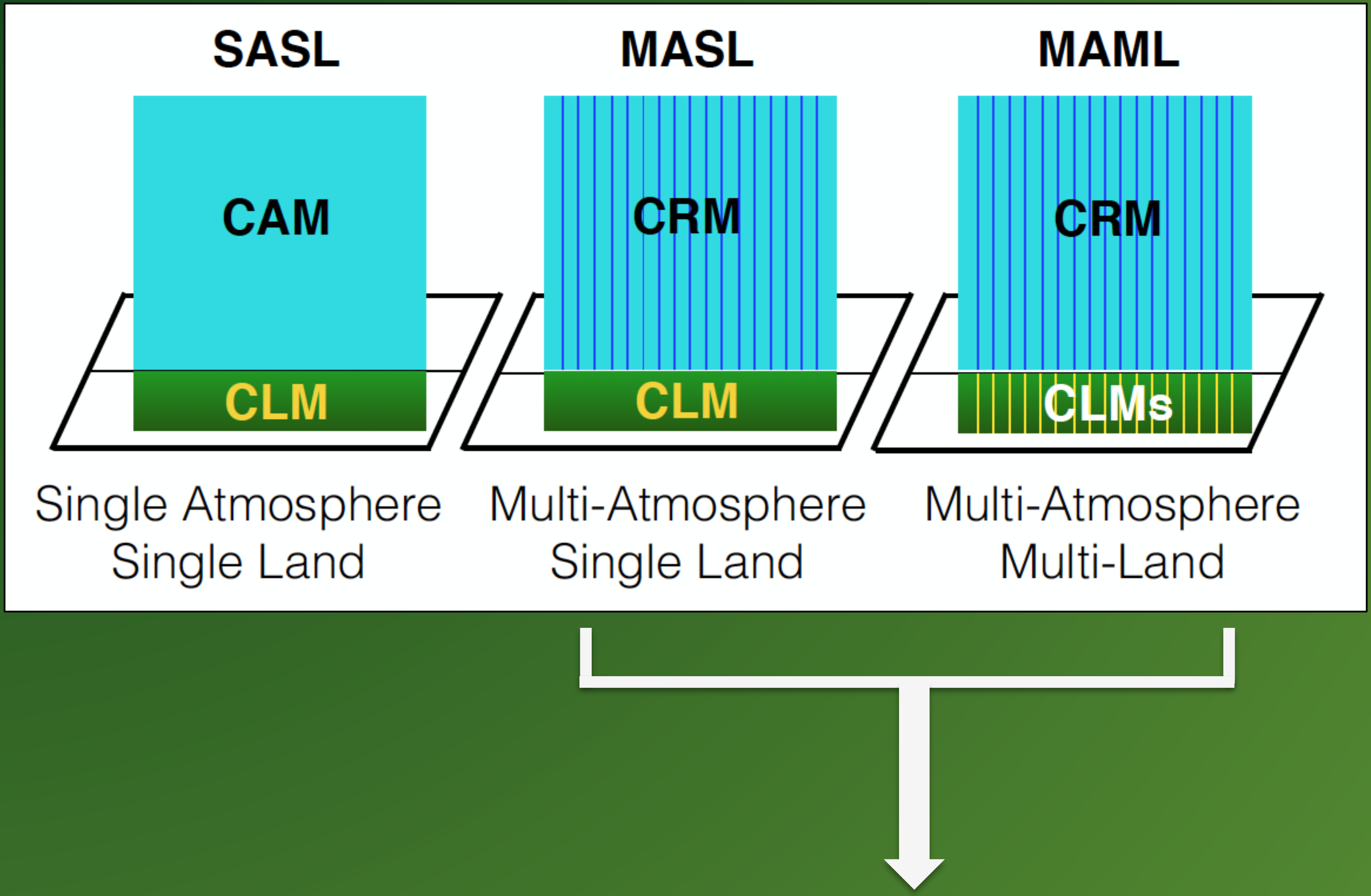
Downscaling techniques

- Statistical
  - Develop relationship between observed quantity and Global Climate Model (GCM) quantity
- Dynamical
  - GCM quantities used to force regional mesoscale model

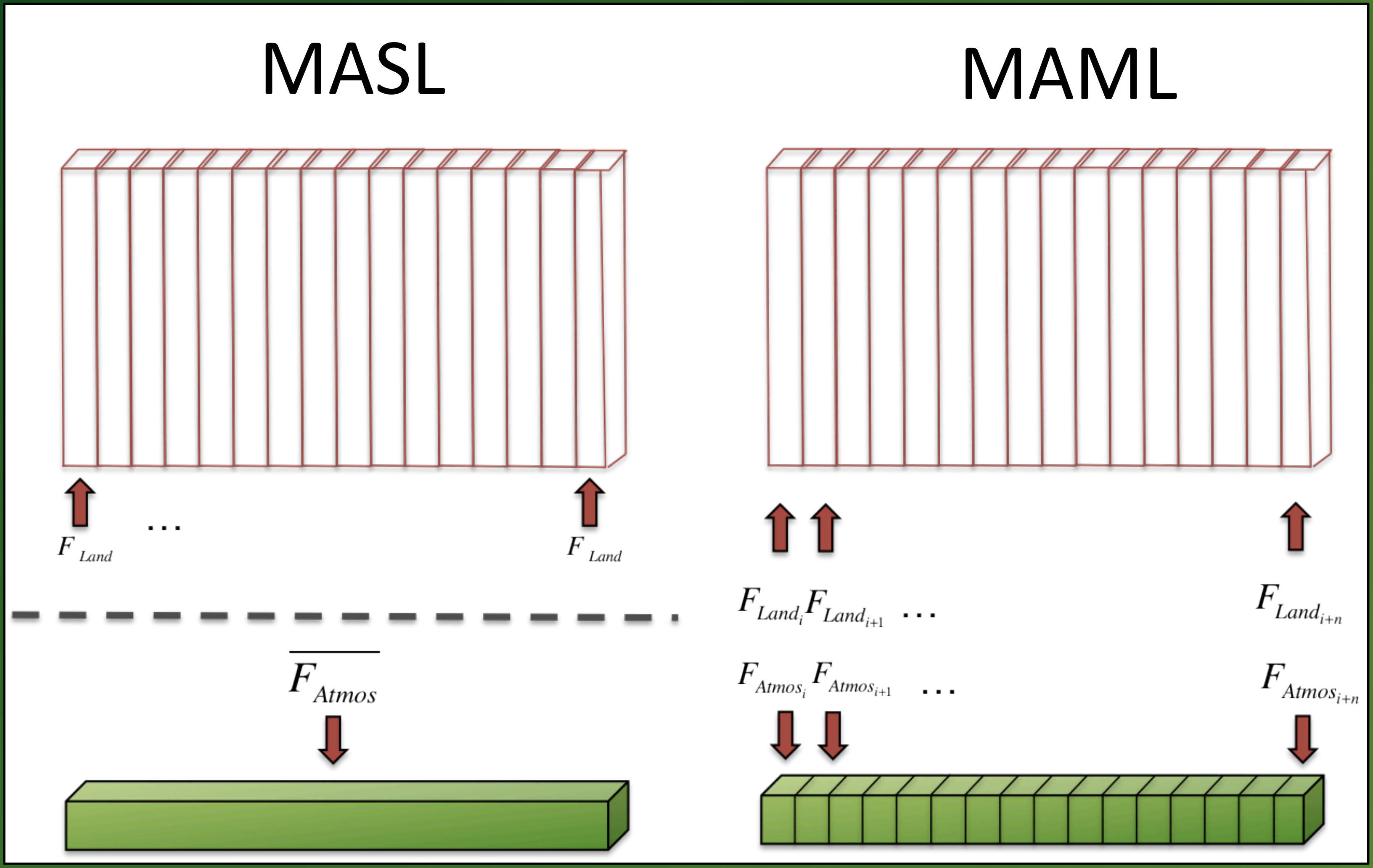


- Multi-scale Model Framework (MMF)
  - Cloud Resolving Model (CRM): Information about atmospheric structure on O[1 km]
  - MMF correctly simulates intense rainfall events compared to traditional GCM [DeMott et al., 2007]

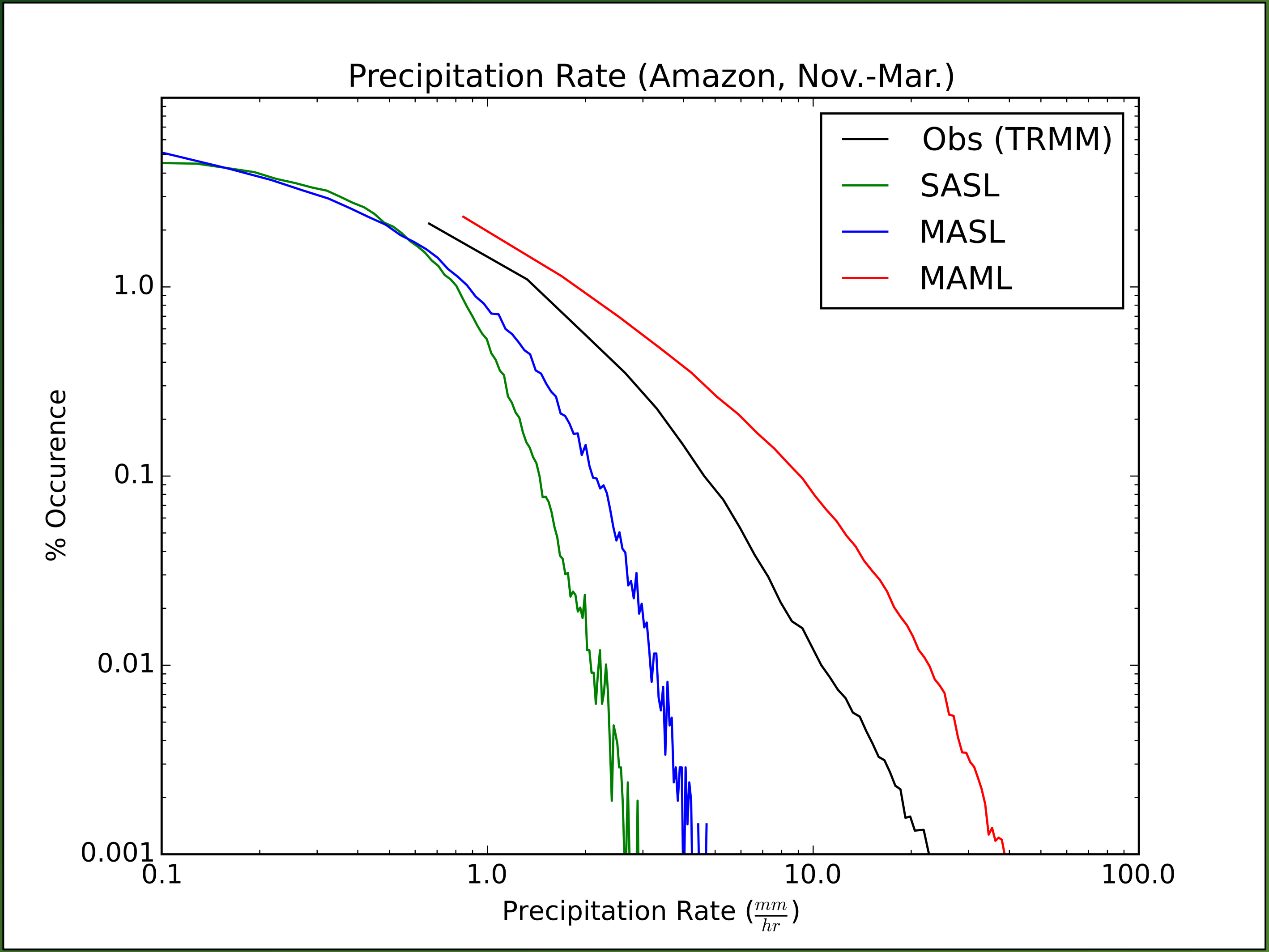
Introduction: Land Atmosphere Coupling



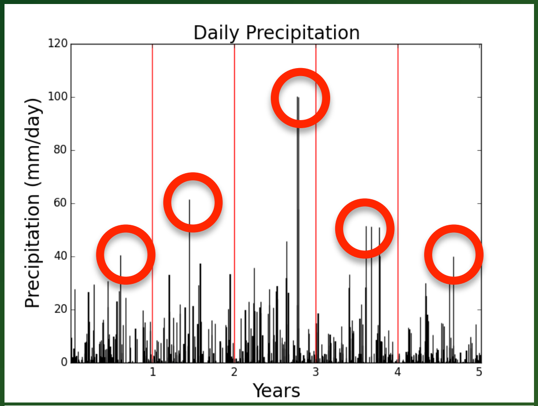
Introduction: Flux at Land-Atmosphere Interface



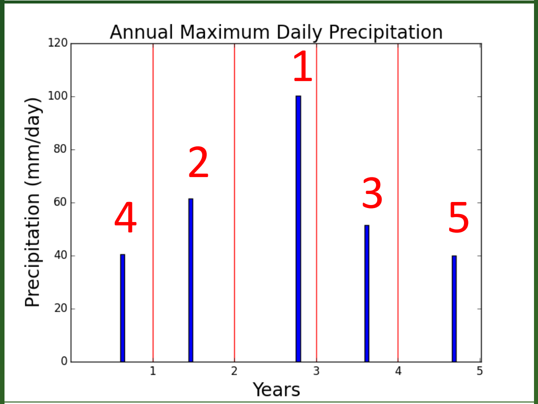
Introduction: Precipitation Intensity at Land-Atmosphere Interface



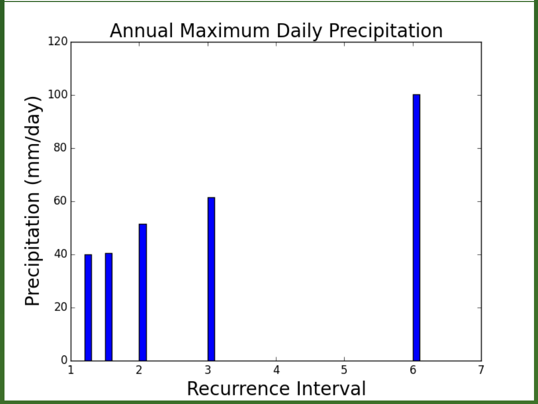
Methods: Annual Maximum Series



Select largest annual precipitation from time-series



Rank by magnitude



Express in terms of Recurrence Interval (T) (Gumbel, 1945)

$$T = \frac{1+n}{m}$$

$$n = \#\, years$$
$$m = rank$$

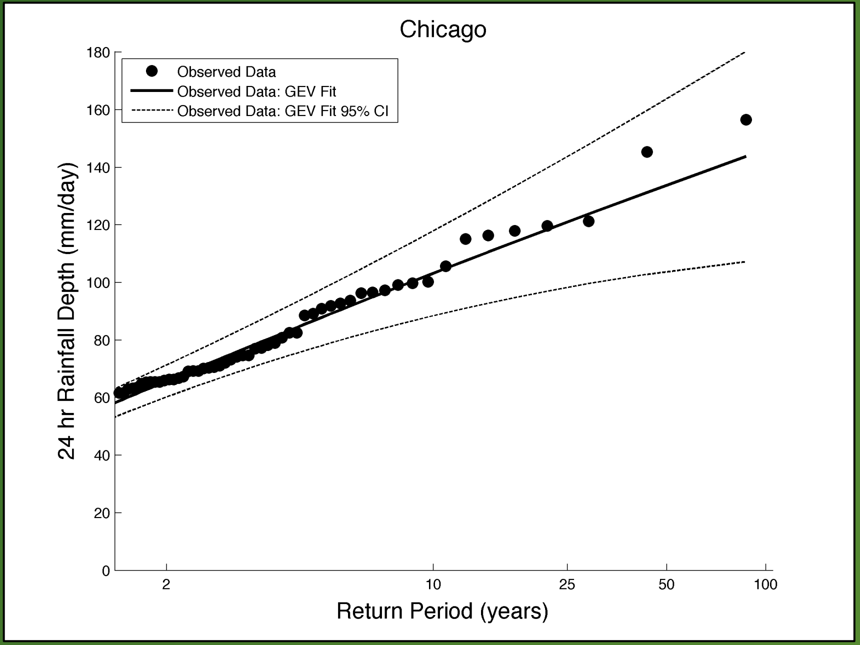
$$P = \frac{1}{T}$$

Methods: Annual Maximum Series

- Distribution follows extreme value type [Gumbel, 1941 and Chow, 1951]
- General Extreme Value distribution best suited for meteorological variables [Jenkinson, 1955]

General Extreme Value Distribution

- Estimate 3 parameters: Shape, Scale and Location [Jenkinson, 1969]
- Evaluate uncertainty in parameter estimates using confidence intervals



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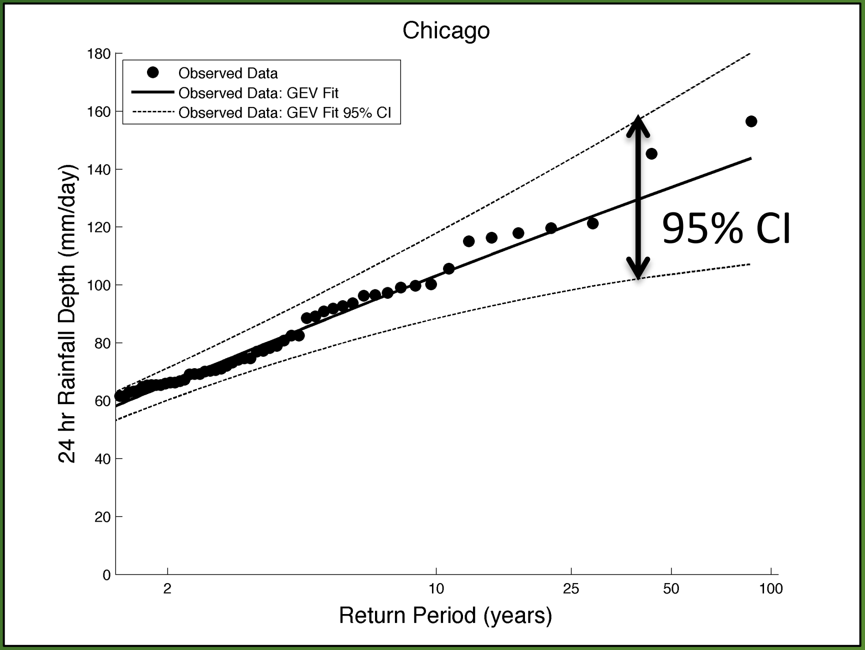
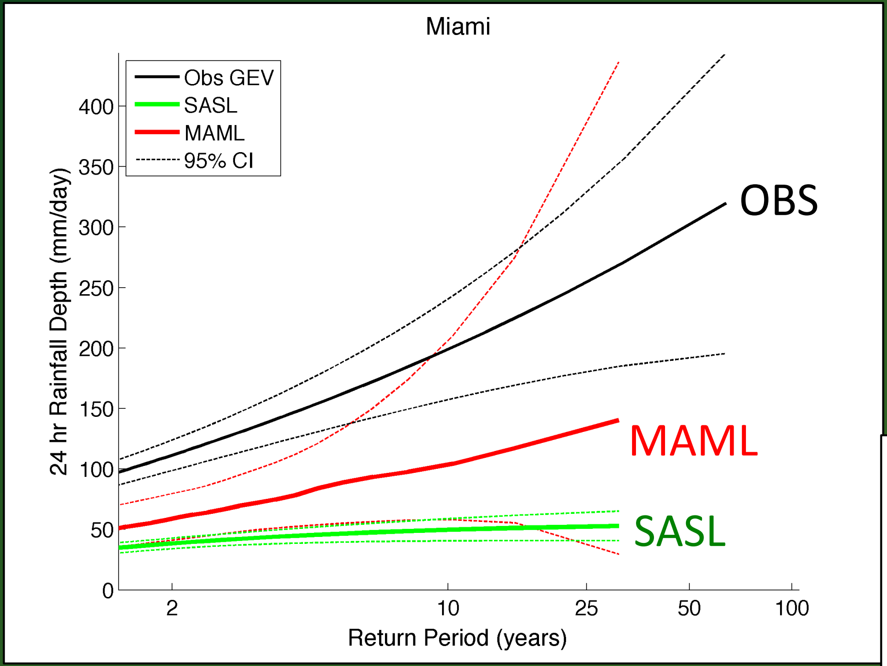


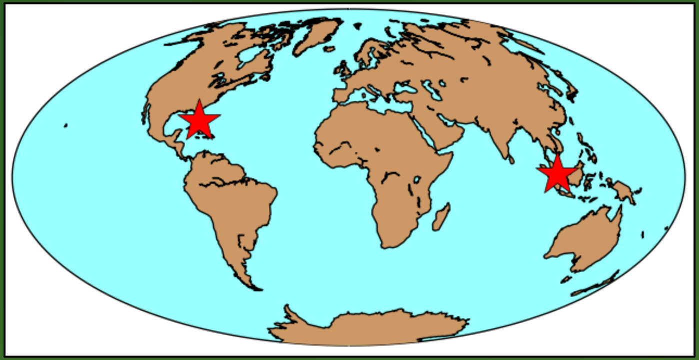
Methods: Model Experiment

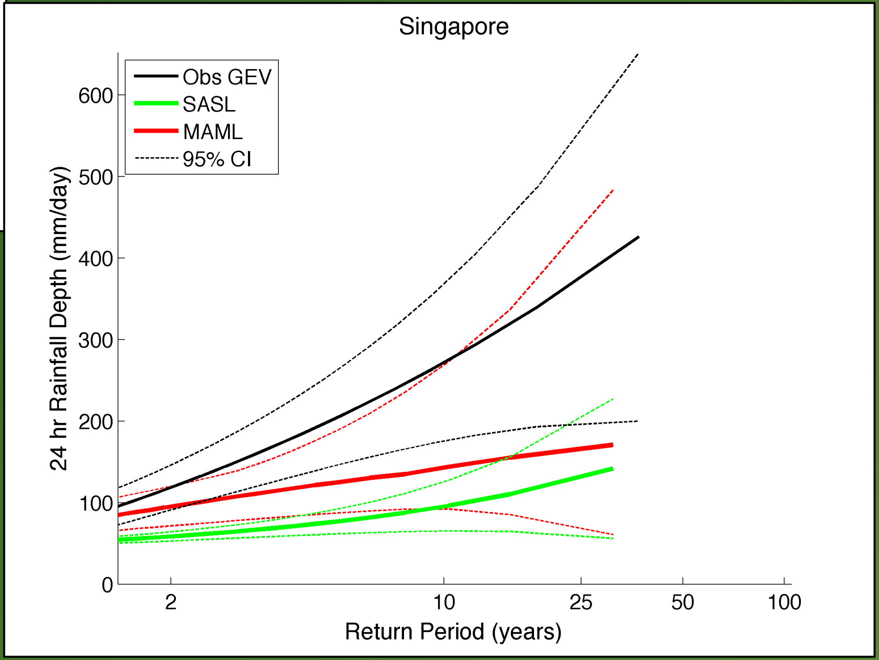
- Community Climate System Model
  - Prescribed ocean/ice, interactive land

- SASL, MASL and MAML simulations
  - 30 years integration with precipitation history output @ 24 hours
  - Climatological SST (fixed monthly average)
  - GCM resolution of 1.9 x 2.5 degree
- MASL and MAML
  - CRM resolution of 32 x 4 km

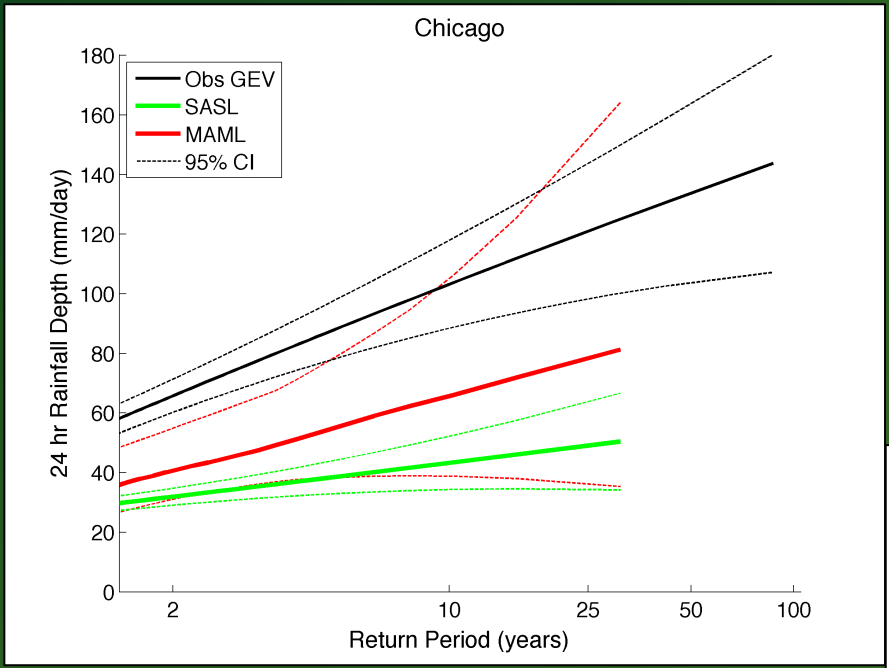
Results: Coastal Convective

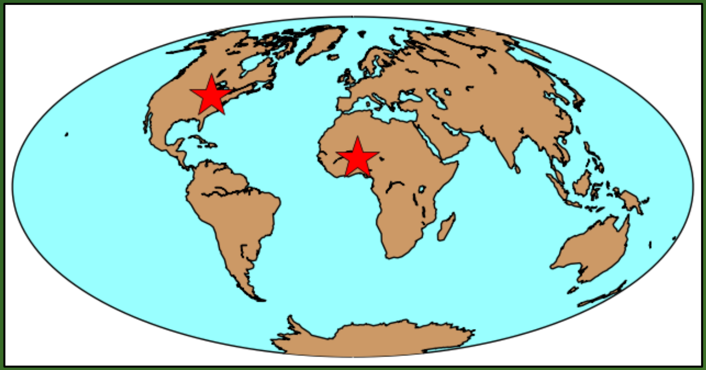


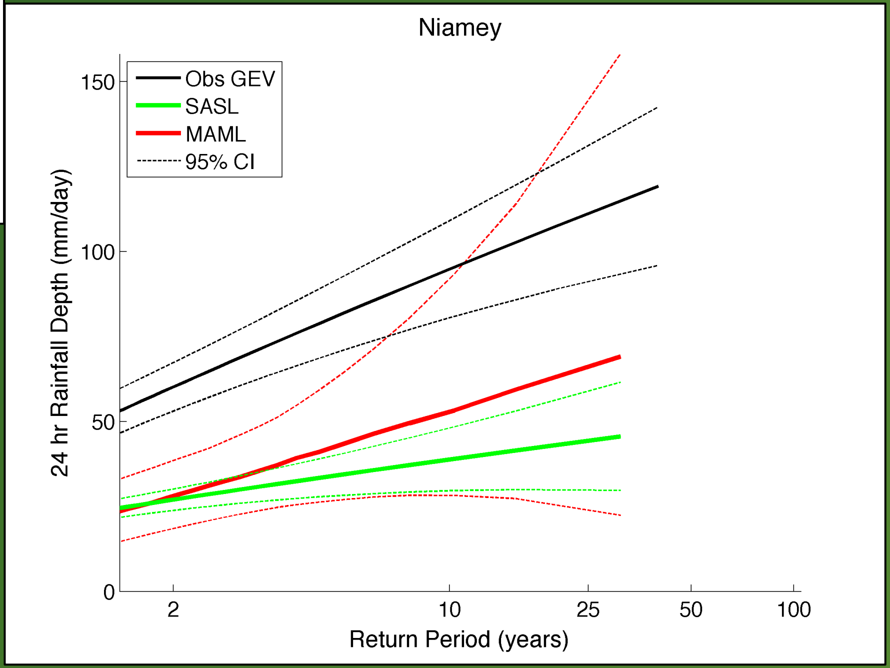




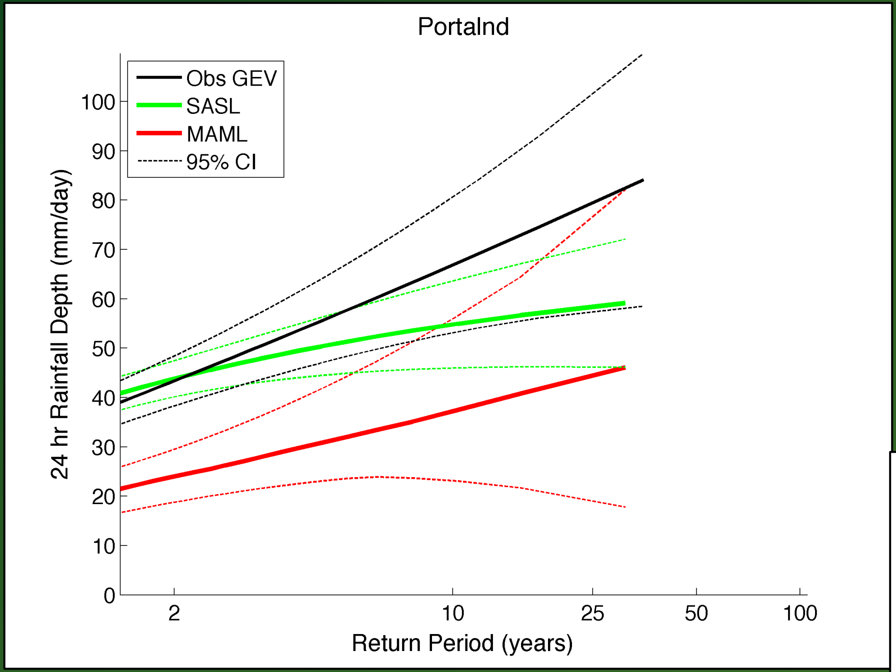
Results: Continental Convective

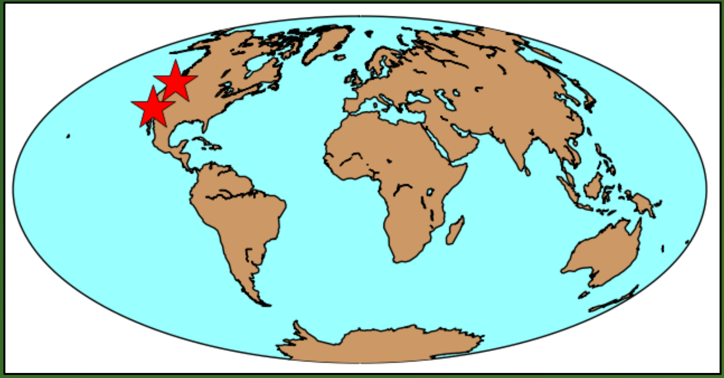


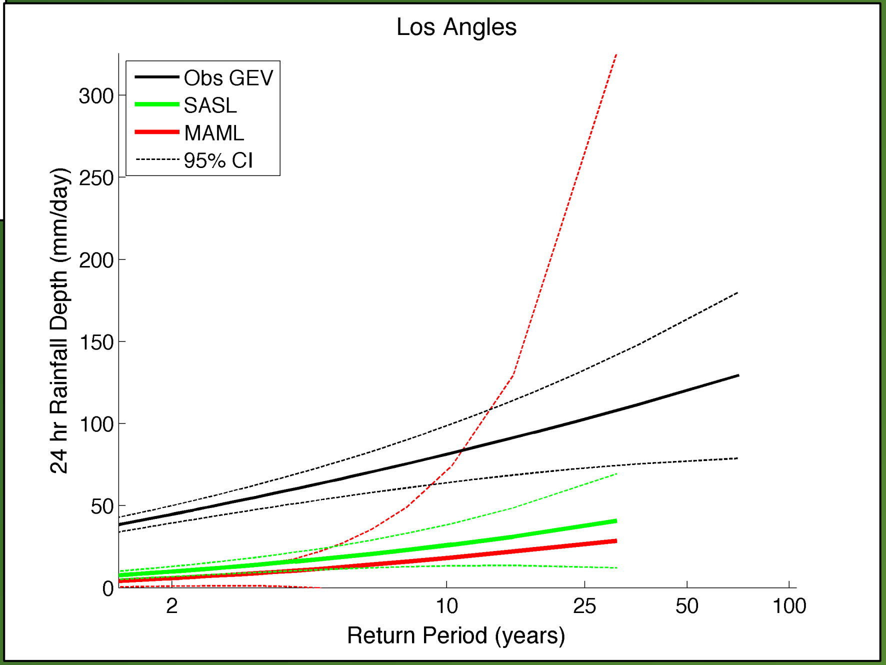




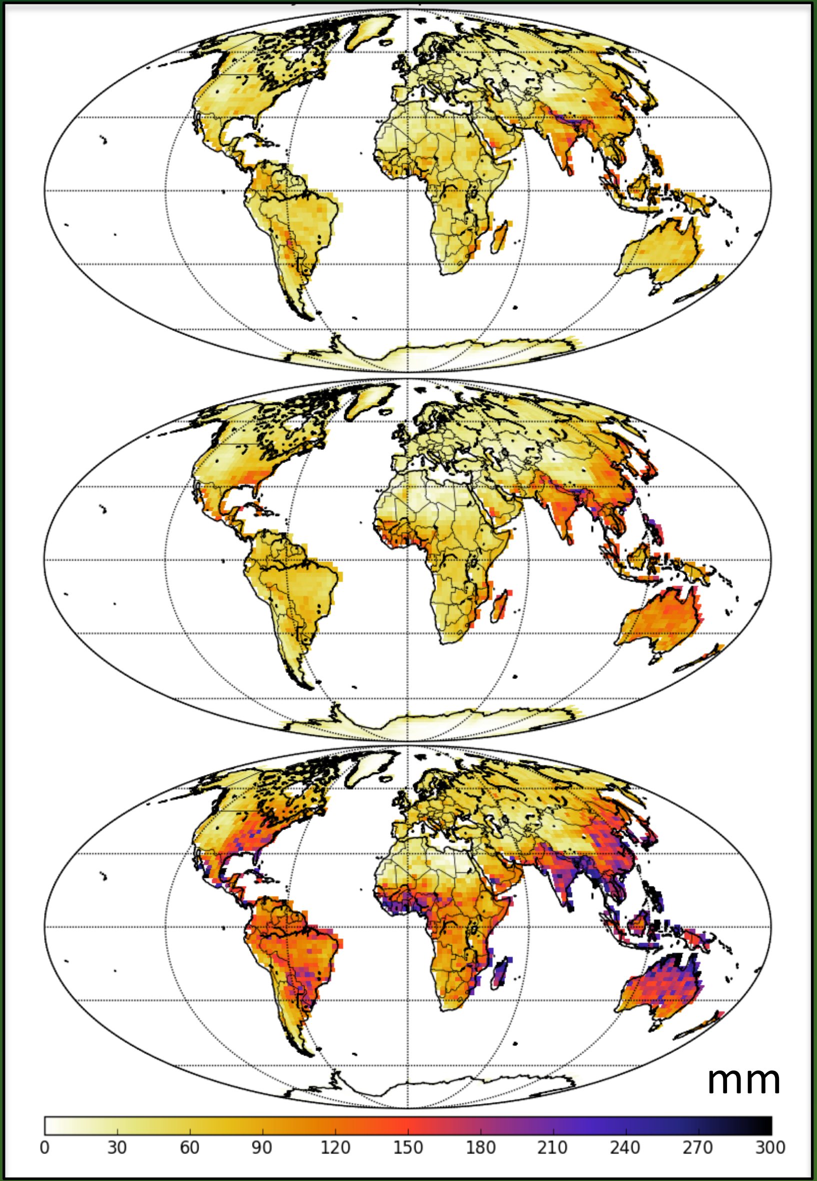
Results: Coastal Stratiform







Results: 30 Year, 24-Hour Storm Depth



SASL

MASL

MAML

Future Work

- Quantitative measure to evaluate simulated distributions against observations
- Global evaluation of model statistics against observations
- Investigate regions where MMF extremes are more like observations
- Sub-daily statistics and climate variability

References

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Jenkinson, A. F., 1955. The frequency distribution of the annual maximum (or minimum) values of meteorological elements. Quarterly Journal of the Royal Meteorological Society. 81(348), 158-171.

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Acknowledgements

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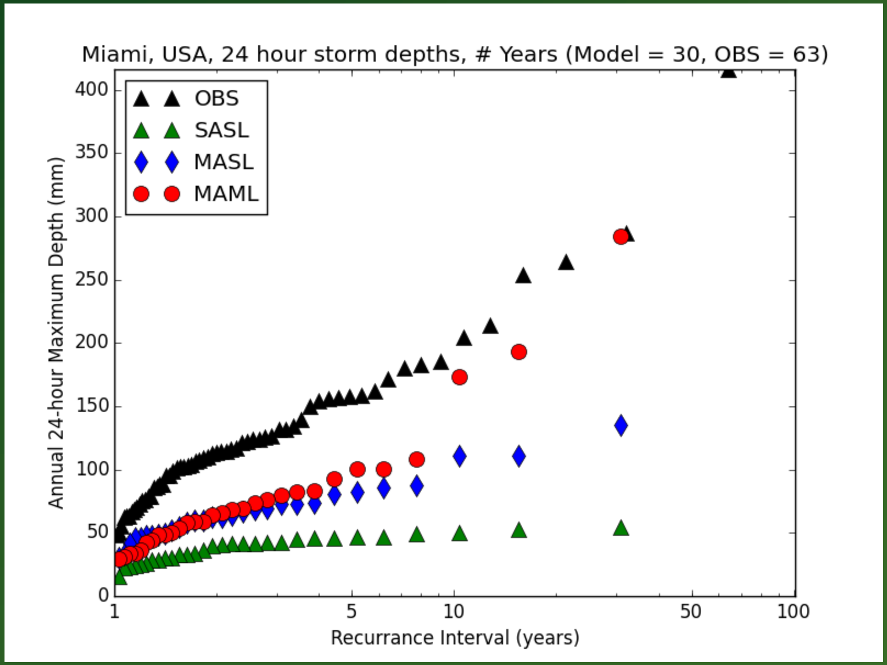
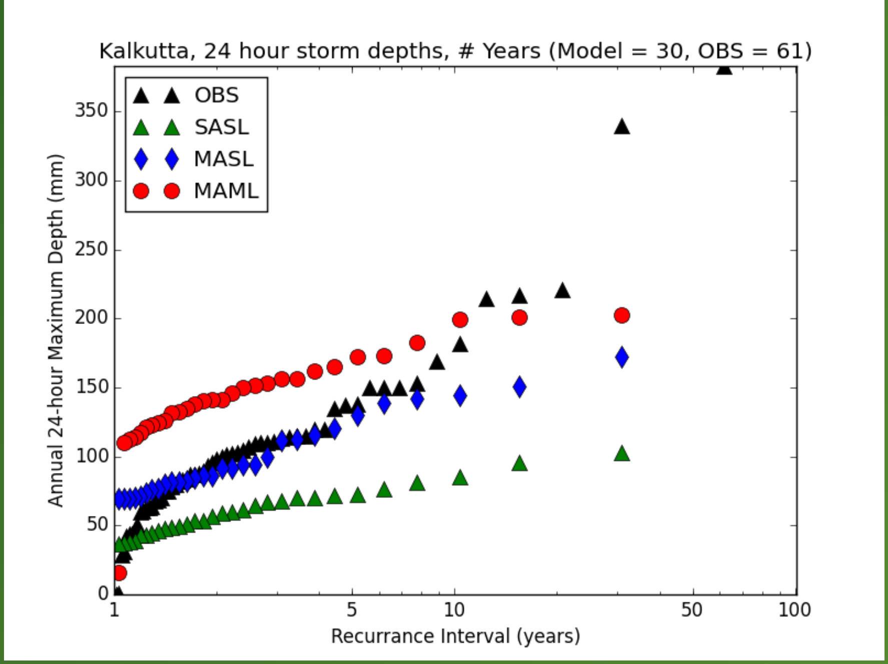
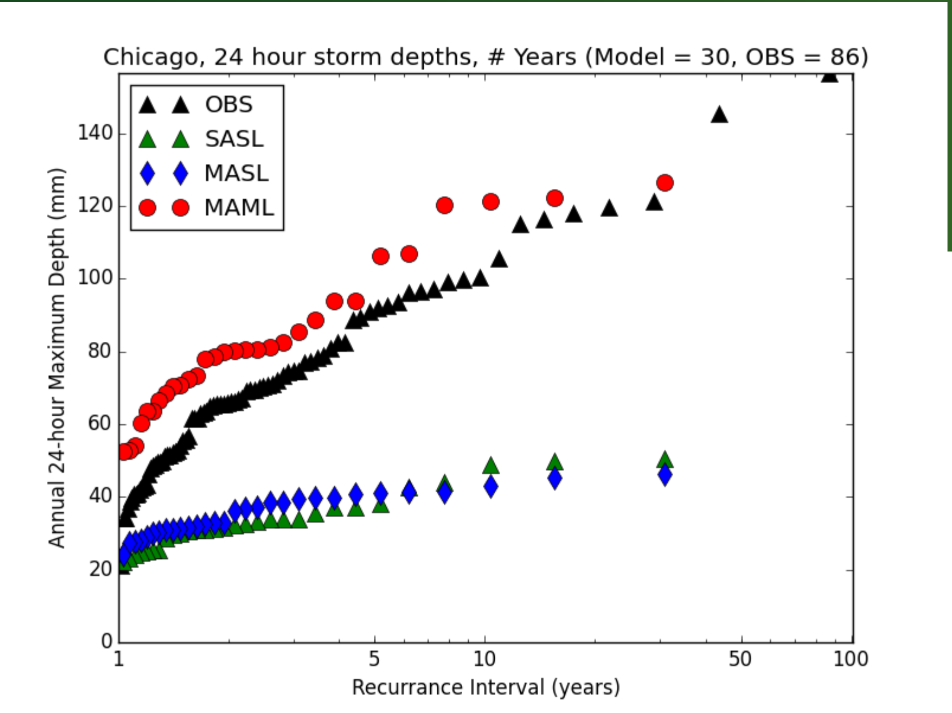
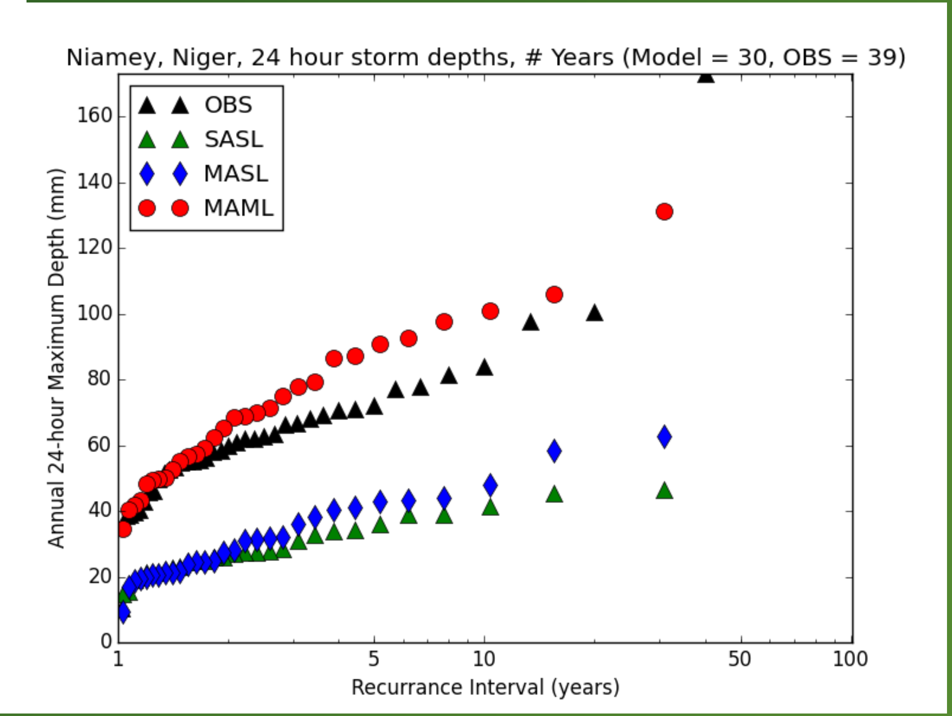
Appendix: SASL-MASL-MAML



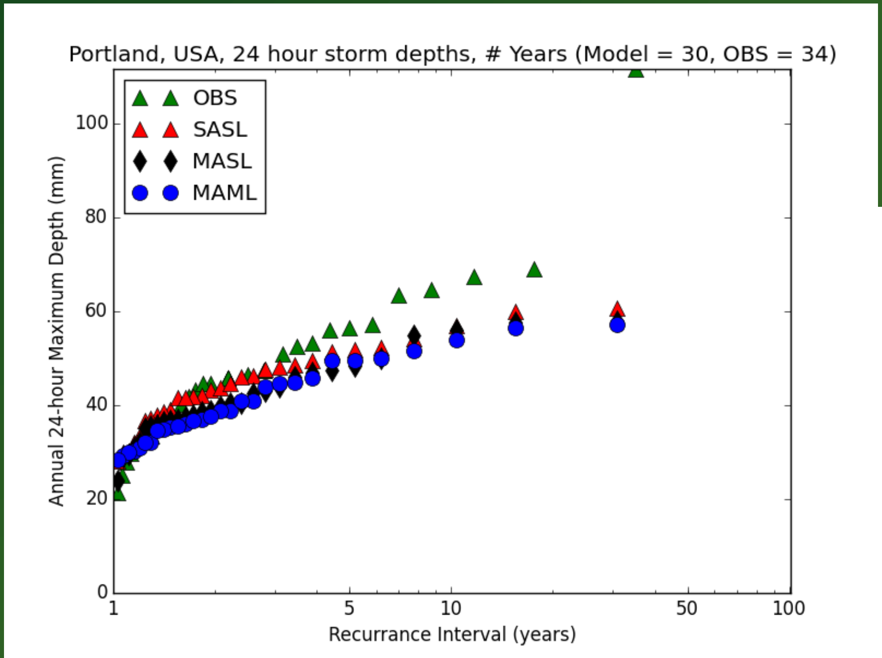


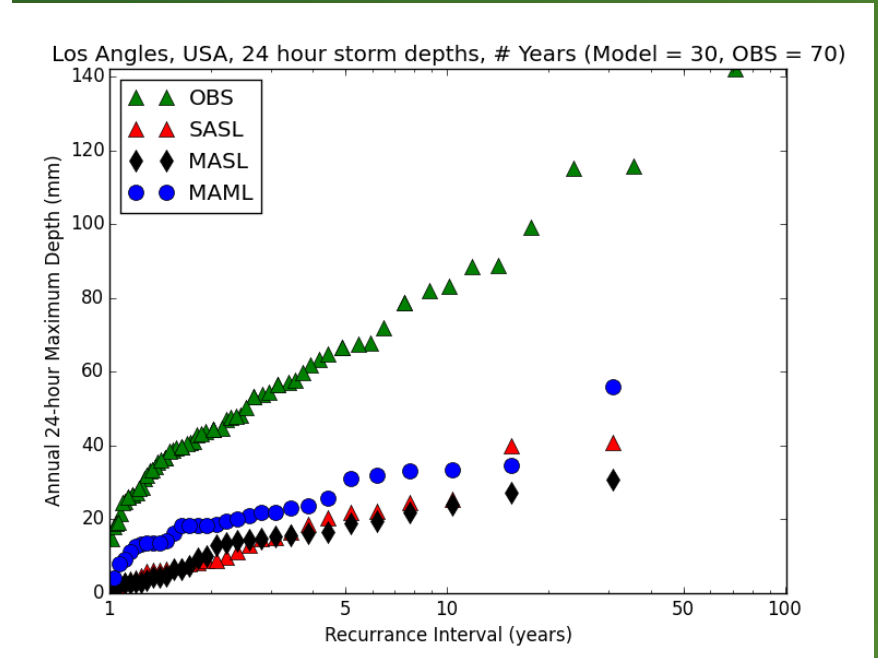
Appendix: SASL-MASL-MAML





Appendix: SASL-MASL-MAML





Outline

- Introduction
  - Extreme Rainfall in traditional Global Climate Models
    - Why do we care
    - Current methods to evaluate extreme rainfall from climate models (statistical vs dynamical)
  - MAML, MASL and SASL model architecture
- Methods/Results
  - Annual Maximum Series
    - Extreme Value Fitting
  - Spatial Trends
  - Future Work

Extreme Value Fitting: General Extreme Value Distribution

$$f(x) = \frac{1}{\sigma}\left[1+\zeta\left(\frac{x-\mu}{\sigma}\right)\right]^{-\frac{1}{\zeta}-1} \exp\left\{-\left[1+\zeta\left(\frac{x-\mu}{\sigma}\right)\right]^{-\frac{1}{\zeta}}\right\}$$

General Extreme Value Distribution (GEV)
Cumulative Density Function
ζ: Shape σ: Scale μ: Location

$$F(x) = \exp-\left[1+\zeta\left(1+\left(\frac{x-\mu}{\sigma}\right)\right)^{-\frac{1}{\zeta}}\right]$$

GEV: Quantile Function

$$x = \mu + \frac{\sigma}{\mu}\left[-1-\ln F(x)\right]^{-\zeta}$$

ζ, σ, μ estimated by maximizing the log-likelihood function of the GEV

$$L(\mu,\sigma) = -\sum_{i=1}^{n}\frac{x_i-\mu}{\sigma} - n\ln\sigma - \sum_{i=1}^{n}\exp\left[-\frac{x_i-\mu}{\sigma}\right]$$

$$\{\mu,\sigma \in \Re \mid \frac{\partial \ln(\mu,\sigma)}{\partial\mu} = \frac{\partial \ln(\mu,\sigma)}{\partial\sigma} = 0\}$$