# Extremes in the Lorenz Energy Cycle

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## SUMMARY

The energy fluxes in the global mean Lorenz energy cycle show a Generalized Extreme Value (GEV) distribution. Energy fluxes include all energy transfers like forcing, dissipation and all conversions between the energy reservoirs. The data basis is a 1000 year simulation with a dynamic model.

## MODEL

PUMA, a simplified hydrostatic model, dynamical core, resolution: T21L10, 1000 years, present-day climate. Note that the model is dry and the radiation is parameterized with Newtonian cooling. The model provides 6h data used to calculate the Lorenz energy cycle.

## METHOD

The analysis is based on two distributions:

1. GEV distribution

$$f(z) = (1/s)(1+\xi z)^{-1-1/\xi}, \quad z = (x-\mu)/s$$

2. Generalized Gumbel distribution

$$G_a(x) = \frac{\theta_a a^a}{\Gamma(a)} \exp\{-[\theta_a(x+\nu_a) + e^{-\theta_a(x+\nu_a)}]\}$$

$$\theta_a^2 = \frac{d^2 \ln \Gamma}{da^2}, \quad \nu_a = \frac{1}{\theta_a}\left(\ln a - \frac{d \ln \Gamma}{da}\right).$$

**References:**

Blender, R., D. Gohlke, F. Lunkeit, 2018: Fluctuation analysis of the atmospheric energy cycle. Physical Review E 98, 023101

Bramwell, S. T., P. C. W. Holdsworth, J.-F. Pinton, 1998: Universality of rare fluctuations in turbulence and critical phenomena, Nature 396, 552.

Messori, G. A. Czaja, 2013: On the sporadic nature of meridional heat transport by transient eddies, Quart J. Roy. Met. Soc., 139, 999-1008

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## LORENZ ENERGY CYCLE

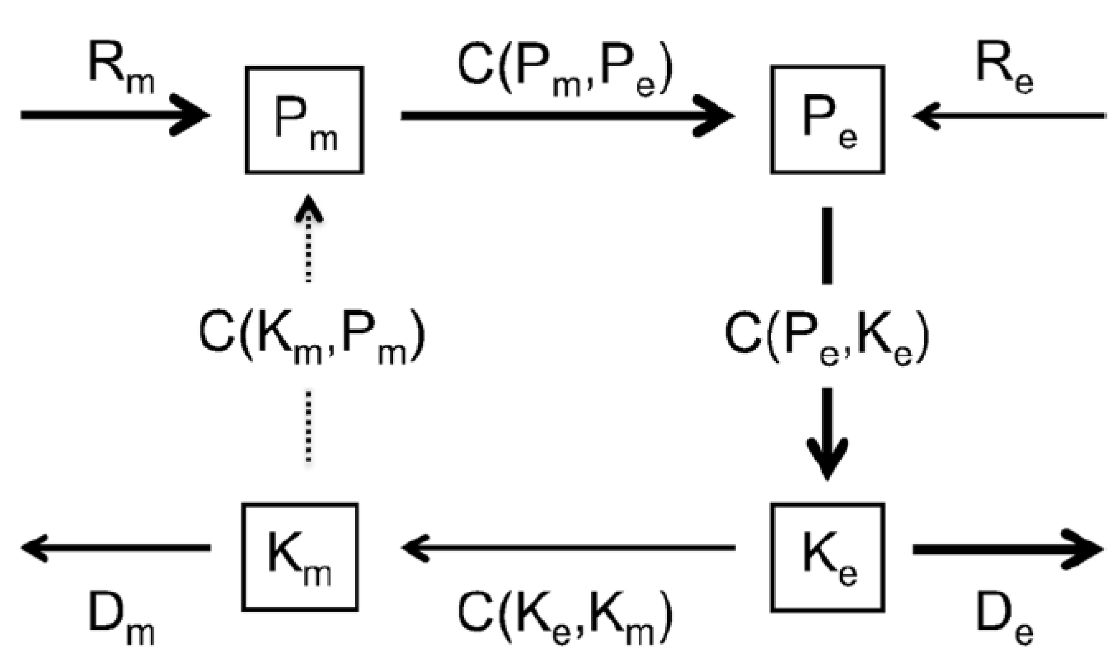



Fig. 1: Energy compartments of the cycle: P = Available potential energy, K = Kinetic energy, R = Forcing, and D = Dissipation. C denotes the conversions between the energy compartments: $C(P_m, P_e)$, $C(P_e, K_e)$, $C(K_e, K_m)$, $C(K_m, P_m)$. The indices are m for zonal means and e for eddies. Intense currents thick, moderate thin, and weak dotted.

## CONCLUSIONS

**Interpretation:**

- The energy currents behave like extremes (in the whole data range). This result is a pure dynamic effect.

**Physical origin:**

- This behaviour is a general property in correlated physical systems. The physical origin are long-range correlations

**Consequences:**

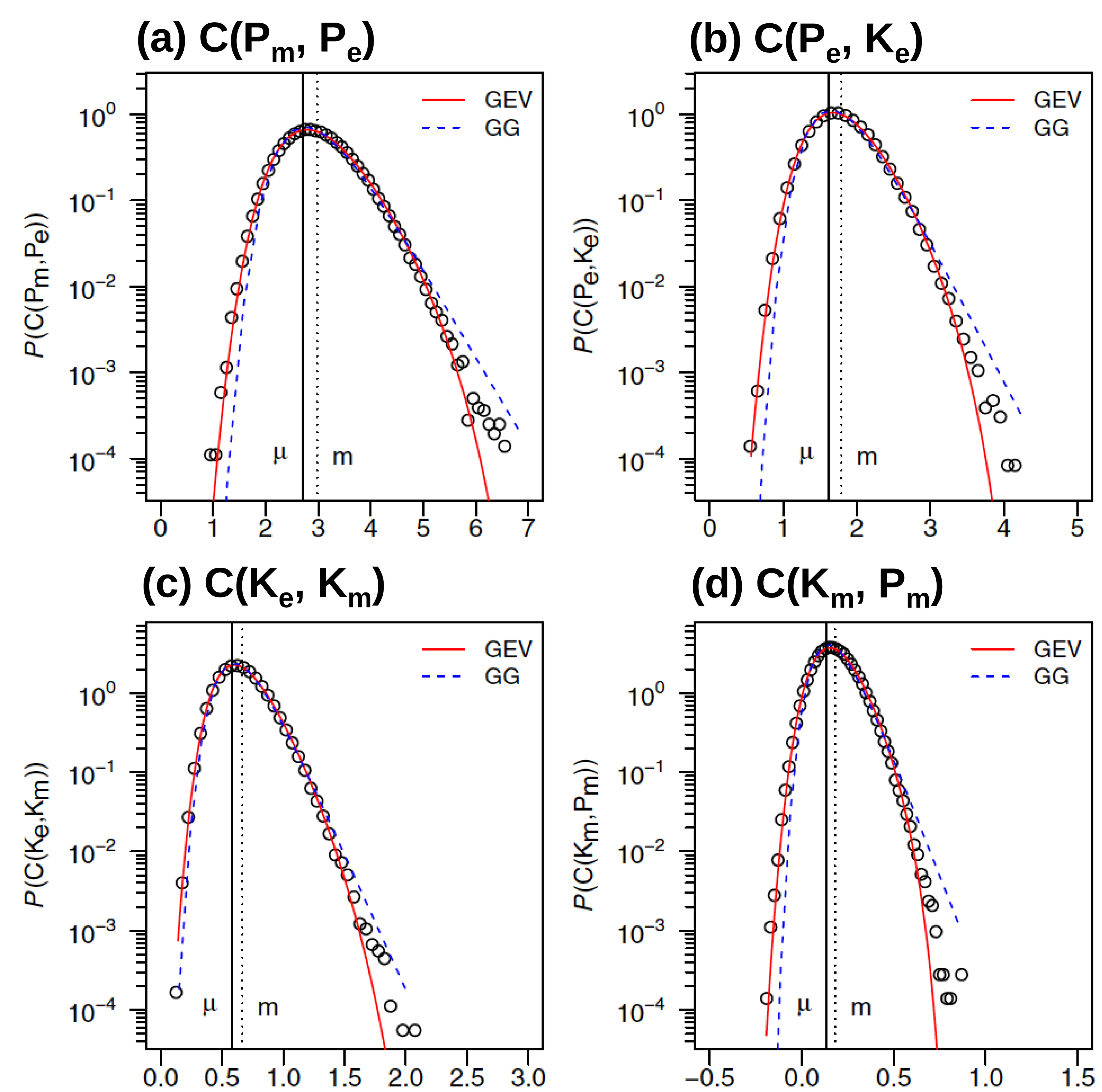
- The currents are skewed and not Gaussian as expected for means. This has to be considered in statistical analyses.

**Related work:**

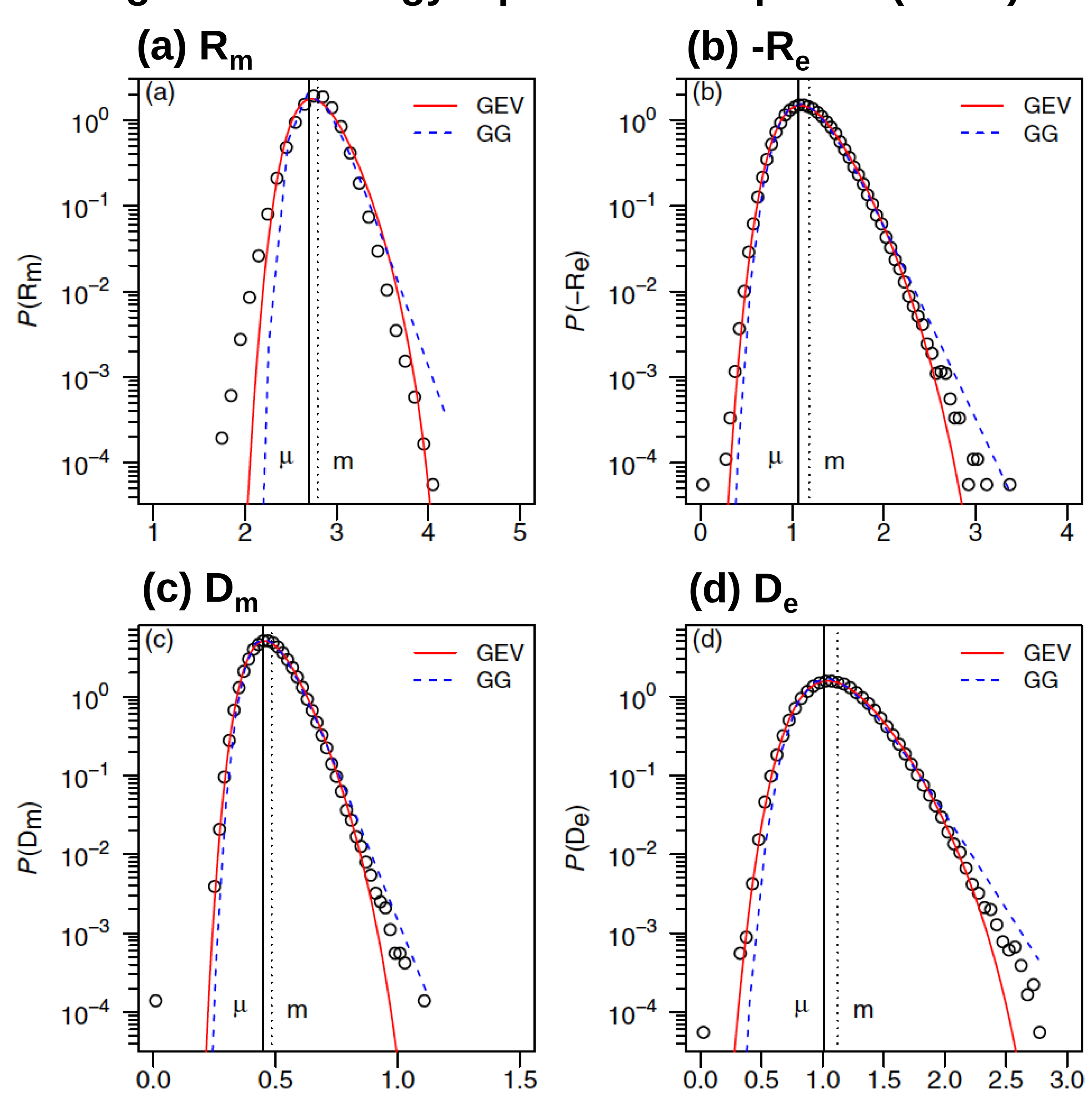
- Extreme value distributions are found in many different complex physical systems (Bramwell et. al. 1998). In heat flux distributions, Messori and Czaja (2013) find similar skewness.

## RESULTS

### Histograms of internal currents (conversions in W/m²)




### Histograms of energy input and dissipation (W/m²)




**μ GEV location parameter**

**m mean**