The Stochastic Framework for Understanding Climate

(Not all randomness is created equal)

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A high-resolution GCM may be able to generate chaotic structures that we want to parameterize in a simpler, coarse-resolution model. The *Central Limit Theorem* says when and how we can treat this variability as a Gaussian *or a Gaussian-driven* (not itself Gaussian) process.

\[ e.g., \text{Sardeshmukh and Penland (2015)} \]
NAO acts as stochastic forcing of North Tropical Atlantic SST

(Essentially) Gaussian example: \[
\frac{dx_i}{dt} = \sum_j L_{ij} x_j + \xi_i
\]

Penland and Hartten (2014)
Example with forcing that is nearly, but not quite, Gaussian: Tropical SSTs. Predictable on seasonal timescales, but…

\[ R = 0.73 \]
Example with forcing that is nearly, but not quite, Gaussian (cont.):

\[ \frac{dx_i}{dt} = \sum_j L_{ij} x_j + \xi_i \]

\( \xi(t) \) may be estimated as white even on sub-monthly timescales.

About 10% of the stochastic forcing variance of tropical SSTA is MJO.
Daily anomalies of

1) Relative vorticity
2) Temperature
3) Vertical velocity

are well-approximated by

\[
\frac{dx}{dt} = Lx + (Ex + g)\xi_1 + b\xi_2 - \frac{Eg}{2}
\]

Sardeshmukh et al. (2015)
Sardeshmukh and Penland (2015)
Summary and Conclusions

• The stochastic forcing the Earth system cares about has a dynamical/physical basis. It may not be Gaussian.

• We can objectively estimate the time series of stochastic forcing using Linear Inverse Modeling in a multi-resolution setting.

• We can use these estimations to investigate the multiscale nature of the climate system.

• We may be the only ones doing this type of work.