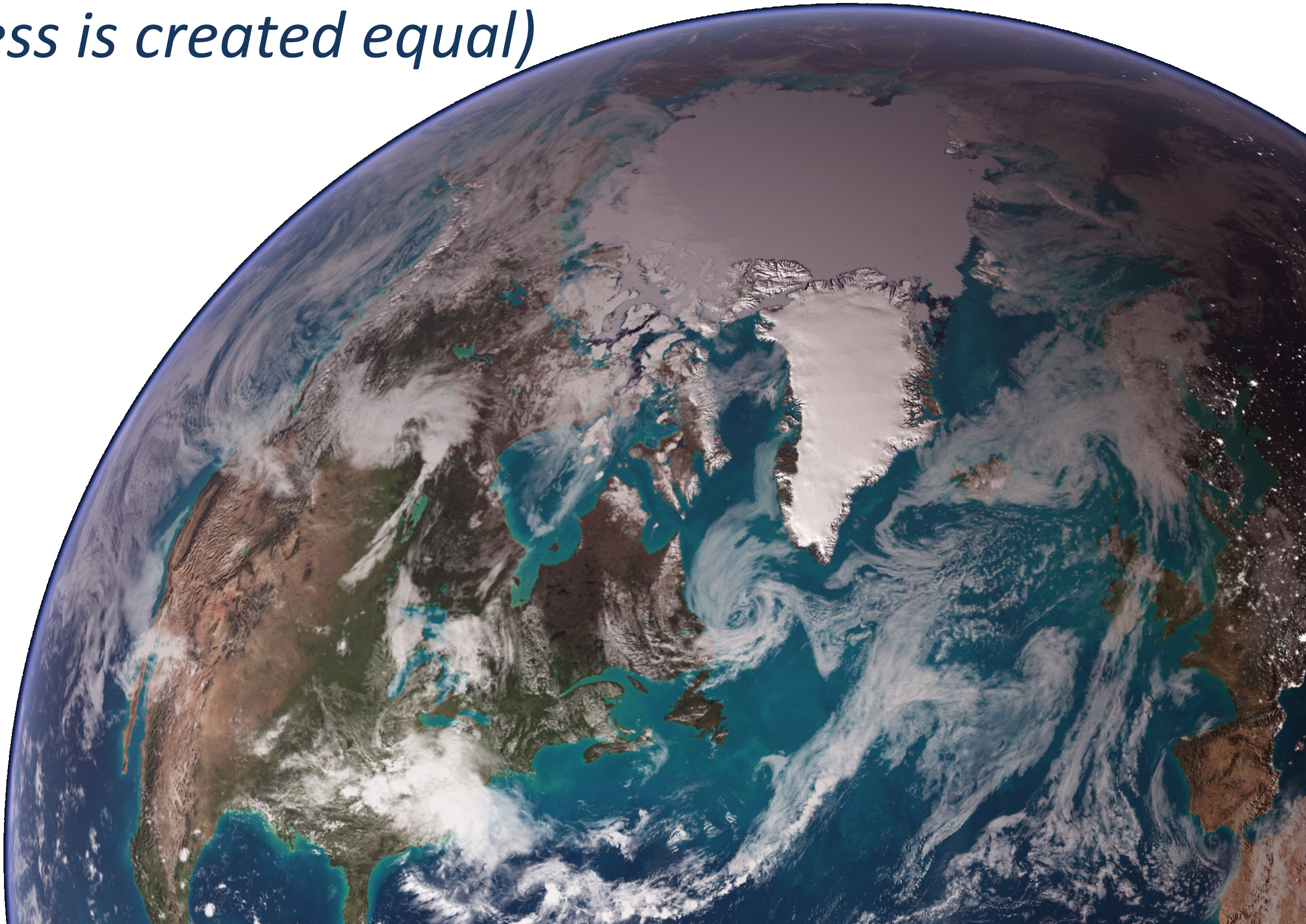
The Stochastic Framework for Understanding Climate

(Not all randomness is created equal)



Cécile Penland

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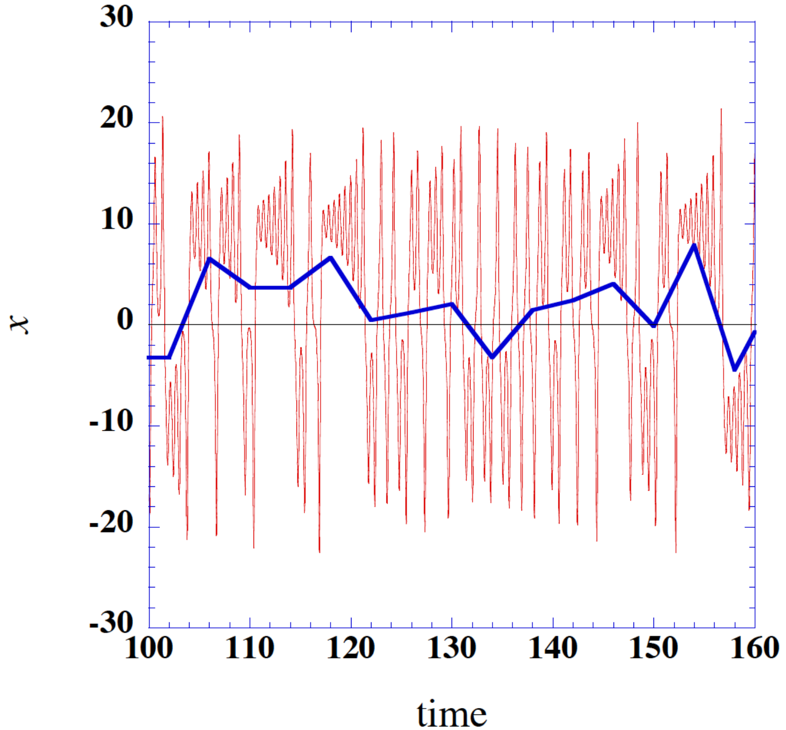
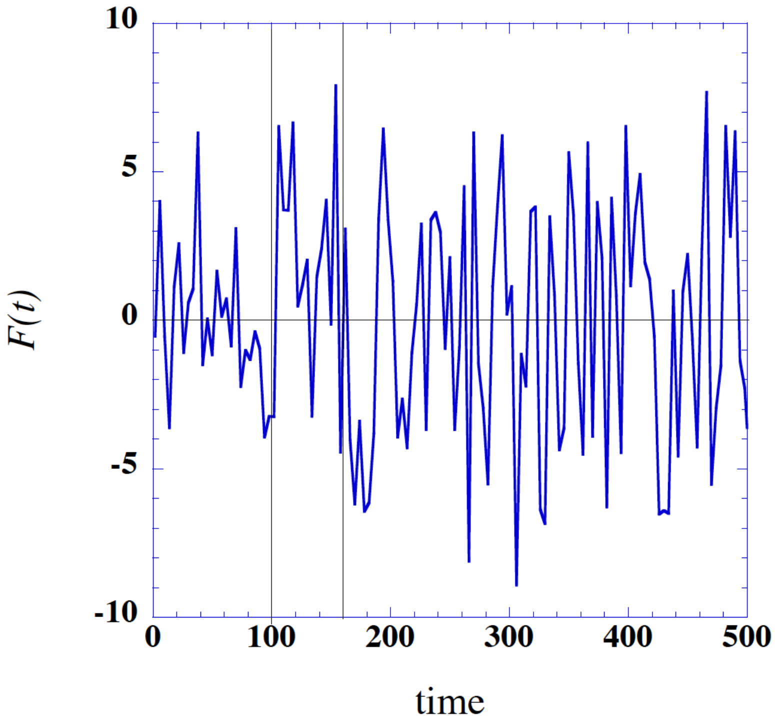
A high-resolution GCM may be able to generate chaotic structures that we want to parameterize in a simpler, coarse-resolution model. The ***Central Limit Theorem*** says when and how we can treat this variability as a Gaussian *or a Gaussian-driven* (not itself Gaussian) process.

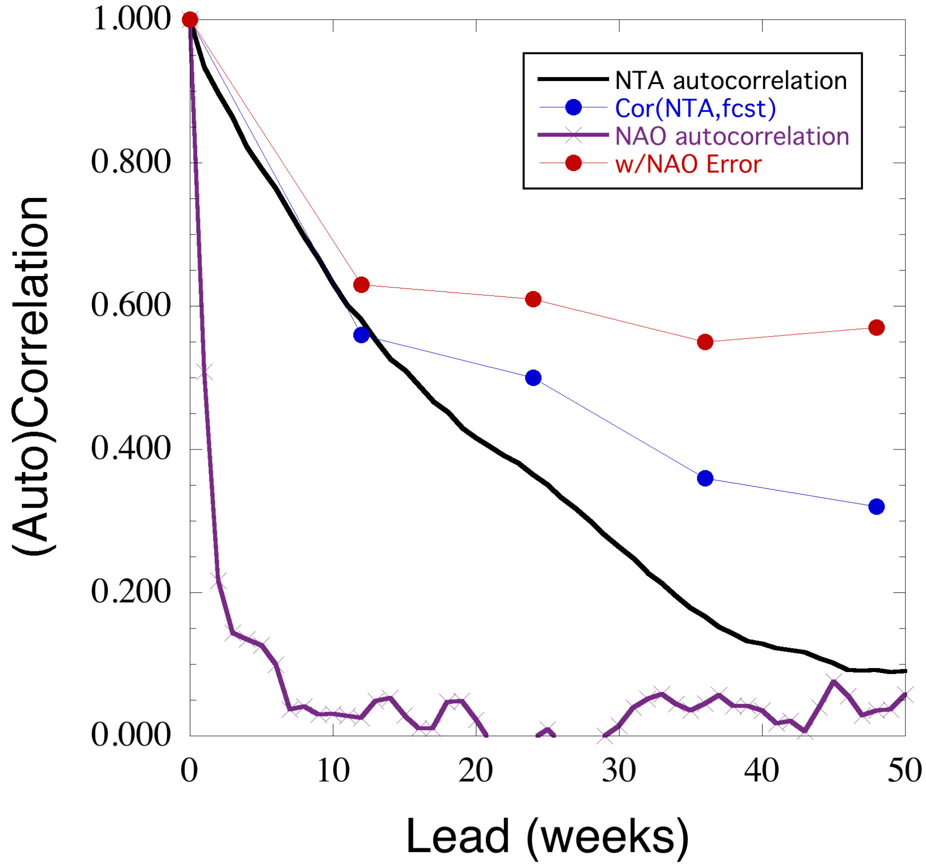


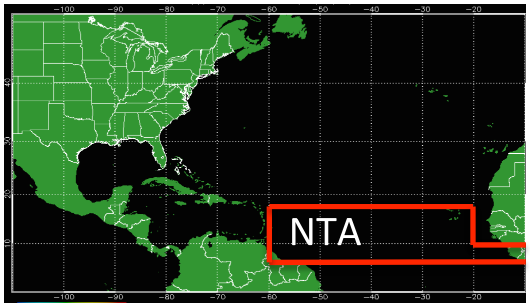


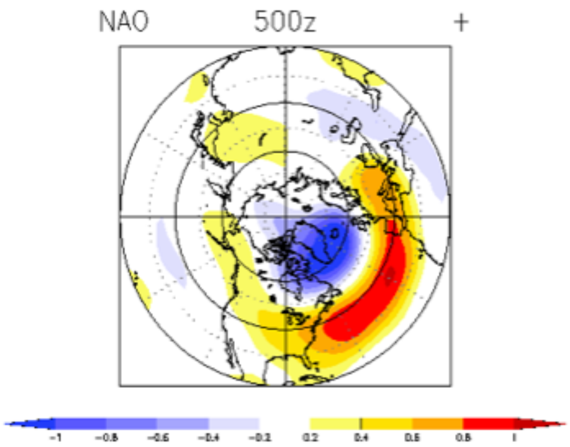
 e.g., Sardeshmukh and Penland (2015)

NAO acts as stochastic forcing of North Tropical Atlantic SST

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

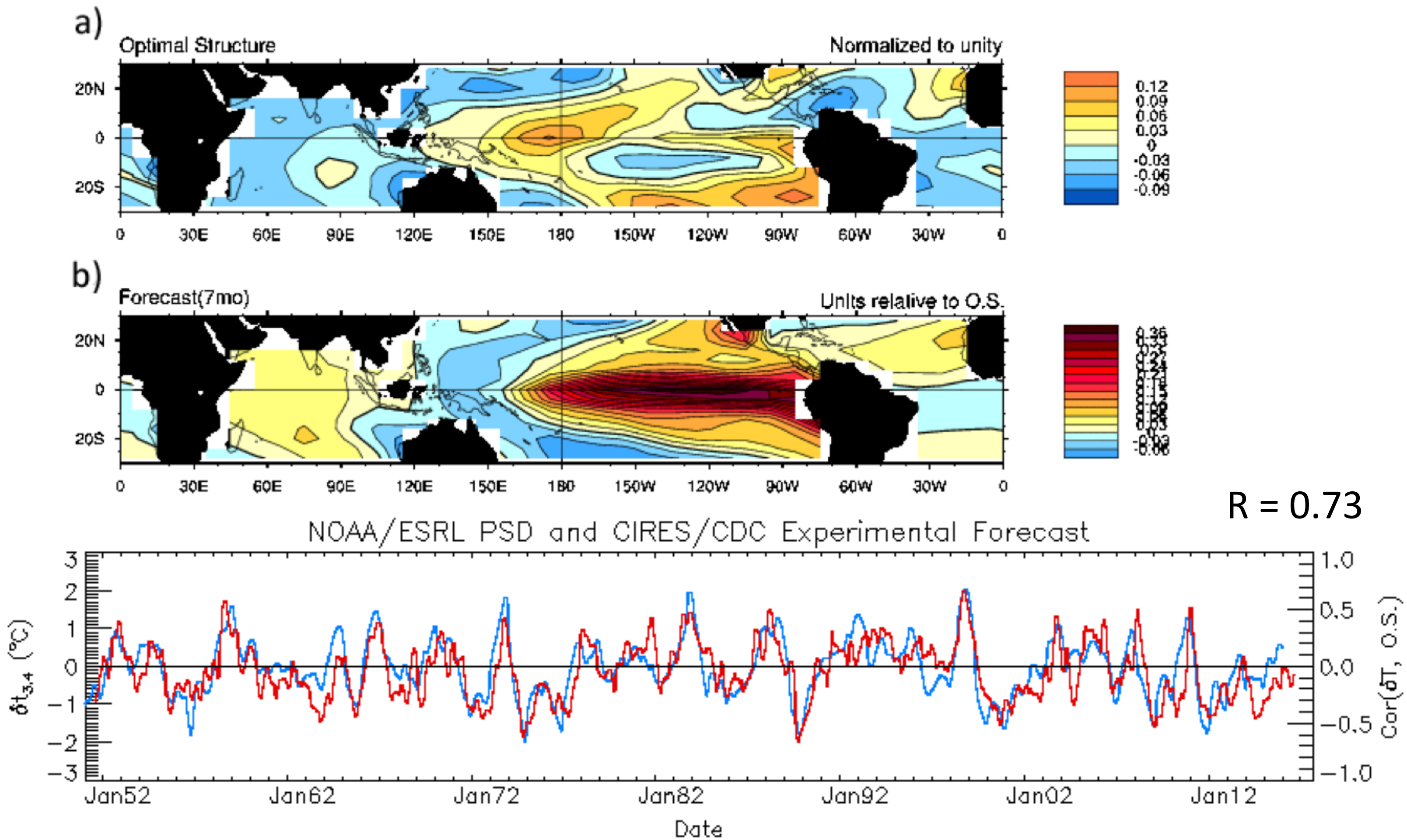






 Penland and Hartten (2014)

Example with forcing that is nearly, but not quite, Gaussian: Tropical SSTs. Predictable on seasonal timescales, but…

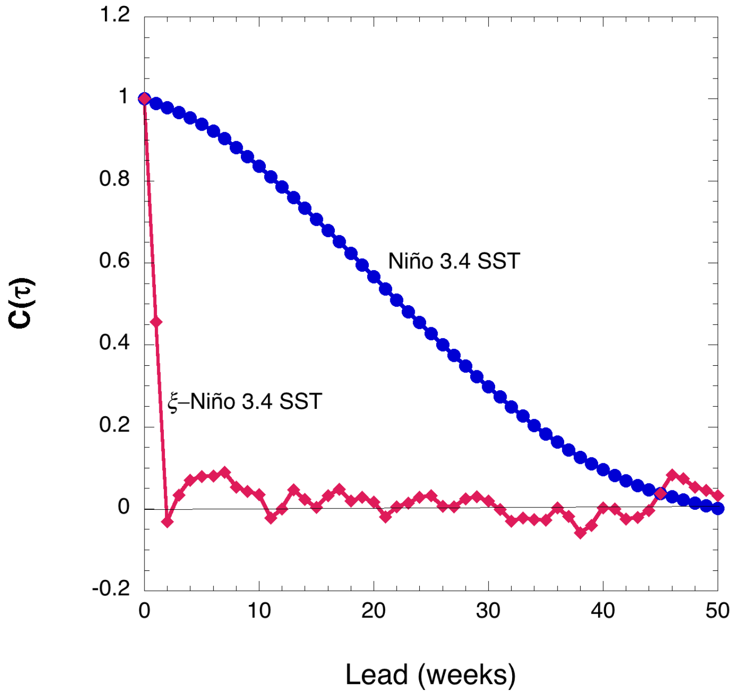


(*Penland and Sardeshmukh (1995)*

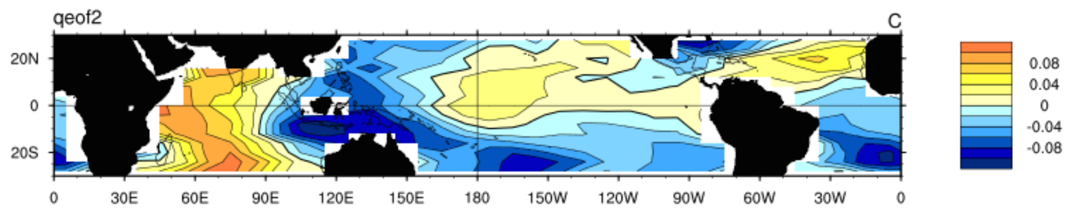
Example with forcing that is nearly, but not quite, Gaussian (cont.):

…stochastic forcing still important.

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



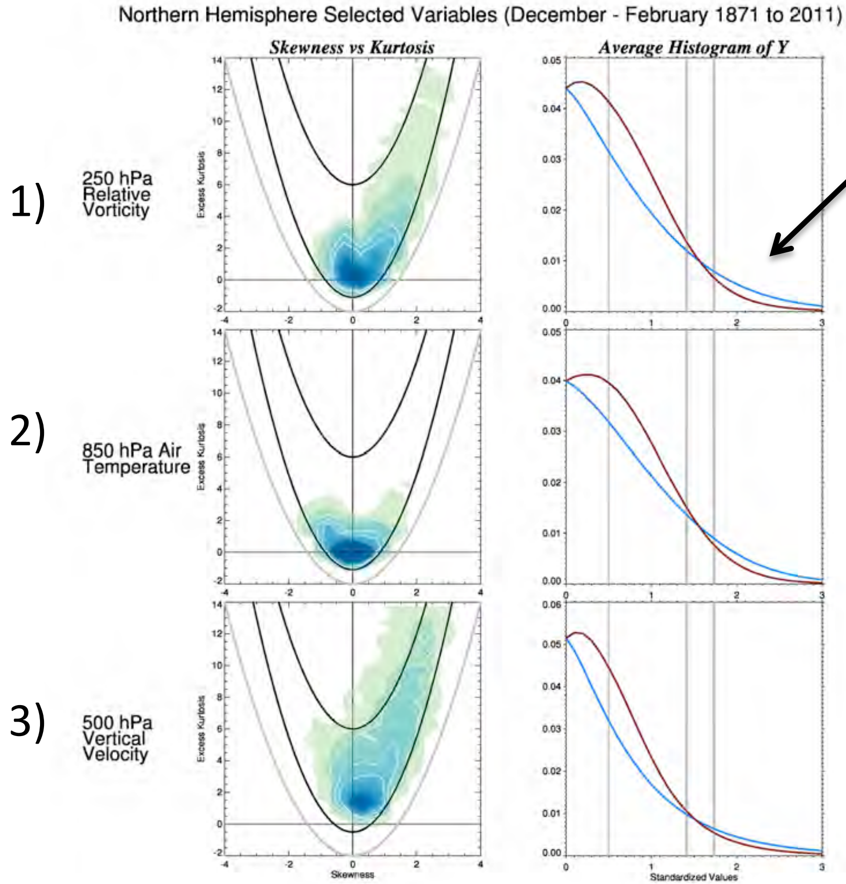
$\xi(t)$ may be estimated as white even on sub-monthly timescales.



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

Non-Gaussian example: (with heavy tails)

Skew vs. Kurtosis PDF



Daily anomalies of

1) Relative vorticity
2)Temperature
3)Vertical velocity

are well-approximated by

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

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.