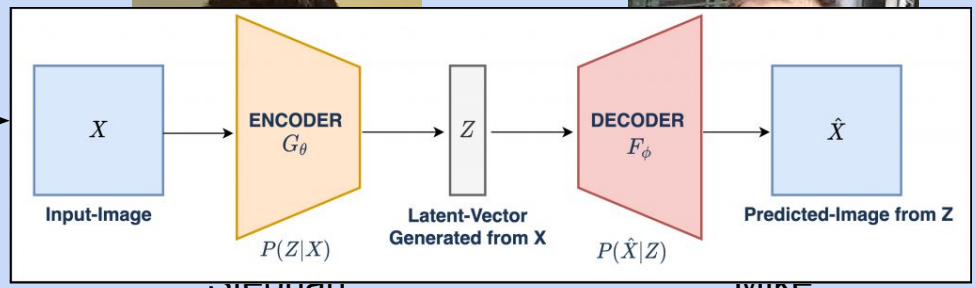
An Unsupervised Learning Perspective on the Dynamic Contribution to Extreme Precipitation Changes



Mooers

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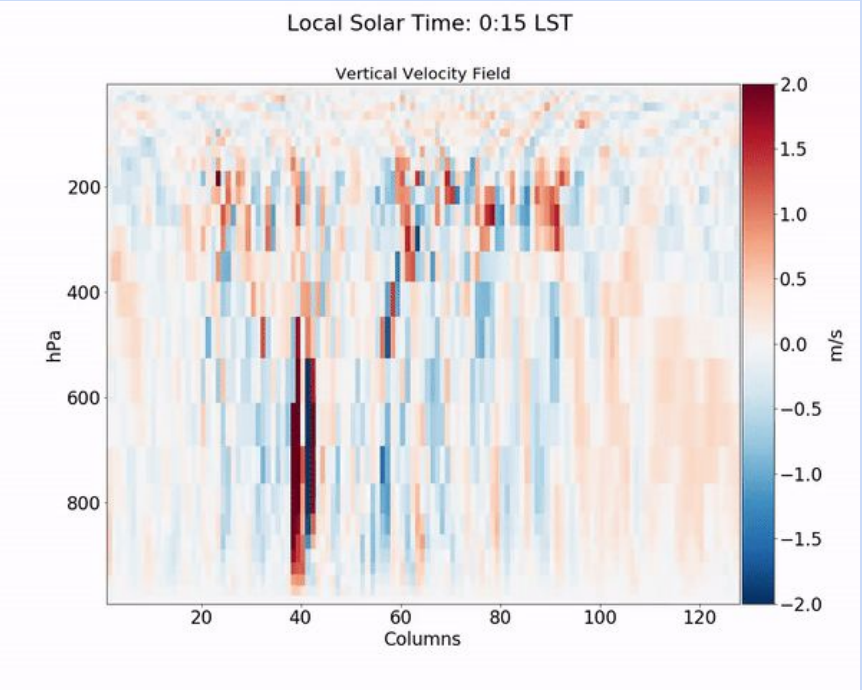
Our Claims

Unsupervised Machine Learning Extracts Planetary Patterns of Convective Responses to Global Warming

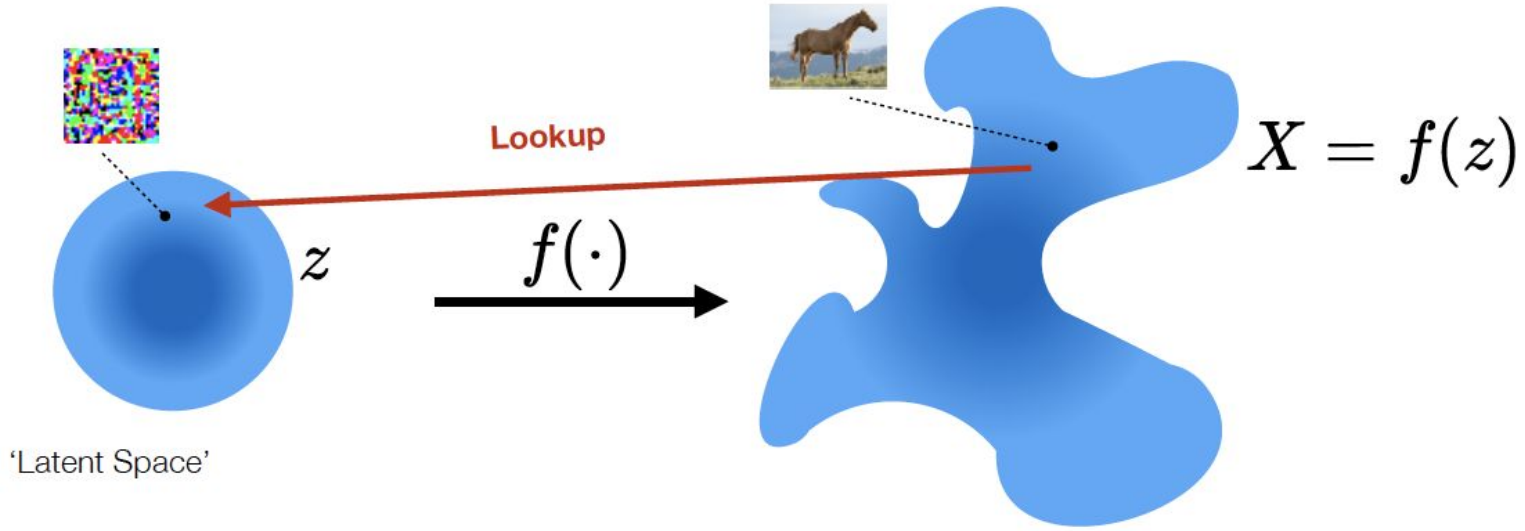
Changes in Extreme Precipitation with Global Warming are Controlled by the Changes in Patterns of Storm Dynamics

Background: Extreme Precipitation Uncertainty



- High confidence of an increase in extreme precipitation with global warming (IPCC)
- Leading to increase in flood related risks, issues in water management, threats to significant populations.
- Large uncertainty about the details of this increase, especially at local/regional level.
- To better understand controls on extreme precipitation we look at the dynamical component through vertical velocity fields.

Popular Model Class: Deep Latent Gaussian Models (GANs/VAEs)



Deep generative models (VAEs, GANs) may also serve for data compression

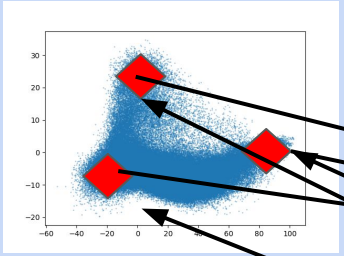
For a given X, we can look up it's *latent variable (or code)* z

Slide from Dr. Stephan Mandt, Deep Generative Models 2020 (CS 295)

Latent Space Analysis of Climate Change

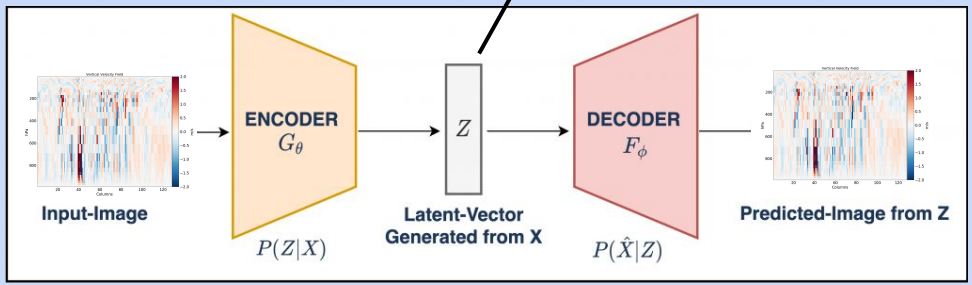
Standard Simulation

+4K Simulation



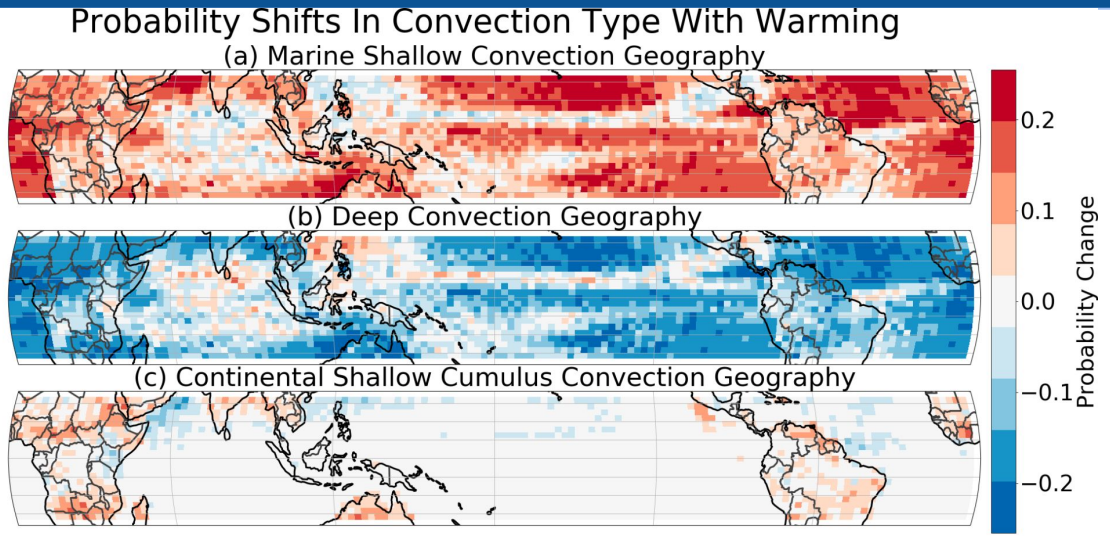
Perform K Means Clustering on Latent Space.

Save Centers From Clustering.



Use saved centers to initialize K-Means Clustering on +4K data and track how each convective regime shifts.

Data Driven View of Global Warming



Concentration of Deep Convection over warm waters

Expansion of dry zones over the continents

$$\pi_k^{+4K} - \pi_k^{0K}$$

At every geographic location we get the probability of a type of convection forming in both our control and warmed climates

m/s

Our Claims

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Unresolved: *What controls the changes in the patterns of extreme precipitation?*

1. Do shifts in extreme precipitation follow changes in deep convection?

2. Or are there more complex changes in how deep convection produces rain?

Building a Simple Model

We can approximate the dynamical changes, D(w), in extreme precipitation with just the following:

- Values for extreme precipitation and saturation specific humidity from our simulation data allowing us to implement a linear regression model

$$P_{\text{extreme}} \approx q_{\text{sat}} \times \mathcal{D}(w)$$

- Geographically conditioned convection probabilities from our clustered VAE latent space which we can use to estimate Dynamical Pre-factors

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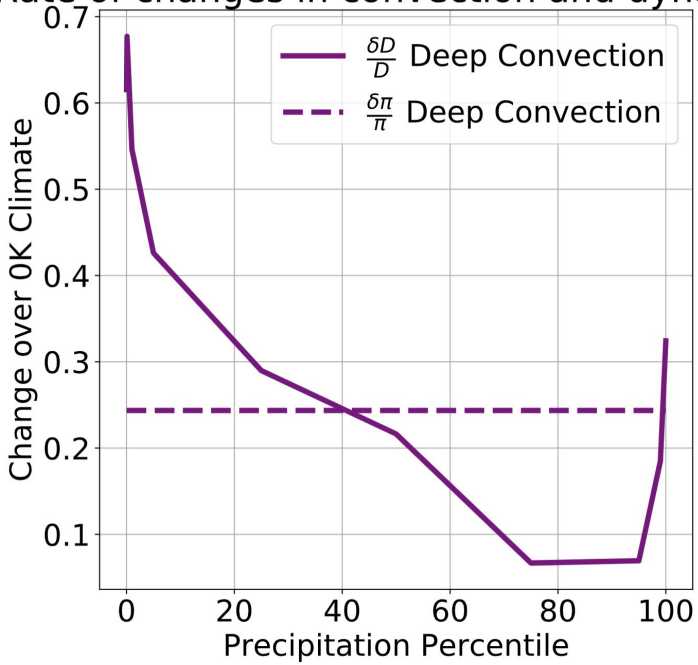
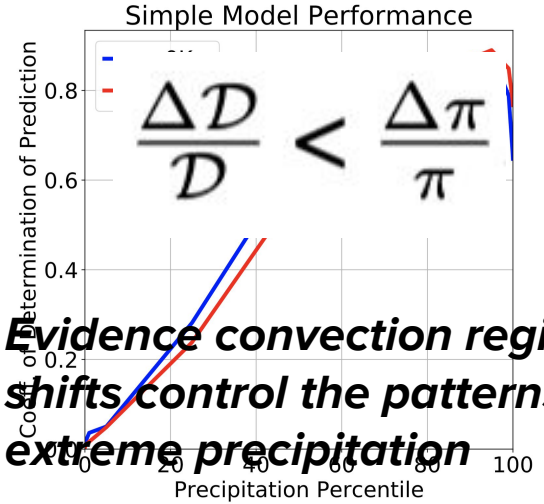
$$\mathcal{D}(w) \approx \mathcal{D}_0 + \sum_{i=1}^{N} \pi_i \mathcal{D}_i,$$

Model Findings

Rate of changes in convection and dynamics

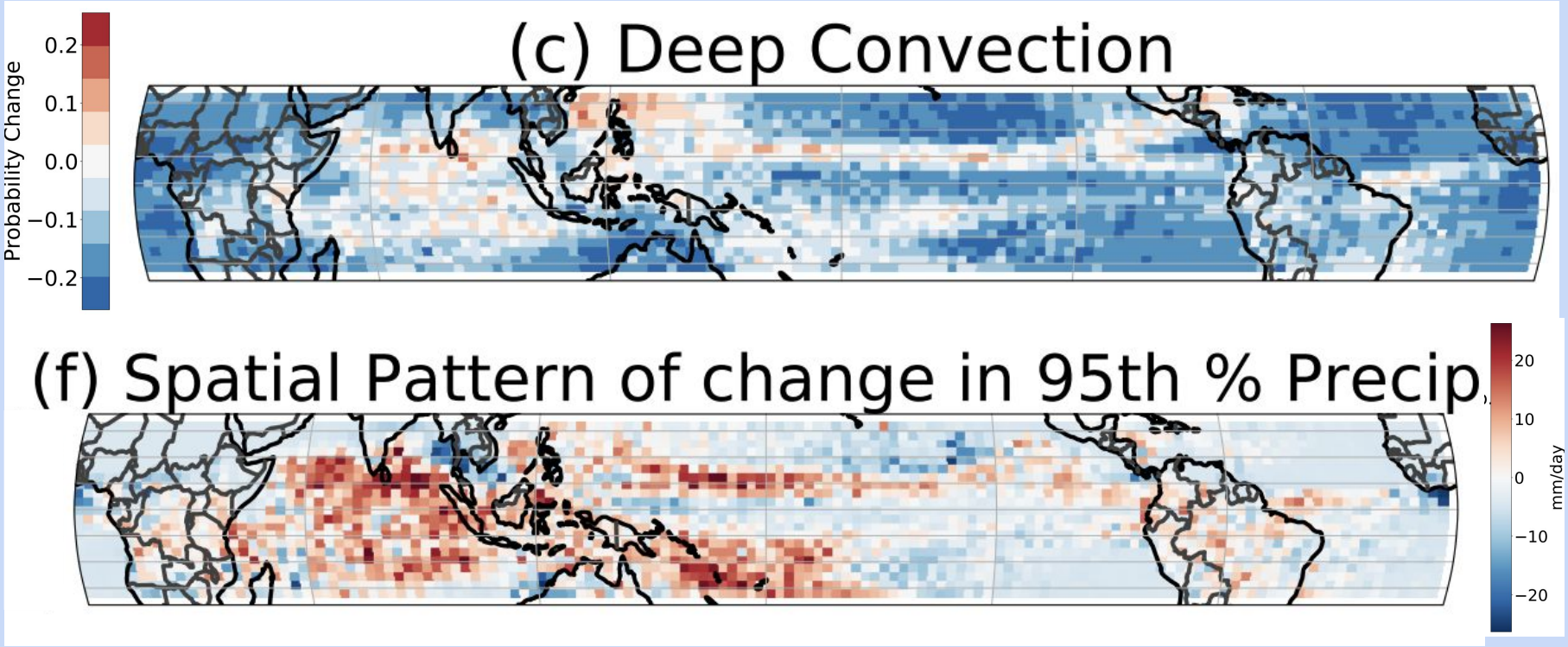


Where our model is valid (High Precipitation percentiles where thermodynamic role is smaller):



Evidence convection regime shifts control the patterns of extreme precipitation

Deep Convection Controls Extreme Precip Dynamics



Discussion

We provide a framework by which unsupervised machine learning compares different climates.

Supports and provides a complementary view of the the anticipated signals of climate change.

Allows us to better understand and anticipate flood risks and hydrological changes.

Highlights the role of deep learning in understanding global warming.

Full Preprint