Loosely Conditioned Emulation of Global Climate Models With Generative Adversarial Networks

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Introduction

- Climate models encapsulate our understanding of the Earth system
    - Allows research on future realizations of Earth
    - Estimating risks of extreme weather events requires numerous realizations

- Current climate models are computationally expensive (days to months)

- Deep learning can provide a solution:
    - Train a Generative Adversarial Network (GAN) to emulate Earth System Models (ESMs)
    - Generate realizations rapidly («1s)

Data

- Daily global precipitation output from the MIROC5 ESM
  - 725, 45, and 45 years of ESM data for train, validation, and test
  - Model 32-day sequences (“months”)
  - Two models, loosely conditioned by training on disjoint boreal “seasons”
    - Fall-Winter
    - Spring-Summer

Problem Formulation

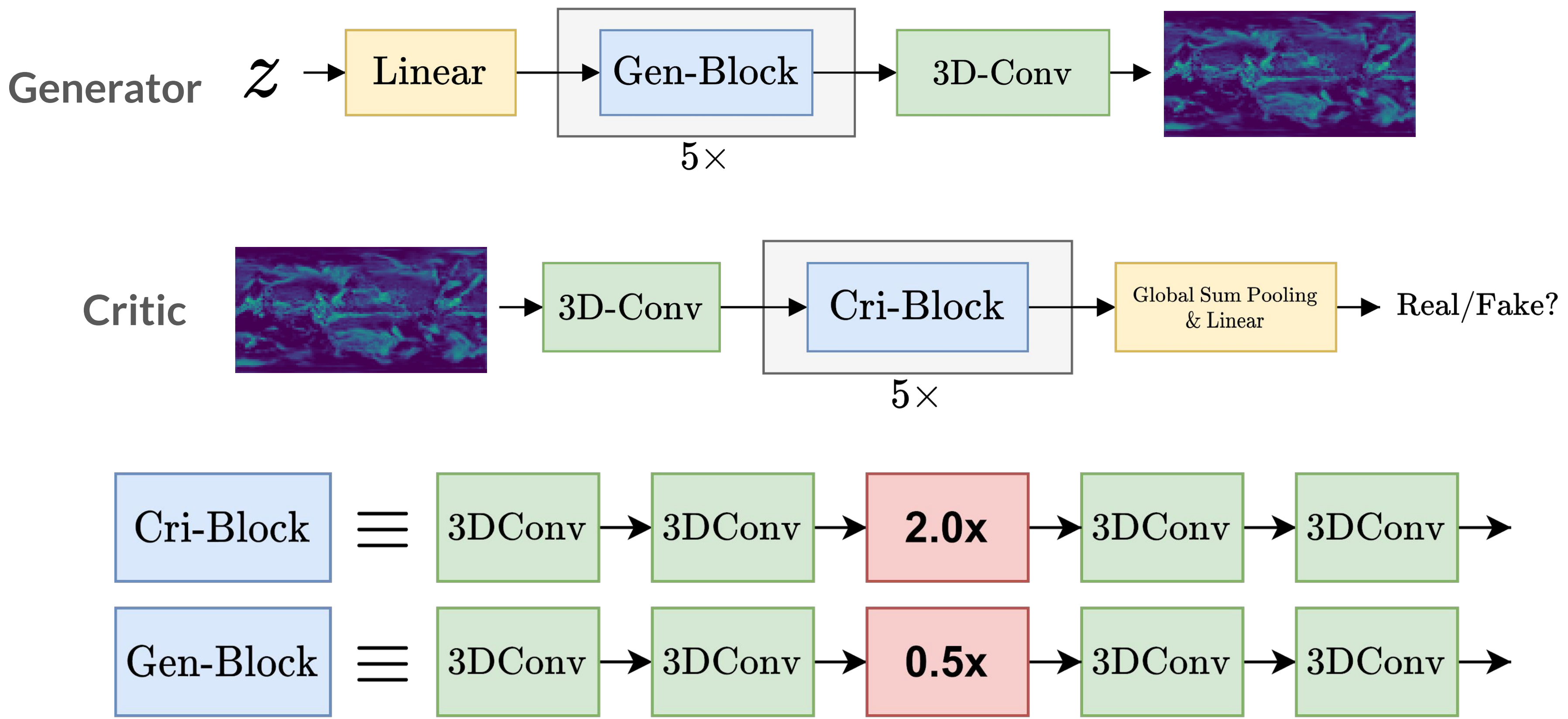
Real data: $x \in \mathbb{R}^{32\times64\times128} \sim P$

Train a GAN to induce a distribution G that approximates *P*

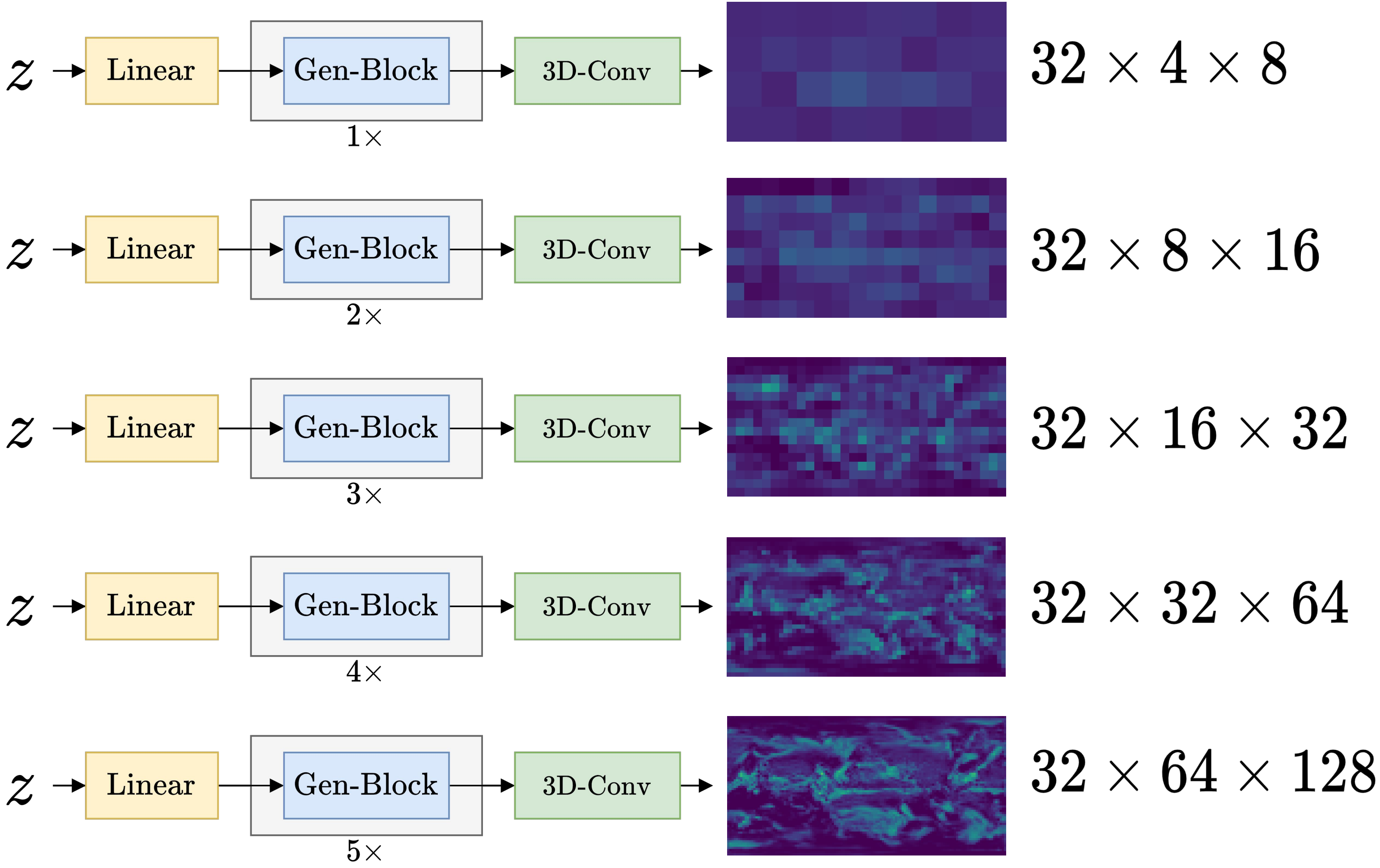
Performance metrics:

- Compare mean number of dry days in samples from G vs P
- KL-divergence-based scores between G and P

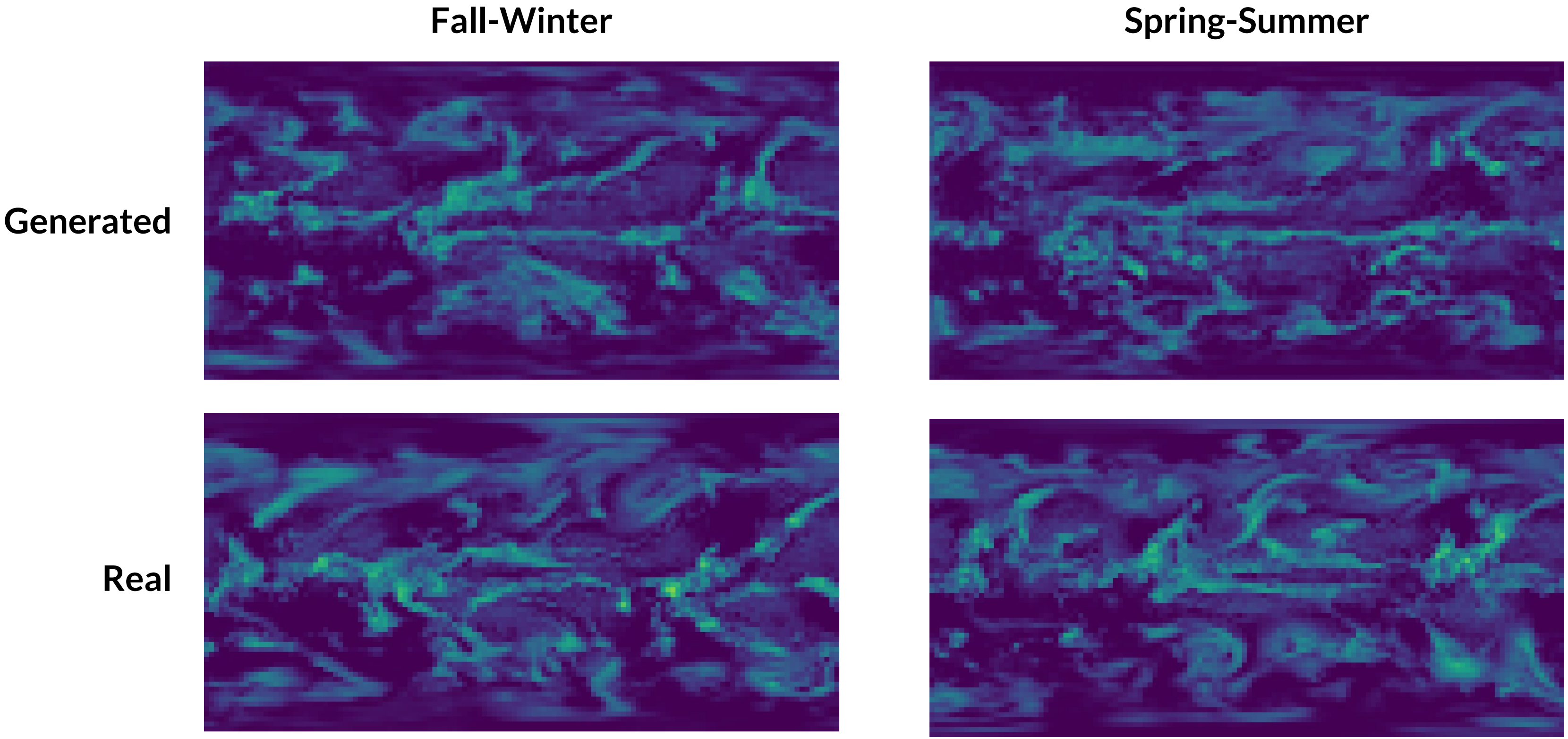
Model Architecture



Progressive Growing

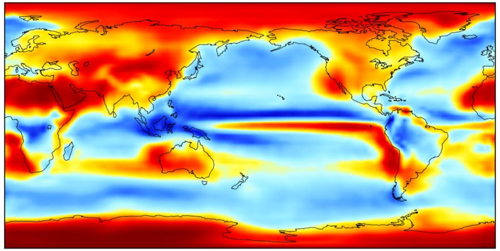


Samples

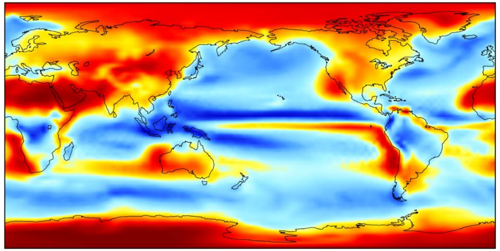


Mean Number of Dry Days

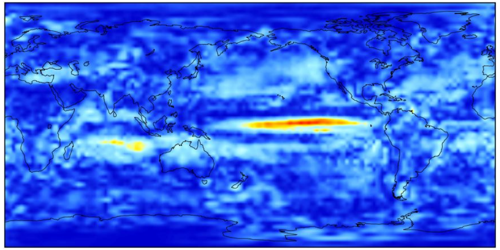
- Averaged per-sample across ~8000 months
- Performs well globally
- Slightly wider dry tongue near equator



a) Generated



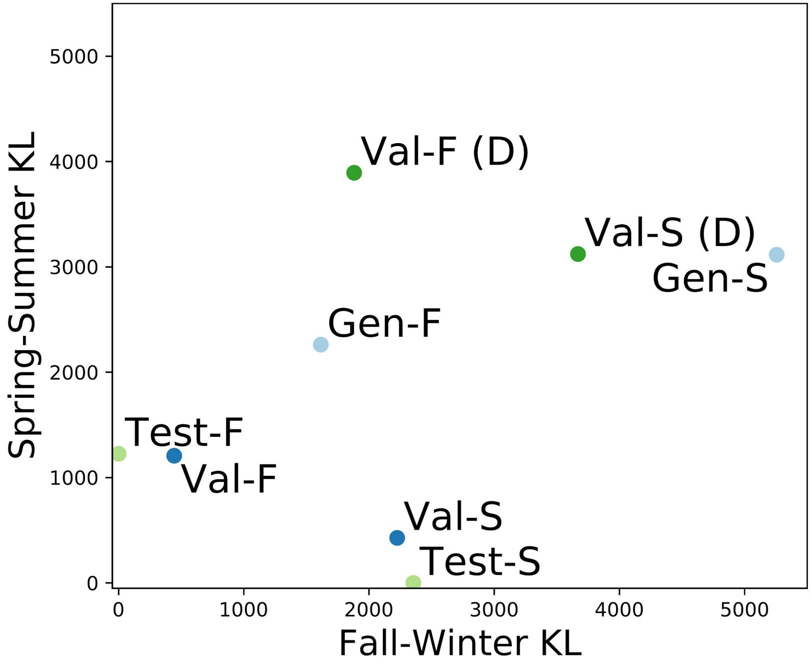
b) Test



c) Absolute Difference

KL Divergence

- **X-axis:** KL-Div against Fall-Winter Test Set
- **Y-axis:** KL-Div against Spring-Summer Test Set
- Degrade validation sets by applying zero-centered noise
    - Serves as our upper bound
- Generated data differs by a variance of 0.024 mm/Day (less than 1% off)



$$\text{Val (D)} = \text{Val} + \epsilon$$
$$\epsilon \sim N(0, 0.024)$$

Conclusion

- Take-away:
    - GANs can generate realistic spatio-temporal precipitation

- Future work:
    - Joint generation of precipitation and temperature
    - Conditioning on low temporal resolution climate averages