Diffusion-Based Joint Temperature and Precipitation Emulation of Earth System Models

Katie Christensen[1], Lyric Otto[1], Seth Bassetti[2],
Claudia Tebaldi[3], Brian Hutchinson[1,4]

[1]Department of Computer Science, Western Washington University
[2] Computer Science Department, Utah State University
[3]Joint Global Change Research Institute, Pacific Northwest National Laboratory
[4]AI and Data Analytics Division, Pacific Northwest National Laboratory

Overview

Motivation: Some extreme weather phenomena depend on the joint behavior of climate variables (e.g., temperature and precipitation); jointly modeling these phenomena can help to estimate risks associated with climate change.

Goal: Rapidly generate daily sequences of temperature and precipitation across a global spatial grid, conditioned on monthly means from novel climate scenarios.

Approach: Extend the DiffESM diffusion model emulator for Earth System Models (ESMs) to support conditioning on and generation of multiple climate variables.

Background

Earth System Models:
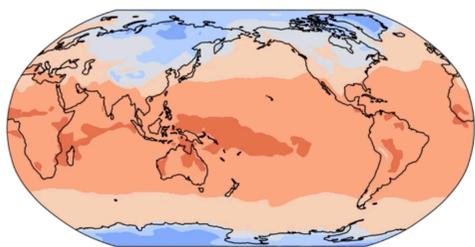- Generate climate variables under future projections

Figure: A single day of temperature data

DiffESM:
- Denoising generative probabilistic diffusion model
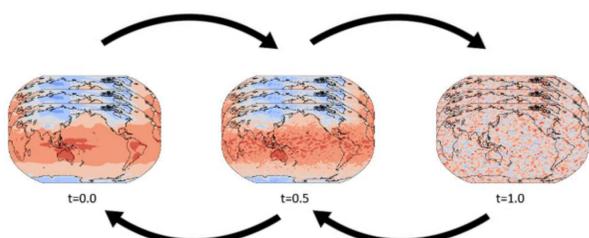- Generates T×H×W samples over one variable of interest

Figure: Diffusion forward and reverse process

Methods

- Extend DiffESM to condition on and generate multiple variables simultaneously.
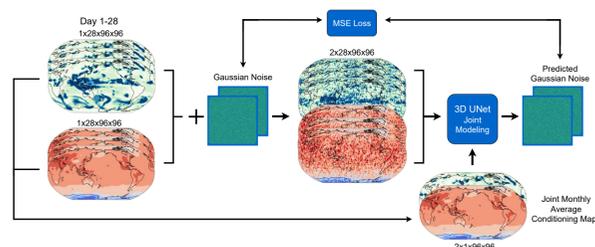- We generate daily temp. and precip. over global grid for 28-day "months"

Figure: Training loop

Results

- DiffESM captures the relationship between variables for the IPSL-CM5A ESM
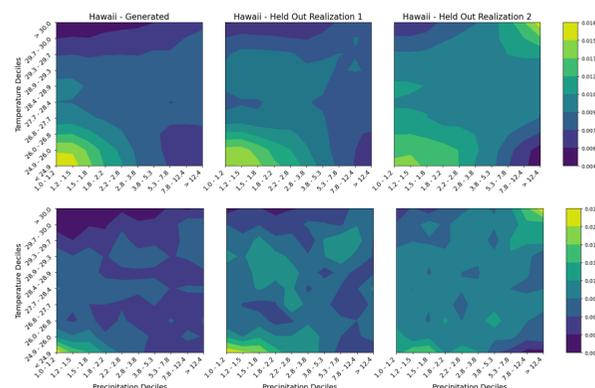

Figure: Joint distribution of temperature and precipitation on wet days (Hawaii)
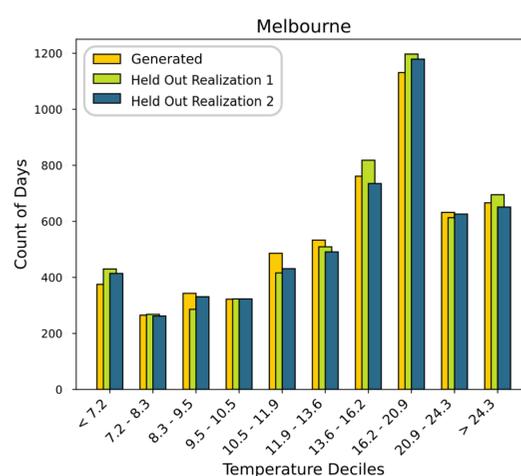

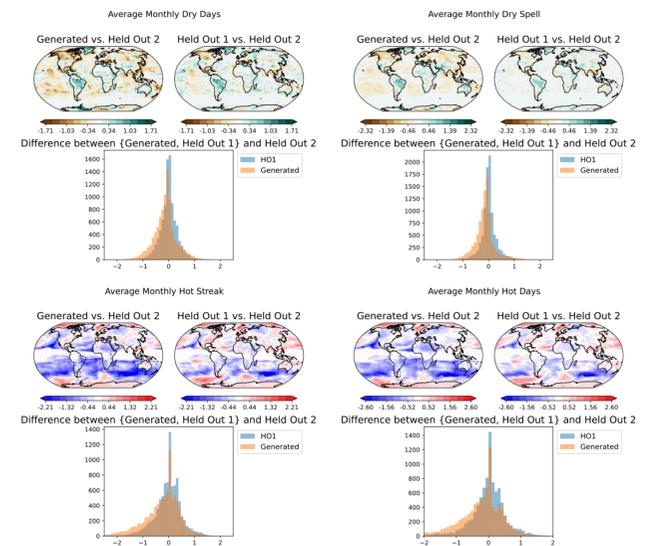
Figure: Temperature distribution on dry days (Melbourne)

Figure: Pairs of difference maps and the corresponding superimposed grid-box error histograms for various metrics

Conclusions & Future Work

- Joint variable samples match the ESM in the marginal distributions and in their joint distribution
- Future work includes additional variables such as daily relative humidity, and daily high and low temperatures and additional ESMs

Acknowledgments