Parallel Algorithms to Recognize Spatial Patterns in Climate Analysis

Anil Alper

Mentors: Ethan Gutmann and Rachel McCrary

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

Motivation

- We want to predict atmospheric conditions accurately to adapt to the local effects of climate change.

- Having a better understanding of future changes in precipitation patterns can help us manage water resources more efficiently.

Atmospheric Simulation Models

- We use global models to make future climate projections.
- But these models are run on very large scales making them less useful for local scale changes.
- To account for this, many downscaling methods are developed.

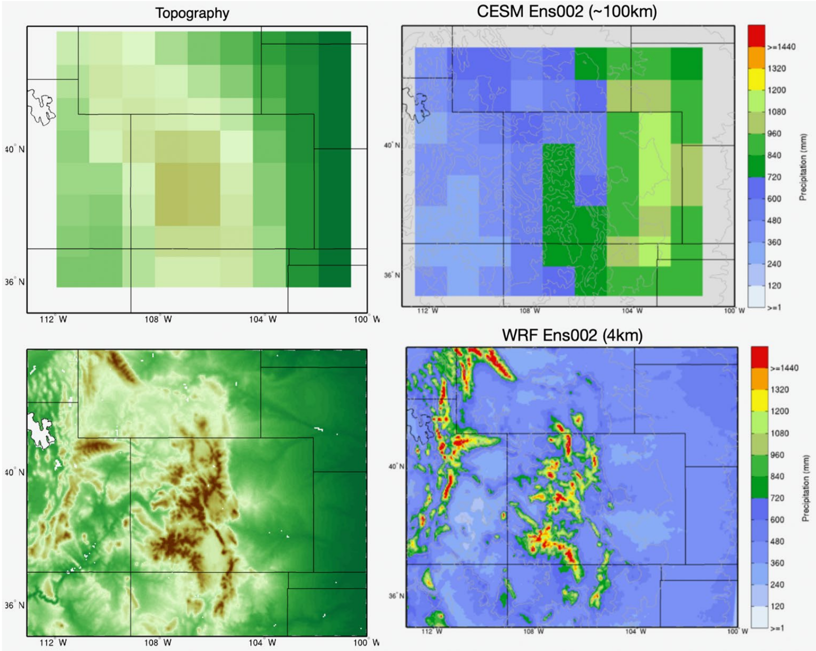


Figure 1: Top figures show the global model output and the bottom figures show the downscaled output

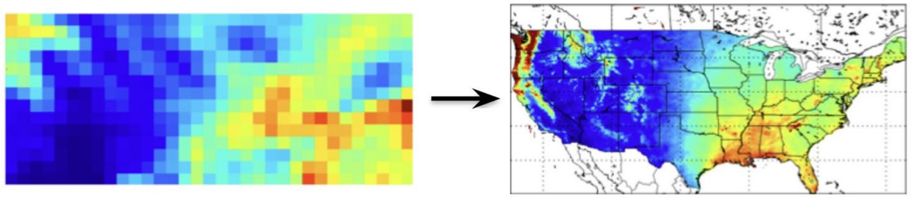
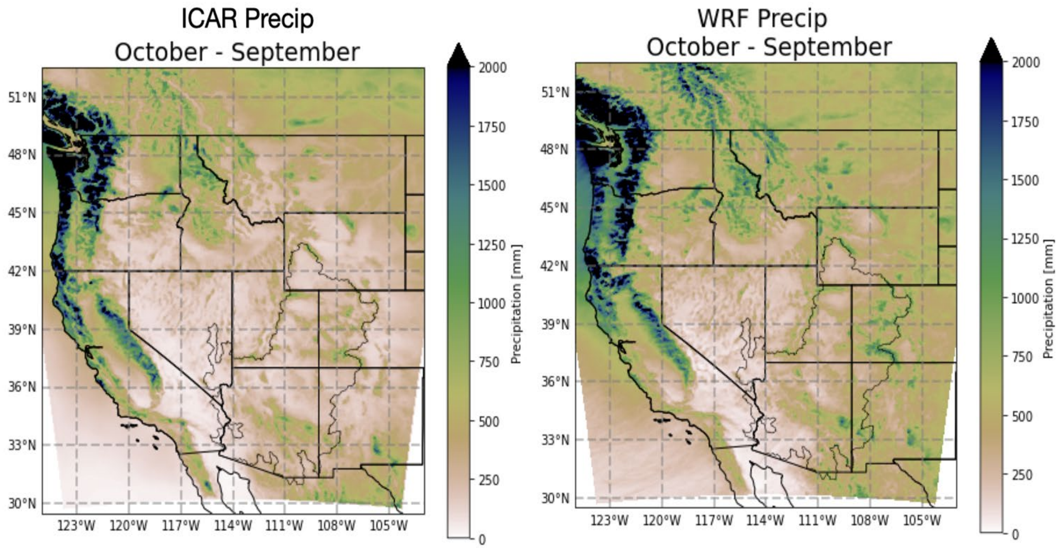


Figure 2: From Global Model Output to Downscaled Data

One Such Downscaling Method is ICAR

- ICAR a *regional atmospheric model* developed by the scientists at NCAR. It allows us to get similar results for local scale changes with less computational cost.
- Takes large scale information from the global models and simulates high resolution precipitation using physical processes.
- Because of the simplifications, the resulting data are biased compared to observations.



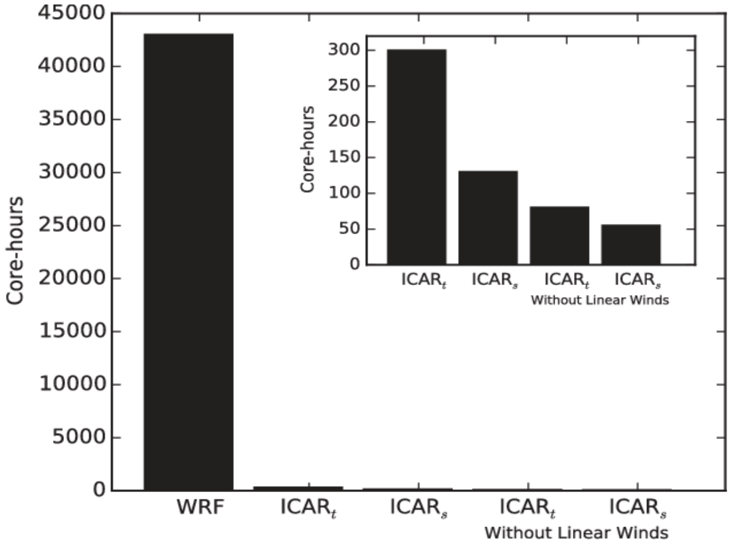
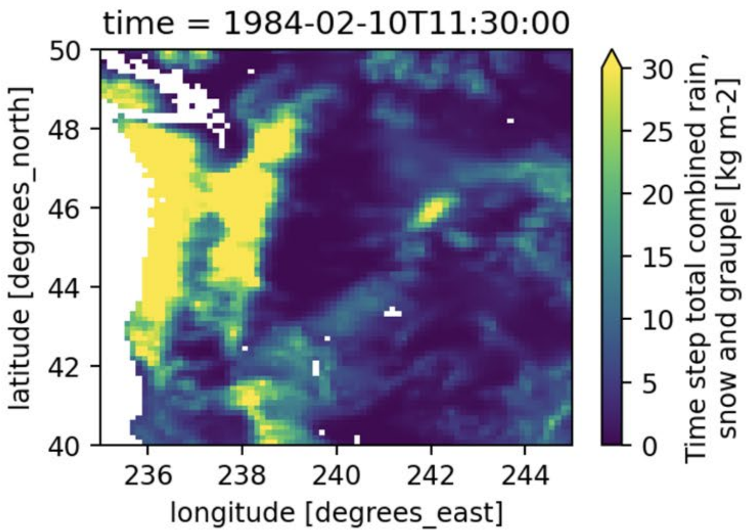


FIG. 11 Computational requirements for 1 year of simulated

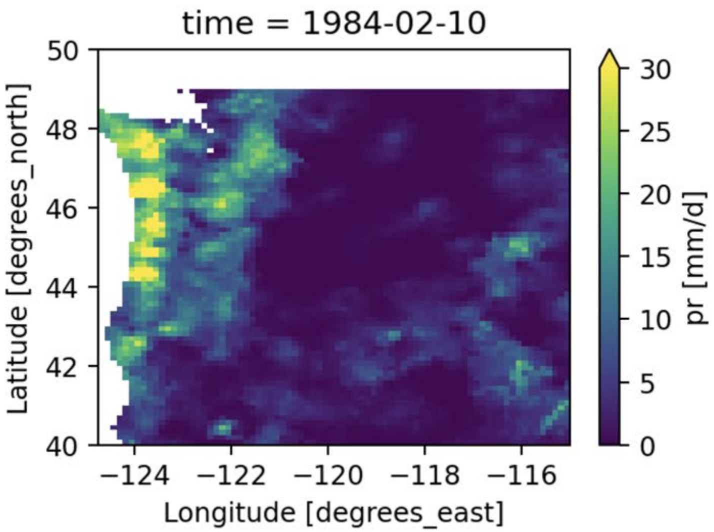
Systematic Errors and Bias Correction

- For example, ICAR overestimates precipitation rates on the mountains in northwest United States.
- To correct these biases, there are various computationally expensive statistical methods and algorithms.

ICAR Output



Observations



Our Goal

- To bias correct spatial patterns in ICAR.
- We developed a spatial analog method with multiple levels of complexity.
- This method is computationally expensive.
- We accelerated this process using high performance computing.

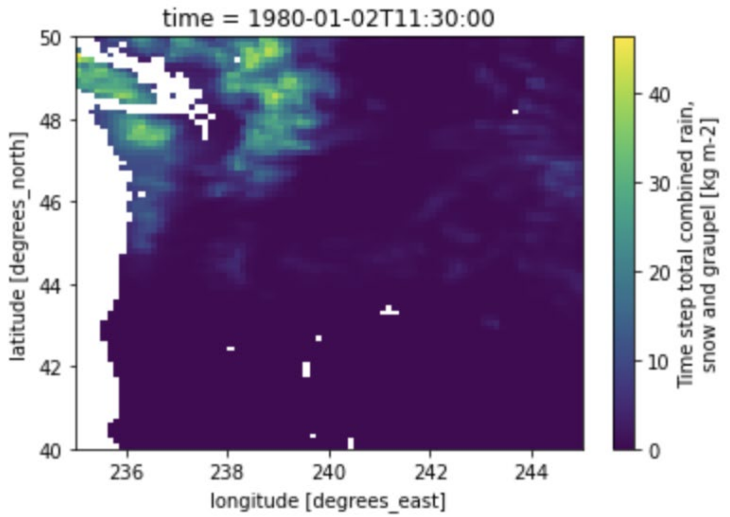
Experimental Setup

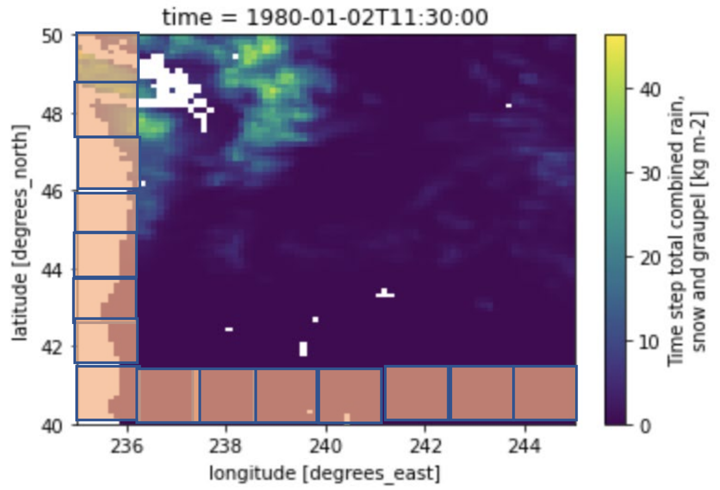
- Northwest United States, from 1980 to 2010

- For every 10 by 10 grid, find the day with closest precipitation pattern and insert the corresponding observation to this grid

Inputs: ICAR dataset and Observation dataset

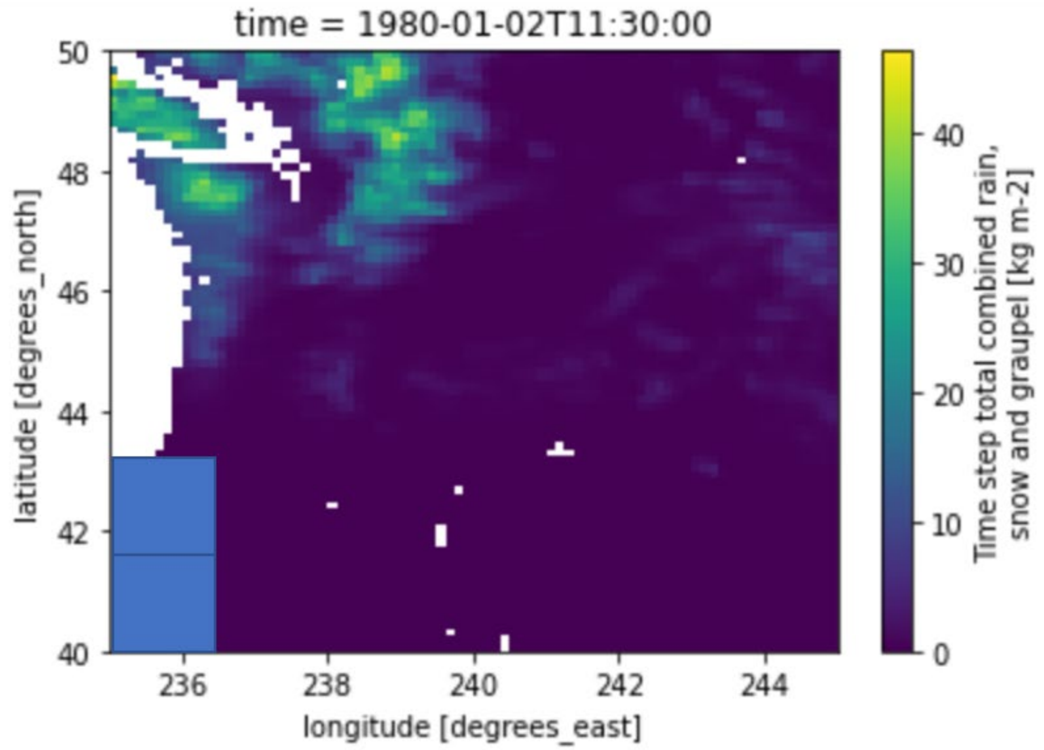
Output: Bias corrected ICAR dataset

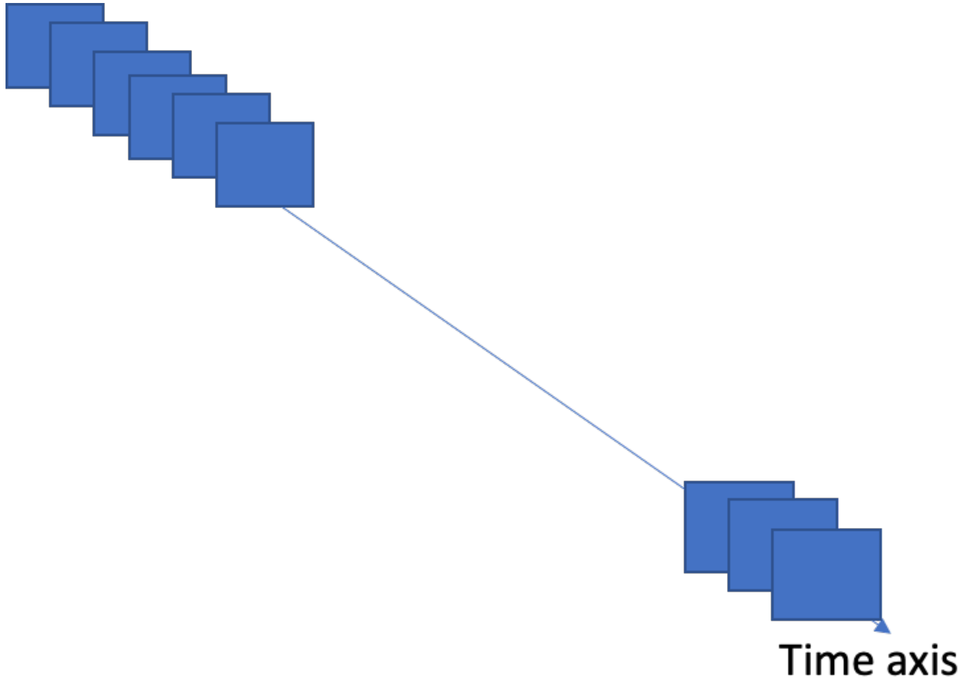




Naive Algorithm

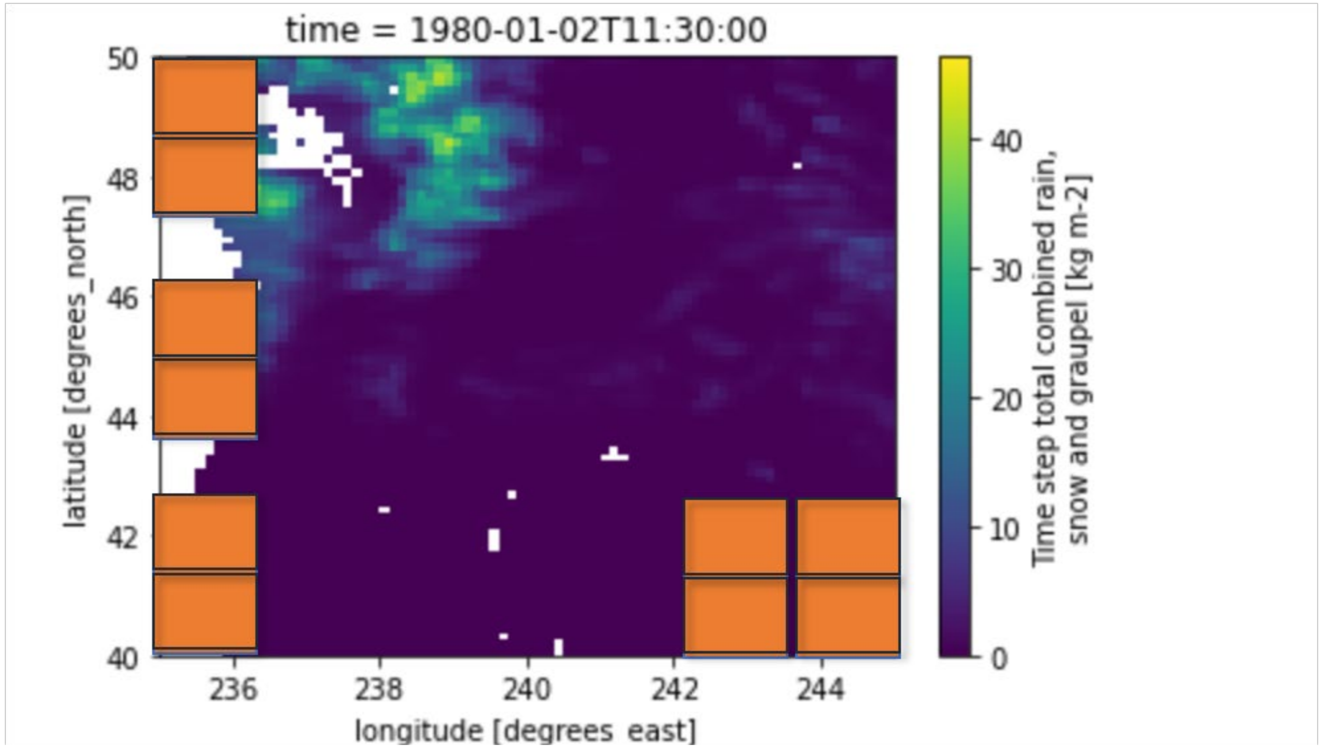
- Look at each grid and time sequentially one by one.
- Tested this implementation on Python and C.

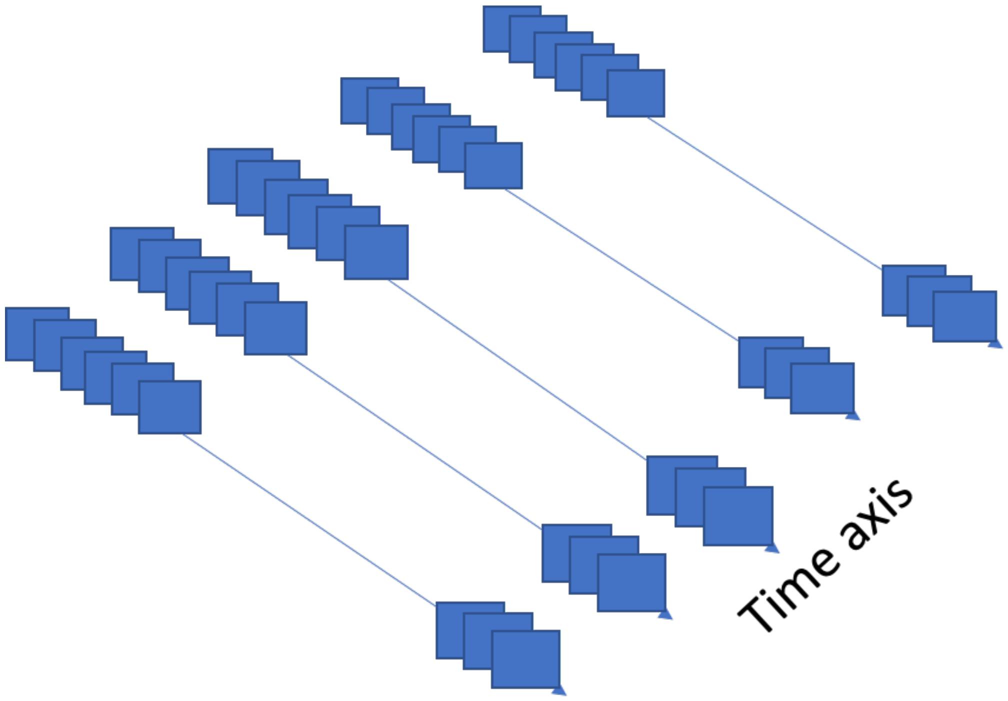




Algorithm with Threads on CPU

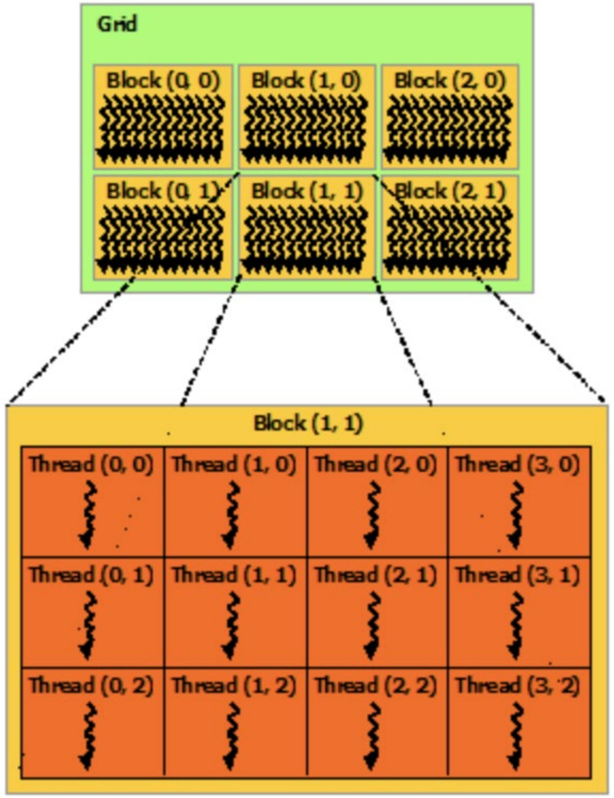
- Split up the grid work among different threads.
- Implemented with C.



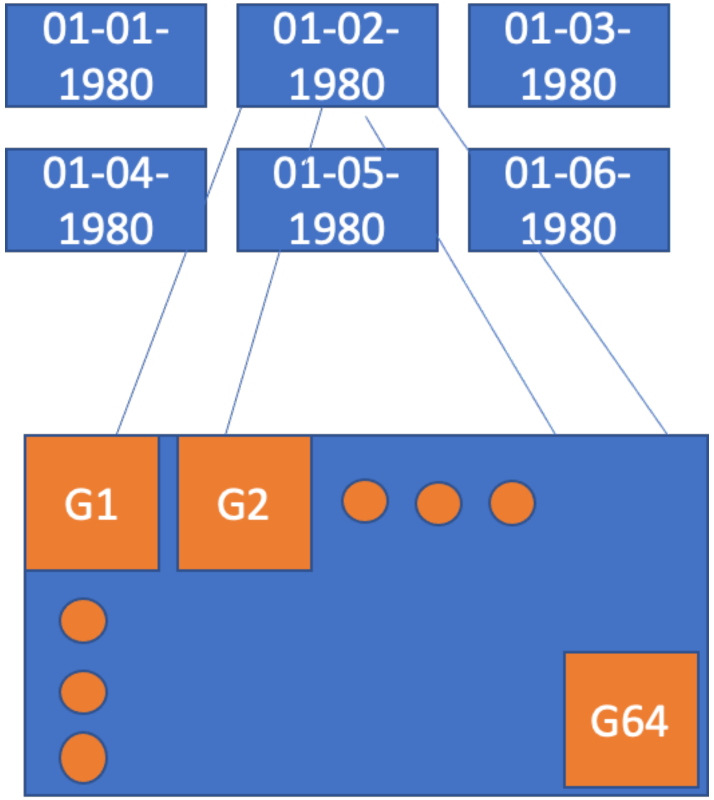


GPU Programming

- In GPU, there are blocks of threads (each can run up to 1024 threads).
- We ran two GPU implementations.
- Grids are parallelized in blocks and each thread handles about 11 days. (GPU 1)
- All the time steps and grids are parallelized (GPU 2).



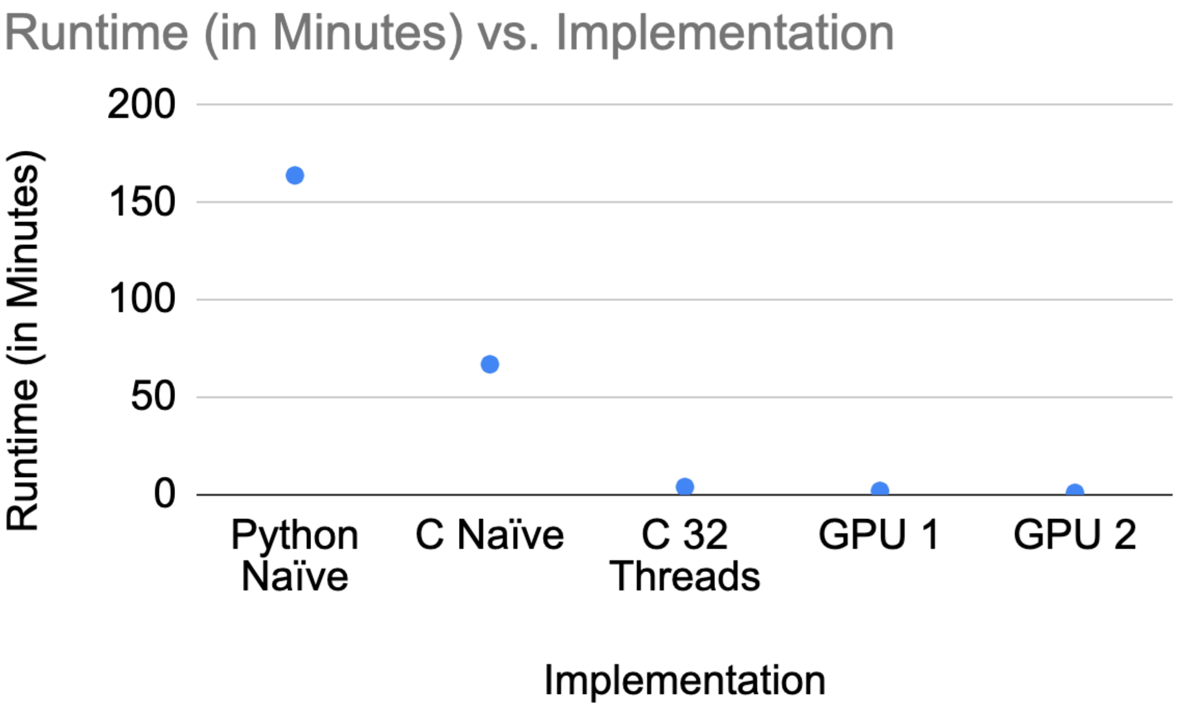
Nvidia GPU Setup

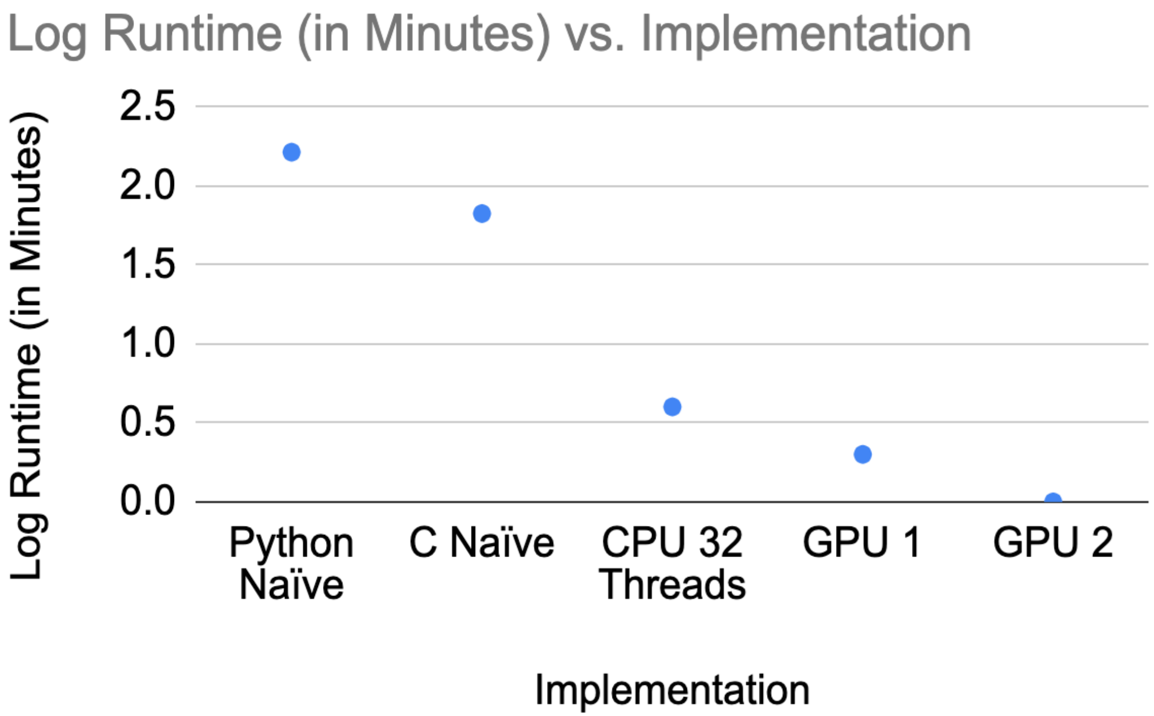


GPU 2: Implementation

Performance Improvement

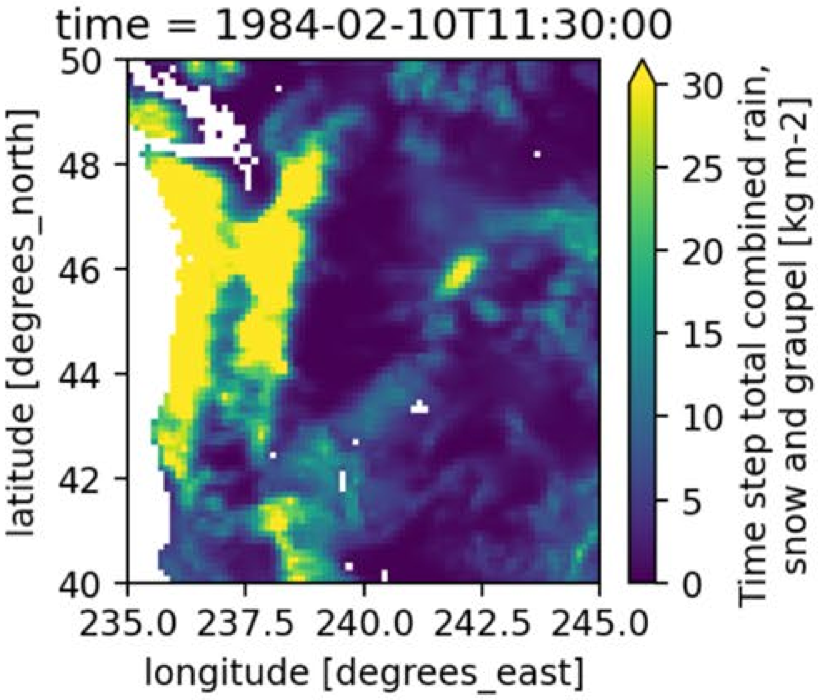
The runtime is reduced from 164 minutes to 1 minute.



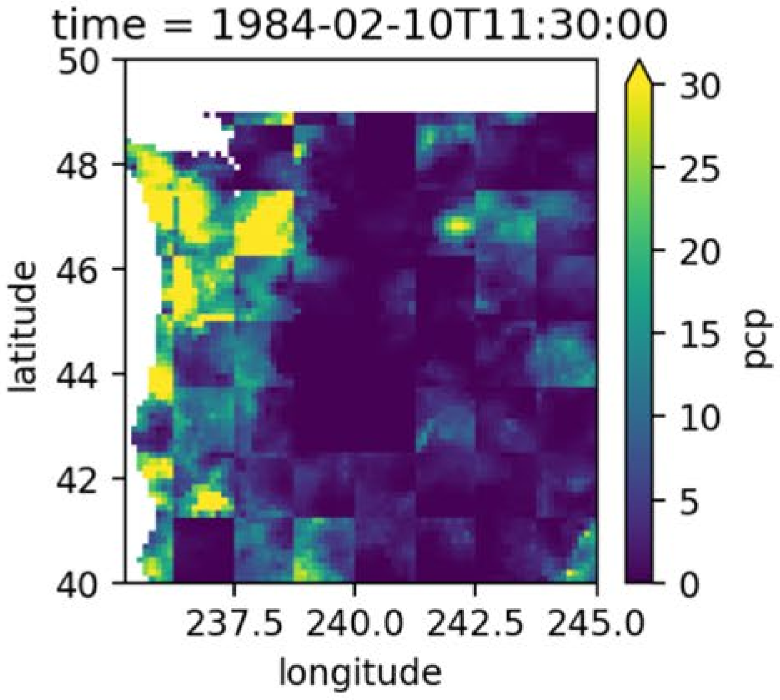


Bias Corrected Output

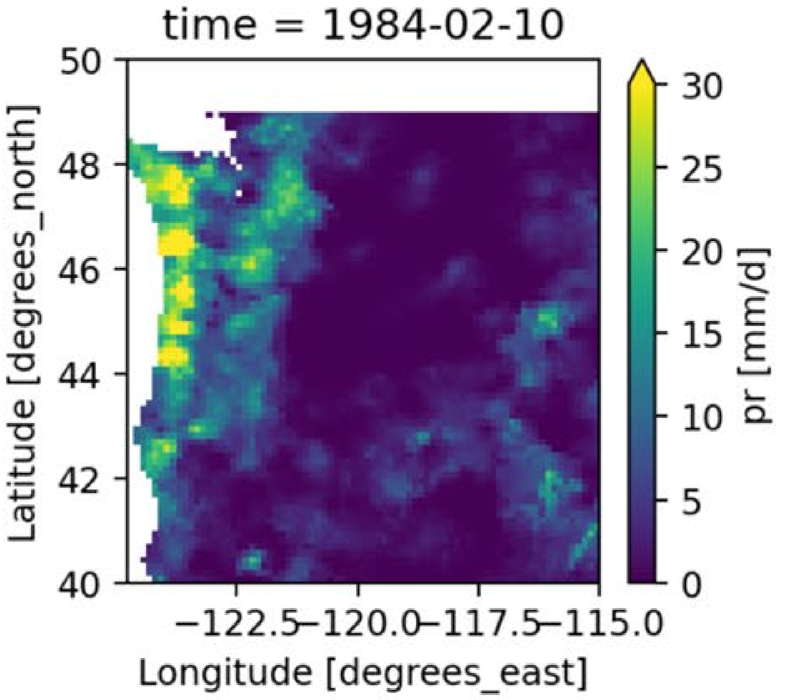
ICAR Output



Bias Corrected ICAR Output



Observations



Conclusion and Future Work

- Computationally more expensive bias correction methods can be implemented. We want to make the new data points more continuous.
- Blocks and threads in GPU can be utilized in a different way depending on the bias correction method to make the process even more efficient.
- Same bias correction methods can be run on different downscaled data.
- Other regions across the world can also be considered.

Sources

Images

- https://www.rff.org/topics/natural-resources/water/
- https://www.itu.int/en/mediacentre/backgrounders/Pages/climate-change.aspx
- https://github.com/NCAR/icar
- https://www.nvidia.com/en-in/about-nvidia/legal-info/logo-brand-usage/
- https://www.wyomingnews.com/news/local_news/new-ncar-wyoming-supercomputer-to-accelerate-scientific-discovery/article_cdabb8b5-5c86-500c-997f-bfe0767f4dab.html

Documentation and Papers

- Gutmann, Ethan, Idar Barstad, Martyn Clark, Jeffrey Arnold, and Roy Rasmussen. "The Intermediate Complexity Atmospheric Research Model (ICAR)." *Journal of Hydrometeorology* 17, no. 3 (March 1, 2016): 957–73. https://doi.org/10.1175/JHM-D-15-0155.1.
- https://docs.nvidia.com/cuda/cuda-c-programming-guide/index.html