Accelerating Climate Model Computation

by Neural Networks

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Contents

1 Introduction

2 Model Acceleration Approaches

3 Experiment

4 Results

5 Conclusion

Contents

1 Introduction

2 Model Acceleration Approaches

3 Experiment

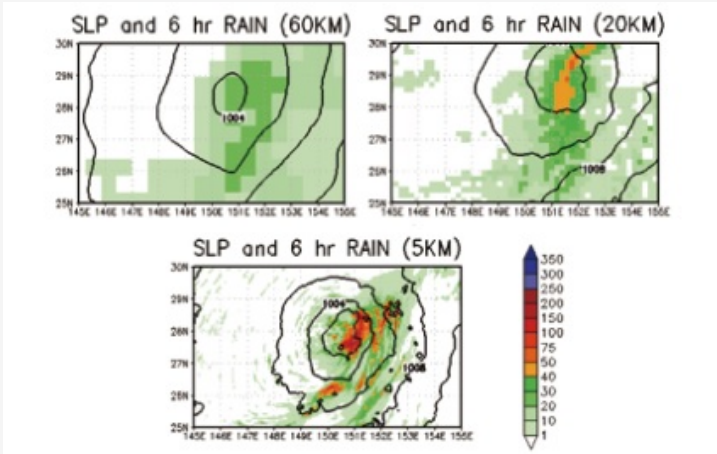
4 Results

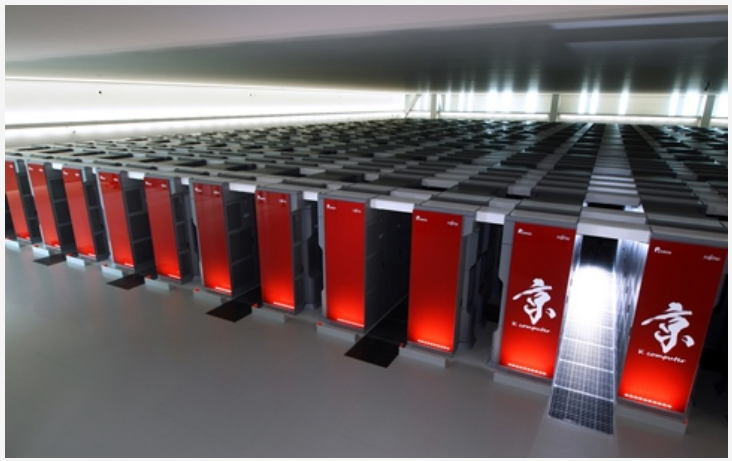
5 Conclusion

Introduction

Figure by Koji IKEUCHI, Water and Disaster Management Bureau, MLIT, Japan

require HR climate models





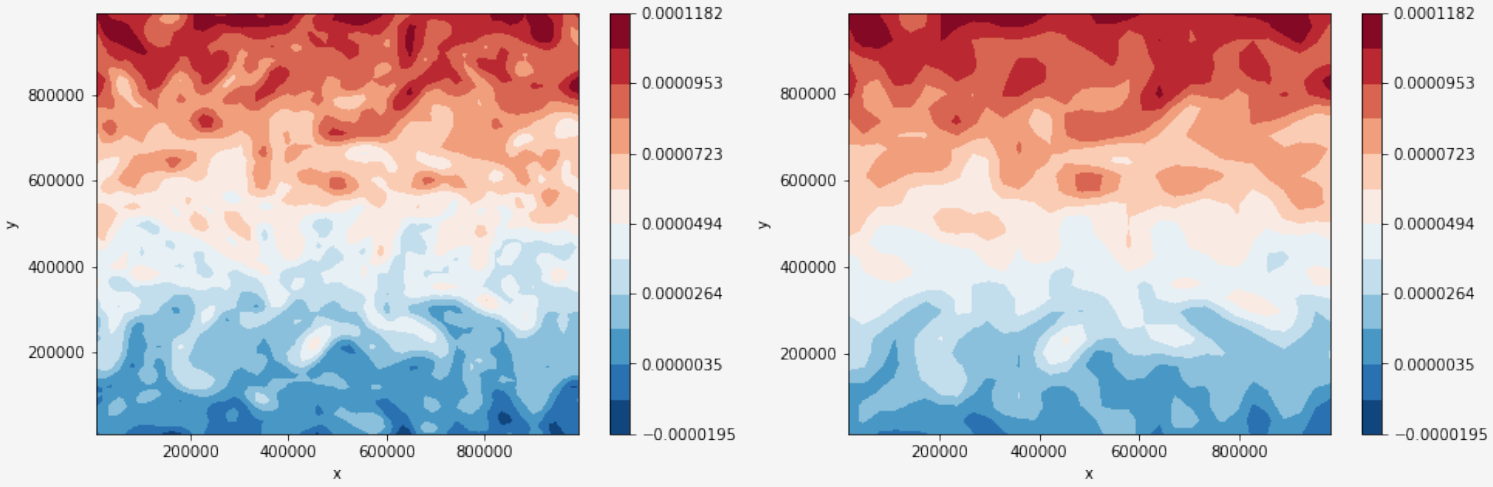
require super-computing

So, What are the possible avenues to accelerate climate models?

Introduction

1. Process-Driven Physical Model (PDPM)
2. Data-Driven Statistical Model (DDSM)
3. Hybrid Physical-Statistical Model (HPSM)

- Quasi-Geostrophic (QG) model: Potential vorticity



High Resolution Low Resolution

Contents

1 Introduction

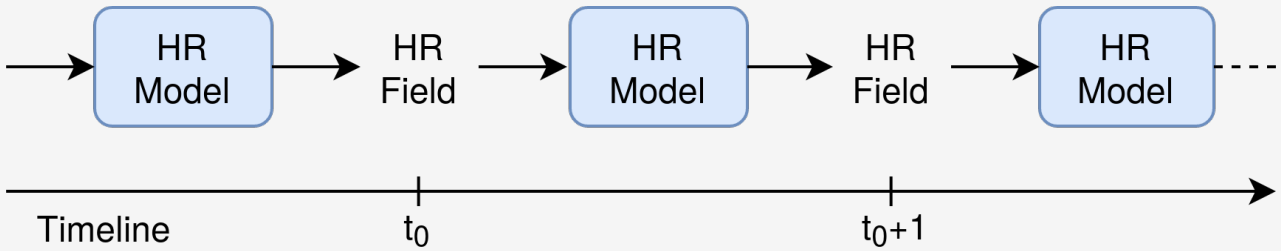
2 Model Acceleration Approaches

3 Experiment

4 Results

5 Conclusion

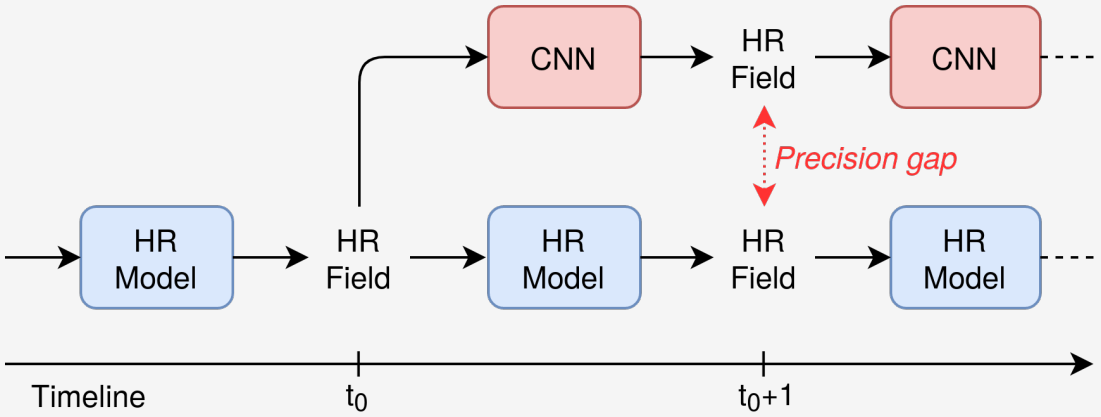
Process-Driven Physical Model (PDPM)



PDPM time evolution

- Each time step, we compute the HR field using the HR model.
- The output at t_n is the the input for $t_n + 1$.

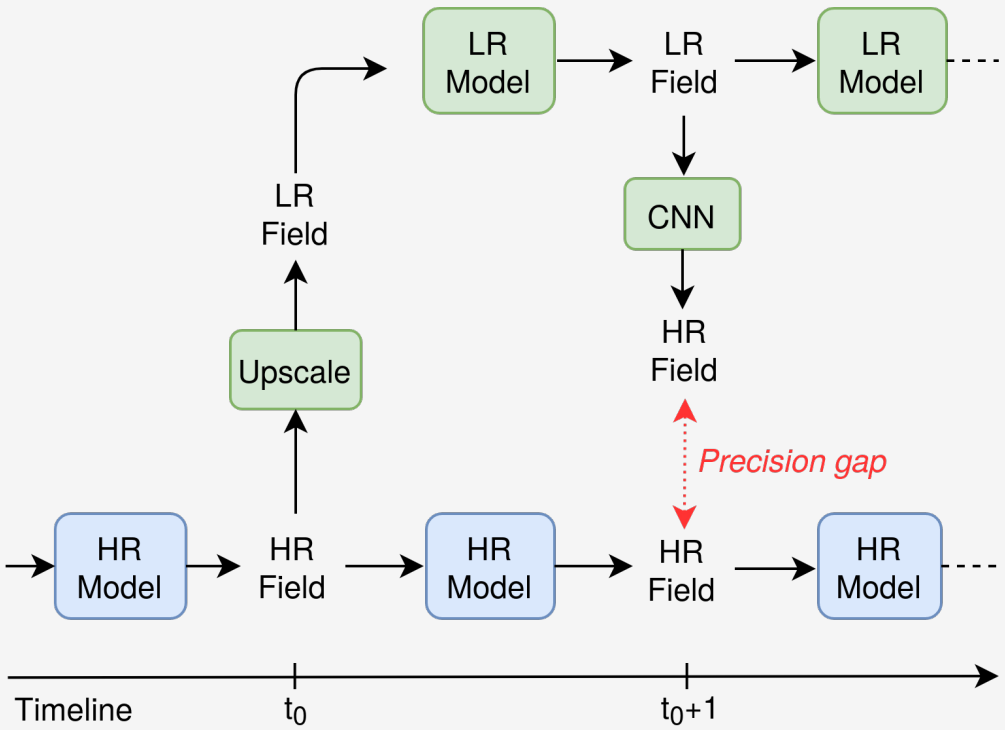
Data-Driven Statistical Model (DDSM)



DDSM time evolution

- We initialize with the output of the HR model output at t_0.
- Each time step, we use a Convolutional Neural Network (CNN) to predict the next field.
- The output at t_n is the the input for $t_n + 1$.

Hybrid Physical-Statistical Model (HPSM)



HPSM time evolution

- We upscale the output of the HR model output at t_0 to initialize the LR model.
- Each time step, we run the LR model to compute the LR field.
- We map the LR field to the HR domain using a CNN.

Contents

1 Introduction

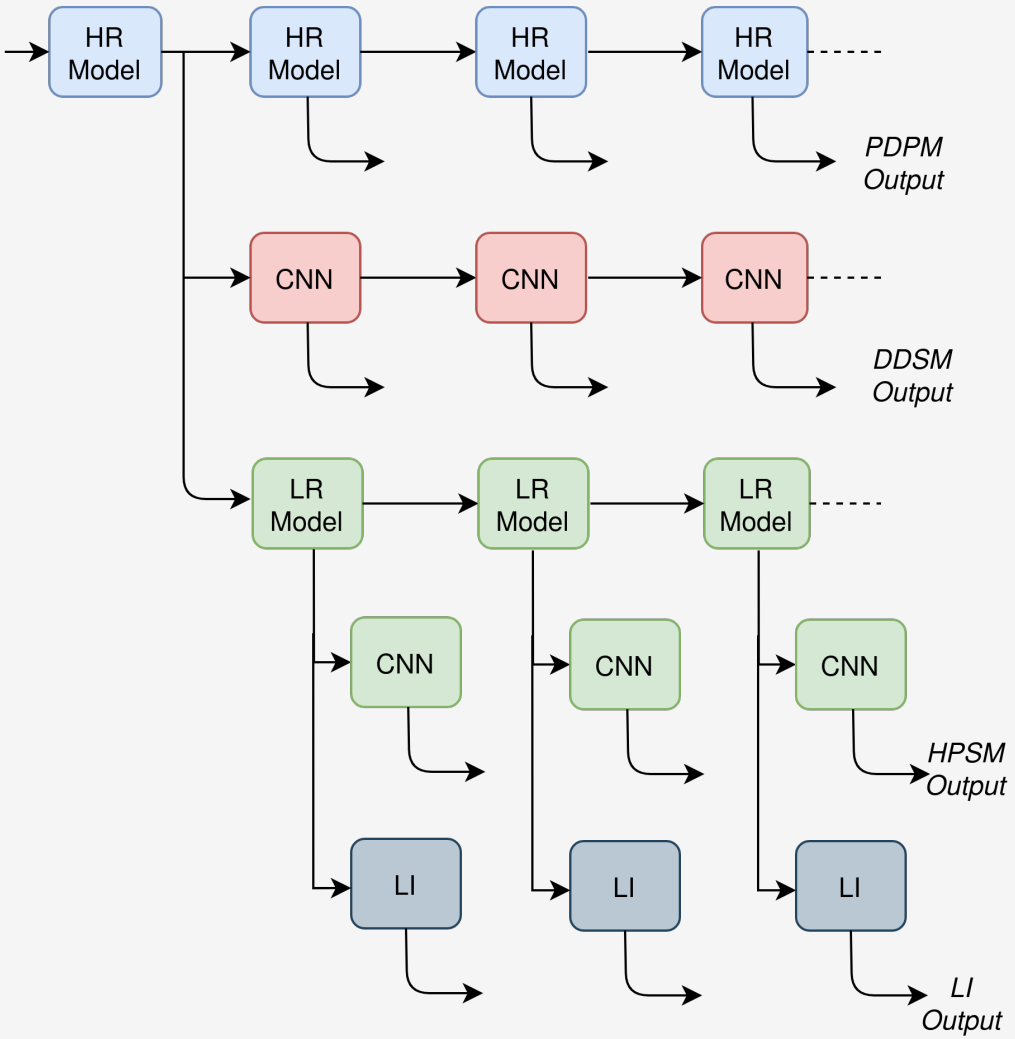
2 Model Acceleration Approaches

3 Experiment

4 Results

5 Conclusion

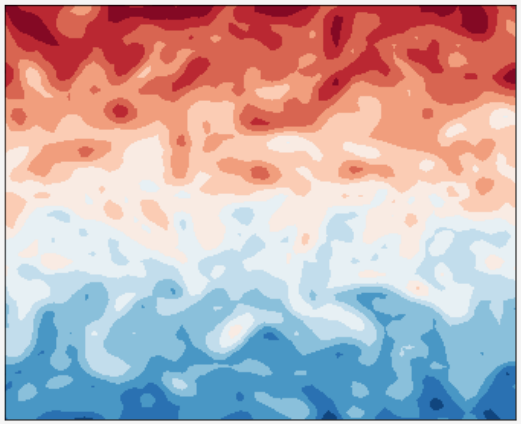
Simulation Protocol



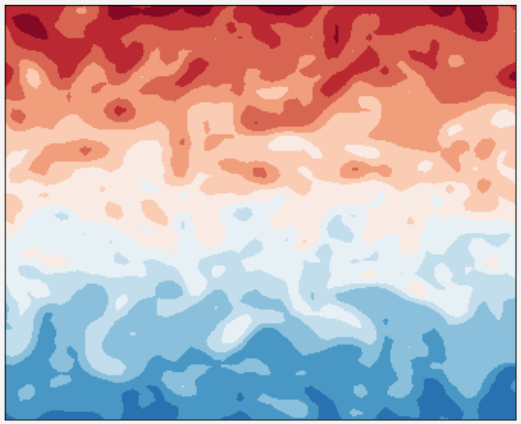
Simulation steps:

- Train CNNs in DDSM and HPSM.
- Run the HR model until convergence.
- Run simultaneously PDPM, DDSM and HPSM.
- Apply Linear Interpolation (LI) to the output of LR model in HPSM.
- LI is a baseline for the evaluation of the CNN in HPSM.

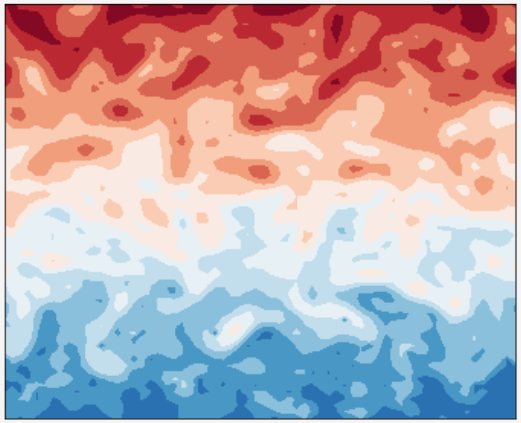
Simulation Outputs: 6 hours



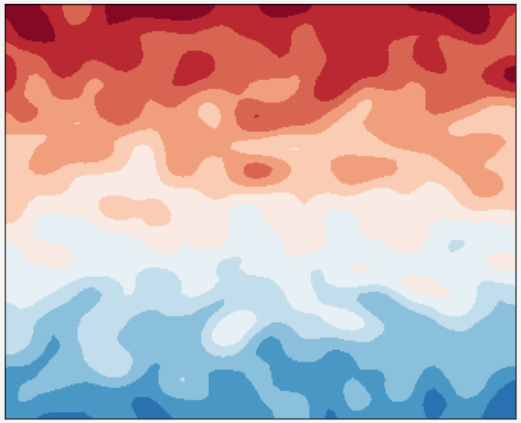
PDPM



DDSM

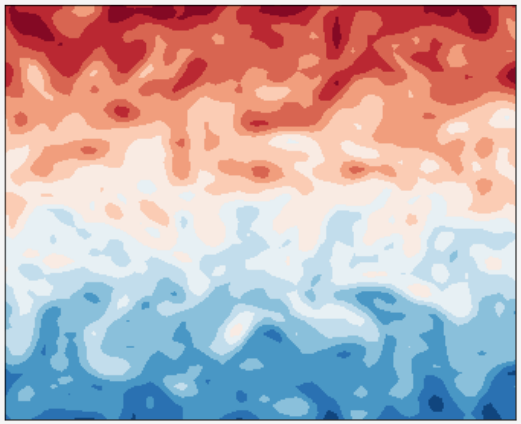


HPSM

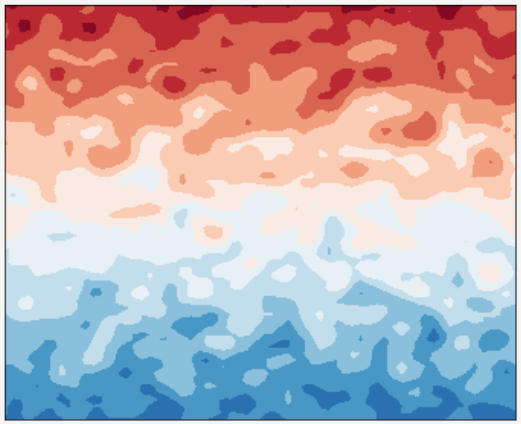


LRM + LI

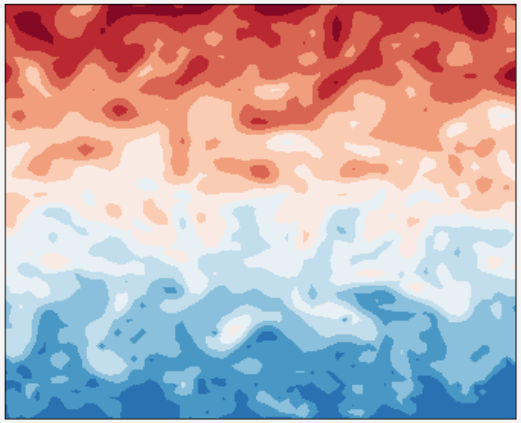
Simulation Outputs: 3 days



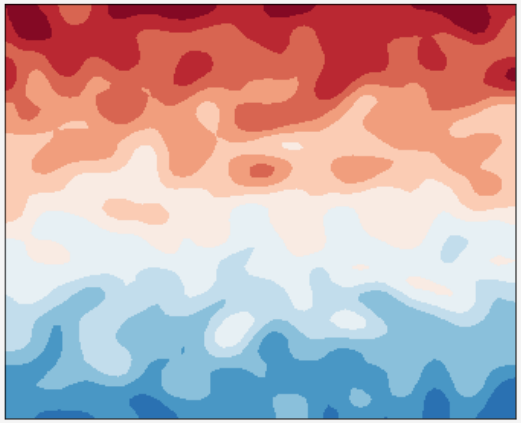
PDPM



DDSM

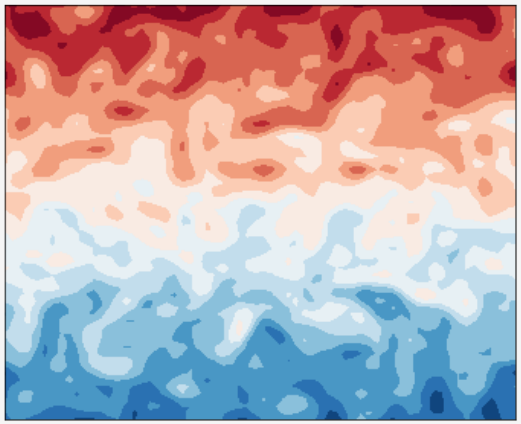


HPSM

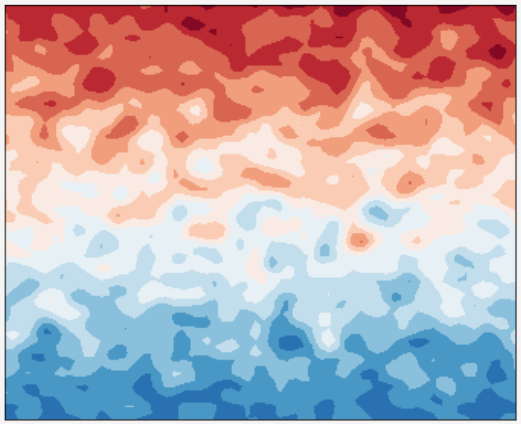


LRM + LI

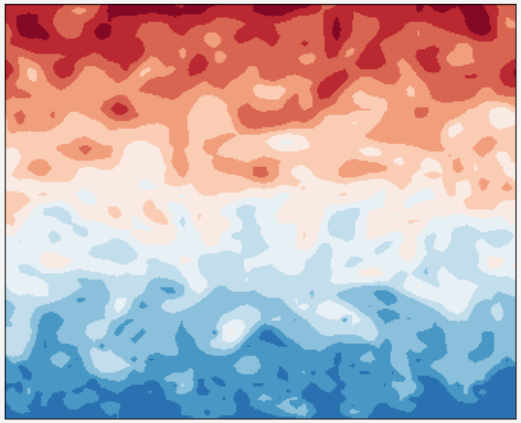
Simulation Outputs: 7 days



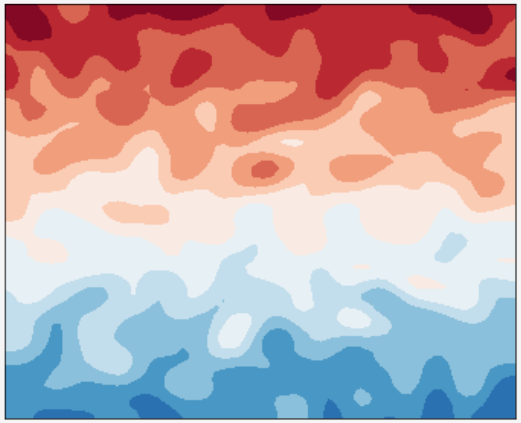
PDPM



DDSM

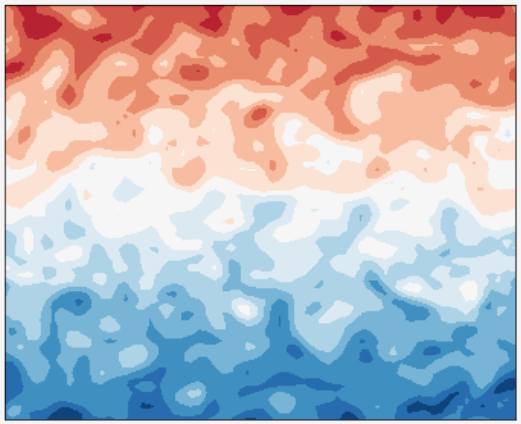


HPSM

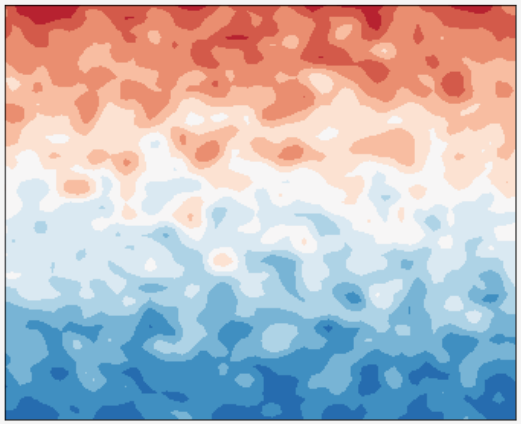


LRM + LI

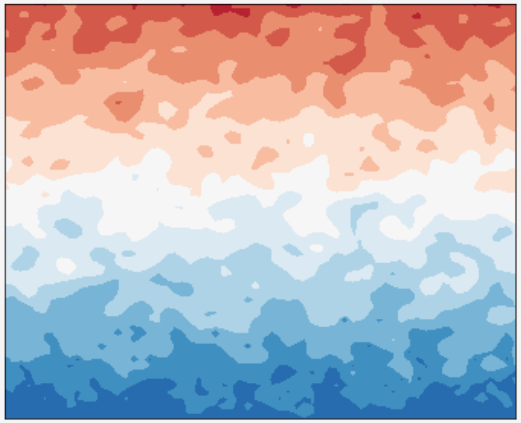
Simulation Outputs: 30 days



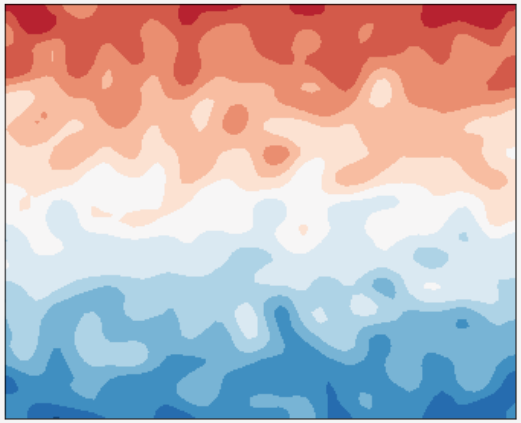
PDPM



DDSM



HPSM



LRM + LI

Contents

1 Introduction

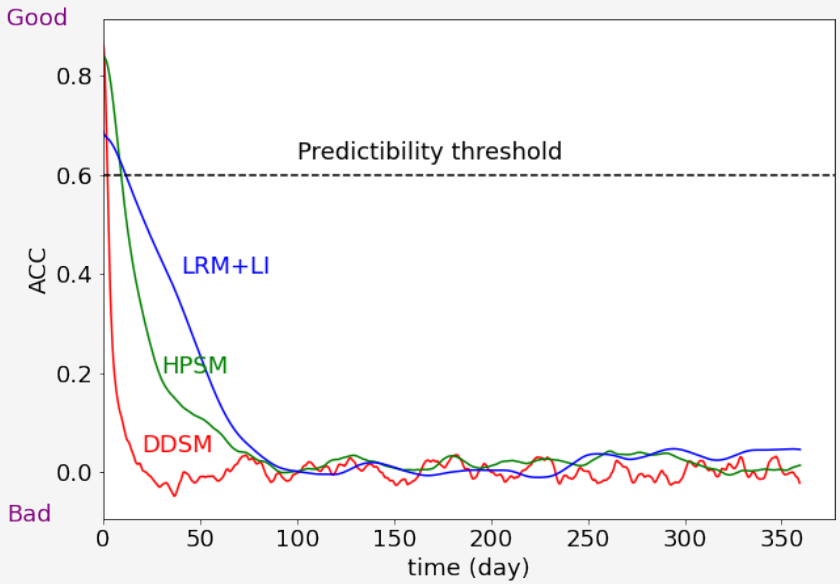
2 Model Acceleration Approaches

3 Experiment

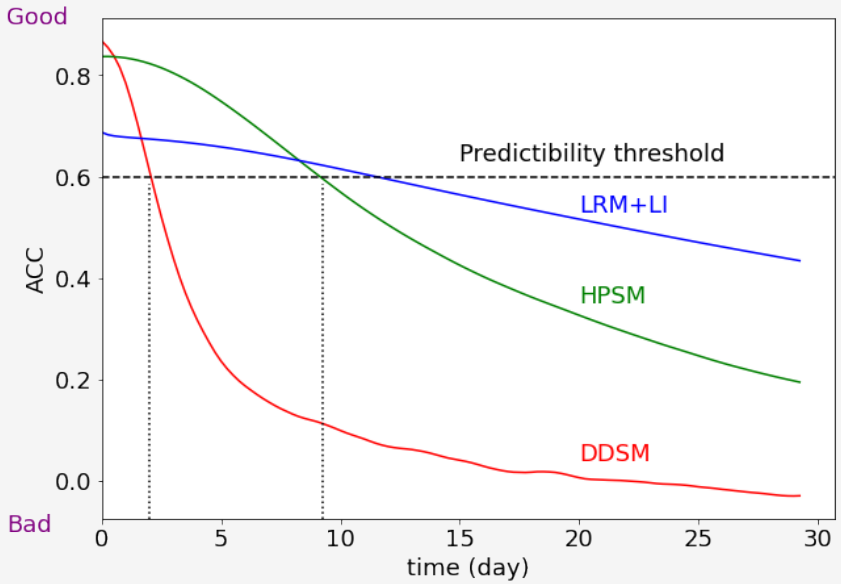
4 Results

5 Conclusion

Results: Predictability Range (ACC: Anomaly Correlation Coefficient)



One year period



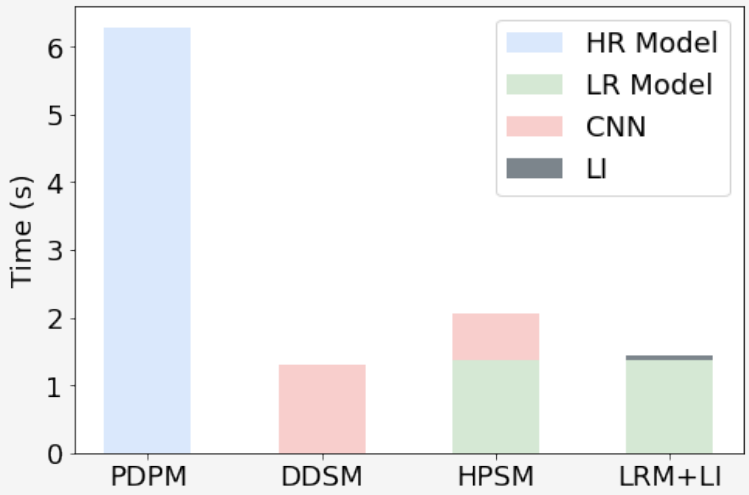
One month period
(Zoom-in)

Predictability range ($ACC > .6$):

- DDSM: 2 days
- HPSM: 9.25 days

Results: Computation Time

- PDPM: HR QG model computation time
- DDSM: CNN prediction time
- HPSM: LR QG model time + CNN super-resolution time



Computation Time

Computation time reduction factor:

- DDSM: ¼
- HPSM: ⅓

Contents

1 Introduction

2 Model Acceleration Approaches

3 Experiment

4 Results

5 Conclusion

Next Steps

- Multi-variable model acceleration:
  - Test QG variables other than PV.
  - Combine multiple variables.
- Apply model acceleration to other climate models.
- Test different performance verification methods in performance evaluation.

Thank you!