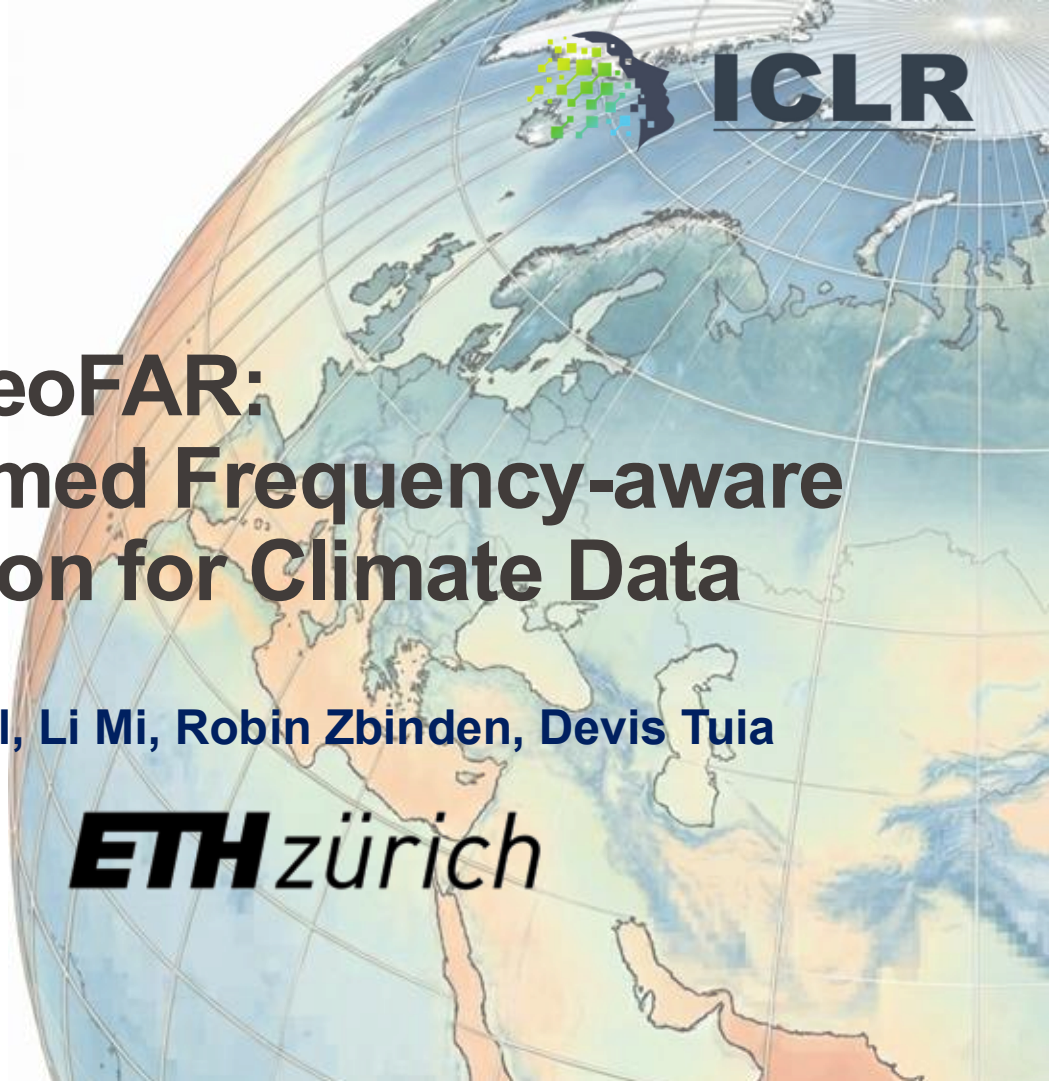


GeoFAR: Geography-informed Frequency-aware Super-resolution for Climate Data

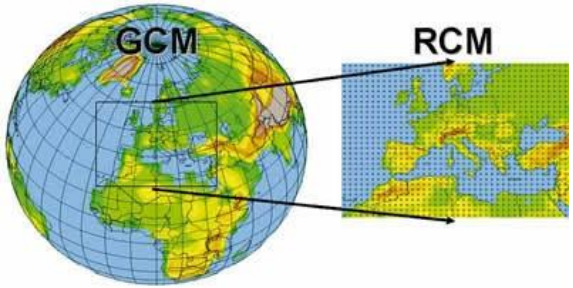
Chang Xu, Gencer Sumbul, Li Mi, Robin Zbinden, Devis Tuia

Outline

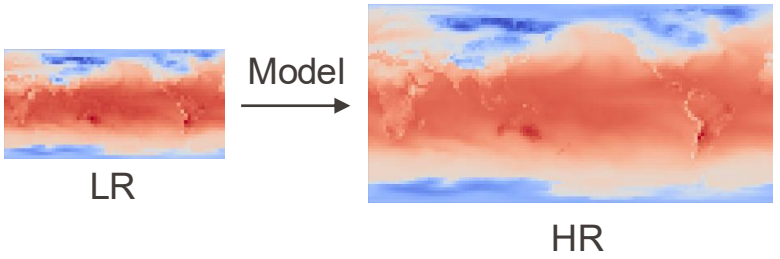
- Background
- Motivation
- Method
- Results

Background

- Super-resolving climate variables (Climate downscaling)



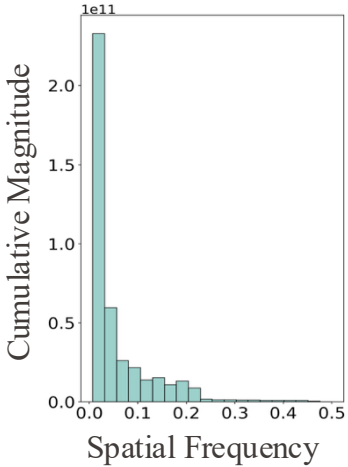
Dynamical Downscaling

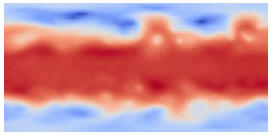


Statistical Downscaling

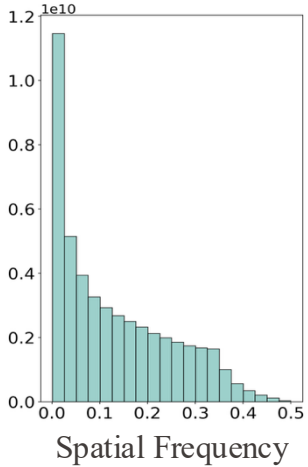
Motivation

- Geography-denepednet frequency bias in climate SR

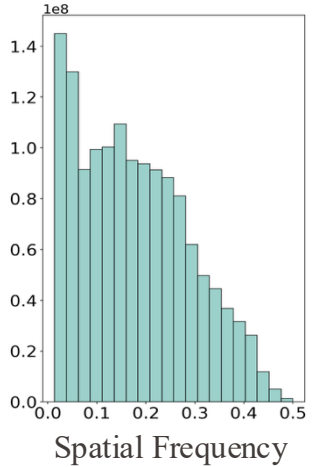




ERA5 (z500)



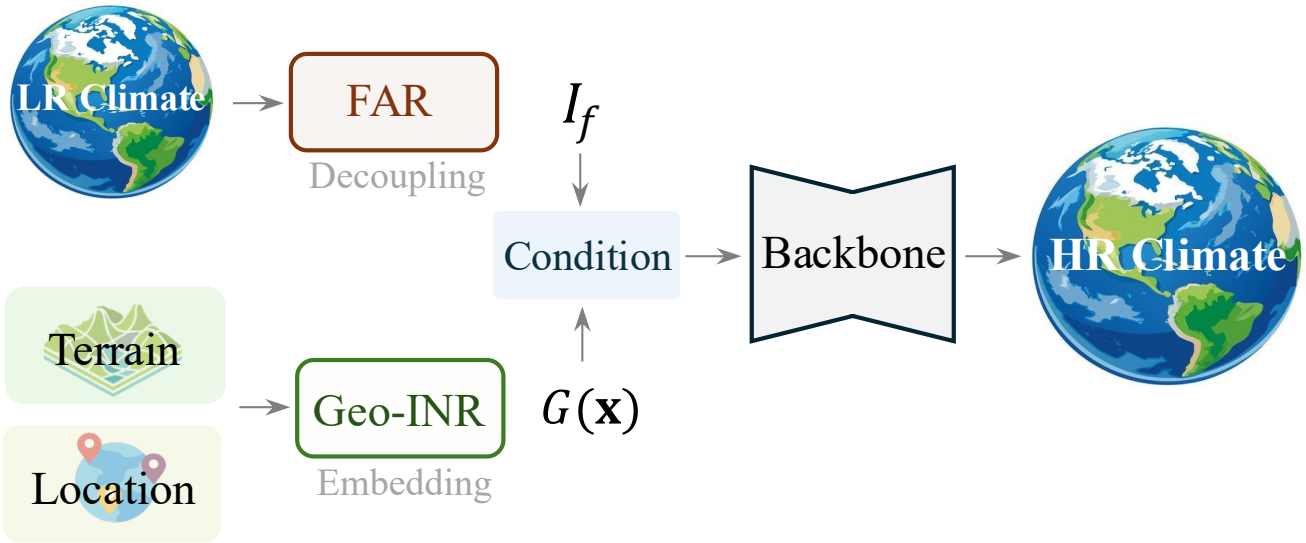
CERRA (t2m)



BSD100

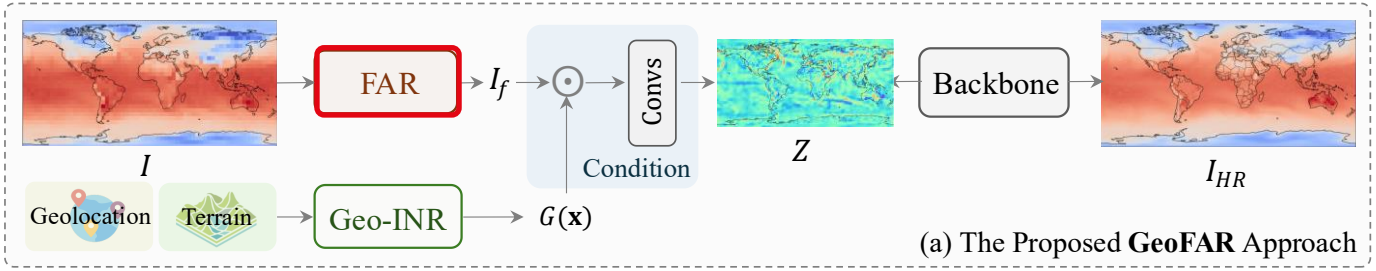
Method

- GeoFAR: Geography-Informed Frequency-Aware Super-Resolution

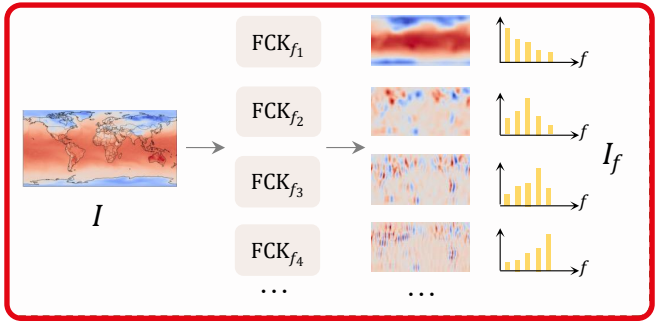


Method

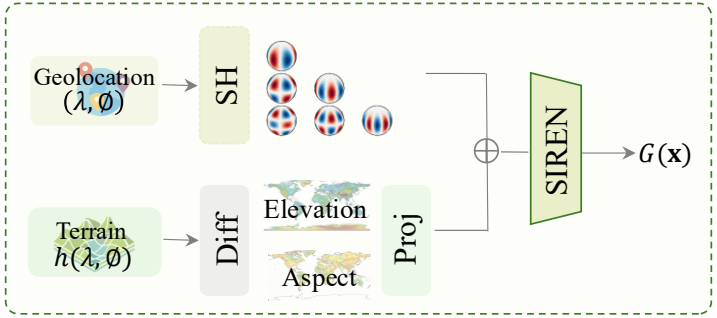
- FAR: Frequency-aware Representation



(a) The Proposed **GeoFAR** Approach



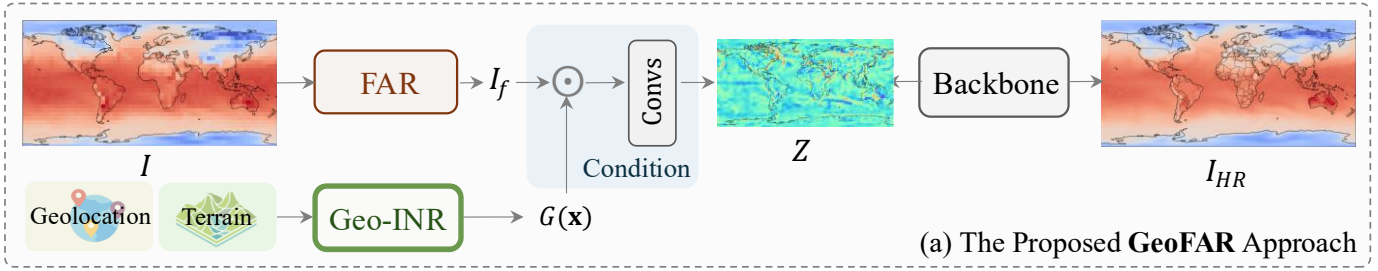
(b) **FAR**: Frequency-Aware Representation

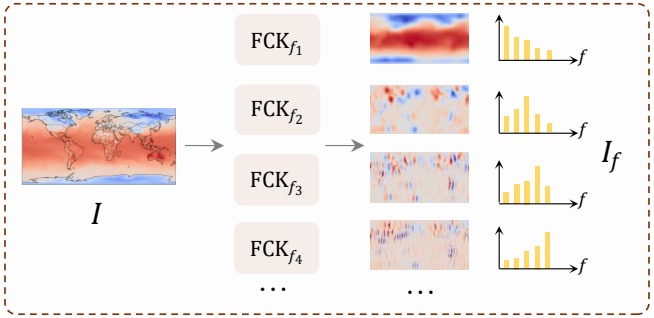


(c) **Geo-INR**: Implicit Neural Representation for Geography

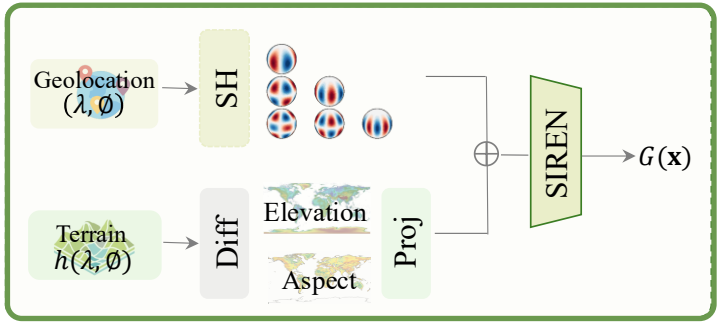
Method

- Geo-INR: Implicit Neural Representation for Geography





(b) **FAR**: Frequency-Aware Representation



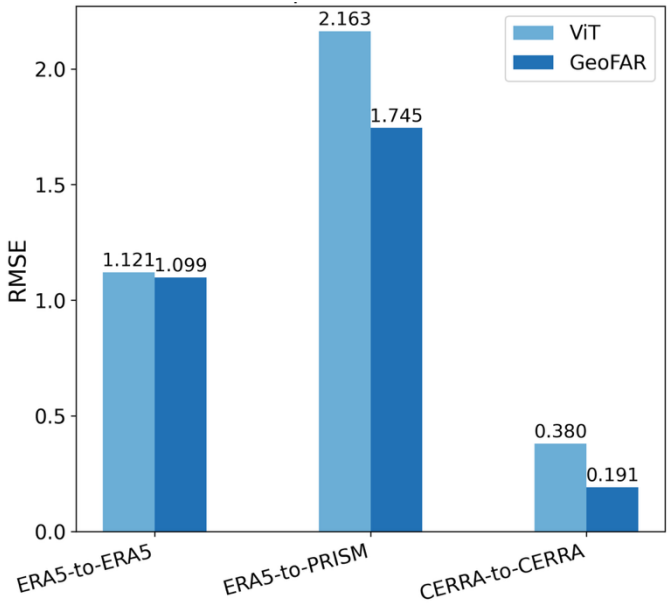
(c) **Geo-INR**: Implicit Neural Representation for Geography

Results

- Datasets
  - Global: ERA5 (2x)
  - Global-to-local: ERA5 (2.8125°) to PRISM (0.75°)
  - Local: CERRA (2x, 4x, 8x)
- Variables:
  - Surface variables: T2m, 10u, 10v, Rh2m, Sp
  - Atmospheric variables: Z500, T850
- Evaluation
  - RMSE, Mean bias, Pearson Coefficients
  - Log Frequency Distance (LFD), Frequency-aware RMSE

Results

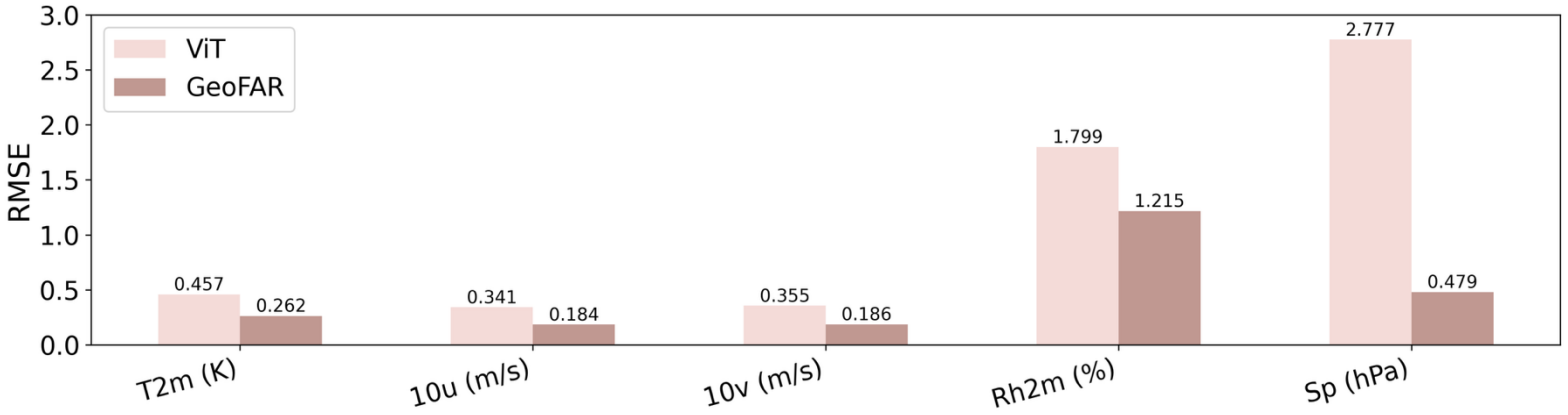
- Results across spatial resolutions (RMSE)



Method	ERA5	PRISM	CERRA
Bilinear	2.457	2.637	0.517
U-Net	1.103	1.501	0.272
ViT	1.121	2.163	0.380
SRGAN	1.149	1.718	0.245
GeoFAR[SRGAN]	1.137	1.561	0.192
GeoFAR[ViT]	1.099	1.745	0.191
GeoFAR[U-Net]	**1.076**	**1.468**	**0.180**

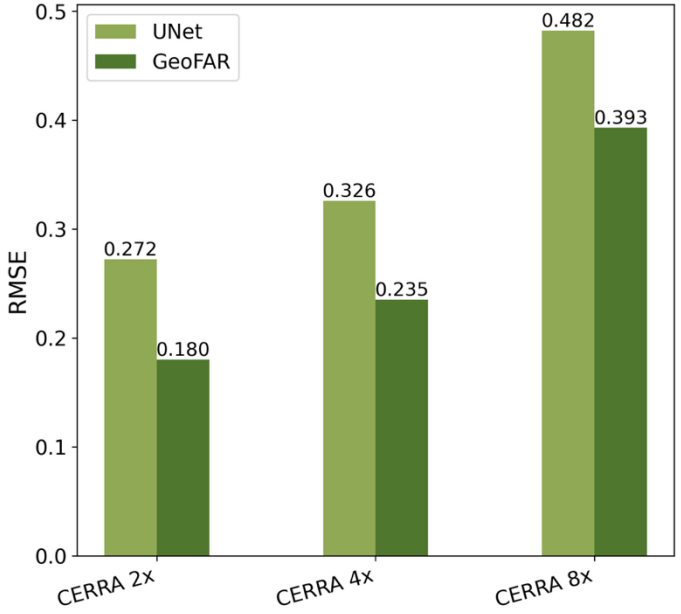
Results

- Results across climate variables (RMSE)



Results

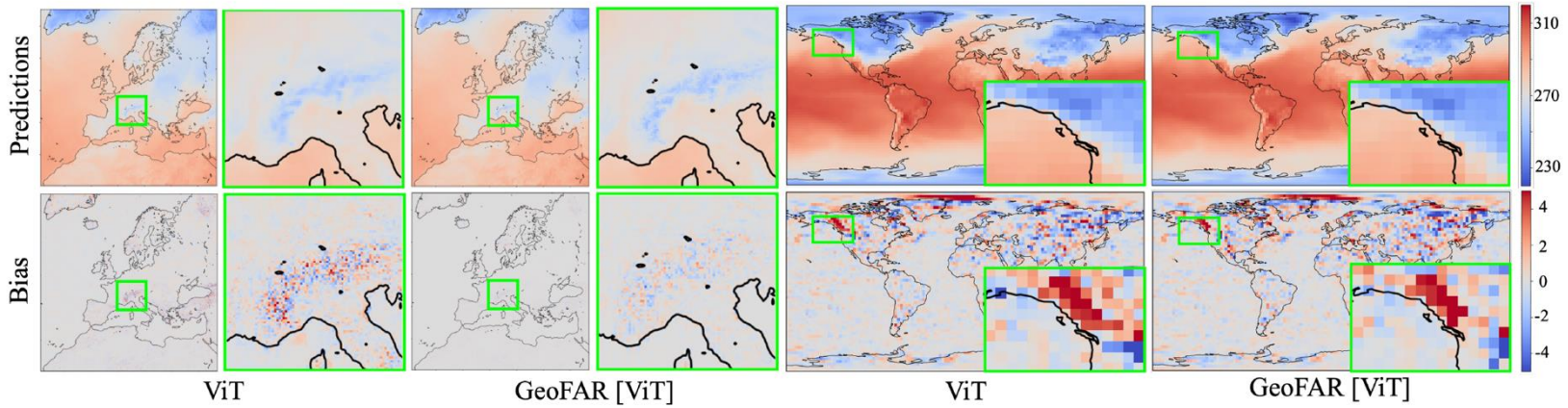
- Results across downscaling ratios on CERRA (RMSE)



Method	× 2	× 4	× 8
Bilinear	0.517	0.610	0.861
U-Net	0.272	0.326	0.482
ViT	0.380	0.458	0.564
SRGAN	0.245	0.375	0.594
GeoFAR[SRGAN]	0.192	0.253	0.434
GeoFAR[U-Net]	**0.180**	**0.235**	**0.393**

Results

- Analysis

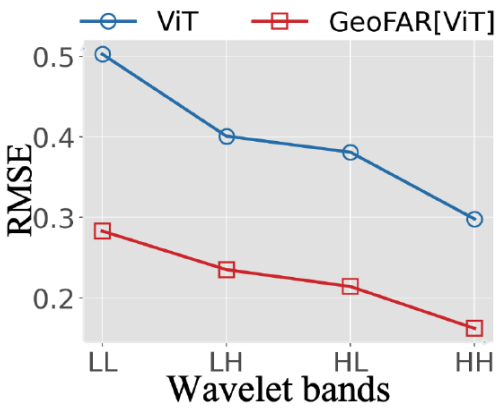


Results on CERRA

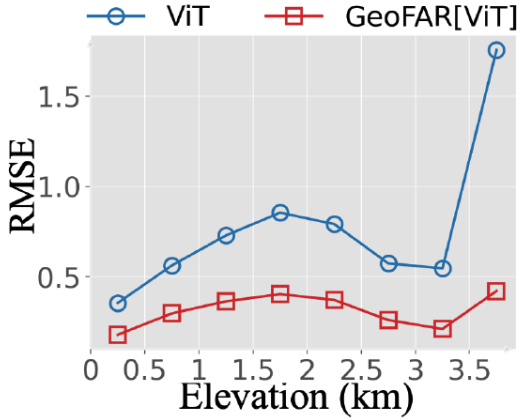
Results on ERA5

Results

- Analysis



Frequency-aware RMSE



Elevation-aware RMSE

Thank you!

Summary:

- *A Geography-Informed and Frequency-Aware (GeoFAR) approach for high-fidelity climate SR*
- *Mitigating geography-dependent frequency bias in climate SR with significant improvements in regions with complex terrain*
- *Compared with over 15 (deterministic and generative) SR methods for climate SR, achieving SOTA performance across spatial resolutions, atmospheric variables, and downscaling ratios*