A Seamless Approach for Evaluating Climate Models Across Spatial Scales

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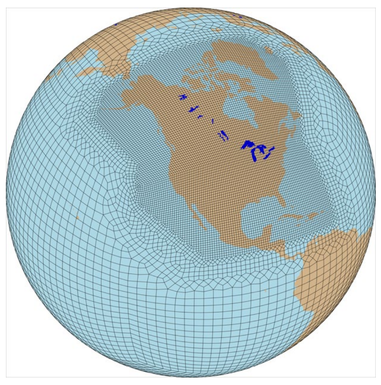
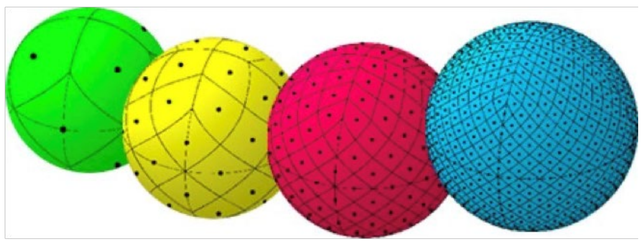
Introduction

- Climate simulations at finer spatial scales:
  - Important in regions of complex topography
  - Require exponentially more computational power to run
- Benefits of high resolution > increased computational costs?
- No framework to quantitatively evaluate the benefits vs. drawbacks
- Objective: Develop a cross-disciplinary framework for quantifying the benefits of high spatial resolution
  - Evaluate precipitation simulations in regionally refined models (RRM's) and global climate models (GCM's) with respect to NASA satellite observations

Data/Methods

- Energy Exascale Earth System Model version 2 (E3SM v2)
  - Low Resolution (LR): ~100 km
  - North American Regionally Refined Model (NARRM): ~25 km over North America
- Global Precipitation Measurement Integrated Multi-Satellite Retrievals (GPM IMERG): 0.1°
- Temporal scales: monthly, daily, 3-hour
- CONUS domain: 130° W to 60° W, 20° N to 60° N
- Hierarchical Equal-Area isoLatitude Pixelization (HEALPix)
  - Equal-area pixels
  - Partitions low resolution pixels to achieve higher resolution
- Remap precipitation data onto the HEALPix framework
- Compare simulations of fine-scale spatial precipitation patterns
- Metrics:
  - Regionally Averaged Precipitation
  - Spatial Variance in Precipitation Rates:
    - Sensitivity to Spatial Resolution
    - % Relative Change
    - % of Observed Variance Explained by models

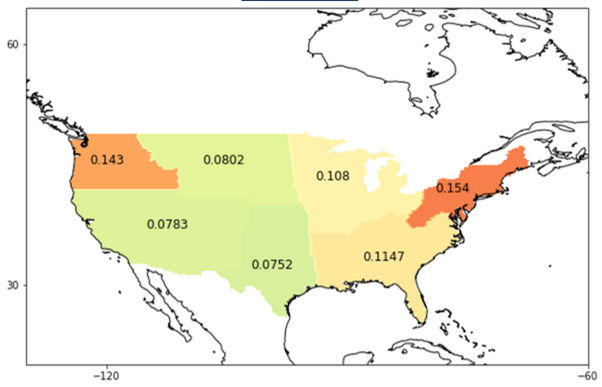




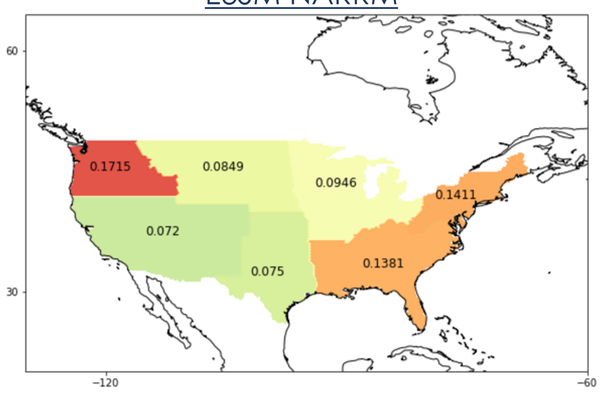
Results: Regional Precipitation

Regionally Averaged Precipitation

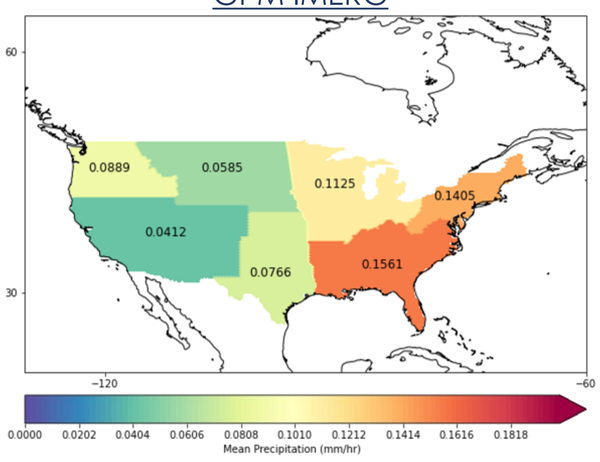
E3SM LR



E3SM NARRM



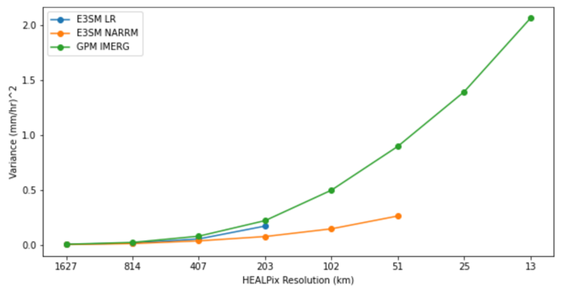
GPM IMERG



- Precipitation higher in models than observations: 3/7 regions
- Precipitation lower in models than observations: 1/7 regions
- Precipitation about equal in models and observations: 3/7 regions

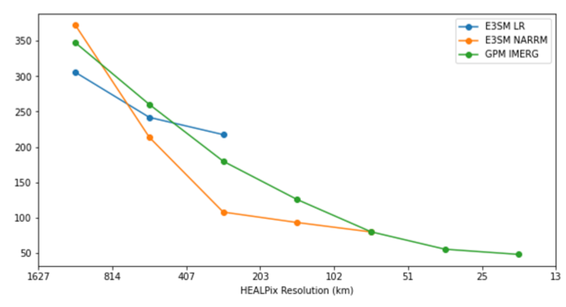
Results: Spatial Variance Changes

Spatial Variance Sensitivity to Spatial Resolution



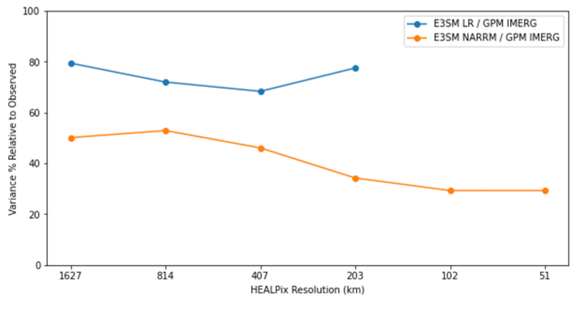
- Spatial variance increases as spatial resolution increases
- Spatial variance in E3SM NARRM lower than in LR
- Spatial variance in E3SM lower than in GPM IMERG

Relative % Change in Spatial Variance of Precipitation



- Relative change in variance decreases at higher spatial resolution

% of Variance in Precipitation Explained by Models



- Spatial variance ratio in NARRM lower than that of LR
- Spatial variance ratio in models generally higher at lower spatial resolution

Conclusions

- Several statistics were analyzed to assess the effects of spatial resolution
- Data remapped to HEALPix grid enables the multi-resolution analysis of observed and simulated precipitation
- Framework can be extended to other datasets, disciplines, etc.
- Next Steps:
  - Expand this framework to other models, datasets, variables
  - Incorporate metrics to assess computational cost of analyses at higher resolutions
  - Cost-benefit analysis of computational power vs. spatial resolution
  - Justify the use of RRM's and quantify the added benefit of higher resolution
  - Use RRM Simulations to assess future climate change in topographically complex areas

References

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