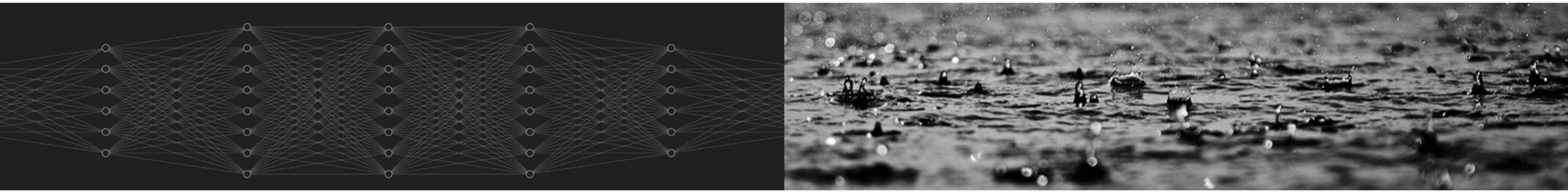
Deep Learning for Subseasonal Precipitation and Temperature *Errors*

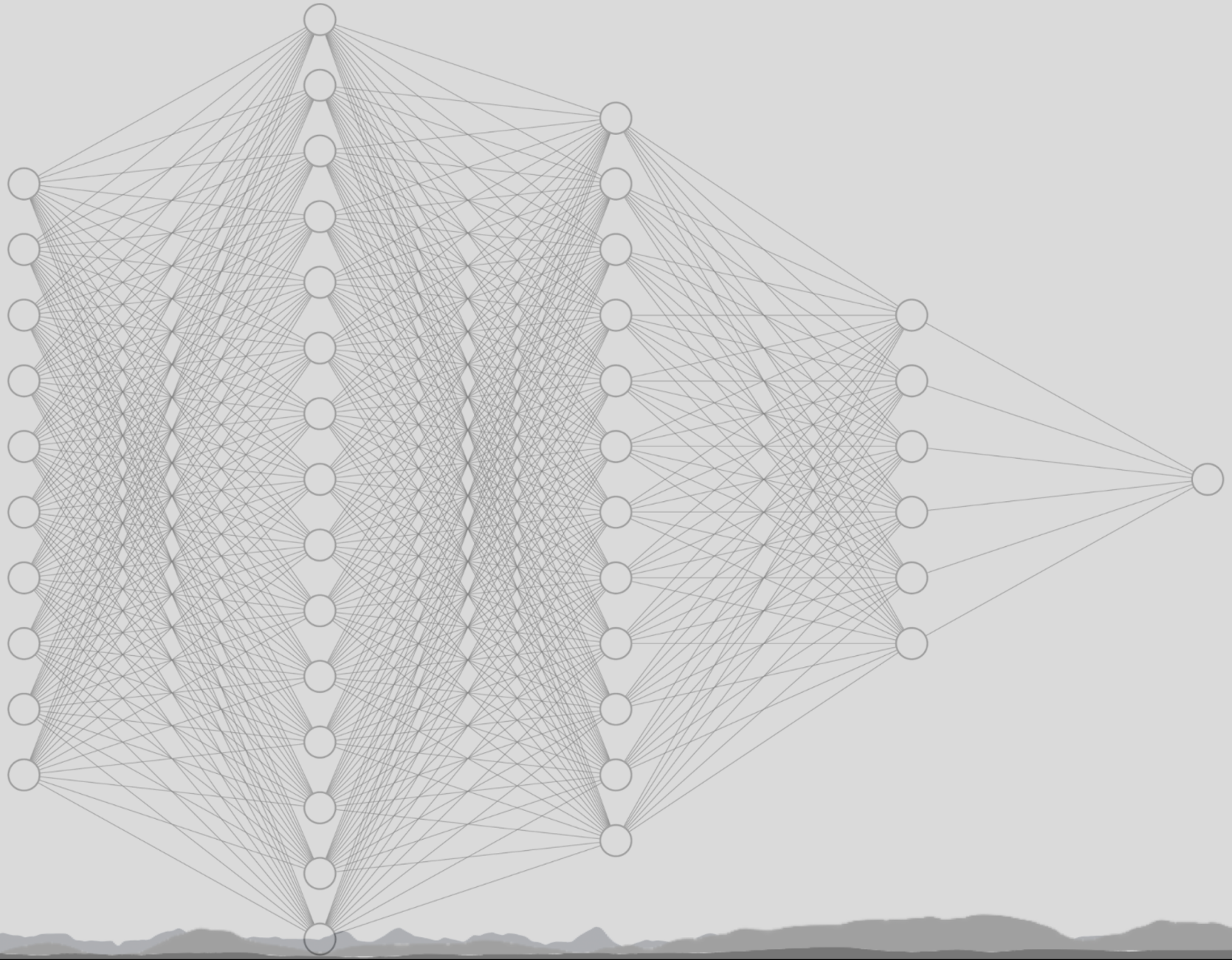


Maria J. Molina

National Center for Atmospheric Research, Boulder, Colorado

In collaboration with Jadwiga Richter, Judith Berner, Anne Sasha Glanville, Katie Dagon, Abby Jaye, Aixue Hu, Gerald Meehl, and others

NCAR U.S. DEPARTMENT OF ENERGY | Office of Science NSF catalyst



1959, ML defined

1986,

Backpropagation

Since 1990s,

GPUs

ImageNet

DL advances

Where does machine learning fit in Earth system modeling?

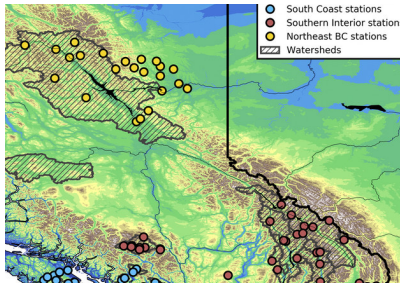
Where does machine learning fit in Earth system modeling?

Input
Observations
Initialization

Run Model
Parameterizations
HPC Costs

Output
S2S Predictions
Feature Detection

Sha, Y., Gagne, D.J., West, G. and Stull, R., 2021. **Deep-learning-based precipitation observation quality control.** Journal of Atmospheric and Oceanic Technology.



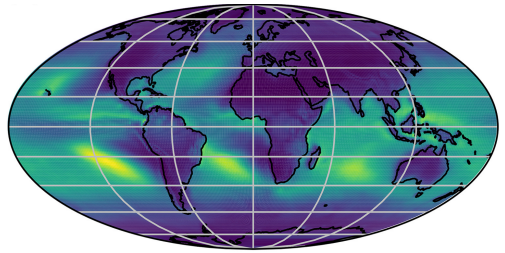
Where does machine learning fit in Earth system modeling?

Input
Observations
Initialization

Run Model
Parameterizations
HPC Costs

Output
S2S Predictions
Feature Detection

Gettelman, A., Gagne, D.J., Chen, C.C., Christensen, M.W., Lebo, Z.J., Morrison, H. and Gantos, G., 2021. **Machine learning the warm rain process.** Journal of Advances in Modeling Earth Systems.

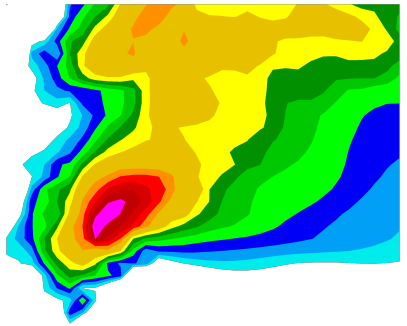


Where does machine learning fit in Earth system modeling?

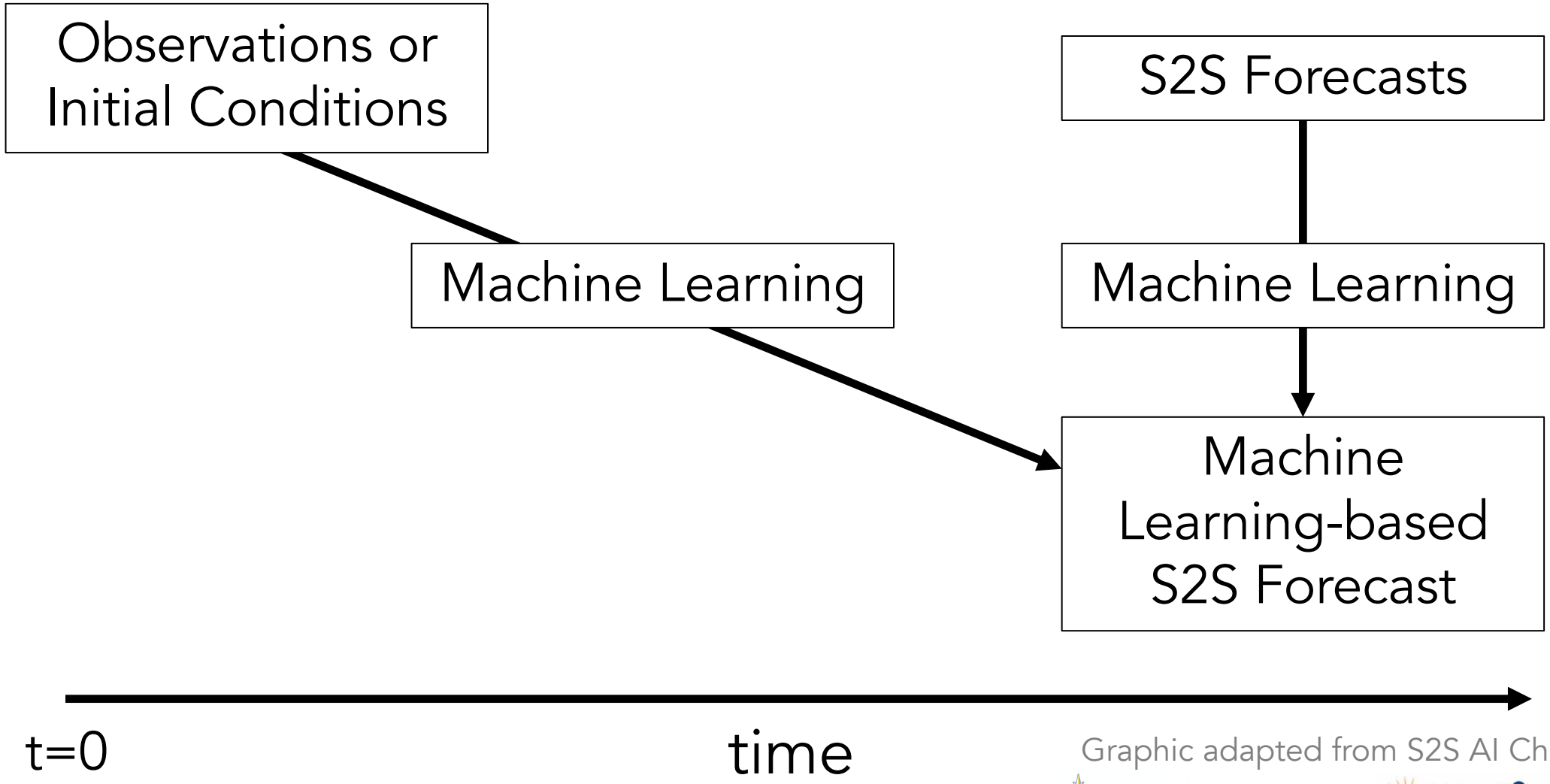
Input
Observations
Initialization

Run Model
Parameterizations
HPC Costs

Output
S2S Predictions
Feature Detection

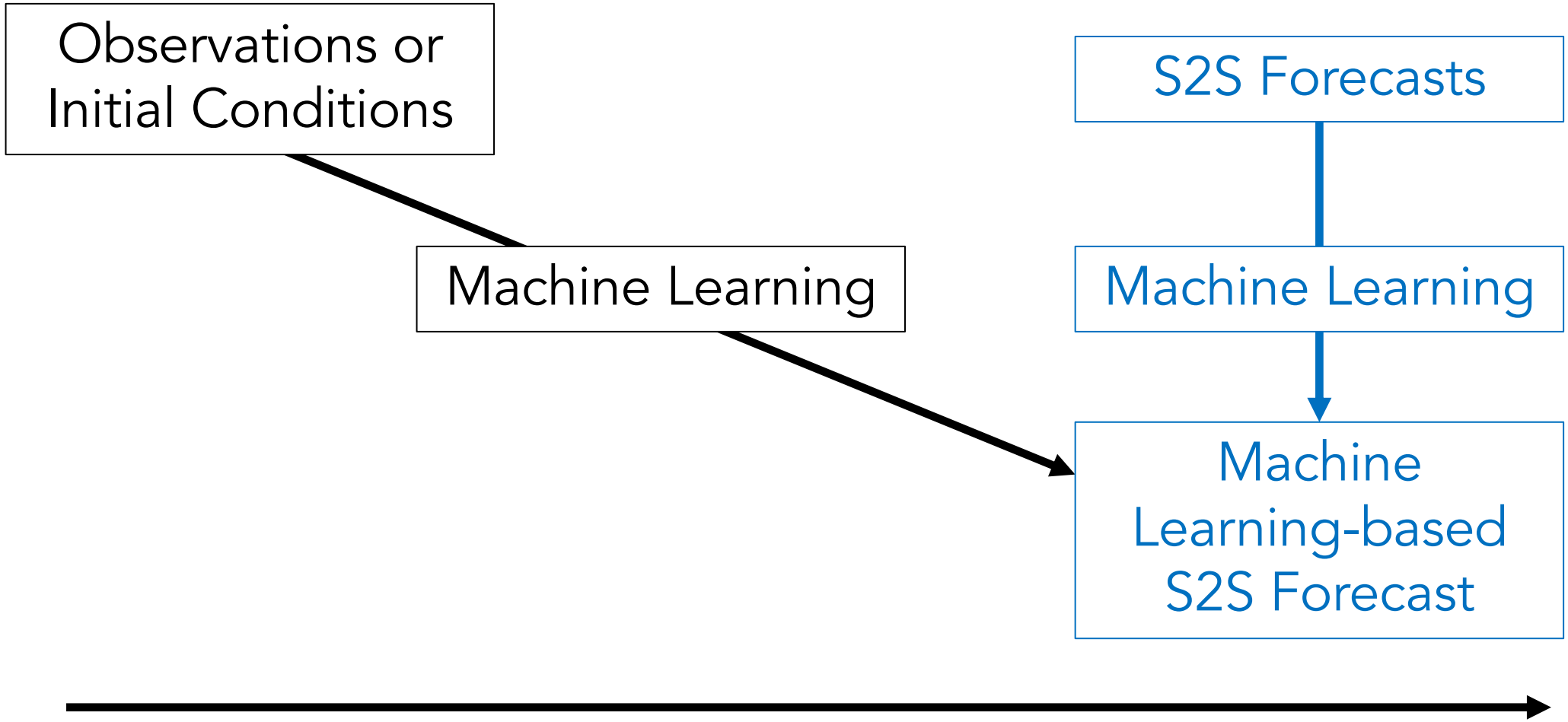


Molina, M.J., Gagne, D.J., Prein, A.F., 2021. **A benchmark to test generalization capabilities of deep learning methods to classify severe convective storms in a changing climate.** Earth and Space Science.



Graphic adapted from S2S AI Challenge 2021

(Pegion et al. 2019, Merryfield et al. 2020, Barnes et al. 2020, Meehl et al. 2021)



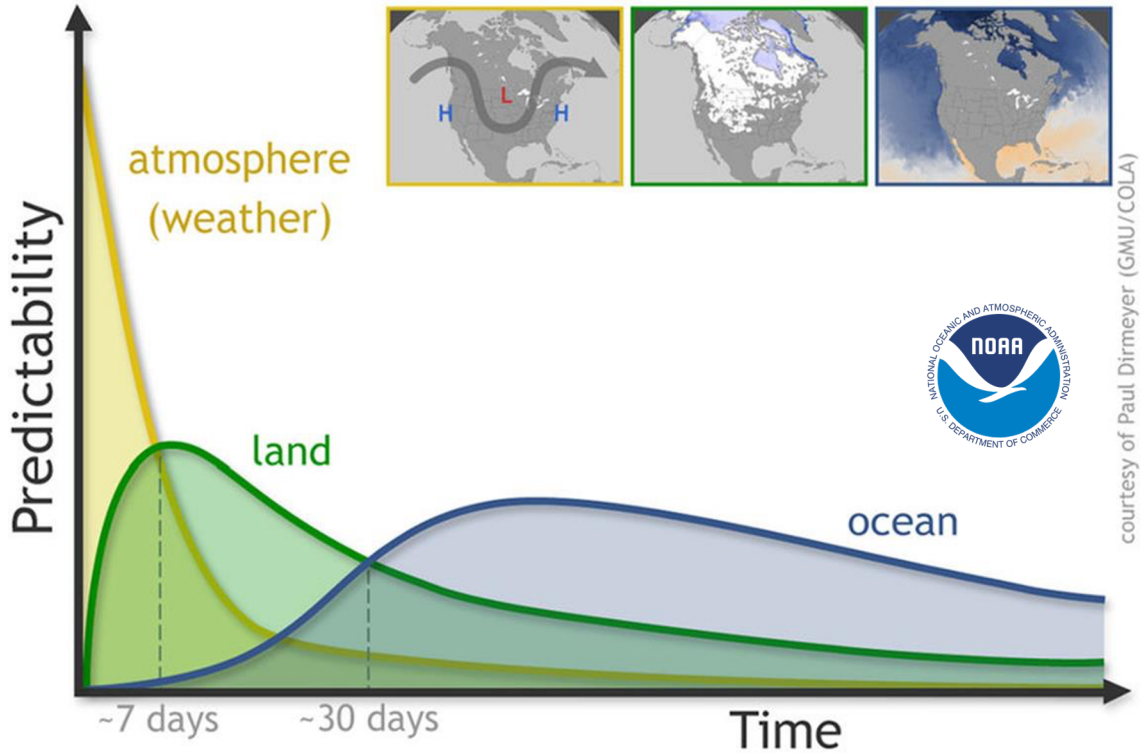
Graphic adapted from S2S AI Challenge 2021

(Pegion et al. 2019, Merryfield et al. 2020, Barnes et al. 2020, Meehl et al. 2021)

S2S simulations created using CESM2 (Richter et al. 2021; under review).

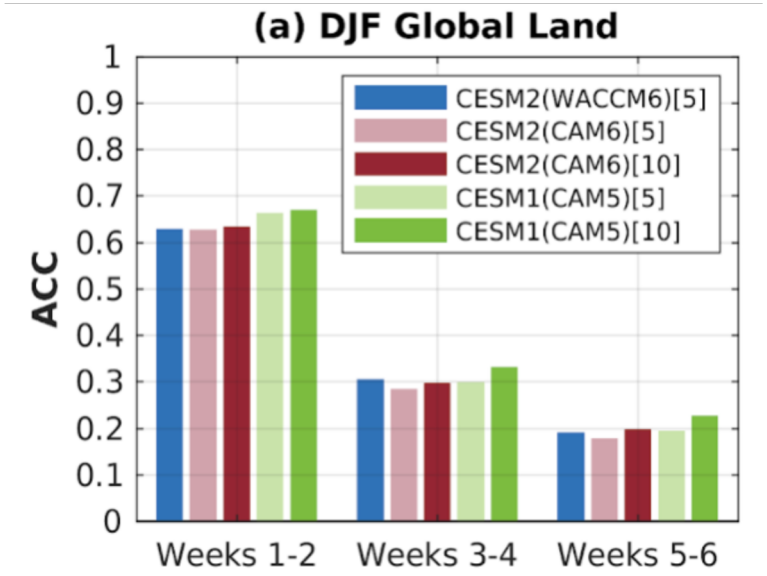
Subseasonal reforecasts follow SubX protocol (Pegion et al. 2019).

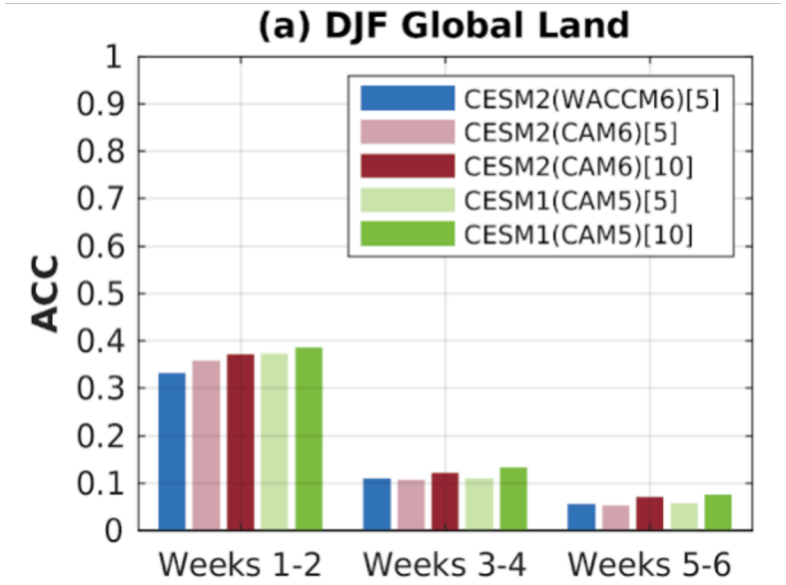
Near real-time forecasts are ongoing and contribute to the SubX multi-model mean ensemble.



Temperature skill

Precipitation skill

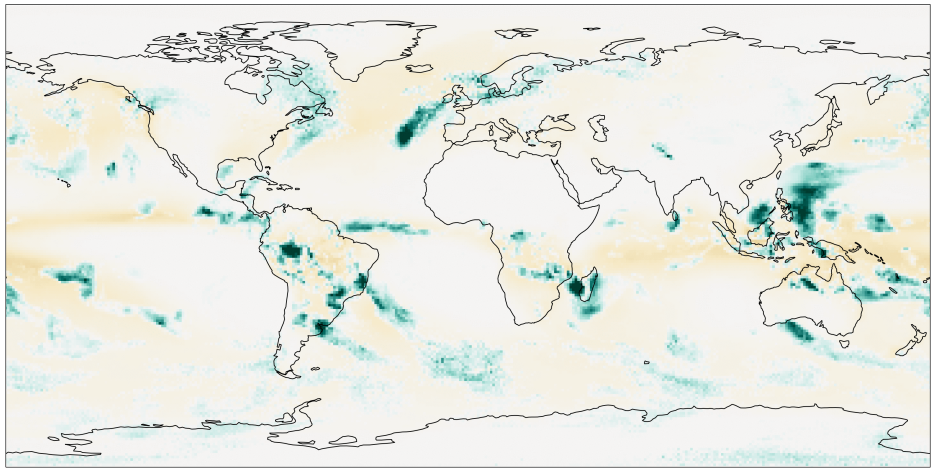




(Richter et al. 2021; under review)

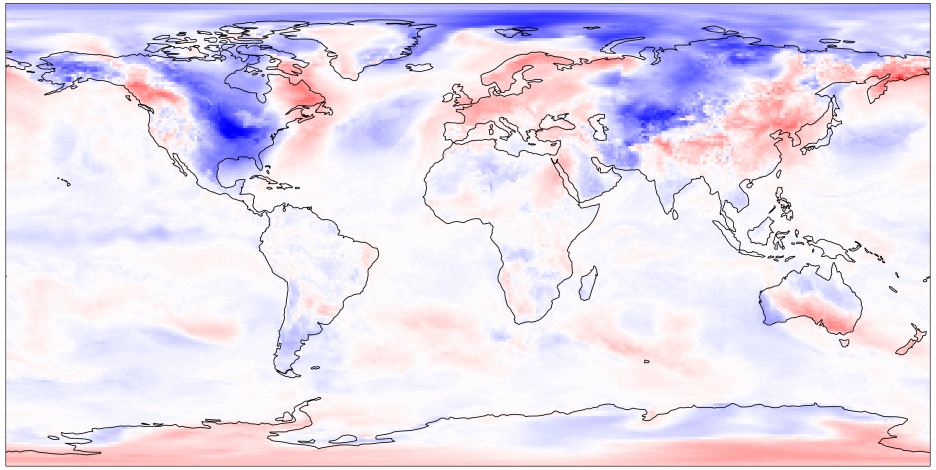
Climatology and lead time bias corrected anomalies

NOAA Global Precipitation Climatology Project (GPCP) Climate Data Record (CDR), Daily V1.3 (1999-2020).



(Adler et al. 2017)

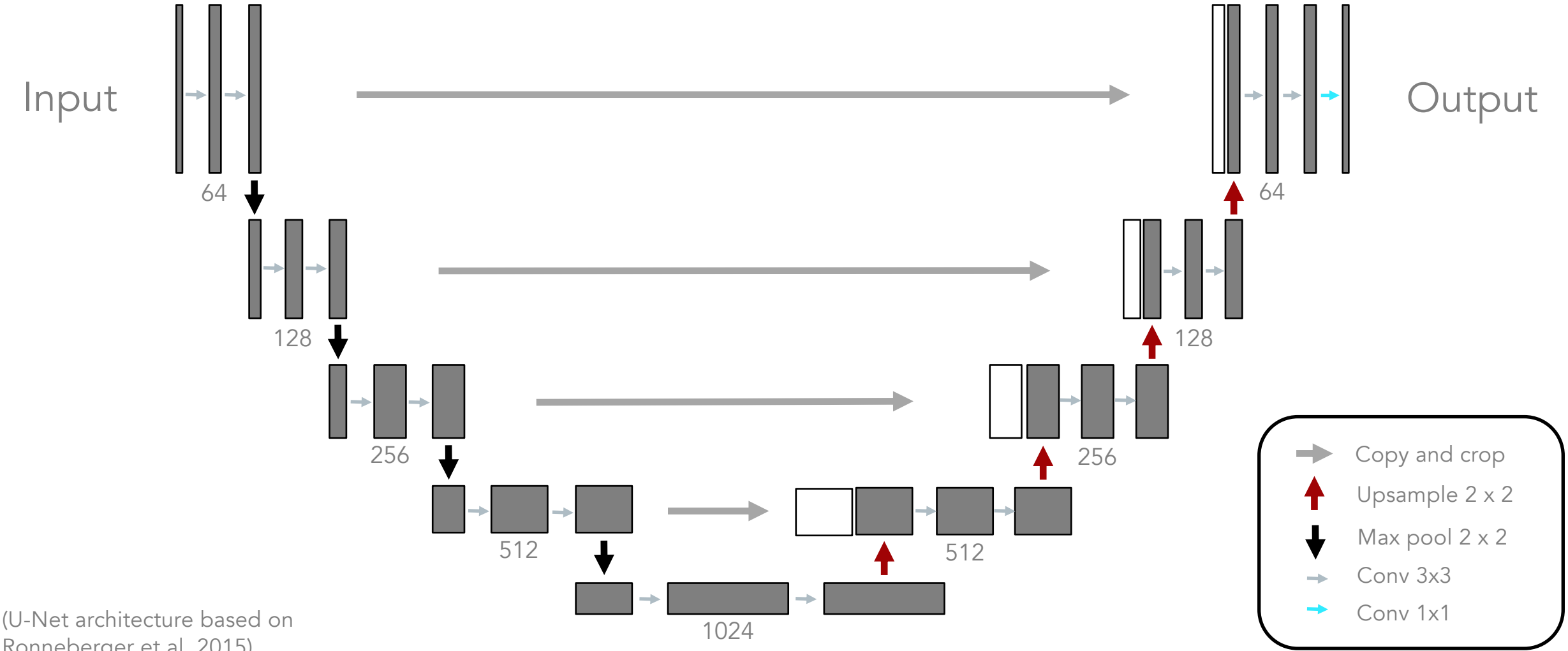
Climatology and lead time bias corrected anomalies



(Hersbach et al. 2020)

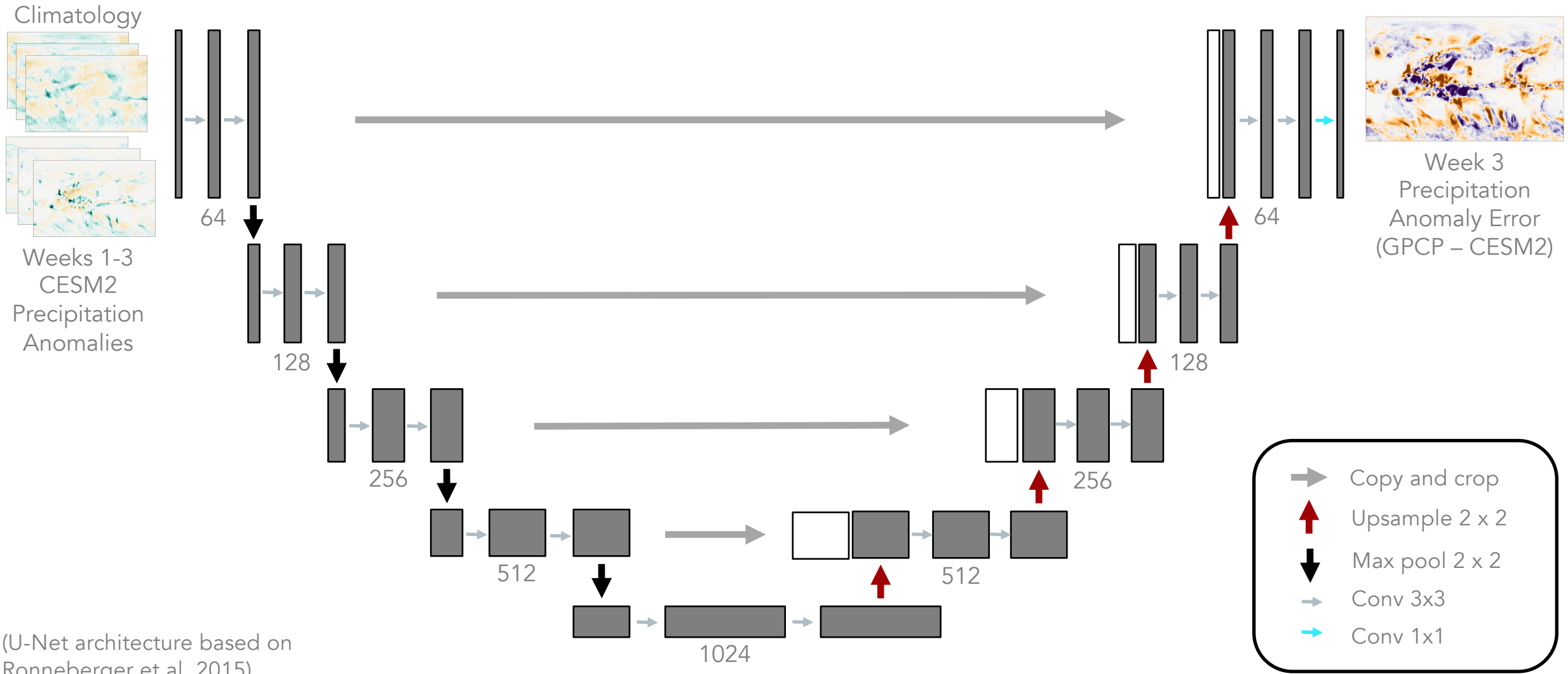
ERA5 Daily Maximum and Minimum Temperature Average (1999-2020).

U-Net Architecture (training and validation: 1999-2015)



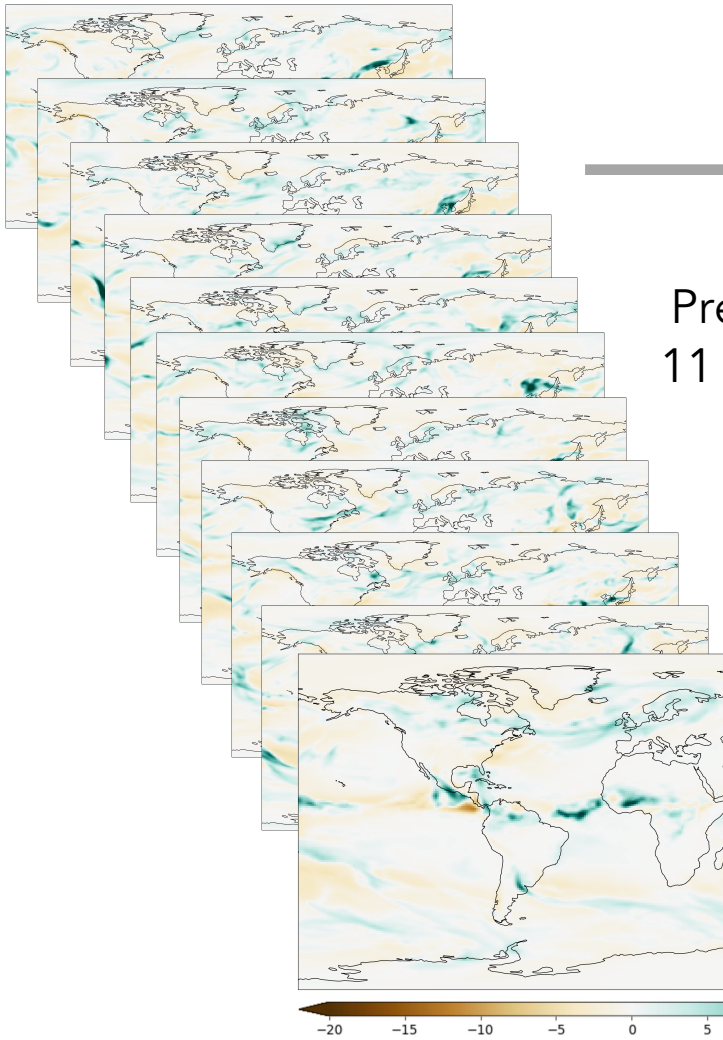
(U-Net architecture based on Ronneberger et al. 2015)

U-Net Architecture (training and validation: 1999-2015)



(U-Net architecture based on Ronneberger et al. 2015)

U-Net Architecture (training and validation: 1999-2015)



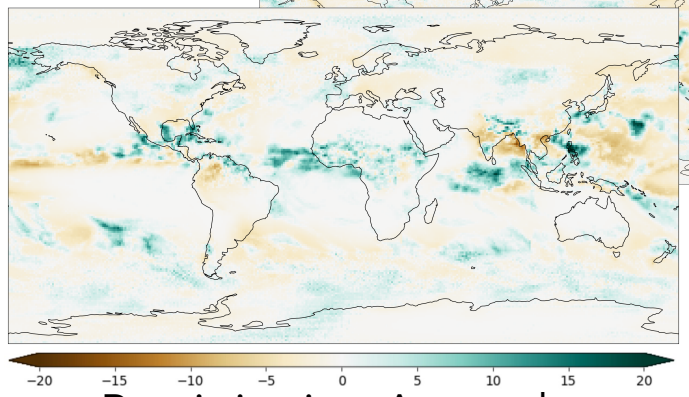
CESM2
Precipitation Anomaly
11 Ensemble Members

3 Week Lead Time

Precipitation Anomaly

NOAA GPCP
Precipitation
Anomaly

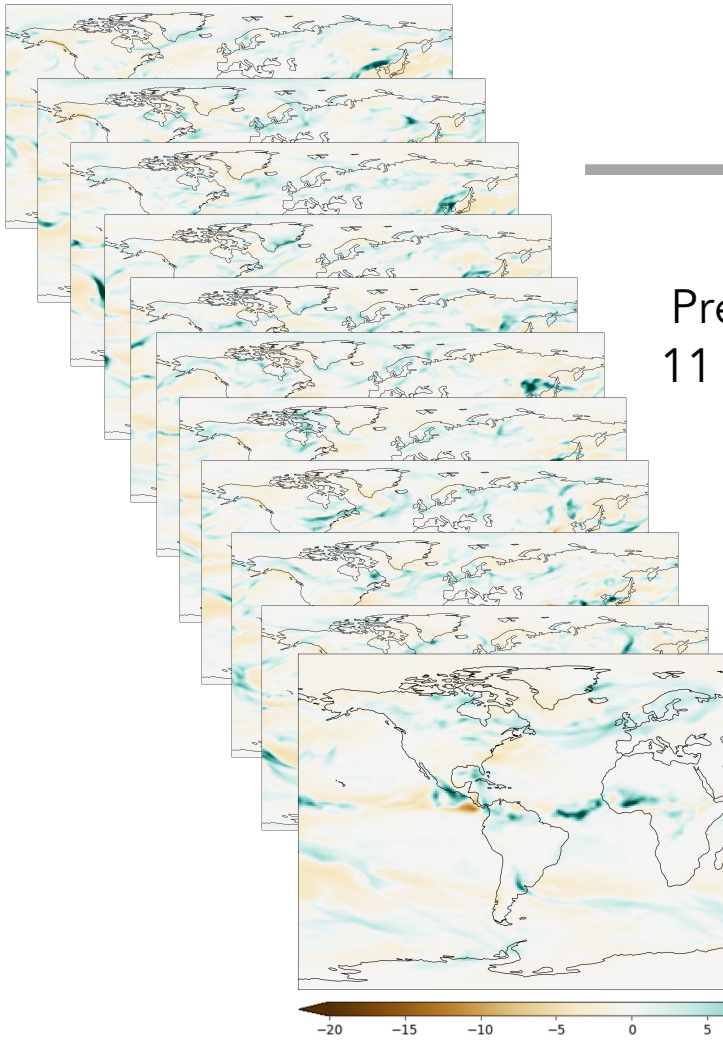
Week 3



Precipitation Anomaly

Molina et al. (in prep.)

U-Net Architecture (training and validation: 1999-2015)



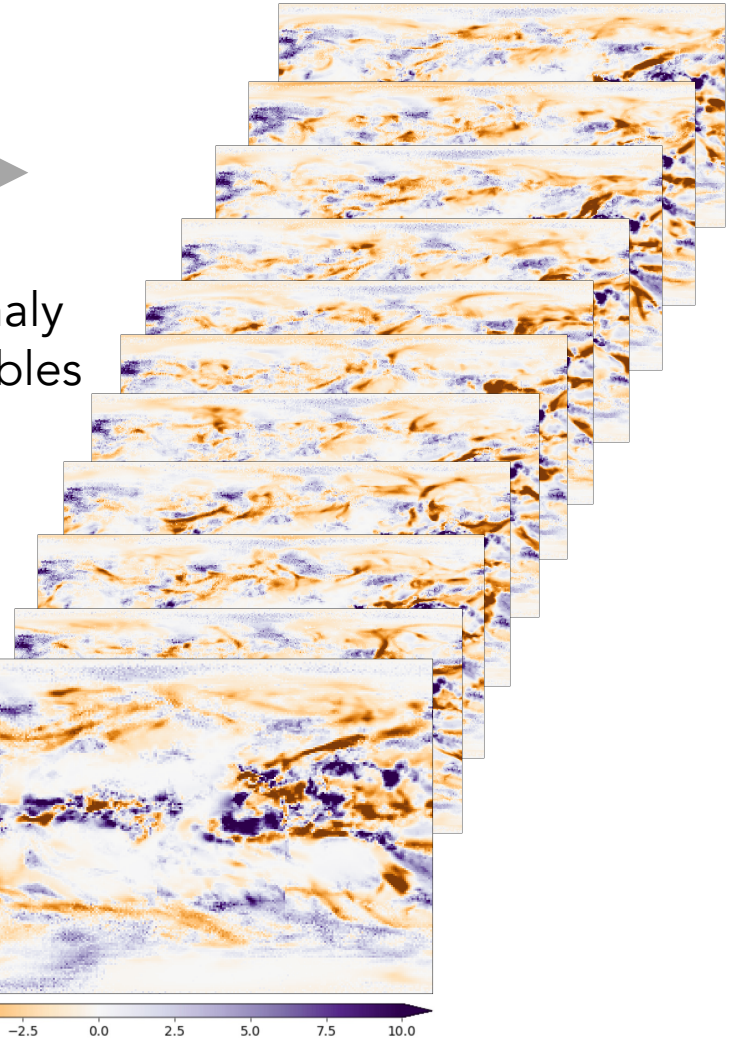
CESM2
Precipitation Anomaly
11 Ensemble Members

3 Week Lead Time

Precipitation Anomaly

NOAA GPCP
Precipitation Anomaly
Errors for 11 Ensembles

Week 3
(GPCP-CESM2)

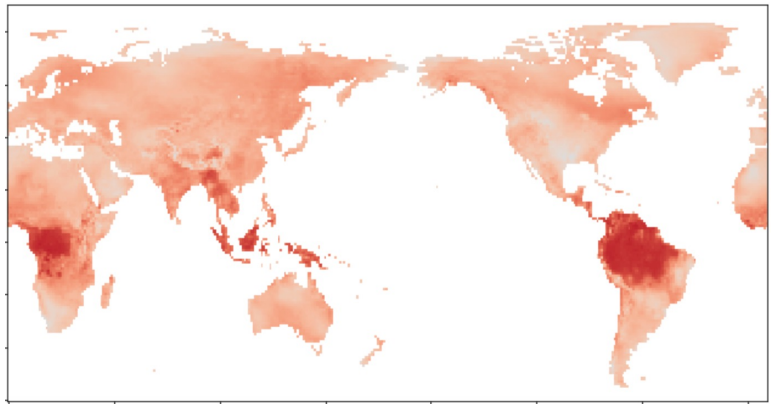


Precipitation Error

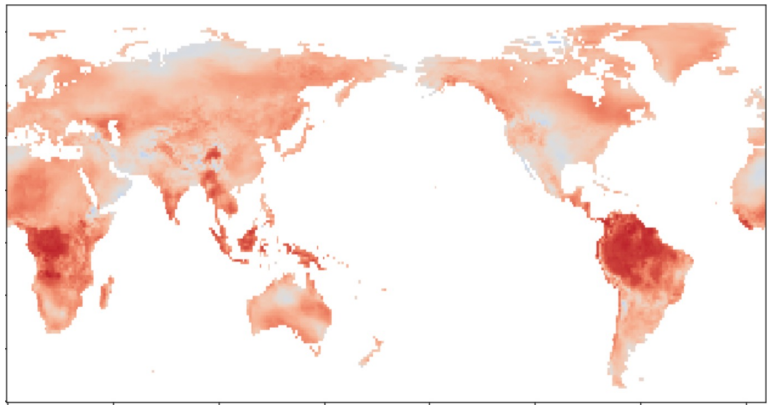
Molina et al. (in prep.)

Skill of Week 3 Temperature Error Prediction (2016-2019)

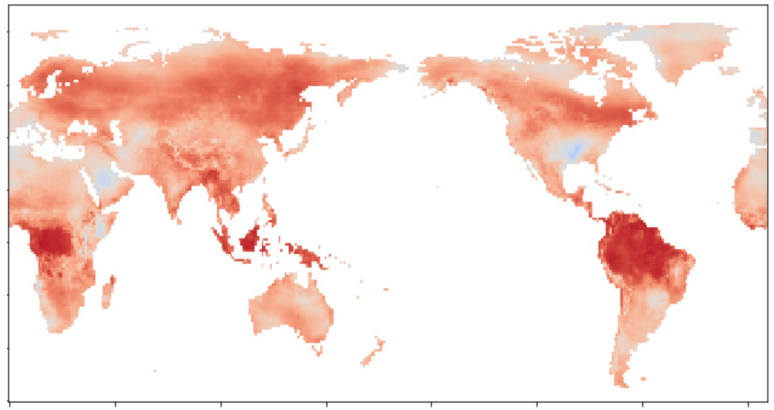
All Seasons (0.41)



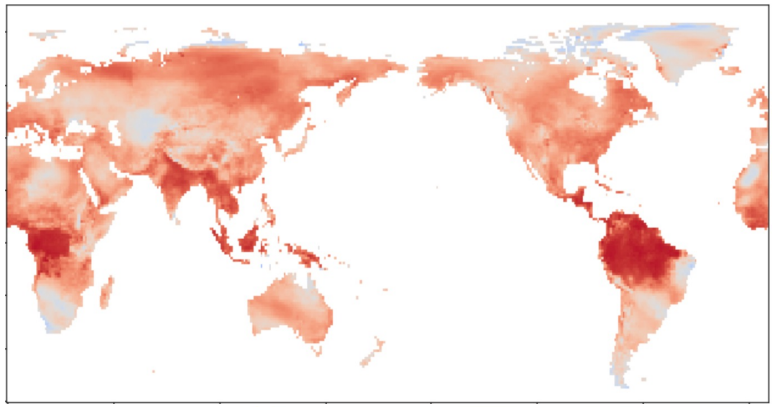
DJF (0.39)



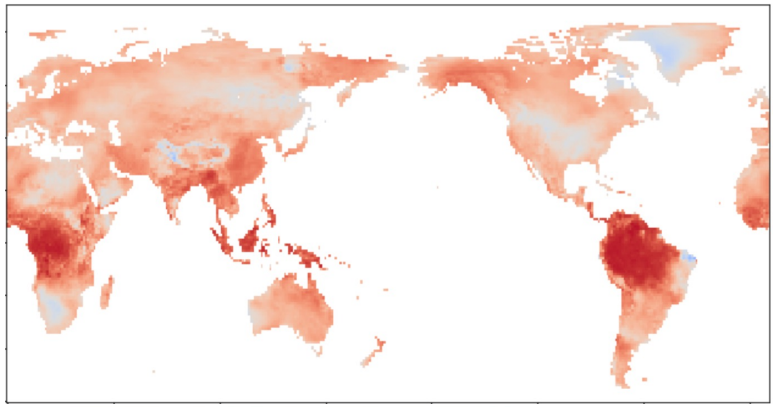
MAM (0.44)

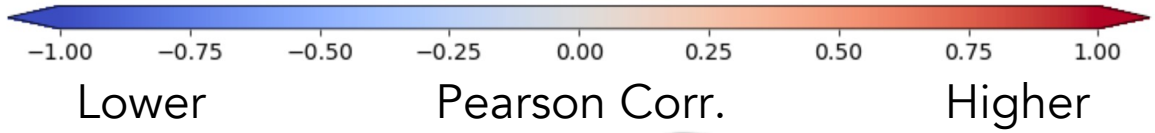


JJA (0.44)



SON (0.40)

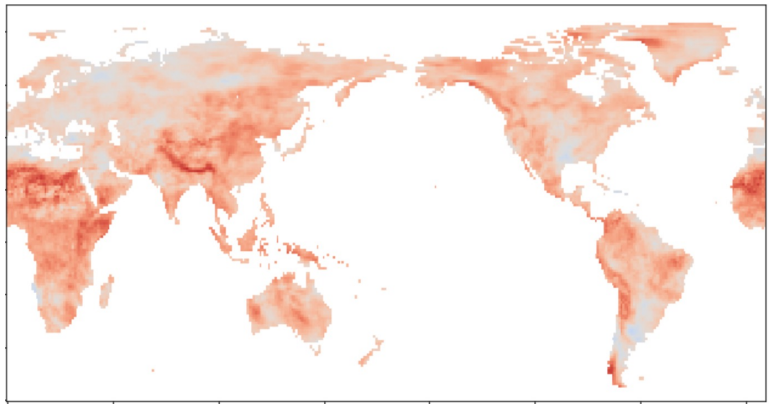




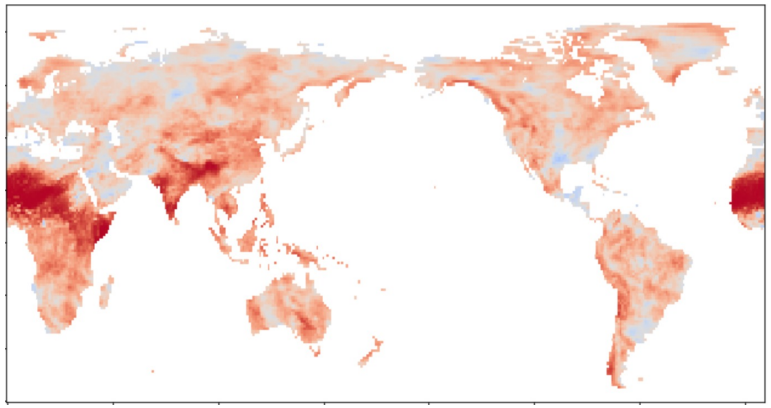
Molina et al. (in prep.)

Skill of Week 3 Precipitation Error Prediction (2016-2019)

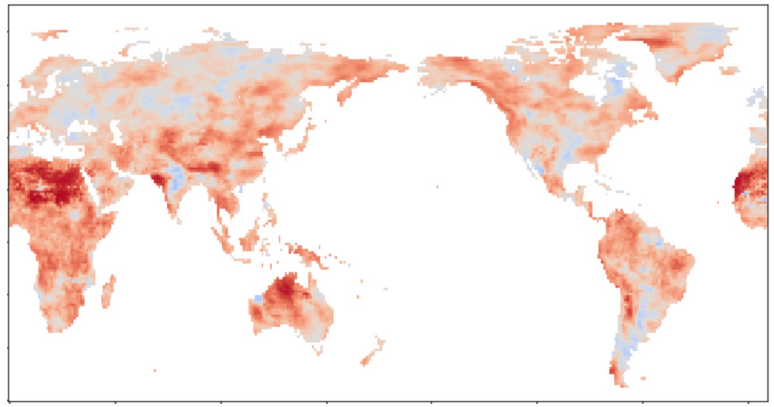
All Seasons (0.31)



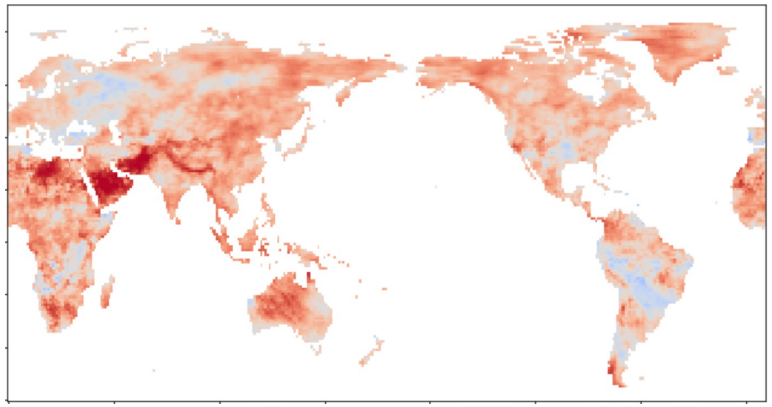
DJF (0.34)



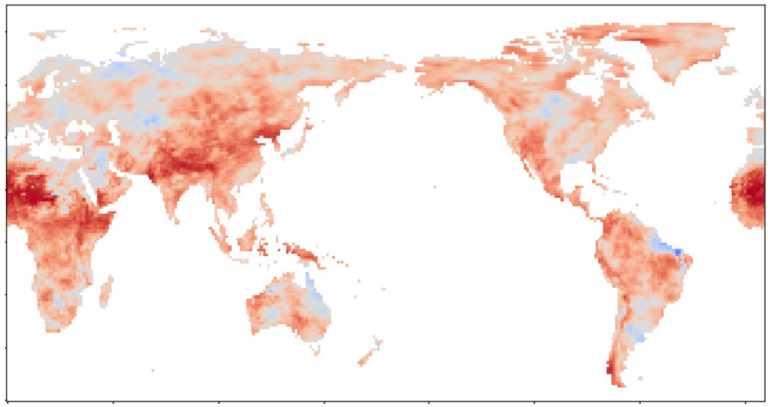
MAM (0.32)

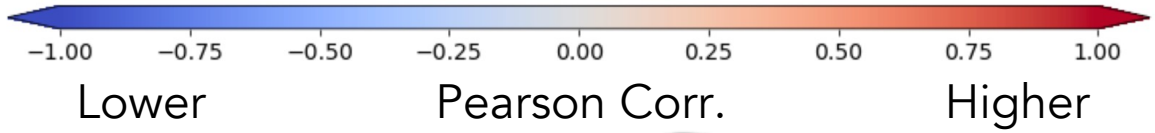


JJA (0.32)



SON (0.33)

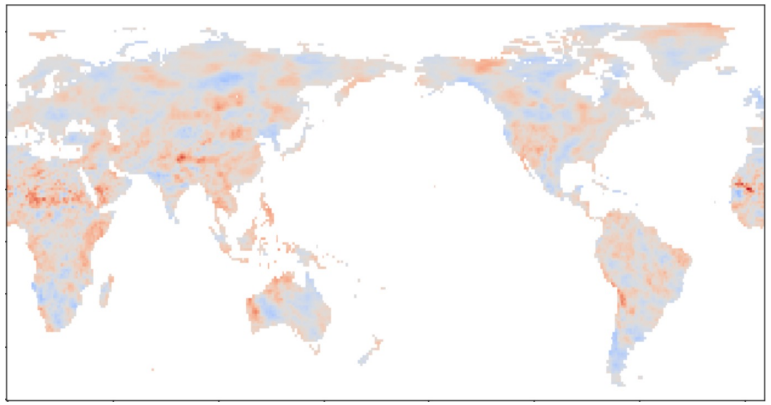




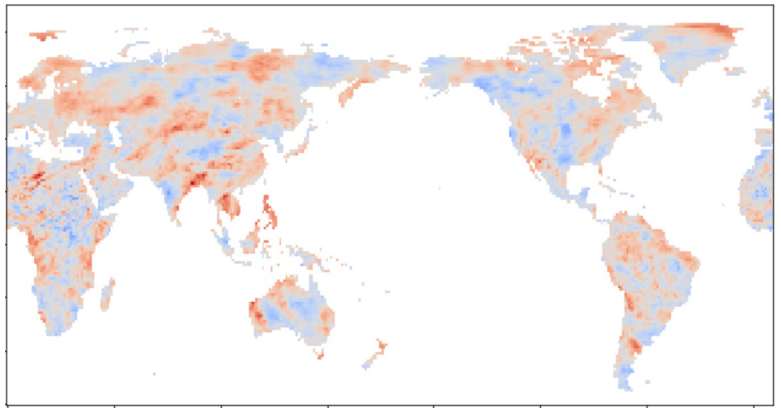
Molina et al. (in prep.)

Skill of Week 3 Precipitation Prediction (2016-2019)

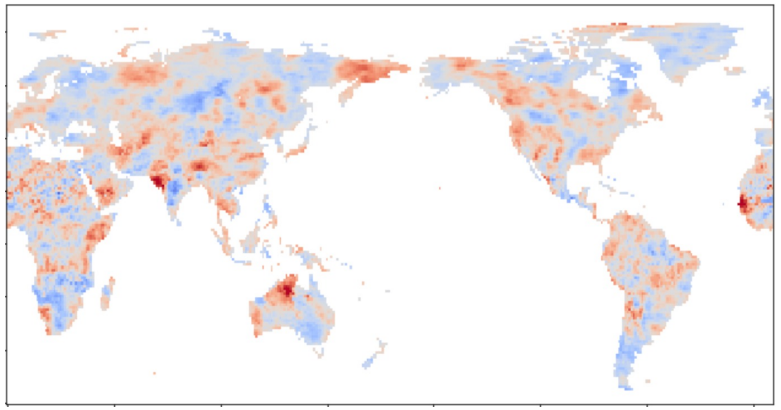
All Seasons



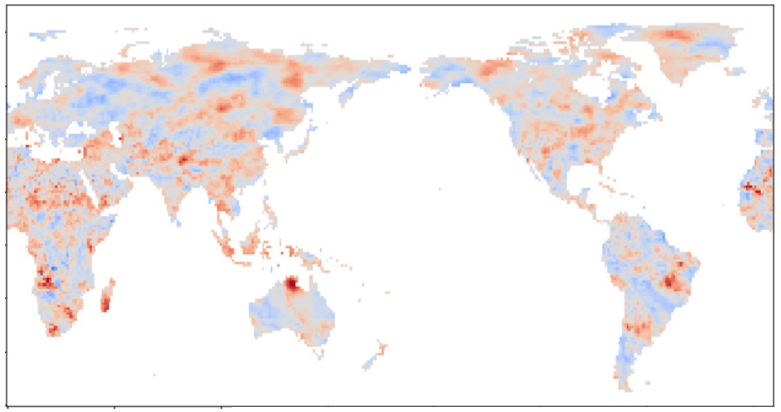
DJF (+0.66%)



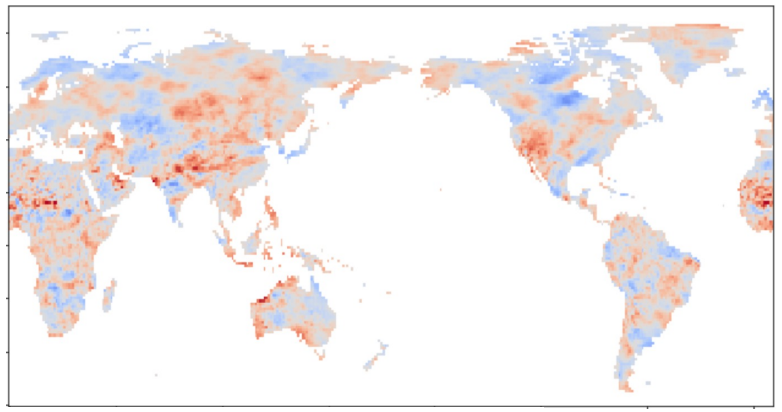
MAM (+1.59%)

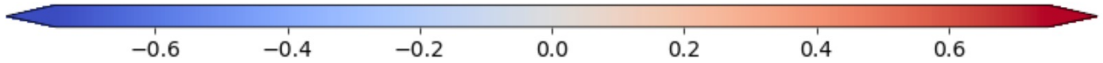


JJA (+1.45%)



SON (+0.17%)



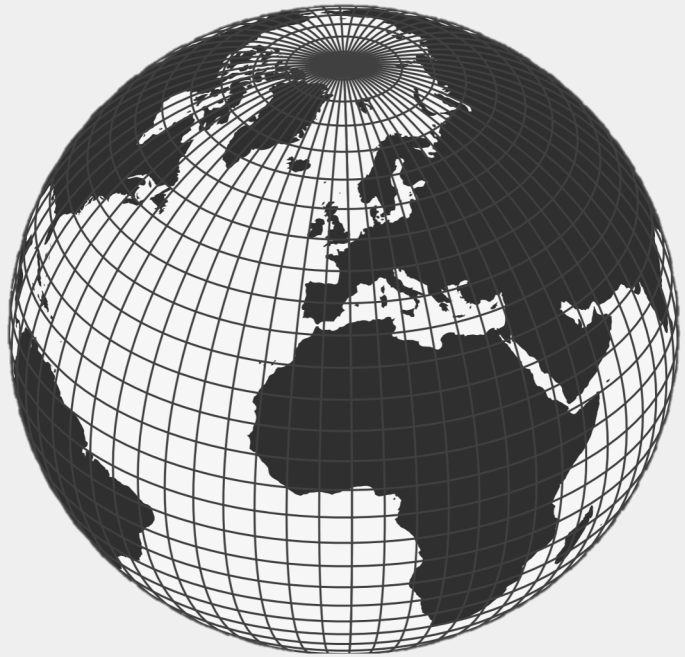


Less Skill ACC More Skill

Molina et al. (in prep.)

Future work and opportunities:

- Application of Explainable AI.
- Comparison to other bias correction methods.
- Creation of a large ML-based ensemble.



DERECHO
NCAR Supercomputer