Testing Machine Learning for Regional Climate Applications in the Pacific Northwest

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SIParCS

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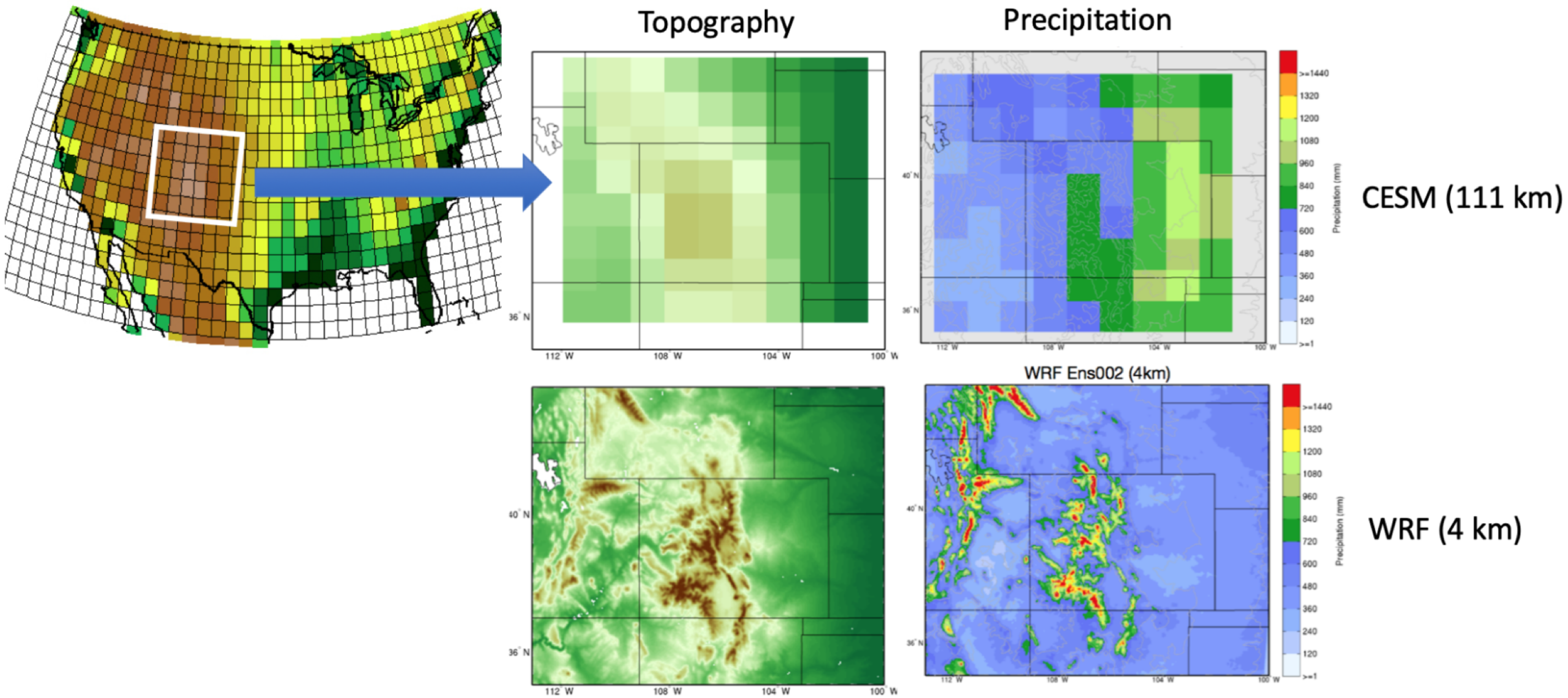
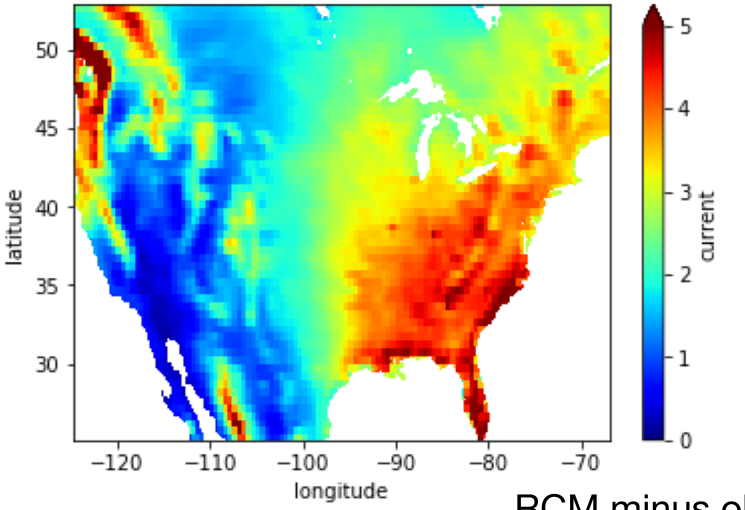
We need more detailed precipitation data than RCMs can directly provide

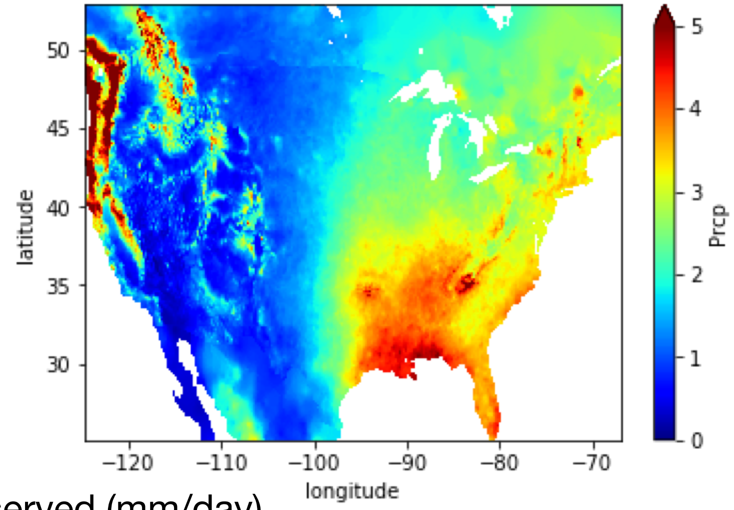
Climate Model Native Resolution and Application Resolution



RCM WRF -- ERA-Interim, average daily precipitation (mm/day)



Maurer observed average annual daily (mm/day)



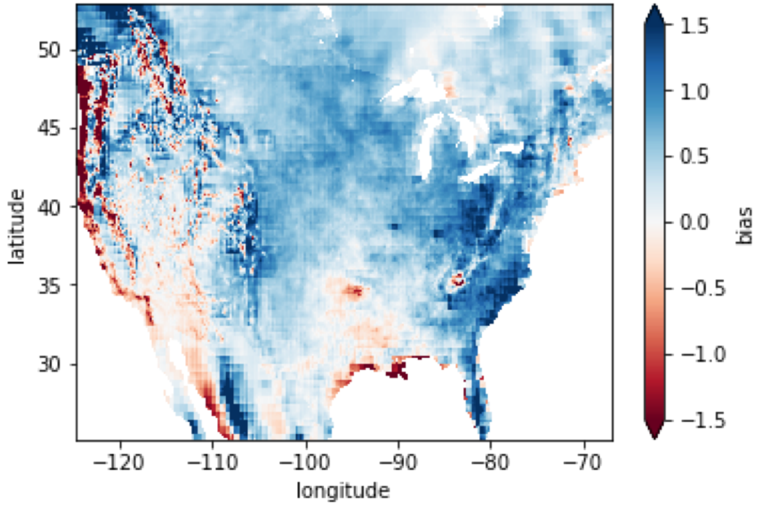
Observations

- Maurer gridded observed precipitation.
- ⅛ - degree (~12km) US-wide data.
- Covers 1980-2010.

Regional Climate Model Output

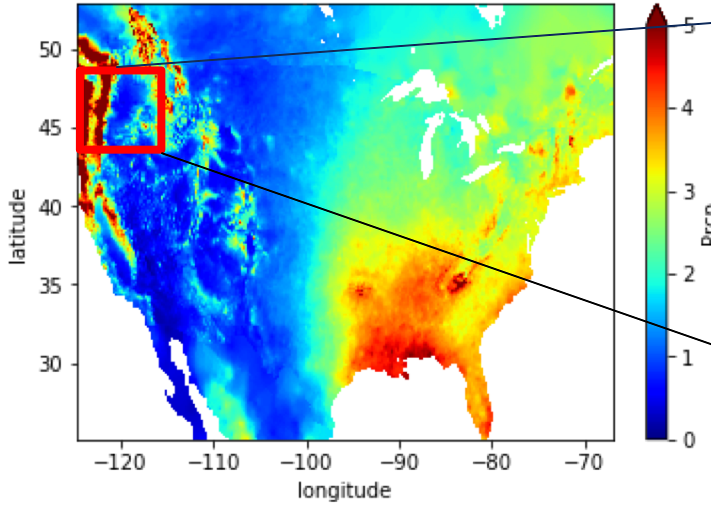
- All simulations are part of NA-CORDEX.
- ERA-Interim driven WRF simulations at 50km. Simulations run over 1980-2010.
- MPI GCM driven WRF simulations at 50km.
- Historical period is 1976-2005.
- Future period is 2070-2099.
- RCP8.5 climate scenario from CMIP5.

RCM minus observed (mm/day)

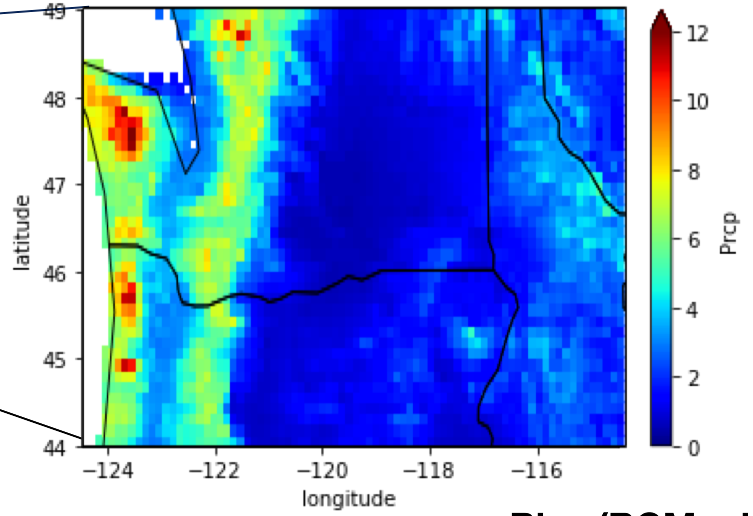


Focusing on the Pacific Northwest

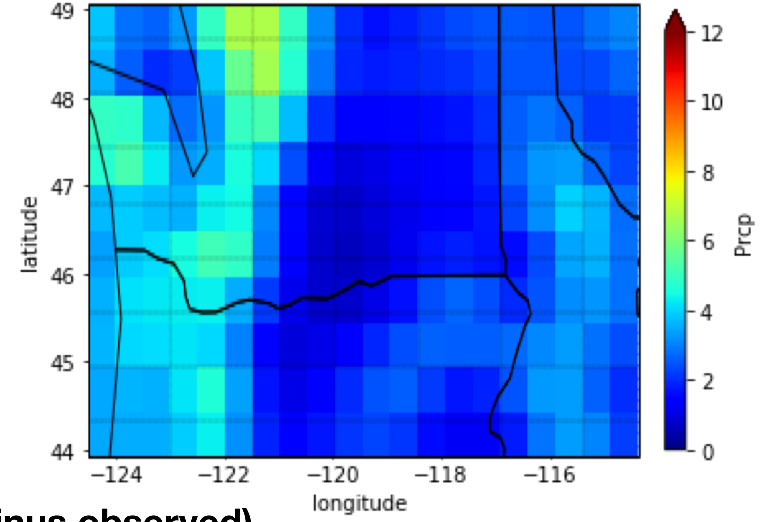
Maurer observed average daily precipitation, 1979-1999 (mm/day)



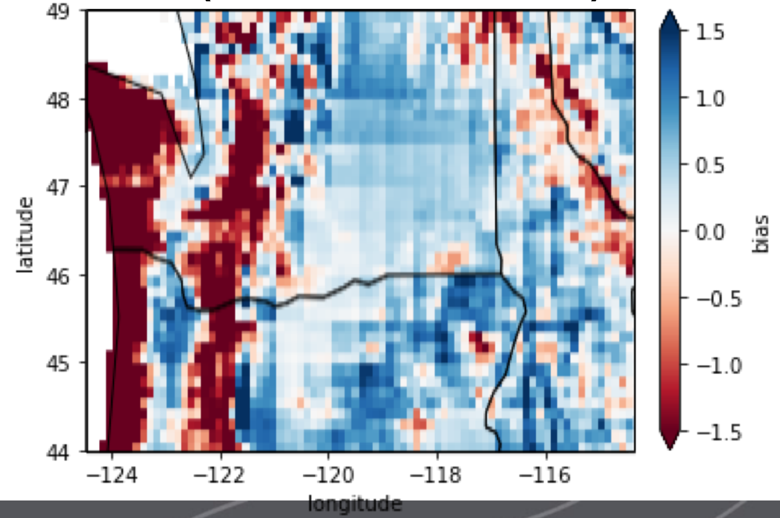
Maurer observed average daily precipitation (mm/day)



RCM output average daily precipitation (mm/day)



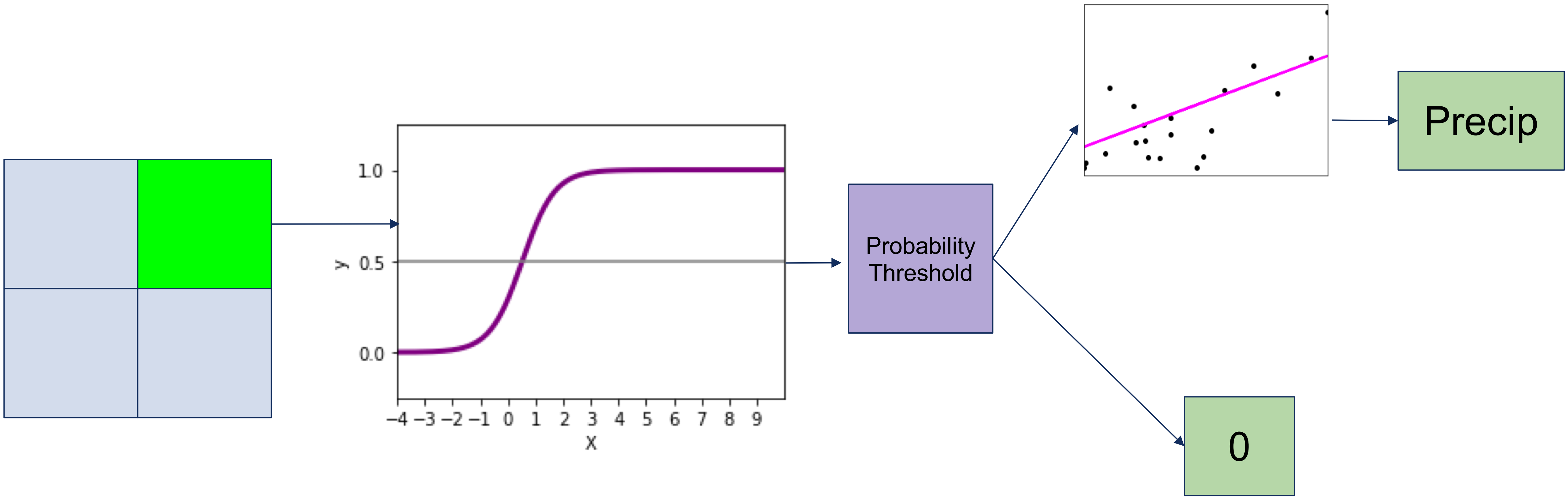
Bias (RCM minus observed)



Three methods for statistical downscaling

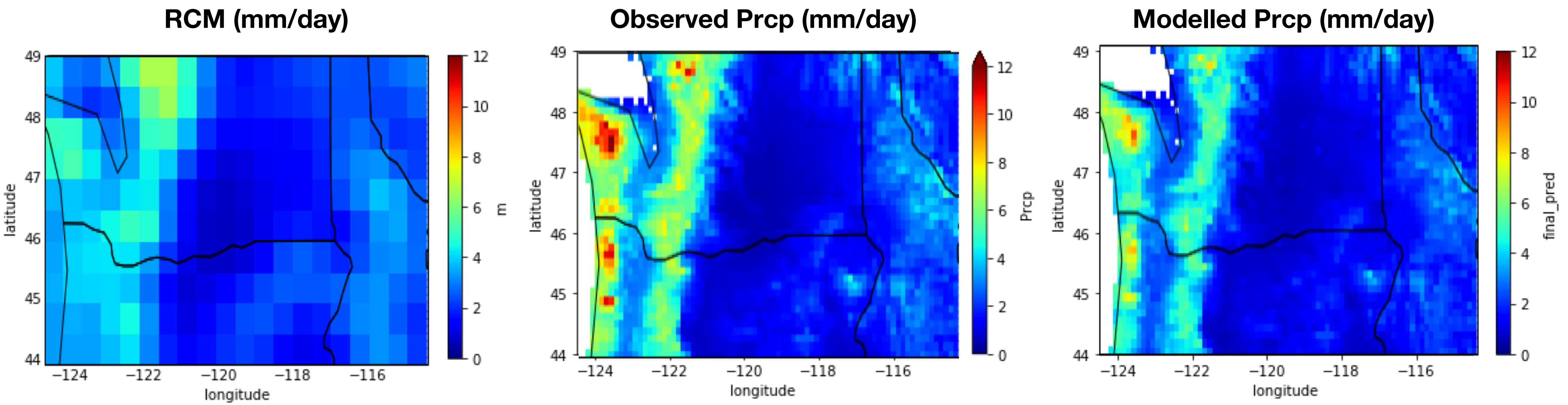
1. Cellwise Linear Regression
2. Cellwise Random Forests
3. Convolutional Neural Network

1. Cellwise Linear Regression - the details

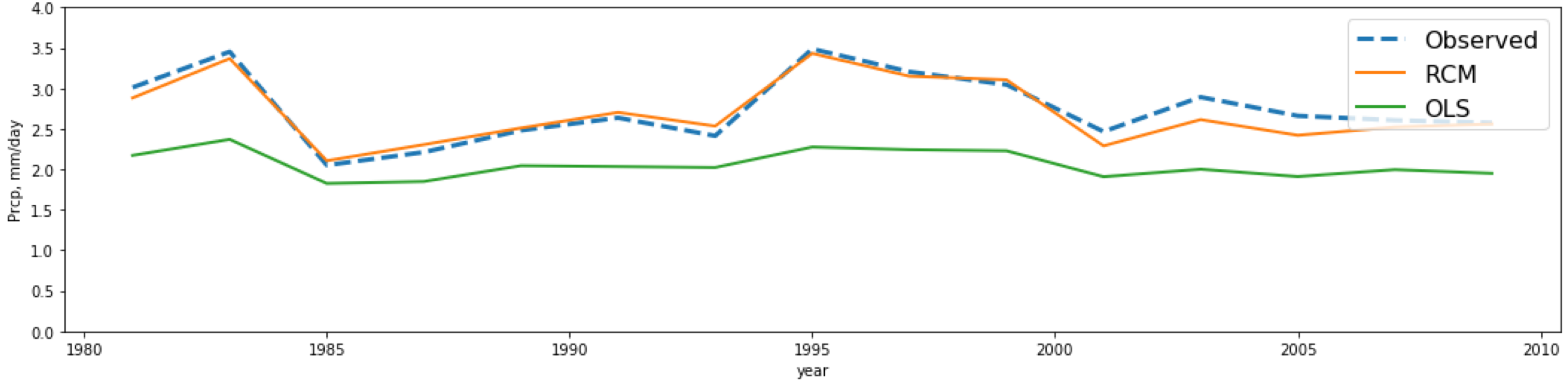


1. Cellwise Linear Regression - the results

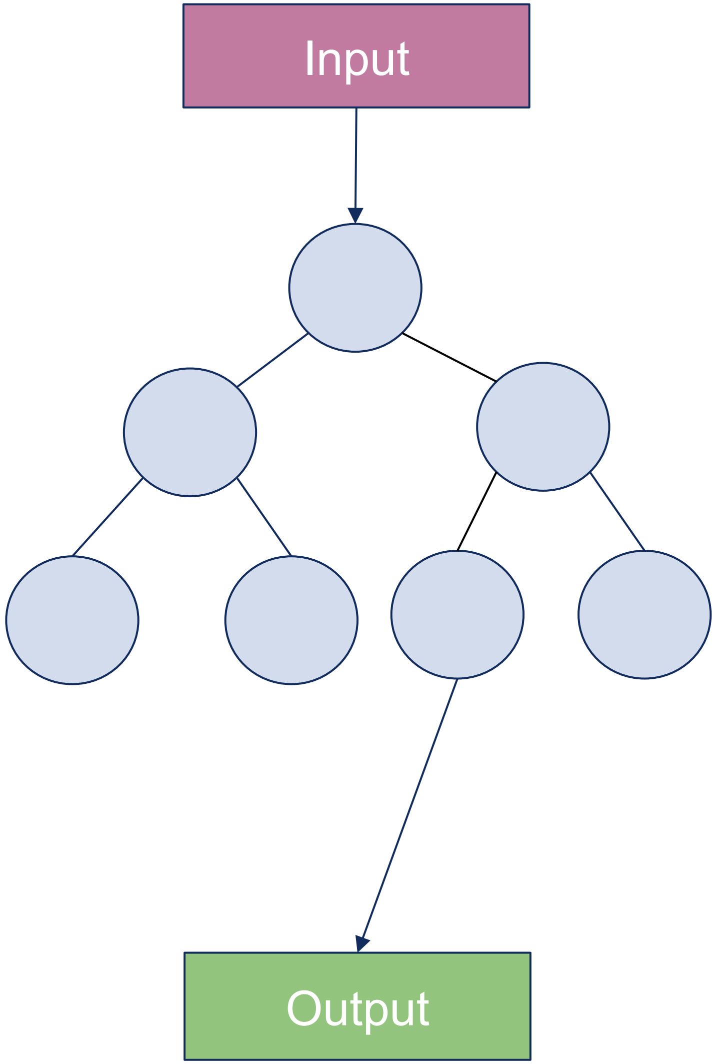
Odd year average



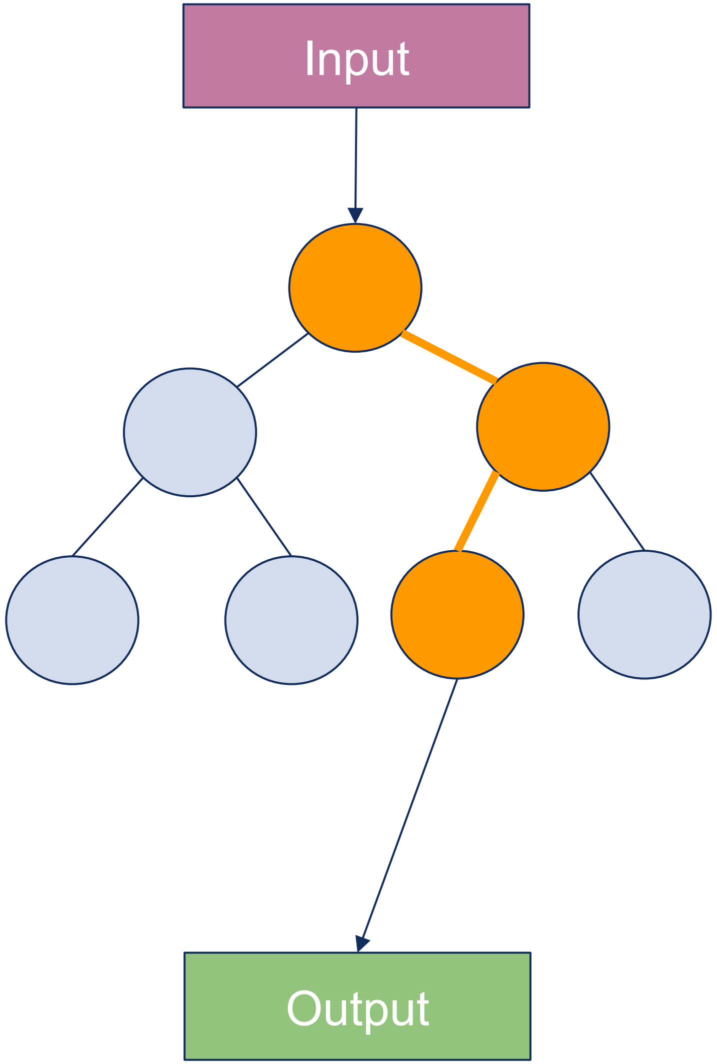
Yearly averages



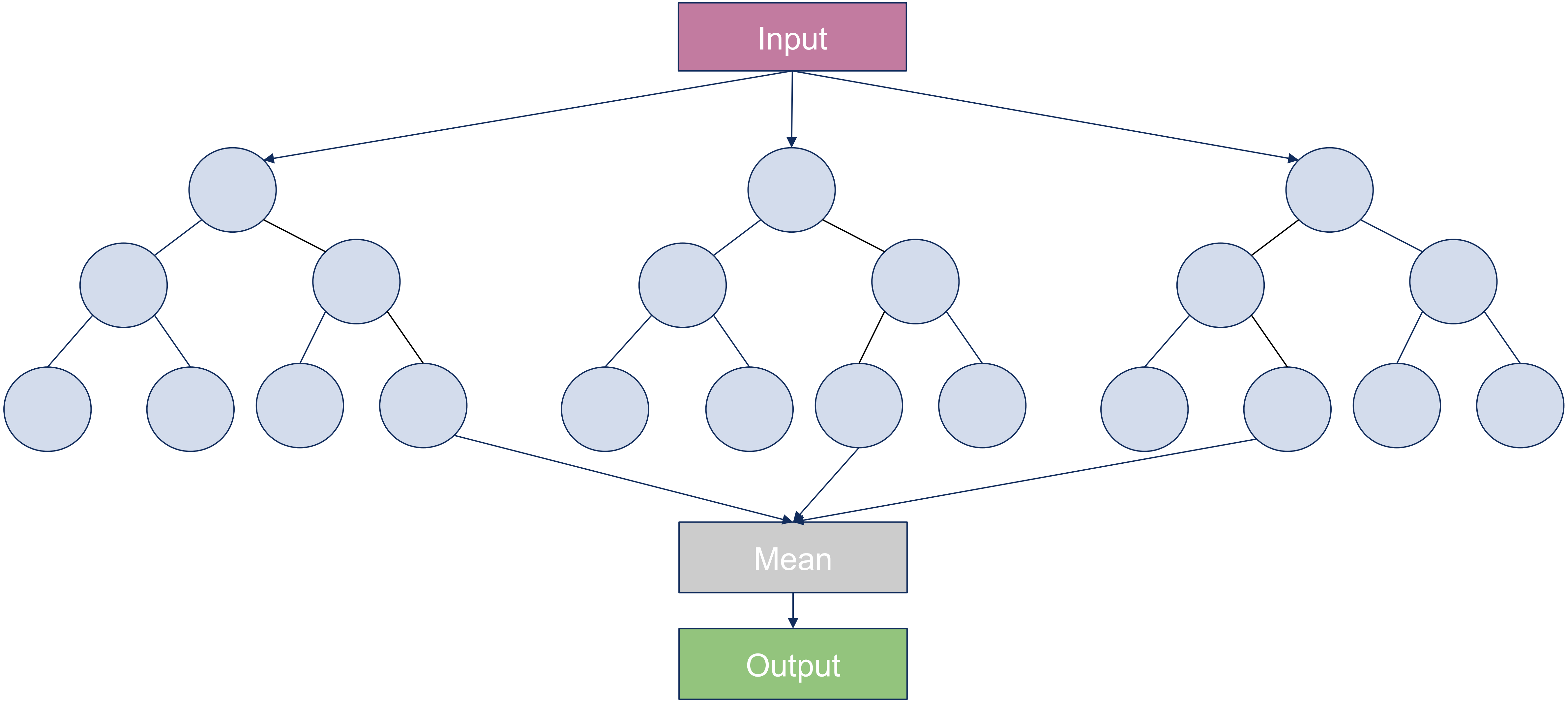
A decision tree



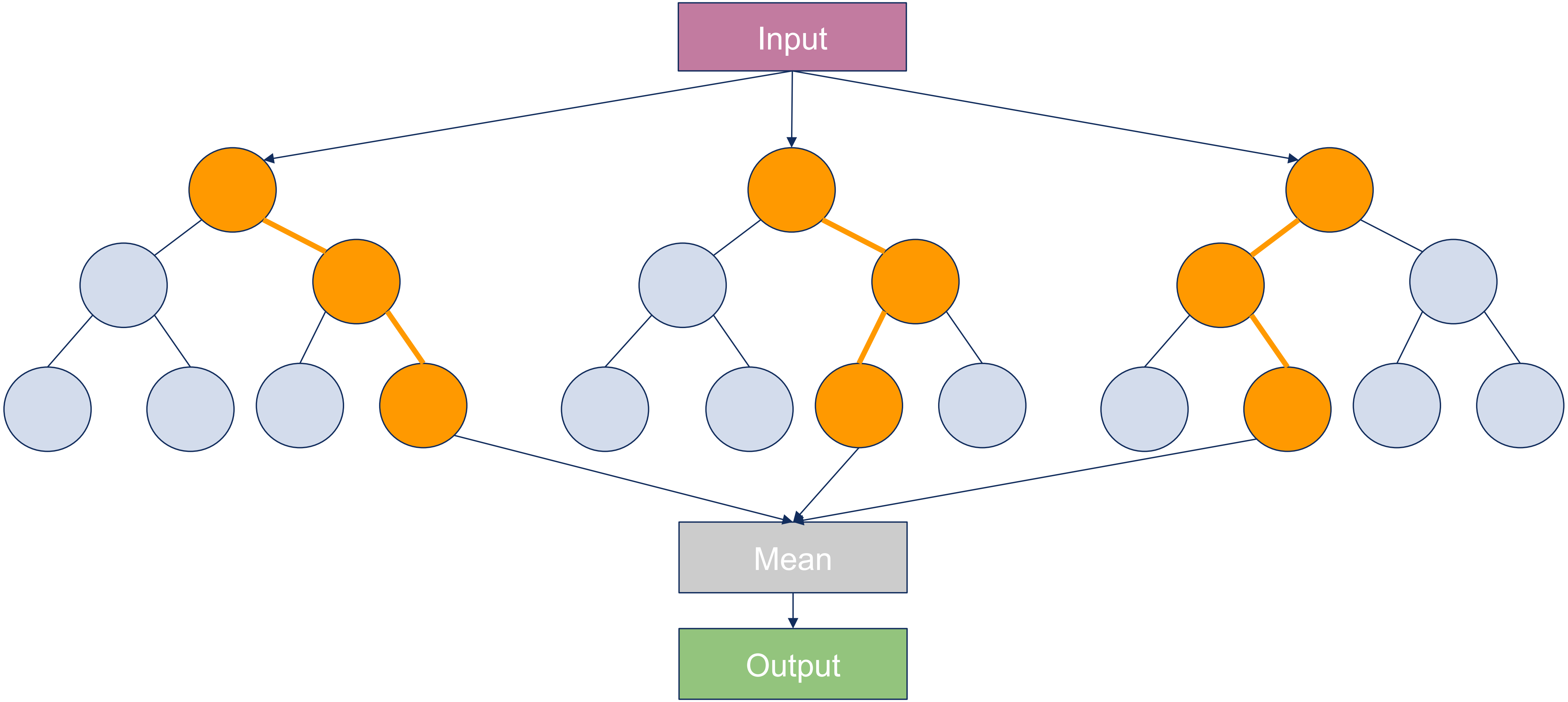
Traversing a decision tree



A random forest

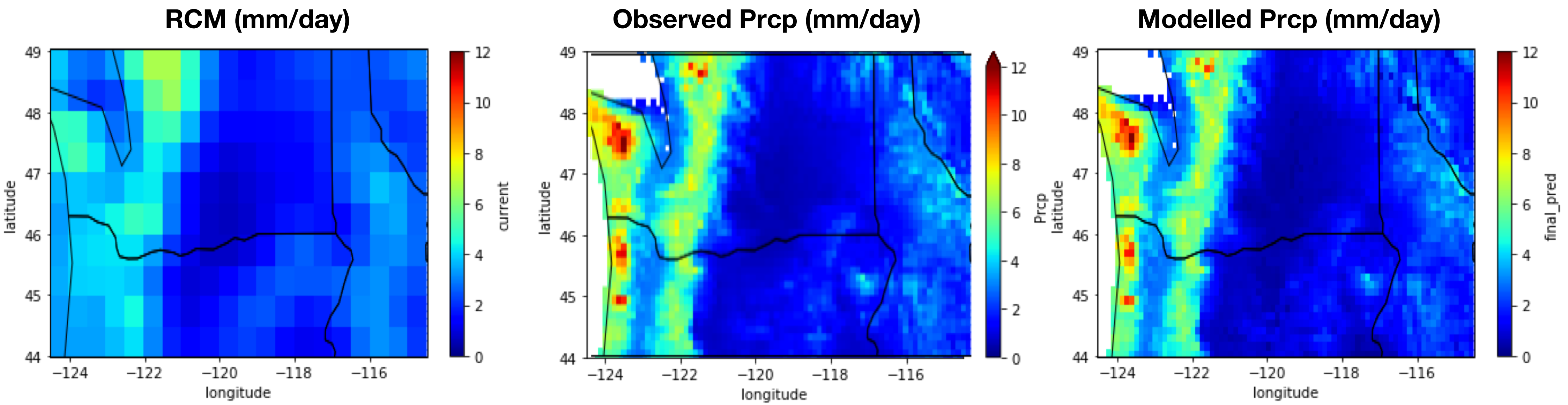


Traversing a random forest

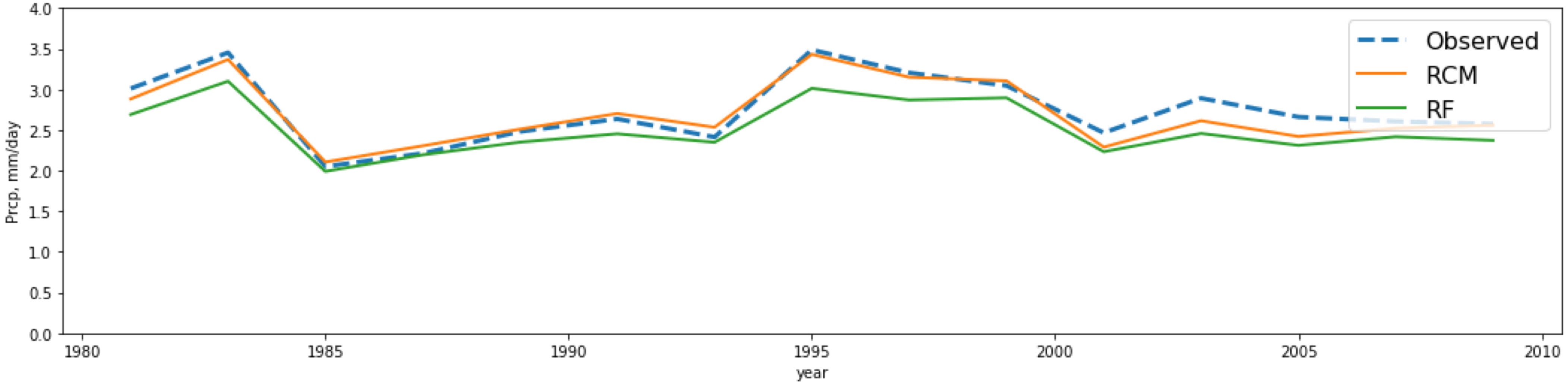


2. Cellwise Random Forest - the results

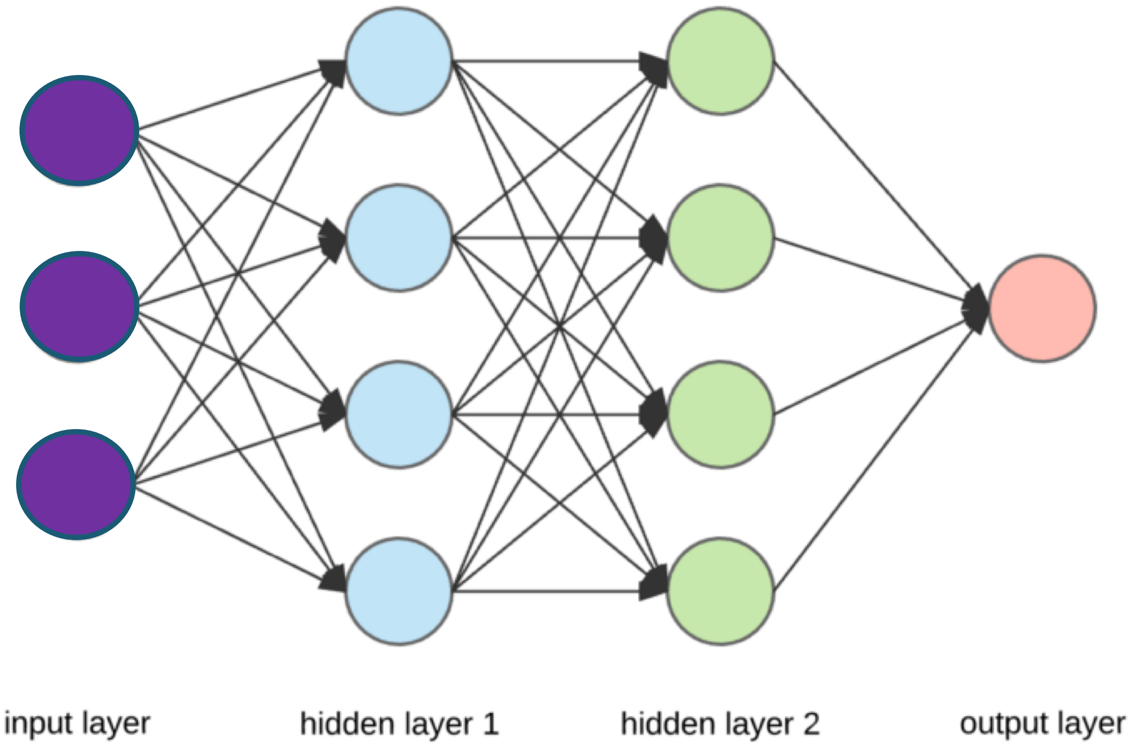
Odd year average

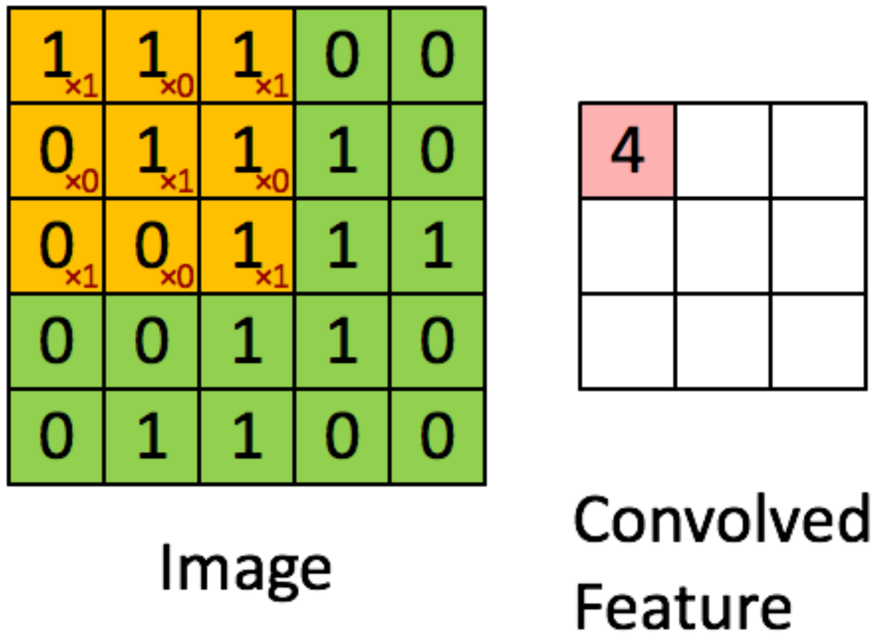


Yearly averages



3. Convolutional Neural Network - the details





https://towardsdatascience.com/applied-deep-learning-part-1-artificial-neural-networks-d7834f67a4f6

https://hackernoon.com/visualizing-parts-of-convolutional-neural-networks-using-keras-and-cats-5cc01b214e59

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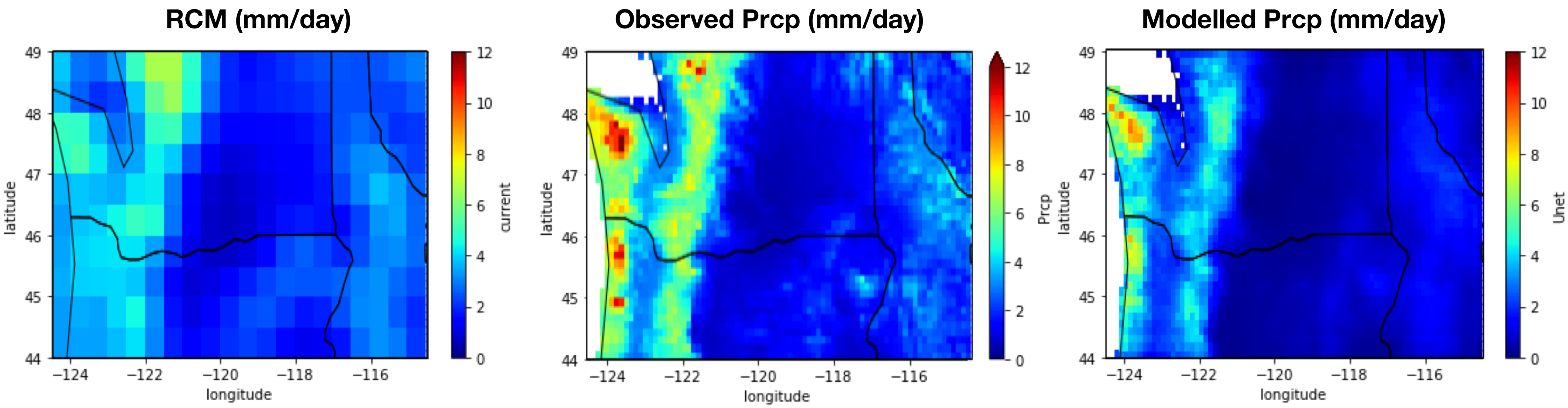
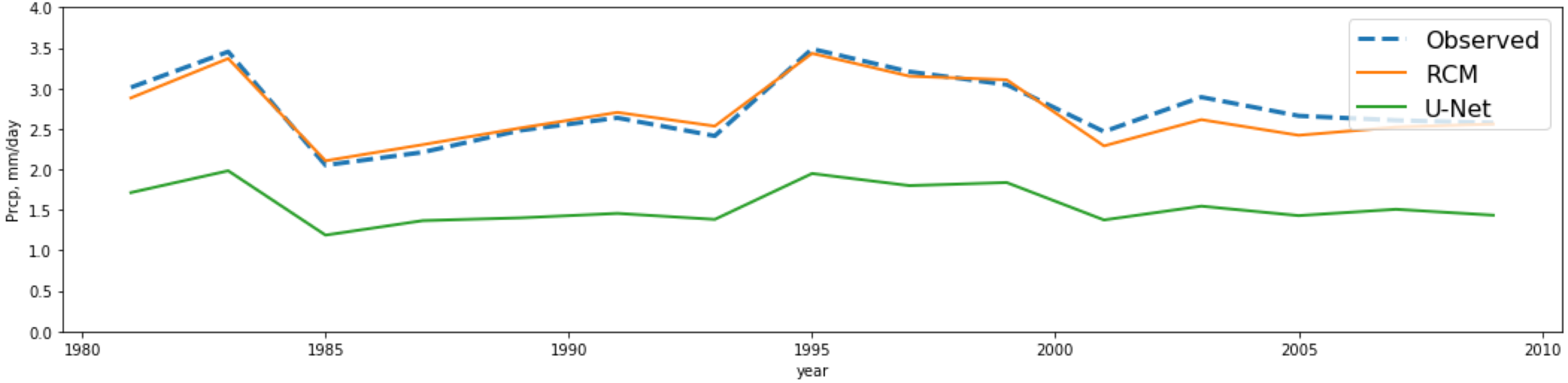
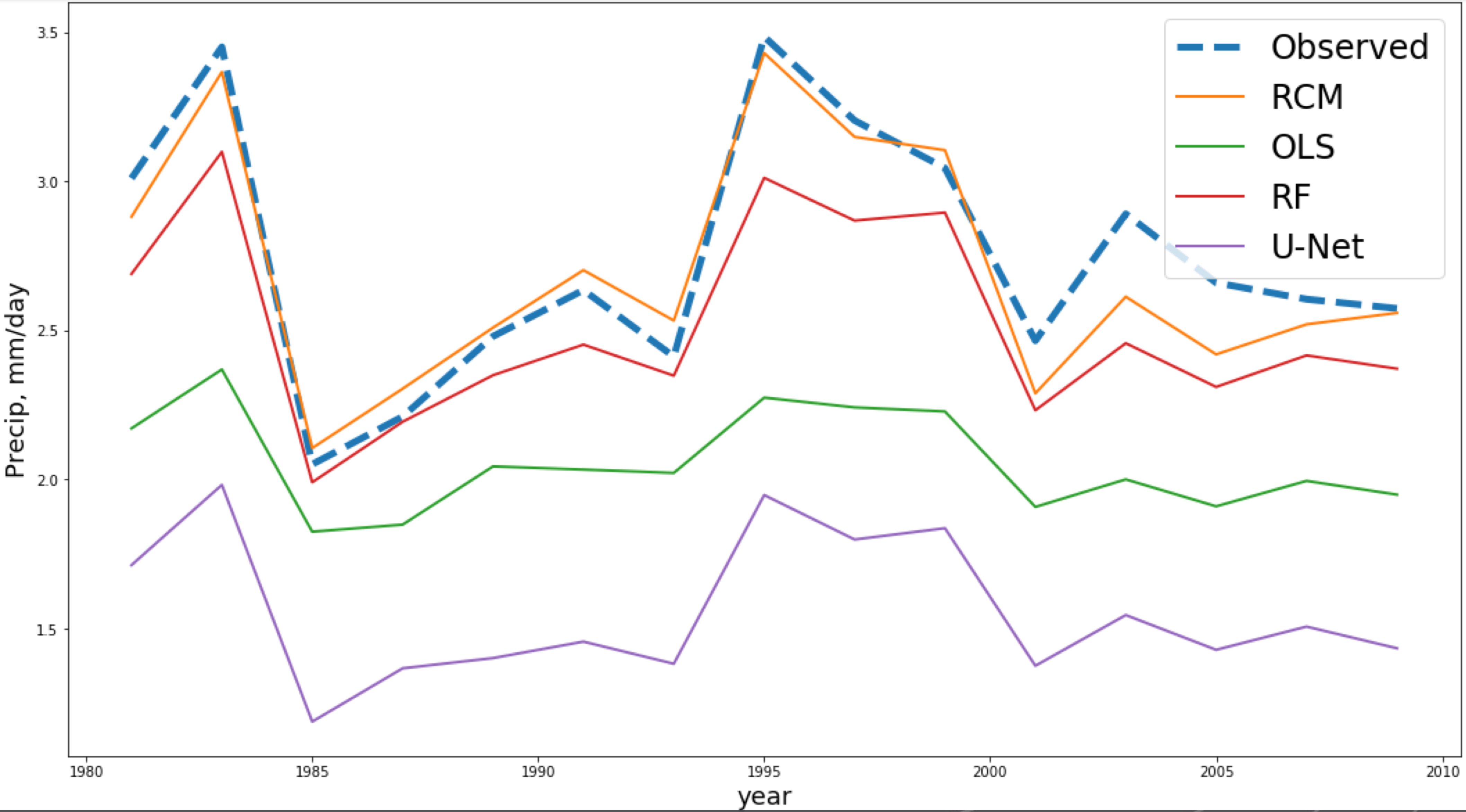
Odd year average



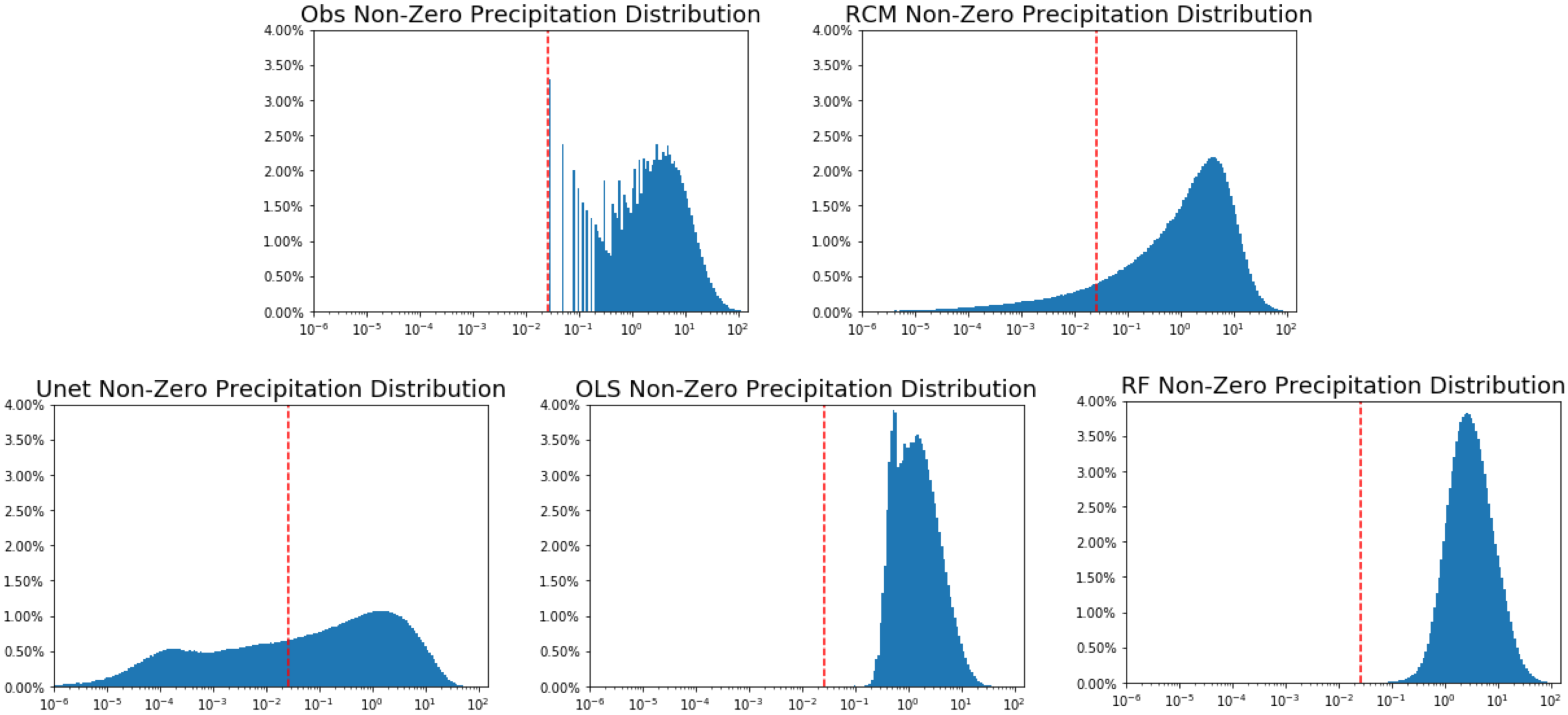
Yearly averages



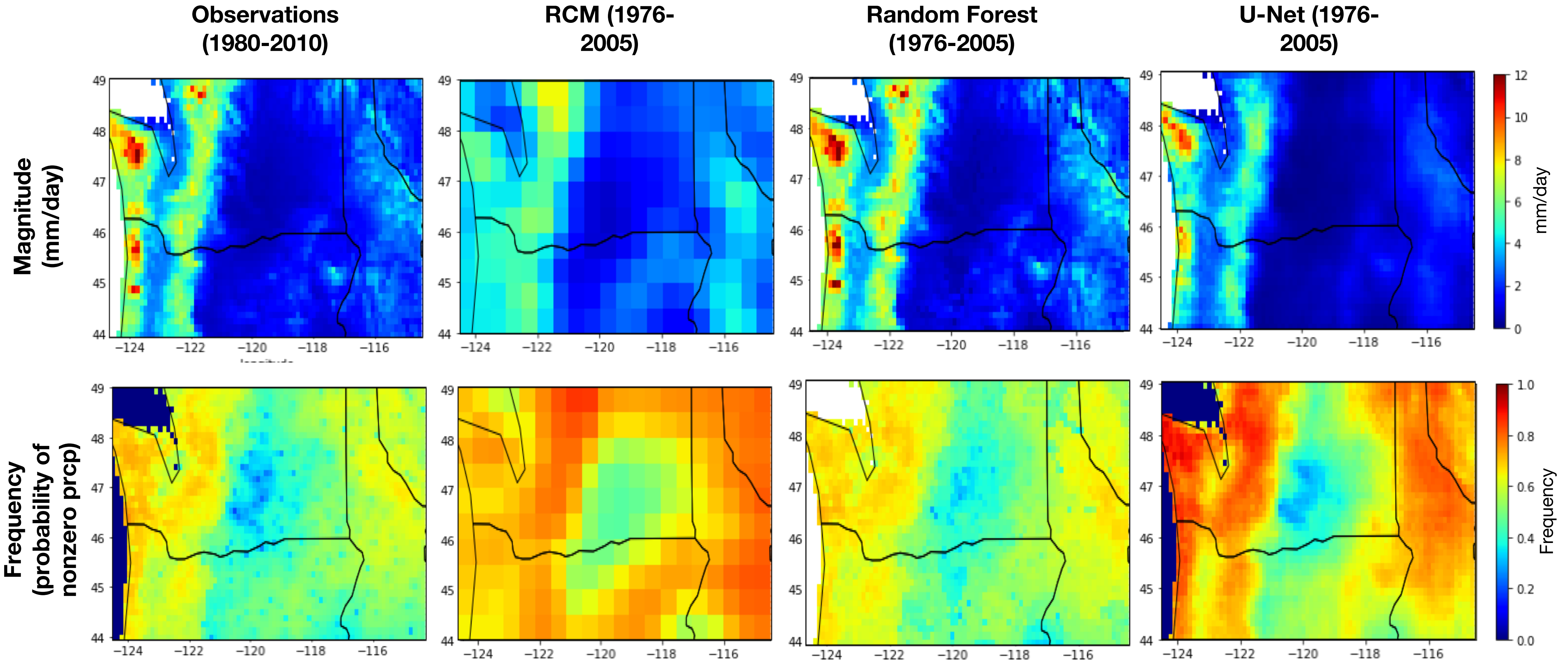
Models underpredict extreme precipitation events



The underprediction comes from the distributions



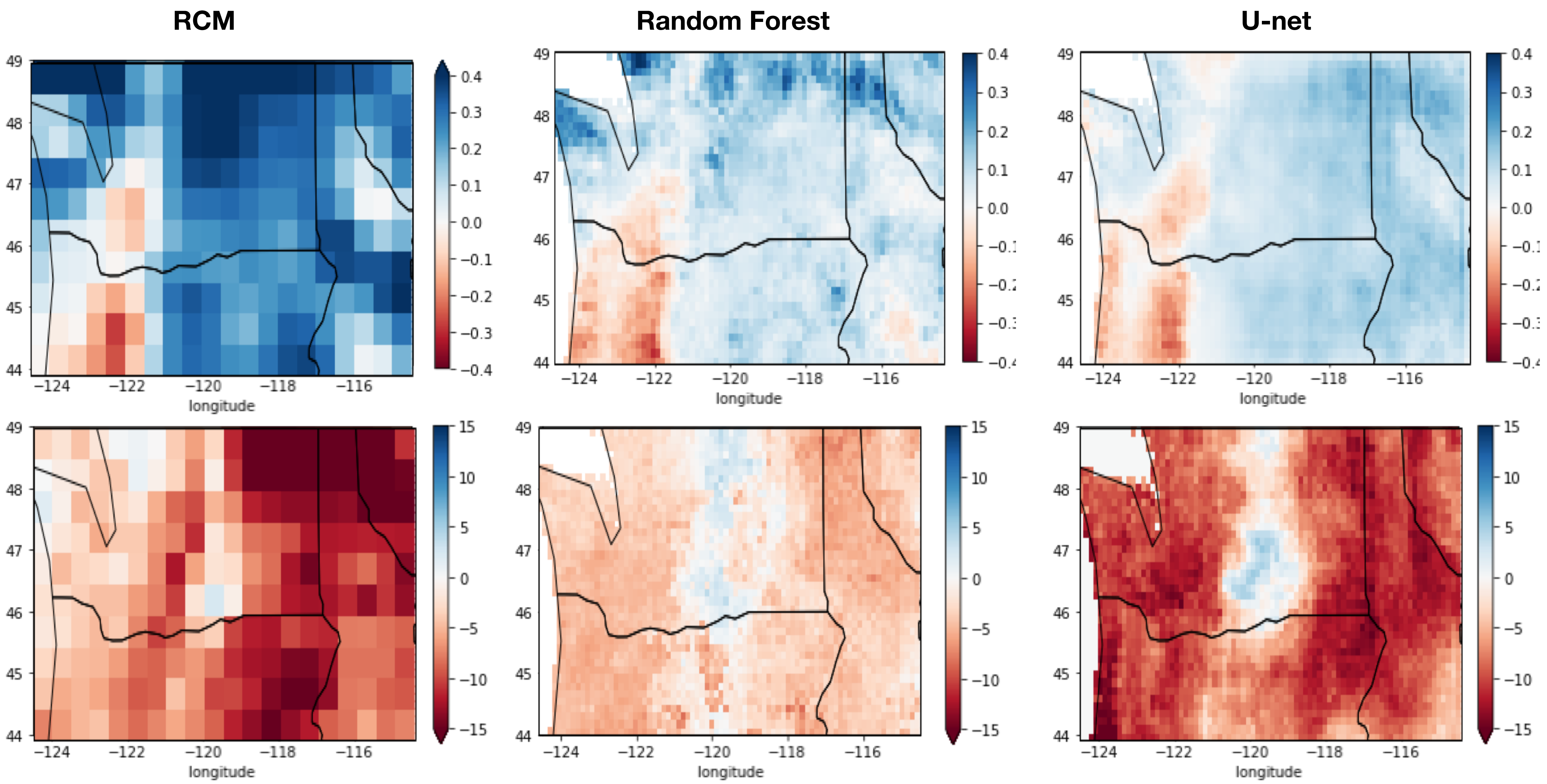
Historical Climate Evaluation



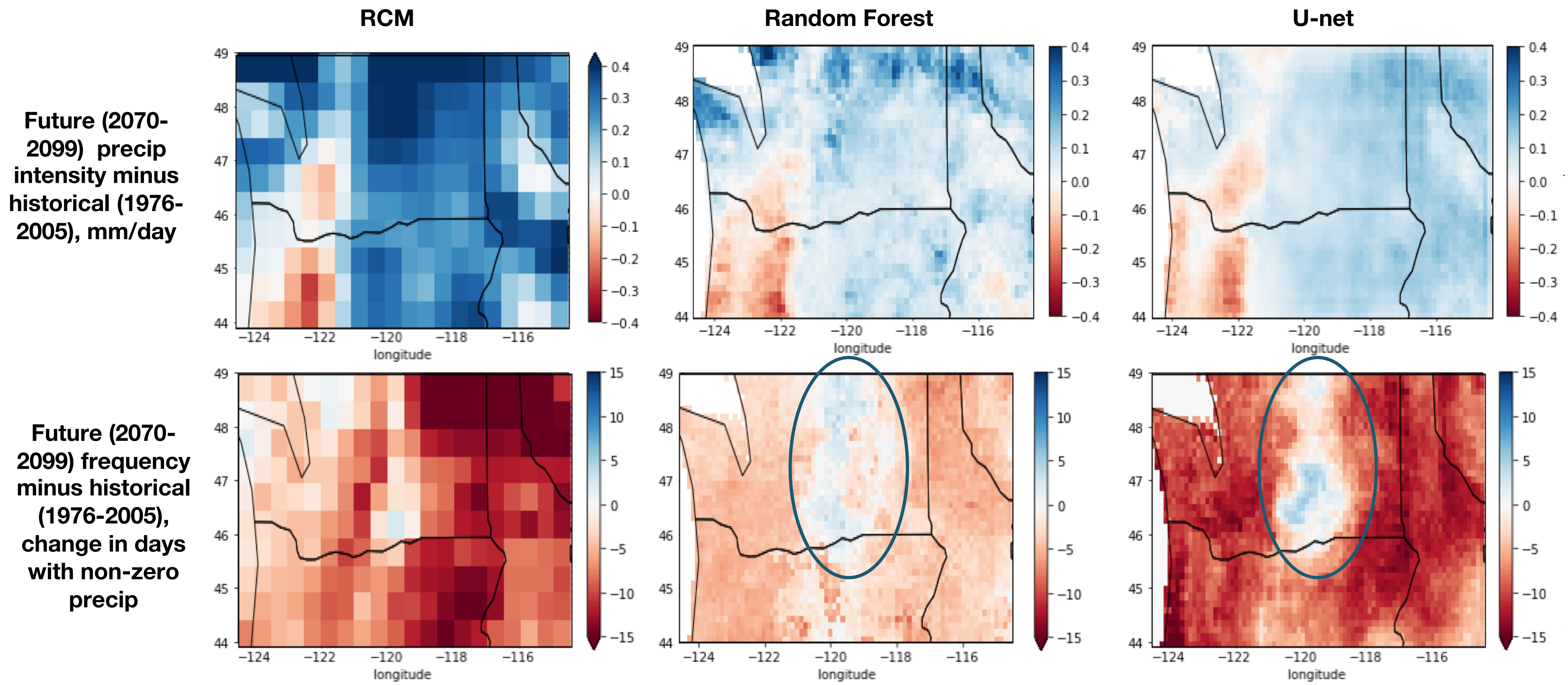
Difference Plots: More intense, less frequent precipitation

Future (2070-2099) precip intensity minus historical (1976-2005), mm/day

Future (2070-2099) frequency minus historical (1976-2005), change in days with non-zero precip



Difference Plots: More intense, less frequent precipitation

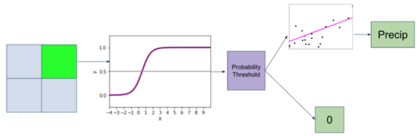


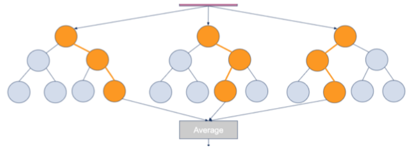
Conclusions

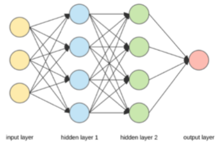
- We implemented three methods for statistical downscaling
- Random forests best capture magnitude and variability of precipitation
- The U-Net and linear models underpredict variation and, as a result, magnitude
- Downscaling future WRF simulations suggests an increase in average and a decrease in frequency of precipitation

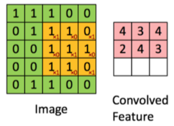
Future Works

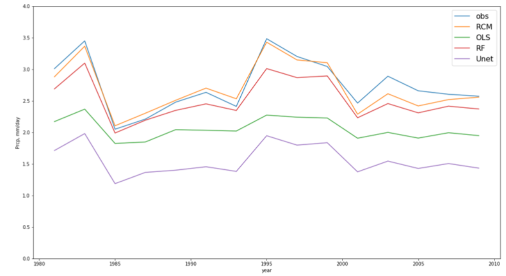
- Adding stochasticity to zero/non-zero precipitation binary
- Further optimizing the U-Net

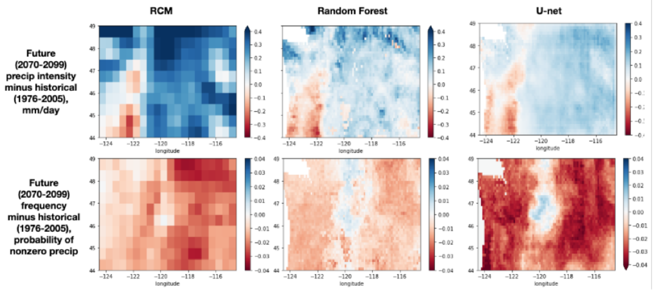












Acknowledgements

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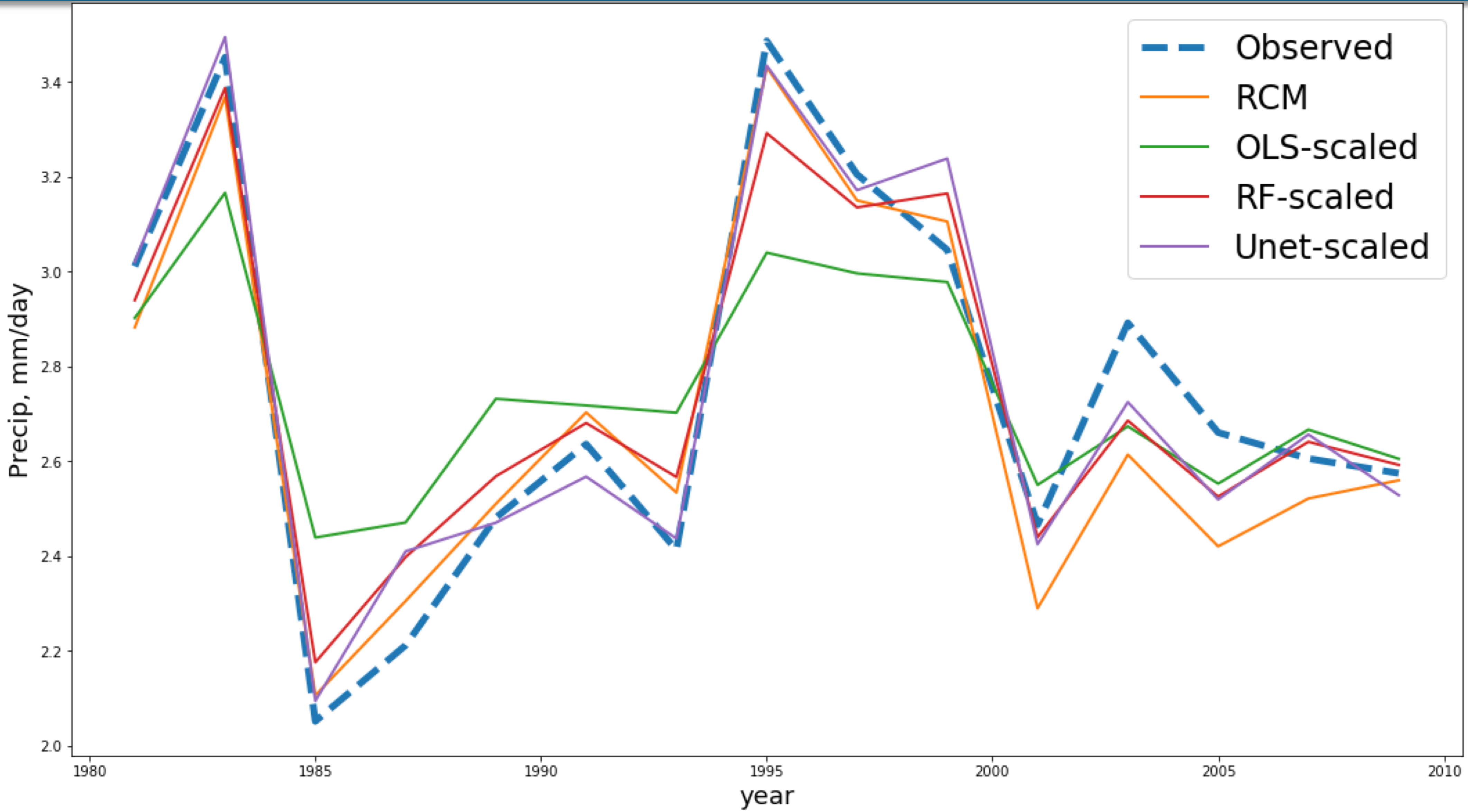
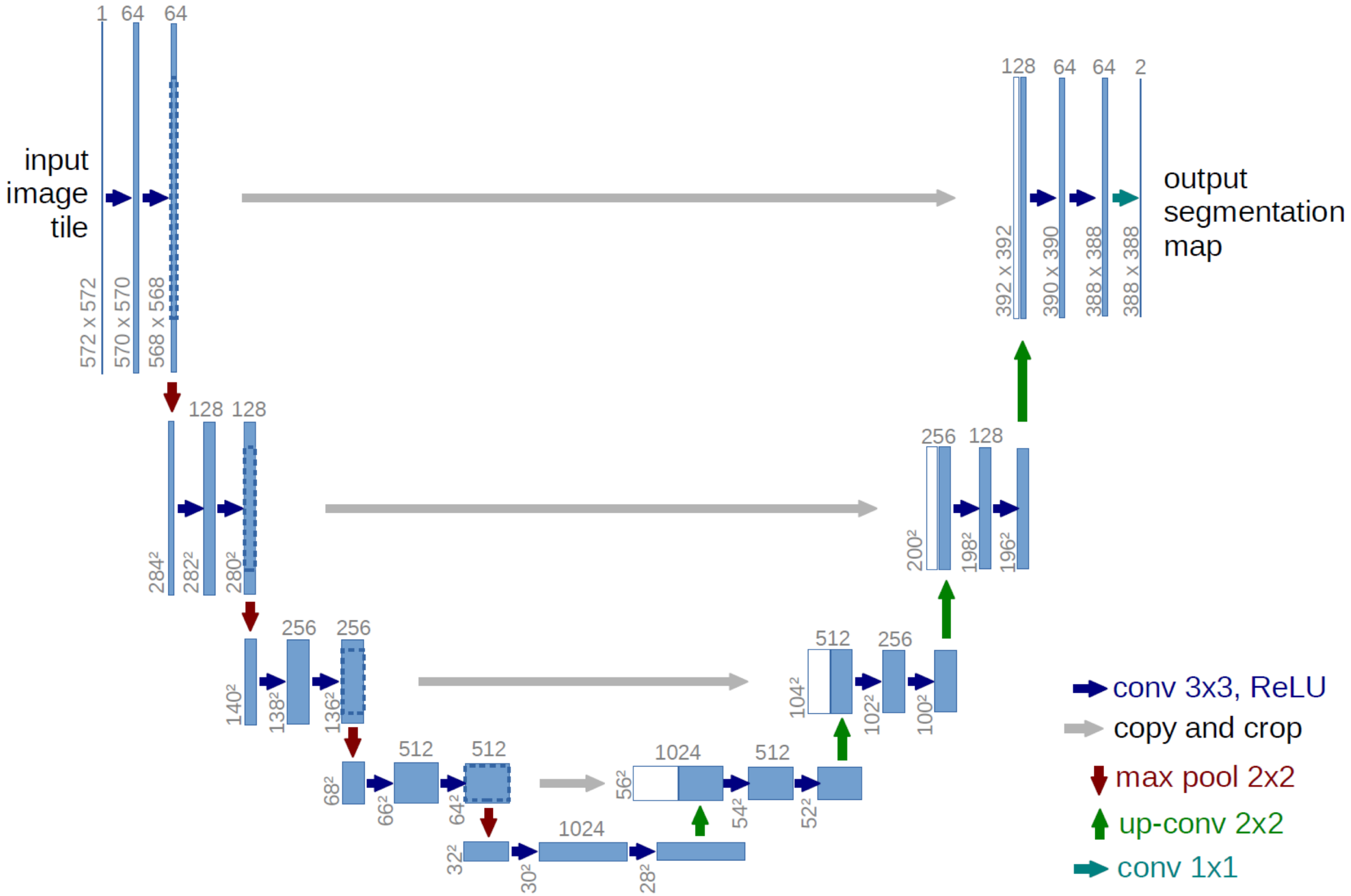
SIParCS
NCAR/UCAR
NSF

Extra Slides: Scaling the Models

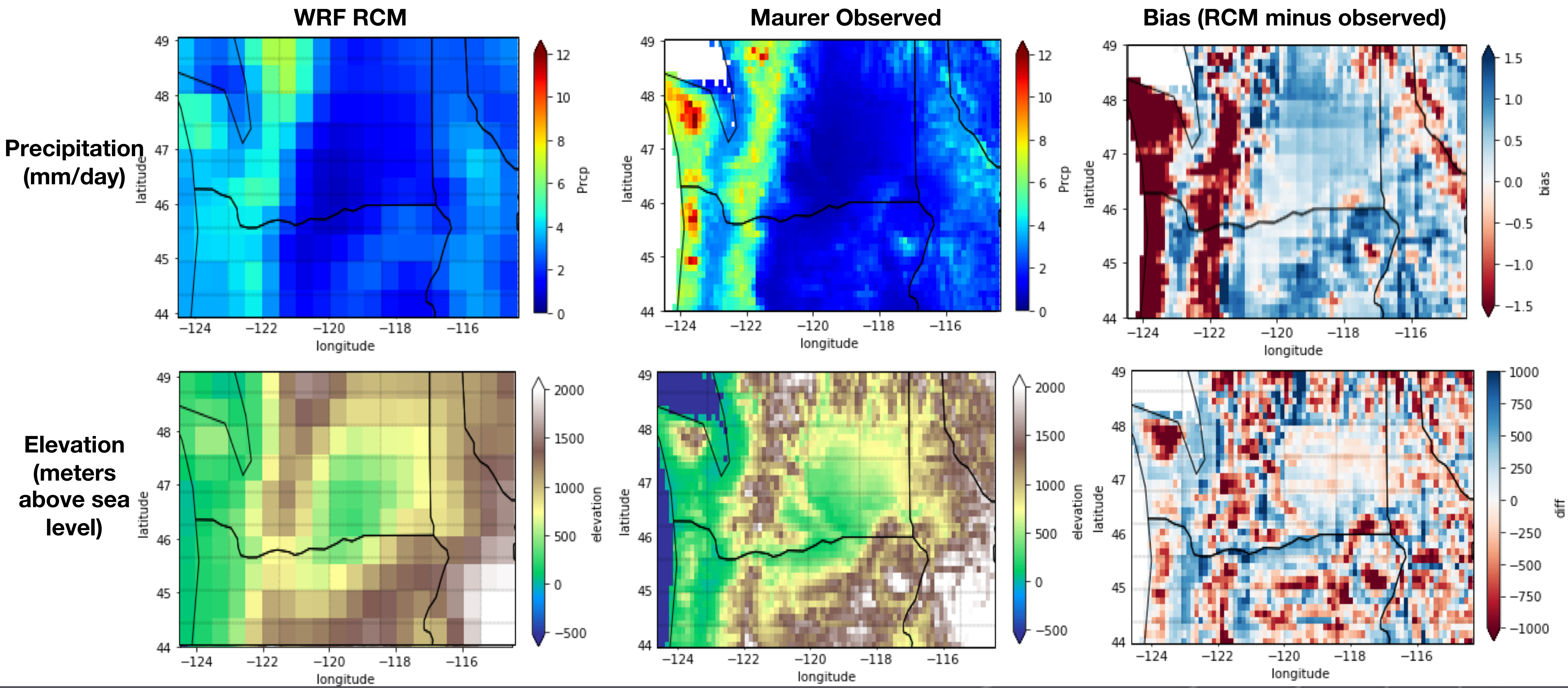


Extra slides: a U-Net example



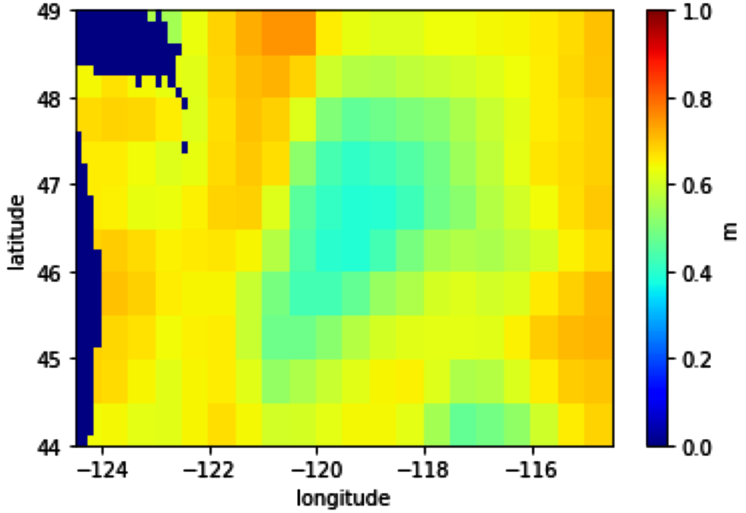
https://lmb.informatik.uni-freiburg.de/people/ronneber/u-net/

Extra Slides: Topography

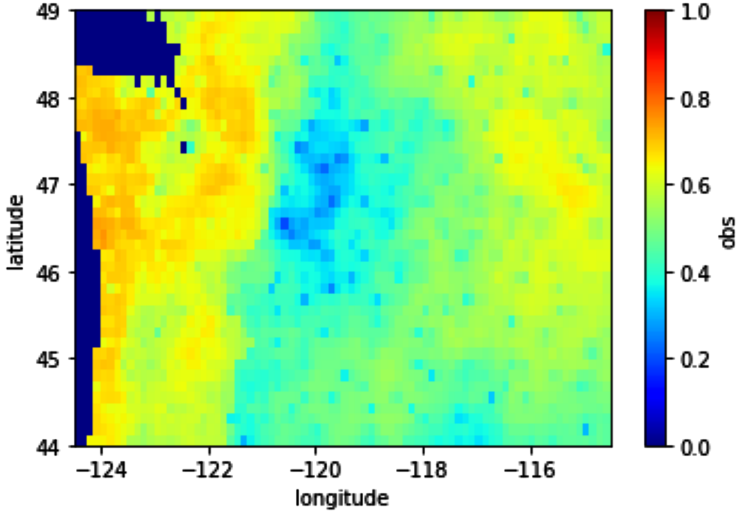


Extra Slides: Frequency of Precipitation

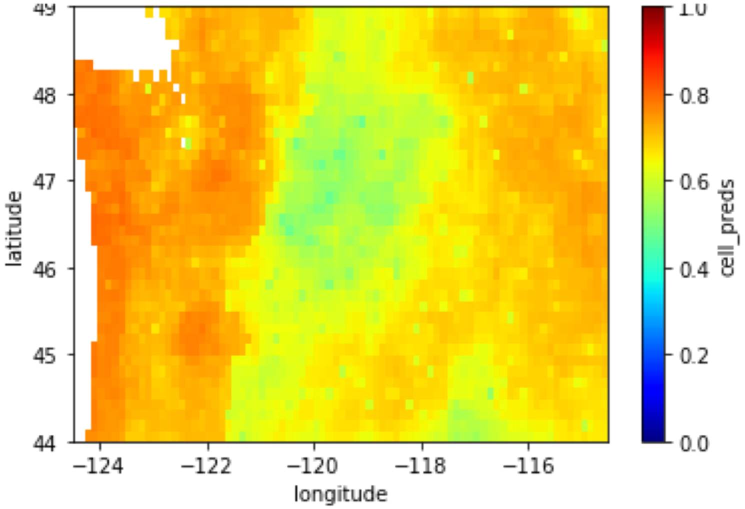
RCM Probability of Prcp



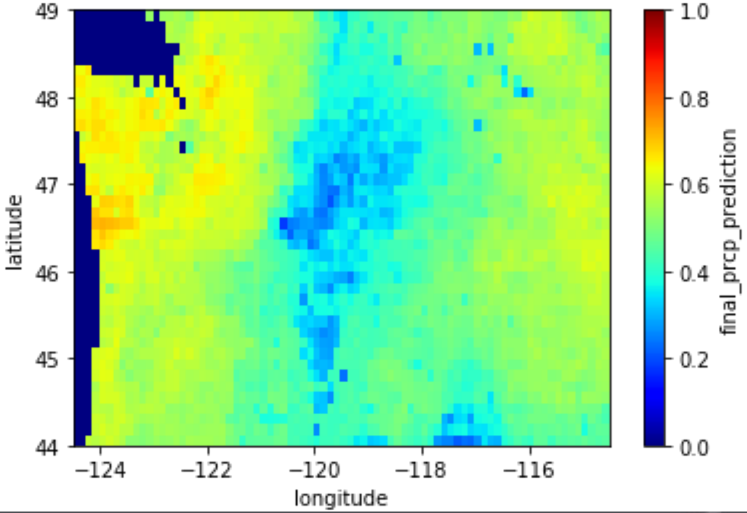
Observed Probability of Prcp



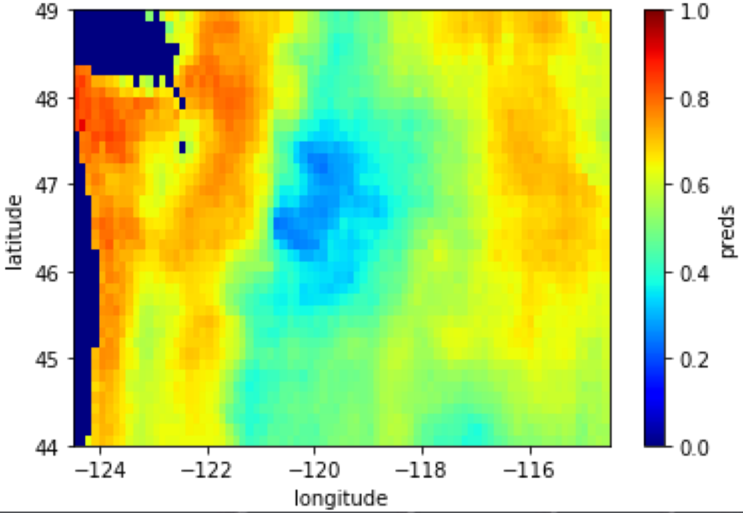
OLS Probability of Prcp



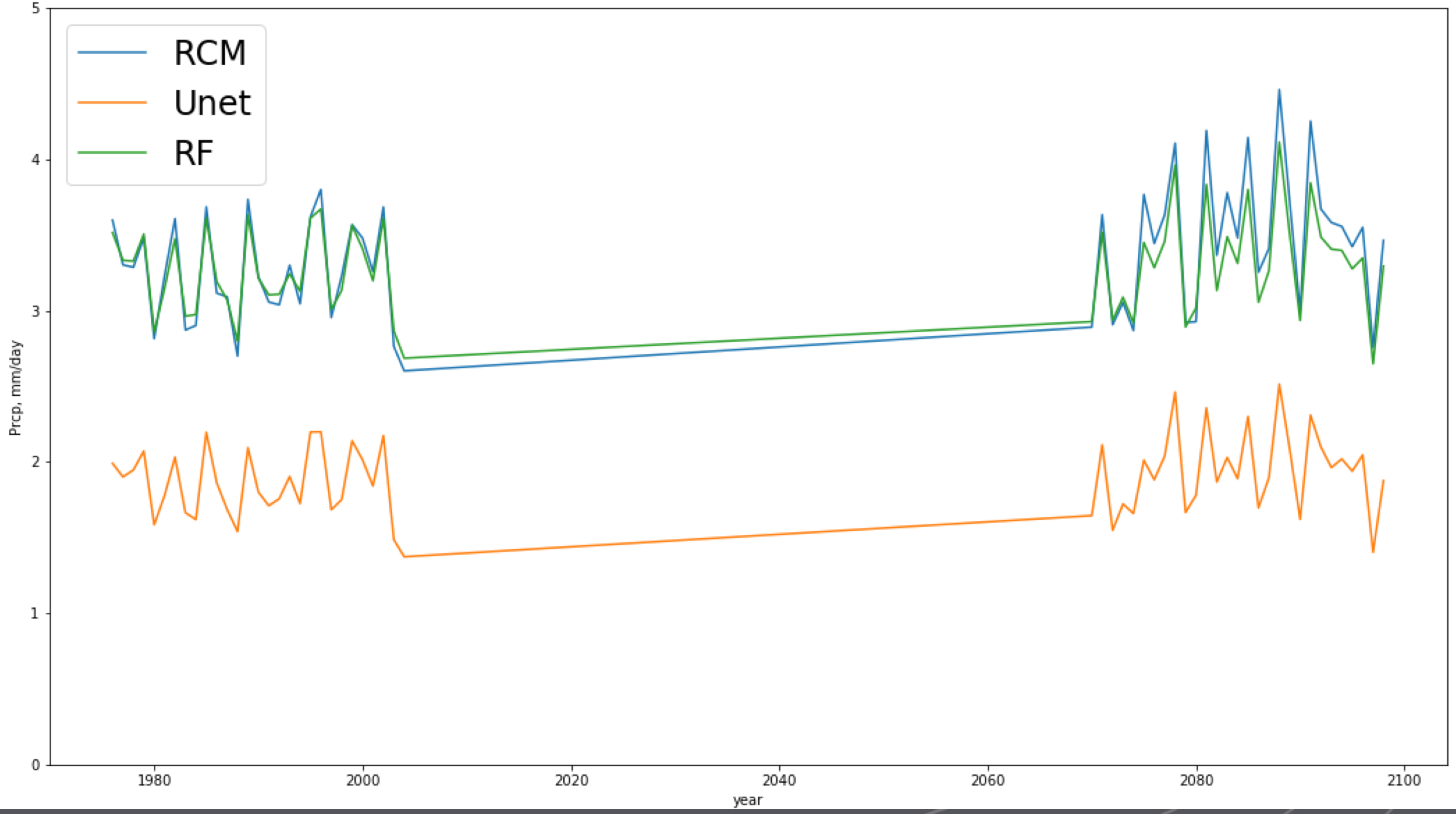
Random Forest Probability of Prcp



Neural Net Probability of Prcp



Extra Slides: Future Precipitation Trends



Extra Slides: Distribution Stats

Model	Mean	50th percentile	95th percentile	Variance
Observations	2.75	0.12	10.42	39.61
RCM	2.70	0.74	10.29	32.24
Linear Regression	2.06	1.51	9.18	7.59
Random Forest	2.51	0.26	11.33	24.81
U-Net	1.56	0.09	8.40	13.80