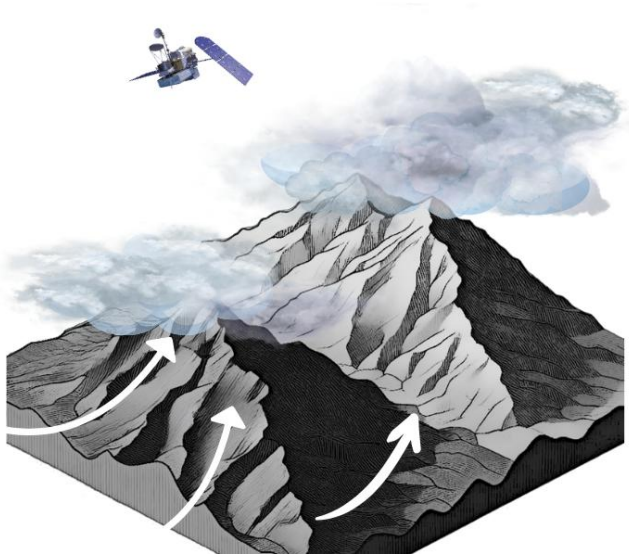
భారతీయ సాంకేతిక విజ్ఞాన సంస్థ హైదరాబాద్
भारतीय प्रौद्योगिकी संस्थान हैदराबाद
Indian Institute of Technology Hyderabad

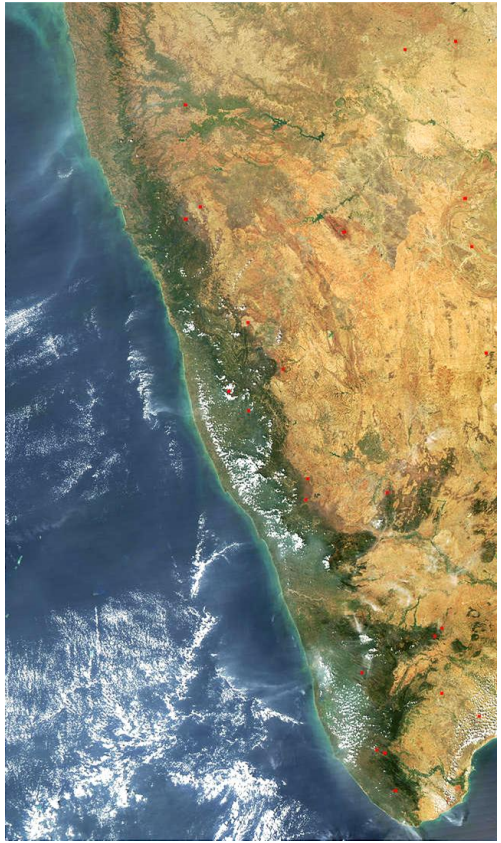
Utilizing Dynamic Meteorological Variables and Static Topographic Variables to Enhance Satellite Rainfall Estimates through Deep Learning Algorithm



Yashraj Upase[1], Abhigyan Chakraborty[1] , Shruti Upadhyaya[1,2], Malarvizhi Arulraj[3], Kishalay Mitra[1]

[1] Indian Institute of Technology, Hyderabad, India
[2] Advanced Radar Research Center, University of Oklahoma, USA
[3] Earth System Science Interdisciplinary Center, University of Maryland, College Park, Maryland, USA

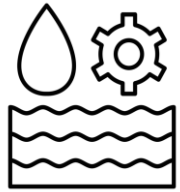
Why Orographic Precipitation Is Important?



Predictive Modeling [1]

land and the atmosphere interaction [1]

Extreme Weather Events [4]



Water Resource Management [3]

[1] Roe G. 2005 [2] Image Source [3] Barros A, 2003 [4] Marra F. et. al., 2021

icons from vecteezy, flaticon

Observations of Orographic Precipitation

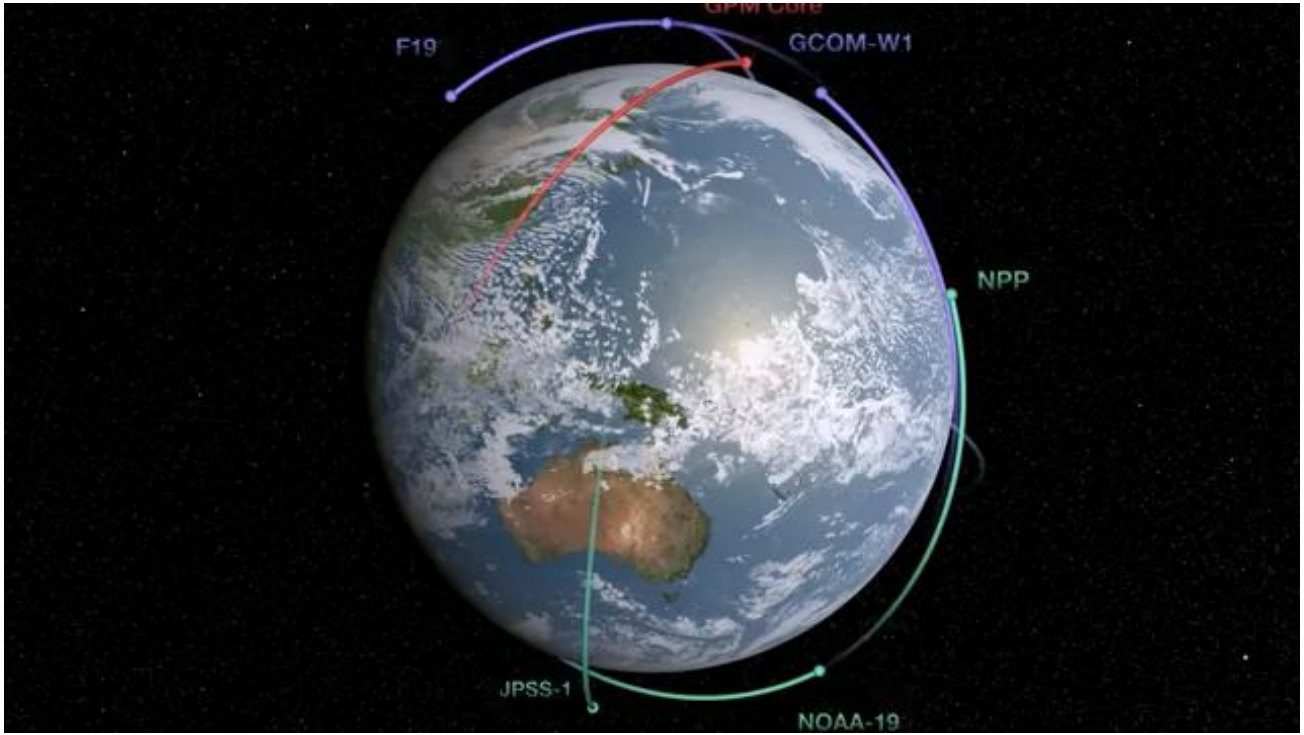
Image Source

Observations of Orographic Precipitation

Observations of Orographic Precipitation

Observations of Orographic Precipitation

Observations of Orographic Precipitation



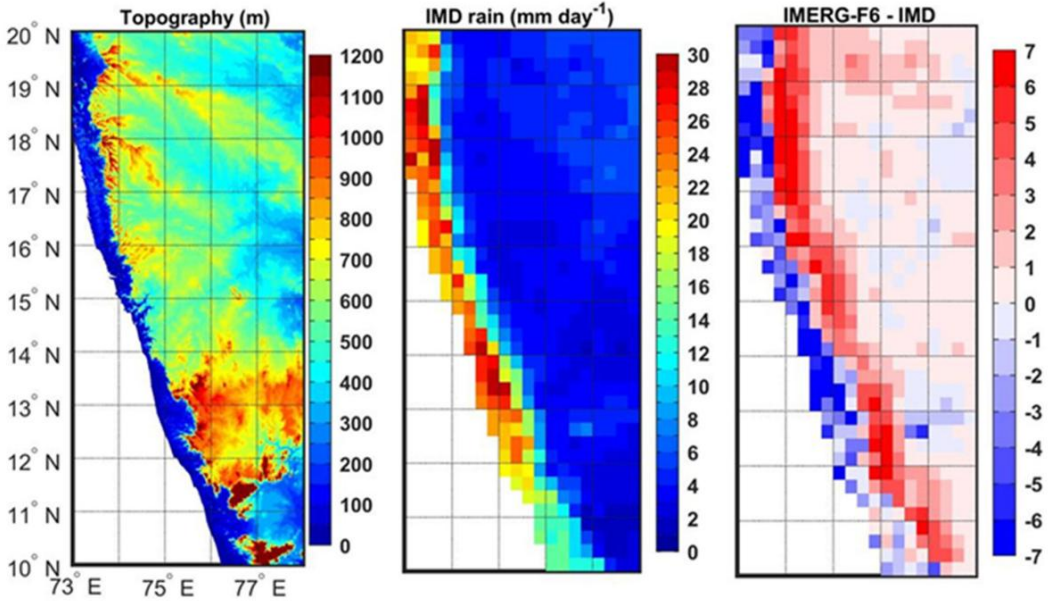
[1] Huffman et al 2019 [2] Joyce and Xie, 2011 [3] Video Credits : NASA

Orographic Satellite Rainfall Estimates: Challenges and Limitations

1. Warm orographic rainfall detection
2. Temporal sampling problems
3. Spatial resolution constraints
4. Seasonal dependencies
5. Gauge adjustment calibration limitations
6. Satellite-sensor specific technical reasons

Derin et al 2014, Derin et al 2016, Derin et al 2019, Barros and Arulraj, 2020

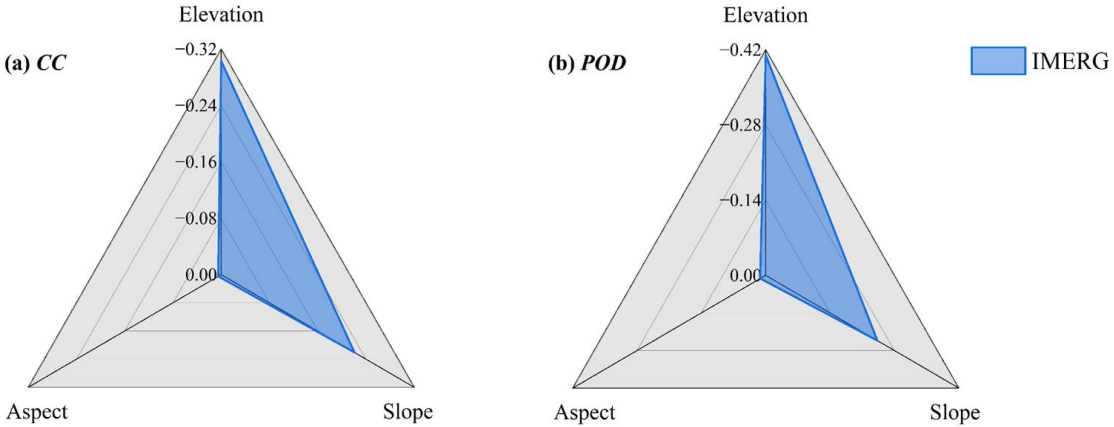
Bias in Orographic Precipitation



(Prakash S and Srinivasan J, 2021)

Study highlight the need to improve the estimates of orographic rainfall estimates

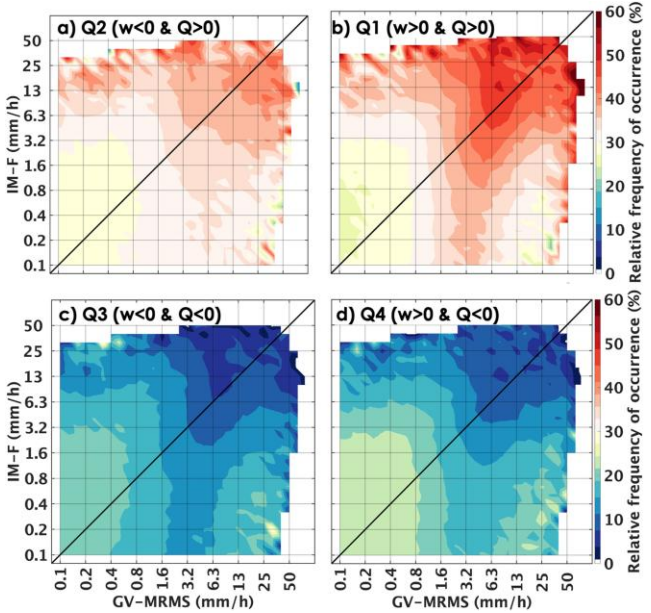
Role of Static Variables in SPE Performance



(Tang et al. 2023)

Highlight the dependence of the performance of SPE on topography

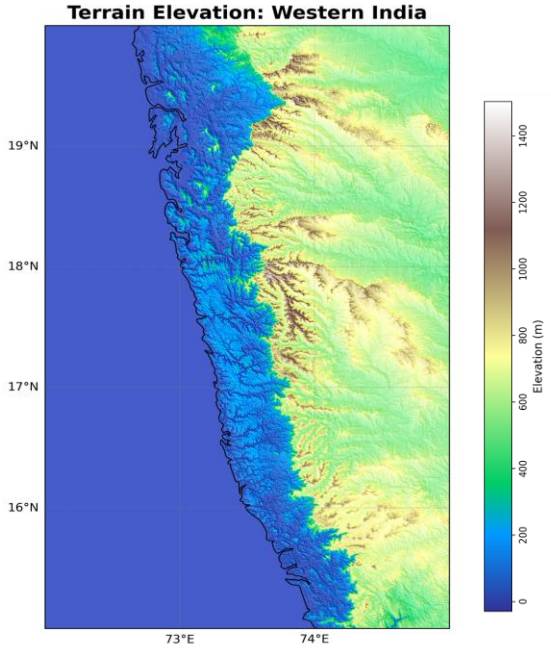
Role of Dynamic Variables in SPE Performance

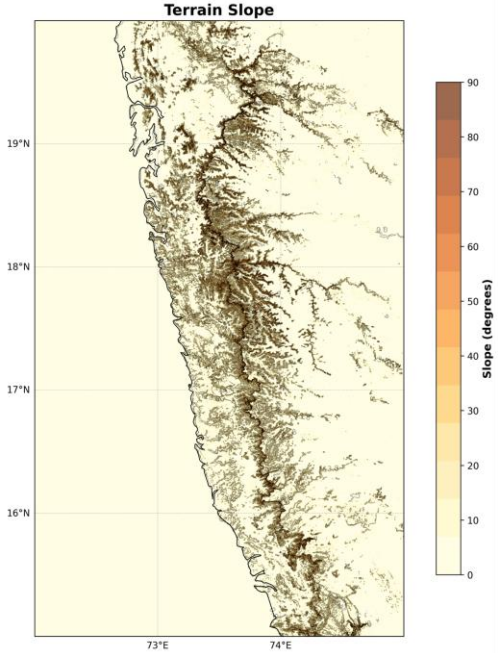


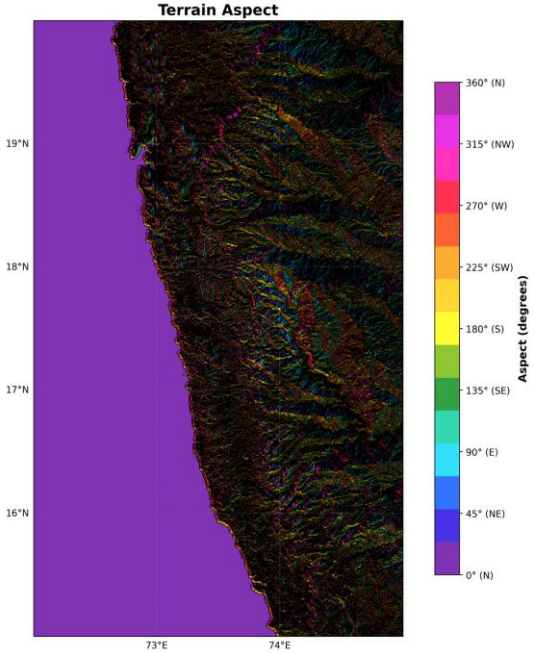
(Derin and Kirstetter, 2022)

Performance of SPE is dependent on dynamical variables

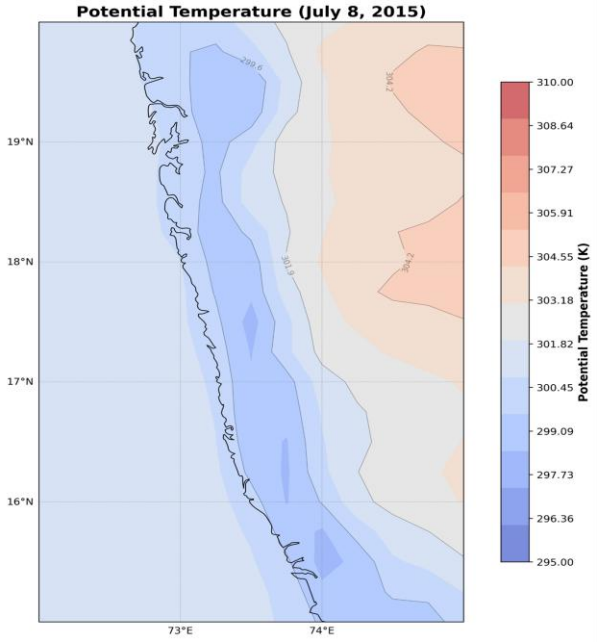
Static Variables Considered

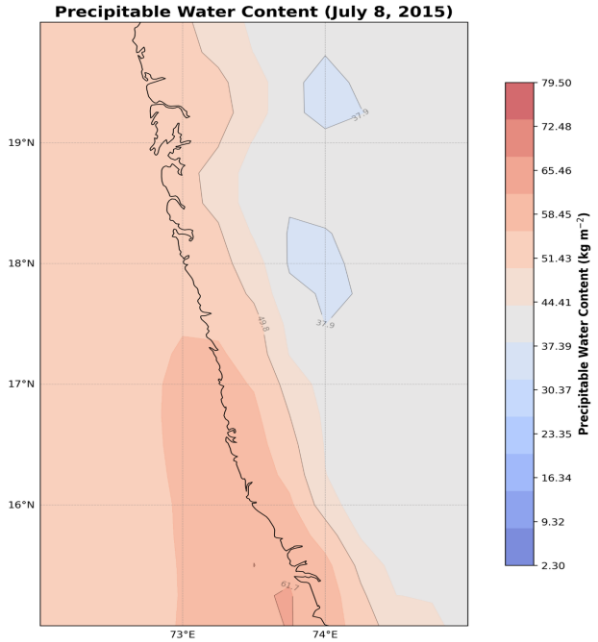


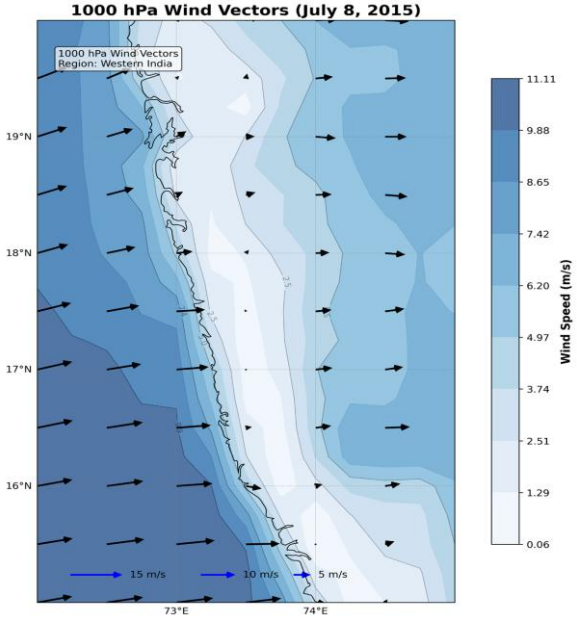


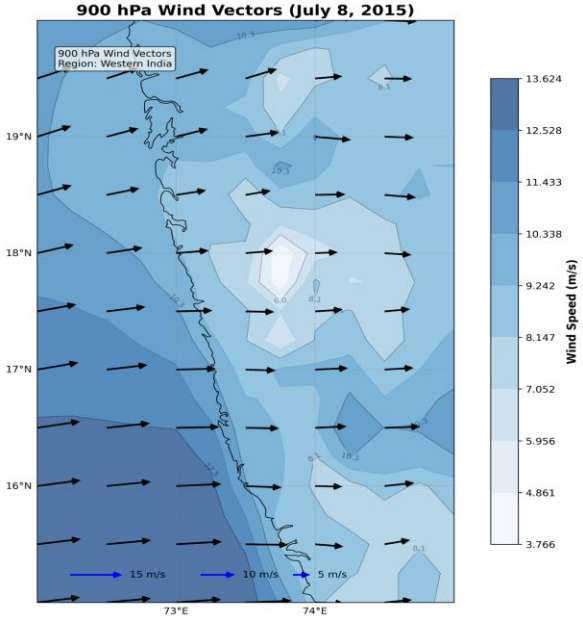


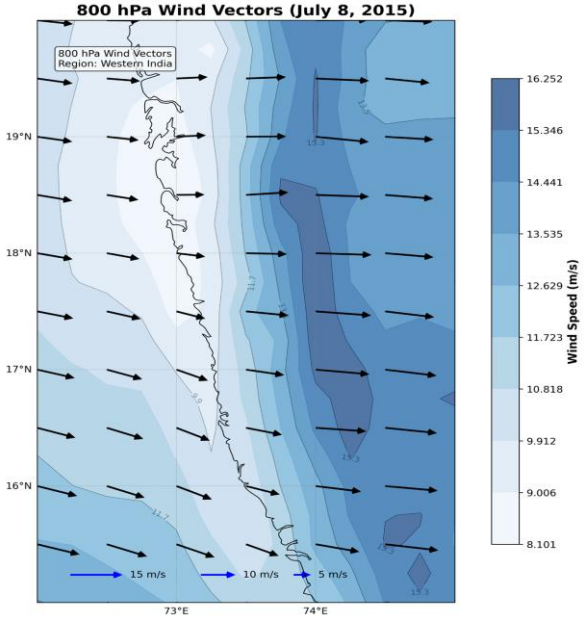
Dynamic Variables Considered

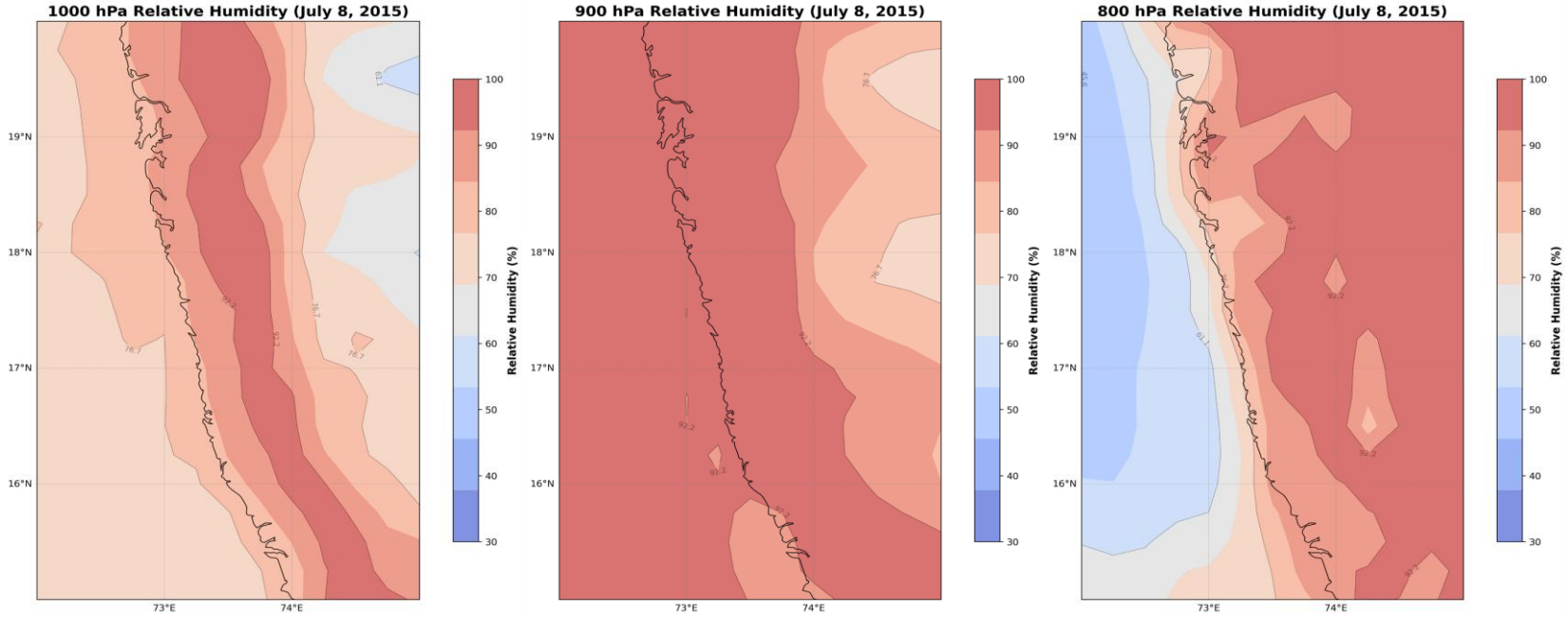





1000 hPa Wind Vectors (July 8, 2015)
1000 hPa Wind Vectors
Region: Western India
19°N
18°N
17°N
16°N
73°E
74°E
15 m/s
10 m/s
5 m/s
11.11
9.88
8.65
7.42
6.20
4.97
3.74
2.51
1.29
0.06
Wind Speed (m/s)


900 hPa Wind Vectors (July 8, 2015)
900 hPa Wind Vectors
Region: Western India
19°N
18°N
17°N
16°N
73°E
74°E
15 m/s
10 m/s
5 m/s
13.624
12.528
11.433
10.338
9.242
8.147
7.052
5.956
4.861
3.766
Wind Speed (m/s)

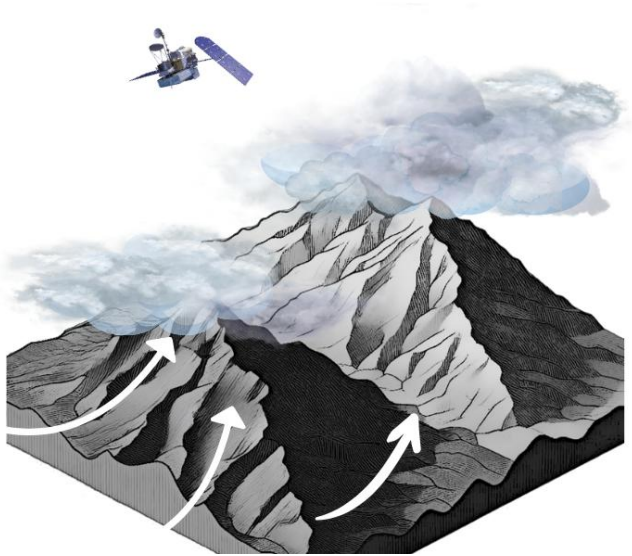

800 hPa Wind Vectors (July 8, 2015)
800 hPa Wind Vectors
Region: Western India
19°N
18°N
17°N
16°N
73°E
74°E
15 m/s
10 m/s
5 m/s
16.252
15.346
14.441
13.535
12.629
11.723
10.818
9.912
9.006
8.101
Wind Speed (m/s)


1000 hPa Relative Humidity (July 8, 2015)
900 hPa Relative Humidity (July 8, 2015)
800 hPa Relative Humidity (July 8, 2015)
19°N
18°N
17°N
16°N
73°E
74°E
Relative Humidity (%)
100
90
80
70
60
50
40
30

Research Question

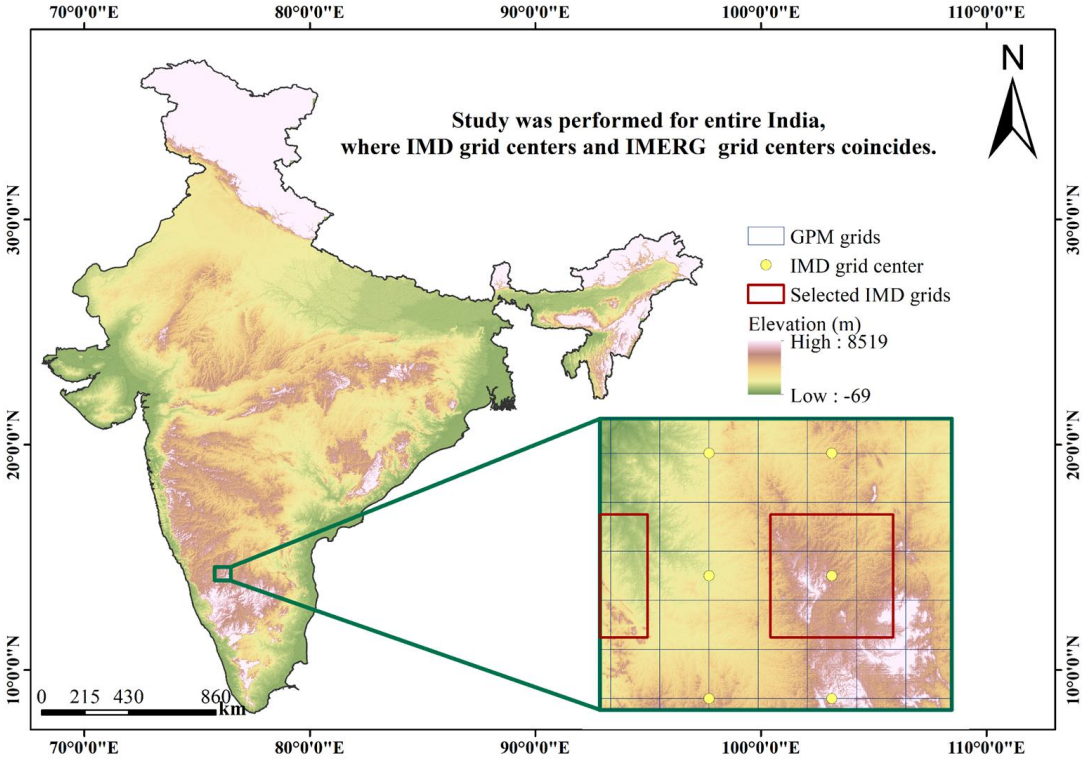
How the static variables can be leveraged to improve SPE?

What role the dynamic variables conditioned by topography can play in improving the SPE?



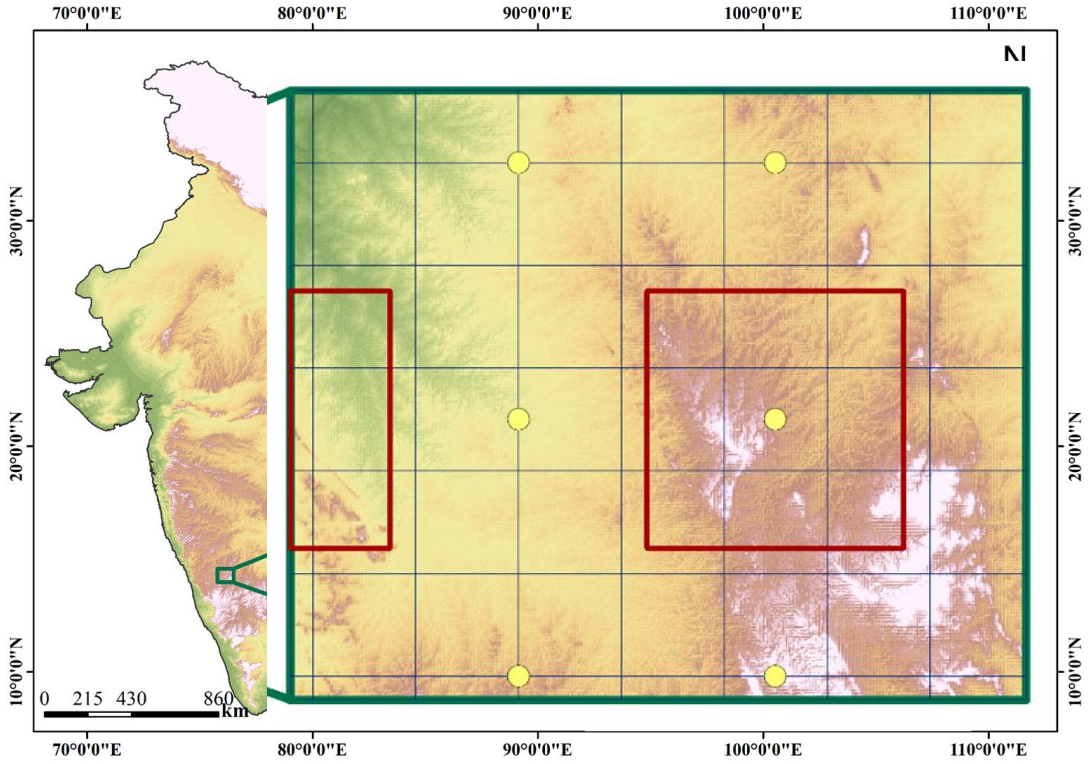
Dataset

Data	Resolution
Precipitation, (2015-2018, 2021-2022, June-September)	
IMERG Final Run(V07B)	0.1° x 0.1°
IMD Gridded Rainfall	0.25° x 0.25°
Static Variables	
SRTM derived elevation	90m (resampled)
Aspect	90m
Slope	90m
Dynamic Variables	
NCEP GDAS/FNL	
u-component of wind (1000/900/800hPa)	0.25° x 0.25°
v-component of wind (1000/900/800hPa)	0.25° x 0.25°
Relative Humidity (1000/900/800 hPa)	0.25° x 0.25°
Potential temperature	0.25° x 0.25°
Precipitable Water Content	0.25° x 0.25°

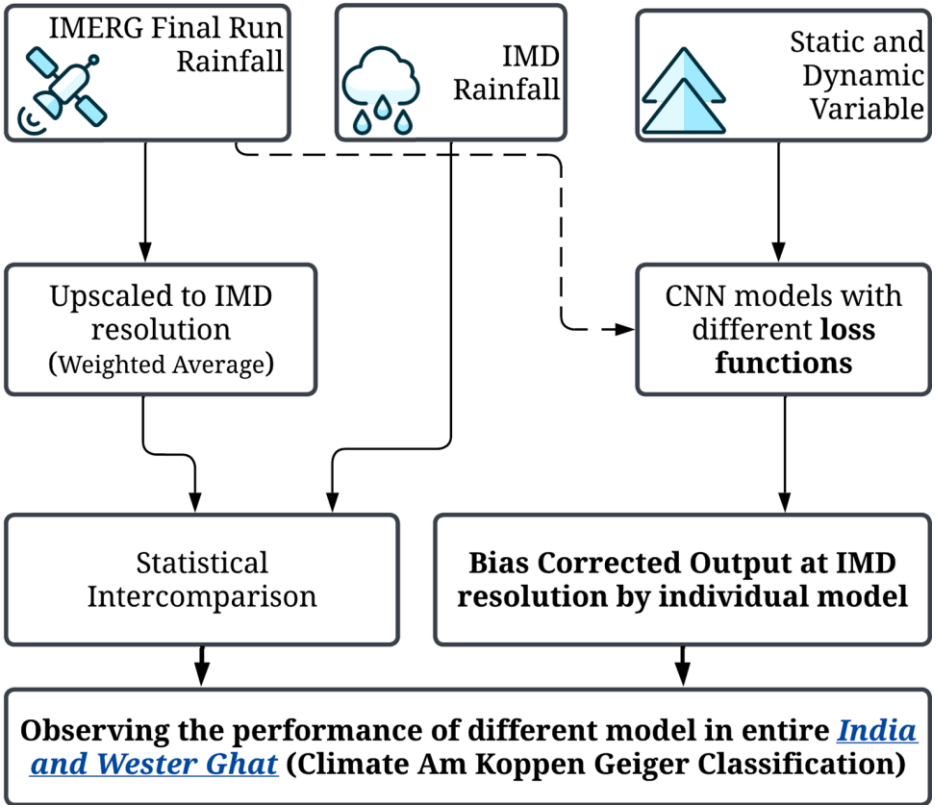


Dataset

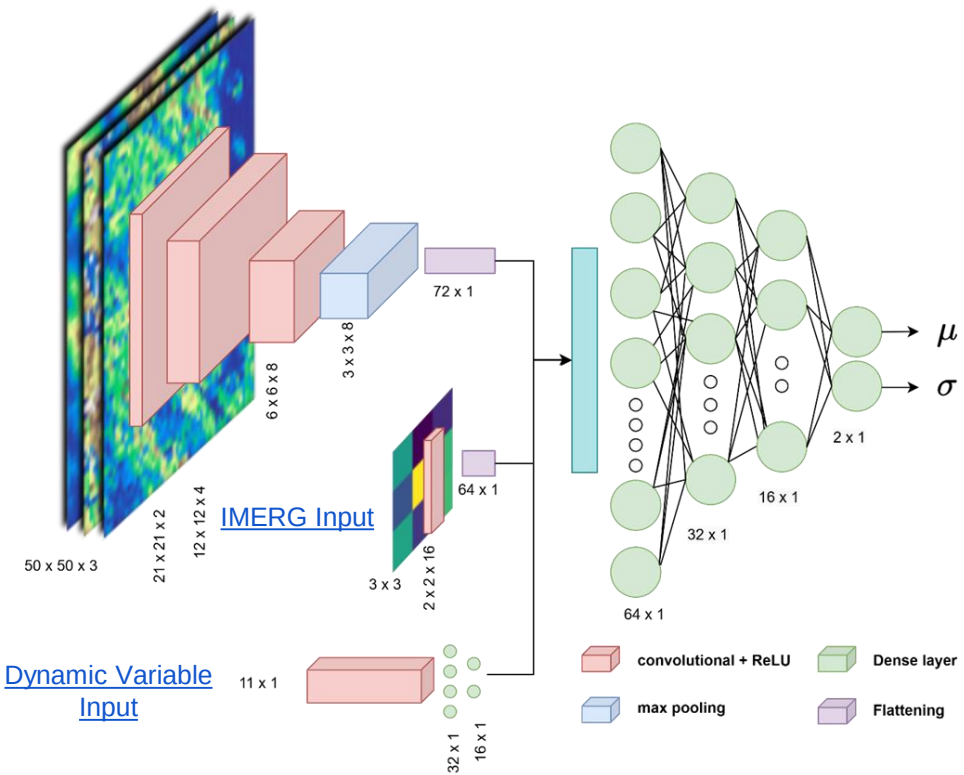
Data	Resolution
Precipitation, (2015-2018, 2021-2022, June-September)	
IMERG Final Run(V07B)	0.1° x 0.1°
IMD Gridded Rainfall	0.25° x 0.25°
Static Variables	
SRTM derived elevation	90m (resampled)
Aspect	90m
Slope	90m
Dynamic Variables	
NCEP GDAS/FNL	
u-component of wind (1000/900/800hPa)	0.25° x 0.25°
v-component of wind (1000/900/800hPa)	0.25° x 0.25°
Relative Humidity (1000/900/800 hPa)	0.25° x 0.25°
Potential temperature	0.25° x 0.25°
Precipitable Water Content	0.25° x 0.25°



Methodology



Model Architecture



$$MSE = \frac{\sum_{i=1}^{n}(y_i - \hat{y}_i)^2}{n}$$

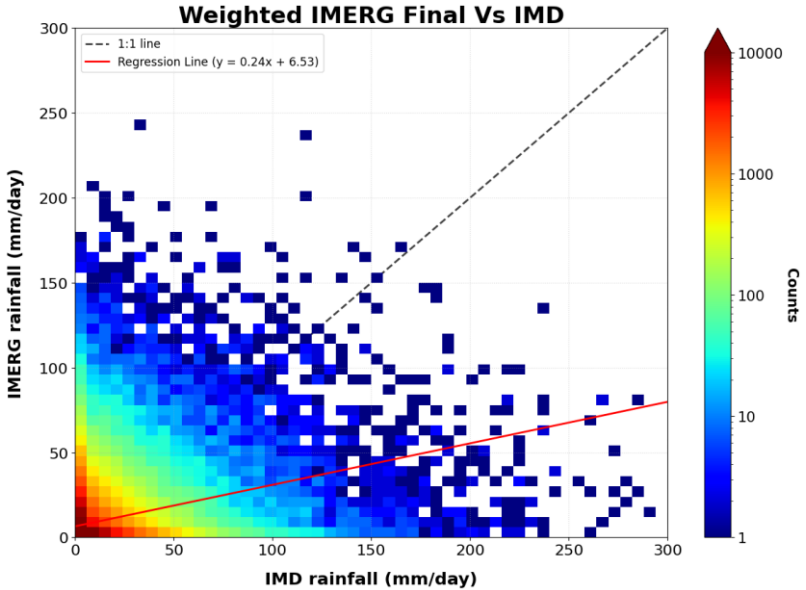
$$\mathcal{L} = -\frac{1}{N}\sum_{i=1}^{N}\log P(y_i \mid \hat{\mu}_i, \hat{\sigma}_i)$$

Epochs = 100
LR= 0.0001
ReLU activation
Batch Size = 32
Train-Test = 85:15

IMD vs IMERG (vTest dataset only)

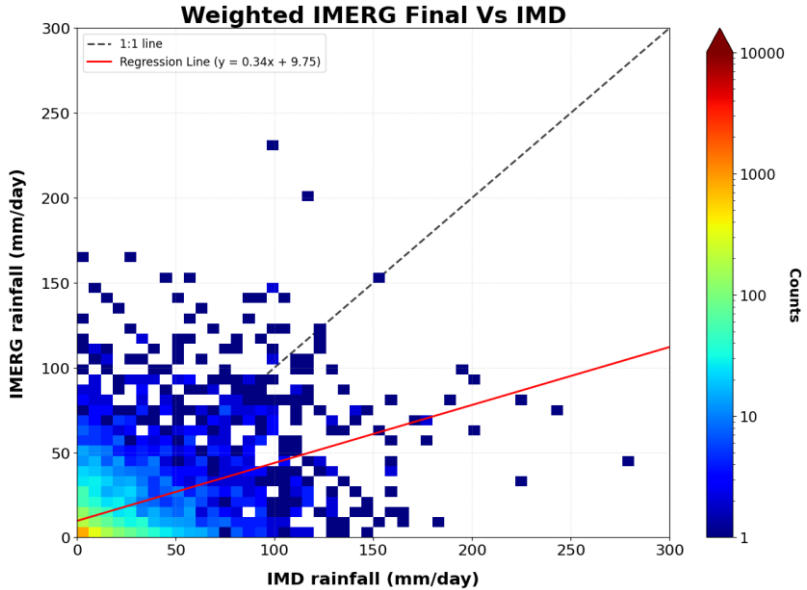
All India

(CC, RMSE, KLDiv)
(0.27 , 18.49 , 0.09)



Western Ghat

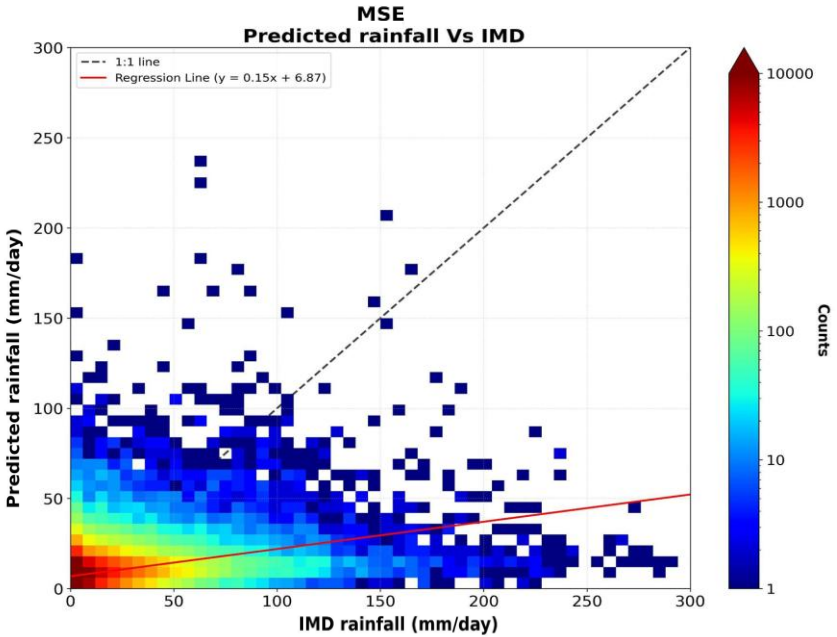
(CC, RMSE, KLDiv)
(0.42 , 29.72 , 0.11)



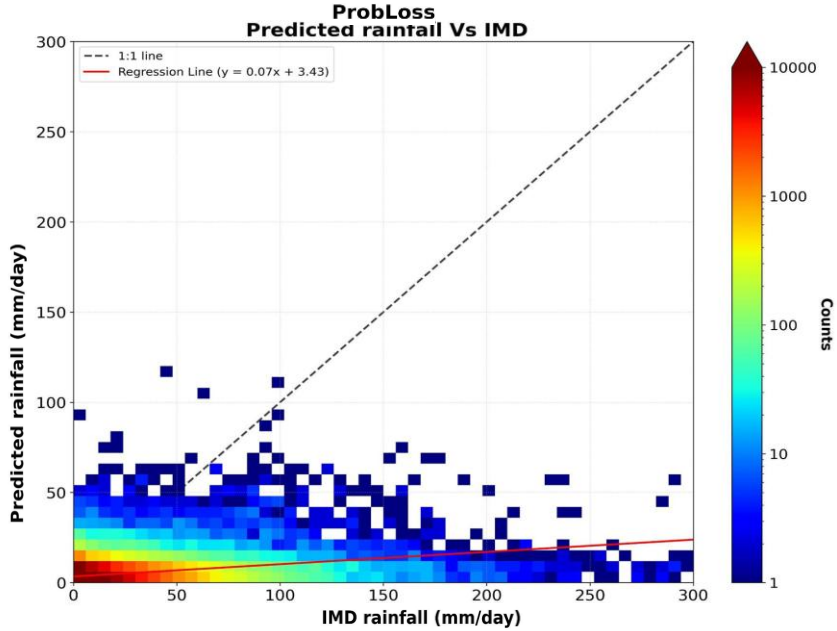
Model Results

Static Variables

All India

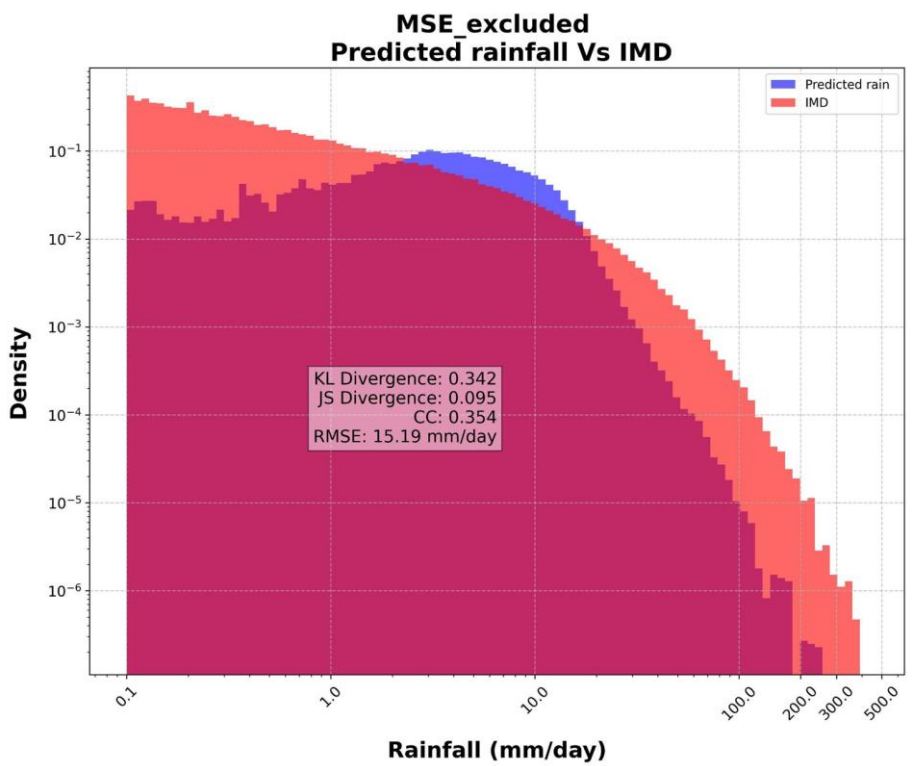


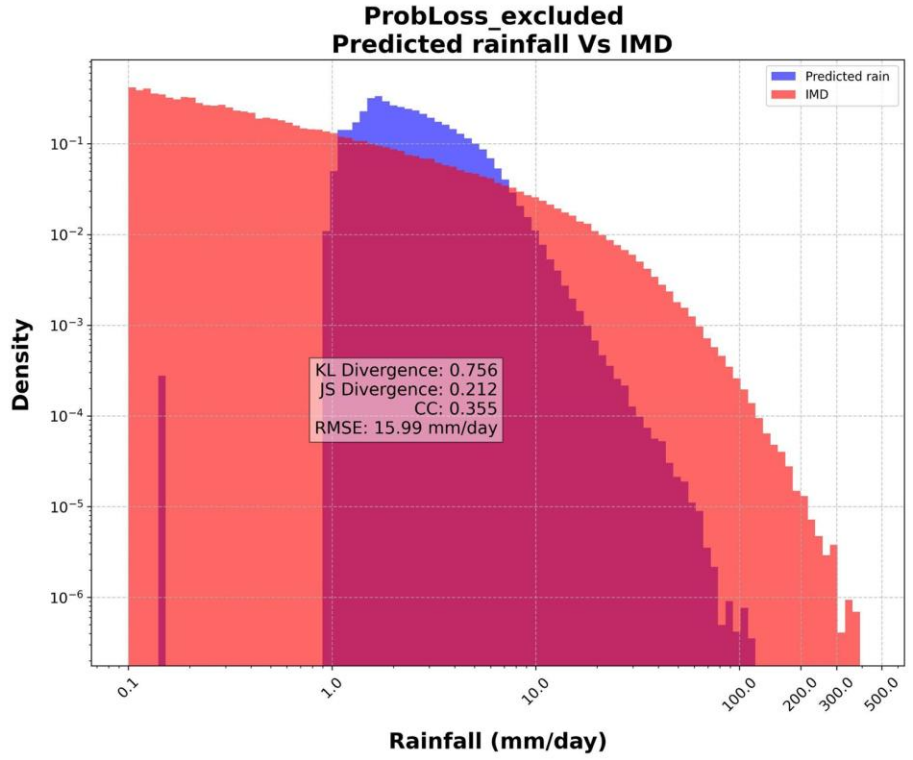
(0.35, 15.19, 0.342)



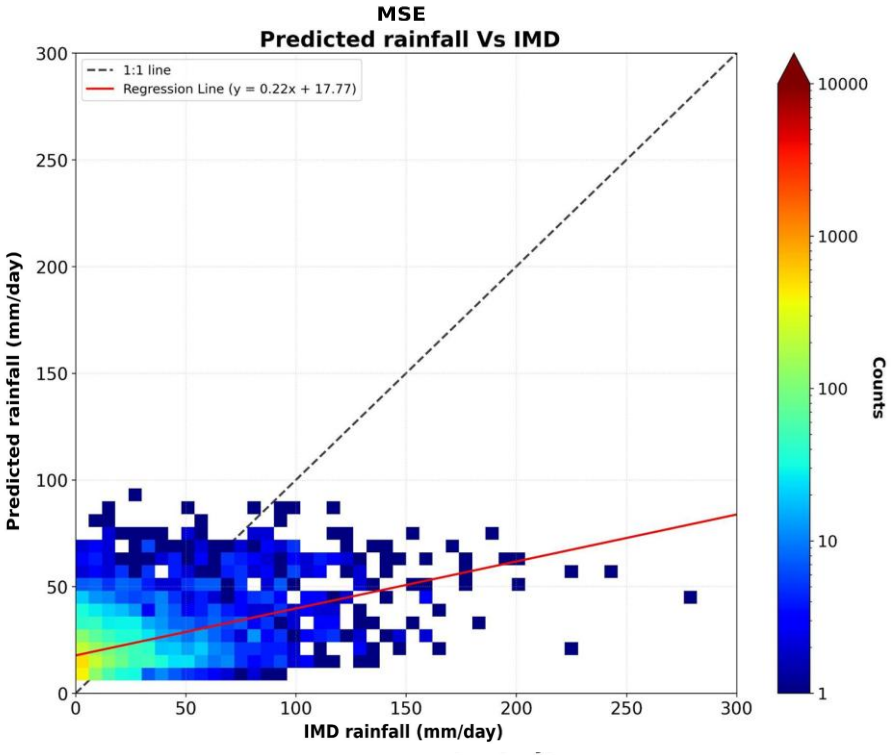
(0.35, 15.99, 0.756)

All India

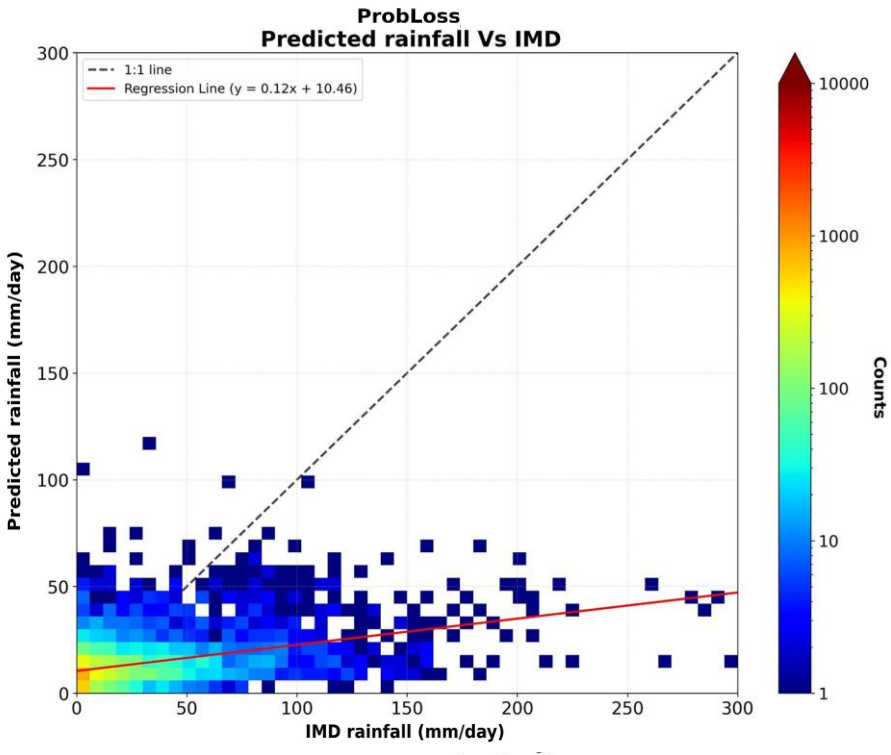

MSE_excluded
Predicted rainfall Vs IMD
Predicted rain
IMD
KL Divergence: 0.342
JS Divergence: 0.095
CC: 0.354
RMSE: 15.19 mm/day
Density
Rainfall (mm/day)


ProbLoss_excluded
Predicted rainfall Vs IMD
Predicted rain
IMD
KL Divergence: 0.756
JS Divergence: 0.212
CC: 0.355
RMSE: 15.99 mm/day
Density
Rainfall (mm/day)

Western Ghat
(Climate Region Am)



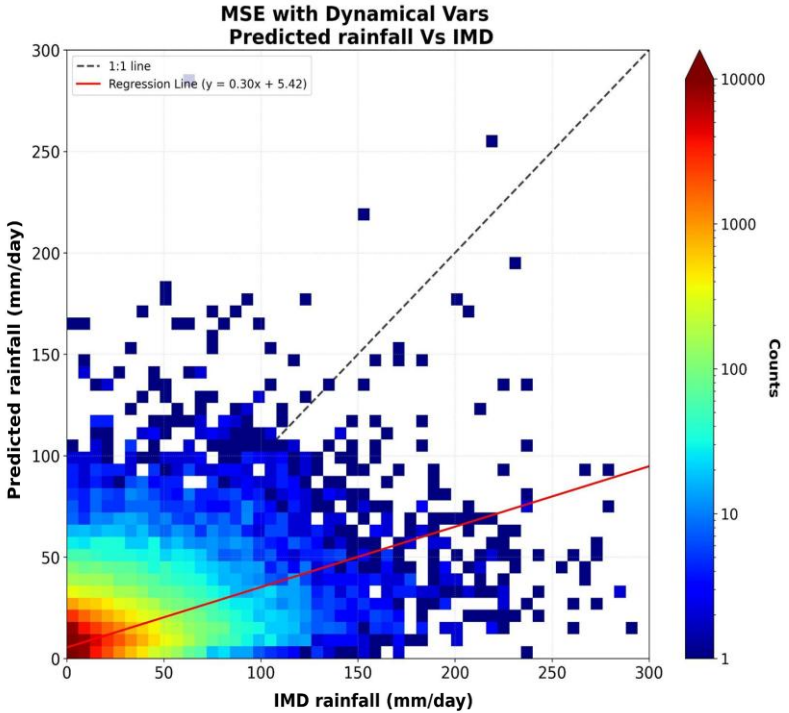
(0.47, 26.38, 0.590)



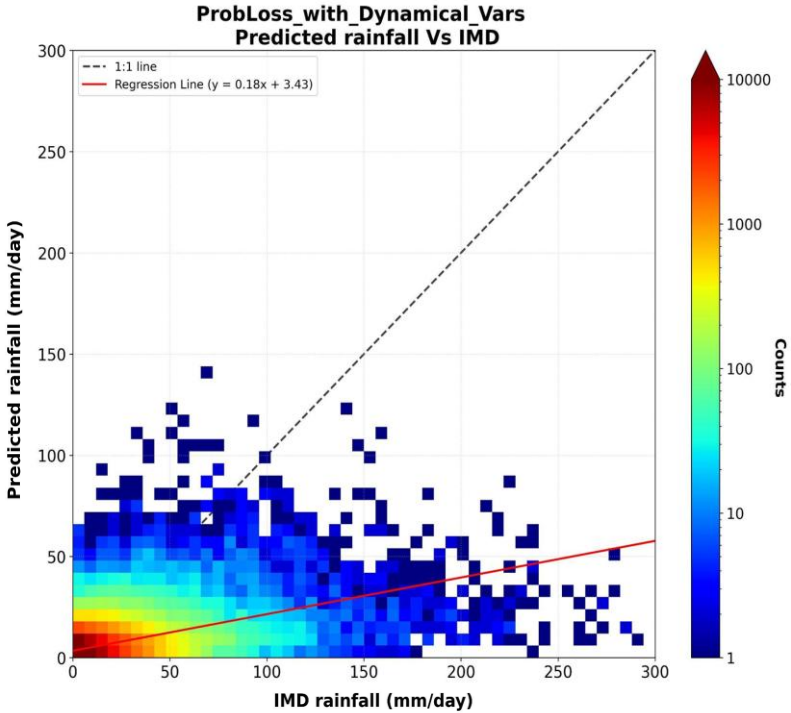
(0.40, 30.60, 0.342)

Static+Dynamic Variables

All India

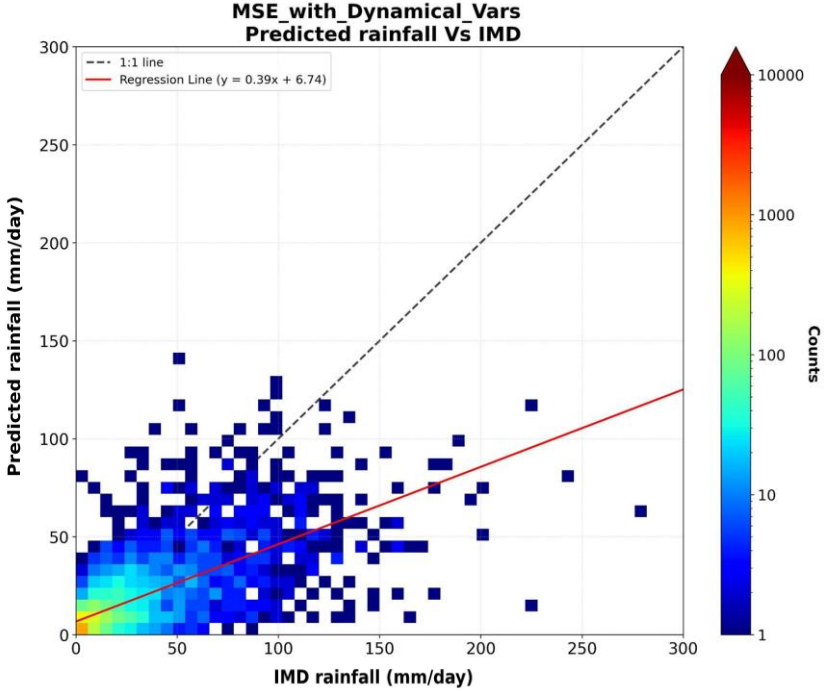


(0.51, 13.96, 0.17)

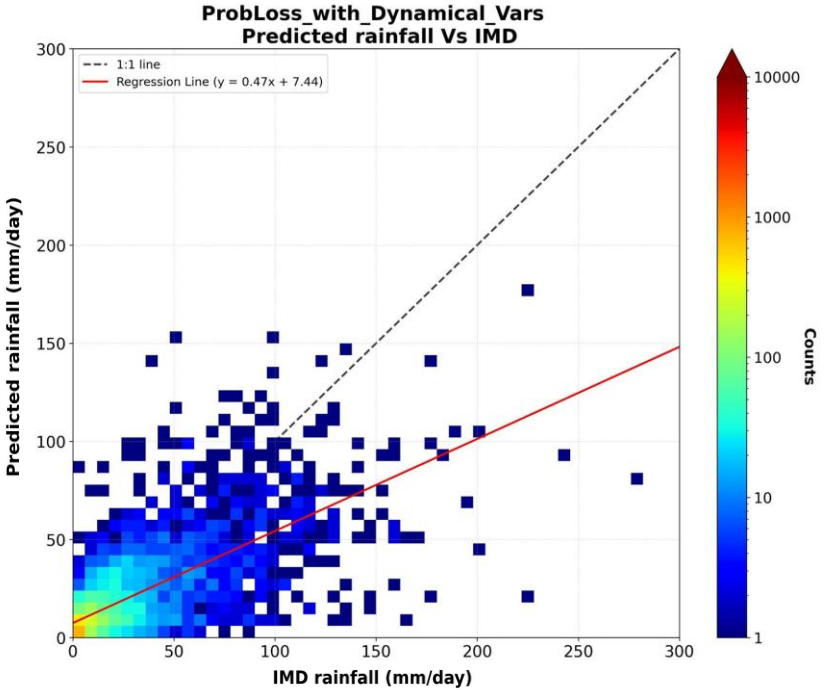


(0.51, 14.42, 0.546)

Western Ghat (Climate Region Am)

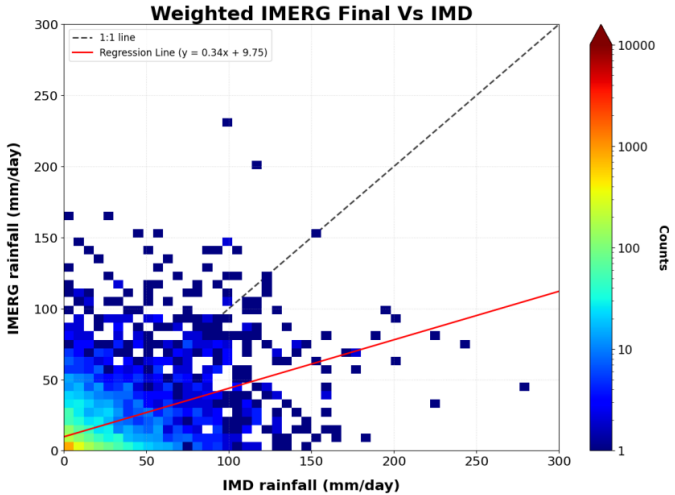


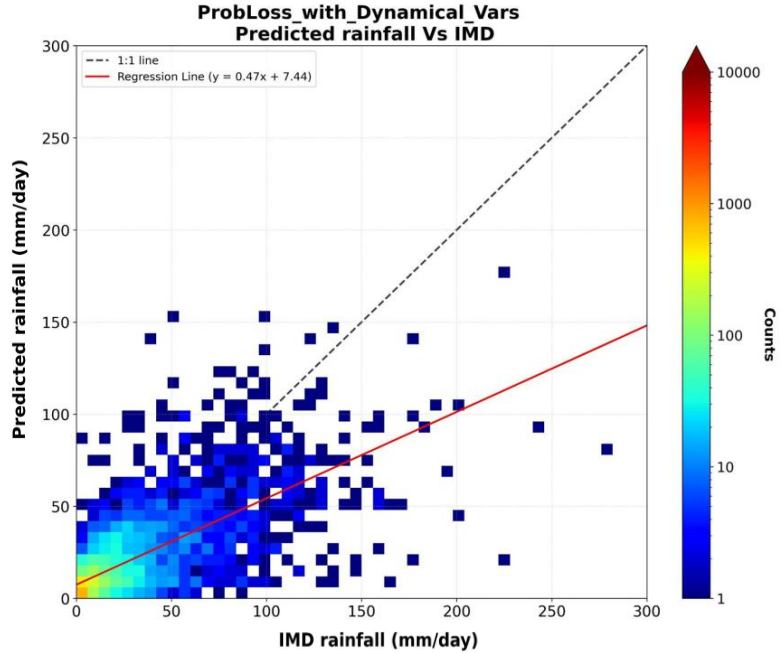
(0.69, 23, 0.20)



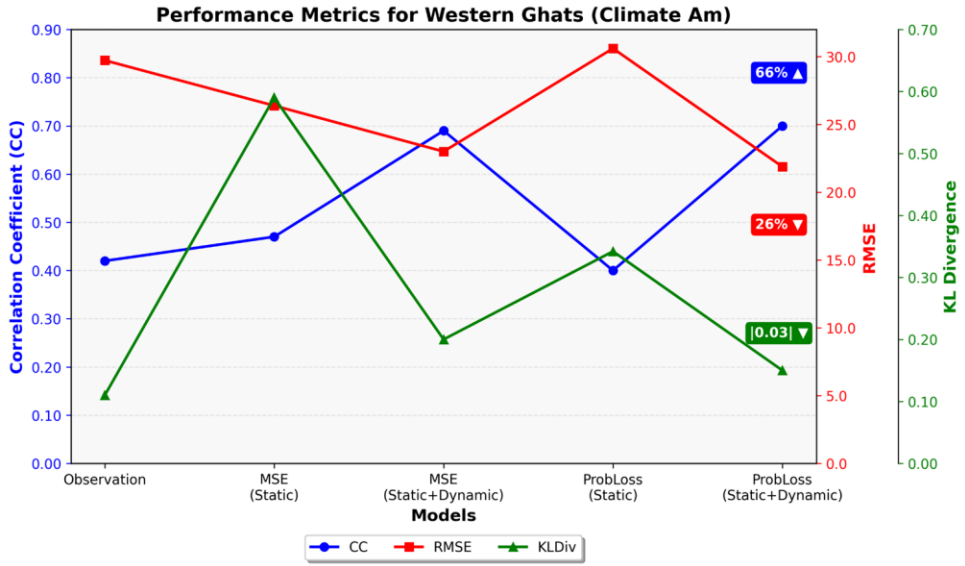
(0.70, 21.88, 0.15)

Summary


Weighted IMERG Final Vs IMD
1:1 line
Regression Line (y = 0.34x + 9.75)
IMERG rainfall (mm/day)
IMD rainfall (mm/day)
Counts
0
50
100
150
200
250
300
1
10
100
1000
10000


ProbLoss_with_Dynamical_Vars
Predicted rainfall Vs IMD
1:1 line
Regression Line (y = 0.47x + 7.44)
Predicted rainfall (mm/day)
IMD rainfall (mm/day)
Counts
0
50
100
150
200
250
300
1
10
100
1000
10000

Summary



Future Work

- Process based understanding of model results
- Validation and transferability of model understanding

Thank You!

Questions ?

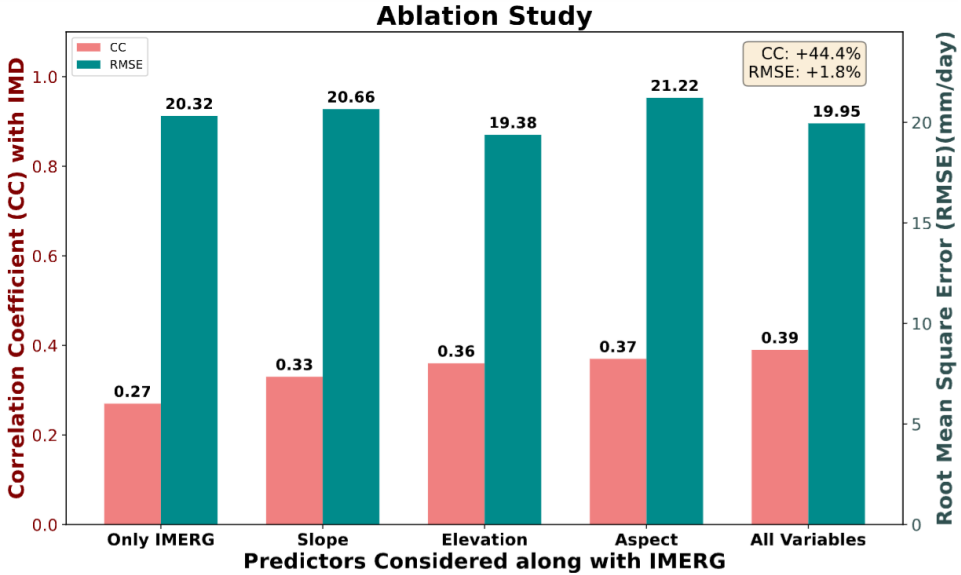
Thank You!

cc23resch@iith.ac.in

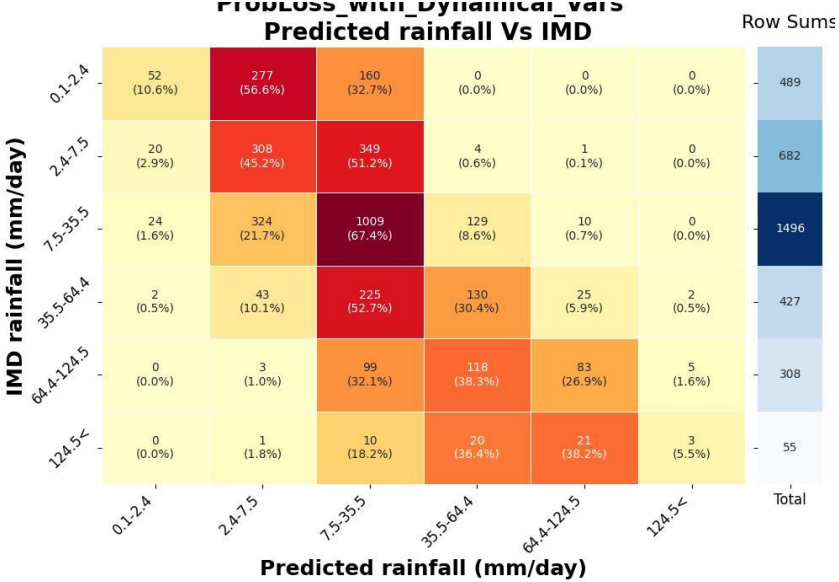
yash.upase27@gmail.com

yash-upase

Appendix



*Ablation Study,
Although the dataset considered is different



Contingency Matrix