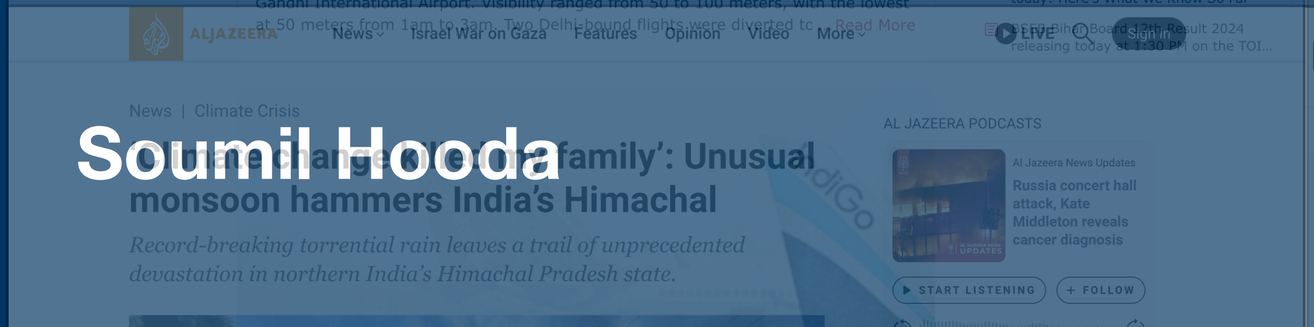
Indian Weather Risk Management

A derivatives based framework.

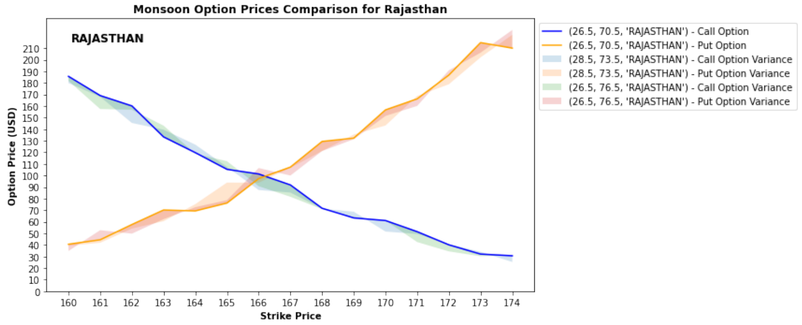
India experiences extreme weather events almost everyday [1].

And with Securities and Exchange Board of India making weather-based derivatives legal tender on the 1st of March 2024 [2], I got to working.

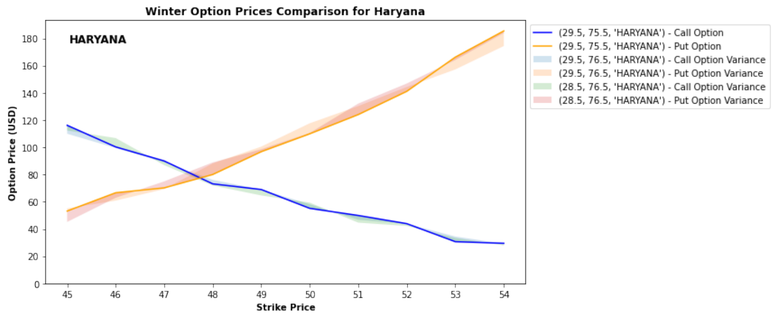


Soumil Hooda

Monsoon/Winter CDD/HDD based Temperature Options Contracts Priced (Energy Sector)



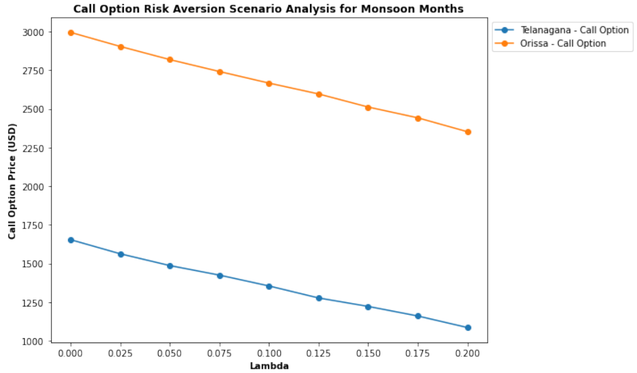
2024-03-05 to 2024-08-20



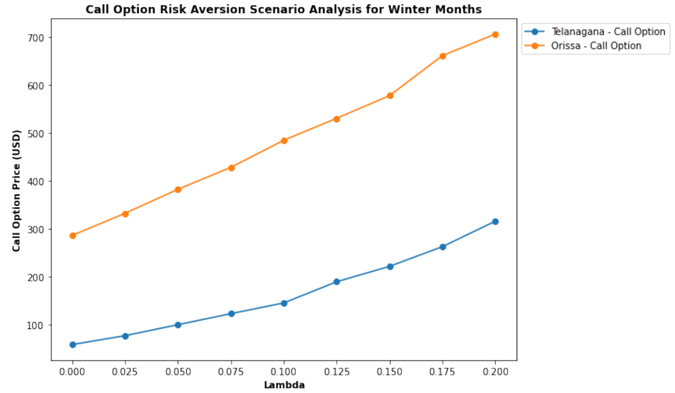
2024-10-05 to 2025-02-20

Indian States	HDD Base Temperature ($^{\circ}C$)	CDD Base Temperature ($^{\circ}C$)
PUNJAB	16.46	27.78
GUJARAT	23.49	29.29
HARYANA	13.93	29.16
HIMACHAL PRADESH	12.38	24.45
MADHYA PRADESH	19.92	27.12
BIHAR	19.80	25.23
UTTAR PRADESH	14.95	28.64
KARNATAKA	23.29	25.57
TELANGANA	21.49	27.19
ANDHRA PRADESH	23.01	27.52
RAJASTHAN	15.72	25.69
ORISSA	19.63	28.18

Base temperature values calculated by taking 30D rolling correlations between energy consumption and temperature, 1 standard deviation away from average temperature.



Monsoon Months: 3, 4, 5, 6, 7, 8, 9, and 10



Winter Months: 11, 12, 1 and 2

$$T_{trend} = ax^3 + bx^2 + cx + d$$

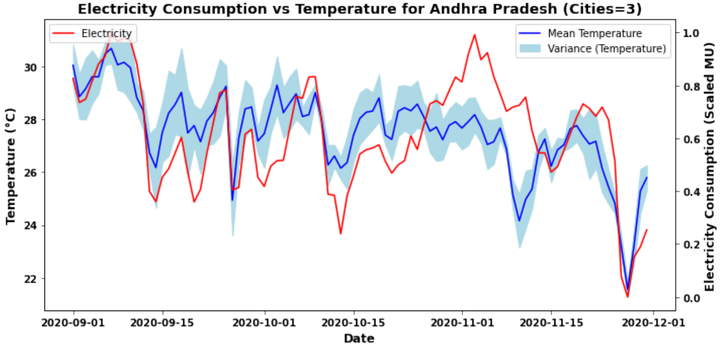
$$T_{\text{seasonal}} = \alpha \sin(wt + \theta) + \beta \cos(wt + \theta)$$

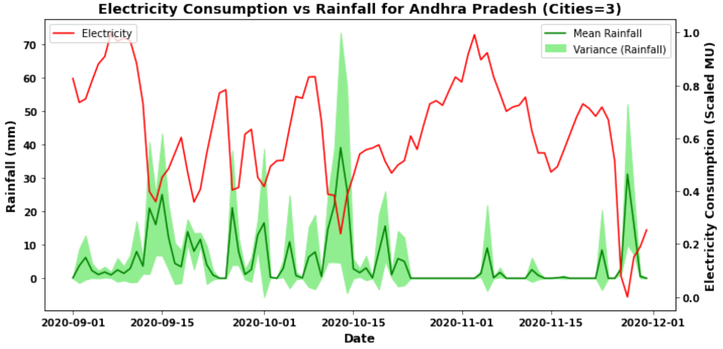
$$[T_t = \overline{T}_t + (T_s - \overline{T}_s)e^{-\kappa(t-s)} + \int_s^t e^{-\kappa(t-s)}\sigma_t dW_u]$$

LSTM integrated B-Spline volatility measures

$$T = T_{\text{det}} + T_{\text{mrev}} + (\sigma - \lambda) \cdot \text{volatility}$$

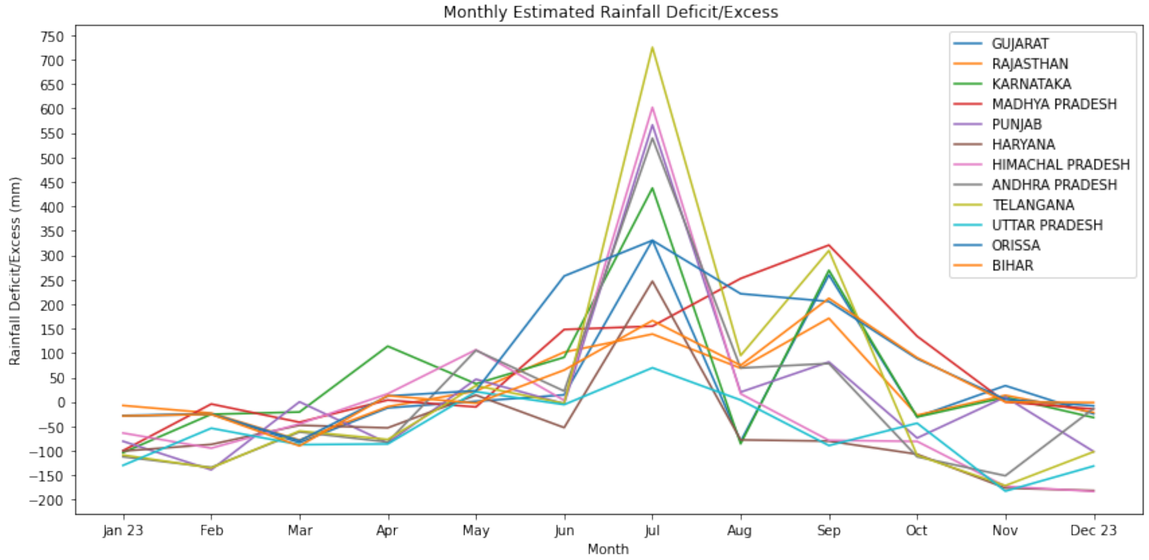
Euler Approximated Modified Mean-Reverting Ornstein Uhlenbeck Process Temperature Simulations





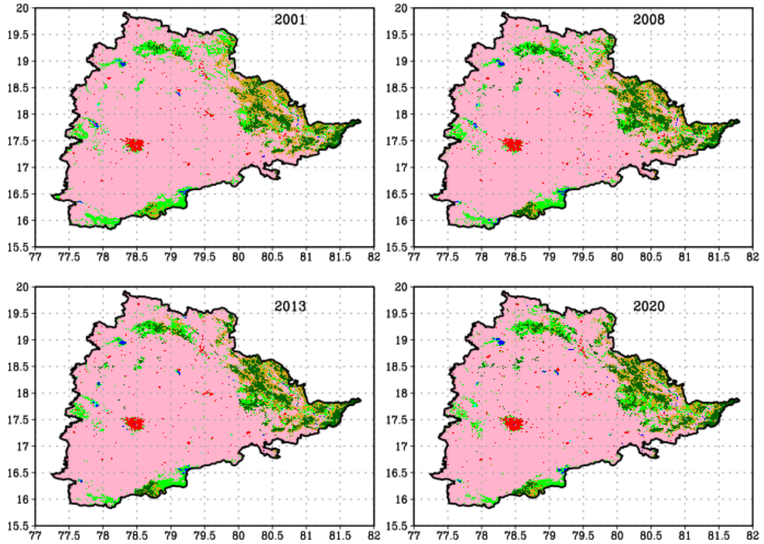
Discounted payoffs for Heating Degree Days (Winter)/Cooling Degree Days (Monsoon) contracts type temperature options under risk neutral pricing using Monte Carlo Valuation of Monte Carlo Simulations.

Yearlong/Monthly Rainfall based Swaps (Agriculture Sector)

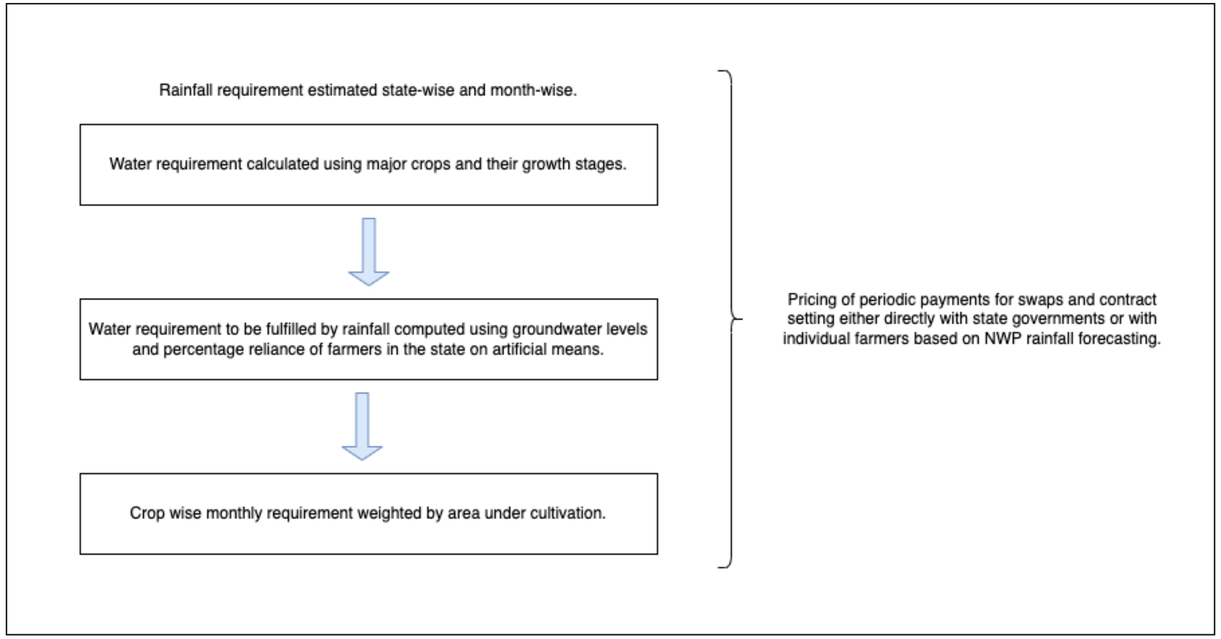


Base rainfall values to price periodic payments for swaps. Also could be used to price Excess Rainfall or Deficit Rainfall options.

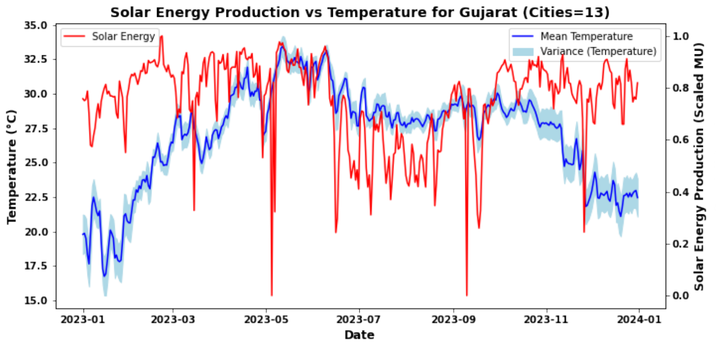
State	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
ANDHRA PRADESH	103.013	93.044	103.013	99.69	103.013	99.152	102.457	102.457	99.152	102.457	99.69	103.013
BIHAR	32.51	29.364	32.51	31.461	114.421	181.112	187.15	187.15	181.112	131.636	31.461	32.51
GUJARAT	28.604	25.836	106.392	99.528	106.392	108.489	112.105	112.105	108.489	129.672	27.681	28.604
HARYANA	45.754	16.522	8.923	8.635	102.67	99.358	102.67	102.67	99.358	32.613	14.689	18.292
KARNATAKA	104.041	93.973	104.041	100.685	104.041	77.874	112.424	118.849	120.638	102.374	100.685	104.041
MADHYA PRADESH	14.385	12.992	6.492	6.283	104.309	70.043	115.59	124.972	129.219	85.963	13.921	14.385
ORISSA	0.0	0.0	0.0	0.0	0.0	176.471	182.353	182.353	176.471	182.353	0.0	0.0
PUNJAB	14.601	13.188	14.601	14.13	0.0	0.0	0.0	0.0	0.0	14.601	14.13	14.601
RAJASTHAN	25.224	22.783	25.224	4.245	138.781	86.842	127.21	133.744	134.865	53.72	24.411	25.224
TELANGANA	0.0	0.0	0.0	0.0	0.0	102.513	105.93	105.93	102.513	105.93	0.0	0.0
UTTAR PRADESH	31.257	28.232	31.257	29.613	99.64	116.599	120.485	120.485	116.599	61.935	30.249	31.257

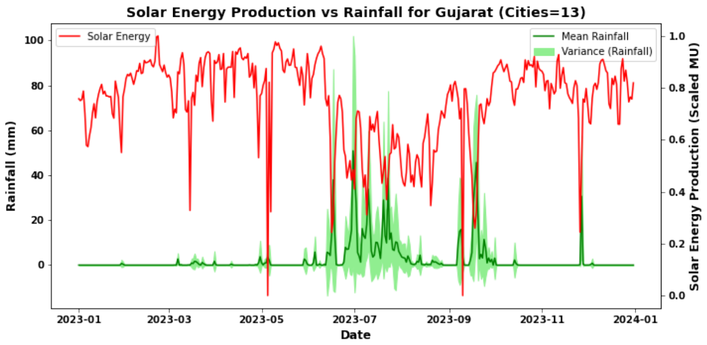


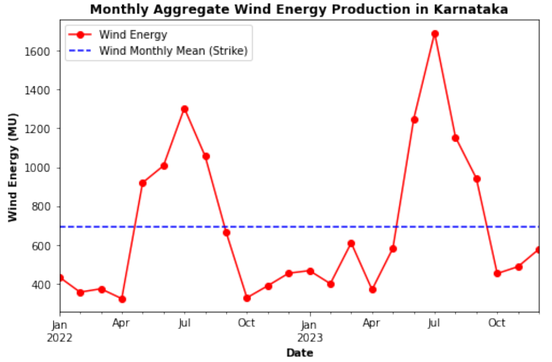
Telangana state land use/land cover distribution for agriculture land types.

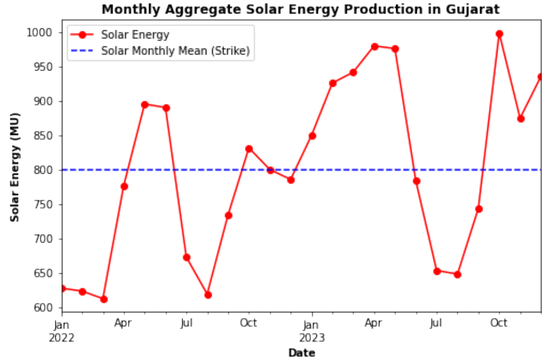


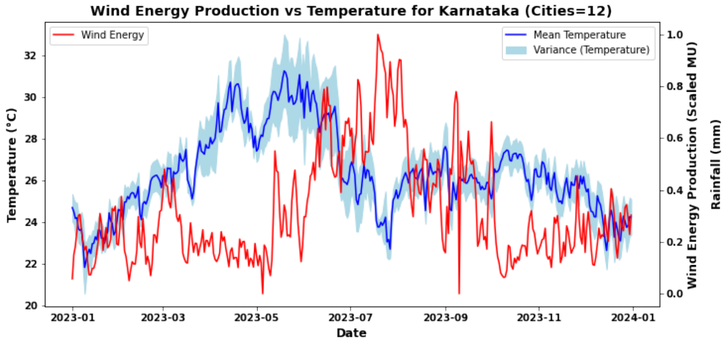
Yearlong/Monthly Renewable Energy Swaps (Energy Sector)

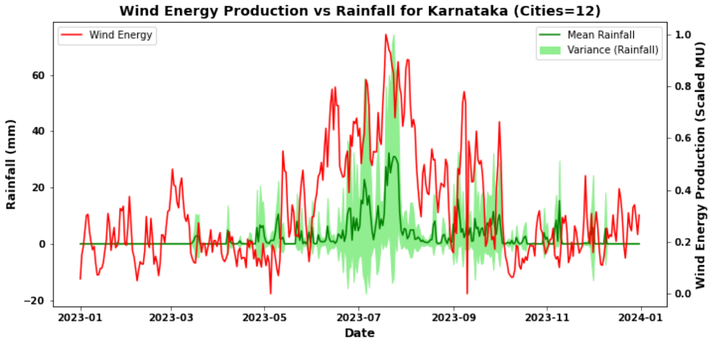












High temperatures can cause thermal inversions or disrupt pressure gradients, leading to decreased wind speeds. (As can be visually confirmed in the plot.)

Heavy rainfall can lead to cloud cover, reducing solar irradiance, leading to decreased solar energy production. (As can be visually confirmed in the plot.)

The solar energy production swaps are structured to provide payouts to the company if solar energy generation during the monsoon season is significantly lower than expected due to heavy rainfall and cloud cover. Payouts are based on the difference between actual and expected energy production levels. Similarly a case can be made for wind energy production swaps.

Study Limitations

Study is limited in compute. Forecasting rainfall and even more complex weather phenomenon such as fog or cyclones, requires numerical weather prediction models, or more complex graphical global embedding based models. Study is also hugely impacted by the lack of structured and complete data releases, if released at all. Some of the better quality data is paid and inaccessible. Access to more fine grain agricultural produce data, or commodity exchange rates at exchanges such as NCDEX could be used to further refine the base temperature and base rainfall values.

References

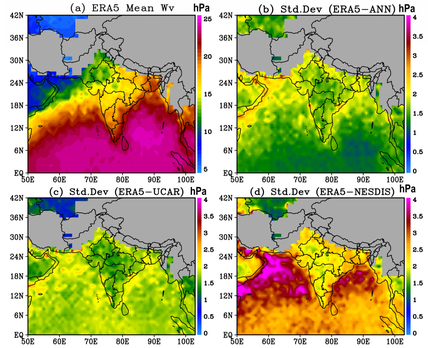
1. "The Weather Channel. 'India Experienced Extreme Weather Nearly Every Day in 2023'. Accessed March 24, 2024. https://weather.com/en-IN/india/news/news/2024-02-29-india-experienced-extreme-weather-nearly-every-day-in-2023"
2. Securities and Exchange Board of India (SEBI). "Notification for List of Commodities under SCRA, 1956, Accessed March 24, 2024." Gazette Notification. March 2024. Available online: https://www.sebi.gov.in/legal/gazette-notification/mar-2024/notification-for-list-of-commodities-under-scra-1956-dated-march-01-2024_82030.html.
3. DownToEarth. "Latest in farmer woes: heavy unseasonal rain, pending payouts from Centre's crop insurance scheme." DownToEarth, Accessed March 24, 2024. Available online: https://www.downtoearth.org.in/news/agriculture/latest-in-farmer-woes-heavy-unseasonal-rain-pending-payouts-from-centre-s-crop-insurance-scheme-89235

Who am I?

Soumil Hooda
MSc. Physics @ BITS Pilani, Hyderabad, India [2020-2025]
BE Electrical and Electronics @ BITS Pilani, Hyderabad, India [2020-2025]
LinkedIn | Personal Webpage | Google Scholar

BITS Pilani is the alma mater of founders of Hotmail, SanDisk, Akamai, BlueJeans, Postman, Swiggy and several Indian unicorns.

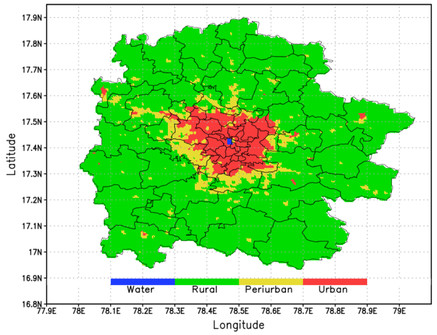
My prior work in Indian weather thermodynamic profile estimation and urbanity forecasting.



S. Hooda, M. Gupta, R. Singh and S. P. Ojha, "Retrieval of Atmospheric Water Vapor Profiles From COSMIC-2 Radio Occultation Constellation Using Machine Learning," in *IEEE Transactions on Geoscience and Remote Sensing*, vol. 61, pp. 1-7, 2023, Art no. 4107907.
DOI: 10.1109/TGRS.2023.3331187.

Delivered a model that surpasses NESDIS-retrieved Wv, with the Wv values from the proposed models exhibiting lower error rates compared to UCAR's in the lower atmosphere, and demonstrating similar performance to UCAR's in the middle and upper troposphere. The proposed model can retrieve the Wv solely from C2 data and does not require any external meteorological data.

Water vapor is one of the key components for models built to forecast rainfall accurately, in-turn needed to price potential derivatives based on rainfall for the agricultural sector.



R. Bhushan*, S. Hooda*, H. Vidhani, M. Gupta, L. Suresh and T. Clune, "Supervised Model for Peri-Urban Area Demarcation in Hyderabad, India," in *IEEE Geoscience and Remote Sensing Letters*, vol. 21, pp. 1-5, 2024, Art no. 2501605. *Co-first authors
DOI: 10.1109/LGRS.2024.3359632.

Developed a model that integrates multiple spatial parameters and domain knowledge-driven thresholds to reveal a remarkable 107.96% increase in peri-urban regions around Hyderabad between 2013 and 2020. Important to underscore that the proposed model holds relevance for developing countries, where the timely availability and accuracy of socio-economic data pose notable challenges for peri-urban classification.

Urbanity estimation and forecasting studies are important to properly price potential derivatives based on current and future, temperature and urban heating effects for energy markets.