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C-CARGO

Forecasting over region (Pakistan) lacking air quality monitoring networks

Statistical models do not require an elaborated inputs of systems Detailed emissions information are required for deterministic modelling

Spatio-temporal performance of statistical model (VAR) to forecast CO and O₃

At country scale **At provincial scale** **At city scale**

Statistical evaluation of VAR performance

t-test **MAPE**

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VAR model performed well over the most polluted regions and the O₃ precursors (NO₂ and HCHO) played an important role in forecasting CO and O₃

	2013	2014	2015	2016	2017
CO (ppbv)					
Actual	130.69	123.76	108.76	110.10	108.87
Forecast	124.22	125.40	125.51	124.74	125.27
Difference	6.46	-1.65	-16.75	-14.64	-16.40
%Percentage error	4.94	1.33	15.40	13.29	15.06
O₃ (DU)					
Actual	33.02	32.79	36.16	35.70	37.13
Forecast	32.13	32.13	32.12	32.36	32.33
Difference	0.89	0.66	3.80	3.35	4.80
%Percentage error	2.69	2.02	10.52	9.37	12.92

Figure 2

(a) CO

Punjab

Forecast Actual

(b) O₃

Figure 4

Figure 4 displays two time-series plots for Sindh, showing the concentration of CO (a) and O₃ (b) over time. The x-axis represents years from 2010 to 2025. The y-axis for CO (a) ranges from 0 to 200, and for O₃ (b) ranges from 20 to 50. Both plots show a blue line representing the 'Forecast' and a red line representing the 'Actual' data. A vertical green line indicates the start of the forecast period around 2012. The plots show seasonal oscillations and a general upward trend in CO concentration over time.

Figure 3: The actual (observed) and forecasted (predicted) concentrations of (a)CO and (b) O₃ over Balochistan

Figure 5: The actual (observed) and forecasted (predicted) concentrations of (a) CO and (b) O₃ over KPK

Figure 6 and 7: The actual (observed) and forecasted (predicted) concentrations of (a) CO and (b) O₃ over Lahore and Peshawar

CO (ppbv)				
Actual	168.87	126.47	110.75	101.00
Forecast	171.19	136.83	123.40	115.43
Difference	-2.33	-10.36	-12.66	-14.43
%Percentage error	1.38	8.19	11.43	14.28
O₃ (DU)				
Actual	39.02	38.85	35.98	32.52
Forecast	36.90	36.40	33.53	30.34
Difference	2.12	2.45	2.44	2.18
%Percentage error	5.42	6.31	6.79	6.70

	Peshawar	Lahore	Quetta	Faisalabad	Mirpur
CO (ppbv)					
Actual	134.45	194.91	103.24	108.57	46.17
Forecast	137.86	200.82	114.64	120.23	89.90
Difference	-3.41	-5.91	-11.40	-11.66	-43.74
%Percentage error	2.54	3.03	11.04	10.74	94.74
O₃ (DU)					
Actual	35.48	39.87	34.28	36.11	27.63
Forecast	33.68	37.69	32.01	33.63	25.37
Difference	1.80	2.18	2.27	2.49	2.26
%Percentage error	5.07	5.46	6.61	6.88	8.17

Table 3: The actual and forecasted yearly concentrations of CO and O₃ over Cities (2013-2017)

	CO	O ₃
	MAPE (%)	MAPE (%)
Pakistan	11.00	9.44
Punjab	10.50	7.25
Sindh	12.59	7.72
Baloch	13.17	9.03
KPK	18.78	10.50
Peshawar	10.00	9.78
Lahore	11.24	7.48
Quetta	12.50	8.69
Panjiur	15.41	7.34
Chitral	19.65	17.75

- The VAR model provided successful results at both spatial and temporal scales.
- Comparatively, its performance is better over regions with more anthropogenic activities as compared to the clean regions.
- Finer results of VAR model are observed over the province of Punjab and the city of Lahore and Peshawar (relatively more polluted)
- The model is not recommended for non-polluted sites as it failed to forecast over Gilgit (relatively cleaner city). It is observed that O_3 precursors (NO_2 and $HCHO$) played an important role in forecasting CO and O_3 over study region. Furthermore, VAR Model has shown more promising results for O_3 forecasts as compared to CO forecasts.
- The VAR model used in this study has prognostic capabilities to forecast atmospheric pollutants over region with least data inputs to compensate for deterministic modelling.
- It can be further tested for daily forecasts to provide early warnings in areas with limited resources.
- Future scenarios with high and low concentrations of CO and O_3 precursors can be created using VAR model to explore the role of precursors in forecasting.

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