Regime-dependent expression of regional aerosol signals in urban PM_{10} and $PM_{2.5}$ across arid northern China

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Table S1. Full classification of all cities with corresponding PM10 and PM2.5 correlations with the regional signal.

City	Category	PM_{10} correlation with regional signal	$PM_{2.5}$ correlation with regional signal	PM_{10} - $PM_{2.5}$ correlation difference	PM_{10} rank	$PM_{2.5}$ rank
Aksu	PM_{10}-dominated synchronization	0.776	0.667	0.109	19	35
Altay	$PM_{2.5}$-dominated synchronization	0.030	0.755	-0.725	47	25
Alxa_League	PM_{10}-dominated synchronization	0.798	0.560	0.238	13	42
Baiyin	Strongly regionally synchronized	0.851	0.839	0.011	9	12
Baotou	Moderately synchronized	0.782	0.797	-0.015	17	18
Bayannur	Moderately synchronized	0.759	0.751	0.008	22	26
Bortala	$PM_{2.5}$-dominated synchronization	0.532	0.860	-0.327	37	9
Changji	$PM_{2.5}$-dominated synchronization	0.417	0.779	-0.363	39	22
Chifeng	$PM_{2.5}$-dominated synchronization	0.663	0.793	-0.130	30	20
Dingxi	Strongly regionally synchronized	0.868	0.889	-0.021	7	3
Gannan	Strongly regionally synchronized	0.809	0.830	-0.021	12	14
Guyuan	Strongly regionally synchronized	0.899	0.888	0.011	2	4
Haixi	PM_{10}-dominated synchronization	0.689	0.382	0.307	28	45
Hami	Moderately synchronized	0.754	0.844	-0.090	23	11
Hohhot	Moderately synchronized	0.774	0.784	-0.009	20	21
Hotan	PM_{10}-dominated synchronization	0.398	0.004	0.394	40	47
Hulunbuir	$PM_{2.5}$-dominated synchronization	0.370	0.613	-0.243	43	40
Ili	$PM_{2.5}$-dominated synchronization	0.315	0.759	-0.444	45	23
Jiayuguan	PM_{10}-dominated synchronization	0.683	0.358	0.324	29	46

Jinchang	PM_{10}-dominated synchronization	0.797	0.640	0.157	15	37
Jiuquan	Moderately synchronized	0.654	0.596	0.059	32	41
Karamay	$PM_{2.5}$-dominated synchronization	0.395	0.812	-0.417	42	17
Kashgar	Moderately synchronized	0.660	0.647	0.013	31	36
Kizilsu	PM_{10}-dominated synchronization	0.640	0.478	0.162	34	43
Korla	Moderately synchronized	0.738	0.728	0.010	26	30
Lanzhou	Strongly regionally synchronized	0.843	0.888	-0.045	10	5
Linxia	Moderately synchronized	0.781	0.747	0.033	18	27
Ordos	Moderately synchronized	0.734	0.636	0.099	27	38
Pingliang	Strongly regionally synchronized	0.876	0.818	0.059	4	15
Qingyang	Strongly regionally synchronized	0.865	0.895	-0.030	8	1
Shihezi	$PM_{2.5}$-dominated synchronization	0.395	0.733	-0.338	41	28
Shizuishan	Strongly regionally synchronized	0.886	0.878	0.008	3	6
Tacheng	$PM_{2.5}$-dominated synchronization	0.097	0.688	-0.591	46	33
Tianshui	$PM_{2.5}$-dominated synchronization	0.752	0.876	-0.124	24	8
Tongliao	Moderately synchronized	0.649	0.705	-0.056	33	32
Turpan	$PM_{2.5}$-dominated synchronization	0.741	0.878	-0.136	25	7
Ulanqab	Moderately synchronized	0.798	0.706	0.091	14	31
Urumqi	$PM_{2.5}$-dominated synchronization	0.479	0.833	-0.354	38	13
Wuhai	Strongly regionally synchronized	0.870	0.815	0.055	5	16
Wujiaqu	$PM_{2.5}$-dominated synchronization	0.343	0.759	-0.416	44	24
Wuwei	Moderately synchronized	0.770	0.731	0.039	21	29

Wuzhong	Strongly regionally synchronized	0.901	0.857	0.043	1	10
Xilingol_League	PM_{10}-dominated synchronization	0.620	0.477	0.142	36	44
Xingan_League	Moderately synchronized	0.624	0.678	-0.054	35	34
Yinchuan	Strongly regionally synchronized	0.869	0.893	-0.024	6	2
Zhangye	PM_{10}-dominated synchronization	0.783	0.625	0.158	16	39
Zhongwei	Moderately synchronized	0.838	0.795	0.044	11	19

Table S2. Sensitivity of the threshold-based typology to alternative R^2 and ΔR^2 criteria.

R^2 threshold	ΔR^2 threshold	Cities retaining classification (n)	Cities retaining classification (%)	Cities changing class (n)
0.60	0.08	45	95.74	2
0.64	0.10	47	100.00	0
0.70	0.12	44	93.62	3

Summary of sensitivity analysis for the threshold-based typology. The table reports the number and percentage of cities retaining their original classification under alternative threshold combinations relative to the baseline criteria ($R^2 = 0.64$, $\Delta R^2 = 0.10$). Changes are limited to a small number of boundary cases.

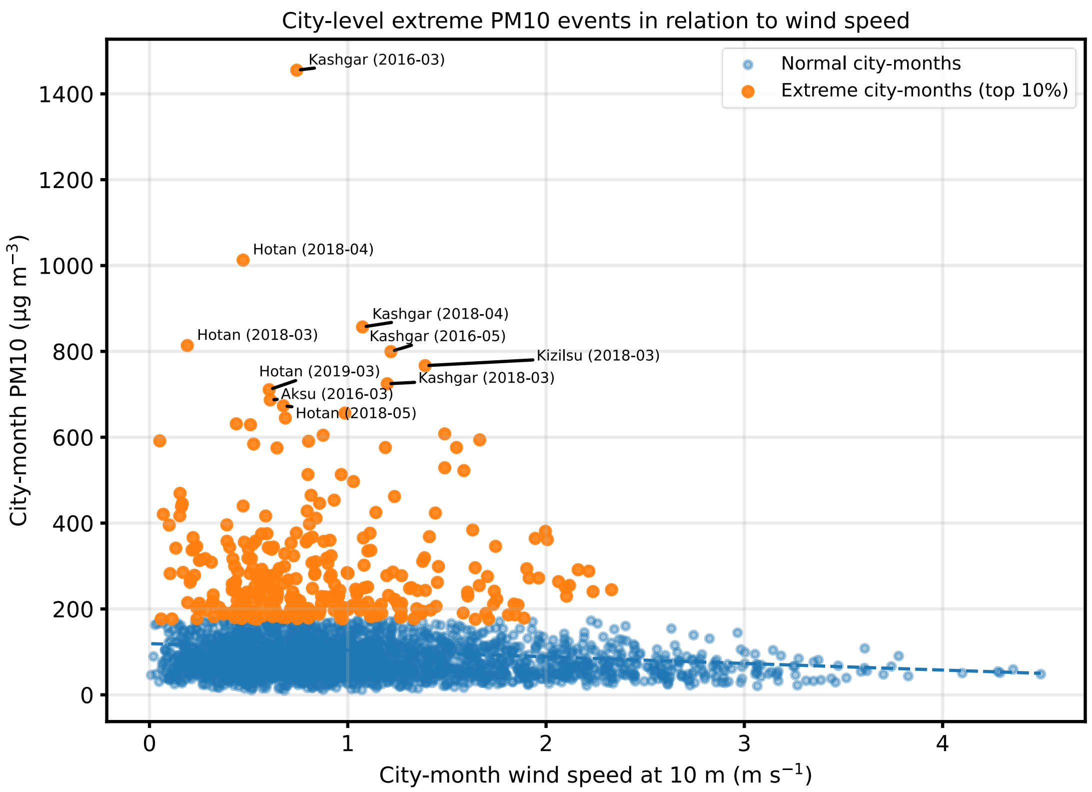

Figure S1. Mean relationships of regional PM10 with wind speed across arid cities of northern China.

Supplementary analysis of additional correlates of ΔR^2

To further examine factors associated with inter-city heterogeneity in differential regional control, ΔR^2 was additionally compared with latitude and mean PM_{10} concentration (Figure S2).

A statistically significant negative relationship is observed between ΔR^2 and latitude ($\rho = -0.520$, $p = 0.001$), indicating systematic variation of control regimes with geographic position. Cities located in the southern and central parts of the study area tend to exhibit positive ΔR^2 values, whereas negative values dominate in northern regions. However, this latitudinal gradient is not interpreted as a direct physical effect of latitude itself. Instead, latitude likely acts as a proxy variable reflecting the spatial position of cities relative to major dust sources, such as the Taklamakan and Gobi deserts, and to dominant transport pathways. In particular, northern cities are generally located farther from key dust source regions, which may lead to weakening of the regional dust signal and a relative increase in the role of $PM_{2.5}$.

The relationship between ΔR^2 and mean PM_{10} concentration is also statistically significant ($\rho = 0.344$, $p = 0.018$), but notably weaker than that observed for aerosol composition and desert-source distance in the main analysis. This suggests that higher PM_{10} levels may be associated with enhanced PM_{10}-dominated regimes; however, absolute concentration alone does not represent a primary control on inter-city variability. Instead, it likely reflects underlying differences in aerosol composition and regional dust influence.

These results are consistent with the interpretation that ΔR^2 is influenced by a combination of aerosol characteristics and geographic context. However, compared to the stronger relationships observed for the $PM_{2.5}/PM_{10}$ ratio and distance to desert sources (Figure 4), both latitude and mean PM_{10} should be considered secondary or proxy variables rather than direct drivers of differential regional control.

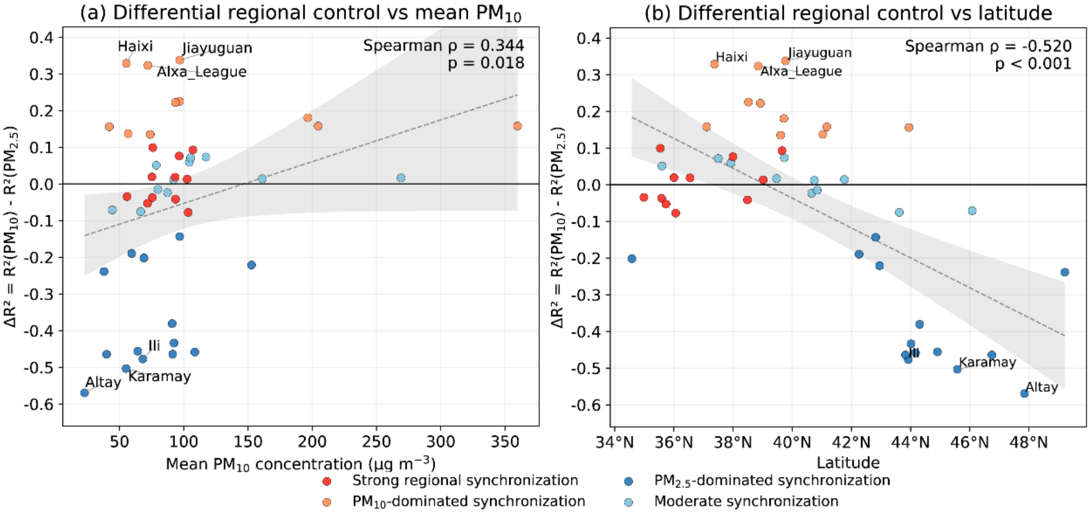

Figure S2. Additional relationships between ΔR^2 and (a) mean PM_{10} concentration and (b) latitude across arid cities of northern China. Both relationships are statistically significant but weaker than those observed for aerosol composition and desert-source distance (Figure 4). These variables are therefore interpreted as indirect or proxy indicators reflecting geographic positioning and aerosol characteristics rather than primary controls of inter-city heterogeneity in differential regional control.