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快 讯

雄安新区大气污染的气象特征分析

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公益性行业(气象)科研专项(GYHY201106033)、中国气象科学研究院基本科研业务费(2017Y002)和国家自然科学基金(41175004, 41465001)资助

摘要 2017 年 4 月, 中国共产党中央委员会和国务院决定在河北设立雄安新区, 以推进京津冀协同发展, 要将雄安新区打造为环境优美的生态城市. 通过分析雄安新区 2016 年 5 月 24 日至 2017 年 4 月 30 日的空气质量数据和气象数据, 对该地区的大气污染现状进行了研究, 并揭示其与气象条件的关系, 旨在为雄安新区的合理规划提供科学依据. 研究发现雄安新区的主要大气污染物为 $PM_{2.5}$ 和 PM_{10}, 其重污染过程主要出现在秋、冬两季, 污染程度与相对湿度呈正相关, 与风速和温度呈负相关. 尽管雄安新区目前的开发程度较低, 但受本地排放和周边污染物输送的共同影响, 大气污染问题不容忽视. 在雄安新区的规划和建设过程中, 需要考虑周边地区的协调发展, 共同治理大气环境.

关键词 京津冀一体化, 气象条件, 大气污染, 区域输送

2017年4月1日, 中国共产党中央委员会(中共中央)和国务院对外发布通知, 决定在河北省设立雄安新区. 雄安新区(图S1)规划范围涉及河北省雄县、容城、安新3县及周边部分区域, 地处北京、天津和保定的腹地, 现有的城市化程度较低, 发展空间充裕, 具备高起点高标准的开发建设基本条件. 雄安新区是继深圳经济特区和上海浦东新区之后又一具有全国意义的新区, 是推进京津冀协同发展的重要工程. 对于雄安新区的规划建设, 中共中央明确强调要将其打造为优美生态环境, 构建蓝绿交织、清新明亮、水城共融的生态城市. 因此, 很有必要对雄安新区的生态环境现状进行调研, 为新区的合理规划提供科学依据.

目前, 京津冀地区的大气污染形势十分严峻[1~6], 已引起国内外学者的广泛关注, 但还没有针对雄安新区的系统性研究. 本文利用雄县、容城、安新3县2016年5月24日至2017年4月30日的逐小时空气质量监测数据和气象观测数据(站点位置如图S1所示), 对雄安新区的大气环境现状进行分析, 并揭示6种大气污染物($PM_{2.5}$, PM_{10}, CO, SO_2, NO_2, O_3)与气象条件的关系. 在进行分析之前, 本文计算了各个要素的日均值. 针对所有的观测要素, 只有当一日之内有20 h以上的有效观测, 才进行日均值的计算, 否则该日就记为缺测; 其中, 风向使用的是矢量平均, 其他要素为算术平均.

在这近一年的研究时段内, 雄安新区的首要大气污染物为$PM_{2.5}$和PM_{10}(表1), 二者的超标天分别为170 d(52%)和118 d(36%), 年均浓度高达101.3和144.2 μg m^{-3}, 分别是国家二级标准($PM_{2.5}$为35 μg m^{-3}, PM_{10}为70 μg m^{-3})的2.9和2.1倍. 在一年之中, $PM_{2.5}$和PM_{10}的重污染事件主要出现在秋冬两季(图1), 这不仅与排放源的季节变化有关[7,8], 也与气象条件的季节变化有关[9~12]. 其他存在超标情况的大气污染物, 还有NO_2, O_3和CO. 与$PM_{2.5}$和PM_{10}相似, CO和NO_2也是在秋冬两季的浓度较高(图1). O_3浓度的季节变化与上述污染物不同, 夏季的辐射和温度条件都有利于O_3的生成[13], 因此O_3污染主要出现在夏季(图1), 其次为春季和秋季, 冬季的浓度最低. SO_2尽管没有出现超标, 但在冬季和春季的浓度也较高(图1).

表2给出了不同季节大气污染物

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表 1　雄安新区大气污染物与气象要素日均值的统计结果(2016 年 5 月 24 日至 2017 年 4 月 30 日)[a)]

Table 1　Statistical summary of the daily average values of air pollutants and meteorological parameters during the entire sampling period (from 24 May 2016 to 30 April 2017)

	$PM_{2.5}$ (μg m^{-3})	PM_{10} (μg m^{-3})	CO (mg m^{-3})	SO_2 (μg m^{-3})	NO_2 (μg m^{-3})	O_3 (μg m^{-3})	风速 (m s^{-1})	温度 (℃)	相对湿度 (%)
国家二级日均标准	75	150	4	150	80	–	–	–	–
超标天数(d)	170	118	13	0	79	36	–	–	–
总天数(d)	324	324	324	324	324	324	342	342	342
平均值	101.3	144.2	1.46	32.6	61.2	46.6	1.60	13.3	63.7
最小值	11.2	16.8	0.27	1.90	21.6	5.90	0.50	−5.5	20.1
中位数	80.0	119.7	1.02	25.9	52.0	35.6	1.50	14.0	65.2
最大值	540.1	642.1	8.38	149.1	186.3	141.7	4.4	30.4	98.1

a) 判断O_3的标准为当日的最大小时值是否超过200 μg m^{-3}

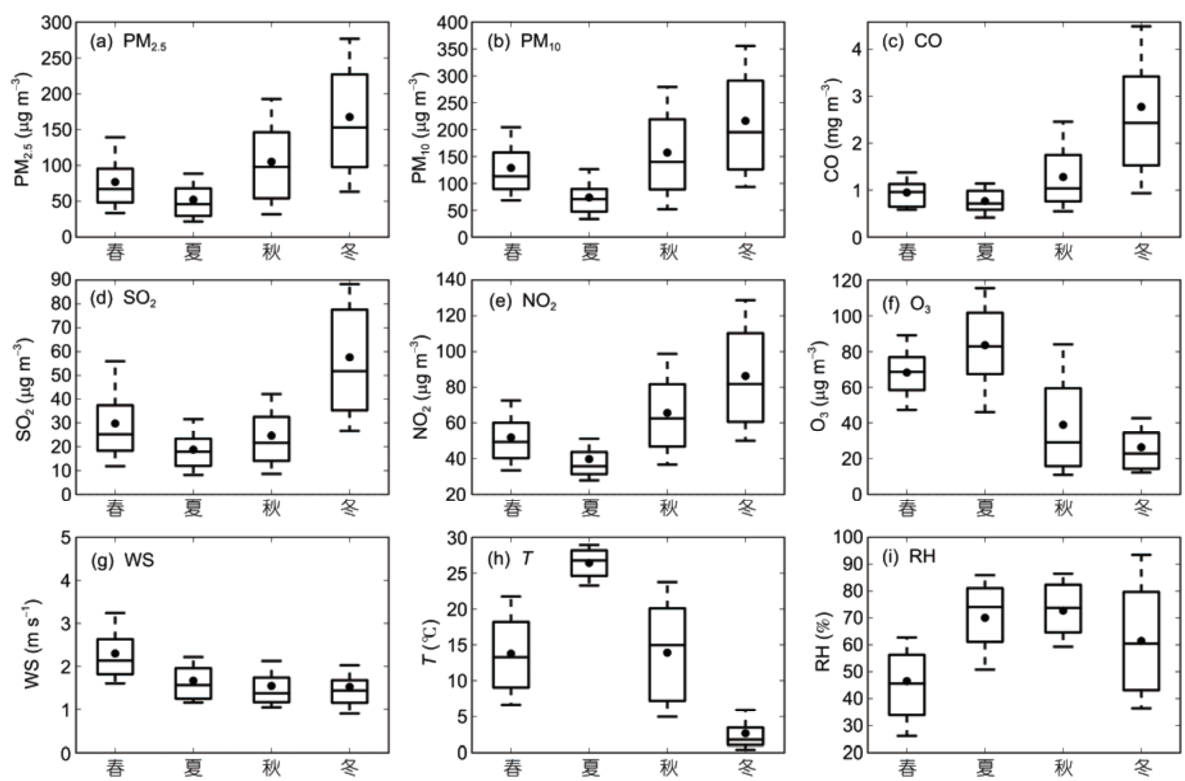

图 1　雄安新区大气污染物((a)~(f))和气象要素((g)~(i))(风速 WS、温度 *T* 和相对湿度 RH)在不同季节的箱图. 箱图给出了 10, 25, 50, 75 和 90 分位值, 黑点给出了平均值

Figure 1　Seasonal variations of criteria air pollutants and meteorological parameters. The central box represents the values from the lower to upper quartile (25th to 75th percentile). The vertical line extends from the 10th percentile to the 90th percentile. The middle solid lines represent the median, and the dots mark the average value

的日均浓度与近地面风速、温度和相对湿度的相关系数. 可以发现, 在$PM_{2.5}$和PM_{10}污染较重的秋冬两季, $PM_{2.5}$和PM_{10}与风速和温度呈负相关, 而与相对湿度呈正相关(图S2). 通过图1(g)可以知道, 雄安新区在秋冬两季小风频率高, 且温度较低, 不利于边界层的发展和大气污染物的扩散[10,14]; 因此, 在雄安新区的规划和建设过程中, 需要在这两个季节采取更为严格的措施控制污染物的排放, 避免重污染事件的发生.

与$PM_{2.5}$和PM_{10}相似, CO和NO_2也大部分时间内与风速和温度呈负相关关系, 与湿度呈正相关关系(图S2). SO_2的重污染事件也主要发生在静风和低温的条件下(图S2), 但与相对湿度的相关关系在不同季节有所不同,

表 2 不同大气污染物日均浓度与气象要素在不同季节的相关系数 a)

Table 2 Correlation coefficients between the daily values of pollutant concentration and meteorological parameters

气象要素	季节	$PM_{2.5}$	PM_{10}	CO	SO_2	NO_2	O_3
风速	春	**−0.41**	**−0.25**	**−0.48**	**−0.31**	**−0.52**	0.29
	夏	**−0.04**	**−0.03**	**−0.19**	**−0.02**	**−0.34**	0.15
	秋	**−0.33**	**−0.34**	**−0.28**	**−0.17**	**−0.26**	**−0.06**
	冬	**−0.39**	**−0.35**	**−0.51**	**−0.27**	**−0.50**	0.57
温度	春	**−0.09**	0.18	**−0.09**	**−0.12**	**−0.10**	0.51
	夏	0.23	0.18	**−0.02**	**−0.06**	**−0.31**	0.16
	秋	**−0.30**	**−0.27**	**−0.42**	**−0.13**	**−0.47**	0.76
	冬	**−0.08**	**−0.04**	**−0.06**	0.02	0.15	0.03
相对湿度	春	0.72	0.50	0.65	0.40	0.36	**−0.19**
	夏	0.31	0.10	0.40	**−0.17**	**−0.13**	**−0.23**
	秋	0.43	0.42	0.46	**−0.10**	0.27	**−0.20**
	冬	0.59	0.57	0.71	0.06	0.67	**−0.87**

a) 黑体标注了负相关系数. 在计算相关系数时, 当24 h累计降水量大于1 mm时, 该日的相关观测将被排除; 在研究时段内, 被排除的降水日数总共35 d, 包括夏季的25 d和秋季的10 d

在SO_2浓度较高的冬春两季, 与相对湿度呈正相关关系, 在另外两季则为负相关. O_3污染则与上述污染物明显不同, 与温度呈正相关, 与湿度呈负相关, 在高温和干燥的情况下容易出现重污染(图S2); 另外, O_3在一些季节与风速呈正相关关系, 这可能与输送有关[15,16].

此外, 风向也有可能通过影响污染物的输送对局地的空气质量产生影响[17,18], 例如北京地区的污染事件就与南风条件下的外来输送密切相关. 但是, 通过对雄安新区不同风向下的污染状况进行分析, 发现雄安新区与北京等地区不同, 其污染状况对风向并不十分敏感(图S3). 这可能与雄安新区的地理位置有关, 雄新区位于京津冀地区的腹地, 被多个城市包围, 在各个风向上都可能有污染物的跨区域输送(图2).

综上所述, 尽管目前雄安新区的开发程度较低, 但受本地排放和周边地区污染物输送的共同影响, 大气环境问题不容忽视. 在雄安新区的规划和建设过程中, 需要考虑周边地区的协调发展, 共同治理大气环境.

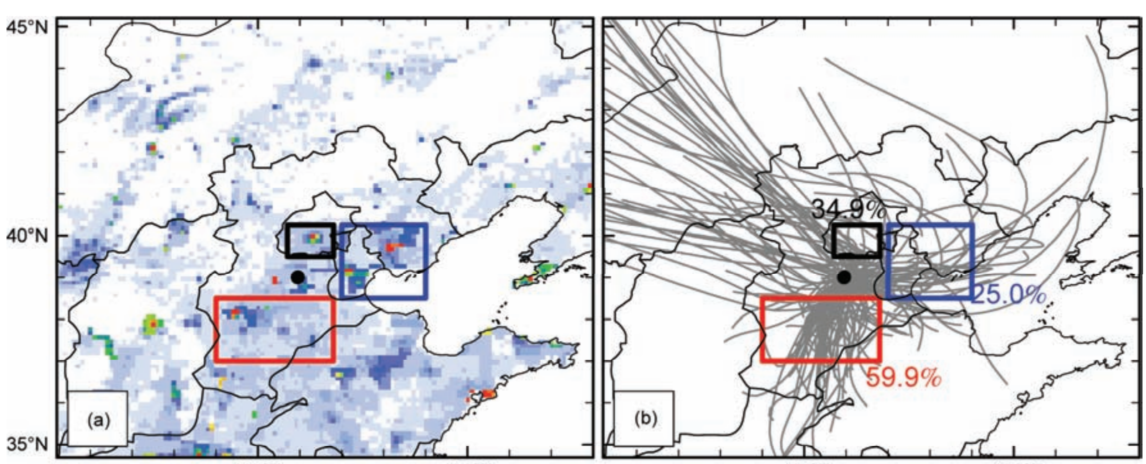

图 2 华北地区2014年的$PM_{2.5}$排放情况(a)(http://inventory.pku.edu.cn/)和雄安新区出现$PM_{2.5}$和PM_{10}浓度超标时的24 h后向轨迹分布图(b). 这些后向轨迹由 HYSPLIT 模式计算得到, 经过北京区域(黑色方框)、天津-唐山区域(蓝色方案)和河北省南部(红色方框)的概率分别为 34.9%, 25.0%和59.9%. 在24 h之内, 一条轨迹有可能会经过一个以上的方框标注区域. 追踪点(黑色圆点)位于雄安新区中部(115.95°E, 39.0°N, 100 m AGL), 后向轨迹模拟始于每日 20 时(北京时间)

Figure 2 Spatial distributions of $PM_{2.5}$ emission in 2014 in the northern China (a) (http://inventory.pku.edu.cn/), and 24-h backward trajectories ending at the center of Xiong'an (115.95°E, 39.0°N, 100 m AGL, shown by the black dot) during the aerosol pollution episodes (b). The backward trajectories were calculated using the HYbrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model, tracing from 2000 LT of each day. The trajectories travelled backwards over the Beijing area (black square), the Tianjin-Tangshan region (blue square), and the south of Hebei Province (red square), with each area accounting for 34.9%, 25.0%, and 59.9% of the total, respectively

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补充材料

图 S1 雄安新区及周边地区的地图

图 S2 不同污染物在浓度极高和极低情况下，不同气象要素的对比图

图 S3 不同风向下，不同污染物的浓度箱图

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Summary for “雄安新区大气污染的气象特征分析”

Meteorological characteristics associated with air pollution in Xiong’an, China

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In April 2017, the central government of China announced it would establish the Xiong’an New Area in Hebei Province, as part of measures to advance the coordinated development of the Beijing-Tianjin-Hebei (BTH) region. The area is expected to become an innovative, market-driven green city; thus, it is urgent to address its environmental issues before urban construction begins. This study involved a systematic analysis of atmospheric pollutants $PM_{2.5}$, PM_{10}, CO, SO_2, NO_2, and O_3, and their relationship to meteorological parameters in the Xiong’an area for a continuous period from May 2016 to April 2017. It used observations of 2-m temperature, 2-m relative humidity, and 10-m wind speed along with measurements of the concentration of these six criteria pollutants in Anxin, Rongcheng, and Xiongxian taken on an hourly basis.

Results revealed that the Xiong’an area experienced severe air pollution, with heavy aerosol loadings. The annual averaged concentrations of $PM_{2.5}$ and PM_{10} were 101.3 and 144.2 μg m^{-3}, respectively, significantly exceeding the Grade II standard of the Chinese Ambient Air Quality Standards. The maximum 24-h average concentrations of $PM_{2.5}$ and PM_{10} were 540.1 and 642.1 μg m^{-3}, respectively. Distinct seasonal trends were observed for $PM_{2.5}$ and PM_{10}, with the maximum concentrations occurring in winter and the minimum in summer. Other trace gaseous pollutants, including CO, SO_2, and NO_2 demonstrated similar seasonal variations. Contrarily, O_3 demonstrated a reversed seasonal trend, with concentration peaking in summer, decreasing in spring and fall, and at its lowest in winter.

Seasonal variations of atmospheric pollutants were modulated by the seasonal variations in pollutant emissions, but they were also strongly related to meteorological conditions. The relatively cool thermal conditions and low wind speeds in fall and winter can limit the development of the planetary boundary layer and the horizontal transport of pollutants. Such conditions may be partially responsible for the higher concentrations of the primary pollutants during these seasons. On the contrary, secondary pollutant O_3 exhibited positive correlations with temperature.

When the pollutants $PM_{2.5}$ or PM_{10} exceeded standards, the Hybrid Single-Particle Lagrangian Integrated Trajectory (HYSPLIT) model was used to calculate 24-h air mass backward trajectories ending at Xiong’an area (115.95°E, 39.0°N, 100 m AGL). The trajectories travelled backwards over the Beijing area, the Tianjin-Tangshan region, and the south of Hebei Province, with each area accounting for 34.9%, 25.0%, and 59.9% of the total, respectively. This spatial distribution suggests that pollutants released from adjacent regions may be transported to the Xiong’an area, and play a role in exacerbating the level of pollutants. Thus, joint efforts to reduce emissions in the whole BTH region are necessary to control the heavy pollution in Xiong’an.

Overall, this study of air pollution in Xiong’an provides insight into the fundamental role of meteorological parameters in relation to different air pollutants. These key findings can enhance the accuracy of forecasting air pollution, and provide scientific support for policy makers who seek its mitigation.

Beijing-Tianjin-Hebei coordinated development, meteorological conditions, air pollution, regional transport

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