Observations of Dew Condensation in Northeastern Chinese Cities and Their Relationship with Routine Meteorological Elements: Postprint

Authors: Xu Yingying, Tang Jie, Zhu Hui, Lin Yingzi, Jin Minglan, Zhu Xinyue

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Abstract

Dew constitutes a component of the water cycle in urban ecosystems and represents an important source of condensation water and humidity. To elucidate the impacts of “global warming”on urban dew condensation in Northeast China, dew intensity and meteorological factors were monitored and subjected to correlation analysis in green spaces, road areas, and bare soil zones of Changchun City during the plant growing seasons of 2014 and 2015. Results demonstrate that dew intensity in urban green areas of Northeast China exhibits positive correlations with relative humidity, dew point temperature, air temperature, wind chill temperature, and solar radiation (n=254, P<0.01), and negative correlations with PM2.5, PM10, Air Quality Index, nighttime wind speed, and atmospheric pressure (n=254, P<0.01). The annual dew day frequency in Northeastern cities ranges from 132–136 d, accounting for approximately 62.5% of the frost-free period. Green spaces constitute the primary regions for water vapor condensation in urban ecosystems, with the proportion of green area to urban area serving as the determinant factor for annual urban dew volume. The annual dew condensation amount in Changchun City is approximately 23–35 mm; should the proportion of urban green space decrease to 5%, the annual dew volume would become essentially negligible. Dew intensity in Northeastern cities can be simulated using the model I=(-5.9+0.156RH-0.86Vnight + 0.117Rn)$×$10-2(R2 =0.857). Based on trends in climate factors during the nighttime dew condensation period of the plant growing season from 1965–2015 in the study area, the change rate of dew amount in the urban ecosystem of Northeast China is determined to be -1.07 mm/ 10a (P<0.01). Under the combined influence of relative humidity, nighttime wind speed, and solar radiation, climate change in the study area exerts minimal influence on dew condensation. This study provides methodologies for monitoring and calculating dew across different urban underlying surfaces, enhances the dew monitoring system for various ecosystems, constructs a dew intensity simulation model through the indirect modeling approach, and further clarifies the impacts of climate change on near-surface water cycles.

Full Text

Monitoring Dew Condensation and Its Response to Conventional Meteorological Factors in an Urban Ecosystem of Northeastern China

XU Yingying[1],[2],*, TANG Jie[1], ZHU Hui[1], LIN Yingzi[1], JIN Minglan[1], ZHU Xinyue[1]

[1]Key Laboratory of Songliao Aquatic Environment, Ministry of Education, Jilin Jianzhu University, Changchun 130118, China
[2]College of Resources and Environment, Jilin University, Changchun 130021, China
[3]Northeast Institute of Geography and Agroecology, Chinese Academy of Sciences, Changchun 130102, China

Abstract

Dew represents a crucial component of the water cycle in urban ecosystems, serving as an important source of condensation water and atmospheric humidity. Over the past four decades, global warming in northeastern China has led to decreased precipitation and increased temperatures, intensifying evaporation and reducing soil moisture. To investigate how global warming affects dew variation in urban ecosystems, we monitored dew daily using poplar wooden sticks, asphalt blocks, and soil blocks across complex urban landscapes in Changchun, northeastern China, during the 2014-2015 plant growing seasons. Correlation analysis revealed that dew intensity in greenbelt areas correlated positively with relative humidity, dew point temperature, air temperature, wind chill temperature, and solar radiation ($n = 254$, $P < 0.01$), while correlating negatively with PM2.5, PM10, air quality index, nocturnal wind speed, and atmospheric pressure ($n = 254$, $P < 0.01$). During the monitoring period, we observed 132-136 dew days annually, accounting for 62.5% of the frost-free season. Substrate type played a notable role in dew formation, with average nightly dew intensities varying significantly ($P < 0.01$) among landscapes: greenbelt (0.0607 mm), bare land (0.0100 mm), and roads (0.0049 mm). Dewfall in July, August, and September equaled 22.52% and 23.61% of rainfall for the same periods in 2014 and 2015, respectively. Based on landscape proportions, annual dewfall in Changchun was 23-25 mm. The proportion of greenbelt area emerged as a decisive factor controlling urban dew amounts—when reduced to 5%, annual dewfall became negligible. Using synchronous meteorological data, we developed a stepwise linear multiple regression model ($I = (-5.9 + 0.156RH - 0.86V\ \ g\ \ + 0.117R\ ) \times 10^{-3}$, $R^2 = 0.857$) that successfully predicted dew intensity. Combined with climate data from 1965-2015, the model indicated a decreasing trend of -1.07 mm/10a ($P < 0.01$) in annual dewfall. However, under the mutual influence of relative humidity, wind speed, and solar radiation, climate change impacts on dew condensation were not obvious. This study provides a comprehensive method for monitoring and calculating dew across different urban underlying surfaces, improving dew surveillance systems and clarifying climate change impacts on the near-surface water cycle.

Keywords: urban ecosystem; dew condensation; warm-dry trend; impact factors; stepwise linear multiple regression model

Introduction

Water vapor condensation is a ubiquitous meteorological phenomenon that has attracted increasing scholarly attention. Dew serves as an important condensation water resource and humidity source in urban ecosystems, with multiple ecological functions. It maintains leaf surface moisture, supplements water regulation in leaves during nighttime, slows plant transpiration, and provides essential nutrients (N, K, P). During formation, dew uses atmospheric aerosols as condensation nuclei, purifying air and revealing near-surface pollutants. Accurate quantification of urban dew condensation is therefore essential.

Compared with other precipitation forms, dew is closely related not only to local meteorological conditions but also to surface physical characteristics and aerodynamic properties, increasing observation difficulty and limiting understanding. Dew monitoring and calculation methods remain in early development stages, particularly for urban ecosystems. Current methods include direct monitoring (in-situ difference methods using collectors like wooden sticks, cloth pieces, or dew plates) and indirect modeling. Direct methods provide accurate measurements but require precise timing and risk human error. Indirect methods, derived from direct measurements, save labor but require auxiliary meteorological monitoring.

Urban landscape heterogeneity complicates dew monitoring. Existing methods cannot accurately measure system-wide dew condensation across different underlying surfaces, and are limited to single events rather than continuous periods. With rapid urbanization, providing a comprehensive monitoring method for different surfaces is imperative. Global warming has affected the water cycle, and northeastern China—warming at 0.25°C/10a—represents one of China' s most significantly warming regions. Projections indicate temperatures may rise by 3.0°C or more, with precipitation decreasing at -5.71 mm/10a ($P > 0.05$). The frost-free period' s climate characteristics suit dew condensation, making dew an important water balance component. However, systematic monitoring and simulation of urban dew in northeastern China remain unaddressed. This study monitors dew condensation intensity across different underlying surfaces in Changchun, analyzes key influencing factors, and develops monitoring methods and simulation models to elucidate climate change impacts on dew formation.

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1 Study Area

Changchun (43°05 -45°15 N, 124°18 -127°02 E) experiences a continental monsoon climate with an average annual temperature of 4.8°C and precipitation of 522-615 mm. Autumn brings clear weather with large diurnal temperature differences, creating favorable conditions for heavy dew formation. The urban ecosystem comprises diverse underlying surfaces. Dew forms when near-surface air temperature drops rapidly, saturating water vapor into droplets. This study focuses on greenbelt, road, and bare soil areas, excluding tall buildings and water bodies where condensation is difficult to monitor.

The experimental site was established at Jilin Jianzhu University in southeastern Changchun, representing a transitional zone between urban and suburban areas with complete underlying surface types. Greenbelt monitoring was conducted in campus green areas planted with common northeastern urban shrubs and small trees (*Buxus sinica* var. *parvifolia*, *Berberis thunbergii* 'Atropurpurea' , *Ligustrum quihoui*). Road monitoring used asphalt-paved surfaces, while bare land monitoring was conducted on undeveloped soil. Observations were performed daily during the plant growing season.

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2 Methods

2.1 Experimental Observations We used poplar sticks for greenbelt areas, asphalt blocks for hardened road surfaces, and aluminum-box soil for bare land areas. The poplar sticks were polished solid rectangular wood blocks (4 cm × 4 cm × 20 cm). Asphalt blocks were solid rectangular asphalt bodies (15 cm × 15 cm × 15 cm). Aluminum boxes were cylindrical (radius 5 cm, height 1 cm) filled with in-situ soil.

Each monitor was sealed in a clean plastic box, weighed precisely (0.001 g), and deployed at sunset. At sunrise, monitors were retrieved, resealed, and weighed again. For greenbelt areas, leaf area index (LAI) was recorded using an LAI-2200C. Precipitation events during deployment periods invalidated dew measurements for that day.

Meteorological factors were monitored at the experimental site, including air temperature (Ta, °C), dew point temperature (Td, °C), relative humidity (RH, %), atmospheric pressure (mm), nocturnal wind speed (V g , m/s), and solar radiation (R , MJ/m^2). All parameters were recorded hourly. Air quality index (AQI) and particulate matter (PM2.5, PM10) data were obtained from real-time Jilin Provincial Environmental Protection Bureau releases. Other meteorological indicators were sourced from a MILOS 520 weather station.

2.2 Dew Amount Calculation Daily dew intensity at experimental points:

$$I_i^q = \frac{10 \times (W_i^r - W_i^s)}{S_i}$$

where W_i^s is monitor weight at sunset (g), W_i^r is weight at sunrise (g), and S_i is effective surface area (cm^2).

Monthly dew amount for roads and bare land:

$$DF_i^{um} = \sum_{d=1}^{D_d} I_i^q$$

Monthly dew amount for greenbelts:

$$DF_i^{um} = \sum_{d=1}^{D_d} (I_i^q \times LAI \times 2)$$

Annual dew amount for different underlying surfaces:

$$DF_a^i = \sum_{m=1}^{n} DF_i^{um}$$

Urban system annual dew amount:

$$DF_a = \sum_{i=1}^{3} A_i DF_a^i$$

where i represents underlying surface type, A_i is the proportion of each surface in the urban area, D_d is monthly dew days, LAI is daily leaf area index, and the factor 2 accounts for both leaf surfaces.

2.3 Statistical Analysis and Model Construction SPSS 16.0 software was used for normality tests and significance analysis. The monitor difference method was considered to reflect actual dew condensation. Correlation analysis identified meteorological factors affecting dew formation, which were then used as independent variables in stepwise multiple linear regression. This approach avoided multicollinearity while ensuring independent observations, normally distributed residuals, and normally distributed dependent variables. Model accuracy was evaluated using variance analysis and residual analysis, with the highest coefficient of determination (R^2) selected.

2.4 Climate Data Processing Historical climate data (1965-2015) were obtained from Changchun Meteorological Bureau. Dew condensation period was defined as half an hour after sunset to half an hour before sunrise. Climate tendency rates were calculated using linear regression: $y = a + bx$, where b represents the rate of change. Time series correlation analysis tested significance of trends.

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3 Results

3.1 Dew Intensity Monitoring During the 2014-2015 experimental period, we recorded 132 and 136 dew days respectively, accounting for 63.5% and 62.6% of the frost-free season. Non-dew days were associated with nocturnal precipitation. Dew condensation intensity averaged 0.0607 mm in greenbelts, 0.0100 mm in bare land, and 0.0049 mm on roads ($P < 0.01$) [Figure 1: see original paper]. These frequencies were consistent across surfaces, though intensities differed significantly. Greenbelt dew was substantially higher than in Vancouver' s urban grassland (0.07-0.09 mm nightly), likely due to Changchun' s continental climate and higher relative humidity promoting condensation.

3.2 Monthly Dew Amount Variation Monthly dew amounts varied by underlying surface [Figure 2: see original paper]. Greenbelts showed peak condensation in July-August, with monthly amounts significantly exceeding roads and bare land. In 2014 and 2015, greenbelt dew totals were 46.29 mm and 72.24 mm, representing 22.52% and 23.61% of 同期 precipitation. The high leaf area index in greenbelts provided abundant condensation surfaces. With greenbelts comprising 16.68% of Changchun' s area, roads 36.5%, and bare land 0.78% (per 2006-2020 land use planning), annual ecosystem dewfall was approximately 23-35 mm. If greenbelt proportion decreased to 5%, annual dewfall would become negligible.

3.3 Dew Intensity Model Development Given minimal contributions from roads and bare land, modeling focused on greenbelt dew intensity. Correlation analysis of 254 observations showed significant linear relationships ($P < 0.01$) between dew intensity and relative humidity (RH), dew point temperature (Td), air temperature (Ta), wind chill, solar radiation (R), PM2.5, PM10, AQI, nocturnal wind speed (V g), and atmospheric pressure .

Stepwise multiple regression progressively added meteorological factors. Model 1 (RH only) had R = 0.814. Model 2 (RH + R) achieved R = 0.917, explaining 84.1% of variance. Model 3 (RH + R + V g) reached R = 0.926 with $R^2 = 0.857$, providing the best fit . All coefficients were statistically significant ($P < 0.01$) with tolerance values indicating acceptable multicollinearity .

The final model:

$$I = (-5.9 + 0.156RH - 0.86V_{night} + 0.117R_n) \times 10^{-3}$$

Residual normal P-P plots confirmed the model' s validity, with points closely following the diagonal line [Figure 3: see original paper]. Validation using 2015 data showed strong agreement between simulated and measured values [Figure 4: see original paper].

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4 Discussion

Dew formation is closely tied to local climate, particularly temperature, humidity, and radiation. During Changchun' s plant growing season, the dew condensation period experienced significant climate changes from 1965–2015. Average temperature rose at 0.35°C/10a ($P < 0.01$), while precipitation showed no significant trend (-1.34 mm/10a, $P > 0.05$). Relative humidity decreased at -1.14%/10a ($P < 0.01$). Solar radiation declined at -1.53 MJ/m^2/10a ($P < 0.01$), likely due to increased atmospheric turbidity from aerosols and pollution [Figure 5: see original paper]. Nocturnal wind speed decreased at -0.24 m/s/10a ($P < 0.01$), which should enhance condensation given the negative correlation with dew intensity.

Despite these trends, the combined effects of RH, wind speed, and radiation resulted in only a modest dewfall decrease of -1.07 mm/10a ($P < 0.01$). The 2004 anomaly—when RH reached its lowest value while wind speed and radiation were near average—demonstrated significantly reduced dew formation capacity. This underscores dew' s complexity as a microclimate phenomenon influenced by interacting factors.

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5 Conclusion

Northeastern Chinese cities experience 132–136 dew days annually (62.5% of the frost-free season). Greenbelts are the primary condensation zones, with July-September dewfall reaching 22.52–23.61% of 同期 precipitation. Annual ecosystem dewfall is approximately 23–35 mm, heavily dependent on greenbelt area proportion—reducing this to 5% makes dewfall negligible. The developed model $I = (-5.9 + 0.156RH - 0.86V_{night} + 0.117R_n) \times 10^{-3}$ ($R^2 = 0.857$) accurately simulates greenbelt dew intensity. Despite warming and drying trends (temperature +0.35°C/10a, humidity -1.14%/10a, radiation -1.53 MJ/m^2/10a, wind speed -0.24 m/s/10a), the combined meteorological effects result in only a -1.07 mm/10a dewfall decline. This study advances urban dew monitoring systems and clarifies climate change impacts on near-surface water cycling.

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