

Urban land and aerosols amplify hazardous weather, steer storms toward cities

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Intensified convection is just one way urban land and anthropogenically produced aerosols may shape hazardous weather. Longer-lasting rainfall and larger hail are other potential byproducts of the interactions between cityscapes and storms, according to new research from PNNL scientists. Credit: 12019 | Pixabay.com

Urban landscapes and human-made aerosols—particles suspended in the atmosphere—have the potential to not only make gusts stronger and hail larger; they can also start storms sooner and even pull them toward cities, according to new research exploring the impact of urban development on hazardous weather, led by scientists at the U.S. Department of Energy's Pacific Northwest National Laboratory.

By modeling two thunderstorms—one near Houston, Texas, and another in Kansas City, Missouri.—atmospheric scientist Jiwen Fan teased out the separate and synergistic effects that [urban landscapes](#) and human-caused aerosols can have on storms, rain and hail.

In the case of the Kansas City [storm](#), urban land and aerosols worked together to amplify the frequency of large hail by roughly 20 percent. In Houston, an otherwise gentler thunderstorm saw amplified, longer-lasting rainfall that developed sooner, among other changes.

Fan shared her findings at the American Geophysical Union's 2020 fall meeting, on Tuesday, Dec. 1, and answered questions virtually on Tuesday, Dec. 15.

"The novelty of our study is that we consider both urban land and aerosols together," said Fan, "instead of their separate impacts."

In previous work, researchers have shown that urban land shapes weather, both through its topographical nature and the heat it produces. Cities are often warmer than their surroundings, because buildings not only absorb and retain the sun's heat differently than trees and agricultural land, but also block wind flow.

Yet many studies focus primarily on how cities and aerosols change precipitation and temperature, or only examine the influence of those factors separately, rather than their joint effect.

Simulated storms reveal changes in hazardous weather

Fan modeled two very different types of storms: Kansas City's violent, rotating, hail-filled thunderstorm, and Houston's gentler, sea breeze-induced thunderstorm. She simulated multiple versions of the same storms, with and without cities and aerosols present, to isolate the effects of these two distinct factors.

In Houston, afternoon showers swelled as urban land and aerosols worked synergistically to amplify rainfall. Compared to simulations without cities, rain drenched Houston roughly a half-hour sooner, increasing its total by an extra 1.5 millimeters. Sea breeze winds blew stronger as well, whipped up by the influence of urban land.

When cooler, denser air from the sea breeze flowed toward Houston, it brought moisture with it and clashed with warmer, lighter city air. The two mixed upon meeting, creating stronger convection compared to simulations without urban land.

Houston's thunderstorm clouds began as warm clouds with only liquid drops, but the strengthened sea breeze caused a quickened transition to mixed-phase clouds, named for their simultaneous mixture of water vapor, ice particles and supercooled water droplets. Even after the sea breeze trickled off, said Fan, residual heat from the city continued feeding storm convection well through the night, causing longer-lasting rain. Contrast that with Fan's simulation where the city was removed, showing a weaker sea breeze and a storm that dissipated sooner.

Aerosols played a larger role in enhancing precipitation than urban land in Houston. As mixed-phase clouds formed and convection grew stronger, numerous ultrafine particles were transformed into cloud

droplets. This transformation enhanced the conversion of water vapor into cloud condensates, thereby increasing latent heating and further strengthening the storm.

In the case of the Kansas City storm, heat from the [city](#) was carried downwind, where it met the already formed storm at the northern urban-rural boundary. When warmer, drier air met with cooler, moister rural air, it intensified convergence, creating turbulent mixing and a more [violent storm](#) that moved toward urban land.

In contrast with Houston's thunderstorm, Kansas City's aerosols did not influence storm initiation or propagation, nor did they, on their own, greatly influence hail. But, when simulated alongside urban land, the two amplified hail, synergistically producing a more hazardous hailstorm. Because of this relationship, said Fan, it's important to consider both [urban land](#) and aerosols when exploring the impact cities have on weather and associated hazards.

Hail alone inflicts billions of dollars of damage in the U.S. and, according to the National Oceanic and Atmospheric Administration, it is possible for especially large hailstones to fall at over 100 miles per hour.

Accounting for aerosols

Urban land and aerosols shape weather differently, according to Fan, depending on other environmental conditions, like whether air is already polluted.

"The aerosol effect really depends on the background concentration," said Fan. "If the environment is already polluted, adding more aerosols doesn't seem to affect much. But if you're already in clean a condition and you add aerosols, it may produce a large impact."

Houston's busy shipping channel and nearby oil refineries, three of which are in its metro area, regularly discharge aerosols into the atmosphere, said Fan. Humidity, too, she added, can amplify the [aerosol](#) effect.

Fan hopes her work may lead to more accurate predictions of hazardous weather, mitigating the death and damage dealt by storms. She plans to more deeply explore how sprawling urbanization will shape severe storms in future climate scenarios.

More information: Jiwen Fan et al, Urbanization-induced land and aerosol impacts on sea-breeze circulation and convective precipitation, *Atmospheric Chemistry and Physics* (2020). [DOI: 10.5194/acp-20-14163-2020](#)

Provided by Pacific Northwest National Laboratory

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