Crazy bad air

"There simply aren't enough ground-based air quality monitors in many regions of the world."

Erica Zell
Battelle Memorial Institute

by Natasha Vizcarra

It is obscure. It is scientific jargon. But to Chinese urbanites, $PM_{2.5}$ is now as ubiquitous as tea. The term refers to airborne particles—from vehicle exhaust and from burning wood and coal—that are so small, several thousand could perch snugly on the pointy end of a sesame seed. These tiny particles can slip into your lungs and blood stream and aggravate heart disease and other illnesses. When $PM_{2.5}$ levels in the cities rise, the chatter on Weibo, the Chinese version of Twitter, swells. Case in point: when concentrations rose to hazardous levels in Beijing on January 12, 2013, there were nearly 40 million messages on "pollution" and "$PM_{2.5}$."

"The term is technical and wonky," said Angel Hsu, who studies Chinese environmental policy at Yale University. "But Chinese citizens have become very aware of air pollution issues, specially those involving fine particulate matter. I even saw an ad for a rock music festival called $PM_{2.5}$." Because of the extremely bad air days in Beijing, residents, visitors, scientists, and policymakers are discovering that open access

Retirees perform tai chi during a smoggy day in Fuyang, China in January 2013. (Courtesy ImagineChina)

to air quality data could help warn people when everyone—children, the elderly and even healthy adults—should stay indoors because of dangerous pollution. The data are crucial in the dialogue between citizens and the government in cleaning up the air for years to come. Hsu said it all began in early October 2010 when Beijing residents looked out their windows and saw not the city's cosmopolitan skyline, but something that looked like a whole lot of *wu*.

Beyond index

"*Wu* is the Mandarin word for fog," said Hsu. "Often, Chinese won't describe a poor air quality day as the result of air pollution, which is called *wuran*. They will say that it's fog." However, it was not a misty blanket of *wu*; it was *wuran* so dense that locals could not make out buildings a mere hundred feet away. The thick smog caused road accidents and flight cancellations in the city, and lingered in the area for about a month. Although Twitter is blocked in China, people found a way to check air quality readings tweeted from a monitor installed at the U.S. Embassy in Beijing and were shocked at the numbers that they saw on a particularly smoggy mid-November day.

The Air Quality Index (AQI) had surged to 557, way beyond the hazardous threshold of 500. AQI levels of 301 to 500 mean that children, older adults and people with heart or lung disease should remain indoors and that everybody else should not exercise outdoors. The embassy ran out of adjectives for AQI levels beyond 500, and had assigned the phrase "Crazy Bad" to AQI levels above 500. Of course, when embassy officials realized that the Crazy Bad AQI level had actually been reached, they quickly replaced it with the more benign "Beyond Index."

However, word of the gaffe had already spread worldwide through news reports and social media sites. Residents were confused when they compared the U.S. Embassy's readings with the Chinese government's numbers, which said pollution levels were moderate. While the embassy's numbers were based on $PM_{2.5}$ particles, the Chinese government's figures were based on PM_{10} particles, which are larger, coarser air particles, like dust. Government-approved data on $PM_{2.5}$, which have greater health impacts than PM_{10}, were simply not available to the public. Hsu said, "Many Chinese citizens felt something wasn't right. That's when they turned to the Internet. They really felt that the Chinese government was hiding information from them."

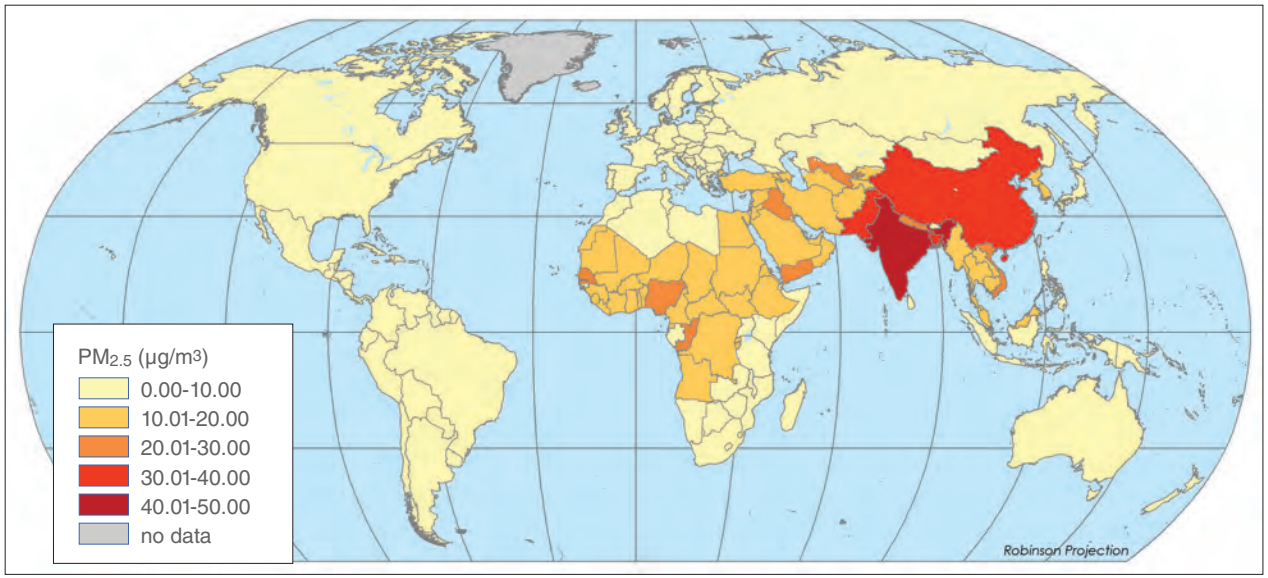
People and pollution

China is not the only country that had not been offering $PM_{2.5}$ data to its citizens. Erica Zell, an environmental engineer at Battelle Memorial Institute said, "There simply aren't enough ground-based air quality monitors in many regions of the world." Even where governments measure air quality, they may focus on different parameters, like NO_x or PM_{10}, or the measurements may not be well calibrated. Zell's colleague, Jill Engel-Cox, added, "Some countries do not have monitoring programs at all."

Although ground instruments like the one in the U.S. Embassy in Beijing are useful in alerting people to their daily exposure to $PM_{2.5}$ pollution, data that span several years can say a lot about air pollution trends. Governments need these data trends to make decisions about air pollution policies. Zell, Engel-Cox, and colleague Stephanie Weber knew that there were not enough ground instruments in China and worldwide to tease out these trends. "We wanted to consistently measure air quality across the globe so policy makers can better address the sources of this both global and local problem," Engel-Cox said.

So they developed a way to use satellite and population density data to measure country-level $PM_{2.5}$ all over the world for the last ten years. The researchers at Battelle collaborated with Aaron van Donkelaar and Randall Martin at Dalhousie University to make $PM_{2.5}$ maps using aerosol optical depth (AOD) data from the Moderate Resolution Imaging Spectroradiometer (MODIS) and Multi-Angle Imaging Spectroradiometer (MISR) sensors on the NASA Terra satellite. They also used a world population data product from the NASA Socioeconomic Data and Applications Center to weigh the results by population distribution so that $PM_{2.5}$ concentrations in more densely populated areas were more heavily weighted than concentrations in less populated areas. "Pollution concentrations are highest near population centers, since the industrial and transportation sectors are leading sources of emissions," Zell said.

The researchers then worked with Hsu and her colleagues at the Center for International Earth Science Information Network (CIESIN) at Columbia University to integrate these data into the 2012 Environmental Performance Index. Hsu said, "The index compares countries on a key set of environmental issues, air quality being one of them. While developing this index for the last twelve years, we did not have country-level $PM_{2.5}$ data because not all countries are at the stage of development where they can measure it," Hsu said. "Using satellite data gave us a more consistent measure of $PM_{2.5}$ at the country level, using the same data set and the same measures for each country." Their findings showed that while China's air pollution problems have been in the



This map shows average annual human exposure to $PM_{2.5}$ by country for 2010. Reds and oranges indicate the highest levels of exposure; India, Bangladesh, Pakistan, and China scored the worst. (Data courtesy NASA, van Donkelaar et al., 2010, processed by Battelle Memorial Institute)

spotlight in recent years, India had the worst air quality in the world, followed by Bangladesh and Pakistan. China came in fourth.

Seeing through the smog

As news of the 2012 Environmental Performance Index results added to the $PM_{2.5}$ chatter in social media, Chinese citizens seemed to be getting results from their Internet campaigns. In November 2011, a Chinese property tycoon launched a Weibo campaign calling for tighter air pollution monitoring procedures in the country. In two days, China's vice minister of environment conceded that Beijing relied on a "limited" system of pollution measurement.

Chinese citizens were also sharing other sources of data. In January 2012, Chinese filmmaker Michael Zhao launched a Web site featuring daily skyline images of major Chinese cities and other major cities in the world. The site, China Air Daily, also published the U.S. Embassy $PM_{2.5}$ readings, along with views of the cities from space, using MODIS images from the NASA Land-Atmosphere Near Real-time Capability for EOS (LANCE) system. Zhao's site was featured in news stories around the world and drew even more attention to China's air quality woes.

Around this time, Hsu said, the Chinese government announced that it had been collecting $PM_{2.5}$ data all along but had not seen the need to release it and that $PM_{2.5}$ concentrations in China had actually decreased over the last ten years. "None of the data have been transparent," Hsu said. "So none of the citizens believed it. That was a big lesson for the Chinese government; transparency is absolutely essential for effective environmental management and communication."

A wind shift

Finally, in January 2013, China began publishing $PM_{2.5}$ air quality ratings for seventy-four of its cities. "It looks pretty consistent with how you would expect air quality to be in these cities—a lot of them are showing very severe $PM_{2.5}$ pollution," Hsu said. China has also started to address some sources of pollution. A month after publishing $PM_{2.5}$ data, the government announced a plan to curb emissions with a ban on sub-standard diesel-fueled vehicles.

Chinese citizens continue to be passionate about improving the air they breathe and compulsively check both official Chinese air quality readings and those tweeted by the U.S. Embassy in Beijing. On January 12, 2013, netizens noted that AQI readings at the U.S. Embassy in Beijing reached a staggering 755. The government did not publish the actual value, but only noted that it was "Beyond Index."

Hsu says it is a great start. She said, "Scientists say that if you start releasing $PM_{2.5}$ data today, citizens will have a better idea of the dangers and the extent of the pollution that they are facing. Still, experts in China say it will take about twenty to thirty years to clean up the air in Beijing."

To access this article online, please visit http://earthdata.nasa.gov/sensing-our-planet/2013/crazy-bad-air

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Satellites		Terra	Terra
Sensors		Moderate Resolution Imaging Spectroradiometer (MODIS)	Multi-angle Imaging Spectroradiometer (MISR)
Data sets	Global Rural-Urban Mapping Project, version 1 (GRUMPv1)	MODIS Level 2 Aerosol	MISR Level 2 Aerosol
Resolution	30 arc-seconds, latitude/longitude	10 kilometer	16 x 16 array of 1.1 kilometer radiance pixels
Parameters	Human population density	Aerosol optical depth	Aerosol optical depth
Data centers	NASA Socioeconomic Data and Applications Center (SEDAC)	NASA MODIS Level 1 and Atmosphere Archive and Distribution System (MODAPS LAADS)	NASA Langley Research Center Atmospheric Science Data Center (LaRC ASDC)

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About the scientists

Jill Engel-Cox is a senior program manager at Battelle Memorial Institute. Her research focuses on applying complex environmental data to public policy as well as clear and useful communication of environmental data to policymakers, stakeholders, and the public. NASA supported her research. Read more at http://www.engel-cox.org/jill/resume.html. (Photograph courtesy J. Engel-Cox)

Angel Hsu is a postdoctoral associate and project manager of the Environmental Performance Measurement Program at the Yale School of Forestry and Environmental Studies in New Haven, Connecticut. Her research focuses on environmental performance measurement and data-driven approaches to environmental policy-making and governance. NASA supported her research. Read more at http://hsu.me. (Photograph courtesy D. Constable)

Erica Zell is a program manager at Battelle Memorial Institute. Her research focuses on the application of satellite data for environmental analysis and training, including environmental indicator design and air quality and climate change analysis; and geospatial analysis of environmental data for land use, ecosystems analysis, climate change, and renewable energy. The NASA Applied Sciences Program supported her research. (Photograph courtesy E. Zell)

For more information

NASA Socioeconomic Data and Applications Center (SEDAC)
http://sedac.ciesin.columbia.edu

NASA MODIS Level 1 and Atmosphere Archive and Distribution System (MODAPS LAADS)
http://laadsweb.nascom.nasa.gov

NASA Langley Research Center Atmospheric Science Data Center (LaRC ASDC)
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NASA Land-Atmosphere Near Real-time Capability for EOS (LANCE)
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Moderate Resolution Imaging Spectroradiometer (MODIS)
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