

Asian Air Pollution

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Note: In PDF format most of the images in this web paper
can be enlarged for greater detail.

Introduction

Air pollution has long been a problem in the industrial nations of the West. It has now become an increasing source of environmental degradation in the developing nations of east Asia. China in particular, because of its rapid push to industrialize, is experiencing dramatic levels of aerosol pollution over a large portion of the country (Liu & Diamond, 2005; Bradsher & Barboza, 2006; Kahn & Yardley, 2007).

China has also experienced increasingly severe dust storms, which are commonly believed to be caused by over-farming, over-grazing, and increasing use of irrigation. Plumes of dust from north China, mixed with toxic air pollution, now are a major public health concern in China, Korea, and Japan. Some of these aerosols even reach the United States. Dust events have prompted Chinese officials to spend hundreds of billions of yuan to increase forests and green belts to combat the dust storms.

Such measures are generally beneficial. However, research over the last decade suggests that the observed trend toward increased summer floods in south China and drought in north China, thought to be the largest change in precipitation trends since 950 A.D., may have an alternative explanation: human-made absorbing aerosols, mainly black carbon soot, that alter the regional atmospheric circulation and contribute to regional climate change (Menon, et al., 2002; Rosenfeld, et al., 2007). If this interpretation is correct, reducing the amount of anthropogenic black carbon aerosols, in addition to having human health benefits, may help diminish the intensity of floods in the south and droughts and dust storms in the north.

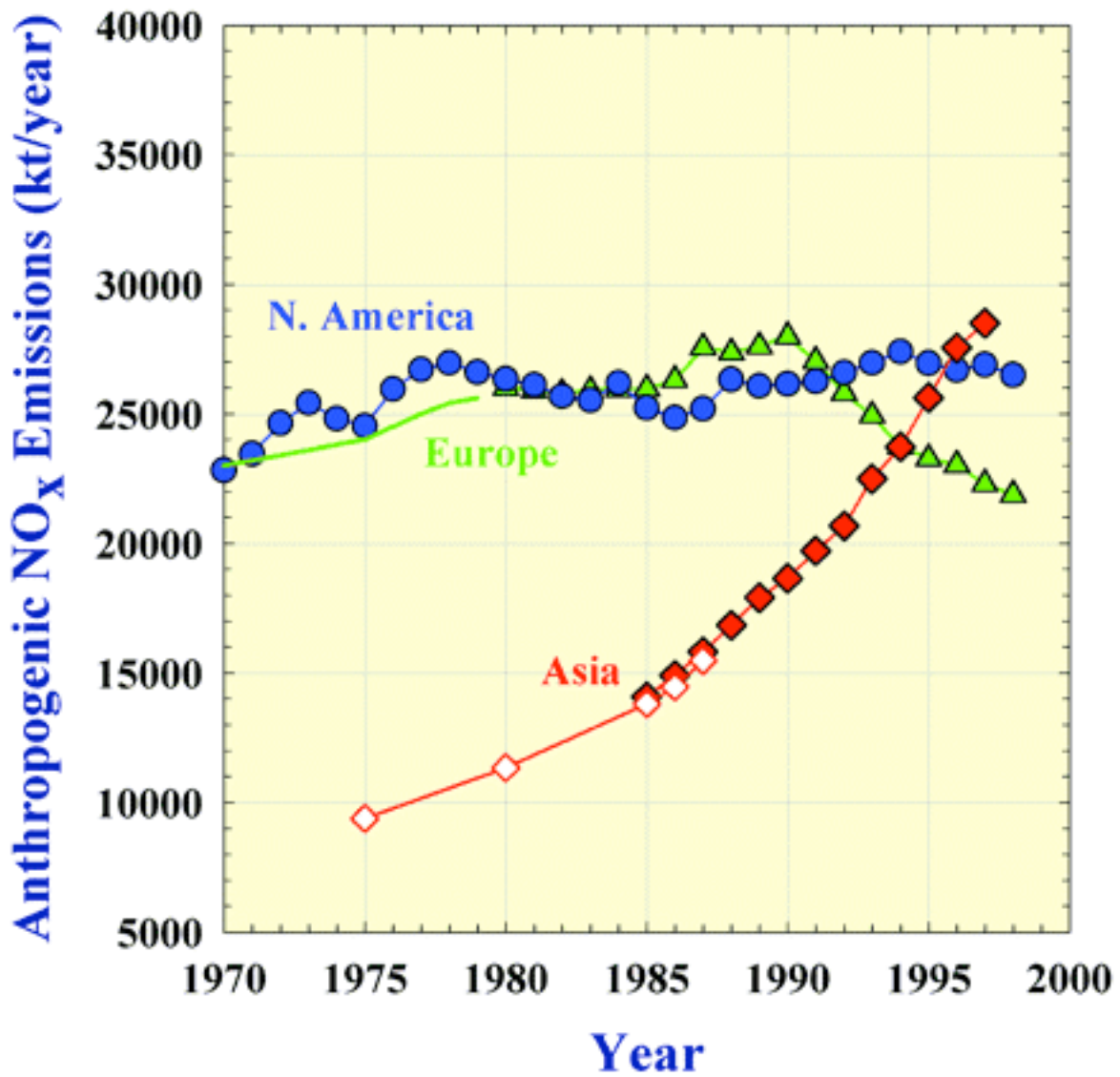
Similar considerations apply to India. India's air pollution, because it is also rich in black carbon, has reached the point where scientists fear it may have already altered the seasonal climate cycle of the monsoons.

For more on dust storms in China go to:

<http://fire.biol.wvu.edu/trent/alles/WaterShortage.pdf>

For more on Rosenfeld study (Rosenfeld, et al., 2007) go to:

<http://earthobservatory.nasa.gov/Study/Pollution/>



This chart shows the dramatic increase in anthropogenic NO_x air pollution (here used as an approximate measure of all of air pollutants) in Asia between the years 1975 to 2000 (Akimoto, 2003).



Remote Sensing of Air Pollution in East Asia

Remote sensing involves the use of instruments or sensors to "capture" the spectral and spatial relations of objects and materials observable at a distance, typically from above. Aerosol particles are visible from space, enabling a global estimate of the presence of a variety of pollutants, including black carbon soot, using satellite images.

The images in this paper were taken by NASA's Moderate-resolution Imaging Spectroradiometer (MODIS) aboard either the Terra or Aqua spacecrafts. The map of China above is provided to help orientate you to the geographic landmarks of China that can be seen in the satellite images.

For more on the geography of China go to:
http://en.wikipedia.org/wiki/Geography_of_China



Above is a satellite topographic relief image that includes all of China.

It shows as little else can the extremes of topography that exist in modern China. The river basin plains of east central China stand out as dark green against the mountain ranges that border them, and make them seem small in comparison to the rest of north and western China. And yet, the vast majority of the people of China live on the eastern plains. With this in mind the following images of air pollution in China then starts to make sense of the distribution of air pollutants over China.

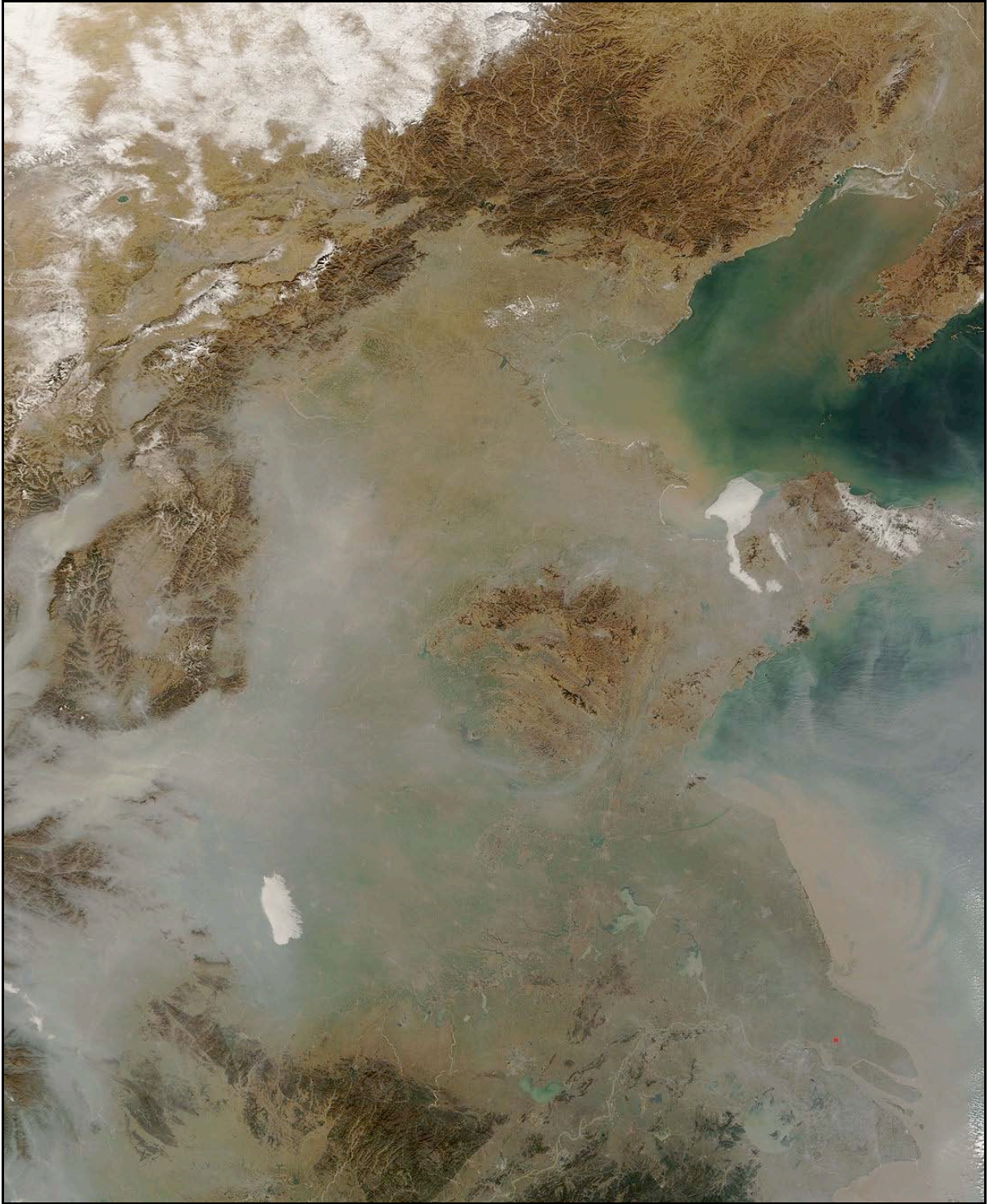


East Central China is shown in this **July 12, 2001** image taken by the MODIS instrument aboard NASA's Terra satellite. It is one of the earliest MODIS Gallery images of aerosols over China. The "Bo hai" or "Bohai Sea" is in the center of the image with the port city of Tianjin on the western shore of Bohai Bay (Bo hai wan) just north of the Yellow River delta. Beijing, in the upper left, is roughly 150 kilometers (93 mi) northwest of Tianjin. The mouth of the Yellow River (Huang He) empties into the Bo hai just below center.

The Shantung Peninsula, below and right of center, lies between the Bohai Sea and Yellow Sea and provides a useful landmark in the following satellite images. The Shantung Peninsula to the south and the Liaodong Peninsula to the north define the entrance into the Bo hai.

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=1608>



If you use air pollution as a surrogate for altitude, this MODIS/Terra FAS4 image from **December 22, 2006**, clearly shows the low-lying eastern coastal plains of China from the Shandong Hills (center), the Taihang Mountains (upper left), and Yanshan Mountains (top) that rise above them.

The North China Plain borders on the Taihang Mountains in the west, the coast in the east, the Yanshan Mountains in the north and the Huaihe River in the south. The plain covers 300,000 square km, with an average elevation lower than 100 meters. Formed of alluvial deposits from the Yellow, Huai he and Hai he rivers, it is also known as the Yellow River-Huaihe-Haihe Plain. It is a densely populated flat and fertile land.

The Middle-Lower Yangtze Plain stretches eastward from Wushan Mountain to the coast. The plain was formed by alluvial deposits from the Yangtze River and its tributaries. With an average elevation lower than 50 meters, and part of it lying below 5 meters above sea level, it is generally lower than the North China Plain. Crisscrossed by many rivers and dotted with lakes, it's known as "a swampy region."

The Shandong Hills sit in the center between the two coastal plains. The Shandong Hills of central and eastern Shandong are bounded by the Mount Tai area in the west which is 500-1,000 meters above sea level and consists of the Mount Tai and Lushan, Mengshan and Yishan Mountains; the Laoshan hills (Jiaodong Hills) in the east which jut out between the Huanghai and Bohai seas and are strewn with harbors and islands; and the Jiaolai Valleys in the Middle, which consist of hillock plains.

The central part of Shandong province is a mountainous highland, with the summit of Mount Taishan, 1,545 meters above sea level, being the highest point. Most hills distributed in its eastern part are at the altitude of 500 meters and lower. Plains lying in its west and north are mostly below 50 meters in elevation. The lowest area of the province is the Yellow River Delta, which is generally 2-10 meters above sea level. Shandong's topography is complicated and interwoven with nine types of landform, including plains, basins, hills, terraces, deltas and mountains. Mountainous area and plains account for 15.5% and 55% of the province's territory, while hilly areas are of 13.2%, and rivers and lakes, 1.1%.

Henan Province is in the transitional area between the second and third steps of China's four-step terrain rising from east to west, with rolling mountains over 1,000 meters above sea level in its western part and plains of 100 meters or lower in its east. Laoyacha in Lingbao City, 2413.8 meters above sea level, is the highest peak in Henan. The province's lowest point, 23.2 meters, is where the Huai he River leaves the province. High in the west and low in the east, even in the north and concave in the south, Henan is surrounded by four mountain ranges, the Taihang, Funiu, Tongbai and Dabie, which stand in its north, west and south, leaving subsidence basins here and there. In its middle and eastern parts there is a vast fluvial plain created by the Yellow, Huai he and Hai he rivers. Mountainous regions comprise 44.3% of its total area, and the plains, 55.7%. Four rivers run across Henan, the Yellow River, Huai he, Wei he and Han Shui, with the Huai he valley covering up 53% of the province.

The topography of Hebei Province is composed of three major geomorphic features; the Bashang highland with an average elevation of 1,200-1,500 meters above sea level, making up 8.5% of the total area; Mt. Yanshan and Mt. Taihangshan, including hilly land and basins, with an elevation below 2,000 meters, accounting for 48.1% of the total area, and the Hebei Plain which is part of the North China Plain, and has an average elevation below 50 meters. It is 43.4% of the total area of the province.

Some representative elevations:

Jinan, Shandong Province, 58 m (190 ft) above sea level.

Zhengzhou, Henan Province, 111 m (364 ft) above sea level.

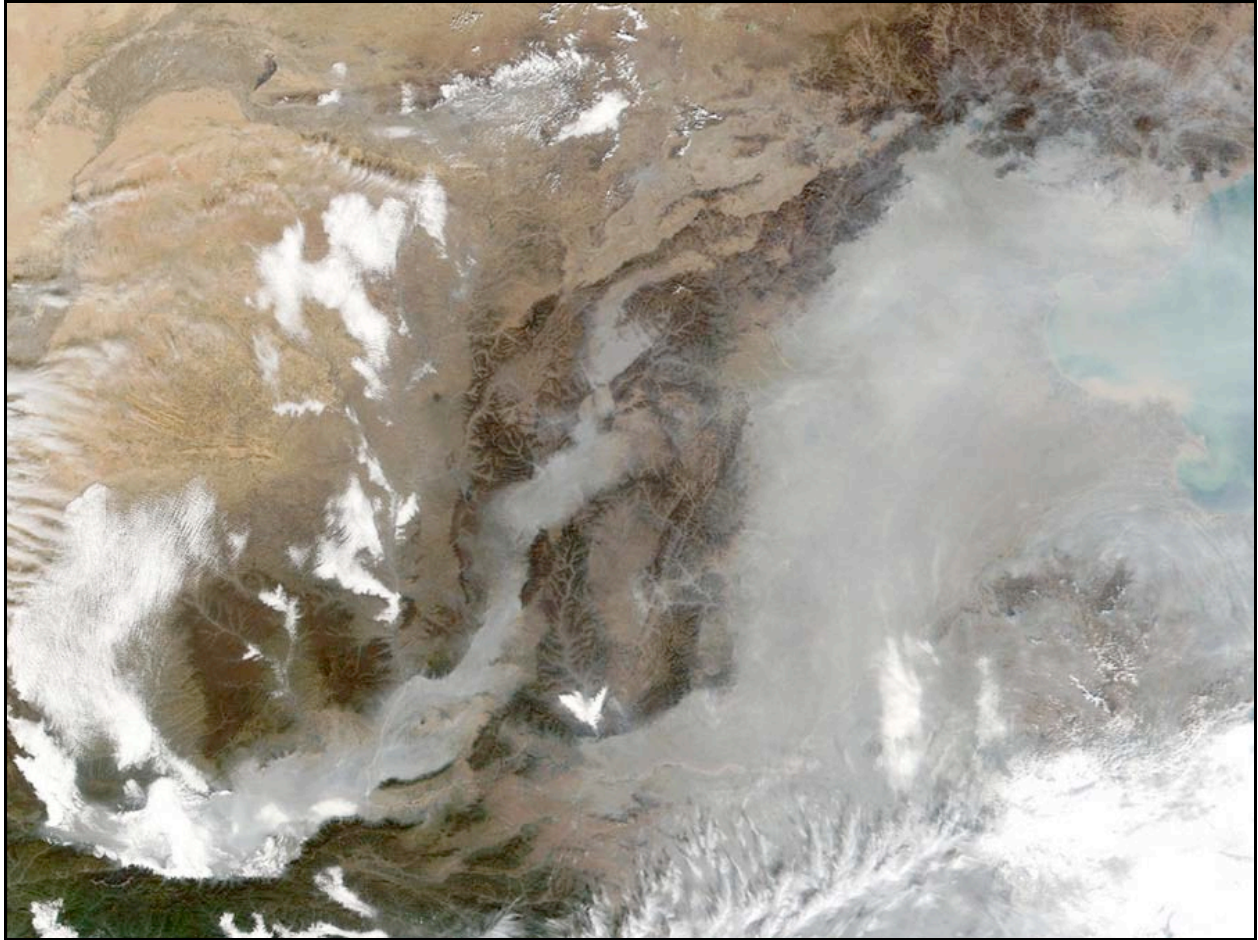
Both cities are adjacent to the Yellow River, Zhengzhou to the south and Jinan in the north.

Web References

http://en.wikipedia.org/wiki/Geography_of_China_-_Topography

http://en.wikipedia.org/wiki/North_China_Plain

<http://www.china.org.cn/english/features/ProvinceView/156474.htm>



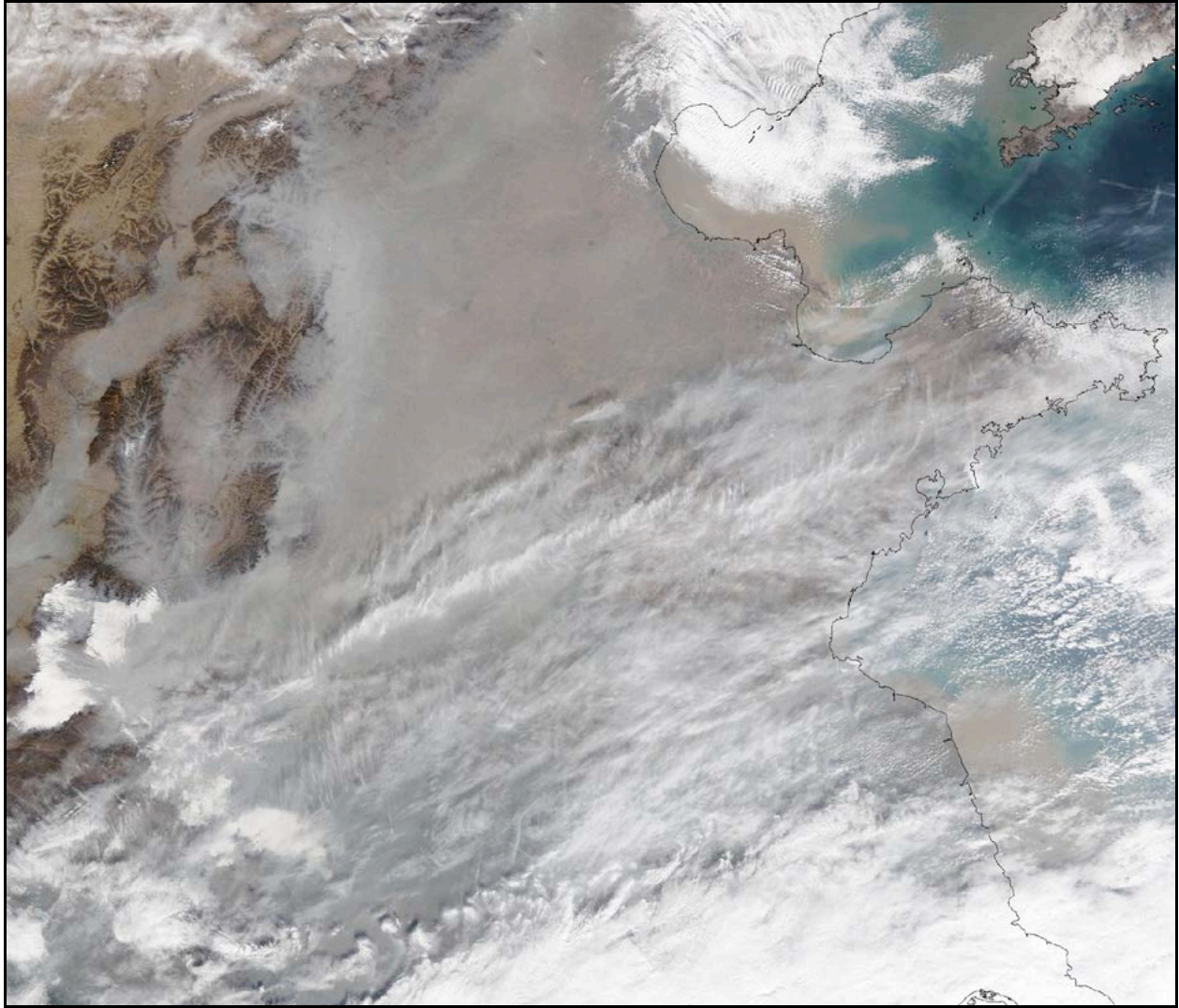
In this MODIS/Terra image from **October 22, 2001**, thick aerosols blanket much of China's lower Yellow River. The river begins in the image at the upper left flowing north, then east before turning south around the Yellow River's "Great Bend". This part of the river that flows around the Ordos Region is relatively undeveloped, with few large towns or cities. Near the bottom left of the image where it meets the Fen and Wei rivers, the river makes a second turn eastward and flows across the mountains before it again turns north crossing the North China Plain to empty into the Bohai Sea.

The location of the aerosols reflects the interaction of human geography, topography, and regional weather. Large cities, sources for aerosol emissions, are located along major river valleys. For example, left of center in the image, aerosols are packed into the Fen River Valley, which flows southwest to the Yellow River, and in the lower left the Wei River flows east to the Yellow River.

Web References

<http://earthobservatory.nasa.gov/IOTD/view.php?id=1934>

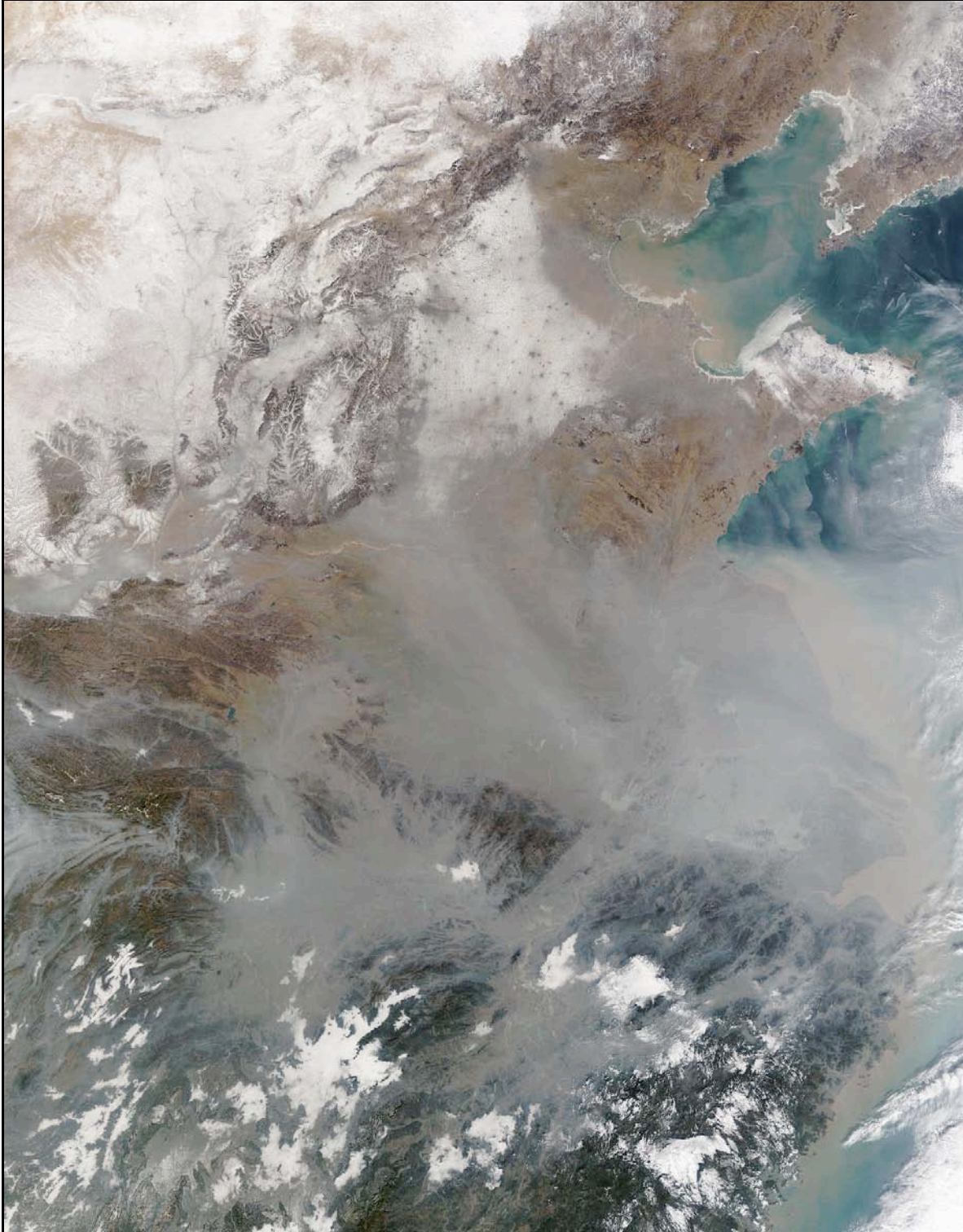
http://en.wikipedia.org/wiki/Ordos_Region



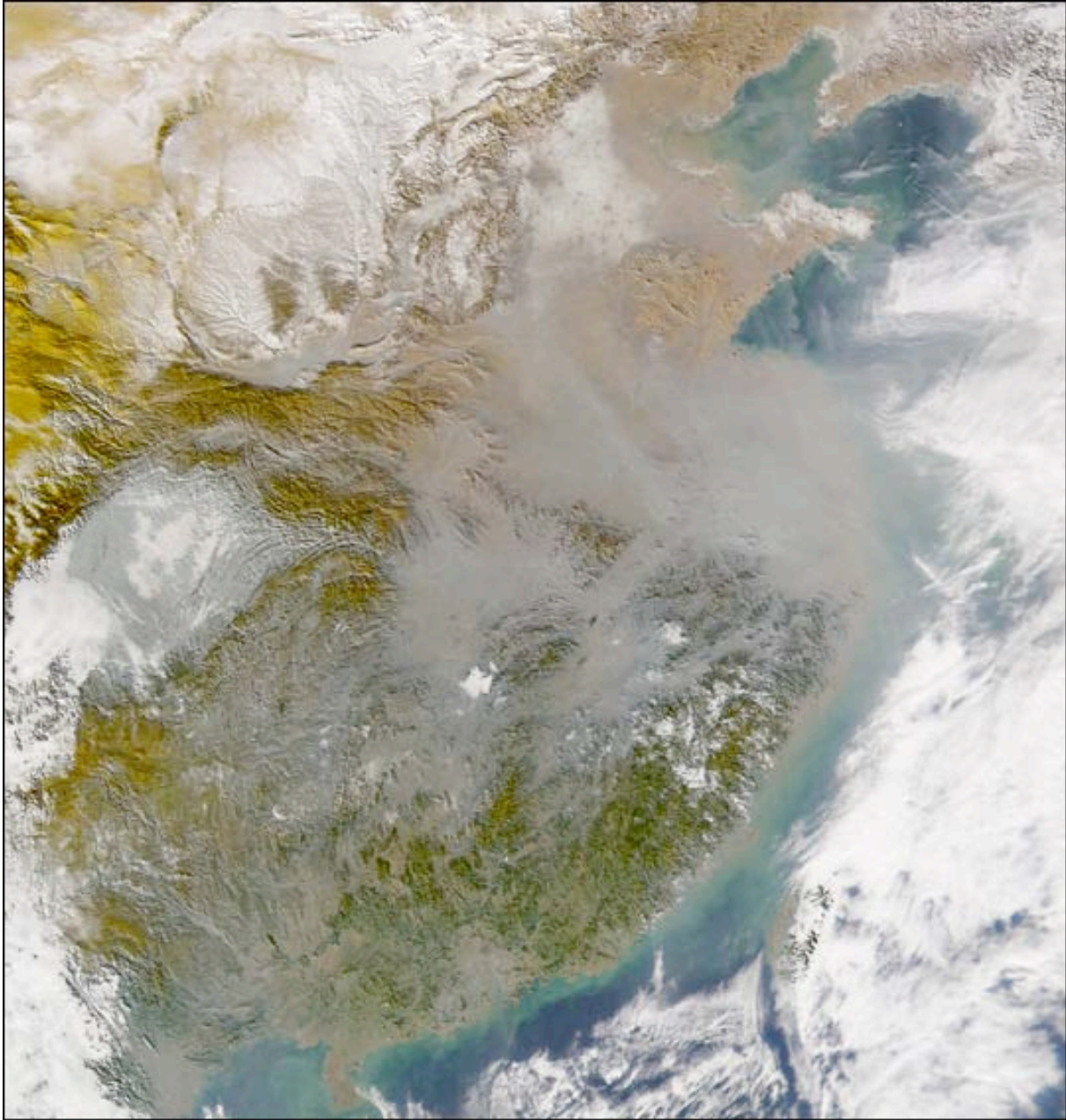
This image of northeast China was acquired **November 21, 2002**, by the MODIS/Terra instrument. What kept the aerosols confined to the lower elevations this day was a strong temperature inversion. Normally, air temperature decreases as altitude increases. On those days, the temperature and pressure gradients cause warmer surface air to move upward, allowing the aerosol emissions to escape from the surface and disperse.

On this day, however, a temperature inversion occurred, and cold, dense air was trapped near the surface, while the air above was warmer. In this situation, mixing of the atmosphere is suppressed, the cold dense air can't rise, and emissions stayed trapped at lower elevations. Note the cloud cover above the air pollution which is characteristic of strong temperature inversions.

For more on Temperature Inversions go to:
<http://www.wrh.noaa.gov/slc/climate/TemperatureInversions.php>



In this **January 10, 2003**, MODIS/Terra image, snow and haze are mixed over the North China Plain. But China's air pollution problems are not confined to the northeastern. This image also includes the Yangtze (Chang Jiang) River valley and the mountains to the south, both of which are covered in thick smog.



This image by the SeaWiFS instrument aboard the OrbView-2 satellite was acquired the same day, **January 10, 2003**, as the previous MODIS/Terra image. Note the expanded view of this SeaWiFS image which clearly shows intense smog from Sichuan Province down the Yangtze River valley to Shanghai, and out over the East China Sea. Note also that the prevailing winds on this day are from the west northwest.

Definitions of Haze and Smog — A Clarification



Tiananmen Square, Beijing 2007-12-28

Definitions of Haze

1. "haze, a mass of ash, acids, aerosols and other particles"

Source— "Asian Brown Cloud: Climate and Other Environmental Impacts" UNEP Assessment Report 2002.

2. "**Haze** is traditionally an atmospheric phenomenon where dust, smoke and other dry particles obscure the clarity of the sky. The World Meteorological Organization manual of codes includes a classification of horizontal obscuration into categories of fog, ice fog, steam fog, mist, haze, smoke, volcanic ash, dust, sand and snow. Sources for haze particles include farming (ploughing in dry weather), traffic, industry, and wildfires.

Haze often occurs when dust and smoke particles accumulate in relatively dry air. When weather conditions block the dispersal of smoke and other pollutants they concentrate and form a usually low-hanging shroud that impairs visibility and may become a respiratory health threat. Industrial pollution can result in dense haze, which is known as **smog**."

Source— Wikipedia entry for "haze" — <http://en.wikipedia.org/wiki/Haze>



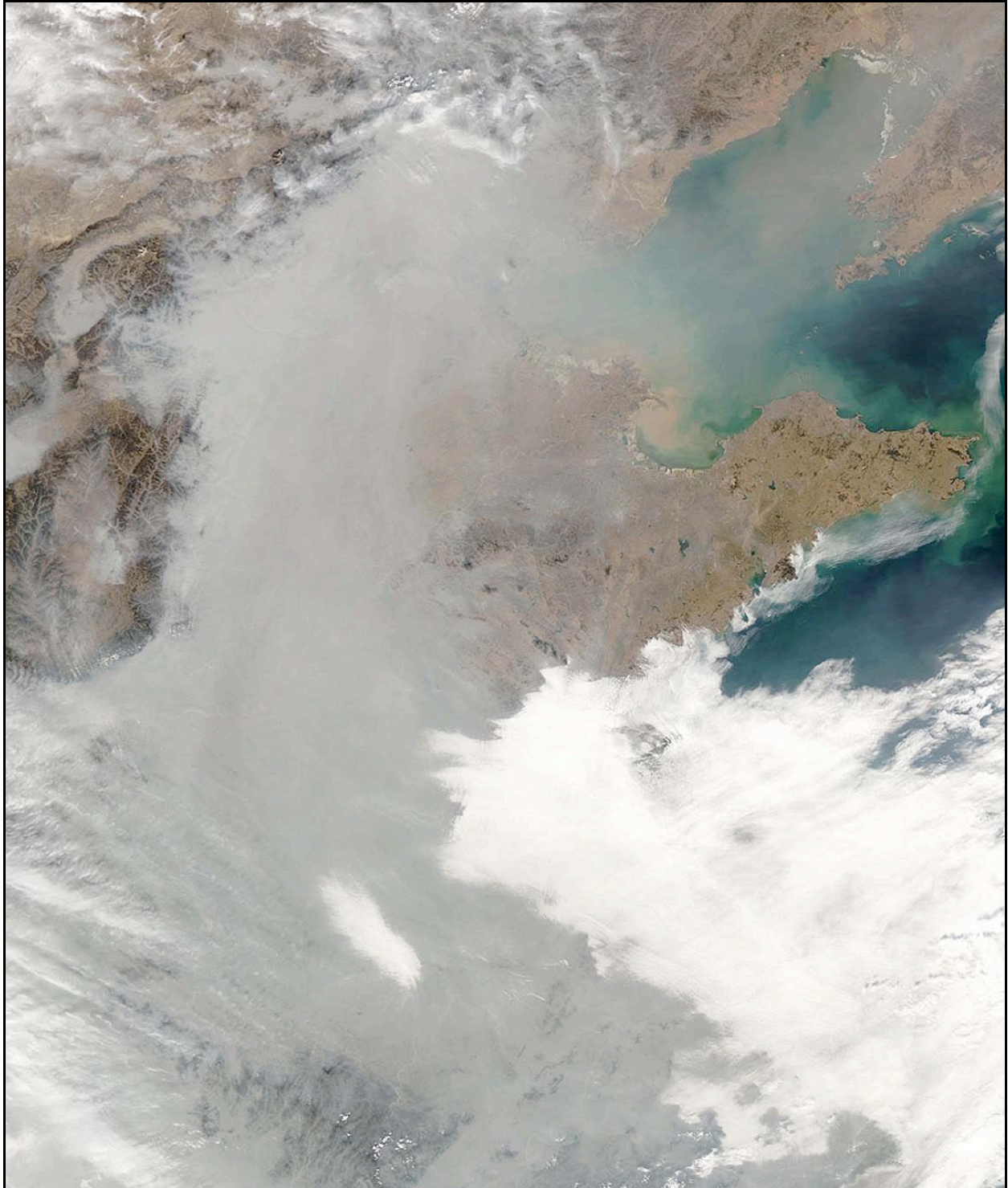
A "Pea Soup Smog" in London 1952

The Great Smog of 1952 darkened the streets of London and killed approximately 4,000 people in the short time of 4 days. A further 8,000 died from its effects in the following weeks and months.

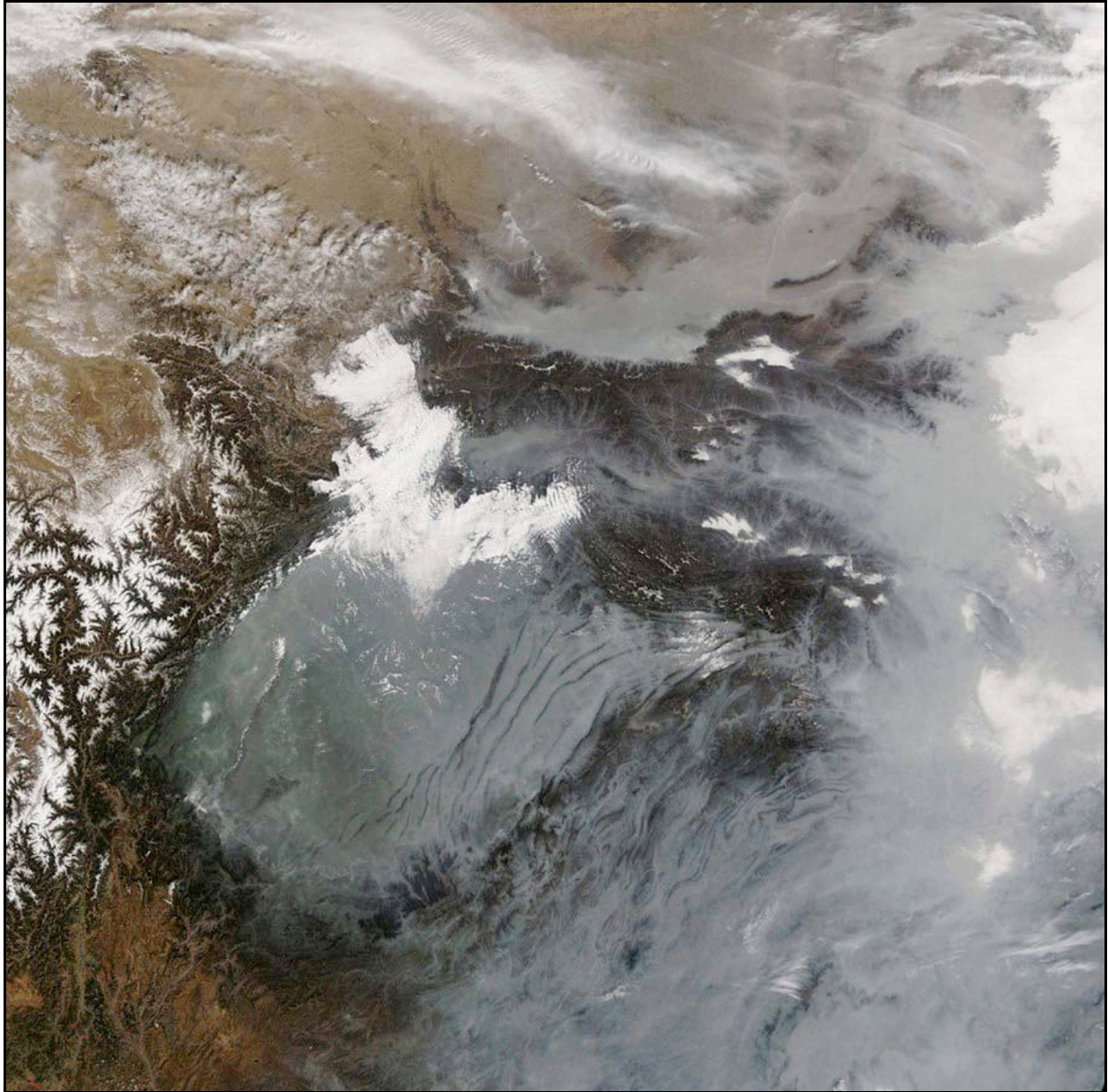
Definition of Smog

1. **Smog** is a type of air pollution; the word "smog" was coined in the mid 20th century as a portmanteau of the words smoke and fog to refer to smoky fog. The word was then intended to refer to what was sometimes known as pea soup fog, a familiar and serious problem in London from the 19th century to the mid 20th century. This kind of smog is caused by the burning of large amounts of coal within a city; this smog contains soot particulates from smoke, sulfur dioxide and other components.

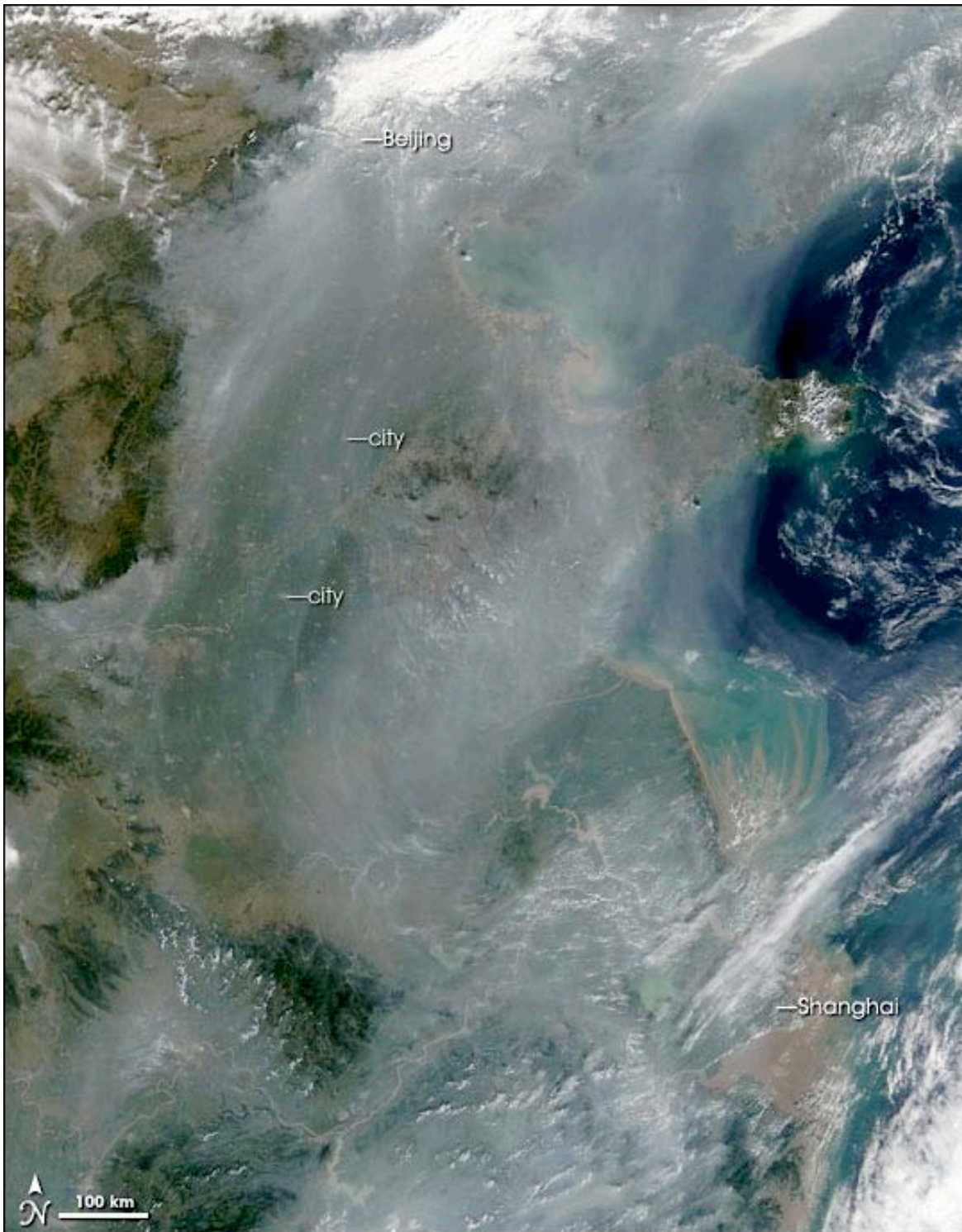
Source—Wikipedia entry for "smog" — <http://en.wikipedia.org/wiki/Smog>



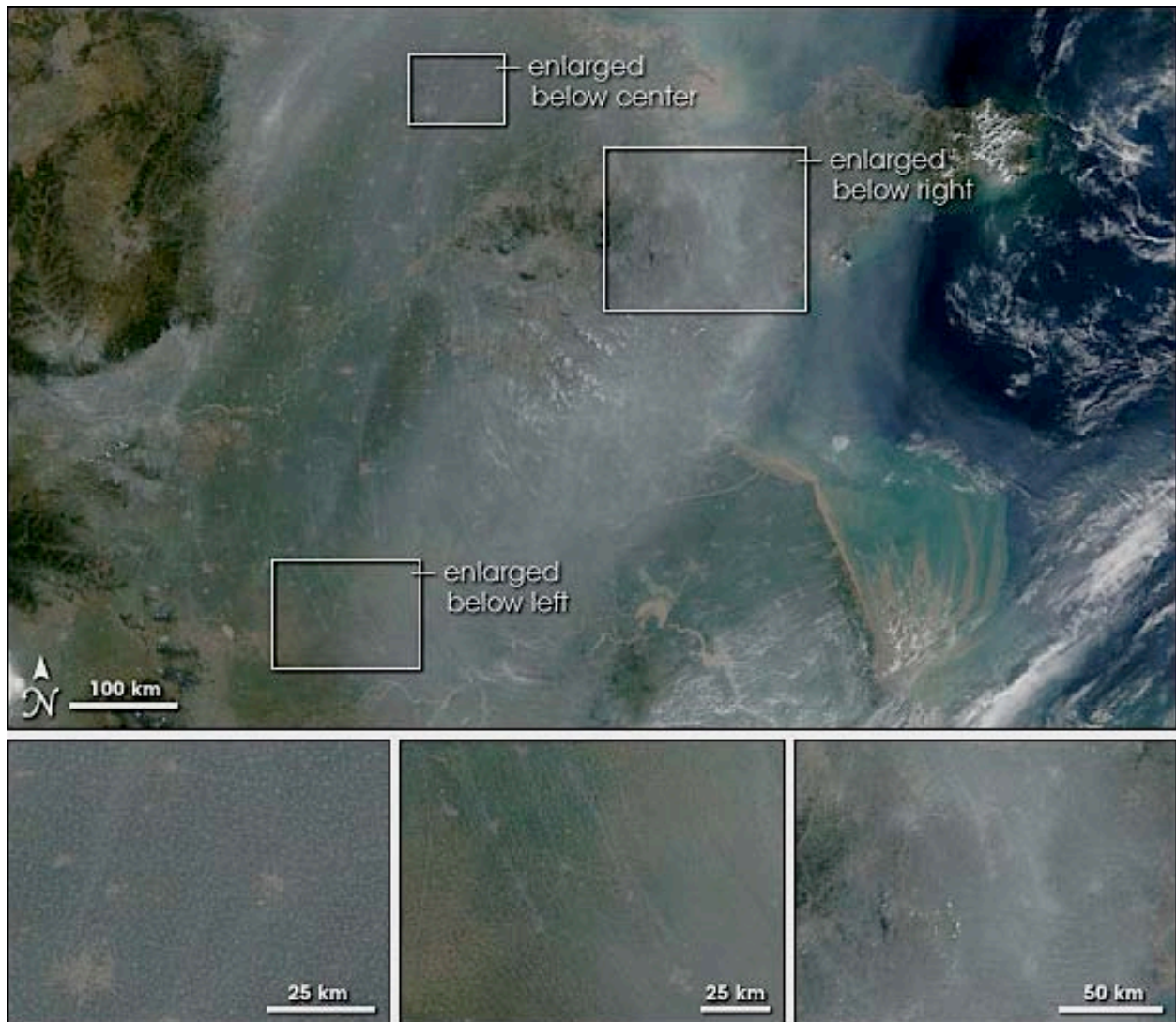
In this MODIS/Aqua image from **February 19, 2004**, smog covers both the Yellow and Yangtze River basins. The eastern coastal plains, ringed on the west and south by mountain ranges, are like a bowl that fills with hazy air. The clear skies over the Shandong Peninsula indicates winds from the southeast are pushing smog up against the mountains concentrating and intensifying the pollution.



This MODIS/Terra image from **February 24, 2005**, shows most of west-central China covered in dense smog. The oval shaped Sichuan Basin (below and left of center) is surrounded by mountains, heavily populated and industrialized, and has a foggy humid climate, all of which contribute to intense air pollution. Note that the Wei and Fen river valleys in the upper right are also filled with smog. The two valleys meet where the Yellow River turns east toward the North China Plain (upper far right).



This MODIS/Terra image from **September 10, 2005**, supports research (Richter, et al., 2005) that shows China's air pollution problems are increasing. Direct satellite measurements of a key pollutant—nitrogen dioxide—show that concentrations of nitrogen dioxide in the atmosphere over China have risen by 50% during the past decade, and the build-up is accelerating.

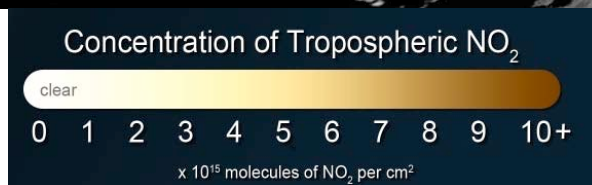
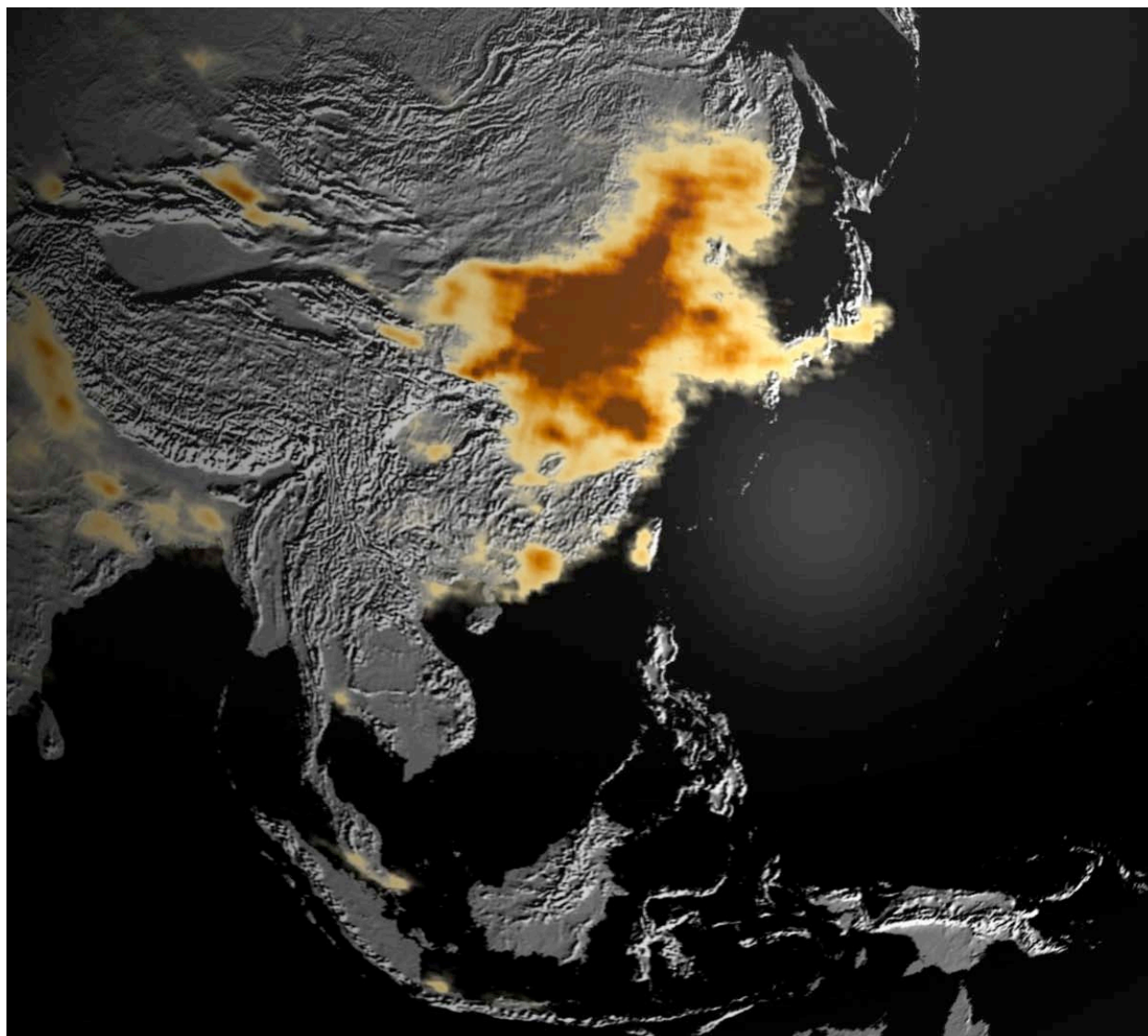


The cropped image above taken from the full image on the previous page shows areas of different concentrations of pollutants caused by differences in topography (right insert) and population density (center insert) or both (left insert).

Over-all the research found substantial reductions in nitrogen dioxide concentrations over some areas of Europe and the USA, but a highly significant increase of approximately 50% from 1996 to 2004, over the industrial areas of China. The satellite data comes from the Global Ozone Monitoring Experiment (GOME), launched aboard a European Space Agency craft in 1995, and the Scanning Imaging Absorption Spectrometer for Atmospheric Chartography (SCIAMACHY), launched in 2002. Both experiments measure concentrations of trace gases in the atmosphere from the Earth's surface to about 10 kilometers high (Cyranoski, 2005; Richter, et al., 2005).

Web Site Reference

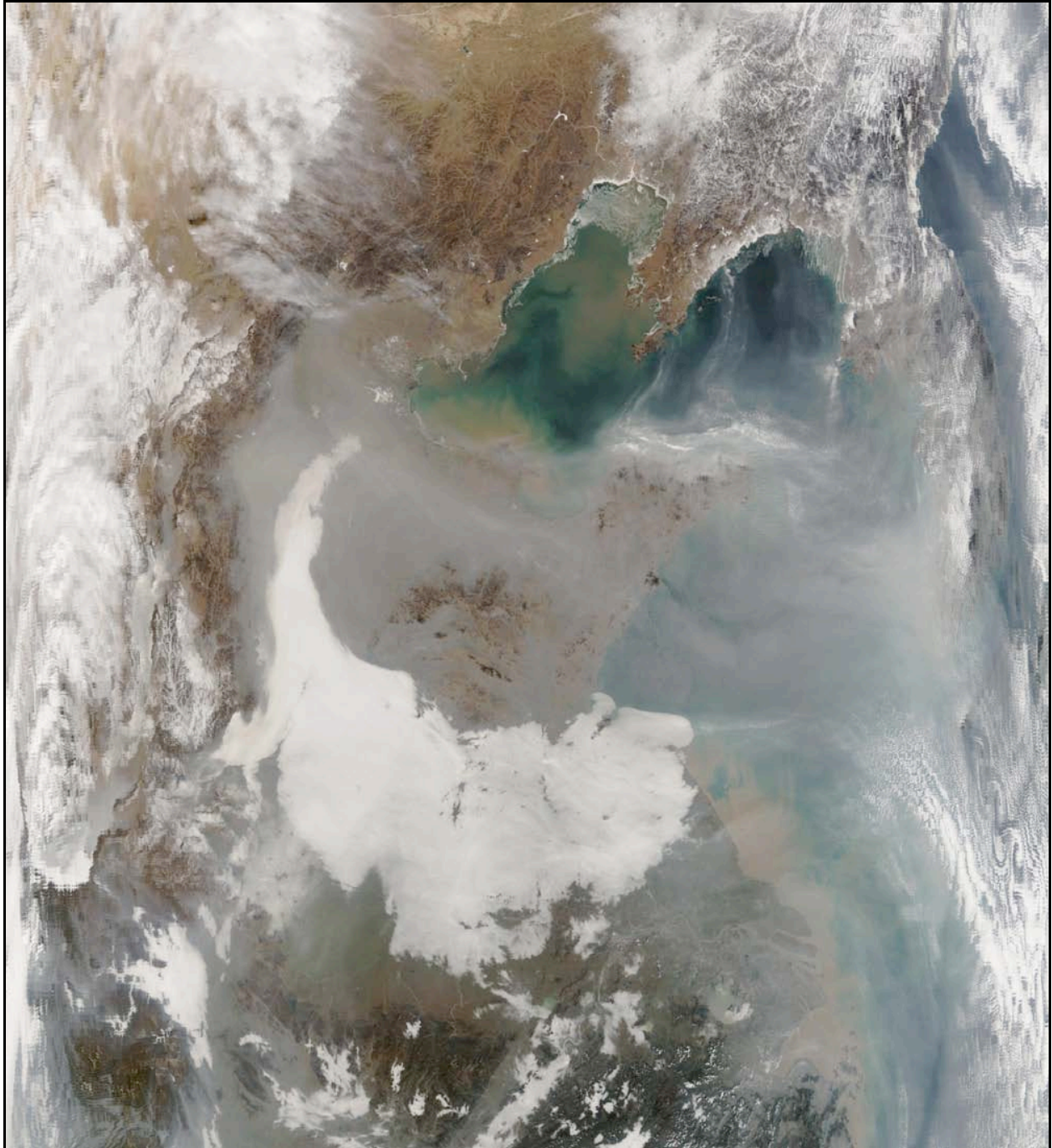
<http://earthobservatory.nasa.gov/IOTD/view.php?id=5865>



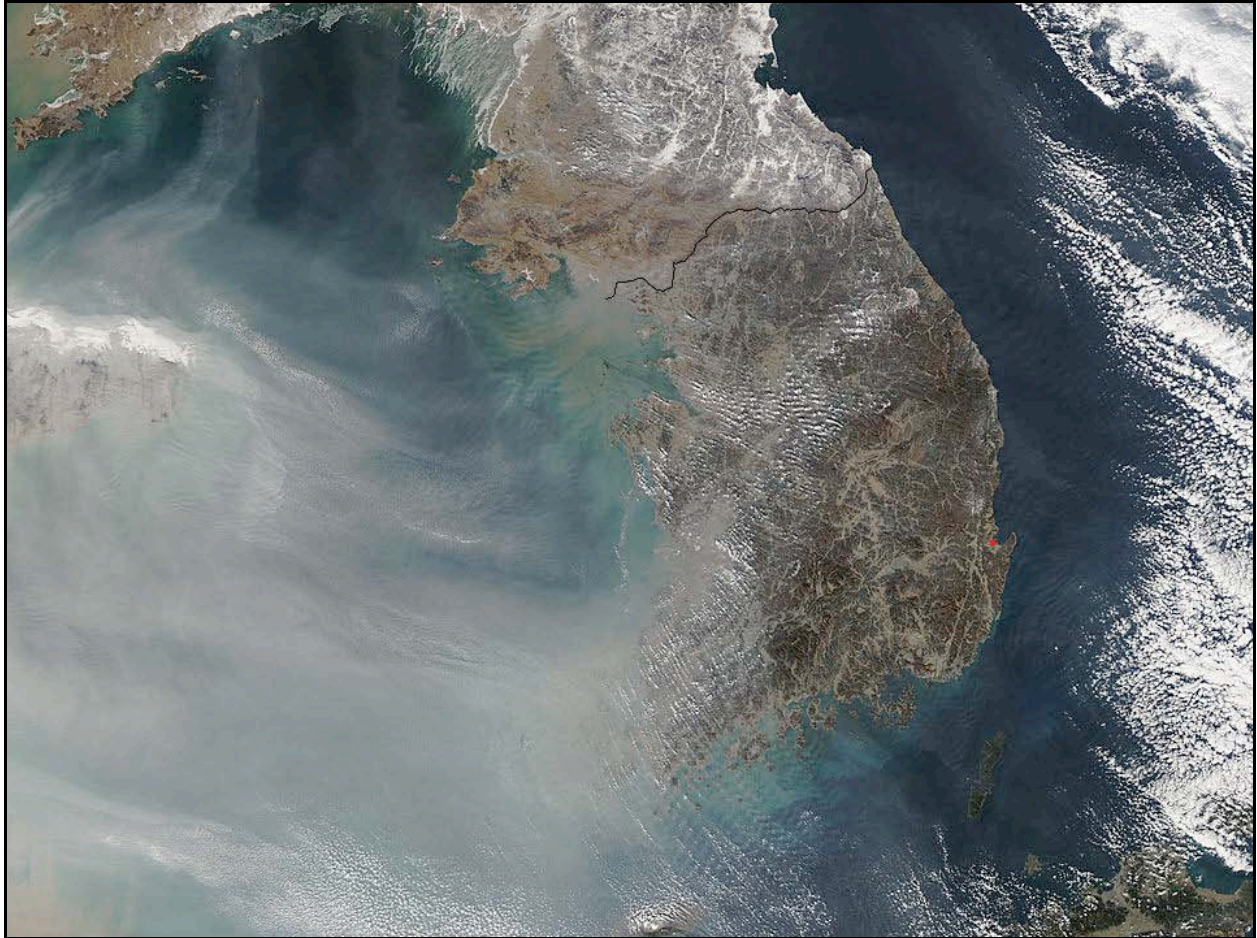
Massive plumes of the gas nitrogen dioxide can be seen hovering in the troposphere (low atmosphere) above China. Nitrogen dioxide is a by-product of fossil fuel combustion. The gas acts as a pollutant and also promotes the formation of low-level ozone, which is harmful to human health. Most major industrial areas have high concentrations of nitrogen dioxide in the surrounding atmosphere, though China's was the worst in **October 2010**. This image was generated by accumulating all of the data taken during the month of October by the GOME-2 sensor on board the MetOp-A satellite.

Web Site Reference

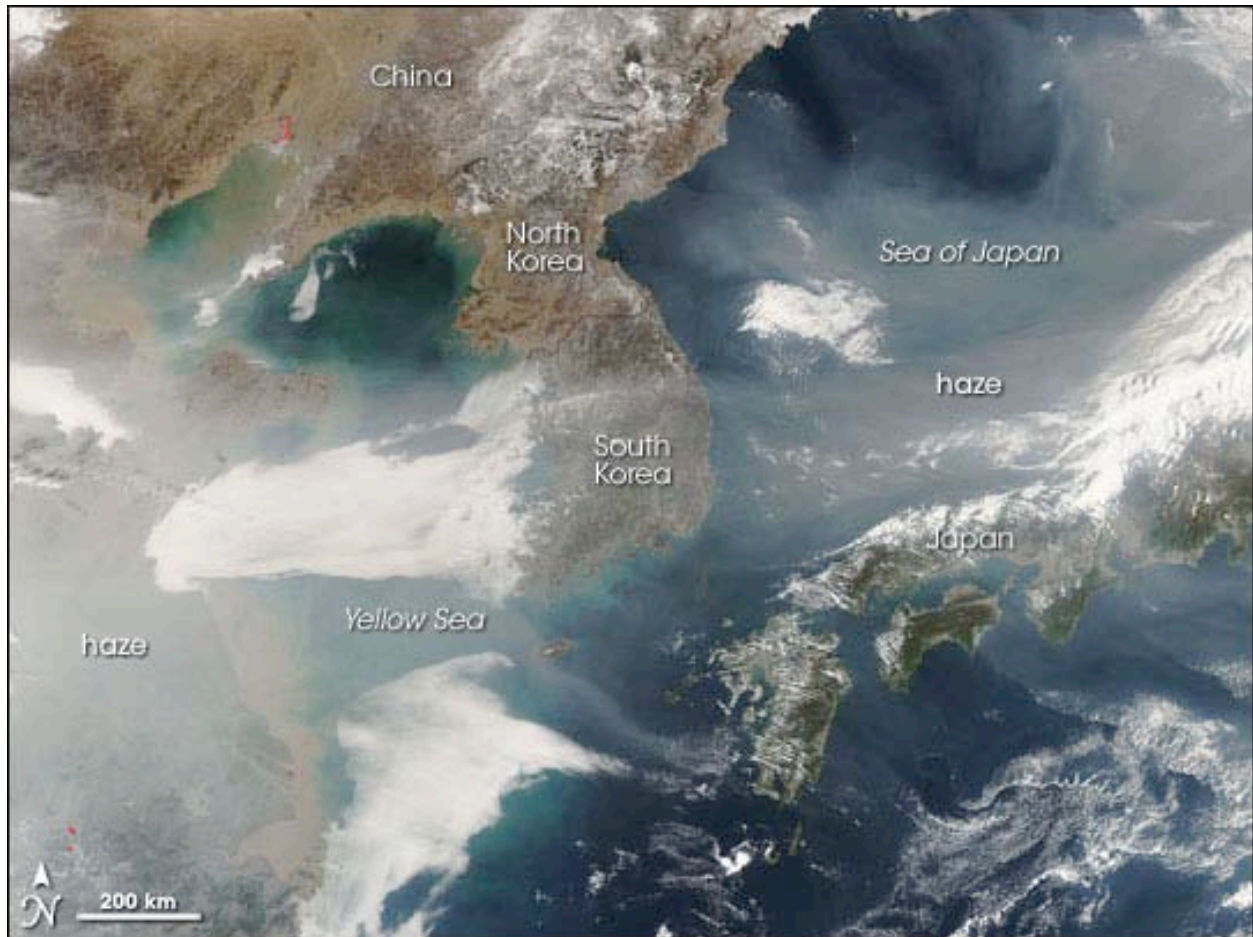
<http://www.nvnl.noaa.gov/MediaDetail.php?MediaID=577&MediaTypeID=1>



This **January 27, 2006**, MODIS/Terra image shows the effects of prevailing northwest winds during the winter. Smog is being blown by the winds across east central China, and over the Yellow Sea to the Korean Peninsula and Japan. Note the ground fog below the haze in the southern portion of the coastal plains. Fog forms when warm moist air flows over colder air near the ground. The fog, and the associated humidity, tend to concentrate air pollution near the ground.



Taken the same day as the previous image, this **January 27, 2006**, MODIS/Aqua image of the Korean Peninsula shows the dramatic influence that China's air pollution has on its neighbors to the east. The Japanese island of Kyushu can just be seen in the bottom right corner of the image. Kyushu Island is just across the Korean Strait from the South Korean port city of Busan. China's Shandong Peninsula, which is covered with thick smog, is just above center on the left edge of the image.



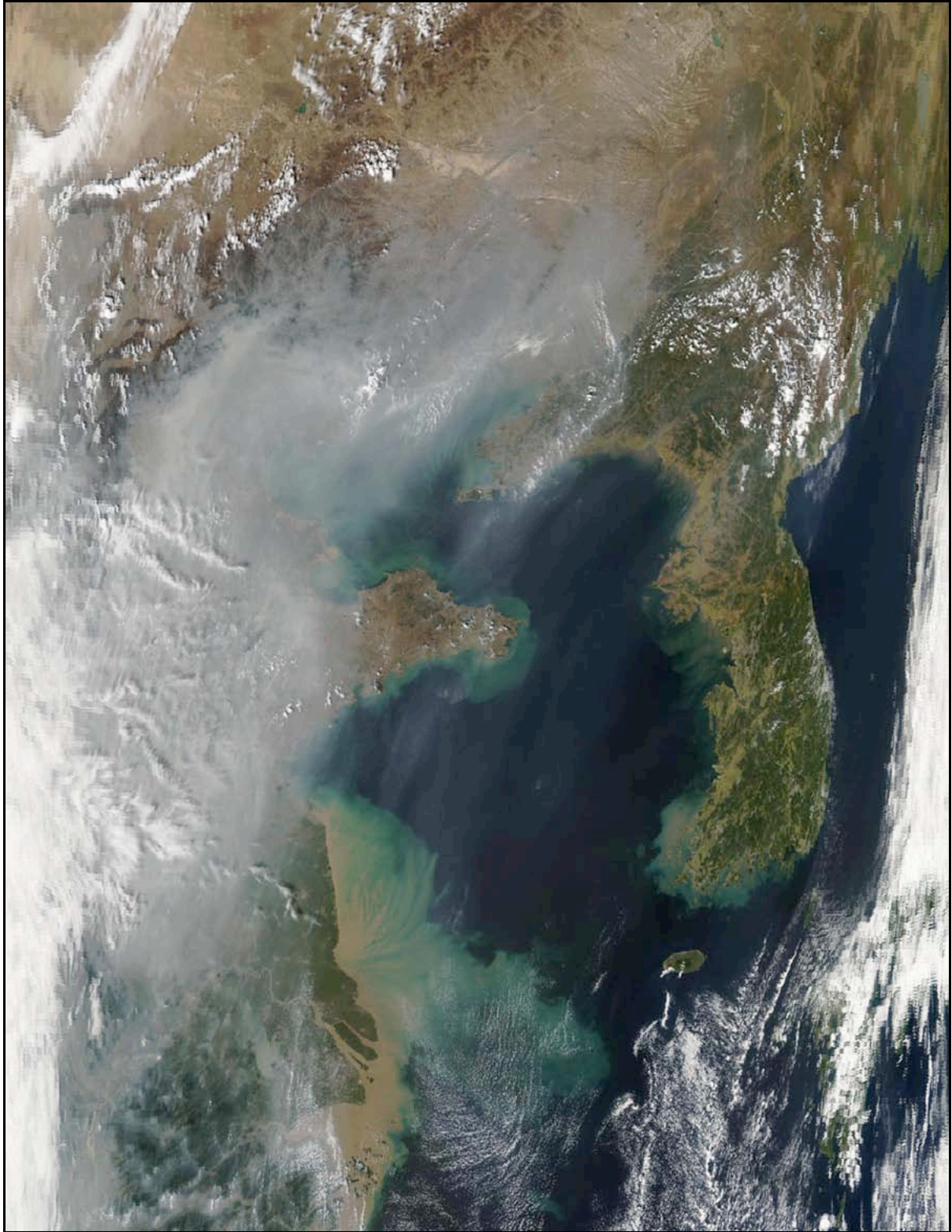
Chinese Air Pollution over Korea and Japan

The amount of air pollution produced on any given day in China is relatively the same, but is increasing over the long term as China's industries grow. The air quality for any single location in China, on the other hand, is a function of the winds and weather on that day. If there were no weather systems to blow away the air pollution that is produced daily in China, the air would quickly become un-breathable over most of the east central areas of the country. Where, then, does the pollution go? As shown above, it is blown eastward to Korea and Japan especially in winter.

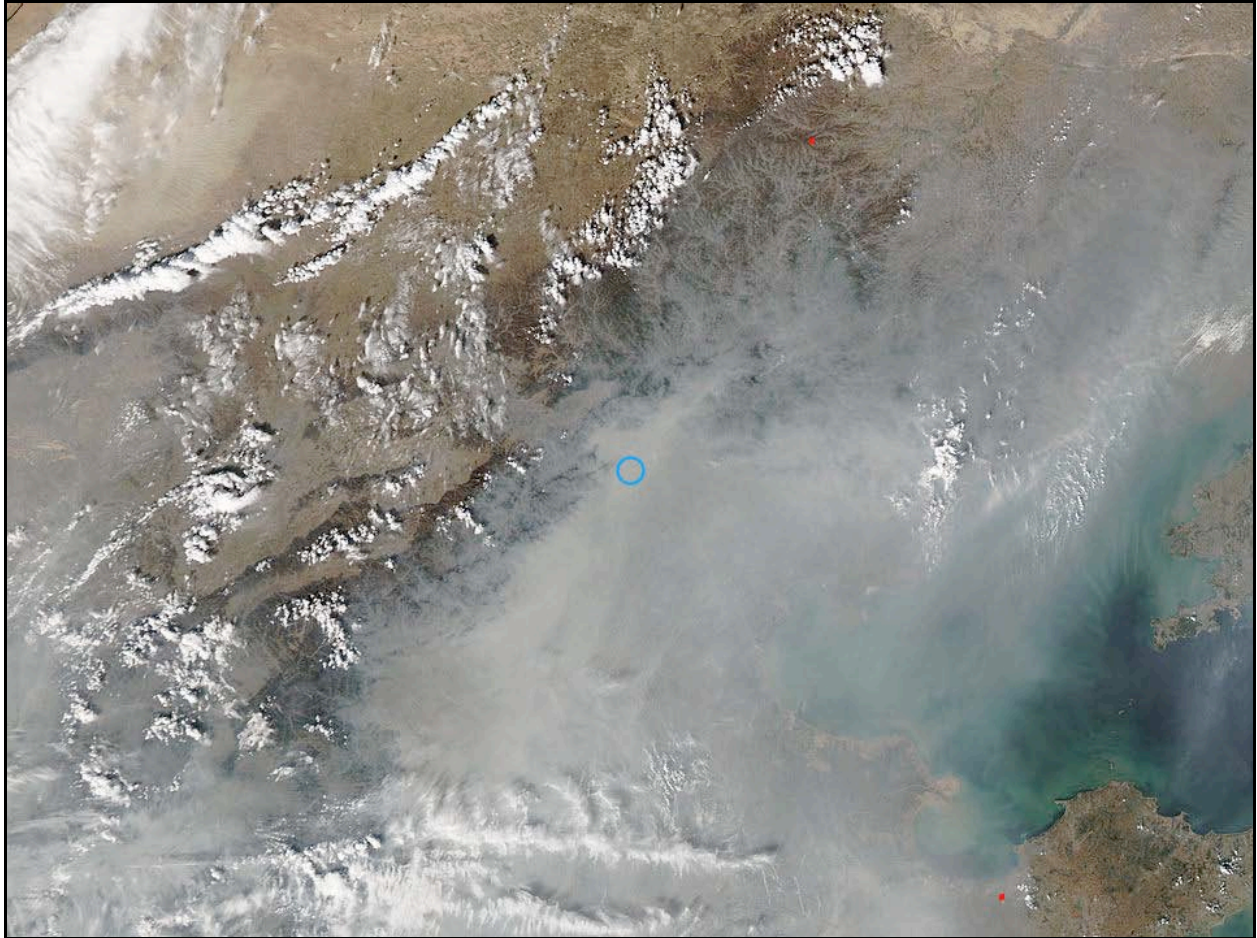
On **February 6, 2007**, thick haze was blown across the Yellow Sea and the Korean Peninsula toward Japan. The MODIS instrument on NASA's Aqua satellite acquired this image the same day. The haze appears particularly thick in east central China. Then opaque white clouds mix with the haze over the Yellow Sea as it blows eastward. The band of haze appears to narrow as it crosses over South Korea, then spreads out over the Sea of Japan. Skies over North Korea and the northern portion of the Sea of Japan are relatively clear as the pollution is blown up the west coast of Japan.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=17968>



This MODIS/Aqua image from **October 6, 2006**, shows south winds pushing smog against the Taihang and Yanshan Mountains. Note the clear skies over Korea and the Shandong Peninsula (left of center) in China.

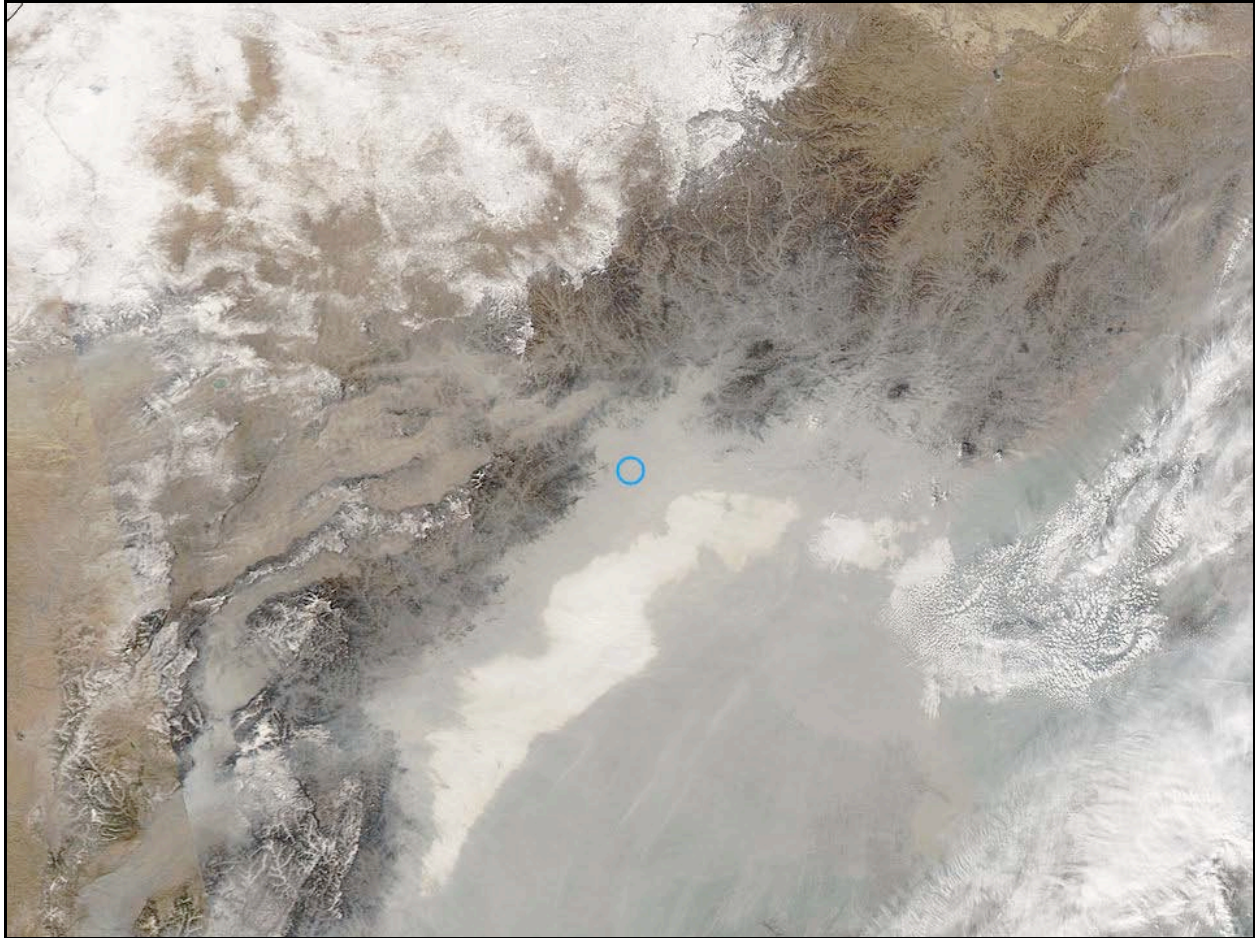


Weather systems that concentrate air pollution are a serious problem in China. When it comes to regional air pollution, physical geography and weather patterns often make the problem much worse. In particular, the mountains to the west and south of the eastern coastal plains form a barricade that prevents pollution from dispersing.

Beijing is centered on the blue circle of this AERONET Beijing Subset MODIS/Aqua image from **October 6, 2006**, the same day as the previous image, and shows the effect of winds that have driven and concentrated the smog up against the Taihang and Yanshan Mountains. Because of its geographic location and population size Beijing suffers some of the worst air pollution in China. As a result, Beijing's air pollution index (API) is often reported as an example of air quality in China. But this can be very misleading because of the vagrancies of the weather systems that cross eastern China. Beijing's API for this day was reported as **194 on a scale that goes to 500**.

AERONET Beijing Subset

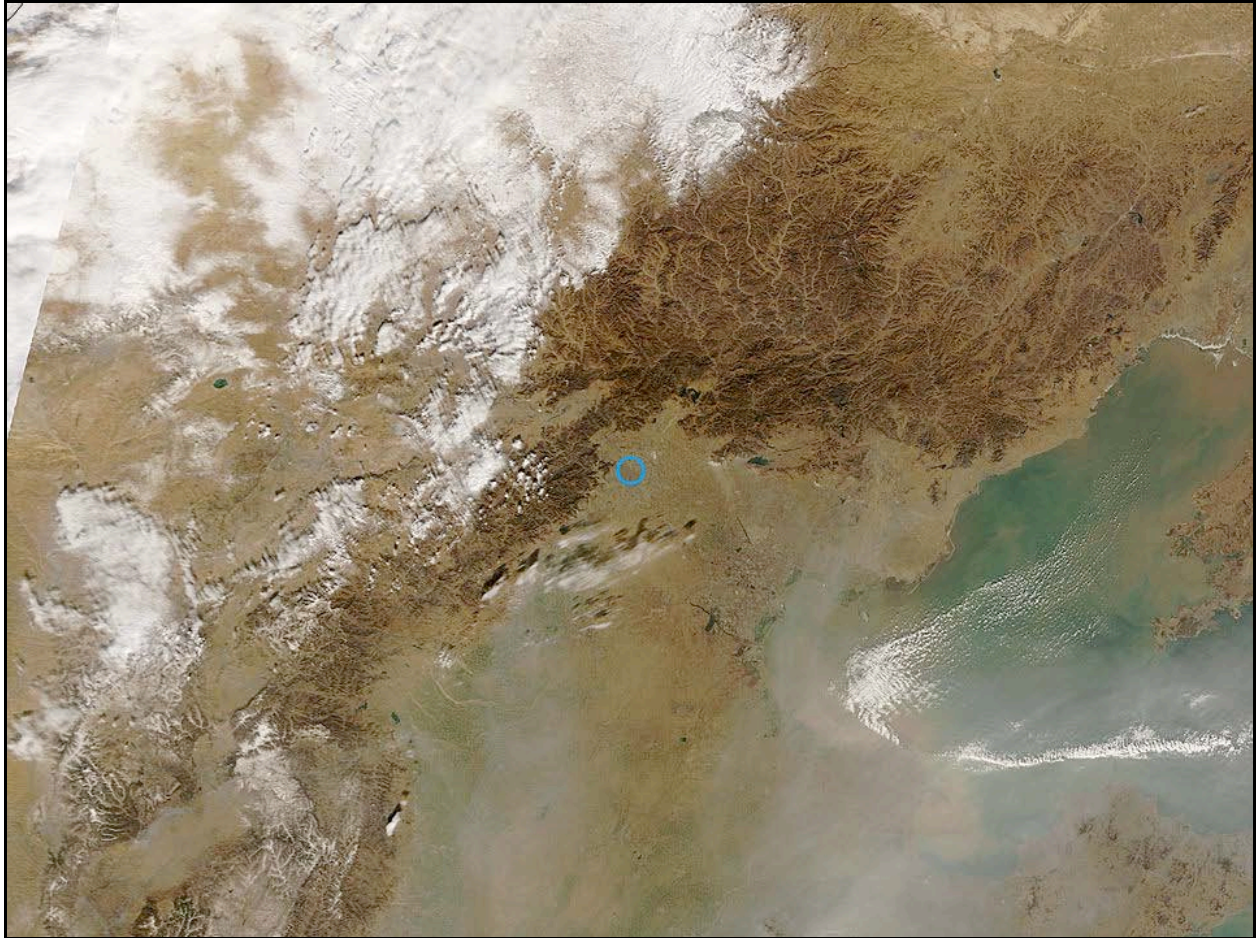
<http://lance-modis.eosdis.nasa.gov/imagery/subsets/?project=aeronet&subset=Beijing>



This MODIS/Aqua, AERONET Subset image from **December 11, 2006**, shows Beijing obscured by a blanket of air pollution. Note the ground fog beneath the smog. China's State Environmental Protection Administration (SEPA), now the Ministry of Environmental Protection (MEP), uses an air pollution index that measures from 0 to 500. Particulates are a major component of the API and measured as micrograms of inhalable particles per cubic meter of air. In China, particulates 10 microns in diameter (PM10) are measured. An API up to 100 is rated safe. 200 is a bad day. **Beijing's 24 hour unofficial average for December 11-12 was at or above 500.** The official SEPA reading was given as 500, the top of the scale.

In 2006, Beijing had ten days with a Grade 5 (>300) air pollution index. Of those ten days, four were associated with dust storms, and five with smog. One day (May 17) appears to have been a combination of smog and dust. Of the five days of intense smog, four were associated with ground fog and south winds. Beijing's average PM10 level in 2006 was 141 (Kahn & Yardley, 2007).

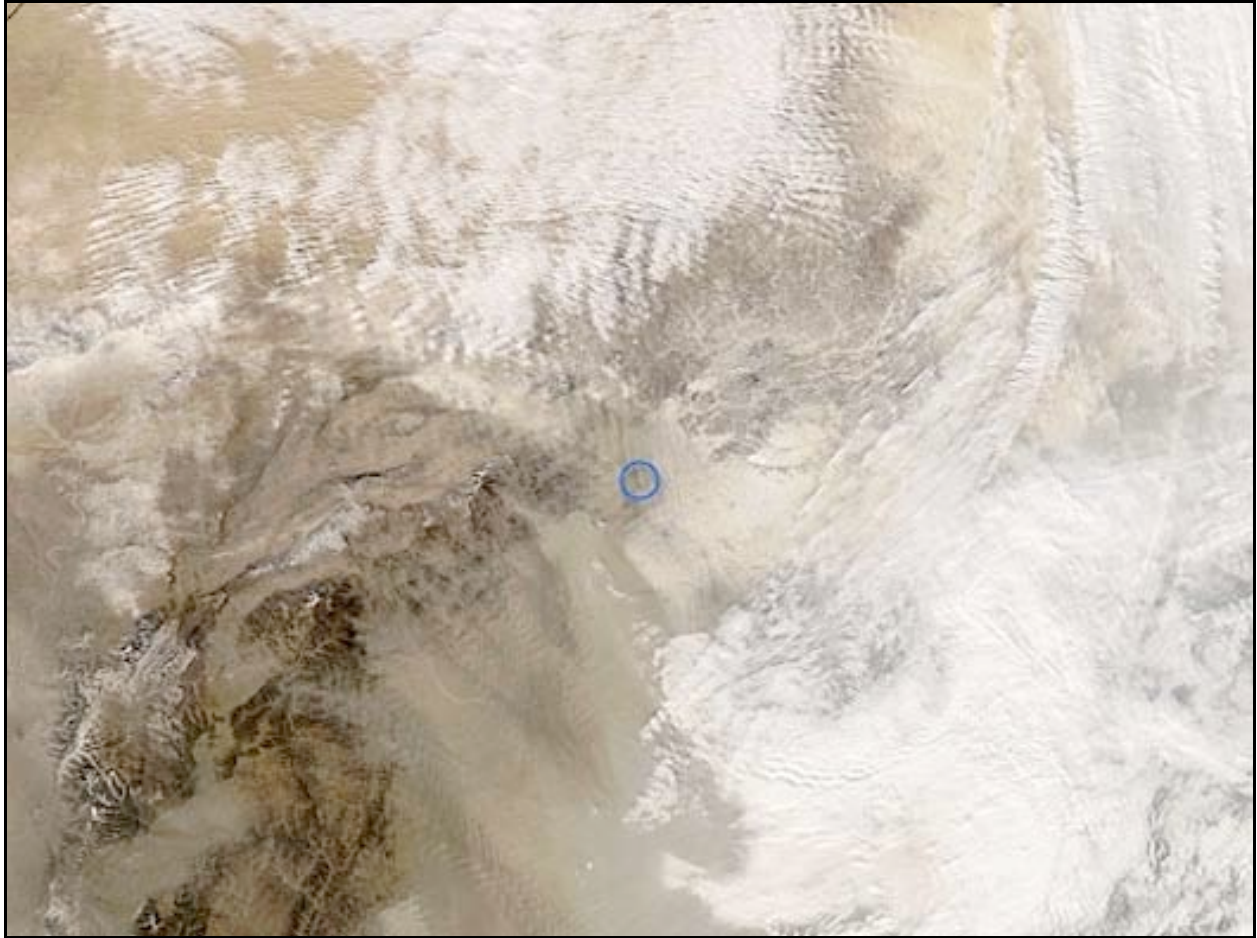
For more on how China's API was calculated in 2006 go to:
<http://fire.biol.wvu.edu/trent/alles/CAPIRules.pdf>



But four days later on **December 15, 2006** this MODIS/Aqua, AERONET Subset image shows clear skies over Beijing. This is just one example of how the vagrancies of the weather systems that cross eastern China make it impossible to pick any single city or location as representative of the country's air pollution as a whole.

MEP Air Pollution Index Grades (Levels) as of 2006

<u>API</u>	<u>Grade</u>	<u>Air quality description</u>
0-50	Grade 1	Excellent
51-100	Grade 2	Good
101-150	Grade 3A	Slightly polluted
151-200	Grade 3B	Light polluted
201-250	Grade 4A	Moderate polluted
251-300	Grade 4B	Moderate-heavy polluted
>300	Grade 5	Heavy polluted

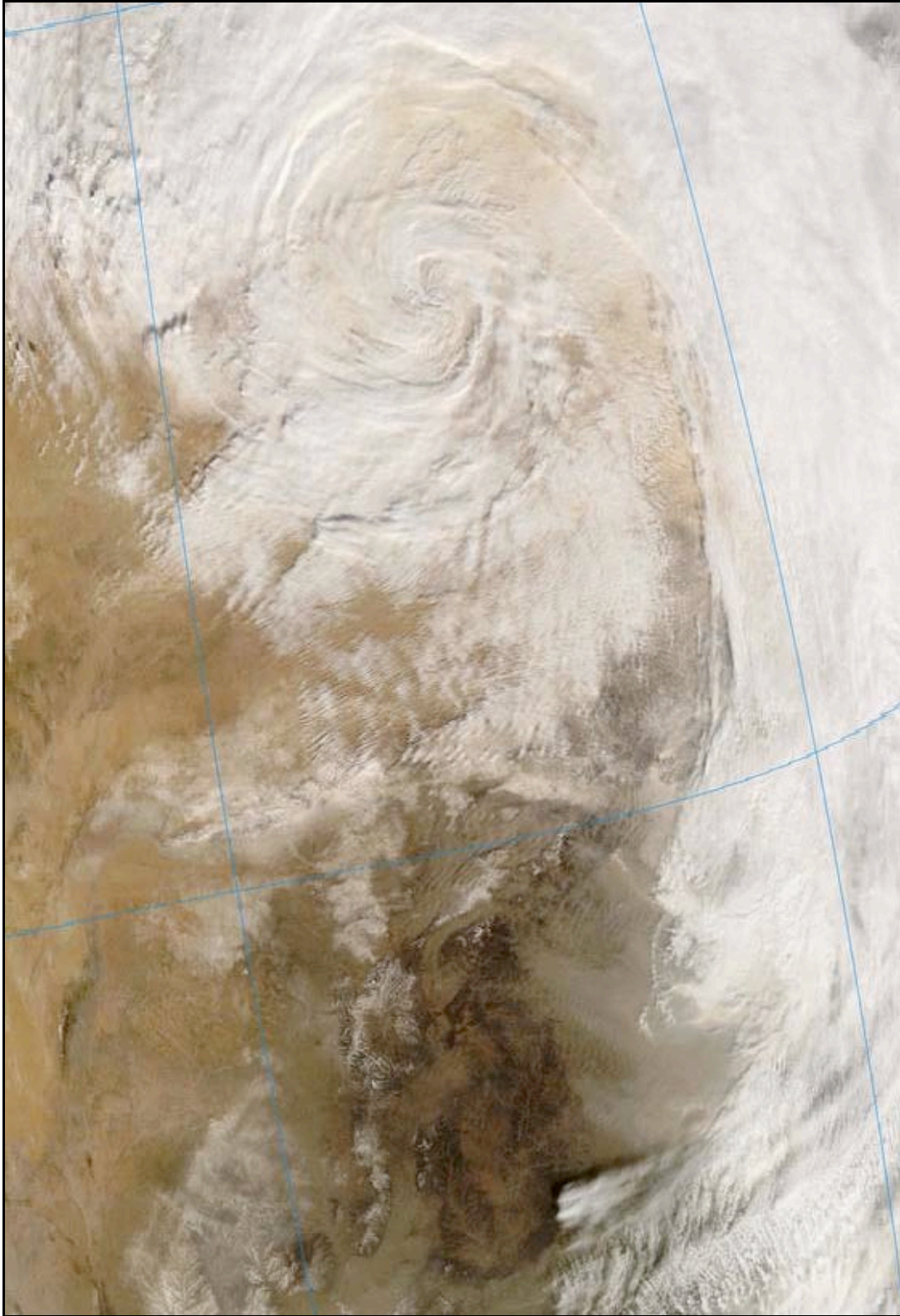


This MODIS/Aqua, AERONET Subset image is from December 28, 2007. Again, Beijing is centered on the blue circle in the image. **December 28 had the worst air quality in 2007 with an API of 500.** In 2007 there was a total of 3 days with a Grade 5 API. In contrast, 2006 had 10 days with Grade 5 air quality. Beijing was hit by only one dust storm during 2007, on March 24-25 with an API of 250. In 2006, the city was hit by 8 dust storms.

Altogether during 2007, Beijing had 15 days with severe air pollution, defined here as an API of 200 or above. There were 6 days with an API near 200, five near 250, one day at 280, one at 322, one at 421, and one day at or above 500. Ironically, four of the worst days for air quality occurred during the last week of 2007.

Note how complex the weather pattern and winds are that affected Beijing this day. In this image a west wind, possibly combined with dust, is blowing east, north of the Yanshan Mountains. It then combines with powerful winds blowing directly north on the east side of the Yanshan Mountains toward a powerful low pressure cyclone to the north.

The combined system draws pollution from the east side of the Taihang Mountains around the east end of the Yanshan Mountains northward toward the center of the low pressure system. Beijing is, however, far enough north along the east side of the Taihang Mountains not to feel the full effects.



Above is a Real-Time MODIS/Terra true-color image of the low pressure cyclone north of Beijing on **December 28, 2007**.



Smog over Tiananmen Square December 28, 2007

Beijing residents in Tiananmen Square, used to pea-soup smog, ignored a citywide stay-indoors warning on Friday the 28th. The gray, acrid skies on Thursday rated an API of 421. Friday's air rated at or above 500. Both days far exceeded pollution levels deemed safe by the World Health Organization. Beijing officials warned residents to stay indoors until Saturday, but residents here are accustomed to breathing foul air. One man, seemingly indifferent to the air quality, is shown above flying a kite in Tiananmen Square on Friday (Yardley, 2007).

"Beijing has long ranked as one of the world's most polluted cities. To win the Games, Beijing promised a 'Green Olympics' and undertook environmental initiatives now considered models for the rest of the country. But greening Beijing has not meant slowing it down. Officials also have encouraged an astonishing urbanization boom that has made environmental gains seem modest, if not illusory." (Yardley, 2007)

(Photograph by Oded Balilty for the Associated Press
courtesy of *The New York Times*)

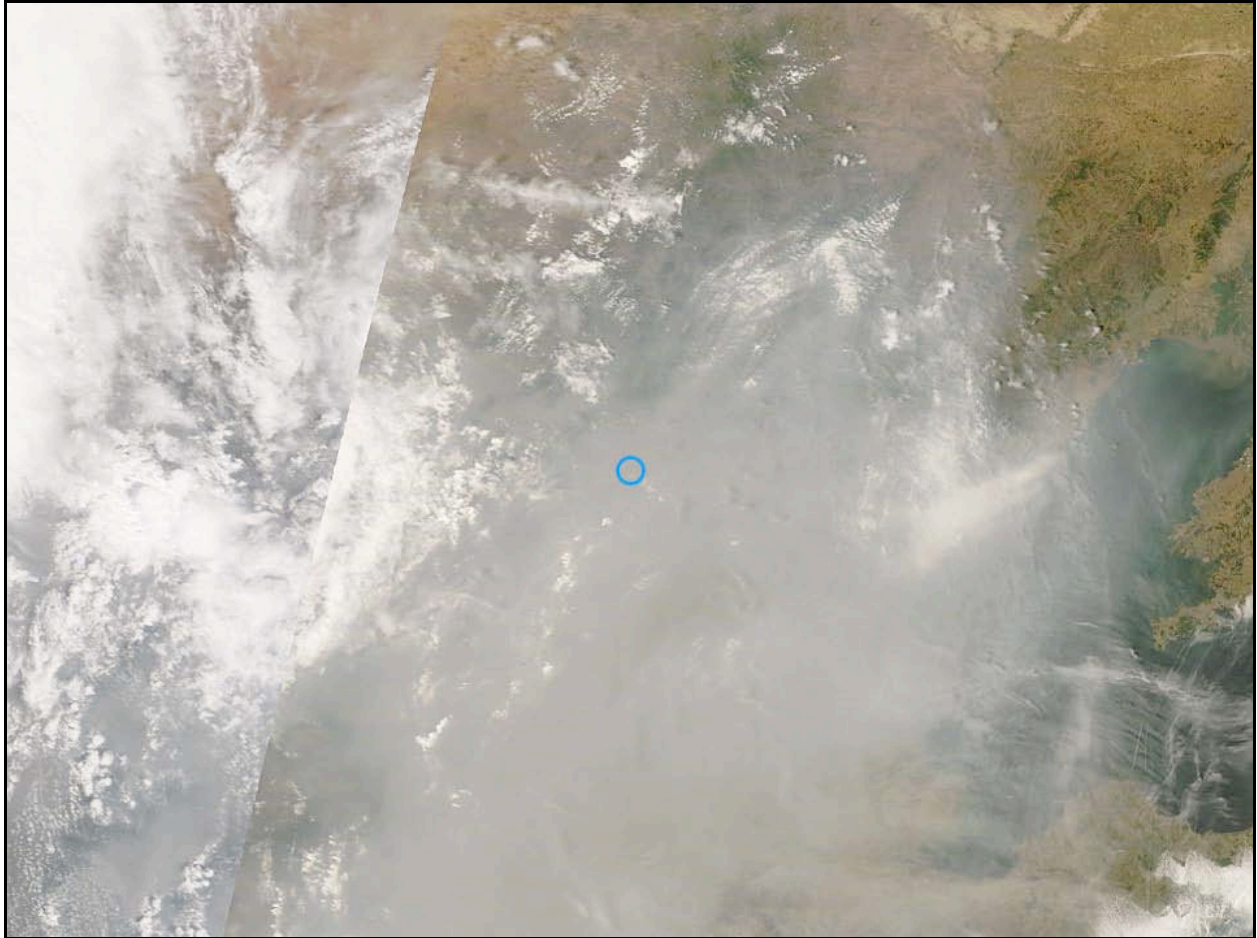
For the World Health Organization (WHO) air pollution standards go to:
http://www.who.int/phe/health_topics/outdoorair_aqg/en/index.html



Auto emissions are rising as Beijing adds up to 1,200 new cars and trucks every day. This explosion of car ownership has brought gridlocked traffic and a shroud of auto fumes. Beijing now has more than three million vehicles and is adding more than 400,000 new cars and trucks each year. The city's reliance on cars and trucks leaves its air with few reprieves (Yardley, 2007).

Beijing is fighting auto pollution by instituting China's highest vehicle emissions standards. Nearly 79,000 new taxis with lower emissions have replaced older, outdated models. But Beijing has been unwilling to discourage private car ownership by instituting exorbitant fees as Shanghai has done. Depending on the car, license plates in Shanghai can cost as much as \$7,000; as a result, Shanghai adds only one-fourth as many cars per year as Beijing (Yardley, 2007).

(Photograph by Aaron Kuo-Deemer courtesy of *The New York Times*)

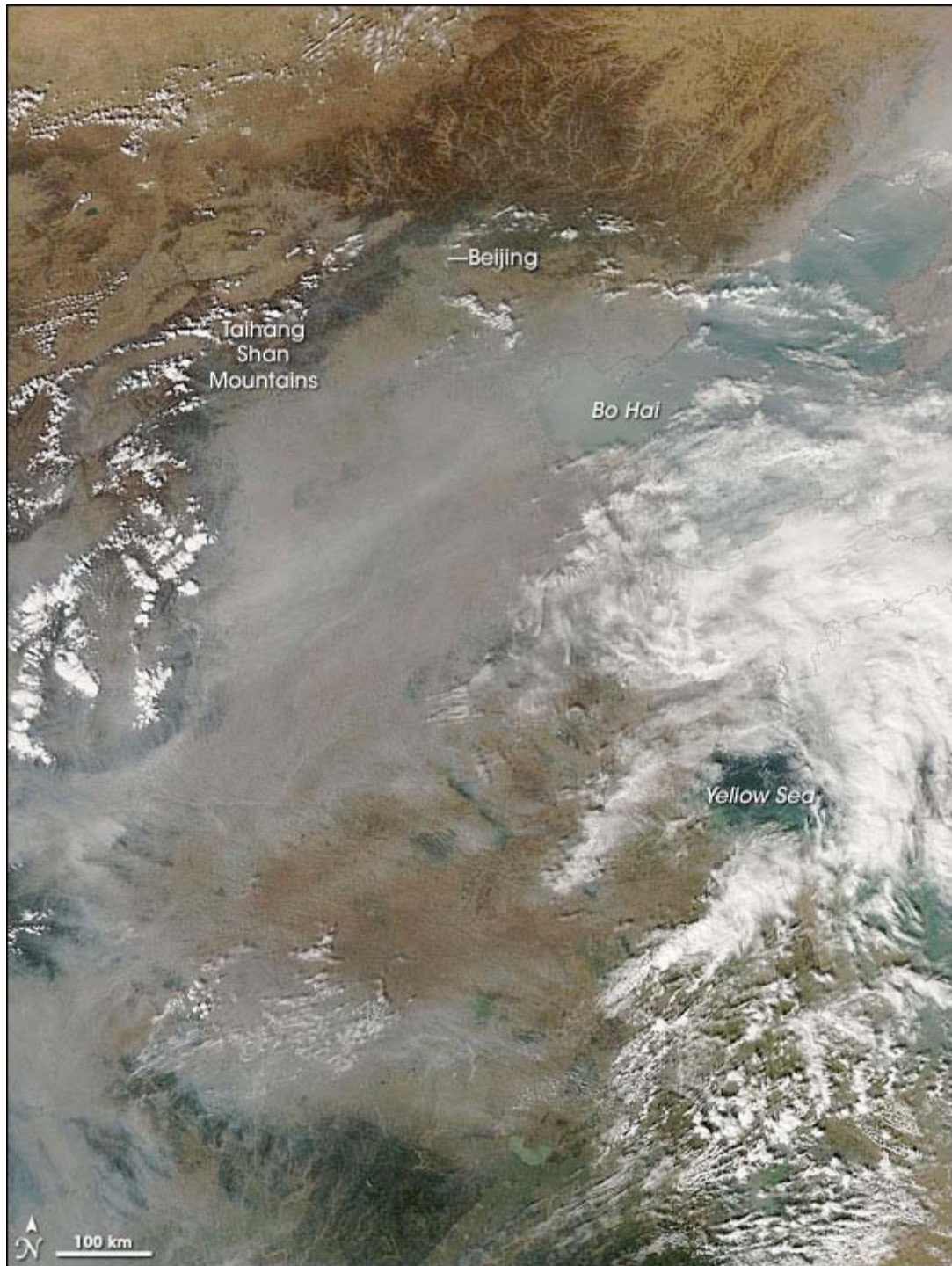


Beijing is centered on the blue circle in this **June 13, 2008** MODIS/Terra, AERONET Subset image. **Beijing's API for June 13th was given as 105**, seemingly a low value for the conditions shown above.

Earlier this year the MEP removed all information from its English language web site: <http://www.zhb.gov.cn/english/air-list.php3>, then shut it down. And access to their Chinese language web site was difficult and erratic during the transition from agency (SEPA) to ministry (MEP). All of these situations have raised questions about the credibility of Beijing's API reports.

China's Ministry of Environmental Protection's (MEP) web sites for API reporting:
<http://datacenter.mep.gov.cn/> or <http://english.mep.gov.cn/>

For more on China's Ministry of Environmental Protection go to:
http://en.wikipedia.org/wiki/State_Environmental_Protection_Administration

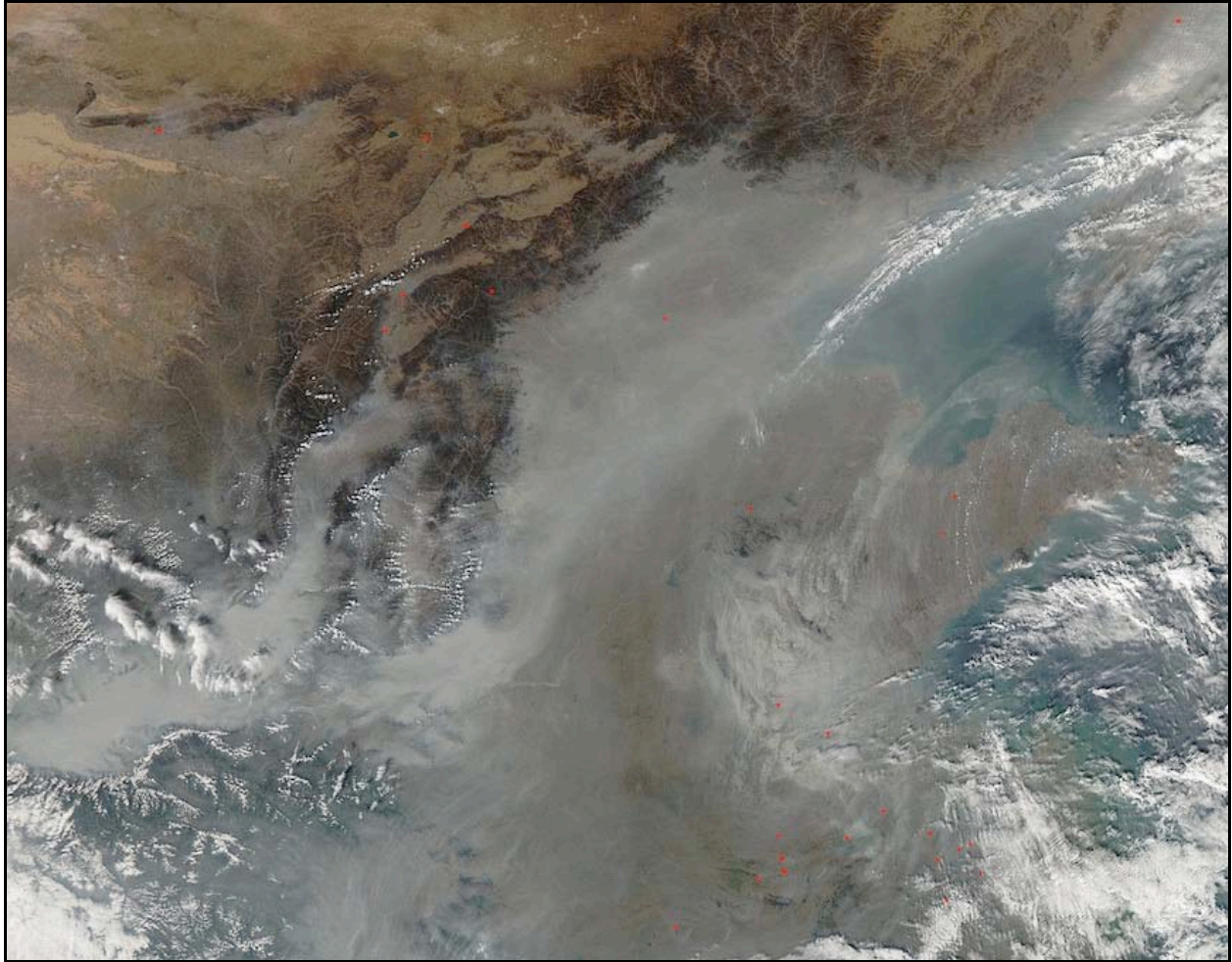


Smog over China October 16, 2008

This MODIS/Aqua image shows Beijing by-passed by the smog being blown northeast across the eastern plains and the Bo Hai by southwest winds.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=35591>



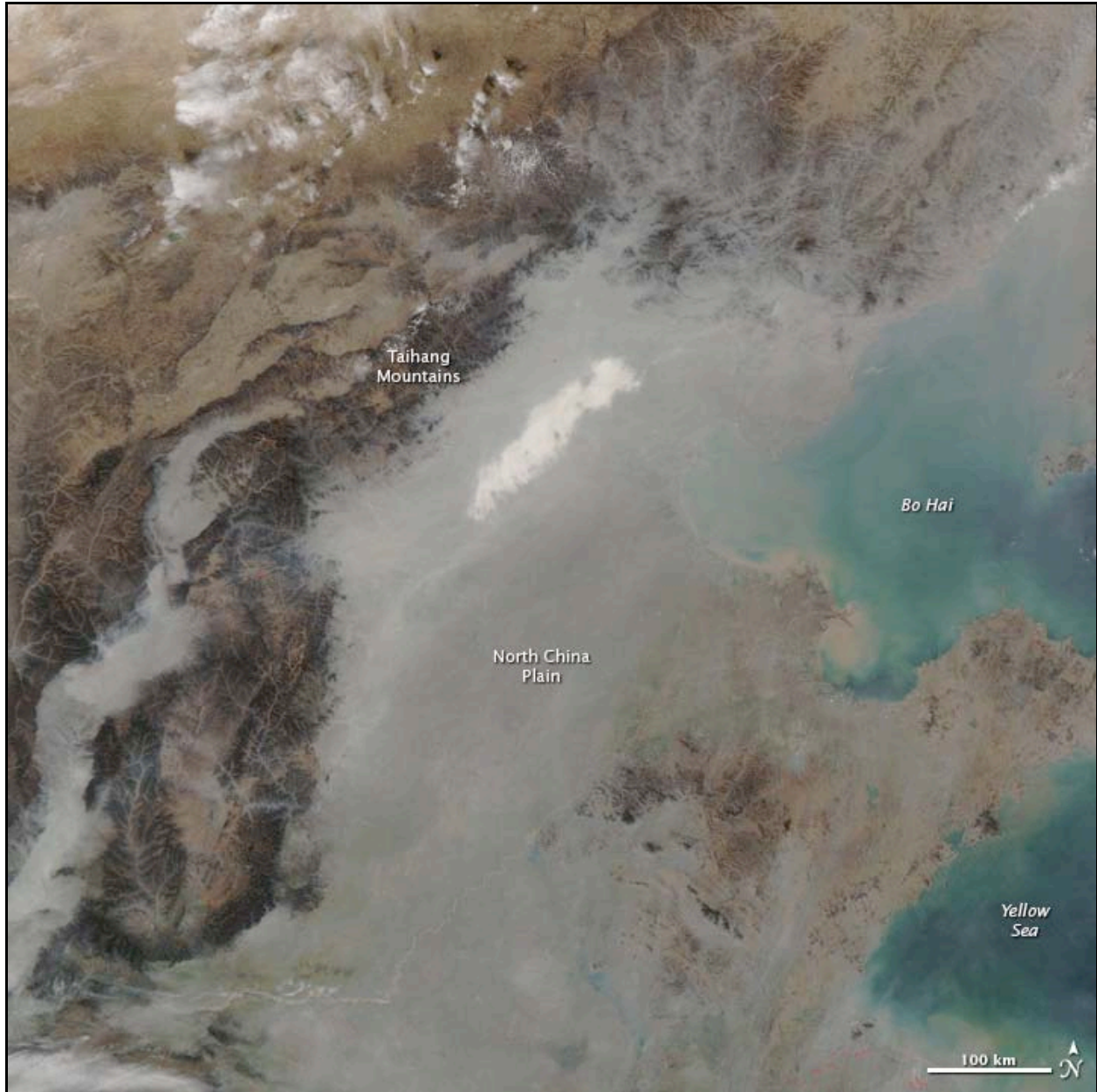
Smog over the North China Plain

Thick smog and haze settled over much of eastern China on **October 28, 2009**. In this image captured by the MODIS/Aqua instrument, the gray-brown smog conforms to the low-lying contours on the north side of the Yellow River Valley across the North China Plain, and on across the Bohai Sea.

Note, however the thickest smog is pushed up against the Shandong Hills by south winds. Also, dense smog is being pushed out of the Fen and Wei river valleys by southwest winds through the gap at the southern end of the Taihang Mountains where the course of the Yellow River flows out onto the North China Plain. Note the intense smog as it rounds the turn against the mountains.

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=40941>

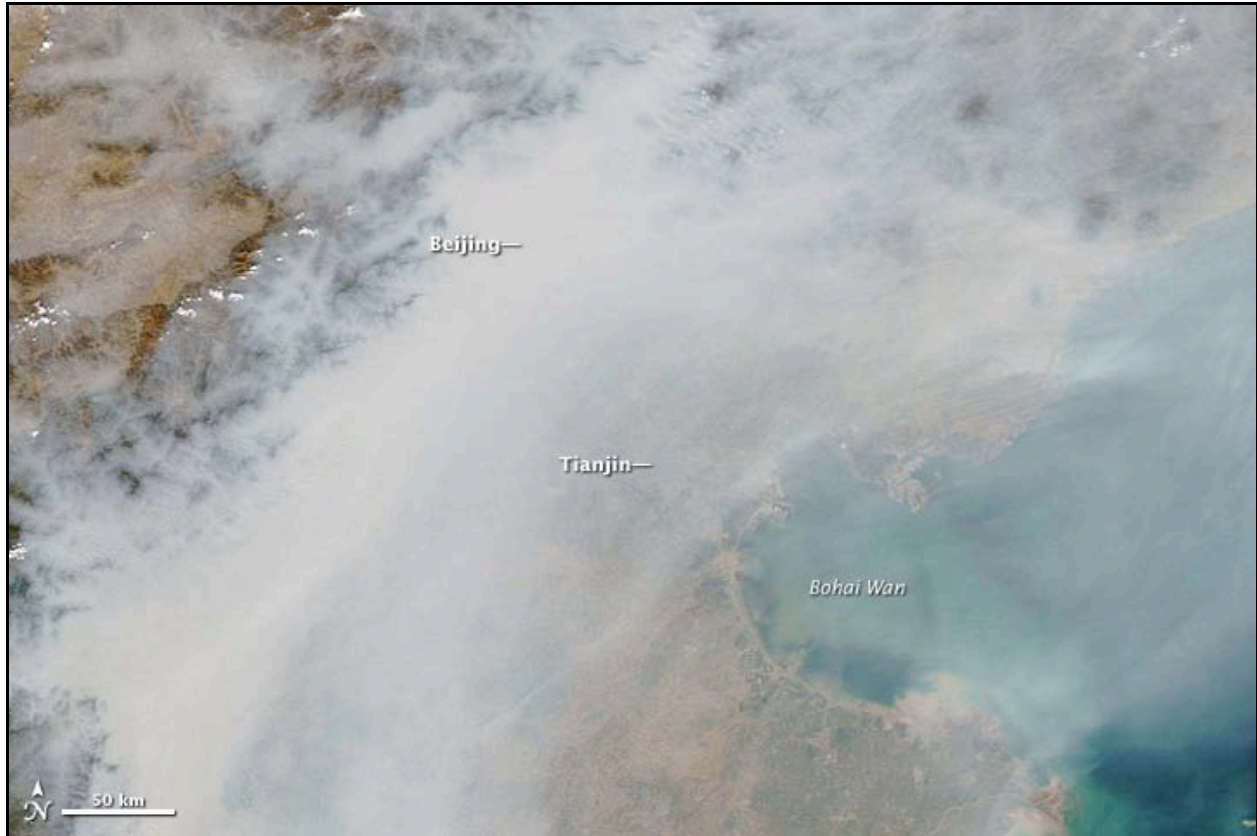


Smog over Eastern China November 6, 2009

A gray-white film of haze and smog again blanketed eastern China on November 6, 2009. The low-lying haze seeps into mountain valleys along the edge of the North China Plain, leaving the dark brown peaks clear. The haze also drifts east over the Bo Hai and the Yellow Sea. The MODIS/Aqua instrument acquired this natural colored image in the early afternoon. A day earlier Beijing's API reached 136.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=41101>

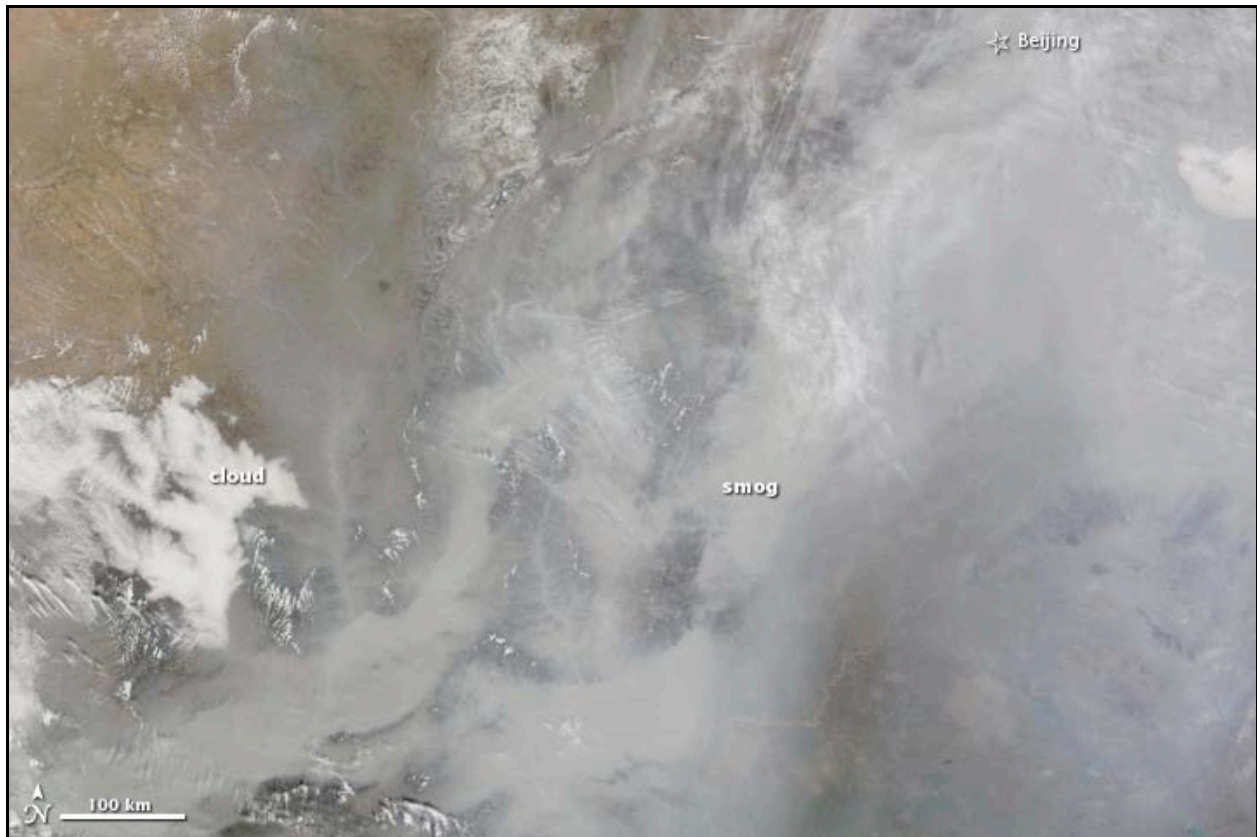


Smog over Beijing, Tianjin & Bohai Wan October 9, 2010

The importance of this MODIS/Aqua image is the source Earth Observatory article it came from *Aerosols: Tiny Particles, Big Impact*, which is referenced below. But note how little has changed in China's problems with air pollution over the past decade. It may be a case where any improvements in reducing air pollution have been off-set by the tremendous growth in manufacturing and car ownership that has occurred during the same period. Beijing's API reached 177, a Grade 3B level on this day.

Web Site Reference

<http://earthobservatory.nasa.gov/Features/Aerosols/page1.php>



Smog over China February 20, 2011

Dense smog settled over the North China Plain during February 2011. The featureless gray-brown haze is so thick that the ground is not visible in parts of this image taken by the MODIS instrument on NASA's Terra satellite. At that time, a weather station at Beijing's airport reported visibility of 1.9 miles (3.1 kilometers). Visibility dropped as low as 1.1 miles (1.8 km) later in the afternoon.

Smog frequently builds up in eastern China during the winter when weather conditions trap pollutants over the plain. Haze had been reported over Beijing for much of the previous week and following week. Beijing's API the 20th was 100, a Grade 2 level. Beijing's API reached 333 on the 21st a Grade 5 level, the top of China's reporting scale.

It is not possible to tell from this view exactly what pollutants made up the haze on February 20, but it probably contains mostly soot or black carbon and possibly some ground-level ozone. Soot is released from burning fossil fuels (particularly diesel and coal), wood, and other biofuels. These same processes also release chemicals that combine in sunlight to form ozone: methane, nitrogen oxides, volatile organic compounds, and carbon monoxide. In China, coal is an important fuel burned in home heating and cooking and energy production.

Both soot and ozone cause respiratory problems and can permanently damage the lungs. Ozone harms plants, which decreases food production. Soot and methane (one of the gases that create ozone) also contribute to global warming. In fact, a UN report to be released this week found that reducing emissions of black carbon and methane would cut global warming in half over the next forty years. By cutting carbon dioxide emissions as well as controlling soot and methane, the global temperature change could be kept under 2 degrees Celsius (4 degrees Fahrenheit) in the short term.

The panel of 70 scientists that prepared the report for the United Nations Environment Program identified 16 control measures, such as installing clean-burning cooking stoves and putting particle filters on vehicles, that would significantly reduce black carbon and methane pollution using existing technologies. The measures would also improve air quality and increase food production, preventing as many as 2.5 million deaths.

Asian countries, particularly China and India, emit the most soot and would, therefore, see the greatest economic and health benefits in reducing emissions. To read more, see "Cleaning the air would limit short-term climate warming" below.

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Voiland, A. (2011, February 20). Cleaning the air would limit short-term climate warming. NASA. <http://www.nasa.gov/topics/earth/features/cleanair-warming.html>

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=49398>

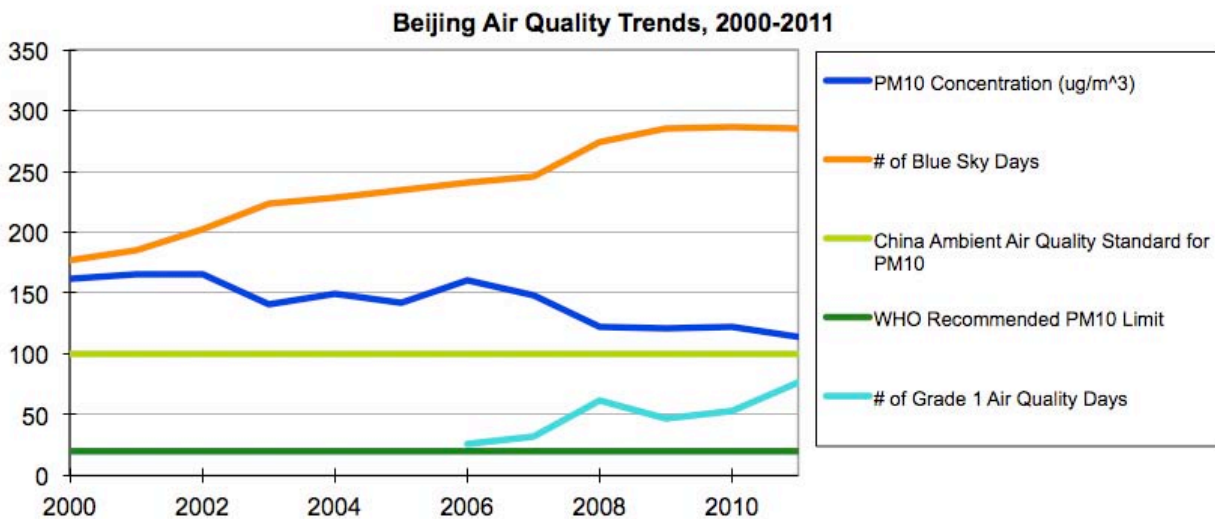
Summary of Beijing's Air Quality from 2000 through 2011

by Vance on the blog [livefrombeijing](http://www.livefrombeijing.com)

"Each year for the past few years around this time, I've posted an overall summary of Beijing's annual air quality. Although I've had less time this year to update this blog regularly, I thought I would come out of hiding this weekend to take a look again at overall trends.

I won't repeat my methodology in this post (it's described in detail in previous years' summaries); let's just jump straight to the conclusions.

Using MEP's own data, I calculate that Beijing in 2011 had a Blue Sky Day (< 101) count of 285 and a calculated **average PM10 concentration of 114 ug/m³**. Trends of Beijing's Blue Sky Days and PM10 concentrations are shown here:



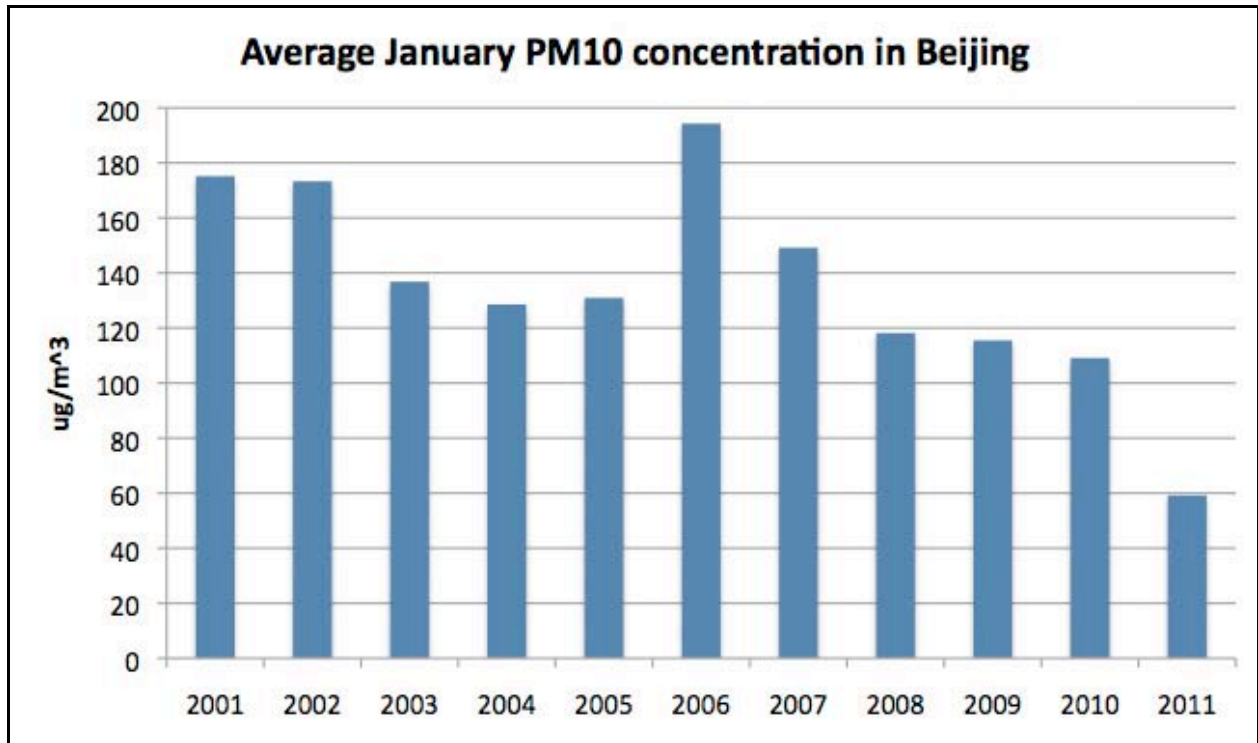
Beijing's air quality still does not meet China's own air quality standard, and is still nearly six times worse than the recommended particulate matter target set by the WHO. In other words, the air here is still just awful. We even saw reports this year (the first in the Chinese media that I can remember) directly linking air pollution episodes to acute health impacts and even grounded flights."

Web Reference for text and web links high-lighted above

<http://www.livefrombeijing.com/2011/12/summary-of-beijings-2011-air-quality/>

Web Reference for general site:

Blog livefrombeijing: <http://www.livefrombeijing.com/>



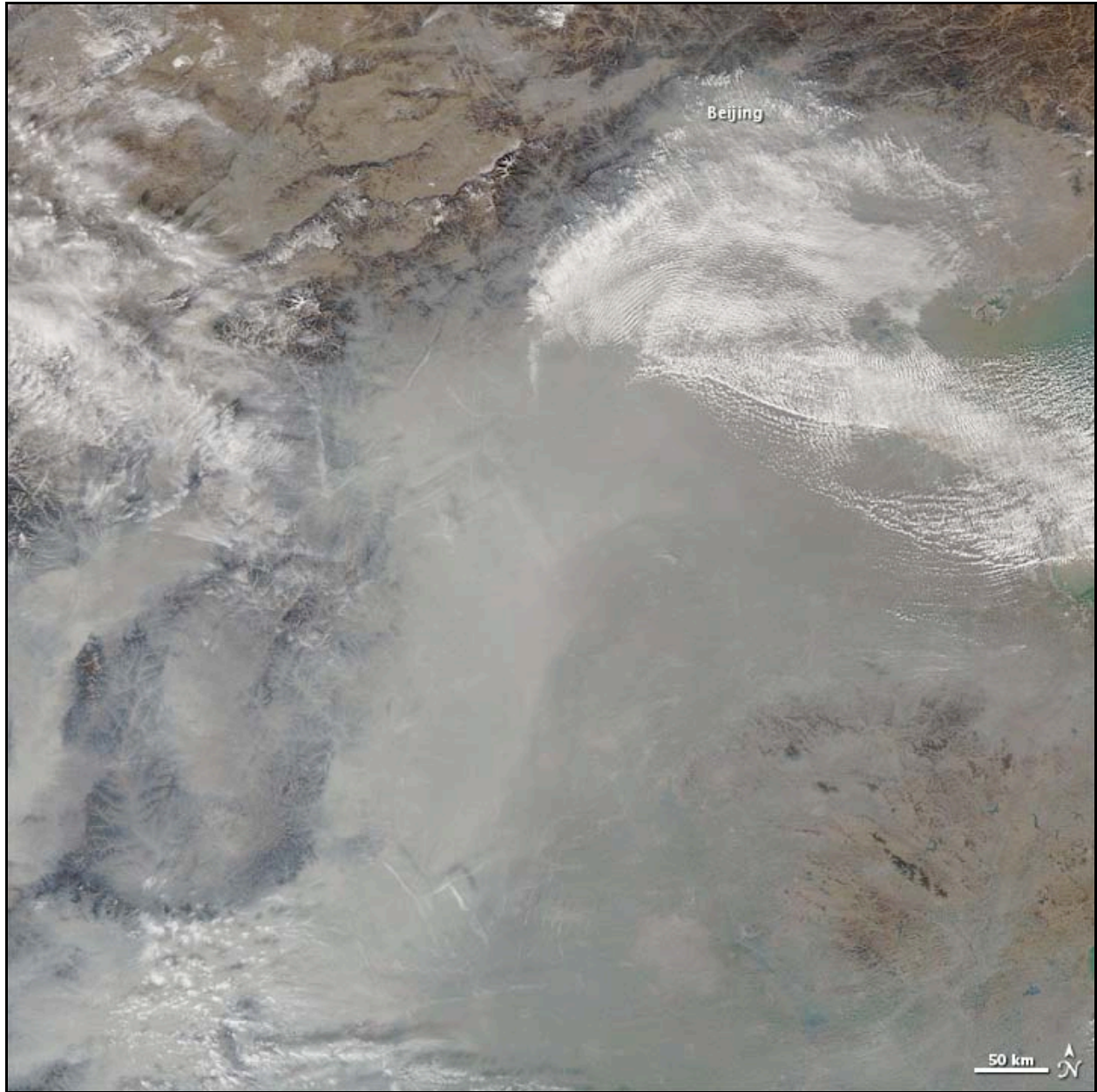
Vance chart of January PM10 from 2001 to 2011

"The summary from Chinese officials is rather understated given how dramatically improved the air quality was this month. My guess is that the Beijing EPB is as surprised as the rest of us at how terrific the air quality has been recently, and are reluctant to claim too much credit before further analysis is done. While it's true that we are certainly seeing some fruits of the variety of emission control programs implemented over the past decade.

I think that a bigger factor recently has been consistent weather patterns favorable to pollutant dispersion as opposed to major changes in source emissions."

Web Reference

<http://www.livefrombeijing.com/2011/01/>



China Smog January 6, 2012

Haze filled the skies over eastern China in early January 2012, extending south from Beijing over the North China Plain and southeast toward the Yellow Sea. The MODIS instrument on NASA's Aqua satellite captured this natural-color image on **January 6, 2012**. In some places, especially up against the Taihang Mountains the gray-beige haze is thick enough to completely hide the land surface below. On this day **Beijing had an API of 95**. Shijiazhuang, further south along the mountain front, had an **API of 114**.

On January 6, Reuters reported that the city government of Beijing planned to release the results of stricter air pollution standards. Airborne particles are generally measured in microns, or micrometers. A micron is one-millionth of a meter. Beijing's air-monitoring center has historically tracked particles at 10 microns (PM10) or larger. Particles with diameters of 2.5 microns or smaller, known as PM2.5, are believed to pose the greatest health risks because they can lodge deeply in the lungs, says the World Health Organization and the U.S. EPA. Beijing's new air-quality standards are expected to monitor PM2.5 particles.

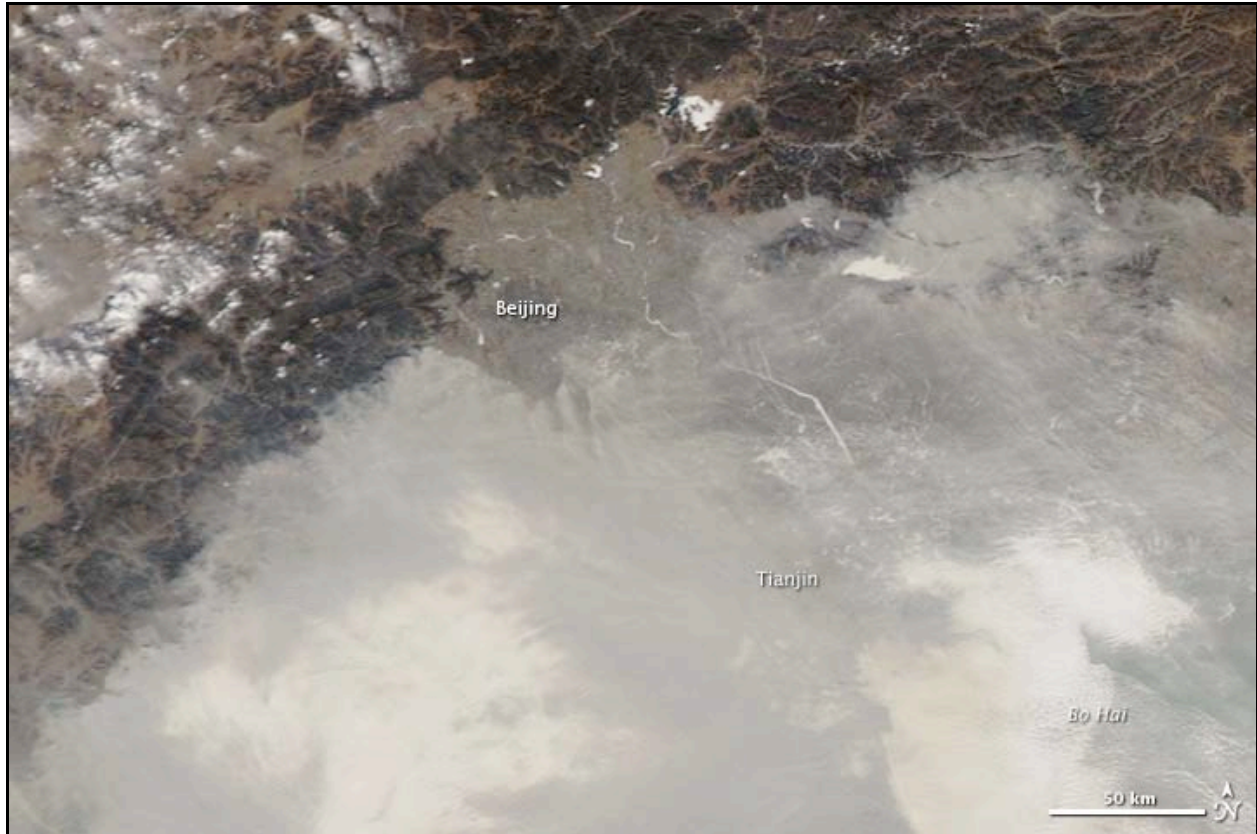
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Reuters. (2012, January 6). China to release stricter Beijing pollution measure. <http://www.reuters.com/article/2012/01/06/us-china-pollution-idUSTRE8050AY20120106>

U.S. Environmental Protection Agency. (2010, August 6). Fine Particle Designations: Frequently Asked Questions: <http://www.epa.gov/pmdesignations/faq.htm>

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=76888>



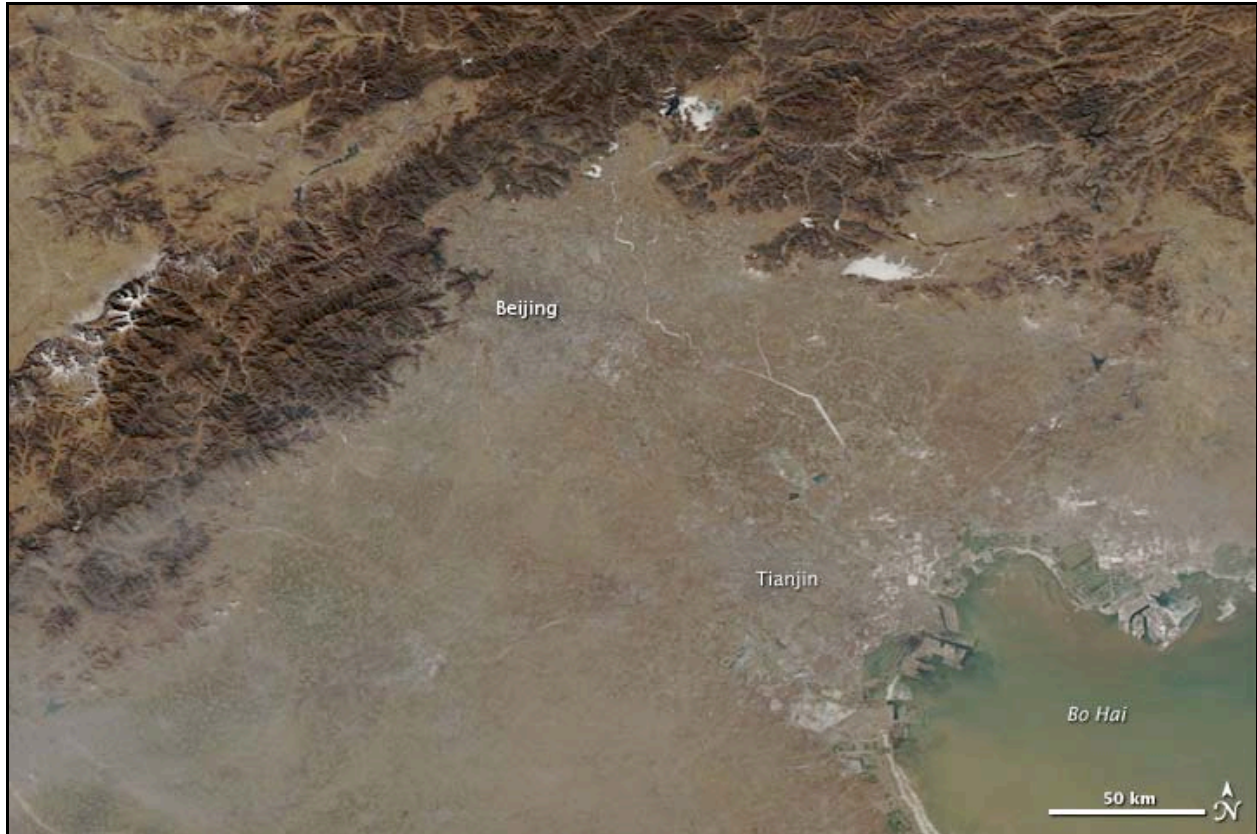
Beijing January 10, 2012

Fog and smog blanketed the North China Plain on January 10, 2012, making travel difficult. The Beijing airport cancelled 43 flights and delayed 80 more in the morning hours, when visibility dropped to 200 meters, according to state news reports. **The official API reading for Beijing for January 10, 2012 was 161 PM10.**

Provinces all across the North China Plain reported low visibility on the 10th. **The city of Shijiazhuang reported an unusually high PM10 reading of 239.** The smog decreased visibility in satellite images too. A milky, gray pall entirely blocks the ground from view in the above image, taken in the early afternoon by the MODIS instrument on the Aqua satellite. Patches of white fog or low cloud hang below the gray smog. By 04:50 hours UTC, when the image above was acquired, northwest winds had already begun to push the smog out of Beijing in the north, while the rest of the North China Plain still suffered from poor air quality.

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=76935>



Beijing January 11, 2012

By the next day, when the Aqua MODIS acquired this image, skies were mostly clear across the region. **Beijing reported an API of 25 for PM10** on the 11th. One major constituent of smog is particle pollution, such as dust, liquid drops, and soot from burning fuel or coal. Particles smaller than 10 micrometers (called PM10) are small enough to enter the lungs, where they can cause respiratory problems. The density of PM10 reached 560 micrograms per cubic meter of air on January 10, said the Beijing Environment Protection Bureau. By contrast, U.S. cities exceed air quality standards when PM10 concentrations reach 150 micrograms per cubic meter.

But most of the pollution that makes up smog isn't PM10; **it's finer particles, smaller than 2.5 micrometers in diameter (PM2.5)**. These particles can embed themselves deep in the lungs and occasionally enter the blood stream. The fine particles are highly reflective, sending sunlight back into space. The Chinese government does not currently measure PM2.5, but the U.S. Embassy in Beijing reports their measurements hourly in a Twitter feed (<https://twitter.com/BeijingAir>). On the morning of January 10, PM2.5 measurements were off the scale, though by afternoon they had dropped to moderate levels. The Beijing Environmental Bureau will start releasing PM2.5 measurements sometime before January 23, the Chinese New Year.

The Chinese government is implementing a plan to monitor PM2.5 across the nation by **2016**. Even with improved monitoring, winter smog events may be difficult to control. One common cause of poor air quality in the winter are temperature inversions in which a layer of cold, dense air gets trapped beneath a more buoyant layer of warm air. As long as the temperature inversion persists, pollution builds in the trapped pocket of air near the ground.

However, it is becoming clearer with the passage of time that the major controlling factors in how severe and where air pollution ends up in China are to be found in the winds and geomorphology of China, rather than just the amount of pollution produced.

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Wheeler, C. (2012, January 3). Air pollution hazardous to China's economic health. The Globe and Mail. <http://www.theglobeandmail.com/report-on-business/international-news/air-pollution-hazardous-to-chinas-economic-health/article2279684/>

Xinhua. (2012, January 10). PM2.5: Easy to monitor but hard to control. http://www.chinadaily.com.cn/china/2012-01/10/content_14417799.htm

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=76935>

Scientists Find New Dangers in Tiny but Pervasive Particles in Air Pollution

New York Times, 2012-2-18

Fine atmospheric particles — smaller than one-thirtieth of the diameter of a human hair — were identified more than 20 years ago as the most lethal of the widely dispersed air pollutants in the United States. Linked to both heart and lung disease, they kill an estimated 50,000 Americans each year. [They are now designated as PM 2.5].

But more recently, scientists have been puzzled to learn that a subset of these particles, called **secondary organic aerosols (SOA)**, has a greater total mass, and is thus more dangerous, than previously understood. A batch of new scientific findings is helping sort out the discrepancy, including, most recently, a study led by scientists at the University of California, Irvine, and the Pacific Northwest National Laboratory in Richland, Wash., that is scheduled to be released on Tuesday. It indicates that the compounds' persistence in the atmosphere was under-represented in older scientific models. "If the authors' analysis is correct, the public is now facing a false sense of security in knowing whether the air they breathe is indeed safe," said Bill Becker, of the National Association of Clean Air Agencies.

Taken together, the findings of the new study and of a handful of others published in the past two years could mean that two decades' worth of pollution-control strategies — focused on keeping tiny particles from escaping into the atmosphere — have addressed only part of the problem. Scientists and regulators say that new models, strategies and technologies would be needed to address the secondary organic aerosol particles, which are formed not during combustion but later, in the wake of interactions between pollutants and natural chemical compounds. Paul Shepson, a professor of analytical and atmospheric chemistry at Purdue University and one of the reviewers of the Irvine paper, called it "highly significant in scientific terms," adding that current models of fine particulates "grossly under predict" their density, "sometimes by as much as a factor of 10." A former regulator agreed. "There's no doubt this is important stuff," said Jeffrey R. Holmstead, who ran the Environmental Protection Agency's air and radiation program during the administration of President George W. Bush. "It may be harder than we thought" to clean the fine particles out of the air and protect public health, he said, "but if we really know what's causing it, we can focus our efforts more." Mr. Holmstead added that the findings could significantly affect the future design and implementation of air-pollution control strategies and that regulators would have to rethink the models that inform air quality rules.

This new information has scientists questioning whether climate change modeling should be adjusted as well. The E.P.A. has announced that it is reassessing the national ambient air quality standards for fine particulates (PM2.5), which were last set in 2006 at levels higher than the agency's staff and scientific advisers had recommended.

The agency's most recent data show that airborne particles decreased 27 percent from 2000 to 2010. A spokeswoman for the E.P.A. said the agency usually declined to comment on individual studies, preferring to incorporate them into its larger analyses during the rule making process.

The Irvine study of the formation of secondary compounds in the atmosphere, which will be published in the Proceedings of the National Academy of Science, upends previous assumptions about the fate of the by products of the pollution from internal-combustion engines. These gaseous byproducts were thought to incorporate themselves into tiny airborne drops of liquid that would then dissipate quickly as the drops evaporated.

The new study finds instead that they attach themselves more tightly to airborne organic particles, creating tiny tar balls that evaporate more slowly and persist longer than anyone had thought. E.P.A. models built on these assumptions now appear to understate the total amount of fine particles (PM_{2.5}), according to Barbara J. Finlayson-Pitts, a professor at Irvine and one of the study's authors. "If you're going to use models in a predictive sense, you need to make sure they are getting the right answer for the right reasons," she said. "Right now most models are not getting the right answer."

References

Barringer, Felicity (2012). Scientists Find Dangers in Tiny Particles in Air Pollution. New York Times, 2012-2-18.

Véronique Perraud, et. al. (2012). Nonequilibrium atmospheric secondary organic aerosol formation and growth. PNAS 2012 109 (8) 2836-2841; published ahead of print January 30, 2012, doi:10.1073/pnas.1119909109

However, not all countries have ground-based monitoring systems that measure such fine-grained pollutants. China, like most countries, has traditionally only monitored a larger type of particle pollution known as PM10. Though Chinese leaders have announced a plan to monitor PM2.5 more broadly in the future, to date only a handful of cities have started to publish PM2.5 numbers.

Satellites offer a perspective on PM2.5 that is particularly useful when ground instruments are unavailable or offer limited information. With that in mind, researchers at Columbia University's Earth Institute and Batelle Memorial Institute have developed maps based on satellite data that depict annual PM2.5 exposure in all of China's provinces.

The map above, which shows annual exposure between 2008-2010, indicates that most areas had PM2.5 levels that exceeded World Health Organization guidelines (10 micrograms per cubic meter). Areas surrounding Beijing and to the south along the coast, which fall in China's industrial heartland, had the most pollution. In many cases, annual exposure was above 40 micrograms per cubic meter. Other provinces in eastern and south central China had pollution levels above 30 micrograms per cubic meter. For comparison, the New York, Chicago, and Los Angeles metro areas have PM2.5 levels that average between 10 and 20 micrograms per cubic meter."

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=77495>

Particulate Matter 2.5 & Secondary Organic Aerosols

The discovery of **secondary organic aerosols (SOA)** and the greater importance of **PM 2.5** has altered our thinking about the dangers of these forms of air pollution. In turn this has placed a greater importance on monitoring these small particulates. From 2010 to the present we have seen a slow shift in China which now recognizes this and reports PM 2.5 for a number of cities across the country.

Web Reference for China Cities Reporting PM 2.5

<http://www.aqicn.info/?map&loc=china>

The United States Embassy in Beijing has also promoted a greater openness about the importance of **PM 2.5** by maintaining a Twitter feed of hourly PM 2.5 readings from its monitor on the grounds of the embassy.

Web Reference for U.S Embassy Twitter feed BeijingAir

<https://twitter.com/BeijingAir>

To further show the importance of open monitoring of air pollution in China, I have put together four essays on extreme air pollution events in Beijing for the years of 2010 and 2013 to date. A link to the essays is below.

Extreme Air Pollution Events in Beijing during 2010 & 2013

by David L. Alles

2013-4-24

Web Site Reference

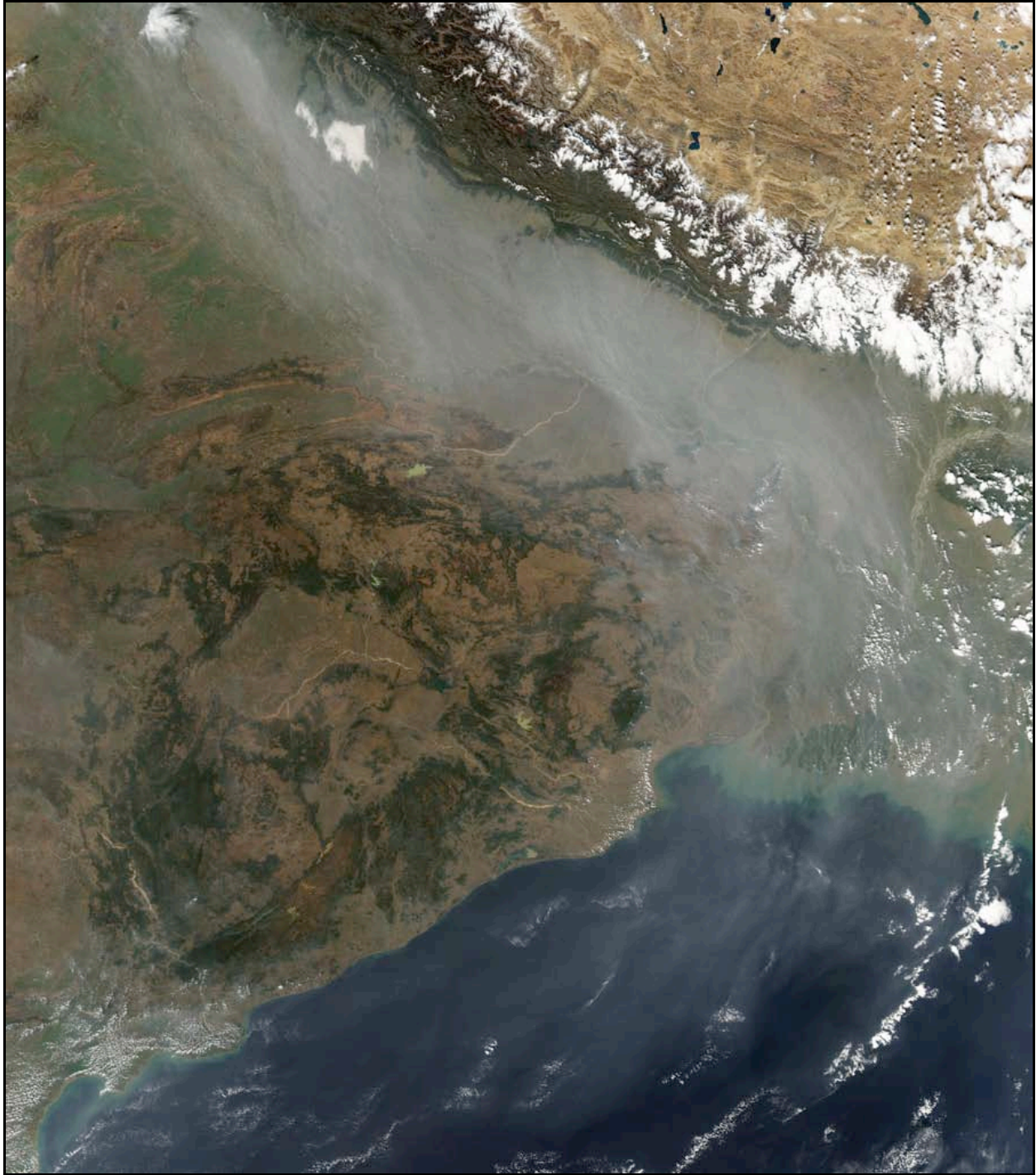
<http://fire.biol.wvu.edu/trent/alles/ExtremeAirPollutionEventsBeijing.pdf>



Air Pollution over the Indian Sub-Continent

India's air pollution is caused by many of the same sources as China's, urban growth, auto emissions, etc., with the exception that coal fired power plants contribute a smaller percentage of air pollution in India. In contrast to China, research has found that the burning of biofuels, such as wood, agricultural waste, and dried animal manure in cooking stoves, is the largest source of black carbon emissions in India contributing 42% of the total (Venkataraman, et al., 2005).

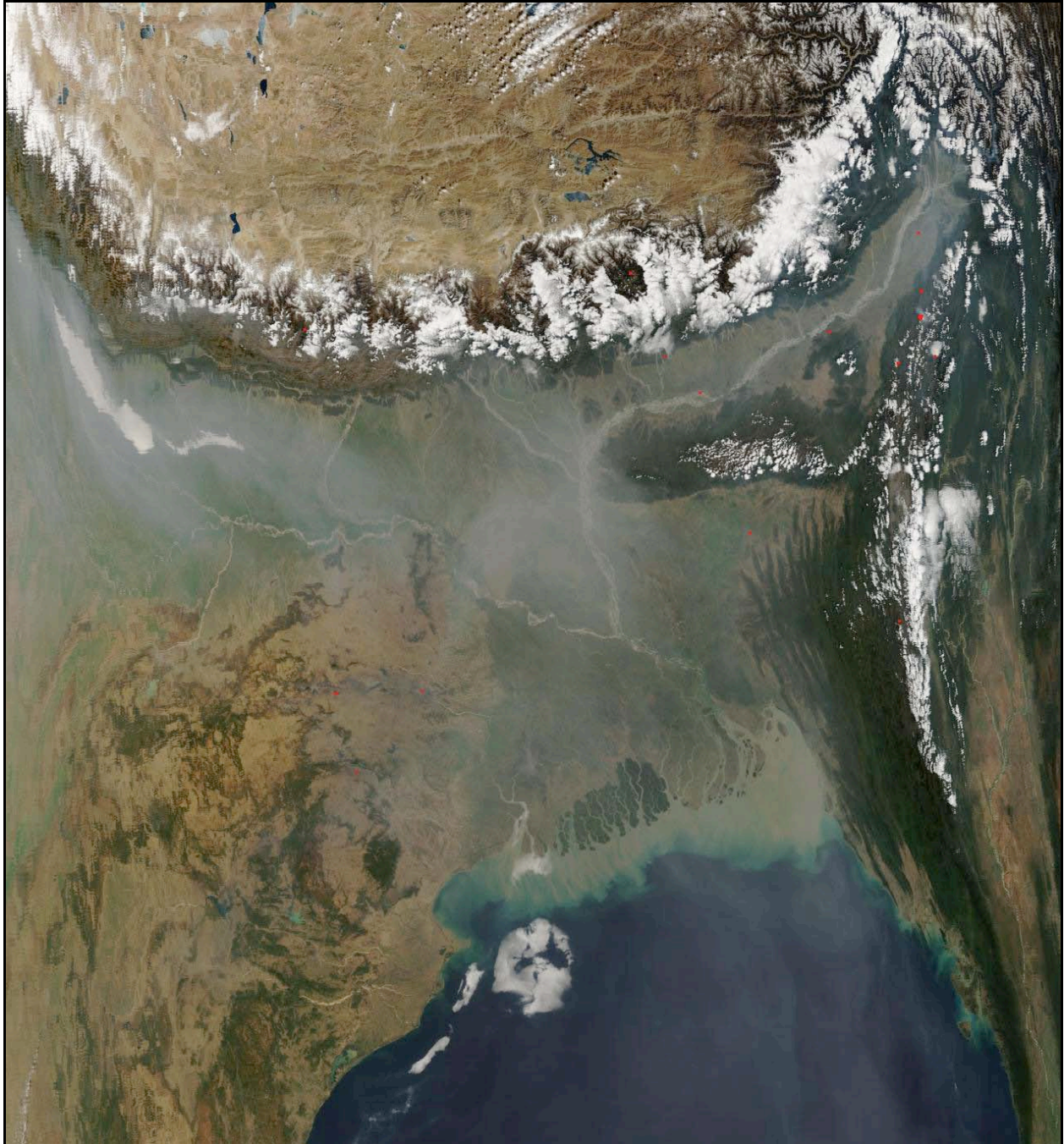
For more geography of India go to: http://en.wikipedia.org/wiki/Geography_of_India



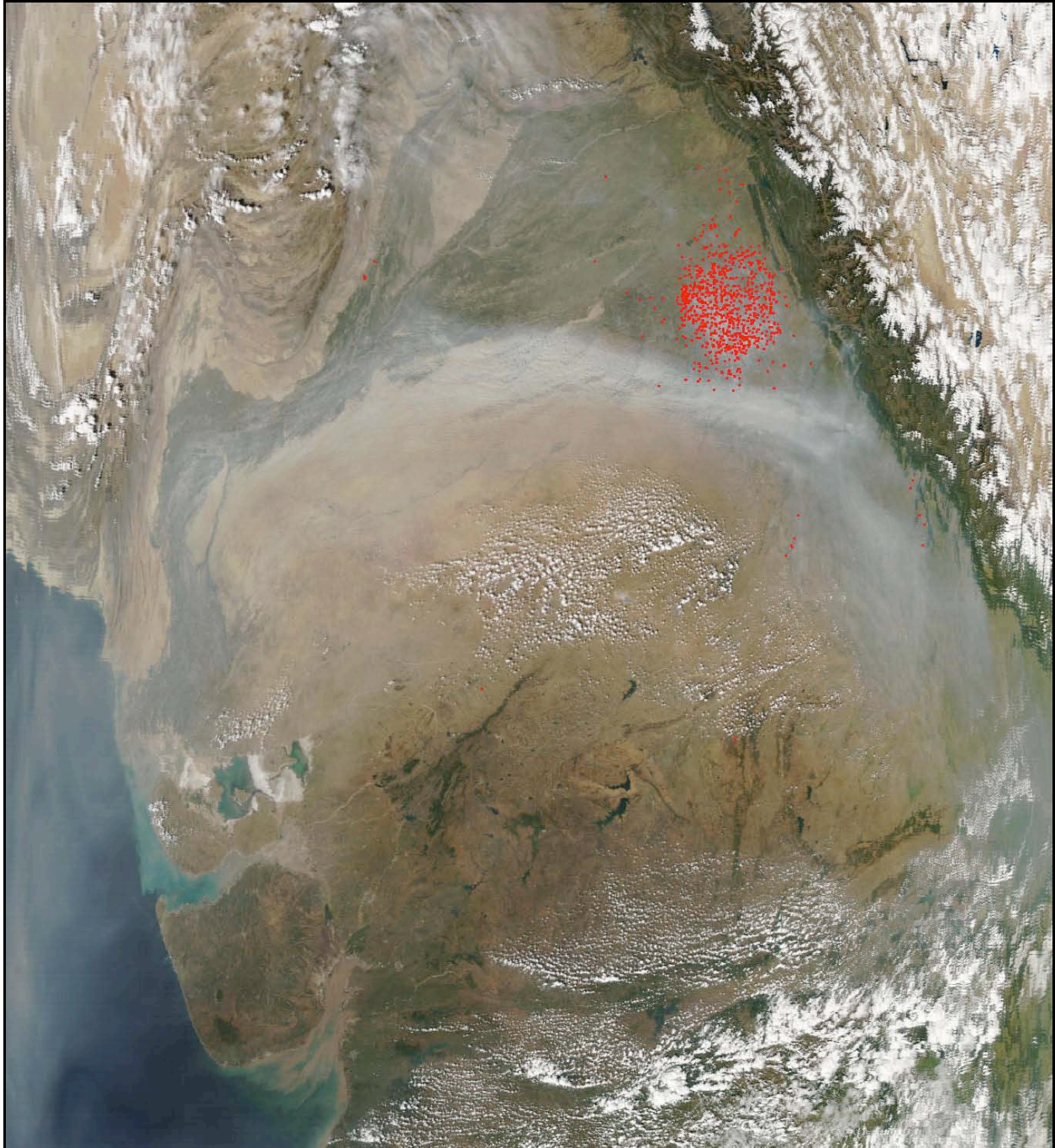
In this MODIS/Aqua image of northern India taken **December 16, 2004**, haze follows the course of the Ganges River eastward along the base of the Himalaya Mountains before turning south over Bangladesh and out into the Bay of Bengal.

Web Reference

<http://en.wikipedia.org/wiki/Ganges>



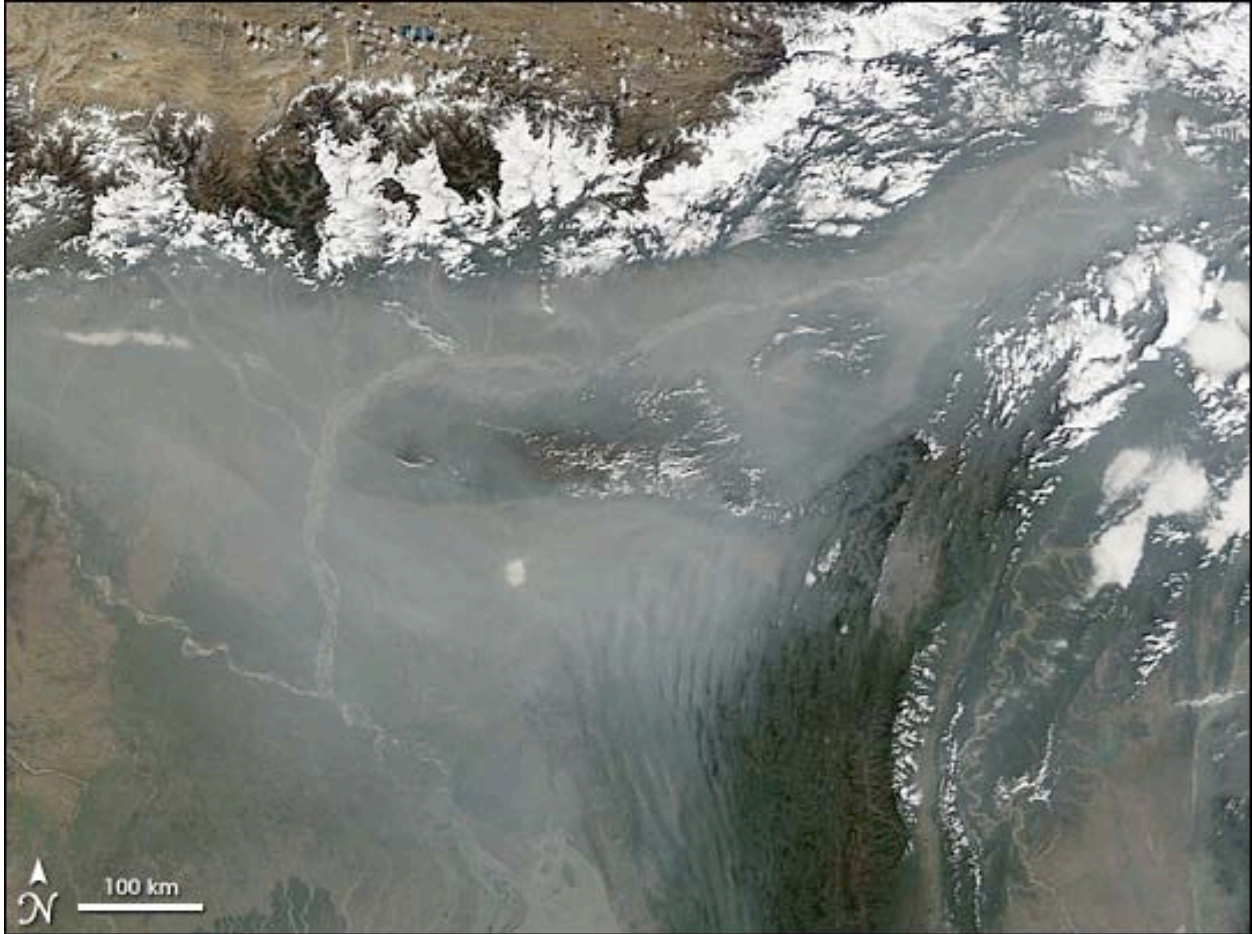
It is common to see dense haze in northern India and Bangladesh during the winter. The haze lingers near the base of the mountains because of temperature inversions. During the winter cold air flows down the mountains to the plains making the air near the ground cooler than the air above it. This traps pollution from agricultural fires and cities near the ground. (**February 3, 2006**, MODIS/ Terra image courtesy of NASA)



In this **October 29, 2006**, MODIS/Aqua image an intense area of agricultural fires (shown as red dots) in the Indian State of Punjab is spreading smoke down, both, the Indus River valley in Pakistan (left) and the Ganges River valley in India (right).



This MODIS/Natural Hazards image from **November 7, 2007**, shows smog flowing from Pakistan and India southeast along the Himalayan front toward Bangladesh making air pollution truly an international problem on the Indian sub-continent.



This MODIS/Terra image of smog over India and Bangladesh was captured **January 15, 2008**. Note the Brahmaputra River (top right), and Ganges River (left center), the Ganges Delta and Bay of Bengal in the lower center.

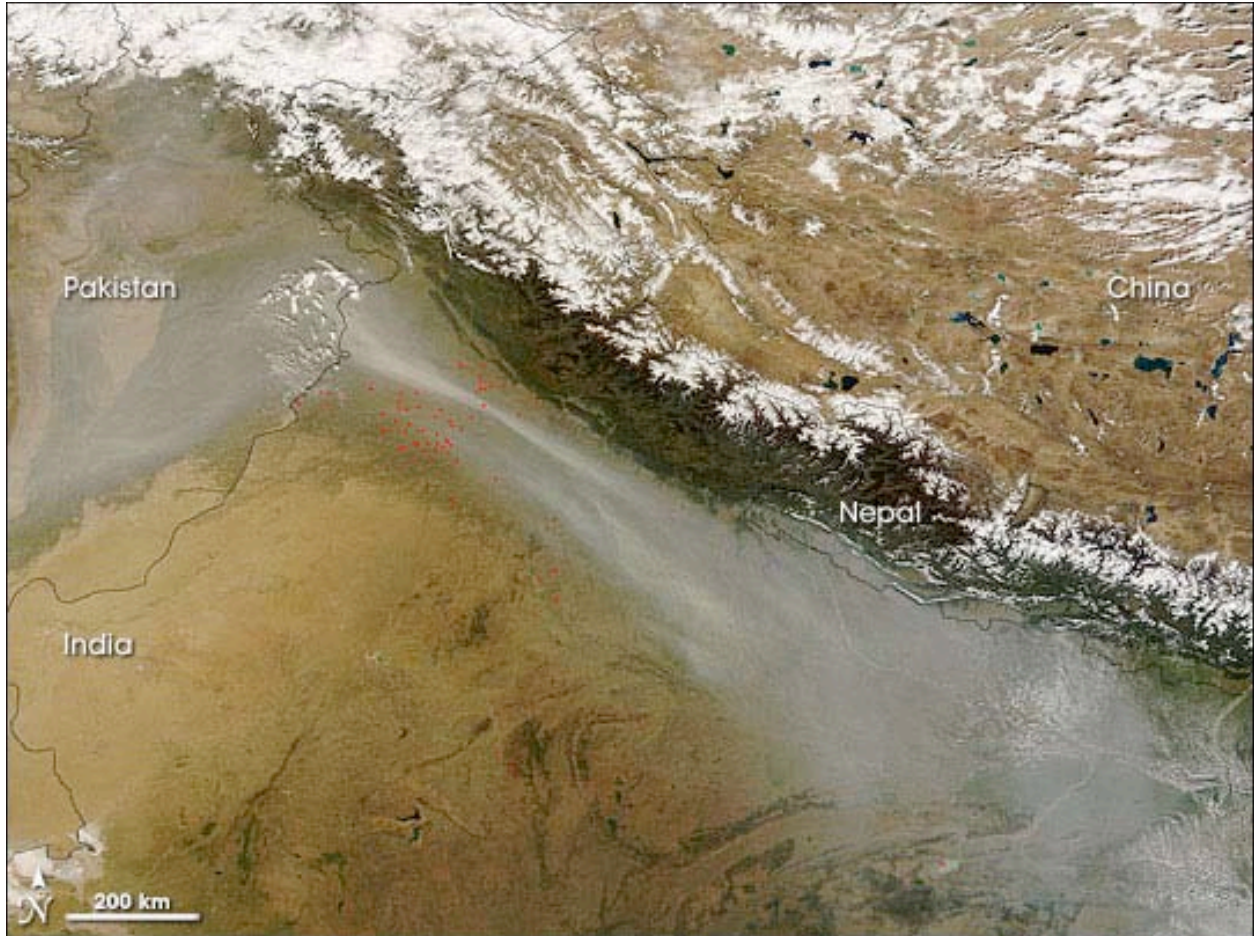
Haze continued to cloud the skies south of the Himalaya in mid-January 2008, continuing a pattern of thick haze from earlier in the month. In this image, the haze appears as a dull gray blur that hugs the Himalaya and extends southward into India and particularly Bangladesh.

Web References

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=19485>

http://en.wikipedia.org/wiki/Brahmaputra_River

http://en.wikipedia.org/wiki/Ganges_Delta

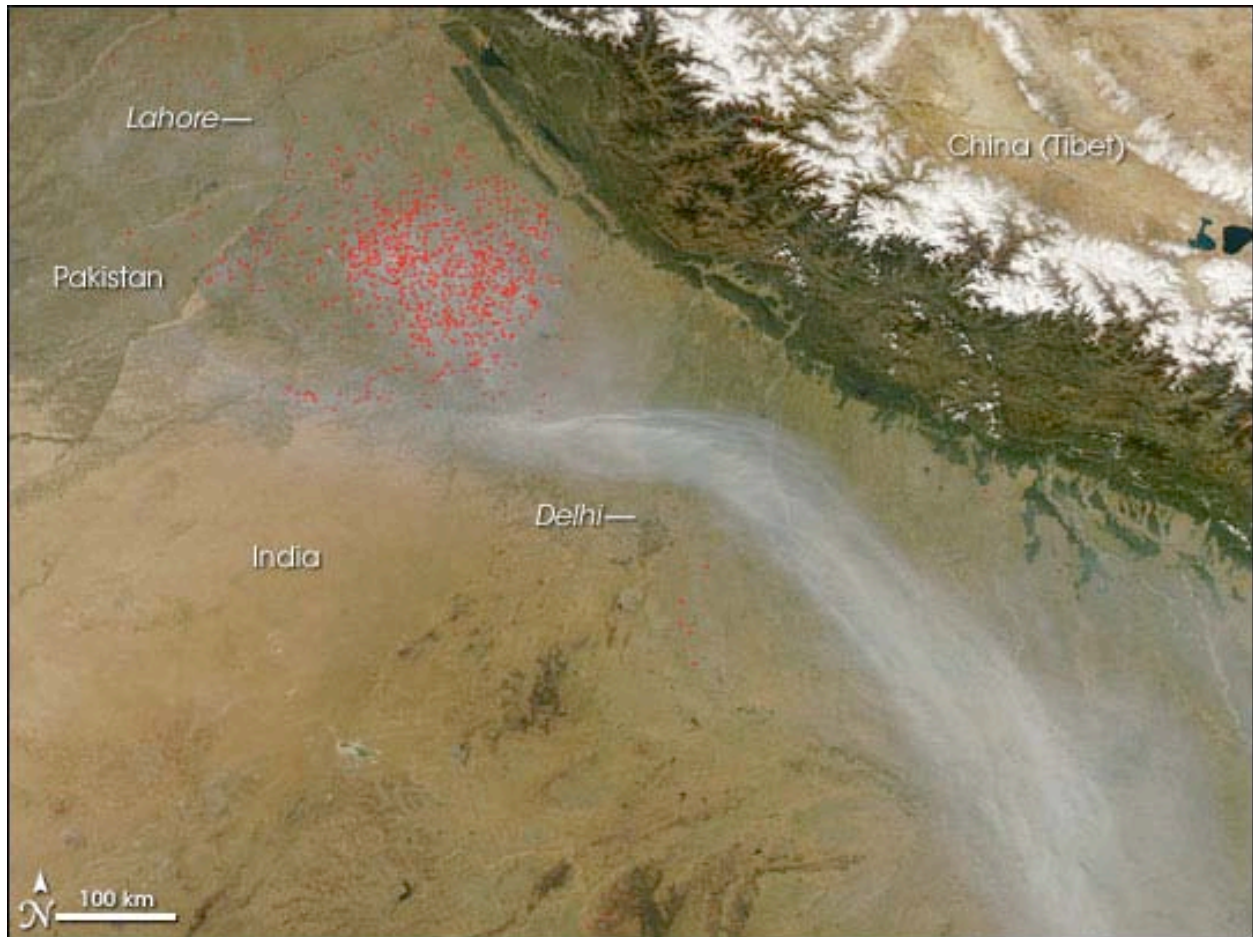


Haze along the Himalayan Front October 30, 2008

Haze hugged the Himalayas in late October 2008. This MODIS/Terra satellite image was captured on October 30. In the image haze obscures the satellite's view of the ground surface along the southwestern face of the Himalayas. An especially thick band of haze appears near the India-Pakistan border. A thick cluster of fires—indicated by red dots—occurs in the same area, although the band of haze passes over them. The haze in this image probably results from a combination of agricultural fires and urban pollution.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=35726>



Fires in the State of Punjab November 3, 2008

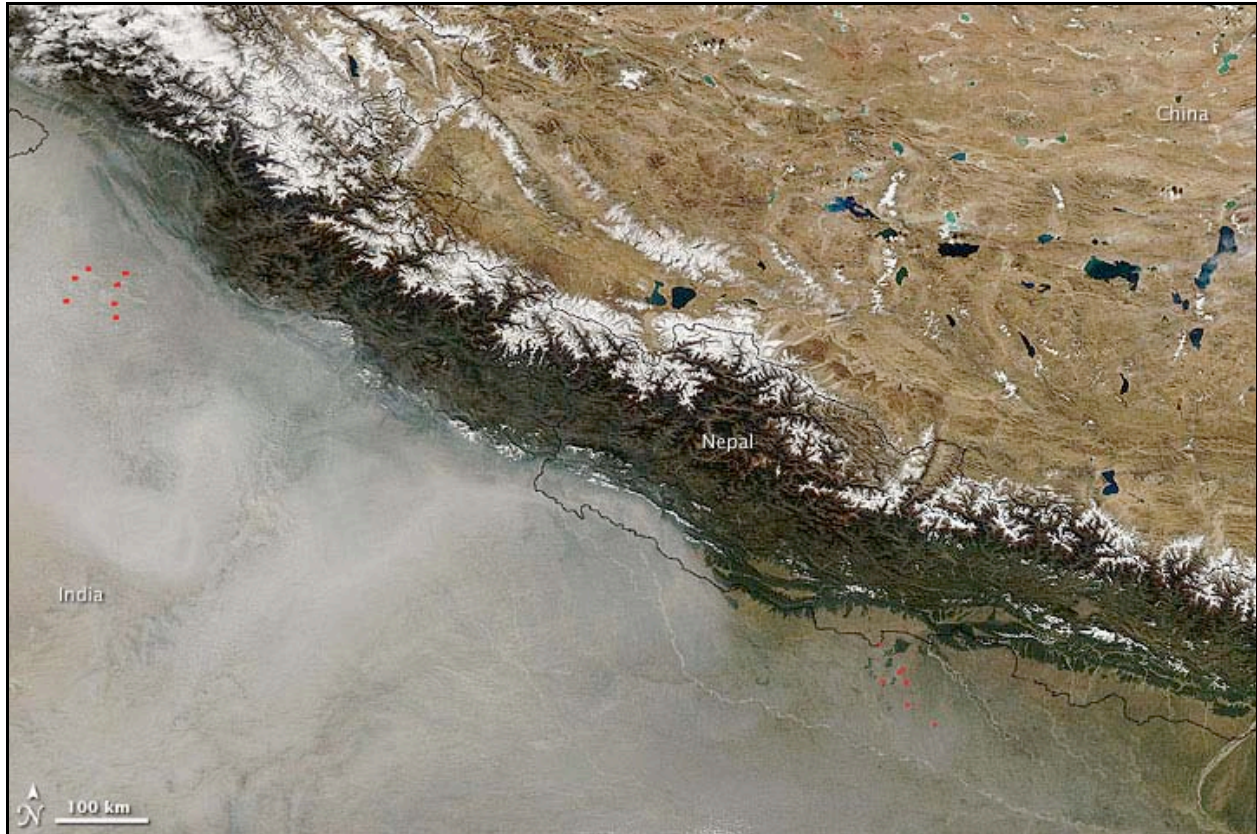
At the base of the Himalaya Mountains in northwestern India, the annual agricultural fire season was underway in the states of Punjab (closest to Pakistan) and Haryana (to the southeast). In this MODIS/Terra image captured on November 3, actively burning fires are marked with red dots.

Punjab occupies less than two percent of the area of the country, yet it produces about two-thirds of the food grains in India. Wheat and rice are the two most commonly grown food crops. Farmers use fire to clear fields and get them ready for new plantings. Although the fires are not necessarily immediately hazardous, such widespread burning can have a strong impact on weather, climate, human health, and natural resources.

A plume of haze flows southeastward, along the path of the Ganges River, which is hidden from view. Although some of the haze is probably smoke from the fires, urban pollution is a major problem in this part of India. Several large cities are found here, including Delhi, India, where soot from diesel cars is a major (and still increasing) source of air pollution.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=35765>

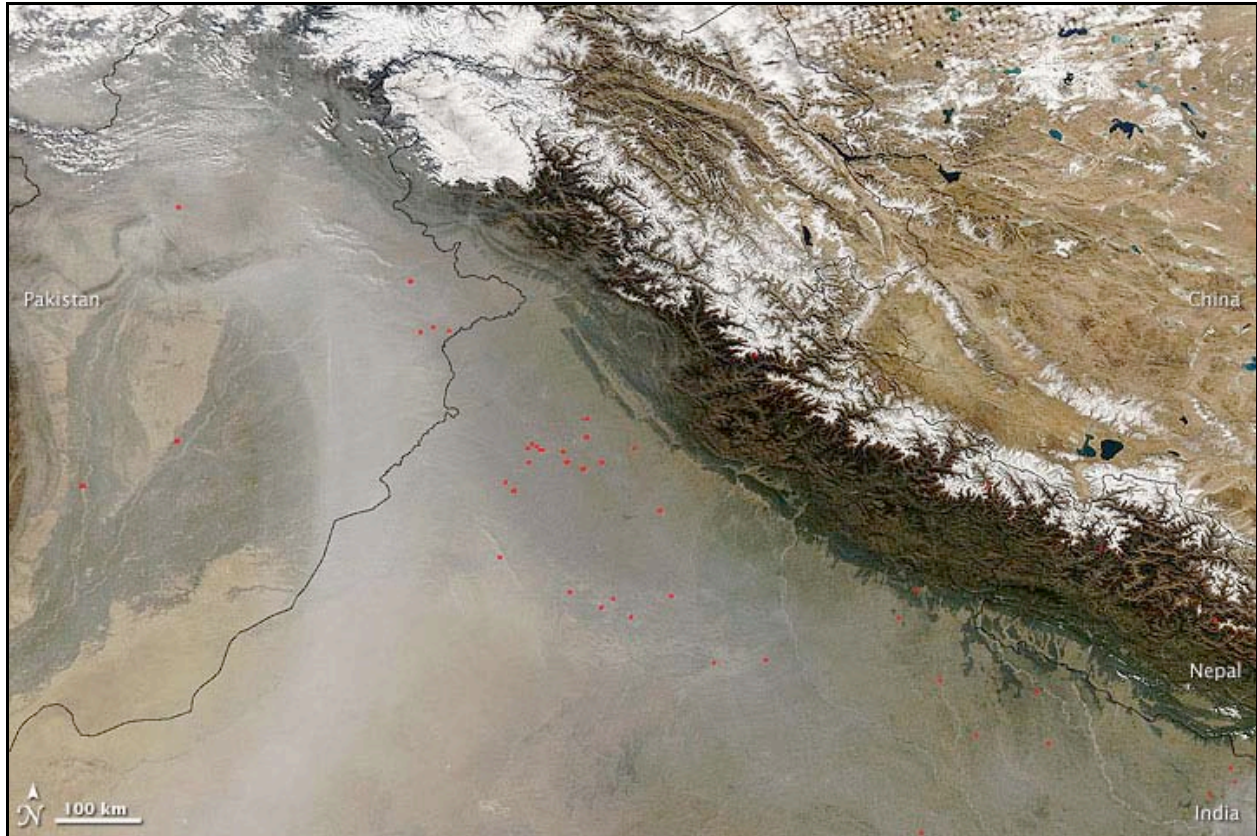


Haze along the Himalayan Front November 11, 2008

Haze lingered along the southern face of the Himalaya in early November 2008, continuing a pattern from the previous month. The MODIS/Aqua instrument captured this image of the region on November 11. In this image, a likely combination of smoke and dust swirls through northern India, west of Nepal. The red dots near the upper left corner of the image indicate fires. Fires—sometimes far more numerous than those shown in this image—burned intermittently in this area in early November, but probably cannot account for all of the haze. Urban pollution and dust from neighboring Pakistan might play a role.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=35888>



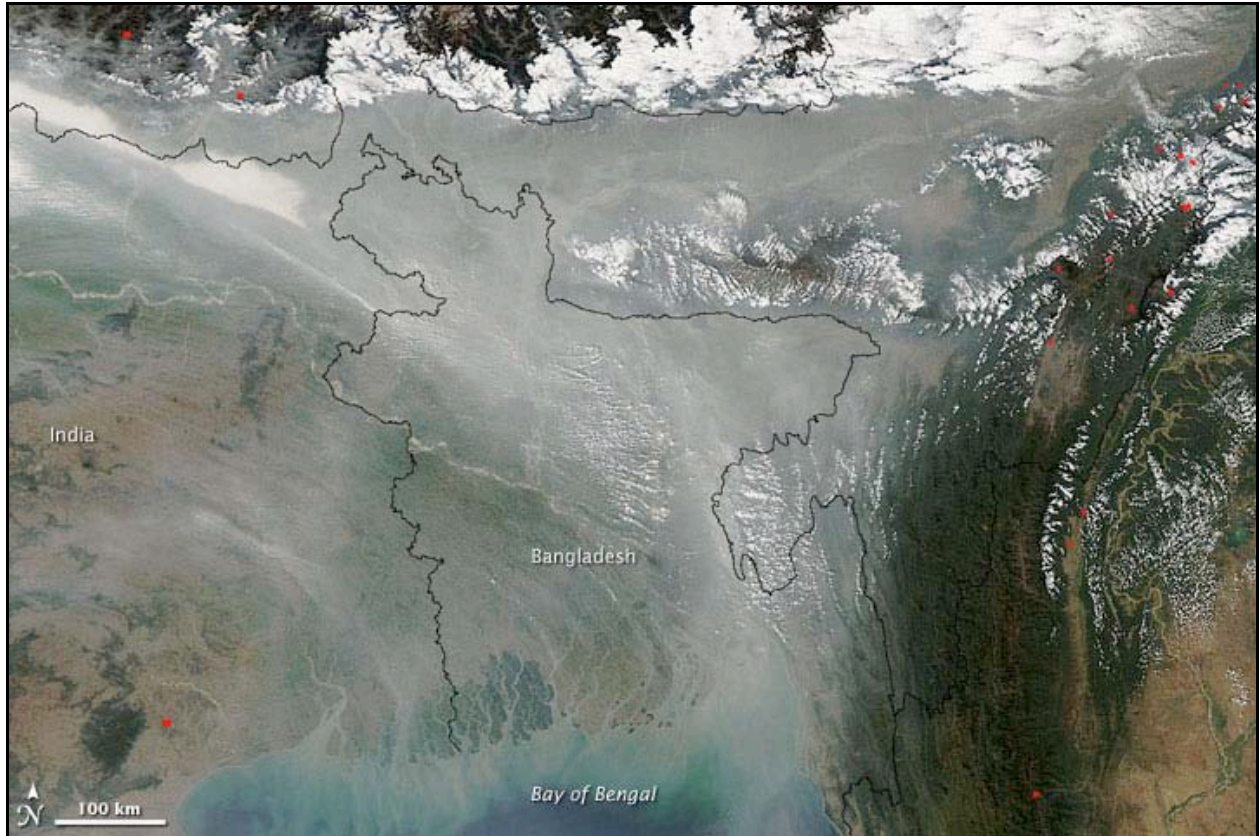
Northwest India November 16, 2008

Haze continued to hover over northern India and Pakistan in mid-November 2008. The MODIS/Aqua instrument took this picture on November 16. In this image, gray-beige haze hugs the southwestern face of the Himalaya, and in some areas, the haze appears to infiltrate the low-lying mountain valleys. To the south, an especially thick plume of haze forms an arc along the border between Pakistan and India.

The red dots scattered through the image are hotspots where MODIS has detected anomalously warm surface temperatures indicative of wildfires or agricultural fires. Although these fires contribute to the haze, they are not solely responsible. The haze probably results from a combination of smoke, pollution, and dust.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=35917>



Haze over Bangladesh January 20, 2009

The MODIS/Aqua instrument took this picture of haze concentrated over Bangladesh on January 20, 2009. In the image, pale gray haze forms an inverted triangle just south of the Himalaya. The haze stretches southward toward the Bay of Bengal along Bangladesh's eastern border.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=36702>



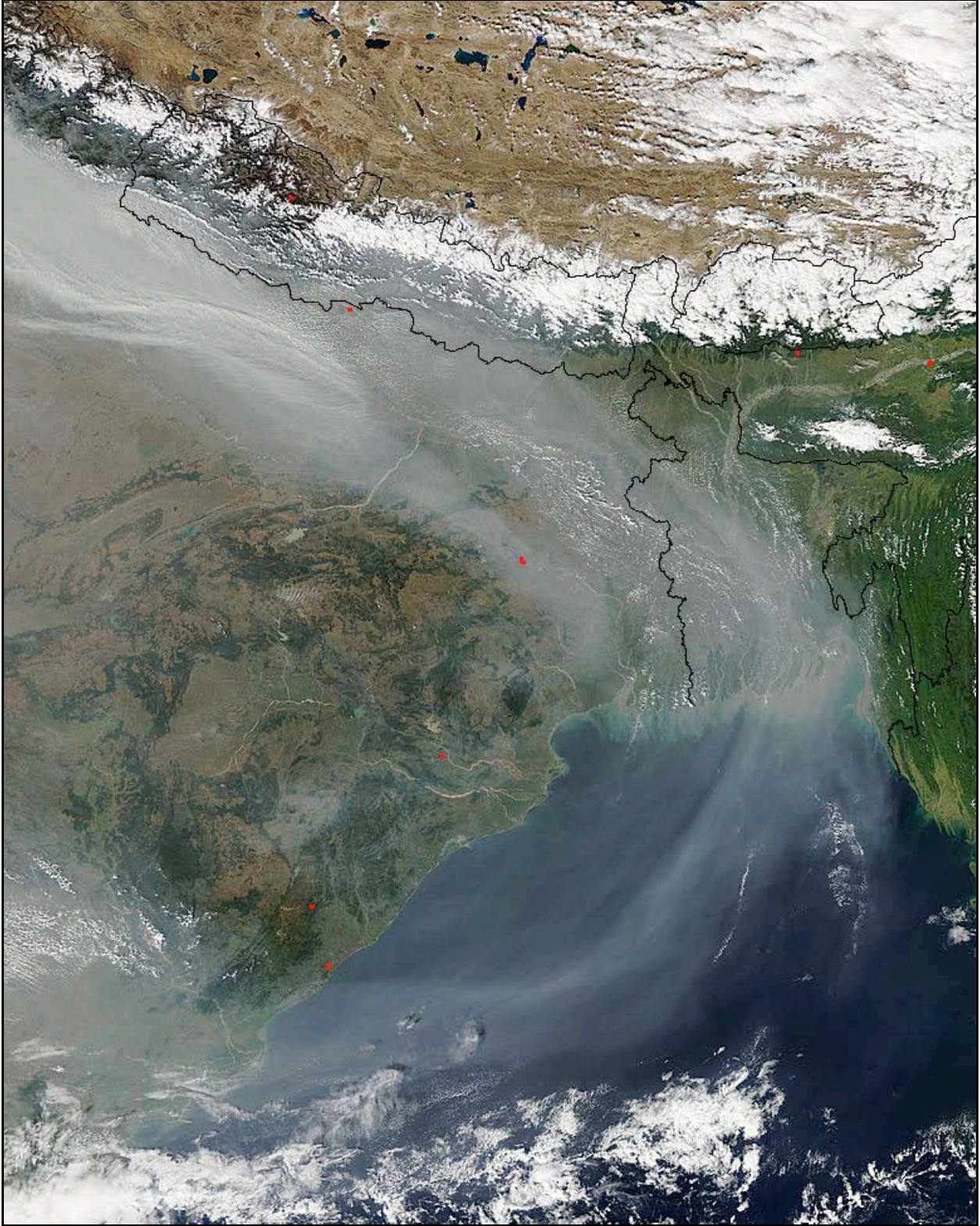
Haze over Pakistan, India and Bangladesh November 3, 2011

Haze hugged the southern slopes of the Himalaya in early November 2011. The MODIS/Terra instrument captured this natural-color image of haze stretching from Pakistan southeastward to Bangladesh.

Haze is common at this time of year when farmers in northwestern India set fires to clear their fields of excess vegetation. MODIS detects areas of high surface temperatures associated with fires, but fires burn more intensely in the afternoon, and few blazes appear as hotspots (red dots) in this morning scene. The haze may result from additional factors besides agricultural fires, including urban and industrial pollution.

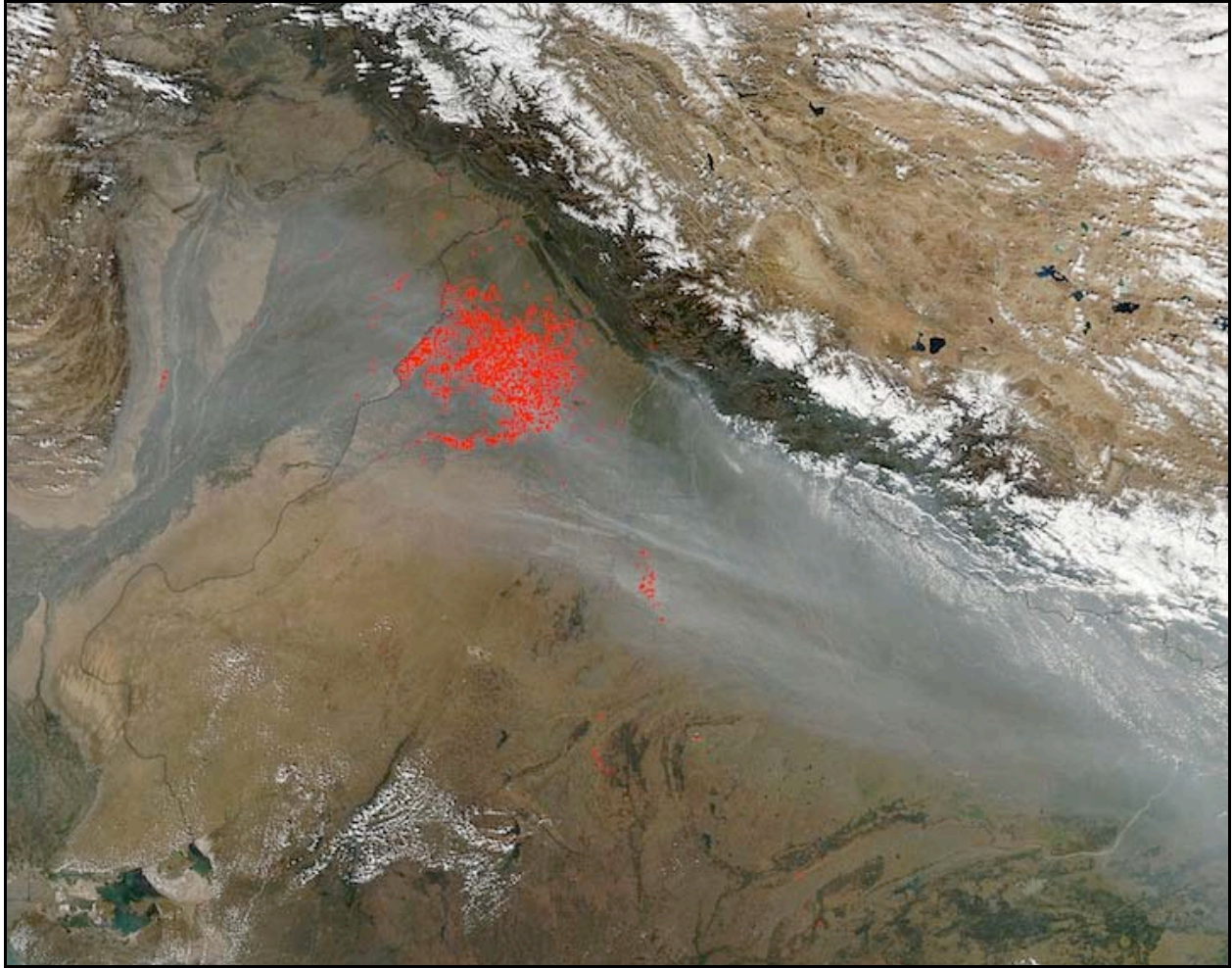
Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=76343>



November 4, 2011 MODIS/Aqua Image of Haze over India and Bangladesh

Note the similarities to the image taken **December 16, 2004.**



Fires in the State of Punjab November 5, 2011

In this Earth Observatory Gallery MODIS/Aqua image agricultural fires in Northwest India are sending smoke and haze down both the Indus Valley in Pakistan and the Ganges Valley in India. Note the timing of these fires to the **October 29, 2006** and **November 3, 2008** images.



Haze over the Bay of Bengal November 7, 2011

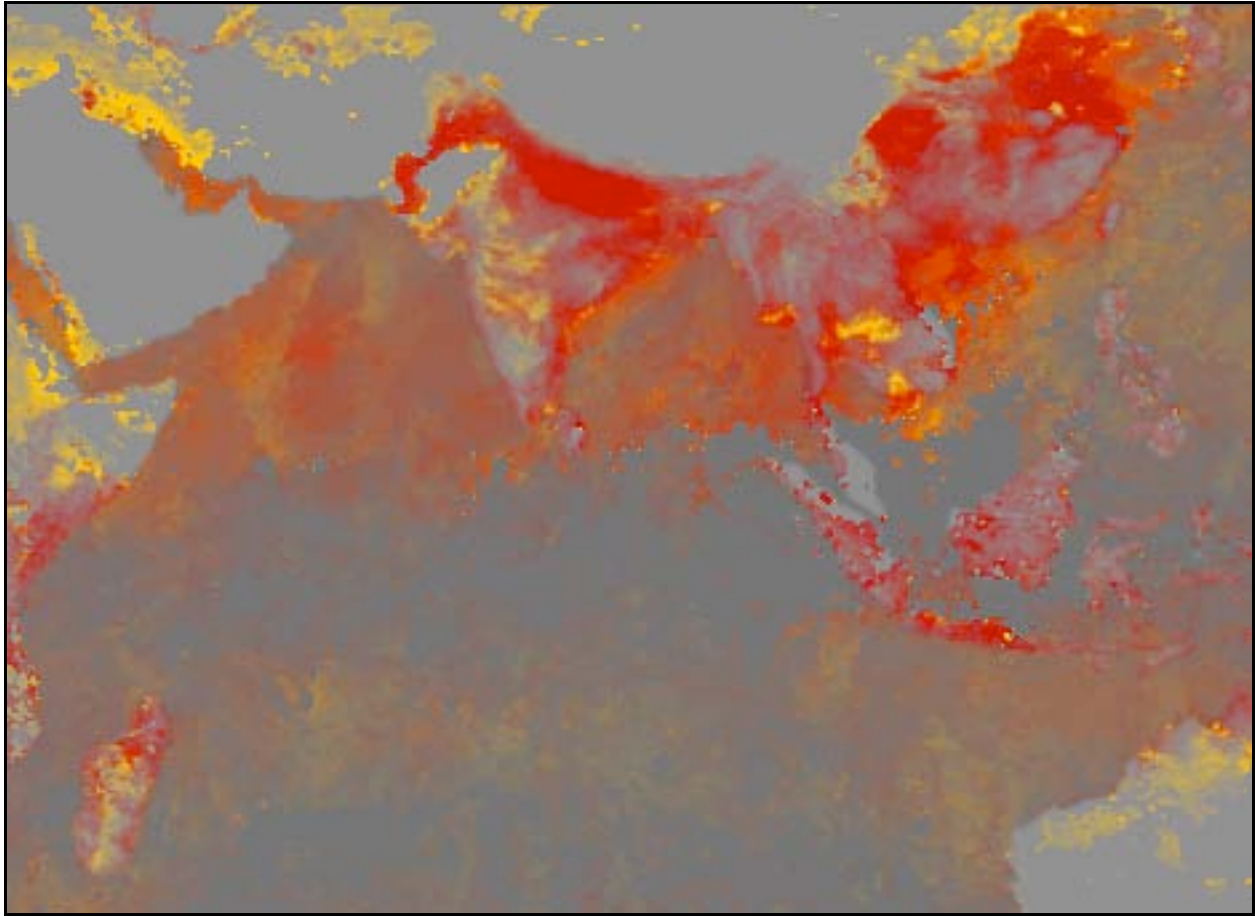
By early November 2011, haze had hovered along the southern slopes of the Himalaya for days. The river of haze flowed toward the southeast along the mountain range, and turned southward over Bangladesh. On **November 7, 2011**, the MODIS/Terra instrument captured this natural-color image of haze over Bangladesh and the Bay of Bengal.

Farmers in northwestern India have annually set agricultural fires at this time of year producing massive amounts of haze. Other factors in the mixture include urban and industrial pollution picked up on its flow along the Himalayan Front. Most, but not all, of this haze will cross Bangladesh on its way to the Bay of Bengal. But not before having already crossed one of the most densely populated areas in the world.

Web Site Reference

<http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=76360>

Select NASA Earth Observatory Air Pollution Studies 2004 to 2010

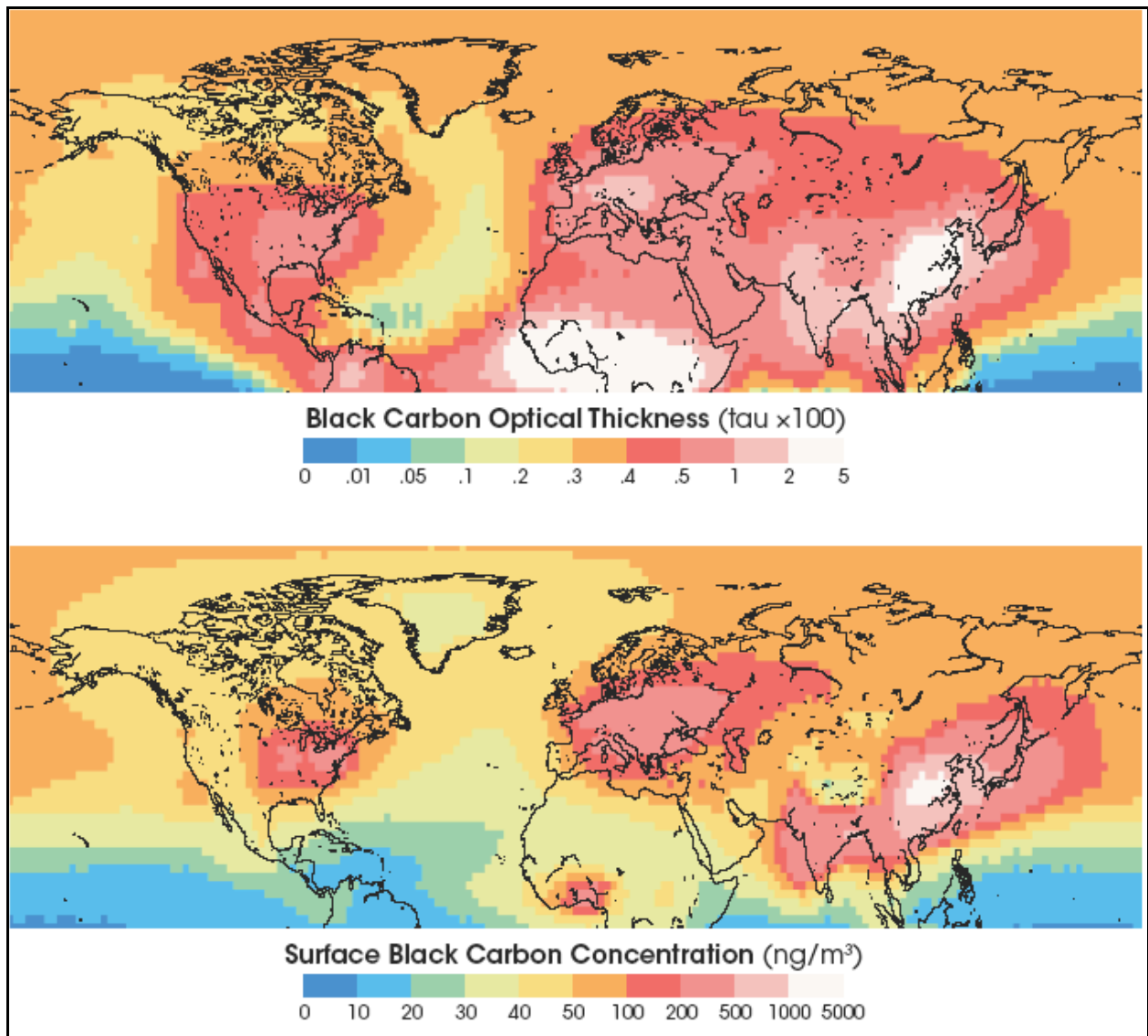


Aerosol Particles over Southern Asia 2004

Shown above are concentrations of aerosol particles over southern Asia between **December 8 to 12, 2004**. Small particles are colored red and large particles gold. The brighter the color, the more aerosols present. Particle size is a key indication of the source of the aerosols. Large particles tend to be dust from deserts, or salt crystals from wind-whipped white caps on the ocean. Small, fine, particles usually come from the burning of vegetation or fossil fuels. December is a time for large-scale agricultural burning in Southeast Asia. In places north of the equator, like China (upper right), colder winter temperatures cause people to burn more coal, and wood for heating. This image was compiled from data collected by the MODIS instrument aboard the Terra satellite.

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=5092>



Black Carbon Aerosols March 26, 2005

Far in the frigid north, glaciers rule and temperatures are harsh. It is not the sort of place one would expect pollution to be a problem, but new NASA research reveals that soot is traveling farther north than previously believed. Soot, or black carbon, could have a huge impact on the delicate Arctic environment by speeding up the melting of Arctic ice, altering temperatures and cloud formation, and changing weather patterns.

Black carbon is released into the atmosphere when fossil fuels are not completely burned, either in vehicles, home heating appliances, or when trees and other plants are burned. When large quantities of soot enter the atmosphere, they create a haze that absorbs energy from the sun, so the temperature of the atmosphere increases. This atmospheric heating can affect weather patterns and cloud formation.

Dorothy Koch and James Hansen, climate scientists at NASA's Goddard Institute for Space Studies (GISS), modeled the transport of black carbon particles around the world using the GISS general circulation model. The above images show some of their results. The top image shows where black carbon is concentrated in the atmosphere, and thus where surface temperatures and weather patterns might be affected, and the lower image shows where carbon is predicted to settle on the ground.

In the top image, the regions with the most haze—higher optical thickness—are white, while the least-affected areas are blue. As the image shows, Koch and Hansen found that soot in the atmosphere is most concentrated over southern and eastern China, where industry pumps black carbon into the atmosphere, and over central Africa, where fires are widely used for agriculture. Other regions with high concentrations of black carbon include the United States, Central Europe, and India. The model also reveals that instead of being clear of soot, the Arctic is blanketed with black carbon haze. About one-third of the haze, Koch and Hansen say, comes from Asia, one-third comes from fire around the world, and the remaining third comes from the United States, Russia, and Europe.

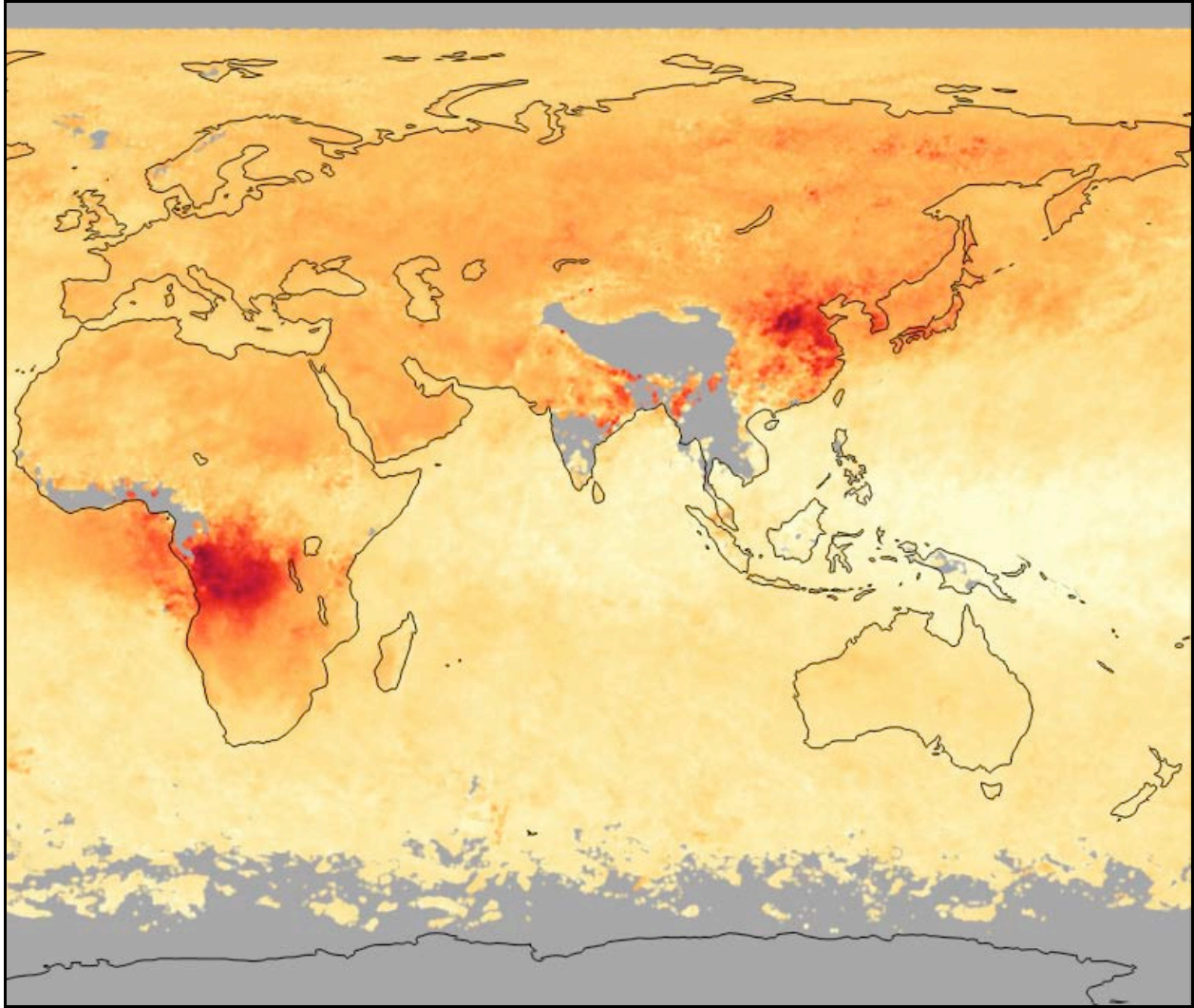
Soot does not stay in the atmosphere; it falls out in rain or with dust. Koch and Hansen's research reveals that soot might have a longer range than previously believed, with higher concentrations reaching far into the Arctic. As dark soot falls on the snow and ice of the Arctic, it turns the white, reflective surface into a dark surface that absorbs the sun's energy. This extra energy makes the snow melt more quickly.

The lower image shows where the model predicted the black carbon to fall onto the surface. The highest concentrations are again in eastern China, Europe, and the Eastern United States. The model predicts that more soot falls over parts of the Arctic than in parts of the developed world.

NASA image courtesy Dorothy Koch and James Hansen, NASA GISS 2005-3-26

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=5363>



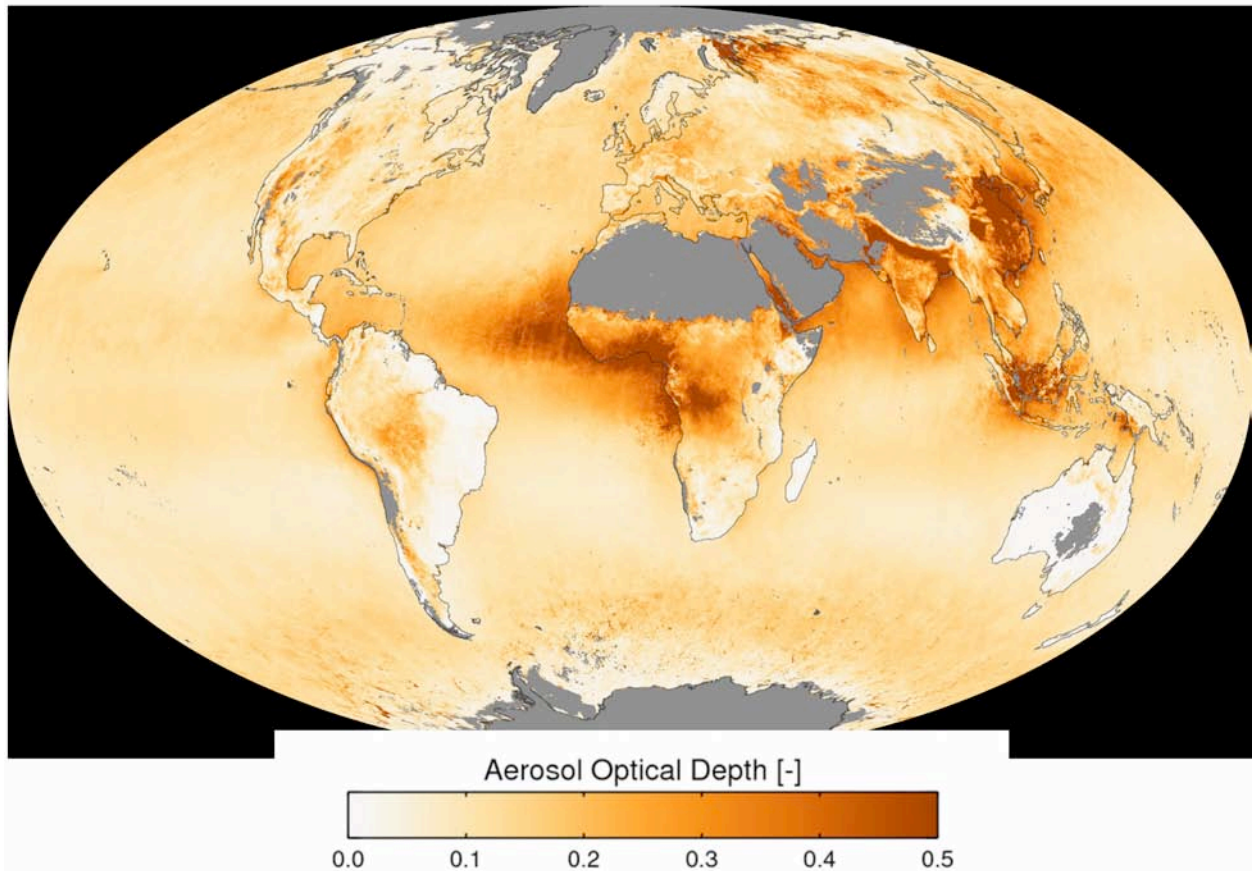
Carbon monoxide in the Eastern Hemisphere Summer 2005

Fires release carbon monoxide and nitrogen oxides—all of which, when exposed to sunlight, take part in the chemical reactions that create ground-level ozone. Unlike the ozone in the stratosphere, which absorbs dangerous ultraviolet light, ozone near the Earth's surface is a harmful air pollutant.

Carbon monoxide observations collected from satellites are used to track the spread of emissions. This image shows carbon monoxide concentrations in the eastern hemisphere during the summer of 2005. The data was collected by the MOPITT (short for "Measurements of Pollution in the Troposphere") sensor on NASA's Terra satellite. Red indicates high concentrations, while yellow indicates low concentrations. The high levels over China are caused by industrial and urban pollution. While those over west central Africa are from agricultural burning.

Web Site Reference

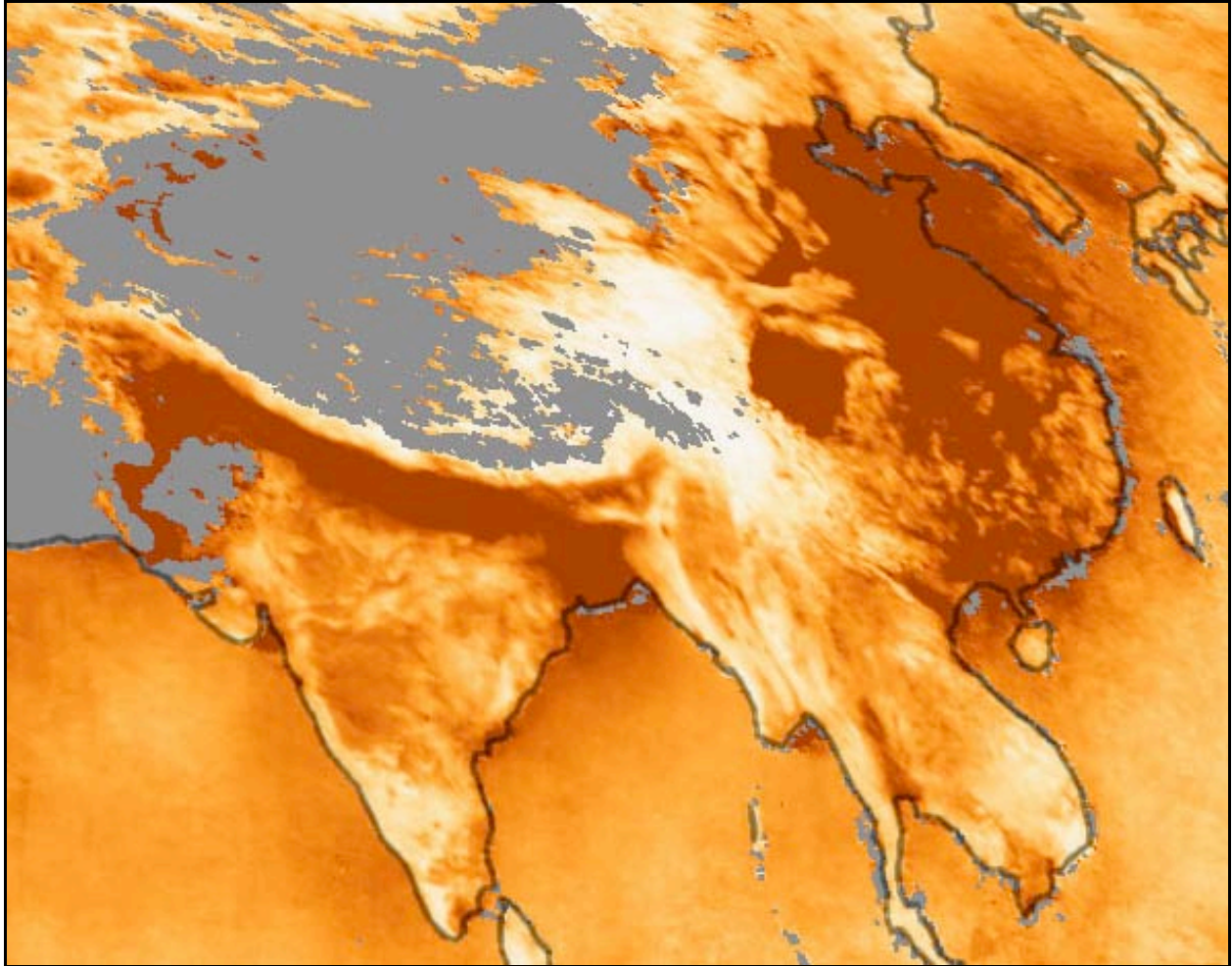
<http://earthobservatory.nasa.gov/IOTD/view.php?id=7033>



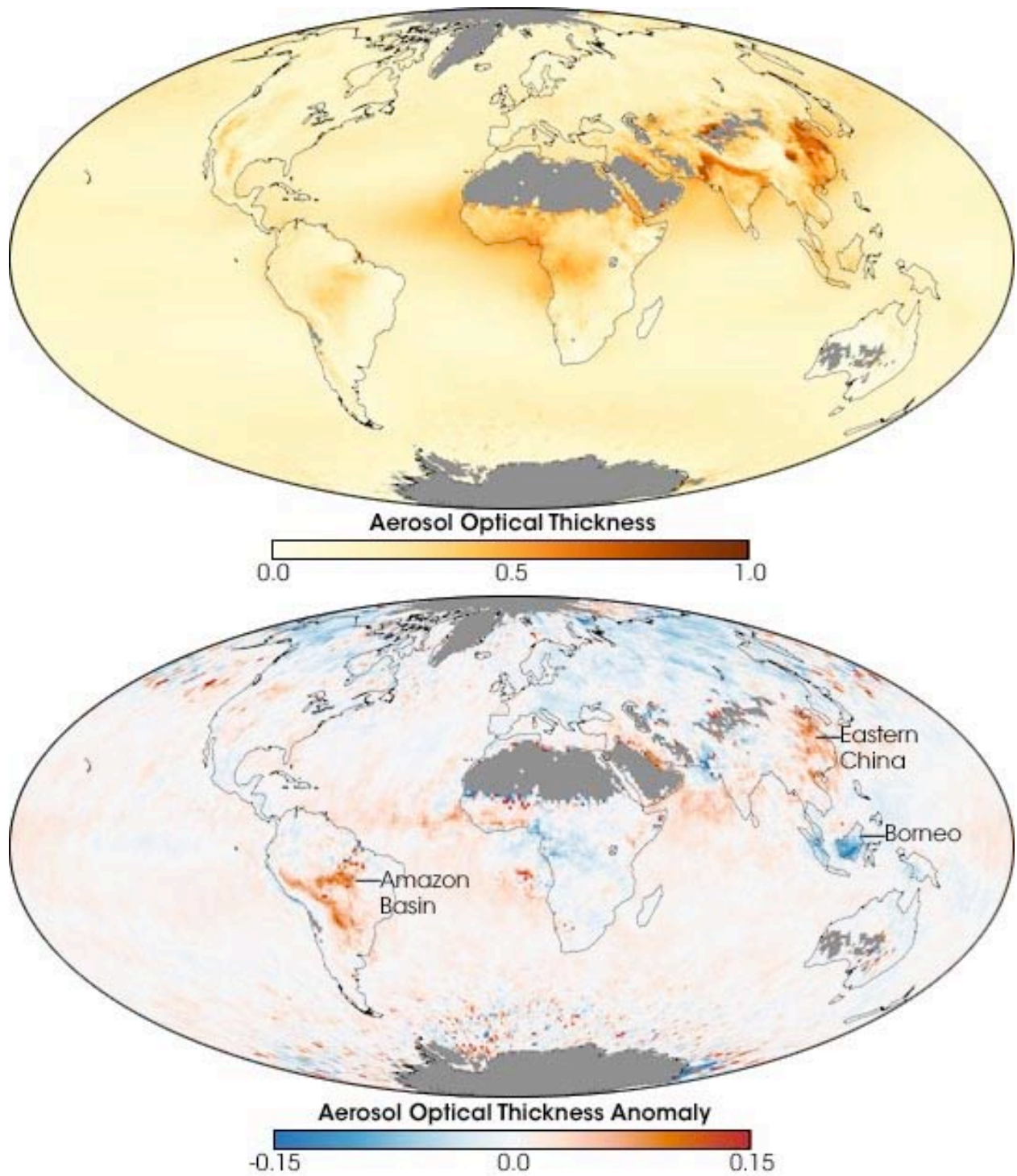
The Moderate Resolution Imaging Spectroradiometer (MODIS) flying on NASA's Terra and Aqua satellites can detect aerosols. This image shows the annual mean aerosol optical depth for **2006**, based on daily measurements made by MODIS. Aerosol optical thickness or depth is the scale used that describes how much pollution was in the air based on how much of the incoming sunlight the particles absorbed. In this image, white represents little or no aerosol interference with sunlight, and dark orange indicates considerable interference. Areas where data could not be collected appear in gray.

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=7469>



This enlarged and cropped image taken from the image on the previous page shows the annual mean of aerosol particles over southeast Asia during **2006**, based on daily measurements made by MODIS. In the image, white represents little or no aerosol interference with sunlight, and dark orange indicates considerable interference. Areas where data could not be collected appear in gray.



The maps above show average global aerosol patterns based on data from **2000-2007** (top) and **2007** aerosols compared to the average (bottom).

Global Aerosol System 2000-2007
June 24, 2008

"The top map shows aerosol optical thickness in shades of yellow (few aerosols) to dark red (many aerosols). Aerosol optical thickness indicates how much light aerosols prevented from passing through the atmosphere. (In this case, MODIS measured light with a 550-nanometer wavelength, which is yellow-green.) Gray areas, such as Antarctica and the Sahara Desert, show where the Earth's surface is too bright for scientists to be able to calculate the fainter "signal" from aerosols.

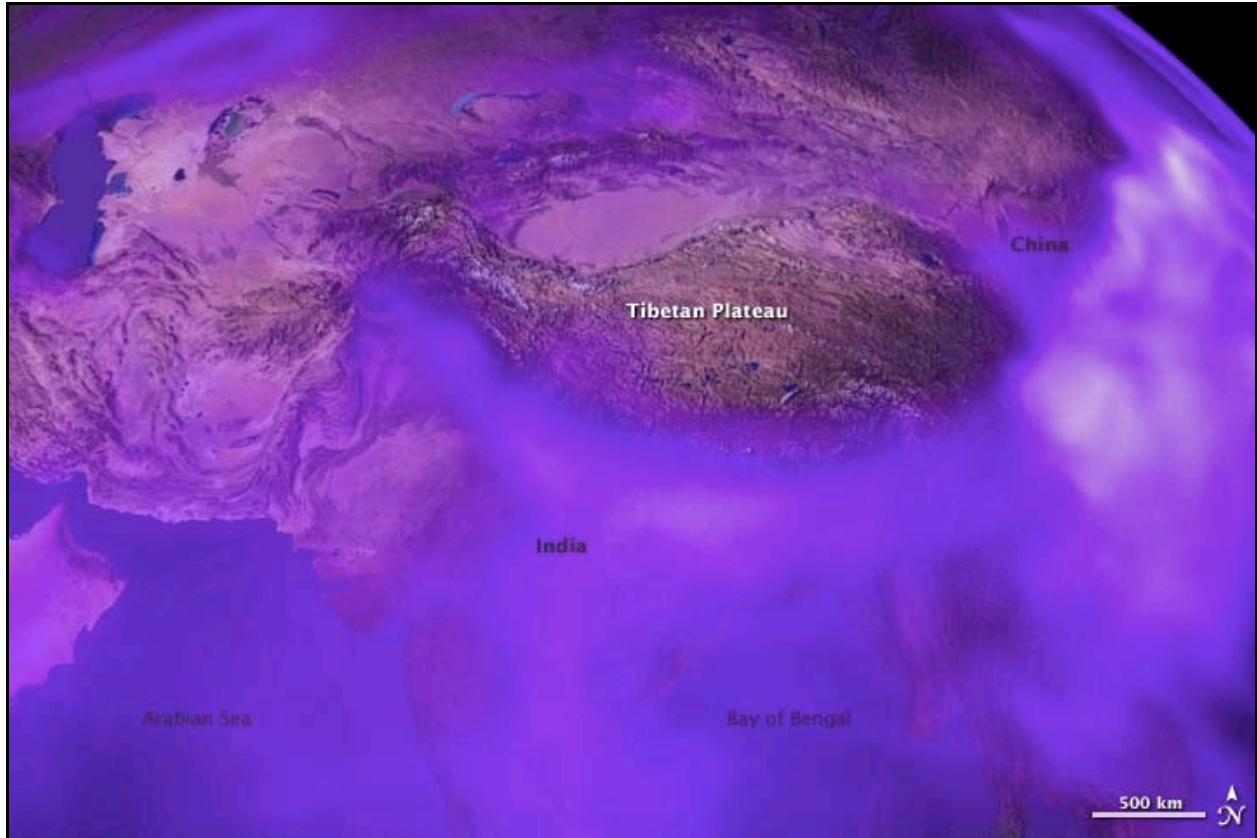
The aerosol patterns shown result from a mixture of human and natural activities. Northern Africa, eastern China, and the Middle East all experience dust storms. China's coal-fired power plants and vehicles produce large amounts of aerosols. Northern and central Africa, Southeast Asia, Indonesia, and Central and South America all have significant agricultural burning seasons.

The second map shows how the 2007 annual mean deviated from the eight-year mean. Places where there were more aerosols than average are red, while places where there were fewer aerosols than average are blue. Burning in South America was particularly strong in 2007. Smoke from the Amazon Basin spread southward to coastal Uruguay and northern Argentina. India shows a slightly positive anomaly, as does the Sahel region of West Africa.

Eastern China stands out as a strong positive anomaly in 2007, exhibiting higher annual mean aerosols than even its already high, eight-year mean."

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=8857>



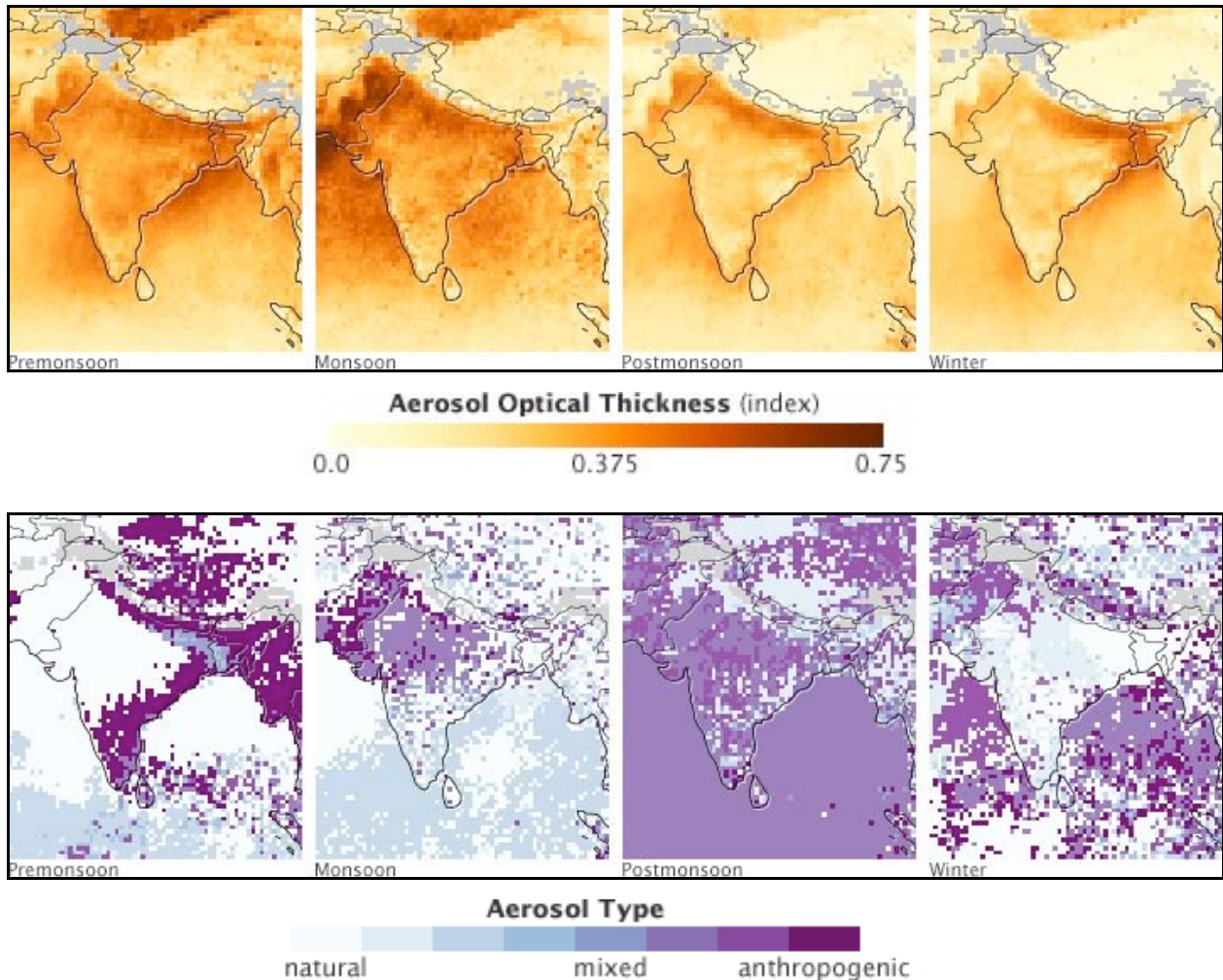
Black Soot and the Survival of Tibetan Glaciers

On the Himalayan Front of the Tibetan Plateau, temperatures are rising and glaciers are melting faster than climate scientists would expect based on global warming alone. A 2009 study of ice cores from five Tibetan glaciers by NASA and Chinese scientists confirmed the likely culprit: rapid increases in black soot concentrations since the 1990s, mostly from air pollution sources over Asia, especially the Indian subcontinent. Soot-darkened snow and glaciers absorb sunlight, which hastens melting, adding to the impact of global warming.

NASA climate scientists combine satellite and ground-based observations of soot and other particles in the air with weather and air chemistry models to study how the atmosphere moves pollution from one place to another. This image is from a computer simulation of the spread of black carbon *aerosol optical thickness* on **September 26, 2009**. Places where the air was thick with soot are white, while lower concentrations are transparent purple.

Web Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=41854>



Seasonal Changes in Indian Aerosols November 24, 2010

In recent years, scientists have detected very high levels of aerosol pollution in the air over India. Some of it is the result of industrial and agricultural activity, and some of it is nature at work. New research released this fall shows that the amount, size, and source of the aerosol particles hovering in the air over India changes by season.

These maps were built from data from the Multi-angle Imaging Spectroradiometer (MISR) instrument on NASA's Terra spacecraft. The top image shows aerosol optical depth, a measure of the amount of light that the aerosols scatter and absorb in the atmosphere, and a proxy for how many particles are in the air. The lower map shows the likely source—natural or human-made (anthropogenic)—based on the size of the particles and other factors. Data depicted are averages for the pre-monsoon season (March through May), the monsoon (June to September), post-monsoon (October, November), and winter (Dec. to Feb.) for the years 2000 to 2008.

Aerosols are tiny solid and liquid particles suspended in the air, and they come from many natural sources, including volcano emissions, sand and dust storms, and salt from sea spray. Nearly 90 percent of all aerosols (by mass) arise naturally, and most tend to be relatively large particles. The rest of the aerosol load in the air comes from man: sulfates, black and brown carbon, and other pollutants associated with the burning of fossil fuels and of agricultural land. Aerosols produced by human activity tend to be smaller and more damaging to human lungs.

Researchers Sagnik Dey and Larry Di Girolamo of the University of Illinois at Urbana-Champaign assembled and analyzed nine years worth of measurements and found that the level of aerosol pollution was, depending on the season and location, two to five times higher than World Health Organization guidelines. More significantly, the dominant sources of the pollution shift with seasonal weather patterns.

In the spring months leading up to the monsoon, winds blow onshore and inland, carrying dust from Africa and the Arabian peninsula...and something more. “Just before the rains come, the air gets really polluted, and for a long time everyone blamed the dust,” said Di Girolamo. “But MISR has shown that there’s also a massive buildup of manmade pollutants hidden within the dust.”

The rains of the monsoon tend to wash dust and soot from the air, though some anthropogenic pollutants build up. After monsoon season, damp ground means dust transport is reduced, while human-made pollutants skyrocket because of land-clearing for farming and because weather patterns do not disperse vehicle exhaust. During winter, seaward-blowing breezes disperse the pollutants across the subcontinent and out to sea.

Web Site Reference

<http://earthobservatory.nasa.gov/IOTD/view.php?id=47056>

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