Freshwater Shortage and Desertification

edited by

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

Introduction

Approximately one-third of the world's population lives in countries suffering from moderate-to-high water stress, defined as water consumption greater than 10 per cent of renewable freshwater resources. Some 80 countries, constituting 40 per cent of the world's population, were suffering from serious water shortages by the mid-1990s. Global per capita water supplies decreased by one-third between 1970 and 1990, and are likely to drop by a third over the next 20 years. Increasing water demand has been caused by population growth, industrial development, and the expansion of irrigated agriculture. China, for all these reasons, now faces severe water shortages in the northern part of the country, and thus provides a case study of freshwater shortage worldwide.

Northern China has also experienced an increasing number of severe dust storms (Normile, 2007), which is symptomatic of over-farming, and over-grazing in semi-arid regions in a process called desertification. Plumes of dust from northern China mixed with toxic air pollution have become a major public health issue in China, Korea, and Japan. Atmospheric research, however, suggests that the observed trend toward increased summer floods in southern China and drought in northern China, thought to be the largest change in precipitation trends since 950 A.D., may be caused by human-made absorbing aerosols, mainly black carbon soot, that alters regional atmospheric circulation and contributes to regional climate change (Menon, et al. 2002; Rosenfeld, et al., 2007). It is also possible that drought caused by increased absorbing aerosols has only accelerated the process of desertification started by over-farming, and over-grazing. In either case, there's a growing understanding that human overuse and misuse of the environment, as opposed to natural climate change, is causing an increasing shortage of freshwater, not just in northern China, but worldwide.

Web References

http://www.unep.org/geo/geo3/english/index.htm

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

This web paper is part of a series of papers on global ecology. In addition to this paper the series includes:

Asian Air Pollution
http://fire.biol.wwu.edu/trent/alles/AirPollution.pdf

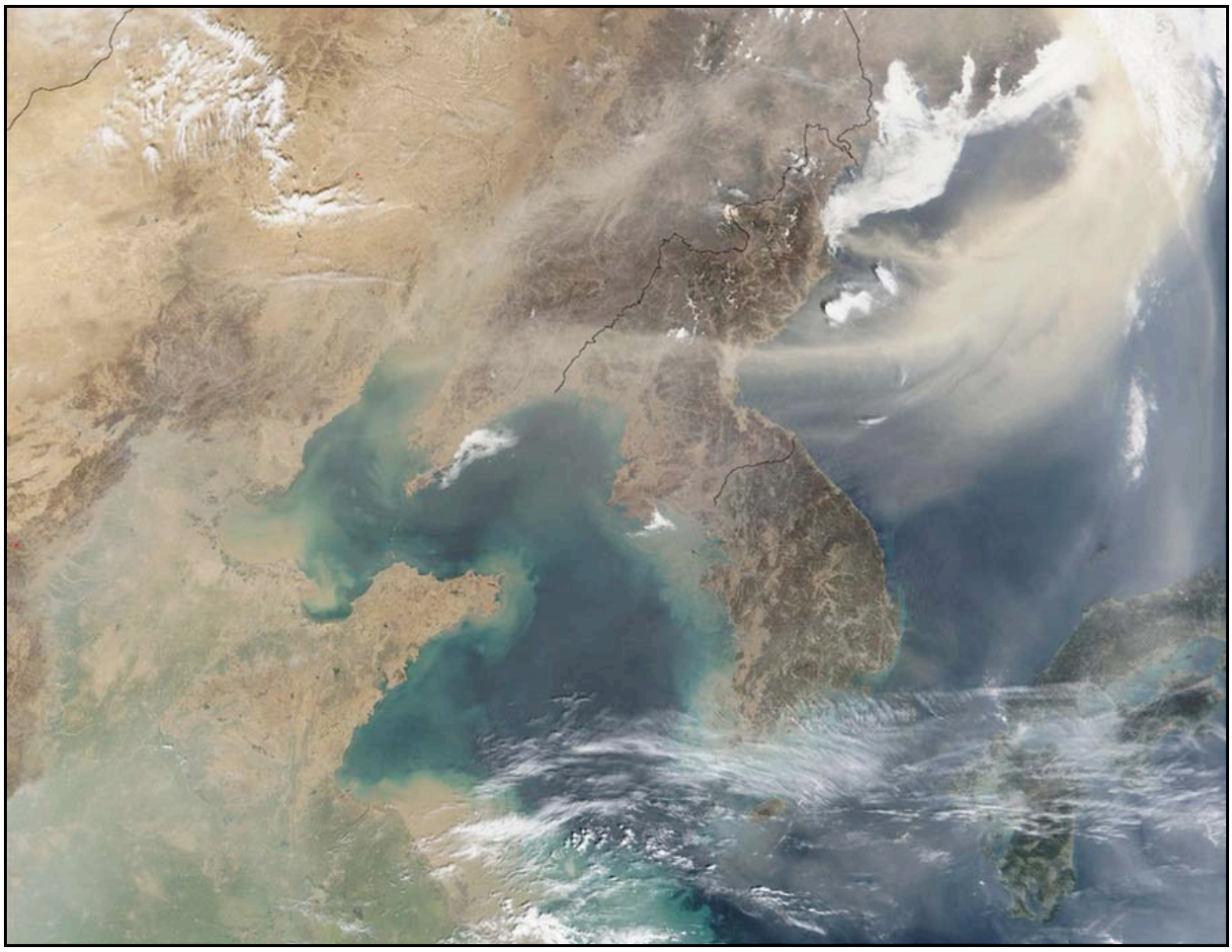
China's Deserts
http://fire.biol.wwu.edu/trent/alles/ChinaDeserts.pdf

Geomorphology and Dust Storms in China
http://fire.biol.wwu.edu/trent/alles/ChinaDust.pdf

The Aral Sea
http://fire.biol.wwu.edu/trent/alles/AralSea.pdf

The Colorado River: An Ecological Case Study
http://fire.biol.wwu.edu/trent/alles/ColoradoRiver.html

The common thread in all of these papers is how complex coupled natural systems and human interactions have led to the ecological crises of our times.



In this MODIS/Terra image of northeastern China, Korea, and Japan acquired **April 1, 2002**, dust mingled with air pollution can be seen billowing out from Korea and over the Sea of Japan. Dust from China's interior deserts had been blowing eastward off and on since mid-March 2002. There is also considerable air pollution (grayish pixels) over the North China Plain in the lower left-hand corner. China's Shandong Peninsula is below and left of center, between the Yellow and the Bohai seas. The peninsula is a notable landmark that can be easily identified in satellite images of the region.

Web Reference
http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=9288

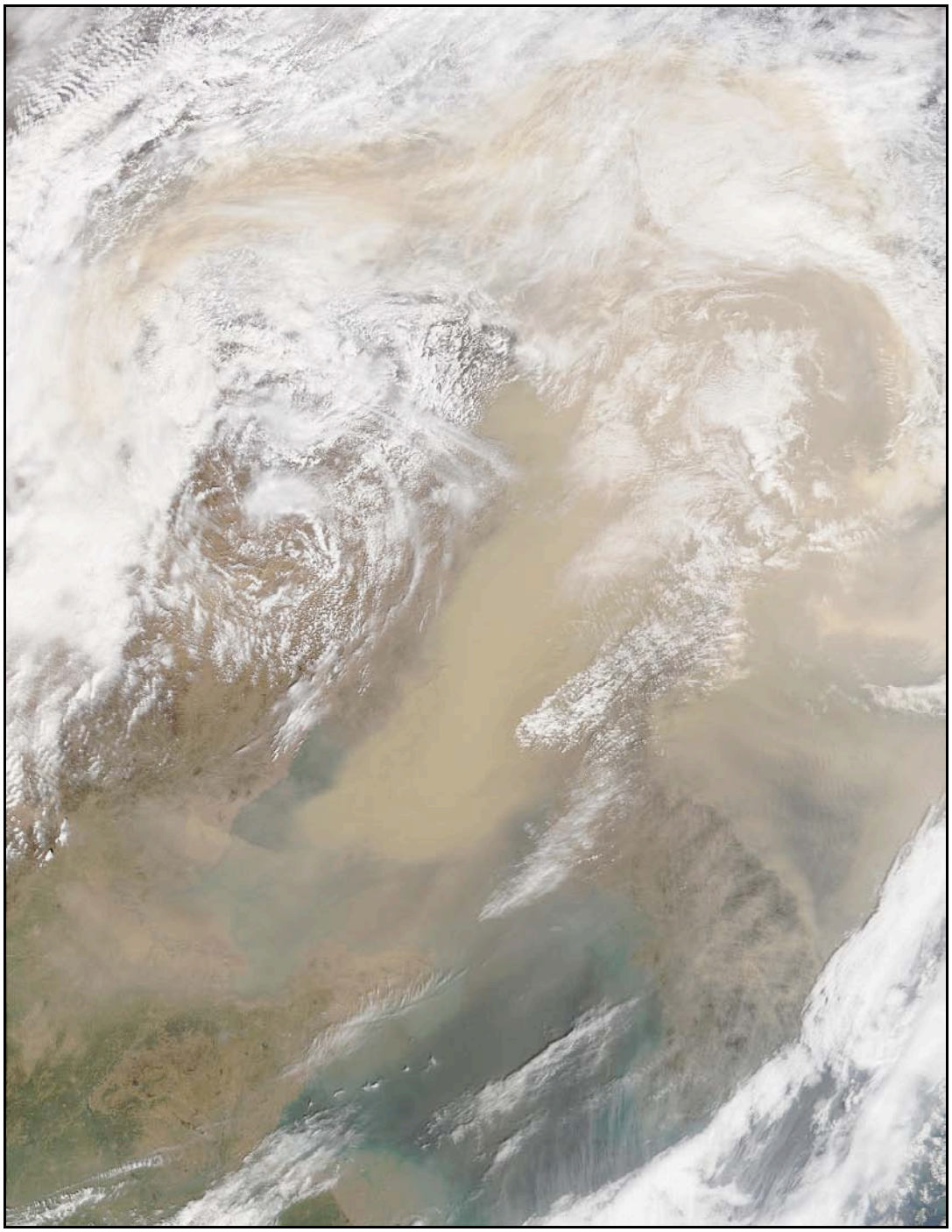
Excerpts from: **China's Growing Deserts Are Suffocating Korea**

"SEOUL, South Korea—School was called off throughout much of this sprawling city last Monday (April 8, 2002) because of inclement weather. It was not a freak spring snow storm, a heat wave or torrential rains. Rather, it was an immense cloud of dust that blew in from China's fast-spreading deserts, about 750 miles away. It hid Seoul from view throughout the morning, obscuring the sunrise just as surely as the heaviest of fogs. Clinics overflowed with patients complaining of breathing problems, drugstores experienced a run on cough medicines and face masks that supposedly filter the air, and parks and outdoor malls were nearly empty of pedestrians. With the arrival of the huge dust storms for the third consecutive year, Koreans have begun to grimly resign themselves to the addition of an unwelcome fifth season—already dubbed the season of yellow dust—to the usual four seasons that any temperate country knows.

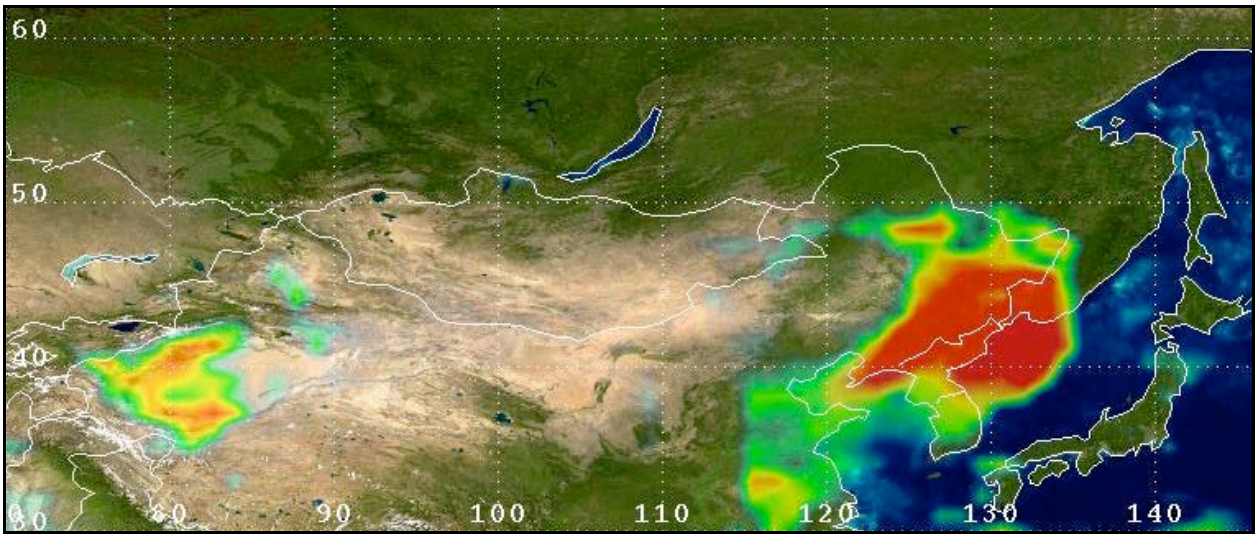
Like the harmattan in West Africa, when skies throughout that region turn a soupy gray for weeks at a time because of seasonal wind patterns that bring airborne dust southward from the Sahara, Korea's new season is a disturbing reminder for Asians of global interconnectedness and the perils of environmental degradation. "There is no way for us to deter this," said Kim Seung Bae, deputy director of South Korea's national weather service. "All we can do is try to forecast the yellow dust storms as early as possible, but with the current technology we can only detect it one day ahead of time at best."

In Seoul, a measurement of 70 micrograms of dust per cubic meter of air is considered normal during most of the year. At 1,000 micrograms, experts say, serious health warnings are indicated. Earlier this week, in the fourth storm of the season, a record measurement of 2,070 micrograms was reached in this city.

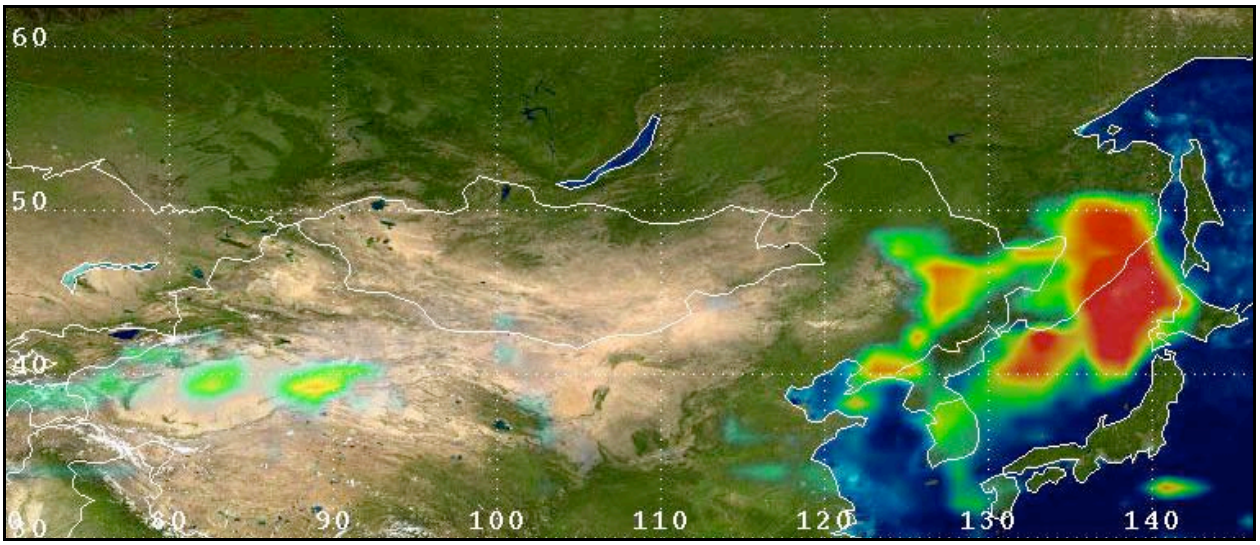
Scientists say the dust storms, which are distinctly visible on regional satellite weather maps as gigantic red blobs, are the result of the rapid desertification in China and a prolonged drought affecting that country and other parts of Northeast Asia." (French, 2002, New York Times)



This MODIS/Terra image from **April 8, 2002**, shows the dust storm over eastern China and Korea. Beijing was particularly hard hit by this dust storm. Beijing's air pollution index (API) was 500 on the 7th and the 8th. The real values, however, were probably much greater than this because the reporting scale stops at 500. Dust also reached as far south as Shanghai which had an API of 434 on the 8th.



April 8, 2002, location of dust storm is shown in red



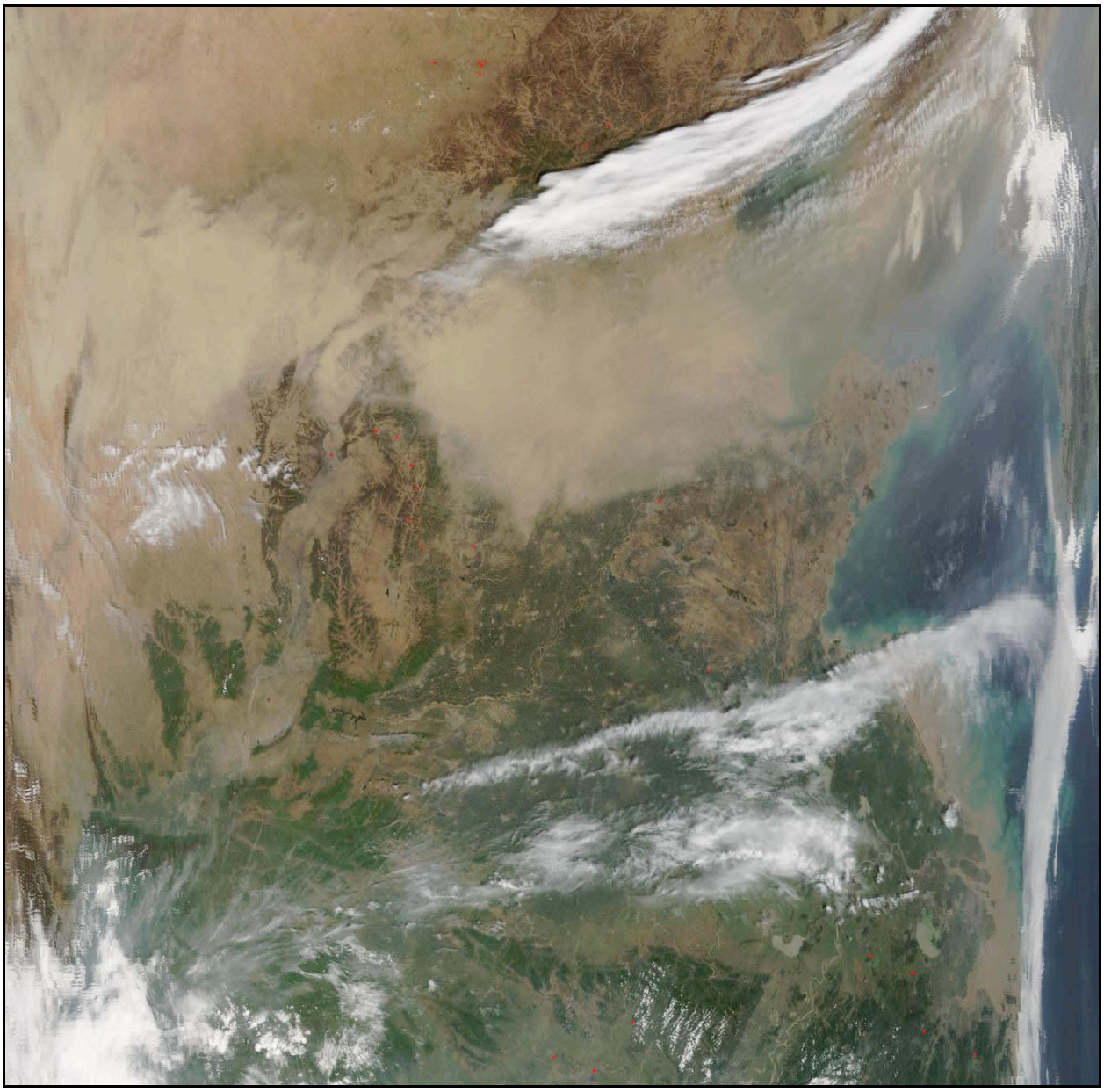
April 9, 2002, storm has passed over Korea headed for Japan

In these images deserts are shown in tan. From left to right are the Taklimakan Desert (far left), the Badain Jaran and Tengger deserts (below and left of center), and the Gobi Desert (center). The Badain Jaran and Tengger deserts are often considered the southwestern region of the Gobi Desert. Others consider all of these areas combine to make up the "Gobi Desert", making it one of the largest deserts in the world.

(Images courtesy of NASA)

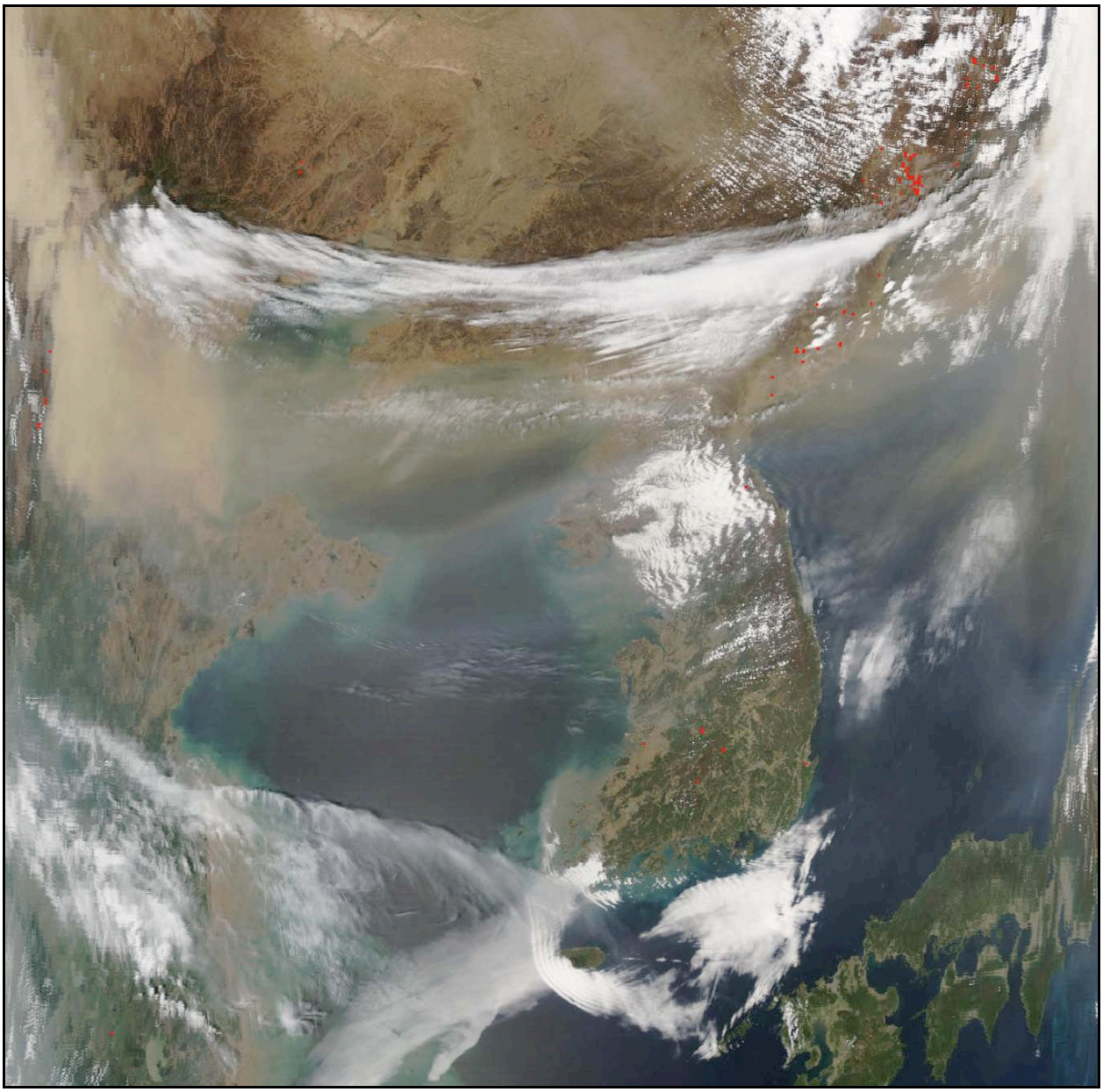
"According to China's Environmental Protection Agency [now MEP], the Gobi Desert grew by 20,000 square miles (51,800 sq. km) from 1994 to 1999, and its steadily advancing edge now sits 150 miles (241 km) north of Beijing. As in West Africa, which weather experts say is the world's leading source of dust, China's environmental changes are accelerating because of over-farming, over-grazing, and increased use of irrigation. But unlike West Africa's dust, which is carried to the southern United States by the tropical easterlies, dust from the Gobi and Taklimakan deserts in rapidly industrializing China is binding with toxic industrial pollutants, including arsenic, cadmium and lead, increasing the health threat." (French, 2002, New York Times)

For more on China's Deserts go to:
http://fire.biol.wwu.edu/trent/alles/ChinaDeserts.pdf

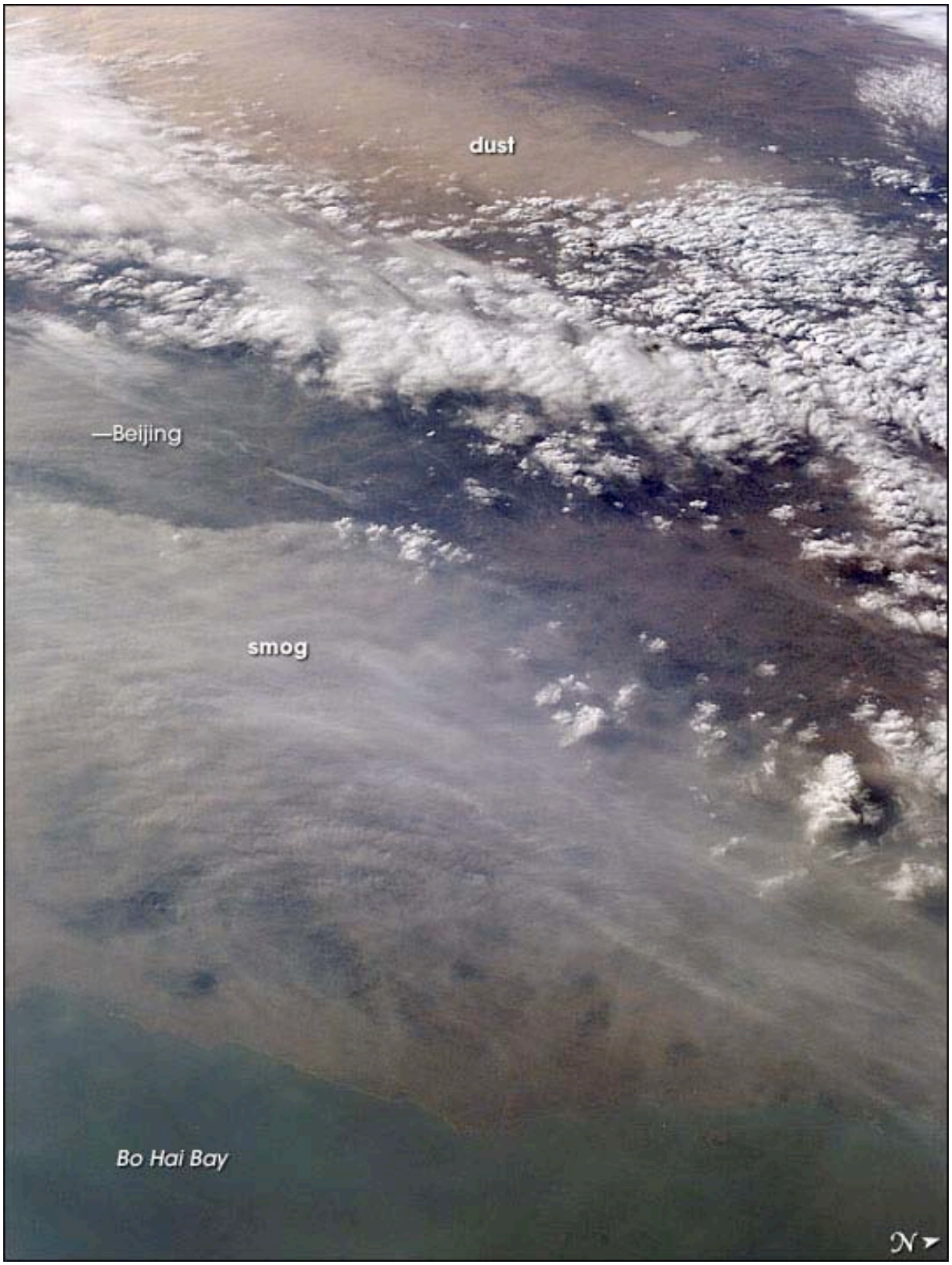


On **April 28, 2005**, a dust storm swept out of the Gobi Desert and over northeast China, as shown in this MODIS/Terra image. The storm stretches from the Gobi Desert (top left corner), across the North China Plain to the Bohai Sea, and on to North Korea (top right corner). Note the long thin clouds from left to right that mark the north and south boundaries of the high speed band of winds that carried the dust from the Gobi.

Web Reference
http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=14861



This **April 28, 2005**, MODIS/Aqua image, acquired the same day, shows the jet stream across North Korea and over the Sea of Japan. Note the dark clouds to the right of the main dust front of what may be dust mixed with air pollution over the Yellow Sea and the Sea of Japan.



Much of the North China Plain and parts of Inner Mongolia are obscured in this image taken from the International Space Station (ISS) **March 2, 2006**.

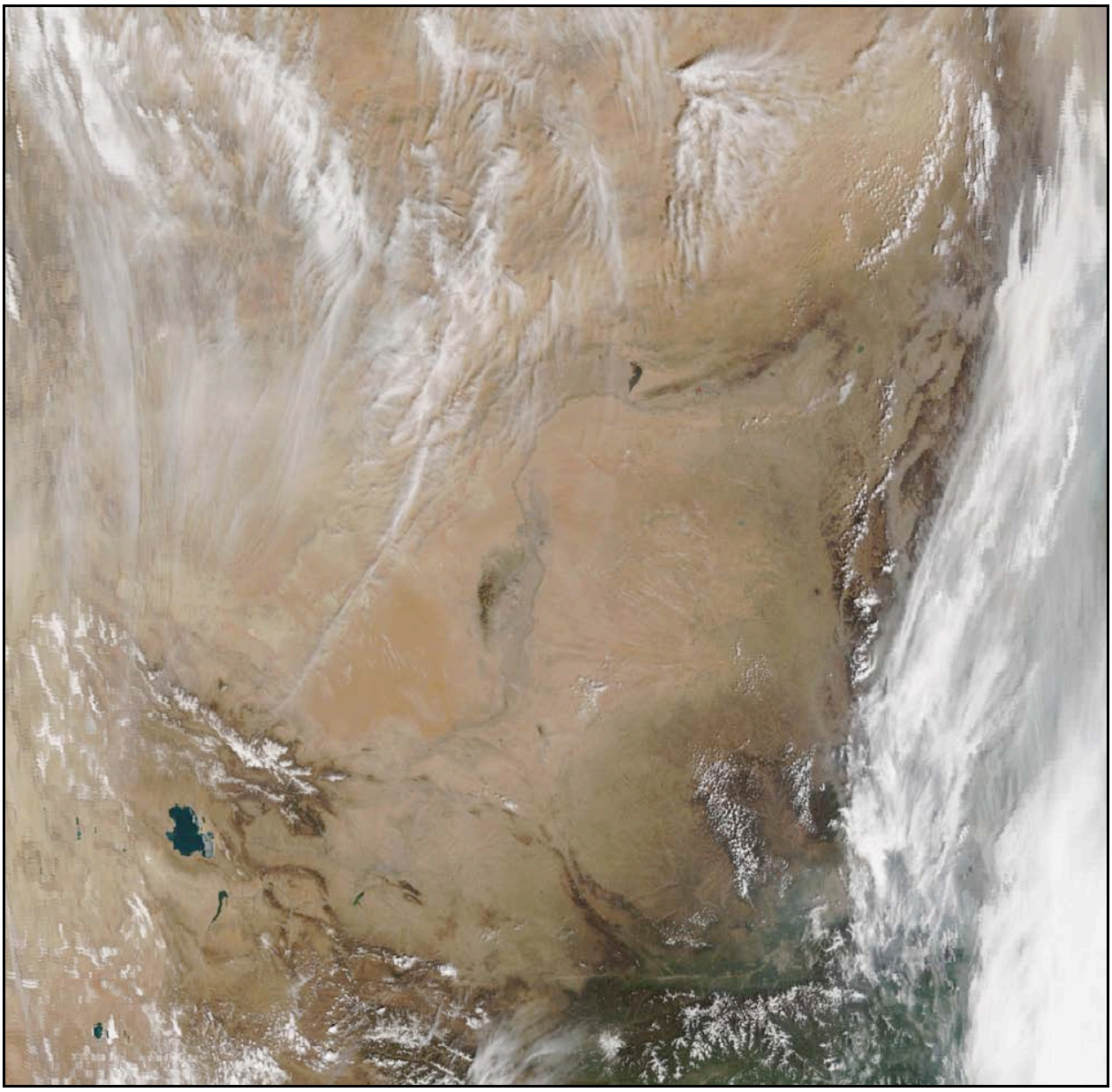
In the image, a mass of gray smog, mainly industrial pollution and smoke from domestic burning, obscures Beijing and surrounding cities. Numerous plumes with their source points appear within the mass. Beijing suffers some of the worst air pollution in the world from these chronic sources (Bradsher & Barboza, 2006), and the characteristic colors and textures of smog can easily be seen from space.

Separated from the smog mass by a band of white cumulus clouds is a light brown plume of dust. The line of white clouds developed along the steep slope that separates the heavily populated eastern coastal plains—the location of the largest population concentration on Earth—and the sparsely populated semi-desert plains of Inner Mongolia. Most Northern Hemisphere deserts saw dust storms in the Spring of 2006, and the Taklimakan and Gobi Deserts of western China were no exception. China experienced an unusual number of severe dust storms the Spring of 2006, when weather patterns in Siberia swept powerful winds across the western deserts and carried dust over eastern China, the Korean Peninsula, and Japan.

(ISS photograph courtesy of NASA)

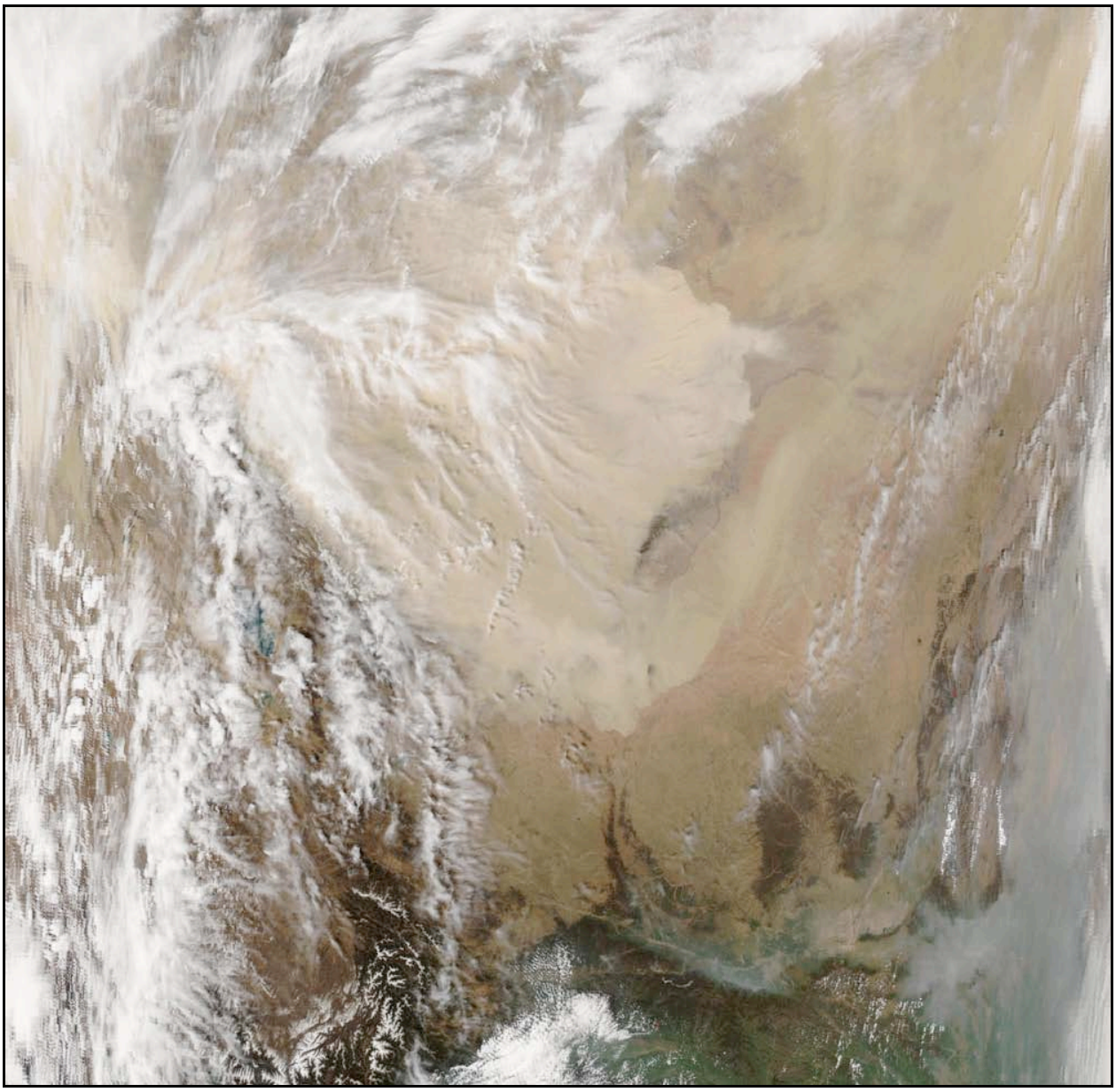
For more on Asian air pollution go to:
http://fire.biol.wwu.edu/trent/alles/AirPollution.pdf

Web Reference
http://earthobservatory.nasa.gov/IOTD/view.php?id=6557



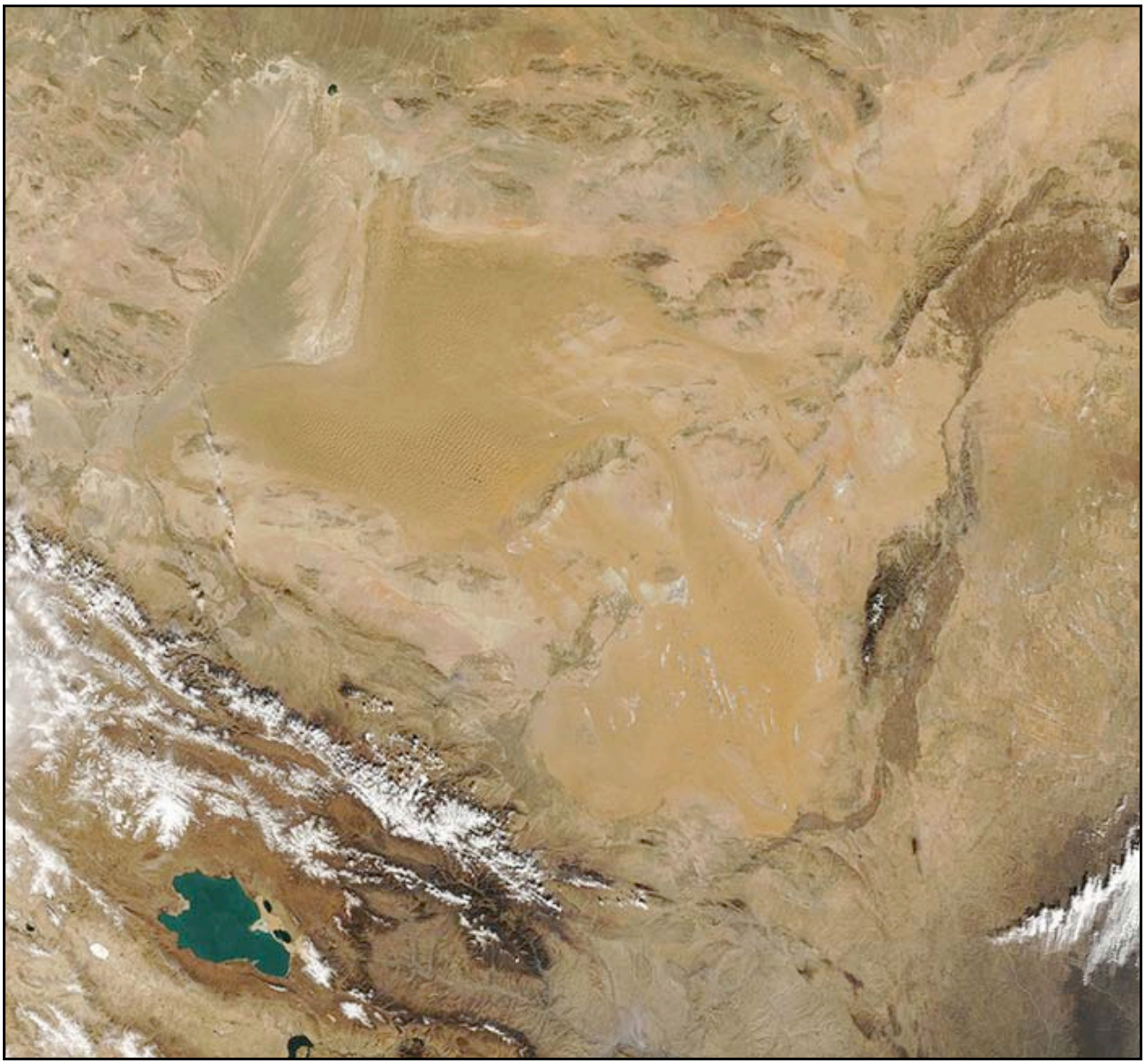
This MODIS/Aqua image from **April 9, 2006**, shows clear skies over north-central China. The dark area below and left of center is the Helan Mountains near the city of Yinchuan in Ningxia Province. The Yellow River's Great Bend, and the Loess Plateau of north-central China, are to the east of the mountains. The Badain Jaran and Tengger deserts are to the west. On the right edge of the image clouds and smog cover the North China Plain.

Note the clouds on the left that billow out from the west. These clouds are the leading edge of a storm front moving east from the Taklimakan Desert. Just a day later the area shown was engulfed by a wave of dust and sand.



On **April 10, 2006**, a massive wave of dust and sand blew out of the western deserts and over north-central China. The Taklimakan Desert is on the upper left edge of the image. The central deserts, the Badain Jaran and Tengger, are completely hidden in the image by the wave that reaches beyond the Yellow River. The dark Helan Mountains in Ningxia Province, however, are still visible just right of center.

Web Reference
http://earthobservatory.nasa.gov/NaturalHazards/view.php?id=16437



The Central Deserts of Northern China

Minqin county is located in the Hexi Corridor on the lower reaches of the Shiyang River (below center). The county lies northeast of the Qilian mountains (lower left) between Badain Jaran and Tengger deserts. The Minqin oasis was once a natural barrier to encroaching sand. But in the last two decades it has changed into a major source of airborne dust. Two factors led to this. First land was reclaimed and water diverted for irrigation along the upper Shiyang River, up-steam from Minqin County. This was followed by years of unprecedented drought. Today the county is one of the most affected by desertification in all of China (Casey, 2007). The dry bed of Qingtu Lake in Minqin county, one of the largest in China's northwest until the diversion of the Shiyang, is the gray blotch just below and right of center in this **November 8, 2006**, MODIS/Terra image.

Pictured above the Badain Jaran Desert is fast sweeping into the Minqin oasis.

It is a common misconception that droughts cause desertification. Droughts are common in arid and semiarid lands. Well-managed lands can recover from drought when the rains return. Continued land abuse during droughts, however, increases land degradation. Increased population and livestock pressure on marginal lands has accelerated desertification. This is one reason China's long campaign to cultivate its vast arid northwest is in retreat. An ever-rising tide of sand has claimed grasslands, lakes, and forests, swallowed whole villages, and forced tens of thousands of people to flee as it surges south (Kahn, 2006).

(Photograph by Chang W. Lee courtesy of *The New York Times*)

Web References

http://www.china.org.cn/english/2004/Sep/105977.htm

http://www.china.org.cn/english/2006/Apr/166159.htm

Except from: **Inner Mongolia's Lost Water**

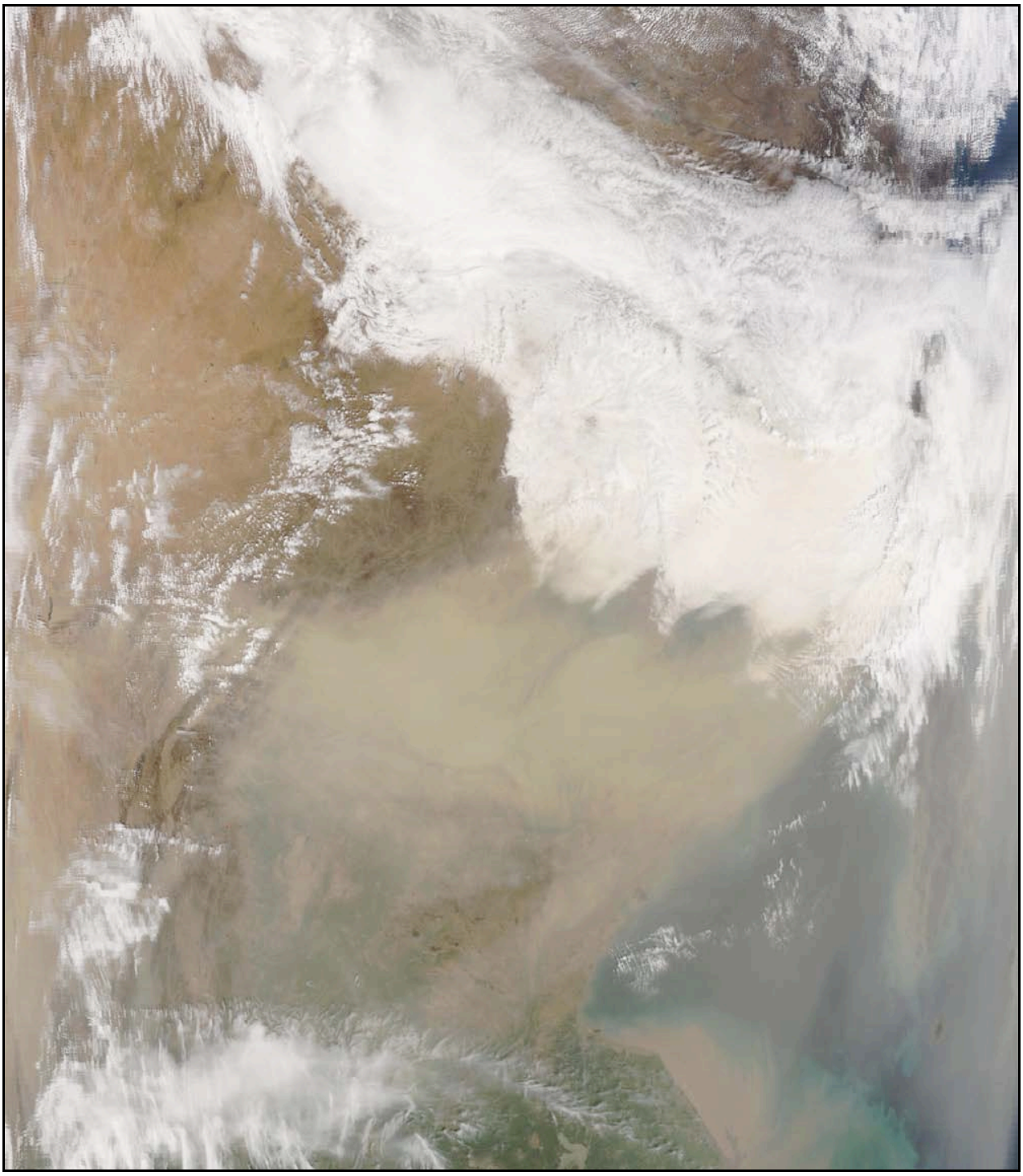
by Wei-Zu Gu and Klaus-Peter Seiler (Gu & Seiler, 2006)

"About 33 percent of China is arid to semi-arid, and about 27 percent (2.6 million km2) of the land is prone to desertification, or becoming desert. It is also estimated that desert regions are increasing at a rate of 2460 km2/year. This developing crisis is a matter of vital importance to China, as desert lands are often uninhabitable, and China's population keeps growing. While there has been some effort to manage and prevent desertification, the problem continues to intensify.

Effective rehabilitation and management are dependent upon a firm understanding of the ecohydrological processes that cause desertification in the ecosystems of particular regions. The western portion of Inner Mongolia, the largest arid region of the country, has a long history of desertification, which has led to the demise of ancient cities and prosperous cultures. The western portion of Inner Mongolia also suffers from modern anthropogenic impacts that accelerate desertification and the degeneration of grasslands. The end result of this damage is the invasion of dunes, destruction of ecosystem homeostasis, decline of biomass productivity, deterioration of water quality, reduction of available arable land, and the spread of endemic diseases. In addition, this area appears to be the main source of the frequent dust storms during recent years. These dust storms sometimes extend to Beijing, and reach even across the Yangtze River to Nanjing.

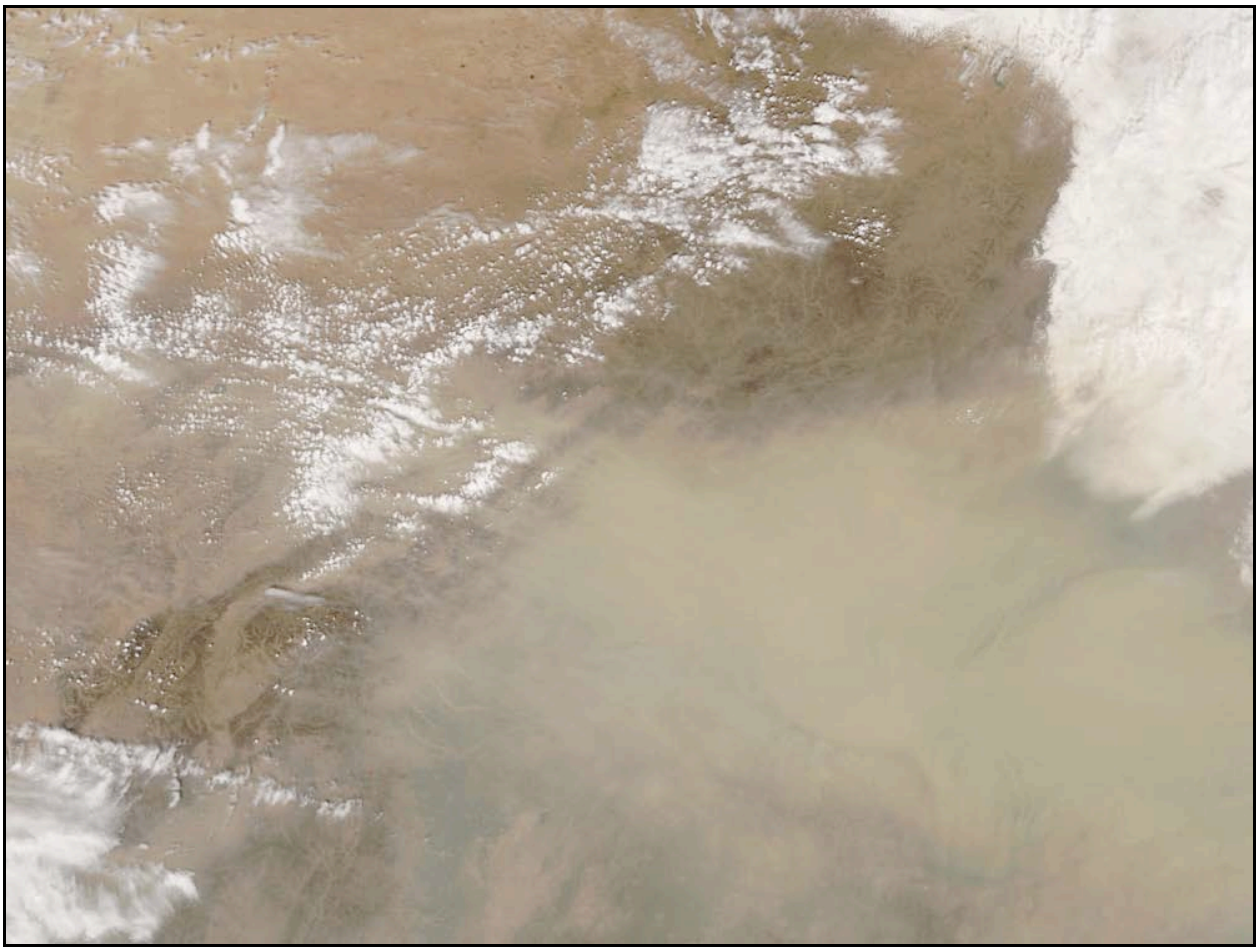
The degradation has been made worse by steadily increasing economic demands within this region of China. These demands are the result of a population exceeding the land's carrying capacity and depleting the already limited water resources. The development and exploitation of China's remaining semi-arid regions seems unavoidable."

(For more on desertification in western China see Yang, Dong & White, 2006)



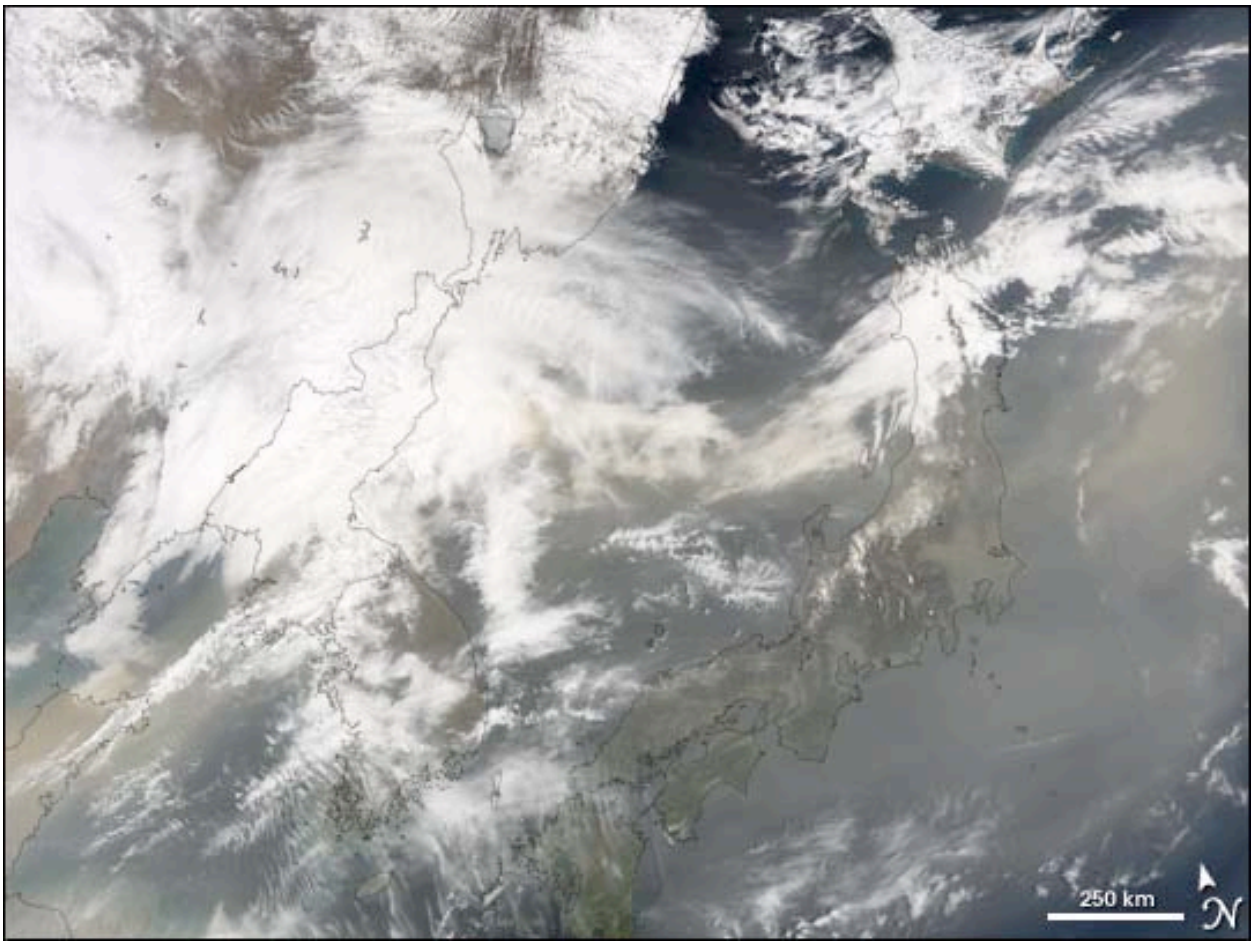
On **April 17, 2006**, another major dust storm swept out of the western deserts and covered the northern half of China's eastern coastal plain. The Bohai Sea, in the center of the image, and the Shandong Peninsula below it are completely obscured by dust. Beijing is below and to the left of center.

(MODIS/Terra image courtesy of NASA)



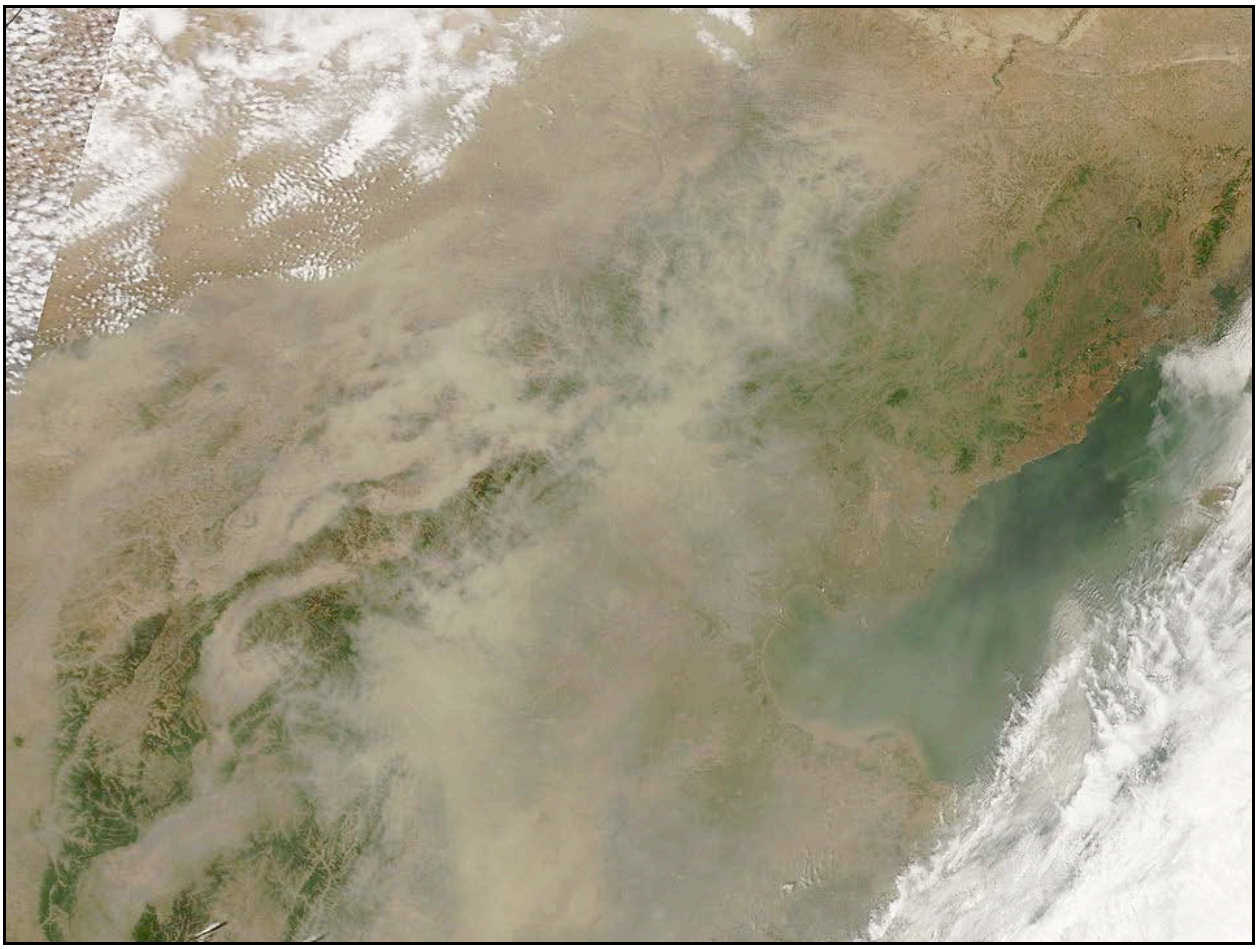
Beijing is in the center of this enlarged MODIS/Terra image from **April 17, 2006.** This dust storm was one of the worst in five years (Papayannis, et al., 2007), dumping an estimated 330,000 metric tonnes of dust on Beijing. This translates into 20 kg (44 lb) of dust per person for everyone living in Beijing (Yang, et al., 2007).

In 2005, a paper in the journal *Nature* (Liu & Diamond, 2005) examined China's changing environment. Partially worsened by human actions such as overgrazing and grassland degradation, dust storms began to increase in the 20th century. Between AD 300 and 1949, northeastern China saw a dust storm on average every 31 years. After 1990, the average jumped to one such storm per year. According to news reports at the time this storm hit, the average rate of dust storms for the Beijing region in northeastern China was five or six a year. This storm was the eighth to hit the region in 2006.



On **April 18, 2006** the MODIS/Terra instrument took this image of dust from China bellowing over Korea to Japan and the Pacific Ocean. In the image, the eastward-moving, tan dust mingles with white clouds. An especially thick plume of dust extends from the Shandong Peninsula to the Korean Peninsula and the islands of Japan. The same day this image was captured, Japan's Meteorological Agency announced that the dust had reached Tokyo, the first such weather event for Tokyo in six years.

Web reference
http://earthobservatory.nasa.gov/IOTD/view.php?id=6477



Above is a MODIS/Terra image from **May 24, 2007** that shows Beijing's first dust storm of the year. Beijing is in the center of the image.

"The battle against deserts is playing out across much of western China. Desertification has caused as much as $7 billion in annual economic losses, the China Daily reported. Over the past decade, Chinese deserts expanded at a rate of 950 square miles a year, according to Wang Tao of the Chinese Academy of Sciences in Lanzhou.

Expanding deserts have contributed to a nearly six-fold increase in dust storms in the past 50 years to two dozen annually, Wang said. Global warming will worsen the problem, as rising temperatures lead to widespread drought and melt most glaciers on the Tibetan Plateau, depriving lakes and rivers of a crucial water source, according to the U.N.-funded Intergovernmental Panel on Climate Change. Hotter, drier land is more vulnerable to soil erosion, Wang said. 'This is the same problem the United States faced in the 1930s with the dust bowl.'" (Casey, 2007)

Dust storm approaching Stratford, Texas 1935

The land of the Great Plains of the United States was originally covered with grasses that held the fine soil in place. The settlers who homesteaded this region brought their traditional farming techniques from back east when they settled the area, and they plowed the land deeply. The remaining land that wasn't plowed had already been damaged by over-grazing from too many cattle and sheep. The situation became so serious that, by 1935, the government developed conservation programs to improve the Dust Bowl by changing the basic farming methods of the region. Even with these measures, the Dust Bowl lasted almost a decade and contributed to the length of the Great Depression of the 1930s. This ecological disaster caused an exodus from Texas, Arkansas, Oklahoma, and the surrounding Great Plains, of over 500,000 Americans displaced from their homes.

(Photograph courtesy of NOAA George E. Marsh Album)

Above is an early example of remote sensing, an aerial view of the beginning of a dust storm over the prairie lands east of Denver, Colorado, **June 1936**. Northerly winds removed the topsoil and then the clouds of dust were raised as high as 16,000 feet by colliding southerly winds. Prevailing west winds then carried some of the dust as far east as the Atlantic coast.

(Photograph courtesy *Monthly Weather Review*)

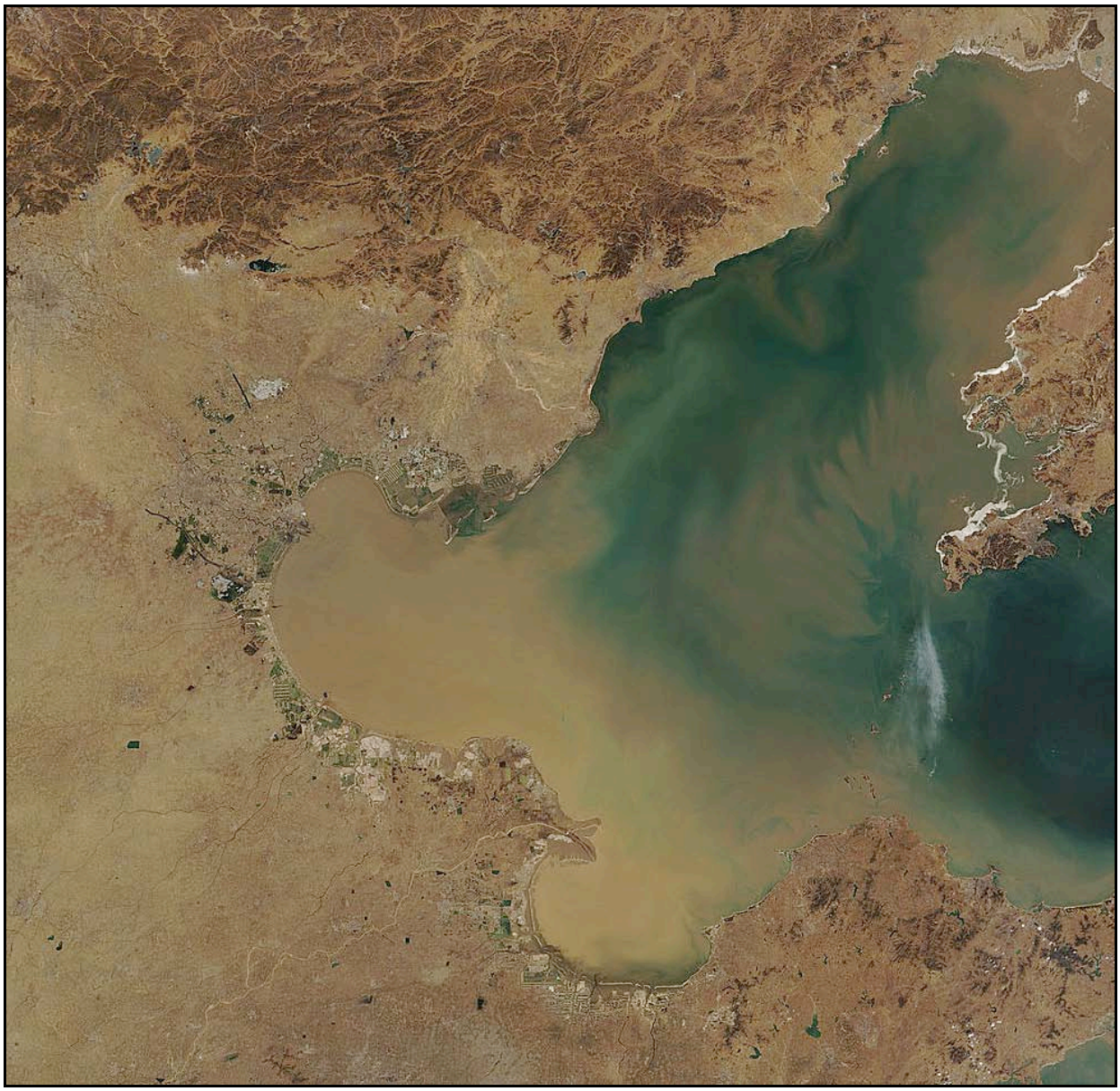
Web Reference
http://en.wikipedia.org/wiki/Dust_Bowl

The Dry Bed of the Yellow River

Dust storms are symptomatic of freshwater shortage in northern China. In addition to direct damage from over-plowing and over-grazing, the northern half of China is literally drying out as rainfall declines and aquifers are depleted by over-pumping. Other countries have aquifers that are being drained to dangerously low levels including the United States. But scientists say the aquifers below the North China Plain may be drained within 30 years (Yardley, 2007). As water tables fall, springs dry up, streams no longer flow, lakes disappear, and rivers run dry. U.S. satellites, which have been monitoring land use in China for over 30 years, show that literally thousands of lakes in northern China have disappeared (Brown, 2001). Between 1965 and 1995, the water table under Beijing, itself, dropped 121 feet. And starting in 1972, even the Yellow River has gone dry almost yearly through part of its course (Pearce, 2006).

Increased use of upstream Yellow River water has progressively depleted the river's resources. Its lower reaches first dried up in 1972 for 21 days, but the dry period has since grown rapidly. In 1992, the river failed to reach the sea for 82 days. In 1995, the dry spell lasted 118 days. During the summer of 1998, the river failed to reach its mouth for over 250 days (Zusman, 2000).

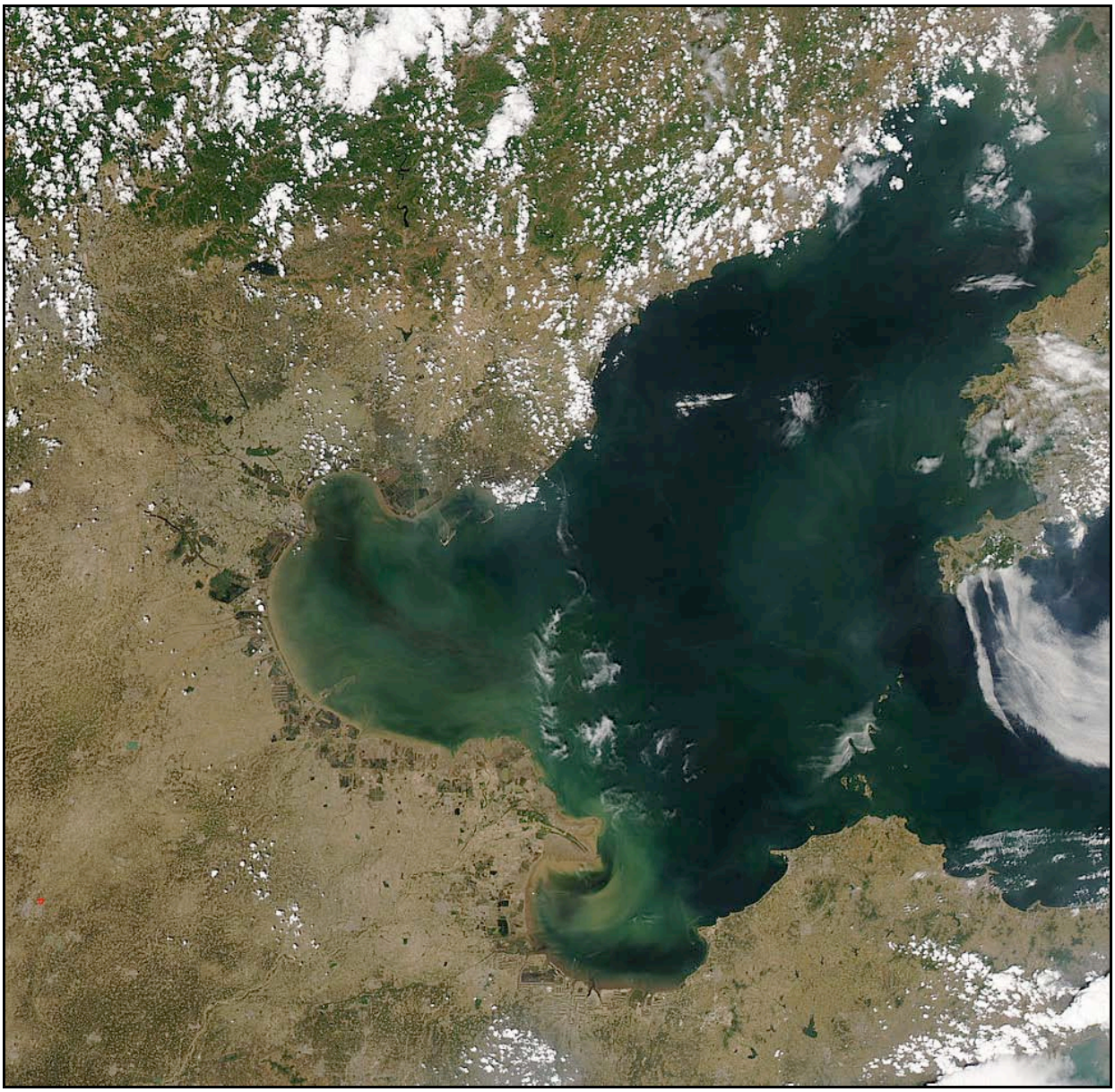
(Photograph by Greg Baker courtesy of the journal *Science*)



Mouth of the Yellow River March 13, 2005

Sediments in the Bohai Sea are an indicator of river flow. During the winter months the Yellow River flows steadily into the sea as shown above. The mouth of the Yellow River is below center in this image.

(MODIS/Terra image courtesy of NASA)



In this image of the Bohai Sea taken **June 2, 2005**, note the lack of sediments at the mouth of the Yellow River compared to the previous image. The explanation is that almost all of the flow of the Yellow River is diverted to irrigation during the summer growing season.

(MODIS/Aqua image courtesy of NASA)

Excerpts from: **Chinese Will Move Waters to Quench Thirst of Cities**

(Eckholm, 2002)

"China, with water scarcity reaching the critical stage in sprawling showcase cities like Beijing and Tianjin in northern China, has embarked on one of history's great water-moving projects. At huge cost and great risk to the environment, the government plans to rechannel vast rivers of water from the Yangtze basin to the thirsty north, over three pathways of nearly 1,000 miles each. The official price tag of $58 billion, nearly half to be spent in the next eight years, is more than twice that of the Three Gorges Dam, China's most recent mega-project now nearing completion.

Some officials speak of delivering new waters to a "green Beijing" in time for the 2008 Olympics, an indication of the political overtones of the project as well as the crash timetable. "We have to sacrifice so that people in Beijing can drink water," said Zhang Jize, a 32-year-old farmer and father of two daughters who is among 370,000 people the plan will uproot.

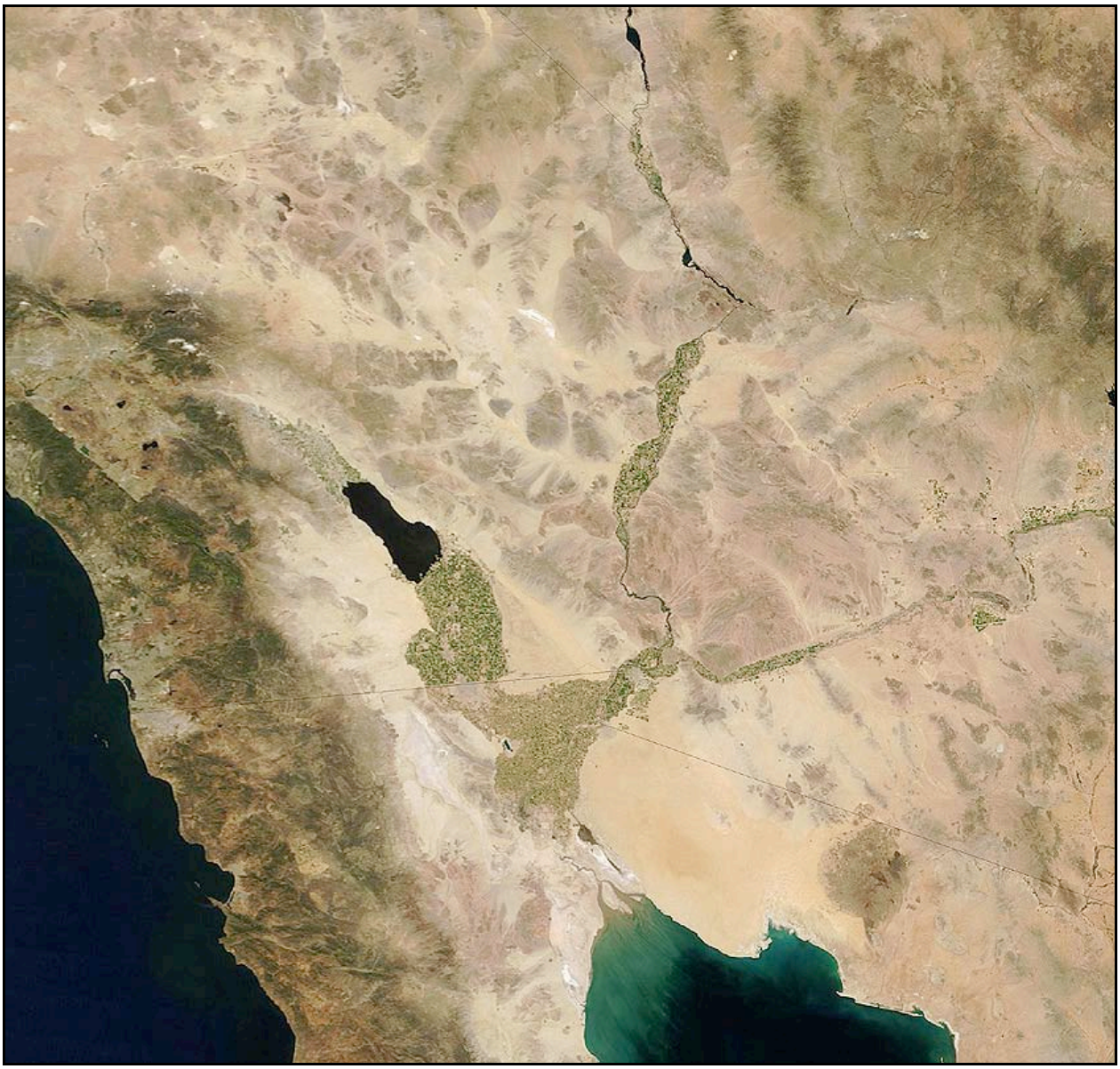
Such immense, centrally planned projects have been tried before, notably in Central Asia, where a Soviet-era plan has steadily drained the Aral Sea, turning what was one of the world's largest inland bodies of water into a salty desert and providing a vivid illustration of the dangers of bending nature to economic needs.

But China, convinced of its future as a great power, believes the project is essential to avoid freshwater becoming a limiting factor in China's push to industrialize. Some have drawn parallels to the great water works of the United States, like the Tennessee Valley Authority that spurred rural development beginning in the 1930's or, more appropriately, the dams and canals that have diverted Colorado River water to fuel fantastic growth in arid Southern California, Arizona, and Nevada."

(For more on China's water diversions see Yardley, 2007)

For more on the Aral Sea go to:
http://fire.biol.wwu.edu/trent/alles/AralSea.pdf

For more on the Colorado River go to:
http://fire.biol.wwu.edu/trent/alles/ColoradoRiver.html



The Colorado River from Nevada to the Gulf of California

The Colorado River, however, may be a poor example of what China should do. Today, with all its water already diverted for irrigation and municipal use, the Colorado runs dry before reaching the sea. The region now faces increasing political turmoil over how to allocate a limited supply of water in the face of continued population growth.

For more on the politics of Colorado River water go to:
http://fire.biol.wwu.edu/trent/alles/LowerColorado.pdf

(May 2, 2004, MODIS/Aqua image courtesy of NASA)

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