Environmental Information System Centre

Acid Rain and Atmospheric Pollution(ARAP)

(Sponsored by Ministry of Environment, Forest & Climate Change, Govt. of India)

INDIAN INSTITUTE OF TROPICAL METEOROLOGY, PUNE

EXTREME WEATHER & POLLUTION EVENTS

Global & National

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Extreme Weather Event - National

EVENT: Hailstone in Maharashtra, 2014

CATEGORY: Natural

Marathwada, Vidarbha, Northern Maharashtra and parts of Western Maharashtra are reeling under unprecedented hail storms and unseasonal rainfall. Hailstorms in end of February 2014, initially thought of as a one-off phenomenon, continue to affect places like Solapur for nearly two weeks, absolutely destroying the farmer.

Cause: The hailstorms developed as a response to hot, damp air from Bay of Bengal as well as Arabian Sea, rising and meeting the cold air coming south from the Himalayas, which led to formation of huge hail. According to reports, Madha Taluka in Solapur alone received 208 mm rainfall, Kurduwadi received 154.1 mm rainfall and Pandharpur received 63.95 mm rainfall in a single day. SANDRP (South Asia Network on Dams, Rivers & People) compared this rainfall with the 1901-2002 district wise rainfall dataset of IMD available at India Water Portal. 208 mm rainfall in Madha in March 2014 is 771.79% higher than the highest recorded monthly district rainfall for Solapur District for the entire month of March in the 100 years between 1901-2002. The highest total recorded rainfall of March for the district was 26.95 mm in 1915. Similarly, 65 mm rainfall received by Ausa Taluka in Latur is 146 % higher than the highest 100 year recorded March rainfall of the district in 1944. Similar is the case with Parbhani, Akola, Wardha, etc. While district rainfall masks extreme spikes due to averaging and also due to the distribution and location of rain gauges, this is truly unprecedented.

Effects: Rabi crops like Wheat, Harbhara, Cotton, Jowar, summer onion are lost, horticultural crops like Papaya, sweet lime, grapes are battered and orchards which took years to grow are ridden to the ground. For many farmers the tragedy is unbearable as majority of crops were about to be harvested. Turmeric was drying in the sun, grapes were waiting to be graded, wheat was harvested and lying in the fields.

Hail in drought-prone Baramati.

According to a preliminary estimate and news reports, crops over 12 lakh hectares have been severely affected, thousands of livestock, animals and birds have succumbed to injuries and diseases, which threaten to spread. Around 21 people have lost their lives to the disaster.

Grapes destroyed.

Destruction in Latur

Predictions: IPCC has predicted that in peninsular India, rainfall patterns will become more and more erratic, with a possible decrease in overall rainfall, but an increase in extreme weather events. What we are witnessing is certainly an extreme weather event.
Linking climate change to singular events is difficult, though climate scientists are unanimous that there is footprint of climate change in each such extreme weather event.

EVENT: Hailstones in Southern India, 2013

CATEGORY: Natural

Hailstones the size of boulders rained down on villages in southern India. At least nine people were killed when the violent weather hit several villages in the state of Andhra Pradesh. The hailstorm which lasted for almost 20 minutes, destroyed crops, houses and live stock, causing devastating financial implications for residents. It was once-in-lifetime experience for people living in seven villages in Chevella, Moinabad and Shankarpally.

Sweeping up of the massive boulders

Cause: The hailstones started falling from the sky on Tuesday night and covered the entire villages under the snow-like blanket. The hailstorm was caused by an intense thunderstorm. Such occurrences are highly localized and restricted to a small area. The storm in the south was extremely rare as the deadliest hailstorms, and perhaps the largest hailstones, in the world occur on the Deccan Plateau of northern India and in Bangladesh.

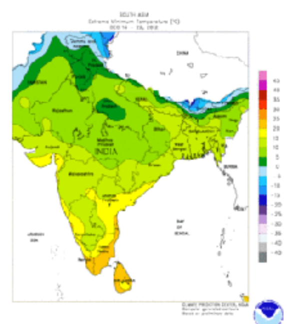
Meteorological department director said humidity incursion in the lower layers of atmosphere and colder air incursion in the upper air led to a severe thunderstorm associated with hail in parts of Chevella mandal. The hailstorm was confined to a small area. Experts said that typical snow flake formation was noticed at Chevella indicates that the precipitation pattern has changed and also indicates drastic changes in local weather conditions.

Effects: It damaged crops and killed livestock. Parts of these affected areas were left in one-foot thick sheet of ice. All the trees were left shorn of leaves. Exposed heavy duty plastic pipes were shattered. Thick leaves of agave plants were shredded.

EVENT: Indian cold wave, 2012

CATEGORY: Natural

Indian cold wave during the winter months of 2012 killed at least 92 people across the northern and eastern India. The drop in temperature had a devastating effect on the hundreds of thousands of homeless people in India.



Extreme minimum temperature 16 to 22 December 2012, computer generated contours, based on preliminary data.

Most of the dead were homeless and elderly people, living in the state of Uttar Pradesh, Rajasthan, Punjab, Haryana, New Delhi, Jammu and Kashmir, Himachal Pradesh, Madhya Pradesh, Bihar and Tripura who were also affected by this cold snap.

New Delhi has also been gripped by cold weather, with the temperature dipping to 7^{o}C on the Christmas Day and 1^{o}C after New Year. In January Delhi experienced night temperatures below 3 °C (37 °F), which was 4 to 5 degrees lower than the normal seasonal average.

In Uttar Pradesh and Bihar the cold wave dropped the mercury to as low as −1 °C (30 °F) which forced closure of all schools up to grade 13 until January 12.

Although there are shelter homes, these are largely poorly furnished, and the poor who seek shelter are forced to lie on the ground, with no blankets.

India Meteorological Department has predicted that the cold spell will continue for a number of days. It was predicted that January could bring even harsher cold conditions in India. It is known that a fresh weather-setting western disturbance would start affecting the western Himalayas later in the first week of January. This could bring back the threat of snow and rain for the higher reaches of Northwest India and fog for the Indo - Gangetic plains.

EVENT: Eastern Indian storm, 2010

CATEGORY: Natural

Map of affected areas On 13 April 2010, at approximately 11 pm local time, a severe storm struck parts of Bangladesh and eastern India. It lasted for about 90 minutes, with the most intense portion spanning 30–40 minutes. As of 16 April, more than 140 deaths have been reported. At least 91 people died in the Indian state of Bihar, 44 in West Bengal, and 4 in Assam. In Bangladesh, five deaths and two hundred injuries were reported. Most of the deaths were women and children crushed when their huts were destroyed. Over 91,000 dwellings were destroyed in India and several thousand in Bangladesh; approximately 3,00,000 dwellings were at least partially damaged. Both mud and pucca housing was damaged by the storm. Nearly 5,00,000 people were left homeless or otherwise affected by the storm.

The storm: According to local officials the storm was an extreme northwestern commonly formed over the Bay of Bengal during the hot months of the year. Meteorologists said the storm was due to an unstable atmosphere caused by excessive heat and humidity. The severity of the storm was likely due to wind pulling the moisture from the Bay of Bengal northward to north Bihar, where it converged with another cloud formation to form a 20 km tall cloud mass. The cool air in the clouds was met by hot air rising from the ground, which caused the storm to start rotating. Although thunderstorms had been predicted, the severity of the storm was unexpected.

Damage: The storm struck in northeastern parts of West Bengal and Bihar states, with winds estimated from 120–160 kilometers /hour (75–100 miles/hour), and then moved into Bangladesh. The strong winds uprooted trees, displaced roof tops, and snapped telephone and electricity lines. The worst damage was reported in the towns of Hemtabad, Islampur, Kaliaganj, Karandighi, and Raiganj. Purina had the most reported casualties. Power was lost throughout the area, and communication was difficult due to severed phone lines and damaged rail lines. Nepal, which relies on India for part of its power generation, was also affected by the outages. The initial strong winds were followed by heavy rains, causing further damage to weakened structures. Widespread damage to crops and livestock was also reported in both West Bengal and Bihar, as well as in Bangladesh. More than 8,000 hectares of maize was destroyed in West Bengal. More than 4,000 hectares of maize was destroyed in Bangladesh. In Assam, paddy crops, bananas, and other vegetation were damaged. Assam crops were already in poor shape due to earlier hail storms before 13 April storm, and were further damaged by another strong storm on 15 April.

Aftermath and rescue efforts: Rescue efforts have been inhibited as many roads, including National Highway 34, are blocked by downed trees and telephone poles. Medical personnel and supplies were quickly rushed to the affected areas, and aid packages were announced. Aid workers began to distribute rice, dried fruits, water, and temporary tarpaulin shelters on 15 April. However, many remote regions remained inaccessible as of 16 April. Aid workers said that hundreds of thousands of victims had not received any relief by 16 April. Another rainstorm on 15 April added to frustrations.

EVENT: Indian cold wave, 2008
CATEGORY: Natural

The raging cold wave that has kept over 400 million people in the northern plains shivering, not only continued unabated, but appeared to have spread the chill to the western parts of the country as well. Intense cold wave gripped North India and Mumbai. In Northern several regions reeled under extremely low temperatures.

In Delhi temperature plummeted to 5.6 degrees Celsius with chilly winds. Amritsar recorded the lowest temperature at 0.1 degree Celsius, six degrees below normal. While Adampur shivered at 1.8 degrees Celsius. Piercing cold wave also lashed Haryana as the mercury hovered at three and 3.2 degrees Celsius at Ambala and Karnal respectively. Rajasthan is also experiencing intense cold wave. The hill resort Mount Abu reeled under freezing temperature. Frigid temperatures in Punjab and Haryana forced residents to lit bonfires.

Cold wave also swept most places in Himachal Pradesh. Keylong and Kinnaur towns continued to be under the impact of severe cold wave with minus 11.3 degrees Celsius and minus 7.2 degrees Celsius respectively.

The Jammu-Srinagar Highway was closed for seven consecutive days following heavy snowfall and landslides. The traffic on the arterial road was restricted to one-way. The 300-kilometers highway was closed on February 3 after heavy snowfall and landslides at Panthal, Ramban, Patnitop and Jawahar Tunnel. The highway is the only road link between the Kashmir Valley and the rest of the country.

The cold wave also had in its grip several parts of western Maharashtra, Marathawada, Vidarbha, and west Madhya Pradesh. In Maharashtra Nasik reeled under a low of minus 4.6 degrees Celsius. Mumbai recorded the lowest temperature in 48 years at 8.5 degrees Celsius. The minimum temperature recorded at Colaba, in south Mumbai, was 13.4 degrees Celsius, while at Santacruz in north Mumbai it was 8.5 degrees Celsius. People preferred to stay indoors to keep warm. The cold wave was expected to continue for at least another two-three days.

Experts said that the cold wave that swept Maharashtra and other parts of India could be attributed to the phenomenon of global warming. Fluctuating climatic conditions due to global warming posed a threat to the very survival of the planet.

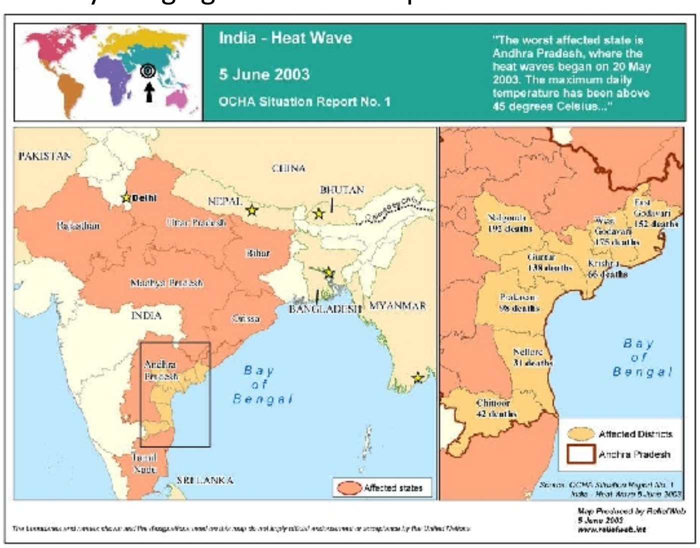
EVENT: Indian Heat Wave, 2003

CATEGORY: Natural

Severe heat wave conditions in several coastal south districts of Andhra Pradesh and adjoining coastal districts of north Tamil Nadu since May are imperiling the lives of people in the region. Heat wave conditions have also developed in parts of Vidarbha region of Maharashtra, eastern Uttar Pradesh, Rajasthan, Madhya Pradesh, Bihar, Jharkhand and Chattisgarh.

Temperatures have risen to between 45 and 50 degrees Celsius (113 to 122 degrees Fahrenheit), nearly 10 degrees above the normal level, with the highest reading of 50 degrees reported in Visakhapatnam, 600 kilometres northeast of Hyderabad. At Nungambakkam in Chennai, capital of the southern state of Tamil Nadu, temperatures have reached 45 degrees, the highest recorded in 93 years. The maximum temperature recorded in Andhra Pradesh was 47.5 degree centigrade at Gannavaran in East Godavari district on 22 May 2003 while in Orissa it touched 48.1 degree centigrade at Titlagarh on 3 June 2003. The severity of the heat wave has been aggravated by the continuing drought in most of these states.

This severe heat wave has affected 23 districts of Andhra Pradesh, eight of them most severely. The maximum temperature has been 7 to 10 degrees above normal. In Andhra Pradesh, more than 1300 people are reported to have lost their lives due to the severe heat wave. Most of the victims were daily wage labourers, rickshaw pullers or construction workers and are from the Below Poverty Line (BPL) households. Andhra Pradesh has almost 12 million poor people, about 15 per cent of its population, in the Below Poverty Line category. Andhra Pradesh faces not only record heat, but also its worst drought in 40 years, with June monsoon rains already delayed. Despite this, the state government has simply told people to remain indoors and drink plenty of water, demonstrating its total disregard for the poor. The Government of Andhra Pradesh has announced an ex-gratia compensation of Rs. 10,000/- to the next of kin of the victim and have advised the people not to work from 12.00 noon to 3.00 p.m. The monsoon rains normally start by the first week of June, but this year expected to be delayed by at least ten days. This monsoon rains will bring reprieve to the situation by bringing down the temperature.



Map showing the heat wave affected areas

Effects: A severe heat wave killed more than 1,200 people over the past three weeks in India with more than 1,065 deaths recorded in the southern state of Andhra Pradesh. Women, children and the elderly are among the dead. Deaths from heat stroke have also been reported in other Indian states, including East Orissa where nearly 100 have died, three in Rajasthan, six in Uttar Pradesh and three in Bihar's Newada district. A large number of people who have been killed are those who survive on daily wages as they have no choice but to go out in search of work every day. People suffered from sunstroke and severe dehydration, with vomiting and high fever. The bodies of several unidentified people aged between 28 and 75 have been found on the streets in various towns.

Extreme Pollution Event - National

EVENT: Particulate Carbon and Dust Deposition Discolouring the Taj Mahal 2014

CATEGORY: Human induced

The white marble domes of the Taj Mahal are iconic images of India that attract millions of visitors every year. Over the past several decades the outer marble surfaces of the Taj Mahal have begun to discolour with time and must be painstakingly cleaned every several years. Although it has been generally believed that the discoloration is in some way linked with poor air quality in the Agra region, the specific components of air pollution responsible have yet to be identified.

A recent study of ambient particulate matter (PM) samples over a one- year period found to contain relatively high concentrations of light absorbing particles that could potentially discolour the Taj Mahal marble surfaces, that include black carbon (BC), light absorbing organic carbon (brown carbon, BrC) and dust. Analyses of particles deposited to marble surrogate surfaces at the Taj Mahal indicate that a large fraction of the outer Taj Mahal surfaces are covered with particles that contain both carbonaceous components and dust. Results indicate that deposited light absorbing dust and carbonaceous particles (both BC and BrC from the combustion of fossil fuels and biomass) are responsible for the surface discoloration of the Taj Mahal. Overall, the results suggest that the deposition of light absorbing particulate matter in regions of high aerosol loading are not only influencing cultural heritage but also the aesthetics of both natural and urban surfaces.

On the timescale of several years the outer marble surfaces of the Taj Mahal become discolored and must be cleaned in a time consuming process. Many measures have been undertaken to avoid the impact of local air pollution, including restricting traffic within 1 km of 53 the grounds and limiting the emissions of industrial pollution in the city of Agra, where the Taj Mahal is located. Despite efforts to keep the outer surfaces of the Taj Mahal white, it continues to become discoloured with time, and the reason for the discoloration is not currently understood.

While detailed scientific studies have not been reported in the literature, past efforts focusing on the discoloration have hypothesized that local air quality is responsible and suggestions have included surface reactions with gas-phase SO2, as well as aqueous phase chemistry linked with the deposition of fog droplets, and water condensation, as well as dust .

Recent work has reported poor air quality throughout the Indo-Gangetic plain, including relatively high concentrations of particulate matter in Agra. Particulate matter in the region includes the light absorbing components black carbon (BC), light absorbing organic carbon (a fraction of which can absorb light preferentially in the UV region and is often termed brown carbon, BrC), and dust. Both organic carbon and dust have the potential to preferentially absorb solar light in the blue region of the spectrum, which can give the atmosphere a brown hue and has thus been dubbed the Atmospheric Brown Cloud. The presence of these light absorbing aerosols, and in particular those that can take on a dark hue against a light colored background, suggest that the deposition of ambient particulate matter may be playing a role in the discoloration of the outer white marble surfaces of the Taj Mahal.

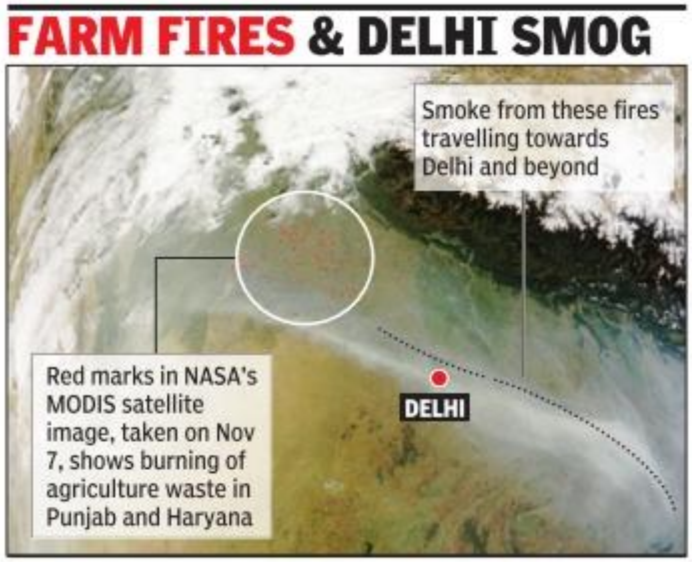
The discoloration impacts not only cultural artifacts but also the aesthetics of the environment through the modification of surface albedo, and hence perceived color.

EVENT: Smog in Delhi, 2014

CATEGORY: Human induced aggravated by weather conditions

Smog intensified in the city as wind speeds reduced, leading to an accumulation of pollutants and aerosols. A NASA satellite image showed agricultural fires in Punjab and Haryana were contributing to pollution in the region in a big way. According to IGI's Met office, a 20-25kmph wind had helped clear the pollution over the city, leading to a good visibility of 4,000 metres. The wind calmed and visibility dropped to about 1100 metres in most parts of the city. It was forecasted that a western disturbance (WD), currently moving across Jammu and Kashmir, may bring fresh moisture and help in intensifying the smog.

Assessment showed that air pollution levels have gone up in Delhi because of biomass burning in Punjab in October 2014. It stands to reason as Patiala has been recording very high PM2.5 and PM10 levels. The winds blowing towards Delhi from the northwest are passing by the area where a lot of agricultural waste is being burned. PM 2.5 (fine, respirable particles) was 189 micrograms per cubic metre, three times more than the safe level of 60. PM 10 (coarse pollution particles) was about 320 microgram per cubic metre as against a safe level of 100 microgram per cubic metre. Experts say biomass burning is only adding to the already high local emissions.



Images released by National Aeronautics and Space Administration (NASA) from its Moderate Resolution Imaging Spectroradiometer (MODIS)'s aqua satellite shows low visibility and smog forming a channel from north-northwest region, fed by smoke coming from Punjab and Haryana where farmers are currently burning leftover stubbles from the paddy crop.

Effects: The combination of pollution from neighbouring states and local emissions is already taking its toll. Every year after Diwali (Oct-Nov), complaints from people with asthma and bronchitis go up. Their aggravated condition is clearly linked to high air pollution which also leads to more hospitalization. Nasal and sinus problems also increase. Those who are healthy often experience with cough or throat problems.

EVENT: Extreme CO event during Unusual Monsoon Progression over Delhi, 2014

CATEGORY: Human induced aggravated by weather conditions

Delhi falls under monsoon-influenced humid subtropical semi-arid climate type, where the normal onset of summer monsoon brings in cleaner air and reduces the level of gaseous pollutants while the monsoon onset during 2013, registered a reversal with a dramatically high CO (Carbon monoxide) level compared to the past years. The air quality in the city worsened owing to a dramatic rise in carbon monoxide (CO) levels in some areas. Many parts of Delhi, including Dheerpur and Mathura Road, have almost double the limit of 1,700ppb. This is mainly because the winds blowing in Delhi are emerging from Bay of Bengal and sweeping through the Indo Gangetic plains, where CO levels are already very high because of the burning of firewood and emissions from the transport sector. CO takes much longer to dissipate and can stay in the atmosphere for almost a month. It can also travel great distances. Parts of southwest Delhi like IGI airport, Aya Nagar as well as Noida are less likely to be affected.

Ozone levels, which had gone up in the month of June, but were again within the safe range below 50ppb in most areas. Particulate pollution, levels of both PM2.5 (fine, respirable particles) and PM10 (coarse particles), also come down with the increase in humidity. But the CO level was building up with the advancing monsoon winds which were predicted to continue to rise for some more days.

Effect: Increased CO levels can lead to shortness of breath, weakness and impact oxygen delivery to organs. According to the US Environment Protection Agency, heart patients already have a reduced capacity for pumping oxygenated blood to the heart, which can lead to myocardial ischemia, a condition often accompanied by chest pain (angina), when exercising or under stress. Short term CO exposure further affect their body's already compromised ability to provide extra oxygen for exercise or exertion. An eight hour standard is generally considered for CO levels.

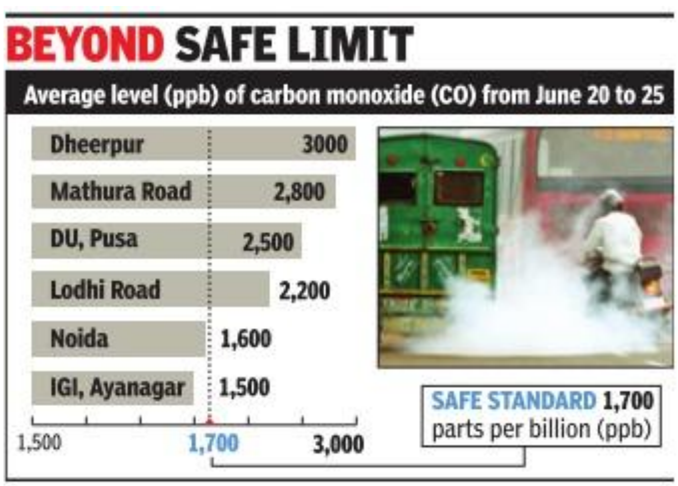


Figure shows the CO concentration from June 20 to 25, 2014

EVENT: Air pollution turning Charminar black 2013

CATEGORY: Human induced

The bad effects of pollution are prevailing all around the world. The increase in vehicles has given a wide upgradation to the air pollution The 400-year-old Charminar the most recognizable symbol of Hyderabad -and other ancient monuments within the 300 metre heritage zone in the area are turning black due to pollution and their plasters are peeling off due to constant vibrations caused by passing vehicles, opinions expressed by conservation architects and environmentalists.

Over the past five years, the Charminar precincts, home to several ancient structures like Mecca Masjid, Jama Masjid, Char Kaman (the four arches) and the Badeshahi Ashoorkhana, have recorded the highest pollution figures.

Cause: The major damage to the monument was on account of vibrations caused by relentless movement of vehicles around it. Heavy traffic movement, particularly the fleet of RTC buses, which make about 2,000 trips touching the monument, has been a cause of concern. Recently, some of the buses have been diverted in the downward direction as part of the Charminar Pedestrianisation Project. Construction activity within 100 metres of the Charminar, is also posing a big threat to the structure's stability.

Charminar was in most polluted area the TSPM recorded in 2010 was 267.5 and in 2012 it was 287. Some of the other oldest structures like Jama Masjid, Mecca Masjid and Badeshali Ashoorkhana are all affected by dust particulates. Architects notice that high levels of the TSPM are the biggest threat to monuments.

According to the experts the measurable total particulate suspended matter (TSPM), respirable suspended particulate matter (RSPM) and oxides of sulphur and nitrogen are all posing huge threats to the ancient structures. The dust forms a layer after accumulating over a period of time. This is causing blackening of the surface. The organic matter that settles on the structure along with the dust leads to moth formation when it rains. Architects say high levels of the TSPM are the biggest threat to structures, particularly monuments.

Effects: The formation of the layer happens much faster on structures with a rough surface. Mecca Masjid, compared to the structure with smooth and plastered surface like

Charminar. It has also been identified that it may take about eight to twelve month for a layer of 1 mm to form over the surface of Charminar, but it happens faster on structures like Mecca Masjid where the rugged stone is exposed. Charminar is the most famous icon of Hyderabad, now it has been suffering from deadly effect of air pollution. It was identified that the minarets of the monuments have developed air cracks at some places. Moss and Lichen growth has been identified on the walls facing the mosque on the second floor and it was also noticed on the steps leading to the upper portions. It was decided by Archaeological Survey of India (ASI) to take up repair activities at a cost of Rs 10 lacks. According to the available sources it was believed that the air cracks formed might be the result of climatic change. The heavy rains that lashed the city recently were believed to form precipitated matters on the surface of the structure. The seepage of rain water and the dampness have also shown their impact on air cracks.

Conservationists blamed the government for failing to protect the Charminar precincts, a key requisite for acquiring UNESCO's world heritage status. They have urged the government to immediately implement the long-pending pedestrianization project, which involves traffic management and development of environs to conserve the heritage identity of the precinct. The archaeology department and the GHMC are solely responsible for the bad state of monuments and their failure to educate the government on the importance of taking immediate steps to protect the structures.

EVENT: Poisonous event in Delhi Oct- Nov, 2012

CATEGORY: Human induced

Megacities are the engines of growing economy where local emissions are steadily leading to a significant rise in air pollution. However, it is for the first time in recent history that Delhi, the capital of India, experienced a unique extreme pollution event where level of fine particulate matters rich in organic carbon concentration crossed from moderate to dangerous unhealthy level within overnight without any additional local emission source and lasted for prolonged 12 days. It prompted about half a million additional hospital visits and admissions with respiratory ailments and increased mortality rate treating environment sustainability and ecosystem. An interpretation to this extreme event was provided by the SAFAR (System of Air Quality Forecasting And Research) monitoring and modelling network established by India and piloted by WMO. It is triggered by unusual synoptic weather conditions which pumped huge amount of biomass plume of north Indian crop burning.

What followed was a vortex like fringe formation within which a stratified stationary condition prevailed with extremely low boundary layer prevented dispersion.

Delhi is industrialized and urbanized megacity of India which is about 1100km away from the nearest coast of Arabian Sea and surrounded by the Thar Desert of Rajasthan in its west and plains of central India in its south. It has a semiarid climate with extremely hot summer and very cold weather during the winters. The city is known for its high levels of air pollution and hazy skies during the winter. Wind speeds are typically higher in the summer and monsoon periods, and generally calm in the winter season. Delhi usually experiences surface inversions and heavy fog events during the winter season. This leads to restriction of dilution of the emissions from specifically motor vehicles and episodic events in Delhi. In December, reduced visibility leads to disruption of road, air and rail traffic.

There is no doubt that the composition of the atmosphere is changing because of human activities, and today particulate pollution by both natural and anthropogenic activities become very serious issue to increased problems like premature deaths, respiratory diseases, and heart attacks. Results showed that apart from local emissions, non-local emissions (either natural or anthropogenic) also played a key role in degradation of air quality in 2012 over Delhi. There are varying sources of emission for particulate pollutants in the winter months, due to an increase in the bio-mass burning for heating purposes which explains higher peaks of PM10 at residential sites at Delhi in winter. Measured values along with satellite imagery revealed that the transport of anthropogenic fine particulate pollutants originating from a distant biomass burning source, rich in organic carbon contributed to solar dimming which along with post westerly disturbance cooling (by 4-5°C) and unusual wind trajectory, forced an vortex like fringe formation over Delhi. Injected and trapped pollutants levels of PM10 and PM2.5 has touched 800 $\mu g/m^3$ and 500 $\mu g/m^3$ respectively, which are more than double the level assigned for emergency or critical category and highly unexpected under normal conditions. The vortex like fringe broken on 14th day with the return of sunlight and change in wind direction which rapidly dispersed the pollutants within overnight and made an end to event and brought back normal winter pollution days. The level of particulate pollution during Diwali has touched all time high during the past 2 years. The highest particulate pollution (PM2.5) 682 $\mu g/m^3$ is observed at Pusa and Noida on 13th November which is just 90% increase from the already elevated background level of 11th November. But this level is more than 2.5 times higher than the "critical" (or very unhealthy level of 253 $\mu g/m^3$).

Back trajectory analysis indicates that suddenly the wind direction has changed and clouds of pollutants emerging from seasonal crop residue burning from neighbouring Punjab and

Haryana states started to envelop Delhi. Thereafter, winds have become significantly calm and with a perfect condition of cold temperature and high humidity, boundary layer has come down and vortex (envelop) is formed where pollutants got trapped (or arrested) which has elevated the pollution. Both natural and anthropogenic activities are deteriorating air quality over megacity Delhi in 2012. The main sources, contributing to the deterioration of air quality in New Delhi, are motor vehicle traffic, domestic fuel burning, industrial sources and power plants. The major source of aerosol particles in Indian mega cities is transportation.

EVENT: Acid Rain in Pune & Nagpur, September 2007

CATEGORY: Human induced

Analysis of rainwater quality over the decade in Nagpur and Pune by the Indian Meteorological Department (IMD) shows a disturbing rise in levels of acid in rainwater.

Analysis of rainwater quality over the decade in Nagpur and Pune by the IMD shows a disturbing rise in levels of acid in rainwater. A study shows a substantial rise in sulphate and nitrate concentration in rainwater in almost all parts of the country. Environmentalists warn that the trend, if not checked, may pose a grave risk to public health.

The IMD has a network of 10 stations across the country to collect and analyse rainwater samples. For the past 26 years, the centres have been monitoring and documenting long-term changes in the chemical composition of rainwater, as part of a world-wide survey under the aegis of the World Meteorological Organisation (WMO).

Analysis of the samples reveals the mean sulphate concentration in rainwater at Pune rose from 0.94 mgl in 1986-95 to 1.62 mgl in 1996-2005, while nitrate levels went up from 2.43 mgl to 3.04 mgl. In Nagpur, for the same timeframe, sulphate concentration saw a sharp increase from 1.06 mgl to 3.48 mgl, while nitrate levels went up marginally from 4.67 mgl to 4.73 mgl. The study attributes this increase to rapid industrialisation and urbanisation in and around the two cities. Though Nagpur recorded a slight recovery in 2007, rainwater samples from Pune largely remained in the 'safe range'.

In 2006, only 5 of the 88 samples collected in Pune were found acidic, but all the monthly samples in Nagpur the same year were acidic. Pune has not recorded any acid rain in 2007 so far. However, at Nagpur, rainwater samples for the months of March, May and June were found acidic.

Scientists at the National Environmental Engineering Research Institute (NEERI), Nagpur, warn that the low pH levels (acidity) in rainwater may affect human health, vegetation, forests and aquatic life adversely. Research has shown a rise in the frequency of chest colds, cough and allergies. High acid content in rainwater may pollute ground water, impacting farm yield and quality of produce.

Compared to the worldwide figures, India is better off than other countries as far as acid rain is concerned. Actions like introduction of regulations regarding ultra-low sulphur emission norms for vehicles and automobiles, which have been extended to cover the whole country, will considerably arrest the identified acidification trend.

EVENT: BHOPAL GAS TRAGEDY 1984

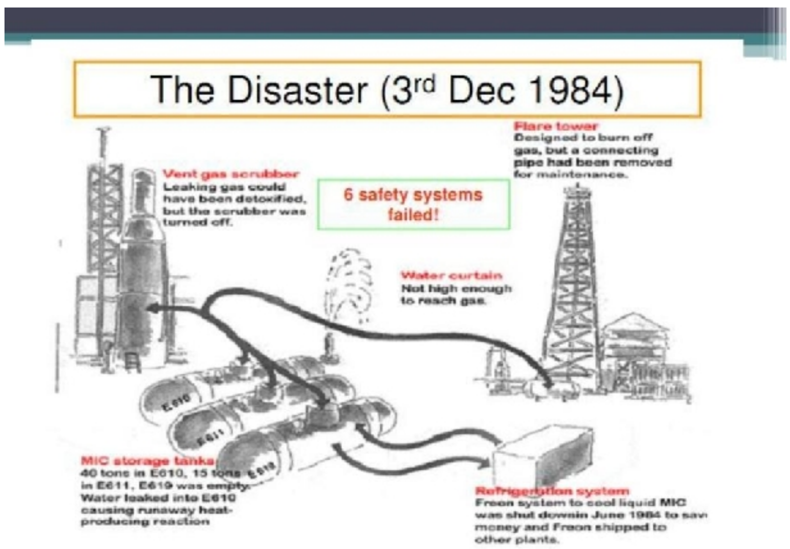
CATEGORY: Human induced

The Bhopal Gas Tragedy, 1984 was a catastrophe that had no parallel in the world's industrial history. In the early morning hours of December 3, 1984, a rolling wind carried a poisonous gray cloud from the Union Carbide Plant in Bhopal, Madhya Pradesh (India). Forty tons of toxic gas (Methy-Iso-Cyanate, MIC) was accidentally released from Union Carbide's Bhopal plant, which leaked and spread throughout the city. The result was a nightmare that still has no end, residents awoke to clouds of suffocating gas and began running desperately through the dark streets, victims arrived at hospitals; breathless and blind. The lungs, brain, eyes, muscles as well as gastro-intestinal, neurological, reproductive and immune systems of those who survived were severely affected. When the sun rose the next morning, the magnitude of devastation was clear. About 5,00,000 more people suffered agonizing injuries with disastrous effects of the massive poisoning.

Cause: The Union Carbide India Limited (UCIL) pesticide plant in Bhopal, India. A leak of methyl isocyanate gas and other chemicals from the plant resulted in the exposure of hundreds of thousands of people. The UCIL factory was built in 1969 to produce the pesticide Sevin (UCC's brand name for carbaryl) using methyl isocyanate (MIC) as an intermediate. An MIC production plant was added in 1979.

Incident: During the night of December 2–3, 1984, water entered a tank containing 42 tons of MIC. The resulting exothermic reaction increased the temperature inside the tank to over 200 °C (392 °F) and raised the pressure. The tank vented releasing toxic gases into the atmosphere. The gases were blown by north-westerly winds over Bhopal. The problem was made worse by the mushrooming of slums in the vicinity of the plant, non-existent catastrophe plans, and shortcomings in health care and socio-economic rehabilitation.

The composition of the gas, as per Union Carbide report, was 26,000 pounds of reaction products along with 54,000 pounds of un-reacted MIC got released into the atmosphere of Bhopal that night. The mixture of gas contains more than two dozens of different types of chemicals and, that also included hydrogen Cyanide.



Factors leading to the magnitude of the gas leak include:

- Storing MIC (methyl isocyanate) in large tanks and filling beyond recommended levels
- Poor maintenance after the plant ceased MIC production at the end of 1984
- Failure of several safety systems (due to poor maintenance)
- Safety systems being switched off to save money—including the MIC tank refrigeration system which could have mitigated the disaster severity


Effects: Estimates vary on the death toll. The official immediate death toll was 2,259 and the government of Madhya Pradesh confirmed a total of 3,787 deaths related to the gas release. Others estimate 3,000-8000 {Greenpeace} died within weeks and another 8,000-20,000 {Greenpeace} have since died from gas-related diseases. According to the Indian Council for Medical Research, 25,000 people have died from exposure **since the initial explosion. But this is not some quarter-century-old tragedy to shake one's head over and move on. It's estimated that** 10 to 30 people continue to die from exposure every month**. A government affidavit in 2006 stated the leak caused 558,125 injuries including 38,478 temporary partial and approximately 3,900 severely and permanently disabling injuries.**

Battle: Union Carbide negotiated a settlement with the Indian Government in 1989 for $470 million – a total of only $370 to $533 per victim – a sum too small to pay for most medical bills. In 1987, a Bhopal District Court charged Union Carbide officials, including then CEO.
Union Carbide was bought by Dow Chemical (the company that made napalm for the U.S. to use in the Vietnam War) in 2001, and Dow claims the legal case was resolved in 1989, with responsibility for continued cleanup now falling to the local state government.
In June 2010, seven ex-employees, including the former UCIL chairman, were convicted in Bhopal of causing death by negligence and sentenced to two years imprisonment and a fine of about $2,000 each, the maximum punishment allowed by law. An eighth former employee was also convicted, but died before judgment was passed.

EVENT: Acid Rain effects on Taj Mahal since 1970s

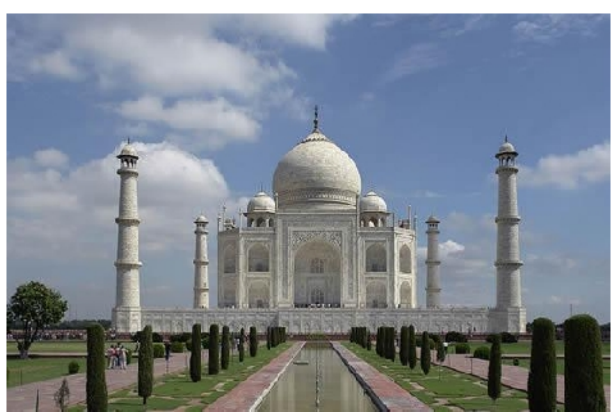
CATEGORY: Human induced

The Taj Mahal, one of the Seven Wonders of the World, and India's pride, greatest land mark is also being threatened from air and water pollution. Agra, where the Taj Mahal stands, has been **polluted heavily** by industries and traffic over the past **decades. Illegal factories** are **springing up** around the Taj Mahal and uncontrolled **construction** around the monument seems to be **endless.** The air in this place contains serious levels of sulphur and nitrogen oxides. This polluted air at the end leads to acid rain. Acid rain has reacted with the marble (calcium carbonate) of Taj Mahal. This caused damage to this wonderful structure, which had attracted many people from different parts of the world. Taj is changing colour due to deposition of dust and carbon-containing particles emitted in the burning of fossil fuels, biomass and garbage.

The white marble domes of the Taj Mahal are iconic images of India that attract millions of visitors every year. Over the past several decades the outer marble surfaces of the Taj Mahal have begun to discolour with time and must be painstakingly cleaned every several years. Although it has been generally believed that the discoloration is in some way linked with poor air quality in the Agra region, the specific components of air pollution responsible have yet to be identified.

Cause: The Mathura Refinery, owned by Indian Oil Corporation, is located in Mathura, Uttar Pradesh. The refinery processes low sulphur crude from Bombay High, imported low sulphur crude from Nigeria, and high sulphur crude from the Middle East. The refinery was in the news for allegedly causing the white marble of the Taj Mahal to yellow. It is located about 50 kilometres away from the Taj Mahal. It was found that the air has high levels of suspended particulate matter, caused by factory emissions, dust, construction, and exhaust from automobiles. These are causing the Taj Mahal to change colour. The other reasons are the carbon particles which come from a variety of sources, including fuel combustion, cooking and brick-making, trash and refuse burning and vehicle exhaust or from distant sources. The sources could be local and the government has already taken steps to reduce vehicle and industrial emissions in the area.

Many experts declared that the measurable Total Particulate Suspended Matter (TSPM), Respirable Suspended Particulate Matter (RSPM) and Oxides of sulphur and nitrogen are all posing huge threats to the ancient monumental structures.



Effects: Beginning in the 1970s, observers noted a brownish cast to the white marble that makes up the structures. Black carbon gives a greyish colour to the surface while the presence of brown carbon and dust results in yellowish-brown hues. The pollution has been turning the Taj Mahal yellow. In 2010, cracks appeared in parts of the tomb, and the minarets which surround the monument were showing signs of tilting, as the wooden foundation of the tomb may be rotting due to lack of water. In 2011 it was reported that some predictions indicated that the tomb could collapse within 5 years.

Measures: At the end of the last **century** the government **realized** the growing problem and started a program to save the monument's **shiny** white **marble facade** because it was turning yellow. Over $150 million were spent on **restoration** but it did not help much. **Corrosion** has continued and **acid rain** has also caused a change in the color of the **facade.** Some years ago **restoration** experts started putting **mud packs** around the **facade** to bring back the building's shiny white color.

The government of India is constantly enacting laws to prevent the factories from causing pollution in to the atmosphere which would directly cause adverse change to Taj Mahal. To help control the pollution, the Indian government has set up the Taj Trapezium Zone (TTZ), a 10,400-square-kilometre (4,000 sq mi) area around the monument where strict emissions standards are in place. A series of serious banning measures have been taken including avoiding running of vehicles 500 meters away from the structure and sophisticated devices are arranged to provide running count of air pollution. To cut back on pollution, cars and buses are not permitted to drive to the Taj Mahal but must be parked at a lot about 2km away, where visitors can take battery-run buses or horse-drawn carriages. Factories and industries around Agra should be **persuaded** to change to cleaner forms of energy.

EVENT: Acid rain in India Overview

CATEGORY: Human induced

Urban air pollution is probably the most well-known problem created by rapid industrialisation. Air pollution around major factories, thermal power plants, open mines and quarries has attracted a lot of attention. Rain over India is much less acidic than most of the other countries in Asia, Europe and North America. However, it has become more and more acidic over the last few decades.

The pH of rain in India ranges from 5.9 to 8.4, and the average is about 6.7. India seems to be much better off than the USA (4.15–6.19), Canada (4.23–5.96), Germany (4.05–4.25), Norway (4.10–4.40), and most other countries. However, there are places in India where things are not so good. Parts of south Bihar and West Bengal are likely to be the worst affected, along with the southernmost tip of the Indian peninsula. Occasional rains with a pH of 4.8 have been reported from Chembur in Mumbai and a pH of 4.5 from Delhi. The more worrying trend is the gradual acidification of the rain in India over the last couple of decades – the pH has decreased from 7.0 to 6.1 in Delhi, and from 9.1 to 6.3 in Agra.

Causes and impacts: Thermal power plants in India, which generally use coal with relatively high sulphur content (0.5 per cent to three per cent), are the major source of oxides of sulphur – they release about 2,500 tons per year. Oxides of nitrogen are produced during high-temperature combustion. The greatest source of nitrogen oxides is road vehicles.

India has been rather lucky to have predominantly alkaline-rich soils. For example, in the Thar Desert in the northwest of India, the aerosols from coastal areas help reduce the acidity to a considerable extent. Higher temperatures prevalent in India also contribute towards transforming the oxides of sulphur to sulphates and oxides of nitrogen to nitrates. India also does not have natural sources of sulphur emission like volcanoes. These factors have kept the acid rain in check so far. However, the emissions from the increasing number of power plants, industries, fossil-fuel burning and vehicles have gradually begun to overcome the natural checks. In 1990, none of the ecosystems in India was threatened by acid rain. However, if steps are not taken to control emissions, by the year 2020 about 85 per cent of the ecosystems will be threatened by acid rain.

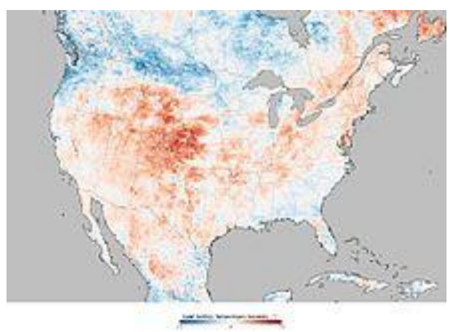
Possible solutions: India’s solutions are similar to that of many other countries: the use of cleaner fuels, a gradual switching to renewable energy and the use of catalytic converters.

Extreme Weather Event - Global

EVENT: North American heat wave summer 2012

CATEGORY: Natural

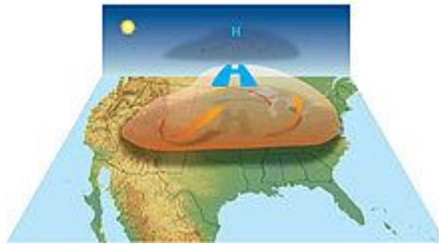
In the summer of 2012, a heat wave took place, leading to more than 82 heat-related deaths across the United States and Canada. An additional twenty-two lives were lost in the resultant June 2012 North American derecho. This long-lived, straight-line wind and its thunderstorms cut electrical power to 3.7 million customers. Over 500,000 were still without power on July 6, as the heat wave continued. Temperatures generally decreased somewhat the week of July 9 in the east, but the high pressure shifted to the west, causing the core of the hot weather to the build in the Mountain States and the southwest U. S. shifting eastwards again by mid-July. By early August, the core of the heat remained over the Southern Plains.



Map of land surface temperature anomalies for June 17–24, 2012. The map depicts temperatures compared to the 2000–2011 average for the same eight-day period in June. (Land surface temperatures (LST) are distinct from the air temperatures that meteorological stations typically measure.)

Cause: The heat wave formed when high pressure aloft over the Baja of Mexico strengthened and moved over the southern plains around June 20–23 and then spread east and northward, remaining fixed over the centre of North America through July 2012. The heat is due to the fact that, under high pressure, the air subsides (sinks) toward the surface. This sinking air acts as a dome capping the atmosphere. This cap helps to trap heat instead of allowing it to lift. Without the lift there is little or no convection and therefore little or no convective clouds (cumulus clouds) with minimal chances for rain. The end result is a continual build-up of heat at the surface resulting in drought conditions over wide areas.

This heat wave, like all extreme weather events, has its direct cause in a complex set of atmospheric conditions that produce short-term weather. However, weather occurs within the broader context of the climate, and there's a high level of agreement among scientists that global warming has made it more likely that heat wave of this magnitude will occur.



High pressure aloft traps heat near the ground, causing a heat wave

Heat wave: The intense heat wave in the West was initiated around June 20–23 when the high pressure system cantered over the Baja of California shifted upward into the plains and caused temperatures to approach or even surpass 110 degrees for the next several days, breaking many records for the area.

The heat spread east from the Rocky Mountains and a massive high-pressure system over the Midwest caused extreme temperatures not seen on such a scale since the 1930s. The heat further spread to south eastern U.S, mid Atlantic and mid-west. After some modification in the heat during the past week over the mid-west and northeast, the jet once again moved further north into Canada allowing intense heat to build across eastern North America.

Impacts: Wildfires raged across the western United States during the time of the heat wave, in part attributable to the dry conditions caused by the heat. The Waldo Canyon fire in Colorado attracted the most attention after spreading into Colorado Springs and charring hundreds of homes (investigators determined it to be human caused, rather than from "the heat"), but large wildfires also burned throughout Utah, Wyoming, Montana, New Mexico, Arizona and Idaho.

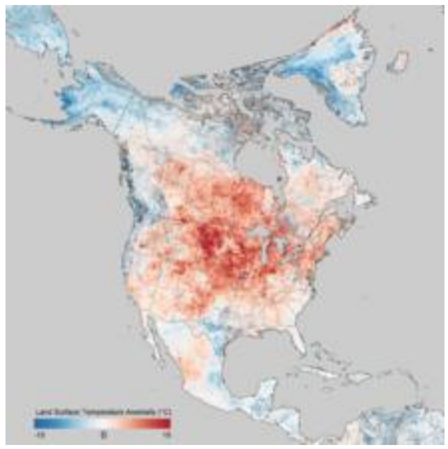
The heatwave has also contributed to the record-shattering 2012 North American drought, which has caused massive crop failures throughout the Midwest and most likely will cause food prices to rise. This drought affects 80% of the contiguous US as of July 24, and is considered the worst drought since the 1950s but not yet on the scale of devastation endured during the dust bowl of the 1930s.

Severe storms: On July 26, 2012, the heat wave contributed to the formation of a multi-bow serial derecho in the Midwest and Northeast. On June 29–30, 2012, The heat and humidity from the heat wave caused a small thunderstorm in Iowa to develop into a violent and unprecedented derecho, which tracked across the Midwest and Mid-Atlantic regions of the United States while causing 80 MPH or higher winds, doing hundreds of millions of dollars in damage, and downing trees and power lines, leaving four million people in the eastern U. S. without power.

EVENT: North American heat wave March 2012

CATEGORY: Natural

In March 2012, one of the greatest heat waves was observed in many regions of North America. Very warm air pushed northward west of the Great Lakes region, and subsequently spread eastward. The intense poleward air mass movement was propelled by an unusually intense low level southerly jet that stretched from Louisiana to western Wisconsin. Once this warm surge inundated the area, a remarkably prolonged period of record setting temperatures ensued.



Land surface temperatures of March 8–15, 2012.
(Land surface temperatures are distinct from the air temperatures that meteorological stations typically measure).

NOAA's National Climate Data Centre reported that over 7,000 daily record high temperatures were tied or broken from 1 March through 27 March. In some places the temperature exceeded 86°F (30°C). For instance, in Grand Rapids, Michigan, the highest temperature recorded was 87°F (March 21), in Chicago 84°F (March 20) etc. Records were broken in unusual ways.

Temperature records across much of southern Canada also were shattered. Some of the most impressive readings came from Nova Scotia on March 22, when the mercury climbed to 30C (86°F) at a climate station in Lake Major, making it the highest March temperature recorded in Nova Scotia, and the third highest March temperature recorded in Canada. Non-severe thunderstorms were reported on the evening hours of March 21, through to the early morning hours March 22 into northern Ontario.

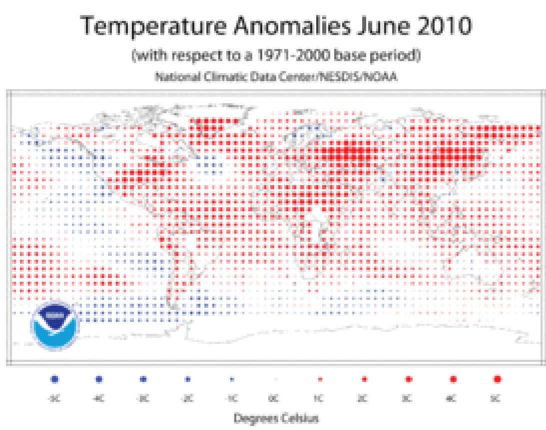
Averaged over the seven-day period from March 16 to March 22 inclusive, nearly the entire area of the Midwest and Northeast U.S. and most of Ontario and Quebec had temperatures 10°C (18°F) or more above the 1981-2010 average. Even more dramatically, most of Iowa and Minnesota, all of Wisconsin and Michigan, and most of south-eastern Ontario had seven-day mean temperatures more than 15°C (27^{o}F) above the climatological average for the same period.

The continued heat following the lack of snow the previous winter was a contributor to the record-shattering 2012 North American drought.

EVENT: Northern Hemisphere summer heat waves 2010

CATEGORY: Natural

The **2010 Northern Hemisphere summer heat waves** included severe heat waves that impacted most of the United States, Kazakhstan, Mongolia, China, Hong Kong, North Africa and the European continent as a whole, along with parts of Canada, Russia, Indochina, South Korea and Japan during May, June, July, and August 2010.



A map of the above-average temperatures, caused by the global heat waves, in June 2010.

The heatwave processed in two phases:

1) The first phase of the global heatwaves was caused by a moderate El Nino event, which lasted from June 2009 to May 2010. It lasted only from April 2010 to June 2010, and caused only moderate above average temperatures in the areas affected. But it also set new record high temperatures for most of the area affected, in the Northern Hemisphere.

2) The second phase (the main and most devastating phase) was caused by a very strong La Nina event, which lasted from June 2010 to June 2011. According to meteorologists, the 2010–11 La Nina events was one of the strongest La Nina events ever observed. This phase lasted from June 2010 to October 2010, caused severe heat waves, and multiple record-breaking temperatures. The heat waves began on April 2010, when strong Anticyclones began to develop, over most of the affected

regions, in the Northern Hemisphere. The heat waves ended on October 2010, when the powerful Anticyclones over most of the affected areas dissipated.

June 2010 marked the fourth consecutive warmest month on record globally, at 0.66°C (1.22°F) above average, while the period April–June was the warmest ever recorded for land areas in the Northern Hemisphere, at 1.25°C (2.25°F) above average. During June 2010, the highest recorded temperature caused by the heatwave was 128.3°F (53.5°C), in South-eastern Russia, just north of Kazakhstan. The weather caused forest fires in China. A major drought was reported across the Sahel as early as January.

The heat waves ended in late October 2010 and about $500 billion (2011 USD) of damage was done, in the Northern Hemisphere alone. The heat waves had caused around 17,905,000 deaths globally, with 3,000+ direct, 17,821,672+ indirect, and 21+ unconfirmed deaths, through factors including famines and heat strokes.

The World Meteorological Organization stated that the heat waves, droughts and flooding events fit with predictions based on global warming for the 21st century, include those based on the Intergovernmental Panel on Climate Change's 2007 4th Assessment Report although still no specific weather events can be linked directly to climate change. However, some climatologists argue that these weather events would not have happened if the atmospheric carbon dioxide was at pre-industrial levels. NOAA and other researchers have found the 2010 heat wave was caused by natural atmospheric variability.

EVENT: China drought and dust storms 2010

CATEGORY: Natural

The **2010 China drought and dust storms** were a series of severe droughts during the spring of 2010 that affected Yunnan, Guizhou, Guangxi, Sichuan, Shanxi, Henan, Shaanxi, Chongqing, Hebei and Gansu in the People's Republic of China as well as parts of Southeast Asia including Vietnam and Thailand, and dust storms in March and April that affected much of East Asia. The drought has been referred to as the worst in a century in south-western China.

A sandstorm hits Longjing Township, Taichung County, in Taiwan on March 21, 2010.

Causes: Prior to the drought in Yunnan and Guizhou, the China Meteorological Administration recorded temperatures averaging 2°C warmer than normal over six months and half the average precipitation for the past year across the region, both unprecedented since at least the 1950s. The effects of El Niño are believed to be contributing to the drought, which may be exacerbated by global warming, as some areas in Yunnan have recorded record high temperatures during the winter since record-keeping began in 1950. Some areas in the drought-affected regions have seen no rainfall since before October. Spring dust storms are common in China, but have become more severe in recent years due to desertification, deforestation, drought, urban sprawl and overgrazing. A severe drought in 2009 also affected much of Northern China and North-eastern China, resulting in agricultural losses of up to 50%.

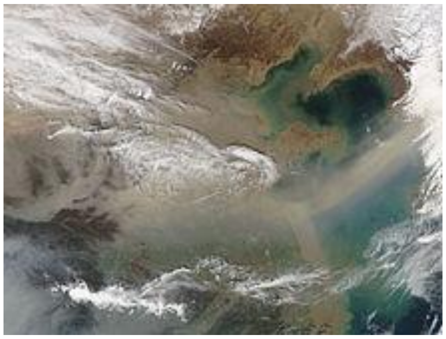
Effects:

- By March 22, 2010, about 51 million people faced water shortages in a number of provinces.
- Commodities including sugar cane, flowers, tea, fruit, potatoes, rapeseed, medicinal ingredients, tobacco, wheat, rubber and coffee have been severely affected with output reduced by as much as 50%.
- More than 20 million people left without adequate drinking water.
- Economic damage to agriculture and failed electricity generation from hydroelectric dams from the drought was estimated to be at least 24 billion Chinese yuan ($3.5 billion USD).
- Around 3,600 rivers and brooks ran dry, while 916,000 ha of crops were affected by drought in the province and one million farmers have left to find work in other provinces.
- The drought affected over 28 million farmers, and a grain shortage has affected 8 million people. The Chinese government has transferred 1.7 million tonnes of grain to the region to reduce potential inflation.
- By early June, the drought had affected close to 5 million hectares of land.
- The drought has affected non-ferrous metal production including electrolytic zinc, with companies in Nandan County cutting production by 30%.

The El Niño conditions of the winter prior to the drought has raised concerns that the rice crop in Vietnam, Thailand and the Philippines may be significantly reduced by the summer.

Most provinces in South China affected by the drought were hit by a series of floods beginning in mid-May that ended most of the drought but also destroyed large areas of farmland.

Dust storms:



The dust storm on March 12, 2010 over eastern China.

Strong dust storms from the Gobi Desert in Mongolia hit Xinjiang Autonomous Region, Inner Mongolia, Shaanxi, Shanxi, Hebei, Beijing, Hong Kong, Taiwan, South Korea, North Korea and Japan by March 22, before being carried across the Pacific Ocean by the jet stream, with some dust reaching the West Coast of the United States.

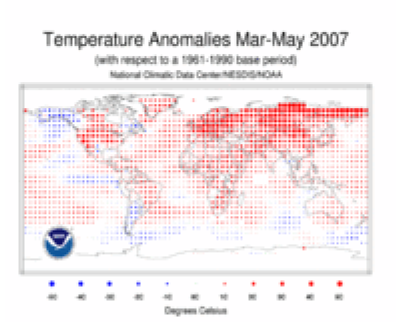
The dust storm in late March spiralled around a strong low pressure system. Many areas recorded an extremely rare level 5 "hazardous" rating for air quality. Many flights in Beijing were also delayed or cancelled. Air pollution readings in Hong Kong reached a record high, reaching at least 15 times the recommended maximum levels by the World Health Organization. Taiwan also reported a new record for worst sandstorm conditions.

A strong sandstorm tore through Turpan in Xinjiang on April 23, sparking fires that killed two people and forcing a shutdown of rail and road traffic for six hours.

EVENT: Asian heat wave 2007

CATEGORY: Natural

The **2007 Asian heat wave** affected the South Asian countries of India, Pakistan, Bangladesh, and Nepal, as well as Russia, Japan and the People's Republic of China. The heat wave ran during the months of May and June, which continued to September in Japan.



2007 temperature anomalies in March–May, with respect to a 1961–1990 base period.

Countries Affected:

- India: Heat-related deaths were reported from the capital New Delhi, northern Haryana, Uttar Pradesh, Rajasthan and Madhya Pradesh. After three days of intense heat with temperatures hovering about 4 °C (104°F), New Delhi was relieved as the temperature slid down to 37.2°C (99.0°F). Meanwhile, the temperature soared to more than 46°C (115°F) at several places in northern Madhya Pradesh, with Datia turning out to be the hottest at 48 °C (118 °F). More than 120 peacocks died in Tughlakabad Fort and Surajkund due to the heat; additionally, reports of severe water shortages were common. A total of 400 peacocks died in Madhya Pradesh, about 200 of those being in Haryana and Punjab alone. The cotton crop in Punjab was severely affected by the heat wave. Meanwhile, the persisting heat wave in various parts of Chandigarh rendered milk cattle dry. When the day temperature hovered around +48°C (118°F), milk supply to various milk plants of cooperative unions went down by 40,000 litres per day. In addition, milk collection by private-sector plants was reduced by 160,000 litres during the same period.

- Bangladesh: Coming at the end of May, a heat wave left at least 26 people dead. According to hospital sources most victims of the heat were rice farmers working in terraces exposed to the blazing sun for long periods. Nearly 200 people, including several children, were admitted to hospitals with symptoms of heat stroke. According to the meteorological office in Dhaka many northern towns showed day temperatures reaching over +40°C (104°F), which is not normal in the Bangladeshi summer. Additionally, there was a high level of humidity.

- Nepal: A heat wave affected the livelihood of a large number of poverty-stricken families who depend on day outdoor labour done outdoors, such as constructing roads, driving rickshaws, selling vegetables, making quilts and farming. According to the government's Department of Meteorology the temperature in Nepalganj got up as high as +44°C (111°F). It is estimated that at least 11 people died.

- Pakistan: The heat wave over Pakistan was claimed to have brought the death toll there up to 192. The meteorological department registered a record maximum temperature of +52°C (126°F) in Sibi. Four people died as the temperature in Lahore touched +48°C (118°F) on 9 June, which was a record for the previous 78 years.

- Russia: The heat waves hit Russia at the end of May. The temperature in Moscow reached +32.9°C (91.2 °F) on 27 May. The Russian capital had not seen such a sustained heat wave for 128 years. On 28 May an absolute temperature record for May was set, breaking the record of +31.8 °C (89.2 °F) that had been registered back in 1891. The heat also affected agriculture, wiping out about 5,000 km² of spring sown fields. Animals at Moscow Zoo found it hard to keep cool. Staff had to prevent walruses from bathing in their pool because the water was too warm for them.

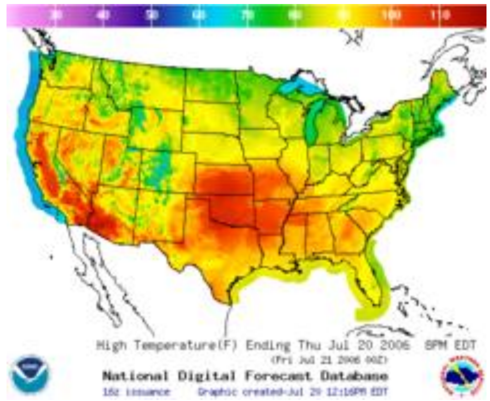
- China: Beijing opened up its warren of old air raid shelters to help people escape from the heat. The heat also set off explosives at a chemical plant in Shanxi. The explosions injured hundreds of people nearby.

- Japan: Most of Japanese cities are highest level of an average temperature, since May to September. According to Meteorological Agency of Japan confirm report, the highest temperature recorded on Celsius 40.9 degrees hitting in Kumagaya, Saitama and Tajimi, Gifu, Celsius 40.3 degrees hitting in Koshigaya, Saitama, on 16 August. And above Celsius 29 degrees of average temperature points are Tokyo, Nagoya, Osaka, Takamatsu, Shikoku. In September, major Japanese cities are recorded to high temperature of Celsius 32 to 37 degrees levels, with highest level of an average temperature in September, since 1868. According to Ministry of Health, Labour and Welfare in Japan confirm report, resulting to 923 people death of hyperthermia by heat wave in around Japan, and worst heat stroke disaster of Japanese and North East Asia's history.

EVENT: North American heat wave 2006

CATEGORY: Natural

The **2006 North American heat wave** spread throughout most of the United States and Canada beginning on July 15, 2006, killing at least 225 people. That day the temperature reached 117 °F (47 °C) in Pierre, South Dakota, with many places in South Dakota that hit well into the 120s.



The heat wave went through several distinct periods:

- From July 15 to July 22 very high temperatures spread across most all of the United States and Canada. On Monday, July 17, every state except Alaska, Minnesota, and North Dakota recorded temperatures of 90°F (32°C) or greater. North Dakota had recorded a temperature of 104°F (40°C) the previous day.
- From July 23 to July 29 the abnormal heat was concentrated in the West coast and South West deserts. 164 fatalities were reported in California during this period.
- From July 29 to August 4 the heat wave moved eastward, causing further fatalities as it progressed.
- From August 4 to August 27, high temperatures persisted in the South and Southeast United States. The heat wave finally ended with the progression of a cold front through the Southern Plains.

Mortality: Reported deaths reached 22 in ten states by July 21, the end of the first stage of this heat wave. At least 31 deaths due to the heat were reported in New York City by August 16. In the early August heat, Chicago saw at least 23 deaths, but the City was widely praised for avoiding the disaster that occurred in the 1995 Chicago heat wave which saw over 700 deaths.

Meteorology : Temperatures hit 118°F (48°C) on July 21 in Phoenix, making it the hottest day since 1995 and one of the 11 hottest since 1895, when temperature records were first kept in the city. California temperatures began reaching record levels by July 22.

The California heat wave broke local records. According to some reports it was hotter for longer than ever before, and the weather patterns that caused the scorching temperatures were positively freakish. Fresno, in the central California valley, had six consecutive days of 110 degree-plus Fahrenheit temperatures.

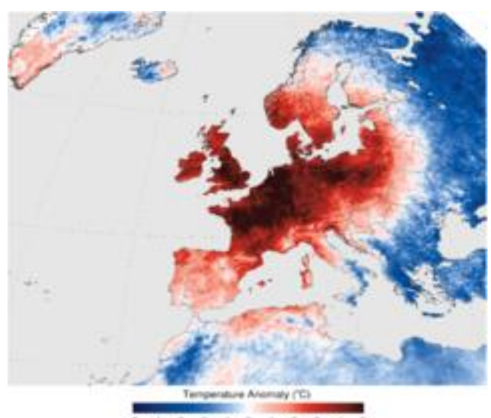
Reported physical damage: Dallas, Texas; Shreveport, Louisiana; the New England region; and other areas have reported damage such as ruptured water lines and buckled roads. The heat wave has been blamed for the damage. Interstate 44 had two traffic lanes temporarily closed in Oklahoma City after they buckled under the heat. In addition, overworked power transformers have been damaged or rendered useless because of the heat, resulting in blackouts, notably in St. Louis, Missouri; Queens, New York; Los Angeles, California; and the Delaware Valley. Some wildfires, including forest fires, and greater thunderstorm intensity, have both been blamed on the heat wave.

Impact of heat waves: Although comparatively little reporting is made about the health effects of extraordinarily hot conditions, heat waves are responsible for more deaths annually than more energetic natural disasters such as lightning, rain, floods, hurricanes, and tornadoes.

EVENT: European heat wave 2006

CATEGORY: Natural

The **2006 European heat wave** was a period of exceptionally hot weather that arrived at the end of June 2006 in certain European countries. The United Kingdom, France, Belgium, Netherlands, Luxembourg, Italy, Poland, the Czech Republic, Hungary, Germany and western part of Russia were most affected. Several records were broken. In the Netherlands, Belgium, Germany, Ireland, and the United Kingdom, July 2006 was the warmest month since official measurements began.



Countries affected:

- Belgium experienced two heat waves in July 2006. Before 1990 a heat wave occurred about once every 8 years, but during the last decade the country averages one heat wave per year. On 19 July 2006, temperatures throughout the entire country rose to 36 °C (97 °F), making it the hottest July day in almost 60 years.
- In United Kingdom, Drought was an issue in many parts, after a very dry winter. There was warning of drought occurring from the early months of 2006. Following the dry winter, with extreme temperatures occurring in the country and little rain, increasing strain was put on water supplies, and hose-pipe bans were issued in many

counties. The Environment Agency claimed that the UK may have had the most severe drought in 100 years. The Met Office confirmed that July 2006 was the warmest July, as well as the warmest single month, overall, across the UK, and a number of regional records were also broken.

- In Germany most of the July temperature average records were broken. The biggest problem was the precipitation, which mostly fell in intense thunderstorms. At least 20 people died in this heatwave.
- Denmark experienced the warmest July ever with an average temperature (day and night) of 19.8 °C (67.6 °F), breaking a record of 19.5 °C (67.1 °F) set in 1994.
- High temperatures in France destroyed many crops, just days before the harvest period, while French officials said at least 40 people were confirmed to have been killed by the heat wave directly. Temperatures as high as 37 °C (99 °F) were recorded in Paris during the heatwave. July 2006 was in many regions the warmest July ever recorded (and often the second warmest month after August 2003).
- Ireland was affected from the heat wave from the start of June, and the warm weather continued until the end of July. May 2006 was the warmest for 20 years and sunniest since 2000.
- In Netherlands July 2006, with a monthly average of 22.3 °C (72.1 °F), KNMI statistics show July 2006 was the warmest-ever month on record for the Netherlands. Around 500 or 1,000 more people than usual died in July 2006. The Netherlands also had to deal with extreme drought in June and July.
- In Poland July 2006 was the warmest in Poland since the beginning of the meteorological measurements (from 1779). July 2006 was also extremely dry. In many regions it was not raining from the 3–4 weeks. The rivers reported the lowest states of water in history. In the absence of rain dried up many crops.
- In Sweden According to the Swedish Meteorological and Hydrological Institute (SMHI), the city of Lund in Skane in southern Sweden had the highest average temperatures (day and night: 21.6 °C (70.9 °F)) for the month of July since records began in 1859. The highest temperature in Sweden in July 2006 was recorded in Malilla in Smaland, where a temperature of 34.2 °C (93.6 °F) was recorded on 6 July which was the highest temperature recorded since July 1994.
- In Russia Absolute maxima of July 2006 have been broken in Pskov +35°C (95°F), Saint Petersburg +34.3°C (93.7°F). The warmest July in Kaliningrad +21.2°C (70.2°F)

Period after the heat wave:

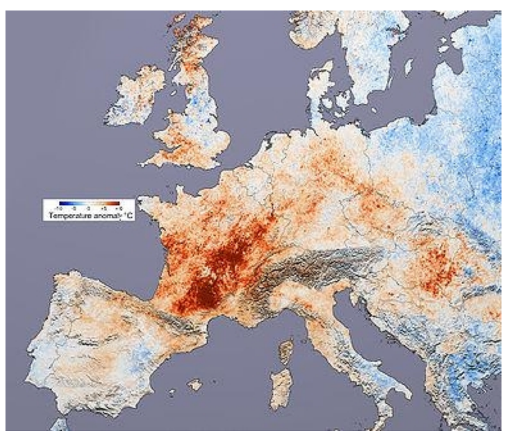
- Due to the extreme heat in July 2006, the ocean water reached a temperature normally reached in September. This increase in water temperature led to faster evaporation of ocean waters, making August one of the cloudiest and wettest months in recorded history in various western European countries.
- Many weather experts report this to be a direct consequence of the heat wave, as the high evaporation rate caused the atmosphere to generate many low pressure areas.

- Despite this, September 2006 was again the warmest September on record, in the UK and elsewhere, due to high ocean temperatures, altered atmospheric pressure zones, and consequent different wind directions over Europe. The pressure zone changes were a consequence of the extra-tropical remnants of Atlantic hurricanes settling over the British isles.
- While the heat was not record breaking, the drought was, less than half of the average summer rainfall was received in large areas, and almost all of the country received less than 75% of the usual rain.
- After the unusually hot July, August brought a big contrast with cool weather, cloudy skies and pretty wet weather patterns all around the country, with the exception of the Mediterranean coast.

EVENT: European heat wave 2003

CATEGORY: Natural

The **2003 European heat wave** was the hottest summer on record in Europe since at least 1540. France was hit especially hard. The heat wave led to health crises in several countries and combined with drought to create a crop shortfall in parts of Southern Europe. Peer-reviewed analysis reveals the European death toll of 70,000.



Difference in average temperature (2000, 2001, 2002 and 2004) from 2003, covering the date range of 20 July – 20 August

Countries affected:

- In France, 14,802 heat-related deaths (mostly among the elderly) occurred during the heat wave, according to the French National Institute of Health. France does not commonly have very hot summers, particularly in the northern areas, but seven days with temperatures of more than 40°C (104 °F) were recorded in Auxerre, Yonne during July and August 2003.

- In Portugal, an estimated 1,866 to 2,039 people died of heat-related causes. August 1, 2003, was the hottest day in centuries, with night temperatures well above 30°C (86°F). At dawn that same day, a freak storm developed in the southern region of the country. Over the next week, a hot, strong *sirocco* wind contributed to the spread of extensive forest-fires. Five percent of Portugal's countryside and 10% of the forests (215,000 hectares or an estimated 2,150 km^2 (830 sq mi)), were destroyed, and 18 people died in the flames.
- In Netherlands about 1,500 heat-related deaths occurred, again largely the elderly. The highest temperature recorded this heatwave was on 7 August, when in Arcen, in Limburg, a temperature of 37.8°C was reached, 0.8°C below the national record (since 1704). Officially, 141 deaths were attributed to the heat wave in Spain.
- In Italy the summer of 2003 was among the warmest in the last three centuries, and the maximum temperatures of July and August remained above 30°C.
- In Germany, a record temperature of 40.4°C (104.7°F) was recorded at Roth bei Nurnberg, Bavaria. Around 9,000 people mostly elderly died during the 2003 heatwave in Germany.
- In Switzerland melting glaciers in the Alps caused avalanches and flash floods in Switzerland. A new nationwide record temperature of 41.5°C (106.7°F) was recorded in Grono, Graubunden.
- The United Kingdom experienced a warm summer with temperatures well above average. Several weather records were broken including the UK's highest recorded temperature 38.5°C (101.3°F) at Faversham in Kent on 10 August. According to the BBC, around 2,000 more people than usual may have died during the 2003 heatwave.

Effects on crops: Crops in Southern Europe suffered the most from drought.

- **Wheat:** There were shortfalls in wheat harvest occurred as a result of the long drought.
- **Grapes**: The heat wave greatly accelerated the ripening of grapes; also, the heat dehydrated the grapes, making more concentrated juice.

Effects on the sea: The anomalous overheating affecting the atmosphere also created anomalies on sea surface stratification in the Mediterranean Sea and on the surface currents, as well. A seasonal current of the central Mediterranean Sea, the Atlantic Ionian Stream (AIS), was affected by the warm temperatures, resulting in modifications in its path and intensity. The AIS is important for the reproduction biology of important pelagic commercial fish species, so the heat wave may have influenced indirectly the stocks of these species.

EVENT: Chicago heat wave 1995

CATEGORY: Natural

The **1995 Chicago heat wave** was a heat wave which led to approximately 750 heat-related deaths in Chicago over a period of five days. Most of the victims of the heat wave were elderly poor residents of the inner city, who could not afford air conditioning and did not open windows or sleep outside for fear of crime. The heat wave also heavily impacted the wider Midwestern region, with additional deaths in both St. Louis, Missouri and Milwaukee, Wisconsin.

Weather: The temperatures soared to record highs in July with the hottest weather occurring from July 12 to July 16. The high of 106 °F (41 °C) on July 13 was the second warmest July temperature (warmest being 110 °F (43 °C) set on July 23, 1934) since records began at Chicago Midway International Airport in 1928. Night time low temperatures were unusually high in the upper 70s and lower 80s °F (about 26 °C). Record humidity levels also accompanied the hot weather. Moisture from previous rains and transpiration by plants drove up the humidity to record levels and the most humid air mass originated over Iowa previous to and during the early stages of the heat wave. A few days after, the heat moved to the east, with temperatures in Pittsburgh, Pennsylvania reaching 100 °F (38 °C) and in Danbury, Connecticut, 106 °F (41 °C) which is Connecticut's highest recorded temperature. Dew point records are not as widely kept as those of temperature, however the dew points during the heat wave were at or near national and continental records. The world record most likely being close to or in excess of 100 °F (38 °C) at locations along the Red Sea coast of Saudi Arabia.

Victims: Most of the heat wave victims were the elderly poor living in the heart of the city, who either had no working air conditioning or could not afford to turn it on. Many older citizens were also hesitant to open windows and doors at night for fear of crime. Elderly women, who may have been more socially engaged, were less vulnerable than elderly men. By contrast, during the heat waves of the 1930s, many residents slept outside in the parks or along the shore of Lake Michigan. Because of the nature of the disaster, and the slow response of authorities to recognize it, no official "death toll" has been determined. However, figures show that 739 additional people died in that particular week above the usual weekly average.

Aggravating factors: Impacts in the Chicago urban centre were exacerbated by an urban heat island that raised nocturnal temperatures by more than 2°C (3.6 °F). Urban heat islands are caused by the concentration of buildings and pavement in urban areas, which tend to absorb more heat in the day and radiate less heat at night into their immediate surroundings than comparable rural sites. Therefore, built-up areas get hotter and stay hotter. Other aggravating factors were inadequate warnings, power failures, inadequate ambulance service and hospital facilities, and lack of preparation.

City officials did not release a heat emergency warning until the last day of the heat wave. Thus, such emergency measures as Chicago's five cooling centres were not fully utilized. The medical system of Chicago was severely taxed as thousands were taken to local hospitals with heat-related problems.

Another powerful factor in the heat wave was that a temperature inversion grew over the city, and air stagnated in this situation. Pollutants and humidity were confined to ground level, and the air was becalmed and devoid of wind. Without wind to stir the air, temperatures grew even hotter than could be expected with just an urban heat island, and without wind there was truly no relief. Without any way to relieve the heat, even the inside of homes became ovens, with indoor temperature exceeding 90 °F (32 °C) at night.

In Chicago, people still debate whether the medical examiner exaggerated the numbers and wonder if the crisis was a "media event”.

EVENT: Melbourne dust storm 1983

CATEGORY: Natural

The 1983 Melbourne dust storm was a meteorological phenomenon that occurred during the afternoon of 8 February 1983, throughout much of Victoria, Australia and affected the capital, Melbourne. Red soil, dust and sand from Central and South-eastern Australia was swept up in high winds and carried southeast through Victoria. The dust storm was one of the most dramatic consequences of the 1982/83 drought, at the time the worst in Australian history.

Cause: In late 1982 and early 1983, the El Nino weather cycle had brought record drought to almost all of eastern Australia, with Victoria's Mallee and northern Wimmera severely affected. During the morning of Tuesday 8 February 1983, a strong but dry cold front began to cross Victoria, preceded by hot, gusty northerly winds. The loose topsoil in the Mallee and Wimmera was picked up by the wind and collected into a huge cloud of dust that heralded the cool change. At Horsham in western Victoria, raised dust was observed. Within an hour, it had obscured the sky. Fed by the strong northerly, the temperature in Melbourne rose quickly and it had reached 43.2 °C (109.8 °F), at that time a record February maximum. Around the same time, a dramatic red-brown cloud could be seen approaching the city.

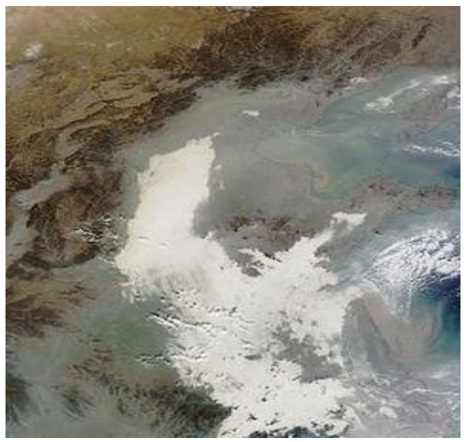
Effect: The dust storm hit Melbourne, accompanied by a rapid drop in temperature and a fierce wind change that uprooted trees and damaged houses. Within minutes, visibility in the capital had plunged to 100 metres (330 ft). City workers huddled in doorways, covering their mouths from the choking dust, and traffic came to a standstill. The dust cloud was approximately 320 metres (1,050 ft) high when it struck Melbourne, but in other areas of Victoria it extended thousands of metres into the atmosphere. It was estimated that about 50,000 tonnes of topsoil were stripped from the Mallee (approximately 1,000 tonnes of it being dumped on the city). The combined effect of drought and dust storm inflicted damage on the land that, would take up to 10 years and tens of millions of dollars to repair. The exact weather pattern that had caused the dust storm was repeated one week later, when the Ash Wednesday fires (series of bushfires) caused enormous destruction and loss of life.

Extreme Pollution Event - Global

EVENT: Eastern China smog 2013

CATEGORY: Human induced aggravated by weather conditions.

The **2013 Eastern China smog** was a severe air pollution episode that affected East China, including all or parts of the municipalities of Shanghai and Tianjin, and the provinces of Hebei, Shandong, Jiangsu, Anhui, Henan, and Zhejiang, during December 2013.



7 December 2013 image from the NASA's Terra satellite shows the severity of smog blanketing Eastern China.

According to a NASA Terra Satellite image, the thick haze stretches over Eastern China, across a distance of around 1,200 kilometres (750 mi). The polluted air appears gray on the image and most of the pollution is trapped in the lower boundary layer of a few hundred meters.

A lack of cold air flow, combined with slow-moving air masses carrying industrial emissions, collected airborne pollutants to form a thick layer of smog over the region. Levels of $PM_{2.5}$ particulate matter averaged over 150 micrograms per cubic metre; in some areas, they were 300 to 500 micrograms per cubic metre. It is one of the worst bouts of air pollution in the area, cutting visibility and causing major disruption in transportation and daily activities. Airports, highways, and schools were closed. January 2013 saw China's massive fog and haze outbreak affect about 600 million people and cover seventeen provinces, municipalities and autonomous regions, a fourth of the China's territory**.**

Causes: Coal burning is a primary source of fine particle air pollution. It increased as the weather worsened during winter months and residents burned more coal to keep warm. This increased the amount of sulphate and nitrate (results of coal combusting), which led to higher $PM_{2.5}$. Research suggests that 41% of the carbon that made up these high

$PM_{2.5}$ levels in Shanghai were also from coal burning. Additionally, there was pollution from industrial sources. Jiangsu, Anhui, Shandong, Henan and many eastern provinces are heavy coal-burning regions. Research shows that prevailing winds blew low-hanging air masses of factory emissions (mostly SO_2) towards the east coast of China. Regional transportation also had a significant impact on air quality.

Weather: The mixture of natural fog and unnatural smog started accumulating over the first weekend of December 2013. In Shanghai, the Air Quality Index (AQI) crossed the threshold of 300 on 2 December. The lingering smog also left the air qualities in neighbouring cities at seriously polluted levels. The National Meteorological Center (NMC) issued yellow alert for smog and fog, the third most serious alert in China's four-tiered system. $PM_{2.5}$ particulate levels reached their highest point on 6 December 2013, with Shanghai reaching a high of 507. U.S. Embassy categorizes air quality readings over 300 as hazardous to all humans, not just those with heart or lung ailments.

Effects: Air in Shanghai was reported to have strange taste – astringent and smoky, with an aftertaste of earthy bitterness. It was possible to feel the dust-like particulate matter on tongues. With such a high concentration of air pollutants, government authorities warned residents of health symptoms, such as coughing, headache. Citizens were advised to wear protective masks and use air purifiers. Many sanitation workers were required to wear dust masks during work early in the morning. Schools were closed as government ordered children to stay indoors, and reduce outdoor activities as much as possible. Construction work was halted and authorities pulled nearly one-third of government vehicles from the roads. A majority of inbound flights were cancelled and more than 50 flights were diverted.

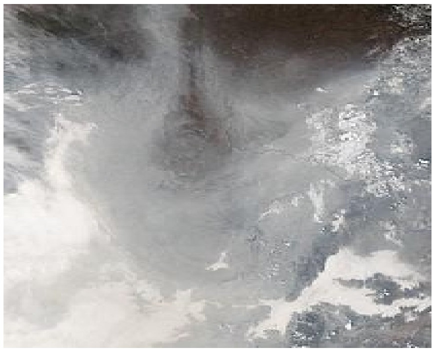
EVENT: North-eastern China smog 2013

CATEGORY: Human induced aggravated by weather conditions.

A dense wave of smog began in Northeast China, especially in major cities including Harbin, Changchun and Shenyang, as well as the surrounding Heilongjiang, Jilin, and Liaoning provinces on 20 October 2013.

Unseasonably warm temperatures with very little wind across north-eastern China coincided with the initiation of Harbin's coal-powered municipal heating system. Record densities of fine particulates were measured in the city.
In Harbin, the levels of $PM_{2.5}$ particulate matter rose to 1,000 micrograms per cubic metre, worse than Beijing's historic highs. Visibility dropped to 50 metres (160 ft) and authorities grounded flights and closed more than 2,000 schools. The smog eased on 25 October 2013

and had completely dissipated by the 28th due to a cold front that had moved in from Russia.



Smog (grey) and fog (white) cloak northeast China   Smog in Shenyang, China

Cause: Officials blamed the dense pollution on lack of wind, burning of crop waste in farmers' fields, and 20 October start-up of Harbin's coal-powered district heating system. Harbin lies in the north of China where winter temperatures can drop to −40 °C (−40 °F), necessitating a six-month heating season.

The smog remained as of 23 October, when almost all monitoring stations in Heilongjiang, Jilin, and Liaoning provinces reported readings above 200 [μg/m³] for $PM_{2.5}$. $PM_{2.5}$ is the amount of particulate matter less than 2.5 micrometres in diameter in the air, with the World Health Organization recommending a maximum 24-hour mean of 25 micrograms per cubic meter (μg/m³). On the morning of 23 October, $PM_{2.5}$ measurements in Harbin had fallen to an average of 123 μg/m³.

Effects: All highways in the surrounding Heilongjiang province were closed. In Harbin, all primary and middle schools and the airport were closed for three days. Hospitals reported a 23 percent increase in admissions for respiratory problems. Visibility was reduced to below 50 m (160 ft) in parts of Harbin, and below 500 m (1,600 ft) in most of the neighbouring Jilin province. Daily particulate levels of more than 40 times the World Health Organization recommended maximum level were reported in parts of Harbin municipality.

EVENT: Southeast Asian haze 2013

CATEGORY: Human induced

The **2013 Southeast Asian haze** was a haze crisis that affected several countries in the Southeast Asian region, including Brunei, Indonesia, Malaysia, Singapore and Southern Thailand, mainly during June and July 2013. The haze period was caused by large-scale burning in many parts of Sumatra and Borneo. Satellite imagery from NASA's Terra and

Aqua satellites showed that the haze was mainly due to smoke from fires burning in Riau province, Indonesia.

A NASA satellite image of the haze on 19 June 2013.

The extent of the haze as of 19 June 2013 The extent of the haze as of 23 June 2013

The 2013 Southeast Asian haze was notable for causing record high levels of pollution in Singapore and several parts of Malaysia.

The 3-hour Pollution Standards Index in Singapore reached a record high of 401 on 21 June 2013, surpassing the previous record of 226 set during the 1997 South East Asian Haze. It was more than 100 higher than the previous record as well. On 23 June, the Air Pollution Index (API) in Muar, Johor spiked to 746 at 7 a.m. which was almost 2.5 times above the minimum range of the *Hazardous* level thus resulting in the declaration of emergency in Muar and Ledang (which was afterwards lifted on 25 June in the morning), leaving the towns in virtual shutdown.

Chronology of events:

- On 19 June 2013, NASA's Terra and Aqua satellites captured images of smoke from illegal wildfires on the Indonesian island of Sumatra blowing east toward southern Malaysia and Singapore, causing thick clouds of haze in the region.

- On 21 June 2013, a total of 437 hotspots were detected in Sumatra. Two days later, the number was down to 119. On 24 June 159 hotspots were detected in Riau, out of a total of 227 detected in Sumatra.
- Many of the hotspots were owned by palm oil companies or smallholder farmers who supply palm oil to these companies and use traditional slash-and-burn methods to clear their land for the next planting season.
- On 25 June, Indonesia issued a formal apology to Malaysia and Singapore for the hazardous smog.
- On 26 June 2013, 265 hotspots were detected by satellites, but decreased to 54 on 27 June after heavy rain fell overnight between the two days.
- The number of hotspots in Sumatra continued to decrease on 27 June, with 42 hotspots recorded at 4pm. At the same time on 28 June, only 15 hotspots were detected by satellites. Singapore's National Environment Agency said that this could be the reason for the improving haze conditions in Singapore and Malaysia over the past week. The number of hotspots decreased further to just 7 on 29 June.

The World Wide Fund for Nature (WWF) renewed calls for the enaction and enforcement of zero-burn policies. Based on satellite detection of hotspots, the province of Riau in Sumatra was found to contain over 88% of the hotspots that caused the worst haze over Singapore and Peninsular Malaysia since 1997. From 1 to 24 June, NASA satellites have detected a total of more than 9,000 hotspots in Sumatra, and more than 8,000 of them were located in Riau.

Effects: The public was also advised to regularly check the PSI (Pollutant Standard Index), follow the health advisory and seek immediate treatment at any nearest hospital or health centre if they feel unwell due to haze. Airport had to be closed for several hours, causing several flights to be diverted to nearby airports. Visibility remained poor in Kuala Lumpur and several other states. Schools that are located in several areas where the Air Pollution Index (API) readings had exceeded the hazardous point of 300 had to be closed. Schools in areas with the API reaching 150 are advised to avoid outdoor activities. Citizens were advised to reduce outdoor activities while the haze is still present.

Comparison of the effects of the haze on Singapore

Left: Before the haze (Taken 4 May, PSI "Good")
Middle: During the haze (Taken 19 June, PSI "Unhealthy")
Right: After the haze (Taken 23 June, PSI "Moderate")

Measures taken: The Indonesian government used weather-changing technology to create artificial rain and extinguish raging fires. It has earmarked around 200 billion rupiah (around US$20M, S$25.6M at the time) to handle the disaster and deployed seven military aircraft for water bombings and cloud-seeding to fight raging forest fires on 21 June 2013.

EVENT: Fukushima Accident 2011
CATEGORY: Natural aggravated by human activities

Following a major earthquake, a 15-metre tsunami disabled the power supply and cooling of three Fukushima Daiichi reactors, causing a nuclear accident on 11 March 2011. All three cores largely melted in the first three days. The accident was rated 7 on the INES scale, due to high radioactive releases over days 4 to 6, eventually a total of some 940 PBq (I-131 eq).

There have been no deaths or cases of radiation sickness from the nuclear accident, but over 100,000 people had to be evacuated from their homes. Official figures show that there have been well over 1000 deaths from maintaining the evacuation, in contrast to little risk from radiation if early return had been allowed.

Incident: Most of the radioactive releases from the site appeared to come from unit 2. This explosion created a lot of debris, and some of that on the ground near unit 3 was very radioactive. In defueled unit 4, at about 6 am on Tuesday 15 March, there was an explosion which destroyed the top of the building and damaged unit 3's superstructure further. This was apparently from hydrogen arising in unit 3 and reaching unit 4 by backflow in shared ducts when vented from unit 3. There was a peak of radioactive release on 15th, apparently mostly from unit 2, but the precise source remains uncertain. Due to volatile and easily-airborne fission products being carried with the hydrogen and steam, the venting and hydrogen explosions discharged a lot of radioactive material into the atmosphere, notably iodine and caesium.

Regarding releases to air and also water leakage from Fukushima, the main radionuclide from among the many kinds of fission products in the fuel was volatile iodine-131, which has a half-life of 8 days. The other main radionuclide is caesium-137, which has a 30-year half-life, is easily carried in a plume, and when it lands it may contaminate land for some time. It is a strong gamma-emitter in its decay. Cs-134 is also produced and dispersed; it has a two-year half-life. Caesium is soluble and can be taken into the body, but does not concentrate in any particular organs, and has a biological half-life of about 70 days. In assessing the significance of atmospheric releases, the Cs-137 figure is multiplied by 40 and added to the I-131 number to give an "iodine-131 equivalent" figure.

A significant problem in tracking radioactive release was that 23 out of the 24 radiation monitoring stations on the plant site were disabled by the tsunami.
After the hydrogen explosion in unit 1 on 12 March, some radioactive caesium and iodine were detected in the vicinity of the plant, having been released via the venting. Further I-131 and Cs-137 and Cs-134 were apparently released during the following few days, particularly following the hydrogen explosion at unit 3 on 14th and in unit 4 on 15th.

Measures: On 16 March, Japan's Nuclear Safety Commission recommended local authorities to instruct evacuees under 40 years of age leaving the 20 km zone to ingest stable iodine as a precaution against ingestion (eg via milk) of radioactive iodine-131. The pills and syrup (for children) had been pre-positioned at evacuation centres. The order recommended taking a single dose, with an amount dependent on age. However, it is not clear that this was implemented. The population within a 20km radius had been evacuated three days earlier. Considerable work was done to reduce the amount of radioactive debris on site and to stabilise dust.

France's Institute for Radiological Protection & Nuclear Safety (IRSN) estimated that maximum external doses to people living around the plant were unlikely to exceed 30 mSv/yr in the first year. This was based on airborne measurements between 30 March and 4 April, and appears to be confirmed by the above figures. It compares with natural background levels mostly 2-3 mSv/yr, but ranging up to 50 mSv/yr elswhere.
The main concentration of radioactive pollution stretches northwest from the plant, and levels of Cs-137 reached over 3 MBq/m2 in soil here, out to 35km away. In mid-May about 15,000 residents in a contaminated area 20-40 km northwest of the plant were evacuated, making a total of over 100,000 displaced persons.

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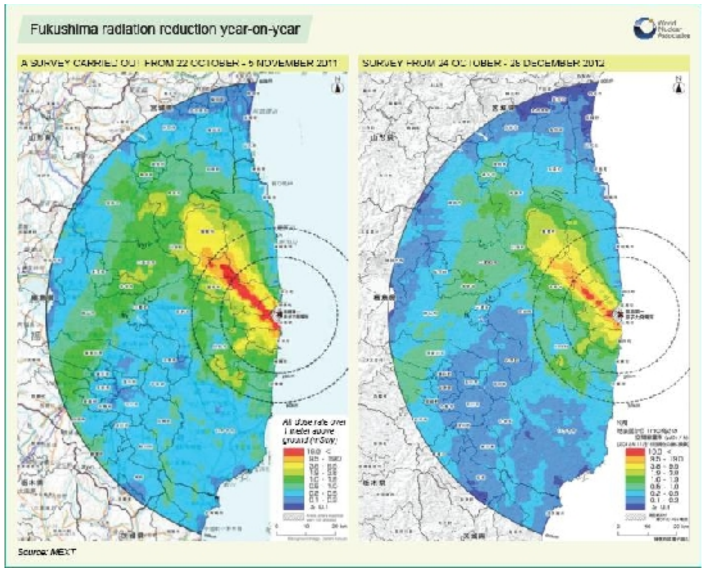


Maps from MEXT aerial surveys carried out approximately one year apart show the reduction in contamination from late 2011 to late 2012. Areas with colour changes in 2012 showed approximately half the contamination as surveyed in 2011, the difference coming from decay of caesium-134 (two year half-life) and natural processes like wind and rain. In blue areas, ambient radiation is very similar to global background levels at <0.5uSv/h which is equal to <4.38 mSv/y.

Effects: No radiation casualties (acute radiation syndrome) occurred, and few other injuries, though higher than normal doses were being accumulated by several hundred workers on site. High radiation levels in the three reactor buildings hindered access there through into 2012.

In May 2013, the UN Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reported, following a detailed study by 80 international experts. It concluded that "Radiation exposure following the nuclear accident at Fukushima Daiichi did not cause any immediate health effects. It is unlikely to be able to attribute any health effects in the future among the general public and the vast majority of workers." The results of UNSCEAR’s 12-month study on the magnitude of radioactive releases to the atmosphere and ocean, and the range of radiation doses received by the public and workers were announced and concluded that the rates of cancer or hereditary diseases were unlikely to show any discernible rise in affected areas because the radiation doses people received were too low. People were promptly evacuated from the vicinity of the nuclear power plant, and later from a neighbouring area where radionuclides had accumulated. The most important health effect is on mental and social well-being, related to the enormous impact of the earthquake, tsunami and nuclear accident, and the fear and stigma related to the perceived risk of exposure to radiation."

EVENT: Mexico City Smog, Mexico 2010

CATEGORY: Human induced aggravated by weather conditions.

Due to its location in a highland "bowl", cold air sinks down onto the urban area of Mexico City, trapping industrial and vehicle pollution underneath, and turning it into the most infamously smog-plagued city of Latin America. Within one generation, the city has changed from being known for some of the cleanest air of the world into one with some of the worst pollution, with pollutants like nitrogen dioxide being double or even triple international standards.

Photochemical smog over Mexico City.
December 2010.

EVENT: Acid rain in China, 2010

CATEGORY: Human induced

In China, acid rain has become a large problem. It cannot be denied and the effect of toxic rain is visible even on The Leshan Buddha. The giant statue that has drawn Buddhist pilgrims, tourists, and scholars for 1200 years is now discoloured, its face appearing “sooty.” This is thanks to acid rain. Because of the statues importance in the culture, acid rain is no longer considered just an environmental problem, but also a threat to heritage.

Image of The Leshan Buddha

China's highly industrialized society has resulted in this man-made pollutant, the highest concentrations of the problem being in southeast China where the most people, power-plants, and factories are located. The rain has received little international attention due to China's many other environmental problems, but is a very serious problem.

Effects: It not only erodes monuments, but also eats away at the outside of buildings, destroys paint finishes, poisons land (a problem for farming), and turns bodies of water into lifeless puddles. Acid rain also results in serious health effects including lung disease, heart attacks, and asthma. Acid rain and SO2 emissions (which are among the causes of acid rain) affect many different parts of China –from the basic wear and tear of buildings, to the poisoning of farmland and destruction of national monuments.

Measures: In 2001, Beijing implemented a national target for reducing SO2 levels in the 10^{th} Five Year Plan (2001-2005). Beijing aimed to cut sulphur dioxide emissions 10 percent below that of 2001 by 2005, but instead emissions increased 28 percent. There is hope however. Between 2006 and 2009, China's SO2 levels decreased by more than 13 percent. The government has begun to shut down hundreds of inefficient coal-run plants. The monitoring systems implemented by the government are not perfect, and the country has a long way to go. Still, China's recent change in thinking and acting is a reason for hope globally.

EVENT: Southeast Asian haze 2009

CATEGORY: Human induced aggravated by weather conditions

2009 Southeast Asian haze is large scale air pollution primarily caused by slash and burn practice done for agricultural purpose in Sumatra, Indonesia. It affects the areas surrounding the Straits of Malacca which beside Indonesia include Malaysia and Singapore.

The haze began in early June 2009 and progressively became worse toward July. With a prevailing dry season caused by El Nino, burning and hence the haze was expected to continue until August or September till the monsoon season arrived.

EVENT: Southeast Asian haze 2006

CATEGORY: Human induced aggravated by weather conditions

The **2006 Southeast Asian haze** event was caused by continued uncontrolled burning from "slash and burn" cultivation in Indonesia, and affected several countries in the Southeast

Asian region and beyond, such as Malaysia, Singapore, southern Thailand, and as far as Saipan; the effects of the haze may have spread to South Korea.

Satellite photograph of the haze above Borneo

Local sources of pollution partly contributed to the increased toxicity, particularly in high-pollution areas such as ports, oil refineries, and dense urban areas. In the highly urbanised and industrialised Klang Valley of Malaysia in particular, the surrounding terrain acted as a natural retainer of polluted air, aggravating the situation when the haze set in.

There is also a link to El Niño. The haze was made worse than during previous occurrences by the El Nino-Southern Oscillation which delayed the year's monsoon season. Fires in Kalimantan produce great amounts of smoke, burn a long time and are difficult to extinguish because they are on peat land, and once lit the fires can burn for months and release gases that produce sulfuric acid. Air quality across the region appeared to improve in late October as heavy rainfall doused fires in Indonesia. With the arrival of the north-eastern winter monsoons in December, the haze problem was effectively ended for 2006.

The business district of Kuala Lumpur in the evening of 29 September 2006. Menara Kuala Lumpur was barely visible. The average API for that day was in between 70 and 80.

ASEAN Ministerial Meeting on Transboundary Haze Pollution: Malaysia and Singapore criticized the way Indonesia handled the issue. Both urged the latter to ratify the ASEAN Agreement on Transboundary Haze Pollution. Indonesia stated that it lacked the resources to combat the burning effectively. Malaysia proposed the setting up of a regional fund to help combat the environmental disaster.

EVENT: Acid Rain in China 2006

CATEGORY: Human induced

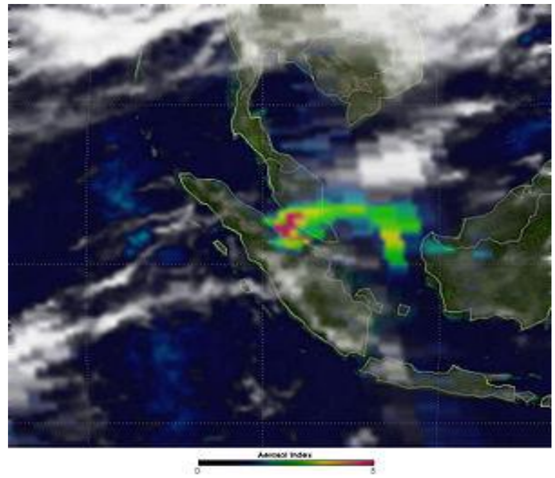
One third of China is suffering from acid rain caused by rapid industrial growth**.** Pollution levels have risen and air quality has deteriorated. In the latest incident, a reservoir serving 100,000 people in north-west China was polluted by a chemical spill. China has some of the world's most polluted cities and rivers.

The pollution inspection report to the standing committee of parliament found that 25.5 million tonnes of sulphur dioxide were spewed out, mainly from the country's coal-burning factories last year - up 27% from 2000. Emissions of sulphur dioxide - the chemical that causes acid rain - were double the safe level, the report said. In some areas, rainfall was 100% acid rain, it added. Increased sulphur dioxide emissions meant that one-third of China's territory was affected by acid rain, posing a major threat to soil and food safety.

EVENT: Malaysian haze 2005

CATEGORY: Human induced

The **2005 Malaysian haze** was a week-long choking smog-like haze over Malaysia that almost brought the central part of Peninsular Malaysia to a standstill, prompted crisis talks with Indonesia and caused widespread inconvenience. The haze was at its worst on August 11, 2005. This was a comeback of the haze crisis which had last hit Malaysia in September 1997.



Haze over Kuala Lumpur

Density of the smoke on August 10, 2005

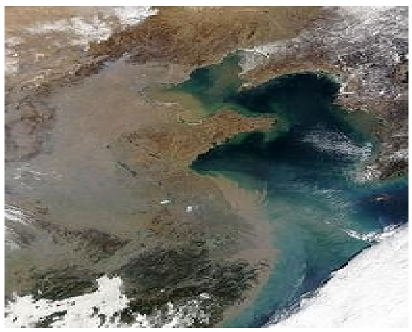
Cause: Haze is caused by "hotspots" (zones with high temperature levels as seen via satellite imagery) in Malaysia and Indonesia. Lingering smoke from forest fires on the Indonesian island of Sumatra are identified as the primary cause. Farmers regularly burn scrub and forest to clear land during the dry season for agricultural purposes, but this had been the worst haze to hit Malaysia since the 1997 haze.

Effect: On August 10, 2005, air quality in the Malaysian capital city of Kuala Lumpur was so poor that health officials advised citizens to stay at home with doors closed. Some schools were closed to keep children from being exposed to the haze. On August 11, 2005 a state of emergency was announced for the world's 12th largest port, Port Klang and the district of Kuala Selangor after air pollution there reached dangerous levels (defined as a value greater than 500 on the Air Pollution Index or API). This was the first time the state of emergency had been imposed in Malaysia since the September 1997 haze, when Sarawak was placed in a state of emergency due to similar reasons. The state of emergency in the two affected areas meant that school, government officials, the port, and offices were closed. Shops carrying necessities, however, such as supermarkets and pharmacies remained open. After the API levels dropped to acceptable levels, the state of emergency was lifted on August 13.

EVENT: Asian brown cloud

CATEGORY: Human induced

The **Indian Ocean brown cloud** or **Asian brown cloud** is a layer of air pollution that recurrently covers parts of South Asia, namely the northern Indian Ocean, India, and Pakistan. Viewed from satellite photos, the cloud appears as a giant brown stain hanging in the air over much of South Asia and the Indian Ocean every year between January and March, possibly also during earlier and later months. The term was coined in reports from the UNEP Indian Ocean Experiment (INDOEX).



Atmospheric Brown Cloud over China   Big Brown Cloud Storm over Asia

The term **Atmospheric brown cloud** is used for a more generic context not specific to the Asian region.

Causes: The Asian brown cloud is created by a range of airborne particles and pollutants from combustion (e.g., woodfires, cars, and factories), biomass burning and industrial processes with incomplete burning. The cloud is associated with the winter monsoon (November/December to April) during which there is no rain to wash pollutants from the air.

Observations: This pollution layer was observed during the Indian Ocean Experiment (INDOEX) intensive field observation in 1999 and described in the UNEP impact assessment study published 2002. Scientists in India claimed that the Asian Brown cloud is not something specific to Asia. Subsequently, when the United Nations Environment Programme (UNEP) organized a follow-up international project, the subject of study was renamed *the Atmospheric Brown Cloud* with focus on Asia. The cloud was also reported by NASA in 2004 and 2007. Although aerosol particles are generally associated with a global cooling effect, recent studies have shown that they can actually have a warming effect in certain regions such as the Himalayas.

Impacts:

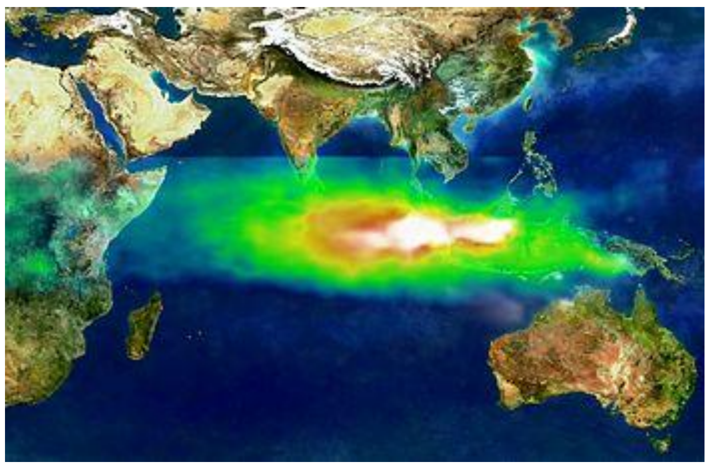
1) **Health**: One major impact is on health. A 2002 study indicated nearly two million people die each year, in India alone, from conditions related to the brown cloud.

2) **Regional weather**: A second assessment study was published in 2008. It highlighted regional concerns regarding:
    - Changes of rainfall patterns with the Asian monsoon, as well as a delaying of the start of the Asian monsoon, by several weeks. The observed weakening Indian monsoon and in China northern drought and southern flooding is influenced by the clouds. Increase in rainfall over the Australian Top End and Kimberley regions.
    - A CSIRO study has found that by displacing the thermal equator southwards via cooling of the air over East Asia, the monsoon which brings most of the rain to these regions has been intensified and displaced southward. Retreat of the Hindu Kush-Himalayan glaciers and snow packs.
    - The cause is attributed to rising air temperatures that are more pronounced in elevated regions, a combined warming effect of greenhouse gases and the Asian Brown Cloud.
    - Also deposition of black carbon decreases the reflection and exacerbates the retreat. Asian glacial melting could lead to water shortages and floods for the hundreds of millions of people who live downstream.
    - Decrease of crop harvests. Elevated concentrations of surface ozone are likely to affect crop yields negatively. The impact is crop specific.
3) **Cyclone intensity in Arabian Sea**: A 2011 study found that pollution is making Arabian Sea cyclones more intense as the atmospheric brown clouds has been producing weakening wind patterns which prevent wind shear patterns that historically have prohibited cyclones in the Arabian Sea from becoming major storms. This phenomenon was found responsible for the formation of stronger storms in 2007 and 2010 that were the first recorded storms to enter the Gulf of Oman.
4) **Global warming and dimming**: The 2008 report also addressed the global concern of warming and concluded that the brown clouds have masked 20 to 80 percent of greenhouse gas forcing in the past century. The report suggested that air pollution regulations can have large amplifying effects on global warming. Another major impact is on the polar ice caps. Black carbon (soot) in the Asian Brown Cloud may be reflecting sunlight and dimming Earth below but it is warming other places by absorbing incoming radiation and warming the atmosphere and whatever it touches. Black carbon is three times more effective than carbon dioxide—the most common greenhouse gas—at melting polar ice and snow. Black carbon in snow causes about three times the temperature change as carbon dioxide in the atmosphere. On snow —even at concentrations below five parts per billion— dark carbon triggers melting, and may be responsible for as much as 94 percent of Arctic warming.

EVENT: Southeast Asian haze 1997

CATEGORY: Human induced

The **1997 Southeast Asian haze** was a large-scale air quality disaster which occurred during the second half of 1997, its after-effects causing widespread atmospheric visibility and health problems within Southeast Asia. The total costs of the Southeast Asian haze are estimated at USD $9 billion, due mainly to health care and disruption of air travel and business activities.



Air pollution over Southeast Asia in October 1997

The influence of the 1997 fires in Kalimantan and Sumatra on ambient air quality was evident by July and peaked in September/October before weakening by November, when the delayed monsoonal rain extinguished the fires and improved air quality within the region. During the peak episode, satellite imagery (NASA/TOMS aerosol index maps) showed a haze layer which expanded over an area of more than 3,000,000 km^2 (1,200,000 sq mi), covering large parts of Sumatra and Kalimantan. Its northward extension partially reached Malaysia, Singapore, Brunei and Thailand. During this period, particulate matter concentrations frequently exceeded national ambient air quality standards. Monthly mean horizontal visibility at most locations in Sumatra and Kalimantan in September was below 1 km (0.62 mi) and daily maximum visibility was frequently below 100 metres (330 ft).

Countries affected: Indonesia, Singapore, Malaysia, Thailand and Brunei.

Causes: The 1997 Southeast Asian haze was caused mainly by slash and burn techniques adopted by farmers in Indonesia. Slash and burn has been extensively used for many years as the cheapest and easiest means to clear the lands for traditional agriculture. Fire is also used during the long fallow rotation of the so-called jungle rubber in Sumatra and Kalimantan to remove most of the biomass, including the woody parts before new plantations are re-established. During the dry season, dry fuels readily ignite and lead to large wild fires. These accidental fires may have the same underlying socio-economic and institutional problems. In cases like this, fire suppression can be very difficult and costly especially when they reach the highly flammable peat-swamp areas.

Effects: Atmospheric particulate matter was the form of air pollutant that predominantly contributed to the haze and degradation in ambient air quality standards during this crisis. In all countries affected by the smoke haze, an increase of acute health outcomes was observed. The smoke haze episode has added to the urban and industrial air pollution in Southeast Asia, causing it to reach alarming levels in many metropolitan areas. By scattering and absorbing light, the fire-related particulate also resulted in reduced visibility; impairing transportation by air, land and water and seriously affecting the economies of Indonesia, Malaysia and Singapore. Among the economic sectors affected most were air, land and sea transportation, construction, tourism and agricultural industries.

Health effects: Included emergency room visits due to respiratory symptoms such as asthma, upper respiratory infection, decreased lung function as well as eye and skin irritation, were caused mainly by this particulate matter. In Singapore, for instance, health surveillance showed a 30% increase in hospital attendance due to air quality related symptoms. Generally, children and the elderly, as well as those with pre-existing respiratory and cardiac diseases were the most susceptible to adverse health outcomes from the haze exposure.

Economic Loss: EEPSEA/WWF roughly estimated the economic value of the damages caused by the 1997 fires and haze. They estimated one billion US$ from haze-related damages for Indonesia only. The damages to Malaysia and Singapore are figured at 0.4 billion US$. Including the fire related damages, the total damages are estimated to amount to 4.5 billion US$. However, a variety of the damages such as decreased quality of life, loss of biodiversity and atmospheric impacts are difficult to establish.

EVENT: Manchester crumbles under worst 'acid air' in Europe 1995

CATEGORY: Human induced

Manchester is not only one of the cradles of the Industrial Revolution; it is also the home of acid rain. It was first described there 143 years ago by the pioneering chemist, Robert Angus Smith, who coined the evocative phrase. In 1852, Smith correlated the relationship between acid rain and atmospheric pollution. This discovery was later (1872) labelled as "Acid Rain". Later he reported how stones and bricks crumble more rapidly due to the slow, but constant, action of the acid rain caused by the industrial pollution of the time.

Manchester is rapidly dissolving under the impact of air pollution, a new European Union study has found. The study, which examined the effects of acid rain on historic buildings all over Western Europe, has found that stone is being eaten away more quickly in the city than anywhere else investigated. The research discovered that the damage was occurring twice as fast as on the Acropolis in Athens - which has come to epitomise the ravages of air pollution - and faster even than under experimental conditions where stone was exposed to high levels of sulphur dioxide.

Many of the city's most famous Victorian buildings are being eroded by the pollution. The gargoyles on Alfred Waterhouse's celebrated town hall are losing their sharpness, the stone of the Central Library is becoming mottled and eroded by dirt from car exhausts, and the Whitworth Art Gallery is also among those affected. Manchester City Council, which is busily trying to build a new reputation for the fading industrial centre as an attractive conference venue, is reluctant to accept the study's findings, insisting that it has been reducing pollution in the city over recent years.

Scientists now agree that the crumbling of Britain's historic buildings has accelerated over the last few decades even though emissions from factories have greatly declined. The main culprit is thought to be pollution from car exhausts.

In Manchester the stones were placed on the roof of a building in the city centre which, the study says, would have been subjected to pollution from traffic and office heating. In Athens they were exposed on the Acropolis where the four draped female statues (the caryatids) have been so badly damaged by air pollution that they have had to be replaced by replicas.

The most harm is not done by acid rain itself (it was surprisingly dry in Manchester during the study period) but by sulphur dioxide pollution settling on the stones directly from the air and interacting with the city's damp atmosphere.

EVENT: Chernobyl Accident 1986

CATEGORY: Human induced

On April 26, 1986, a sudden surge of power during a reactor systems test destroyed Unit 4 of the nuclear power station at Chernobyl, Ukraine, in the former Soviet Union. The accident and the fire that followed released massive amounts of radioactive material into the environment. Emergency crews responding to the accident used helicopters to pour sand and boron on the reactor debris. The sand was to stop the fire and additional releases of radioactive material; the boron was to prevent additional nuclear reactions.

A few weeks after the accident, the crews completely covered the damaged unit in a temporary concrete structure, called the "sarcophagus," to limit further release of radioactive material. The Soviet government also cut down and buried about a square mile of pine forest near the plant to reduce radioactive contamination at and near the site.
Chernobyl's three other reactors were subsequently restarted but all eventually shut down for good, with the last reactor closing in 1999. The Soviet nuclear power authorities presented their initial accident report to an International Atomic Energy Agency meeting in Vienna, Austria, in August 1986.

After the accident, officials closed off the area within 30 kilometres (18 miles) of the plant, except for persons with official business at the plant and those people evaluating and dealing with the consequences of the accident and operating the undamaged reactors.
The Soviet (and later on, Russian) government evacuated about 115,000 people from the most heavily contaminated areas in 1986, and another 220,000 people in subsequent years (Source: UNSCEAR 2008).

The Chernobyl disaster was a unique event and the only accident in the history of commercial nuclear power where radiation-related fatalities occurred.

The 1986 Chernobyl accident: On 25 April, prior to a routine shutdown, the reactor crew at Chernobyl 4 began preparing for a test to determine how long turbines would spin and supply power to the main circulating pumps following a loss of main electrical power supply. This test had been carried out at Chernobyl the previous year, but the power from the turbine ran down too rapidly, so new voltage regulator designs were to be tested.
A series of operator actions, including the disabling of automatic shutdown mechanisms, preceded the attempted test early on 26 April. By the time that the operator moved to shut down the reactor, the reactor was in an extremely unstable condition. A peculiarity of the design of the control rods caused a dramatic power surge as they were inserted into the reactor.The interaction of very hot fuel with the cooling water led to fuel fragmentation along with rapid steam production and an increase in pressure. The design characteristics of the reactor were such that substantial damage to even three or four fuel assemblies can – and did – result in the destruction of the reactor. The overpressure caused the 1000 t cover plate of the reactor to become partially detached, rupturing the fuel channels and jamming all the control rods, which by that time were only halfway down. Intense steam generation then spread throughout the whole core (fed by water dumped into the core due to the rupture of the emergency cooling circuit) causing a steam explosion and releasing fission products to the atmosphere. About two to three seconds later, a second explosion threw out fragments from the fuel channels and hot graphite. There is some dispute among experts about the character of this second explosion, but it is likely to have been caused by the production of hydrogen from zirconium-steam reactions.

Two workers died as a result of these explosions. The graphite (about a quarter of the 1200 tonnes of it was estimated to have been ejected) and fuel became incandescent and started a number of fires, causing the main release of radioactivity into the environment. A total of about 14 EBq (14 x 10^{18} Bq) of radioactivity was released, over half of it being from biologically-inert noble gases.

About 200-300 tonnes of water per hour were injected into the intact half of the reactor using the auxiliary feed-water pumps but this was stopped after half a day owing to the danger of it flowing into and flooding units 1 and 2. From the second to tenth day after the accident, some 5000 tonnes of boron, dolomite, sand, clay and lead were dropped on to the burning core by helicopter in an effort to extinguish the blaze and limit the release of radioactive particles.

The nuclear reactor after the disaster. Reactor 4 (center). Turbine building (lower left). Reactor 3 (center right).

Aerial view of the damaged core on 3 May 1986. Roof of the turbine hall is damaged (image center). Roof of the adjacent reactor 3 (image lower left) shows minor fire damage.

Immediate impact of the Chernobyl accident: The accident caused the largest uncontrolled radioactive release into the environment ever recorded for any civilian operation, and large quantities of radioactive substances were released into the air for about 10 days. This caused serious social and economic disruption for large populations in Belarus, Russia and Ukraine. Two radionuclides, the short-lived iodine-131 and the long-lived caesium-137, were particularly significant for the radiation dose they delivered to members of the public.

It is estimated that all of the xenon gas, about half of the iodine and caesium, and at least 5% of the remaining radioactive material in the Chernobyl 4 reactor core (which had 192 tonnes of fuel) was released in the accident. Most of the released material was deposited close by as dust and debris, but the lighter material was carried by wind over Ukraine, Belarus, Russia and to some extent over Scandinavia and Europe.

The casualties included firefighters who attended the initial fires on the roof of the turbine building. All these were put out in a few hours, but radiation doses on the first day were estimated to range up to 20,000 millisieverts (mSv), causing 28 deaths – six of which were firemen – by the end of July 1986.

The next task was cleaning up the radioactivity at the site so that the remaining three reactors could be restarted, and the damaged reactor shielded more permanently. About 200,000 people ('liquidators') from all over the Soviet Union were involved in the recovery and clean-up during 1986 and 1987. They received high doses of radiation, averaging around 100 millisieverts. Some 20,000 of them received about 250 mSv and a few received 500 mSv. Later, the number of liquidators swelled to over 600,000 but most of these received only low radiation doses. The highest doses were received by about 1000 emergency workers and on-site personnel during the first day of the accident.

The plant operators' town of Pripyat was evacuated on 27 April (45,000 residents). By 14 May, some 116,000 people that had been living within a 30-kilometre radius had been evacuated and later relocated. About 1000 of these returned unofficially to live within the contaminated zone. Most of those evacuated received radiation doses of less than 50 mSv, although a few received 100 mSv or more.

In the years following the accident, a further 220,000 people were resettled into less contaminated areas, and the initial 30 km radius exclusion zone (2800 km^2) was modified and extended to cover 4300 square kilometres. This resettlement was due to application of a criterion of 350 mSv projected lifetime radiation dose, though in fact radiation in most of the affected area (apart from half a square kilometre) fell rapidly so that average doses were less than 50% above normal background of 2.5 mSv/yr.

Health Effects from the Accident:

The Chernobyl accident's severe radiation effects killed 28 of the site's 600 workers in the first four months after the event. Another 106 workers received high enough doses to cause acute radiation sickness. Two workers died within hours of the reactor explosion from non-radiological causes. Another 200,000 cleanup workers in 1986 and 1987 received doses of between 1 and 100 rem (The average annual radiation dose for a U.S. citizen is about 6 rem). Chernobyl cleanup activities eventually required about 600,000 workers, although only a small fraction of these workers were exposed to elevated levels of radiation. Government agencies continue to monitor cleanup and recovery workers' health.

The Chernobyl accident contaminated wide areas of Belarus, the Russian Federation, and Ukraine inhabited by millions of residents. Agencies such as the World Health Organization have been concerned about radiation exposure to people evacuated from these areas. The majority of the five million residents living in contaminated areas, however, received very small radiation doses comparable to natural background levels (0.1 rem per year).

Today the available evidence does not strongly connect the accident to radiation-induced increases of leukemia or solid cancer, other than thyroid cancer. Many children and adolescents in the area in 1986 drank milk contaminated with radioactive iodine, which delivered substantial doses to their thyroid glands. To date, about 6,000 thyroid cancer cases have been detected among these children. Ninety-nine percent of these children were successfully treated; 15 children and adolescents in the three countries died from thyroid cancer by 2005. The available evidence does not show any effect on the number of adverse pregnancy outcomes, delivery complications, stillbirths or overall health of children among the families living in the most contaminated areas. Experts conclude some cancer deaths may eventually be attributed to Chernobyl over the lifetime of the emergency workers, evacuees and residents living in the most contaminated areas. These health effects are far lower than initial speculations of tens of thousands of radiation-related deaths.
Source: (UNSCEAR 2008)

Environmental Effects: Major releases of radionuclides from unit 4 of the Chernobyl reactor continued for ten days following the April 26 explosion. These included radioactive gases, condensed aerosols and a large amount of fuel particles. The total release of radioactive substances was about 14 Ebq[5] [1 EBq = 10^{18} Bq (Becquerel)], including 1.8 EBq of iodine-131, 0.085 EBq of ^{137}Cs, 0.01 EBq of ^{90}Sr and 0.003 EBq of plutonium radioisotopes. The noble gases contributed about 50% of the total release.
More than 200 000 square kilometres of Europe received levels of ^{137}Cs above 37 kBq m^{-2}. Over 70 percent of this area was in the three most affected countries, Belarus, Russia and Ukraine. The deposition was extremely varied, as it was enhanced in areas where it was raining when the contaminated air masses passed. Most of the strontium and plutonium radioisotopes were deposited within 100 km of the destroyed reactor due to larger particle sizes. Many of the most significant radionuclides had short physical half-lives. Thus, most of the radionuclides released by the accident have decayed away. The releases of radioactive iodines caused great concern immediately after the accident. For the decades to come ^{137}Cs contamination will continue to be of greatest importance, with secondary attention to ^{90}Sr. Over the longer term (hundreds to thousands of years) the plutonium isotopes andamericium-241 will remain, although at levels not significant radiologically.

Progressive closure of the Chernobyl plant: In the early 1990s, some US$400 million was spent on improvements to the remaining reactors at Chernobyl, considerably enhancing their safety. Energy shortages necessitated the continued operation of one of them (unit 3) until December 2000. (Unit 2 was shut down after a turbine hall fire in 1991, and unit 1 at the end of 1997) Almost 6000 people worked at the plant every day, and their radiation dose has been within internationally accepted limits. A small team of scientists works within the wrecked reactor building itself, inside the shelter[l].

Workers and their families now live in a new town, Slavutich, 30 km from the plant. This was built following the evacuation of Pripyat, which was just 3 km away.

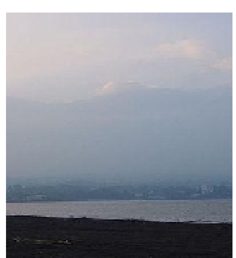
Ukraine depends upon, and is deeply in debt to, Russia for energy supplies, particularly oil and gas, but also nuclear fuel. Although this dependence is gradually being reduced, continued operation of nuclear power stations, which supply half of total electricity, is now even more important than in 1986.

When it was announced in 1995 that the two operating reactors at Chernobyl would be closed by 2000, a memorandum of understanding was signed by Ukraine and G7 nations to progress this, but its implementation was conspicuously delayed. Alternative generating capacity was needed, either gas-fired, which has ongoing fuel cost and supply implications, or nuclear, by completing Khmelnitski unit 2 and Rovno unit 4 ('K2R4') in Ukraine. Construction of these was halted in 1989 but then resumed, and both reactors came on line late in 2004, financed by Ukraine rather than international grants as expected on the basis of Chernobyl's closure.

EVENT: Vog in Hawaii Islands

CATEGORY: Natural

Vog is a form of air pollution that results when sulphur dioxide and other gases and particles emitted by an erupting volcano react with oxygen and moisture in the presence of sunlight. The word is a portmanteau of the words "volcanic", "smog", and "fog". The term is in common use in the Hawaiian Islands, where the Kilauea volcano, on the Island of Hawaii (aka "The Big Island"), has been erupting continuously since 1983. Based on June 2008 measurements, Kilauea emits 2,000–4,000 tons of sulphur dioxides every day.



Dense **vog** as seen from Hilo Bay, Hawaii.

Causes: Vog is created when volcanic gases (primarily oxides of sulphur) react with sunlight, oxygen and moisture. The result includes sulphuric acid and other sulphates. Vog is made up of a mixture of gases and aerosols which makes it hard to study and potentially more dangerous than either on their own.

Vog in Hawaii: In Hawaii, the gas plumes of Kilauea rise up from three locations and enter the ocean. The plumes create a blanket of vog that can envelop the island. Vog mostly affects the Kona coast on the west side of the Island of Hawaii, where the prevailing trade winds blow the vog to the south-west and southern winds then blow it north up the Kohala coast. Prolonged periods of southerly Kona winds, however, can cause vog to affect the eastern side of the Island on rare occasions, and affect islands across the entire state as well. By the time the vog reaches other islands, the sulphur dioxide has largely dissipated, leaving behind ash, smoke, sulphates, and ammonia.

Health Effects: Most studies of vog have been in areas where vog is naturally present, and not in controlled conditions. Vog contains chemicals that can damage the environment, and the health of plants, humans and other animals. Most of the aerosols are acidic and of a size where they can remain in the lungs to damage the lungs and impair function. Headaches, watery eyes, sore throat, breathing difficulties (inducing asthma attacks), flu-like symptoms, and general lethargy are commonly reported. These effects are especially pronounced in people with respiratory conditions and children. Vog generally reduces visibility, creating a hazard for drivers, and for air and ocean traffic.

The long-term health effects of vog are unknown.

Recent events: Several studies are underway to measure the air quality near volcanoes more carefully. Sulphur dioxide emissions increased on March 12, 2008, when a new vent opened. The increased vog level has caused evacuations and damaged crops. In the summer of 2008 and in 2012, Hawaii received a disaster designation due to the agricultural damage.

Sulphur dioxide emissions from the Halemaumau vent creates vog.

EVENT: Acid Rain on Statue of Liberty 1981

CATEGORY: Human induced

Wear and tear, acid rain, and other pollutants have caught up with the 98 -year-old Statue of Liberty, which hasn't had a major inspection and overhaul in more than 40 years. Erosion of the statue's copper skin, fatigue of its steel skeleton, and decay of the fasteners that hold skin to skeleton worry conservators and metallurgists. Its condition is not critical nor is the statue unsafe for visitors, but expensive preventive measures should be taken soon. Most of the erosion has happened in the past 20 years. The most suspected culprit is the rain acidity. Acid rain which fall to earth and erode stone and metal and kill fish in lakes.

Exposed to years of a non acidic environment, the statue's copper skin formed a coating of the green mineral brochantite, a protective patina. But showered with acid rain, the brochantite is converting to antlerite, which is less protective because it is water soluble and washes away. Given enough time, acid rain would dissolve the statue's skin.

Structural engineers make visual inspections every 12 to 18 months, but a more thorough study is needed. A thorough study detailed with chemical analyses of corrosion products to find ways to halt or stabilize the damage. The study will also use ultrasonics high frequency sound waves to measure how much of the copper skin has eroded from its original 3/32-inch thickness. X-ray analysis will also help determine whether parts of the skeleton need reinforcement or replacement. There appear to be several different kinds of corrosion that may need separate treatment. Once the corrosion products are identified, the next step is to find a way to stabilize them and seal off the skin from further corrosion. Efforts are on for preserving its structure

EVENT: Seveso disaster 1976

CATEGORY: Human induced

The Seveso disaster was an industrial accident that occurred around 12:37 pm July 10, 1976, in a small chemical manufacturing plant approximately 15 kilometres (9 mi) north of Milan in the Lombardy region in Italy. It resulted in the highest known exposure to

2,3,7,8-tetrachlorodibenzo-p-dioxin (TCDD) in residential populations which gave rise to numerous scientific studies and standardized industrial safety regulations.

The Seveso disaster was so named because Seveso, with a population of 17,000 in 1976, was the community most affected.

The factory building had been built many years earlier and the local population did not perceive it as a potential source of danger. Moreover, although several exposures of populations to dioxins had occurred before; mostly in industrial accidents, they were of a more limited scale.

Accident: Occurred in the chemical plant's where the chemical 2,4,5-trichlorophenol was being produced from 1,2,4,5-tetrachlorobenzene by the nucleophilic aromatic substitution reaction with sodium hydroxide. The 2,4,5-trichlorophenol was intended as an intermediate for hexachlorophene, although it can also be used as an intermediate for the herbicide 2,4,5-T (2,4,5-trichlorophenoxyacetic acid). This reaction must be carried out at a temperature above what was achievable using the normal process utilities available at the plant, so it was decided to use the exhaust steam from the onsite electricity generation turbine, and pass that around an external heating coil installed on the chemical reactor vessel. The chemical-release accident occurred when a batch process was interrupted prior to the completion of the final step - removal of ethylene glycol from the reaction mixture by distillation.

Hotter steam proceeded to heat the portion of the metal wall of the accident reactor above the level of the liquid within it to the same temperature. Operators of the reactor were unaware of the presence of this additional heating, and they stopped the batch as they normally would - by isolating the steam and turning off the stirrer in the reactor vessel. The abnormally-hot upper region of the reactor jacket then heated the adjacent reaction mixture. With the stirrer not running, the heating was highly localised - confined to just the portion of the upper layers of reaction mixture adjacent to the reactor wall, and increased the local temperature to the critical temperature for the exothermic side reaction seen in testing. Indeed, the critical temperature proved to be only 180 °C, 50 °C lower than believed. At that lower critical temperature, a slow runaway decomposition began, releasing more heat and leading to the onset of a rapid runaway reaction when the temperature reached 230 °C seven hours later.

The reactor relief valve eventually opened, causing the aerial release of 6 tonnes of chemicals, which settled over 18 km^2 (6.9 sq mi) of the surrounding area. Among the substances released was 1 kg of 2,3,7,8-tetrachlorodibenzodioxin (TCDD). At the nominal reaction temperature, TCDD is normally seen only in trace amounts of less than 1 ppm (parts per million). However, in the higher-temperature conditions associated with the runaway reaction, TCDD production apparently reached 100 ppm or more.

Effects: The local population was advised not to touch or eat locally grown fruits or vegetables. Within days a total of 3,300 animals were found dead, mostly poultry and rabbits. Emergency slaughtering commenced to prevent TCDD from entering the food chain, and by 1978 over 80,000 animals had been slaughtered. 15 children were quickly hospitalised with skin inflammation. By the end of August, some zones had been completely evacuated and fenced, 1,600 people of all ages had been examined and 447 were found to suffer from skin lesions or chloracne. An advice centre was set up for pregnant women.

A 1991 study 14 years after the accident sought to assess the effects to the thousands of persons that had been exposed to dioxin. The most evident adverse health effect ascertained was chloracne (193 cases).

A study published in 1998 concluded that chloracne (nearly 200 cases with definite exposure dependence) was the only effect established with certainty. Early health investigations including liver function, immune function, neurologic impairment, and reproductive effects yielded inconclusive results.

A 2001 study observed no increase in all-cause and all-cancer mortality. However, results support that dioxin is carcinogenic to humans and corroborate the hypotheses of its association with cardiovascular- and endocrine-related effects.

Impact: Industrial safety regulations were passed in the European Community in 1982 called the Seveso Directive which imposed much harsher industrial regulations. The Seveso Directive was updated in 1996, amended lastly in 2008 and is currently referred to as the Seveso II Directive (or COMAH Regulations in the United Kingdom).

EVENT: Los Angeles Smog, 1973
CATEGORY: Human induced

Photochemical air pollution—a new phenomenon, distinct from sulphurous smog—clouded the skies over Los Angeles, first recognized in the 1950s. This type of air pollution results from photochemical reactions involving nitrogen oxides (NO_x) and volatile organic compounds (VOCs; e.g., ethylene and benzene) that produce ozone (O_3) and particulate matter. Both cause lung problems, among other deleterious effects, and particulate matter reduces visibility. An average of 63 pphm oxidants was observed. Ozone concentrations were observed to be the highest. Brown haze over the town was observed for 3 days.

In Los angeles, on rare occasions, ozone concentrations exceeded 600 parts per billion by volume (ppbv, representing nanomoles per mole ambient air), and 8-hour averages sometimes exceeded 300 ppbv.

Reasons: Vehicular emissions are mainly responsible. NOx came from the combustion of fuels. Los Angeles is a valley so it contributed to inversion.

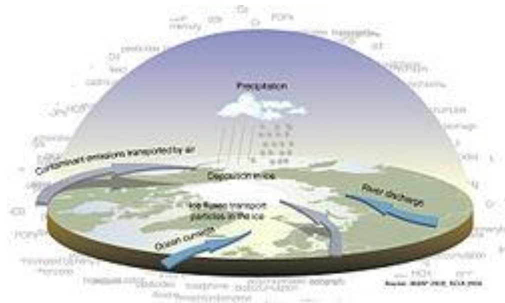
Effects: At its height in the 1950s and 1960s, air pollution got so bad in Los Angeles that reportedly parents kept their kids out of school; athletes trained indoors; citrus growers and sugar-beet producers watched in dismay as their crops withered; the elderly and young crowded into doctors' offices and hospital ERs with throbbing heads and shortness of breath. Motorcycle couriers even donned gas masks during particularly severe episodes. Loss of visibility and respiratory problems were the major issues.

Measures: In Los Angeles, scientific and engineering advances combined with political and societal commitment sustained over decades resulted in remarkable air quality improvement. The city took a comprehensive approach that addressed all emission sources. Officials banned open burning and passed laws that curbed industrial pollution. They regulated emissions from electrical power generation; plants emitting in excess of certain thresholds closed. Companies built new power plants elsewhere and transmitted electricity into the city.
However, the most critical and effective efforts addressed motor vehicle emissions. Initial efforts controlled emissions of VOCs and included notably catalytic convertors, engine redesign, and fuel reformulation to minimize evaporation and optimize performance of emission controls.

EVENT: Arctic haze

CATEGORY: Natural/ Human induced

Arctic haze is the phenomenon of a visible reddish-brown springtime haze in the atmosphere at high latitudes in the Arctic due to anthropogenic air pollution. A major distinguishing factor of Arctic haze is the ability of its chemical ingredients to persist in the atmosphere for an extended period of time compared to other pollutants. Due to limited amounts of snow, rain, or turbulent air to displace pollutants from the polar air mass in spring, Arctic haze can linger for more than a month in the northern atmosphere.



Long-range pollution pathways to the Arctic

The haze is seasonal, reaching a peak in late winter and spring. When an aircraft is within a layer of Arctic haze, pilots report that horizontal visibility can drop to one tenth that of normally clear sky. At this time it was unknown whether the haze was natural or was formed by pollutants.

In 1972 this smog was attributed to trans-boundary anthropogenic pollution, whereby the Arctic is the recipient of contaminants whose sources are thousands of miles away. Further research continues with the aim of understanding the impact of this pollution on global warming.

Origin of pollutants: The pollutants are commonly thought to originate from coal-burning in northern mid-latitudes, especially in Asia. The aerosols contain about 90% sulphur and the rest is carbon, which makes the haze reddish in colour. This pollution is helping the Arctic warm up faster than any other region, although increases in greenhouse gases are the main driver of this climatic change. Sulphur aerosols in the atmosphere affect cloud formation, leading to localized cooling effects over industrialized regions due to increased reflection of sunlight, which masks the opposite effect of trapped warmth beneath the cloud cover. During the Arctic winter, however, there is no sunlight to reflect. In the absence of this cooling effect, the dominant effect of changes to Arctic clouds is an increased trapping of infrared radiation from the surface.

Recent studies: According to a study, mid-latitude cities contribute pollution to the Arctic, and it mixes with thin clouds, allowing them to trap heat more easily. Study found that during the dark Arctic winter, when there is no precipitation to wash out pollution, the effects are strongest, because pollutants can warm the environment up to three degrees Fahrenheit.

Scientific predictions: European climatologists predicted in 2009 that by the end of the 21st century, the temperature of the Arctic region is expected to rise 3° Celsius on an average day. Previous climate models have suggested that the Arctic's summer sea ice may completely disappear by 2040 if warming continues unabated.

EVENT: LONDON SMOG 1952

CATEGORY: Human induced aggravated by weather conditions.

The **Great Smog** or **Big Smoke** was a severe air-pollution event that affected London during December 1952. A period of cold weather, combined with an anticyclone and windless conditions, collected airborne pollutants mostly from the use of coal to form a thick layer of smog over the city. It lasted from Friday 5 to Tuesday 9 December 1952, and then dispersed quickly after a change of weather.

Nelson's Column during the Great Smog of 1952

Although it caused major disruption due to the effect on visibility, and even penetrated indoor areas, it was not thought to be a significant event at the time, with London having experienced many smog events in the past, so-called "pea soupers".

It is known to be the worst air-pollution event in the history of the United Kingdom, and the most significant in terms of its effect on environmental research, government regulation, and public awareness of the relationship between air quality and health. It led to several changes in practices and regulations, including the Clean Air Act 1956.

Cause: The cold weather preceding and during the smog meant that Londoners were burning more coal than usual to keep warm. Post-war domestic coal tended to be of a relatively low-grade, sulphurous variety (economic necessity meant that better-quality "hard" coals tended to be exported), which increased the amount of sulphur dioxide in the smoke. There were also numerous coal-fired power stations in the Greater London area all of which added to the pollution. According to the United Kingdom's National Weather Service, the following pollutants were emitted each day during the foggy period: 1,000 tonnes of smoke particles, 2,000 tonnes of carbon dioxide, 140 tonnes of hydrochloric acid, 14 tonnes of fluorine compounds and 370 tonnes of sulphur dioxide. Additionally, there were pollution and smoke from vehicle exhaust, particularly from diesel-fuelled buses, which had replaced the recently abandoned electric tram system and from other industrial and commercial sources. Prevailing winds had also blown heavily polluted air across the English Channel from industrial areas of Continental Europe.

Weather: On 4 December 1952, an anticyclone settled over a windless London, causing a temperature inversion with cold, stagnant air trapped under a layer (or "lid") of warm air. The resultant fog, mixed with chimney smoke, particulates such as those from vehicle exhausts, and other pollutants such as sulphur dioxide, formed a persistent smog, which blanketed the capital the following day. The presence of tarry particles of soot gave the smog its yellow-black colour, hence the nickname "pea-souper". The absence of significant wind prevented its dispersal and allowed an unprecedented accumulation of pollutants.

Effect on London: Although London was accustomed to heavy fogs, this one was denser and longer-lasting than any previous fog. Visibility was reduced to a few yards ("It's like you were blind") making driving difficult or impossible. Public transport ceased, apart from the London Underground; and the ambulance service stopped functioning, forcing users to transport themselves to hospital. The smog even seeped indoors, resulting in the cancellation or abandonment of concerts and film screenings as visibility decreased in large enclosed spaces, and stages and screens became harder to see from the seats. Outdoor sports events were also affected.

Health effects: There was no panic, as London was renowned for its fog. The fog had caused 6,000 deaths and that 25,000 more people had claimed sickness benefits in London during that period. Most of the victims were very young or elderly, or had pre-existing respiratory problems. Most of the deaths were caused by respiratory tract infections from hypoxia and as a result of mechanical obstruction of the air passages by pus arising from lung infections caused by the smog. The lung infections were mainly bronchopneumonia or acute purulent bronchitis superimposed upon chronic bronchitis. More recent research suggests that the number of fatalities was considerably greater, at about 12,000.

Environmental impact: The death toll formed an important impetus to modern environmentalism, and it caused a rethinking of air pollution, as the smog had demonstrated its lethal potential. New regulations were implemented, restricting the use of dirty fuels in industry and banning black smoke. Environmental legislation since 1952, such as the City of London (Various Powers) Act 1954 and the Clean Air Acts of 1956 and 1968, led to a reduction in air pollution. Financial incentives were offered to householders to replace open coal fires with alternatives (such as installing gas fires), or for those who preferred, to burn coke instead (a by product of town gas production) which produces minimal smoke. Central heating (using gas, electricity, and oil or permitted solid fuel) was rare in most dwellings at that time, not finding favour until the late 1960s onwards. Despite improvements, insufficient progress had been made to prevent one further smog event exactly ten years later, in early December 1962.

EVENT: Donora smog 1948

CATEGORY: Human induced aggravated by weather conditions

The 1948 Donora smog was a historic air inversion resulting in a wall of smog that killed 20 people and sickened 7,000 more in Donora, Pennsylvania, a mill town on the Monongahela River, 24 miles (39 km) southeast of Pittsburgh. The event is the basis of the Donora Smog Museum.

Incident: The fog started building up in Donora on October 27, 1948. By the following day it was causing coughing and other signs of respiratory distress for many residents of the community in the Monongahela River valley. Many of the illnesses and deaths were initially attributed to asthma. The smog continued until it rained on October 31, by which time 20 residents of Donora had died and approximately a third to one half of the town's population of 14,000 residents had been sickened. Another 50 residents died of respiratory causes within a month after the incident. Sixty years later, the incident was described by The New York Times as "one of the worst air pollution disasters in the nation's history". Even ten years after the incident, mortality rates in Donora were significantly higher than those in other communities nearby.

1948: Donora, PA at noon.

Cause: Hydrogen fluoride and sulphur emissions from U.S. Steel's Donora Zinc Works and its American Steel & Wire plant were frequent occurrences in Donora. What made the 1948 event more severe was a temperature inversion, a situation in which warmer air aloft traps pollution in a layer of colder air near the surface. The pollutants in the air mixed with fog to form thick, yellowish, acid smog that hung over Donora for five days. The sulfuric acid, nitrogen dioxide, fluorine and other poisonous gases that usually dispersed into the atmosphere were caught in the inversion and accumulated until the rain ended the weather pattern.

Aftermath: A study showed that thousands more Donora residents could have been killed if the smog had lasted any longer than it had, in addition to the 20 humans and nearly 800 other animals killed during the incident. The Donora Smog marked one of the incidents where Americans recognized that exposure to large amounts of pollution in a short period of time can result in injuries and fatalities.

EVENT: St. Louis smog 1939

CATEGORY: Human induced aggravated by weather conditions.

The **1939 St. Louis smog** was a severe smog episode that affected St. Louis, Missouri, in the United States in 1939. Visibility was so limited that streetlights remained lit throughout the day and motorists needed their headlights to navigate city streets**.**

Problem: Smoke pollution had been a problem in St. Louis for many decades prior to the event, due to the large-scale burning of bituminous (soft) coal to provide heat and power for homes, businesses and transport.

The smog episode and its aftermath: On Tuesday, November 28, 1939, a meteorological temperature inversion trapped emissions from coal burning close to the ground, resulting in "the day the sun didn't shine". A cloud of thick black smoke enveloped St. Louis, far worse than any previously seen in the city. The day came to be known as "Black Tuesday". The smog hung about for 9 days over the course of the following month. New cleaner, affordable supplies of coal (semi-anthracite) were quickly secured from Arkansas in time for the next winter. This, together with a new smoke ordinance, improvements to the efficiency of furnaces and the ongoing public education campaign resulted in a significant and permanent improvement in air quality in the city.

EVENT: Meuse Valley fog 1930

CATEGORY: Human induced aggravated by weather conditions

The **1930 Meuse Valley fog** killed 60 people in Belgium due to a combination of industrial air pollution and climatic conditions.

The Meuse river flows from France, through Belgium and the Netherlands before entering the North Sea. The area in the Meuse Valley where the incident occurred is densely populated as well as having many factories. There were several thousand cases of illness over the period of two or three days with the sixty deaths occurring at the same time. Fifty six of the deaths were to the east of Engis.

The main symptom was dyspnea (shortness of breath) and the average age of those who died was 62, over a range of ages of 20 to 89 years. Cattle in the area were also affected. It was determined that the fluorine gas from the nearby factories was the killer. A statue and plaque commemorating those who died was inaugurated in Engis on 2 December 2000.