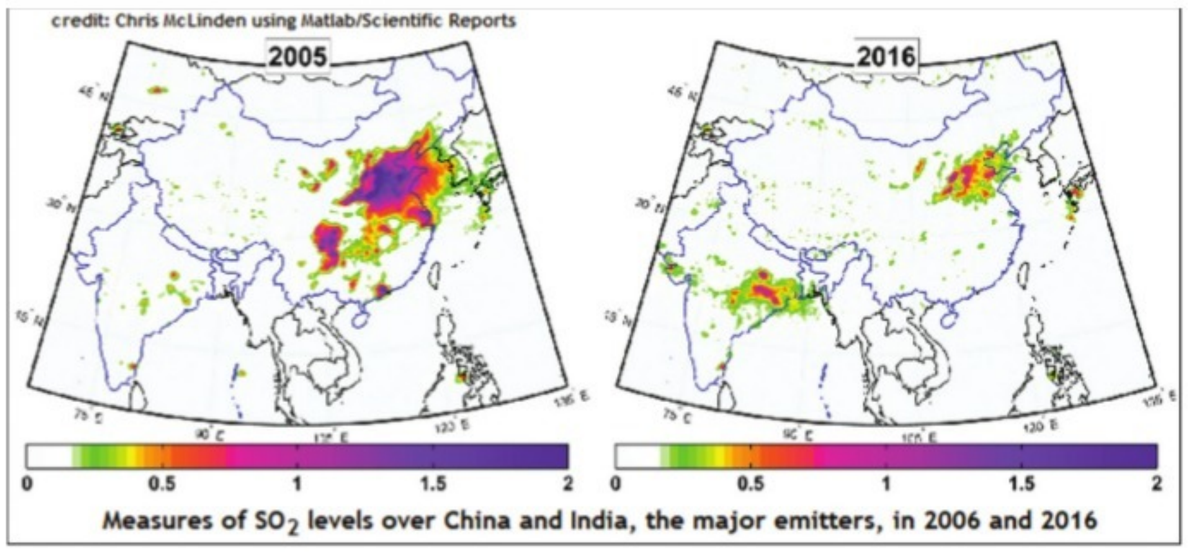
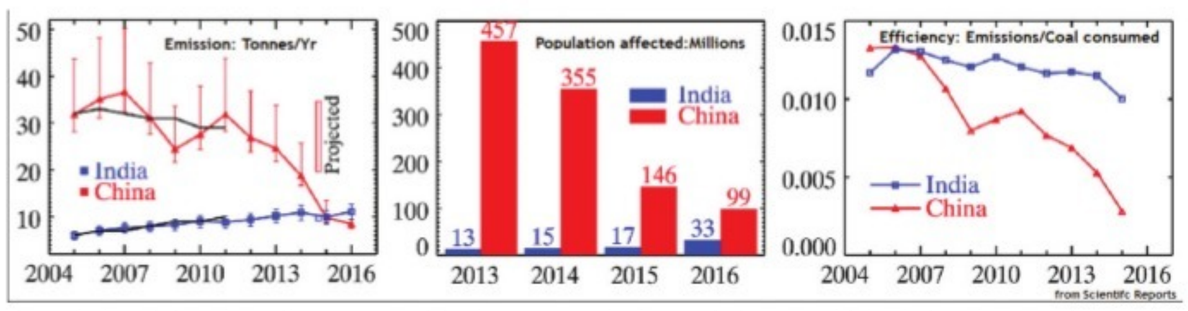
# Unflattering first place

**While there has been some movement towards containing pollution, it is nowhere near what China has done. The sulphur dioxide pollution in India is now higher than that of our neighbouring country**

S ANANTHANARAYANAN



Measures of $SO_2$ levels over China and India, the major emitters, in 2006 and 2016




India is the global leader in sulphurous air pollution. The US held the honour through the 1970s and 80s, till it was surpassed by China. China's performance peaked in 2006 but has been slipping since then. India, a non-starter at the time, has made rapid progress and is now ranked number one.

Can Li, Chris McLinden, Vitali Fioletov, Nickolay Krotkov, Simon Carn, Joanna Joiner, David Streets, Hao He, Xinrong, Zhanqing Li and Russell R Dickerson, from the University of Maryland, Nasa's atmospheric chemistry and dynamics laboratory and the Air Resources Laboratory at Maryland, and from laboratories in Canada, Michigan and Illinois, explain in their paper in the journal, *Scientific Reports* (a *Nature* group publication), that the switch is because of measures China has taken like emission controls in the generation of power.

The $CO_2$ emission when coal and petroleum are burned is inevitable so long as we need the energy. Coal and mineral oil, which are mainly carbon and hydrocarbons, contain sulphur and this gives rise to sulphur dioxide or $SO_2$. While $SO_2$ is a greenhouse gas too, it is of concern even in low concentration because it is poisonous and a health hazard leading to respiratory failure. $SO_2$ is the principal pollutant that causes the infamous "London Fog", which could reduce visibility to an arm's length on cold and wet evenings.

It is again the cause of the serious haze problem faced by China and India and the *Scientific Reports* paper says $SO_2$ pollution leads to over a million premature deaths every year. Apart from effects on health, high levels in the atmosphere lead to "acid rain", which degrades the soil and impacts plant, insect and aquatic life as well as steel and stone structures. The first legal action in respect of $SO_2$, in fact, was in 1929, when the House of Lords upheld the claim of a landowner against the Barton Electricity Works of the Manchester Corporation for damages to his land because of $SO_2$ emissions.

There are practically no natural sources of sulphur dioxide, except for volcanic eruptions. There was hence negligible average $SO_2$ in the atmosphere before the industrial revolution. The steam engine and the burning of coal started the build-up with rising releases from industry — for generation of electricity, the railways to power machinery, steel making and chemical processes. And then, there has been an increase in the number of petrol and diesel-driven vehicles, which emit $SO_2$ mainly inside crowded cities.

The US rapidly became the largest source, peaking at 28.3 million tonnes of $SO_2$ every year in 1970. Steps to clean fuels of sulphur content and to wash gas emissions to reduce $SO_2$ release then started having their effects. The rapid industrialisation of China, mostly with coal based electricity, however, pushed up emissions and in 2006, China became emitter number one at 23.1 million tonnes. That is where the US was in 1980.

In 2006, the emissions from India were less than a fifth of that from China. The Scientific Reports paper says that while China has taken measures that have reduced emissions, those from India have doubled since 2006 and levelled with China in 2015.

There are many drivers of emissions from burning fossil fuels in a growing economy, market forces that demand energy and the rise in motor vehicles being the most important. While there is now the awareness to control generation of $SO_2$, the *Scientific Reports* paper says the plurality of sources makes it difficult to know where the emissions are coming from and to exercise control. "To predict and mitigate air pollution, air quality models require accurate information on the emissions," the paper says. The conventional approach has been to create inventories of the related activities and the emission factors to arrive at estimates. The data available, however, is generally a few years old and is far from accurate. Estimates of pollution are hence highly uncertain, particularly in China and India, where the economy is changing by the hour and the mechanisms to regulate what is being done and to collect data are barely developed.

The researchers hence took recourse to satellite measurements and data that have now become available. The way $SO_2$ acts to create fog is by first combining with water to form sulphuric acid vapour. The vapour then condenses on particles of dust or soot. This suspension of particles, an aerosol, scatters light and is the reason for the fog in wintry mornings where there is dust in the air.

$SO_2$ aerosols can also play a useful role, albeit not enough to compensate for the harm they cause, by reflecting sunlight in the upper atmosphere to cause "global dimming". This reflection, however, helps satellite sensors work out the levels of $SO_2$ aerosols, as distinct from other particulate reflectors, in the atmosphere.

Data has been collected since the "Total Ozone Mapping Spectrometers", aboard Nasa's satellites, provided daily information of the total ozone column, from 1978 to 2006. In 2006, the Toms series was replaced by the "Ozone Monitoring Instrument" aboard Nasa's research satellite, Aura. The Scientific Reports paper says the superior ground resolution of the OMI has been particularly useful in observing distribution and levels of $SO_2$ pollution.

It was this data, the paper says, that uncovered the evidence that $SO_2$ pollution was reducing in China, which had had installed devices that removed the sulphur content of flue gases in coal-based power plants. The data also showed the major reduction of emissions from power plants in the US, the paper says. It is the OMI data, along with "bottom-up" field data, that has enabled assessment of the pollution levels in China and India.

Rapid industrial progress in China led to pollution and smog and haze in cities, particularly Beijing, which drew attention worldwide. China itself took measures to address particulate and toxic emissions from power plants and motor vehicles but still struggles with the problem in cities. The measures, however, have brought the $SO_2$ pollution levels substantially down — from 35 million tonnes a year in 2007 to below 10 million tonnes in 2016.

The 2000s have also seen great industrialisation in India and power generation capacity has increased from 74 GW in 2002 to 218 GW in 2017. As for motor vehicles, against the million vehicles registered during 1993, 19 million vehicles were registered in 2014. While there has been some movement towards containing pollution, it is nowhere near what China has done and the $SO_2$ pollution in India is now higher than that of our neighbouring country.

A comparison of the levels of $SO_2$ over China and India, as of 2005 and 2016, is shown in the maps in the picture. What's indicated in the maps are only the $SO_2$ levels and there are other components that China still needs to take care of. The message for India, however, is clear — to match steps with China, control the use of fossil fuels and reduce all emissions, rather than move towards levels of China and the US in years past.

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# Thanks to 'levitating' water

**Simulations in a special chamber suggest how the Martian landscape could have been shaped under certain conditions**


Slopes on the surface of Mars

JAN RAACK

The surface of Mars, with its dune flows, gullies and slope movements, is the result of sediment being transported downwards in the recent past as well as today. But this "mass wasting", typically caused by flows of water — for example, how the gullies on Earth are shaped — has proved a mystery to planetary scientists. This is because it is assumed that huge amounts of water are needed to form these features.

The problem is there is a lack of enough water on Mars now and in the planet's recent past. In a new study published in Nature Communications, we simulated the atmospheric conditions on Mars to discover how these features could have come about without a big flow of water.

For example, scientists have made assumptions about the water budget necessary to form the so-called "recurring slope lineae" -- dark streaks at the surface, which appear annually (687 days) during peak temperatures and which dissolve in colder months at the Martian surface. But the water needed to create these features would be too high to come from the Martian weather each year.

In our experiments, however, we identified that it is possible to transport sediment down a slope without the need for so much water. We did this using the Mars Simulation Chamber, specialised equipment that is able to simulate the atmospheric conditions on Mars.

To explain how mass wasting can happen without lots of water, it's important to know that the present-day atmosphere of Mars is very thin — the mean pressure is around seven mb (millibars) (compared with 1,000mb on Earth). In relatively recent times (around 20 million years) the pressure has also been low. These low pressures mean that liquid water will boil at low sediment temperatures of around 5°C. It means that liquid water will effectively "levitate" on the surface of Mars (when temperatures are above the zero). This "levitating" and boiling water can entrain a large amount of sand and other sediment when flowing down a slope. This process would require much less water than would be needed otherwise.

With this background information we wanted to test how liquid water flows behave under low pressures and with relatively warm surfaces (between 5°C and 24°C, which is warm for surfaces of Mars, but not impossible). The questions we posed in our experiment were — how does the boiling affect transportation mechanisms? Will there be more or less sediment transported with the effect of boiling? And can we see new transportation mechanisms taking place?

Previous work has investigated sediment transport by liquid water or melting ice under Martian conditions but the phenomenon of levitation or hovering of a water-sediment mixture over warm sediment was not observed in their experiments.

This phenomenon is comparable with the so-called "Leidenfrost effect", easily seen when you put some water drops on a hot cooking plate. The water sublimates immediately and the drop floats on a cushion of gas emanating from the drop. This mechanism could also happen on Mars, but as described before with much lower temperatures slightly above the frost point.


The Leidenfrost effect

Our experiments show that this phenomenon can move huge amounts of sediment down a slope without the need for much water — around nine times more sediment was moved down a slope with the effect of levitation than without the effect. Our model also showed that the lower gravity on Mars would have a positive effect on levitation — with lower gravity we would expect an increased rate of the amount of transported sediment over longer distances.

This means in particular for Mars that it is possible to explain already observed mass movements on its surface with the involvement of less water than previously predicted and that the amount of water needed for some transportation processes could have been previously been overestimated.

The "warm" sediment temperatures we chose for our experiments are possible on Mars. So the effect of levitation could only occur when sediment temperatures are relatively high (the annual mean temperature is about 55°C, but surface temperatures can rise up to around 30°C during the day in the summer).

The question of a possible origin of the water needed for the levitation could not be solved during our experiments, and also here further work has to be made to solve this uncertainty. Nevertheless, our experiments show that such a mechanism is possible on Mars (when the parameters are correct) and should be taken into account when thinking about water-related mass wasting features on Mars. Our experiments will not give the answer of how recent and present-day mass wasting features of the Martian surface (in particular gullies and recurring slope lines) are forming but we do provide a new perspective.

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The independent

PLUS POINTS

## Juno's jaunt

Nasa has released awe-inspiring new images of Jupiter sent back by its Juno probe. A mass of clouds swirling in a huge storm over the planet's southern hemisphere can be seen in intricate detail in one picture taken by the spacecraft.

The colour-enhanced image was captured on 24 October during Juno's ninth close flyby of the gas giant, said Nasa. The spacecraft was 20,577 miles (33,115km) from the tops of the clouds in the "String of Pearls" — one of the planet's eight massive storms — when the image was taken. The picture was processed by citizen scientists Gerald Eichstädt and Seán Doran using data from Juno's camera, the agency said.

It is part of a trove of new pictures released by Nasa this week. The agency releases raw data captured by the probe to the public, allowing scientists, artists and photographers to create stunning images of the planet.

The images require processing because Nasa and its ship take pictures with red, green, blue and infrared filters, which then need combining. That means that they can be altered and changed as they are pulled into full colour, allowing for different colours and textures.

Juno successfully entered Jupiter's orbit in July 2016, five years it launched from Earth. The spacecraft completed a high-risk manoeuvre to slow down as it approached the planet, firing a rocket based on calculations which, if only slightly wrong, would have seen the £890m probe blast into oblivion.

As well as capturing images, Juno is also equipped with sensors to explore the Jupiter's magnetic field and atmosphere.

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## 'Discovery' criticised

An Egyptian archaeologist overseeing a project to scan a pyramid for voids criticised the announcement of a discovery of a passenger plane-sized cavity in the Great Pyramid.

Scientists with the ScanPyramids project revealed last week that the void discovered with subatomic particle scans was the first major structure found inside the pyramid since the 19th century. It is thought to be at least 30 metres long and located above the "Grand Gallery" — a sloped corridor almost 50 metres long and nine metres high, which links Khufu's burial chamber at the pyramid's centre to a tunnel leading outside. The findings were published by the science journal, *Nature*.

But Zahi Hawass, who heads the ScanPyramids science committee overseeing the project, said there was no new "discovery". He said he had met other scientists from ScanPyramids who "showed us their conclusions, and we informed them this is not a discovery," he told *AFP*.

"The pyramid is full of voids and that does not mean there is a secret chamber or a new discovery," he said.

In a statement on Friday, the head of the government's antiquities council, Mustafa Waziri also criticised the announcement. "The project has to proceed in a scientific way that follows the steps of scientific research and its discussion before publication," he said.

The monument — 139 metres high today, and 230 metres wide — was erected as a tomb for Khufu, also known as Cheops. To this day, nobody knows quite how it was built. The pharaohs of ancient Egypt built these monumental tombs for themselves, complete with sarcophagus to hold their embalmed mummies, and stocked with everything they could require for the afterlife, including food, clothing and jewellery.

The straits times/ann