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**Global Dimming**

Programme transcript.

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NARRATOR (JACK FORTUNE): This is a film that demands action. It reveals that we may have grossly underestimated the speed at which our climate is changing. At its heart is a deadly new phenomenon. One that until very recently scientists refused to believe even existed. But it may already have led to the starvation of millions. Tonight Horizon examines for the first time the power of what scientists are calling Global Dimming.

NARRATOR: September 12th 2001, the aftermath of tragedy. While America mourned, the weather all over the country was unusually fine. Eight hundred miles west of New York, in Madison, Wisconsin a climate scientist called David Travis was on his way to work.

DR DAVID TRAVIS (University of Wisconsin, Whitewater): Around the twelfth, later on in the day, when I was driving to work, and I noticed how bright blue and clear the sky was. And at first I didn't think about it, then I realised the sky was unusually clear.

NARRATOR: For 15 years Travis had been researching an apparently obscure topic, whether the vapour trails left by aircraft were having a significant effect on the climate. In the aftermath of 9/11 the entire US fleet was grounded, and Travis finally had a chance to find out.

DR DAVID TRAVIS: It was certainly, you know, one of the tiny positives that may have come out of this, an opportunity to do research that hopefully will never happen again.

NARRATOR: Travis suspected the grounding might make a small but detectable change to the climate. But what he observed was both immediate and dramatic.

DR DAVID TRAVIS: We found that the change in temperature range during those three days was just over one degrees C. And you have to realise that from a layman's perspective that doesn't sound like much, but from a climate perspective that is huge.

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NARRATOR: One degree in just three days no one had ever seen such a big climatic change happen so fast. This was a new kind of climate change. Scientists call it Global Dimming. Two years ago most of them had never even heard of it, yet now they believe it may mean all their predictions about the future of our climate could be wrong. The trail that would lead to the discovery of Global Dimming began 40 years ago, in Israel with the work of a young English immigrant called Gerry Stanhill. A trained biologist, Gerry got a job helping to design irrigation schemes. His task was to measure how strongly the sun shone over Israel.

DR GERALD STANHILL (Agricultural Research Organisation, Israel): It was important for this work to measure solar radiation, because that is the factor that basically determines how much water crops require.

NARRATOR: For a year Gerry collected data from a network of light meters; the results were much as expected, and were used to help design the national irrigation system. But twenty years later, in the 1980s, Gerry decided to repeat his measurements to check that they were still valid. What he found, stunned him.

DR GERALD STANHILL: Well I was amazed to find that there was a very serious reduction in sunlight, the amount of sunlight in Israel. In fact, if we compare those very early measurements in the 1950s with the current measurements, there was a staggering 22% drop in the sunlight, and that really amazed me.

NARRATOR: A 22% drop in solar energy was simply massive. If it was true surely Israelis should be freezing. There had to be something wrong. So when Gerry published his results they were ignored. DR GERALD STANHILL: I must say the publications had almost no effect whatsoever on the scientific community.

NARRATOR: But in fact Gerry was not the only scientist who had noticed a fall in sunlight. In Germany a young graduate climatologist called Beate Liepert found that the same thing seemed to be happening over the Bavarian Alps too. DR BEATE LIEPERT (Lamont-Doherty Earth Observatory): I was the same, I was as sceptical as any other climatologist. But then, um, I, I saw the same results er in Germany, so um I believed him.

NARRATOR: Germany, Israel, what about the rest of the world? Working independently of each other, Liepert and Stanhill began searching through publications, journals and meteorological records from around the world. And they both found the same extraordinary story. Between the 1950s and the early 1990s the level of solar energy reaching the earth's surface had dropped 9% in Antarctica, 10% in the USA, by almost 30% in Russia. And by 16% in parts of the British Isles. This was a truly global phenomenon, and Gerry gave it a suitable name - Global Dimming. But again, the response from other scientists was one of sheer disbelief.

DR GERALD STANHILL: The scientific community was obviously not ready to deal with the fact that there was a Global Dimming phenomena.

NARRATOR: Of course, there was a good reason for the scepticism. Less energy from the Sun should be making the world cooler. Yet scientists knew the Earth was getting hotter. As the carbon dioxide

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and other greenhouse gases we emit trap ever more heat in the Earth's atmosphere and cause Global Warming.

DR BEATE LIEPERT: My friends' reaction actually to Gerry's and to my work at the same time too was, oh my God this is really extreme, you are um contradicting global warming. Er do you know how many billions of dollars was spent on global warming research and you and this old guy er are contradicting er us.

NARRATOR: So Liepert and Stanhill's work was widely dismissed. But Global Dimming was not the only phenomenon that didn't seem to fit with Global Warming. In Australia two more biologists, Michael Roderick and Graham Farquhar were intrigued by another paradoxical result - the world-wide decline in something called the pan evaporation rate.

PROF GRAHAM FARQUHAR (Australian National University): It's called pan evaporation rate because it's evaporation rate from a pan. Every day all over the world people come out in the morning and see how much water they've got to add to a pan to bring it back to the level it was the same time the morning before. It's that simple.

NARRATOR: In some places agricultural scientists have been performing this rather dull daily task for more than a hundred years.
PROF GRAHAM FARQUHAR: The long-term measurements of pan evaporation are what gives it its real value.

DR MICHAEL RODERICK (Australian National University): And the fact that they're doing the same thing day in day out with the same instrument.

PROF GRAHAM FARQUHAR: Yeah, they deserve a medal. Each of them.

DR MICHAEL RODERICK: Yeah.

NARRATOR: For decades, nobody took much notice of the pan evaporation measurements. But in the 1990s scientists spotted something very strange, the rate of evaporation was falling.

PROF GRAHAM FARQUHAR: There is a paradox here about the fact that the pan evaporation rate's going down, an apparent paradox, but the global temperature's going up.

NARRATOR: This was a puzzle. Most scientists reasoned that like a pan on the stove, turning up the global temperature should increase the rate at which water evaporated. But Roderick and Farquhar did some calculations and worked out that temperature was not the most important factor in pan evaporation.

DR MICHAEL RODERICK: Well it turns out in fact that the key things for pan evaporation are the sunlight, the humidity and the wind. But really the sunlight is a really dominant term there.

NARRATOR: They found that it was the energy of the photons hitting the surface, the actual sunlight, that kicks the water molecules out of the pan and into the atmosphere. And so they too reached an

extraordinary conclusion.

DR MICHAEL RODERICK: You know, if the pan is going down then maybe that's the sunlight going down. NARRATOR: Was the fall in pan evaporation in fact evidence of Global Dimming? Somewhere in the journals, they felt, must be the hard numbers that could tie the two things together.

DR MICHAEL RODERICK: And then one day, just by accident, I had to go to the library to get an article out Nature. As you do, I couldn't find it. And I just glanced at a, through the thing, and there was an article called Evaporation Losing Its Strength. Which reported a decline in pan evaporation over Russia, United States and Eastern Europe. And there in the, in the measurements, they said that the, the pans had on average, evaporated about a hundred millimetres less of water in the last thirty years.

NARRATOR: Mike knew how much sunlight was needed to evaporate a millimetre of water. So he put the two sets of figures together - the drop in evaporation with the drop in sunlight.

DR MICHAEL RODERICK: And so you just do the sum in your head. A hundred millimetres of water, less a pan evaporation, two and a half mega joules, so two and a half times a hundred is two hundred and fifty mega joules. And that is in fact what the Russians have measured with the decline in sunlight in the last thirty years. It was quite amazing.

NARRATOR: It was the same with Europe and the USA. The drop in evaporation rate matched exactly the drop in sunlight reported by Beate Liepert and Gerry Stanhill. Two completely independent sets of observations had come to the same conclusion. Though it seemed incredible, there was no doubting Global Dimming now.

DR BEATE LIEPERT: All of a sudden you see, oh my God the world is dimming, and then you, all of a sudden you see oh my God this really has a tremendous impact.

PROF GRAHAM FARQUHAR: There had to be dimming in Europe in America and in Russia, this is on a global scale. And we thought, this is really important because the amount of dimming was enormous. So this is BIG on a global scale.

NARRATOR: But what was causing it? Scientists knew that there was nothing wrong with the sun itself. The culprit had to be here on Earth. And as they searched for clues, they would make another startling discovery. Global dimming is a killer. It may have been behind the worst climatic disaster of recent times, responsible for famine and death on a biblical scale. And Global Dimming is poised to strike again.

NARRATOR: The Maldives: a nation of a thousand tiny islands in the middle of the Indian Ocean, so recently battered by the Asian tsunami. It was here that Veerabhadran Ramanathan, one of the world's leading climate scientists first began to unravel the mystery of what's causing Global Dimming. He had first noticed declining sunlight over large areas of the Pacific Ocean in the mid-1990s.

PROF VEERABHADRAN RAMANATHAN (University of California): But

we didn't know at that time it was part of a much larger global picture, but I knew we had to find out what was causing that.

NARRATOR: Ramanathan was certain of one thing, the big drop in sunlight reaching the ground had to be something to do with changes in the Earth's atmosphere. There was one obvious suspect.

PROF VEERABHADRAN RAMANATHAN: Almost everything we do to create energy causes pollution.

NARRATOR: Burning fuel doesn't just produce the invisible greenhouse gases which cause global warming. It also produces visible pollution, tiny airborne particles of soot and other pollutants. These produce the haze which shrouds our cities. So Ramanathan wondered: Could this pollution be causing Global Dimming? The Maldives were the perfect place to find out. The Maldives seem unpolluted, but in fact the northern islands sit in a stream of dirty air descending from India. Only the southern tip of the long island chain enjoys clean air coming all the way from Antarctica. So by comparing the northern islands with the southern ones, Ramanathan and his colleagues would be able to see exactly what difference the pollution made to the atmosphere and the sunlight. Project INDOEX, as it was called, was a huge multinational effort. For four years every possible technique was used to sample and monitor the atmosphere over the Maldives. INDOEX cost twenty-five million dollars, but it produced results - and they surprised everyone.

PROF VEERABHADRAN RAMANATHAN: The stunning part of the experiment was this pollutant layer which was three kilometre thick, cut down the sunlight reaching the ocean by more than 10%.

NARRATOR: A 10% fall in sunlight meant that particle pollution was having a far bigger effect than anyone had thought possible.

PROF VEERABHADRAN RAMANATHAN: Our models led us to believe the human impact on the dimming was close to half to one per cent. So what we discovered was tenfold.

NARRATOR: INDOEX showed that the pollution particles were blocking some sunlight themselves; but far more significant was what they were doing to the clouds. They were turning them into giant mirrors. Clouds are made of droplets of water. These only form when water vapour in the atmosphere starts to condense on the surface of naturally occurring airborne particles, typically pollen or sea salt. As they grow, the water droplets eventually become so heavy they fall as rain. But Ramanathan found that polluted air contained far more particles than the unpolluted air, particles of ash, soot and sulphur dioxide.

PROF VEERABHADRAN RAMANATHAN: We saw ten times more particles in the polluted air mass north of the Maldives compared with what we saw south of the Maldives which was a pristine air mass.

NARRATOR: In the polluted air billions of man-made particles provided ten times as many sites around which water droplets could form. So polluted clouds contained many more water droplets, each one far smaller than it would be naturally. Many small droplets reflect more light than fewer big ones. So the polluted clouds were

reflecting more light back into space, preventing the heat of the sun getting through. This was the cause of Global Dimming.

PROF VEERABHADRAN RAMANATHAN: Basically the Global Dimming we saw in the North Indian Ocean, it was contributed on the one hand by the particles themselves shielding the ocean from the sunlight, on the other hand making the clouds brighter. So this insidious soup, consisting of soot, sulphates, nitrates, ash and what have you, was having a double whammy on the Global Dimming.

NARRATOR: And when he looked at satellite images, Ramanathan found the same thing was happening all over the world. Over India. Over China, and extending into the Pacific. Over Western Europe... extending into Africa. Over the British Isles. But it was when scientists started to investigate the effects of Global Dimming that they made the most disturbing discovery of all. Those more reflective clouds could alter the pattern of the world's rainfall. With tragic consequences.

NEWS REPORT - MICHAEL BUERK VOICE OVER: Dawn, and as the sun breaks through the piercing chill of night on the plain outside Korum it lights up a biblical famine, now in the 20th Century. This place say workers here is the closest thing to hell on earth.

NARRATOR: The 1984 Ethiopian famine shocked the world. It was partly caused by a decade's long drought right across sub-Saharan Africa - a region known as the Sahel. For year after year the summer rains failed. At the time some scientists blamed overgrazing and poor land management. But now there's evidence that the real culprit was Global Dimming. The Sahel's lifeblood has always been a seasonal monsoon. For most of the year it is completely dry. But every summer, the heat of the sun warms the oceans north of the equator. This draws the rain belt that forms over the equator northwards, bringing rain to the Sahel. But for twenty years in the 1970s and 80s the tropical rain belt consistently failed to shift northwards - and the African monsoon failed. For climate scientists like Leon Rotstayn the disappearance of the rains had long been a puzzle. He could see that pollution from Europe and North America blew right across the Atlantic, but all the climate models suggested it should have little effect on the monsoon. But then Rotstayn decided to find out what would happen if he took the Maldivian findings into account.

DR LEON ROTSTAYN (CSIRO Atmospheric Research): What we found in our model was that when we allowed the pollution from Europe and North America to affect the properties of the clouds in the northern hemisphere the clouds reflected more sunlight back to space and this cooled the oceans of the northern hemisphere. And to our surprise the result of this was that the tropical rain bands moved southwards tracking away from the more polluted northern hemisphere towards the southern hemisphere.

NARRATOR: Polluted clouds stopped the heat of the sun getting through. That heat was needed to draw the tropical rains northwards. So the life giving rain belt never made it to the Sahel.

DR LEON ROTSTAYN: So what our model is suggesting is that these droughts in the Sahel in the 1970s and the 1980s may have been caused by pollution from Europe and North America affecting the properties of the clouds and cooling the oceans of the northern

hemisphere.

NARRATOR: Rotstayn has found a direct link between Global Dimming and the Sahel drought. If his model is correct, what came out of our exhaust pipes and power stations contributed to the deaths of a million people in Africa, and afflicted 50 million more. But this could be just a taste of what Global Dimming has in store.

PROF VEERABHADRAN RAMANATHAN: The Sahel is just one example of the monsoon system. Let me take you to another part of the world. Asia, where the same monsoon brings rainfall to three point six billion people, roughly half the world's population. My main concern is this air pollution and the Global Dimming will also have a detrimental impact on this Asian monsoon. We are not talking about a few millions of people we are talking about billions of people.

NARRATOR: For Ramanathan the implications are clear.

PROF VEERABHADRAN RAMANATHAN: There is no choice here we have to cut down air pollution, if not eliminate it altogether.

NARRATOR: Fortunately, tackling air pollution needn't be too difficult. It wouldn't mean giving up on oil and coal altogether. We'd just have to burn them more cleanly. And in Europe we've already made a start: scrubbers in power stations, catalytic converters in cars and low sulphur fuels, though they do nothing to reduce greenhouse gases, have already begun to cut down visible air pollution. This should be good news for the Sahel, and in recent years the droughts have been nothing like as bad. But there's a terrible catch. Because while Global Dimming is itself a major threat to humanity, it now appears it has been protecting us from an even greater threat. Which means that as we reduce the dimming, we may find ourselves faced by something even worse.

NARRATOR: It was David Travis who first caught a glimpse of what the world could be like without Global Dimming. It happened in those chaotic days following the tragedy of 9/11. For fifteen years, Travis had been studying the vapour trails, or contrails, left behind by high-flying aircraft. Though each individual contrail seems small, when they all spread out, they can blanket the sky.

DR DAVID TRAVIS: Here are some examples of what we call outbreaks of contrails. These are large clusters of contrails. And here's a particularly good one from Southern California. Here's the west coast of the United States. And you can see here this lacing network of contrails covering at least fifty per cent, if not seventy five per cent or more of the sky in that area. It doesn't take an expert to realise that if, if you look at the satellite picture and see this kind of contrail coverage that they've got to be having an effect on temperature at the surface.

NARRATOR: But the problem Travis faced was to establish exactly how big an effect the contrails were actually having. The only way to do that was to find a period of time when, although conditions were right for contrails to form, there were no flights. And, of course, that never happened. Until September 2001. Then, for three days after the 11th virtually all commercial aircraft in the US were grounded. It was an opportunity Travis could not afford to miss. He set about gathering temperature records from all over the USA.

DR DAVID TRAVIS: Initially data from over 5,000 weather stations across the 48 united states, the areas that was most dominantly affected by the grounding.

NARRATOR: Travis was not looking just at temperature - that varies a lot from day to day anyway. Instead he focused on something that normally only changes quite slowly: the temperature range. The difference between the highest temperature during the day and the lowest at night. Had this changed at all during the three days of the grounding?

DR DAVID TRAVIS: As we began to look at the climate data and the evidence began to grow I got more and more excited. The actual results were much larger than I expected. So here we see for the 3 days preceding September 11th a slightly negative value of temperature range with lots of contrails as normal. Then we have this sudden spike right here of the 3 day period. This reflects lack of clouds, lack of contrails, warmer days cooler nights, exactly what we expected but even larger than what we expected. So what this indicates is that during this 3 day period we had a sudden drop in Global Dimming contributed from airplanes.

NARRATOR: During the grounding the temperature range jumped by over a degree Celsius. Travis had never seen anything like it before.

DR DAVID TRAVIS: This was the largest temperature swing of this magnitude in the last thirty years.

NARRATOR: If so much could happen in such a short time, removing just one form of pollution, then it suggests that the overall effect of Global Dimming on world temperatures could be huge.

DR DAVID TRAVIS: The nine eleven study showed that if you remove a contributor to Global Dimming, jet contrails, just for a three day period, we see an immediate response of the surface of temperature. Do the same thing globally we might see a large scale increase in global warming.

NARRATOR: This is the real sting in the tail. Solve the problem of Global Dimming and the world could get considerably hotter. And this is not just theory, it may already be happening. In Western Europe the steps we have taken to cut air pollution have started to bear fruit in a noticeable improvement in air quality and even a slight reduction in Global Dimming over the last few years. Yet at the same time, after decades in which they held steady, European temperatures have started rapidly to rise culminating in the savage summer of 2003.

Forest fires devastated Portugal. Glaciers melted in the Alps. And in France people died by the thousand. Could this be the penalty of reducing Global Dimming without tackling the root cause of global warming?

DR BEATE LIEPERT: We thought we live in a global warming world, um but this is actually er not right. We lived in a global warming plus a Global Dimming world, and now we are taking out Global Dimming. So we end up with the global warming world, which will be much worse than we thought it will be, much hotter.

NARRATOR: This is the crux of the problem. While the greenhouse effect has been warming the planet, it now seems Global Dimming has been cooling it down. So the warming caused by carbon dioxide has been hidden from us by the cooling from air pollution. But that situation is now starting to change.

DR PETER COX (Hadley Centre, Met Office): We're gonna be in a situation unless we act where the cooling pollutant is dropping off while the warming pollutant is going up, CO2 will be going up and particles will be dropping off and that means we'll get an accelerated warming. We'll get a double whammy, we'll get, we'll get reducing cooling and increased heating at the same time and that's, that's a problem for us.

NARRATOR: And that's not all. Climatologists like Peter Cox have begun to worry that Global Dimming has led them to underestimate the true power of global warming. They fear that the Earth could be far more vulnerable to greenhouse gases than they had previously thought.

DR PETER COX: We've got two competing effects really, that we've got the greenhouse effect, which has tended to warm up the climate. But then we've got this other effect that's much stronger than we thought, which is a cooling effect that comes from particles in the atmosphere. And they're competing with one another. And we know the climate's moved to a warmer state by about point six of a degree over the last hundred years. So the whole thing's moved this way. If it turns out that the cooling is stronger than we thought then the warming also is a lot stronger than we thought, and that means the climate's more sensitive to carbon dioxide than we originally thought, and it means our models may be under sensitive to carbon dioxide.

NARRATOR: The models that everyone has been using to forecast climate change predict a maximum warming of 5 degrees by the end of the century. But Cox and his colleagues now fear those models may be wrong. Temperatures could rise twice as fast as they previously thought with irreversible damage just twenty-five years away.

DR PETER COX: If we don't do anything by about twenty thirty we could have a global warming of exceeding two degrees, and at that point it's believed the Greenland ice sheet would start to melt in a way that you wouldn't be able to stop it once it started it, it would melt. Take a long time to melt but ultimately it would lead to a sea level rise of seven or eight metres.

NARRATOR: Once the Greenland ice cap begins to melt, nothing will stop it. Many of the world's major cities will be living on borrowed time. Decade by decade, the risk of catastrophic flooding would increase inexorably. But unless action is taken it won't stop there. Because after Greenland, the world's tropical rainforests will start to wither in the heat.

DR PETER COX: 2040 it could be four degrees warmer, the climate change could have led to big drying particularly in the Amazon Basin, that would make the forest unsustainable, we'd expect the forest to catch fire probably, turn into savannah and maybe ultimately even desert if it gets really really dry as our model suggests.

NARRATOR: And as the rainforest burnt away, it would release vast amounts of carbon dioxide into the atmosphere, driving global warming still further. Cox calculates that in just a century, the world could be 10 degrees hotter, a warming more rapid than any in Earth history. If this were to happen, the landscape of England would be utterly transformed.

DR PETER COX: We're talking about a change from a lush, moist climate, environment like this, to a North African climate in just a few decades or a hundred years.

NARRATOR: Most British plant species could not survive a North African climate. With vegetation dying everywhere, soil erosion would become a severe problem. From a green and pleasant land, England would become a country of extremes, with winter flooding giving way to summer dust storms. And it will be far worse elsewhere.

DR PETER COX: You can imagine ten degree warming in the UK in a hundred years is catastrophic. Ten degree warming in a hot country already makes it essentially uninhabitable.

NARRATOR: And just when one might think things could get no worse in the far North a ten degree warming might be enough to release a vast natural store of greenhouse gas bigger than all the oil and coal reserves of the planet.

DR PETER COX: We will be in danger of destabilising these things called methane hydrates which store a lot of methane at the bottom of the ocean in a kind of frozen form, ten thousand billions tons of this stuff, and they're known to be destabilised by warming.

NARRATOR: At this point, whatever we did to curb our emissions, it would be too late. Ten thousand billion tons of methane, a greenhouse gas eight times stronger than carbon dioxide, would be released into the atmosphere. The Earth's climate would be spinning out of control, heading towards temperatures unseen in four billion years. But this is not a prediction - it is a warning. It is what will happen if we clean up pollution while doing nothing about greenhouse gases. However, the easy solution - just keep on polluting and hope that Global Dimming will protect us - would be suicidal.

DR PETER COX: If we carried on pumping out the particles it would have terrible impact on human health, I mean particles are involved in all sorts of respiratory diseases, that's why they're being brought under control, and of course they effect climate anyway. If you, if you fiddle with the, the balance of the planet, the radiative balance of the planet, you affect all sorts of circulation patterns like monsoons, which would have horrible effects on people. So it would be extremely difficult, in fact impossible, to cancel out the greenhouse effect just by carrying on pumping out particles, even if it wasn't for the fact that particles are damaging for human health.

NARRATOR: Instead we have to take urgent action to tackle the root cause of both global warming and Global Dimming - the burning of coal, oil and gas. We may have to make very difficult choices, about how we live and how we generate our electricity. We have been talking about such things for 20 years. But so far very little has been done in practical terms. The discovery of Global Dimming makes it

clear that we are rapidly running out of time.

DR PETER COX: One of the real driving forces is that you leave an environment that is comfortable for your children. And we carry on going the way we're going, we're not going to do that, we're going to leave an environment that's much worse than the environment we lived in; and it will be down to what we did when we were using that environment, and that would be, um, tragic really, if that happened.

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