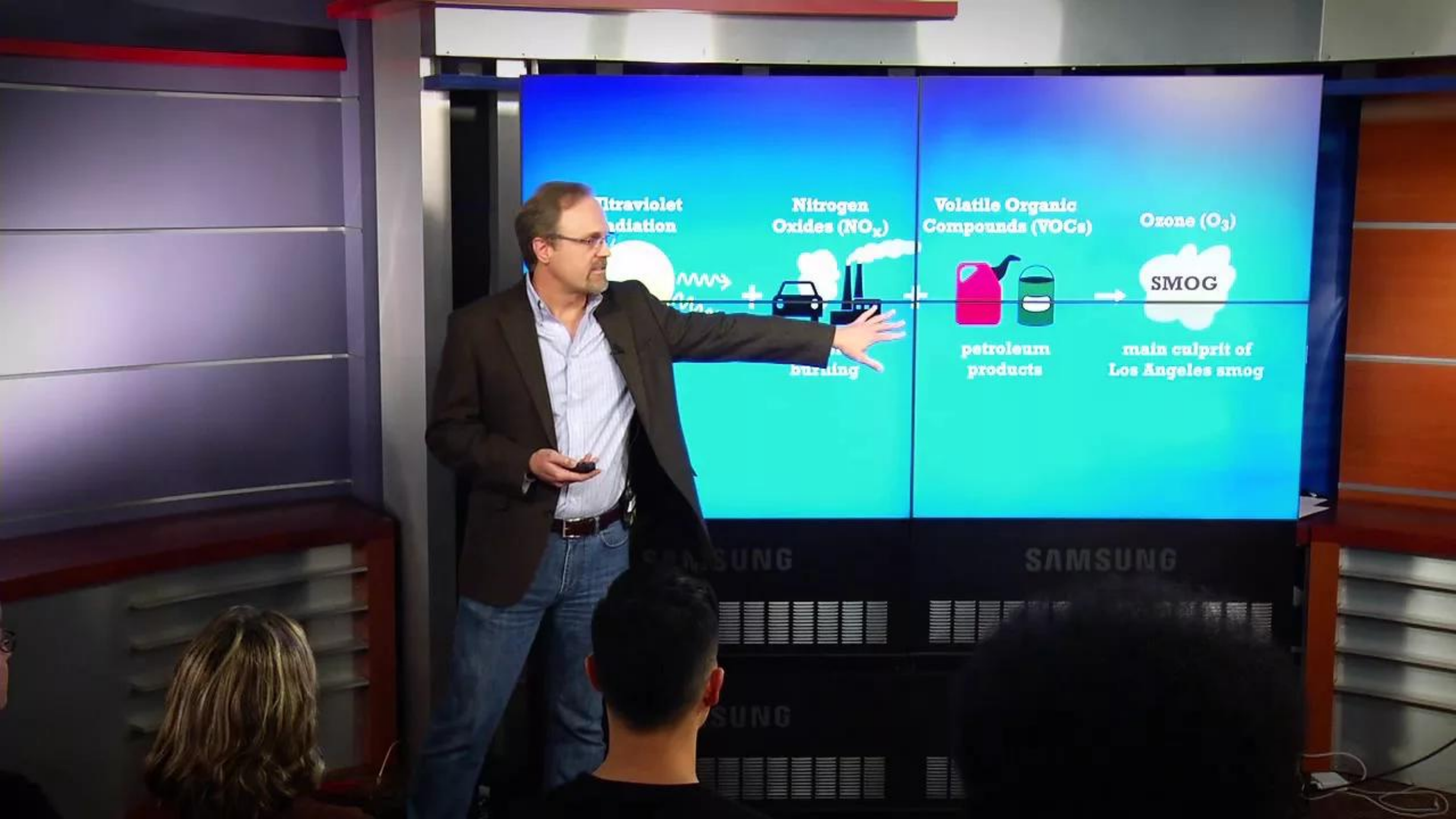
Nitrogen Oxides (NO_x)
Volatile Organic Compounds (VOCs)
Ozone (O_3)
SMOG
petroleum products
main culprit of Los Angeles smog
SAMSUNG

1
00:00:00,010 --> 00:00:04,010
[chiming music]

2
00:00:04,030 --> 00:00:08,050
[music fades out] [new music starts]

3
00:00:08,070 --> 00:00:12,090
[upbeat but concerned music]

4
00:00:12,110 --> 00:00:16,110
>>BRYAN: I'm going to tell you a tale of air quality in three very different

5
00:00:16,130 --> 00:00:20,150
cities. Beijing, China; Los Angeles, California; and

6
00:00:20,170 --> 00:00:24,180
Atlanta, Georgia. And since I work for NASA, I'll be telling this from the perspective of

7
00:00:24,200 --> 00:00:28,190
space. This is a satellite image

8
00:00:28,210 --> 00:00:32,210
of northeastern China. And you can see this thick, thick

9
00:00:32,230 --> 00:00:36,230
smog enveloping the entire area, and

10
00:00:36,250 --> 00:00:40,270
including the city of Beijing, China.

11
00:00:40,290 --> 00:00:44,330
And from the ground, the pollution, the smog is stifling. It's not uncommon

12
00:00:44,350 --> 00:00:48,360
to see people wearing these face masks to help protect

13
00:00:48,380 --> 00:00:52,390

them from the pollution. So,

14
00:00:52,410 --> 00:00:56,420
what is smog? Smog is a combination of the word "smoke" and

15
00:00:56,440 --> 00:01:00,450
"fog", and it's really just a catch-all for any

16
00:01:00,470 --> 00:01:04,470
noxious soup of pollutants. In the case of Beijing, the primary

17
00:01:04,490 --> 00:01:08,540
component is particulates coming out of the tailpipes of cars, and out of

18
00:01:08,560 --> 00:01:12,570
smoke stacks. So it occurs whenever you burn fuel,

19
00:01:12,590 --> 00:01:16,640
such as gasoline and coal. And the problem with these particulates is

20
00:01:16,660 --> 00:01:20,700
that when we inhale them, they can go deep into our

21
00:01:20,720 --> 00:01:24,760
lungs and they're toxic, and they can embed themselves into the lining of our lungs.

22
00:01:24,780 --> 00:01:28,800
And the smallest of these particles can actually

23
00:01:28,820 --> 00:01:32,820
enter our bloodstream. Okay, here is

24
00:01:32,840 --> 00:01:36,840
an image of the Forbidden City, one of Beijing's top tourist attractions.

25
00:01:36,860 --> 00:01:40,850
And this is on a clear day.

26
00:01:40,870 --> 00:01:44,880
And this is on a horribly polluted day. So I'd rather be a tourist on the

27
00:01:44,900 --> 00:01:48,950
clear day here. Now on the polluted day, the levels of

28
00:01:48,970 --> 00:01:53,020
pollutants can be ten times greater than what's considered

29
00:01:53,040 --> 00:01:57,070
hazardous, and 40 times greater than what's considered to be healthy.

30
00:01:57,090 --> 00:02:01,140
Okay, now the Chinese government has

31
00:02:01,160 --> 00:02:05,170
developed their own air quality index, similar to the one we have in the US.

32
00:02:05,190 --> 00:02:09,210
And they developed, or they created these cartoon characters

33
00:02:09,230 --> 00:02:13,220
to convey the daily air quality index to the Chinese people, and

34
00:02:13,240 --> 00:02:17,250
they call these the Shanghai girls.

35
00:02:17,270 --> 00:02:21,270
The Shanghai girls become increasingly distressed as the AQI goes up,

36
00:02:21,290 --> 00:02:25,310
as the pollution worsens.

37
00:02:33,410 --> 00:02:29,350
[no sound]

38
00:02:33,430 --> 00:02:37,430

you wouldn't be surprised to hear that this is not an official Shanghai girl,

39
00:02:37,450 --> 00:02:41,450
this is called the "Beijing girl", and she's created by a concerned Chinese

40
00:02:41,470 --> 00:02:45,470
citizen. And this citizen was concerned because

41
00:02:45,490 --> 00:02:49,490
these levels are above the highest level of the air quality index.

42
00:02:49,510 --> 00:02:53,510
And in these situations,

43
00:02:53,530 --> 00:02:57,540
this air quality is considered to be beyond index.

44
00:02:57,560 --> 00:03:01,570
So, why is China so polluted?

45
00:03:01,590 --> 00:03:05,630
Well, in the last several decades, they've undergone an industrial revolution

46
00:03:05,650 --> 00:03:09,650
and this has been fueled by China's cheap and abundant

47
00:03:09,670 --> 00:03:13,670
coal. And along with this industrialization,

48
00:03:13,690 --> 00:03:17,690
there's been an increase in urbanization as well as

49
00:03:17,710 --> 00:03:21,710
the standard of living. So the Chinese people are manufacturing more goods

50
00:03:21,730 --> 00:03:25,730
and they're consuming more goods. But more importantly, they are exporting

51
00:03:25,750 --> 00:03:29,750
many of these goods and is considered to be the world's manufacturing hub.

52
00:03:29,770 --> 00:03:33,780
When you burn coal, sulfur dioxide is

53
00:03:33,800 --> 00:03:37,850
released, and it's a precursor to acid rain, it's a

54
00:03:37,870 --> 00:03:41,860
primary ingredient. And it also is a contributor to these particulates that

55
00:03:41,880 --> 00:03:45,880
plague Chinese cities. Here's a representation of satellite data,

56
00:03:45,900 --> 00:03:49,900
of sulfur dioxide, and you can see it's pretty high over much of China.

57
00:03:49,920 --> 00:03:53,920
And it's highest here in this region and that region where there's

58
00:03:53,940 --> 00:03:57,960
a high density of power plants.

59
00:03:57,980 --> 00:04:01,980
For perspective, here is the United States, and you

60
00:04:02,000 --> 00:04:06,010
can see that the pollutant levels are much, much lower.

61
00:04:06,030 --> 00:04:10,020
The Ohio River Valley has the highest concentration of power plants in the

62
00:04:10,040 --> 00:04:14,090
US. And it's much lower in the US because

63
00:04:14,110 --> 00:04:18,160

it's required by law for these power plants to operate scrubber

64
00:04:18,180 --> 00:04:22,190
technology. And these scrubbers literally scrub or remove

65
00:04:22,210 --> 00:04:26,240
the SO2, the sulfur dioxide from the effluent of the power plant

66
00:04:26,260 --> 00:04:30,270
before it's released to the atmosphere. The problem here is

67
00:04:30,290 --> 00:04:34,320
the scrubber technology is incredibly expensive to operate. So places like

68
00:04:34,340 --> 00:04:38,350
China and India simply can't afford to.

69
00:04:38,370 --> 00:04:42,390
But it wasn't so long ago that pollutant levels in the US

70
00:04:42,410 --> 00:04:46,390
were very high, and some of the most polluted cities in the world were in the US.

71
00:04:46,410 --> 00:04:50,430
And Los Angeles was a poster child for this.

72
00:04:50,450 --> 00:04:54,450
And you can see in this image, which is not a satellite image, it's actually

73
00:04:54,470 --> 00:04:58,500
a photograph from NASA's Skylab space station in 1973,

74
00:04:58,520 --> 00:05:02,520
you can see this thick smog in the Los Angeles basin.

75
00:05:02,540 --> 00:05:06,570
The first smog event,

76
00:05:06,590 --> 00:05:10,600
major smog event, occured in 1943 during World War II.

77
00:05:10,620 --> 00:05:14,640
And the residents of LA initially thought they were under attack by a foreign power.

78
00:05:14,660 --> 00:05:18,660
And this is because the smog was stinging their eyes,

79
00:05:18,680 --> 00:05:22,680
burning their throats, and there was an odd bleach-like odor.

80
00:05:22,700 --> 00:05:26,710
It smelled like chemicals.

81
00:05:26,730 --> 00:05:30,770
And interestingly, they noticed during these smog events

82
00:05:30,790 --> 00:05:34,790
that the rubber tires on their cars were cracking.

83
00:05:34,810 --> 00:05:38,840
So, the residents of LA, they

84
00:05:38,860 --> 00:05:42,890
protested to the city government. They said they wanted cleaner air.

85
00:05:42,910 --> 00:05:46,900
And this is a protest by the Highland Park Optimists club.

86
00:05:46,920 --> 00:05:50,940
So city officials responded by

87
00:05:50,960 --> 00:05:54,970
initially banning the burning of trash, which was a common practice

88
00:05:54,990 --> 00:05:58,990

at the time. And they also shuttered a few factories

89
00:05:59,010 --> 00:06:03,020
that they thought were particularly polluting. But unfortunately the smog

90
00:06:03,040 --> 00:06:07,040
persisted. Scientists finally figured out

91
00:06:07,060 --> 00:06:11,100
that the primary ingredient in this smog

92
00:06:11,120 --> 00:06:15,150
was ozone. And as

93
00:06:15,170 --> 00:06:19,200
time went on, these ozone episodes just got worse. Here's an example

94
00:06:19,220 --> 00:06:23,230
of 1955 and 1956,

95
00:06:23,250 --> 00:06:27,250
all the days listed here had ozone levels above 500 ppb, that's

96
00:06:27,270 --> 00:06:31,280
an incredible level. And on this one horrible day, September 13th,

97
00:06:31,300 --> 00:06:35,300
it was as high as 900 ppb. And that's 15 times acceptable levels.

98
00:06:35,320 --> 00:06:39,370
Just for reference, from personal experience,

99
00:06:39,390 --> 00:06:43,440
I actually experienced 350 ppb

100
00:06:43,460 --> 00:06:47,500
quite by accident in a lab one time. I was working with a chemical

101
00:06:47,520 --> 00:06:51,540
instrument that generated ozone internally to the instrument, and

102
00:06:51,560 --> 00:06:55,580
unknown to me, a hose cracked and was allowing this ozone to build up in the lab.

103
00:06:55,600 --> 00:06:59,620
And at first my eyes were stinging, my throat was burning, and finally

104
00:06:59,640 --> 00:07:03,640
when I smelled this chemical odor, this bleach-like odor, I knew it was ozone. So I took a quick

105
00:07:03,660 --> 00:07:07,670
reading, and it was only 350 ppb. I can't imagine

106
00:07:07,690 --> 00:07:11,700
what it would feel like to experience 500 ppb regularly, and

107
00:07:11,720 --> 00:07:15,790
900 ppb for hours on end. Okay,

108
00:07:15,810 --> 00:07:19,860
so, the question still remained, where was this ozone coming from?

109
00:07:19,880 --> 00:07:23,930
Scientists figured out it wasn't coming from tailpipes and smoke stacks, so it

110
00:07:23,950 --> 00:07:27,990
wasn't directly being emitted. Instead, it was being

111
00:07:28,010 --> 00:07:32,020
generated within the smog itself.

112
00:07:32,040 --> 00:07:36,070
So here, today we know that there are three primary ingredients necessary

113
00:07:36,090 --> 00:07:40,090

to form these unhealthy levels of ozone in an urban environment.

114
00:07:40,110 --> 00:07:44,110
The first, sunlight, that drives these chemical

115
00:07:44,130 --> 00:07:48,130
reactions, that provides energy. And of course LA is in sunny California.

116
00:07:48,150 --> 00:07:52,140
The second is a family of compounds called nitrogen oxides

117
00:07:52,160 --> 00:07:56,180
and they are generated whenever coal and gasoline are combusted,

118
00:07:56,200 --> 00:08:00,230
so it comes out of tailpipes and smoke stacks. The third

119
00:08:00,250 --> 00:08:04,260
ingredient are volatile organic compounds, and they primarily come out of the tailpipes of

120
00:08:04,280 --> 00:08:08,280
cars and some factories. And if you've ever smelled gasoline

121
00:08:08,300 --> 00:08:12,320
or paint fumes, you've smelled VOCs, they're very common. There are literally thousands of

122
00:08:12,340 --> 00:08:16,360
these in the urban environment.

123
00:08:16,380 --> 00:08:20,380
Here is a representation

124
00:08:20,400 --> 00:08:24,400
of satellite data, nitrogen dioxide, it's one of the nitrogen oxides.

125
00:08:24,420 --> 00:08:28,410
And you can see all these red

126
00:08:28,430 --> 00:08:32,430
splotches on here, they're high levels of nitrogen dioxide.

127
00:08:32,450 --> 00:08:36,480
And the highest, one of the highest levels is here in Los Angeles.

128
00:08:36,500 --> 00:08:40,510
And all of these occur or coincide with America's largest

129
00:08:40,530 --> 00:08:44,550
cities. The most populated areas.

130
00:08:44,570 --> 00:08:48,580
Okay, so scientists have figured out that

131
00:08:48,600 --> 00:08:52,610
ozone was a primary ingredient in this smog, and they had a basic

132
00:08:52,630 --> 00:08:56,630
understanding of how it was being generated within this smog. So initially

133
00:08:56,650 --> 00:09:00,650
government officials controlled the emissions of

134
00:09:00,670 --> 00:09:04,730
volatile organic compounds from cars and from factories, and the ozone levels went down.

135
00:09:04,750 --> 00:09:08,760
Then they later, they tried to control

136
00:09:08,780 --> 00:09:12,780
nitrogen oxide emissions from power plants and cars and the ozone went down even further.

137
00:09:12,800 --> 00:09:16,810
As an example, cars were required to have

138
00:09:16,830 --> 00:09:20,860

catalytic converters installed on them, and a car today

139
00:09:20,880 --> 00:09:24,910
is about 20 times less polluting than a car was in 1960.

140
00:09:24,930 --> 00:09:28,940
But the situation was a little harder in the eastern US,

141
00:09:28,960 --> 00:09:32,960
they had an ozone problem, but it wasn't so easy to reduce the ozone as it was in

142
00:09:32,980 --> 00:09:36,980
California. Here is a satellite image of

143
00:09:37,000 --> 00:09:41,020
the Atlanta metro area, and the thing you notice is that there are a lot of trees.

144
00:09:41,040 --> 00:09:45,030
And that's the case for many cities in the US, or eastern US.

145
00:09:45,050 --> 00:09:49,100
And these trees

146
00:09:49,120 --> 00:09:53,120
put out lots of volatile organic compounds naturally.

147
00:09:53,140 --> 00:09:57,150
Here is a representation of satellite data of one of these

148
00:09:57,170 --> 00:10:01,180
VOCs. On a hot summer day, you see that their concentrations are very high.

149
00:10:01,200 --> 00:10:05,190
Less so on a warm summer day, and

150
00:10:05,210 --> 00:10:09,200
even lower still on a cool summer day. And it's not exactly

151
00:10:09,220 --> 00:10:13,210
understood why trees are doing this. It's thought that maybe somehow

152
00:10:13,230 --> 00:10:17,280
releasing these VOCs protects them from heat stress. But the exact mechanisms

153
00:10:17,300 --> 00:10:21,330
are just not known yet. Okay,

154
00:10:21,350 --> 00:10:25,380
so, in a city, in the eastern cities like Atlanta,

155
00:10:25,400 --> 00:10:29,400
the only way that you can really reduce ozone

156
00:10:29,420 --> 00:10:33,430
is to reduce nitrogen oxides. It's because there are so many

157
00:10:33,450 --> 00:10:37,460
VOCs occurring naturally from these trees

158
00:10:37,480 --> 00:10:41,500
that the amount coming out of the tailpipe of a car or factory is just very

159
00:10:41,520 --> 00:10:45,520
small in comparison. Over the last two decades, there's been

160
00:10:45,540 --> 00:10:49,540
a tremendous decrease in emissions of what the EPA calls

161
00:10:49,560 --> 00:10:53,600
the six common pollutants. They've gone down by almost 60 percent.

162
00:10:53,620 --> 00:10:57,660
And I've talked about five of these, sulfur dioxide,

163
00:10:57,680 --> 00:11:01,710

nitrogen dioxide, ozone, volatile organic compounds, and particulates.

164
00:11:01,730 --> 00:11:05,750
I didn't talk about lead because as far as I'm aware, we can't measure that from space yet.

165
00:11:05,770 --> 00:11:09,770
And even though this may seem pretty

166
00:11:09,790 --> 00:11:13,830
impressive or significant that it went down by 60 percent, it's even more

167
00:11:13,850 --> 00:11:17,860
impressive when you take into account that our economy

168
00:11:17,880 --> 00:11:21,860
has grown, our population has gone up, the number of cars on the road

169
00:11:21,880 --> 00:11:25,880
have gone up, and the amount of energy we're consuming has gone up.

170
00:11:25,900 --> 00:11:29,960
[silence]

171
00:11:29,980 --> 00:11:34,040
And we can see this from space, this major decrease

172
00:11:34,060 --> 00:11:38,070
in emissions just in the last decade. Here's a representation of nitrogen dioxide,

173
00:11:38,090 --> 00:11:42,100
one of the nitrogen oxides, in 2005 and 2011.

174
00:11:42,120 --> 00:11:46,130
And the concentrations went down by 30-40 percent just over that time.

175
00:11:46,150 --> 00:11:50,160
Sulfur dioxide, a similar story. Emissions

176
00:11:50,180 --> 00:11:54,180
went down by anywhere from 50 to about 90

177
00:11:54,200 --> 00:11:58,220
percent. So it's been a real success story.

178
00:11:58,240 --> 00:12:02,240
But the job isn't done yet, because about

179
00:12:02,260 --> 00:12:06,250
120 million Americans still live in areas with poor air quality.

180
00:12:06,270 --> 00:12:10,290
So we need to keep reducing our emissions. Now

181
00:12:10,310 --> 00:12:14,340
most smog that we're breathing in any particular city is home-grown,

182
00:12:14,360 --> 00:12:18,390
it's locally produced or regionally emitted. However,

183
00:12:18,410 --> 00:12:22,450
the pollution that we emit today will affect someone downwind tomorrow.

184
00:12:22,470 --> 00:12:26,500
For instance, Europeans grumble that American

185
00:12:26,520 --> 00:12:30,520
pollution is blowing in the wind across the Atlantic and degrading their air quality.

186
00:12:30,540 --> 00:12:34,540
And people in California complain that Asian pollution

187
00:12:34,560 --> 00:12:38,560
is blowing across the Pacific and impacting them.

188
00:12:38,580 --> 00:12:42,580

So, air quality is not just a local or regional problem, it's actually

189
00:12:42,600 --> 00:12:46,650
a global problem now these days. So we need satellites to continue

190
00:12:46,670 --> 00:12:50,700
to monitor our air quality from space. There's a fleet of satellites,

191
00:12:50,720 --> 00:12:54,740
Earth-observing satellites, that are orbiting the planet right now. And they observe

192
00:12:54,760 --> 00:12:58,770
everything from ice sheets to oceans to forests and so on

193
00:12:58,790 --> 00:13:02,790
and including our air quality. And I've presented data from

194
00:13:02,810 --> 00:13:06,810
some of those satellites, primarily the Aura satellite mission. And NASA will

195
00:13:06,830 --> 00:13:10,850
continue to design and build bigger and better satellites and monitor our

196
00:13:10,870 --> 00:13:14,880
Earth and our air quality in the future. Thank you.

197
00:13:22,950 --> 00:13:18,900
[applause]