
SAMSUNG
SAMSUNG

1
00:00:00,010 --> 00:00:04,020
[chimes]

2
00:00:04,040 --> 00:00:08,040
[chimes fade out] [concerned driving music starts]

3
00:00:08,060 --> 00:00:12,090
[music fades out] >>Paul: I'm going to tell a real

4
00:00:12,110 --> 00:00:16,100
scientific and I think public policy success story, and it's about the ozone layer.

5
00:00:16,120 --> 00:00:20,140
You can see the globe here. We divide

6
00:00:20,160 --> 00:00:24,170
the atmosphere into a variety of layers. The troposphere is the lowest layer,

7
00:00:24,190 --> 00:00:28,180
it's where all of our weather occurs. The stratosphere is the next layer

8
00:00:28,200 --> 00:00:32,180
up, and that's what I'm going to really focus on, because that's where most of our atmospheric

9
00:00:32,200 --> 00:00:36,210
ozone is located. Now ozone is critical in our atmosphere

10
00:00:36,230 --> 00:00:40,250
because it screens ultraviolet radiation. Ultraviolet radiation,

11
00:00:40,270 --> 00:00:44,260
these are energetic solar photons,

12
00:00:44,280 --> 00:00:48,280
there are, they are strong enough to break the bonds

13
00:00:48,300 --> 00:00:52,310

of biologically active molecules, like DNA for example.

14
00:00:52,330 --> 00:00:56,370
So, if you decrease the amount of ozone, which is screening this

15
00:00:56,390 --> 00:01:00,400
UV radiation, you get more at the surface,

16
00:01:00,420 --> 00:01:04,430
and what that'll do is that you get, you sunburn a little more

17
00:01:04,450 --> 00:01:08,460
quickly. For example a person like me, I'm out for about 15

18
00:01:08,480 --> 00:01:12,480
minutes and I'll get a sunburn. But it does a lot of other things. It impacts crops,

19
00:01:12,500 --> 00:01:16,510
it can cause cataracts. There's a famous study of water men

20
00:01:16,530 --> 00:01:20,550
out here on the Chesapeake Bay in which they found that their amount of

21
00:01:20,570 --> 00:01:24,580
time on the bay was proportional to the cataracts that they got.

22
00:01:24,600 --> 00:01:28,610
The longer you were out there, the more cataracts you got. But that's extended

23
00:01:28,630 --> 00:01:32,660
exposure over the years. So ozone is really a critical gas in our atmosphere.

24
00:01:32,680 --> 00:01:36,680
In 1974, these two

25
00:01:36,700 --> 00:01:40,700
gentleman on the right, this is Sherry Rowland, and this is

26
00:01:40,720 --> 00:01:44,720
Mario Molina. They proposed that there were a class of gases

27
00:01:44,740 --> 00:01:48,780
being emitted into our atmosphere that could destroy the ozone layer.

28
00:01:48,800 --> 00:01:52,800
These are chlorofluorocarbons, or CFCs.

29
00:01:52,820 --> 00:01:56,810
So, they proposed this, and it was quite controversial at the time.

30
00:01:56,830 --> 00:02:00,840
They took a lot of heat because this chlorofluorocarbon

31
00:02:00,860 --> 00:02:04,890
industry, chemical industry, was used in a

32
00:02:04,910 --> 00:02:08,960
variety of different kinds of products. You can see some of these,

33
00:02:08,980 --> 00:02:12,990
many of us remember, it used to be used as a propellant for hairspray,

34
00:02:13,010 --> 00:02:17,020
and deodorants. It was used to make

35
00:02:17,040 --> 00:02:21,040
foam products, like these cups you would get from McDonalds or other

36
00:02:21,060 --> 00:02:25,060
companies. It was used, CFCs were used in air conditioning

37
00:02:25,080 --> 00:02:29,090
and in car air conditioners. It was also,

38
00:02:29,110 --> 00:02:33,110

there's another kind of gas called a halon. Halons are used in fire extinguishers,

39
00:02:33,130 --> 00:02:37,140
they contain bromine. They can also destroy ozone.

40
00:02:37,160 --> 00:02:41,190
So this is proposed in 1974, and there was a huge

41
00:02:41,210 --> 00:02:45,200
amount of energy and effort that was going in in the late 70s and early

42
00:02:45,220 --> 00:02:49,220
80s to see what the impact is on ozone, to measure

43
00:02:49,240 --> 00:02:53,260
ozone and these gases in particular. Now,

44
00:02:53,280 --> 00:02:57,300
in 1985, there was a publication of a paper

45
00:02:57,320 --> 00:03:01,320
on ozone down over Antarctica. And these three

46
00:03:01,340 --> 00:03:05,350
gentleman here, this is Joe Farman, Brian Gardiner,

47
00:03:05,370 --> 00:03:09,390
and John Shanklin. They're standing in front of an instrument that measures

48
00:03:09,410 --> 00:03:13,420
the total amount of ozone between the surface and space.

49
00:03:13,440 --> 00:03:17,430
And they published their data. And you can see it here, this is a

50
00:03:17,450 --> 00:03:21,440
measurement, this is the total amount of ozone between the surface and space over the

51
00:03:21,460 --> 00:03:25,480
station. It's Halley Station down in Antarctica. And what that shows

52
00:03:25,500 --> 00:03:29,490
is that the level of ozone was dropping and it was dropping

53
00:03:29,510 --> 00:03:33,520
really fast. Okay. It was an amazing

54
00:03:33,540 --> 00:03:37,570
study that they published, and the quality of these data are such

55
00:03:37,590 --> 00:03:41,600
that there was no dispute to this. Ozone was going down, and it was

56
00:03:41,620 --> 00:03:45,610
going down fast. This was a real shock to the atmospheric community,

57
00:03:45,630 --> 00:03:49,670
when this paper was published. Shortly thereafter,

58
00:03:49,690 --> 00:03:53,690
and this was in the, in 1985

59
00:03:53,710 --> 00:03:57,730
also, a scientist at the NASA Goddard Space Flight Center

60
00:03:57,750 --> 00:04:01,740
P.K. Bhartia made an image of what this

61
00:04:01,760 --> 00:04:05,780
ozone looked like over Antarctica. And so you can see

62
00:04:05,800 --> 00:04:09,810
Antarctica here in the center, South America, Africa, Australia, and here in the

63
00:04:09,830 --> 00:04:13,870

middle is this very low ozone area, these red colors

64
00:04:13,890 --> 00:04:17,890
and yellows that you see here indicate very low ozone.

65
00:04:17,910 --> 00:04:21,930
And it was dubbed "the Antarctic ozone hole". So ozone

66
00:04:21,950 --> 00:04:25,970
was going down fast, and it was a huge region. This is a

67
00:04:25,990 --> 00:04:29,990
very large region, comparable to, this continent of Antarctica is

68
00:04:30,010 --> 00:04:34,010
a large area, so there's a large depletion over a large area.

69
00:04:34,030 --> 00:04:38,020
And we didn't actually understand what was going on at the time. But within a couple of

70
00:04:38,040 --> 00:04:42,080
years, we figured out it was actually due to these chlorofluorocarbons

71
00:04:42,100 --> 00:04:46,090
and halons.

72
00:04:46,110 --> 00:04:50,130
So there was a lot of

73
00:04:50,150 --> 00:04:54,150
consternation about this. What are we going to do? How can we stop it? What are

74
00:04:54,170 --> 00:04:58,200
other measurements can we make? So the rising concern about the problem

75
00:04:58,220 --> 00:05:02,230
amongst the nations of the world, there was already

76
00:05:02,250 --> 00:05:06,250
discussion about, should we get together and create an agreement? And in fact

77
00:05:06,270 --> 00:05:10,280
after a couple years, they did create an agreement.

78
00:05:10,300 --> 00:05:14,320
This is an agreement called the Montreal

79
00:05:14,340 --> 00:05:21,550
Protocol. These are, this is a, this shows a

80
00:05:21,570 --> 00:05:25,570
meeting of the parties to the Montreal Protocol.

81
00:05:25,590 --> 00:05:29,610
And here you can see the Montreal Protocol had a series of agreements

82
00:05:29,630 --> 00:05:33,620
the initial one, and they were added on to, further strengthening

83
00:05:33,640 --> 00:05:37,650
regulations of these chlorofluorocarbons. So eventually,

84
00:05:37,670 --> 00:05:41,710
the production of chlorofluorocarbons and halons

85
00:05:41,730 --> 00:05:45,740
was fully agreed to. Now, you can see the nations of the world,

86
00:05:45,760 --> 00:05:49,750
there are little signs here. Here you can see, this is me sitting way

87
00:05:49,770 --> 00:05:53,810
in the back of this meeting. Even though

88
00:05:53,830 --> 00:05:57,850

the scientists, we bring them all the information, we're always put at the back of the

89
00:05:57,870 --> 00:06:01,860
meeting. When they need us, they'll call on us, but we sit in the back and listen to

90
00:06:01,880 --> 00:06:05,930
all the discussions. And mostly these discussions are about countries'

91
00:06:05,950 --> 00:06:09,960
ability to maybe use a CFC for a short time. There are a lot of different

92
00:06:09,980 --> 00:06:14,010
things going on in these meetings.

93
00:06:14,030 --> 00:06:18,020
Okay. So now what's happened with ozone. Well first of all

94
00:06:18,040 --> 00:06:22,070
let me talk about chlorine. So chlorine, it was going

95
00:06:22,090 --> 00:06:26,090
up and up and up through the 1960s, 1970s, 1980s. These are

96
00:06:26,110 --> 00:06:30,120
a combination of all the CFCs and halons. And then the Montreal

97
00:06:30,140 --> 00:06:34,170
Protocol was signed here in 1987, and

98
00:06:34,190 --> 00:06:38,210
slowly those regulations began to take hold, and in fact

99
00:06:38,230 --> 00:06:42,240
the projection is that these ozone-depleting

100
00:06:42,260 --> 00:06:46,280
substances are going to decline with time. Now this is going to take a long time,

101
00:06:46,300 --> 00:06:50,290
because CFCs, these chlorofluorocarbons have long lifetimes. For example,

102
00:06:50,310 --> 00:06:54,340
CFC 11 has a lifetime of about

103
00:06:54,360 --> 00:06:58,400
52 years. CFC 12, which was used in your

104
00:06:58,420 --> 00:07:02,400
car air conditioners, has a lifetime of over 100 years.

105
00:07:02,420 --> 00:07:06,440
So it's going to take a long time, even though the production and emission of these

106
00:07:06,460 --> 00:07:10,480
gases has been regulated, it's going to take a long time for them to come out

107
00:07:10,500 --> 00:07:14,500
of our atmosphere.

108
00:07:14,520 --> 00:07:18,540
So what's happening with ozone now? So this is showing

109
00:07:18,560 --> 00:07:22,550
this is in percentage, the change of ozone over time in percentage.

110
00:07:22,570 --> 00:07:26,580
You can see the observations as you go into the 80s. You can see

111
00:07:26,600 --> 00:07:30,630
that ozone was going down, the CFCs were increasing,

112
00:07:30,650 --> 00:07:34,640
the Montreal Protocol is signed here. Pretty soon the chlorine

113
00:07:34,660 --> 00:07:38,650

has started to decrease, and you can almost,

114
00:07:38,670 --> 00:07:42,680
there's a Mt. Pinatubo effect right here, but you can almost see that ozone isn't going down

115
00:07:42,700 --> 00:07:46,720
anymore, and maybe there's a hint that things are starting

116
00:07:46,740 --> 00:07:50,780
to go up. We can't say that, as scientists we can't that's true yet,

117
00:07:50,800 --> 00:07:54,800
but I think we're getting to the point, within the next few years, I think

118
00:07:54,820 --> 00:07:58,830
we'll actually be able to say statistically that ozone is increasing

119
00:07:58,850 --> 00:08:02,870
in our atmosphere. Let's keep our fingers crossed.

120
00:08:02,890 --> 00:08:06,930
Now, the other way of looking at this is we can use a model

121
00:08:06,950 --> 00:08:10,950
to take a look at what would have happened to ozone if we'd done nothing. So I'm

122
00:08:10,970 --> 00:08:14,970
going to show you a little model study here. And on the top left, I'm going to show you

123
00:08:14,990 --> 00:08:18,990
the expected world. And this is with the Montreal Protocol,

124
00:08:19,010 --> 00:08:23,040
CFCs are going to decline. Over here is what we call "the world avoided".

125
00:08:23,060 --> 00:08:27,050
And this is chlorine going up. If you look on the picture, you can see

126
00:08:27,070 --> 00:08:31,080
the amount of chlorine in the expected world and the amount of chlorine

127
00:08:31,100 --> 00:08:35,130
in the world avoided. So you can see here it's 4.5,

128
00:08:35,150 --> 00:08:39,150
there it's already a little bit higher because of the Montreal Protocol,

129
00:08:39,170 --> 00:08:43,190
this is because of the Montreal Protocol, that's without one. And you can see this

130
00:08:43,210 --> 00:08:47,240
flying by fairly quickly, as you can see the date on the right, you can see the ozone hole appearing

131
00:08:47,260 --> 00:08:51,260
every year. Chlorine continues to go up

132
00:08:51,280 --> 00:08:55,300
in this world avoided, and now you can actually see it peaked down at about 4

133
00:08:55,320 --> 00:09:02,080
and it's in a slow decline as we're out to 2022, 24.

134
00:09:02,100 --> 00:09:06,100
If you look here at this world avoided you can now start seeing a little ozone hole

135
00:09:06,120 --> 00:09:10,150
deep low values appearing over the Arctic. And you see the very very large

136
00:09:10,170 --> 00:09:14,160
ozone loss in over the Antarctic region. If you look at the

137
00:09:14,180 --> 00:09:18,190
expected world, you don't see any of those things. And in fact this

138
00:09:18,210 --> 00:09:22,220

chlorine continues to increase, you can see ozone going down now

139
00:09:22,240 --> 00:09:26,270
in the tropics and in the subtropics. So you can see that here you're

140
00:09:26,290 --> 00:09:30,280
dominated by reds and oranges, the higher ozone levels. In the world

141
00:09:30,300 --> 00:09:34,310
avoided, you can see that ozone is declining

142
00:09:34,330 --> 00:09:38,360
and declining and declining. Now, this is about 40 to 50

143
00:09:38,380 --> 00:09:42,370
times, by the time you get out to 2065 here, this 40

144
00:09:42,390 --> 00:09:46,410
to 50 times the natural level of chlorine in our

145
00:09:46,430 --> 00:09:50,470
atmosphere. Chlorine and bromine combined. And this has gone down, it about

146
00:09:50,490 --> 00:09:54,490
needs to go down to about 1.2, this is about halfway

147
00:09:54,510 --> 00:09:58,520
there. But you can see the difference in ozone. 65

148
00:09:58,540 --> 00:10:02,560
per-, or excuse me, about two thirds of the ozone layer is destroyed

149
00:10:02,580 --> 00:10:06,570
if there had been no Montreal Protocol, if nothing had been done.

150
00:10:06,590 --> 00:10:10,580
Okay. Now what does that mean? That means huge impacts

151
00:10:10,600 --> 00:10:14,610
on crops. For somebody like me, I mentioned that if I go outside,

152
00:10:14,630 --> 00:10:18,660
15 minutes I'll get a perceptible burn. In that world it's

153
00:10:18,680 --> 00:10:22,670
5 minutes. Okay. So you go out and you walk

154
00:10:22,690 --> 00:10:26,700
for a quarter of a mile, you would get a perceptible sunburn.

155
00:10:26,720 --> 00:10:30,750
So, this is an incredibly bad world, we don't want to live in

156
00:10:30,770 --> 00:10:34,760
that world. This is the one that we expect.

157
00:10:34,780 --> 00:10:38,790
Now, we can do, as I've already shown, we can do these projections of where

158
00:10:38,810 --> 00:10:42,840
ozone is going. Here we can see the observations, this shows a model

159
00:10:42,860 --> 00:10:46,900
projection, and now I put two model projections on here. The

160
00:10:46,920 --> 00:10:50,930
lower one is a world in which

161
00:10:50,950 --> 00:10:54,940
both ozone-depleting substances, it has a Montreal Protocol in it, they've been regulated

162
00:10:54,960 --> 00:10:58,990
and so ozone is going up. But in one, greenhouse

163
00:10:59,010 --> 00:11:03,010

gases are regulated. In the other, greenhouses gases

164
00:11:03,030 --> 00:11:07,040
continue to go up. And in fact, ozone continues to go up.

165
00:11:07,060 --> 00:11:11,100
So, the net impact of increasing greenhouse gases is

166
00:11:11,120 --> 00:11:15,130
that the ozone layer begins to pile up lots of ozone. So instead of a

167
00:11:15,150 --> 00:11:19,180
depleted ozone world, we're going to go to an ozone world where there's probably too much

168
00:11:19,200 --> 00:11:23,190
ozone. Now what does that mean for the environment? I actually

169
00:11:23,210 --> 00:11:27,210
don't know. I don't think we know as scientists what's going

170
00:11:27,230 --> 00:11:31,240
to happen there. So let me say another word about

171
00:11:31,260 --> 00:11:39,240
what happened.

172
00:11:39,260 --> 00:11:43,250
This is, I love this picture, it's a 1967 Ford mustang. It was a hot car. I love this car.

173
00:11:43,270 --> 00:11:47,260
It has a CFC air conditioner in it. So I was

174
00:11:47,280 --> 00:11:51,260
using CFC-12 in that particular air conditioner.

175
00:11:51,280 --> 00:11:55,280
Here is a Tesla, a modern Tesla. It uses a replacement compound

176
00:11:55,300 --> 00:11:59,290
called an HFC, in fact HFC-134a. And in fact

177
00:11:59,310 --> 00:12:03,310
in all your cars right now, you have that particular

178
00:12:03,330 --> 00:12:07,340
refrigerant in your car air conditioner. So this

179
00:12:07,360 --> 00:12:11,350
is the compound that replaced the CFCs. Now the beauty of this is this is a

180
00:12:11,370 --> 00:12:15,370
hydrogen, a fluorine, and a carbon. It doesn't have chlorine, so it doesn't

181
00:12:15,390 --> 00:12:19,420
destroy the ozone layer. The problem with HFCs though

182
00:12:19,440 --> 00:12:23,430
is they're greenhouse gases. The particular HFC

183
00:12:23,450 --> 00:12:27,470
134a is about, pound for pound, it's about

184
00:12:27,490 --> 00:12:31,480
14 hundred times more efficient at warming

185
00:12:31,500 --> 00:12:35,500
than CO2. So you could take one pound

186
00:12:35,520 --> 00:12:39,530
of this HFC-134a, is equivalent to about

187
00:12:39,550 --> 00:12:43,560
14 hundred pounds of CO2. So the replacement compounds

188
00:12:43,580 --> 00:12:47,580

for the CFCs are greenhouse gases. And the

189
00:12:47,600 --> 00:12:51,620
question is, what are we going to actually do about these? Now this shows a particular HFC,

190
00:12:51,640 --> 00:12:55,670
this is HFC-23. You can see these are observations

191
00:12:55,690 --> 00:12:59,680
they're increasing with time. Because we replaced the CFCs. There are many

192
00:12:59,700 --> 00:13:03,700
other HFCs. This is the one I talked about, it's in your car air

193
00:13:03,720 --> 00:13:07,740
conditioner, 134a.

194
00:13:07,760 --> 00:13:11,750
This one 32 and 125, these are probably in your home air conditioning

195
00:13:11,770 --> 00:13:15,770
units. So all these HFCs are increasing with time, and these

196
00:13:15,790 --> 00:13:19,800
HFCs are all powerful greenhouse gases.

197
00:13:19,820 --> 00:13:23,850
So, we solved the problem, that is the problem of ozone depletion,

198
00:13:23,870 --> 00:13:27,860
but in fact, and in fact those CFCs were also powerful greenhouse gases,

199
00:13:27,880 --> 00:13:31,900
but we replaced them with compounds that are also

200
00:13:31,920 --> 00:13:35,950
powerful greenhouse gases. So you could do a lot

201
00:13:35,970 --> 00:13:39,970
for climate if you figured out how to take these compounds and replace

202
00:13:39,990 --> 00:13:44,010
them with compounds that are both friendly to the ozone layer

203
00:13:44,030 --> 00:13:48,060
and friendly to climate. And in fact there are technological solutions.

204
00:13:48,080 --> 00:13:52,100
So that goes back to the Montreal Protocol. The Montreal Protocol could in fact

205
00:13:52,120 --> 00:13:56,110
take action on these HFCs. We don't know that that's

206
00:13:56,130 --> 00:14:00,130
going to happen, but it might.

207
00:14:00,150 --> 00:14:04,170
So let me kind of summarize where we've been. So I told you a good

208
00:14:04,190 --> 00:14:08,230
story. We got rid of these CFCs, they're now regulated, they still exist in

209
00:14:08,250 --> 00:14:12,270
various places around the atmosphere, but they're slowly declining. That's a great story.

210
00:14:12,290 --> 00:14:16,320
In fact, the outcome of that would have been an environmental

211
00:14:16,340 --> 00:14:20,370
disaster if they had kept growing. We

212
00:14:20,390 --> 00:14:24,390
used a lot of satellite information to take a look at the ozone problem.

213
00:14:24,410 --> 00:14:28,420

Most of the observations you've seen on this

214
00:14:28,440 --> 00:14:32,440
presentation have come from NASA satellites, including the Aura satellite

215
00:14:32,460 --> 00:14:36,480
that you can see here. Now what does the future hold? Well,

216
00:14:36,500 --> 00:14:40,540
the future's in our own hands. We have two things we

217
00:14:40,560 --> 00:14:44,550
can, you can regulate these compounds, and that may happen.

218
00:14:44,570 --> 00:14:48,570
But the one thing that we really need to do is we need to continue to look at the atmosphere

219
00:14:48,590 --> 00:14:52,610
continue to make measurements of what's happening to our atmosphere.

220
00:14:52,630 --> 00:14:56,630
And that's where satellites like Aura and its follow-ons are crucial

221
00:14:56,650 --> 00:15:00,660
to knowing where we're going to be in the future. Thank you.

222
00:15:00,680 --> 00:15:04,670
[applause]

223
00:15:04,690 --> 00:15:08,700
[applause dies out]