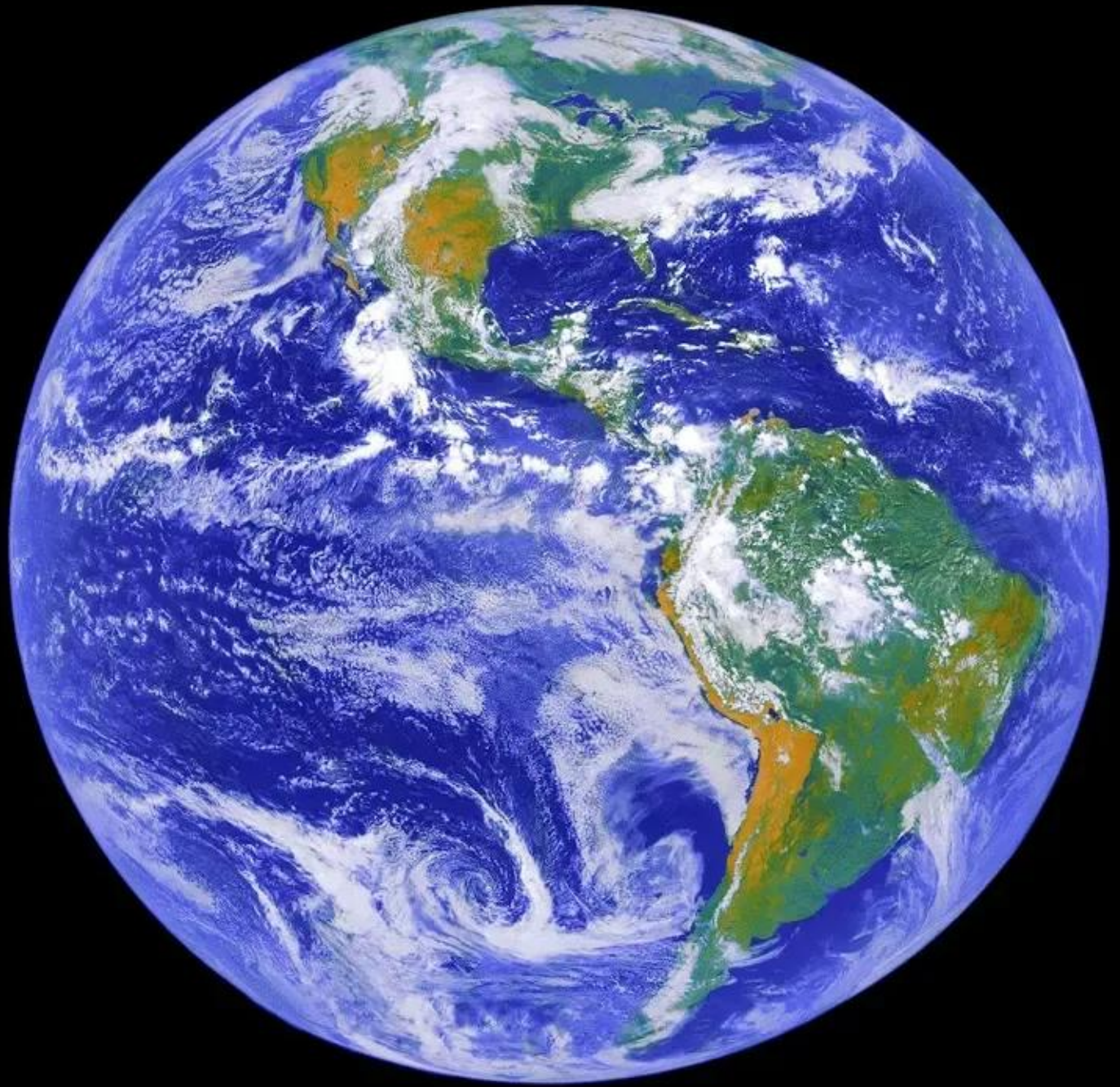

1
00:00:07,760 --> 00:00:03,560
NASA's Jet Propulsion Laboratory

2
00:00:10,190 --> 00:00:07,770
presents the von Karman lecture a series

3
00:00:12,560 --> 00:00:10,200
of talks by scientists and engineers who

4
00:00:15,300 --> 00:00:12,570
are exploring our planet our solar

5
00:00:24,960 --> 00:00:15,310
system and all that lies beyond

6
00:00:29,710 --> 00:00:27,610
good evening everybody here on lab and

7
00:00:31,600 --> 00:00:29,720
all of you watching at home my name is

8
00:00:33,190 --> 00:00:31,610
Brian white with JPL's office of

9
00:00:35,970 --> 00:00:33,200
education and communication

10
00:00:38,590 --> 00:00:35,980
welcome to the von Karman lecture series

11
00:00:39,880 --> 00:00:38,600
when I was younger personally I was

12
00:00:41,170 --> 00:00:39,890
playing a little league baseball and as

13
00:00:44,380 --> 00:00:41,180

you may know there's a lot of downtime

14
00:00:46,000 --> 00:00:44,390
in baseball and I would look up at the

15
00:00:48,010 --> 00:00:46,010
clouds I would just watch them glide

16
00:00:49,689 --> 00:00:48,020
over which probably explains why I

17
00:00:53,020 --> 00:00:49,699
wasn't very good at Little League

18
00:00:54,780 --> 00:00:53,030
baseball but what I did do was I would

19
00:00:59,829 --> 00:00:54,790
find shapes in them like everyone else

20
00:01:01,840 --> 00:00:59,839
around me what I didn't learn about or

21
00:01:03,939 --> 00:01:01,850
know about was what these clouds really

22
00:01:06,969 --> 00:01:03,949
did to our climate how they would affect

23
00:01:08,410 --> 00:01:06,979
what would happen down the road really

24
00:01:11,500 --> 00:01:08,420
their affect on what was happening at

25
00:01:13,390 --> 00:01:11,510
that moment what can the attributes of

26
00:01:15,010 --> 00:01:13,400
these wondrous feather canyons tell us

27
00:01:18,580 --> 00:01:15,020
about the future and as the great

28
00:01:20,110 --> 00:01:18,590
scientist Joni Mitchell once said we

29
00:01:23,020 --> 00:01:20,120
looked at clouds from both sides now

30
00:01:26,200 --> 00:01:23,030
from up and down and still somehow we

31
00:01:27,490 --> 00:01:26,210
really don't know clouds at all tonight

32
00:01:29,260 --> 00:01:27,500
we'll have three speakers followed by a

33
00:01:30,429 --> 00:01:29,270
brief discussion and some Q&A and if

34
00:01:32,950 --> 00:01:30,439
you're watching at home please feel free

35
00:01:34,389 --> 00:01:32,960
to ask we'll make sure you get those

36
00:01:36,819 --> 00:01:34,399
questions up or social media team will

37
00:01:38,469 --> 00:01:36,829
do that but our first speaker received

38
00:01:40,749 --> 00:01:38,479

his PhD at the University of Melbourne

39
00:01:42,399 --> 00:01:40,759
Australia and literally wrote the

40
00:01:44,770 --> 00:01:42,409
textbook when it comes to remote sensing

41
00:01:47,020 --> 00:01:44,780
dr. professor Stevens has made major

42
00:01:49,719 --> 00:01:47,030
research contributions in three related

43
00:01:52,359 --> 00:01:49,729
areas atmospheric radiative transfer

44
00:01:54,910 --> 00:01:52,369
remote sensing and the topic of cloud

45
00:01:58,840 --> 00:01:54,920
climate feedbacks he has a citation

46
00:02:01,289 --> 00:01:58,850
count over 27,000 he is a member of the

47
00:02:03,730 --> 00:02:01,299
US National Academy of Engineering

48
00:02:05,529 --> 00:02:03,740
fellow of the Royal Society and the

49
00:02:07,899 --> 00:02:05,539
co-chair of the scientific steering

50
00:02:09,969 --> 00:02:07,909
group for the global energy and water

51
00:02:10,990 --> 00:02:09,979
exchanges project of the world climate

52
00:02:12,820 --> 00:02:11,000
research program

53
00:02:14,980 --> 00:02:12,830
he is the co-director of the Center for

54
00:02:23,450 --> 00:02:14,990
climate sciences please welcome dr.

55
00:02:29,970 --> 00:02:27,210
okay I'm on yeah oh thank you all for

56
00:02:31,260 --> 00:02:29,980
coming this evening and to give us an

57
00:02:35,699 --> 00:02:31,270
opportunity to talk about one of my

58
00:02:37,710 --> 00:02:35,709
favorite topics clouds you know you no

59
00:02:40,110 --> 00:02:37,720
doubt you've all heard the phrase earth

60
00:02:41,820 --> 00:02:40,120
is a blue planet right but something

61
00:02:46,740 --> 00:02:41,830
that's a common kind of way of

62
00:02:49,290 --> 00:02:46,750
describing earth but as you as we look

63
00:02:52,229 --> 00:02:49,300

at Earth from from the perspective of

64
00:02:56,190 --> 00:02:52,239
the moon we notice that a course earth

65
00:02:57,990 --> 00:02:56,200
is also wrapped in a thin veil of white

66
00:02:59,729 --> 00:02:58,000
border is only the blue water that

67
00:03:02,910 --> 00:02:59,739
covers 70% of the Earth's surface in the

68
00:03:05,010 --> 00:03:02,920
oceans but about the same area of the

69
00:03:07,530 --> 00:03:05,020
others of the earth is covered by this

70
00:03:10,800 --> 00:03:07,540
thin veil of white and this combination

71
00:03:15,000 --> 00:03:10,810
of this veil of white war in form of

72
00:03:17,570 --> 00:03:15,010
clouds together with the accommodation

73
00:03:21,690 --> 00:03:17,580
of snow and ice at the Earth's surface

74
00:03:23,940 --> 00:03:21,700
truly saw you truly would be forgiven to

75
00:03:25,620 --> 00:03:23,950
think of Earth as a white planet just as

76
00:03:27,930 --> 00:03:25,630
much as as a blue planet and it's the

77
00:03:29,699 --> 00:03:27,940
whiteness of the planet Earth to me in

78
00:03:31,620 --> 00:03:29,709
many respects that's really quite

79
00:03:34,289 --> 00:03:31,630
important to understanding the role of

80
00:03:35,640 --> 00:03:34,299
clouds in climate and we're going to get

81
00:03:39,479 --> 00:03:35,650
into this topic a little bit more in a

82
00:03:41,880 --> 00:03:39,489
minute okay so let's think about water

83
00:03:44,430 --> 00:03:41,890
on Earth and you'll be you'll be shocked

84
00:03:47,360 --> 00:03:44,440
I think as to how thin this veil of

85
00:03:50,130 --> 00:03:47,370
water is in the sky in form of clouds

86
00:03:53,580 --> 00:03:50,140
but yet how important it is for life on

87
00:03:55,259 --> 00:03:53,590
Earth okay so about 90% of the all the

88
00:03:57,180 --> 00:03:55,269

water on Earth is in the oceans it's a

89
00:03:59,910 --> 00:03:57,190
line and it's a lot and it's basically

90
00:04:02,130 --> 00:03:59,920
contained in the oceans about two and a

91
00:04:04,490 --> 00:04:02,140
half three percent of the of the water

92
00:04:07,380 --> 00:04:04,500
on earth it's fresh the word that we

93
00:04:08,940 --> 00:04:07,390
rely on to sort of support life for us

94
00:04:12,420 --> 00:04:08,950
as we know it

95
00:04:16,069 --> 00:04:12,430
about one percent roughly one percentage

96
00:04:18,780 --> 00:04:16,079
of the fresh water is in the atmosphere

97
00:04:19,620 --> 00:04:18,790
so it's one percent of two percent or

98
00:04:22,170 --> 00:04:19,630
there abouts

99
00:04:24,780 --> 00:04:22,180
about one percent of that one percent is

100
00:04:26,339 --> 00:04:24,790
a water in these clouds that control and

101
00:04:28,890 --> 00:04:26,349
influence climate as we're going to

102
00:04:30,690 --> 00:04:28,900
learn so it's tiny now the water in the

103
00:04:31,230 --> 00:04:30,700
atmosphere is about an inch deep which

104
00:04:32,850 --> 00:04:31,240
barely a

105
00:04:34,770 --> 00:04:32,860
puddle if you wrapped all the water

106
00:04:37,350 --> 00:04:34,780
around Earth from there from the sky

107
00:04:39,360 --> 00:04:37,360
it's about an inch deep and the watering

108
00:04:41,129 --> 00:04:39,370
clouds is even tinier than that and the

109
00:04:43,499 --> 00:04:41,139
water that comes as rain is even smaller

110
00:04:46,260 --> 00:04:43,509
than that so the water in the atmosphere

111
00:04:48,749 --> 00:04:46,270
is a tiny tiny fraction of what's in the

112
00:04:49,740 --> 00:04:48,759
planet as a whole but as you see as

113
00:04:51,360 --> 00:04:49,750

you'll see it has such a

114
00:04:53,730 --> 00:04:51,370
disproportionate influence on the

115
00:04:56,400 --> 00:04:53,740
climate and trying to understand predict

116
00:04:58,950 --> 00:04:56,410
the movement of these tiny slivers of

117
00:05:00,719 --> 00:04:58,960
water in the sky is really one of the

118
00:05:03,510 --> 00:05:00,729
great challenges in understand climate

119
00:05:05,430 --> 00:05:03,520
climate change so so just as another way

120
00:05:06,899 --> 00:05:05,440
of thinking about this if you took all

121
00:05:08,939 --> 00:05:06,909
the water in the oceans and wrapped it

122
00:05:12,719 --> 00:05:08,949
around us in a uniform layer it form a

123
00:05:14,580 --> 00:05:12,729
layer about about it's merely three

124
00:05:16,409 --> 00:05:14,590
kilometers deep compared to the one inch

125
00:05:17,390 --> 00:05:16,419
of water the wraps around in the sky so

126
00:05:21,540 --> 00:05:17,400
this kind of gives you a kind of

127
00:05:23,490 --> 00:05:21,550
perspective another interesting fact

128
00:05:26,550 --> 00:05:23,500
about the water in the sky a water in

129
00:05:29,460 --> 00:05:26,560
the planet and as it relates to the

130
00:05:31,409 --> 00:05:29,470
atmosphere if you if we took all the

131
00:05:33,059 --> 00:05:31,419
water in the oceans and allowed to

132
00:05:34,920 --> 00:05:33,069
evaporate at this rate it is today

133
00:05:37,550 --> 00:05:34,930
without water coming back in the oceans

134
00:05:39,659 --> 00:05:37,560
has runoff a rain in it would take about

135
00:05:41,850 --> 00:05:39,669
three and a half thousand years or

136
00:05:44,520 --> 00:05:41,860
thereabouts to remove all the water out

137
00:05:46,140 --> 00:05:44,530
of the oceans now the in the atmosphere

138
00:05:49,680 --> 00:05:46,150

this tiny one inch of water in the

139
00:05:51,330 --> 00:05:49,690
atmosphere it gets rained out basically

140
00:05:52,950 --> 00:05:51,340
your brain rains about three millimeters

141
00:05:53,370 --> 00:05:52,960
a day it gets rained out in about ten

142
00:05:54,959 --> 00:05:53,380
days

143
00:05:57,839 --> 00:05:54,969
so water in the atmosphere is slightly

144
00:05:59,700 --> 00:05:57,849
rapidly water in the oceans is very

145
00:06:02,040 --> 00:05:59,710
sluggish to sort of revolve moving

146
00:06:04,290 --> 00:06:02,050
around in a very long time scales both

147
00:06:06,809 --> 00:06:04,300
of these forms of water fundamentally

148
00:06:08,459 --> 00:06:06,819
make earth earth and make our climate as

149
00:06:10,200 --> 00:06:08,469
we understand today they're both so

150
00:06:11,999 --> 00:06:10,210
fundamentally important understanding

151
00:06:16,439 --> 00:06:12,009
our climate so we're going to focus on

152
00:06:18,300 --> 00:06:16,449
this this formal water in the sky in the

153
00:06:21,089 --> 00:06:18,310
form of clouds and why it's important

154
00:06:23,089 --> 00:06:21,099
our climate so one question might ask is

155
00:06:26,760 --> 00:06:23,099
what would it be like without clouds

156
00:06:29,909 --> 00:06:26,770
right well it's a simple answer we

157
00:06:31,770 --> 00:06:29,919
wouldn't be here to answer it because it

158
00:06:34,050 --> 00:06:31,780
there these are the vessels by which

159
00:06:36,029 --> 00:06:34,060
fresh water is delivered and by which

160
00:06:39,300 --> 00:06:36,039
and the fresh water that we rely on to

161
00:06:41,159 --> 00:06:39,310
live I'd delivered so earth wouldn't be

162
00:06:43,140 --> 00:06:41,169
worth wouldn't have the climate it has

163
00:06:45,500 --> 00:06:43,150

we wouldn't have the fresh waters and to

164
00:06:48,180 --> 00:06:45,510
support life as without clouds

165
00:06:49,380 --> 00:06:48,190
okay so clouds are important and we're

166
00:06:51,510 --> 00:06:49,390
going to hear over the next couple of

167
00:06:52,800 --> 00:06:51,520
talks who will touch on these important

168
00:06:55,620 --> 00:06:52,810
aspects clouds are important because

169
00:06:57,510 --> 00:06:55,630
they're basically a central role or the

170
00:06:59,850 --> 00:06:57,520
hydrological cycle of Earth they deliver

171
00:07:01,920 --> 00:06:59,860
the rains in the freshwater to the

172
00:07:04,110 --> 00:07:01,930
surface of the earth so they're really

173
00:07:06,120 --> 00:07:04,120
the key part of bringing water back down

174
00:07:09,660 --> 00:07:06,130
from the sky back to the surface

175
00:07:11,640 --> 00:07:09,670
okay they basically have very major

176
00:07:13,890 --> 00:07:11,650
radiative impacts they cook their white

177
00:07:16,080 --> 00:07:13,900
on one hand but their black on another

178
00:07:17,780 --> 00:07:16,090
hand and I'll explain a little bit of

179
00:07:20,310 --> 00:07:17,790
that so both have a long wave effect

180
00:07:23,220 --> 00:07:20,320
blackness in the infrared and the short

181
00:07:26,160 --> 00:07:23,230
wave effect white in the Solar and these

182
00:07:27,750 --> 00:07:26,170
two feck factors really shaped the role

183
00:07:29,250 --> 00:07:27,760
clouds playing climate and Kate's going

184
00:07:31,380 --> 00:07:29,260
to talk a lot more about this in the

185
00:07:35,100 --> 00:07:31,390
role class blank line but then these two

186
00:07:37,950 --> 00:07:35,110
aspects of of clouds and then the other

187
00:07:42,750 --> 00:07:37,960
cupcake apart is of course they are a

188
00:07:44,600 --> 00:07:42,760

key aspect of as water gets transformed

189
00:07:47,160 --> 00:07:44,610
through different phases inside clouds

190
00:07:48,900 --> 00:07:47,170
it's a source of major heating driving

191
00:07:51,650 --> 00:07:48,910
the major storm systems of our planet

192
00:07:54,120 --> 00:07:51,660
which in turn deliver the precipitation

193
00:07:56,910 --> 00:07:54,130
so with some they play a kind of a

194
00:07:58,890 --> 00:07:56,920
critical role and Brian's going to talk

195
00:08:01,470 --> 00:07:58,900
about their different ways we being able

196
00:08:04,230 --> 00:08:01,480
to see these clouds from space and a

197
00:08:06,150 --> 00:08:04,240
very global context so so be together we

198
00:08:09,330 --> 00:08:06,160
sort of have the topic covered covered I

199
00:08:11,040 --> 00:08:09,340
hope for your point of view okay one way

200
00:08:12,420 --> 00:08:11,050
we can measure one way you can think

201
00:08:14,880 --> 00:08:12,430
about measuring the whiteness of the

202
00:08:16,410 --> 00:08:14,890
planet is in the context of this

203
00:08:18,060 --> 00:08:16,420
quantity we call the albedo it's

204
00:08:19,980 --> 00:08:18,070
basically how much sunlight gets

205
00:08:21,780 --> 00:08:19,990
reflected how much income is sunlight

206
00:08:24,210 --> 00:08:21,790
gets reflected back to space it's about

207
00:08:25,770 --> 00:08:24,220
30% of the incoming sunlight of the

208
00:08:29,780 --> 00:08:25,780
entire earth gets reflected back to

209
00:08:31,530 --> 00:08:29,790
space so SLB there's about point 0.3 and

210
00:08:33,840 --> 00:08:31,540
there are some really interesting

211
00:08:35,190 --> 00:08:33,850
puzzles about this albedo that we debt

212
00:08:37,530 --> 00:08:35,200
we as scientists haven't quite figured

213
00:08:41,280 --> 00:08:37,540

out the full answers to which makes eyes

214
00:08:45,690 --> 00:08:41,290
really kind of exciting and basically in

215
00:08:47,910 --> 00:08:45,700
expressed in terms of energy about 340

216
00:08:50,580 --> 00:08:47,920
watts of energy in the mean sense come

217
00:08:52,350 --> 00:08:50,590
into the planet from the Sun averaged

218
00:08:54,270 --> 00:08:52,360
around the earth and about a hundred

219
00:08:56,640 --> 00:08:54,280
watts per meter squared average around

220
00:08:58,000 --> 00:08:56,650
the earth get reflected back and so this

221
00:08:59,800 --> 00:08:58,010
albedo can be also

222
00:09:02,110 --> 00:08:59,810
express in terms of this energy and what

223
00:09:04,120 --> 00:09:02,120
spurred me squid so and and what we know

224
00:09:07,570 --> 00:09:04,130
from our measurements that we've made

225
00:09:09,370 --> 00:09:07,580
over time is that basically large

226
00:09:11,950 --> 00:09:09,380
fraction of this hundred watts comes

227
00:09:13,420 --> 00:09:11,960
from reflections in something like being

228
00:09:15,940 --> 00:09:13,430
bounced back from the atmosphere from

229
00:09:17,980 --> 00:09:15,950
clouds and another part of its from the

230
00:09:19,900 --> 00:09:17,990
surface so most comes from inflection by

231
00:09:23,380 --> 00:09:19,910
the atmosphere in clouds as I've already

232
00:09:24,970 --> 00:09:23,390
said right here's sort of the puzzle if

233
00:09:27,700 --> 00:09:24,980
you look at the northern hemisphere in

234
00:09:29,860 --> 00:09:27,710
southern hemisphere it turns out that

235
00:09:33,070 --> 00:09:29,870
the hemisphere is both hemispheres

236
00:09:34,390 --> 00:09:33,080
reflect identically the same amount of

237
00:09:37,450 --> 00:09:34,400
energy we can't tell the difference from

238
00:09:38,770 --> 00:09:37,460

my measurements as that as there's no

239
00:09:39,910 --> 00:09:38,780
difference in terms of the amount of

240
00:09:45,220 --> 00:09:39,920
sunlight coming from the different

241
00:09:48,580 --> 00:09:45,230
hemispheres yet oops the point is gone

242
00:09:50,380 --> 00:09:48,590
yet the yet the southern hemisphere is

243
00:09:52,270 --> 00:09:50,390
we return out as much cloudier than an

244
00:09:54,040 --> 00:09:52,280
audience fear the norm of the hemisphere

245
00:09:56,920 --> 00:09:54,050
has much more landmass and snow cover

246
00:10:00,270 --> 00:09:56,930
and so forth and mother nature acts that

247
00:10:02,860 --> 00:10:00,280
these two factors entirely cancel and

248
00:10:04,570 --> 00:10:02,870
giving us an albedo this is the same now

249
00:10:06,250 --> 00:10:04,580
we are don't quite understand whether

250
00:10:08,020 --> 00:10:06,260
the significance of this and but what we

251
00:10:11,110 --> 00:10:08,030
do understand and what we see is a

252
00:10:16,150 --> 00:10:11,120
clouds a main way earth regulates energy

253
00:10:18,040 --> 00:10:16,160
going out after space okay so this is

254
00:10:20,350 --> 00:10:18,050
just an illustration to give you a sense

255
00:10:22,390 --> 00:10:20,360
for the sensitivity of a system to

256
00:10:24,220 --> 00:10:22,400
changing in the whiteness of the planet

257
00:10:26,500 --> 00:10:24,230
and basically it's there's two panels

258
00:10:29,140 --> 00:10:26,510
one panel represents different

259
00:10:32,530 --> 00:10:29,150
simulations from one of our advance or

260
00:10:34,360 --> 00:10:32,540
system models of the warming of the 20th

261
00:10:37,090 --> 00:10:34,370
century that's on the left as you see it

262
00:10:38,860 --> 00:10:37,100
and the second is the changes of the

263
00:10:40,600 --> 00:10:38,870

reflected sunlight in watts per meter

264
00:10:43,630 --> 00:10:40,610
squared on the right that's given rise

265
00:10:45,750 --> 00:10:43,640
to this that can be metro traceable to

266
00:10:48,430 --> 00:10:45,760
this

267
00:10:50,080 --> 00:10:48,440
20th century warming and the differences

268
00:10:51,610 --> 00:10:50,090
between these simulations is just how

269
00:10:53,740 --> 00:10:51,620
you turn rain on and off in the clouds

270
00:10:55,930 --> 00:10:53,750
it's just a certain knob that models

271
00:10:57,850 --> 00:10:55,940
have rain on and often what you see is

272
00:11:00,280 --> 00:10:57,860
it's very sensitive the warming and so

273
00:11:02,320 --> 00:11:00,290
is very sensitive to the details of the

274
00:11:04,600 --> 00:11:02,330
clouds and the wave rain develops that

275
00:11:07,570 --> 00:11:04,610
in turn can have a quite a marked effect

276
00:11:10,660 --> 00:11:07,580
on the on how much sunlight is reflected

277
00:11:11,560 --> 00:11:10,670
the sunlight reflected from the planet

278
00:11:13,390 --> 00:11:11,570
is influenced by

279
00:11:14,770 --> 00:11:13,400
volcanoes these are these letters

280
00:11:16,750 --> 00:11:14,780
they're basically different volcanoes

281
00:11:18,580 --> 00:11:16,760
each which have a kind of a very

282
00:11:20,890 --> 00:11:18,590
convoluted influence back on the clouds

283
00:11:22,960 --> 00:11:20,900
and but by the line is about a two watt

284
00:11:25,150 --> 00:11:22,970
per meter squared two percent change and

285
00:11:27,790 --> 00:11:25,160
we've somewhat reflected you can go from

286
00:11:29,530 --> 00:11:27,800
a state of warming of the planet - a

287
00:11:31,000 --> 00:11:29,540
planet that hasn't warmed in twenty

288
00:11:32,290 --> 00:11:31,010

century just weather - what change so

289
00:11:34,930 --> 00:11:32,300
this gives you a sense of how sensitive

290
00:11:37,110 --> 00:11:34,940
the whiteness of the plant the planets

291
00:11:40,360 --> 00:11:37,120
warming is to the whiteness so to speak

292
00:11:41,620 --> 00:11:40,370
okay well we've had a decade of progress

293
00:11:42,850 --> 00:11:41,630
hadn't watch more than a decade of

294
00:11:44,560 --> 00:11:42,860
progress and Bryan's going to talk about

295
00:11:45,850 --> 00:11:44,570
you know going back from the early days

296
00:11:47,710 --> 00:11:45,860
of satellites all the way through but

297
00:11:49,750 --> 00:11:47,720
I've had a decade of progress where

298
00:11:51,430 --> 00:11:49,760
we've had some quite unique measurements

299
00:11:53,470 --> 00:11:51,440
about clouds that have come from active

300
00:11:56,020 --> 00:11:53,480
instruments lasers and radars allowed us

301
00:11:57,700 --> 00:11:56,030
to sort of kind of like do a cat scan

302
00:11:59,740 --> 00:11:57,710
through the atmosphere and look at

303
00:12:01,540 --> 00:11:59,750
things working inside the atmosphere in

304
00:12:04,060 --> 00:12:01,550
terms of clouds and this was called the

305
00:12:05,440 --> 00:12:04,070
a train and arrived at said there's

306
00:12:07,360 --> 00:12:05,450
right with a big bang they wouldn't let

307
00:12:10,690 --> 00:12:07,370
me show this image but basically the

308
00:12:12,250 --> 00:12:10,700
poster of the aid train is at Caltech it

309
00:12:13,780 --> 00:12:12,260
happens to be in a scene from the Big

310
00:12:15,820 --> 00:12:13,790
Bang so there's a scene a big bang and

311
00:12:17,650 --> 00:12:15,830
there's our poster of the a-train right

312
00:12:20,440 --> 00:12:17,660
there in Big Bang they wouldn't let show

313
00:12:23,200 --> 00:12:20,450

this because I guess it's a it's it's

314
00:12:25,960 --> 00:12:23,210
it's not kosher to show it anyway so

315
00:12:27,970 --> 00:12:25,970
we've had these measurements in the last

316
00:12:30,700 --> 00:12:27,980
10 years and what and this has told us a

317
00:12:32,920 --> 00:12:30,710
lot about these tiny slivers of water in

318
00:12:34,540 --> 00:12:32,930
the sky that we think is so important to

319
00:12:38,920 --> 00:12:34,550
our controlling our climate system so

320
00:12:40,870 --> 00:12:38,930
here for example we've determined for

321
00:12:42,490 --> 00:12:40,880
example from these measurements how

322
00:12:43,300 --> 00:12:42,500
often it rains it snows around us we

323
00:12:44,860 --> 00:12:43,310
didn't know this until these

324
00:12:47,080 --> 00:12:44,870
measurements we know and how frequently

325
00:12:48,850 --> 00:12:47,090
it rains and snows and this is a kind of

326
00:12:50,380 --> 00:12:48,860
a diagram here that shows you kind of

327
00:12:52,180 --> 00:12:50,390
distribution of how frequently it rains

328
00:12:54,940 --> 00:12:52,190
it snows and you can see the high

329
00:12:57,250 --> 00:12:54,950
latitudes as there's kind of a dreary

330
00:12:58,840 --> 00:12:57,260
place that's always raining and sowing

331
00:13:02,350 --> 00:12:58,850
there if you know if you lived in London

332
00:13:04,900 --> 00:13:02,360
it's always raining in London so on but

333
00:13:06,130 --> 00:13:04,910
that this rain formation and we can even

334
00:13:08,530 --> 00:13:06,140
see them not to talk about that but

335
00:13:10,330 --> 00:13:08,540
could even see rain forming in in these

336
00:13:13,030 --> 00:13:10,340
clouds from space this is quite amazing

337
00:13:14,530 --> 00:13:13,040
so this is this allows us to begin to

338
00:13:15,820 --> 00:13:14,540

answer some really big questions one big

339
00:13:19,810 --> 00:13:15,830
question I'm going to close with in a

340
00:13:22,090 --> 00:13:19,820
minute the second thing is we now know

341
00:13:23,650 --> 00:13:22,100
how much water and ice is suspended in

342
00:13:25,210 --> 00:13:23,660
the sky so this probe this shows a

343
00:13:27,010 --> 00:13:25,220
profile of height

344
00:13:29,530 --> 00:13:27,020
and latitude from the equator in the

345
00:13:31,510 --> 00:13:29,540
middle to the polar regions either side

346
00:13:33,790 --> 00:13:31,520
left and right and so you can see clouds

347
00:13:36,220 --> 00:13:33,800
and the tropics waters lofted high in

348
00:13:37,660 --> 00:13:36,230
the clouds up to 15 16 kilometers and

349
00:13:40,870 --> 00:13:37,670
you can see the major cloud the storm

350
00:13:42,610 --> 00:13:40,880
regions so we now know how much ice is

351
00:13:44,860 --> 00:13:42,620
suspended how high it's suspended this

352
00:13:45,820 --> 00:13:44,870
is really important because whoops I

353
00:13:49,600 --> 00:13:45,830
won't go back but this is really

354
00:13:51,340 --> 00:13:49,610
important because because the height at

355
00:13:53,740 --> 00:13:51,350
which the water sits in the atmosphere

356
00:13:55,540 --> 00:13:53,750
dictates the ability to act as a

357
00:13:58,360 --> 00:13:55,550
greenhouse factor act like a thermal

358
00:14:00,430 --> 00:13:58,370
blanket right and amount of water in the

359
00:14:01,600 --> 00:14:00,440
clouds themselves dictate how white they

360
00:14:03,400 --> 00:14:01,610
are so you've got these two things how

361
00:14:05,080 --> 00:14:03,410
high they are and how wet they are

362
00:14:06,790 --> 00:14:05,090
controlling the whiteness and the

363
00:14:07,690 --> 00:14:06,800

blackness of the cloud so to speak where

364
00:14:12,280 --> 00:14:07,700
the blackness is a greenhouse effect

365
00:14:13,870 --> 00:14:12,290
okay so this is a big question how are

366
00:14:15,250 --> 00:14:13,880
clouds and the hydrological cycle

367
00:14:18,370 --> 00:14:15,260
changing this is kind of a really big

368
00:14:21,160 --> 00:14:18,380
question that sort of motivates our our

369
00:14:22,870 --> 00:14:21,170
science as you go forward and it's

370
00:14:26,320 --> 00:14:22,880
posing is slightly different in a simple

371
00:14:28,360 --> 00:14:26,330
way by a UK minister to the chief

372
00:14:31,150 --> 00:14:28,370
sciences of the UK UK Meteorological

373
00:14:33,400 --> 00:14:31,160
Office after a major flooding event

374
00:14:36,100 --> 00:14:33,410
happened in the UK this Minister asked

375
00:14:39,880 --> 00:14:36,110
the chief science a very simple question

376
00:14:42,130 --> 00:14:39,890
how bad are the rains going to be in the

377
00:14:44,530 --> 00:14:42,140
future we can't expect more of this kind

378
00:14:47,380 --> 00:14:44,540
of flooding now we have some sort of

379
00:14:50,410 --> 00:14:47,390
broad understanding of why we think the

380
00:14:52,930 --> 00:14:50,420
rains will become more intense in a

381
00:14:55,180 --> 00:14:52,940
warming world but there's much more to

382
00:14:58,030 --> 00:14:55,190
it than just the simple thermodynamic

383
00:14:59,500 --> 00:14:58,040
controls on the cloud systems that that

384
00:15:01,630 --> 00:14:59,510
sort of suggests that the rains will

385
00:15:03,160 --> 00:15:01,640
become more intense so we don't we can't

386
00:15:04,930 --> 00:15:03,170
give really definitive answers we can

387
00:15:06,430 --> 00:15:04,940
give suggestive answers that this kind

388
00:15:08,710 --> 00:15:06,440

of important question but we can't yet

389
00:15:10,329 --> 00:15:08,720
to give definitive answers but our

390
00:15:13,090 --> 00:15:10,339
science is really progressing and I

391
00:15:13,990 --> 00:15:13,100
expect that by the time I retire where

392
00:15:16,120 --> 00:15:14,000
we are that gives her much more

393
00:15:18,100 --> 00:15:16,130
definitive answers with the modeling

394
00:15:21,490 --> 00:15:18,110
systems that we have so let me just

395
00:15:23,020 --> 00:15:21,500
close summary comments we've made

396
00:15:25,000 --> 00:15:23,030
significant progress in a number of

397
00:15:26,950 --> 00:15:25,010
areas in terms of trying to understand

398
00:15:31,000 --> 00:15:26,960
this sliver of water wrapped around

399
00:15:33,120 --> 00:15:31,010
Earth how much we kind of can quantify

400
00:15:35,680 --> 00:15:33,130
now how much water is suspended in air

401
00:15:37,180 --> 00:15:35,690
very difficult you see why it's such a

402
00:15:39,850 --> 00:15:37,190
challenge because such a tiny amount of

403
00:15:41,860 --> 00:15:39,860
water but it has such a big effect

404
00:15:43,960 --> 00:15:41,870
we we I sort of understand how it rises

405
00:15:45,310 --> 00:15:43,970
and how now it falls to the surface so

406
00:15:47,800 --> 00:15:45,320
that we can understand as part of the

407
00:15:49,240 --> 00:15:47,810
cycle in a quantitative way and the

408
00:15:50,890 --> 00:15:49,250
influence of this tiny amount of water

409
00:15:52,570 --> 00:15:50,900
on the Earth's energy balance and just

410
00:15:54,190 --> 00:15:52,580
how wide earth is and why it matters we

411
00:15:56,200 --> 00:15:54,200
kind of much more quantitative

412
00:15:58,420 --> 00:15:56,210
understanding of this but there are big

413
00:16:00,610 --> 00:15:58,430

challenges that remain like the UK

414
00:16:02,560 --> 00:16:00,620
Minister simple question that still runs

415
00:16:05,350 --> 00:16:02,570
deep and influences our thinking in

416
00:16:08,320 --> 00:16:05,360
terms of our science so that's my spiel

417
00:16:19,630 --> 00:16:08,330
for the twelve minutes and I guess I

418
00:16:21,780 --> 00:16:19,640
move our next speaker dr. Brian Cahn got

419
00:16:24,580 --> 00:16:21,790
his master's in PhD in atmospheric

420
00:16:26,260 --> 00:16:24,590
sciences at UCLA he is currently a

421
00:16:28,300 --> 00:16:26,270
research scientist working closely with

422
00:16:31,480 --> 00:16:28,310
the atmospheric infrared sounder or airs

423
00:16:32,740 --> 00:16:31,490
group his research includes active and

424
00:16:34,690 --> 00:16:32,750
passive remote sensing of clouds

425
00:16:36,760 --> 00:16:34,700
temperature and water vapor with a

426
00:16:38,430 --> 00:16:36,770
specific focus on observing cloud and

427
00:16:40,780 --> 00:16:38,440
climate related atmospheric processes

428
00:16:42,640 --> 00:16:40,790
leveraging the natural synergy of

429
00:16:44,230 --> 00:16:42,650
satellite satellite sensor

430
00:16:52,930 --> 00:16:44,240
constellations welcome to the stage dr.

431
00:16:56,110 --> 00:16:52,940
Brian Cahn well thanks very much for

432
00:16:57,790 --> 00:16:56,120
coming to the von Karman lecture so I'll

433
00:17:02,500 --> 00:16:57,800
start with something slightly different

434
00:17:05,050 --> 00:17:02,510
if I could switch forward here I know we

435
00:17:07,150 --> 00:17:05,060
all love moon landings the moon landings

436
00:17:09,699 --> 00:17:07,160
were incredible a great human

437
00:17:12,520 --> 00:17:09,709
achievement and the future moon landings

438
00:17:16,449 --> 00:17:12,530

to come but I think this was an equally

439
00:17:21,340 --> 00:17:16,459
important moment in NASA's and in human

440
00:17:24,400 --> 00:17:21,350
history frankly in April 1960 59 years

441
00:17:26,170 --> 00:17:24,410
ago to this month we finally launched a

442
00:17:28,449 --> 00:17:26,180
satellite in the space where he looked

443
00:17:31,540 --> 00:17:28,459
back down at Earth and we got a picture

444
00:17:34,510 --> 00:17:31,550
of the planet and the clouds in the

445
00:17:38,310 --> 00:17:34,520
atmosphere and what you see here are the

446
00:17:41,560 --> 00:17:38,320
first light images from the tyrus one

447
00:17:44,350 --> 00:17:41,570
satellite you can see we're over the the

448
00:17:48,250 --> 00:17:44,360
middle east in this this general region

449
00:17:51,910 --> 00:17:48,260
here and you could see see the movement

450
00:17:53,049 --> 00:17:51,920
in the images to the west so these were

451
00:17:57,519 --> 00:17:53,059
the first light image

452
00:18:00,450 --> 00:17:57,529
of our planet from from a polar orbiting

453
00:18:03,310 --> 00:18:00,460
satellite so I think it's a great moment

454
00:18:06,940 --> 00:18:03,320
we've come a long way in these 59 years

455
00:18:09,879 --> 00:18:06,950
however we have much more advanced

456
00:18:12,899 --> 00:18:09,889
instrument in calibration and

457
00:18:15,519 --> 00:18:12,909
engineering with methodologies and

458
00:18:19,210 --> 00:18:15,529
technology has advanced rapidly in this

459
00:18:23,039 --> 00:18:19,220
time we have a much greater ability now

460
00:18:25,840 --> 00:18:23,049
to cover the entire earth constantly

461
00:18:29,499 --> 00:18:25,850
within a matter of minutes with with

462
00:18:31,989 --> 00:18:29,509
satellite images there's advancements in

463
00:18:34,930 --> 00:18:31,999

the data storage how we downlink data

464
00:18:37,930 --> 00:18:34,940
from the satellite to the ground these

465
00:18:42,609 --> 00:18:37,940
are not trivially trivial issues how we

466
00:18:44,409 --> 00:18:42,619
process these data and software and also

467
00:18:46,899 --> 00:18:44,419
the the other thing that we probably

468
00:18:49,690 --> 00:18:46,909
don't appreciate very much and as Graham

469
00:18:51,909 --> 00:18:49,700
alluded to we have knowledge not only of

470
00:18:53,799 --> 00:18:51,919
where the clouds are but what they're

471
00:18:56,830 --> 00:18:53,809
made of whether they're ice or liquid

472
00:18:59,320 --> 00:18:56,840
and there are scientific advancements in

473
00:19:02,759 --> 00:18:59,330
how we actually obtain these cloud

474
00:19:06,220 --> 00:19:02,769
properties so I want to acknowledge that

475
00:19:08,980 --> 00:19:06,230
ok so this is the state of the art this

476
00:19:12,190 --> 00:19:08,990
is the advanced baseline imager and what

477
00:19:15,220 --> 00:19:12,200
you see here are 16 channels and this is

478
00:19:18,070 --> 00:19:15,230
from a geostationary imager that's high

479
00:19:21,519 --> 00:19:18,080
enough above the surface of Earth that

480
00:19:23,739 --> 00:19:21,529
it actually rotates with earth it's at

481
00:19:25,509 --> 00:19:23,749
the at the same rotation rate so it

482
00:19:27,580 --> 00:19:25,519
looks at the same place on earth all the

483
00:19:30,820 --> 00:19:27,590
time and this is just a small little

484
00:19:33,909 --> 00:19:30,830
region over the United States and these

485
00:19:37,239 --> 00:19:33,919
are 16 different channels you'll see

486
00:19:38,859 --> 00:19:37,249
visible and near-infrared sort of sort

487
00:19:41,499 --> 00:19:38,869
of the whiteness that that Graham

488
00:19:44,139 --> 00:19:41,509

alluded to in the upper 4 or 5 channels

489
00:19:46,359 --> 00:19:44,149
and then the the blackness the the

490
00:19:48,340 --> 00:19:46,369
infrared or the emission is in these

491
00:19:50,739 --> 00:19:48,350
different channels here down low you

492
00:19:53,169 --> 00:19:50,749
could see storms and movement of clouds

493
00:19:55,389 --> 00:19:53,179
through the United States there are much

494
00:20:00,039 --> 00:19:55,399
more detailed images than than this

495
00:20:02,379 --> 00:20:00,049
available as well so having just such

496
00:20:04,869 --> 00:20:02,389
the level of detail now available to us

497
00:20:06,050 --> 00:20:04,879
as revolutionising how we think about

498
00:20:09,390 --> 00:20:06,060
clouds

499
00:20:11,030 --> 00:20:09,400
so I thought this is an appropriate

500
00:20:14,070 --> 00:20:11,040
image since we're in the von Karman

501
00:20:15,990 --> 00:20:14,080
auditorium which you actually see here

502
00:20:18,270 --> 00:20:16,000
in the the Southern California Bight

503
00:20:22,380 --> 00:20:18,280
right off the coast are these little von

504
00:20:26,310 --> 00:20:22,390
Karman vortices and these indicate wind

505
00:20:28,950 --> 00:20:26,320
flow past the Channel Islands so you'll

506
00:20:31,200 --> 00:20:28,960
see some some of the islands right here

507
00:20:33,090 --> 00:20:31,210
and as the wind flows past the islands

508
00:20:36,690 --> 00:20:33,100
they create these little circulations in

509
00:20:39,840 --> 00:20:36,700
in the Lee of the island so when you

510
00:20:42,120 --> 00:20:39,850
look at a satellite image it's not just

511
00:20:45,210 --> 00:20:42,130
the image or the whiteness that's

512
00:20:47,700 --> 00:20:45,220
important that's just the visible part

513
00:20:50,160 --> 00:20:47,710

of a larger process a complex process

514
00:20:53,190 --> 00:20:50,170
happening in the atmosphere where you

515
00:20:56,100 --> 00:20:53,200
have temperature water vapor wind is

516
00:20:58,710 --> 00:20:56,110
flowing and the clouds are just sort of

517
00:21:01,470 --> 00:20:58,720
the visible part of it that you see that

518
00:21:02,360 --> 00:21:01,480
there's much more to clouds than meets

519
00:21:05,280 --> 00:21:02,370
the eye

520
00:21:08,390 --> 00:21:05,290
so the key is that we need to observe

521
00:21:12,480 --> 00:21:08,400
these things at the same time in place

522
00:21:15,480 --> 00:21:12,490
so another exciting recent development

523
00:21:18,360 --> 00:21:15,490
is this a bi instrument is actually

524
00:21:20,280 --> 00:21:18,370
coupled with a geostationary lightning

525
00:21:23,070 --> 00:21:20,290
mapper and what you see here is a

526
00:21:25,020 --> 00:21:23,080
visible data so this is the the

527
00:21:27,780 --> 00:21:25,030
whiteness of clouds the the reflected

528
00:21:29,850 --> 00:21:27,790
solar radiation and then lightning

529
00:21:33,000 --> 00:21:29,860
detection is actually mapped within the

530
00:21:37,620 --> 00:21:33,010
clouds so so that's this is really cool

531
00:21:40,380 --> 00:21:37,630
so you'll see thunderstorms just going

532
00:21:42,390 --> 00:21:40,390
like crazy in the central US but only

533
00:21:45,540 --> 00:21:42,400
certain parts of the clouds are really

534
00:21:48,810 --> 00:21:45,550
active okay so the the lesson here is

535
00:21:51,150 --> 00:21:48,820
just because you see a big bright cloud

536
00:21:53,610 --> 00:21:51,160
doesn't mean that there's a violent

537
00:21:55,800 --> 00:21:53,620
thunderstorm everywhere in that cloud so

538
00:21:58,200 --> 00:21:55,810

these types of observations are giving

539
00:22:01,520 --> 00:21:58,210
us more insight as to how these storms

540
00:22:04,440 --> 00:22:01,530
work and how things are structured so

541
00:22:06,630 --> 00:22:04,450
those are geostationary satellites and

542
00:22:09,470 --> 00:22:06,640
Graham talked about the a-train so the

543
00:22:13,230 --> 00:22:09,480
a-train is our most state-of-the-art

544
00:22:15,800 --> 00:22:13,240
polar orbiting satellite constellation

545
00:22:18,000 --> 00:22:15,810
that that that we have to date and

546
00:22:19,680 --> 00:22:18,010
geostationary satellites are really

547
00:22:23,039 --> 00:22:19,690
great tools for weather for

548
00:22:25,529 --> 00:22:23,049
casting for severe weather warnings for

549
00:22:27,990 --> 00:22:25,539
commerce there's a lot of applications

550
00:22:31,889 --> 00:22:28,000
that that geostationary data is very

551
00:22:34,080 --> 00:22:31,899
important for but these satellites

552
00:22:35,549 --> 00:22:34,090
they're still not quite accurate enough

553
00:22:37,350 --> 00:22:35,559
to monitor climate change at least

554
00:22:40,350 --> 00:22:37,360
that's that's sort of the the current

555
00:22:42,600 --> 00:22:40,360
thinking also another problem is that

556
00:22:44,940 --> 00:22:42,610
geostationary satellites do not observe

557
00:22:46,680 --> 00:22:44,950
polar regions so since they're they're

558
00:22:49,409 --> 00:22:46,690
sitting above the equator staring at the

559
00:22:51,720 --> 00:22:49,419
same place all the time they actually

560
00:22:54,930 --> 00:22:51,730
don't observe the poles where climate is

561
00:22:57,720 --> 00:22:54,940
changing most rapidly okay so polar

562
00:23:00,629 --> 00:22:57,730
orbiting satellites will fill in these

563
00:23:03,810 --> 00:23:00,639

regions and this is sort of where our

564
00:23:06,600 --> 00:23:03,820
state-of-the-art instrumentation is

565
00:23:10,560 --> 00:23:06,610
located in these particular instruments

566
00:23:13,860 --> 00:23:10,570
so I'm just showing you an example of my

567
00:23:16,259 --> 00:23:13,870
own personal research here getting at

568
00:23:18,060 --> 00:23:16,269
it's not just whether there's a cloud or

569
00:23:21,029 --> 00:23:18,070
not but it's the characteristics of the

570
00:23:23,249 --> 00:23:21,039
clouds that really matter for for

571
00:23:27,259 --> 00:23:23,259
understanding how how the atmosphere

572
00:23:29,820 --> 00:23:27,269
works so this is ice cloud frequency

573
00:23:33,060 --> 00:23:29,830
over a 14-year period you could see the

574
00:23:35,070 --> 00:23:33,070
time at the top and these are monthly

575
00:23:37,259 --> 00:23:35,080
averages of the entire globe and you

576
00:23:39,299 --> 00:23:37,269
could see that ice clouds kind of move

577
00:23:41,810 --> 00:23:39,309
around with the seasons so the seasonal

578
00:23:43,830 --> 00:23:41,820
cycle it kind of waves up and down

579
00:23:47,070 --> 00:23:43,840
paradoxically there are much more ice

580
00:23:50,490 --> 00:23:47,080
clouds in the hot tropics so maybe even

581
00:23:53,759 --> 00:23:50,500
a lot of you don't know that it's it's

582
00:23:55,950 --> 00:23:53,769
it's pretty pretty interesting but

583
00:23:58,019 --> 00:23:55,960
notice watch the clouds move a little

584
00:24:01,350 --> 00:23:58,029
bit east here in the Central Pacific

585
00:24:03,389 --> 00:24:01,360
that was actually an El Nino that

586
00:24:05,669 --> 00:24:03,399
occurred in 2016 you might have

587
00:24:07,619 --> 00:24:05,679
remembered the strong El Nino that we

588
00:24:12,180 --> 00:24:07,629

had where it didn't rain in Southern

589
00:24:14,100 --> 00:24:12,190
California okay so the the next loop

590
00:24:16,980 --> 00:24:14,110
that I want to show you here is not the

591
00:24:18,680 --> 00:24:16,990
ice cloud but it's all clouds you could

592
00:24:21,389 --> 00:24:18,690
immediately see the pattern is different

593
00:24:24,240 --> 00:24:21,399
so the ice clouds tend to occur in the

594
00:24:25,950 --> 00:24:24,250
tropics but the liquid clouds tend to

595
00:24:27,990 --> 00:24:25,960
occur and maybe middle on higher

596
00:24:31,049 --> 00:24:28,000
latitudes and they have different

597
00:24:33,720 --> 00:24:31,059
seasonal cycles associated with them so

598
00:24:36,990 --> 00:24:33,730
that that's really kind of like the

599
00:24:39,150 --> 00:24:37,000
online message here is there are

600
00:24:42,000 --> 00:24:39,160
different types of cloud properties that

601
00:24:44,130 --> 00:24:42,010
matter with these issues that that have

602
00:24:46,650 --> 00:24:44,140
been discussed by Graham and will be

603
00:24:50,130 --> 00:24:46,660
discussed by Kate as well so I just want

604
00:24:52,440 --> 00:24:50,140
to end on some summary research results

605
00:24:55,700 --> 00:24:52,450
that I think are very interesting in the

606
00:24:59,820 --> 00:24:55,710
upper left is a 25 year record of

607
00:25:02,400 --> 00:24:59,830
satellite data that shows where clouds

608
00:25:05,400 --> 00:25:02,410
are increasing which is in green and

609
00:25:08,700 --> 00:25:05,410
where clouds are decreasing which is in

610
00:25:11,100 --> 00:25:08,710
red over the last 25 years so you can

611
00:25:13,110 --> 00:25:11,110
see some areas of the earth are getting

612
00:25:13,850 --> 00:25:13,120
cloudier some places are getting clearer

613
00:25:16,620 --> 00:25:13,860

okay

614
00:25:19,590 --> 00:25:16,630
the climate models which which Kate will

615
00:25:21,960 --> 00:25:19,600
get into shows similar patterns like

616
00:25:24,300 --> 00:25:21,970
this region here where clouds are

617
00:25:27,270 --> 00:25:24,310
increasing seems to be pretty similar to

618
00:25:29,460 --> 00:25:27,280
the observations but there are other

619
00:25:32,700 --> 00:25:29,470
areas that disagree so you can make a

620
00:25:34,470 --> 00:25:32,710
plot of where they agree and where

621
00:25:36,780 --> 00:25:34,480
clouds are increasing both in the

622
00:25:39,330 --> 00:25:36,790
observations and models and those are

623
00:25:41,580 --> 00:25:39,340
the green areas down here and then where

624
00:25:43,160 --> 00:25:41,590
clouds are decreasing both in the

625
00:25:46,860 --> 00:25:43,170
observations and models

626
00:25:48,900 --> 00:25:46,870
that those are the red areas so we're

627
00:25:51,210 --> 00:25:48,910
we're we're definitely starting to peel

628
00:25:53,510 --> 00:25:51,220
apart the behavior of the atmosphere in

629
00:25:56,310 --> 00:25:53,520
a little bit more of a fine-tooth comb

630
00:25:59,550 --> 00:25:56,320
detail than then we're capable in the

631
00:26:06,200 --> 00:25:59,560
past yeah I think that that's about it

632
00:26:09,330 --> 00:26:07,740
Thank You Bryan

633
00:26:12,299 --> 00:26:09,340
you always gotta trust a person named

634
00:26:13,700 --> 00:26:12,309
Bryan now our final speaker and special

635
00:26:15,990 --> 00:26:13,710
guest comes to us from the East Coast

636
00:26:18,000 --> 00:26:16,000
dr. Kate Marvel is an associate research

637
00:26:20,190 --> 00:26:18,010
scientist at the NASA Goddard Institute

638
00:26:22,380 --> 00:26:20,200

for Space Studies and at Columbia

639
00:26:24,990 --> 00:26:22,390
University where she uses supercomputers

640
00:26:27,480 --> 00:26:25,000
big data and satellite observations to

641
00:26:29,669 --> 00:26:27,490
study climate change before becoming a

642
00:26:31,020 --> 00:26:29,679
sky mad scientist Kate received a PhD in

643
00:26:33,630 --> 00:26:31,030
theoretical particle physics from

644
00:26:35,669 --> 00:26:33,640
Cambridge University she has given a TED

645
00:26:39,210 --> 00:26:35,679
talk appeared on Meet the Press

646
00:26:40,770 --> 00:26:39,220
NPR's weekend edition and Startalk she

647
00:26:42,810 --> 00:26:40,780
writes the hot planet column for

648
00:26:44,850 --> 00:26:42,820
Scientific American has written for

649
00:26:47,070 --> 00:26:44,860
Nautilus magazine and the on being

650
00:26:59,880 --> 00:26:47,080
project she's got some game folks please

651
00:27:01,890 --> 00:26:59,890
welcome dr. Kate Marvell so I work on

652
00:27:04,649 --> 00:27:01,900
climate models because I'm really

653
00:27:07,260 --> 00:27:04,659
interested in the future and nobody has

654
00:27:10,710 --> 00:27:07,270
invented a time machine yet so that's

655
00:27:12,330 --> 00:27:10,720
one of I don't get on at NASA so this is

656
00:27:14,669 --> 00:27:12,340
this is one of the only ways that we can

657
00:27:16,770 --> 00:27:14,679
actually see the future and fortunately

658
00:27:18,450 --> 00:27:16,780
we have some confidence in the ability

659
00:27:21,060 --> 00:27:18,460
of climate models to tell us something

660
00:27:23,730 --> 00:27:21,070
useful because if you look at how they

661
00:27:25,590 --> 00:27:23,740
act over the recent history they're able

662
00:27:28,169 --> 00:27:25,600
to reproduce the warming trend that

663
00:27:29,970 --> 00:27:28,179

we've seen fairly well but when you look

664
00:27:32,669 --> 00:27:29,980
forward into the future it's a different

665
00:27:34,620 --> 00:27:32,679
story so these are different climate

666
00:27:37,260 --> 00:27:34,630
models that are all run subject to the

667
00:27:40,140 --> 00:27:37,270
exact same scenario and I want to be

668
00:27:42,480 --> 00:27:40,150
clear all of them are warming because

669
00:27:45,029 --> 00:27:42,490
carbon dioxide is a greenhouse gas and

670
00:27:47,070 --> 00:27:45,039
it warms the planet but some of them are

671
00:27:51,690 --> 00:27:47,080
warming only about two or three degrees

672
00:27:53,669 --> 00:27:51,700
Celsius and some are warming four five

673
00:27:55,740 --> 00:27:53,679
six degrees by the end of the century

674
00:27:56,310 --> 00:27:55,750
and I want to put that in the context

675
00:27:58,169 --> 00:27:56,320
for you

676
00:28:00,360 --> 00:27:58,179
four and a half degrees is the

677
00:28:03,899 --> 00:28:00,370
difference between now and the last ice

678
00:28:05,820 --> 00:28:03,909
age so this is something that is kind of

679
00:28:07,680 --> 00:28:05,830
embarrassing for climate scientists that

680
00:28:09,480 --> 00:28:07,690
we know it's going to get hot but we

681
00:28:11,700 --> 00:28:09,490
don't know exactly how hot it's gonna

682
00:28:13,310 --> 00:28:11,710
get and you know like we had one job

683
00:28:16,940 --> 00:28:13,320
right

684
00:28:18,440 --> 00:28:16,950
but one of the reasons the main reason I

685
00:28:19,970 --> 00:28:18,450
think that we don't know how hot it's

686
00:28:22,160 --> 00:28:19,980
going to get is because we don't know

687
00:28:23,780 --> 00:28:22,170
what people are going to do we don't

688
00:28:25,520 --> 00:28:23,790

know what emissions are going to look

689
00:28:27,320 --> 00:28:25,530
like by the end of the century are we

690
00:28:30,230 --> 00:28:27,330
going to cut emissions or is it going to

691
00:28:32,180 --> 00:28:30,240
be business as usual but even if we

692
00:28:35,330 --> 00:28:32,190
remove that uncertainty of human

693
00:28:37,400 --> 00:28:35,340
behavior there's still uncertainties in

694
00:28:39,590 --> 00:28:37,410
the climate system physical things about

695
00:28:41,660 --> 00:28:39,600
the way the planet works that means that

696
00:28:44,270 --> 00:28:41,670
we're not a hundred percent sure exactly

697
00:28:46,430 --> 00:28:44,280
what the climates going to do and so in

698
00:28:49,340 --> 00:28:46,440
order to remove that uncertainty

699
00:28:52,010 --> 00:28:49,350
associated with human behavior we define

700
00:28:53,600 --> 00:28:52,020
a metric which is artificial exists only

701
00:28:55,940 --> 00:28:53,610
in climate models but is extremely

702
00:28:59,060 --> 00:28:55,950
useful and we call that equilibrium

703
00:29:00,920 --> 00:28:59,070
climate sensitivity so what we do is we

704
00:29:03,230 --> 00:29:00,930
abruptly double atmospheric carbon

705
00:29:05,110 --> 00:29:03,240
dioxide in a model we're trying to do

706
00:29:08,180 --> 00:29:05,120
that in the real world let's not do that

707
00:29:09,980 --> 00:29:08,190
and then we wait for the climate to come

708
00:29:11,720 --> 00:29:09,990
into equilibrium and this is a process

709
00:29:14,300 --> 00:29:11,730
that takes hundreds or thousands of

710
00:29:16,310 --> 00:29:14,310
years and after the climate comes into

711
00:29:18,170 --> 00:29:16,320
equilibrium we see how Hanukkah we

712
00:29:19,940 --> 00:29:18,180
measure the global average temperature

713
00:29:21,620 --> 00:29:19,950

change so this is something that's

714
00:29:24,020 --> 00:29:21,630
really simple you can do this in any

715
00:29:26,060 --> 00:29:24,030
climate model but if you look at what

716
00:29:28,820 --> 00:29:26,070
different climate models do in response

717
00:29:32,390 --> 00:29:28,830
to this simple experiment you see a wide

718
00:29:34,760 --> 00:29:32,400
variation so our best estimate right now

719
00:29:36,770 --> 00:29:34,770
of this value of climate sensitivity how

720
00:29:40,280 --> 00:29:36,780
warm it gets when you double atmospheric

721
00:29:42,350 --> 00:29:40,290
carbon dioxide is somewhere between 1.5

722
00:29:44,840 --> 00:29:42,360
degrees and four and a half degrees

723
00:29:48,410 --> 00:29:44,850
Celsius and that's a really big range

724
00:29:50,030 --> 00:29:48,420
right there so why aren't we a hundred

725
00:29:52,400 --> 00:29:50,040
percent sure how hot it's going to get

726
00:29:55,790 --> 00:29:52,410
well that's because temperature changes

727
00:29:57,200 --> 00:29:55,800
cause changes to the climate changes the

728
00:30:01,520 --> 00:29:57,210
things we care about like rainfall

729
00:30:04,550 --> 00:30:01,530
patterns and clouds and those climate

730
00:30:07,280 --> 00:30:04,560
changes can then themselves speed up or

731
00:30:10,160 --> 00:30:07,290
slow down the warming they feed back

732
00:30:12,560 --> 00:30:10,170
onto those temperature changes so for me

733
00:30:14,720 --> 00:30:12,570
personally the most intuitive feedback

734
00:30:16,970 --> 00:30:14,730
is Grand mentioned albedo the most

735
00:30:18,950 --> 00:30:16,980
intuitive feedback is what is going to

736
00:30:20,930 --> 00:30:18,960
happen to the albedo of the planner as

737
00:30:23,330 --> 00:30:20,940
it warms up right now the poles are

738
00:30:27,020 --> 00:30:23,340

covered in ice and when you make it hot

739
00:30:28,970 --> 00:30:27,030
ice melts so that ice which used to do

740
00:30:32,240 --> 00:30:28,980
a pretty good job of reflecting sunlight

741
00:30:35,600 --> 00:30:32,250
back to space is now gone and reveals

742
00:30:37,550 --> 00:30:35,610
darker ocean or land below and that is a

743
00:30:40,070 --> 00:30:37,560
lot less good at reflecting sunlight

744
00:30:42,020 --> 00:30:40,080
back to space than ice so this is what

745
00:30:44,240 --> 00:30:42,030
scientists call and this is the worst

746
00:30:47,750 --> 00:30:44,250
terminology scientists have ever come up

747
00:30:50,030 --> 00:30:47,760
with a positive feedback because when

748
00:30:52,150 --> 00:30:50,040
normal people hear positive feedback

749
00:30:55,220 --> 00:30:52,160
they think I'm doing a great job and

750
00:30:56,680 --> 00:30:55,230
when scientists say positive feedback we

751
00:30:59,000 --> 00:30:56,690
mean something that is going to

752
00:31:01,610 --> 00:30:59,010
destabilize the planet and make climate

753
00:31:03,140 --> 00:31:01,620
change even worse so another example of

754
00:31:05,870 --> 00:31:03,150
a positive feedback

755
00:31:07,550 --> 00:31:05,880
aka vicious cycle trying to get

756
00:31:10,940 --> 00:31:07,560
scientists to adopt this new terminology

757
00:31:14,210 --> 00:31:10,950
is water vapor so water vapor itself is

758
00:31:16,970 --> 00:31:14,220
a very powerful greenhouse gas and warm

759
00:31:19,010 --> 00:31:16,980
air holds more water vapor so if you

760
00:31:21,680 --> 00:31:19,020
warm up the atmosphere by for example

761
00:31:24,110 --> 00:31:21,690
putting carbon dioxide in it that warm

762
00:31:26,720 --> 00:31:24,120
air will hold more water vapor itself a

763
00:31:28,610 --> 00:31:26,730

very powerful greenhouse gas so this is

764
00:31:31,970 --> 00:31:28,620
an example of another positive feedback

765
00:31:35,000 --> 00:31:31,980
but these ice albedo and water vapor are

766
00:31:36,890 --> 00:31:35,010
fairly well understood this is not

767
00:31:38,870 --> 00:31:36,900
what's responsible for that spread and

768
00:31:40,880 --> 00:31:38,880
model predictions the thing that's

769
00:31:43,790 --> 00:31:40,890
largely responsible for the spread is

770
00:31:47,180 --> 00:31:43,800
clouds so in large part we don't

771
00:31:49,610 --> 00:31:47,190
understand what climate is going to do

772
00:31:51,500 --> 00:31:49,620
we don't understand exactly how hot it's

773
00:31:53,750 --> 00:31:51,510
gonna get because we don't know what

774
00:31:55,910 --> 00:31:53,760
clouds are going to do and that's

775
00:31:57,860 --> 00:31:55,920
because clouds play kind of a dual role

776
00:32:01,090 --> 00:31:57,870
in regulating the climate as Graham

777
00:32:03,770 --> 00:32:01,100
talked about so these here these clouds

778
00:32:06,530 --> 00:32:03,780
preferentially low thick clouds these

779
00:32:09,530 --> 00:32:06,540
are doing a really good job at blocking

780
00:32:11,600 --> 00:32:09,540
sunlight so if you are living underneath

781
00:32:14,390 --> 00:32:11,610
one of those cloud decks you are having

782
00:32:16,420 --> 00:32:14,400
a pretty gloomy day right now and we

783
00:32:19,130 --> 00:32:16,430
know that these low thick clouds are

784
00:32:21,020 --> 00:32:19,140
extremely effective at cooling the

785
00:32:22,490 --> 00:32:21,030
planet because they block some that

786
00:32:26,240 --> 00:32:22,500
would otherwise reach the planet surface

787
00:32:28,430 --> 00:32:26,250
so low clouds block the Sun and they

788
00:32:31,130 --> 00:32:28,440

make it colder but cows also do

789
00:32:33,470 --> 00:32:31,140
something else as Graham talked about

790
00:32:35,780 --> 00:32:33,480
clouds are have a really powerful kind

791
00:32:37,190 --> 00:32:35,790
of blanket effect clouds themselves have

792
00:32:39,350 --> 00:32:37,200
a powerful greenhouse gas if a

793
00:32:40,940 --> 00:32:39,360
greenhouse effect which you can see in

794
00:32:42,769 --> 00:32:40,950
this slide taken in the info

795
00:32:45,590 --> 00:32:42,779
and these are mostly those high clouds

796
00:32:47,749 --> 00:32:45,600
they trap thermal energy from the

797
00:32:50,180 --> 00:32:47,759
Earth's surface and they make it warmer

798
00:32:52,369 --> 00:32:50,190
so clouds are really confusing for many

799
00:32:53,840 --> 00:32:52,379
reasons but primarily because they play

800
00:32:56,330 --> 00:32:53,850
this dual role in the climate system

801
00:32:58,159 --> 00:32:56,340
they make it hotter but they also make a

802
00:32:59,810 --> 00:32:58,169
colder and that's one of the reasons

803
00:33:01,159 --> 00:32:59,820
that they're really hard to understand

804
00:33:05,869 --> 00:33:01,169
how they're going to go forward in the

805
00:33:07,700 --> 00:33:05,879
future so one idea is to turn to recent

806
00:33:09,859 --> 00:33:07,710
history to try to get some clues about

807
00:33:13,249 --> 00:33:09,869
the future because we've emitted carbon

808
00:33:15,830 --> 00:33:13,259
dioxide and it's gotten warmer so maybe

809
00:33:17,629 --> 00:33:15,840
we can take observations of the global

810
00:33:19,519 --> 00:33:17,639
temperature change and the carbon

811
00:33:22,430 --> 00:33:19,529
dioxide that we've emitted so far and

812
00:33:24,259 --> 00:33:22,440
use that to try to estimate this value

813
00:33:26,659 --> 00:33:24,269

of climate sensitivity how hot it's

814
00:33:29,720 --> 00:33:26,669
eventually gonna get so when you do that

815
00:33:32,810 --> 00:33:29,730
your best guess is about a little bit

816
00:33:35,499 --> 00:33:32,820
less than two degrees Celsius which is

817
00:33:37,899 --> 00:33:35,509
bad don't get me wrong but it's not

818
00:33:40,369 --> 00:33:37,909
necessarily catastrophic

819
00:33:42,320 --> 00:33:40,379
however the equilibrium climate

820
00:33:44,419 --> 00:33:42,330
sensitivity the best guessed estimate

821
00:33:46,519 --> 00:33:44,429
that you would get from climate models

822
00:33:49,850 --> 00:33:46,529
participating in an inter comparison

823
00:33:52,039 --> 00:33:49,860
project called seam at five is more than

824
00:33:54,289 --> 00:33:52,049
a degree hotter than this 3.1 degrees

825
00:33:56,600 --> 00:33:54,299
Celsius and so this begs the question

826
00:33:58,999 --> 00:33:56,610
are the models running hot are these

827
00:34:01,399 --> 00:33:59,009
models overly sensitive and this is

828
00:34:03,950 --> 00:34:01,409
something that I really want to be true

829
00:34:07,549 --> 00:34:03,960
because I really don't want climate

830
00:34:10,099 --> 00:34:07,559
change to be bad but unfortunately we

831
00:34:12,740 --> 00:34:10,109
have to be very very careful when we are

832
00:34:15,500 --> 00:34:12,750
making inferences about what is to come

833
00:34:17,299 --> 00:34:15,510
from what we've experienced so far the

834
00:34:20,389 --> 00:34:17,309
past is very different than the future

835
00:34:22,099 --> 00:34:20,399
so this is a slide of what actually

836
00:34:24,379 --> 00:34:22,109
happened this is the warming pattern

837
00:34:26,750 --> 00:34:24,389
that we have actually experienced in

838
00:34:28,909 --> 00:34:26,760

recent decades and I've subtracted off

839
00:34:30,230 --> 00:34:28,919
the global average temperature increase

840
00:34:31,819 --> 00:34:30,240
because otherwise you would just see a

841
00:34:33,710 --> 00:34:31,829
sea of red here to really bring out the

842
00:34:37,129 --> 00:34:33,720
pattern here and you can see that this

843
00:34:39,409 --> 00:34:37,139
has been characterized by anomalously

844
00:34:43,190 --> 00:34:39,419
cool temperatures right here in the

845
00:34:45,950 --> 00:34:43,200
equatorial Pacific and those anomalously

846
00:34:48,500 --> 00:34:45,960
cool temperatures have been really good

847
00:34:51,589 --> 00:34:48,510
at spurring cloud formation in

848
00:34:52,070 --> 00:34:51,599
particular low marine strata cumulus

849
00:34:55,220 --> 00:34:52,080
clouds

850
00:34:58,040 --> 00:34:55,230
so in recent decades we've actually seen

851
00:35:00,440 --> 00:34:58,050
an increase in clouds in these marine

852
00:35:02,810 --> 00:35:00,450
strata cumulus regions and these are

853
00:35:04,910 --> 00:35:02,820
those low thick clouds that are very

854
00:35:06,470 --> 00:35:04,920
effective at cooling the planet at

855
00:35:10,190 --> 00:35:06,480
turning away sunlight that we would

856
00:35:12,650 --> 00:35:10,200
otherwise get but we just happen to have

857
00:35:16,400 --> 00:35:12,660
experienced one iteration of reality

858
00:35:17,810 --> 00:35:16,410
climate change is occurring on top of a

859
00:35:20,860 --> 00:35:17,820
background of natural climate

860
00:35:24,080 --> 00:35:20,870
variability weather El Nino La Nina

861
00:35:27,080 --> 00:35:24,090
natural climate oscillations and right

862
00:35:29,630 --> 00:35:27,090
now the signal the signature of that

863
00:35:31,610 --> 00:35:29,640

carbon dioxide is not strong enough to

864
00:35:33,800 --> 00:35:31,620
overwhelm that natural variability

865
00:35:36,080 --> 00:35:33,810
completely so we happen to have

866
00:35:37,610 --> 00:35:36,090
experienced one iteration of climate

867
00:35:40,100 --> 00:35:37,620
variability but it could have been

868
00:35:42,530 --> 00:35:40,110
otherwise and we can use climate models

869
00:35:45,830 --> 00:35:42,540
to explore different counterfactual

870
00:35:48,260 --> 00:35:45,840
scenarios what warming patterns and what

871
00:35:50,420 --> 00:35:48,270
cloud patterns could we have experienced

872
00:35:52,520 --> 00:35:50,430
how do we just happen to have experience

873
00:35:55,610 --> 00:35:52,530
in different weather just by sheer

874
00:35:58,790 --> 00:35:55,620
randomness and all of these patterns in

875
00:36:01,370 --> 00:35:58,800
turn look very different than what we

876
00:36:03,710 --> 00:36:01,380
think is to come so when we're talking

877
00:36:05,720 --> 00:36:03,720
about the climate and equilibrium we're

878
00:36:08,780 --> 00:36:05,730
talking about a planet that's had a long

879
00:36:11,600 --> 00:36:08,790
time to adjust to what's been done with

880
00:36:14,210 --> 00:36:11,610
us in particular regions that are really

881
00:36:17,210 --> 00:36:14,220
really slow to warm for example the

882
00:36:20,360 --> 00:36:17,220
Southern Ocean down here those regions

883
00:36:23,480 --> 00:36:20,370
will eventually warm up and this is not

884
00:36:26,060 --> 00:36:23,490
a pattern that we think is achievable by

885
00:36:28,220 --> 00:36:26,070
random internal variability this is not

886
00:36:30,800 --> 00:36:28,230
a warming pattern that we have seen

887
00:36:33,710 --> 00:36:30,810
before so what the climate models are

888
00:36:35,660 --> 00:36:33,720

telling us is that we are moving into a

889
00:36:38,090 --> 00:36:35,670
future with a warming pattern and

890
00:36:40,250 --> 00:36:38,100
subsequent cloud cover that's perhaps

891
00:36:44,510 --> 00:36:40,260
different than anything we have ever

892
00:36:47,270 --> 00:36:44,520
experienced before so that long-term

893
00:36:49,970 --> 00:36:47,280
warming pattern that possible new normal

894
00:36:51,710 --> 00:36:49,980
is what the models are using when they

895
00:36:54,500 --> 00:36:51,720
are telling us this future distribution

896
00:36:58,190 --> 00:36:54,510
so that best guess of three degrees

897
00:37:01,160 --> 00:36:58,200
climate sensitivity that comes from that

898
00:37:03,350 --> 00:37:01,170
warming pattern in the far future what

899
00:37:04,690 --> 00:37:03,360
we could have experienced this purple

900
00:37:07,150 --> 00:37:04,700
distribution is

901
00:37:09,400 --> 00:37:07,160
happens when you run climate models with

902
00:37:11,890 --> 00:37:09,410
the present-day greenhouse gas emissions

903
00:37:14,620 --> 00:37:11,900
but you don't allow them to evolve

904
00:37:16,450 --> 00:37:14,630
forward into equilibrium and you'll note

905
00:37:18,910 --> 00:37:16,460
the fact that right now we are

906
00:37:21,819 --> 00:37:18,920
experiencing a disturbed climate that's

907
00:37:23,620 --> 00:37:21,829
really very far out of equilibrium means

908
00:37:25,390 --> 00:37:23,630
that the climate models say no you

909
00:37:27,760 --> 00:37:25,400
actually should infer a climate

910
00:37:31,150 --> 00:37:27,770
sensitivity that's less than what you'll

911
00:37:33,849 --> 00:37:31,160
get in the future and that in the mode

912
00:37:36,280 --> 00:37:33,859
of variability that we just happened to

913
00:37:38,109 --> 00:37:36,290

have experienced we just happen to have

914
00:37:40,030 --> 00:37:38,119
gotten lucky and that gives us an

915
00:37:43,270 --> 00:37:40,040
estimate of climate sensitivity that's

916
00:37:46,089 --> 00:37:43,280
even lower still and commensurate with

917
00:37:49,329 --> 00:37:46,099
the observations so I want to back up

918
00:37:51,220 --> 00:37:49,339
and end with some conclusions so the

919
00:37:54,970 --> 00:37:51,230
first is the reason I don't get invited

920
00:37:57,940 --> 00:37:54,980
to parties anymore which is that I think

921
00:37:59,079 --> 00:37:57,950
it's probably going to get worse as time

922
00:38:01,950 --> 00:37:59,089
goes on

923
00:38:04,690 --> 00:38:01,960
almost all the climate models project

924
00:38:06,700 --> 00:38:04,700
higher climate sensitivities climate

925
00:38:09,040 --> 00:38:06,710
models project that clouds will

926
00:38:12,059 --> 00:38:09,050
rearrange themselves and change in ways

927
00:38:14,680 --> 00:38:12,069
that will make the warming worse and

928
00:38:17,829 --> 00:38:14,690
moreover we happen to have gotten really

929
00:38:20,380 --> 00:38:17,839
lucky in the real world we just so

930
00:38:22,569 --> 00:38:20,390
happen to have experienced a pattern of

931
00:38:24,309 --> 00:38:22,579
natural variability that led to a period

932
00:38:27,430 --> 00:38:24,319
of cool temperatures particularly in the

933
00:38:29,800 --> 00:38:27,440
equatorial Pacific and we know why this

934
00:38:32,349 --> 00:38:29,810
led us to infer low values of climate

935
00:38:34,839 --> 00:38:32,359
sensitivity because these this warming

936
00:38:36,910 --> 00:38:34,849
pattern sparked low cloud formation

937
00:38:39,190 --> 00:38:36,920
which blocked sunlight and slowed down

938
00:38:42,400 --> 00:38:39,200

the warming and I think the real

939
00:38:44,470 --> 00:38:42,410
takeaway from this is that the past is

940
00:38:45,370 --> 00:38:44,480
not the future and we have to be very

941
00:38:47,470 --> 00:38:45,380
very careful

942
00:38:49,210 --> 00:38:47,480
when we make projections from the future

943
00:38:51,819 --> 00:38:49,220
by just extrapolating forward to the

944
00:38:54,700 --> 00:38:51,829
past because we may be moving toward a

945
00:38:57,160 --> 00:38:54,710
future where warming patterns and

946
00:38:59,410 --> 00:38:57,170
particularly cloud cover are such that

947
00:39:01,720 --> 00:38:59,420
we've never experienced them before we

948
00:39:04,480 --> 00:39:01,730
may be moving into a future for which

949
00:39:14,010 --> 00:39:04,490
there is no analog so thank you very

950
00:39:19,810 --> 00:39:16,870
thank you very much Kate before we head

951
00:39:21,670 --> 00:39:19,820
into our discussion I would like to let

952
00:39:23,740 --> 00:39:21,680
you know that you can also become a

953
00:39:25,900 --> 00:39:23,750
citizen scientist pretty much

954
00:39:28,240 --> 00:39:25,910
everybody's got a phone or a laptop or

955
00:39:30,970 --> 00:39:28,250
some sort of mobile device now but if

956
00:39:32,650 --> 00:39:30,980
you go there particularly with clouds we

957
00:39:34,510 --> 00:39:32,660
have the globe observer app it's

958
00:39:36,370 --> 00:39:34,520
actually a NASA app you can go on there

959
00:39:38,200 --> 00:39:36,380
and download and you can help us see

960
00:39:40,480 --> 00:39:38,210
what's happening around the skies where

961
00:39:42,580 --> 00:39:40,490
you are you can take a picture of it and

962
00:39:44,230 --> 00:39:42,590
you would become a citizen scientists

963
00:39:45,760 --> 00:39:44,240

it's all all the hard work is really

964
00:39:48,070 --> 00:39:45,770
done for you so I urge you to go find

965
00:39:50,740 --> 00:39:48,080
that on your website or on your app or

966
00:39:52,360 --> 00:39:50,750
whatever you got now you're all

967
00:39:54,190 --> 00:39:52,370
magically sitting down it's magic it's

968
00:39:55,840 --> 00:39:54,200
TV magic so one of the more fascinating

969
00:39:57,070 --> 00:39:55,850
topics for me and this is what I've

970
00:40:01,180 --> 00:39:57,080
enjoyed about putting this all together

971
00:40:03,940 --> 00:40:01,190
is is I guess the science aspect of it

972
00:40:05,080 --> 00:40:03,950
and the fact that there was a time

973
00:40:06,700 --> 00:40:05,090
yesterday when we were all talking about

974
00:40:09,580 --> 00:40:06,710
this that you all disagreed with each

975
00:40:10,990 --> 00:40:09,590
other and I loved seeing that and it's

976
00:40:12,640 --> 00:40:11,000
Kate reference the models are tough to

977
00:40:15,370 --> 00:40:12,650
match up and one of the reasons is the

978
00:40:17,260 --> 00:40:15,380
feedback the poorly named positive

979
00:40:18,490 --> 00:40:17,270
feedback and negative feedback and I

980
00:40:21,910 --> 00:40:18,500
hope right now online we're only getting

981
00:40:24,040 --> 00:40:21,920
our kind of positive feedback is there

982
00:40:25,360 --> 00:40:24,050
feedback both negative and positive that

983
00:40:28,420 --> 00:40:25,370
we're still discovering or that could

984
00:40:31,710 --> 00:40:28,430
drastically change the models easily

985
00:40:33,790 --> 00:40:31,720
like today I mean first you go first

986
00:40:38,620 --> 00:40:33,800
this is where we disagree a little bit

987
00:40:40,660 --> 00:40:38,630
that's good so I we know a lot about

988
00:40:45,070 --> 00:40:40,670

clouds but there's still a lot that we

989
00:40:47,560 --> 00:40:45,080
have yet to understand so as as Brian

990
00:40:49,690 --> 00:40:47,570
showed we have evidence that clouds are

991
00:40:52,330 --> 00:40:49,700
changing in a lot of the ways that

992
00:40:54,640 --> 00:40:52,340
models say they should we have evidence

993
00:40:56,650 --> 00:40:54,650
that high clouds those those sort of

994
00:40:58,270 --> 00:40:56,660
blanket clouds that are so good at

995
00:41:00,430 --> 00:40:58,280
trapping radiation from the Earth's

996
00:41:02,800 --> 00:41:00,440
surface we have evidence that those are

997
00:41:04,930 --> 00:41:02,810
probably moving higher which actually

998
00:41:07,030 --> 00:41:04,940
increases their their thermal blanket

999
00:41:09,880 --> 00:41:07,040
power so that is an example of a

1000
00:41:11,920 --> 00:41:09,890
positive feedback or vicious cycle we

1001
00:41:14,080 --> 00:41:11,930
have some evidence that those low thick

1002
00:41:16,810 --> 00:41:14,090
clouds in the tropics are being pushed

1003
00:41:20,020 --> 00:41:16,820
toward the poles by changes in the

1004
00:41:21,970 --> 00:41:20,030
circulation and that is also a positive

1005
00:41:23,430 --> 00:41:21,980
feedback because if you're really good

1006
00:41:24,870 --> 00:41:23,440
at blocking sunlight

1007
00:41:26,670 --> 00:41:24,880
you probably want to live in the tropics

1008
00:41:29,579 --> 00:41:26,680
where the sunlight is the most intense

1009
00:41:31,380 --> 00:41:29,589
and if you move toward the poles you're

1010
00:41:34,309 --> 00:41:31,390
probably gonna be less effective just

1011
00:41:37,589 --> 00:41:34,319
because you're blocking weaker sunlight

1012
00:41:40,319 --> 00:41:37,599
there are there there is an example of a

1013
00:41:42,390 --> 00:41:40,329

negative feedback which is as Brian

1014
00:41:44,249 --> 00:41:42,400
mentioned the composition of clouds we

1015
00:41:46,589 --> 00:41:44,259
expect some of those ice clouds are what

1016
00:41:48,990 --> 00:41:46,599
we call mixed phase clouds to become

1017
00:41:52,079 --> 00:41:49,000
kind of juicier as the ice melts in a

1018
00:41:53,819 --> 00:41:52,089
warmer world that's a that's an example

1019
00:41:55,499 --> 00:41:53,829
of a negative feedback because those

1020
00:41:58,589 --> 00:41:55,509
juicier clouds will actually become

1021
00:42:00,539 --> 00:41:58,599
better at blocking sunlight this is

1022
00:42:03,359 --> 00:42:00,549
something that's already incorporated in

1023
00:42:05,640 --> 00:42:03,369
climate models and unfortunately there

1024
00:42:08,249 --> 00:42:05,650
may be evidence that we at least in the

1025
00:42:10,620 --> 00:42:08,259
last generation of models overestimated

1026
00:42:15,839 --> 00:42:10,630
that impact so that may be less

1027
00:42:18,630 --> 00:42:15,849
mitigating than perhaps we would have I

1028
00:42:21,950 --> 00:42:18,640
guess my take-home point is that it is

1029
00:42:24,359 --> 00:42:21,960
hard for me to think of clouds

1030
00:42:26,130 --> 00:42:24,369
constituting a significant negative

1031
00:42:28,109 --> 00:42:26,140
feedback and in plain English that means

1032
00:42:32,670 --> 00:42:28,119
I don't think clouds are gonna save us

1033
00:42:35,099 --> 00:42:32,680
from global warming yeah some ways are

1034
00:42:37,200 --> 00:42:35,109
kind of a great Kait that we we can't

1035
00:42:39,180 --> 00:42:37,210
hope that clouds are gonna save us

1036
00:42:42,630 --> 00:42:39,190
because we I don't know we can think

1037
00:42:44,249 --> 00:42:42,640
that way but there are pathways where

1038
00:42:45,690 --> 00:42:44,259

which negative feedbacks can occur and

1039
00:42:47,849 --> 00:42:45,700
then we don't really fully understand

1040
00:42:49,499 --> 00:42:47,859
all the interactions that take place in

1041
00:42:51,480 --> 00:42:49,509
the Earth's climate system and how Clapp

1042
00:42:53,759 --> 00:42:51,490
the role clouds play so for example just

1043
00:42:55,859 --> 00:42:53,769
as a center simple observation we know

1044
00:42:57,839 --> 00:42:55,869
that for those regions were those big

1045
00:43:00,240 --> 00:42:57,849
high clouds are the big thermal blanket

1046
00:43:02,609 --> 00:43:00,250
clouds are in the tropics that those are

1047
00:43:03,569 --> 00:43:02,619
ice clouds that Brian shows you moving

1048
00:43:06,599 --> 00:43:03,579
back and forth but they're in the

1049
00:43:08,490 --> 00:43:06,609
tropical latitudes well over multi-angle

1050
00:43:10,620 --> 00:43:08,500
timescales the tropical atmosphere

1051
00:43:13,650 --> 00:43:10,630
breathes it goes up and it goes down

1052
00:43:16,259 --> 00:43:13,660
goes up and it goes down and as a

1053
00:43:18,359 --> 00:43:16,269
breathe the high clouds go up and goes

1054
00:43:20,970 --> 00:43:18,369
down just like Kate said but they also

1055
00:43:23,549 --> 00:43:20,980
get thicker and wider and that's a

1056
00:43:25,430 --> 00:43:23,559
negative feedback you see so aspects of

1057
00:43:27,569 --> 00:43:25,440
those clouds and how ties to the

1058
00:43:29,400 --> 00:43:27,579
breathing of the atmosphere we don't

1059
00:43:31,230 --> 00:43:29,410
fully understand that there is a pathway

1060
00:43:34,230 --> 00:43:31,240
by which a negative feedback could kick

1061
00:43:36,130 --> 00:43:34,240
in but he won't be I can't see it

1062
00:43:39,100 --> 00:43:36,140
overriding the

1063
00:43:42,040 --> 00:43:39,110

the effect of the continuous buildup of

1064
00:43:45,430 --> 00:43:42,050
greenhouse gases it could mitigate could

1065
00:43:48,190 --> 00:43:45,440
mitigate in certain areas but we can't

1066
00:43:50,800 --> 00:43:48,200
we can't the feedbacks we know of that

1067
00:43:52,840 --> 00:43:50,810
we're somewhat confident about or seem

1068
00:43:54,580 --> 00:43:52,850
to be positive but it does not rule out

1069
00:43:56,920 --> 00:43:54,590
that there are negative feedbacks in

1070
00:43:58,570 --> 00:43:56,930
your system just like I said right so

1071
00:44:00,280 --> 00:43:58,580
that's where I come from I'm sort of

1072
00:44:03,250 --> 00:44:00,290
more open-minded that suggests that

1073
00:44:04,600 --> 00:44:03,260
there there are negative pathways but I

1074
00:44:08,380 --> 00:44:04,610
just don't know that they're gonna be

1075
00:44:10,060 --> 00:44:08,390
strong enough to save us yeah I just

1076
00:44:11,710 --> 00:44:10,070
like to have fell onto something that

1077
00:44:14,170 --> 00:44:11,720
Kate said at the end of your talk about

1078
00:44:16,350 --> 00:44:14,180
the pattern the pattern really matters

1079
00:44:18,910 --> 00:44:16,360
you know whether you have more warm

1080
00:44:21,280 --> 00:44:18,920
water in the future and one side of the

1081
00:44:23,560 --> 00:44:21,290
Pacific versus the other is really key

1082
00:44:25,300 --> 00:44:23,570
to telling you whether there's going to

1083
00:44:27,700 --> 00:44:25,310
be more low cloud may be a negative

1084
00:44:29,170 --> 00:44:27,710
feedback versus a positive feedback so

1085
00:44:32,920 --> 00:44:29,180
we really don't know what's going to

1086
00:44:34,540 --> 00:44:32,930
happen in the future also despite all

1087
00:44:37,780 --> 00:44:34,550
those wonderful observations that we

1088
00:44:40,600 --> 00:44:37,790

have now we we really can't see with in

1089
00:44:43,630 --> 00:44:40,610
deeper precipitating clouds very well so

1090
00:44:45,840 --> 00:44:43,640
we don't know how fast the air is rising

1091
00:44:48,880 --> 00:44:45,850
we don't know whether it's a slow

1092
00:44:52,030 --> 00:44:48,890
large-scale movement or small little

1093
00:44:55,270 --> 00:44:52,040
violent movements and how that actually

1094
00:44:58,000 --> 00:44:55,280
maps on to creating cloud structures so

1095
00:45:06,880 --> 00:44:58,010
there is plenty for us to do in the

1096
00:45:09,370 --> 00:45:06,890
future just fine I think that you all

1097
00:45:10,810 --> 00:45:09,380
get along it's very nice Brian you had

1098
00:45:13,600 --> 00:45:10,820
that great image of the storms rolling

1099
00:45:16,510 --> 00:45:13,610
across the cut I really enjoyed that it

1100
00:45:18,130 --> 00:45:16,520
was very cool to look at but what is one

1101
00:45:21,730 --> 00:45:18,140
of those links between clouds and storms

1102
00:45:23,170 --> 00:45:21,740
what are what this feedback affect the

1103
00:45:27,940 --> 00:45:23,180
future of these storms does it make a

1104
00:45:31,330 --> 00:45:27,950
more severe please yeah that's a great

1105
00:45:34,660 --> 00:45:31,340
question Brian I know that the way that

1106
00:45:37,690 --> 00:45:34,670
I had view it is how Kate and Graham

1107
00:45:41,200 --> 00:45:37,700
discussed it in two different pieces you

1108
00:45:43,950 --> 00:45:41,210
have a hydrological cycle aspect so

1109
00:45:46,510 --> 00:45:43,960
that's how fast water moves around

1110
00:45:47,150 --> 00:45:46,520
evaporated you know forms precipitation

1111
00:45:49,400 --> 00:45:47,160
and comes back

1112
00:45:52,090 --> 00:45:49,410
down so that's about a time scale of 9

1113
00:45:54,340 --> 00:45:52,100

to 10 days or so for a given molecule

1114
00:45:55,520 --> 00:45:54,350
and then there's the radiative

1115
00:45:58,540 --> 00:45:55,530
consequences

1116
00:46:01,880 --> 00:45:58,550
so the Cloud distributions as a whole

1117
00:46:04,130 --> 00:46:01,890
control the climate sensitive is

1118
00:46:05,540 --> 00:46:04,140
sensitivity to some degree and then

1119
00:46:07,550 --> 00:46:05,550
there seems to be an inverse

1120
00:46:09,590 --> 00:46:07,560
relationship between the strength of the

1121
00:46:11,630 --> 00:46:09,600
climate sensitivity and the strength of

1122
00:46:14,900 --> 00:46:11,640
the hydrological cycle it appears that

1123
00:46:17,030 --> 00:46:14,910
some models that have a lower climate

1124
00:46:19,640 --> 00:46:17,040
sensitivity actually have a stronger

1125
00:46:24,200 --> 00:46:19,650
hydrological cycle increase which

1126
00:46:26,420 --> 00:46:24,210
implies an intensification of storms so

1127
00:46:29,060 --> 00:46:26,430
so that but it's but it's definitely

1128
00:46:31,310 --> 00:46:29,070
like an area that we're thinking hard

1129
00:46:33,110 --> 00:46:31,320
about right now and we don't have firm

1130
00:46:35,060 --> 00:46:33,120
answers on this so there's a very simple

1131
00:46:37,400 --> 00:46:35,070
reason why we think storms will get more

1132
00:46:39,920 --> 00:46:37,410
intense and one of the most really

1133
00:46:41,210 --> 00:46:39,930
undeniable feedbacks in your system as

1134
00:46:44,570 --> 00:46:41,220
Kate mentioned was this water vapor

1135
00:46:46,220 --> 00:46:44,580
feedback as as the air gets warmer all

1136
00:46:49,550 --> 00:46:46,230
things being equal it'll hold more water

1137
00:46:52,430 --> 00:46:49,560
will in the form of vapor the more water

1138
00:46:54,230 --> 00:46:52,440

in a volume of air that condenses the

1139
00:46:55,940 --> 00:46:54,240
more latent heat is released the more

1140
00:46:57,650 --> 00:46:55,950
latent heat is released and more violent

1141
00:47:00,170 --> 00:46:57,660
other storms because that's the dynamic

1142
00:47:02,720 --> 00:47:00,180
or heat that's the forcing function of

1143
00:47:05,060 --> 00:47:02,730
the storms is this Laden heating so we

1144
00:47:07,700 --> 00:47:05,070
think all things being equal that

1145
00:47:10,220 --> 00:47:07,710
greater condensation will lead to more

1146
00:47:12,830 --> 00:47:10,230
intense vigorous storms which means

1147
00:47:14,990 --> 00:47:12,840
probably heavier rain but I said all

1148
00:47:17,150 --> 00:47:15,000
things being equal and one of the key

1149
00:47:18,860 --> 00:47:17,160
things we don't yet resolving models

1150
00:47:21,470 --> 00:47:18,870
they do a great job but you know the

1151
00:47:23,420 --> 00:47:21,480
major convective storms that give us the

1152
00:47:25,520 --> 00:47:23,430
midwest storms and tornadoes and those

1153
00:47:27,470 --> 00:47:25,530
other things those major storms are

1154
00:47:29,870 --> 00:47:27,480
really poorly resolved right now in the

1155
00:47:33,200 --> 00:47:29,880
climate models so while we think there's

1156
00:47:35,330 --> 00:47:33,210
an overriding basic physical process but

1157
00:47:37,430 --> 00:47:35,340
which storms would get more intense the

1158
00:47:39,860 --> 00:47:37,440
models don't quite resolve them

1159
00:47:41,960 --> 00:47:39,870
faithfully enough for us to be a hundred

1160
00:47:44,240 --> 00:47:41,970
percent sure but that's going to change

1161
00:47:45,800 --> 00:47:44,250
you know in in the next 10 years we're

1162
00:47:47,870 --> 00:47:45,810
going to see models actually resolve

1163
00:47:49,610 --> 00:47:47,880

individual thunderstorm we actually see

1164
00:47:52,280 --> 00:47:49,620
them now they're not quite climate

1165
00:47:54,200 --> 00:47:52,290
models but that's the evolution so I

1166
00:47:55,700 --> 00:47:54,210
think we're gonna it's gonna be an

1167
00:47:57,050 --> 00:47:55,710
exciting time because we can be able to

1168
00:47:58,690 --> 00:47:57,060
say something we're quite quantitative

1169
00:48:00,460 --> 00:47:58,700
about storms and house

1170
00:48:03,839 --> 00:48:00,470
dorms will change in a warming world and

1171
00:48:12,790 --> 00:48:03,849
that's kind of a big issue for society

1172
00:48:14,410 --> 00:48:12,800
anything great like you tomorrow we're

1173
00:48:15,550 --> 00:48:14,420
gonna open it up for questions if

1174
00:48:17,290 --> 00:48:15,560
anybody in the audience has a question

1175
00:48:18,490 --> 00:48:17,300
there's there's a microphone right there

1176
00:48:20,200 --> 00:48:18,500
in the milk go ahead and line up while

1177
00:48:22,569 --> 00:48:20,210
you're working your way over there we're

1178
00:48:23,740 --> 00:48:22,579
gonna ask some the online questions and

1179
00:48:25,560 --> 00:48:23,750
this one really kinda has to do with

1180
00:48:29,050 --> 00:48:25,570
what we just heard

1181
00:48:34,140 --> 00:48:29,060
Nintendo m-- on YouTube asks will this

1182
00:48:41,620 --> 00:48:38,109
think so I mean I have an embarrassing

1183
00:48:45,970 --> 00:48:41,630
admission which is that I actually do

1184
00:48:49,150 --> 00:48:45,980
not care that much about clouds I came

1185
00:48:51,450 --> 00:48:49,160
to I came to cloud research because I

1186
00:48:55,630 --> 00:48:51,460
care about how hot it's gonna get and

1187
00:48:59,140 --> 00:48:55,640
clouds are such a vital part of the

1188
00:49:01,300 --> 00:48:59,150

climate system clouds are so important

1189
00:49:03,160 --> 00:49:01,310
and understanding and it's determining

1190
00:49:04,990 --> 00:49:03,170
basically how hot it's going to get and

1191
00:49:07,510 --> 00:49:05,000
then all of the consequences that flow

1192
00:49:09,430 --> 00:49:07,520
from that so if we could really sort of

1193
00:49:11,740 --> 00:49:09,440
determine and learn more about cloud

1194
00:49:14,680 --> 00:49:11,750
behavior we could be a lot more precise

1195
00:49:20,609 --> 00:49:14,690
with our predictions for the future

1196
00:49:24,510 --> 00:49:21,849
hello

1197
00:49:27,430 --> 00:49:24,520
my question actually is for Brian and

1198
00:49:29,230 --> 00:49:27,440
you earlier had put in or not put in

1199
00:49:31,240 --> 00:49:29,240
that doesn't make sense you earlier in

1200
00:49:36,000 --> 00:49:31,250
your speech had done a great job of

1201
00:49:40,599 --> 00:49:36,010
showing your evidence and one of your

1202
00:49:45,130 --> 00:49:40,609
slides had what was called e C F yeah

1203
00:49:47,260 --> 00:49:45,140
can you please explain what ecfs that

1204
00:49:51,099 --> 00:49:47,270
that's something it's called an

1205
00:49:52,839 --> 00:49:51,109
effective cloud fraction so I should

1206
00:49:55,510 --> 00:49:52,849
have changed the title to something more

1207
00:49:59,319 --> 00:49:55,520
simple Wow yeah it's basically just

1208
00:50:01,480 --> 00:49:59,329
tells you how much cloud there is kind

1209
00:50:04,150 --> 00:50:01,490
of the area and also like how thick the

1210
00:50:07,059 --> 00:50:04,160
clouds are but multiplied together so

1211
00:50:09,130 --> 00:50:07,069
it's not fresh yeah it's not just a

1212
00:50:12,160 --> 00:50:09,140
coverage but it also accounts for how

1213
00:50:14,440 --> 00:50:12,170

kind of opaque or transparent

1214
00:50:17,500 --> 00:50:14,450
clouds are to radiation it's like a

1215
00:50:19,030 --> 00:50:17,510
volume right like a volume yeah

1216
00:50:21,880 --> 00:50:19,040
while he's finishing taking that note

1217
00:50:24,970 --> 00:50:21,890
we'll ask another question from online

1218
00:50:27,640 --> 00:50:24,980
how do geostationary satellites exist in

1219
00:50:31,299 --> 00:50:27,650
the hot thermosphere Dean on YouTube

1220
00:50:33,039 --> 00:50:31,309
wants to know that juicy research than a

1221
00:50:36,670 --> 00:50:33,049
hot thermos spirits so they're way above

1222
00:50:39,430 --> 00:50:36,680
it they're at about 36,000 kilometers or

1223
00:50:41,170 --> 00:50:39,440
so they're way out there I mean way up

1224
00:50:42,910 --> 00:50:41,180
there there's six radio out there

1225
00:50:44,470 --> 00:50:42,920
there's so far out there

1226
00:50:46,990 --> 00:50:44,480
there you go Dean they're so far up

1227
00:50:48,490 --> 00:50:47,000
there next question but they have to be

1228
00:50:50,589 --> 00:50:48,500
able that way out there so that they can

1229
00:50:53,140 --> 00:50:50,599
basically wrap around move with the

1230
00:50:54,549 --> 00:50:53,150
earth and allows you to stare their

1231
00:50:56,140 --> 00:50:54,559
unique thing about geostationary they

1232
00:50:58,240 --> 00:50:56,150
allow us to stare at earth and see

1233
00:51:00,670 --> 00:50:58,250
things changing whether polar orbiting

1234
00:51:03,549 --> 00:51:00,680
satellites are going whizzing over in 90

1235
00:51:05,650 --> 00:51:03,559
minutes they wrapped around Earth so

1236
00:51:07,510 --> 00:51:05,660
geostationary is very valuable and the

1237
00:51:09,819 --> 00:51:07,520
geostationary satellites interestingly

1238
00:51:12,280 --> 00:51:09,829

enough for getting more and more capable

1239
00:51:14,289 --> 00:51:12,290
before they were just like cameras and

1240
00:51:16,480 --> 00:51:14,299
now they gain to be really serious kinds

1241
00:51:18,819 --> 00:51:16,490
of measurement tools that we can still

1242
00:51:20,710 --> 00:51:18,829
see from 36,000 kilometers they're even

1243
00:51:23,380 --> 00:51:20,720
talking here at JPL about putting radars

1244
00:51:25,839 --> 00:51:23,390
up until station 3 6,000 kilometers with

1245
00:51:30,000 --> 00:51:25,849
with an antenna so big it's gonna block

1246
00:51:34,539 --> 00:51:30,010
the Sun and that'll cool the earth yeah

1247
00:51:36,670 --> 00:51:34,549
geoengineering we call that I did have

1248
00:51:39,339 --> 00:51:36,680
one last question and that was 4k which

1249
00:51:41,770 --> 00:51:39,349
is earlier you had given co2 is carbon

1250
00:51:50,589 --> 00:51:41,780
dioxide is there a chemical formula for

1251
00:51:53,470 --> 00:51:50,599
water vapor okay thank you very special

1252
00:51:55,510 --> 00:51:53,480
molecule two very special shape that

1253
00:52:00,880 --> 00:51:55,520
allows it to radiate that is my favorite

1254
00:52:06,970 --> 00:52:00,890
molecule a very very good set of

1255
00:52:09,760 --> 00:52:06,980
presentations I so much focus has been

1256
00:52:12,039 --> 00:52:09,770
on what the climate will be in 2100 and

1257
00:52:17,770 --> 00:52:12,049
as very few of us who are here today

1258
00:52:21,359 --> 00:52:17,780
that's going to be here in 2100 and so

1259
00:52:25,750 --> 00:52:21,369
I'm asking how much we can say about say

1260
00:52:29,950 --> 00:52:25,760
2050 so that's 31 years from now

1261
00:52:33,820 --> 00:52:29,960
and it would seem you you talked about

1262
00:52:38,830 --> 00:52:33,830
the the tendency to have more intense

1263
00:52:41,590 --> 00:52:38,840

storms it would seem like the storms are

1264
00:52:44,410 --> 00:52:41,600
getting worse over just the last 10

1265
00:52:47,860 --> 00:52:44,420
years versus the previous 10 years but

1266
00:52:52,000 --> 00:52:47,870
of course that could be variability so I

1267
00:52:56,020 --> 00:52:52,010
know that the things are happening as

1268
00:52:59,080 --> 00:52:56,030
far as melting of the of the ice sheets

1269
00:53:02,470 --> 00:52:59,090
in Greenland and the Arctic Ocean and

1270
00:53:05,380 --> 00:53:02,480
Antarctica those processes tend to be

1271
00:53:07,170 --> 00:53:05,390
nonlinear and so you you you get you

1272
00:53:13,930 --> 00:53:07,180
know you're getting rather dramatic

1273
00:53:15,880 --> 00:53:13,940
shifts so the question is I mean this is

1274
00:53:19,780 --> 00:53:15,890
very hard because the models are so

1275
00:53:22,150 --> 00:53:19,790
complex but do is there do we think it's

1276
00:53:26,050 --> 00:53:22,160
going to be kind of exponentially

1277
00:53:30,910 --> 00:53:26,060
getting worse in the next 30 years or

1278
00:53:33,520 --> 00:53:30,920
just kind of gradually came I mean that

1279
00:53:36,760 --> 00:53:33,530
is that's a really great question with

1280
00:53:38,350 --> 00:53:36,770
so many layers to it because it gets at

1281
00:53:41,770 --> 00:53:38,360
something that I think about a lot which

1282
00:53:43,720 --> 00:53:41,780
is when I think about global warming so

1283
00:53:46,390 --> 00:53:43,730
you know the increase in the average

1284
00:53:49,360 --> 00:53:46,400
temperature of the planet my first

1285
00:53:51,910 --> 00:53:49,370
question is who cares because nobody

1286
00:53:53,560 --> 00:53:51,920
actually feels the average temperature

1287
00:53:56,740 --> 00:53:53,570
of the planet you know what we what we

1288
00:53:59,410 --> 00:53:56,750

feel is the impacts of that so in

1289
00:54:02,530 --> 00:53:59,420
California you know forest fires

1290
00:54:04,870 --> 00:54:02,540
you know mudslides you know in New York

1291
00:54:08,800 --> 00:54:04,880
we're worried about sea level rise and

1292
00:54:11,860 --> 00:54:08,810
those impacts so asking about badness

1293
00:54:15,250 --> 00:54:11,870
you know is is really complex because a

1294
00:54:17,920 --> 00:54:15,260
lot of those impacts scale nicely and

1295
00:54:20,620 --> 00:54:17,930
linearly with the temperature and some

1296
00:54:22,330 --> 00:54:20,630
don't and then even when you're looking

1297
00:54:23,950 --> 00:54:22,340
at just the global average temperature

1298
00:54:27,190 --> 00:54:23,960
itself there's always the possibility

1299
00:54:29,480 --> 00:54:27,200
for for tipping points you know so I

1300
00:54:32,420 --> 00:54:29,490
talked a lot about

1301
00:54:36,109 --> 00:54:32,430
unknowns so things that we know we don't

1302
00:54:38,660 --> 00:54:36,119
know there are also unknown unknowns so

1303
00:54:45,500 --> 00:54:38,670
things that we don't even know we don't

1304
00:54:47,690 --> 00:54:45,510
know and you know those those could be

1305
00:54:50,180 --> 00:54:47,700
things like you know substantial

1306
00:54:52,460 --> 00:54:50,190
negative out feedbacks but those could

1307
00:54:54,770 --> 00:54:52,470
also be tipping points in the climate

1308
00:54:56,420 --> 00:54:54,780
system that kind of push us away from

1309
00:54:58,609 --> 00:54:56,430
this sort of linear increase in

1310
00:55:00,800 --> 00:54:58,619
temperature to a totally new regime and

1311
00:55:01,880 --> 00:55:00,810
so that's that's something to think

1312
00:55:04,190 --> 00:55:01,890
about that's something to worry about

1313
00:55:05,510 --> 00:55:04,200

but the thing about unknown unknowns is

1314
00:55:09,200 --> 00:55:05,520
that they're hard to think about because

1315
00:55:10,730 --> 00:55:09,210
you don't know them so you know I think

1316
00:55:12,140 --> 00:55:10,740
I think it's a great question and I

1317
00:55:16,930 --> 00:55:12,150
think it's probably worth like several

1318
00:55:24,260 --> 00:55:20,329
specific thing is the is a possibility

1319
00:55:26,240 --> 00:55:24,270
that the permafrost will accelerate the

1320
00:55:29,570 --> 00:55:26,250
melting the melting of permafrost will

1321
00:55:32,680 --> 00:55:29,580
accelerate and would have more methane

1322
00:55:35,540 --> 00:55:32,690
and more co2 released and that would be

1323
00:55:38,089 --> 00:55:35,550
an example of one of your your your

1324
00:55:41,089 --> 00:55:38,099
known unknowns right so permafrost

1325
00:55:43,160 --> 00:55:41,099
melting almost certainly will definitely

1326
00:55:45,500 --> 00:55:43,170
releases methane into the atmosphere and

1327
00:55:49,010 --> 00:55:45,510
methane is a very very potent greenhouse

1328
00:55:52,220 --> 00:55:49,020
gas sometimes I think periodically in

1329
00:55:54,380 --> 00:55:52,230
the media there is a lot of in for you

1330
00:55:56,300 --> 00:55:54,390
know a sort of a scare about is there a

1331
00:55:58,430 --> 00:55:56,310
methane bomb is it going to happen all

1332
00:56:00,349 --> 00:55:58,440
of a sudden and I think there's not a

1333
00:56:03,410 --> 00:56:00,359
lot of evidence to support kind of an

1334
00:56:04,970 --> 00:56:03,420
abrupt bomb of methane going off but

1335
00:56:07,690 --> 00:56:04,980
there is a lot of evidence to support

1336
00:56:10,870 --> 00:56:07,700
that sort of slow and gradual feedback

1337
00:56:14,450 --> 00:56:10,880
so is it going to make things worse

1338
00:56:15,670 --> 00:56:14,460

almost certainly is it going to dump a

1339
00:56:20,300 --> 00:56:15,680
lot of methane into the atmosphere

1340
00:56:22,370 --> 00:56:20,310
immediately probably not thank you thank

1341
00:56:24,800 --> 00:56:22,380
you before our next question in house

1342
00:56:27,320 --> 00:56:24,810
these two from from the interwebs are

1343
00:56:29,210 --> 00:56:27,330
closely related Wesley and Caleb both on

1344
00:56:31,250 --> 00:56:29,220
YouTube one of them asks why there's so

1345
00:56:34,910 --> 00:56:31,260
many different types of clouds and Caleb

1346
00:56:38,420 --> 00:56:34,920
asked wire clouds great there's so many

1347
00:56:40,700 --> 00:56:38,430
different types of clouds it it's really

1348
00:56:41,890 --> 00:56:40,710
sort of an arbitrary set of definitions

1349
00:56:44,910 --> 00:56:41,900
that we have

1350
00:56:47,529 --> 00:56:44,920
for cloud types you mean the wmo

1351
00:56:51,099 --> 00:56:47,539
classification system i think is close

1352
00:56:53,680 --> 00:56:51,109
to 200 different cloud types from

1353
00:56:57,240 --> 00:56:53,690
surface observers there's typically

1354
00:57:00,010 --> 00:56:57,250
eight to nine types that dominate

1355
00:57:02,140 --> 00:57:00,020
sometimes you just call clouds liquid

1356
00:57:04,390 --> 00:57:02,150
versus ice or they may have the two

1357
00:57:06,640 --> 00:57:04,400
phases mixed together so it really

1358
00:57:09,130 --> 00:57:06,650
depends on how you think about clouds

1359
00:57:12,760 --> 00:57:09,140
and what you know what aspect of them

1360
00:57:15,400 --> 00:57:12,770
you want to want to quantify so how much

1361
00:57:18,910 --> 00:57:15,410
does that make a comment actually the

1362
00:57:20,230 --> 00:57:18,920
naming of the clouds was was has been

1363
00:57:22,690 --> 00:57:20,240

considered to be one of the great

1364
00:57:24,760 --> 00:57:22,700
achievements in the human endeavor and

1365
00:57:27,430 --> 00:57:24,770
the reason for that it was done by a

1366
00:57:30,700 --> 00:57:27,440
book a chemist name is Luke Elwood back

1367
00:57:32,289 --> 00:57:30,710
in 1800 and - and before that time that

1368
00:57:34,599 --> 00:57:32,299
was felt that clouds could never be

1369
00:57:37,089 --> 00:57:34,609
categorized because they're so variable

1370
00:57:39,069 --> 00:57:37,099
and so moving and so forth and he was

1371
00:57:40,870 --> 00:57:39,079
able to come up with a strategy to name

1372
00:57:44,140 --> 00:57:40,880
them that's persisted ever since and

1373
00:57:46,589 --> 00:57:44,150
that naming of clouds were it was

1374
00:57:49,750 --> 00:57:46,599
perceived to be a great sort of

1375
00:57:51,010 --> 00:57:49,760
philosophical advance of the time and it

1376
00:57:53,410 --> 00:57:51,020
was actually what gave rise to

1377
00:57:55,210 --> 00:57:53,420
meteorology as a science which was until

1378
00:57:57,490 --> 00:57:55,220
the naming of clouds that we begin to

1379
00:57:59,680 --> 00:57:57,500
realize that clouds played a role in

1380
00:58:01,750 --> 00:57:59,690
science they so speculate about you know

1381
00:58:03,640 --> 00:58:01,760
what Ella made of and so for back of a

1382
00:58:07,120 --> 00:58:03,650
hundred so the name in the clouds of the

1383
00:58:09,250 --> 00:58:07,130
cloud types has a deep rooted deeper

1384
00:58:12,760 --> 00:58:09,260
influence in the history of the study of

1385
00:58:14,819 --> 00:58:12,770
the atmosphere so it's something that's

1386
00:58:17,680 --> 00:58:14,829
sort of near and dear to me in some ways

1387
00:58:19,750 --> 00:58:17,690
the reason there are so there are there

1388
00:58:22,089 --> 00:58:19,760

aren't an inference of clouds there's

1389
00:58:23,740 --> 00:58:22,099
cloud different cloud types that are

1390
00:58:26,980 --> 00:58:23,750
organized by the dynamics of the

1391
00:58:28,569 --> 00:58:26,990
atmosphere so air that so the strata

1392
00:58:30,700 --> 00:58:28,579
from those clouds are Kate talked about

1393
00:58:32,859 --> 00:58:30,710
the low clouds that are that are highly

1394
00:58:34,390 --> 00:58:32,869
reflective and block the sunlight they

1395
00:58:37,329 --> 00:58:34,400
live in a world where the air and

1396
00:58:39,579 --> 00:58:37,339
primarily actually sinking above and

1397
00:58:41,170 --> 00:58:39,589
they keep their flat they it's back in

1398
00:58:43,000 --> 00:58:41,180
the lower part of the atmosphere because

1399
00:58:44,920 --> 00:58:43,010
the air sinking below so that sort of

1400
00:58:46,839 --> 00:58:44,930
sets up one sort of cloud type other

1401
00:58:48,400 --> 00:58:46,849
cloud types of where it's turbulent and

1402
00:58:50,260 --> 00:58:48,410
you know you got slain service and

1403
00:58:52,240 --> 00:58:50,270
mixing and and then the other cloud

1404
00:58:53,400 --> 00:58:52,250
types are where you got major movement

1405
00:58:56,010 --> 00:58:53,410
of air pushing

1406
00:58:58,350 --> 00:58:56,020
doreen and it goes deep convection so

1407
00:59:00,870 --> 00:58:58,360
it's sort of it's sort of controlled by

1408
00:59:03,300 --> 00:59:00,880
the modes in which air moves around and

1409
00:59:04,950 --> 00:59:03,310
lifts water and there's only different

1410
00:59:06,900 --> 00:59:04,960
there only a handful of modes in which

1411
00:59:08,730 --> 00:59:06,910
ways that sort of really happens and

1412
00:59:11,490 --> 00:59:08,740
that's why sort of an out the types of

1413
00:59:13,290 --> 00:59:11,500

clouds are you know there are eight

1414
00:59:17,340 --> 00:59:13,300
broad categories but there are

1415
00:59:19,080 --> 00:59:17,350
subcategories of those you see so in you

1416
00:59:21,000 --> 00:59:19,090
know the name of Klaus was as I said

1417
00:59:22,530 --> 00:59:21,010
game was one of the perceived to be one

1418
00:59:24,660 --> 00:59:22,540
of the great endeavors of human

1419
00:59:26,310 --> 00:59:24,670
philosophy at the time where we name

1420
00:59:28,470 --> 00:59:26,320
something if they thought could never be

1421
00:59:31,350 --> 00:59:28,480
named I think God could name clouds

1422
00:59:32,970 --> 00:59:31,360
because God he had control and humans

1423
00:59:35,490 --> 00:59:32,980
could not understand but you know Luke

1424
00:59:37,770 --> 00:59:35,500
Elwood came forward and he wasn't even

1425
00:59:39,000 --> 00:59:37,780
atmospheric scientists chemists that was

1426
00:59:42,410 --> 00:59:39,010
quite amazing anyway that's it

1427
00:59:44,760 --> 00:59:42,420
that's it all slide thought history so

1428
00:59:46,170 --> 00:59:44,770
we've got one big time from one more

1429
00:59:47,040 --> 00:59:46,180
question or gentleman standing right

1430
00:59:48,690 --> 00:59:47,050
there in the middle

1431
00:59:54,450 --> 00:59:48,700
is it possible has a pair of questions

1432
00:59:55,710 --> 00:59:54,460
yeah sure speakers will stick around for

1433
00:59:57,030 --> 00:59:55,720
a couple minutes afterwards so if you

1434
00:59:58,740 --> 00:59:57,040
have questions you can come up and ask

1435
01:00:01,980 --> 00:59:58,750
them that first one should be a quickie

1436
01:00:04,890 --> 01:00:01,990
in the embedded lightning strikes and

1437
01:00:07,740 --> 01:00:04,900
discharges overlaid with the clouds do

1438
01:00:10,290 --> 01:00:07,750

those function as a proxy for how much

1439
01:00:13,920 --> 01:00:10,300
vertical lift there is in a in a given

1440
01:00:15,690 --> 01:00:13,930
environment yet people do do use

1441
01:00:17,820 --> 01:00:15,700
lightning data as a proxy for the

1442
01:00:21,840 --> 01:00:17,830
vertical motion it's also an interesting

1443
01:00:24,390 --> 01:00:21,850
proxy for what the the ice particles are

1444
01:00:26,310 --> 01:00:24,400
shaped like in the cloud to use it's

1445
01:00:28,470 --> 01:00:26,320
typically you're like the big mixture of

1446
01:00:30,360 --> 01:00:28,480
water and ice yeah makes the charge

1447
01:00:32,130 --> 01:00:30,370
separation so it's a kind of a proxy for

1448
01:00:35,460 --> 01:00:32,140
you gotta air moving up that has both

1449
01:00:40,550 --> 01:00:35,470
water and ice in it and the second

1450
01:00:47,690 --> 01:00:40,560
question what are your thoughts on

1451
01:00:50,060 --> 01:00:47,700
efficacy scale and morality of using

1452
01:00:52,680 --> 01:00:50,070
geoengineering in the context of

1453
01:00:55,560 --> 01:00:52,690
generating clouds like if you had rafts

1454
01:00:57,360 --> 01:00:55,570
of black and white reflectors that were

1455
01:00:59,010 --> 01:00:57,370
powered by solar energy that you could

1456
01:01:00,840 --> 01:00:59,020
change the albedo of regional areas in

1457
01:01:02,880 --> 01:01:00,850
the ocean generating low cloud types

1458
01:01:05,370 --> 01:01:02,890
what would be what would be your

1459
01:01:05,760 --> 01:01:05,380
thoughts on using nature to help undo

1460
01:01:07,440 --> 01:01:05,770
what we

1461
01:01:11,190 --> 01:01:07,450
crudo life strong thoughts on this but

1462
01:01:14,130 --> 01:01:11,200
I'll let someone else this okay okay so

1463
01:01:15,950 --> 01:01:14,140

one I'm from Australia obviously because

1464
01:01:19,290 --> 01:01:15,960
my accent right and you know we've done

1465
01:01:21,060 --> 01:01:19,300
bio geoengineering game which screwed up

1466
01:01:22,230 --> 01:01:21,070
totally up so if you don't understand

1467
01:01:24,360 --> 01:01:22,240
the system you don't want to kind of

1468
01:01:25,890 --> 01:01:24,370
engineer but he's a problem you know

1469
01:01:27,240 --> 01:01:25,900
there's a hypothesis that you just put

1470
01:01:28,920 --> 01:01:27,250
stuff in the cloud and make the brighter

1471
01:01:30,870 --> 01:01:28,930
right this is one of the concepts like

1472
01:01:32,490 --> 01:01:30,880
the brightening of the clouds well it

1473
01:01:35,340 --> 01:01:32,500
turns out if you actually really study

1474
01:01:37,020 --> 01:01:35,350
this carefully in which we have done you

1475
01:01:38,450 --> 01:01:37,030
know thirty percent of the time the

1476
01:01:42,090 --> 01:01:38,460
clouds actually get darker when you put

1477
01:01:44,280 --> 01:01:42,100
aerosol in so it's not clear that just

1478
01:01:46,290 --> 01:01:44,290
putting aerosol in our priori will

1479
01:01:48,390 --> 01:01:46,300
brighten the clouds so that's just an

1480
01:01:50,640 --> 01:01:48,400
example of if you don't understand the

1481
01:01:52,020 --> 01:01:50,650
system fully you better not tinker with

1482
01:01:53,940 --> 01:01:52,030
it because you know you could actually

1483
01:01:58,560 --> 01:01:53,950
get a response that's actually quite

1484
01:02:01,560 --> 01:01:58,570
different than you expect I would just

1485
01:02:03,750 --> 01:02:01,570
say even if it did work even if you did

1486
01:02:06,210 --> 01:02:03,760
manage to lower the global average

1487
01:02:07,530 --> 01:02:06,220
temperature there is so much that

1488
01:02:09,810 --> 01:02:07,540

accompanies that so you know that

1489
01:02:11,520 --> 01:02:09,820
doesn't if we don't cut emissions at the

1490
01:02:15,420 --> 01:02:11,530
same time that doesn't do anything about

1491
01:02:17,100 --> 01:02:15,430
ocean acidification that you know we

1492
01:02:19,170 --> 01:02:17,110
still probably see disruptions to

1493
01:02:21,210 --> 01:02:19,180
rainfall patterns because you know

1494
01:02:24,020 --> 01:02:21,220
blocking sunlight is not a perfect

1495
01:02:28,560 --> 01:02:24,030
mirror image of the greenhouse effect

1496
01:02:30,300 --> 01:02:28,570
and I I totally agree you know I we

1497
01:02:32,070 --> 01:02:30,310
there's so much about the climate system

1498
01:02:34,740 --> 01:02:32,080
that we do understand but there is so

1499
01:02:36,120 --> 01:02:34,750
much that we don't understand and you

1500
01:02:37,800 --> 01:02:36,130
know you can make an argument that we

1501
01:02:40,260 --> 01:02:37,810
are actually geoengineering the planet

1502
01:02:42,270 --> 01:02:40,270
right now inadvertently but I don't

1503
01:02:45,570 --> 01:02:42,280
think that that for me is a compelling

1504
01:02:49,230 --> 01:02:45,580
argument to then turn around and and do

1505
01:02:50,580 --> 01:02:49,240
this deliberately made the point that we

1506
01:02:53,340 --> 01:02:50,590
still have uncertainties about clouds

1507
01:02:55,110 --> 01:02:53,350
and the climate models right so why

1508
01:02:56,790 --> 01:02:55,120
would you why would you run inquire

1509
01:02:57,690 --> 01:02:56,800
model and Geoengineer clouds in a

1510
01:02:59,970 --> 01:02:57,700
climate model when there's such big

1511
01:03:02,070 --> 01:02:59,980
uncertainty on them and be and try to

1512
01:03:03,210 --> 01:03:02,080
convince anyone that that's the way

1513
01:03:06,630 --> 01:03:03,220

you're going to bring their planet back

1514
01:03:08,610 --> 01:03:06,640
I mean that's it's no logic to it really

1515
01:03:10,350 --> 01:03:08,620
you gotta have the right tools to be

1516
01:03:13,140 --> 01:03:10,360
convincing and right now I don't think

1517
01:03:15,180 --> 01:03:13,150
our tools are precise enough to you know

1518
01:03:18,009 --> 01:03:15,190
guide us

1519
01:03:23,140 --> 01:03:18,019
well thank you do have one more question

1520
01:03:25,990 --> 01:03:23,150
actually so my question is just related

1521
01:03:28,359 --> 01:03:26,000
to the variable of frequency and I'm

1522
01:03:30,099 --> 01:03:28,369
curious because from some of the stuff

1523
01:03:33,190 --> 01:03:30,109
that I've read about in my opinion

1524
01:03:35,019 --> 01:03:33,200
frequency technologies would be one of

1525
01:03:37,329 --> 01:03:35,029
the most dangerous threats to mankind or

1526
01:03:38,589 --> 01:03:37,339
I guess could be the most helpful too so

1527
01:03:41,200 --> 01:03:38,599
I'm wondering if we look at that and

1528
01:03:42,910 --> 01:03:41,210
things like HAARP technology and some of

1529
01:03:46,240 --> 01:03:42,920
the things just myself as a regular

1530
01:03:47,650 --> 01:03:46,250
civilian notices in the sky such as you

1531
01:03:49,450 --> 01:03:47,660
know people talk about contrails and

1532
01:03:50,829 --> 01:03:49,460
chemtrails I know there's a difference

1533
01:03:53,589 --> 01:03:50,839
like contrails aren't gonna last very

1534
01:03:56,319 --> 01:03:53,599
long chemtrails seem like they would

1535
01:03:59,349 --> 01:03:56,329
last longer in the sky and I see

1536
01:04:02,589 --> 01:03:59,359
patterns that I never studied in a

1537
01:04:04,930 --> 01:04:02,599
science class related to cloud imagery

1538
01:04:06,819 --> 01:04:04,940

when I look up in the sky so there's

1539
01:04:08,859 --> 01:04:06,829
definitely something going on and I'm

1540
01:04:10,329 --> 01:04:08,869
wondering if on I don't know what kind

1541
01:04:12,700 --> 01:04:10,339
of security access the three of you have

1542
01:04:13,900 --> 01:04:12,710
but what could you in light in this

1543
01:04:18,339 --> 01:04:13,910
audience tonight with that information

1544
01:04:20,740 --> 01:04:18,349
hey Brian yeah so I think you're

1545
01:04:22,960 --> 01:04:20,750
referring to these somewhat linear

1546
01:04:25,240 --> 01:04:22,970
trails that you see in the atmosphere

1547
01:04:29,259 --> 01:04:25,250
usually associated with cirrus clouds

1548
01:04:32,380 --> 01:04:29,269
right just let you tell us yeah yeah so

1549
01:04:35,559 --> 01:04:32,390
those are called condensation trails so

1550
01:04:38,370 --> 01:04:35,569
they occur from the seeding of aircraft

1551
01:04:41,559 --> 01:04:38,380
emissions in a supersaturated

1552
01:04:45,160 --> 01:04:41,569
environment with respect to relative

1553
01:04:47,440 --> 01:04:45,170
humidity so as this stuff is seated in

1554
01:04:50,440 --> 01:04:47,450
the upper troposphere it actually

1555
01:04:52,720 --> 01:04:50,450
condenses what available moisture is

1556
01:04:55,450 --> 01:04:52,730
around there into these tiny little ice

1557
01:04:59,109 --> 01:04:55,460
particles and they're very dense so you

1558
01:05:00,490 --> 01:04:59,119
see a very you know very thick stream of

1559
01:05:04,029 --> 01:05:00,500
this coming from the back of the

1560
01:05:06,819 --> 01:05:04,039
airplane now sometimes if the relative

1561
01:05:08,950 --> 01:05:06,829
humidity is high enough these will last

1562
01:05:12,339 --> 01:05:08,960
for a while like you'll you'll see a

1563
01:05:14,170 --> 01:05:12,349

long contrails but you know I can look

1564
01:05:16,170 --> 01:05:14,180
in academic databases and I can see

1565
01:05:18,670 --> 01:05:16,180
evidence that you know weather

1566
01:05:20,019 --> 01:05:18,680
modification is something that's part of

1567
01:05:23,740 --> 01:05:20,029
our history but it's not something that

1568
01:05:25,599 --> 01:05:23,750
is acknowledged on a mainstream level so

1569
01:05:27,609 --> 01:05:25,609
I mean I'm talking about the HAARP

1570
01:05:28,769 --> 01:05:27,619
technology it's there I'm talking about

1571
01:05:31,569 --> 01:05:28,779
weather car

1572
01:05:33,699 --> 01:05:31,579
there well Brian Brian was answering

1573
01:05:35,439 --> 01:05:33,709
your question contrails though but I'm

1574
01:05:38,079 --> 01:05:35,449
talking about specifically what would

1575
01:05:40,029 --> 01:05:38,089
appear to be chemtrails if they're

1576
01:05:42,489 --> 01:05:40,039
lasting longer than just a momentary

1577
01:05:45,189 --> 01:05:42,499
thing which a contrail what they do they

1578
01:05:47,559 --> 01:05:45,199
can last and then sometimes they're not

1579
01:05:50,109 --> 01:05:47,569
only just linear but they'll spread out

1580
01:05:51,819 --> 01:05:50,119
they'll spread out so the ex hatches

1581
01:05:53,919 --> 01:05:51,829
that we're seeing what is all that about

1582
01:05:55,959 --> 01:05:53,929
it's this very distance because you have

1583
01:05:57,219 --> 01:05:55,969
planes flying underneath each other

1584
01:05:59,469 --> 01:05:57,229
orthogonal to each other

1585
01:06:00,669 --> 01:05:59,479
another thing well that's actually all

1586
01:06:02,319 --> 01:06:00,679
the time that we do have if you want to

1587
01:06:03,819 --> 01:06:02,329
keep asking we can ask more as we come

1588
01:06:08,559 --> 01:06:03,829

up I'm also aware the thing that the

1589
01:06:10,059 --> 01:06:08,569
results can prevent lift so no that's

1590
01:06:11,289 --> 01:06:10,069
great we've got plenty time to stick

1591
01:06:12,939 --> 01:06:11,299
around and answer for but we're actually

1592
01:06:15,939 --> 01:06:12,949
just out of time we're actually a little

1593
01:06:18,370 --> 01:06:15,949
over on time so thank you all for your

1594
01:06:24,880 --> 01:06:18,380
questions I do want to thank dr. Graham

1595
01:06:28,900 --> 01:06:24,890
Stevens big round of applause dr. Brian

1596
01:06:30,339 --> 01:06:28,910
Cahn round of applause and dr. Kate

1597
01:06:36,549 --> 01:06:30,349
Marvel who flew all the way out here

1598
01:06:37,929 --> 01:06:36,559
from NASA gifts please join us next week

1599
01:06:39,219 --> 01:06:37,939
when we'll be taught next month I

1600
01:06:41,859 --> 01:06:39,229
apologize next month when we talk about

1601
01:06:43,160 --> 01:06:41,869
Cube sets and small sets thank you have

1602
01:06:48,030 --> 01:06:43,170
a great night everybody