
CLOUDS STABILIZE EARTH'S LONG TERM CLIMATE
COLIN GOLDBLATT

1
00:00:11,150 --> 00:00:06,849
[Music]

2
00:00:13,640 --> 00:00:11,160
okay thank you everyone and as we're in

3
00:00:16,730 --> 00:00:13,650
the sleepy sloth before lunch in a dark

4
00:00:20,179 --> 00:00:16,740
room with increasing co2 I'd like to

5
00:00:22,189 --> 00:00:20,189
take you back to earlier we shared some

6
00:00:26,839 --> 00:00:22,199
properties with this and talking about

7
00:00:28,490 --> 00:00:26,849
some work I've been doing with an

8
00:00:30,439 --> 00:00:28,500
excellent undergraduate students

9
00:00:32,600 --> 00:00:30,449
Victoria McDonald is now to grad school

10
00:00:37,160 --> 00:00:32,610
at u Dobbin like great clouds later as

11
00:00:38,930 --> 00:00:37,170
Kelly McCusker so we're talking about a

12
00:00:41,110 --> 00:00:38,940
problem that I've worked on quite a lot

13
00:00:43,940 --> 00:00:41,120

which is the faint young Sun paradox is

14
00:00:46,760 --> 00:00:43,950
main sequence stars get brighter through

15
00:00:48,560 --> 00:00:46,770
their lifetime so for a planet hanging

16
00:00:50,270 --> 00:00:48,570
out in the habitable zone like Earth

17
00:00:52,880 --> 00:00:50,280
that means we're going to get a

18
00:00:56,150 --> 00:00:52,890
monotonic increase in the solar constant

19
00:00:57,860 --> 00:00:56,160
through time and the geologic record on

20
00:01:00,740 --> 00:00:57,870
earth is well results about the last

21
00:01:04,340 --> 00:01:00,750
three and a half billion years and it

22
00:01:06,649 --> 00:01:04,350
looks like earth with mostly warmer that

23
00:01:09,440 --> 00:01:06,659
it is now we are in a glacial period now

24
00:01:11,899 --> 00:01:09,450
but evidence of glaciation is large yet

25
00:01:15,410 --> 00:01:11,909
absent for Earth history and in the

26
00:01:17,719 --> 00:01:15,420
first 8/9 of Earth history which we call

27
00:01:20,480 --> 00:01:17,729
the Precambrian there are a few low

28
00:01:26,289 --> 00:01:20,490
latitude glaciations but largely earth

29
00:01:31,130 --> 00:01:29,390
that's the introduction for problem ur a

30
00:01:32,990 --> 00:01:31,140
quantity I'm going to use quite a lot

31
00:01:34,760 --> 00:01:33,000
advaita de forcing which to first

32
00:01:35,840 --> 00:01:34,770
approximation is proportional to third

33
00:01:38,539 --> 00:01:35,850
the temperature change

34
00:01:41,480 --> 00:01:38,549
if we want to go back to a fashionable

35
00:01:43,039 --> 00:01:41,490
time period we need about 50 watts per

36
00:01:44,359 --> 00:01:43,049
square meter of radiative forcing

37
00:01:46,550 --> 00:01:44,369
remember that number it's going to

38
00:01:50,359 --> 00:01:46,560

become important if we're going to do

39
00:01:52,819 --> 00:01:50,369
that with co2 alone and in a 1d model so

40
00:01:56,959 --> 00:01:52,829
where we took out all the cloud feedback

41
00:01:59,929 --> 00:01:56,969
we'd need about a hundred thousand ppm

42
00:02:02,289 --> 00:01:59,939
and that's not consistent with Joe

43
00:02:04,819 --> 00:02:02,299
chemical forcing there have been some

44
00:02:07,340 --> 00:02:04,829
indications in fire work and three

45
00:02:10,990 --> 00:02:07,350
dimensions began to work by Benjamin

46
00:02:13,490 --> 00:02:11,000
Shan a and Eric wolf that in 3d lower

47
00:02:14,600 --> 00:02:13,500
co2 is needed and what I

48
00:02:16,630 --> 00:02:14,610
during this talk is really

49
00:02:21,290 --> 00:02:16,640
systematically look at the feedbacks

50
00:02:23,030 --> 00:02:21,300
involved there they will give you a bit

51
00:02:25,430 --> 00:02:23,040
of background first because no one yet

52
00:02:27,980 --> 00:02:25,440
has talked too much about evolution of

53
00:02:32,140 --> 00:02:27,990
terrestrial planet climate so this is a

54
00:02:35,810 --> 00:02:32,150
cartoon of the evolution of Earth

55
00:02:37,850 --> 00:02:35,820
atmosphere it had twelve orders of

56
00:02:40,540 --> 00:02:37,860
magnitude of dynamic range so when

57
00:02:44,630 --> 00:02:40,550
you're thinking about how might you

58
00:02:46,280 --> 00:02:44,640
detect an earth-like planet remember

59
00:02:49,190 --> 00:02:46,290
that it's really weird and there's a lot

60
00:02:52,690 --> 00:02:49,200
of big changes some places we could

61
00:02:55,340 --> 00:02:52,700
constrain how little we know other

62
00:02:57,140 --> 00:02:55,350
things whether than absence of error

63
00:02:59,979 --> 00:02:57,150

bars that include that implies that I

64
00:03:03,800 --> 00:02:59,989
don't even know what the error bars are

65
00:03:06,410 --> 00:03:03,810
and there's lots of stuff back here but

66
00:03:09,110 --> 00:03:06,420
in the non simplified version I might

67
00:03:11,330 --> 00:03:09,120
put back in the gist of this is we're

68
00:03:16,330 --> 00:03:11,340
looking at a high co2 atmosphere co2

69
00:03:18,440 --> 00:03:16,340
I've sketched in red here without oxygen

70
00:03:21,500 --> 00:03:18,450
bit of me phone we're not going to be

71
00:03:26,000 --> 00:03:21,510
using that today that's the kind of

72
00:03:27,440 --> 00:03:26,010
atmosphere that we're looking at and

73
00:03:30,949 --> 00:03:27,450
we're going to be looking at clouds and

74
00:03:33,500 --> 00:03:30,959
here is uh an older paper of mine where

75
00:03:35,509 --> 00:03:33,510
I did a parabola space exploration of

76
00:03:38,240 --> 00:03:35,519
clouds in one dimension this is a good

77
00:03:43,039 --> 00:03:38,250
plot for looking at what clouds have

78
00:03:45,590 --> 00:03:43,049
ever done for long and short ways that

79
00:03:48,110 --> 00:03:45,600
is reflecting incoming sunlight and long

80
00:03:51,110 --> 00:03:48,120
ways other to that is thermal emission

81
00:03:54,220 --> 00:03:51,120
are the two effects that we would sum to

82
00:03:56,990 --> 00:03:54,230
get nursing first clouds reflect

83
00:04:00,039 --> 00:03:57,000
incoming sunlight if the cloud cover the

84
00:04:02,680 --> 00:04:00,049
bigger faction of the skies if they have

85
00:04:06,110 --> 00:04:02,690
more water in them

86
00:04:08,000 --> 00:04:06,120
they reflect more sunlight so they're

87
00:04:09,920 --> 00:04:08,010
more blue that means they're more of a

88
00:04:14,229 --> 00:04:09,930

cooling effect and it doesn't really

89
00:04:17,270 --> 00:04:14,239
matter that much how high we put them

90
00:04:19,370 --> 00:04:17,280
but for the long wave the thermal effect

91
00:04:21,920 --> 00:04:19,380
it really does matter how high we put

92
00:04:24,409 --> 00:04:21,930
them because low clouds if we get a put

93
00:04:27,230 --> 00:04:24,419
a cloud just hovering around the top of

94
00:04:31,820 --> 00:04:30,469
you're different from the surface so the

95
00:04:33,890 --> 00:04:31,830
greenhouse effect come from a

96
00:04:35,390 --> 00:04:33,900
temperature difference so these low

97
00:04:37,460 --> 00:04:35,400
clouds won't have it like the

98
00:04:39,800 --> 00:04:37,470
temperature difference if I got a few

99
00:04:41,600 --> 00:04:39,810
tall people if we stood have someone on

100
00:04:44,029 --> 00:04:41,610
Dori and children and put the clouds

101
00:04:46,430 --> 00:04:44,039
quite high there'd be a lot colder than

102
00:04:48,320 --> 00:04:46,440
we were down here so that's going to be

103
00:04:50,990 --> 00:04:48,330
a big greenhouse effect from that pile

104
00:04:53,570 --> 00:04:51,000
to look big bed that means they've got a

105
00:04:56,150 --> 00:04:53,580
big warming effect so we sum these

106
00:04:58,909 --> 00:04:56,160
together high cloud more them's going to

107
00:05:00,290 --> 00:04:58,919
give the warming no clouds more of them

108
00:05:02,839 --> 00:05:00,300
is going to give the cooling but if we

109
00:05:06,020 --> 00:05:02,849
want to resolve the fade young Sun we

110
00:05:08,300 --> 00:05:06,030
need to take our low cloud this is how

111
00:05:11,870 --> 00:05:08,310
much we have today and we need to get

112
00:05:14,140 --> 00:05:11,880
rid of them we need to get them down

113
00:05:17,240 --> 00:05:14,150

here this talk I'm going to be talking

114
00:05:20,210 --> 00:05:17,250
mostly about these low clouds and

115
00:05:22,820 --> 00:05:20,220
getting rid of them using physics on

116
00:05:25,399 --> 00:05:22,830
earlier this is an unusual talk for me

117
00:05:31,550 --> 00:05:25,409
because no chemistry or biology will be

118
00:05:33,469 --> 00:05:31,560
invoked so yes a photo I took where are

119
00:05:35,390 --> 00:05:33,479
the postdoc at NASA Ames and I was out

120
00:05:37,219 --> 00:05:35,400
hiking improving counties this isn't

121
00:05:41,089 --> 00:05:37,229
very high we're looking at low clouds

122
00:05:42,740 --> 00:05:41,099
offshore of San Francisco these are the

123
00:05:45,110 --> 00:05:42,750
same clouds and satellite so these are

124
00:05:46,839 --> 00:05:45,120
really good clouds for getting

125
00:05:48,499 --> 00:05:46,849
reflection and they have a lousy

126
00:05:51,950 --> 00:05:48,509
greenhouse effect

127
00:05:55,189 --> 00:05:51,960
so visualize this visualize a miserable

128
00:06:01,700 --> 00:05:55,199
day at AG you where you've just been

129
00:06:04,100 --> 00:06:01,710
totally clouded out so this is the most

130
00:06:05,959 --> 00:06:04,110
important slide of the talk so pay

131
00:06:10,999 --> 00:06:05,969
attention we're going to talk about the

132
00:06:12,800 --> 00:06:11,009
physics here so we're where we get low

133
00:06:16,339 --> 00:06:12,810
clouds typically in the descending limb

134
00:06:18,320 --> 00:06:16,349
of the Hadley cell over really it's

135
00:06:20,779 --> 00:06:18,330
really good if we've got upwelling cold

136
00:06:23,510 --> 00:06:20,789
water fat loss chance of just go that's

137
00:06:26,029 --> 00:06:23,520
off Pulu off Namibia that kind of place

138
00:06:28,580 --> 00:06:26,039

is really good we've got climatological

139
00:06:33,320 --> 00:06:28,590
descent here but a cold sea surface

140
00:06:37,820 --> 00:06:33,330
temperature so we might have warmer

141
00:06:39,860 --> 00:06:37,830
level off this is Sigma W is a constant

142
00:06:40,610 --> 00:06:39,870
wet bulb potential temperature because

143
00:06:43,850 --> 00:06:40,620
this is the moist

144
00:06:46,400 --> 00:06:43,860
a bat and then here we've got a

145
00:06:48,800 --> 00:06:46,410
temperature inversion at the top of the

146
00:06:50,300 --> 00:06:48,810
atmospheric boundary layer and we could

147
00:06:52,430 --> 00:06:50,310
measure the strength of that inversion

148
00:06:53,840 --> 00:06:52,440
with a potential temperature difference

149
00:06:57,080 --> 00:06:53,850
which is called

150
00:06:59,420 --> 00:06:57,090
lower trophic stability or a wet bulb

151
00:07:02,180 --> 00:06:59,430
potential temperature difference which

152
00:07:04,219 --> 00:07:02,190
is called estimated inversion strength

153
00:07:07,189 --> 00:07:04,229
see the terms and the meteorology

154
00:07:11,689 --> 00:07:07,199
literature so what do we do with our low

155
00:07:13,520 --> 00:07:11,699
clouds well convection shallow

156
00:07:17,600 --> 00:07:13,530
convection in the boundary layer is

157
00:07:20,960 --> 00:07:17,610
driven by net thermal cooling from the

158
00:07:22,790 --> 00:07:20,970
cloud so these clouds will go to a emit

159
00:07:24,740 --> 00:07:22,800
black body radiation they're going to

160
00:07:26,810 --> 00:07:24,750
receive back radiation from the

161
00:07:30,560 --> 00:07:26,820
atmosphere and then there's a net

162
00:07:34,600 --> 00:07:30,570
cooling and that net cooling is what

163
00:07:36,920 --> 00:07:34,610

drives this shallow circulation here

164
00:07:39,439 --> 00:07:36,930
that's going to help us build the cloud

165
00:07:42,710 --> 00:07:39,449
it's going to bring air up to the point

166
00:07:44,960 --> 00:07:42,720
that it condensed here now if we want to

167
00:07:47,180 --> 00:07:44,970
get rid of these clouds we want to

168
00:07:49,100 --> 00:07:47,190
entertain dry air from the three

169
00:07:51,890 --> 00:07:49,110
troposphere remember this is descending

170
00:07:54,830 --> 00:07:51,900
limb of the Hadley cell so this is nice

171
00:07:56,750 --> 00:07:54,840
dry air and if we entrained this into

172
00:08:01,070 --> 00:07:56,760
the boundary layer that's going to dry

173
00:08:03,230 --> 00:08:01,080
out our cloud so let we're back in this

174
00:08:08,600 --> 00:08:03,240
room and we're in a dark room not many

175
00:08:09,770 --> 00:08:08,610
photons high co2 so high co2 is going to

176
00:08:12,950 --> 00:08:09,780
mean that we've got a stronger

177
00:08:19,279 --> 00:08:12,960
greenhouse so this back radiation term

178
00:08:21,260 --> 00:08:19,289
here is going to be bigger so this net

179
00:08:23,900 --> 00:08:21,270
radiative cooling is going to be weaker

180
00:08:28,189 --> 00:08:23,910
so that bad for our clouds we're not

181
00:08:30,680 --> 00:08:28,199
going to form clouds as well now become

182
00:08:32,839 --> 00:08:30,690
obvious and aside or to time when we've

183
00:08:35,659 --> 00:08:32,849
got a weaker solar constant that's going

184
00:08:36,800 --> 00:08:35,669
to be less good at driving convection in

185
00:08:39,170 --> 00:08:36,810
the tropics we've got less sunlight

186
00:08:41,779 --> 00:08:39,180
coming in we'll drive less convection

187
00:08:44,329 --> 00:08:41,789
and it's the moist convection in the

188
00:08:46,510 --> 00:08:44,339

tropics which sets the temperature in

189
00:08:50,630 --> 00:08:46,520
the hole aloft in the whole atmosphere

190
00:08:53,090 --> 00:08:50,640
so we go to cool the free troposphere

191
00:08:54,020 --> 00:08:53,100
here so we're going to have a weaker

192
00:08:56,810 --> 00:08:54,030
inversion here

193
00:09:00,650 --> 00:08:56,820
that we conversion means that we go to

194
00:09:04,430 --> 00:09:00,660
into a more dry air and we can dry out

195
00:09:06,830 --> 00:09:04,440
those clouds so no solo concert - OH -

196
00:09:09,830 --> 00:09:06,840
atmosphere the hypothesis is is that we

197
00:09:12,710 --> 00:09:09,840
should have less low clouds so let's do

198
00:09:14,180 --> 00:09:12,720
some model experiment for that and we're

199
00:09:15,860 --> 00:09:14,190
running this with an off-the-shelf

200
00:09:19,040 --> 00:09:15,870
version and back to off-the-shelf

201
00:09:25,330 --> 00:09:19,050
version of the community our system

202
00:09:29,270 --> 00:09:25,340
model we're using the five ocean cam for

203
00:09:31,760 --> 00:09:29,280
40 years average last 20 everything

204
00:09:34,700 --> 00:09:31,770
we're doing modern-day except we're

205
00:09:38,000 --> 00:09:34,710
tolling solar constant down and turning

206
00:09:41,060 --> 00:09:38,010
co2 up but we get the same mean surface

207
00:09:42,770 --> 00:09:41,070
temperature modern continents non ozone

208
00:09:45,680 --> 00:09:42,780
modern everything else because we just

209
00:09:48,080 --> 00:09:45,690
want to look at this one feedback and do

210
00:09:52,880 --> 00:09:48,090
have controlled an experiment of

211
00:09:55,340 --> 00:09:52,890
possible keeping the model near modern

212
00:09:57,680 --> 00:09:55,350
day conditions too much as we can so

213
00:10:00,980 --> 00:09:57,690

that we might actually trust what the

214
00:10:03,710 --> 00:10:00,990
model does there is a hope then if you

215
00:10:05,510 --> 00:10:03,720
want to look at a papers where other

216
00:10:08,240 --> 00:10:05,520
things have been changed like rotation

217
00:10:09,770 --> 00:10:08,250
rates continent positions all that kind

218
00:10:12,140 --> 00:10:09,780
of thing that I refer you to paper by a

219
00:10:13,940 --> 00:10:12,150
12 inch mesh on a look to this kind of

220
00:10:16,460 --> 00:10:13,950
problem before we also did some ones

221
00:10:18,590 --> 00:10:16,470
with cam 5 for smaller range of solar

222
00:10:20,780 --> 00:10:18,600
constant the tendency seems to be the

223
00:10:22,850 --> 00:10:20,790
more modern the climate model the left

224
00:10:27,829 --> 00:10:22,860
range of conditions we can run it for

225
00:10:32,660 --> 00:10:27,839
that is focus so here's the beginning of

226
00:10:35,480 --> 00:10:32,670
our model climatology all these baths on

227
00:10:38,930 --> 00:10:35,490
the left-hand side we have our control

228
00:10:40,550 --> 00:10:38,940
case on the right-hand side so this is

229
00:10:43,550 --> 00:10:40,560
the right-hand side of the left hand

230
00:10:45,620 --> 00:10:43,560
plots that is the middle we have point

231
00:10:49,760 --> 00:10:45,630
eight solar constants and then we have a

232
00:10:51,710 --> 00:10:49,770
different field here so less L are

233
00:10:56,480 --> 00:10:51,720
constant higher co2 we have warm up old

234
00:10:57,829 --> 00:10:56,490
cooler low latitudes will that pick up

235
00:10:59,720 --> 00:10:57,839
we've got a stronger greenhouse effect

236
00:11:02,060 --> 00:10:59,730
that really matters at the poles where

237
00:11:03,800 --> 00:11:02,070
it's low water vapor low solar constant

238
00:11:06,199 --> 00:11:03,810

well that really matters at the low

239
00:11:07,750 --> 00:11:06,209
latitude this is also good for avoiding

240
00:11:11,949 --> 00:11:07,760
glaciation

241
00:11:18,220 --> 00:11:11,959
we have less laces hayflacks not much

242
00:11:23,019 --> 00:11:18,230
different to sensible heat flux bit more

243
00:11:24,850 --> 00:11:23,029
model climatology less free fit that

244
00:11:27,579 --> 00:11:24,860
goes with less latent heat flux this is

245
00:11:30,610 --> 00:11:27,589
really let big of us tropical convection

246
00:11:31,960 --> 00:11:30,620
and then these measurement of how strong

247
00:11:34,720 --> 00:11:31,970
that inversion at the top of the

248
00:11:37,540 --> 00:11:34,730
boundary layer it the no drop affects

249
00:11:39,189 --> 00:11:37,550
the ability that if the potential

250
00:11:41,650 --> 00:11:39,199
temperature difference well look we see

251
00:11:44,759 --> 00:11:41,660
that is smaller everywhere we've got a

252
00:11:47,319 --> 00:11:44,769
weakling version then the fancier

253
00:11:48,759 --> 00:11:47,329
measure which is the estimated inversion

254
00:11:52,000 --> 00:11:48,769
strength the difference in wet-bulb

255
00:11:54,639 --> 00:11:52,010
potential temperature also just the same

256
00:11:56,410 --> 00:11:54,649
thing that is left over us we've got

257
00:11:58,569 --> 00:11:56,420
this weaker inversion this is implying

258
00:12:01,660 --> 00:11:58,579
to us straight away that we're going to

259
00:12:05,650 --> 00:12:01,670
get less low clouds because these low

260
00:12:08,650 --> 00:12:05,660
clouds are so well correlated to yes to

261
00:12:11,170 --> 00:12:08,660
the strength of that inversion that's in

262
00:12:15,819 --> 00:12:11,180
the metrology literature that's the 1990

263
00:12:18,850 --> 00:12:15,829

paper from Tony Flynn go another so this

264
00:12:22,420 --> 00:12:18,860
is our climatology looking in slices

265
00:12:25,480 --> 00:12:22,430
through the atmosphere temperature we do

266
00:12:31,540 --> 00:12:25,490
the same potential temperature we are

267
00:12:33,009 --> 00:12:31,550
cooler aloft as we're expecting we see

268
00:12:34,300 --> 00:12:33,019
that a wet bulb potential temperature

269
00:12:41,530 --> 00:12:34,310
here we're cooler

270
00:12:45,900 --> 00:12:41,540
aloft will also drier here as well so

271
00:12:54,110 --> 00:12:51,100
here we are low cloud changes so white

272
00:12:59,510 --> 00:12:56,240
less clouds we can even see it without

273
00:13:04,579 --> 00:12:59,520
taking a different field here so we have

274
00:13:07,480 --> 00:13:04,589
annihilated our low clouds here this is

275
00:13:10,040 --> 00:13:07,490
a good result for us we have completely

276
00:13:13,130 --> 00:13:10,050
annihilated then we've also made their

277
00:13:16,160 --> 00:13:13,140
mum thinner there's less water in them

278
00:13:18,350 --> 00:13:16,170
and then if we look at this short wave

279
00:13:20,780 --> 00:13:18,360
cloud forcing here I remember that a

280
00:13:22,519 --> 00:13:20,790
global average hence we want 50 watts

281
00:13:25,730 --> 00:13:22,529
per square meter to resolve the faint

282
00:13:29,290 --> 00:13:25,740
young Sun and we've got numbers that are

283
00:13:31,250 --> 00:13:29,300
strongly positive you know pretty much

284
00:13:34,910 --> 00:13:31,260
everywhere here so we're getting a

285
00:13:39,320 --> 00:13:34,920
really kickin shortwave cloud forcing

286
00:13:43,579 --> 00:13:39,330
from reducing these low clouds so this

287
00:13:46,600 --> 00:13:43,589
is looking for 110 percent down to 70

288
00:13:51,920 --> 00:13:46,610

percent solar for think this is a merely

289
00:13:53,269 --> 00:13:51,930
systemic effect going slow so wish what

290
00:13:55,490 --> 00:13:53,279
we're showing here is that these

291
00:13:57,950 --> 00:13:55,500
physical feedbacks on low cloud which

292
00:13:59,960 --> 00:13:57,960
arise from first-order changes the

293
00:14:02,780 --> 00:13:59,970
planetary climate are making a really

294
00:14:06,890 --> 00:14:02,790
big contribution to stabilizing

295
00:14:09,710 --> 00:14:06,900
planetary climate look at high cloud

296
00:14:13,329 --> 00:14:09,720
changes just the kicks well what we see

297
00:14:17,780 --> 00:14:13,339
is that we do have more high clouds but

298
00:14:23,600 --> 00:14:17,790
they're thinner so the net effect is

299
00:14:25,850 --> 00:14:23,610
quite small we were if one word lighting

300
00:14:28,070 --> 00:14:25,860
a paper on high cloud feedback for would

301
00:14:30,800 --> 00:14:28,080
want to think very carefully about the

302
00:14:33,170 --> 00:14:30,810
convection scheme in the model I'm not

303
00:14:35,030 --> 00:14:33,180
writing such a paper so I'm not thinking

304
00:14:38,320 --> 00:14:35,040
that carefully about the convection

305
00:14:42,050 --> 00:14:38,330
schemes and what we see is that merely

306
00:14:47,120 --> 00:14:42,060
not much happens if near net net zero

307
00:14:52,010 --> 00:14:47,130
here as we go through time so altogether

308
00:14:53,600 --> 00:14:52,020
now this is looking as we increase L a

309
00:14:56,840 --> 00:14:53,610
constant from the beginning of our

310
00:15:00,110 --> 00:14:56,850
history to some billion years in the

311
00:15:02,600 --> 00:15:00,120
future well this is the gray line here

312
00:15:06,260 --> 00:15:02,610
of how much co2 would expect from a 1d

313
00:15:06,920 --> 00:15:06,270

model this is how much co2 we use this

314
00:15:09,319 --> 00:15:06,930
is less

315
00:15:12,049 --> 00:15:09,329
consistent with fire work and here is

316
00:15:16,269 --> 00:15:12,059
the reason here we have our strong short

317
00:15:18,769 --> 00:15:16,279
wave cloud forcing here so if we look at

318
00:15:22,129 --> 00:15:18,779
the kind of time we're interested in

319
00:15:24,619 --> 00:15:22,139
compared to now that net changing that

320
00:15:29,150 --> 00:15:24,629
if about 20 watts per square meters out

321
00:15:30,710 --> 00:15:29,160
of the 50 we needed we've got 20 watts

322
00:15:33,530 --> 00:15:30,720
per square meter out of this low cloud

323
00:15:35,949 --> 00:15:33,540
forcing as I only have 1 minutes and 38

324
00:15:38,239 --> 00:15:35,959
seconds I will move to my conclusions

325
00:15:39,259 --> 00:15:38,249
instead of reading you my conclusion

326
00:15:41,809 --> 00:15:39,269
that'll say there's an interesting

327
00:15:43,879 --> 00:15:41,819
recent work so I think of a paper by

328
00:15:46,220 --> 00:15:43,889
tapioca row in next year science this

329
00:15:49,309 --> 00:15:46,230
year actually showed these clouds

330
00:15:51,590 --> 00:15:49,319
changes if you go from a GCM to a large

331
00:15:53,809 --> 00:15:51,600
Eddy simulation could be been nonlinear

332
00:15:56,600 --> 00:15:53,819
as well certain the weakness in this

333
00:15:59,119 --> 00:15:56,610
work in GCM we show these smooth changes

334
00:16:02,179 --> 00:15:59,129
I might expect to see some even stronger

335
00:16:05,389 --> 00:16:02,189
changes than the ones we see possibly

336
00:16:08,769 --> 00:16:05,399
with nonlinearities involved but that

337
00:16:14,689 --> 00:16:08,779
aside the take-home message here is that

338
00:16:16,910 --> 00:16:14,699

I would like to reclaim for physics 40

339
00:16:20,239 --> 00:16:16,920
percent of the feedback necessary to

340
00:16:26,780 --> 00:16:20,249
resolve stabilizing Earth's climate so a

341
00:16:37,610 --> 00:16:28,100
[Applause]

342
00:16:39,680 --> 00:16:37,620
I call them very very interesting as I

343
00:16:42,889 --> 00:16:39,690
discuss in my recent book on the history

344
00:16:45,769 --> 00:16:42,899
of planetary climate studies in the 70s

345
00:16:48,380 --> 00:16:45,779
cloud feedbacks were were noted as being

346
00:16:50,060 --> 00:16:48,390
the sort of strongest lever available to

347
00:16:52,699 --> 00:16:50,070
talk the climate back in the past

348
00:16:57,790 --> 00:16:52,709
there's a very interesting paper in 2001

349
00:17:01,100 --> 00:16:57,800
by Chen Wang who at Columbia where he

350
00:17:03,500 --> 00:17:01,110
purports to show how the changing

351
00:17:05,510 --> 00:17:03,510
balance between low and high cloud could

352
00:17:08,059 --> 00:17:05,520
completely stabilize the Earth's

353
00:17:09,799 --> 00:17:08,069
feedback through our geologic time I

354
00:17:12,890 --> 00:17:09,809
mean it's a 1d model there's some hand

355
00:17:14,630 --> 00:17:12,900
waving but you're sort of advancing some

356
00:17:17,480 --> 00:17:14,640
some already well shot and ground I

357
00:17:18,799 --> 00:17:17,490
think okay thanks how could you say if

358
00:17:20,980 --> 00:17:18,809
you could send me that lesson that'd be

359
00:17:24,799 --> 00:17:20,990
great

360
00:17:26,600 --> 00:17:24,809
hi Caitlin Loftus Harvard I guess kind

361
00:17:29,049 --> 00:17:26,610
of following up in what you're talking

362
00:17:33,470 --> 00:17:29,059
about in Tapia's somewhere kind of

363
00:17:36,070 --> 00:17:33,480

resolving cloud models how much do you

364
00:17:38,450 --> 00:17:36,080
expect that we can trust the cloud

365
00:17:39,799 --> 00:17:38,460
parameterizations and cam even we're

366
00:17:43,750 --> 00:17:39,809
looking at such a radically different

367
00:17:46,970 --> 00:17:43,760
environment here so we use two different

368
00:17:50,320 --> 00:17:46,980
versions of the community atmosphere

369
00:17:54,770 --> 00:17:50,330
model here and in the different versions

370
00:17:58,820 --> 00:17:54,780
the radiation boundary layer and low

371
00:18:02,870 --> 00:17:58,830
cloud schemes are all changed so that

372
00:18:04,430 --> 00:18:02,880
gives me live actually it's not two

373
00:18:07,310 --> 00:18:04,440
different models it's like what are the

374
00:18:10,039 --> 00:18:07,320
half different models and the general

375
00:18:13,909 --> 00:18:10,049
theme of I think less low cloud we've

376
00:18:17,930 --> 00:18:13,919
also seen and Jeremy maybe could comment

377
00:18:21,130 --> 00:18:17,940
on this in the LMDC model and I think

378
00:18:24,970 --> 00:18:21,140
we've got a good physically-based

379
00:18:28,970 --> 00:18:24,980
explanation for it so I'm feeling fairly

380
00:18:31,580 --> 00:18:28,980
comfortable at the moment but I always a

381
00:18:35,510 --> 00:18:31,590
hierarchy of climate models and always

382
00:18:40,419 --> 00:18:35,520
more climate model would be would be

383
00:18:45,350 --> 00:18:43,460
you mentioned polar amplification how

384
00:18:51,470 --> 00:18:45,360
BIG's the clear skies shortwave feedback

385
00:18:56,620 --> 00:18:51,480
does that help you as well I have let's

386
00:18:59,210 --> 00:18:56,630
see if it's on here is it on here I I

387
00:19:14,119 --> 00:18:59,220
have no idea of the answer I would have

388
00:19:16,789 --> 00:19:14,129

to look that up yeah okay could the

389
00:19:19,519 --> 00:19:16,799
non-linearity if you included it could

390
00:19:21,259 --> 00:19:19,529
it like you know turn on the cloud deck

391
00:19:22,820 --> 00:19:21,269
at some point and then cause the first

392
00:19:26,749 --> 00:19:22,830
snowball for example like do you think

393
00:19:29,930 --> 00:19:26,759
that's a reasonable hypothesis Oh

394
00:19:35,509 --> 00:19:29,940
so let me think about that for a moment

395
00:19:39,470 --> 00:19:35,519
I would be no I do not believe it could

396
00:19:45,169 --> 00:19:39,480
do that the reason is if that if you if

397
00:19:48,379 --> 00:19:45,179
you decreasing co2 will help you get low

398
00:19:51,310 --> 00:19:48,389
clouds but then the low carbon fund

399
00:19:54,440 --> 00:19:51,320
really quickly so if you start cooling

400
00:19:55,879 --> 00:19:54,450
well unless you build low clouds more

401
00:20:00,980 --> 00:19:55,889
when you cool which I don't think you

402
00:20:03,649 --> 00:20:00,990
will then those clouds feedback can come

403
00:20:06,379 --> 00:20:03,659
off or on quicker than you can glaciated

404
00:20:08,210 --> 00:20:06,389
panet so that wouldn't be my preferred

405
00:20:10,220 --> 00:20:08,220
way of making if noble my preferred way

406
00:20:16,850 --> 00:20:10,230
of making phob all is just to bring down

407
00:20:18,830 --> 00:20:16,860
co2 gotcha just to follow on from a

408
00:20:20,810 --> 00:20:18,840
previous question another big positive

409
00:20:22,519 --> 00:20:20,820
feedback potentially is what happens to

410
00:20:24,590 --> 00:20:22,529
the ocean if you've got a big polar

411
00:20:26,899 --> 00:20:24,600
amplification you're warming the polar

412
00:20:29,330 --> 00:20:26,909
regions parts of the inversion is set by

413
00:20:31,220 --> 00:20:29,340

these cold waters from cold currents if

414
00:20:33,350 --> 00:20:31,230
the intermediate ocean starts to warm up

415
00:20:35,720 --> 00:20:33,360
you start removing the conditions

416
00:20:37,369 --> 00:20:35,730
irrespective of co2 so if you think

417
00:20:38,600 --> 00:20:37,379
about what the ocean is doing with polar

418
00:20:40,610 --> 00:20:38,610
amplification that could make this

419
00:20:42,649 --> 00:20:40,620
effect potentially bigger but you need a

420
00:20:45,019 --> 00:20:42,659
couple GCM to look at it so I'll be

421
00:20:46,909 --> 00:20:45,029
difficult yeah thanks manager and we

422
00:20:48,769 --> 00:20:46,919
could also protect we could do it

423
00:20:51,560 --> 00:20:48,779
coupled or we could potentially do it

424
00:20:52,970 --> 00:20:51,570
with just making prescribed queue for

425
00:20:57,320 --> 00:20:52,980
making

426
00:20:59,120 --> 00:20:57,330
imaginary queue flux files and one of my

427
00:21:00,650 --> 00:20:59,130
colleagues have been trying to tell me I

428
00:21:02,390 --> 00:21:00,660
should do that anyway so now you're the

429
00:21:05,890 --> 00:21:02,400
second person to tell me to do that

430
00:21:10,610 --> 00:21:08,450
hey so Robin Wordsworth Harvard

431
00:21:13,460 --> 00:21:10,620
University and thanks : I think it's a

432
00:21:18,580 --> 00:21:13,470
nice work how well do you really think

433
00:21:34,670 --> 00:21:24,590
well thanks Robin can we can we cut off

434
00:21:36,830 --> 00:21:34,680
the video feed yeah you know I kind I

435
00:21:41,960 --> 00:21:36,840
don't understand the Paleo cell work so

436
00:21:43,880 --> 00:21:41,970
I won't comment on it I think you know

437
00:21:46,610 --> 00:21:43,890
Clara blackbirds work with calcium

438
00:21:53,360 --> 00:21:46,620

isotopes where really what it's showing

439
00:21:55,640 --> 00:21:53,370
of the DI c2 alkalinity ratio which

440
00:21:59,660 --> 00:21:55,650
isn't a co2 constraint but it's used as

441
00:22:02,750 --> 00:21:59,670
one I think that is probably more only

442
00:22:08,000 --> 00:22:02,760
that for simple-minded people like me I

443
00:22:17,560 --> 00:22:08,010
can understand that better so I I'm