Case 1: If seafloor weathering is independent of surface temperature, there can be no climate stabilizing weathering feedback on a waterworld.

take derivative of weathering relation w.r.t. insolation

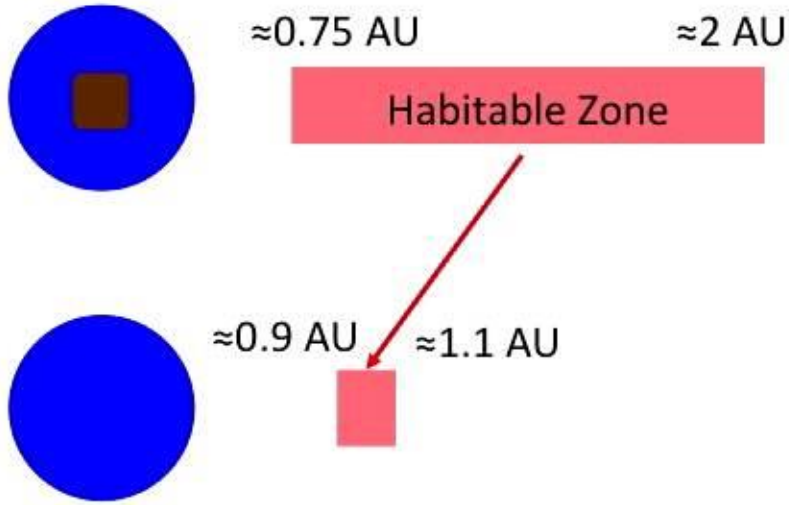
$$0 = \cancel{f(\gamma)\left(\frac{\partial W_i^*}{\partial \phi}\frac{\partial \phi}{\partial S} + \frac{\partial W_i^*}{\partial T}\frac{\partial T}{\partial S}\right)} + g(\gamma)\left(\frac{\partial W_o^*}{\partial \phi}\frac{\partial \phi}{\partial S} + \cancel{\frac{\partial W_o^*}{\partial T}}\frac{\partial T}{\partial S}\right)$$

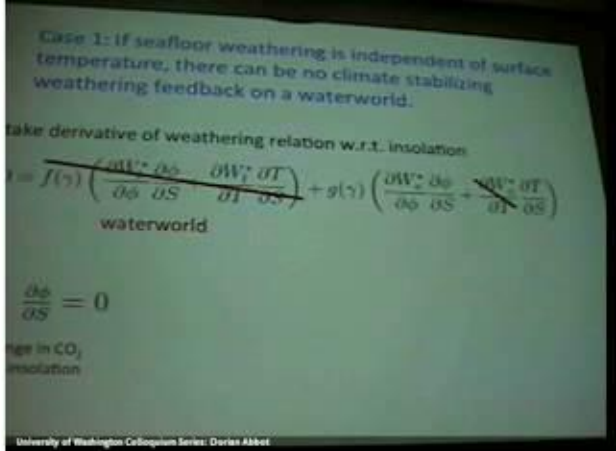
waterworld

$$\frac{\partial \phi}{\partial S} = 0 \longrightarrow \left(\frac{\partial T}{\partial S}\right)_0 = \frac{1-\alpha}{4\omega_1}$$

change in CO_2 wrt insolation

change in surf. temp. wrt insolation





1
00:00:04,370 --> 00:00:02,090
okay welcome everyone again to the

2
00:00:07,610 --> 00:00:04,380
University of Washington astrobiology

3
00:00:09,830 --> 00:00:07,620
programs fall seminar series today's

4
00:00:12,950 --> 00:00:09,840
speaker is a saurian Abbott from the

5
00:00:16,519 --> 00:00:12,960
University of Chicago joining out his

6
00:00:19,310 --> 00:00:16,529
PhD in 2008 is that right from Harvard

7
00:00:21,560 --> 00:00:19,320
spent a year there as a postdoc and then

8
00:00:24,349 --> 00:00:21,570
went to use Chicago is a TC Chamberlain

9
00:00:28,370 --> 00:00:24,359
postdoctoral fellow and after two years

10
00:00:31,189 --> 00:00:28,380
as a postdoc there became faculty and so

11
00:00:33,440 --> 00:00:31,199
now he is an assistant professor so

12
00:00:35,479 --> 00:00:33,450
Dorian's going to speak for about 50

13
00:00:38,049 --> 00:00:35,489

minutes or so then we'll take questions

14
00:00:40,819 --> 00:00:38,059
from the audience both near and far

15
00:00:42,410 --> 00:00:40,829
whoever's in there remote you can type

16
00:00:44,779 --> 00:00:42,420
your questions into the Adobe Connect

17
00:00:46,760 --> 00:00:44,789
chat room and we'll read those the crowd

18
00:00:48,950 --> 00:00:46,770
that's here and today's a little bit

19
00:00:51,680 --> 00:00:48,960
special and easy and pretty sharp at

20
00:00:54,200 --> 00:00:51,690
four because I'll more shields general

21
00:00:55,970 --> 00:00:54,210
exam is immediately following this event

22
00:00:57,979 --> 00:00:55,980
in the same room so I also hope that you

23
00:00:59,900 --> 00:00:57,989
all will say and listen to Omaha talk

24
00:01:01,939 --> 00:00:59,910
about the runaway greenhouse okay take

25
00:01:05,990 --> 00:01:01,949
the blade Orion okay thank you for

26
00:01:09,530 --> 00:01:06,000
coming nice to be standing oh no it just

27
00:01:11,870 --> 00:01:09,540
rotated really so if you have a question

28
00:01:13,880 --> 00:01:11,880
please interrupt me well I'm going

29
00:01:16,160 --> 00:01:13,890
because we might run out of time at the

30
00:01:18,350 --> 00:01:16,170
end I'll try to end early but I feel

31
00:01:20,480 --> 00:01:18,360
free to interrupt so I can be talking

32
00:01:23,600 --> 00:01:20,490
about alleble zone and you've got this

33
00:01:26,240 --> 00:01:23,610
is a picture of alleble zone based on

34
00:01:29,690 --> 00:01:26,250
serve classic casting concept and so

35
00:01:32,300 --> 00:01:29,700
this is different masses of stars star

36
00:01:34,910 --> 00:01:32,310
likes on less massive and this is

37
00:01:37,069 --> 00:01:34,920
distance from the star and the happy

38
00:01:39,170 --> 00:01:37,079

blue area is habitable zone where you

39
00:01:41,450 --> 00:01:39,180
can sustain liquid water at the surface

40
00:01:43,850 --> 00:01:41,460
and at the inner edge in Apple's own is

41
00:01:47,030 --> 00:01:43,860
moist free house or runaway greenhouse

42
00:01:50,389 --> 00:01:47,040
depending and at the outer edge you have

43
00:01:51,889 --> 00:01:50,399
either co2 compensation or increase in

44
00:01:54,289 --> 00:01:51,899
rayleigh scattering due to co tube so

45
00:01:56,780 --> 00:01:54,299
that you too can no longer cause warming

46
00:02:00,319 --> 00:01:56,790
and the assumption is that anywhere in

47
00:02:01,940 --> 00:02:00,329
here if you move the planet out further

48
00:02:04,700 --> 00:02:01,950
from the Sun and it wants to cool down

49
00:02:06,770 --> 00:02:04,710
at the co2 will adjust through silicate

50
00:02:08,869 --> 00:02:06,780
weathering feedback continental feedback

51
00:02:10,490 --> 00:02:08,879
and get as high as it needs to be keep

52
00:02:12,710 --> 00:02:10,500
you in the Hubble so that's consumption

53
00:02:13,730 --> 00:02:12,720
and that's important because if you

54
00:02:16,040 --> 00:02:13,740
don't include that

55
00:02:18,340 --> 00:02:16,050
Chemical feedback and so it's not

56
00:02:21,950 --> 00:02:18,350
included in this early paper by harsh

57
00:02:23,450 --> 00:02:21,960
what you find is a bubble zone if you

58
00:02:26,030 --> 00:02:23,460
don't include that feedback but you do

59
00:02:29,540 --> 00:02:26,040
include the positive feedbacks of ISIL

60
00:02:31,070 --> 00:02:29,550
veto and moisture a green ops feedback

61
00:02:32,990 --> 00:02:31,080
just an increase in moisture and wear

62
00:02:37,790 --> 00:02:33,000
green owes you get a habitable zone

63
00:02:40,430 --> 00:02:37,800

that's something like maybe point 05

64
00:02:42,950 --> 00:02:40,440
2.18 use so something like an order of

65
00:02:45,140 --> 00:02:42,960
magnitude smaller ten times smaller so

66
00:02:47,690 --> 00:02:45,150
this why Abbott was own depends on

67
00:02:49,250 --> 00:02:47,700
silicate whether it came back and what

68
00:02:51,170 --> 00:02:49,260
I'm interested in and when we talk about

69
00:02:54,560 --> 00:02:51,180
today is what if you start changing the

70
00:02:56,930 --> 00:02:54,570
land fraction of the planet what can we

71
00:02:58,970 --> 00:02:56,940
say just adjust in general terms about

72
00:03:01,550 --> 00:02:58,980
what that's going to do the habitable

73
00:03:03,230 --> 00:03:01,560
zone and there are a lot of

74
00:03:05,660 --> 00:03:03,240
uncertainties a lot of like and drink

75
00:03:06,770 --> 00:03:05,670
Martin's aspects and this problem so

76
00:03:08,480 --> 00:03:06,780
what I'm going to do is I'm going to try

77
00:03:12,710 --> 00:03:08,490
to state the assumptions that I'm making

78
00:03:13,880 --> 00:03:12,720
and see where they need it may turn out

79
00:03:15,050 --> 00:03:13,890
that some of those assumptions are

80
00:03:17,900 --> 00:03:15,060
correct and some of the things that are

81
00:03:20,870 --> 00:03:17,910
based on those assumptions what won't be

82
00:03:23,000 --> 00:03:20,880
correct but I think the appropriate way

83
00:03:25,220 --> 00:03:23,010
to proceed when you have a problem that

84
00:03:27,020 --> 00:03:25,230
time constrained at least you can do is

85
00:03:29,750 --> 00:03:27,030
say what you're assuming and see where

86
00:03:32,630 --> 00:03:29,760
that takes you and the co-authors are

87
00:03:36,530 --> 00:03:32,640
Nick Cowan was one of yours for a few

88
00:03:39,920 --> 00:03:36,540

years ago yes that's five year mostafa

89
00:03:44,990 --> 00:03:39,930
northwestern and Francesca who

90
00:03:45,980 --> 00:03:45,000
is on faculty receive Chicago okay so

91
00:03:48,710 --> 00:03:45,990
this is just sort of an outline of

92
00:03:51,580 --> 00:03:48,720
loading the Ajanta low first just

93
00:03:54,350 --> 00:03:51,590
introduction to weathering and

94
00:03:56,960 --> 00:03:54,360
weathering the cabinet on continental at

95
00:04:02,930 --> 00:03:56,970
the sea floor then this is the meat of

96
00:04:07,520 --> 00:04:02,940
the top do you know why that happened

97
00:04:13,580 --> 00:04:07,530
tie it didn't like gross oh how we need

98
00:04:15,590 --> 00:04:13,590
to reassure the body but I go back so

99
00:04:17,150 --> 00:04:15,600
actually I think the most important part

100
00:04:20,270 --> 00:04:17,160
is how it will off the club in Adobe

101
00:04:22,670 --> 00:04:20,280
Connect sorry it can you reach we share

102
00:04:26,330 --> 00:04:22,680
a couple different limits that are

103
00:04:27,830 --> 00:04:26,340
instructive for the behavior of the full

104
00:04:29,240 --> 00:04:27,840
model and those of

105
00:04:30,790 --> 00:04:29,250
that's the part of this that I believe

106
00:04:32,990 --> 00:04:30,800
that I would put the most certainty on

107
00:04:36,590 --> 00:04:33,000
at least if you believe the assumptions

108
00:04:38,629 --> 00:04:36,600
that I make in the limits that cake so I

109
00:04:43,129 --> 00:04:38,639
think that's that's something so pay

110
00:04:45,050 --> 00:04:43,139
attention to that and then this water

111
00:04:47,420 --> 00:04:45,060
world self arrest idea this is where the

112
00:04:49,040 --> 00:04:47,430
wild things are in the sock or in for

113
00:04:50,950 --> 00:04:49,050

having issues with the online part I

114
00:04:57,710 --> 00:04:50,960
think we get here me know when a

115
00:05:01,219 --> 00:04:57,720
two-second sickness or quit out yeah so

116
00:05:03,800 --> 00:05:01,229
the waterworld self arrest part that's

117
00:05:06,290 --> 00:05:03,810
the more specula sort of an interesting

118
00:05:10,100 --> 00:05:06,300
idea and I'd be interested in here put

119
00:05:13,430 --> 00:05:10,110
any with things about it she's it on huh

120
00:05:14,990 --> 00:05:13,440
ok I also forgot to mention that the

121
00:05:16,670 --> 00:05:15,000
paper describing this work is on my

122
00:05:21,830 --> 00:05:16,680
website if you want to look at that

123
00:05:23,629 --> 00:05:21,840
after this this this section

124
00:05:25,250 --> 00:05:23,639
observational prospects probably i'm

125
00:05:27,610 --> 00:05:25,260
going to have to skip given the given

126
00:05:32,240 --> 00:05:27,620
that it has to be a short seminar and

127
00:05:34,510 --> 00:05:32,250
then just some some more general issues

128
00:05:36,920 --> 00:05:34,520
about see for weathering outer edge of

129
00:05:38,719 --> 00:05:36,930
albums that i'll introduce this term c

130
00:05:40,879 --> 00:05:38,729
for weathering in a second this last

131
00:05:41,810 --> 00:05:40,889
section so everything up here then i'm

132
00:05:44,060 --> 00:05:41,820
going to tell you i'm not going to show

133
00:05:46,070 --> 00:05:44,070
any sensitivity tests but this is all

134
00:05:49,270 --> 00:05:46,080
stuff that is very robust to changes and

135
00:05:53,270 --> 00:05:49,280
model parameters this last section is

136
00:05:54,950 --> 00:05:53,280
parts that are not so robust and the non

137
00:05:55,909 --> 00:05:54,960
robust aspects of them is actually

138
00:05:57,890 --> 00:05:55,919

what's interesting i should probably

139
00:06:01,750 --> 00:05:57,900
stop believing this round it's going to

140
00:06:04,190 --> 00:06:01,760
get distracting and so that's something

141
00:06:06,110 --> 00:06:04,200
that's another sort of speculative part

142
00:06:07,670 --> 00:06:06,120
and apart with another aspect of

143
00:06:10,279 --> 00:06:07,680
weathering at the sea floor that could

144
00:06:12,020 --> 00:06:10,289
be important for for how ilysm okay

145
00:06:14,800 --> 00:06:12,030
introduction everyone probably knows

146
00:06:18,219 --> 00:06:14,810
about this you have a balanced

147
00:06:20,870 --> 00:06:18,229
maintaining the co2 in the atmosphere

148
00:06:24,230 --> 00:06:20,880
along time scales and carbon cycle you

149
00:06:27,379 --> 00:06:24,240
have outgassing of co2 into the

150
00:06:29,690 --> 00:06:27,389
atmosphere ocean system and you normally

151
00:06:30,710 --> 00:06:29,700
have the silicate weathering i'm not

152
00:06:32,270 --> 00:06:30,720
gonna spend too much time on this

153
00:06:33,650 --> 00:06:32,280
because i think everyone knows this on

154
00:06:36,080 --> 00:06:33,660
the continent that responds to

155
00:06:39,100 --> 00:06:36,090
temperature and co2 so higher

156
00:06:41,439 --> 00:06:39,110
temperature high co2 it runs faster

157
00:06:44,920 --> 00:06:41,449
which is a negative feedback

158
00:06:46,420 --> 00:06:44,930
so choose I just keep talking yeah you

159
00:06:49,510 --> 00:06:46,430
can keep talking they can hear you and

160
00:06:53,439 --> 00:06:49,520
it can see walking around but they can't

161
00:06:54,760 --> 00:06:53,449
see the spot it since the issue okay but

162
00:06:57,040 --> 00:06:54,770
to do a statement the thing that I'm

163
00:07:00,219 --> 00:06:57,050

going to talk about that's not in most

164
00:07:11,409 --> 00:07:00,229
habitable zone pictures is weathering

165
00:07:12,820 --> 00:07:11,419
that can happen at the seafloor so I'm

166
00:07:14,739 --> 00:07:12,830
going to be changing I'm going to be

167
00:07:15,969 --> 00:07:14,749
trying to take into account weathering

168
00:07:17,800 --> 00:07:15,979
that can happen at the sea floor so

169
00:07:19,989 --> 00:07:17,810
removal obscure to from the ocean

170
00:07:28,959 --> 00:07:19,999
atmosphere system happening at the sea

171
00:07:31,179 --> 00:07:28,969
floor where you could out yeah basalt is

172
00:07:33,070 --> 00:07:31,189
exposed at the mid-ocean ridge and then

173
00:07:36,070 --> 00:07:33,080
you have hydrothermal systems and

174
00:07:38,649 --> 00:07:36,080
seawater working into them salt reacting

175
00:07:40,089 --> 00:07:38,659
with the basalt carbonizing it removing

176
00:07:42,610 --> 00:07:40,099
carpet promotion atmosphere system

177
00:07:45,489 --> 00:07:42,620
that's eventually buried in a similar

178
00:07:48,519 --> 00:07:45,499
way how the calcium carbonate that's

179
00:07:50,739 --> 00:07:48,529
precipitated from continental weathering

180
00:07:53,800 --> 00:07:50,749
is buried and set in the sediment that

181
00:07:55,329 --> 00:07:53,810
eventually into mental and so I'm going

182
00:07:57,969 --> 00:07:55,339
to try to add the sea floor weathering

183
00:08:00,159 --> 00:07:57,979
into this picture of what sustains

184
00:08:03,519 --> 00:08:00,169
palpable zone and then see what happens

185
00:08:07,360 --> 00:08:03,529
as you change the land fraction and how

186
00:08:08,980 --> 00:08:07,370
the hobbled zone result responds okay so

187
00:08:11,019 --> 00:08:08,990
first of all I just want to say

188
00:08:20,019 --> 00:08:11,029

something about the continental

189
00:08:22,089 --> 00:08:20,029
weathering something to keep rolling so

190
00:08:24,909 --> 00:08:22,099
I'm going to report the camera at spring

191
00:08:36,579 --> 00:08:24,919
so it isn't quite as you normally would

192
00:08:37,959 --> 00:08:36,589
ok that's it I'm is good to me ok so so

193
00:08:40,170 --> 00:08:37,969
this is this paper by these French guys

194
00:08:42,309 --> 00:08:40,180
and what they're doing is they're

195
00:08:43,659 --> 00:08:42,319
plotting they look at a bunch of

196
00:08:45,040 --> 00:08:43,669
different rivers each of these dots as

197
00:08:47,410 --> 00:08:45,050
rivers I'll explain what the little dot

198
00:08:49,600 --> 00:08:47,420
the different colors of things mean and

199
00:08:51,189 --> 00:08:49,610
what they're doing is they look at the

200
00:08:53,390 --> 00:08:51,199
runoff which is sort of like the total

201
00:08:55,610 --> 00:08:53,400
amount of precipitation the hit that

202
00:08:56,690 --> 00:08:55,620
catchment area and its flow you know the

203
00:08:58,610 --> 00:08:56,700
amount of water is flowing out in the

204
00:09:01,310 --> 00:08:58,620
river and they plot the chemical

205
00:09:03,680 --> 00:09:01,320
weathering great images they're plotting

206
00:09:06,350 --> 00:09:03,690
basically what we want to know for the

207
00:09:07,490 --> 00:09:06,360
content of the weather which can see is

208
00:09:10,490 --> 00:09:07,500
there's some sort of reasonable

209
00:09:12,890 --> 00:09:10,500
correlation between precipitation or

210
00:09:14,420 --> 00:09:12,900
runoff and chemical weathering great and

211
00:09:16,400 --> 00:09:14,430
then down here they're doing the same

212
00:09:22,130 --> 00:09:16,410
thing with the mean annual temperature

213
00:09:23,240 --> 00:09:22,140

and it was the question no and what you

214
00:09:25,040 --> 00:09:23,250
can see when they do its function of

215
00:09:27,650 --> 00:09:25,050
temperature is that there seems to be a

216
00:09:30,950 --> 00:09:27,660
correlation except for these ones where

217
00:09:33,530 --> 00:09:30,960
there isn't a correlation is it runoff

218
00:09:35,690 --> 00:09:33,540
is that that rainfall number ya like

219
00:09:38,930 --> 00:09:35,700
like how much water so humming out in

220
00:09:41,870 --> 00:09:38,940
the river you know like help what's the

221
00:09:44,420 --> 00:09:41,880
rivers flow okay so it's not rainbow

222
00:09:46,700 --> 00:09:44,430
millions I go integrated in the cat

223
00:09:48,620 --> 00:09:46,710
integrated over the catchment rainfall I

224
00:09:51,130 --> 00:09:48,630
think that was the River alpha loss that

225
00:09:53,450 --> 00:09:51,140
divided by the area of the catchment uh

226
00:09:55,400 --> 00:09:53,460
yeah I think that's what that's what

227
00:10:02,740 --> 00:09:55,410
we're talking about that exactly so

228
00:10:07,220 --> 00:10:05,960
okay so about great so obviously this is

229
00:10:09,860 --> 00:10:07,230
supposed to be a function of both these

230
00:10:13,370 --> 00:10:09,870
things so the situation could exist

231
00:10:15,140 --> 00:10:13,380
where you have low runoff and that's

232
00:10:17,090 --> 00:10:15,150
what caused it and even if the

233
00:10:19,040 --> 00:10:17,100
temperature is high enough that you

234
00:10:21,890 --> 00:10:19,050
don't have enough run off to get the

235
00:10:23,660 --> 00:10:21,900
value of of of weathering that you would

236
00:10:25,790 --> 00:10:23,670
expect and so there may be some of that

237
00:10:28,430 --> 00:10:25,800
going well but you also have the Amazon

238
00:10:31,250 --> 00:10:28,440

which has a high runoff having a below

239
00:10:33,740 --> 00:10:31,260
what you would expect a value of

240
00:10:35,120 --> 00:10:33,750
chemical weather and so the point is

241
00:10:37,970 --> 00:10:35,130
that there's a bunch of things can

242
00:10:40,010 --> 00:10:37,980
affect this and it's and it's not sort

243
00:10:44,920 --> 00:10:40,020
of a dead-on one-to-one correlation and

244
00:10:47,780 --> 00:10:44,930
if you go in the new update of how to

245
00:10:49,640 --> 00:10:47,790
build a habitable planet by line here

246
00:10:51,860 --> 00:10:49,650
and grow period they have a scale where

247
00:10:55,280 --> 00:10:51,870
they sort of there's a qualitative

248
00:10:56,960 --> 00:10:55,290
ranking of all the theories that they go

249
00:10:59,240 --> 00:10:56,970
through they sort of present the

250
00:11:00,920 --> 00:10:59,250
evidence and then they and then they and

251
00:11:05,030 --> 00:11:00,930
then they rank them on a scale of 0-10

252
00:11:06,140 --> 00:11:05,040
and so they gave they give the big bang

253
00:11:08,240 --> 00:11:06,150
theory or nine point nine

254
00:11:12,230 --> 00:11:08,250
and they give theory of nucleosynthesis

255
00:11:14,870 --> 00:11:12,240
and stars and and they give the silicate

256
00:11:16,970 --> 00:11:14,880
weathering a six and that's important

257
00:11:19,310 --> 00:11:16,980
because that's what ever anyone talks

258
00:11:20,930 --> 00:11:19,320
about the habitable zone they're talking

259
00:11:22,700 --> 00:11:20,940
about silicate weathering feedback and

260
00:11:25,280 --> 00:11:22,710
the evidence we have that this is

261
00:11:26,990 --> 00:11:25,290
functioning on earth is only a six and

262
00:11:28,310 --> 00:11:27,000
that's the lowest value of anything that

263
00:11:32,510 --> 00:11:28,320

they're willing to put into their

264
00:11:33,770 --> 00:11:32,520
textbook so this is something there's

265
00:11:36,070 --> 00:11:33,780
still a lot of interesting problems to

266
00:11:38,180 --> 00:11:36,080
work on with this that's what I'm saying

267
00:11:40,400 --> 00:11:38,190
now the other hand sea floor whether

268
00:11:42,350 --> 00:11:40,410
that this is what I'm talking about when

269
00:11:44,270 --> 00:11:42,360
I talk about see available you have some

270
00:11:46,400 --> 00:11:44,280
basalt that you took from from the ocean

271
00:11:48,980 --> 00:11:46,410
ocean basement and it's got a little

272
00:11:51,230 --> 00:11:48,990
craft sitting and into these cracks

273
00:11:52,970 --> 00:11:51,240
there's a hydrothermal circulation and

274
00:11:55,220 --> 00:11:52,980
there's a percolation into them of

275
00:11:58,250 --> 00:11:55,230
seawater and then it reacts with the

276
00:12:00,980 --> 00:11:58,260
basalt and it precipitates out

277
00:12:03,200 --> 00:12:00,990
carbonates and so you can see these

278
00:12:04,850 --> 00:12:03,210
veins so these are these are considered

279
00:12:05,960 --> 00:12:04,860
younger ones the fair ones and the older

280
00:12:08,240 --> 00:12:05,970
ones are thicker ones and they can

281
00:12:10,420 --> 00:12:08,250
eventually merge together and the idea

282
00:12:12,800 --> 00:12:10,430
is you can store a huge amount of carbon

283
00:12:15,020 --> 00:12:12,810
in the ocean result and then it can get

284
00:12:18,380 --> 00:12:15,030
subducted later and if you look at these

285
00:12:20,660 --> 00:12:18,390
reactions in the laboratory and crush up

286
00:12:22,310 --> 00:12:20,670
a bunch of basalt that you reacted with

287
00:12:24,830 --> 00:12:22,320
seawater of different temperatures and

288
00:12:26,990 --> 00:12:24,840

different in this case they're changing

289
00:12:29,570 --> 00:12:27,000
the pH which corresponds to changing the

290
00:12:33,890 --> 00:12:29,580
co2 you see a strong function of

291
00:12:35,270 --> 00:12:33,900
temperature and pH you see that the

292
00:12:37,820 --> 00:12:35,280
reactions so strong function of

293
00:12:40,190 --> 00:12:37,830
temperature pH and so in theory you

294
00:12:42,140 --> 00:12:40,200
could build a negative feedback on

295
00:12:43,700 --> 00:12:42,150
climate based on that you know the

296
00:12:45,710 --> 00:12:43,710
temperature could increase could

297
00:12:47,180 --> 00:12:45,720
increase the ocean water temperature

298
00:12:48,950 --> 00:12:47,190
increase the bottom of the ocean

299
00:12:52,130 --> 00:12:48,960
temperature and eventually you could

300
00:12:53,990 --> 00:12:52,140
increase see slow weathering and and

301
00:12:57,310 --> 00:12:54,000
ameliorate the climate change that were

302
00:12:59,450 --> 00:12:57,320
resulting that but the problem is that

303
00:13:03,080 --> 00:12:59,460
there are a number of reasons to think

304
00:13:04,940 --> 00:13:03,090
that these laboratory changes are not

305
00:13:06,770 --> 00:13:04,950
what you're actually going to see if you

306
00:13:09,460 --> 00:13:06,780
do this in the real system and in

307
00:13:11,390 --> 00:13:09,470
particular you had these really crappie

308
00:13:14,840 --> 00:13:11,400
correlations when you go measure in the

309
00:13:17,150 --> 00:13:14,850
river but you get the same sort of

310
00:13:19,460 --> 00:13:17,160
relationship if you if you crush up the

311
00:13:19,940 --> 00:13:19,470
right types of rocks in the lab and so

312
00:13:22,010 --> 00:13:19,950
there are

313
00:13:26,360 --> 00:13:22,020

complicating factors that can mess this

314
00:13:28,730 --> 00:13:26,370
up even more so this the surface

315
00:13:30,290 --> 00:13:28,740
temperature is a lot different from the

316
00:13:32,420 --> 00:13:30,300
temperature that these reactions feel

317
00:13:35,350 --> 00:13:32,430
and in particular most of these

318
00:13:38,150 --> 00:13:35,360
reactions at the sea floor are happening

319
00:13:40,580 --> 00:13:38,160
they're happening maybe 500 meters to a

320
00:13:43,640 --> 00:13:40,590
plum they're down into the basalt at 20

321
00:13:45,530 --> 00:13:43,650
to 40 Celsius and that temperature what

322
00:13:47,840 --> 00:13:45,540
determines that temperature is probably

323
00:13:49,580 --> 00:13:47,850
the heat flux from the interior and not

324
00:13:51,470 --> 00:13:49,590
the upper boundary condition to that

325
00:13:53,300 --> 00:13:51,480
system which is the temperature at the

326
00:13:55,550 --> 00:13:53,310
bottom of the ocean and so the standard

327
00:13:57,560 --> 00:13:55,560
assumption when people consider the sea

328
00:13:59,860 --> 00:13:57,570
floor weather is to assume that there's

329
00:14:03,680 --> 00:13:59,870
no dependence on the surface temperature

330
00:14:07,850 --> 00:14:03,690
and based on these type of laboratory

331
00:14:10,280 --> 00:14:07,860
measurements to assume that that the

332
00:14:11,650 --> 00:14:10,290
dependence on co2 is eat and so this is

333
00:14:16,820 --> 00:14:11,660
kind of a classic paper on the subject

334
00:14:18,980 --> 00:14:16,830
caldera men 1995 and this just shows

335
00:14:21,200 --> 00:14:18,990
yeah he has a number of these different

336
00:14:23,840 --> 00:14:21,210
boxes to simulate different processes

337
00:14:26,600 --> 00:14:23,850
atmosphere ocean system and then down to

338
00:14:27,920 --> 00:14:26,610

the to the seafloor weathering and when

339
00:14:30,740 --> 00:14:27,930
he gets out of the bottle into the

340
00:14:33,260 --> 00:14:30,750
pendants of co2 of seafloor weathering

341
00:14:35,000 --> 00:14:33,270
in this case shown here and silicate

342
00:14:37,400 --> 00:14:35,010
weathering out men what you can see is

343
00:14:39,230 --> 00:14:37,410
you've got to get the co2 extremely high

344
00:14:42,920 --> 00:14:39,240
to get much changes at all in the

345
00:14:44,720 --> 00:14:42,930
seafloor weather so most people have

346
00:14:47,960 --> 00:14:44,730
considered this problem have concluded

347
00:14:50,000 --> 00:14:47,970
that c4 weathering should have very weak

348
00:14:52,130 --> 00:14:50,010
or no dependence but surface temperature

349
00:14:54,230 --> 00:14:52,140
of the planet and a weak dependence on

350
00:14:55,510 --> 00:14:54,240
the co2 the pudding and that's those are

351
00:14:59,060 --> 00:14:55,520
the assumptions I'm going to make you

352
00:15:01,340 --> 00:14:59,070
now it's possible that in certain cases

353
00:15:02,720 --> 00:15:01,350
those assumptions could be wrong it's

354
00:15:04,600 --> 00:15:02,730
also possible to those that some things

355
00:15:09,320 --> 00:15:04,610
are wrong on current so in particular

356
00:15:11,930 --> 00:15:09,330
this type of work is based on 5 to 10

357
00:15:13,790 --> 00:15:11,940
cores down into the result so it's not

358
00:15:18,320 --> 00:15:13,800
like there's a huge sample what's going

359
00:15:21,830 --> 00:15:18,330
on down there but that's what I'm you

360
00:15:23,120 --> 00:15:21,840
too soon okay okay so I just argued that

361
00:15:26,690 --> 00:15:23,130
the weathering could be very different

362
00:15:28,220 --> 00:15:26,700
on the Continental weathering and sea

363
00:15:30,620 --> 00:15:28,230

floor weather could behave very

364
00:15:32,840 --> 00:15:30,630
differently at the same time we have

365
00:15:33,890 --> 00:15:32,850
numerical simulations that suggests that

366
00:15:37,430 --> 00:15:33,900
plants in

367
00:15:39,140 --> 00:15:37,440
halibel zone of stars like the Sun could

368
00:15:41,450 --> 00:15:39,150
have vastly different quantities of

369
00:15:43,250 --> 00:15:41,460
water delivers them so by orders of

370
00:15:46,550 --> 00:15:43,260
magnitude so you could have clinic to

371
00:15:49,310 --> 00:15:46,560
end up you know very dry right around

372
00:15:51,730 --> 00:15:49,320
the hospital zone or planets that end up

373
00:15:54,800 --> 00:15:51,740
very wet these colors sorry indicate

374
00:15:57,590 --> 00:15:54,810
this is a wet planet drypoint it's a log

375
00:16:00,200 --> 00:15:57,600
and then this is earth somewhere in this

376
00:16:02,210 --> 00:16:00,210
range so you can have planets 10 to 100

377
00:16:04,790 --> 00:16:02,220
times wetter 10 200 times drive in

378
00:16:08,810 --> 00:16:04,800
abbeville and this is also by someone

379
00:16:11,060 --> 00:16:08,820
your program created so they so at the

380
00:16:13,490 --> 00:16:11,070
same time that weathering the weathering

381
00:16:16,040 --> 00:16:13,500
of planets could have a strong

382
00:16:17,300 --> 00:16:16,050
dependence on how much land you have we

383
00:16:20,090 --> 00:16:17,310
could expect a habitable zone planets

384
00:16:23,000 --> 00:16:20,100
but at least at the delivery level have

385
00:16:25,490 --> 00:16:23,010
vastly different amounts of of land

386
00:16:27,380 --> 00:16:25,500
exposed and so what I want to do is I

387
00:16:29,090 --> 00:16:27,390
want to try to make a stab at this

388
00:16:31,280 --> 00:16:29,100

problem and I want to see what the

389
00:16:33,920 --> 00:16:31,290
effect of changing the land fraction on

390
00:16:37,430 --> 00:16:33,930
when it is it turns into every behavior

391
00:16:39,020 --> 00:16:37,440
and with the metabolism and so I can be

392
00:16:42,440 --> 00:16:39,030
considering things ranging from water

393
00:16:45,230 --> 00:16:42,450
world to something with maybe like

394
00:16:47,450 --> 00:16:45,240
ninety percent of the planet covered by

395
00:16:51,260 --> 00:16:47,460
land and I'm not going to be considering

396
00:16:52,970 --> 00:16:51,270
a completely land planet so the

397
00:16:55,010 --> 00:16:52,980
complement of what I'm talking about

398
00:17:00,020 --> 00:16:55,020
today is this augment paper where they

399
00:17:01,810 --> 00:17:00,030
talk about a dry clinic and these are

400
00:17:04,910 --> 00:17:01,820
some of the assumptions that I'm making

401
00:17:07,250 --> 00:17:04,920
so the first thing is I want to plan it

402
00:17:09,620 --> 00:17:07,260
that's geologically active so let's say

403
00:17:10,880 --> 00:17:09,630
plate tectonics to make it simple maybe

404
00:17:13,630 --> 00:17:10,890
there's something else that works like

405
00:17:17,180 --> 00:17:13,640
plate tectonics that can release co2 and

406
00:17:19,550 --> 00:17:17,190
Mary carbonates that you create I don't

407
00:17:21,790 --> 00:17:19,560
want a carbon planet so silicate rocks

408
00:17:25,280 --> 00:17:21,800
get these these types of things working

409
00:17:28,100 --> 00:17:25,290
I want a large reservoir of carbon and

410
00:17:30,170 --> 00:17:28,110
carbonate rocks so I can build up large

411
00:17:32,050 --> 00:17:30,180
amounts of co2 if I need to going

412
00:17:35,390 --> 00:17:32,060
further out in the habitable zone and

413
00:17:38,510 --> 00:17:35,400

this is important when I say Waterworld

414
00:17:40,880 --> 00:17:38,520
in this talk I could mean one metre of

415
00:17:43,160 --> 00:17:40,890
water above the highest topography I

416
00:17:46,220 --> 00:17:43,170
couldn't mean you know ten kilometers of

417
00:17:47,360 --> 00:17:46,230
water 20 kilometers of water but I

418
00:17:49,340 --> 00:17:47,370
definitely don't me

419
00:17:51,530 --> 00:17:49,350
thousand kilometers with all kinds of

420
00:17:53,330 --> 00:17:51,540
strange license under pressure at the

421
00:17:55,670 --> 00:17:53,340
bottom of the ocean I'm talking about

422
00:17:57,230 --> 00:17:55,680
something that looks like hers but maybe

423
00:17:59,390 --> 00:17:57,240
has ten times as much water to those

424
00:18:02,450 --> 00:17:59,400
ducks that's a water world in the

425
00:18:03,680 --> 00:18:02,460
context of this time this is not that

426
00:18:06,230 --> 00:18:03,690
important and I already talked about

427
00:18:11,980 --> 00:18:06,240
this assumption assume that that is

428
00:18:15,500 --> 00:18:11,990
alive or not ah not explicitly anywhere

429
00:18:18,530 --> 00:18:15,510
not explicitly Edward this is the depth

430
00:18:21,890 --> 00:18:18,540
of the ocean another so the depth of the

431
00:18:24,620 --> 00:18:21,900
ocean couldn't come into play for

432
00:18:27,799 --> 00:18:24,630
example if you had I'm kind of trying to

433
00:18:29,870 --> 00:18:27,809
get rid of that it's a problem by saying

434
00:18:32,930 --> 00:18:29,880
small water fractions suppose you added

435
00:18:35,360 --> 00:18:32,940
a 200 kilometer deep ocean you could

436
00:18:37,880 --> 00:18:35,370
have so much pressure that it could make

437
00:18:39,530 --> 00:18:37,890
this you to cut off co2 outgassing if

438
00:18:40,669 --> 00:18:39,540

you could have the facts like that but

439
00:18:43,070 --> 00:18:40,679
I'm not considering those texts

440
00:18:46,010 --> 00:18:43,080
appointments so I'm taking something

441
00:18:49,430 --> 00:18:46,020
like Earth and the only thing I want to

442
00:18:51,830 --> 00:18:49,440
toggle is the amount of water it happens

443
00:18:53,540 --> 00:18:51,840
and I that it has on the surface and I

444
00:18:59,150 --> 00:18:53,550
only want to toggle that within maybe an

445
00:19:01,580 --> 00:18:59,160
order magnitude each way ok this is the

446
00:19:04,820 --> 00:19:01,590
meat of the top so the next maybe 10

447
00:19:08,510 --> 00:19:04,830
slides if you need to take a nap wait

448
00:19:14,120 --> 00:19:08,520
till after those are done pay attention

449
00:19:16,610 --> 00:19:14,130
now now don't ya so ok so there can be

450
00:19:19,400 --> 00:19:16,620
some equations please don't take a nap

451
00:19:21,770 --> 00:19:19,410
yet because that dr. what is important

452
00:19:25,730 --> 00:19:21,780
about this time but I tried to put in

453
00:19:26,900 --> 00:19:25,740
some diagrams and stuff too ok so now

454
00:19:28,340 --> 00:19:26,910
I'm going to tell you about the actual

455
00:19:30,169 --> 00:19:28,350
model that I'm using how am I

456
00:19:33,830 --> 00:19:30,179
calculating whether calculating weather

457
00:19:37,160 --> 00:19:33,840
grades so I'm basing it on this wack is

458
00:19:40,160 --> 00:19:37,170
wack paper from 1981 the content of

459
00:19:43,070 --> 00:19:40,170
weather so W hell that's that's whether

460
00:19:45,110 --> 00:19:43,080
it on land and this is this is all the

461
00:19:46,549 --> 00:19:45,120
dimensions full stuff and so it's going

462
00:19:48,770 --> 00:19:46,559
to depend on precipitation which I'm

463
00:19:50,299 --> 00:19:48,780

going to be a function of pressure it's

464
00:19:52,850 --> 00:19:50,309
going to have some power law depends on

465
00:19:54,140 --> 00:19:52,860
co2 which I'm calling fee here and an

466
00:19:58,550 --> 00:19:54,150
exponential dependence on temperature

467
00:20:00,169 --> 00:19:58,560
based on an arena state relationship sea

468
00:20:01,130 --> 00:20:00,179
floor whether I'm pulling this in

469
00:20:03,260 --> 00:20:01,140
caldera

470
00:20:04,940 --> 00:20:03,270
is basically going to be a power-law

471
00:20:07,460 --> 00:20:04,950
dependence on the proton concentration

472
00:20:09,200 --> 00:20:07,470
in the ocean no dependence on

473
00:20:10,640 --> 00:20:09,210
temperature so that's actually important

474
00:20:12,320 --> 00:20:10,650
what's going to come these are the

475
00:20:14,210 --> 00:20:12,330
standard assumptions the only difference

476
00:20:16,810 --> 00:20:14,220
the only main difference that some

477
00:20:19,280 --> 00:20:16,820
people will use is instead of using

478
00:20:21,770 --> 00:20:19,290
making a function of the proton

479
00:20:23,240 --> 00:20:21,780
concentration in the water they'll make

480
00:20:26,960 --> 00:20:23,250
it a function of the total dissolved

481
00:20:30,050 --> 00:20:26,970
inorganic carbon it turns out that when

482
00:20:31,730 --> 00:20:30,060
you do that the only difference when

483
00:20:34,010 --> 00:20:31,740
you're related to co2 is just changing

484
00:20:35,390 --> 00:20:34,020
that exponent so still give you a

485
00:20:37,070 --> 00:20:35,400
slightly different exponent but not very

486
00:20:39,980 --> 00:20:37,080
much it's not not an important

487
00:20:41,870 --> 00:20:39,990
difference when I combine these I get

488
00:20:43,850 --> 00:20:41,880

this relationship for weathering so

489
00:20:46,610 --> 00:20:43,860
again this is a zero dimensional picture

490
00:20:48,950 --> 00:20:46,620
of the weathering on the planet non

491
00:20:53,330 --> 00:20:48,960
dimensionalized everything so one unit

492
00:20:56,450 --> 00:20:53,340
of t wiggle is t 1 unit of key no wiggle

493
00:21:01,550 --> 00:20:56,460
is equivalent to tu units of T wiggled

494
00:21:03,830 --> 00:21:01,560
of the dimensional quantity and then so

495
00:21:05,750 --> 00:21:03,840
this this is the sea floor whether Bart

496
00:21:08,330 --> 00:21:05,760
the Continental weathering part comes in

497
00:21:10,280 --> 00:21:08,340
here this is important gammas the land

498
00:21:11,960 --> 00:21:10,290
fraction i'm making a particular

499
00:21:15,170 --> 00:21:11,970
assumption for how the land fraction is

500
00:21:18,020 --> 00:21:15,180
going to scale is going to scale with

501
00:21:20,090 --> 00:21:18,030
how the continental weathering is going

502
00:21:23,270 --> 00:21:20,100
to scale with land fraction this

503
00:21:25,340 --> 00:21:23,280
assumption corresponds to just growing

504
00:21:27,680 --> 00:21:25,350
to just growing yourself some water

505
00:21:29,750 --> 00:21:27,690
pocket if you imagine the continent

506
00:21:31,880 --> 00:21:29,760
growing in different ways you might have

507
00:21:35,390 --> 00:21:31,890
like a square root dependence if it's

508
00:21:37,100 --> 00:21:35,400
the area if it's the perimeter rather

509
00:21:38,450 --> 00:21:37,110
than the area of the continent that's

510
00:21:40,400 --> 00:21:38,460
important for the sea floor weathering

511
00:21:42,710 --> 00:21:40,410
which it might be the comments all

512
00:21:45,620 --> 00:21:42,720
broken up in that doesn't end up

513
00:21:49,040 --> 00:21:45,630

affecting the results very much and this

514
00:21:50,600 --> 00:21:49,050
data 0 term it says if you put all your

515
00:21:55,190 --> 00:21:50,610
parameters that their standard value

516
00:21:56,630 --> 00:21:55,200
this goes to 1 this goes to one if land

517
00:21:58,790 --> 00:21:56,640
fraction is equal to the value and

518
00:22:01,760 --> 00:21:58,800
current earth this goes to 1 this goes

519
00:22:04,760 --> 00:22:01,770
to 1 and beta 0 is your estimate for how

520
00:22:06,440 --> 00:22:04,770
much sea floor weathering happens as a

521
00:22:08,330 --> 00:22:06,450
fraction of the total weather in current

522
00:22:10,100 --> 00:22:08,340
earth and our best estimate is that it's

523
00:22:12,110 --> 00:22:10,110
about twenty-five percent of total

524
00:22:14,990 --> 00:22:12,120
weathering on current earth but there's

525
00:22:16,580 --> 00:22:15,000
an uncertainty of probably roughly 100

526
00:22:20,660 --> 00:22:16,590
not so it's probably between zero and

527
00:22:23,360 --> 00:22:20,670
fifty percent and then this assumption

528
00:22:25,220 --> 00:22:23,370
if you have a closed system gap I'm

529
00:22:27,650 --> 00:22:25,230
calling the outcasts in gamma the big

530
00:22:29,600 --> 00:22:27,660
gambler little gammas land fraction big

531
00:22:31,790 --> 00:22:29,610
game is outgassing it's never going to

532
00:22:33,800 --> 00:22:31,800
come back in for the rest of the top

533
00:22:35,840 --> 00:22:33,810
because I'm just going to assume there's

534
00:22:38,840 --> 00:22:35,850
some constant outgassing that doesn't

535
00:22:41,030 --> 00:22:38,850
depend on where the planet is in the

536
00:22:42,230 --> 00:22:41,040
hobbles own or anything else surface

537
00:22:44,390 --> 00:22:42,240
temperature of the planet is going to

538
00:22:46,280 --> 00:22:44,400

set that to a constant and the constant

539
00:22:50,690 --> 00:22:46,290
outgassing has to equal the weather so

540
00:22:52,910 --> 00:22:50,700
that's how you get a closed system ok so

541
00:22:55,280 --> 00:22:52,920
to solve this you need a couple you need

542
00:22:56,600 --> 00:22:55,290
a weathering so I need to solve I need

543
00:22:58,520 --> 00:22:56,610
to write down equations that I can solve

544
00:22:59,780 --> 00:22:58,530
for temperature in co2 so I need

545
00:23:02,030 --> 00:22:59,790
something for weathering a weather

546
00:23:05,300 --> 00:23:02,040
relationship which was big gamma equals

547
00:23:07,420 --> 00:23:05,310
the weathering function of of P and T

548
00:23:10,420 --> 00:23:07,430
and then I need some sort of climate

549
00:23:12,950 --> 00:23:10,430
model and so this is my client wall so

550
00:23:15,140 --> 00:23:12,960
any of my friends I don't think any of

551
00:23:17,630 --> 00:23:15,150
them were here so atmosphere and climate

552
00:23:20,990 --> 00:23:17,640
here would probably take me out back and

553
00:23:25,010 --> 00:23:21,000
shoot me for this but this is my climate

554
00:23:27,730 --> 00:23:25,020
model it's zero dimensional and what it

555
00:23:30,200 --> 00:23:27,740
is is we have incoming solar radiation

556
00:23:32,600 --> 00:23:30,210
we have an OB know that can reflect and

557
00:23:34,630 --> 00:23:32,610
then we have the outgoing of red a

558
00:23:37,490 --> 00:23:34,640
mission to space so I have one equation

559
00:23:44,720 --> 00:23:37,500
take us from the Alpha the Omega of

560
00:23:46,880 --> 00:23:44,730
climate I'm going to do is I cake first

561
00:23:50,900 --> 00:23:46,890
they non dimensionalize my red a mission

562
00:23:53,210 --> 00:23:50,910
to space and then I expand it so if I

563
00:23:55,940 --> 00:23:53,220

non-dimensionalize this I just set this

564
00:23:59,120 --> 00:23:55,950
to a non dimensionalize everything by

565
00:24:00,680 --> 00:23:59,130
the current insulation and so I'm left

566
00:24:03,920 --> 00:24:00,690
it on this side is a quarter 1 minus

567
00:24:06,950 --> 00:24:03,930
alpha and so I expand around that so in

568
00:24:08,660 --> 00:24:06,960
the base climate I just need to have my

569
00:24:10,160 --> 00:24:08,670
outgoing mission to space equal the

570
00:24:15,020 --> 00:24:10,170
absorb radiation that's what this term

571
00:24:16,520 --> 00:24:15,030
means and then I capture this is if I

572
00:24:17,810 --> 00:24:16,530
increase the temperature the planet I'm

573
00:24:20,600 --> 00:24:17,820
going to want to admit more radiation

574
00:24:23,300 --> 00:24:20,610
spaced and I capture all of that physics

575
00:24:25,850 --> 00:24:23,310
in this one parameter and if i increase

576
00:24:28,430 --> 00:24:25,860
the log of the co 2 i'm in a bit less

577
00:24:30,620 --> 00:24:28,440
radiation space and i calculate

578
00:24:32,420 --> 00:24:30,630
I capture all that physics in this one

579
00:24:35,930 --> 00:24:32,430
perimeter so only have two parameters

580
00:24:38,660 --> 00:24:35,940
for the radiation scheme I grab those

581
00:24:42,050 --> 00:24:38,670
parameters from rape your hunger it's

582
00:24:44,030 --> 00:24:42,060
kind of book where he used a radio to

583
00:24:47,510 --> 00:24:44,040
connect them all and calculates their

584
00:24:49,160 --> 00:24:47,520
value and when I'm left with when i plug

585
00:24:51,260 --> 00:24:49,170
this back in is this for the climbing

586
00:24:52,670 --> 00:24:51,270
wall so I have a simple climate model

587
00:24:56,870 --> 00:24:52,680
and what you should know about it is if

588
00:24:58,880 --> 00:24:56,880

i increase the insulation s volume the

589
00:25:03,290 --> 00:24:58,890
amount of radiation that from this star

590
00:25:04,730 --> 00:25:03,300
that the planet is hit with i can deal

591
00:25:06,350 --> 00:25:04,740
with that either by increasing

592
00:25:11,150 --> 00:25:06,360
temperature by an appropriate amount of

593
00:25:15,290 --> 00:25:11,160
units regulated by this mega one or i

594
00:25:18,410 --> 00:25:15,300
can deal with it by decreasing the co2

595
00:25:20,210 --> 00:25:18,420
and so in the standard silicate

596
00:25:21,800 --> 00:25:20,220
weathering feedback you get some

597
00:25:23,600 --> 00:25:21,810
combination of both to increase the

598
00:25:26,480 --> 00:25:23,610
insulation you increase the temperature

599
00:25:28,160 --> 00:25:26,490
some and you decrease the co2 some and

600
00:25:29,660 --> 00:25:28,170
that's why they temperature didn't

601
00:25:30,980 --> 00:25:29,670
increase as thought as much as you

602
00:25:34,790 --> 00:25:30,990
thought it might what happened to Sigma

603
00:25:38,180 --> 00:25:34,800
Theta reform yeah that's that's right

604
00:25:42,200 --> 00:25:38,190
there now it turns out that if you

605
00:25:45,170 --> 00:25:42,210
linearize if you linearize roughly

606
00:25:48,560 --> 00:25:45,180
between let's say minus 10 Celsius to 40

607
00:25:51,080 --> 00:25:48,570
Celsius you might think sigma t to the

608
00:25:54,170 --> 00:25:51,090
fourth is going to deviate fairly far

609
00:25:56,870 --> 00:25:54,180
from a linearization but because of the

610
00:25:59,090 --> 00:25:56,880
water vapor feedback it actually looks

611
00:26:00,410 --> 00:25:59,100
that the actual function isn't Sigma to

612
00:26:01,700 --> 00:26:00,420
do the fourth it actually looks more

613
00:26:04,700 --> 00:26:01,710

linear so it makes us a better

614
00:26:06,950 --> 00:26:04,710
approximation and that's not to say I'm

615
00:26:08,720 --> 00:26:06,960
really defending you know bottling all

616
00:26:10,730 --> 00:26:08,730
of climate in 20 dimensions and doing

617
00:26:15,800 --> 00:26:10,740
this but that's Sigma to you that's

618
00:26:19,250 --> 00:26:15,810
worth okay this this is an important

619
00:26:21,380 --> 00:26:19,260
equation so what I do it I kick them all

620
00:26:23,030 --> 00:26:21,390
and what I'm interested in the most

621
00:26:26,870 --> 00:26:23,040
important quantity for the rest of this

622
00:26:29,390 --> 00:26:26,880
is D tds so how much does surface

623
00:26:30,710 --> 00:26:29,400
temperature of the planet rather explain

624
00:26:32,540 --> 00:26:30,720
what those are I should have put some

625
00:26:33,590 --> 00:26:32,550
little things explaining with these how

626
00:26:35,420 --> 00:26:33,600
much the service temperature of the

627
00:26:37,010 --> 00:26:35,430
planet can respond to changes in

628
00:26:39,350 --> 00:26:37,020
solutions you could get insulation

629
00:26:41,450 --> 00:26:39,360
changes and stars warming up with time

630
00:26:42,010 --> 00:26:41,460
getting more luminous and you could get

631
00:26:43,810 --> 00:26:42,020
insulation

632
00:26:45,820 --> 00:26:43,820
changes because you're going further

633
00:26:47,650 --> 00:26:45,830
further from the star or closer to the

634
00:26:49,660 --> 00:26:47,660
star but what's important for the

635
00:26:52,000 --> 00:26:49,670
habitable zone is that this value be as

636
00:26:53,770 --> 00:26:52,010
small as it possibly can be and the

637
00:26:55,390 --> 00:26:53,780
limit that this 40 and you could just

638
00:26:57,250 --> 00:26:55,400

move the planet anywhere you wanted and

639
00:26:59,200 --> 00:26:57,260
the surface temperature wouldn't care so

640
00:27:01,240 --> 00:26:59,210
if you started in the Hubble zone you'll

641
00:27:03,060 --> 00:27:01,250
always be the Hamilton but we want this

642
00:27:07,630 --> 00:27:03,070
to get small as it possibly can be and

643
00:27:10,870 --> 00:27:07,640
this term right here this is the climate

644
00:27:13,570 --> 00:27:10,880
sensitivity if you don't have any

645
00:27:16,030 --> 00:27:13,580
changes in co2 so every unit of

646
00:27:17,410 --> 00:27:16,040
insulation change gets converted into a

647
00:27:19,450 --> 00:27:17,420
temperature change this is the maximum

648
00:27:22,270 --> 00:27:19,460
you can get for the Clemson student

649
00:27:24,910 --> 00:27:22,280
external forcing and this term describes

650
00:27:26,620 --> 00:27:24,920
any weather and feedbacks we're going to

651
00:27:30,700 --> 00:27:26,630
change in the co2 in order to keep the

652
00:27:35,890 --> 00:27:30,710
temperature in a smaller range so we

653
00:27:37,630 --> 00:27:35,900
want that to be low and after writing

654
00:27:39,700 --> 00:27:37,640
down the complicated weathering

655
00:27:42,820 --> 00:27:39,710
memorization I'm going to simplify here

656
00:27:44,200 --> 00:27:42,830
because the explicit form of those terms

657
00:27:46,240 --> 00:27:44,210
doesn't matter for i'm going to say in

658
00:27:48,040 --> 00:27:46,250
the next two slides and so i'm going to

659
00:27:50,770 --> 00:27:48,050
do is I'm going to say the total weather

660
00:27:52,810 --> 00:27:50,780
is equal to some function of the land

661
00:27:56,140 --> 00:27:52,820
pratchett time to the Continental

662
00:27:59,320 --> 00:27:56,150
lettering which is a function of co2 and

663
00:28:01,600 --> 00:27:59,330

temperature plus some function on the

664
00:28:03,550 --> 00:28:01,610
land fraction time to the ocean weather

665
00:28:07,210 --> 00:28:03,560
which is a function of co2 and the

666
00:28:10,060 --> 00:28:07,220
temperature it's pretty hard to cook up

667
00:28:12,730 --> 00:28:10,070
a parameterization where this gamma

668
00:28:14,710 --> 00:28:12,740
function is somehow inside here so this

669
00:28:17,590 --> 00:28:14,720
is a very safe assumption that you can

670
00:28:18,970 --> 00:28:17,600
separate these variables out and all I'm

671
00:28:21,700 --> 00:28:18,980
going to require about these functions

672
00:28:23,200 --> 00:28:21,710
is that if you have a water world you

673
00:28:25,840 --> 00:28:23,210
can't have any continental weather and

674
00:28:27,820 --> 00:28:25,850
if you have and when planet you can't

675
00:28:32,050 --> 00:28:27,830
have any seeds for weathering so I think

676
00:28:33,580 --> 00:28:32,060
those are basic safe assumptions and now

677
00:28:36,190 --> 00:28:33,590
and now is when you when you should wake

678
00:28:41,620 --> 00:28:36,200
up so these two slides that you should

679
00:28:43,810 --> 00:28:41,630
pay extra attention sleep so most people

680
00:28:45,070 --> 00:28:43,820
think that c4 weather is independent of

681
00:28:46,600 --> 00:28:45,080
surface temperature that's something

682
00:28:48,520 --> 00:28:46,610
that more work should be done on but

683
00:28:50,140 --> 00:28:48,530
that's that would that sort of the null

684
00:28:53,080 --> 00:28:50,150
hypothesis right now that's what people

685
00:28:55,390 --> 00:28:53,090
think and so what I'm going to show here

686
00:28:55,840 --> 00:28:55,400
is that if that's true that a water

687
00:28:57,430 --> 00:28:55,850
world

688
00:28:59,320 --> 00:28:57,440

and have known climate stabilizing

689
00:29:00,909 --> 00:28:59,330
weather and feedback and therefore is

690
00:29:04,000 --> 00:29:00,919
going to have a much smaller navigable

691
00:29:06,669 --> 00:29:04,010
zone so that has direct implications for

692
00:29:10,360 --> 00:29:06,679
planets being detected today it's the

693
00:29:13,720 --> 00:29:10,370
way I do that is I take this last I take

694
00:29:16,840 --> 00:29:13,730
this equation and I differentiate with

695
00:29:20,289 --> 00:29:16,850
respect to s and we remember that w is

696
00:29:24,039 --> 00:29:20,299
equal to a constant so the DDT of this

697
00:29:25,570 --> 00:29:24,049
equation has to be zero and you get you

698
00:29:26,860 --> 00:29:25,580
just sort of move the terms through and

699
00:29:28,779 --> 00:29:26,870
this is what you get when you

700
00:29:33,220 --> 00:29:28,789
differentiate the weather with respect

701
00:29:38,440 --> 00:29:33,230
to s and I'm going to be considering

702
00:29:40,270 --> 00:29:38,450
Waterworld so f of gamma equals zero

703
00:29:43,240 --> 00:29:40,280
past equals zero so this term is gone

704
00:29:47,080 --> 00:29:43,250
and I've constructed that by

705
00:29:49,990 --> 00:29:47,090
construction the sea floor wondering

706
00:29:52,600 --> 00:29:50,000
whether oceans wo doesn't depend on

707
00:29:55,510 --> 00:29:52,610
temperature so that's the basis umph

708
00:29:58,810 --> 00:29:55,520
shin and so this term goes away and what

709
00:30:00,700 --> 00:29:58,820
you're left with is that defeat es

710
00:30:02,890 --> 00:30:00,710
changes in co2 as you change the

711
00:30:04,270 --> 00:30:02,900
installation have to be zero and so the

712
00:30:07,419 --> 00:30:04,280
physical picture you shop in your mind

713
00:30:09,970 --> 00:30:07,429

is if the if the weathering of the

714
00:30:11,740 --> 00:30:09,980
planet can only depend on co2 you've got

715
00:30:13,659 --> 00:30:11,750
a certain out gassing rate and you're

716
00:30:15,730 --> 00:30:13,669
going to have to keep putting out more

717
00:30:19,360 --> 00:30:15,740
and worse into until you until you've

718
00:30:21,270 --> 00:30:19,370
got your your weather and high enough to

719
00:30:24,549 --> 00:30:21,280
balance the co2 that you help guests and

720
00:30:27,159 --> 00:30:24,559
only then can you stop outgassing co2

721
00:30:29,529 --> 00:30:27,169
and you'll just build up to some events

722
00:30:32,230 --> 00:30:29,539
high co2 value maybe it's point one Mars

723
00:30:33,640 --> 00:30:32,240
maybe it's 10 bars something high and

724
00:30:35,529 --> 00:30:33,650
it's just going to stay there it doesn't

725
00:30:38,950 --> 00:30:35,539
care the co2 doesn't care what you do

726
00:30:41,470 --> 00:30:38,960
about the where the planet is relative

727
00:30:43,029 --> 00:30:41,480
to the star what the insulation is and

728
00:30:45,250 --> 00:30:43,039
so you can have no weather and feedback

729
00:30:47,940 --> 00:30:45,260
and so that's why you get physically

730
00:30:52,060 --> 00:30:47,950
while you get the CD s equals zero and

731
00:30:54,039 --> 00:30:52,070
so what that means is your DTS your

732
00:30:57,190 --> 00:30:54,049
climate sensitivity to external forcing

733
00:30:59,440 --> 00:30:57,200
is just equal to its maximum value that

734
00:31:00,760 --> 00:30:59,450
it can take as long as there's no

735
00:31:02,919 --> 00:31:00,770
positive I'm assuming there's no

736
00:31:04,990 --> 00:31:02,929
positive feedback weathering feedback so

737
00:31:07,960 --> 00:31:05,000
you just get the maximum possible value

738
00:31:09,200 --> 00:31:07,970

every unit of s goes into a unit

739
00:31:10,970 --> 00:31:09,210
increase of tea

740
00:31:12,860 --> 00:31:10,980
and this is the change you get in the

741
00:31:14,720 --> 00:31:12,870
habit though so here's here's deserves

742
00:31:16,880 --> 00:31:14,730
schematic picture what's going to happen

743
00:31:19,880 --> 00:31:16,890
you go from colliding with some land a

744
00:31:22,070 --> 00:31:19,890
lot of ocean some sort of relatively

745
00:31:24,230 --> 00:31:22,080
wide album zone like this and now all of

746
00:31:25,789 --> 00:31:24,240
a sudden on the water world these are

747
00:31:29,000 --> 00:31:25,799
your habitable zone limits so it's an

748
00:31:30,500 --> 00:31:29,010
order of magnitude smaller and so all of

749
00:31:37,370 --> 00:31:30,510
that follows just from these basic

750
00:31:39,139 --> 00:31:37,380
assumptions the second thing I'm going

751
00:31:40,960 --> 00:31:39,149
to consider is I'm going to say what if

752
00:31:43,340 --> 00:31:40,970
see for weathering to the constant

753
00:31:46,130 --> 00:31:43,350
what's going to happen to this to this

754
00:31:47,960 --> 00:31:46,140
climate weather and feedback the reason

755
00:31:51,409 --> 00:31:47,970
that I'm considering that limit there

756
00:31:54,260 --> 00:31:51,419
are two reasons the first is we saw from

757
00:31:56,210 --> 00:31:54,270
from the caldera word the sea floor

758
00:31:58,940 --> 00:31:56,220
weather in is that week has a weak

759
00:32:02,360 --> 00:31:58,950
dependence on co2 and its peak enough

760
00:32:04,250 --> 00:32:02,370
then this limit is a pretty good

761
00:32:06,200 --> 00:32:04,260
description of the full model which I'm

762
00:32:08,649 --> 00:32:06,210
going to show us so it's an instructive

763
00:32:12,950 --> 00:32:08,659

limit to consider the second reason is

764
00:32:14,720 --> 00:32:12,960
there's a possibility that that c4

765
00:32:17,149 --> 00:32:14,730
weathering is actually limited by the

766
00:32:19,789 --> 00:32:17,159
circulation ocean water and hydrothermal

767
00:32:21,980 --> 00:32:19,799
vents through the basalt and if that's

768
00:32:23,690 --> 00:32:21,990
the case then it doesn't really care

769
00:32:24,980 --> 00:32:23,700
about the co2 or temperature at all so

770
00:32:29,720 --> 00:32:24,990
there is a physical limit where this is

771
00:32:30,919 --> 00:32:29,730
actually correct we don't know currently

772
00:32:35,060 --> 00:32:30,929
people think that that's not the case

773
00:32:40,610 --> 00:32:35,070
but it's possible that's kid okay so

774
00:32:41,630 --> 00:32:40,620
what happened in this limit so I said

775
00:32:43,810 --> 00:32:41,640
that the sea floor weather and his

776
00:32:50,149 --> 00:32:43,820
confidence that knocks these terms out

777
00:32:52,610 --> 00:32:50,159
and then right away because I assume

778
00:32:54,320 --> 00:32:52,620
that that the land fraction function was

779
00:32:56,570 --> 00:32:54,330
separable which is the safe assumption

780
00:33:00,200 --> 00:32:56,580
you're left with this and so you can

781
00:33:01,880 --> 00:33:00,210
solve for D feed ES and plug it in to

782
00:33:04,130 --> 00:33:01,890
the pds and you get something that has

783
00:33:06,320 --> 00:33:04,140
no dependence on gamma so there's just

784
00:33:13,610 --> 00:33:06,330
no dependence on the land fraction left

785
00:33:15,139 --> 00:33:13,620
and what this means is so if you go to a

786
00:33:17,419 --> 00:33:15,149
clinic with more land to a play with

787
00:33:19,669 --> 00:33:17,429
less than you're definitely you've got

788
00:33:21,740 --> 00:33:19,679

if the land fractioning if the land

789
00:33:23,120 --> 00:33:21,750
weathering is is the dominant term and

790
00:33:24,950 --> 00:33:23,130
you go to

791
00:33:26,780 --> 00:33:24,960
with less wind you're going to get a

792
00:33:28,880 --> 00:33:26,790
higher co2 you're going to get a higher

793
00:33:31,430 --> 00:33:28,890
temperature but you're not going to get

794
00:33:33,380 --> 00:33:31,440
a higher change in temperature as you

795
00:33:35,330 --> 00:33:33,390
change the insulation so you'll get a

796
00:33:37,310 --> 00:33:35,340
small shifting and where the habitable

797
00:33:39,380 --> 00:33:37,320
zone exists so it's going to shift

798
00:33:43,280 --> 00:33:39,390
outwards a bit but the width is going to

799
00:33:45,230 --> 00:33:43,290
stay the same and so this is a

800
00:33:47,960 --> 00:33:45,240
relationship that holds up in the full

801
00:33:49,990 --> 00:33:47,970
model so the basic picture that you can

802
00:33:53,330 --> 00:33:50,000
construct just from the simple examples

803
00:33:58,370 --> 00:33:53,340
is that a water world a very narrow

804
00:34:00,350 --> 00:33:58,380
alleble zone and a and and planets that

805
00:34:02,120 --> 00:34:00,360
have some Lin should so show weak

806
00:34:04,550 --> 00:34:02,130
dependence of their habitable zone of

807
00:34:06,860 --> 00:34:04,560
land fraction which is the powerful

808
00:34:08,960 --> 00:34:06,870
result because what it means is that the

809
00:34:12,560 --> 00:34:08,970
previous habitable zone theory should be

810
00:34:14,869 --> 00:34:12,570
robust in these cases which has been

811
00:34:18,320 --> 00:34:14,879
drive without any explicit reference to

812
00:34:21,830 --> 00:34:18,330
what the land fraction is okay more meat

813
00:34:23,480 --> 00:34:21,840

this is the this is the full model

814
00:34:25,970 --> 00:34:23,490
results so I'm not considering my

815
00:34:28,430 --> 00:34:25,980
bicycle limits anymore I've gone back to

816
00:34:31,700 --> 00:34:28,440
the complete law and what I'm showing

817
00:34:34,190 --> 00:34:31,710
here is imagine the evolution of a

818
00:34:36,139 --> 00:34:34,200
planet like Earth these are different

819
00:34:38,540 --> 00:34:36,149
land fractions as a function of

820
00:34:40,940 --> 00:34:38,550
insulation here I've just plotted for a

821
00:34:43,190 --> 00:34:40,950
star like the Sun what time these would

822
00:34:44,480 --> 00:34:43,200
be these are my non dimensional

823
00:34:50,030 --> 00:34:44,490
variables in here I turn them back into

824
00:34:52,220 --> 00:34:50,040
visible log co2 in bars and this is the

825
00:34:54,290 --> 00:34:52,230
temperature and I just sort of draw the

826
00:34:56,659 --> 00:34:54,300
kind of rough habitable zone limits

827
00:34:58,850 --> 00:34:56,669
where moist green odds might be where a

828
00:35:01,190 --> 00:34:58,860
snowball might be this is some other

829
00:35:04,040 --> 00:35:01,200
people's I needed it I don't think it's

830
00:35:05,840 --> 00:35:04,050
all that useful of where floorset

831
00:35:07,040 --> 00:35:05,850
business might shut up because there

832
00:35:08,540 --> 00:35:07,050
could be other types of life that don't

833
00:35:11,840 --> 00:35:08,550
need there are other types of life that

834
00:35:15,230 --> 00:35:11,850
don't need to Lucis I want you can see

835
00:35:19,370 --> 00:35:15,240
is as you increase the insulation so

836
00:35:20,960 --> 00:35:19,380
you're going your plan is the star is

837
00:35:23,180 --> 00:35:20,970
aging where you're going closer to the

838
00:35:26,150 --> 00:35:23,190

star you get increases in temperature

839
00:35:28,040 --> 00:35:26,160
but but they're ameliorated by the fact

840
00:35:30,050 --> 00:35:28,050
that the co2 is decreasing and so that's

841
00:35:32,390 --> 00:35:30,060
the silicate weathering feedback and as

842
00:35:34,700 --> 00:35:32,400
we increase the interaction like this

843
00:35:36,810 --> 00:35:34,710
you get higher temperatures but you

844
00:35:39,300 --> 00:35:36,820
still get a

845
00:35:41,310 --> 00:35:39,310
tds this slope that's about to say and

846
00:35:45,450 --> 00:35:41,320
say your howl zone is just shifting

847
00:35:48,390 --> 00:35:45,460
rather than shrinking or expanding now

848
00:35:50,340 --> 00:35:48,400
if we put on top of that a planet where

849
00:35:52,980 --> 00:35:50,350
we set the land fraction is zero and you

850
00:35:56,940 --> 00:35:52,990
can no longer do any land whether you

851
00:35:59,580 --> 00:35:56,950
get a much more rapid increase in to the

852
00:36:02,190 --> 00:35:59,590
moist greenhouse and the reason is this

853
00:36:04,050 --> 00:36:02,200
is what I was describing before the co2

854
00:36:06,210 --> 00:36:04,060
just builds up until its height up to

855
00:36:07,440 --> 00:36:06,220
balance the outgassing so the weather

856
00:36:09,990 --> 00:36:07,450
and get tired of balance the outgassing

857
00:36:12,000 --> 00:36:10,000
and sticks at that I body value in this

858
00:36:14,940 --> 00:36:12,010
case it's like six bars of seven bars

859
00:36:17,100 --> 00:36:14,950
co2 and so you just rapidly go into the

860
00:36:20,250 --> 00:36:17,110
moisture you know state and so what that

861
00:36:28,620 --> 00:36:20,260
means is you get a much narrower however

862
00:36:30,630 --> 00:36:28,630
rules and habitable zone okay so I just

863
00:36:33,480 --> 00:36:30,640

want to say something about why that's

864
00:36:36,660 --> 00:36:33,490
happening in the model basically what

865
00:36:40,230 --> 00:36:36,670
I'm plotting here forget about what B is

866
00:36:43,200 --> 00:36:40,240
is the scaling of of co2 in the wac

867
00:36:45,450 --> 00:36:43,210
primer ization the point is it looks you

868
00:36:47,640 --> 00:36:45,460
get a similar picture at both of these

869
00:36:49,200 --> 00:36:47,650
potential values and feet which might be

870
00:36:51,900 --> 00:36:49,210
different because of the affected land

871
00:36:55,980 --> 00:36:51,910
plants but the idea is this is the

872
00:36:58,350 --> 00:36:55,990
insulation level modern higher lower

873
00:37:00,810 --> 00:36:58,360
this is the land fraction so this is ten

874
00:37:02,850 --> 00:37:00,820
percent one percent one hundred percent

875
00:37:05,640 --> 00:37:02,860
and you can see there there are these

876
00:37:07,500 --> 00:37:05,650
broad regions where dt bf's this this

877
00:37:09,690 --> 00:37:07,510
climate sensitivity to external forcing

878
00:37:11,880 --> 00:37:09,700
parameter is roughly constant in both

879
00:37:13,770 --> 00:37:11,890
cases and they tend to happen when the

880
00:37:15,660 --> 00:37:13,780
planet is warmer and the planet might be

881
00:37:18,240 --> 00:37:15,670
warmer because you make the land

882
00:37:19,970 --> 00:37:18,250
fraction smaller or it might be warmer

883
00:37:23,460 --> 00:37:19,980
just because you increase the insulation

884
00:37:25,860 --> 00:37:23,470
and so why does that happen well we can

885
00:37:30,180 --> 00:37:25,870
write down in the full model what key

886
00:37:32,250 --> 00:37:30,190
tds is it's this value you get with no

887
00:37:34,530 --> 00:37:32,260
weather and feedback time something

888
00:37:36,060 --> 00:37:34,540

that's always between 0 and 1 which

889
00:37:38,880 --> 00:37:36,070
describes the weather and keep that if

890
00:37:42,540 --> 00:37:38,890
there's no seas for weathering then this

891
00:37:44,100 --> 00:37:42,550
term equals 0 and you get sort of this

892
00:37:47,820 --> 00:37:44,110
term describes the land weather and

893
00:37:49,950 --> 00:37:47,830
feedback and this kind of annoying term

894
00:37:50,700 --> 00:37:49,960
is the one that comes into the sea floor

895
00:37:52,320 --> 00:37:50,710
weather

896
00:37:54,750 --> 00:37:52,330
but what you can see and this is

897
00:37:56,820 --> 00:37:54,760
critical is there's this ego minus T and

898
00:37:58,890 --> 00:37:56,830
so anything that gets temperature more

899
00:38:00,720 --> 00:37:58,900
than you know 10 degrees 20 degrees

900
00:38:03,839 --> 00:38:00,730
warmer than today is going to kill this

901
00:38:05,550 --> 00:38:03,849
term even if it's you know even if it's

902
00:38:08,370 --> 00:38:05,560
just 10 degrees you get this term

903
00:38:12,329 --> 00:38:08,380
totally killed and you end up in a limit

904
00:38:14,640 --> 00:38:12,339
where dgds is just equal is constant and

905
00:38:18,390 --> 00:38:14,650
that actually is a very good description

906
00:38:19,440 --> 00:38:18,400
of all of those planets problems over it

907
00:38:22,230 --> 00:38:19,450
so this is an actuation of

908
00:38:24,870 --> 00:38:22,240
mathematically of why in the model you

909
00:38:29,240 --> 00:38:24,880
get those constant DTD esas and those

910
00:38:35,670 --> 00:38:29,250
lied alleble zones for such large

911
00:38:37,710 --> 00:38:35,680
interaction ridge okay this the part is

912
00:38:40,050 --> 00:38:37,720
talk with where the wild things are so

913
00:38:43,890 --> 00:38:40,060

this is the more speculative stuff and

914
00:38:45,990 --> 00:38:43,900
be interested in your comments on it so

915
00:38:50,370 --> 00:38:46,000
I just said that I just made an argument

916
00:38:52,050 --> 00:38:50,380
that I just made an argument that a

917
00:38:54,510 --> 00:38:52,060
water world is not to be attractive

918
00:38:57,300 --> 00:38:54,520
place to look for life other than the

919
00:38:58,560 --> 00:38:57,310
problems biologists might have that it's

920
00:39:01,079 --> 00:38:58,570
not going to be a place with a light

921
00:39:02,280 --> 00:39:01,089
apples over and so now I'm going to talk

922
00:39:05,280 --> 00:39:02,290
about something that might be able to

923
00:39:07,859 --> 00:39:05,290
save water world's attention and so the

924
00:39:10,950 --> 00:39:07,869
idea is if if the water world get such a

925
00:39:14,010 --> 00:39:10,960
high co2 that it puts itself into a

926
00:39:15,570 --> 00:39:14,020
moist greenhouse cape and their water

927
00:39:17,490 --> 00:39:15,580
and the stratosphere is being broken

928
00:39:20,670 --> 00:39:17,500
apart and hydrogen escaping and you're

929
00:39:23,250 --> 00:39:20,680
losing oceans of water what if you reach

930
00:39:25,710 --> 00:39:23,260
a point as you decrease your water

931
00:39:28,230 --> 00:39:25,720
levels where you start to expose some

932
00:39:29,880 --> 00:39:28,240
type of some sort of wind it might be

933
00:39:33,570 --> 00:39:29,890
the salt it doesn't really matter what

934
00:39:36,089 --> 00:39:33,580
it is and then you can engage these land

935
00:39:37,620 --> 00:39:36,099
weathering feedbacks that are a strong

936
00:39:39,300 --> 00:39:37,630
function of temperature and are going to

937
00:39:41,520 --> 00:39:39,310
be extremely rapid if you're in a moist

938
00:39:45,150 --> 00:39:41,530

Reno of state is it possible that you

939
00:39:48,660 --> 00:39:45,160
could decrease the co2 fast enough to

940
00:39:52,500 --> 00:39:48,670
stop arrest this water loss while you

941
00:39:57,740 --> 00:39:52,510
still have a partially exposed land and

942
00:40:00,630 --> 00:39:57,750
some amount of ocean so there's some t0

943
00:40:02,670 --> 00:40:00,640
the time it takes to initially expose

944
00:40:03,700 --> 00:40:02,680
the continent that's going to depend on

945
00:40:07,390 --> 00:40:03,710
how much water is in

946
00:40:09,630 --> 00:40:07,400
let it and for some very moist water

947
00:40:15,099 --> 00:40:09,640
world but it's not t0 is going to be

948
00:40:17,650 --> 00:40:15,109
potentially infinitely large but for a

949
00:40:21,250 --> 00:40:17,660
planet where t0 is small enough and you

950
00:40:23,620 --> 00:40:21,260
essentially exposed confident it's going

951
00:40:25,930 --> 00:40:23,630
to take you know the time scale for this

952
00:40:28,120 --> 00:40:25,940
water loss to occur it depends a lot of

953
00:40:30,849 --> 00:40:28,130
parameters for example it's going to

954
00:40:32,920 --> 00:40:30,859
probably be longer on a super earth but

955
00:40:34,750 --> 00:40:32,930
for South planet like Earth 100 million

956
00:40:37,990 --> 00:40:34,760
years as a good time skip keep in mind

957
00:40:39,880 --> 00:40:38,000
Hank where's the weathering feedbacks we

958
00:40:42,099 --> 00:40:39,890
have reason to believe that they're more

959
00:40:43,960 --> 00:40:42,109
like they have been more like on at the

960
00:40:45,849 --> 00:40:43,970
scale of 10 million years and there are

961
00:40:48,070 --> 00:40:45,859
some things that could mess this up and

962
00:40:50,470 --> 00:40:48,080
make it take longer but it's reasonable

963
00:40:53,500 --> 00:40:50,480

to believe that at least some planets

964
00:40:55,990 --> 00:40:53,510
you could have a short time skill to

965
00:40:57,910 --> 00:40:56,000
draw it out co2 and for example we have

966
00:41:00,190 --> 00:40:57,920
in Earth's history the snowball earth

967
00:41:04,599 --> 00:41:00,200
where we think the co2 was built up to

968
00:41:08,010 --> 00:41:04,609
immense gongs maybe a tenth of a bar of

969
00:41:10,930 --> 00:41:08,020
co2 and on a very short time scale

970
00:41:13,750 --> 00:41:10,940
10,000 years 100,000 years after the

971
00:41:15,160 --> 00:41:13,760
snowboarder that all that seemed to was

972
00:41:17,560 --> 00:41:15,170
able to be drawn on the atmosphere

973
00:41:19,450 --> 00:41:17,570
through mother so it could be in fact a

974
00:41:20,710 --> 00:41:19,460
very short time scale but it's

975
00:41:22,930 --> 00:41:20,720
definitely reasonable that's under 10

976
00:41:25,720 --> 00:41:22,940
million years so what the combination of

977
00:41:27,190 --> 00:41:25,730
these means is it looks like it's at

978
00:41:29,349 --> 00:41:27,200
least possible if you could have a

979
00:41:31,300 --> 00:41:29,359
situation that you're reducing water and

980
00:41:33,790 --> 00:41:31,310
voice greenhouse to expose some kind of

981
00:41:35,500 --> 00:41:33,800
continent or LED and that stops the

982
00:41:38,079 --> 00:41:35,510
water loss because you engage weather

983
00:41:41,680 --> 00:41:38,089
then weathering and so it's a mechanism

984
00:41:44,950 --> 00:41:41,690
that water world's could turn into into

985
00:41:47,230 --> 00:41:44,960
planets that have steph planets that

986
00:41:49,240 --> 00:41:47,240
have a more robust weather and feedback

987
00:41:51,060 --> 00:41:49,250
on a wider Howl's OH and the way it

988
00:41:53,740 --> 00:41:51,070

would look in that diagram again

989
00:41:56,890 --> 00:41:53,750
insulation temperature is your cooking

990
00:41:58,839 --> 00:41:56,900
along as the moist greenhouse you're

991
00:42:00,579 --> 00:41:58,849
cooking along as a lot of Rome who hit

992
00:42:03,099 --> 00:42:00,589
the moist greenhouse and then on a

993
00:42:05,800 --> 00:42:03,109
geologically very short time scale you

994
00:42:07,900 --> 00:42:05,810
go through that but stop it at the

995
00:42:10,120 --> 00:42:07,910
tapenade and then you go through as a

996
00:42:11,600 --> 00:42:10,130
planet that has you know thirty percent

997
00:42:14,450 --> 00:42:11,610
fifty percent

998
00:42:17,500 --> 00:42:14,460
mater water as a lighthouse so it's a

999
00:42:20,810 --> 00:42:17,510
way that the water world can save itself

1000
00:42:24,380 --> 00:42:20,820
running out of time so I'm going to skip

1001
00:42:26,240 --> 00:42:24,390
this observational stuff we can talk

1002
00:42:28,850 --> 00:42:26,250
about it later if anyone wants to I just

1003
00:42:30,770 --> 00:42:28,860
want to make one quick point this is

1004
00:42:32,150 --> 00:42:30,780
what it means this is the bottom line if

1005
00:42:33,920 --> 00:42:32,160
the stuff I'm saying is correct in your

1006
00:42:36,680 --> 00:42:33,930
astronomer this is what it means with

1007
00:42:42,020 --> 00:42:36,690
you point one and I'm assuming that your

1008
00:42:43,700 --> 00:42:42,030
villain Ted really strong so if you if

1009
00:42:45,820 --> 00:42:43,710
you if you think the planet has some

1010
00:42:48,260 --> 00:42:45,830
sort of land fraction then you're happy

1011
00:42:50,990 --> 00:42:48,270
it doesn't matter how much you've got a

1012
00:42:52,820 --> 00:42:51,000
wide habitable zone the the previous

1013
00:42:56,390 --> 00:42:52,830

scaling is derived for where the hobbles

1014
00:42:57,470 --> 00:42:56,400
onus is should be roughly right if you

1015
00:43:00,290 --> 00:42:57,480
think you're dealing with the water

1016
00:43:02,000 --> 00:43:00,300
world that you're not happening because

1017
00:43:04,100 --> 00:43:02,010
it should have a very narrow habitable

1018
00:43:05,330 --> 00:43:04,110
zone and things that can find that you

1019
00:43:11,570 --> 00:43:05,340
might think are in the habitable zone

1020
00:43:14,420 --> 00:43:11,580
are unlikely to be actually there your

1021
00:43:15,890 --> 00:43:14,430
guy Nick Cowan has to work on how you

1022
00:43:18,860 --> 00:43:15,900
could estimate in the infraction I'm not

1023
00:43:21,710 --> 00:43:18,870
going to go into that and then I have to

1024
00:43:24,140 --> 00:43:21,720
skip these ones and I just want to make

1025
00:43:26,420 --> 00:43:24,150
a couple brief points about sea floor

1026
00:43:28,040 --> 00:43:26,430
weathering and the outer edge of the

1027
00:43:29,810 --> 00:43:28,050
habitable zone and then I'll go to a

1028
00:43:33,800 --> 00:43:29,820
question so they do it like two more

1029
00:43:35,480 --> 00:43:33,810
minutes okay so everything I told you

1030
00:43:36,950 --> 00:43:35,490
before we're sir bust when I changed

1031
00:43:38,960 --> 00:43:36,960
things in the model now I'm going to

1032
00:43:42,920 --> 00:43:38,970
tell you something that is not robust so

1033
00:43:44,450 --> 00:43:42,930
I this was what my c for weathering

1034
00:43:47,140 --> 00:43:44,460
parameterization looking good there was

1035
00:43:52,340 --> 00:43:47,150
some constant and then there was some

1036
00:43:55,580 --> 00:43:52,350
exponential powering of co2 of feet okay

1037
00:43:58,340 --> 00:43:55,590
so we can imagine a second we get the

1038
00:44:00,680 --> 00:43:58,350

most possible that the seafloor

1039
00:44:03,320 --> 00:44:00,690
muttering can impose a limit on the co2

1040
00:44:04,610 --> 00:44:03,330
that the planet can attain and the way

1041
00:44:06,350 --> 00:44:04,620
you can imagine this happening is

1042
00:44:09,440 --> 00:44:06,360
imagined you start going to a lower

1043
00:44:13,300 --> 00:44:09,450
lower insulation so low that that the

1044
00:44:15,920 --> 00:44:13,310
temperature and future dependencies of

1045
00:44:17,960 --> 00:44:15,930
the land whether and just shut Lynch

1046
00:44:20,300 --> 00:44:17,970
whether or not there's no longer anyway

1047
00:44:21,950 --> 00:44:20,310
land weathering and now you have to

1048
00:44:25,370 --> 00:44:21,960
balance all your outgassing with sea

1049
00:44:28,010 --> 00:44:25,380
floor weather and if you have a strong

1050
00:44:29,870 --> 00:44:28,020
it's on co2 you won't need to increase

1051
00:44:31,820 --> 00:44:29,880
this year to very much to do that if you

1052
00:44:34,100 --> 00:44:31,830
have a weak dependence on co2 got to

1053
00:44:35,870 --> 00:44:34,110
crank the co2 way up and you'll have not

1054
00:44:39,550 --> 00:44:35,880
very much of a limit on this suture you

1055
00:44:43,070 --> 00:44:39,560
can get but it turns out that it's it's

1056
00:44:44,990 --> 00:44:43,080
exquisitely highly dependent on what

1057
00:44:47,500 --> 00:44:45,000
value you choose for him so for example

1058
00:44:51,950 --> 00:44:47,510
I chose that of one-third which

1059
00:44:53,660 --> 00:44:51,960
corresponds to what caldera did if you

1060
00:44:56,300 --> 00:44:53,670
change any two points and when I did

1061
00:44:59,240 --> 00:44:56,310
that the maximum co2 I could build up on

1062
00:45:02,960 --> 00:44:59,250
my planet + love seven dollars if i

1063
00:45:04,730 --> 00:45:02,970

change that 2.5 which is totally within

1064
00:45:07,970 --> 00:45:04,740
the error bars all of a sudden i can

1065
00:45:09,860 --> 00:45:07,980
only get a tenth of a bar of co2 before

1066
00:45:14,540 --> 00:45:09,870
see for weather and chokes you off and

1067
00:45:16,160 --> 00:45:14,550
that's critical because if you look at

1068
00:45:20,180 --> 00:45:16,170
the outer edge of the habitable zone so

1069
00:45:22,520 --> 00:45:20,190
for example in this Lisa 581 system I'm

1070
00:45:24,350 --> 00:45:22,530
not plotting the planet but nobody knows

1071
00:45:27,500 --> 00:45:24,360
if it's there or not but applauding only

1072
00:45:29,330 --> 00:45:27,510
planets that we think are there there is

1073
00:45:31,370 --> 00:45:29,340
this planet I don't think anyone argues

1074
00:45:34,930 --> 00:45:31,380
with that this planet that somewhere

1075
00:45:39,680 --> 00:45:37,460
GCM calculations suggest you need

1076
00:45:42,050 --> 00:45:39,690
something like 10 bars to make this

1077
00:45:43,760 --> 00:45:42,060
plated habitable of co2 well if sea

1078
00:45:46,130 --> 00:45:43,770
floor weathering limits you so that you

1079
00:45:47,540 --> 00:45:46,140
can only generate a tenth of a bar then

1080
00:45:49,790 --> 00:45:47,550
you're not going to be able to keep that

1081
00:45:53,540 --> 00:45:49,800
guy habitable at least with the classic

1082
00:45:57,950 --> 00:45:53,550
mechanism of just increasing the co2 so

1083
00:46:01,400 --> 00:45:57,960
that's why this is important and their

1084
00:46:04,550 --> 00:46:01,410
stuff I never wrap up but basically

1085
00:46:06,830 --> 00:46:04,560
clip-ins on they have made similar

1086
00:46:08,570 --> 00:46:06,840
arguments for early Earth and they find

1087
00:46:11,870 --> 00:46:08,580
that if you have a stronger relationship

1088
00:46:14,030 --> 00:46:11,880

of seafloor weathering on co2 it gets a

1089
00:46:16,190 --> 00:46:14,040
lot harder to keep to get to see you're

1090
00:46:21,470 --> 00:46:16,200
too high on early Earth fake em son

1091
00:46:23,930 --> 00:46:21,480
problem and Geon woo here considered

1092
00:46:26,480 --> 00:46:23,940
this problem for the snowball and he

1093
00:46:28,670 --> 00:46:26,490
actually found that sea floor weathering

1094
00:46:30,410 --> 00:46:28,680
in his model was so high that he could

1095
00:46:32,510 --> 00:46:30,420
only get a couple tenths of a bar of co2

1096
00:46:34,580 --> 00:46:32,520
and that was potentially a problem for

1097
00:46:36,590 --> 00:46:34,590
escaping from the snowball so there's

1098
00:46:38,980 --> 00:46:36,600
clearly some uncertainty in terms of the

1099
00:46:41,900 --> 00:46:38,990
sea floor wedding prayer

1100
00:46:43,730 --> 00:46:41,910
but suppose we find out that it's strong

1101
00:46:45,440 --> 00:46:43,740
that there's a strong dependence on co2

1102
00:46:47,960 --> 00:46:45,450
this could really kill the outer edge of

1103
00:46:50,240 --> 00:46:47,970
the album ilysm I'm gonna skip this one

1104
00:46:53,120 --> 00:46:50,250
and that one okay so there's a loss

1105
00:46:59,089 --> 00:46:53,130
slide so these are the take-home

1106
00:47:01,849 --> 00:46:59,099
messages but first is that a planet that

1107
00:47:04,220 --> 00:47:01,859
has some sort of land fraction something

1108
00:47:06,410 --> 00:47:04,230
between a few percent and ninety percent

1109
00:47:09,920 --> 00:47:06,420
or something like that we should have a

1110
00:47:11,299 --> 00:47:09,930
robust y habitable zone if previous

1111
00:47:12,769 --> 00:47:11,309
comment below and furious correct of

1112
00:47:14,809 --> 00:47:12,779
course if the silicate weathering idea

1113
00:47:17,539 --> 00:47:14,819

is correct we should have a robust white

1114
00:47:19,940 --> 00:47:17,549
alleble zone that could shift around a

1115
00:47:21,079 --> 00:47:19,950
little based on the land fraction and if

1116
00:47:22,910 --> 00:47:21,089
you're doing more than a zero

1117
00:47:25,099 --> 00:47:22,920
dimensional model you know based on how

1118
00:47:28,099 --> 00:47:25,109
these continents break up but it should

1119
00:47:29,630 --> 00:47:28,109
show a strong dependence however if what

1120
00:47:31,250 --> 00:47:29,640
we think we know about the seafloor

1121
00:47:34,460 --> 00:47:31,260
weathering and cottonelle weathering is

1122
00:47:36,319 --> 00:47:34,470
correct we can show with a simple

1123
00:47:39,079 --> 00:47:36,329
mathematical model we can show that

1124
00:47:42,319 --> 00:47:39,089
implies that a water world is going to

1125
00:47:44,299 --> 00:47:42,329
have no weather and feedback and a very

1126
00:47:47,539 --> 00:47:44,309
narrow habitable zone those are the

1127
00:47:49,549 --> 00:47:47,549
gentle messages and if you enjoyed this

1128
00:47:52,069 --> 00:47:49,559
I have another talk on snow lovers on

1129
00:47:58,430 --> 00:47:52,079
Thursday I don't know where this

1130
00:48:06,650 --> 00:47:58,440
building is wherever a JJ is so thank

1131
00:48:08,120 --> 00:48:06,660
you for example you Dorian for

1132
00:48:09,710 --> 00:48:08,130
persevering through all of our technical

1133
00:48:16,069 --> 00:48:09,720
issues so we have time for a couple

1134
00:48:19,339 --> 00:48:16,079
questions yeah serious we're super all

1135
00:48:21,200 --> 00:48:19,349
living doesn't happen I mean like worlds

1136
00:48:25,400 --> 00:48:21,210
where you have sediments to completely

1137
00:48:27,740 --> 00:48:25,410
cover everything and good mean the

1138
00:48:29,809 --> 00:48:27,750

surface phenomena right yeah you have to

1139
00:48:32,569 --> 00:48:29,819
be able to get the hydrothermal

1140
00:48:36,500 --> 00:48:32,579
circulations to the salt yeah but it's a

1141
00:48:38,539 --> 00:48:36,510
dumb there are situations yeah i mean ii

1142
00:48:42,890 --> 00:48:38,549
none of those sediments you know yeah if

1143
00:48:45,500 --> 00:48:42,900
you really have to well so i'm sure the

1144
00:48:48,190 --> 00:48:45,510
answer is yes i'm sure you could

1145
00:48:50,930 --> 00:48:48,200
construct examples but at least on earth

1146
00:48:52,700 --> 00:48:50,940
a lot of this important

1147
00:48:54,380 --> 00:48:52,710
for weathering is happening near mid

1148
00:48:56,630 --> 00:48:54,390
ocean ridge yeah there's not much

1149
00:48:57,710 --> 00:48:56,640
sediment and then eventually it's

1150
00:48:59,089 --> 00:48:57,720
getting covered with sediment and

1151
00:49:01,819 --> 00:48:59,099
there's probably less action happening

1152
00:49:04,579 --> 00:49:01,829
for the last 20 30 40 million years

1153
00:49:08,839 --> 00:49:04,589
budget gets dragged over and seductive

1154
00:49:12,290 --> 00:49:08,849
like Mars wouldn't object if you

1155
00:49:16,250 --> 00:49:12,300
promotional todd's got a fifties the

1156
00:49:18,020 --> 00:49:16,260
other x + well so yeah one of my issue

1157
00:49:20,630 --> 00:49:18,030
assumptions of course list that would

1158
00:49:23,329 --> 00:49:20,640
you want to be active so if you don't

1159
00:49:25,250 --> 00:49:23,339
ask you to be an outcast you know if you

1160
00:49:28,160 --> 00:49:25,260
watch my thing you also go down soon to

1161
00:49:29,809 --> 00:49:28,170
being upright so it's not for any of

1162
00:49:36,770 --> 00:49:29,819
these apples that I guess are going to

1163
00:49:38,540 --> 00:49:36,780

work in that case so we have the ave

1164
00:49:40,309 --> 00:49:38,550
toilet paper on dry papers yeah right

1165
00:49:42,589 --> 00:49:40,319
right but they got to have a phone to

1166
00:49:44,120 --> 00:49:42,599
expand in both wrists yeah and here when

1167
00:49:47,569 --> 00:49:44,130
you're going from a small amount of plan

1168
00:49:49,309 --> 00:49:47,579
to get help is to move out so gently at

1169
00:49:50,750 --> 00:49:49,319
some point you should small enough quite

1170
00:49:52,550 --> 00:49:50,760
a large enough fraction of land that

1171
00:49:54,589 --> 00:49:52,560
then you kind of give to the op amp Anna

1172
00:49:56,329 --> 00:49:54,599
silk did you sort of explore when that

1173
00:49:58,520 --> 00:49:56,339
happened like oh yeah I've also need two

1174
00:50:01,309 --> 00:49:58,530
different strictly visit holiday but

1175
00:50:03,819 --> 00:50:01,319
actually a very important point is my

1176
00:50:07,550 --> 00:50:03,829
climate model is little rinky dinky and

1177
00:50:09,620 --> 00:50:07,560
i'll be at all put all of their effort

1178
00:50:11,150 --> 00:50:09,630
into their bottom lock so first they

1179
00:50:13,430 --> 00:50:11,160
brought a movie and zindies mannequin

1180
00:50:15,230 --> 00:50:13,440
how to read and they worked really hard

1181
00:50:17,569 --> 00:50:15,240
a radius convective model from the inner

1182
00:50:19,940 --> 00:50:17,579
edge but they never actually do any

1183
00:50:22,700 --> 00:50:19,950
explicit calculations of whether where I

1184
00:50:24,920 --> 00:50:22,710
put all my effort so we're actually kind

1185
00:50:26,630 --> 00:50:24,930
of looking at different different

1186
00:50:30,380 --> 00:50:26,640
aspects of the problem other than the

1187
00:50:31,370 --> 00:50:30,390
different land and ocean direction we're

1188
00:50:35,030 --> 00:50:31,380

looking at different aspects of the

1189
00:50:40,069 --> 00:50:35,040
problem they are considering how the

1190
00:50:41,839 --> 00:50:40,079
climate out any weather and feedback I'm

1191
00:50:43,910 --> 00:50:41,849
considering the weather in the feedback

1192
00:50:45,950 --> 00:50:43,920
and so you never got any of your cases

1193
00:50:48,859 --> 00:50:45,960
they expand handles them at the Internet

1194
00:50:51,559 --> 00:50:48,869
as you've changed line pressure no okay

1195
00:50:54,859 --> 00:50:51,569
I didn't know a question from safe

1196
00:50:57,710 --> 00:50:54,869
online crowd so chicken grease truck has

1197
00:50:58,880 --> 00:50:57,720
a comment yep item it soon has performed

1198
00:50:59,740 --> 00:50:58,890
calculations of clutter the block

1199
00:51:02,530 --> 00:50:59,750
earth-like

1200
00:51:04,720 --> 00:51:02,540
orbiting low-mass stars yeah who's like

1201
00:51:06,610 --> 00:51:04,730
geography and found that the atmospheric

1202
00:51:09,430 --> 00:51:06,620
co2 strongly depends on whether

1203
00:51:13,360 --> 00:51:09,440
substellar point downing water or land

1204
00:51:17,770 --> 00:51:13,370
yeah publishes he received system yeah

1205
00:51:20,170 --> 00:51:17,780
exactly okay so that's in the class so i

1206
00:51:22,030 --> 00:51:20,180
assume zero dimensions so i can't

1207
00:51:24,280 --> 00:51:22,040
consider a problem like that what what

1208
00:51:25,810 --> 00:51:24,290
he's saying is if i move it's

1209
00:51:28,210 --> 00:51:25,820
essentially into two dimensional issue

1210
00:51:30,550 --> 00:51:28,220
whether i move my son my continents

1211
00:51:31,840 --> 00:51:30,560
under the sun or out of the Sun and a

1212
00:51:33,430 --> 00:51:31,850
related issue is how I break my

1213
00:51:36,610 --> 00:51:33,440

continents up and all of those things

1214
00:51:40,450 --> 00:51:36,620
could have could definitely out of facts

1215
00:51:45,190 --> 00:51:40,460
and in a case in a case where you have a

1216
00:51:46,510 --> 00:51:45,200
huge asymmetry in the forcing where you

1217
00:51:48,340 --> 00:51:46,520
have all of your installation on one

1218
00:51:50,260 --> 00:51:48,350
side and on the other and you would

1219
00:51:52,330 --> 00:51:50,270
expect spatial heterogeneity needs to be

1220
00:51:55,690 --> 00:51:52,340
more important and this is an example of

1221
00:51:59,280 --> 00:51:55,700
that are you going to draw it on the co2

1222
00:52:02,080 --> 00:51:59,290
if you put them put the land underneath

1223
00:52:03,850 --> 00:52:02,090
okay a few quick announcements so next

1224
00:52:05,470 --> 00:52:03,860
week we have Boswell Ling who's going to

1225
00:52:07,570 --> 00:52:05,480
be speaking he's on sabbatical here

1226
00:52:10,060 --> 00:52:07,580
we're not broadcasting that talk for the

1227
00:52:12,520 --> 00:52:10,070
online people joining us online in two

1228
00:52:14,020 --> 00:52:12,530
weeks please join us for professor David

1229
00:52:16,270 --> 00:52:14,030
brain who's going to be talking about

1230
00:52:17,710 --> 00:52:16,280
whether or not plant planetary magnetic

1231
00:52:19,810 --> 00:52:17,720
fields matter for planetary habitability

1232
00:52:22,090 --> 00:52:19,820
that is going to be broadcast so a

1233
00:52:23,920 --> 00:52:22,100
problem I'd people join us for that home

1234
00:52:25,720 --> 00:52:23,930
was general exam immediately follows

1235
00:52:27,940 --> 00:52:25,730
this I'm going to be taking Dorian out

1236
00:52:29,980 --> 00:52:27,950
to dinner tonight and if interested in

1237
00:52:31,930 --> 00:52:29,990
joining please come speak to myself or

1238
00:52:33,910 --> 00:52:31,940

maybe Vicki because I'm gonna have to

1239
00:52:37,210 --> 00:52:33,920
jump out here so maybe she can help was