
AbSciCon
2019

1
00:00:00,790 --> 00:00:07,320
[Music]

2
00:00:12,490 --> 00:00:09,250
[Applause]

3
00:00:13,670 --> 00:00:12,500
thank you very much I can't speak for my

4
00:00:18,050 --> 00:00:13,680
co-author

5
00:00:20,120 --> 00:00:18,060
but I'm from Earth that is to mean my

6
00:00:23,390 --> 00:00:20,130
background is looking at the earth and

7
00:00:27,170 --> 00:00:23,400
looking at the early Earth and paleo and

8
00:00:30,260 --> 00:00:27,180
I build model tools for looking at some

9
00:00:33,440 --> 00:00:30,270
paleo questions primarily it means that

10
00:00:37,459 --> 00:00:33,450
when looking at exoplanets the tools are

11
00:00:39,319 --> 00:00:37,469
well-established but they bring with

12
00:00:43,220 --> 00:00:39,329
them a lot of baggage of earth-like

13
00:00:47,090 --> 00:00:43,230

assumptions and overall this this work

14
00:00:49,280 --> 00:00:47,100
is it's somewhat a work in progress as I

15
00:00:52,310 --> 00:00:49,290
try and apply tools really designed for

16
00:00:53,479 --> 00:00:52,320
Earth to look at non earth-like

17
00:00:58,670 --> 00:00:53,489
situations

18
00:01:00,560 --> 00:00:58,680
I sort of wish this wasn't a was a joke

19
00:01:04,100 --> 00:01:00,570
but it's actually sort of my perspective

20
00:01:06,260 --> 00:01:04,110
of at least how I build a model tools

21
00:01:09,710 --> 00:01:06,270
there's a rotating rock it's got a

22
00:01:11,179 --> 00:01:09,720
bathtub of water that sloshes around and

23
00:01:12,709 --> 00:01:11,189
that's sort of the important bit for

24
00:01:16,129 --> 00:01:12,719
this talk and for a lot of sort of

25
00:01:17,749 --> 00:01:16,139
questions in in in past evolution of

26
00:01:19,789 --> 00:01:17,759
life in the ocean and logical cycles and

27
00:01:22,249 --> 00:01:19,799
things unfortunately there are no rubber

28
00:01:23,690 --> 00:01:22,259
ducks these are actually smaller than

29
00:01:26,419 --> 00:01:23,700
the grid of the models so they're not

30
00:01:29,239 --> 00:01:26,429
resolved well the duck really represents

31
00:01:31,940 --> 00:01:29,249
there is at least on on earth we we

32
00:01:33,949 --> 00:01:31,950
don't have all water and there is like a

33
00:01:35,719 --> 00:01:33,959
very convenient amount of land that come

34
00:01:38,929 --> 00:01:35,729
whether it can supply nutrients it can

35
00:01:41,179 --> 00:01:38,939
supply cations also things to the ocean

36
00:01:44,120 --> 00:01:41,189
that can fuel biology and can lead to

37
00:01:47,929 --> 00:01:44,130
things being deposited and lost to the

38
00:01:50,660 --> 00:01:47,939

system that are important and I sort of

39
00:01:52,339 --> 00:01:50,670
concentrate on and this is sort of like

40
00:01:54,949 --> 00:01:52,349
the thinking for the talk is is what

41
00:01:58,219 --> 00:01:54,959
goes on within the ocean so we have some

42
00:02:00,199 --> 00:01:58,229
at least on earth on non fully water

43
00:02:03,889 --> 00:02:00,209
world plants we have significant supply

44
00:02:05,719 --> 00:02:03,899
of nutrients to the ocean importantly

45
00:02:09,040 --> 00:02:05,729
these are very heavily recycled today

46
00:02:11,540 --> 00:02:09,050
and and through much of Earth's history

47
00:02:13,370 --> 00:02:11,550
there is productivity at the at the

48
00:02:15,949 --> 00:02:13,380
ocean surface and you op taking

49
00:02:19,399 --> 00:02:15,959
nutrients fixation of carbon material

50
00:02:20,860 --> 00:02:19,409
sinks with Mary with very may be varying

51
00:02:24,490 --> 00:02:20,870
efficiency through

52
00:02:27,100 --> 00:02:24,500
Earth's history typically recycled very

53
00:02:30,759 --> 00:02:27,110
rapidly near the surface and then

54
00:02:32,559 --> 00:02:30,769
material a small fraction maybe 5% is is

55
00:02:34,390 --> 00:02:32,569
reaching a number of kilometers depths

56
00:02:36,729 --> 00:02:34,400
and in today's ocean maybe because the

57
00:02:39,820 --> 00:02:36,739
compounds are federate Kallstrom because

58
00:02:41,380 --> 00:02:39,830
the material is is part of our gets sink

59
00:02:43,900 --> 00:02:41,390
very quickly or maybe there is some

60
00:02:47,140 --> 00:02:43,910
protection of compounds absorbed within

61
00:02:50,440 --> 00:02:47,150
within minerals in today's ocean ocean

62
00:02:53,920 --> 00:02:50,450
circulation on earth and other planets

63
00:02:55,930 --> 00:02:53,930

will be very important because sustained

64
00:02:57,580 --> 00:02:55,940
over time in a very even a very small

65
00:03:00,100 --> 00:02:57,590
fraction of nutrients and material

66
00:03:02,979 --> 00:03:00,110
reaching that the bottom of the ocean or

67
00:03:06,400 --> 00:03:02,989
on a planet will tend to then accumulate

68
00:03:08,170 --> 00:03:06,410
and you need the nutrients back at the

69
00:03:11,860 --> 00:03:08,180
surface if your if your to have a very

70
00:03:16,240 --> 00:03:11,870
vigorous and cycle of biochemical

71
00:03:18,430 --> 00:03:16,250
cycling why does that matter if you can

72
00:03:20,650 --> 00:03:18,440
bring in a lot of nutrients you could

73
00:03:22,479 --> 00:03:20,660
lose nutrients and if you can lose

74
00:03:24,100 --> 00:03:22,489
nutrients you can lose carbon with the

75
00:03:26,110 --> 00:03:24,110
nutrients and if you're losing carbon

76
00:03:29,259 --> 00:03:26,120
effectively you're releasing oxygen so

77
00:03:31,780 --> 00:03:29,269
the like honor the earlier earth perhaps

78
00:03:34,150 --> 00:03:31,790
mostly the the burial of organic Matt

79
00:03:36,430 --> 00:03:34,160
Carpenter over the rise of oxygen and

80
00:03:40,180 --> 00:03:36,440
the great transition of the oxidation of

81
00:03:42,250 --> 00:03:40,190
the Earth's surface the formation of

82
00:03:45,250 --> 00:03:42,260
ozone and then sort of potentially

83
00:03:47,259 --> 00:03:45,260
biosignatures from that the other the

84
00:03:49,839 --> 00:03:47,269
other thing that a vigorous logical

85
00:03:51,819 --> 00:03:49,849
cycle in in the in the ocean and the

86
00:03:55,240 --> 00:03:51,829
earth or any ocean can do for you it can

87
00:03:58,030 --> 00:03:55,250
create significant heterogeneity in for

88
00:03:59,770 --> 00:03:58,040

instance redox you have the release of

89
00:04:01,659 --> 00:03:59,780
oxygen at the ocean surface is gonna be

90
00:04:04,330 --> 00:04:01,669
released into the atmosphere if you have

91
00:04:06,789 --> 00:04:04,340
a very vigorous biogeochemical cycle

92
00:04:09,490 --> 00:04:06,799
that consumes all the oxygen further

93
00:04:12,099 --> 00:04:09,500
down in the ocean interior you might

94
00:04:14,530 --> 00:04:12,109
produce hydrogen sulfide dissolved in

95
00:04:16,089 --> 00:04:14,540
the water you might produce methane once

96
00:04:18,580 --> 00:04:16,099
your if you have like a low sulfate

97
00:04:20,349 --> 00:04:18,590
ocean there is the potential of these

98
00:04:22,990 --> 00:04:20,359
waters that are high in hydrogen sulfide

99
00:04:24,219 --> 00:04:23,000
or methane also to be exposed to the

100
00:04:27,010 --> 00:04:24,229
atmosphere you could have the release

101
00:04:29,860 --> 00:04:27,020
both both of oxygen and hydrogen sulfide

102
00:04:31,360 --> 00:04:29,870
or methane so you can have species that

103
00:04:33,080 --> 00:04:31,370
really shouldn't be together being

104
00:04:35,900 --> 00:04:33,090
really stems here at the same time

105
00:04:42,680 --> 00:04:35,910
and and this could also provide ways of

106
00:04:44,300 --> 00:04:42,690
detecting life anyway so on a water only

107
00:04:46,310 --> 00:04:44,310
world you don't have the luxury of

108
00:04:49,159 --> 00:04:46,320
overland and weathering and supply of

109
00:04:51,470 --> 00:04:49,169
fresh nutrients there will be some sort

110
00:04:54,470 --> 00:04:51,480
of supply of dust micrometeoroids being

111
00:04:56,570 --> 00:04:54,480
obliged in in the atmosphere but this is

112
00:04:59,750 --> 00:04:56,580
pretty small on the earth today compared

113
00:05:01,580 --> 00:04:59,760

with with weathering you may have

114
00:05:02,600 --> 00:05:01,590
release of nutrients and substances from

115
00:05:04,220 --> 00:05:02,610
the ocean floor from hydrothermal

116
00:05:05,629 --> 00:05:04,230
systems but that's at the bottom of the

117
00:05:06,230 --> 00:05:05,639
ocean you've got to get this back up to

118
00:05:09,200 --> 00:05:06,240
the surface

119
00:05:11,900 --> 00:05:09,210
so so really just saying on on an ocean

120
00:05:14,060 --> 00:05:11,910
world even more than than today it's

121
00:05:17,840 --> 00:05:14,070
critical that the ocean mixes pretty

122
00:05:19,520 --> 00:05:17,850
well either you want the materials

123
00:05:21,320 --> 00:05:19,530
released at the ocean floor to be

124
00:05:22,850 --> 00:05:21,330
efficiently moved to the surface so

125
00:05:25,150 --> 00:05:22,860
they're available to photosynthetic life

126
00:05:29,330 --> 00:05:25,160
I would just say I'm here I'm assuming

127
00:05:32,330 --> 00:05:29,340
for the purpose of thinking about how

128
00:05:34,219 --> 00:05:32,340
productive a water world might be in

129
00:05:38,330 --> 00:05:34,229
terms of life I'm thinking of

130
00:05:39,830 --> 00:05:38,340
photosynthetic life and if you have a

131
00:05:41,960 --> 00:05:39,840
very small flux of nutrients to the

132
00:05:43,940 --> 00:05:41,970
surface from space you don't want this

133
00:05:45,650 --> 00:05:43,950
loss nor the bottom the ocean again you

134
00:05:47,830 --> 00:05:45,660
want you want an ocean circulation but

135
00:05:51,680 --> 00:05:47,840
that those things around quite quite

136
00:05:54,500 --> 00:05:51,690
nicely and efficiently so here's a

137
00:05:56,510 --> 00:05:54,510
question well how deep might the ocean

138
00:06:00,680 --> 00:05:56,520

on the water will be I mean we we sort

139
00:06:02,990 --> 00:06:00,690
of think the earth sort of frames I

140
00:06:06,670 --> 00:06:03,000
think a lot of work in terms of ocean

141
00:06:09,140 --> 00:06:06,680
depth and the model tools the previous

142
00:06:11,810 --> 00:06:09,150
talk was really interesting this is a

143
00:06:13,159 --> 00:06:11,820
very common thing to have a cellphone

144
00:06:15,560 --> 00:06:13,169
model with a few kilometers of ocean

145
00:06:17,900 --> 00:06:15,570
depth I'm trying to think here a little

146
00:06:19,219 --> 00:06:17,910
bit more like well how deep might the

147
00:06:21,140 --> 00:06:19,229
ocean be and what that what are the

148
00:06:24,860 --> 00:06:21,150
consequences are much deeper than than a

149
00:06:26,450 --> 00:06:24,870
modern ocean sort of really thinking my

150
00:06:29,750 --> 00:06:26,460
motivation for the entire talk was just

151
00:06:32,000 --> 00:06:29,760
thinking is is the is the is a depth of

152
00:06:33,800 --> 00:06:32,010
an ocean on the water world such that

153
00:06:35,629 --> 00:06:33,810
you wouldn't actually return material

154
00:06:37,550 --> 00:06:35,639
from the depth so if you had a very

155
00:06:38,840 --> 00:06:37,560
small nutrient supply to the ocean

156
00:06:40,129 --> 00:06:38,850
surface and you lose a very small

157
00:06:41,450 --> 00:06:40,139
fraction that's a great depth then you

158
00:06:44,390 --> 00:06:41,460
never return that then you've got a

159
00:06:45,709 --> 00:06:44,400
really very low production biosphere you

160
00:06:49,249 --> 00:06:45,719
have very little capable

161
00:06:52,339 --> 00:06:49,259
of burying organic matter were using

162
00:06:54,199 --> 00:06:52,349
that oxygen making any sort of great

163
00:06:56,659 --> 00:06:54,209

spatial heterogeneity and things in the

164
00:07:00,079 --> 00:06:56,669
ocean and and sort of your ability to

165
00:07:02,949 --> 00:07:00,089
detect sort of biosignatures may be very

166
00:07:07,219 --> 00:07:02,959
very limited so I can sort of consider

167
00:07:10,279 --> 00:07:07,229
just really sort of ocean depth and then

168
00:07:12,279 --> 00:07:10,289
I can consider some other factors and

169
00:07:15,289 --> 00:07:12,289
that might help control the circulation

170
00:07:19,669 --> 00:07:15,299
principally energy at the surface and

171
00:07:24,409 --> 00:07:19,679
energy at the at the ocean for the model

172
00:07:26,299 --> 00:07:24,419
is it's it's an earth model and there

173
00:07:28,449 --> 00:07:26,309
are caveats to that and there are the

174
00:07:32,290 --> 00:07:28,459
issues with with with spin up and the

175
00:07:35,299 --> 00:07:32,300
generality of the physics this model is

176
00:07:37,850 --> 00:07:35,309
run on a very low resolution just to

177
00:07:41,659 --> 00:07:37,860
start to explore the parameter space the

178
00:07:43,669 --> 00:07:41,669
grid is only eighteen by by eighteen at

179
00:07:45,889 --> 00:07:43,679
the surface and as I'll show the

180
00:07:49,429 --> 00:07:45,899
variable number of layers there are all

181
00:07:51,499 --> 00:07:49,439
sorts of modern earth assumptions

182
00:07:53,899 --> 00:07:51,509
entrained in this it's just gonna be a

183
00:07:56,479 --> 00:07:53,909
normal ocean you know normal salty ocean

184
00:07:59,809 --> 00:07:56,489
it's gonna be modern nutrients you know

185
00:08:03,079 --> 00:07:59,819
I'm really just considering a modern

186
00:08:06,049 --> 00:08:03,089
earth-like ocean but covering the whole

187
00:08:07,579 --> 00:08:06,059
planetary surface but now but just

188
00:08:10,189 --> 00:08:07,589

really just thinking about the variable

189
00:08:13,279 --> 00:08:10,199
depth the ocean and this is my favorite

190
00:08:16,339 --> 00:08:13,289
plot because there's no both imagery in

191
00:08:17,689 --> 00:08:16,349
this model if there is on a order water

192
00:08:19,579 --> 00:08:17,699
world what is the better retreat you

193
00:08:21,409 --> 00:08:19,589
have spreading ridges on a water world

194
00:08:23,749 --> 00:08:21,419
you have like volcanic surrounds is it's

195
00:08:25,100 --> 00:08:23,759
smooth at the bottom you know the answer

196
00:08:28,219 --> 00:08:25,110
could be anything you want so this is

197
00:08:30,949 --> 00:08:28,229
gonna be a smooth ocean bottom for that

198
00:08:32,839 --> 00:08:30,959
purpose of this talk this model also

199
00:08:36,019 --> 00:08:32,849
differs from the one in the previous

200
00:08:37,490 --> 00:08:36,029
talk CSM in that this is very simply

201
00:08:39,170 --> 00:08:37,500
forced at the surface I do not have a

202
00:08:42,379 --> 00:08:39,180
dynamical atmosphere which which saves

203
00:08:45,019 --> 00:08:42,389
me a lot of computational time so it's

204
00:08:48,079 --> 00:08:45,029
having a zonal in stress profile applied

205
00:08:51,170 --> 00:08:48,089
to drive ocean circulation I'm almost

206
00:08:53,340 --> 00:08:51,180
always also assuming a very simple as in

207
00:08:55,080 --> 00:08:53,350
the average planetary albedo and

208
00:08:57,360 --> 00:08:55,090
in the absence of the dynamical

209
00:09:00,060 --> 00:08:57,370
atmosphere in clouds I'm running the

210
00:09:02,490 --> 00:09:00,070
model for 10,000 years I'm spinning up

211
00:09:04,560 --> 00:09:02,500
from cold which means that the ocean is

212
00:09:07,170 --> 00:09:04,570
is starting at 0 degrees and we'll just

213
00:09:10,560 --> 00:09:07,180

see how it pans out after that so a

214
00:09:12,840 --> 00:09:10,570
typical modern cell the constant modern

215
00:09:14,520 --> 00:09:12,850
co2 concentration atmosphere which would

216
00:09:16,830 --> 00:09:14,530
have sea ice that there is some sea ice

217
00:09:19,860 --> 00:09:16,840
at each Paul that spreads out a little

218
00:09:24,420 --> 00:09:19,870
bit but but a little bit like the zones

219
00:09:27,510 --> 00:09:24,430
today so how deep should it be well the

220
00:09:29,520 --> 00:09:27,520
mean depth of today's oceans about 3.5

221
00:09:31,590 --> 00:09:29,530
kilometers if you're going to take away

222
00:09:34,340 --> 00:09:31,600
all the crayons and make it a true water

223
00:09:40,050 --> 00:09:34,350
world the average eques don't you about

224
00:09:42,360 --> 00:09:40,060
2.5 kilometres typically in the the

225
00:09:45,150 --> 00:09:42,370
modern model I use the the maximum depth

226
00:09:46,920 --> 00:09:45,160
is 5 kilometers with 16 levels I'm going

227
00:09:48,900 --> 00:09:46,930
to keep the layer structure so that I'm

228
00:09:50,490 --> 00:09:48,910
not changing the thickness of the

229
00:09:52,290 --> 00:09:50,500
surface layer where life lives I'm

230
00:09:55,950 --> 00:09:52,300
basically just going to add more and

231
00:09:58,500 --> 00:09:55,960
more layers deeper down and I'm going to

232
00:10:00,510 --> 00:09:58,510
test these difference not all have

233
00:10:03,210 --> 00:10:00,520
successfully run but all these these

234
00:10:05,400 --> 00:10:03,220
difference assumptions about ocean depth

235
00:10:08,220 --> 00:10:05,410
so the 2.5 is just the water on today's

236
00:10:10,860 --> 00:10:08,230
ocean spread over a smooth billiard ball

237
00:10:14,340 --> 00:10:10,870
there is a 3.5 which is the the mean

238
00:10:16,470 --> 00:10:14,350

depth of today's ocean 5 which is which

239
00:10:19,110 --> 00:10:16,480
is a typical reasonably deep bit of the

240
00:10:23,760 --> 00:10:19,120
ocean today I'm going to just keep sort

241
00:10:25,680 --> 00:10:23,770
of adding levels 10 15 21 I've not yet

242
00:10:28,440 --> 00:10:25,690
successfully run 13 kilometer deep

243
00:10:32,070 --> 00:10:28,450
oceans but it's it's a it's a technical

244
00:10:34,170 --> 00:10:32,080
spin up problem the max in the phase

245
00:10:37,560 --> 00:10:34,180
diagram at least in this off Wikipedia

246
00:10:39,540 --> 00:10:37,570
the phase diagram of water in in

247
00:10:41,430 --> 00:10:39,550
temperature and pressure space you could

248
00:10:43,740 --> 00:10:41,440
you could get to a hundred kilometers or

249
00:10:47,790 --> 00:10:43,750
so before you start worrying about the

250
00:10:49,920 --> 00:10:47,800
water becoming ice so and you just

251
00:10:51,990 --> 00:10:49,930
pursue just show you very briefly the

252
00:10:55,020 --> 00:10:52,000
initial results of some little ensemble

253
00:10:57,090 --> 00:10:55,030
experiments where I'm just testing the

254
00:11:00,540 --> 00:10:57,100
different configurations the model 2.5

255
00:11:02,880 --> 00:11:00,550
3.5 etc kilometer ocean depth of a pure

256
00:11:05,850 --> 00:11:02,890
water world with otherwise modern like

257
00:11:06,690 --> 00:11:05,860
orbits and solar constant and density of

258
00:11:10,730 --> 00:11:06,700
the water and

259
00:11:13,410 --> 00:11:10,740
and salinity etc and in this grid of

260
00:11:15,510 --> 00:11:13,420
different su-24 things so this is

261
00:11:18,660 --> 00:11:15,520
relative to pre-industrial so x 1.is

262
00:11:21,420 --> 00:11:18,670
would be a climate like today I'm going

263
00:11:24,720 --> 00:11:21,430

to do x 4 x 16 I'd also make it a little

264
00:11:26,550 --> 00:11:24,730
bit colder so a little bit below the

265
00:11:28,620 --> 00:11:26,560
last glacial in terms of at least in

266
00:11:33,480 --> 00:11:28,630
terms of greenhouse gas forcing a

267
00:11:37,020 --> 00:11:33,490
hundred milli watts is the modern sort

268
00:11:38,940 --> 00:11:37,030
of mean geothermal heat input so I've

269
00:11:42,570 --> 00:11:38,950
got a similar like factor of four each

270
00:11:46,200 --> 00:11:42,580
time so 25 is is getting close to

271
00:11:47,820 --> 00:11:46,210
nothing four times and 16 times the

272
00:11:49,470 --> 00:11:47,830
modern geothermal heat input so really

273
00:11:51,660 --> 00:11:49,480
I'm trying to different things I know

274
00:11:52,890 --> 00:11:51,670
trying heat or call it from the surface

275
00:11:54,440 --> 00:11:52,900
I'm going to try different sort of

276
00:11:57,780 --> 00:11:54,450
heating's from them from the ocean floor

277
00:12:00,150 --> 00:11:57,790
and like I say so far in these very

278
00:12:04,760 --> 00:12:00,160
initial experiments because it's a it's

279
00:12:07,200 --> 00:12:04,770
a modern earth earth system model and

280
00:12:10,110 --> 00:12:07,210
when trying a 32 kilometer

281
00:12:12,300 --> 00:12:10,120
spin up there are some teething problems

282
00:12:14,610 --> 00:12:12,310
so there are going to be some plots

283
00:12:17,580 --> 00:12:14,620
where the computer is cheating at

284
00:12:21,870 --> 00:12:17,590
tic-tac-toe and not all the results of

285
00:12:24,210 --> 00:12:21,880
them so this is the simplest case of

286
00:12:28,110 --> 00:12:24,220
just the water on the modern earth we

287
00:12:31,710 --> 00:12:28,120
disputed over a billiard ball this is

288
00:12:34,740 --> 00:12:31,720

just a plot of sea ice extent so there's

289
00:12:37,470 --> 00:12:34,750
there's nothing you wouldn't guess here

290
00:12:39,540 --> 00:12:37,480
at all low C you to there's more sea ice

291
00:12:40,980 --> 00:12:39,550
highest you to that's less yes so I

292
00:12:44,160 --> 00:12:40,990
don't think there's a Nobel Prize in

293
00:12:48,420 --> 00:12:44,170
this there is some impact of this change

294
00:12:50,360 --> 00:12:48,430
of the geothermal Andy yep I'm almost

295
00:12:54,240 --> 00:12:50,370
done

296
00:12:56,460 --> 00:12:54,250
there is no it's like I say there is

297
00:12:58,860 --> 00:12:56,470
some effect of the the geothermal heat

298
00:13:04,230 --> 00:12:58,870
input so there's less sea ice as you go

299
00:13:09,500 --> 00:13:04,240
to 16,000 milli watts or 1600 milli

300
00:13:14,389 --> 00:13:11,210
there's sort of the sort of the most

301
00:13:16,220 --> 00:13:14,399
useful results so far this is the the

302
00:13:20,090 --> 00:13:16,230
export production of these these

303
00:13:22,340 --> 00:13:20,100
different water worlds you had the

304
00:13:25,910 --> 00:13:22,350
highest export production in a inner

305
00:13:28,519 --> 00:13:25,920
planet or in a world where you have a

306
00:13:31,730 --> 00:13:28,529
fairly cold forcing at the surface but

307
00:13:34,310 --> 00:13:31,740
you have high geothermal heating but so

308
00:13:36,530 --> 00:13:34,320
it's really maybe not very surprising

309
00:13:39,769 --> 00:13:36,540
but but here we can start to quantify

310
00:13:41,569 --> 00:13:39,779
what sort of how much more biological or

311
00:13:42,889 --> 00:13:41,579
productivity would you have in a world

312
00:13:45,439 --> 00:13:42,899
where you dis stabilized you

313
00:13:48,170 --> 00:13:45,449

deliberately destabilize the ocean by

314
00:13:53,660 --> 00:13:48,180
having higher higher heat input at the

315
00:13:56,600 --> 00:13:53,670
surface and lower co2 and cooling at the

316
00:13:58,100 --> 00:13:56,610
at the surface high you know he didn't

317
00:14:01,310 --> 00:13:58,110
go to depth there cooling at the surface

318
00:14:03,319 --> 00:14:01,320
and the rest really they're not all spun

319
00:14:04,730 --> 00:14:03,329
up with a case that the game really is

320
00:14:07,639 --> 00:14:04,740
just a run through the different

321
00:14:10,810 --> 00:14:07,649
ensembles different configurations look

322
00:14:12,889 --> 00:14:10,820
at how the patterns change from one

323
00:14:16,490 --> 00:14:12,899
configuration to going to a deeper and

324
00:14:19,069 --> 00:14:16,500
deeper ocean to another so they didn't

325
00:14:22,490 --> 00:14:19,079
all pan out and the the very deepest

326
00:14:26,680 --> 00:14:22,500
ones there are still some issues

327
00:14:29,329 --> 00:14:26,690
spinning up such a system

328
00:14:32,180 --> 00:14:29,339
so really the other thing I've taken

329
00:14:34,460 --> 00:14:32,190
away you initially is is just the the

330
00:14:37,670 --> 00:14:34,470
thought may be that younger planets

331
00:14:39,680 --> 00:14:37,680
water worlds might have a much higher

332
00:14:43,370 --> 00:14:39,690
productivity a much more potential for

333
00:14:46,430 --> 00:14:43,380
biosignatures in in that the the Sun

334
00:14:48,769 --> 00:14:46,440
will tend to be have less output so you

335
00:14:50,750 --> 00:14:48,779
might tend to have a like less less

336
00:14:52,579 --> 00:14:50,760
heating at the surface but you have

337
00:14:55,400 --> 00:14:52,589
mobile radio to decay still in the ocean

338
00:14:57,050 --> 00:14:55,410

in the planetary interior to heat the

339
00:14:59,360 --> 00:14:57,060
the bottom of the ocean so you have a

340
00:15:00,949 --> 00:14:59,370
situation where you have much more

341
00:15:02,960 --> 00:15:00,959
vigorous circulation and much more

342
00:15:05,629 --> 00:15:02,970
recycling of what nutrient supply there

343
00:15:09,230 --> 00:15:05,639
is and thereafter your planets of Ages

344
00:15:12,379 --> 00:15:09,240
calls inside the Sun warms up you tend

345
00:15:14,269 --> 00:15:12,389
to go progressively to a to a less

346
00:15:15,740 --> 00:15:14,279
vigorous circulation and and a lower

347
00:15:16,759 --> 00:15:15,750
productivity and potential for

348
00:15:19,390 --> 00:15:16,769
biosignatures

349
00:15:19,740 --> 00:15:19,400
thank you

350
00:15:25,310 --> 00:15:19,750
[Applause]

351
00:15:34,950 --> 00:15:27,990
okay we have time for one very quick

352
00:15:36,600 --> 00:15:34,960
question yeah in the case where you have

353
00:15:38,220 --> 00:15:36,610
a lot of pressure therefore you have a

354
00:15:40,050 --> 00:15:38,230
the rock and then you have the ice on

355
00:15:41,580 --> 00:15:40,060
top of it but don't you have enough heat

356
00:15:43,560 --> 00:15:41,590
coming out of that rock that it would

357
00:15:45,000 --> 00:15:43,570
make either cracks or plumes through

358
00:15:46,710 --> 00:15:45,010
that ice and so therefore wouldn't be a

359
00:15:48,390 --> 00:15:46,720
very effective barrier to the nutrients

360
00:15:49,740 --> 00:15:48,400
that you're trying to get up so the the

361
00:15:51,870 --> 00:15:49,750
ice with sea ice at the surface I I

362
00:15:53,880 --> 00:15:51,880
don't have any ice at depth so the the

363
00:15:56,760 --> 00:15:53,890

the depth of the ocean is not sufficient

364
00:15:59,400 --> 00:15:56,770
to have ice between the water and the

365
00:16:02,090 --> 00:15:59,410
rock and so far the equation of state is

366
00:16:05,430 --> 00:16:02,100
very very simple so I'd not aggressed

367
00:16:08,280 --> 00:16:05,440
too far beyond taking a model developed

368
00:16:11,610 --> 00:16:08,290
really for the last few tens of millions

369
00:16:14,640 --> 00:16:11,620
of years to more generalized conditions

370
00:16:15,870 --> 00:16:14,650
on on other worlds okay let's thank the