
AbSciCon
2019

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

2
00:00:11,619 --> 00:00:09,120
[Applause]

3
00:00:14,500 --> 00:00:11,629
good morning everyone and thank you to

4
00:00:17,140 --> 00:00:14,510
the conveners for the invitation today

5
00:00:18,519 --> 00:00:17,150
I'm going to be speaking about something

6
00:00:20,470 --> 00:00:18,529
that I don't think many people are

7
00:00:22,830 --> 00:00:20,480
thinking about and that is the role of

8
00:00:25,450 --> 00:00:22,840
ocean salinity in Earth's climate system

9
00:00:27,549 --> 00:00:25,460
I'm going to develop this story in the

10
00:00:30,700 --> 00:00:27,559
context of the faint young Sun paradox

11
00:00:33,130 --> 00:00:30,710
and Archaean habitability but I'd like

12
00:00:34,660 --> 00:00:33,140
to note that these relationships are

13
00:00:37,690 --> 00:00:34,670

relevant across the entirety of the

14
00:00:39,280 --> 00:00:37,700
geologic time scale and represent a

15
00:00:41,079 --> 00:00:39,290
major challenge when it comes to

16
00:00:43,750 --> 00:00:41,089
modeling the climates of potentially

17
00:00:45,579 --> 00:00:43,760
habitable exoplanets and so even if the

18
00:00:47,799 --> 00:00:45,589
faint young Sun paradox isn't keeping

19
00:00:49,720 --> 00:00:47,809
you up at night I hope you'll agree that

20
00:00:52,930 --> 00:00:49,730
these are really important results

21
00:00:54,849 --> 00:00:52,940
nonetheless so we've already heard about

22
00:00:57,340 --> 00:00:54,859
the phantom Sun paradox a couple of

23
00:00:59,950 --> 00:00:57,350
times today but just to briefly recap

24
00:01:02,349 --> 00:00:59,960
that issue the problem is that the

25
00:01:04,350 --> 00:01:02,359
luminosity of the Sun has been steadily

26
00:01:07,870 --> 00:01:04,360
increasing throughout Earth's history

27
00:01:10,180 --> 00:01:07,880
with the implication that early Earth

28
00:01:12,600 --> 00:01:10,190
might have been much colder than today

29
00:01:16,030 --> 00:01:12,610
and so here I'm just tracking a

30
00:01:17,800 --> 00:01:16,040
potential surface temperatures assuming

31
00:01:20,709 --> 00:01:17,810
a current green house versus no

32
00:01:23,560 --> 00:01:20,719
greenhouse and the ANA take-home here is

33
00:01:25,389 --> 00:01:23,570
that Earth's surface temperature was

34
00:01:29,170 --> 00:01:25,399
potentially below the freezing point of

35
00:01:33,039 --> 00:01:29,180
water for most of Earth's history unless

36
00:01:34,660 --> 00:01:33,049
we had an additional source of one so

37
00:01:36,999 --> 00:01:34,670
conventional solutions to the faint

38
00:01:39,969 --> 00:01:37,009

young Sun paradox involve higher levels

39
00:01:42,520 --> 00:01:39,979
of carbon dioxide and or methane like

40
00:01:45,249 --> 00:01:42,530
we've already heard about today and so

41
00:01:48,520 --> 00:01:45,259
on the left here i'm just showing GCM

42
00:01:50,560 --> 00:01:48,530
results for a planet that has a modern

43
00:01:52,719 --> 00:01:50,570
atmospheric composition but Archaean

44
00:01:54,609 --> 00:01:52,729
insulation and the result is of course

45
00:01:56,440 --> 00:01:54,619
snowball glaciation that's not a

46
00:02:00,039 --> 00:01:56,450
profound result that is just simply the

47
00:02:04,029 --> 00:02:00,049
definition of the fan son paradox then

48
00:02:07,090 --> 00:02:04,039
on the right here I am showing a planet

49
00:02:09,040 --> 00:02:07,100
that has a little bit extra co2 and a

50
00:02:11,950 --> 00:02:09,050
little bit extra methane within the

51
00:02:13,890 --> 00:02:11,960
range of uncertainty allowed by the by

52
00:02:16,869 --> 00:02:13,900
the rock record and other models and

53
00:02:20,320 --> 00:02:16,879
problem solved it's no longer a snowball

54
00:02:21,200 --> 00:02:20,330
and so some people are willing to put

55
00:02:23,300 --> 00:02:21,210
the

56
00:02:27,410 --> 00:02:23,310
young Sun paradox to rest and accept

57
00:02:30,110 --> 00:02:27,420
this as a as a solution it's not my goal

58
00:02:32,030 --> 00:02:30,120
to challenge the importance of co2 our

59
00:02:34,160 --> 00:02:32,040
methane and resolving this climate

60
00:02:35,870 --> 00:02:34,170
problem but instead today I just like to

61
00:02:37,730 --> 00:02:35,880
point out that the composition of our

62
00:02:40,310 --> 00:02:37,740
atmosphere has not been changing in

63
00:02:43,100 --> 00:02:40,320

isolation and the composition of our

64
00:02:44,540 --> 00:02:43,110
ocean has been changing as well and in

65
00:02:48,170 --> 00:02:44,550
ways that we don't understand

66
00:02:50,960 --> 00:02:48,180
particularly well and so for example our

67
00:02:54,200 --> 00:02:50,970
ki and salinity is extremely poorly

68
00:02:55,940 --> 00:02:54,210
constrained the the theorists have

69
00:02:59,360 --> 00:02:55,950
speculated that well if you take all of

70
00:03:01,340 --> 00:02:59,370
the evaporates on land and you just put

71
00:03:03,230 --> 00:03:01,350
them back in the ocean the the

72
00:03:04,490 --> 00:03:03,240
inevitable result is that our key in

73
00:03:05,180 --> 00:03:04,500
salinity should have been much higher

74
00:03:08,260 --> 00:03:05,190
than today

75
00:03:11,180 --> 00:03:08,270
potentially by a factor of two

76
00:03:16,130 --> 00:03:11,190
geochemical proxies for salinity are

77
00:03:19,510 --> 00:03:16,140
limited and fairly ambiguous and the the

78
00:03:21,740 --> 00:03:19,520
geochemists have had a hard time

79
00:03:23,870 --> 00:03:21,750
demonstrating the likelihood of higher

80
00:03:25,970 --> 00:03:23,880
salinity and in fact have even suggested

81
00:03:28,520 --> 00:03:25,980
that well maybe our ki and salinity was

82
00:03:30,860 --> 00:03:28,530
lower than today and so the bottom line

83
00:03:35,900 --> 00:03:30,870
here is we have no idea what our kina

84
00:03:38,630 --> 00:03:35,910
salinity was and this matters a lot the

85
00:03:40,400 --> 00:03:38,640
reason is that the salinity of the ocean

86
00:03:45,160 --> 00:03:40,410
interacts with the climate system in a

87
00:03:47,810 --> 00:03:45,170
number of ways so for example salinity

88
00:03:50,690 --> 00:03:47,820

determines the temperature at which

89
00:03:52,310 --> 00:03:50,700
water sea water has its maximum density

90
00:03:54,890 --> 00:03:52,320
and so it'll affect the density

91
00:03:57,080 --> 00:03:54,900
stratification of the ocean and ocean

92
00:03:58,670 --> 00:03:57,090
circulation patterns in ocean heat

93
00:04:02,360 --> 00:03:58,680
transport so that's a relatively direct

94
00:04:03,560 --> 00:04:02,370
impact on planetary climate but it turns

95
00:04:06,200 --> 00:04:03,570
out that that's only important for

96
00:04:07,940 --> 00:04:06,210
really big changes in salinity and so

97
00:04:09,290 --> 00:04:07,950
I'm not going to talk about that further

98
00:04:11,450 --> 00:04:09,300
today but that's something we should be

99
00:04:12,950 --> 00:04:11,460
thinking about for for exoplanets for

100
00:04:17,000 --> 00:04:12,960
which we have no constraints on salinity

101
00:04:20,030 --> 00:04:17,010
in the context of the potential range of

102
00:04:22,130 --> 00:04:20,040
our key in salinity though turns out

103
00:04:24,680 --> 00:04:22,140
that freezing point suppression with

104
00:04:28,560 --> 00:04:24,690
increasing salinity could potentially be

105
00:04:33,510 --> 00:04:31,560
so the the difference is in freezing

106
00:04:36,090 --> 00:04:33,520
point as you change salinity are small

107
00:04:40,080 --> 00:04:36,100
we're talking about a degree or so in

108
00:04:41,880 --> 00:04:40,090
either direction but it's nonetheless is

109
00:04:44,550 --> 00:04:41,890
important because if you change the

110
00:04:46,190 --> 00:04:44,560
amount of CI is just a little bit by

111
00:04:50,030 --> 00:04:46,200
changing the freezing point of water

112
00:04:52,770 --> 00:04:50,040
when you actually do is you increase

113
00:04:55,500 --> 00:04:52,780

absorption of incident radiation and

114
00:04:58,620 --> 00:04:55,510
that actually yields warming so this is

115
00:05:02,820 --> 00:04:58,630
a positive feedback that salinity

116
00:05:04,530 --> 00:05:02,830
directly interacts with and so the

117
00:05:06,540 --> 00:05:04,540
specific hypothesis that I set out to

118
00:05:09,240 --> 00:05:06,550
test was that small changes in salinity

119
00:05:11,640 --> 00:05:09,250
could actually yield big changes and

120
00:05:15,930 --> 00:05:11,650
climate due to the interaction with this

121
00:05:18,000 --> 00:05:15,940
positive positive feedback and so that

122
00:05:20,750 --> 00:05:18,010
is exactly what I found

123
00:05:26,190 --> 00:05:20,760
so now I'm going to walk through several

124
00:05:31,260 --> 00:05:26,200
GCM experiments all simulating an

125
00:05:33,600 --> 00:05:31,270
Archaean like aqua planet I assumed the

126
00:05:36,780 --> 00:05:33,610
equivalent of 500 ppm methane and all of

127
00:05:38,940 --> 00:05:36,790
my simulations I assumed Archaean like

128
00:05:41,730 --> 00:05:38,950
insulation of 1106 watts per meter

129
00:05:45,360 --> 00:05:41,740
squared and I assumed in our teen day

130
00:05:46,860 --> 00:05:45,370
length of just under 17 hours and so all

131
00:05:49,080 --> 00:05:46,870
the simulations I'm going to show you

132
00:05:52,200 --> 00:05:49,090
today just simply differ in their

133
00:05:55,110 --> 00:05:52,210
salinity and in the co2 content of their

134
00:05:57,590 --> 00:05:55,120
atmospheres and so as we move across the

135
00:06:00,330 --> 00:05:57,600
rows here I'm changing salinity from

136
00:06:02,040 --> 00:06:00,340
somewhat less then modern to somewhat

137
00:06:05,280 --> 00:06:02,050
more than modern relatively small

138
00:06:08,220 --> 00:06:05,290

changes and as we move down the columns

139
00:06:10,800 --> 00:06:08,230
I'm changing co2 levels in the

140
00:06:13,170 --> 00:06:10,810
atmosphere and so these three panels

141
00:06:15,230 --> 00:06:13,180
here really highlight the the headline

142
00:06:18,750 --> 00:06:15,240
result of my study and that is that

143
00:06:23,310 --> 00:06:18,760
salinity has a big impact on ice cover

144
00:06:27,450 --> 00:06:23,320
in these simulations for a burn ocean

145
00:06:30,900 --> 00:06:27,460
with 20 PSU practical salinity units I

146
00:06:33,510 --> 00:06:30,910
am generating a climate that has a

147
00:06:35,430 --> 00:06:33,520
stable ice margin all the way down to 15

148
00:06:39,150 --> 00:06:35,440
degrees north and south of the equator

149
00:06:40,560 --> 00:06:39,160
and if I increase salinity slightly up

150
00:06:42,870 --> 00:06:40,570
to 50 PSU

151
00:06:45,510 --> 00:06:42,880
the result is a climate that is

152
00:06:48,270 --> 00:06:45,520
effectively ice-free and is in fact

153
00:06:52,530 --> 00:06:48,280
warmer than present-day earth so this is

154
00:06:56,460 --> 00:06:52,540
this is a huge difference and as we look

155
00:06:59,040 --> 00:06:56,470
at much lower co2 levels only 20 times

156
00:07:03,030 --> 00:06:59,050
the pre-industrial level you see that

157
00:07:04,410 --> 00:07:03,040
the difference between the salinity

158
00:07:06,900 --> 00:07:04,420
scenario is it's the difference between

159
00:07:09,180 --> 00:07:06,910
being a snowball and not being a

160
00:07:12,060 --> 00:07:09,190
snowball and so visually this is not as

161
00:07:17,400 --> 00:07:12,070
dramatic as the top row but biologically

162
00:07:20,190 --> 00:07:17,410
this is a big deal and so these these

163
00:07:22,590 --> 00:07:20,200

results here demonstrate that a salinity

164
00:07:26,460 --> 00:07:22,600
really is an important component of our

165
00:07:30,750 --> 00:07:26,470
Earth's climate system now if we look at

166
00:07:33,210 --> 00:07:30,760
an intermediate co2 scenario though we

167
00:07:36,900 --> 00:07:33,220
see that the extent of ice cover isn't

168
00:07:38,400 --> 00:07:36,910
actually that sensitive to salinity

169
00:07:40,920 --> 00:07:38,410
within this region of parameter space

170
00:07:43,500 --> 00:07:40,930
now this is not a counter example to the

171
00:07:45,960 --> 00:07:43,510
importance of salinity and this is

172
00:07:47,600 --> 00:07:45,970
actually itself an interesting result

173
00:07:51,630 --> 00:07:47,610
because the emergence of this stable

174
00:07:54,330 --> 00:07:51,640
climate state is somewhat unexpected so

175
00:07:57,260 --> 00:07:54,340
this is referred to as the your Malinda

176
00:08:00,030 --> 00:07:57,270
climate state and it's characterized by

177
00:08:02,910 --> 00:08:00,040
the stability of very low latitude ice

178
00:08:05,130 --> 00:08:02,920
in this case down all the way to five

179
00:08:08,130 --> 00:08:05,140
degrees and north and south of the

180
00:08:12,270 --> 00:08:08,140
equator and this is somewhat unexpected

181
00:08:15,620 --> 00:08:12,280
because the ice Obito feedback tends to

182
00:08:18,150 --> 00:08:15,630
destabilize a low latitude ice and favor

183
00:08:19,920 --> 00:08:18,160
runaway glaciation - a snowball state

184
00:08:24,030 --> 00:08:19,930
and so the fact that this is not a

185
00:08:26,700 --> 00:08:24,040
snowball his itself interesting so

186
00:08:30,290 --> 00:08:26,710
what's going on here has everything to

187
00:08:32,400 --> 00:08:30,300
do with atmospheric circulation and

188
00:08:35,940 --> 00:08:32,410

specifically the descending branch of

189
00:08:39,480 --> 00:08:35,950
the Hadley cell these latitudes are very

190
00:08:42,330 --> 00:08:39,490
dry and have low cloud cover and very

191
00:08:45,150 --> 00:08:42,340
limited precipitation with the result

192
00:08:48,330 --> 00:08:45,160
that sea ice at these latitudes is bare

193
00:08:50,970 --> 00:08:48,340
sea ice rather than snow-covered sea ice

194
00:08:53,010 --> 00:08:50,980
and bare sea ice is much less reflective

195
00:08:57,030 --> 00:08:53,020
than snowy sea ice

196
00:09:00,200 --> 00:08:57,040
and so the result is that this bear C is

197
00:09:04,770 --> 00:09:00,210
plus low cloud covers low albedo and

198
00:09:09,270 --> 00:09:04,780
this compensates against the ice albedo

199
00:09:11,790 --> 00:09:09,280
feedback I should also note that I I

200
00:09:14,190 --> 00:09:11,800
sped up the rotation rate of the planet

201
00:09:16,440 --> 00:09:14,200
to simulate an arc and a Lang and I

202
00:09:20,010 --> 00:09:16,450
reduced atmospheric pressure to half a

203
00:09:21,960 --> 00:09:20,020
bar compared to 1 bar today and both of

204
00:09:23,670 --> 00:09:21,970
those changes actually limit meridian

205
00:09:26,340 --> 00:09:23,680
all heat transport away from the equator

206
00:09:28,590 --> 00:09:26,350
with the the added benefit of making the

207
00:09:31,080 --> 00:09:28,600
equator just a little bit harder to

208
00:09:32,900 --> 00:09:31,090
glaciation so both of those changes in

209
00:09:36,510 --> 00:09:32,910
combination with the albedo

210
00:09:39,810 --> 00:09:36,520
relationships favor the emergence of

211
00:09:41,370 --> 00:09:39,820
this normal and climate state and so the

212
00:09:44,850 --> 00:09:41,380
next thing that I was interested and

213
00:09:47,550 --> 00:09:44,860

thinking about was what it would take to

214
00:09:50,850 --> 00:09:47,560
push the system into snowball glaciation

215
00:09:52,590 --> 00:09:50,860
or whether or not we might expect that

216
00:09:55,890 --> 00:09:52,600
the normal gun is more likely for an

217
00:10:00,600 --> 00:09:55,900
arcane or a paleo Poros oeq glaciation

218
00:10:04,350 --> 00:10:00,610
than a snowball and so what I did is I

219
00:10:06,170 --> 00:10:04,360
started with each of the three distinct

220
00:10:09,570 --> 00:10:06,180
climate states that I simulated for the

221
00:10:11,880 --> 00:10:09,580
100 times co2 scenarios corresponding to

222
00:10:14,430 --> 00:10:11,890
the three different salinities so I have

223
00:10:17,550 --> 00:10:14,440
the twenty PSU scenario and orange and

224
00:10:21,530 --> 00:10:17,560
the 50 PSU scenario in gray so you can

225
00:10:24,600 --> 00:10:21,540
see that over at the hundred times co2

226
00:10:28,380 --> 00:10:24,610
the the 50 PSU scenario is basically

227
00:10:31,410 --> 00:10:28,390
ice-free whereas the twenty PSU scenario

228
00:10:34,110 --> 00:10:31,420
is heavily glaciated and then from those

229
00:10:37,290 --> 00:10:34,120
steady states I progressively decreased

230
00:10:39,960 --> 00:10:37,300
co2 until all of my simulations achieved

231
00:10:43,190 --> 00:10:39,970
snowball status and so the take-home

232
00:10:48,150 --> 00:10:43,200
message here is that within the

233
00:10:51,150 --> 00:10:48,160
intermediate ranges of co2 all all three

234
00:10:55,080 --> 00:10:51,160
salinities are producing a normal gun to

235
00:10:58,050 --> 00:10:55,090
climate state that is not different in

236
00:10:59,850 --> 00:10:58,060
its total ice cover but the critical co2

237
00:11:02,100 --> 00:10:59,860
thresholds in which you enter the your

238
00:11:04,320 --> 00:11:02,110

mogan state and in which global

239
00:11:06,420 --> 00:11:04,330
glaciation becomes inevitable are very

240
00:11:09,889 --> 00:11:06,430
different and

241
00:11:13,370 --> 00:11:09,899
so even though salinity doesn't always

242
00:11:16,410 --> 00:11:13,380
manifest as differences in sea ice cover

243
00:11:18,960 --> 00:11:16,420
having higher salinity does impart

244
00:11:22,769 --> 00:11:18,970
resiliency against global glaciation and

245
00:11:25,110 --> 00:11:22,779
so salinity is a bit of a master

246
00:11:29,190 --> 00:11:25,120
variable with regard to the climate

247
00:11:31,260 --> 00:11:29,200
system okay and so that brings me to the

248
00:11:33,960 --> 00:11:31,270
end of my talk and I will just summarize

249
00:11:36,240 --> 00:11:33,970
by saying I hope I've convinced you that

250
00:11:40,019 --> 00:11:36,250
salinity is a really important

251
00:11:42,600 --> 00:11:40,029
consideration and salt may in fact be an

252
00:11:54,389 --> 00:11:42,610
essential ingredient to the habitability

253
00:11:57,300 --> 00:11:54,399
of archaea you Stephanie questions yeah

254
00:12:00,480 --> 00:11:57,310
the connection between salinity and sea

255
00:12:02,670 --> 00:12:00,490
ice goes I'm wondering about the

256
00:12:04,620 --> 00:12:02,680
connection with clouds because clouds

257
00:12:06,750 --> 00:12:04,630
are not randomly distributed over the

258
00:12:08,310 --> 00:12:06,760
earth and I'm wondering if if you have a

259
00:12:10,740 --> 00:12:08,320
polar cap that's white

260
00:12:13,050 --> 00:12:10,750
do you preferentially you don't have

261
00:12:14,699 --> 00:12:13,060
clouds there or because if you had more

262
00:12:17,280 --> 00:12:14,709
clouds there then the effect you're

263
00:12:18,120 --> 00:12:17,290

talking about would go away so so can

264
00:12:19,380 --> 00:12:18,130
you talk a little bit about the

265
00:12:22,460 --> 00:12:19,390
correlation or anti correlation with

266
00:12:25,019 --> 00:12:22,470
cloud cover and the ice so I have not

267
00:12:27,690 --> 00:12:25,029
specifically looked at how cloud cover

268
00:12:29,250 --> 00:12:27,700
differs between my my simulations but

269
00:12:31,980 --> 00:12:29,260
you are you are right to point out that

270
00:12:33,780 --> 00:12:31,990
it should matter in particular the

271
00:12:37,230 --> 00:12:33,790
emergence of the normal gun state is

272
00:12:39,180 --> 00:12:37,240
directly tied to snow and so I would

273
00:12:41,970 --> 00:12:39,190
expect that there could be differences

274
00:12:44,550 --> 00:12:41,980
here since the threshold for initiating

275
00:12:45,690 --> 00:12:44,560
that differs so dramatically but you

276
00:12:47,250 --> 00:12:45,700
would agree that ice cover doesn't

277
00:12:50,819 --> 00:12:47,260
matter if you just cloud covered above

278
00:12:52,530 --> 00:12:50,829
it oh right yeah yeah and so that's why

279
00:12:54,390 --> 00:12:52,540
the descending branch of the Hadley cell

280
00:12:59,610 --> 00:12:54,400
is really controlling

281
00:13:03,030 --> 00:12:59,620
yep hi john toter from university of

282
00:13:04,920 --> 00:13:03,040
washington so if you form ice on on a

283
00:13:07,500 --> 00:13:04,930
snowball earth you're gonna concentrate

284
00:13:09,660 --> 00:13:07,510
the residual sea water and so you're

285
00:13:12,930 --> 00:13:09,670
gonna have a pea pod effect there have

286
00:13:16,769 --> 00:13:12,940
you have you looked at that I have not

287
00:13:18,980 --> 00:13:16,779
specifically looked at that but rocky 3d

288
00:13:22,220 --> 00:13:18,990

the GCM that I use does

289
00:13:24,140 --> 00:13:22,230
for serve mass and so assault is

290
00:13:28,850 --> 00:13:24,150
concentrating as as glaciation is

291
00:13:32,120 --> 00:13:28,860
progressing and so my gut instinct is

292
00:13:32,930 --> 00:13:32,130
that that feedback does not have a big

293
00:13:35,120 --> 00:13:32,940
impact

294
00:13:37,100 --> 00:13:35,130
okay so that was included in this mom

295
00:13:38,930 --> 00:13:37,110
yeah I didn't specifically set out to

296
00:13:45,740 --> 00:13:38,940
study that but it is implicitly included

297
00:13:50,320 --> 00:13:45,750
yeah uh uh hi Eli more Rowan University

298
00:13:53,480 --> 00:13:50,330
um so the presence of ice cover could

299
00:13:55,190 --> 00:13:53,490
potentially really reduce weathering

300
00:13:57,470 --> 00:13:55,200
although you know it's night it's hard

301
00:13:59,510 --> 00:13:57,480
to say what continents were like early

302
00:14:00,680 --> 00:13:59,520
Earth but without with reduced

303
00:14:02,750 --> 00:14:00,690
weathering you'd have even reduced

304
00:14:06,430 --> 00:14:02,760
salinity so do you think that could even

305
00:14:09,920 --> 00:14:06,440
be a further feedback towards glaciation

306
00:14:12,950 --> 00:14:09,930
hmm well that that really depends on

307
00:14:17,240 --> 00:14:12,960
what sets the salinity of the ocean um a

308
00:14:19,490 --> 00:14:17,250
long time skills so first some ions the

309
00:14:23,180 --> 00:14:19,500
weathering will be really important for

310
00:14:25,520 --> 00:14:23,190
other ions that is less so and so that's

311
00:14:27,080 --> 00:14:25,530
certainly something worth worth

312
00:14:29,300 --> 00:14:27,090
considering that I have that I have not

313
00:14:40,200 --> 00:14:29,310

done um I actually used an aqua planet