AB GRAD CON23

1
00:00:04,230 --> 00:00:11,169
[Music]

2
00:00:15,829 --> 00:00:14,030
thank you uh so yeah I'm Sarah Miller

3
00:00:18,470 --> 00:00:15,839
I'm working with Professor Brittany

4
00:00:20,689 --> 00:00:18,480
Schmidt at Cornell University and I am

5
00:00:23,510 --> 00:00:20,699
working to build a global circulation

6
00:00:25,250 --> 00:00:23,520
model for the ocean at Europa

7
00:00:26,810 --> 00:00:25,260
um so before we move on I wanted to kind

8
00:00:29,029 --> 00:00:26,820
of point out the cover image I chose

9
00:00:30,589 --> 00:00:29,039
which is primarily because I thought the

10
00:00:33,110 --> 00:00:30,599
colors made for a pretty PowerPoint

11
00:00:35,510 --> 00:00:33,120
theme and secondarily because it shows

12
00:00:37,610 --> 00:00:35,520
some interesting kind of structures that

13
00:00:39,290 --> 00:00:37,620

exist on the ice crust on Europa so as

14
00:00:41,690 --> 00:00:39,300
you can see it's not a smooth ice

15
00:00:44,510 --> 00:00:41,700
skating rink it's a very interesting and

16
00:00:46,790 --> 00:00:44,520
geologically active Zone which hints

17
00:00:48,229 --> 00:00:46,800
that probably the interior is a dynamic

18
00:00:50,569 --> 00:00:48,239
and very interesting place to study

19
00:00:53,209 --> 00:00:50,579
which is what I'm going to talk about

20
00:00:54,889 --> 00:00:53,219
next before I dive into the science I do

21
00:00:56,330 --> 00:00:54,899
want to take a moment to thank my team

22
00:00:58,610 --> 00:00:56,340
and kind of the people who have helped

23
00:00:59,990 --> 00:00:58,620
me bring my understanding

24
00:01:01,549 --> 00:01:00,000
um in this field up so I have a

25
00:01:03,110 --> 00:01:01,559
background in fluid dynamics and

26
00:01:04,430 --> 00:01:03,120
aerospace engineering which I'll talk a

27
00:01:05,870 --> 00:01:04,440
little bit about throughout this talk

28
00:01:08,090 --> 00:01:05,880
but these people have been really

29
00:01:09,890 --> 00:01:08,100
instrumental in kind of working with me

30
00:01:12,950 --> 00:01:09,900
on the planetary aspect as well as my

31
00:01:14,750 --> 00:01:12,960
funding sources through an NSF grfp and

32
00:01:17,090 --> 00:01:14,760
a NASA finest in an Amelia Earhart

33
00:01:18,469 --> 00:01:17,100
fellowship and some wonderful people who

34
00:01:20,990 --> 00:01:18,479
support this work

35
00:01:22,670 --> 00:01:21,000
okay so as I mentioned uh Europa has a

36
00:01:26,690 --> 00:01:22,680
very interesting surface and it hints

37
00:01:28,730 --> 00:01:26,700
that there is a dynamic ocean interior

38
00:01:30,649 --> 00:01:28,740

and I think that the ocean circulation

39
00:01:32,450 --> 00:01:30,659
the physical oceanography piece of this

40
00:01:34,070 --> 00:01:32,460
puzzle is a really interesting one in

41
00:01:35,690 --> 00:01:34,080
terms of habitability because when we

42
00:01:37,609 --> 00:01:35,700
look at Earth's ocean

43
00:01:39,710 --> 00:01:37,619
um the transport of heat and salt and

44
00:01:41,630 --> 00:01:39,720
nutrients throughout the ocean column is

45
00:01:42,530 --> 00:01:41,640
really what sustains our biosphere so I

46
00:01:44,149 --> 00:01:42,540
think it has really interesting

47
00:01:47,149 --> 00:01:44,159
habitability implications on other

48
00:01:48,770 --> 00:01:47,159
planets as well and specifically I want

49
00:01:51,830 --> 00:01:48,780
to narrow this down even further the

50
00:01:54,350 --> 00:01:51,840
region of our ocean that separates the

51
00:01:56,929 --> 00:01:54,360
glacial glacially covered parts of our

52
00:01:58,850 --> 00:01:56,939
ocean from the liquid layer that ice

53
00:02:01,010 --> 00:01:58,860
ocean boundary layer is really

54
00:02:03,289 --> 00:02:01,020
instrumental in setting far-field ocean

55
00:02:04,730 --> 00:02:03,299
properties so that tiny boundary layer

56
00:02:07,249 --> 00:02:04,740
region between the ice and the ocean

57
00:02:09,650 --> 00:02:07,259
actually has an outsized effect on

58
00:02:12,350 --> 00:02:09,660
affecting Global Mass Water mass

59
00:02:14,630 --> 00:02:12,360
transport and so I think that's very

60
00:02:17,089 --> 00:02:14,640
much worthy of intense study in the

61
00:02:19,130 --> 00:02:17,099
modeling realm for Europa

62
00:02:21,229 --> 00:02:19,140
so I'm not the first person to attempt

63
00:02:22,550 --> 00:02:21,239

to build a global circulation model for

64
00:02:24,229 --> 00:02:22,560
Europa

65
00:02:27,410 --> 00:02:24,239
um but the the state of the field is

66
00:02:29,150 --> 00:02:27,420
really kind of Divergent so um models of

67
00:02:31,670 --> 00:02:29,160
Europa generally fall into one of two

68
00:02:33,290 --> 00:02:31,680
categories depending on kind of how you

69
00:02:35,350 --> 00:02:33,300
set your boundary conditions and really

70
00:02:38,030 --> 00:02:35,360
how you set up this ice ocean interface

71
00:02:39,650 --> 00:02:38,040
mathematically so usually there's kind

72
00:02:42,770 --> 00:02:39,660
of an outsized effect of either the

73
00:02:44,449 --> 00:02:42,780
rotation driven or buoyancy driven so

74
00:02:47,630 --> 00:02:44,459
kind of temperature salinity gradients

75
00:02:50,270 --> 00:02:47,640
in the model and the results are very

76
00:02:51,890 --> 00:02:50,280
different so Global circulation models

77
00:02:53,390 --> 00:02:51,900
exist they usually fall into one of

78
00:02:55,610 --> 00:02:53,400
these two categories and they do not

79
00:02:57,170 --> 00:02:55,620
agree with each other now if we look at

80
00:02:59,210 --> 00:02:57,180
terrestrial Ocean Models on the other

81
00:03:00,350 --> 00:02:59,220
hand they look very different and that's

82
00:03:02,990 --> 00:03:00,360
because they've had a lot more

83
00:03:06,229 --> 00:03:03,000
scientific Manpower in years of study

84
00:03:09,170 --> 00:03:06,239
and actual data so how nice for them so

85
00:03:10,910 --> 00:03:09,180
their models are very sophisticated

86
00:03:12,530 --> 00:03:10,920
compared to what we see in planetary

87
00:03:14,449 --> 00:03:12,540
Ocean Models

88
00:03:15,770 --> 00:03:14,459

that being said there are still kind of

89
00:03:18,410 --> 00:03:15,780
parts of Earth's ocean that we don't

90
00:03:20,270 --> 00:03:18,420
understand so it's very much ocean

91
00:03:22,130 --> 00:03:20,280
modeling is an active area of research

92
00:03:23,809 --> 00:03:22,140
and there's still some mechanisms that

93
00:03:25,729 --> 00:03:23,819
remain poorly constrained which is

94
00:03:28,190 --> 00:03:25,739
really humbling to think about doing

95
00:03:31,250 --> 00:03:28,200
this on a body that we have zero data

96
00:03:33,949 --> 00:03:31,260
for and know a lot less about

97
00:03:35,210 --> 00:03:33,959
but I'm going to try anyway

98
00:03:36,830 --> 00:03:35,220
um so let me introduce you to the tool

99
00:03:39,910 --> 00:03:36,840
that I'm using so I'm using the MIT

100
00:03:43,449 --> 00:03:39,920
General circulation model so it's a 3D

101
00:03:45,830 --> 00:03:43,459
circulation model that employs the full

102
00:03:47,570 --> 00:03:45,840
non-hydrostatic incompressible navier

103
00:03:49,250 --> 00:03:47,580
Stokes equations

104
00:03:51,649 --> 00:03:49,260
it also has some really interesting and

105
00:03:53,390 --> 00:03:51,659
very useful packages for Europa so an

106
00:03:53,990 --> 00:03:53,400
ice shelf package

107
00:03:56,030 --> 00:03:54,000
um

108
00:03:58,250 --> 00:03:56,040
a deep convection package which is

109
00:04:00,350 --> 00:03:58,260
really helpful because Europa unlike

110
00:04:03,170 --> 00:04:00,360
Earth has a really deep ocean compared

111
00:04:04,369 --> 00:04:03,180
to its planetary radius and that is

112
00:04:07,309 --> 00:04:04,379
important when you're talking about

113
00:04:09,050 --> 00:04:07,319

large scale flow features so I won't

114
00:04:10,550 --> 00:04:09,060
kind of dive into the nitty-gritty it's

115
00:04:12,229 --> 00:04:10,560
written in Fortran

116
00:04:15,289 --> 00:04:12,239
um so if you're a modeler you're

117
00:04:18,469 --> 00:04:15,299
probably just cringed uh but yeah it's a

118
00:04:19,969 --> 00:04:18,479
very powerful very useful tool

119
00:04:21,890 --> 00:04:19,979
so there's lots of knobs that you can

120
00:04:23,570 --> 00:04:21,900
turn within this model and I'm working

121
00:04:25,370 --> 00:04:23,580
on turning kind of all of these through

122
00:04:27,290 --> 00:04:25,380
sensitivity studies throughout my PhD

123
00:04:29,689 --> 00:04:27,300
but what I want to focus on in this talk

124
00:04:32,090 --> 00:04:29,699
is the role of topography underneath the

125
00:04:34,490 --> 00:04:32,100
ice shelf so in this case I'm talking

126
00:04:36,650 --> 00:04:34,500
about both the small scale topography so

127
00:04:38,990 --> 00:04:36,660
surfness roughness surface roughness of

128
00:04:42,050 --> 00:04:39,000
the ice which affects things like

129
00:04:44,990 --> 00:04:42,060
turbulence in the boundary layer as well

130
00:04:47,270 --> 00:04:45,000
as large scale features on the ice that

131
00:04:48,770 --> 00:04:47,280
can form large scale flow features now

132
00:04:51,050 --> 00:04:48,780
you might be thinking like why would a

133
00:04:52,550 --> 00:04:51,060
turbulent boundary layer affect global

134
00:04:55,850 --> 00:04:52,560
ocean circulation

135
00:04:58,249 --> 00:04:55,860
and specifically habitability for this

136
00:05:00,110 --> 00:04:58,259
interest and I want you to remember that

137
00:05:03,170 --> 00:05:00,120
the ocean time scales operate a lot

138
00:05:04,909 --> 00:05:03,180

faster than planetary time scales and

139
00:05:07,370 --> 00:05:04,919
that could be an important link for a

140
00:05:09,290 --> 00:05:07,380
habitability argument

141
00:05:11,270 --> 00:05:09,300
so quick review of kind of boundary

142
00:05:12,770 --> 00:05:11,280
layer of physics

143
00:05:14,150 --> 00:05:12,780
um I took out the full equations because

144
00:05:16,390 --> 00:05:14,160
they're pretty ugly and I just have

145
00:05:19,010 --> 00:05:16,400
these like nice kind of simplified

146
00:05:20,830 --> 00:05:19,020
relationships that I want to discuss

147
00:05:22,550 --> 00:05:20,840
um so I'm using kind of a widely adopted

148
00:05:24,770 --> 00:05:22,560
parameterization called the three

149
00:05:27,290 --> 00:05:24,780
equation parameterization it's very

150
00:05:29,150 --> 00:05:27,300
creatively named and essentially it's

151
00:05:32,330 --> 00:05:29,160
just looking at this fluxes those are

152
00:05:35,810 --> 00:05:32,340
those Q values between a solid ice shelf

153
00:05:38,390 --> 00:05:35,820
which is fresh water or fresh ice a

154
00:05:40,670 --> 00:05:38,400
mixed boundary layer region and then the

155
00:05:42,290 --> 00:05:40,680
mixed layer the liquid ocean

156
00:05:44,210 --> 00:05:42,300
so we're looking at kind of the three

157
00:05:45,529 --> 00:05:44,220
unknowns in these equations are the

158
00:05:48,650 --> 00:05:45,539
temperature and salinity of the boundary

159
00:05:50,270 --> 00:05:48,660
layer as well as a melt rate or MDOT

160
00:05:53,270 --> 00:05:50,280
which is negative if it's melting

161
00:05:55,310 --> 00:05:53,280
positive if it's freezing and that's

162
00:05:58,730 --> 00:05:55,320
kind of how we're constraining the phase

163
00:06:01,249 --> 00:05:58,740

change that's happening at this region

164
00:06:03,830 --> 00:06:01,259
so I'm using a model that's um

165
00:06:07,969 --> 00:06:03,840
kind of an ongoing International effort

166
00:06:10,850 --> 00:06:07,979
within the MIT GCM Community to uh

167
00:06:12,890 --> 00:06:10,860
model this kind of physics

168
00:06:15,050 --> 00:06:12,900
um for Earth's ocean and so this is a

169
00:06:16,550 --> 00:06:15,060
simplified version of that map and so

170
00:06:18,950 --> 00:06:16,560
it's a two equation parameterization

171
00:06:20,390 --> 00:06:18,960
that's assuming the salinity of the

172
00:06:22,070 --> 00:06:20,400
boundary layer and the mixed layer is

173
00:06:23,930 --> 00:06:22,080
the same

174
00:06:25,850 --> 00:06:23,940
um current research and kind of more

175
00:06:27,770 --> 00:06:25,860
recent results since submitting this

176
00:06:29,570 --> 00:06:27,780
abstract I've been able to like use the

177
00:06:32,090 --> 00:06:29,580
three equation parameterization but

178
00:06:34,309 --> 00:06:32,100
those graphs are still pretty ugly so

179
00:06:35,629 --> 00:06:34,319
maybe next at gradcon

180
00:06:37,550 --> 00:06:35,639
um

181
00:06:39,350 --> 00:06:37,560
yeah and kind of one other thing that's

182
00:06:41,809 --> 00:06:39,360
very common on Earth but not a great

183
00:06:45,010 --> 00:06:41,819
approximation for Europa is that often

184
00:06:47,809 --> 00:06:45,020
in Ocean Models the pressure dependence

185
00:06:49,850 --> 00:06:47,819
of density is approximated by depth

186
00:06:52,430 --> 00:06:49,860
dependence I mentioned that europa's

187
00:06:53,809 --> 00:06:52,440
ocean is a lot deeper than Earth's so

188
00:06:55,070 --> 00:06:53,819

this is something that I've removed as

189
00:06:57,950 --> 00:06:55,080
well because I think

190
00:07:01,010 --> 00:06:57,960
no longer holds for europa's ocean

191
00:07:03,469 --> 00:07:01,020
so I mentioned it's probably not like a

192
00:07:04,790 --> 00:07:03,479
flat ice skating rink under europa's eye

193
00:07:06,890 --> 00:07:04,800
shell we don't know what it looks like

194
00:07:07,790 --> 00:07:06,900
but it's probably not that beautiful and

195
00:07:09,409 --> 00:07:07,800
simple

196
00:07:11,210 --> 00:07:09,419
um it's probably not this beautiful and

197
00:07:13,129 --> 00:07:11,220
simple either but to start with to kind

198
00:07:14,390 --> 00:07:13,139
of demonstrate some of the flow features

199
00:07:16,370 --> 00:07:14,400
that might develop with ice shelf

200
00:07:19,850 --> 00:07:16,380
topography here's like a very simple

201
00:07:22,270 --> 00:07:19,860
ramp that I'm introducing so it's not a

202
00:07:25,189 --> 00:07:22,280
global model quite yet it's just a

203
00:07:26,089 --> 00:07:25,199
rectangular domain starting at a fixed

204
00:07:27,650 --> 00:07:26,099
initial

205
00:07:28,309 --> 00:07:27,660
temperature

206
00:07:30,589 --> 00:07:28,319
um

207
00:07:33,830 --> 00:07:30,599
and we're going to introduce a heat

208
00:07:36,589 --> 00:07:33,840
gradient and a flow through ice melting

209
00:07:38,629 --> 00:07:36,599
and see what develops

210
00:07:40,909 --> 00:07:38,639
so we're seeing some already just with

211
00:07:42,770 --> 00:07:40,919
very simple geometry interesting and

212
00:07:44,749 --> 00:07:42,780
kind of recognizable flow features so we

213
00:07:46,249 --> 00:07:44,759

see the development of what looks kind

214
00:07:48,230 --> 00:07:46,259
of like a western boundary current on

215
00:07:49,969 --> 00:07:48,240
the left and an ocean gyre on the right

216
00:07:53,270 --> 00:07:49,979
and these are happening because there is

217
00:07:54,710 --> 00:07:53,280
melting happening at depth so if you

218
00:07:56,330 --> 00:07:54,720
remember the phase diagram of water

219
00:07:59,089 --> 00:07:56,340
there is a pressure dependence on the

220
00:08:00,830 --> 00:07:59,099
melting point of ice and so we see

221
00:08:03,290 --> 00:08:00,840
melting happening on the bottom of this

222
00:08:06,170 --> 00:08:03,300
ramp and then as the fresh waters Rising

223
00:08:07,909 --> 00:08:06,180
along the Melt water the ramp it's

224
00:08:11,510 --> 00:08:07,919
circulating and that's creating a

225
00:08:14,029 --> 00:08:11,520
circular flow feature this dryer

226
00:08:16,249 --> 00:08:14,039
so we have on the left these are just

227
00:08:18,290 --> 00:08:16,259
stream functions the barotrope extreme

228
00:08:19,969 --> 00:08:18,300
function and then the right and

229
00:08:21,710 --> 00:08:19,979
overturning stream function just in a

230
00:08:24,110 --> 00:08:21,720
couple different directions

231
00:08:26,510 --> 00:08:24,120
so maybe more importantly uh

232
00:08:28,189 --> 00:08:26,520
the Melt rate what's happening so we're

233
00:08:30,290 --> 00:08:28,199
seeing both regions of melting and

234
00:08:31,730 --> 00:08:30,300
freezing The Contours got a little dense

235
00:08:33,649 --> 00:08:31,740
for the melting so I just kind of

236
00:08:36,949 --> 00:08:33,659
outlined that where that's happening

237
00:08:39,050 --> 00:08:36,959
there but that's happening um kind of as

238
00:08:42,469 --> 00:08:39,060

the warmer Ocean mixed layer water is

239
00:08:44,870 --> 00:08:42,479
interacting with this Frozen ramp

240
00:08:47,090 --> 00:08:44,880
and so we see that kind of

241
00:08:48,769 --> 00:08:47,100
um already just very simple geometry

242
00:08:50,690 --> 00:08:48,779
there's lots of Dynamics happening

243
00:08:52,430 --> 00:08:50,700
there's freezing there's melting there's

244
00:08:53,269 --> 00:08:52,440
flow features

245
00:08:56,509 --> 00:08:53,279
um

246
00:08:58,310 --> 00:08:56,519
but this is probably not very realistic

247
00:09:01,130 --> 00:08:58,320
maybe more realistic is something like

248
00:09:04,190 --> 00:09:01,140
this so

249
00:09:07,490 --> 00:09:04,200
this is a almost Global

250
00:09:09,769 --> 00:09:07,500
um topography that I stole from what

251
00:09:11,590 --> 00:09:09,779
Earth's ice shelves look like I cut out

252
00:09:14,090 --> 00:09:11,600
the poles because of convergence issues

253
00:09:15,829 --> 00:09:14,100
and it's a pretty coarse resolution but

254
00:09:18,009 --> 00:09:15,839
it still captures a lot of the large

255
00:09:20,329 --> 00:09:18,019
scale flow features that we see on Earth

256
00:09:23,110 --> 00:09:20,339
as well as some turbulence and mixing

257
00:09:25,970 --> 00:09:23,120
events effects from small scale features

258
00:09:27,410 --> 00:09:25,980
that are missing and so

259
00:09:29,509 --> 00:09:27,420
I think it's really important to think

260
00:09:30,290 --> 00:09:29,519
that like when you're modeling

261
00:09:32,810 --> 00:09:30,300
um

262
00:09:35,509 --> 00:09:32,820
heat transfer like your grid resolution

263
00:09:38,030 --> 00:09:35,519

is really important so the size of your

264
00:09:39,889 --> 00:09:38,040
grid cell in your model affects kind of

265
00:09:41,810 --> 00:09:39,899
how quickly heat is transferred through

266
00:09:43,490 --> 00:09:41,820
your ocean and so this is really too

267
00:09:44,210 --> 00:09:43,500
course to understand

268
00:09:45,949 --> 00:09:44,220
um

269
00:09:49,009 --> 00:09:45,959
what's happening in turbulence and

270
00:09:50,509 --> 00:09:49,019
Boundary layer effects so I'm

271
00:09:52,730 --> 00:09:50,519
kind of

272
00:09:55,850 --> 00:09:52,740
accommodating that in the model by

273
00:09:58,370 --> 00:09:55,860
modifying the MIT GCM to have like

274
00:10:00,050 --> 00:09:58,380
spatial grid remeshing so I'm slicing up

275
00:10:02,030 --> 00:10:00,060
the grid cells

276
00:10:03,949 --> 00:10:02,040
so that I can have melting and freezing

277
00:10:05,449 --> 00:10:03,959
happening within a single model run

278
00:10:06,790 --> 00:10:05,459
which is not kind of the standard

279
00:10:09,410 --> 00:10:06,800
configuration

280
00:10:11,269 --> 00:10:09,420
within the boundary layer so this has

281
00:10:12,410 --> 00:10:11,279
been kind of very helpful in

282
00:10:13,310 --> 00:10:12,420
understanding

283
00:10:15,470 --> 00:10:13,320
um

284
00:10:20,150 --> 00:10:15,480
turbulence and more quick time scale

285
00:10:23,449 --> 00:10:22,009
now this is kind of one of several

286
00:10:25,610 --> 00:10:23,459
things that needs to happen to have a

287
00:10:27,470 --> 00:10:25,620
more realistic ice shells like greater

288
00:10:28,670 --> 00:10:27,480

spatial grid density in the boundary

289
00:10:29,329 --> 00:10:28,680
layer

290
00:10:31,670 --> 00:10:29,339
um

291
00:10:33,829 --> 00:10:31,680
there's also but even so you know it's

292
00:10:34,430 --> 00:10:33,839
not going to be a simple ramp

293
00:10:36,410 --> 00:10:34,440
um

294
00:10:38,570 --> 00:10:36,420
there's other things to introduce like

295
00:10:40,310 --> 00:10:38,580
salt different heat and salt transfer

296
00:10:41,750 --> 00:10:40,320
coefficients

297
00:10:43,610 --> 00:10:41,760
um

298
00:10:45,710 --> 00:10:43,620
a mushy layer there's interesting work

299
00:10:47,389 --> 00:10:45,720
that's being done by this on this by

300
00:10:48,530 --> 00:10:47,399
Jacob buffo if you want to look at his

301
00:10:49,190 --> 00:10:48,540
work

302
00:10:51,410 --> 00:10:49,200
um

303
00:10:52,850 --> 00:10:51,420
so in my model currently the ice is

304
00:10:55,430 --> 00:10:52,860
assumed as a completely fresh water

305
00:10:57,949 --> 00:10:55,440
layer that's probably not the case there

306
00:11:01,490 --> 00:10:57,959
might be zones or brines and interesting

307
00:11:05,150 --> 00:11:01,500
kind of pockets of heterogeneities that

308
00:11:07,009 --> 00:11:05,160
will affect these processes but this is

309
00:11:09,710 --> 00:11:07,019
kind of all just taking steps to like

310
00:11:12,050 --> 00:11:09,720
introduce more realistic features into

311
00:11:14,389 --> 00:11:12,060
an ice shell model and then look at the

312
00:11:16,370 --> 00:11:14,399
global circulation effects of those

313
00:11:18,110 --> 00:11:16,380

features

314
00:11:20,329 --> 00:11:18,120
so kind of to kind of wrap up this

315
00:11:20,930 --> 00:11:20,339
little bit that I've discussed

316
00:11:22,670 --> 00:11:20,940
um

317
00:11:25,090 --> 00:11:22,680
terrestrial models I think can be very

318
00:11:27,710 --> 00:11:25,100
valuable in the planetary Community

319
00:11:28,850 --> 00:11:27,720
within those models specifically I think

320
00:11:30,829 --> 00:11:28,860
there still needs to be a lot of work

321
00:11:33,050 --> 00:11:30,839
done on the ice ocean boundary layer

322
00:11:35,690 --> 00:11:33,060
which is what I've been focusing on this

323
00:11:38,329 --> 00:11:35,700
past year of my PhD and the potential

324
00:11:41,509 --> 00:11:38,339
impacts for habitability of this kind of

325
00:11:43,850 --> 00:11:41,519
great uh resolution on an ISO student

326
00:11:46,490 --> 00:11:43,860
boundary layer could be very important

327
00:11:48,470 --> 00:11:46,500
for habitability

328
00:11:56,510 --> 00:11:48,480
all right and I'm happy to take

329
00:11:56,520 --> 00:12:00,769
[Applause]

330
00:12:08,449 --> 00:12:05,690
so if you are assuming uh so with the

331
00:12:11,750 --> 00:12:08,459
mushy layer you know like a slurry for

332
00:12:15,290 --> 00:12:11,760
instance is the Assumption of uh

333
00:12:18,170 --> 00:12:15,300
incompressible fluid still valid and

334
00:12:20,870 --> 00:12:18,180
does that change that makes never Stokes

335
00:12:23,930 --> 00:12:20,880
much more complicated right so how would

336
00:12:26,090 --> 00:12:23,940
that really affect the your modeling

337
00:12:28,910 --> 00:12:26,100
would you have to change some things or

338
00:12:31,910 --> 00:12:28,920

yeah no that's a really good question so

339
00:12:34,130 --> 00:12:31,920
um realistically yes you would change uh

340
00:12:36,290 --> 00:12:34,140
the kind of forcing equations so the

341
00:12:37,790 --> 00:12:36,300
model as it currently runs it assumes

342
00:12:39,350 --> 00:12:37,800
that um

343
00:12:40,910 --> 00:12:39,360
kind of backing up a little bit the

344
00:12:42,530 --> 00:12:40,920
equation of state of seawater is a

345
00:12:44,650 --> 00:12:42,540
linear function of salinity so if you

346
00:12:47,090 --> 00:12:44,660
introduce something like a brine

347
00:12:49,250 --> 00:12:47,100
it's removing that kind of linear

348
00:12:51,170 --> 00:12:49,260
assumption that said like the model as

349
00:12:52,790 --> 00:12:51,180
it currently stands it does have a solid

350
00:12:55,370 --> 00:12:52,800
ice layer so it doesn't look at brine

351
00:12:55,970 --> 00:12:55,380
Pockets or mushy layers yet

352
00:12:58,490 --> 00:12:55,980
um

353
00:13:01,370 --> 00:12:58,500
if you wanted to do that I do think that

354
00:13:04,550 --> 00:13:01,380
yeah you'd need to change the equation

355
00:13:06,110 --> 00:13:04,560
of State at seawater locally yeah to

356
00:13:08,870 --> 00:13:06,120
accommodate those and what about the

357
00:13:10,370 --> 00:13:08,880
incompressibility assumption I think

358
00:13:11,870 --> 00:13:10,380
that's a small enough one where if

359
00:13:14,030 --> 00:13:11,880
you're looking at the effects on

360
00:13:15,230 --> 00:13:14,040
overturning in flow it wouldn't have an

361
00:13:16,910 --> 00:13:15,240
effect but it would be a very cool

362
00:13:25,850 --> 00:13:16,920
sensitivity study so it's a good

363
00:13:31,430 --> 00:13:29,329

sorry a really ignorant question so

364
00:13:33,110 --> 00:13:31,440
Europa it seems like there's a

365
00:13:35,569 --> 00:13:33,120
very kind of notice

366
00:13:38,329 --> 00:13:35,579
notice gradient is that just due to

367
00:13:40,430 --> 00:13:38,339
pressure kind of like what what's the

368
00:13:42,829 --> 00:13:40,440
middle of Europa oh interesting question

369
00:13:45,650 --> 00:13:42,839
okay I think I have

370
00:13:47,389 --> 00:13:45,660
um a backup slide that might help so

371
00:13:50,150 --> 00:13:47,399
yeah so the mechanisms that are kind of

372
00:13:52,129 --> 00:13:50,160
important for Europa Heating and what's

373
00:13:54,889 --> 00:13:52,139
sustaining the ocean are like tidal

374
00:13:57,310 --> 00:13:54,899
heating that it bottom heating from

375
00:13:59,690 --> 00:13:57,320
residual heat of formation internal heat

376
00:14:01,430 --> 00:13:59,700
if there is this Dynamic eye shell

377
00:14:03,949 --> 00:14:01,440
that's freezing and melting like I think

378
00:14:05,990 --> 00:14:03,959
it is then you have heat fluxes from

379
00:14:06,590 --> 00:14:06,000
freezing and melting

380
00:14:08,810 --> 00:14:06,600
um

381
00:14:10,610 --> 00:14:08,820
yeah so there's a lot going on

382
00:14:13,009 --> 00:14:10,620
um the kind of Weights of these effects

383
00:14:14,090 --> 00:14:13,019
is still very much unknown and so that's

384
00:14:16,730 --> 00:14:14,100
why I'm really trying to use

385
00:14:18,590 --> 00:14:16,740
observations from Earth so for instance

386
00:14:20,449 --> 00:14:18,600
I'm using like turbulent turbulent

387
00:14:22,490 --> 00:14:20,459
transfer coefficients of freezing and

388
00:14:25,129 --> 00:14:22,500

melting from Antarctic field studies to

389
00:14:26,870 --> 00:14:25,139
kind of influence this model but yeah

390
00:14:28,850 --> 00:14:26,880
it's really like there's a lot going on

391
00:14:30,110 --> 00:14:28,860
so it's really kind of the challenge is

392
00:14:31,550 --> 00:14:30,120
trying to figure out which one is

393
00:14:32,210 --> 00:14:31,560
driving

394
00:14:38,870 --> 00:14:32,220
um

395
00:14:38,880 --> 00:14:47,269
okay we have time for one more question

396
00:14:50,689 --> 00:14:49,430
Taylor plattner at Georgia Tech great

397
00:14:52,730 --> 00:14:50,699
talk Sarah

398
00:14:55,250 --> 00:14:52,740
um you were talking about Brian Pockets

399
00:14:58,790 --> 00:14:55,260
to like make it the model more realistic

400
00:15:01,910 --> 00:14:58,800
did you have do you plan on doing that

401
00:15:04,189 --> 00:15:01,920
with your model and have they done it on

402
00:15:06,710 --> 00:15:04,199
earth like with like Earth models have

403
00:15:08,449 --> 00:15:06,720
they even thought of like incorporating

404
00:15:10,310 --> 00:15:08,459
bride pockets

405
00:15:12,230 --> 00:15:10,320
yeah it's a good question so the answer

406
00:15:13,790 --> 00:15:12,240
is like no most

407
00:15:16,490 --> 00:15:13,800
um like

408
00:15:18,650 --> 00:15:16,500
glacial models and Earth Global ocean

409
00:15:20,269 --> 00:15:18,660
circulation models don't include brine

410
00:15:22,550 --> 00:15:20,279
Pockets because on Earth those are more

411
00:15:25,430 --> 00:15:22,560
seen in like Lake environments or kind

412
00:15:26,930 --> 00:15:25,440
of like the like hyper saline lakes and

413
00:15:27,949 --> 00:15:26,940

Flash bows and lakes that like Jacob

414
00:15:28,610 --> 00:15:27,959
works on

415
00:15:30,829 --> 00:15:28,620
um

416
00:15:32,210 --> 00:15:30,839
they might Europe as a yeah different

417
00:15:32,990 --> 00:15:32,220
conditions though

418
00:15:35,030 --> 00:15:33,000
um

419
00:15:37,790 --> 00:15:35,040
and so they could exist there so at most

420
00:15:40,310 --> 00:15:37,800
I think I would do a like a case study

421
00:15:41,750 --> 00:15:40,320
on what would happen if Brian Pockets

422
00:15:42,650 --> 00:15:41,760
exist so it's something I'm working on

423
00:15:44,030 --> 00:15:42,660
now

424
00:15:45,650 --> 00:15:44,040
um but it's not something I'd include in

425
00:15:48,110 --> 00:15:45,660
every run because it's just still very

426
00:15:49,310 --> 00:15:48,120
much an unknown yeah I was going to say

427
00:15:51,410 --> 00:15:49,320
that was kind of like a loaded question

428
00:15:55,430 --> 00:15:51,420
but I was curious no it's a good

429
00:15:55,440 --> 00:16:02,420
thank you so much for the time

430
00:16:10,750 --> 00:16:08,949
[Music]