



ABSciCON 2017

MESA, ARIZONA

1
00:00:12,250 --> 00:00:06,150

you

2
00:00:17,769 --> 00:00:14,520

[Music]

3
00:00:19,690 --> 00:00:17,779

all right Thank You Tyler so go easy on

4
00:00:21,580 --> 00:00:19,700

me I just learned about this work about

5
00:00:24,630 --> 00:00:21,590

two days ago so I'm going to hopefully I

6
00:00:28,420 --> 00:00:24,640

do June justice he does very good work

7
00:00:30,700 --> 00:00:28,430

so we're going to be talking about today

8
00:00:35,439 --> 00:00:30,710

and abrupt transition from a snowball

9
00:00:39,189 --> 00:00:35,449

state to a runaway greenhouse state the

10
00:00:42,220 --> 00:00:39,199

point is somewhere in particular Oh

11
00:00:44,770 --> 00:00:42,230

all right and that's me the presenter so

12
00:00:49,200 --> 00:00:44,780

I see worlds are common we see them in

13
00:00:52,209 --> 00:00:49,210

our own solar system Europa Enceladus

14

00:00:54,130 --> 00:00:52,219

Triton also the earth is believed to

15

00:00:55,810 --> 00:00:54,140

have entered into snowball phases and

16

00:00:58,000 --> 00:00:55,820

distant and distant times in its past

17

00:00:59,889 --> 00:00:58,010

and we're going to be talking about how

18

00:01:02,770 --> 00:00:59,899

would you degree she ate these planets

19

00:01:04,749 --> 00:01:02,780

but not by a buildup of co2 is Jacob

20

00:01:07,060 --> 00:01:04,759

nicely described for us earlier but

21

00:01:09,730 --> 00:01:07,070

rather by a solar deglaciation which for

22

00:01:14,380 --> 00:01:09,740

the Sun is reasonable that occur because

23

00:01:16,750 --> 00:01:14,390

we know the Sun brightens over time so

24

00:01:18,490 --> 00:01:16,760

previous studies using complex

25

00:01:21,039 --> 00:01:18,500

three-dimensional climate models have

26
00:01:25,480 --> 00:01:21,049
shown and predicted that you could solar

27
00:01:27,219 --> 00:01:25,490
deglaciation shields 2014's work Sordi

28
00:01:30,249 --> 00:01:27,229
glaciated snowball state into a

29
00:01:32,859 --> 00:01:30,259
habitable world so you do have a

30
00:01:36,609 --> 00:01:32,869
hysteresis as Jay described and you do

31
00:01:39,100 --> 00:01:36,619
need more solar insulation to D Galatia

32
00:01:41,289 --> 00:01:39,110
table all as opposed to entering into it

33
00:01:43,749 --> 00:01:41,299
but the end state once the ice breaks

34
00:01:46,990 --> 00:01:43,759
apart is typically predicted to be a

35
00:01:48,460 --> 00:01:47,000
habitable world however in this study

36
00:01:51,429 --> 00:01:48,470
you'll see that assumptions made

37
00:01:52,810 --> 00:01:51,439
particularly the ice model if we do a

38
00:01:55,120 --> 00:01:52,820

better trick June does a better

39

00:01:57,460 --> 00:01:55,130

treatment of the ice model you actually

40

00:02:00,510 --> 00:01:57,470

see you would transition from a snowball

41

00:02:03,490 --> 00:02:00,520

state into an uninhabited Lea hot world

42

00:02:05,440 --> 00:02:03,500

so June and colleagues have used a

43

00:02:06,639 --> 00:02:05,450

community atmosphere model version 3

44

00:02:09,160 --> 00:02:06,649

from the National Center for Atmospheric

45

00:02:11,440 --> 00:02:09,170

Research it's a three dimensional

46

00:02:12,580 --> 00:02:11,450

climate system model with that the

47

00:02:14,890 --> 00:02:12,590

three-dimensional atmospheric

48

00:02:17,590 --> 00:02:14,900

circulation radio transfer convection

49

00:02:20,890 --> 00:02:17,600

precipitation clouds boundary layer

50

00:02:22,990 --> 00:02:20,900

processes you can put in a nice model

51
00:02:23,720 --> 00:02:23,000
ocean models the varying complexity I

52
00:02:26,000 --> 00:02:23,730
don't

53
00:02:28,339 --> 00:02:26,010
they use aqua planets here so they pitch

54
00:02:31,430 --> 00:02:28,349
the land model they assume an earth-like

55
00:02:34,369 --> 00:02:31,440
atmosphere composition barbed nitrogen

56
00:02:36,589 --> 00:02:34,379
just a little bit of co2 modern co2

57
00:02:39,199 --> 00:02:36,599
extra pre-industrial co2 and then water

58
00:02:41,530 --> 00:02:39,209
vapor which is variable in the model

59
00:02:45,199 --> 00:02:41,540
depending upon your surface temperature

60
00:02:47,420 --> 00:02:45,209
resolution 2.8 by 2.8 degree with 26

61
00:02:49,100 --> 00:02:47,430
Berger's levels and that the big

62
00:02:52,309 --> 00:02:49,110
improvement they've made upon these

63
00:02:55,160 --> 00:02:52,319

previous studies is they've improved the

64

00:02:58,250 --> 00:02:55,170

ice model so they use a ten layer

65

00:03:00,800 --> 00:02:58,260

glacial ice model in order to determine

66

00:03:04,490 --> 00:03:00,810

when the snowball melting still our flux

67

00:03:08,119 --> 00:03:04,500

threshold will occur and this I smell

68

00:03:11,780 --> 00:03:08,129

ice model is laid on top of a 50 meter

69

00:03:14,210 --> 00:03:11,790

slab ocean model I'm assuming with zero

70

00:03:19,280 --> 00:03:14,220

heat transport for simplification

71

00:03:21,380 --> 00:03:19,290

purposes so the first key here is they

72

00:03:23,900 --> 00:03:21,390

use a higher resolution higher vertical

73

00:03:25,819 --> 00:03:23,910

resolution to simulate the ice so in

74

00:03:28,190 --> 00:03:25,829

this figure here from a paper of Doherty

75

00:03:30,650 --> 00:03:28,200

and Abbott's in 2010 they took a single

76
00:03:32,569 --> 00:03:30,660
column version of the cam sea ice model

77
00:03:36,289 --> 00:03:32,579
and they experiment with different

78
00:03:39,319 --> 00:03:36,299
vertical levels so I think for the solid

79
00:03:41,720 --> 00:03:39,329
black line is the default they also try

80
00:03:44,150 --> 00:03:41,730
to and they also try 60 and what you

81
00:03:46,670 --> 00:03:44,160
have here is time in days of the diurnal

82
00:03:49,000 --> 00:03:46,680
cycle of temperature surface air

83
00:03:51,860 --> 00:03:49,010
temperature right above the sea ice and

84
00:03:55,580 --> 00:03:51,870
they find that the default number of

85
00:03:58,069 --> 00:03:55,590
levels at four greatly exaggerate your

86
00:03:59,930 --> 00:03:58,079
diurnal cycle and they call this and

87
00:04:03,050 --> 00:03:59,940
June say for the melt ratcheting effect

88
00:04:04,670 --> 00:04:03,060

that you in these warm perturbations you

89

00:04:06,879 --> 00:04:04,680

actually get some melting of the sea ice

90

00:04:10,039 --> 00:04:06,889

and then you get an incomplete freeze

91

00:04:11,270 --> 00:04:10,049

during the night time and this cabins

92

00:04:13,069 --> 00:04:11,280

over and over again and the net effect

93

00:04:15,259 --> 00:04:13,079

that your melting more of the sea ice

94

00:04:17,330 --> 00:04:15,269

and then your refreezing at night and

95

00:04:19,190 --> 00:04:17,340

it's an artificial effects due to a lack

96

00:04:23,900 --> 00:04:19,200

of vertical resolution in your sea ice

97

00:04:25,730 --> 00:04:23,910

model so here Dorian did 60 vertical

98

00:04:28,460 --> 00:04:25,740

levels in the ice and he finds the

99

00:04:32,020 --> 00:04:28,470

dashed line where these perturbative

100

00:04:34,969 --> 00:04:32,030

diurnal cycles and also seasonal cycles

101

00:04:36,370 --> 00:04:34,979

are much lessened

102

00:04:38,770 --> 00:04:36,380

so June use 10

103

00:04:41,230 --> 00:04:38,780

the levels in a study I assumed that he

104

00:04:43,600 --> 00:04:41,240

did some sensitivity tests and found

105

00:04:47,890 --> 00:04:43,610

that 10 was good enough compared to 60

106

00:04:50,740 --> 00:04:47,900

and then the other difference between

107

00:04:53,590 --> 00:04:50,750

previous studies of the sort was the

108

00:04:59,470 --> 00:04:53,600

type of snow and ice obito's that you

109

00:05:01,330 --> 00:04:59,480

assume so cam like most GCMs have a have

110

00:05:04,470 --> 00:05:01,340

snow and ice albedo separated with

111

00:05:06,550 --> 00:05:04,480

visible and near IR and these are

112

00:05:08,320 --> 00:05:06,560

assuming spectrally integrated

113

00:05:10,030 --> 00:05:08,330

quantities so you have the snow snow

114

00:05:13,180 --> 00:05:10,040

albedo was greater than the ice albedo

115

00:05:15,820 --> 00:05:13,190

and I think that the take-home point

116

00:05:19,870 --> 00:05:15,830

from what Jun did was that so in shields

117

00:05:21,820 --> 00:05:19,880

work in 2014 in the cold start case if

118

00:05:25,480 --> 00:05:21,830

one assumes that you have a planet

119

00:05:27,970 --> 00:05:25,490

covered by sea ice you actually are

120

00:05:30,460 --> 00:05:27,980

drawing out a lower specially integrated

121

00:05:32,980 --> 00:05:30,470

albedo of about 0.5 when in reality

122

00:05:35,440 --> 00:05:32,990

we're thinking about a snowball planet

123

00:05:36,010 --> 00:05:35,450

that's been a snowball for billions of

124

00:05:38,740 --> 00:05:36,020

years

125

00:05:41,200 --> 00:05:38,750

you have kilometers thick ice that's

126
00:05:46,080 --> 00:05:41,210
compacted layers of ice and snow and

127
00:05:49,960 --> 00:05:46,090
actually be much brighter than 0.5 so

128
00:05:52,570 --> 00:05:49,970
for example in cam if you specify sea

129
00:05:56,020 --> 00:05:52,580
ice your spectrally integrated albedo is

130
00:05:57,820 --> 00:05:56,030
0.5 snow is 0.8 but also if you assume a

131
00:05:59,050 --> 00:05:57,830
glacier type which that's what we're

132
00:06:00,850 --> 00:05:59,060
really thinking about with snowball

133
00:06:02,380 --> 00:06:00,860
planets everything that's covered in

134
00:06:04,780 --> 00:06:02,390
like the whole planet is covered by the

135
00:06:07,990 --> 00:06:04,790
Greenland ice sheets you actually should

136
00:06:11,680 --> 00:06:08,000
use a higher snow albedo or snow and ice

137
00:06:13,420 --> 00:06:11,690
albedo closer to 0.8 so it's these two

138
00:06:16,150 --> 00:06:13,430

effects that are driving differences

139

00:06:19,570 --> 00:06:16,160

between past models of solar driven

140

00:06:23,230 --> 00:06:19,580

deglaciation so with these improvements

141

00:06:26,020 --> 00:06:23,240

to the ice treatment Jun found that for

142

00:06:28,120 --> 00:06:26,030

the earth around the Sun starting in a

143

00:06:31,180 --> 00:06:28,130

cold state you would need a high very

144

00:06:32,920 --> 00:06:31,190

high stellar flux to D glaciated to 1800

145

00:06:36,070 --> 00:06:32,930

Watts from eard per meter squared

146

00:06:39,340 --> 00:06:36,080

required to melt an icy planet around G

147

00:06:41,110 --> 00:06:39,350

star and this is about 400 watts per

148

00:06:45,070 --> 00:06:41,120

meter squared higher than that is found

149

00:06:47,800 --> 00:06:45,080

in shields at all 2014 and this plot Jun

150

00:06:49,150 --> 00:06:47,810

shows the zonal mean temperature of the

151

00:06:51,430 --> 00:06:49,160

of a cold star

152

00:06:53,710 --> 00:06:51,440

snowball planet as a function of

153

00:06:55,240 --> 00:06:53,720

latitude for different stellar fluxes

154

00:06:57,670 --> 00:06:55,250

and you see they're all cold cold cold

155

00:07:00,190 --> 00:06:57,680

so you get to 1,800 watts per meter

156

00:07:02,470 --> 00:07:00,200

squared and then you just start getting

157

00:07:05,920 --> 00:07:02,480

a little bit of milk around the equator

158

00:07:08,650 --> 00:07:05,930

and this once you start opening up the

159

00:07:11,260 --> 00:07:08,660

sea ice you get you open up the darker

160

00:07:13,360 --> 00:07:11,270

ocean which is more effective at

161

00:07:15,760 --> 00:07:13,370

absorbing solar radiation and so on and

162

00:07:19,480 --> 00:07:15,770

so forth and you could melt the ice away

163

00:07:21,940 --> 00:07:19,490

and to kind of circle back on some of

164

00:07:26,470 --> 00:07:21,950

the reasons why these are different than

165

00:07:29,250 --> 00:07:26,480

the previous work one is one reason as I

166

00:07:32,140 --> 00:07:29,260

mentioned was the vertical sea ice

167

00:07:34,240 --> 00:07:32,150

resolution the number of layers to is

168

00:07:36,310 --> 00:07:34,250

the using a more appropriate surface

169

00:07:39,130 --> 00:07:36,320

albedo and not just assuming that your

170

00:07:41,200 --> 00:07:39,140

cold start is bare sea ice but rather

171

00:07:45,670 --> 00:07:41,210

have a higher albedo more typical of

172

00:07:48,550 --> 00:07:45,680

glacial ice and then as a general point

173

00:07:52,560 --> 00:07:48,560

it's hard to get out of these snowball

174

00:07:54,940 --> 00:07:52,570

with a snowball Earth's without

175

00:07:57,060 --> 00:07:54,950

resorting to greenhouse gases because

176

00:08:00,460 --> 00:07:57,070

you have very about resorting to co2

177

00:08:02,740 --> 00:08:00,470

because you have a very weak water vapor

178

00:08:04,330 --> 00:08:02,750

greenhouse effect shown here these are

179

00:08:06,720 --> 00:08:04,340

snowball cases you have very little

180

00:08:09,610 --> 00:08:06,730

water vapor compared to the modern earth

181

00:08:14,020 --> 00:08:09,620

so June did a number of sensitivity

182

00:08:17,320 --> 00:08:14,030

tests to ensure confidence and his

183

00:08:19,680 --> 00:08:17,330

results so on the y axis we have the

184

00:08:22,870 --> 00:08:19,690

stellar flux required to meet certain

185

00:08:25,830 --> 00:08:22,880

thresholds the dots are snowball melting

186

00:08:28,870 --> 00:08:25,840

threshold and the lines here are various

187

00:08:34,810 --> 00:08:28,880

runaway and moist greenhouse limits from

188

00:08:36,400 --> 00:08:34,820

3d and 1d models right here so and then

189

00:08:40,150 --> 00:08:36,410

June did a bunch of sensitivity test

190

00:08:43,779 --> 00:08:40,160

different abidos gravities cloud

191

00:08:45,850 --> 00:08:43,789

particle sizes topography eccentricity

192

00:08:50,140 --> 00:08:45,860

and ice region clouds again radius

193

00:08:52,510 --> 00:08:50,150

radius albedo and so on and so forth and

194

00:08:55,150 --> 00:08:52,520

what you generally see here is a except

195

00:08:58,300 --> 00:08:55,160

if the albedo is specified to be

196

00:09:01,030 --> 00:08:58,310

unreasonably low perhaps this is that it

197

00:09:03,460 --> 00:09:01,040

would be albe to 0.4 for the glacial ice

198

00:09:05,170 --> 00:09:03,470

would be a dirty snowball which is a

199

00:09:07,840 --> 00:09:05,180

previous idea of how you might be able

200

00:09:10,780 --> 00:09:07,850

to deglaze sheight a snowball but the

201
00:09:14,020 --> 00:09:10,790
majority of these cases are close to are

202
00:09:17,170 --> 00:09:14,030
even higher than these moist and runaway

203
00:09:19,180 --> 00:09:17,180
greenhouse limits so just to melt the

204
00:09:21,760 --> 00:09:19,190
snowball you need enough stellar flux to

205
00:09:24,250 --> 00:09:21,770
just that would trigger a moist and

206
00:09:26,890 --> 00:09:24,260
runaway greenhouse upon the glaciation

207
00:09:30,790 --> 00:09:26,900
of the planet so June also tried this

208
00:09:31,990 --> 00:09:30,800
again with F stars and K stars I should

209
00:09:33,220 --> 00:09:32,000
mention all these are rapidly rotating

210
00:09:35,800 --> 00:09:33,230
planets

211
00:09:38,110 --> 00:09:35,810
none of these are synchronously or slow

212
00:09:40,510 --> 00:09:38,120
rotating and for the F star planet as

213
00:09:43,900 --> 00:09:40,520

one would expect you need more stellar

214

00:09:47,470 --> 00:09:43,910

flux to negotiate because the seller

215

00:09:49,060 --> 00:09:47,480

spectrum is bluer and thus is there

216

00:09:51,610 --> 00:09:49,070

light is reflected more efficiently by

217

00:09:54,040 --> 00:09:51,620

the snow and ice and the opposite is

218

00:09:57,190 --> 00:09:54,050

true of the case our case so in the case

219

00:09:58,840 --> 00:09:57,200

our case you need less stellar flux the

220

00:10:01,930 --> 00:09:58,850

cellar structure is little redder than

221

00:10:05,380 --> 00:10:01,940

were effectively absorbed by the ice so

222

00:10:06,880 --> 00:10:05,390

this abrupt transition from snowball to

223

00:10:08,410 --> 00:10:06,890

a moisture runaway greenhouse does not

224

00:10:10,930 --> 00:10:08,420

occur in the case our case you can

225

00:10:14,230 --> 00:10:10,940

actually recover stable climates the

226

00:10:20,110 --> 00:10:14,240

melt thresholds are below the runaway

227

00:10:23,530 --> 00:10:20,120

limits so here we have transient plots a

228

00:10:27,400 --> 00:10:23,540

time series plots of is melt simulations

229

00:10:29,370 --> 00:10:27,410

around F G and K stars so surface

230

00:10:33,330 --> 00:10:29,380

temperature over here sea ice coverage

231

00:10:36,220 --> 00:10:33,340

over here so first for the case our case

232

00:10:39,180 --> 00:10:36,230

upon the glaciation it does stabilize

233

00:10:43,360 --> 00:10:39,190

into a temperate climate however for the

234

00:10:45,610 --> 00:10:43,370

F and the G star case all the ice melts

235

00:10:49,900 --> 00:10:45,620

in a short timeframe and then the

236

00:10:53,770 --> 00:10:49,910

climate ends up running away and they

237

00:10:56,350 --> 00:10:53,780

can see that clearly as well from a plot

238

00:10:58,690 --> 00:10:56,360

of outgoing long-wave radiation absorbed

239

00:11:00,510 --> 00:10:58,700

solar radiation this is a theoretical

240

00:11:05,020 --> 00:11:00,520

limiting curve for the alcohol

241

00:11:08,620 --> 00:11:05,030

irradiation so just two D glaciated Oh

242

00:11:11,770 --> 00:11:08,630

ball F min G star planet you need enough

243

00:11:14,170 --> 00:11:11,780

solar absorbed radiation that's beyond

244

00:11:14,780 --> 00:11:14,180

the olr limit for a runaway so these

245

00:11:16,160 --> 00:11:14,790

planets

246

00:11:19,190 --> 00:11:16,170

can never recover they can never

247

00:11:20,840 --> 00:11:19,200

stabilize a pond Eagle 8 after

248

00:11:23,170 --> 00:11:20,850

deglaciation and that's not true for the

249

00:11:25,310 --> 00:11:23,180

case our case for the case our case a

250

00:11:27,830 --> 00:11:25,320

lesser amount of stellar flux have seen

251
00:11:30,500 --> 00:11:27,840
it's a melt the ice and the top plot

252
00:11:32,600 --> 00:11:30,510
shows h2o volume mixing ratio in the

253
00:11:35,360 --> 00:11:32,610
stratosphere and it's just showing that

254
00:11:38,180 --> 00:11:35,370
for the G in the f star case you end up

255
00:11:40,850 --> 00:11:38,190
with a enough water vapor in the upper

256
00:11:42,890 --> 00:11:40,860
atmosphere that you'd end up losing even

257
00:11:47,900 --> 00:11:42,900
if these simulations didn't terminally

258
00:11:49,910 --> 00:11:47,910
go to a 1600 K full terminal runaway

259
00:11:52,280 --> 00:11:49,920
state even if they sit theoretically

260
00:11:53,870 --> 00:11:52,290
stabilized somewhere at a hotter

261
00:11:55,370 --> 00:11:53,880
temperature you'd still lose all your

262
00:11:59,300 --> 00:11:55,380
water to space for the moist greenhouse

263
00:12:01,220 --> 00:11:59,310

processes so to conclude there's an

264

00:12:03,050 --> 00:12:01,230

abrupt transition from a snowball state

265

00:12:05,420 --> 00:12:03,060

to a moisture runaway greenhouse state

266

00:12:07,790 --> 00:12:05,430

it's found in June simulations due to an

267

00:12:10,460 --> 00:12:07,800

improved treatment of sea ice and

268

00:12:13,790 --> 00:12:10,470

glacial ice and so this in this

269

00:12:15,890 --> 00:12:13,800

conclusion conclusion applies to F and G

270

00:12:18,620 --> 00:12:15,900

star systems places like Europa

271

00:12:20,720 --> 00:12:18,630

Enceladus Ganymede planets having low

272

00:12:23,570 --> 00:12:20,730

greenhouse gas concentrations in in

273

00:12:25,880 --> 00:12:23,580

active carbon silicates cycling super

274

00:12:28,940 --> 00:12:25,890

Earths if they're little spheres or in

275

00:12:32,210 --> 00:12:28,950

the stagnant lid regime and then these

276

00:12:34,880 --> 00:12:32,220

conclusions do not apply to m and K star

277

00:12:37,370 --> 00:12:34,890

systems because the redder spectra lower

278

00:12:39,770 --> 00:12:37,380

the effective sea ice and snow abidos

279

00:12:41,570 --> 00:12:39,780

and also carbon doesn't apply to earth

280

00:12:43,820 --> 00:12:41,580

with an active carbon silicon cycling

281

00:12:45,980 --> 00:12:43,830

because we'd get processes that occur as

282

00:12:50,030 --> 00:12:45,990

Jacob described in his talk earlier

283

00:12:52,130 --> 00:12:50,040

today so thank you and I guess I'll take

284

00:12:53,960 --> 00:12:52,140

questions but any answers are expressly

285

00:12:55,330 --> 00:12:53,970

my own and don't reflect those of the

286

00:12:56,860 --> 00:12:55,340

authors necessarily

287

00:13:05,700 --> 00:12:56,870

[Music]

288

00:13:13,020 --> 00:13:05,710

[Applause]

289

00:13:14,970 --> 00:13:13,030

any questions yes Charlie I'm not sure

290

00:13:16,560 --> 00:13:14,980

you do the answers but when he says it

291

00:13:19,620 --> 00:13:16,570

doesn't apply to the earth because of an

292

00:13:23,040 --> 00:13:19,630

active carbonate silicon cycle hmm how

293

00:13:25,410 --> 00:13:23,050

active I yeah I can't answer that but

294

00:13:27,180 --> 00:13:25,420

you know enough to Jacob describe the

295

00:13:30,720 --> 00:13:27,190

process with co2 that you'd have these

296

00:13:44,830 --> 00:13:30,730

blips of warming and you wouldn't enter

297

00:13:48,160 --> 00:13:47,170

right right right yeah the idea is the

298

00:13:50,830 --> 00:13:48,170

co2 would accumulate

299

00:13:52,269 --> 00:13:50,840

ud glaciated NC you would be drawn back

300

00:13:53,890 --> 00:13:52,279

down and you'd break out of the

301

00:13:58,720 --> 00:13:53,900

hysteresis oh now you have a warm planet

302

00:14:00,610 --> 00:13:58,730

so no he did not that's the assumption

303

00:14:07,540 --> 00:14:00,620

he just says I think 300 ppm of co2

304

00:14:09,300 --> 00:14:07,550

that's it alright well let's give Erik

305

00:14:11,190 --> 00:14:09,310

another round of applause especially for