
Titan-Earth comparison frames understanding
Radius 2575 km
Gravity 1.35 m/s²

1
00:00:11,509 --> 00:00:10,230
so um yeah my name is eric larson i'm

2
00:00:12,629 --> 00:00:11,519
going to tell you about some

3
00:00:15,430 --> 00:00:12,639
three-dimensional modeling i've been

4
00:00:16,950 --> 00:00:15,440
doing of titan's organic haze

5
00:00:18,950 --> 00:00:16,960
and i'm going to

6
00:00:23,189 --> 00:00:18,960
give you some implications for the early

7
00:00:27,429 --> 00:00:25,429
faint young sun problem there

8
00:00:29,109 --> 00:00:27,439
this image in the background is a image

9
00:00:31,269 --> 00:00:29,119
of titan taken from cassini in true

10
00:00:32,549 --> 00:00:31,279
color and you'll notice that it's an

11
00:00:34,870 --> 00:00:32,559
orange blob

12
00:00:38,630 --> 00:00:34,880
titan's organic haze completely obscures

13
00:00:41,430 --> 00:00:38,640

the surface at visible wavelengths

14
00:00:42,549 --> 00:00:41,440
and the color of this is important

15
00:00:44,549 --> 00:00:42,559
because the fact that it's kind of an

16
00:00:46,310 --> 00:00:44,559
orangish yellow tells you that

17
00:00:48,470 --> 00:00:46,320
it's very good at a but the haze is very

18
00:00:51,750 --> 00:00:48,480
good at absorbing um

19
00:00:54,229 --> 00:00:51,760
uv and blue wavelengths

20
00:00:56,389 --> 00:00:54,239
all right so that'll be important later

21
00:00:57,830 --> 00:00:56,399
so uh let's frame our understanding

22
00:00:59,029 --> 00:00:57,840
about titan for those of you who aren't

23
00:01:01,510 --> 00:00:59,039
familiar with it with a little

24
00:01:03,750 --> 00:01:01,520
comparison for with earth

25
00:01:04,950 --> 00:01:03,760
these sizes are roughly the scale there

26
00:01:07,030 --> 00:01:04,960
might be some

27
00:01:09,190 --> 00:01:07,040
compression in this image

28
00:01:11,270 --> 00:01:09,200
but yeah titan's uh

29
00:01:13,190 --> 00:01:11,280
about 2500 kilometers

30
00:01:15,429 --> 00:01:13,200
in radius so

31
00:01:17,590 --> 00:01:15,439
a little less than half of the earth uh

32
00:01:19,910 --> 00:01:17,600
it's obviously quite a bit less massive

33
00:01:22,070 --> 00:01:19,920
so you have a very low gravity

34
00:01:23,590 --> 00:01:22,080
um with the low gravity and the thick

35
00:01:25,670 --> 00:01:23,600
atmosphere you get a very extended

36
00:01:27,190 --> 00:01:25,680
atmosphere so when i show you some plots

37
00:01:28,469 --> 00:01:27,200
where i talk about the atmosphere and

38
00:01:30,630 --> 00:01:28,479

the aerosols being hundreds of

39
00:01:33,270 --> 00:01:30,640
kilometers over the surface

40
00:01:35,030 --> 00:01:33,280
that's that's normal for titan on earth

41
00:01:37,030 --> 00:01:35,040
that's where like the you know

42
00:01:38,230 --> 00:01:37,040
international space station flies things

43
00:01:40,069 --> 00:01:38,240
like that

44
00:01:42,469 --> 00:01:40,079
um i'm not going to tell you titan's

45
00:01:43,990 --> 00:01:42,479
habitable i don't think it is but i

46
00:01:46,310 --> 00:01:44,000
think there are a lot of processes going

47
00:01:47,749 --> 00:01:46,320
on on titan um

48
00:01:48,789 --> 00:01:47,759
from which we can gain understanding

49
00:01:49,910 --> 00:01:48,799
about what the early earth might have

50
00:01:53,109 --> 00:01:49,920
been like

51
00:01:54,630 --> 00:01:53,119
uh and i'm going to go into those now

52
00:01:55,910 --> 00:01:54,640
so here's a cartoon telling you a little

53
00:01:57,749 --> 00:01:55,920
bit about the

54
00:01:58,950 --> 00:01:57,759
aerosols on titan how they're formed and

55
00:02:01,590 --> 00:01:58,960
what's going on

56
00:02:02,870 --> 00:02:01,600
we have pressure on the y-axis here and

57
00:02:19,750 --> 00:02:02,880
a

58
00:02:23,270 --> 00:02:19,760
so

59
00:02:24,949 --> 00:02:23,280
this organic haze is formed through

60
00:02:26,150 --> 00:02:24,959
photodissociation of methane and

61
00:02:28,390 --> 00:02:26,160
nitrogen

62
00:02:30,309 --> 00:02:28,400
in the upper atmosphere of titan

63
00:02:31,750 --> 00:02:30,319

this photodissociation and abundant

64
00:02:35,670 --> 00:02:31,760
photochemistry

65
00:02:36,869 --> 00:02:35,680
leads to these large organic molecules

66
00:02:38,869 --> 00:02:36,879
and at some point these organic

67
00:02:41,030 --> 00:02:38,879
molecules grow so large chemically that

68
00:02:42,710 --> 00:02:41,040
they start interacting physically so

69
00:02:45,190 --> 00:02:42,720
they start colliding with each other and

70
00:02:47,430 --> 00:02:45,200
sticking and coagulating

71
00:02:49,030 --> 00:02:47,440
at first they grow in spheres

72
00:02:51,110 --> 00:02:49,040
these spheres are charged because this

73
00:02:52,470 --> 00:02:51,120
photochemistry leads

74
00:02:54,229 --> 00:02:52,480
has an abundant

75
00:02:55,910 --> 00:02:54,239
excess of electrons

76
00:02:57,990 --> 00:02:55,920
so you get these little charged spheres

77
00:02:59,430 --> 00:02:58,000
coming down and as they start sticking

78
00:03:01,030 --> 00:02:59,440
and colliding

79
00:03:03,589 --> 00:03:01,040
they start growing

80
00:03:04,710 --> 00:03:03,599
in a fractal nature what i mean by that

81
00:03:06,949 --> 00:03:04,720
is uh

82
00:03:08,630 --> 00:03:06,959
not exactly like fern leaves but kind of

83
00:03:10,550 --> 00:03:08,640
like snowflakes they're they're

84
00:03:12,790 --> 00:03:10,560
aggregate clumps

85
00:03:15,110 --> 00:03:12,800
um these things slowly settle and

86
00:03:16,470 --> 00:03:15,120
coagulate and eventually land on the

87
00:03:18,949 --> 00:03:16,480
surface so they contribute to things

88
00:03:20,869 --> 00:03:18,959

like dunes

89
00:03:22,790 --> 00:03:20,879
titan's really cool one of the neat

90
00:03:24,470 --> 00:03:22,800
things about titan are all these active

91
00:03:26,309 --> 00:03:24,480
processes going on that really make it

92
00:03:29,110 --> 00:03:26,319
one of the most earth-like bodies in the

93
00:03:30,070 --> 00:03:29,120
solar system so not only do we have this

94
00:03:35,190 --> 00:03:30,080
this

95
00:03:36,869 --> 00:03:35,200
but it acts as seed nuclei for

96
00:03:37,990 --> 00:03:36,879
condensation of methane and ethane

97
00:03:40,309 --> 00:03:38,000
clouds

98
00:03:42,070 --> 00:03:40,319
that eventually precipitate out and make

99
00:03:45,030 --> 00:03:42,080
river valleys and seas on titan's

100
00:03:49,430 --> 00:03:47,589
the size that these aerosols

101
00:03:51,190 --> 00:03:49,440
coagulate into

102
00:03:52,949 --> 00:03:51,200
is really determined by the amount of

103
00:03:55,190 --> 00:03:52,959
charge

104
00:03:56,789 --> 00:03:55,200
that's placed on these molecules

105
00:03:59,110 --> 00:03:56,799
and

106
00:04:00,550 --> 00:03:59,120
what i'm going to tell you about is some

107
00:04:02,789 --> 00:04:00,560
modeling efforts i've done using a

108
00:04:04,949 --> 00:04:02,799
three-dimensional gcm so a global

109
00:04:06,789 --> 00:04:04,959
circulation model which calculates all

110
00:04:09,509 --> 00:04:06,799
the temperatures and winds and pressure

111
00:04:11,830 --> 00:04:09,519
profiles everywhere on the planet that's

112
00:04:13,030 --> 00:04:11,840
coupled with an aerosol microphysical

113
00:04:15,270 --> 00:04:13,040

model

114
00:04:17,349 --> 00:04:15,280
that tries to

115
00:04:21,349 --> 00:04:17,359
back out some of these numbers by

116
00:04:24,790 --> 00:04:22,870
if you guys have any questions about any

117
00:04:26,870 --> 00:04:24,800
of this just let me know feel free to

118
00:04:27,670 --> 00:04:26,880
interrupt

119
00:04:28,790 --> 00:04:27,680
so

120
00:04:31,670 --> 00:04:28,800
i'm just going to go through a few

121
00:04:33,350 --> 00:04:31,680
examples of spacecraft data that we use

122
00:04:34,550 --> 00:04:33,360
uh to

123
00:04:36,230 --> 00:04:34,560
try to constrain some of these

124
00:04:38,710 --> 00:04:36,240
parameters so the first one we'll talk

125
00:04:40,950 --> 00:04:38,720
about is the um is the phase function so

126
00:04:42,230 --> 00:04:40,960
the phase function just tells you that

127
00:04:44,550 --> 00:04:42,240
when

128
00:04:46,950 --> 00:04:44,560
a photon interacts with a particle and

129
00:04:48,790 --> 00:04:46,960
it's scattered the angle at which it's

130
00:04:51,030 --> 00:04:48,800
scattered

131
00:04:53,909 --> 00:04:51,040
can tell you something about the size of

132
00:04:54,870 --> 00:04:53,919
the particle the size of the aerosol

133
00:04:59,430 --> 00:04:54,880
so

134
00:05:01,030 --> 00:04:59,440
here's the uh the percentage of photons

135
00:05:03,110 --> 00:05:01,040
that are scattered in each direction

136
00:05:04,710 --> 00:05:03,120
here's the scattering angle so zero

137
00:05:06,629 --> 00:05:04,720
would be forward scattering that's a

138
00:05:09,510 --> 00:05:06,639

photon interacting with that aerosol

139
00:05:10,870 --> 00:05:09,520
particle and keep going forward 180

140
00:05:12,469 --> 00:05:10,880
degrees down here is just completely

141
00:05:14,550 --> 00:05:12,479
back scattered

142
00:05:16,870 --> 00:05:14,560
the solid lines in here

143
00:05:17,590 --> 00:05:16,880
are

144
00:05:19,990 --> 00:05:17,600
our

145
00:05:21,909 --> 00:05:20,000
modeling results the dashed lines are

146
00:05:23,749 --> 00:05:21,919
observations from the huygens probe that

147
00:05:25,029 --> 00:05:23,759
lined up cassini

148
00:05:26,710 --> 00:05:25,039
and

149
00:05:28,310 --> 00:05:26,720
what i've got here is i have a different

150
00:05:30,710 --> 00:05:28,320
charge ratio so this would be five

151
00:05:32,230 --> 00:05:30,720
electrons per micron radius on these

152
00:05:35,189 --> 00:05:32,240
aerosol particles

153
00:05:36,710 --> 00:05:35,199
here's seven and a half 10 15

154
00:05:38,469 --> 00:05:36,720
and you can see that some of these fit

155
00:05:40,469 --> 00:05:38,479
better than others and it's really

156
00:05:42,629 --> 00:05:40,479
somewhere between ten and seven and a

157
00:05:44,070 --> 00:05:42,639
half electrons per micron that gives us

158
00:05:45,350 --> 00:05:44,080
the best

159
00:05:47,590 --> 00:05:45,360
fit to these

160
00:05:50,629 --> 00:05:47,600
phase functions so we can use plots like

161
00:05:52,870 --> 00:05:50,639
this to try and oh it's a lot louder to

162
00:05:55,029 --> 00:05:52,880
try and um

163
00:05:57,189 --> 00:05:55,039

constrain some of these values

164
00:05:59,110 --> 00:05:57,199
and like i mentioned before these charge

165
00:06:00,790 --> 00:05:59,120
ratios really affect the size that the

166
00:06:03,029 --> 00:06:00,800
aerosols grow to and this makes a

167
00:06:04,950 --> 00:06:03,039
difference by about a factor of three or

168
00:06:08,390 --> 00:06:04,960
four in size

169
00:06:11,189 --> 00:06:08,400
um the next one we can use is we can use

170
00:06:12,150 --> 00:06:11,199
the extinction so this is how much

171
00:06:13,350 --> 00:06:12,160
or

172
00:06:15,189 --> 00:06:13,360
how much of the

173
00:06:16,629 --> 00:06:15,199
of the light is scattered or absorbed at

174
00:06:18,950 --> 00:06:16,639
every layer in the atmosphere these are

175
00:06:21,270 --> 00:06:18,960
vertical profiles at the huygens landing

176
00:06:23,670 --> 00:06:21,280
site the black dash line here is the

177
00:06:26,309 --> 00:06:23,680
huygens data this is all different

178
00:06:28,150 --> 00:06:26,319
casino cassini data sets from the

179
00:06:30,550 --> 00:06:28,160
equator

180
00:06:31,990 --> 00:06:30,560
they're at slightly different times

181
00:06:34,469 --> 00:06:32,000
but what i want to show you is that

182
00:06:36,150 --> 00:06:34,479
there's a large diversity in the upper

183
00:06:37,430 --> 00:06:36,160
atmosphere

184
00:06:39,590 --> 00:06:37,440
probably more so than the lower

185
00:06:41,029 --> 00:06:39,600
atmosphere in time anyway we can use

186
00:06:43,350 --> 00:06:41,039
these vertical profiles to help

187
00:06:45,270 --> 00:06:43,360
constrain how much aerosol we should put

188
00:06:46,390 --> 00:06:45,280

in so the more aerosols we dump in the

189
00:06:48,629 --> 00:06:46,400
more lights can be scattered and

190
00:06:50,150 --> 00:06:48,639
absorbed so we can use this to constrain

191
00:06:52,309 --> 00:06:50,160
our production rate

192
00:06:54,390 --> 00:06:52,319
and finally we can use the wavelength

193
00:06:56,550 --> 00:06:54,400
dependence of the optical depth so this

194
00:06:58,469 --> 00:06:56,560
slope here

195
00:07:01,270 --> 00:06:58,479
tells you how much of the light is

196
00:07:03,510 --> 00:07:01,280
absorbed or scattered as a function of

197
00:07:05,670 --> 00:07:03,520
wavelength and the slope of this is

198
00:07:07,830 --> 00:07:05,680
highly sensitive to the shape of that

199
00:07:10,150 --> 00:07:07,840
fractal dimension i told you about these

200
00:07:11,990 --> 00:07:10,160
aerosols these aggregate

201
00:07:13,589 --> 00:07:12,000
clumps right

202
00:07:15,189 --> 00:07:13,599
and if they're very spherical if they're

203
00:07:16,550 --> 00:07:15,199
tightly compact they're going to have a

204
00:07:18,150 --> 00:07:16,560
different slope than if they're very

205
00:07:22,309 --> 00:07:18,160
loose and stringy

206
00:07:24,309 --> 00:07:22,319
and it turns out that the slope of this

207
00:07:26,070 --> 00:07:24,319
changes as you descend farther into the

208
00:07:28,070 --> 00:07:26,080
atmosphere which indicates that the

209
00:07:29,189 --> 00:07:28,080
shape of the aerosols change

210
00:07:31,350 --> 00:07:29,199
and

211
00:07:33,430 --> 00:07:31,360
we find that a fractal dimension of two

212
00:07:36,870 --> 00:07:33,440
which is about like a snowflake

213
00:07:39,110 --> 00:07:36,880

um is what we is is the best fit for

214
00:07:41,110 --> 00:07:39,120
um high in titan's atmosphere above 80

215
00:07:44,469 --> 00:07:41,120
kilometers but as we descend toward

216
00:07:46,230 --> 00:07:44,479
towards the surface we really need to

217
00:07:48,469 --> 00:07:46,240
make the particles more spherical more

218
00:07:50,150 --> 00:07:48,479
compact

219
00:07:52,309 --> 00:07:50,160
all right so we can use these spacecraft

220
00:07:53,909 --> 00:07:52,319
observations to help constrain these

221
00:07:55,830 --> 00:07:53,919
aerosol parameters

222
00:07:57,270 --> 00:07:55,840
but why does that matter to astrobiology

223
00:08:01,029 --> 00:07:57,280
why should you care and what does that

224
00:08:07,189 --> 00:08:05,830
well not only are oh okay well not only

225
00:08:09,510 --> 00:08:07,199
can we constrain these aerosols but

226
00:08:11,749 --> 00:08:09,520
these aerosols are really important for

227
00:08:13,670 --> 00:08:11,759
all kinds of atmospheric properties

228
00:08:15,670 --> 00:08:13,680
especially temperature so these aerosols

229
00:08:17,029 --> 00:08:15,680
they absorb and scatter light

230
00:08:18,629 --> 00:08:17,039
which is going to change the temperature

231
00:08:21,830 --> 00:08:18,639
profiles in the atmosphere which is also

232
00:08:23,749 --> 00:08:21,840
going to drive the circulation

233
00:08:25,510 --> 00:08:23,759
and i'll get into that in a second

234
00:08:27,589 --> 00:08:25,520
but just to go back to this figure

235
00:08:28,950 --> 00:08:27,599
really quick now that we've we've used

236
00:08:30,150 --> 00:08:28,960
these spacecraft observation to

237
00:08:31,670 --> 00:08:30,160
constrain particles we can start

238
00:08:32,550 --> 00:08:31,680

throwing numbers into these different

239
00:08:34,870 --> 00:08:32,560
things

240
00:08:36,709 --> 00:08:34,880
so for instance these spherical

241
00:08:38,230 --> 00:08:36,719
um aerosols

242
00:08:39,509 --> 00:08:38,240
uh we call them monomers if there's

243
00:08:42,550 --> 00:08:39,519
still a sphere at the top of the

244
00:08:43,909 --> 00:08:42,560
atmosphere we get about 50 nanometers

245
00:08:46,070 --> 00:08:43,919
that they grow

246
00:08:47,990 --> 00:08:46,080
so these aerosols grow spheres until

247
00:08:48,949 --> 00:08:48,000
about 50 nanometers after that they

248
00:08:51,350 --> 00:08:48,959
start

249
00:08:52,710 --> 00:08:51,360
sticking together into these

250
00:08:54,550 --> 00:08:52,720
fractals

251
00:08:56,470 --> 00:08:54,560
we find that a production rate

252
00:08:58,310 --> 00:08:56,480
is kind of a meaningless number 10 to

253
00:09:00,230 --> 00:08:58,320
the minus 14 grams per centimeter

254
00:09:03,269 --> 00:09:00,240
squared per second

255
00:09:06,870 --> 00:09:04,710
this charge per

256
00:09:08,790 --> 00:09:06,880
on the particles of seven and a half and

257
00:09:11,910 --> 00:09:08,800
this fractal dimension of two like i

258
00:09:13,430 --> 00:09:11,920
mentioned like a snowflake

259
00:09:14,870 --> 00:09:13,440
so we can start putting numbers to these

260
00:09:16,310 --> 00:09:14,880
so we can we can understand them a

261
00:09:18,070 --> 00:09:16,320
little a little better and get more

262
00:09:19,509 --> 00:09:18,080
accurate results

263
00:09:20,630 --> 00:09:19,519

so this is important because these

264
00:09:23,030 --> 00:09:20,640
aerosols

265
00:09:25,350 --> 00:09:23,040
act as an anti-greenhouse

266
00:09:27,110 --> 00:09:25,360
on titan so you're all probably familiar

267
00:09:29,509 --> 00:09:27,120
with the greenhouse effect

268
00:09:31,509 --> 00:09:29,519
i've got a schematic of it over here the

269
00:09:34,150 --> 00:09:31,519
greenhouse effect we basically have this

270
00:09:35,430 --> 00:09:34,160
layer of atmosphere or in a greenhouse a

271
00:09:37,509 --> 00:09:35,440
layer of glass

272
00:09:39,590 --> 00:09:37,519
that lets visible light through that

273
00:09:41,430 --> 00:09:39,600
light's absorbed

274
00:09:42,389 --> 00:09:41,440
inside inside the atmosphere at the

275
00:09:44,310 --> 00:09:42,399
surface

276
00:09:45,750 --> 00:09:44,320
and then it's that energy is re-emitted

277
00:09:48,230 --> 00:09:45,760
as infrared wavelengths which is

278
00:09:50,550 --> 00:09:48,240
absorbed by your greenhouse gases or by

279
00:09:53,829 --> 00:09:50,560
the glass over a greenhouse and then

280
00:09:55,750 --> 00:09:53,839
it's re-radiated in both directions

281
00:09:57,269 --> 00:09:55,760
so you get more energy coming back and

282
00:09:59,430 --> 00:09:57,279
heats up your surface

283
00:10:01,990 --> 00:09:59,440
the anti-greenhouse from these aerosols

284
00:10:03,350 --> 00:10:02,000
is the exact opposite case

285
00:10:06,070 --> 00:10:03,360
here we have

286
00:10:08,389 --> 00:10:06,080
aerosols which absorb in the visible

287
00:10:10,710 --> 00:10:08,399
light but they're transparent

288
00:10:13,269 --> 00:10:10,720

in the infrared so this tends to cool

289
00:10:14,790 --> 00:10:13,279
the planet's surface

290
00:10:17,509 --> 00:10:14,800
and on titan it's estimated that the

291
00:10:20,949 --> 00:10:17,519
aerosols cool by about nine kelvin

292
00:10:23,269 --> 00:10:20,959
well if the early earth had abundant

293
00:10:25,269 --> 00:10:23,279
organic aerosols similar to titan

294
00:10:26,710 --> 00:10:25,279
the surface of the early earth should

295
00:10:28,710 --> 00:10:26,720
have been quite a bit colder well

296
00:10:29,990 --> 00:10:28,720
there's a lot of geological evidence

297
00:10:30,790 --> 00:10:30,000
that suggests it should have been really

298
00:10:33,030 --> 00:10:30,800
hot

299
00:10:34,630 --> 00:10:33,040
so this contributes to the faint young

300
00:10:36,310 --> 00:10:34,640
sun problem

301
00:10:38,550 --> 00:10:36,320
i'm not trying to i'm not trying to make

302
00:10:40,389 --> 00:10:38,560
a claim of whether or not there was

303
00:10:42,870 --> 00:10:40,399
there were abundant organic aerosols on

304
00:10:44,710 --> 00:10:42,880
the early earth i don't know but people

305
00:10:46,710 --> 00:10:44,720
have said that and if there were this

306
00:10:47,590 --> 00:10:46,720
makes it more complicated

307
00:10:48,870 --> 00:10:47,600
and

308
00:10:51,190 --> 00:10:48,880
i'm going to give you some more things

309
00:10:52,630 --> 00:10:51,200
to think about

310
00:10:54,630 --> 00:10:52,640
so let's just take a look at the effects

311
00:10:56,150 --> 00:10:54,640
of this anti-greenhouse

312
00:10:58,069 --> 00:10:56,160
you can look at this but i can i can

313
00:11:00,389 --> 00:10:58,079

actually have modeling results that

314
00:11:01,829 --> 00:11:00,399
might show you that really it's it's

315
00:11:04,069 --> 00:11:01,839
there it works

316
00:11:06,069 --> 00:11:04,079
so here's the temperature profile

317
00:11:08,710 --> 00:11:06,079
from titan from the modeling work the

318
00:11:11,350 --> 00:11:08,720
dashed lines are observations

319
00:11:13,509 --> 00:11:11,360
black here is at 10 degrees south so

320
00:11:14,550 --> 00:11:13,519
near the equator

321
00:11:17,990 --> 00:11:14,560
red

322
00:11:22,150 --> 00:11:18,000
is at 80 degrees north near the pole

323
00:11:23,670 --> 00:11:22,160
and the solid lines are from my model

324
00:11:25,590 --> 00:11:23,680
and

325
00:11:28,069 --> 00:11:25,600
they're a bit sloppy but

326
00:11:29,670 --> 00:11:28,079
don't worry about that too much

327
00:11:32,069 --> 00:11:29,680
up at the top here i have the aerosol

328
00:11:33,430 --> 00:11:32,079
production

329
00:11:34,949 --> 00:11:33,440
this first number is the one just to

330
00:11:36,870 --> 00:11:34,959
look at this is a half and i'm going to

331
00:11:38,790 --> 00:11:36,880
go through an order of magnitude change

332
00:11:40,790 --> 00:11:38,800
in aerosol production now what you're

333
00:11:42,470 --> 00:11:40,800
going to see is that a strengthening of

334
00:11:44,150 --> 00:11:42,480
this anti-greenhouse

335
00:11:46,069 --> 00:11:44,160
so you're going to see heating in the

336
00:11:48,710 --> 00:11:46,079
upper atmosphere where we're absorbing

337
00:11:50,230 --> 00:11:48,720
that solar radiation that visible light

338
00:11:52,310 --> 00:11:50,240

and you're going to see cooling at the

339
00:11:54,470 --> 00:11:52,320
surface

340
00:11:56,949 --> 00:11:54,480
due to that anti-greenhouse effect so as

341
00:11:59,670 --> 00:11:56,959
we go through a half to one

342
00:12:03,430 --> 00:11:59,680
to three to five you can see that it's

343
00:12:04,630 --> 00:12:03,440
much warmer here especially if i go fast

344
00:12:08,550 --> 00:12:04,640
and you can see that it's quite it gets

345
00:12:11,829 --> 00:12:09,430
all right

346
00:12:14,629 --> 00:12:11,839
so the surface temperature

347
00:12:16,230 --> 00:12:14,639
is greatly affected by these um by these

348
00:12:17,990 --> 00:12:16,240
aerosols and it makes sense if you

349
00:12:19,269 --> 00:12:18,000
change the production rate the number of

350
00:12:20,550 --> 00:12:19,279
aerosols you're going to

351
00:12:22,150 --> 00:12:20,560
change the the effect of the

352
00:12:23,670 --> 00:12:22,160
anti-greenhouse but what about all those

353
00:12:24,790 --> 00:12:23,680
other

354
00:12:27,110 --> 00:12:24,800
properties that i mentioned at the

355
00:12:29,590 --> 00:12:27,120
beginning

356
00:12:30,949 --> 00:12:29,600
well we can look at the production rate

357
00:12:33,670 --> 00:12:30,959
and

358
00:12:36,150 --> 00:12:33,680
for this specific case of runs for titan

359
00:12:38,949 --> 00:12:36,160
we're getting a change in the

360
00:12:41,350 --> 00:12:38,959
in the surface temperature of about

361
00:12:44,389 --> 00:12:41,360
two and a half kelvin

362
00:12:46,790 --> 00:12:44,399
and one interesting thing is that we see

363
00:12:49,269 --> 00:12:46,800

for a low aerosol case

364
00:12:51,750 --> 00:12:49,279
a um

365
00:12:53,750 --> 00:12:51,760
a half kelvin

366
00:12:55,269 --> 00:12:53,760
equator to pole temperature gradient

367
00:12:57,190 --> 00:12:55,279
however when we get to the high aerosol

368
00:12:59,269 --> 00:12:57,200
case that equator pole temperature

369
00:13:01,590 --> 00:12:59,279
gradient completely goes away

370
00:13:03,190 --> 00:13:01,600
this is because the aerosols are

371
00:13:04,710 --> 00:13:03,200
interacting

372
00:13:06,629 --> 00:13:04,720
with the dynamics

373
00:13:08,150 --> 00:13:06,639
and the aerosols tend to accumulate at

374
00:13:09,670 --> 00:13:08,160
the poles so they're heating the pools

375
00:13:11,670 --> 00:13:09,680
which drives the circulation so they're

376
00:13:13,750 --> 00:13:11,680
all these feedback mechanisms that make

377
00:13:17,190 --> 00:13:13,760
this a much more complicated situation

378
00:13:18,550 --> 00:13:17,200
than a 1d model might suggest

379
00:13:20,230 --> 00:13:18,560
we can also look at that charge i

380
00:13:21,990 --> 00:13:20,240
mentioned at the beginning you can see

381
00:13:23,829 --> 00:13:22,000
this has one of the greatest effects

382
00:13:25,990 --> 00:13:23,839
more than three kelvin

383
00:13:28,150 --> 00:13:26,000
um surface chain or a change in uh

384
00:13:29,910 --> 00:13:28,160
surface temperature

385
00:13:31,030 --> 00:13:29,920
we can also look at things like the a

386
00:13:32,870 --> 00:13:31,040
change in the

387
00:13:35,430 --> 00:13:32,880
particle input size at the top of the

388
00:13:37,269 --> 00:13:35,440

model thank you

389
00:13:39,509 --> 00:13:37,279
so if we

390
00:13:41,269 --> 00:13:39,519
put two nanometer particles at the top

391
00:13:43,430 --> 00:13:41,279
of the model which is roughly molecular

392
00:13:45,030 --> 00:13:43,440
size molecules

393
00:13:47,030 --> 00:13:45,040
versus

394
00:13:48,150 --> 00:13:47,040
42 nanometers which are those monomers

395
00:13:51,190 --> 00:13:48,160
and the top of the model i should

396
00:13:52,550 --> 00:13:51,200
mention here is about 580 kelvin

397
00:13:54,310 --> 00:13:52,560
or we can put in something that's

398
00:13:56,150 --> 00:13:54,320
two-thirds of a micron

399
00:13:57,750 --> 00:13:56,160
so the effect of this is saying how

400
00:14:00,230 --> 00:13:57,760
large are these particles by the time

401
00:14:02,389 --> 00:14:00,240
they get to about 500 kilometers and if

402
00:14:03,269 --> 00:14:02,399
they're really large

403
00:14:04,470 --> 00:14:03,279
um

404
00:14:06,550 --> 00:14:04,480
that'll change

405
00:14:07,990 --> 00:14:06,560
you know the way the particles interact

406
00:14:09,590 --> 00:14:08,000
the amount of light that's absorbed and

407
00:14:11,670 --> 00:14:09,600
scattered at different

408
00:14:14,310 --> 00:14:11,680
um altitudes however this has very

409
00:14:16,470 --> 00:14:14,320
little effect on the uh on the overall

410
00:14:18,150 --> 00:14:16,480
surface temperature

411
00:14:20,230 --> 00:14:18,160
where we put the particles in however

412
00:14:21,829 --> 00:14:20,240
where we input that mass of aerosols so

413
00:14:24,389 --> 00:14:21,839

where the methane is destroyed and where

414
00:14:27,030 --> 00:14:24,399
it creates aerosols uh does greatly

415
00:14:29,509 --> 00:14:27,040
affect we get almost a kelvin change if

416
00:14:34,470 --> 00:14:29,519
we change the the input of the aerosol

417
00:14:37,509 --> 00:14:34,480
mass between 250 and 580 k kilometers

418
00:14:39,269 --> 00:14:37,519
all right so to sum it up

419
00:14:41,509 --> 00:14:39,279
spacecraft deals and models can

420
00:14:43,350 --> 00:14:41,519
constrain titan's aerosol microphysical

421
00:14:45,910 --> 00:14:43,360
properties however for earth these

422
00:14:47,030 --> 00:14:45,920
properties are really unconstrained

423
00:14:49,189 --> 00:14:47,040
organic aerosols create an

424
00:14:50,710 --> 00:14:49,199
anti-greenhouse effect that cools a

425
00:14:53,110 --> 00:14:50,720
planet's surface and the strength of

426
00:14:54,870 --> 00:14:53,120
this effect is affected by our choice of

427
00:14:56,710 --> 00:14:54,880
aerosol parameters

428
00:14:58,389 --> 00:14:56,720
and a sensitivity shows that these

429
00:14:59,509 --> 00:14:58,399
aerosol at the aerosol charge and

430
00:15:01,030 --> 00:14:59,519
production rate have the greatest

431
00:15:01,829 --> 00:15:01,040
surface temperature response maybe the

432
00:15:04,389 --> 00:15:01,839
most

433
00:15:05,430 --> 00:15:04,399
uh surprising one is the fact that this

434
00:15:14,230 --> 00:15:05,440
this

435
00:15:18,310 --> 00:15:14,240
account if we think about the

436
00:15:21,750 --> 00:15:19,590
and the

437
00:15:32,150 --> 00:15:21,760
organic aerosols on the early earth all

438
00:15:36,310 --> 00:15:34,470

so thanks eric maybe one quick question

439
00:15:37,910 --> 00:15:36,320
because we are slightly behind schedule

440
00:15:39,189 --> 00:15:37,920
okay uh can you guys hear me we got one

441
00:15:42,150 --> 00:15:39,199
from online

442
00:15:44,310 --> 00:15:42,160
uh this is from uh sanjoy song uh how

443
00:15:46,790 --> 00:15:44,320
does the aerosol cooling compare to

444
00:15:48,710 --> 00:15:46,800
methane greenhouse warming

445
00:15:51,030 --> 00:15:48,720
slash nitrogen pressure

446
00:15:53,509 --> 00:15:51,040
broadening on early earth

447
00:15:55,430 --> 00:15:53,519
oh on early earth well

448
00:15:57,829 --> 00:15:55,440
i'm not sure about the early earth i can

449
00:16:00,550 --> 00:15:57,839
tell you for the um

450
00:16:02,949 --> 00:16:00,560
for titan titan has about a 21 kelvin

451
00:16:04,550 --> 00:16:02,959
greenhouse and about a nine kelvin

452
00:16:08,710 --> 00:16:04,560
anti-greenhouse

453
00:16:09,749 --> 00:16:08,720
so you get a net plus 13 to what um

454
00:16:12,629 --> 00:16:09,759
to what there would be without an

455
00:16:12,639 --> 00:16:15,350
cool thank you

456
00:16:17,749 --> 00:16:16,310
okay

457
00:16:20,870 --> 00:16:17,759
sorry

458
00:16:23,030 --> 00:16:20,880
so the atmosphere on titan is really

459
00:16:24,870 --> 00:16:23,040
thick um you're modeling modeling and

460
00:16:28,470 --> 00:16:24,880
the observations i mean that's more than

461
00:16:30,150 --> 00:16:28,480
500 kilometers of depth uh i'm not sure

462
00:16:31,749 --> 00:16:30,160
what if anyone has an idea of what the

463
00:16:32,790 --> 00:16:31,759

early earth's atmosphere was as far as

464
00:16:34,629 --> 00:16:32,800
depth but

465
00:16:36,710 --> 00:16:34,639
right now i mean the carbon line's 100

466
00:16:38,310 --> 00:16:36,720
kilometers so do you think that would

467
00:16:40,629 --> 00:16:38,320
make a big difference at all in the

468
00:16:42,150 --> 00:16:40,639
early earth having a much smaller

469
00:16:44,310 --> 00:16:42,160
atmosphere so there's not as much of a

470
00:16:45,910 --> 00:16:44,320
depth of particles to pass through

471
00:16:48,550 --> 00:16:45,920
anyway

472
00:16:50,949 --> 00:16:48,560
that's a good question um

473
00:16:53,590 --> 00:16:50,959
so on one hand all your gas is

474
00:16:55,350 --> 00:16:53,600
compressed so you have this well

475
00:16:56,870 --> 00:16:55,360
titan has about 10 times the column mass

476
00:16:58,629 --> 00:16:56,880
but you would have about the you know

477
00:17:02,310 --> 00:16:58,639
you'd have about the same amount

478
00:17:04,470 --> 00:17:02,320
but what would what could make

479
00:17:06,470 --> 00:17:04,480
uh what could have an effect

480
00:17:08,150 --> 00:17:06,480
is the length of time it takes particles

481
00:17:09,270 --> 00:17:08,160
to fall

482
00:17:10,870 --> 00:17:09,280
um

483
00:17:12,230 --> 00:17:10,880
but again that's usually dependent on

484
00:17:14,309 --> 00:17:12,240
pressure as well

485
00:17:16,470 --> 00:17:14,319
so

486
00:17:17,990 --> 00:17:16,480
yeah i don't know you'd have to model it

487
00:17:21,350 --> 00:17:18,000
i don't think it would change any of the

488
00:17:22,549 --> 00:17:21,360

major conclusions about um

489
00:17:24,470 --> 00:17:22,559
yeah about

490
00:17:26,470 --> 00:17:24,480
how these different aerosol properties

491
00:17:28,069 --> 00:17:26,480
affect the anti-greenhouse effect um