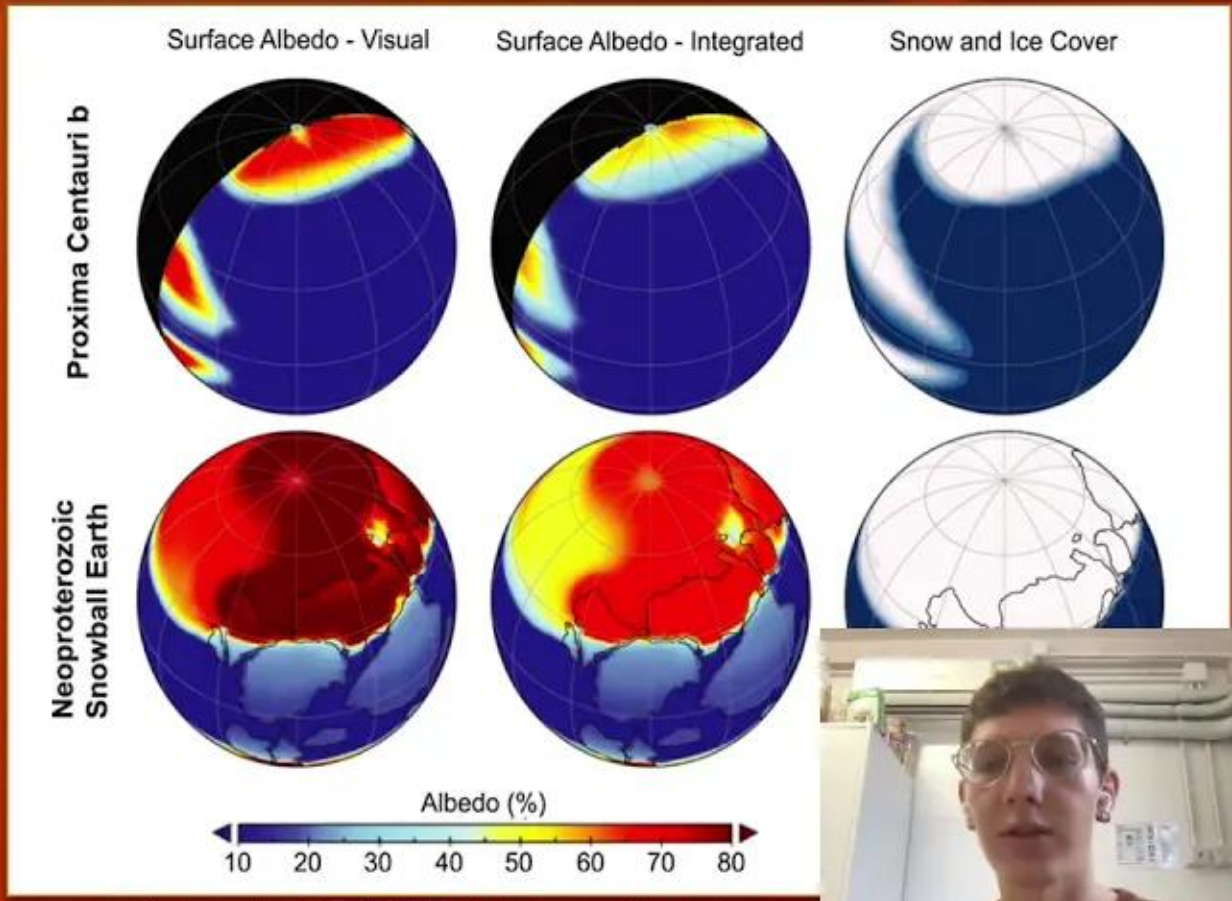
ROCKE-3D Model

- Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics (ROCKE)[11]
- Three-dimensional General Circulation Model
- Expanded capabilities to capture planetary atmospheres
- Coupled topographic influence
- Includes spectral radiance profile for Titan
- Currently working to adapt to Titan's planetary profile



11 Way, M.J. et al., 2017. Resolving Orbital and Climate Keys of Earth and Extraterrestrial Environments with Dynamics (ROCKE-3D) 1.0: A General Circulation Model for Simulating the Climates of Rocky Planets. The Astrophysical Journal Supplement Series 231, 12.. doi:10.3847/1538-4365/aa7a06

1
00:00:04,230 --> 00:00:02,629
hi my name is max collins from the

2
00:00:06,389 --> 00:00:04,240
university of hong kong and today i'll

3
00:00:08,390 --> 00:00:06,399
be presenting on the rocky 3d model and

4
00:00:10,070 --> 00:00:08,400
application to saturn's main titan

5
00:00:12,150 --> 00:00:10,080
developed by the gutter institute for

6
00:00:13,509 --> 00:00:12,160
space studies this is in the very early

7
00:00:14,950 --> 00:00:13,519
stages so i'll be covering some of the

8
00:00:16,390 --> 00:00:14,960
background for the research as well as

9
00:00:17,830 --> 00:00:16,400
what i'm currently working on

10
00:00:20,070 --> 00:00:17,840
i'd like to give a special thanks to

11
00:00:23,029 --> 00:00:20,080
michael wayne for owlnova giss we're

12
00:00:24,870 --> 00:00:23,039
putting up with mindsets and emailing

13
00:00:26,230 --> 00:00:24,880

so before we dive in i'll give a quick

14
00:00:27,589 --> 00:00:26,240
overview of titan

15
00:00:28,950 --> 00:00:27,599
titan is one of the most earth-like

16
00:00:30,390 --> 00:00:28,960
bodies in our solar system with

17
00:00:32,150 --> 00:00:30,400
substantial nitrogen atmosphere

18
00:00:32,389 --> 00:00:32,160
containing about five percent methane

19
00:00:35,350 --> 00:00:32,399
and

20
00:00:37,110 --> 00:00:35,360
surface pressure around 1.45 atmospheres

21
00:00:37,830 --> 00:00:37,120
it's often characterized by this orange

22
00:00:39,990 --> 00:00:37,840
shades

23
00:00:41,910 --> 00:00:40,000
seen here produced through stratospheric

24
00:00:43,590 --> 00:00:41,920
organic photochemistry

25
00:00:45,590 --> 00:00:43,600
it has an active weather system

26
00:00:47,110 --> 00:00:45,600
comparable to earth's hydrological cycle

27
00:00:49,830 --> 00:00:47,120
with methane and ethane

28
00:00:51,670 --> 00:00:49,840
as the main condensable constituents and

29
00:00:54,709 --> 00:00:51,680
stable surface liquid with a temperature

30
00:00:57,510 --> 00:00:54,719
at the triple point of methane

31
00:00:59,189 --> 00:00:57,520
so titan's circulation is dominated by a

32
00:01:00,389 --> 00:00:59,199
strong seasonal cycle driven by

33
00:01:02,229 --> 00:01:00,399
differential heating

34
00:01:03,590 --> 00:01:02,239
creating a virtually global heavy cell

35
00:01:06,630 --> 00:01:03,600
circulation

36
00:01:07,990 --> 00:01:06,640
heat meridianally

37
00:01:09,670 --> 00:01:08,000
homogenizing the temperature of the

38
00:01:11,270 --> 00:01:09,680

choker spirit meaning it's more

39
00:01:14,149 --> 00:01:11,280
sensitive to solar radiative

40
00:01:15,910 --> 00:01:14,159
imbalances than localized effects this

41
00:01:19,350 --> 00:01:15,920
seasonal variation is caused by sun's

42
00:01:21,109 --> 00:01:19,360
ability with a period of 29.5 years

43
00:01:22,710 --> 00:01:21,119
during northern summer the high solar

44
00:01:24,149 --> 00:01:22,720
insulation produces atmospheric

45
00:01:25,990 --> 00:01:24,159
upwelling causing methane cloud

46
00:01:28,070 --> 00:01:26,000
formation and precipitation through the

47
00:01:29,990 --> 00:01:28,080
rapid cooling of air parcels

48
00:01:31,510 --> 00:01:30,000
so lower the latitudes consistently

49
00:01:32,390 --> 00:01:31,520
receive more insulation than higher

50
00:01:34,870 --> 00:01:32,400
latitudes

51
00:01:36,870 --> 00:01:34,880
with the net heating near the equator in

52
00:01:38,550 --> 00:01:36,880
response to this radiative imbalance the

53
00:01:40,149 --> 00:01:38,560
atmospheric circulation acts to

54
00:01:41,670 --> 00:01:40,159
transport heat towards the

55
00:01:43,510 --> 00:01:41,680
colder polar regions to reach

56
00:01:50,230 --> 00:01:43,520
equilibrium which results in low

57
00:01:54,149 --> 00:01:52,069
titan's atmospheric circulation acts to

58
00:01:55,830 --> 00:01:54,159
redistribute methane triangle

59
00:01:57,590 --> 00:01:55,840
latitudes and delivering moisture to the

60
00:01:59,510 --> 00:01:57,600
poles a fundamental

61
00:02:01,030 --> 00:01:59,520
diver of this methane cycle is the

62
00:02:02,950 --> 00:02:01,040
humidity of the troposphere

63
00:02:05,190 --> 00:02:02,960

and so the huen's gas chromatograph max

64
00:02:06,950 --> 00:02:05,200
spectrometer demonstrated the relative

65
00:02:08,469 --> 00:02:06,960
humidity to be 100

66
00:02:10,790 --> 00:02:08,479
from 40 kilometers down to eight

67
00:02:11,190 --> 00:02:10,800
kilometers with a constant mixing ratio

68
00:02:13,190 --> 00:02:11,200
below

69
00:02:14,790 --> 00:02:13,200
indicating a well mixed and subsaturated

70
00:02:16,229 --> 00:02:14,800
lower troposphere

71
00:02:18,070 --> 00:02:16,239
the depletion of methane through

72
00:02:19,350 --> 00:02:18,080
photolysis and subsequent hydrogen

73
00:02:20,949 --> 00:02:19,360
escape would severely limit the

74
00:02:22,470 --> 00:02:20,959
long-term methane cycle

75
00:02:24,949 --> 00:02:22,480
and so it must be recharged through some

76
00:02:26,550 --> 00:02:24,959
mechanism and methane would then cycle

77
00:02:28,070 --> 00:02:26,560
from pool to pole residing at high

78
00:02:29,990 --> 00:02:28,080
latitudes and lakes

79
00:02:31,830 --> 00:02:30,000
when equatorial humidity is high enough

80
00:02:32,470 --> 00:02:31,840
convective storms at low latitudes are

81
00:02:34,830 --> 00:02:32,480
possible

82
00:02:36,790 --> 00:02:34,840
playing a role in carving fluvial

83
00:02:38,710 --> 00:02:36,800
features

84
00:02:40,550 --> 00:02:38,720
so today we'll be focusing mainly on the

85
00:02:41,670 --> 00:02:40,560
surface hydrocarbon reservoirs found in

86
00:02:43,350 --> 00:02:41,680
titan's polar regions

87
00:02:44,790 --> 00:02:43,360
including several large seas and many

88
00:02:46,550 --> 00:02:44,800

smaller lake features occurring at

89
00:02:49,350 --> 00:02:46,560
northern high latitudes

90
00:02:50,949 --> 00:02:49,360
radar measurements from the jmra the

91
00:02:52,630 --> 00:02:50,959
second largest sea suggests a liquid

92
00:02:54,150 --> 00:02:52,640
composition of nearly pure methane

93
00:02:55,030 --> 00:02:54,160
implying these lakes interact with the

94
00:02:56,150 --> 00:02:55,040
atmosphere

95
00:02:58,630 --> 00:02:56,160
and are linked to the weather and

96
00:03:00,229 --> 00:02:58,640
climate systems titan's south pole

97
00:03:00,630 --> 00:03:00,239
contains fewer lakes but still shows

98
00:03:03,830 --> 00:03:00,640
many

99
00:03:05,990 --> 00:03:03,840
like features such as ontario

100
00:03:07,430 --> 00:03:06,000
so both polar regions also appear to

101
00:03:09,270 --> 00:03:07,440
feature empty and partially filled

102
00:03:10,630 --> 00:03:09,280
basins suggesting geologically recent

103
00:03:13,910 --> 00:03:10,640
surface exposures

104
00:03:15,350 --> 00:03:13,920
of liquid or saturated soils original

105
00:03:16,949 --> 00:03:15,360
service features suggested that liquid

106
00:03:18,070 --> 00:03:16,959
flow including channels and floodplains

107
00:03:19,670 --> 00:03:18,080
have also been identified

108
00:03:21,910 --> 00:03:19,680
at many different latitudes including

109
00:03:23,110 --> 00:03:21,920
the equatorial labyrinth regions

110
00:03:24,710 --> 00:03:23,120
it's possible that at least some of

111
00:03:28,550 --> 00:03:24,720
these could be the remnants of a wetter

112
00:03:32,710 --> 00:03:30,229
so all of these lakes are restricted to

113
00:03:34,550 --> 00:03:32,720

latitudes polar 55 degrees

114
00:03:35,910 --> 00:03:34,560
and cover 1.5 percent of titan's

115
00:03:37,589 --> 00:03:35,920
observed surface

116
00:03:39,270 --> 00:03:37,599
dark lake regions cover 10 percent of

117
00:03:41,990 --> 00:03:39,280
the area in the northern polar region

118
00:03:43,990 --> 00:03:42,000
but only 0.4 percent in the southern

119
00:03:46,229 --> 00:03:44,000
the seasonal psycho cycle of polar

120
00:03:48,070 --> 00:03:46,239
precipitation is a sequence of winter

121
00:03:49,509 --> 00:03:48,080
time mid-level tropospheric drying

122
00:03:51,350 --> 00:03:49,519
from descending dry air in the highway

123
00:03:53,670 --> 00:03:51,360
circulation followed by

124
00:03:55,429 --> 00:03:53,680
warming and moistening of low-level air

125
00:03:56,789 --> 00:03:55,439
as the spring pole becomes illuminated

126
00:03:58,550 --> 00:03:56,799
and moistening of the mid-level

127
00:04:00,630 --> 00:03:58,560
troposphere by deep convection over the

128
00:04:02,550 --> 00:04:00,640
summer pole both cassini

129
00:04:04,550 --> 00:04:02,560
and ground-based observations detected

130
00:04:05,910 --> 00:04:04,560
tropospheric cloud activity at southern

131
00:04:08,229 --> 00:04:05,920
mid-latitudes

132
00:04:09,670 --> 00:04:08,239
as well as cloudiness over the pole this

133
00:04:10,149 --> 00:04:09,680
suggests the threats of high moisture

134
00:04:12,830 --> 00:04:10,159
content

135
00:04:15,190 --> 00:04:12,840
precipitation and sustained surface

136
00:04:16,710 --> 00:04:15,200
liquids

137
00:04:18,789 --> 00:04:16,720
this is a global mosaic of titan's

138
00:04:20,150 --> 00:04:18,799

surface brightness from cassini imaging

139
00:04:22,550 --> 00:04:20,160
science subsystem or

140
00:04:24,230 --> 00:04:22,560
iss which shows the distribution of

141
00:04:25,990 --> 00:04:24,240
titan's landforms

142
00:04:27,670 --> 00:04:26,000
as you can see persistent with custom

143
00:04:27,990 --> 00:04:27,680
features include filled lakes near the

144
00:04:30,390 --> 00:04:28,000
polar

145
00:04:31,430 --> 00:04:30,400
regions and dark areas some partially

146
00:04:33,590 --> 00:04:31,440
filled regions

147
00:04:35,030 --> 00:04:33,600
remain radar dark relative to their

148
00:04:35,830 --> 00:04:35,040
surroundings but shown an increase in

149
00:04:37,350 --> 00:04:35,840
backscatter

150
00:04:39,590 --> 00:04:37,360
that can't be explained by incidence

151
00:04:40,469 --> 00:04:39,600
angle variations using common scattering

152
00:04:42,150 --> 00:04:40,479
models

153
00:04:43,749 --> 00:04:42,160
so this is still a topic of debate and

154
00:04:44,710 --> 00:04:43,759
could be the definition of organic

155
00:04:48,070 --> 00:04:44,720
debris

156
00:04:48,710 --> 00:04:48,080
or complex porous nitriles periods in

157
00:04:52,870 --> 00:04:48,720
the wind

158
00:04:56,950 --> 00:04:54,710
so these are the major c's which contain

159
00:04:58,790 --> 00:04:56,960
80 of the observed liquid-filled surface

160
00:04:59,510 --> 00:04:58,800
area and fill northern polar basins

161
00:05:02,469 --> 00:04:59,520
roughly

162
00:05:04,310 --> 00:05:02,479
between 50 and 100 degrees east northern

163
00:05:06,150 --> 00:05:04,320

regional variation can be explained by

164
00:05:07,909 --> 00:05:06,160
changes in observational geometry and

165
00:05:09,430 --> 00:05:07,919
complex in contrast to southern

166
00:05:11,670 --> 00:05:09,440
ephemeral features

167
00:05:13,430 --> 00:05:11,680
while much smaller lakes also ex exist

168
00:05:15,189 --> 00:05:13,440
elsewhere it tightens north pole these

169
00:05:16,710 --> 00:05:15,199
primary large features dominate and

170
00:05:20,469 --> 00:05:16,720
coincide with some of titan's

171
00:05:22,950 --> 00:05:20,479
large-scale topographic depression

172
00:05:25,430 --> 00:05:22,960
um this is a tsar mosaic of titan south

173
00:05:26,950 --> 00:05:25,440
polar region from 90 to 55 degrees south

174
00:05:29,990 --> 00:05:26,960
for september 2005

175
00:05:31,350 --> 00:05:30,000
through january 2010 the three areas

176
00:05:33,189 --> 00:05:31,360
which include ephemeral features are

177
00:05:35,029 --> 00:05:33,199
outlined in red

178
00:05:36,629 --> 00:05:35,039
titan's south polar region was in summer

179
00:05:39,029 --> 00:05:36,639
during assignment expected to be in a

180
00:05:41,350 --> 00:05:39,039
state of volatile evaporation

181
00:05:43,110 --> 00:05:41,360
these ephemeral lakes are found

182
00:05:44,710 --> 00:05:43,120
virtually only in the southern region

183
00:05:46,150 --> 00:05:44,720
and may be due to surface changes

184
00:05:48,950 --> 00:05:46,160
including liquid evaporation

185
00:05:50,790 --> 00:05:48,960
infiltration freezing wave activity and

186
00:05:52,550 --> 00:05:50,800
cryovolcanism

187
00:05:54,150 --> 00:05:52,560
ephemeral feature loss rates are also

188
00:05:55,110 --> 00:05:54,160

consistent with predominantly methane

189
00:05:56,710 --> 00:05:55,120
composition

190
00:05:58,950 --> 00:05:56,720
uh three classes of lakes have been

191
00:06:00,950 --> 00:05:58,960
identified empty lakes

192
00:06:02,150 --> 00:06:00,960
uh partially filled lakes and dark or

193
00:06:03,990 --> 00:06:02,160
liquid filled lakes based on the

194
00:06:06,230 --> 00:06:04,000
microwave reflectivity of site

195
00:06:07,990 --> 00:06:06,240
titan's surface using the normalized

196
00:06:10,230 --> 00:06:08,000
backscatter cross-section which is a

197
00:06:12,230 --> 00:06:10,240
non-dimensional quantity that describes

198
00:06:16,950 --> 00:06:12,240
received radar power as compared to an

199
00:06:20,870 --> 00:06:18,629
this figure shows an equidistant

200
00:06:22,150 --> 00:06:20,880
cylindrical projection of ontario lackis

201
00:06:24,710 --> 00:06:22,160
which is the largest lake in the

202
00:06:27,510 --> 00:06:24,720
southern region the lake border from the

203
00:06:30,790 --> 00:06:27,520
2005 iss image is shown in cyan

204
00:06:32,950 --> 00:06:30,800
while the 2009 sar border is blue figure

205
00:06:36,309 --> 00:06:32,960
a and is an iss image attained

206
00:06:38,230 --> 00:06:36,319
in june 2005 and the iss shoreline is

207
00:06:39,670 --> 00:06:38,240
defined by following a constant contour

208
00:06:41,350 --> 00:06:39,680
of relative brightness

209
00:06:44,070 --> 00:06:41,360
reference to a local offshore pixel

210
00:06:45,430 --> 00:06:44,080
intensity figure b is a star image

211
00:06:48,230 --> 00:06:45,440
obtained in june

212
00:06:50,070 --> 00:06:48,240
and july 2009 the altimetry shows a

213
00:06:50,790 --> 00:06:50,080

smooth and specular surface with 20

214
00:06:53,350 --> 00:06:50,800
kilometers

215
00:06:56,070 --> 00:06:53,360
recession of the southern shoreline

216
00:06:58,070 --> 00:06:56,080
between the iss and radar images

217
00:06:59,189 --> 00:06:58,080
a near shore the symmetry map was

218
00:07:01,749 --> 00:06:59,199
derived in haze at

219
00:07:03,350 --> 00:07:01,759
all suggesting an average depth change

220
00:07:04,550 --> 00:07:03,360
of four meters consistent with an

221
00:07:05,990 --> 00:07:04,560
average loss rate

222
00:07:07,670 --> 00:07:06,000
of one meter during the four years

223
00:07:09,749 --> 00:07:07,680
between observations

224
00:07:11,270 --> 00:07:09,759
the tide is not a dominant contributor

225
00:07:13,189 --> 00:07:11,280
to the observed change in depth as there

226
00:07:15,270 --> 00:07:13,199
are no variations in the magnitude with

227
00:07:16,469 --> 00:07:15,280
the north-south distance from the center

228
00:07:18,230 --> 00:07:16,479
of mass

229
00:07:19,909 --> 00:07:18,240
and if the main process of depth changes

230
00:07:21,510 --> 00:07:19,919
that operation the lake would have to

231
00:07:23,430 --> 00:07:21,520
contain a high methane fraction as

232
00:07:27,189 --> 00:07:23,440
ethane would impede methane evaporation

233
00:07:31,270 --> 00:07:29,350
so shoreline surface changes indicate

234
00:07:32,629 --> 00:07:31,280
local hydraulic conductivity combined

235
00:07:34,390 --> 00:07:32,639
with weather patterns and low-level

236
00:07:36,390 --> 00:07:34,400
humidity measurements and plyomethane

237
00:07:37,830 --> 00:07:36,400
reservoirs in excess of observed surface

238
00:07:39,350 --> 00:07:37,840

liquids

239
00:07:40,790 --> 00:07:39,360
titan's hydroclimate appears to be

240
00:07:41,830 --> 00:07:40,800
especially driven by large-scale

241
00:07:43,749 --> 00:07:41,840
topography

242
00:07:45,189 --> 00:07:43,759
seen through active drainage erosional

243
00:07:47,510 --> 00:07:45,199
modification

244
00:07:49,670 --> 00:07:47,520
saturated sediments and seemingly stable

245
00:07:51,350 --> 00:07:49,680
polar lacustrine features

246
00:07:52,790 --> 00:07:51,360
this evidence suggests that the presence

247
00:07:55,350 --> 00:07:52,800
of subsurface methane

248
00:07:56,950 --> 00:07:55,360
in contact with global climate system

249
00:07:58,070 --> 00:07:56,960
this may be through a continuous

250
00:08:00,150 --> 00:07:58,080
connected methane table

251
00:08:02,070 --> 00:08:00,160
intersecting with the surface expressed

252
00:08:04,150 --> 00:08:02,080
through polar lakes and seas

253
00:08:06,070 --> 00:08:04,160
the atmosphere deposits methane into the

254
00:08:08,150 --> 00:08:06,080
low latitudes to be infiltrated while

255
00:08:10,309 --> 00:08:08,160
surface and subsurface transport routes

256
00:08:12,710 --> 00:08:10,319
methane into high latitude basins which

257
00:08:14,629 --> 00:08:12,720
then feed the atmospheric moisture

258
00:08:16,070 --> 00:08:14,639
this subsurface transport occurs through

259
00:08:17,990 --> 00:08:16,080
lateral flow

260
00:08:19,510 --> 00:08:18,000
of fluid and aquifers dominantly through

261
00:08:21,270 --> 00:08:19,520
fractures and depending on

262
00:08:23,510 --> 00:08:21,280
active aquifer thickness hydraulic

263
00:08:27,830 --> 00:08:23,520

conductivity porosity

264
00:08:29,270 --> 00:08:27,840
and the hydraulic gradient

265
00:08:31,270 --> 00:08:29,280
this is the distribution of surface

266
00:08:33,509 --> 00:08:31,280
liquid methane averaged over the final

267
00:08:34,790 --> 00:08:33,519
20 titan years of each stimulation by

268
00:08:36,469 --> 00:08:34,800
faulk at all

269
00:08:38,310 --> 00:08:36,479
the hydraulic conductivity k of the

270
00:08:39,350 --> 00:08:38,320
surface is shown for each case

271
00:08:42,070 --> 00:08:39,360
and corresponds to different

272
00:08:43,589 --> 00:08:42,080
permeabilities subsurface transport is

273
00:08:45,509 --> 00:08:43,599
dependent on hydraulic conductivity

274
00:08:47,030 --> 00:08:45,519
which describes the ability of liquid

275
00:08:49,190 --> 00:08:47,040
through pore space and depends on the

276
00:08:51,350 --> 00:08:49,200
permeability of the porous medium

277
00:08:53,030 --> 00:08:51,360
liquid density gravity and dynamic

278
00:08:54,389 --> 00:08:53,040
because of viscosity

279
00:08:56,310 --> 00:08:54,399
soil types are currently poorly

280
00:09:00,310 --> 00:08:56,320
constrained and flow is modeled using

281
00:09:03,590 --> 00:09:01,990
so result suggests the subsurface

282
00:09:05,190 --> 00:09:03,600
methane reservoir more massive than the

283
00:09:06,870 --> 00:09:05,200
observed seeds interacting

284
00:09:09,030 --> 00:09:06,880
with the atmosphere and participating in

285
00:09:11,030 --> 00:09:09,040
the methane cycle

286
00:09:12,550 --> 00:09:11,040
model results implies unobserved methane

287
00:09:13,509 --> 00:09:12,560
reservoir participates in titan's

288
00:09:15,430 --> 00:09:13,519

methane cycle

289
00:09:18,389 --> 00:09:15,440
best model with a hydraulic conductivity

290
00:09:19,910 --> 00:09:18,399
of five times ten to the negative fifth

291
00:09:21,990 --> 00:09:19,920
although this still does not explain the

292
00:09:24,070 --> 00:09:22,000
distribution of small lakes which may be

293
00:09:25,509 --> 00:09:24,080
due to the influence of topography or

294
00:09:27,829 --> 00:09:25,519
regional surface variation on the

295
00:09:29,910 --> 00:09:27,839
atmosphere

296
00:09:31,750 --> 00:09:29,920
the model i'm currently using is the

297
00:09:32,150 --> 00:09:31,760
resolving orbital and climate keys of

298
00:09:33,990 --> 00:09:32,160
earth

299
00:09:35,990 --> 00:09:34,000
and extraterrestrial environments with

300
00:09:39,550 --> 00:09:36,000
dynamics a three-dimensional

301
00:09:41,910 --> 00:09:39,560
gcm developed at the giss for modeling

302
00:09:43,590 --> 00:09:41,920
extraterrestrial uh planets

303
00:09:45,350 --> 00:09:43,600
and it's an ongoing effort to handle a

304
00:09:46,230 --> 00:09:45,360
broad range of atmospheric conditions as

305
00:09:48,829 --> 00:09:46,240
well as diverse

306
00:09:52,790 --> 00:09:48,839
oceans land distributions and

307
00:09:56,230 --> 00:09:54,470
so this is just a basic overview of the

308
00:09:58,230 --> 00:09:56,240
land hydrology

309
00:09:59,750 --> 00:09:58,240
in rocky 3d and i'm currently working to

310
00:10:01,509 --> 00:09:59,760
adapt this to titan landscape

311
00:10:03,829 --> 00:10:01,519
and climate through parameterization of

312
00:10:05,590 --> 00:10:03,839
constants such as emissivity albedo

313
00:10:07,190 --> 00:10:05,600

thermodynamics and soil properties to

314
00:10:08,949 --> 00:10:07,200
accurately represent subsurface

315
00:10:12,710 --> 00:10:08,959
transport throughout conifers

316
00:10:14,230 --> 00:10:12,720
or what we confer about future work

317
00:10:15,590 --> 00:10:14,240
may include modeling the influence of

318
00:10:17,350 --> 00:10:15,600
changing orbital forcing on the

319
00:10:19,190 --> 00:10:17,360
asymmetry type surface

320
00:10:20,470 --> 00:10:19,200
and subsurface flow including

321
00:10:22,470 --> 00:10:20,480
topographic influence

322
00:10:24,150 --> 00:10:22,480
spatially dependent soil parameters and

323
00:10:26,230 --> 00:10:24,160
surface evolution

324
00:10:28,630 --> 00:10:26,240
and models such as these can help

325
00:10:30,470 --> 00:10:28,640
constrain key properties and processes

326
00:10:31,590 --> 00:10:30,480
uh useful in preparation for future

327
00:10:33,110 --> 00:10:31,600
institute

328
00:10:34,870 --> 00:10:33,120
exploration of titans such as with