



1
00:00:00,600 --> 00:00:01,701
[light instrumental music]

2
00:00:01,735 --> 00:00:03,536
- [Narrator] NASA'S Jet
Propulsion Laboratory presents

3
00:00:04,403 --> 00:00:06,005
the von Karman Lecture,

4
00:00:06,038 --> 00:00:08,808
a series of talks by
scientists and engineers

5
00:00:08,841 --> 00:00:12,378
who are exploring our
planet, our solar system,

6
00:00:12,411 --> 00:00:19,986
and all that lies beyond.

7
00:00:24,824 --> 00:00:26,526
- Good evening
ladies and gentlemen.

8
00:00:26,559 --> 00:00:28,594
How's everyone tonight?
- Good.

9
00:00:28,627 --> 00:00:30,063
- Good, well thanks
again as always

10
00:00:30,096 --> 00:00:32,765
for coming out to
join us this evening.

11
00:00:32,798 --> 00:00:34,500
One of the greatest

uncertainties

12

00:00:34,533 --> 00:00:36,669

in projections of
future climate change

13

00:00:36,702 --> 00:00:39,572

is how terrestrial
ecosystems contribute to

14

00:00:39,605 --> 00:00:43,576

or help counteract the rise
in atmospheric carbon dioxide.

15

00:00:44,443 --> 00:00:46,245

This is because these
systems can both

16

00:00:46,278 --> 00:00:48,514

absorb carbon and emit it.

17

00:00:48,547 --> 00:00:51,417

Here at JPL we are using
satellite remote sensing

18

00:00:51,450 --> 00:00:53,719

and sophisticated
modeling to understand

19

00:00:53,752 --> 00:00:57,290

how Earth's carbon, water,
and nutrient cycles are linked

20

00:00:57,323 --> 00:01:00,593

and how they impact the
Earth's system as a whole.

21

00:01:00,626 --> 00:01:02,462

Tonight our guest
will give an overview

22

00:01:02,495 --> 00:01:05,631
of the latest data sets and
model developments from JPL,

23

00:01:05,664 --> 00:01:08,768
and discuss new insights into
the behavior and understanding

24

00:01:08,801 --> 00:01:12,138
of terrestrial ecosystems
in a changing climate.

25

00:01:12,171 --> 00:01:14,907
Our guest tonight is a
research scientist here at JPL,

26

00:01:14,940 --> 00:01:17,610
and the science lead of a new
instrument about to launch

27

00:01:17,643 --> 00:01:20,880
to the International Space
Station called ECOSTRESS.

28

00:01:20,913 --> 00:01:22,582
He is originally from LA,

29

00:01:22,615 --> 00:01:24,383
got his undergraduate
and graduate degrees

30

00:01:24,416 --> 00:01:25,751
from UC Berkeley,

31

00:01:25,784 --> 00:01:28,921
and then did a postdoc
at Oxford University

32

00:01:28,954 --> 00:01:33,759
where he taught for a few years
before joining JPL in 2010.

33
00:01:33,792 --> 00:01:36,395
His research focuses on
terrestrial ecosystems,

34
00:01:36,428 --> 00:01:39,565
water, carbon, and nutrients
using a combination

35
00:01:39,598 --> 00:01:42,034
of supercomputer
models, remote sensing,

36
00:01:42,067 --> 00:01:45,505
and field campaigns from
the Amazon to the Arctic.

37
00:01:45,538 --> 00:01:48,474
When he's not sciencing, he's
juggling his six year old

38
00:01:48,507 --> 00:01:51,177
and three year old kids,
playing basketball,

39
00:01:51,210 --> 00:01:53,613
snowboarding, breakdancing,

40
00:01:53,646 --> 00:01:55,415
and doing acrobatic
yoga [laughing].

41
00:01:56,415 --> 00:01:57,950
Ladies and gentlemen,
please help me welcome

42
00:01:57,983 --> 00:02:00,219

tonight's guest,
Dr. Josh Fisher.

43

00:02:00,252 --> 00:02:03,923
[applauding]

44

00:02:08,794 --> 00:02:10,863
- Hello, I'm Josh,

45

00:02:10,896 --> 00:02:13,966
and I will not be doing
acrobatic yoga today.

46

00:02:13,999 --> 00:02:16,369
That will be another
von Karman Series,

47

00:02:16,402 --> 00:02:18,304
I suppose, they'll
have to start up.

48

00:02:19,338 --> 00:02:22,441
So I'm a scientist here at JPL,

49

00:02:22,474 --> 00:02:26,312
and my focus is on plants,

50

00:02:26,345 --> 00:02:30,617
on vegetation and everything
that impacts plants on land.

51

00:02:32,384 --> 00:02:34,020
So I'm gonna take you
through a little bit

52

00:02:34,053 --> 00:02:38,391
of a whirlwind journey
through the types of questions

53

00:02:38,424 --> 00:02:43,396
and puzzles that we try to
solve as ecosystem scientists.

54

00:02:45,898 --> 00:02:50,469
Our story begins in 1835
when Hans Christian Anderson

55

00:02:50,502 --> 00:02:53,072
wrote a children's story
about a young woman

56

00:02:53,105 --> 00:02:56,776
whose royal identity is
established by her test

57

00:02:56,809 --> 00:02:58,744
of her physical sensitivity.

58

00:02:58,777 --> 00:03:01,614
The test, unbeknownst
to her, was that a pea

59

00:03:01,647 --> 00:03:03,950
was placed in her bed
covered by 20 mattresses

60

00:03:03,983 --> 00:03:05,851
and 20 feather beds.

61

00:03:05,884 --> 00:03:07,853
In the morning
she lamented about

62

00:03:07,886 --> 00:03:09,822
the discomfort from the pea.

63

00:03:09,855 --> 00:03:13,726
Only a real princess would
have such sensitivity,

64

00:03:13,759 --> 00:03:15,595

thus verifying her
claims to royalty.

65

00:03:17,863 --> 00:03:21,434

The Earth's land surface,
the plants on Earth,

66

00:03:21,467 --> 00:03:25,071

represent a very small
portion of the total Earth,

67

00:03:25,104 --> 00:03:29,775

yet exert an enormous influence
on the Earth's climate

68

00:03:29,808 --> 00:03:31,811

and the fate of the Earth.

69

00:03:31,844 --> 00:03:35,248

It's the figurative
pea in Earth's bed,

70

00:03:36,248 --> 00:03:39,652

and what we're trying to
establish is the true future,

71

00:03:39,685 --> 00:03:42,855

what is the future,
the royal identity?

72

00:03:44,356 --> 00:03:45,458

How is this done?

73

00:03:45,491 --> 00:03:47,526

It's done in models.

74

00:03:47,559 --> 00:03:48,560

We start with models.

75

00:03:48,594 --> 00:03:51,998

Models that start with
essentially land or soil,

76

00:03:52,031 --> 00:03:54,900

and you kind of throw a
bunch of weather at it,

77

00:03:54,933 --> 00:03:57,770

some CO₂, and up
pops and ecosystem.

78

00:03:57,803 --> 00:04:01,240

If you change the
weather around

79

00:04:01,273 --> 00:04:02,508

or any of these
conditions,

80

00:04:02,541 --> 00:04:04,510

then the ecosystem changes.

81

00:04:06,412 --> 00:04:07,913

A very simple way
of representing

82

00:04:07,946 --> 00:04:09,615

how ecosystems behave.

83

00:04:09,648 --> 00:04:13,152

But these ecosystems and
these plants are made up of

84

00:04:14,253 --> 00:04:17,657

a huge amount of processes
that we're trying to understand

85

00:04:17,690 --> 00:04:20,726

at the biological
to the global scale.

86

00:04:20,759 --> 00:04:23,963

Starting with
microns large pores

87

00:04:23,996 --> 00:04:27,366

we can't see with our eyes
on leaves that when open

88

00:04:27,399 --> 00:04:32,305

allow plants to take up
CO₂ and release water.

89

00:04:32,338 --> 00:04:35,474

But when closed, plants
stop taking up CO₂.

90

00:04:35,507 --> 00:04:40,379

So these microns large
pores exert influence

91

00:04:40,412 --> 00:04:42,115

on the entire Earth.

92

00:04:43,615 --> 00:04:45,951

So they take up CO₂,
they also release water.

93

00:04:45,984 --> 00:04:48,287

It's hard to kind of picture
water coming out of the leaves

94

00:04:48,320 --> 00:04:50,856

so I put this little geyser
coming out of the leaf

95

00:04:50,889 --> 00:04:53,192
so you can imagine water
coming out of leaves.

96
00:04:56,662 --> 00:04:59,966
Within the leaf is the
photosynthetic machinery,

97
00:05:01,834 --> 00:05:04,570
very, very complex
chemical process

98
00:05:04,603 --> 00:05:07,973
that we have to somehow
extend to the global scale,

99
00:05:08,006 --> 00:05:09,909
and we have to make
a lot of assumptions

100
00:05:09,942 --> 00:05:13,379
because we can't model
every single electron

101
00:05:13,412 --> 00:05:15,348
or chemical process
in these leaves.

102
00:05:16,515 --> 00:05:18,518
Not every leaf is
created equally.

103
00:05:19,518 --> 00:05:21,921
Even within a given tree,
there's leaves that are shaded,

104
00:05:21,954 --> 00:05:23,255
there's leaves that are bigger,

105
00:05:23,288 --> 00:05:25,424

there's leaves that are older.

106

00:05:25,457 --> 00:05:28,494

So how do you represent
the diversity of leaves

107

00:05:28,527 --> 00:05:31,364

within a single tree, let
alone across all the trees

108

00:05:31,397 --> 00:05:33,299

and plants of the planet?

109

00:05:35,567 --> 00:05:38,938

We need to understand
how radiation or light

110

00:05:38,971 --> 00:05:42,375

diffuses through canopies
turning on and off

111

00:05:42,408 --> 00:05:44,777

these leaf processes,

112

00:05:44,810 --> 00:05:48,448

and how that light
heats up the planet,

113

00:05:49,348 --> 00:05:52,618

and this is something that we
can see from space as well.

114

00:05:52,651 --> 00:05:54,387

Plants intercept rainfall.

115

00:05:54,420 --> 00:05:56,889

This is water that does
not go to the soil,

116

00:05:56,922 --> 00:05:59,558
and the soil processes are
not turned on with this water.

117
00:05:59,591 --> 00:06:03,462
But a lot of water does
come through the canopy

118
00:06:03,495 --> 00:06:06,165
into the soil, so we
have to understand

119
00:06:06,198 --> 00:06:10,236
and be able to predict
what that difference is.

120
00:06:10,269 --> 00:06:13,038
Plants were actually first
included in climate models

121
00:06:13,071 --> 00:06:14,974
not because of the biology,

122
00:06:15,007 --> 00:06:16,809
but because of the
physical structure.

123
00:06:16,842 --> 00:06:19,845
They got in the way of the
winds of atmospheric models,

124
00:06:19,878 --> 00:06:23,416
so they also have this
not only carbon cycle,

125
00:06:23,449 --> 00:06:25,518
but just physical structure

126
00:06:25,551 --> 00:06:27,387
influence on the

Earth's system.

127

00:06:29,054 --> 00:06:32,858

We need to understand
how leaves drop

128

00:06:32,891 --> 00:06:34,393

in deciduous systems.

129

00:06:34,426 --> 00:06:36,629

Our models shouldn't drop
all the leaves at once,

130

00:06:36,662 --> 00:06:38,697

or keep all the leaves
on at the same time.

131

00:06:38,730 --> 00:06:41,233

So we need to be able to
predict that delicate balance

132

00:06:41,266 --> 00:06:44,537

of leaf phenology.

133

00:06:46,939 --> 00:06:49,308

We know that plants take
up carbon and make sugars

134

00:06:49,341 --> 00:06:51,210

and make wood, but they
also burn that sugar

135

00:06:51,243 --> 00:06:55,314

for metabolism just like we
burn sugar for metabolism.

136

00:06:55,347 --> 00:06:58,317

And we need to understand
how much sugar they store,

137

00:06:58,350 --> 00:07:01,921

how much sugar they burn, and
when they run out of sugar

138

00:07:01,954 --> 00:07:02,955

are they gonna die?

139

00:07:05,424 --> 00:07:08,294

There's a huge diversity of
plants, thousands of species.

140

00:07:08,327 --> 00:07:10,629

We cannot model
every single species,

141

00:07:10,662 --> 00:07:13,132

or even see every
single plant or species,

142

00:07:13,165 --> 00:07:15,568

so we have to make
these assumptions about

143

00:07:15,601 --> 00:07:17,169

groupings of trees.

144

00:07:17,202 --> 00:07:19,805

Sometimes we call them
plan functional types

145

00:07:19,838 --> 00:07:24,310

or other types of
groupings such as grass

146

00:07:24,343 --> 00:07:28,514

or broadleaf trees
or needle leaf trees.

147

00:07:28,547 --> 00:07:31,350

So the amount of plant
types that we define

148
00:07:31,383 --> 00:07:34,987
influences how we
predict the outcomes

149
00:07:35,020 --> 00:07:37,256
to changing climate or CO2.

150
00:07:38,190 --> 00:07:40,159
The more plant functional
types we have in there,

151
00:07:40,192 --> 00:07:42,394
the more computational
demand there is.

152
00:07:42,427 --> 00:07:44,663
So there's this trade
off between realism

153
00:07:44,696 --> 00:07:47,600
and our ability to
conduct these experiments.

154
00:07:49,735 --> 00:07:52,538
Some plants grow
faster than others.

155
00:07:52,571 --> 00:07:57,210
Some plants put their
carbon into wood.

156
00:07:58,310 --> 00:08:00,813
Some plants put their carbon
into roots more than others

157
00:08:00,846 --> 00:08:02,615
and into leaves, so

we need to be able

158

00:08:02,648 --> 00:08:04,116
to understand that balance.

159

00:08:05,684 --> 00:08:10,089
How much nutrients do plants
take up, and how do they do it?

160

00:08:10,122 --> 00:08:11,524
Again, questions we ask.

161

00:08:12,824 --> 00:08:15,961
The layers in the soil
are really important

162

00:08:15,994 --> 00:08:19,131
for understanding the
terrestrial ecosystems

163

00:08:19,164 --> 00:08:20,699
in the Earth's climate.

164

00:08:20,732 --> 00:08:25,671
Soil stores a lot of
carbon and nutrients.

165

00:08:25,704 --> 00:08:28,941
The more soil layers we
include in these models,

166

00:08:28,974 --> 00:08:33,079
again, the more computational
power required, but

167

00:08:34,713 --> 00:08:36,449
the more realism as well.

168

00:08:37,416 --> 00:08:39,818

We need to understand
how leaves decompose,

169

00:08:39,851 --> 00:08:41,487
how fast they decompose.

170

00:08:41,520 --> 00:08:43,656
We don't want our models
just dropping leaves

171

00:08:43,689 --> 00:08:45,057
and instantly decomposing,

172

00:08:45,090 --> 00:08:47,259
or sitting there and piling up,

173

00:08:47,292 --> 00:08:49,361
so again getting
that balance right.

174

00:08:49,394 --> 00:08:51,697
And what about all
the worms and termites

175

00:08:51,730 --> 00:08:55,067
and microbes that eat
these dead leaves and wood,

176

00:08:55,100 --> 00:08:56,969
and then respire back that CO₂?

177

00:08:57,970 --> 00:09:00,339
We have to be able to
understand how that's changing

178

00:09:01,273 --> 00:09:04,744
as temperatures and
water cycling changes.

179

00:09:05,611 --> 00:09:07,846

At the end of the day we're
interested not necessarily

180

00:09:07,879 --> 00:09:10,349

in single trees, but
the entire ecosystems.

181

00:09:10,382 --> 00:09:13,652

How all these different
trees and grass and systems

182

00:09:13,685 --> 00:09:16,556

integrate across
the larger picture.

183

00:09:18,290 --> 00:09:21,527

Hydrologically, snow
melt is a very difficult

184

00:09:21,560 --> 00:09:25,130

process to model, a
process that involves

185

00:09:25,163 --> 00:09:28,133

a lot of radiative
and heat transfer,

186

00:09:28,166 --> 00:09:29,635

but very important
for ecosystems

187

00:09:29,668 --> 00:09:32,738

because when there's snow a
lot of things are turned off,

188

00:09:32,771 --> 00:09:34,840

and when they're wet a lot
of things are turned on,

189

00:09:34,873 --> 00:09:37,410

so we have to get that
balance right as well.

190

00:09:38,477 --> 00:09:40,846

How the water moves
through this top surface

191

00:09:40,879 --> 00:09:44,149

into the deeper ground waters
is also very important,

192

00:09:44,182 --> 00:09:47,153

and how it evaporates
back up to the atmosphere.

193

00:09:48,120 --> 00:09:50,623

And of course the larger
evapotranspiration,

194

00:09:50,656 --> 00:09:51,890

the evaporation off the soil

195

00:09:51,923 --> 00:09:54,760

and the transpiration
out of leaves.

196

00:09:54,793 --> 00:09:56,795

This is not a picture
of evapotranspiration.

197

00:09:56,828 --> 00:09:58,063

You can see this
is just clouds,

198

00:09:58,096 --> 00:10:02,535

but you can imagine water
coming off these trees.

199

00:10:03,635 --> 00:10:05,938

We need to understand
how water runs off

200
00:10:05,971 --> 00:10:08,073
into our rivers and oceans,

201
00:10:08,106 --> 00:10:10,476
and how it's routed
over the landscape.

202
00:10:11,510 --> 00:10:13,312
All these different
water components,

203
00:10:13,345 --> 00:10:15,648
the snow, the ground
water, the soil moisture,

204
00:10:15,681 --> 00:10:18,484
they need to keep a delicate
balance with each other;

205
00:10:18,517 --> 00:10:21,387
otherwise, our models might
build up too much snow

206
00:10:21,420 --> 00:10:22,921
or too much ground water,

207
00:10:22,954 --> 00:10:25,858
so we have to keep a
delicate balance of water.

208
00:10:25,891 --> 00:10:28,160
Hard to visualize so I just
put a guy balancing over water,

209
00:10:28,193 --> 00:10:30,429
but water balance.

210

00:10:31,430 --> 00:10:34,600

Then there's dynamic
components of ecosystems:

211

00:10:34,633 --> 00:10:36,869

How trees compete
with one another.

212

00:10:39,438 --> 00:10:41,807

They compete for
space, for light,

213

00:10:41,840 --> 00:10:43,709

for water, for nutrients.

214

00:10:44,876 --> 00:10:48,180

Which plant wins when
there's that kind of a fight?

215

00:10:48,213 --> 00:10:50,282

And when there's a disturbance,

216

00:10:50,315 --> 00:10:54,319

which plants go colonize
and establish first?

217

00:10:54,352 --> 00:10:56,388

Or when there's a
change in climate,

218

00:10:56,421 --> 00:10:58,957

are there new bioclimatic
envelopes for plants

219

00:10:58,990 --> 00:11:03,229

to move into as other
plants die out from?

220

00:11:05,130 --> 00:11:07,700

Speaking of death, how
do you kill a tree?

221

00:11:07,733 --> 00:11:09,702

This is actually a
harder question to answer

222

00:11:09,735 --> 00:11:11,570

than one may realize.

223

00:11:11,603 --> 00:11:13,505

There's a lot of different
ways trees can die,

224

00:11:13,538 --> 00:11:15,941

and again these models
have to kill the trees

225

00:11:15,974 --> 00:11:17,876

at the right rates
for the right reasons.

226

00:11:17,909 --> 00:11:19,578

Is it because they overheated?

227

00:11:19,611 --> 00:11:22,748

Is it because they ran out
of carbon for metabolism?

228

00:11:22,781 --> 00:11:24,216

Is it because of a wind throw?

229

00:11:24,249 --> 00:11:26,652

Is it because of a
disturbance like fire,

230

00:11:26,685 --> 00:11:29,755

the largest disturbance
in Earth's system?

231
00:11:29,788 --> 00:11:30,890
How do you model fire?

232
00:11:32,224 --> 00:11:33,459
And what comes off of fire?

233
00:11:33,492 --> 00:11:37,229
Smoke and other
gases and aerosols.

234
00:11:37,262 --> 00:11:39,932
So all these processes
get wrapped up

235
00:11:39,965 --> 00:11:44,870
into this simple diagram
of a modeled ecosystem.

236
00:11:44,903 --> 00:11:46,371
Of course we know
that ecosystems

237
00:11:46,404 --> 00:11:48,107
are a lot more complex
than this, right?

238
00:11:48,140 --> 00:11:49,942
They look a lot more like this

239
00:11:49,975 --> 00:11:53,512
with all these processes
embedded within.

240
00:11:54,813 --> 00:11:58,017
So that's what ecosystem
scientists try to understand.

241
00:11:59,684 --> 00:12:00,652
That's all well and good,

242

00:12:00,685 --> 00:12:02,588

but we've thrown another
kind of monkey wrench

243

00:12:02,621 --> 00:12:05,724

into this machinery,
and that's this.

244

00:12:05,757 --> 00:12:09,161

Without even putting
axes or labels on this,

245

00:12:09,194 --> 00:12:12,564

a lot of people can recognize
this; it's becoming iconic.

246

00:12:12,597 --> 00:12:15,501

It's the rise in CO₂
in the atmosphere

247

00:12:15,534 --> 00:12:18,504

influencing plants and
influencing our understanding

248

00:12:18,537 --> 00:12:20,473

of how plants respond.

249

00:12:22,207 --> 00:12:25,644

So all these complexities
and uncertainties

250

00:12:25,677 --> 00:12:27,446

are wrapped together
in these climate models

251

00:12:27,479 --> 00:12:29,915

run by different institutions,

252

00:12:29,948 --> 00:12:33,085

some out of the
US, Japan, France,

253

00:12:33,118 --> 00:12:36,122

and so there's a lot of
disagreement about how to model

254

00:12:37,556 --> 00:12:41,026

carbon metabolism, or
how to model evaporation.

255

00:12:41,059 --> 00:12:43,295

So that's why we get a
lot of these differences

256

00:12:43,328 --> 00:12:46,131

with what we project
into the future.

257

00:12:46,164 --> 00:12:49,368

How a plant behaves
to my French colleague

258

00:12:49,401 --> 00:12:51,236

is different than
how a plant behaves

259

00:12:51,269 --> 00:12:52,771

to my Australian colleague.

260

00:12:52,804 --> 00:12:54,206

So we have to come
together as scientists

261

00:12:54,239 --> 00:12:58,110

to really understand the
world beyond our backyards.

262

00:12:58,143 --> 00:13:01,446

So this is a kind of a classic picture of these models

263

00:13:01,479 --> 00:13:04,483
shooting out into the future
and diverging heavily.

264

00:13:04,516 --> 00:13:06,118
The models that
go up are saying

265

00:13:06,151 --> 00:13:08,120
ecosystems are
gonna do just fine,

266

00:13:08,153 --> 00:13:10,022
and the models
that are going down

267

00:13:10,055 --> 00:13:13,192
are saying ecosystems
are gonna crash.

268

00:13:13,225 --> 00:13:17,830
Now this paper was put out in
2006, a number of years ago,

269

00:13:17,863 --> 00:13:19,731
so a lot of development
has happened

270

00:13:19,764 --> 00:13:21,200
in these models since then.

271

00:13:21,233 --> 00:13:22,968
The authors put
out another paper

272

00:13:23,001 --> 00:13:25,170
just a couple of years

ago, about 10 years later,

273

00:13:25,203 --> 00:13:28,207
and this is what the models
look more like today,

274

00:13:29,241 --> 00:13:31,910
which is not too different.

275

00:13:31,943 --> 00:13:34,580
We're still faced with
a lot of uncertainty.

276

00:13:34,613 --> 00:13:36,782
I think the only thing
that's gotten better

277

00:13:36,815 --> 00:13:38,383
is that we've
picked a more like

278

00:13:38,416 --> 00:13:40,586
modern color scheme
with the lines,

279

00:13:40,619 --> 00:13:45,191
but you know I don't think
that is useful in science.

280

00:13:46,424 --> 00:13:50,062
So what we have
here is essentially

281

00:13:50,095 --> 00:13:53,065
like that fable the Blind
Men and the Elephant,

282

00:13:53,098 --> 00:13:54,867
which I kind of
think of as just

283

00:13:54,900 --> 00:13:56,768
terrestrial ecosystem modelers.

284

00:13:56,801 --> 00:13:59,037
Everyone is saying
something different

285

00:13:59,070 --> 00:14:01,340
about the world
in front of them,

286

00:14:01,373 --> 00:14:03,576
but they're all kinda
saying the same thing.

287

00:14:05,076 --> 00:14:08,247
They're all wrong,
but they're all right.

288

00:14:08,280 --> 00:14:10,749
So how do we put this
knowledge together

289

00:14:10,782 --> 00:14:13,352
to really understand the
elephant in front of us,

290

00:14:13,385 --> 00:14:16,488
the fate of Earth's
ecosystems in the biosphere?

291

00:14:18,623 --> 00:14:20,692
Now a lot of these
models as you can imagine

292

00:14:20,725 --> 00:14:24,163
are built in the US, in Europe,

293

00:14:25,030 --> 00:14:27,566
and so I've put
together this cartogram

294
00:14:27,599 --> 00:14:31,370
which blows up the
size of the country

295
00:14:31,403 --> 00:14:32,604
depending on how
much investment

296
00:14:32,637 --> 00:14:34,306
there is in the models.

297
00:14:34,339 --> 00:14:35,607
So you can see if we're
trying to come up with

298
00:14:35,640 --> 00:14:37,843
a global picture, but
we're developing models

299
00:14:37,876 --> 00:14:39,711
based on our own
inherent biases

300
00:14:39,744 --> 00:14:42,948
from how we understand how
plants work from our backyards,

301
00:14:42,981 --> 00:14:45,450
we're gonna have
these inherent biases

302
00:14:45,483 --> 00:14:46,986
about the world at large.

303
00:14:49,521 --> 00:14:54,326
The way I approach this

problem and this challenge

304

00:14:54,359 --> 00:14:59,298
is through a triangulation of
carbon, water, and nutrients

305

00:14:59,331 --> 00:15:03,035
as they impact climate and as
they're impacted by climate.

306

00:15:03,068 --> 00:15:05,203
You can adjust this from an
ocean, and an atmosphere,

307

00:15:05,236 --> 00:15:06,705
and a land perspective,

308

00:15:06,738 --> 00:15:10,442
and I address it from a land
and ecosystem perspective

309

00:15:10,475 --> 00:15:12,511
but working hand-in-hand
with my atmospheric

310

00:15:12,544 --> 00:15:16,515
and ocean and ice colleagues
at JPL and worldwide.

311

00:15:17,482 --> 00:15:18,917
So one of the first
things that I did

312

00:15:18,950 --> 00:15:21,720
is I started taking all these
models from all over the world

313

00:15:21,753 --> 00:15:25,857
and putting them here in
house on JPL's supercomputers

314

00:15:25,890 --> 00:15:27,993
to run with common conditions.

315

00:15:28,026 --> 00:15:31,763
I didn't want the French
guys running it one way

316

00:15:31,796 --> 00:15:35,233
and the British guys
running it a different way.

317

00:15:35,266 --> 00:15:37,269
We had to run them the same way

318

00:15:37,302 --> 00:15:39,004
so that we can understand
that the differences

319

00:15:39,037 --> 00:15:41,506
are not due to the fact that
somebody started their model

320

00:15:41,539 --> 00:15:45,644
in 1801 and the other
one started in 1850.

321

00:15:45,677 --> 00:15:50,315
So we've been using NASA's
supercomputing infrastructure

322

00:15:50,348 --> 00:15:52,217
to help solve that
part of the problem,

323

00:15:52,250 --> 00:15:53,952
but that's really
not good enough.

324

00:15:53,985 --> 00:15:57,289

We still need to understand
how well the models are doing.

325

00:15:58,323 --> 00:16:02,060

So here's a plot of all the
land on Earth by latitude.

326

00:16:02,093 --> 00:16:05,664

So you can see there's more
land in the higher latitudes.

327

00:16:05,697 --> 00:16:09,201

This blue line is the
breathing of the biosphere,

328

00:16:09,234 --> 00:16:12,137

how much breathing in and
out ecosystems do globally,

329

00:16:12,170 --> 00:16:14,440

and most of it occurs
in the tropics.

330

00:16:15,407 --> 00:16:17,242

But there's actually
what we call two poles

331

00:16:17,275 --> 00:16:18,343

of the carbon cycle.

332

00:16:18,376 --> 00:16:21,847

The amount of carbon
stored in ecosystems is--

333

00:16:21,880 --> 00:16:23,715

maximizes both in the
tropics where you have

334

00:16:23,748 --> 00:16:26,885

all these big trees and in
the Arctic where you have

335

00:16:26,918 --> 00:16:31,924

millennia of carbon locked in
the soils and the permafrost.

336

00:16:33,258 --> 00:16:35,761

Now how well are these
two poles sampled?

337

00:16:35,794 --> 00:16:37,729

As you can imagine
on the ground

338

00:16:37,762 --> 00:16:39,698

we sample
in our backyards:

339

00:16:39,731 --> 00:16:42,300

We sample in the US,
we sample in Europe;

340

00:16:42,333 --> 00:16:45,370

the places that have
the money to do this.

341

00:16:45,403 --> 00:16:48,507

So we are undersampling
the most important

342

00:16:48,540 --> 00:16:50,609

regions on the planet.

343

00:16:50,642 --> 00:16:54,279

That's where NASA and JPL's
satellite remote sensing

344

00:16:54,312 --> 00:16:55,847

can really come into play

345

00:16:55,880 --> 00:16:58,617
because we now have a
global picture across

346

00:16:58,650 --> 00:17:01,186
multiple dimensions of
ecosystem properties,

347

00:17:01,219 --> 00:17:03,589
and I'll go through
some of that now.

348

00:17:04,456 --> 00:17:06,825
Coming into a case
study in Amazonia.

349

00:17:06,858 --> 00:17:08,960
It's our crown
jewel of ecosystems.

350

00:17:08,993 --> 00:17:09,828
This is where

351

00:17:11,663 --> 00:17:13,765
the enormous amounts of,

352

00:17:13,798 --> 00:17:16,935
the largest biodiversity
on the planet exists.

353

00:17:16,968 --> 00:17:19,037
This exerts a huge influence

354

00:17:19,070 --> 00:17:22,007
on the Earth's
climate as a whole.

355

00:17:22,040 --> 00:17:24,543

It breaths in the CO2
that we breathe out,

356
00:17:24,576 --> 00:17:27,512
and it breathes out the
oxygen that we breathe in.

357
00:17:27,545 --> 00:17:29,514
It is the lungs of our planet.

358
00:17:29,547 --> 00:17:31,516
So we are very concerned with

359
00:17:31,549 --> 00:17:33,785
what is gonna
become of our lungs.

360
00:17:33,818 --> 00:17:36,888
Are we gonna be breathing
fine, be breathing fine,

361
00:17:36,921 --> 00:17:38,424
or are we gonna be choking?

362
00:17:40,024 --> 00:17:43,295
Looking at these models we
see that some of the models

363
00:17:43,328 --> 00:17:45,564
are predicting that
the Amazon forest

364
00:17:45,597 --> 00:17:47,499
is gonna die back
into the future.

365
00:17:48,433 --> 00:17:50,235
This is quite worrisome.

366

00:17:50,268 --> 00:17:51,336
How are they doing this?

367
00:17:51,369 --> 00:17:55,006
It's because of a predicted
increase in droughts:

368
00:17:55,039 --> 00:17:58,143
drought intensity,
drought magnitude,

369
00:17:58,176 --> 00:17:59,511
and drought frequency.

370
00:18:02,780 --> 00:18:05,283
The largest drought in
the history of our records

371
00:18:05,316 --> 00:18:08,186
in the Amazon occurred in 2005.

372
00:18:08,219 --> 00:18:10,522
So scientists thought, great!

373
00:18:10,555 --> 00:18:12,390
I mean this is not
great, but this is great

374
00:18:12,423 --> 00:18:14,359
because it's kind
of a test to see

375
00:18:14,392 --> 00:18:17,729
how resilient is the Amazon.

376
00:18:17,762 --> 00:18:20,799
So when this drought
hit in '05 we said,

377

00:18:20,832 --> 00:18:22,234
okay, what did the Amazon do?

378
00:18:22,267 --> 00:18:26,371
Did it choke or did
it do all right?

379
00:18:26,404 --> 00:18:29,641
One of the first studies that
came out after this drought

380
00:18:29,674 --> 00:18:33,512
was very curious, a bit
of a head scratcher.

381
00:18:33,545 --> 00:18:36,815
It showed and suggested
that the Amazon greened-up

382
00:18:36,848 --> 00:18:37,983
during the drought.

383
00:18:38,016 --> 00:18:40,886
This didn't really make much
sense to a lot of people.

384
00:18:40,919 --> 00:18:43,288
But a lot of high
profile papers came out

385
00:18:43,321 --> 00:18:44,689
saying that the Amazon
forest greened-up,

386
00:18:44,722 --> 00:18:47,359
and their argument was that,
yes, there was less rainfall,

387
00:18:47,392 --> 00:18:50,128
but there was still plenty

of water in the soil

388

00:18:50,161 --> 00:18:52,030

and there was actually
more sunlight now

389

00:18:52,063 --> 00:18:54,733

so the plants could
photosynthesize more.

390

00:18:54,766 --> 00:18:57,903

But they didn't actually have
on-the-ground measurements

391

00:18:57,936 --> 00:19:00,172

to substantiate
this hypothesis,

392

00:19:00,205 --> 00:19:02,341

but it was very
intriguing indeed.

393

00:19:03,908 --> 00:19:04,910

So what we did was we took

394

00:19:04,943 --> 00:19:06,811

some of the satellite
measurements.

395

00:19:06,844 --> 00:19:07,879

There as a mission called

396

00:19:07,912 --> 00:19:09,414

the Tropical Rainfall
Measuring Mission

397

00:19:09,447 --> 00:19:11,350

which gave us the
precipitation.

398

00:19:12,450 --> 00:19:15,086

I had actually done
a lot of my PhD work

399

00:19:15,119 --> 00:19:17,989

on evapotranspiration, so
this was able to give us

400

00:19:18,022 --> 00:19:20,692

the amount of water
that actually evaporated

401

00:19:20,725 --> 00:19:21,593

out of the soil.

402

00:19:21,626 --> 00:19:22,594

You need both.

403

00:19:22,627 --> 00:19:24,496

You can't just know that
there was less rainfall

404

00:19:24,529 --> 00:19:27,032

without knowing how much
evaporation there was

405

00:19:27,065 --> 00:19:29,501

to determine how much
water there is in the soil.

406

00:19:30,635 --> 00:19:34,239

So if we look at a record
of rain in the Amazon,

407

00:19:34,272 --> 00:19:36,274

it kind of goes up
and down, up and down.

408

00:19:36,307 --> 00:19:38,109

In '05 during this drought
there was a little dip,

409

00:19:38,142 --> 00:19:41,546

but it was hard to tell
if the soils dried out.

410

00:19:41,579 --> 00:19:44,516

So when we put this
evaporation drought on it,

411

00:19:44,549 --> 00:19:47,119

we can see how much
the Amazon dried.

412

00:19:48,186 --> 00:19:50,055

So that really gave
us a better indicator

413

00:19:50,088 --> 00:19:53,124

of how dry the Amazon was.

414

00:19:53,157 --> 00:19:55,093

But that's only half the coin.

415

00:19:55,126 --> 00:19:57,663

We also need to know if
the trees were dead or not.

416

00:19:58,696 --> 00:20:00,665

Now we couldn't get
this from space.

417

00:20:00,698 --> 00:20:02,567

There was no spaceborne asset.

418

00:20:02,600 --> 00:20:05,670

So we had to go
into the Amazon.

419

00:20:05,703 --> 00:20:08,940

We spent a lot of
time and energy

420

00:20:08,973 --> 00:20:13,345

censusing these longterm
monitoring plots to see

421

00:20:14,646 --> 00:20:17,182

if the trees died or not;
very challenging to do.

422

00:20:18,416 --> 00:20:22,420

The bottom line was that
at the end of the day when

423

00:20:22,453 --> 00:20:23,888

areas that were more dry

424

00:20:23,921 --> 00:20:27,259

according to our rain
and evaporation index,

425

00:20:27,292 --> 00:20:31,930

we also saw a very tight
correlation with tree death.

426

00:20:31,963 --> 00:20:33,865

Drought equals tree
death essentially.

427

00:20:33,898 --> 00:20:34,732

Not too surprising,

428

00:20:34,766 --> 00:20:37,168

but remember those
first papers said

429

00:20:37,201 --> 00:20:39,504

that the Amazon
rainforest greened-up

430
00:20:39,537 --> 00:20:42,173
during this drought, so
we had a bit of conflict

431
00:20:42,206 --> 00:20:43,642
in the scientific literature.

432
00:20:44,575 --> 00:20:47,445
When our paper came out,
some of the original authors

433
00:20:47,478 --> 00:20:50,348
of the Green-Up
paper broke ranks

434
00:20:50,381 --> 00:20:53,918
and they kind of reanalyzed
their data and found that

435
00:20:53,951 --> 00:20:57,255
they had not quite properly
accounted for fire.

436
00:20:57,288 --> 00:20:58,790
There was more fire
in this drought

437
00:20:58,823 --> 00:21:00,258
and the smoke was kind
of getting in the way

438
00:21:00,291 --> 00:21:01,393
of their signals.

439
00:21:01,426 --> 00:21:04,696
So they came up with
a new paper that said

440

00:21:04,729 --> 00:21:06,698

Amazon forest did not green-up.

441

00:21:09,567 --> 00:21:13,505

Yeah, it's kinda like gang warfare, but nerd style.

442

00:21:13,538 --> 00:21:14,973

[laughing]

443

00:21:15,006 --> 00:21:15,974

You don't want to see these guys

444

00:21:16,007 --> 00:21:17,976

in the science conference hallways.

445

00:21:18,009 --> 00:21:19,177

It gets tense.

446

00:21:20,678 --> 00:21:23,415

You know like pocket protectors get thrown down.

447

00:21:23,448 --> 00:21:24,983

I'm kidding.

448

00:21:25,016 --> 00:21:29,988

But, again, so there's been scores of papers on this topic

449

00:21:32,023 --> 00:21:33,258

because it's important,

450

00:21:33,291 --> 00:21:35,560

this is really important for us to understand.

451

00:21:35,593 --> 00:21:39,097

What's gonna happen to
the tropics, the Amazon,

452

00:21:39,130 --> 00:21:42,834

and ecosystems under this
projection of increasing

453

00:21:43,801 --> 00:21:46,305

frequency and
magnitude droughts?

454

00:21:47,705 --> 00:21:49,708

I mentioned that the '05
drought was the biggest

455

00:21:49,741 --> 00:21:51,509

in the history of our records,

456

00:21:51,542 --> 00:21:53,945

and these models are projecting

457

00:21:53,978 --> 00:21:55,180

more frequent, bigger droughts.

458

00:21:55,213 --> 00:21:56,948

In 2010 and even
bigger drought hit.

459

00:21:56,981 --> 00:21:59,884

Just five years later in
the history of our records

460

00:21:59,917 --> 00:22:01,953

a bigger drought
hit the Amazon.

461

00:22:03,554 --> 00:22:06,891

Five years after that an even bigger drought hit the Amazon.

462

00:22:06,924 --> 00:22:09,394

So these projections and the models

463

00:22:09,427 --> 00:22:13,565

are actually starting to play out in front of our eyes.

464

00:22:14,932 --> 00:22:17,268

What's different in the recent droughts,

465

00:22:17,301 --> 00:22:20,739

unlike the '05 drought, is that we have new capabilities,

466

00:22:20,772 --> 00:22:22,707

we have new technical capabilities from space

467

00:22:22,740 --> 00:22:24,309

and from models.

468

00:22:25,910 --> 00:22:30,281

We can now observe the glow of plants, called fluorescence.

469

00:22:30,314 --> 00:22:32,450

This is actually a bit of a mistake.

470

00:22:32,483 --> 00:22:35,387

We didn't intend to do these measurements.

471

00:22:35,420 --> 00:22:37,455

These are measurements from

three different satellites:

472

00:22:37,488 --> 00:22:42,060

OCO-2 is out of JPL, there's
one called GOSAT out of Japan,

473

00:22:42,093 --> 00:22:46,765

and one, a satellite
called GOME, out of Europe.

474

00:22:47,665 --> 00:22:48,933

These satellites
were not intending

475

00:22:48,966 --> 00:22:49,934

to measure fluorescence;

476

00:22:49,967 --> 00:22:52,036

they were intending to
measure something else.

477

00:22:52,069 --> 00:22:55,607

But they happened to have this
measurement of fluorescence

478

00:22:55,640 --> 00:22:59,077

that we started scratching
our heads and thinking,

479

00:22:59,110 --> 00:23:02,313

what is this measurement,
this is quite weird.

480

00:23:02,346 --> 00:23:04,215

We dug into it and
we found that

481

00:23:04,248 --> 00:23:06,484

it was this
glow of plants.

482

00:23:06,517 --> 00:23:10,855

So now for the first time
in the history of humankind

483

00:23:10,888 --> 00:23:15,560

we can see photosynthetic
activity as the glow of plants,

484

00:23:15,593 --> 00:23:18,096

when before we were just seeing
if they were green or not.

485

00:23:18,129 --> 00:23:21,032

We saw that the Amazon
greened-up or it was not green.

486

00:23:21,065 --> 00:23:24,235

This is like going to your
doctor and your doctor saying,

487

00:23:24,268 --> 00:23:26,371

"I can't help you
until you dead."

488

00:23:26,404 --> 00:23:29,007

I can't tell until
you're not green anymore.

489

00:23:29,040 --> 00:23:34,012

Now we can see activity is
slowing down or changing

490

00:23:34,045 --> 00:23:38,483

before plants, crops,
drop their leaves or die.

491

00:23:42,920 --> 00:23:45,523

NASA also established the
Carbon Monitoring System

492

00:23:45,556 --> 00:23:47,592

where we started

integrating our observations

493

00:23:47,625 --> 00:23:51,196

across ocean, land,

and atmosphere,

494

00:23:51,229 --> 00:23:55,167

and anthropogenic

carbon cycling.

495

00:23:56,067 --> 00:23:58,903

This CMS program

has been established

496

00:23:58,936 --> 00:24:02,974

and is not moving into new

applications and new venues.

497

00:24:03,007 --> 00:24:06,444

Another really exciting avenue

that is just on the horizon

498

00:24:06,477 --> 00:24:08,079

is we're starting to look at

499

00:24:08,112 --> 00:24:09,681

the International

Space Station.

500

00:24:11,349 --> 00:24:13,952

We don't see a lot out

of the space station

501

00:24:13,985 --> 00:24:18,122

in terms of Earth observation

for science inquiry

502

00:24:18,155 --> 00:24:21,092

or for, especially
for, ecosystems;

503

00:24:22,527 --> 00:24:26,631

we see astronauts doing their
thing on a space station.

504

00:24:29,066 --> 00:24:32,570

If we look at this year's
calendar starting in March,

505

00:24:32,603 --> 00:24:34,739

there's a series of launches
going to the space station

506

00:24:34,772 --> 00:24:38,043

on SpaceX rockets, cargo
resupplies for the astronauts.

507

00:24:39,043 --> 00:24:42,214

They each tell us something
different about ecosystems.

508

00:24:43,447 --> 00:24:44,916

I'm gonna tell you a
little bit about ECOSTRESS,

509

00:24:44,949 --> 00:24:48,853

which is the first one
coming up out of JPL in June.

510

00:24:48,886 --> 00:24:50,855

It's right on the horizon,

511

00:24:50,888 --> 00:24:52,991

and I happen to be
the science lead of it

512

00:24:53,024 --> 00:24:55,527
so of course I'll
tell you about it.

513
00:24:57,628 --> 00:25:00,765
It starts with this
premise that the landscape

514
00:25:00,798 --> 00:25:03,234
is very heterogeneous.

515
00:25:03,267 --> 00:25:06,137
Lots of plants are doing lots
of things at very small scales

516
00:25:06,170 --> 00:25:09,207
so we need to know what's
going on everywhere

517
00:25:09,240 --> 00:25:10,208
but at small scales.

518
00:25:10,241 --> 00:25:13,244
It's kind of a
conundrum, if you will.

519
00:25:13,277 --> 00:25:16,047
We can measure stuff on
the ground with sensors.

520
00:25:16,080 --> 00:25:20,018
We can run drones around the
landscape, or even aircraft.

521
00:25:20,051 --> 00:25:22,620
Then of course we have
our space satellites.

522
00:25:22,653 --> 00:25:26,624
I've built sensors you

can stick into trees,

523

00:25:26,657 --> 00:25:29,494

and it will tell you how
much water they're taking up.

524

00:25:29,527 --> 00:25:31,195

We put them at these
towers that measure

525

00:25:31,228 --> 00:25:33,498

the water fluxes
and carbon fluxes

526

00:25:33,531 --> 00:25:35,767

in and out of ecosystems.

527

00:25:35,800 --> 00:25:38,269

We have drones that
can fly back and forth

528

00:25:38,302 --> 00:25:41,239

across crops seeing how
much water is needed

529

00:25:41,272 --> 00:25:45,043

or how much is used, as well
as through forests determining

530

00:25:48,346 --> 00:25:49,481

tree inventories.

531

00:25:52,283 --> 00:25:55,587

But we really need something
that does everything in one.

532

00:25:55,620 --> 00:26:00,224

We can't put drones and towers
and aircraft everywhere.

533

00:26:00,257 --> 00:26:02,627

So if we look at our current
satellite capabilities,

534

00:26:02,660 --> 00:26:04,963

this is MODIS, and it
shows this landscape

535

00:26:04,996 --> 00:26:07,231

at one kilometer resolution.

536

00:26:07,264 --> 00:26:09,667

It's kinda picking up that
heterogeneity, but not quite.

537

00:26:09,700 --> 00:26:12,971

This is Landsat at
60 meters resolution,

538

00:26:13,004 --> 00:26:14,606

much sharper picture.

539

00:26:15,506 --> 00:26:17,308

And you can see it's
starting to pick up

540

00:26:17,341 --> 00:26:20,278

those differences
across the landscape.

541

00:26:20,311 --> 00:26:22,714

This is our managed
landscape with agriculture.

542

00:26:22,747 --> 00:26:26,084

If we look at a
natural landscape

543

00:26:26,117 --> 00:26:28,586

and we paint on the
vegetation here,

544

00:26:28,619 --> 00:26:31,889

we can see that the
riparian corridors

545

00:26:31,922 --> 00:26:34,092

require very fine
spatial skills.

546

00:26:34,125 --> 00:26:36,895

MODIS is not gonna pick
that up; Landsat will.

547

00:26:38,362 --> 00:26:40,865

So that's space,
what about time?

548

00:26:40,898 --> 00:26:44,636

This is the evaporation
measured at one of the sites

549

00:26:44,669 --> 00:26:46,905

on the ground every 30 minutes,

550

00:26:47,905 --> 00:26:49,607

and you can see the kind
of bumps and wiggles

551

00:26:49,640 --> 00:26:50,675

over the course of the year.

552

00:26:50,708 --> 00:26:55,213

Landsat comes over only
about every 16 days,

553

00:26:55,246 --> 00:26:56,381

and if there's
clouds in the way

554

00:26:56,414 --> 00:26:59,717

then you know every 32
days or multiples thereof.

555

00:26:59,750 --> 00:27:02,053

So even though it's got
the spatial resolution,

556

00:27:02,086 --> 00:27:05,023

it doesn't quite have
that temporal resolution.

557

00:27:05,056 --> 00:27:09,027

ECOSTRESS is gonna
come in and measure,

558

00:27:09,060 --> 00:27:12,163

or fly over us every
about three to five days

559

00:27:12,196 --> 00:27:14,599

really picking up
that seasonal cycle.

560

00:27:17,501 --> 00:27:20,571

Another interesting aspect
about plants is that

561

00:27:20,604 --> 00:27:22,974

there's a diurnal cycle.

562

00:27:23,007 --> 00:27:25,443

Some plants when
there's water stress

563

00:27:25,476 --> 00:27:27,445

will close those
stomata in the afternoon

564

00:27:27,478 --> 00:27:30,381

when it's really hot so they
don't lose a lot of water,

565

00:27:30,414 --> 00:27:32,784

and then they'll open
back up in early evening

566

00:27:32,817 --> 00:27:36,888

before they lose sunlight to do

567

00:27:36,921 --> 00:27:38,489

a little bit more
photosynthesis.

568

00:27:38,522 --> 00:27:41,826

Most of our satellites pass
over us at the same time

569

00:27:41,859 --> 00:27:46,264

every day at the polar
orbiters, 10:30 every time,

570

00:27:47,131 --> 00:27:48,800

so they miss this
diurnal cycle,

571

00:27:48,833 --> 00:27:52,270

they miss this daily
functioning of plants.

572

00:27:52,303 --> 00:27:54,405

There are some satellites
that hover over us,

573

00:27:54,438 --> 00:27:57,842

geostationary all the time,
but because of the orbit

574

00:27:57,875 --> 00:27:59,644
the pixels are very coarse

575
00:27:59,677 --> 00:28:02,580
so they would lump together
plants that are shutting down

576
00:28:02,613 --> 00:28:05,349
and plants that aren't
shutting down into one,

577
00:28:05,382 --> 00:28:07,352
so you wouldn't be able
to distinguish this.

578
00:28:09,954 --> 00:28:12,857
At the end of the day,
we want to take a look

579
00:28:12,890 --> 00:28:16,260
at this landscape and
apply some color to it.

580
00:28:16,293 --> 00:28:19,263
We want to figure out
if there's droughts

581
00:28:19,296 --> 00:28:22,633
which trees, which species,
are gonna die first?

582
00:28:22,666 --> 00:28:24,635
Because some will
more than others.

583
00:28:24,668 --> 00:28:26,437
Some need more
water than others.

584
00:28:26,470 --> 00:28:28,973

Some are less efficient
with water than others.

585

00:28:30,174 --> 00:28:32,043

So that's a little
bit about ECOSTRESS,

586

00:28:32,076 --> 00:28:36,981

and we're really looking
forward to the launch in June.

587

00:28:37,014 --> 00:28:40,251

Hopefully I'll come back
and give another talk later

588

00:28:40,284 --> 00:28:43,321

on some of those results
when we get them.

589

00:28:44,588 --> 00:28:46,924

I'll just briefly mention
a couple of other missions

590

00:28:46,957 --> 00:28:48,493

going to the space station.

591

00:28:48,526 --> 00:28:50,161

I'm not necessarily
involved in,

592

00:28:50,194 --> 00:28:52,330

but they're my
colleagues and partners,

593

00:28:52,363 --> 00:28:54,732

and there's
synergies among them.

594

00:28:54,765 --> 00:28:58,203

HISUI is coming out of

Japan, and this will measure,

595

00:28:59,370 --> 00:29:02,140

it's called hyperspectral
or spectroscopic signatures,

596

00:29:02,173 --> 00:29:04,108

like the unique
fingerprints of plants.

597

00:29:04,141 --> 00:29:05,910

So even though ECOSTRESS
will be able to tell you

598

00:29:05,943 --> 00:29:08,546

which plants need
more or less water,

599

00:29:08,579 --> 00:29:12,450

this one will tell you kind
of what those plants are.

600

00:29:12,483 --> 00:29:15,386

So that's extremely
useful because we'll know

601

00:29:15,419 --> 00:29:18,923

what the plants are and how
much water they're using.

602

00:29:20,357 --> 00:29:25,096

GEDI is using LIDAR, these
lasers from the space station,

603

00:29:25,129 --> 00:29:28,533

to map out how big trees
are, and that will tell you

604

00:29:28,566 --> 00:29:33,171

how much carbon is

stored in ecosystems.

605

00:29:33,204 --> 00:29:36,741

Then finally, OCO-3,
another one let out of JPL,

606

00:29:36,774 --> 00:29:38,676

will be measuring that
fluorescence again,

607

00:29:38,709 --> 00:29:40,912

as well as CO₂ in
the atmosphere.

608

00:29:40,945 --> 00:29:42,647

All on the space station.

609

00:29:42,680 --> 00:29:45,516

All with that diurnal
cycle sampling.

610

00:29:45,549 --> 00:29:48,253

So very exciting to
have these all up.

611

00:29:49,420 --> 00:29:53,724

So essentially we go up on a
SpaceX rocket, cargo resupply.

612

00:29:53,757 --> 00:29:56,427

I tell people that we're
going up with the pizzas,

613

00:29:56,460 --> 00:29:58,062

the pizzas for the astronauts.

614

00:29:58,095 --> 00:30:01,499

Then the Dragon capsule docks.

615

00:30:01,532 --> 00:30:02,800
What's really interesting about

616
00:30:02,833 --> 00:30:04,168
the International
Space Station is that

617
00:30:04,201 --> 00:30:06,704
we've gone up on
an American rocket,

618
00:30:06,737 --> 00:30:10,174
that's the Canadian robotic
arm removing the instrument,

619
00:30:10,207 --> 00:30:13,544
and we're mounting to
the Japanese module.

620
00:30:13,577 --> 00:30:17,615
So we're very much
internationally coming together

621
00:30:17,648 --> 00:30:22,520
both engineering and
scientifically to tackle

622
00:30:22,553 --> 00:30:24,322
global scale questions.

623
00:30:25,289 --> 00:30:26,691
ECOSTRESS is going
up first so we get

624
00:30:26,724 --> 00:30:28,259
the best real estate on here.

625
00:30:28,292 --> 00:30:29,560
It's kind of like
the cul-de-sac

626

00:30:29,593 --> 00:30:31,028
of the space station,

627

00:30:31,061 --> 00:30:34,833
whereas OCO-3 kinda gets the
side street a little bit.

628

00:30:38,969 --> 00:30:41,839
What's interesting
about these instruments

629

00:30:41,872 --> 00:30:45,843
is that they measure the
structure, GEDI for example,

630

00:30:45,876 --> 00:30:48,646
the composition,
which was HISUI,

631

00:30:48,679 --> 00:30:52,750
the evapotranspiration, the
water use which was ECOSTRESS,

632

00:30:52,783 --> 00:30:55,119
and the fluorescence,
which is OCO-3.

633

00:30:55,152 --> 00:30:57,255
These are essentially
lenses of ecosystems.

634

00:30:57,288 --> 00:30:59,423
These are what
comprises ecosystems.

635

00:30:59,456 --> 00:31:00,925
Ecosystems are
comprised of structure,

636

00:31:00,958 --> 00:31:05,496

composition, and function,
and there's this CO2 aspect.

637

00:31:05,529 --> 00:31:09,567

We can also get all of these
using airborne spacecraft.

638

00:31:09,600 --> 00:31:12,703

Not spacecraft,
airborne platforms,

639

00:31:12,736 --> 00:31:15,239

which is also very useful
for being able to target

640

00:31:15,272 --> 00:31:18,376

certain areas that we can't
see very well like the tropics,

641

00:31:18,409 --> 00:31:20,077

for example, where
it's very cloudy.

642

00:31:20,110 --> 00:31:22,680

So even if we have
the satellite sensors,

643

00:31:22,713 --> 00:31:25,450

we might not be able to see
through the clouds as well.

644

00:31:26,383 --> 00:31:29,053

And we need very high spatial
resolution of the tropics,

645

00:31:29,086 --> 00:31:32,323

because all the plants are very
different from one another,

646

00:31:32,356 --> 00:31:34,225

so we need to
really drill down.

647

00:31:35,125 --> 00:31:37,461

Another important
aspect about the tropics

648

00:31:37,494 --> 00:31:40,231

is that not only are they
very sensitive to climate,

649

00:31:40,264 --> 00:31:43,367

which I've shown, but they're
also very sensitive to CO₂.

650

00:31:43,400 --> 00:31:45,069

If you remember that the plot

651

00:31:45,102 --> 00:31:50,141

of the ecosystem crashing,
that was due to the droughts.

652

00:31:50,174 --> 00:31:52,476

But some of them that
were doing really well,

653

00:31:52,509 --> 00:31:54,245

and that was
because those models

654

00:31:54,278 --> 00:31:56,080

were very responsive to CO₂.

655

00:31:56,113 --> 00:31:57,648

CO₂ being good for plants.

656

00:31:57,681 --> 00:32:01,319

Droughts of course related

to CO2 being bad for plants.

657

00:32:02,419 --> 00:32:04,822

So we need to understand
how these plants,

658

00:32:04,855 --> 00:32:07,792

how these ecosystems, are
going to respond in the future

659

00:32:07,825 --> 00:32:10,027

also to rising CO2.

660

00:32:10,060 --> 00:32:11,429

So what do we do?

661

00:32:11,462 --> 00:32:16,334

We conduct experiments where
we pump CO2 onto ecosystems

662

00:32:16,367 --> 00:32:19,237

and see how they respond.

663

00:32:20,838 --> 00:32:23,341

This is very difficult to do.

664

00:32:23,374 --> 00:32:27,678

As you can imagine it requires
a lot of import of CO2,

665

00:32:27,711 --> 00:32:31,248

expensive infrastructure,
and it costs a lot of money,

666

00:32:31,281 --> 00:32:32,249

tens of millions of dollars,

667

00:32:32,282 --> 00:32:34,552

and you don't actually

get a lot of trees.

668

00:32:38,288 --> 00:32:42,393

More importantly what you
also don't get is this long,

669

00:32:42,426 --> 00:32:44,095

we're interested in
the next century,

670

00:32:44,128 --> 00:32:47,832

over the next 10 years,
20 years, 50 years,

671

00:32:47,865 --> 00:32:50,434

and we can't run these
experiments for that long.

672

00:32:50,467 --> 00:32:53,971

So we don't know how the
ecosystems might be shifting,

673

00:32:54,004 --> 00:32:57,608

adapting, to this
longterm change in CO2.

674

00:32:59,443 --> 00:33:02,513

So these CO2
enrichment experiments

675

00:33:02,546 --> 00:33:04,615

have been incredibly value.

676

00:33:04,648 --> 00:33:07,985

In fact, kind of one of our
only tools to assess this.

677

00:33:08,018 --> 00:33:11,022

It's still limited,
especially in the tropics

678

00:33:11,055 --> 00:33:13,691
because there's not a
single one in the tropics

679

00:33:13,724 --> 00:33:16,027
and this longterm aspect.

680

00:33:16,060 --> 00:33:17,695
So we've been
really stuck there.

681

00:33:18,695 --> 00:33:21,366
With kind of no solution,
we've been just stuck.

682

00:33:22,533 --> 00:33:24,201
Something new that
I've been exploring

683

00:33:24,234 --> 00:33:26,470
in the past couple of
years and spinning up

684

00:33:26,503 --> 00:33:27,872
is an entirely different field.

685

00:33:27,905 --> 00:33:30,141
You thought you were coming
for an ecosystems talk,

686

00:33:30,174 --> 00:33:32,010
I'm gonna talk about
volcanology now.

687

00:33:36,280 --> 00:33:37,715
We tend to think of volcanoes

688

00:33:37,748 --> 00:33:40,918

as that thing in the background

689

00:33:40,951 --> 00:33:44,255
spewing out lava,
or whatever it does,

690

00:33:44,288 --> 00:33:48,626
but the volcano complex
actually extends well in

691

00:33:48,659 --> 00:33:51,562
to the surrounding forest.

692

00:33:53,530 --> 00:33:55,166
So if you think about
a landscape of trees,

693

00:33:55,199 --> 00:33:58,836
when a volcano forms there's
these cracks and fissures

694

00:33:58,869 --> 00:34:02,873
in the Earth's surface,
and the number one dry gas

695

00:34:02,906 --> 00:34:05,543
that comes out of
volcanoes is CO₂,

696

00:34:05,576 --> 00:34:07,478
and it comes out in
very high amounts.

697

00:34:09,113 --> 00:34:12,550
Then it diffuses
into the ecosystems

698

00:34:12,583 --> 00:34:15,619
until it reaches
background conditions.

699

00:34:15,652 --> 00:34:19,290

These are exactly the concentrations that we

700

00:34:19,323 --> 00:34:24,295

expect to see globally over the next 50-100 years.

701

00:34:24,862 --> 00:34:29,100

And this has been occurring since geologic age,

702

00:34:29,133 --> 00:34:30,668

hundreds of years.

703

00:34:30,701 --> 00:34:33,704

So we actually kind of now have a natural

704

00:34:33,737 --> 00:34:37,274

longterm CO2 experiment given to us

705

00:34:37,307 --> 00:34:39,243

by Mother Nature through the volcanoes.

706

00:34:41,545 --> 00:34:44,381

So I kind of stole this image

707

00:34:44,414 --> 00:34:46,550

from the gravitational wave guys.

708

00:34:46,583 --> 00:34:48,519

[laughing]

709

00:34:48,552 --> 00:34:50,387

We now are taking
two communities

710
00:34:50,420 --> 00:34:51,655
that normally actually

711
00:34:51,688 --> 00:34:53,691
don't ever interact,
the ecology community

712
00:34:53,724 --> 00:34:56,527
and volcanology community, and
we're putting them together,

713
00:34:56,560 --> 00:34:59,864
and we think this can
really radically change

714
00:34:59,897 --> 00:35:03,134
our knowledge of ecosystems,

715
00:35:03,167 --> 00:35:05,302
and actually
volcanology as well.

716
00:35:05,335 --> 00:35:06,871
I think I have a slide on that.

717
00:35:07,938 --> 00:35:08,906
One of the first things we did,

718
00:35:08,939 --> 00:35:11,008
we went to our
backyard, Mammoth.

719
00:35:11,041 --> 00:35:14,011
A lot of people don't realize
that it's an active volcano.

720

00:35:14,945 --> 00:35:16,147
I never realized that.

721
00:35:16,180 --> 00:35:18,482
I realized it was a good
place to go snowboarding

722
00:35:18,515 --> 00:35:20,684
if I wanted to spend
a lot of money.

723
00:35:20,717 --> 00:35:23,187
[laughing]

724
00:35:23,220 --> 00:35:25,556
So what we did is
we ran our aircraft

725
00:35:25,589 --> 00:35:29,093
over it to look at the
biomass and the chemistry

726
00:35:29,126 --> 00:35:31,328
and the greenness
and the evaporation,

727
00:35:31,361 --> 00:35:33,964
and we saw these
really tight signals

728
00:35:33,997 --> 00:35:38,569
across the landscape to when
there was increasing CO₂

729
00:35:38,602 --> 00:35:42,473
we saw direct changes in
the ecosystem structure.

730
00:35:42,506 --> 00:35:46,710
We got the CO₂ because the

USGS had mapped on the ground

731

00:35:46,743 --> 00:35:47,745

all the CO2 in the area,

732

00:35:47,778 --> 00:35:49,947

you know, it's in

their backyard as well.

733

00:35:51,615 --> 00:35:53,851

So that's great, and

that was really exciting.

734

00:35:53,884 --> 00:35:55,653

But what we really need

are the tropics, right?

735

00:35:55,686 --> 00:35:57,621

That's the breathing

of the biosphere,

736

00:35:57,654 --> 00:36:02,093

and we don't have the USGS

in the tropics necessarily.

737

00:36:03,694 --> 00:36:07,097

What we've discovered is

there's this chain of volcanoes

738

00:36:07,130 --> 00:36:11,235

in Costa Rica that

has been emitting CO2

739

00:36:11,268 --> 00:36:14,572

into the rainforest

for hundreds of years

740

00:36:14,605 --> 00:36:16,373

at different amounts,

741

00:36:16,406 --> 00:36:18,809

kind of giving us a
nice experimental setup.

742

00:36:20,010 --> 00:36:25,016

We went into these volcanic
jungles a few years ago

743

00:36:25,415 --> 00:36:29,320

to examine and figure out on
the ground what was happening.

744

00:36:29,353 --> 00:36:32,590

So we really wanted to
figure out was there

745

00:36:32,623 --> 00:36:35,593

a window into the
future of the Earth

746

00:36:35,626 --> 00:36:39,663

hidden in the jungles of
Costa Rica's volcanoes.

747

00:36:39,696 --> 00:36:42,833

Here we are taking a
lot of measurements.

748

00:36:42,866 --> 00:36:45,336

So this is a picture to
show we came out alive.

749

00:36:48,372 --> 00:36:51,742

What we found were, again,
clear and direct signals

750

00:36:51,775 --> 00:36:54,912

that when there was
greater CO2 exposure

751
00:36:54,945 --> 00:36:56,814
the plants were changing.

752
00:36:59,283 --> 00:37:01,885
What's also particularly
interesting, at least to me,

753
00:37:01,918 --> 00:37:03,787
is that the CO₂ coming
out of volcanoes

754
00:37:03,820 --> 00:37:06,090
is very different
than the CO₂ in air.

755
00:37:06,123 --> 00:37:08,959
It has a different what we
call isotopic signature.

756
00:37:08,992 --> 00:37:12,129
It's a different kind of
chemical signature if you will.

757
00:37:12,162 --> 00:37:14,531
So trees when they breathe
in the volcanic CO₂,

758
00:37:14,564 --> 00:37:17,501
it becomes part of
their chemistry.

759
00:37:17,534 --> 00:37:21,405
So trees in these systems
are actually made up

760
00:37:21,438 --> 00:37:25,175
of volcanic CO₂ when
they're more exposed.

761

00:37:25,208 --> 00:37:29,079
So they actually keep longterm
records of volcanic CO2

762
00:37:29,112 --> 00:37:30,648
in their wood.

763
00:37:33,317 --> 00:37:35,686
I mentioned that we didn't
have the USGS in there.

764
00:37:35,719 --> 00:37:39,857
What we've been exploring is
we've been developing drones,

765
00:37:39,890 --> 00:37:43,560
a partnership with a
company called Black Swift,

766
00:37:43,593 --> 00:37:45,596
and they have these
drones that can fly

767
00:37:45,629 --> 00:37:49,667
close to the tree tops
and sniff out the CO2

768
00:37:49,700 --> 00:37:51,702
where it's leaking
out of the landscape,

769
00:37:52,636 --> 00:37:55,072
thereby mapping out the CO2

770
00:37:55,105 --> 00:37:58,142
of the larger landscape.

771
00:38:02,879 --> 00:38:05,983
This is also really valuable
not just to me as an ecologist,

772

00:38:06,016 --> 00:38:08,352
but to the volcanologist.

773

00:38:08,385 --> 00:38:11,722
Volcanic CO2 is
an early indicator

774

00:38:11,755 --> 00:38:13,724
of volcanic activity
or eruption.

775

00:38:15,158 --> 00:38:20,097
But they cannot monitor
CO2 on every volcano.

776

00:38:21,098 --> 00:38:23,367
Even in the tropics
they have CO2 monitors

777

00:38:23,400 --> 00:38:24,735
and they get easily damaged.

778

00:38:24,768 --> 00:38:27,504
But if the trees can
act as those sensors,

779

00:38:27,537 --> 00:38:28,872
and not just a
couple of sensors

780

00:38:28,905 --> 00:38:30,574
but thousands of sensors

781

00:38:30,607 --> 00:38:32,309
telling us what the
volcanoes are doing,

782

00:38:32,342 --> 00:38:35,079

this is potentially
a major breakthrough

783
00:38:35,112 --> 00:38:36,980
for the volcanology community.

784
00:38:37,013 --> 00:38:38,782
And I'm not just saying
this as an outsider,

785
00:38:38,815 --> 00:38:41,819
this is words coming from
my volcanology colleagues.

786
00:38:44,888 --> 00:38:48,592
All right, so I've talked
a lot about the tropics,

787
00:38:48,625 --> 00:38:51,228
and that's where a lot
of my interests lie,

788
00:38:51,261 --> 00:38:53,564
but I would remiss not
to talk about the Arctic,

789
00:38:53,597 --> 00:38:55,032
two poles of the carbon cycle.

790
00:38:55,065 --> 00:38:57,801
I'm not gonna talk too much
about it for the sake of time,

791
00:38:57,834 --> 00:39:01,071
but these same
type of techniques,

792
00:39:01,104 --> 00:39:03,741
you know, we've got a
lot of carbon locked up,

793

00:39:03,774 --> 00:39:06,777

methane locked up
that's being released.

794

00:39:06,810 --> 00:39:09,113

The models of course
are all over the place.

795

00:39:09,146 --> 00:39:11,515

This was a paper I
put out on Alaska,

796

00:39:11,548 --> 00:39:12,583

and you can see
different colors

797

00:39:12,616 --> 00:39:15,486

which is basically
each of these Alaskas

798

00:39:15,519 --> 00:39:16,620

are different models.

799

00:39:16,653 --> 00:39:18,222

The point of this
is that almost every

800

00:39:18,255 --> 00:39:20,190

color combination is shown.

801

00:39:20,223 --> 00:39:21,759

It's like a giant
game of Twister

802

00:39:21,792 --> 00:39:23,193

where the models
completely disagree

803

00:39:23,226 --> 00:39:25,896
as to what's going
on in the Arctic.

804
00:39:25,929 --> 00:39:29,933
So NASA's launched this
giant almost 10 year campaign

805
00:39:29,966 --> 00:39:33,137
to really tackle the Arctic,
and I'm a part of that.

806
00:39:33,170 --> 00:39:37,141
I helped write the
study and I'm a PI

807
00:39:37,174 --> 00:39:38,743
on one of the
projects for that.

808
00:39:40,010 --> 00:39:42,112
These airborne capabilities
that I talked about,

809
00:39:42,145 --> 00:39:45,816
we've just flown for the
last two summers in Canada

810
00:39:45,849 --> 00:39:49,620
and Alaska really trying to
tackle the ecosystem responses

811
00:39:49,653 --> 00:39:54,658
to warming and other climate
impacts, but in the Arctic.

812
00:39:57,928 --> 00:40:01,098
Back to this CHANGE diagram.

813
00:40:01,131 --> 00:40:04,334

I mentioned a lot about
the CO2 fertilization.

814
00:40:04,367 --> 00:40:05,803
Plants love CO2.

815
00:40:05,836 --> 00:40:08,872
They'll take up more CO2
if you give them more CO2,

816
00:40:08,905 --> 00:40:13,444
but they also need water
and light and nutrients.

817
00:40:13,477 --> 00:40:15,979
So nutrients is
kind of one of those

818
00:40:16,012 --> 00:40:17,281
things we forget
about with plants.

819
00:40:17,314 --> 00:40:18,882
We always think
to water plants,

820
00:40:18,915 --> 00:40:20,851
and of course they need
light, but nutrients.

821
00:40:20,884 --> 00:40:22,686
And that's the same
with climate models,

822
00:40:22,719 --> 00:40:25,622
it's one of those last things
we've developed in models;

823
00:40:25,655 --> 00:40:27,858
there's a lot to be developed.

824

00:40:27,891 --> 00:40:29,993

So we look at that
CO2 rise again.

825

00:40:30,026 --> 00:40:31,295

What does this mean in terms of

826

00:40:31,328 --> 00:40:33,931

the equation for
photosynthesis?

827

00:40:33,964 --> 00:40:36,667

CO2 being right there
with water and energy

828

00:40:36,700 --> 00:40:41,172

creating oxygen and the CH₂O
is our sugars, or our wood.

829

00:40:42,138 --> 00:40:44,575

So as CO₂ goes up, does
that mean our trees

830

00:40:44,608 --> 00:40:46,343

are continuing to get
bigger and bigger?

831

00:40:46,376 --> 00:40:51,081

So big that they basically
take over our houses?

832

00:40:51,114 --> 00:40:54,485

I mean there's gotta be a limit
to how big these trees get.

833

00:40:55,452 --> 00:40:58,055

The climate models
had originally not had

834

00:40:58,088 --> 00:40:59,923

nutrient limitations in them.

835

00:40:59,956 --> 00:41:03,827

So they were projecting too much CO₂ being taken up.

836

00:41:03,860 --> 00:41:07,464

Plants were too happy in some of the models.

837

00:41:07,497 --> 00:41:09,032

So we started looking at this.

838

00:41:09,065 --> 00:41:13,237

When we put this nitrogen being one of the most

839

00:41:13,270 --> 00:41:15,539

limiting nutrients for plants in the models,

840

00:41:15,572 --> 00:41:17,741

it left a fundamentally altered behavior.

841

00:41:17,774 --> 00:41:20,244

I surveyed my colleagues around the world as to

842

00:41:20,277 --> 00:41:23,080

what processes they were gonna put in their models

843

00:41:23,113 --> 00:41:24,915

over the next five years.

844

00:41:24,948 --> 00:41:29,887

I sized their response by the

frequency of the response.

845

00:41:29,920 --> 00:41:34,492

The most common response across the world was nitrogen.

846

00:41:36,826 --> 00:41:39,563

I've been developing a lot of the nitrogen modeling myself.

847

00:41:39,596 --> 00:41:43,500

There's a lot of mathematics here.

848

00:41:43,533 --> 00:41:45,802

The most important thing with this model

849

00:41:45,835 --> 00:41:47,504

that you should take from this is that

850

00:41:47,537 --> 00:41:50,240

I gave it a really cool name which was FUN,

851

00:41:50,273 --> 00:41:51,909

which is Fixation and Uptake of Nitrogen.

852

00:41:51,942 --> 00:41:54,178

Some I'm literally putting fun into modeling.

853

00:41:56,513 --> 00:41:58,081

Now, again we need these

854

00:41:58,114 --> 00:42:00,717

observational constraints to the models.

855

00:42:00,750 --> 00:42:03,253

One thing that we've
discovered is that

856

00:42:03,286 --> 00:42:06,423

there's this underground
economy associated with plants,

857

00:42:06,456 --> 00:42:08,959

associated with fungi,

858

00:42:08,992 --> 00:42:10,227

mycorrhizal fungi
they're called,

859

00:42:10,260 --> 00:42:13,030

and there's two
dominant types of fungi

860

00:42:13,063 --> 00:42:14,532

that associate with plants,

861

00:42:15,532 --> 00:42:17,067

and they're scattered
throughout the landscape.

862

00:42:17,100 --> 00:42:19,836

Some tree species are
associated with one,

863

00:42:19,869 --> 00:42:22,773

AM, arbuscular, and the
others are associated

864

00:42:22,806 --> 00:42:26,176

with the other, ECM,
ectomycorrhizal.

865

00:42:27,277 --> 00:42:31,181

These fungi go out and get nutrients for the plants.

866

00:42:31,214 --> 00:42:35,018

In exchange, the plants pay them in sugar.

867

00:42:35,051 --> 00:42:37,621

It's a carbon economy for the nutrients.

868

00:42:38,588 --> 00:42:40,891

Now as you can imagine,

869

00:42:40,924 --> 00:42:43,460

some fungi charge more than the others,

870

00:42:43,493 --> 00:42:46,163

and some plants pay more than the others.

871

00:42:46,196 --> 00:42:49,499

So we need to understand this below ground economy

872

00:42:49,532 --> 00:42:51,935

to really understand the nutrient constraints

873

00:42:51,968 --> 00:42:54,104

and functioning of the ecosystems.

874

00:42:54,137 --> 00:42:57,341

So what we've learned is that

875

00:42:57,374 --> 00:43:00,944

these fungi actually

kind of pulse the trees

876

00:43:00,977 --> 00:43:03,313

in different ways
that are visible

877

00:43:03,346 --> 00:43:07,117

to some of the instruments
that we can see from space.

878

00:43:07,150 --> 00:43:10,621

So if we were able to see each
tree species individually,

879

00:43:10,654 --> 00:43:12,589

we'd know which fungi
was associated with it,

880

00:43:12,622 --> 00:43:16,026

but we can't, we can't
see each tree like that.

881

00:43:16,926 --> 00:43:18,261

What we've
found is that

882

00:43:18,294 --> 00:43:19,963

instead of looking
at each tree,

883

00:43:19,996 --> 00:43:24,568

we look at groups of trees
that respond more similarly

884

00:43:24,601 --> 00:43:27,471

to each other than
other groups of trees.

885

00:43:27,504 --> 00:43:31,742

The fungi act like hands to

the trees like they're puppets.

886

00:43:34,244 --> 00:43:36,546

And of course we've gone out
and done a lot of field work.

887

00:43:36,579 --> 00:43:39,516

This is at the top
of the Andes in Peru

888

00:43:39,549 --> 00:43:42,486

looking out into the Amazon
basin in the cloud forest.

889

00:43:42,519 --> 00:43:44,955

I spent four years
in there conducting

890

00:43:44,988 --> 00:43:46,890

a fertilization experiment,

891

00:43:46,923 --> 00:43:48,926

putting nitrogen
and phosphorus down,

892

00:43:50,160 --> 00:43:52,562

and collecting soils and leaves

893

00:43:52,595 --> 00:43:55,966

to really test a lot of
these models and hypotheses.

894

00:43:57,333 --> 00:44:02,072

We're now able to really use
a lot of the remote sensing,

895

00:44:02,105 --> 00:44:06,810

airborne, and ground data to
constrain the nutrient aspects.

896

00:44:06,843 --> 00:44:08,745

We've put these into
the climate models,

897

00:44:08,778 --> 00:44:12,182

so now we have global models
that are now constrained

898

00:44:12,215 --> 00:44:14,951

by nutrients and fungi.

899

00:44:14,984 --> 00:44:18,689

You wouldn't think that
we could see and even care

900

00:44:18,722 --> 00:44:22,192

about fungi when we're
talking about ecosystems

901

00:44:22,225 --> 00:44:25,896

or the global carbon cycle.

902

00:44:30,133 --> 00:44:32,369

Finally, the last
part of the triangle

903

00:44:32,402 --> 00:44:35,806

I'll talk a little
bit about is water.

904

00:44:35,839 --> 00:44:40,343

So we've been interested
in climate and CO₂

905

00:44:40,376 --> 00:44:41,779

and ecosystem response,

906

00:44:43,012 --> 00:44:46,983

but at the end of the day

we're also concerned about us,

907

00:44:47,016 --> 00:44:50,220

people, and what
we need is water,

908

00:44:50,253 --> 00:44:51,955

especially in California,

909

00:44:51,988 --> 00:44:54,091

and we need certainty
in our water,

910

00:44:54,124 --> 00:44:56,460

especially as the
water cycle's changing.

911

00:44:56,493 --> 00:44:58,428

This is all related to climate,

912

00:44:58,461 --> 00:45:00,997

but we need to just
know how much water

913

00:45:01,030 --> 00:45:03,700

we're gonna have and
can we grow our crops,

914

00:45:03,733 --> 00:45:05,936

and when can we thrive
as civilization.

915

00:45:06,803 --> 00:45:11,274

We have this incredible
uncertainty in our water cycle.

916

00:45:11,307 --> 00:45:14,211

The water cycle being
made up of rain and snow

917
00:45:14,244 --> 00:45:15,813
and evapotranspiration.

918
00:45:16,980 --> 00:45:19,282
The surface soil
moisture leading to

919
00:45:19,315 --> 00:45:22,686
the deep ground water storage,
that's that triangle S,

920
00:45:22,719 --> 00:45:24,555
delta S, and the runoff.

921
00:45:25,555 --> 00:45:28,258
So our uncertainty in
our water availability

922
00:45:28,291 --> 00:45:31,528
is tied to each of these
components in the water cycle.

923
00:45:33,029 --> 00:45:36,299
We are now at an age in NASA

924
00:45:36,332 --> 00:45:38,902
and the space community
internationally

925
00:45:38,935 --> 00:45:40,170
where we can observe

926
00:45:40,203 --> 00:45:45,209
every single component of
the water cycle from space,

927
00:45:45,508 --> 00:45:46,810
or about to be from space.

928
00:45:47,911 --> 00:45:49,446
I mentioned that TRMM,

929
00:45:49,479 --> 00:45:51,114
the Tropical Rainfall
Measuring Mission,

930
00:45:51,147 --> 00:45:52,482
that has since died.

931
00:45:52,515 --> 00:45:53,516
We have now launched

932
00:45:53,550 --> 00:45:56,686
a Global Precipitation
Measurement Constellation

933
00:45:56,719 --> 00:46:00,557
in collaboration with space
agencies around the world.

934
00:46:03,259 --> 00:46:06,463
We have some ability
to get snow from space.

935
00:46:06,496 --> 00:46:07,798
We're still working on that.

936
00:46:07,831 --> 00:46:11,802
But JPL has been running an
Airborne Snow Observatory, ASO,

937
00:46:13,136 --> 00:46:15,772
which uses LIDAR, those lasers,

938
00:46:15,805 --> 00:46:18,909
to see how thick
the snowpack is

939
00:46:18,942 --> 00:46:21,144
and also how dark
the snowpack is

940
00:46:21,177 --> 00:46:23,079
because that determines
the melt rate;

941
00:46:23,112 --> 00:46:25,849
darker snow melting
faster than brighter snow.

942
00:46:27,016 --> 00:46:29,319
I've talked a lot about
evapotranspiration.

943
00:46:29,352 --> 00:46:31,421
I won't talk too
much more about that,

944
00:46:31,454 --> 00:46:36,059
but ECOSTRESS is gonna
provide a major breakthrough

945
00:46:36,092 --> 00:46:39,663
in our ability to transcend
scales across the globe.

946
00:46:42,131 --> 00:46:44,835
JPL also launched the SMAP,

947
00:46:44,868 --> 00:46:47,070
the Soil Moisture
Active Passive Mission.

948
00:46:47,103 --> 00:46:48,338
Have you guys heard
of that at all?

949

00:46:48,371 --> 00:46:50,340

It's been out for a
couple of years now.

950

00:46:53,509 --> 00:46:56,146

I used to tell kids
at the open house that

951

00:46:56,179 --> 00:46:58,882

with the active part,
which doesn't work anymore,

952

00:46:58,915 --> 00:47:01,484

it basically is like a
giant finger from the sky

953

00:47:01,517 --> 00:47:03,720

that goes and sticks
its finger in the mud

954

00:47:03,753 --> 00:47:05,989

and comes back and
says, it's this wet.

955

00:47:07,156 --> 00:47:09,292

Now that part doesn't work,

956

00:47:09,325 --> 00:47:10,927

but we have this
passive measurement

957

00:47:10,960 --> 00:47:12,395

that uses light
reflectants to tell us

958

00:47:12,428 --> 00:47:14,264

how much moisture
is in the soil.

959

00:47:17,467 --> 00:47:19,970

There's another
satellite called GRACE.

960
00:47:21,004 --> 00:47:23,607
My colleague Felix Landerer
gave a von Karman talk

961
00:47:23,640 --> 00:47:26,176
I think a few months
ago or some weeks ago

962
00:47:26,209 --> 00:47:29,746
on GRACE Follow-On, which is
continuing this amazing record.

963
00:47:29,779 --> 00:47:33,516
GRACE uses a gravitational
anomaly where

964
00:47:33,549 --> 00:47:36,620
these satellites kind of
get pulled towards the Earth

965
00:47:36,653 --> 00:47:37,921
when there's more mass, right,

966
00:47:37,954 --> 00:47:40,457
'cause more mass
equals more gravity.

967
00:47:40,490 --> 00:47:43,059
So when you have a
lot of groundwater,

968
00:47:43,092 --> 00:47:44,861
it'll get pulled more
towards the Earth.

969
00:47:44,894 --> 00:47:46,763
And if you've sucked

out all the groundwater

970

00:47:46,796 --> 00:47:48,865

'cause you pumped it
out or there's droughts,

971

00:47:48,898 --> 00:47:51,568

next time they fly over
they get pulled less.

972

00:47:51,601 --> 00:47:53,670

So we can actually use
this gravitational anomaly

973

00:47:53,703 --> 00:47:56,006

to figure out how much water
there is in the ground.

974

00:47:56,039 --> 00:48:00,777

They also use this to look at
ice caps and sea level rise.

975

00:48:03,279 --> 00:48:04,981

Then the last component
is river discharge,

976

00:48:05,014 --> 00:48:06,383

how much water's
coming off the rivers.

977

00:48:06,416 --> 00:48:08,218

We actually don't have
this from space yet,

978

00:48:08,251 --> 00:48:09,819

but it will be soon.

979

00:48:09,852 --> 00:48:13,256

The Surface Water Ocean
Topography Mission, SWOT,

980

00:48:13,289 --> 00:48:15,292

again uses those
lasers, the LIDAR,

981

00:48:15,325 --> 00:48:18,361

to measure how tall
those rivers are

982

00:48:18,394 --> 00:48:20,797

and that tells you how
much water's flowing off.

983

00:48:21,898 --> 00:48:23,800

As we start to put
these together,

984

00:48:25,034 --> 00:48:28,805

our uncertainty in the water
cycle starts to come down.

985

00:48:30,840 --> 00:48:32,208

We would never have
zero uncertainty,

986

00:48:32,241 --> 00:48:34,912

but since it's like a cartoon,
I made it come to zero,

987

00:48:36,045 --> 00:48:37,915

but you can get
where this is going.

988

00:48:39,015 --> 00:48:41,685

What's next now is
for us to integrate.

989

00:48:41,718 --> 00:48:45,655

It's about integration and
talking across the missions.

990

00:48:45,688 --> 00:48:48,825

Just like in the International
Space Station those missions,

991

00:48:48,858 --> 00:48:52,262

same with our other missions
that have synergies together

992

00:48:52,295 --> 00:48:54,764

to tell us something about
the Earth's system as a whole

993

00:48:54,797 --> 00:48:56,733

more than the sum of its parts.

994

00:48:57,800 --> 00:49:02,105

So there's been a lot of
droughts worldwide in the US,

995

00:49:02,138 --> 00:49:06,109

in California, affecting
crops, agriculture,

996

00:49:06,142 --> 00:49:08,778

and we were able to pick up
on one of the biggest droughts

997

00:49:08,811 --> 00:49:12,182

in US history
since the Dust Bowl

998

00:49:12,215 --> 00:49:14,284

which happened a few years ago

999

00:49:14,317 --> 00:49:16,286

creating this kind
of bullseye right on

1000

00:49:17,587 --> 00:49:21,725
the Midwest where
almost 80% of our GDP

1001
00:49:21,758 --> 00:49:23,794
was impacted by the drought.

1002
00:49:28,131 --> 00:49:32,502
NASA has stood up a Western
Water Applications Office

1003
00:49:32,535 --> 00:49:37,173
which has a number of
personnel from JPL housed here,

1004
00:49:37,206 --> 00:49:41,111
and we're reaching out to
water resource managers,

1005
00:49:41,144 --> 00:49:46,116
policy makers, farmers,
and trying to make our data

1006
00:49:46,549 --> 00:49:49,953
useful for them in their
decision making process.

1007
00:49:49,986 --> 00:49:52,923
So we're developing
web applications

1008
00:49:55,458 --> 00:49:57,060
and phone apps,

1009
00:49:57,093 --> 00:50:00,263
there's a lot of citizen
science at NASA as well,

1010
00:50:00,296 --> 00:50:04,100
to really enable

society to respond

1011

00:50:04,133 --> 00:50:05,902

to a changing
environment,

1012

00:50:05,935 --> 00:50:07,404

especially with
regards to water.

1013

00:50:11,474 --> 00:50:15,879

So that's a little bit
of what I do here at JPL

1014

00:50:15,912 --> 00:50:20,383

and what my colleagues do here
at JPL and across the world.

1015

00:50:20,416 --> 00:50:25,389

Again, we end with this
fairy tale or this story of

1016

00:50:25,588 --> 00:50:27,257

the princess and the pea.

1017

00:50:27,290 --> 00:50:30,260

We are trying to establish
the true identity,

1018

00:50:30,293 --> 00:50:32,729

the true future of the Earth.

1019

00:50:32,762 --> 00:50:37,333

How are ecosystems
responding in reality

1020

00:50:37,366 --> 00:50:39,002

now and into the future?

1021

00:50:41,671 --> 00:50:43,940

These are some of the take-home points that I hope you

1022

00:50:43,973 --> 00:50:46,476

got from the talk.

1023

00:50:46,509 --> 00:50:49,245

Terrestrial ecosystems exert this dominant force

1024

00:50:49,278 --> 00:50:52,415

in Earth's climate, and they're very complex,

1025

00:50:52,448 --> 00:50:54,517

and that's why we have a lot of uncertainties

1026

00:50:54,550 --> 00:50:57,020

in projections of future responses.

1027

00:50:58,087 --> 00:51:02,158

The projected climate change, particularly in droughts,

1028

00:51:02,191 --> 00:51:04,394

is being borne out in front of our eyes.

1029

00:51:05,928 --> 00:51:09,666

CO2 fertilization sensitivity is a major uncertainty

1030

00:51:09,699 --> 00:51:11,968

in our understanding of ecosystem future responses,

1031

00:51:12,001 --> 00:51:15,004

and we've been developing
innovative technological

1032
00:51:15,037 --> 00:51:17,140
and interdisciplinary
ways to tackle

1033
00:51:17,173 --> 00:51:19,109
this part of the
equation as well.

1034
00:51:20,343 --> 00:51:24,147
NASA, and satellite and
airborne remote sensing

1035
00:51:24,180 --> 00:51:26,683
in general, provides a
deeper understanding

1036
00:51:26,716 --> 00:51:29,953
of ecosystem responses
across the Earth,

1037
00:51:29,986 --> 00:51:32,655
and it enables this reduction
of model uncertainties,

1038
00:51:32,688 --> 00:51:37,594
and can help us improve
societal responses to change.

1039
00:51:37,627 --> 00:51:39,629
Thank you.

1040
00:51:39,662 --> 00:51:43,100
[applauding]

1041
00:51:47,937 --> 00:51:50,707
And I'm happy to
take any questions.

1042

00:51:50,740 --> 00:51:52,041

I think we have
time for questions.

1043

00:51:52,074 --> 00:51:56,112

So if you have any questions,
there's a microphone there,

1044

00:51:56,145 --> 00:51:58,148

'cause they want, they told
me to tell you guys to use

1045

00:51:58,181 --> 00:52:00,049

the microphone.

- Okay.

1046

00:52:00,082 --> 00:52:03,887

- So go line up at the
microphone and pepper away.

1047

00:52:08,724 --> 00:52:10,193

- First, thank you
so much for this.

1048

00:52:10,226 --> 00:52:12,962

I trained with the
former Vice President,

1049

00:52:12,995 --> 00:52:14,531

the honorable Al Gore.

1050

00:52:14,564 --> 00:52:16,332

I'm a climate
reality volunteer.

1051

00:52:16,365 --> 00:52:17,534

- [Josh] Yeah, me too.

1052

00:52:17,567 --> 00:52:20,203
- Fantastic, where's your pin?

1053
00:52:20,236 --> 00:52:22,872
But question is when you
mentioned the lasers,

1054
00:52:22,905 --> 00:52:27,177
can they now measure carbon
emissions in the ice?

1055
00:52:27,210 --> 00:52:28,545
- In the ice?
- Yes.

1056
00:52:31,447 --> 00:52:34,317
- So as carbon
gets released from.

1057
00:52:34,350 --> 00:52:38,354
So, yeah, so it's not using
the lasers or the LIDAR,

1058
00:52:38,387 --> 00:52:42,258
we have other airborne
capabilities that can take,

1059
00:52:42,291 --> 00:52:44,561
that we fly over and
can take air samples,

1060
00:52:44,594 --> 00:52:48,665
and then we measure the
CO2 from those platforms.

1061
00:52:48,698 --> 00:52:52,368
OCO-2 and three and
related satellites

1062
00:52:52,401 --> 00:52:56,372

also can measure the
CO2 in the atmosphere.

1063
00:52:56,405 --> 00:52:59,042
Instead of using lasers,
they use the sun essentially.

1064
00:52:59,075 --> 00:53:01,878
So the sun will bounce
down, hit the Earth,

1065
00:53:01,911 --> 00:53:03,646
and bounce back
through the atmosphere.

1066
00:53:03,679 --> 00:53:06,883
But CO2 absorbs
some of that light,

1067
00:53:06,916 --> 00:53:08,551
so when there's more CO2,

1068
00:53:08,584 --> 00:53:11,621
there's less of that light
hitting the satellite.

1069
00:53:11,654 --> 00:53:13,423
So that's how we get the CO2,

1070
00:53:13,456 --> 00:53:15,792
not just in the
Arctic, but globally.

1071
00:53:15,825 --> 00:53:17,060
- All right, thank
you very much.

1072
00:53:17,093 --> 00:53:18,361
- Did that answer you
question a little bit?

1073

00:53:18,394 --> 00:53:19,729

- Appreciate it, thank you.

1074

00:53:21,831 --> 00:53:26,669

- Hello, are there any
areas in particular

1075

00:53:26,702 --> 00:53:29,939

that are abiotic
that are of interest

1076

00:53:29,972 --> 00:53:34,110

that are not
concerned with biomes?

1077

00:53:36,512 --> 00:53:38,515

- Yeah, so I'm very
much a plant person,

1078

00:53:39,448 --> 00:53:41,417

but I definitely
work with geologist,

1079

00:53:41,450 --> 00:53:44,887

so for instance the
volcanologists in that aspect.

1080

00:53:44,920 --> 00:53:48,324

So my interest in the
abiotic land component

1081

00:53:48,357 --> 00:53:49,459

has been on that.

1082

00:53:49,492 --> 00:53:51,194

I'm also interested in soils,

1083

00:53:51,227 --> 00:53:54,430

but there's always somewhat
of an interaction with plants

1084
00:53:54,463 --> 00:53:56,633
when we're talking about soils.

1085
00:53:58,634 --> 00:54:01,938
But in terms of areas
like deserts or so on

1086
00:54:01,971 --> 00:54:06,743
where there are no plants,
again, there are plants

1087
00:54:06,776 --> 00:54:09,246
kind of everywhere,
even in those deserts.

1088
00:54:10,646 --> 00:54:12,649
Sometimes there are
these rain events,

1089
00:54:12,682 --> 00:54:16,085
and these ecosystems are
adapted to really grow

1090
00:54:16,118 --> 00:54:19,155
and take up a lot of CO₂ when
there are these rain events,

1091
00:54:19,188 --> 00:54:20,690
and we need to be
able to capture that

1092
00:54:20,723 --> 00:54:21,658
and predict that as well.

1093
00:54:21,691 --> 00:54:23,359
I don't know if that
answered your question.

1094

00:54:23,392 --> 00:54:24,827

Did that answer your question?

1095

00:54:24,860 --> 00:54:27,530

- I think you did, thank you.

1096

00:54:27,563 --> 00:54:28,965

- [Josh] Feel free to come
up and talk to me afterwards

1097

00:54:28,998 --> 00:54:30,834

if you wanna.

- Thank you very much.

1098

00:54:33,669 --> 00:54:35,004

- Excellent
presentation, thank you.

1099

00:54:35,037 --> 00:54:38,508

Question, we're all very
familiar on a daily basis

1100

00:54:38,541 --> 00:54:40,276

with weather forecasts,

1101

00:54:40,309 --> 00:54:43,680

and some of us take note
of when they're right

1102

00:54:43,713 --> 00:54:44,814

and when they're wrong,

1103

00:54:44,848 --> 00:54:47,984

but it seems that at least
going about three days out

1104

00:54:48,017 --> 00:54:49,952

we can feel pretty confident

they got a good idea

1105

00:54:49,985 --> 00:54:51,621

about what's happening,
sometimes they're off.

1106

00:54:51,654 --> 00:54:55,058

But beyond that it diverges
wildly with entropy.

1107

00:54:56,492 --> 00:54:58,294

But that means that
as these models

1108

00:54:58,327 --> 00:55:00,630

in weather forecasting improve,

1109

00:55:01,664 --> 00:55:06,670

we can tell almost immediately
if they're any good, right;

1110

00:55:07,002 --> 00:55:09,038

if they say it's gonna
rain and it doesn't rain,

1111

00:55:09,071 --> 00:55:11,974

or if it's really windy
like it was today.

1112

00:55:12,007 --> 00:55:14,711

Can you give us a
little bit of an idea,

1113

00:55:14,744 --> 00:55:17,280

talk a little bit about,
the timeframes that we use

1114

00:55:17,313 --> 00:55:20,283

both what you're trying to
do as far as forecasting,

1115

00:55:20,316 --> 00:55:22,985

is this about knowing
what it's gonna be like

1116

00:55:23,018 --> 00:55:26,456

one season from now, or just
on a 10 year, 20 year model,

1117

00:55:26,489 --> 00:55:31,494

and how have we
been doing recently

1118

00:55:31,827 --> 00:55:34,230

on how that's changed
our accuracy with that?

1119

00:55:34,263 --> 00:55:35,298

- Yeah, absolutely.

1120

00:55:35,331 --> 00:55:38,167

So I know you must
have a lot of questions

1121

00:55:38,200 --> 00:55:39,101

wrapped up in there,

1122

00:55:39,135 --> 00:55:40,536

but these are exactly
the same questions

1123

00:55:40,569 --> 00:55:42,772

we ask ourselves in the
scientific community.

1124

00:55:42,805 --> 00:55:45,875

We've been looking to the
weather forecasting community

1125

00:55:45,908 --> 00:55:48,878
as an analog, as a guide,

1126
00:55:48,911 --> 00:55:50,813
because it didn't
used to be that way

1127
00:55:50,846 --> 00:55:52,115
with weather forecasting.

1128
00:55:52,148 --> 00:55:55,118
They actually had a rigorous,
systematic development

1129
00:55:55,151 --> 00:55:59,122
of their weather models against
key observable benchmarks,

1130
00:55:59,155 --> 00:56:02,358
and structured scoring systems

1131
00:56:02,391 --> 00:56:04,527
that helped improve
the weather models.

1132
00:56:04,560 --> 00:56:07,764
So we are just coming into that

1133
00:56:09,098 --> 00:56:12,068
kind of ability in
the carbon cycle,

1134
00:56:12,101 --> 00:56:14,170
or the rest of the water cycle,

1135
00:56:14,203 --> 00:56:16,873
just talking about the
carbon cycle for now.

1136

00:56:16,906 --> 00:56:21,911

So we're setting up the structure to be able to create

1137

00:56:22,344 --> 00:56:26,215

these forecasts that use these NASA type benchmarks

1138

00:56:26,248 --> 00:56:29,485

that evaluate the models against them

1139

00:56:29,518 --> 00:56:32,088

and improve their predictability

1140

00:56:32,121 --> 00:56:34,290

in the same way that weather models improved

1141

00:56:34,323 --> 00:56:39,295

over their history, and we have to do that.

1142

00:56:39,428 --> 00:56:41,130

With weather, unlike carbon,

1143

00:56:41,163 --> 00:56:44,767

you do kind of need to know every day or within the week.

1144

00:56:44,800 --> 00:56:49,806

Carbon cycle you can be fine with annual time scales.

1145

00:56:50,339 --> 00:56:52,308

So there's this kind of difference as well.

1146

00:56:52,341 --> 00:56:55,278

Weather models, yes, they break
down over a couple of weeks.

1147

00:56:55,311 --> 00:56:56,512

But if you think about it,

1148

00:56:56,546 --> 00:57:00,183

they're actually still pretty
good at an annual time scale

1149

00:57:00,216 --> 00:57:03,986

'cause they kinda know
if the year will be warm

1150

00:57:04,019 --> 00:57:06,222

or hot in a kind of weird way.

1151

00:57:06,255 --> 00:57:11,194

So there is this kind of
predictability based on

1152

00:57:11,227 --> 00:57:13,963

your interest of your
temporal resolution.

1153

00:57:15,898 --> 00:57:17,733

In terms of climate
projections,

1154

00:57:17,766 --> 00:57:18,901

what we're interested
in are like

1155

00:57:18,934 --> 00:57:22,605

more core scale climate
projections, not every day,

1156

00:57:22,638 --> 00:57:26,409

much more five, 10
year time scales.

1157

00:57:29,144 --> 00:57:31,113

In theory, we could drive
it down even further

1158

00:57:31,146 --> 00:57:33,616

if there was a demand for it.

1159

00:57:33,649 --> 00:57:36,119

- Thanks, follow up?

- Yeah.

1160

00:57:37,286 --> 00:57:41,557

- So naturally policy
makers need to see, hey,

1161

00:57:41,590 --> 00:57:44,694

Fritz said it would be
like this, if you will.

1162

00:57:44,727 --> 00:57:46,362

They need to see,

1163

00:57:46,395 --> 00:57:48,931

build confidence by
seeing accuracy in this.

1164

00:57:48,964 --> 00:57:51,934

So would it be accurate to
say that this is almost,

1165

00:57:51,967 --> 00:57:54,770

'cause it sounds almost
like it's in its infancy,

1166

00:57:54,803 --> 00:57:56,339

not the study of the climate,

1167

00:57:56,372 --> 00:57:58,274

but when you talk about all
these different elements

1168
00:57:58,307 --> 00:57:59,642
of finally having the whole

1169
00:58:00,609 --> 00:58:02,879
geological cycle work together.

1170
00:58:02,912 --> 00:58:05,014
Would it be accurate to say
it's almost in its infancy

1171
00:58:05,047 --> 00:58:06,349
trying to work out models?

1172
00:58:06,382 --> 00:58:08,484
Now that we have so much
more information to work with

1173
00:58:08,517 --> 00:58:10,520
that it might be a
while before we'll have

1174
00:58:10,553 --> 00:58:14,290
a timeline that will give
policy makers what they need?

1175
00:58:14,323 --> 00:58:16,626
- Yeah, I mean
you can see that.

1176
00:58:17,493 --> 00:58:20,129
You can see how much
activity there is, right?

1177
00:58:20,162 --> 00:58:22,832
I showed a lot of
activity I'm part of.

1178

00:58:22,865 --> 00:58:24,433

There's even more
as you can imagine.

1179

00:58:24,466 --> 00:58:26,435

So we're definitely developing.

1180

00:58:26,468 --> 00:58:27,770

If you look at the
history of these models,

1181

00:58:27,803 --> 00:58:29,238

they haven't been
around that long.

1182

00:58:29,271 --> 00:58:32,642

So you can, infancy to some,

1183

00:58:32,675 --> 00:58:35,811

you know a whole career
for somebody else.

1184

00:58:35,844 --> 00:58:38,180

My volcanologist works
in geologic time,

1185

00:58:38,213 --> 00:58:40,617

I work in ecological time.

1186

00:58:42,084 --> 00:58:45,488

There's absolutely, we're
not done developing them.

1187

00:58:45,521 --> 00:58:48,858

And I think that there's
this aspect of how much more

1188

00:58:48,891 --> 00:58:51,761

complexly to do we

put into these models

1189

00:58:51,794 --> 00:58:54,831

versus running more
simple models faster.

1190

00:58:55,898 --> 00:58:57,867

At the same time in parallel,

1191

00:58:57,900 --> 00:59:00,736

our computing capabilities
start to come up.

1192

00:59:00,769 --> 00:59:03,406

So sometimes we might
have really great models,

1193

00:59:03,439 --> 00:59:05,341

but our computing
capabilities can't actually

1194

00:59:05,374 --> 00:59:06,943

run the models that well.

1195

00:59:06,976 --> 00:59:08,444

Other times we have
good computing,

1196

00:59:08,477 --> 00:59:10,413

and our models don't
take advantage.

1197

00:59:10,446 --> 00:59:12,615

So there's this
kind of handshake

1198

00:59:12,648 --> 00:59:16,052

between computational
power and model complexity

1199

00:59:16,085 --> 00:59:17,787

in terms of its development.

1200

00:59:17,820 --> 00:59:20,323

In terms of, and again it comes down to your question,

1201

00:59:20,356 --> 00:59:22,992

or the policy maker's question, or my question.

1202

00:59:23,025 --> 00:59:25,761

Am I interested in ecological processes?

1203

00:59:25,794 --> 00:59:28,497

That's actually my main love

1204

00:59:28,530 --> 00:59:33,069

is how do ecosystems function, right?

1205

00:59:33,102 --> 00:59:36,172

But if you're a policy maker, you might wanna know,

1206

00:59:37,539 --> 00:59:39,375

you might wanna know something about CO₂

1207

00:59:39,408 --> 00:59:41,544

or mega storms or whatnot,

1208

00:59:41,577 --> 00:59:43,512

or you might be interested also like me

1209

00:59:43,545 --> 00:59:44,680

in how ecosystems function

1210

00:59:44,713 --> 00:59:47,550

because you wanna know which
trees are gonna die first

1211

00:59:47,583 --> 00:59:49,485

and if your state's gonna
have massive wildfires,

1212

00:59:49,518 --> 00:59:51,887

and how to mobilize,
and things like that.

1213

00:59:51,920 --> 00:59:54,724

So there's different
questions that correspond

1214

00:59:54,757 --> 00:59:56,292

to different types of models

1215

00:59:56,325 --> 00:59:59,095

and required accuracies
as you mentioned.

1216

00:59:59,128 --> 01:00:01,764

That comes back, switching
to the water side,

1217

01:00:01,797 --> 01:00:02,965

to the last bit

1218

01:00:02,998 --> 01:00:04,767

where I mentioned the
water applications.

1219

01:00:04,800 --> 01:00:08,170

They are trying to define
the accuracies required

1220

01:00:08,203 --> 01:00:11,340
by decision makers
in the water realm,

1221
01:00:11,373 --> 01:00:13,542
and whether or not we can
meet them or exceed them

1222
01:00:13,575 --> 01:00:14,810
on the NASA side.

1223
01:00:14,843 --> 01:00:17,179
That helps us drive
our requirements

1224
01:00:17,212 --> 01:00:18,848
both in the observations
and in the models

1225
01:00:18,881 --> 01:00:21,684
to be able to meet
the societal needs.

1226
01:00:21,717 --> 01:00:22,685
- All right, thanks.

1227
01:00:24,620 --> 01:00:27,223
- Hi, thanks for your talk.

1228
01:00:27,256 --> 01:00:30,893
I just wondered, you
touched on nitrogen,

1229
01:00:30,926 --> 01:00:34,931
and my Google alert popped up

1230
01:00:36,165 --> 01:00:37,867
a piece on climate change,

1231

01:00:37,900 --> 01:00:40,569
a piece on nitrogen today
it said that there's

1232
01:00:40,602 --> 01:00:43,105
a very large component
of what we expect to see

1233
01:00:43,138 --> 01:00:47,810
in the amount of nitrogen
in the ecosystem, I guess,

1234
01:00:47,843 --> 01:00:50,579
and terrestrial system
that's not there,

1235
01:00:50,612 --> 01:00:52,948
and they just kind of figured
out where it might be.

1236
01:00:52,981 --> 01:00:54,150
I wondered if you could...

1237
01:00:54,183 --> 01:00:55,518
- [Josh] Yeah, in the
rocks or something.

1238
01:00:55,551 --> 01:00:56,852
- Yeah, do you know anything?

1239
01:00:56,885 --> 01:00:58,421
They said it would
effect models.

1240
01:00:58,454 --> 01:00:59,689
Do you have any idea?

1241
01:00:59,722 --> 01:01:03,159
I didn't quite follow,
but which way it would go?

1242

01:01:04,660 --> 01:01:07,229

- So my buddy Ben Houlton
was the lead author

1243

01:01:07,262 --> 01:01:09,332

of that study up at UC Davis,

1244

01:01:10,299 --> 01:01:12,268

and I just hung out
with him for a bit.

1245

01:01:13,902 --> 01:01:14,837

He's a smart guy.

1246

01:01:14,870 --> 01:01:15,871

I don't want to
say anything bad,

1247

01:01:15,904 --> 01:01:17,873

especially because
I'm being televised.

1248

01:01:17,906 --> 01:01:20,143

[laughing]

1249

01:01:22,811 --> 01:01:26,315

Yeah, so he's coming up
with really good discoveries

1250

01:01:26,348 --> 01:01:29,151

about the nitrogen
and nutrient cycles,

1251

01:01:29,184 --> 01:01:30,486

as well as the rest of us.

1252

01:01:32,588 --> 01:01:33,522

Where I hung out with him was

1253

01:01:33,555 --> 01:01:35,958
at a modeling
workshop at Caltech

1254

01:01:35,991 --> 01:01:37,893
where we were trying to
figure out how to put

1255

01:01:37,926 --> 01:01:40,062
our newest science into
models and whether or not,

1256

01:01:40,095 --> 01:01:42,498
like in my response
to the last question,

1257

01:01:42,531 --> 01:01:46,102
is that complexity
useful to models.

1258

01:01:46,135 --> 01:01:47,803
I mentioned that in
the earlier talk.

1259

01:01:47,836 --> 01:01:49,071
Do we want more soil layers?

1260

01:01:49,104 --> 01:01:50,172
Do we want this aspect?

1261

01:01:50,205 --> 01:01:51,040
Do we want fungi?

1262

01:01:52,007 --> 01:01:54,577
It all just adds
computational demand

1263

01:01:54,610 --> 01:01:56,479

and it slows down our models,

1264

01:01:56,512 --> 01:01:58,180

but maybe it's
really important.

1265

01:01:58,213 --> 01:02:01,450

So these are those questions
that we have to face.

1266

01:02:01,483 --> 01:02:04,653

We're not gonna model every
electron in photosynthesis.

1267

01:02:04,686 --> 01:02:06,989

Maybe we should,
but probably not,

1268

01:02:07,022 --> 01:02:09,425

so we have to make
these decisions.

1269

01:02:09,458 --> 01:02:13,262

It's not obviously
quantifiable.

1270

01:02:13,295 --> 01:02:16,298

I think it comes down to
the previous questions of

1271

01:02:16,331 --> 01:02:18,501

what are your questions,
what are your objectives,

1272

01:02:18,534 --> 01:02:19,935

and what are the
accuracies required

1273

01:02:19,968 --> 01:02:21,103

to meet those objectives,

1274

01:02:21,136 --> 01:02:22,571

and they're different
for different people.

1275

01:02:22,604 --> 01:02:25,775

So something like that
story would relate

1276

01:02:25,808 --> 01:02:27,943

to different types
of questions as well.

1277

01:02:27,976 --> 01:02:29,245

- [Woman] Thank you.

1278

01:02:33,215 --> 01:02:35,718

- All right, I'll take
one more question,

1279

01:02:35,751 --> 01:02:37,553

and then I'll take
a few questions

1280

01:02:37,586 --> 01:02:40,623

from the crazy
internet.

1281

01:02:40,656 --> 01:02:43,626

I'm nervous about this.

[laughing]

1282

01:02:43,659 --> 01:02:46,929

- My question has to do
with the longterm increase

1283

01:02:46,962 --> 01:02:49,165

of carbon dioxide
in the atmosphere.

1284

01:02:49,998 --> 01:02:54,103

A number of years ago I
saw a speaker talk about

1285

01:02:54,136 --> 01:02:56,705

paleolithic times where
he said that the amount

1286

01:02:56,738 --> 01:02:59,275

of carbon dioxide at
that time was 20-50 times

1287

01:02:59,308 --> 01:03:00,509

greater than it is today,

1288

01:03:00,542 --> 01:03:02,678

and I'm wondering if
when we're talking about

1289

01:03:02,711 --> 01:03:04,880

the historical increase
of carbon dioxide

1290

01:03:04,913 --> 01:03:08,617

whether you've included
that in your predictions

1291

01:03:08,650 --> 01:03:10,286

of what's gonna
happen in the future.

1292

01:03:10,319 --> 01:03:12,021

- Yeah, the kind
of paleo record?

1293

01:03:12,054 --> 01:03:14,256

Paleo record's really
value, absolutely.

1294

01:03:14,289 --> 01:03:17,459

I think that we do a lot
of these model evaluations

1295

01:03:17,492 --> 01:03:21,764

against the paleo record,
or the geologic record,

1296

01:03:21,797 --> 01:03:24,133

however you wanna
kinda phrase it.

1297

01:03:24,166 --> 01:03:28,070

It's in some ways easier to
do the past than the present

1298

01:03:28,103 --> 01:03:30,806

or the future, because
we weren't around,

1299

01:03:30,839 --> 01:03:33,042

and we add a lot of complexity.

1300

01:03:33,075 --> 01:03:35,945

So there's very predictable
cycles of how the Earth

1301

01:03:35,978 --> 01:03:40,583

and the climate system operates

1302

01:03:40,616 --> 01:03:43,018

over the history of the Earth
that we have some records

1303

01:03:43,051 --> 01:03:44,787

through paleo record,

1304

01:03:44,820 --> 01:03:48,557

but it's this now time, when
humans came into the picture,

1305

01:03:48,590 --> 01:03:52,328

that has like jolted the signal
out of that historic record.

1306

01:03:54,096 --> 01:03:55,865

That's why a lot of our
interest has been on

1307

01:03:55,898 --> 01:03:57,533

being able to capture
that human element.

1308

01:03:57,566 --> 01:04:00,202

You can imagine how
challenging that is.

1309

01:04:00,235 --> 01:04:05,208

It's not just this is
how much CO₂ we emitted

1310

01:04:05,974 --> 01:04:08,477

and how much are
we going to emit,

1311

01:04:08,510 --> 01:04:11,714

but what's gonna kill
the Amazon first,

1312

01:04:11,747 --> 01:04:15,117

droughts or people chopping
down the Amazon, right?

1313

01:04:15,150 --> 01:04:17,853

And are you gonna be able to
capture that in the models?

1314

01:04:17,886 --> 01:04:21,423

Human behavior and
economics is another beast,

1315

01:04:21,456 --> 01:04:25,060
but there's a whole community
that's focused on that as well

1316

01:04:25,093 --> 01:04:27,229
that handshakes
with my community

1317

01:04:27,262 --> 01:04:29,899
which is a little bit more
biological, physical side.

1318

01:04:31,633 --> 01:04:33,769
I guess that adds a lot
of extra information

1319

01:04:33,802 --> 01:04:35,137
that you probably
weren't asking for,

1320

01:04:35,170 --> 01:04:39,842
but that was kind of
my answer to linking

1321

01:04:39,875 --> 01:04:42,912
that historical record for
the present and the future.

1322

01:04:44,780 --> 01:04:46,682
- And what about
like exoparasites

1323

01:04:46,715 --> 01:04:47,783
like the bark beetle

1324

01:04:47,816 --> 01:04:50,519
is that being included
in the models,

1325

01:04:50,552 --> 01:04:53,455

and what is the overall
global impact of that?

1326

01:04:53,488 --> 01:04:54,757

- Great question!

1327

01:04:54,790 --> 01:04:56,726

We should definitely
do lunch sometime.

1328

01:04:58,293 --> 01:05:00,629

So I mentioned
disturbance, right?

1329

01:05:00,662 --> 01:05:03,132

And I only showed
a picture of fire.

1330

01:05:03,165 --> 01:05:05,834

But when there's a
drought, for example,

1331

01:05:05,867 --> 01:05:09,338

as you can imagine I'm very
much interested in droughts

1332

01:05:09,371 --> 01:05:11,974

having grown up in
California and in my slides,

1333

01:05:12,975 --> 01:05:16,845

it's not necessarily the water
stress that kills the trees,

1334

01:05:16,878 --> 01:05:21,583

it's the infestations,
right, it's the beetles,

1335

01:05:21,616 --> 01:05:24,586

it's the bacteria,
it's the other fungi,

1336

01:05:24,619 --> 01:05:26,322

not the good fungi,
the bad fungi.

1337

01:05:28,423 --> 01:05:33,029

So very critical, and we're
still trying to come to

1338

01:05:34,029 --> 01:05:37,933

grips with how much to include
that complexity in models.

1339

01:05:37,966 --> 01:05:39,068

A lot of the models
do have that,

1340

01:05:39,101 --> 01:05:40,035

but they're kind of more,

1341

01:05:40,068 --> 01:05:41,270

we're not like

1342

01:05:41,303 --> 01:05:43,372

modeling individual
beetles flying around

1343

01:05:43,405 --> 01:05:46,909

or whatever, it's more like
probabilistically speaking

1344

01:05:46,942 --> 01:05:49,144

if plants dry to
a certain extent

1345

01:05:49,177 --> 01:05:52,715

they are more likely

to die because of,

1346

01:05:52,748 --> 01:05:56,285

let's call it,
beetles, or something.

1347

01:05:56,318 --> 01:05:59,421

That's how we kind of
invoke some of this,

1348

01:05:59,454 --> 01:06:01,357

the other disturbances
outside of fire,

1349

01:06:01,390 --> 01:06:03,826

but yeah good question.
- Thank you.

1350

01:06:05,794 --> 01:06:09,098

- Okay, I will take a
few from the internet.

1351

01:06:12,667 --> 01:06:14,103

Ha, okay.

1352

01:06:14,136 --> 01:06:17,072

How much of an impact
could machine learning

1353

01:06:17,105 --> 01:06:21,711

and artificial intelligence
have on future climate models?

1354

01:06:23,311 --> 01:06:25,081

Section nine,
what's section nine?

1355

01:06:26,948 --> 01:06:30,319

Oh, okay, they told me
to say who asked this,

1356

01:06:30,352 --> 01:06:33,155
and I was expecting
like a Twitter handle.

1357

01:06:33,188 --> 01:06:34,723
I don't know, we
have sections at JPL.

1358

01:06:34,756 --> 01:06:36,759
It's like is this one of my
colleagues messing with me?

1359

01:06:36,792 --> 01:06:39,094
[laughing]

1360

01:06:39,127 --> 01:06:41,897
All right, so machine learning
and artificial intelligence,

1361

01:06:41,930 --> 01:06:44,066
I guess I should speak
into one of the cameras.

1362

01:06:44,099 --> 01:06:46,602
This one's not even
looking at me, geez.

1363

01:06:46,635 --> 01:06:49,371
I'm all dressed up and
it's like not even looking.

1364

01:06:49,404 --> 01:06:53,475
Okay, so we are using
machine learning.

1365

01:06:53,508 --> 01:06:56,245
I mentioned to one
of the responses

1366

01:06:56,278 --> 01:06:58,247

that we just had this modeling workshop.

1367

01:06:58,280 --> 01:07:00,149

That was a huge part of our modeling workshop

1368

01:07:00,182 --> 01:07:03,619

was using machine learning.

1369

01:07:03,652 --> 01:07:06,255

So a lot of the models that I talked about actually

1370

01:07:07,422 --> 01:07:11,427

are a little bit biased in my interests,

1371

01:07:11,460 --> 01:07:13,529

which is what we call process modeling.

1372

01:07:13,562 --> 01:07:16,732

I want to understand how something occurs, right?

1373

01:07:16,765 --> 01:07:20,869

It's not that, it's kind of like a model of Newton's apple

1374

01:07:20,902 --> 01:07:24,306

hitting the floor, you could predict it because

1375

01:07:24,339 --> 01:07:27,509

it always hits the ground at a certain time,

1376

01:07:27,542 --> 01:07:29,978
or you could understand
that there's a process

1377
01:07:30,011 --> 01:07:32,214
related to gravity and friction

1378
01:07:32,247 --> 01:07:33,582
and mass and things like that.

1379
01:07:33,615 --> 01:07:35,884
So I'm interest in process.

1380
01:07:35,917 --> 01:07:39,188
Machine learning and
artificial intelligence

1381
01:07:39,221 --> 01:07:43,092
is more in terms of
taking that myriad of data

1382
01:07:43,125 --> 01:07:44,760
and figuring out
signals within it,

1383
01:07:44,793 --> 01:07:46,428
which is certainly helpful,

1384
01:07:46,461 --> 01:07:48,664
at least in terms
of how I use it.

1385
01:07:48,697 --> 01:07:50,065
I do use machine learning.

1386
01:07:50,098 --> 01:07:52,668
I use a lot of neural
networks and so on,

1387

01:07:52,701 --> 01:07:56,004
and data products that
use decision trees

1388
01:07:56,037 --> 01:07:57,372
and other types of
machine learning.

1389
01:07:57,405 --> 01:07:58,641
So they're very valuable.

1390
01:07:59,674 --> 01:08:03,479
The challenge, I guess, is that

1391
01:08:03,512 --> 01:08:07,182
machine learning and AI

1392
01:08:07,215 --> 01:08:10,752
they're trained to
what's available;

1393
01:08:10,785 --> 01:08:12,421
they're trained
to your data set.

1394
01:08:14,022 --> 01:08:16,458
As CO2 and climate

1395
01:08:16,491 --> 01:08:19,028
moves outside of our
existing data set,

1396
01:08:19,794 --> 01:08:24,366
it's not exactly clear how
trustworthy something trained

1397
01:08:24,399 --> 01:08:27,236
to a data set now will
behave in the future

1398

01:08:27,269 --> 01:08:31,207

if there's not something
that's traceable to a process.

1399

01:08:33,275 --> 01:08:34,710

It's definitely a compromise.

1400

01:08:34,743 --> 01:08:36,245

Definitely back and forth.

1401

01:08:36,278 --> 01:08:37,479

I have colleagues
on both sides.

1402

01:08:37,512 --> 01:08:41,650

I use both sides, so I
don't wanna downplay that,

1403

01:08:41,683 --> 01:08:45,421

but that's kind of my
response to that question.

1404

01:08:48,623 --> 01:08:49,592

Anything else?

1405

01:08:51,793 --> 01:08:54,363

All right, well thank you
for your time and attention.

1406

01:08:54,396 --> 01:09:01,303

[applauding]