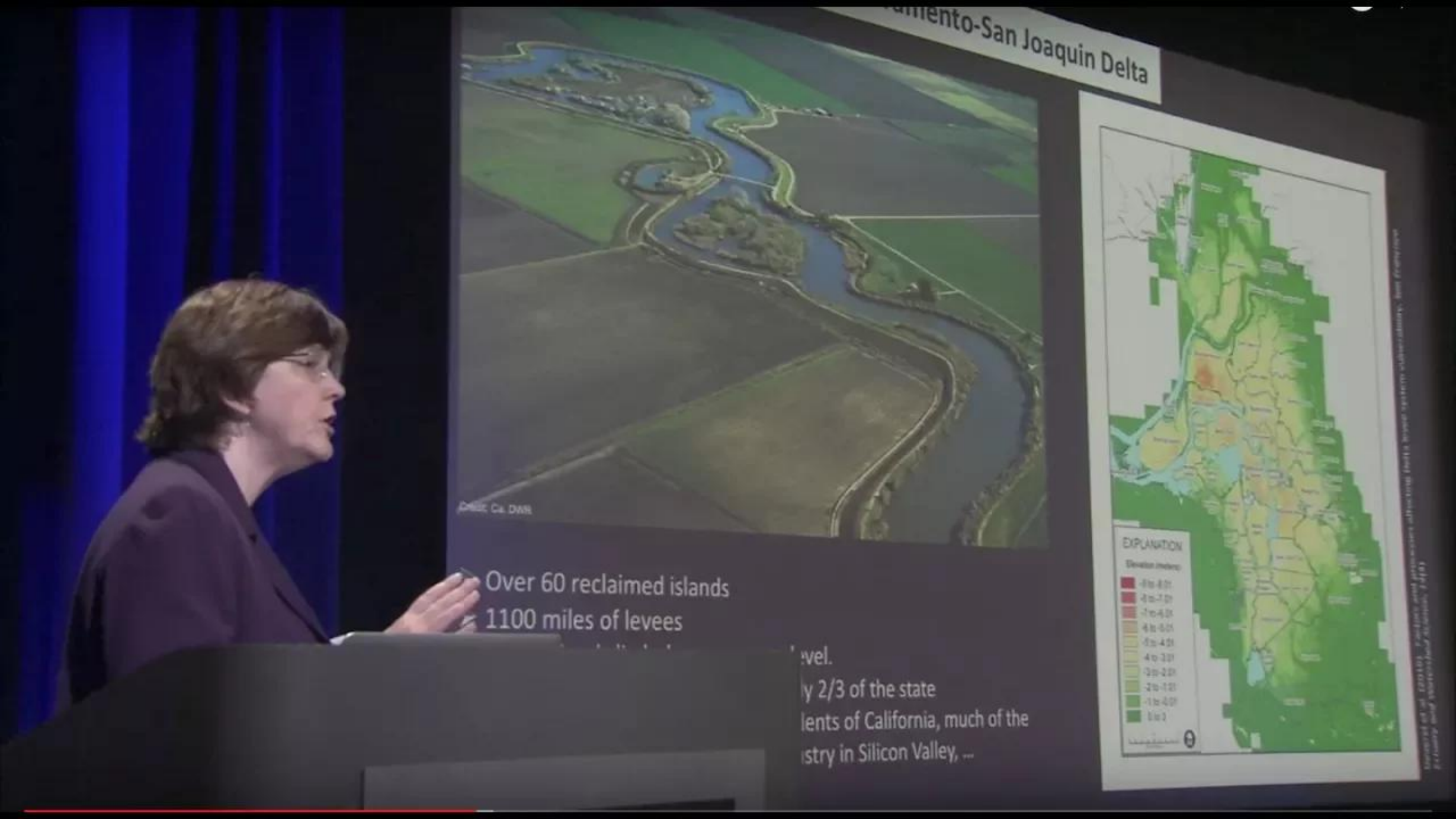
ramento-San Joaquin Delta
Credit: Ca. DWR
Over 60 reclaimed islands
1100 miles of levees
evel.
y 2/3 of the state
lents of California, much of the
istry in Silicon Valley, ...
EXPLANATION

1
00:00:00,600 --> 00:00:01,735
[bright electronic music]

2
00:00:01,768 --> 00:00:04,237
>> Announcer: NASA's Jet
Propulsion Laboratory presents

3
00:00:04,270 --> 00:00:06,239
the von Karman Lecture, a series

4
00:00:06,272 --> 00:00:08,474
of talks by scientists
and engineers

5
00:00:08,507 --> 00:00:12,311
who are exploring our
planet, our solar system,

6
00:00:12,344 --> 00:00:14,414
and all that lies beyond.

7
00:00:26,792 --> 00:00:30,496
>> Good evening, everybody,
how is everyone tonight?

8
00:00:30,529 --> 00:00:31,931
Excellent, good, that's
what we like to hear.

9
00:00:31,964 --> 00:00:33,833
Hope you all like the new chairs

10
00:00:33,866 --> 00:00:36,436
[chuckles] so anyway, shall we?

11
00:00:36,469 --> 00:00:40,239
Among the U.S. states,
California is atypical
in that it has

12
00:00:40,272 --> 00:00:43,576
both highly variable
annual precipitation

13
00:00:43,609 --> 00:00:46,446
as well as a great
disparity between

14
00:00:46,479 --> 00:00:48,815
where and when the
precipitation falls.

15
00:00:48,848 --> 00:00:51,217
To deal with this,
California has a vast array

16
00:00:51,250 --> 00:00:53,820
of infrastructure in place
to store and move water

17
00:00:53,853 --> 00:00:56,589
throughout the state,
much of which also serves

18
00:00:56,622 --> 00:00:58,691
to protect against flooding.

19
00:00:58,724 --> 00:01:00,960
Monitoring and maintaining
this infrastructure

20
00:01:00,993 --> 00:01:04,097
is both critical and
an enormous undertaking

21
00:01:04,130 --> 00:01:07,266
involving local, state,
and federal resources.

22
00:01:07,299 --> 00:01:09,068
Today, most of the
monitoring is done

23
00:01:09,101 --> 00:01:12,772
through visual inspection from
motor vehicles or on foot,

24
00:01:12,805 --> 00:01:14,907
but researchers at JPL
are working to change

25
00:01:14,940 --> 00:01:17,743
that by employing
airborne radar techniques

26
00:01:17,776 --> 00:01:20,713
originally developed
for earth science.

27
00:01:20,746 --> 00:01:23,549
Tonight's talk will
tell us how it's done.

28
00:01:23,582 --> 00:01:25,218
Our guest tonight
is a radar scientist

29
00:01:25,251 --> 00:01:27,987
at NASA's Jet Propulsion
Laboratory where
her main research

30
00:01:28,020 --> 00:01:30,656
is focused on applying
radar remote-sensing

31
00:01:30,689 --> 00:01:32,692
to a variety of hazards.

32
00:01:32,725 --> 00:01:35,795
Her work includes developing
methods to identify threats

33
00:01:35,828 --> 00:01:39,298
to levees, dams, and
aqueducts, measuring subsidence

34
00:01:39,331 --> 00:01:42,835
in New Orleans, tracking and
characterizing oil spills,

35
00:01:42,868 --> 00:01:46,472
and identifying ways in
which the 2010 Gulf oil spill

36
00:01:46,505 --> 00:01:49,842
impacted land loss
in coastal Louisiana.

37
00:01:49,875 --> 00:01:51,644
She has been working
in the radar science

38
00:01:51,677 --> 00:01:55,348
and engineering section
at JPL since 2004

39
00:01:55,381 --> 00:01:57,683
and currently is a
member of the NASA-ISRO

40
00:01:57,716 --> 00:02:01,320
Synthetic Aperture Radar
mission Science Definition Team

41
00:02:01,353 --> 00:02:03,923
leading the
application's subgroup.

42
00:02:03,956 --> 00:02:05,825
Ladies and gentlemen,
please help me welcome

43
00:02:05,858 --> 00:02:08,561
tonight's guest
Dr. Cathleen Jones.

44
00:02:08,594 --> 00:02:11,764
[audience applauding]

45
00:02:17,369 --> 00:02:18,204
>> So

46
00:02:19,605 --> 00:02:22,441
I have to admit that when I
was asked to give this lecture,

47
00:02:22,474 --> 00:02:24,911
I was really concerned
because I know

48
00:02:24,944 --> 00:02:28,814
that the standard for these
lectures is really high

49
00:02:28,847 --> 00:02:31,450
and I don't have
any snazzy videos

50
00:02:31,483 --> 00:02:36,155
of Mars rovers or beautiful
pictures of the moons

51
00:02:36,188 --> 00:02:40,360
but anyway, I think I have
an interesting story to tell

52
00:02:41,527 --> 00:02:45,198

and you might enjoy
it, so NASA does a lot

53
00:02:45,231 --> 00:02:48,334
of earth science and
part of what they do

54
00:02:48,367 --> 00:02:52,004
is applications of earth
science, so figuring out how

55
00:02:52,037 --> 00:02:56,509
to use the techniques that are
developed in order to benefit

56
00:02:56,542 --> 00:03:00,613
society in some way and what
I'm gonna to talk to you today

57
00:03:00,646 --> 00:03:03,249
is about water and what goes on

58
00:03:04,683 --> 00:03:07,220
whenever there's too much
of it or too little of it.

59
00:03:07,253 --> 00:03:09,956
The title of my talk
is Sink or Swim?

60
00:03:09,989 --> 00:03:13,726
Using radar to protect
California's water supply

61
00:03:13,759 --> 00:03:16,696
and that's kind of
a very, actually,

62
00:03:16,729 --> 00:03:18,998
what I do is a little

less than that.

63
00:03:19,031 --> 00:03:22,668
I don't use radar directly
to protect the water supply

64
00:03:22,701 --> 00:03:26,372
but what I use radar
to do is to see things

65
00:03:26,405 --> 00:03:29,008
that are indicative of
the health of the levees

66
00:03:29,041 --> 00:03:31,110
and aqueducts and I'm
gonna explain to you

67
00:03:31,143 --> 00:03:32,812
how I do that today.

68
00:03:34,113 --> 00:03:36,382
Our testbed for developing
these techniques

69
00:03:36,415 --> 00:03:38,918
is here in California
and I work a lot

70
00:03:38,951 --> 00:03:43,923
with the California Department
of Water Resources for this.

71
00:03:43,956 --> 00:03:47,593
So when people
think of California,

72
00:03:47,626 --> 00:03:50,396
maybe they think about
its natural beauty

73
00:03:50,429 --> 00:03:52,865
or they think about
the theme parks.

74
00:03:52,898 --> 00:03:55,268
They almost always
think about Hollywood

75
00:03:55,301 --> 00:03:59,439
and maybe that leads them
to think of NASA or even JPL

76
00:04:00,639 --> 00:04:03,809
or the Mars program but
I'm here to tell you

77
00:04:03,842 --> 00:04:06,812
that that's not what you
should be thinking of

78
00:04:06,845 --> 00:04:10,116
whenever you think
of California.

79
00:04:10,149 --> 00:04:13,486
California is all
about the water, okay?

80
00:04:15,054 --> 00:04:18,958
There's one saying that
exemplifies California.

81
00:04:18,991 --> 00:04:23,162
It's whiskey's for drinking
and water's for fighting

82
00:04:23,195 --> 00:04:27,166
and believe me, that
defines California.

83
00:04:27,199 --> 00:04:29,669
The history of California is one

84
00:04:29,702 --> 00:04:33,039
of amazing technical
achievements

85
00:04:33,072 --> 00:04:36,909
and incredible
political machinations

86
00:04:36,942 --> 00:04:40,446
in order to provide
water for arid regions

87
00:04:41,780 --> 00:04:44,517
and just to show
an example here,

88
00:04:46,285 --> 00:04:50,456
this is a Los Angeles aqueduct
which was built in the 1910s

89
00:04:52,491 --> 00:04:55,528
in order to take water
from the Owens Valley

90
00:04:55,561 --> 00:04:58,264
and supply it to Los Angeles.

91
00:04:58,297 --> 00:05:01,567
This actually engendered
what is known in history

92
00:05:01,600 --> 00:05:06,372
as the Water Wars, there
was a big conflict over this

93

00:05:06,405 --> 00:05:10,576
and pretty much, that's the
history of water in California.

94
00:05:12,144 --> 00:05:15,315
It's contentious so
what's the issues?

95
00:05:17,683 --> 00:05:19,618
Well, let's start
with the weather,

96
00:05:19,651 --> 00:05:22,021
by considering
California's weather.

97
00:05:22,054 --> 00:05:26,092
Well, California has floods;
they have pretty epic floods.

98
00:05:26,125 --> 00:05:29,962
In 1862, there was a
flood that extended from,

99
00:05:31,563 --> 00:05:34,767
it was in Oregon and
extended all the way

100
00:05:34,800 --> 00:05:38,971
through Southern California;
it went on for months.

101
00:05:41,340 --> 00:05:43,809
The entire Central Valley,

102
00:05:43,842 --> 00:05:46,512
300 miles long by 30 miles wide,

103
00:05:47,479 --> 00:05:50,383
was inundated for several months

104
00:05:50,416 --> 00:05:54,854
and people were rowing
down K Street in Sacramento

105
00:05:54,887 --> 00:05:58,624
to get from one government
building to another.

106
00:05:58,657 --> 00:06:02,194
So the reason that
happens in California

107
00:06:02,227 --> 00:06:06,699
is because we get
about 50% of our water

108
00:06:06,732 --> 00:06:10,202
through atmospheric
river events,

109
00:06:10,235 --> 00:06:13,572
and so there's several
atmospheric river events a year

110
00:06:13,605 --> 00:06:17,476
will provide the vast majority
of the water in California,

111
00:06:17,509 --> 00:06:20,679
so this kinda shows
what those events are.

112
00:06:20,712 --> 00:06:23,449
They're also called
the Pineapple Express

113
00:06:23,482 --> 00:06:26,819
because they bring
moisture from the tropics

114
00:06:26,852 --> 00:06:30,189
from here around
Hawaii up to California

115
00:06:31,657 --> 00:06:35,027
and the West Coast
of the United States.

116
00:06:35,060 --> 00:06:38,497
And when they're called
atmospheric rivers,

117
00:06:38,530 --> 00:06:42,134
it's because they carry
the equivalent of water

118
00:06:42,167 --> 00:06:45,805
of the Mississippi River
or even sometimes more

119
00:06:45,838 --> 00:06:48,741
for the big events
and they dump it

120
00:06:49,875 --> 00:06:52,645
on the mountain
ranges in California

121
00:06:52,678 --> 00:06:54,847
and Oregon and Washington.

122
00:06:56,114 --> 00:06:58,951
So that becomes a
source of floods

123
00:07:00,552 --> 00:07:04,457
whenever more than one
happens in close proximity

124
00:07:04,490 --> 00:07:07,160
to each other and 1862 was epic,

125
00:07:08,760 --> 00:07:12,932
but 1997 and even this past
year have had major floods

126
00:07:14,933 --> 00:07:19,638
in California but don't
worry, we have droughts also.

127
00:07:19,671 --> 00:07:23,843
There's a very diverse history
of weather in California.

128
00:07:26,111 --> 00:07:30,283
These spikes are floods and
these troughs are droughts

129
00:07:32,217 --> 00:07:36,655
and we just have come out
of a pretty severe drought.

130
00:07:36,688 --> 00:07:40,860
In 2016, about half of the state
was in the highest category

131
00:07:42,427 --> 00:07:46,565
of drought, which I always
thought that they probably had

132
00:07:46,598 --> 00:07:49,535
to invent this name in
order to add a category

133
00:07:49,568 --> 00:07:51,804
because it's called
exceptional drought.

134

00:07:51,837 --> 00:07:56,408
You'd already had extreme
drought so that was taken

135
00:07:56,441 --> 00:07:59,579
but in 2016, only
this very small part

136
00:08:02,214 --> 00:08:05,518
of California was not in drought

137
00:08:05,551 --> 00:08:08,187
and it was called abnormally dry

138
00:08:08,220 --> 00:08:10,556
so this this was a bad year.

139
00:08:12,758 --> 00:08:16,896
This is Central Valley where
the exceptional drought area

140
00:08:16,929 --> 00:08:20,866
was and this is a farm
in the Central Valley

141
00:08:20,899 --> 00:08:22,401
and a lot of farms

142
00:08:24,870 --> 00:08:27,039
were too dry to be planted

143
00:08:28,373 --> 00:08:31,644
because there weren't sufficient
surface water deliveries

144
00:08:31,677 --> 00:08:34,446
because there just wasn't
sufficient rainfall

145

00:08:34,479 --> 00:08:36,482
in California that year.

146
00:08:37,883 --> 00:08:40,753
But just because there's a
drought one year doesn't mean

147
00:08:40,786 --> 00:08:43,255
there's not can be a
flood to next year.

148
00:08:43,288 --> 00:08:47,460
California also has the most
variable interannual rainfall

149
00:08:48,660 --> 00:08:51,864
of any of the states in
the union, so this shows

150
00:08:51,897 --> 00:08:55,134
Lake Orville in 2005
during the drought

151
00:08:56,602 --> 00:09:00,005
and you can see how
low the reservoir was

152
00:09:00,038 --> 00:09:03,776
but in 2017, 2015, two
years later, in 2017,

153
00:09:07,813 --> 00:09:11,016
the reservoir was full, in
fact, there was problems

154
00:09:11,049 --> 00:09:15,588
where the emergency spillway
was actually came into use

155
00:09:15,621 --> 00:09:20,259

and they had to evacuate
188,000 people downriver

156
00:09:20,292 --> 00:09:24,697
from this one structure,
so that variability

157
00:09:24,730 --> 00:09:27,800
is a problem also in the state.

158
00:09:27,833 --> 00:09:32,237
But the fundamental problem is
that there's a great mismatch

159
00:09:32,270 --> 00:09:35,775
between where and when
precipitation falls

160
00:09:36,642 --> 00:09:39,745
and where and when it's used.

161
00:09:39,778 --> 00:09:43,950
So this map shows that about
75% of this precipitation

162
00:09:45,784 --> 00:09:48,354
occurs in the upper
third of the state

163
00:09:48,387 --> 00:09:52,191
but if you look at where
people live, about,

164
00:09:52,224 --> 00:09:56,395
most of the people live in
the bottom 2/3 of the state,

165
00:09:57,562 --> 00:10:00,065
in fact, 80% of the
water usage occurs

166
00:10:00,098 --> 00:10:03,235
in the lower 2/3 of the state.

167
00:10:03,268 --> 00:10:05,537
And I just wanna point
out several things

168
00:10:05,570 --> 00:10:07,239
about this map here.

169
00:10:08,507 --> 00:10:11,577
The low value here,
this orange value

170
00:10:11,610 --> 00:10:14,747
is under five inches of
precipitation a year.

171
00:10:14,780 --> 00:10:18,284
The high-value up here
is above 120 inches

172
00:10:19,885 --> 00:10:23,722
of precipitation a year,
so whenever somebody says

173
00:10:23,755 --> 00:10:26,225
it's exceptionally
dry down here,

174
00:10:26,258 --> 00:10:28,694
I'm not really
sure what they mean

175
00:10:28,727 --> 00:10:31,797
because [chuckles] it
seems like it's normally

176

00:10:31,830 --> 00:10:35,901
exceptionally dry but
really, droughts that occur

177
00:10:37,369 --> 00:10:41,273
in the northern and the
central part of the state

178
00:10:41,306 --> 00:10:44,577
have a huge impact
on the water supply.

179
00:10:46,178 --> 00:10:49,882
So, most of the
water falls in winter

180
00:10:49,915 --> 00:10:53,719
and it's stored as snowpack in
the mountains and water usage

181
00:10:53,752 --> 00:10:57,523
actually peaks in summer
because of that agriculture use.

182
00:10:57,556 --> 00:11:01,727
Agriculture uses about between
70 and 80% of the water

183
00:11:03,295 --> 00:11:05,564
in the state of California.

184
00:11:06,865 --> 00:11:10,502
So the way that
California deals with this

185
00:11:10,535 --> 00:11:13,472
is through capturing the water

186
00:11:13,505 --> 00:11:17,042
and conveying it

around the state.

187
00:11:17,075 --> 00:11:20,846
They have dams, levees,
canals, aqueducts.

188
00:11:20,879 --> 00:11:25,084
Some of the aqueducts are open
like the South Bay Aqueduct

189
00:11:25,117 --> 00:11:28,687
shown here and some
of them are pipelines

190
00:11:28,720 --> 00:11:31,924
and some of them are
a combination of those

191
00:11:31,957 --> 00:11:36,829
with using different types of
structures in different areas.

192
00:11:36,862 --> 00:11:39,765
Most of them serve a dual use.

193
00:11:39,798 --> 00:11:42,234
They both convey
water around the state

194
00:11:42,267 --> 00:11:45,871
and they also serve
as flood protection

195
00:11:45,904 --> 00:11:50,275
for the land around it and
that's true of the dams

196
00:11:50,308 --> 00:11:53,679
and the levees and the
canals and in some cases,

197
00:11:53,712 --> 00:11:57,216
the aqueducts, and if
you look at this map

198
00:11:59,718 --> 00:12:03,923
which shows the water in
red are the state aqueducts

199
00:12:06,591 --> 00:12:10,562
and yellow are the federal
aqueducts and green

200
00:12:10,595 --> 00:12:14,032
are the local aqueducts
where cities have bought

201
00:12:14,065 --> 00:12:16,502
water supplies on their own.

202
00:12:16,535 --> 00:12:19,471
In the Central Valley, there
are three main aqueducts.

203
00:12:19,504 --> 00:12:22,174
There's the Delta-Mendota Canal,

204
00:12:23,575 --> 00:12:27,112
the East Side Bike Pass and
there's the California Aqueduct.

205
00:12:27,145 --> 00:12:31,317
The California aqueduct is the
granddaddy of all aqueducts.

206
00:12:32,751 --> 00:12:34,520
It is 700 miles long.

207
00:12:36,621 --> 00:12:39,324

It's 30 feet deep on average

208
00:12:39,357 --> 00:12:41,694
and 40 feet wide on average.

209
00:12:42,828 --> 00:12:45,998
It carries over 10,000
gallons per minute

210
00:12:48,967 --> 00:12:50,903
through this structure.

211
00:12:52,337 --> 00:12:55,808
So the California Aqueduct
is a major structure

212
00:12:55,841 --> 00:12:59,311
and a lot of work goes
into maintaining it

213
00:13:02,480 --> 00:13:05,951
but before I move on, I actually
wanna draw your attention

214
00:13:05,984 --> 00:13:08,053
to these blue lines here.

215
00:13:09,454 --> 00:13:12,691
Those are the major rivers
and if you just follow

216
00:13:12,724 --> 00:13:14,760
the pattern of the major rivers,

217
00:13:14,793 --> 00:13:17,563
you see that they
kinda form a funnel

218
00:13:17,596 --> 00:13:21,500

that goes into this
one area and that area

219
00:13:21,533 --> 00:13:24,537
is the Sacramento-San
Joaquin Delta.

220
00:13:26,171 --> 00:13:29,808
So when water managers
around the state

221
00:13:29,841 --> 00:13:32,444
are having their
3:00 a.m. thoughts,

222
00:13:32,477 --> 00:13:34,813
it's a pretty good idea
that they're thinking

223
00:13:34,846 --> 00:13:38,083
about the Sacramento-San
Joaquin Delta.

224
00:13:39,084 --> 00:13:41,687
So the Delta, it collects water

225
00:13:43,521 --> 00:13:47,860
from about 2/3 of the state
and it distributes water

226
00:13:47,893 --> 00:13:50,996
to about 2/3 of the
residents of the state

227
00:13:51,029 --> 00:13:54,499
for a lot of the agriculture
in the Central Valley

228
00:13:54,532 --> 00:13:58,437
and for industry in

Silicon Valley and so on.

229
00:13:58,470 --> 00:14:03,141
A lot of industry uses the
water from the Sacramento Delta.

230
00:14:03,174 --> 00:14:07,345
It was formed around the
late 1800s to early 1900s.

231
00:14:10,415 --> 00:14:13,085
This natural estuary was drained

232
00:14:15,420 --> 00:14:20,158
to form islands that could
be used for agriculture

233
00:14:20,191 --> 00:14:24,229
because the soil was extremely
rich, high peat content,

234
00:14:24,262 --> 00:14:28,066
high carbon content
soil in that area.

235
00:14:28,099 --> 00:14:32,404
There are over 60 reclaimed
islands in this one area.

236
00:14:32,437 --> 00:14:36,175
There's 1,100 miles of
levee in this one area

237
00:14:37,309 --> 00:14:40,112
and most of the
islands in the area

238
00:14:40,145 --> 00:14:43,382
now lie below mean
sea level, in fact,

239
00:14:43,415 --> 00:14:47,452
on this map over here,
only this dark green color

240
00:14:47,485 --> 00:14:51,089
is above mean sea
level and that means

241
00:14:51,122 --> 00:14:53,659
that all of these
areas of islands,

242
00:14:53,692 --> 00:14:57,863
almost every island is below
mean sea level in that area.

243
00:14:59,331 --> 00:15:03,002
And this being the water hub
for the state of California,

244
00:15:04,569 --> 00:15:07,539
maintaining those
levees is a big deal

245
00:15:07,572 --> 00:15:11,443
because if a levee breaks,
then saltwater comes back

246
00:15:11,476 --> 00:15:16,214
in to this area and it reduces
the quality of the water

247
00:15:16,247 --> 00:15:20,919
below the point where it can
be used for human consumption

248
00:15:20,952 --> 00:15:24,957
and it's also in many cases,
not usable by agriculture

249
00:15:24,990 --> 00:15:27,726
because of the
high salt content.

250
00:15:29,861 --> 00:15:33,265
Just to give you a
personal perspective

251
00:15:33,298 --> 00:15:37,469
of what it looks like in
the area, I took this photo

252
00:15:37,502 --> 00:15:40,973
from the top of a levee
on Twitchell Island.

253
00:15:41,006 --> 00:15:43,542
This is the water
and this is the land

254
00:15:43,575 --> 00:15:47,045
and the land is
about 20 feet lower

255
00:15:47,078 --> 00:15:50,015
and that's really not unusual.

256
00:15:50,048 --> 00:15:53,385
Many areas have 30
feet, 20, 25, 30 feet

257
00:15:55,653 --> 00:15:58,324
so it didn't start out this way.

258
00:15:59,424 --> 00:16:02,060
Whenever these
islands were formed,

259

00:16:02,093 --> 00:16:06,265
the land was in equilibrium
with the natural processes

260
00:16:08,466 --> 00:16:12,070
of sediment accumulation
and subsidence

261
00:16:12,103 --> 00:16:15,340
and so all of this
subsidence has occurred

262
00:16:15,373 --> 00:16:18,043
since those islands were formed.

263
00:16:19,144 --> 00:16:22,714
In the Sacramento
Delta, the primary cause

264
00:16:22,747 --> 00:16:26,051
of subsidence is
aerobic oxidation

265
00:16:26,084 --> 00:16:29,321
of the soil, so it's not
groundwater extraction

266
00:16:29,354 --> 00:16:31,523
like it is in some other areas,

267
00:16:31,556 --> 00:16:35,728
actually oxidation of these
high carbon content soil.

268
00:16:37,562 --> 00:16:41,333
There are other processes
at play like compaction

269
00:16:41,366 --> 00:16:44,836
from water withdrawal

but the primary thing

270
00:16:44,869 --> 00:16:48,640
is that whenever you
reduce the water content,

271
00:16:48,673 --> 00:16:51,944
the carbon began to
oxidize off as CO2.

272
00:16:53,311 --> 00:16:56,681
So that's been going on since
these islands are formed

273
00:16:56,714 --> 00:16:59,718
and the net result
is that the higher,

274
00:16:59,751 --> 00:17:02,687
the richer the soil
was at the beginning,

275
00:17:02,720 --> 00:17:05,657
probably the lower
the land is now.

276
00:17:07,926 --> 00:17:11,997
So if that didn't keep
people awake at 3:00 a.m.,

277
00:17:13,531 --> 00:17:16,968
then thinking about the
geological setting of the Delta

278
00:17:17,001 --> 00:17:19,738
certainly will,
here's the Delta.

279
00:17:20,839 --> 00:17:23,509
It's all these

jewel green islands

280
00:17:25,176 --> 00:17:29,948
and here's the Greenville
Fault, here's the Concord Fault,

281
00:17:29,981 --> 00:17:32,851
the Calaveras Fault,
the Hayward Fault,

282
00:17:32,884 --> 00:17:35,420
the San Andreas Fault.

283
00:17:35,453 --> 00:17:38,457
You've got a fault
10 miles, 15 miles,

284
00:17:38,490 --> 00:17:41,159
20 miles, 30 miles,
50 miles away

285
00:17:41,192 --> 00:17:44,229
and they just keep
getting bigger and bigger.

286
00:17:44,262 --> 00:17:46,598
Any rupture, a major rupture

287
00:17:48,533 --> 00:17:52,637
on any of these faults
could cause liquefaction

288
00:17:52,670 --> 00:17:55,841
that causes the levees to fail

289
00:17:55,874 --> 00:18:00,479
and the likelihood is that
in a major earthquake,

290

00:18:00,512 --> 00:18:04,750
you'll have more than one levee
fail in the Sacramento Delta

291
00:18:05,617 --> 00:18:08,087
and so saving the clean water,

292
00:18:11,055 --> 00:18:14,192
the clean water
actually is coming in

293
00:18:14,225 --> 00:18:17,329
from the Sacramento
River in the north

294
00:18:17,362 --> 00:18:20,899
and the water that comes in
and the San Joaquin River

295
00:18:20,932 --> 00:18:24,536
from the South isn't
nearly as high quality

296
00:18:24,569 --> 00:18:28,340
because it's runoff from
these agricultural lands,

297
00:18:28,373 --> 00:18:31,409
has a lot of salts
in it already.

298
00:18:31,442 --> 00:18:34,379
So these channels
through the Delta

299
00:18:35,747 --> 00:18:39,151
don't only protect the
islands from flooding

300
00:18:39,184 --> 00:18:42,154

but they also route
the clean water

301
00:18:42,187 --> 00:18:45,257
from the Sacramento
River through the Delta,

302
00:18:45,290 --> 00:18:47,125
through the east
side of the Delta,

303
00:18:47,158 --> 00:18:50,962
down to pumps that puts the
water into the aqueducts

304
00:18:50,995 --> 00:18:55,734
and sends it south and
west to San Francisco area

305
00:18:55,767 --> 00:18:58,270
and Los Angeles and San Diego.

306
00:18:59,370 --> 00:19:02,707
So there's this delicate
dance that's done

307
00:19:02,740 --> 00:19:06,912
with the control of these
canals in order to prevent

308
00:19:08,546 --> 00:19:12,718
the low-quality water from the
south from interfering with,

309
00:19:14,085 --> 00:19:16,588
from getting into these pumps.

310
00:19:18,022 --> 00:19:21,827
So it is a major source
of concern for the state.

311
00:19:23,461 --> 00:19:27,299
And indeed, levee failures
are not unheard of.

312
00:19:29,767 --> 00:19:33,572
On average, there's
been about slightly less

313
00:19:33,605 --> 00:19:36,108
than one levee failure a year.

314
00:19:37,575 --> 00:19:41,680
It's kind of hard to see here
but these yellow blips up here

315
00:19:42,847 --> 00:19:46,351
are the number of
failures in winter years

316
00:19:47,518 --> 00:19:50,489
from 1900 to 2010,
and there's a few,

317
00:19:53,958 --> 00:19:56,795
not many, but certainly
notable failures

318
00:19:56,828 --> 00:19:59,164
that occurred in summer.

319
00:19:59,197 --> 00:20:04,035
So a lot of these winter
failures or overtoppings

320
00:20:04,068 --> 00:20:07,606
are caused by high
water but in the summer,

321

00:20:07,639 --> 00:20:11,810
that was not the case and
the last serious levee break

322
00:20:13,177 --> 00:20:17,882
that occurred in the Sacramento
Delta was on Jones Tract,

323
00:20:17,915 --> 00:20:20,986
no relation and it
[audience chuckles]

324
00:20:21,019 --> 00:20:23,789
was in 2004 and
this is the canal

325
00:20:26,624 --> 00:20:28,994
and this is the island;
you see the island

326
00:20:29,027 --> 00:20:31,029
is just totally flooded.

327
00:20:32,630 --> 00:20:36,368
In fact, when this end
of the island flooded,

328
00:20:36,401 --> 00:20:39,404
there was a berm that went
across the center of the island

329
00:20:39,437 --> 00:20:41,239
which is then broke and flooded

330
00:20:41,272 --> 00:20:43,708
the other half of the island.

331
00:20:43,741 --> 00:20:47,679
It took about five months
to fully repair this.

332
00:20:49,881 --> 00:20:53,084
The state's water supply
from the Sacramento Delta

333
00:20:53,117 --> 00:20:54,686
was down for weeks.

334
00:20:56,287 --> 00:20:59,491
It took three weeks to
repair the breach here

335
00:20:59,524 --> 00:21:04,229
and then it took about five
months to pump all the water

336
00:21:04,262 --> 00:21:07,732
out of the island and it
cost about $90 million

337
00:21:07,765 --> 00:21:10,935
and that's for one levee break.

338
00:21:10,968 --> 00:21:13,705
So the state worries
about these levees

339
00:21:13,738 --> 00:21:16,241
and they try to maintain them.

340
00:21:17,975 --> 00:21:20,245
So this is where I came in.

341
00:21:22,714 --> 00:21:24,383
It was back in 2007.

342
00:21:25,783 --> 00:21:28,687
I was a new system
engineer at JPL.

343
00:21:30,288 --> 00:21:34,259
I was working on this new
instrument that was being built

344
00:21:34,292 --> 00:21:37,562
for the NASA Airborne
Science Program.

345
00:21:37,595 --> 00:21:41,866
It was a radar, it had nice
properties that I'll talk about

346
00:21:41,899 --> 00:21:46,071
and my colleagues and I
would go and do test flights

347
00:21:48,106 --> 00:21:52,177
around California and the
name of this instrument

348
00:21:53,611 --> 00:21:57,749
is UAVSAR and I'm sure
you notice these portholes

349
00:21:57,782 --> 00:22:00,885
in these windows
in the aircraft.

350
00:22:00,918 --> 00:22:04,522
This is not a UAV; it
was actually designed

351
00:22:04,555 --> 00:22:08,660
so that the radar was in this
pod underneath the aircraft

352
00:22:08,693 --> 00:22:12,664
so it could be popped
off and maybe put on one

353
00:22:12,697 --> 00:22:14,999
of the larger UAVs
but it actually flies

354
00:22:15,032 --> 00:22:16,702
on a Gulfstream III.

355
00:22:18,236 --> 00:22:22,407
And one day in March 2007,
we were collecting data

356
00:22:23,841 --> 00:22:27,479
over San Francisco to look
at some of the faults there

357
00:22:27,512 --> 00:22:31,683
and I noticed this, all
these islands out the window

358
00:22:31,716 --> 00:22:35,420
and I came back and I
looked into what that was

359
00:22:35,453 --> 00:22:40,358
and I realized that this
instrument would be perfect

360
00:22:40,391 --> 00:22:43,828
for looking at the levees
and so the next time

361
00:22:43,861 --> 00:22:47,198
we went out of that area,
I collected a radar image

362
00:22:47,231 --> 00:22:50,569
and the reason that
it's able to be used

363
00:22:52,170 --> 00:22:56,274
is that you can resolve
the levees themselves.

364
00:22:56,307 --> 00:23:00,412
It has high enough
spatial resolution to
resolve the levees.

365
00:23:04,248 --> 00:23:07,919
If you can resolve the levees
and monitor their condition

366
00:23:07,952 --> 00:23:11,956
from remote-sensing, then
there's many advantages,

367
00:23:11,989 --> 00:23:16,027
obvious advantages over
doing this from the ground.

368
00:23:16,060 --> 00:23:20,899
The first is that you can,
this plane flies pretty fast.

369
00:23:20,932 --> 00:23:24,235
You can look at the entire
Delta in a few hours.

370
00:23:24,268 --> 00:23:27,505
That means you can get a
snapshot of the conditions

371
00:23:27,538 --> 00:23:32,310
at one time, driving around
and looking at 1,100 miles

372
00:23:32,343 --> 00:23:36,648
of levees does not happen in
a day or an hour or two hours.

373
00:23:36,681 --> 00:23:38,983
So this allows you
to get a snapshot

374
00:23:39,016 --> 00:23:42,654
and go back and do
frequent imagings.

375
00:23:42,687 --> 00:23:46,491
Also, it provides a
consistent monitoring

376
00:23:46,524 --> 00:23:48,427
across all of the area.

377
00:23:50,595 --> 00:23:54,699
The levees in the Sacramento
Delta are maintained

378
00:23:56,901 --> 00:24:00,705
by the owners with
funding from the state

379
00:24:00,738 --> 00:24:04,042
but the owners, there's
a lot of variance

380
00:24:04,075 --> 00:24:08,012
between the engineering
firms and what kind

381
00:24:08,045 --> 00:24:10,982
of instrumentation they
use to monitor the levees.

382
00:24:11,015 --> 00:24:15,086
There's not a consistent
method for surveying

383
00:24:15,119 --> 00:24:18,590
or keeping track of what's
going on in those levees.

384
00:24:18,623 --> 00:24:22,794
And also, it's just
difficult to access some

385
00:24:22,827 --> 00:24:26,197
of these levees, some
of these islands,

386
00:24:26,230 --> 00:24:29,701
you only get to through by a
ferry that runs a few times

387
00:24:29,734 --> 00:24:32,404
a day and also most importantly,

388
00:24:35,506 --> 00:24:39,711
radar can do things that you
can't do with the human eye.

389
00:24:41,145 --> 00:24:45,083
And a lot of that could be
very useful in an emergency.

390
00:24:46,284 --> 00:24:48,987
So just what's so
cool about UAVSAR?

391
00:24:52,890 --> 00:24:56,327
Well, it has to
be able to do more

392
00:24:56,360 --> 00:24:58,663
than just image the levees.

393
00:24:58,696 --> 00:25:02,567

It's got to be able to
measure something quantitative

394
00:25:02,600 --> 00:25:05,403
that relates to the
health of the levee

395
00:25:05,436 --> 00:25:09,240
in order to be useful because
we don't want to use it

396
00:25:09,273 --> 00:25:11,876
after the levee failed
when an image will tell you

397
00:25:11,909 --> 00:25:14,746
where the levee failed, we
probably already know that.

398
00:25:14,779 --> 00:25:18,216
We want to use it to tell
where problem spots are

399
00:25:18,249 --> 00:25:22,153
before a levee fails,
so let me just tell you

400
00:25:22,186 --> 00:25:25,023
a little bit about
the instrument.

401
00:25:25,056 --> 00:25:29,227
It's actually a radar,
side-looking radar and it hangs

402
00:25:30,561 --> 00:25:33,898
on this pod that's
mounted below the fuselage

403
00:25:33,931 --> 00:25:38,102

of the Gulfstream III,
the antenna is on one side

404
00:25:38,135 --> 00:25:40,638
and all the electronics
that controls it

405
00:25:40,671 --> 00:25:42,974
on the other side in the pod.

406
00:25:43,007 --> 00:25:45,777
It operates at
what's called L-band.

407
00:25:45,810 --> 00:25:50,148
That means it has about
a 10-inch wavelength,

408
00:25:50,181 --> 00:25:53,518
microwave wavelength,
and the advantage of that

409
00:25:53,551 --> 00:25:57,422
is that with that long a
wavelength, you can see through

410
00:25:57,455 --> 00:26:00,692
most vegetation, so that
you're not measuring the top

411
00:26:00,725 --> 00:26:02,694
of the vegetation; you're
measuring what's happening

412
00:26:02,727 --> 00:26:06,130
on the ground below
the vegetation.

413
00:26:06,163 --> 00:26:09,934
It's got really high

spatial resolution,

414
00:26:09,967 --> 00:26:14,339
something like 5.5 feet
by 3.5 feet pixel size

415
00:26:14,372 --> 00:26:17,308
for the instrument
resolution and it operates

416
00:26:17,341 --> 00:26:21,446
from 41,000 feet above
most traffic, air traffic,

417
00:26:22,647 --> 00:26:24,849
so it has a really
wide swath width.

418
00:26:24,882 --> 00:26:29,053
It's got a 22-kilometer
or 14-mile swath width

419
00:26:29,086 --> 00:26:33,258
so you're picking up
your imaging a lot
of area at one time.

420
00:26:34,825 --> 00:26:38,196
It moves, it really goes
along at a clip about

421
00:26:38,229 --> 00:26:41,499
490 miles per hour
and it's what I call

422
00:26:44,568 --> 00:26:49,107
a happy marriage between the
aircraft and the instrument.

423
00:26:49,140 --> 00:26:52,443

The instrument tells
the aircraft what to do

424
00:26:52,476 --> 00:26:55,913
and the aircraft does
it; it's perfect.

425
00:26:55,946 --> 00:27:00,051
So the instrument tracks
the aircraft position

426
00:27:00,084 --> 00:27:03,354
and controls the
flaps of the aircraft

427
00:27:03,387 --> 00:27:08,259
so it flies a repeat tube and
it flies the same position

428
00:27:08,292 --> 00:27:11,329
to an accuracy of about 16 feet,

429
00:27:11,362 --> 00:27:15,467
so about five-meter
accuracy, and what you can do

430
00:27:16,834 --> 00:27:20,472
with that is something
called radar interferometry

431
00:27:22,139 --> 00:27:24,976
where you can use
the radar pulses

432
00:27:25,876 --> 00:27:28,546
to measure surface deformation

433
00:27:28,579 --> 00:27:32,850
and the way it works is kind
of schematically shown here.

434
00:27:32,883 --> 00:27:36,587
So on the first pass,
the aircraft goes over.

435
00:27:36,620 --> 00:27:38,289
It sends out pulses.

436
00:27:39,423 --> 00:27:42,126
They scatter from
the surface down here

437
00:27:42,159 --> 00:27:46,564
and whenever they come back,
you measure the amplitude

438
00:27:46,597 --> 00:27:50,034
of the signal that comes back
and you measure where it is

439
00:27:50,067 --> 00:27:53,671
in that wavelength,
and that relates

440
00:27:53,704 --> 00:27:57,508
to the distance to the
ground but you only know

441
00:27:57,541 --> 00:28:00,912
the distance to the ground to
that kind of wavelength scale,

442
00:28:00,945 --> 00:28:02,980
so you're only measuring,
you're not really

443
00:28:03,013 --> 00:28:05,383
measuring the distance
to the ground.

444
00:28:05,416 --> 00:28:07,919
You're tracking a
phase along here

445
00:28:07,952 --> 00:28:11,456
so you'd get a first image
and then you come along

446
00:28:11,489 --> 00:28:15,860
and you image a second
time and the grounds moved

447
00:28:15,893 --> 00:28:19,030
and now, this is gonna
scatter down here.

448
00:28:19,063 --> 00:28:23,334
It adds a distance and
so the phase changes

449
00:28:23,367 --> 00:28:27,438
and the amount that the phase
changes is related directly

450
00:28:27,471 --> 00:28:30,408
to the change in the
distance to the ground

451
00:28:30,441 --> 00:28:34,879
along that line of
sight, so now you can map

452
00:28:34,912 --> 00:28:39,684
the ground movement
that occurred between
these two passes.

453
00:28:39,717 --> 00:28:43,488
You can get a deformation
map of the surface.

454
00:28:44,355 --> 00:28:46,357
So I just wanna show you

455
00:28:50,227 --> 00:28:54,298
a demonstration of
what an interferogram,

456
00:28:54,331 --> 00:28:58,936
that's what we call that color
fringe picture, tells you.

457
00:28:58,969 --> 00:29:03,541
So this is a picture of
the San Andreas Fault.

458
00:29:03,574 --> 00:29:06,410
It's in Central California,
north of Park Field.

459
00:29:06,443 --> 00:29:08,713
It's in the creeping
section of the fault

460
00:29:08,746 --> 00:29:12,016
and the San Andreas Fault
runs right along here.

461
00:29:12,049 --> 00:29:15,319
This is a radar
image from UAVSAR.

462
00:29:15,352 --> 00:29:18,723
I think it's beautiful but
I've been told by other people

463
00:29:18,756 --> 00:29:22,894
that this is not a
terribly interesting image.

464
00:29:22,927 --> 00:29:26,697
You can see certain things;
you can see individual trees,

465
00:29:26,730 --> 00:29:29,467
so we've got really
good resolution

466
00:29:29,500 --> 00:29:33,671
but now let's compare
this intensity image

467
00:29:33,704 --> 00:29:35,640
with the interferogram.

468
00:29:37,041 --> 00:29:41,079
Wow, now we know that there
are three slow creep landslides

469
00:29:42,613 --> 00:29:45,583
within this one small area.

470
00:29:45,616 --> 00:29:49,788
This one image, interferogram,
tells us the location

471
00:29:51,188 --> 00:29:54,992
and the outline and how much
each of those areas has moved

472
00:29:55,025 --> 00:29:58,296
between the two imaging times.

473
00:29:58,329 --> 00:30:02,167
So that's what I wanted
to apply to the levees

474
00:30:04,034 --> 00:30:07,205
in the Sacramento

Delta, in this case,

475
00:30:08,606 --> 00:30:12,243
this is a very broad area, this
is a really large landslide

476
00:30:13,777 --> 00:30:17,715
so I'm looking for much,
much smaller features.

477
00:30:19,049 --> 00:30:22,954
So in 2008, I put in a proposal
to NASA Applied Science,

478
00:30:24,588 --> 00:30:29,193
which was funded in order
to do a pilot study,

479
00:30:29,226 --> 00:30:32,330
just a feasibility study, to
see if we could really see

480
00:30:32,363 --> 00:30:36,534
motion on the levees, it's
been going on since 2009.

481
00:30:39,270 --> 00:30:43,574
It was initially funded
by NASA and more recently,

482
00:30:43,607 --> 00:30:45,676
it's been funded by
California Department

483
00:30:45,709 --> 00:30:49,547
of Water Resources, with
whom we work very closely

484
00:30:49,580 --> 00:30:53,851
in providing data on what's

going on in the Delta.

485
00:30:53,884 --> 00:30:57,889
So we've had about 55
acquisitions and we image,

486
00:30:59,089 --> 00:31:02,493
we fly along and
we collect swaths

487
00:31:02,526 --> 00:31:06,664
in kind of a racetrack pattern
so we go back and forth

488
00:31:06,697 --> 00:31:10,034
and look at, that way
we image every levee

489
00:31:10,067 --> 00:31:13,771
from multiple directions so
that if that line of sight

490
00:31:13,804 --> 00:31:17,208
movement is along the
slope, we can tell.

491
00:31:19,243 --> 00:31:23,047
There's a lot of things that
can go wrong with levees

492
00:31:23,080 --> 00:31:26,150
that you would hope
to be able to monitor

493
00:31:26,183 --> 00:31:29,820
with remote-sensing and I
just wanted to talk to you

494
00:31:29,853 --> 00:31:33,257
a little bit about the

kinds of things that happen

495
00:31:33,290 --> 00:31:35,493
and the kinds of
things that happen

496
00:31:35,526 --> 00:31:38,462
specifically in the
Sacramento Delta.

497
00:31:38,495 --> 00:31:42,667
Well, there's seeps and when
the seeps carry material,

498
00:31:44,068 --> 00:31:47,571
they're called sand boils;
this is a sand boil.

499
00:31:47,604 --> 00:31:51,776
There's cracks and slumps
and erosion along the side.

500
00:31:54,812 --> 00:31:58,983
This is a slump where you just
have a failure of the slope.

501
00:32:01,151 --> 00:32:05,022
This is a a slope where
you have that slow creep

502
00:32:05,055 --> 00:32:09,660
that doesn't show up as
a failure but it shows up

503
00:32:09,693 --> 00:32:13,264
as very slow deformation
of poles or things

504
00:32:14,965 --> 00:32:17,535
that are put out in this area.

505
00:32:17,568 --> 00:32:20,604
You can get cracks where
the levee just, you know,

506
00:32:20,637 --> 00:32:22,440
one of the slope just pulls away

507
00:32:22,473 --> 00:32:26,410
from the center line, and
you can get subsidence.

508
00:32:26,443 --> 00:32:30,615
Broad area subsidence causes
the levees to go down also

509
00:32:31,982 --> 00:32:35,720
and that raises the
potential for overtopping.

510
00:32:35,753 --> 00:32:39,323
This is a a road and you can
kinda see this dip over here

511
00:32:39,356 --> 00:32:43,728
where subsidence has caused
the levee to be lower

512
00:32:43,761 --> 00:32:46,931
in that one spot
and I point this out

513
00:32:46,964 --> 00:32:49,967
because it kinda shows
the whole challenge

514
00:32:50,000 --> 00:32:53,671
of working in the
Sacramento Delta.

515
00:32:53,704 --> 00:32:57,875
The soils there are so
heterogeneous that they just,

516
00:32:59,910 --> 00:33:04,215
you will get subsidence
that's dramatically different

517
00:33:04,248 --> 00:33:08,186
in one area from a really
closely adjacent area

518
00:33:09,586 --> 00:33:13,691
and so the levee might be
fine here or around the corner

519
00:33:13,724 --> 00:33:16,627
but it doesn't look
so great there.

520
00:33:18,028 --> 00:33:21,298
And the Sacramento Delta,
the speed limit on the levees

521
00:33:21,331 --> 00:33:23,701
is really should
be taken seriously

522
00:33:23,734 --> 00:33:25,970
because potential problems.

523
00:33:28,539 --> 00:33:32,710
So the challenge with
looking for problems on earth

524
00:33:35,746 --> 00:33:39,683
and levees this is
demonstrated in this photo.

525

00:33:39,716 --> 00:33:44,622
This is a photo of the most
rapidly subsiding levee

526
00:33:44,655 --> 00:33:47,291
in the Sacramento
Delta, it's showing

527
00:33:47,324 --> 00:33:50,528
the most rapid movement
and I'm just gonna let you

528
00:33:50,561 --> 00:33:53,431
look at it for a second
and see if you can tell

529
00:33:53,464 --> 00:33:56,467
what's wrong with this levee.

530
00:33:56,500 --> 00:34:00,204
Because people would
have to spot it driving.

531
00:34:02,639 --> 00:34:06,811
So there's a crack and that
crack is about four inches wide.

532
00:34:09,079 --> 00:34:11,282
You practically have
to step in the crack

533
00:34:11,315 --> 00:34:15,753
in order to find it, but it
runs the length of this levee.

534
00:34:15,786 --> 00:34:19,290
So the levee here
is pulling away

535
00:34:19,323 --> 00:34:22,660

and really, you have
to be walking there

536
00:34:25,362 --> 00:34:28,065
or you have to use a
remote-sensing technique

537
00:34:28,098 --> 00:34:32,270
in order to see this in
any readily accessible way.

538
00:34:35,906 --> 00:34:39,443
So, I'm gonna show you
the results that we got

539
00:34:39,476 --> 00:34:42,980
from remotely sensing
the surface displacement

540
00:34:43,013 --> 00:34:45,783
on that levee, so
that photo was taken

541
00:34:45,816 --> 00:34:48,819
from approximately here
looking in this direction

542
00:34:48,852 --> 00:34:51,088
so the cracks ran along here.

543
00:34:51,121 --> 00:34:54,725
This is a surface deformation
pattern in that area

544
00:34:54,758 --> 00:34:58,028
and the different
colors correspond

545
00:34:58,061 --> 00:35:02,233
to different subsidence rates

so downward movement rates

546
00:35:03,634 --> 00:35:07,905
on the levee and that shows
that those cracks formed

547
00:35:07,938 --> 00:35:10,775
where there was a
stress that was,

548
00:35:11,942 --> 00:35:14,812
differential subsidence
was causing the levee

549
00:35:14,845 --> 00:35:17,115
to pull apart in that area.

550
00:35:18,182 --> 00:35:21,318
So we've done similar
things looking

551
00:35:21,351 --> 00:35:25,523
for other potential problem
spots and I show you this map

552
00:35:27,090 --> 00:35:29,760
that where we've just identified

553
00:35:29,793 --> 00:35:33,931
the most rapidly moving areas
that are within about 500 feet

554
00:35:33,964 --> 00:35:37,735
of the crown of the
levee and I show you this

555
00:35:39,136 --> 00:35:43,141
because it looks like there's
a lot of really bad spots

556
00:35:44,508 --> 00:35:46,844
on this island; this
is Jersey island.

557
00:35:46,877 --> 00:35:49,446
It's in the western
part of the Delta

558
00:35:49,479 --> 00:35:54,118
and we're looking at the
western end of Jersey Island

559
00:35:54,151 --> 00:35:58,322
but by working with the state,
we learn which areas are,

560
00:36:01,325 --> 00:36:03,727
they assess from a map like this

561
00:36:03,760 --> 00:36:06,230
which areas are
probably a problem

562
00:36:06,263 --> 00:36:09,667
and which areas
are probably not.

563
00:36:09,700 --> 00:36:12,803
So for instance,
this area is a levee

564
00:36:13,971 --> 00:36:17,107
that was relatively
recently repaired

565
00:36:17,140 --> 00:36:20,678
and when they repair the levee,
they add a lot of material

566

00:36:20,711 --> 00:36:25,249
and they pack it down and
so they load the levee.

567
00:36:25,282 --> 00:36:30,187
It adds a load to the levee
and it begins to subside,

568
00:36:30,220 --> 00:36:34,392
compressing the soils that
are underneath the levee.

569
00:36:35,892 --> 00:36:38,596
And that's really not a
problem because they account

570
00:36:38,629 --> 00:36:41,599
for the fact how much
material they put on,

571
00:36:41,632 --> 00:36:44,635
accounts for the fact that
it's gonna subside some.

572
00:36:44,668 --> 00:36:48,639
But this is an area where
there was a levee break

573
00:36:48,672 --> 00:36:52,376
in the past and there, you
might be having seepage

574
00:36:52,409 --> 00:36:56,581
or some other phenomenon and
over here is another area

575
00:36:57,881 --> 00:37:02,219
where subsidence that
appears to be centered

576

00:37:02,252 --> 00:37:06,357
in a field inland appears
to also be encroaching

577
00:37:06,390 --> 00:37:10,461
on the levee, so I've been
working with the state

578
00:37:14,665 --> 00:37:19,436
in the Sacramento Delta
and during when the drought

579
00:37:19,469 --> 00:37:23,774
happened, the people,
the engineering group

580
00:37:23,807 --> 00:37:26,610
that's responsible for
operations and maintenance

581
00:37:26,643 --> 00:37:29,847
of the California
aqueduct came to JPL

582
00:37:29,880 --> 00:37:34,051
and talked to several people
and I showed them the results

583
00:37:35,185 --> 00:37:38,689
from the Sacramento
Delta and they could see

584
00:37:38,722 --> 00:37:41,892
that with the kind of
resolution that we were getting,

585
00:37:41,925 --> 00:37:45,062
that perhaps they
could use it to tell

586

00:37:45,095 --> 00:37:48,565
whether there was an issue
with the California Aqueduct.

587
00:37:48,598 --> 00:37:51,602
Now they thought, it was
2014, so they thought

588
00:37:51,635 --> 00:37:53,937
that there was
potentially an issue,

589
00:37:53,970 --> 00:37:56,140
going to be an issue because
they were in the middle

590
00:37:56,173 --> 00:37:59,943
of a drought and when
there's a drought,

591
00:37:59,976 --> 00:38:02,613
there's increased
groundwater pumping

592
00:38:02,646 --> 00:38:05,416
and when there's increased
groundwater pumping,

593
00:38:05,449 --> 00:38:08,185
there's very
frequently subsidence,

594
00:38:08,218 --> 00:38:11,989
particularly in the Central
Valley of California.

595
00:38:12,022 --> 00:38:15,026
So the reason is
because groundwater

596

00:38:18,061 --> 00:38:21,732
is kind of the fallback
that the farmers use

597
00:38:24,401 --> 00:38:28,272
whenever surface water
supplies are decreased

598
00:38:28,305 --> 00:38:32,943
so they make up a shortfall
through using groundwater.

599
00:38:32,976 --> 00:38:36,280
And in a typical year,
something like, average year,

600
00:38:36,313 --> 00:38:39,216
40% of the water
demand would be met

601
00:38:39,249 --> 00:38:42,619
through groundwater
withdrawal but in a dry year,

602
00:38:42,652 --> 00:38:46,657
it could go much higher
than that, 60% or even more

603
00:38:46,690 --> 00:38:50,361
for some individual
areas so we were looking

604
00:38:52,829 --> 00:38:57,001
at these two groundwater
basins and what was going on

605
00:38:57,934 --> 00:39:00,137
in this stretch along here.

606
00:39:02,305 --> 00:39:06,310

So subsidence is not new
to the Central Valley.

607
00:39:08,478 --> 00:39:12,149
It's been going on for
as long as the people

608
00:39:13,083 --> 00:39:15,018
have been farming there.

609
00:39:15,051 --> 00:39:18,889
This poll shows the
surface elevation in 1925,

610
00:39:20,390 --> 00:39:22,960
1955, 1977, so this was not new

611
00:39:27,364 --> 00:39:30,701
and this is a USGS
scientist Joe Poland.

612
00:39:33,537 --> 00:39:37,708
More recently, another USGS
scientist Michelle Sneed

613
00:39:39,810 --> 00:39:43,747
has kinda updated this
poll with what's happening

614
00:39:43,780 --> 00:39:47,952
recently to show that the
land has basically subsided

615
00:39:49,052 --> 00:39:52,223
her height since
between 1988 and 2013.

616
00:39:58,195 --> 00:40:02,633
So what happens whenever you
have groundwater withdrawal

617
00:40:02,666 --> 00:40:06,837
that causes subsidence is
kind of outlined over here.

618
00:40:08,271 --> 00:40:12,576
Normally, you'll have, in
an aquifer, you'll have sand

619
00:40:12,609 --> 00:40:16,413
and gravel and the water
is stored in the pores

620
00:40:16,446 --> 00:40:20,618
between the little individual
particles of sand and gravel

621
00:40:22,085 --> 00:40:25,189
and then there's also
what are called aquitards

622
00:40:25,222 --> 00:40:29,393
which are layers of clay and
silt and they're interspersed

623
00:40:30,861 --> 00:40:34,298
with the sand and gravel layers.

624
00:40:34,331 --> 00:40:38,502
And when you withdraw
water, then the land surface

625
00:40:40,036 --> 00:40:43,740
does go down because
you get some compaction

626
00:40:43,773 --> 00:40:47,478
from withdrawing the
water but when it rains

627
00:40:47,511 --> 00:40:51,682
and you get recharge,
then the part that's in

628
00:40:51,715 --> 00:40:54,518
the sand-and-gravel
layer, it can be restored

629
00:40:54,551 --> 00:40:58,456
by adding the amount of
water that you withdrew

630
00:40:59,823 --> 00:41:03,561
but whenever you withdraw water
from these clays aquitards,

631
00:41:05,862 --> 00:41:08,999
then they collapse permanently.

632
00:41:09,032 --> 00:41:12,903
So think of those aquitards,
those clay particles

633
00:41:12,936 --> 00:41:17,107
as being like flat plates
and whenever you pull out

634
00:41:19,075 --> 00:41:22,847
the water, they will
collapse and kind of sit

635
00:41:24,214 --> 00:41:27,484
on top of each other and there's
no fluffing them up again.

636
00:41:27,517 --> 00:41:31,388
They're just permanently
in this arrangement

637

00:41:31,421 --> 00:41:35,159
of their skeleton, so
over time, what you see

638
00:41:37,994 --> 00:41:41,999
is a kind of soil variations
in the water levels

639
00:41:44,200 --> 00:41:47,705
that correspond to
recharge and withdrawal

640
00:41:48,905 --> 00:41:51,975
and then you see this
long-term subsidence

641
00:41:52,008 --> 00:41:55,245
that either corresponds
to withdrawing

642
00:41:55,278 --> 00:41:59,416
more than your recharging or
to collapsing the aquitards.

643
00:42:02,719 --> 00:42:06,624
So this has been going
on in the Central Valley

644
00:42:09,025 --> 00:42:12,829
and the amount of permanent
subsidence depends a lot

645
00:42:12,862 --> 00:42:16,600
on upon how much of those
aquitard layers they are.

646
00:42:16,633 --> 00:42:19,703
This is a map, this
is Stockton here.

647

00:42:21,037 --> 00:42:25,042
Modesto, Merced, Fresno,
Visalia and Bakersfield

648
00:42:26,109 --> 00:42:28,011
and then there's the Grapevine

649
00:42:28,044 --> 00:42:30,981
going over the
mountains down here.

650
00:42:31,014 --> 00:42:35,185
California Aqueduct runs
along here and in some areas,

651
00:42:36,586 --> 00:42:40,357
there have been up to
a 30 feet of subsidence

652
00:42:41,691 --> 00:42:44,862
in the 56 years
between 1949 and 2005,

653
00:42:49,165 --> 00:42:52,536
so just to put that
in perspective,

654
00:42:52,569 --> 00:42:56,573
20 feet of subsidence, you
have a two-story building.

655
00:42:56,606 --> 00:43:00,711
It's now below the ground,
except the whole ground's

656
00:43:02,278 --> 00:43:06,550
gone down but it's now
gone down that far.

657
00:43:06,583 --> 00:43:10,187

So that might not bother
this cow over here

658
00:43:11,655 --> 00:43:15,793
but if you're have a well and
a pipe connected to that well,

659
00:43:17,027 --> 00:43:21,098
then that subsidence
is going to potentially

660
00:43:21,131 --> 00:43:24,702
cause some structural
damage, shall we say.

661
00:43:25,969 --> 00:43:28,739
So critical infrastructure
and structures

662
00:43:28,772 --> 00:43:31,875
in the Central Valley
are often impacted

663
00:43:31,908 --> 00:43:34,144
by this kind of subsidence.

664
00:43:36,079 --> 00:43:39,817
So the aqueduct in
particular can be affected

665
00:43:41,017 --> 00:43:43,988
by two things and I
have examples here.

666
00:43:45,321 --> 00:43:49,826
One is subsidence from
nearby groundwater pumping.

667
00:43:49,859 --> 00:43:54,364
So what happens is that

the aqueduct is gravity fed

668
00:43:54,397 --> 00:43:56,567
and so if a part subsides,

669
00:43:59,269 --> 00:44:02,473
then the water comes
closer to the top.

670
00:44:03,973 --> 00:44:08,345
It has less, what they call
freeboard, and it can overtop

671
00:44:08,378 --> 00:44:12,082
more easily and so
what they have to do

672
00:44:12,115 --> 00:44:16,386
is reduce the amount of water
that flows through this area.

673
00:44:16,419 --> 00:44:19,890
They have to cut the
water flow in the aqueduct

674
00:44:19,923 --> 00:44:23,193
in order to deal with the
fact that there's a low spot,

675
00:44:23,226 --> 00:44:26,063
so that they don't
get overtopping.

676
00:44:26,096 --> 00:44:29,766
I love this photo; this
is a bridge going across

677
00:44:29,799 --> 00:44:33,971
the aqueduct and I promise
you, they did not design

678
00:44:35,171 --> 00:44:37,474
the bridge so that the
water of the aqueduct

679
00:44:37,507 --> 00:44:39,910
was lapping at the bottom of it

680
00:44:39,943 --> 00:44:43,313
but that's the situation today.

681
00:44:43,346 --> 00:44:45,416
This is just one example.

682
00:44:46,583 --> 00:44:49,052
There are many examples
of this kind of thing

683
00:44:49,085 --> 00:44:52,389
that's happening in
the Central Valley.

684
00:44:52,422 --> 00:44:54,524
But the other thing
that can happen

685
00:44:54,557 --> 00:44:57,094
is that for some reason or
another, you get a crack

686
00:44:57,127 --> 00:44:59,563
in the aqueduct lining
and here's an example.

687
00:44:59,596 --> 00:45:01,598
This is a human pumping.

688
00:45:02,732 --> 00:45:05,535
They're pumping

concrete in to fill

689
00:45:05,568 --> 00:45:07,671
this crack in the aqueduct.

690
00:45:07,704 --> 00:45:10,207
This is not a small structure.

691
00:45:11,674 --> 00:45:15,612
But you get water going
through that crack

692
00:45:15,645 --> 00:45:18,181
to blow the aqueduct
or to the side

693
00:45:18,214 --> 00:45:20,784
of the aqueduct and
it causes compaction

694
00:45:20,817 --> 00:45:25,388
of the soil and that causes,
ultimately, it can cause,

695
00:45:25,421 --> 00:45:30,026
show up as subsidence on the
surface and it can also lead

696
00:45:30,059 --> 00:45:32,863
to further cracking
of the aqueduct

697
00:45:32,896 --> 00:45:36,633
because it loses the
soil support from below.

698
00:45:43,640 --> 00:45:47,811
In 2014, we started imaging
the California Aqueduct

699
00:45:48,978 --> 00:45:52,649
and we were not given
any new money to collect

700
00:45:54,584 --> 00:45:57,654
additional flight
time so what we did

701
00:45:57,687 --> 00:45:59,623
was when we flew up to
the Sacramento Delta,

702
00:45:59,656 --> 00:46:03,527
we would just aim the
plane along the aqueduct

703
00:46:03,560 --> 00:46:07,130
and turn on the radar
and collect the data.

704
00:46:07,163 --> 00:46:11,134
And this shows the
cumulative displacement map

705
00:46:11,167 --> 00:46:15,005
between April of 2014
down here and June 2016.

706
00:46:18,441 --> 00:46:21,878
And we had collected
some lines ahead of that,

707
00:46:21,911 --> 00:46:26,249
so we have a longer time
series for this northern line.

708
00:46:26,282 --> 00:46:29,620
It goes back to July
2013 and this shows

709
00:46:34,824 --> 00:46:39,262
the pattern of subsidence that
we see, which is very similar

710
00:46:39,295 --> 00:46:43,266
to what has historically
been seen with the exception

711
00:46:43,299 --> 00:46:47,237
down here and this was
something that showed up

712
00:46:48,638 --> 00:46:53,009
as a hotspot in the very first
time I looked at the data.

713
00:46:53,042 --> 00:46:56,780
This is California
Aqueduct runs through here

714
00:46:58,414 --> 00:47:01,685
and this is kind of
a bull's-eye pattern

715
00:47:03,052 --> 00:47:06,824
is standard for pump groundwater
withdrawal from a pump

716
00:47:09,425 --> 00:47:13,263
that would be located near
the center of this feature.

717
00:47:13,296 --> 00:47:16,233
So I was pretty
startled when I saw

718
00:47:16,266 --> 00:47:20,437
this kind of a deformation so
quickly I went and showed it

719
00:47:21,838 --> 00:47:24,674
to the engineers
and they drove out

720
00:47:24,707 --> 00:47:26,877
and they really couldn't
see anything wrong

721
00:47:26,910 --> 00:47:29,479
so they sent out a leveling
survey and sure enough,

722
00:47:29,512 --> 00:47:33,016
they, too, measured more
than a foot of subsidence

723
00:47:33,049 --> 00:47:37,921
of the California Aqueduct over
less than a two-year period

724
00:47:37,954 --> 00:47:42,459
and what I had seen was that
I had watched it develop

725
00:47:42,492 --> 00:47:45,896
and I'd seen eight inches
of subsidence in this area

726
00:47:45,929 --> 00:47:50,100
over a four-month period,
so over the summer of 2014,

727
00:47:51,401 --> 00:47:53,637
there was eight
inches of subsidence

728
00:47:53,670 --> 00:47:58,275
and they had no idea really
how rapidly these things

729
00:47:58,308 --> 00:48:02,512
could form and how
localized they could be.

730
00:48:02,545 --> 00:48:06,450
So this was a very useful
information for them

731
00:48:07,617 --> 00:48:10,888
and they continued
to support this work

732
00:48:12,689 --> 00:48:17,093
and use the results from
it, so this is a photo

733
00:48:17,126 --> 00:48:19,029
of that subsiding area.

734
00:48:20,430 --> 00:48:23,500
I promised you they would
not be very thrilling

735
00:48:23,533 --> 00:48:27,704
but you really don't
see anything really
hitting end, huh?

736
00:48:31,074 --> 00:48:33,510
So I'm gonna now show
a movie that shows

737
00:48:33,543 --> 00:48:37,514
how the progression of the
subsidence, how it occurred,

738
00:48:37,547 --> 00:48:41,952
and there's a date down here
saying when the scene is from

739
00:48:41,985 --> 00:48:46,690
and I start at a time, not when
there wasn't any subsidence,

740
00:48:46,723 --> 00:48:50,794
but before there was six inches
of subsidence at the area,

741
00:48:50,827 --> 00:48:54,698
so this whole area,
probably it subsided some

742
00:48:54,731 --> 00:48:57,300
but it was less than six
inches so it doesn't show up

743
00:48:57,333 --> 00:49:00,103
on this map, so whenever
you start to see colors,

744
00:49:00,136 --> 00:49:03,874
it'll be six inches up
to 28 inches or more.

745
00:49:07,377 --> 00:49:08,211
Let's see.

746
00:49:11,014 --> 00:49:13,016
So here is the aqueduct.

747
00:49:15,451 --> 00:49:18,388
Here is I-5 and
here at this center

748
00:49:21,290 --> 00:49:25,462
is an irrigation well that
was installed in July 2013.

749
00:49:26,796 --> 00:49:29,699

It's a 2,500-gallon-per-minute
pump and it's drilled

750
00:49:29,732 --> 00:49:32,302
to a depth of about 1,600 feet.

751
00:49:33,636 --> 00:49:37,807
And in January, it
decreased in size slightly

752
00:49:37,840 --> 00:49:41,378
because it got some recharge
and then after that,

753
00:49:41,411 --> 00:49:45,082
it began expanding in
size so this was 2015.

754
00:49:46,649 --> 00:49:49,819
By now, you're up to 15 inches.

755
00:49:49,852 --> 00:49:54,024
Now you're around 18 to
20 inches by the beginning

756
00:49:55,358 --> 00:49:58,094
of the planting season
of the next year

757
00:49:58,127 --> 00:50:02,299
and before it was done, there
was something like 26 inches

758
00:50:03,699 --> 00:50:07,738
of subsidence directly of the
aqueduct at that one area.

759
00:50:09,205 --> 00:50:13,676
And about five miles of
the aqueduct had subsided

760
00:50:13,709 --> 00:50:16,546
by more than 10
inches, so this is

761
00:50:19,749 --> 00:50:22,018
very useful information
for the state

762
00:50:22,051 --> 00:50:24,888
because they usually go out

763
00:50:24,921 --> 00:50:29,092
and they will repair the
aqueduct in 40-mile sections

764
00:50:30,793 --> 00:50:34,664
but this tells them which
sections to focus on.

765
00:50:34,697 --> 00:50:38,769
It allows it to be much
more efficiently repaired

766
00:50:40,069 --> 00:50:42,639
and much more cheaply repaired.

767
00:50:44,107 --> 00:50:48,178
Oh, I do want to say that that
one site decreased the pump,

768
00:50:48,211 --> 00:50:51,581
that one feature
decreased the capacity

769
00:50:51,614 --> 00:50:55,786
of the California Aqueduct
through this area by 20%.

770

00:50:58,254 --> 00:51:02,259
One, so there's also
historically subsiding area.

771
00:51:04,160 --> 00:51:08,331
They have seen over 20 feet
of subsidence in this area

772
00:51:09,866 --> 00:51:12,335
and we see that
it's still subsiding

773
00:51:12,368 --> 00:51:16,172
in kind of a generalized pattern
like they had seen before.

774
00:51:16,205 --> 00:51:19,275
We looked, went to look for more

775
00:51:19,308 --> 00:51:21,878
of these small-scale features

776
00:51:21,911 --> 00:51:25,749
that were not as drastic
as the one at Avenal.

777
00:51:27,850 --> 00:51:31,788
This is a photo taken
from this road back here

778
00:51:31,821 --> 00:51:35,024
looking across this
field and here you have

779
00:51:35,057 --> 00:51:37,460
about nine inches of subsidence

780
00:51:37,493 --> 00:51:40,764
in this area and
about six or so inches

781
00:51:42,365 --> 00:51:45,202
maximum along the
aqueduct itself.

782
00:51:46,536 --> 00:51:49,639
This is an example of
something that's just starting.

783
00:51:49,672 --> 00:51:53,009
Here is an example of
hydro-compaction of the soil.

784
00:51:53,042 --> 00:51:55,645
In this case, we know that
that's what's happening

785
00:51:55,678 --> 00:51:59,783
because the center
of this feature is on
the aqueduct itself

786
00:52:02,351 --> 00:52:04,854
and extends below
it and that means

787
00:52:04,887 --> 00:52:08,691
that whatever's happening is
happening below the aqueduct

788
00:52:08,724 --> 00:52:13,229
and so it has the classic
signature of a crack

789
00:52:13,262 --> 00:52:15,598
in the aqueduct that's
causing compaction

790
00:52:15,631 --> 00:52:19,969
of the soil below it and

then this is an example

791
00:52:20,002 --> 00:52:23,840
where the state knew
they had seep in the past

792
00:52:25,174 --> 00:52:28,811
and they had gone and repaired
it all but we also see

793
00:52:28,844 --> 00:52:32,882
a small subsidence feature
that seems to be centered

794
00:52:32,915 --> 00:52:36,886
less on the aqueduct itself,
the side of the aqueduct

795
00:52:36,919 --> 00:52:41,091
is here, and more on the
ground to the side of it.

796
00:52:42,425 --> 00:52:45,395
In that case, if you
go to Google Earth,

797
00:52:45,428 --> 00:52:48,531
this has this arc
pattern and you can find

798
00:52:48,564 --> 00:52:52,669
that the plants in that area
are growing in an arc pattern

799
00:52:52,702 --> 00:52:56,540
because they have more
moisture in the cracks.

800
00:53:01,677 --> 00:53:04,247
So the next thing that

we're gonna try to do

801
00:53:04,280 --> 00:53:08,451
is to do seep detection; the
current method is shown here.

802
00:53:09,619 --> 00:53:11,888
You're driving along
and it's a hot day

803
00:53:11,921 --> 00:53:14,557
and it hadn't rained in a
long time and you notice water

804
00:53:14,590 --> 00:53:18,127
running across the road at
the bottom of the levee.

805
00:53:18,160 --> 00:53:21,197
Well, that's it.
[audience chuckles]

806
00:53:21,230 --> 00:53:24,334
The other technique
is to drive along

807
00:53:24,367 --> 00:53:28,104
and look for wetland
vegetation in an area

808
00:53:28,137 --> 00:53:32,275
that should be dry, so
we're trying to use,

809
00:53:32,308 --> 00:53:36,479
instead radar images and these
slightly blue areas are areas

810
00:53:39,915 --> 00:53:43,386
where there's increased

moisture in the soil.

811
00:53:43,419 --> 00:53:47,390
And in this case, this is
a Mississippi River levee

812
00:53:47,423 --> 00:53:51,194
and these are relief wells
that have been put in.

813
00:53:51,227 --> 00:53:55,231
This was during the big
flood of 2011 and you can see

814
00:53:55,264 --> 00:53:59,736
these fingers of moisture
coming in from probably

815
00:53:59,769 --> 00:54:04,240
from the relief wells
that have been installed.

816
00:54:04,273 --> 00:54:07,844
You can also use the
interferometry technique

817
00:54:07,877 --> 00:54:10,747
that I talked about before
where you're just looking

818
00:54:10,780 --> 00:54:13,283
for something that's
just a huge change.

819
00:54:13,316 --> 00:54:16,419
It's not really looking
for a surface movement

820
00:54:16,452 --> 00:54:18,621
but just for a place

where the surface

821
00:54:18,654 --> 00:54:20,623
has change dramatically.

822
00:54:20,656 --> 00:54:24,494
This is an example where we
flew at high tide and low tide

823
00:54:24,527 --> 00:54:28,698
one day and we noticed
change right along the bottom

824
00:54:30,766 --> 00:54:33,770
of the levee and
when we went out

825
00:54:33,803 --> 00:54:36,372
to look at it in the
field, we actually saw,

826
00:54:36,405 --> 00:54:39,609
this is the photo of
that particular site.

827
00:54:39,642 --> 00:54:43,112
But this technique, where
you're just looking for a change

828
00:54:43,145 --> 00:54:45,214
in the surface doesn't
doesn't tell you

829
00:54:45,247 --> 00:54:47,350
what the cause of the change is.

830
00:54:47,383 --> 00:54:51,754
You really have to go out
and see what happened there.

831
00:54:51,787 --> 00:54:54,324
And we saw several
signatures like this

832
00:54:54,357 --> 00:54:57,527
and I just want to point
out that in one case,

833
00:54:57,560 --> 00:55:00,363
[audience chuckles]
we were looking at sheep,

834
00:55:00,396 --> 00:55:04,100
so having that
partnership with the state

835
00:55:04,133 --> 00:55:07,203
where they have knowledge
of what's going on

836
00:55:07,236 --> 00:55:09,205
and we can work
with them has been

837
00:55:09,238 --> 00:55:13,142
really, really valuable in
this particular project.

838
00:55:13,175 --> 00:55:15,679
So today, we use this aircraft

839
00:55:17,580 --> 00:55:21,751
and it's kind of the prototype
for the NISAR mission,

840
00:55:22,852 --> 00:55:25,421
which NASA is now developing.

841
00:55:25,454 --> 00:55:29,125

It's supposed to launch in
2021 and it will provide

842
00:55:29,158 --> 00:55:32,962
comprehensive coverage of
most of the land surface

843
00:55:32,995 --> 00:55:36,799
of the planet and certainly,
all of the United States.

844
00:55:36,832 --> 00:55:39,535
Could be used for
all kinds of hazards.

845
00:55:39,568 --> 00:55:42,405
You can still do things
with the aircraft

846
00:55:42,438 --> 00:55:44,107
that you can't do
with a satellite.

847
00:55:44,140 --> 00:55:46,676
In an emergency, you have
to wait for the satellite

848
00:55:46,709 --> 00:55:49,145
to come over an area
in order to image it,

849
00:55:49,178 --> 00:55:53,750
whereas, you can send
the aircraft out to
image right away.

850
00:55:53,783 --> 00:55:58,421
So they're complementary but
one thing that you can't do

851

00:55:58,454 --> 00:56:02,291
with the aircraft is image
every 12 days consistently

852
00:56:02,324 --> 00:56:04,794
the entire country
and that's something

853
00:56:04,827 --> 00:56:07,864
that will be possible
with this satellite.

854
00:56:07,897 --> 00:56:10,400
So takes a village, of course,

855
00:56:12,168 --> 00:56:14,904
so I had a lot of
funding from NASA,

856
00:56:14,937 --> 00:56:17,640
from California Department
of Water Resources

857
00:56:17,673 --> 00:56:21,611
and from the Department
of Homeland Security

858
00:56:21,644 --> 00:56:23,980
in getting this project
going and I have

859
00:56:24,013 --> 00:56:26,916
many, many colleagues
who contributed

860
00:56:26,949 --> 00:56:29,719
to the work that I've
shown and finally,

861
00:56:29,752 --> 00:56:32,789

I wanna really thank
the UAVSAR teams

862
00:56:32,822 --> 00:56:34,991
at both JPL and Armstrong.

863
00:56:36,692 --> 00:56:40,864
JPL operates the radar and
Armstrong operates the aircraft.

864
00:56:42,064 --> 00:56:45,835
So I will take
questions while you look

865
00:56:45,868 --> 00:56:50,106
at this rapidly subsiding
area in the Central Valley.

866
00:56:50,139 --> 00:56:52,408
[audience chuckles]

867
00:56:52,441 --> 00:56:56,446
Thank you.
[audience applauding]

868
00:56:59,515 --> 00:57:02,752
So I'll take questions but
I'm gonna ask that you use

869
00:57:02,785 --> 00:57:06,122
the microphone over there
so that it's recorded

870
00:57:06,155 --> 00:57:09,659
for posterity [chuckles].

871
00:57:23,506 --> 00:57:27,410
>> Hello, very interesting,
in regard to JPSS-1,

872
00:57:30,379 --> 00:57:34,350
can you tell me whether or
not it's equipped with radar?

873
00:57:34,383 --> 00:57:36,552
>> Catherine: I'm sorry,
can you repeat the question?

874
00:57:36,585 --> 00:57:38,822
>> Yes, in regard to JPSS-1,

875
00:57:41,557 --> 00:57:45,728
can you tell me whether or
not it's equipped with radar?

876
00:57:47,162 --> 00:57:50,900
>> I don't know what JPSS-1
is, I'm sorry [chuckles].

877
00:57:50,933 --> 00:57:54,537
>> Okay it's Joint Polar
Satellite Systems--

878
00:57:58,040 --> 00:57:59,509
>> Oh.
>> One.

879
00:57:59,542 --> 00:58:01,911
>> Okay,
>> And it's gonna go

880
00:58:01,944 --> 00:58:05,348
from Vandenberg in
November, next month,

881
00:58:06,515 --> 00:58:09,886
and one of a series of
four that will go up

882

00:58:11,086 --> 00:58:14,491
and hopefully, utilize
radar if they have it.

883
00:58:17,159 --> 00:58:19,395
>> I'm sure is not
the same frequency

884
00:58:19,428 --> 00:58:21,864
as this particular radar.

885
00:58:21,897 --> 00:58:25,568
It would have probably
a shorter wavelength

886
00:58:25,601 --> 00:58:29,038
so it would be one of
the things that's better

887
00:58:29,071 --> 00:58:32,542
for looking at
ice, and less good

888
00:58:32,575 --> 00:58:35,878
for looking through
vegetation at the soil

889
00:58:35,911 --> 00:58:39,248
but we should talk
afterwards and I can get you

890
00:58:39,281 --> 00:58:41,718
more information.
>> Thank you.

891
00:58:43,052 --> 00:58:46,723
>> So I have some questions
from people online.

892
00:58:50,159 --> 00:58:54,330

Lazy TV asks [chuckles] I'm
assuming that's not his name,

893
00:58:56,365 --> 00:59:00,470
are the UAVSAR image scans
used with ground surveys?

894
00:59:01,637 --> 00:59:04,974
What we do is how
often we don't do it

895
00:59:05,007 --> 00:59:08,344
in conjunction with them
because it's such a large area

896
00:59:08,377 --> 00:59:12,448
that rapidly subsiding
site where I showed you

897
00:59:12,481 --> 00:59:15,718
the cracked levee
and that does have

898
00:59:15,751 --> 00:59:20,456
some ground survey data there
and whenever we give the state

899
00:59:20,489 --> 00:59:23,593
a particularly bad spot
like that Avenal hotspot,

900
00:59:23,626 --> 00:59:27,797
they will go out and do a
survey to verify what they see.

901
00:59:30,532 --> 00:59:33,836
Lucas asked, what
is the probability

902
00:59:33,869 --> 00:59:36,739

of subsidence due
to an earthquake?

903
00:59:36,772 --> 00:59:39,709
That's a very good
question, Lucas.

904
00:59:39,742 --> 00:59:43,680
So I don't know what the
probability is per se.

905
00:59:46,015 --> 00:59:49,285
That has been
calculated and there's

906
00:59:49,318 --> 00:59:52,322
some uncertainty
in the calculation.

907
00:59:55,024 --> 00:59:58,527
The subsidence that happens
whenever there's an earthquake

908
00:59:58,560 --> 01:00:02,732
is called liquefaction so it's
like you've jostled the soil

909
01:00:04,833 --> 01:00:09,271
and it settled out and the
water has come out on top of it

910
01:00:09,304 --> 01:00:13,676
and you get rapid, very rapid
subsidence when that happens

911
01:00:13,709 --> 01:00:16,279
and there's an issue about how,

912
01:00:18,180 --> 01:00:21,717
whether that would happen

in the Sacramento Delta.

913
01:00:21,750 --> 01:00:25,922
They've done calculations
for the levees themselves

914
01:00:27,723 --> 01:00:30,726
to show that the
levees themselves

915
01:00:30,759 --> 01:00:34,597
are almost certainly
gonna survive independent

916
01:00:37,833 --> 01:00:42,638
of what happens
interior, however, you
could get subsidence

917
01:00:42,671 --> 01:00:47,343
inside the island that
causes a loss of support

918
01:00:47,376 --> 01:00:49,879
on the landside for the levee.

919
01:00:51,046 --> 01:00:55,051
Anyway, I don't know
what the probability is

920
01:00:55,084 --> 01:00:57,754
but definitely is one, yes, sir?

921
01:00:59,555 --> 01:01:03,026
>> So you showed examples
of the subsidence

922
01:01:05,060 --> 01:01:09,165
right next to the aqueduct
caused by the pumping.

923
01:01:10,566 --> 01:01:14,404
Is there any plans to tell those
people please stop pumping?

924
01:01:17,506 --> 01:01:20,943
>> Yeah, so I'm not
sure whether the state

925
01:01:23,979 --> 01:01:26,916
approached them
but in California,

926
01:01:26,949 --> 01:01:31,487
there isn't a law that prevents
people from doing that.

927
01:01:31,520 --> 01:01:35,191
There's a law that prevents
people from wasting water

928
01:01:35,224 --> 01:01:39,295
but there's not a law that
prevents them from using water

929
01:01:39,328 --> 01:01:41,931
and since that
pump was permitted,

930
01:01:41,964 --> 01:01:44,900
they have the right
to use that water.

931
01:01:44,933 --> 01:01:48,437
So what the state is gonna
do in the future, I think,

932
01:01:48,470 --> 01:01:51,640
I'm pretty sure that
they've already done this

933
01:01:51,673 --> 01:01:54,610
is go to local
communities and say,

934
01:01:54,643 --> 01:01:58,914
don't permit wells this
close to these structures

935
01:01:58,947 --> 01:02:00,382
in the future.
>> Yeah.

936
01:02:00,415 --> 01:02:03,686
I would think they would
need to be a boundary layer,

937
01:02:03,719 --> 01:02:07,523
a boundary region around the
aqueduct where no permits

938
01:02:07,556 --> 01:02:11,427
are permitted when the
aqueduct was built.

939
01:02:11,460 --> 01:02:13,863
It's a little late to do it now.

940
01:02:13,896 --> 01:02:16,799
>> I don't think that they
realized what the problem was.

941
01:02:16,832 --> 01:02:19,602
This was built in
1960s and '70s.

942
01:02:21,003 --> 01:02:23,339
It's kind of a shame
but they are building

943
01:02:23,372 --> 01:02:27,676
the high-speed rail and other
transportation structures

944
01:02:27,709 --> 01:02:29,879
that this can be used for.

945
01:02:32,815 --> 01:02:35,584
>> Thank you for the lecture.

946
01:02:35,617 --> 01:02:38,320
I actually enjoyed even more
than I anticipated [chuckles].

947
01:02:38,353 --> 01:02:40,289
[Catherine laughs]

948
01:02:40,322 --> 01:02:43,692
With all of the pumping
that causes this subsidence,

949
01:02:43,725 --> 01:02:46,095
do we have a much
of an understanding

950
01:02:46,128 --> 01:02:49,298
of what it takes to
recharge the aquifer

951
01:02:49,331 --> 01:02:53,135
from rainfall and how
long that might take?

952
01:02:53,168 --> 01:02:57,340
I think that people now
are looking at how quickly

953
01:02:58,540 --> 01:03:01,177
the ground is coming

back in this area

954
01:03:01,210 --> 01:03:04,380
with the rains from
this past season.

955
01:03:04,413 --> 01:03:08,851
There are models of how
fast it could be restored.

956
01:03:08,884 --> 01:03:12,321
I don't think all of
the elevation change

957
01:03:14,056 --> 01:03:18,727
is reasonable to restore but
part of it could be restored

958
01:03:18,760 --> 01:03:22,431
from that, so there are
models and data like

959
01:03:23,632 --> 01:03:25,701
this helps to
improve the models.

960
01:03:25,734 --> 01:03:27,837
>> Man In Cap: Okay, thank you.

961
01:03:27,870 --> 01:03:32,041
>> So Oscar asks, how can
we contribute as educators?

962
01:03:33,208 --> 01:03:36,979
We have eager students
for citizen science.

963
01:03:37,012 --> 01:03:39,682
That's a really
interesting question.

964
01:03:39,715 --> 01:03:43,886
I think that citizen science,
if I understand correctly,

965
01:03:43,919 --> 01:03:47,256
is people, just regular
people going out

966
01:03:48,590 --> 01:03:52,127
and providing data to
scientists so they take photos

967
01:03:52,160 --> 01:03:55,665
of ares or they report
when there's a leak

968
01:03:57,099 --> 01:04:00,903
or something like that,
so I actually could see

969
01:04:00,936 --> 01:04:05,007
a lot of value in something
like that in areas

970
01:04:05,040 --> 01:04:08,277
where there's public
access, of course.

971
01:04:09,378 --> 01:04:11,213
So that's a great question.

972
01:04:11,246 --> 01:04:14,383
Oscar, you should contact us.
[chuckling]

973
01:04:14,416 --> 01:04:15,251
Okay.

974

01:04:16,551 --> 01:04:19,121
>> I know that there's
certain members

975
01:04:19,154 --> 01:04:21,757
of certain
congressional committees

976
01:04:21,790 --> 01:04:25,828
who have oversight over
NASA who have said that NASA

977
01:04:25,861 --> 01:04:28,664
can look at all the
planets except Earth.

978
01:04:28,697 --> 01:04:31,200
Have you run into that at all?

979
01:04:36,271 --> 01:04:39,642
>> What I know is that
the earth science budget

980
01:04:39,675 --> 01:04:43,846
this year is really robust,
so we're quite lucky, yeah.

981
01:04:47,316 --> 01:04:50,319
And I do, you're probably
well aware, that NASA

982
01:04:50,352 --> 01:04:53,289
does a lot of earth science.
>> Oh, yes.

983
01:04:53,322 --> 01:04:54,156
>> Yes.

984
01:04:56,591 --> 01:04:59,095
Thank you, any more questions?