1
00:00:00,000 --> 00:00:02,961
[helicopter sound]

2
00:00:02,961 --> 00:00:05,922
Narrator: Five years ago, a NASA-funded science

3
00:00:05,922 --> 00:00:08,883
team ventured onto an ever-changing region

4
00:00:08,883 --> 00:00:11,845
of the Greenland Ice Sheet in the peak of summer melt season,

5
00:00:11,845 --> 00:00:14,806
when the ice was literally melting

6
00:00:14,806 --> 00:00:17,767
out from under their feet.

7
00:00:17,767 --> 00:00:20,729
[music builds, sound of crunching ice]

8
00:00:20,729 --> 00:00:23,690
What they learned is changing the way we think
about the movement of ice sheets,

9
00:00:23,690 --> 00:00:26,651
and possibly changing our computer models

10
00:00:26,651 --> 00:00:29,612
models that predict how fast ice will melt,

11
00:00:29,612 --> 00:00:33,700
a question which matters to every coastline on the planet.

12
00:00:34,617 --> 00:00:41,041
Smith: So the number one reason we are here
is all about global sea level rise.

13
00:00:42,751 --> 00:00:46,296
Greenland is the single largest melting chunk of ice in the world.

14
00:00:46,838 --> 00:00:51,843
What really matters to the world is how much of that water melted on the ice sheet gets out to the ocean.

15
00:00:52,260 --> 00:00:55,221
Narrator: In order to collect this data, the team had to first transport

16
00:00:55,221 --> 00:01:00,060
scientific equipment and survival gear to Greenland

17
00:01:00,060 --> 00:01:03,688
and then travel via helicopter to set up camp

18
00:01:03,688 --> 00:01:07,567
in the ablation zone, a region of melting ice.

19
00:01:08,109 --> 00:01:10,820
Chu: Camping out here logistically is very difficult.

20
00:01:11,613 --> 00:01:14,574
We're camping in the ablation zone. It's very wet, as you can see.

21
00:01:15,033 --> 00:01:17,994
The ablation zone is where it is melting over the summer.

22
00:01:18,244 --> 00:01:21,498
Even talking to the logistics coordinators,
they're very interested in our camp

23
00:01:21,498 --> 00:01:25,210
because they're trying to learn things about,
how do you camp in the ablation zone?

24
00:01:26,211 --> 00:01:31,716
Narrator: One lesson is to be quick and nimble – the team had to evacuate from the first spot they scouted,

25
00:01:32,133 --> 00:01:35,095
because the surface started melting right under their camp.

26
00:01:36,262 --> 00:01:40,767
So what big science questions are at the heart of this bold undertaking?

27
00:01:41,351 --> 00:01:47,315
Smith: In 2015, when we started this study,
there was surprisingly little attention paid to

28
00:01:47,816 --> 00:01:54,030
the hydrology of streams and rivers on the ice sheet,
especially inland away from the ice edge.

29
00:01:55,365 --> 00:01:59,160
And we felt that this was a critical scientific gap.

30
00:01:59,452 --> 00:02:04,165
Just from looking at satellite images of the ice sheet, it was very apparent that

31
00:02:04,165 --> 00:02:08,002
very large volumes of meltwater were moving through these systems.

32
00:02:08,002 --> 00:02:11,381
And one of the things we learned is that the

33
00:02:11,381 --> 00:02:19,889
total volume of water passing through these river systems far exceeds the volume of water contained by lakes.

34
00:02:19,889 --> 00:02:26,479
Much like the terrestrial land surface, you know, lakes catch your eye because they're so big, but the real actio

35
00:02:26,479 --> 00:02:29,440
[sound of rushing water]

36
00:02:29,440 --> 00:02:34,362
All of these rivers terminate in a stunning

37
00:02:34,362 --> 00:02:39,367
and dangerous feature called a moulin, which is essentially a sinkhole

38
00:02:39,367 --> 00:02:46,082
in the glacier surface that develops when these large rivers

39
00:02:46,916 --> 00:02:52,630
melt down into the ice to a point
where they encounter a crack of some type.

40
00:02:52,630 --> 00:02:58,845
At that point, the river is captured, and it ceases to flow over the surface of the ice sheet

41
00:02:58,845 --> 00:03:02,432
and instead plummets down into the interior.

42
00:03:02,432 --> 00:03:08,730
And this year we mapped 538 of these very large blue rivers

43
00:03:08,730 --> 00:03:13,193
and showed that every single one them terminates in one of these moulins.

44
00:03:13,193 --> 00:03:19,407
So water that's melted on top of the ice sheet
is quickly and effectively gathered

45
00:03:19,407 --> 00:03:24,370
and transferred through these branching
stream and river network systems.

46
00:03:24,370 --> 00:03:31,169
They are swept off the surface of the sheet
within a matter of a few hours or even less

47
00:03:31,169 --> 00:03:35,340
and ultimately emerge 80 kilometers from here at the ice edge.

48
00:03:36,549 --> 00:03:40,470

Narrator: The team used a couple innovative
techniques to measure the river.

49
00:03:41,054 --> 00:03:46,601
First, working in shifts they measured stream flow for 72 straight hours

50
00:03:46,601 --> 00:03:49,812
using an instrument mounted on a boogie board

51
00:03:49,812 --> 00:03:55,068
that uses sonic beams to measure the depth of the water and the speed of the current.

52
00:03:55,068 --> 00:03:58,863
To do so they had to climb out to the very edge of the water.

53
00:04:00,490 --> 00:04:04,953
Rennermalm: Basically, the most important here is that we all come back home.

54
00:04:05,620 --> 00:04:10,375
The reason why this is a dangerous place is because only a couple of

55
00:04:10,375 --> 00:04:14,837
100 meters or maybe 200 meters downstream
to where these guys are working right now,

56
00:04:14,837 --> 00:04:21,427
is a moulin. This is a vertical passageway – a hole – where melt water

57
00:04:21,427 --> 00:04:28,101
goes straight into the ice. You see this river behind us?

58
00:04:28,101 --> 00:04:33,898
This blue river, flowing very fast, very powerful, very cold.

59
00:04:33,898 --> 00:04:40,238
If one of us would fall into this river without being secured to something,

60
00:04:40,238 --> 00:04:47,245

we would just flow like a little leaf into that big hole and that’s it.

61
00:04:48,997 --> 00:04:54,502
Smith: By far the best solution to ever
having to deal with someone taking a spill

62
00:04:54,502 --> 00:04:59,299
is to make it impossible for them to fall in in
the first place, and so the way we do that

63
00:04:59,299 --> 00:05:03,469
is to put them on a leash where the leash is exactly long enough

64
00:05:03,469 --> 00:05:07,724
to get close to the water's edge but not one inch more.

65
00:05:07,724 --> 00:05:09,559
[helicopter noise]

66
00:05:09,559 --> 00:05:13,187
Narrator: In addition to measuring stream flow with instruments on boogie boards,

67
00:05:13,187 --> 00:05:19,485
they also flew several kilometers upstream,
to three different tributaries of their study river,

68
00:05:19,485 --> 00:05:27,744
and deployed the last three autonomous drifters built by the late scientist and engineering wizard Alberto Beha

69
00:05:28,161 --> 00:05:32,999
[crunches boot into ice, drifter gently splashes in water]

70
00:05:39,505 --> 00:05:42,467
[boots crunch away over the ice]

71
00:05:45,261 --> 00:05:49,349
Chu: These are GPS autonomous drifters which

72

00:05:49,349 --> 00:05:54,103
will send the GPS coordinates of the location as they flow down our river.

73
00:05:54,103 --> 00:06:00,735
What that tells us is its velocity. And that's very helpful because when we set up these cross sections, we're in

74
00:06:00,735 --> 00:06:06,866
With the drifters we get a longitudinal long profile and then we lose the signal when they go down into a moulin

75
00:06:06,866 --> 00:06:11,037
And as it gets closer to a moulin,
the rivers actually don't get that much deeper.

76
00:06:11,037 --> 00:06:15,833
They just get kinda faster and then they incise into the ice, so these big canyons

77
00:06:16,626 --> 00:06:22,673
So the point of the drifters is to map the hydraulics of the big fast rivers that we can't get close to.

78
00:06:24,842 --> 00:06:31,432
Narrator: An hour later, all three drifters, which had been placed in
three separate streams at different times,

79
00:06:31,432 --> 00:06:37,522
came floating into view at once, sending a chill of excitement through everyone on the team.

80
00:06:40,191 --> 00:06:43,152
[sounds of helicopter and rushing stream]

81
00:06:48,366 --> 00:06:54,122
After analyzing their hard-won 2015 data,
the team was a bit puzzled by one thing.

82
00:06:54,122 --> 00:07:02,130
The heat budget calculated by satellite observations, computer models,
and the scientists' mobile weather stations

83
00:07:02,130 --> 00:07:07,135
predicted that current temperatures should be warm enough to melt more ice

84
00:07:07,135 --> 00:07:11,139
and create more runoff than the scientists were actually measuring

85
00:07:11,931 --> 00:07:14,100
So what was missing from the models?

86
00:07:14,976 --> 00:07:18,312
The team returned to the field site the following year,

87
00:07:18,312 --> 00:07:21,983
this time collecting an entire week of flow data,

88
00:07:21,983 --> 00:07:27,071
and also decided to look more closely at the surface of the ice itself.

89
00:07:27,864 --> 00:07:33,536
Smith: And when we drilled into it, we found up to a meter of soaking wet

90
00:07:33,536 --> 00:07:38,666
rotten, fragmented ice. You could break it apart with your hands.

91
00:07:38,666 --> 00:07:43,337
And it stores a non-trivial amount of water.
And it also creates the opportunity

92
00:07:43,337 --> 00:07:47,133
for water that is melted during the day to refreeze at night.

93
00:07:47,133 --> 00:07:53,097
And when it refreezes at night, it needs to be refrozen the following day in order to turn back into meltwater aga

94
00:07:54,015 --> 00:07:57,727
Narrator: Melting again the next day requires more energy.

95
00:07:57,727 --> 00:08:04,734
This was the energy that models assume was only melting ice once,
rather than having to do it twice.

96
00:08:05,943 --> 00:08:10,573
Smith: And this is great because we're working with modelers and we're going to get that process now into the

97
00:08:10,573 --> 00:08:14,869
and the models will get even better. And field teams and modelers

98
00:08:14,869 --> 00:08:19,832
have been working this way, hand-in-hand since the 1960s. And that’s why the models keep getting better and

99
00:08:20,958 --> 00:08:25,546
Narrator: In addition to measuring stream flow and solving the mystery of the missing meltwater,

100
00:08:25,546 --> 00:08:30,885
the team learned something about the reflectivity
of the ice, known as the ice albedo.

101
00:08:31,677 --> 00:08:37,475
Basic physics tells us that the darker something is,
the faster it absorbs the sun's heat.

102
00:08:38,226 --> 00:08:42,522
Smith: And you can see this when you fly around Greenland
and you look at it when that snowline pulls back,

103
00:08:42,522 --> 00:08:46,192
you can see the darker blue ice revealed

104
00:08:46,192 --> 00:08:52,281
and that bare exposed, darker ice absorbs more sunlight
than it would if it was snow covered.

105
00:08:53,199 --> 00:08:57,745
Narrator: And likewise, other things covering the ice, like algae, or dust,

106
00:08:57,745 --> 00:09:01,916
or soot from engines and factories, or volcanic ash,

107

00:09:01,916 --> 00:09:07,088
can also have a darkening affect. But their study showed that the snowline itself

108
00:09:07,088 --> 00:09:12,093
was five times more important to melt rates than these other processes.

109
00:09:12,885 --> 00:09:18,808
Smith: One factor that's a little worrisome is that owing to
the topographic profile of the ice sheet,

110
00:09:18,808 --> 00:09:22,436
as it gets flatter as you go to higher elevation.

111
00:09:22,436 --> 00:09:28,776
So what that means is, as the snowline elevation
goes higher under a warming climate,

112
00:09:28,776 --> 00:09:35,366
the area of ice exposed will increase as we approach
the flatter parts of the ice sheet.

113
00:09:36,617 --> 00:09:42,873
Narrator: Finally, the team observed that when surges of water enter a moulin in a particular location,

114
00:09:42,873 --> 00:09:48,045
it’s often followed within a couple hours by a surge of ice movement above.

115
00:09:48,921 --> 00:09:56,053
That meltwater can act like a layer of lubrication and allow regions of the ice sheet to slide more rapidly

116
00:09:56,887 --> 00:10:01,392
Increased ice motion can result in an increase in iceberg calving

117
00:10:01,392 --> 00:10:04,895
and other positive feedbacks which affect sea-level rise.

118
00:10:06,314 --> 00:10:12,069
A new study including members of the team and
NASA Goddard glaciologist Lauren Andrews,

119
00:10:12,069 --> 00:10:18,868
concluded that the most important factor influencing daily
changes in glacier speed in southwest Greenland

120
00:10:18,868 --> 00:10:27,043
was not necessarily the volume of the water, but how quickly the volume of water entering the subglacial syste

121
00:10:27,043 --> 00:10:32,840
The faster water enters the subglacial system, the higher the subglacial water pressure,

122
00:10:32,840 --> 00:10:37,219
essentially creating an effect like when the tread on tires of a car

123
00:10:37,219 --> 00:10:42,183
are overwhelmed by water on a wet road, causing the car to hydroplane.

124
00:10:44,810 --> 00:10:51,817
The intimate workings of the Greenland Icesheet may seem like a distant concern to those of us thousands of

125
00:10:51,817 --> 00:10:54,487
but their effects will be widespread.

126
00:10:55,780 --> 00:11:00,326
Smith: Sea level rise presents an existential threat to

127
00:11:00,326 --> 00:11:04,330
core cities and populations all around the world.

128
00:11:05,247 --> 00:11:11,128
A majority of our cities are on coastal deltas. So it's very important.

129
00:11:11,879 --> 00:11:17,718
And our ice sheets are a biggest contributor to that. And Greenland is one of them, but

130
00:11:17,718 --> 00:11:23,516
of course, Antarctica and the stability of the West Antarctic ice sheet
is the other elephant in the room.

131
00:11:27,436 --> 00:11:33,275
I think five years from now,
our sea level rise projection models from Greenland,