DDAHS 2026 Summer School Tuesday morning keynotes-20260714_090257-Meeting Recording

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1h 39m 1s

Gianni Vesuviano started transcription

Helen Baron 0:03
Make it in the.
so far. Yeah, I'm really, really thrilled to be able to introduce this summer school to everyone. Let me just share. Oh, I cannot share my screen.
Sorry, I've just spotted that that's greyed out for me, Gianni.

Gianni Vesuviano 0:22
You can't share the screen.

Helen Baron 0:23
Can’t share the screen.

Gianni Vesuviano 0:25
Oh, sure, I set that up.
I'm very sorry about this, everybody.

Helen Baron 0:31
I could pop the presentation on the T drive if that's the quickest option.

Gianni Vesuviano 0:38
Yes, and then just tell me when to do the next slide.

Gianni Vesuviano 0:44
Alright, I'm in your TDrive folder.
Yeah.

Helen Baron 0:47
It is moving across.

Helen Baron 0:54
Okay.
Yeah, so as I was saying, the summer school has been running off in one form or another since probably, well, I think 2021. And I've been involved for at least three years, so not the most recent thing necessarily.

Helen Baron 1:18
Yeah, it's been really fun watching it evolve, watching it grow.
Yeah, and just lovely to have so many people wanting to come and learn and hear about science we do and, you know, get involved in some of the hands on stuff. It is a really good, really good week. So yeah, next slide, please, Gianni.

Helen Baron 1:42
Yeah, as well as welcoming you all to the summer school. Hopefully you've got, you know, a vague idea of what's happening. You've had your pre-course information packs, you've had a good look at the schedule, you've seen those workshops, there's virtual field trips, lots of really interesting keynotes. I'm going to be introducing

Helen Baron 2:01
Just a really high level overview of the projects that are behind this summer school. So we've got two projects that are involved this year. We've got the Hydro-JULES project and the Floods and Droughts Research Infrastructure project, which from this point forward shall be the FDRI project.

Helen Baron 2:20
And they're complementary projects you'll see in a minute. But yeah, so the summer school started as a Hydro-JULES thing. And over the years, it's developed and it's been supported by FDRI, I think, for the last couple of years, and they'll probably be taking it forward.

Helen Baron 2:39
Yeah, Hydro-JULES has been running since.
2018 in one form or another. Pretty sure the moose wasn't in the presentation. No, it's great.

Gianni Vesuviano 2:49

Yeah, I'm sorry, I'm trying to find the arrows again. Okay.

Helen Baron 2:53

Everyone loves to surprise me. Yeah, we'll have the next slide, please, Gianni.

Helen Baron 3:02

Yep. Anyway, it's been running a lot of years now. It's in its second iteration. And it's one of those multi-partner projects. So there's us, there's the British Geological Survey, National Centre for Atmospheric Science and for Earth Observation, they're all involved.
Yeah.

Helen Baron 3:20

And the whole point of Hydro-JULES is, as the tagline says, to advance modelling and data infrastructures to understand floods and water scarcity in the UK and internationally. So it's been looking a lot at our modelling capabilities, but also all of the things that go around that.
Yeah.

Helen Baron 3:39

So there's been lots of new data sets, lots of new methods of data handling, lots of analysis done on the data, either observed data or the model data, lots of model development and lots of analysis done on the outputs from the model development.

Helen Baron 3:58

So it's been running, like I said, a goodly number of years. So I will give you a very sort of taste of some of the stuff that's been going on. It is by no means comprehensive. And lots of it I only know a little bit about. So do excuse that.

Helen Baron 4:17

But it's just really exciting to see all the different kinds of things that are happening under this one project.

Helen Baron 4:24
I've also throughout added little notes in linking some of the science that's happening to some of the things that you'll be seeing or doing throughout the summer school.

Helen Baron 4:36
So, yeah, keep an eye out for those. Next slide, please, Gianni.

Helen Baron 4:44
Right, first of all, we've got some of the stuff relating to the modelling. So one huge piece of work that's been ongoing is the 3D time varying groundwater dynamics model of Great Britain.

Helen Baron 5:01
Could we get a mute, yeah, thank you.
And you'll get a keynote on that. So, yeah, see your little icon with our key in there. I enjoyed that too much. But yeah, I won't talk too much about this because you will be hearing about it later. But essentially, it's just this fantastically in-depth, high resolution, you know,
lat long depth, because groundwater model of Great Britain. And if you live anywhere in the south, you know that, you know, that's really important to supply of groundwater in the north, you know, important to do with sort of correct runoff estimation.
It's really useful to be able to have a proper representation of this to link it in with our models.
It produces wonderfully colorful.
graphics, which is great fun as well. But yeah, that's enough of me pontificating on how excited this model is. Next, could you just click to the next bin on slide, please? Yeah, fabulous. And we've also had some high resolution flood modelling. And we looked at that over Oxford as a case study. But as you produce these finer and finer resolution models that are more and more computationally heavy, you also have to consider different options for how you're going to undertake your computing.
So I've been exploring different computing resources there, including the Dawn supercomputer. So that's really exciting as well. Yeah, high resolution, obviously very

important for flood modelling. Next slide, please, Gianni.
So one big aspect of the Hydro-JULES programme has been model development, and a lot of that has revolved around the Jules lab surface model, which is the Joint UK Land Environment Simulator Model.
Lots of it has involved other models. But you know, a lot of scientific development has been happening in the Joules model, which is quite a key model in the UK and it's used a lot internationally as well. So this is one that we work on a lot at UKCEH, also in the Met Office and various other institutes and universities.
So traditionally, it's a land surface model, which means it's very interested in vertical fluxes and sort of stopped a few, maybe not literally centimetres onto the ground, but it didn't have the most thorough ground water representation. So that's been updated. We've got a dynamic one.
that allows for horizontal fluxes as well as vertical, which is pretty useful. Looking at different river routing options, so there's already a couple in there, but we wanted to include one that had overbank inundation, which really is vital if you want to look at flooding, because otherwise rivers wouldn't flood ever.
and various bits and bobs of water management as well. So not just ignoring the people, but including some of the things like reservoirs, water transfers, water abstractions, irrigation. I've got our icon here for workshop 2 because we will be looking a little bit at
water management in hydrological models in workshop two. Not actually with the Jules model, with a different model, the guava model. But yeah, very much along the same kind of scientific theme there. So excited to see people this afternoon for that.
Do you click on, please, Gianni?
Yeah, so just kind of explaining how JULS is a real underpinning model for various capabilities we have in the UK. It forms the land bit of the land atmosphere ocean models the Met Office use and they use that for all kinds of weather and climate applications.
And I'm sure we're all aware of the importance of, you know, weather and climate modelling.
And.
Yeah, also a little icon here, so talking about, you know, as soon as you expand beyond the land surface, you get to be able to model things like multiple hazards, things like flooding with the oceans involved, as well as the rivers, as well as the ground water.

So yeah, used in the UK very heavily, but also around the world for various applications. Yeah, various agricultural things, as well as water, as well as carbon, as well as energy flux, as well as fire modelling. Yeah, the Joules model is a
A wonderful multi-hitter. Next click, please, Gianni.
Because, in addition to the JULES model, one of the key outputs from Hydro-JULES has been a modelling framework. So, Jules model, a big...
Code base all done in Fortran, lots of sort of...
historical stuff there, you know, as code grows, it gets added to by lots of contributors. Really great, but a little bit hard to access, particularly if you're not, if you haven't been coding for a long time. So the idea behind the modelling framework was that they'd take
particularly bits from the JULES model, but also other hydrological models, break them down into their various components, surface, subsurface, open water, give them standardised fluxes so they can talk to each other throughout it. And then you can work in it in a really modular way. So you can sub out your ground water model for a different ground water model or your open water model for a different one. Or you can set up your model for a data stream if you had a solid data set that you want to input. And that's what happened in Python and it's all happened in a more accessible way. That's a real step forward in terms of
Um...
just flexibility for modelling.
That's a really wonderful output, which you can find on GitHub and you can contribute to. Yeah, it's open at the moment. There's a paper to go along with that to explain some of the functionality there. So, yeah, it's really nice, really nice output. Next slide, please, Gianni.
So I've talked about the modelling A lot. That's clearly where my focus is, where I know the most. Yeah, on to more kind of analysis stuff. So we've got some lovely data sets and people have been looking at how the frequency of droughts
has changed historically over the UK, over different regions of the UK. Again, we've got a keynote on this, so I shan't say too much. Yeah, next clip, please, Gianni.
Yeah.
Uh, yeah, and...
So, you know, of course.
We've got all these fancy new modelling capabilities, time to use them for various things, including future projections, using some climate future projections that are

specific for the UK from the EURO-CORDEX UK, putting those through our hydrological models and seeing how that impacts
future high flows, really vital if you want to look at changes in risk to flooding in the future. I have one more click, please, Gianni.
Ah, yes, and the unseen events, this is where it gets a bit theoretical, but also lots of fun. So the idea behind this is that any historical high or low event might plausibly have turned out differently if things were slightly different.
So the unseen ensemble tweaks things so that you've got an ensemble of potentially viable events to go along with your historical actual event. So you can see here, there's a sort of little plot of what might have happened, the 2022 drought, how might it have
played out in all these theoretical other universes, which is just a really nice kind of concrete way of looking at the envelope of risk around some of the events that we've seen in the UK. That's always good fun as well.
Right. Next slide, please.
along with all of our modelling, lots of data work as well, lots and lots of data work, would never, you know.
I don't think you can overstate the importance of well-curated data sets.
So had a couple of new ones, through Hydro-JULES, sub daily river flow, really vital if you want to look at flood modelling because floods often rise and peak quicker than a daily time step. And various different high resolution driving data for models. So here we can see air temperature and precipitation at 1 kilometer.
over the UK.
That's the full UK this time. Next click, please.
Yeah, and also...
kind of using data in new and novel ways for hydrological modelling. So we've got a nice example here of a technique called data assimilation, where data is used alongside the model.
throughout the model run, either to parameterize things or to nudge the states.
Here, in this case, we're parameterizing the pedotransfer functions. But essentially, the soil moisture data from our COSMOS-UK data set went into improving the soil moisture estimates.
For the Jules model, and that was really wonderful work from Liz Cooper and Doran Khamis.
So yeah, lots more scope for that kind of activity as well, using different types of data

that we've not used before, using final resolution data that we're producing.
so that we've got more confidence in our modelling output elsewhere.
All right, next slide, please, Gianni.
Yeah. So, yeah, obviously, lovely to have all this work. Lovely to have all these outputs. Really, we want other people to see them, to use them, to do more work with them. And we want them to be as accessible as possible. So we've worked through various different ways of making it accessible. We've made notebooks, we've made
You know, there are GitHub repositories. We run a summer school. We've got a data labs area as well to help people get up and start with the data. Another click, please, Gianni.
Yep, just to help people get running quickly with the model. So if you do go and cheque out the unified framework, you'll find that there's various walkthrough notebooks that you can use to explore it. We've got lots of portals as well. This example is the eFLaG portal, and that just really helps people to visualise the data very, very quickly.

Helen Baron 16:26
and with minimal coding knowledge as well, which is wonderful because it means it's an easy way to get it out to more people as well. And this has various data sets from future projections model and comparison project that was run and will be hosting

Helen Baron 16:46
historical simulations for the Hydro MIP that you'll hear about later this morning, I believe, as well. So that's grand.

Helen Baron 16:56
Yeah, essentially, you really got to make your outputs accessible. Yeah, thanks, Gianni. Yeah, next one, please.

Helen Baron 17:05
Lots about Hydro-JULES. And of course, now we get to hear about FDRI as well. FDRI is in a much earlier phase of its life cycle compared to Hydro-JULES, but it's by no means at the beginning. There was

a number of years of scoping and planning to make sure, you know, kind of knew what we wanted to do with this money.

Helen Baron 17:34
potential money. And we're sort of about midway through the implementation phase now, which is just really nice. It's really nice to see some outputs from something that we've been thinking about as an institution for quite a while.

Helen Baron 17:49
We've got ourselves involved again, British Geological Survey, but alongside these two institutions, there's London or Imperial College London, University of Bristol, and all of that's under the Natural Environment Research Council.

Helen Baron 18:07
And the idea behind FDRI is, it's really foundational stuff. So it's trying to underpin all of the science that we can do on top of that. So it's looking very heavily at data, not just data collation, but data collection.
data storage, all of all of the fundamentals that then lay the ground work for all of the other science we do on top. So, you know, you can say you're supercharging new field monitoring and data-driven research, which is just very exciting.
Again, next slide, please, Gianni.
with a focus on floods and droughts. I mean, it's in the name, isn't it?

Helen Baron 18:55
So yeah, the first aspect, one of the big aspects of it, is to get a sort of network of monitoring together. That includes new monitoring, but also kind of streamlining and getting existing monitoring.
sort of under one platform. This isn't just going to be historical data either. It's going to be near real-time data, which is, you know, really, really great. And it's going to be sort of, you'll hear, I believe, in one of the workshops about sort of fair principles of data. So it'll be really accessible.
really well documented, really usable.
It's bringing together the community. We love to say that, but we do mean it.
in all earnestness. There's no point all the researchers working away in their little corners. We want people to come together and to share data and to learn from each

other in managing and handling and using data. And that will come along with a fair whack of training as well.
Again, I just want to close on the school.
And essentially all of that.
Will underpin.
the science that we do that will help us manage hydrological extremes. So looking at better forecasts, better short term predictions, managing water better. If you happen to be UK based, you probably not failed to notice the lack of water we've had lately. Um, and then they'll be sort of...
moments of heavy precipitation and flooding to go along with that. So yeah, the...
It's an increasing challenge, I would say, and we're looking to provide the science for that.
help tackle that better. Next slide, please, Gianni.
Yes, I'm monitoring equipment. It's great fun. If you ever happen to visit UKCEH Wallingford, you'll notice that more and more of our green grassy areas are becoming inhabited by strange looking
breaches, where essentially the fieldwork teams are testing out some of their sensors and networks. And you know, there's solar panels popping up this way and that way and sort of everywhere really, which is really fun.
But yeah, this is measuring various things, various...
kind of incoming radiation, outgoing radiation.
Lots of different things actually. I don't know why I started describing this. I don't know enough about this to tell you. But yeah, I have had a few tours. Clearly it's not stuck. But yeah, all of this, you can see a little rain gauge in the background as well. But as well as collecting the data, it's looking at ways to make it more usable as you go along. So automatic quality control, infilling. So it's a lovely plot here of kind of, you know, what you do when you've got data missing.
Yeah, having all of that kind of integrated to make it a more usable product at the end. If you've got any modellers in the room, you'll know your frustration of discovering that you've got years or months data gap in the middle of your nice clean data set. Next.
Slide, please, Gianni.
Yep, new observations and in new places. So I've put a little keynote here. That's next to the Earth observation surveys square here. You're hearing from Nick Everard, one of our hydrometrists.

But as well as that aspect, there's lots of different kind of regions and things to measure as well. Looking kind of from the ground water to the rivers to the weather to the water quality, which is really key as well, either with sensors that are permanently in place or with mobile sensors.
and bringing that all under the one sort of umbrella of the FDRI digital systems and services.
be looking really deeply into 3 heavily monitored sub-catchments with some more monitoring at the wider catchments as well. And in workshop 4, you'll be looking at some of the data in the Severn. You can look forward to learning a bit more about the precipitation in the Severn.
Yep, but we also have the Tweed up in Scotland, the Severn in Wales, those are familiar.
and England, and the Chess, which is in the Thames River Basin. So that's the three key sites that are happening around the UK under the FDRI project. And they're all underway at the moment with their monitoring and their river basin champions. And that's
Really nice to see. Next slide, please, Gianni.
Yeah, lots of data sets already flowing out of this project, which is wonderful. 15 minute flow data, that's up and out there. All of these are, you know, available for people to find, to use. The CAMELS data set, version two. If you're not familiar, that's part of the large sample hydrology
push and it includes
climatology, hydrology, but also lots of catchment characteristics. And that makes it really well suited for various different machine learning applications. So already we've got multiple machine learning models for predicting flow across the UK, just based on this one data set.
And you'll be using that in Workshop 6 as well, the CAMELS-GB data set. Still to come is the 15-minute, 1 kilometre gridded rainfall data set. All of this is UK or Great Britain based, I should say. But yeah, that's
going to be feeding into the flood event database as well, which is really vital if you kind of want to look at.
umm...
frequency and strength of various flood events.
Hey, next slide, please, Gianni.
Ah, yeah.

This is a great slide. For some people, this is background and you never want to know any more about it than this slide will tell you. But it's really, really fundamental. We've got huge data series now, huge data sets.
and we need more efficient ways of reading them and using them.
This you'll look at a little bit in Workshop 3 as well, different chunks of data and different tools for pulling big data sets. But essentially, yeah, alongside all of the kind of more obvious impact science, there's all of this underpinning fundamental making it actually work science. So it very much deserves a slide and in fact a workshop so you'll all get to enjoy that.
Next slide, please, Gianni.
We'll leave this one up for a few moments, but FDRI has a website and a newsletter. So yeah, give you a chance to whip out your phones and scan that in.
And in the background you can see a lovely picture of the arc boat, which I was going to say runs around and takes measurements. Unless they sometimes I shouldn't be allowed to talk about these things. I'm sure Nick will mention the arc boat.

Gianni Vesuviano 27:11
Okay, thank you for that great presentation, Helen. Clearly, Hydro-JULES, FDRI, both covering a huge range of different topics and different areas of research. If there are any questions about this, then you can either type them into the chat

Gianni Vesuviano 27:31
Or you can raise your hand in Teams and speak. If you do speak, remember to turn off your microphone after you've asked the question.

Gianni Vesuviano 27:42
Okay, we got one question. Martha, go ahead.

MM **Martha McKee** 27:48
Thank you, and thanks for that talk there, Helen. That was really interesting. I was just wondering, one of the things that you mentioned for the FDRI projects that all of your kind of sensors and monitors are recording is water quality. And I was just wondering if water quality has any actual direct effect on flooding and drought events, or whether that's just something you've

added in to monitor that gets passed on to maybe ecologists and water quality experts.

Helen Baron 28:15
So it often doesn't come into the formal definition of drought. But one of the key areas where water quality can really impact supply is that when it falls below a certain standard, we can't use it. So I know, for instance, that
water companies.
So.
if they have an algal bloom in their reservoir or in the source that they use to draw to their reservoir.
despite the fact that there is flow there, they cannot have that abstraction.
In groundwater, you have various nitrate limitations. So if there's too much nitrate in your groundwater, you can't pull from one particular well, or you have to balance it out with water from other sources, or you have to undertake very costly treatment processes. So yeah, it's not
part of the formal definition of drought, but it does really impact supply. And part of the problem is
but these things go hand in hand. So hotter, drier weather leads to more algal blooms. So you have less water and less of your water is usable.
Yeah, hope that answered your question.

MM **Martha McKee** 29:34
Yeah, that answers my question perfectly. Thank you. That was great.

Gianni Vesuviano 29:40
Okay, there's also one question in the chat from Mayuran, who is asking, do you have any digital twin models?

Helen Baron 29:54
I don't know if FDRI is working on that actually. It might be because we are doing real time data acquisition. So it would be a really obvious use case for digital twin. But I don't know. Is there anyone? I don't think there's anyone here who's more FDRI facing, are there?

Helen Baron 30:13

That will be one we will get back to you on.

Nick Everard 30:17

Yeah, so I was just sort of unmuting and trying to turn my camera back on.

I think it will. I don't know whether it's been defined specifically as digital twins, but elements of what I'm doing are going to require elements of what you could call digital twins. So when I go into my presentation, some of it will be clearer. But for example, if we want to improve our ability to monitor and understand flows, particularly peak flood flows in catchments, if we've got some elements of what you could call a digital twin in place,

We can do that, so I, so I think that you know the short answer is probably yes, the long answer is perhaps in in various different guises.

Gianni Vesuviano 30:48

OK.

Thank you. And there's another question from Tlakale, who is asking, is the UniFHy model only applicable in the UK?

Helen Baron 31:03

Yeah, spotted that one.

Nope, the UniFHy modelling framework is a generic framework. So I think the test examples have been run in the UK, but there's no reason to restrict it to the UK. As with any other model, you should make sure your modelling assumptions are suitable for your location.

But the whole idea of the framework is that you can substitute in any model that you like.

So yeah, if you live in a snowy catchment and your model in no way accounts for snow, maybe consider changing it. But yeah, it's a general use piece of software.

Gianni Vesuviano 31:52

Great.

Thank you for the presentation, Helen, and sorry about the technical issues.

Helen Baron 32:00

You did wonderfully.

Gianni Vesuviano 32:00

Ahh.

Yeah, so next.

Helen Baron 32:05

Thanks everyone.

Gianni Vesuviano 32:06

Yeah, thank you. Next we have Nick Everard, who's going to present measuring rivers and floods with drones, phones and satellites. So over to you when you're ready.

Nick Everard 32:19

All right, cool. Let me see if I can share.

Here we go.

You'd think I'd have done this often enough that I'd know exactly where these buttons are, but all right, here we go. Oh, that's a little sneaky peek of a slide I just added just this minute in response to the question. Right, okay, so let's go and make this. Is that looking sort of full screen-ish now?

Gianni Vesuviano 32:38

Uh, yes.

Nick Everard 32:47

It should be. Yeah, I think it is, yeah. All right, so yeah, so now something a bit more focused. My name is Nick Everard. I've described myself as a senior hydrometric obsessive. I think my job title says senior hydrometric scientist, but you know, I get quite obsessed by this stuff. So really, this is about

measuring river and flood flows and some of the tools and techniques that we're using for that. And I put a little asterisk there because I think the phones may have fallen out now, replaced by more exciting stuff, but we'll see as we go. So also, I'll say there's quite a lot of content here because Gianni said some of the others might be

shorter than expected. So
you know, brace yourselves. There's quite a lot to take in, but hopefully I'll keep it entertaining and lively. So basically, this is kind of technology led science, also known as cool gadgets and gizmos to measure things. So we're talking drones and satellites and maybe phones if they're still in there. But a little bit of my background, who am I?

NE **Nick Everard** 33:45
I've spent three, well it's actually nearly 3.8 decades now, crazily, measuring rivers. I used to work at the Environment Agency where I led on the technology and techniques that we use for measuring river discharge. And yeah, as I already hinted, this whole presentation is about measuring river flow
which has been described by many people, not only me, as the most important hydrological variable, because all the rain, all the groundwater, everything else, you know, the river is the conduit in which this stuff ends up. So it's arguably the most important hydrological variable. I'm going to go with that because it's my hydrological variable.
So anyway, about a year ago, I was, this is a modified version of a presentation I gave about a year ago. I asked AI what it knew about measuring river discharge and asked it to create an image for me. And this is what it came up with. And it's sort of, it's sort of not a million miles from being sensible, but I've never seen anybody with equipment that looks quite like this. But
But the basic principle is not 1,000,000 miles off. This fan-like thing is actually a propeller, or more correctly, an impeller. The principle being the flow of the water is causing this thing to rotate. And this complex and highly expensive looking thing on its back is actually nothing more sophisticated than a counter.
It counts the number of revolutions of this thing. So this is actually a valid method. The tools don't look like this, but the principle is not a million miles off. And standing in the water is something that is very much part of the process. So, but why is it important? Why do we need to know river discharge? Here's a great big list that you can read yourselves, but you know, water resources,
Once it comes out of its hat, without that, we wouldn't be very successful. It's needed for industry and so on. But flooding, agriculture, environmental flows, blah, blah, blah. I was talking in Oxford when I gave this one, so I put rowing as well, because rowing is quite a big thing in Oxford. But anyway, yeah, measurement of flows. I just

chucked this one in as well, because Helen was talking FDRI.
Everything I'm going to talk about is relevant to FDRI. A lot of the stuff we're doing here, a lot of the developments we're making are pretty directly linked to FDRI and FDRI has funded some of the science that we're going to talk about. So important to get that in there and recognise that. So anyway,
Measuring river discharge, here's a few of the things that we used to do. So this guy top left, he's doing something like what that AI image was suggesting. He's wading across a river that happens to be frozen, so it's probably going to be pretty cold and unpleasant. And on the bottom of this stick is one of these little things rotating, and he's got a little counter in his hand.
and he's counting the rotations. More rotations equals faster water. So he's going to do that at a number of locations across the river until he's built up a picture of the velocity, a whole range of places across the river. He's also going to use the same pole to measure the river depth. And you can see he's got a tape stretched across the river to measure the width. So he's ending up with
the cross-sectional area, so that's width times depth, and a series of velocity measurements, so we can calculate discharge, which is basically cross-sectional area times mean velocity. So that's what he's doing. He's taking a number of measurements of depth, number of measurements of velocity, and he's measuring width, and he gets there. Same thing here.
We've got one of those little rotating things just up here with a big heavy sinker weight because this thing is going to be winched down off a bridge down into the water. And again, a number of measurements will be made across the bridge. We don't do this anymore. It was kind of hazardous. You could easily cut your finger off. This thing weighed about 25 kilos. And when you laid this thing down onto this sharp edge metal bridge or many other stone bridges, for example, it was very easy to injure yourself. Plus, there's going to be traffic whizzing past you whilst you're doing this. So it's not great. We used to do this. This is five of those things on a pole. The pole was about 7 or 8 metres long. We would put a cable all the way across the River Thames.
And this is me as a boy hydrometrist wrestling with this thing in a low flow condition. But we would also do this in a flood when it became really quite hazardous. We can say now, because we don't do it anymore, that it was really quite dangerous, but it was also kind of fun at the time. Something we still do, Helen mentioned the arc boat, she guessed correctly that I would mention it.

So this is Steve Turner from the National River Flow Archive at UKCEH driving the remote control arc boat. So this is basically what I just said. It's a remote control boat built in Wallingford, actually, by HR Wallingford, who are our neighbours just up the road. And on board is an acoustic sensor called an acoustic Doppler current profiler. which is a river discharge measurement tool that I'll talk about very briefly in the next couple of slides. So we still do some of these, but some of these not so much because there's better technology and methods now. So what's an ADTP? What's the arc boat? The arc boat is just really, it's just a means of moving the thing around. It's the Uber for the sensor. It just moves it around.

NE **Nick Everard** 38:41

But the sensor uses pulses of sound to measure the speed and the depth of the water. And it uses some other pulses of sound. It sort of sends 2 pings out. We call them pings. First one gets depth and velocity. The next one gets speed over the bed. And speed over the bed multiplied by time gives us
the width of the river. So it builds up this beautiful cross section. So I've simulated that here. This is the River Spey in Scotland looking glorious. Here's our boat going across. And by the time it's halfway across, it's already mapped the velocities and the colours represent velocity. So as you might sort of logically expect, at the edges, it's slow and shallow.
As you come out into the middle, it gets deeper. It also gets faster. So the warmer colours, the red is the fastest, and these kind of purples are the slow water. So we get this really detailed picture of the velocity across the river. So a really accurate representation of discharge from these things. But
They are kind of, they're not past it. They're the kind of established method. But what we're more excited about and focusing on in this discussion is new methods. So for these new methods, the ADTP is still crucial because it's an enabling technology. It enables us to use new methods. So as I'm going to start talking about sensors that don't make contact with the water, that they've either flown above the water, they might be in space, they might be held from a bridge. They're only looking at the surface velocity at the moment. They're giving us the speed of the surface. So we need to know how does the surface velocity relate to the velocity beneath. So this is a velocity profile taken from some ADCP data.
What it represents is at the bed, we have 0 velocity and then it gets faster and faster. This is our measured data. So we fit a curve through the measured data that

represents the sort of extrapolation of these trends down to the bottom, which always drawn to 0 and up to the surface.
And we're also using the ADCPs, the acoustic sensors, to give us this really detailed cross-section. We're going to use this bed profile to give us the cross-section when we're using the tools that I'm going to talk about from now on. And this surface alpha thing I refer to here, that is the relationship between the measured velocity at the surface
compared to what we think the mean velocity is derived from all of these samples here. And you might probably someone will ask at the end, well, how do you know what that velocity profile is when you're using your non-contact instrument? I'll try and preempt that. Actually, you don't. But what you can do, what FDRI is going to do is build up
a kind of a database of all of these thousands of ADP measurements that we've already got, so that we have a pretty good idea of what it probably was when we, you know, when we do our drone-based measurement or whatever it is, we have a pretty good idea of what multiplier to use to get us to mean velocity. So anyway, why are we doing this stuff? Why don't we use these tools that work great?
Well, here's a big flood situation. This is a river in Scotland. There was not a boat in the river at the time. I've sort of photoshopped that in. But this is what would have happened to it. We would have lost it. We'd have kissed goodbye to it. If we were lucky, it would have crashed into the bridge because then we might have been able to get it back. But we would lose it. We wouldn't get a management.
Monitoring networks, this is another driver for this. So globally, there are river flow monitoring networks, the UK, in England alone, there's something like 1700 river flow monitoring stations. I probably should have shown one that was intact and in good condition, but imagine this little hut here, and this is what this looked like before a flood came along.
And actually, this little hut is, you can just see it, there it is. This was a storm called Storm Desmond in 2015, which hit the UK, the north of the UK in particular, really hard. It was a wake up call for us, really. It washed away and destroyed this hut. This one was still there, but you notice it looks a bit wonky. That's not just a bad photo. It was about to fall into the river. You notice how this bank here looks a bit loose and rough. That's because the river had become about 10 metres wider. It had eroded away all of this stuff over here. So these big floods are really hard to measure and we're going to get more of them. Climate change, surprise, surprise, it's a thing. It's

going to hit us hard.
It's going to create bigger floods. They're going to be more destructive. They're going to be more difficult to measure. But as they become bigger and more difficult to measure, they become more and more important for us to measure so we can track and understand trends in peak floods and try to protect ourselves against them. So these are some floods that happened. All of them happened in the space of about three months.
in 2014. This one was Storm Boris at the time when we still had a PM called Boris. Or did we? I don't know. Maybe he'd gone by then, but we were not long shot of him. This one is North Carolina in the US, Hurricane Helen. This one was in Nepal. I'm afraid I can't remember the name of the storm. And this is the Valencia flood, the Dana flood, as it was called.
that just washed hundreds of cars through the streets of Valencia. And sadly, all of these cost a significant number of lives. So how are we going to measure these things? Again, these are the impacts. These are all from Hurricane Helen. Do you want to go anywhere near this flood? Looking at the destructive power of this flood, no, you don't.
You don't want to be anywhere near this, but you could hover something above it, or you could look at it from space, right? So that's what we want to do. And why is this important? So taking this back to the UK context, these are all the river flow gauging stations in the National River Flow Archive, which is the UKCEH curated database of river flow information for the UK.
And what I've done here, I've represented the maximum measured, there's a relationship between the maximum reported discharge for the gauging stations related to the maximum that's been checked and validated. So what I mean by that is if we think, if the NRFA says the highest river flow for say Reading Bridge gauging station on the Thames,
Let's say it's 330 cumecs, it's something like that, cubic metres per second. Have we measured, have we gone out and checked and validated with our ADCP at 330 cumecs? And very often we haven't. So if that one were an example, if the true discharge was or the reported discharge was 330,
we would have gauged about 165 at this point. So in other words, this is the point at which the reported flow is twice as big as anything we've measured. And this is the point at which is four times as big. So in other words, for 135 or so gauging stations, we might have, if we've reported, say, 400 cubic metres per second,

We've never gauged, we've never checked at more than 100. So that 300 extra cubic metres per second is purely extrapolated based upon modeling, based upon looking at the curve and extending it. We've really got to try harder to measure peak discharge. And the picture is generally worse around the world because they don't have such established networks.
And this is no criticism of the monetary authorities. It's been really difficult, potentially dangerous to get these measurements. But this is our challenge. That's what we're facing up to. And why is it so difficult? Well, we show you the really, we showed you the really fast turbulent water smashing the bird against the bridge. But another problem is this. This is a gauging station in the Scottish borders on the River Tweed.
The section that's measured by the station is represented by this little arrow and I've sort of inset an ADCP cross section. So that's what we can measure with the station and what we can validate with an ADCP. But I visited this place in 2023 and I could see rack marks, debris marks all across the field.
across here. And I took a drone picture so I could see where they were, which tells me that at the peak of the flood, this was the extent of the flood. So if we're only able to measure this bit, how the heck do we know what all of this stuff is? And this is the footbridge you can see down here. This is all the debris on it. And this is why they can't get there to measure. Even this section cannot be measured at the peak of the flood.
because you cannot get over this bridge for reasons that are made obvious by all this debris. But a drone flown from this field would be completely happy with all of this stuff. You just whiz it over here and get some observations and probably get a measurement. So I've kind of given away the next part of the story. The next part of the story, I think this is going to be a video.
Video velocimetry, it's a non-contact method. You can use handheld cameras, standing on a bridge with your smartphone, a phone thing. You can put a camera that's mounted on a bridge, like a CCTV camera, or even a wildlife camera, a trail camera we've used recently, quite successfully. But it works most nicely with a drone. So with a drone, you hover the thing above the river,
You point the camera straight down and you capture a 20 second video. And this is one of those videos. And what I've done, I've processed it and we're just processing to see your eyes can see that this water is moving, right? So can a piece of computer software. So it's analysing the displacement, the visible features within the frame of

the video.
to work out velocity. And the only thing we really need to do that's critical to this is scale this imagery. We need to tell it so that it knows how big is a pixel. So when we see the displacement of these features from one pixel to another or through 6 pixels or whatever it might be, what's that in terms of distance on the ground? So we can really easily do that.
with drones, because actually when we're looking straight down, just using the width of the river or the distance between 2 distinctive points on the banks is enough to scale the imagery, because there's very little distortion because of that straight down nadir view. Bear that in mind as we come on to some of the more exciting stuff later on.
So how does this work? Just very briefly, this is your dream site for this. The pint of beer here, the relevance of that is the more your river looks like it's full of beer, the better this works. Because what we've got is this nice dark brown water, but we've got all these foamy bits on the top, just like the beer. And we're tracking the movement of these foamy bits.
And the method I'm using is called space-time imaging velocimetry. It's a fancy sort of name, but it's basically tracking brightness along these lines, which are user defined. The user draws a grid of lines on the surface of the video, and we're tracking the movement of these little bits of foam down these lines. And that gives us the velocity. And it's a really simple
really robust method, but we're looking for these foam features are perfect. Some rivers don't have the foam features. Sometimes it's roughness, just ripples and so on going down the river. Sometimes it's debris like leaves and twigs, but we're tracking the movement of those visible features. And here's how it works then. So for each one of the frames of the video,
We're taking this line and we're going to stack it. I've rotated them through 90 degrees, but here's the brightness. So this is one of those bits of foam. It's in that line. And then you can see in the next frame, it's moved along the line a little bit and then a bit further. And we can see that for several different features in each line.
So then we stack them all together, squash them down so there's no gaps. We end up with these streaks, these diagonal streaks. The angle of the diagonal streak equals the velocity. The software just basically analyses the angle of all these streaks. So you can see there's multiple samples in each frame. And we get a really nice
really accurate estimate of surface velocity. And keeping this beer thing going along,

your real dream site, this, I mean, part of this one is the best one I've ever been to. This is the River Garry at a place called Killiecrankie in Scotland, and it looks like Guinness. The water's just inky dark, but it's got this lovely white foam on the top. and it's distributed all the way across. So we get really robust readings all the way across the river. The Thames has an annoying habit of either having no foam or the foam all tracks down the middle. Something else to bear in mind as we come on to talk about thermal cameras later on. But yeah, a river that looks like Guinness is your friend when you come to try and do this stuff.

So we already kind of talked about this, but just as a reminder, knowing the surface velocity is not enough. You also need to know the cross-sectional area and you need to know that vertical velocity profile. So that's where ideally we will obtain these measurements where we've previously got ADCP measurements.

And what are these lines going across the river? These are deployment systems for ADCPs. This is a cableway system operated by Scottish Environment Protection Agency, SEPA. So they had cross sections here, they have velocity profiles here. So we could take this data that we've got for surface velocity, multiply it by cross section,

apply a little correction factor for surface to midsection or mean rather, velocity and calculate discharge really quite effectively. So we do need those additional components. FDRI is going to try and make them available to the community so that drone-based measurements become much simpler and much less sort of effort intensive to get good results. So I said at the start, you have to have your camera above the river. Having your camera above the river with a drone is cheap and easy. But what if we could have a camera above the river that was in space? Could we do that? So grinning over the top of the hill here was a guy called Mark Randall, who is a hydrometrist in Australia.

I should have left him in, really. I don't know why I took him out. It was his idea, credit to Mark. He said, Planet Labs can shoot video from space, high resolution video from space. This is one of their SkySat satellites. They can shoot 30 second videos. I think they can do up to 90, but they've got 30 seconds for us at sub metre pixel sizes.

30 frames per second. So we thought, well, hey, can we do this velocimetry thing from space? There you go. There's the slide. It looks nice, but it doesn't contain much information. So a little bit of background to this. Can we measure velocity from space? Can we measure rivers from space? People have been looking at rivers from

space for a long time. Initially with radar altimeters,
This thing looks as though it was built in about 1882 to me, but apparently this was the first surface or first radar altimeter. It was called NASA GEOS mission in 1975. It looks a bit Jules Verne, but it was looking at sea surface height. This thing was up in space, could detect the height of the sea surface. So we've been looking at water for quite a long time, from 1975. This is even earlier, 1973, 80 metre resolution. And that to me is kind of shockingly low res. But this is the Mississippi River. This is a flood on the Mississippi River at St. Louis. This is the river in normal conditions. This is the flood condition. So even with 80 metre resolution on big rivers,
You could get useful stuff, but this is just extent. This is not velocity or anything like that.
This radar altimetry thing, you know, the little satellite I showed you at the start, that has become refined so that it can not only look at sea surface, but it can look at rivers. So for a large river like the Congo, there's a time series going back to 2002 of radar altimetry. So this is water surface height in metres on a large river.
So it's been going on for quite a long time. And yeah, now we're going to look at resolution things. Sorry, we're sort of darting this way and that a little bit. But what I've been doing, my science, the advances I'm trying to drive here are driven by high resolution data. If it's not sub meter, I'm basically not interested. So
This is a 10 meter. This is what was described as high resolution imagery. This is Sentinel 2. And I'm not rubbishing Sentinel 2 because it's amazing when you look at large scale what it does. But what is this? Who has a clue what this is? We really can't tell from this image, can we? But when we go to high resolution data, this is the exact same scene cropped exactly the same.
This is Sentinel 2. This is Airbus Pléiades Neo. And this is 15 centimeters. This is 10 meters. So this is the Eiffel Tower. Believe it or not, if you squint, maybe step to the back of your room, you're looking at the same thing, the Eiffel Tower from the same angle. So huge advances in resolution. You can see each individual person on the street.
You can see things like these lines where the traffic markings are on the road, and you see the structure of the tower. So incredible detail. The same is happening. Oh yeah, but swath width. So just to just sort of put the other side of that argument, if you're interested in large scale stuff, Sentinel is what you want. This is the Sentinel swath. It's 290 kilometers.
the fancy stuff, the trade-off, it's just like zooming with a camera. You get a smaller

image. So it's only a small image, but it's super high resolution. So it's horses for courses. Sentinel is fabulous, but for what I'm doing, it just sort of doesn't work. So then when we move to radar, the same thing is true. Sentinel 1 radar, again, hugely valuable, amazing resource, but this is the exact same scene imaged by a company called ICEYE with their radars. This is actually about 40 or 50 centimetre resolution, but they can now go, well, they're about to go to 16 centimeters. But we wanted to see the inundation and the storage of water in the floodplains of this small river in North Oxfordshire, the Evenlode.

Here, you can see this, I think this is a pond, it might be flooding in the field, but here we can see in between each furrow in the field, and here we can see interconnection of the flood plain to the river. We can see all the individual trees. We can see everything. We can see an awful lot.

But again, the same thing is true. The trade-off on swath, 250 kilometres versus for this super high resolution stuff, it's 5 by 5. So you've got to choose very carefully where you have a look. Revisit times are the other big advance that's coming with the high resolution constellations with Sentinel 1 and Sentinel 2.

It can be as much as five or six days. Sometimes it's less than that, especially at more northerly latitudes. But with these new high resolution operators, ICEYE now has, I think, 70 of their SAR radar satellites in space. So they and Planet Labs and a few others can look at the same place multiple times a day.

And this is a time lapse of a glacier. So this is kind of looking a bit like the science we're doing, right? So this is just taking the same approach. This is velocimetry, but it's an image a day. And you can see the movement of the glacier for an image a day, which you could probably also do with Sentinel 2, but it would be much more sort of stop-start because you'd only have an image every five days or so.

And you might not see through the clouds. This is radar, so it can see through clouds. But yeah, water moves. So we're coming back to this velocity thing. This is a fast moving river. This is the Congo. And on a rare occasion when there were no clouds and you can actually see it, you can get the idea. It's not a video. We couldn't get a video of the Congo yet, but actually you can see the movement of the water. It's fast moving, right?

So the FluviSAT concept, we had published a paper in Nature Scientific Reports about a year and a half ago on this, but we called it the Fluvial Video Measurements Obtained by Satellite, FluviSAT. ESA wanted it to have a nice sort of title. That's what we called it. But it's exactly the same thing. It's just the same process we're using with

the drone.
except the camera is 450 kilometres above the Earth up in space. But with just the same, we're getting multiple readings of velocity across the river. And all of these vectors, each one of these is derived independently. So if one of them looks bad, you know, the fact that they all look good, rather, gives us a great deal of confidence that they're probably right. And we've got
anything up to 21 readings of velocity across this section of the river. So is this magic? Is Nick making this stuff up? Hopefully this is one of the videos. You'll notice it wanders a bit. If you've ever used a zoom camera, you'll understand why. This is a zoom that's got 450 kilometre reach. So it's not 100% stable.
But hopefully you can see the surface features and you can see the movement of those surface features. So as soon as we got one of these videos that was well targeted and good river conditions with high flows, we knew it was going to work because you can already see the flow. So as long as we can scale this and stabilise the video, chances are it was going to work.
And sure enough, it did. So this is that location. And we were able to get not just one, but three observation points from it. And from that, every one of these vectors, remember, is derived independently. We can see a logical distribution of velocity getting faster from the banks to the middle. And here we see where the flow is coming around this bend.
very clearly fastest towards, you know, sort of offset from the middle. And then here we can see the flow is pushed over by this kind of almost island here over towards this bank. And anybody who's ever worked on a river will know downstream of this kind of thing, you get very slow or even backwards flowing water. So incredible results where we could validate.
We found that we were always within 10%, which was kind of crazy, and often we were within 5% of validation measurements that we got with drones.
I mentioned this already, because there's 21 satellites in the constellation, they can image the same place multiple times a day. This is the River Tweed in Scotland, and they got 4 observations within about 23 hours at the same location, because there are so many satellites. But problems and challenges, these things are not perfect. There are clouds. Clouds are annoying. Clouds have an annoying kind of correlation with floods. Without clouds, you don't often get floods. And we can't see through them. With optical satellites, you cannot see through the clouds. If you can't see through the clouds, you can't do the magic to work out the velocity. So what's the

potential answer to this? I already mentioned this company, ICEYE.
This was something they published as open data. They put it as an example out on their website a year or two ago, and it got me really excited. This is not a river, this is the sea, but you can see the movement of these waves. You can see features, one or two of these ones they had, yeah, here, you can see the wake of a ship that's moving through the water.
So we can see motion in water from this, but we can see the impact of motion in the radar data. So having recognised that we could measure velocity from space, but we couldn't see through clouds, the question is, can we use ISAR data to solve this problem? And the answer is, we don't know yet, because we've only just started mucking about.
But we are seeing what we think are velocity signals on rivers. This is the Nile. This is the Nile in Africa. Again, just for comparison, this is Sentinel-1 data. You can see this large kind of feature here where the rivers broadened out and created some islands and so on. But this kind of fuzz, this haze,
we think is actually probably to do with the movement of the water and something that we can analyse and get us water motion from. So this is real cutting edge stuff we're really just starting out on, but we think we might be able to get velocity from SAR, which would be amazing. Am I over running time yet, Gianni, or can I still waffle on for a bit longer? I can see you, by the way. You can nod or...
Or say, you know, zip it.

Gianni Vesuviano 1:01:34
Uh, you still have some time.

Nick Everard 1:01:36
Oh, do I? Crikey. All right. So bringing it right back to another end of the scale spectrum, we were trying to do this same stuff on a small river in, where was this, in Hertfordshire. But there was no foam, there were no roughness features, there was nothing to track. So we bought a box of Rice Krispies. I'm chucking them in from the side here.
And then I've got my drone hovering above the river. And we've got a ruler here to measure the width to give us the scaling. And it worked. These velocities were generated by the movement of Rice Krispies down the river. So sometimes you need to be creative in your methods of solving problems when measuring food,

measuring, I nearly said measuring food.
measuring flows out in the field. It can be fun. But yeah, just moving towards, I think the last thing I'm going to talk about, I told you there was a lot, told you it was dense. Thermal velocimetry. If you don't have Rice Krispies or you have a large river, but you've got none of these sort of surface features, your river's not made of beer, doesn't have the foam on the top. What can you do? Well, it turns out there are now drones available with thermal cameras, have been for some time, but the thermal cameras are pretty good now. And it turns out that you can actually see, is this a video? Yes, it is. So this is the River Chess in Buckinghamshire. It's only about two metres wide.
But it looks kind of smudgy and vague, but these velocity vectors were generated from the signal here, which is variations in temperature. So we can see variations in temperature moving down the river. You can just about see them here. But this processing technique, the space-time imaging technique, is so robust.
that even these smudgy kind of movements can be processed to give us these vectors that compare really, really well with reality. By contrast, the same drone captures standard optical imagery at the same time. When we tried to process that, we just got 2 vectors. The rest of these, we had 15 vectors, and they all failed, with the exception of these two, because it was just nothing.
visible in the water to track. It was clear water, no foam on the surface, didn't look like beer, looked more like vodka, it didn't work. Thermal solved the problem.
This one I threw in just now as well, because the water quality question was asked and I think reservoirs were mentioned. This was about two weeks ago. I flew my thermal drone over Clywedog Reservoir in Wales, mid Wales, and we saw these incredible thermal patterns driven by the wind. It was quite a breezy day, but the land surface
is the kind of red stuff you can see in the corners here. This is a kind of inlet into a sort of shallow area. So there's warm water in there, very warm water. And then there's a big body of cool water probably moving through the centre here, I would guess, from top of the screen to the bottom of the screen, looking at the state of it. But you get some clue.
of different bodies of water here, different masses of water here. But when you look at it with the thermal camera, it becomes really apparent that there is structure to the water here. It's not just one uniform, homogeneous body of water. There's things going on and thermal really shows you what's going on. So that could probably be

very powerful for understanding things like
algal blooms, where they're going to generate, where they're going to move around to. So brand new stuff, we only flew it for the first time two weeks ago, and it's sort of FDRI related. Bringing it back to the flow thing, we probably already did this, didn't we? We did, we need the cross section, we need the velocity profile. So sorry about that, sort of duplication.

Just a final couple of thoughts. We've talked about having an ADCP measurement, which might be at, say, one location, typically close to a bridge. So it might be that we've got a measurement point here. It might be that it's here, but we wouldn't know in between what was going on. So if we couldn't get here for some reason, we could only get here.

How could we work? How could we calculate discharge? Well, happily, the Environment Agency has driven multi-beam sonar for the Thames up as far as Oxford. And what that is, is a really detailed map of river bathymetry all the way up the river. So they drive a nice big boat up the middle of the river, and they're mapping the whole darn thing at super high resolution. And it's open data.

So I got this data off the internet, mapped it up, then I flew my drone over the river, just used their bathymetric data to use a sort of a representative velocity profile, calculated discharge at a place where we'd never measured before, and I was within about 1.5 percent. So if we can get rivers mapped for bathymetry,
with multibeam, with green LIDAR, whatever it might be, we can start to enable ourselves to make measurements wherever we need to in the future. So another exciting development. Oh, yeah, here we go. This is that. This is the results of that one that I did. And this is LIDAR coverage. So the other thing, yeah, the other thing we had here was this is multibeam bathymetry.

They've also got open LIDAR data, which is land surface topographic data. So I merged the two so I could get the water surface height and match it to the land surface height and know my water surface height on the day so that I could normalise that and get my correct cross-sectional area. So open data from the EA and others is really potentially useful to us.

And here we are with a sort of summary, which probably isn't really relevant to this thing here, but it was about wholly remotely sensory river discharge is probably quite close from space. And it's going to be particularly valuable in data sparse areas such as Africa, Arctic rivers. I've had a lot of fun looking at Arctic rivers the last few months.

They get nice chunks of ice, which are really good to track floating down the river. And very low latency and rapid repeat observations. This is all satellite stuff are now possible because we've got hundreds of satellites in space that we can use to look at rivers. We just need to be clever at working with the commercial sector to enable it. And I think that's it. Questions, I just have this final statement on what you can do with satellite, you can probably do with a drone and vice versa. So, you know, if you're studying high-res satellites, make sure you study drones. If you're studying the other, make sure you study the other. I forgot which way around it was. That's it. That's all I've got, Gianni. I hope that was enough.

Gianni Vesuviano 1:07:46
Yeah, that was that was good. Thank you, Nick.
Any questions? Again, please put them in the chat or raise your hands.
First question, Martha.

Martha McKee 1:08:02
Hi, yeah, hi. Thank you very much for that, Nick. That was a very entertaining presentation. I was just wondering about whether there's a kind of size limit to what you can do with these things. You know, is there a point where a river is too small in this and these drones become useless if you've got a really small stream or if you're working on maybe a lake or something and there's not enough flow going on, do they
do they become redundant? You know, how, what's that kind of threshold that you can work within with this technology?

Nick Everard 1:08:30
Yeah, it's a really good question. And actually this image here with the Rice Krispies is sort of about the smallest I've measured. But with the thermal drone, we went even smaller. It was a sunny, lovely sunny day. It was a spring-fed river. It was about 0.2 metre wide. So I hovered my drone.

Martha McKee 1:08:39
Mm.
Okay, so really small.

NE **Nick Everard** 1:08:51

About 3 meters, it was just, you know, above head height. We made sure there were no people around, so we weren't going to hit them or anything, but yeah, it still works, so, so...

Perhaps the bigger challenge is at the other end of the spectrum, really. I think the challenge is on the smallish rivers, you often don't have these tracers, as we call them. So the Rice Krispies were important for that. You're not always going to have a thermal drone, and the thermal drones are bigger, so you can't always fly them. The CAA, Civil Aviation Authority, limits where you can fly drones.

You can fly pretty much anywhere if your drone is less than 250 grams, but if it's more than 250 grammes and the thermal one is about 1 1/2 kilos, you're a bit more limited. So yeah, you're going to need to throw in your own tracers. We've used grass before now, if we didn't have cereal, you can just chop a handful of grass in a few times and track it.

MM **Martha McKee** 1:09:26

Mm.

NE **Nick Everard** 1:09:40

But at the other end of the spectrum, yeah, if we wanted to, where we're getting these satellite observations of large rivers like the Congo, you can't get your drone high enough that you can see the full width of the Congo. So there are going to be ways around that. You can just get it up to the height limit. And in this country, 120 meters. If you went to 120 meters,

MM **Martha McKee** 1:09:51

Mm.

Yeah.

NE **Nick Everard** 1:10:01

above the Congo, you would see roughly 200 metres of the Congo. So you could then do it in a section by section method. You'd do the 200 metres nearest to the bank, then the next 200 meters, then the next 200 meters, then the next 200 meters.

And you can scale based upon your understanding of the optical properties of the camera. So you know

MM **Martha McKee** 1:10:11

Yeah.

NE **Nick Everard** 1:10:20

If you're 200 meters, 120 metres above the river, you know what the footprint of the camera is going to be on the water surface. And these drones are so stable that once you get the thing up in the air and you let go of the controls, they just stay there. They're like kestrels. So, you know, you could do that on a very large river. And the comms range on them is something like
like 10 or 20 kilometers. So, you know, yeah, so bigger rivers are going to be a bit more of a challenge. Rivers in the UK, there's nothing big enough that we can't measure with a drone. Internationally, yeah, you run into these problems, but there are solutions.

MM **Martha McKee** 1:10:41

Okay, yeah.
Yeah, no, that was a great answer to that question. Thank you. I didn't realise you could, hadn't thought about, you know, just taking sections of the river when you're working at such a big scale. If you don't mind, I've also got a follow up question to that now. You've answered. I'm actually a marine ecologist, so I'm like trying to think about how this could apply to the marine environment as well. So
Would this also be applicable in estuaries and these kind of coastal areas as well, if you can take sections and work along at scale? Because I was kind of concerned that maybe some areas, estuarine areas or coastal areas would be too big to monitor, but it sounds like it would maybe be possible.

NE **Nick Everard** 1:11:31

Yeah, it certainly should be. I think, yeah, the same principle. Yeah, in an estuary it is going to be exceeding the scale where you can get the whole thing in. There are, you can also, the other thing you can do, this is an oblique view, this is not a straight down view. When you go to an oblique view, you know, you can see, so an angle view, you know, you can see a bit more.

Martha McKee 1:11:38
Mm.

Martha McKee 1:11:44
Yeah.
Yeah.

Nick Everard 1:11:50
But yeah, doing that sort of section by section approach. The other thing that we're really excited about at the moment is we've started working with a company called SatVu, who are launching a constellation of thermal satellites. And thermal satellites are not new, but what's new is that they're going at 3, 3 1/2 metre resolution and they can do video.

Nick Everard 1:12:09
So we haven't seen the results yet, but we are hoping that they're going to task, I asked them to task this same reservoir at the same time that I was there with the drone so we could compare. But I think for estuaries, the thermal satellite video could be really powerful for what you're interested in, but drones also will be useful.

Martha McKee 1:12:28
Yeah.
Yeah, yeah, I'm already using ADCPs as well, so just curious about what you can pair with that to kind of get better data and a better understanding of the area. But yeah, no, that's answered my questions perfectly. Thank you.

Nick Everard 1:12:44
Cool.

Gianni Vesuviano 1:12:47
Okay, thank you. We also have a question in the chat from Mayuran who's asking, what is your opinion on rivers in the tropical regions? Usually our satellite data is full of clouds and we have rainfall throughout the year. What would be the methods that we should explore besides the conventional methods?

Nick Everard 1:13:10

Yeah, well, I think, I mean, the radar altimetry is good on big rivers. And there's a, I mean, if you ever go, what's the site? There's a site that has loads of, I mean, I'm just opening a little window on my Hydro Web Next. Have a look at Hydro Web Next. You may already have, but

Nick Everard 1:13:28

There's masses of sites where there's satellite altimetry going back for a long period of time. There's thousands of, they call them virtual stations all across Africa and other large rivers in sort of towards the tropics. So there's that. For velocity though, you know, if we want to, if we want to get to velocity,

You know, the SWOT mission, I had slides on the SWOT mission, but I took them out because I thought it was too much content. But NASA and CANALES launched the SWOT mission, Surface Water Ocean Topography, it stands for. The objective of which was to map and measure all the world's water. And it is pretty effective. It's a large swath.

Nick Everard 1:14:06

altimeter. So it's kind of like a combination of Sentinel-1-2 and altimetry. It's looking across about, I think it's 150 kilometres wide, but giving you pretty high resolution altimetry data. So from that, you can get water surface slope accurately. And from water surface slope, you can infer

a likely velocity. But from the point of view of my research and what I'm interested in, it's going to be high resolution SAR, synthetic aperture radar, that we think is going to give us velocity, but it's just, you know, it's too early days to say whether it will at this point. But the radar is, you know, radar can see through clouds. It's untroubled by clouds.

Gianni Vesuviano 1:14:50

Okay, thank you. If there are no more questions, I'll go over to Rosie's presentation. on, where is it, how well can we model river flows across Great Britain?

Thank you, Rosie.

Rosanna Lane 1:15:11

Hi, thanks, Gianni. So I'm Rosie Lane. I'm a hydrological modeller here at UKCEH. And I'm going to be talking about some results from a model into comparison project that we've been doing and talking you through how well can we model river flows across Great Britain.

Rosanna Lane 1:15:30

and some of the major challenges that we see.
So first, it's really important that we're able to model river flows. We need models for water resource assessment, so ensuring that we've got enough water to meet demands from household, from industry and from agriculture. We need models for flood forecasting and more long-term flow forecasts.
So for example, for the UK hydrological outlook that UKCEH produces, we provide flow forecasts for one to three months ahead.
across the whole country. And we also need models if we want to explore how river flows could change under different scenarios. So if we want to see how climate or land use change might impact flows.
And there are many different models that we have available that are used for different purposes for modelling in the UK and elsewhere.
And we've broadly categorised them into these four different categories for the purpose of this intercomparison.
So first we've got the lumped models, which treat the entire catchment as a single unit. This makes them really fast to run, with relatively low data requirements.
which is a big bonus. They tend to use spatially averaged input data, so most of these lumped hydrological models just take lumped catchment precipitation, potential evaporation and temperature, and then they simulate flows at the catchment outlet.
And they're often quite simple, representing different catchment stores as a series of interconnected buckets. And this is an example.

Rosanna Lane 1:17:20

of four different models and different ways that they can be set up.
So you see we've got different stores and each of the different model structures represents these in a different way, different processes and different numbers of buckets and numbers of parameters.
So these can result in very different and distinct river flows, and although they're

usually calibrated, you can get quite different results.
We then have distributed and semi-distributed models, which bring a spatial element back into the modelling.
Semi-distributed models often split the catchment into sub-catchments or hydrological response units, which are areas of the catchment expected to behave in a hydrologically similar way.
And then we also have distributed models which further separate the catchment and often these split up the catchment into grids.
So these are much higher data requirements, usually requiring gridded data sets for driving data, and they might parameterize using spatial land cover or topography.
But they have the advantage that they might be able to simulate flows in ungauged areas, and you get the spatial element to see flows within a catchment.
But again, within these categories, there's a vast array of different models, each have different assumptions and includes different processes. And these also include a distinction between the more conceptual models, ranging all the way to physically based models.
We then have land surface models, which simulate interactions between the land surface and the atmosphere, including water exchanges. This includes models such as Joules, and although these models often aren't specifically calibrated for river flows, they include this as an output.
And then increasingly we have the machine learning models that Helen also mentioned, which are used to predict river flows based on time series of meteorological outputs and static catchment characteristics. So these are normally trained on data from hundreds of catchments at the same time to kind of learn general rainfall runoff relationships.
and transferable hydrological processes, which they can then use to make predictions.
So it's great that we've got all of these different models, but it does also raise questions. With an abundance of different models, how different would your results be if you choose a different model? We don't know which models might be more appropriate for different catchments or for different purposes.
and it's important that we understand common issues that are across models or whether issues are specific to a particular model that you've chosen.
So I particularly liked this paper in 2019, which found that model choice was often the result of legacy rather than adequacy. And by that they meant that most people

chose the model that was commonly used in their institution, rather than picking the model that was best for their purpose. And this paper
Said that a reason for that is because we often don't know which models are best.
So, really?
It is rigorous model evaluation and
And then foremost.
RR models.
And are there some catchments where model choice is more or less important?
So, we've carried out a community modelling to comparison project that we've termed the UK Hydro-MIP.
And this is really a big community effort. We've organised workshops and seminars to bring modellers together and tried to get as many people as possible engaged in the whole process, with feedback from the community at every stage.
So, we first defined a modelling protocol, and this specified how we wanted everyone to run models to have them included in the intercomparison.
And this was also a back and forth with the community until we'd had a protocol that we agreed on.
And we then invited modellers to submit flows, and this was an open invitation to anyone who wanted to take part.
And we asked for a few specific things. So everyone followed, everyone used the same meteorological inputs derived from the same source. So we all have the same precipitation, temperature, and potential evapotranspiration data driving our models.
We all ran models from 1980 to...
to 2020, with the first 20 years as a calibration period for any of the models that required calibration, and the following 20 years being an evaluation period where most of the models were evaluated.
We all ran models over these 673 catchments, highlighted here, so you can see there's really good spatial coverage across Great Britain.
And from that we identified a core list of 628 catchments, which are the ones you see in yellow, and these are the ones with really good data availability where nearly all of the models could be run.
All of the models output daily mean flows in metres cubed per second, which is what we then used to evaluate performance relative to observed flows.
But we decided to leave a lot of other decisions to specific modellers. For example, how models were calibrated, how models, whether they had a spin-up period, and

the resolution that the models were applied at.
And the reason we left this to the expert judgement of modellers was partly because we wanted to capture each model performance as it was typically run, and partly because it was very difficult to come up with a strategy that would be appropriate for all of the models.
So we then received submissions from a diverse range of model structures. We had over 14 different model structures submitted to the MIP with three machine learning models. So this was the LSTM machine learning model with three different sets of attributes.
Six different lumped conceptual hydrological models, 5 distributed models, and two runs of the JULES land surface model.
And in total, we received 27 submissions, some of these being duplicates of the same model, but with different processes turned on or off, or different calibration attempts.
And this resulted in the...
The UK hydrology.
Okay.
So, to evaluate flows, we decided to compare them to a set of lower benchmarks. We first calculated performance metrics for each model and for each catchment, and we...

Gianni Vesuviano 1:24:52
I.

Rosanna Lane 1:25:02
We calculated a whole different range of different performance metrics.
And the aim to summarise performance across the whole flow regime.
And they were, but these performance metrics.
It's difficult to decide if a catchment is doing if different values of performance metrics are good or not, because the values that are good differ for each different catchment. So we also decided to compare flows to lower benchmarks.

Rosanna Lane 1:25:35
And these lower benchmarks aim to be intuitive reference points, which the model should be able to beat. So they're really simple things that set a lower bar for each

model.
And here we're focusing on mean flow for each day of the year as a benchmark. And this is just what that looks like for two different catchments. So for each day of the year in the calibration period, we calculated mean flow. And then in the evaluation period,
we use that as a lower benchmark for what our model should be able to beat.

Rosanna Lane 1:26:14
And then within that, we also focused on the Kling-Gupta Efficiency performance metric. This is a measure of overall skill that evaluates the model in terms of three different components. It looks at model bias, model variability, and correlation with observed flows.
So we calculated the KGE for all catchments for each model and also for the benchmark. And then we're hoping that the model KGE values should beat the benchmark KGE values.
So, this is the first plot, which summarises all of the models across all of the catchments.
Each different bar is a different model, and this is the model skill compared to the benchmark.
So a value of zero means the model is doing no better than.
Just using mean flows.
So, the fact that the model has information.

Rosanna Lane 1:27:24
And each of these bars shows all of the different the range across all of the 600-odd catchments.
So if we first have a look, there's a clear difference in performance across the models.
Model selection does really matter. We've got the machine learning models here in yellow, which are generally beating the benchmark, although there are many catchments where they are not.
We've got the lumped hydrological models in green, which tend to be doing the best, particularly GR6J and PDM, which are outperforming many of the other models in terms of KGE.
The distributed hydrological models here in pink, some of which are calibrated, such as Shetran, and doing a comparable result to the lumped models. Others are

uncalibrated and are not doing quite as well. And then here we have the JULES land surface model.
Which isn't doing as good a job for flows, which is kind of expected because the model is doing so much else.

Rosanna Lane 1:28:44
So, we find that while the models beat the benchmark overall.
There are many catchments where we don't add value compared to our mean daily flow benchmark.

Rosanna Lane 1:28:56
And this is looking at the percentage of models where we beat our benchmark KGE. So where we have blue, that means that all of the models are doing really well. We're beating the benchmark for these catchments. And where we have red and yellow dots, that's where some of the models are struggling and giving a poor result.
So you can see that all of the models do really well for catchments in the west. We're beating the benchmark for nearly all catchments in the west of Great Britain and for most catchments across Scotland. But there's a band of catchments in the southeast here and a couple of individual catchments dotted around.
where most of the models are failing to beat the benchmark. And also some catchments where pretty much all of the models are failing.
So, the rest of the presentation, I'm quickly going to look at what properties of these catchments might be the reason that they're so challenging to model.
Firstly, something that always crops up when we're looking at modelling flows across Great Britain is this band of chalk geology over here. And you can see that this, the pattern of the chalk
What we see here, aligns quite closely.
of models which aren't a strip of gauges where many of the models are failing to capture flows.
And this is part.
In these catchments, we might have inter-catchment water transfers, where catchments are gaining or losing water through groundwater. And this isn't something that most of the models can represent.
We don't know which catchments are lossy and which catchments are gaining water.
We also generally struggle with catchments with a high base flow.

which might have longer catchment memory and the catchments affected by water that might have happened many months ago.
Another common characteristic is that the models tend to do less well in catchments where it's drier.
So you can see here that we receive much lower rainfall in the east and southeast, which also is where most of the catchments are where not all of the models are beating the benchmark.
And we see this when we look at the catchment wetness index. So this is the wetness index across all of our gauges, the wetness index across just the gauges where many of the models are failing to beat the benchmark, and then the wetness index across the models where the gauges where we're doing well.
So you can see that there's a relatively low wetness index in the gauges where the models are failing.
We also see that the models struggle for catchments with low or very high, so above one, runoff ratios.
The runoff ratio is the ratio of precipitation that becomes runoff. So where you've got, where your runoff ratio is very low, then a very small fraction of precipitation becomes runoff. So you might have water being lost to evapotranspiration, you might have water being lost to ground water, or you might have
Human influences, such as abstractions taking water out of the system.
that the model might be unaware of.
And when the rainfall runoff ratio is above 1, then we're seeing more runoff than precipitation. And again, precipitation is the main source of input into the models. So if we're seeing more runoff than precipitation, there's something else going on that the models aren't able to catch.
Sure.
And this could be human influences, so it could be discharges into the water, into the rivers, it could be groundwater entering the catchment, or it could be issues with data quality, so undercatch from rain gauges, insufficient cover of rain gauges, meaning we're not
Getting enough rain into the catchment.
or issues with the river flow measurement themselves.
So those are three of the things that crop up when you look at reasons why models might not do very well on the nationwide scale.
But there are also a few of these catchments where many of the models fail that

don't necessarily fit these categories.
There are catchments where this might be due to unreliable or poor quality observations. So this is 1 catchment that we've picked out where pre-2002 the gaugings indicated flows going up to around 6 to 8 metres cubed per second. They then installed a new gauging station.
And suddenly, the flows were much lower.
And it just so happens that this is our calibration period, and then this is our model evaluation period.
So given this data, and according to the National River Flow Archive, both flow estimates before and after the new gauging station are poor.
It's not surprising that none of our models can capture flows well in this catchment.
We might have processes missing from models that are specific to individual catchments, particularly reservoirs, abstractions and discharges, or urban drainage.
So this catchment down here, there are issues with the high flow measurement, so also data quality issues, alongside an abstraction immediately upstream.
And A reservoir regulating flows, so this would be a massive challenge to many of the models.
And finally...
Sometimes there's a scale mismatch. So some of the catchments are very small. This one's only 7 kilometres squared. And for many of the gridded models, which run at a 1 kilometre or 5 kilometre grid, they just can't capture the processes at this small scale.
So to kind of summarise what I've talked about, we carried out a model into comparison called the UK Hydro-MIP, which compared simulated flows from machine learning, hydrological and land surface models, all following the same modelling protocol.
The highest model performance is seen for the lumped calibrated models, and this is often because they are simply calibrated to the observed discharge and many of them don't have the same water balance constraints.
But when choosing a model, others have other strengths. For example, being able to simulate flows in uncalibrated, ungauged bases.
We find that for most catchments, most models are doing a decent job and able to add value compared to using the daily mean flow benchmark.
But there are some common challenges.
when we find that some...

overlaying chalk aquifers.
ratios and also we have issues with equality.
And then finally to leave it on this slide to just show.
that this is a massive community effort and there are so many people who've been involved with this project running models. And one of the main goals of this intercomparison was really to bring the community together so that we could all learn from each other and share our different modelling techniques.
So, thank you very much for listening.

Gianni Vesuviano 1:37:24
Okay, thank you, thank you, Rosie, for this presentation. We're very interested in everything. If there are any questions about this, either raise your hand or write in the chat.
And if there are no questions, then I think we should go to the break. Oh, okay. Question from Mayuran. Were the models checked for overfitting and underfitting?

Rosanna Lane 1:38:03
Yeah, that's a great question. This isn't something that we checked specifically. We left it up to each of the modelling groups to decide how to calibrate their models. So it's kind of up to them to check their models for if they thought the calibration was appropriate.

Rosanna Lane 1:38:20
And whether they thought they were overfitting or underfitting.

Gianni Vesuviano 1:38:29
OK.
Thank you, Rosie. Thank you for all the presenters who presented in this session. We're going to break now. The next session starts at 11 o'clock. Please note it's in a different Teams meeting, so check your emails for the timetable and I will see you in that other meeting at 11. Thank you.

Gianni Vesuviano stopped transcription