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0:00:05.7 Sarah Crespi: This is the Science Podcast for November 17th, 2023. I'm Sarah Crespi. First up this week, have you been talking to Alexa about the weather lately? Staff writer, Paul Voosen joins us to discuss how artificial intelligence is suddenly and shockingly good at forecasting the weather using way fewer resources than other modeling systems. Next, we're focusing on municipal solid waste, things like landfills, composting centers, garbage dumps, and how these sites may offer a more straightforward path to lower carbon emissions. Researcher Zheng Xuan Hoy discusses his science paper on this overlooked source of methane and some plausible solutions for reducing these emissions.

0:00:53.0 SC: I used to live in a large metropolitan area, and one of the big city perks that I enjoyed the most was that there was a daily weather blog run by experts, including meteorologists, just talking about the weather for the day, giving in depth explanations of what I was seeing out my window or what happened last night. And I learned a lot, and I learned a lot about some weather phenomena on the podcast. I do know we have about a 10-day forecast range with some certainty, and we're pretty darn good at six days of forecasting, six days out, and that there are competing models used to make these type of predictions, but now there's a new modeler in town. This week, staff writer Paul Voosen wrote about AI's contribution to Weather forecasting and the surprising leaps these systems are making in predictive power. Hi Paul, Welcome back to the Science Podcast.

0:01:45.2 Paul Voosen: Hi. Good to be here.

0:01:46.5 SC: I know all of us have been taken off guard at some point by improvements in AI, whether it's writing an email or predicting protein structures, but I hate to say it, weather was not on my radar. Did you see this coming, Paul, this leap in forecasting by AI?

0:02:02.7 PV: I don't think a lot of people saw it coming, if you go back even two, two and a half years ago, people had been trying this five years ago, and it just didn't seem like it worked that well and then all of a sudden it did work.

0:02:18.0 SC: There are modelers out there using supercomputers basically to put out forecasts. They're using math and measurements and physics. And this has improved over the years, kind of at a large cost, like in terms of computing power. And now these AI models are turning out pretty competitive results, how do they stack up? How do the European model and the AI modelers, how do they compare?

0:02:40.7 PV: Yeah, so the European Weather Forecasting Agency is the top performer in the world, and they use these very physically based models that ingest all the observations from satellites and everything, and then solve all the equations of fluid motion on a little grid that stimulates the entire atmosphere. So that's the top in class. Now, these kind of AI models are matching the top weather forecasting model, or exceeding it, in some cases, 90% of the different metrics looked at over a 10-day forecast.

0:03:13.8 SC: Right, and what are they doing differently?

0:03:16.4 PV: So, fundamentally, these have been trained by the weather models, they take the data, the weather data has then been run through these models, and they've been doing this now for 40 years, so they take this gigantic data set, they ingest it, and this is classic deep learning, but on a very kind of large scale, over a graph versus an image type processing. They're not solving equations, they're just learning patterns, really, over a very complex, incomprehensible scale to us in this black box, and it's spitting out what should come next.

0:03:49.6 SC: This is what we see with the ones that write emails for us. They have this huge corpus that they've studied it has a really good model for saying that's the word that comes next in an email, that's the most likely next word. And doing that at the paragraph scale, or doing it at the global scale for weather, are all the models that are out there, all the different AIs, because there's not just one company or one academic institution working on this, are they all doing the same thing or should we lump them all together, or are some of them different than others?

0:04:19.0 PV: You know what I would lump them.

[laughter]

0:04:22.8 SC: Okay.

0:04:23.5 PV: There are differences in the architecture, but as these have gotten big enough, and as long as you have enough computing power to throw at it at the start, enough data, it doesn't seem to matter that much. It's kind of 1%, 2% differences. You can have different approaches, but really, in the end, you're getting to about the same place.

0:04:43.5 SC: Right. We should talk about computing power here. I mentioned supercomputers being involved in the forecasting that's been done for the past 40 years. That's not what happens when you've already trained your model and now you want to have an AI in your newsroom, it doesn't need multiple banks of servers and processors.

0:05:03.5 PV: No, it just needs one fancy desktop computer that's designed for running these type of models and it can run it in one minute versus, say 2 hours for a gigantic supercomputer.

0:05:16.7 SC: What does that mean? How does that change the world? I feel like it should, but maybe I don't need to model weather in my house. You don't need to model weather in your house. What is the impact here?

0:05:26.8 PV: The impact is going to be more for these weather agencies who are really starting to look at this closely, right now they run these models a lot of times over, 50 times, the European model is run at a slightly higher or lower resolution every 6 hours they kind of do this over and over, four times a day and that kind of running it over and over gives you some more sense of the possibility in the future because butterfly effect and chaos in the atmosphere, that's all super expensive, if they're able to figure out how to make these AI models first, able to continue to verify that they are fit for purpose in all the different ways that are needed and establish some trust in them, you can maybe start kind of doing this a lot more cheaply, maybe that's just less CO2 emissions from what you're running, or you can kind of devote that computing power to solving other problems, like how to better ingest all this weather data or things like that.

0:06:21.4 SC: Yeah, speaking of ingesting, do we need to keep training these AI models? Do they need to keep refining their predictions?

0:06:28.6 PV: Yeah, they would certainly have to periodically update these, this Google DeepMind model that is in science this week they ran, it took like four weeks on their dedicated machines to train it. So it's something you could see it, theoretically doing every year without being a huge issue.

0:06:48.0 SC: We're talking about weather here, what happens day to day but could an AI like this model climate change, big predictions about climate change?

0:06:56.6 PV: Yeah, climate is a totally different issue in many ways because the past this data we have is not necessarily predictive of the future of the climate. We're changing things a lot, there are things in the future, ice sheets melting, things collapsing that, just wouldn't be in the training data, so it would be very difficult to trust these projections going forward. But there are ways that it could be very helpful where you can take these climate models, there's this new class of climate model that runs in super high resolutions directly recreating lots of stuff in the atmosphere, and we can only afford to run this on super computers for a few years at a time. It's kind of solely pushing out. So you get that running long enough and then you can train the AI on that and run it a bunch of times, and then you really start to get a lot more value from all that computing power that you've poured into it. So there's a lot of promise there.

0:07:52.1 SC: Are we gonna stop doing the numerical modeling using physics, using measurement to make forecast?

0:07:58.7 PV: Not anytime in the near future, we have a lot of trust in this numerical weather modeling and if AI is a black box, there's that question of how far do you trust it? Also, these numerical weather models are producing the data sets that the AI is being trained on, there's kind of can't get there without that. There's some theoretical future where perhaps the AI can start ingesting the satellite data directly or all the sensor data directly and take it end to end but we are very far away from that, I believe, or maybe we're just two years away who knows.

[laughter]

0:08:32.5 SC: Okay, what will AI do next? How is it gonna affect your beat next Paul? What area is it gonna affect?

0:08:44.2 PV: It's filtering in lots of ways there just the image recognition as of parts of it are just almost unremarkable at this point where like, oh, this can spot icebergs better, it's like, yeah, of course it can, anything that's like a visual learning type of thing, I'll have another story in a few weeks that will also be about AI and satellites and look out for that.

[chuckle]

0:09:05.3 SC: That's great, well thank you so much for coming on the show, Paul I appreciate it.

0:09:09.1 PV: Yeah, thank you.

0:09:10.7 SC: Paul Voosen. Is a staff writer for science. You can find a link to the story and a related science paper at science.org/podcast. Stay tuned for a big steaming pile of science. Researcher Zheng Xuan Hoy talks about modeling landfill emissions on a global scale.

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0:09:36.9 SC: We don't think about garbage enough. According to a paper this week in science, global municipal waste is a missed opportunity for reducing emissions and meeting climate goals. Zheng Xuan Hoy is an author on the article and he's here to talk about it. Hi Hoy, welcome to the Science podcast.

0:09:55.2 Zheng Xuan Hoy: Hi, thanks for having me.

0:09:56.6 SC: Oh, sure. So how is the landfill in my town or in your town related to climate chains and emissions? Why is it a carbon source?

0:10:06.5 ZH: Solid wastes are actually made up of a large variety of compositions. It is made up of, for example, food waste, paper waste, plastic waste, and so on. So the organic content in waste decomposers and predominantly generates methane gas making solid waste one of the top methane emit sectors in the world.

0:10:27.3 SC: And methane is an even stronger greenhouse gas than carbon dioxide?

0:10:32.0 ZH: Yeah. So methane is a potent greenhouse gas that traps significantly higher amounts of heat than that of carbon dioxide. So for example, let's consider a scenario where we have two different sources of emissions, one releasing methane and the other releasing carbon dioxide in the same quantities over 20 years, the methane emission will trap 80 times more heat than the carbon dioxide emissions over those 20 years and this emphasizes the urgency of addressing methane emission to effectively mitigate short-term climate change.

0:11:06.6 SC: Yeah, so we do hear a lot about reducing emissions from things like energy sources, like going solar or reducing emissions from cars by switching to electrical vehicles. There are a lot of sources of carbon out there. Why is it important to focus on municipal waste, garbage, landfills, that kinds of thing?

0:11:25.8 ZH: I think solid waste management is a powerful but overlooked climate solution. Some may perceive waste management as a relatively minor contributor to overall greenhouse gas emissions compared to the big boys such as energy and transportation. But we may be undermining its climate impact because the major greenhouse gas emissions from solid waste is methane and methane actually traps significantly higher amounts of heat than carbon dioxide.

0:11:55.4 SC: So in your paper, you attempted to quantify this to count up to some extent how much is coming off of these sources for carbon emissions. Can you talk a little bit about what timescale you looked at and how you counted this up?

0:12:10.0 ZH: We forecasted the business as usual greenhouse gas emissions that would be emitted from the global solid waste sector from 2021 until 2050. After we did this forecast, we actually tried to explore whether there are any technical and financially plausible mitigation strategies within the solid waste management, and we visualize them into future emissions pathway as well.

0:12:32.9 SC: So what are some of the ways that we could cut back on emissions from landfills from solid waste?

0:12:39.4 ZH: Yeah, so we understand that every country faces a unique and exclusive version of this challenge to improve their solid waste management. And it is important to propose mitigation strategies based on their diverse situation regarding its required cost technology readiness, skilled worker requirements and they're standing in the waste management hierarchy. So considering these requirements, we explored four individual mitigation strategies for reducing emissions from the solid waste sector. So firstly, it is retrofitting landfills with biogas capture. Secondly, diverting organic waste for composting. Thirdly, diverting organic waste for anaerobic digestion, and lastly, reducing waste generation by 50% relative to 2020 levels.

0:13:27.5 SC: Okay. So looking across these four different scenarios, some of these are more social or behavioral interventions. I'm thinking reducing how much waste we create in the first place, or sorting out trash from compost. Others are more technological and these are things that you're talking about, like retrofitting landfills to capture methane. Or another kind of technical intervention is these biogas digesters. So you basically digest compost with microbes and then you get that methane and either the retrofitted landfill methane or the digest methane that can be burned as fuel, which is a less carbon intense approach than just releasing the methane to the atmosphere. You know, when you calculate across all these different waste situations that countries have, who fits best with what, like who should be doing which of these things to get the most benefit from these strategies?

0:14:21.8 ZH: Our findings found that high income countries should prioritize reducing their waste volume and lower income countries should prioritize managing their organic waste more sustainably. This is because lower income countries generally tend to generate waste compositions with a higher organic content as opposed to high income countries. But generally speaking, the two levers that we identified for minimizing greenhouse gas emissions from global solid waste system is firstly to reduce the waste volume being generated, and secondly, managing organic waste more sustainably.

0:14:54.9 SC: And if these were maximized, if this was something that people did and took on, how much reduction could we potentially see in emissions from solid waste?

0:15:06.2 ZH: These proposed mitigation strategies by themselves would be able to reduce the greenhouse gas emissions that would be emitted and accumulated in the atmosphere in the next 30 years by 27-70% relative to business as usual.

0:15:20.5 SC: Okay. So how does that translate into the 1.5 degree limit that we're trying to stay under?

0:15:27.8 ZH: Staying within the 1.5 degrees celsius limit requires adopting more than one strategy. But we find that if we adopt multiple strategies, including retrofitting landfills, composting our organic waste and halfing our waste generation could actually prevent overshooting the Paris agreement temperature limits. What's more interesting is this will also result in a global solid waste system with net zero warming relative to 2020 levels. In other words, no further warming is induced compared to 2020 levels.

0:16:00.1 SC: Let's talk about the global methane pledge. I think most people are familiar with climate agreements, but maybe they haven't heard about this other one about methane.

0:16:07.1 ZH: Methane was determined to be of particular importance at the 26th United Nation Climate Change Conference of the parties because it has a short lifetime of approximately one decade, so cutting its emission can rapidly decelerate near term global warming, so more than 100 countries come together to sign the global methane pledge, aiming to curb 30% of global methane emission by 2030 using a 2020 level baseline.

0:16:34.6 SC: How does this help with that?

0:16:36.0 ZH: We actually look into whether the mitigation strategies that we propose can actually help us to achieve the global methane pledge. Well, it's actually achievable, but there's a catch because we designed this mitigation strategies only to be fully adopted by 2050 so it cannot actually reduce 30% of methane emission from the solid waste sector in a timely manner. We will actually need to accelerate the complete adoption of mitigation strategies by at least nine to 17 years, which is to completely adopt all these strategies by 2033 to 2044, depending on the mitigation strategies in order for us to be on track with the progress to achieve the global methane pledge.

0:17:19.6 SC: Kind of the surprise here, I think besides the fact that this is such an impactful intervention, is that all the technologies that you're talking about are already in existence. So they don't rely on a bunch of innovations to say take carbon out of the air or invent a new kind of battery. It's just do these things we already know how to do. What do you see as the hurdles to getting this to happen?

0:17:45.5 ZH: So the good thing is these technologies are actually readily available technologies, but to realize an efficient waste management system, policy makers need to utilize three types of policy tools to also promote people to actually do these kind of things. I want to highlight that the first one is direct regulation, which is encompassing laws to be enforced rigorously, such as mandating waste segregation in each household. Secondly, economic incentive and disincentive to encourage reduction in waste generation and increased recycling efforts. And thirdly, social tools such as the promotion of education campaigns to inculcate environmental values in communities to generate less waste.

0:18:28.6 SC: Thank you so much, Hoy.

0:18:29.8 ZH: Thank you. Happy to be on here.

0:18:32.0 SC: Zheng Xuan Hoy was a MPHIL graduate student at the time that this research was conducted at the New Energy Science and Engineering department at Xiamen University in Malaysia. You can find a link to the paper we discussed at science.org/podcast.

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0:18:38.2 SC: And that concludes this edition of the Science Podcast. If you have any comments or suggestions, write to us at science podcast@aaas.org to find us on the Apps, search for Science magazine, or you can listen to the show on our website science.org/podcast. This show was edited by me, Sarah Crespi and Kevin McLean with production help from Prodigy. Jeffrey Cook composed the music. On behalf of science and its publisher AAAS thanks for joining us.