Gavin Schmidt: What's up everybody, welcome to another episode of Hidden Forces with me Demetri Kofinas. Today I speak with Gavin Schmidt, a climate scientist who heads NASA guarded institute for space studies in New York city. He is the coauthor of climate change picturing the science and the 2011 inaugural awardee [00:00:30] of the AGU climate communications prize. What's driving the warming of our planet?

The acidification of the oceans, the shrinking of the ice sheets, the rising of sea level, decreasing snow cover and retreading glaciers. Weather is prototypical complex system. Edward Lorenz one of the pioneers of chaos theory was a meteorologist. Why is the science of climate so controversial? In today's episode we cut though controversy [00:01:00] and dive right into heart of climate science. We pass though the data, explore the models, proper pre dictations and consider the implications and what they might mean for humanity in the decades to come. What of the feedback mechanisms of climate? How do we measure the impact of losing the reflective layers of ice exposing permafrost or releasing vapor into the atmosphere? What is the cooling of the upper atmosphere tell us about the cost of global warming and how will humanity [00:01:30] respond to more extreme weather events, hurricanes, droughts, floods and forest fires as our populations grow and the density of our coastal regions increases? Is there anything we can do to prepare?

As always you can gain access to reading lists put together by me ahead of every episode by visiting the show's website at HiddenForces.io. Lastly, if you're listening to this show on iPhone or Android make sure to subscribe. If [00:02:00] you like the show, write us a review and if you want a sneak peek on how the show is made or for special story lines told through pictures and questions then like us on Facebook and follow us on Twitter and Instagram at @HiddenForcesPod and now let's get right to this week's conversation.

Demetri Kofinas: Dr. Schmidt, welcome to Hidden Forces.

Gavin Schmidt: Thank you very much.

Demetri Kofinas: I'm very excited to have you on the program.

Gavin Schmidt: I'm excited to be here.

Demetri Kofinas: It a little late considering the hurricane season. [00:02:30] It would have been more news timely. I actually wanted to do something on climate change and global warming for a while. Like everything on the show I want to make sure that we have the right guest and that I'm properly researched and its interesting so I cover a wide variety of topics this program. Complexity runs though many of them and in fact we sort of embrace complexity on the program. I rank each show in terms of how I prepare for it in terms of the difficulty and things like that. This was in its own particular way [00:03:00] the most difficult but had less to do with the complexity of the subject than the difficulty of the science. It really had to do with, I think, what makes the subject so difficult for everyone to encounter, which is the enormity of the message in the data. I think that's a very difficult thing to disconnect override.

Gavin Schmidt: That's absolutely right. The science and the details is complex. The system that you're trying to study is complex. The discussion [00:03:30] about what the science means is complex and so you got like 3 levels of complexity layers on top of each other there so no, I feel for you.

Demetri Kofinas: Well I should feel for you cause this is your profession. So listen before we start I want you to give our audience, you know, tell them a little bit about who you are and your background and then I want to contextualize our discussion. Why don't we begin that way. Why don't you give our audience a little bit of background who Gavin Schmidt is, where you came from, what train [00:04:00] you took to get down here. No, I'm just kidding. Go ahead.

Gavin Schmidt: Sure. My name is Gavin Schmidt. I'm a climate scientist and I now run a NASA lab here in Manhattan that really focuses on understanding climate changes and then working out what the impacts of those changes are going to be. We look at all sorts of climate change. Back in the past what causes the ice ages? What causes the crust to be so warm but also what's been going [00:04:30] on in the 21st Century. What's going to happen in the 21st Century?

Now I go to this through a roundabout route. I was a mathematician when I was younger when I was doing my undergraduate. All I really wanted to do was math.

Demetri Kofinas: What kinds of mathematics?

Gavin Schmidt: Applied math but problem solving, things that had nice neat answers and it was pretty and aesthetically pleasing. I realized after my PHD that aesthetically wasn't the same as something you can actually get a [00:05:00] job with so I worked towards doing more stuff that was of more interest to more people. I started off doing ocean studies, which is more interesting.

Demetri Kofinas: Oceanography?

Gavin Schmidt: Yeah. That's much more interesting than pure mathematics and the ocean to climates and first of all simple models and then more complex. Now we work with the most complex models there are.

Demetri Kofinas: You've been at Goddard for 20 years is that correct?

Gavin Schmidt: About that yeah, 1996, I came [00:05:30] here.

Demetri Kofinas: You took over for Hansen about 3 years ago?

Gavin Schmidt: Yes, so James Hansen was the previous director. He'd been there since the early 80s and he retired in 2014 and then I've been the director since then.

Demetri Kofinas: Audience, Dr. Schmidt's done a good deal of media and I suggest that you google his name on YouTube and you will be able to find some interesting talks including a Tedx talk, which he gave.

Gavin Schmidt: Ted talk. Not TEDx.

Demetri Kofinas: I'm sorry. There is a difference. No you are very correct to point that out. [00:06:00] I apologize. Our last guest was TEDx and that Intro was in my memory.

Gavin Schmidt: That's okay. Not all Ted talks are brilliant.

Demetri Kofinas: You are very correct to point that out. It is an important point. Here's my thinking. We've done one previous, and I should also mention to anyone who is new to the program we did an episode with Brian Arthur, I think it's episode 8 on complexity science and if you're interested in understanding the science of complexity you can go to that episode. We also did an episode recently with [00:06:30] Daniel Drezner on the sort of thought leadership and politicization on thinking and sort of intellectualism and sort of the attack on experts, etc. I think one of the things I try to do with every subject and especially with this one I want to really break from any kind of advocacy here.

I just want to talk about the science and not the "science", which is what we sort of. I want to talk about the data. I want to talk about the models. [00:07:00] I want to talk about the predictions and the projections and the forecast that comes from all that data and from those models and then I want to talk about what the implications of that are assuming we sort of prescribe to it. I don't want to push that on anyone else. Everyone is up to themselves if they want to understand those or not. I think it's important to understand it because I think understanding it helps to... I'm not actually a believer in thermometers work we should just believe it. You should try to understand everything possible.

Gavin Schmidt: Sure.

Demetri Kofinas: Let's begin with that and before we do [00:07:30] I also want to take a quote of yours. That's something I've been doing recently, which there are a few that I really liked. One is "Models are not right or wrong. They are approximations. The question you have to ask yourself is whether a model tells you more information than you would have had otherwise and if it does its skillful." I think that's super important to begin our conversation, which is science is not a fact. Science is an evolving empirical methodology for understanding the world. It's an approximation and we have to understand [00:08:00] that because these, I think, it's held to unfair standards.

Alright so let's begin. The first question I want to ask you is what is the relevant data that climate scientists are looking at? What are the inputs that you think about when you are sort of building your models?

Gavin Schmidt: It's very multifaceted. The kind of things that people see in the public... This goes by this. Changes of temperature in the oceans and on land. Changes in the amount of carbon monoxide in the atmosphere. [00:08:30] Changes in the solar activity over the last few decades. You can find all of this data on line. The real data that tells us what's going on or gives us the insight into the processes behinds this is actually much more voluminous and much more diverse. NASA, we have about 20 satellites that are either in polar orbit or in geosynchronous orbit that are measuring [00:09:00] everything from ground water changes, ice sheet mass changes, ozone levels, temperature levels, the wind speed on the ocean, the amount of wind vapor in the atmosphere, the amount of aerosols in the atmosphere.

There are small particles in the air, dust and uncertain things like that. The amount of clouds, amount of radiation and it's through putting together all of that very, very data and then connecting it to the processes to [00:09:30] the things that give rise to those changes. Convection in the tropics so it's horror. You've got these big massive clouds that changes, the radiation changes, the rain fall. That's one process that has this kind of multivariate expression or this multivariate fingerprint. What we're trying to do with the satellite data, with the weather forecast data, with the ground observations is really pin down what's going on in those processes. Once [00:10:00] we've done that, we can bring those things out. We can encapsulate them in code. We can approximate them as best we can and then we put them into simulations. Now those simulations are used for weather forecast. They're used for climate predictions. They're used for attribution into the past. For exploring just how things connect each other but that's where the complexity comes in. Right.

Demetri Kofinas: In the translation.

Gavin Schmidt: Well it's in the translation of those huge data sets that measure everything [00:10:30] and then trying to kind of pour out of that what the processes are that are important and we use our physical intuition. We use ground measurements. We use satellite measurements. We have airplanes that fly in between measuring, looking down and looking up just in order to be able to say well why does convection occur when it does occur. When does a cloud fall? When does a cloud dissipate? When does it start to rain? When does it not start to rain?

Demetri Kofinas: Are you looking at correlations and all [00:11:00] the set of correlations then you're saying okay, let's investigate these correlations and try to ... I mean how do you do that? What's that process like?

Gavin Schmidt: It's not quite like that.

Demetri Kofinas: Not so neat.

Gavin Schmidt: No. We partner for instance with the Department of Energy and they have these sites where they will just sit somewhere and measure everything they can possibly measure in a column. They do it in areas where we think something interesting is going to happen. Right so a front comes over and we see it's dry here, it's wet there. Okay, when did the clouds form? When did the rain come in? How much [00:11:30] did the radiation change? Was there a change in the ozone? Was there a change in the dust? Then can we simulate that? Can we understand what happened? Can we understand that sequence just from our physical understanding, our physical intuition, which over the years, has become pretty good.

You just go around try to find more and more cases that test your models. Now your models are really great when it's something very clean happening here with nothing else going on and they work fine but suddenly you got something else comes in [00:12:00] and it's a little bit more confusing. It's a little bit more complex and now your model fails completely. Those are the kinds of opportunities we look for. We say well hey we can make the model better. We can do a better job with that trigger for understanding when convection starts for instance.

Demetri Kofinas: We are going to get into that because I want to get into details on how you formulate these models. Before we do that how reliable is the data itself?

Gavin Schmidt: Well I mean...

Demetri Kofinas: The instrumental data that we have before we even get into the proxy data.

Gavin Schmidt: Right. Old data [00:12:30] is collected by humans or by machines that were built by humans and of course we're all imperfect. If you're looking at historical data, then things have changed for all sorts of reasons that you would never have designed to have them change but they change because there was a war and then people moved this over here and then that building moved down and they moved their instrument to the airport. All of these things happen.

Demetri Kofinas: Sure.

Gavin Schmidt: You get somebody who's really, really lazy whose task is to get up at 5 o'clock in the morning to record it and they never [00:13:00] do and they always write the same number in.

Demetri Kofinas: Right. Right. Right.

Gavin Schmidt: You have data that is imperfect.

Demetri Kofinas: Sure.

Gavin Schmidt: There is no question.

Demetri Kofinas: Imperfect data is not going to tell you that the ice sheet is melting.

Gavin Schmidt: Right.

Demetri Kofinas: Within the bounds of reasonable reliability.

Gavin Schmidt: What you look for is conciliate. What you look for different sources of data, different kinds of data that point you towards the same thing. If you got 1000 weather stations and their all telling you the same thing and [00:13:30] it doesn't matter that one of them was run by a drunkard that never got up at 5. Right.

Demetri Kofinas: Right.

Gavin Schmidt: If you have observations on the ground that tell you that the ice has dropped by 100 meters in the last 50 years and then you've got a satellite that says no there is less mass there than there used to be. Okay, you've got a conciliate of evidence and so you can have some confidence ...

Demetri Kofinas: Let's talk about some of these measurements cause some of them are really cool and interesting. One I actually learned about with respect to the drought that's going on [00:14:00] in California and I think it also applies to the ice sheets and the mass of ice and the poles, which is the use of lasers in order to determine the change in gravity.

Gavin Schmidt: Yes.

Demetri Kofinas: Could you explain to our audience a little bit on how that works and the science behind that? It's very fascinating and the technology.

Gavin Schmidt: Right. Your right this is totally fascinating technology and when you're talking about the great satellites, which unfortunately have just been decommissioned.

Demetri Kofinas: Is that right?

Gavin Schmidt: Yes.

Demetri Kofinas: When did that happen?

Gavin Schmidt: They stopped working on October 12th and there was an announcement actually today.

Demetri Kofinas: Why is that?

Gavin Schmidt: Because they had been in orbit since 2003 so [00:14:30] that's 14 years, which is about 3 times they're design lifetime so the batteries that allowed them to store solar energy when they're in the sun and then use it to...

Demetri Kofinas: They haven't been repaired?

Gavin Schmidt: They can't be repaired.

Demetri Kofinas: Oh. Why, they're satellites.

Gavin Schmidt: Right. Once things go into space there's very, very few satellites that...

Demetri Kofinas: Are they going to be replaced?

Gavin Schmidt: There is a grace follow on mission that is slighted to be launched next year.

Demetri Kofinas: Okay.

Gavin Schmidt: It was an absolutely... I mean you're right to highlight that. It was a great day. The idea is that [00:15:00] there are two satellites and what they do is they measure how far apart them are from each other. As they are going over the planet, the planet doesn't have an even gravity field, right so where there is a mountain there is actually a little bit more gravity. You are tugged a little bit closer to the earth where there is a mountain and over the ocean you are tugged a little bit less. As the satellites go over a mountain they would be tugged a little bit more, they would come a little bit closer together. Over the ocean they would separate out by tiny, tiny amounts and so the technology [00:15:30] there allows us to measure exactly how far apart they are is incredibly precise. What that allows you to do is get a sense of where the gravity hot spots are and that is very neat.

The neatest thing was because they were in orbit for so long, right since 2003, they've been able to show us where gravity has been changing. And you think what gravity doesn't change? But you're wrong. Gravity does change. There are two main reasons why gravity is changing on earth right [00:16:00] now. One is that the ice sheets, particularly in Greenland, are melting. Ice that was there, a mass that was there has melted and it has gone into the ocean and so there is a change in mass and it's large enough that we can register it by using instruments that are measuring the total amount of gravity.

Places where we are taking out a lot of groundwater. We have taken out so much ground water, in fact, there is less gravity.

Demetri Kofinas: It's remarkable.

Gavin Schmidt: It's not like people are walking like they're on the moon or anything but it is a [00:16:30] detectable signal that we can see in these things and you can see. You see it in California. You can see it in China. There are places where we are totally unsustainably mining the ground water. That is problematic.

Demetri Kofinas: That is directly related to climate change because droughts require...

Gavin Schmidt: Actually it's more related to agricultural policy.

Demetri Kofinas: Well that's what I mean. The fact that there is drought in California and the desire to continue to use that water they're pulling it from the water table and they're using it to...

Gavin Schmidt: Right. Well [00:17:00] a lot of California is arid anyway and so they've been mining this since the beginning. It's not because there's a specific drought. [crosstalk 00:17:08]

Demetri Kofinas: Okay. Interesting. I was going off entirely off a 60 minute piece where that was the implication. They have been pulling from that water for decades is what you're saying?

Gavin Schmidt: Yes. Yes.

Demetri Kofinas: Wow. Remarkable.

Gavin Schmidt: In a way it's totally unsustainable. It's not just in California but it is something you see worldwide.

Demetri Kofinas: That's a perfect example. We run a capitalist system but we are not able to price everything [00:17:30] and that is a perfect example of an extra anally that we're priced in the correct manner.

Gavin Schmidt: Right.

Demetri Kofinas: You can't replenish the ground water.

Gavin Schmidt: Well you can but it's very, very slow. For it to be sustainable...

Demetri Kofinas: Right.

Gavin Schmidt: You can only take a small amount of ground water and the older the ground water is the slower it refreshes and so the less you can take out sustainably.

Demetri Kofinas: Right. One good argument in the future maybe much more valuable to have water to use to sustain edible food as opposed to wine crops.

Gavin Schmidt: I like [00:18:00] wine so...

Demetri Kofinas: Well, I'll tell you what I'll put it this way. I love wine. Right. I might get some wine after this interview but I think when we talk about what we are going to speak of today and when we look forward in terms of time horizons these are perishable resources and water is obviously not a perishable resource but potable water is and so I think this is really what are our priorities.

Gavin Schmidt: Right.

Demetri Kofinas: I think this is central to our conversation. That's instrumental data. Talk to us a little bit about proxy data [00:18:30] because that's important because your data set is formed by instrumental data, which is data that you are able to collect since 1800 or 1850 something like that.

Gavin Schmidt: Yeah. If you're looking at weather stations that are networked across the world you can go back to about 1880, 1850 and still get a good sense of what the whole planet was doing. If you go back further than you've only got a few stations in Europe or in the U.S. and that's not enough to give you a global picture. We still have a good idea about what happened across the world [00:19:00] in times past. Right? We know that there were ice ages. We know that there were hot periods millions of years before that. We have a pretty good idea of what the history of climate on the planet is and that comes from what you said, proxy data. These are measurements that are not direct temperatures but are things that are related to temperature. They can be kind of course, kind of geo-morphological things so you can see them end murrain like then end part of a glacier. We are in New York City. Brooklyn and Prospect [00:19:30] Park is the end murrain for the glacier at the last glacier maximum. About 20,000 years ago the glaciers came all the way down from the Arctic Circle across Canada and they stopped in Prospect Park.

Demetri Kofinas: That's interesting. So how do we know that?

Gavin Schmidt: Because you can go there. If you kind of stand at a top of a mountain and you're looking down and you see a little kind of ridge of small hills and you dig into that. It's all glacial till.

Demetri Kofinas: Wow.

Gavin Schmidt: It's a feature that you get when the glaciers kind of pushes all of the [00:20:00] stuff in front of them and then when they stop there's just a pile of rubble and things like that.

Demetri Kofinas: And how long ago was that?

Gavin Schmidt: That was about 20,000 years ago.

Demetri Kofinas: That's amazing.

Gavin Schmidt: Yeah. Yeah. You can see that in the landscape. Right?

Demetri Kofinas: Wow.

Gavin Schmidt: You can see where the shorelines used to be when the sea levels were higher or lower. You can see in the ocean mud there are geochemical traces that you can measure. There are kinds of animals that lived when it was warmer and when it was cold and you can kind of piece together the history of the climate on the planet. [00:20:30] The different and diverse ways that people have got clues about past climate are really very impressive.

There is one guy that goes to the high arctic in the summer and what he looks at as when we are losing ice, right. So there are a lot of places where it snowed at one point and never melted. Right? But as it's melting now what it's revealing is the mosses and the plants that have been underneath that [00:21:00] snow and ice.

Demetri Kofinas: The cover crust. The crust underneath there.

Gavin Schmidt: There are mosses and things and they died when the snow fell and so they keep track of the carbon. They can be carbon dated. You can go back and you can say so how old is that thing that was just covered in snow and you get some stuff that's like a 1000 years old and you think oh okay, so that's interesting. It was there when it was 1000 years ago when it snows and now it's being revealed. There's other stuff that's like 4000 years old and you go okay that's interesting. There's other stuff that's like 10,000 years [00:21:30] old and you go okay. Then there is stuff that's so old that there's no radiocarbon left in it and that means that it is at least 50,000 years old. What it actually means it probably comes from the last, what we call is the interglacial period, which is about 125,000 years ago. That was the last time that that was uncovered. We are finding places where the melt that we've caused is the biggest thing that's happened somewhere in 100,000 years. [00:22:00] Right? That's kind of important.

Demetri Kofinas: Right. We'll get into why you believe in and I believe in I think you know...

Gavin Schmidt: We don't believe. We look at the data and ...

Demetri Kofinas: Exactly.

Gavin Schmidt: You find what explains the data to the best of its ability.

Demetri Kofinas: Yeah. I agree. I'm trying to find a way to say this because I really want to give people... I don't think there are going to be many in my audience that question this but for any listener... I don't want it to be kind of pushed on them. I want to be able to find a way for people to actually kind of learn as much as possible from this [00:22:30] conversation.

Gavin Schmidt: Sure.

Demetri Kofinas: Which is why I tried to state it that way. So let's talk a little bit about the drivers of climate change as we know them. Like the earth's orbit, solar cycles, the ozone, etc., greenhouse gasses, absolutely...

Gavin Schmidt: Yep. The volcanoes, continents shifting around, changes in ocean circulation, massive asteroids coming in and destroying everything. All of these things have happened and have changed the climate. Evolution has changed the climate, before there were land plants the climate was very different, before there were blue [00:23:00] green algae the climate was very different. The kinds of things that can change the climate are enormously diverse. It don't all happen at once. We know, for instance in the 20th Century, there was a really big asteroid impact that caused everything to go extinct. We would have noticed. We do know that we have increased the amount of greenhouse gasses in the 20th Century. We do know that we increased the amount of air pollution in the 20th Century. We know we chopped down a whole bunch of forests. We know that there are a few big volcanoes [00:23:30] that went off. We know that the orbit of the earth didn't actually change that much. We know that the sun had these 11 year cycles over that entire period and maybe a little trend as well. We know that we changed the ozone layer because of our use of CFC's and other ozone depleting chemicals.

What we do for any particular period that you might be interested in is you think about all the different things that could be [00:24:00] going on. The orbit, the volcanoes, the sun, the greenhouse gasses and what you do is you try and calculate the fingerprint that is associated with just that effect. They are not all the same.

Demetri Kofinas: You try to isolate all the variables.

Gavin Schmidt: Yes. That's exactly right. There are a lot of things that are going on. What are the fingerprints of each of those changes look like? Just calculating assuming nothing else is going on and what happens is they are very distinct. The fingerprint [00:24:30] for changes driven by the sun. It gets warmer during the day and not so much at night. It gets warmer all the way through the atmosphere from the surface all the way up to the mesa pods. If you look at the change from greenhouse gases, right, now greenhouse gasses are kind of blanket over the earth. They stop radiation from escaping from the earth and so that's something that happens all day and night as well.

Demetri Kofinas: [00:25:00] Let's talk about that a little bit. I want to get into the science of the greenhouse effect.

Gavin Schmidt: Okay.

Demetri Kofinas: Let's talk about that. Let's explain it a little bit. I also want to talk about it because there's a really great example in the science that I think helps people understand it, which is the difference in temperature gradient in the upper atmosphere versus the lower atmosphere. That's why that's a perfectly explanation for it that it's easily explained by the greenhouse effect. So why don't you just tell our audience a little bit about this?

Gavin Schmidt: Okay. The greenhouse effect is what really makes life possible on this planet at all. This is something that was worked out by Foy [00:25:30] in the 19th Century, by John Tindle who worked out with the gasses that were involved. It's very old science. The idea is everything gives off heat right. You are sitting across from me now. You are radiating about 100 watts of energy right now and it's mostly coming from your head. If you had an IR camera you'd be able to see your head glowing yellow and pretty much nothing anywhere else. Everything radiates like the chair that we're sitting on, the table radiates, the earth radiates, [00:26:00] the trees radiate and so anything that has a temperature radiates. If you are a planet you have some energy that's coming in right from the sun or from your star and then for your planet to be stable the same amount of energy has to be leaving. The same amount of energy that's leaving and it has to leave in the way that you're radiating and that depends on your temperature. That kind of infrared radiation for the whole planet is kind of going off this.

Demetri Kofinas: The science of thermodynamics we're talking about.

Gavin Schmidt: Sure.

Demetri Kofinas: The same science that accounts why we're able to determine the temperature from a thermometer.

Gavin Schmidt: [00:26:30] Kinda.

Demetri Kofinas: This space of heat that expands or contracts the liquid.

Gavin Schmidt: Kinda.

Demetri Kofinas: Alright. I won't venture into that area.

Gavin Schmidt: So your planet basically has this energy balance. This sum of energy goes in, this infrared energy goes out. Greenhouse gasses get in the way. Right. Literally they get in the way. Most of the air in the atmosphere it doesn't care about infrared radiation. If you have an atmosphere that was pure nitrogen or pure oxygen [00:27:00] than the radiation from the surface would just go straight out to space and there would be no interaction. But other gasses have specific absorption lines. They absorb photons that have a particular energy. Right. Carbon monoxide and water vapor and methane and nitrous oxides they absorb energy kind of by coincidence at the same frequency that the earth is giving it off. Right. The absorption bands for carbon dioxide are right in the middle of the spectrum for the earth [00:27:30] and that means instead of the energy going straight out to space it gets absorbed in the atmosphere. When it gets absorbed in the atmosphere it then radiates in both directions and so it's like you put an extra blanket on. It's hard for that energy to get out. When you add to that blanket you put in more water vapor, you put in more carbon monoxide, you put in more nitrous oxide it becomes ever harder for the earth to get rid of its energy.

Demetri Kofinas: That's a good metaphor you're using so put a blanket on.

Gavin Schmidt: Right. The blanket is not actually a heater. Right. It's not actually producing [00:28:00] heat but it keeps you warmer. Right. That's exactly what these greenhouse gasses are doing. Adding more and more carbon monoxide in the system is like piling on the blankets. You have to heat up more in order to kind of get past that barrier and so the surface temperature increases in response to that.

Demetri Kofinas: You know you mentioned water vapor there and you mentioned permafrost earlier. Both of these have important feedback effects in warming.

Gavin Schmidt: Yes.

Demetri Kofinas: Why don't we talk about that a little bit more before we get into the models because I don't want to forget about that.

Gavin Schmidt: Okay. [00:28:30] You're absolutely right. Those are what are called feedbacks. We're amplifying factors.

Demetri Kofinas: Which for me and please tell me those are for me the scariest because these are the nonlinearity in the system of climate change.

Gavin Schmidt: That's right. These things can be nonlinear.

Demetri Kofinas: Which are very difficult to predict right? Nonlinear effects...

Gavin Schmidt: Yeah. That's obviously true. Right? Things like linear and like smoothing increasing those are relatively easy to predict. When are you going to have things that have big sharp thresholds or kind of expediential growth then it [00:29:00] is much harder to predict. That's very true. It's very important to understand that there's lots of different feedbacks in the system, and as the temperature increases what happens is the capacity of the air to basically soak up water also increases. For a 1 degree change in temperature you get about a 7% increase in how much water the air can hold. That means we have actually gone up by about a degree celsius since the 19th Century about 2 degrees Fahrenheit. [00:29:30] The amount of water vapor in the air has also increased. It turns out that water vapor itself is also a greenhouse gas. It also produces clouds and rainfall and more intense rainfall but it is itself a greenhouse gas. The more carbon dioxide you put in the more water vapor emerges cause it got warmer and it gets warmer again because the water vapor itself is a greenhouse gas.

Demetri Kofinas: How significant is water vapor among the different feedback mechanisms?

Gavin Schmidt: It's the biggest feedback mechanism so it's [00:30:00] really important.

Demetri Kofinas: Right.

Gavin Schmidt: Yes.

Demetri Kofinas: Can you tell us a little bit about permafrost and how that's relevant and actually let's also talk about the ice sheet and the reflectivity of the ice sheet.

Gavin Schmidt: Okay so that's another great example of an amplifying feedback. You've got a lot of places in the north that are covered in snow or in sea ice or in ice sheets and as the planet warms up that snow melts. It reveals a dark ocean underneath it or a darker ground underneath it and that absorbs more solar radiation and so that warms up more than it otherwise [00:30:30] would have been. That kind of ice albeit feedback, which is also one of the reasons why the Arctic, for instance, is warming up faster than any other part of the planet.

Demetri Kofinas: Because it has...

Gavin Schmidt: Because the planet is getting warmer, the ice is melting and that means that more solar radiation is being absorbed, which means that it's getting warmer and warmer and more ice is melting.

Demetri Kofinas: Right. What about the permafrost?

Gavin Schmidt: The permafrost regions that have kind of like deep layers of frozen ground and what's happening there [00:31:00] is some of it is a relic from the last ice age but other things, you know, there have been permafrost there for years and what's happening now is we are warming up and that permafrost is melting. It's disintegrating, and the carbon that was stored in there a lot of it was peat organic matter is now oxidizing, and it's becoming more carbon monoxide, more methane all of which are greenhouse gasses all of which are adding to the problem that started this.

Demetri Kofinas: Those are like carbon bombs. Right? No?

Gavin Schmidt: [00:31:30] There has been some numbers that have been kind of thrown out there in the literature, which aren't really very well based so this talk of an arctic methane bomb from permafrost is rather overblown in my opinion.

Demetri Kofinas: Okay. So let me rephrase what I'm saying. Let me be more detailed. The way I view the feedback mechanisms like the ice sheet and like the vapor is that they are smoother in a way. There's something about the permafrost that you just get a big burst of it. Is that incorrect [00:32:00] in my thinking? Or is it really irrelevant?

Gavin Schmidt: It's not irrelevant but it's one of many...

Demetri Kofinas: Okay.

Gavin Schmidt: Many factors that are causing the carbon cycle to change or causing the hydrological cycle to change. We started off with this notion of complexity. The fundamental issue when you have a complex system is that pretty much anything you change eventually kinda feeds back and it causes it to change.

Demetri Kofinas: Exactly.

Gavin Schmidt: Some of the orbit will cause it to dampen. Some of it will cause it to accelerate and it's the balance of those things [00:32:30] that give you those kind of emergent patents that you see.

Demetri Kofinas: Nonequilibrium.

Gavin Schmidt: Right. It is kinda causing equilibrium but it's not equilibrium locally but the whole thing is kinda like what we call equilibrium.

Demetri Kofinas: How detrimental, for example I'm pretty ignorant on this subject, but that's why I don't really go out and pontificate on it. How detrimental is the pontification of advocates for environmental change on behalf of climate change, how detrimental is it that you have many people going out [00:33:00] pontificating and making speeches and arguments based on a manipulation of the fact when they really don't have too so if they just understood the science we'd all be better off cause there would be credibility in the community. What I'm saying is there a phenomena that I've experienced, which is I see in subjects that I care about that there are people and intuitions whatever that poison the well and so the skeptical community within it and point to those and say look you know X, Y, Z is saying that and that's [00:33:30] not true and then it just destroys the entire sort of edifice of argument.

Gavin Schmidt: So I recognize the picture that you are drawing.

Demetri Kofinas: The reason that I'm even mentioning it is that I'm sitting here and I'm saying certain things and I see your hesitation with stuff and I'm just saying well you know it's a good thing I'm not going out and pontificating on this.

Gavin Schmidt: In any topic there are people with louder voices than their knowledge would justify. Right?

Demetri Kofinas: Right.

Gavin Schmidt: That's true for any topic. You can find [00:34:00] communities or lines where people are just bullshitting the entire time. What makes it more problematic with climate is that those fringe voice's kind of weaponize by people who have political agendas that prefer that we not pay any attention to what's happening to the earth. That's really the issue. It's why do these people have a megaphone? Why do these people have a TV station? Why do these people get flown all over the place to present [00:34:30] their arguments or to testify in court cases or to testify in committee hearings in the house? How does that happen? Right? That doesn't happen because there is somebody loudly tapping at their keyboard in their mother's basement. That happens because it's politically convenient for people to have kind of sand thrown in their eyes when there's a topic that people don't want to them to focus on.

Demetri Kofinas: Money and politics.

Gavin Schmidt: Money and politics. [00:35:00] There's no question. The vested interested associated in oil and gas and coal are well entrenched and powerful but they're still a role for discourse, though right?

Demetri Kofinas: Right.

Gavin Schmidt: It's not because there are people who are pontificating and talking nonsense that we have to have a discussion. We have to have a discussion because this is a really important topic. Right?

Demetri Kofinas: Right.

Gavin Schmidt: We have to have a discussion about this because we are implicated [00:35:30] in causing this problem and we should understand what those consequences of our actions both individually and as a society should be.

Demetri Kofinas: It's interesting you say that. I want to make one point and then we'll move to the models. One of the arguments you hear by people who believe that we should act on climate change is that irrespective of the cause we should do X, Y, Z because the earth is warming, and we can all agree it's warming regardless of what the cause is, but I actually think that understanding [00:36:00] the cause is partial of understanding the solution. If we recognize that we are causing the warming then "A" we have some credibility and "B" we know what we can do to fix the problem because we would be causing that. What do you think of that?

Gavin Schmidt: I agree with you. The idea is that just because the planet is warming but we have no idea why therefore we should reduce carbon emissions makes no sense to me at all. You reduce carbon emissions because carbon dioxide is the driver of [00:36:30] the warmth. Right? Otherwise why would you bother. There are lots of things that we could do that would make our lives better that we could have more efficient cars and better insulated buildings. These would be good things in and of themselves but they also reduce greenhouse gasses. You might say well let's do these things here and I don't really care about what happens to greenhouse gasses cause I don't understand it but it's better to understand why things happen and then you can actually choose to do things that make a difference as opposed to doing things that just make you feel better.

Demetri Kofinas: Let's talk about the modeling now.

Gavin Schmidt: Sure.

Demetri Kofinas: [00:37:00] What is a climate model? What is some of the earliest weather or climate models that we have had and how have they evolved over the years to where we are today?

Gavin Schmidt: We just actually had the 50th anniversary of the first real climate model by Syukuro Manabe and Richard T. Wetherald. Which was probably established...

Demetri Kofinas: Thermal equilibrium…what do I have here? Thermal equilibrium of the atmosphere with a given distribution of relative humidity. I actually looked it up to see what it was.

Gavin Schmidt: What that even means.

Demetri Kofinas: Yeah. Yeah. Yeah.

Gavin Schmidt: What they actually do is this is [00:37:30] the first climate model that has all the things you need in terms of working out what happens to radiation when you change the amount of carbon dioxide. The relative humidity term there is they are saying well we really don't know how the water vapor part is going to change so we are just going to keep that fixed. It was a reasonable approximation though it wasn't perfect. We are doing a lot better now than we did 50 years ago.

Demetri Kofinas: It was much simpler.

Gavin Schmidt: It was much simpler. The computers we had for working it out were much less powerful. You could run that model on your Apple watch.

Demetri Kofinas: [00:38:00] They were using punch cards for that.

Gavin Schmidt: Oh, yeah. This is all done in punch cards. No graphical user in spaces or anything. They made a number of predictions. They made a number of predictions for what they expected the surface temperature to be after 50 years. They expected that it would warm by the rate that it has. They made a very interesting prediction, which you kind of eluded too before was that as carbon dioxide increases the ground would warm but the air aloft kind of above 15-20 [00:38:30] kilometers would actually cool and this was before we'd made any measurements of stratosphere and they say well you know it's because of this very special thing that happens with carbon dioxide so the reason why the stratosphere causes it is a little technical but effectively in the frequencies that carbon dioxide likes to absorb in there's so much carbon dioxide below that almost nothing gets through those to cool.

Demetri Kofinas: Like those frequencies.

Gavin Schmidt: When you add more carbon dioxide there [00:39:00] it just radiates cause radiation and emission are about the same physical phenomena. It radiates more and so it cools and that was a prediction that was made well before there were any measurements of the trends and what's happened is that it's become abundantly clear that we are seeing this cooling not just in the stratosphere but in the upper stratosphere but in the mesosphere and in the thermosphere all of these things are cooling because of the increased amount of carbon dioxide, which is opposite to what you would have got if the warming had been from the sun for instance.

Demetri Kofinas: [00:39:30] How many orders of magnitude can we currently model with our climate models?

Gavin Schmidt: Right. What we do with the climate models you take the planet right and you kind of chop it up into little weather and little bits until you basically fill up your computer and the level in which you can do that detail is changing. Every decade we can do more and more details.

Demetri Kofinas: So you're starting off with the most macro-picture and then you start to get more and more refined and detailed.

Gavin Schmidt: Right. If you think we are only going to [00:40:00] just average everything and make it an equation. Well that's very simple that was done many, many moons ago. We can do better than that so let's split it into hemispheres north and south. Let's put it into latitude bands. Let's put it into group boxes that are only a few hundred kilometers 50 kilometers square and you in each of those cases you can add in more and more detail and you can get more and more complexity. Right.

Once you get below about a 1000 kilometers, you start to see weather systems. Right. You didn't get that [00:40:30] when you were doing like 4000 kilometer boxes and when you get to 4 kilometer boxes you have convection kind of spontaneously happening. At every point you have to stop right because the computers aren't infinite. That point away you stop kind of the cut off distance. You then have to kind of make approximations for everything that's happening on all the smaller scales or that is happening very, very fast. What we're doing as computers get better is we're kind of encroaching into that small, fast [00:41:00] area of physics to make better and better approximations.

Demetri Kofinas: Are the computers the bottleneck? Is the process in capacity the bottleneck here? What are the bottlenecks if you can think of it that way?

Gavin Schmidt: Right. We generally kind of use whatever computing we have and that's been increasing dramatically over the last 20-30 years so we've been able to do better. You know our understanding of the processes and the observations all of these things actually go hand in hand. If you gave us a million times faster computer [00:41:30] tomorrow right we wouldn't be able to use it really effectively because we wouldn't have set up the observational programs, the analysis programs that would allow us to fill in the details, those extra scales that we had to do. One of the nice things is science gets better on all these fronts pretty much simultaneously. We have more detail in our understanding. We have more detail in our processes and we have more capacity in our computers pretty much at the same rate. That [00:42:00] allows us to kind of keep things balanced as you go forward.

Demetri Kofinas: There's been a huge revolution we've covered on this show in biology and genomics and certainly in financial markets with big data analytics but also machine learning and artificial intelligence. What role is that playing in climate science?

Gavin Schmidt: That's a great question. I'd have to say it's not playing the role that you might [00:42:30] of thought possible and maybe it's because it's still early days but the topic that we're dealing with climate is the archetype of a multi-scale system. Right. You know you've got things that are happening at the micron level, cloud formation, the microphysics of a cloud droplet that matters for radiation, for rainfall for all sorts of things. Then all the way out to massive weather systems, hurricanes. They're really, really large systems…or the circulation in the ocean. [00:43:00] We're generating huge amounts of data. I mean big data is our really number one problem. You think no well let's throw in some machine learning and see what's going on see if it can recognize patterns that we haven't seen before. What tends to happen is that the people that come in with the machine learning come in with algorithms that they worked on with Facebook and with Apple and with Google and they say can we apply these algorithms to your problem. And you go [00:43:30] that's not really a recognition problem. It's not really a ranking problem. We are trying to find that physical process.

There is a community that I've been part of that's trying to make a conversation between the people that are coming in with these tools and with these skills and people who understand the system and try and apply it. It hasn't really clicked as yet.

Demetri Kofinas: What about the community of game developers and engineers? That seems like one area that we could possibly find some synergy because they're commercial applications that are developing simulations that run on things [00:44:00] like unity or whatever.

Gavin Schmidt: Okay. Here's a slight problem that comes in GPU chips. Right. Very fast. Would normally allow you to do a lot more calculations than we can do with a normal chip but they were developed for games where it doesn't matter if it gives you the same answer all the time. Right. They are actually pretty error tolerant but the produce a lot of errors. Right. You can't have that in a scientific application because if something [00:44:30] goes wrong and then it just goes blah then you're going to go "oh my model crashed you know what's going on," but then it does a different calculation the next time you run it, then you can never debug anything.

Demetri Kofinas: I see what you're saying.

Gavin Schmidt: It really matters that you can be able to do that with scientific codes. We've never been able to use GPU technology and I know they are much better error correcting than they used to be but, in the beginning, no we just can't use that technology. There are computing that you [00:45:00] can do but it doesn't fit. We are not a large enough community in and out of ourselves to get people to build chips just for us.

Demetri Kofinas: That's really interesting because there is such a revolution that's going on in computer science and technology and, you know, speaking of that, and I wanted to get into this towards the end, but we might as well touch on it now. How realistic are some of the potential technological solutions that go beyond renewables but that actually have to do with sea crustacean or actually extracting greenhouse [00:45:30] gases? I mean what's the field there?

Gavin Schmidt: There's a number of different things that people are pursuing. One of them you have mentioned is there's air capture. You capture from flues or from air the carbon dioxide that's in it and you try and bury it somewhere. In theory there's no problem with this. The chemistry is well understood. How you can do that with enough energy to kind of lower the ground state of the carbon, and you have to put energy into do that, [00:46:00] you know, it's fine theoretically. The issue is how much does it cost them, does it scale? The problem is that it costs too much money. You might have heard people talk about the cost of carbon. The social cost of carbon and what carbon tax should be if the damages were to be taken into account and the numbers people come up with, $40.00, $60.00, $100 something like that. That's pretty much the price in a perfect market you would be paying to not emit carbon dioxide in [00:46:30] the first place.

Unfortunately the cost of that capture is more like $600.00, $1000.00 a ton of carbon, which means you're paying more over the odds to remove it and there's lots and lots of other things you would do first that do not involve that. The big problem there is cost. Now there are more efficient ways to capture carbon right for instance from a smoke stack. I mean not quite a smoke stack but through like a pipe...

Demetri Kofinas: At the source of pollution.

Gavin Schmidt: Carbon dioxide is [00:47:00] much more concentrated there. You can design it so that you get a stream basically carbon dioxide. You say well okay now I'm going to just capture that and now I have to do something with. What people are doing they are pumping it into oil wells and kind of putting it back into the ground but there isn't really quite enough space to do that for all of the carbon that you would want to capture. Some people are putting it into rock formations whereas it's actually reacting with the rock and making different kinds of rock and that's [00:47:30] a pretty permanent solution. Other people are saying well I can just pump it into the deep ocean but that's also rather expensive and ecologically ...

Demetri Kofinas: That contributes to the acidification of the ocean.

Gavin Schmidt: Yes. The acidification of the ocean is happening because we increased the amount of carbon dioxide very, very quickly and so the top layer of the ocean has become much more acidic.

Demetri Kofinas: Can you explain what that means for our audience?

Gavin Schmidt: The amount of ocean that is kind of being mixed by the winds depends kind a little bit where you are and how strong the winds are, but it kind of ranges from about the top 60 [00:48:00] feet to maybe the top 1000 feet in the North Atlantic and that's the part of the ocean that is being mixed in with the air. Right. It's always being seen by the air.

Demetri Kofinas: It's mixing with the air.

Gavin Schmidt: Carbon dioxide is like coming in and out of the ocean at that point. Because of the chemistry of carbonate and the chemistry of carbon dioxide the more carbon you put in the atmosphere the more acidity it becomes. The smaller the pH and so you've got changes we've increased the acidity of about 30% [00:48:30] in the last 100 years or so and that's having noticeable effects on animals that make shells out of calcium carbonate so oysters, muscles, crabs, lobsters, corals. Those kinds of things.

Demetri Kofinas: Well I want to get into that towards the end when we start to look at predictions. One thing I want to state, and we can actually get there right now but one thing I want to state that I was thinking about when we're talking about these technologies is that the same time I don't want listeners and please correct me if I'm wrong here, but [00:49:00] I don't want listeners to come away with the idea that even if we could just somehow extract the carbon from the atmosphere, extract however much we want that, that certainly would solve the problem now. There comes a point in time and I think about it is terms of like the melting of an ice cube on a table it takes a certain amount of heat to melt a cube but you can't just form that right into an ice cube again. In other words if we get a certain amount of warming we can't just reverse that. Right? In other words there's a runaway warming effect and you talked about the vapor.

Gavin Schmidt: [00:49:30] Right. I mean in practice we're not going to go back to the situation that we had 150 years ago. Right. I mean the planet is still catching up with what we've done to the atmosphere. We're not slowing down.

Demetri Kofinas: When you say we're not going to go back to the way we were 150 years ago, we're not going to get...

Gavin Schmidt: Yeah, we're not going to get back to the temperatures we saw then. The choices that we have in practice do we accelerate this level in trend by burning more and more fossil fuels or do we try [00:50:00] to bring down the emissions and then it's only going to warm a little bit more.

Demetri Kofinas: Right.

Gavin Schmidt: Like stopping global warming or reversing global warming. Those are no longer on the cards.

Demetri Kofinas: I think something else is important and I want to say this again in my own words and please offer your opinion on this. I think it's important for us to contextualize our conversation with the understanding that we're living in a world with expediential population growth and growth not just experientially in the earth but in low lying areas. [00:50:30] I mean we've built a society around a particular sort of stable climate.

Gavin Schmidt: Right.

Demetri Kofinas: That's why I think this is so relevant.

Gavin Schmidt: And you're absolutely right. That's exactly why this is an issue. The issue is not, you know, what's the perfect temperature for the planet or what's the perfect level of carbon dioxide? None of those things are really sensible questions. The question is what have we built our infrastructure with the expectation of and how is that expectation changing?

Demetri Kofinas: What have [00:51:00] we adapted for both biologically and technologically?

Gavin Schmidt: Right. Biologically we can adapt to a lot. We have people living in Dubai and people living in the high Arctic. Physiologically we can cope with a wide range so that's not really the issue. The issue is that we have built a society based on expectations about climate. How close to the shore do you build your houses? Where do you build your agriculture infrastructure? Where do you build your trains? Where do you build your cities? All of these things have [00:51:30] basic expectations about what sea level rise is going to do, what storm surges are going to be like, what extreme weather is going to arise.

Demetri Kofinas: Extreme. That's a great point. So it's the extreme events that are the concern because in complex systems it's the outliers that create the most damage and that is what we need to worry about.

Gavin Schmidt: Exactly.

Demetri Kofinas: Let me ask you this in the interest of time let me just get straight to the projections that our current models are giving for us and sort of what we can understand in terms of best case scenarios, worse case scenarios [00:52:00] take into account what we may or may not be able to do to influence all of this?

Gavin Schmidt: Right. When we are going forward there is this target that the Paris Accords talked about. This 2 degrees warming above but really nobody really understands what that means. What is 2 degrees mean?

Demetri Kofinas: Celsius.

Gavin Schmidt: Yes, 2 degrees celsius. Nobody knows.

Demetri Kofinas: 4 point what?

Gavin Schmidt: It's just under 4 degrees Fahrenheit.

Demetri Kofinas: 4.

Gavin Schmidt: You know that doesn't seem like a really big number but in terms of the planets it's a huge deal. Right. We mentioned the ice age [00:52:30] earlier on. How cold was the ice age compared to today? It's only about 8 or 9 degrees Fahrenheit colder. Right. So 2 degrees, 4 degrees Fahrenheit well that's halfway to an ice age but in the other direction. The worst case scenarios is like a full ice age unit in the other direction. You think about how different it was during the ice age. Where the ecosystems were? What sea level rise was in? What are the ice sheets are doing? What the temperature was? All these things are massively different.

Demetri Kofinas: The population of the earth, which was [00:53:00] a few human beings was much...

Gavin Schmidt: Much, much only a fraction. The changes we saw at the end of the ice age those are bigger than the changes we are going to see now but we didn't have a huge investment in the status quo. You know if you are a hunter or gatherer and the sea level rises you just walk.

Demetri Kofinas: That's hundred percent correct.

Gavin Schmidt: Right. If you are living in New York City then you know you're not going to do that.

Demetri Kofinas: Or if your sewage treatment plant is located in a city with 10 million people and all of a sudden salt water comes in through the pipes.

Gavin Schmidt: Your outflow is like 3 feet above [00:53:30] high tide level and then it doesn't outflow at all once you got sea level rise.

Demetri Kofinas: Or the fact that the breadbaskets of the world are located in areas that get ample amount of sunlight and could potentially become dust bowls in this scenario. It's not so simple to just move those farming communities up north where there's less sunlight.

Gavin Schmidt: No. Also things like soil right. So everyone says like okay I'll do well we can go ahead and grow our wheat in Canada. The problem is that Canada has seen so many ice ages in the past that there's almost no topsoil. The rich fertile areas, [00:54:00] you know, there's a reason why they are where they are and we just can't move everything towards the pole.

Demetri Kofinas: The migration as well. That's one of the first impacts, right? The migration crisis that would occur as a result.

Gavin Schmidt: Right. We can see a little bit of this now. After Katrina lots of people left New Orleans and ended up in Houston and after half the year a lot of people are leaving Houston. We can see after Maria something like 70,000 people have moved to Florida and you say okay well that can be managed but maybe it can't be managed. Right. You look at Bangladesh [00:54:30] and you look at the floods there and now you've got 100 thousand and millions of people who are looking for somewhere else to go. That scares me not because ...

Demetri Kofinas: It scares me too.

Gavin Schmidt: Not because it's people moving, I'm a big fan of people moving but it can get uncontrolled and when it's uncontrolled, right, systems break down. We have seen systems break down in Puerto Rico. We've seen communication systems and power systems; sewage systems and water systems break down when the stressors are too high. That's the thing that really worries me.

Demetri Kofinas: [00:55:00] Correct. It worries me as well and the way I think about that is that you don't want to be playing catch up and it feels like that's sort of where we're going. We're getting into a place where there's a full court press on and we're just trying not to lose and that's really not a good place to be. It's not how you want to approach anything.

Gavin Schmidt: No. You want to prep. You want to be prepared. You want to be in a position where you're not surprised by the outcome, and one of the things that we do in the science and predictions that we make [00:55:30] is to try and get people to think about those worse case scenarios so that they will be prepped.

Demetri Kofinas: What do you think the likely outcome is based on the models are projecting and based on let's say what most political forecasters are forecasting in terms of sort of political outcomes and as well as potential commercial solutions that may come along because we have had a sort of clean energy evolution, which is an exciting phenomenon. What do the next 10, 20, 30, 50, 100 years [00:56:00] look like and if you want to give a few maybe best middle, worst case scenario or something?

Gavin Schmidt: Predicting the future is hard.

Demetri Kofinas: You know it's really interesting. I'm sitting here looking at you right and I'm thinking I'm coming again from a place of ignorance as is the audience but you're not. You actually know way more than all of us right. So your feelings on this subject actually matter. I'm actually searching your facial expressions to give myself a sense of ... How do you feel? I'm curious to ask you this.

Gavin Schmidt: [00:56:30] Sometimes I wake up and I see that there's been another round of bullshit and people like making things up in order to ignore the problem and I think we're never going to do anything. Then it makes me feel sad. I have a 2-year-old daughter and she is kind of getting into how her feelings are and she has kind of worked out when she's angry and when she's sad so that's pretty much how I'm seeing emotions at this particular moment.

Then I see [00:57:00] another story about penetration of solar energy in energy markets and the latest bid price for windows plant in India or Scotland and I'm thinking oh no, maybe we will turn it around and then I see lots of non-joined thinking. People that are trying to cost things without taking into the core benefits of moving away from internal combustion engine. Even [00:57:30] if carbon dioxide wasn't the problem moving to electric vehicles and internal combustion is much healthier for everybody involved. It's healthier for people working in gas stations. It's healthier for people that live near main roads. It's healthier for people in the cities. It's healthier for crops because you're not putting out so much nitrous oxide, which causes ozone pollution, which reduces crop yields. There's enormous amounts of public health and productivity bonuses to be had [00:58:00] by moving away from oil and then you've got the climate thing, which really just adds to all of that. You say okay this is a good thing to be doing.

You see some of the technological breakthroughs and you see the price of electric vehicles coming down. You see electric buses coming on line and electric trucks coming on line. You think okay we're making progress. Then you see ...

Demetri Kofinas: Pulling out of Paris for example. Do you think that was a ... I mean certainly if you want to do something [00:58:30] productive of a climate the stipulations within the accord were positive, but given the fact that it was nonbinding and given the fact that it was positive effects of pulling out in terms of awareness. I mean are there ways to sort of ...

Gavin Schmidt: That's a big argument. There's a big difference between setting a target and actually doing something on the ground to make that target happen. Right. So I think we've got past the point where setting more targets is really helpful. We've got to the stage where people need to be demonstrating that they can make [00:59:00] progress. How do you make progress. Do you make progress with technology in senses with taxation, with mandates, with greater awareness. Much of these things work. The whole Paris process was really designed to help new ideas flourish, those new successful ideas to kind of spread around the world and to be implemented in more and more places, to kind of scale up what people can do and how fast [00:59:30] they can do it. In being part of the Paris process would help us do that as the U.S. and I think help the world move towards those targets more quickly but you know.

Demetri Kofinas: Do you think that the devastation that has occurred in China is air pollution to the environment and their reaction, which has been to sort of strongly invest in alternative renewable forms of energy coupled with their emergence as a leading power in the world in [01:00:00] a way can actually be of significant force for progress in this domain?

Gavin Schmidt: Possibly. You know China is not a perfect society in any respect and the pollution problems there are unbelievably bad. The number of people that are dying prematurely because of the air quality in Beijing and Tanghin or even in Deli are enormous and deeply troubling.

Demetri Kofinas: Well people and lots of countries have been [01:00:30] looking at that and decided not to invest in coal as a result.

Gavin Schmidt: Right. Their problem is not just coal. Their problem is coal, its factories, its domestic burning like of low quality coal cause nitrous oxides and one of the problems with China is it's not a democratic society. A lot of the checks and balances that you would have in the U.S. or Europe don't exist.

Demetri Kofinas: Right.

Gavin Schmidt: There is a lot of autonomy in the state operating [01:01:00] enterprises. There's a lot of autonomy in the regional governments where the central government can say oh you should reduce your pollution and they will say yes, we did that already but nothing actually happens. The central government thinks that people are paying attention to them. Everybody pretends they are paying attention but nothing actually happens. You have cases where people have built new technology to clean water or to reduce pollution. Somebody from the central government turns up. They turn it on. Everybody's very happy and as soon as the guy from central government has gone [01:01:30] away, they turn it off again because it's too expensive to run.

Demetri Kofinas: Well we've kind of covered some of those obscurities with that and on episode 16 I think it was on the Chinese financial assist and banking system. One of those examples in just the way in which the authorities' sort of the commercial interest would leave the lights on in the buildings because the financial analysts had decided that they didn't trust the original occupancy numbers of the buildings and so the developer started leaving the lights on to trick them and an incredible amount of waste because the number itself [01:02:00] became the target as opposed to the actual sort of positive.

Gavin Schmidt: Right and that's the kind of thing that happens where you don't have trust and where you don't have checks and balances, and you don't have a real democracy. Looking at China as a model to kind of save us in this situation is tricky to a point cause you can't really trust what's going on.

I'll give you another example. The official statements about how much China remits in terms of short term pollutants not just oxides, sulfa dioxides. We can measure that from satellite. Right. We know exactly how much stuff is in the air. [01:02:30] You say give us your numbers and you put in their numbers and it just doesn't match. You know their numbers are not accurate. There is all sorts of reasons why that is but the basic reason is that there's no democracy. There's no accountability and there's no checks and balances in their system so it's very hard to know what's going on.

Demetri Kofinas: Let me ask you this in closing because I think rather than have you do the sort of typical sort of best case, worse case you mentioned you have a daughter. Do you have just one child?

Gavin Schmidt: Yes.

Demetri Kofinas: Obviously she matters a great deal [01:03:00] to you I'm sure and your family does.

Gavin Schmidt: Yes, sure.

Demetri Kofinas: As a father you must feel some level of personal responsibility for her?

Gavin Schmidt: Yes indeed.

Demetri Kofinas: What are you doing as an individual separate from your advocacy? How are you planning to meet the changes that may come? I mean for example. A simple sort of thought in someone's head is well I can move to a certain area like if I live in Miami, south Florida I should get out and I should move to some other place.

Gavin Schmidt: Yes. I would not buy beach front property [01:03:30] in Miami.

Demetri Kofinas: Right and they have the limestone also where the water comes up right to the water table.

Gavin Schmidt: Yes.

Demetri Kofinas: They can't even put dams and sort of... What will you do, what are you planning to do in order to sort of deal with the unpredictability of this situation?

Gavin Schmidt: So sometimes as terrifying and anybody that is a parent is occasionally terrified by what lies in store for their children. We choose to do things [01:04:00] I think are sustainable. We choose to live in New York City. We live in a multiunit apartment block with solar panels on the roof and good insulation and with very, very low electricity bills so that's a good thing. We don't have a car. We don't need a car. We don't eat very much meat or no meat at all. We kind of think about the consequences of our actions. The one [01:04:30] caveat to that for whatever work purposes and going to conferences and things I fly more than your average bear and in terms of my carbon footprint that's the biggest thing that I do.

Demetri Kofinas: Those are the things... Let the Gandhi be the change you wish to see in the world.

Gavin Schmidt: Yes.

Demetri Kofinas: That's sort of you being a responsible citizen but as a private citizen if your models are telling you that in let's say 30 years. I'm not saying this is the case but in 30 years there will be regular inundation of New York [01:05:00] and you are looking at the political climate and you were looking at the commercial climate and you're saying okay there's nothing going to stop this. You're going to leave New York. That's a perfect example, right? You're not going to stay?

Gavin Schmidt: Well I'm also not buying riverside property in Red Hook.

Demetri Kofinas: Right. What I'm saying is.. Well you do live on the upper west side probably right.

Gavin Schmidt: Well I live in Harland.

Demetri Kofinas: Right but that's actually mountainous in relative to other areas of Manhattan.

Gavin Schmidt: Yes so, it's not in one of the flood zones.

Demetri Kofinas: [01:05:30] Right.

Gavin Schmidt: I look at the flood zone maps and I look at the flood maps in Miami. I look at them in D.C. I look at them in New York and people ask me all the time should I buy a house there? I would not.

Demetri Kofinas: Where can people see flood zones... Where can people see these maps?

Gavin Schmidt: The New York City maps are on the New York City website. Plan MIC was the old name for it. It might have changed with the Palazzi administration but you can see all these things on the website, New York City. Gov.

Demetri Kofinas: Is there [01:06:00] a good resource in general or a few good resources in general for people that want to plan their lives. If you believe... If you look at the data and you understand that the climate is warming and there will be repercussions regardless of what we do now and you want to understand what those probability functions are, are there good resources for people on an individual basis to plan their lives?

Gavin Schmidt: Yes. I mean if you live near a river or a flood plain you should know about it. FIMA has maps and they're not always totally up-to-date and they can fool [01:06:30] you if you're quite close to the edge. There's a number of sites where you can go in and you can put a sea level rise amount and you can see how close your house is to the high tide zone. Those are useful to find. I cannot remember the site offhand but I can give you that afterwards.

Demetri Kofinas: We're talking of course... I would love to actually. I would love for you to give me anything that I could share with our audience cause I think this is actually really practical but also again these are complex phenomena. Right.

Gavin Schmidt: Right.

Demetri Kofinas: Is it great to move to Norway? Not that you could easily get citizenship [01:07:00] in Norway but those are sort of obvious things but at the same time they are these nonlinearity. I mean you could say okay I'll move to Colorado but then let's say the supply chain for food in Colorado gets disrupted based on the climate change but is it so complex that...

Gavin Schmidt: I can't predict any of that.

Demetri Kofinas: Right. Exactly.

Gavin Schmidt: The moles that we have are the moles of the physical assistant. They are not models of sociology of humans. They are not models of economies. They are not models of governments. They are not models of democracy. The kinds of things that we can model [01:07:30] are not the answers that people need. Right because that's what you want to know. How's society going to react. What's going to happen to supply chains? What's going to happen to transportation? What's the technology that's going to allow all of these things to happen? Those aren't the kinds of things that we know how to predict.

You go back 10 years. Could they have predicted how society has really worked out here? Right. No. There are so many contingent things but they [01:08:00] may have been able to work out what the climate was going to do. Right. People often assume that I'm some guru of the sociology of how people are going to react to things and I'm not. I'm a mathematician turned physicist turned climate scientist and I understand things like radiation and clouds and ocean circulation and sea ice, vegetation feedbacks but the important things, the key things are the human feedbacks.

Demetri Kofinas: Right.

Gavin Schmidt: [01:08:30] I'm as much in the dark as anyone.

Demetri Kofinas: Well on that note of humility I hope we don't... I'm trying myself not to sort of be passive.

Gavin Schmidt: Right.

Demetri Kofinas: I mean of course it's very difficult. I think it's interesting. I'll just leave our audience with this. Last night I was listening to some audio. It might have been one of your sort of conversations on this and I was driving actually. I had gone away for the weekend. I was driving back to the city and it was pouring rain and I was thinking about this and I was getting anxious in a way that I don't [01:09:00] normally ever become anxious and I almost hydroplaned. I said to myself woe, there you go, immediate risks like you know sort of recalculation and I was relieved almost that I had that moment of recognition that I almost hydroplaned because now is what matters and then I went back to just being able to ignore this.

Gavin Schmidt: Right.

Demetri Kofinas: When you spend time with your subject my experience is that it is ... There are some interesting esoteric subjects that we cover on this program like goal setting and utility functions and artificial intelligence, [01:09:30] engineering, etc. etc., disease vectors as a result of antibiotic resistance etc. This has been the most upsetting and that is the word I would use. I would just say it's upsetting in a way and anxiety provoking in a way that's unique.

Gavin Schmidt: I don't think it needs to be but you do got to understand that you got two kinds of problems. You got your acute problems, things that demand your attention right now. You break your arm. You hydroplane. You crash your car. [01:10:00] All of these things are immediate problems that exclude everything else while you deal with those things and then you've got chronic problems. Climate change is a chronic problem. It's something that's just like building slowly day after day after day, but we do deal with chronic problems all the time. Right. The fact that we're getting older. The fact that people have diabetes. The fact that you have high cholesterol. That you don't exercise enough or that you need to save for your retirement. All of these things are long term chronic issues that you have to deal [01:10:30] with and we manage that. We do manage to get a mortgage and pay off after 30 years. We can think in long terms. We can lose weight. We can reduce our cholesterol.

Climate changes are another one of those problems and I think part of the problem that we've had in how people talk about it is that people confuse it with an acute problem with having broken their arm and there has to be an urgent response. Then when nothing happens then people go well okay then maybe it wasn't that urgent but all the time it's going to be building [01:11:00] and building and building. You have to recognize the nature of the problem if you're going to come close to finding sustainable ways to deal with it. I'm not just talking about sustainability. I'm just talking about having conversations that can be sustainable for the decades that it's going to take to deal with this problem.

Demetri Kofinas: Dr. Schmidt thank you so much for coming on the program and I hope to put a list of reading materials on our website for our audience as well after this that maybe you can sort of give me a few recommendations?

Gavin Schmidt: [01:11:30] I would love too. Thank you very much.

Demetri Kofinas: Thanks for coming on the program.

Gavin Schmidt: Thank you.

Demetri Kofinas: That was my episode with Gavin Schmidt. I want to thank Dr. Schmidt for being on my program. Today's episode was produced by me and Genevieve Annable. Edits and engineering are Stylianos Nicolaou For more episodes you can check out our website at HiddenForces.io. Join the conversation through Facebook, Twitter and Instagram at @HiddenForcesPod or send me an email [01:12:00]. Thanks for listening. Will see you next week.