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Science AMA Series: We authored two recent studies covering options for human intervention to address climate change for the National Academies of Science, Engineering, and Medicine, Ask Us Anything!

Climate$_I ntervention$[1]$andr/ScienceAMAs$[1]

[1]Affiliation not available

April 17, 2023

Abstract

Hi reddit, I'm Scott Doney, a Senior Scientist at the Woods Hole Oceanographic Institution. My research focuses on how the global carbon cycle and ocean ecology respond to natural and human-driven climate change. I'm Waleed Abdalati, Director of the Cooperative Institute for Research in Environmental Sciences at CU-Boulder's Geography Department. My research focuses on the use of satellites and aircraft to understand how Earth's ice cover, particularly glaciers and ice sheets, is changing and what those changes mean for life on Earth. We're talking about risks and possibilities of climate intervention, or as it is often referred to, geoengineering. Ask us anything! You can read more about the work the National Academies are doing here. We will be back at 1 pm ET to answer your questions, ask us anything! We're signing out now. Thanks for these great questions and discussion. If you are interested in learning more, please visit the webpage for the study: http://nas-sites.org/americasclimatechoices/

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CLIMATE_INTERVENTION R/SCIENCE

ABSTRACT

Hi reddit,
I'm Scott Doney, a Senior Scientist at the Woods Hole Oceanographic Institution. My research focuses on how the global carbon cycle and ocean ecology respond to natural and human-driven climate change.
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Scott, what is the status of directly extracting carbon from seawater? The Navy Research Lab has some projects, and this Xerox PARC/DARPA process is supposedly the most efficient method of carbon extraction from the atmosphere because carbonic acid is in equilbrium with CO2. When will we start seeing industrial carbon extraction plants like desalination plants?

jsalsman
Thank you for the link to the recent paper on a electrochemical method for removing CO2 from seawater; I had not seen this particular work. All approaches to carbon capture and sequestration have to deal with a series of trade-offs such as energy use, inputs of other resources, scalability to industrial scale, good locations relative to likely carbon sequestration sites, and environmental impacts. While interesting, the energy use for the seawater electrochemical approach at 242 kJ/mole CO2 appears relatively high compared to the theoretical minimum for direct air capture (~20 kJ/mol CO2) (though that is only a theoretical minimum. There would need to be more work done to address complications of scaling from laboratory to a larger scale, and there are also the issues of seawater pumping and handling as well as disposal of the seawater after CO2 removal (the water would have a rather basic pH after removal of half the inorganic carbon load).

What is the single most important thing I, as an individual, can do to help/not make the situation worse?

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najing_ftw

From Waleed: The single most important thing individuals can do is recognize and understand the challenges that we face, and make sure our thinking, as individuals and as a society reflects an awareness of those challenges. I don't want to point to one thing, like driving less or turning down our heat, but rather successfully meeting the challenges of climate change requires a mentality that recognizes them, appreciates them, and is willing to make the difficult choices necessary to meet those challenges. It starts with individuals, and can grow to a group, and ultimately grow to be pervasive in the broader culture. So the single most important thing any of us can do, as adopt an attitude that recognizes the challenges, and let that attitude permeate the way we live and shape the choices we make.

What would an industrial scale carbon removal effort look like? In the best case scenario, how long would it take to put such a system in place? Once in place, how long would it take to begin to see measurable impacts on the global climate?

realultimatepower

From Scott: Present-day fossil fuel emissions to the atmosphere are about 10 billion metric tons of carbon per year and have been growing with time. About another billion tons per year coming from deforestation in the tropics. Roughly about 45% of these human emissions remain in the atmosphere. The Global Carbon Project (http://www.globalcarbonproject.org/) releases up to date summaries of emissions and also natural land and ocean carbon sinks that are helping by removing a substantial fraction of human emissions. Unfortunately these natural sinks cannot keep up with current human emissions. To have a substantial effect on slowing (and perhaps in the future even reducing) atmospheric CO2, any carbon capture and sequestration approach would have to be of large industrial scale, roughly comparable in size to the fossil fuel industry which is the source of the hydrocarbon fuels that form the majority of human CO2 emissions through electricity production, heating, transportation fuels, etc. Carbon dioxide has built up slowly with time over many decades and any technological approach would require similarly long time-scales to slow and then reverse that build up. There is no magic bullet here. Some scoping exercises have been done to evaluate different approaches. Carbon capture pilot studies are being conducted at some power plants taking CO2 from the gases emitted from the plant before they reach the atmosphere; these add to the size and cost of the power plant but could be relatively efficient because the waster gas has high CO2 levels. Other technological approaches for direct air capture from the atmosphere have been proposed that could be more decentralized (for example to be close to renewable energy sources or geological sequestration sites). In any case, once you have concentrated the CO2 you also need to safely sequester the CO2 away from the atmosphere for many decades to centuries. Various approaches have been suggested including old oil/gas fields, salt domes. Biological approaches are also addressed in the 2015 NRC report on Carbon Dixoide Removal and Sequstration: http://www.nap.edu/catalog/18805/climate-intervention-carbon-dioxide-removal-and-reliable-sequestration

What's our best bet for turning climate change around?

crw1000

From Scott: Here's a direct quote from the NRC report summaries: "The two main options for responding to the risks of climate change involve mitigation—reducing and eventually eliminating human-caused emissions of CO2 and other greenhouse gases (GHGs)—and adaptation—reducing the vulnerability of human and natural systems to changes in climate." Limiting future carbon dioxide emissions to the atmosphere is challenging; there is no single approach that can do the job. That said, people are pursuing a number of options ranging from improved energy efficiency to use of renewable energy and carbon capture and sequestration from power plants. A good summary can be found in the National Climate Assessment chapter on mitigation: http://nca2014.globalchange.gov/report/response-strategies/mitigation At this point our best approach is probably to invest in a number of technologies

and then determine over time which are having the best payoffs in terms of scalability and minimal environmental and social impacts.

1) How seriously are the national academies considering research into solar radiation management? And what do you expect the research outlay will be in technology vs political/social science and governance concerns about SRM? The reason I ask is that the concerns of a rouge state or individual using SRM for personal benefits at the expense of others seems high, and is more of a problem than specific technologies. E.g., the "cure is worse than the disease" argument. To be clear, I'm specifically asking about research on how governments will likely use SRM, not the governance of the research itself.

2) What top 1-2 impacts of climate change are YOU most concerned about? What top 1-2 impacts of climate change are YOUR FUNDERS most concerned about? Are they different, if so, why?

3) If you had to make an estimate comparing a metric ton of ghg emissions to a health metric, disability-adjusted live years or something like that, what would you deem necessary for that calculation?

4) Lots of science is justified by working on specific macro-problems that are aggregations of smaller problems or research. For example, "climate change" can justify any research from drought-stress crops to finely measuring gases in ice cores. "ocean health" can be used to justify anything from the acoustic environment for cetaceans to photodegradations of plastics. You've probably seen a lot of research tagged with the "for climate" label recently because that where a lot of the money is. What "tag" did your research follow before this? What were the main problems that aggregated and framed a lot of research two or three decades ago?

diogenesintheUS
From Waleed: i will try to take them by number:

1) The Academies provided its views through the Climate Intervention reports that Scott and I contributed to. The Academies itself does not support research, but rather issues findings and recommendations for the agencies and others to consider. Our findings and recommendations can be found at: https://nas-sites.org/americasclimatechoices/other-reports-on-climate-change/2015-2/climate-intervention-reports/ These matters are discussed thoroughly in there.

2) all of the impacts are significant in many ways. I think water availability is the most significant from my perspective, because it effects life, health, livelihood, national security, and every dimension of human life. I don't think agencies really prioritize, except with respect to how it aligns with their missions. The intelligence community, for example would presumably be interested in matters most directly related to national security. The National Institutes of Health would presumably be most interested in health issues. It is hard to pick one or two. People who live in coastal communities might be most concerned about sea level rise. People with health issues that are exacerbated by warm temperatures would be most concerned with that. If I were a farmer, i would be most concerned about drought and stress on my crops and livestock. There are many very important dimensions to the climate change challenges.

3) I really don't have an answer for this. i guess what would be necessary would be statistics on how GHG and certain health effects correlate, but there would be so many other factors, that isolating the direct cause and effect would be extremely difficult, if not impossible.

4) My research is in glaciers, ice sheets, and sea level rise, so from the time I started in this field, 20+ years ago, understanding how glaciers contribute to sea level rise was one selling point for my research. When one is seeking funding from an agency with a specific mission, one always has to make the link between the research proposed and the mission of the agency in order to convey the

value to that agency as it invests limited resources. that is a little different than latching on to climate change as a selling point. Also, however, it is important that people understand that knowledge for knowledge's sake, and the pursuit of knowledge is in and of itself valuable, and important for society. Increasingly there has been pressure to have a "hook" for the value of your research, but there is a beauty and importance in just trying to understand. Often these lead to societally relevant outcomes, but they need not always do so.

Is the option of putting particles into the atmosphere that will reflect sunlight back into space actually a possibility?

mcgillycuddy412
From Waleed: Yes, it is a possibility. We have seen from past volcanic eruptions that the Earth's temperature goes down when the stratosphere is full of light-blocking particles, and it is possible for humans to deploy enough particles to lower temperatures. There are two MAJOR issues associated with our doing that. The first is that we do not know what the side-effects would be (e.g. rain, drought, ecosystem damage, health effects, etc.), so we would be potential entering a situation in which the "cure" is worse than the disease. The second is that these effects are transient. If we were to put particles into the atmosphere to reflect sunlight, they would not stay there forever (volcanic material from past eruptions has largely been gone in about a year or 18 months). After that, the climate will return to the state it would have been in without the intervention, and do so more rapidly. This means that once we start this approach, we are committed to it for the long haul.

Isn't it too late to address climate change to avoid consequences for human life on Earth? I remember being told by a climatologist friend 20 years ago that the point of no return was sometime around the early 2000's, and after that, we were pretty much condemned to melted ice caps, increasing sea levels, and lower salinity in the oceans with whatever damage to human life that may bring.

philips_66
From Waleed: it is too late to avoid some significant climate change. The die has been cast on that. As we look to the future, however, there is a range of possibilities out there. The more we continue to stress the climate system, the more we nudge ourselves in the direction of a future with greater negative consequences. So yes, climate change is with us, and there is a pressing need to adapt, but it could get a lot worse, or a little worse. The steps we take now, will help determine how bad - or not - that future will be.

Hi guys, and welcome to /r/science.

Waleed, what do you think is the biggest data source that's lacking with regard to monitoring of glaciers and ice sheets? Also, if you could design an instrument to go into orbit to aid your research, what features would it have and what would be the most exciting thing you could do with it?

Scott, do you think that a certain degree of geoengineering is now vital to limiting global warming to 2C? Additionally, given current technologies, what is the least risky and most beneficial geoengineering approach we could take today?

Cheers

IceBean
From Waleed: We have some key observations that have been made: Ice sheet elevation change, thickness, velocities, etc. however, interpreting them still requires better bed information, and information on snow density, as well as what is happening at the ice water interface where the glacier

tongues reach the sea. Research is being done in all of these areas, and remarkable progress has been made. If i were to launch my ideal instrument, it would measure - for all the world's glaciers and ice sheets - elevation, elevation change, flow speeds, thickness, bed conditions (wet vs. dry), and snow density, and i would fly a series of these for at least 15 years. We have all of these capabilities today but not all are doable from space, and to really address the challenge would require a sustained approach.

How do you see the future of transportation in the next 20 years?

What are some low-cost initiatives we can take to pave the way for these changes?

Merrcury_Staff
From Scott: transportation engineering is a bit outside my area of expertise; you may want to take a look at some of the larger groups tackling energy problems such as the MIT Energy Initiative: http://mitei.mit.edu/research and the Stanford Precourt Institute for Energy: https://energy.stanford.edu/ Not focused solely on transportation, but could be helpful.

If we stop all carbon emissions now, to what changes to climate have we already committed?

Given RCP8.5, how much carbon do we need to sequester annually to net 0 carbon output?

How do you feel about cloud brightening?

b-n4rd
Several modeling studies have looked at the consequences of a hypothetical case where we were able to stop all human carbon emissions instantaneously. Atmospheric CO2 will gradually decline (more quickly over the first couple of decades and then much slower over the following centuries); global surface temperature tends to continue to rise for a couple of decades and then stabilize (a combination of the fact that the present-day climate is not in equilibrium with the rapid, transient rise in atmospheric CO2 and the gradual decline in atmospheric CO2); the ocean continues to warm over time leading to sea-level rise over many decades; land ice continues to melt.

With regards to the second question, the RCP8.5 scenario has CO2 emissions increasing from present-day levels roughly 10 billion tons carbon per year to close to 30 billion tons carbon per year by the end of the 21st century. Some modeling studies suggest one would need to remove 80-90% of human emissions to stabilize atmospheric CO2 at any particular level (the natural sinks remove the remainder). Although a few years old, you may want to take a look at an NRC report on Climate Stabilization Targets: http://www.nap.edu/catalog/12877/climate-stabilization-targets-emissions-concentrations-and-impacts-over-decades-to

Is iron-fertilization of the ocean still considered a viable sequestration method? To the extant that it even works, ocean sequestration only serves to increase the rate of acidification of the oceans so I don't understand why it's still being discussed.

sverdrupian
From Scott: As you note, deliberate iron fertilization has been proposed as as a carbon dioxide removal and sequestration approach but has number of potential drawbacks with efficacy, monitoring requirements, scalability, and environmental impacts topping the list. We go into detail in the actual NRC report, and in terms of a comparison with other possible carbon dioxide removal approaches, we did not rank iron fertilization that high. With respect to ocean acidification, the surface and upper ocean will continue to acidify as long as atmospheric CO2 continues to rise. The mid-depth and deep ocean will acidify over longer time-scales (decades to centuries). The goal of iron fertilization is to use biology to strip carbon dioxide from the surface ocean and deposit it in the deep ocean. In that sense the

technique could partially limit acidification in some parts of the surface ocean but at the expense of accelerating acidification in the deep ocean. I don't think that is most important factor for or against acidification; fertilization is not likely our best approach to the problem irregardless. Also keep in mind that if we don't do anything, the ocean will soak up the majority of human CO2 emissions.

People hearing "the temperature will go up two degrees" don't know or understand what that means. Or, rather, they know exactly what two degrees warmer means to them and it's no big deal. So they can't relate to any consequence of climate change and hence don't react like it's a big deal.

What are some plausible scenarios for how climate change might impact people's daily life in 15 years? 30 years?

Paint us a picture we can have an emotional reaction to.

jplindstrom
From Waleed: You are right that a couple of degrees doesn't sound like a lot to most people. By the way, it is 2 degrees celsius, so to most people it would be closer to 3.5 or 4 degrees Fahrenheit However, human civilization has evolved under temperature characteristics that have not wavered much outside of about a degree celsius, so two degrees takes us to a place we don't have experience with. At these temperature increases the Arctic Ocean will very likely be ice free in the Summer, which is something human civilization has never experienced before and constitutes a major perturbation to the planet's climate. So while 2C may not sound like much, it will take human civilization into very unfamiliar territory. Some scenarios that will effect people are: continued sea level rise, with coastal communities becoming more and more inundated with storms; ecosystem shifts, in which plants/crops that could thrive in one location may be challenged and not as healthy (think of the farmers and the prices of farm products at the grocery store); increased drought (water restrictions in California are very real and personally felt today); increased fire hazards; increased flooding from more intense rainfall and dryer soils, etc. Also, warmer temperatures have been shown to significantly increase health risks (see: http://nca2014.globalchange.gov/report/sectors/human-health). There are others associated with potential changes in ocean and atmospheric circulation, but these are some key ones.

Just wanted to say that I appreciate what you do. Really good job guys.

JSKim
Thank you. We appreciate your interest in the subject.

"Cloud reflectivity modification" also known as "cloud brightening": 1-Have you heard about it? 2-Does it work? 3-Is it a potential solution to global warming?

-Tim-maC-
From Waleed: The committee that Scott and i were on discuss this quite a bit in the Climate Intervention Report (https://nas-sites.org/americasclimatechoices/other-reports-on-climate-change/2015-2/climate-intervention-reports/). It does work in terms of reflecting sunlight to cool the Earth in the areas in which the clouds are brightened. however, as a solution to global warming, there are too many unknowns associated with it, and the scale on which it works is limited. For example, we don't know what the implications for precipitation would be, if we were to brighten the clouds be seeding them, so they would become thicker and whiter. Our recommendation in the report was that albedo modification should not be deployed at this time. We just don't know about the ancillary effects.

I have heard of an idea on recent TED talks that spoke of administering sulfuric acid into the atmosphere to counter rising global temperatures. They used volcanoes as an example of

sulfuric acid being introduced naturally, reflecting solar energy away from the planet. Is this a viable tool to combat rising temperature or more of a pipe dream?

chimpleton
From Waleed: See response above to mcgillicuddy412. however, note that sulphuric acid is not what is put into the atmosphere. Rather it would be sulphur dioxide. While sulphuric acid is a common byproduct of that, it is not what would be injected.

Hi Dr. Doney,

Just wondering if you'd had a chance to read this paper, and if so, what your thoughts on it are:

Mathesius et al. 2015: Long-term response of oceans to CO2 removal from the atmosphere

BTW- We recently did an AMA on correcting a bias in model-obs comparisons for the surface temperature record, and geoengineering seemed to be quite a popular topic. So I think this AMA is needed and will be much appreciated.

past_is_future
From Scott: Thanks for the link to your recent paper; I have not read it in detail but I did just skim the abstract. Your modeling study found that even with relatively aggressive carbon dioxide removal strategies, "past CO2 emissions would leave a substantial legacy in the marine environments" (such as reduced pH, warming, and lower dissolved oxygen). Your results highlight the fact that we are already seeing from ocean observations substantial changes in the ocean caused by rising atmospheric CO2 and associated ocean acidification and climate change. That said, we need to work to reduce future emissions if we want to limit the magnitude of the impact in the future, and it is possible that carbon dioxide removal may fit into a portfolio of approaches for carbon and climate change mitigation.

Hi Dr. Doney, welcome to Reddit and thanks for coming to answer our questions today.

Why is it that all the current methods for addressing climate change seem to concentrate on keeping more greenhouse gasses from entering our atmosphere rather than deploying methods to remedy the damage already incurred?

Thanks again for coming to answer our questions today and for your continued work on behalf of our planet. Hmmm.

CompMolNeuro
From Scott: Actually most groups argue that we need efforts in both mitigation (addressing the underlying causes of climate change, for example by decreasing future carbon dioxide emissions or actively removing excess carbon dioxide from the atmosphere) and adaptation (limiting the negative impact of climate change). The two really go hand in hand. There is a nice discussion on these two topics in the 2014 National Climate Assessment: Mitigation Chapter: http://nca2014.globalchange.gov/report/response-strategies/mitigation Adaptation Chapter: http://nca2014.globalchange.gov/report/response-strategies/adaptation

Hi Scott! Hi Waleed! Thank you both for making time to be with us here today.

If you had the opportunity to speak to climate change deniers directly, but only had 30 seconds to convince them of your findings, what would you say?

challenge4
From Waleed: If someone is denying the science of climate change, i don't think a 30-second response would be of much use. I would probably use the 30 seconds to ask for a longer conversation. I would

concede that it is complicated, and that the challenge of climate change should not be limited to "It's bad and we've got to do something" but rather should consider the human, economic, social, AND physical dimensions of our changing environment. Solutions will only come from thoughtful consideration of all of those dimensions. Often where skeptics and I disagree is not on the fundamentals, but on how to weight each of those dimensions.

Morality aside, is diversion of crops and cropland to biofuel, since it reduces overall food supply to humans, a highly effective way to reduce greenhouse gas emissions considering its potential to reduce human population growth?

4ray
From Scott: Agricultural-based carbon dioxide removal methods (e.g. bioenergy-carbon capture & sequestration) do run up against the issue of competition for land (and water, possibly fertilizer, etc.). Similar problems arise when considering some types of biofuels (bioenergy), which have been suggested as part of a portfolio of climate mitigation approaches (along with other renewables, energy efficiency, etc.). One way to minimize direct land competition between food production and either bioenergy or bioenergy-carbon capture & sequestration is to grow crops on marginal lands less suited for food production. Some approaches have been suggested, for example, using switch grasses on land less suitable for crops. Nevertheless, as you identify land competition is a serious issue and in many climate-energy-carbon-economic models, the use of a bioenergy approach drives up the price of food.

Have you seen the Arctic Sea Ice Volume observations vs IPCC projections graphs? If the graphs I've seen are true we are losing the Arctic Sea Ice during summer much sooner than the IPCC projects. In my opinion losing the arctic so early means that the IPCC is catastrophically wrong and we will have abrupt climate change.

When was the last time the arctic had an ice free summer?

Why do you think the IPCC missed the target by so much?

Do you think we can deploy technology in less than 5 years to somehow mitigate the loss of Arctic Sea Ice in earths temperature?

Thank you for what you do.

Archimid
From Waleed: Yes, i am familiar with the projection graphs. The fact that reality has shown a more severe decline than our model projections is, of course, concerning, but it is important to keep in mind 2 things. First, the IPCC estimates reflect the current state of knowledge based on continually evolving models. These models capture complex physical processes, and do a pretty good job of it. Second, the models are estimates, with probabilities associated with them, and the fact that the reality is different from what has been projected, doesn't mean the models are wrong or bad, but that within the range a probabilities these models suggest, and the reality falls at the edges (tails of the distribution), meaning the models found these outcome as unlikely, but not impossible.

We don't know quite when the Arctic was last ice free, but it has not been during the period of modern human civilization, so this is new territory for us.

So if we're shelving albedo modification for now, and the industrial-needed scale of carbon removal from the atmosphere makes it seem prohibitive as well.. what's the best way forward considering we've already put too much carbon out and simply scaling back, while needed, won't be enough to undo the anthropological nature of climate change? What are the options

for human intervention?

ReisGuy
From Scott: The answer may not be very satisfying but this is a hard problem to tackle, and it has taken us many decades (actually almost a couple of centuries) to get us in the current situation, and there is no easy or quick solution. The best approach will be to 1) limit as best as we can further emissions of carbon dioxide and other greenhouse gases in order to minimize a growing climate change problem; 2) develop better strategies to adapt to the amount of climate change that is already here (and the additional amount we are committed to from current elevated atmospheric CO2 and greenhouse gases). No single approach will work for either mitigation or adaptation, and we need to pursue multiple paths, requiring investment in R&D, field testing, implementation, and monitoring to determine what are the most successful strategies.

what do you think about the natural cycles of climate change discovered by Milutin Milankovitch (https://en.wikipedia.org/wiki/Milankovitch_cycles), is there any new data confirming his theories? Could the human impact start some kind of a cascade reaction disrupting all the cycles?

Crossover_Pachytene
From Waleed: The Milankovitch cycles are well understood and their impacts on climate in the past are clear in the record. The eccentricity (ellipticity) of the Earth's orbit, the changing tilt of the Earth's axis and the precession of the axis occur on time scales of tens of thousands to 100,000 years, and have led to ice ages and warm periods. I don't think of the human impact as triggering a cascade of Milankovitch-like cycles, but rather as having impacts on par with those cycles. the temperature effects from the Earth changing the shape of its orbit or the nature of its tilt have dramatically changed climate in the past, long before the human presence. it is unclear what similar scales of disruption to our planet will do today, but as one example, there have been times in our planet's past in which sea levels have been several meters higher than today (when temperatures were about as warm as where we seem to be heading). I am not saying that this is what we can expect in the next century (thought it is not out of the question), but we are applying forcings to our climate in ways that are comparable to past Milankovitch cycles.

Livestock and their byproducts account for at least 32,000 million tons of carbon dioxide (CO2) per year,

51% of all worldwide greenhouse gas emissions.

What are your thoughts on these statistics and the others listed in the link below.

http://www.cowspiracy.com/facts/

Cowspiracy is a documentary highlighting the massive environmental problem animal agriculture is.

It seem a big part of the solution , is to provide plant-based food for all communities in a efficient manner and stop subsidizing factory farming, and create jobs growing food everywhere possible. Plant trees where crops are now subsidized to be grown to feed these farmed animals. Restore our planet back to its natural state because the balance is lost due to humanities selfish and barbaric behavior. We are not living within the laws of nature. Consuming flesh, stealing milk from babies, caging animals etc , is barbaric, subsidizing it is insane. Our reliance on animals as food needs to stop and a massive movement to grow plants within the laws of nature needs to happen now. Are you aware of the massive environmental problem Animal Agriculture is and the effect it is having?

thetimeisnow

From Scott: As you point out, carbon dioxide is not the only heat-trapping or greenhouse gas that can effect climate. Methane and nitrous oxide are actually much more potent greenhouse gases than carbon dioxide on a molecule for molecule basis. Often methane and other greenhouse gases to equivalent tons of CO2 for direct comparison. The atmospheric increase in methane and nitrous oxide have been smaller than that of carbon dioxide in an absolute sense, and even accounting for there larger warming potential, carbon dioxide is still the dominant greenhouse gas. Because of the long lifetime of CO2 in the atmosphere, this will likely remain true in the future (or even become even more CO2 dominated). Agriculture is are most certainly a large contributor to human emissions of methane and nitrous oxide, though there are still many issues in closing the global budgets for those gases and understanding all of the process driving their increase over time. Agriculture also contributes to carbon dioxide emissions (usually from clearing land and loss of soil carbon) but is a much smaller contributor than fossil fuel emissions at present. and there NOAA has a nice website that track the trends in all of the major greenhouse gases and their impact on Earth's radiative forcing (it's the imbalance in radiative forcing between heating and cooling that causes net global warming): http://www.esrl.noaa.gov/gmd/aggi/aggi.html They come up with a single index for the total and the contributions from carbon dioxide.