

Climate-Change Challenge Today: Some Thoughts on Science & Policy  
(with good news and bad news on each)  
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On science, my topline:

GOOD NEWS

- Continuing observations & paleoclimatological analyses are clarifying what is extraordinary about current climate change.
- GCMs & integrated-assessment models are improving and shedding new light on challenges & options.

BAD NEWS

- Most of the new insights from additional observations, better GCMs, and new analyses indicate that the reality is worse rather than better than previously supposed.
- Runs of current integrated-assessment models under-score that any delay in implementing rapid & deep emissions-reductions worldwide will likely entrain an unmanageable degree of climate change.

A few, more detailed observations on the state of the science, under four headings: realities, likelihoods, downside dangers, remedies:

Realities

Notwithstanding uncertainties & areas of ignorance, on which today's presentations appropriately focused because that's what interests scientists, there is much in climate science that is settled beyond reasonable doubt. I would summarize this settled climate science as follows.

1<sup>st</sup>, climate is changing at a pace and in a pattern not explainable by the quite well understood natural forcings.

2<sup>nd</sup>, the pace and pattern are well explained as the expected consequences of changes in atmospheric composition brought about by human activities, most importantly combustion and land-use change. In other words, human activities are the dominant cause of what we've been observing in the way of changes in global climate.

- I've found it helpful, in explaining our confidence in this conclusion to laypeople, to note that the world was rather steadily cooling for the 6500 or so years leading up to the Industrial Revolution, when the trend sharply reversed.

3<sup>rd</sup>, the observed changes in climate are already causing harm to human life, health, property, economies, and ecosystems, with more extreme heat, more torrential downpours, more destructive wildfires, more of the most powerful storms, rising sea level, worse smog, and growing impacts on ecosystem dynamics (including those governing pests and pathogens).

- The debate about whether it is possible to avoid “dangerous anthropogenic interference in the climate system”, as called for in the UN Framework Convention on Climate Change, should be over. We are already experiencing “dangerous” by any reasonable definition.
- A closely related point is that 2°C, the internationally agreed upon level of T increase above the pre-industrial value the world should aim not to exceed, is not “safe”. It cannot be safe if we are already experiencing danger at 1°C. The 2° figure is merely a round number on which many experts reached consensus, in the early 2000s, as the best the world could plausibly do.

4<sup>th</sup>, human-caused changes in climate—and the harm resulting from them—will continue to grow for decades, and in some respects for centuries and millennia, no matter what humans do going forward to reduce their emissions, because of the very long atmospheric lifetime of CO<sub>2</sub>, the long time for the ocean to reach equilibrium with altered radiation flow in the atmosphere, and the even longer time for the great land ice sheets to come to equilibrium with changes in the ocean-atmosphere system.

But, 5<sup>th</sup>, the harm to be expected will nonetheless be much smaller if countries around the world achieve rapid and deep reductions in their emissions than if they don't.

So much for realities; let me turn to...

### Likelihoods

I begin this subtopic with the disclaimer that has been variously attributed to Enrico Fermi and Yogi Berra, namely that “Predictions are difficult, particularly about the future.”

The first likelihood I want to assert is that the incidence of extreme heat will likely be the most rapidly growing of the conspicuously dangerous impacts of climate change in the decades immediately ahead.

- This trend, already well underway, arises from the elementary statistical proposition that sliding a normal probability distribution of temperature to the right a little bit, associated with a modest increase in the mean, produces

a very large increase in the probabilities of what were previously 3-sigma or 4-sigma high-T events.

- A real-world example may be helpful. Many of you will recall the 2003 heat wave in southern Europe, which affected parts of Spain, Italy, and France and was blamed for between 35,000 and 70,000 premature deaths. Analyses have indicated that this was a 1-in-200-year event before humans started to increase the global-average surface temperature and was a 1-in-100-year event by the early 2000s, when it occurred, but would be a 1-in-2 year event by 2040 and would constitute an unusually cool summer by 2070.

A 2nd likelihood of concern: We are likely to see a continuing increase in the fraction of precipitation falling in extreme downpours and the amount of precipitation falling in the most extreme ones, in many cases with associated flooding events and landslides., as well as greater water losses to flood runoff. (To zeroth order, the physics of this phenomenon is pretty straightforward—a warmer atmosphere can hold more moisture, and if more moisture is there at one time, more can fall more or less at one time.)

My 3rd point in this category is that a continuing increase in extent and intensity of wildfires is also likely—a result of the combination of heat, drought, and dead trees—with associated property damage, air pollution, and GHG emissions. This trend is already quite clear in many regions, but perhaps most importantly in the Arctic, which is warming 2 or more times faster than most of the rest of the world and where, for the first time in modern times, even the tundra is burning.

The 4<sup>th</sup> likelihood I want to mention is the one persuasive covered by Gabe Vecchi this morning, namely that we are likely to see a significant increase in the number of tropical cyclones in categories 3, 4, and 5 and, even more seriously, the number of these making landfall, including all up and down the U.S. East Coast.

- My own view, based on more preliminary evidence of an increase in U.S. conditions conducive to severe thunderstorms, is that we will likely eventually document increases in both severe thunderstorms and tornadoes in this country.

My 5th likelihood relates to the fate of the world's tropical coral reefs, which are at risk both from ocean warming and from acidification (as well as from dynamiting, cruise-ship anchoring, and some other stresses). My reading of the published evidence is that there's a better than even chance that we'll have killed off most of the world's tropical coral reefs by the time the global average surface temperature reaches 1.5°C.

- These reefs, by the way, house the second largest reservoir of biodiversity on the planet, after the tropical forests. It is a sad irony of the climate-

change challenge that these two ecosystems are both, for different reasons, particularly endangered.

As my 6th and last point on likelihoods, I will assert that global-average sea-level rise in the rest of this century is more likely to be near the high end of the range of recent projections than near the low end—that is, 1-2 meters, rather than less. (Rob Socolow mentioned this morning recent evidence that 2 meters is possible, but I note that NOAA in a 2012 report had already included 2 meters as the high end of its sea-level-increase projections for 2100.)

I turn next, very briefly, to...

### Downside Dangers

Let me offer a short list of so-called “tipping points”, where the state of the science doesn’t yet permit assigning a probability with any confidence, but which I fear are all too possible.

1<sup>st</sup> is massive CH<sub>4</sub> & CO<sub>2</sub> release from the warming Arctic. (As many of you know, there is 2-3 times as much carbon in the northern permafrost alone as is currently in the atmosphere, and there is growing evidence that much of what is coming out as the permafrost thaws is coming out as methane.)

2<sup>nd</sup> is greatly accelerated sea-level rise from rapid disintegration of Greenland and Antarctic ice sheets. Understanding of the mechanisms by which this could happen is improving, but is not yet adequate to predict how rapidly it could happen in the warming world we are moving into. But two things we have a pretty good handle on are:

- The ultimate, probably millennial scale increase in sea-level from the combination of thermal expansion and loss of land ice is probably around 2 meters per degree C of global-average warming;
- Twice in the last 20,000 years, in the course of naturally driven deglaciations, there were periods in which global-mean sea level increased at rates of 2-4 meters per century.

3<sup>rd</sup> is drastic changes in major atmospheric and/or oceanic circulation patterns affecting regional extreme temperatures, droughts, and agricultural production. Examples would be collapse of the Atlantic Meridional Overturning Circulation and changes in Northern Hemisphere midlatitude circulation associated with changes in the equator to pole temperature gradient and the behavior of the Polar Vortex.

4th on my list of downside dangers is widespread ocean food-web collapse from multiple stresses:  $\Delta T$ , acidification,  $O_2$  depletion, circulation changes, and overfishing, among other stresses.

Now, just a couple of comments about...

### Remedies

The challenges of remedial action in the form of rapid and steep emission reductions, coupled with finding ways to “recycle”  $CO_2$  and/or store carbon in biota, soils, and geologic formations, have been so well covered in today’s presentations that I hardly need to say more about it.

In the briefest terms, the potential is there, but much more technical work needs to be done to bring many of the most promising technologies to the point it would become attractive to deploy them. And at least as much progress needs to be made on the nontechnical determinants of large-scale deployment before the reductions needed over the remainder of this century if the world is not to careen through  $3^\circ C$ , never mind 2.

If mitigation is understood to mean steps taken to reduce the pace and ultimate magnitude of the changes in climate that occur, while adaptation means steps taken to reduce the damages from the changes that mitigation does not avoid, then geoengineering belongs with emissions reductions in the mitigation category.

We did not really discuss geoengineering here, but it pretty clearly is not close to ready for prime time. We need much more study of the potential leverage of specific geoengineering approaches, their costs, and their side effects ...

As for adaptation—often described as “adaptation, preparedness, and resilience”—this has become recognized over the past decade as more or less equal in importance to mitigation. Yes, we need enough mitigation to avoid an unmanageable degree of climate change; but we also need enough adaptation to manage effectively the changes in climate that mitigation does not avoid.

I think a major achievement of the Obama Administration in the climate space was to lift up the priority on adaptation, preparedness, and resilience to essential parity with mitigation, with the creation of an interagency Council on Climate Preparedness and Resilience; the State, Local, and Tribal Leaders Task Force; the development of new flood-risk standards and wildfire-management strategies; and a series of executive orders requiring that climate preparedness and resilience be

incorporated into the policies and programs, both domestic and international, of every Executive Branch department and agency.

Turning now to...

## POLICY

My topline good news and bad news points are

### GOOD NEWS

- Smart policies (assisted by technology & economics) have reduced (U.S.) or leveled off (global) emissions over the past several years.
- Obama-Xi leadership (Nov 2014) led to Paris success (Dec 2015) w ~200 countries committing to emissions reductions under nationally determined targets.

### BAD NEWS

- Meeting Paris commitments to 2025-2030 will be difficult; much deeper reductions thereafter needed for  $\Delta T < 2^\circ\text{C}$  will be more so.
- Trump wants to undo Obama policies, with potential adverse impact on U.S. emissions & maybe others'.

### President Trump's policies

- Drastic cuts in budget & authority for EPA
- Other cuts in climate-change monitoring & analysis
  - Zeroes Earth-observation functions of DISCOVER (NASA)
  - Zeroes OCO-3, PACE, and CLARREO missions (NASA)
  - Cuts ocean grants & programs by \$250M (NOAA)
- Drastic cuts in energy R&D at DOE
  - Zeroes ARPA-E
  - Cuts other energy R&D by \$2B
- Roll-back / “re-examination” of Obama climate EOs
  - Clean Power Plan, coal-plant NSPS, methane strategy
  - Social Cost of Carbon, NEPA need to consider climate change
  - Preparedness EOs: USA and international

### What should the climate-science community do?

- Keep doing our science, while looking for alternatives to government funding.
- Keep talking about the results and their implications

- Get better at explaining the science to laypeople, not just what we know, but...
  - How we know it
    - Diversity & robustness of reinforcing lines of evidence
    - Sources of credibility in science
  - The imprudence of ignoring it
    - Two-sidedness of uncertainties
    - Rarity of “revolutions” overturning scientific consensus
- Tithe 10% of our time to public & policy-maker education and policy/political activism

Thank you!