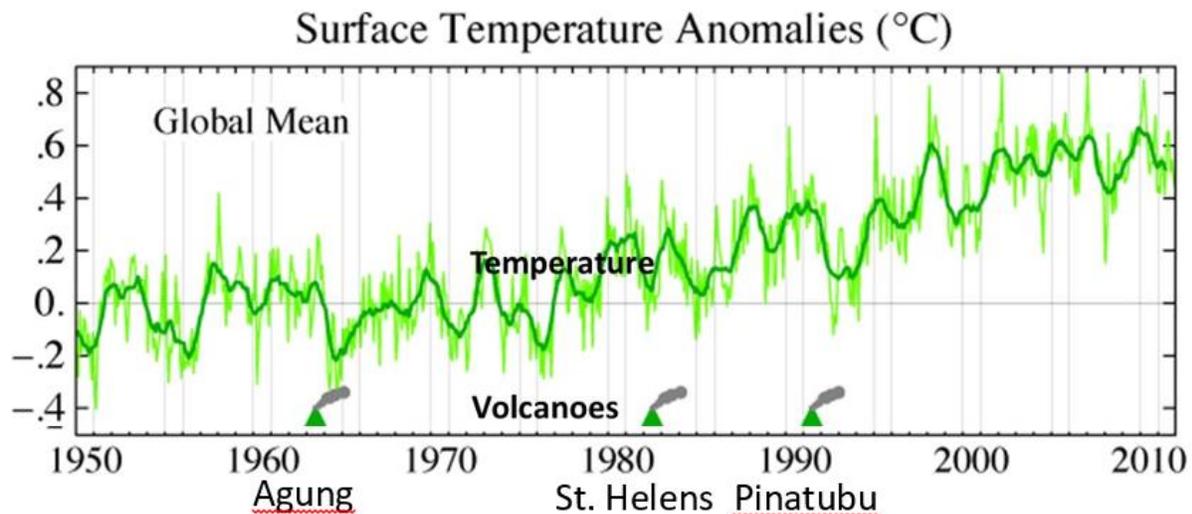


Thank you for your note. I will try to address your questions as best I can.

You are, of course, correct in noting that global climate has changed over the millennia, and some of the factors you identify are certainly responsible for some of these changes, so let's look at them:

i - volcanic activity.

When we look at how major volcanic events influence global temperature, we see the following

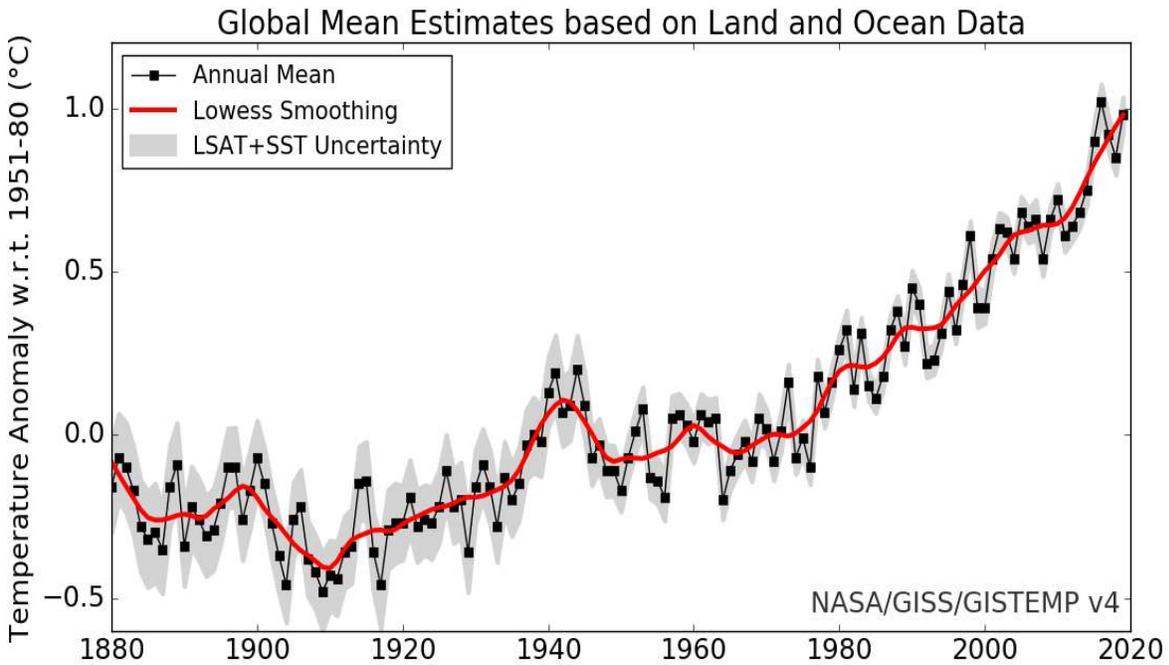


<https://www.carbonbrief.org/nasa-scientists-expect-record-breaking-warm-years-soon>

This reveals that volcanoes cause cooling rather than warming; a major volcanic eruption can cause global cooling that lasts a couple of years. This is because the carbon dioxide released is small relative to the emissions resulting from human activity. On average, volcanic emissions run at about 200 million tons of CO<sub>2</sub> while human induced emissions run at some 40 billion tons. Volcanic output is a drop in the bucket. Meanwhile, the major output from volcanoes affecting climate are the ash and liquid aerosol droplets that reach the upper atmosphere and reflect back outwards incoming solar radiation.

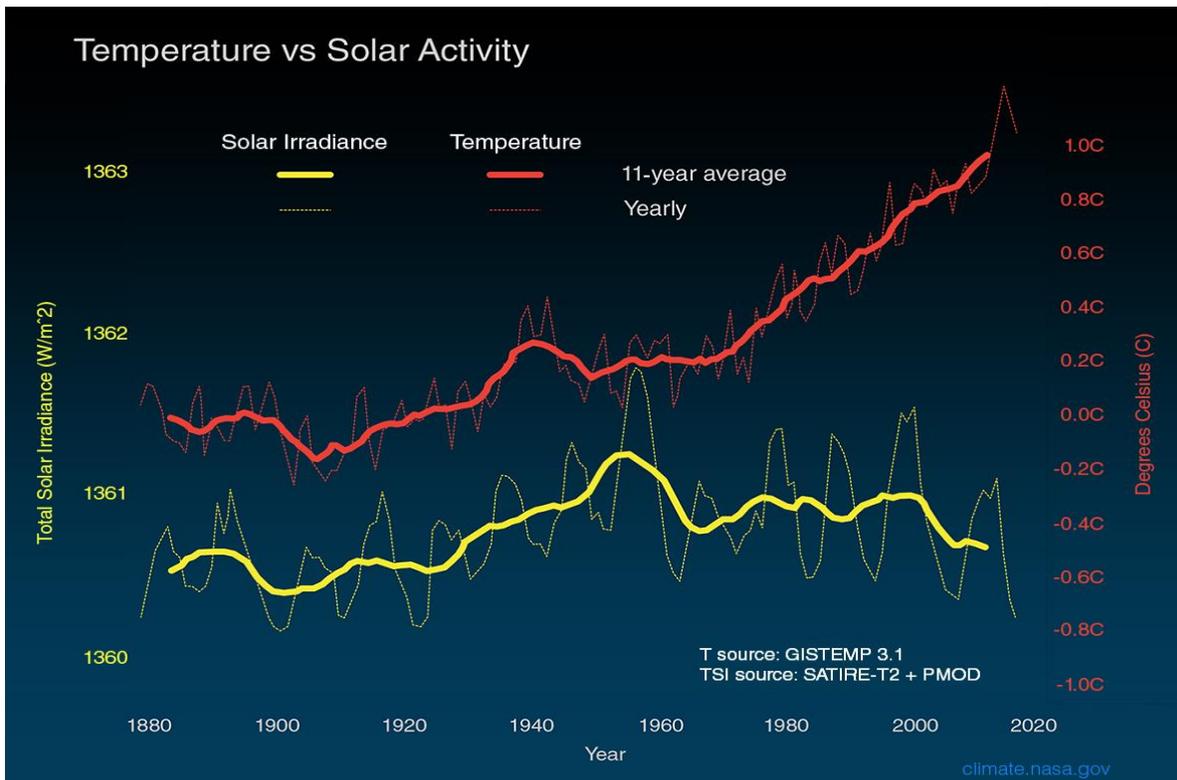
ii variations in solar activity

Since over 99% of the energy driving our planet comes from the sun, it is reasonable to wonder about this as a contributor to warming. However, when we can look at solar radiation trends during the latter decades of the last century, and the current period - which is when global warming has been most evident (see below)



<https://data.giss.nasa.gov/gistemp/graphs/>

If we then plot the temperature against incoming solar radiation, we see the following pattern:



From this, it is evident that as the global temperature has been increasing from mid-last century, solar radiation has been decreasing.

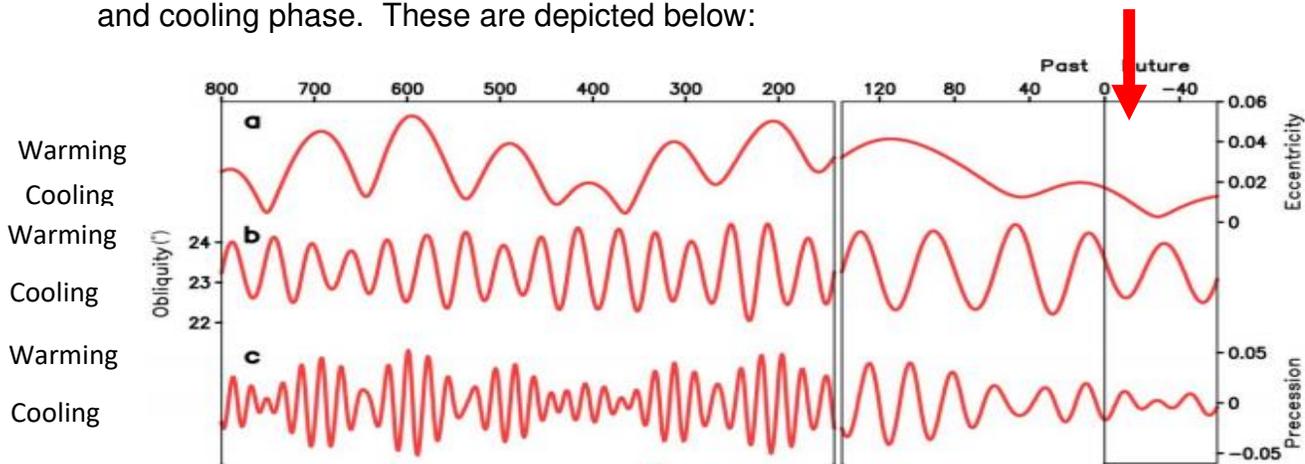
### iii naturally occurring wildfires and forest fires

Wildfires certainly result in greenhouse gas emissions - notably carbon dioxide. However, if we take Oregon as an example, we find that the carbon dioxide released by wildfires is actually much less than the carbon dioxide released by the natural cycle of death and decay of trees. In tropical regions, where a higher percentage of the carbon is locked up in the above-ground vegetation than is the case in temperate forests (where some 50% of carbon is locked up in soils which are largely untouched by all but the most extreme fires) fires may well release substantial carbon dioxide.

### iv natural climate cycles,

I infer that this means the natural cycles that have caused the glacial / inter-glacial cycles over the last two million years.

Fortunately, our understanding of the prime causes of these cycles improved much during the last century. These [patterns are now attributed to the Milankovitch cycle, which is actually a combination of three cycles: a 100,000 cycle in the shape of the earth's orbit around the sun - the 'eccentricity of the orbit,' a 40,000 year cycle in the tilt of the Earth, the 'obliquity of the ecliptic,' and a 20,000 year cycle as that the angle itself rotates, 'the precession of the equinoxes.' In turn, these three cycles have a warming and cooling phase. These are depicted below:



Note that the arrow identifies where we are now. What we can see is that currently we should be experiencing cooling. Interestingly, that the Milankovitch cycle offers a reasonable explanation of the glacial-inter-glacial sequences was only accepted in the 1960s / 70s. Although the atmospheric scientists were then abundantly reporting that we were on a warming trend, that we should be cooling started to gain media traction and was abundantly reported. This is the source

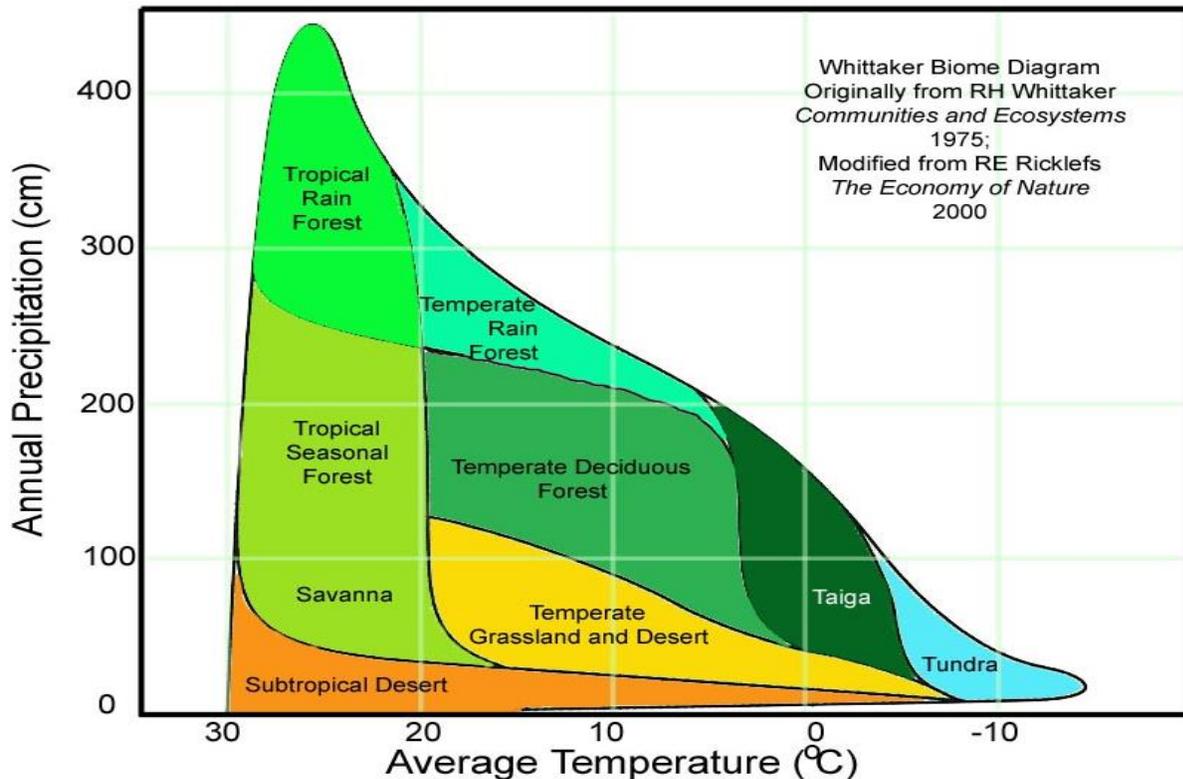
for the mistaken claim that 'they' told us back in the 70s we were cooling. Actually, 'they' didn't make any such claim; rather the science suggested we should be cooling - and this is where we are still today, despite the fact that the planet is warming.

1. What percentage of the change to the earth's climate is due to man-made carbon emissions? Is it 50%? 10%? 1%? 0.01%?

You may have been wondering why I expounded as above. The answer is that it helps answer this question. Since the natural factors that are known to have an impact on climate are reasonably well known, we can see that actually we should now be cooling (both solar radiation and Milankovitch suggest this). This leads to the rather counter-intuitive response that we are probably responsible for over 100% of the warming. This is because our emissions of greenhouse gases (carbon dioxide, methane, nitrous oxide and others) has first negated the cooling, and second, induced warming.

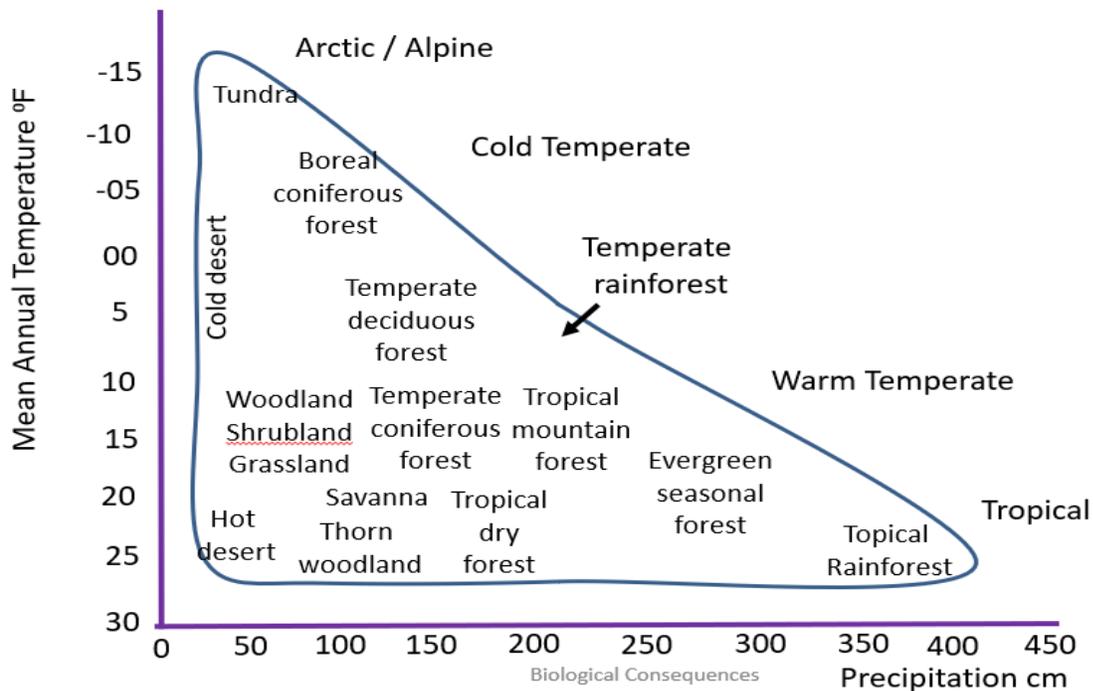
- 2. Is our current worldwide climate optimal?
- 3. Is any change to our climate necessarily a bad thing?

Of course, the concept of 'optimal' is loaded. I shall infer that you mean 'optimal for life as we know it.' as I tried to indicate in the column, this is what caused me initially to engage in an exploration of the climate science literature. As I was teaching community ecology, I used the following chart:



[http://www.marietta.edu/~biol/biomes/biome\\_main.htm](http://www.marietta.edu/~biol/biomes/biome_main.htm)

I modified and expanded this a little as below:



The message that this conveyed to me was that if global temperatures changes as the projections suggest they might absent substantial adjustments in our emissions behavior, the very existence of these natural systems on the planet will be threatened. While slow changes in climate allow natural systems to shift their range accordingly, the speed of current climate changes (compounded by our farming, forestry, and infrastructure blocking the route for potential range shift) is too great to allow range adjustment commensurate with climate change. This, clearly poses a massive threat to our global biodiversity. However, it also threatens our agriculture, forestry, and fisheries since these are dependent on the same climatic variables that are shifting in response to global warming caused by our greenhouse gas emissions.

4. If any climate change is bad, and the earth were in a natural cooling cycle, should we try to increase carbon emissions, if we thought it could reverse the trend?

I wouldn't suggest 'any climate change is bad' since, as you note, it is a natural component in the existence of life on our planet, and life can adapt to slow changes. The problem is simply the speed that we are imposing it. This is an interesting question. When we start exploring geoengineering management questions such as this, we probably confront our own hubris. Our current rate of emissions has over-compensated for the cooling trend, so if we increased emissions, the problem would be worse. Geoengineering schemes that either reduce incoming solar radiation by releasing aerosols in the upper atmosphere to mimic volcanoes has been suggested as have techniques for trapping the greenhouse gases (mainly carbon dioxide) from the atmosphere. Planting trees, and adjusting our agriculture to build up soil carbon rather than

volatilize it as industrial agriculture currently does, are two such ideas.

If we were to plan such an 'experiment,' what do we do if it seems to be 'going wrong?' And, just as some now refuse to accept that our greenhouse gas emissions are causing global warming and climate change, would those committed to the experiment (or benefitting financially from it) refuse to accept that it's 'going wrong?'

Another problem with any plan that allows continued or expanded carbon dioxide release (such as the solar radiation management scheme) is that the carbon dioxide increase in our atmosphere is absorbed into oceans and causes ocean acidification - which is already threatening our fisheries (especially crustaceans and mollusks).

The questions you raised are interesting in that the answers to them essentially ran me through the thinking and understanding that leads me to conclude that we desperately need legislation to restrict our greenhouse gas emissions and promote activities that extract them from the atmosphere. Oregon has had a voluntary program in place since 2007 but we are not on a trajectory to achieve the emissions reductions that program demands. We need more than a purely voluntary program.

To those who argue that Oregon's emissions are so small that we shouldn't do anything, I urge a more ethical and realistic approach. If we accept the danger posed by our emissions, we need to urge everyone across the globe to address the problem. But we will have no moral authority or credibility trying to do that unless we are doing it ourselves.