Climate Change Calculated 3

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Introduction

- In part 1 we saw that the CO2 concentration of the atmosphere has risen from an already high level of 280 ppm to currently 410 ppm due to the use of fossil energy.
- In part 2 we saw that the current CO2 concentration leads to a global temperature rise of 1 degree Celsius in 40 years.
- In the following I calculate that the current CO2 concentration causes the sea level to rise by about 8 mm per year,
- I show the sensitivity of global supply chains,
- and I calculate that as the South Pole melts, the sea level rises about 67 meters.
- If you are interested, stay tuned :-)

Question: What sea level rise can we expect?

- The sea level rise is caused by the heat expansion of the sea water and the melt water of the earth.
- For our calculation, for the sake of simplicity we focus on the **meltwater of Greenland and the Antarctic.**
- We must therefore keep in mind that the actual sea level increase might be higher.

- We can again take the radiative forcing of 2 W/m² to compute the melting of water.
- The **latent heat** of ice is: https://en.wikipedia.org/wiki/Properties_of_water For melting of 1 kg of ice we need the energy c_s = 333.5 * 10³ J / kg.
- The energy Joule (J) is identical to Watt seconds (Ws)
- By reformulating the units, we get the mass of molten water in kg per second for a power in Watt, **c_s = Ws / kg => kg/s = W / c_s**

- This formula calculates the **melt water in kg which flows in 1 second with a power in Watt**, assuming that the surface is about 0 degrees C.

- Since we have the energy per unit area from the radiative forcing, we need the **area of** the considered ice:
  https: //de.wikipedia.org/wiki/Eisschild
  The largest areas are:
  Antarctic: 14 million km²
  Greenland: 1.7 million km²
  Together **15.7 * 10⁶ km² = 15.7 * 10⁶ * 10⁶ = 15.7 * 10¹² m²**

- This gives us the incident power on the ice surfaces by the radiative forcing: Area times power per unit area (with Python notation):
  15.7 *10¹² m² *2 W/m² = 15.7e12 * 2W = 31.4e12W
- This power is now inserted into our formula:
  kg / s = W / c_s = 31.4 * 10¹² W / (333.5 * 10³ Ws/kg) = 31.4e12 / 333.5e3 kg/s
  =94.1529e6 kg/s
- This is the resulting **melting water** in **kg or liters per second**.

- For the melting water per year instead of a second we have to multiply it by the number of seconds per year:
  94.1529e6 kg/s * 60 * 60 * 24 * 365 s/year = 94.1529e6 * 60 * 60 * 24 * 365 kg/year
  = 2.969e15 kg/year = **2.969 * 10¹⁵ kg / year**
- We can convert this into a volume, with the density of water:

1 kg equals 1 cubic decimetre,
1 $dm^3 = 10^{-3} m^3$,
so **1 kg equals 10^{-3} m^3**

- Hence multiplication by 10^{-3} gives the volume in m^3 per Year:
  $2.969 * 10^{15}$ kg / year$*10^{-3} m^3/kg$= **$2.969 * 10^{12}$ m^3 / year**

- For the corresponding sea level rise, we now have to divide this volume by the area of the oceans.
- The surface of the earth and the oceans can be found here: https://de.wikipedia.org/wiki/Erdoberfl%C3%A4che: "Surface of 510 million km ², of which about 71% are covered by oceans."
- The area of the oceans is thus:
  $510 * 0.71 * 10^6$ km^2 = $362.1 * 10^6$ km^2 = 362.1e6 * 1e6 m^2 **= 362.1e12 m^2**

- The sea level rise is now our Volume divided by this surface area:
  $2.969 * 10^{12}$ m^3/year /(362.1e12 m^2) =
  =2.969e12 / 362.1e12 m/year
  = 0.0082 m/year = **8.2 mm/year**

- We get an increase of about **8 mm per year**.
- Comparison: https://de.wikipedia.org/wiki/Meeresspiegelanstieg_seit_1850

- And: https://datahub.io/core/sea-level-rise "Between 1901 and 2010, the sea level rose by 1.7 millimeters per year. From 1993 to 2010, the average was 3.2 mm per year. For the year 2018, the record of **3.7 millimeters per year was** measured. " So the speed of sea level rise has **doubled in the last 25 years** or so.
- So our rough estimate again fits pretty well.

Conclusion

- It is plausible that the rise in sea level is caused by the increased CO2 concentration.

Risk Analysis: Global Supply Chains

- As sea levels rise, floods are becoming more frequent and severe.
- One example is the floods in Thailand in 2011: https://en.wikipedia.org/wiki/2011_Thailand_floods
- There, e.g. computer hard disks are produced on a large scale.
- Consequence: "As a result, most hard disk drive prices almost doubled globally, which took approximately two years to recover."

Risk analysis: Sea level rise due to melting of the South Pole

- **Question**: How much will the sea level rise only by the melting of the South Pole, the largest piece?

- For this we need the volume of the ice of the South Pole, convert it into the volume of water, and divide it by the area of the oceans to get the resulting sea-level rise.
  https://de.wikipedia.org/wiki/Antarktischer_Eisschild

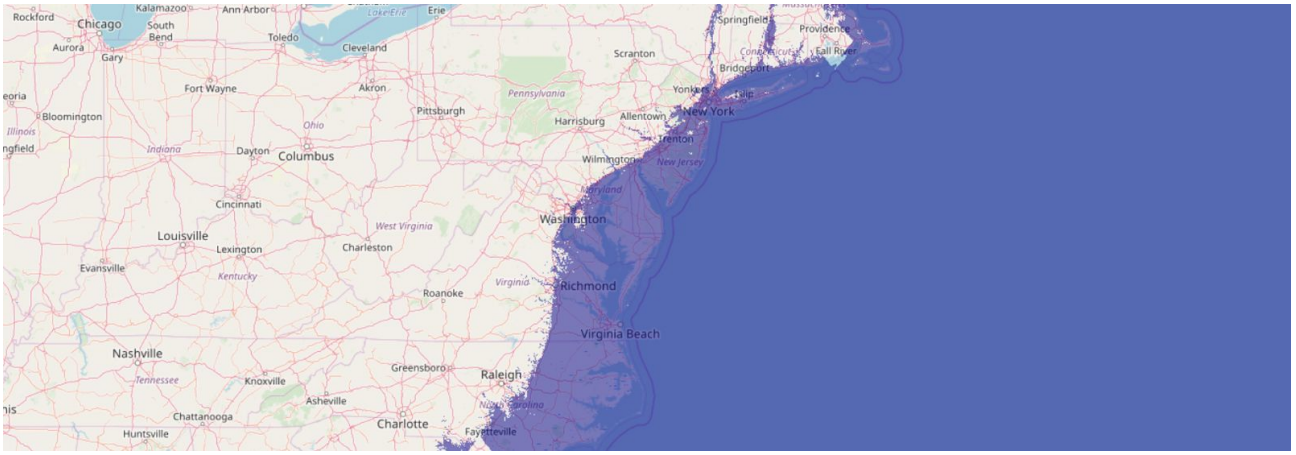
  The "ice volume estimated at 26.37 million cubic kilometers"

- Conversion of ice volume to water volume:
  https://de.wikipedia.org/wiki/Eis:
  "Its density of 0.918 g/cm³ (pure, air-free ice at 0 °C) is lower than that of water (1 g / cm³)", hence water has a lower volume by this factor.
- Ice of the Antarctic as water volume: 26.37 * 0.918 = **24.2 million cubic kilometers**
- Oceans surface again: 510 * 0.71 = 362.1 10^6 km^2
- The resulting sea-level rise is thus this volume divided by the area:
  24.2*10^6 km^3 / 362.1*10^6 km^2 = 0.0668 km**= 66.8m**

- With complete melting of the Antarctic alone, at the end we get a **sea level rise of almost 70m! (ca. 220 ft)**
- However, it is not clear how long it will take for a complete melting because meltwater flows have formed within and below the ice sheets recently, thereby significantly increasing the melting surface, further accelerating the melting. This is an ongoing research topic.
- Plus it depends on our **future CO2 emissions.**
- The **risk becomes clear**.

- The risk of a sea level rise of about 60 m can be seen when using a "Flood Map", which indicates the new shorelines: http://flood.firetree.net/
- One sees, for example: Major parts of the US east coast sinks completely into the ocean, including Boston, New York, and Washington!

Risk analysis: Sea level rise due to melting of the South Pole



Conclusions

- The risk of doing nothing becomes clear
- When the South Pole melts, the sea level rises by about 70m.
- It's flooding all the lower regions of the world. Including all coastal metropolitan areas
- From part 1 we know: in order not to further increase only the **current CO2 concentration** of the atmosphere, we would have to **reduce global CO2 emissions by 80%!**

What can we do about it?

- Fossil CO2 is in principle a problem of air pollution
- We've solved air pollution problems before:
  - In the **1980s** with the **catalytic converter** and unleaded gasoline, which successfully improved the air in cities and reduced dying forests.

    - In the 1990s with the **worldwide ban on CFCs** as coolants and propellants, and their replacement, which indeed reduced the hole in the ozone layer.
    - We must now come to the **worldwide ban on fossil energy**.
- This can only be **achieved politically**.
- There are plenty of **technical substitutes**.
- More about this in the **next video**.