Desalination of seawater by direct sunlight

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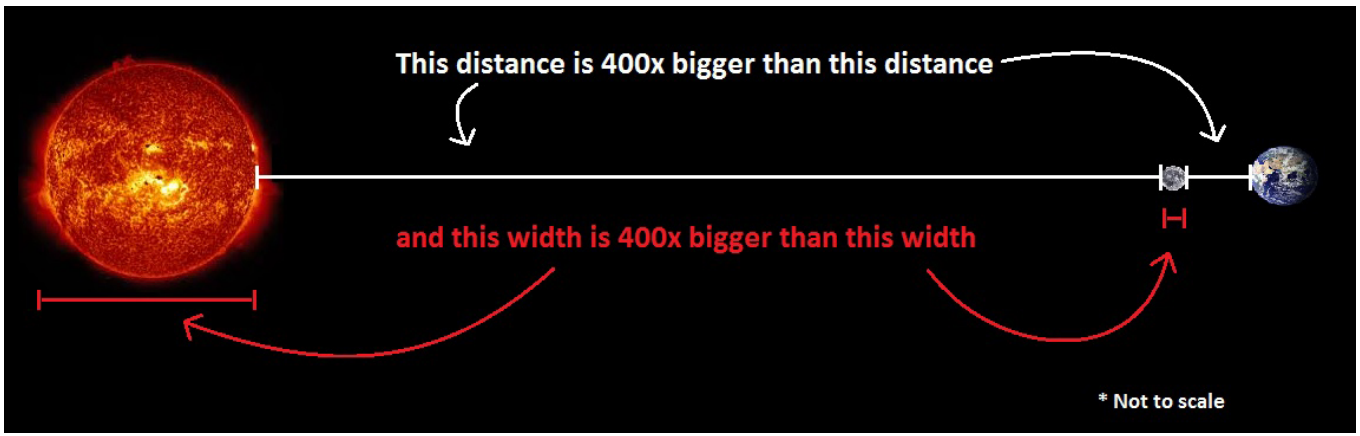
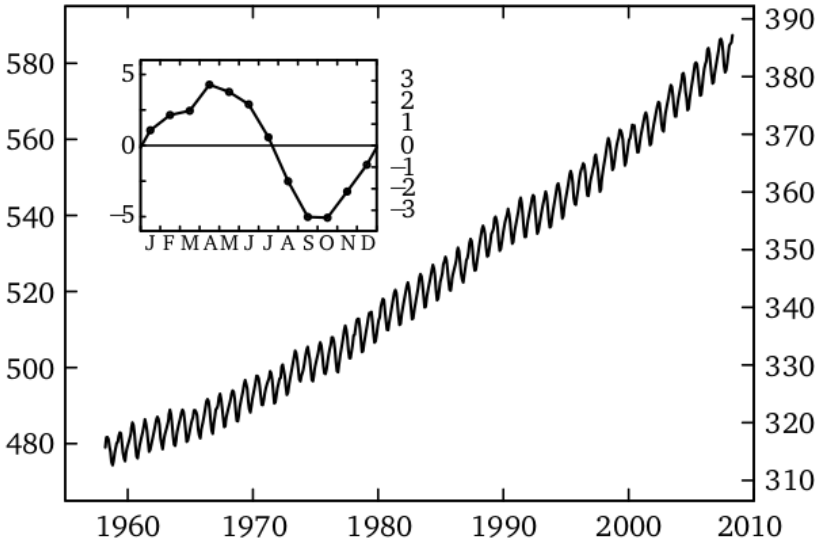
Problem statement

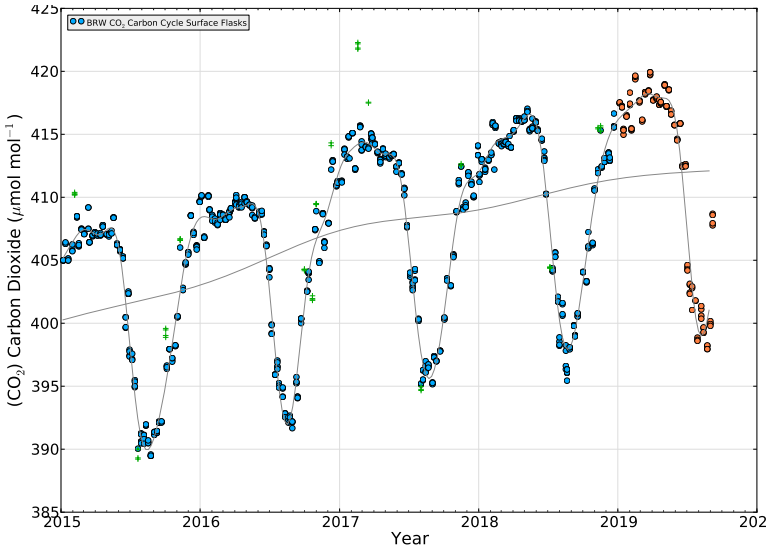
- Intro + Objectives
  - Global warming: What and Why
- Black–body radiation (better to think "microwave")
- Sun (T=7000°C) vs. 1.3 [kW/m^2] on Earth (**T=25°C**)



- Earth: More than @400 [ppm] of CO_2 tips the energy balance
- **Mars:** CO_2 (95%) and an ocean of H_2O a *billion* years ago
  Water on Mars today? Gone! **[Chang 2021]**

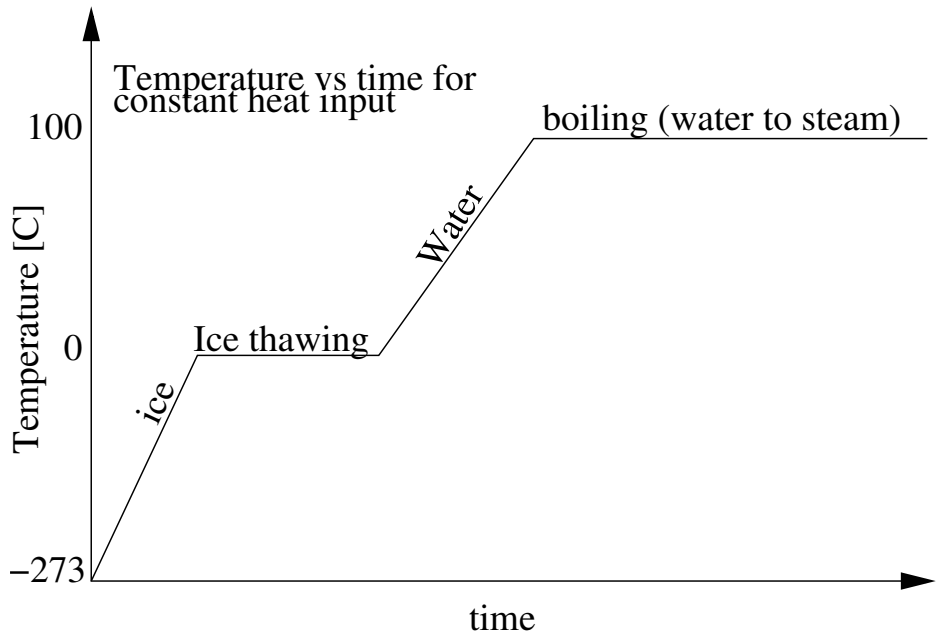
CO_2 levels since 1950 (60 and 5 years)





1. What is the source of climate change?
   - The CO_2 increases by 1.667 ppm each year?
   - It has increased 100 ppm in 60 years
   - The slope has increased to 2 ppm in the last 20 years
   - The CO_2 oscillate, decreasing in summer, increasing in winter.
2. CO_2 is the main source of "climate change"
3. $CO_2(H_2CO_3)$ accounts for the ($\uparrow$) ocean acidity (PH $\downarrow$)

States of water with a constant solar heat input Q_o



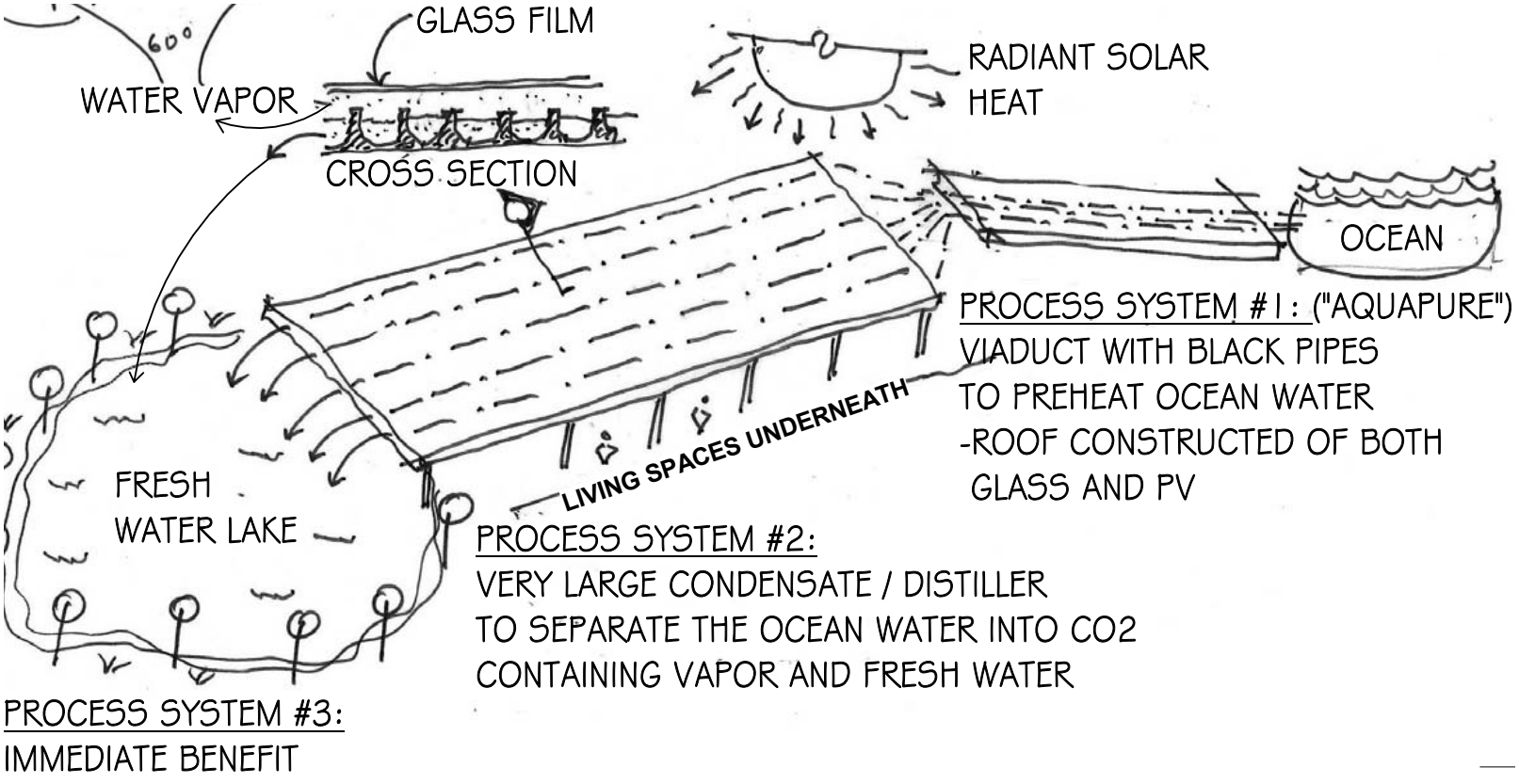
- For ice: $T(t) = c_p Q_o$ (T [°C], Q_o [heat energy input/sec])
- For thawing: $\Delta Q = L_o Q_0$ and $T = 0$ [°C] (is constant)
- Once all the ice is thawed, $T \uparrow$ & the water begins to evaporate
- When boiling, $T = 100$ [°C] (is constant)

How to proceed?

- " We don't have enought water?" We have the oceans!
- Massive desalination is needed
  1. Use solar warming to evaporate water ($T \uparrow$) and seawater's cold to condense the vapor ($T \downarrow$)
  2. This $\uparrow\downarrow$ cycle can produce huge amounts of water at low cost
  3. Goal: Sun as the energy source $\Rightarrow$ seawater $\rightarrow$ pure water
  4. But HOW???

Sunlight (solar radiant heat) to pure H_2O, direct

–The cold ocean water is pumped into the evaporation chamber.

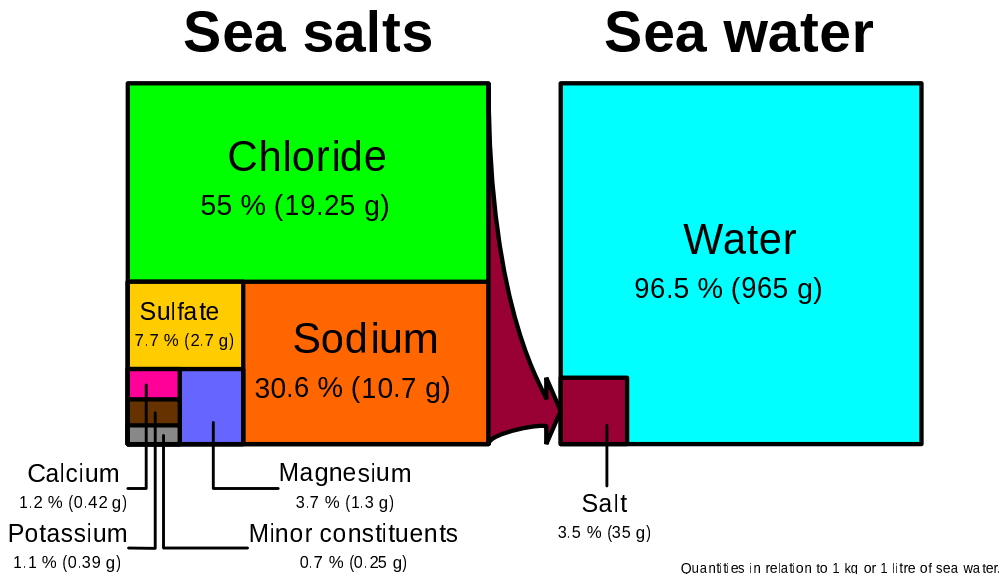


–The 60 [°C] vapor is *condensed* to 20 [°C], warming the seawater

–Explain how this works (Allen 2021) **[Video]**

Questions? (https://www.youtube.com/watch?v=009qvgRoiLo)

Composition of seawater



- The CO_2 is only 0.04%, which determines the PH, and the destruction of coral reefs (life in the ocean).
- Evaporation gives pure water, leaving the salt behind
- The water can be used to grow plants in the desert, which consumes the CO_2.
- You can't grow plants in salty seawater!!!

Massive desalination: How?

1. CO_2@415 [ppm] tips earth's delicate energy balance
2. We can use direct sunlight to heat & evaporate cold seawater.
3. How?
   - The sun heats the seawater to 5% vapor (dew-point 40 °C)
   - Water vapor is pure (0% salt)
   - The water vapor is then cooled using the cold (15 °C) seawater
   - Cooling the water vapor releases the vapor latent heat.
     This raise the water temperture further, increasing the yield!

   Condensation using cold seawater $\Rightarrow$ maximum yield!
4. $\underset{1\text{ kgm}}{\text{Seawater}} \underset{\text{sun}}{\rightarrow} \underset{H_2O}{\text{vapor}}\ (93\%) + \text{salt}\ (3.5\%) + H_2O\ (7\%)$
   - Seawater $\rightarrow$ pure water + brine (100% solar powered)
   - No inefficient solar panels (>77% $\approx$ 4/5 energy loss).
   - No power–hungry RO, or clogged membranes
   - ulta **GREEN**

The key question is the recovery of the latent heat

- The main question is: *How much of the heat of vaporization from the condensed vapor, may be recovered?*
  - First the sun heats the water to the dew-point $\Rightarrow$ 5% vapor
  - Vapor is cooled using the cold seawater (via a heat-exchanger), heating it even more than the daytime solar input.
  - Thus less sunlight is needed to reach T_{max} (40-60 [°C])
  -
  - Given a proper design, and assuming (e.g. 15 °C) inlet seawater (and -3.9 [°C] night air), the $T\uparrow,\downarrow$ efficiency could be >95%
  - The air temperature in the Sahara desert at night is below freezing, so the water vapor could be iced:

    "During the day, desert temperatures rise to an average of 38°C (a little over 100°F). At night, Sahara temperatures fall to an average of -3.9°C (about 25°F)"

Concept: Flow the vapor under the inlet seawater, exposing it to the inlet seawater (or night air), cooling (or iceing) the vapor, further heating the seawater.

History of the Railroad & Auto industries

- Who will pay for it?
- The billionaires (c1870) in the United States made their money on the railroads
- There was a huge need for inexpensive transportation
- Likewise, today there is a huge need for cheap clean water
- The water industry today and the transportation industry have a great deal in common.
- The is huge opportunity here: Clean water $\equiv$ "mega-bucks."
- A business model is need to proceed.

Questions? Comments? Thoughts?

Bibliography

Wang et al. 2019
Chang 2021
Allen 2020