SCIENCE HACK 2019 @ TUM – ALTAIR

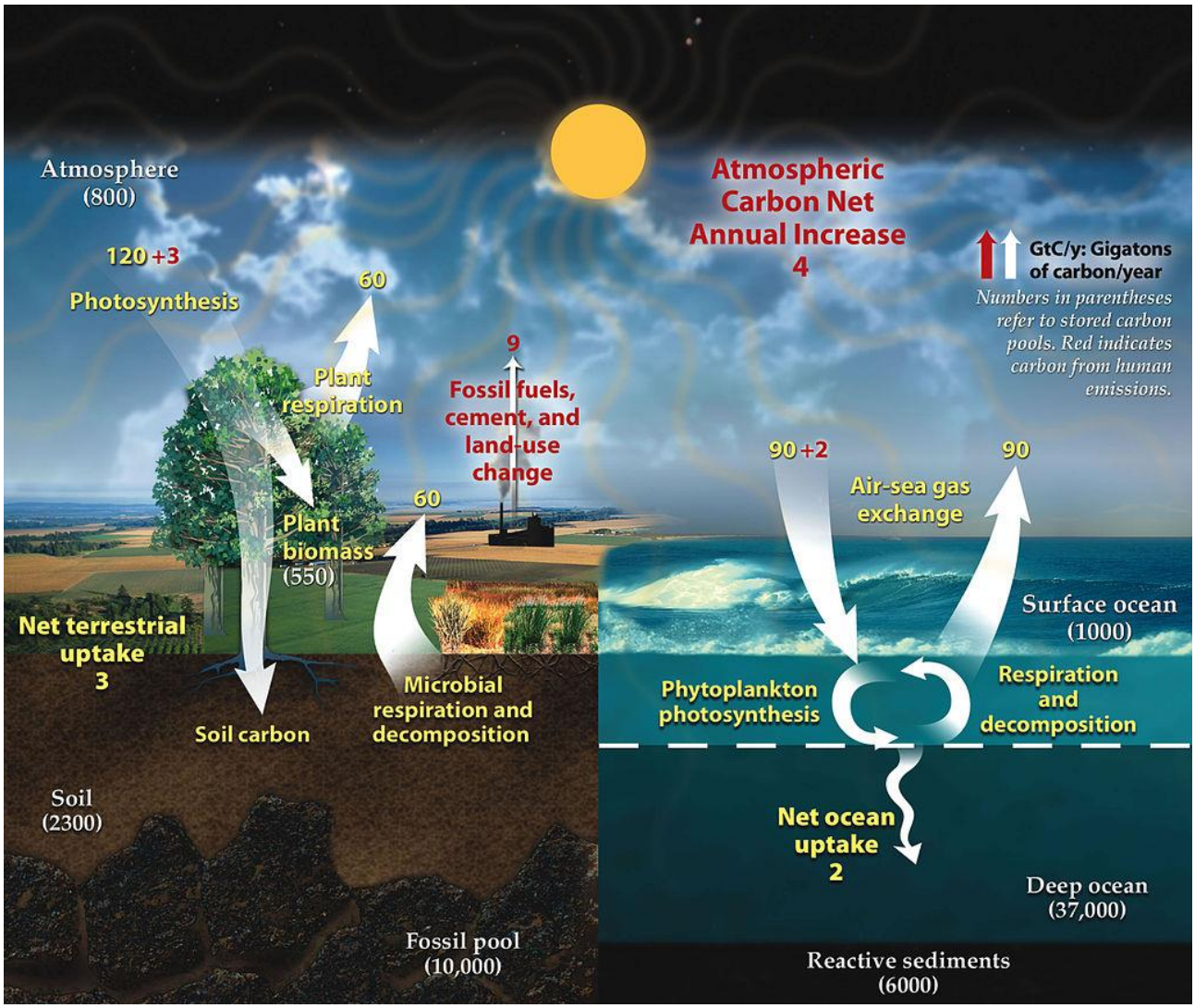
7th - 8th DECEMBER 2019

PREDICT GLOBAL WARMING WITH ALTAIR COMPOSE

Eighteen of the Nineteen warmest years have occurred since 2001, except for 1998. The year 2016 ranks as the warmest on record. It's well known that the C02 concentration in the air plays a big role in making our world warmer.

But where C02 comes from? Why is it increasing? Can we build models to quantify its average concentration?

Here you will find a snapshot of the annual Carbon Cycle:



We can see that the equilibrium condition (which was reigning in nature) has been broken by humankind (whose contributions can be seen in what is written in read), causing an annual net increase in Atmospheric Carbon.

Model

The proposed model connects the C02 emissions to the Global Average Temperature.

It can be set up in 5 steps.

1. CO2 emission – KAYA IDENTITY

The annual C02 emissions can be estimated by the following equation:

$$CO2_{human\ emission} = P * GDP * EI * CI$$

Where

- P is population.
- GDP is the GDP pro capita. It represents the welfare.
- EI is the energy intensity. It is a measure of economic structure and energy efficiency.
- CI is the carbon intensity. It represents the energy "cleanness". Solar energy it's cleaner than burning petrol.

2. CO2 Sinks – Airborne Factor

Luckily not all the C02 emitted remains in the Atmosphere. A great portion of that is sequestered by the nature (ocean, forest, soil, …). The Airborn Factor estimates the amount of CO2 which remains in the atmosphere:

$$\mathrm{C02}_{\text{emission to atmosphere}} = AF * \mathrm{C02}_{\text{human emission}}$$

In the last century the Airborne Factor has been roughly constant between 0.4 and 0.5.

3. Gtons to ppm

How are the CO2 emission connected to the CO2 concentration?

In order to convert from Gtons to ppm the following equation can be used:

$$\mathrm{C02\ [ppm]} = \frac{\mathrm{C02[Gtons]}}{7.81}$$

This means that if we are increasing the CO2 in the atmosphere by 7.81 Gtons, this will correspond to 1 ppm increase.

4. CO2 Adjustment Time – Exponential decay

If the CO2 emission will get null, the atmospheric CO2 will decrease over time in order to get to a new equilibrium point. This natural decay can be described defining the time constant τ of decay (which is estimated to be several hundreds of years). Translating into math:

$$CO2_{atmosphere\ PPM}[ii] = \left(CO2_{atmosphere\ PPM}[ii-1]\right)e^{-\tau} + CO2_{emission\ PPM}[ii]$$

Eventually more advanced decay model can be studied. Multiple constants of time (for example 3 or 4) can be defined with respect to different percentage of CO2 in the atmosphere.

5. Global Avg. Temperature Dependency on CO2

Once we know the CO2 concentration (in ppm) we can use this empirical formula to determine the new global average temperature:

$$T(ii) = T_0 + S\log_2\frac{CO2_{atmosphere\ PPM}[ii]}{CO2_0}$$

Where:

- T_0 is the reference temperature: 14.2 °C;
- $CO2_0$ is the reference C02 concentration: 326 ppm;
- S is the climate sensitivity factor: in the range 2 – 4.5 °C/ppm.

Validation

The model can be tuned and validated comparing the estimated global average temperature with the measured one.

Historical Data

All the data you need to build up and validate this model can be found in the Spreadsheet "ChallengeData.xlsx".

Model Results and Forecast

Once your model runs and has been validated, you can use it for do your forecast about Global Warming. For example, you can predict if we will be able to respect the "Paris 2015 Protocol":

> "keep the temperature below 2°C increase with respect to pre-industrial level by 2100."

The pre–industrial level means roughly 14 °C.

This part can be divided in 4 steps.

1) Given the forecasts for Kaya Identity members (P, GDP, EI, CI), randomly select a certain number of scenarios, and simulate them.
2) Study the temperature sensitivity to some factors.
3) Simulate a scenario defined by a user.
4) Find which scenario/s ensure the respect of the Protocol.
5) Once the scenario is found analyze draw your conclusions.

Other Ideas

You don't have to stick to this model, if you don't want to or if you have better ideas. We suggest though that you use it as skeleton on top of that you can add whatever you wish to include in your model.

Moreover, if you have enough time you can focus on the user experience, building up a Graphical User Interface!

Enjoy the challenge!