Earth is
an ecosystem

One square foot (David Liittschwager)

A Polynesian reef

The biosphere

- What is it to be alive ?
  - To eat
  - To reproduce
- The dilemma of life: cooperation or conflict ?
- Who carries the dilemma ?
  - The individual
  - The species
  - The gene

Mathematics and biology 1: probability theory

- If children are a mixture of both parents, how come we observe such diversity among individuals instead of an averaging out ?
- Mendel (1866): traits are discrete and not continuous (alleles)
- A computation by Hardy et Weinberg (1908)

The Hardy-Weinberg model

- Two alleles A et B. Each individuals has two chromosomes, so AA, AB, et BB are present

- First generation: proportions x,y,z. So A for instance has frequency x+y/2

- If mating is random, next generation will have A et B with frequencies p = x+y/2 et q = z+y/2 = 1-p

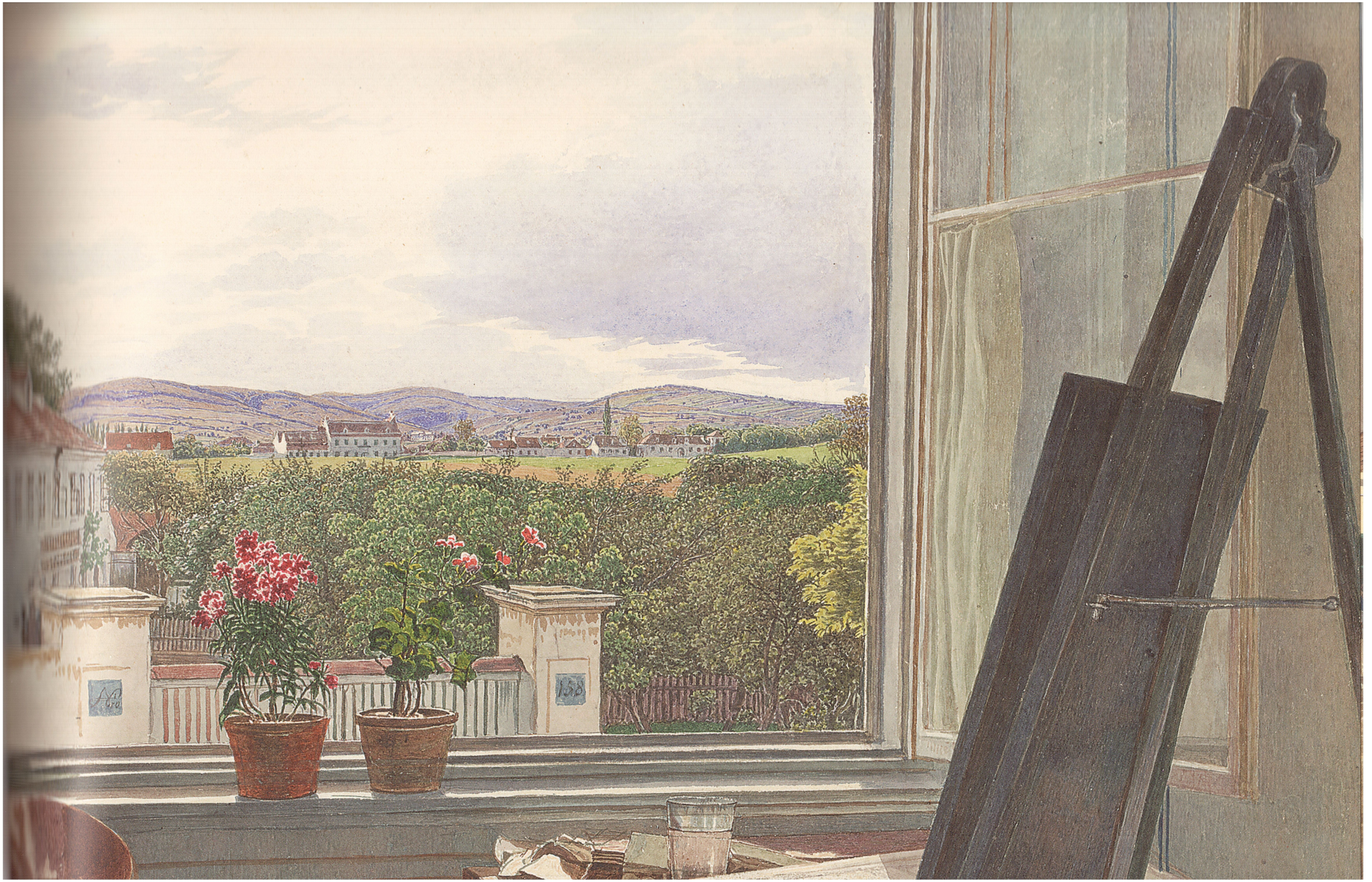
- So AA, AB, and BB will be observed with frequencies p^2, pq et q^2 which are now stable

Mathematics and biology 2: Game theory

- The prisoner's dilemma: A and B are suspected of a crime. They are asked separately to tell on the other
  - If one does, he gets out but the other gets a 5 year sentence
  - If both do, both get a 10 year sentence
  - If none does, both get a 1 year sentence
- One-shot game: you are always better off telling
- Repeated games (evolutionary dynamics):
  - Cooperation vs Betrayal in a population
  - The game of sex

Earth is a society

Earth as we see it

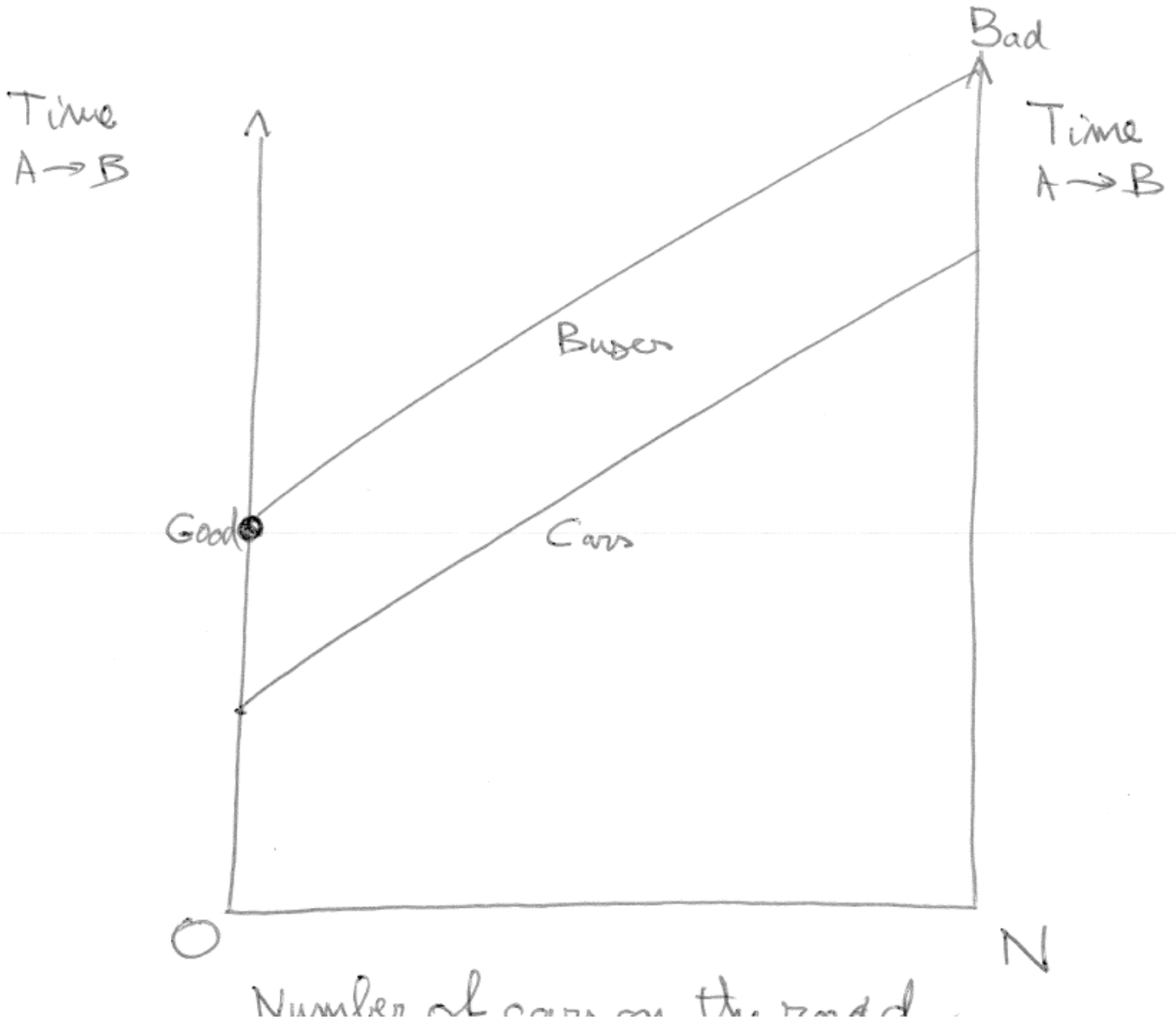


Mathematics of society

- Since the industrial revolution, the time scale of history is much shorter than the time scale of biology: we cannot wait for evolution to solve our problems
- The rationality axiom: humans have a reason for everything they do
- For human beings, the dilemma of life takes a particular form: individual rationality or collective rationality : what is good for me may not be good for society.

Urban transportation

- Driving from A to B takes 2 H when everyone is out, 30 mn if the road is empty
- City Hall install a bus line: the bus takes 50 mn if there are no cars on the road, 2H 20 mn if all the cars are out
- If everyone takes the bus, everyone gets from A to B in 50mn
- If everyone drives, everyone gets from A to B in 2H
- What will people do ?

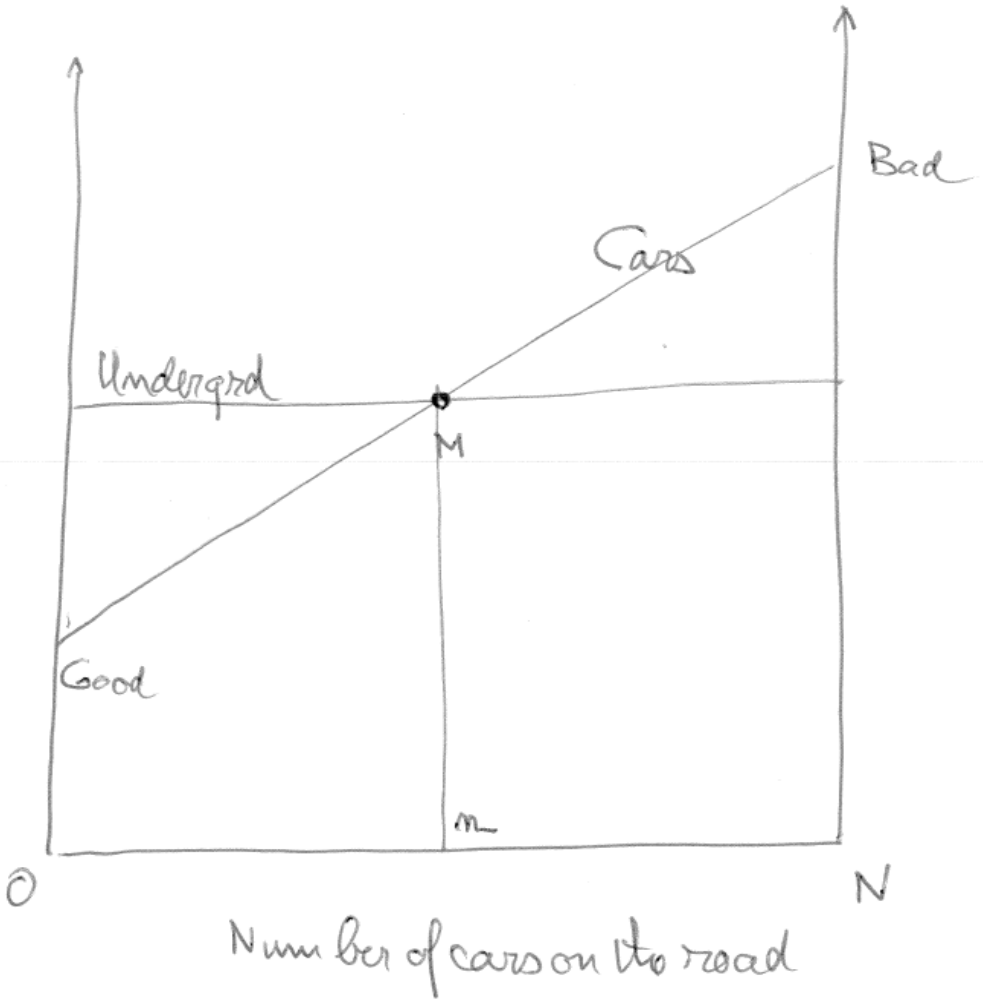

Bad
Time
A → B
Time
A → B
Buses
Good
Cars
O
N
Number of cars on the road

The lemmings

- A society of rational people deliberately chooses to spend 2H getting to work every day when they could do it in less than half the time
- General problem:
  - Public goods and taxes
  - Not in my backyard
  - Climate change

Social engineering

- City Hall installs an underground line which connects A to B in 50 mn, regardless of traffic on the road
- If everyone takes the metro, everyone gets from A to B in 50 mn
- If everyone takes the car, everyone gets from A to B in 2 H
- What will people do ?


Bad
Cars
Underground
M
Good
m
O
N
Number of cars on the road

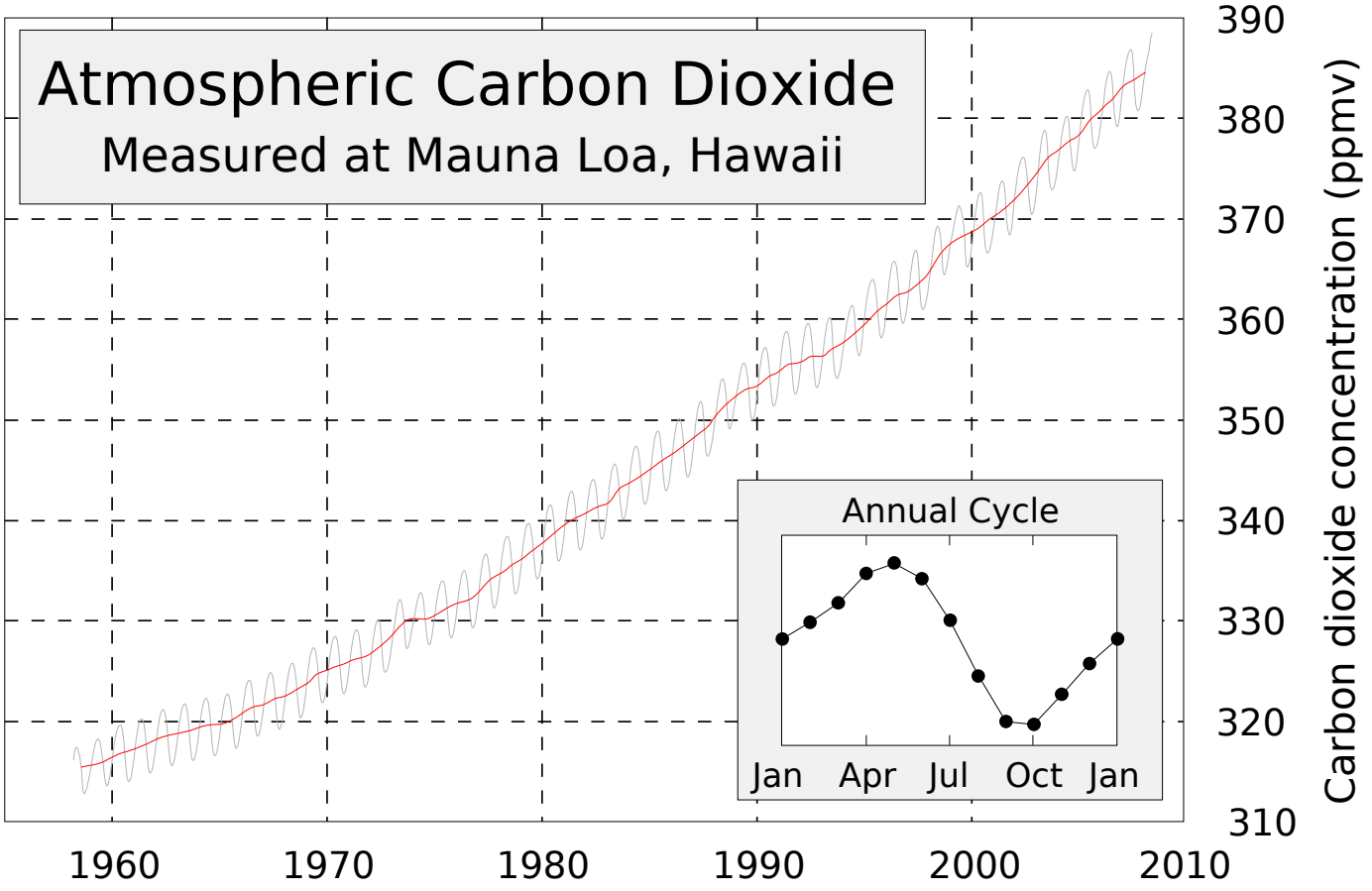
Earth is a spaceship

The lights

No pilot on board

- Earth is a spaceship which carries mankind in the interstellar vacuum
- The crew has taken command
- We have explored the ship, we don't understand it fully, but we have already spotted some weak spots:
  - End of biodiversity
  - Climate change
- The speed of changes is such that mankind cannot rely on the inboard computer to correct them

A cause for worry

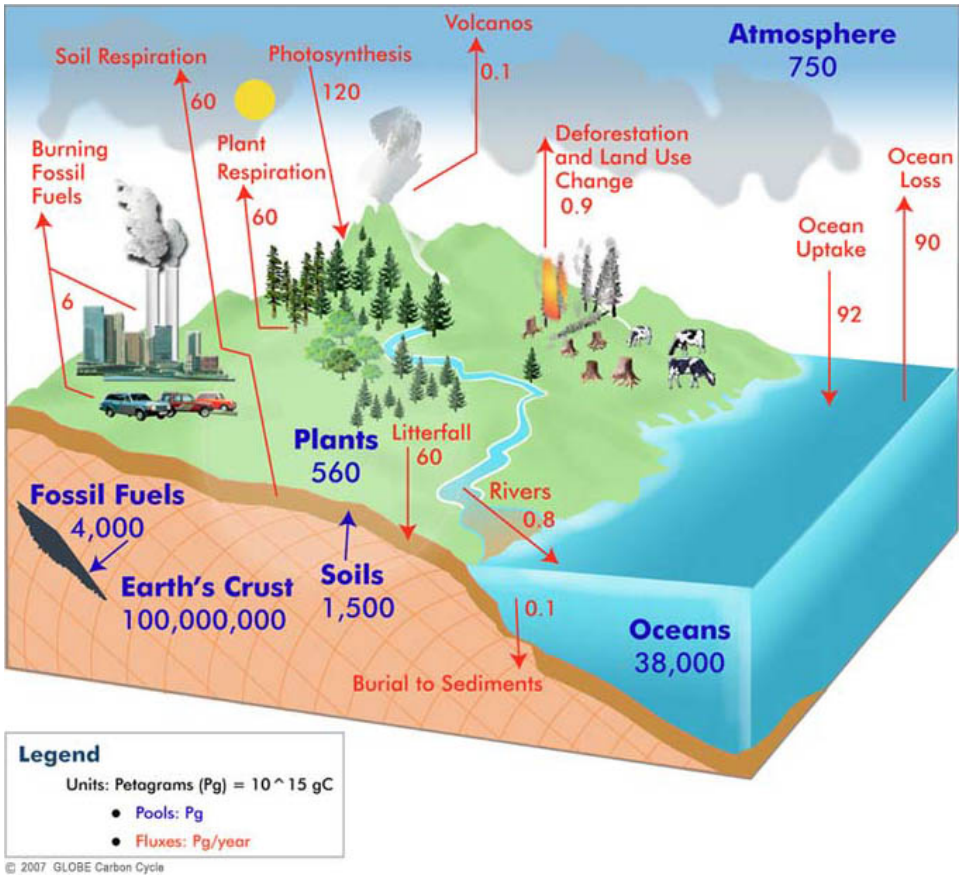


The case of climate change

Some relevant factors:

- Variations of the Earth's orbit around the Sun
- Solar activity
- Volcanic activity
- Internal processes (clouds, icecaps, winds, currents)
- Biological activity (forests, plankton, herbivores)
- Emissions (aerosols, greeenhouse gases)

The carbon cycle



Climate models

- Climate models are is a complex : there are many relevant factors, many equations, many time scales, many variables to compute and many to enter
- A new type of science: such models require the collaboration of thousands of scientists with different backgrounds (IPCC)
- Standard difficulties due to complexity and chaos:
  - Many models
  - Many runs

Les obstacles à la prévision:

- Les phénomènes de seuil: des changements continus peuvent induire des catastrophes.
- Le progrès technologique: effets ambigüs
  - Effet rebond
  - Paradoxe vert
- Ce que l'on ne soupçonne pas
  - Epidémies
  - Guerres

The human factor

- Alternative climate policies:
  - Business As Usual (BAU)
  - Nuclear energy
  - Transition to gas
- Individual rationality:
  - Green paradox
  - Bouncing back
- Noncooperative solutions
  - Famines
  - Wars

BAU / transition towards gas

- (Cryosat) From 2030, the Arctic Ocean will be icefree in the summer
- (International Energy Agency) By 2100, on current trends, mean temperatures will increase by 6 degrees Celsius
- (World Bank) An increas of 4 degrees would be catastrophic. Mediterranean summers will be hotter by 9 degrees Celsius
- As of May 2013, concentration of CO^2 in the atmosphere has reached 400 ppm

What should be done

- The risk is very unevenly distributed
  - North vs South
  - Rich vs poor
  - Environment vs development
  - The present generation vs the future ones
  - Mankind vs the rest of the biosphere
- There will be losers and winners, and there is no consensus on what should be done

What could be done ?

- Climate policies are the hardest to implement
  - No agreement on objectives
  - The commitment problem (IE)
  - The prisoner's dilemma
  - Effects have great local variation
  - Effects are far away into the future
  - Predictions are uncertain

What will happen

- Non-cooperative solutions
  - BAU, with adaptation and mitigation
  - Wars, pandemics and famines
- Cooperative solutions: this would require the emergence of new social norms, more or less inclusive:
  - Everyone alive today
  - Future generations
  - Other living species
  - Earth itself (Gaia)
- Where are they going to come from ?

What is mankind ?