Challenge to the Future Society
How to handle a Complex System？

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Our present situation

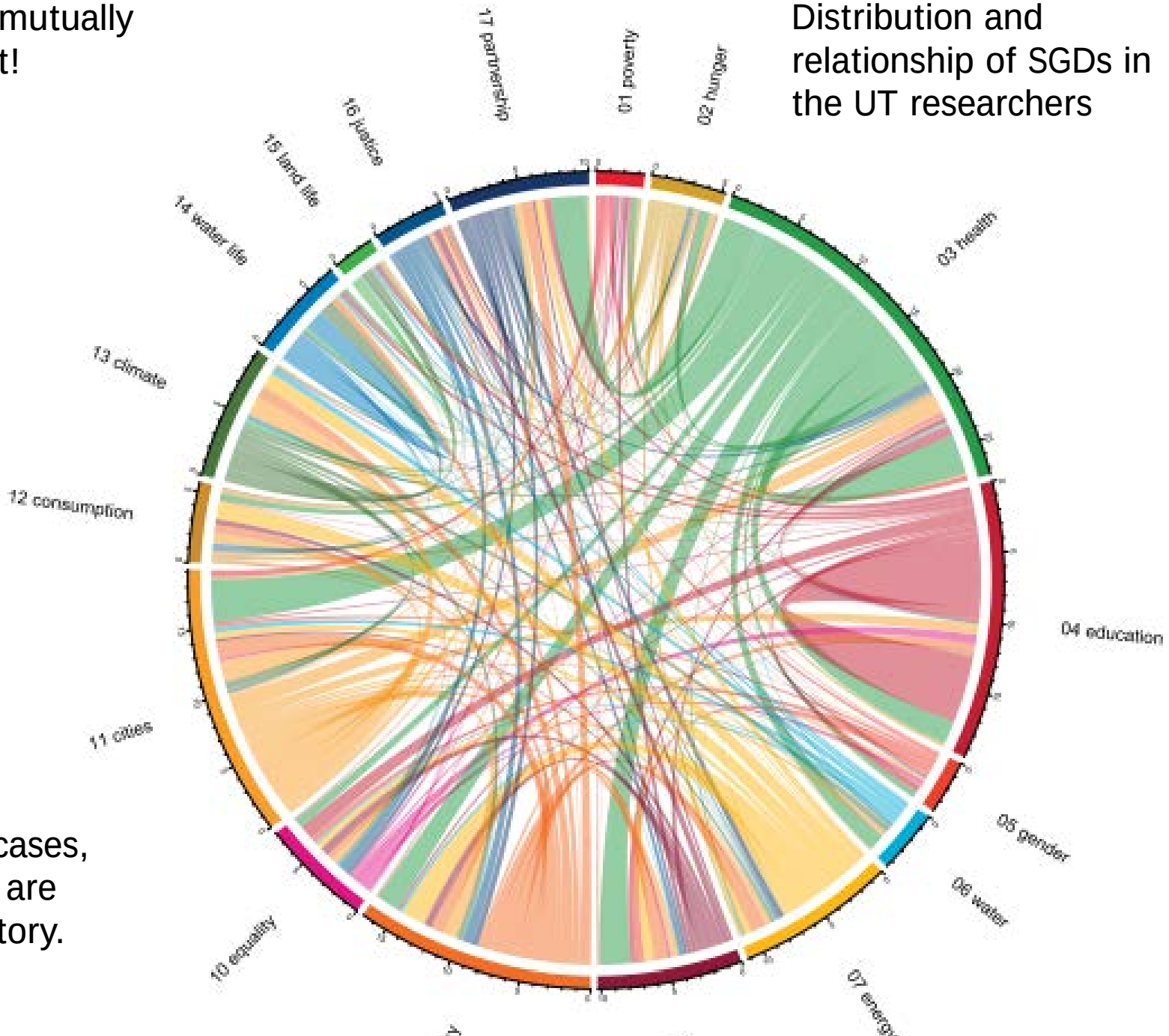
- 2015　Big Changes
- Sendai Framework(Disaster Prevention）
- Sustainable Development Goals(SGDs)
- Paris Agreement

Various issues around us!

- There are many, many issues.
- Issues are not independent.
- Solutions are dependent on a society.
- Many stakeholders with different viewpoints and values.
- When action is taken, social agreement is necessary.
- How?

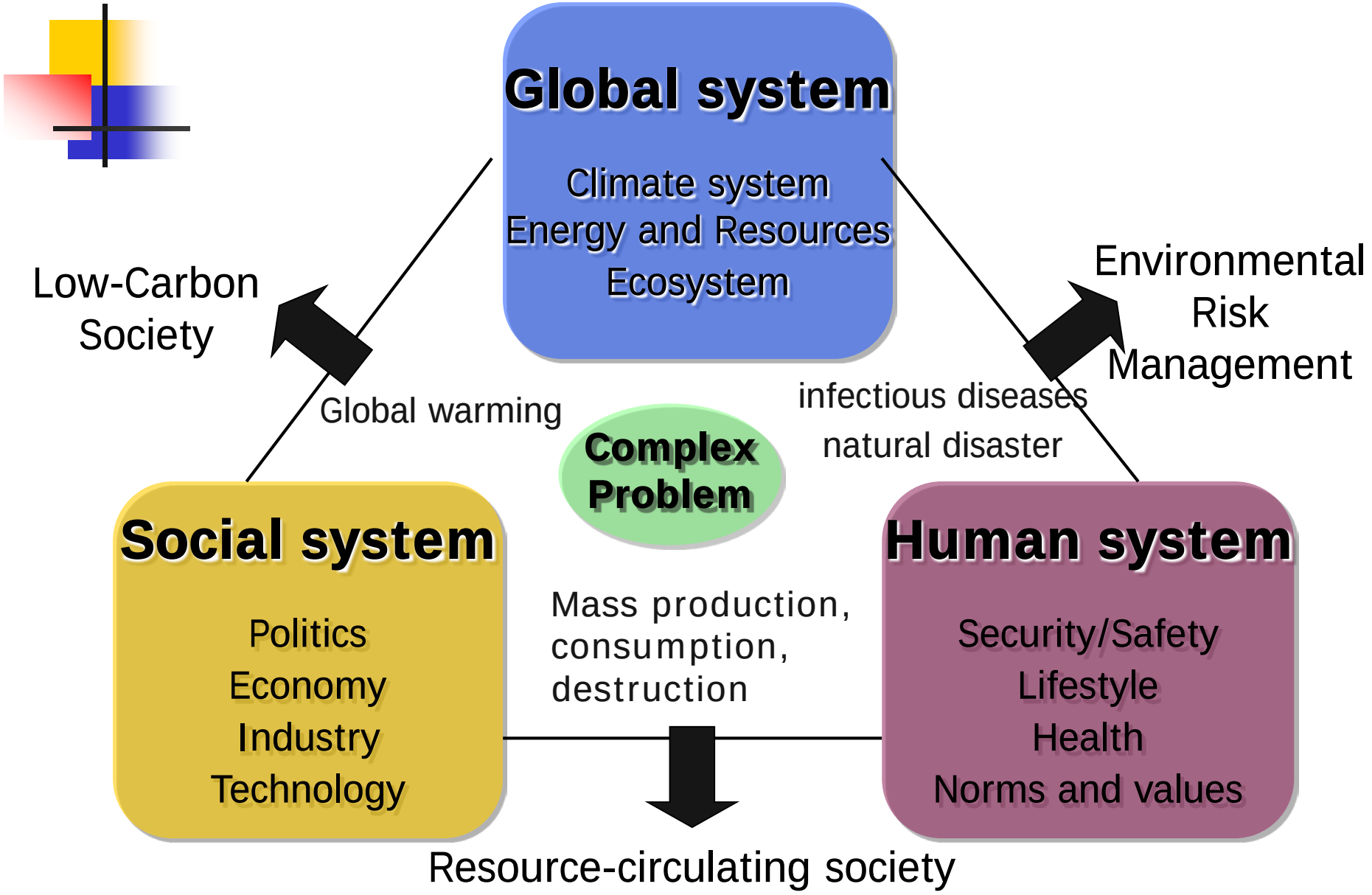
SDGs are mutually dependent!

Distribution and relationship of SGDs in the UT researchers

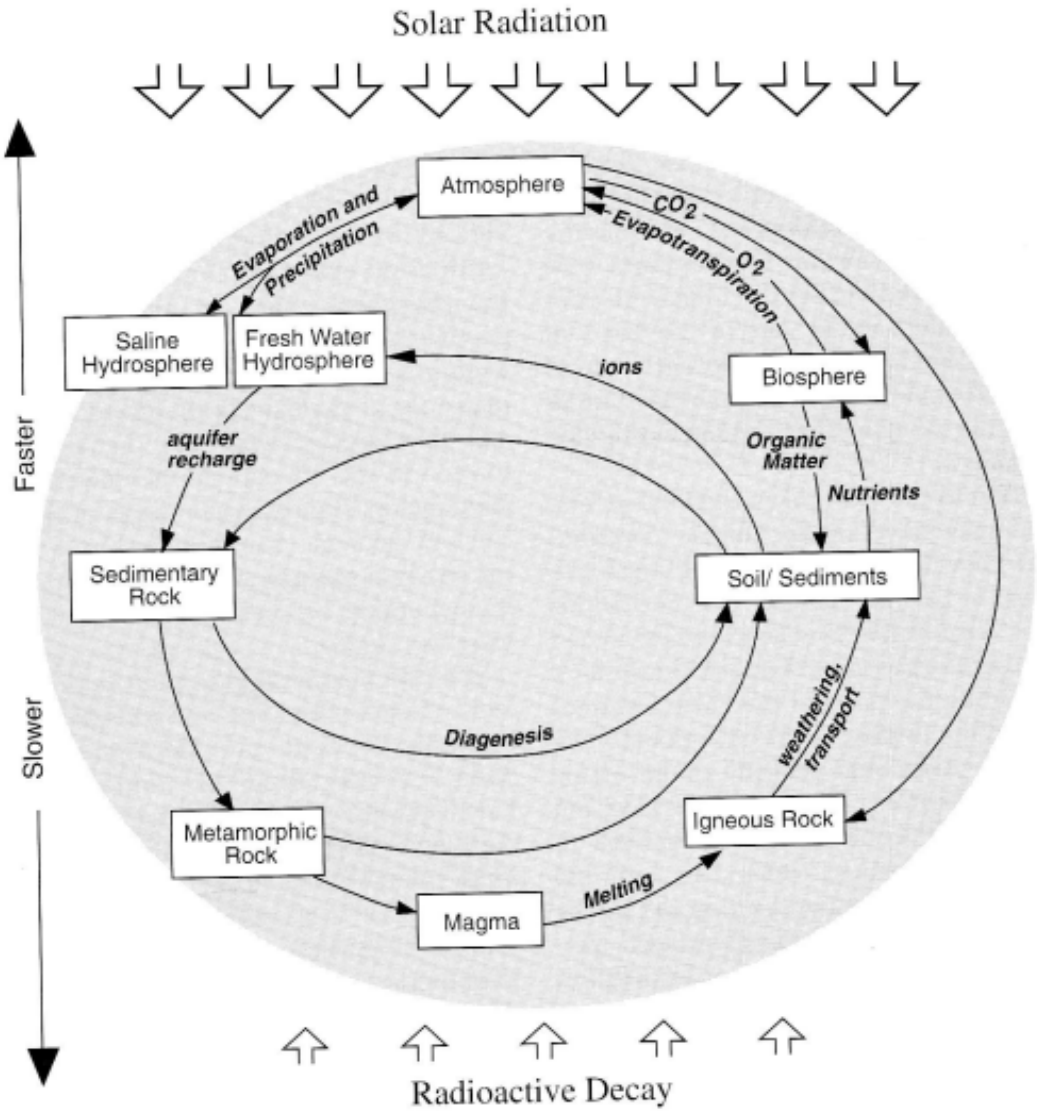


In some cases, Solutions are contradictory.

Linkages among three systems



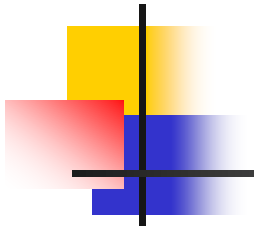
The Earth system



ig. 1-1 Diagram of cyclic processes and fluxes between the major reservoirs on Earth.

Complex System

- What is complex system?
- Definition: A system which is not simple. Same as a non-linear system, which is not a linear system. Why is a linear system easy to handle? In most of case, it can be reduced to one – dimension. Linear algebra. Eigen-value and eigen mode or normal mode.



- Complex system, where its behavior is complex, it means it is difficult for us to understand the behavior. For example, Lorentz “Caos” system.

Lorentz “Caos”

- Dx/dt=σ（y－x）
- Dy/dt=x(ρ-z)-y
- Dz/d=xy-βz

シミュレーションモデル

Lorenz 方程式

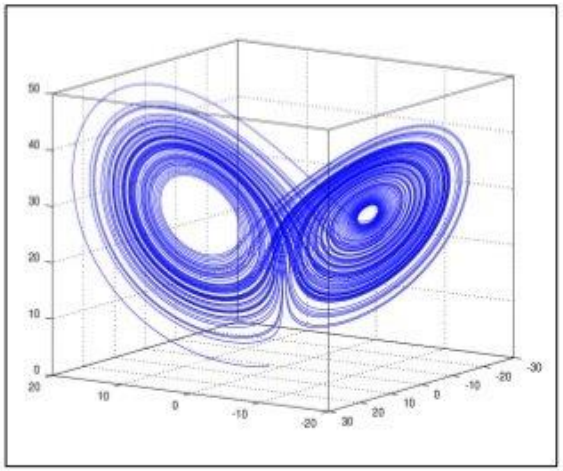
$$\begin{cases} \dot{x} &= \sigma(y-x) \\ \dot{y} &= rx-y-z \\ \dot{z} &= -bz+xy \end{cases}$$

$$\sigma = 10, r = 28, b = \frac{8}{3}$$

カオス理論の始まりとなった方程式

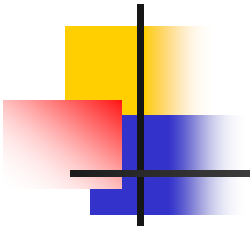
4 次の Runge-Kutta 法により差分化

$\Delta t = 0.01$

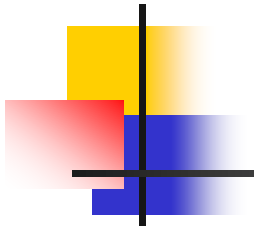


Objection from Biology!

- Other examples: Biology, Medical Sciences, Virs,Cell,Gene etc.
- Here, claim from biology and others, that the Lorentz system is not a complex system. A biota is a complex system.
- Remarks: **complex system and complicated system**



- **Complicated system** is a system which is not easy to analyze, but governed by determined principles
- **Complex systems** are based on relationships of elements, and their properties is self-organisation, interconnections and evolution.

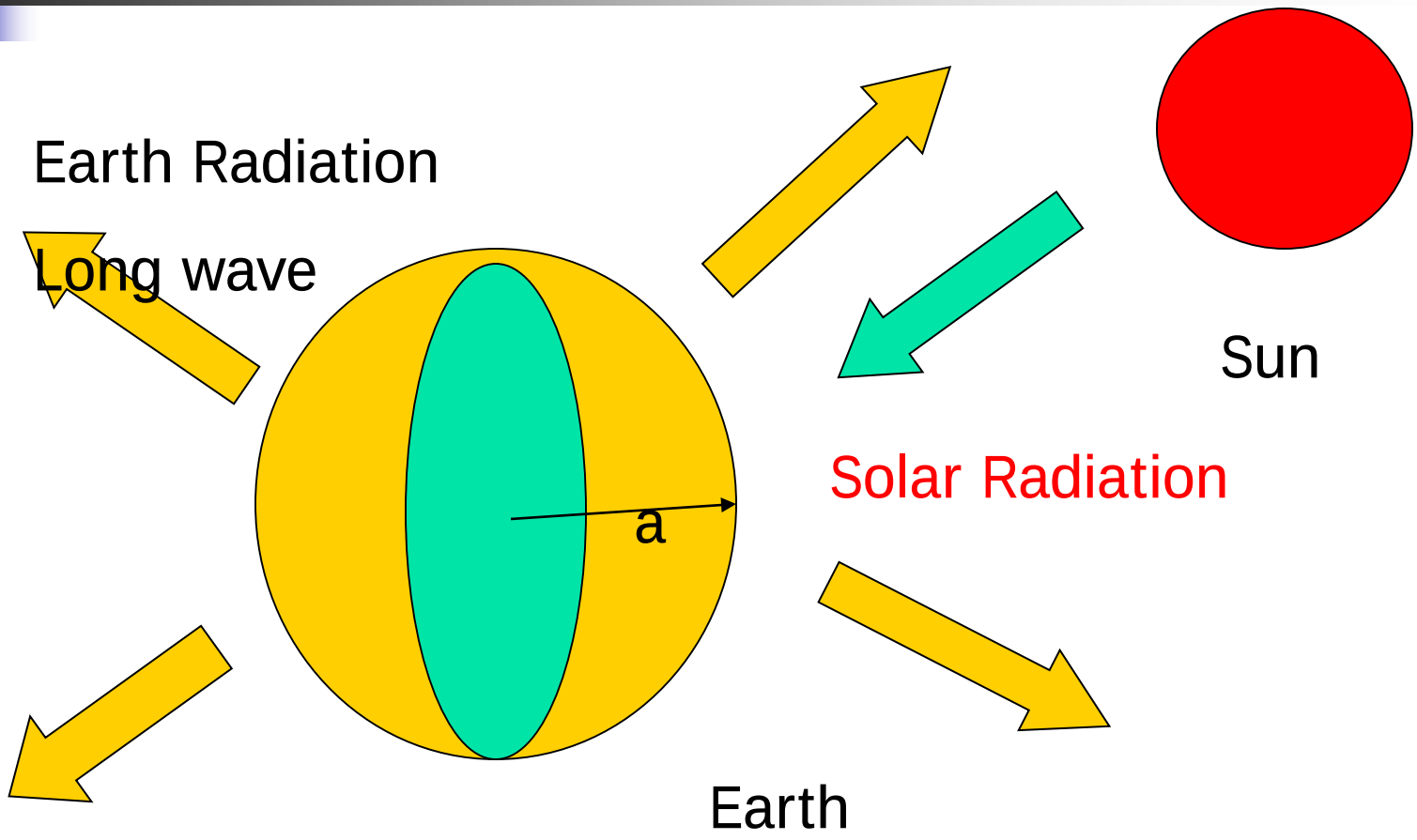


- Complex system is an evolving system such as eco-system
- Evolution 進化
- Emergence　創発
- Many components and various mutual interactions.
- As an example, the Earth system and Society and a Human Body..

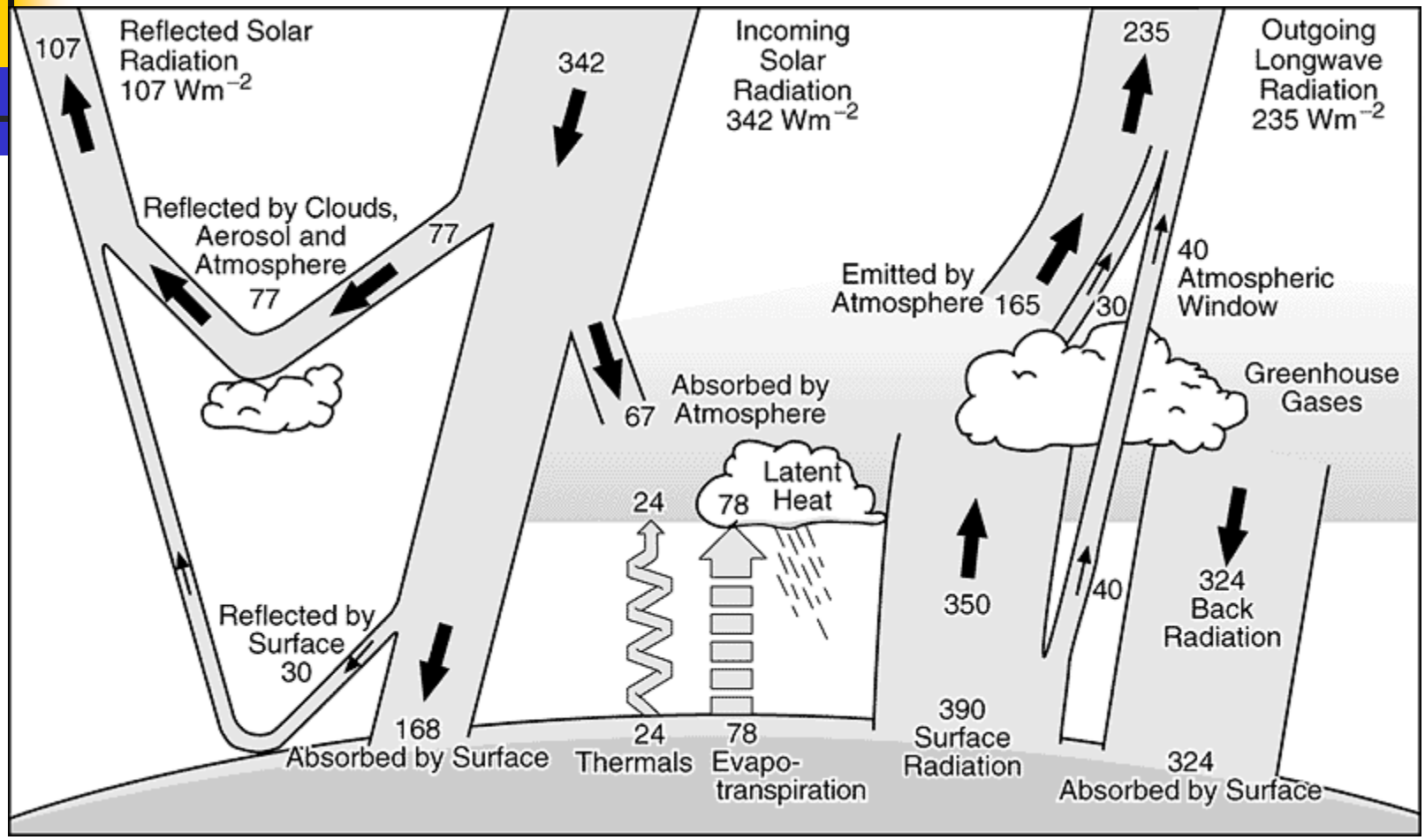
What is an “interaction”?

- Exchange of “Something”
- Energy
- Matter or substance
- Information
- Interactions of physical quantities are governed by physical laws!

Radiation Balance on the Earth



Radiation Balance(Energy Flow)



IPCC,AR4(2001)

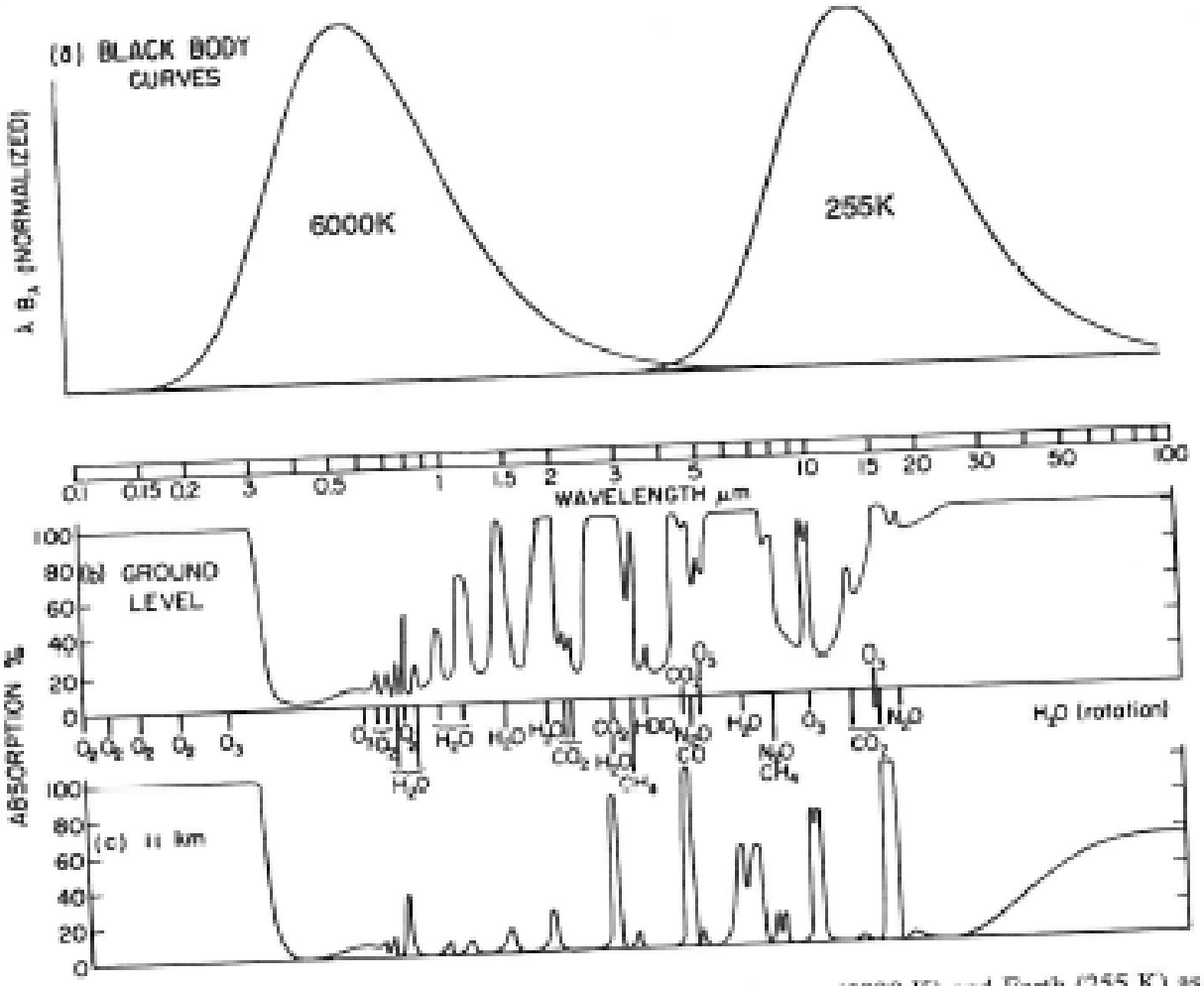


Fig. 3.2 The normalized blackbody emission spectra for the sun (6000 K) and Earth (255 K) as a function of wavelength (top). The fraction of radiation absorbed while passing from the surface to the top of the atmosphere as a function of wavelength (middle). The fraction of radiation absorbed from the tropopause to the top of the atmosphere as a function of wavelength (bottom). The atmospheric molecules contributing the important absorption features at each frequency are indicated. [Taken from Goody and Yung (1989). Reprinted with permission from Oxford University Press.]

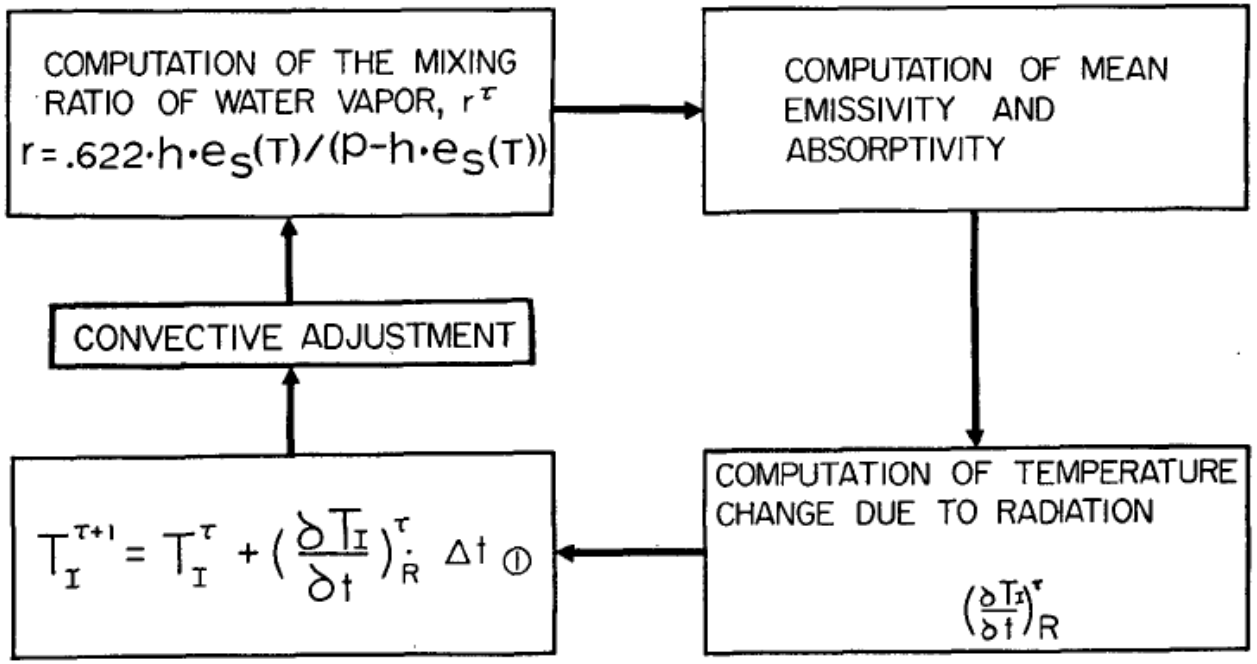


FIG. 2. Flow chart for the numerical time integration.

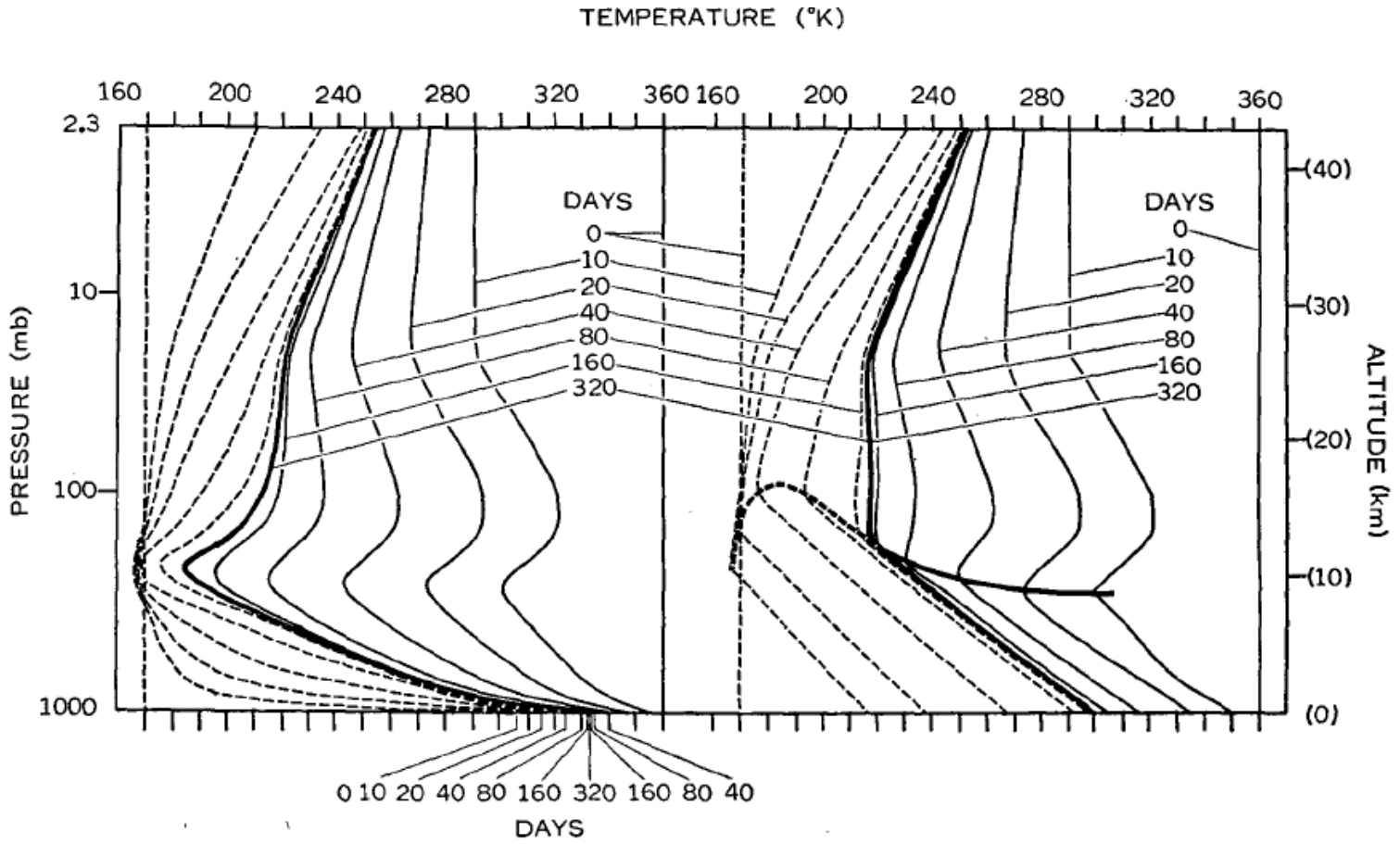


FIG. 1. The left and right hand sides of the figure, respectively, show the approach to states of pure radiative and thermal equilibrium. The solid and dashed lines show the approach from a warm and cold isothermal atmosphere.

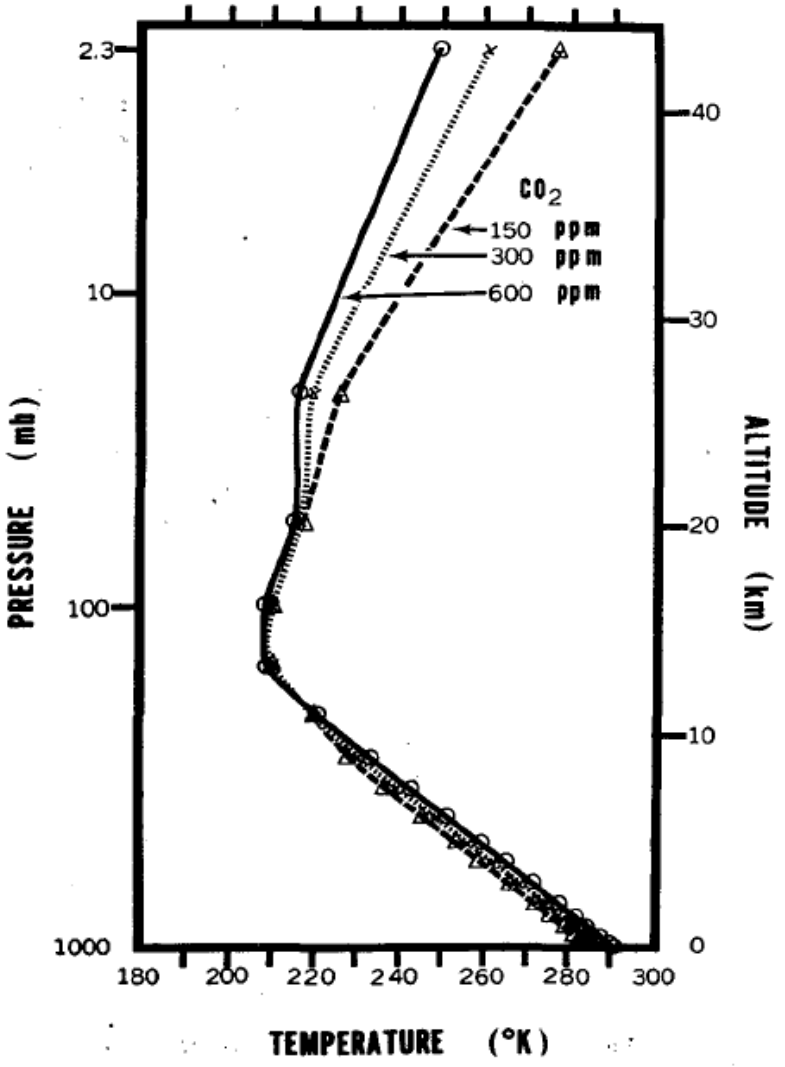
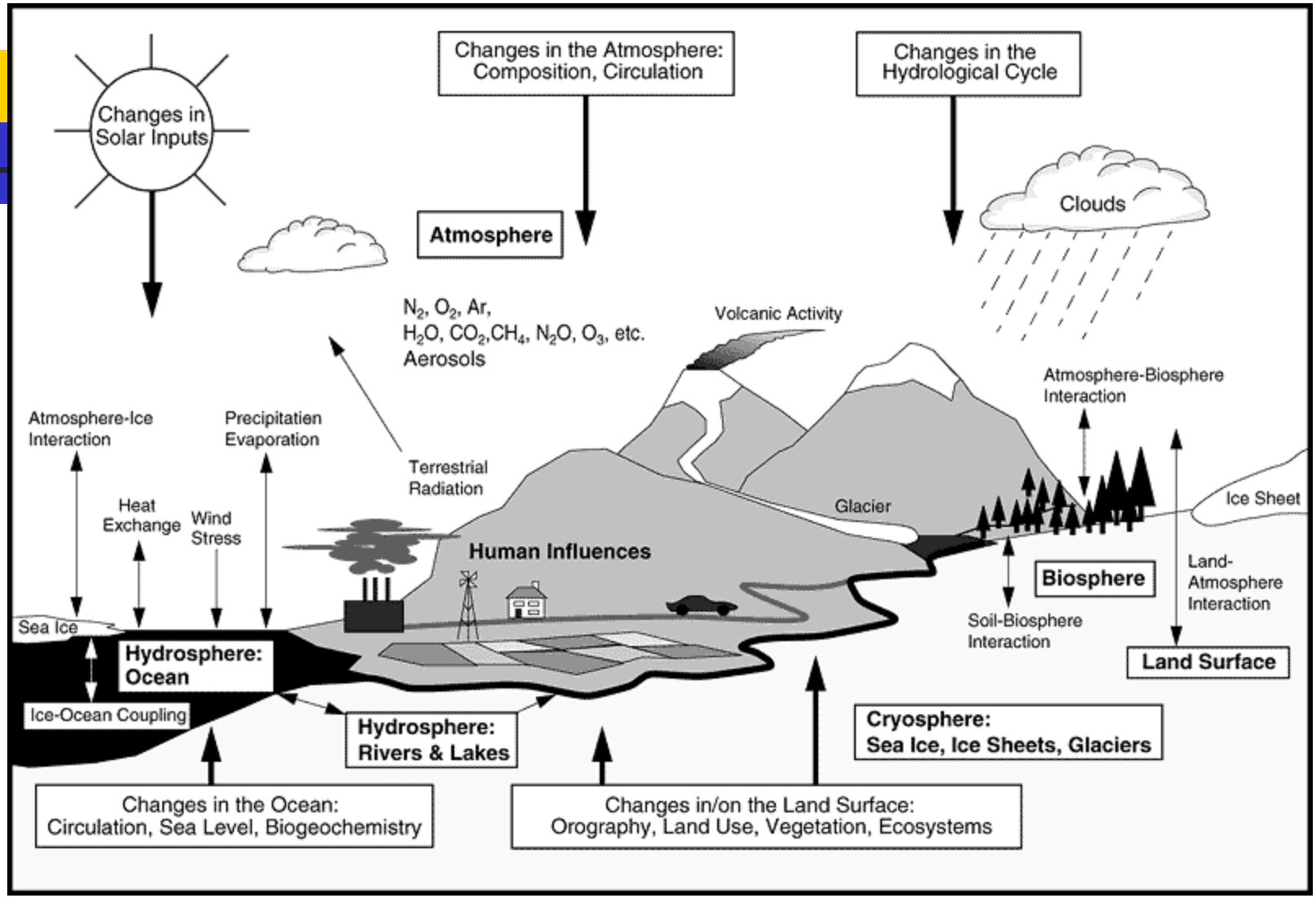


FIG. 16. Vertical distributions of temperature in radiative convective equilibrium for various values of CO_2 content.

Climate System

- Many different components (physical, chemical, biological systems and so on)
- Many sub-systems with different characteristics!
- Coupled system
- Mutual Interaction

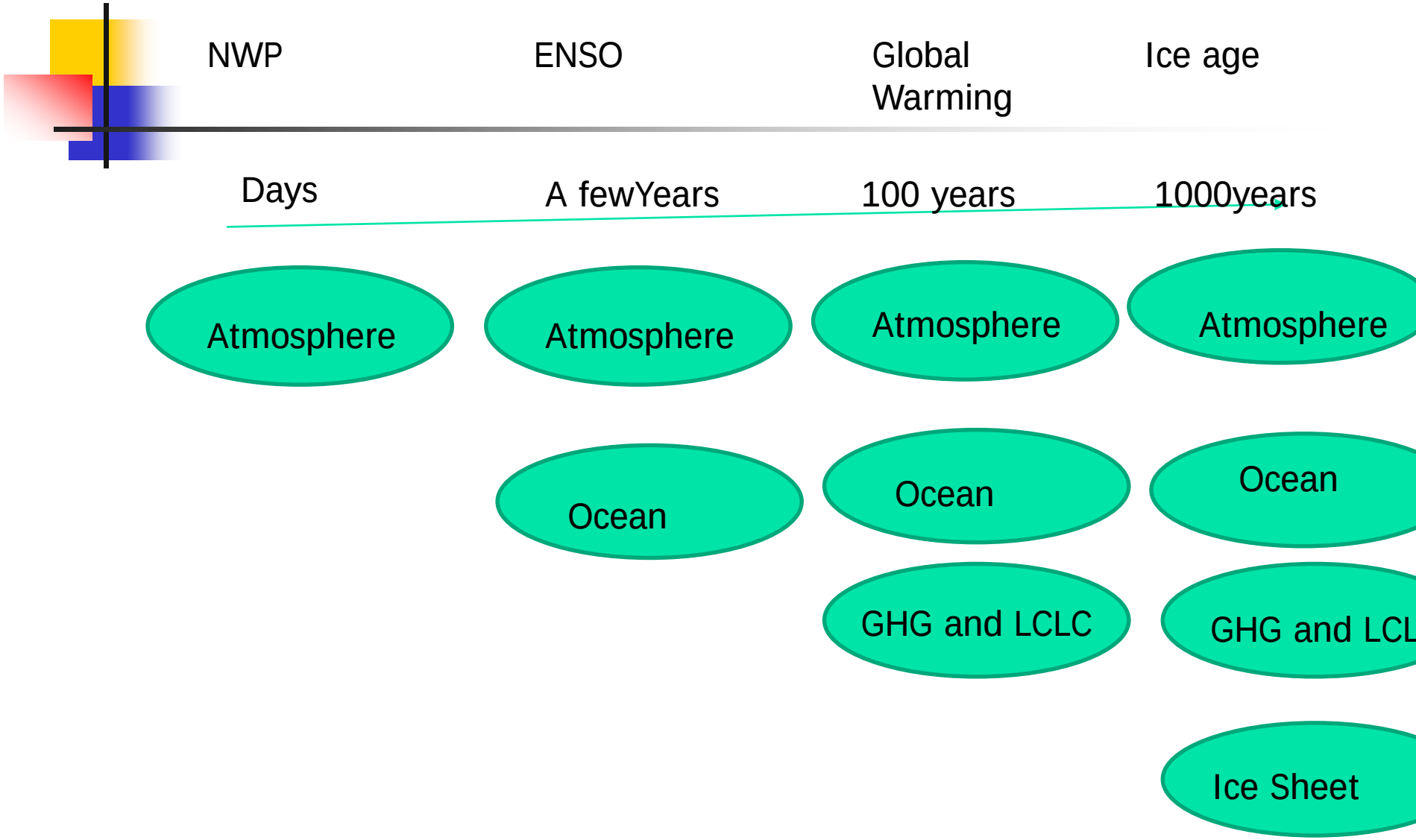
Climate System



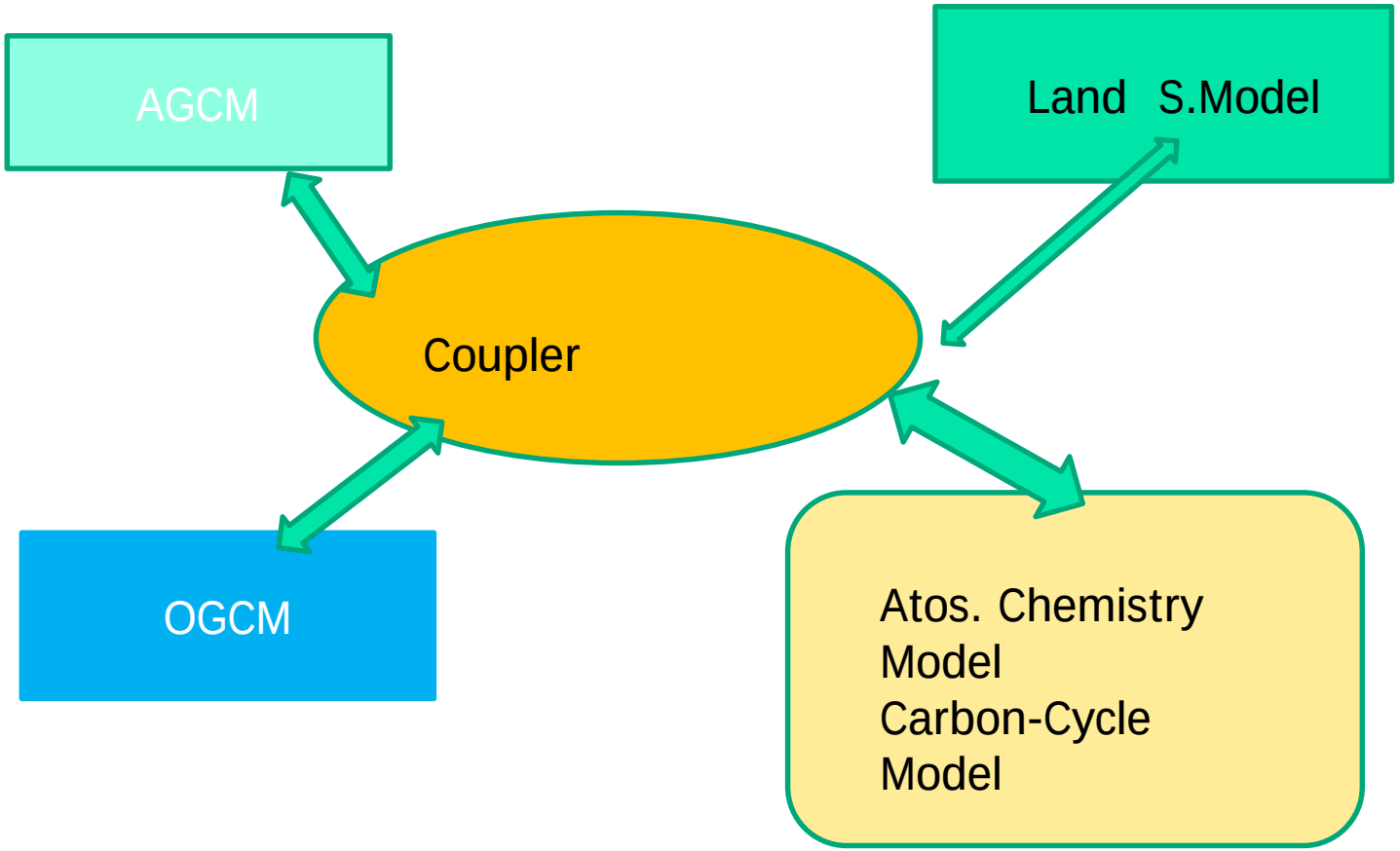
IPCC,AR3(2001)

Introduction of other sub-systems

- Interaction is a key process!
- Time-scale is different
- Horizontal-scale is different!
- Coupler system is developed!


NWP
ENSO
Global Warming
Ice age
Days
A fewYears
100 years
1000years
Atmosphere
Atmosphere
Atmosphere
Atmosphere
Ocean
Ocean
Ocean
GHG and LCLC
GHG and LCL
Ice Sheet

Coupler J-Cup



Further expansion to Human Activity

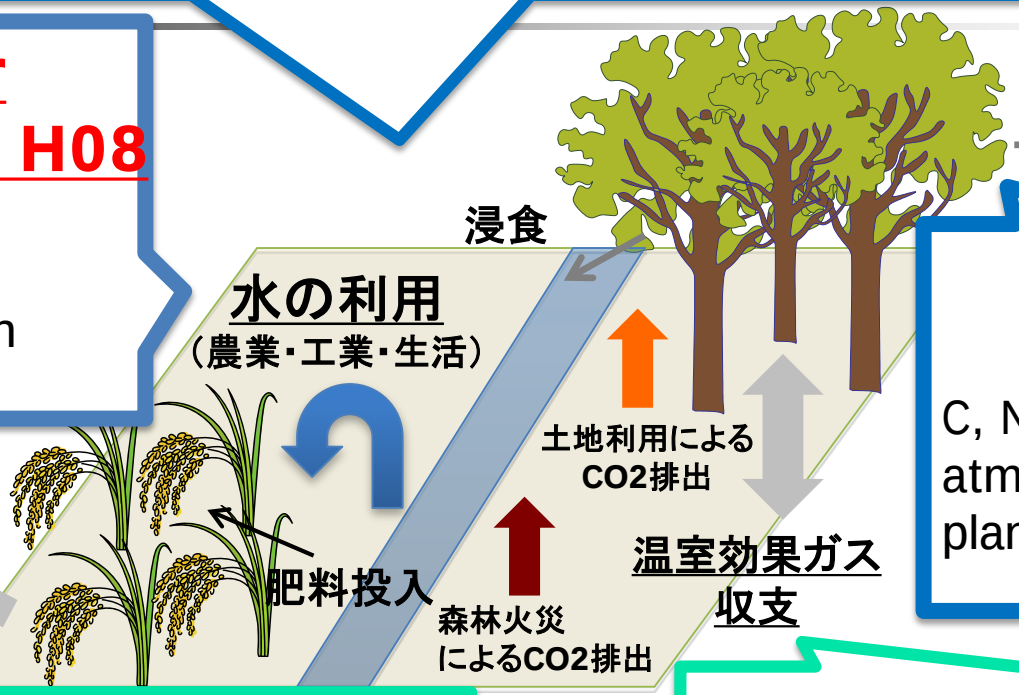
（＊仮　あるいはMIROC-INTEG とか。MIROC5.0 をベースにしたバージョン）

Climate（Land S. Model MATSIRO）

Soil temperature Soil wetness etc

Water Res.Model H08

Water Use of Agriculture and Industry Polution



Eco-System VISIT

C, N distribution between atmosphere, land and plants

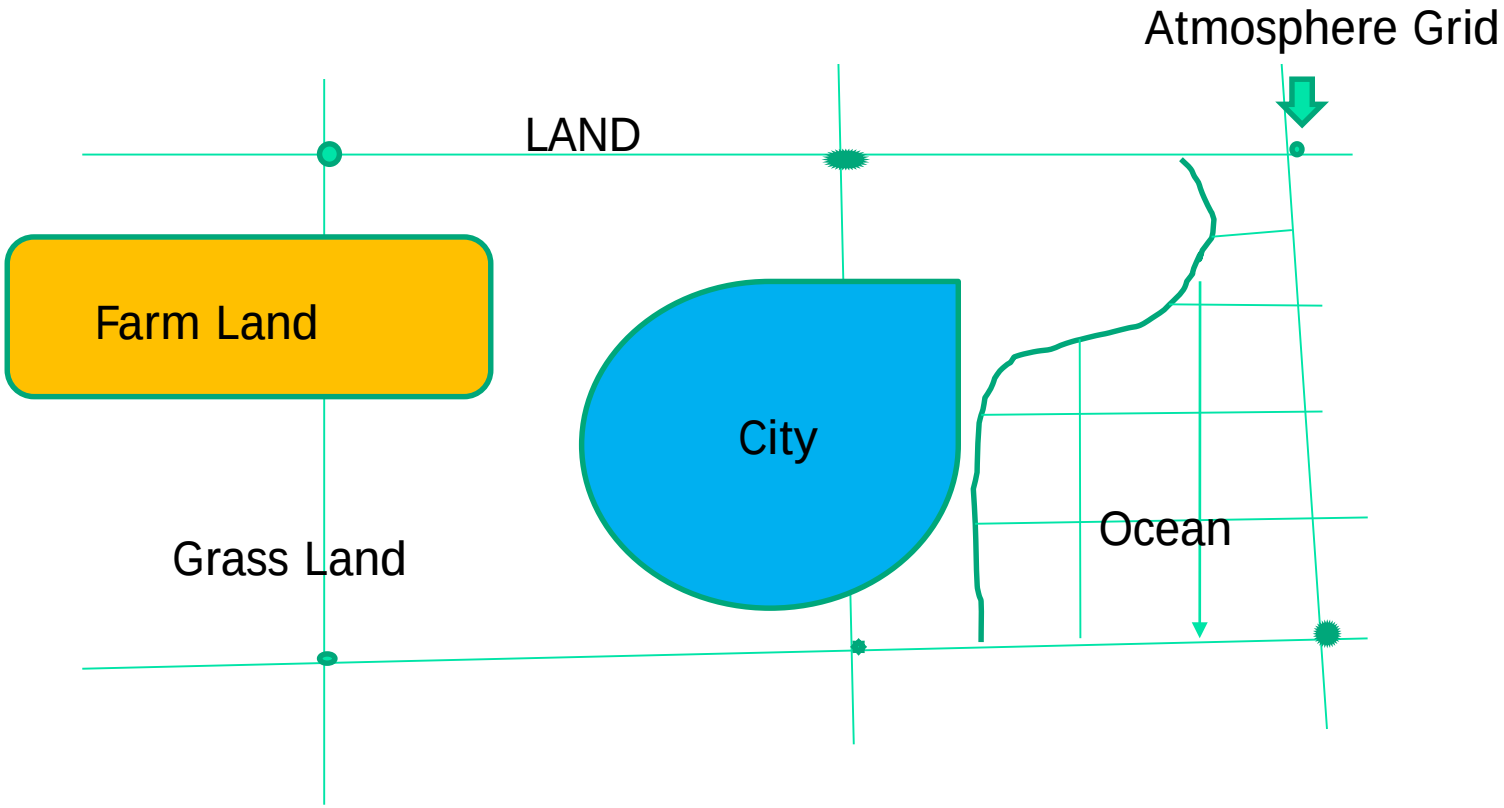
Crop Model PRYSBI2

Crops, Bio-Energy, N-burden etc

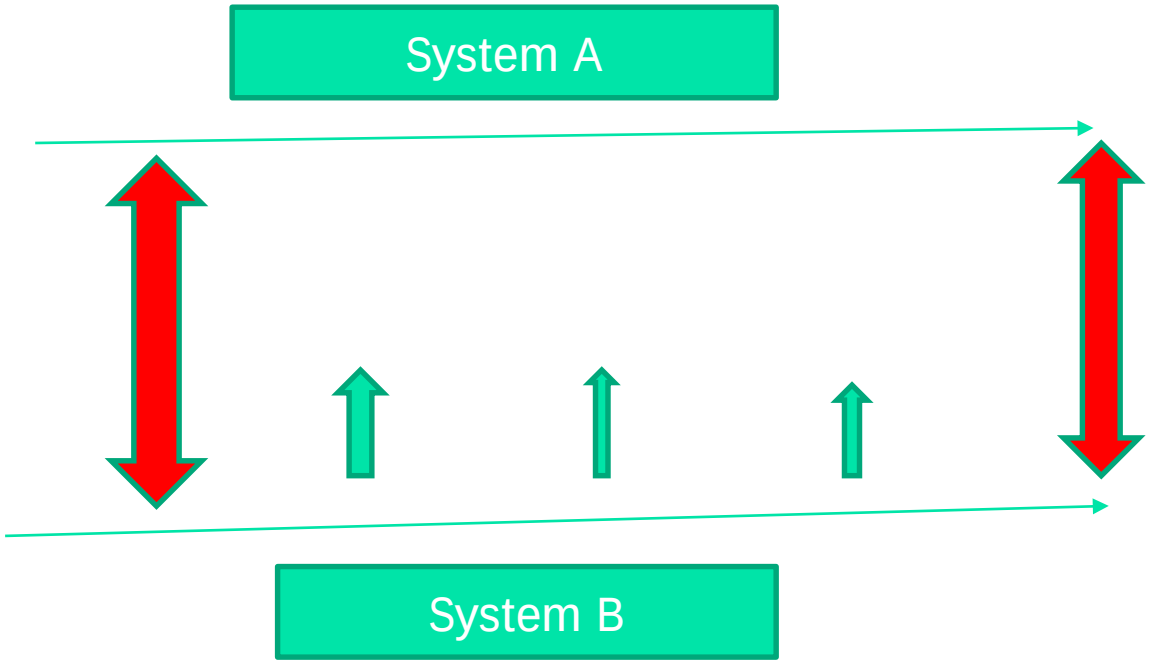
Land Use Model TELMO

Land Use and Land Cover Change due to human activity

How to handle a hetrogenious interaction?



Different time-scale



Many processes but

- Many processes are included,but only quantitative elements!
- How to evaluate model results?
- For global warming, ΔTs
- For Sustainability, ?
- Not NDP, not money, but money is important!
- Many indecies, but ?

Summary

- For an integration study, integration by using a model is one possible way.
- Increase of computer power
- Agent-based Model for human-behavior
- How to make a judgement?
- Index like a NDP