World Journal of Geomatics and Geosciences, 2023, 3, 523
www.scipublications.org/journal/index.php/wjgg
DOI: 10.31586/wjgg.2023.523

Research Article

Hypercycle of Geoscience, Nonlinear Whole Geoscience and Possible Entropy Decrease

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Abstract: First, based on the many levels and their cycles in geoscience, we research the hypercycle of geoscience. This is the hypercycle as a tool of self-organization applied to geoscience. It may form from a level to other higher levels. These levels influence each other and the co-evolution. Second, we discuss some possible mathematical methods, which include graph, vector, matrix, some equations, similar theories, etc. This method can be developed and perfected. Third, we propose the nonlinear whole geoscience and its three basic laws. Fourth, we discuss thermodynamics of geoscience, and in which possible entropy decrease under some sates, such as evolution and cycles of Earth, etc. Sustainable development of society must study the mode from high entropy to low entropy. Various cycles in geoscience cannot all be entropy increases, and cannot all be originated from the external interactions.

Keywords: Geoscience, Hypercycle, Level, Mathematics, Thermodynamics, Entropy

How to cite this paper:
Chang, Y.-F. (2023). Hypercycle of Geoscience, Nonlinear Whole Geoscience and Possible Entropy Decrease. *World Journal of Geomatics and Geosciences*, *3*(1), 1–12. Retrieved from https://www.scipublications.com/journal/index.php/wjgg/article/view/523

Received: October 10, 2022
Accepted: December 30, 2022
Published: January 2, 2023

1. Introduction

Geoscience, i.e., Earth Science is the study of Earth. It includes various levels: Earth core, mantle, lithosphere, hydrosphere, atmospheric sphere, biosphere and human society. These levels are closely related and various complex interacts with each other [1-4]. These levels have various cycles, such as atmospheric circulation [5], ocean circulation [6], the convection of the mantle [7], lithosphere cycle [1]. The ocean has El Niño phenomena. The water cycle is the most obvious. There have also the carbon cycle [8, 9], the cycles of phosphorus and nitrogen [4], and the periodic reversal of the geomagnetic field, etc.

Geoscience studies the processes that form and shape Earth's surface, and various natural resources, and uses tools and techniques from other science fields, such as chemistry, physics, biology, and mathematics. From Wegener's continental drift hypothesis to Plate tectonics is the greatest scientific advance in geoscience, and is very important contribution for mankind.

In Nature Geoscience (2022) Vol.15, Wang, et al., discussed El Niño/Southern Oscillation inhibited by submesoscale ocean eddies [10]. Pontes, et al., studied Mid-Pliocene El Niño/Southern Oscillation suppressed by Pacific intertropical convergence zone shift [11]. Biological soil crusts (biocrusts) cover ~12% of the global land surface. Rodriguez-Caballero, et al., combined the currently limited experimental data with a global climate model to investigate the global cycling and climate effects of aeolian dust controlled by biological soil crusts [12]. Wu, et al., searched imbalance of global nutrient cycles exacerbated by the greater retention of phosphorus over nitrogen in lakes [13]. Sheward discussed cycling carbon with coccolithophores [14]. In this paper, based on the many levels and their cycles in geoscience, we research the hypercycle on geoscience and

some possible mathematical methods, and propose the nonlinear whole geoscience, and discuss thermodynamics of geoscience and possible entropy decrease.

2. Hypercycle of Geoscience

In 1970s Eigen and Schuster proposed the hypercycle [15-19]. This is a scientific theory on the relationship between protein and nuclei acid, and on the origin of life, and discussed self-organization of matter and the evolution of biological macromolecules [16].

It is in order to model prebiotic evolution governed by the Darwinian principles of competition between species and mutations, and leads to a new level of evolution. Here cooperative behaviors are reflected by intrinsically nonlinear reaction mechanisms. Further, the hypercycle is a principle of natural self-organization [18], and it as a beautiful form is also a tool not only in biomolecules, and may be widely applied to many fields. In the hypercycle cooperative behavior is reflected by intrinsically nonlinear reaction mechanisms, and the dynamics is described by a system of coupled nonlinear differential equations. In the hypercycle each cycle as a whole has self-enhancing growth properties, and different sets of the nonlinear equations carry function, etc [16].

Since the nonlinearity of the hypercycle, its size can be amplified or reduced, and each hypercycle, as a whole, has a self-promoting growth nature. The hypercycle is an orderly mechanism formed by its internal factors for self-regulation and self-organization. This is an important theory and method for complex systems to produce self-organized structures such as life and constantly evolve. This is a quantization theory on a large cycle containing many small cycles, which also contains some basic characters of the fractal. Eigen also noted that organizational forms of hypercycle also exist in neural network organizations and social systems. Therefore, the hypercycle has not only meaning of natural science, but also meaning of social science, especially when studying the evolution and complexity of social systems.

The hypercycle proposes the hierarchical organization of cycles, where function is causal to each other. Diversity of organisms, their cells have only one basic molecular mechanism, namely the universal genetic code, basically consistent translation mechanism and a macromolecular chirality. This is unity. There is competition in the system, also synergy, and has nonlinear selection behavior, and produce hypercycle structure. The hypercycle applies self-organization, and form from a level to the next higher level.

Smith discussed hypercycles and the origin of life [20]. Braxenthalar, et al., proposed that the dynamic evolution of proteins exhibits chaos property, which is related to the hypercycle [21]. Kaneko discussed recursiveness, switching and fluctuations in a replicating catalytic network, and relation with hypercycle [22]. Solenov, et al., analysed the nonunitary quantum walks on hypercycles [23]. Campos, et al., studied the steady-state regime of a network of n error-prone self-replicating templates forming an asymmetric hypercycle and its error tail [24]. Ferreira, et al., investigated analytically the molecules modeled by hypercyclic, and this method allows an unambiguous identification of the order of the nonequilibrium phase transition [25]. Montina, et al., discussed non-Gaussian statistics and extreme waves in a nonlinear optical cavity, and identified a mechanism of spatial symmetry breaking, due to hypercycle-type amplification through the nonlocal coupling of the cavity field [26]. Sardanyés applied the hypercycle from molecular to ecosystems dynamics [27]. Szostak, et al., researched hypercycle in biology [28].

Geoscience has different levels of cycles, which can be linked to each other. Based on these cycles, we propose that geoscience can form the hypercycle and the extensive hypercycle.

1. It is known that Earth has the revolution and the rotation, and both are all cycles for a year and a day. Both are related with motion of the earth-core. They combine with the mantle movement within the Earth leading to various cycles. The moon also leads to

periodic tides. 2. The mantle contains a large convection system with cycle energy and matter cycle [29]. In plate tectonics, Earth's outermost lithosphere made up of the crust and upper mantle, and is broken into large rocky plates, which form the convection of the asthenosphere and lithosphere. Mantle motion and circulation lead to plate movement and collision, from which the crust formation and its evolution. 3. Cycles in the ocean, such as various ocean circulations [6] and El Niño phenomena [9, 10], etc. 4. Cycles in the atmosphere [5], such as atmospheric Hadley circulation, etc. 5. Many cycles in the ecology, such as carbon-nitrogen cycle [30]. Ecosystems have energy conversion, material cycle, information transfer, etc. The biosphere also has the food chain and its cycle. These cycles include the biosphere and the ubiquitous human cycles, and they influence each other and the co-evolution, and form the geological hypercycle. Wang, et al., searched deep hydration and lithospheric thinning at oceanic transform plate boundaries [31]. Cappa, et al., discussed fluid migration in low-permeability faults driven by decoupling of fault slip and opening [32]. In the biosphere it is linked to the usual hypercycle. The fifth level has various life periods and cycles in biology.

This is the hypercycle as a tool of self-organization applied to geoscience. It may form from a level to the next higher level, even other levels.

3. Possible Mathematics of Hypercycle

Further, we research some possible mathematical methods of this hypercycle:

3.1. Graph

Hypercycle applies usually some graphs. In Figure 1, each cycle as a whole has self-enhancing growth properties [16].

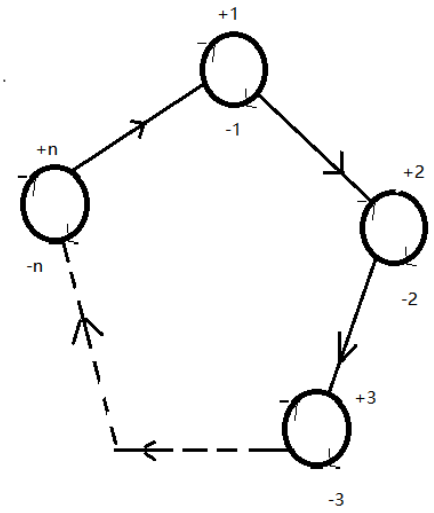

Figure 1. Hypercycle [16]

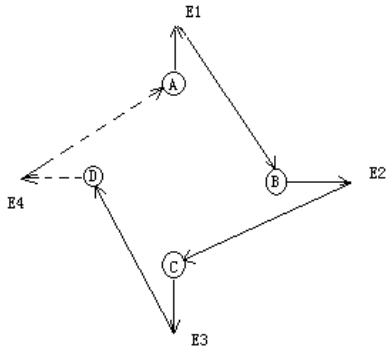

Figure 2. Second-order hypercycle model [18]

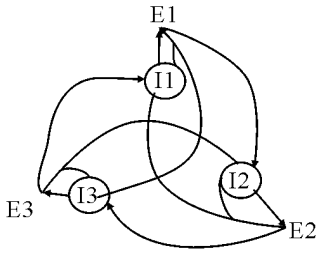

Figure 3. An extension of hypercycle evolution principle [18]

The hypercycle may form a topology that constitutes increasingly complex structures.

3.2. Vector and Matrix

Figure 1 may be a vector ***V***, and corresponding rotation ***H***=rot***V***.

For geoscience the different levels have different vectors V_i and rotations $H_i = rotV_i$, which can describe cycles and hypercycles. Speed circulations (or vortex strengths) are:

$$\Gamma_i = \oint_l V_i dl = \iint_S rotV_i dS = \iint_S H_i dS \,. \tag{1}$$

In geoscience different Γ_i may influence each other, and transform each other. For an ideal fluid, the density is only a function of the pressure, and the full force acting on the fluid has a potential, so $\frac{d\Gamma}{dt} = 0$, i.e. Γ is invariant. It is Helmholtz law in hydrodynamics, and hold for the magma and volcanic formation.

We use the graph theory [33,34] and its matrix representations to the hypercycle (Figures 1-3). Here the graph G=(V,E), in which V is point set and E is border set.

Assume the graph of hypercycle as the non-directed graph. Every element is a cycle in Figure 1, so G=(n,2n). Various E as points and ABCD self-cycles as information carrier in Figure 2 (A,E1,B.E2,C,E3,D,E4), then G=(8,12). Its corresponding matrix is:

$$A_2 = \begin{pmatrix} 1 & 1 & 0 & 0 & 0 & 0 & 0 & 1 \\ 1 & 0 & 1 & 0 & 0 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 0 & 1 & 1 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 1 & 1 \\ 1 & 0 & 0 & 0 & 0 & 0 & 1 & 0 \end{pmatrix}. \quad (2)$$

Figure 3 Represents an extension of hypercycle evolution principle, G=(6,12), and matrix is:

$$A_{30} = \begin{pmatrix} 1 & 2 & 0 & 1 & 0 & 1 \\ 2 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 1 & 2 & 0 & 1 \\ 1 & 0 & 2 & 0 & 1 & 0 \\ 0 & 1 & 0 & 1 & 1 & 2 \\ 1 & 0 & 1 & 0 & 2 & 0 \end{pmatrix}. \quad (3)$$

If the graph of hypercycle is the directed graph, for Figure 3 (I1,E1,I2.E2,I3,E3) the corresponding matrix will be:

$$A_3 = \begin{pmatrix} 1 & 1 & 0 & 1 & 0 & 0 \\ 1 & 0 & 1 & 0 & 0 & 0 \\ 0 & 0 & 1 & 1 & 0 & 1 \\ 0 & 0 & 1 & 0 & 1 & 0 \\ 0 & 1 & 0 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 & 1 & 0 \end{pmatrix}. \quad (4)$$

In Figure 2 the point connectivity k(G)=2, and the border connectivity λ(G)=2. In Figure 3 the point connectivity k(G)=3 except three I, and the border connectivity λ(G)=4. Therefore, based on the graph theory, hypercycle can be defined by a degree of connectivity, which is bigger, corresponds to higher hypercycle.

For general matrix, we set a row as one level cycle, and n columns indicate n kinds of cycles. Constant Γ=1. Variable Γ is m/n. There are 5-level cycles in geoscience, and 5 rows. These levels in geoscience have certain interactions with each other, and n cycles in each layer. They form matrix, which can be directed graph or non-directed graph. Geoscience may apply matrix.

3.3. Some Possible Equations

The dynamics of the elementary hypercycle can be modelled using the following differential equation [28]:

$$\frac{dx_i}{dt} = x_i(k_i + \sum_j k_{i,j}x_j - \frac{1}{\sum_i x_i}\phi), \quad (5)$$

where $k_i = f_i - d_i$. In the equation (5), x_i is the concentration of template I_i; x is the total concentration of all templates; k_i is the excess production rate of template I_i, which is a difference between formation f_i by self-replication of the template and its degradation d_i, usually by hydrolysis; $k_{i,j}$ is the production rate of template Ii catalysed by I_j, and $k_{i,j}$ may be expressed as a matrix; and ϕ is a dilution flux, which guarantees that the total concentration is constant. Production and degradation rates are expressed in numbers of molecules per time unit at unit concentration ($x_i = 1$). Assuming that at high concentration x the term k_i can be neglected, and, moreover, in the hypercycle, a template can be replicated only by itself and the previous member of the cycle. This equation can be simplified to:

$$\frac{dx_i}{dt} = x_i(k_{i,j-1}x_{i-1} - \frac{1}{\sum_i x_i}\phi). \tag{6}$$

In the selection dynamics that is consistent with molecular evolution, the simplest system can be described by Eigen evolutionary differential equations mutually coupled in the form [18]:

$$\frac{dx}{dt} = (A_iQ_i - D_i)x_i + \sum_{k\neq i} w_{ik}x_k + \phi_i. \tag{7}$$

Here the subscript i belongs to all distinguishable self-replication molecular units, which also represents their special genetic information; x_i represent the corresponding population variable or concentration, metabolism is reflected by the spontaneous generation ($A_iQ_ix_i$) and decomposition (D_ix_i) of molecular species, and self-replication appears in the x_i relevant terms of the generation rate; ϕ_i is flux.

In Eqs.(5)-(7), x_i may be replaced by Γ_i, etc. Γ_i can be different cycles of the same level, or be cycles of different levels.

The main parts of the Earth system are incompressible fluids. From the mantle to the atmosphere, both matter and energy flow, so the basic theory is hydrodynamics, and the corresponding nonlinear hydrodynamic equations. Only their parameters and the interactions vary.

Based on general geodynamics [35], the fundamental nonlinear equations of fluid mechanics for Earth with energy-momentum conservation are:

$$\rho\frac{DV}{Dt} = \rho(\frac{\partial V}{\partial t} + V\nabla V) = F_0 - gradp + f. \tag{8}$$

Here the frictional force for Newtonian fluid is:

$$f = \eta\Delta v + (\zeta + \frac{\eta}{3})graddivV. \tag{9}$$

Usual solutions of the nonlinear fluid mechanics are very difficult.

Evolutionary dynamics is a mathematical model according to the definition of hypercycle. This is a nonlinear dynamic system, and in the simplest case. Assumed that it grows at a rate determined by a system of quadratic differential equation, then the

competition between evolving hypercycles can be modelled using the differential equation.

Moreover, these equations can all add some external forces, such as tides caused by the moon, or even alien impacts. Ulrich, et al, researched stress, rigidity and sediment strength control megathrust earthquake and tsunami dynamics [36].

Chaos possesses a chaotic region with 2^n period, and the quasi-period. Different chaotic regions in biological systems form the chaotic hypercycle. It will be a development of hypercycle.

3.4. Some Similar Theories

This may combine the fluid mechanics. A well-known example is that the Lorenz nonlinear equations describe the atmosphere. We may extend Lorenz equations and Lotka-Volterra equations, and by these equations describe periodic or quasi-periodic cycle. Based on the fluid a similar Kirchhoff circuit voltage law can be introduced:

$$\sum I_i R_i = \sum E_i \,. \tag{10}$$

Γ may be analogy of the magnetic field.

d Γ (V,H)/dt may develop to similar Heisenberg matrix equation in quantum mechanics:

$$\frac{dF}{dt} = \frac{\partial F}{\partial t} + [F, H] \,. \tag{11}$$

In the matrix representation of quantum mechanics the matrix corresponds to quantum. It seems to imply a type of quantum biology and the extensive quantum biology [37].

This may develops to the matrix equation and the periodic equation, and combine the quantum equation, the S matrix, and the input-output open model $(E - A)X = B$, etc.

The hypercycle shows the fundamental nature of the self-organization. All basic hypercycle is characterized by the synergistic behaviour of their components. Hypercycle is not the end of evolution, but rather leads to new levels of evolution.

The whole ecosystem is actually a multi-level hypercycle. Individual species cycle (breeding), and n related species cycle. For example, developing from a big tree to the same local area, and then developing to a larger area and the whole region. Human development should all be a hypercycle. Social developing structures can be grouped as large hypercycle. All types of hypercycle in social sciences have all benign or malignant, such as education, economy, legal system, reform, etc. These can all be studied and developed using various methods of hypercycle.

In geoscience as the level increases, the system becomes more and more complex, and this system has more and more cycles. Further, there are various cycles in the social systems, which are linked to the extensive social hypercycle. The urban ecosystems correspond to the dissipative structure theory. The large accumulation of assets and wealth without cycle does not conform to the principles of human social ecology.

Hypercycle may apply to the Yin-Yang, Tai-Ji diagram and Five-Elements, etc., in the Chinese traditional culture. Further is the life-death cycle, and the possible body-mind cycle, body-soul cycle.

This method can be applied, developed and perfected.

4. Nonlinear Whole Geoscience

Based on the nonlinear equations (8) of fluid dynamics in Earth's crust, we obtained a chaos equation, in which chaos corresponds to the earthquake, and shows complexity

on seismology. But, combining the Carlson-Langer model and the Gutenberg-Richter relation, we derived a simplified nonlinear solution of earthquakes [38], and corresponding magnitude-period formula [39, 40]:

$$T = 10^{-b(M_0 - M)} T_0. \tag{12}$$

From Eq.(12) some predictions can be calculated quantitatively and are already tested. Combining the Lorenz nonlinear model, we discussed the earthquake migration to and fro [38]. If various modern scientific instruments, different scientific theories and some paranormal ways for earthquake are combined each other, the accuracy of multilevel prediction will be increased [41, 42, 38]. This formula can not only be applied, but can also be developed and perfected.

Further, we proposed the nonlinear whole seismology and its three basic laws, and researched the topological seismology [38].

Based on the most basic features of modern geoscience, we propose the nonlinear whole geoscience and its three basic laws:

First law: Earth and geoscience as whole is a complex huge system composed of various levels (subsystems).

Second law: Various interactions in geoscience all are nonlinear. Corresponding equations all are nonlinear, and possess chaos and fractals, etc.

Third law: The solar system, even Galaxy as environment is closely related to Earth. The environment of a subsystem is formed from other subsystems. They are regarded as boundary conditions of this system, which have often various nonlinear relations.

Two main characters of geoscience are nonlinearity and whole. Three laws are a whole: Because of complexity, the description of geoscience must apply the nonlinear theory with the interaction terms. In earth system science there are the diversity and complexity of components, the coherence or correlation between components. Nonlinearity produces the whole-emergence.

Generally, we think that the any complex system can all propose the corresponding nonlinear whole theory. This includes nonlinear whole biology and neurobiology [37,43], nonlinear whole medicine [44], and nonlinear whole sociology [45], nonlinear whole ecology [46], etc.

5. Thermodynamics in Geoscience and Possible Entropy Decrease

It is undoubtedly that thermodynamics is very important in science. Not only mechanics, thermodynamic and statistical mechanics, electrodynamics, and quantum mechanics are called the big four major mechanics of theoretical physics, but entropy is considered to be a new world view that dominates the whole world [47]. Although Nimmo discussed thermal and compositional evolution of the core [48], but, it has so often been ignored in geoscience, and is not included in *New Research Opportunities in the Earth Sciences* [29], etc.

Now we research briefly thermodynamics in geoscience. It is certain that the first law of thermodynamics, the conservation of energy must hold. In geoscience heat conduction and the thermal stress still holds. From Eq.(8) the energy equation is:

$$\rho C_V \left(\frac{\partial T}{\partial t} + v\nabla T\right) = k\Delta T + \Phi. \tag{13}$$

The third law of thermodynamics does not exist because the temperature cannot be zero. So the second law of thermodynamics is mainly studied. This should be divided into open systems and isolated systems. It is known that the atmospheric circulation is mainly influenced by the sun. Entropy is different for various levels in geoscience. Mantle and lithosphere have all solid-liquid interconversion such as volcanoes and magma.

Hydrosphere and atmospheric sphere are also rain-snow-ice interconversion and water cycle.

The second law of thermodynamics is based on statistical independence, etc. When these prerequisites do not hold, self-organized structures whose entropy is smaller may be formed. We proposed generally that if interactions, fluctuations and its magnified exist among various subsystems of an isolated system, entropy decrease in the isolated system will be possible [49, 50], which includes physics [51-53], chemistry [54], biology [55, 56], astronomy [57] and social sciences [58-60]. For attractive process, internal energy, system entropy, and nonlinear interactions, etc., an isolated system may form a self-organized structure with lower entropy. Some possible entropy decreases are calculated quantitatively [50, 53].

We discuss possible entropy decrease in various Earth's evolutions. The evolutionary history of Earth affirms that Earth has evolved from an environment of main magma ocean to a human-friendly environment dominated by plate.

The general physical evolution is also from high temperature to low temperature, from gas, liquid to semi-solid. The order degree always increases, so entropy should decrease.

$$dS = \frac{dE}{T} - \frac{dE_0}{T_0} = \frac{T_0 dE - T dE_0}{T_0 T} . \tag{14}$$

If $T_0 dE - T dE_0 > 0$, dS>0; if $T_0 dE - T dE_0 < 0$, dS<0. If energy E is invariant, it will be dS>0.

For entropy in fluid mechanics, generally high temperature liquid entropy is larger, while low temperature solid entropy is smaller [61]. Between the liquid and solid states is a mantle with convection.

The year-round climate cycle originates from the Earth's movement around the Sun. But the long-time-scale climate cycle is still being explored. The periodicity of climate change corresponds to the periodicity of entropy change.

We discuss the thermodynamics with geomagnetic field. Its basis is the magnetothermodynamics [62], and the energy equation is:

$$dU = TdS + \mu_0 VHdM . \tag{15}$$

Here μ_0 is magnetoconductivity. Entropy of a simple magnetic matter is:

$$dS = \frac{c_H}{T} dT + \mu_0 V (\frac{\partial M}{\partial T})_H dH . \tag{16}$$

Experiments point out that for paramagnetic materials $\mu_0 > 0$, and $(\frac{\partial M}{\partial T})_H$ is always negative. Therefore, when the exoheat dH is positive, so TdS<0. Since T>0, so dS<0.

If the Earth is assumed to resemble paramagnets, then entropy decrease will appear probably. Moreover, for magnetic field there has the negative temperature [61,63], namely, entropy decrease [51]. And the geomagnetic pole will also change.

So far, except the microscopic statistics and quantum mechanics, three major mechanics of geoscience has been discussed.

The mantle circulation originates from the residual native heat when the Earth formed and the radioactive heat inside the Earth, and the rock cycles are mainly driven by plate tectonic processes [4]. They are all internal mechanisms. However, the basic characteristics of Earth are: 1. As a whole, the approximate system is an isolated system, which resembles the Galaxy as an isolated system [64]. 2. There are various complex

internal interactions. 3. There are extremely strong external interactions under certain special conditions, such as the Permian-Triassic mass extinction [65, 66] and dinosaur extinction probably caused by giant alien impacts.

In geoscience the highest level is biosphere and human society, which have many cycles. Entropy is very important in sustainable development. The cycle of resources is also an important aspect of sustainability. In summary, sustainability must reduce the rate of entropy increase [67, 68], and even entropy decrease [59, 60].

Although the Earth can be influenced by the sun's gravity and magnetic field, cosmic lines, etc., it can be approximated as isolated systems with nonlinear complexity. But, main interactions in Earth are internal, such as changes in the interior and surface of the crust. Earth can increase in heat and entropy, or become cold, such as multiple ice ages. Both are opposite, and cannot be always entropy increases. It should have two directions of entropy increase or entropy decrease, at least in different periods. For Earth some complex interacts among different levels are all internal interactions [1-4].

Although the total entropy for whole system is positive and increase possibly, but, so long as different entropy states for any systems exist, entropy should decrease in transformation process from a higher entropy state to a lower entropy state (in Figure 4 from A to B), for example, from chaos to order, from war to peace and so on [52,53,60]. If this system is isolated, it will correct and develop the second law of thermodynamics. Sustainable development must study the mode of social development from high entropy to low entropy.

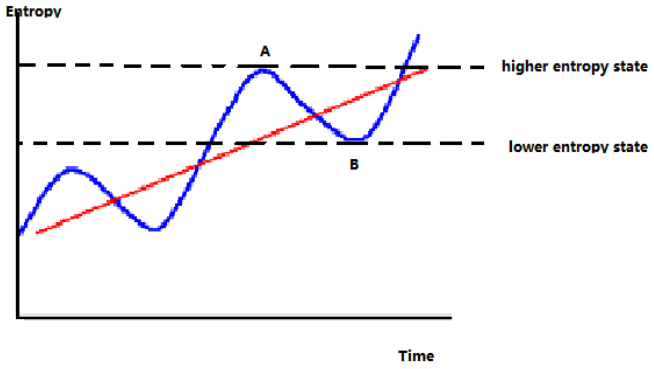

Figure 4. Transformation processes between states with higher entropy and lower entropy

6. Discussion

An open system corresponds to the dissipative structure theory; the disorder results can lead to chaos. In geoscience the local regions are all open systems, but for some systems can be approximated as isolated systems, or plus environments, for example, surrounded by cities, islands, etc. Under some conditions, entropy decrease can be achieved by regulating internal interactions, such as entry into wartime systems.

In a word, various cycles in geoscience cannot all be entropy increases, and cannot all be originated from the external interactions.

Wegener first presented his theory in lectures in 1912. This study is also commemoration 110th anniversary of great scientist Wegener and his very advanced theory.

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