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Global vegetation change analysis based on MODIS data in recent twelve years①

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Abstract

Vegetation cover change is critical for understanding impacts and responses of vegetation to climate change. A study found that vegetation in the regions between 45°N-70°N was increasing using normalized difference vegetation index (NDVI) from 1981 to 1991 ten years ago. The global vegetation growth has changed because of climate change in recent twelve years (2001 – 2012). After thorough analysis based on satellite data, it is found that it is evident that the global vegetation changed (NDVI) little, and it is increasing slightly in Northern hemisphere while it is decreasing slightly in Southern Hemisphere. For different latitudes, vegetation is increasing 0.17% every year from 60°N to 70 °N ($R^2 = 0.47$, $P > 0.013$), while the vegetation is decreasing 0.11% every year from 10°N to 10°S ($R^2 = 0.54$, $P > 0.004$). For different continents, the vegetation in South America is decreasing 0.16% every year ($R^2 = 0.78$, $P > 0.0001$) and it is increasing 0.05% every year in Asia ($R^2 = 0.28$, $P > 0.072$) and 0.25% every year in Oceania ($R^2 = 0.24$, $P > 0.1$). The analysis of global vegetation in different seasons indicates that spatial distribution of global temperature and water vapor will affect the spatial distribution of vegetation, in turn, the spatial distribution of vegetation will also regulate the global temperature and water vapor spatial distribution at large scale. The growth and distribution of vegetation are mainly caused by the orbit of the celestial bodies, and a big data model based on gravitational-magmatic change with the solar or the galactic system as its center is proposed to be built for analyzing how the earth's orbit position in the solar and galaxy system affects spatial-temporal variations of global vegetation and temperature at large scale. These findings promise a holistic understanding of the global climate change and potential underlying mechanisms.

Key words: vegetation, global, climate change, remote sensing

0 Introduction

Vegetation is the main part of terrestrial ecosystem, which is a bridge among the atmosphere, biosphere and soil. Solar radiation is the source of energy for plant photosynthesis, and vegetation is also the main source of heat storage, which affects the growth rate of vegetation directly. The heat capacity transferred from solar radiation is determined largely by the vegetation types. NASA has two polar-orbiting Earth Observing System (EOS) satellites (Terra and Aqua) in orbit at all time. One of the primary purposes of the EOS program is to study the role of terrestrial vegetation in large-scale global processes with the goal of understanding how the Earth functions as a system. The NDVI of MODIS data is robust, empirical measures of vegetation activity at the land surface. It is designed to enhance the vegetation reflected signal from measured

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spectral responses by combining two wavebands, in the red (wavelengths 0.62 ~ 0.67μm) and NIR wavelengths (0.84 ~ 0.87μm) regions. NDVI is strong with the fraction of photosynthetically active radiation (wavelength 0.4 ~ 0.7μm) absorbed by vegetation[1-3]. Numerous studies have shown that there is a linear relationship between green vegetation fraction and NDVI[4-12]. Thus the change of NDVI can also be used to present the change of vegetation cover and growth.

1 Materials and methods

The National Aeronautics and Space Administration (NASA) provides global NDVI product MOD13C2 data, which are cloud-free spatial composites of the gridded 16-day 1-kilometer MOD13A2, and are provided monthly as a level-3 product. Cloud-free global coverage is achieved by replacing clouds with the historical MODIS data. Version-5 MODIS/Terra Vegetation Indices products are validated, meaning that accuracy has been assessed over a widely distributed set of locations and time periods via several ground-truth and validation efforts. Mean monthly NDVI is used to analyze the distribution of the vegetation. There is a linear relationship between green vegetation fraction and NDVI[4-12]. So it can be speculated the change of vegetation cover through the change of NDVI. Eq. (1) is used to estimate statistical average of NDVI in global and regional scale.

$$NDVI_m = \frac{1}{n}\sum_{i=1}^{i=n}\sum_{j=1}^{j=m} S(j)NDVI_{ij} \qquad (1)$$

where $NDVI_m$ is the mean of NDVI, i is the number of day every year, j is the number of pixel, $S(j)$ is the area weighting function of the pixel j which is obtained from the model of earth, $NDVI_{ij}$ is NDVI in *ith* day for the same location. Statistical average ($NDVI_m$) can be used to characterize the vegetation coverage in global and region scale. Eq. (2) is used to estimate the rate of vegetation (NDVI) from 2001 to 2012[13].

$$Slope\_Rate = \frac{n\sum_{k=1}^{n}(k \times NDVI_{mk}) - \sum_{k=1}^{n}k\sum_{k=1}^{n}NDVI_{mk}}{n \times \sum_{k=1}^{n}k^2 - (\sum_{k=1}^{n}k)^2} \qquad (2)$$

$Slope\_Rate$ is change rate, k is the number of year, $NDVI_{mk}$ is the mean NDVI of kth year, and n is 12.

2 Results

Statistical analysis is condusted for global (except Antarctica) in different regional scale from 2001 to 2012. Fig. 1(a) is the global mean land NDVI. Which is 0.384, and change trend of global vegetation is weak and insignificant in recent twelve years. Fig. 1(b) is the mean NDVI of northern hemisphere, and the mean NDVI is 0.342. The vegetation is increasing slightly in northern hemisphere. Fig. 1(c) is the mean NDVI of southern hemisphere, and the mean NDVI is 0.506. The vegetation is decreasing slightly in southern hemisphere.

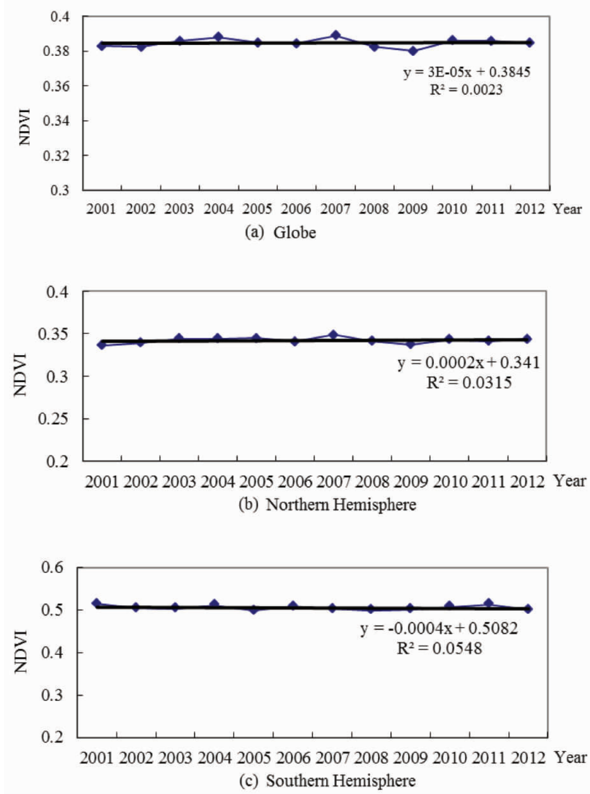

Fig. 1 (a) The mean NDVI of Globe, (b) Northern Hemisphere, (c) Southern Hemisphere from 2001 to 2012

Mynenl, et al. found that the vegetation in the regions between 45°N-70°N was increasing using NDVI from 1981 to 1991[2]. Now the vegetation growth has been changed because the climate changes. Shown from Fig. 2, the change of mean NDVI in different latitudes is different. The vegetation is increasing 0.17% ever year from 60°N and 70°N ($R^2 = 0.47$, $P > 0.013$), while the vegetation is decreasing 0.11% from 10°N to 10°S ($R^2 = 0.54$, $P > 0.004$). The vegetation is increasing slightly in 10°N ~ 40°N and 20°S-30°S, while the vegetation is decreasing slightly in 40°N ~ 50°N, 10°S ~ 20°S, 30°S ~ 60°S.

For different continents, the vegetation change is also different (see Fig. 3). The vegetation in South America is decreasing 0.16% every year ($R^2 = 0.78$, $P > 0.0001$) and it is increasing 0.05% every year in

Asia ($R^2 = 0.28$, $P > 0.072$) and 0.25% every year in Oceania ($R^2 = 0.24$, $P > 0.1$). The vegetation in North America, Africa, and Europe are decreasing slightly.

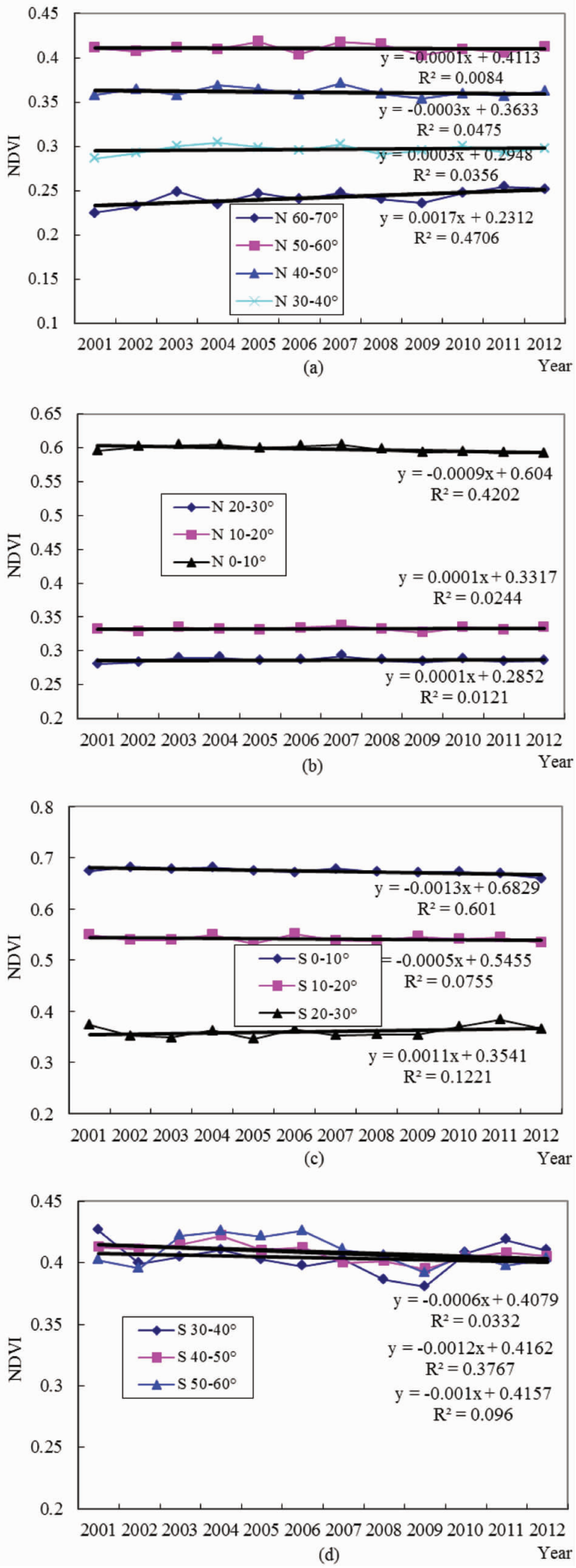

Fig. 2 The mean NDVI of different latitude from 2001 to 2012

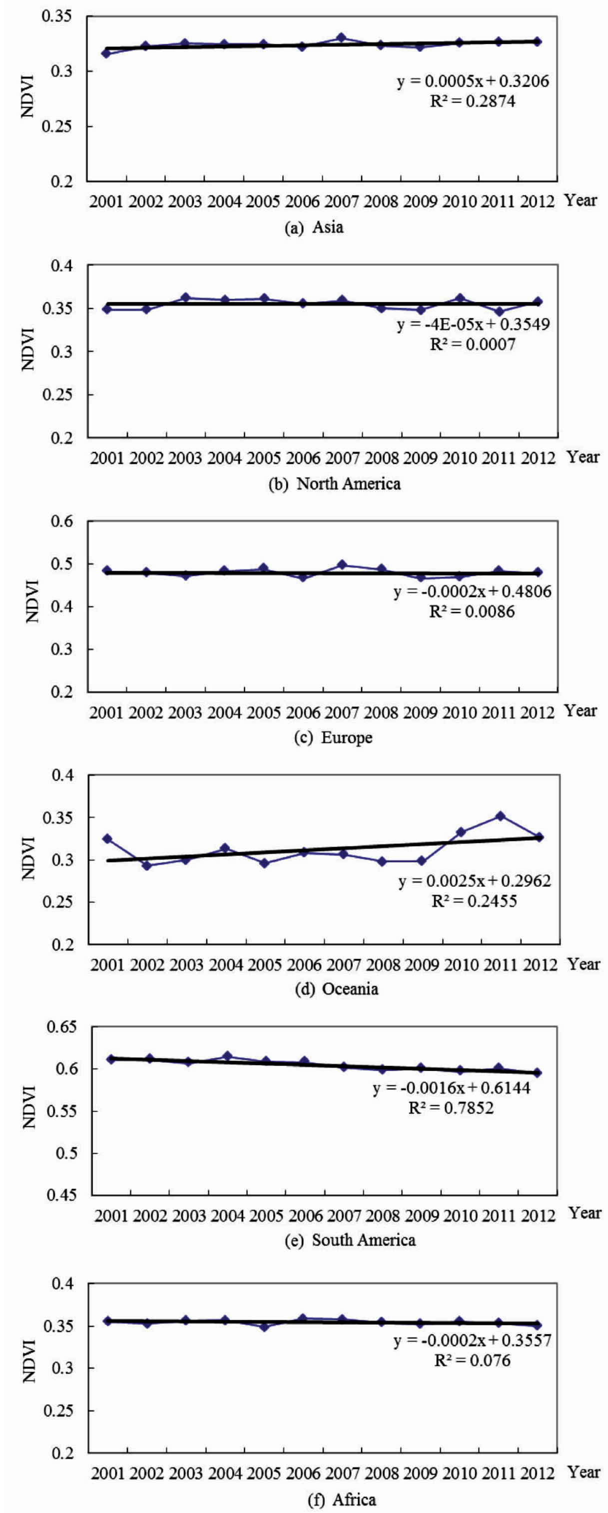

Fig. 3 The mean NDVI of six continents from 2001 to 2012

The spatial variations of global average of the vegetation (NDVI) from 2001 to 2012 are shown in Fig. 4(a). The high concentration of vegetation is mainly in South America and the central regions of Africa. In order to get the global change rate of vegetation in detail, a linear regression has been made for every pixel from 2001 to 2012, and the slope rate Eq. (2) is used to represent the change rate of vegetation (Fig. 4(b)). The vegetation in high latitude regions (especially in Russia), the eastern region of China, the western regions of Indian peninsula, eastern regions of Australia, North-eastern regions of North America, and the southern tip of Africa are increasing. The vegetation in central regions of Africa, South America, western regions of Australia, south-east regions of America, western regions of Asia are decreasing.

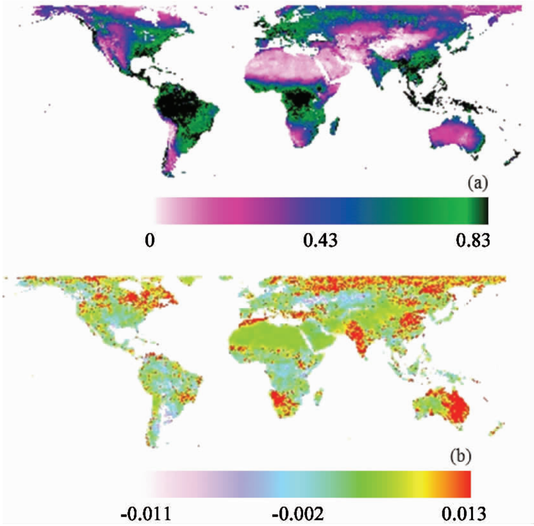

Fig. 4 (a) The distribution of mean NDVI from 2001 to 2012, (b) Rate of NDVI change from 2001 to 2012, shown as the slope of a linear regression

The seasonal variations of the NDVI from 2001 to 2012 are further analyzed, and the results are given in Fig. 5. It is interesting to find that the vegetation changes are very obvious from spring (March to May) to winter (December to January) in northern hemisphere. On the contrary, the vegetation changes with the seasons change are not obvious in the southern hemisphere. Most of vegetation is distributed in North and South Americas, North Asia, central Africa and Southeast Asia, while vegetation is relatively less in the northern part of North Africa, Western Australia and West Asia. In spring, vegetation is relatively very large in Europe, South America and central Africa. In summer, the vegetation grows very fast in North America and North Asia. In autumn, the vegetation began to decrease in north hemisphere, while vegetation began to increase in south hemisphere. In winter, vegetation is at the minimum in the northern hemisphere, while vegetation is at maximum in the southern hemisphere.

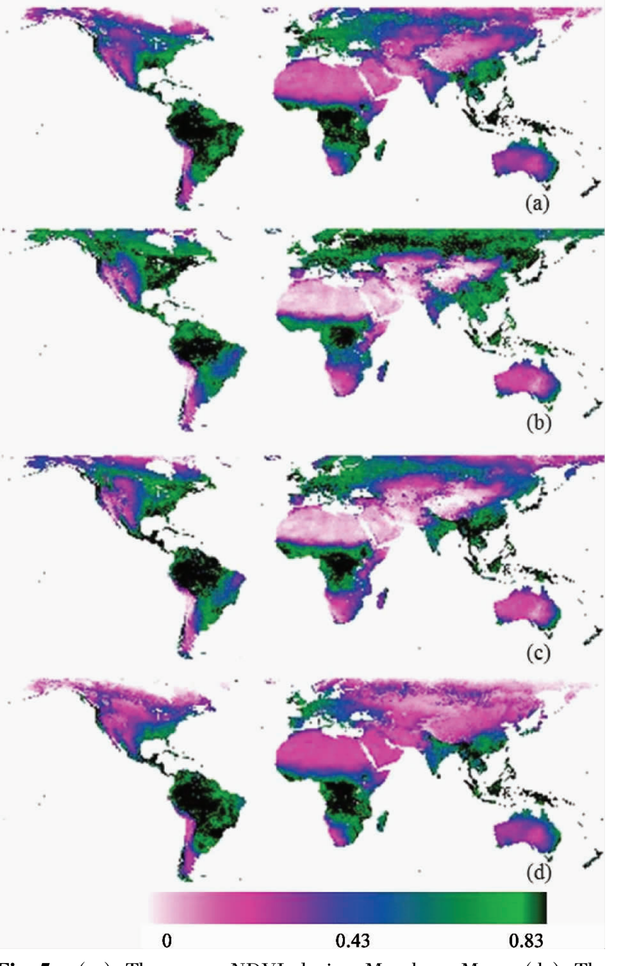

Fig. 5 (a) The mean NDVI during March to May; (b) The mean NDVI during June to August; (c) The mean NDVI during September to November; (d) The mean NDVI during December to February in the last ten years

The change trends of the global NDVI (Vegetation) by seasons in the last decades are given in Fig. 6. A year- round increasing trend would be found in the north-east part of North America and Eastern Australia. It is increasing obviously in North Asia in spring and autumn. There is a clear increasing trend in the west of Indian peninsula and north China from summer to winter, while there is an obviously decreasing trend in the south of south America and near the equator regions in the whole year. Humans have little impact on the change of the spatial distribution of vegetation at global scale, which is mainly affected by temperature changes, and water vapor content. Shown from Fig. 5 and Fig. 6, the seasonal variations of vegetation are determined by the earth's revolution. The vegetation growth and distribution are mainly affected by temperature changes and water cycle. Mao et al.[14,15] made an analysis for global surface temperature and global water vapor content, and they found that the surface temperature and water vapor content in North high latitudes are increasing which is the main reason for the increasing of vegetation in North Asia. The vegetation is decreasing 0.11% in the equatorial regions from 10°N to 10°S and the water vapor content is also decreasing in this region. Shown from Fig. 7, the global vegetation change is the bridge among the temperature and water vapor content and CO_2, and global vegetation through the water vapor and carbon dioxide to regulate the global temperature change. In fact, the change of global temperature and water vapor content is also influenced by the earth's rotation and revolution which affects the growth and development of vegetation through the effects of respiration and photosynthesis. Therefore, a theory is put forward that the

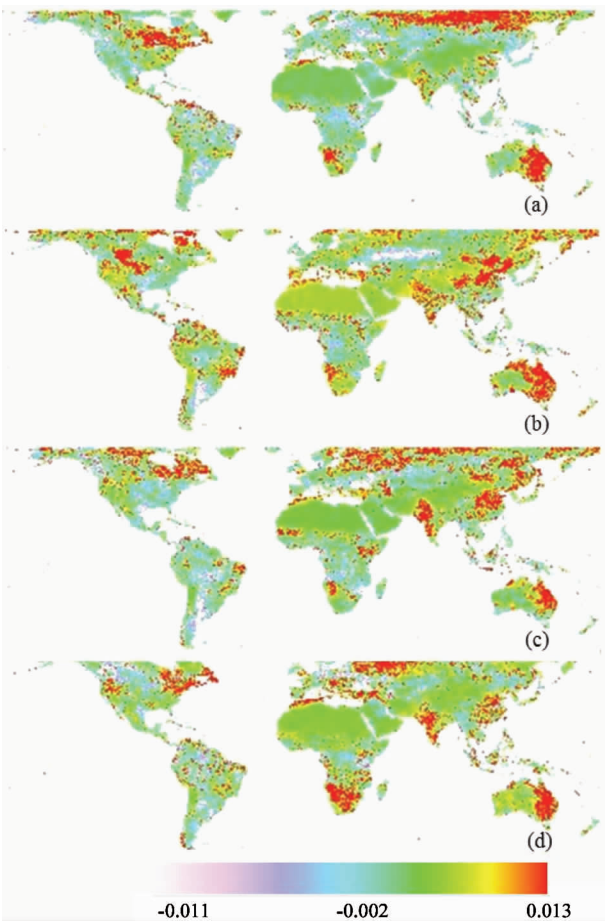

Fig. 6 The overall change rate of the NDVI by seasons from 2001 to 2012: (a) March to May; (b) June to August; (c) September to November; (d) December to February

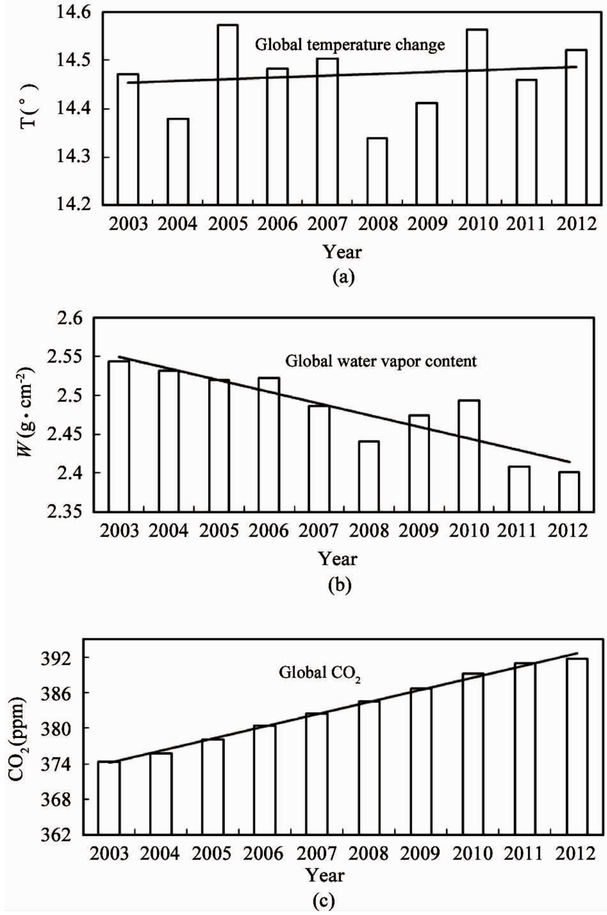

Fig. 7 (a) The Global surface temperature; (b) Global water vapor content; (c) Global CO2 from 2003 to 2012

growth, temporal and spatial variation, appear and disappear of vegetation (including other species) are mainly determined by the variation of orbit of celestial body (like Fig. 8), because magnetic field and gravitational field changes of celestial body influence the atoms and molecules of each species. The study of ecological systems (especially for temporal and spatial variation of vegetation) should be divided into three levels.

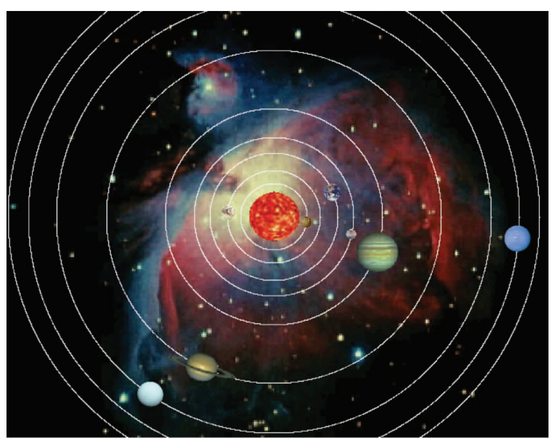

Fig. 8 Solar system simulator provided by Moose O'Malley

The first level is that the respiration and photosynthesis of vegetation is mainly influenced by the earth's rotation, and the second level is that the temporal and spatial variation of growth of vegetation are mainly determined by the revolution of the earth, and the third level is that the appear and extinction of vegetation (including other species) are determined by the revolution of sun and other planets. These three levels interact with each other, but the latter level determines the previous level. It is proposed to build a big data model based on gravitational-magmatic change with the solar or the galactic system as its center, and the thought of this model is that the climate and ecosystem change such as temperature and water cycle are mainly determined by the earth's orbit position in the solar and galaxy system which indirectly affects the temporal and spatial variation of vegetation at large scale. Part of ideas and discourses has been described in the paper[16]. Because of the long running cycle of stars, People have not enough observation data, and extreme climate change cycle can be used to reverse the motion of the celestial bodies and discover new objects. Building the complex climate change model and the ecological species evolution model based on the orbit of the celestial body with big data method is the trend in the future. The theory for studying spatio-temporal change of climate and ecological system provides a new research direction, which is very important to study climate change, disaster prediction and ecological species evolution.

3 Conclusions

Many reports suggest that extreme floods, heat waves, droughts, and wildfires that occurred on a global scale over the past decade might be exacerbated by climate change[17]. The vegetation cover change is critical for understanding the impacts and responses of vegetation to climate change. After thorough analysis based on satellite data, this study finds evident that the global vegetation change little, and it is increasing slightly in northern hemisphere while it is decreasing slightly in southern hemisphere. For different latitudes, the vegetation is increasing every year from 60°N to 70 °N, while the vegetation is decreasing from 10°N to 10°S. For different continents, the vegetation in South America is decreasing and it is increasing in Asia and Oceania. This comprehensive examination of vegetation changes promises a holistic understanding of the global climate change and potential underlying mechanisms. The main reason of vegetation change at small scale is determined by climate change, such as drought, and the second reason is human destruction. The distribution and grows of vegetation at large scale are different for different regions, and the main reasons are the change of global surface temperature and water cycle which are mainly determined by the earth's orbit position in the solar and galaxy system. Finally, a theory is put forward that the growth, temporal and spatial variation, appear and disappear of vegetation (including other species), and global temperature are mainly determined by the variation of orbit of celestial body, and three levels study of big data model based on gravitational-magmatic change should be made in the future research. More research should be done which will be reported in the future.

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