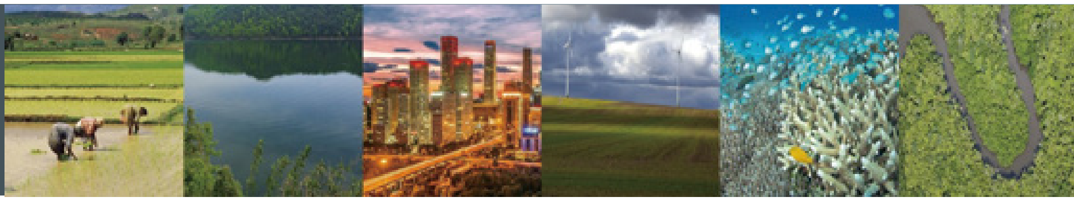
Big Earth Data Report (2018)

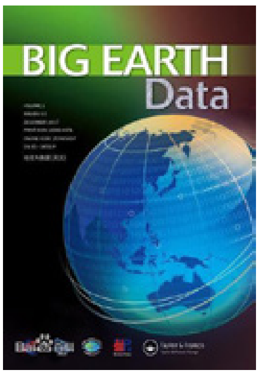
Strategic Priority Research Program (Class A) of the Chinese Academy of Sciences (CAS)

BIG EARTH DATA

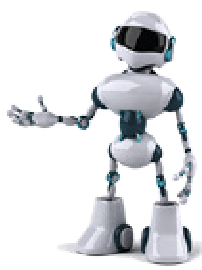
Science Engineering Project (CASEarth)

CONTENT




BIG EARTH
Data


nature COMMENT
Steps to the digital Silk Road



MESSAGE FROM CHIEF SCIENTIST

Big Earth Data refers to the data in the field of Earth sciences with spatial attributes, especially massive ground observation data acquired from satellites and airborne sensors. These data sources mainly include large-scale scientific experimental devices, detection equipment, sensors, socioeconomic observations, and computer simulations. It has strong spatio-temporal connections and physical linkage, with controllable data generation methods and sources.

The Big Earth Data Science Engineering Project (CASEarth) was officially launched in January 2018 as a Strategic Priority Research Program (Category A) of the Chinese Academy of Sciences (CAS). It aims at integrating data and technologies from relevant institutes at home and abroad, building a cloud-based international Big Earth Data platform to provide long-term, high quality, and stable data and information services for decision-makers and researchers with cloud platform and high-performance computing. The Big Earth Data system consists of biosphere, hydrosphere, cryosphere and atmosphere subsystems, as well as regional subsystems such as the Belt and Road region and China.

In 2018, CASEarth made early achievements that facilitated scientific discovery, decision-making, and data sharing and integration based on Big Earth Data platform. This annual Big Earth Data Report focuses on the milestones in platform development, data sharing, decision support and scientific discovery in the year. The report consists of “Big Earth Data Technical Report,” “Data Sharing Report” and “Big Earth Data in Support of the Sustainable Development Goals.” The General Report includes CASEarth annual highlights and 8 projects, focusing mainly on major output and international influences. Three special reports discuss the key technology and systematic modules of CASEarth, data sharing technology, regulations and standards at the level of CASEarth and even the CAS, and methods and case studies in Big Earth Data supporting the 2030 Sustainable Development Goals.

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▶ Introduction to CASEarth

The challenges of global climate change and sustainable development require precise, scientific, and timely decision-making systems, with comprehensive and innovative technological support in the field of resource management, environmental science, biology and ecology. Big Data is becoming the new driver of scientific discovery, technological innovation and discipline development. Big Earth Data is big data in the field of Earth sciences with spatial attributes, and Earth observation is an important source of Big Earth Data. CASEarth encourages interdisciplinary research, which will give full play to integrated data and bring innovative scientific methodologies and research perspectives.

CASEarth aims at removing bottlenecks concerning data access and sharing, and developing a multidisciplinary Big Earth Data Service Platform, forming a CASEarth Platform driven by big data with global coverage, providing panoramic display and dynamic understanding of the underlying development process along the Belt and Road region, and enabling accurate assessment and decision support towards the realization of The Beautiful China Initiative. CASEarth will also explore new big data-driven, multidisciplinary, globally collaborative paradigm of scientific discovery, and showcase as well as spur breakthroughs in Earth system sciences, life sciences, and associated disciplines, constructing an international Big Data Science Center with global influence, comprehensively improving the major achievements in supporting national technological innovation, scientific discovery, macro-decision-making and public dissemination.

Research Objectives and Annual Goals

Guided by its mission, CASEarth has set up 9 projects including CASEarth Satellites, Big Data and Cloud Service Platform, Biodiversity and Ecological Security, 3-D Digital Ocean, Interconnected Three poles Environment, Digital Earth Science Platform, and CASEarth Administration. In accordance with four major themes of technological innovation, scientific discovery, macro decision-making and knowledge dissemination, CASEarth aims to integrate data on resource and environment, ecology and biology, social statistics, aviation, from satellites, navigation and ground surveys, using big data technology to establish Big Earth Data and Cloud Service Platform, Digital Earth Science Platform, Digital Belt and Road Decision Support System, Evaluation System for “Beautiful China”, and BioONE Biodiversity and Ecological Safety Information Sharing Platform.

CASEarth has gathered over 1200 scientists in the fields of biology, ecology and environmental science, as well as computer engineering, network engineering, cloud technology and remote sensing, including 9 Academicians of CAS.

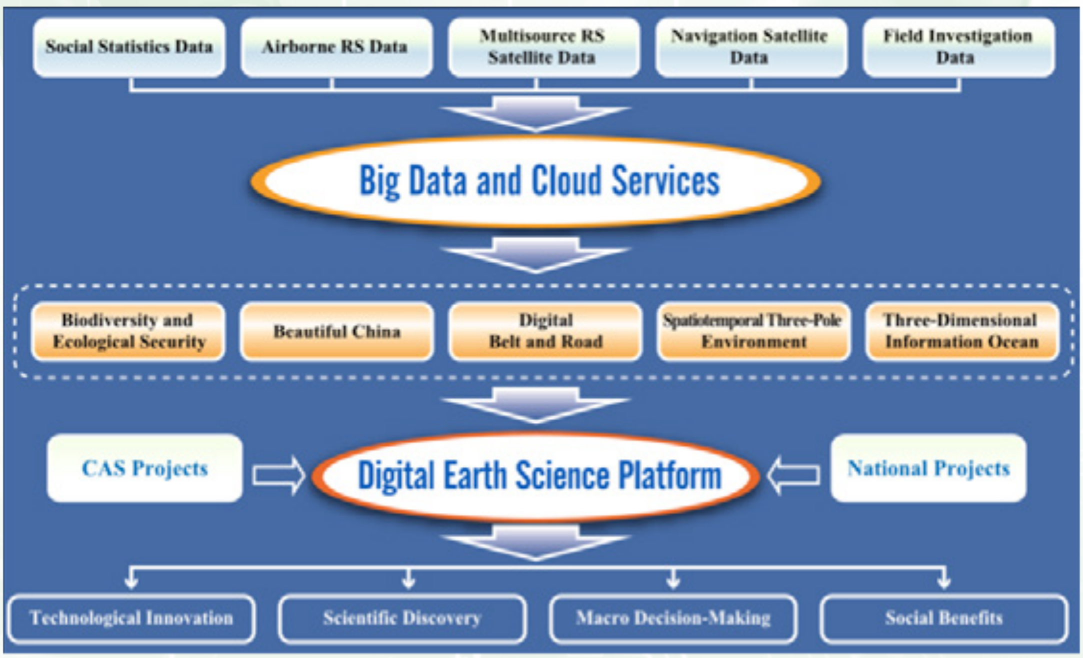

Fig.1 Framework of CASEarth

Research Objectives and Overall Design

Research Objectives

The overall objective of CASEarth is to establish an International Science Center for Big Earth Data to facilitate technological innovation, scientific discovery, and high-level decision support.

Building the state-of-the-art Big Earth Data infrastructure. To remove the bottlenecks of data access and sharing, CASEarth will develop a multidisciplinary Big Earth Data and cloud service platform, which will operate as a part of national major S&T data infrastructure to support national macro-level decisions and to promote major scientific discoveries.

Forming an innovative Big Earth Data platform to drive the development of relevant disciplines. CASEarth explores the new big data-driven, multidisciplinary, globally collaborative paradigm of scientific discovery, illustrating and spurring breakthroughs in Earth system sciences, life sciences, and associated disciplines.

Constructing a decision support system. The system will provide panoramic display for understanding the sustainable development process along the Belt and Road, enable accurate assessment and decision support for Beautiful China Project, and contribute to the establishment of Digital China.

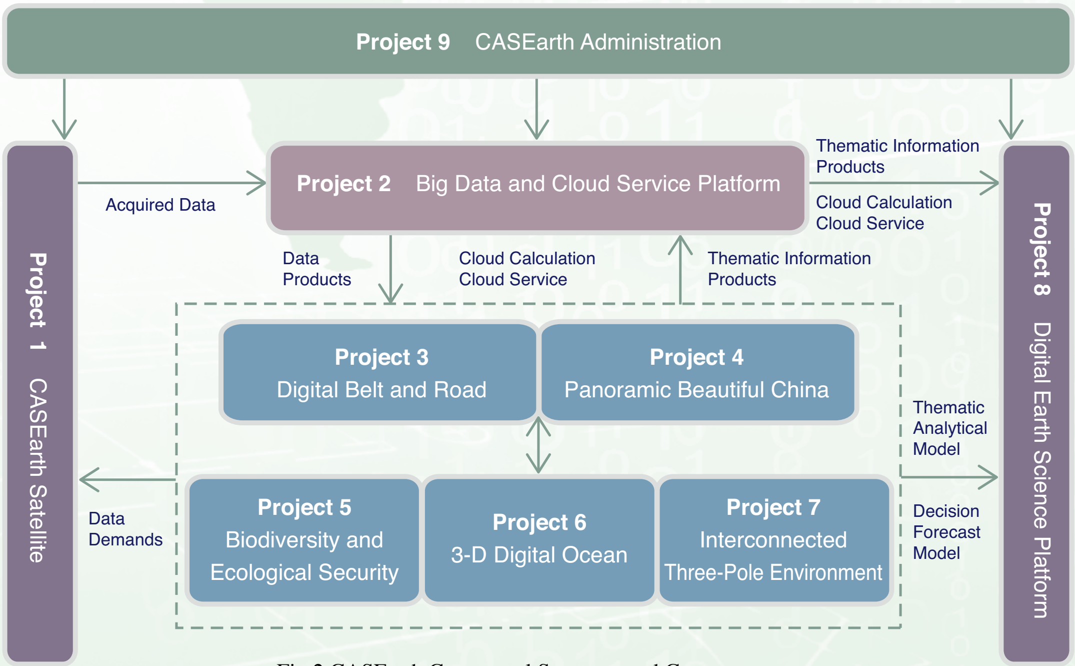

Fig.2 CASEarth Conceptual Structure and Components

CASEarth Overall Design

CASEarth consists of the following nine research components: CASEarth Satellite, Big Data and Cloud Service Platform, Biodiversity and Ecological Security, 3-D Digital Ocean, Interconnected Three poles Environment, Digital Earth Science Platform, and CASEarth Administration.

The CASEarth Satellite will provide reliable onboard satellite data tailored for the project; The Big Data Cloud Service Platform will build an innovative platform that integrates data storage, computing and analysis that connects different components in the field of Earth Science; Digital Belt and Road project will form “Big Earth Data Sharing Platform” to provide decision-making support for Belt and Road Initiative; The Panoramic Beautiful China will carry out research on the background and distribution of resources and environment, clean air and environmental health, as well as the ecological protection, realizing the big data-driven evaluation and support for Panoramic Beautiful China; Biodiversity and Ecological Security Platform fully integrates the biological and ecological information resources in CAS, and provides scientific support; The 3-D Digital Ocean will produce multidisciplinary marine scientific data products which will be real-time updated and open to the public. It aims to make breakthroughs for the advances of marine science and technologies, and to enhance people’s understanding of the ocean and the Earth system; The Interconnected Three-Pole Environment focuses on Three-Pole ecology, water, climate change, Arctic waterways and cryosphere etc., providing decision support for national polar governance and Arctic development; The Digital Earth Science Platform, once completed, will serve as a comprehensive Big Earth Data management, analysis, and outreach platform for CASEarth and its decision support, while CASEarth Administration provides the top-level, planning, overview, guidance monitoring and management responsibilities of the entire project.

The advantages of CAS, the openness and long term maintenance of the system and the arrangement of the nine projects require major outputs in three aspects: technological innovation, scientific discovery and decision support.

Technology Innovation

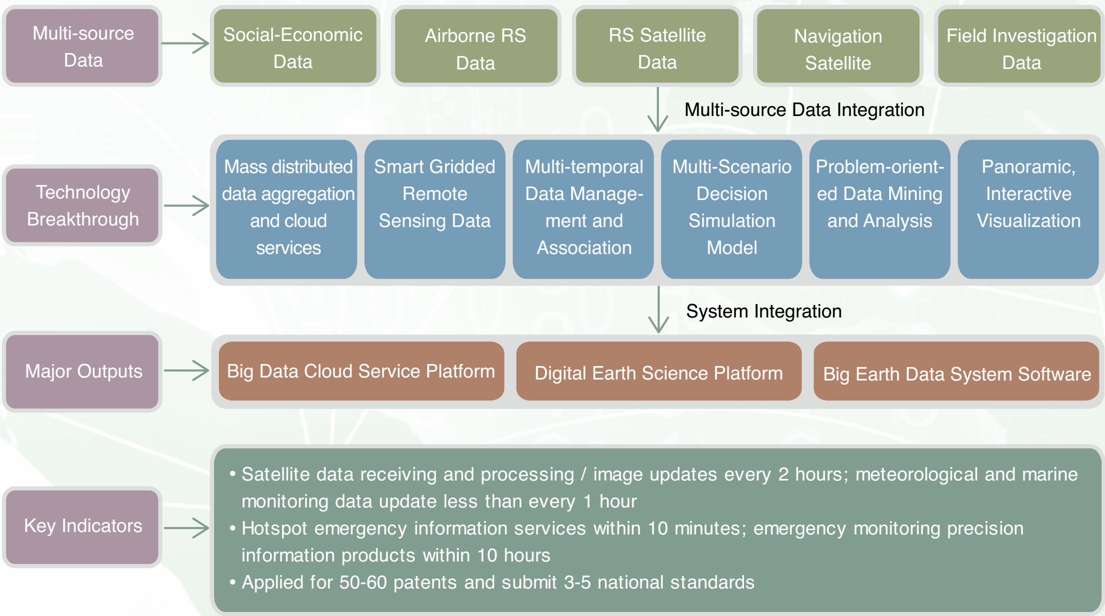

Fig.3 Technology Innovation

Based on CASEarth Satellite, Big Data Cloud Service Platform and Digital Earth Science Platform, CASEarth will construct Big Earth Data micro-nano observing satellites, a state-of-the-art Big Earth Data Service System, a Resource System with massive Big Earth Data and the Digital Earth Science Platform. The state-of-the-art Big Earth Data Service Platform will be constructed with 1P computing capacity, 100 PB storage, 100 billion-level metadata, EB-level data service capacity and 3-5 computing engines and mining & analysis engines; the Resource System with massive Big Earth Data will be equipped with interconnected data that is dynamically updated and over 10PB data resources with integrated management and automatic distribution on demand; the Digital Earth Science Platform with continued impact will be realized through the development of key technologies such as rapid cross-domain support, data-driven service, relationship visual analysis and comprehensive service organization.

Research Objectives and Annual Goals

Scientific Discovery

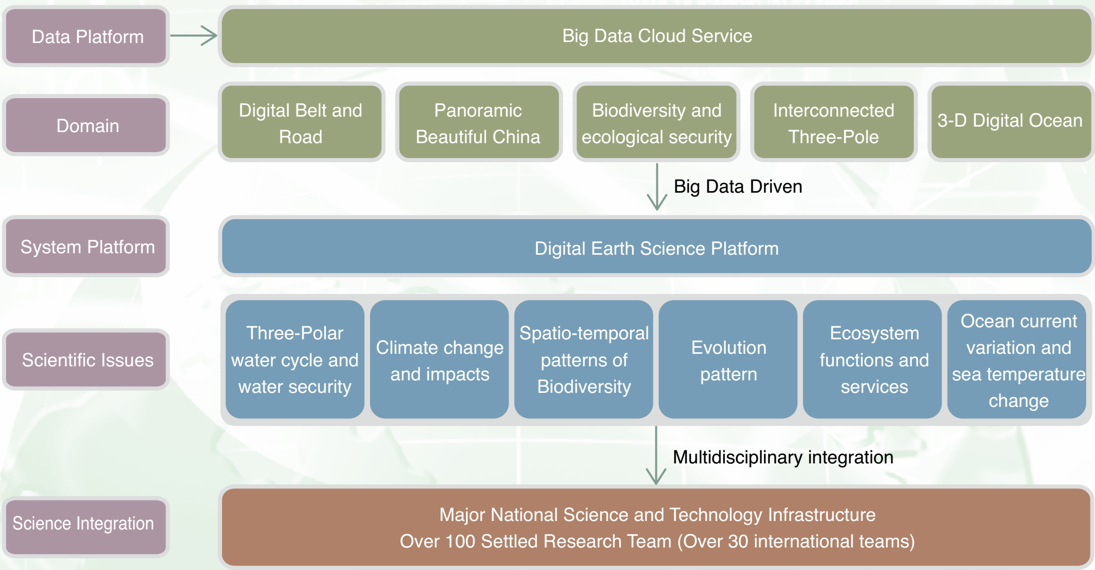

Fig.4 Scientific Discovery

In order to support big data-driven scientific discovery and decision-making, CASEarth will build a set of customized analysis tools for the development of five projects – Digital Belt and Road, Panoramic Beautiful China, Biodiversity and Ecological Security, Interconnected Three Poles Environment, and 3-D Digital Ocean. This will be realized through the design and deployment of a global Big Earth Data Resource Library and cloud service platform, bringing together a large number of multi-source scientific data accumulated in the fields of biology, ecology, resources, environment, etc. of CAS, as well as the integrated Big Earth Data, and making full use of big data technology and new methods of analysis & mining. Digital Earth Platform and Decision Support System – the comprehensive display platform for CASEarth and its decision support will introduce relevant information from big data and cloud service platform, access application model from related projects and manage them, and realize information integration, cross analysis and display in a unified environment, so as to resolve frontier scientific problems related to three-polar water circulation and future water safety, three-polar climate change and its influence on China, ecosystem functions and service dynamics, bio-diversity and its pattern succession, the spread of major infectious animal borne diseases and pathogen evolution mechanisms, ocean circulation anomaly and sea temperature variation. With the support of multi-disciplinary data and methods, major output such as changes in the earth's three poles ecological environment and its mechanisms, biodiversity hotspots, and protection measures for endangered species have been formed, achieving the goal of constructing the international Big Earth Data Science Center as a Major national science and technology infrastructure.

Decision Support

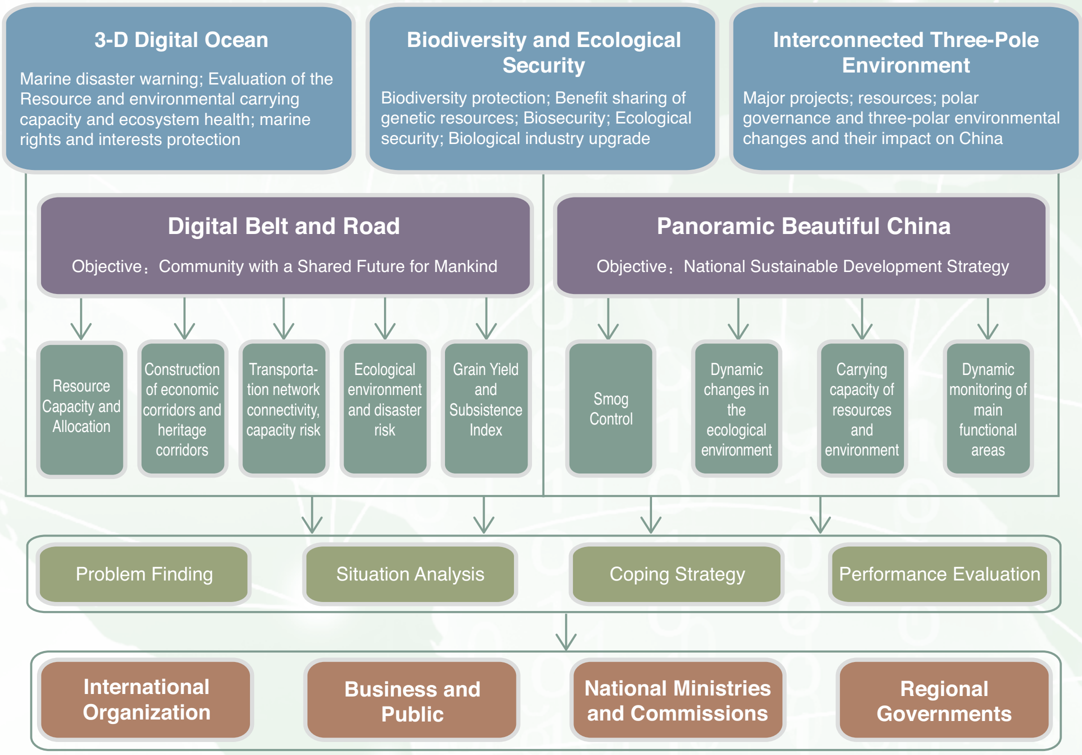

Fig.5 Macro-Decision Support

CASEarth will provide decision support through a four steps process of research and analysis. The first step includes research on marine disaster early warning, resource and environmental carrying capacity, ecosystem health assessment and maritime rights and interests based on the 3-D Digital Ocean project; research on biodiversity protection, benefit sharing of genetic resources, bio-safety, ecological safety, bio-industrial upgrading based on the Biodiversity project; major projects and research on the influence of resource, polar region governance and three poles environmental change. These will provide resource, environment, ecology and biology information products to support the decision making of BRI, Panoramic Beautiful China and other major initiatives. On the second level, in order to achieve the United Nations Sustainable Development Goals (SDGs), the goal of constructing the Community with a Shared Future for Mankind along the Belt and Road, and the sustainable development goal of the Panoramic Beautiful China, CASEarth will conduct dynamic monitoring and research on resource, grain yield estimation index, food and clothing, smog control, dynamic change of ecological environment, as well as resource and environmental carry capacity. The third level would be problem-finding, situation analysis, coping strategies and performance evaluation. On the fourth level, the data and products generated by research in previous steps will facilitate decision making by providing information and methodological support for international organizations, national ministries and local governments.

Accomplishments of CASEarth in 2018

CASEarth Research: we have formulated a technical framework, set Big Earth Data sharing policies and CASEarth Data Standard; Developed a data evaluation system and realized data integration; Designed the framework of CASEarth DataBank, formulated the Data Standard, and developed the data engine.

Data Sharing: Formulated a policy system and specific plan for CASEarth data integration, management and sharing, including the CASEarth Data Sharing Regulation; Developed a detailed data management and integration plan, forming a 2018-2022 data sharing task list, and identifying the target volume of 17PB in 2022; Initiated the preparation of Data Sharing Report and the trial of publishing high-quality data sets; Completed data collection before the launch of CASEarth, including about 850TB data from 9 projects (81 sb-projects); Formulated data standards and specifications, developed the data sharing service system, conducted data assessment and shared high-quality data to the public in batches.

CASEarth Satellite: Designed sensors of thermal infrared imager and hyperspectral imager, compiled general plan for the CASEarth Satellite, implementing plans operation and monitoring system construction plan, the calibration system plan, and data production plan, which were all approved by the technical committee.

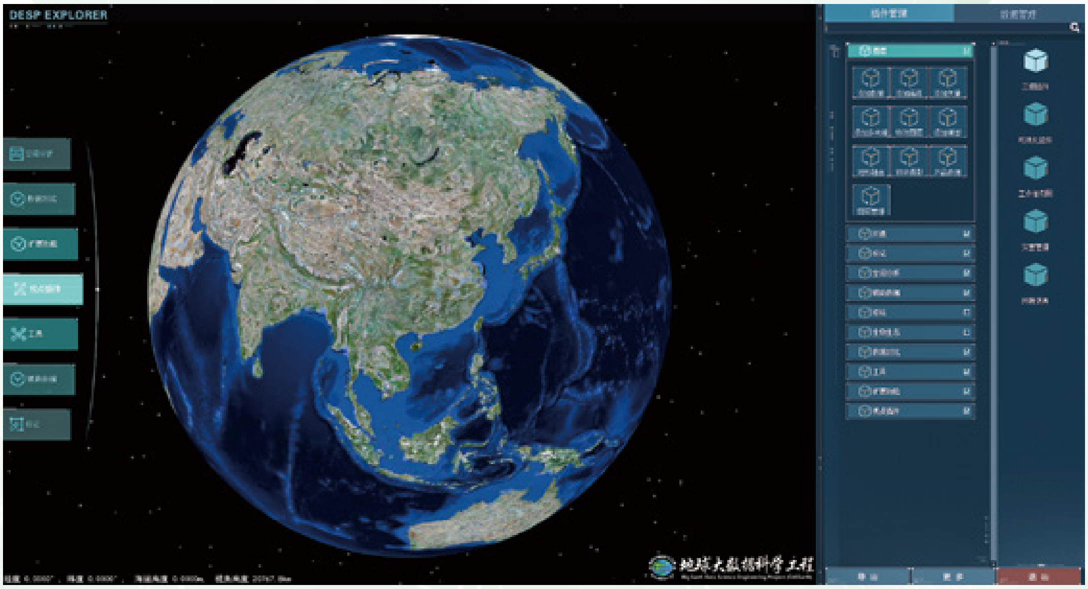

Fig. 6 DESP Explorer - CS Version

Cloud Service Platform and Digital Earth Science Platform: Constructed basic platform with computing power of 7PF and storage capability of 10PB; Developed Grid Data Engine Prototype System, Data Search and Service, Data Publishing Cloud Service System, and Big Earth Data Mining & Analysis System V1.0; Established the layered framework of Digital Earth Platform, completed the secondary development engine of Digital Earth Platform; Developed the unified authentication subsystem, and the public service subsystem for the network information service system, as well as the prototype system for Big Earth Data resource services, realizing the unified organization and quick launch of data and products.

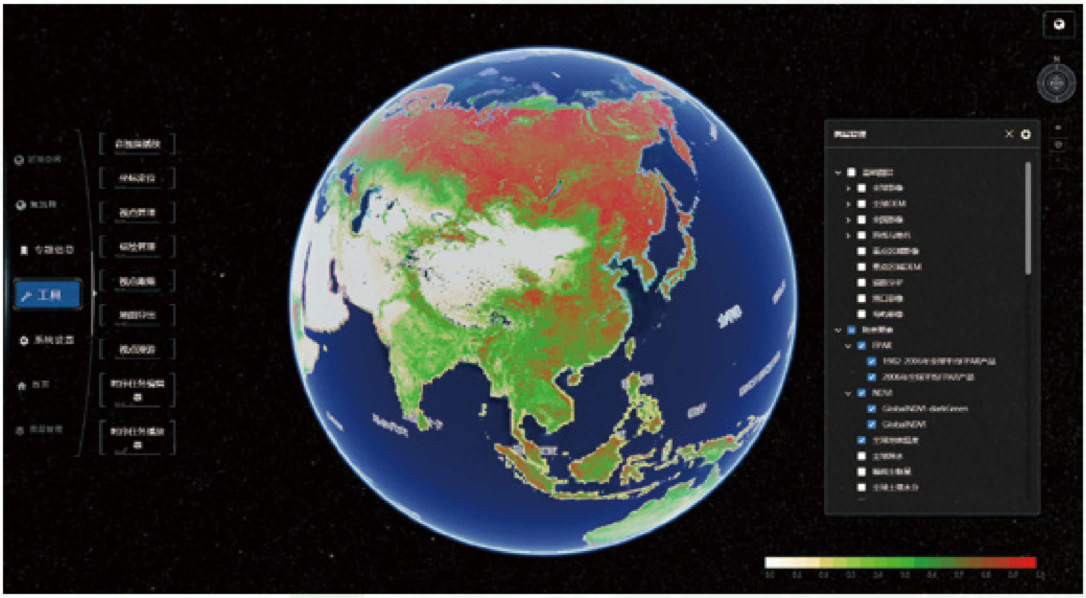

Fig. 7 DESP Explorer - BS Version

Scientific Discovery and Decision Support: Completed detailed design of Digital Belt and Road Decision Support Information System and the construction of its visualization subsystem; Developed source tracking module for complex chemical reactions of gaseous pollutants; Completed the regional sustainable development evaluation technology that fits the situation in China, and constructed the index system for the integrated evaluation of Beautiful China; Developed a framework for BioONE data integration and launched the first version of the BioONE platform; Established the evaluation index system for different types of offshore ecosystems and an atmospheric-wave assimilation system in the Indian Ocean, formulating global ocean and climate model; Constructed the prototype system for the three poles (Qinghai Tibet Plateau, Antarctic and Arctic) big data sharing platform, and approved the application scheme of the new generation earth system model with its own intellectual property rights in the three poles region.

▶ Highlight I: PB-Level CASEarth Prototype System

Introduction

CASEarth Prototype System serves as a core platform – its construction concerns the international strategic position of China and CAS in the field of Big Earth Data. This year, we have developed the first PB-level CASEarth Prototype System in China that integrates data storage, management, and mining. This system realizes the integration of multi-source Big Earth Data, large-scale real-time on-demand computing, and visual analysis, forming a Big Earth Data Solution for spatial-temporal data analysis. The Prototype System is a key step in achieving the ultimate goal of establishing the international Big Earth Data Science Center, and the main components of the system are as follow:

Established a CASEarth testbed. Built a data management system with 2PB distributed storage and 4PB object-based storage, gathering 5PF CPU computing resources, 10PF GPU computing resources and 53PB storage resources from CAS; Deployed over 800TB of multi-source Earth sciences data and over 60 data products / data sets; Established a multi-source and multi-dimensional big data management structure, realizing the 100 million-level Earth grid segmentation and the retrieval of PB-level metadata in seconds; Integrated the visualization environment for the presentation of digital earth.

Developed a set of software for analyzing and processing Big Earth Data. Independently designed and developed the four core systems – Big Earth Data Storage Management System, Grid Data Engine, MPP Database Engine, and Big Data Analysis and Mining System; Established the Cloud based Big Earth Data analysis engine, and the big data mining analysis model and algorithm library; Constructed the CASEarth Databank Prototype System.

Fig.8 CASEarth Plaform Testbed

Created CASEarth Visualization Engine – Digital Earth Foundation Platform. Developed the engine for Digital Earth and assembled core functional components of the platform; Developed the B/S and C/S version of the Digital Earth Science Platform, which preliminarily possessed the ability to display and analyze data in the field of resource management, environment, ecology, biology and other fields at both the global and regional level, realizing the Digital Earth Science Platform in support of decision making and scientific discovery.

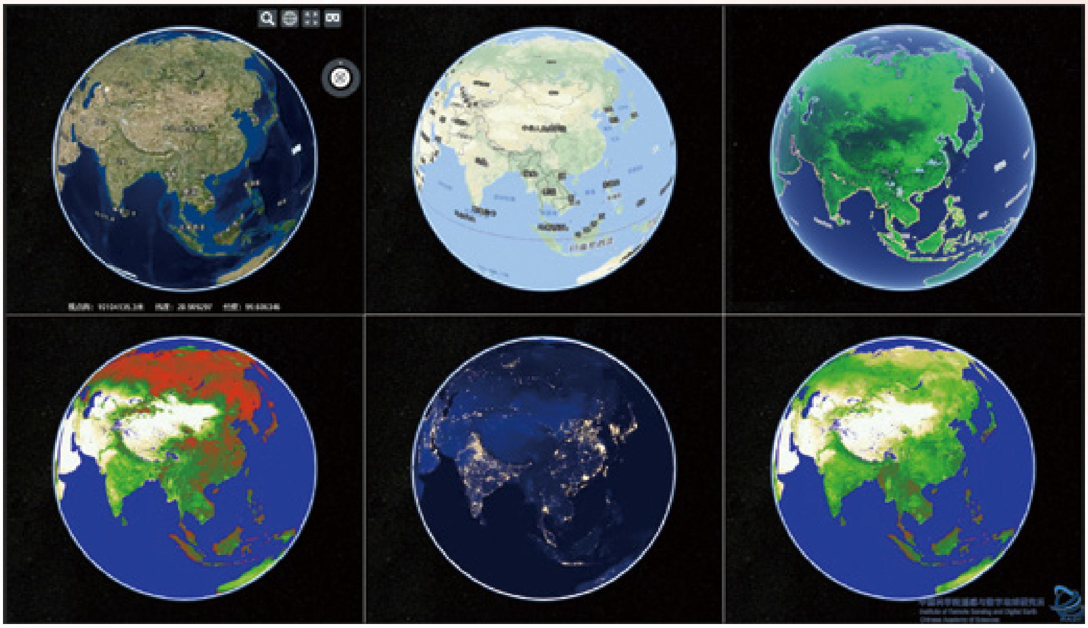

Fig. 9 CASEarth Visualization Engine – Digital Earth Foundation Platform

Outreach and Impacts

Developed the prototype of PB-level Big Earth Data system, forming a universal solution for spatiotemporal data analysis services. The system will strengthen the integration, sharing, mining, analysis, visualization applications and information decision support in the field of resource management, environment, ecology, and biology etc., so as to better support scientific discovery, public services, and macro decision making. It is expected that with the support of the Big Earth Data Platform, important scientific discoveries and breakthroughs will be achieved.

▶ Highlight II: Big Earth Data-Digital Silk Road System

Many countries along the Belt and Road are facing challenges in sustainable development such as water shortages, frequent disasters, and major ecosystem changes. In the Belt and Road region, the speed of data processing and analyzing is much lower than the data acquisition, resulting in a bulk of scientific data and information underutilized.

Fig.10 Digital Silk Road System

For the better use of Big Earth Data, we have proposed new data management and mining models and established a Digital Silk Road System as a regional sub-system of CASEarth.

The system serves the countries along the Belt and Road, providing Big Earth Data sharing and cloud-based online analysis features at the regional, sub-regional and national level. It is not only a timely and reliable information source for international organizations, governments and the public, but a spatial information tank and decision-making tool for the Belt and Road region.

The first generation of the Digital Silk Road System has provided necessary Big Earth Data support to CASEarth. It includes the Big Earth Data Analysis and Decision-Making Support System 1.0, the Integrated Big Earth Data for the Belt and Road, and the International Collaborative Data Integration and Research Network.

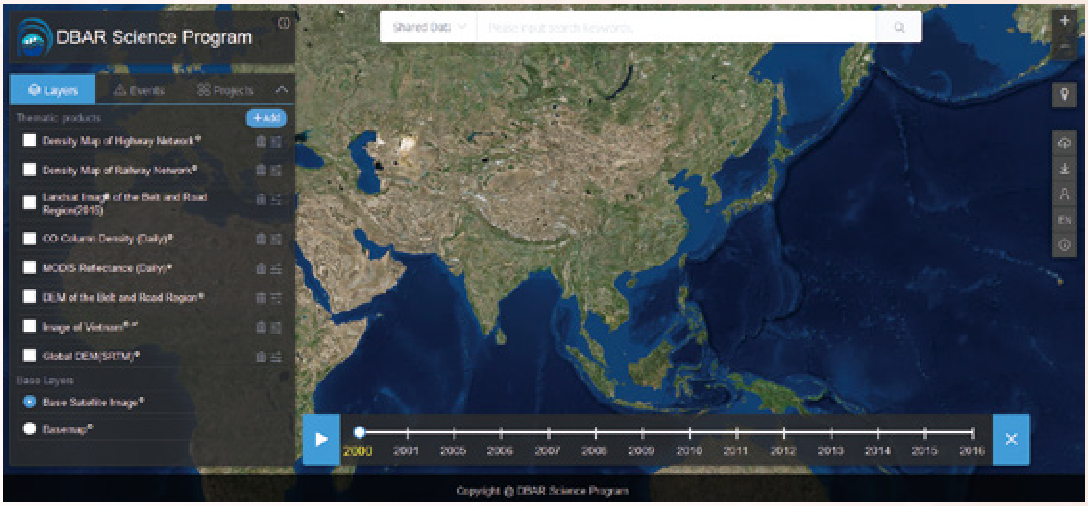

Fig. 11 The Big Earth Data Analysis and Decision-Making Support System (English Version) 1.0

i. The Big Earth Data Analysis and Decision-Making Support System 1.0

Equipped with a PB-level software and hardware environment, the project lead to the development of Big Earth Data ETL toolkit under the common big data platform, supporting data retrieval and sharing and providing six categories of data visualization. The system can be accessed online in Chinese, English and French versions, supporting online data-sharing from 8 International Centre of Excellence (ICoE) of the Digital Belt and Road program (DBAR).

ii. Integrated Big Earth Data Bank for the Belt and Road

The project has developed 94 thematic data sets related to the Belt and Road Initiative for natural resources, environment, climate, disasters, heritage, etc., 57 types of proprietary intellectual property data products, and more than 120 TB of shared data. The research and development of data products is based on a number of innovative technologies.

For example, using cloud computing method of farmland monitoring based on crowd source data collection, the overall accuracy of the 10-meter arable land dataset in the Zambezi Basin (5 countries) is 84.5%, which improved the existing international product accuracy by 10%.

iii. International Collaborative Data Integration and Research Network

Eight DBAR International Centre of Excellence (ICoE) have been established in Thailand, Pakistan, Finland, Italy, Russia, Morocco, Zambia and the United States. Through the network of ICoEs collaborative research and data sharing and acquisition, it has provided foundation to establish an innovative network for data acquisition and validation, monitoring regional SDG indicators and joint development of the Big Earth Data System.

Fig.12 Establishment of the ICoE-Bankok

iv. Supporting the Belt and Road Decision-Making Process

Based on the Digital Silk Road System, CASEarth provided effective decision-making support in the Belt and Road region during the initial year. The CASEarth spatial information mapping supported the UN Environment's Sixth Global Environment Outlook (GEO-6) report (CASEarth has been listed as a global partner in the report). The evaluation metrics to measure the increase of degraded land is adopted by the SDG assessment system of the United Nations Convention to Combat Desertification (UNCCD). The Portuguese agricultural monitoring system is implemented in Mozambique, and the monitoring results have been incorporated into its national agricultural monitoring report and introduced at the China-African Forum. The results of the ecological and environmental impact assessment of 21 industrial parks along the Belt and Road are applied by the Ministry of Commerce and the Ministry of Science and Technology of the People's Republic of China. The discovery at the Silk Road archaeological sites in Tunisia supported by CASEarth is recognized by the Tunisian government.

The establishment of Digital Silk Road System has greatly promoted the use of Big Earth Data for UN SDGs decision-making support, and provided the Belt and Road regional demonstrations. The DBAR International Centre of Excellence (ICoE) Network works as a reliable platform for international data exchange and sharing, cooperative research, and regional decision-making support along the Belt and Road.

▶ Highlight III: Big Earth Data reveals synergic change of climate-ecosystem of Three Poles

Introduction

Focusing on the major scientific objectives of CASEarth: exploring and forming a big data-driven multi-disciplinary international paradigm, demonstrating and making major breakthroughs for Earth system sciences, life sciences and related disciplines, and cultivating an International Big Earth Data Science Center, as well as focusing on the key science issues of Big Earth Data- driven scientific discovery such as synergic change amplitude, impact on temporal-spatial scale, possible threshold range of three poles cryosphere, CASEarth has developed new perspectives of scientific discovery paradigms. Through cross-projects multi-source massive data analysis and joint research, CASEarth has made new discoveries including the change of the three poles ecosystem and its effects on carbon cycle process, three poles multi-sphere interaction and the mechanism of Arctic amplification and global environmental change response mechanism, laying a solid foundation for the comprehensive simulation of earth system science supported by the Big Earth Data Platform.

Research Topics

Through Big Earth Data (flux observation, satellite remote sensing images, numerical simulation and position experiments) analysis, it is found that a large amount of carbon sink loss in the three pole terrestrial ecosystem were driven by global climate change and may need to be re-evaluated: in Qinghai-Tibet Plateau, vegetation index was found to be significantly related to the temperature sensitivity of ecosystem respiration(Q10) compared with the other factors such as soil and climate, and there's a positive correlation between the vegetation index and the Q10. However, in some high latitude areas of the northern hemisphere such as those with the tundra ecosystem, Q10 increases as the Carbon / Nitrogen ratio increases. In addition, within the context of the global warming, the complex carbon cycle process in the Arctic will affect the climate system as feedback, and the study on the ecological effect of air pollution from the fire emissions reveals the growth effect of aerosol scattering on vegetation productivity in the Arctic (Yue and Unger, 2018, *Nature Communication*,).

The Arctic has attracted much attention in recent years, not only because of the "Arctic Amplification" Effect in the context of global warming, but also the feedback of the complex carbon cycle to climate system in this region. Recently, Xu Yue, a researcher from CAS Institute of Atmospheric Physics published an article in *Nature Communication*, expounding the ecological effects of air pollution caused by fire emissions. The study found that fire dust (mainly carbon-containing aerosols) can be transmitted over long distances, increasing the productivity of ecosystems in the Arctic (GPP.) This is because the aerosols may enhance diffuse radiation, and thus promote the photosynthetic rates of shaded leaves, referred to as the diffuse fertilization effects (DFE). Plants at the Arctic have much larger shaded portions (that is, the leaves cannot receive direct solar radiation) because of the smaller solar zenith in high latitudes, so aerosol radiative effects have a relatively significant impact on vegetation growth in this region.

The study further evaluates the effect of clouds on the DFE of aerosols. Under cloud free conditions, GPP of Siberia and northern North America increases by 3-5% due to fire emitted aerosols while in the presence of clouds, the effects of these aerosols are greatly reduced. This is because cloud particles have similar fertilization effects as aerosols, and can enhance vegetation photosynthesis under certain conditions. However, the increase in cloud depth and their amount can significantly reduce the total amount of radiation, weakening ecosystem GPP, and balance out the effects of aerosols. Therefore, it is necessary to consider the interaction between cloud-radiation-aerosol and the ecosystem when studying the impact of aerosols on vegetation productivity in the three poles region.

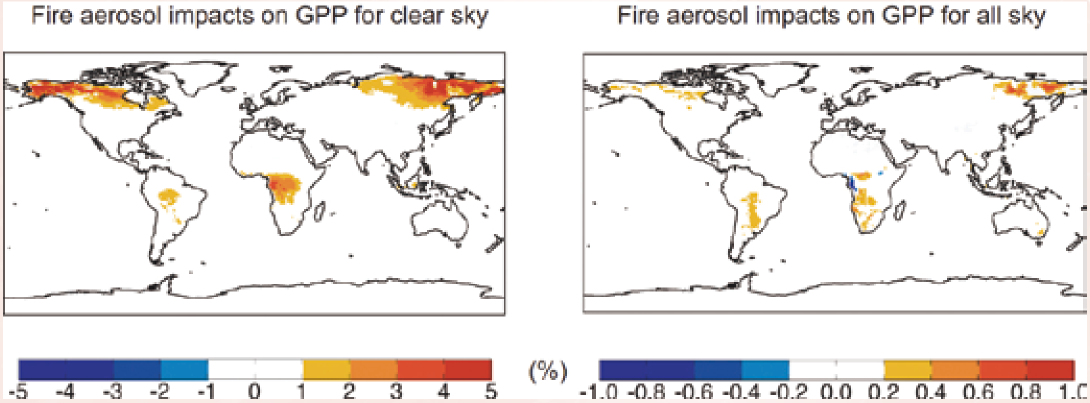

Fig.13 The effect of fire aerosol on GPP under clear(left) and all sky(right) conditions

Based on a high resolution earth climate system model (FGOALS-f) developed by CAS, the numerical simulation of the multi-sphere interaction between the Three Poles has been conducted, which further confirms that changes in polar processes have “pull and move” effects.

It is well known that in the past 40 years, global temperature has been constantly rising. Studies have shown that warming in the Arctic has been much faster than the rest of the world, a phenomenon known as the Arctic Amplification (AA).

Enhanced warming in the Arctic with increasing greenhouse gases (GHGs) has attracted wide attention. In the past, the positive ice-albedo feedback was considered as the main reason for AA. However, recent studies have found that the seasonal storage and release of the absorbed solar radiation in Arctic waters may also be an important process in the formation of AA, but its effect on AA remains uncertain in the case of increased greenhouse gases. Is sea-ice loss necessary for large AA to occur? Can the reduced long-wave cooling or the increased heating still produce AA under GHG-induced global warming without significant sea-ice loss? These questions still need to be answered.

Based on ERA-Interim reanalysis data and over 38 CMIP5 models, the research group led by Dr. Luo Dehai has cooperated with scientists from State University of New York, and conducted an in-depth research on the historical trends of the season variation of Arctic Amplification, Arctic sea-ice cover (SIC), radiation and heat fluxes (Luo et al., 2018, *Nature Communications*).

According to this study, rapid Arctic sea-ice melting is a key factor in AA. Faster sea-ice melting leads to stronger AA while water vapor feedback, increased poleward heat transport and other physical processes can only indirectly affect AA through sea ice reduction. Specifically, large AA occurs only in cold seasons and only over areas with significant sea-ice loss. Seasonal sea-ice melting from May to September allows a larger area of water surface to absorb sunlight during the warm season, and the energy, stored in the surface of the water, is released to the atmosphere through longwave (LW) radiation, latent and sensible heat fluxes during the cold season (October to April) when the Arctic Ocean becomes a heat source to the atmosphere, rapidly increasing the temperature in the Arctic.

The result shows that AA largely disappears when Arctic sea ice melts away or is held fixed for calculating surface fluxes. Therefore, this study found that under greenhouse gas (GHG)-induced global warming, strong AA occurs only from October to April over the areas with significant sea-ice loss in both observations and model simulations.

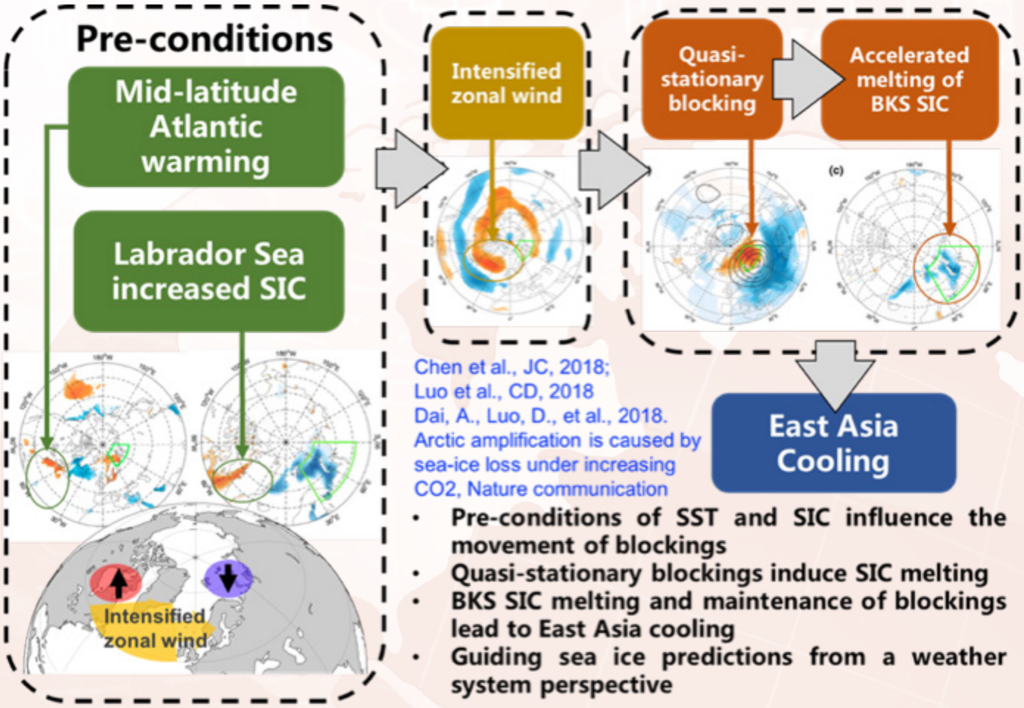

Fig.14 The Atmospheric Blocking – Sea Ice – East Asia Cooling Correlation

Big Earth Data revealed the variability of vegetation autumn phenology in the high latitude regions. Using long-term ground phenological records (14,536 time series since the 1900s) and satellite greenness observations between 1982 and 2015, we found that rising pre-season maximum daytime (Tday) and minimum nighttime (Tnight) temperatures had contrasting effects on the timing of autumn leaf senescence date (LSD) in the Northern Hemisphere. If higher Tday leads to an earlier or later LSD, an increase in Tnight systematically drives LSD to occur oppositely. A new LSD model (DNGDD) considering these opposite effects was developed. This model improved autumn phenology modelling and predicted an overall earlier autumn LSD by the end of this century compared with traditional projections. These results challenge the notion of prolonged growth under higher autumn temperatures, suggesting instead that leaf senescence in the northern hemisphere will begin earlier than currently expected, causing a positive climate feedback.

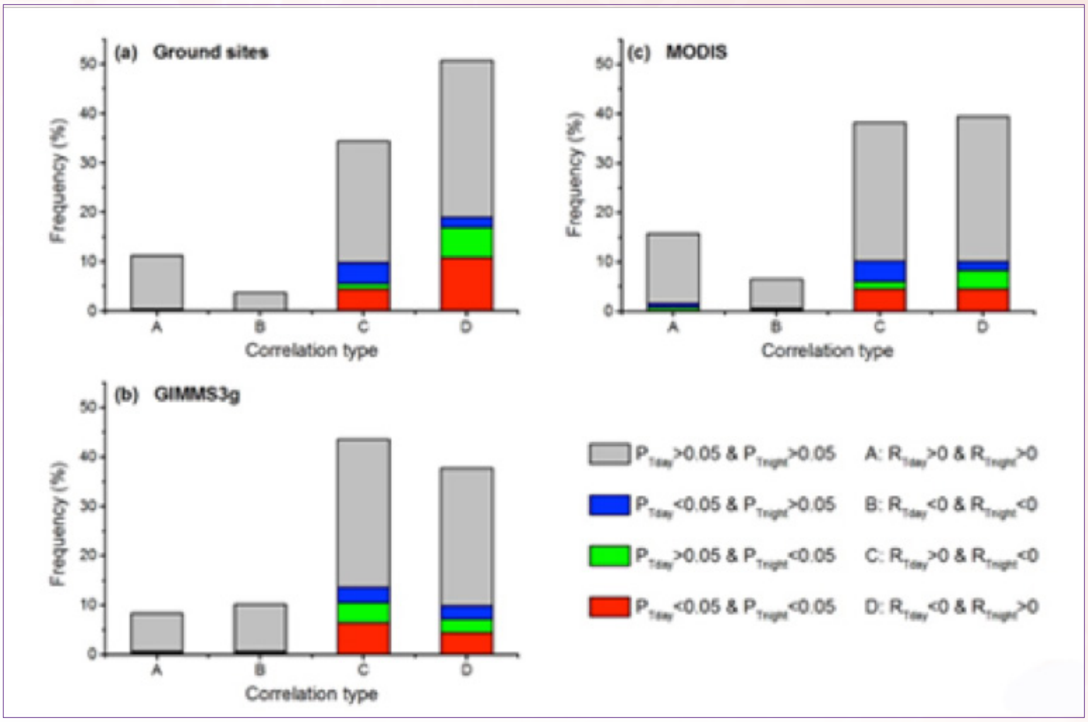

Fig.15 The effect of diurnal temperature on phenological changes in deciduous vegetation

Outreach and Impacts

The above research results are of great scientific significance and have great influence at home and abroad. Research results on the change of three poles ecosystem and its influence on carbon cycle clarify the spatial pattern of ozone and aerosols affecting land productivity, improving the scientific understanding of the ecological effect of air pollution. The new way that fire affects carbon budget of the ecosystem is revealed, which complements the relevant theories and knowledge of global carbon cycle. After the publication of the paper, it was widely reported by the media at home and abroad, with the Altmetric of 319 (attention index), and has become one of the top 4% of papers published on *Nature Communications*.

Research on AA and its mechanism analyzed the seasonal differences of amplification in the Arctic against the background of continuous increasing of greenhouse gas, and interpreted the AA phenomenon which only occurs in the cold season and areas where the sea ice is significantly decreasing, meaning that sea ice reduction plays a key role in the occurrence of AA. In addition, model simulations show that AA will not disappear until the Arctic sea ice melts in the 23rd century. In the next few decades or even hundreds of years, melting sea ice will lead to stronger AA, and then affect the climate in the middle latitude, leading to more frequent polar vortices in winter and more extreme weather events in China and North America. The above results are of great significance for climate change mitigation and response.

The result of the contrasting effect of daytime and nighttime temperatures on autumn phenology implied the lack of mechanism of using mean temperature to explain the variation in autumn phenology, while the improved model incorporates daytime and nighttime temperatures in terrestrial models for better simulation. This result deepens the understanding of global climate change and the carbon cycle of vegetation ecosystems.

▶ Highlight IV: Decision-making based on Big Earth Data

The interactive and dynamic visualized decision support environment that is driven by Big Earth Data can provide comprehensive and dynamic understanding of the sustainable development process at regional and global levels, firmly supporting global governance and macro decision-making.

In 2018, based on the PB-level CASEarth Prototype System, we made breakthroughs in data fusion, data assimilation, automatic extraction of key objects and the normalization of multi-source satellite data, etc. We also carried out big data analysis and research on hotspot issues such as air pollution, offshore disasters, oil and gas fields based on important research results focusing on haze and marine, providing scientific support for decision-making.

Fig.16 Sustainable Development Goals of the United Nations

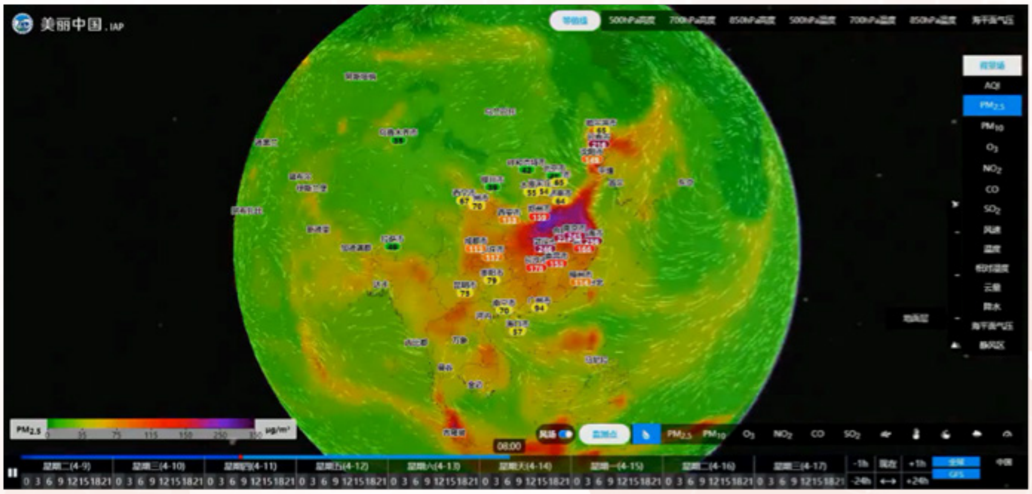

Fig. 17 High-precision and High-resolution 14-day National Air Quality Forecast System

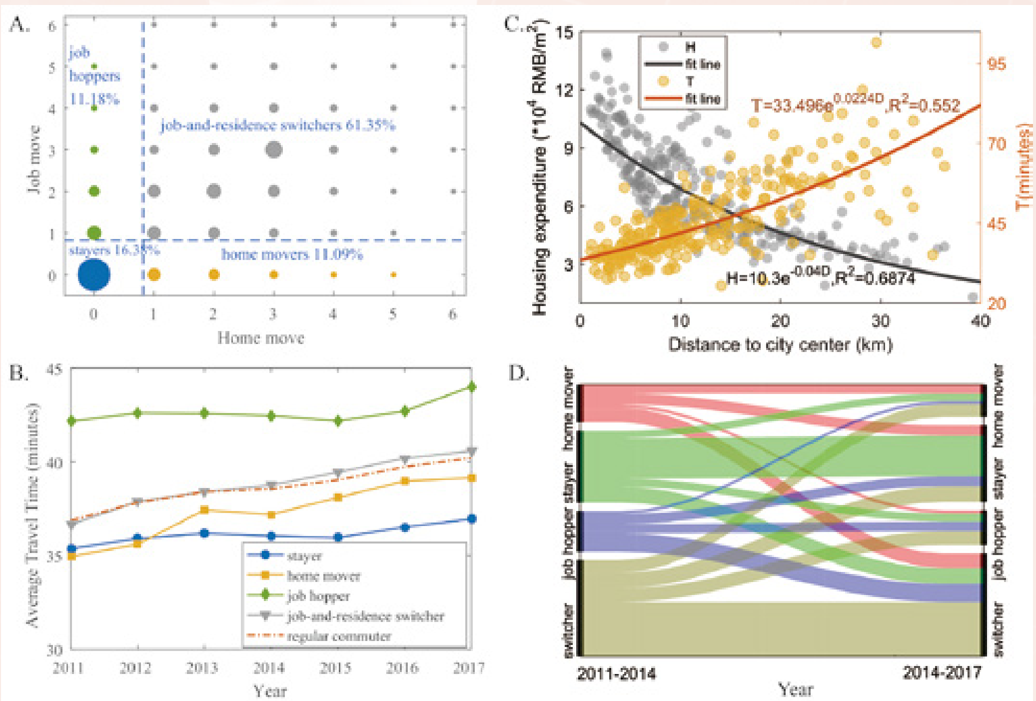

Fig.18 (A) Quasi-four-quadrant diagram classifying regular commuters and percentages of groups;
(B) Average travel time in the subway system
(C) Housing expenditure (h) by distance to city center (d) and average travel time in the subway system (t);
(D) Variation of job and housing status. (st, sw, jh, and hm denote stayer, switcher, job hopper, and home mover.)

Based on the research with focuses on haze, we have established the historical, up-to-date, and influential grid data of the key elements of the atmospheric environment and driving forces that have affected clean air and human settlements in the past 5 years in China. For the first time in the world, a grid re-analysis dataset of China was built with 5km*5km resolution from 2013 to 2017; a global weather and air quality forecasting system with 10km*10km resolution was constructed to provide air quality forecast for China 14 days in advance. This system provides independent and controllable meteorological forecast products for real-time air quality forecasting, and meet the need of enterprise-level emergency air pollution regulation. We solved high-resolution grid GIS data displaying problems, and developed an “CASEarth-Atmosphere” Platform which shows the past scenaries, current status, and 7-day forecast results of high-precision weather and air pollution in the world, in China, as well as at cities and city block levels. In addition, we also analysed the regional characteristics of national PM2.5 pollution to support the collaborative pollution control of Ministry of Ecology and Environmental Protection conducted in Fenwei Plain. These analyses were especially helpful for the division of control area and short-term forecast of regional air pollution. The Atmospheric Platform also quantifies the contributions of environmental capacity and emission sources to the reduced pollutant emissions, and provides solid support for the scientific assessment of national pollution control.

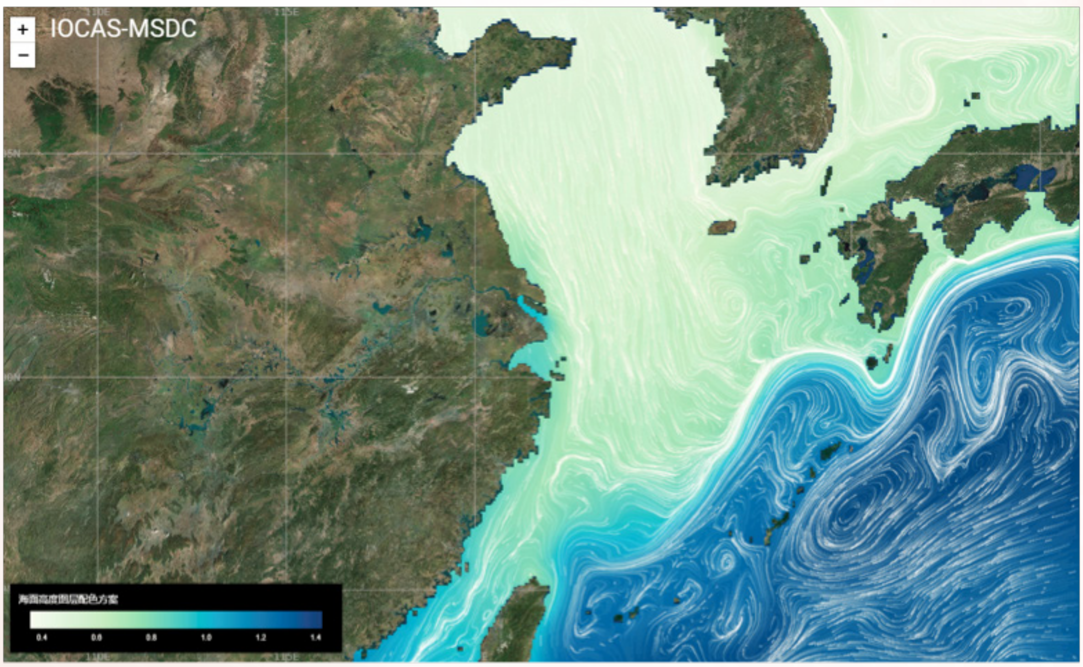

Fig.19 Monitoring the oil spills based on the Big Earth Data Platform

Based on systematic collection of geological, hydrologic, chemical and biological data of China sea areas, the “CASEarth-Ocean” platform was developed by CASEarth and its technology platform, as well as the high-resolution (4km) ocean circulation numerical model of ROMS. This achieved fine analysis of oceanographic processes in important offshore ecological disaster zones and the dynamic monitoring of oil and gas platforms in the South China Sea, and fulfilled the urgent needs of the government for coastal environment assessment and oil / gas field monitoring. Based on analysis of the occurrence mechanism of Enteromorpha prolifera green tide in the southern Yellow Sea, we put forward a policy suggestion to construct “three lines of defence” to prevent and control the green tide disaster in the Yellow Sea, to protect the marine environment for the SCO Summit. for the SCO Summit. Responding to the accident of Sanchi, we proposed to evaluate the influence of the oil spill on China coastal waters based on the analysis results of the hydrodynamics numerical model, and our suggestions were adopted by local government. Based on remote sensing data and automatic offshore platform extraction method, a system for dynamic monitoring and evaluating oil and gas resources was developed using Gaofen satellite data. The location, number and depth of offshore platforms were assessed. Meanwhile, the specific suggestions related to the space delineation of China-Philippines oil and gas cooperation area were initiated, aiming at promoting the oil and gas resources development in China as well as the international cooperation in the South China Sea.

Global, national and regional vegetation products, including Land Use, Vegetation Leaf Area Index, Vegetation Chlorophyll Content, Fraction of Absorbed Photosynthetically Active Radiation and other moderate-to-high (2-30 m) and low-to-moderate (500-5000 m) resolution temporal

Fig.20 Impact of Wheat Disease on the Global Scale

spatial information products have been produced based on CASEarth resources. We brought together and produced cutting-edge research to provide crop pests and diseases monitoring and forecasting information, integrating these vegetation products and multi-source dataset (Earth Observation-EO, meteorological, entomological and plant pathological, etc.) to support decision making in sustainable management of pests and diseases. We provided monitoring and early warning models and big data analysis service for main crop pests and diseases at multi-scales—global, intercontinental, national, provincial and county levels; furthermore, we released first scientific report on damaged areas and the extent of main crop pests and diseases in both Chinese and English to the public. The research results have been adopted and recognized by the government to support dynamic decision making for crop control. The outcomes of the project would not only promote efficiency of pests and diseases management and prevention by improving the accuracy of monitoring and forecasting, but also help to reduce the use of chemical pesticides, and thus contribute to the food security and sustainable development of agriculture at home and abroad. Moreover, we have been sharing temporal global and key regional products within 2-5000m spatial resolutions to the public through the Digital Earth Scientific Platform, which not only significantly enriches the databank for global geoscience research, but also provides data support for the continuous development of CASEarth, promoting global and regional comprehensive analysis and application for national global strategic decision-making.

In addition, we also improved the global high-resolution ocean model LICOM 3.0 based on the analysis of Big Earth Data, successfully simulating the ocean currents crossing the arctic point; we conducted sea ice analysis and navigation risk assessment of key straits in the Arctic Channel, establishing the Arctic sea ice forecast system, which provides a scientific foundation for the launch of the Polar Silk Road. In addition, based on the long-term monitoring data of 6 field stations from last 20 years and multi-source remote sensing data of the past 40 years, we analyzed the changes in regional ecosystems and the effectiveness of the eco-projects in this region, identifying existing problems and causes, proposing solutions.

▶ Highlight V: Big Earth Data Sharing Platform

Constructing the Big Earth Data System Platform is the core objective of CASEarth. Based on the scientific principle of the Earth System, the Big Earth Data System consists of a number of sub-systems including the biosphere, hydrosphere, cryosphere, and atmosphere, together with regional sub-systems such as the Belt and Road region, and the area of China. The Digital Silk Road Regional System is part of the CASEarth. During the first year after its launch, the Digital Silk Road Integrated Subsystem of Big Earth Data System was completed. This regional system directly serves the countries along the Belt and Road, enabling comprehensive Big Earth Data Sharing and online analysis based on the Cloud Service Platform at the global, regional and country levels. As an important spatial information database and decision support tool for the Belt and Road Initiative, it provides timely and reliable information to international institutions, governments and the public.

Introduction

i. Package of Policies, Regulations and Standards for CASEarth

We have drawn up a package of documents such as "CASEarth Data Sharing Regulation," "CASEArth Data Sharing Proposal," "Enforcement Regulation of the Data Sharing Prospectus" and "Measures for the Implementation of the Delivery of CASEarth Achievements." CASEarth data is divided into different scientific fields. we have formulated, recommended, and organized regulations for the standards of metadata and basic data.

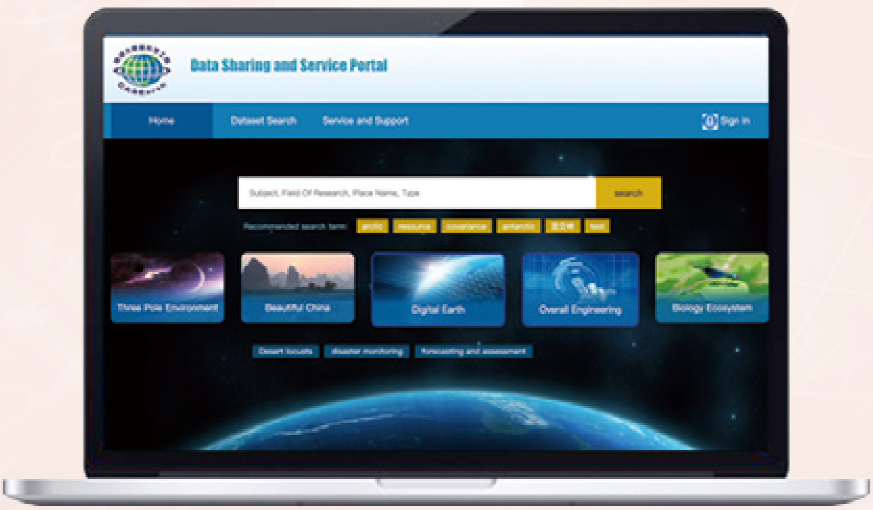

Fig.21 Interface of CASEarth Data Sharing Portal

ii. Launching Big Earth Data Sharing Portal

Big Earth Data Sharing Portal is a scientific platform that integrates massive multi-disciplinary datasets from various sources, and aims to assist data-driven scientific discovery and decision-making support. The platform provides users with global access to systematic, diversified, dynamic, continuous and standardized Big Earth Data with Global Unique Identifier (GUID), and promotes the formation of a new model of online data sharing system. By the end of 2018, the total amount of data shared on this platform was approximately 5PB, including 1.8PB of Earth observation data, 2.6PB of biological and ecological data, 0.4PB of atmosphere and ocean data, 0.2PB of basic geographical information and ground observation data; including 490,000 items in the stratigraphic and paleontological databases, 3.6 million items in the Catalogue of Life in China, 420,000 items in the Microbes Database of China, and 1 billion pieces of Omics data. Users can now retrieve 40% of the data online. With improving infrastructure, more data will be released online in the future, and about 3PB of data will be updated each year.

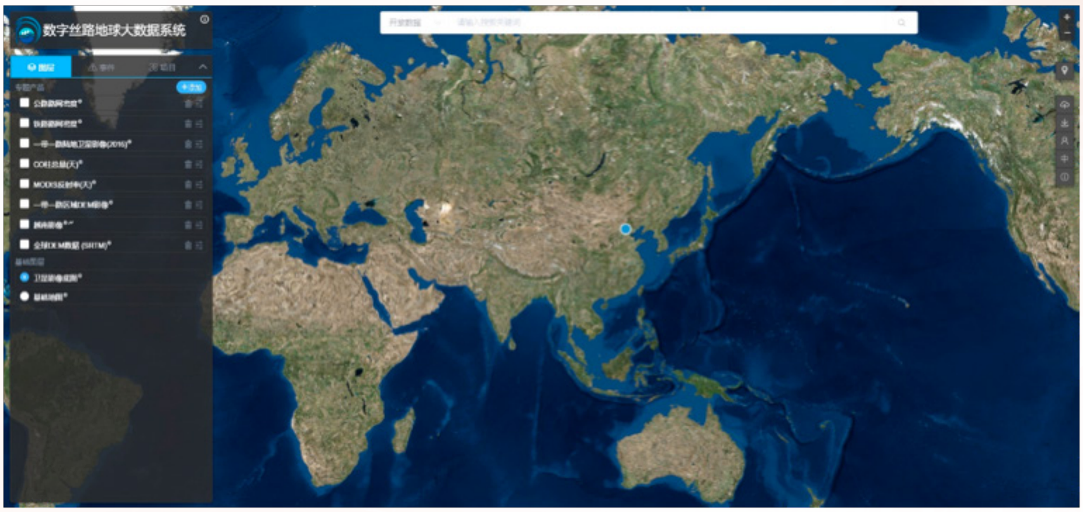

Fig.22 Main interface of CASEarth Data Sharing Portal

On January 15th, 2019, CAS held a press conference in Beijing and officially launched its Big Earth Data Sharing Service Platform, one of the most significant achievements of CASEarth. This release focused on three systems, two of which are core systems of the global data sharing service platform, namely, Data Sharing Service System (http://data.casearth.cn) and the CASEarth Databank system. The third is the Digital Belt and Road Big Earth Data system with regional coverage.

Data Sharing Service System, one of the core systems of the Big Earth Data Sharing Service Platform, is a portal for publishing and sharing CASEarth data resources. Currently it provides 5PB of data and a variety of data discovery modes, such as project classification, keyword search, tags cloud filtering, and relevant data recommendation. The data can be downloaded directly from the internet or it can also be access through Application Programming Interface (API). Online data interactive services support online data viewing, preview and search, and also provides personalized services for data survey, collection, recommendation, download, and evaluation, etc. This is for the first time in China that data references of major national projects are published in accordance with Chinese national standard “Information Technology Scientific Ddata Reference” (GB/T 35294-2017), which allows orderly association of data and the whole life cycle management. Users can use this system to access all metadata gathered and released by CASEarth, and share the data according to the sharing permission.

CASEarth Databank provides long-term, multi-source ready-to-use Earth observation datasets, including: 200,000-scene of long-term land satellite data products (12 products per scene, 2.4 million products in total) since the establishment of China Remote Sensing Satellite Ground Station (RSGS) in 1986; The Dynamic Map of China (with a resolution of 2m) based on the data provided by Gaofen-1/2 Satellite, Resources satellite three (ZY-3) and other domestic high-resolution remote sensing satellites; The Dynamic World Map (with a resolution of 30m) based on the data provided by Gaofen Satellites, land satellites and other domestic and foreign satellites; as well as ready-to-use sub-meter level product sets. The system has established a global remote sensing data grid standard, and an independently developed Databox, which is an efficient data engine for Earth observation, providing advanced services such as artificial intelligence, various data analysis techniques, information mining services for the general public, industry users and scientists. In the future, users can not only use data, computing resources, and technical resources from CASEarth DataBank for their applications, but can also upload multi-source data, embedding algorithm models, and combine the system resources of CASEarth DataBank to complete scientific thematic information mining, knowledge discovery and decision-making.

The DBAR Big Earth Data System contains 94 regional thematic datasets that cover various research themes such as resource management, environment, climate, disaster, and heritage etc., 57 categories of independent intellectual property data products, and more than 120 trillion bytes of shared data. Currently the system can process terabyte-level" information. It is the first international research and development tool set for extracting, transforming and loading large datasets about earth. It has the capability to retrieve, share and visualize six categories of data, shared by relevant institutes around the world and provide user- interface in multiple languages including Chinese, English and French.

Outreach and Impacts

i. Enhancing the Impact of Earth Science Data Sharing

On January 15, 2019, a number of mainstream media reported on the launch of the Big Earth Data Sharing Service Platform, which attracted the attention of geoscience research institutions and experts both at home and abroad. As of May 11, 2019, the system has been visited by 27,270 independent IPs, with a total of 1,727,227 page-visits, 68,461 total visitors, 52,489 total searches, 1,467 total download applications, 62,808 total downloads, and a total download data volume of 5.730.38G.

ii. Facilitating Enhanced International Data Sharing

After the launch of the Big Earth Data Sharing Service Platform, it has attracted the attention of many countries along the Belt and Road, and many of them have shown willingness to share data and cooperate with CASEarth, using Big Earth Data to improve data management and environmental monitoring.

Cases of publications

COMMENT

TAYLOR WEIDMAN/BLOOMBERG/GETTY

Many developing countries, such as Mongolia, have rural economies, so projects that can provide farmers with up-to-date agricultural information are crucial.

Steps to the digital Silk Road

Sharing big data from satellite imagery and other Earth observations across Asia, the Middle East and east Africa is key to sustainability, urges **Guo Huadong**.

The ancient Silk Road trade routes connecting Asia, Europe and Africa lay behind the development of many great civilizations. Today, solar panels and smartphones have replaced silk, and trains and aeroplanes have superseded camels. But the Silk Road spirit of peace, mutual benefit and learning has been revived in an ambitious plan to bridge East and West, launched in 2013 by Chinese President Xi Jinping.

The 'Belt and Road' initiative promises more than US$1 trillion of Chinese investment in some 60 countries (see 'Belt and Road'). All other nations are welcome to join in. The main aim is socio-economic development through improving the routes for land and sea trade. The initiative will also boost science and technology across the region, for example through research into artificial intelligence, nanotechnology, quantum computing and smart cities (see go.nature.com/2mvfec6).

But protecting the environment while supporting economic growth will be challenging. The Belt and Road region is home to more than 65% of the world's population. It includes 18 cities that have populations of greater than 10 million, such as Beijing, Cairo, Moscow, Manila and Istanbul.

Environments are diverse and fragile. ▶

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LETTERS
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nature climate change

Corrected: Publisher Correction

Contrasting responses of autumn-leaf senescence to daytime and night-time warming

Chaoyang Wu[1,2*], Xiaoyue Wang[1,2], Huanjiong Wang[1,2*], Philippe Ciais[3], Josep Peñuelas[4,5], Ranga B. Myneni[6], Ankur R. Desai[7], Christopher M. Gough[8], Alemu Gonsamo[9], Andrew T. Black[10], Rachhpal S. Jassal[10], Weimin Ju[11], Wenping Yuan[12], Yongshuo Fu[13], Miaogen Shen[14], Shihua Li[15], Ronggao Liu[16], Jing M. Chen[9] and Quansheng Ge[1,2*]

Plant phenology is a sensitive indicator of climate change[1–4] and plays an important role in regulating carbon uptake by plants[5–7]. Previous studies have focused on spring leaf-out by daytime temperature and the onset of snow-melt time[8,9], but the drivers controlling leaf senescence date (LSD) in autumn remain largely unknown[10–12]. Using long-term ground phenological records (14,536 time series since the 1900s) and satellite greenness observations dating back to the 1980s, we show that rising pre-season maximum daytime (T_{day}) and minimum night-time (T_{night}) temperatures had contrasting effects on the timing of autumn LSD in the Northern Hemisphere (> 20° N). If higher T_{day} leads to an earlier or later LSD, an increase in T_{night} systematically drives LSD to occur oppositely. Contrasting impacts of daytime and night-time warming on drought stress may be the underlying mechanism. Our LSD model considering these opposite effects improved autumn phenology modelling and predicted an overall earlier autumn LSD by the end of this century compared with traditional projections. These results challenge the notion of prolonged growth under higher autumn temperatures, suggesting instead that leaf senescence in the Northern Hemisphere will begin earlier than currently expected, causing a positive climate feedback.

Climate change over the past several decades has modified the dates of plant flowering, leaf emergence, growth stages and senescence, collectively termed phenology[13], with substantial ecological and environmental consequences[4]. Both observations and model simulations have found that air temperature has a positive influence on the onset of plant growth in the Northern Hemisphere; for example, higher spring temperature triggers earlier leaf-out and flowering dates and hence extends the growing season[8,14,15]. In contrast to those extensive research efforts on spring phenology, autumn phenology, particularly LSD, is more challenging to understand and has not received sufficient attention[16,17], while also serving as an important indicator of changing foliar physiological properties. However, autumn phenology may be as important as spring in regulating the interannual variability of carbon balance[7].

LSD has been occurring later in most regions over the past few decades[18], but providing an explanation for this change is difficult[9]. An increase in global temperature is assumed to be a driver of LSD trends[19], but studies have indicated that the contribution of temperature to LSD variability is low, especially compared with spring phenology[20,21]. We argue that ignoring the asymmetric effects[22] of T_{day} versus T_{night} and their differing impacts on LSD contributes to the reported overall low contribution of temperature to LSD variability. To test this, we used measured and gridded pre-season (defined as months from June to LSD) T_{day} and T_{night} values in the Northern Hemisphere, together with LSD data from three different datasets: (1) long-term phenological observations at ground sites from 14,536 time series since the 1900s (Supplementary Fig. 1), (2) the latest third generation of the normalized difference vegetation index (NDVI; Global Inventory Modeling and Mapping Studies NDVI3g version 1) for 1982–2015 and (3) NDVI and enhanced vegetation index (EVI) values from the Moderate-Resolution Imaging Spectroradiometer (MODIS) products for 2001–2015.

Pre-season forcing had a better predictive strength on LSD than either summer or autumn climate forcing alone (Supplementary Fig. 2). Because pre-season T_{day} and T_{night} were highly correlated, we used a partial correlation to remove the effects of T_{night} and of precipitation and radiation (similarly for T_{night}) to investigate the response of LSD to T_{day}. Correlations were classified into four types, $T_{day}^{+}T_{night}^{+}$ (type A), $T_{day}^{-}T_{night}^{-}$ (type B), $T_{day}^{+}T_{night}^{-}$ (type C) and $T_{day}^{-}T_{night}^{+}$ (type D), where T^{+} and T^{-} represent the positive and negative partial correlation coefficient, R, respectively, of temperature T with LSD.

Overall, all three datasets suggest that the onset of autumn LSD responded oppositely to T_{day} and T_{night}. The proportions of ground sites of types A and B were significantly lower than those of types C and D (Fig. 1a). More significant R values for both T_{day} and T_{night} were found within types C and D, with only two and one records out of 2,231 time series having significant R values within types

[1]The Key Laboratory of Land Surface Pattern and Simulation, Institute of Geographical Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing, China. [2]University of the Chinese Academy of Sciences, Beijing, China. [3]Laboratoire des Sciences du Climat et de l'Environnement, IPSL-LSCE CEA CNRS UVSQ, Gif-sur-Yvette, France. [4]CSIC, Global Ecology Unit CREAF-CSIC-UAB, Barcelona, Spain. [5]CREAF, Barcelona, Spain. [6]Department of Earth and Environment, Boston University, Boston, MA, USA. [7]Department of Atmospheric and Oceanic Sciences, University of Wisconsin–Madison, Madison, WI, USA. [8]Department of Biology, Virginia Commonwealth University, Richmond, VA, USA. [9]Department of Geography and Planning, University of Toronto, Toronto, Ontario, Canada. [10]Faculty of Land and Food Systems, University of British Columbia, Vancouver, British Columbia, Canada. [11]International Institute for Earth System Science, Nanjing University, Nanjing, China. [12]School of Atmospheric Sciences, Center for Monsoon and Environment Research, Sun Yat-Sen University, Guangzhou, China. [13]College of Water Sciences, Beijing Normal University, Beijing, China. [14]CAS Center for Excellence in Tibetan Plateau Earth Sciences, Beijing, China. [15]School of Resources and Environment, University of Electronic Science and Technology of China, Chengdu, China. [16]State Key Laboratory of Resources and Environmental Information System, Institute of Geographic Sciences and Natural Resources Research, CAS, Beijing, China. *e-mail: wucy@igsnrr.ac.cn; wanghj@igsnrr.ac.cn; geqs@igsnrr.ac.cn

Tracking job and housing dynamics with smartcard data

Jie Huang[a], David Levinson[b], Jiaoe Wang[a,c,1], Jiangping Zhou[d], and Zi-jia Wang[e]

[a]Key Laboratory of Regional Sustainable Development Modeling, Institute of Geographic Sciences and Natural Resources Research, Chinese Academy of Sciences, Beijing 100101, China; [b]School of Civil Engineering, University of Sydney, Sydney, NSW 2006, Australia; [c]College of Resources and Environment, University of Chinese Academy of Sciences, Beijing 100049, China; [d]Department of Urban Planning and Design, Faculty of Architecture, The University of Hong Kong, Hong Kong 999077, China; and [e]School of Civil Engineering, Beijing Jiaotong University, Beijing 100044, China

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Residential locations, the jobs–housing relationship, and commuting patterns are key elements to understand urban spatial structure and how city dwellers live. Their successive interaction is important for various fields including urban planning, transport, intraurban migration studies, and social science. However, understanding of the long-term trajectories of workplace and home location, and the resulting commuting patterns, is still limited due to lack of year-to-year data tracking individual behavior. With a 7-y transit smartcard dataset, this paper traces individual trajectories of residences and workplaces. Based on in-metro travel times before and after job and/or home moves, we find that 45 min is an inflection point where the behavioral preference changes. Commuters whose travel time exceeds the point prefer to shorten commutes via moves, while others with shorter commutes tend to increase travel time for better jobs and/or residences. Moreover, we capture four mobility groups: home mover, job hopper, job-and-residence switcher, and stayer. This paper studies how these groups trade off travel time and housing expenditure with their job and housing patterns. Stayers with high job and housing stability tend to be home (apartment unit) owners subject to middle- to high-income groups. Home movers work at places similar to stayers, while they may upgrade from tenancy to ownership. Switchers increase commute time as well as housing expenditure via job and home moves, as they pay for better residences and work farther from home. Job hoppers mainly reside in the suburbs, suffer from long commutes, change jobs frequently, and are likely to be low-income migrants.

commuting pattern | job dynamics | housing dynamics | mobility group | smartcard data

Linking mobility patterns to socioeconomic characteristics of city dwellers is important to economists, sociologists, geographers, and urban planners (1–4). Recent studies have explored the distribution of poverty and wealth, mobility rhythms of returners and explorers, human contact networks, demographic characteristics and neighborhood isolation phenomena from human mobility patterns by mobile phone call records, GPS data, transit smartcard data, and geocoded messages from social media (3, 5–8). In the era of big data, studies have uncovered individual patterns and scaling laws and pose the prospect of predicting human mobility (9–11). Of course, one advantage of big data is volume, but big data rarely include socioeconomic attributes directly and the availability is usually of a short duration. In contrast, household surveys (relatively small data in comparison) provide more socioeconomic attributes and travel information. Investigating human mobility, including travel behavior and the journey to work, has traditionally relied on household surveys (12, 13). Still, some limitations exist in the surveys such as the data resolution of travel trajectories and time use.

Mobility patterns can reflect human movement at various spatial scales so that they can be used to critique and address increasing social challenges. Recently, many researchers have investigated patterns of international or intercity migration (14–16), while fewer have explored intraurban migration or residential mobility (17). In the field of residential mobility, empirical studies often harness the life course framework (18), while theoretical models describe housing choice with the trade-off between commuting cost and housing expenditures (19). Indeed, the jobs–housing relationship, job and housing tenures, and their dynamics affect daily commutes and travel behavior and vice versa (2, 20, 21). However, few studies have assessed the job and housing dynamics with a longitudinal analysis at the individual level.

Transit station choice can be a proxy to capture patterns of individual mobility in a city (22). With the help of smartcard data, we probe consecutive trajectories of workplaces and residences over 7 y in Beijing to understand urban dwellers' job and housing dynamics. We identify the most preferred station near each traveler's workplace and residence (i.e., the work and home stations) according to individual commuting regularity (23). As transit use is a major part of commutes in megacities, regular public transport commuters present higher temporal regularity than nonregular commuters (Fig. 1*A*). From 2011 to 2017, the annual proportion of regular commuters rose from 23.74% to 31.40%, and their trip records account for over 80% of transit trips. We observed that 5,001 regular commuters retained their smartcard for seven consecutive years. The sampling process is shown in Fig. 1*B*. After assessing the spatiotemporal regularity of trips, we find 4,248 sample commuters whose workplaces and residences can be identified successively. The sample size is more than equivalent to a travel survey. Each sample commuter

Significance

This paper uses transit smartcards from travelers in Beijing retained over a 7-y period to track boarding and alighting stations, which are associated with home and work location. This allows us to track who moves and who remains at their homes and workplaces. Therefore, this paper provides a longitudinal study of job and housing dynamics with group conceptualization and characterization. This paper identifies four mobility groups and then infers their socioeconomic profiles. How these groups trade off housing expenditure and travel time budget is examined.

Author contributions: J.H., D.L., and J.W. designed research; J.H., D.L., and J.W. performed research; J.H., D.L., and J.Z. contributed new reagents/analytic tools; J.H. and Z.-j.W. analyzed data; and J.H., D.L., and J.W. wrote the paper.

The authors declare no conflict of interest.

This article is a PNAS Direct Submission.

Data deposition: The dataset about home stations, work stations, average travel time in the subway, and housing expenditure estimated from 4,248 regular commuters from 2011 to 2017 has been deposited at english.igsnrr.cas.cn/sd/dataset/201811/t20181108_201066.html.

[1]To whom correspondence should be addressed. Email: wangje@igsnrr.ac.cn.

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LETTER

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A Triassic stem turtle with an edentulous beak

Chun Li[1,2]*, Nicholas C. Fraser[3], Olivier Rieppel[4] & Xiao-Chun Wu[5]*

The early evolution of turtles continues to be a contentious issue in vertebrate palaeontology. Recent reports have suggested that they are diapsids[1–6], but the position of turtles within Diapsida is controversial[7–12] and the sequence of acquisition of turtle synapomorphies remains unclear[1–3]. Here we describe a Triassic turtle from China that has a mixture of derived characters and plesiomorphic features. To our knowledge, it represents the earliest known stem turtle with an edentulous beak and a rigid puboischiadic plate. The discovery of this new form reveals a complex early history of turtles.

The turtle is represented by a nearly complete skeleton from the lower Carnian (about 228 million years ago) of the Guanling District, Guizhou Province, southwestern China (Fig. 1a); it was collected from sediments approximately 7.5 m below the horizon that contained the stem turtle *Odontochelys*[13] (Extended Data Fig. 1). The most notable features of the newly described taxon are the edentulous beak formed by the anterior parts of the upper and lower jaws, the closure of the supratemporal fenestra by the contact of the parietal with the postorbital and postfrontal, the reduced number of the dorsal vertebrae with the transversely broadened ribs, and the formation of a rigid puboischiadic plate, whereas a carapace and plastron are absent.

Reptilia Laurenti, 1768
Pantestudines Joyce, Parham and Gauthier, 2004[14]
Eorhynchochelys sinensis gen. et sp. nov.

Etymology. *Eo-* (dawn), *rhyncho-* (beak), *chelys* (turtle): the earliest turtle with a beak; *sinensis,* from China.
Holotype. Sanya Museum of Marine Paleontology (SMMP) 000016 in Hainan Province, China, an articulated specimen displaying the postcranium in dorsal view, and the skull in ventral view (the skull and pelvis were prepared from both sides).
Locality. Heshangjing of Baiyuncun, Xinpuxiang, Guanling District, Guizhou Province, southwestern China.
Horizon. The upper unit of the lower part of the Wayao Member of the Falang Formation, approximately 8.5 m above the top of the Zhuganpo Member; Late Triassic (Carnian age).
Diagnosis. A stem pantestudine of large size; proportionately small skull broadly triangular in outline; supratemporal fenestra closed; infratemporal fenestra partially open; edentulous beak; pleurodont tooth implantation; teeth on parabasisphenoid; 12 dorsal vertebrae; neural spines with disc-like dorsal tables in cervical vertebra 8 to caudal 5; dorsal ribs 1 through 10 horizontally (anteroposteriorly) broadened, T-shaped in cross-section; rigid puboischiadic plate with median ventral keel; and ischium with posterior elongation.

The edentulous premaxillae and the anterior parts of the dentaries show a noticeably rugose surface with small pits and fine grooves, indicating the presence of a keratinous beak in *Eorhynchochelys* (Fig. 2a, c, e, f and Extended Data Fig. 2a–d). The exposed anterior teeth of the right maxilla are conical, but the exposed posterior teeth of the left maxilla are pleurodont, column-like and have a blunt tip (Extended Data Fig. 2a, e). The supratemporal fenestra is closed and the supratemporal bone is absent (Fig. 2a, c and Extended Data Fig. 3).

The pterygoid exhibits a distinct transverse flange and numerous conical teeth scattered across its entire ventral surface. The prominent parabasisphenoid has well-developed basipterygoid processes, and anteriorly extends into a broad-based, dentigerous cultriform process (Fig. 2b, d). The large basioccipital displays robust basal tubera. The sutures remain unfused in the exoccipital–opisthotic complex, which extends into a robust paroccipital process. The disarticulated supraoccipital shows a concave inner (ventral) surface.

There are 9 cervical, 12 dorsal, 2 sacral and 56 caudal vertebrae, all of which are non-notochordal and amphicoelous. The vertebral column is characterized by mid-dorsals that bear elongate prezygapophyses with a small, concave articular facet and short postzygapophyses and by neural spines that have broadened dorsal tables in posterior cervical vertebrae through anterior caudal vertebrae (Figs. 1a–c, 3a, b and Extended Data Fig. 4).

Cervical ribs 7 to 9 are complete and lack an anterior process (Fig. 1b, c). Cervical rib 9 has a much more elongate distal shaft of uniform diameter, a sharp transition that occurs at the eighth vertebra in *Proganochelys*[15]. Dorsal ribs 1 to 10 are dichocephalous and approximately T-shaped in cross-section as they expand to form prominent anterior and posterior horizontal flanges. These ribs extend laterally with minimal ventral curvature and together form a flattened carapace-like shield (Fig. 1a). There is, however, no contact or overlap of successive ribs. Dorsal ribs 11 and 12 are shorter and much less expanded than the more anterior ones. The sacral ribs are stout and fused to the sacral vertebrae (Fig. 3a, b and Extended Data Fig. 5).

The scapular blade is long and narrow with a slight distal expansion. There is a very weak development of an acromion (Fig. 1b, c). The clavicle is broad and stout anteromedially along its articulation with the rather narrow lateral process of the dorsoventrally expanded interclavicle; posterolaterally the scapular process of the clavicle becomes more slender.

With a pronounced postacetabular process, the ilium is similar to that of *Pappochelys* and *Odontochelys* (Fig. 3a, b). As preserved, the puboischiadic plate was broken, the right portion partially obscuring the left portion in ventral view. The rounded anterior edge of the pubis shows no evidence of an epipubic process; however, an incipient lateral process is present (Fig. 3c–e). A deep incision in the posterior margin of the pubis, closed posteriorly by the ischium, marks the obturator foramen. A second foramen piercing the ischium lies immediately behind the latter. In ventral view the ischium is practically indistinguishable from that of *Odontochelys* (Fig. 3c–g), exhibiting a prominent lateral tubercle behind the acetabulum. Posteromedial to the lateral tubercle, the ischium narrows to form an elongate process. The pubes and ischia meet in a broad suture along the ventral midline, thus forming a robust and solid puboischiadic plate with a distinct medioventral keel, as is also the case in *Odontochelys* (Fig. 3c–g). The posterior elongation of the ischium terminates in a blunt tip, similar to *Odontochelys*; however, *Eorhynchochelys* lacks a separate hypoischium that is present in *Odontochelys* and *Proganochelys* (Extended Data Fig. 6).

The arrangement of the gastralia remains unclear. Some rod-like gastral elements are loosely scattered below the dorsal ribs (Fig. 3a, b),

[1]Key Laboratory of Vertebrate Evolution and Human Origins, Institute of Vertebrate Paleontology and Paleoanthropology (IVPP), Chinese Academy of Sciences, Beijing, China. [2]Center for Excellence in Life and Paleoenvironment, Chinese Academy of Sciences, Beijing, China. [3]National Museums Scotland, Edinburgh, UK. [4]Field Museum of Natural History, Chicago, IL, USA. [5]Canadian Museum of Nature, Ottawa, Ontario, Canada. *e-mail: lichun@ivpp.ac.cn; xcwu@nature.ca

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Fire air pollution reduces global terrestrial productivity

Xu Yue [1] & Nadine Unger [2]

Fire emissions generate air pollutants ozone (O_3) and aerosols that influence the land carbon cycle. Surface O_3 damages vegetation photosynthesis through stomatal uptake, while aerosols influence photosynthesis by increasing diffuse radiation. Here we combine several state-of-the-art models and multiple measurement datasets to assess the net impacts of fire-induced O_3 damage and the aerosol diffuse fertilization effect on gross primary productivity (GPP) for the 2002–2011 period. With all emissions except fires, O_3 decreases global GPP by 4.0 ± 1.9 Pg C yr^{-1} while aerosols increase GPP by 1.0 ± 0.2 Pg C yr^{-1} with contrasting spatial impacts. Inclusion of fire pollution causes a further GPP reduction of 0.86 ± 0.74 Pg C yr^{-1} during 2002–2011, resulting from a reduction of 0.91 ± 0.44 Pg C yr^{-1} by O_3 and an increase of 0.05 ± 0.30 Pg C yr^{-1} by aerosols. The net negative impact of fire pollution poses an increasing threat to ecosystem productivity in a warming future world.

[1] Climate Change Research Center, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing 100029, China. [2] College of Engineering, Mathematics and Physical Sciences, University of Exeter, Exeter EX4 4QE, UK. Correspondence and requests for materials should be addressed to X.Y. (email: yuexu@mail.iap.ac.cn) or to N.U. (email: N.Unger@exeter.ac.uk)

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Emerging negative impact of warming on summer carbon uptake in northern ecosystems

Tao Wang[1,2], Dan Liu[2], Shilong Piao[1,2,3], Yilong Wang[4], Xiaoyi Wang[2], Hui Guo[2], Xu Lian[3], John F Burkhart[5], Philippe Ciais[4], Mengtian Huang[3], Ivan Janssens[6], Yue Li[3], Yongwen Liu[3], Josep Peñuelas[7,8], Shushi Peng[3], Hui Yang[3], Yitong Yao[3], Yi Yin[4] & Yutong Zhao[2]

Most studies of the northern hemisphere carbon cycle based on atmospheric CO_2 concentration have focused on spring and autumn, but the climate change impact on summer carbon cycle remains unclear. Here we used atmospheric CO_2 record from Point Barrow (Alaska) to show that summer CO_2 drawdown between July and August, a proxy of summer carbon uptake, is significantly negatively correlated with terrestrial temperature north of 50° N interannually during 1979–2012. However, a refined analysis at the decadal scale reveals strong differences between the earlier (1979–1995) and later (1996–2012) periods, with the significant negative correlation only in the later period. This emerging negative temperature response is due to the disappearance of the positive temperature response of summer vegetation activities that prevailed in the earlier period. Our finding, together with the reported weakening temperature control on spring carbon uptake, suggests a diminished positive effect of warming on high-latitude carbon uptake.

[1] Center for Excellence in Tibetan Earth Science, Chinese Academy of Sciences, Beijing 100085, China. [2] Key Laboratory of Alpine Ecology, Institute of Tibetan Plateau Research, Chinese Academy of Sciences, Beijing 100085, China. [3] Sino-French Institute for Earth System Science, College of Urban and Environmental Sciences, Peking University, Beijing 100871, China. [4] Laboratoire des Sciences du Climat et de l'Environnement, LSCE, Gif-sur-Yvette F-91191, France. [5] Department of Geosciences, University of Oslo, Oslo 0371, Norway. [6] Department of Biology, University of Antwerp, Universiteitsplein 1, 2610 Wilrijk, Belgium. [7] CREAF, Cerdanyola del Valles, Barcelona 08193 Catalonia, Spain. [8] CSIC, Global Ecology Unit CREAF-CEAB-CSIC-UAB, Cerdanyola del Valles, Barcelona 08193 Catalonia, Spain. Correspondence and requests for materials should be addressed to T.W. (email: twang@itpcas.ac.cn)

List of all Publications

[1] Lin Zhengyang; Chen Fang; Li Bin; Yu Bo; Jia Huicong; Zhang Meimei, An active fire detection algorithm based on multi-temporal FengYun-3C VIRR data, REMOTE SENSING OF ENVIRONMENT.

[2] Chen Yaning, Li Zhi, Fang Gonghuan, Li Weihong, Large hydrological processes changes in the transboundary rivers of Central Asia, Journal of Geophysical Research.

[3] Jie Bai, Hao Shi, Qiang Yu, Zunyi Xie, Satellite-observed vegetation stability in response to changes in climate and total water storage in Central Asia, Science of the Total Environment.

[4] Zheng Yi, Zhang Li, et al., Sources of uncertainty in gross primary productivity simulated by light use efficiency models: Model structure, parameters, input data, and spatial resolution, Agricultural and Forest Meteorology.

[5] Zhou Yu, Zhang Li, et al., Spatiotemporal Transition of Institutional and Socioeconomic Impacts on Vegetation Productivity in Central Asia over Last Three Decades, Science of the Total Environment.

[6] Bian J., Li A., Huang C., Zhang R. & Zhan X, A self-adaptive approach for producing clear-sky composites from VIIRS surface reflectance datasets, ISPRS Journal of Photogrammetry and Remote Sensing.

[7] Zhang Jiahua, Satellite-based estimate of the variability of warm cloud properties associated with aerosol and meteorological conditions, Atmos. Chem. Phys.

[8] Y. Tang, J. Zhang, L. Jing, H. Gao, Geostatistical modelling of spatial dependence in area-class occurrences for improved object-based classifications of remote-sensing images, ISPRS Journal of Photogrammetry and Remote Sensing.

[9] Tang P., Chen F., Jiang A., Zhou W., Wang H., Leucci G., Giorgi L., Sileo M., Luo R., Lasaponara R., Masini N., Multi-frequency EMI survey for archaeological prospection: approach and results in Han Hangu Pass and Xishan Yang in China, Surveys in Geophysics.

[10] Xiaoyue Wang, Snow cover phenology affects alpine vegetation growth dynamics on the Tibetan Plateau: Satellite observed evidence, impacts of different biomes, and climate drivers, Agricultural and Forest Meteorology.

[11] Chaoyang Wu, Contrasting responses of autumn leaf coloration to daytime and nighttime warming, Nature Climate Change.

[12] Zhaoyang Zhanga, Meng Fan, Weiling Wu, Zifeng Wang, Minghui Tao, Jing Wei, Quan Wang, A simplified aerosol retrieval algorithm for Himawari-8 Advanced Himawari Imager over Beijing, Atmospheric Environment.

[13] Han, X., Zhu, L., Wang, S., Meng, X., Zhang, M., Hu, J., Modeling study of impacts on surface ozone of regional transport and emissions reductions over North China Plain in summer 2015, Atmos. Chem. Phys.

[14] Chen, L., Zhang, M., Zhu, J., Wang, Y., & Skorokhod, A., Modeling impacts of urbanization and urban heat island mitigation on boundary layer meteorology and air quality in beijing under different weather conditions, J. Geophys. Res.

[15] Zhao, G S., Dong, J W., Cui, Y P., et al., Evapotranspiration-dominated biogeophysical warming effect of urbanization in the Beijing-Tianjin-Hebei region, China, Climate Dynamics.

[16] Ma, S F., Zhou, Y T., Gowda, P H., et al, Application of the water-related spectral reflectance indices: A review, Ecological Indicators.

[17] Zhigang Sun, Zhu Ouyang, Junfang Zhao, Shiji Li, Xubo Zhang, Wei Ren., Recent rebound in observational large-pan evaporation driven by heat wave and droughts by the Lower Yellow River, Journal of Hydrology.

[18] HUANG Jie, LEVINSON David, WANG Jiaoe, ZHOU Jiangping, WANG Zi-jia, Tracking job and housing dynamics with smartcard data, PNAS.

[19] 李佳洺、徐成东、陈明星、孙威 , Balanced Development: Nature Environment and Economic and Social Power in China, Journal of Cleaner Production.

[20] Lianfa Li, Jiehao Zhang, Xia Meng, Ying Fang, Yong Ge, Jinfeng Wang, Chengyi Wang , Jun Wu, Haidong Kan, Estimation of PM2.5 Concentrations at a High Spatiotemporal Resolution Using Constrained Mixed-Effect Bagging Models with MAIAC Aerosol Optical Depth, Remote Sensing of Environment.

[21] Dehua Mao, Zongming Wang, Bingfang Wu, Yuan Zeng, Ling Luo, Bai Zhang, Land degradation and restoration in the arid and semiarid zones of China: Quantified evidence and implications from satellites, Land Degradation and Development.

[22] Li Y, et al., Evaluation of soil resistance formulations for estimates of sensible heat flux in a desert vineyard, Agricultural and Forest Meteorology.

[23] Huang G, et al, Towards a Broadband Parameterization Scheme for Estimating Surface Solar Irradiance: Development and Preliminary Results on MODIS Products, Journal of Geophysical Research – Atmospheres.

[24] Chun Li, Nicholas C. Fraser, Olivier Rieppel & Xiao-Chun Wu, A Triassic stem turtle with an edentulous beak, Nature.

[25] Licheng Guo, Shangfa Xiong , Zhongli Ding, Guiyun Jin, Jiabin Wu,Wei Ye, Role of the mid-Holocene environmental transition in the decline of late Neolithic cultures in the deserts of NE China, Quaternary Science Reviews.

[26] Zhiheng Li1,2, Julia A. Clarke3, Chad M. Eliason4, Thomas A. Stidham1,2, Tao Deng1,2 & Zhiheng Li1,2, Julia A. Clarke3, Chad M. Eliason4, Thomas A. Stidham1,2, Tao Deng1,2 & Zhiheng Li, Julia A. Clarke, Chad M. Eliason, Thomas A. Stidham Tao Deng & Zhonghe Zhou, Vocal specialization through. tracheal elongation in an extinct Vocal specialization tracheal elongation in an extinct through Miocene pheasant from China, Scientific Reports.

[27] Yumei Li, Yun Zhang, Guobang Tong, Chunhai Li, Long Zhao, Zhaochen Kong, Pollen assemblages and anthropogenic influences in the central and western regions of Yunnan Province, Science of the Total Environment.

[28] Qiansheng Huang, Yiyao Liu, Yajie Chen, Chao Fang, Yulang Chi, Huimin Zhu, Yi Lin, Guozhu Ye, Sijun Dong, New insights into the metabolism and toxicity of bisphenol A on marine fish under long-term exposure, Environmental Pollution.

[29] Yulang Chi, Yi, Lin, Yanyang Lu, Qiansheng Huang, Guozhu Ye, Sijun Dong, Gut microbiota dysbiosis correlates with a low-dose PCB126-induced dyslipidemia and non-alcoholic fatty liver disease, Science of the Total Environment.

[30] BIG Data Center Members, Database Resources of the BIG Data Center in 2019, Nucleic Acids Research.

[31] Lina Ma, Jiabao Cao, Lin Liu, Qiang Du, Zhao Li, Dong Zou, Vladimir B. Bajic 5 and Zhang Zhang, LncBook: a curated knowledgebase of human long non-coding RNAs, Nucleic Acids Research.

[32] Mengwei Li, Dong Zou, Zhaohua Li, Ran Gao, Jian Sang, Yuansheng Zhang, Rujiao Li, Lin Xia, Tao Zhang, Guangyi Niu, Yiming Bao and Zhang Zhang, EWAS Atlas: a curated knowledgebase of epigenome-wide association studies, Nucleic Acids Research.

[33] Man Li, Lin Xia, Yuansheng Zhang, Guangyi Niu, Mengwei Li, Pei Wang, Yang Zhang, Jian Sang, Dong Zou, Songnian Hu, Lili Hao and Zhang Zhang, Plant editosome database: a curated database of RNA editosome in plants, Nucleic Acids Research.

[34] Guangyi Niu, Dong Zou, Mengwei Li, Yuansheng Zhang, Jian Sang, Lin Xia, Man Li, Lin Liu, Jiabao Cao, Yang Zhang, Pei Wang, Songnian Hu, Lili Hao and Zhang Zhang, Editome Disease Knowledgebase (EDK): a curated knowledgebase of editome-disease associations in human, Nucleic Acids Research.

[35] Liu C., Wang X., Köhl A., Wang F., Liu Z., The Northeast-Southwest Oscillating Equatorial Mode of the Tropical Instability Wave and Its Impact on Equatorial Mixing, Geophysical Research Letters.

[36] Tao Lingjiang, Gao Chuan and Zhang Rong.-Hua, Model parameter-related optimal perturbations and their contributions to El Niño prediction errors, Climate Dynamics.

[37] Li, Y., Peng, S., Wang, J., Yan, J., & Huang, H., On the mechanism of the generation and interannual variations of the summer upwellings west and southwest off the Hainan Island., Journal of Geophysical Research: Oceans.

[38] Wu Xuejiao, Che Tao, Li Xin, et al., Slower Snowmelt in Spring along with Climate Warming across the Northern Hemisphere, Geophysical Research Letters.

[39] Guo Yanlong, Li Xin, Zhao Zefang, et al., Predicting the impacts of climate change, soils and vegetation types on the geographic distribution of Polyporus umbellatus in China, Science of the Total Environment.

[40] Wang Lili, Li Xin, Bai Yulong, Short-term wind speed prediction using an extreme learning machine model with error correction, Energy Conversion and Management.

[41] Zhiheng Du, Cunde Xiao, Vasile. Furdui, Wangbin Zhang, The perchlorate record during 1956–2004 from Tienshan ice core, East Asia, Science of the Total Environment.

[42] Feng Ma, Lifeng Luo, Aizhong Ye, and Qingyun Duan, Seasonal drought predictability and forecast skill in the semi-arid endorheic Heihe River basin in northwestern China, Hydrology and Earth System Sciences.

[43] Jingwen Hou, Aizhong Ye, Jinjun You, Feng Ma and Qingyun Duan, An estimate of human and natural contributions to changes in water resources in the upper reaches of the Minjiang River, Science of The Total Environment.

[44] Liu Yong,Chen Huopo,Wang Huijun, Qiu Yubao, The Impact of the NAO on the Delayed Break-Up Date of Lake Ice over the Southern Tibetan Plateau, Journal of Climate.

[45] Yahui Che, Yong Xue, Jie Guang, Lu She, Jianping Guo, Evaluation of the AVHRR DeepBlue aerosol optical depth dataset over mainland China, ISPRS Journal of Photogrammetry and Remote Sensing.

[46] Li T, Shokr M, Liu Y, et al., Monitoring the tabular icebergs C28A and C28B calved from the Mertz Ice Tongue using radar remote sensing data, Remote Sensing of Environment.

[47] Lv Mingyang, et al, Characterising the behavior of surge and no-surge type glacier in the Kingata Mountains, Eastern Pamir, from 1999 to 2016, Cryosphere.

[48] Le Xu, Fire air pollution reduces global terrestrial productivity, Nature Communications.

[49] Tao Wang, Dan Liu, Shilong Piao, Yilong Wang, Xiaoyi Wang, Hui Guo, Xu Lian, John F Burkhart, Philippe Ciais, Mengtian Huang, Ivan Janssens, Yue Li, Yongwen Liu, Josep Peñuelas, Shushi Peng, Hui Yang, Yitong Yao, Yi Yin & Yutong Zhao, Emerging negative impact of warming on summer carbon uptake in northern ecosystems, Nature Communications.

[50] Youhua Ran, Xin Li, Guodong Cheng, Climate warming over the past half century has led to thermal degradation of permafrost on the Qinghai-Tibet Plateau, Cryosphere.

[51] Dongliang Luo, Huijun Jin, Xiaoying Jin, Ruixia He, Xiaoying Li, Reginald R. Muskett, Sergey S. Marchenko, Vladimir E. Romanovsky, Elevation-dependent thermal regime and dynamics of frozen ground in the Bayan Har Mountains, Qinghai-Tibet Plateau, Permafrost and Periglacial Processes.

[52] Shao Donghuang, Xu Wenbo, Li Hongyi, Wang Jian, and Hao Xiaohua, Reconstruction of remotely sensed snow albedo for quality improvements based on a combination of Forward and Retrieval Models, IEEE Transactions on Geoscience and Remote Sensing.

[53] Yangjian Zhang, Ke Huang, Tao Zhang, Juntao Zhu, and Yangping Di, Soil nutrient availability regulated global carbon use efficiency, Global and Planetary Change.

[54] Kang Zhao, Weidong Kong, Fei Wang, Xi-En Long, Linyan Yue, Chunyan Guo, Huaiying Yao, and Xiaobin Dong, Desert and steppe soils exhibit lower autotrophic microbial abundance but higher atmospheric CO2 fixation capacity than meadow soils, Soil Biology and Biochemistry.

[55] Jianyu Liu, Yongqiang Zhang, Yuting Yang, Xihui Gu, Mingzhong Xiao, Investigating Relationships Between Australian Flooding and Large-Scale Climate Indices and Possible Mechanism, Journal of Geophysical Research-Atmospheres.

[56] Chen, X.et al, Impact of Winter Ural Blocking on Arctic Sea Ice: Short-Time Variability, Journal of Climate.

[57] Luo B.et al, The Winter Midlatitude-Arctic Interaction: Effects of North Atlantic SST and High-latitude Blocking on Arctic Sea Ice and Eurasian Cooling, Climate Dynamics.

[58] Meng X., S. Lu, T. Zhang, L. Zhao, Z. Li, B. Han, S. Li, D. Ma, H. Chen, Y. Ao, S. Luo and L. Wen, Simulated cold bias being improved by using MODIS time-varying albedo in the Tibetan Plateau in WRF model, Environmental Research Letters.

[59] Zhang Yulan, Kang Shichang Gao Tanguang, Dissolved organic carbin in snow cover of the Chinese Altai Mountains Central Asia: Concentration, sources and light-absorption Properties, Science of the Total Environment.

[60] Anjum, M.N.,Ding, Y.J., Shangguan, D.H., Performance evaluation of latest integrated multi-satellite retrievals for Global Precipitation Measurement (IMERG) over the northern highlands of Pakistan, Atmospheric Research.

[61] Wen, Z., K. Song, G. Liu, Y. Shang, C. Fang, J. Du and L. Lyu, Quantifying the trophic status of lakes using total light absorption of optically active components, Environmental Pollution.

[62] Li R., Soil thermal conductivity and its influencing factors at the Tanggula permafrost region on the Qinhai-Tibet Plateau, Agricultural and Forest Meteorology.

[63] Mengmeng Wang, Guojin He, Zhaoming Zhang, et al., A radiance-based split-window algorithm for land surface temperature retrieval: Theory and application to MODIS data, Int J Appl Earth Obs Geoinformation.

[64] Yujie Liu, Effects of climate change and agronomic practice on changes in wheat phenology, Climatic Change.

[65] Jing Chen, Yuan Wang, Man Qin, Li-Yun Jiang, Ge-Xia Qiao, The mitochondrial genome of Greenidea psidii van der Goot (Hemiptera: Aphididae: Greenideinae) and comparisons with other Aphididae aphids, International Journal of Biological Macromolecules.

SUMMARY AND PROSPECT

2018 marked the beginning of CASEarth. Under the leadership of the governance board, all members of CASEarth worked together to innovate and have made a series of important achievements in scientific discovery, technological innovation, and decision support based on Big Earth Data. The deployment of 9 projects, 41 sub-projects, and 138 research teams has been completed. There are 7 working groups set under the administrative panel, forming a collaborative working mechanism of the administrative panel, working groups and the CASEarth Administration Office. In terms of the major outputs, 3 Nature / Science articles were published this year, as well as 152 SCI articles, including 65 TOP25 articles; 51 patents and 22 software patents were applied. We offered national level policy support with 18 consultant reports and provided national/regional policy support services for 31 times.

In 2019, CASEarth will work on the overall goal of “constructing an International Big Earth Data Science Center,” focusing on breaking the bottleneck of open data sharing and achieving the full integration of scattered data, models and services in the fields of resources, environment, biology and ecology. Emphasis will be put on the four core tasks of “Five sub-systems, One Satellite, One Facility, Six SDGs.” Five sub-systems include the Belt and Road regional system, the Beautiful China national system, the global biosphere sub-system, the global ocean sub-system and the global cryosphere sub-system. CASEarth Satellite will enter into flight model phase from prototype phase. The facility indicates the construction of state-of-the-art Big Earth Data Infrastructure. Six SDGs are oriented towards the UN Sustainable Development Goals (SDGs-2, 6, 11, 13, 14, 15) and based on the Big Earth Data Platform, comprehensively integrating the databases, models and decision-making methods of CAS in the fields of resources, environment, ecology and biology , and building sustainable development evaluation indicators system and decision support platform. “Big Earth Data in Support of Sustainable Development Goals” Report will be released, exploring a new paradigm driven by big data and the integration of disciplines, so as to lead technological innovation, scientific discovery, macro-decision making, and social and public knowledge dissemination.

PART 06

CASEarth Timeline

S/N	Time	Event
1	October 21st, 2016	BAI Chunli, president of CAS, convened a conference on the construction of a geo-information platform in the field of resource, environment and bio-environment;
2	March 1st, 2017	The first meeting of CASEarth Governance Board: Approved the proposal, suggested to complete the feasibility report, and promoted project approval;
3	July 21st, 2017	The feasibility report was approved in the Academic Consultant Meeting of CAS;
4	July 29th, 2017	The feasibility report reviewed and approved by the President of CAS; "Big Earth Data Science Engineering Project (CASEArth)" entered into the pre-proposal phase;
5	August 30th, 2017	Reported the construction plan of "Big Earth Data International Science Center;"
6	September 25th, 2017	Implementation Plans of CASEarth and its projects approved by the Academic Consultation and Review Meeting;
7	October 10th-11th, 2017	Implementation Plans of sub-projects and research teams reviewed and selected;
8	October 12th, 2017	Implementation Plans of CASEarth and its projects approved by the Bureau of Science and Technology;
9	November 3rd, 2017	CASEarth Implementation Plan approved by CAS Governing Board and the project was officially funded.
10	December 20th-30th, 2017	Implementation Plans of sub-projects and research team reassessed, and 12 of them were temporally postponed;
11	January 30th, 2018	"Steps to the Digital Silk Road" published in *Nature*;
12	February 12th, 2018	CASEarth Launch Conference held in Beijing; Launched the new *Journal of Big Earth Data*, which is published by Taylor & Francis 
13	March, 2018	Assessment and approval of 5-year science plan and budget;
14	June 19th, 2018	Reassessed the proposal of the postponed research teams;
15	June 28th, 2018	Convened the Seminar of CASEarth Technical Panel – over 100 experts from nine projects attended the seminar and made comments on technology and methodology across the entire project;
16	August 13rd, 2018	The second meeting of CASEarth Governance Board: decided the physical site of the prototype system;
17	October 10th, 2018	Approval of CASEarth Satellite Designing Plan and technical parameters;
18	October, 2018	Annual Meetings of CASEarth and its nine projects;
19	November 1st, 2018	The third meeting of CASEarth Governance Board: evaluated the annual progress of CASEarth and its projects
20	November 3rd, 2018	CASEarth Signed Strategic Cooperation Agreement with UNEP, in support of its global environmental outlook
21	November 30th, 2018	Assessment and approval of CASEarth Prototype System and its development plan;
22	December 5th–7th, 2018	Organized International Science Conference on Digital Belt and Road

CASEarth Launch Conference

“Steps to the Digital Silk Road”published in *Nature*;

CASEarth Signed Strategic Cooperation Agreement with UNEP, in support of its global environmental outlook

CASEarth outreach and public communication

CASEarth Signed Strategic Cooperation Agreement with UNESCO

DBAR- Heritage Research Group in the field

Project Management Office of CASEarth

Address: No.9, Dengzhuang South Road, Haidian District, Beijing

Zip code: 100094

Telephone: +86 10 82178985

E-mail: casearth@radi.ac.cn

Website: www.casearth.com