An Integrated Visualization System for Multi-Source Carbon Concentration Datasets

Fan Hong [1] Qingya Shu [1] Jiang Zhang [1] Richen Liu [1] Xiaoru Yuan [1,2*] Xiaoguang Ma [3†]

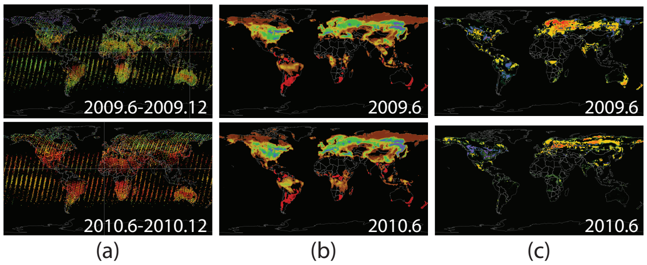
1) Key Laboratory of Machine Perception (Ministry of Education), and School of EECS, Peking University, Beijing, P.R. China
2) Beijing Engineering Technology Research Center of Virtual Simulation and Visualization, Peking University, Beijing, P.R. China
3) State Key Laboratory of Numerical Modeling for Atmospheric Sciences and Geophysical Fluid Dynamics, Institute of Atmospheric Physics, Chinese Academy of Sciences, Beijing, P.R. China

ABSTRACT

To study worldwide carbon emission and flux, domain scientists gather data from multiple sources, such as satellite observation data, assimilation data, modeling and simulation data, etc. In this work, we propose an integrated visualization system which provides uniformed interface to analyze multiple types of data ranging from points, surfaces, to volumes. Especially for ensemble simulation data, techniques of variation fields and ensemble graph are employed to provide non-trivial uncertainty analysis of their models.

1 BACKGROUND AND DATA DESCRIPTIOIN

Scientists have gathered a plenty of datasets from multiple sources to study worldwide carbon emission and flux. These datasets include satellite observation data, assimilation data, modeling and simulation data, etc. For the property of datasets, they are ranging from points, surfaces, to volumes. In addition, the datasets are all time-varying and multi-dimensional. For the simulation datasets, some of them even contain hundreds of simulations. For the domain scientists, they usually have difficulties in integrating all these multi-faceted dataset for their analysis [1]. In this work, we present our integrated visualization system for multi-source datasets analysis, which could assist domain scientists greatly.



(a) (b) (c)

Figure 1: (a) GOSAT L2 SWIR dataset; (b) GOSAT L4 Flux dataset; (c) CarbonTracker CO_2 flux simulation.

One part of the multi-source datasets used in our system comes from the GOSAT satellite observation as well as its processing products. The Greenhouse Gases Observing Satellite "IBUKI" (GOSAT) is the world's first spacecraft to measure the concentrations of carbon dioxide and methane, the two major greenhouse gases, from space[1]. The spacecraft was launched successfully on January 23, 2009, and is collecting data since then. By observing the sunlight reflected from the earth's surface and light emitted from the atmosphere and the surface, the onboard observation instrument is able to estimate the concentration column abundances of the gases. The SWIR (Short-Wavelength InfraRed) data comes from the Level 2 processing (Figure 1(a)), which is in the form of sampling points with latitude, longitude, timestamp, and many attributes, such as height, total column abundances of CO_2 and CH_4, etc. The global Flux data is from the Level 4 processing (Figure 1(b)), which describe the three-dimensional global distribution of CO_2/CH_4 flux. What we use in our system is monthly data in 2.5° grids, which records the imposed flux from anthropogenic activity, biomass burning, natural emission, and optimized measure and uncertainty.

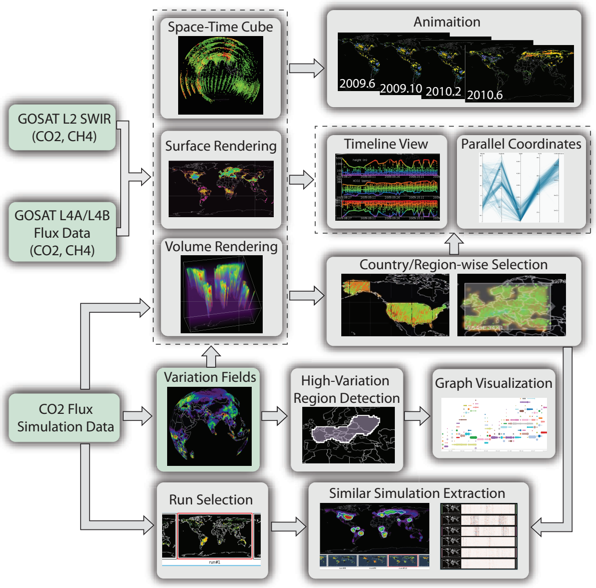


Figure 2: System pipeline

The other part of datasets comes from the CarbonTracker which is a CO_2 measurement and modeling system to keep track of carbon dioxide uptake and release at the Earth's surface over time (Figure 1(c)). It estimates the carbon dioxide exchange using a 'top-down atmospheric inversion' method[2]. Several simulations are initiated to study global CO_2 flux using different temporal resolutions ranging from weekly, monthly, yearly, to long-term. Basically, these data are three-dimensional, i.e. date, latitude, and longitude, measuring average surface flux from terrestrial vegetation, open ocean, biomass burning, and fossil fuel burning, and their standard

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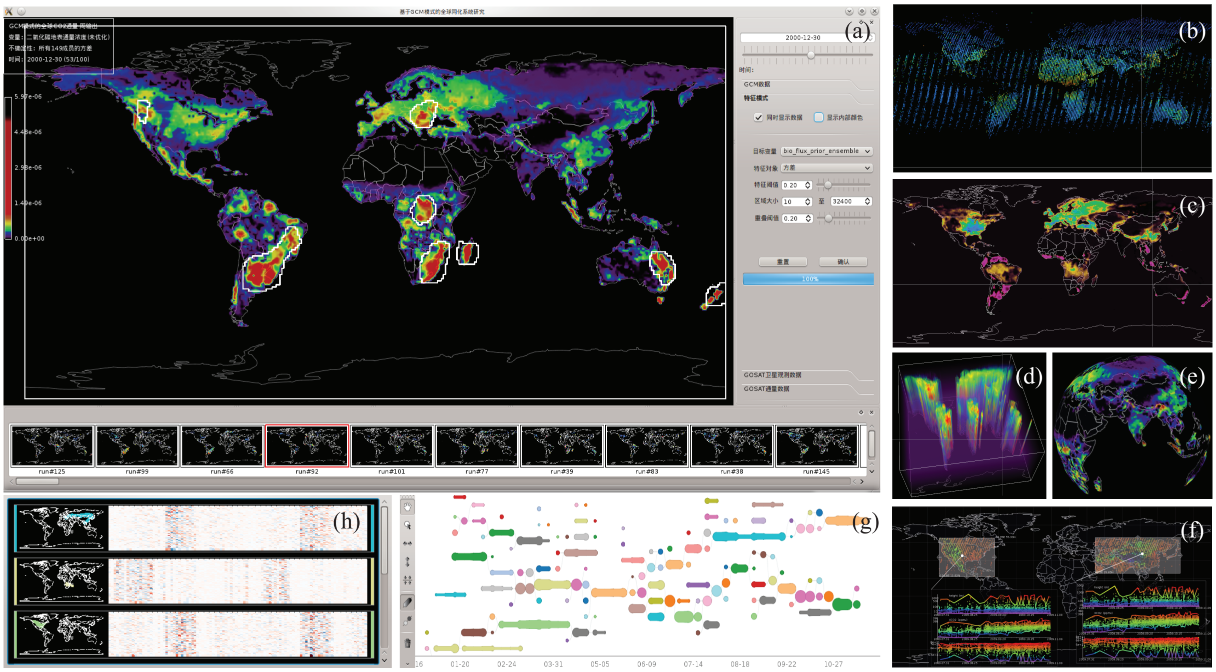
*e-mail: {fan.hong,qingya.shu,jiang.zhang,richen,xiaoru.yuan}@pku.edu.cn
†e-mail: maxg@mail.iap.ac.cn

[1] http://www.gosat.nies.go.jp/eng/gosat/page1.htm

[2] http://www.carbontracker.net/index.html



GCM模式的全球CO2通量 周输出
变量：二氧化碳地表通量浓度(未优化)
不确定性：所有149成员的方差
时间：2000-12-30 (53/100)

2000-12-30

☑ 同时显示数据 ☐ 显示内部颜色

目标变量 bio_flux_prior_ensemble
特征对象 方差
特征阈值 0.20
区域大小 10 至 32400
重叠阈值 0.20

Figure 3: (a) The main system interface showing the variation field with high variation regions highlighted; (b-e) Three basic visualization: space-time cube, surface and volume render; (f) Multi-focus region comparison with time-series; (g) Graph structure illustrating temporal evolution of high variation regions; (h) Detailed information of selected region in (g).

deviation. All of these variables have prior version and optimized one which results from assimilation. Especially for weekly data, simulation results of 150 runs are recorded for the prior and optimized surface CO_2 flux from terrestrial vegetation and open ocean.

From the visualization aspect, these datasets range from point, surface (longitude-latitude), to volume (time-longitude-latitude), and have the features of time-varying , multi-dimensional and ensemble simulations. This poses great challenge to fuse them for integrated analysis.

2 SYSTEM DESIGN

Figure 2 shows the pipeline of our integrated visualization system. We firstly provide three basic visualization techniques, i.e. space-time cube visualization [2], surface and volume rendering, to help domain scientists directly learn the spatial distribution of the data. A time slider is used to control the current time step or time range for rendering. Users can select any rectangular region or any country to inspect the temporal evolution of variables, as well as their local statistics, e.g. mean values. Multiple focuses can be selected for regional comparison. A parallel coordinate plot is developed to study the relationships among multiple variables. For ensemble simulations in the datasets, users can analyze them either by comparing simulations or by visualizing their variation as uncertainty (Figure 3). Besides juxtaposed comparison of individual simulations, we allow users to specify regions and variables of interest to extract those most similar simulations respect to users' choices. To visualize uncertainty information, in addition to direct rendering of uncertainty fields, we also extract those highly uncertain regions and organize them in to a graph structure [3], which is analogue to the storyline visualization [4]. Users can select nodes to investigate the temporal evolution of variables on those high variation regions and compare them across simulation members.

Our integrated visualization system has gained very positive feedback from domain collaborators. Our system covered large portion of data types the scientists daily used, they could easily investigate more similar datasets. The region selection function is very helpful for they research. With its assistance, they could easily extract and study region-wise or country-wise data and compare it with other regions. For the ensemble visualization techniques, in general, the scientists consider that they provide convenient and efficient way to explore so large number of simulation members. Especially, they found it very helpful that our tool could automatically detect similar members in user defined regions, while previous tools only support whole domain analysis.

ACKNOWLEDGEMENTS

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