[EJ] Oral | M (Multidisciplinary and Interdisciplinary) | M-GI General Geosciences, Information Geosciences & Simulations

[M-GI29] [EJ] Data-driven analysis, modeling and prediction in geosciences

convener:Tatsu Kuwatani(Japan Agency for Marine-Earth Science and Technology), Dmitri Kondrashov(University of California, Los Angeles), Hiromichi Nagao(Earthquake Research Institute, The University of Tokyo), Sergey Kravtsov(University of Wisconsin Milwaukee), Chairperson:Kenta Yoshida(Japan Agency for Marine-earth Science and Technology), Chairperson:Dmitri Kondrashov(University of California, Los Angeles,)

Sat. May 20, 2017 3:30 PM - 5:00 PM 102 (International Conference Hall 1F)

It is important to extract essential processes and structures from observed datasets in order to understand and predict the dynamic behavior of the earth and planetary systems. Recently, powerful data-driven methodologies have been proposed to extract, model and predict useful information contained in high-dimensional datasets that are ubiquitous in earth and space. This session aims to provide an opportunity to highlight recent advances in such data-driven techniques across disciplines and to have a productive discussion for interdisciplinary collaborations.

[MGI29-13] **Data-driven Nonlinear Dynamical Models for Forecast of Climate Variability**

*Alexander M Feigin[1], Dmitry N Mukhin[1], Andrey S Gavrilov[1], Aleksey F Selesnev[1], Evgeny M Loskutov[1] （1.Institute of Applied Physics RAS）

3:30 PM - 3:45 PM

[MGI29-14] Data-driven model for investigation of the mid-Pleistocene transition

*Evgeny M Loskutov[1], Dmitry N Mukhin[1], Andrey S Gavrilov[1], Alexander M Feigin[1] （1.Institute of Applied Physics RAS）

3:45 PM - 4:00 PM

[MGI29-15] Analysis of zonal structure of phenocryst minerals considering element diffusion: Approach based on Bayesian statistics

*Fumitoshi Morisato[1], Kazuhito Ozawa[1] （1.Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo）

4:00 PM - 4:15 PM

[MGI29-16] Managing soil organic carbon sequestration in China’ s croplands

*Guocheng Wang[1] （1.Institute of Atmospheric Physics, Chinese Academy of Sciences）

4:15 PM - 4:30 PM

[MGI29-17] **Spatial modeling by joint use of physical law and geostatistics for grade analysis in geofluid-caused ore deposit**

*LEI LU[1], Katsuaki KOIKE[1], Koki KASHIWAYA[1], Mohamad N. HERIAWAN[2], Ryoichi YAMADA[3] （1.Department of Urban Management, Graduate School of Engineering, Kyoto University, Japan, 2.Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology, Indonesia., 3.Graduate School of Science, Tohoku University, Japan）

4:30 PM - 4:45 PM

[MGI29-18] Solar terrestrial modelling: Application of systems methodologies

*Simon N Walker[1], Michael Balikhin[1], Richard Boynton[1] （1.ACSE, University of Sheffield, Sheffield, UK）

4:45 PM - 5:00 PM

Data-driven Nonlinear Dynamical Models for Forecast of Climate Variability

*Alexander M Feigin[1], Dmitry N Mukhin[1], Andrey S Gavrilov[1], Aleksey F Selesnev[1], Evgeny M Loskutov[1]

1. Institute of Applied Physics RAS

We apply new methodology of empirical modeling and forecast of nonlinear dynamical system variability [1] to study of climate systems' variability. The methodology is based on two approaches: (i) nonlinear decomposition of spatially distributed data [2], that provides low-dimensional embedding for further modeling, and (ii) construction of empirical model in the form of low dimensional random dynamical ("stochastic") system [3].
The methodology abilities are demonstrated by modeling and forecast of ENSO system variability. Three monthly data sets are used: global sea surface temperature anomalies, troposphere zonal wind speed, and thermocline depth; all data sets are limited by 30 S, 30 N and have horizontal resolution 1^0x1^0.
We compare results of optimal data decomposition as well as prognostic skill of the constructed models for different combinations of involved data sets. We also present comparative analysis of ENSO indices forecasts fulfilled by our models and by IRI/CPC ENSO Predictions Plume.

[1] A. Gavrilov, D. Mukhin, E. Loskutov, A. Feigin, 2016: Construction of Optimally Reduced Empirical Model by Spatially Distributed Climate Data. 2016 AGU Fall Meeting, Abstract NG31A-1824.
[2] D. Mukhin, A. Gavrilov, E. Loskutov , A.Feigin, J.Kurths, 2015: Principal nonlinear dynamical modes of climate variability, Scientific Reports, rep. 5, 15510; doi: 10.1038/srep15510.
[3] Ya. Molkov, D. Mukhin, E. Loskutov, A. Feigin, 2012: Random dynamical models from time series. Phys. Rev. E, Vol. 85, n.3.

Keywords: Nonlinear Dynamical Model, Forecast of Climate Variability, Nonlinear Data Decomposition

Data-driven model for investigation of the mid-Pleistocene transition

*Evgeny M Loskutov[1], Dmitry N Mukhin[1], Andrey S Gavrilov[1], Alexander M Feigin[1]

1. Institute of Applied Physics RAS

In this work we apply a data-driven model for the analysis of complex spatially distributed geophysical data. We are focused on the investigation of critical transitions on paleo timescales. Namely we investigated mid-Pleistocene transition which led to change of dominate cycles of glacial variability in Pleistocene.

We demonstrate the good performance of applying our data-driven model to analysis of paleoclimate variability. In particular, we discuss the possibility of detecting, identifying and prediction of the mid-Pleistocene transition by means of nonlinear empirical modeling using the paleoclimate record time series.

The study is supported by Government of Russian Federation (agreement #14.Z50.31.0033 with the Institute of Applied Physics of RAS).

Keywords: Data-driven Modeling, Critical Transitions, Time Series Analysis, Mid Pleistocene Transition

Analysis of zonal structure of phenocryst minerals considering element diffusion: Approach based on Bayesian statistics

*Fumitoshi Morisato[1], Kazuhito Ozawa[1]

1. Department of Earth and Planetary Science, Graduate School of Science, The University of Tokyo

From the zonation structure found in the phenocrysts in the volcanic rocks, when the equilibrium with the melt is guaranteed, sequence data on melt composition with high degree of freedom and short time scale of homogenization can be obtained by using partitioning coefficients. Then, it is expected that constraints on physical processes related to the differentiation process inside the crust and on primary magma will be possible. However, due to the diffusion of elements in the crystal, analysis using partitioning coefficients is often insufficient. On the other hand, if the influence of diffusion can be estimated from the compositional zoning structure affected by element diffusion, time information can be obtained. However, when the zonal structure becomes complicated, such as when formed in multiple crystal growth stages, the number of parameters to be considered in analysis increases and the dependence among the parameters becomes complicated.
In this study, we developed a method to elucidate the physical processes experienced by magma system through restored information on temporal change of melt composition by evaluating the influence of element diffusion quantitatively from the zonation structure of the phenocryst mineral that experienced the multistage crystallization process.

In this study, we have constructed a forward model for the formation of zonal structure by crystal growth and subsequent element diffusion, and estimated the parameters characterizing the model by Parallel tempering Markov Chain Monte Carlo (PT-MCMC) method. We conducted validation test for our method by using numerically generated zonal structure which is added noise. In our crystal growth model, the zonal structure is formed by several stages where the element diffusion progresses after crystal growth. Classification of the crystal growth stage was constrained based on a profile with a low diffusion rate such as Cr_2O_3 in the case of orthopyroxene.

In our model on crystal growth, the melt composition as the starting point of calculation is the whole rock composition of the most primitive natural lava. The melt composition change is calculated by fractionation or addition of small amount of olivine, orthopyroxene, and spinel repeatedly. Each solid phase is spherically symmetric and the spherical shell with the composition that is local equilibrium with melt grows for each calculation step. Calculation was made with assuming that the partition coefficients are always constant. It is assumed that olivine and orthopyroxene affect trace elements and major components MgO, FeO and SiO_2, and spinel affects a trace element only.

In our model on element diffusion, based on the method of Ozawa (2004), nondimensionalized was calculated. The diffusion coefficient considered only temperature dependence. In the calculation scheme, the second order center difference is adopted in the spatial direction, and the backward difference was adopted in the time direction.

Using the simulated zonal structure by the forward model and the analyzed zonal structure, eight series of Markov chains expanded with parameters expressing pseudo temperature were generated, and parameter estimation was performed by parallel tempering Markov Chain Monte Carlo method (Hukushima & Nemoto, 1996). After a given sampling times, the optimum value of the parameter was determined from the average value or the mode value while checking the histogram shape of the obtained sample.

Sampled parameters are following five types in each zoning section: initial Mg#, final Mg#, modal fraction of orthopyroxene, and modal fraction of spinel in the crystal growth stage; logarithm of maximum compression time in element diffusion stage.

Keywords: Volcanic rocks, Crystal growth, Element diffusion

Managing soil organic carbon sequestration in China’s croplands

*Guocheng Wang[1]

1. Institute of Atmospheric Physics, Chinese Academy of Sciences

Increasing the soil organic carbon (SOC) pool in croplands can not only promote crop production but also mitigate climate change; however, the amounts of organic C that are input to balance the soil C loss and for targeted soil C sequestration in China’s croplands are unclear. By using a biogeophysical model (Agro-C), we performed simulations with a high spatial resolution (10 km×10 km) across China’s croplands to quantify the rate of C input under given scenarios. The model simulations showed that an average C input of 2.1 Mg C ha^{-1} yr^{-1} is required to stop soil C loss and that SOC density could approach the global mean of 55 Mg C ha^{-1} by 2050 when 5.1 Mg C ha^{-1} per year is incorporated into the soils of China’s croplands. The quantified C inputs showed a large spatial disparity, depending on the existing SOC level, mean annual temperature and precipitation. The existing SOC level in Heilongjiang Province, where the cropland area accounts for 9.2% of the national total, is much higher but the current C input is much lower than it is in other regions in China. Increasing the organic C input should be given priority in this province; otherwise, the risk of SOC loss may increase.

Spatial modeling by joint use of physical law and geostatistics for grade analysis in geofluid-caused ore deposit

*LEI LU[1], Katsuaki KOIKE[1], Koki KASHIWAYA[1], Mohamad N. HERIAWAN[2], Ryoichi YAMADA[3]

1. Department of Urban Management, Graduate School of Engineering, Kyoto University, Japan, 2. Faculty of Mining and Petroleum Engineering, Bandung Institute of Technology, Indonesia., 3. Graduate School of Science, Tohoku University, Japan

Fluids play an important role in various aspects related to ore deposits and are crucial to the formation and development of ore deposits. This study aims to develop a method combines spatial statistics and physical law for metal contents in an ore deposit. Semivariogram clarified spatial correlation structure of the metal data and then kriging and sequential Gaussian simulation were used to generate spatial distribution of ore grade in three-dimensions. Transports of ore fluid and deposition process of metals were assumed as a physical process governed by the advection and diffusion. Analytical and numerical solution of an advection-diffusion equation was applied to ore grade data by calculating key parameters, advective velocity and diffusion coefficient. In order to simulate accurately, parameters were then revised as variables in different zone according to geological structure and geostatistical model. Matsumine and Fukazawa mines, typical large kuroko deposits in the Hokuroku district, Akita Pref., northern Japan, are selected to verify the combined method. Metal elements such as Cu, Zn, and Pb (chief metals of kuroko) of drilling cores were used for the spatial and physical modeling analyses. This method termed SPG (Spatial modeling by joint use of Physical law & Geostatistics) presents general main paths of ore fluid with respect to source, flow direction, and flow rate. The same technique and SPG are applied to a hydrothermal deposit in Sulawesi Islands, Indonesia. As the result, high metal content zones are well clarified and characterized, and a fluid flow pattern that formed the zones is expressed as colloidal texture which could indicate temperature and pressure changes in shallow subvolcanic activities.
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Keywords: ore deposit, metal content, fluid flow, geostatistics, advection-diffusion

Solar terrestrial modelling: Application of systems methodologies

*Simon N Walker[1], Michael Balikhin[1], Richard Boynton[1]

1. ACSE, University of Sheffield, Sheffield, UK

The response of the magnetosphere to changes in the solar wind is the result of the a complex series of processes, each acting over disparate scales in both space and time. The basic premise of physics based modelling is to understand each of these processes separately before coupling them into a single model. This diversity in process mechanisms and their temporal/spatial scales is one of the main reasons that such models have not been developed. Systems science provides a complementary route for modeling. This data driven approach involves the study of the evolution of a system as a whole based on a set of driving parameters. In this presentation we show how the application of systems modelling can be used to investigate such complex problems in space physics as magnetospheric response to the solar wind to the evolution of turbulence. In contrast to other data driven methodologies, systems techniques can also advance understanding of the micro-processes within the system. In addition, use of the systems approach, and especially frequency domain analysis, may be employed to validate analytical and numerical models.

Keywords: systems modelling, magnetospheric processes, solar wind response