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# MODELLING DEPENDENT RISK WITH COPULAS: AN APPLICATION ON FLOODING USING AGENT-BASED MODELLING

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In the present work we introduce a copula approach to model dependencies between risks in large scale networks and show how this could be used to avoid underestimation of extreme events. Furthermore, we apply the approach within an agent based model to determine the macroeconomic consequences due to flood events. We show that without a copula approach only average annual losses on the country level would be available. However, with the copula approach, which includes the estimation of basin scale loss distribution through catastrophe modelling, exposure estimation through Corine land cover mapping, assessment of appropriate copulas and parameter estimation, including a algorithm to couple coupled basins as well as an upscaling procedure to the country level, the whole risk spectrum can be, for the first time on this scale, estimated. The direct loss estimates from the copula approach, separated into different risk bearers, are used to build a damage scenario generator which gives the input for the agent based model. The agent based model in turn assesses the additional indirect losses due to the event which can be much larger than the direct losses alone.

# CODATA: A DATA STRATEGY FOR A BIG DATA WORLD

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Talk of a data revolution is not hyperbole. The IT revolution has now given us the means of collecting huge amounts of data and, with the advent of the Cloud, unprecedented computing power to analyse this data and find new and important discoveries. The data revolution, the phenomenon of Big Data and advances in data science are everywhere impacting both scientific research and industry.

Importantly, the data revolution has many dimensions. What has been characterized as 'Big Data' or 'data intensive research' is an important part of the phenomenon, as are associated means of gathering data through a plethora of devices at unprecedented scale. Also important however are the opportunities for comparatively small data, including that of making bespoke, hard-won data sets more accessible and reusable, enhancing their value, through providing contextual information, linking or integrating with other datasets and through enhanced visualizations and analyses.

Exploiting the opportunities and addressing the challenges afforded by the data revolution and using them to generate wider societal benefit will fundamentally depend on the creation of a complementary 'Open Data' environment. Open data is crucial to the maintenance of scientific 'self-correction' whereby the data underlying published concepts are open to scrutiny, replication or invalidation. Open data is also essential to extract the greatest reuse value from data collection exercises: the importance and value of this is particularly evident in fields relying on earth observation and remote sensing data.

Responding to the challenges and exploiting the opportunities will depend upon new technical solutions for presenting, sharing and analysing data; on capacity building in "data science"; and on changing the habits and norms of researchers and their institutions to create a culture of openness and data sharing. Science is an international activity, done in a national cultural setting, thereby requiring national strategies to fit within a common international frame. The role of international bodies such as CODATA and the International Council of Science is to facilitate the fit between national priorities and processes and rapidly developing international norms.

To help address these issues, CODATA promotes Open Data and Open Science through three strategic priorities:

- Supporting implementation of data principles, policies and practices
- Addressing the frontiers of data science and its adaptation to scientific research.
- Capacity building for data science (particularly in low and middle income countries - LMICs)

This presentation will examine the context of the 'Data Revolution' and provide an introduction to CODATA's analysis of these issues and activities in the priority areas identified. Particular emphasis will be placed on the policy environment, a holistic approach to capacity building and the research data skills that benefit various role in science systems. The presentation will also address how important such work is for the study of hazards and other areas of research that rely on international collaboration and coordination around Earth Observation Data.

# IMPACTS OF GEOPHYSICAL HAZARDS ON CRITICAL INFRASTRUCTURE: CASE STUDY OF ELECTRICITY TRANSMISSION NETWORKS

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Geophysical hazards such as earthquakes, floods, tsunamis, volcanic eruptions and storms affect electricity transmission infrastructure by destroying its elements including grids, masts, interconnectors and other elements of the electricity transmission system. Extreme temperatures also have negative impacts on transmission capacities of electricity networks. This paper discusses historical evidence of impacts of geophysical hazards and how they lead to major blackouts, which took place during the last decades in France, in the Balkans region and in China.

In 1999 France experienced the storms Lothar and Martin, which had the wind speed of 200 km/h and had severe impacts on electricity transmission infrastructure. For instance 0.5% of the total number of towers were affected, 10% of circuits and 180 substations were out of order (Eurelectric, 2006). In the middle of 2015 the heavy rainfall resulted in extensive flooding in the Balkan region, which affected Serbia, Bosnia and Herzegovina as well as Croatia. This was a real multi-risk event, which was followed by landslides, which damaged overhead lines and underground infrastructure as well as transformer stations, customer connections and metering equipment. This resulted in an interruption of power supply, which affected more than 250,000 customers. The Wenchuan earthquake, which happened in May 2008, was one of the most devastating earthquakes in the history of China for the last 60 years. It had the magnitude of 8.0 on the Richter scale and severely damaged regional infrastructure, including electricity systems, such as regional high voltage power transmission lines and distribution lines. The earthquake damaged three 500 kV electricity transmission lines, fifty six 220 kV transmission lines, one hundred and ten 35 kV lines and seven hundred ninety five 10kV lines. The lines tripped mainly because of the broken poles, fallen pylons and damages to transformers and circuit breakers (Eidinger, 2009). The destruction of electricity transmission infrastructure resulted in a blackout, which affected 2.5 million people.

Based on the analysis of the reports about these blackouts, lessons learned as well as elicitations from stakeholders from different sectors such as transmission systems operations, NGOs, academia and international organizations, this paper provides recommendations on risk management and short and medium term response and recovery measures.

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# WHAT IS BIG DATA AND HOW HAS IT CHANGED?

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There are many different ways to describe Big Data. Whereas Massive Data has a precise definition (data not fitting into computer memory, thus requiring out of memory algorithms for solving complex problems), Big Data has no such definition. This talk will look at Big Data operationally, namely data so large that what to save is at question and, in some cases, decisions on that data have to made instantaneously. The most obvious change for data science is that a few years ago there was just not enough data and now, in many cases, there is just too much. This is a relatively new problem and we need methods to identify the relevant data, or most relevant data at the given time, and even which data needs to be saved for later use as it might become relevant. Big Data is sometimes described in terms of the three V's, volume, variety, and velocity, with the emphasis that it is not necessarily an increase in any one of them that has created a challenge but the concomitant increase in all three. Perhaps more importantly is that it is not volume, variety, or velocity even together that define Big Data, but it is something more difficult to define and capture, namely complexity. Simply put, data today is very large, heterogeneous, interrelated and complex. This talk will expand on these ideas.

# RECONCILING INFORMATION FROM CLIMATE-ECONOMIC MODEL ENSEMBLES

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To date, no model building process can ensure full representation of the complex climate-economic processes – instead, multiple highly detailed models are put forward by individual research groups to capture some selected aspects. On the other hand, a number of the simplified integrated assessment models (IAMs) have been developed attempting to consider the full causal loop between accumulated emissions, economy and climate, and study associated uncertainty.

Here we present a simplified system dynamics IAM based on the model from Kovalevsky and Hasselmann (2014) with stochastic climate sensitivity and a nonlinear climate damage function. We explore the structural sensitivity of the long-term projections (focusing on global temperature, global economy output, GHG emissions and atmospheric concentrations) to a probabilistic distribution describing the climate sensitivity. We investigate the model robustness under different assumptions on climate sensitivity distribution. For this purpose, we use the approach suggested by Kryazhimskiy (2016), which attempts to 'integrate' several independent distributions representing the same variable into one posterior distribution using a Bayesian approach based on the posterior event being the one when stochastic variables in all models have the same realization. The results show that model 'integration' leads to a higher mean global output, emissions and concentrations and lower mean global temperature than both prior means, coming along with lower uncertainty in the integrated scenario.

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# MULTISET APPROACH TO THE ANALYSIS OF CONSEQUENCES OF NATURAL DISASTERS IMPACTS ON INDUSTRIAL SYSTEMS

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In the previous work [1] we introduced multiset grammars as a convenient and efficiently implemented tool for problem solving in various areas of systems analysis. In the present work we suggest application of multiset approach to modeling of impacts on industrial systems (IS) and estimation of their consequences. The main idea is use of the so called composite objects of the form $[a, z]$, where $a$ is name of local industrial object or resource while $z$ is its location, so unitary rule (UR) is written as $[a_0, z_0] \leftarrow n_1 \cdot [a_1, z_1], \dots, n_m \cdot [a_m, z_m]$, that means one unit of the object (resource) $a_0$ at location $z_0$ may be manufactured if there are $n_1$ units of object (resource) $a_1$ at location $z_1$, … , $n_m$ units of object (resource) $a_m$ at location $z_m$. The resource base of IS, which potential is $R$ set of URs, is multiset $\overline{v}$, and IS is robust to impact $\Delta\overline{v}$, if set of terminal multisets (TMS) $\overline{V}_s$ generated by unitary multigrammar $S =< [a_0, z_0], R >$ contains at least one TMS $v$ such that $v \subset \overline{v} - \Delta\overline{v}$. Natural disaster impact is represented by set $Z$ of locations destructed, so $\Delta\overline{v}_Z = \{\, [a, z] \mid z \in Z\}$. In these conditions IS $S$ is robust to NDI $Z$ if there exists at least one TMS $v \in \overline{V}_s$ such that $v \in \overline{v} - \Delta\overline{v}(Z)$. The described approach is software implemented and tested by real examples.

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# SYSTEM ANALYSIS IN RIHMI-WDC FOR THE MULTI-PURPOSE DATA COLLECTION, STATISTICAL PROCESSING AND ANALYSIS OF HYDROMETEOROLOGICAL HAZARDOUS PHENOMENA

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The paper contains the assessment of approaches and technologies that are implemented at RIHMI-WDC for the goals of data management and analysis. The technologies are based on original software solutions and own products of RIHMI-WDC, on the commercial (such as SAS, IDL, ArcGIS, etc.), and on free and open-source software products. This complex enables to successfully solve the “Big Data” problems specific for RIHMI-WDC, and problems of detection, analysis and presentation of extremes and hazardous phenomena among them.

RIHMI-WDC under the World Bank Project “Roshydromet-2” is starting the sub-project “Preparation of Hydrometeorological Safety Passports for Territories of Russian Federation”.

A complex system analysis of meteorological, hydrological, climatological factors for the territories, as well as of natural, ecological and socio-economic specific of the territories is starting within this effort.