Chapter 17


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ABSTRACT

The problem of uncertainty analysis in multi-component systems is considered. As an example a problem of decision making under uncertainty in task of modeling of carbon balance and analysis of greenhouse gases (GHG) emissions using satellite tools was considered. Approaches to decision making under uncertainty are described: interval, fuzzy, and stochastic assessments. Different approaches and algorithms to calculate carbon and GHG emissions are described. For every algorithm (deterministic inventory, ecological modeling, and satellite control of emissions) errors and uncertainties are analyzed and estimated. Algorithms for uncertainty analysis are presented. Algorithm for analysis of components of uncertainty of vegetation productivity assessment using satellite data is proposed. Uncertainty component analysis allows understand important properties of the system studied and its feedback to anthropogenic load and climate impact. It was demonstrated that the comprehensive analysis of uncertainties not only reduces errors but also obtains new knowledge about the systems studied.

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INTRODUCTION

Decision Making Under Uncertainty: Problem Description and Task Definition

The problem of uncertainty analysis in multi-component systems and multi-physics processes is very complicated and urgent task, which cannot be reduced to measurements accuracy control. Management of anthropogenic, engineering and natural systems is aimed to secured and sustainable development, and so closely connected with multi-scale decision making.

In many problems of control and monitoring, engineering, communication, management and other practices, we should select a systems design, parameters of a process, so make a decision. This decision must be optimal, the best for the users, as well as industrial and public. In traditional operations research, we assume that we know the objective function $f(x)$ whose values describe what is best for the users. Problems of ecology, pollutions and greenhouse gases (GHG) emissions are most complicated for decision makers because it connected with industry and energy, public health, ecological safety and environmental services, climate and food production. So the instruments for decision support, including uncertainty analysis, should be comprehensive and enough complicated relating to complexity of the system studied.

For example, for a GHG analysis, this function $f(x)$ may represent the carbon stock rate (or calculated emissions) resulting from change ecosystems productivity represented by parameters $x$.

In such situations, the problem is to find parameters $x$ that optimizes (e.g., maximizes) the given function $f(x)$ on the given range $X$. In work (Nguyen & Kreinovich, 2006) a good overview of existing engineering approaches and algorithm to decision making under uncertainty is presented.

Optimization of well-defined functions is what started calculus in the first place: once we know the objective function $f(x)$, we can use differentiation to find its maximum, e.g., as the point $x$ at which the derivative of $f$ with respect to $x$ is equal to 0. Sometimes, this equation $f'(x) = 0$ can be solved directly; sometimes, it is difficult to solve it directly, so we use gradient-based (i.e., derivatives-based) techniques to either solve this equation or to optimize the original objective function $f(x)$.

In many decision-making problems, instead of finitely many situations $v$, we have a continuum of possible situations. We may have one or more continuous variables that describe possible situations. In such problems, instead of finitely many probabilities $p(v)$, we have a probability distribution with a probability density $p(v)$, and instead of a sum, we represent the expected value as an integral $f(x) = \int p(v) \cdot f(x, v) dv$. In real situation, we often do not know the probabilities of different possible situations, or at least we only have partial and limited knowledge about these probabilities.

Decision making in environmental management and climate risk analysis requires carbon emission calculating under uncertainty. These uncertainties have different nature. Its connected with imperfection of emission account tools and methods, insufficient comprehensiveness of carbon cycle models, and incomplete account of variations of crop productivity. All these cases characterizing by different types of uncertainty and could be analyzed and reduced separately. But at the same time, the comprehensive analysis of uncertainties allow not only control and reduce errors, but also obtain new knowledge about the systems we study – multi-component ecosystem characterizing by multi-physics processes.