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# APPLICATION OF THE OBJECT-ORIENTED APPROACH IN THE UPPER ATMOSPHERE MODELING

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## Abstract

A universal modeling tool is being developed for the research of interrelation of the broad range of various processes and phenomena in the upper atmosphere. It is organized as an open framework, which united several models of separate atmospheric regions and processes. Each included model is independent of others and calculates certain physical parameters of the modeling object. This sub-models exchange data using the standardized interface. This approach allows an easy integration of wide range of the data sources of different kind, both experimental and modeled.

The framework is created on the object-oriented approach basis. The presented paper describes the object hierarchy and object interoperation within the frame structure.

## Introduction

The universal modeling tool is being developed on the basis of the global Upper Atmosphere Model (UAM) [Namgaladze, 1988, 1998] for the research of interrelation of the broad range of various processes and phenomena in the upper atmosphere. For this purpose the UAM structure has been reorganized into the OPEN FRAMEWORK of several subordinate models of separate atmospheric regions and processes, for example, such as ionosphere model, neutral atmosphere model, electric field model, wind model etc. Each included model is independent of others and calculates certain physical parameters of the modeling object. This sub-models exchange data using the unified interface. This approach allows an easy integration of wide range of data sources of different kind, both experimental and modeled.

### Framework model object hierarchy

The framework is created on the object-oriented approach basis. At the present stage the object hierarchy (fig. 1) and obligatory functional and interface specifications have been developed for each object. The compliance to these specifications allows to connect the object to the framework model.

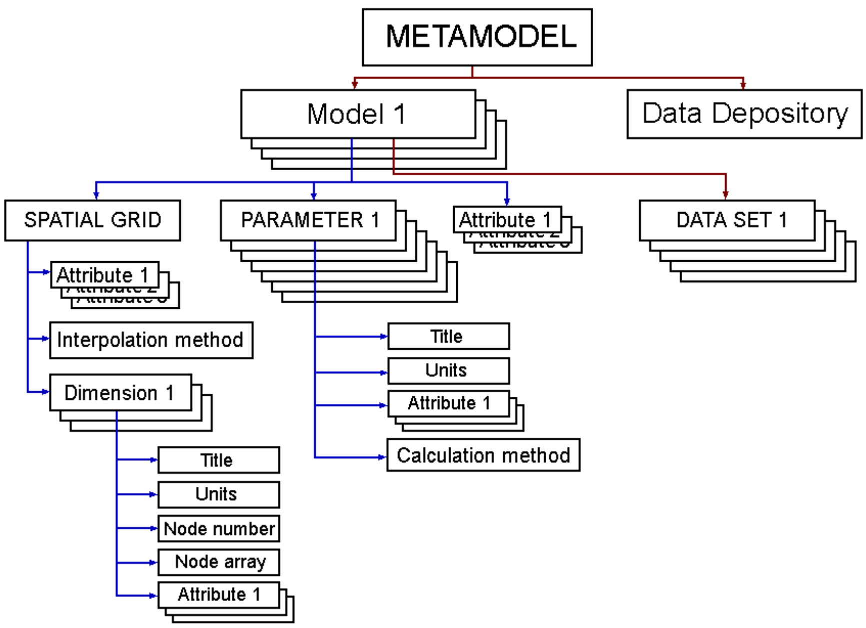


**Fig.1**. The framework model object hierarchy

At the top level of hierarchy there is a METAMODEL – frame structure itself, whose functions are to organize the connected objects interaction and to provide the user with a comprehensive control facility.

The MODELS are connected to the Metamodel. Functionally each Model is a method of obtaining the numerical values of a certain set of physical parameters in certain spatial grid nodes (as one can see, the experimental data sources fall into this formal definition as well). The parameter set and grid position are obligatory properties of the Model, and they are described by formal specification rules.

Each Model, in turn, includes objects of the following level – a space GRID, DATA DEFINITION (what these parameters are, units, etc.), and DATA – parameter values in grid nodes. Formal specifications are developed for each of these objects.

Another object connected to the Metamodel is the DATA DEPOSITORY. It "knows how" to save necessary data to the disk file and to load data from there with the complete information about parameters, the grid and which Model had provided them.

## Framework model elements interaction

The interaction of the above-mentioned objects is carried out in the following way (fig. 2).

The user can interact either with the Metamodel (through the Metamodel MANAGER) for the control of calculation process, or (through the special application – the Data Control Center) immediately with Depository for the analysis and processing the earlier received data – previous modeling calculations results. With the help of Data Control Center the user prepares initial conditions for the new modeling calculation. Then the Metamodel Manager can be used to configure the calculation task – to select what Models should be connected to calculation and specify all necessary control parameters for each connected Model. The Manager collects and provides the user with the information about all available Models and also checks the completeness and the validity of the received task: checks that for each demanded parameter its calculating Model is selected, and that each Model has all the necessary for the operation. The calculation task includes also the list of data which should be saved during the calculation: what calculated parameters, in what areas of space (cut, profile, etc.), in what kind and how often they should be saved, etc.

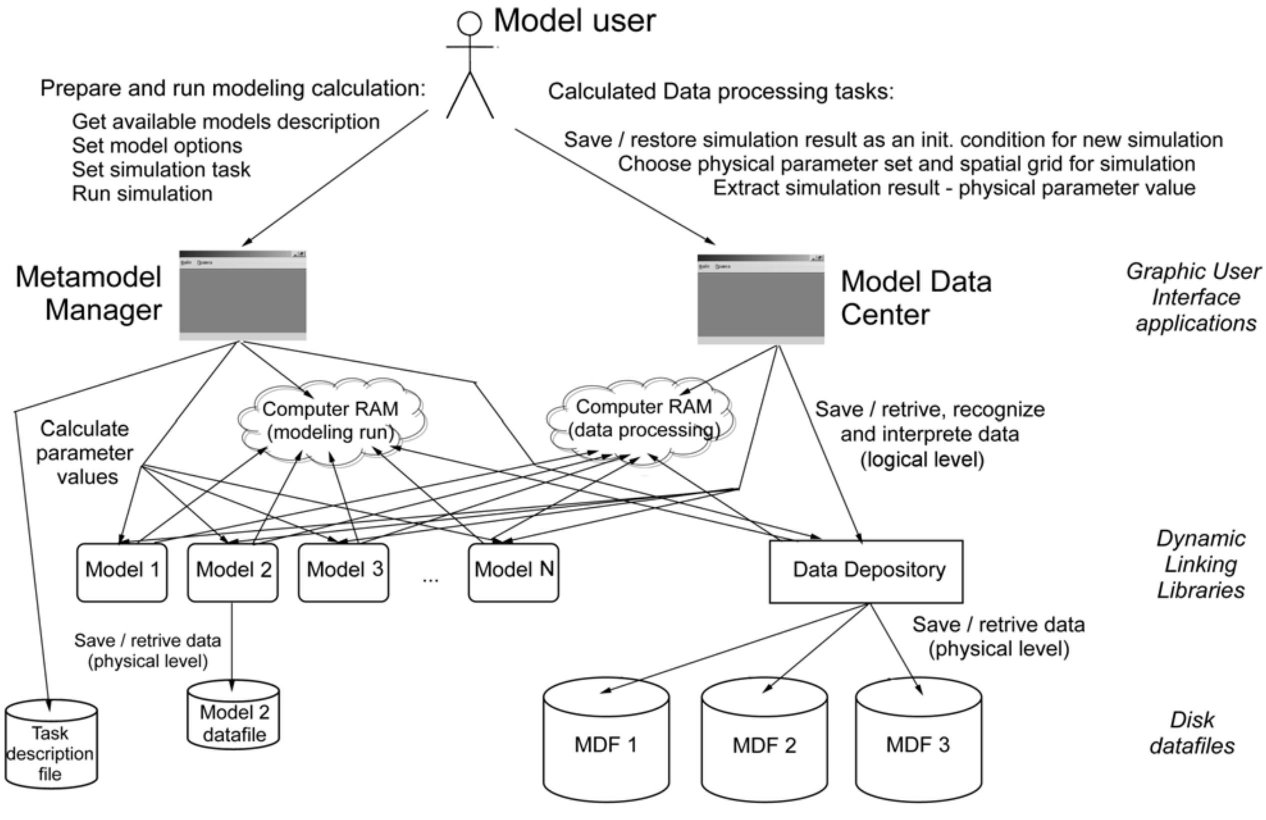


**Fig.2**. The framework model objects interaction scheme

During model calculation the Metamodel Manager controls the process: it sequentially executes procedures of the connected Models, transmits necessary data to them, including data received from other Models. Models return the calculation results to the Manager – values of physical parameters in the grid nodes. The actual method of obtaining these values is the Model internal matter and it does not concern Manager at all. Models cannot cooperate directly, and exchange any information only through the proxy of the Manager. The Manager also provides all interaction with the Depository: to read of initial conditions and to store the current state of the modeled

environment. The saving of the selected in the calculation task parameters is also carried out by the Metamodel Manager.
The main and mandatory modeling calculation results are spatial distributions of all physical parameters (their values in grid nodes) in a final time moment, which is an instant snapshot of the modeled environment. Any intermediate distributions of parameters and timeline of their modification are saved only if that was specially specified for saving in the calculation task.

## Model datafile structure

To prepare the new calculation the user creates a new modeling "world" in the Data Control Center: defines physical parameters sets and spatial grids in which nodes these parameters should be calculated. It is possible to set irregular spatial grids. For these data special MODEL DATA FILE (MDF) is created. Its structure contains the complete description of data and grid and full set of data values (actually – a projection of the above-described object data model to the internal file structure).
In the simplest case for each Model which is supposed to be used in the future calculation, there is a separate data structure (a projection of the "model" object to internal file structure), containing the description of physical parameters calculated by this Model and used co-ordinate grid and parameter value arrays in grid nodes. But this requirement is not mandatory: in the MDF of the present UAM model in case of connection of empirical MSISE and/or HWM models [Hedin, 1987, 1996] to the calculation of neutral atmosphere parameters, their data are stored in the same dataset with the another atmospheric parameters calculated by the theoretical thermosphere and lower ionosphere model ("Sphere") as all of them are calculated in the nodes of the same co-ordinate grids.
The array of all physical parameter values in the grid nodes forms the DATASET object. Each Dataset relates to one time moment and represents an instant snapshot of the modeled environment. The description of the included parameters and the used co-ordinate grid is stored in MDF for each Dataset. One such description can be related to several Datasets available in MDF if they store the same parameters in the same grid nodes and differ only in the snapshot time moment. The time tag, to which the Dataset refers, is stored inside the Dataset.
One MDF can contain the arbitrary amount of Datasets which can differ either only in the time moment of data (in the elementary case – one instant snapshot of one Model), or store different Datasets of calculated parameters in the nodes of different grids (Datasets of different Models). In the second case either parameter sets can intersect, i.e. some physical parameters can be stored in several data sets, or co-ordinate grids can envelop intersected areas of near-Earth space environment. For example, in the present main blocks of UAM model – "Sphere" (thermosphere and the lower ionosphere theoretical model) and "Tube" (upper ionosphere and plasmasphere theoretical model) intersected parameters are ion and electron temperatures, and co-ordinate grids of these models are intersected in the height range from 175 up to 500 km.
The special application – DATA CONTROL CENTER – is developed for working with a datafile of the described structure. It provides the user with the information on the data containing in MDF (saved physical parameters and co-ordinate grids description, the available Datasets list with the information on Model by which each parameter is calculated, and related time moments). Data Control Center also allows to copy Datasets inside MDF and between several MDFs (if it is necessary, with interpolation to the other grid nodes), to extract parameter values of the specified space areas (slits, profiles, etc.) for graphical presentation.
Besides for various operations with already calculated data (copying, saving, extracting, graphical presentation, etc.), Data Control Center allows to create new modeling "world" and to fill it with initial conditions for new calculation.

## Initial conditions definition

After creation of the modeling "world" (new MDF) the user by means of the same Data Control Center fills it with initial conditions – parameter distributions at the initial time moment from which during modeling calculation the modeled environment evolution under specified external impacts will be reproduced. The initial conditions definition is not necessary in general for all parameters, but only for those, whose modeling equations contain a time derivative (or initial value of the calculated parameter in any other form).
Initial conditions filling procedure consists in the defining of all necessary parameter values in all grid nodes. For this purpose the results of any previous calculation suitable on a set of calculated parameters and helio-geophysical conditions can be used (they are copied or – in case of different grids – are interpolated in new grid nodes) or they can be calculated by any empirical model which needs only time moment and helio-geophysical situation for the parameter calculation. Several such models (NRL MSISE2000, HWM, IRI-2000) are integrated into UAM model Data Control Center that allows to fill at once the newly-created "empty" modeling "world" with "reasonable" initial parameter values calculated by these models .
If there are no earlier calculated data for some necessary for the user initial parameter values, and there are no integrated empirical models then user himself should ensure filling of such initial conditions by any means prior to the start of modeling calculation.

## Conclusion

Such system organization allows using the same software for data access and processing and in particular, to submit data, obtained by various methods, in a uniform way that simplifies their comparison and analysis. Moreover, data transfer from data sources (Models) through the Metamodel to the data recipients (other Models) as input parameters allows to study interference of various processes and the phenomena, distributing self-consistence property of global theoretical models on the wide range of other models if they meet the framework requirements.

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