Supercomputer Modelling of Physical Processes in Climate System

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In the report, a review of problems related to the issue of how the climate modeling and weather forecasting depend on physical grounds and mathematical technologies has been presented. Among the most complicated scientific problems that are principally important for sustainable development of society the problem of climate and environment change is of specific interest. The major tool providing an assessment of future climate change is numerical models of the climate system. High complexity of these models makes the efficient use of multiprocessor computers a critical factor of their further development. Computational technologies for solving problems of mathematical physics, arising in climate studies, and the approaches for their efficient implementation on various computational platforms are now developed by scientific groups in different countries, including Russia.

It is well known that during long history of Numerical Weather Prediction the model resolution was one of the major concerns to improve the accuracy of weather forecasting. The main directions of modern upgrading of weather prediction methods and climate models are the improvement of physical parameterizations of sub-grid scale processes and the increase of spatial resolution. The level of spatial resolution is limited by the capacity of the most powerful computational systems (supercomputers). Thus, the peak performance power of computational complexes (tens and hundreds teraflops) available mostly for developers of climate models allows them to perform continuous (for hundreds of years) calculations on grids with the resolution of approximately 100 km. This resolution gives one no possibility to estimate climate change effects at the regional level, which are of the most interest.

In order to produce regional forecasts, non-hydrostatic high-resolution (of 1 - 10 km) mesoscale models are used. In their turn, mesoscale models of this mentioned resolution are not capable to reproduce explicitly the structure of atmospheric flows of the spatial scale less then several kilometers. Such flows can be reproduced by the method of large-eddy simulation (LES) that allows one to describe explicitly the non-stationary dynamics of coherent structures. The spatial resolution of LES-models varies from several meters to several tens of meters.

In the nearest future, global climate models will have resolutions typical for modern mesoscale models, and the grid size of models used for regional simulation will be about 100 m. The experience obtained by Japan researchers in modeling global climatic processes with the mesoscale horizontal resolution has led to necessity of future strategy for climate model development taking into account the perspectives of high-performance computations. In this context, a revision of many parameterizations of sub-grid scale processes used in modern climate models is needed. Thus, the passage to a more detailed resolution and to the development of multiscale modeling systems cannot be performed "mechanically" without essential revision of existing computational technologies and without reformulation of parameterizations and equations used now for approximate description of the hydrodynamics and thermodynamics of the climate system.