Toward the Seamless Simulation with Multi-Scale Simulator for the Geoenvironment (MSSG)

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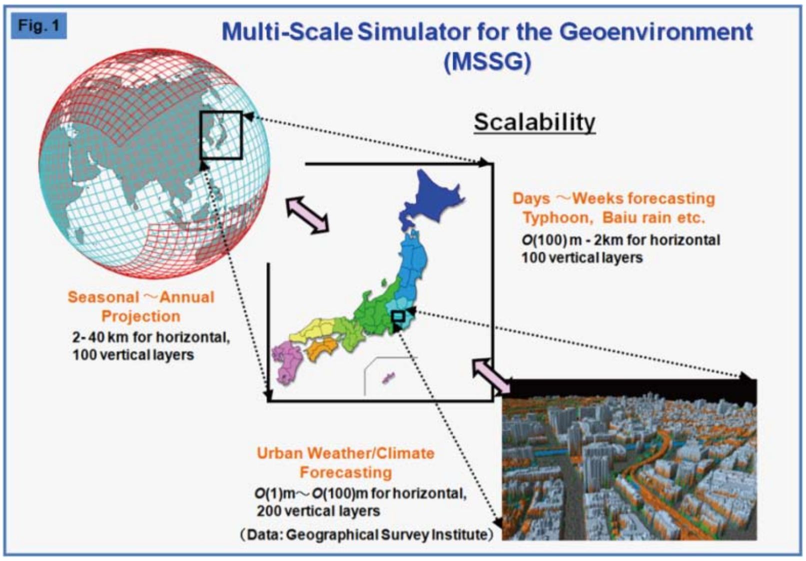
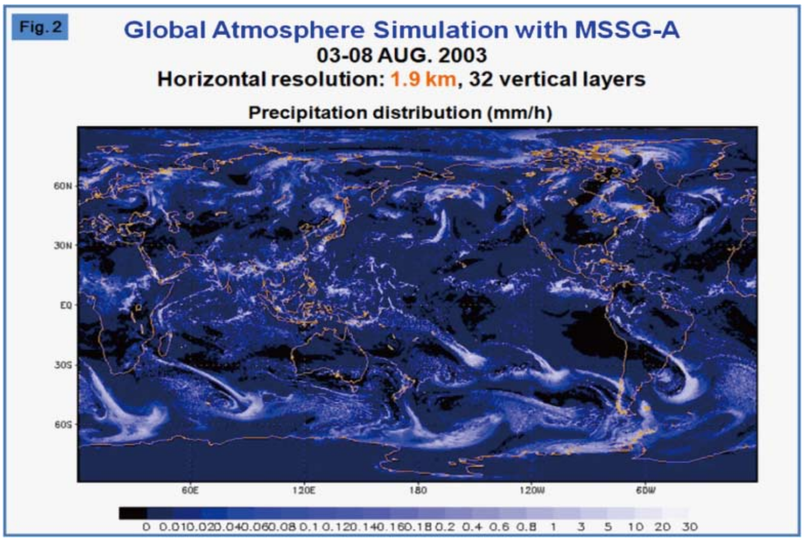
The Earth Simulator Center have been developed coupled non-hydrostatic atmosphere-ocean-land general circulation model which is called Multi-Scale Simulator for the Geoenvironment (MSSG), to be run on the Earth Simulator with ultra high resolution and really high performance computing architectures. When MSSG has been designed to execute seamless simulations between weather and climate in order to understand the mechanisms of various multi-scale phenomena of the Earth System. High qualified information from simulations of multi-scale forecasting, more significant impacts might be brought by results of the simulations. Each scale simulations with target scale shown in Fig.1 will be planed in near future.

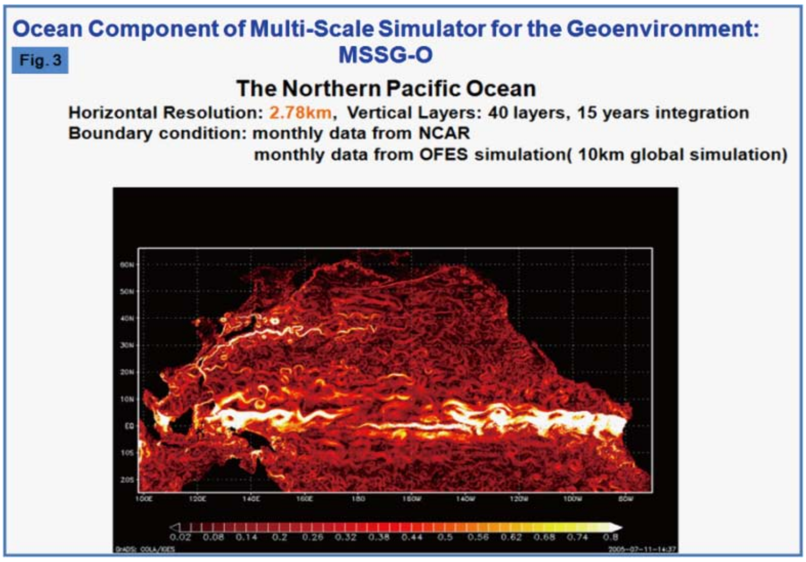
It is widely accepted that the most powerful tools available for assessing future weather/climate are fully coupled general circulation models. Intense research effort is focused on understanding the climate/weather system using coupled atmosphere-ocean models. MSSG is a useful coupled model to get information about scale interaction of not only each atmospheric or oceanic phenomena but boundaries between atmosphere and ocean. Components in MSSG such as atmosphere, ocean, land and sea ice are coupled with various interactive ways. Getting further information on perspectives of future weather/climate should be capable using seamless simulations with a coupled model such as MSSG.

Global atmospheric simulation has been performed to validate physical performance under the condition of 1.9 km horizontal resolution and 32 vertical layers. 144 hours integration was executed with the atmospheric component: MSSG-A. Initialized data was interpolated at 00UTC08Aug2003 from Grid Point Value (GPV) data provided by Japan Meteorological Business Support Center. Sea surface data was also made by GPV data at 00UTC08Aug2003 and fixed during the simulation. Fine structure, especially daily cycle of precipitation distribution was captured in Fig.2.

Fig. 3 shows simulation results of 15 years integration with MSSG-O for North Pacific basin, which is defined area between the equator and 30ºS. Surface heat fluxes and boundary data are computed from climatological data provided by World Ocean Atlas (WOA). Momentum fluxes are obtained by interpolating from climatological data by NCAR.







Distribution of absolute value of horizontal velocity at 105m depth are presented in Fig. 3. Eddy resolved distributions have been recognized in the results.

Fig. 4 shows a snap shot of cloud water distribution and sea surface temperature while ETAU in 2003 was attacking Japan. Those simulations was done with a atmosphere-ocean coupled model ; MSSG. hose experiments have been performed for 120 hours (5 days) without fluxes correction. Three dimensional structure of cloud water such as rain bands was captured in those experiments. Furthermore, cooler sea surface temperature (SST) was represented along the area where strong wind blew under the typhoon. White color of SST becomes being cooler compared ocean with dark blue color.

Fig.5 is a snap shot of thermal plume in Marunouchi and Yuraku-cho area in the center of Tokyo. Those experiments were performed with 5m grid for both horizontal and vertical resolution and as non-equilibrium simulations. Dynamics of thermal plumes and eddies have been well captured in those simulations. Statistical analysis is underway compared with observation data.

The computational performance of MSSG, MSSG-A and MSSG-O are analyzed with a tool FTRACE which is a built-in counter in the Earth Simulator. We obtained computational performance information about the number of floating-point operations and vector instructions, clock counts, averaged vector loop length and delay time due to out-of-cache operations. The most upper figure shows the details on computational performance of MSSG. Each component model has achieved high peak performance over 50% compared the theoretical ratio.

Fig. 2-5 show performances of MSSGs for the each scale phenomena which are target to understand the multi-scale mechanisms. Even though using Earth Simulator , scale interaction analysis in multiple scale simulations with MSSGs can not been performed on the Earth Simulator. In near future, multiple-scale simulations will be executed in the Earth Simulator 2, which will start operating from March in 2009.

MSSG Computational performance on the Earth Simulator

TPN is the total number of nodes; TAP is the total number of arithmetic processors; Grid pts is the number of grid points in MSSG or the each component with stand alone; Mflops/AP is the corresponding megaflops per an arithmetic processor; Vector length is averaged length of vector processing; V. OP ratio is the vector operation ratio; Tflops is the total telaflops sustained over the duration, exclusive of I/O; Peak ratio is the percentage of total telaflops to the theoretical peak performance; Parallel efficiency and Speedup are measured by degradation in elapse time relative to single arithmetic processor, respectively.

	TPN	TAP	Grid pts	Mflops/AP	Vector length	V. OP ratio	Tflops	Peak ratio	Speedup	Parallel ratio
MSSG	512	4096	3662807040	4166.7	229	99.3%	17.07	52.1%	461.0	99.9973
	384	3072		4273.8	229	99.3%	13.13	53.4%	354.6	99.9968
	256	2048		4401.9	229	99.3%	9.02	55.0%	242.6	—
MSSG-A	512	4096	2713190400	4575.2	228	99.5%	18.74	57.2%	479.1	99.9983
	384	3072		4606.1	228	99.5%	14.15	57.6%	365.2	99.9969
	256	2048		4692.4	228	99.5%	9.61	58.7%	247.5	—
MSSG-O	498	3984	4718592000	3629.3	240	99.3%	14.46	45.4%	401.3	99.994
	398	3184		3568.5	240	99.3%	11.36	44.6%	333.7	99.989
	207	1656		4234.3	240	99.3%	7.01	52.9%	188.2	—

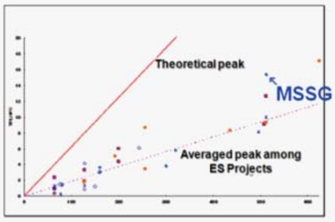


Fig. 4

Simulation result of Etau in 2003 with MSSG (Multi-Scale Simulator for the Geoenvironment)

Coupled Atmosphere-Ocean-Land Model

Global/Regional Scale Simulation MSSG

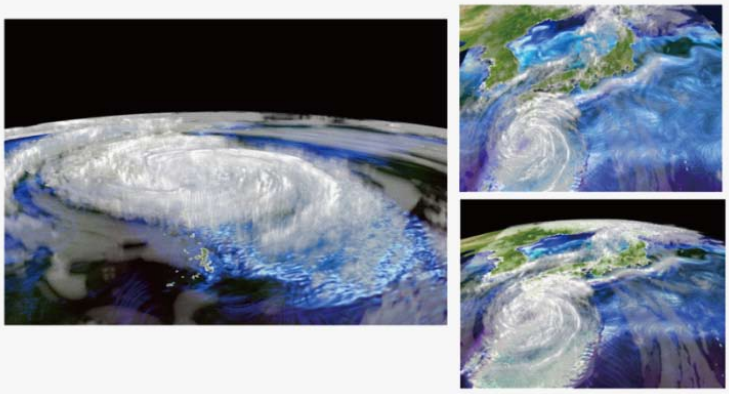


Fig. 5

Thermal Plume Distribbution in Urban Area

Marunouchi and Yurakucho area in Tokyo

15:00 -15:10 on 5th August 2006

5m for horizontal resolution, 32 vertical layers