Accelerate Weather Forecast and Applications with GPU

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Abstract

Heterogeneous computation has shown great potential in speeding up the weather model. In this study, we use a regional model, COSOM, to simulate the weather around Taiwan in 6-km spatial resolution and provide the boundary condition for our large-eddy simulation (LES) model. COSMO has physics schemes that incorporated the OPENACC directives, which allows computation off-loading to GPGPUs. With the dynamic core and part of the physics schemes still relying on the CPU computation, we profile the COSMO computation and optimize the CPU-to-GPGPU ratio for our simulation. Also, we will present a preliminary analysis of COMSO performance with the other regional weather model

Finally, a case study is proposed with a dataset of an intensive observation period experiment of tracer gas and radio sounding in middle Taiwan on 2018/03/22 to verify simulation results of the COSMO and Parallel-Large-Eddy-Simulation-Model (PALM), a turbulence-resolving LES model that is specially designed for performing on massively parallel computer architectures. Overall, a GPGPU base model is a time-effectively computational tool to be applied to provide a detailed weather forecast and reanalysis dataset in fine resolution for the investigation of the micro-meteorological study.

Key word: Weather Forecast, GPGPU, COSMO, PALM, large eddy simulation

1. Introduction

Recently more and more weather models have been adapted to use OpenACC or CUDA code to utilize the massive floating point processing units of GPGPU, and Consortium of Small-scale Modeling (COSMO) is one among many efforts. (Fuhrer et al., 2018). COSMO is a non-hydrostatic regional atmospheric model that is developed by various institutions, including DWD of Germany, MCH of Switzerland, and etc. MCH has converted the COSMO code with CUDA and OpenACC directives to achieved ~ 10 times the performance running on GPGPU versus CPU. (Fuhrer et al., 2018) While the released version of COSMO hasn't been fully ported for full GPGPU efficiency, part of the physics schemes have been ported with the OpenACC directives. In this study, we use COSMO to provide boundary conditions for the LES model. While porting COSMO to our HPC system, we will also investigate into the performance boost with the addition of OpenACC directives.

We use PALM LES model in this study. (Maronga et al. 2015) Since Smagorinsky (1963) and Deardorff (1970), large eddy simulation (LES), has been developed to solve the Navier-Stokes equations, which required resolving wide range of time and the wave length scales, in an effectively computational approach. Different kinds of LES model such as - Dutch atmospheric large eddy simulation (DALES) (Heus et al., 2010) and Parallel large eddy simulation model (PALM) (Raasch et al., 2001; Maronga et al., 2015) - have been developed. In the study, we applied the PALM as our numerical tool to simulate the micro-scale flow field with a high resolution topography. The model domain in PALM is discretized in space using finite differences and equidistant horizontal grid spacings, namely the Arakawa staggered C-grid (Harlow and Welch, 1965; Arakawa and Lamb, 1977). Otherwise, PALM has applied a prescribed kinematic fluxes of the heat and moisture or the vertical and humid vertical profiles as initial boundary conditions. Moreover, a Cartesian topography based on the mask method (Briscolini & Santangelo, 1989) has been applied in PALM for simulation of a topography and building obstacle.

Numeric experiment could collaborate with field measurement to investigate a real case or the mechanism behind the phenomena. There were serious air pollutant events in middle Taiwan. Therefore, an intensive observation period (IOP) has been implemented during the march, 2018. Particularly, a trace gas releasing experiment has been processed on 22th March 2018 to investigate the pathway of the air pollutant of the greatest coal fired power plant in Taiwan. The results of the IOP field campaign could be compared to the PALM model simulation with the boundary conditions which have been generated by the COSMO to reproduce the dispersion pathway of the air pollutant emitted from the coal fired power plant.

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2. Description of the models

We use COSMO version 5 for simulation of large-scale wind filed on March 22nd, 2018. The domain is adapted from the Asia 0.625-degrees domain and centered in Taiwan. The vertical grid follows the tropical experiment settings by DWD and has 50 vertical layers. The boundary conditions was provided by the ICON climate model output by DWD.

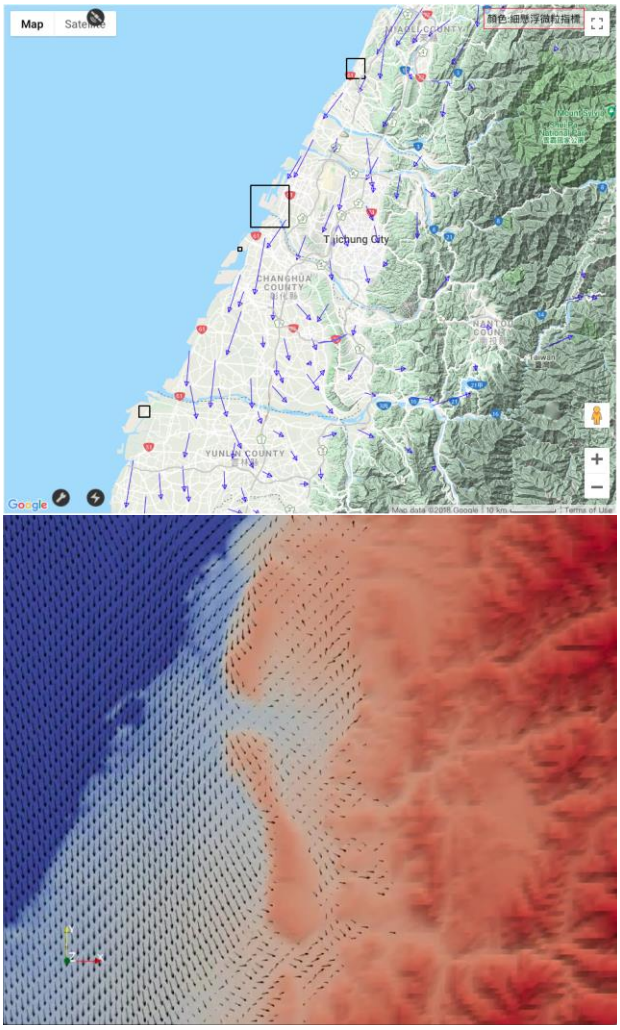
PALM as a LES-model requires a prescribe initial conditions to start the simulation. Therefore, in the study, we apply Neumann boundary conditions to lead a horizontal free-slip conditions of the velocity components. In the study, we apply the cyclic lateral boundary and the solution of the Poisson equation can only be achieved by using a direct fast Fourier transform (FFT) with the simulation setting.

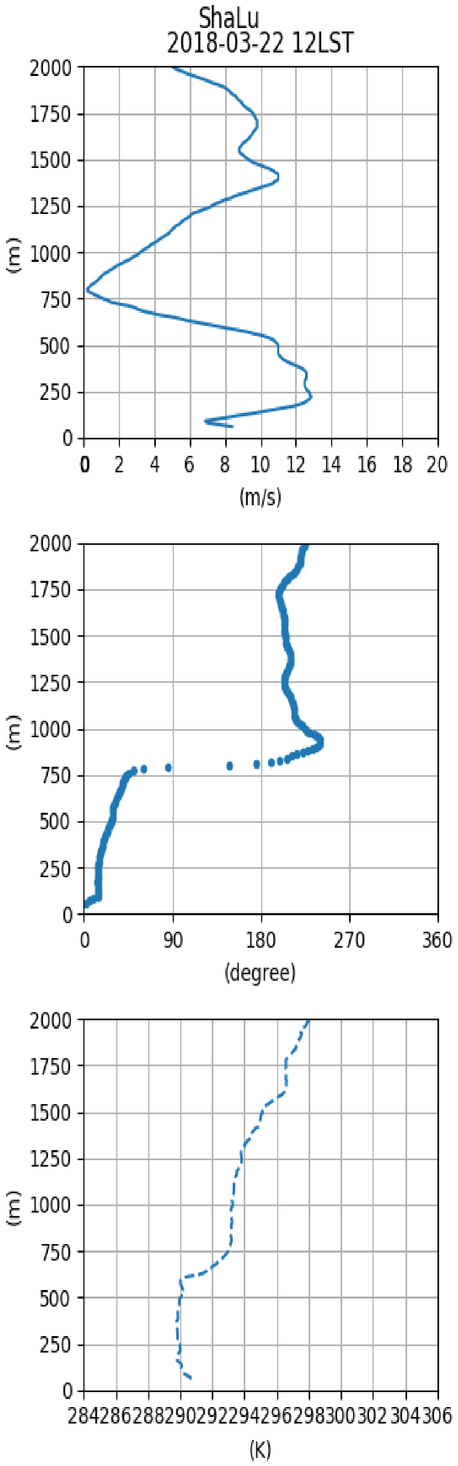
Moreover, a 560 * 560 horizontal grids in resolution in 200 m and 48 vertical layers in resolution in 50 m have been applied as the simulation domain with a topography model in a 2.5 dimensional elevation map. The time step of the simulation has been set up in 1 second.

During the period from 12th March to 7th April 2018, a joint field campaign of the EMeRGe-Asia and the ProACT3 has been performed. Besides the snapshots of atmospheric composition taken by the instruments on board the HALO research aircraft of the DLR, the mass concentration and chemical composition of fine particulate matters (PM2.5) at ground level were also measured continuously at the CAFÉ, a background station at the northern tip of Taiwan, and also a network of 12 sampling sites in the central Taiwan. Moreover, the concentrations of criteria gaseous pollutants (CO, O3, SO2, NOx) have been also reported from the official air quality monitoring stations of Taiwan- EPA. Also, PFC (perfluorocarbon) tracer experiments has been evident for air pollutant dispersion. All the ground-based measurements will be investigated in this study, which will be integrated with the aircraft-based measurements later on and then contribute to a better understanding upon the variations in the air quality over Taiwan.

3. Results and discussions

The COSMO and PALM simulation of wind filed in central Taiwan area on March 22nd 2018 is verified with the filed observation. We will show more of the results in the poster session.





4. Summaries

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