Coupled simulations using Varsha – WRF: Massive data and computing requirements

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1 Introduction

Numerical modelling of the atmosphere is one of the fields which requires high-performance computing (HPC). In addition, simulations using climate and weather models generate large datasets. Therefore such computations pose a challenge for large HPC systems.

The Varsha General Circulation Model (GCM), is a spectral weather prediction code developed at Flosolver Unit of the CSIR - National Aerospace Laboratories (NAL), Bangalore [1]. A significant feature of the Varsha GCM is the boundary layer module [2, 3] with "heat-flux" scaling, which is more appropriate for the low winds which are generally present over India.

Varsha GCM has been used for making studies and forecasts at different resolutions (80, 40 and 20) [4, 5]. While using a global model has its advantages, at very high resolutions (10km or lower), issues such as non-hydrostatic effects, surface effects, and more complex cloud scale processes make it difficult to use GCMs. One way to model such problems is to use an embedded regional model at a higher resolution which uses the GCM output for lateral boundary conditions.

To enable making such high resolution simulations and forecasts, an interface has been developed between the Varsha GCM and the WRF model. Given that individually both the Varsha GCM and WRF model need large computational resources, their combination would require even larger resources. A sample case is presented here and estimates made for higher resolutions.

2 Varsha - WRF coupling

The output of Varsha contains variables like geopotential height, temperature, surface pressure, divergence, vorticity, specific humidity etc on a spectral truncation of 120 or 170 modes on 18 or 28 sigma levels in the vertical and surface fields like zonal & meridional wind at 10-meter height, temperature and relative humidity at 2-meter height on the model resolution. There are different approaches possible for making the output from the Varsha model compatible with the WRF lateral boundary conditions, the one we have chosen is as follows:

The output fields from the Varsha model are converted to standard pressure levels and are merged along with the fields available in the NCEP-FNL [6] dataset to create a "pseudo-FNL" file for each time. These files are then used as input to the WPS program. More details are available in [7].

3 Simulation Results

The tropical cyclones Nilam and Mahasen were simulated using the WRF model (with lateral boundary conditions generated from Varsha output) and studied. The spatial distribution of rainfall and wind from the simulation of cyclone Nilam is shown as an example in Figure 1. The computations were made on the following two parallel computing platforms: 1) Flosolver Mk8 [8] of NAL and 2) ICE HPC system [9] at CMMACS. These simulations were made with nested domains of 27km and 9km horizontal resolution.

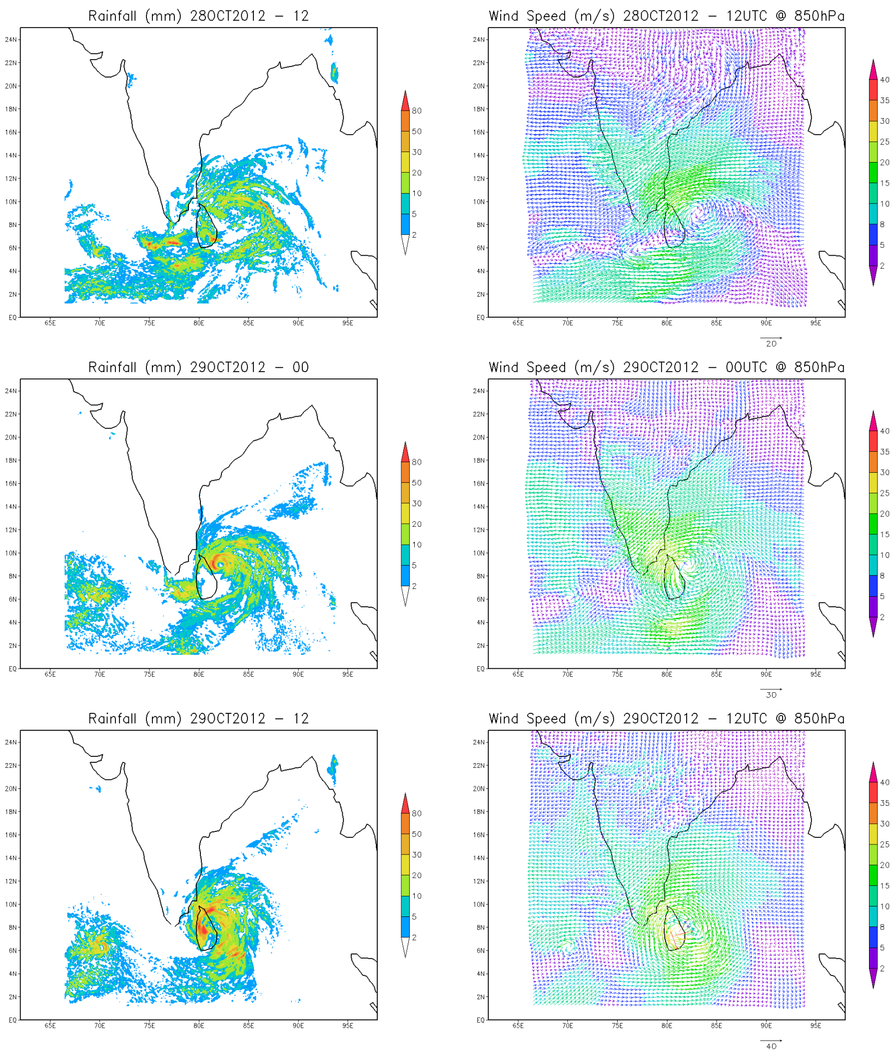

Figure 1: Rainfall and Wind simulations of cyclone Nilam at 9km

4 Data and computing requirements

The computational and storage requirement for Varsha GCM and WRF model is presented in the section. For the current study Varsha GCM was run with a spectral truncation of 170 waves in triangular truncation with a transform grid of 1024 points in the east-west and 512 points in the north-south. 18 vertical levels were used and the time-step was 450 sec. The wall-clock time requirement is listed in table 1. The two domains chosen for WRF (27km & 9km) were run with 221x221 & 331x331 grids in horizontal, 28 levels in vertical and with a time interval of 120 seconds. The computing time/day for WRF in this configuration using different number of processors are given in table 2.

Cores	1	8	64	256
Time (sec)	5536	904	226	180

Table 1: *Wall-clock time for a one-day run of the Varsha code on the ICE cluster*

Cores	32	64	128	256
Time (sec)	1500	900	480	360

Table 2: *Wall-clock time for a one-day run of WRF on the ICE cluster*

The disk-space requirements for a five day forecast are as follows: Varsha $\sim$ 7GB (prognostic variables at every six hours requires 1.5GB and surface fields at every hour needs 5.5GB of storage) and WRF around 200GB (fields are stored every three hours).

Given the figures for a particular resolution on a computational platform, required time for larger problems can be estimated as follows. If we are to run the Varsha at a resolution of 20km and WRF with outer grid spacing of 9km (330 x 330) and inner nests of 3 (660 x 660) and 1 km (990 x 990) a factor of 8 (2x2x2) in time for Varsha and a factor of 60 (10x6) for WRF would be required. Thus a factor of nearly 500 increase in computational resources. A possible scenario is: 2048 cores for Varsha and 15360 cores for WRF (assuming good scalability for WRF and moderate scalability for Varsha GCM).

5 Conclusion

Numerical simulations using weather and climate models require large computing systems and will generate huge datasets. Efficiency / scalability of these models depend also on the inter-connectivity of computing nodes. In this study, we are presenting the methodology developed for interfacing Varsha GCM and WRF model. This coupled model is tested by simulating the tropical cyclones Nilam and Mahasen and the preliminary results are encouraging.

An estimate of the computing and storage requirements has also been presented. We find that for resolutions of interest, a large number of cores, high storage space and a fast interconnect are required for scalability. As coupling of more components is likely in the future, these requirements are also likely to increase.

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