Atmospheric Modelling Systems for Southeast Asian Region

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Abstract. Atmospheric Modelling Systems have been set up on 3 High Performance Computing (HPC) environments in the Southeast Asian Region. Weather Research and Forecasting with Chemistry (WRF- Chem) model, various versions from 3.5.1 to 3.9.1, has been implemented over regional domains; 1) stretching across 5000 x 4500 km centred at Kathmandu, 2) covering parts of Karakolum mountains and Hindu-Kush Himalayas in Northern Pakistan, 3) extending from Myanmar to Thailand and Indochina. The chemical transport model has been used for making assessments with the attempt to understand atmospheric processes and eventually forecast the air pollution episodes, not only during the winter seasons in Nepal and northern India, such as persistent fog or smog, but also the interaction between atmospheric chemistry and South Asian Monsoon, focussing on the monsoon onset dates and precipitation trends on the mountains, during recent past. Meteorological data from routine observation from each country are compared with meteorological output of the WRF simulation for each time periods, so to find the best fit microphysics, short and long-wave radiation parameterization and boundary layer schemes. Preliminary finding is that WRF-Chem is suitable for the region, provided that the emission inventory is improved to capture the actual activities. Only then the modelling systems become useful for supplying the necessary information to policy makers in the region by generating scenarios on possible mitigation actions within each country or across the region, in order to make a joint implementation plan on the transboundary issues of air pollution.

1. Introduction

The attempts to simulate the regional air flow and air quality (AQ) in Southeast Asia have been carried out by a number of researchers in Asia, as well as other countries in ASEAN nations, e.g. the Philippines, Thailand, Vietnam, etc.. Cheng et al. (2013) [1] used Weather Research and Forecasting (WRF) meteorological model simulating, over Southeast Asia, at 27-km and 9-km spatial grid resolution during March 2007 to illustrate the transport of biomass-burning emissions in Indochina to the area of Taiwan. This work, similar to other earlier modelling works tried to study the transboundary air pollution being motivated by the downwind nations, treating Southeast Asia as the source region.

While working at National Center for Atmospheric Research (NCAR), Amnuaylojaroen et al. (2018) [2] explored the sensitivity of Southeast Asian air quality simulations using the Nested Regional Climate Model coupled with Chemistry (NRCM-Chem) for the time periods during March and December of 2005–2009, and projected to 2030–2034. They performed the model at 60 and 12 km grid sizes, and employed initial and boundary conditions from the Community Climate System Version 3 (CCSM3) for meteorological variables and Community Atmospheric Model with Chemistry (CAM-Chem) for chemical species. The emission inventories include anthropogenic, biogenic, and biomass burning emissions, with RCP4.5 scenario for future anthropogenic emission projection. They found, by

comparing the NRCM-Chem results with the CAM-Chem results (at a coarser grid spacing of ~200 km), that the two model results have a similar spatial pattern in the present day over Southeast Asia, and agree fairly well compared to ground-based observations from Pollution Control Department in Thailand. The model results were useful indicating that climate change alone may increases ozone concentrations by about 30% in Southeast Asia. It was also found that the combination of climate and emission changes in the future may increase ozone by another 10% on top of the impact from future climate change.

At Phayao University in Northern Thailand, Pimonsree et al. (2018) [3] has conducted WRF-CMAQ (Weather Research and Forecasting/Community Multiscale Air Quality) simulations over Mainland Southeast Asia (MSEA), using Fire Inventory from NCAR (FINN) as the biomass emissions with the new method to solve the uncertainty in FINN using Fire Radiative Power (FRP) during smog episode in March 2012. They have done the comparison of simulated PM with modified FINN by FRP (PMFINN-FRP), and the result showed generally good agreement. The modelling system captured most of the important observed features. The simulated PMFINN-FRP are in factor of two of the observations more than 70% and spatial correlation with the observation are greater than 0.8. It was pointed out through this work that further study using AQ modelling should be conducted to investigate the transport and transformation processes of atmospheric aerosols. The AQ modelling system should be able to assess the impacts to AQ, in order to address effective mitigation strategies of biomass burning and AQ management as a whole.

This work investigates Atmospheric Modelling System installed at 3 institutes in 3 South Asian countries that covers the Southeast Asian domains. It gives overview of the 3 installations based on WRF-Chem, which is the most comprehensive AQ modelling used across the globe at present.

2. The Modelling Systems
2.1. Model setting in Nepal
Since 2013, the simulations have been performed using the WRF version 3.5.1 over the domain extended 5000 km x 4500 km. The model was configured with three nested domains, with horizontal grid spacing of 25, 5, and 1 km (Figure 1), with 41 vertical levels between the surface and 50 Hecto-Pascal, specifying the top of the atmosphere. Microphysics scheme was WRF Single-Moment 3-class Scheme, while cumulus parameterization used Kain-Fritsch scheme (based on Ma and Tan, 2009), and planetary boundary layer took Yonsei University scheme (Hong et al, 2006). The surface layer was estimated by Monin-Obukhov (revised MM5), and the land-surface physics took Noah-MP (Niu et al., 2011).
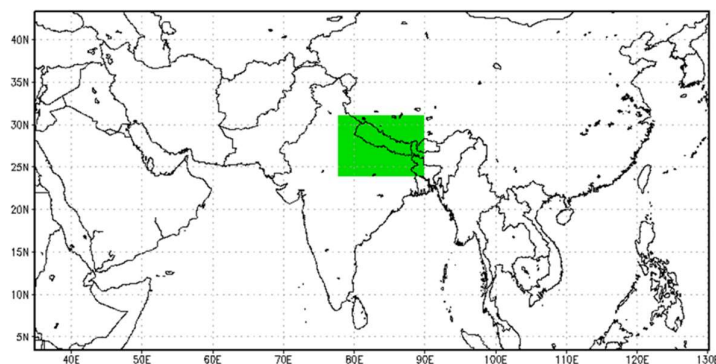

Figure 1. Modelling domain as set in WRF installed at ICIMOD.

2.2. Model setting in Pakistan
Near the end of 2017, WRF model version 3.9.1 was installed and used in the analysis generating 3 nested domains with horizontal resolutions of 25, 5, 1 km, but 32 vertical levels, due to that the tried machine was only a single workstation, not a cluster. The model physical options take the physics suite

called CONUS, where microphysics scheme is New Thompson et al. (2008) Scheme, cumulus parameterization uses Tiedtke scheme (1989) with improvement by Zhang et al. (2011). Long-wave and short-wave radiations are calculated using RRTMG scheme, and planetary boundary layer is simulated using Mellor-Yamada-Janjic scheme (Janjic, 1994), with the surface layer estimated following Eta similarity. The land-surface physics takes Noah Land Surface Model (Tewari et al., 2014), which has improved representation of the processes over ice sheets and snow covered area from the previous versions of WRF as used in the valleys of Nepal, and so considered suitable to the mountains in Northern Pakistan.

2.3. Model setting in Thailand

From early 2017 before newer version was available, WRF-Chem version 3.8 was installed on the NARIT's HPC for the simulation with horizontal resolution 10 km. The meteorological setting was similar to the above setting for Nepal, while chemistry option is turned on. The chemical mechanism used in the study is Model for Ozone and Related chemical Tracers (MOZART4) (Emmons 2010, Knote 2014) linked with Goddard Chemistry Aerosol Radiation and Transport (GOCART) bulk aerosol scheme (MOZCART) (Chin et al., 2002, Pfister et al., 2011).

Anthropogenic emissions are obtained from Emission Database for Global Atmospheric Research collaboratively with Task Force Hemispheric Transport of Air Pollution (EDGAR-HTAP) at global horizontal grid resolution of 0.10 x 0.10. The biogenic emissions are calculated online using Model of Emissions of Gases and Aerosols from Nature (MEGAN) (Guenther 2006) and the biomass burning emissions are acquired from FINN v.1 (Wiedinmyer et al., 2011). Dry deposition and photolysis procedure of gases are parameterized based on Wesely (1989).

3. Results and Discussion

Due to limit of space, here only the results of WRF-Chem at NARIT are shown; the modelling results of the other 2 systems are published elsewhere (Surapipith et al. papers are in preparation). It is found that WRF-Chem performed reasonably during the dry season as shown in the Figure 2. There are rooms for improvement in chemistry & deposition; the discrepancy of the ozone concentrations at night is likely due to poor temporal variation of the emission used by the model. It may be better to use the PMFINN-FRP as described above by Pimonsree et al. (2018). Particulate matter diameters less than 10 micron (PM10) was much overestimated by the model, and the team at NARIT is working on improving the results by checking sensitivity of each model inputs.
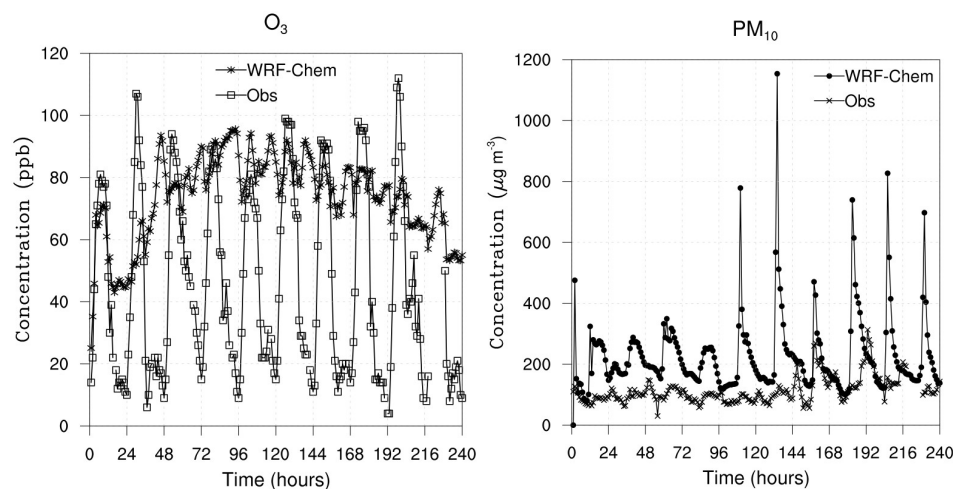

Figure 2. Hourly time series of ozone and PM10 concentrations simulated by WRF-Chem at NARIT being compared with the observed concentrations at Chiang Mai City Hall station during April 10 – 20, 2016.

4. Conclusion

The atmospheric modelling systems for weather and air pollution forecast, i.e. WRF-Chem, are set up efficiently on 3 HPCs in South-Southeast Asia. The schemes chosen for each model settings are tailored to simulate the issues of each country, i.e. fog in Himalayan valley for Nepal, climate change and precipitation in Pakistan, and city air pollution in Northern Thailand. They are the necessary research tools for understanding of the atmospheric processes, and will pave way towards effective air quality management in a near future. Capacity building is required so that joint effort to improve the model performance comes hand-in-hand with model applications to fit needs of the Southeast Asian nations.

5. References

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