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Simulation of forest fires smoke using WRF-Chem model with FINN fire emissions in Sumatera

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Abstract

The forest fires smoke event of 7 March 2014 in Sumatera-Indonesia has been simulated using WRF-Chem with the Fire Inventory from NCAR (FINN) fire emissions dataset. These simulations begun 6 March 2014 at 12 UTC until 9 March 2014 at 00 UTC. The results show that the smoke moved to southwest direction covering Riau Province. Moreover, the source of the smoke was also detected from Malaysia which could be seen from both satellite images and the output model. This simulations model have revealed most of the location of forest fires and the spreading of the smoke were properly captured.

Selection and peer-review under responsibility of the LISAT-FSEM Symposium Committee

Keywords: forest fires; smoke; FINN; WRF-CHEM; CO

1. Introduction

Recently, the forest fires in Indonesian Riau province caused a haze crisis that may affected many countries in Southeast Asia. Forest fires in Indonesia are driven by a complex set of issues. The forest fires could be happened naturalllyor from human activities. The natural factors could be causes by prolonged drought and lightning strikes. While the human factors, for example, is negligence throw cigarette butts, burning forest for land clearing, bonfire that forgot to shut down etc. There can be no doubt that the forest fires produce a toxic haze with severe negative impacts to the environment, economy, and human health [1]. Satellites model could be used to map the forest fires as well as the extend of the dispersed smokes.

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The Weather Research Forecasting model coupled with Chemistry (WRF-Chem) is a WRF regional model that makes use of chemical compounds in its calculation [2, 3, 4] and allows for coupled simulations of atmospheric chemistry and meteorology. Previous study of WRF-chem and its application to the distribution of forest fire smoke has been done using an earlier version of the code which was included in WRF release as WRF-Fire [5]. While the other researchers were using two regional atmospheric chemistry models: i.e. WRF-Chem and EMEP MSC-W [6]. Recently, some researchers modeled the largest fire-induced haze episode in the past decade (2006) in Indonesia using the WRF-Chem [7].

Therefore, the forest fires smoke event of 7 March 2014 in Sumatera-Indonesia has been simulated in this study using WRF-Chem with the Fire Inventory from NCAR (FINN) fire emissions dataset. The FINN dataset inserts smoke tracers into WRF-Chem to model the movement of fire emissions. The FINN dataset is generate daily with 1 km resolution of global estimates of the trace gas and particle emissions from biomass open burning [8]. This dataset uses satellite observations of active forest fires and land cover, together with emission factors and estimated fuel loadings. This paper focuses only on carbon monoxide (CO) compound as one of the forest fires' emissions.

2. Methodology

The regional atmospheric chemistry model (WRF-Chem) was applied. The initial and lateral boundary conditions were inserted using 6 hourly Global Forecast System (GFS) data with 0.5 x 0.5 degree horizontal resolution. This simulation started on 6 March 2014 at 12 UTC until 9 March 2014 at 00 UTC. The WRF-Chem model domain is centred over the Riau Province, covers most of the West Sumatera Province to the south, and extended up to Malaysia country to the north (Fig. 1). The model used a horizontal resolution of 5 km × 5 km, and has been run for three days on March 2014. Table 1 shows detail of model properties and configuration options employed by WRF-Chem in this study.

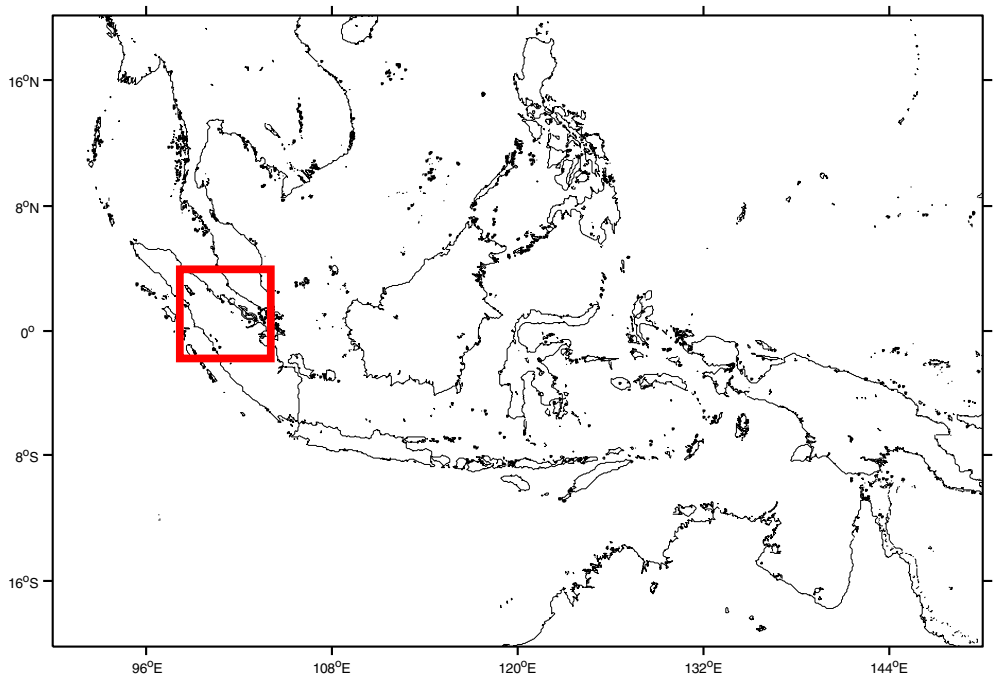

Fig. 1. Location of the domain used in the WRF-Chem simulation. The study region (98.2°E – 103.8°E, 1.6°S – 3.6°S) covering most of the Riau Province.

Table 1. Configuration options

Chemistry and Atmospheric Process	Model Options
Horizontal resolution	5 km x 5 km
Horizontal grid size	121 x 121
Number of vertical levels	20
Model top	50 hPa
Meteorology	WRF coupled with chemistry
Meteorological initial and boundary conditions	GFS
Chemistry scheme	RADM2 [9]
Biomass burning emissions	FINN [8]
Biogenic emissions	MEGAN [10] online calculation

The core of the system is the WRF-Chem model, that provides forecast of the forest fires spread of the smoke based on the meteorological conditions. There is a feedback between the fire and the atmosphere [11]. In general the forest fires smoke emitted from the fire is transported within the atmosphere and the chemical reactions resolved by WRF-Chem. The FINN emission factors are directly compatible with the Model for Ozone and Related chemical Tracers (MOZART) [12], in this case the fluxes computed directly into the WRF-Chem. The diagram showing the WRF-Chem model components is presented in Figure 2.

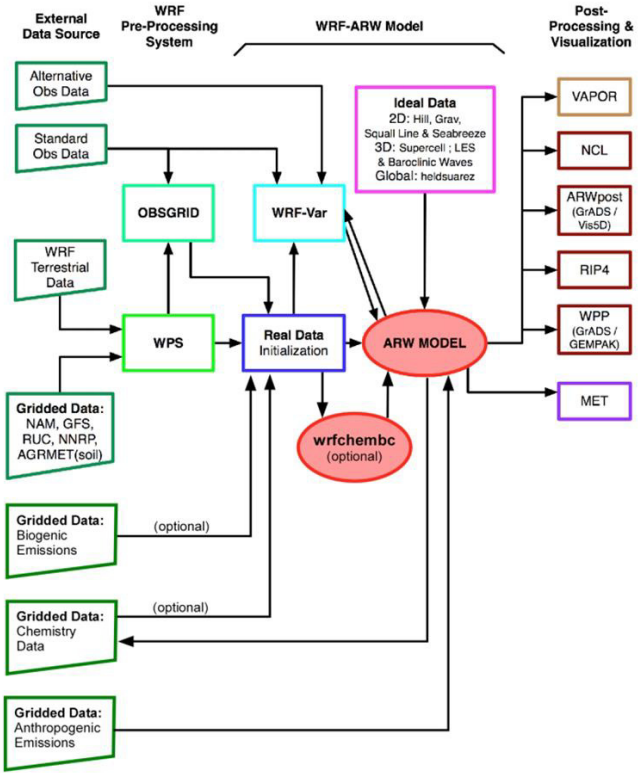

Fig. 2. Diagram of WRF-Chem processess [13].

The analysis presented here will focus on the model simulations that are performed using WRF-Chem. The model has been evaluated against satellite image from the Moderate Resolution Imaging Spectroradiometer (MODIS) of NASA's Aqua satellite. Fire detections from the MODIS sensors on the Aqua satellite plays a significant role in monitoring burning area especially in Indonesia. For evaluation purposes, the model output was adjusted with time approaching aqua orbit track, i.e. at 06 UTC.

3. Results and Discussions

The simulation results were saved in *wrfout* output files. The simulation started on 6 March 2014 at 12 UTC until 9 March 2014 at 00 UTC Figure 3 shows the forest fires smoke as a result from WRF-Chem Model. Fig. 3a shows the hotspots that occurred in some areas in Sumatra and Malaysia. It clearly seen that the hotspots around Riau Province moved towards the southwest direction. In addition, the smokes from Malaysian areas were also moving to the southwest.

Meanwhile, Figure 3c shows that on 7 March 2014 at 06 UTC, smoke moved to southwest direction covering Riau Province. Furthermore, other sources of the smoke from Malaysia was also seen both in the satellite image and the model output. By comparing with MODIS image, it could be seen clearly that this simulation model revealed most of the location of the smoke and its spreading direction (Fig. 3b). It is also noteworthy that the location of the hotspots in the MODIS image (Fig. 3b) corresponds well to the simulated active fire regions presented in Fig. 3c). There is a visible resemblance between the simulated and observed smoke dispersion. However, the model magnitude of CO in the plume was too low. This was probably caused by underestimation of CO in the emission inventories. It is quite clear from these simulations that the emission inventory is more important than the model. It is suggested that the CO ratios of fire emissions should be re-assessed.

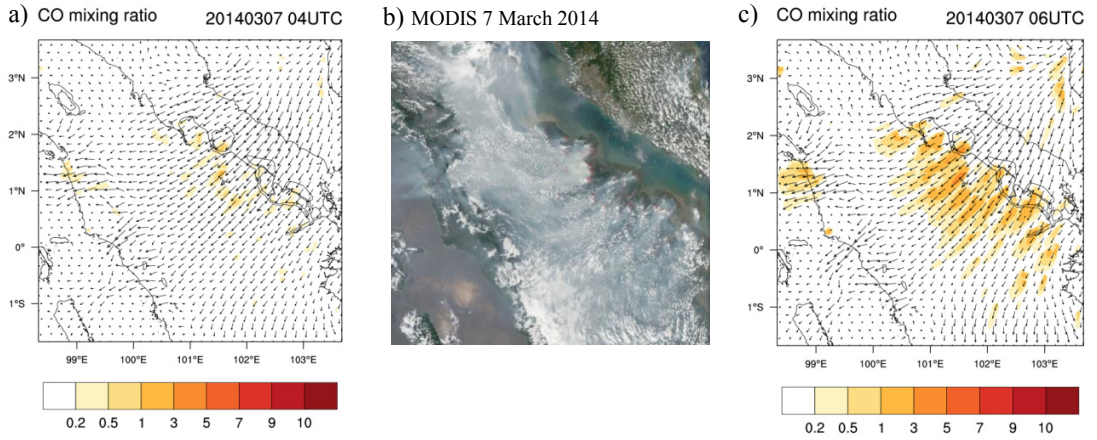

Fig. 3. (a) Visualization forest fires smoke from WRF-Chem Model in 7 March 2014 at 04.00 UTC. Comparison of forest fires smoke between (b) MODIS on NASA's Aqua satellite; and (c) WRF-Chem model with FINN fire emissions in 7 March 2014 event represent by CO (ppm)

4. Conclusions

The forest fires smoke event of 7 March 2014 in Sumatera-Indonesia has been simulated using WRF-Chem with the Fire Inventory from NCAR (FINN) fire emissions dataset. This simulation conducted on 6 March 2014 at 12 UTC until 9 March 2014 at 00 UTC. The model has been validated using satellite image from the Moderate Resolution Imaging Spectroradiometer (MODIS) of NASA's Aqua satellite. The result shows that smokes moved to southwest direction covering Riau Province on 06 UTC. In addition, the source of the smoke was also came from Malaysia area which was seen from both satellite image and the output model. Model simulations revealed most of

the location of fire incidence in Sumatra and Malaysia, and the spreading of the smoke relatively well captured. However, the magnitude of CO in the plume is too low using the simulation model. This is probably caused by underestimation of CO in the emission inventories. It is suggested that the CO ratios of fire emissions should be re-assessed to get a better result.

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