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Evaluation of the operational atmospheric model used in emergency response system at Kalpakkam on the east coast of India

C.V. Srinivas*, R. Venkatesan, V. Yesubabu, C. Nagaraju, B. Venkatraman, P. Chellapandi

Radiological Safety Division, Indira Gandhi Centre for Atomic Research, Kalpakkam, Tamil Nadu 603102, India

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The performance of a triple-nested mesoscale atmospheric model (MM5) implemented in the Online Nuclear Emergency Response System (ONERS) at Kalpakkam on southeast coast of India is evaluated. Real-time atmospheric model predictions are used to compute radiological plume dispersion in the mesoscale ranges using Lagrangian particle models. About 280 days falling in dry and wet weather and distributed in 2006, 2007, 2008 and 2009 years are considered. About 25 upper air, 100 surface station data including radiosonde, GPS sonde, micrometeorological tower and automated weather stations are used for model evaluation. Results indicate that model could reproduce the synoptic pressure, geopotential heights, winds and precipitation patterns in the coarse domain as well as the fine scale features of the atmospheric circulation in the inner fine domain. Model diagnosis with observations shows correlation (r), mean absolute error (MAE) and bias as (0.685, 1.87 C, 1.28 C) for temperature, (0.93, 1.55 hPa, 0.113 hpa) for pressure, (0.56,15 m, 0.53 m) for geopotential, (0.55, 12%, −10.5%) for humidity and (0.45, 2.3 m s^{-1}, 1.70 m s^{-1}) for wind speed indicating appreciable performance in the lower atmosphere for both dry and wet weather events. Model error in wind speed/direction reduced with height and slightly increased for temperature and humidity. Model performance is relatively better for dry weather cases than for the rainfall events. Also simulations from high resolution domain-3 are found to be better with relatively lower error metrics than those over coarse domains 1 and 2.

1. Introduction

Assessment of environmental impact due to inadvertent hazardous air-borne releases from nuclear installations is a prerequisite for emergency management and mitigation planning. Real-time dispersion models are useful for assessing the environmental radioactive contamination and dose to the public due to inadvertent releases from a nuclear site (Knox et al., 1981; Sullivan et al., 1993; Satomura et al., 1994; Raskob, 2004; Lagzi et al., 2004). Kalpakkam is a tropical coastal site on southern peninsular India. Considerable mesoscale forcing exists in this coastal region due to land–sea interface and consequent thermal contrast across the coast. Mesoscale wind systems such as land/sea breeze cause non-stationary and non-homogeneous meteorological conditions and influence the plume dispersion in the region. The site has several nuclear reactors and associated facilities. An Online Nuclear Emergency Response System (ONERS) has been developed for the Kalpakkam site to provide environmental decision support in the event of nuclear/radiological accidents. The ONERS is a GIS based decision support system with integration of weather, dispersion models to facilitate rapid query and spatial analysis of air concentration, deposition and radiological dose in different spatio–temporal scales due to normal or off-normal release scenarios from any of the nuclear facilities at the site. It includes two ranges of dispersion calculation i.e., i) a local 20 km range where wind field is derived from onsite real-time meteorological observations from meterological towers using mass consistent wind field-cum-random walk particle dispersion model SPEEDI (System for Prediction of Environmental Emergecny Dose Information) (Imai et al., 1985) and ii) a 100-km mesoscale range in which a weather prediction model is used to predict the input meteorological fields required for dispersion assessment. A nested grid non-hydrostatic mesoscale model PSU/NCAR MM5 is operationally run to forecast the wind field, temperature, humidity, rainfall, mixing height and other necessary meteorological parameters up to 48 h (Srinivas et al., 2006b; Venkatesan et al., 2007) to simulate dispersion using two lagrangian particle dispersion models FLEXPART (Srinivas et al., 2006b) and HYSPLIT (Srinivas et al., 2009) in mesoscale range.

It is well known that errors in the meteorological fields lead to large inaccuracies in the dispersion model results (viz., Lewellen and

* Corresponding author. Tel.: +91 44 27480062.
E-mail address: cvsri@igcar.gov.in (C.V. Srinivas).

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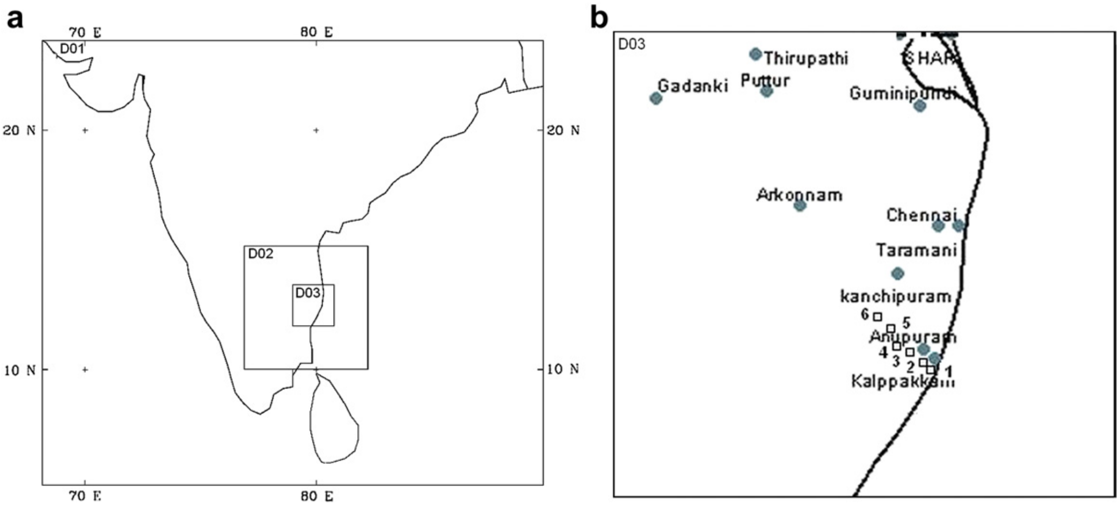

Fig. 1. Model domains used for operational predictions (a) and observation stations in 3rd domain (b).

Sykes, 1989; Shankar Rao, 2005). The meteorological processes involved in atmospheric dispersion are horizontal and vertical transport, turbulent mixing, dry and wet deposition to the surface which are dependent on wind field, temperature profiles, humidity, boundary layer depth, turbulent fluxes, surface pressure, cloud characteristics and rainfall/precipitation in the lowest 2 or 3 km of the atmosphere (Hanna, 1994; Seaman, 2000). Thus, it is important to evaluate the mean errors in forecast meteorological fields used in ONERS to determine its confidence limits. Several studies reported meteorological model evaluations in the context of air quality modeling (Jimenez et al., 2006; Mao et al., 2006; Zhang et al., 2006; Chandrasekhar et al., 2003; Gilliam et al., 2006 among others). In a wind field modeling study WIND (Wind in Non-uniform Domains) Gross (1994) has carried out a comparison of MM5 simulations using

Table 1
Results of statistical analysis in respect of dry and wet weather cases for temperature, surface pressure, geopotential, relative humidity, u-wind, v-wind and wind speed from model domain-1.

Variable	Level	Dry Weather Cases					Wet Weather Cases				
		R	*B*	MB	MAE	RMSE	*R*	*B*	MB	MAE	RMSE
Temperature (°C)	2 m	0.69	0.81	1.00	1.60	2.19	0.69	1.17	1.00	1.58	2.06
	1000	0.57	0.07	1.00	2.09	2.56	0.58	0.45	1.00	1.45	1.80
	925	0.65	−0.37	1.00	2.15	3.20	0.57	−0.37	1.00	1.85	2.60
	850	0.66	−0.36	1.00	1.75	2.27	0.55	−0.27	1.00	1.53	2.09
	700	0.59	−0.25	1.00	1.72	2.29	0.46	0.40	1.00	1.55	2.10
Pressure (hPa)	Surface	0.80	0.48	1.00	2.39	4.78	0.81	−0.429	1.00	2.463	4.838
Geopotential Height (m)	1000	0.44	−16.10	0.69	27.65	40.38	0.51	−19.16	0.61	23.17	29.84
	925	0.57	4.76	1.01	10.21	12.94	0.71	0.31	1.00	10.53	13.15
	850	0.52	6.92	1.00	10.66	13.83	0.65	4.98	1.00	11.89	15.39
	700	0.47	10.53	1.00	17.87	22.64	0.51	11.16	1.00	18.03	22.92
Relative Humidity (%)	2 m	0.63	−9.63	0.88	11.67	14.46	0.55	−8.04	0.90	10.36	13.22
	1000	0.55	−10.45	0.87	14.07	17.77	0.58	−10.50	0.88	11.92	14.43
	925	0.72	−6.74	0.89	15.50	19.90	0.56	−3.08	0.96	11.62	14.60
	850	0.68	−7.98	0.86	15.07	19.04	0.60	−2.42	0.97	11.41	14.15
	700	0.54	−3.40	0.92	17.26	22.53	0.59	−0.62	0.99	14.24	18.12
U-wind (m s^{-1})	1000	0.69	0.92	−3.76	1.98	2.41	0.52	0.77	2.19	2.55	2.98
	925	0.60	0.44	5.57	2.46	3.16	0.61	0.68	1.27	2.50	3.24
	850	0.68	0.48	1.52	2.51	3.39	0.62	1.33	1.03	3.61	6.10
	700	0.76	−0.03	0.76	2.84	3.60	0.64	−0.48	−0.18	3.23	4.30
V-wind (m s^{-1})	1000	0.67	−0.37	1.49	2.51	2.91	0.52	−0.06	3.31	2.51	3.10
	925	0.72	0.32	−0.27	2.48	3.16	0.55	−0.31	0.36	2.66	3.37
	850	0.64	0.16	0.50	2.38	2.87	0.53	−0.13	0.21	3.14	4.03
	700	0.72	−0.61	2.14	2.33	2.93	0.53	−0.20	2.72	2.57	3.23
Wind speed (m s^{-1})	10 m	0.36	1.01	2.06	2.27	2.98	0.40	1.09	1.82	2.68	3.70
	1000	0.67	2.93	2.51	3.01	3.44	0.50	3.32	2.63	3.36	3.79
	925	0.65	1.22	1.24	2.02	2.56	0.52	1.32	1.23	2.61	3.28
	850	0.56	−0.32	0.96	2.53	3.43	0.56	0.99	1.15	2.80	3.54
	700	0.68	−0.45	0.94	2.14	2.68	0.53	−0.36	0.93	2.56	3.50