Location-specific forecast at Sriharikota during the launch of GSLV-F01

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The present study was carried out to examine the performance of two high-resolution mesoscale/regional atmospheric models to provide real time short range forecast during the GSLV-F01 launch on 20 September 2004. The main objective was to provide vertical shear of horizontal wind, which is very important for launch operations. The models are integrated to provide forecasts 36 h in advance. The model predictions are compared with observations and their performances are evaluated in terms of statistical skill scores. The mesoscale model of Pennsylvania State University (PSU)/National Center for Atmospheric Research (NCAR) MM5 was found to perform better than the High-resolution Regional Model (HRM) though marginally. Performance of MM5 model was further investigated after improvement of model initial condition with insertion of conventional observations into the large-scale global analysis to perform reanalysis at high resolution (horizontal resolution of 9 km). Results indicate significant improvement in model performance with improvement in initial condition.

Keywords: Mesoscale and regional model, satellite launch, vertical profile.

THE desire for reliable short-range weather prediction can be as simple as knowing whether a lightning storm will ruin a camping trip or as important as confirming clear skies for launch vehicle programmes. Capability to forecast wind, wind shears and thunderstorm activities is of paramount importance at launch time operations of satellite launch vehicles. The Indian Space Research Organization (ISRO) had put into orbit the satellite *EDUSAT* onboard the first operational Geosynchronous Satellite Launch Vehicle (GSLV)-F01 on 20 September 2004. The launch site of ISRO is located at the Sriharikota High Altitude Range (SHAR) complex. SHAR is a tiny island located close to the east coast of India and has a complex terrain, with the Eastern Ghats located on its west and surrounded by the Pulicat Lake and the Bay of Bengal. It is therefore obvious that the underlying complex terrain could affect the local winds, resulting at times in the development of thunderstorms. The depressions that develop over the Bay of Bengal also affect the short-term weather over SHAR. Accurate wind prediction is required as optimum wind biasing techniques are in use for launch vehicles including on the day of launch[1].

Forecasting requirements for launch vehicle programme can be satisfactorily met only with a high-resolution numerical weather prediction model. Use of mesoscale models to provide forecasts for local and regional applications is well accepted widely. McQueen *et al.*[2] performed mesoscale simulations for the northeastern US and Manobianco *et al.*[3] using a mesoscale model to provide forecasts for the Kennedy Space Center in Cape Canaveral. Snook *et al.*[4] demonstrated the use of mesoscale models during the 1996 summer Olympics at Atlanta. Keyser and Anthes[5] developed a method for estimating forecast skill of a weather prediction model. Various other studies describe the skill of mesoscale model for local and regional applications.

Providing reasonably accurate initial condition to regional and mesoscale models is an important issue in the present day numerical weather prediction research. Delineation of fine structure of the large-scale phenomenon by numerical model is important for the accurate prediction of the local activities such as thunderstorm or location-specific forecast at the launch site of satellite launch vehicle. There have been several studies on performance evaluation of mesoscale models based on limited simulation results[6], but evaluation of real time forecast (with observations) is very few. Earlier studies reported the forecast of the wind parameters, temperature and precipitation at SHAR[7–9]. The present study deals with simulations using the mesoscale model MM5 and a high-resolution regional model (HRM), which were run operationally to provide forecasts up to 36 h during the launch of GSLV-F01 for a period of one week (14 to 20 September 2004).

Model description

In the present study, two models MM5 and HRM have been integrated operationally for providing real-time forecasts at SHAR for a week during satellite launch.

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Table 1. *a*, MM5 model configuration

Model	Penn State University/NCAR Mesoscale Model (MM5)
Dynamics	Non-hydrostatic with 3-D Coriolis force
Main prognostic variables	u, v, w, t, p' and q
Map projection	Mercator
Domain	D–I: (65–95 E, 4–23 N), D-II: (76–86 E, 10–17 N)
Resolution	D–I: (27 km), D-II (9 km)
Number of vertical levels	23
Horizontal grid scheme	Arakawa B grid
Time integration scheme	Leap-frog scheme with time splitting technique
Lateral boundary conditions	Nudged to NCEP/NCAR AVN Forecast
Radiation scheme	Dhudhia's shortwave/longwave simple cloud radiation scheme with frequency of 30 min
Planetary boundary layer parameterization schemes	MRF (Hong and Pan[16])
Cumulus parameterization schemes	Grell (Grell, 1993)
Microphysics	Simple ice
Soil model	Multi layer soil model
Topography	30 s elevation data (USGS)
SST and surface parameters	NCEP/NCAR (AVN)

Table 1. *b*, HRM model configuration

Model	High resolution Regional Model (HRM) of DWD, Germany
Dynamics	Hydrostatic
Main prognostic variables	u, v, t, p_s, q_v, q_c, q_i
Map projection	Mercator
Domain	D–I: (67–94 E, 0–30 N)
Resolution	D–I: 28 km
Number of vertical levels	31
Horizontal grid scheme	Arakawa C grid with 2nd order centered difference scheme
Time integration scheme	Split semi-implicit time step
Lateral boundary conditions	GME data of DWD
Radiation scheme	Delta two-stream radiation scheme with long-wave and short-wave radiation at the surface.
Planetary boundary layer parameterization schemes	Mellor and Yamada[17], Similarity theory (Louis[18])
Convection parameterization schemes	Tiedke (1989)
Soil model	Two-layered soil model including snow and interception storage and a three layer version of the soil moisture
Topography	8 m elevation data
SST and surface parameters	GME data of DWD

The MM5 model

The nonhydrostatic mesoscale model MM5 developed at Pennsylvania State University (PSU)/National Center for Atmospheric Research (NCAR) is one of most widely used mesoscale model for simulation/prediction of mesoscale/regional weather events. MM5 is a primitive equation model with pressure perturbation p', three velocity components (u, v, w), temperature T, and specific humidity q as the main prognostic variables. Model equations in the terrain following sigma co-ordinate are written in surface pressure weighted flux form and solved in Arakawa B grid. Leap-frog time integration scheme with time splitting technique was used in model integration. In time splitting technique, the slowly varying terms are integrated with longer time steps and the terms giving rise to fast moving waves are integrated with shorter time steps.

The most useful feature of MM5 model is its flexibility in terms of many options that are user specified and by setting these parameters to appropriate values, the model can be used for a wide range of applications. These include number of nests, type of convection, PBL and radiation parameterization schemes, etc. Another advantage of this modelling system is that it is a state-of-the-art model. The detailed description of the model is provided by Dudhia[10] and Grell *et al.*[11]. Table 1 *a* summarizes the model configuration and various options used in the present study.

The HRM model

The high-resolution regional model (HRM) is a flexible tool for numerical weather prediction developed by the Deutscher Wetter Dienst (DWD) of Germany[12]. It is a hydrostatic regional model capable of simulating/predicting the meso/regional scale atmospheric circulation features. The model consists of topographic data sets which can be obtained in regular or rotated latitude/longitude grid for any region of the world at mesh sizes between 30 km and 5 km. The prognostic equations of HRM are expressed in differential form in terms of spherical coordinates and a hybrid (sigma-pressure) vertical coordinate in Arakawa C grid with second ordered centered difference scheme and the time integration is through a semi-implicit scheme. Radiative transfer of solar and thermal radiation in clear and cloudy atmospheres is based on a scheme developed by Ritter and Geleyn[13]. A full radiation step is performed every hour at all grid points, solar fluxes are computed at each time step taking the actual zenith angle into account but the atmospheric transmission from the previous full radiation step is used. The long wave cooling rate is kept constant during the one-hour period. Cloudiness is derived from specific cloud liquid water and ice contents, relative humidity, convective activity and stability. The grid-scale precipitation scheme of HRM includes parameterized cloud microphysics[14] with the three prognostic water species water vapour, cloud liquid water and cloud ice. The precipitation phases (rain and snow) are treated diagnostically. These five phases interact in many ways (e.g. aggregation, deposition, riming, shedding) described by microphysical processes, which are formulated depending on the mixing ratios of the different water phases.

The parameterization of deep and shallow convection in HRM is based on a mass flux approach[15]. The convection scheme distinguishes three different convection types, namely shallow, mid-level and penetrative (deep). The three-dimensional convergence of water vapour is used as closure assumption for shallow and deep convection. Convective precipitation is initiated only if the cloud depth exceeds 3000 m over land and 1000 m over water.

The HRM model is in use in operational mode at the Space Physics Laboratory, Vikram Sarabhai Space Research Center since September 2002. Details of the HRM modelling system can be obtained from the Majewski[12]. Table 1 *b* summarizes the model configuration and various options used in the present study.

Weather over SHAR during GSLV-F01 launch

The synoptic situation at SHAR three days prior to the launch of the satellite, i.e. from 17 September 2004 is provided in this section. It is observed that the region was partly cloudy and isolated rain was recorded over the region in the evenings. On 18 September 2004, the sky was clear up to about mid-day but local thunderstorm within 20 km of SHAR was observed between 09:00 UTC to 09 : 45 UTC (i.e. between 14:30 and 15:15 hrs IST). Severe lightning discharges occurred and a rainfall of about 17.5 mm was received in 20 min, but fair weather appeared again at 10:30 UTC. On 19 September 2004, the sky was partly cloudy and around 14:00 UTC, severe lightning was noticed in the northwest of SHAR at a distance of about 40 km followed by similar weather in the southwest sector. On 20 September 2004, i.e. on the day of launch, severe lightning and precipitation occurred over SHAR in the morning at about 01:30 UTC. From 02:00 UTC onward the weather was fairly good. The cloudy weather with thunderstorm reappeared again in the northwest of SHAR around 09:00 UTC causing rainfall around 10:00 UTC. It dissipated before the schedule launch time 11:00 UTC (local time 16:30 h IST). A brief weather summary over SHAR during this period is given in Table 2. Also the minimum and maximum temperature with rainfall at SHAR is presented in Table 3.

Table 2. Weather description over SHAR

On 17-9-2004 (Friday)	Partly cloudy, isolated rain over the region in the evening.
On 18-9-2004 (Saturday)	Morning clear sky and hot dry weather. Local thunderstorm within 20 km of SHAR during 14:30 to 15:15 h. Severe lightning discharges and 17.5 mm rain in 20 min. Fair weather from 16:00 h onward.
On 19-9-2004 (Sunday)	Morning partly cloudy. From evening 1930 h, North West of SHAR, at about 40 km, severe lightning activity in evening hours (19:30 h) both in northwest and southwest of SHAR within 40 km.
On 20-9-2004 (Monday) Launch day	Severe lightning, rain and wind over SHAR during 23:45 h (previous day) to 07 : 00 h. Weather started improving at 07:30 h onwards. At 14:30 h, at about 35 km northwest of SHAR thunderstorm was observed.

Experimental design and data used

The mesoscale model MM5 is integrated up to 36 h to provide forecast for the launch site at Sriharikota. The double nested-model with the coarse domain (27 km resolution) over latitude range 4–23°N and longitude range 65–95°E and fine domain (9 km resolution) over latitude range 10–17°N and longitude range 76–86°E is used in the present study. The model has 23 levels up to a height of 30 km in the vertical. Two experiments have been carried out with MM5 model. In the first experiment the National Centre for Environmental Prediction (NCEP)/NCAR Aviation Model (AVN) analysis and forecasts are used to provide initial and lateral boundary conditions to the model respectively. As the large-scale AVN analysis is of coarse resolution, high resolution reanalysis is prepared and hence the model initial condition is improved with the insertion of the IMD station observations into the large-scale analysis by using the Cressman technique and the lateral boundary conditions are obtained from the NCEP AVN forecasts, which is the second experiment using the MM5.

The high-resolution regional model HRM is also used to provide the forecasts up to 48 h in advance at the launch site. The model is integrated with the horizontal resolution of about 28 km covering a latitude range 0–30°N and a longitude range 67–94°E. The model has 31 vertical levels up to 20 km in the vertical. Only one experiment is carried out with this model. The model initial and lateral boundary conditions are taken from the global model (GME) analysis/forecast systems. Both the models are integrated with initial condition derived from different analyses. Hence, it is not our purpose to compare performance of these models, but we made an attempt to examine the performance of each model against observations.

Results and discussion

The geographical domains of the models MM5 and HRM as used in the present study are shown in Figure 1 *a* and *b* respectively. The MM5 has a double-nested domain whereas HRM has single domain only. The results obtained from 36 h real time forecasts are described in this section.

Table 3. Observed temperature and rainfall over SHAR

Date	Temperature (°C)		Rain (mm)
	Maximum	Minimum	
17–9–2004	39	26	5
18–9–2004	38	27	17.5 (Due to thunderstorm at 14:30 IST)
19–9–2004	37	23	0.0
20–9–2004	32	25	30 (Thunderstorm in early hours)

The objective statistical measures for comparing model predictions and observations used in this study were taken largely from Cox *et al.*[6] that compared a suite of mesoscale predictions for a variety of global locations.

In this study, the zonal (u ms^{-1}) and meridional (v ms^{-1}) component of winds predicted by MM5 and HRM are compared with observations and also the respective error statistics are computed/presented. The following parameters are computed from forecasted fields and the observed data to quantify the errors.

The root mean square error (RMSE) is given as

$$\text{RMSE} = \sqrt{\frac{1}{n}\sum_{i=1}^{n}(O_i - F_i)^2}. \quad (1)$$

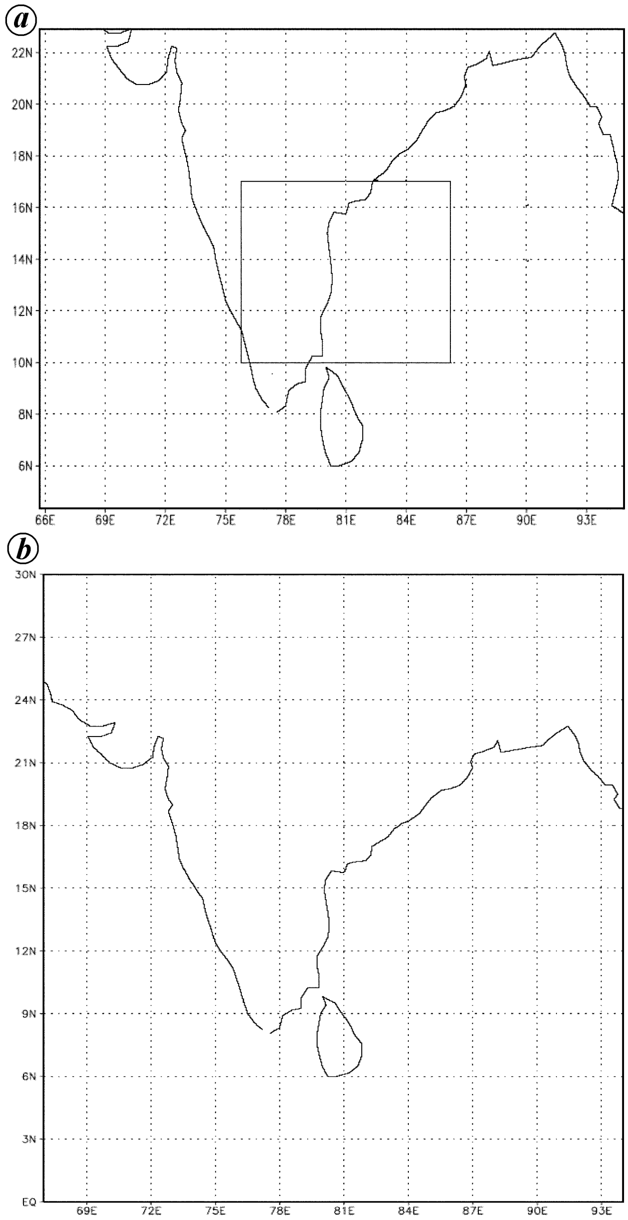

Figure 1. Model geographical domain. (***a***) MM5, (***b***) HRM.

Correlation coefficient (COR)

$$\mathrm{COR} = \frac{\sum_{i=1}^{n}[(O_i - \bar{O})(F_i - \bar{F})]}{\left[\left(\sum_{i=1}^{n}(O_i - \bar{O})^2 \times \sum_{i=1}^{n}(F_i - \bar{F})^2\right)\right]^{1/2}}. \quad (2)$$

Here O_i represents the observation at a particular height and F_i represents the corresponding forecast. n is the number of available observations/forecasts in the vertical. A good agreement between observation and forecast leads to smaller values of RMSE. Regarding the correlation coefficient, values close to 1 show good positive correlation between observations and forecast.

Vertical profile of wind components

Figure 2 represents the observed and model predicted (27 h) zonal and meridional wind components at SHAR valid at 03 UTC 20 September 2004. It shows that the low level wind is reasonably well predicted by both the models, but the upper level tropical easterly jet is not captured by any of the models. Table 4 shows that for the zonal wind component, the mean wind in the low wind regime is better predicted by the MM5 model compared to that of HRM and is very close to the observed wind. In the high wind regime, both the models have similar performance which is not satisfactory with large root mean square errors 7.57 and 7.80 m/s and correlation co-efficients 0.8 and 0.61 in MM5 and HRM model forecast respectively. The RMS errors are high as both the models are unable to cap-

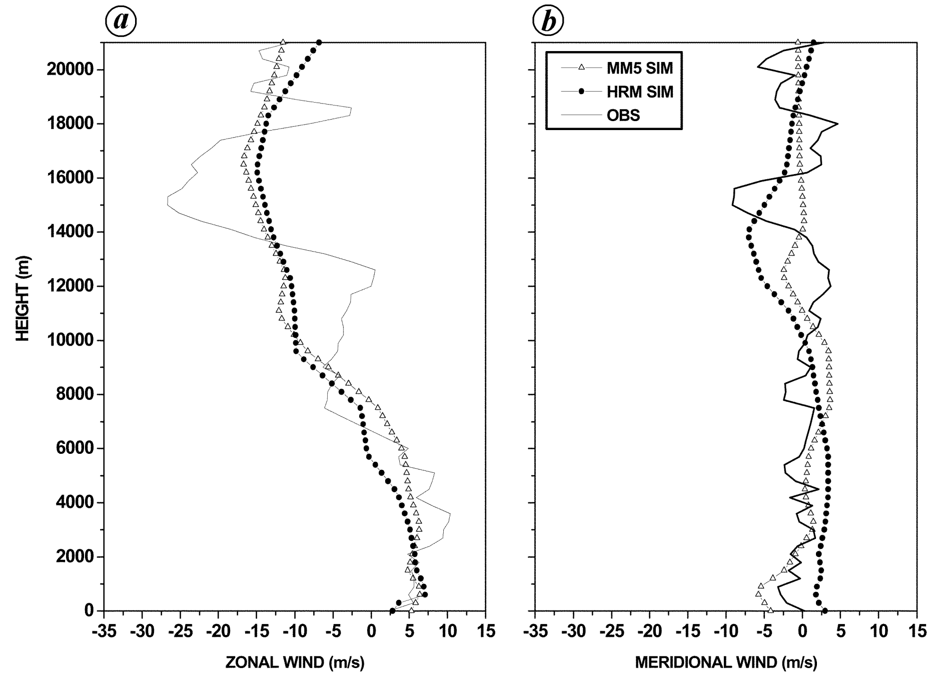

Figure 2. Observed and predicted (***a***) Zonal (m/s) and (***b***) Meridional (m/s) wind at SHAR using MM5 and HRM models valid at 03 UTC 20 September 2004.

Table 4. Statistical parameters for zonal and meridional wind component at SHAR valid at 03 UTC 20 September 2004

		Mean wind			RMS error		Correlation coefficient	
Wind component	Level	OBS	MM5	HRM	MM5	HRM	MM5	HRM
Zonal wind	Low level wind (0–10000 m)	2.59	2.46	–0.72	3.15	3.66	0.83	0.83
	High level wind (10300–21000 m)	–12.2	–13.4	–11.8	7.57	7.80	0.8	0.61
Meridional wind	Low level wind (0–10000 m)	–0.44	0.6	2.44	2.7	3.24	0.38	0.03
	High level wind (10300–21000 m)	–0.67	–0.87	–2.6	4.29	5.10	–0.4	–0.06

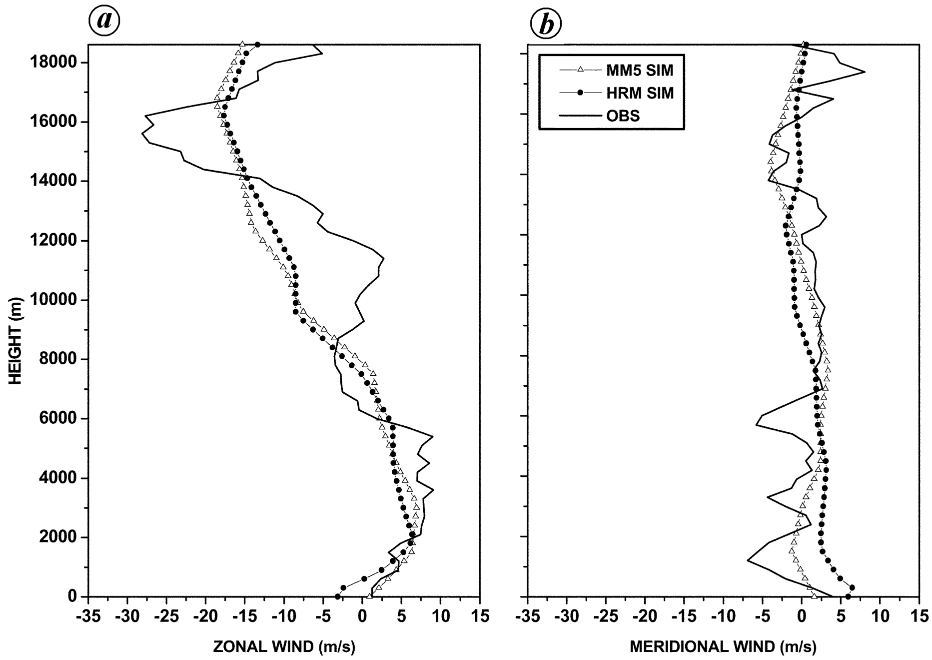

Figure 3. Same as Figure 2, but valid at 09 UTC 20 September 2004.

Table 5. Statistical parameters for zonal and meridional wind component at SHAR valid at 09 UTC 20 September 2004

		Mean wind			RMS error		Correlation coefficient	
Wind component	Level	OBS	MM5	HRM	MM5	HRM	MM5	HRM
Zonal wind	Low level wind (0–10000 m)	3.83	2.1	2.0	2.50	2.87	0.84	0.77
	High level wind (10300–21000 m)	–9.6	–13.5	–12.9	8.30	7.74	0.82	0.90
Meridional wind	Low level wind (0–10000 m)	–0.68	1.5	2.56	3.23	4.67	0.6	–0.14
	High level wind (10300–21000 m)	0.77	–0.77	–0.70	3.13	3.34	0.6	–0.09

Table 6. Statistical parameters for zonal and meridional wind component at SHAR valid at 12 UTC 20 September 2004

		Mean wind			RMS error		Correlation coefficient	
Wind component	Level	OBS	MM5	HRM	MM5	HRM	MM5	HRM
Zonal wind	Low level wind (0–10000 m)	3.78	1.6	3.6	5.50	3.15	0.25	0.43
	High level wind (10300–21000 m)	–12.4	–14.1	–11.7	7.0	6.65	0.75	0.69
Meridional wind	Low level wind (0–10000 m)	0.2	1.4	1.9	2.22	3.62	0.43	–0.33
	High level wind (10300–21000 m)	–1.08	3.14	0.4	5.34	4.34	–0.11	0.36

ture the easterly jet stream. The meridional wind predicted by the MM5 model is reasonably close to the observed wind both in the low and high wind regimes, whereas the HRM model could not predict well the mean wind at this time as well. For meridional wind component, the correlation with the observed wind is low, even in MM5 forecast though the mean wind is well predicted.

Figure 3 represents the observed and model predicted (33 h) vertical profile of wind components valid at 09 UTC 20 September 2004. The zonal component of low

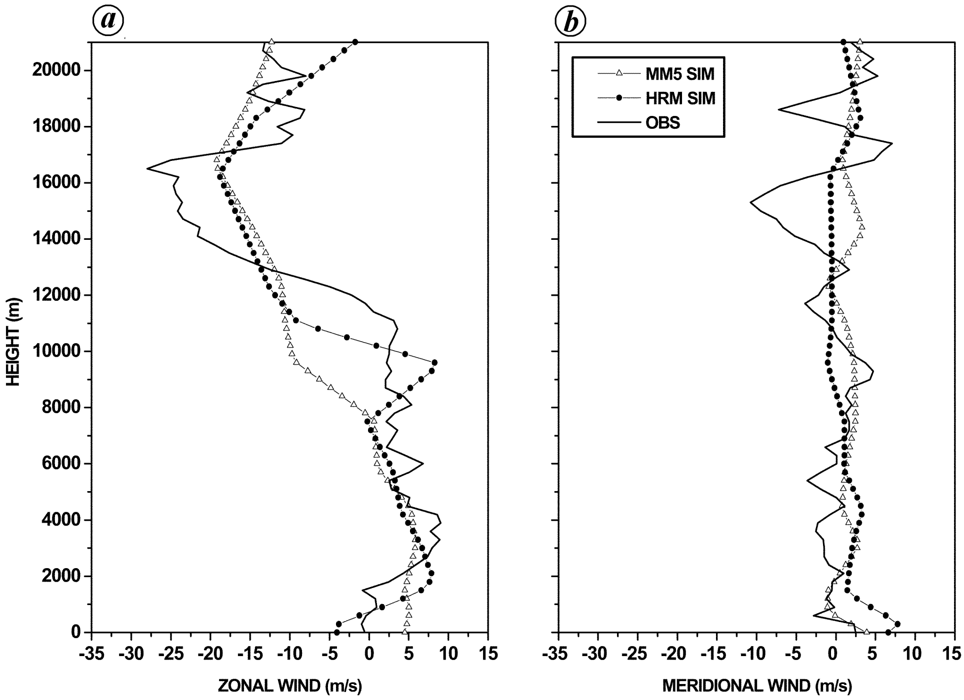

Figure 4. Same as Figure 2, but valid at 12 UTC 20 September 2004.

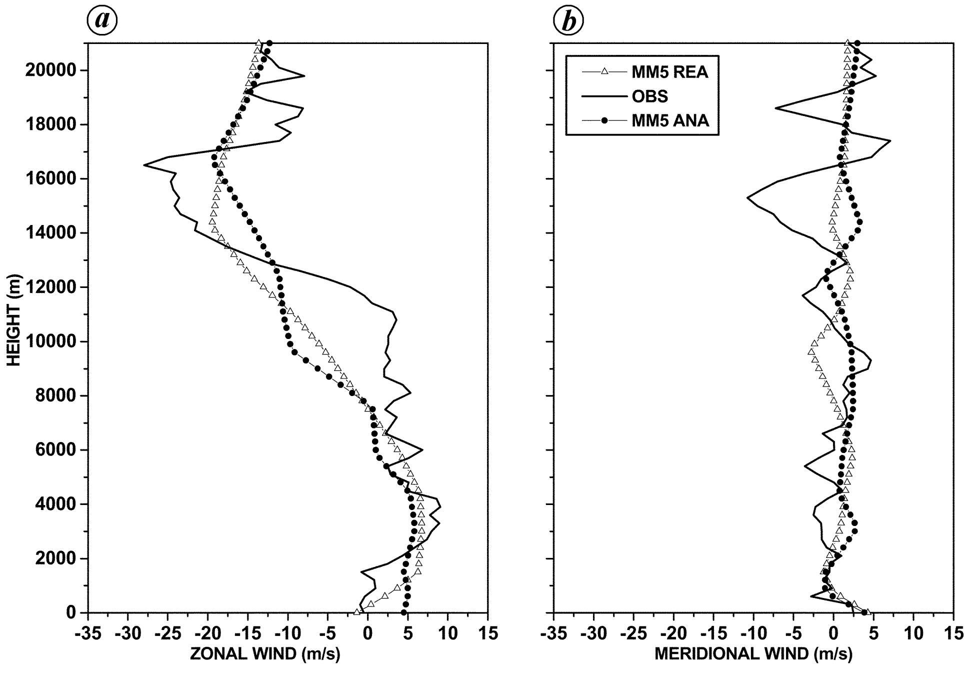

Figure 5. Observed and predicted (***a***) Zonal (m/s) and (***b***) Meridional (m/s) wind at SHAR using MM5 model valid at 12 UTC 20 September 2004.

level wind is well predicted by the MM5 model with RMS error 2.5 m/s and correlation co-efficient 0.84 (Table 5) and better than that predicted by HRM. But at the high wind regime, the performance of HRM model is slightly better than MM5 at this time. The meridional wind component is once again better predicted by the MM5 model compared to HRM and is reasonably close to the observed wind. This is well reflected in the statistical parameters provided in Table 5 where HRM prediction has negative correlation with observation.

Figure 4 represents the vertical profile of the wind components as obtained from observations and model predictions valid at 12 UTC 20 September 2004. At this time (36 h forecast), the zonal wind at low level is slightly better predicted by HRM compared to MM5, though both the models show low forecast skill. The forecast skill is

Table 7. Statistical parameters for zonal and meridional wind component at Chennai with reanalysis valid at 00 UTC 19 September 2004

		Mean wind			RMS error			Correlation coefficient		
Wind component	Level	OBS	ANA	REA	ANA	REA	% IMPR	ANA	REA	% IMPR
Zonal wind	Low level wind (0–10000 m)	1.9	1.0	1.5	1.67	0.5	70	0.59	0.96	62
	High level wind (10300–21000 m)	–12.1	–12.6	–13.0	1.75	1.96	–10	0.93	0.91	–2
Meridional wind	Low level wind (0–10000 m)	–0.39	–0.1	–0.21	1.1	0.4	63	0.87	0.99	13
	High level wind (10300–21000 m)	–3.13	–4.6	–3.75	3.9	3.0	23	0.54	0.74	37

Table 8. Statistical parameters for zonal and meridional wind component at SHAR with reanalysis valid at 12 UTC 20 September 2004

		Mean wind			RMS error		Correlation coefficient	
Wind component	Level	OBS	MM5	MM5-ASSIM	MM5	MM5-ASSIM	MM5	MM5-ASSIM
Zonal wind	Low level wind (0–10000 m)	3.78	1.6	2.3	5.5	4.1	0.25	0.5
	High level wind (10300–21000 m)	–12.4	–14.1	–15.4	7.0	6.7	0.75	0.92
Meridional wind	Low level wind (0–10000 m)	0.2	1.4	0.3	2.22	3.0	0.43	–0.1
	High level wind (10300–21000 m)	–1.08	3.14	1.0	5.34	4.5	–0.11	0.5

slightly better in upper level. Both the models show low skill in prediction of meridional wind with the maximum correlation of model predicted value where observation is 0.43 only (in MM5). It is well reflected in Table 6.

In order to enhance the model performance an experiment is conducted with improved initial condition in MM5 model which is found to perform slightly better than HRM. In the reanalysis, surface and upper air data of Chennai, Karaikal and Machlipatnam have been included and the high-resolution reanalysis is prepared by using Cressman successive correction technique. As SHAR observational data is not available at the model initial time, the improvement in the initial condition is tested at Chennai, a station nearest to SHAR. In the initial condition for zonal wind component, in low-level wind an improvement of 70% in RMSE and 62% in correlation coefficient is observed and for high-level wind it is deteriorated by 10% in RMSE and 2% in correlation co-efficient. For meridional wind component in low-level wind, an improvement of 63% in RMSE and 13% in correlation coefficient is obtained and for high-level wind an improvement of 23% in RMSE and 37% in correlation co-efficient is observed. This is shown in Table 7. Figure 5 shows the vertical profile of observed and model predicted zonal and meridional wind components valid at 12 UTC 20 September 2004. Here, two predictions from MM5 are obtained using model initial condition from AVN analysis and the high-resolution reanalysis is prepared. The result shows that there is slight improvement in the model performance with improved initial condition. In both the zonal and meridional component of the wind, the root mean square error is comparatively less and correlation coefficient relatively higher with the use of improved model initial condition (Table 8).

Wind at 850 hPa

Figure 6*a* represents the wind at 850 hPa as obtained from AVN analysis interpolated to model grids and Figure 6*e* is the corresponding prepared high resolution analysis valid at 00 UTC 19 September 2004. Both analyses show strong wind over SHAR but no visible change between the two is observed as limited number of observations over the domain is used in the process of preparation of the high-resolution analysis. Figure 6*b* and *f* provide the verification analysis and 12 h forecast respectively valid at 12 UTC 19 September 2004. As the AVN analysis is of coarse resolution, the overall flow pattern is quite smooth. Model simulation shows relatively stronger wind over SHAR and adjoining areas and also some mesoscale features, which are not present in the large-scale analysis. Thunderstorm activity was reported in the NW and SW of SHAR in the evening. Probably, the high wind that is simulated at this time is a signature of such activity. Figure 6 *c* and *g* represent the verification analysis and 24 h forecast respectively valid at 00 UTC 20 September 2004. The model predicted wind is stronger than that in the analysis and the direction is similar to that in the analysis. Figure 6 *d* and *h* show verification analysis and 36 h forecast respectively valid at 12 UTC 20 September 2004. Though slightly stronger, the model predicted flow pattern is the same as that in the verification analysis. The mesoscale features shown in the model prediction could not be validated due to lack of meso network of observations in the region of study.

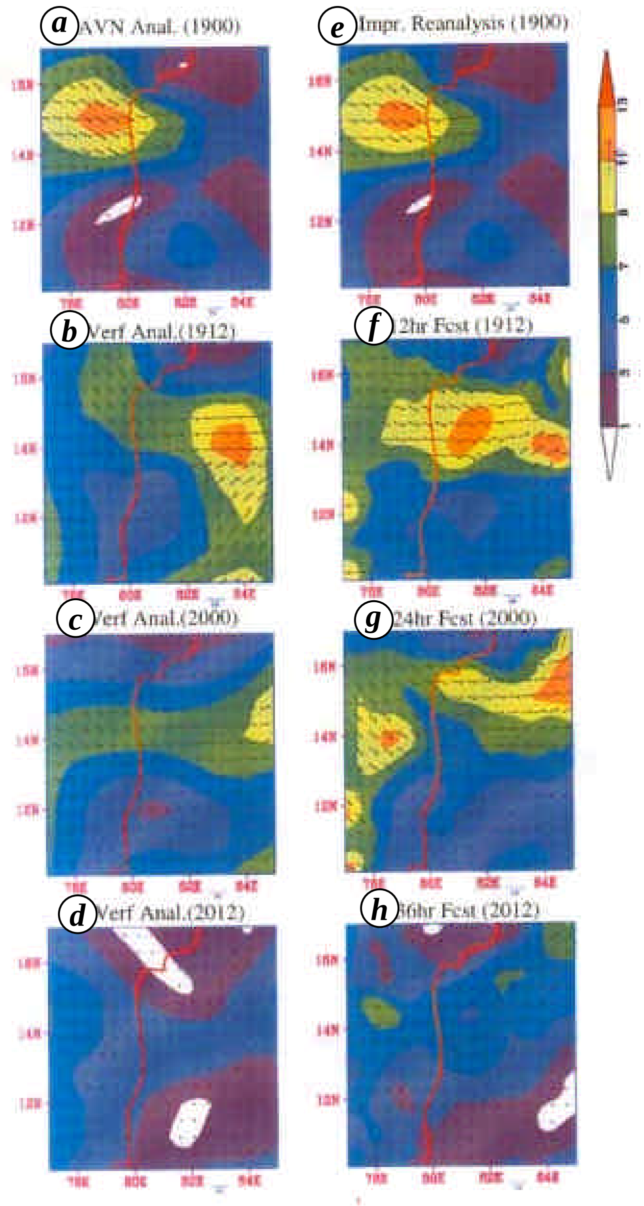

Figure 6. Wind at 850 hPa (***a***) verification analysis (***e***) high resolution reanalysis valid at 00 UTC 19 September 2004 (***b***) verification analysis valid at 12 UTC 19 September 2004. (***f***) 12 h forecast valid at 12 UTC 19 September 2004 (***c***) Same as (***b***) valid at 00 UTC 20 September 2004, (***g***) 24 h forecast valid at 00 UTC 20 September 2004 and (***d***) same as (***b***) valid at 12 UTC 20 September 2004, (***h***) 36 h forecast valid at 12 UTC 20 September 2004.

Wind at 200 hPa

Figure 7 *a* represents the wind at 200 hPa as obtained from AVN analysis interpolated to model grids and Figure 7 *e* shows the corresponding prepared high resolution analysis valid at 00 UTC 19 September 2004. The high-resolution analysis shows stronger wind than in the large-scale AVN analysis and is due to the inclusion of nearby station data sets in the high-resolution analysis. Figure 7 *b* and *f* show verification analysis and 12 h forecast respectively, valid at 12 UTC 19 September 2004. The intensity of the fore-

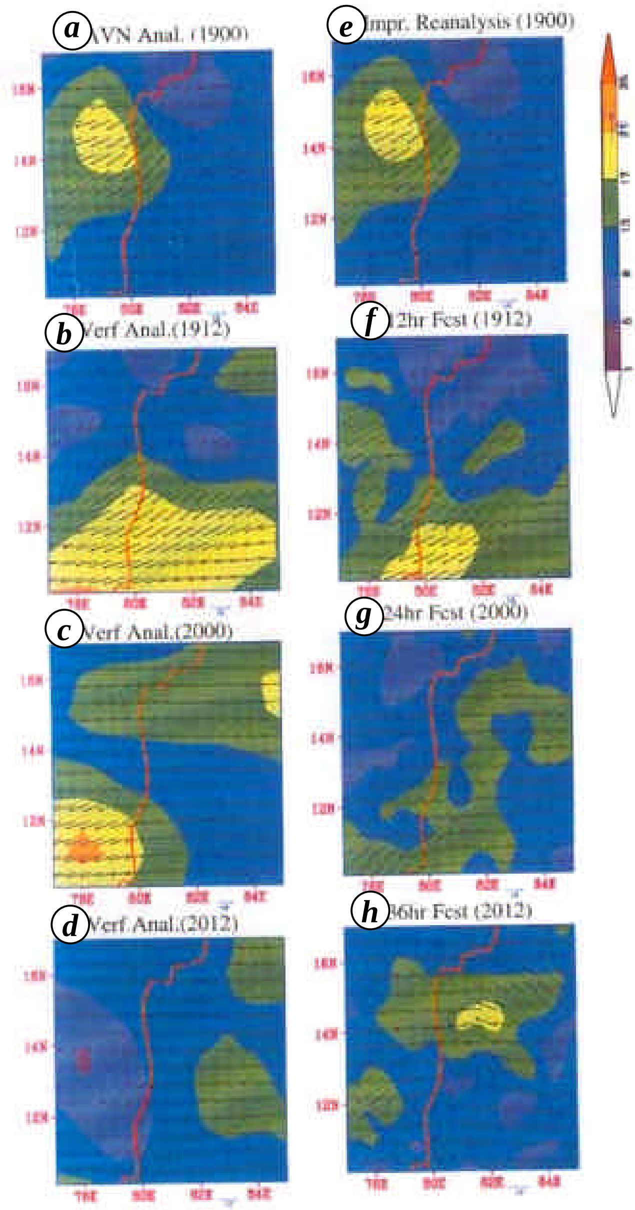

Figure 7. Same as Figure 6, but valid for wind at 200 hPa.

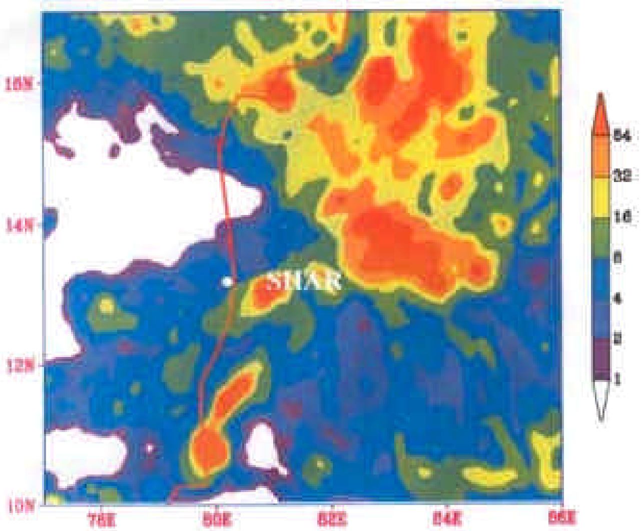

Figure 8. MM5 predicted 24 h accumulated rainfall valid at 03 UTC 20 September 2004.

casted wind is slightly higher than that in the analysis near SHAR and the mesoscale structures are also better resolved. Similar results are obtained in 24 and 36 h predictions as well valid at 00 UTC and 12 UTC 20 September 2004 respectively.

The overall flow pattern is well simulated by the model, especially the upper level easterly which is found to be stronger in the prepared high-resolution reanalysis. The strength of the wind, particularly in the upper level is found to vary notably from that of the verification analysis. This is attributed to mesoscale features captured effectively by the very high-resolution model.

Precipitation

Severe lighting with thunderstorm was reported on the morning hours of 20 September 2004 and 30 mm rainfall was recorded over SHAR. Figure 8 shows the model predicted 24 h accumulated precipitation valid at 03 UTC 20 September 2004. This shows 4 mm precipitation over SHAR and adjoining areas. The model prediction shows maximum precipitation in the east and northeast of SHAR. Though the precipitation over SHAR is under-estimated, it is to be noted that the model could capture the thunderstorm event over SHAR and adjoining area.

Summary and conclusion

Performance of two high resolution regional/mesoscale models in providing real time forecast at the launch site of the satellite launch vehicle GSLV-F01 is presented and discussed. The discussion can be summarized as follows:

Both the models MM5 and HRM show better forecast skill in predicting zonal component of wind than the meridional component. Also the performance of MM5 model is marginally better than HRM. The upper level easterly jet is not well captured by both the models. The large-scale flow pattern predicted by MM5 in general agrees with the analysis, though the mesoscale structure shown in model prediction could not be validated due of lack of sufficient observations.

The performance of the model MM5 is found to slightly improve by improving the model initial condition through preparation of high-resolution reanalysis with insertion of additional observations. The strength of tropical jet stream is better captured after using reanalysis data.

Though the amount of precipitation is under-predicted, the model could capture the precipitation pattern associated with the thunderstorm event over SHAR and adjoining area.

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