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Numerical Study of Diurnal Circulations of Tropical Coastal Site Visakhapatnam Using the ARW MesoScale Model

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Abstract: Land and Sea breezes are the most commonly observed meso scale local systems on coastal zones. They have been significant role on transport and diffusion of air pollutants in coastal areas. In the present study we have simulated the sea breeze circulation for the coastal city of Visakhapatnam (17.42'N,83.15').The mesoscale model WRF ARW is used for this study. Modeling period is selected for typical summer (18 may 2011). The WRF model used with 2 nested domains with 9km and 3 km horizontal resolution. The initial and boundary conditions were taken from NOAA NOMADS GFS data with horizontal resolution of 1 degree by 1 degree. The model could predict the essential features like onset, strength and decay of sea breeze. The model outputs of temperature, potential temperature, Relative humidity, Wind speed are compared with the radiosonde observations of the Viskhapatnam.The horizontal and vertical extent of Sea / Land Breezes also simulated well.

Keywords: Mesoscale model, Land and sea breeze, diurnal variations

I.INTRODUCTION

A study of coastal meteorology is important as several atmospheric phenomena in coastal regions influence turbulent diffusion, convective thunderstorms and local weather. The coastal weather systems are influenced by the coastal mesoscale processes that develop due to the land-ocean thermal contrast and topography variation (SSVS Ramakrishna et al.2013).One of the dominant features of the local circulation of coastal stations is persistence of Sea breeze during day time and Land breeze during night time. Sea breeze is associated with changes in temperature, rainfall; wind vector and water vapor pressure (humidity).There will be a sudden wind direction change, drop in temperature and increase in humidity with the onset of Sea breeze. Very often changes are seen in temperature, wind vector and water vapor pressure (humidity) associated with these circulations. These features mark the onset of Sea breeze. Of all the other meso scale phenomena, Sea and Land breezes over flat terrain appear to have been the most studies, both observationally and theoretically(Bechtold P et al 1991) This is undoubtedly a result of the geographical fixed nature of the phenomena (the location of land-water boundaries), as well as the repetitive nature of the event. The Sea breeze is defined to occur when the wind is onshore, where as the Land breeze occurs when the opposite flow exists. Pollutant plumes in the coastal zones are influenced by development of mesoscale sea breeze circulations that develop due to differential heating of the land and water surfaces (Pielke et a ., 1991; Lu et al., 1995). Differential land-sea temperatures and the incidence of local circulations initiate development of internal boundary layer (IBL), which has a critical effect on dispersion (Luhar et al., 1998; Lu et al., 2001). These local effects need to be accounted in the coastal dispersion simulation for realistic estimations of pollutant concentrations. Accurate meteorological inputs are required to obtain realistic estimation of concentrations. The studies of transport and diffusion over land are generally invalid when applied to the coastal environments. In this context, the present work is carried out to examine the suitability of a high-resolution meso-scale atmospheric model for the simulation of land–sea breeze circulation on the East coast for operational meso-scale atmospheric dispersion prediction(C V Srinivas et al. 2006). In this study we have studied the Sea breeze circulation for peak summer case studied with two domains of the Visakhapatnam coast which is highly complex terrain city. When the synoptic flow is westerly and the simulations are compared with observations. The characteristics of simulated Sea breeze circulations such as onset, strength, intensity, duration, horizontal and vertical extents, of Visakhapatnam coast are analyzed. The mesoscale model WRF ARW is used for the simulations with

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incorporation of nested domains and necessary physics. The objective of our work is to examine the fidelity of Advanced Research Weather Research and Forecasting (ARW) mesoscale model for the application of wind field prediction over this coastal region. Mesoscale models include complete physics for convection, radiation, boundary layer turbulence and land surface processes which play an important role in simulations of the atmosphere and short-range weather predictions.

II.DATA AND METHODOLOGY

In the present study, we have used the Weather Research and Forecasting (WRF) 2 (Skamarock, 2008) (model version 3.2 for the simulations of the Sea breeze Circulation. We have simulated the Sea breeze for Visakhapatnam for a peak summer day. For this study we have used WRF ARW model with physics options like WSM6 (WRF Single Model) for microphysics, KF2 (Kain-Fritsch) for cumulus convection, MYJ (Mellor-Yamada Janjic) for planetary boundary layer physics and TDS (Thermal Diffusion Scheme) for Land surface physics. The simulation is conducted for 18 May 2011, which is considered to be representative of summer, while analyzing nested model simulation, the focus is mainly on the results of the innermost nest. However, as the simulation in the outer domain would influence results in the inner domains, and since the outer domain covers a wider perspective of the thermally induced coastal circulations, the results from outermost nest are also discussed briefly.

Table 1. Details of the grids and the physics options used in the WRF ARW model.

Dynamics	**Primitive equation, non-hydrostatic**	
Vertical resolution	**26 sigma levels**	
Horizontal resolution	**9km**	**3km**
Domains of integration	**74E-92E**	**82E-88E**
	8N-26N	**6N-25N**
Radiation	**Dudhia scheme for short wave radiation**	
	Rapid Radiation Transfer Model (RRTM) for long wave radiation	
Surface processes	**TDS land surface model**	
Planetary boundary layer	**Mellor-Yamada (MY) level 2 turbulence closure scheme**	
Sea surface temperature	**Real Sea Surface temperatures**	
Convection	**KF2**	
Explicit moisture	**WSM6**	

Table 1. Represents the model Components of WRF ARW

III RESULTS AND DISCUSSIONS

Figure 1 is represents the outer and innermost domain, the inner most domain is covering the Visakhapatnam coastal Region i.e studying area.Figures 2(a),(b),(c) & (d) are Simulated wind field on 18 May in the larger region, i.e., domain 1 indicates the presence of westerly to northwesterly winds along the west coast, westerly winds over central parts and southerly/southwesterly winds over Bay of Bengal at 0600 IST.The Simulated surface wind in the afternoon at 1400 IST indicates a change in the circulation pattern in oceanic region adjacent to the east coast and development of Sea breeze circulation along the east coast in figure 2(b). The influence of sea breeze is seen on the flow pattern several hundred kilometers adjacent to the coast. It is seen to spread inland 60 to 150 km along the east coast at. The direction of Sea breeze incidence is seen to vary along the coast according to the variation in the coastline curvature and latitude. At 2000IST the direction of the synoptic flow is more towards the coast of Visakhapatnam in fig. 2(c) it indicates the onshore progress of the sea breeze circulation, on morning of the 18th may i.e., 0500IST.The direction of synoptic flow will be changed, the flow from land sea i.e, showing the land breeze circulation. The winds are off shore along the coast indicating development of land-breeze circulation. The surface wind during noon is seen to turn southeasterly and enter land at 1400 IST indicating the onset of sea breeze .This transition in the surface wind field during sea breeze onset time is not clearly seen in the results of the outer domain. Figures 3(a),(b),(c) & (d) are Simulated wind field on 18

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May in the concentrated region i.e., domain II It is seen that the model could bring out the contrast between night time and day time surface winds in the simulation from the innermost nest covering the Visakhapatnam region. Figures 4(a),(b),(c),(d),(e),(f),(g),&(h) are a comparison of observed and model estimated values of potential temperature observed at 000 UTC there is a good agreement between model and observed values. The model values are in under estimate up to 1000m later with height the deviation is slightly more and the observation values are an over estimate by 1^0 or 2^0 both considered at 5000m after 3 hours .The model values continues to be under estimate up to 1000m and from 1000m to 6000m there are less than observed values and the values considered at the 6000m. However at 006UTC up to 1000m there is a vast variation between model and observations. The observation values are low drastic degrees there are unstable where as the model values shows stability rather inversion at lower levels and the model values and the overestimation up to 1000m under estimate up to 5000m 009UTC the trend continuous except the model values become over estimate at 5000m to 6000m at 1200UTC the same trend continuous however the model values under estimate between 1000m to 4000m and over estimate at lower and higher levels .The same trend continued at 1500UTC however 1800UTC at lower levels the model values are less but at 1000m the model values are more however, from 1500m to 4500m the model values for under estimate and they are over estimate at higher heights. same trend continuous however the deviation are less which means model prediction are better at 000UTC 19-05-2011 both the trend and prediction as coinciding well with observed values. Figures 5(a),(b),(c),(d),(e),(f),(g)&(h) are the simulated wind speed prediction is good with observed values. The wind speed is maximum at 1000m is 10m/s and reduces to a minimum values at 2000m again increasing and getting a maximum between 4000m to 5000m.The trend is captured well is model values the maximum at 1000m can be attributed to the sea breeze (meso circulation) which clearly indicate the sea breeze can transport the air pollutant with greater velocity 10m/s which tantamount to dilution and horizontal transport of air pollution. The wind trend 003UTC is exactly same at the peak values at 1000m is more than 10m/s (slight increase)the 006 UTC indicates the sea breeze front is well developed even in lower heights so the maximum wind speed nearly 10m/s is achieved at very much lower levels .At 009UTC there is decreasing a sea breeze front the same trend continuous however at higher levels the model values are very much under estimate compare to observed values at 0012UTC the same trend continuous at 1200UTC but the observed values are less at lower levels but are over estimate at higher levels. at 1500UTC the consistency of under estimate of model values at higher levels continuous at 1800UTC the deviation is much more between model and observed values at higher levels .the 2100UTC is having same trend but the deviation between observed and model values are less compared to previous 1800UTC.the same trend continuous.Figures 6(a),(b),(c),(d),(e),(f),(g)&(h) are the observation of actual temperature variation with height shows a better trend that is the decrease with height and the deviation are not much as potential temperature.Figures 7(a),(b),(c),(d),(e),(f),(g),&(h) are the observation of relative humidity also shows a maximum at 500m showing a decrease up to 2000m to 2500m and then there is increase however the striking point the relative humidity is 80 to 100 at lower maxima but the higher maxima is less than the lower maxima where as the maximum wind speed area at higher levels this is natural as the lower sea breeze front advection is comes more moisture in land from sea.

IV SUMMARY AND CONCLUSIONS

In the present study, we have simulated the sea breeze for Visakhapatnam from a peak summer day. For this study we have used WRF ARW model with physics options like WSM6 (WRF Single Model) for microphysics, KF2 (Kain-Fritsch) for cumulus convection, MYJ (Mellor-Yamada Janjic) for planetary boundary layer physics and TDS (Thermal Diffusion Scheme) for Land surface physics. Thus the simulations of atmospheric flow field characteristics at the tropical coastal city Visakhapatnam. The intensity, strength and inland penetration of sea breeze are found to be higher in the summer. It is clearly seen that in the cases study, the sea breeze is found to set late in the model as compared to the observations. We also compared this model output with radiosonde observations over Visakhapatnam for the parameters temperature, wind speed, relative humidity and potential temperature. These parameters are well coincided with model output. The overall observation about wind show that the model structures how the meso scale, model very well however the model continuous over estimated compared to observed values at higher levels. The sea breeze circulation is primarily forced by the land-sea temperature contrast. So, the model could able to simulate local coastal circulations like land and sea breeze.

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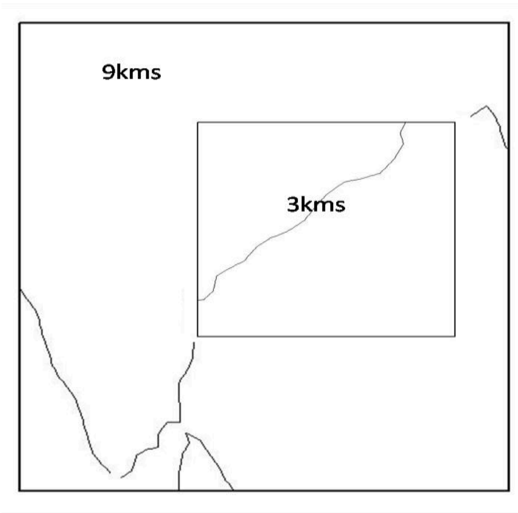
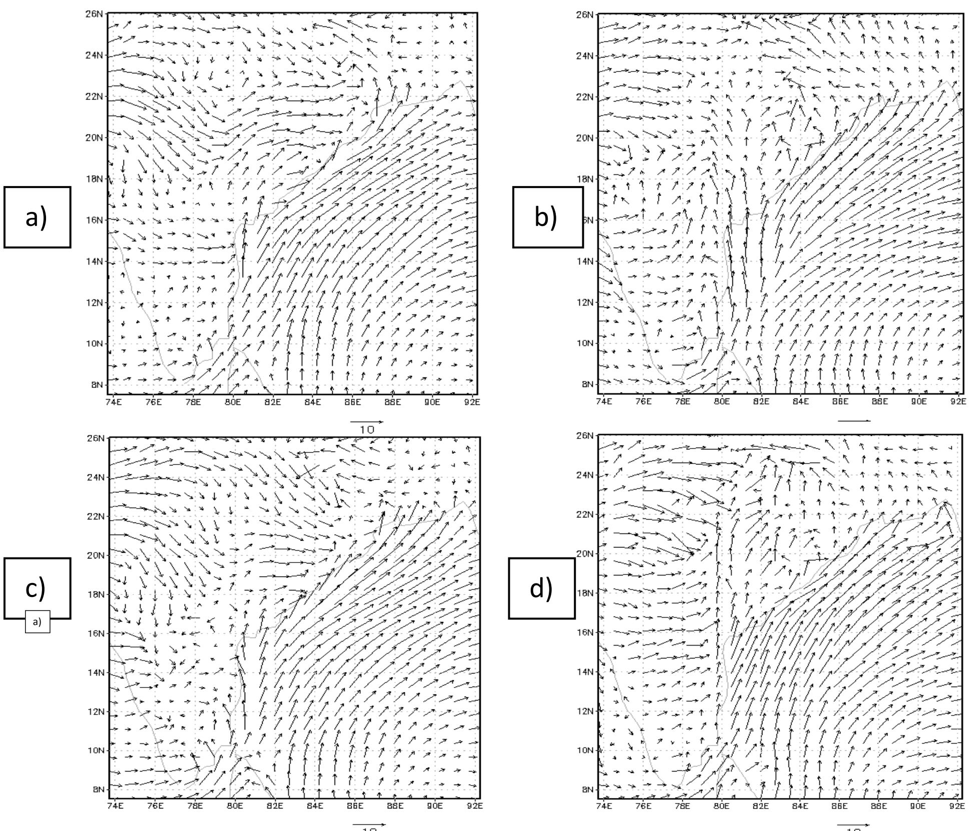


Fig 1: shows domain I (9 km) resolution and domain II (3 km) resolution.



Figures 2(a),(b),(c) & (d) are Simulated wind field on 18 May in the larger region, i.e., domain II.

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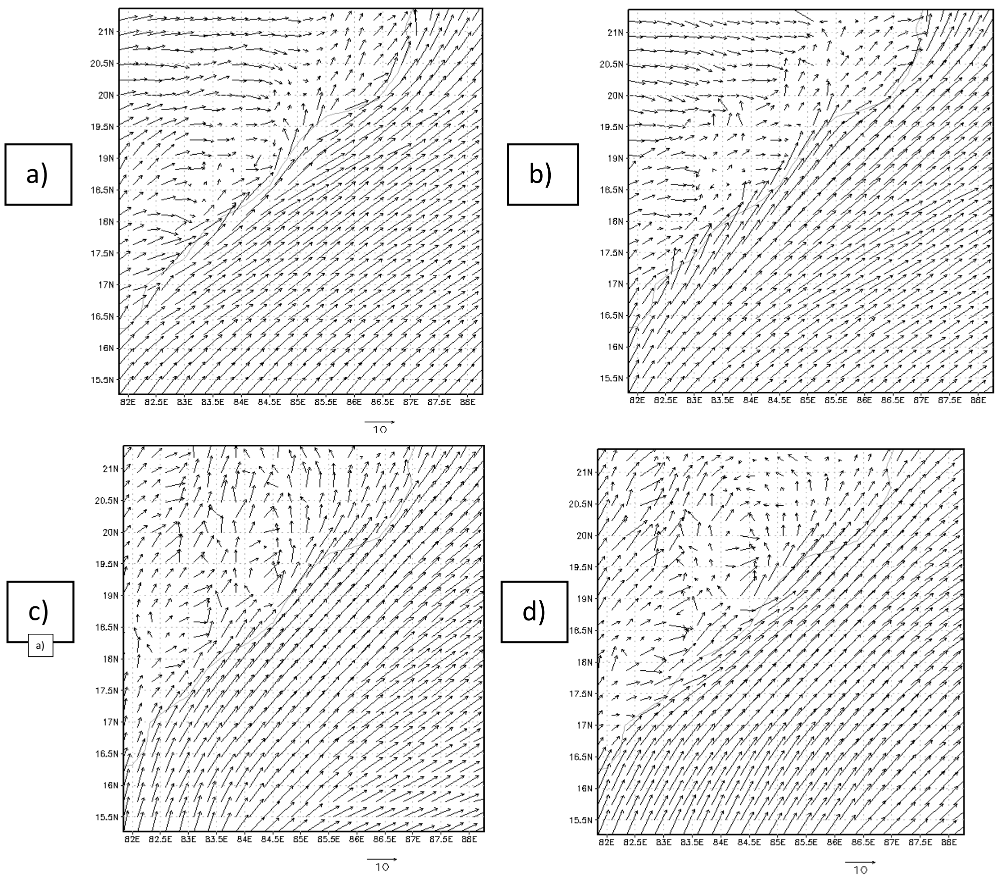

Figures 3(a),(b),(c) & (d) are Simulated wind field on 18 May in the Inner region, i.e., domain II

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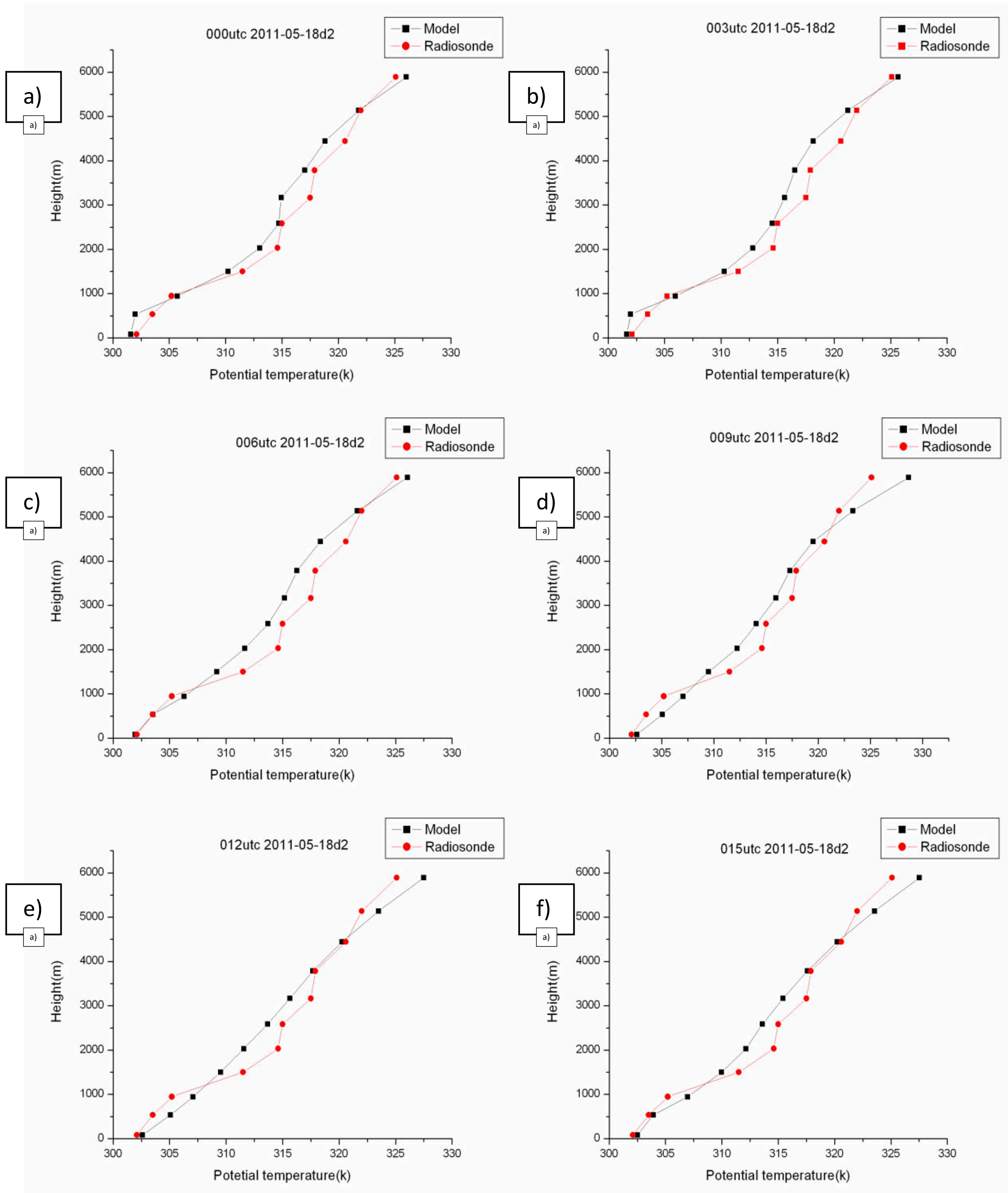

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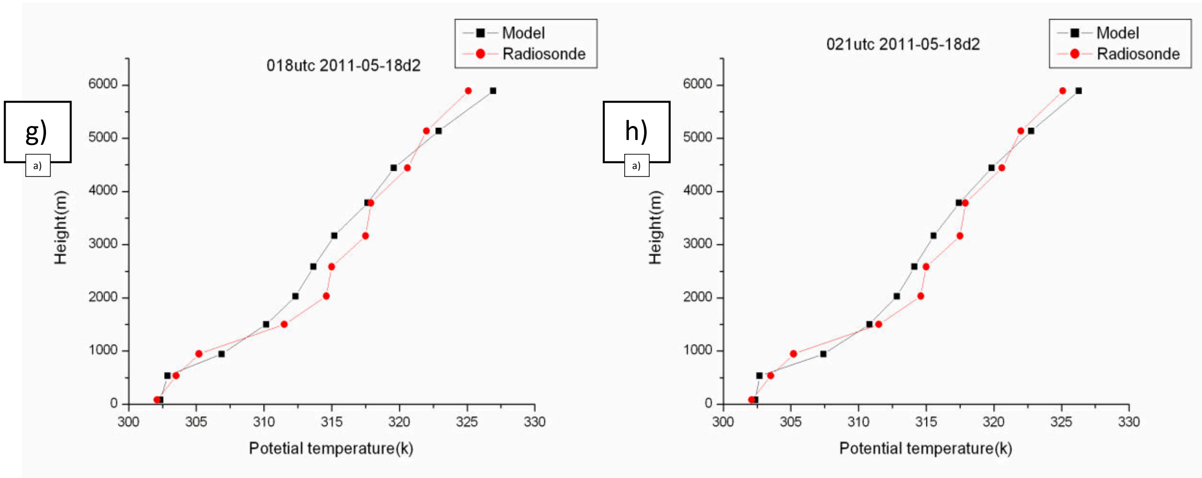
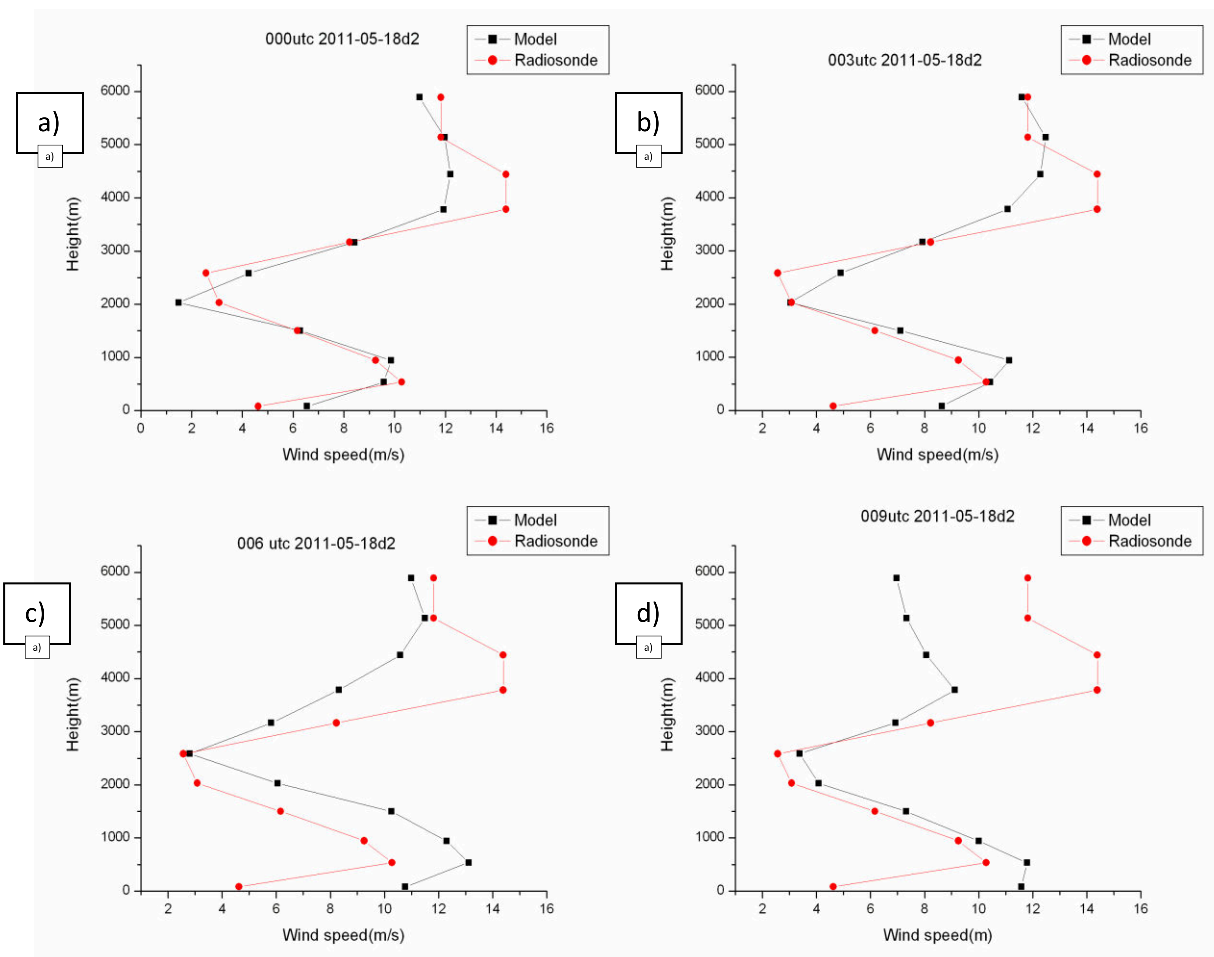


Figures 4(a),(b),(c),(d),(e),(f),(g),&(h) Comparison of Model & Observed Potential temperature with Height of Domain II.



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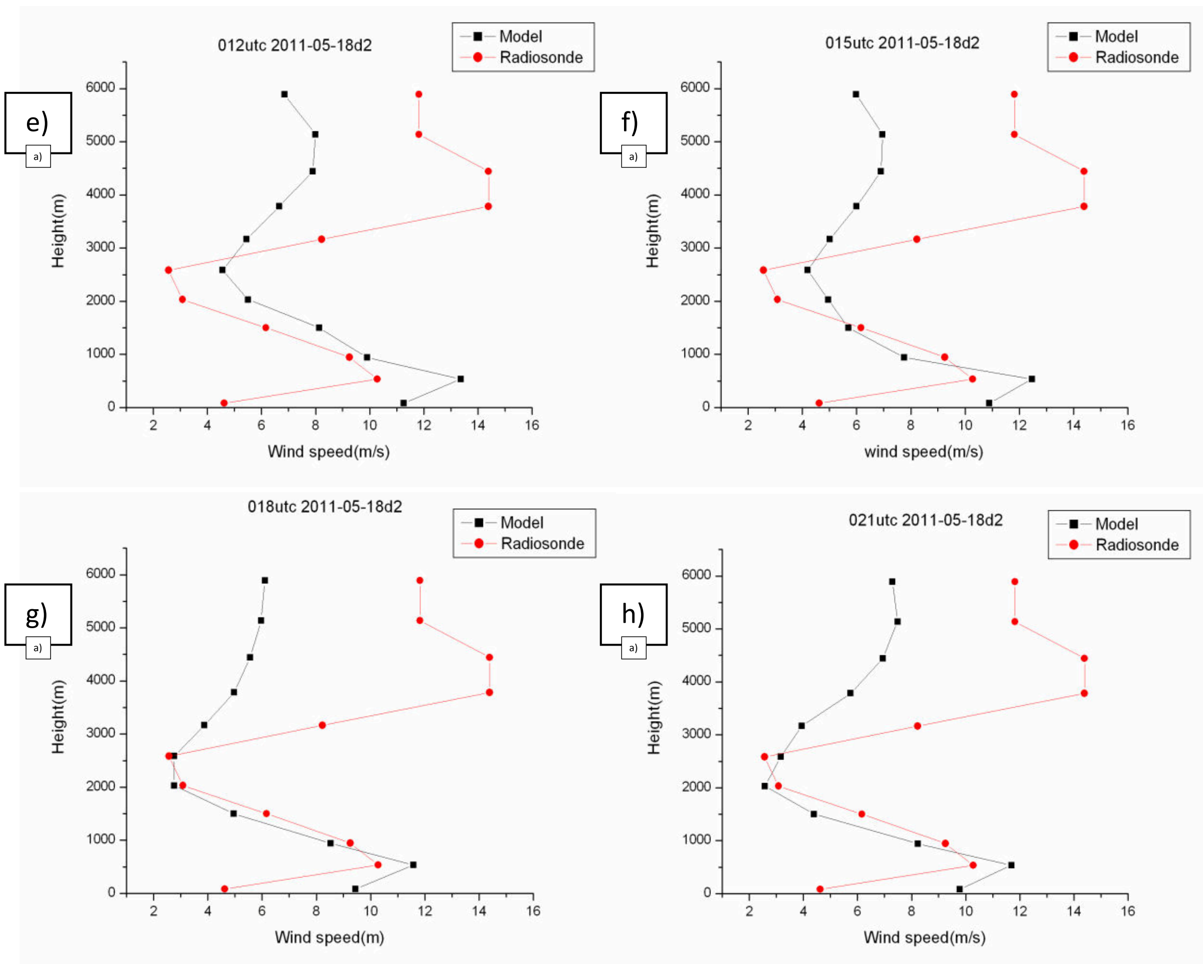

Figure 5(a),(b),(c),(d),(e),(f),(g),&(h) Comparison of Model and Observed Wind speed (m/s) with Height of Domain II.

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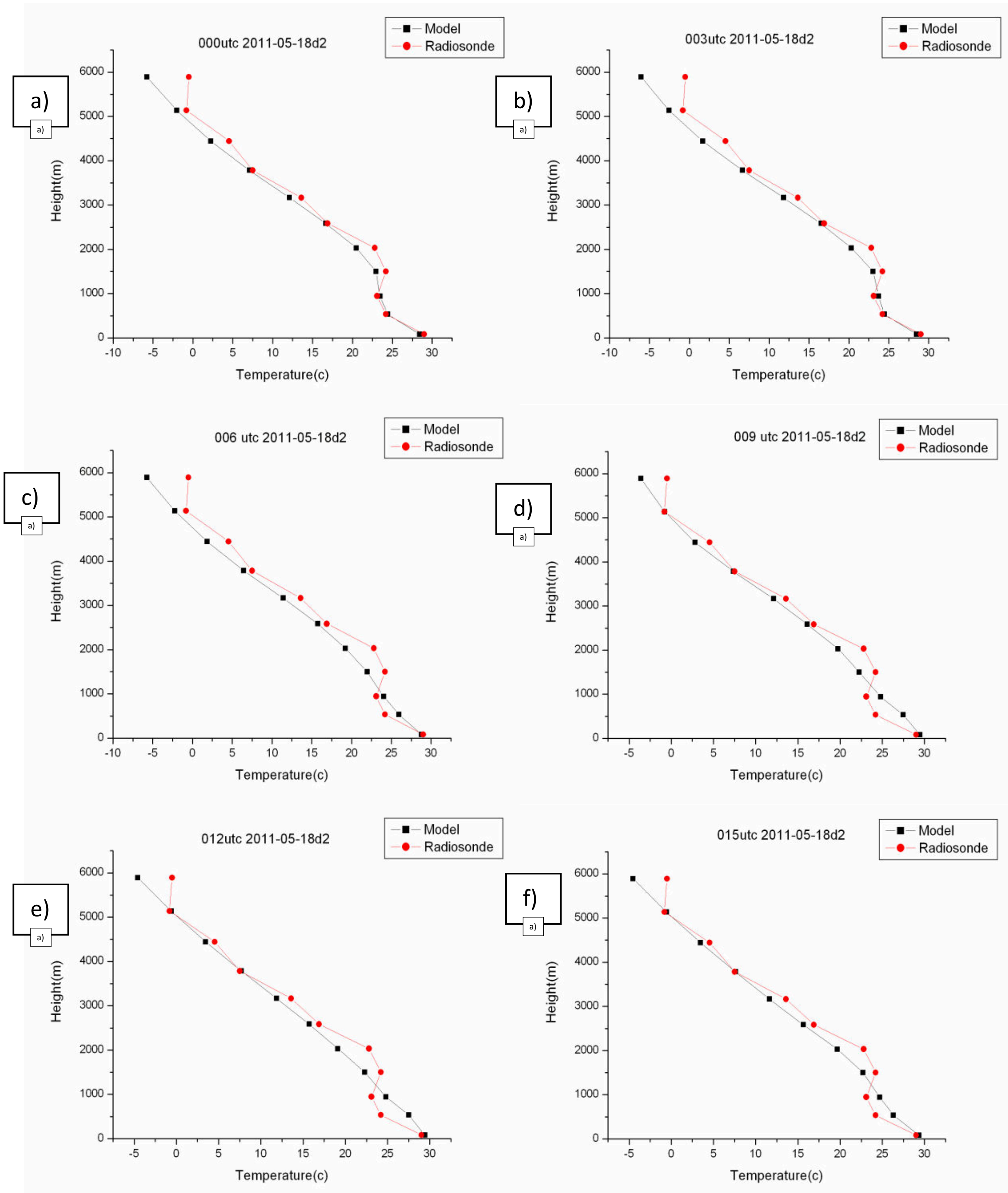

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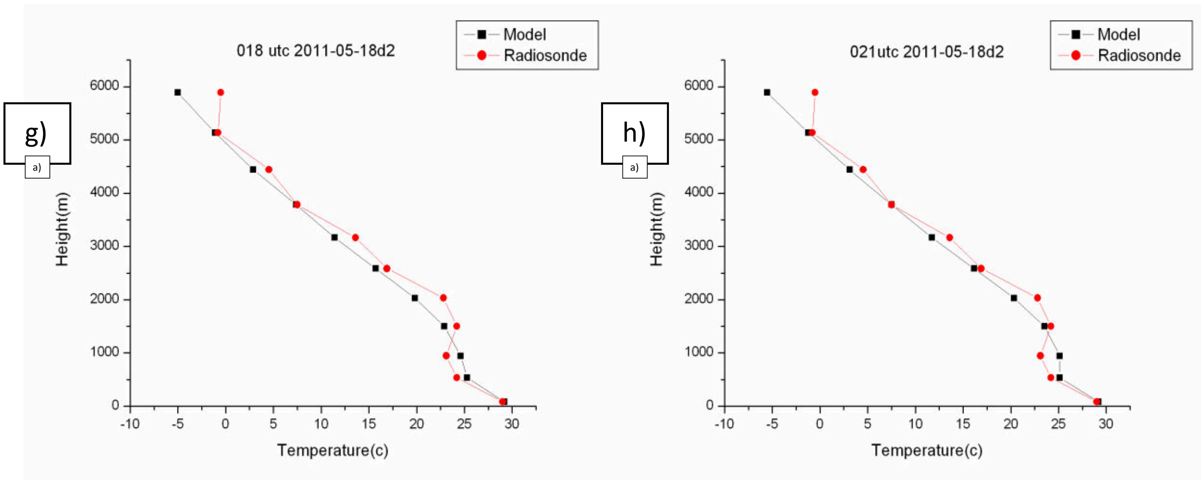
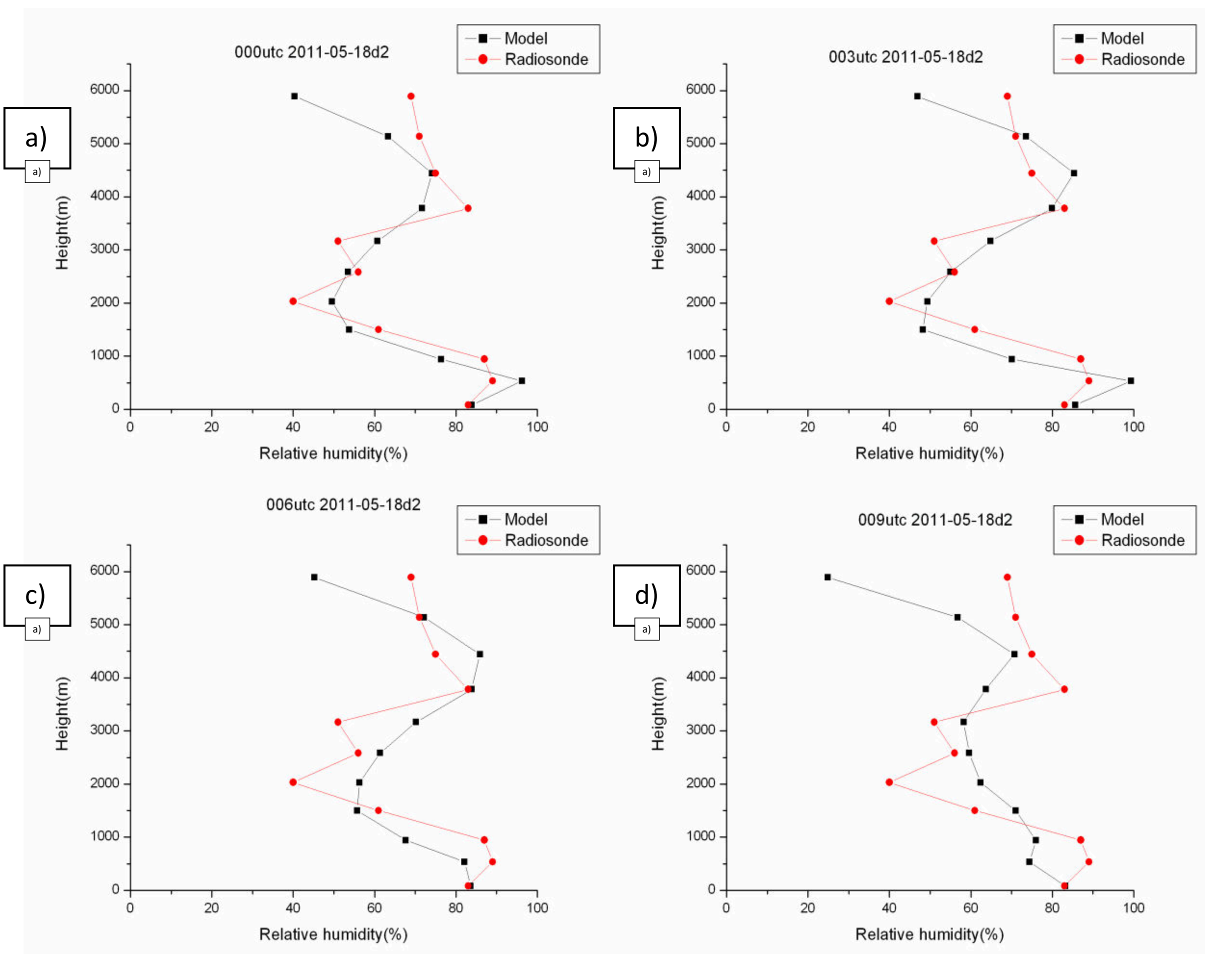


Figure 6(a),(b),(c),(d),(e),(f),(g),&(h) Comparison of Model and Observed temperature with Height of Domain II.



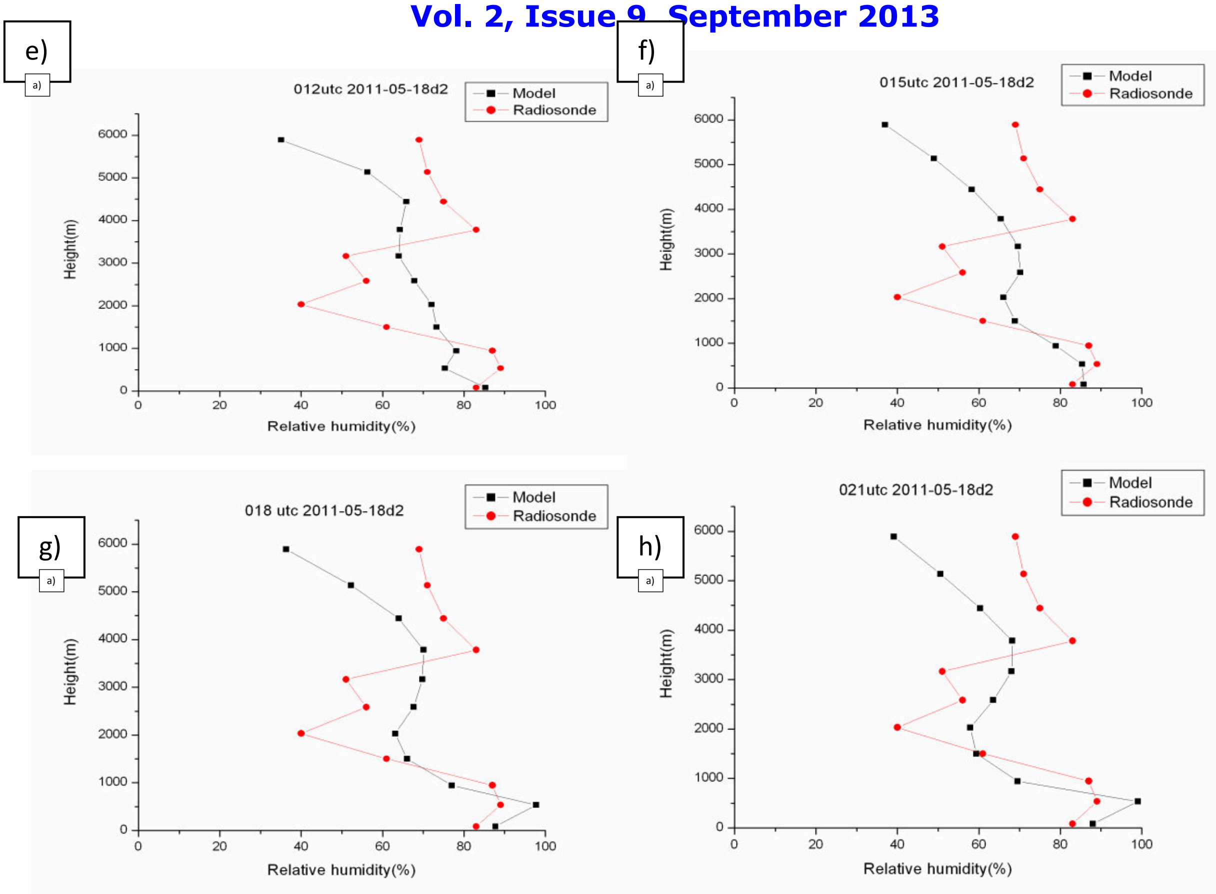


Figure 7(a),(b),(c),(d),(e),(f),(g),&(h) Comparison of Model and Observed Relative humidity with Height of Domain II.

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