Chapter 7

Simulation of the effect of Mascarene high on the strength of Somali Jet

7.1 Introduction

Indian monsoon is one of the most dramatic monsoon systems in the northern hemisphere. Various elements constitute the monsoon system which include pressure of the monsoon trough, pressure of the Mascarene high, Somali Jet (cross-equatorial low level jet), Tibetan high, tropical easterly jet, monsoon cloud cover, monsoon rainfall, dry and moist static stability of the lower troposphere. Somali jet is an essential part of the Indian summer monsoon. This jet constitutes the strongest cross-equatorial flow in the lower troposphere at any level and forms part of a major low-level air current in the monsoon system.

The Mascarene high is a high pressure area south of the equator. The name Mascarene high came from the Mascarene Islands east of Madagascar. The center of this anticyclone is located near 30°S and 50°E. Synoptic meteorologists and operational weather forecasters in these regions have long recognized that this high pressure area has some importance during the monsoon months, although no definitive analysis of its importance has been demonstrated (Krishnamurti and Bhalme, 1976). From observations Huang and Tang (1987) and Xue et al. (2003) also pointed out that the Mascarene high plays a crucial role in the interaction between the southern winter circulation and the summer monsoon circulation in the Northern hemisphere.

The simple and handy way to understand the different aspects of India monsoon is the use of the climate models. Numerical simulation of the Indian monsoon has advantages over conventional analysis of data (Das, 1980). The climate models allow us to perform experiments
and as a result one could learn/understand the processes involved in the monsoon. However there are uncertainties in the regional climate projections due to the inaccuracies of the global climate models (Bhate et al., 2012).

The numerical models have been used extensively to study Low Level Jet (LLJ) development and evolution and have reproduced the basic features of many observed LLJs (Stensrud, 1996). Typically these studies have been conducted using either a case study approach (Brill et al., 1985; Doyle and Warner, 1993; Lapenta and Seaman, 1990) or simplified analytic initial conditions to examine LLJ sensitivities to various model parameters (Fast and McCorcle, 1990; Krishnamurti et al., 1976; McNider and Pielke, 1981; Paegle and Rasch, 1973; Savijarvi, 1991). The advantage of using numerical models is the ability to separate the effects of various physical processes on the jet evolution (Stensrud, 1996).

Washington and Daggupaty (1975) simulated some of the features of LLJ. Simulation of Somali jet from a state of rest was presented by Krishnamurti et al. (1976). They showed by offering a lateral forcing near 75°E, the flows over the domain 30°S-30°N and 30°E-85°E can be somewhat realistically simulated if the beta effect and the bottom topography are included in a simple adiabatic primitive equation model. Further the baroclinicity and its effect on the LLJ was studied by Krishnamurti and Wong (1979a) and Krishnamurti et al. (1983).

In another study Anderson (1976) considered the LLJ essentially as a boundary current bounded on the west by the East African mountain chain. Hart (1977) felt that vertical diffusion was more important than Anderson (1976) horizontal diffusion. Thereafter a series of experiments were performed with a simple barotropic primitive
equation (P.E.) model by Bannon (1979a, 1979b) and able to simulate features of Somali jet which resemble the real jet.

Sashegyi and Geisler (1987) studied the effect of diabatic heating on the strength of jet in a linear model and concluded that the strong meridional jet near the African coast is a western boundary current. Later similar attempt was made by Mawson and Cullen (1992), they studied the impact of diabatic heating on the Somali Jet with linear primitive equation model.

Later with the help of a primitive equation model with specified zonal flow study of LLJ was carried out by Hoskins and Rodwell (1995) and Rodwell and Hoskins (1995). They showed that presence of land-sea contrast and East African orography plays an important role in intensification of cross equatorial flow.

Some research has also been conducted to study the interaction of Somali Jet with the west coast of India (Grossman and Durran, 1984; Ogura and Yoshizaki, 1988; Sarker et al., 1978; Smith and Lin, 1983; Wu et al., 1999). Chakraborty et al. (2002); Chakraborty et al. (2009) studied the effect of African orography on the Indian summer monsoon. They found that weaker cross-equatorial flow occurs even in the absence of African orography.

It is necessary to mention here that promising performance have been shown by regional climate models for consideration as one of the downscaling techniques in reproducing the regional detail in surface climate characteristics as forced by regional details e.g. topography, lakes, coastline and land use distribution (Leung et al., 2006; Leung et al., 2003). Systematic and wider application of regional climate models have been proposed by Giorgi et al. (2001) for adequately assessing their performance and uncertainties in producing the regional climate information. Fu et al. (2005) mention that simulating regional climate poses difficulties such as capturing effects of forcing and circulations at
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the planetary, regional and local scales along with tele-connection effects of regional anomalies. Due to availability of various dynamical and physical schemes regional models are able to simulate the meteorological features at very high resolutions. This is the reason for thinking regional climate models as an alternative solution. Main difficulty is the high sensitivity of regional models towards large set of parameters (including the size and location of the domain, lateral boundary conditions, horizontal and vertical resolutions) and both atmospheric and surface physics are also likely to affect their simulated fields (Bhate et al., 2012).

A number of attempts have been made in the past to demonstrate the capability of regional models embedded in a GCM in simulating the Indian summer monsoon climatology (Bhaskaran et al., 1996; Dash et al., 2006; Jacob and Podzun, 1997; Lee and Suh, 2000; Mukhopadhyay et al., 2010; Ratnam et al., 2011; Srinivas et al., 2012; Vernekar and Ji, 1999). The general conclusion of all these studies is that the regional models are able to show an improvement in the spatio-temporal distribution of monsoon rainfall, which is attributed to the increased resolution of these models (Bhate et al., 2012; Mukhopadhyay et al., 2010).

With the advent of high performance computing, regional models are preferably used to simulate the climate at moderately high resolutions (Mukhopadhyay et al., 2010; Ratnam et al., 2011; Taraphdar et al., 2010). In recent study, Mukhopadhyay et al. (2010) used the Advance Research WRF (ARW) model at 15 km resolution to study the ISM rainfall climatology over 2001–2007 and compared with 1°x1° India Meteorological Department (IMD) rainfall data. They reported that the model monsoon rainfall was sensitive to the convective parameterization.
Several studies on regional climate modeling described earlier (Cui et al., 2007; Dobler and Ahrens, 2010; Heikkilä et al., 2011; Polanski et al., 2010; Sato, 2009) considered typical grid sizes of 30–50 km as sufficient to resolve the hydrology-related processes for seasonal scale simulations. The numerical integration of a non-linear system for considerable periods of time is another feature of models. A model can at best represent the atmosphere, a continuous medium, with a specified degree of resolution (Das, 1980).

One of the major difficulties with monsoon modeling is concerned with the Himalayas. This is a large barrier which, according to geologists, had its origin about twenty million years ago. For example when Das (1980) tried to include the Himalayas in a numerical model, he was not clear what boundary conditions should be applied at the earth’s surface, because the earth’s surface is at 500hPa, which is roughly one half the depth of the atmosphere. So for the present simulation we have confined our study to onset of monsoon over Kerala only. Also there is no simulation study seen in the literature relating the Mascarene high with the strength of Somali jet. Therefore main aim of the simulation study is to check whether Mascarene high has any effect on the strength of Somali jet.

7.2 Model and data used

(a) Model

The non-hydrostatic, fully compressible, terrain-following sigma coordinate mesoscale model Weather Research Forecast (WRF), version 3.1.1, developed by NCAR, was used in the present study. Details of the model are given in section 2.7 of second chapter. Single domain is used for the simulation purpose with horizontal resolution of dx=94 and dy=74 km and 27 vertical levels. The domain covers a large region 43.56°S – 43.61°N and 24.06°E-108.4872°E with 100 grid points in
east-west direction and 131 grid points in north-south direction (Fig. 7.1). The model time step was chosen to be 250 second.

The physical parameterization schemes used in the model are WRF Single Moment 3 class microphysics scheme, Rapid Radiative Transfer Model (RRTM) scheme for longwave radiation and Dudhia scheme for shortwave radiation, Eta similarity (which is based on Monin-Obukhov with Zilitinkevich thermal roughness length and standard similarity functions from look-up tables) for surface layer physics, Noah land surface model for land surface processes, Mellor-Yamada-Janjic (MYJ) scheme for planetary boundary layer purpose and Grell-Devenyi (GD) parameterization scheme for cumulus parameterization.

![Fig. 7.1: Plot showing WRF domain having 100x131 grid points at 94x74 km resolution and also shows the model topography.](image)

(b) **Data Used**

Global analysis data or the global model forecast data can be used for both initial and lateral boundary conditions purpose. In our study, the simulations are driven by the National Centers for Environmental Prediction (NCEP) FNL (Final) operational global
analysis data at a resolution of 1 x 1 degree grid. The later boundary conditions are updated every 6 hour.

There are 28 vertical levels used in the model which corresponds to normalized pressure levels following topography. United States Geological Survey (USGS) climatological dataset is used for all the forced values (e.g. albedo, vegetation, etc.) and these values are interpolated to six hour time step for maintaining the coherence with boundary conditions.

Real Time Global (RTG) is daily, high-resolution, real-time, global, sea surface temperature (SST) analysis (Thiébaux et al., 2003) that has been developed at the NCEP/Marine Modeling and Analysis Branch (MMAB). The RTG_SST is produced on a 0.5° (latitude–longitude) grid by an optimum interpolation analysis of the most recent 24hr receipts of buoy and ship data, satellite-retrieved SST data, and SST derived from satellite-observed sea ice coverage (Thiébaux et al., 2003).

7.3 Experimental Design

In 2011 monsoon had set in over Kerala on 29 May, 3 days prior to its normal date of 1 June. One of the interesting features of 2011 monsoon was that no onset vortex formed over the Arabian Sea (Tyagi and Pai, 2012). Therefore the model simulation spans from 20May to 30May for the year 2011 to study the effect of Mascarene high on Somali jet intensity. The first five days are allowed as a model spin-up time period. A five day spin-up period is sufficient for the system to attain dynamic equilibrium between the lateral boundary and internal model forcing (Diaconescu et al., 2007). Three experiments have been conducted, first with keeping the pressure value over the Mascarene high region as it is observed in the FNL dataset in order to check whether model is able to simulate the climatology, in second experiment the intensity of Mascarene high is reduced by 10hPa. It is
noted that the Mascarene high center has the tendency of swinging to the east and west of its normal position while changing in intensity (Manatsa et al., 2013). Therefore third experiment conducted where the position of Mascarene high region is shifted towards east.

Figure 7.2 shows the mean sea level pressure map used for these experiments. Upper panel shows the mean sea level pressure as seen in NCEP FNL data (actual observations) and lower panel shows modified mean sea level pressure at the center of Mascarene high used for second experiment.

![Image](image1)

Fig. 7.2: Mean sea level pressure (Pa) for three experiments (a) with keeping Mascarene high, (b) with reducing the intensity of Mascarene high and (c) shifting Mascarene high towards east.
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7.4 Results and Discussion

Mascarene high a zone of high pressure off the coast of Madagascar and anti-cyclonic air circulation is predominant around the high. Plausible reason behind formation of anticyclonic flow is the passage of migratory low pressure systems off the coast of South Africa. The centre pressure of Mascarene high is around 1035hPa with center approximately lying over 30°S and 60°E. Therefore three experiments have been carried out to find the effect of Mascarene high on strength of Somali Jet.

7.4.1 Analysis of NCEP wind

In the beginning for three days i.e. for 20, 21 and 22 May NCEP wind (Fig 7.3 (a)) shows presence of westerly winds over the coastal Somali region and can also be seen over the Gujarat region. Light westerlies (~2-4m/s) are noticed over the equatorial oceanic region. From 23 May onwards winds along the Arabian coast slowly start decreasing and also similar trend seen over the Gujarat region. On 24, 25 and 26 May two branches were noticed one flowing along the Arabian coast and reaching to northern part of west coast and second branch flowing towards Sri-Lanka. The northern branch disappears on 27 May and strengthening of westerly winds was observed from 28 May onwards. On 29 May westerly winds reach the Kerala region. During this period winds of the order of 14-16 m/s can be seen over the latitudinal belt of equator to 15°N.

7.4.2 Experiment-I

First experiment conducted with FNL reanalyzed data. Main aim of this experiment was to check whether model is able to simulate the jet stream or not.

Analysis of winds at 850hPa shows beginning of cross-equatorial flow on 20 May. Light westerlies of the order of ~8m/s set in on 22 May
and become stronger as we approach the onset date. Winds of the order of 15 m/s can be seen on 25 May over the central Arabian Sea; strong winds can also be seen over the northern tip of Madagascar in the southern hemisphere (Fig.7.3(b)).

From 27 May onwards winds become more organized and decrease in the wind speed observed over the northern tip of Madagascar. Rapid increase noticed on 28 May over the central Arabian Sea. The two branches of jet stream are not observed in this experiment. This experiment shows that model is able to capture the jet stream very well except the strength of model generated winds is slightly more as compared to winds observed in NCEP.

Therefore we shifted our attention towards finding out the effect of Mascarene high on the strength of Somali jet. For this purpose two more experiments have been conducted.

7.4.3 Experiment-II

In second experiment the intensity of Mascarene high is reduced by 10hPa. In this case model is able to simulate jet stream very well (Fig.7.3(c)). The main difference noticed is the decrease in maximum wind. In the first experiment the maximum wind was of the order of 20m/s whereas in this experiment maximum wind is reduced by 2m/s. Significant difference in the wind speed can be seen in the southern hemisphere over the latitudinal belt of 10°S-equator. Over this region the difference is of the order of 4-5 m/s.

One interesting thing noticed in this experiment is the formation of vortex in the central Arabian Sea on 25 May. The vortex formed to the north of jet stream. Formation of similar vortex to the north of the jet was also suggested by Krishnamurti et al. (1981). On 27 May jet slightly changes direction and flows in northeast direction. Decrease in the intensity is noticed on 30 May.
7.4.4 Experiment-III

In the third experiment the position of the Mascarene high is shifted towards east with center lying over 30°S and 85°E. The maximum pressure is kept at 1027hPa. In this case model shows similar pattern of winds i.e. light westerlies on 22May prevailing in the latitudinal belt of equator to 10°N, formation of vortex in the Arabian Sea, etc. as observed in the second experiment. Main difference noticed was in the wind speed around 10° latitudes in both the hemisphere. In southern hemisphere strong easterlies (≥15m/s) was noticed over the northern tip of Madagascar and in northern hemisphere westerlies of the order of 15m/s and more can be noticed over the latitudinal region of equator to 10°N (Fig.7.3 (d)). Vortex formation can also be seen in this experiment and the intensity increases as the onset date approaches. In addition circulation can also be noticed to the south of maximum wind around equatorial region.

(a) NCEP wind (b) Expt.-I
Fig. 7.3: Plot shows 850hPa wind (m/s) from 20 to 30 May 2011 (a) NCEP and wind of three experiments (b) (Expt.-I) run with actual observations, (c) (Expt.-II) decreasing pressure at the Mascarene high, and (d) (Expt.-III) shifting the position of Mascarene high.

It can be seen that in all the three experiments (i.e. with Mascarene high and with lower value of the central pressure of Mascarene high, and shifting the position of Mascarene high) model is able to simulate Somali jet very well (Fig.7.3).

Our main intention was to look at the changes occurring in Somali jet strength due to decrease in the intensity as well as shift in the position of Mascarene high. Therefore we have computed the difference between the wind speed obtained by these simulations i.e. (a) wind speed of experiment-I minus wind speed of experiment-II and (b) wind speed of experiment-I minus wind speed of experiment-III. These are shown in figure 7.4.
Fig. 7.4: Plot showing difference in the wind speed at 850hPa (a) between original minus decrease in Mascarene high pressure and (b) between original minus changing position of Mascarene high.
In experiment-II the intensity of Mascarene high was reduced, main difference is found in the wind speed over the central Arabian Sea region where wind speed decreases by 5 m/s. Initially on 22 and 23 May the decrease in wind speed was observed over the equator to 10°N and 45-75°E region and later increase in the wind speed is noticed over the same region on 24 and 25 May. In the southern hemisphere from 25 May onwards increase in the wind speed was noticed over the region Equator to 10°S and 40-50°E. On 29 and 30 May increase (~4 m/s) in wind speed can be seen along 10°S and over the region 45-75°E (Fig. 7.4(a)).

More interesting results is observed in the second experiment (Fig. 7.4(b)) when the position of the Mascarene high is shifted towards east. On 21 May decrease in the wind speed (between 0-5 m/s) is noticed over the tip of Somalia. Most of the region in the southern hemisphere shows similar trend whereas on 22 May decrease in the wind speed is observed over the region equator to 25°S and 45-75°E while increase noticed in the northern hemisphere over the region from equator to 10°N and 45-75°E.

On 23 May an increase in wind speed is noticed over the region 5-15°N and 50-65°E and also along the west coast of India. While in the southern hemisphere increase is also noticed over the region 20-30°S and 75-105°E. From 24 May till 26 May increase of the order of 10-15 m/s in wind speed is noticed over the region 5-15°N and 50-65°E. Increase over the northern tip of Somalia and adjoining oceanic region can be seen on 27 May. Strengthening can be seen on 28 May over the Bay of Bengal region which gets compressed as we approach towards the onset day. The increase over the Somalia and adjoining region has become less intense. On the northern side of jet stream over the Arabian Sea decrease can be seen on 28 May onwards which progresses northward till 30 May.
In both the experiments i.e. reducing the intensity (expt-II) and shifting the position of Mascarene high (expt-III); formation of vortex has been noticed over the Arabian Sea. That is most prominent when the Mascarene high shifted towards east. The plausible reason behind the formation of vortex in the Arabian Sea could be two fold, 1) it may be due to the presence of shear to the north of the jet stream or 2) as a result of intensification of shear caused by decrease in the intensity of Mascarene high. Krishnamurti et al. (1981) has also mentioned that the horizontal shear of the monsoon current provides substantial energy during the evolution of onset vortex.

Fig. 7.5: Low level shear (900hPa-10m) of zonal component for three experiments
Analysis of low level shear is also carried out (Fig. 7.5) and it is observed that when the intensity of Mascarene high is reduced an increase in the low level shear is noticed over the Northwestern part of the Arabian Sea. When the position of Mascarene high is shifted towards east then increase in the shear is noticed from 26 May onwards in the Arabian Sea as well as near the Kerala coast. These experiments shows an increase in the low level shear over the Arabian Sea and this indicate that atmosphere become more baroclinic over the Arabian Sea in the lowest one kilometer.

7.5 Integration for short duration

We have also tried to simulate the same event but with shorter integration time. In this case we have integrated model for 3 days starting from 28 May. Two experiments have been carried out one without any modification and the second with reducing the intensity of Mascarene high (Fig. 7.6). In the earlier experiment the location of Mascarene high was much close to the southern boundary of the domain. Therefore for these experiments we have extended our domain a little more towards south in the southern hemisphere while rest of the parameterization scheme is kept similar to that of the earlier experiments. For this purpose the horizontal resolution is set to \( dx=31\text{km} \) and \( dy=26\text{km} \) and 27 vertical levels with 234 grid points in east-west direction and 344 grid points in north-south direction. The model time step was 180 second. The modified domain is as shown in Fig. 7.7.
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Fig. 7.6: Mean sea level pressure map (Pa) of two experiments for year 2011 (a) without modification (b) reducing the intensity of Mascarene high

Fig. 7.7: Plot showing WRF domain having 234x344 grid points at 31km x 26km resolution and also shows the model topography.

In these cases also we have observed the formation of vortex when the intensity of Mascarene high is reduced.

In the first experiment at 1000hPa level 10-15m/s westerly winds were noticed near the Somali coast, which later started progressing...
towards east as we approach the onset date (Fig.7.8 (a)). Slight increase in strength of the winds was noticed at 925hPa level (Fig.7.8(b)) whereas westerly winds of the order of 15-20 m/s was noticed over the latitudinal belt of equator to 15°N at 850hPa level (Fig.7.8(c)). Around the equatorial region westerly winds were also noticeable and northerly winds observed over the Arabian Peninsula at 700hPa level (Fig.7.8(d)).

Fig. 7.8: Wind speed (m/s) at 6hr intervals for three days starting from 28 May 2011 (without any modification) at a) 1000hPa, b) 925hPa, c) 850hPa, and d) 700hPa respectively

Similar pattern of winds was observed in the second experiment where intensity of Mascarene high is reduced (Fig.7. 9).
Fig. 7.9: Wind speed (m/s) at 6hr interval for three days starting from 28 May 2011 (reduced intensity) at a) 1000hPa, b) 925hPa, c) 850hPa and d) 700hPa respectively.

The difference was observed mainly in the northern hemisphere over the region between equator-15°N and 45-60°E and also over the region in the southern hemisphere i.e. between 30-40°S and 60-75°E where decrease in the wind speed was noticed (Fig. 7.10).
7.6 Simulation of Cyclone case of year 2010

Thereafter another attempt was made to simulate one more case of year 2010 where onset was on 31 May i.e. just one day before the normal date of 1 June. The reason behind choosing year 2010 case is the formation of a low pressure area over the Arabian Sea on 31 morning (Fig. 7.11), which later intensified into the Very Severe Cyclonic Storm (Phet) during the period 31 May – 7 June (Tyagi et al., 2011). Similar methodology was adopted for the simulation as mentioned above.
First experiment is carried out without any modification (Fig. 7.12(a)). From the beginning model clearly shows presence of low level westerlies (~15 m/s) near the Somali coast region. It has also been observed that model captures the cyclonic circulation on the morning of
31 May and shows intensification of cyclonic winds in later hours (Fig. 7.13).

In the NCEP FNL data it can be observed that the intensity of Mascarene high was of the order of 1035 hPa. Therefore for the second experiment the intensity of Mascarene high is decreased by 5 hPa (Fig. 7.12(b)). Slight decrease (~2 m/s) in the wind speed is noticeable in Fig. 7.14 which is also reflected in Fig. 7.15 where we have plotted the wind speed difference between two experiments.

Fig. 7.13: Wind speed (m/s) at 6hr intervals for year 2010 (without any modification at 850hPa)
Fig. 7.14: Wind speed (m/s) at 6hr interval for year 2010 (with modification) at 850hPa

Fig. 7.15: Wind speed difference between two runs i.e. without modification – modified Mascarene high at 6 hr interval for year 2010 at 850hPa.
All these experiments shows the decrease in the strength of Somali jet when the intensity of Mascarene high is reduced. A dramatic formation of vortex in the east-central Arabian Sea is also noticed when the intensity of the Mascarene high is reduced. The plausible reason behind this could be two fold, 1) due to presence of shear to the north of the jet stream or 2) as a result of intensification of shear caused by decrease in the intensity of Mascarene high. Our results shows that vortex can form even though the jet is weak which contradicts the suggestion made by Deepa et al. (2007) who stated that an onset vortex may not form if the jet wind at 850hPa is weak.

Since these are the results based on only two cases and therefore in order to make any conclusive comment on this aspect of monsoon more experiments are required.

### 7.7 Conclusion

The climate models allow us to perform experiments and as a result one could learn/understand the processes involved in the monsoon. Therefore an attempt was made with the help of WRF model to simulate the effect of Mascarene high on the strength of Somali jet.

Seven experiments have been carried out for the year 2011 and 2010 with WRF model. The first run was conducted for testing whether model is able to simulate the Somali jet or not. It is found that model is able to capture and simulate the jet stream very well. Comparison made between the model simulated winds and NCEP winds, it is observed that model winds are slightly stronger than that of NCEP. Thereafter experiments with reduced intensity of Mascarene high and then shifting the position of Mascarene high have been carried out. From these two experiments it is observed that the strength of Somali jet decreases by reducing the intensity. Dramatic formation of vortex in the east-central Arabian Sea was observed when the intensity of
Mascarene high is reduced. In order to cross check we have carried out 4 run of 3 day integration for year 2010 and 2011 i.e. two runs without any modification and two runs with reduced intensity. The year 2010 was chosen due to formation of cyclonic circulation on 31 May morning and it allowed us to see the effect of Mascarene high on Somali jet as well as over the cyclonic winds.

These experiments also show decrease in the strength of winds when the intensity of Mascarene high is reduced. For 2010 year run, it is observed that the model is able to capture the cyclonic circulation very well on 31 May and a decrease in the strength of winds is noticed when the intensity is reduced. While for 2011, when the intensity of Mascarene high was reduced model shows vortex formation in the east-central Arabian Sea.

Thus on the basis of seven experiments it can be said that the strength of Somali jet decreases when the intensity of Mascarene high is reduced.

In this study we have simulated the jet stream during onset period of monsoon over Kerala and the start of monsoon is usually signaled by a burst in the cross equatorial wind flow near the surface. Therefore the plausible reason behind the formation of vortex in the Arabian Sea could be two fold, 1) may be due to presence of shear to the north of the jet stream or 2) as a result of intensification of shear caused by decrease in the intensity of Mascarene high.

These are the groundwork results based on cases for only two years. Therefore in order to make any conclusive comment on this aspect of monsoon more experiments are required in this regard. Also the presence and effect of barotropic, baroclinic or effect of combined barotropic-baroclinic instability is also to be incorporated.