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The Numerical Investigation of Thunderstorms Using WRF-ARW Model in Tehran (ten Case Studies)

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Introduction

Thunderstorm is mesoscale and in some cases microscale and Most of the numerical weather forecast models encounter problem predicting them. Lack of access to upper atmospheric data in many parts of the earth's atmosphere makes the numerical forecast models one of the most important tools in determining such indices (Lopez et al, 2009). in another one by simulation of two violent storms through convective parameterization scheme model of WRF-NMM, it was manifested that the cumulus scheme Grell-Devenyi has a better function than the other schemes in calculating instability indices TTI, LI, KI and CAPE, and there is also a proper correspondence between the spatial and temporal patterns of precipitation with the observations (Prosenjit et al, 2008). In addition, in another study, Tompson's scheme in calculating the instability indices of CAPE, LI and TTI has a better function than the other microphysics schemes of model WRF (Litta et al, 2012). In Iran, also some studies carried out regarding the prediction of thunderstorm by the model of MM5 (Tajbakhsh et al, 2008) and or based on the researchers conducted, in simulating the rain showers of the south and southwest of the country, Grell and the Blackadar boundary layer were identified as the most appropriate schemes (Qandehari et al, 2006). Nevertheless, fewer studies carried out regarding the model of WRF and the instability indices resulted from the output of the model. Thus, in this research 10 thunderstorms in Tehran were simulated using the advanced numerical weather research and forecasting WRF-ARW.Since this research is an attempt to evaluate the function of the model in predicting instability in the atmosphere, some of the instability indices including KI and LI, Showalter index (SI), total totals index (TT), SWEAT index and the convective available potential energy (CAPE+) were selected and calculated by the output of the model.

Materials and Methods

The data set includes

- Observational data of Tehran- Mehrabad station used in this research, is related to 10 thunderstorms that was diagnosed by the observer and recorded with the codes of 95, 96 and 97.
- By using of Tehran upper air sounding data were calculated the instability indices resulting from the thermodynamic charts in 00UTC and 12UTC times.
- Global data FNL that have the power to segregate one degree along with the latitude and longitude, can be used as the input of model WRF- ARW.

Model WRF-ARW:

Advanced modeling system WRF-ARW is a mesoscale model and a flexible system with abundant capabilities that can be used to simulate different states of the atmosphere. it also can be used in wide range of between some meters to thousands of kilometers and Using the different changes of physical parameterization in the model, we can carry out wide range of performances (meteorological research center, 2009). Physical parameterizations of the model are divided into several groups each of which has different state. The groups include Microphysics, Cumulus, Surface layer, Land-surface, Boundary layer and Radiation.

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Instability indices

Stability indices, the so-called instability indices, are experimental relations through which we can determine unstable areas of the atmosphere. The instability indexes to which most of the meteorologists pay close attention, are used to predict the thunderstorms of air mass.

Mean absolute error and Mean bias error

In this research, to determine validity of the model, considering the values resulted from the four configurations and the radio sound the attention of each configuration from schemes are calculated with regard to the statistical criteria of Mean absolute error (MAE) and Mean bias error (MBE).

The research method

In this research, the model has four different configurations and with 48 hour predictions is executed and the time step between the outputs is one hour. Some of the parameters resulting from the output of the model including temperature, dew point and relative moisture are used to estimate instability indexes of the atmosphere such as KI index, LI index, show alter index (SI), total totals index (TT), SWEAT index and convective available potential energy (CAPE). Thus, prognosis of the instability at the time of storm will be accomplished through these indices

Results and discussion

In this study 10 thunderstorms with four configurations of the physical schemes were simulated through the model of WRF-ARW and the values of TT, KI, SI, LI, SWEAT and CAPE indices were calculated for each configuration by the model. The mean absolute error and the mean bias error have been calculated for each index. Considering the results, the third configuration with the physical parameterization including microphysics of Thompson, Cumulus (convection) of Grell-Devenyi, the boundary layer of Mellor-Yamad-Janjic, the high atmosphere radiation RRTM and low radiation Dudhia, land-surface Noah 1sm and the surface layer Janjic have provided more reliable values for the above-mentioned indices in the simulation and prediction of thunderstorm of Mehrabad station. Therefore, the output of the scheme is used to evaluate the capability of the model in identifying instability in the environment.

Conclusion

In this article ten storms were studied and simulated by using some instability indices resulting from the output of the model. Considering the results, TT index resulting from the output of the model in 12 UTC predicted 30% probability of violent storm, 60% moderate storms and 10% Weak storm. At the same time, the K index predicted ten storms that include one case with the probability of 100%, three cases with 80%, three cases with 75% and three other cases with 55% in order. The SI index also predicts probability of medium instability in 30%, low instability in 40% and a stable atmosphere at 12 UTC in 20%. The LI index resulting from the output of the model at 12 UTC also has predicted probability of a moderate storm in 20%, low probability of rain shower in 60% and probability of a stable atmosphere in 20%. At the same time, the CAPE+ index has predicted probability of Weak storm in 40% and a stable atmosphere in 60%. Considering the results, it seems like the SWEAT index is only used for violent storms, it needs to be studied in more detail, though.

Keywords: Tehran, Thunderstorm, Numerical Mesoscale Model WRF-ARW, Physical Schemas, Instability Indices.