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Using and Evaluating the Efficiency of GRIMs Model in Making Some Simulations of Weather Variables in Three Countries in Middle East: A Snowfall Case Study

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Abstract

Predicting weather by numerical models have been used extensively in research works for Middle East, mostly for dust storms, rain showers, and flash floods with a less deal of interest on snow precipitation. In this study, the Global/Regional Integrated Model System (GRIMs) that was developed in South Korea was used to predict a rare snowfall event occurred in three countries in Middle East (Syria, Jordan and Iraq) located between (25-65 °E; 12-42 °N) in year 2008. The main aim of this study was to test GRIMs efficiency, which would be used for the first time in Middle East, to make predictions of weather parameters such as pressure, temperature, and relative humidity especially in the selected area. In addition, the study would investigate the conditions that caused the snowfall event. GRIMs model was installed, compiled, and run on a Linux platform by using NCEP-NCAR reanalysis dataset as initial conditions on 0.5 × 0.5 grid resolution to make simulations for three days at intervals of three hours. The output of the model was evaluated by making comparisons with actual data obtained from the GFS Agency dataset and the model showed its efficiency. The snowfall event was synoptically discussed in details. It was found that the snowfall event was a result of fast succession systems of a strong cold high pressure and then a deep warm low pressure. The high instability in the region had led to form large cumuliform clouds with snow precipitation as a rare event in very long period.

Keywords: Middle East, GRIMs, Numerical Weather Prediction, Snowfall

استعمال وتقييم كفاءة نموذج كرمس في عمل بعض المحاكاة للمتغيرات الطقسية في ثلاث دول في الشرق الأوسط: دراسة حالة التساقط الثلجي

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الخلاصة

التنبؤ بالطقس من خلال النماذج العددية استعمل على نطاق واسع في الأعمال البحثية لمنطقة الشرق الأوسط، على الاغلب للعواصف الغبارية وزخات المطر والفيضانات المفاجئة مع قدر أقل من الاهتمام بتساقط الثلوج. في هذه الدراسة، تم استعمال نظام الانموذج العالمي / الإقليمي المتكامل (GRIMs) الذي تم تطويره في كوريا الجنوبية للتنبؤ بحدوث تساقط ثلوج نادر في ثلاث دول في الشرق الأوسط (سوريا والأردن والعراق)

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في عام 2008. الهدف الرئيسي لهذه الدراسة هو اختبار كفاءة GRIMS، وهو الذي يستعمل لأول مرة في الشرق الأوسط، لعمل تنبؤات لمتغيرات الطقس مثل الضغط ودرجة الحرارة والرطوبة النسبية خاصة في المنطقة المختارة. بالإضافة إلى ذلك، ستبحث الدراسة في الظروف التي تسببت في تساقط الثلوج. تم تثبيت نموذج GRIMS وتجميعه وتشغيله على منصة Linux باستخدام مجموعة بيانات NCEP-NCAR كشروط أولية بدقة شبكة 0.5×0.5 لإجراء عمليات محاكاة لمدة ثلاثة أيام على فترات من ثلاث ساعات. تم تقييم مخرجات النموذج من خلال إجراء مقارنات مع البيانات الفعلية التي تم الحصول عليها من مجموعة بيانات وكالة GFS وأثبت النموذج مهارته الجيدة. تمت مناقشة حدث تساقط الثلوج بشكل شامل بالتفصيل. وجد أن حدث تساقط الثلوج كان نتيجة لتعاقب سريع لنظام ضغط مرتفع بارد وقوي ومن ثم ضغط منخفض دافئ عميق. أدى عدم الاستقرار المرتفع في المنطقة إلى تكوين سحب ركامية كبيرة مع تساقط ثلوج كحدث نادر في فترة طويلة جدًا.

Introduction

Numerical Weather Prediction (NWP) could be started by the work of Bjerknes (1904) who considered the problem of weather prediction based on physical laws [1]. The first trial of NWP was done by Richardson (1922) employing the finite difference method by solving the governing partial differential equations [2]. Unfortunately, he failed in his trial after enormous calculations because the problem of imbalance in the initial conditions. A quarter of century later, Charney's team in Princeton University succeeded in achieving the first ever numerical weather prediction in late 1940s by using ENIAC computer that had been just developed [3]. Progress in computing power and modeling led to continuous improvement in NWP and knowledge of working of atmosphere. NWP models for weather forecasting and climate research include a software package that consists of numerically discretized mathematical equations written in programming languages [4]. Models have been created into Global Circulation Models GCMs and Regional Models RMs. GCMs are essential tools for weather and climate studies [5]. The rapid development of theories and modeling of large-scale atmospheric motion, expansion of internal processes and use of higher resolutions, the GCMs have gone a long way in the process of developing and updating. The development included basic approximations, boundary conditions, discretization of the governing equations, and problem of parameterization of physical processes [6]. The first global NWP model, a finite-difference model with 2.5° latitude/longitude grid, became operational there on 18 September 1974. A second global grid-point model that was run by the European Centre for Medium-Range Weather Forecasts (ECMWF), became operational in August 1979, with 1.875° resolution. Global grid-point models became operational at the Met Office and the US Navy in 1982 [7]. Spectral models took over for global prediction at NMC and ECMWF in 1980 and 1983, respectively [8]. The forecast skill of GCMs can be attributed to improvement in initial condition, model dynamics and physics [9]. However, since spatial resolutions that normally used in GCMs are coarse which cannot tackle the mesospheric processes and dynamics, the idea of employing high resolution and dynamically downscaled regional climate models (RCMs) has been essential [10 & 11].

In Iraq, many researches used numerical weather models in tackling various phenomena. Roomi [12] implemented a comparison among three models, barotropic model, shallow water equations model, and weather and research forecasting model (WRF). Al-Dabbagh [13] used Barcelona Supercomputing Center-Dust Regional Atmospheric Model version 2.0 (BSC-DREAM8b v2.0) to simulate some dust outbreaks cases in Iraq. Abed-Abbas [14] used the Regional Climate Model (RegCM4) to simulate 10 dust storm cases in Iraq.

The Global/Regional Integrated Model System GRIMS is a model that was developed in South Korea [4]. GRIMS was created for operational and research purposes in numerical weather prediction, short- and medium- range for days, seasonal and climate from months to several years. It has been applied for various studies such as for mesoscale and climate [15]. It

was one of the models that were used to predict the rice production in the Korean Peninsula (KP) in the near future (2021–2050) in terms of the climatic yield potential [16].

In this study, GRIMs was used to predict some meteorological parameters concerning a rare snowfall event in three Arabian countries from 21–24 January 2008. It is worth mentioning that according to the researchers' information, this model is used for the first time in this region. The study would investigate the conditions that caused the snowfall event. In addition, the outputs of GRIMs will be evaluated with the dataset of the Global Forecast System (GFS), which is a weather forecast model produced by the National Centers for Environmental Prediction (NCEP).

Material and Methods

Location and Data

The GRIMs model would be used to simulate a rare snowfall event that was occurred in 22 January 2008 in three countries in Middle East (Syria, Jordan, and Iraq) located between (25–65 °E, 12–42 °N). The initial and boundary conditions were given by Final Operational Global Analysis Data FNL/NCEP starting at 00 UTC. The GFS/NCEP analyzed dataset was used as an actual data to make comparison with the output of GRIMs model.

Simulation of the Model

In this study, GRIMs was installed and run on a Linux operating system platform. The source code of the model was unpacked, compiled and integrated for 72 hours on a 3 hours' time steps for period from 21 to 24 January 2008 with a 0.5×0.5 grid cell resolution.

The elements that were studied include: air temperature measured at two meters height, mean sea level pressure (MSL), and relative humidity. These were visualized in charts with focusing on Baghdad, Damascus, and Amman. Many tools were used in drawing charts such as GrADs, CDO and NASA Panoply. To make quantitative comparisons, some statistical calculations were used such as Bias Error (BE), Mean Absolute Error (MAE), Root Mean Square Error (RMSE) and correlation coefficient (R) [17].

$$BE = \frac{1}{n} \sum_{i=1}^n (c_i - o_i) \quad (1)$$

$$MAE = \frac{1}{n} \left[\sum_{i=1}^n |c_i - o_i| \right] \quad (2)$$

$$RMSE = \sqrt{\frac{1}{n} \sum_{i=1}^n (c_i - o_i)^2} \quad (3)$$

$$R = \frac{\sum_{i=1}^n (c_i - \bar{c}) \cdot (o_i - \bar{o})}{\sqrt{\sum_{i=1}^n (c_i - \bar{c})^2} \cdot \sqrt{\sum_{i=1}^n (o_i - \bar{o})^2}} \quad (4)$$

Where n : is the number of forecasts, c : is the predicted values, \bar{c} : is the arithmetic mean of c values, o : is the observed values, \bar{o} : is the arithmetic mean of o values.

Results

Mean Sea Level Pressure

The results of the model were compared with the GFS datasets. Figure 1, on 21 Jan. 2008 at 12 UTC, shows existence of two atmospheric high-pressure systems. One of which is the Siberian high to northeast and the Azores high to the northwestern to the Arabian Peninsula. On 22 January 2008 there were a coupled effect of each of the Mediterranean low from the northeast and the Red Sea low from the south. Those low systems then formed a significant low-pressure system on 23 January 2008 (See Figure 2). As it is clear, the model simulated perfectly the actual data of GFS. Figure 3 shows the comparison between the predicted and actual data of the surface atmospheric pressure values for Baghdad, Damascus, and Amman.

It is clear that there was a gradual decrease in pressure during days 21-23, January 2008, reaching the lowest value of about 1010 hPa on 22 January 2008, with respect to Damascus and Amman and on 23 Jan. with respect to Baghdad. The statistics in Table 1, shows that Bias BE was -0.031, -0.036 and -0.043 for Baghdad, Damascus and Amman, respectively. As much as the Bias is close to zero, the similarity would be better. Negative values mean that the predicted values are less than the actual ones. Values of MAE were 0.032, 0.036 and 0.045 for Baghdad, Damascus, and Amman, respectively. These represent low values of the amount of error rate and not the direction. On the other hand, RMSE values were 0.185, 0,236 and 0.271 for Baghdad, Damascus, and Amman, respectively. RMSE measures the average magnitude of the error, which was found low in this study. Finally, the correlation (R) values were 0.990, 0,960 and 0.0958 for Baghdad, Damascus, and Amman, respectively. These values mean that there is a strong linear correlation between the predicted and actual values.

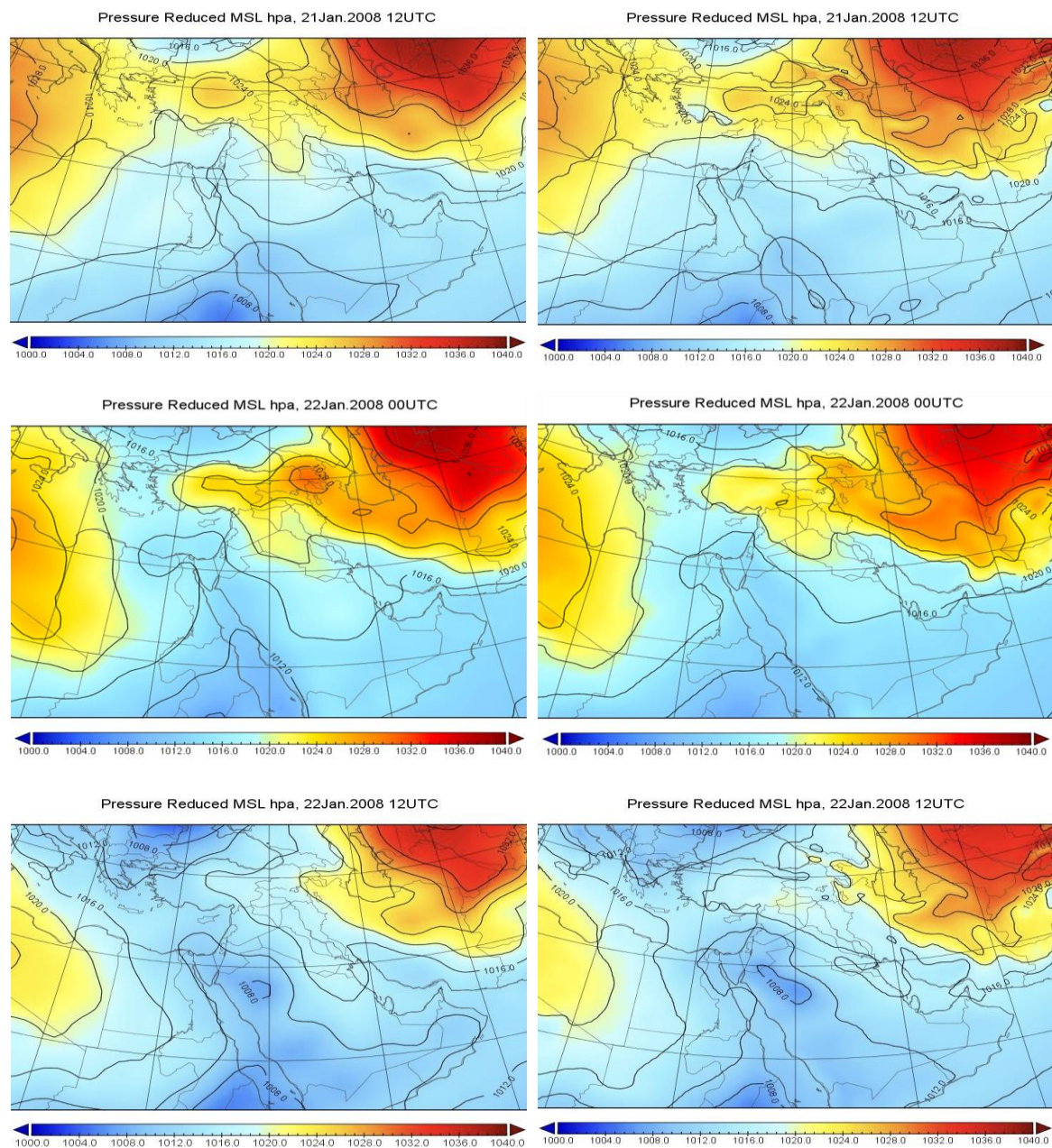


Figure 1- Mean sea level pressure charts (hPa) on 21 January 2008 at 12 UTC and 22 January 2008 at 00 and 12 UTC for GRIMs (right) and GFS (left).

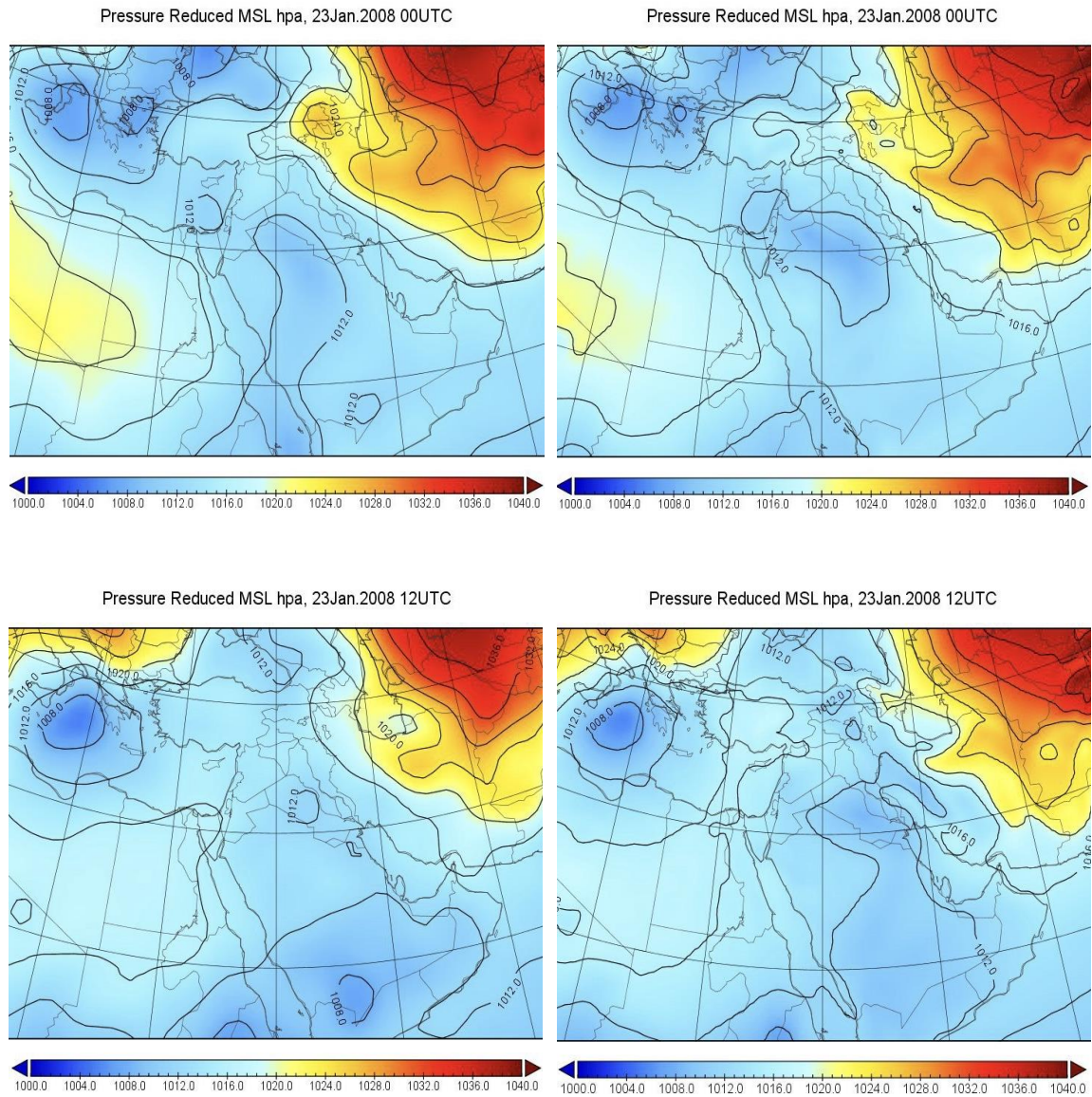


Figure 2- Mean sea level pressure charts (hPa) on 23 January 2008 at 00 and 12 UTC for GRIMs (right) and GFS (left).

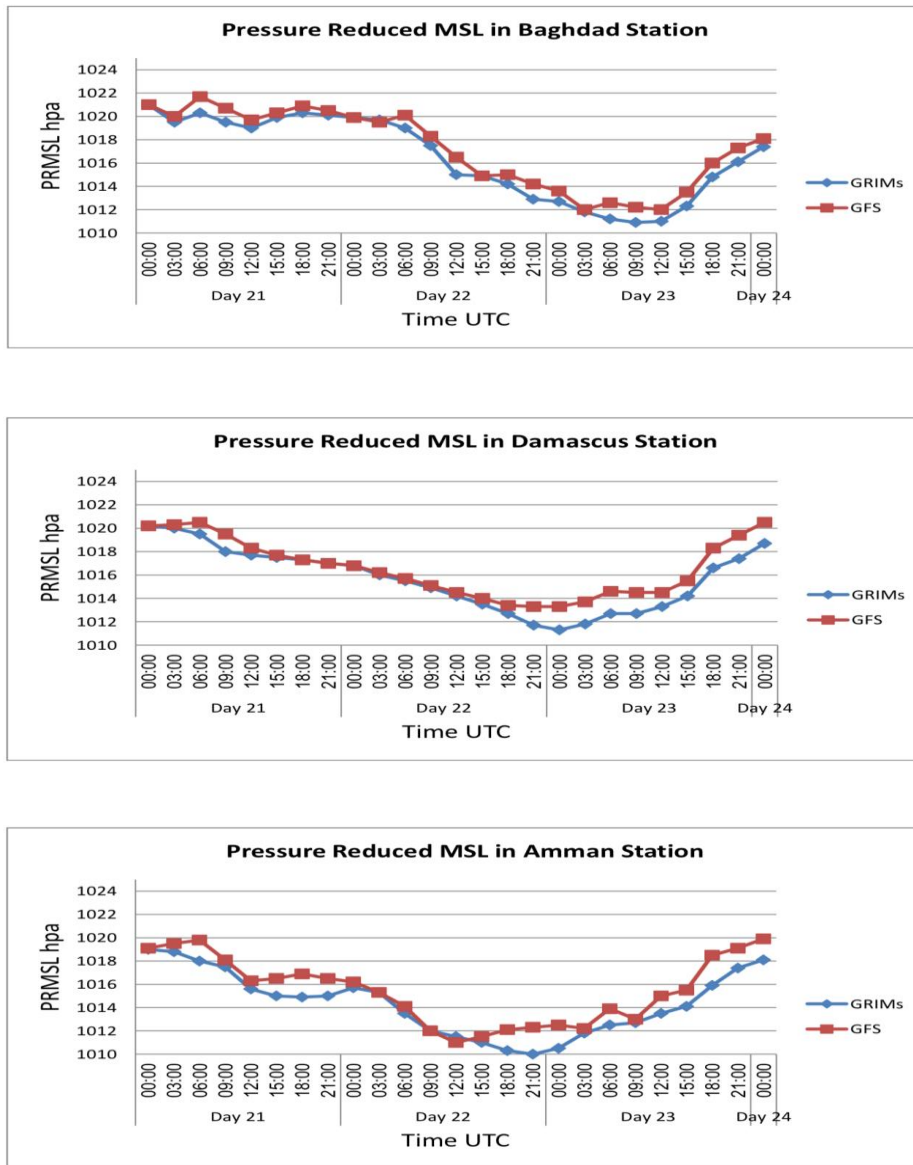


Figure 3- Mean Sea Level pressure curves (hPa) on 21, 22, and 23 January 2008 to the stations of Baghdad, Damascus and Amman for the GRIMs (blue) and GFS (red)

Table 1-Statistics of the comparison between the predicted and the actual data of pressure for Baghdad, Damascus and Amman on 21, 22, and 23 January 2008

City	BE	MAE	RMSE	R
Baghdad	-0.031	0.032	0.185	0.990
Damascus	-0.036	0.036	0.236	0.960
Amman	-0.043	0.045	0.271	0.958

Surface Air Temperature

Figures (4 and 5) show air temperature charts of the predicted values by GRIMs model and the actual values from GFS. It is clear that the Siberian high-pressure system extended toward the north of the Arabian Peninsula from the northern east with a cold air mass from 21 to 23 January. Figure 6 shows the change of air temperatures in Baghdad, Damascus and Amman cities for period from 21 to 23 January 2008. There was a significant and gradual decrease in temperature. The predicted values were very close to the actual values of air temperature. In Table 2, statistics confirmed strong agreement between the predicted and the actual data.

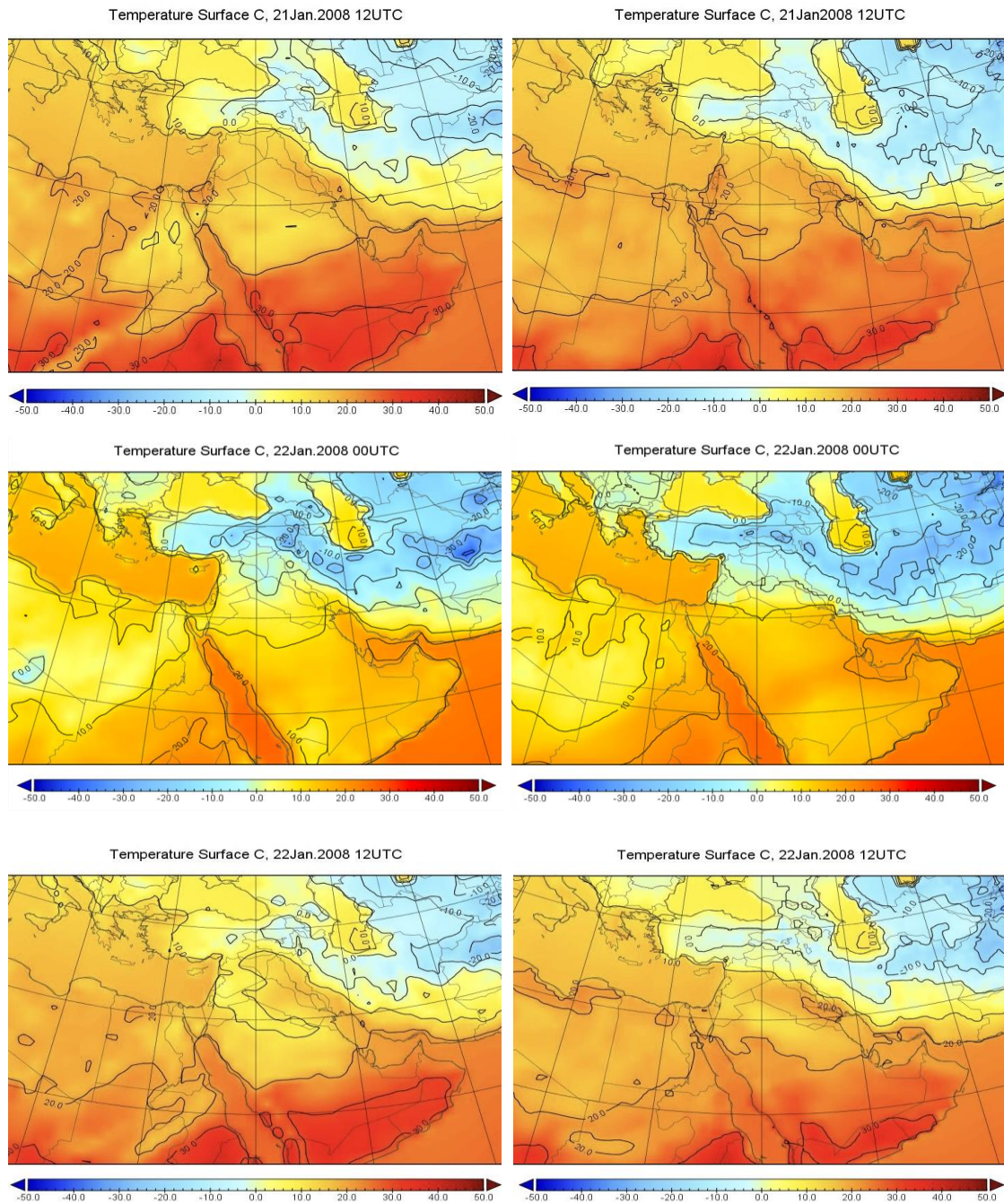


Figure 4-The surface temperature (oC) on 21 and 22 January 2008 for GRIMs (right) and GFS (left)

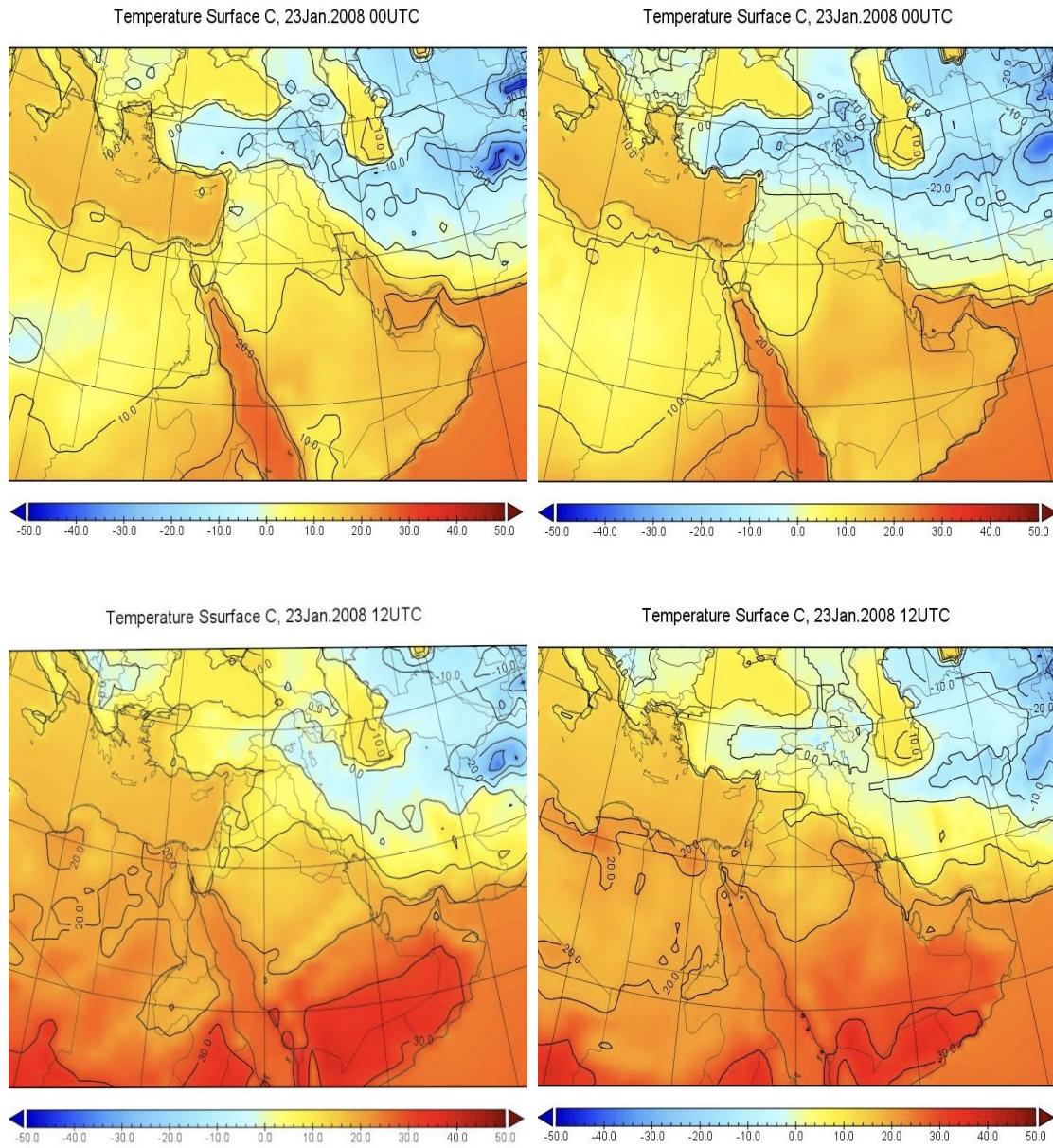


Figure 5- The surface temperature (°C) on 23 January 2008 for GRIMs (right) and GFS (left)

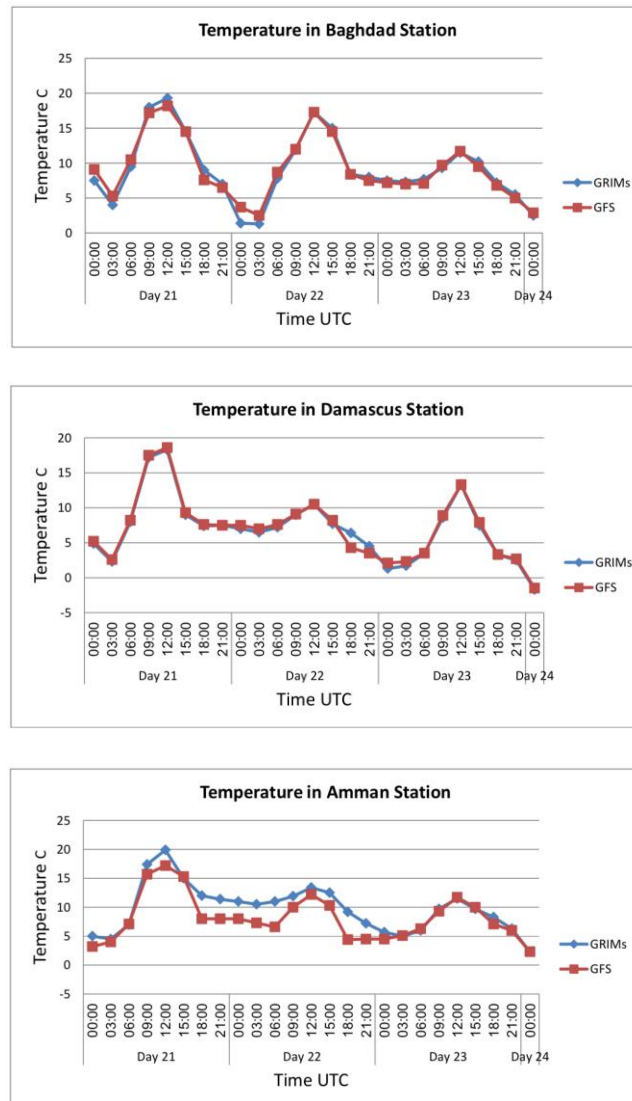


Figure 6-Air temperature curves (°C) on 21, 22, and 23 January 2008 for Baghdad, Damascus and Amman for GRIMs (blue) and GFS (red)

Table 2-Statistics of comparison between predicted and actual data of air temperature for Baghdad, Damascus and Amman on 21, 22, and 23 January 2008

City	BE	MAE	RMSE	R
Baghdad	-0.002	0.027	0.175	0.985
Damascus	-0.005	0.051	0.114	0.992
Amman	0.062	0.067	0.444	0.923

Relative humidity

Figures (7 and 8) show the relative humidity charts. It is clear that the advance of Red Sea low-pressure system from the south have come with a warm humid air mass. The humid air mass affected west and east parts of the northern Arabian. In Figure 9, curves of relative humidity show that humidity decreases rapidly in 22 January to reach 100% in the three cities. However, the increase started in Amman then Damascus and Baghdad. Table 3 lists statistics

of errors and correlation. As in the previous cases of pressure and temperature, the agreement was strong between the predicted and the actual values.

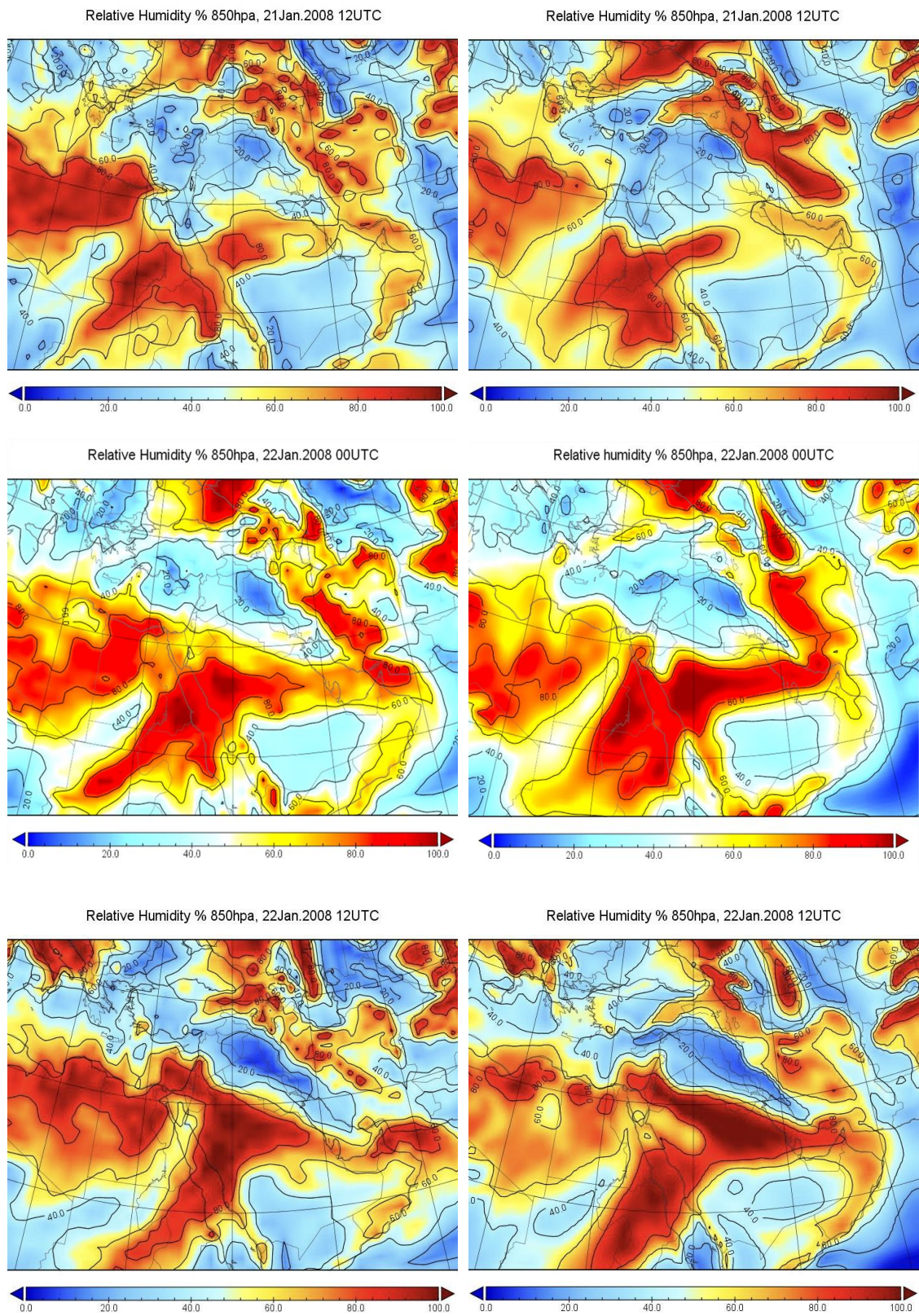


Figure 7-The relative humidity on 21 and 22 January 2008 for GRIMs (right) and GFS (left)

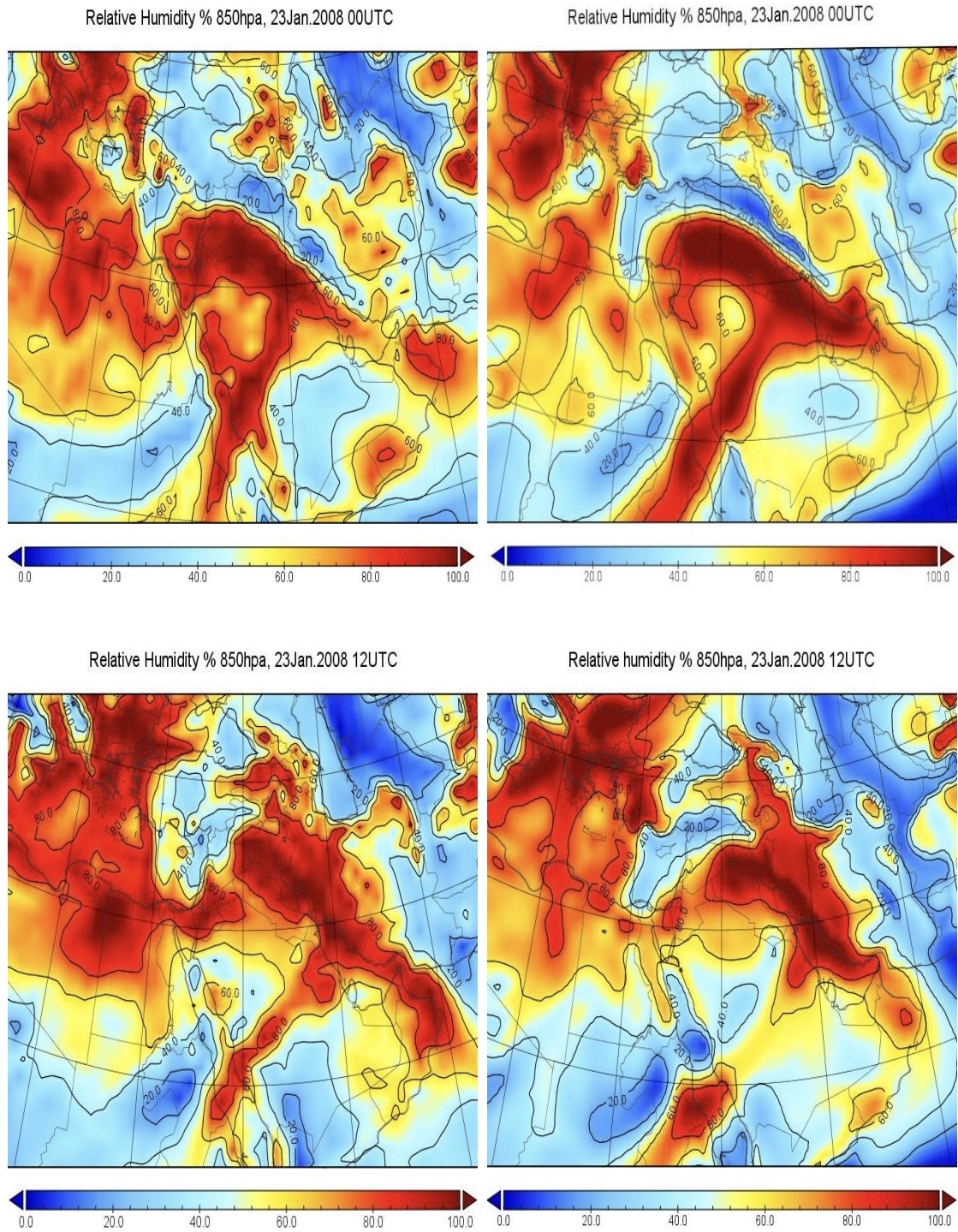


Figure 8-The relative humidity on 23 January 2008 for GRIMs (right) and GFS (left)

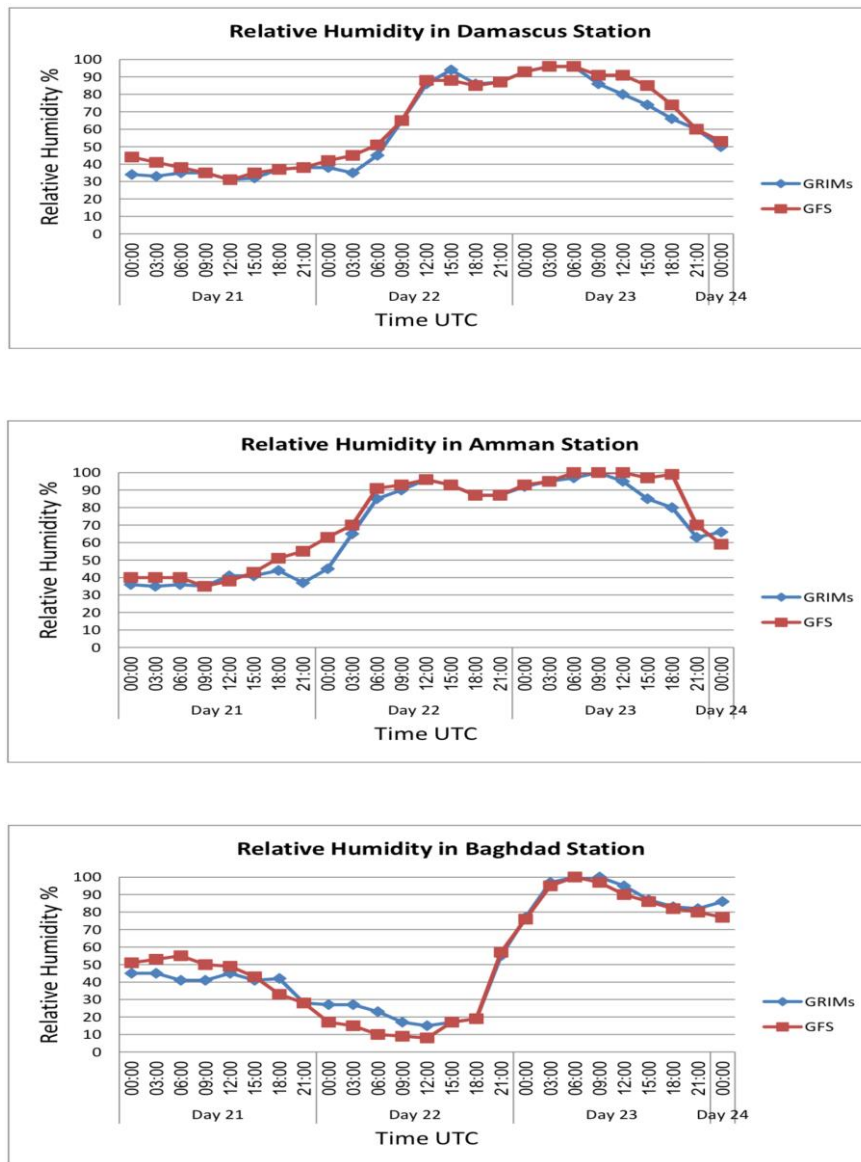


Figure 9-Relative humidity curves on 21, 22, and 23 January 2008 for Baghdad, Damascus and Amman for GRIMs (blue) and GFS (red)

Table 3-Statistics of the comparison between predicted and actual data of relative humidity for Baghdad, Damascus and Amman on 21, 22 and 23 January 2008

City	BE	MAE	RMSE	R
Baghdad	-0.060	0.204	1.346	0.976
Damascus	-0.123	0.145	1.069	0.984
Amman	-0.174	0.206	1.536	0.966

Discussion

The above results of comparison between predicted values of GRIMs model and actual values of GFS proved that the model accurately predicted the climatic elements and it is suitable to use in the Middle East. The values of difference between predicted values and actual values were very small and the correlation factor was very high.

The study of the snowfall event from the charts, the curves and the statistics gave the following interpretation: in the beginning, there was a strong Siberian high pressure with very cold air mass affecting the Middle East, especially Syria, Iraq, and Jordan. Then, a relatively warm, humid low pressure approached the region coming from the Red Sea side. This fast-low-pressure system could not push away the cold, high-density air mass so it was forced to ascend the cold air mass. This rapid ascent enhanced the process of cumuliform clouds formation leading to produce clouds with sufficient amounts of ice. Finally, under these conditions, the precipitation was in form of snow.

Conclusions

The study of using GRIMs model to simulate the case study of a rare snowfall event in the Middle East gave the following conclusions:

1. GRIMs model successfully simulated the weather in three countries in Middle East (Syria, Iraq, and Jordan).
2. The calculated errors between predicted values with GRIMs model and actual values of air pressures, air temperatures, and humidity were very small and the correlation factor was high.
3. The rare snowfall event was a result of a rapid entry of warm, humid low pressure into a region of very cold air mass, which was already existed over the region. The low-pressure system could not push away the cold air mass so it was forced to ascend and form cumuliform clouds filled with a sufficient amount of ice. This ended with snowfall precipitation.

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References

- [1] G. Kariniotakis, "Renewable Energy Forecasting: From Models to Applications", Woodhead Publishing, 2017.
- [2] Z. Pu and E. Kalnay, "Numerical Weather Prediction Basics: Models, Numerical Methods, and Data Assimilation", 2018.
- [3] S. Yoden, "Atmospheric predictability", *J. Meteorol. Soc. Japan*, vol. 85 B, pp. 77–102, 2007, doi: 10.2151/jmsj.85B.77.
- [4] S.-Y. Hong *et al.*, "The Global/Regional Integrated Model system (GRIMs)", *Asia-Pacific J. Atmos. Sci.*, vol. 49, no. 2, pp. 219–243, 2013, doi: 10.1007/s13143-013-0023-0.
- [5] K. Ahmed, D. A. Sachindra, S. Shahid, M. C. Demirel, and E. S. Chung, "Selection of Multi-Model Ensemble of General Circulation Models for The Simulation of Precipitation and Maximum And Minimum Temperature Based On Spatial Assessment Metrics", *Hydrol. Earth Syst. Sci.*, vol. 23, no. 11, pp. 4803–4824, 2019, doi: 10.5194/hess-23-4803-2019.
- [6] G. R. North, P. John, and Z. Fuqing, "Encyclopedia of Atmospheric Sciences", Elsevier Ltd., 2015.
- [7] J. G. Sela, "The NMC Spectral Model", US Department of Commerce, National Oceanic and Atmospheric Administration, National Weather Service., 1982.
- [8] W. Simmons, A. J., Burridge, D. M., Jarraud, M., Girard, C., & Wergen, "The ECMWF Medium-Range Prediction Models Development of the Numerical Formulations and the Impact of Increased Resolution", *Meteorol. Atmos. Phys.*, vol. 40, no. 1–3, pp. 28–60, 1989.
- [9] E. Kalnay, "Atmospheric Modeling, Data Assimilation and Predictability", Cambridge University

Press, 2003.

- [10] F. Giorgi and W. J. Gutowski, "Regional Dynamical Downscaling and the CORDEX Initiative", *Annu. Rev. Environ. Resour.*, vol. 40, no. 1, pp. 467–490, 2015.
- [11] B. Rockel, "The Regional Downscaling Approach: a Brief History and Recent Advances", pp. 22–29, 2015, doi: 10.1007/s40641-014-0001-3.
- [12] T. O. Roomi, "Evaluation of Three Numerical Weather Prediction Models over the Middle East", Mustansiriyah University, 2013.
- [13] S. K. M. Al-dabbagh, "Analysis of Dust Events Using BSC- DREAM8b Regional Model and NCEP", Mustansiriyah University, 2015.
- [14] N. M. Abed-Abbas, "Study of Dust Storms over Iraq using Regional Climate Model 4 (RefCM4)", Mustansiriyah University, 2017.
- [15] Y. C. Jeong, "A Global / Regional Integrated Model System - Chemistry Climate Model: 1. Simulation Characteristics", 2019, doi: 10.1029/2019EA000727.
- [16] J. Ahn, Y. Kim, M. S. D. Cha, S. P. H. Kang, and S. Min, "Climatic Yield Potential of Japonica-Type Rice in the Korean Peninsula under RCP Scenarios using the Ensemble of Multi-GCM and Multi-RCM Chains", no. July, pp. 1–16, 2020, doi: 10.1002/joc.6767.
- [17] H. R. Stanski, L. J. Wilson, and W. R. Burrows, "Survey of Common Verification Methods in Meteorology", Technical Report No. 8, WMO/TD No. 358, 1989.