Annual WWW Technical Progress Report

On the Global Data Processing and Forecasting System 2004

OMAN

- **Summary of highlights**

Oman Meteorological Service, located in Muscat, Oman develops, produces and disseminates real time forecasts since 1971. This department is part of the Directorate General of Civil Aviation and Meteorology (DGCAM) under the Ministry of Transportation and Telecommunications.
Oman Meteorological Service is operationally running an Atmospheric High Resolution Model (HRM), called Oman Regional Model (ORM) since October 1999. The model was obtained from the Deutscher Wetterdienst (DWD) of the Federal Republic of Germany. The German global model GME is used to provide necessary initial and lateral boundary conditions for ORM. DGCAM is also running a regional wave model called WAM, which was obtained from GKSS of Germany.

- **Equipment in use at the service.**

The current computational environment consists of two shared memory computer, SUN Enterprise E4500 (12 processors) for the operational use and E450 (4 processors) for backup and development purposes.

The main data storage system consists of Dell PowerAdge 2600 with 2 Tbytes. Some of the data are stored using Mysql database and others are stored in file structure storage.
The following table shows the configuration of the SUN Enterprise E4500

Processor	
Number of processors	12, 84 MHz
Cache per processor	8 MB external cache
System Interconnect	Giga plane TM, 2.68 GB/sec
Main Memory	
Main Memory	28-GB memory
Software	
Operating system	Solaris TM Operating Environment 2.8
Languages	C, C++, FORTRAN

- **NWP Human resource at the service**

The NWP team of DGCAM consists of four scientists, one programmer and two technical support people, and it is planning to increase the team.

Name	Job	Background
Juma Al-Maskari	Scientist (HRM)	PHD (Forecasting the Local Activates and thunderstorms)
Fauzi AL-Busaidi		Bsc. (Meteorology)

Khalid AL-Jahwari		
Rahma AL-Nedhari	Scientist (WAM)	Bsc. (Physics)
Sultan AL-Yahyai	Programmer	Msc. (Clustering& Grid Computing)
Hussein AL-Moqbali	Tech. Support	Bsc. (Computer Science)
Omar AL-Kabi		Msc. (Computational Physics)

- **Observation Data Quality Control System**

To avoid taken wrong OBS when are used on any statistical analysis or study, the following Quality Controls are applied on the observations.

1. Elements value thresholds: for example,
   T_2M: - 25 °C < T_2m < 65 °C
2. Tmax_2m: Tmax_2m >= max(T_2m) of the day
3. Tmin_2m: Tmin_2m <= min(T_2m) of the day
4. Comparing OBS with model first guess to ensure that observed values are reasonable For T_2m, TD_2M: 10 degrees difference between model first guess and the observation should be allowed. For MSLP: 15 hpa differences between model first guess and the observation should be allowed.

- **Regional NWP model used for Short range forecast**

ORM is a hydrostatic model, of primitive equations. DGCAM is running ORM with two resolutions 28km x 28 km (ORM_28) and 7km x 7km (ORM_07), two times a day at 00UTC and 12UTC .

ORM_28 has 193 grid points in the east-west direction, 114 grid points in the north-south direction, 40 vertical layers and with a domain running from 7 N to 35.25N, and from 30E to 78E. Figure 1 below shows the domain of ORM_28km.

Figure 1: The Domain of ORM_28km

ORM_07 has 241 grid points in the east-west direction, 241 grid points in the north-south direction, 40 vertical layers and with domain running from 14 N to 29N, and from 48.5E to 63.5E. Figure 2 below shows the domain of ORM_07km. The domain of ORM_07km is clearly much smaller than that of ORM_28km. However, ORM_07km has more grid points and therefore requires more computation time. Because of its high resolution, ORM_07km is better than ORM_28km in forecasting summer convection that takes place in the chain of mountains in Northern Oman.

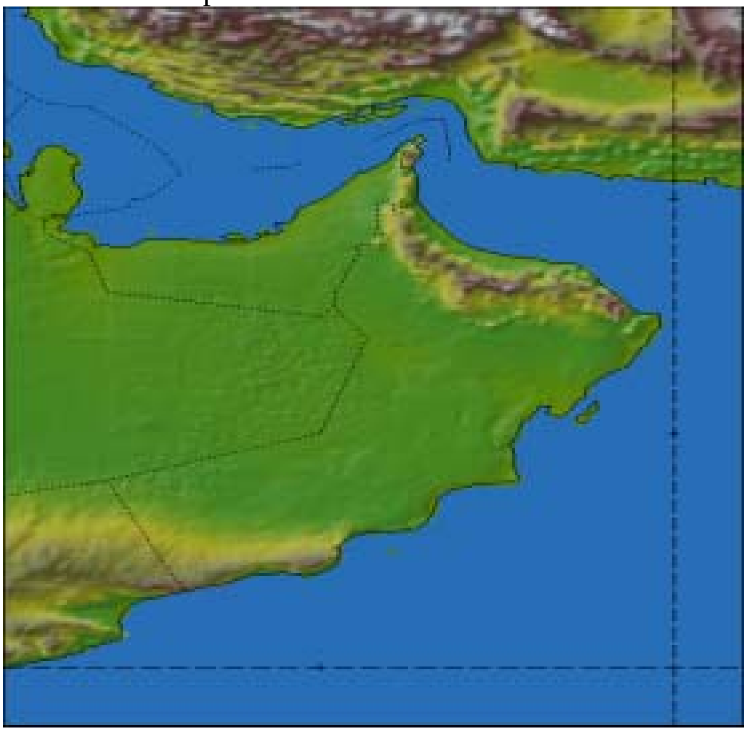

Figure2 : The Domain of ORM_07km

The main goal of the use of ORM is to provide a guide lines for the forecasters on their dissemination of the weather conditions to the public. Some examples of ORM products are: dew point temperature, geopotential height, grid scale rain, convective rain, temperature, vertical velocity, relative humidity and winds. In Figure 3 below is an example of ORM products. In addition, the ORM_28km 10m wind field forecast is also used to run a wave model WAM_28km. WAM_28km provides a forecast for wave heights, wave direction, wave period, energy transport, swell waves for sea waters within the domain of ORM_28km. ORM_28, ORM_07 and WAM_28 generate forecasts for 78 hours. Some of ORM products are released to the public through DGCAM's web page www.met.gov.om .

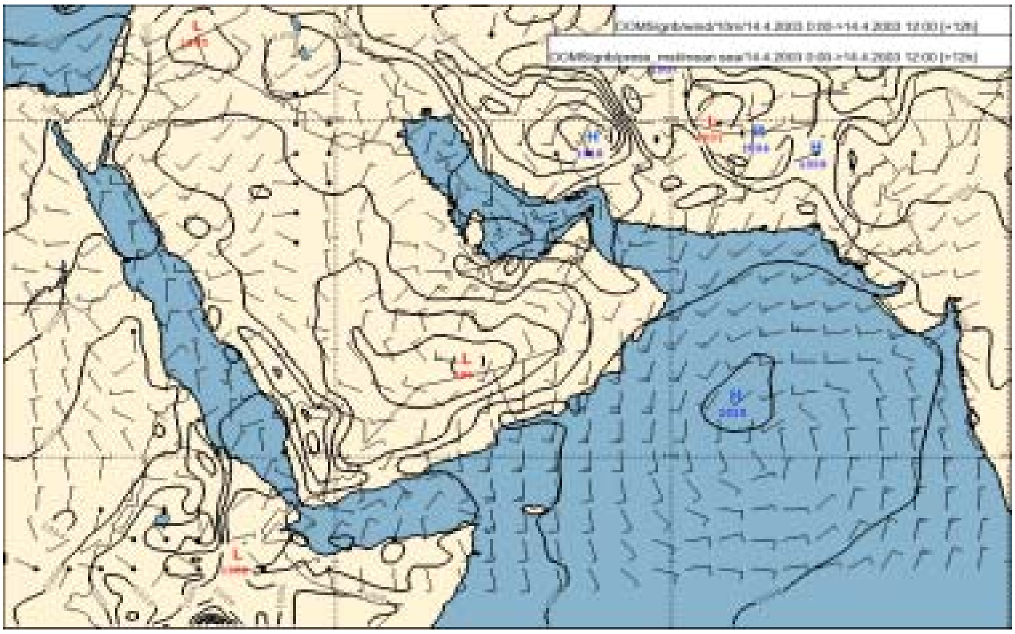

Figure 3: ORM_28km MSLP and 10m wind forecast.

In addition, ORM can also be used to help scientists conduct case studies. For example, the Oman NWP team has conducted a study to find out the relationship between the land/sea temperature difference and the extent of sea breeze inland penetration. Figure 4 below shows the extent of the sea breeze inland penetration in the original field on the UAE side with no changes being made. The blue zone in the graph represents the sea breeze front with the winds blowing in behind it off of the sea. The maximum sea breeze inland penetration in this case was measured to be 194 km. However, when the land/sea temperature difference was amplified by 5 k, the maximum sea breeze inland penetration reached 198km, (4 km more than the original field).

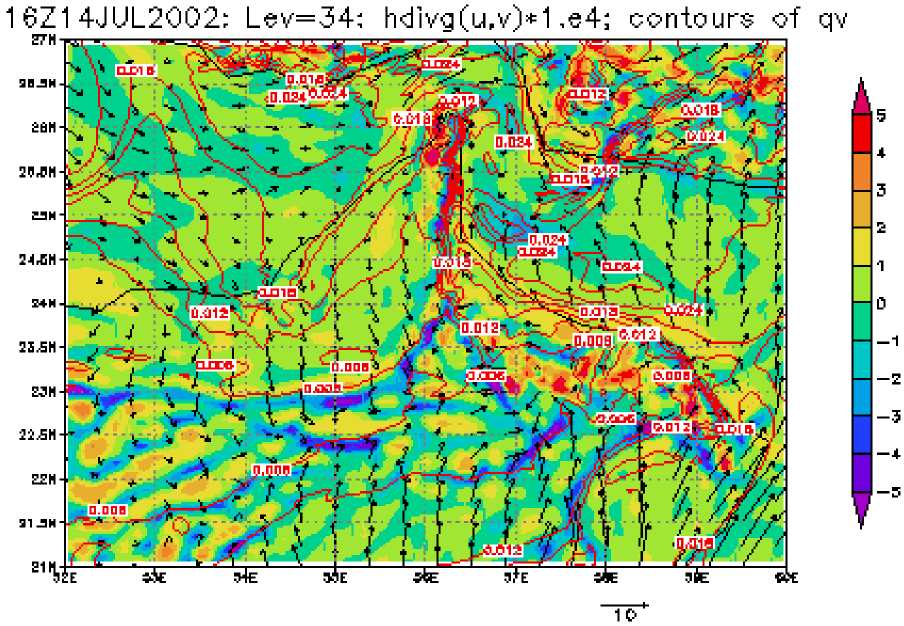

Figure 4: Maximum inland penetration in UAE for the original field.

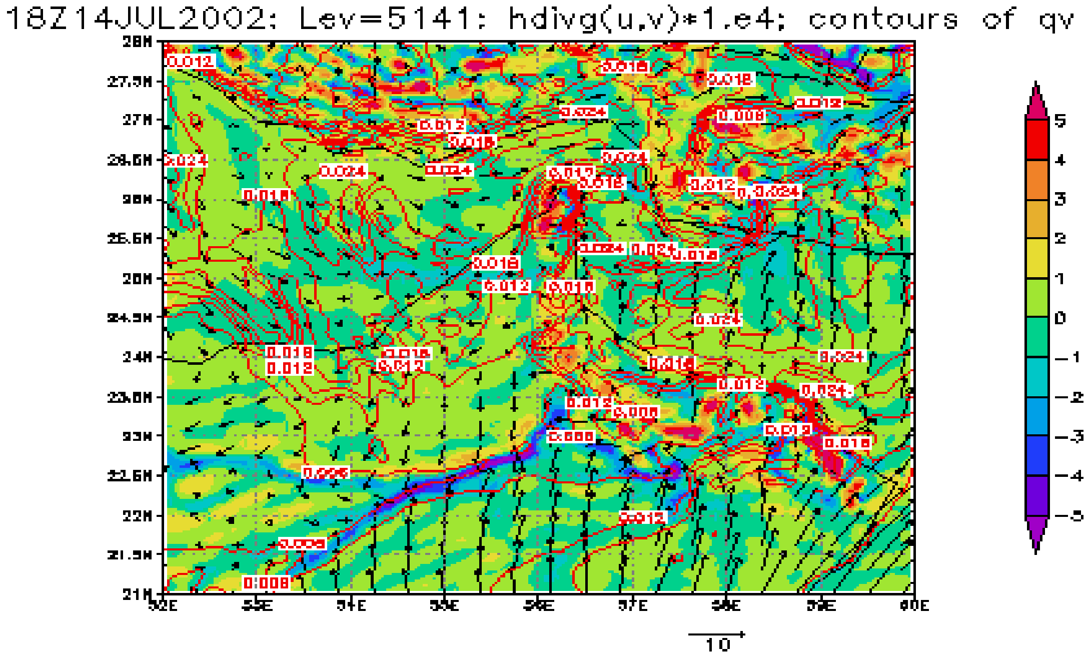

Figure 5 : Maximum SB inland penetration on UAE side with dt = 5 K

Moreover, GME boundary data are stored in archive server. This data can be used anytime to generate reruns for any desired date to help anyone who is interested in investigating an old weather case. The NWP team is currently rerunning old summer cases to help conduct a study on local thunderstorms in the chain of mountains (Al-Hajir) in Northern Oman.

- **Medium range forecast system**

For the medium range forecast is available up to seven days through German Global Model (GME), which we receive through the GTS. Other global models are also received through the GTS, such as ECMWF, EGRR, and KWBC.

- **MOS System / Verification Package**

From a subjective point of view, ORM has helped significantly in improving the accuracy of forecasts released to the public. To further enhance the quality of forecasts, DGCAM has also installed a Model Output Statistic (MOS) package in March 2003. MOS helped to filter out some systematic errors in the model, which resulted in better forecasts for parameters such as surface temperature and dew point, wind speed and direction, maximum and minimum temperatures. Moreover, MOS made it possible to introduce probability forecasts such as probability of fog and thunderstorms. Many scripts and applications have been introduced to manipulate the ORM outputs for Visualization, MOS and model verification.

From an objective point of view and in order to evaluate the quality of ORM, DGCAM has developed a verification package to verify some of ORM products against the observations. The ORM products, MOS products and the OBS are stored in a database for later use by the verification package. The package also applies several quality checks to avoid wrong observations. The package has a user friendly GUI to help the user select the desired options. For example, the user can select to verify observation against direct model output from ORM_07km, ORM_28km or to verify observations against MOS. The user also can select the element type (continuous or categorical), statistic to be used, the observation time, and the forecast range. The verification program can plot the results for a certain station or for a group of stations.

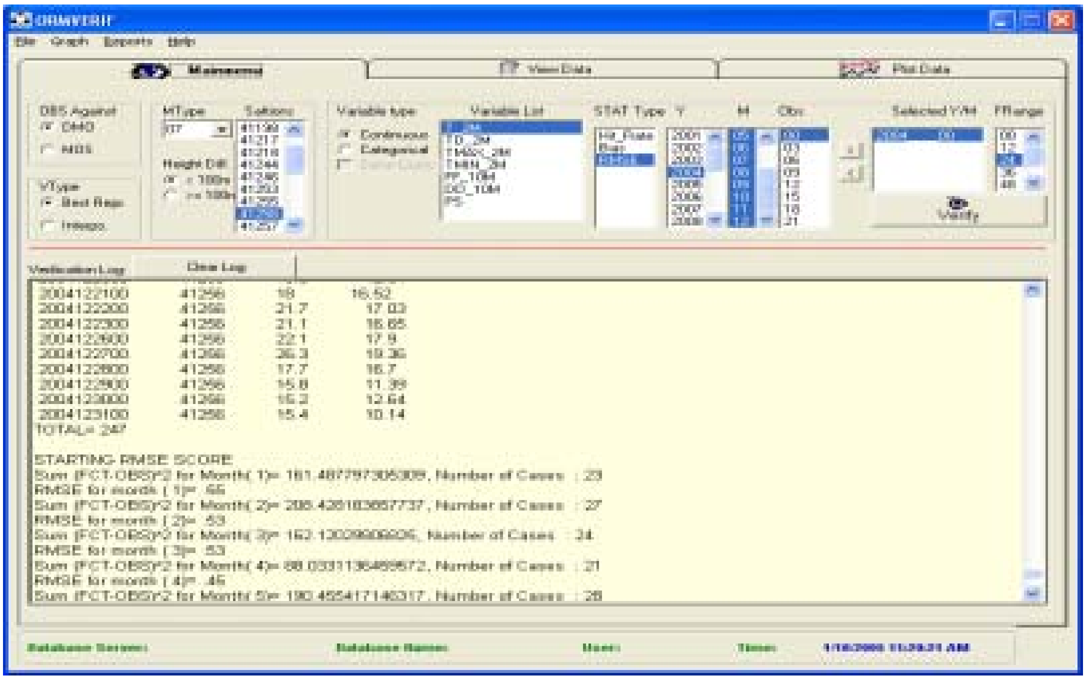

Figure 6 : Main GUI of the verification package

Statistic results tend to be much better for stations with height difference between the actual station height and the Grid point model height is less than 100m. Moreover, ORM_07km scores better results than ORM_28km. Figure 7 below is the ORM_28km T_2m bias for AbuDhabi (UAE capital) from January to August 2004 using the 09UTC observation against 09 hour forecast range. The results show little bias for Abudhabi with highest bias only slightly higher than 2 degrees during the month of April.

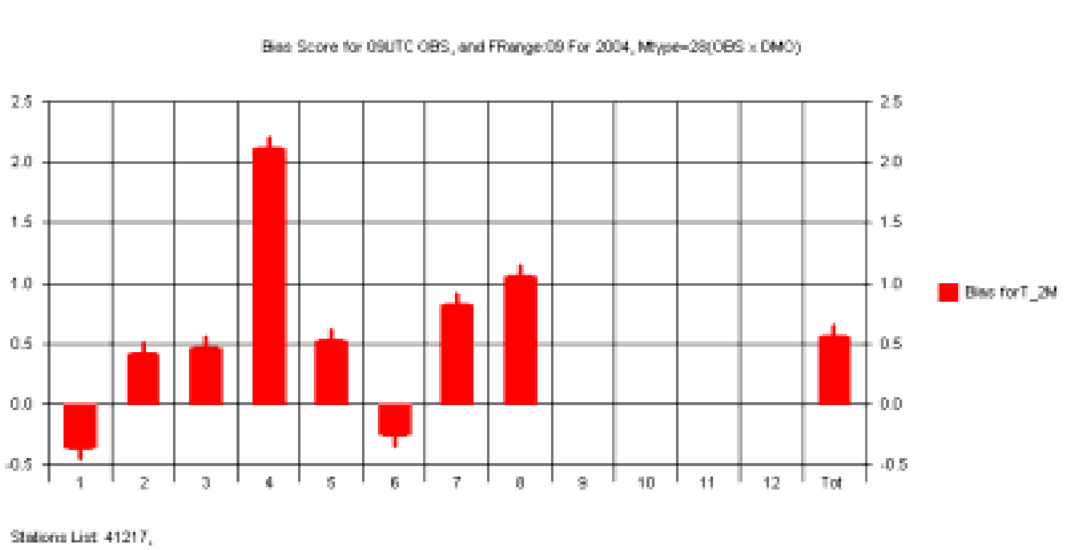

Figure 7: ORM_28km T_2m Bias for AbuDhabi from January to August 2004.

Figure 8 below is the ORM_07km T_2m for the same station and same forecast time. The bias results here are even better than those for ORM_28km with a close to zero bias during the month of May. The good results can be attributed to the fact that Abudhabi is a coastal station with no surrounding mountains in the area.

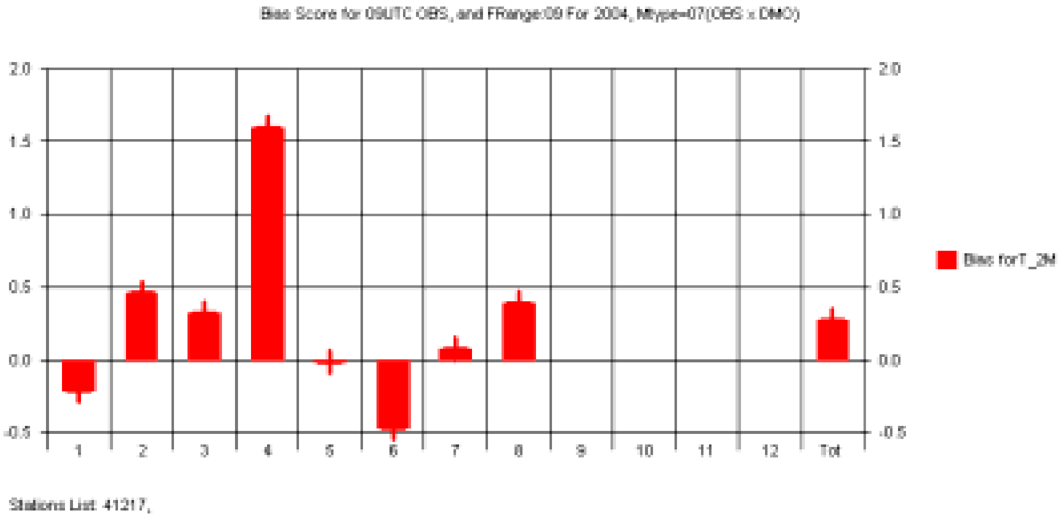

Figure 8: ORM_07km T_2m Bias for AbuDhabi from January to August 2004

However, ORM tends to show a big bias in mountainous areas. Figure 9 below shows the ORM_28km T_2m bias for Seeb from January to August 2004 comparing the 09 UTC observation against the 09 hour forecast. Seeb is a coastal station, which lies close to the chain of Al-Hajir Mountains in northern Oman. The height difference between the model and the actual station height of Seeb is greater than 100m in ORM_28km. As shown in the figure, ORM_28km tends to overestimate T_2m by an overall average of almost 8 degrees. However, the bias results are improved when using ORM_07km as shown in figure 10 below, where the total average bias drops to 3 degrees. This improvement is due to the fact that ORM_07km is able to see topography details much better than ORM_28km. The height difference between the model and the actual station height in ORM_07km is less than 100 m.

The use of MOS to filter out model systematic errors helps a lot in reducing model biases. Figure 11 is the MOS_ORM_28km T_2m bias for Seeb. Clearly, there is a major improvement and the total average bias is now dropped to .6 degrees only.

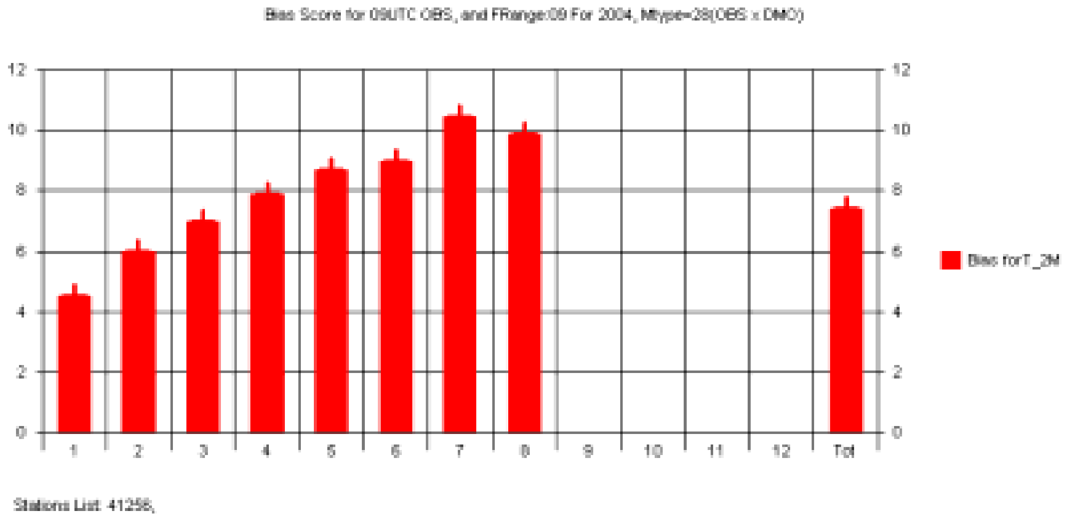

Figure 9: ORM_28km T_2m Bias for Seeb from January to August 2004

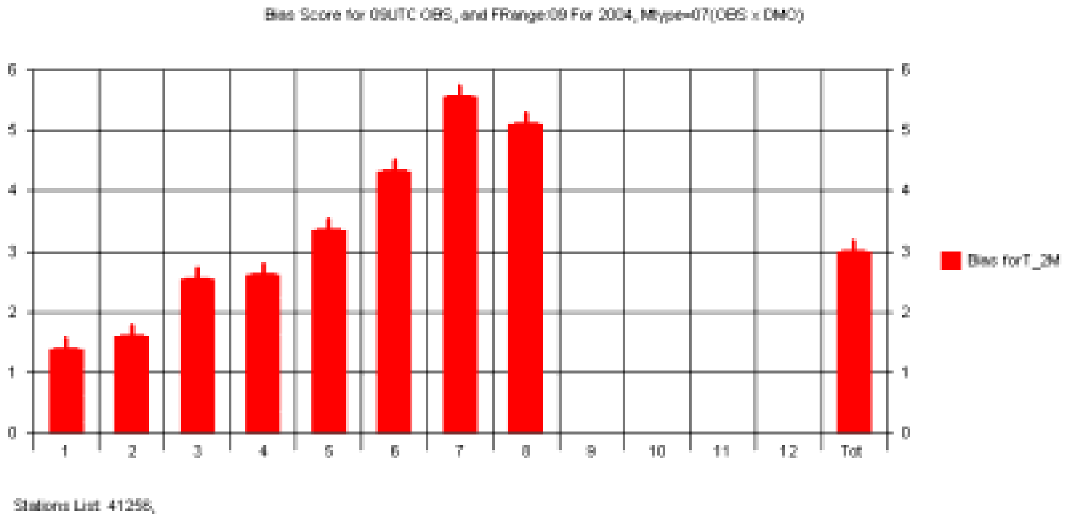

Figure 10: ORM_07km T_2m Bias for Seeb from January to August 2004.

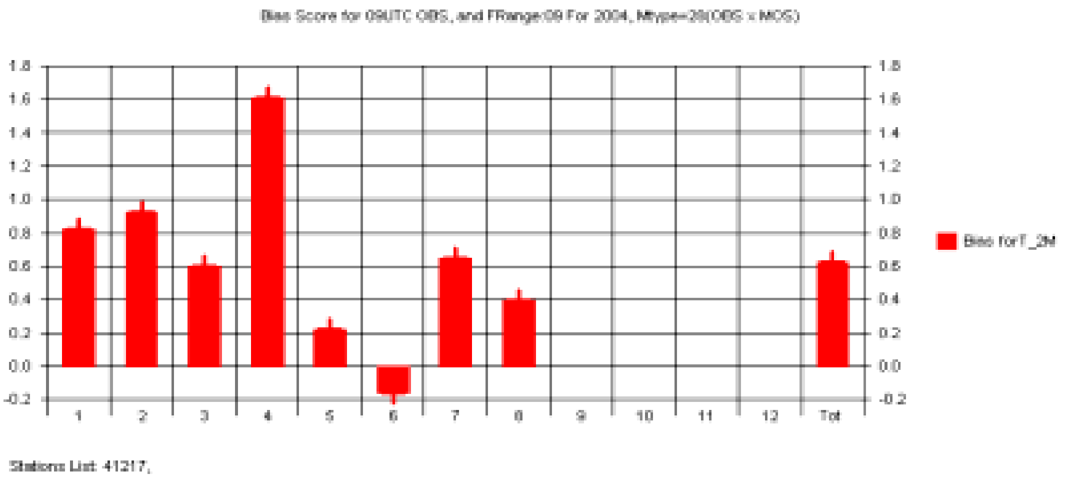

Figure 11: MOS_ORM_28km T_2m Bias for Seeb from January to August 2004.

The verification program can also plot an average values for (OBS, DMO and MOS) data in one graph in order to compare how these three parameters change with time.
Figure 12 below shows a one month average (June 2004) for the 78 hour forecast of T_2m and the corresponding MOS forecast and observations. The x-axis shows the forecast range in hours. This averaging confirms the superiority of MOS over DMO as illustrated by the closeness of the MOS curve (in blue) to the Observation curve (in red). The green curve is the direct model output (DMO). The averaging reveals that the temperature bias in this case is more pronounced during daytime as the DMO curve gets close to the OBS curve at nighttime as shown in the figure. This is probably due to the inability of ORM_28km to correctly forecast the onset of the sea breeze.

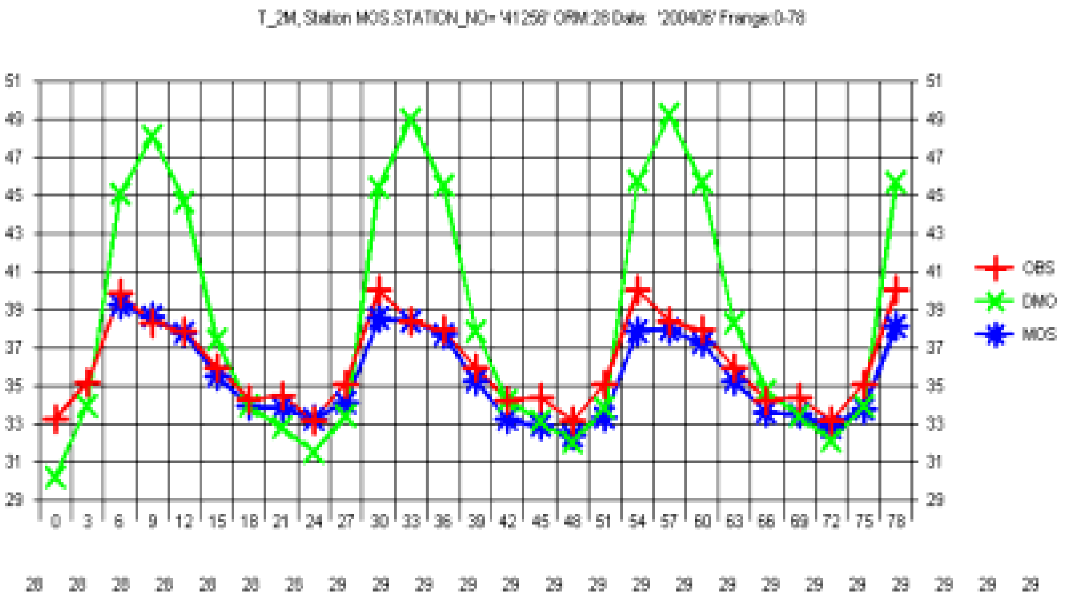

Figure 12: Seeb Station ORM_28km T_2m DMO, MOS, OBS Averages for June 2004.

- **Future Outlook**

Forecasting local summer thunderstorms over the chain of Al-Hajir Mountains in Northern Oman is a serious challenge. In order to improve the ability to forecast this local phenomenon, DGCAM is planning to run a regional non-hydrostatic model. Since non-hydrostatic models require powerful computer resources, DGCAM is planning to build it's own Linux Clustering System for running it's NWP models and applications.

DGCAM has recently activated a research section that will, with the help of ORM, perform case studies on weather phenomena affecting the region.

Moreover, DGCAM is in the process of objectively assessing the quality of its current regional model ORM using the locally developed verification package.