RevMexAA (Serie de Conferencias), **41**, 64–67 (2011)

VALIDATION OF THE VERTICAL PROFILES OF THREE METEOROLOGICAL MODELS USING RADIOSONDES FROM ANTOFAGASTA, PARANAL AND LLANO DE CHAJNANTOR

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RESUMEN

Esta investigación presenta una evaluación de tres modelos meteorológicos, el Global Forecast System (GFS), el European Centre for Medium-Range Weather Forecasts (ECMWF) y el modelo mesoescalar WRF (Weather Research and Forecasting) para tres sitios localizados en el norte de Chile. El Aeropuerto Cerro Moreno, el Observatorio Paranal y el Llano de Chajnantor estan ubicados a 25, 130 y 283 km de la ciudad de Antofagasta, respectivamente. Los resultados para los tres sitios, demuestran que la correlación más baja y los errores más altos se producen en superficie, donde el modelo ECMWF es el que presenta los mejores resultados en estos niveles para las dos horas analizadas. Esto podría ser por el hecho de que el modelo ECMWF cuenta con 91 niveles verticales, en comparación de los 64 y 27 niveles verticales que poseen los modelos GFS y WRF, respectivamente, por lo que puede representar mejor los procesos en la Capa Límite Planetaria (CLP). En relación a la tropósfera media-alta, los tres modelos presentan buenos resultados.

ABSTRACT

This research presents an evaluation of three meteorological models, the Global Forecast System (GFS), the European Centre for Medium-Range Weather Forecasts (ECMWF) and the mesoscale model WRF (Weather Research and Forecasting) for three sites located in north of Chile. Cerro Moreno Airport, the Paranal Observatory and Llano de Chajnantor are located at 25, 130 and 283 km from the city of Antofagasta, respectively. Results for the three sites show that the lowest correlation and the highest errors occur at the surface. ECMWF model presents the best results at these levels for the two hours analyzed. This could be due to the fact that the ECMWF model has 91 vertical levels, compared to the 64 and 27 vertical levels of GFS and WRF models, respectively. Therefore, it can represent better the processes in the Planetary Boundary Layer (PBL). In relation to the middle and upper troposphere, the three models show good agreement.

Key Words: atmospheric effects — site testing

1. INTRODUCTION

It is necessary and important for astronomers to assess the outputs of meteorological models in order to obtain reliable atmospheric forecasts for the next 12 to 72 hours. This will improve the quality of astronomical observations and will ensure an effective scheduling of telescopes and radiotelescopes. For this reason, temperature and wind speed vertical profiles from the GFS (Global Forecast System), ECMWF (European Centre for Medium Range Weather Forecast) and WRF (Weather Research and Forecasting) models were evaluated with operational radiosondes launched at Antofagasta (Cerro Moreno) and radiosondes launched during several campaigns at the Llano de Chajnantor and the Paranal Observatory (Table 1). These campaigns were carried out by Valparaíso University in conjunction with ESO (European Southern Observatory).

TABLE 1

GEOGRAPHIC COORDINATES AND ALTITUDES OF THREE SITES

Sites	Latitude	Longitude	Altitude
Cerro Moreno	23° 27′ S	70° 27′ W	140 m
Cerro Paranal	24° 40′ S	70° 25′ W	2635 m
Ll. Chajnantor	23° 01′ S	67° 46′ W	5104 m

2. MODEL DESCRIPTIONS

2.1. *GFS Model*

The GFS is a 384-hour global model for short range and medium range forecasting. It was developed by NCEP and is run every six hours at 00, 06, 12 and 18 UTC. Its domain encompasses the entire

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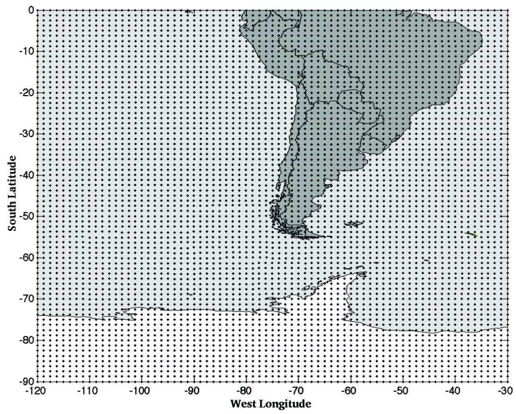

Fig. 1. Octant P of GFS model.

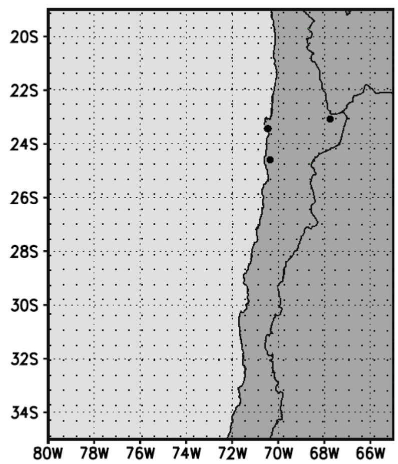

Fig. 2. ECMWF model.

earth, dividing the globe into eight octants giving to South America the octant P (see Figure 1). It has a horizontal resolution of around 120 km and the vertical resolution is 64 levels but provides information in 12 mandatory pressure levels (from 1000 hPa to 70 hPa).

2.2. *ECMWF Model*

The ECMWF (the Centre) was founded in 1975 as a consortium of European countries agreed to join forces to create a center specializes in forecasting the medium term (between 2 and 10 days). The horizontal resolution is about 60 km at Chilean latitudes (Figure 2) and divides the atmosphere into 91 layers up to 0.1 hPa (≈64 km) but provides information in 9 mandatory pressure levels (from 1000 hPa to 100 hPa). ECMWF produces routine global analyses for the four main synoptic hours 00, 06, 12 and 18 UTC and global 10-day forecasts.

TABLE 2

RESOLUTION OF THE DOMAINS USED IN THIS STUDY BY WRF MODEL

Domain	Resolution	Grid points
1	27 km	43 × 47
2	9 km	52 × 49
3	3 km	61 × 64
4	1 km	70 × 70

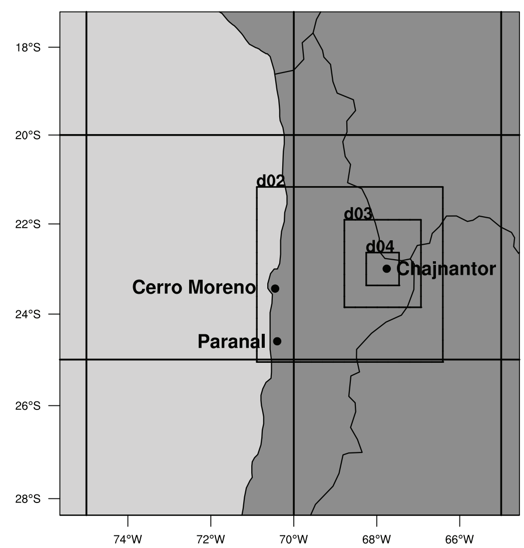

Fig. 3. Nesting map used in this study by WRF for three sites.

2.3. *WRF Model*

WRF is non-hydrostatic, with several dynamic cores as well as many different choices for physical parameterizations to represent processes that cannot be resolved by the model (Michalakes et al. 2001). This allows the model to be applicable on many different scales. The WRF model was configured with 27 vertical levels and the horizontal resolutions used were:

Initial and boundary conditions for WRF are provided from FNL analysis. We used domains 1 and 2 for Cerro Moreno and Paranal, and domain 4 for the Llano de Chajnantor (Table 2).

3. DATA AND METHODOLOGY

3.1. *Data*

For different study periods (Table 3), we only used the 12 and 36 hours forecasts of the 00 UTC run of three models and we only used the models the radiosondes launched at 12 UTC.

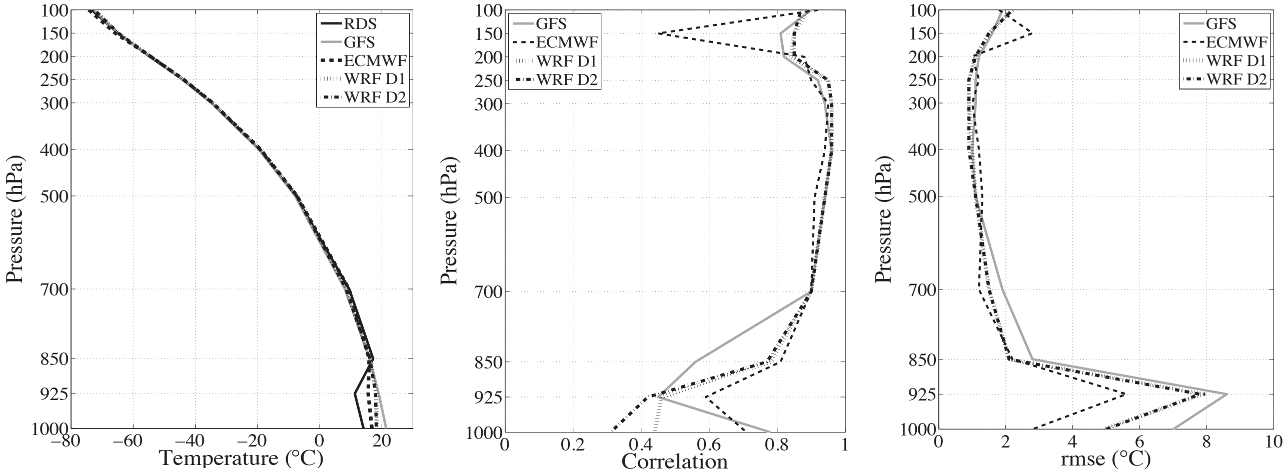

Fig. 4. Vertical (a) mean, (b) correlation and (c) rmse profiles at Cerro Moreno for 12 hour forecast temperature.

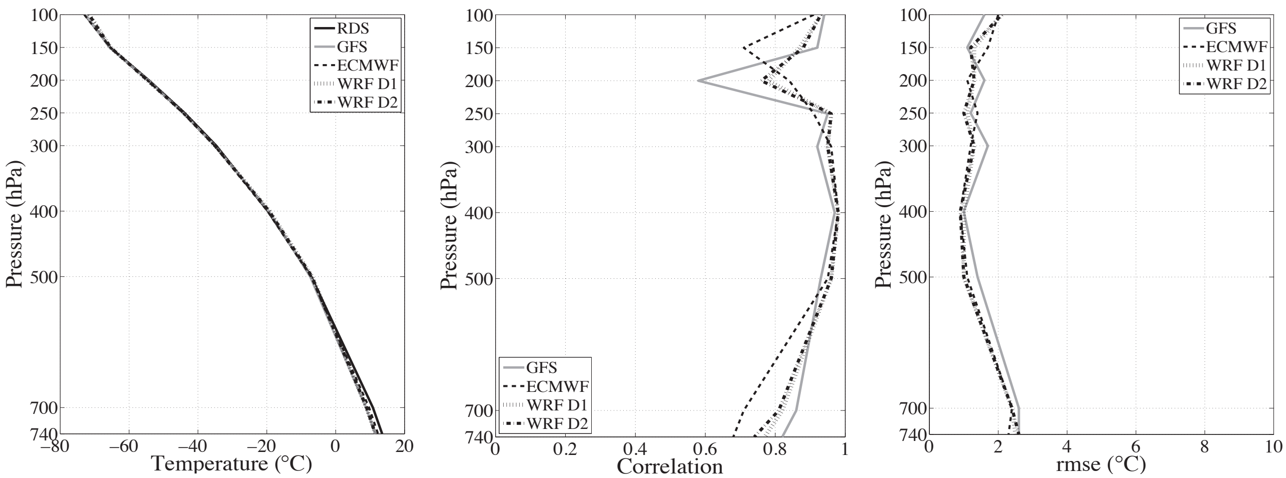

Fig. 5. Vertical (a) mean, (b) correlation and (c) rmse profiles at Cerro Paranal for 12 hour forecast temperature.

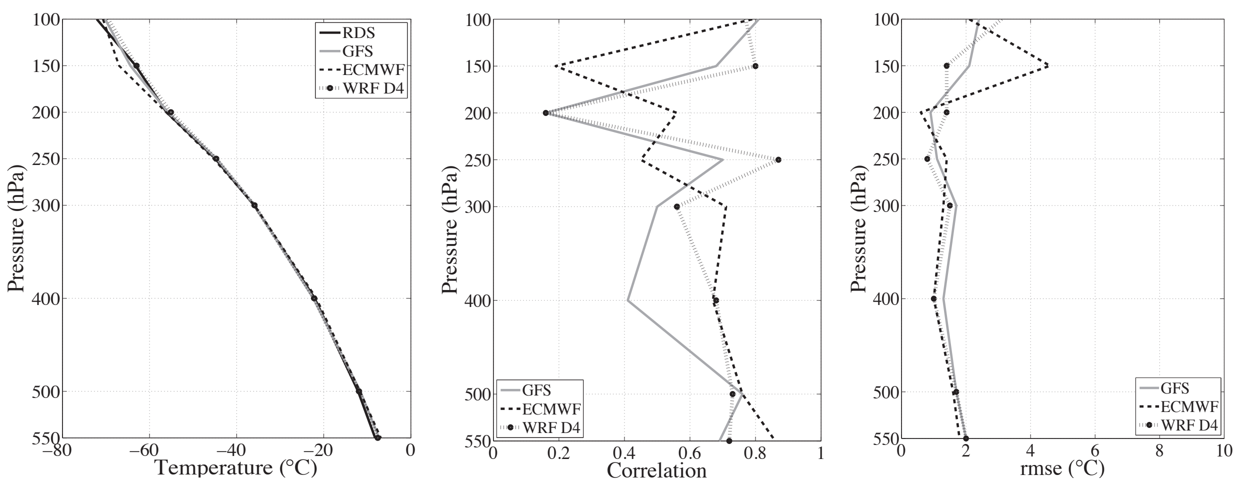

Fig. 6. Vertical (a) mean, (b) correlation and (c) rmse profiles at Llano de Chajnantor for 12 hour forecast temperature.

TABLE 3

STUDY PERIODS FOR EACH SITE

Site	Period
Cerro Moreno	March 2007 - February 2008
Llano de Chajnantor	July 7-16, 2009
Cerro Paranal	July 29 to August 10 and November 8-19, 2009

3.2. *Methodology*

1. Variables from the models were obtained using a bilineal interpolation at each pressure level (Benzi et al. 1997).

2. A spline cubic interpolation was used to obtain model variables at different mandatory pressure levels (Press et al. 2007).

3. Statical analysis, lineal correlation and root mean square error (rmse).

4. RESULTS

In this proceeding we present only the results of the temperature for three models. Only the results of temperature for the 12 hour forecasts are presented (the results for the 36 hour forecasts show the same trend, but the errors increase).

4.1. *Cerro Moreno*

The Figure 4a show that the three models do not reproduce the increase of temperature with height defined as subsidence inversion (black solid line, at 925 hPa and 850 hPa) produced by adiabatic heating of air as it sinks and is associated with South Pacific Subtropical Anticyclone (SPSA), thus producing the lowest correlation (Figure 4b) and highest rmse (Figure 4c) values near the surface. ECMWF model presents the best results at these levels. This could be due to the fact that the ECMWF model has 91 vertical levels, compared to the 64 and 27 vertical levels of GFS and WRF models, respectively. Therefore, it can represent better the processes in the Planetary Boundary Layer (PBL). From 700 hPa to 100 hPa the three models show good agreement except the result of the interpolation at 150 hPa of the ECMWF model (dashed line) is not good, thus producing the lowest correlation and highest rmse values at this level.

4.2. *Cerro Paranal*

The three models show a good agreement reproducing the mean temperature vertical profile at middle and upper levels (Figure 5a). The three models show high correlations at all levels (Figure 5b). As at Cerro Moreno, the three models show large rmse (Figure 5c) values near the surface where the ECMWF produces the best results at and below 700 hPa. This could be because Cerro Moreno and Paranal are directly influenced by SPSA, so that the ECMWF model can better simulate patterns worldwide.

4.3. *Llano de Chajnantor*

The three models show a good agreement reproducing the mean temperature vertical profile at all levels (Figure 6a) except the ECMWF model at 150 hPa. Overall, the correlation coefficient is bellow 0.8 (Figure 6b). May be due to the complex terrain and high altitude of the Llano de Chajnantor could bring difficulties to the simulations for three models. With respect to rmse ((Figure 6c), overall, is bellow 2°C except the result of the interpolation at 150 hPa of the ECMWF model (dashed line) is not good, thus producing the lowest correlation and highest rmse values at this level.

5. CONCLUSIONS

The temperature vertical profile at low levels is better represented in the ECMWF model than the GFS and WRF model in Cerro Moreno and Paranal. This could be due to the fact that the ECMWF model has 91 vertical levels, compared to the 64 and 27 vertical levels of GFS and WRF models, respectively. Therefore, it can represent better the processes in the Planetary Boundary Layer (PBL).

The three models show a good agreement reproducing the mean temperature vertical profile at middle and upper levels, because surface friction decreases with height and the atmosphere is more homogeneous, being easier to simulate its behavior.

To Marck Sarazin from ESO for providing data of the ECMWF model and Diana Pozo from Universidad de Valparaíso for her support of this work.

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