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Evaluation of the NUV Forecast Performance Against Ground-based Measurements in Southern South America

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Abstract. Reliable UV Index (UVI) forecast is a relevant tool to inform the population about the potential health risks of sun exposure in a specific temporal horizon. In this work, the 1-day local-noon Near-Real-Time UV index forecast (NUV) for clear sky (NUV/CLEAR) and for all-sky condition (NUV/CLOUD) is evaluated against ground-based measurements in six sites of the Argentine solar radiation network *Saver-Net*, covering the latitudinal range from ~30ºS to ~52°S. NUV/CLEAR is calculated using GOME-2 assimilated total ozone (ATO) as the only forecasted dynamic input, while all other atmospheric parameters and surface albedo are taken from climatology. NUV/CLOUD incorporates clouds to NUV/CLEAR using the ECMWF cloud cover fraction forecast as input. NUV/CLEAR presents an excellent correspondence with respect to ground-based observations, with low values of RMSE and MAE and high correlation with coefficient of determination above 0.99. As expected, the correspondence decreases when cloudiness is included, although NUV/CLOUD still shows a reasonable agreement.

INTRODUCTION

The interest in monitoring surface UV radiation and ozone levels increased since the 1980s stratospheric ozone depletion as the ozone layer acts as a natural filter to radiation in this wavelength band, particularly UVB. The importance of providing information about the UV index lies in the risks that this type of radiation has on people's health and other biological consequences due to overexposure. In turn, a small dose of UVB is essential for the synthesis of Vitamin D in human skin, although this dose is significantly lower than that to produce erythema [1].

The Near Real-Time UV Index (NUV) forecasts based on satellite information is a valuable tool to inform the population about the potential risks. On the other hand, high quality ground-based measurement is the more accurate technique to determine locally the surface solar radiation. Thus, the evaluation of the performance of a given satellite-based UVI forecast against ground-based measurements is the most rigorous test for a punctual location and allow determining the representativeness of the forecast in a site.

The aim of this work is to evaluate the NUV forecast by comparison with ground based UVI observation in six sites of the Saver-Net solar radiation network installed in Argentina [2]. This region is particularly interesting due to the ozone hole often reach sub-polar regions and overpass the South of South America during southern spring deriving in unusual increases of surface UV Index [3-4]. This fact highlights the importance to provide reliable information about the surface solar UV Index in the evaluated region.

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METHODOLOGY AND DATABASES

NUV Forecast

NUV forecast produces the UVI in clear-sky (NUV/CLEAR) and all-sky condition (NUV/CLOUD) for local noon (i.e. maximum solar elevation) with a spatial resolution of 0.25° x 0.25°. The forecast is daily available at 2 UTC of the current date. It employs the UVSPEC [5] radiative transfer model using the discrete ordinates algorithm (DISORT) [6]. The calculations are performed with total ozone as the only dynamic input parameter. All the other atmospheric inputs and the surface albedo include climatological values. Forecasted GOME-2 Assimilated Total Ozone data (ATO, version 4.2) produced by KNMI is used as the primary input source, available every day at 2 UTC. In the case of unavailability of ATO data, ECMWF total ozone forecast or total ozone climatology from TOMS are used as second and third ozone input options, respectively. NUV/CLOUD is obtained from NUV/CLEAR applying a correction factor that accounts the cloud cover using fractional cloud cover forecast from ECMWF (European Centre for Medium-Range Weather Forecasts) in three levels: low (approximate altitude 0-2 km), medium (2-6 km) and high (above 6 km) clouds (available since 2016). A damping coefficient, empirically derived from calibration against ground-based measurements, applies to each layer. A full description of the NUV product can be found in http://nuv.dmi.dk/nuv/. Data are available upon request.

Study Area and Ground-based Observations

The comparison between NUV data and ground-based measurements was carried out in the Southern cone of South America. Table 1 describes the location, instrument and the period considered in the comparison, belonging to the Saver-Net solar radiation network [2].

TABLE 1. Ground-based stations, location, instrument used and period analyzed for each site.

Station City (Province)	Location(altitude)	Instruments	Period
Pilar (Córdoba)	31.68ºS, 63.87ºW (330 m a.s.l.)	K&Z UVB	1/11/2017 – 31/10/2019
Villa Martelli (Buenos Aires)	34.58ºS, 58.48ºW (25 m a.s.l.)	YES UVB	1/1/2016 – 30/12/2018
Neuquén (Neuquén)	38.95ºS, 68.14ºW (270 m a.s.l.)	YES UVB	14/12/2016 - 13/12/2018
Bariloche (Rio Negro)	41.15ºS, 71.16ºW (846 m a.s.l.)	YES UVB	16/3/2016 – 27/2/2018
Comodoro Rivadavia (Chubut)	45.78ºS, 67.50ºW (43 m a.s.l.)	YES UVB	19/1/2016 – 17/1/2018
Río Gallegos (Santa Cruz)	51.60ºS, 69.32ºW (15 m a.s.l.)	YES UVB	1/1/2016 – 30/12/2017

The ground-based measurements of erythemal UV (UVE: UV filtered with the erythema reference action spectrum ISO/CIE 17166:2019) were obtained from YES UVB-1 radiometers, except for Tucumán and Córdoba which have installed a radiometer Kipp&Zonen serie SUV-E. A factor of 40 is applied to obtain the UV index following the definition of the WMO [7].

NUV Forecast Evaluation

The evaluation of the NUV forecast at local noon for each site is performed by comparing with UVI ground-based measurements at the minimum SZA (one-minute averaging) by means of a linear regression analysis. Other larger averaging times periods up to one hour were tested and was found little change in the results. The root mean squared error (RMSE) and the mean absolute error (MAE) are also analyzed. Table 1 describes the time period compared in each station. As the fractional cloud cover forecast from ECMWF has been available since the beginning of 2016, the comparison starts in that year except in sites where the ground-based instrument was installed after 2016. As a strategy to minimize the effect of sensor degradation, the first available two years of data since 2016 are used for the comparison. A filter to determine clear-sky conditions from the ground-based measurement was implemented to also evaluate the performance of the forecast under clear-sky conditions (NUV/CLEAR).

RESULTS

Figure 1 presents the scatter plot between 1-day local-noon NUV forecast UVI vs. ground-based UVI for clear-sky and all-sky condition together with the corresponding linear regression analysis.

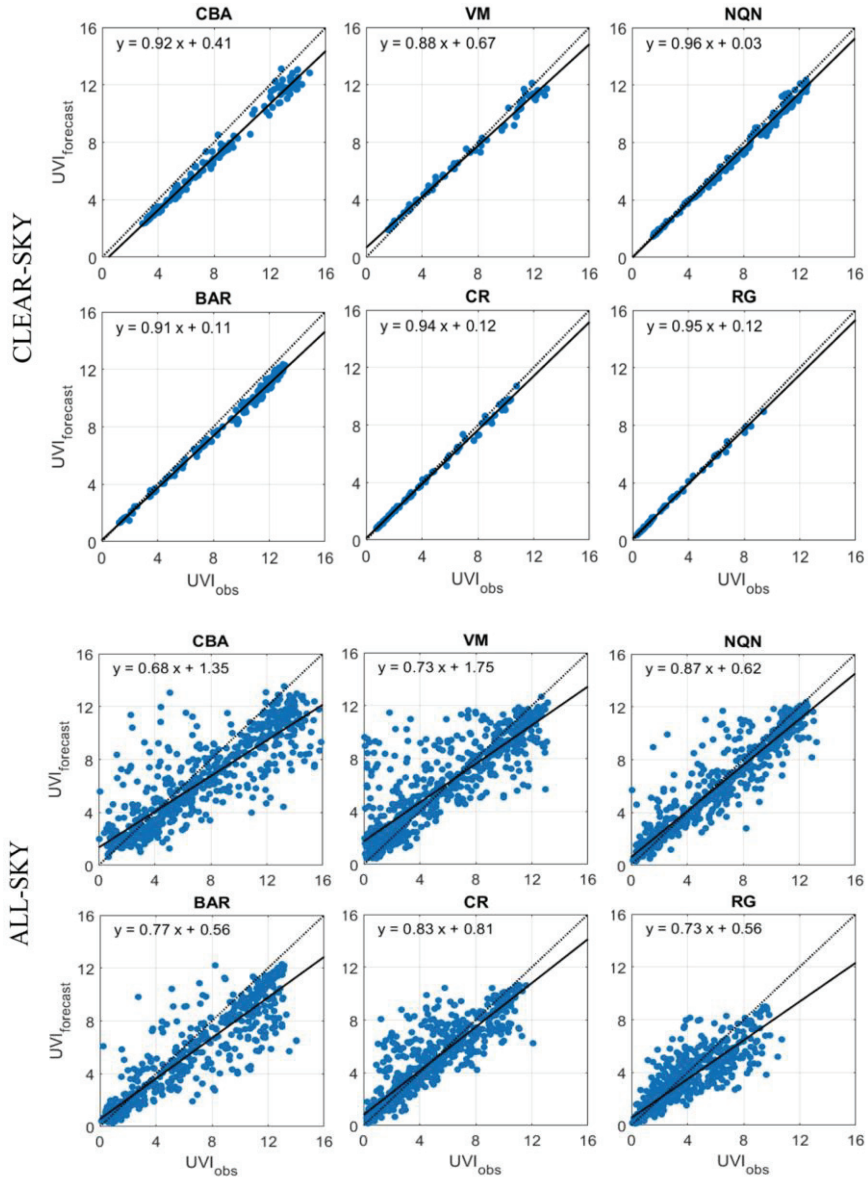

FIGURE 1. Scatter plot of the UV Index forecast versus ground-based observations for clear-sky (top) and all-sky (bottom) condition, linear regression (black line) and 1:1 line (black dotted line) for each station.

Table 2 presents the metrics of the comparison for clear-sky and all-sky conditions. As expected, all the metrics improve under clear-sky condition reflecting an excellent correspondence between forecast and measurement with coefficient of determination greater than 0.98 for all sites, and low RMSE and MAE values. In general, the linear regressions analysis under clear-sky condition suggests that the forecast slightly underestimates the UVI in all the sites. The slope present values above 0.9 except for Buenos Aires (0.88) given account that the difference between measurement and model can reach 12% for clear-sky condition. The correspondence between forecast and ground-based measurement decreases significantly including cloudiness. Pilar shows the weakest correspondence with highest values of RMSE and MAE despite the fact that this site presents the highest ratio between clear-sky pairs and all-sky pairs (N_{clear}/N_{all}) in the period analyzed. It is observed that Neuquén and Río Gallegos present the best performance in terms of RMSE and MAE with values below 1.30 and 0.90, respectively.

TABLE 2. Metrics of the UVI forecast and ground-based linear regression for each station and for clear and all-sky conditions. N: number of pairs compared for all-sky (N_{all}) and clear-sky (N_{clear}). R2: coefficient of determination. RMSE: root mean squared error; MAE: mean absolute error.

	ALL SKY				CLEAR SKY			
Site	N_{all}	R^2	**RMSE**	**MAE**	N_{clear}	R^2	**RMSE**	**MAE**
Pilar (CBA)	643	0.73	2.42	1.79	160	0.99	1.10	1.00
Villa Martelli (VM)	702	0.73	2.07	1.32	77	0.99	0.57	0.46
Neuquén (NQN)	666	0.89	1.29	0.84	153	0.99	0.48	0.39
Bariloche (BAR)	549	0.83	2.04	1.40	131	0.99	0.82	0.71
Comodoro Rivadavia (CR)	723	0.81	1.42	0.87	103	1.00	0.28	0.17
Río Gallegos (RG)	705	0.77	1.27	0.79	74	1.00	0.16	0.10

CONCLUSIONS

We evaluate the performance of the NUV forecast at local noon by comparison with ground-based measurements for clear and all-sky conditions in 6 sites of Argentina. It is noted that the correspondence decreases when the forecast incorporates the cloudiness in the calculation. It is expected due to the uncertainty introduced by the cloudiness forecast in the calculation. On the other hand, part of the difference can be attributed to the difference between the spatial resolution of the forecast and the punctual ground-based measurement, which have intrinsic limitations. For example, while ground measurement can observe increases for enhancement due to the increase in the diffuse component by reflections in the edge of clouds, the forecast will be accounting that situation as attenuation due to the cloud cover above zero. This fact can introduce differences that are related with limitations of each technique and thus limit the representativeness of the forecast in punctual sites that should be taken into account when using the information or even when assessing the risk of exposure.

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