Short- and Medium-Range Rainfall Attenuation Forecast for South America and the Caribbean

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Abstract

An automated experimental forecast system for telecommunication signal attenuation due to rainfall in South America and the Caribbean is presented and discussed. The rationale is to take advantage of the available state-of-the-art weather and climate models in addition to the traditional approach that makes use of the probability of rainfall exceedance estimation for a certain period. The system, called CAVeAT, consists of a combination of a high resolution (30 km) downscaling atmospheric circulation model and the standard ITU-R rain attenuation model, providing 72 h and seasonal scale experimental forecast for the considered regions. It is argued that CAVeAT should be employed as a first guess forecast system for rain attenuation until field campaigns can validate its results. The system is freely available on the Centro de Modelado Científico (CMC) of Zulia University (Venezuela) web portal: http://cmc.org.ve/ole2/iwp.html*, as part of the Observatorio Andino Project.*

Keywords: rainfall attenuation forecast, precipitation forecast, ITU-R.

1. Introduction

The atmosphere, being constituted in a stratified and not very homogeneous way, makes electromagnetic (e-m, from now on) signals propagating through it to experiment different kind of variations [1]. Attenuation is one of the most important concerns for actual telecommunication technologies, as it involves intensity changes on the e-m waves propagation [2] that need to be considered so quality products can be provided to the "last mile" user. The magnitude of the attenuation depends on several factors: beam trajectory, atmospheric gases concentration, dust and aerosols presence and rain. Nevertheless hydrometeor attenuation is responsible of the main effects for frequencies above about 10 GHz [3,4], but must always be considered when interested in frequencies above 1 GHz.

In South America and the Caribbean, like in the rest of the planet, the planning of Earth-space telecommunication and also "surface" systems follows the International Telecommunication Union (ITU) recommendations [3], which for attenuation prediction make use of expressions involving the probability of rainfall exceedance time for a certain period (e.g., a year). Thus, a precise determination of the typical and extremes precipitation values for a region is of capital importance for telecommunication industry.

With the aim of characterizing the mean rain attenuation and its variability in space and time, the Centro de Modelado Científico (CMC) of Zulia University (Venezuela) has recently developed [4] a software package called CAVeAT: Código Abierto Venezolano de Atenuación Troposférica (i.e. Venezuelan Open Source for Tropospheric Attenuation), which has been freely accessible for a while now [5]. Originally designed for Venezuela, CAVeAT is mainly a system that, using the ITU-R standards and historical rain gauges, or satellite/model gridded precipitation data, can compute the attenuation for e-m waves according to season, location and e-m wave frequency. The system is now being generalized for considering the whole South America and the Caribbean domain.

Nonetheless, taking advantage of the modern models for weather and seasonal forecast, it is possible to predict (on a experimental basis at least) the expected behavior of the rain attenuation component for a few hours or, in a more "statistical" way, the next season. Obviously this is not a zero uncertainty system due to the non-linear character of the Climate System and other factors, and still a study about the frequency of extreme precipitations and also about the mean and variability of rainfall for space and time will be needed for telecommunication links long-term planning. But it is expected that this kind of forecasting tool will be able to provide at least an approximate idea of the general behavior for liquid hydrometeor attenuation for the short- and medium-term, which in turn will help the telecommunication service provider to make the possible adjustments, if necessary, so a quality product could be delivered to the users.

Thus, CAVeAT will be able to provide both a retrospective characterization (as extended as quality rain gauge data is available), and a short- and medium range prediction for the of the rain attenuation behavior in a sector. There is no such a system nowadays for South America and the Caribbean, and it is expected that its use will provide in general a better telecommunication service in the region.

The CAVeAT "prediction component" being still in an experimental stage, the aim of this paper is to explain the methodologies and structure designed for such a system. In the next section the precipitation model and its configuration are presented for both short- and medium-range forecasts. Section 3 treats the rain attenuation model, following the ITU-R standard expressions. The system considering the coupling of the precipitation and attenuation models is discussed in section 4. Finally, the general discussion and conclusions appear in section 5.

2. The Rainfall Model

The Weather Research and Forecast (WRF) system is employed for the purpose of (liquid) precipitation forecasting. The WRF model is designed to be a flexible, state-of-the-art, portable code that is efficient in a massively parallel computing environment [6]. A modular single-source code is maintained that can be configured for both research and operations. It offers numerous physics options, thus tapping into the experience of the broad modeling community. For additional information about WRF model see [6].

CAVeAT makes use of the WRF products available from CMC as part of the Andean Observatory Project [7]. Both kinds of products are briefly explained in the following subsections.

2.1. Short-Term Forecast

The WRF model uses the Global Forecast System (GFS) [8] output as initial conditions for the integration. The downscaling process provides precipitation maps for South America and the Caribbean at 30 km spatial resolution, accumulated each 3 hours, for the next 3 days. This kind of temporal resolution enables the telecommunication service provider to be aware of possible extreme events in a specific region of interest, at a certain time of day.

An example of the precipitation forecast product (in mm) is presented in Figure 1. It can be seen that the output considers the effects of complex topographic features present in the domain, due to the high resolution achieved by the configuration.

2.2. Medium-Term Forecast

In this case, a global forecast is needed, with high (at least 6 hours) temporal resolution, so the downscaling process can be effectively done. The Community Atmospheric Model (CAM, [8]) is used at CMC for providing this kind of planetary products. Then the CAM output is transformed to the necessary WRF format and the latter is executed on a seasonal (three months) basis using as boundary conditions the global fields of the former.

Figure 2 exhibits a typical seasonal product for precipitation, in terms of the rainfall anomaly (in %).

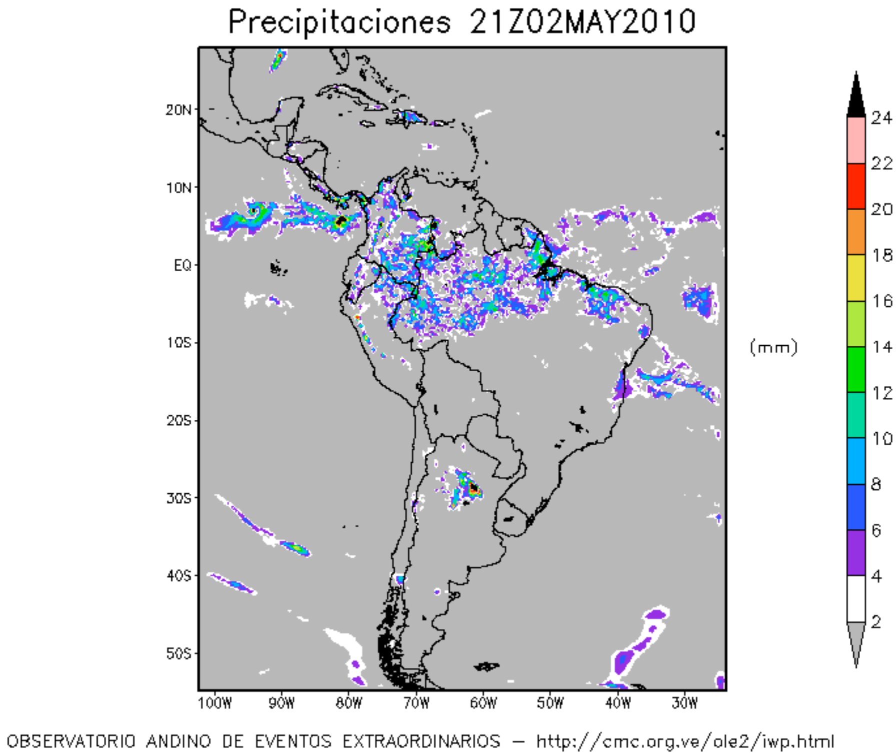

Figure1. Accumulated Precipitation (3-hours) at 21Z for May 2th, 2010

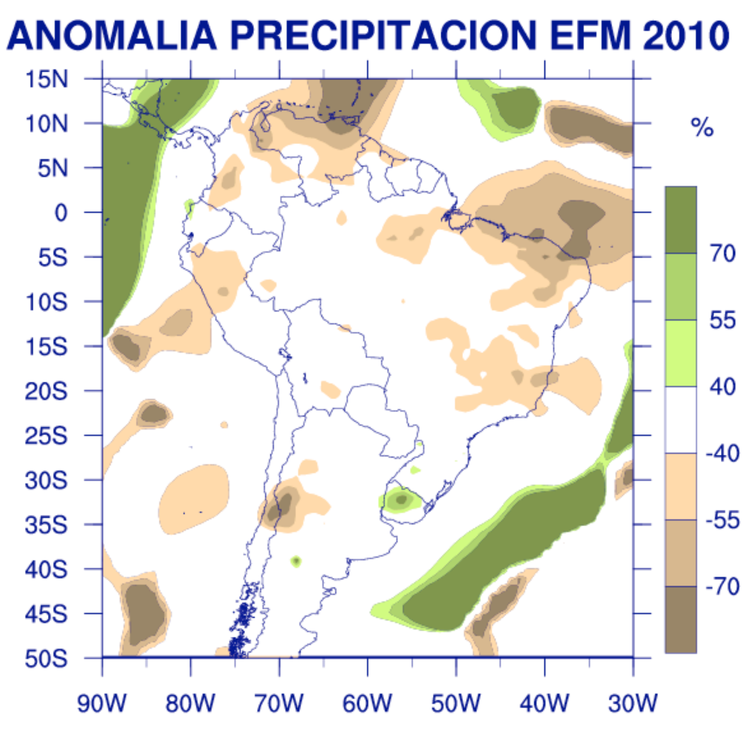

Figure 2. Precipitation seasonal (anomaly) forecast for January-February-March 2010

3. The Attenuation Model

As mentioned before, hydrometeors like rain, snow and hail, behave as an attenuation factor for the e-m waves, causing losses in their intensity and according to the ITU recommendations [3] can be calculated in a pretty exact way through the following expressions

$$\gamma = LR^{\beta} \tag{1}$$

where R is the rain intensity in mm/h, and L and β are constants that depend on the frequency and differ for vertical and horizontal polarization. (L_h, L_v, β_h, β_v).

The coefficients L and β can be calculated, alternatively, as a function of the frequency [3], from equations that have been obtained from curve adjustments done to the coefficients of low power derived for scattering calculations, which are:

$$\log(L) = \sum_{j=1}^{3}\left(a_j \exp\left[-\left(\frac{\log(f)-b_j}{c_j}\right)^2\right]\right) + m_L \log(f) + C_L \tag{2}$$

$$\beta = \sum_{i=1}^{4}\left(a_i \exp\left[-\left(\frac{\log(f)-b_i}{c_i}\right)^2\right]\right) + m_\beta \log(f) + C_\beta \tag{3}$$

where
f: frequency (GHz)
L and β: are $L_h$and L_v, β_h and β_v are the corresponding components for horizontal and vertical polarizations.

4. Experimental Attenuation Forecast System

The CAVeAT system makes use of the weather and seasonal products explained in Section 2 and, with the help of equations (1)-(3), the rain attenuation maps are computed at 30 km cell resolution and for the whole time period under consideration.

The before mentioned precipitation fields, for both short- and medium-range scales, are introduced in equation (1) via the rain intensity *R*, which varies in space. Thus, knowing L_h, L_v, β_h and β_v, equation (1) provides the spatial map for rain attenuation in dB/km. The maps are generated using the Grid Analysis and Display System (GrADS).

Two examples of the results are sketched in Figures 3 and 4. The general rain attenuation distribution, as expected, strongly follows the precipitation pattern in the domain. Nevertheless, even when the orders of magnitude for attenuation and its spatial structure seems to represent adequately the mean behavior, it is necessary to remember that CAVeAT forecast are still experimental, and that there is a need for direct measurements on field campaigns so the results can be validated.

5. Discussion and Concluding Remarks

An experimental system, part of the CAVeAT package [1,2,4], for providing rain attenuation forecasts for South America and the Caribbean has been presented in the present pages. The general idea is simple: to take advantage of the modern weather and seasonal atmospheric models so the rain intensity can be provided and thus the ITU-R standard expressions (equations (1)-(3)) can be directly used for generation of the attenuation maps.

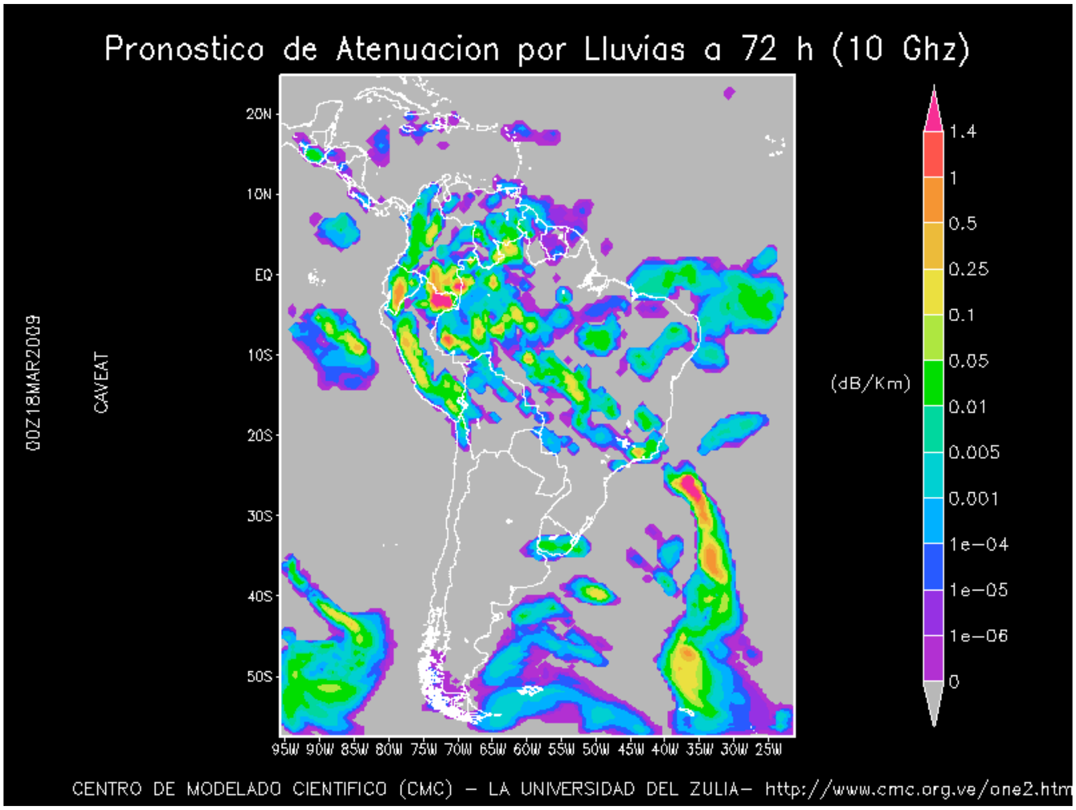

Figure 3. Short-term (72 h) rainfall attenuation forecast for South America at 10 GHz.

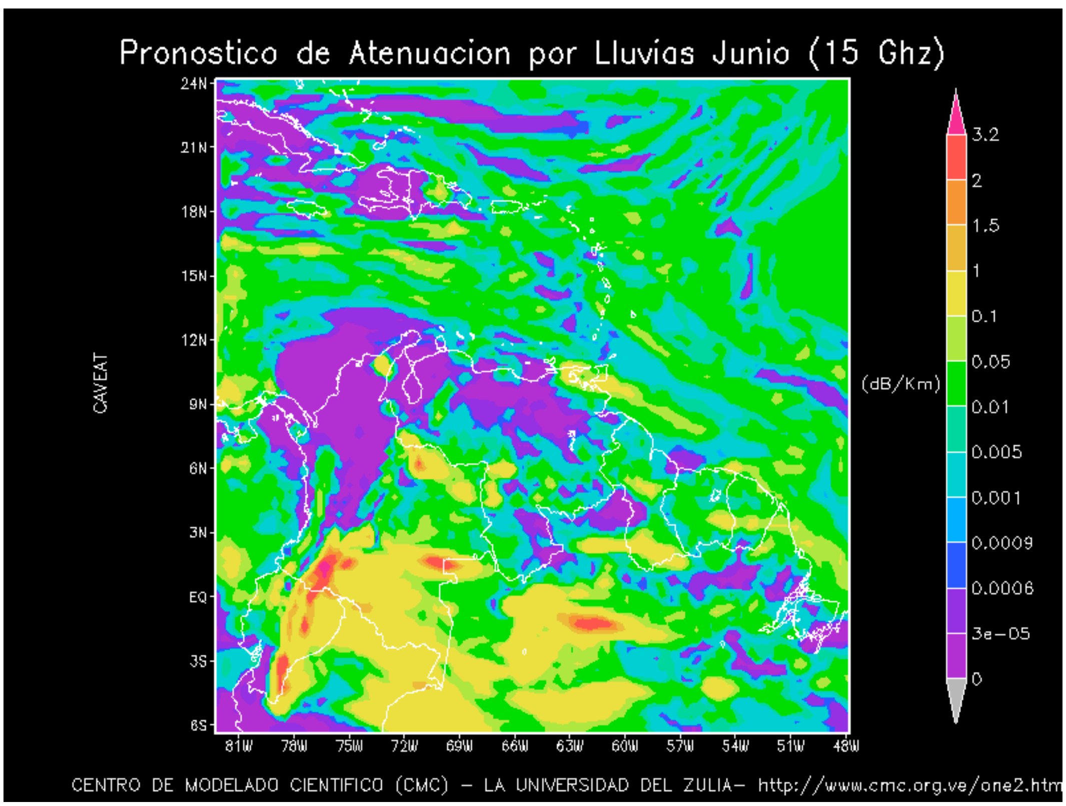

Figure 4. Monthly (June 2009) rainfall attenuation forecast for northern South America and the Caribbean at 15 GHz.

The implementation needs a complex set of different components: from the computational infrastructure and available storage, to the broad band internet connection for downloading on a daily basis the initial/boundary conditions needed for running the weather model. In addition, the medium-range attenuation forecast needs boundary conditions generally provided by a global circulation model, which in this case is also executed at CMC. After the coupling has been done with GrADS, the products are freely available on the CMC Forecast Web Interface [5].

It is expected that CAVeAT forecasts will help to improve the way in which the short- and medium range attenuation due to liquid hydrometeors is estimated. It can also be used as an additional tool for long term Earth-space system planning, as it can help to characterize the typical attenuation distribution on time and space for a specific region. However, it should be employed for now as a first guess forecast system for rain attenuation until field campaigns can validate its results.

6. References

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