CONVECTIVE PARAMETERIZATION OF ENSEMBLE WEIGHTED APPROACH FOR THE REGIONAL MODEL BRAMS

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RESUMO: No presente trabalho, a metodologia de problema inverso de estimação de parâmetros é aplicada ao modelo BRAMS. O problema inverso é resolvido pelo método de otimização *Firefly* (FA) e o modelo direto é dado pelas simulações de precipitação utilizando diferentes parametrizações de convecção do modelo. O objetivo é determinar numericamente os pesos de cada parametrização para ponderar o conjunto de parametrizações convectivas. Como resultado, é obtido o campo de chuva reconstruído a partir da combinação entre as simulações e os campos de pesos. Os resultados indicaram um campo de precipitação recosntruído mais próxima das observações.

ABSTRACT: In this study, the methodology of inverse problem of parameter estimation is applied using the regional model BRAMS. The inverse problem is solved by the Firefly (FA) optimization method and the direct model is given by the simulations of precipitation expressed by different cumulus parameterizations of the model. The goal is to determine numerically the weights of each parameterization to weight the ensemble of cumulus parameterizations. The results showed a retrieved precipitation field closest to the observations.

INTRODUCTION

Clouds processes operate on scales smaller than model resolutions, with a strong effect at resolvable scales (Cotton and Anthes, 1989). These subgrid-scale processes cannot be explicitly predicted in full detail on the model grid points, but their effects on the resolvable variables in the model are crucial for correct forecasting. A cumulus parameterization is an attempt to account for these effect on the scale of the atmospheric model.

Grell and Dévényi (2002), hereafter GD, developed a deterministic scheme for the convective cloud processes, including several assumptions of classical closures and parameters commonly used in convective parameterizations. The ensemble members are chosen to allow a large spread in terms of accumulated convective rainfall. However, the influence of each member of the GD ensemble for a given place must be quantified. In order to address this problem, an inverse problem methodology is applied for parameter estimation. The inverse problem is formulated as an optimization problem for retrieving the weights of the GD convective parameterization ensemble, and it is solved using the Firefly algorithm (FA). The forward problem is computed by the Brazilian developments on the Regional

Atmospheric Modeling System (BRAMS) (Freitas et al., 2007). The goal is to find the weights for each ensemble member in the GD convective parameterization implemented in the BRAMS.

EXPERIMENTAL DESIGN

The FA algorithm was proposed by Yang (2008), and it is based on the bioluminescence process which characterizes fireflies. More details about the Firefly algorithm can bee found in Yang (2008). The BRAMS version 4.2 was used to simulate precipitation over South America from 02 to 13 December 2004. The model was performed for a forecast length of 24 hours, once a day, from 01 December 2004 until 12 December at 12:00 UTC, with a restart every 24h. It was used the GD convective parameterization scheme and model grid with 25 km horizontal resolution covering South America. As initial and boundary conditions, we used the CPTEC/INPE Atmospheric General Circulation Model (AGCM) analysis with T126L28 resolution. Six precipitation fields were used, each one using a single closure option. One of the fields was performed using the ensemble simple mean (ENS) option. This precipitation field was used as the control experiment, which was compared with the results obtained with the FA algorithm.

The inverse solution is obtained by identifying the optimum weight values associated with each member of the GD ensemble. The objective function consists of the square of the difference between observations and predictions. The precipitation fields were computed from the model (P_M , a linear combination of five precipitation outputs using five parameterization closures) and the precipitation MERGE data (P_O , Rozante et al., 2010). The estimator P is a random variable that minimizes the Euclidian norm square of $P_M - P_O$:

$$J(P) = \min\left\{\left[\sum_{i=1}^{5} P_M^{w_i} - P_O\right]^2\right\} \tag{1}$$

where ($i=1,2,\ldots,N_w$) and N_w denotes the dimension of the parameter vector, as well as the dimension of the ensemble. For GD parameterization closures, we have w_{GR}, w_{MC}, w_{LO}, w_{AS}, w_{KF}, and the subscripts GR , MC , LO , AS and KF denote the classical closures assumed in the parameterization (see GD, 2002). In the FA algorithm, each firefly represents a candidate solution, and the brightest identifies the best weight set for the five closures.

The sensitivity of the algorithm with respect to the chosen parameters was tested, allowing the choice of the best parameters to be used together to solve the proposed inverse problem. These parameters are: the number of fireflies (*n*), the initial actractiveness (β_0) , the random parameter (α) and the number of generations (*G*), i.e., the number of iterations used in the FA code. The parameters α , β_0 , γ were tested with respect to the variations in the weight results. When one was tested, the other one was fixed. Later, the number of fireflies used was modified, to verify the impact of the number of fireflies on the representation of the best solution for solving the inverse problem. With the best values for the parameters, a new experiment was performed, and then the unknown vector was computed at each grid point over South America. The set of weights at each grid point was determined and they were used to retrieve the precipitation fields for the period of 02-13 December (2004). For each day, the set of weights was used; however, to simplify the analysis, the mean field for the period was computed. Finally, the retrieved precipitation was compared with the BRAMS model precipitation computed with the ENS closure. A simple difference was computed to compare both fields.

The results were analyzed using the RMS index, defined as follows:

(2)

where θ is a given variable, I and J are the total number of model grid points in the horizontal and the superscripts P and O are the forecasts (or the new precipitation field) and observations, respectively.

RESULTS

The observed accumulated precipitation during 02-13 December and the average precipitation for this period are shown in Figure (1). The accumulated precipitation was of the order of 200 mm over several places over Southern and Central Brazil, as well as over the latitude belt of 10^o N (Figure 1a). The average precipitation (Figure 1b) indicates that higher values are seen over the tropical region at 10^o N, with precipitation higher than 20 mm. Over most of Southern and Central Brazil, precipitation is the order of 5 mm to 20 mm in some places.

The average simulated precipitation is shown in Figure 2. To the AS and KF closures (Figure 2a and 2c, respectively), it can be seen that the average accumulated precipitation during 24h of simulation is larger than when the other closures are used. A simple average of the results with different precipitation parameterizations (ENS closure, Figure 2f) basically represents the contribution from the AS and KF schemes, because other schemes have very low estimated precipitation (Figures 2b, 2d, 2e).

The retrieved precipitation is shown in Figure 3. Comparing the retrieved mean precipitation (Figure 3a) with the control experiment (Figure 2f), a gain by using the proposed methodology is verified. The retrieved mean precipitation shows less precipitation over tropical regions compared with the control experiment. This pattern is better identified using the RMSE score (Figures 3b-c). Shaded red areas are associated with overestimation of the model and shaded blue areas are associated with underestimation of the model. The retrieved mean precipitation (Figure 3b) overestimates and underestimates less than the control experiment (Figure 3c).

CONCLUDING DISCUSSION

The best performance for the FA algorithm was obtained (considering the range selected for the firefly parameters to our application) with $\alpha = 0.1$, $\beta_0 = 0.5$, $\gamma = 10$. As a final result, using the best parameters, it was possible improve the BRAMS model precipitation fields using the weights for weighting the precipitation fields computed with each closure.

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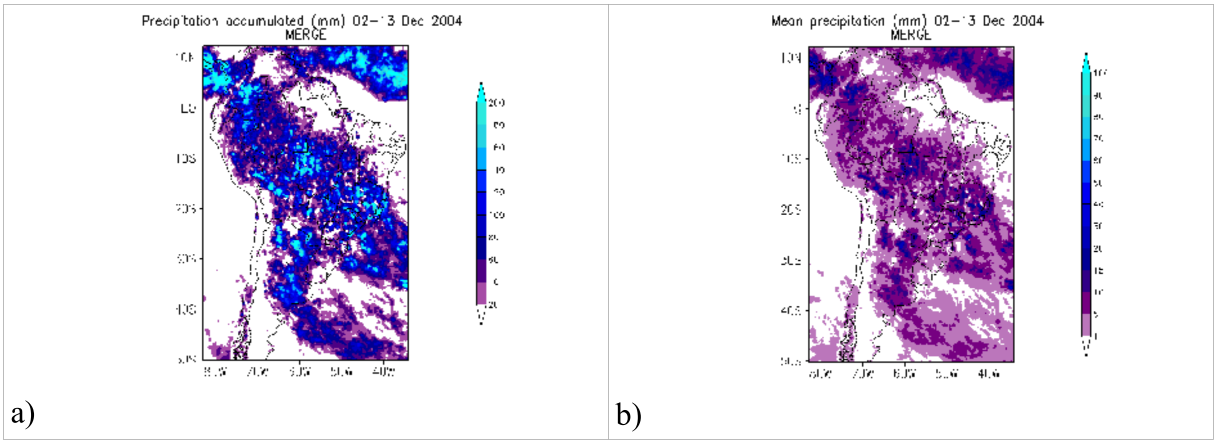
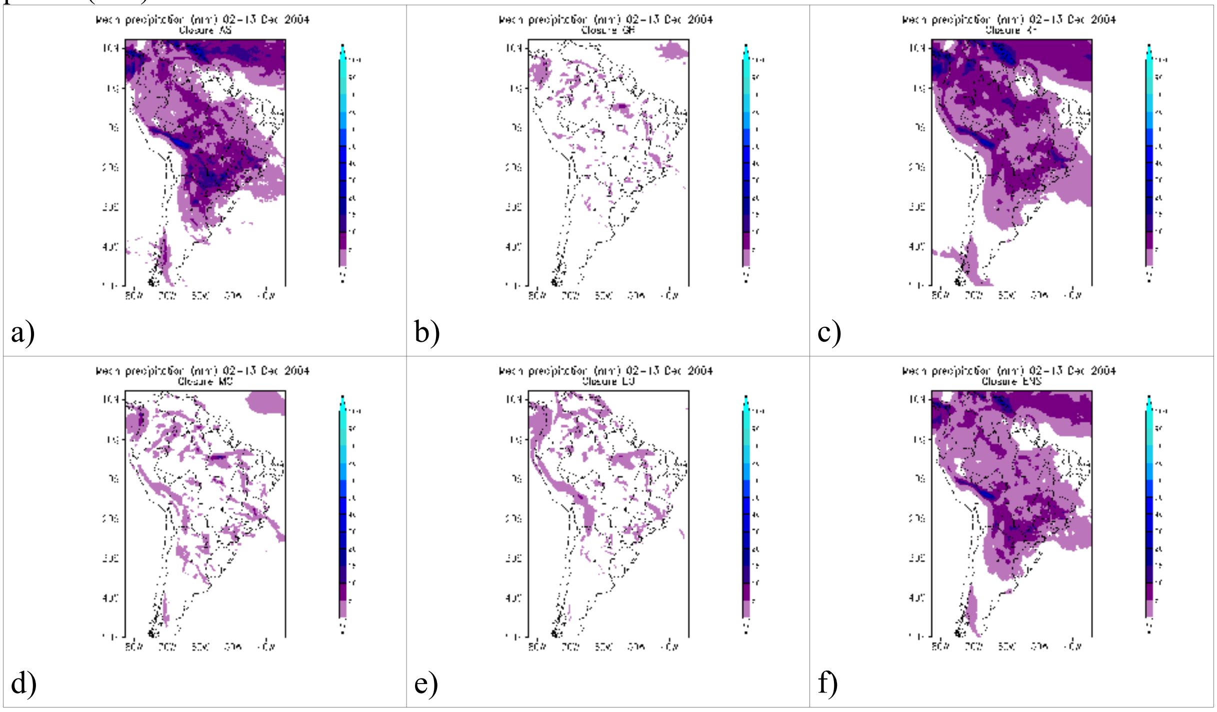


a) b)

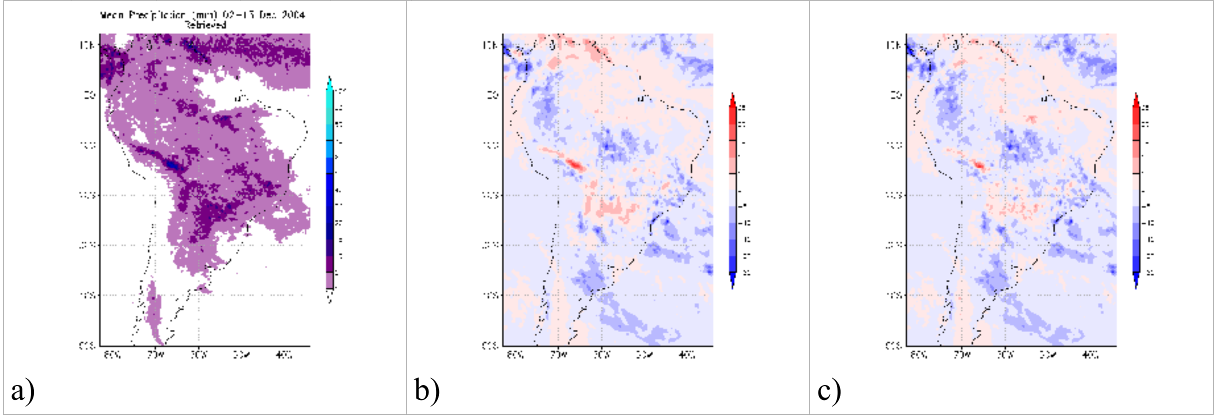
Figure 1: Observed precipitatin during 2-13 December and the average precipitation for the same period (mm) from MERGE data.



a) b) c)

d) e) f)

Figure 2: Mean accumulated precipitation (mm) in simulations to 24h using the following closures: a) AS, b) GR, c) KF, d) MC, e) LO, f)ENS.



a) b) c)

Figure 3: Mean precipitation (mm) on 02-13 Dec 2004 of a) retrieved field, and mean RMSE of b) control experiment (ENS) and c) retrieved (mm) on the same period.