AN ENSEMBLE APPROACH TO WEIGHTING CONVECTIVE PARAMETERIZATIONS OF THE REGIONAL MODEL BRAMS

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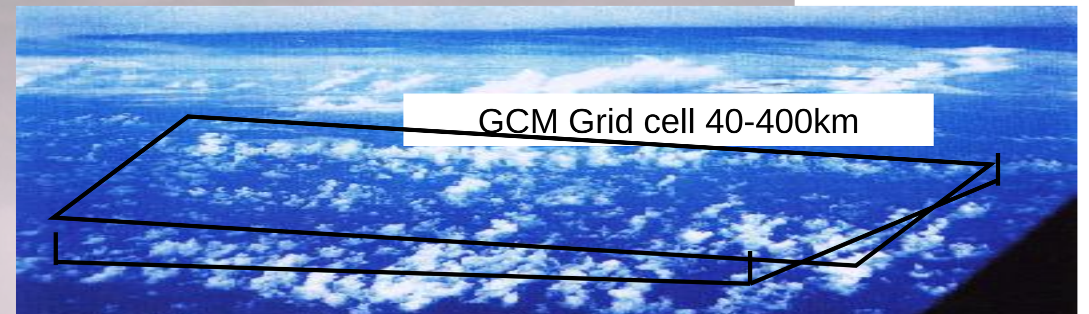
ABSTRACT

In this paper we consider the parameter estimation problem of weighting the ensemble of convective parameterizations implemented in the Brazilian developments on the Regional Atmospheric Modeling System (BRAMS). The inverse problem methodology is applied to BRAMS precipitation simulations over South America for December 2004. The forward problem is addressed by BRAMS, and the ensemble of convective parameterizations are expressed by several methodologies used to parameterize convection derived from the convective parameterization of Grell and Dévényi. The inverse problem is formulated as an optimization problem applying the metaheuristic Firefly algorithm (FA) to retrieve the weights of the ensemble members. The FA algorithm represents the patterns of short and rhythmic fashes emitted by fireflies in order to attract other individuals. The flashing light is formulated in such a way that it is associated with the objective function. The precipitation data estimated by the Tropical Rainfall Measuring Mission (TRMM) satellite was used as the observed data. The quadratic difference between the model and the observed data was used as the objective function to determine the best combination of the ensemble members to reproduce the TRMM measurements. Sensitivity analysis was used to test the FA algorithm parameters to adjust the algorithm to retrieve precipitation observations. The tested parameters were the initial attractiveness and the gamma parameter, which characterizes the variation of the attractiveness and is very important in determining the speed of convergence of the method. The results showed a high sensitivity to the gamma parameter variation, and the largest values resulted in the best combinations of weights, resulting in a retrieved precipitation field closest to the observations.

INTRODUCTION

Why is so difficult represent clouds in the numerical models?



Parameterization of cumulus convection in numerical models is recognized as one of the most important and complex issues in model physical parameterizations (Xie et. al, 2001).

Since a numerical model cannot represent the complex microphysical processes that form, evolve and dissipate clouds, as well as the processes related with clouds and the environment, as they occur on scales much smaller than the size of a model grid box, parameterization is needed for models to represent clouds

METHODOLOGY

Regional model BRAMS

Horizontal resolution: 25 km
Vertical resolution: 30 levels
Forecasts: each 24h
Period: 01 until 12 December 2004 at 12:00 UTC
Cumulus parameterization: Grell & Devényi (2002)
Closures: Grell (**GR**, 1993), Arakawa & Shubert (**AS**, 1974), Kain & Fritsch (**KF**, 1992), Low-level Omega (**LO**, Brow, 1979), Moisture Convergente (**MC**, Kuo, 1974), Ensemble (**ENS**)
Initial and boundary conditions: MCGA/CPTEC T126L28 each 6h

Weights estimation – Inverse Problems

Real experimental data (TRMM)

$$J(P)=\sum_{i=1}^{W}[P_M(W)-P_{TRMM}]^2 \quad \text{where} \quad P_M=\sum_{i}^{5} w_i P_i$$

Numerical experiments: the use of the firefly algorithm, with variations in the Firefly algorithm parameters

Experimental tests with the FA algorithm parameters.

Parameter	initial value	final value	increment
α	0.01	0.1	0.01
β	0.1	1.0	0.1
γ	1.0	10.0	1.0
n	5	50	5
G	10	100	10

Verification: it was computed the Root Mean Square Error

$$RMSE(\theta)=\frac{1}{N}\sum_{n=1}^{N}\left[\frac{1}{I,J}\sum_{i=1}^{I}\sum_{j=1}^{J}\left(\theta^{P}_{i,j,n}-\theta^{O}_{i,j,n}\right)^2\right]^{1/2}$$

θ is a given variable; *I* and *J* are the total number of grid points in the horizontal and the superscripts *P* and *O* are the forecasts (or the new precipitation field) and observations, respectively. The RMSE from 02-13 December was computed for each value of the parameters in Table above.

FIREFLY ALGORITHM

Pseudo code

```
begin
 Objective function f(x),      x=(x1, ..., xd)^T
Generate initial population of fireflies xi (i=1, 2, ..., n)
Light intensity Ii at xi is determined by f(xi)
Define light absorption coefficient γ
while (t < MaxGeneration)  (Number of iterations)
      for i = 1 : n all n fireflies
          for j = 1 : d loop over all d dimensions
              if (Ij > Ii), Move firefly i towards j: end if
              Attractiveness varies with distance r via exp[- γr]
              evaluate new solutions and update light intensity
          end for j
      end for i
      Rank the fireflies and find the current best
end while
Postprocess results and visualization
end
```

Adapted of Yang (2008)

Light intensity $I(x)\propto f(x)$ ➡ **In a simplest form** $I_r=\frac{I_{fonte}}{r^2}$

Movement of the firefly i toward firefly j (brightest)

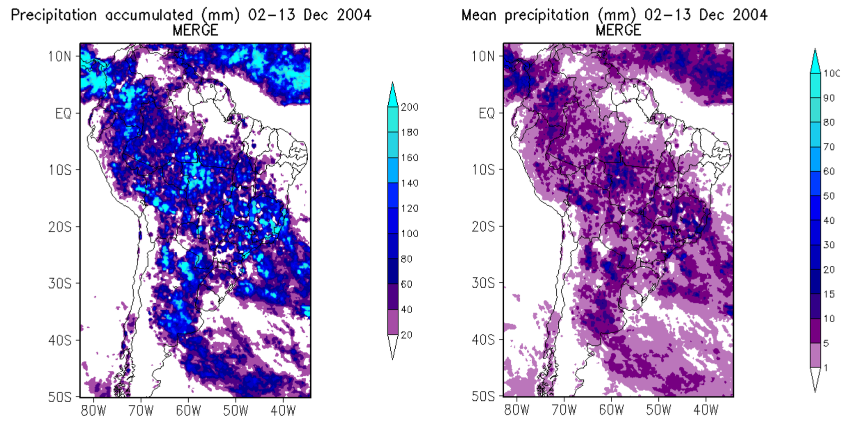
$$x_i = x_i + \underbrace{\frac{\beta_0}{1+r^2\gamma}(x_j-x_i)}_{\text{atraction}} + \underbrace{\alpha\left(rand-\frac{1}{2}\right)}_{\text{randomness}}$$

γ =O(1) => determines the convergence velocity

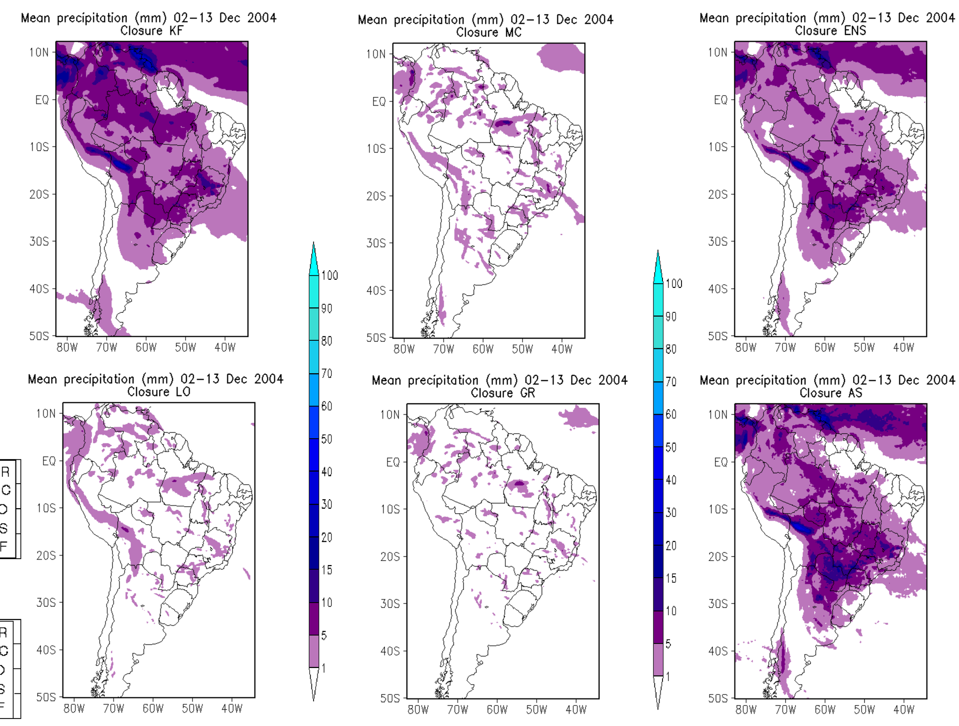
To an environment light absorption coefficient fix γ

$$I=I_0e^{-r\gamma} \Rightarrow I=I_0e^{-r^2\gamma} \Rightarrow I_r=\frac{I_{fonte}}{1+r^2\gamma}$$

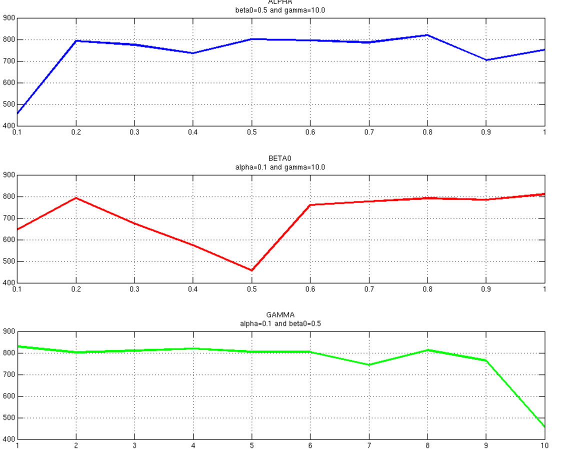
RESULTS



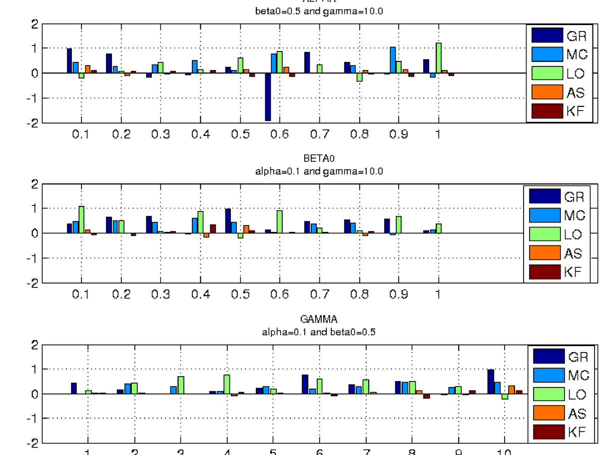
Observed observed precipitation during 02 to 13 December and the average precipitation for the same period (mm) from the MERGE data



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

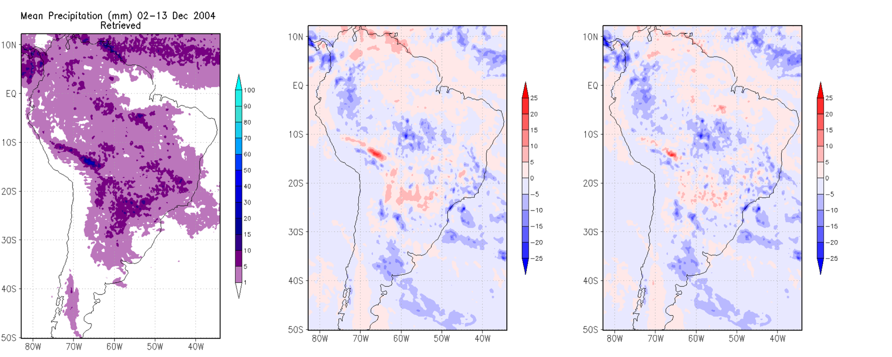


Root mean square error (RMS) of the mean precipitation (mm) over South America



Distribution of the weights according to variations in the FA parameters.
The dark blue, light blue, green, orange and brown bars represent, respectively, the variations of the weights for the closure members of GR, MC, LO, AS and KF

Comparing the retrieved mean precipitation with the control experiment (ENS), 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 difference between the retrieved mean precipitation and MERGE data and the difference between the ENS and MERGE data. In these Figures, shaded red areas are associated with overestimation of the models and shaded blue areas are associated with underestimation of the models. The retrieved mean precipitation overestimates and underestimates less than the control experiment.



Mean retrieved precipitation (mm), difference between the control experiment (ENS) and MERGE (mm) and between the retrieved precipitation and MERGE, respectively

CONCLUSION

A numerical experiment was designed to identify the best parameters to be employed to the Firefly algorithm with focus on the application to the retrieval of model precipitation fields. The best performance for the Firefly algorithm was obtained (considering the range selected for the firefly parameters to our application) with the values: α=0.1, β= 0.5, γ=10.

The resulting RMSE always increases when the value of α increases, for fixed values for β and γ. On the other hand, when α and γ are fixed and β is variable, the RMSE decreases between values of 0.2 and 0.5, with a minimum at 0.5. The γ variation indicated a decrease of RMSE when γ increases. 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. It is a first step to include the weight vector in the BRAMS model for weighting the GD parameterization ensemble.

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