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# WEIGHTS ESTIMATION BY FIREFLY WITH PREDATION OPTIMIZATION FOR ENSEMBLE PRECIPITATION PREDICTION USING BRAMS

Eduardo F. P. da Luz[1], Ariane F. dos Santos[1], José C. Becceneri[1], Haroldo F. de Campos Velho[1], Saulo R. Freitas[1], Manoel A. Gan[1], João G. Z. de Mattos[1], Georg A. Grell[2]

[1] Instituto Nacional de Pesquisas Espaciais (INPE), São José dos Campos (SP), Brazil.
[2] National Oceanic and Atmospheric Administration (NOAA), Boulder (CO), USA./;
ariane.frassoni@cptec.inpe.br, eduardo.luz@lac.inpe.br, saulo.freitas@cptec.inpe.br , haroldo@lac.inpe.br ,
manoel.gan@cptec.inpe.br , Georg.A.Grell@noaa.gov

## ABSTRACT

The precipitation prediction is addressed by weighted average. The weight identification is a parameter estimation inverse problem formulated by the square difference between measurements and computed precipitations. The metaheuristic Firefly Algorithm with Predation (FAP) is used to compute the best weights. The method is applied to the BRAMS code.

## RESUMO

Uma média ponderada usando diferentes esquemas de convecção pode ser usada em previsão. O problema inverso de estimação de parâmetros é formulado pela a diferença quadrática entre a precipitação medida e a calculada. A função objetivo é minimizada pelo Algoritmo Firefly com Predação. O método é aplicado ao código BRAMS.

## INTRODUCTION

The precipitation process is not well understood and/or represented on atmospheric computer models. The process is parameterized. Many approaches try to model the precipitation. Grell and Dévényi (2002) proposed an ensemble scheme (for simplicity: GD), where several models for precipitation are combined. The output from the GD's scheme is the ensemble average (ENS). An improved GD's approach is to apply a weighted average (Santos et al. 2013a, 2013b). The estimation of weights is done by minimizing the square difference on computed and measured precipitation. The optimization problem is solved by Firefly Algorithm with Predation (FAP).

## FORWARD PROBLEM: SIMULATION BY BRAMS CODE

The BRAMS code is supported and developed by the CPTEC-INPE (http://brams.cptec.inpe.br/). This model has several parameterizations, including the ensemble version for the cited GD's approach. The turbulence kinetic energy (TKE) is the key issue to activate the convection parameterization. BRAMS can run with five closure schemes for convection: moisture convergence (MC: Kuo, 1974), low-level Omega (LO: Frank-Cohen, 1987), Kain-Fritsch (KF), Arakawa-Schubert (AS), and Grell (GR) (Santos et al., 2013a). The parameterizations for precipitation can be combined (GD-ENS), or the user can use only one closure option.

## INVERSE SOLUTION BY WEIGHTED ENSEMBLE

The goal is to minimize a cost function $J(\boldsymbol{w})$, given by:

$$J(\mathbf{w}) = \sum_{j=1}^{M}\left[\left(\sum_{i=1}^{N_w} w_i P_i^{\mathrm{Par}}\right) - P^{\mathrm{Obs}}\right]^2 \tag{1}$$

where $w_i$ is the weight associated to each parameterization, $i$ = MC, LO, KF, AS, GR; $N_w$ is the number of parameterizations used ($N_w = 5$); $M$ is the number of measurements, $P^{\mathrm{Obs}}$ is the measured precipitation (for instance, from satellite data).

## THE FIREFLY ALGORITHM

Yang (2008) has proposed the Firefly Algorithm (FA) based on bioluminescence process from the fireflies. For the FA development, it was considered: (i) fireflies attracted one each other; (ii) the attractiveness is proportional to their brightness, and both decrease as their distance increases – if there is no brighter firefly, it will move randomly; (iii) the brightness of a firefly is affected or determined by the landscape of the objective function. The attractiveness is determined by the brightness (the objective function).
The firefly position represents a candidate solution. The new position of a firefly is computed as following:

$$x_i^{m+1} = x_i^m + \beta_0 e^{-\gamma r_{ij}^2}\left(x_i^m - x_j^m\right) + \alpha\left(rand - 1/2\right) \tag{2}$$

where $x_i^m = [w_{MC,i}^m, w_{LO,i}^m, w_{KF,i}^m, w_{AS,i}^m, w_{GR,i}^m]^T$ is an element (vector) from the firefly population ($i$, $j = N_f$), and $\alpha$, $\beta_0$, and $\gamma$ are free parameters for the FA meta-heuristics. The second term in RHS in Eq. (2) is the attractiveness, representing the decay of light intensity seen by other fireflies, with $\beta_0$ the attractiveness at $r = 0$. The parameter $\alpha$ is the degree of influence for the stochastic forcing, and *rand* is a random number with uniform distribution on [0, 1]. The attractiveness is proportional to the light intensity, i.e., the objective function expressed by Eq. (1).

## PREDATION OPERATOR

It is applied on cycles: after some iterations, the fireflies with larger values for objective function are removed from the population, and new fireflies are added – their values are randomly generated (Luz, 2012).

## RESULTS AND FINAL COMMENTS

The BRAMS was executed for each convection scheme cited in Section 2, over the Amazon region at February 21, 2004. The BRAMS outputs were combined with different weights, and a 5% noise level was added for representing the measured quantity. True weight values are shown in Table 1.

For the numerical experiment, the following values were used: $\alpha = 0.2$, $\beta_0 = 1$, and $\gamma = 1$. Firefly population has 40 individuals, and the predation is activated every 20 iterations, remaining the 10 best fireflies, and other are randomly inserted. The estimated weights (average:$\mu$) are shown in Table 1, where $\sigma$ is the standard deviation for 25 realizations.

Table 1: Estimated weights by the Firefly-p algorithm.

| Parameterizations | True $w_i$ | Estimation ($\mu$) | $\sigma$ |
|---|---|---|---|
| AS | 0.25 | 0.2402 | $3.22\times10^{-2}$ |
| GR | 0.35 | 0.3423 | $2.12\times10^{-2}$ |
| KF | 0.20 | 0.2007 | $5.98\times10^{-2}$ |
| LO | 0.15 | 0.1561 | $3.11\times10^{-2}$ |
| MC | 0.05 | 0.0506 | $1.77\times10^{-2}$ |

The performance for the FAP is better than standard FA (Luz, 2012). The procedure to select the best parameters to the FAP could be the same used by Santos et al. (2012). The strategy sketched here is part of the effort for improving the BRAMS forecasting precipitation skill.

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