IN13A-23: OPTIMIZATION FIREFLY METHOD FOR WEIGHTED ENSEMBLE OF CONVECTIVE PARAMETERIZATIONS. PART I: SENSITIVITY EXPERIMENT USING TRMM SATELLITE DATA

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ABSTRACT

The inverse problem methodology for parameter estimation is applied to a meteorological phenomenon that causes intense rainfall over South America. It is formulated as an optimization problem, where the goal is to apply the Firefly method (FA) as an optimizer for retrieving the weights of the ensemble of convective parameterizations of Grell and Dévényi. The forward problem is the precipitation field of the ensemble of convective parameterizations expressed by several methodologies. The precipitation fields were used as the direct problem (see companion paper), and the precipitation field estimated by the Tropical Rainfall Measuring Mission (TRMM) satellite as the observed data. The inverse problem is solved as an optimization problem with regularization operator of Tikhonov of zero order.

INTRODUCTION

Parameterization of convection

Many different approaches exist concern to:

- What do you use to decide where convection will form
- How strong it will be (*closure*)
- What is important with respect to how convection modulates the environment (*feedback*)

Ensemble version of convective parameterization

- Build more stochasticism into parameterization
- Allows to find objective ways to determine weighting of ensembles for feedback

FIREFLY METHOD

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)

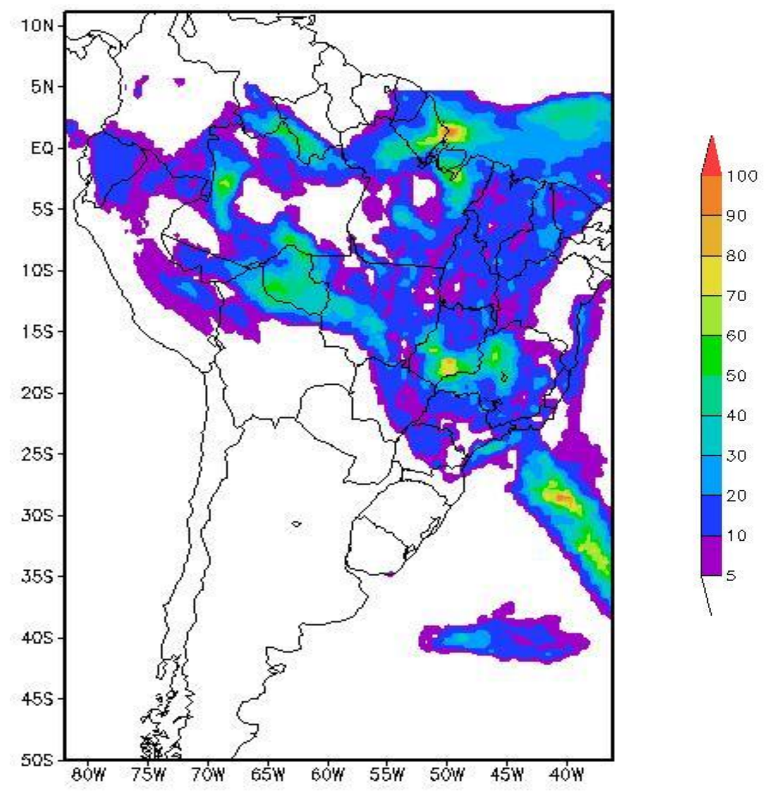
$$x_i = x_i + \underbrace{\frac{\beta_0}{1+r^2\gamma}(x_j - x_i)}_{\text{attraction}} + \underbrace{\alpha\left(rand - \frac{1}{2}\right)}_{\text{randomness}}$$

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

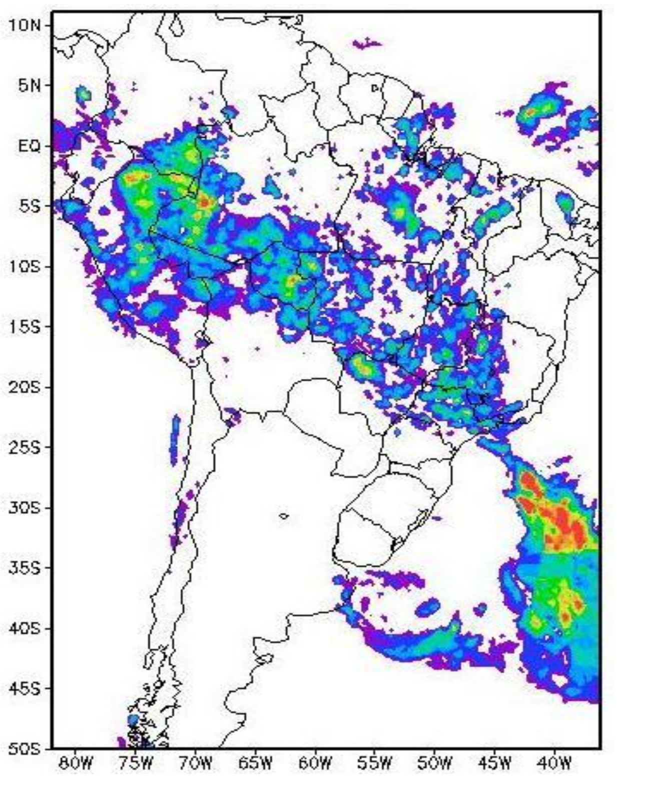
To an environment light absorption coefficient fix γ

$$I = I_0 e^{-r\gamma} \Rightarrow I = I_0 e^{-r^2\gamma} \Rightarrow I_r = \frac{I_{fonte}}{1+r^2\gamma}$$

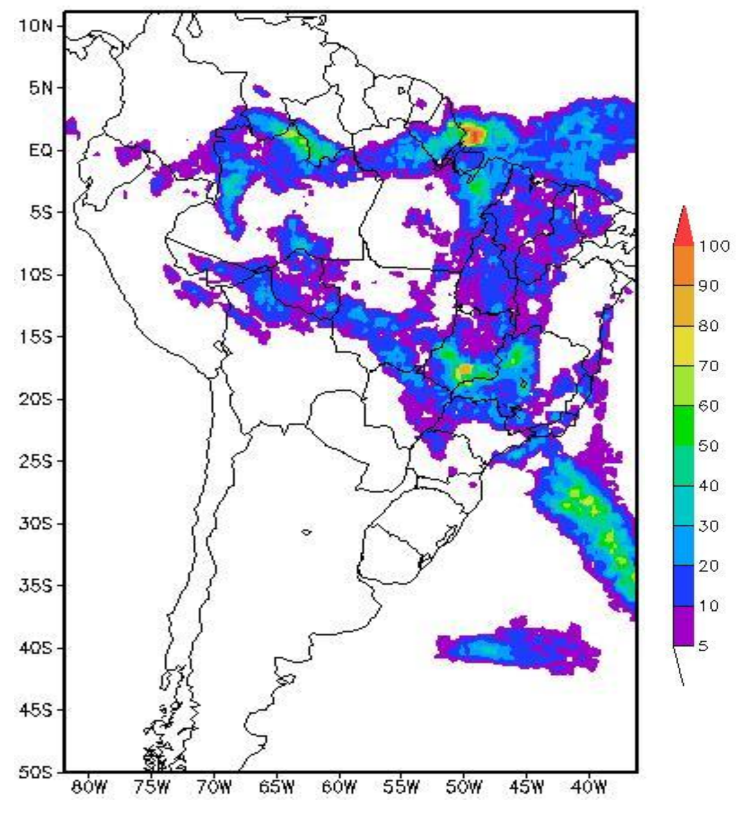
RESULTS



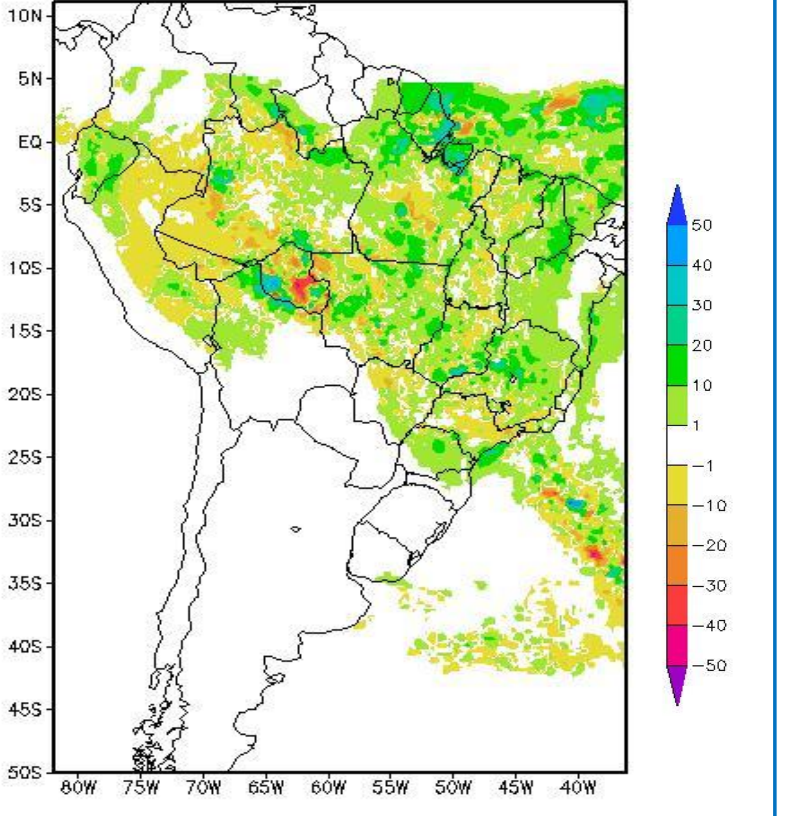
CCATT-BRAMS total precipitation (mm) from ensemble mean



TRMM total precipitation (mm)



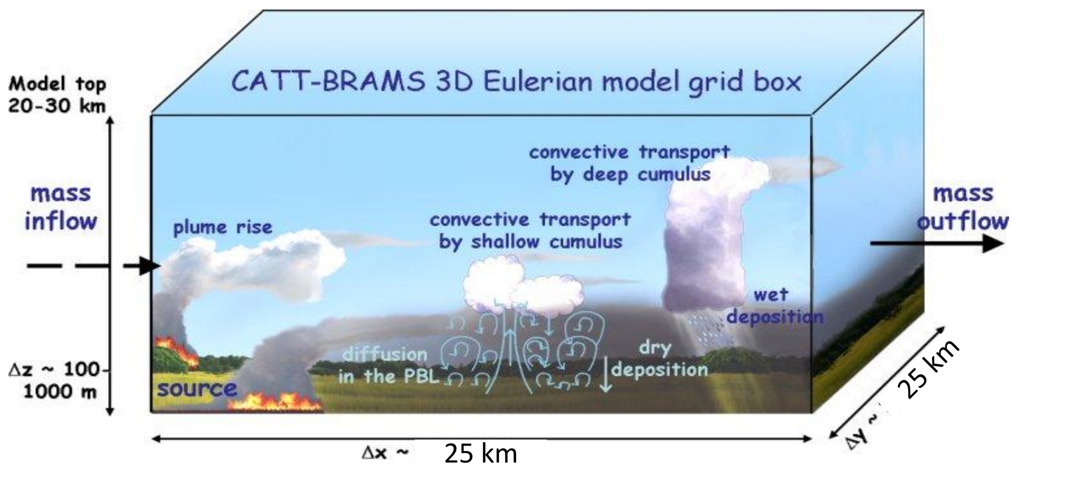
Retrieved total precipitation (mm) using the Firefly algorithm



Difference (mm) between absolute error of ensemble mean total precipitation (ensemble-observation) and absolute error of retrieved total precipitation (firefly-observation)

METHODOLOGY

The model CATT-BRAMS



Cumulus Parametrization of de Grell & Dévényi

Multidimensional ensemble

- ✓ ***Trigger function (dimension 3)***
- ✓ ***Precipitation efficiency (dimension 3)***
- ✓ ***Closures (dimension 5 x 3) :***
  - **Grell, 1993**
  - **Arakawa & Schubert, 1974**
  - **Kain e Fritsch, 1993**
  - **Moisture convergence (tipo Kuo 1965, 1974)**
  - **Low-level omega (Brown 1979, Frank e Cohen 1987)**

Weights estimation – Inverse Problems

Real experimental data (TRMM)

$$J(P) = \sum_{i=1}^{W} [P_M(W) - P_{TRMM}]^2$$

where

$$P_M = \sum_{i}^{5} w_i P_i$$

Numerical experiment: the use of the firefly algorithm, with different number of iterations and number of fireflies

Iterations (MaxGeneration)= 10
Nº fireflies (n) = 5

$B_0 = 1$
$\alpha = 0,2$
$\gamma = 1$

CONCLUSION

The retrieved field of precipitation was in agreement with the observed field. We computed the error precipitation field obtained with simple ensemble average and the error to the retrieved precipitation: errors of the ensemble average are greater than the errors of the retrieved precipitation. We expect to employ the method introduced here to improve the simulated precipitation of the CCATT-BRAMS system.

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