# CENTER FOR WEATHER FORECASTS AND CLIMATE STUDIES
# CPTEC/INPE - BRAZIL

## Update of CPTEC activities :

## 2013-2014

**Saulo R. Freitas**

saulo.freitas@cptec.inpe.br

# Outline

- Report developments on:
  - Regional Atmospheric and Environmental Modeling
  - Global Atmospheric Modeling
  - Data Assimilation
  - Ensemble Prediction

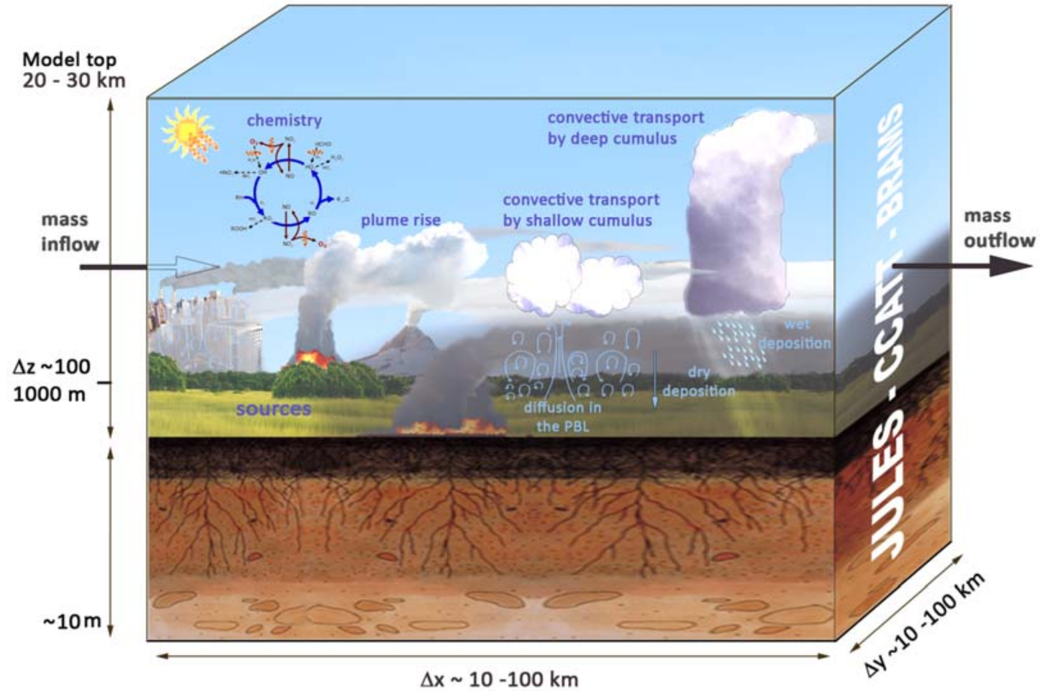
- Going-on developments and research

# Models configuration in 2013 and expected for the this year

| MODEL – FOCUS - DOMAIN – FORECAST TIME LENGHT | Year 2013 | Year 2014 |
|---|---|---|
| BRAMS – severe weather – 500x500 $km^2$ over S. America – 1 ½ day (on-demand) | 1 km | 1 km |
| BRAMS – weather– S. America – 3.5 days (00 and 12 UTC) | 5 km | 5 km |
| Eta - weather – S. America - 11 days (00 and 12 UTC) | 15 km | 15 km |
| CCATT – weather + Air Quality (on-line) – S. America – 3 days (00 UTC) | 25 km | 15 km |
| AGCM with NCEP analysis – weather – Global – 7 days | T299L64 | T666L96 |
| AGCM with 3dVAR/GSI analysis – weather – Global- 7days | T299L64 | T299L64 |
| OA-GCM– 30 days– global | T126L28 | 80 km / L42 |
| Eta – seasonal climate – S. America - 5 days | 40 km | 40km |
| AGCM – Ensemble 15 members – 15 days | T126L28 | T126L28 |
| Ocean Waves – 3 days – global domain | 0.25 degree | 0.25 degree |

- Regional Scale

# Brazilian developments on the RAMS Model version 2013




- Regional to local scales.
- Chemistry – aerosols - on-line with meteorology and including feedbacks.
- monotonic advection for scalars, 2-moment cloud microphysics, scale and aerosol aware convective parameterization, TEB urban surface scheme
- Running over a massive parallel system using MPI
- Includes now JULES surface scheme: fully interactive carbon cycle; urban surface

# Regional weather forecast for South America on 5km resolution with BRAMS **(1st year)**

- Grid spacing:
  - Horizontal: 5 km x 5 km.
  - Vertical: 50 to 800 meters

•Time step: 15 seconds

- Model domain:
  - # grid points: 1360 x 1489 x 55 ~ $100 \times 10^6$
  - Model top at 21 km height ASL

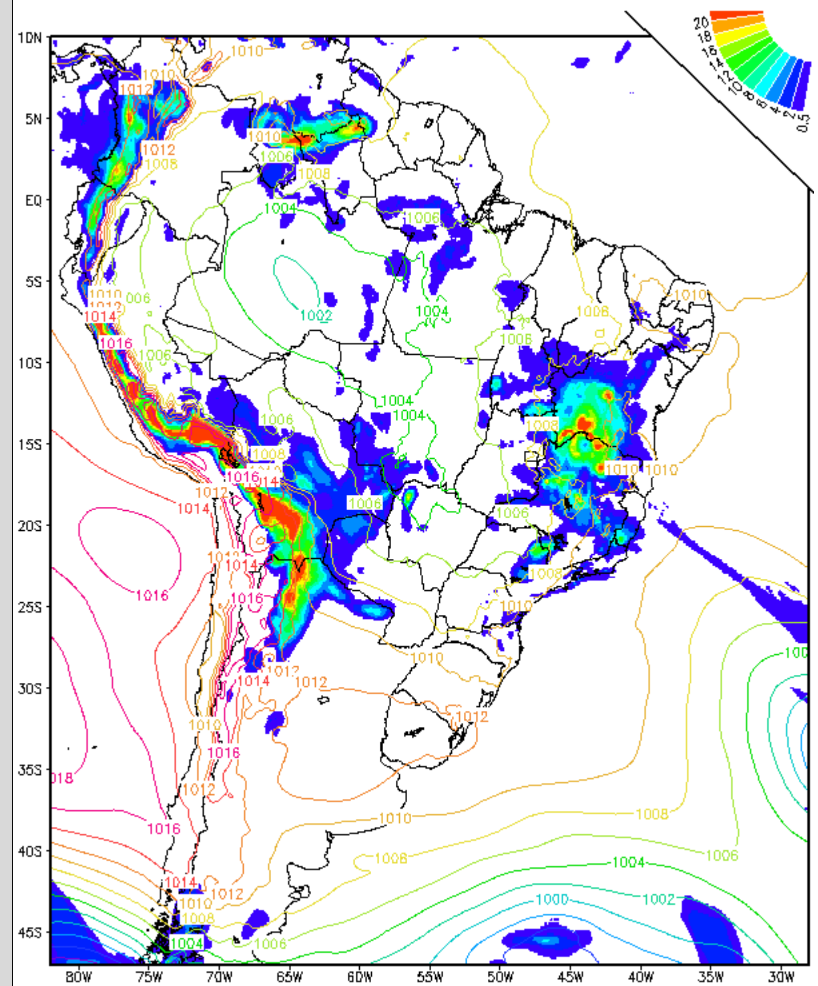
- Forecast length:
  - 3 ½ days, starting at 00, 12 UTC.
- Execution time :
  - 20 mn on 9600 cores produces 1 day forecast (I/O is the bigger bottleneck)

BRAMS 05 Km

Análise Inicializada em: 02/11/2012, 00 UTC (Sexta-feira) Válida para: 02/11/2012, 06 UTC (Sexta-feira)

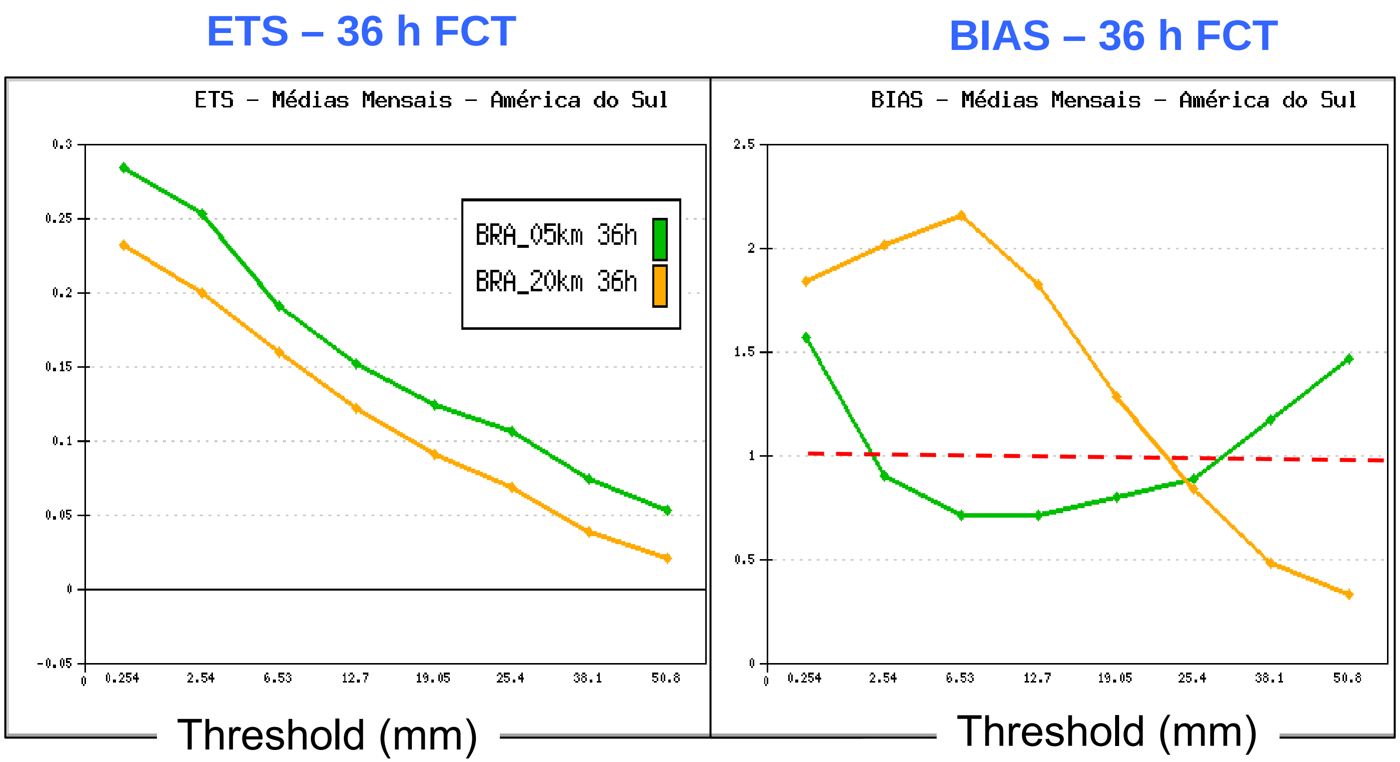
Variável: Precipitação Acumulada 6h/Pressão ao nível médio do mar

CPTEC/INPE



# Evolution of ETS and BIAS of precipitation forecast of with BRAMS 05 km at CPTEC/INPE

Evaluation with a full year (2013) data for South America




OLD 20km NEW 05km

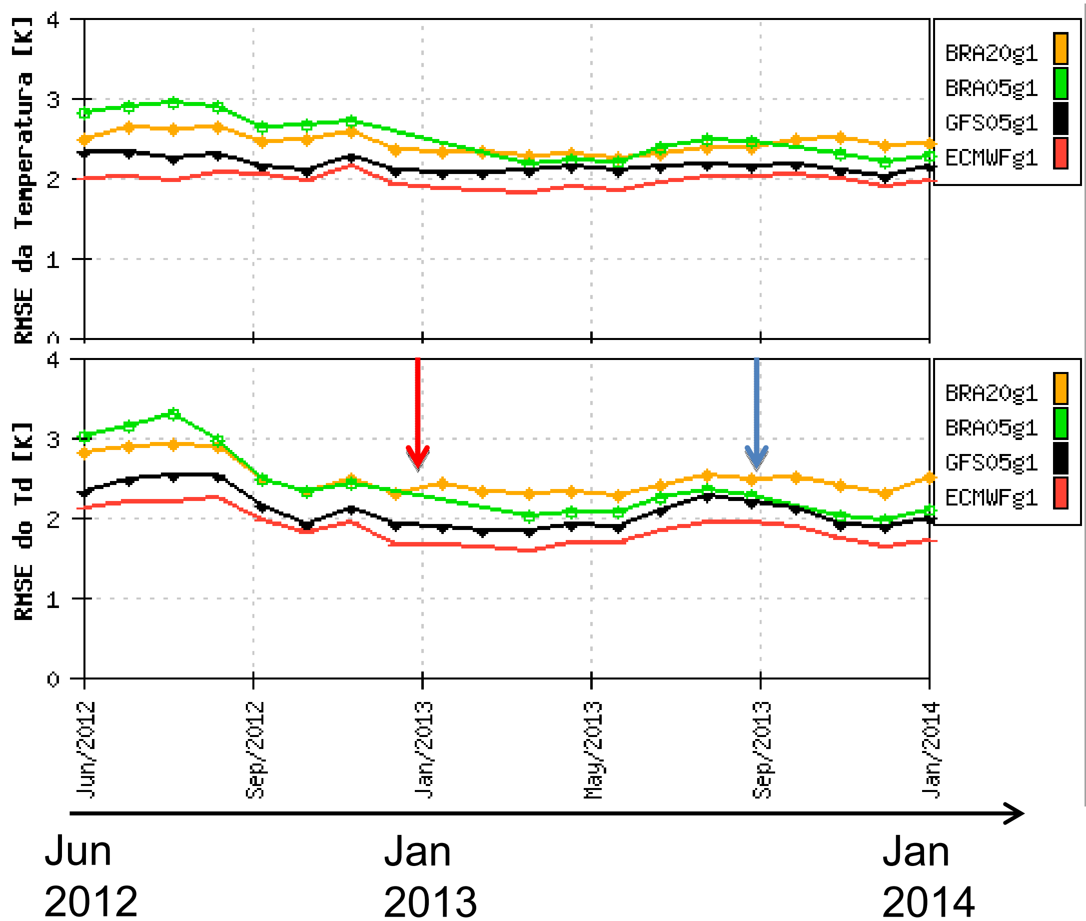
# Evolution of RMSE with BRAMS at CPTEC/INPE

## 2meters – T and Td for S. America

New BRAMS 5km (BRA05), old BRAMS 20km (BRA20), GFS and ECMWF

**RMSE 2m-Temp**

**RMSE 2m-Dew-Point Temp**



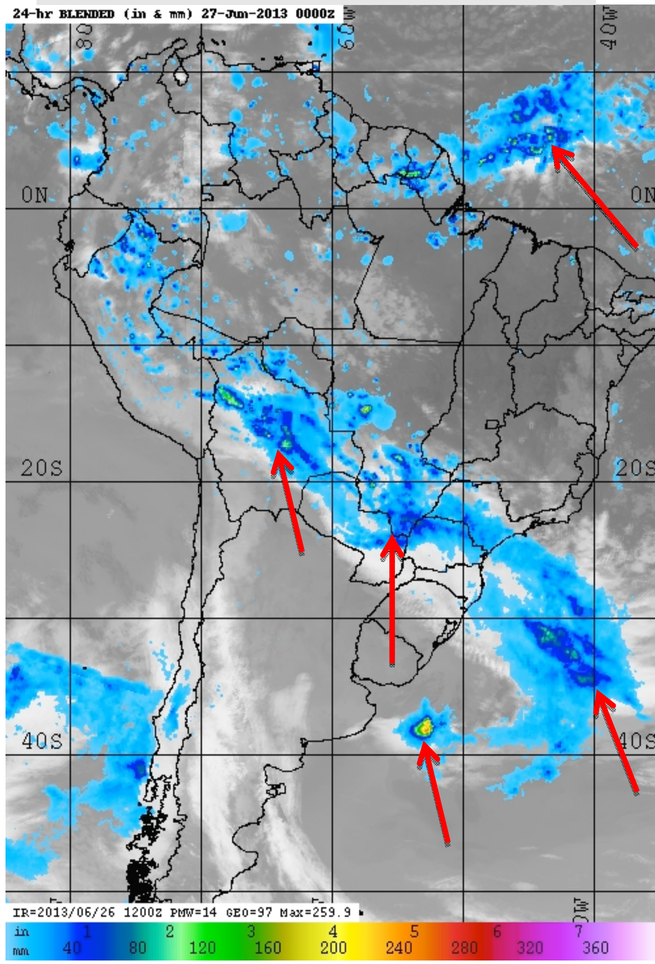

BRA20g1
BRA05g1
GFS05g1
ECMWFg1

New surface scheme (JULES)

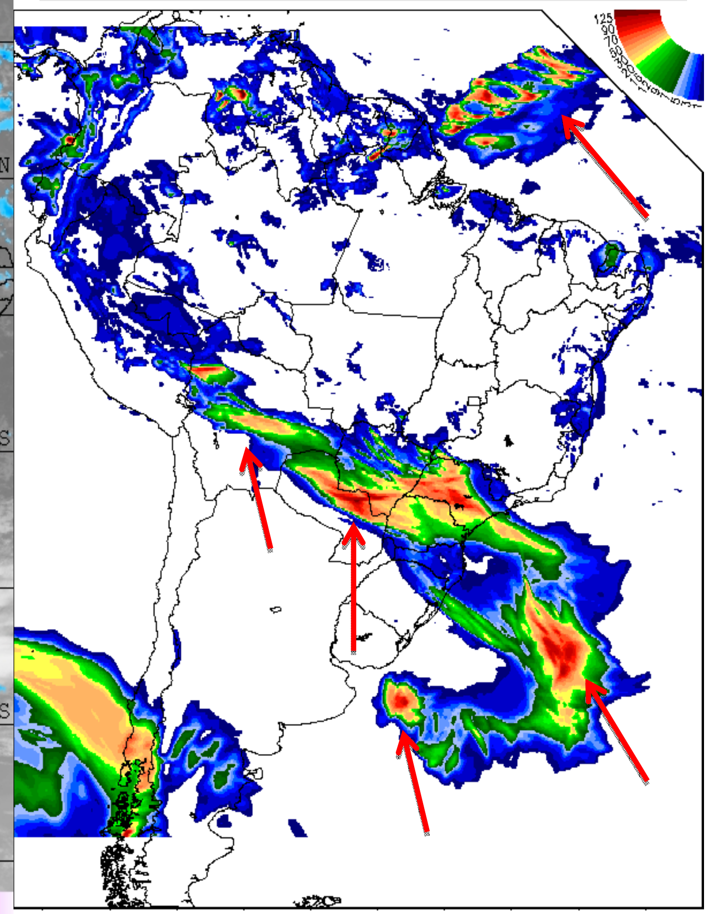
Tuning on the initial soil moisture

# A visual comparison of 24-h accumulated rainfall TRMM x BRAMS 5 km - Forecast for 00UTC27JUN2013

Rainfall estimated by TRMM (mm/day)

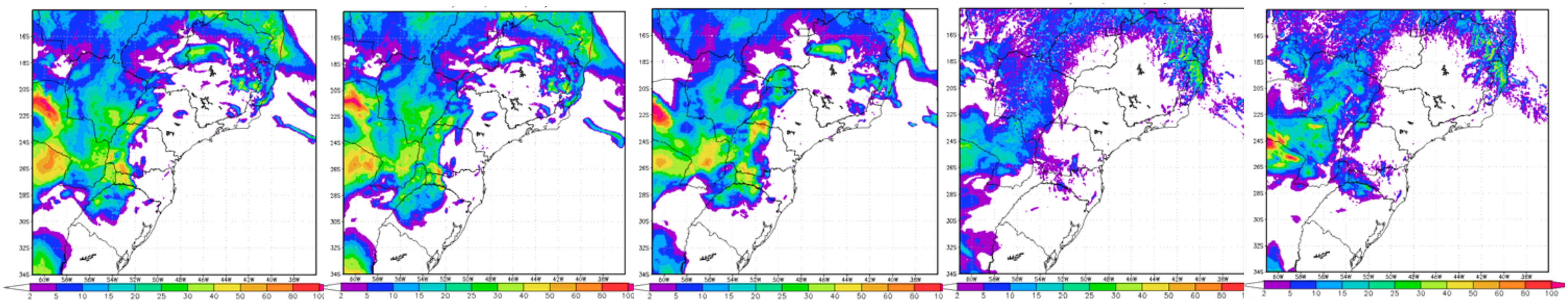



BRAMS 5 km Forecast

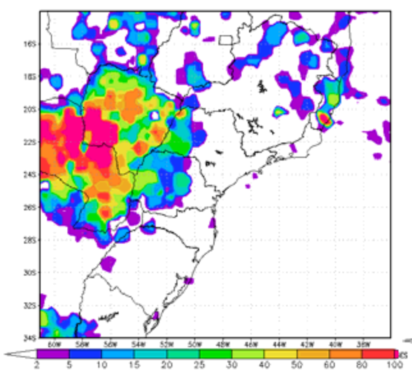


# Mesoscale Eta/INPE model
## **High-resolution (5-km) physics ensemble**

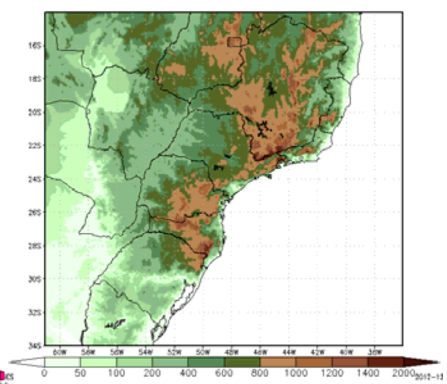
### 5-km resolution,  5-member model perturbations



BMJ_Ferrier_C   BMJ_Zhao   BMJ_Ferrier_G   KF_G   KF_M_G



**OBSERVATIONS**



**Model topography**

**Eta model, version of Mesinger et al 2012**

- Convection schemes: BMJ, KF, KFM
- Cloud microphysics schemes: Ferrier, Zhao
- LBC: Eta-40km, GFS
- Runs daily twice: 00Z and 12 Z.
- Domain: part of Brasil and of South America

- Global Atmospheric Modeling

# IMPROVEMENTS on CPTEC AGCM

A new version of the CPTEC AGCM has been developed recently:

•transport using a semi-Lagrangean scheme

•new physical parameterizations:

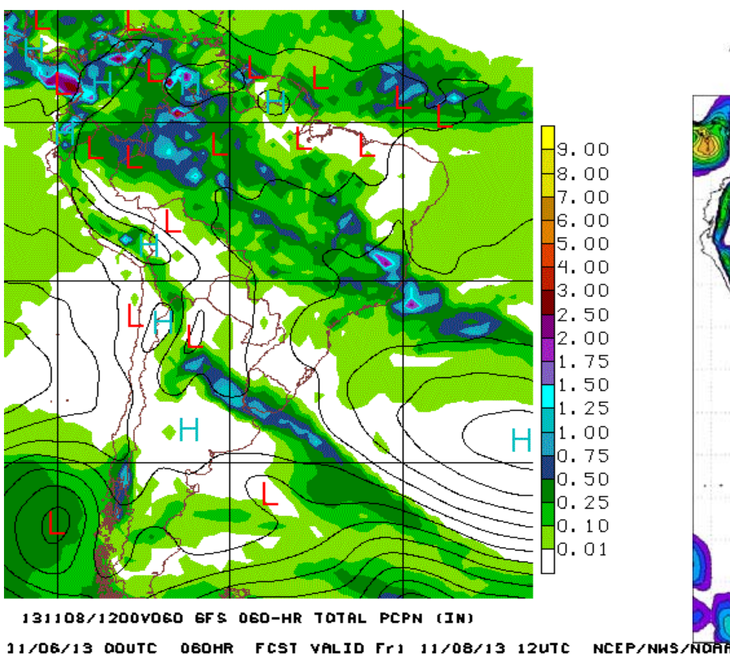
- double-moment microphysics,
- cumulus parameterization with six mass flux closures,
- IBIS surface scheme, including dynamic vegetation,
- non-local PBL,
- RRTMG radiation,
- gravity-wave with low level blocking.

•Evaluation of the new version in weather and long term time-scale are in progress.

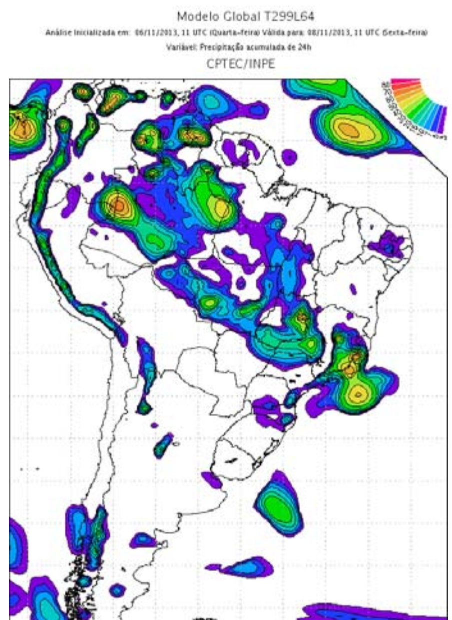
# NEW CPTEC AGCM : a visual comparison

Below is showed 48 h rainfall forecasting over South America from GFS (left), old AGCM (middle) and new AGCM (right panel) to illustrate the performance of the new model, where can be seen that the new model precipitation forecasting is similar to GFS.  (IC: 2013110600).

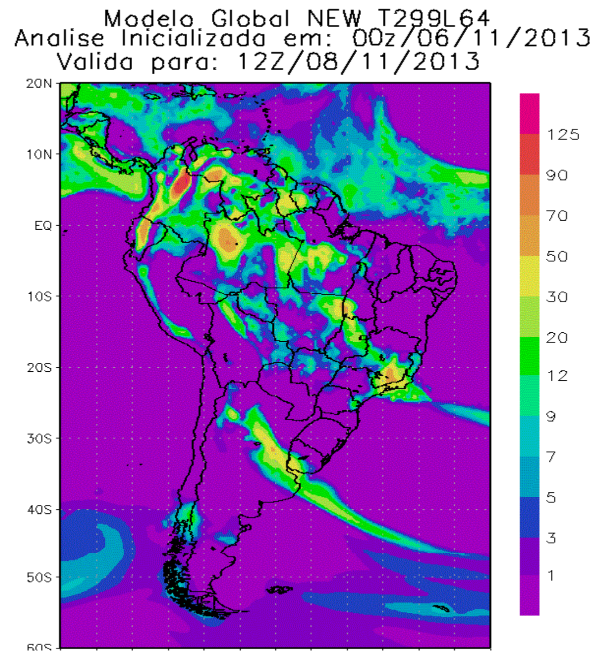
**GFS**




**OLD AGCM**




**NEW AGCM**



www.cptec.inpe.br

# Recent Developments on Data Assimilation at CPTEC/INPE

## Data Assimilation Systems:

- **PSAS** – *Physical-space Statistical Assimilation System* (Variacional 3D, Observer ~10e4, Global/Regional) FORMER OPERATIONAL (discontinued on Jan/2013)

- **GSI** – *Gridpoint Statistical Interpolation* (Variacional 3D/4D, Observer ~10e5, Global) CURRENT OPERATIONAL (since 2013)

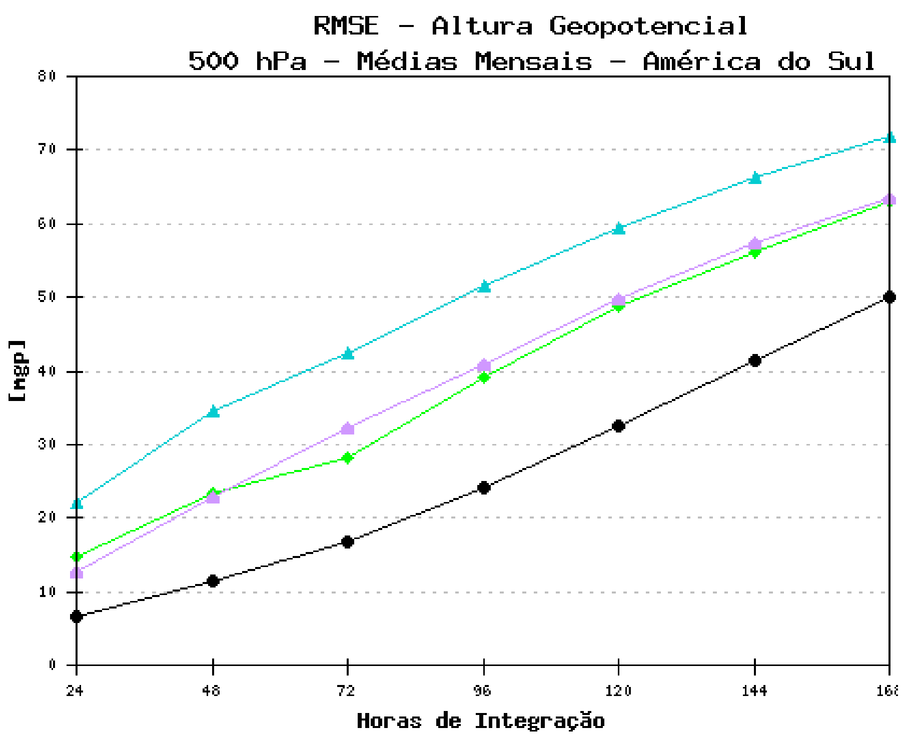
- **LETKF** – *Local Ensemble Transform Kalman Filter* (Sequencial, Observer ~10e5, Global) RESEARCH MODE (since 2008)

www.cptec.inpe.br

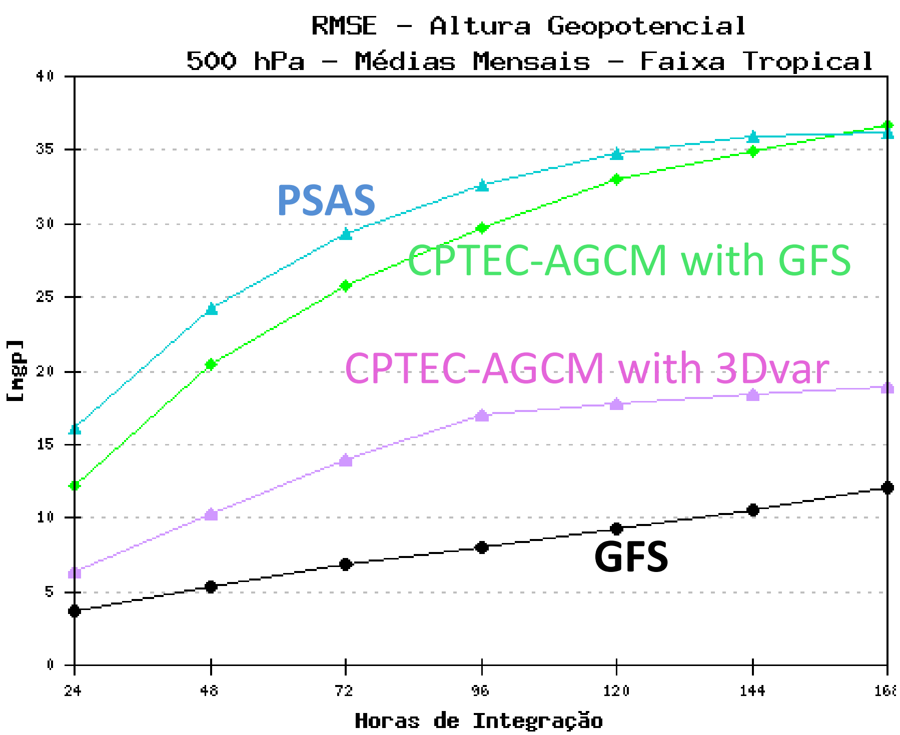
# Performance of GSI - 3dVAR versus PSAS
# RMSE of Geopotential Height at 500 hPa

T299_L64 00h
GFS 00h
GPSAS213 00h
G3_D_VAR 00h

South America

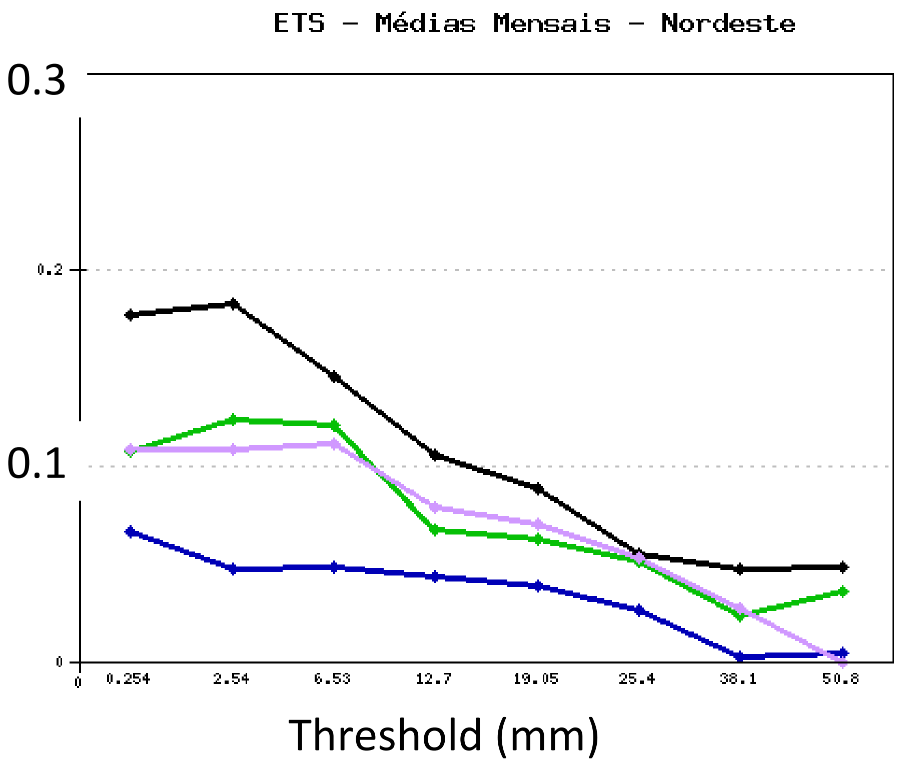


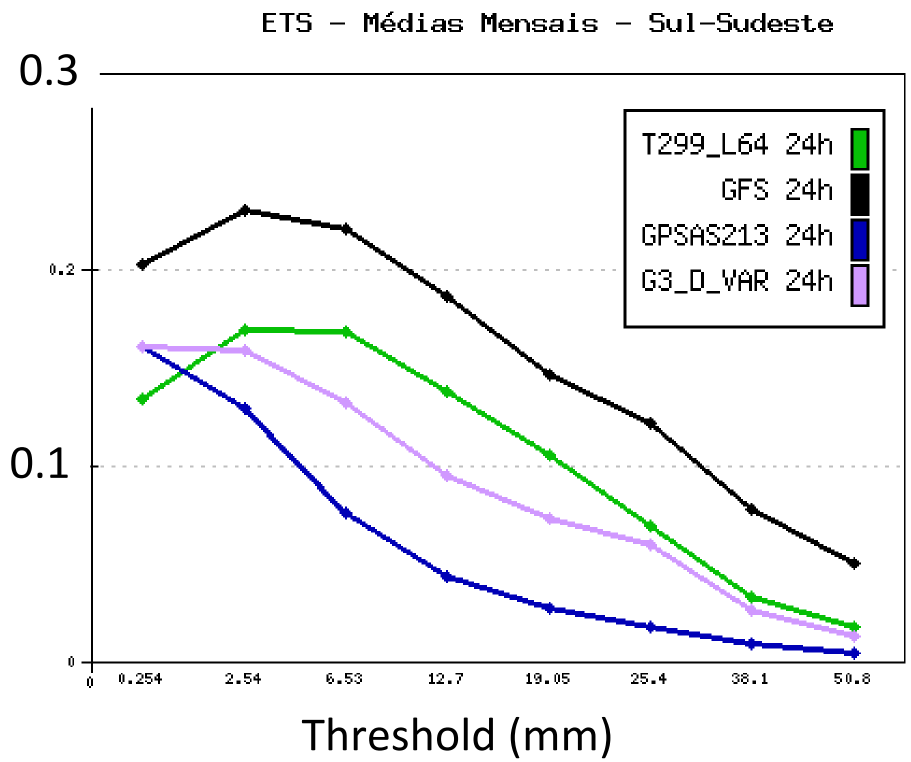

Tropical Área (30S-30N)



www.cptec.inpe.br

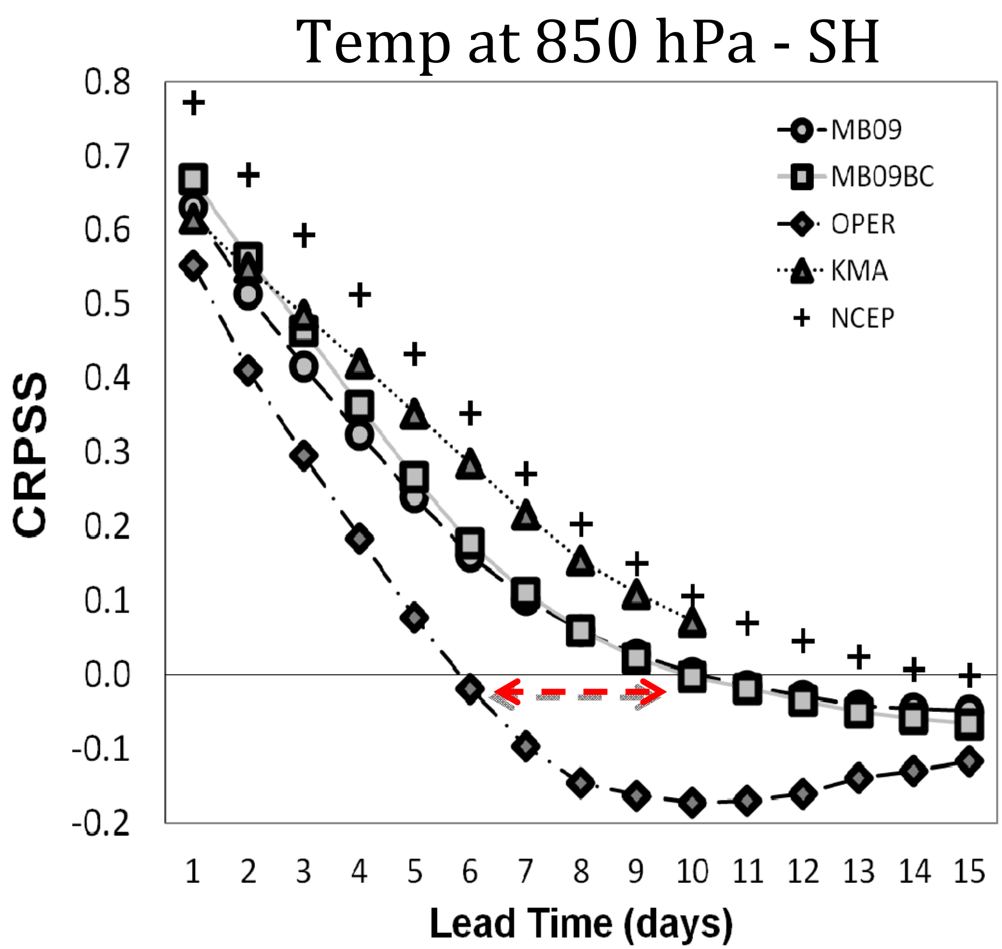
# Performance of GSI - 3dVAR versus PSAS
# ETS of 24 h accum. rainfall over the most populated areas



# Ensemble Prediction on Global Scale

- Improving the skill of the CPTEC-EPS with the methodology of Mendonça and Bonatti (2009)
- Calibrated outputs (Bias Removed): + MB09 – MB09BC
- Operational since 2013.




Gain of 4 days with the new EPS (MB09BC)

# Brazilian Earth System Model (BESM) Ocean-Atmosphere Recent Developments

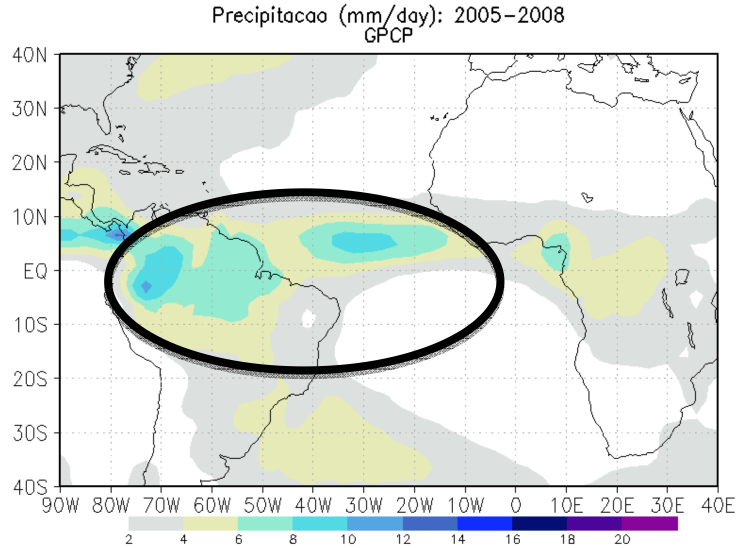
Paulo Nobre, Marta Malagutti, Emanuel Giarolla, Leo Siqueira, Paulo Kubota,
Silvio Nilo, José P. Bonatti, Vinicius Capistrano, Manoel Baptista.

National Institute for Space Research, INPE
Center for Weather Forecast and Climate Studies – CPTEC

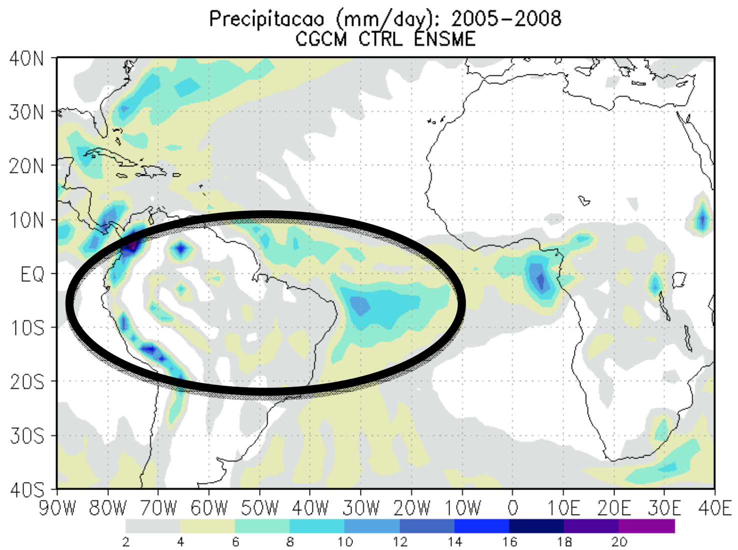
27 NOVEMBER 2013

# BESM Rainfall over the Amazon

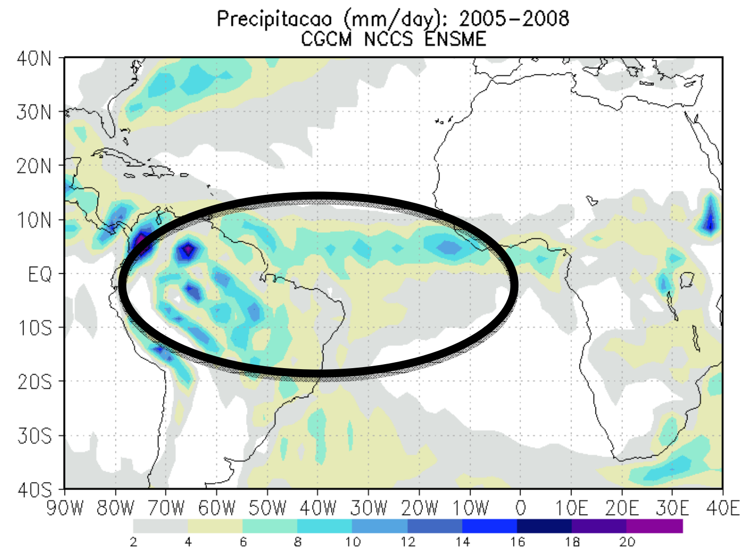
GPCP




BESM 2.3




BESM 2.3.1




From: Bottino and Nobre (2014, in preparation)

- Recent and planned developments and research

# New time integration scheme for BRAMS regional model

## 3rd order Adams-Bashforth-Moulton from Wicker (2009)

The ABM3 time-stepping scheme can be written as

$$q^* = q^t + \frac{\Delta t}{2}[3f(q^t) - f(q^{t-\Delta t})] \quad \text{and} \qquad (7a)$$

$$q^{t+\Delta t} = q^t + \frac{\Delta t}{12}[5f(q^*) + 8f(q^t) - f(q^{t-\Delta t})], \qquad (7b)$$

where $f$ represents the right-hand-side slow-mode operator. The splitting algorithm is then written as follows:

$$\mathbf{V}^* = F[S(\mathbf{V}^{\mathrm{AB2}}), NS]_t^{t+\Delta t} \quad \text{and}$$

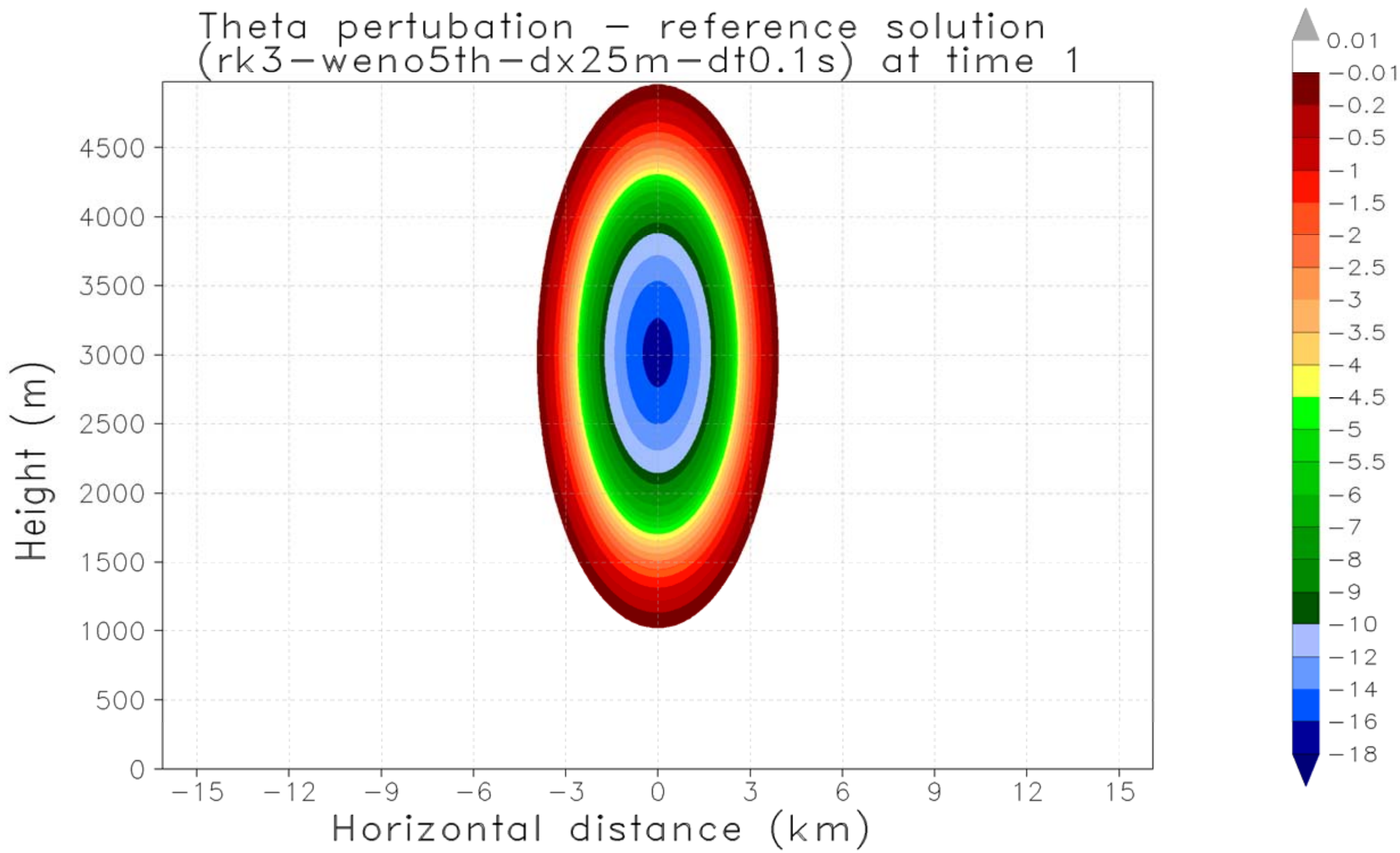
$$\mathbf{V}^{t+\Delta t} = F[S(\mathbf{V}^{\mathrm{AM3}}), NS]_t^{t+\Delta t}. \qquad (7c)$$

The $\mathbf{V}^{\mathrm{AB2}}$and $\mathbf{V}^{\mathrm{AM3}}$ represent the terms on each of the right-hand sides of (7a) and (7b), respectively, used to compute slow-mode terms.[2] This algorithm requires $2NS$ time steps, and two slow-mode evaluations. The required internal storage increases to $4N$ as three time levels are needed to be stored for the corrector step. The stability analysis requires an initial solution vector to have eight elements:

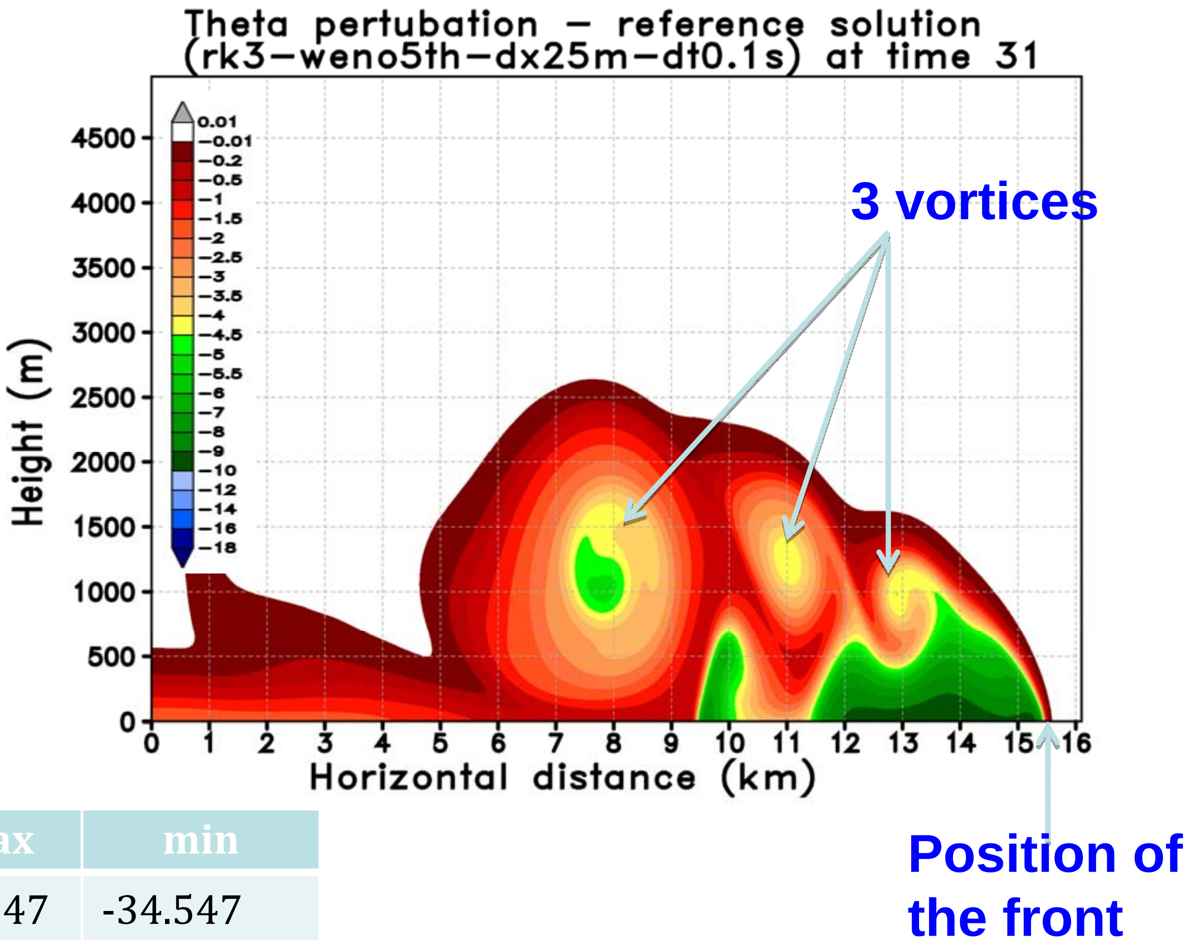
$$\mathbf{X} = (u^m, \pi^m, u^*, \pi^*, u^t, \pi^t, u^{t-\Delta t}, \pi^{t-\Delta t})^{\mathrm{T}}. \qquad (8)$$

- ABM3 has 2 stages:
  - ⇒ 2 evaluations of the slow-mode tendencies,
  - ⇒ 2 integrations of the fast-waves solver.
- RK3 has 3 steps.
- Wicker (2009) suggests that ABM3 might be competitive in comparison with RK3 when aerosol/cloud prognostic schemes dictates the time integration step.

# Reference Solution - Straka Density Current

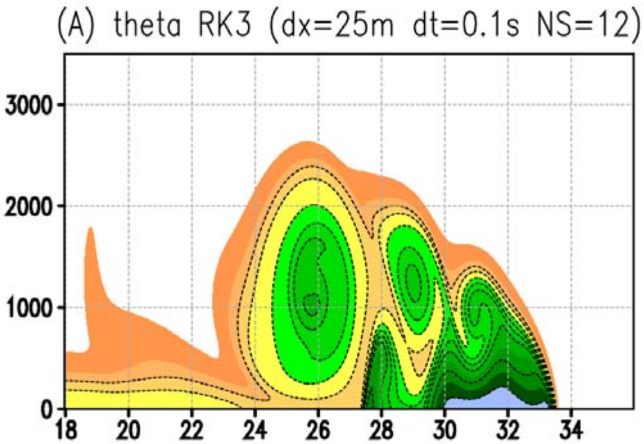


# Reference Solution at time 900 sec




| Variable | max | min |
|---|---|---|
| U (m/s) | 34.547 | -34.547 |
| W (m/s) | 13.195 | -16.142 |
| P' (hPa) | 2.2242 | -4.3603 |
| Theta' (K) | 0.0027 | -9.6861 |

# Comparison – RK3 x ABM3

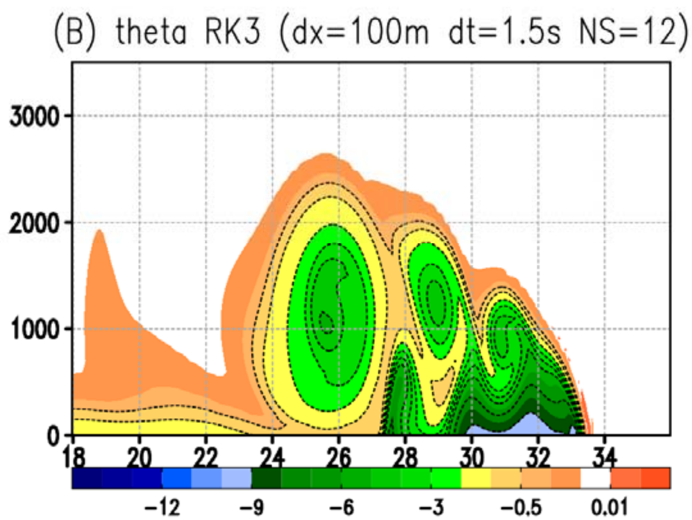


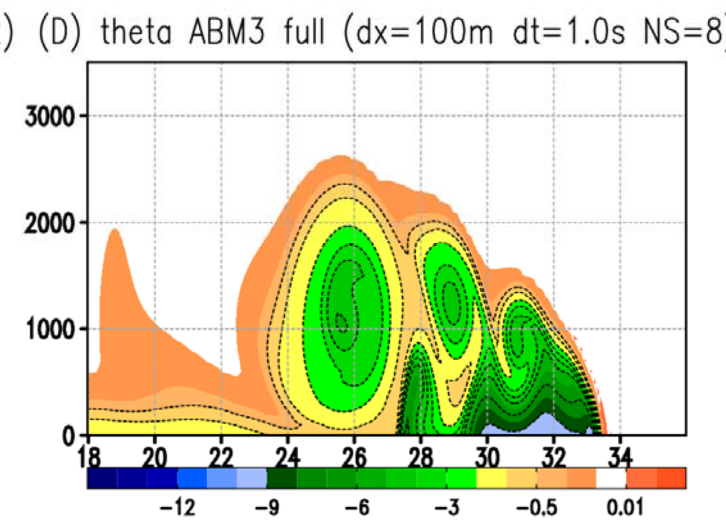

Reference solution:
dx=dz=25m
dt=0.1 sec / 12 sub-steps with RK3
advection: WENO 5th

dx=dz=100 m
time step /number of sub-steps (fast waves)
RK3 : 1.5 sec / 12
ABM3: 1.0 sec / 08
advection: 5th order

CPU TIME:

| RK3 | ABM3 |
|---|---|
| 3.14 s | 3.39 s |



# A scale and aerosol aware stochastic convective parameterization

Arakawa et al (2011) propose the following equation for the vertical eddy transport that includes the scale dependence trough σ parameter:

$$\overline{w\phi} - \bar{w}\bar{\phi} = (1-\sigma)^2 \left(\overline{w\phi} - \bar{w}\bar{\phi}\right)_{adj}$$

where $\sigma$ and $\left(\overline{w\phi} - \bar{w}\bar{\phi}\right)_{adj}$ must be determined to close the unified parameterization.

$\left(\overline{w\phi} - \bar{w}\bar{\phi}\right)_{adj}$ { eddy transport for a full adjustment to a quasi-equilibrium state / can be calculated from a conventional cumulus parameterization.

$\sigma$ is the fraction of the area covered by active updraft and downdraft plumes.

In the proposed scheme, $\sigma$ is calculated by the entrainment ($\varepsilon$) rate and the grid-cell area:

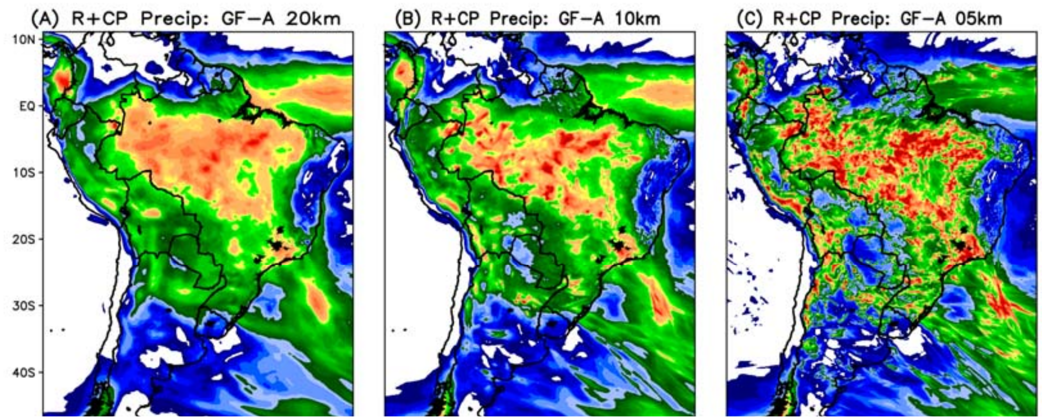
$\varepsilon = \frac{b}{R}$, where $R$ is the radius of the convective plumes (up and downdraft), $b = 0.2$

$$\therefore \sigma = \frac{2\pi R^2}{\Delta x \Delta y} = \frac{2\pi b^2}{\Delta x \Delta y \ \varepsilon^2}$$

In collaboration with G. Grell (NOAA/ESRL)

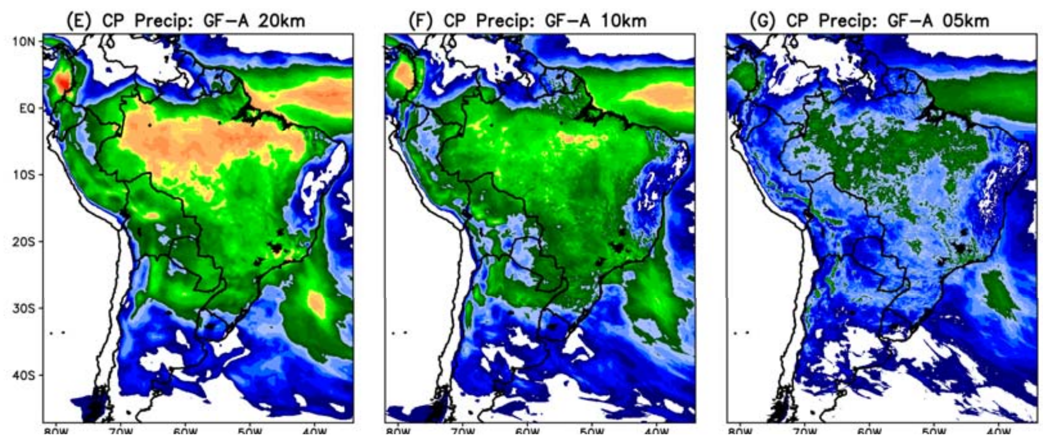
# BRAMS Simulations with 20, 10 and 5 km grid spacing
# Jan 2013 – 15 days 36horas FCT

**Total rainfall: resolved + from parameteri-zation**




Mean rainfall: 4.3 mm/day 4.1 mm/day 4.5 mm/day

**Only from parameteri-zation rainfall**



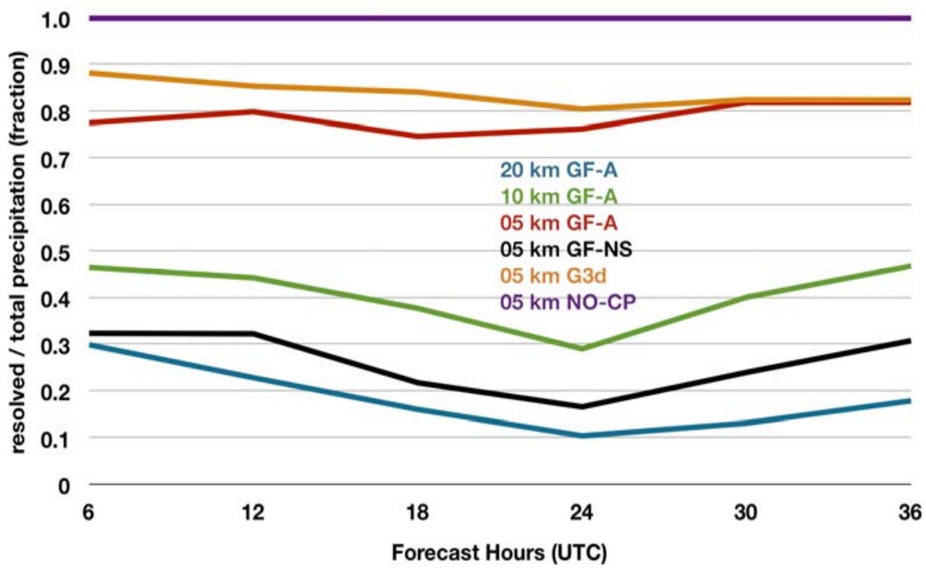

Mean rainfall: 3.5 mm/day 2.5 mm/day 1.0 mm/day

**20km** **10km** **05km**

with scale dependence

# Transition from parameterized to resolved rainfall
# January 2013 – 36-hour forecast over S. America

Fraction of resolved / total rainfall

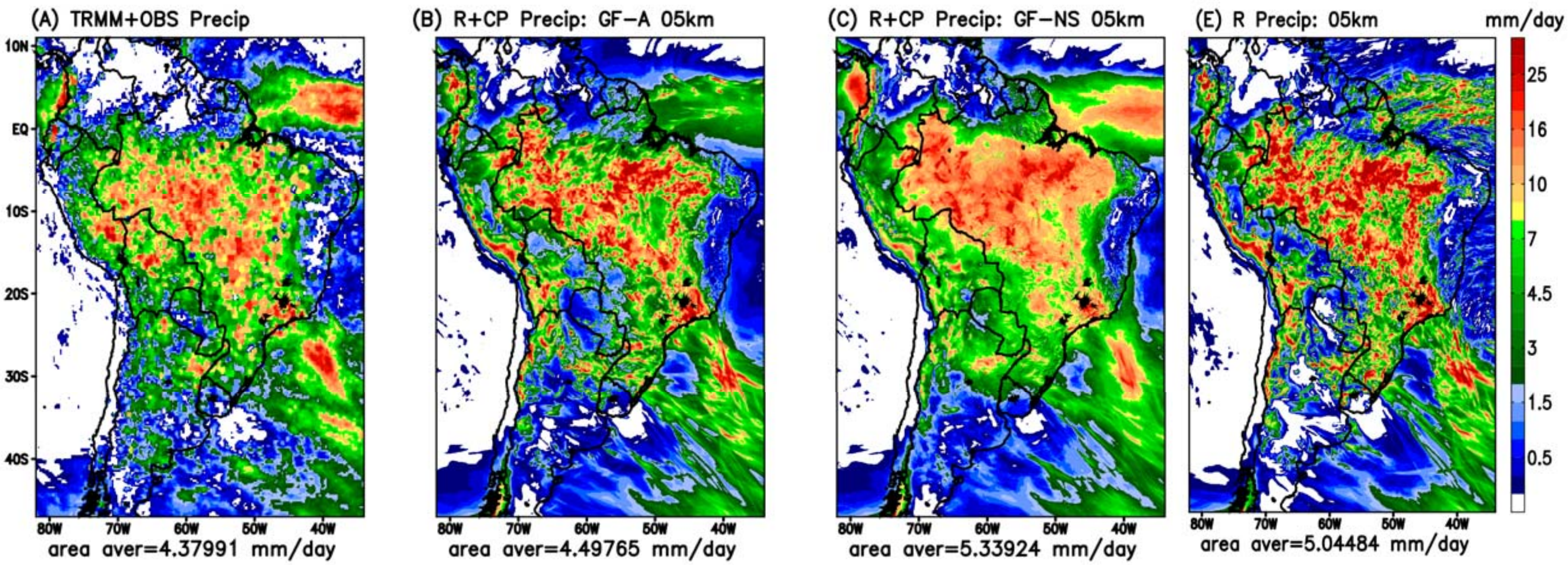



Transition from parameterized to resolved from 20 to 5 km (but not for 05km GF-NS, similar fraction as 20km)

**20 km** – with scale dependence
**10 km** – with scale dependence
**05 km** – with scale dependence
**05 km** – NO scale dependence
**05 km** – NO cumulus parameterization

# Application with BRAMS 5km
# January 2013 - monthly mean precipitation (mm/day)

| **TRMM + OBS** | **R+CP: with scale** | **R+CP: without scale dependence** | **Only R** |
|---|---|---|---|




| **4.38** mm/day | **4.50** mm/day | **5.34** mm/day | **5.04** mm/day |
|---|---|---|---|

**R : resolved precipitation**
**CP : parameterized precipitation**