Update of CPTEC activities - 2012

by

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• Recent developments on:
  – Regional Atmospheric Modeling
  – Global Atmospheric Modeling
  – Data Assimilation
  – Ensemble Prediction

• Recent Activities
# Plans of 2011: Current models resolution and expected for the next year

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BRAMS - Brazilian developments on the Regional Atmospheric Modeling System: recent developments < 2 years

- Ensemble version of convective parameterization G3d appropriated for high resolutions simulations (deltax < 10 km), that including also aerosol indirect effects.
- Nakanishi and Nino turbulence scheme
- JULES Surface scheme with fully coupled carbon cycle
- UK-Met Office Radiation Scheme (fully coupled with aerosols, cloud microphysics)
- Updated cloud microphysics from CSU with input of CCN field (ready for inclusion of aerosol indirect effects)
- Digital Filter for model initialization
- Monotonic advection for scalars (theta, tke, hydrometeors, tracers, aerosols, ..)
- Adams-Bashforth (2\textsuperscript{nd}, 3\textsuperscript{rd} and 4\textsuperscript{th} orders) for time integration: but not fully successful, planning to include Adams-Bashforth–Moulton (Wicker, 2009) or Runge Kutta (Skamarock et co-authors, 200X)
- Huge improvements in the code scalability (thousands of processors), parallel I/O and memory usage.
New regional weather forecast for South America on 5km resolution (under evaluation)

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

- Time step: 15 seconds

- Model domain:
  - # grid points: 1360x1489x55 ~ 100 x 10^6
  - Model top @ 21 km

- Forecast length:
  - 5 days, starting at 00 UTC,
    (near future will be implemented at 12 UTC).

- Execution time:
  - 1h 40 mn on 9600 cores
    produces 5 days forecast (I/O is the bigger bottleneck)
BRAMS 5 km
Some computational aspects

Elapsed time for 1 day

<table>
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<tr>
<th>Process</th>
<th>Computer time (s) with 9600 cores</th>
</tr>
</thead>
<tbody>
<tr>
<td>Model Integration</td>
<td>732 (62%)</td>
</tr>
<tr>
<td>INPUT</td>
<td>300 (25%)</td>
</tr>
<tr>
<td>OUTPUT</td>
<td>148 (13%)</td>
</tr>
<tr>
<td>Total</td>
<td>1180 (~20mn/day)</td>
</tr>
</tbody>
</table>

Graph showing the breakdown of computer time for each process (Input, Model Integration, Output). The total time is approximately 1180 seconds (about 20 minutes per day) with 9600 cores.
To allow for a smooth transition on “gray” scales, where more and more of the convection is resolved:

We apply the new Grell’s cumulus scheme: G3d
Environmental subsidence

Lateral entrainment and detrainment

Downdraft detrainment

Updraft detrainment

G3d: nine or more grid boxes

Slide from G. Grell
Application of BRAMS 5 km with G3d convection scheme (a visual comparison)

In collaboration with G. Grell
BRAMS 5 km resolution
Some examples of model performance

Remote Sensing Rainfall

Model Rainfall – 24 hr accum.
Comparison (RMSE) between BRAMS 20km and 5 km (with G3d convection scheme)

- Temp 2m
- Temp Dewp 2m
- 10m wind magnitude
- MSLP
Comparison (RMSE) between BRAMS 20km and 5 km (with G3d convection scheme)

Rainfall using 363 rain gauges

Rainfall using TRMM + 1000 observations
Examples of rainfall evaluation (RMSE)

July 2012

Some models running over S. America (on resolutions from 5 to 50 km):

1-22/10/2012

120 hours forecast
JULES-CCATT-BRAMS
Coupling between the land-surface scheme JULES and the atmospheric-chemistry model CCATT-BRAMS
Coupling between the land-surface scheme JULES and the atmospheric-chemistry model CCATT-BRAMS

Comparison of near surface CO2 (LBA Tower km 67)

Moreira et al (in prep.)
BRAMS Weather Forecast Evaluation with JULES

Evaluation for dry and wet seasons: 1 month with 5 days forecast each day

~ 300 stations
Model Evaluation:

BRAMS/LEAF; BRAMS/JULES+NewAdvection; BRAMS/JULES+new Turbulence (NN) and ECMWF

Moreira et al (in prep.)
• Global Atmospheric modeling
Experimental configuration for the CPTEC global atmospheric model

### Configuração do MCGA-CPTEC/INPE TQ0299L64 (~44 km)

<table>
<thead>
<tr>
<th>Opcões</th>
<th>Descrição (OPERACIONAL)</th>
<th>Descrição (EXPERIMENTAL)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dinâmica</td>
<td>Euleriana com grade Reduzida</td>
<td>Semi-Lagrangiano con grade Reduzida</td>
</tr>
<tr>
<td>Radiação de onda Curta</td>
<td>CLIRAD (Tarasova et al. 2007)</td>
<td>CLIRAD (Tarasova et al 2007)</td>
</tr>
<tr>
<td>Convecção Profunda</td>
<td>KUO(Kuo, 1965)</td>
<td>Grell e Devenyi(2002)-VersCPTEC</td>
</tr>
<tr>
<td>P. de Larga escala</td>
<td>Precipitação de Larga escala</td>
<td>Microfísica</td>
</tr>
<tr>
<td></td>
<td>(ajustamento devido a saturação)</td>
<td>(Rasch and Kristjánsson (1998) )</td>
</tr>
<tr>
<td>Fluxo sobre oceano</td>
<td>Bucket model (COLA)</td>
<td>Bulk aerodynamic algorithm (NCEP)</td>
</tr>
</tbody>
</table>
Experimental AGCM at CPTEC: Evaluation using RMSE
Development of an on-line atmospheric chemistry global model based on coupling CCATT + CPTEC/AGCM
Emissions including plume-rise for vegetation fires
BRAMS e MCGA;
Sedimentation/Dry deposition
Advection by Semi-Lagrangian transport scheme (positive-definite, monotonic)
Convective transport + wet removal of gases/aerosols fully coupled with cumulus scheme.
Both model (regional and global) presents similar results
Bit reproducibility for different parallel runs
Data Assimilation
CPTEC is replacing its former DA system (PSAS) by the Gridpoint Statistical Interpolation (GSI), currently at NCEP and NASA, starting in the GCM (T299L64) by the end of 2011. During 2013, the same system is going to be implemented in the regional BRAMS model. LETKF research continues with the mid/long term goal of a hybrid DA system.

<table>
<thead>
<tr>
<th>DA System</th>
<th>Operational?</th>
<th>Model/Config</th>
<th>Obs Type</th>
<th>Number of Obs</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Global PSAS</td>
<td>Since 2002</td>
<td>TQ213L42</td>
<td>Conventional, satellite retrievals</td>
<td>~10^5</td>
<td>Decommissioning on Mar/2013</td>
</tr>
<tr>
<td>Regional PSAS</td>
<td>Since 2000</td>
<td>Eta 40Km, 38 levs</td>
<td>Conventional, satellite retrievals</td>
<td>~10^5</td>
<td>Decommissioned on Mar/2012</td>
</tr>
<tr>
<td>Global GSI</td>
<td>In pre-ops since Jul/2012</td>
<td>T299L64</td>
<td>Conventional, Radiances, GPS</td>
<td>~10^6</td>
<td>To operational on Dec/2012</td>
</tr>
<tr>
<td>Global LETKF</td>
<td>Research Mode</td>
<td>T299L64</td>
<td>Conventional, satellite retrievals</td>
<td>~10^5</td>
<td>Towards inclusion radiances and GPS</td>
</tr>
<tr>
<td>Regional GSI</td>
<td>No</td>
<td>BRAMS, 5 km</td>
<td>Conventional, Radiances, GPS</td>
<td>~10^6</td>
<td>Begin of work on Jan/2013</td>
</tr>
</tbody>
</table>
GSI implementation at CPTEC/INPE

- Preliminary results comparing the newly implemented Global GSI system (G3DVar) against the current Global PSAS (GPSAS) operational DA are presented.

- RMSE and Biases averaged over Jun, Jul, Aug/2012 were computed for different regions: Northern (HN) and South (SH) Hemispheres, Tropical region and South America.

- In the panels that follow, GPSAS is shown in blue, G3DVar in green and GFS (for reference purposes only) in black.
RMSE averaged over Jun, Jul, Aug/2012 for different regions: Northern (HN) and South (SH) Hemispheres, Tropical region and South America.
Geopotential Height at 500 hPa – Bias

Bias averaged over Jun, Jul, Aug/2012 for different regions: Northern (HN) and South (SH) Hemispheres, Tropical region and South America.
RMSE averaged over Jun, Jul, Aug/2012 were computed for different regions: Northern (HN) and South (SH) Hemispheres, Tropical region and South America. GPSAS is shown in blue, G3DVar in green and GFS (for reference purposes only) in black.
Bias averaged over Jun, Jul, Aug/2012 for different regions:
Northern (HN) and South (SH) Hemispheres, Tropical region and South America.
Gain of 4 days with the new EPS (MB09BC)

Ensemble Prediction on Global Scale

Improving the skill of the CPTEC-EPS with the methodology of Mendonça and Bonatti (2009)
Projects aiming to develop products

- Applying of a probabilistic calibration method to the CPTEC-EPS outputs;
- Development of an extreme precipitation forecast index

A Forecast Demonstration Project
CPTEC is leading a pioneer initiative in partnership with CHUVA project aiming to create an ensemble of high resolution LAM (°LT. 5 km). Three high resolution LAM (Eta, BRAMS and WRF) will be driven by two TIGGE-EPS (CPTEC and NCEP). One member of each EPS will be selected.
The first tutorial of the CCATT-BRAMS modeling system
CPTEC 22/01-03/02 /2012

- Over 50 participants: Brazil, Peru, Argentina, Colombia e Cuba
SAMBBBA
(South American Biomass Burning Analysis)
Smoke plume in LIDAR

On end of this November, INPE will host the 1st SAMBBA Modeling Workshop
CPTEC has made some advances on NWP on several scales:

- On regional scale, a locally adaptive emergency system is running with BRAMS model on 1 km resolution to provide guidance on severe weather occurrence.

- Also a new product using BRAMS on 5 km resolution covering the entire South America is running and is under evaluation. Rainfall forecast presents good improvement. Very soon, a set of new physical parameterizations will be tested in this configuration.

- On global scale, preliminary results using an new set of physical parameterizations indicate better scores. More robust evaluation will appear soon.

- The GSI 3d-VAR data assimilation approach has been adopt by CPTEC and this system was implemented with the AGCM. The new analysis presents huge improvement in comparison with the old GPSAS system. Next January, the same methodology will be applied for the regional modeling with BRAMS.

- The ensemble forecast has been improved with new methodology for the application of random perturbations developed at CPTEC.
Thanks for your attention!
Backup slides
Brazilian Model of the Global Climate System

IBIS

GFDL’s MOM4p1 + ISIS ocean ice model + Topaz ocean biogeochemistry model

CPTEC’s Atmos
Global spectral model

CCATT-BRAMS
Current and Future Data Assimilation System on CPTEC

Current Data Assimilation System: PSAS (3DVar/OI based system)
Future Data Assimilation System: LETKF (under implementation)

**Physical-space Statistical Analysis System**

\[
\delta x_a = (BH^T)(R + HBH^T)^{-1}\delta y_o
\]
(Analysis increment)

\[
J(w) = \frac{1}{2}w^T(R + HBH^T)w - w^T[y_o - H(x_b)]
\]
(Minimize cost function)

**Local Ensemble Transform Kalman Filter**

\[
x^a = x^b + E_{loc} \cdot \tilde{K} \cdot y^o
\]
(Kalman Filter Analysis update)

\[
\tilde{K} = (I + Z^TR^{-1}Z)^{-1}Z^TR^{-1}
\]
(Kalman Gain)
### CPTEC’s Global Model on CRAY XT6

<table>
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<tr>
<th>STATUS</th>
<th>Production</th>
<th>Production Tests</th>
<th>Ready for Production Tests</th>
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<tr>
<td>CONFIGURATION</td>
<td>T299L64 Eulerian Red. Grid</td>
<td>T299L64 Eulerian Red. Grid</td>
<td>T666L96 SemiLagran Red. Grid</td>
</tr>
<tr>
<td>EXEC TIME/Day</td>
<td>920 s</td>
<td>540 s</td>
<td>447 s</td>
</tr>
<tr>
<td>CORES</td>
<td>384</td>
<td>576</td>
<td>2280</td>
</tr>
<tr>
<td>MPI / OpenMP</td>
<td>384 / 1</td>
<td>64 / 6</td>
<td>380 / 6</td>
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BRAMS Speed-up
One Fcst Day over South America @ 10km
(20M Grid Points)
## Current models resolution and expected for the next year

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Current model ensembles resolution and expected for the next year

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<th>Next Year</th>
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<tr>
<td>Eta - NCEP analyses – 5 members</td>
<td>40km 5 days</td>
<td>20 km/ 38 levels</td>
</tr>
<tr>
<td>AGCM with NCEP – Weather – Global – 15 days</td>
<td>105 km/ L 28 15 members</td>
<td>80 km / L 42 51 members</td>
</tr>
<tr>
<td>AGCM with NCEP – Seasonal climate – Global – up to 6 months</td>
<td>210 km / L 28 105 members</td>
<td>100 km / L 42 105 members</td>
</tr>
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Cray XT6 supercomputer
1272 nodes, 2 six-core AMD Opteron, 192 Gflops, 32 GB, SeaStar2
Performance: 244 Tflops  (storage capacity: 3,84 PB)
Sustained: 15.8 Tflops (CPTEC benchmark)
Peak performance: approximately 250 Tflops
8- FUTURA CONFIGURAÇÃO PNT—META TQ666L096 (20KM)

Tempo de Integração: 10 dias.
Integração no Tempo: Semi-Lagrangiana, GRADE: Reduzida
Radiação de Onda Curta: CLIRAD ou UK Met Office
Radiação de Onda Longa: UK Met Office
Esquema de Nuvem: CAM5 Superfície: IBIS estático
Camada Limite: CAM-5 (CLP-ÚMIDO) e ajustes com outras implementações
Arrasto por Ondas de Gravidade: NCEP
Convecção Profunda: Grell-Devenyi e Convecção Rasa: CPTEC
Precipitação de Grande Escala: Microfísica CAM-3 (ou CAM-5)
Umidade do Solo: anomalia da análise do CPTEC somada à climatologia de rodada
longa do MCGA

Temperatura da Superfície do Mar (TSM): Persistência da Média dos Últimos 5 Dias Proveniente da NOAA
Gelo Marinho: proveniente da NOAA, Campo Independente da TSM.
Neve: proveniente da NOAA
Concentração de CO₂: Campo Inicial Constante (370 ppm), Transportado e Iterativo com a Radiação
Ozônio: Campo Inicial Proveniente da NOAA, Transportado e Iterativo com a Radiação
Transporte de Traçadores: CO₂, Ozônio, Água Líquida e outros para Micro-Física
Introdução da Química: Mesmo código que CCATT-BRAMS (exige PAD)
• A three-dimensional application of the feedback to the model.
• Inner most/convective box only experiences lateral entrainment/detrainment
• The environmental subsidence is spread over neighboring grid points (currently only 9 neighboring grid points)
• When spreading is turned on, the fraction of resolved precipitation increases drastically, especially for large thresholds
TIGGE multi-model forecast and reforecast-calibrated EPS forecasts:

- **Multi-model.** Combining single-model forecasts from several models into a multi-model forecast.
- **Reforecast-calibration.** Calibrating single-model forecasts with the help of specific training datasets.

- Multi-model ensemble seems to be the most reliable approach for seasonal forecasts.
- THORPEX Interactive Grand Global Ensemble (TIGGE) – CPTEC faz parte com dados desde 10/2006

\[
CRPSS = \frac{\text{CRPS}_{\text{forecast}} - \text{CRPS}_{\text{reference}}}{\text{CRPS}_{\text{perfect}} - \text{CRPS}_{\text{reference}}}
\]

*Figure 1* Continuous Ranked Probability Skill Score (CRPSS) versus lead time for 850-hPa temperature forecasts. The TIGGE-9 multi-model composed of nine single models and the scores of all nine contributing single models are shown. Symbols are only plotted for cases in which the single-model score differs significantly from the multi-model score on a 1% significance level. The significance levels have been assessed using a paired block bootstrap algorithm following *Hamill* (1999). All scores are for forecasts starting in DJF (December, January, February) 2008/09 and averaged over the northern hemisphere (20°–90°N).
7- ENSEMBLE

META IMEDIATA: ter em operação uma versão atualizada do Sistema de Previsão por Conjuntos (SPCON) do CPTEC/INPE.
PRAZO: até o final de 2012
JUSTIFICATIVA: a versão que utiliza as modificações propostas por Mendonça e Bonatti (2009) na criação das condições iniciais perturbadas apresenta, de maneira geral, produz melhores índices que a versão atualmente em operação.

Fig. CRPSS de T850, médio no Hemisfério Norte. Losangos indicam o SPCON-OPER, círculos o SPCON-MB2009, quadrados o SPCON-MB2009 calibrado, e triângulos o SPCON da KMA. Este índice é uma média para o período DJF2008-09.
In the SH, besides 4 days improvement, there is a better ranking among TIGGE partners.
Model Evaluation (RMSE):
BRAMS/LEAF; BRAMS/JULES;
BRAMS/JULES+NewAdvection and ECMWF

RMSE = root mean square error

Moreira et al (in prep.)
Equitable threat score (ETS) for 24, 48, 72 and 96 hours forecast