Update of CPTEC activities - 2008
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Operational Activities

MODELS
Global Model
Regional Model
Coupled Atmosphere-Ocean Model
Wave model
Environmental Air Quality Model
Ensemble Weather Prediction (15 days - 15 members - 2X/day)
Ensemble Seasonal Forecasting (3 - 6 month - 4 groups of 25 members)

Ingestion, Processing and generation of satellite products
Vis, IR, WV images
TOVS, AIRS, ATOVS soundings
Vegetation indices
Sea-surface temperature
Ultra-Violet indices
Biomass burning monitoring
Solar and terrestrial radiation
Cloud classification
Satellite winds
Satellite Precipitation estimate
Storm and lighting detection
GPS tropospheric delay
**Operational NWP at CPTEC**

Weather Forecasting Operational Suite:

- **Global Spectral Model** T299L62 up to 7 days, twice a day from (a) NCEP analysis and (b) T213L42 GPSAS/DAO assimilation system;
- **Regional Eta Model** – 20kmL38, up to 5 days, twice a day from NCEP analysis and from RPSAS/DAO CPTEC regional analysis with CPTEC global model BC; remarkable progress in quality since April 2007.
- **Regional air quality forecast** (S.America+Africa) - biomass burning+urban sources - BRAMS - 30km resolution 2 day.
- **Global Ensemble** T126L28, up to 15 days, twice a day, 15 members; CPTEC/FSU ensemble principal components IC perturbation scheme;
- **Regional Ensemble** Eta40km up to 5 days, twice a day, 5 members; BC forcing from global EPS clustering, 5 members with perturbed physics (to be implemented in early 2006);
- **Global coupled ocean/atmosphere model** (T126L28)+ MOM3/4 (20km), 30 days twice a day;
- **Seasonal forecasting ensemble** T62 (18 initial conditions+3 physics)

**Modeling Challenges at CPTEC:**

- **Convection in the Amazon.**
  - Thermal and aerosol hypothesis for the “Green Ocean”
  - Large scale dynamics is primary forcing
  - Thermodynamics is modified by surface
  - Given the same dynamics/thermodynamics, aerosol plays a role in the convection regime
New HPC system: procurement in progress (early December)
CPTEC/INPE will be close to the leading institutions

New challenge – be an open computing center for weather, climate and climate change studies
Resolution and Machine Performance
January 2007

Resolution and Machine Performance Planned
2008-2009
Model development: the future of CPTEC

- New Global CPTEC model
- Environmental model – BRAMS
  - Coupling of the New Global CPTEC model and of the BRAMS Environmental model to MOZART (Max Plank Institute global chemistry transport model)

Data Assimilation
Data assimilation in the CPTEC models

http://assimila.cptec.inpe.br/
New efforts on Land Surface Data Assimilation

Global soil moisture analysis
Impact on LH and SH
Cooperation with NASA - Goddard
Future Data Assimilation

• Local Kalman Filter - Cooperation with Eugenia Kalnay at Univ. of Maryland

The LEKF algorithm:

1. Make a 6hr ensemble forecast with K+1 members. At each grid point \( i \) consider a local 3D volume of ~800km by 800km and a few layers.

2. Use all the observations in the volume and solve exactly the Kalman Filter equations. This gives the analysis and the analysis error covariance at the grid point \( i \).

3. Solve the square root equation and obtain the analysis increments at the grid point \( i \).

4. Transform back to the grid-point coordinates

5. Create the new initial conditions for the ensemble

6. Go to 1

Current Status: Final implementation of the parallel cycle expected to take place in early 2009.
Began operation in October 2001

The EOF-based perturbations method (Zhang and Krishnamurti, 1999) is used to generate the perturbed initial conditions:
- Perturbed region: 45S-30N/0-360E
- Perturbed fields: T, U and V
- Two runs are performed starting from 00 and 12 UTC analysis
- Each run represents a set of 15 forecasts (1 control plus 14 perturbed) up to 15 days
- Domain: Global
- Resolution: T126L28
- Products: ensemble mean, ensemble spread, spaghetti diagrams, probability forecast, probability plumes, cluster analysis, week mean precipitation anomaly and evolution of high level potential velocity

Ensemble Weather Prediction at CPTEC

Comparison with breeding
Plans for Near Future

Currently

- Additional EOF perturbations in the extratropics and on surface pressure and specific humidity, use the last 12-hours lagged forecasts to generate products (Dec 2008);

- Increase the number of ensemble members (20-30 per run), increase the resolution (T170L42), stochastic perturbations, bias correction on probabilistic forecasts (2009 - depends on new computer system)

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Performance of Ensemble Mean and Spread – Monthly Average for Jan/2005

New perturbations reduce the forecast error and increase the ensemble spread
Better probabilistic forecasts are obtained with new initial perturbations

Ensemble prediction with the atmosphere/ocean coupled model (2X 35 day forecasts)

“Lagged Average Forecast”

- 10 members from recent analysis and 9 previous => up to 5 days before;
- Integration for 35 days;
- > 30 days;
- Goal: role of SPCZ, SACZ interaction, intraseasonal signal
Coupled model ensemble products

Mean Ensemble + Spread
MSLP

Mean Ensemble + Spread
T850

Precipitation Probability

Integrated: Prob. of most likely precip. tercile (%)
Issued: Aug 2008    Valid for SON 2008
Regional model ensemble

24hr Precipitation - physics perturbation

Global Models: CPTEC, NCEP, UKMET
Regional Models
• CPTEC regional model (ETA)
• Brazilian Navy (DWD model)
  • Smaller domain – limited to S/SE
  • Univ. of São Paulo – BRAMS
• Federal University of Rio de Janeiro - WRF
• National Laboratory for Computational Sciences – ETA,BRAMS
• Univ. of Buenos Aires - WRF and BRAMS
• Federal University of Santa Maria - BRAMS
• 3 regional offices - WRF

This is work has been supporting regional activities on the THORPEX/TIGGE - WMO.
Initial Page

**Optimal Forecast at a particular station**

\[
X = \sum (X_i - B^X_i) / MSE^X_i \quad I=1,\ldots,N
\]

Where

- \(X_i\) is the forecast provided by the \(i_{th}\) model
- \(B^X_i\) is the \(i_{th}\) model bias of the \(X\) variable
- \(MSE^X_i\) is the \(i_{th}\) model mean square error
- \(N\) is the number of model estimates at a particular location (lat,lon of the station)
What is the impact of the regional models???

Red: all available models

Yellow: only global models

Temperature forecast

Mean square error

No data assimilation in most regional models

Bias – 3hr to 6hr precipitation accumulation

TRMM/GOES estimate

Mean square error – 24h precipitation accumulation

Hydroestimator/CPTEC

Normalized mean square error

Only global models here

No data assimilation in most regional models
Environmental Prediction

Real time monitoring of the transport of biomass burning emissions in South America. http://meioambiente.cptec.inpe.br

General flow of the real time monitoring the transport of biomass burning emissions in South America. Vegetation map: 1 km IGBP 2.0. RAMS grid 40 Km.

The GOES-8 ABB Fire Product on 1745Z September 7, 2002, depicting the vegetation fires on South America. GOES resolution is 1 Km in the visible channel, 7 and 14 Km for infrared.

The parameterized CO source emission for September 7, 2002. Some places on Brazil with forest biomes emitted over 2 ton km$^{-2}$ of carbon monoxide.

Source: Saulo Freitas and Karla Longo
Time series of PM$_{2.5}$ mass concentration (µg m$^{-3}$) as simulated by the model (black) and measured at surface (gray) on Ji-Paraná site, Rondônia.

Source: Saulo Freitas and Karla Longo

Role of radiative forcing of aerosols

Reduction on the Convective precipitation (mm)

$\Delta P = (P - P_{\text{aer}})$

Freitas et al. 2005

Longo et al. 2004

Low Troposphere and Long Distance Transport of PM$_{2.5}$ and CO

Andes
Experimental: Ozone forecasting - biomass burning and urban sources

- Coupling of the New Global CPTEC model and of the BRAMS Environmental model to MOZART (Max Plank Institute global chemistry transport model)

Regional Air Quality Monitoring - interaction with Univ. of São Paulo

A simple photochemical module in RAMS for operational forecast
- 15 main reactions related with ozone formation
- semi-implicit numerical integration

Time of sugar cane burning time - O3
08-14Z 14-20Z 18-23Z
Possible choice for new dynamical core:

OLAM – Ocean Land Atmosphere Model –

developed at Duke University by

Robert Walko and Roni Avissar


Primary Motivation for OLAM at CPTEC

- Large national effort on RAMS since early 90's lead to BRAMS: new deep and shallow cumulus parameterizations, radiation module (aerosol), aerosol transport module, simplified ozone photochemistry, SIB2.5 (carbon), dynamic, urban turbulence (TEB), vegetation with LEAF2,3, more efficient parallelization and scalar performance;
- To enable RAMS/BRAMS-type regional simulations to be run on the model's own global grid, without the need for one-way nesting inside another large-scale model;
- To enable global simulations that incorporate RAMS/BRAMS type parameterizations;
- To combine water and energy cycles of the global ocean-land-atmosphere system into a unified climate modeling system
- To enable climate studies that depend on two-way interactions between global, regional, and micro-scales.
New development: parallel version:
Global resolution: 150km
Regional: 75 km

Next generation computers: higher resolution over S. America.

Validation: 3 semi-operational forecast cycles – differences in parameterizations, grid refinement
Example of validation (global 200km): fit to surface obs

CPTEC insertion in the WMO System

- **WIS** – WMO Information System
  - Functional centres:
  - National Centres (NC)
  - Global Information System Centres (GISC)
  - Data Collection and Production Centres (DCPC) and
  - Data communication networks

  WIS concerns only information exchange and data management functions
Global Producing Centres (GPCs) of Long Range Forecasts

The following are the officially designated WMO Global Producing Centres (GPCs) of Long Range Forecasts:

- Bureau of Meteorology (BoM), Australia
  [Link]

- China Meteorological Administration (CMA)/Beijing Climate Center (BCC)
  [Link]

- Climate Prediction Center (CPC), NOAA, United States of America
  [Link]

- European Centre for Medium-Range Weather Forecasts (ECMWF)
  [Link]

- Japan Meteorological Agency (JMA)/Tokyo Climate Centre (TCC)
  [Link]

- Korea Meteorological Administration (KMA)
  [Link]

- Meteo-France
  [Link]

- Met Office (United Kingdom)
  [Link]

- Meteorological Service of Canada (MSC)
  [Link]

- Other leading centres providing global seasonal forecasts:
  - Center for Weather Forecasting and Climate Studies/National Institute for Space Research (CPTEC/INPE), Brazil
    [Link]
  - International Research Institute for Climate and Society (IRI), USA
    [Link]
SIGMACast

Geographical Information System for Environmental Applications – Data Broadcast

SIGMACast access the CPTEC’s database using WMS (Web Map Services), WCS (Web Coverage Services) and WFS (Web Features Services)

• CPTEC status:
  • Synergism between research and operational communities lead to significant improvement in the last 15 years;
    • Air quality environmental forecasting particularly strong
    • Seasonal forecasting: role of Atlantic Ocean – coupled ocean atmosphere models
    • Multi-model ensemble forecasting (internal and external)
    • Biosphere/atmosphere interaction - interaction with research programs in the Amazon - LBA
    • Development of efficient codes for MPI and OpenMP architectures – strong interaction with Applied Mathematics groups
    • Future dynamical cores - adaptative grids - cooperation with other groups (LNCC, USP)
    • Data assimilation: application of estimation theory - cooperation
    • New computer system: competitive