



*The Abdus Salam*  
*International Centre for Theoretical Physics*



**1966-2**

**Fall Colloquium on the Physics of Weather and Climate: Regional  
Weather Predictability and Modelling**

*29 September - 10 October, 2008*

**Eta at INPE**

Sin Chan Chou  
*Centro de Previsao de Tempo e Estudos Climaticos/INPE*  
*Brazil*



**Ministério da Ciência e Tecnologia - MCT**  
**Instituto Nacional de Pesquisas Espaciais - INPE**  
Centro de Previsão de Tempo e Estudos Climáticos - CPTEC

## Eta Model at INPE: Applications

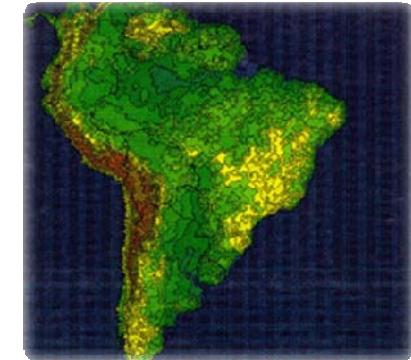
**Sin Chan Chou**

**INPE**  
**National Institute for Space**  
**Research**

[chou@cppec.inpe.br](mailto:chou@cppec.inpe.br)  
+55-12-3186-8424

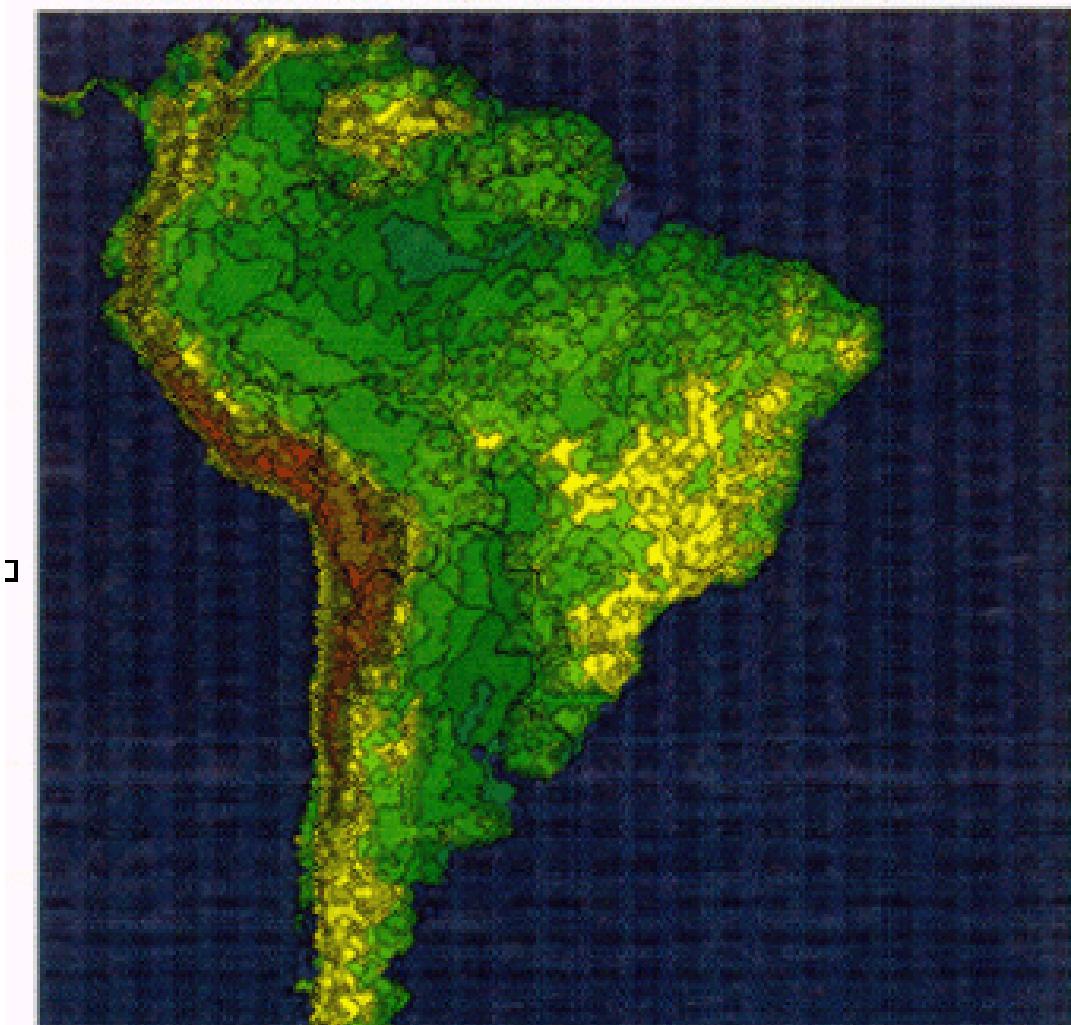
# Eta Model at INPE operational since 1997

## NWP characteristics

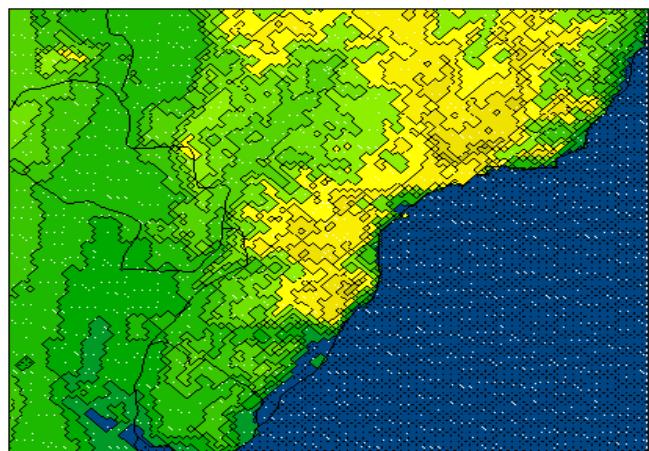
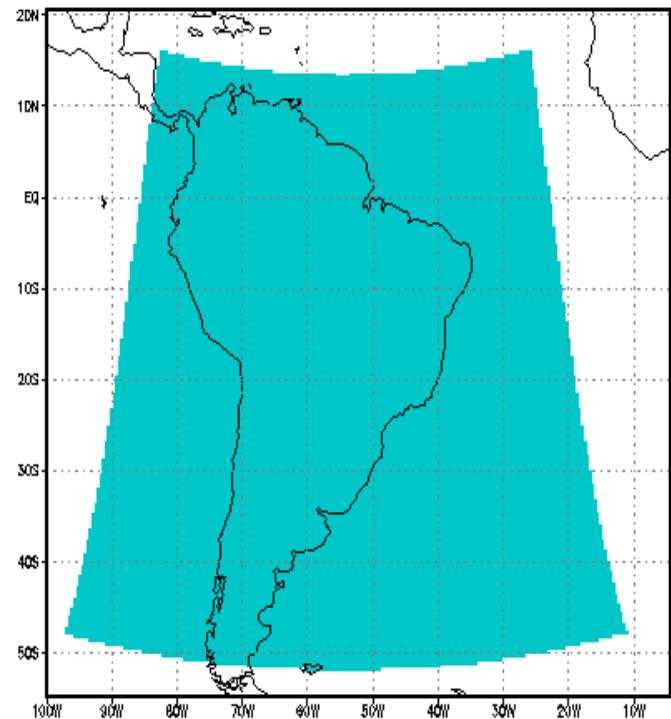


- **Domain:**
  - Most part of South America
  - Southeast Brazil
  - Northeast Brazil
- **Resolution:**      40 km/38 layers;
  - 20km/38 layers;
  - 10km/38 layers;
  - 5km/50 layers NH
- **Grid-point model**
  - Arakawa E grid and Lorenz grid
- **Eta vertical coordinate** (Mesinger, 1984)
- **Prognostic variables:**
  - T, q, u, v,  $p_s$ , TKE, cloud water/ice, hydrometeors
- **Time integration:**
  - 2 level, split-explicit
  - **Adjustmet:** forward-backward
  - **Advection:** first forward and then centered
- **Convection:**
  1. Betts-Miller-Janjic scheme,
  2. Kain-Fritsch scheme
- **Stratiform rain:**
  1. Zhao scheme
  2. Ferrier scheme
- **Turbulence:**
  - Mellor Yamada 2.5, MO surface layer, Paulson functions
- **Radiation:**
  - GFDL package
- **Land surface scheme:**
  - NOAH scheme, 4 soil layers,
- **Initial conditions**
  - NCEP T126L28 analyses,
- **L.B.C.**
  - CPTEC T126L28 GCM, updt 6/6 h,
- **Initial soil moisture:** 12h Global model forecast or climatology
- **Initial albedo:** seasonal climatology

# Step mountains

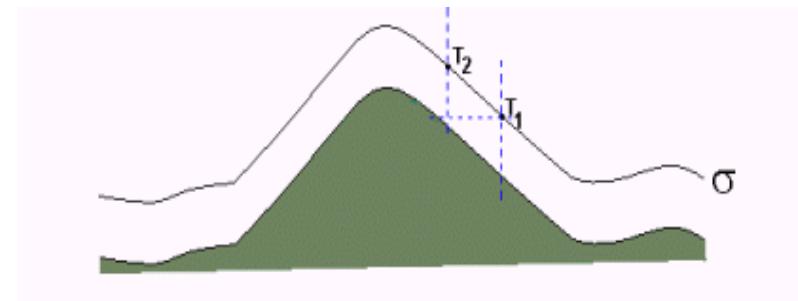


3364	3763	4166	4643	5129
1487	1743	2021	2321	2644
388	520	672	845	1038
0	20	63	115	166



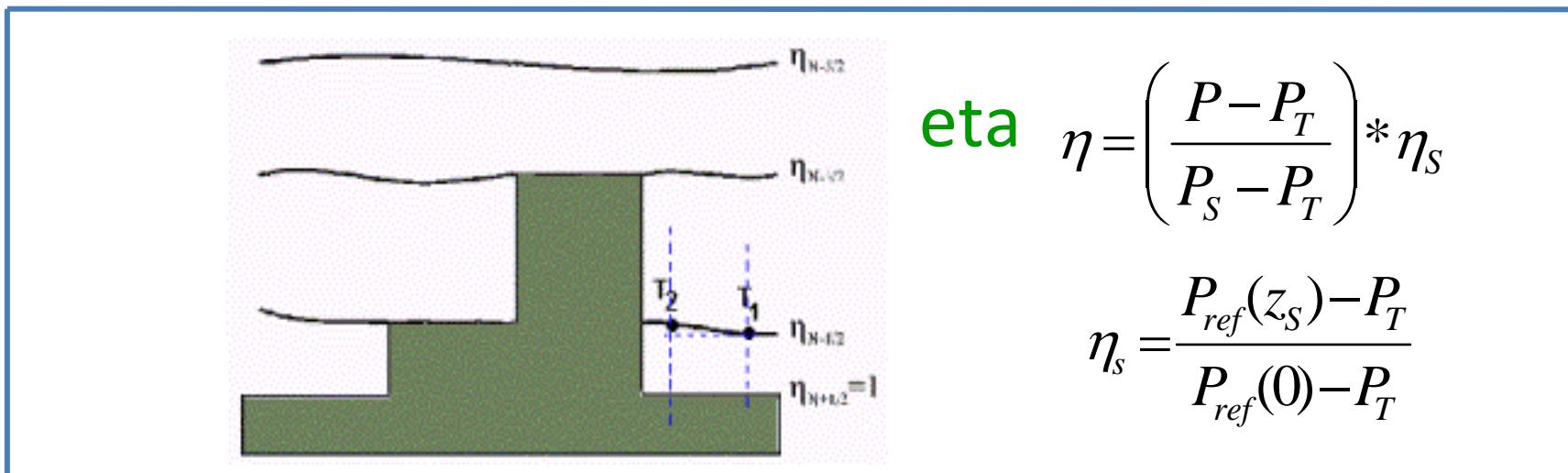
1487	1743
388	520
0	20
63	672

# Eta Vertical Coordinate



sigma

$$\sigma = \left( \frac{P - P_T}{P_S - P_T} \right)$$



eta

$$\eta = \left( \frac{P - P_T}{P_S - P_T} \right) * \eta_s$$

$$\eta_s = \frac{P_{ref}(z_s) - P_T}{P_{ref}(0) - P_T}$$

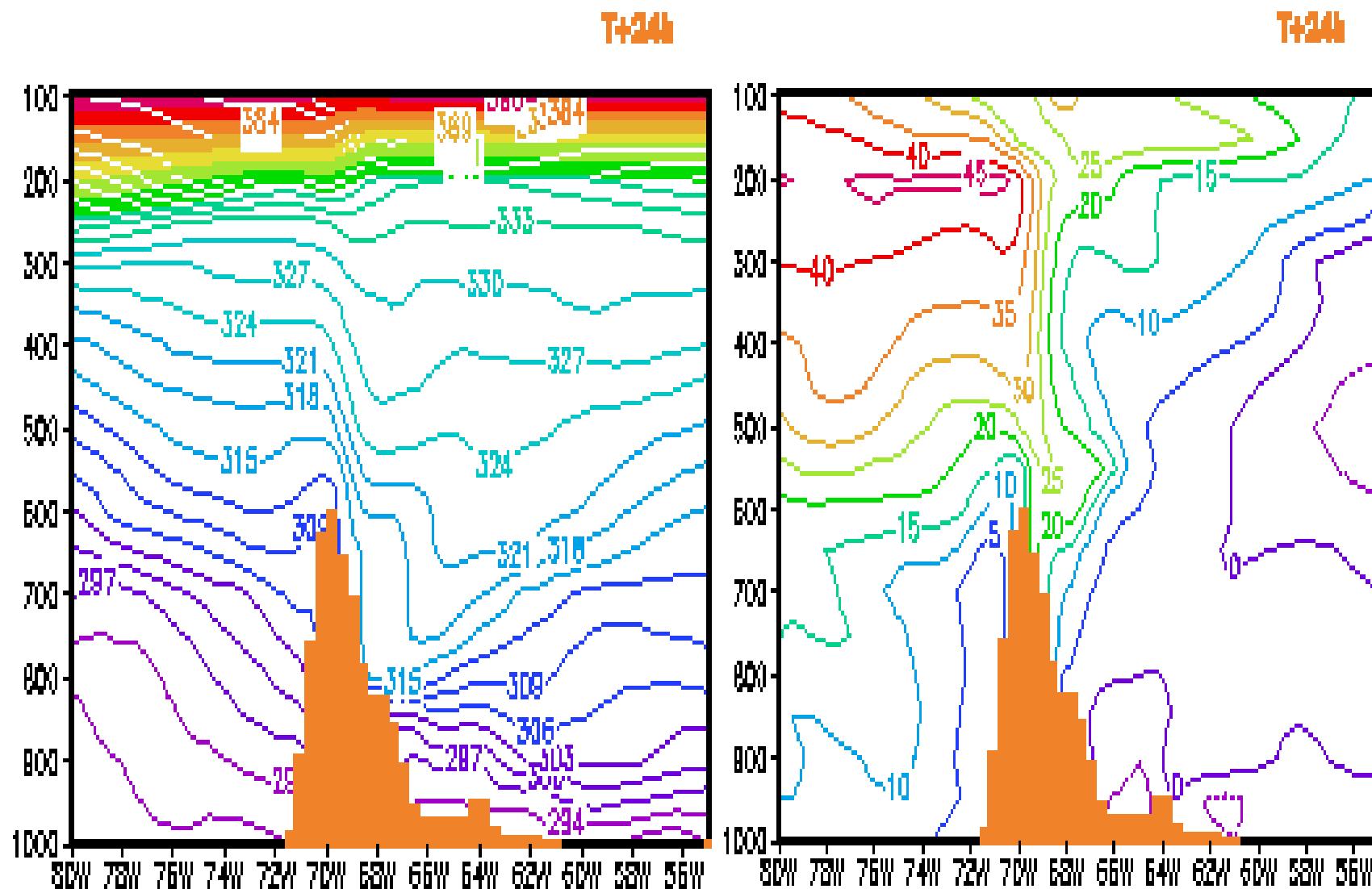
Mountain tops coincide  
with coordinate

Mesinger, 1984

Step Mountains

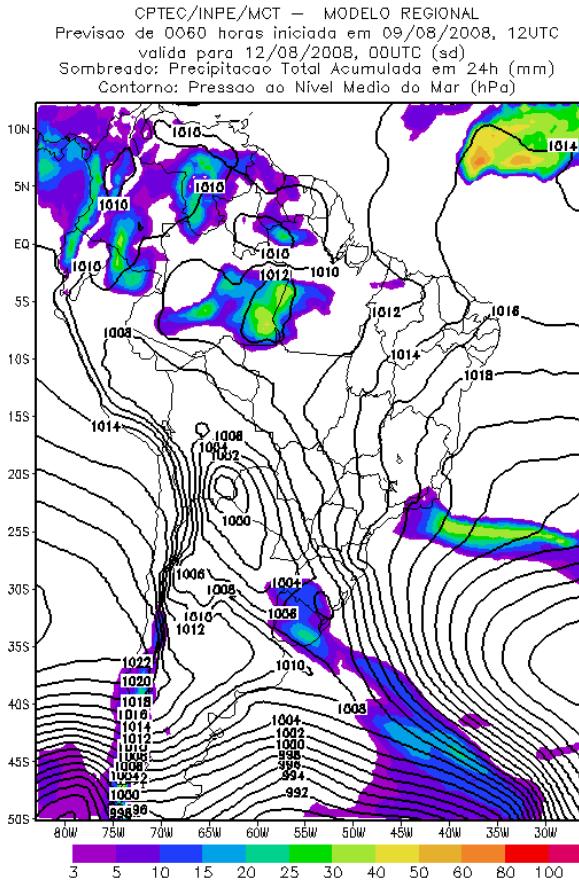
Developed to reduce errors in the  
calculation of horizontal derivatives,  
mainly pressure gradient forces, near  
mountains

# Zonda Wind (foën wind)

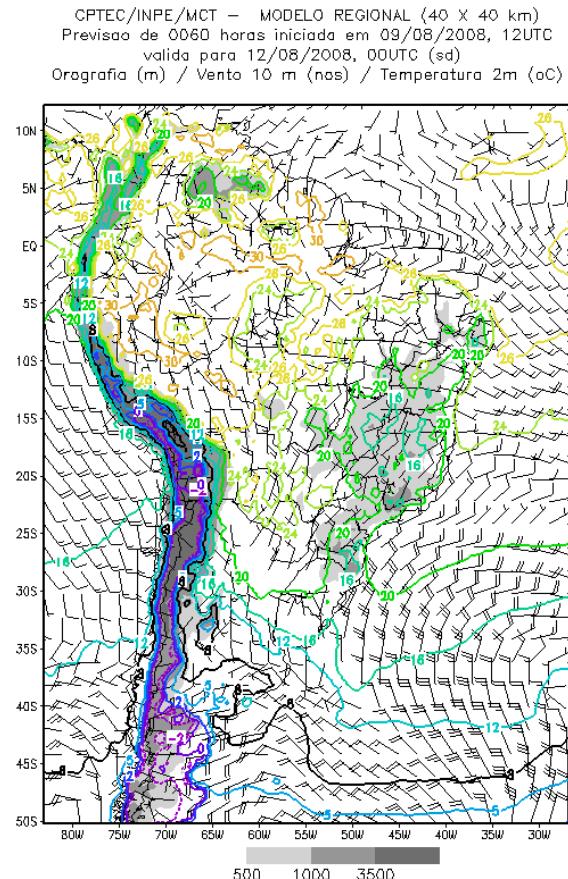


# Eta-40km and 20km Forecasts up to 7 days:

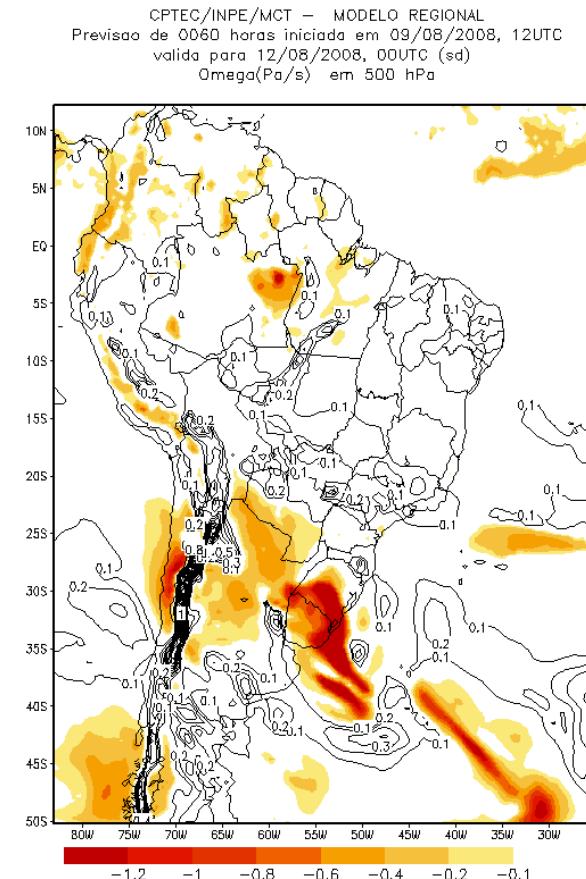
<http://www cptec.inpe.br/prevnum/>



24-h accum  
precipitation



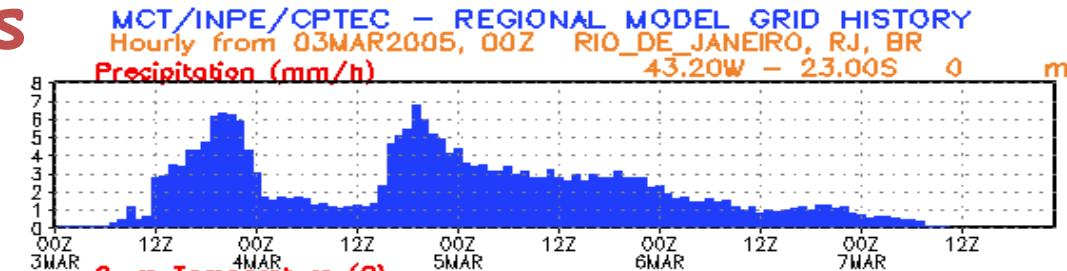
2-m temperature  
and 10-m winds



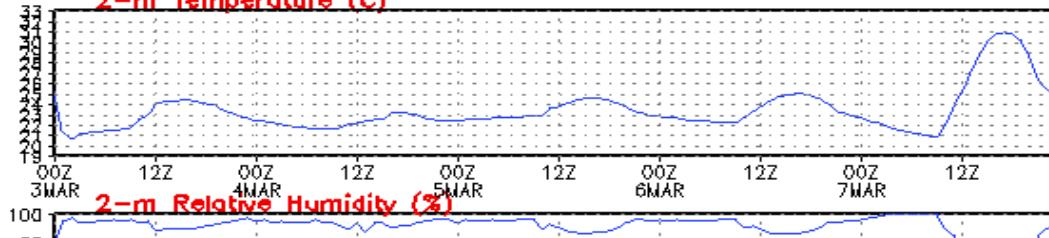
Vertical motion

# Site Hourly Forecasts

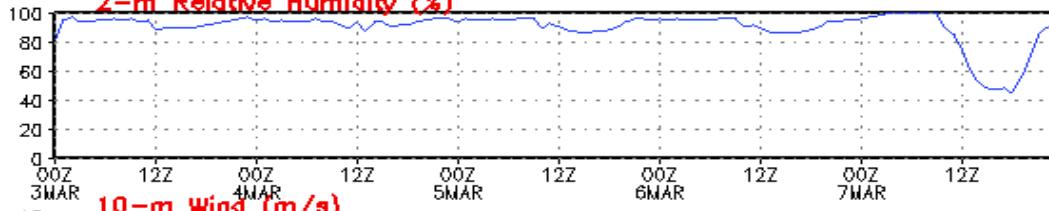
Precipitation



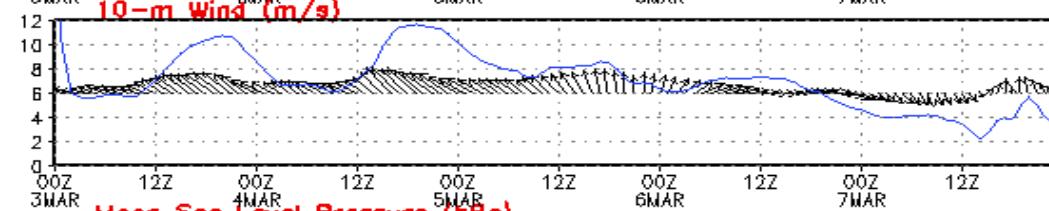
Temperature



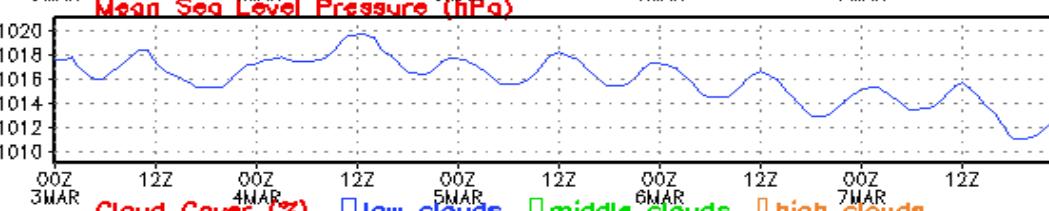
Relative Humidity



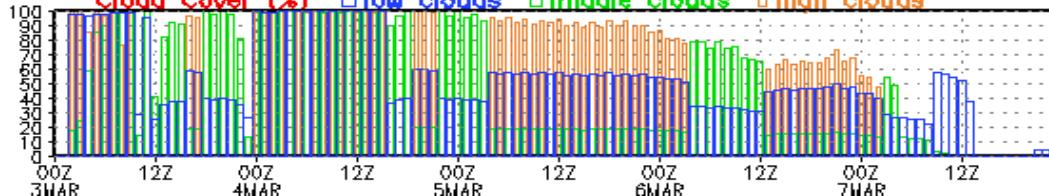
10-m winds



Mean Sea Level Pressure

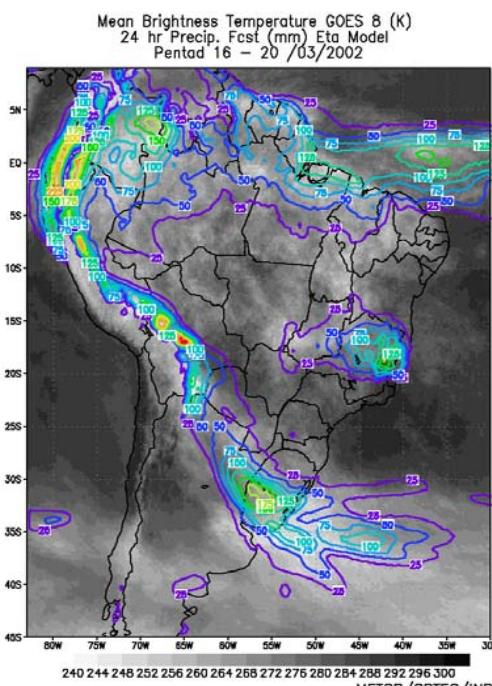
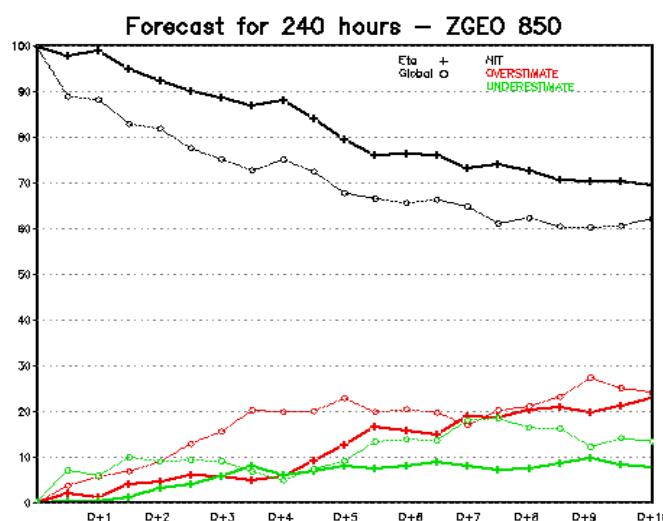
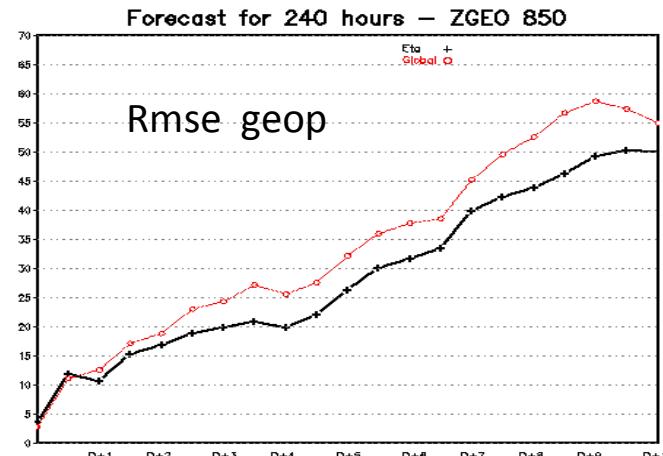


Cloud covers



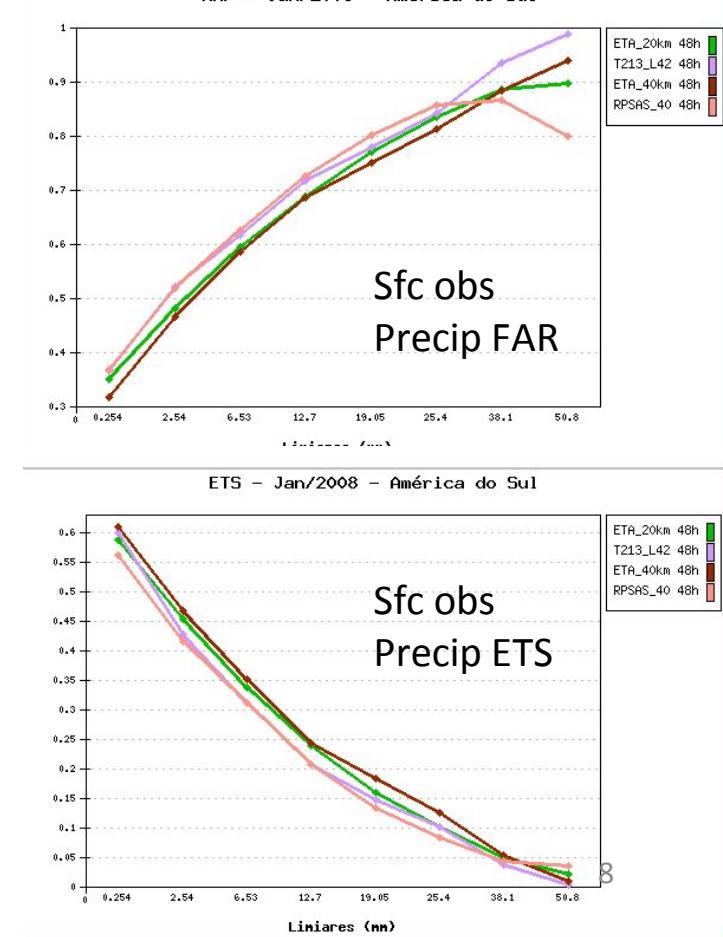
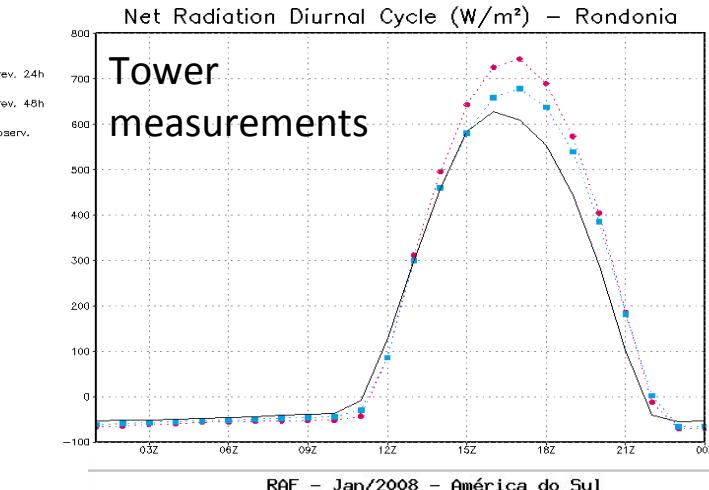
<http://www.cptec.inpe.br/prevnum/>

# Systematic evaluation of Eta Model forecasts

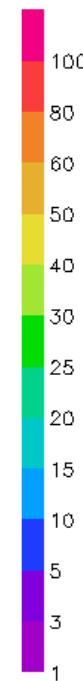
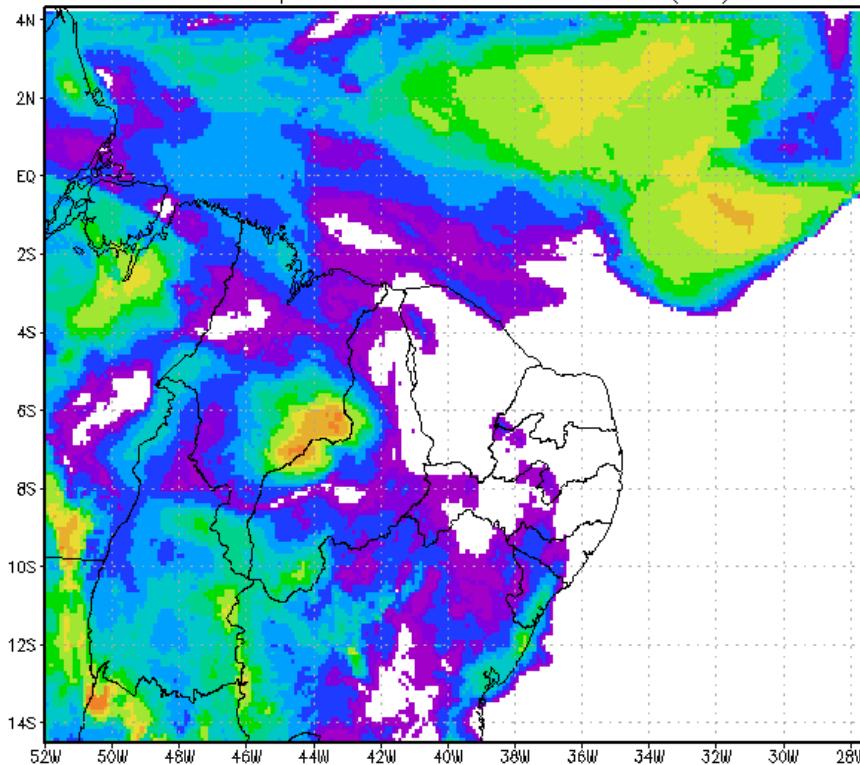


Satellite images

ICTP, 2008



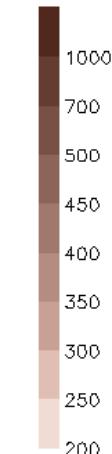
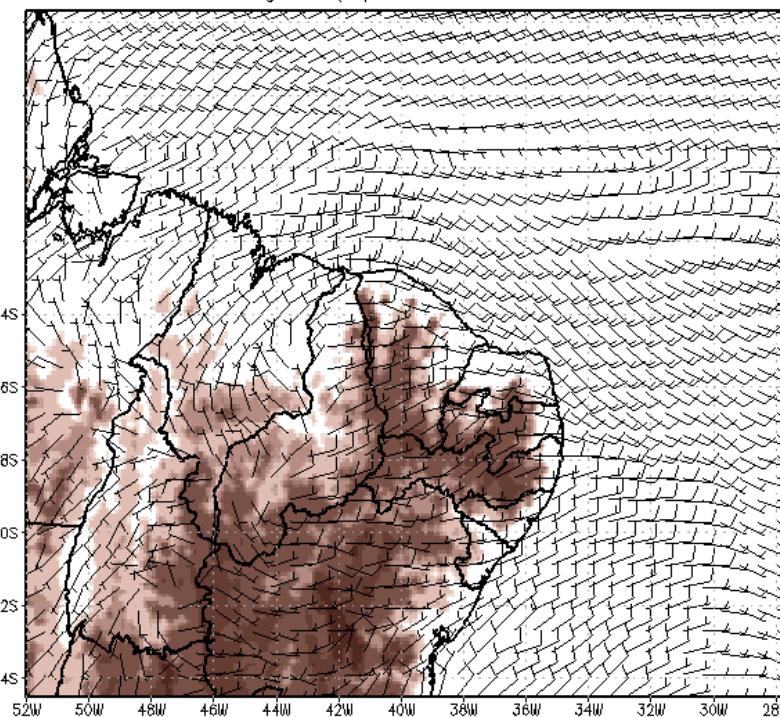
CPTEC/INPE/MCT – MODELO REGIONAL  
Previsao 2005120200+72h, valida para 05/12/2005, 00UTC  
Precipitacao Total acumulada em 24h (mm)



## HIGH RESOLUTION FORECASTS for Northeast Brazil

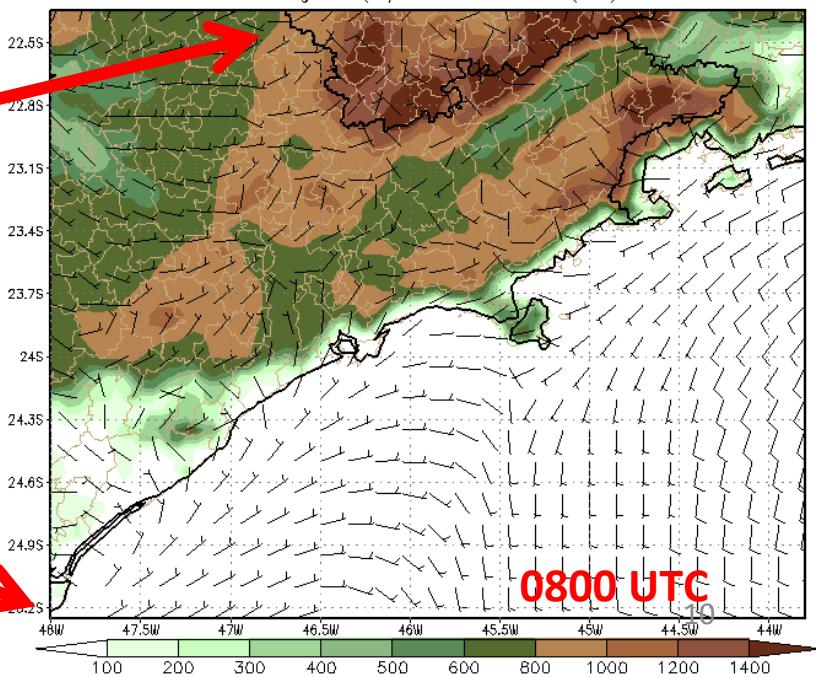
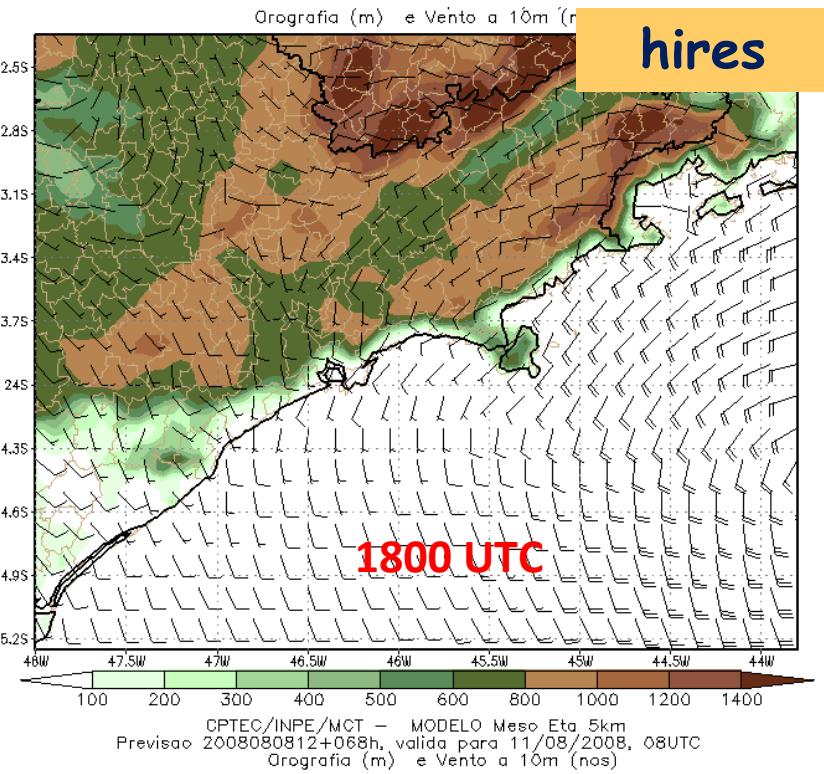
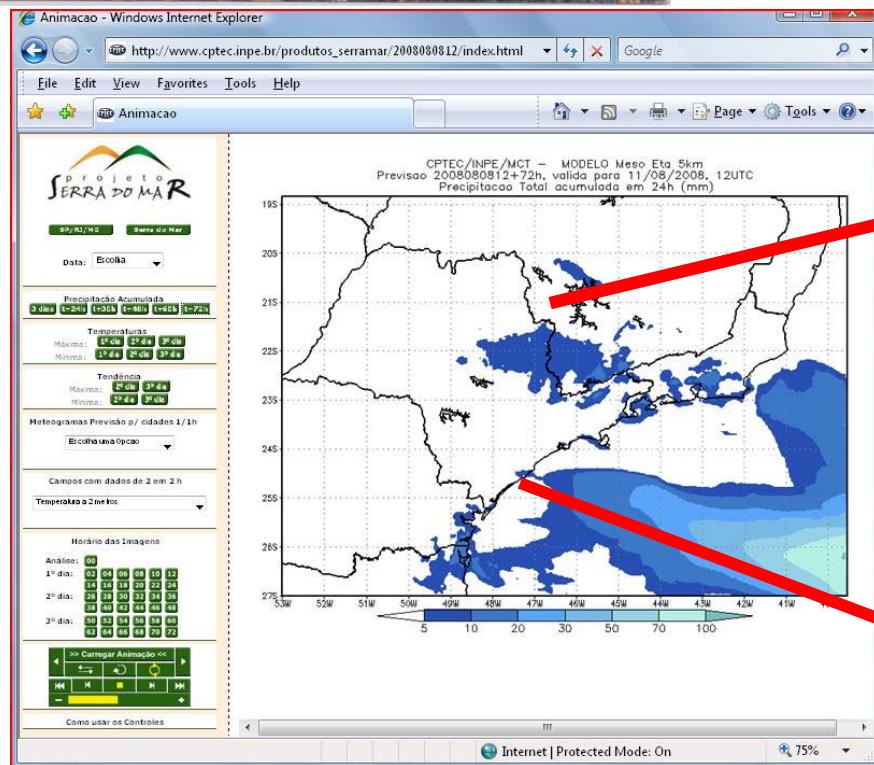
### Eta Model – 10km

CPTEC/INPE/MCT – MODELO Meso Eta 10km  
Previsao 2005120200+036h, valida para 03/12/2005, 12UTC  
Orografia (m) e Vento em 950 hPa



# HIGH RESOLUTION FORECASTS for Serra do Mar :

## Eta Model – 5km/ 50 layers – Non-hydrostatic run



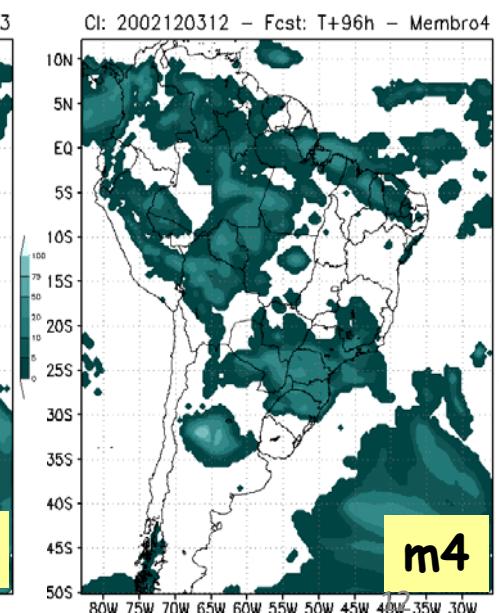
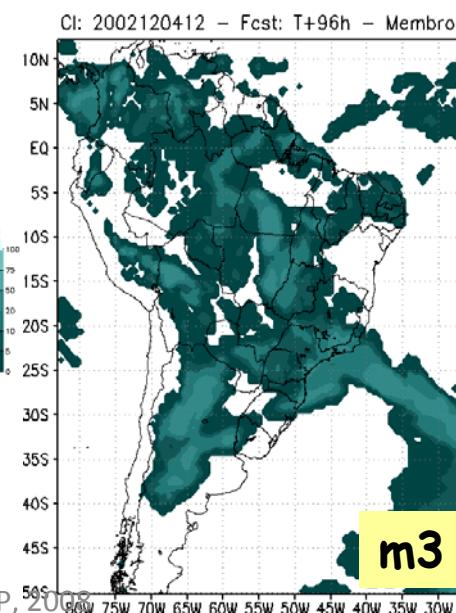
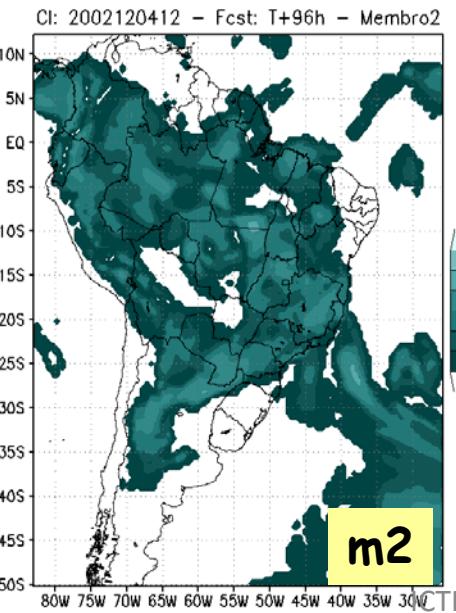
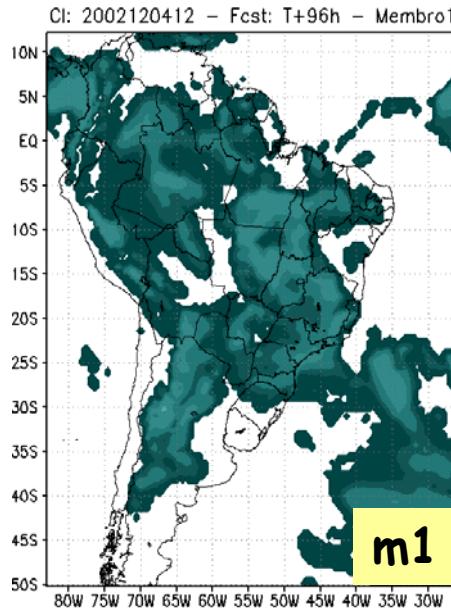
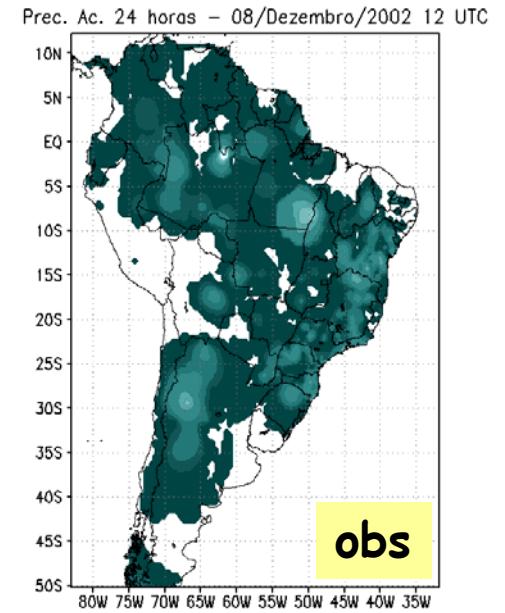
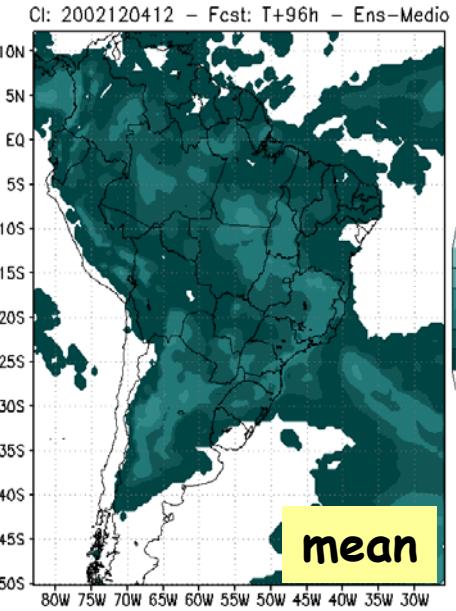
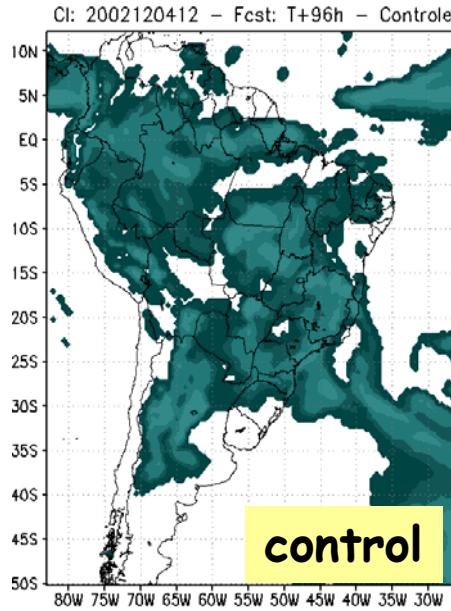
# SREPS

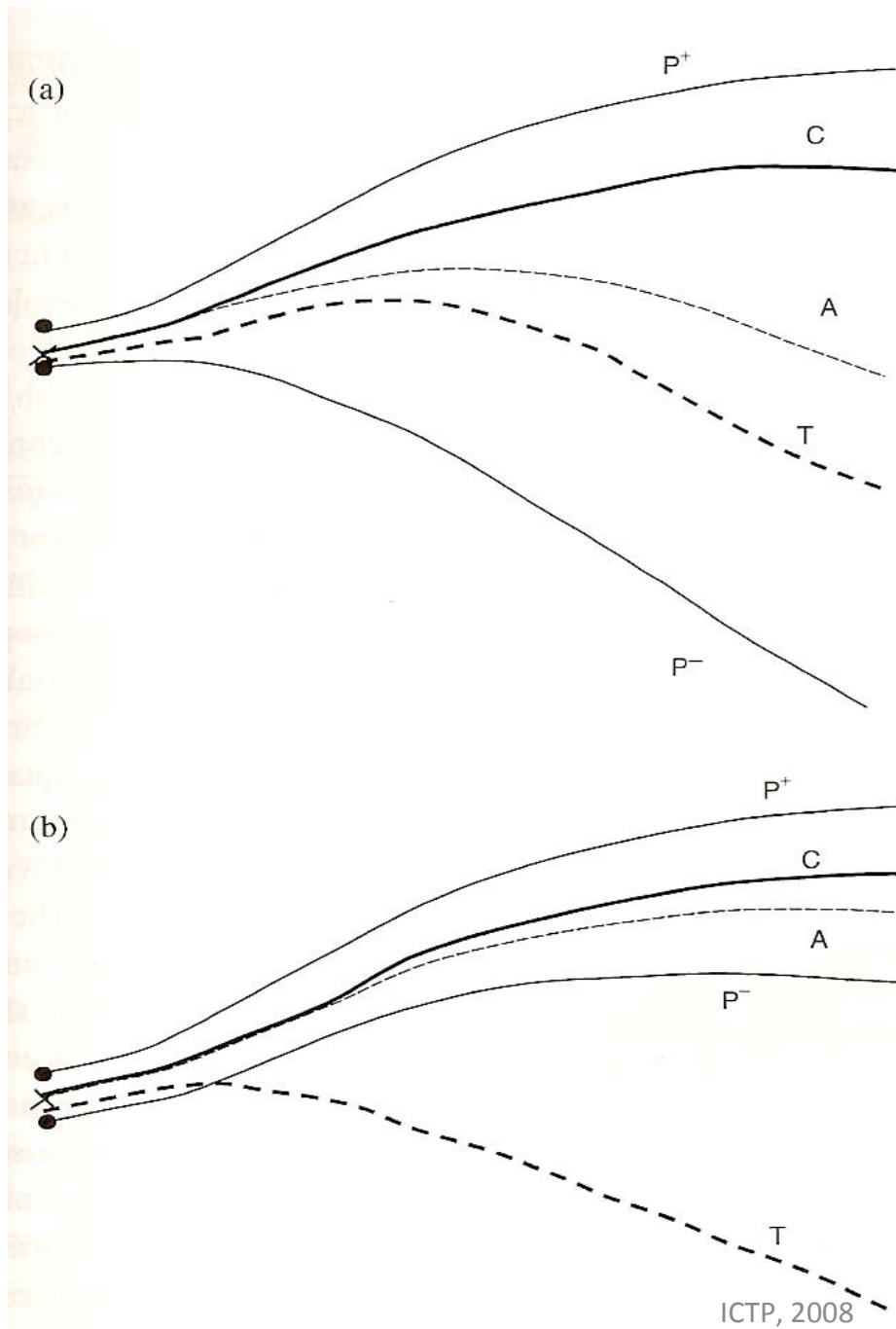
## Short Range Ensemble Prediction System

- Method: perturbed initial conditions
- The perturbed initial conditions are obtained from the ensemble weather forecasts generated by the CPTEC global model at T126L28 (GCM EPS);
- The perturbations of CPTEC GCM EPS are based on Empirical orthogonal Functions (EOF);
- These perturbations are applied to wind and temperature fields (at 850 hPa) in the tropical region;
- 15 members (1 control + 14 perturbations) are generated;
- Cluster analysis is applied and generates 4 groups. One representative member is extracted from each group.

Forecast valid on 08 december 2002 - T+96h

SREPS

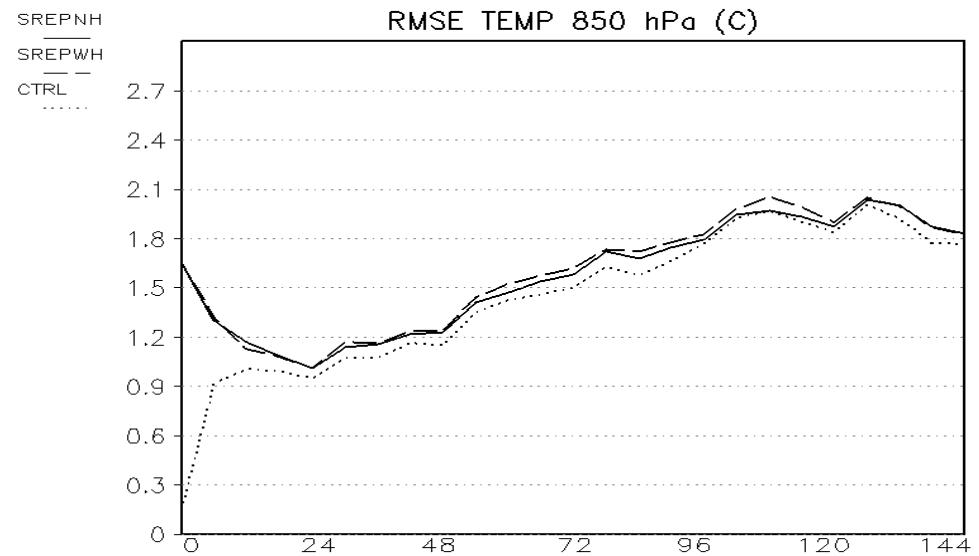
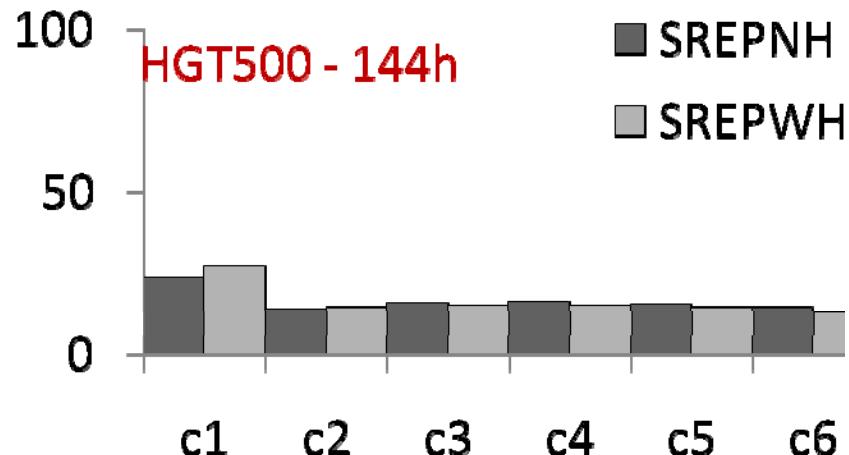




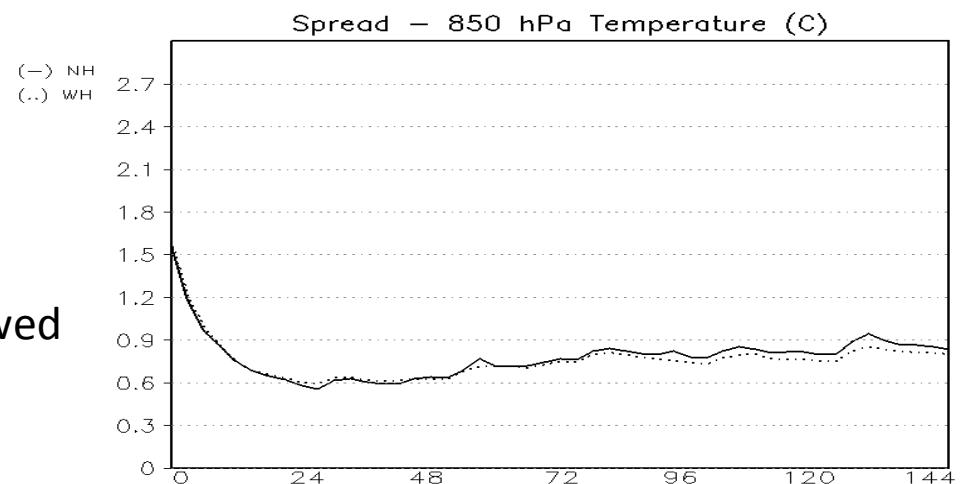
$C$  - previsão controle  
 $P^+$  - perturbação positiva  
 $P^-$  - perturbação negativa  
 $A$  - ensemble médio  
 $T$  - estado real da atmosfera

Good ensemble, includes true state

Bad Ensemble

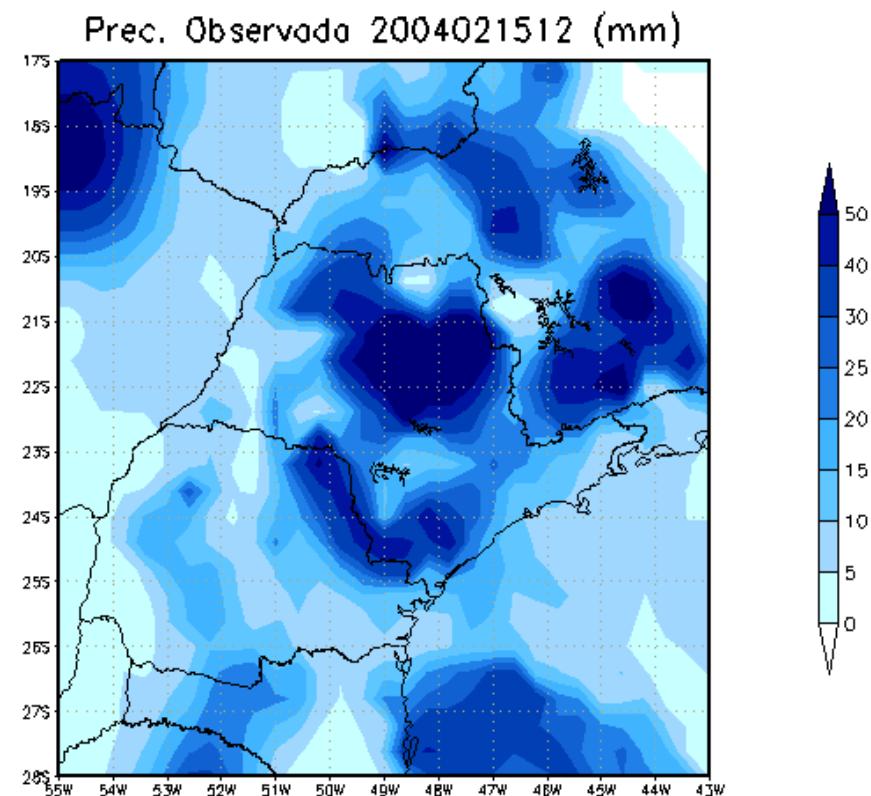


- HGT500 Talagrand diagrams in both experiments indicate satisfactory spread.
- All variables show spread magnitude smaller than RMSE.
- Inclusion of moisture perturbation showed improvement for the rain forecasts

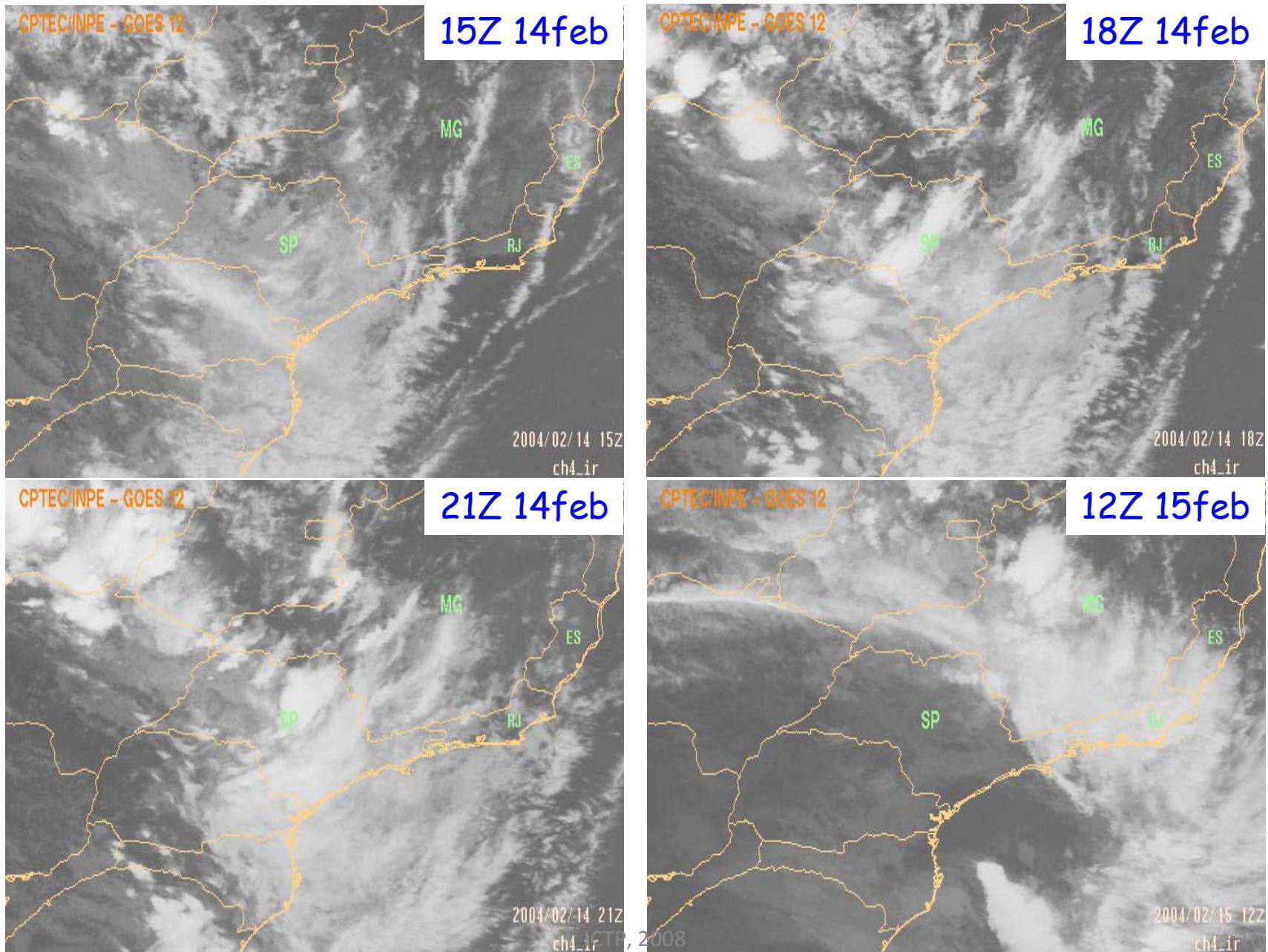


## Heavy rainfall in São Paulo State

Rainfall over 80mm in Bauru on  
15 February 2004.

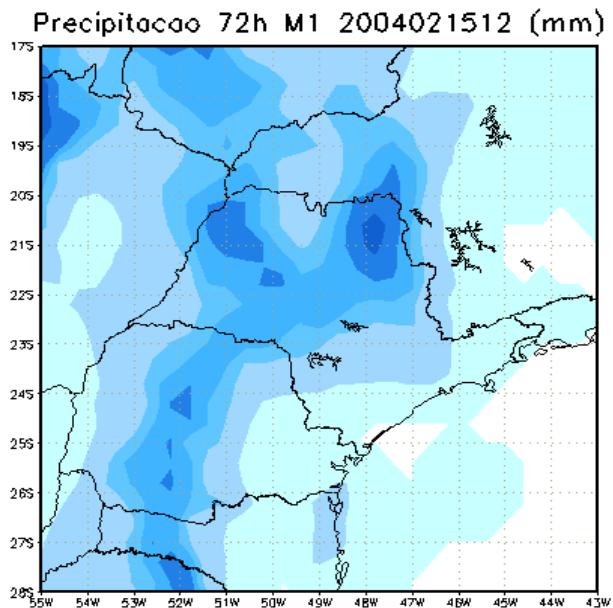


## IR Satellite Images

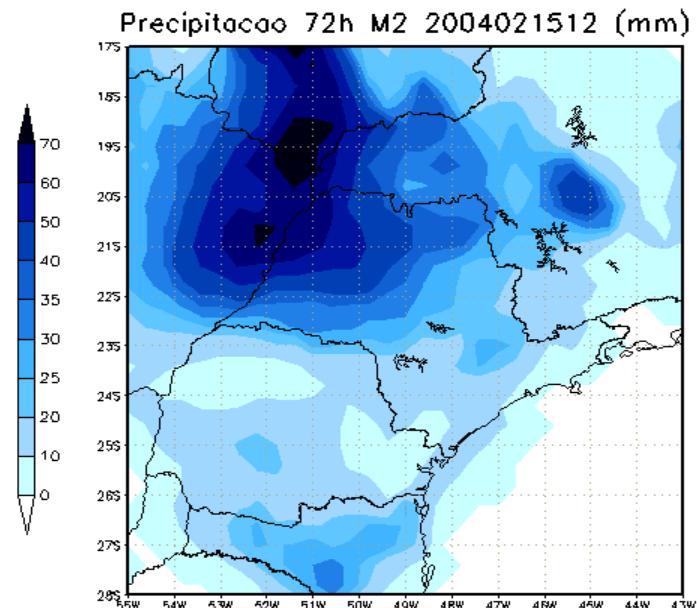


## Precipitation (mm) - T+72h -IC Perturbations - 40km

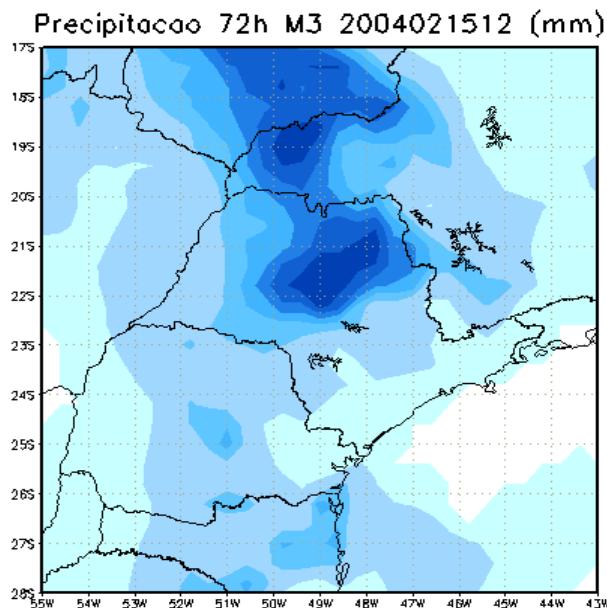
Mi1



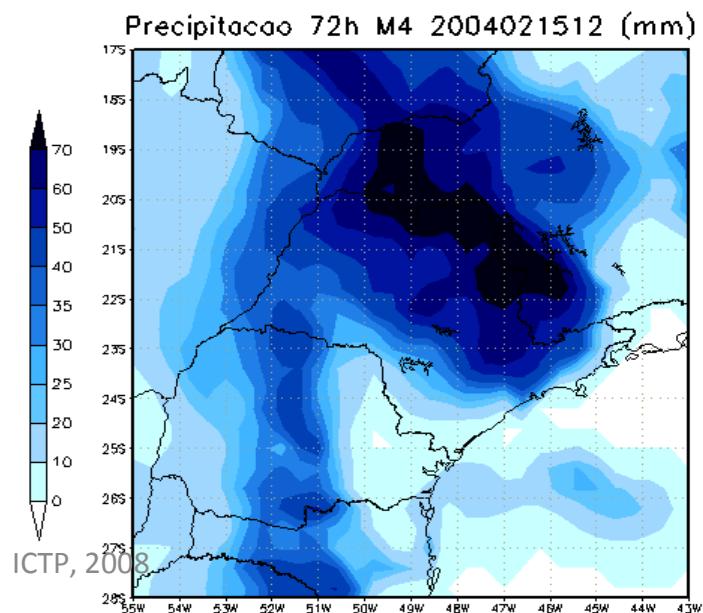
Mi2



Mi3



Mi4

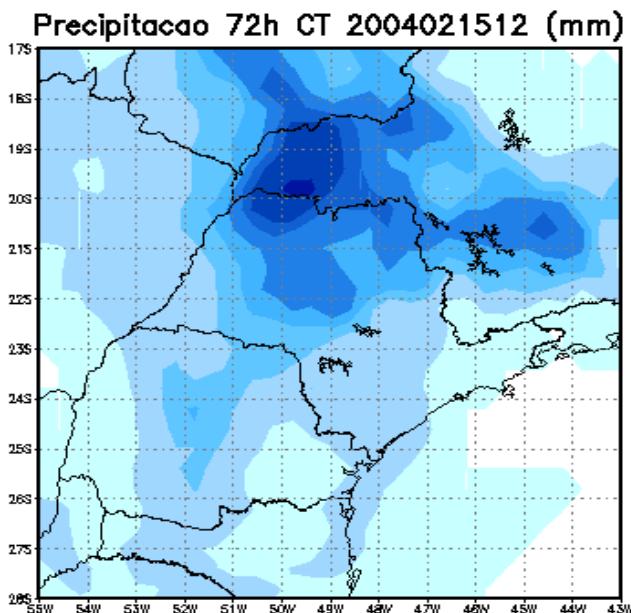


ICTP, 2008

# Precipitation (mm) - T+72h -IC Perturbations - 40km

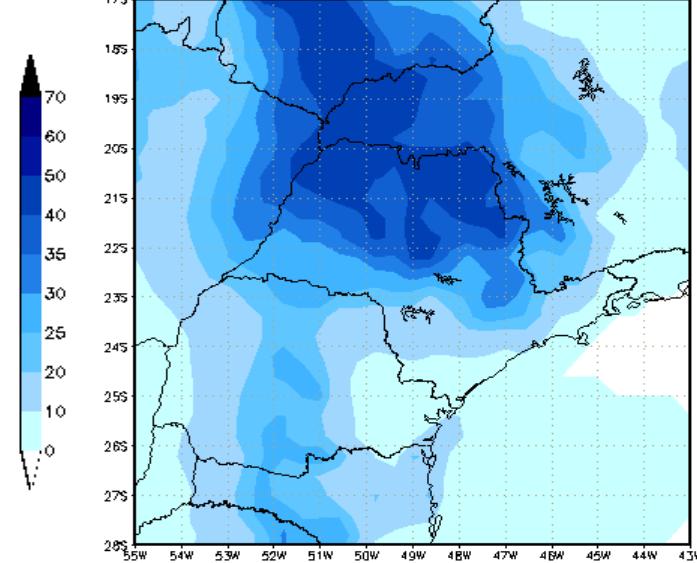
Cntrl  
=M5

T+72h



Ensemble Mean Precipitation forecast

rec. Media dos Membros 72h 2004021512 (mm)

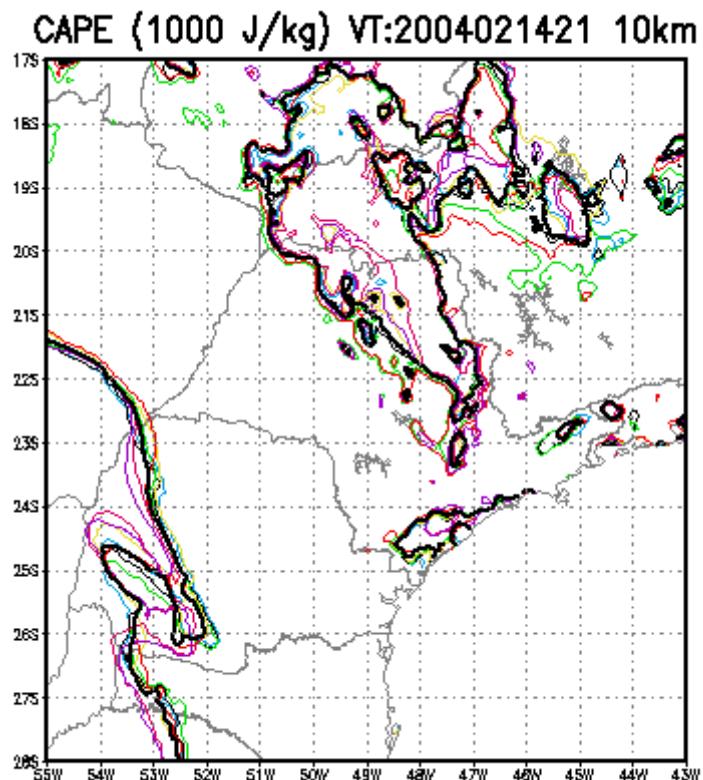


Mean

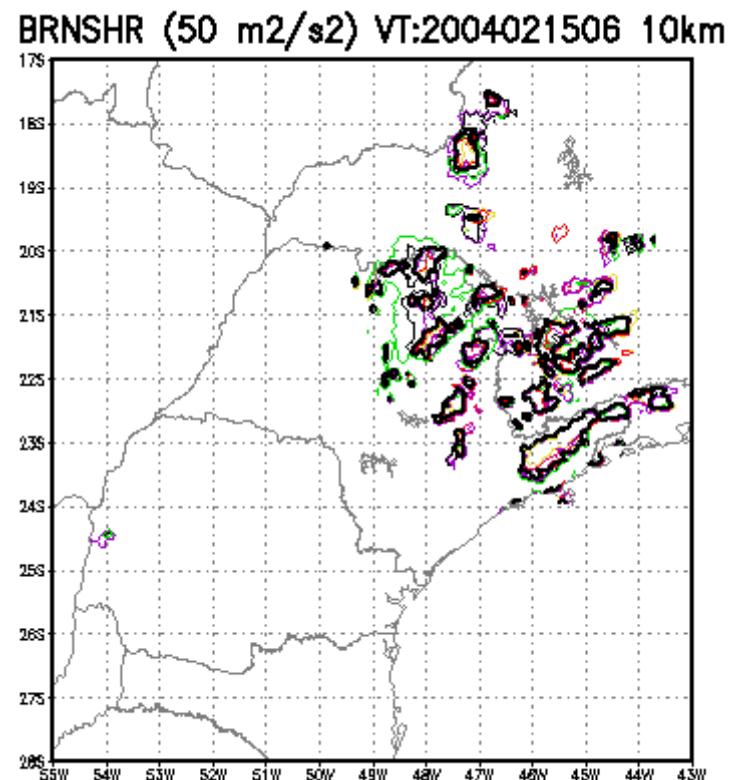
T+72h

# Spread of Instability Indices

CAPE

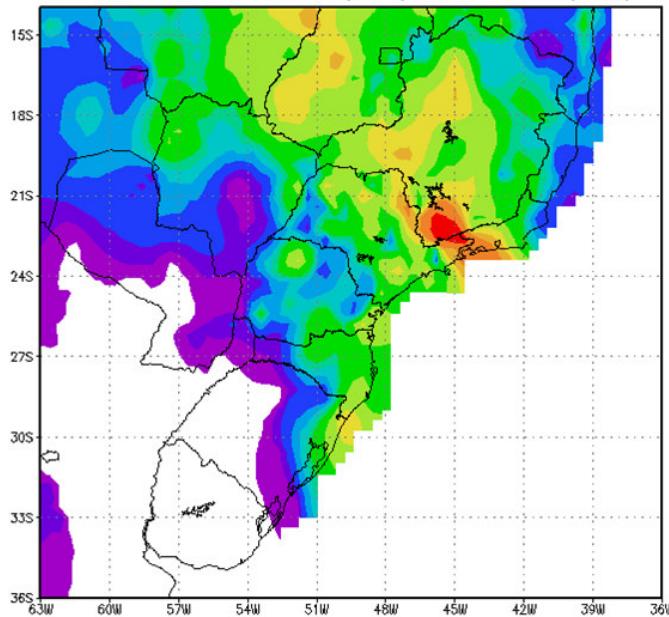


BRNSHR



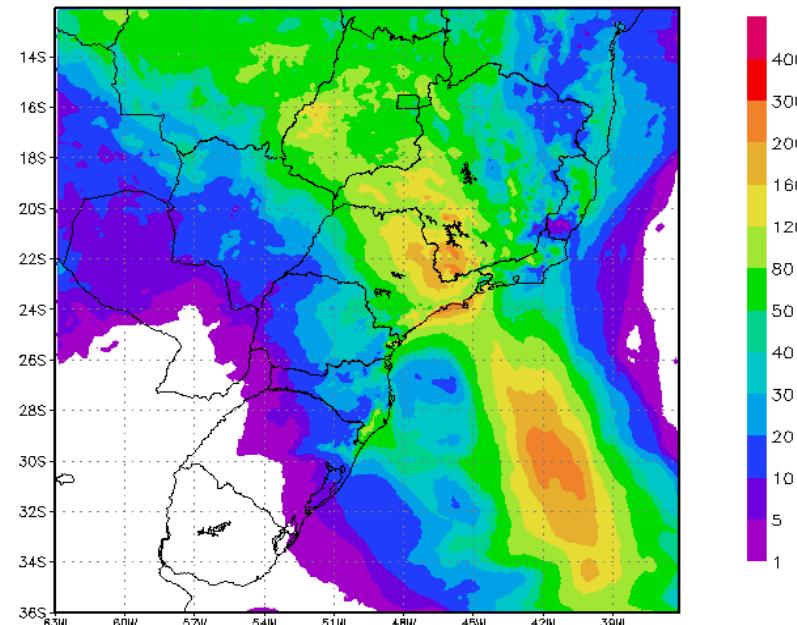
# Eta Model Ensemble Forecasts South Atlantic Convergence Zone

Precipitacao Acumulada de 31/12/1999 a 06/01/2000



OBSERVATION

Prec. Total acumulada 31/12/1999 a 05/01/2000 12UTC  
Ensemble Media



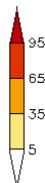
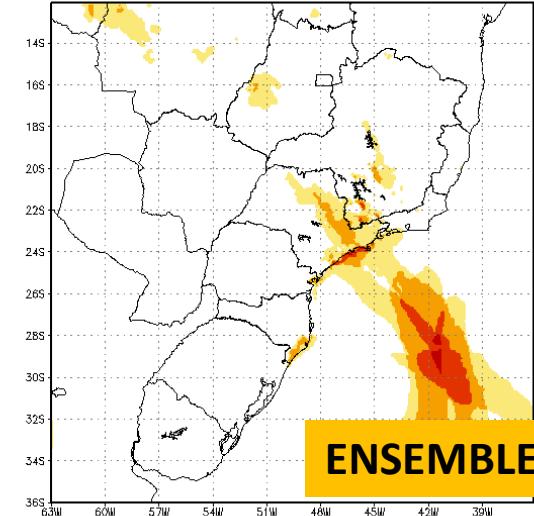
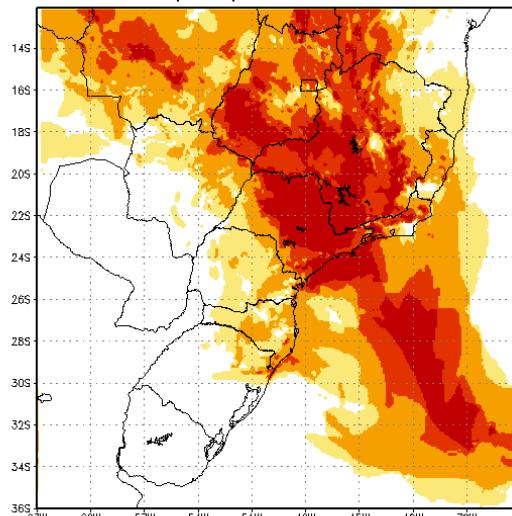
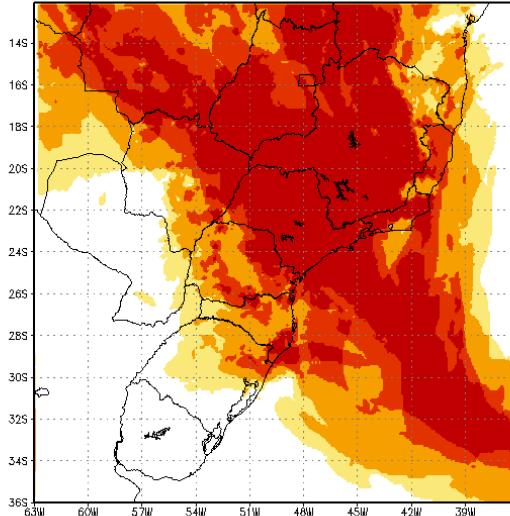
ENSEMBLE mean FORECAST

Accumulated Precipitation between  
31/12/1999 – 05/01/2000

# Eta Ensemble Forecast Products

## Probability forecasts

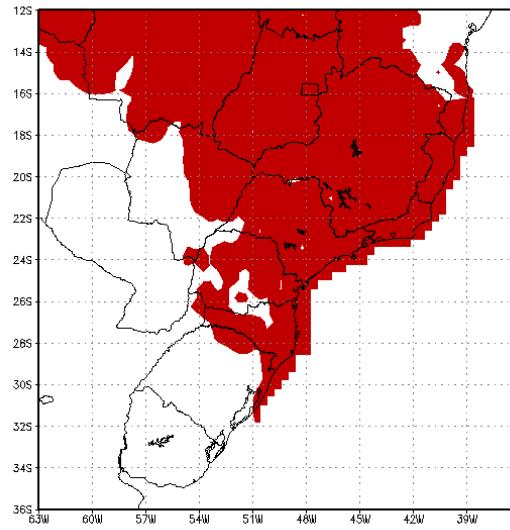
Probabilidade de precipitacao > 1,0 mm - T+7 Probabilidade de precipitacao > 10,0 mm - T Probabilidade de precipitacao > 50,0 mm - T+72h



**ENSEMBLE FCSTS**

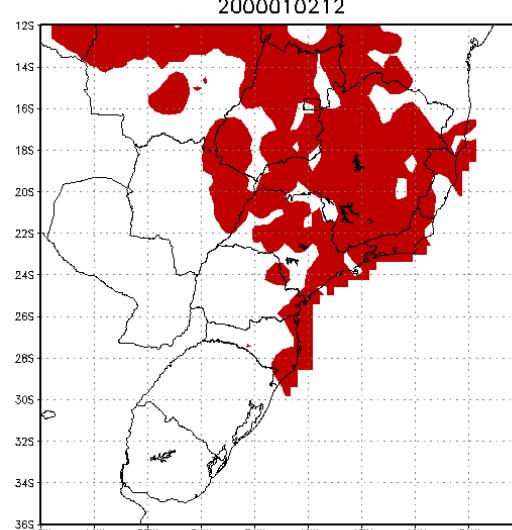
Precip > 1mm

Precipitacao acima de 1 mm  
2000010212



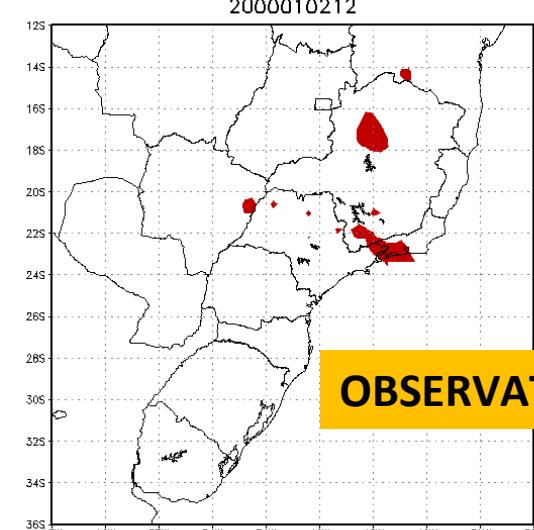
Precip > 10mm

Precipitacao acima de 10 mm  
2000010212



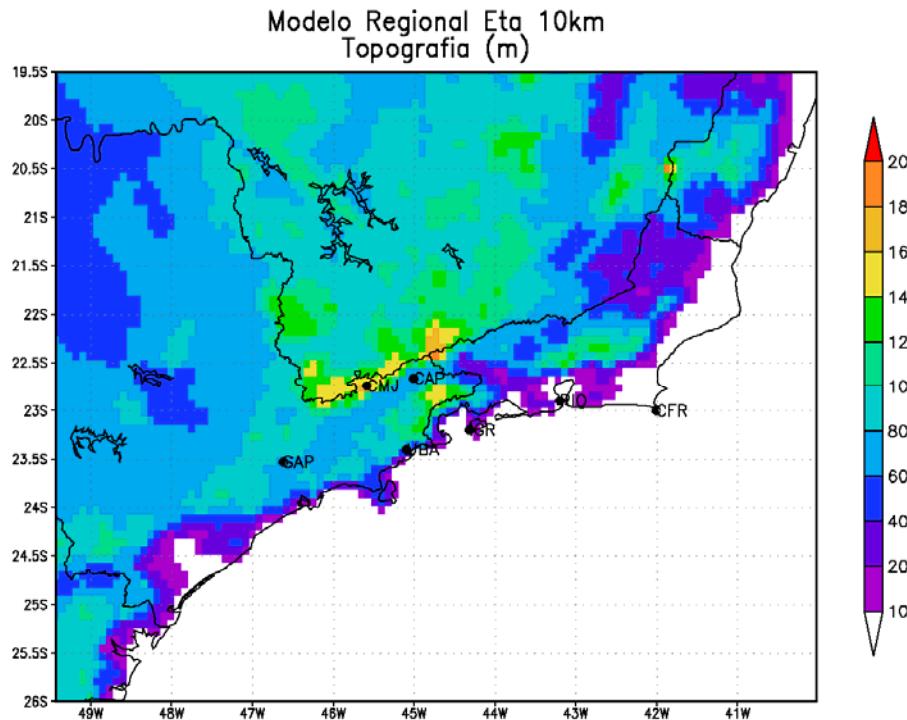
Precip > 50mm

Precipitacao acima de 50 mm  
2000010212



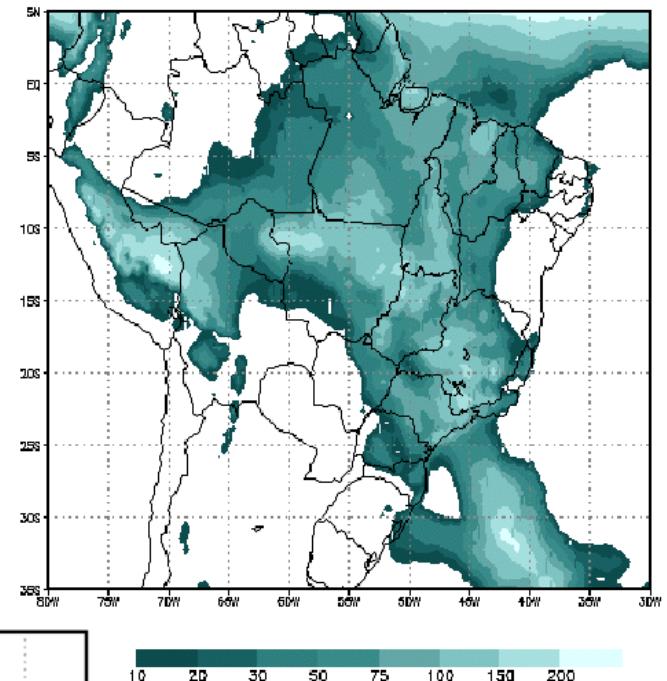
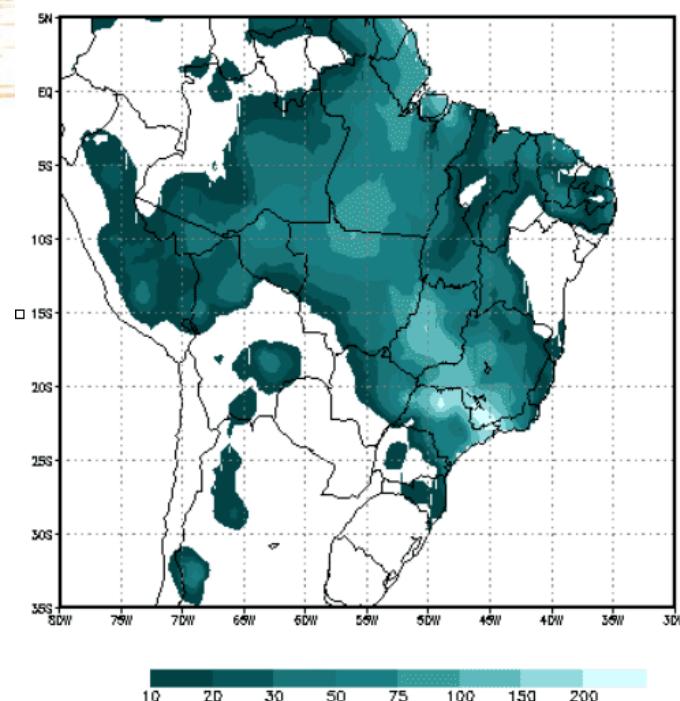
**OBSERVATIONS**

## High Resolution Forecasts - flood case



## Floods Early 2000

Forecast Accumulated Precipitation  
Eta Model  
January 02-06, 2000



Observed Precipitation  
January 02-06, 2000



# Instability Indices for Severe Weather

$$\text{CAPE} = g \int_{\text{NCE}}^{\text{NEL}} \frac{\theta_v(z) - \bar{\theta}_v(z)}{\bar{\theta}_v(z)} dz \quad [\text{J kg}^{-1}]$$

> 1500 J kg<sup>-1</sup>

$$\text{DNRV} = 0.5 (\bar{u}^2 + \bar{v}^2) \quad [\text{m}^2 \text{s}^{-2}],$$

> 50 m<sup>2</sup> s<sup>-2</sup>

$$\text{HR} = - \int_{z_s}^{h_s} \hat{k} \cdot (\vec{V} - \vec{c}) \times \frac{\partial \vec{V}}{\partial z} dz \quad [\text{m}^2 \text{s}^{-2}],$$

< -150 m<sup>2</sup> s<sup>-2</sup> (HS)

$$\text{IEH} = \frac{\text{CAPE} \times \text{HR}}{1.6 \cdot 10^5}$$

< -4 m<sup>2</sup> s<sup>-2</sup> (HS)

$$\text{SUP} = \left( \frac{\text{CAPE\_MI}}{\lim_{\text{cape}}} \right) \cdot \left( \frac{\text{HR3K}}{\lim_{\text{hr}}} \right) \cdot \left( \frac{\text{DNRV}}{\lim_{\text{dnrv}}} \right)$$

X -1      > 1

$$K = T_{850} - T_{500} + Td_{850} - Dep_{700} \quad [^{\circ}\text{C}], \quad > 35 \text{ oC}$$

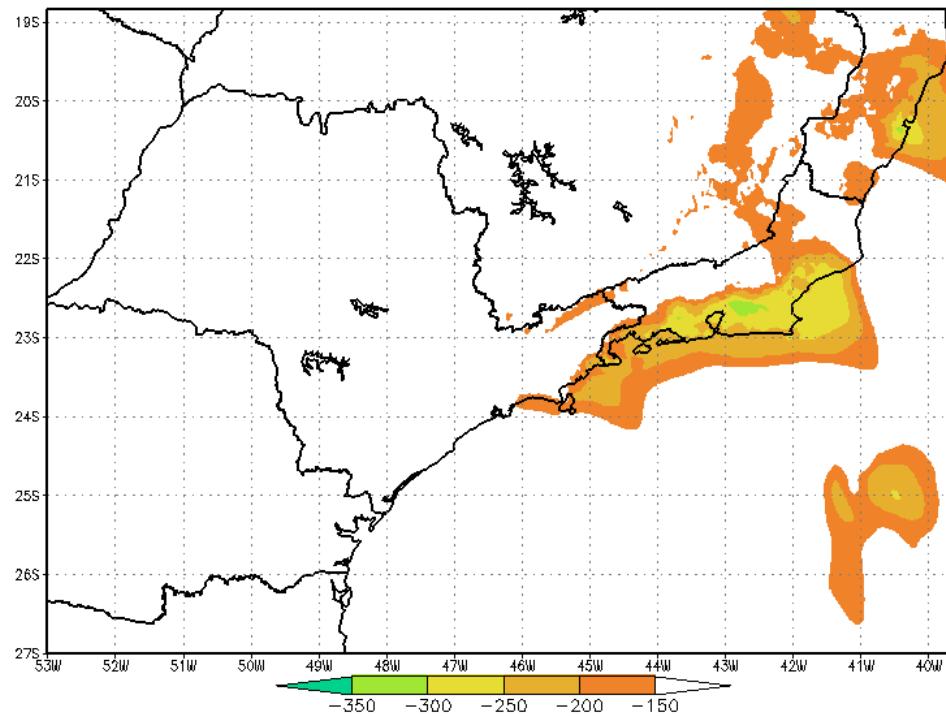
$$ILEV = T_{500} - Tp_{500} \quad [^{\circ}\text{C}], \quad < -5 \text{ oC}$$

$$ITT = T_{850} + Td_{850} - 2 T_{500} \quad [^{\circ}\text{C}], \quad > 40 \text{ oC}$$

$$NRV = \frac{CAPE}{DNRV}$$

$$SHR = V300 - V700$$

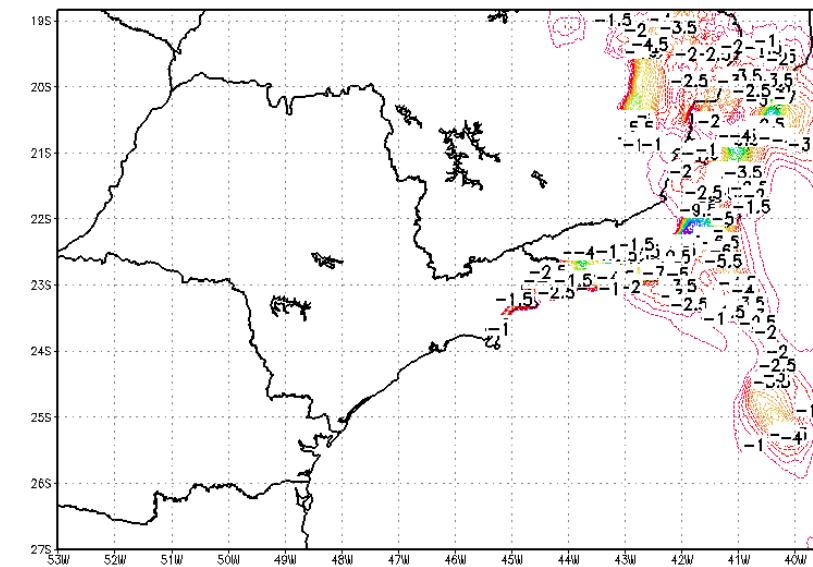
CPTEC/INPE/MCT – MODELO Meso Eta 5km  
Previsão 2008092200+018h, válida para 17Z22SEP2008  
Helic. Rel. à Tempest. (m<sup>2</sup>/s<sup>2</sup>)



Supercell  
Parameter

Helicity

CPTEC/INPE/MCT – MODELO Meso Eta 5km  
Previsão 2008092200+018h, válida para 17Z22SEP2008  
Parametro de Super Celula

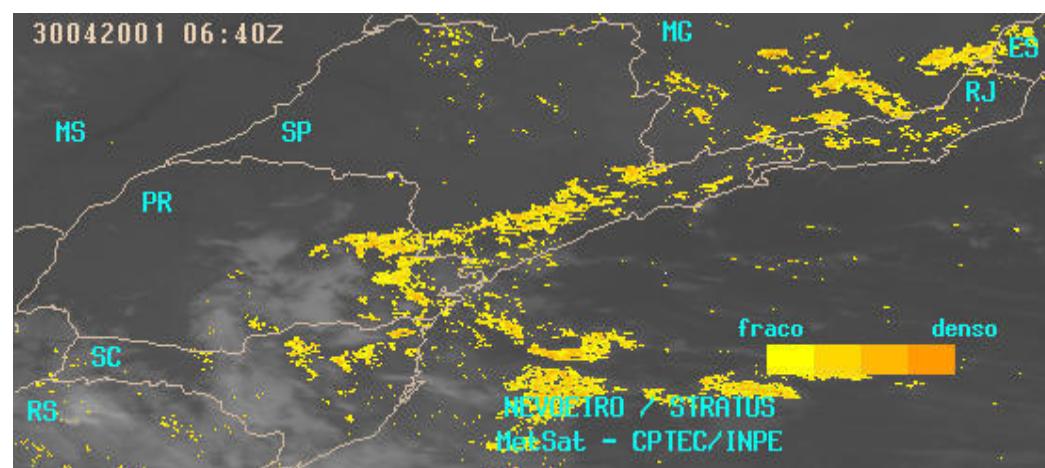
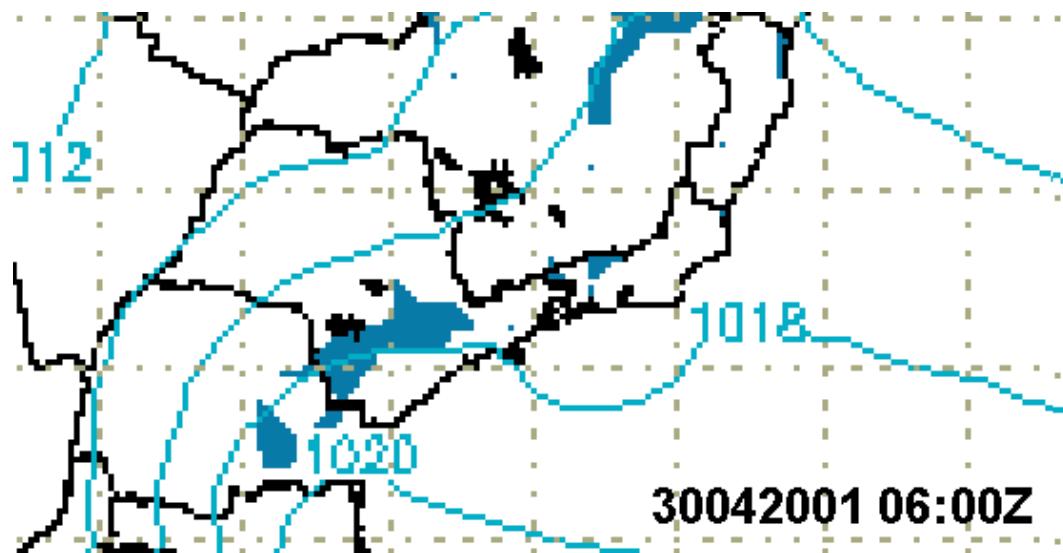


road safety

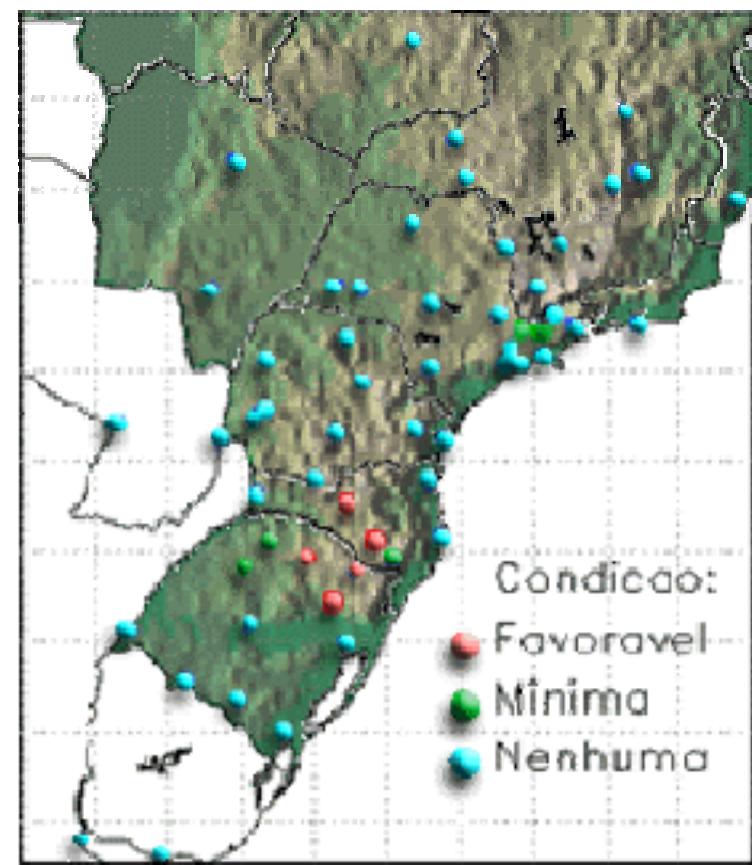
Agriculture

Fog forecast

Frost forecast

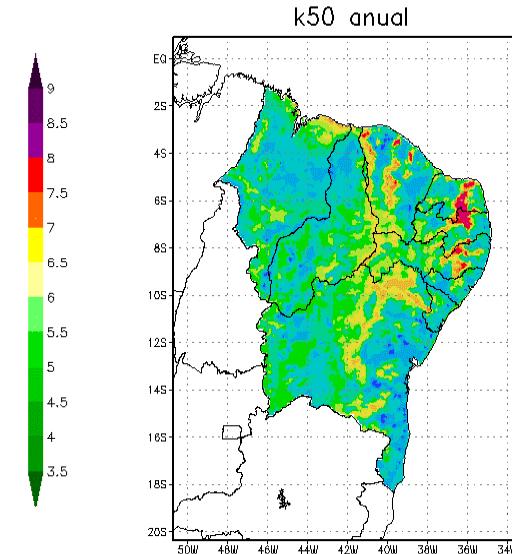
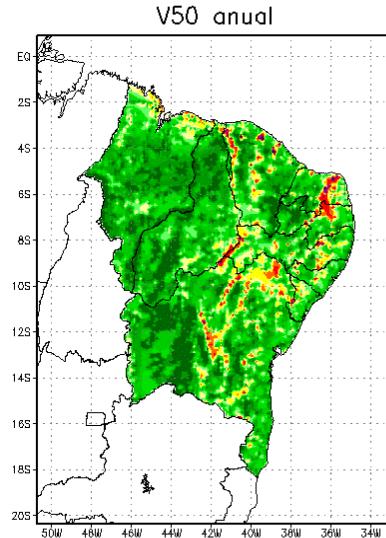


Previsão de Geadas  
04/07/2000 00Z + 34 horas

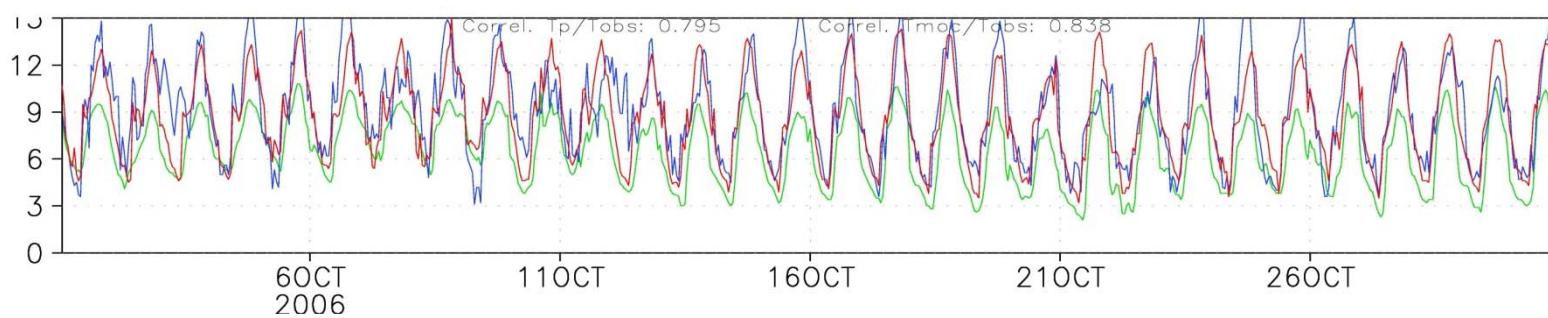


# Wind power mapping

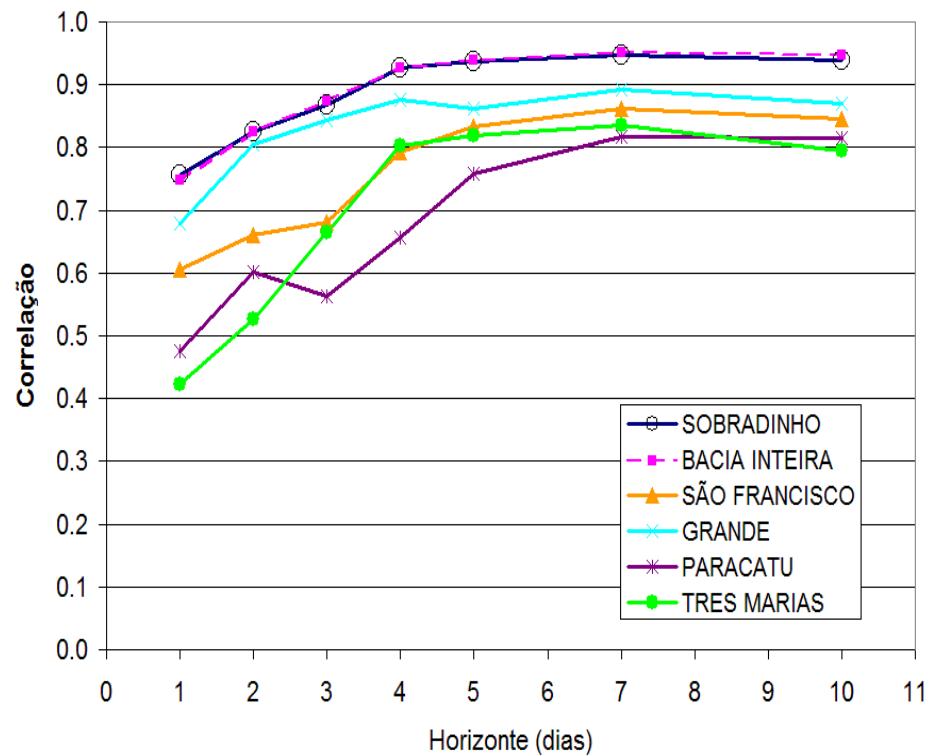
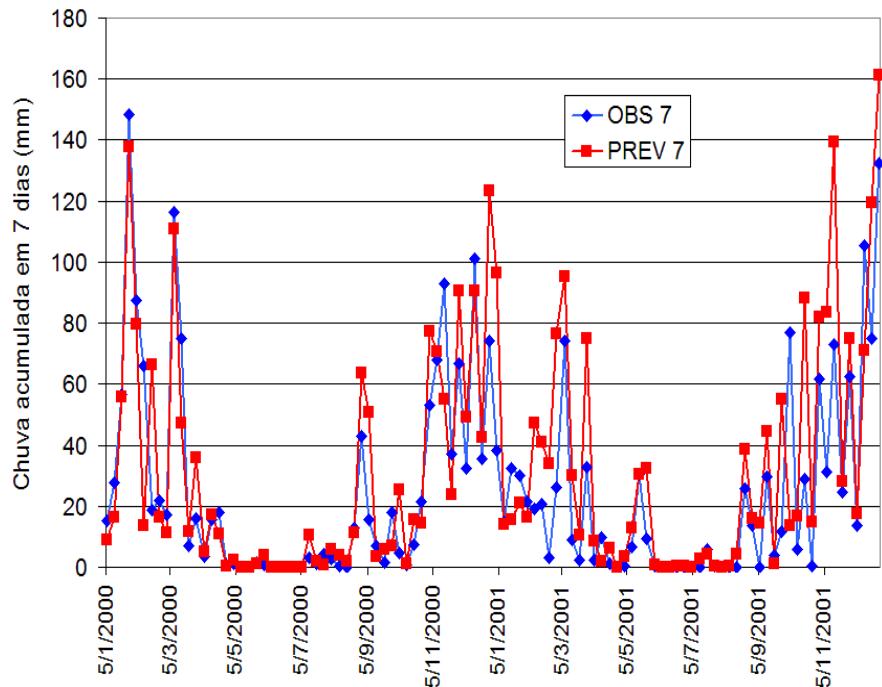
- Mapping at 10m, 50m ou 100m



- Forecasts at 10m, 50m ou 100m



## 7-day accumulated precipitation forecasts for hydropower short term operations



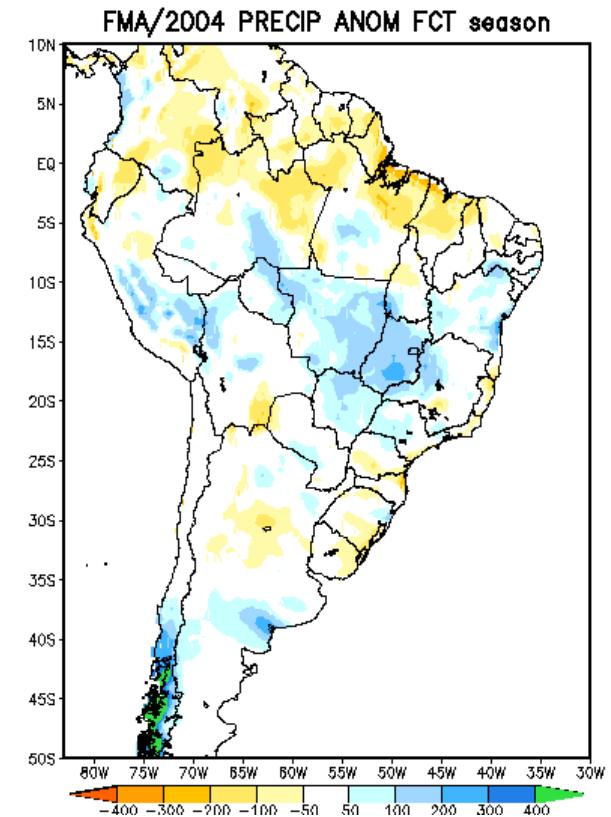
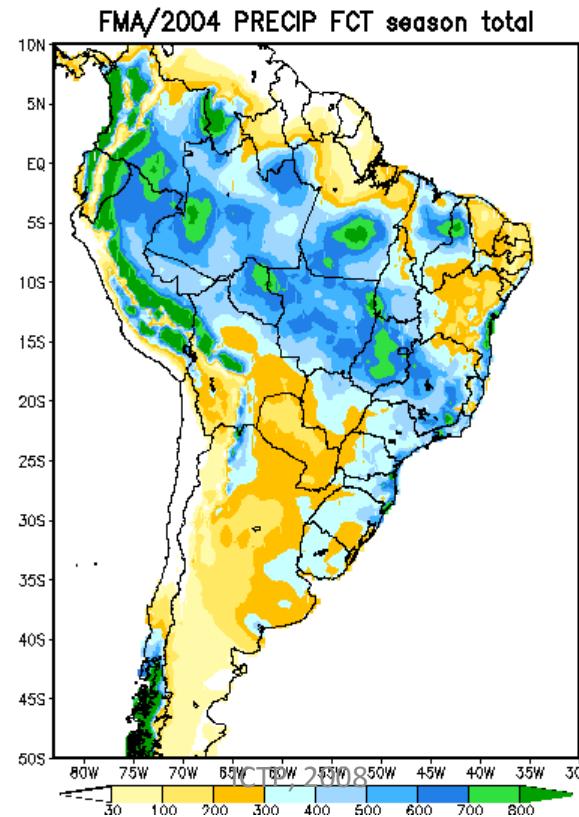
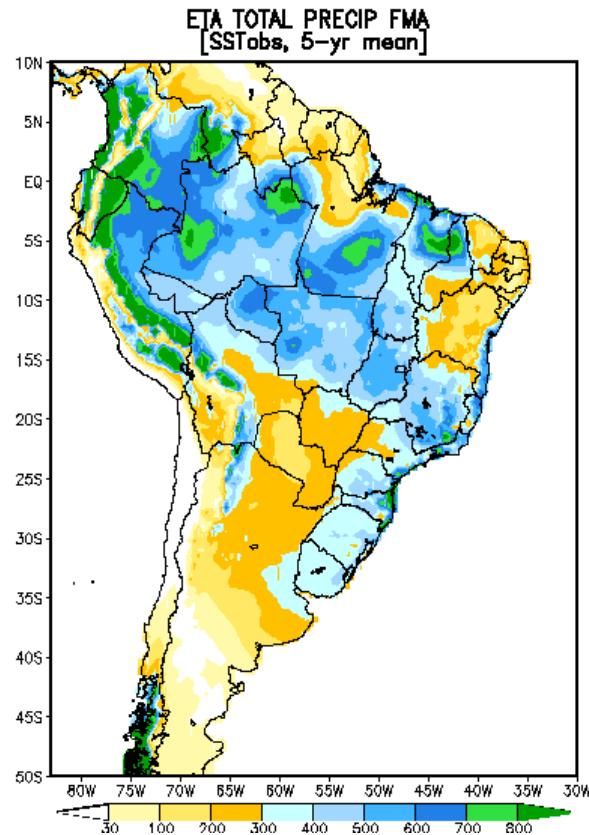
# Seasonal Forecasts

Poor's man model climatology

5-year 4,5 month integrations:  
1996, 1997, 1998, 1999, 2000

seasonal forecasts

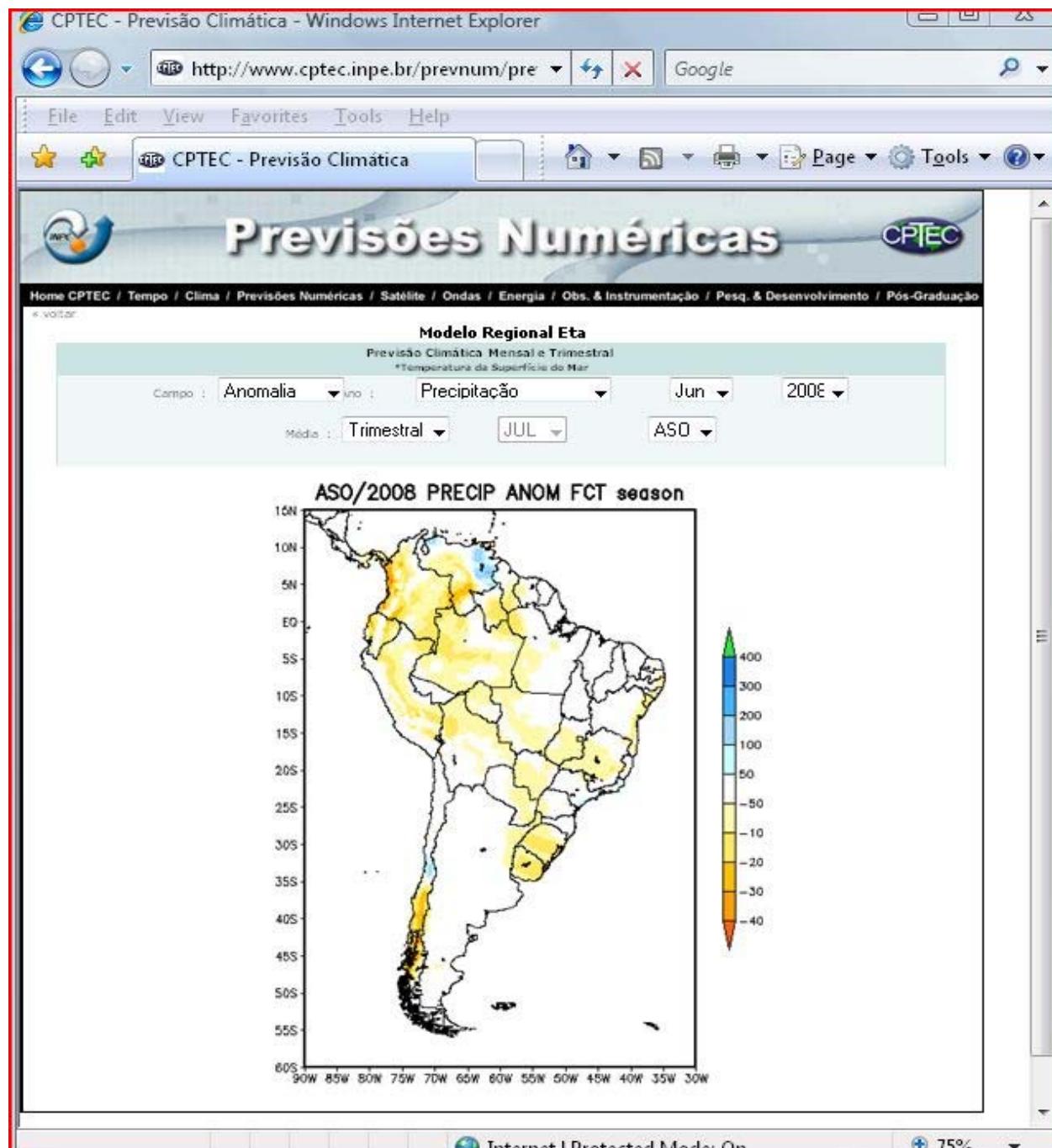
Model seasonal climatology = anomaly forecast



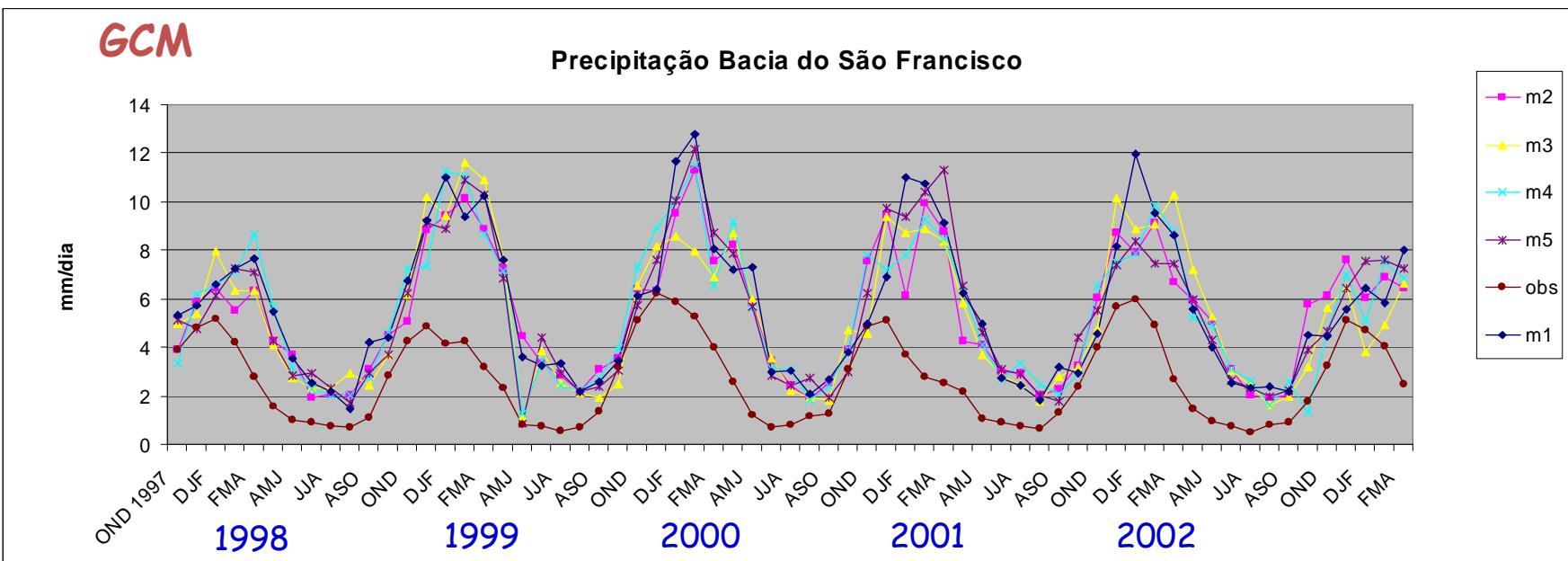
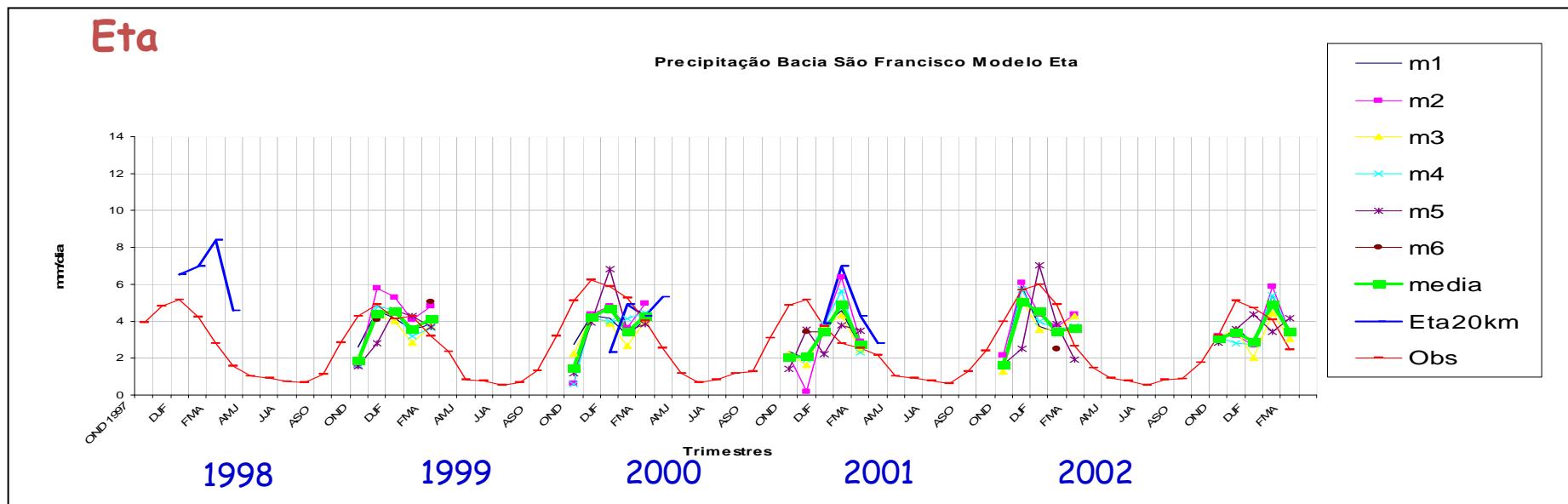
FMA 2004

Assume: climatology and model systematic errors have been removed

[http://www.cptec.inpe.br/prevnum/prev\\_clima/reg\\_eta\\_clima.shtml](http://www.cptec.inpe.br/prevnum/prev_clima/reg_eta_clima.shtml)

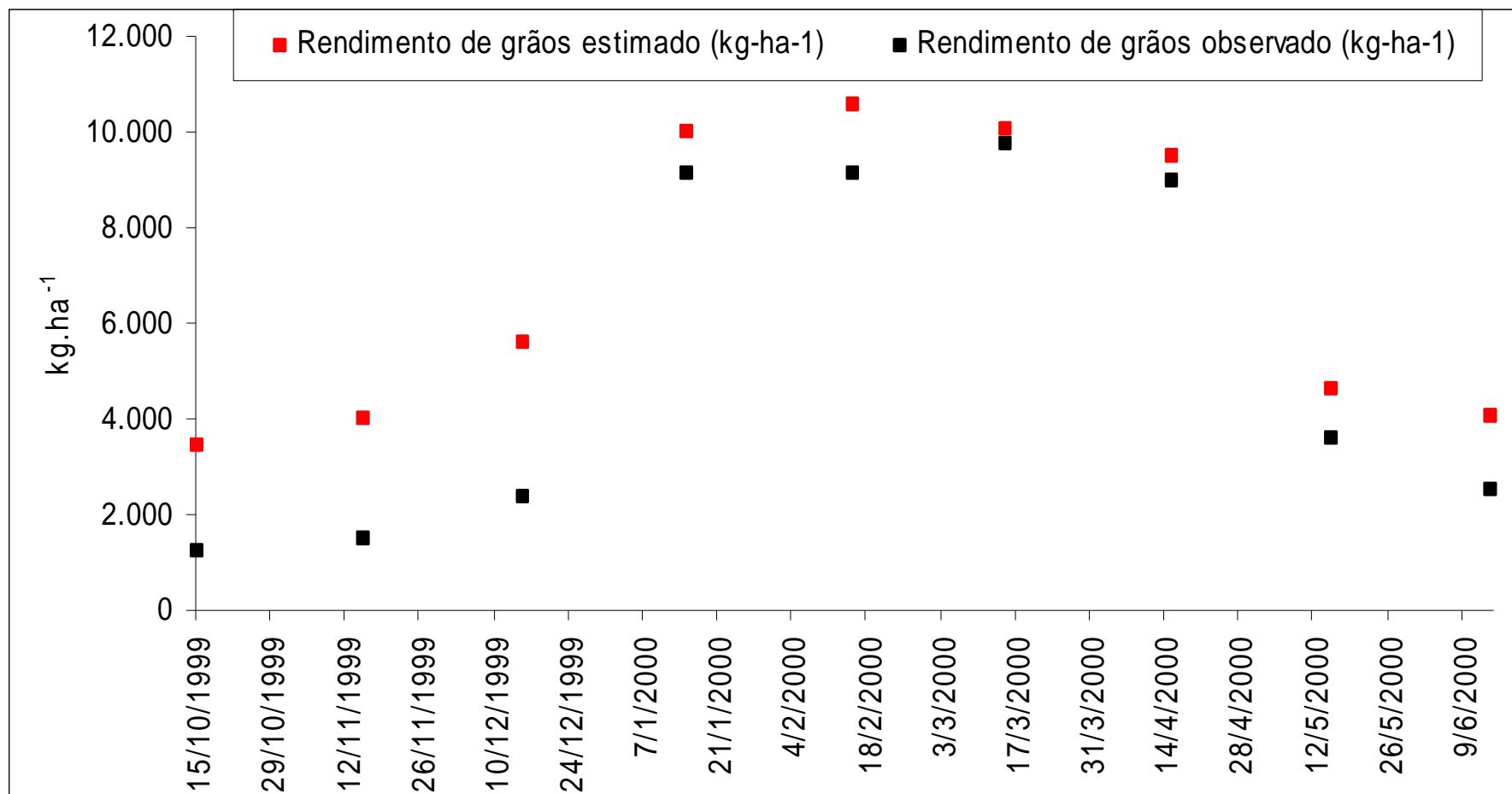


# Totais trimestrais de precipitação sobre a Bacia do São Francisco Previsões x Observações



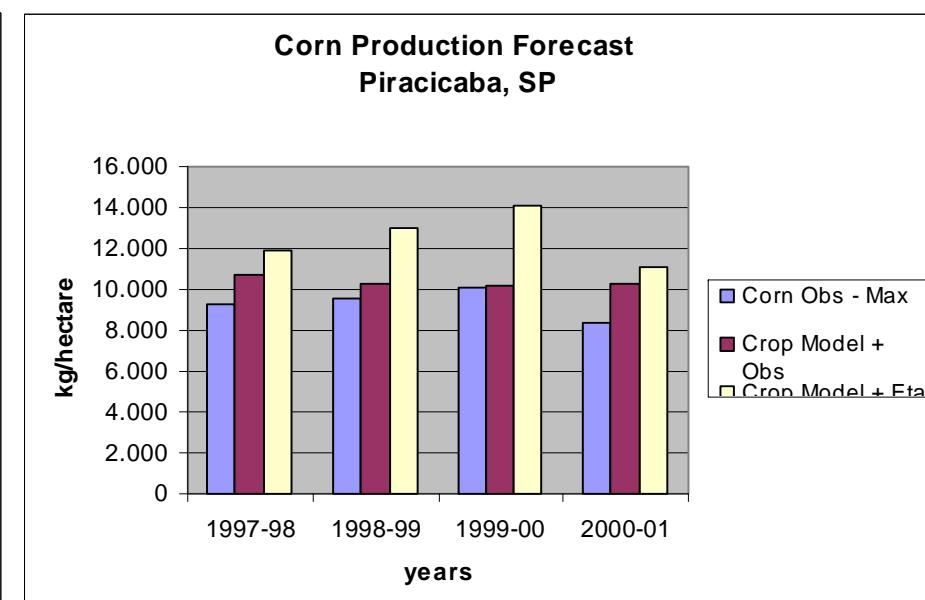
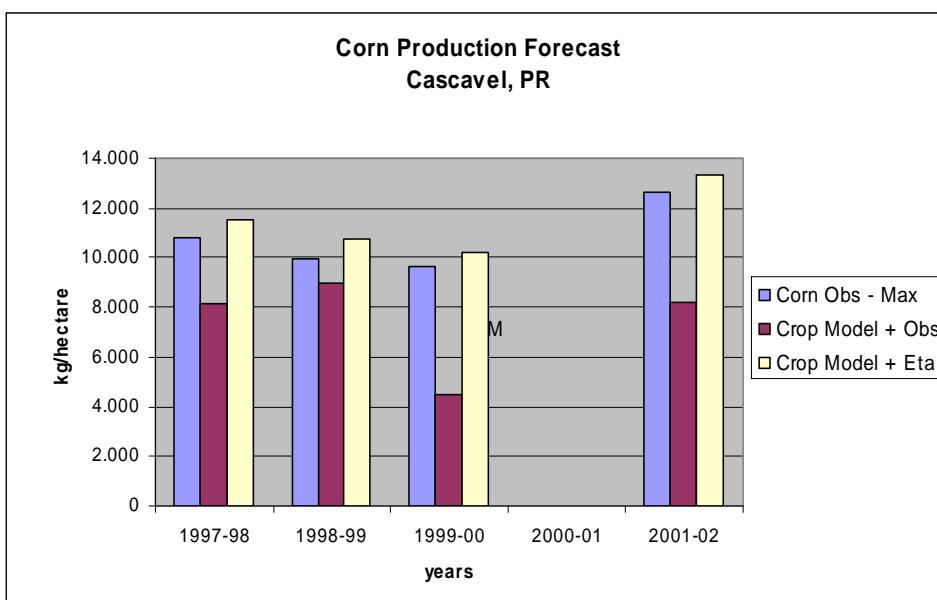
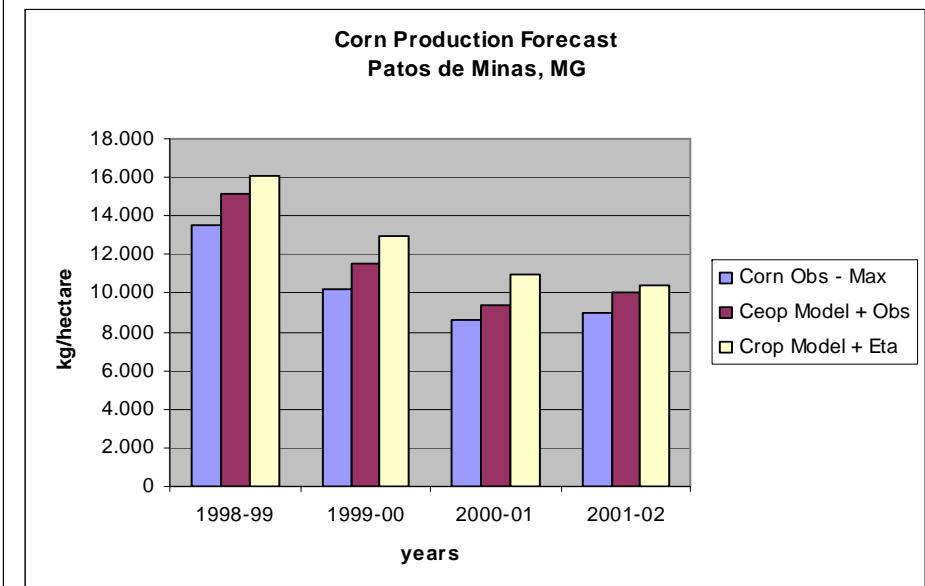
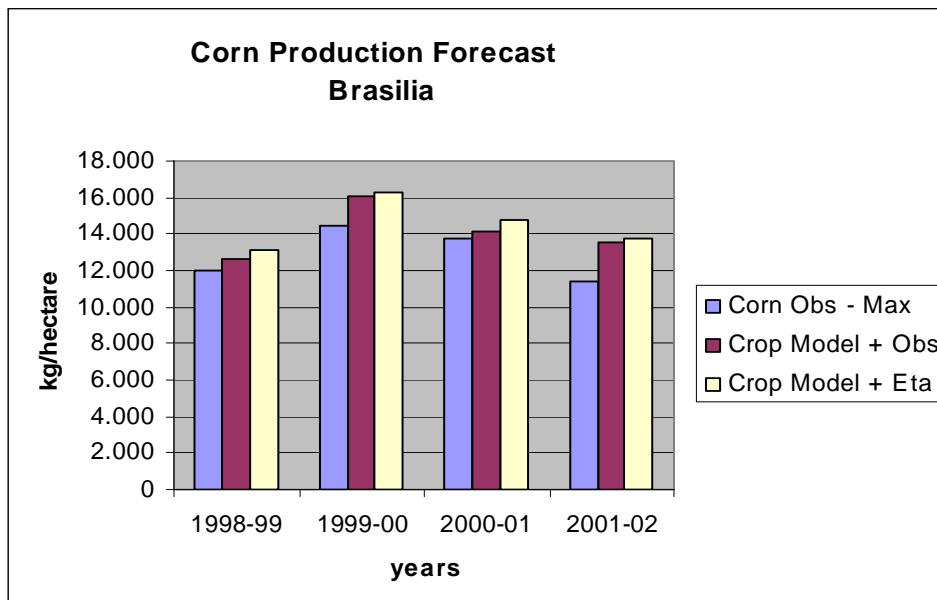
## Crop model driven by Eta model seasonal forecasts

oct1999 - jun2000  
forecast vs observed corn production - Piracicaba, SP



# Crop model driven by Eta model seasonal forecasts

Obs corn production X Crop Model + Obs X Crop Model + Eta

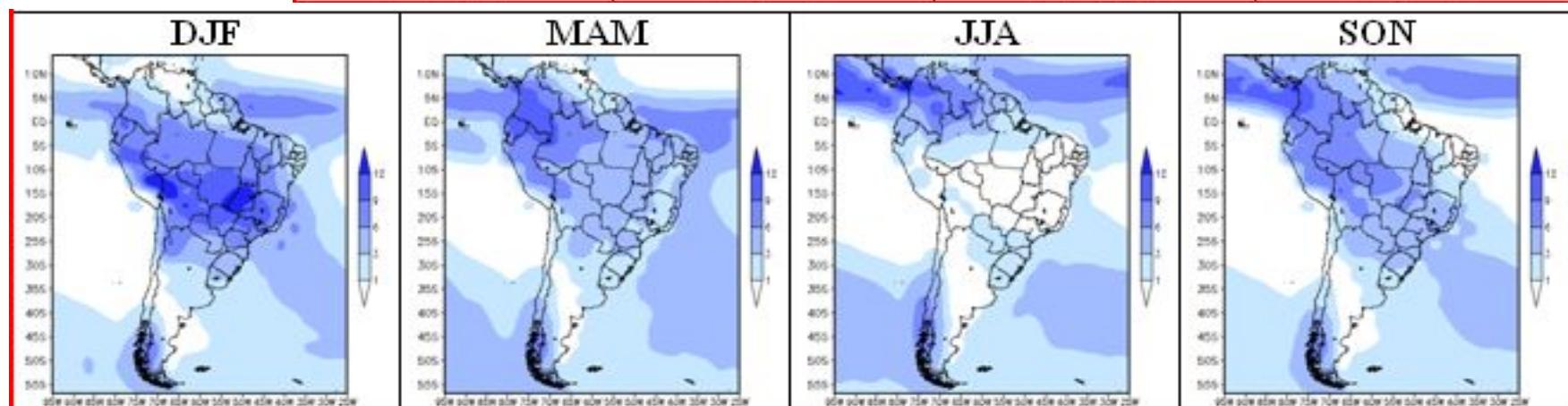
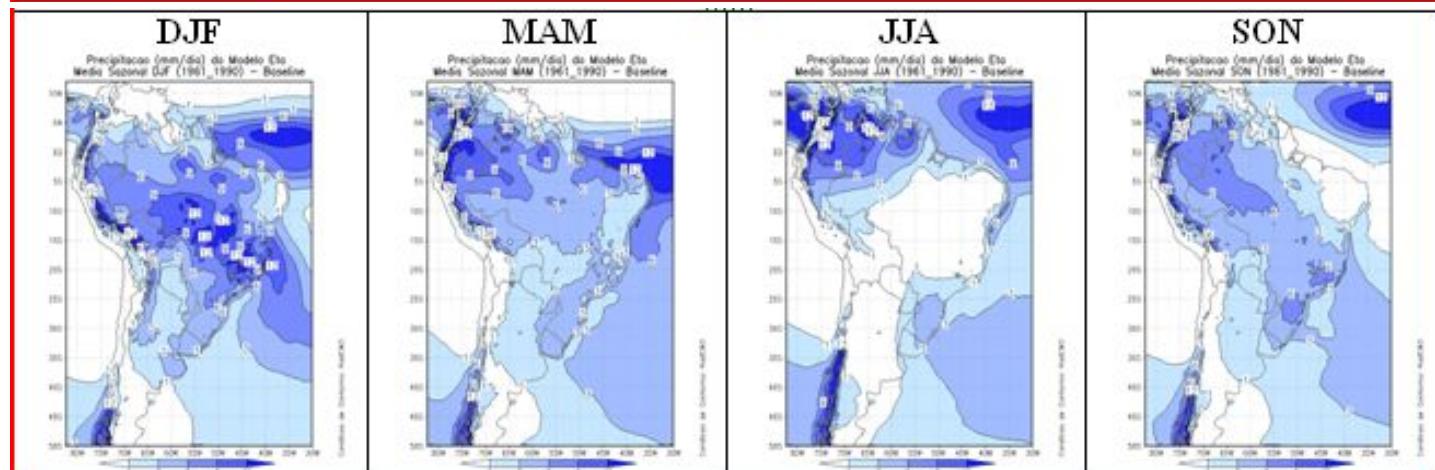
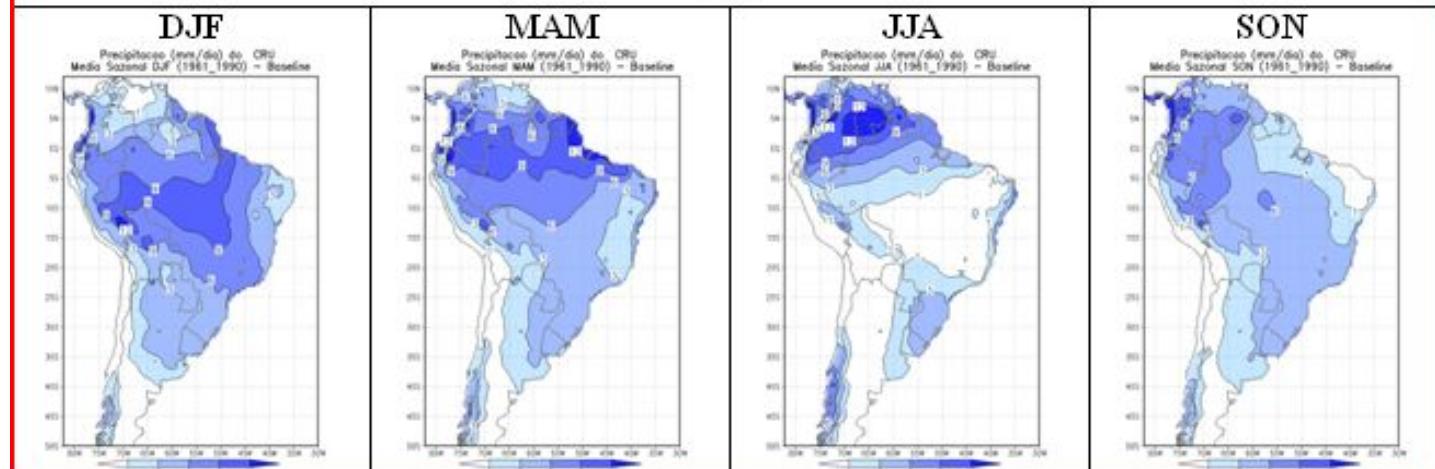


# Eta Climate Change Version

!961-1990 obs

30-year Eta Model  
**Present Climate**  
Integration  
(HADCM3 Forcing)

30-year HADCM3  
**Present Climate**  
Integration



## Future developments in weather and climate of the Eta Model at INPE

- Short-range Ensemble forecasts with Eta Model: IC+phys, increase no of members
- Increase horizontal resolution in weather forecasts,
- Forecasts from OAGCM lateral boundary conditions,
- Extended range forecasts with the Eta and CPTEC GCM models,
- Eta seasonal forecasts climatology
- Ensemble seasonal forecasts using Eta Model IC+ phys
- Coupling with hydrological model
- High resolution SST input for weather prediction
- Improvements in physics parameterizations

**ETA MODEL - Windows Internet Explorer**

http://www.cptec.inpe.br/etaweb/

File Edit View Favorites Tools Help

EtaModel

The Eta Model is a state-of-the-art atmospheric model used for research and operational purposes. The model is a descendent of the earlier HIBU (Hydrometeorological Institute and Belgrade University) model, developed in the seventies in the former Yugoslavia (the earliest reference being Mesinger and Janjic, 1974). In the eighties, the code has been upgraded to the Arakawa-style horizontal advection scheme of Janjic (1984), then rewritten to use the eta vertical coordinate (Mesinger et al. 1988), and subsequently, at NCEP, supplied with an advanced physics package (Janjic 1990, Mesinger and Lobocki 1991). It became officially operational at NCEP on 8 June 1993 (Black 1994). In its various versions, the model has been and/or is widely used in numerous countries, including Algeria, Argentina, Belgium, Brazil, Cameroon, China, Costa Rica, Cyprus, Czech Republic, Denmark, Egypt, Finland, Germany, Greece, Iceland, India, Israel, Italy, Malta, Tunisia, Turkey, Peru, Philippines, Serbia and Montenegro, South Africa, Spain, Sweden, and the United States.

The code is available for downloading at the [NCEP site](#), and, in an updated version, [at this site](#). It is a very efficient code which can run on small personal computers in UNIX or LINUX systems.

The name of the model derives from the Greek letter ( $\eta$ ) which denotes the vertical coordinate (Mesinger 1984), one of the model features, defined as

$$\eta = \left[ \frac{(p - p_s)}{(p_t - p_s)} \right] \cdot \left[ \frac{(p_{ref}(z) - p_t)}{(p_{ref}(0) - p_t)} \right]$$

where  $p$  is the atmospheric pressure. The indices  $s$  and  $t$  refer to the surface and the top of the model atmosphere, respectively. The index  $ref$  refers to a prescribed reference atmosphere, and  $z$  is the surface height. The model orography is formed of steps. The steps can have slopes in the version downloadable here (Mesinger and Jovic 2004).

Internet | Protected Mode: On 75%

<http://www.cptec.inpe.br/etaweb>

**ETA MODEL - Windows Internet Explorer**

http://www.cptec.inpe.br/etaweb/do

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EtaModel

Download

Model Code and scripts

worketa\_all.tar.gz: version ICTP, Trieste 2005. Sloping Eta.

Features included that are considered improvements/refinements compared to the NCEP WS Eta:

- Sloping steps eta discretization (e.g., Mesinger and Jovic 2004);
- Changes in the continuity and hydrostatic equations to account for mass removal and addition due to precipitation and evaporation, and the presence of condensates (Mesinger and Lazio, "Blue Book" 2004);
- Changes in the BMJ convection to remove/ameliorate the problem of undergoing intense convection (reversed DSSPs, and no extension of relaxation time);
- Averaging of all four surrounding velocities at h points (including those that are zero at vertical sides) to do turbulence quantities (improves lowest layer winds over topography);

updates

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Comentários e/ou sugestões:  
mihama@cppec.inpe.br

http://www.cptec.inpe.br/etaweb

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# List of products addresses:

Eta-40km and 20km Forecasts:

<http://www.cptec.inpe.br/prevnum/>

Eta-40km Ensemble Forecasts

[http://www6.cptec.inpe.br/iodopweb/ioweb/Etaens\\_40km.shtml](http://www6.cptec.inpe.br/iodopweb/ioweb/Etaens_40km.shtml)

High resolution 5-km Southeast Brazil

[http://www.cptec.inpe.br/produtos\\_serramar/etaserra/index.html](http://www.cptec.inpe.br/produtos_serramar/etaserra/index.html)

[\(temporary\)](http://tucupi.cptec.inpe.br/serradomar/tabela.shtml)

Eta Nordeste Brazil

[http://www.cptec.inpe.br/eta/produtos/prod\\_eta/eta\\_sx6/Eta\\_NE/gif](http://www.cptec.inpe.br/eta/produtos/prod_eta/eta_sx6/Eta_NE/gif)

Seasonal forecasts

[http://www.cptec.inpe.br/prevnum/prev\\_clima/reg\\_eta\\_clima.shtml](http://www.cptec.inpe.br/prevnum/prev_clima/reg_eta_clima.shtml)

Climate Change scenarios

[\*\*\(soon\)\*\*](http://www6.cptec.inpe.br/pnud_bra)



**Ministério da Ciência e Tecnologia  
Instituto Nacional de Pesquisas Espaciais  
Centro de Previsão de Tempo e Estudos Climáticos**

**THANK YOU!**

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**+55-12-3186-8424**

**16/10/2008**  
ICTP, 2008