



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

*Previsões climáticas sazonais geradas pelo
Modelo Eta do CPTEC/INPE*

Chou Sin Chan

chou@cptec.inpe.br

+55-12-3186-8424

COMO SÃO PRODUZIDAS AS PREVISÕES NUMÉRICAS DE TEMPO E CLIMA?

Modelos numéricos baseados em leis da física

- Conservação do momentum angular
- Conservação da massa
- Conservação da energia total

MODELAGEM DA ATMOSFERA

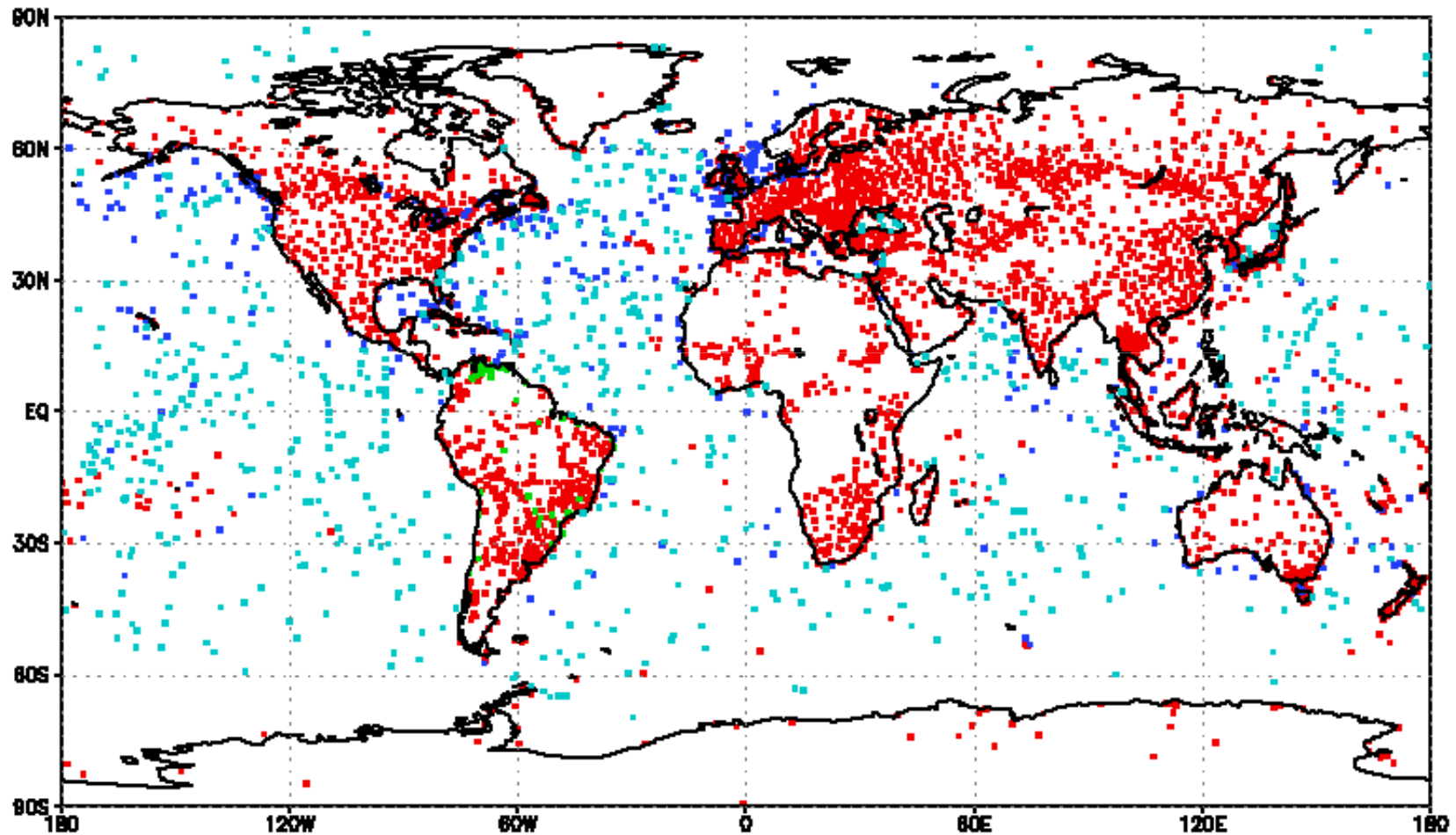
Equações Primitivas

1. Vento horizontal $\frac{DV_H}{Dt} = -2\Omega_z \times V_H - \frac{1}{\rho} \nabla_H p + F_H$
2. Equil hidrostático $0 = -\frac{1}{\rho} \frac{\partial p}{\partial z} - g$
3. da continuidade $\frac{D\rho}{Dt} = -\rho \nabla \cdot V$
4. da termodinâmica $c_v \frac{DT}{Dt} = -p \frac{D\alpha}{Dt} + Q$
5. do estado $p = \rho R T$
6. umidade do ar $\frac{Dq}{Dt} = Q'$

Equações diferenciais parciais não-lineares

CPTEC Surface Observations on 12z 18 June 2002, $\pm 3h$

Distribuição dos dados: Superfície 18 Jun 2002 12Z [-3h:+3h]

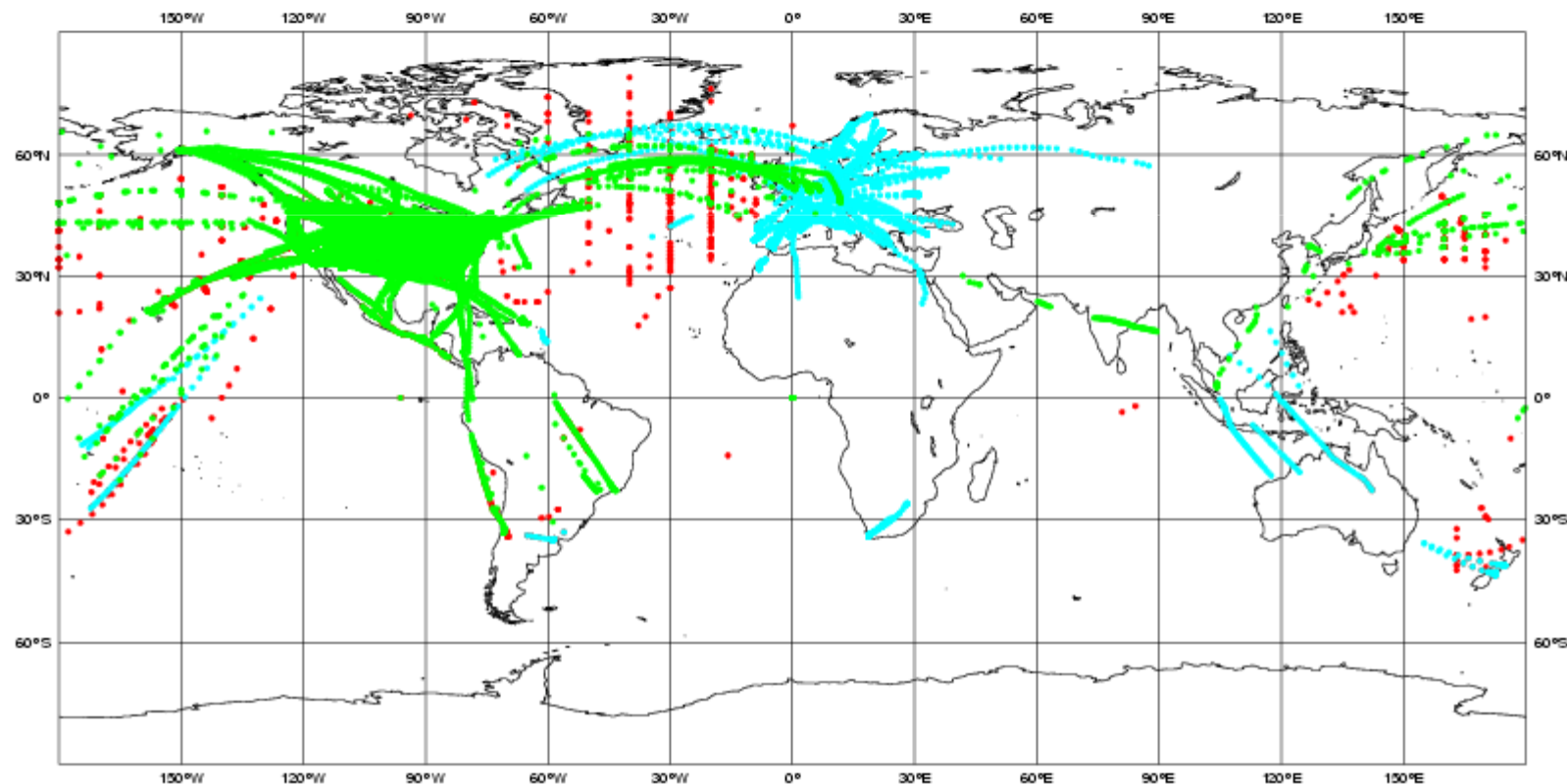


Synop	Metar	Ship	Buoy
4166	122	770	3065

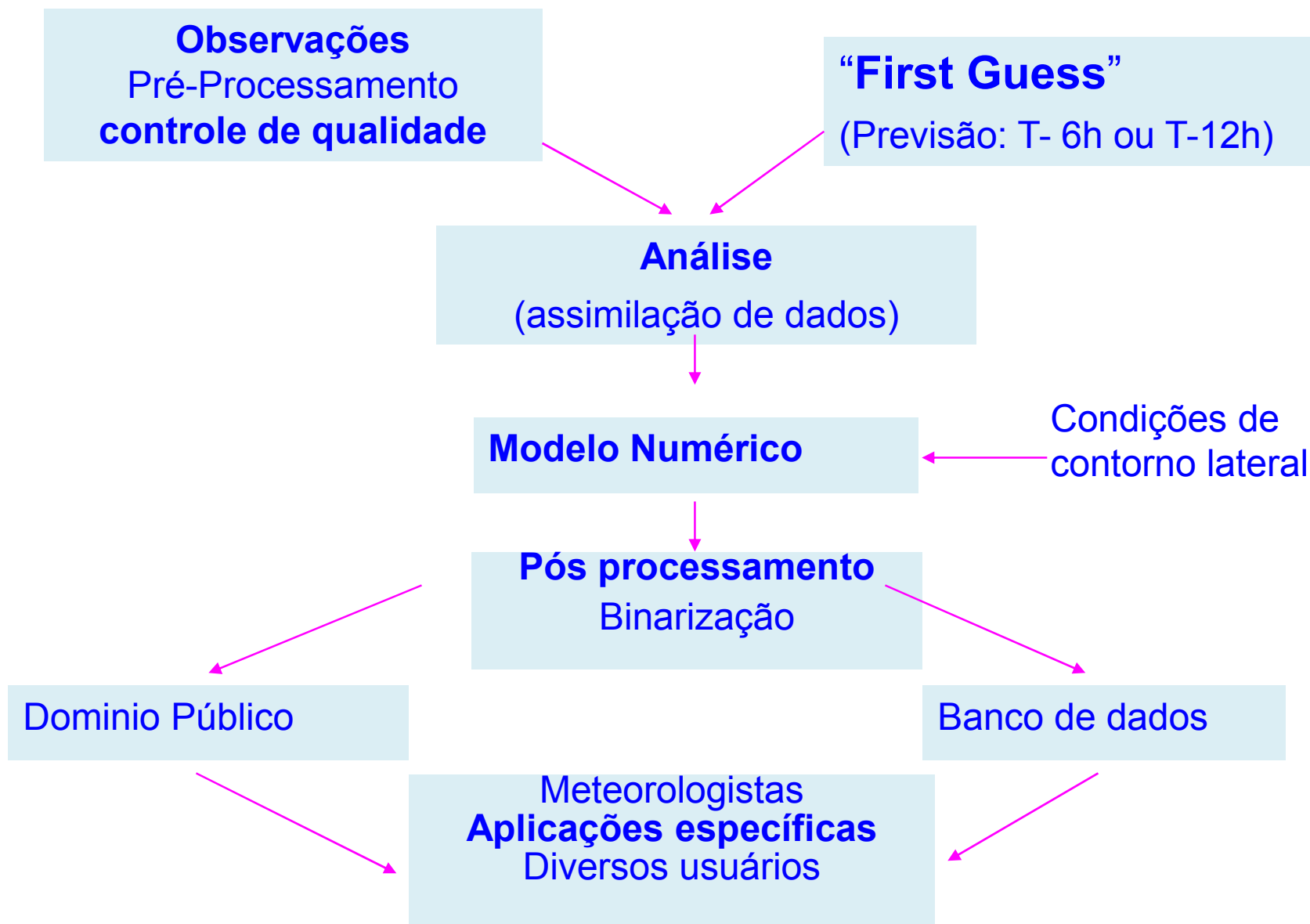
ECMWF Data Coverage (All obs) - AIRCRAFT
18/JUN/2002; 12 UTC
Total number of obs = 40854

Obs Type

- 5579 AIREP
- 7730 AMDAR
- 27545 ACARS



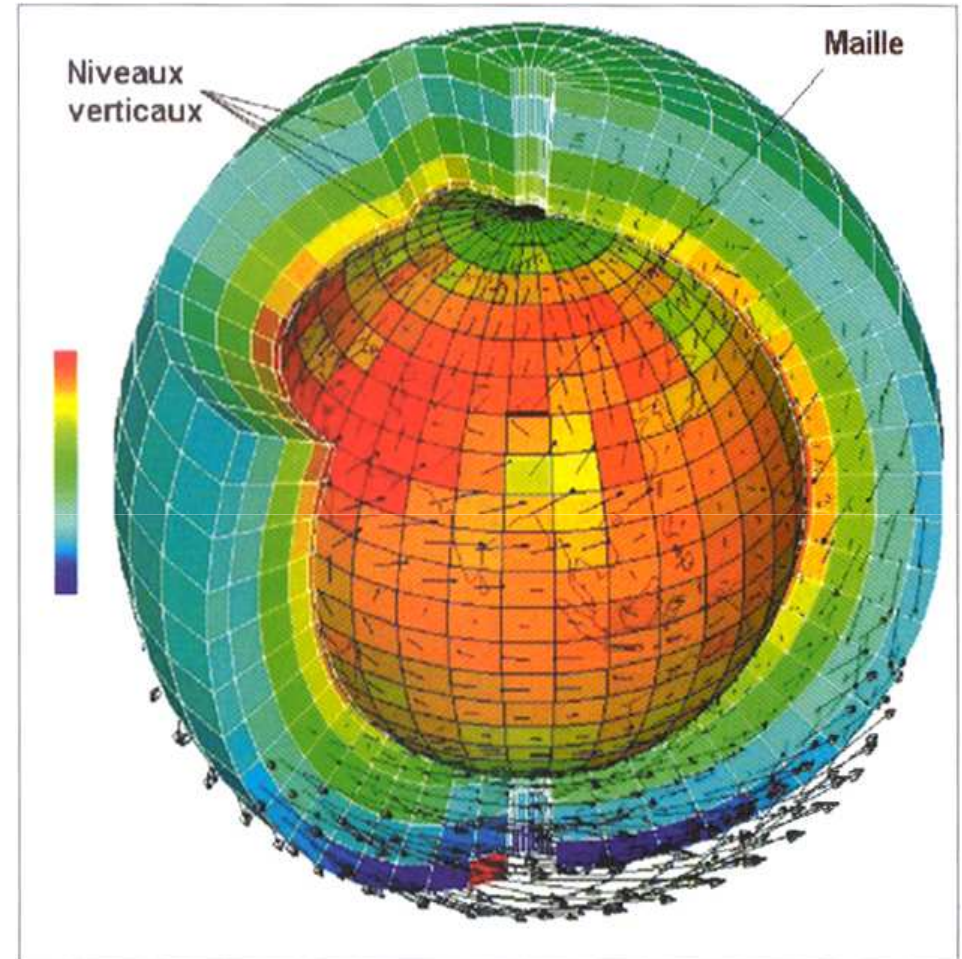
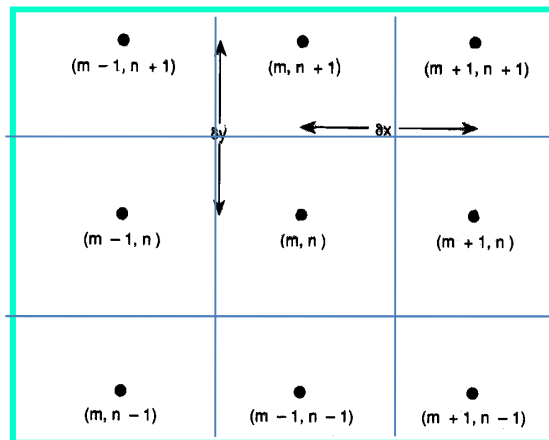
Etapas para produzir PNT



Modelo em "ponto de grade"

O espaço é dividido em caixas definidas por grades horizontais e níveis verticais.

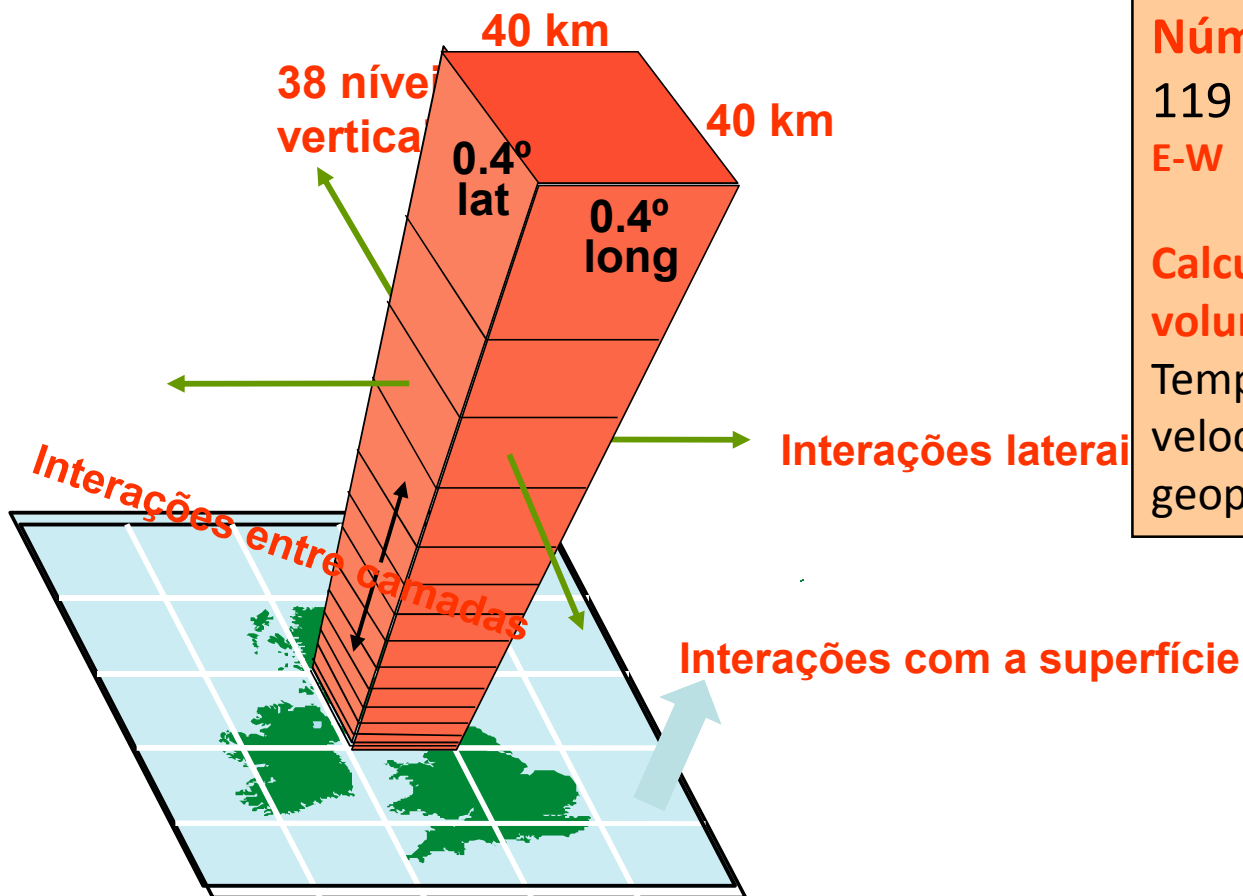
Em cada caixa a atmosfera é homogênea e é suficiente conhecer o valor em 1 ponto da caixa.



Modelo Numérico Atmosférico

Código computacional (centenas de milhares de linhas de comando) que representa aproximações numéricas das equações matemáticas.

O cálculo é feito para alguns dias de previsão, uma estação do ano, vários anos, décadas, e para cenários de mudanças climáticas.



Número de elementos:

$$119 \times 211 \times 38 = 954142$$

E-W N-S Vertical

Calcula-se para cada um destes volumes:

Temperatura, umidade, direção e velocidade do vento, altura geopotencial.

Fenômenos

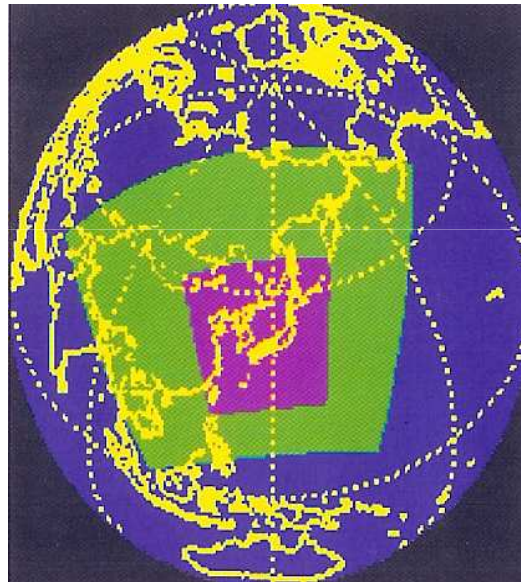
ESCALA ESPACIAL

ESCALA TEMPORAL

1. El Niño/La Niña	Aprox 15000 km	3 – 6 anos
2. Osc. Madden Julian – MJO	Aprox 10000 km	30 – 60 dias
3. Zona Convg Atl Sul – ZCAS	Aprox 6000 km	5 – 10 dias
4. Ciclone extratropical	1000 – 6000 km	1 – 7 dias
5. Ciclone tropical (furacão)	500 – 1000 km	1 – 2 dias
6. Frentes Frias/Quentes	50 – 500 km	3 – 24 h
7. Complexos Convectivos -MCC	50 – 500 km	12 h – 30 h
8. Linhas de instabilidade	50 – 500 km	12 h – 30h
9. Fenômenos orográficos	10 – 200 km	< 24 h
10. Convecção profunda	1 – 50 km	< 3 h
11. Efeitos urbanos	1 – 20 km	< 3 h
12. Tornado	500 m – 1 km	< 30 min
13. Plumas de fumaça	< 500 m	< 30 min
14. Turbulência	< 50 m	< 3 min

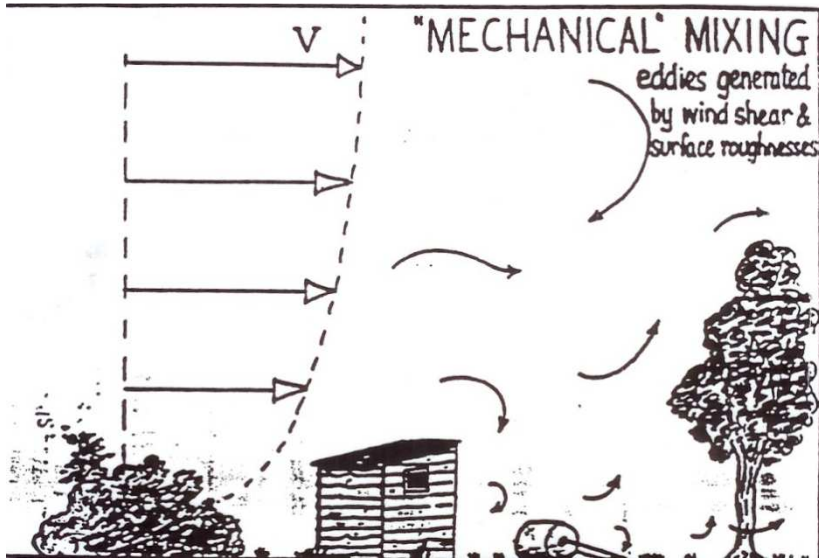
Papel dos Modelos de Previsão Numérica de Tempo

- **Globais**: Acompanhamento dos padrões de escala sinótica para todo o globo.
- **Regionais**: Aplicação semelhante aos modelos globais, mas com resolução maior sobre uma área limitada de interesse.
- **Mesoescala**: Acrescenta detalhes aos padrões de escala sinótica previstos no modelo regional.



Interação entre os modelos

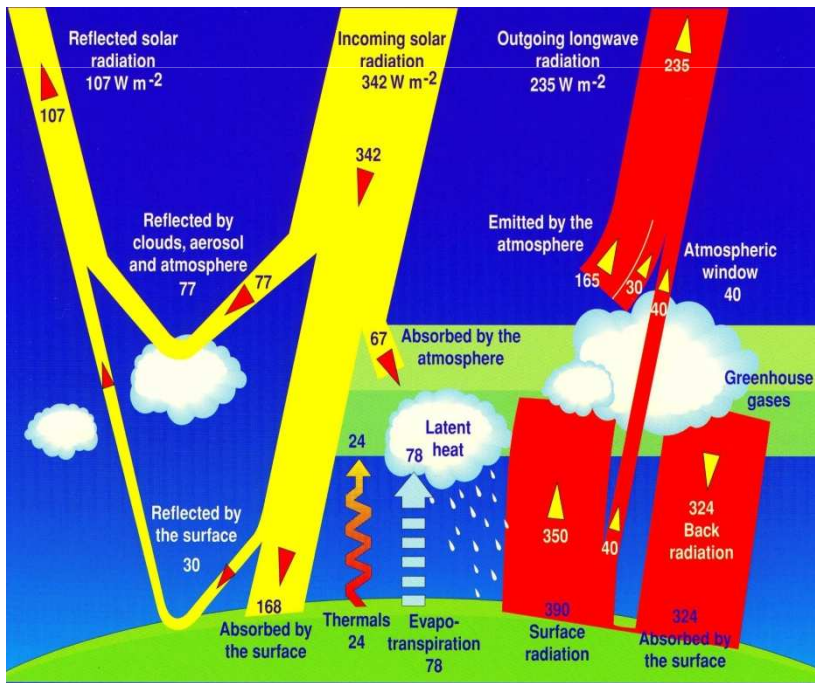




Turbulência

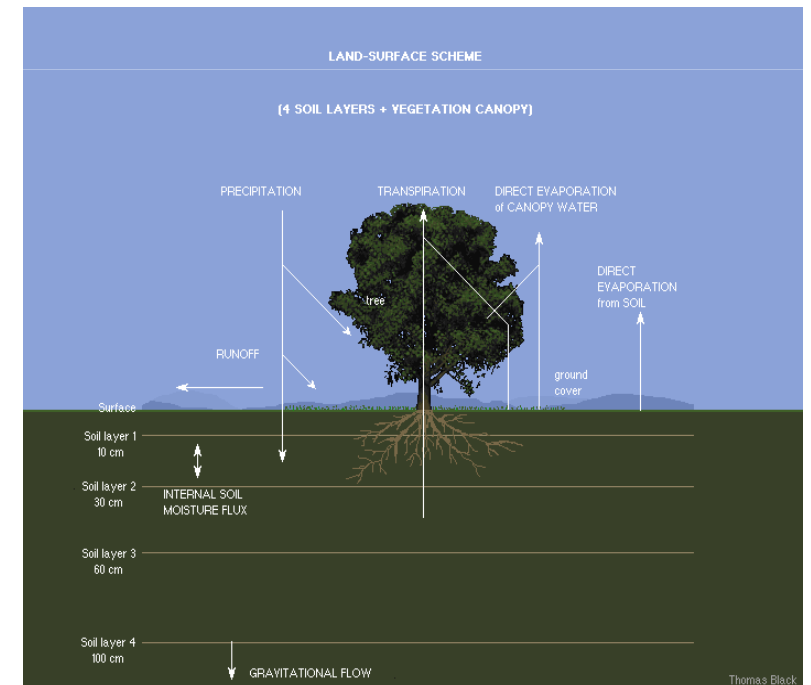


Cumulus profundo



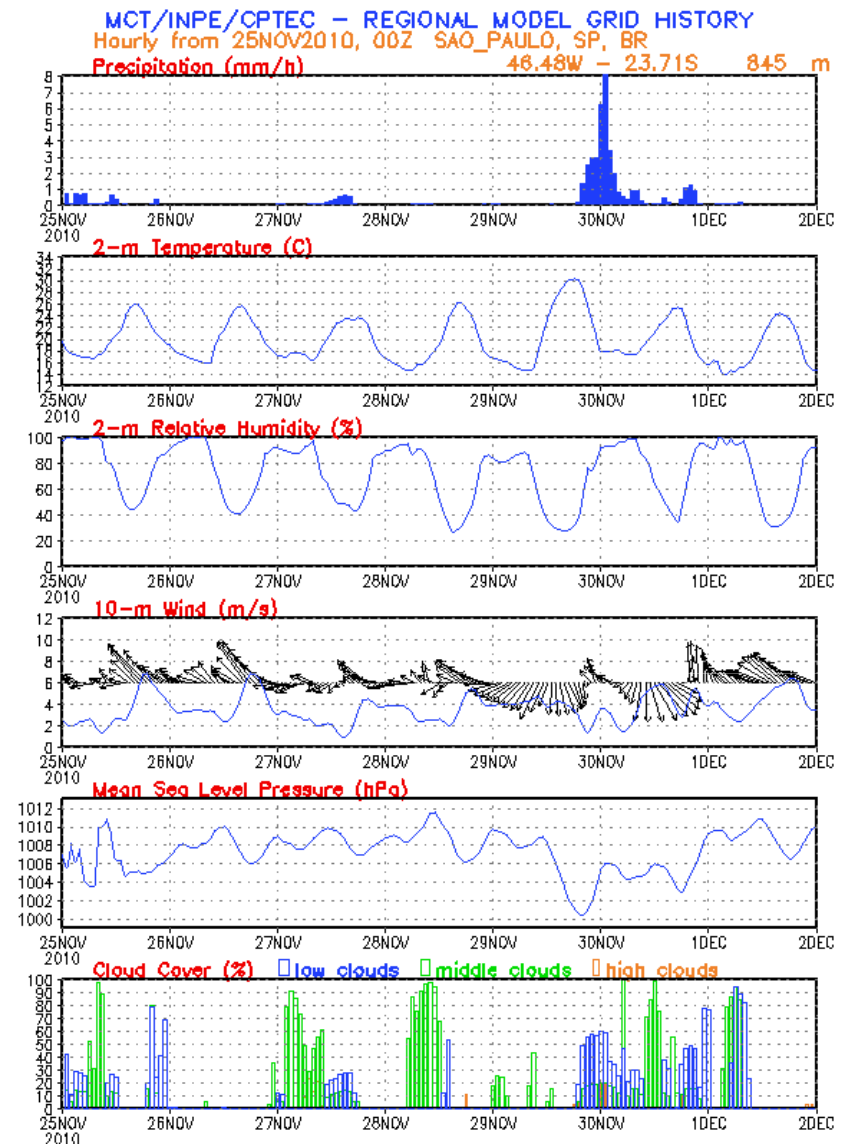
Radiation Balance of the Earth's Surface and Atmosphere

Radiação



hidrologia

Produtos do Modelo Eta



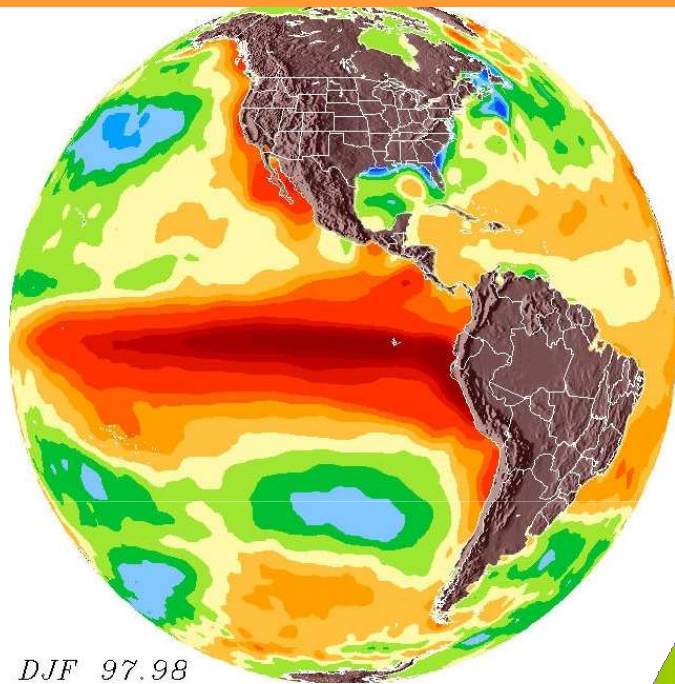
If there is no predictability beyond few days, why to use long-term integration?

Deterministic forecast skill (location and time of weather event) range is of few days.

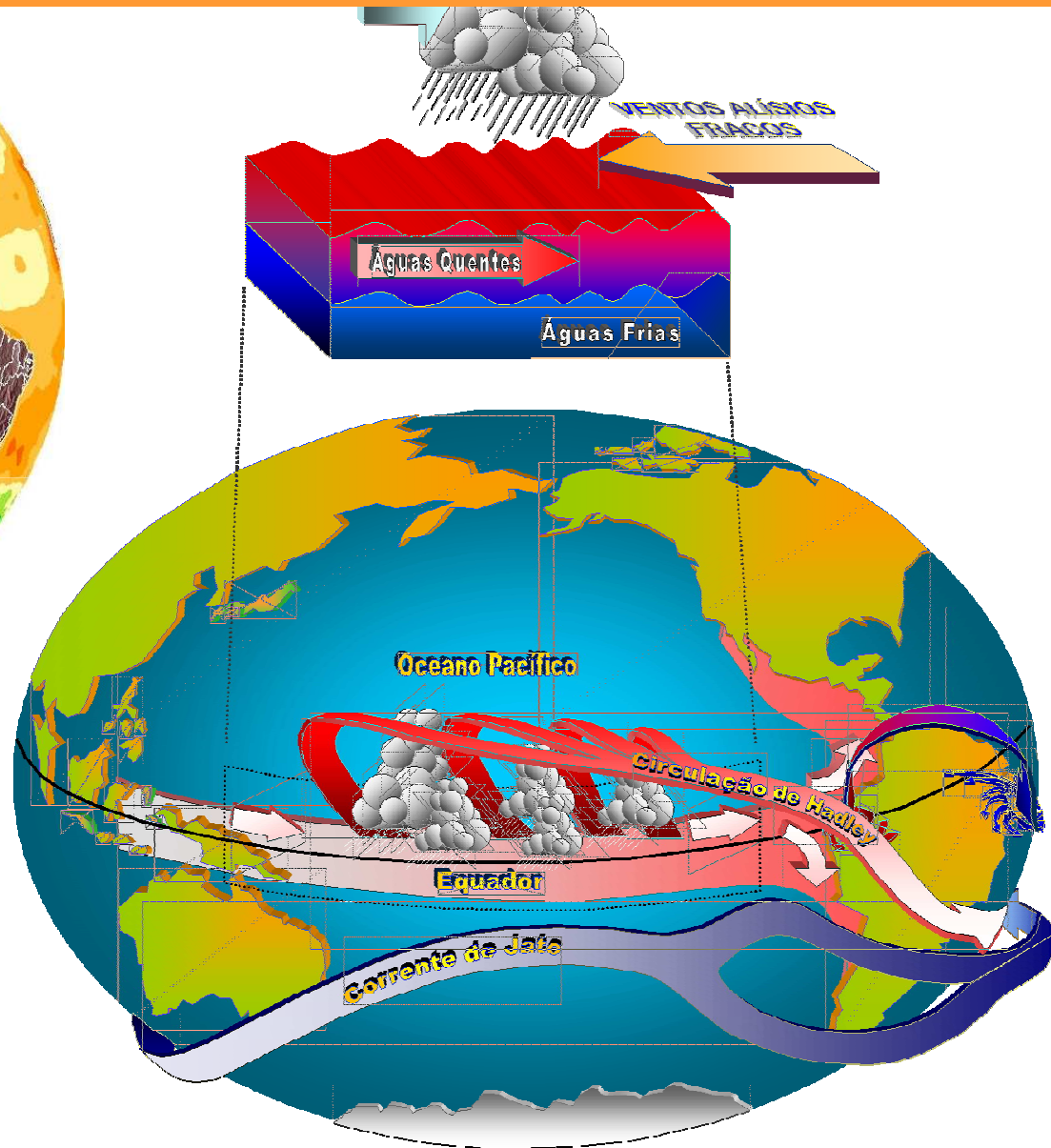
However, for long term integration, the climate statistics matters.

The RCM develops physically consistent, both internally and with the driving large-scale flow through the lateral boundary condition (LBC)

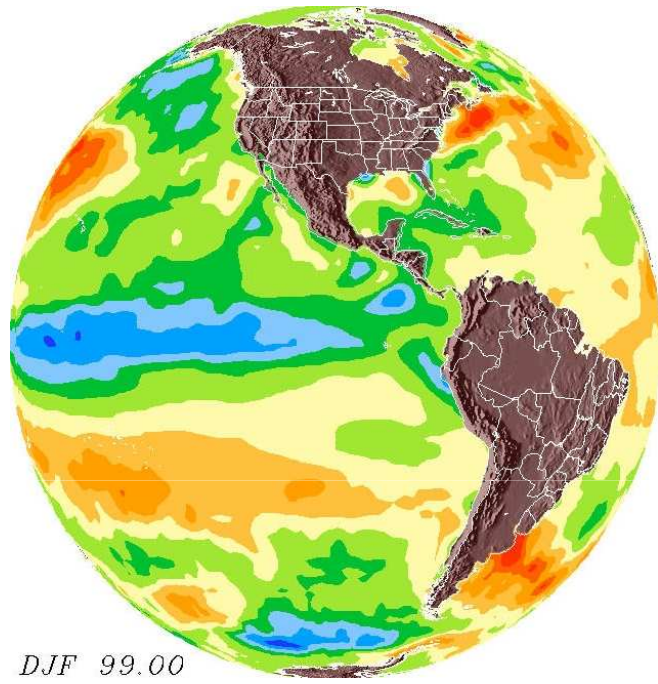
Anomalia positiva da Temperatura da Superfície do Mar sobre o Oceano Pacífico



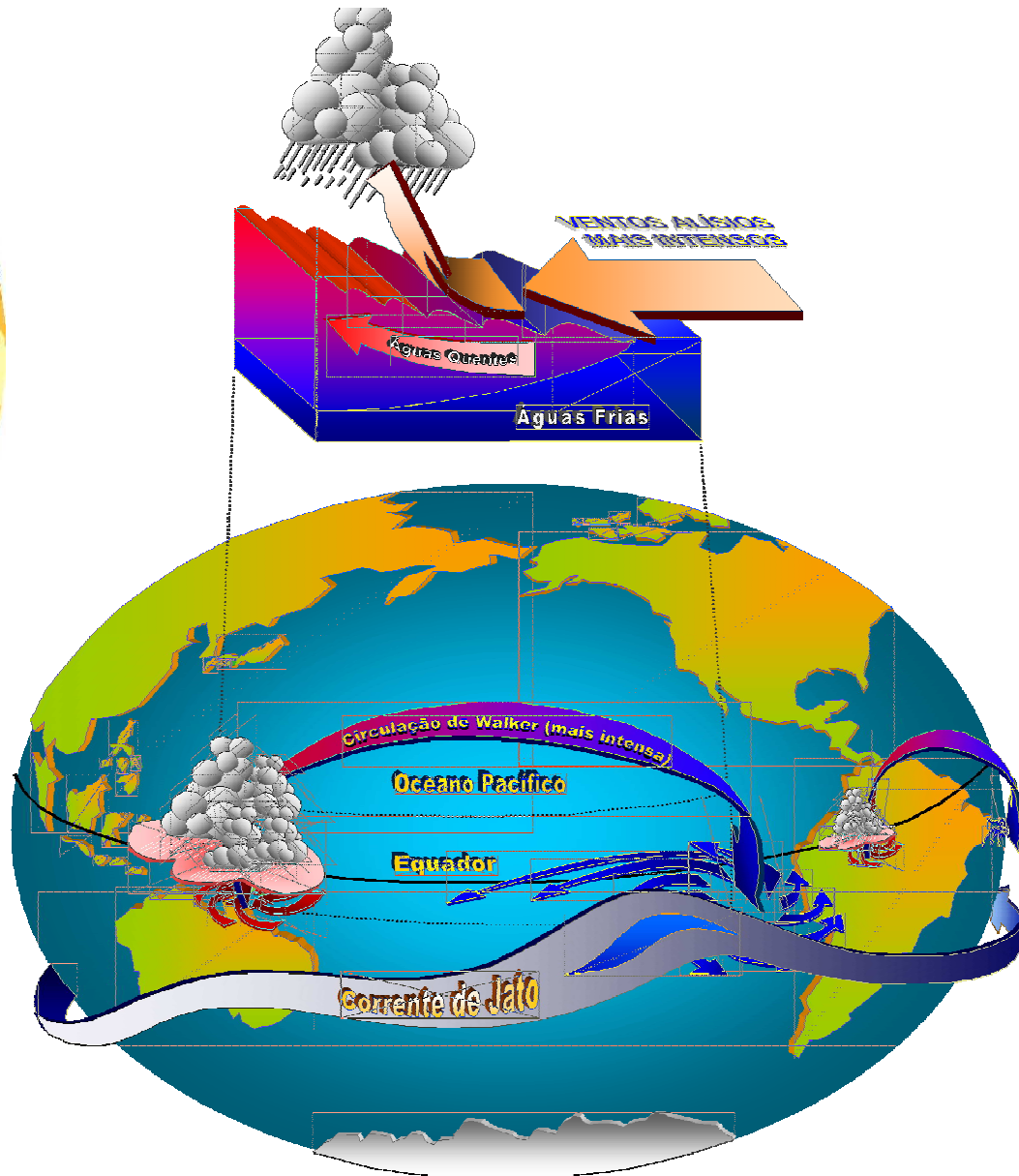
El Niño



Anomalia negativa da Temperatura da Superfície do Mar sobre o Oceano Pacífico

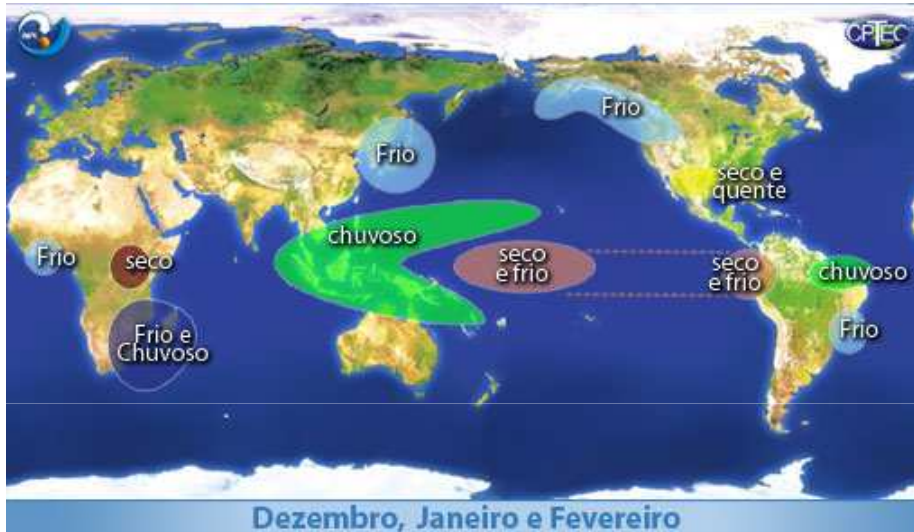


La Niña

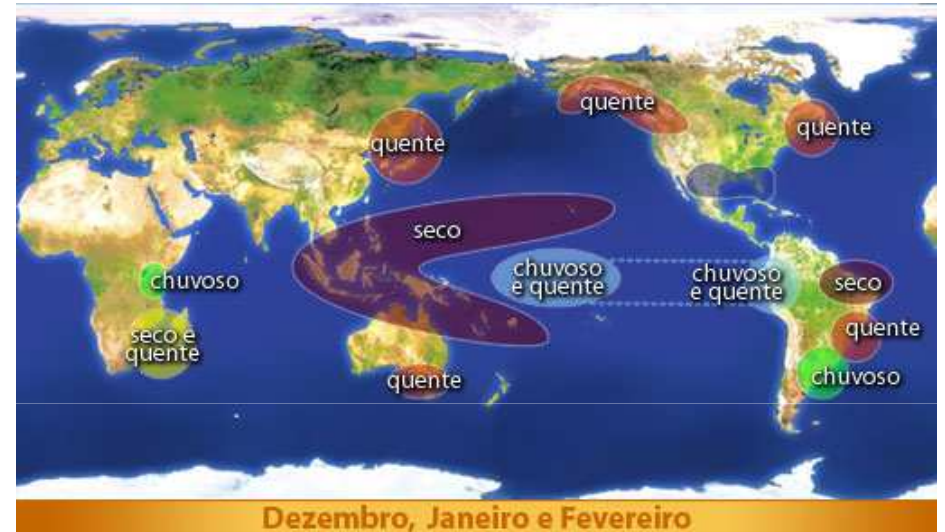


IMPACTOS

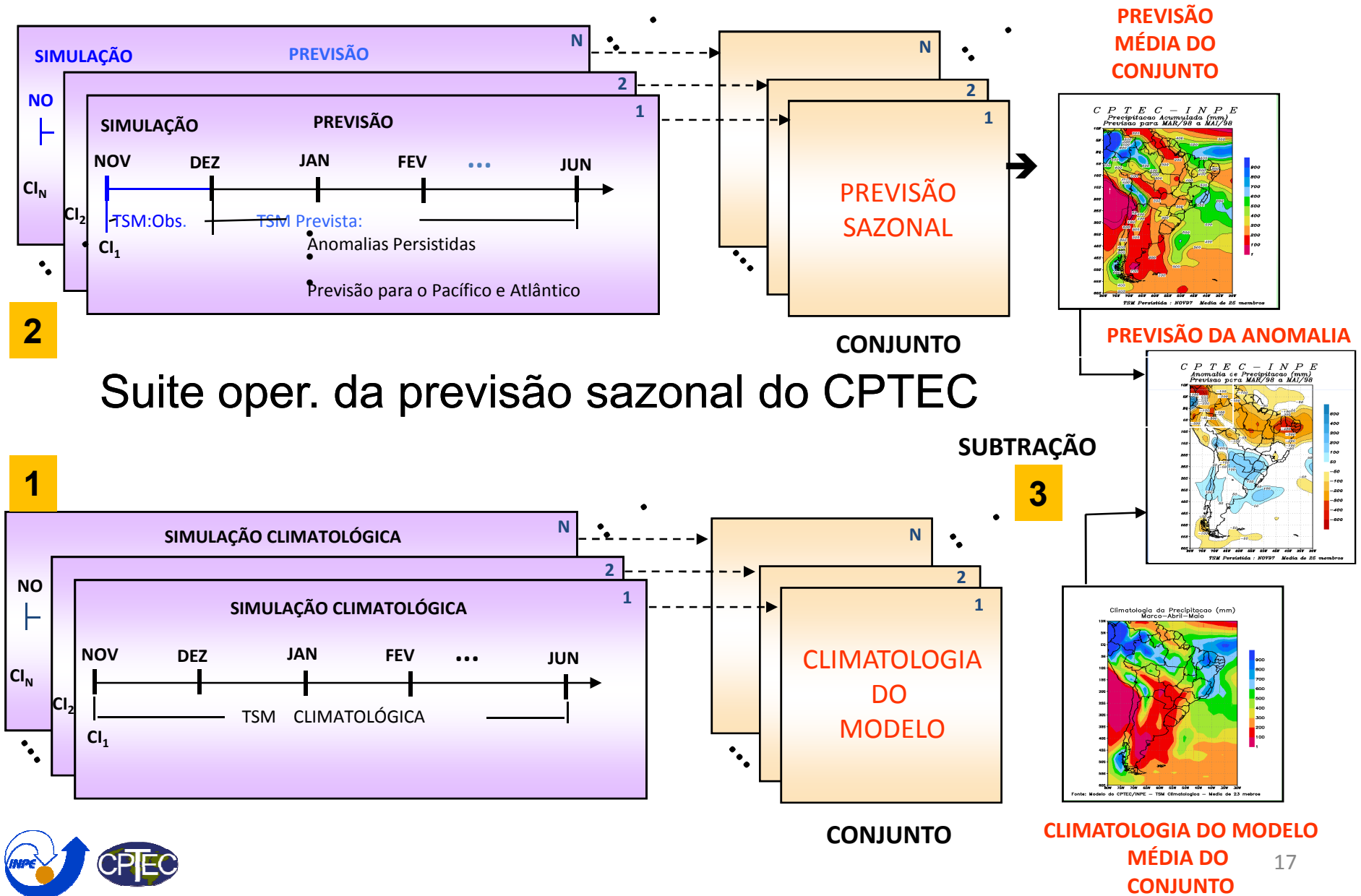
La Niña



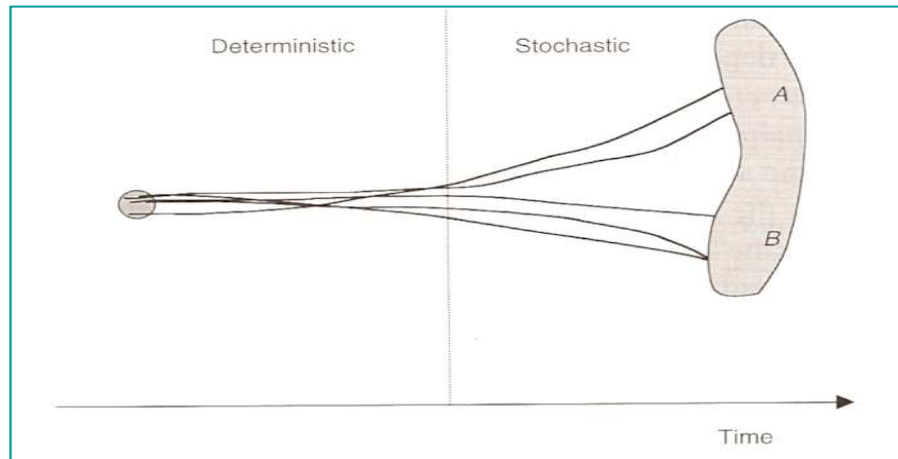
El Niño



QUAIS SÃO AS ETAPAS DA PREVISÃO CLIMÁTICA SAZONAL?



Need of ensemble forecasts due to various uncertainties

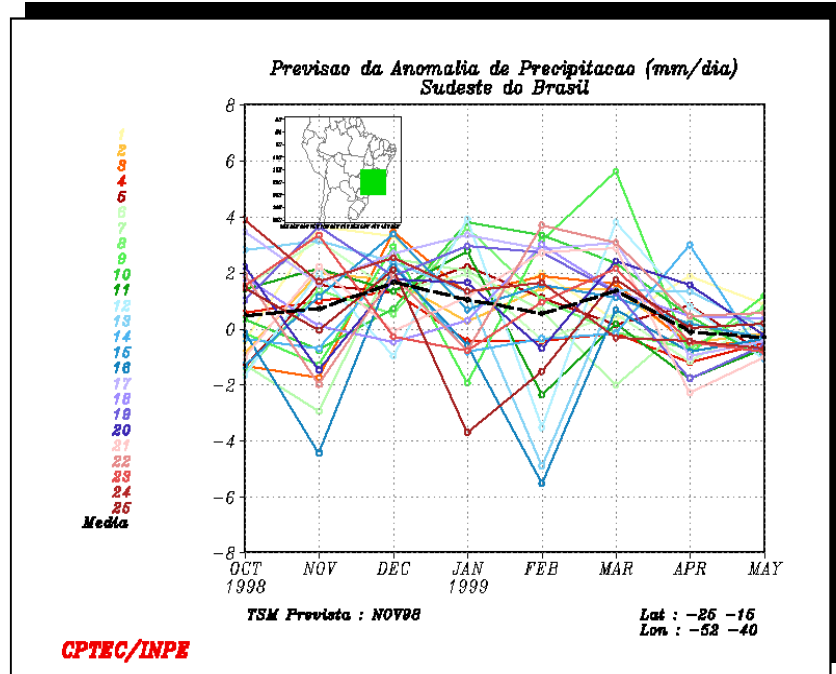


Different methods to generate ensemble forecasts

- 1 - Initial conditions perturbations;
- 2 - Multi-model ensemble;
- 3 - Model physics perturbations

The ensemble forecast provides a set of possible cenarios
> > Probability of the forecast of an event

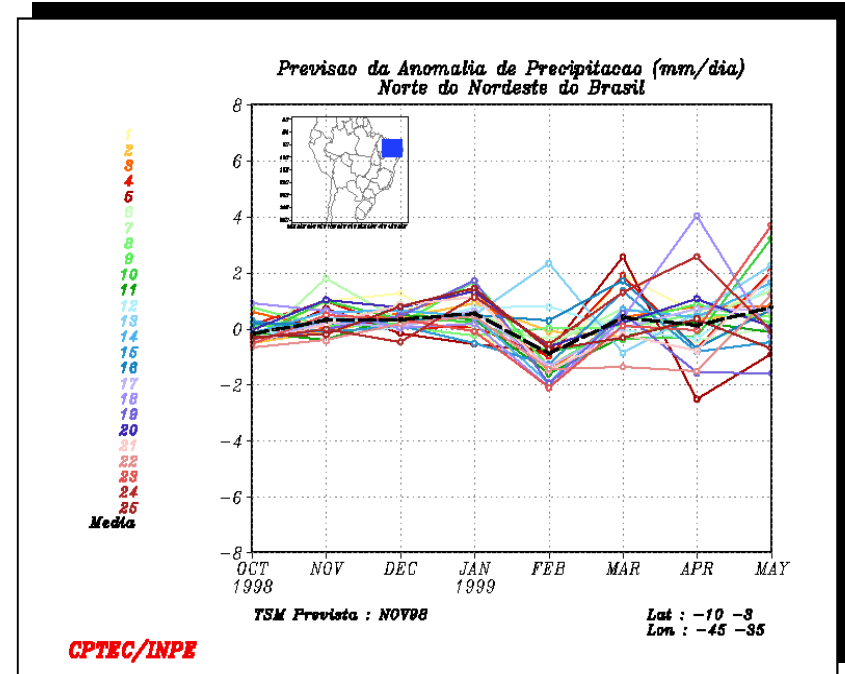
Evaluation of predictability



Dispersion among the members



Lower predictability



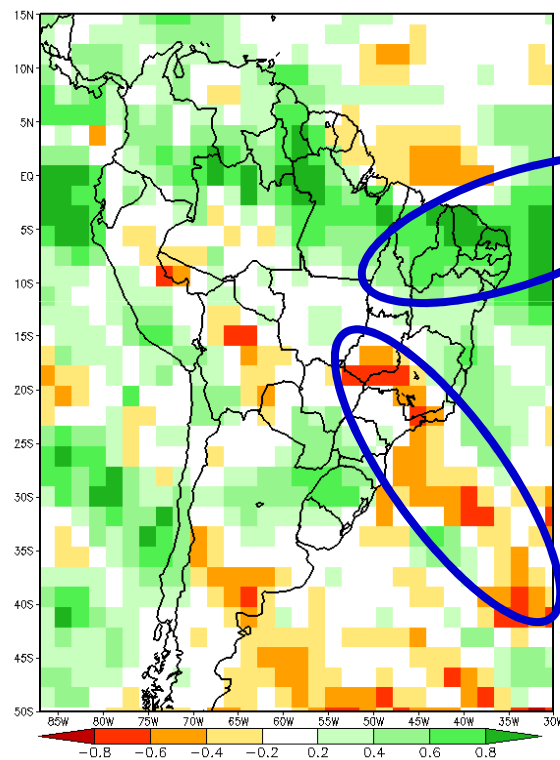
Small dispersion among the members



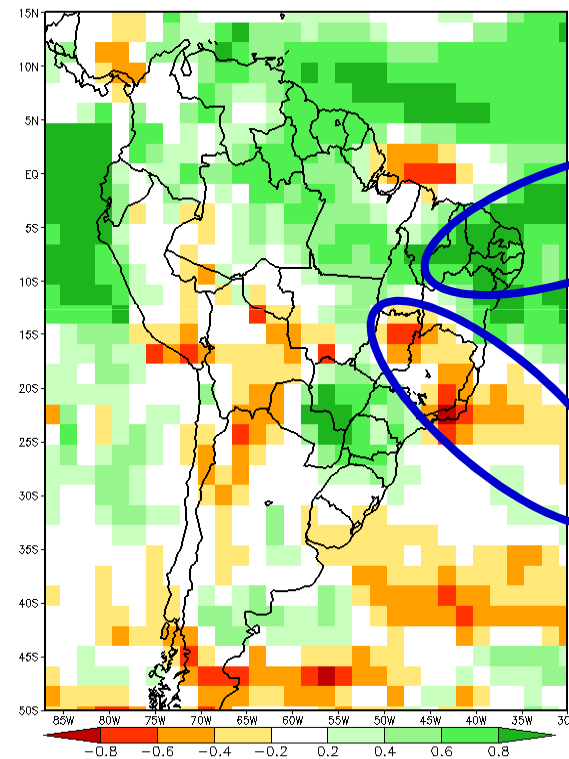
Higher predictability

Scientific Challenge: SACZ low predictability

DJF



MAM



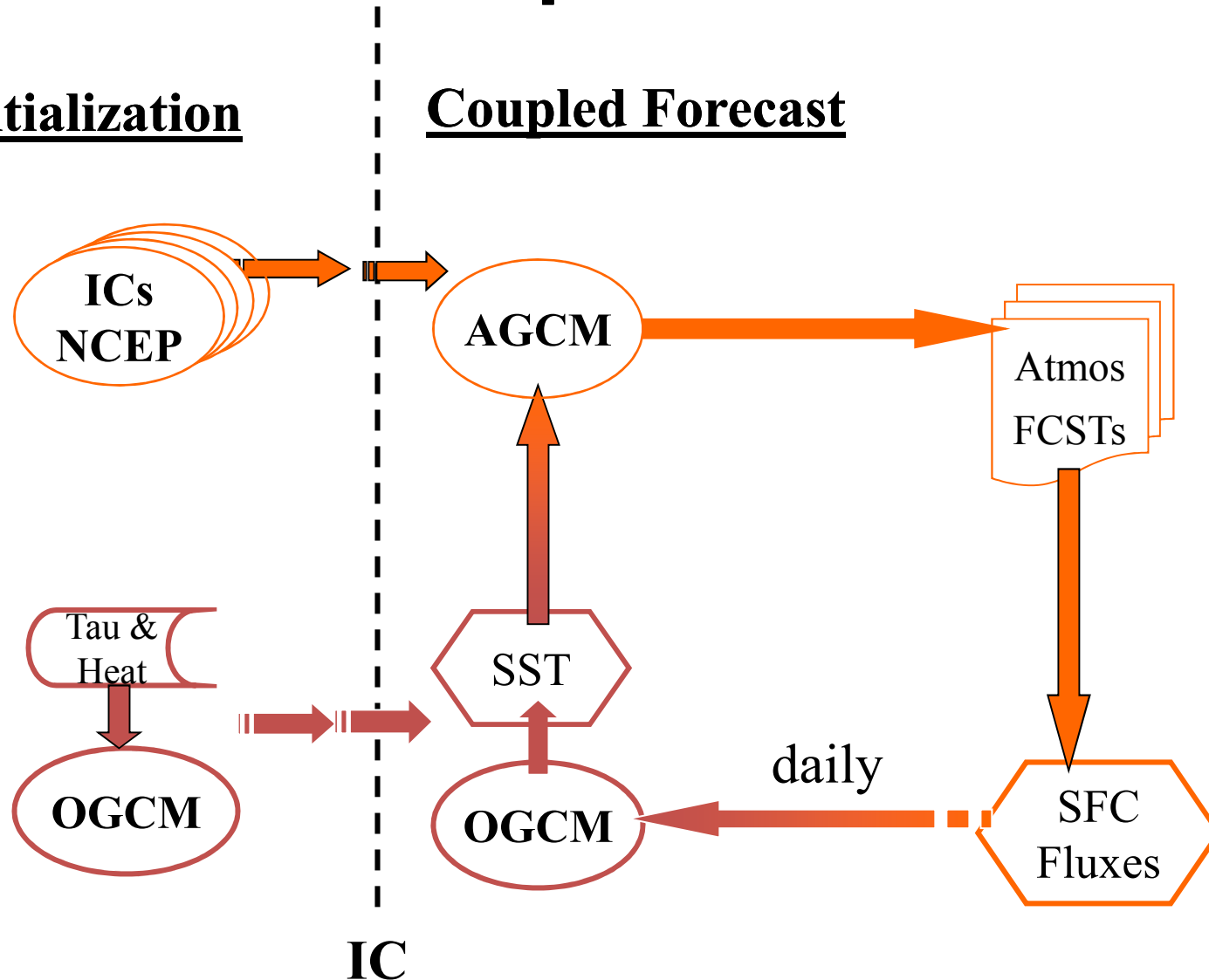
CPTEC AGCM, 50 years, 10 Member Ensemble, Kuo, T062L28, Obs SST

Marengo et al. (2002)

CPTEC's Coupled GCM V.1.0

Initialization

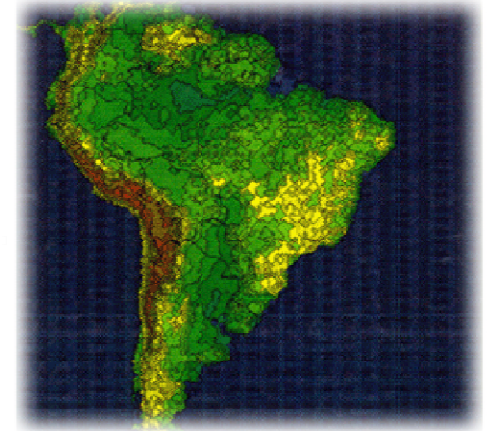
Coupled Forecast



CPTEC seasonal prediction operational runs

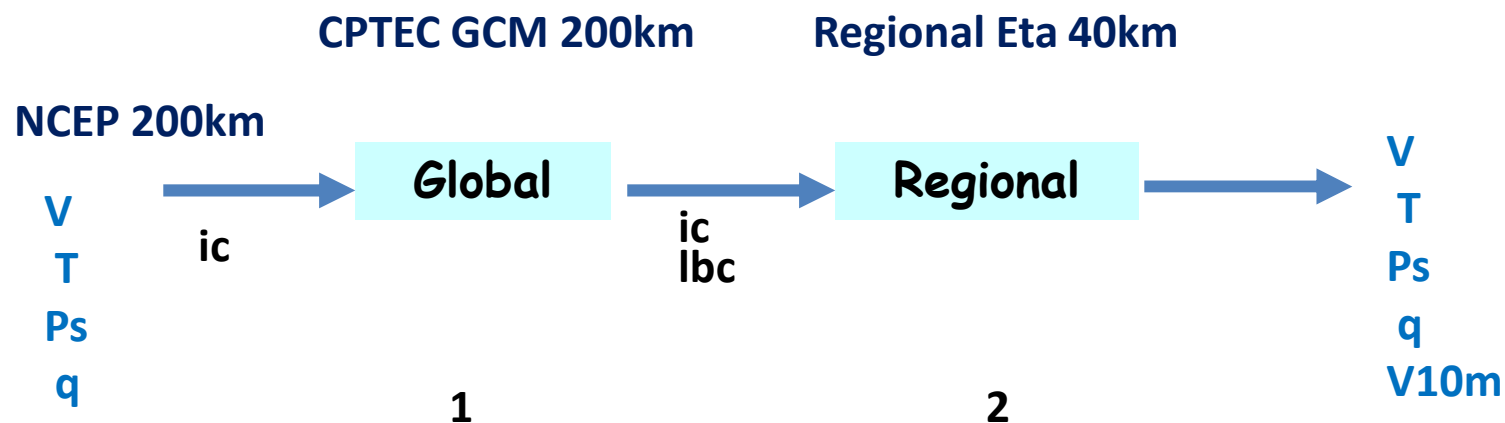
- **AGCM 1.7**
 - KUO, RAS, GRELL, DERF
 - FCST SSTA, PRESCRIBED SSTA
 - 15 Members each: 120 total
 - 4-month forecasts
- **CGCM 1.0**
 - T062L28, RAS CPTEC AGCM
 - $\frac{1}{4}$ degree deep tropics, L20 MOM3 OGCM
 - 10 Members per month
 - 7-month forecasts
- **Eta**
 - 40 km grid L38
 - LBC AGCM T062L28, Kuo
 - 5 members, iC, days 13,14,15,16,17
 - 4-month forecasts

Eta Model at INPE operational since 1997,
Seasonal climate runs since 2003
(Chou et al, Nonlinear Processes in Geophysics, 2005)



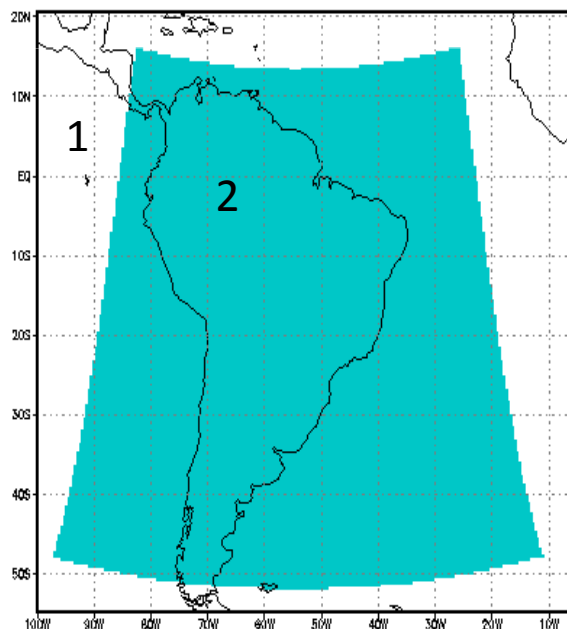
Model characteristics

- **Domain**
 - Most part of South America
 - Southeast Brazil
 - Northeast Brazil
- **Resolution:** 40 km/38 layers;
- **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
- **Time integration:**
 - 2 level, split-explicit
 - **Adjustmet:** forward-backward
 - **Advection:** first forward and then centered
- **Convection:**
 1. Betts-Miller-Janjic scheme,
- **Stratiform rain:**
 1. Zhao 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 analyses,
- **L.B.C.**
 - CPTEC T62L28 GCM, updt 6/6 h,
- **Initial soil moisture:** monthly climatology
- **Initial albedo:** seasonal climatology



IC: 13,14,15,16,17

1200 UTC cycle,
Run continuous 4,5 month
integrations



Seasonal Forecasts

(Chou et al, 2005)

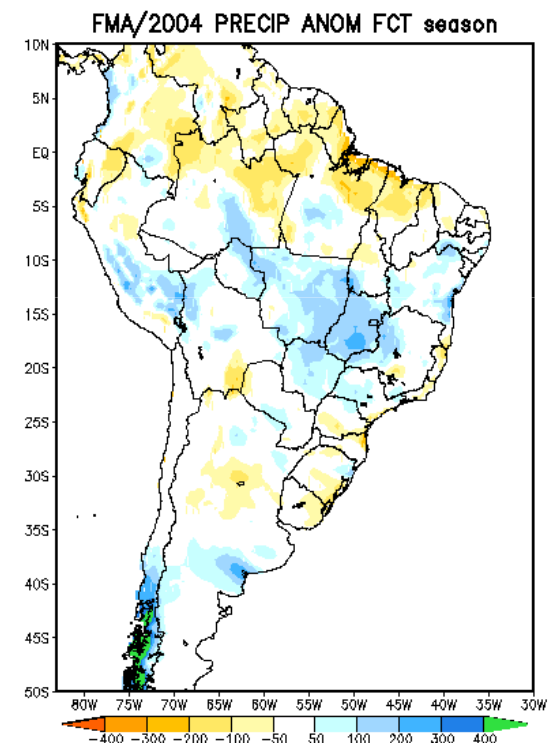
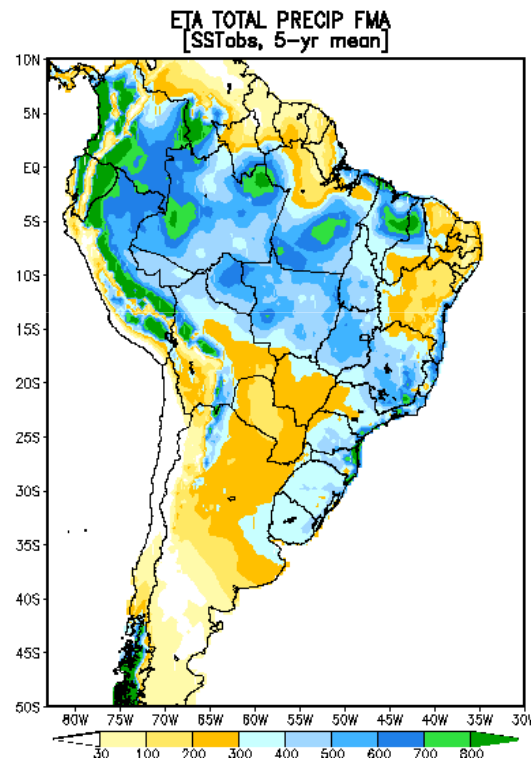
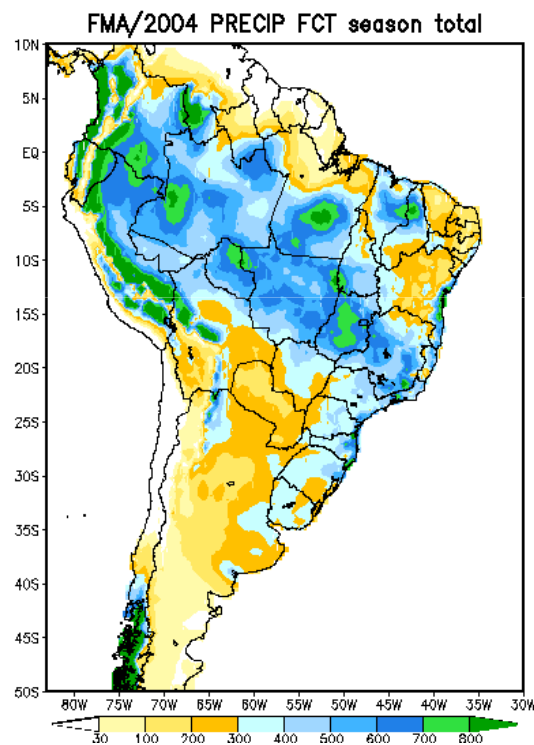
Poor's man model climatology

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

seasonal forecasts

Model seasonal climatology

= anomaly forecast



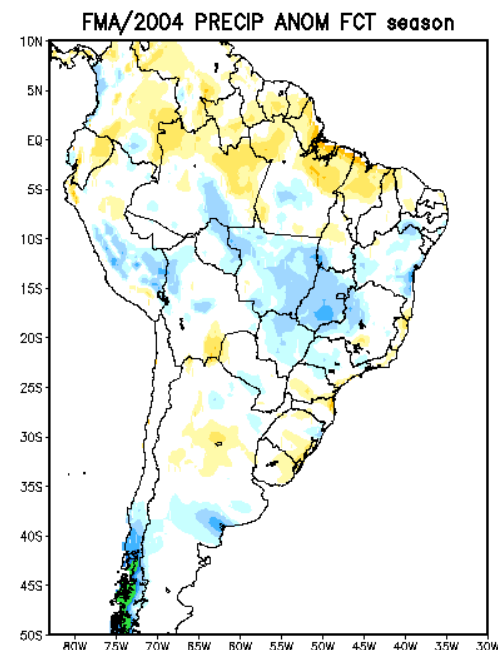
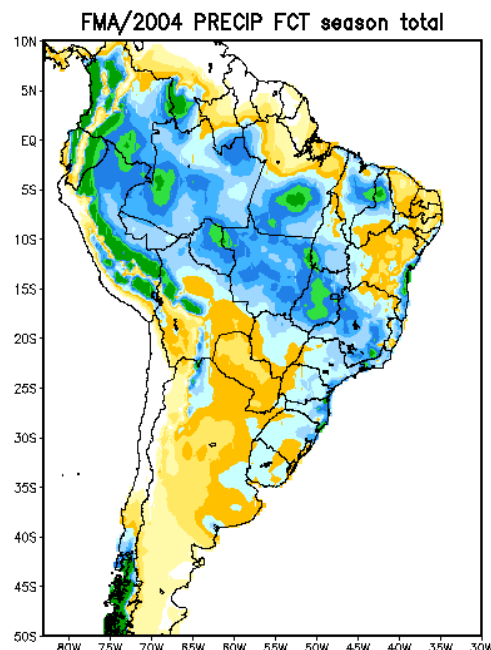
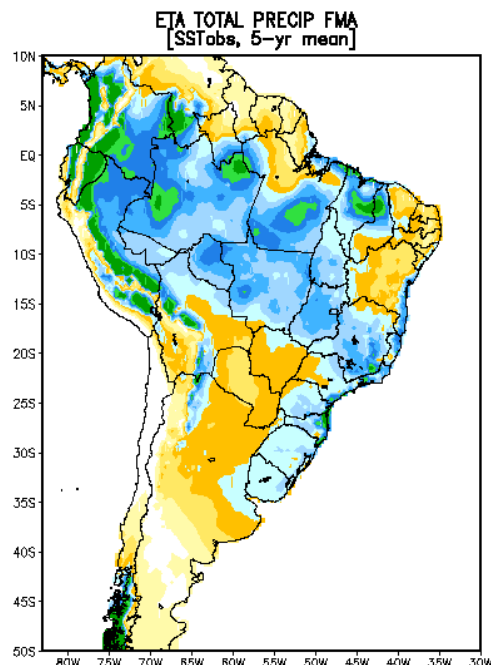
FMA 2004

Assume: climatology and model systematic errors have been *removed*

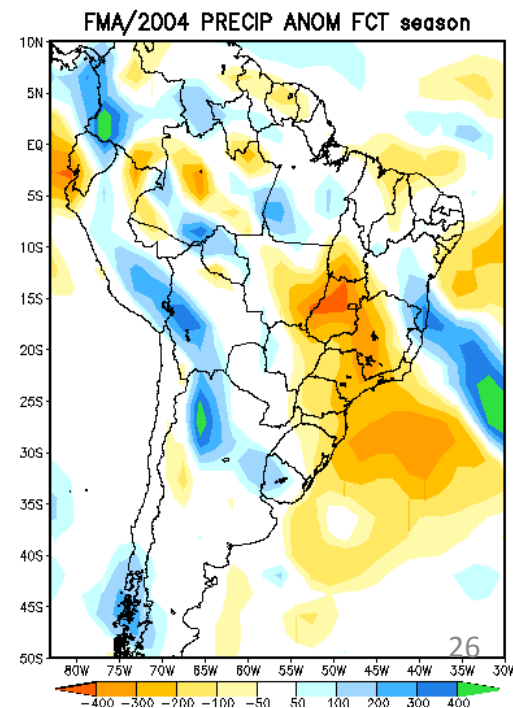
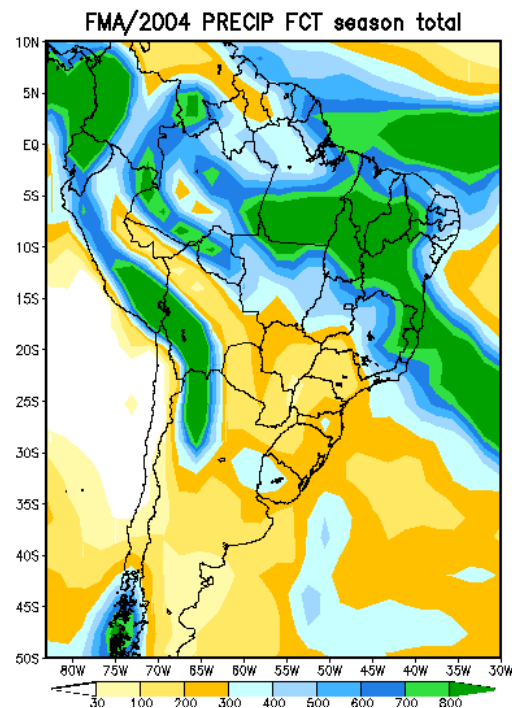
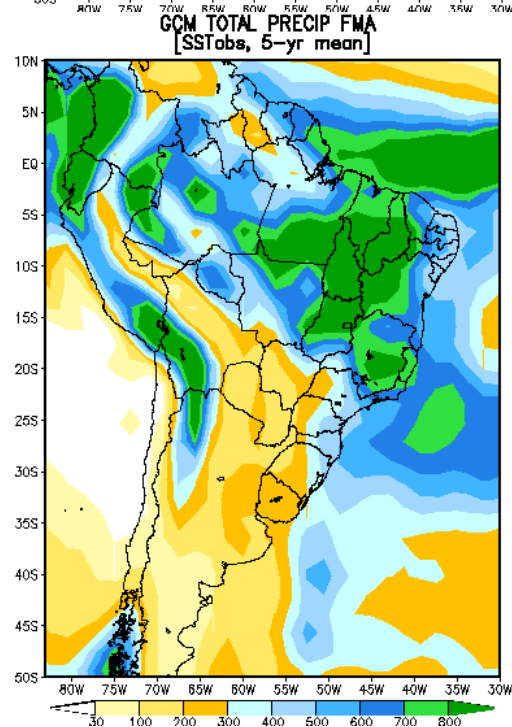


FMA 2004

Eta

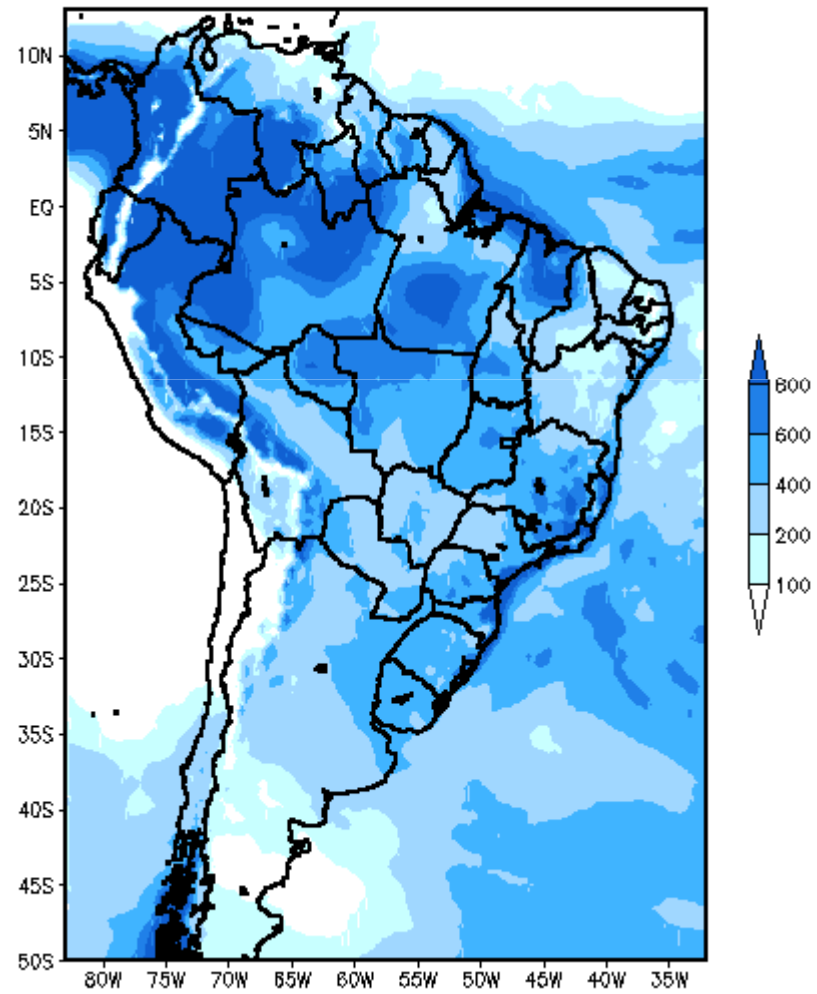


GCM

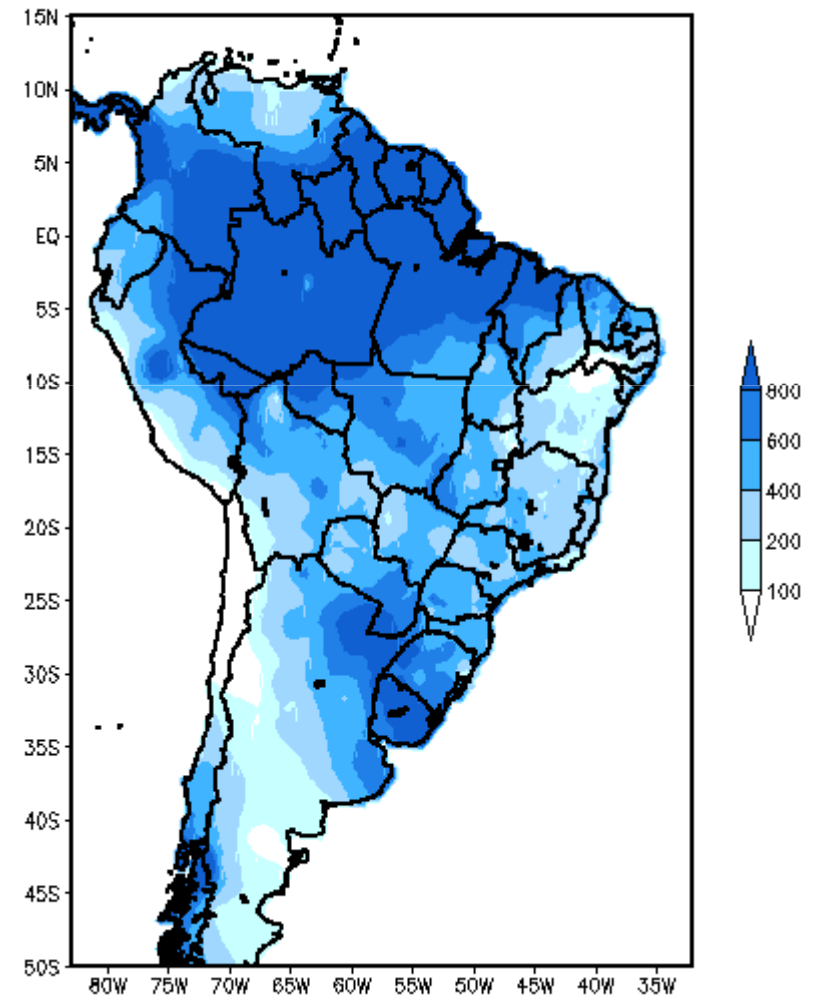


FMAM - 2002

Eta

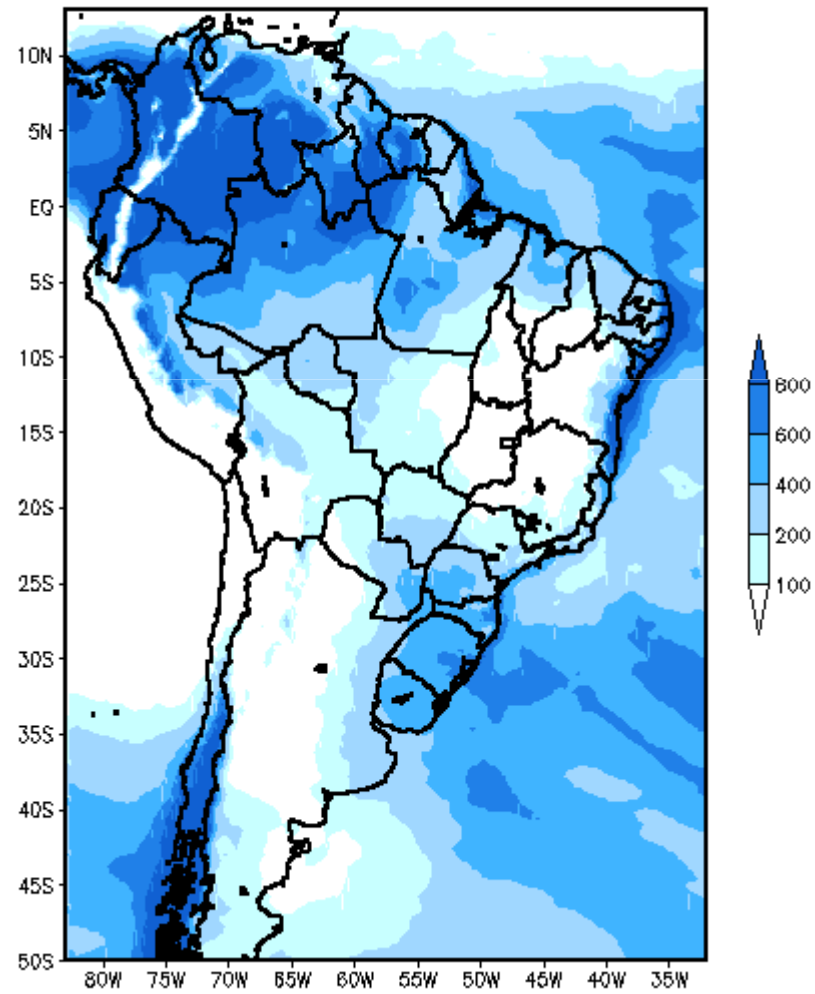


Obs

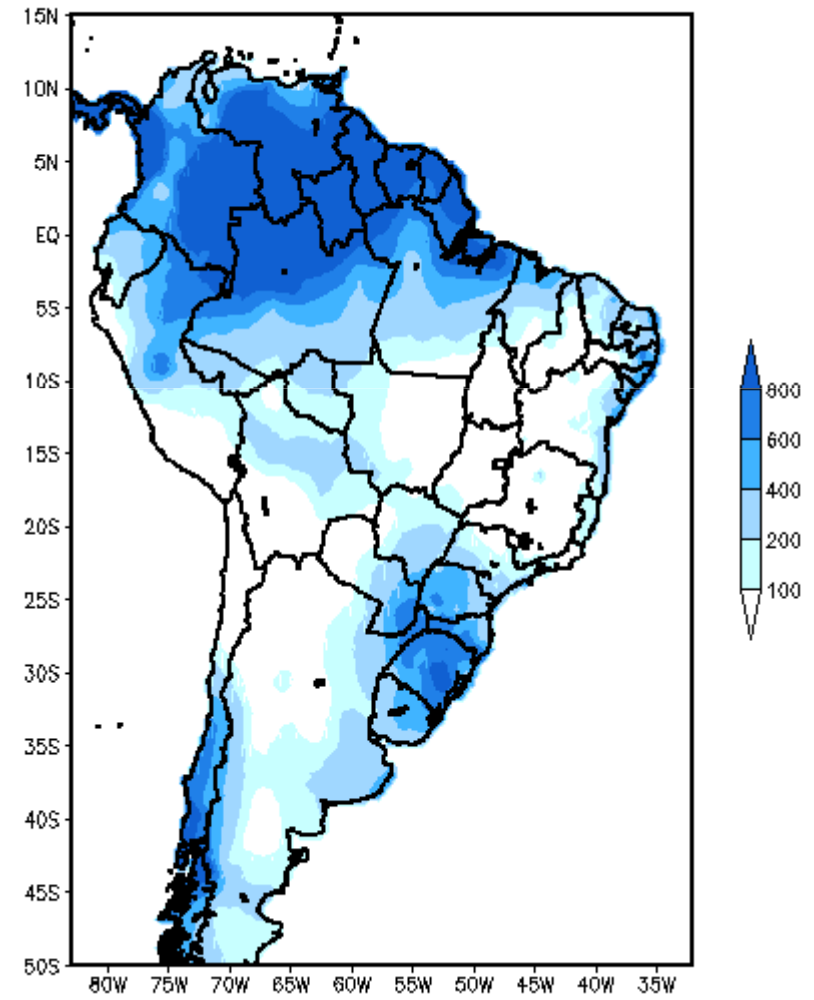


MJJA - 2002

Eta

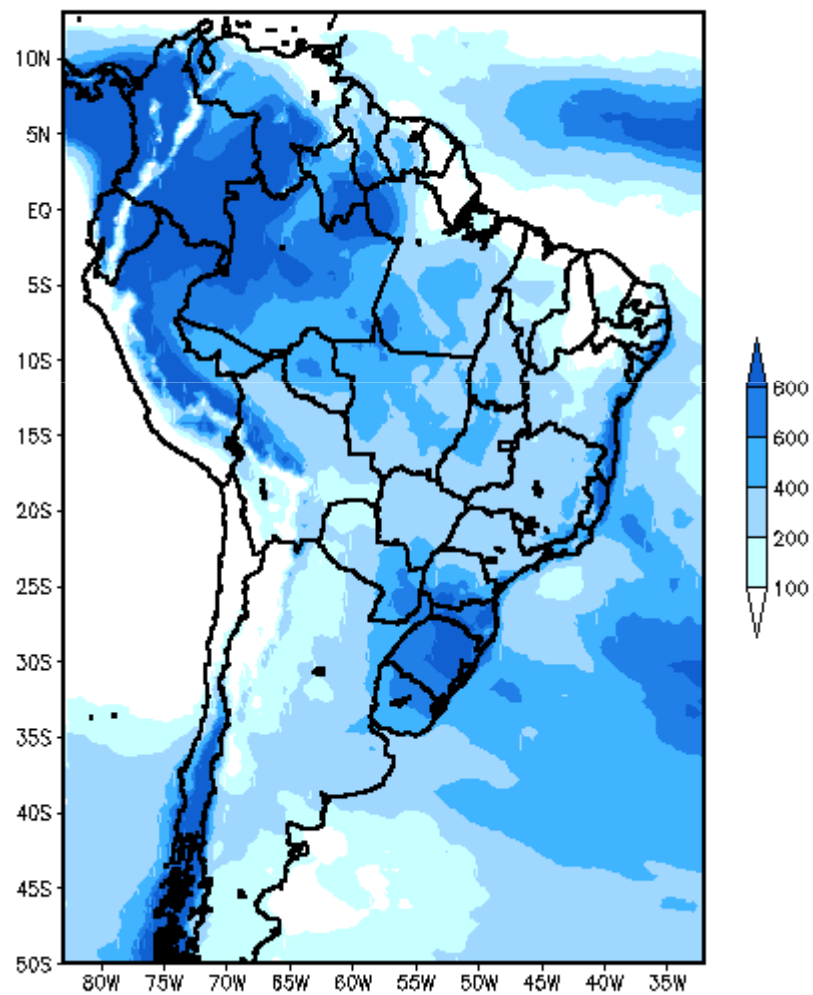


Obs

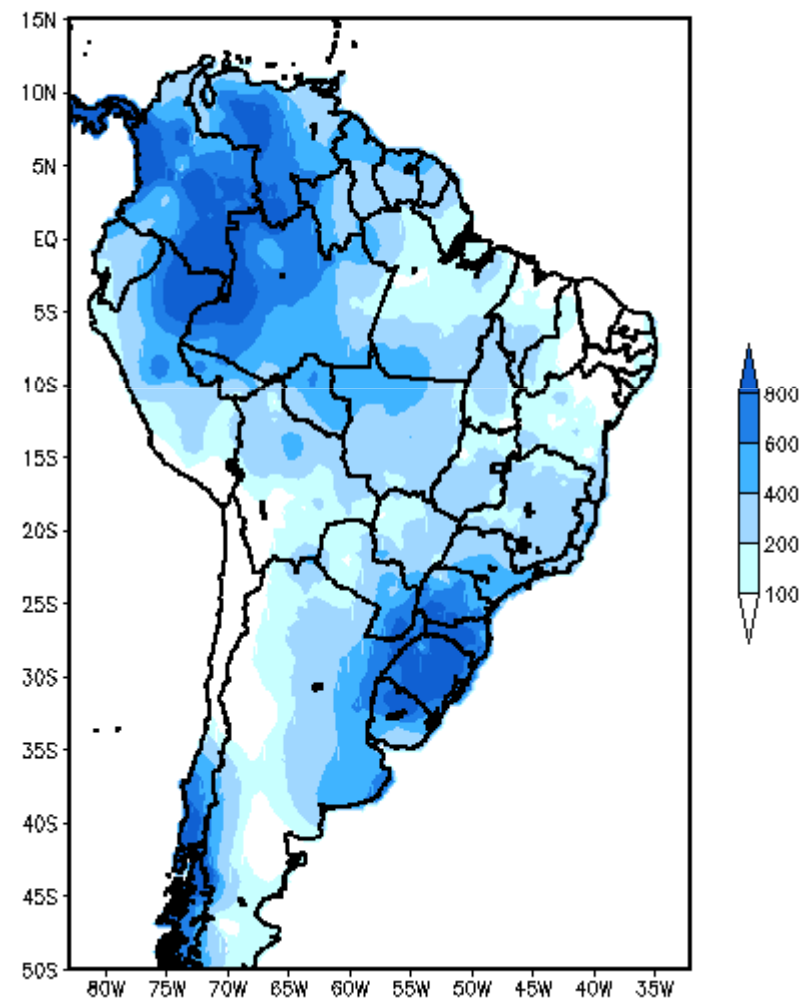


ASON - 2002

Eta

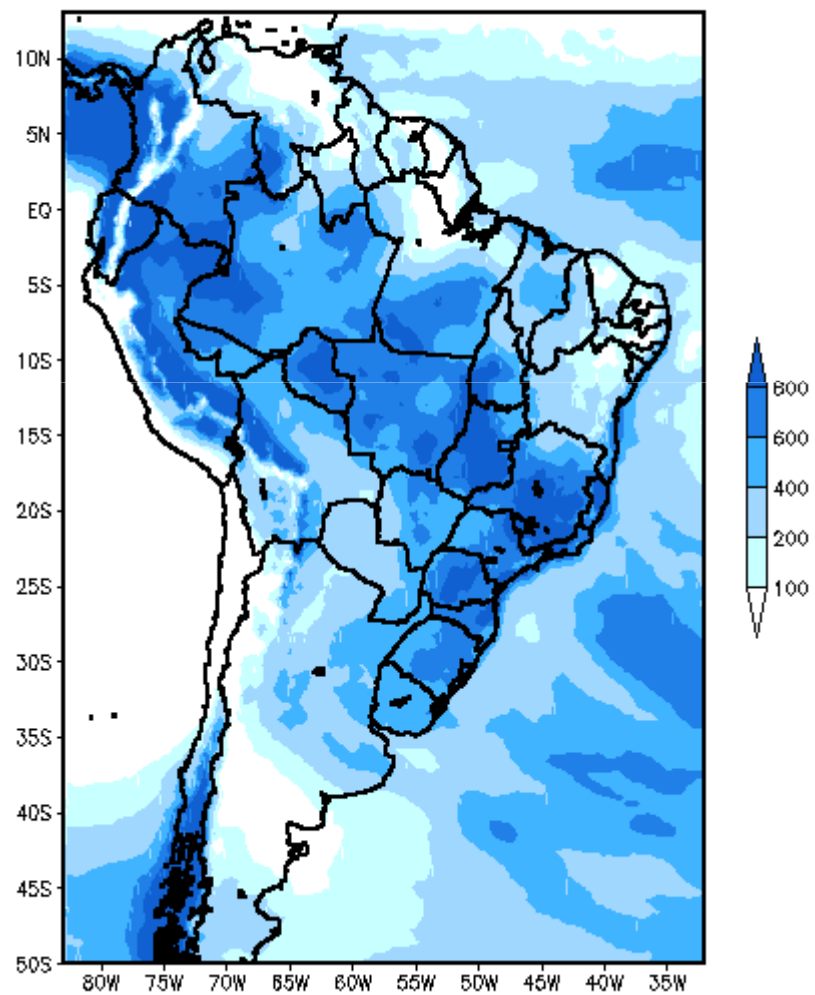


Obs

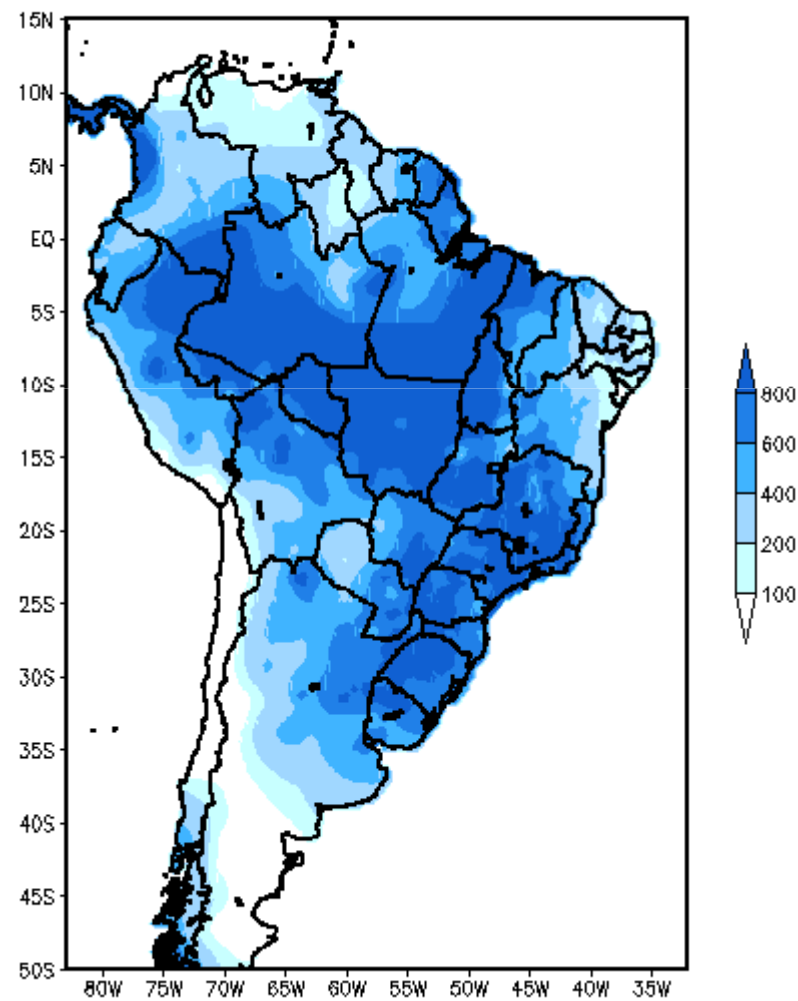


NDJF - 2002

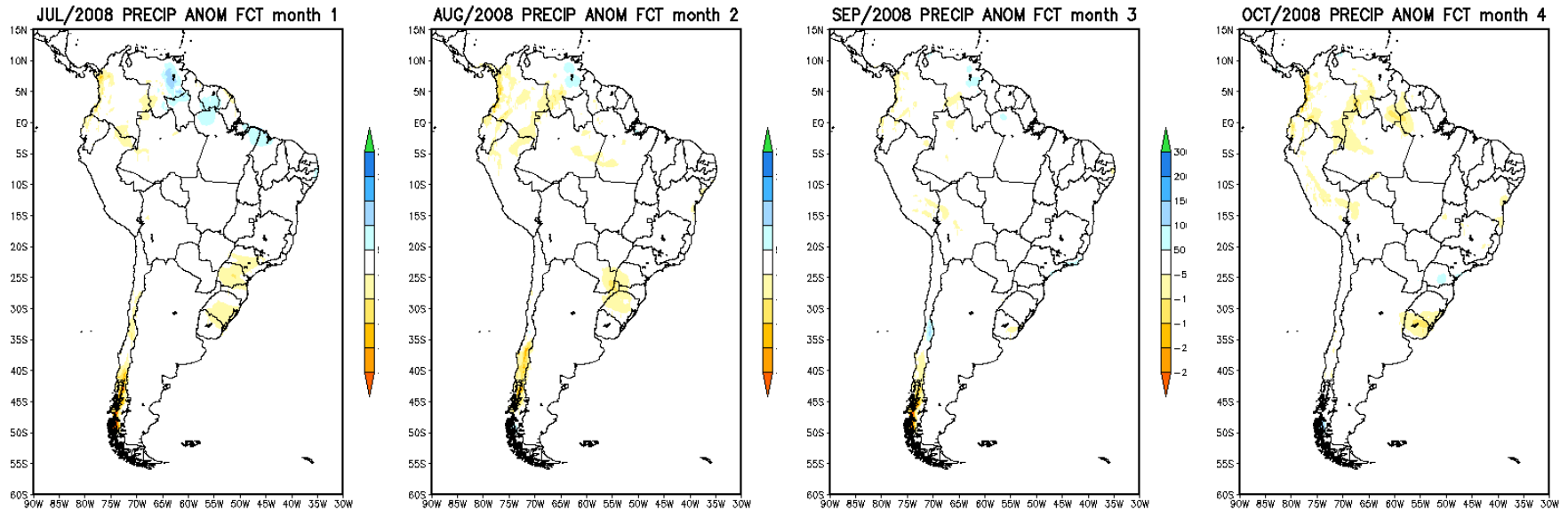
Eta



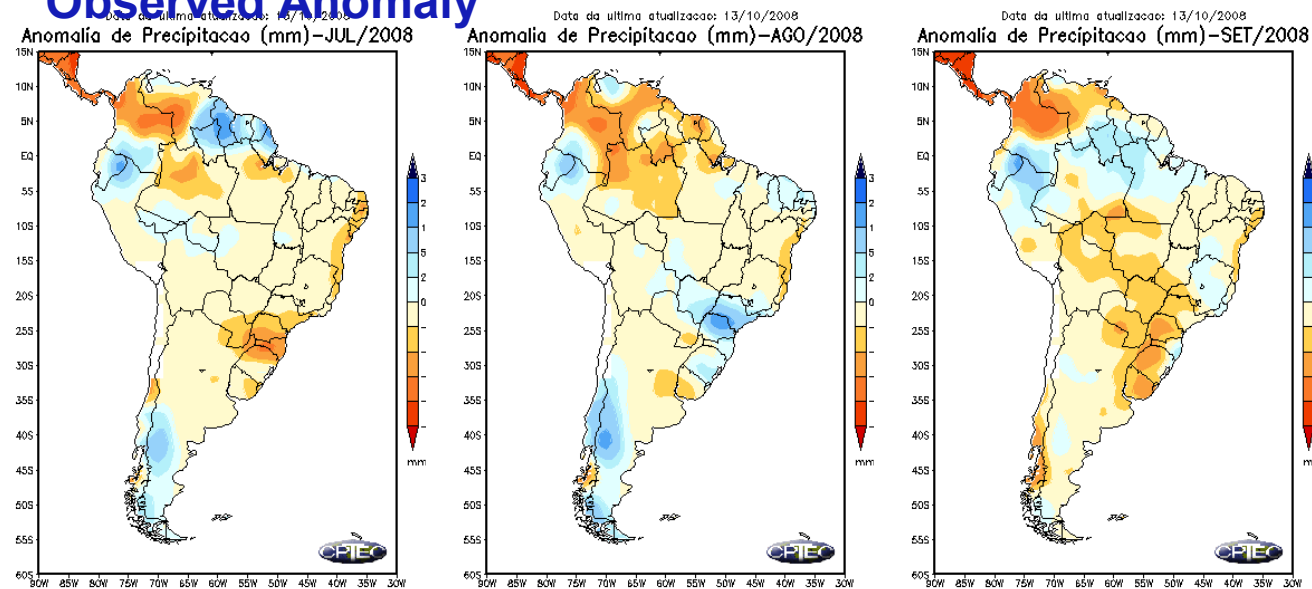
Obs



Anomaly forecast

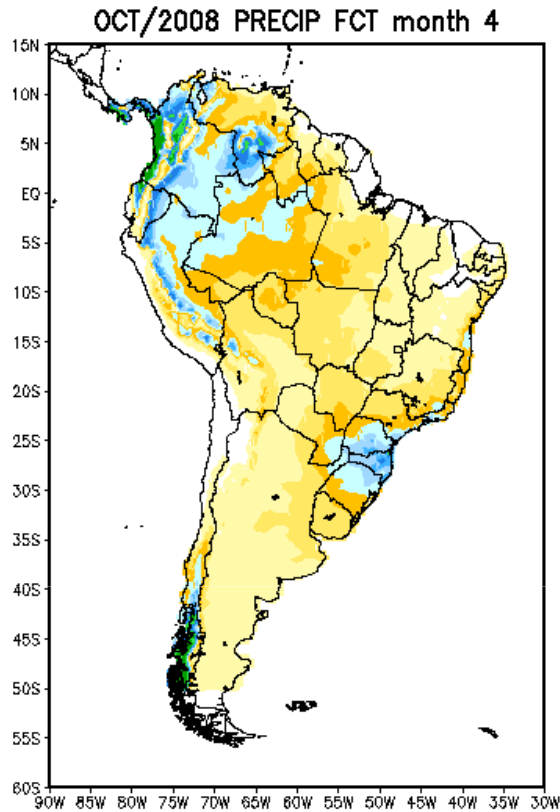


Observed Anomaly

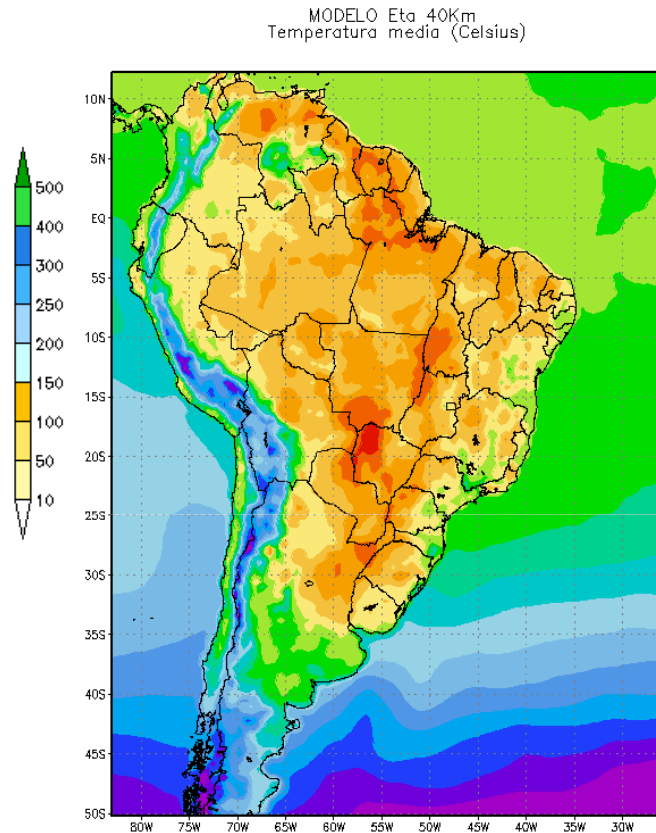


Fonte de Dados: CPTEC-INPE/INMET/FUNCEME-CE/SRH-BA/CEMIG/SIME-MG
 LMR3-PB/EMPARN-RN/DMRH-RS/IAG-SP/ELDER-GO/SIMEPAR-PR/CLIMEXH-SC
 Fonte de Dados: CPTEC-INPE/INMET/FUNCEME-CE/SRH-BA/CEMIG/SIME-MG
 LMR3-PB/EMPARN-RN/DMRH-RS/IAG-SP/ELDER-GO/SIMEPAR-PR/CLIMEXH-SC
 Fonte de Dados: CPTEC-INPE/INMET/FUNCEME-CE/SRH-BA/CEMIG/SIME-MG
 LMR3-PB/EMPARN-RN/DMRH-RS/IAG-SP/ELDER-GO/SIMEPAR-PR/CLIMEXH-SC

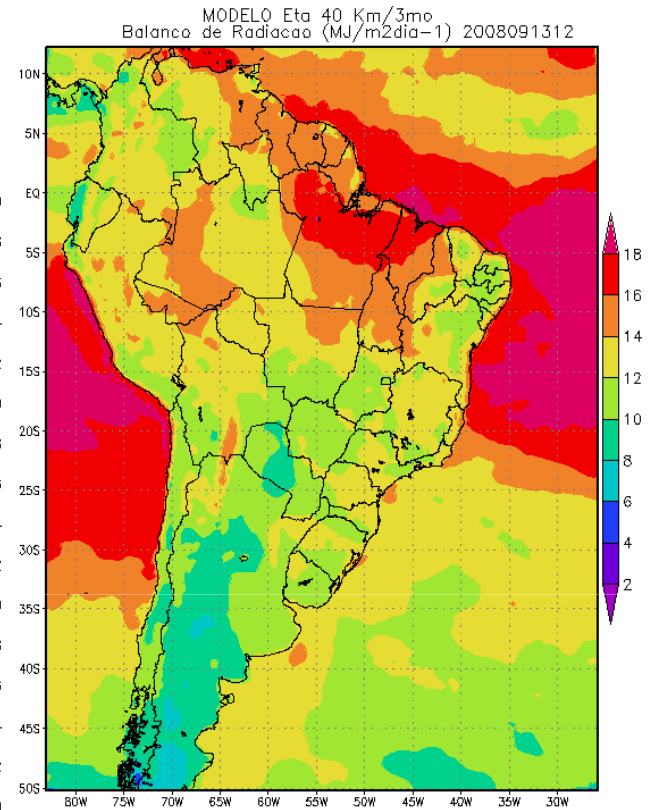
Eta-40km seasonal Forecasts



OCT 2008 Precipitation
T+4mo forecast



18z 2-m temperature
for NOV 2008
T+2mo forecast
Approx Tmax



Net Radiation forecast
for DEC 2008
(T+3mo forecast)

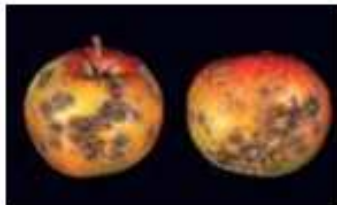
De que forma as informações meteorológicas podem auxiliar a agricultura ?

<i>Base de Dados</i>	<i>Tomada de Decisão</i>	<i>Aplicações</i>	<i>Utilidades</i>
Previsão de Tempo	Manejo	- Mapas de chuva - Mapas de geadas - Riscos de incêndio - Compactação solo - Irrigação - Tratamento fitossanitário	-Planejamento das equipes com 24, 48 h ou mais, evitando por exemplo, aplicação de defensivos, -irrigação desnecessária, etc.
Previsão Climática sazonal	Planejamento da atividade agrícola	- Informações sobre quebra de produção em função das adversidades climáticas - Períodos para plantio, etc.	- Informações para planejamento - Prever possíveis quebra na safra,

SISALERT – dados de previsão do tempo (José Maurício Fernandes, Embrapa, Passo Fundo)

Graus Dia / Unidades de Frio

A Sarna da Maçã



Temperatura média deg. F	Leve hrs	Moderada hrs	Severa hrs	Sintomas dias
75	13	17	26	
77	11	14	21	
78	9.5	12	19	
84 to 75	9	12	18	9
82	9	12	19	10
81	9	13	20	10
80	9.5	13	20	11
59	10	13	21	12
58	10	14	21	12
57	10	14	22	13
56	11	15	22	13
55	11	16	24	14
54	11.5	16	24	14
53	12	17	25	15
52	12	18	26	15
51	13	18	27	16
50	14	19	29	16
49	14.5	20	30	17
48	15	20	30	17
47	17	22	35	
46	19	25	38	
45	20	27	41	
44	22	30	45	
43	25	34	51	
42	30	40	60	
33 to 41(c)				17

Modificada de Mills, 1944.

SISALERT
simulação de sistemas de alerta

Cálculo de Graus Dia

Estação climática: EMBRAPA-EE (5178)

Data Inicial: 1 de Janeiro de 2003

Data Final: 31 de Janeiro de 2003

Temperatura Base: 5

Temperatura Limite: 40

Graus: 502.1

Cálculo de Horas Frio

Estação climática: LAZZERIS - Pomar 1 (2000)

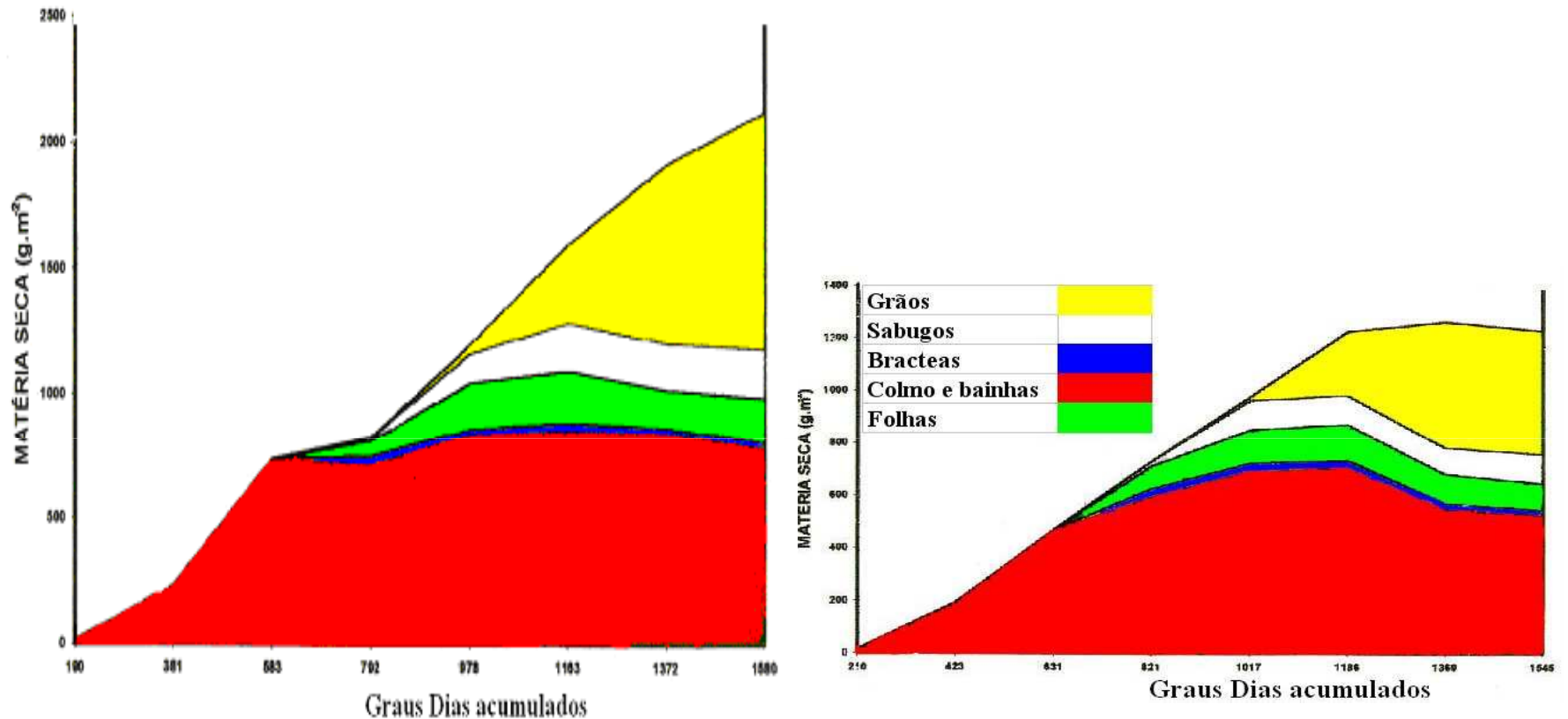
Data Inicial: 1 de Julho de 2003

Data Final: 31 de Agosto de 2003

Horas: 6.675

José Maurício Fernandes - Embrapa Trigo

Dry mass production at different parts of the corn sown in summer (A) and winter(B) (Dourado Neto (1999))

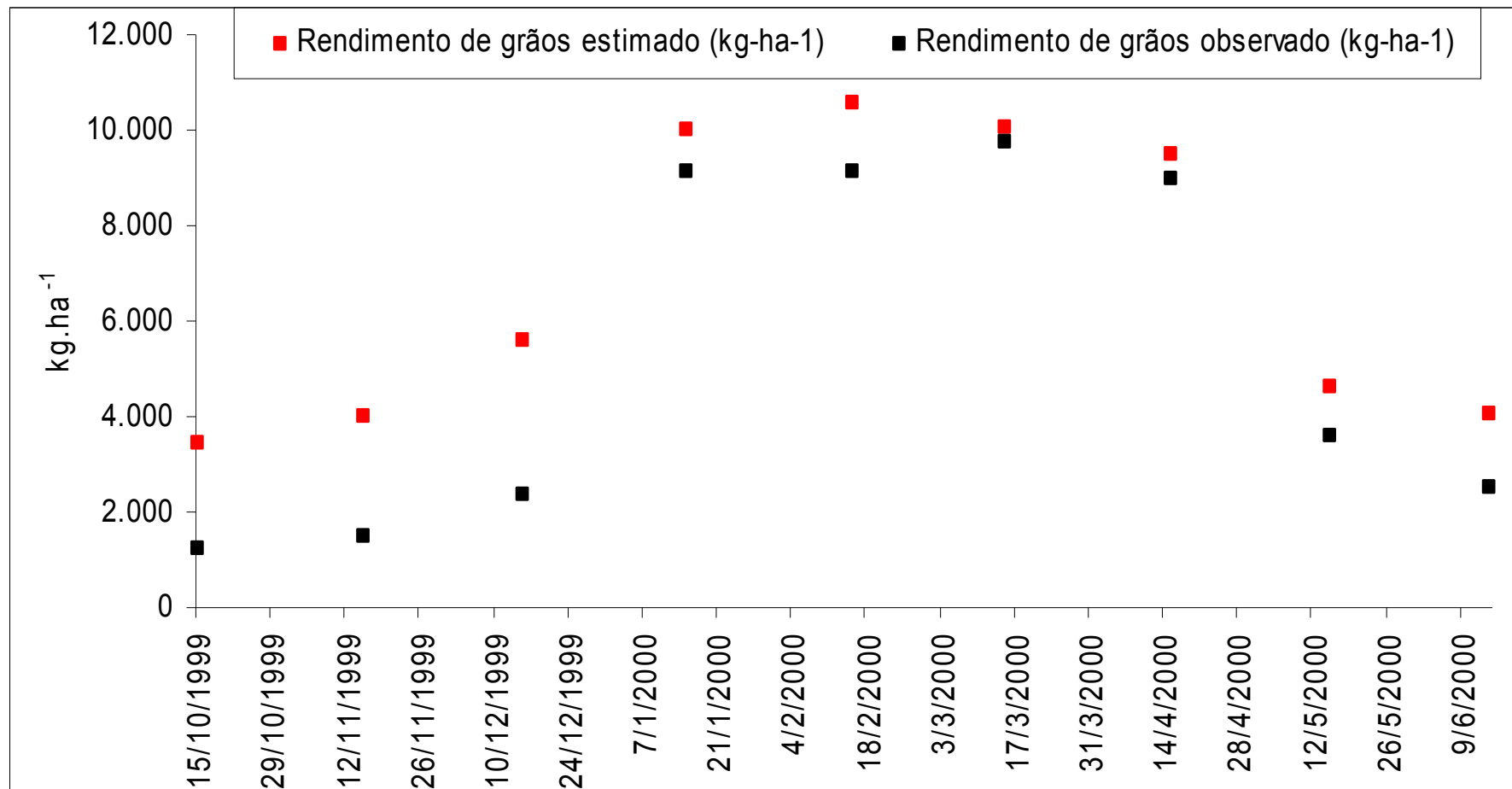


Tmax and Tmin daily forecasts > Degree-day estimation > crop production

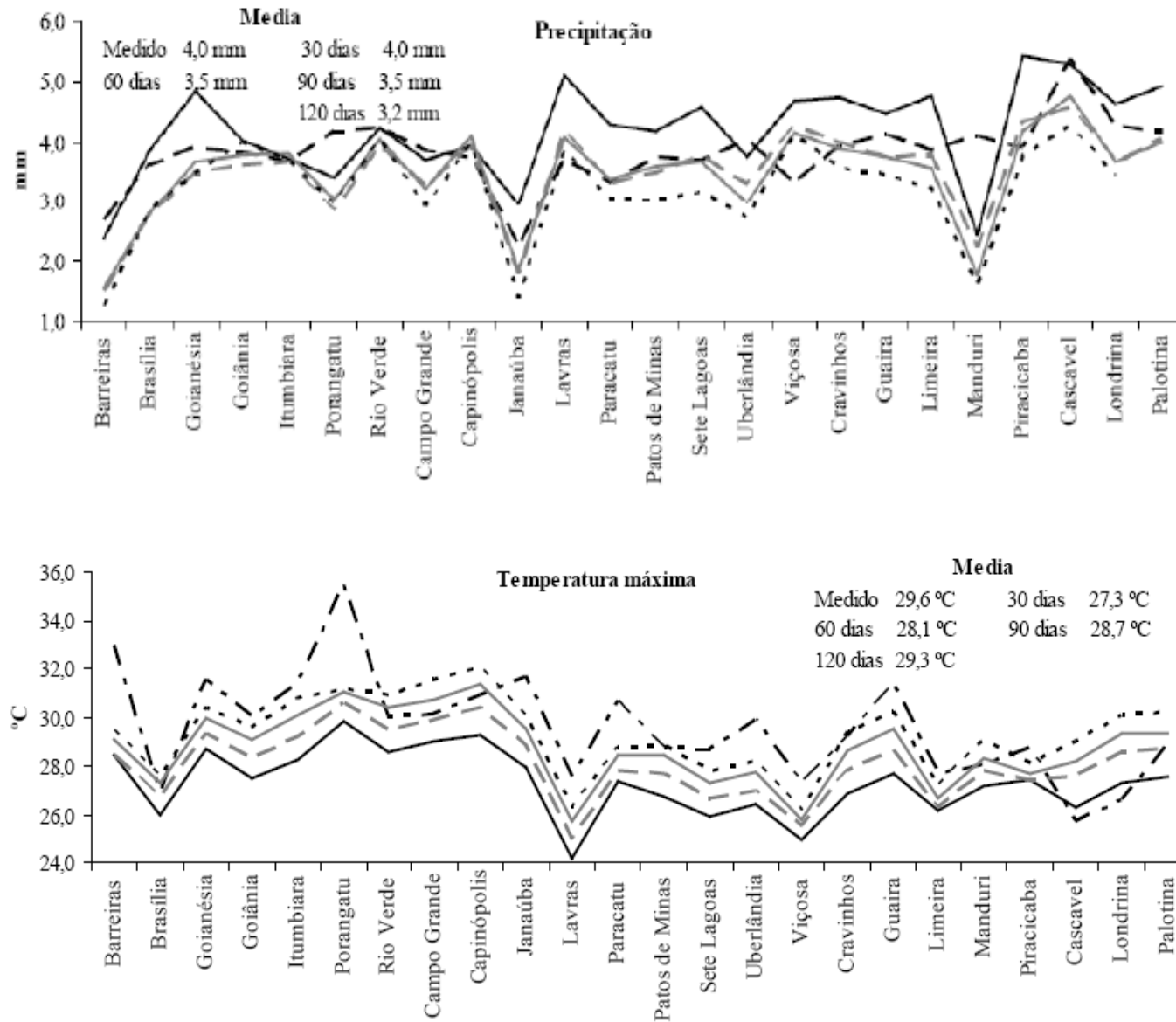
Crop model driven by Eta model seasonal forecasts

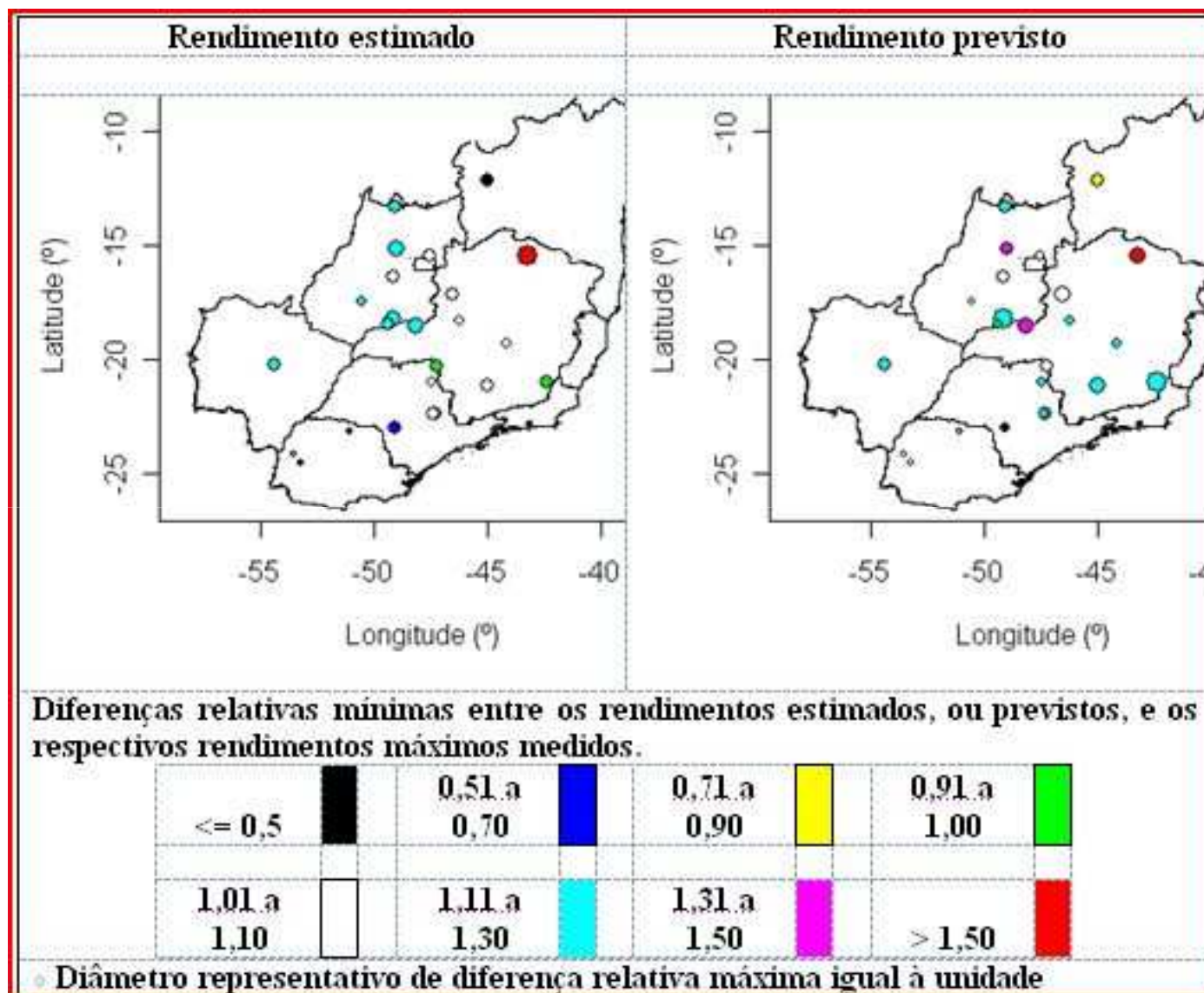
oct1999 - jun2000
forecast vs observed corn production - Piracicaba, SP

(Vieira Junior & Dourado Neto, 2006)



Vieira Junior et al. Previsões meteorológicas do Modelo Eta para subsidiar o uso de modelos de previsão agrícola no Centro-Sul do Brasil, Ciência Rural, 2009.



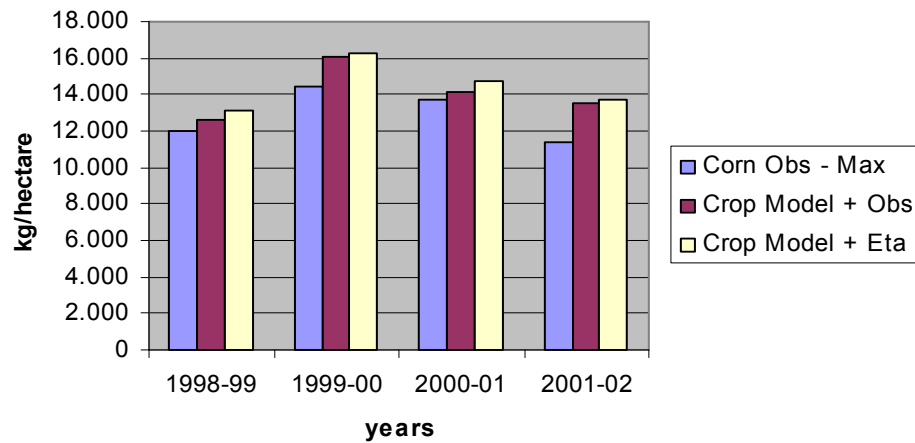


Crop model driven by Eta model seasonal forecasts

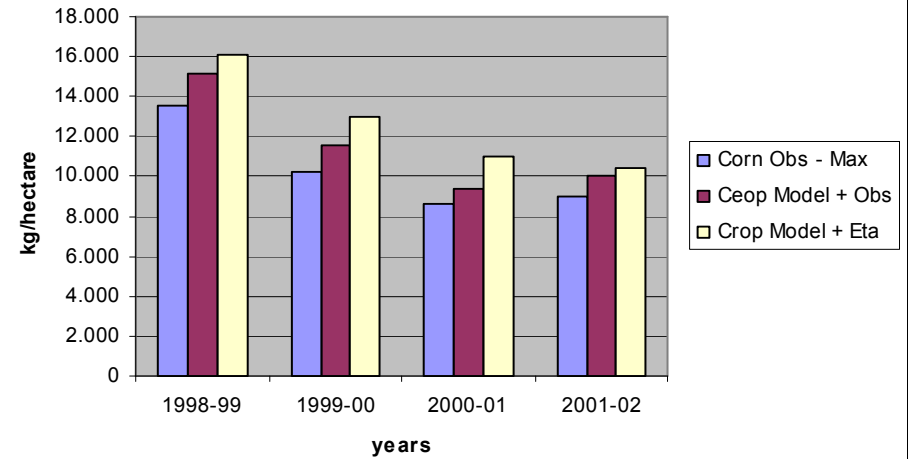
(Vieira Junior, 2006)

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

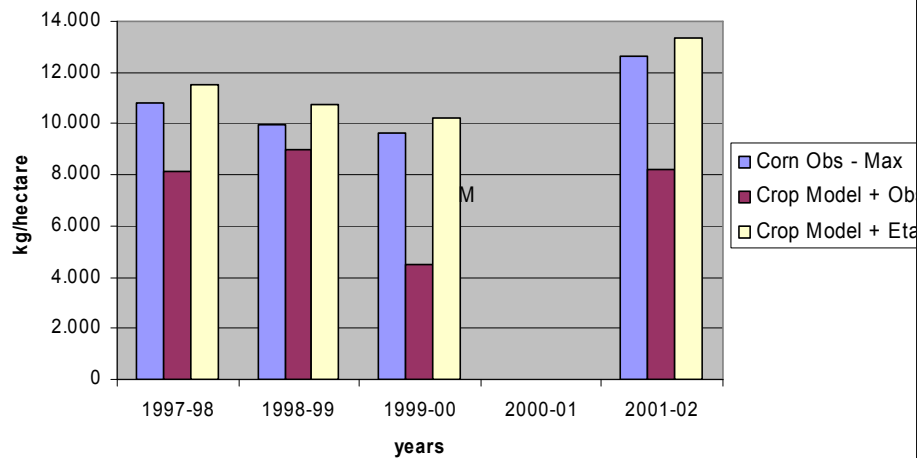
**Corn Production Forecast
Brasilia**



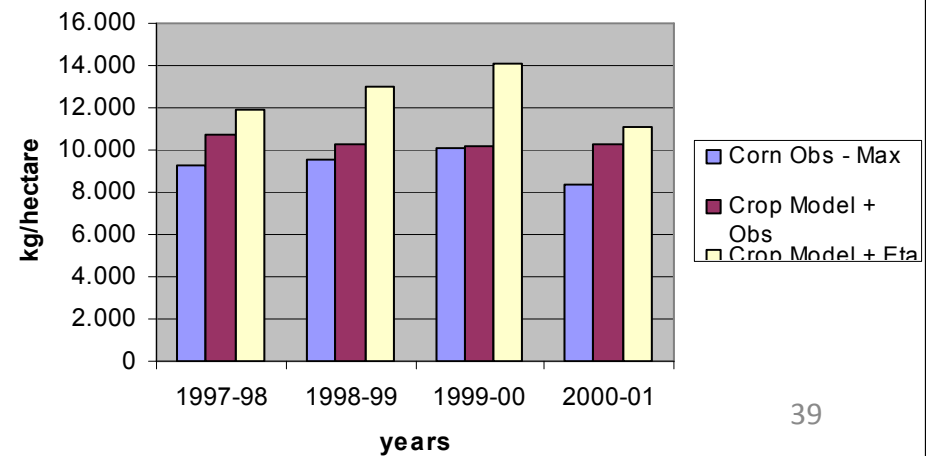
**Corn Production Forecast
Patos de Minas, MG**



**Corn Production Forecast
Cascavel, PR**

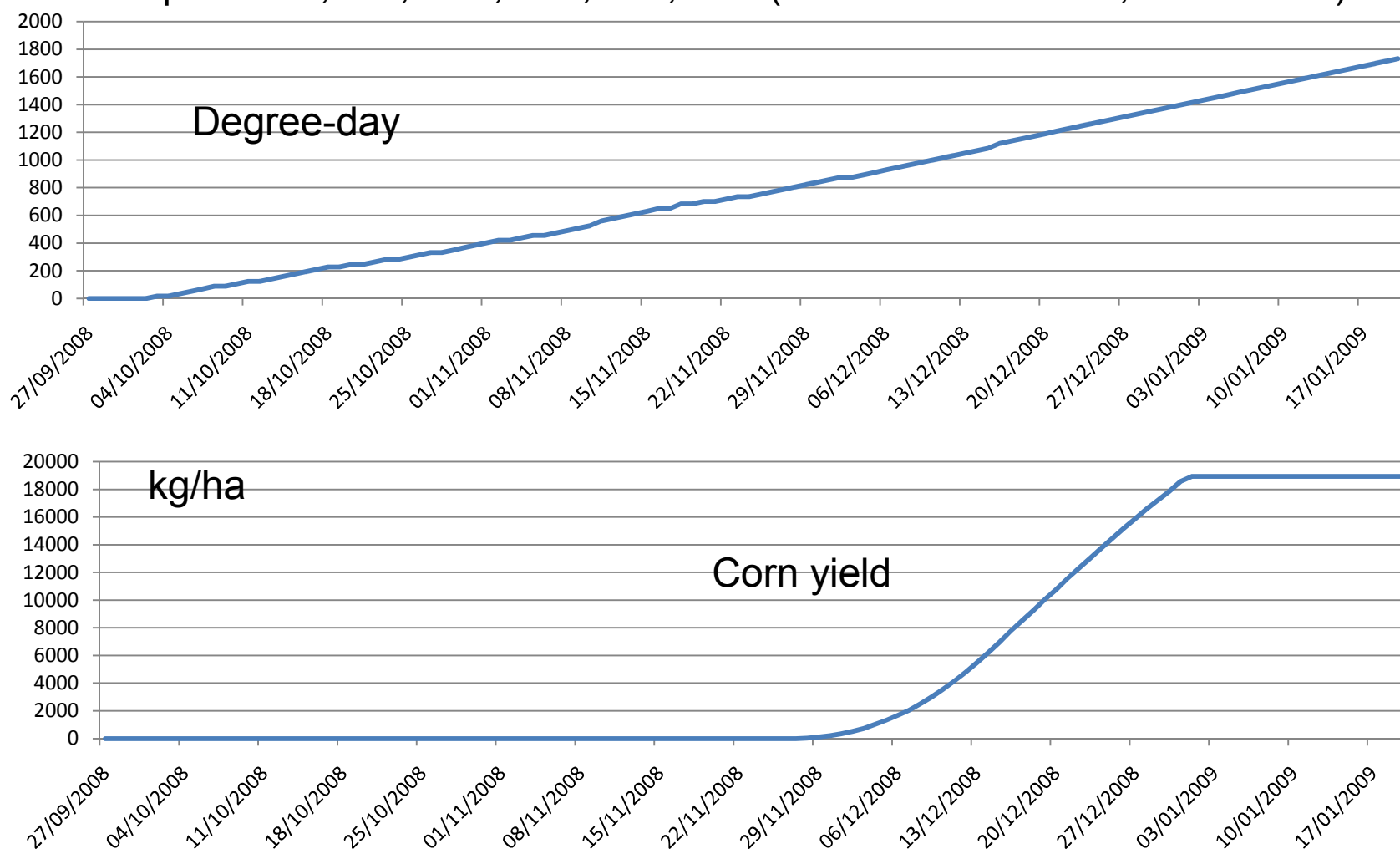


**Corn Production Forecast
Piracicaba, SP**



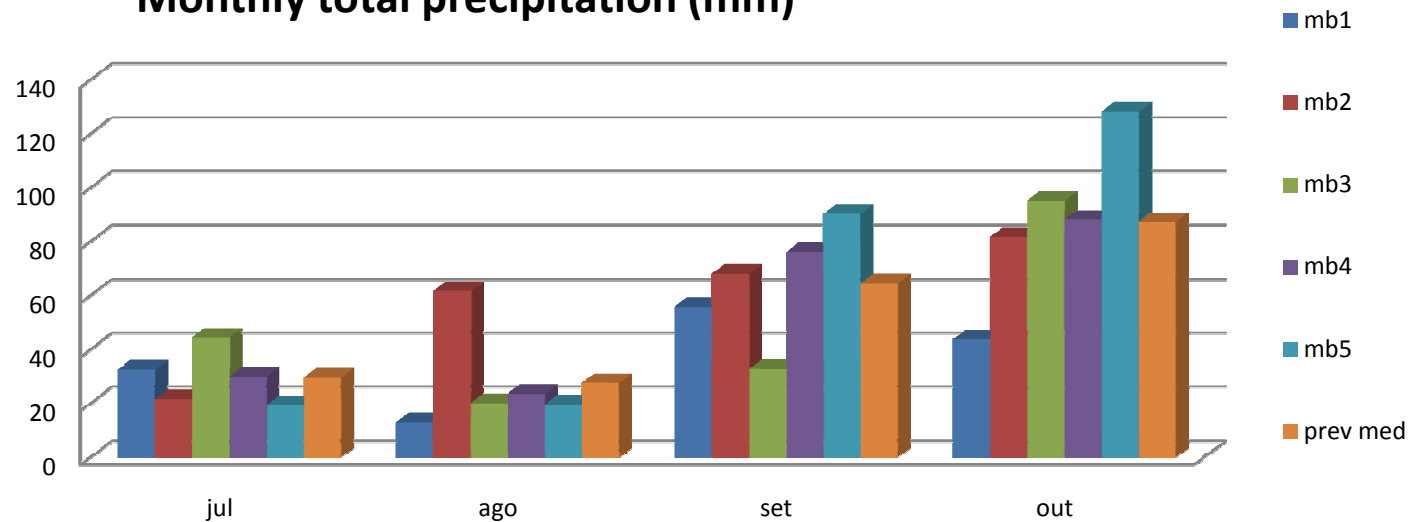
Degree-day and corn potential yield predicted from seasonal forecast for Cascavel, PR, OND 2008

Input: T2m, RH, Tsfc, rain, SW, LW (Pedro Vieira Junior, EMBRAPA)



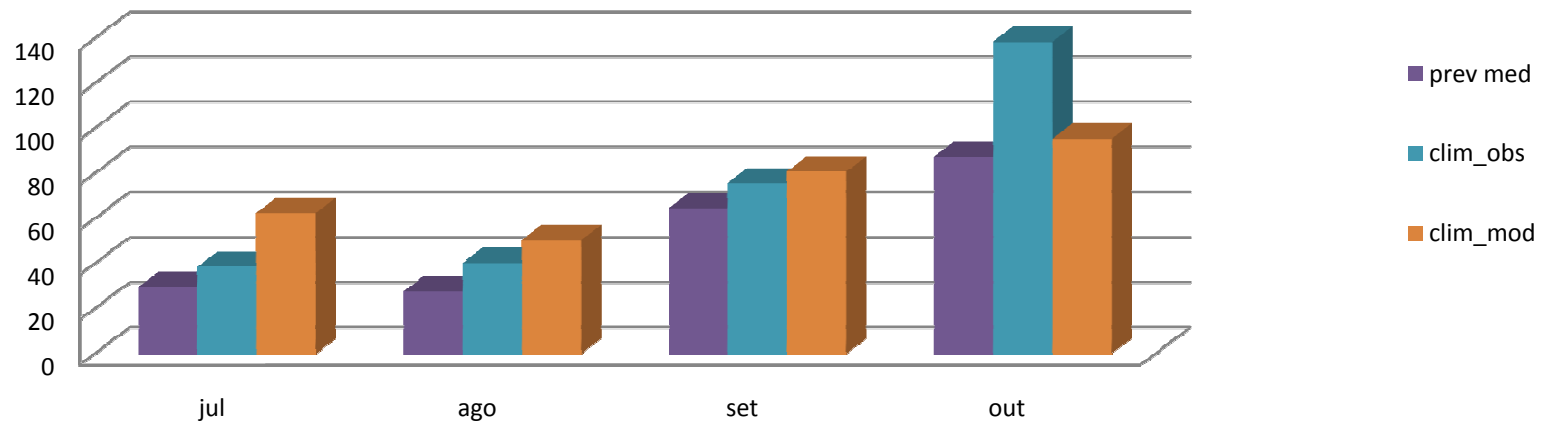
Member forecasts- 200806

Monthly total precipitation (mm)



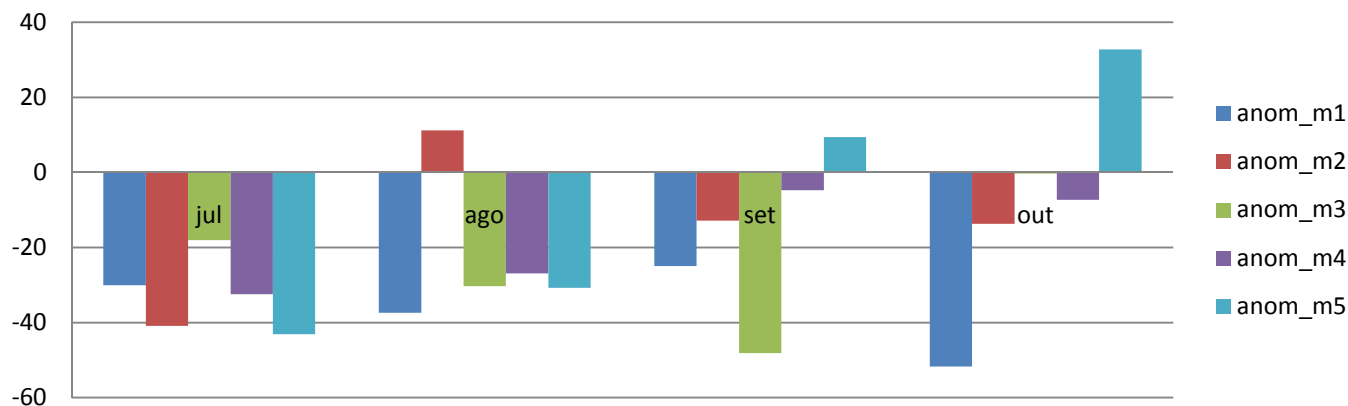
Forecast X Observed Climatology X Model Climatology

Monthly total precipitation (mm)



Anomaly = Member forecast – Model climatology

Forecast Anomaly Each member

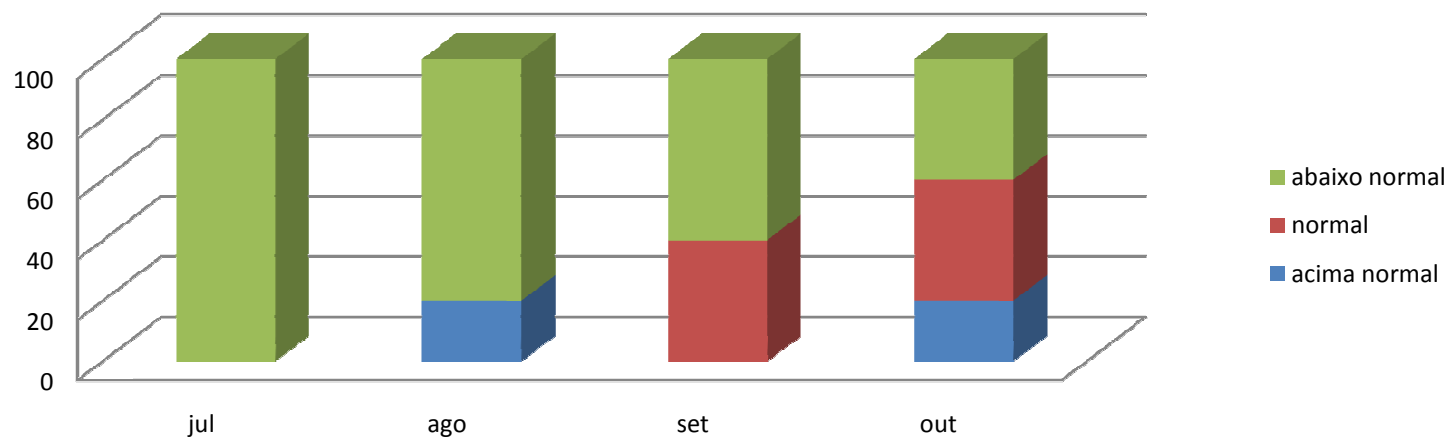


Above normal: anomaly > 10mm

Normal: -10 mm > anomaly > 10 mm

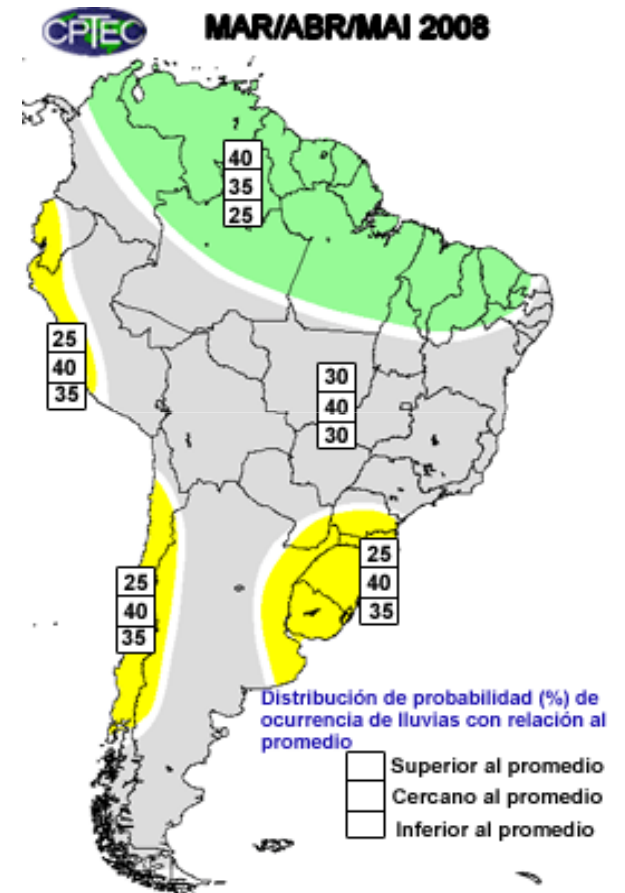
Below normal: anomaly < -10 mm

Probability of Anomaly Forecasts



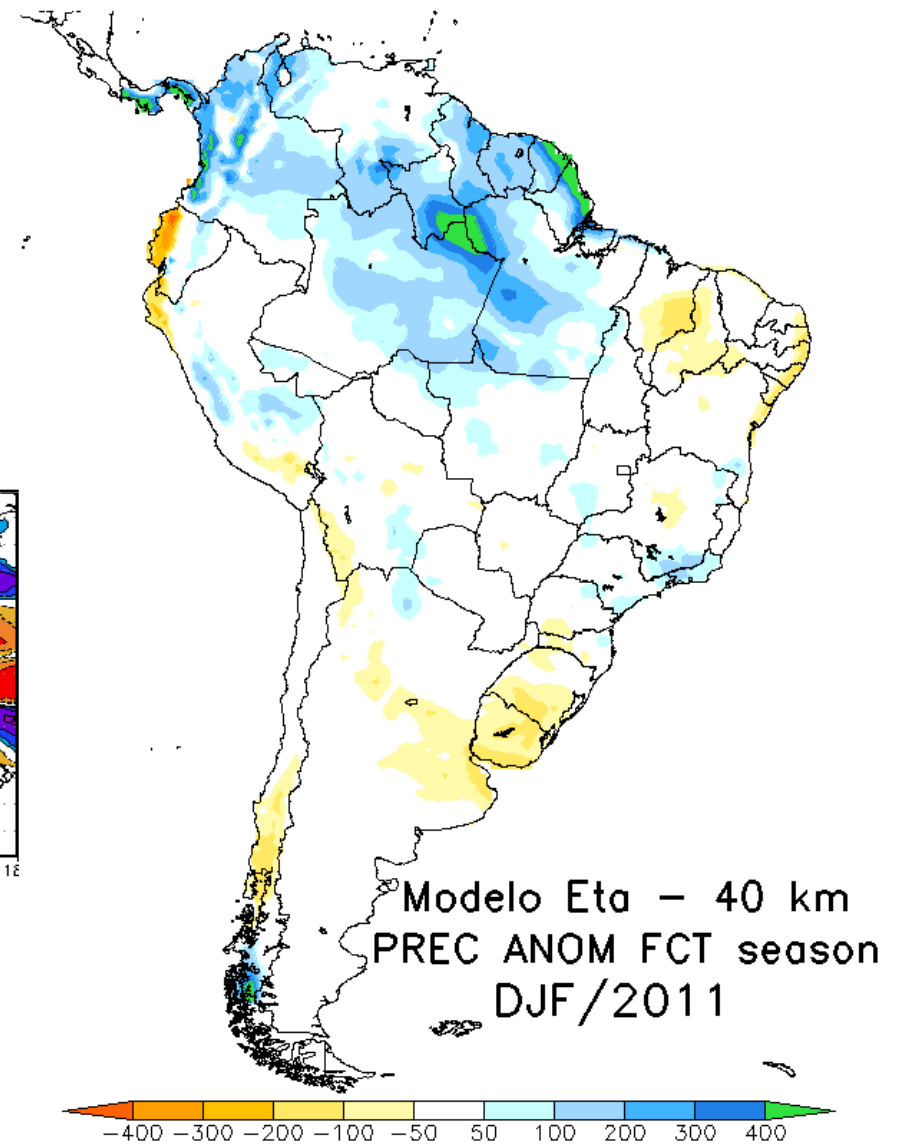
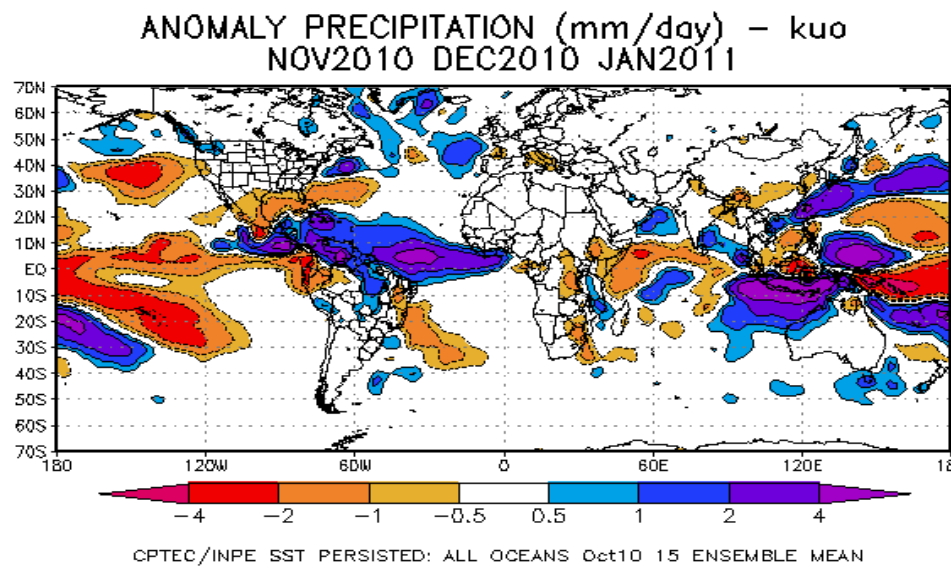
Seasonal Climate Prediction at INPE-CPTEC

- Real-time monthly meetings encompassing several institutions from South America
- Ensemble of AGCM and CGCM runs done at CPTEC as well as those done at IRI
- Dynamical downscaling using RCMs nested at CPTEC AGCM outputs
- Consensus precipitation forecast in terciles: Above, Normal, Below
- Consensus temperature forecast Above/Below



March-April-May 2008
Consensus Precipitation Forecast

Produtos do Modelo Global



To follow INPE-CPTEC real time
monthly seasonal climate prediction
Forum discussions can be accessed
over the internet

(Demo)

<http://visitview.cptec.inpe.br/clima/0108/poia.html>



Final remarks

CPTEC Seasonal climate forecasts are available at different horizontal resolutions 200km and 40km.

Data are available at request.

Quality of these forecasts are low, but there is some advantage over climatology information;

Need of combination of dynamical forecasts with statistical model/tools;

Need to explore more the use of seasonal forecast in different economic sectors: agriculture, energy, etc.

Are current systems and users prepared to take in model outputs, seasonal forecasts, probability forecasts?