Advances in South America seasonal precipitation predictions

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PLAN OF TALK

1. Introduction
2. EUROBRISA forecasting system and its evolution
3. System performance since 2007
4. Contribution to seasonal forecasting practice in S. America
5. Summary

VAMOS Modeling Workshop, Petrópolis, Brazil, 4-6 Jun 2012
Assessing Progress and Defining the Future Directions

Introduction

South American seasonal precipitation predictions have been produced since around the mid-nineties using both ***empirical (statistical) models*** and physically based ***dynamical models***

Empirical (statistical): based on past (historical) observations for the predictand (e.g. precipitation over South America) and for relevant predictors (e.g. SST)

Dynamical: based on prognostic physical equations

- 2-tier systems (first predict SST, next climate variables)
- 1-tier systems (predict ocean and atmos. together)

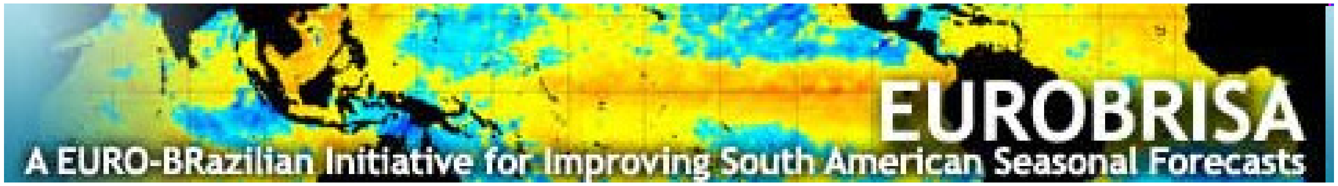
Comparing statistical and dynamical prediction systems:

	Advantages	Disadvantages
Stati-stical	• Entirely based on real-world past climate observations • Simple to build: many climate relationships are quasi-linear, quasi-Gaussian • Cheap (fast) to run	• Depends on quality and length of past climate observations • Does not fully account for changes in climate or new climate conditions
Dyna-mical	• Uses well established laws of physics • Can potentially reproduce climate conditions never previously observed	• Physical laws must be abbreviated or statistically estimated, leading to errors and biases • Expensive to run (require powerful computers)

Seasonal forecast availability

- Empirical/statistical models
- Dynamical atmospheric models
- Dynamical coupled (ocean-atmosphere) models

EUROBRISA conception



http://eurobrisa.cptec.inpe.br

Why not combine all available state-of-the-art forecast information from both sources (empirical and dynamical)?

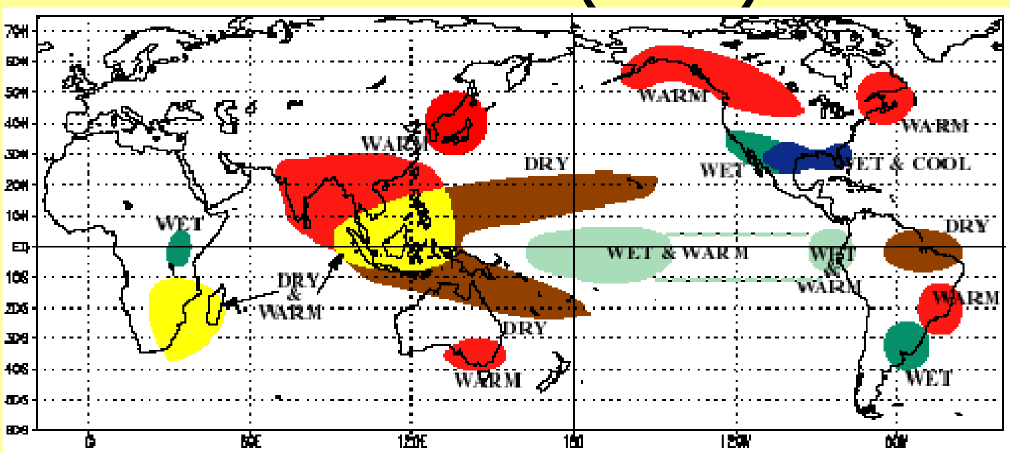
↓

EUROBRISA Integrated (combined and calibrated) precipitation seasonal forecasting system for South America

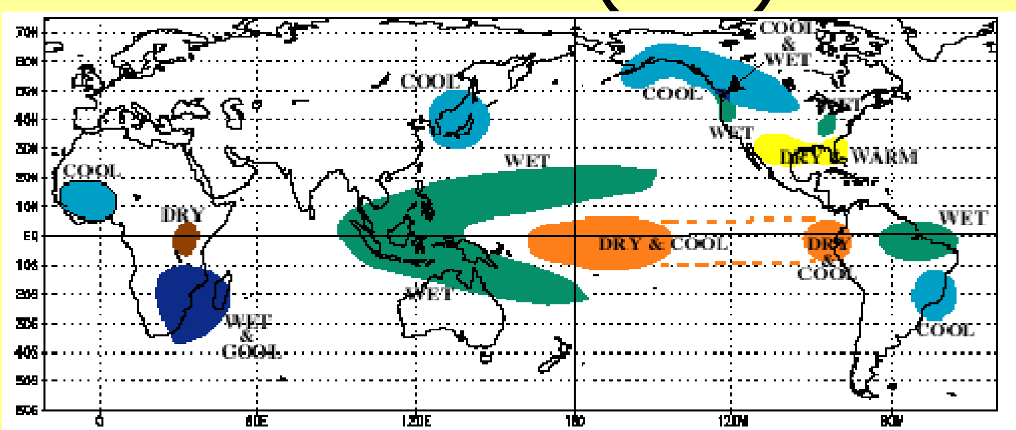
Why South America?

EUROBRISA key Idea: To improve seasonal forecasts in S. America a region where there is seasonal forecast skill and useful value

El Niño (DJF)

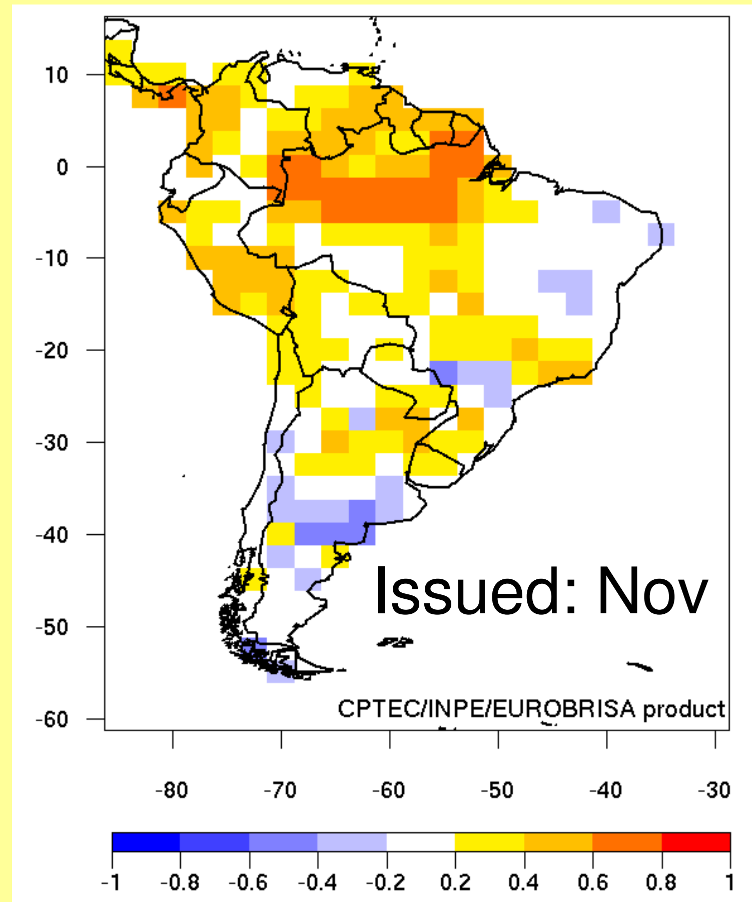


La Niña (DJF)



Fonte: Climate Prediction Center (http://www.cpc.ncep.noaa.gov)

Correlation skill precipitation forecasts for DJF



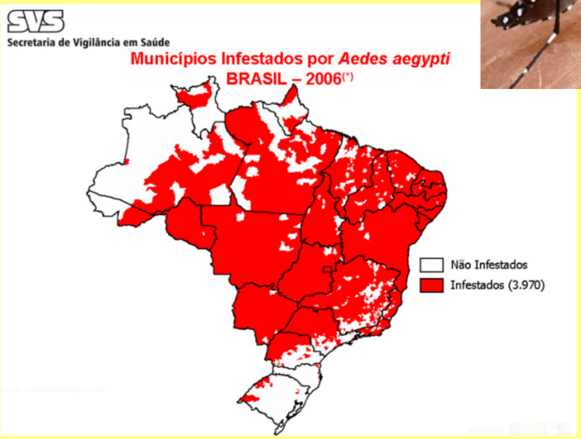
Pos. values: moderate-good skill

Application areas in need of seasonal forecasts

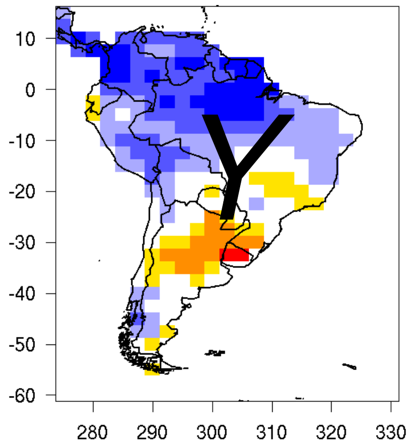
→ Electricity: Brazil, about 70% produced by hydropower stations

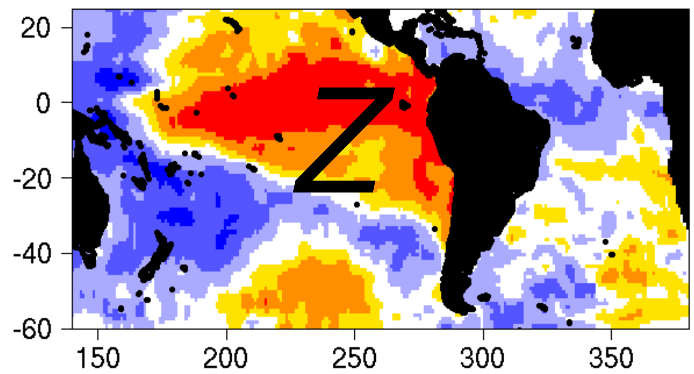
→ Agriculture (e.g. crop yield)

→Health (e.g. dengue)



The Empirical model





Data sources:

• SST: Reynolds OI v2
Reynolds *et al.* (2002)

• Precipitation: GPCP v2
Adler *et al.* (2003)

$$Y|Z \sim N(M(Z - Z_o), T)$$

Y: DJF precipitation

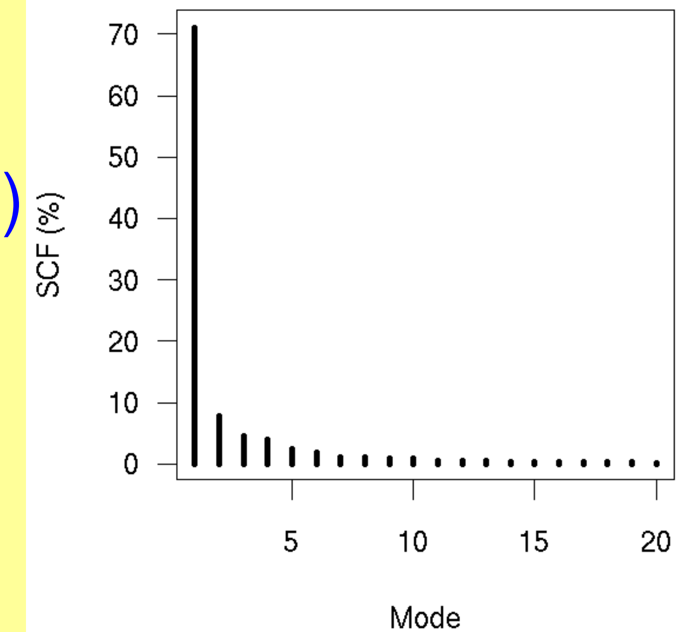
Z: October sea surface temp. (SST)

$$M = S_{YZ} S_{ZZ}^{-1} \qquad Y : n \times q$$

$$-M Z_o = \bar{Y} - \bar{Z} M \qquad Z : n \times v$$

$$T = S_{YY} - S_{YZ} S_{ZZ}^{-1} S_{YZ}^{T} \qquad T : q \times q$$

Model uses first three leading Maximum Covariance Analysis (MCA) modes of the matrix $Y^T Z$.



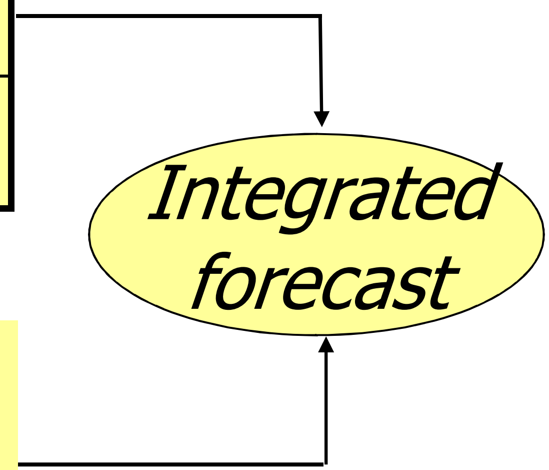
Coelho *et al.* (2006)
***J. Climate*, *19*, 3704-3721**

First version: EUROBRISA integrated forecasting system for South America

→Combined and calibrated coupled + empirical precip. forecasts

→Hybrid multi-model probabilistic system

Coupled model	Country
ECMWF System 3	International
UKMO (GloSea 3)	U.K.



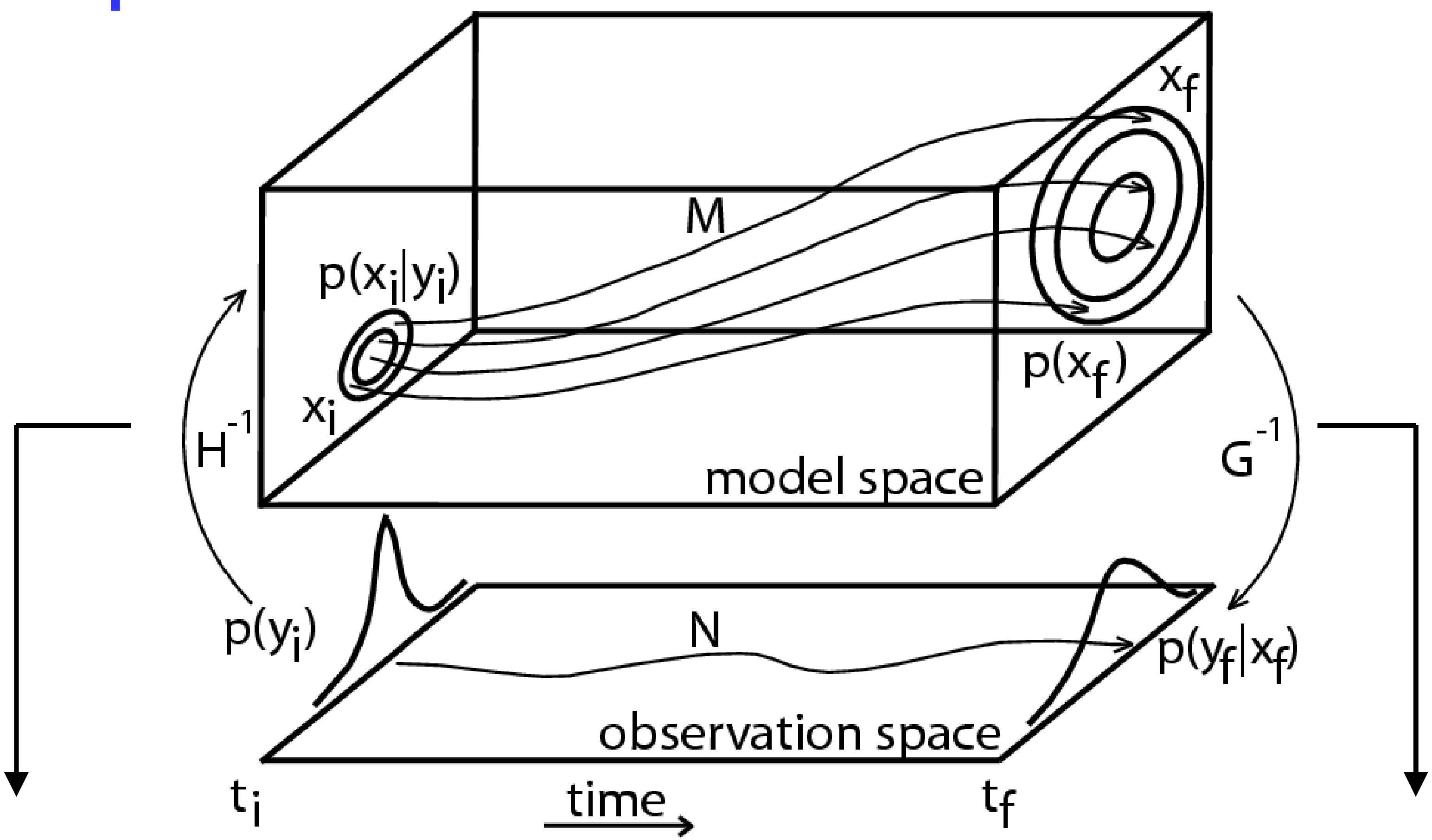
Empirical model
Predictors: Atlantic and Pacific SST
Predictand: Precipitation
Coelho *et al.* (2006) *J. Climate, 19*, 3704-3721

Produced with forecast assimilation
Stephenson et al (2005) Tellus A . Vol. 57, 253-264

Hindcast period: 1987-2001

Implemented in Oct 2007

Conceptual framework



Data Assimilation

$$p(x_i \mid y_i) = \frac{p(y_i \mid x_i)p(x_i)}{p(y_i)}$$

"*Forecast Assimilation*"

$$p(y_f \mid x_f) = \frac{p(x_f \mid y_f)p(y_f)}{p(x_f)}$$

Stephenson *et al.* (2005)

Calibration and combination procedure: Forecast Assimilation

Stephenson *et al.* (2005)
Tellus, 57A, 253-264

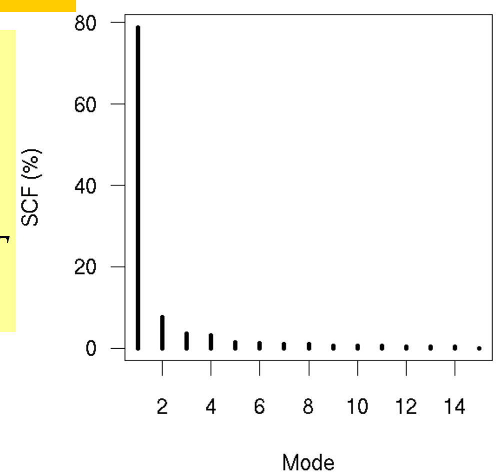
$$p(Y \mid X) = \frac{p(X \mid Y)\, p(Y)}{p(X)}$$

X: precip. fcsts (coupled + empir.)
Y: DJF precipitation

Prior: $Y \sim N(Y_b, C)$

Likelihood: $X \mid Y \sim N(G(Y - Y_o), S)$

$$G = S_{XY} S_{YY}^{-1}$$
$$-GY_o = \bar{X} - \bar{Y} G$$
$$S = S_{XX} - G S_{YY} G^T$$



Matrices

$X : n \times p$
$Y : n \times q$
$Y_b : 1 \times q$
$C : q \times q$
$S : p \times p$
$Y_a : n \times q$
$D : q \times q$

Posterior: $Y \mid X \sim N(Y_a, D)$

$$Y_a = Y_b + L(X - G(Y_b - Y_o))$$
$$D = (G^T S^{-1} G + C^{-1})^{-1} = (I - LG)C$$
$$L = CG^T (GCG^T + S)^{-1}$$

Forecast assimilation uses the first three MCA modes of the matrix $Y^T X$.

Calibration and combination procedure: Forecast Assimilation

Stephenson *et al.* (2005)
Tellus, 57A, 253-264

X: precip. fcsts (coupled + empir.)
Y: DJF precipitation

If prior param.: $Y_b = \overline{Y} \qquad C = S_{YY}$

FA becomes: $Y \mid X \sim N(L(X - X_o), D)$

$$L = S_{YX} S_{XX}^{-1}$$
$$-LX_o = \overline{Y} - \overline{X} L$$
$$D = S_{YY} - S_{YX} S_{XX}^{-1} S_{YX}^{T}$$

Posterior: $Y \mid X \sim N(Y_a, D)$

$$Y_a = Y_b + L(X - \overline{X})$$

Matrices

$X : n \times p$

$Y : n \times q$

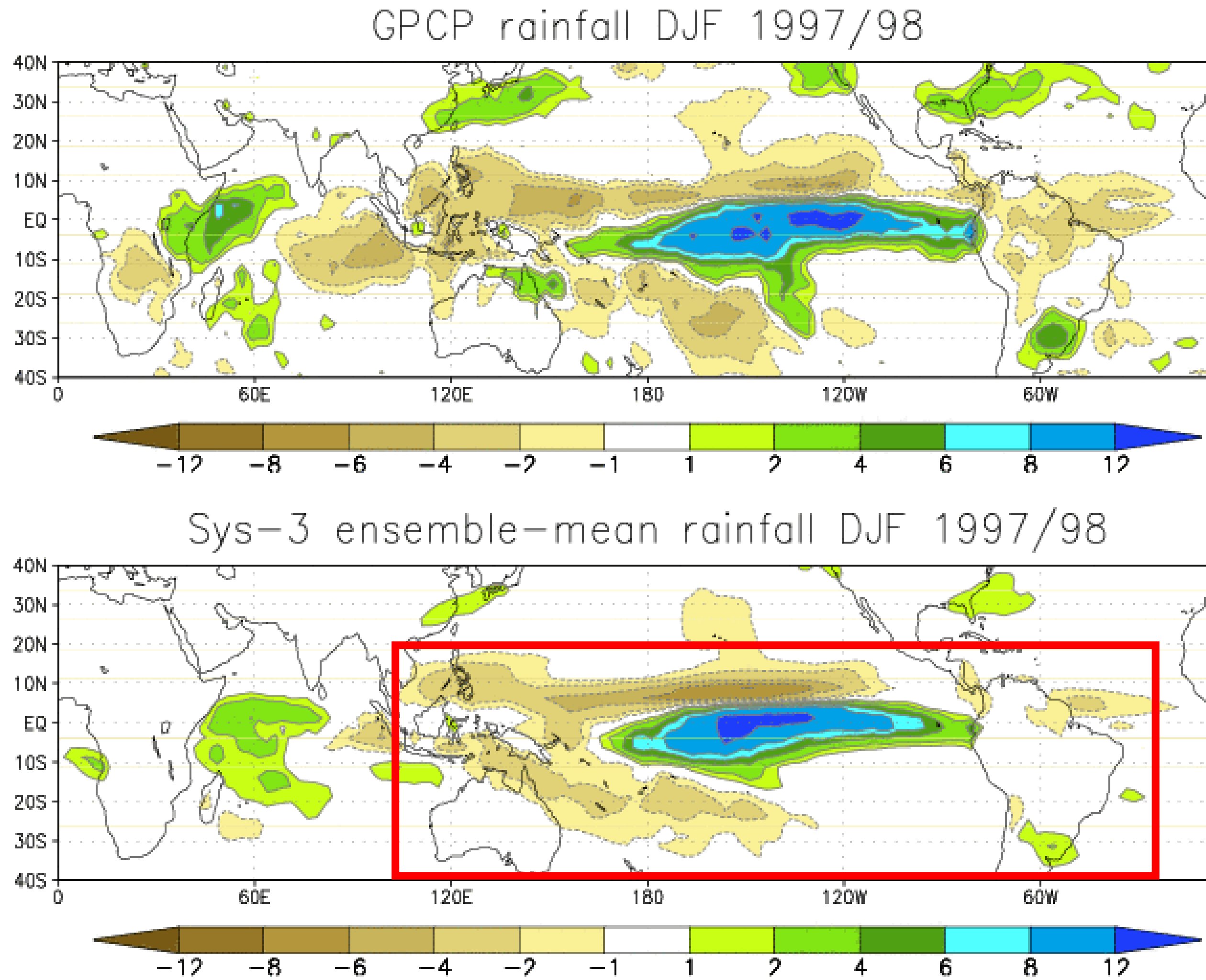
$Y_b : 1 \times q$

$C : q \times q$

$Y_a : n \times q$

$D : q \times q$

Can precipitation forecasts over the Pacific help improve forecasts over land?



Taking advantage of forecast skill over the Pacific to improve forecasts over land

Source: Franco Molteni (ECMWF)

Current EUROBRISA integrated forecasting system for South America

→Combined and calibrated coupled + empirical precip. forecasts

→Hybrid multi-model probabilistic system

Couple model	*Country*
ECMWF Sys 4 (New!)	International
UKMO GloSea 4	U.K.
Meteo-France Sys 3	France
CPTEC	Brazil

Integrated forecast

Empirical model

Predictors: Atlantic and Pacific SST

Predictand: Precipitation

Coelho *et al.* (2006) *J. Climate, 19*, 3704-3721

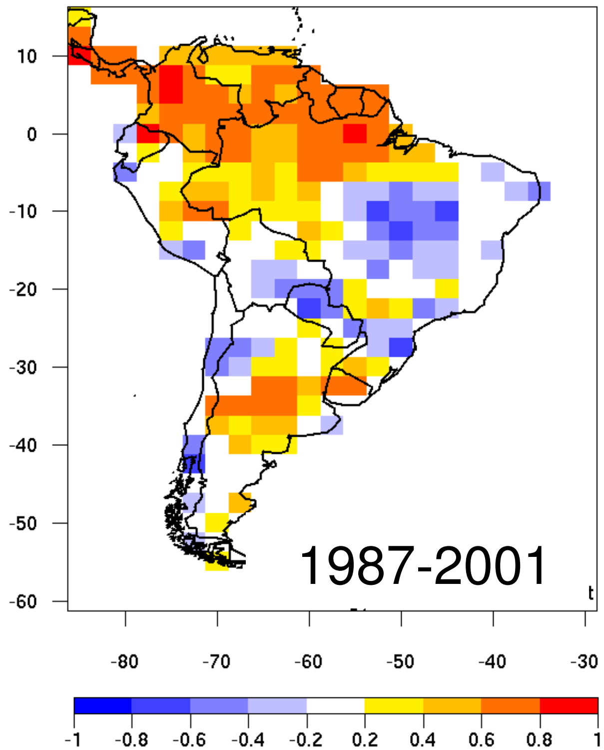
Produced with forecast assimilation Stephenson et al (2005) Tellus A . Vol. 57, 253-264

Hindcast period: 1981-2005

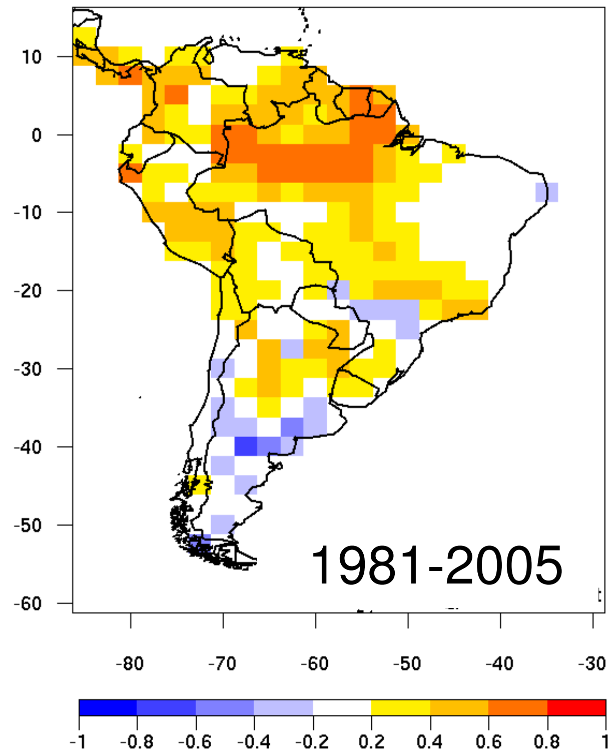
Implemented in Mar 2012

Can skill be improved by adding more models to the system and using forecasts over the Pacific?

Correlation skill: Integrated forecast (precipitation)



South America domain:
ECMWF, UKMO and empirical
(limited to common hindcast period)

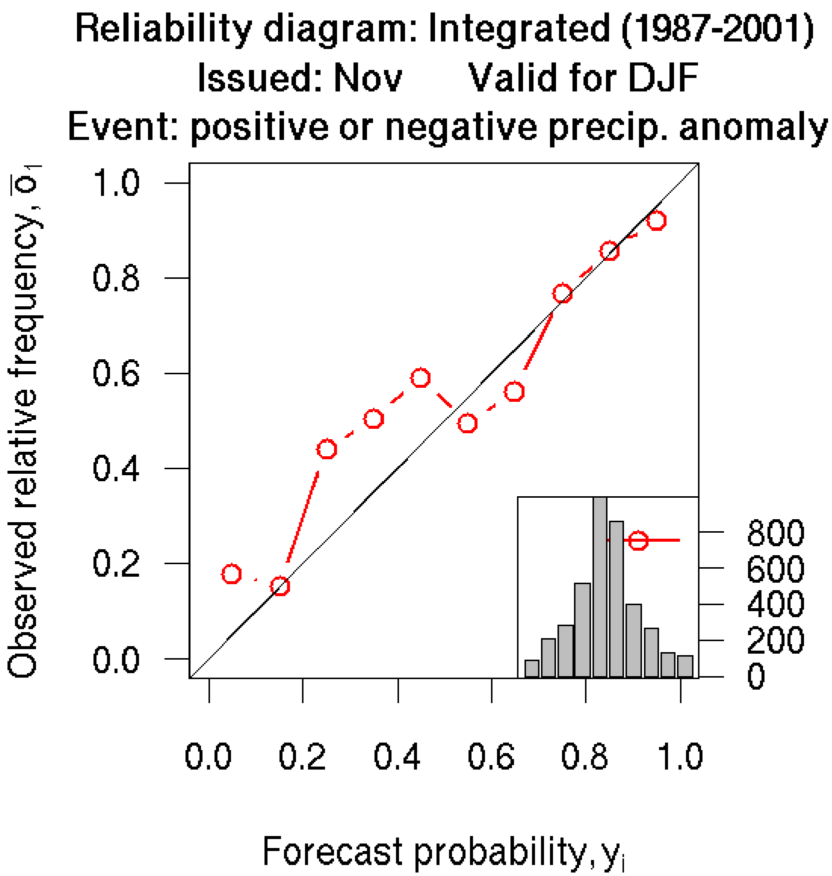


South America + Pacific domain:
ECMWF, UKMO, MF, CPTEC
and empirical (diff. hind. periods)

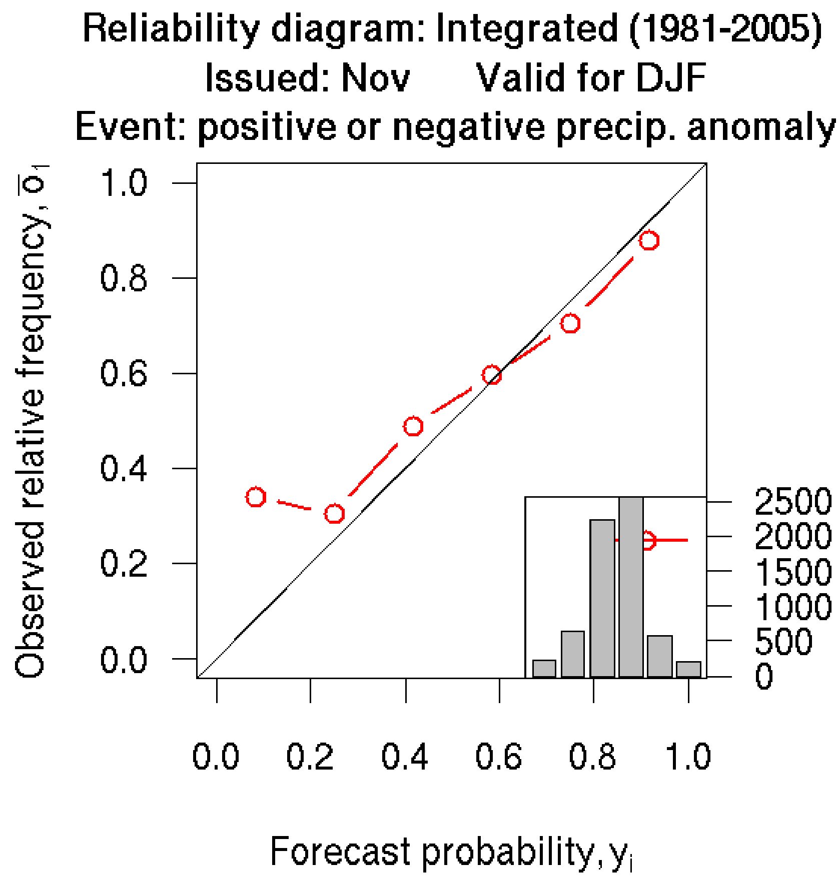
Issued: Nov
Valid: DJF

→ Adding more models and using precip. fcsts over Pac. does help improve fcst. skill in S. America

How reliable are EUROBRISA integrated precipitation forecasts?



South America domain:
ECMWF, UKMO and empirical
(limited to common hindcast period)

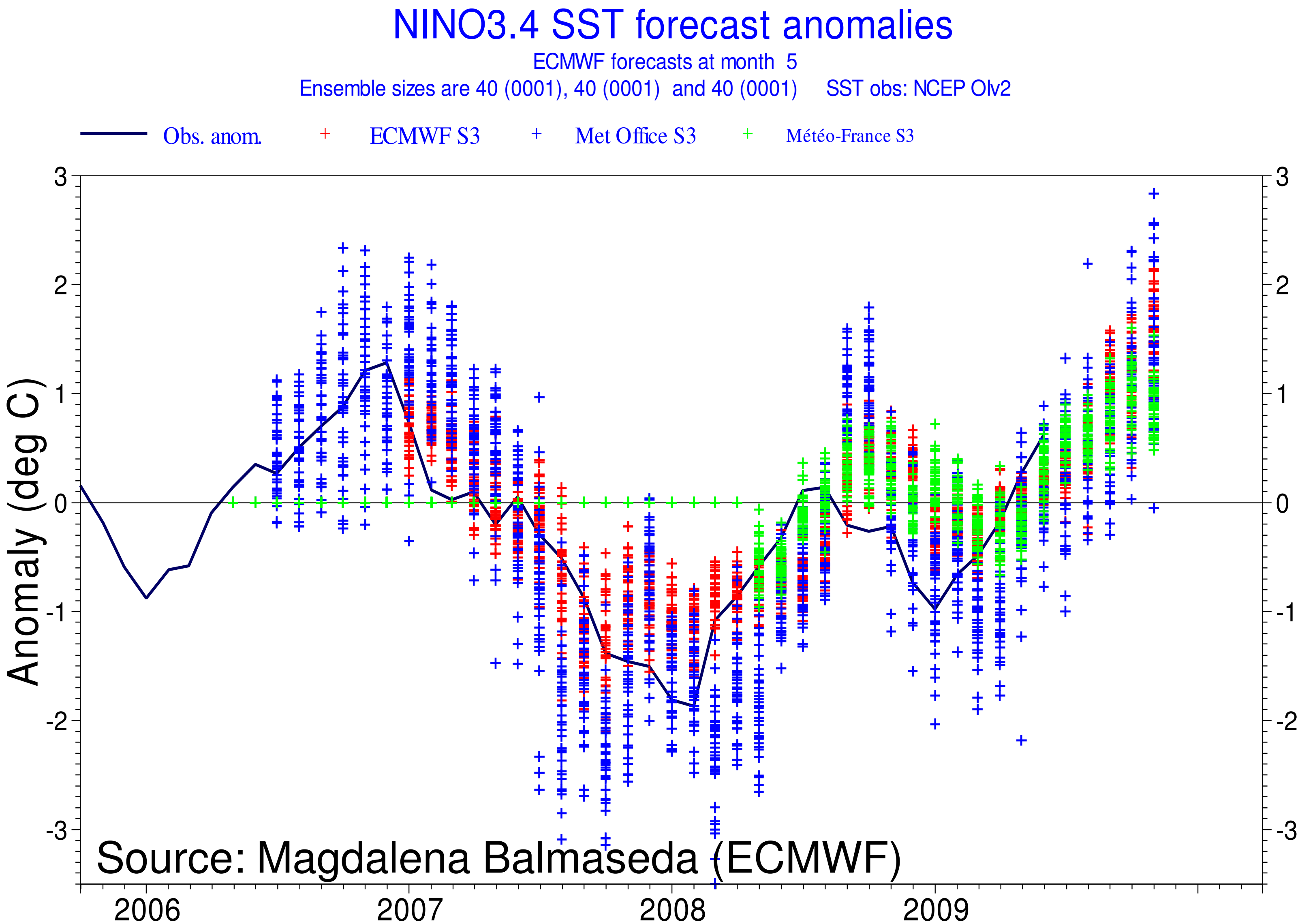


South America + Pacific domain:
ECMWF, UKMO, MF, CPTEC
and empirical (diff. hind. periods)

→Current system (right) has improved reliability comp. to previous (left)

How did the EUROBRISA integrated forecasting system perform since 2007?

La Niña 2007/2008/2009

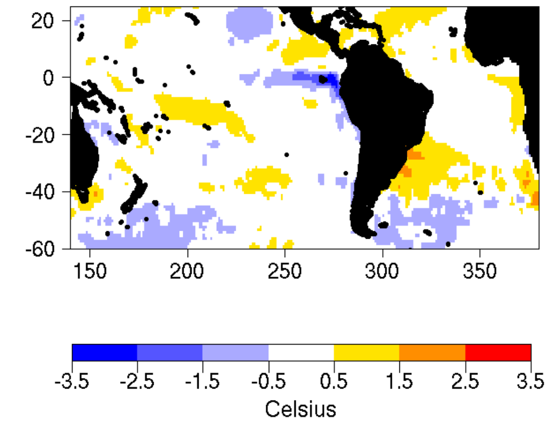


The EUROSIP multimodel captured well the onset, amplitude and long duration of La Nina conditions

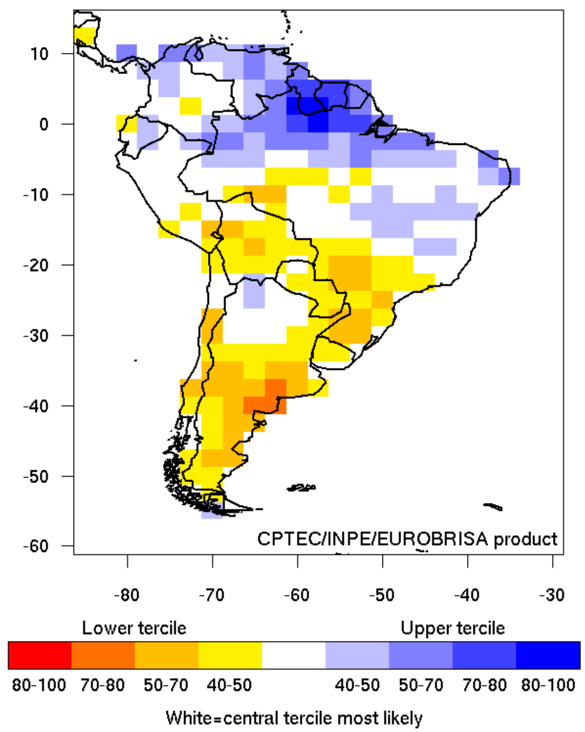
EUROBRISA integrated forecast for JJA 2007

Issued: May 2007

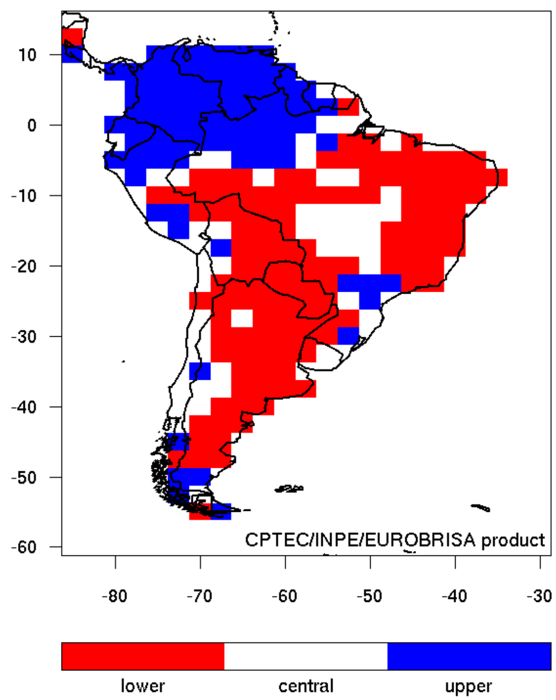
Obs. SST anomaly Apr 2007



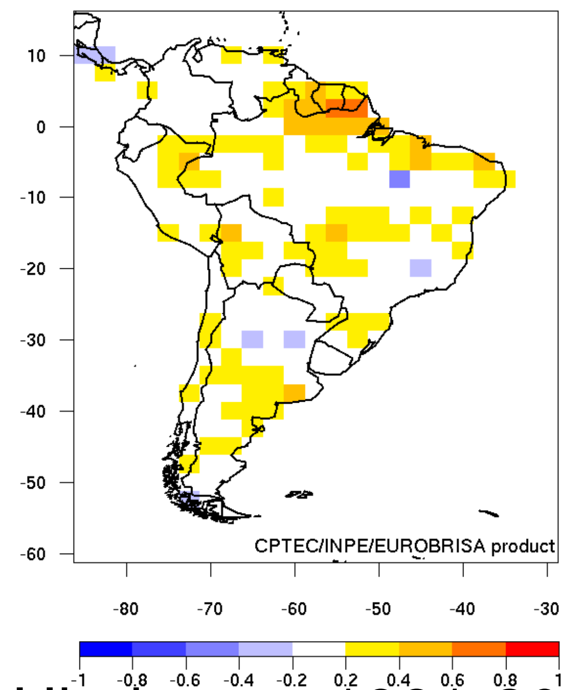
Prob. of most likely precip. tercile (%)



Observed precip. tercile



Gerrity score (tercile categories)

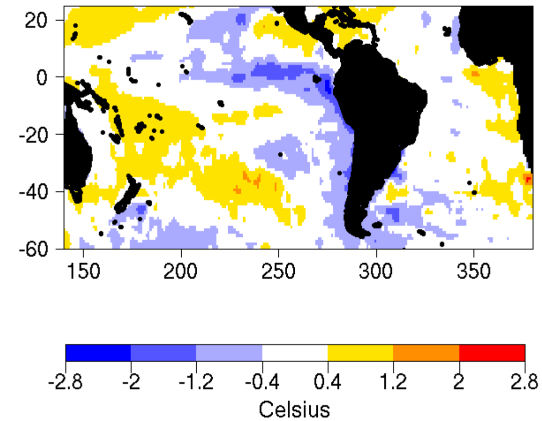


Hindcasts: 1981-2005

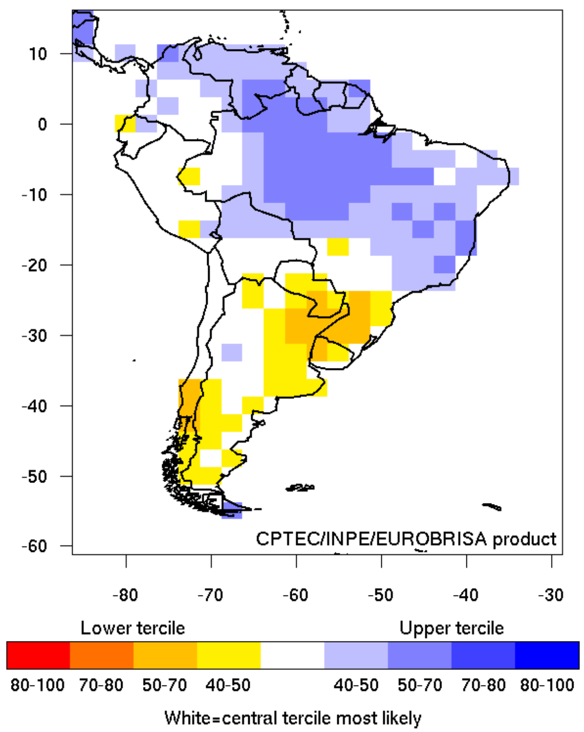
EUROBRISA integrated forecast for SON 2007

Issued: Aug 2007

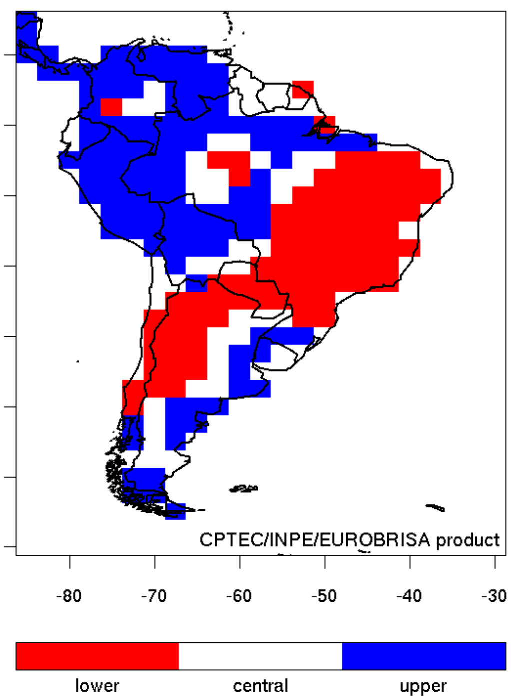
Obs. SST anomaly Jul 2007



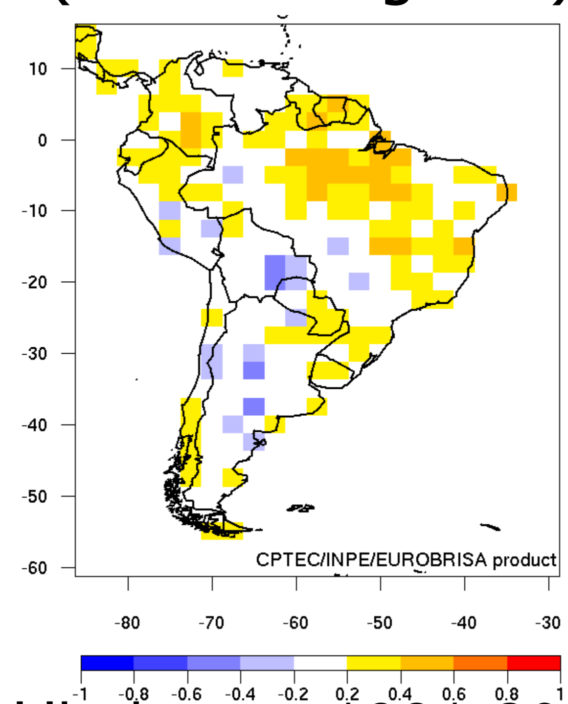
Prob. of most likely precip. tercile (%)



Observed precip. tercile



Gerrity score (tercile categories)

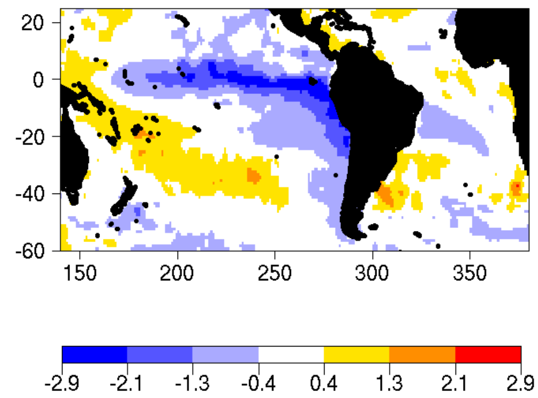


Hindcasts: 1981-2005

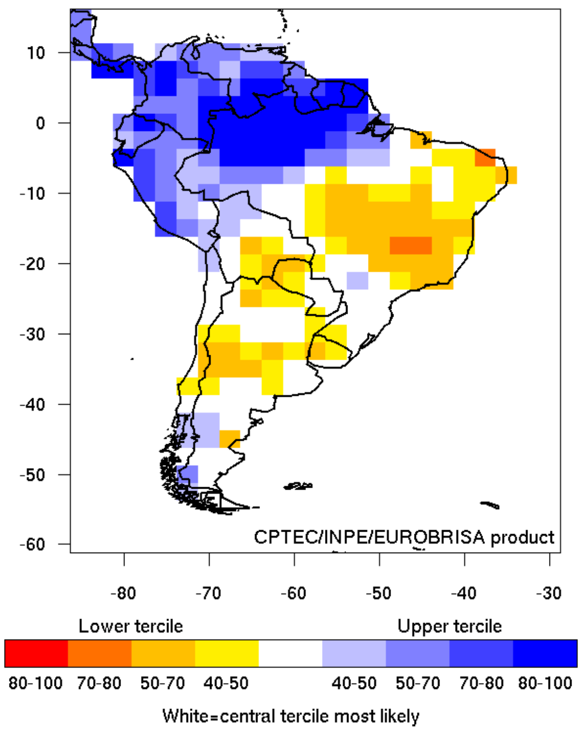
EUROBRISA integrated forecast for DJF 2007/2008

Issued: Nov 2007

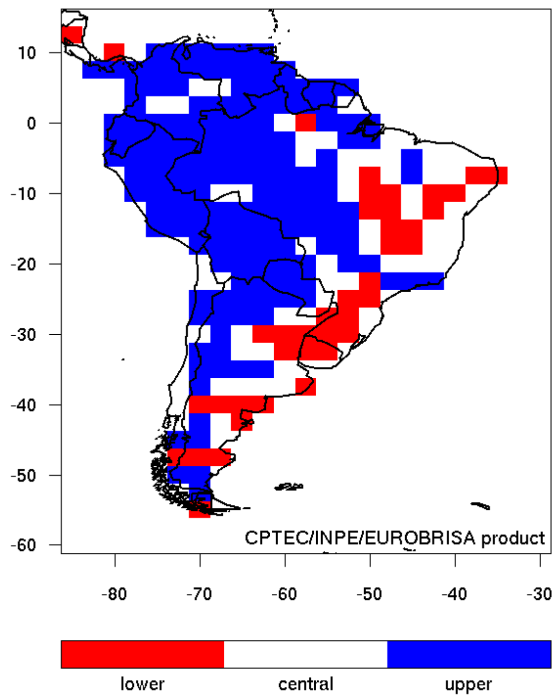
Obs. SST anomaly Oct 2007



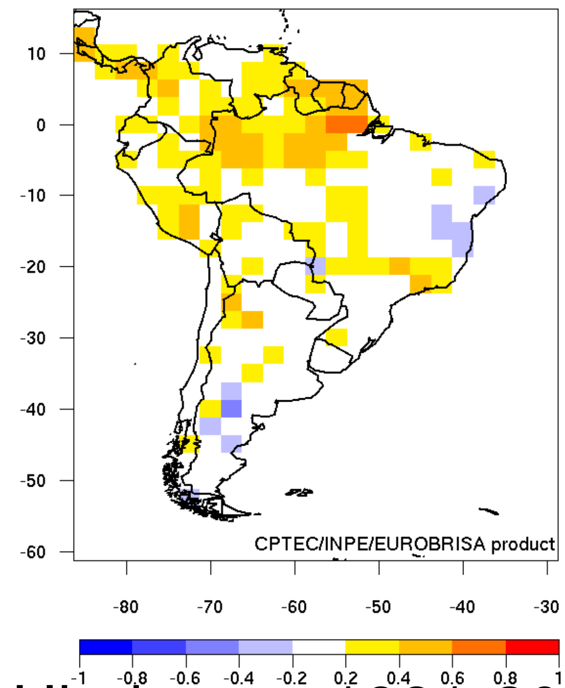
Prob. of most likely precip. tercile (%)



Observed precip. tercile



Gerrity score (tercile categories)

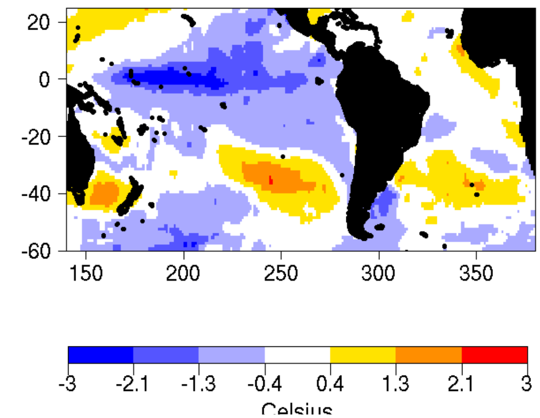


Hindcasts: 1981-2005

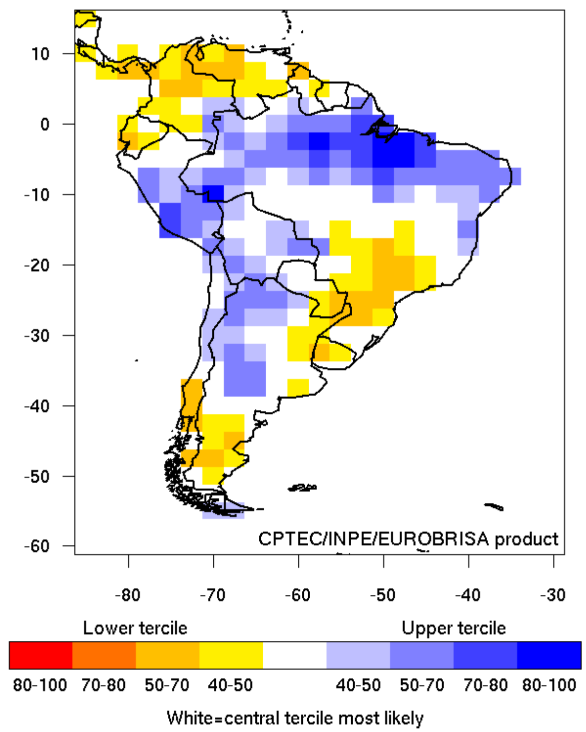
EUROBRISA integrated forecast for MAM 2008

Issued: Feb 2008

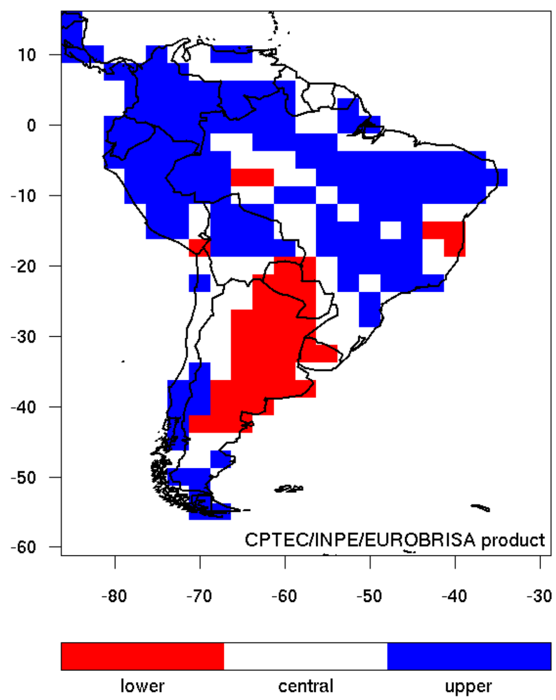
Obs. SST anomaly Jan 2008



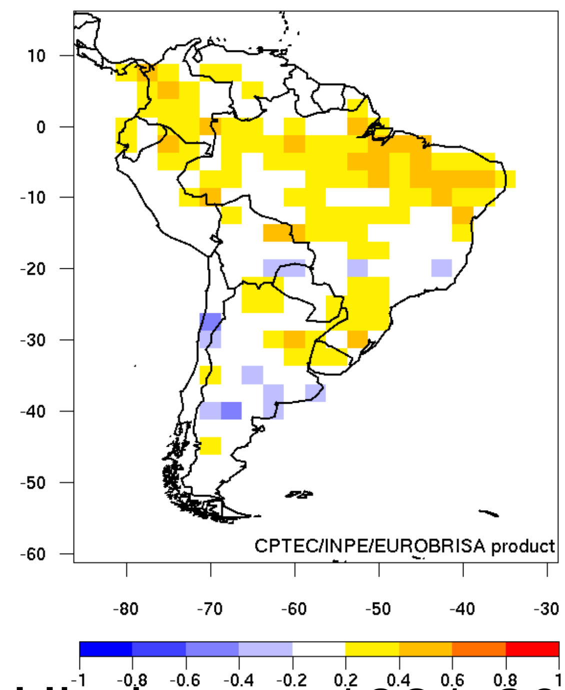
Prob. of most likely precip. tercile (%)



Observed precip. tercile



Gerrity score (tercile categories)

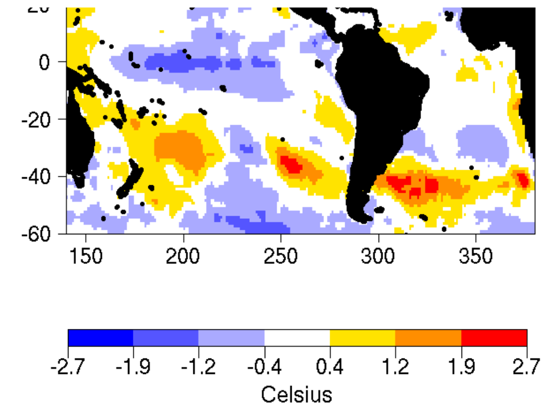


Hindcasts: 1981-2005

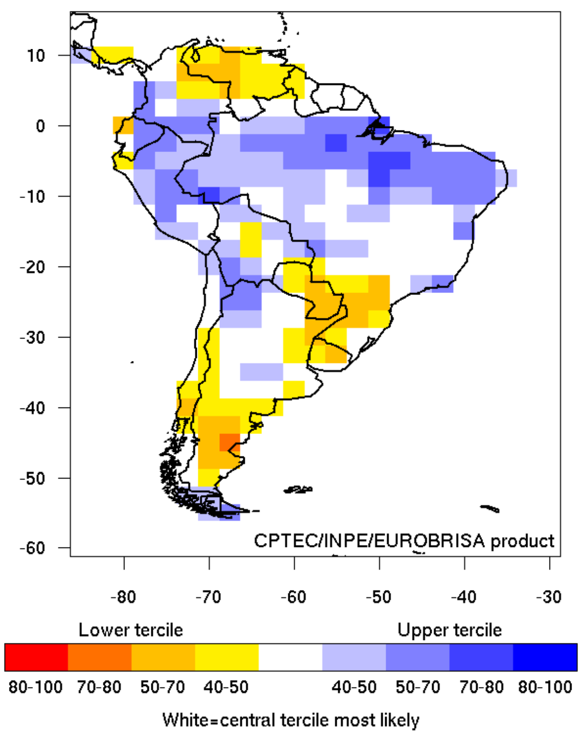
EUROBRISA integrated forecast for MAM 2009

Issued: Feb 2009

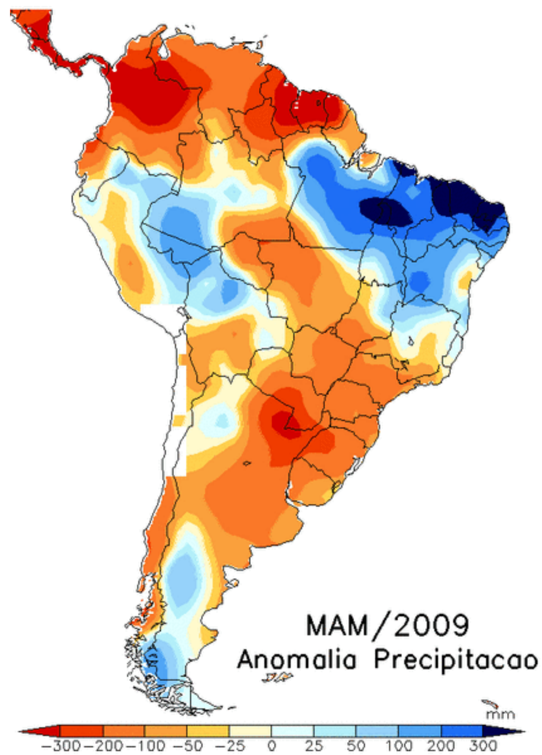
Obs. SST anomaly Jan 2009



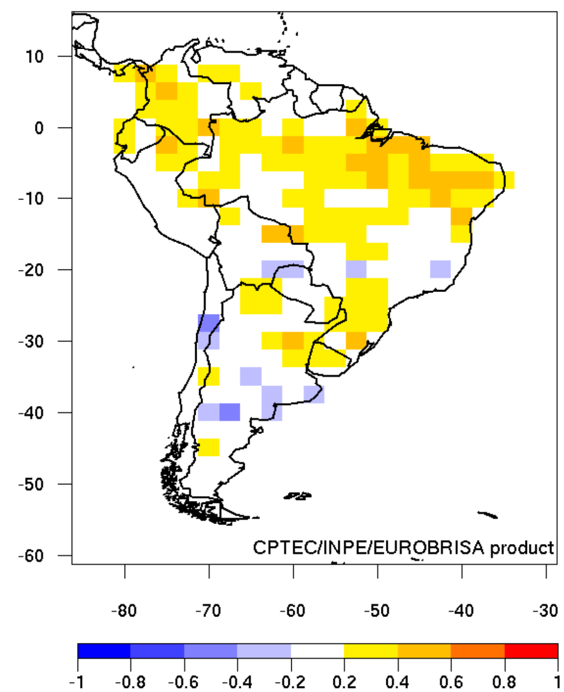
Prob. of most likely precip. tercile (%)



Observed precip.



Gerrity score (tercile categories)

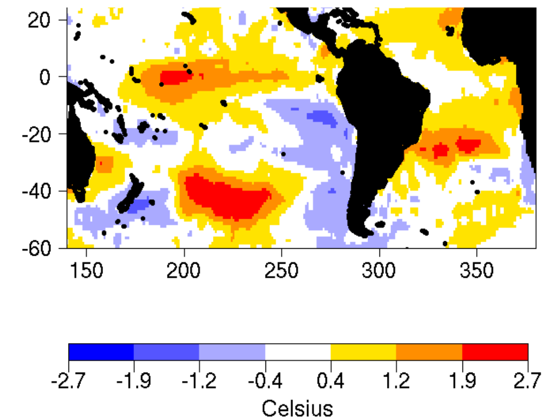


Hindcasts: 1981-2005

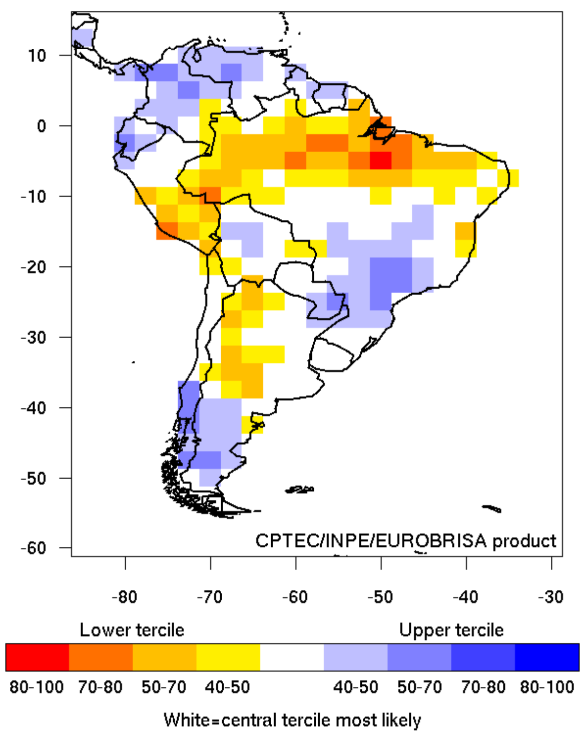
EUROBRISA integrated forecast for MAM 2010

Issued: Feb 2010

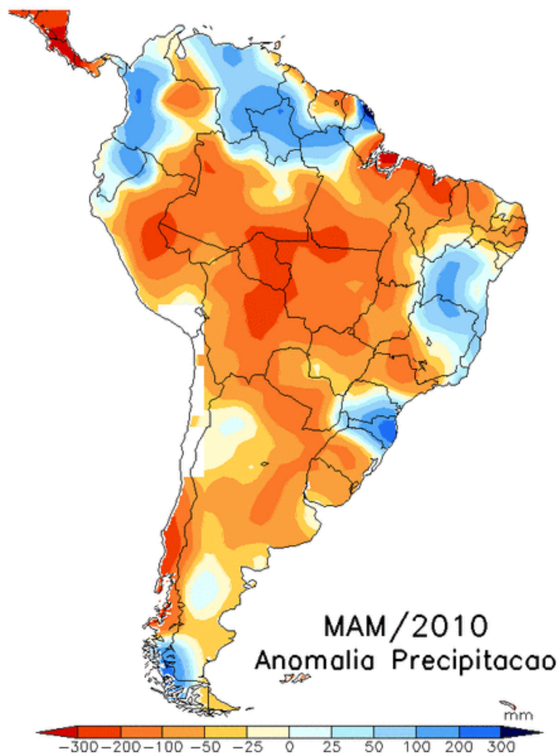
Obs. SST anomaly Jan 2010



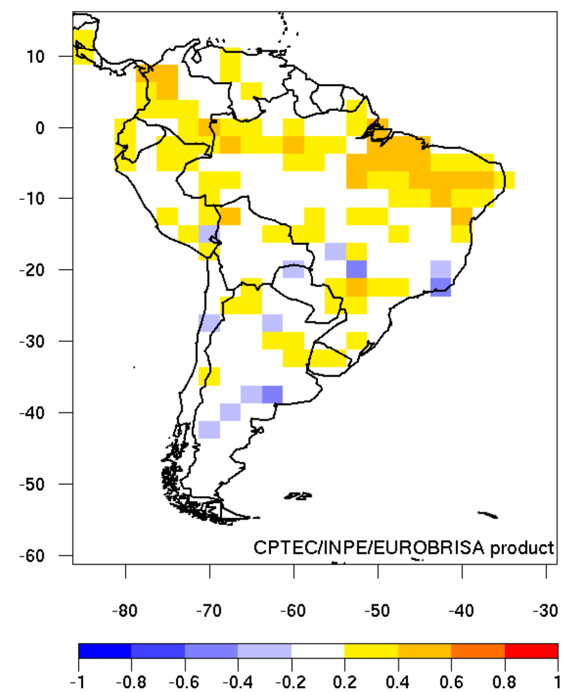
Prob. of most likely precip. tercile (%)



Observed precip.



Gerrity score (tercile categories)

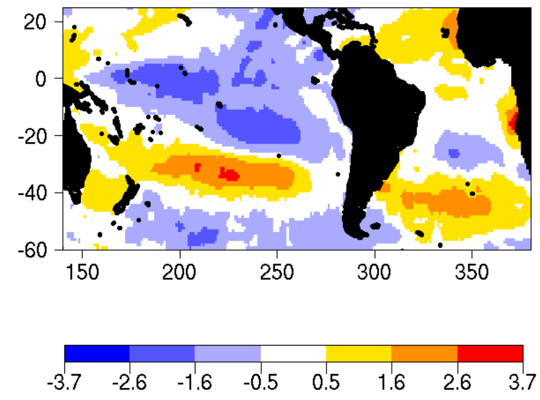


Hindcasts: 1981-2005

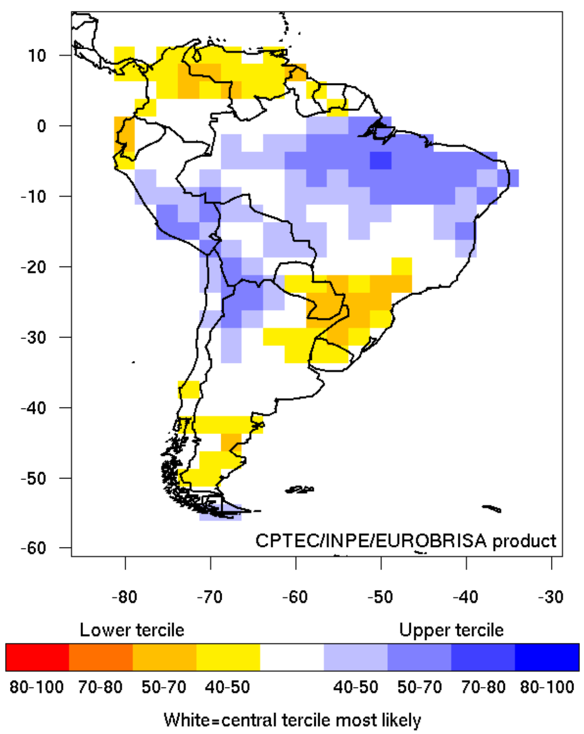
EUROBRISA integrated forecast for MAM 2011

Issued: Feb 2011

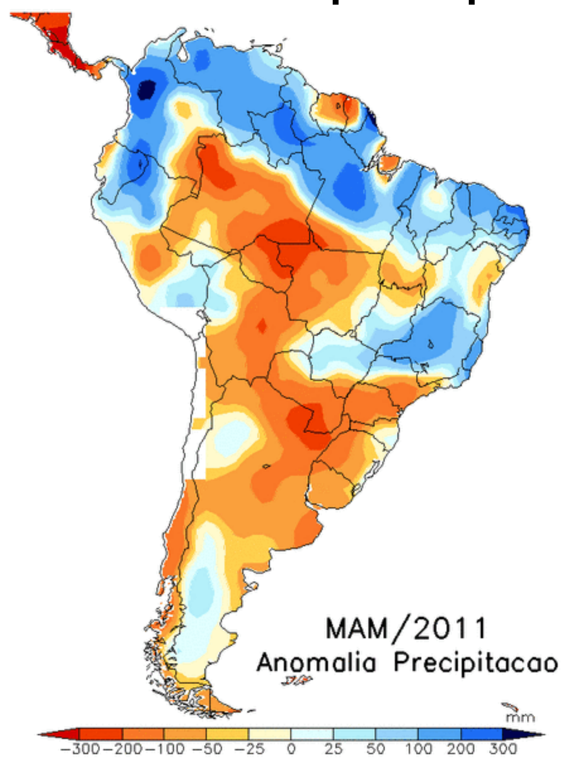
Obs. SST anomaly Jan 2011



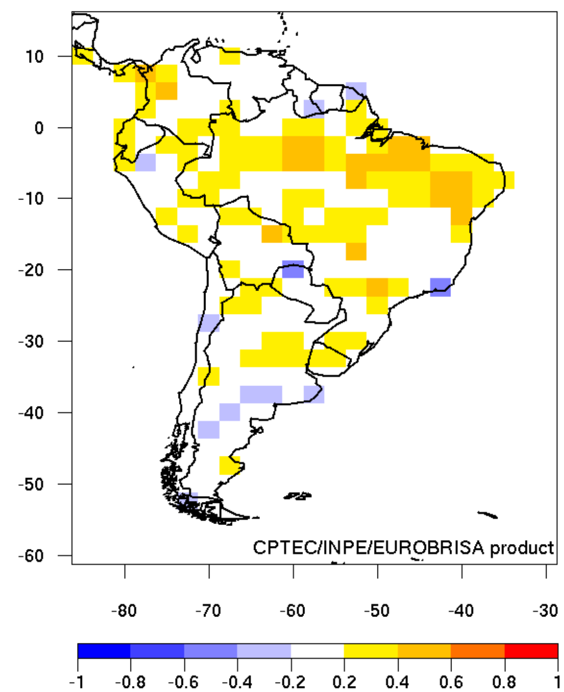
Prob. of most likely precip. tercile (%)



Observed precip.



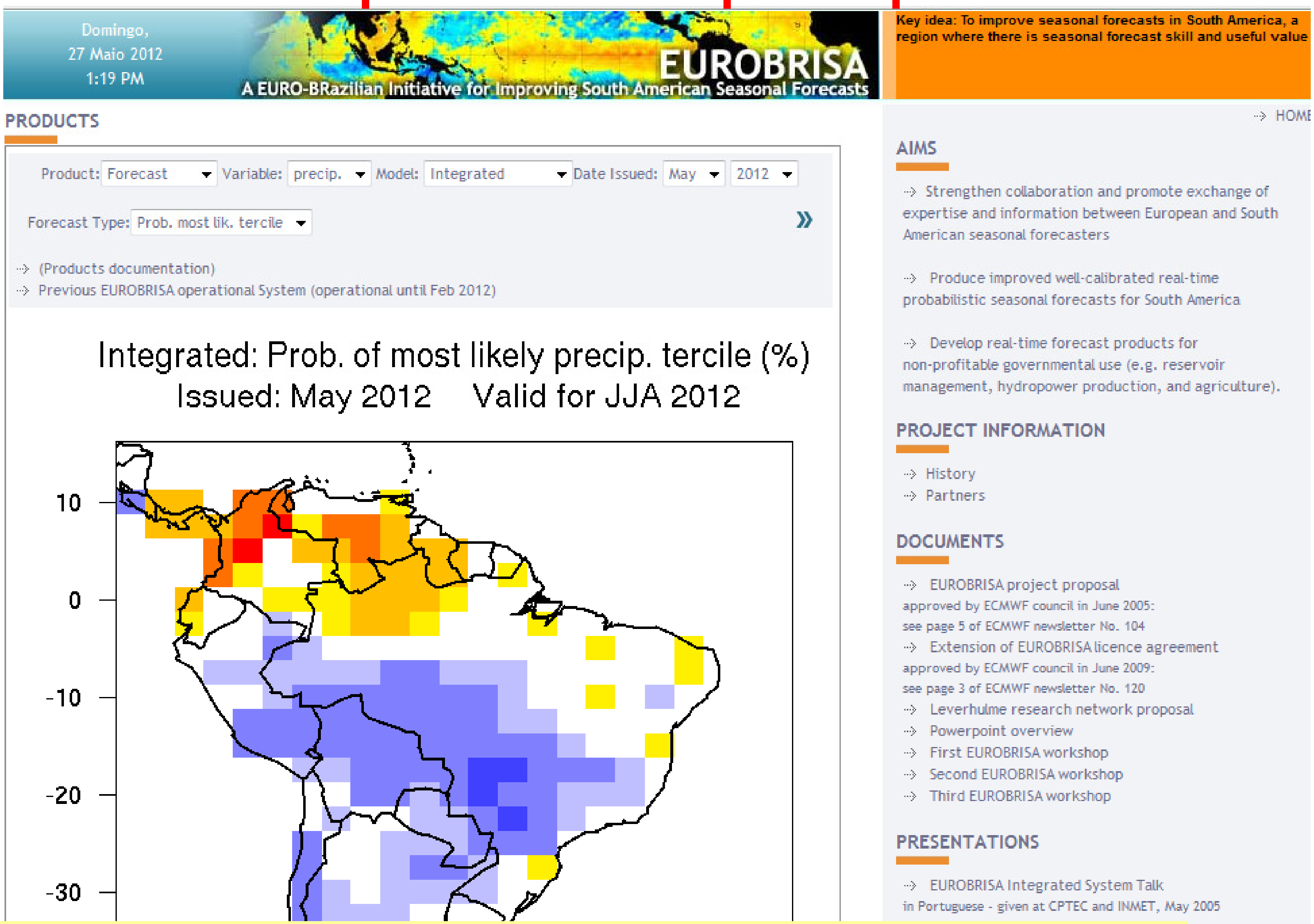
Gerrity score (tercile categories)



Hindcasts: 1981-2005

New version of EUROBRISA system updated in March 2012

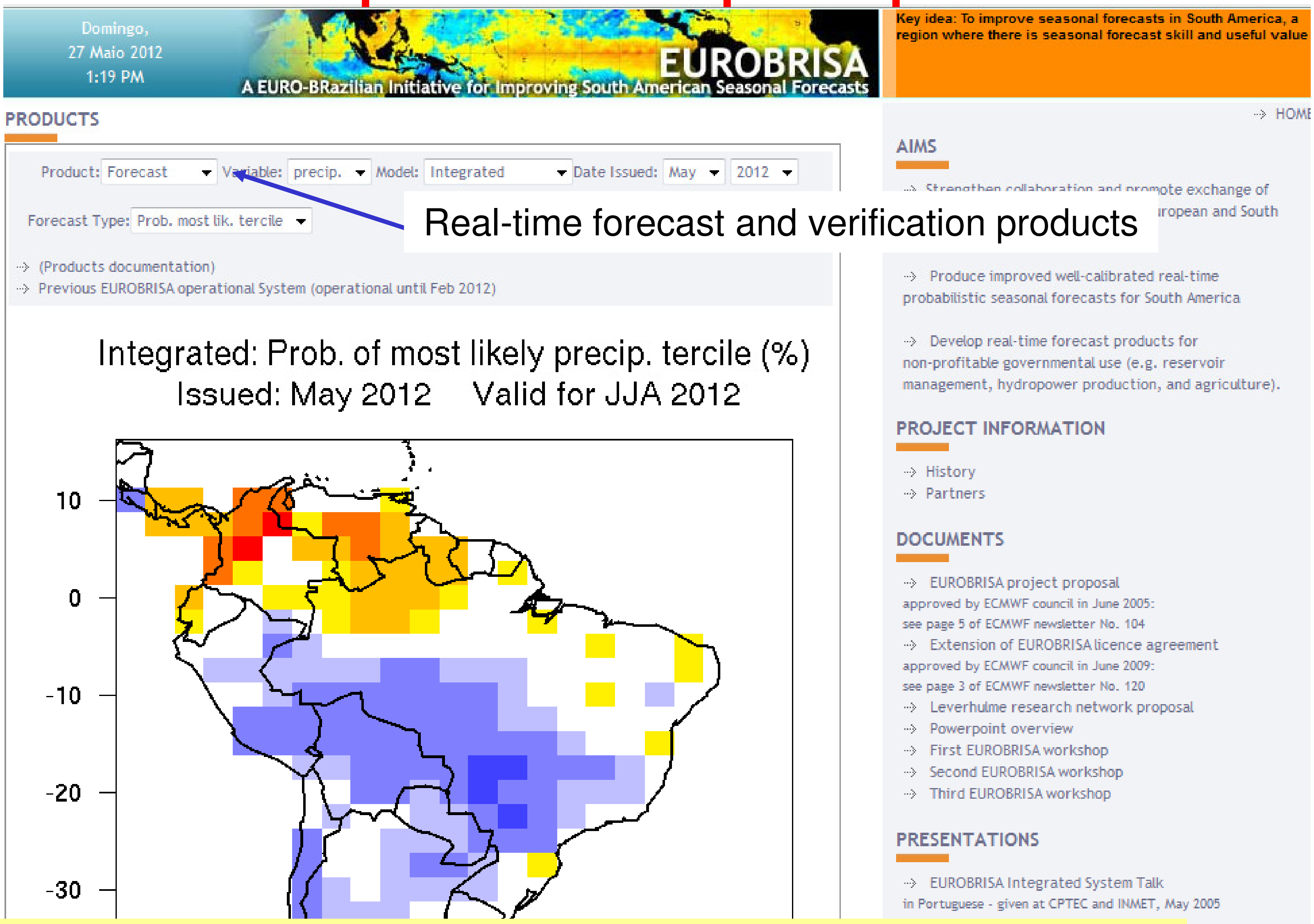
http://eurobrisa.cptec.inpe.br



Hybrid (empirical-dynamical) multi-model ensemble system for South America

New version of EUROBRISA system updated in March 2012

http://eurobrisa.cptec.inpe.br

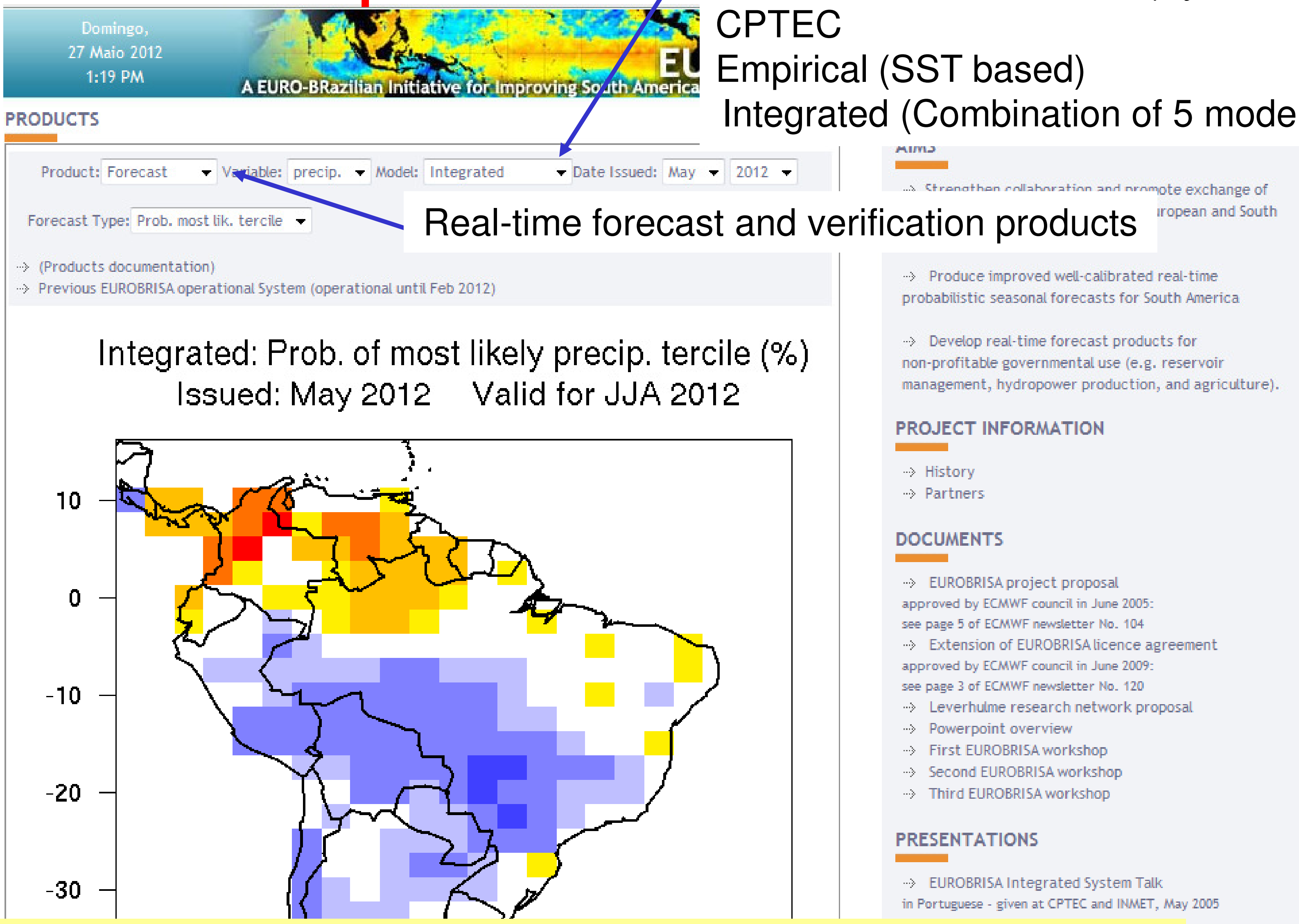


Real-time forecast and verification products

Hybrid (empirical-dynamical) multi-model ensemble system for South America

New version of EU
updated in
http://eurobrisa.c

1-month lead forecasts
EUROSIP: ECMWF (System 4) (NEW)
UKMO (GloSea 4)
Meteo-France (System 3)
CPTEC
Empirical (SST based)
Integrated (Combination of 5 models above)

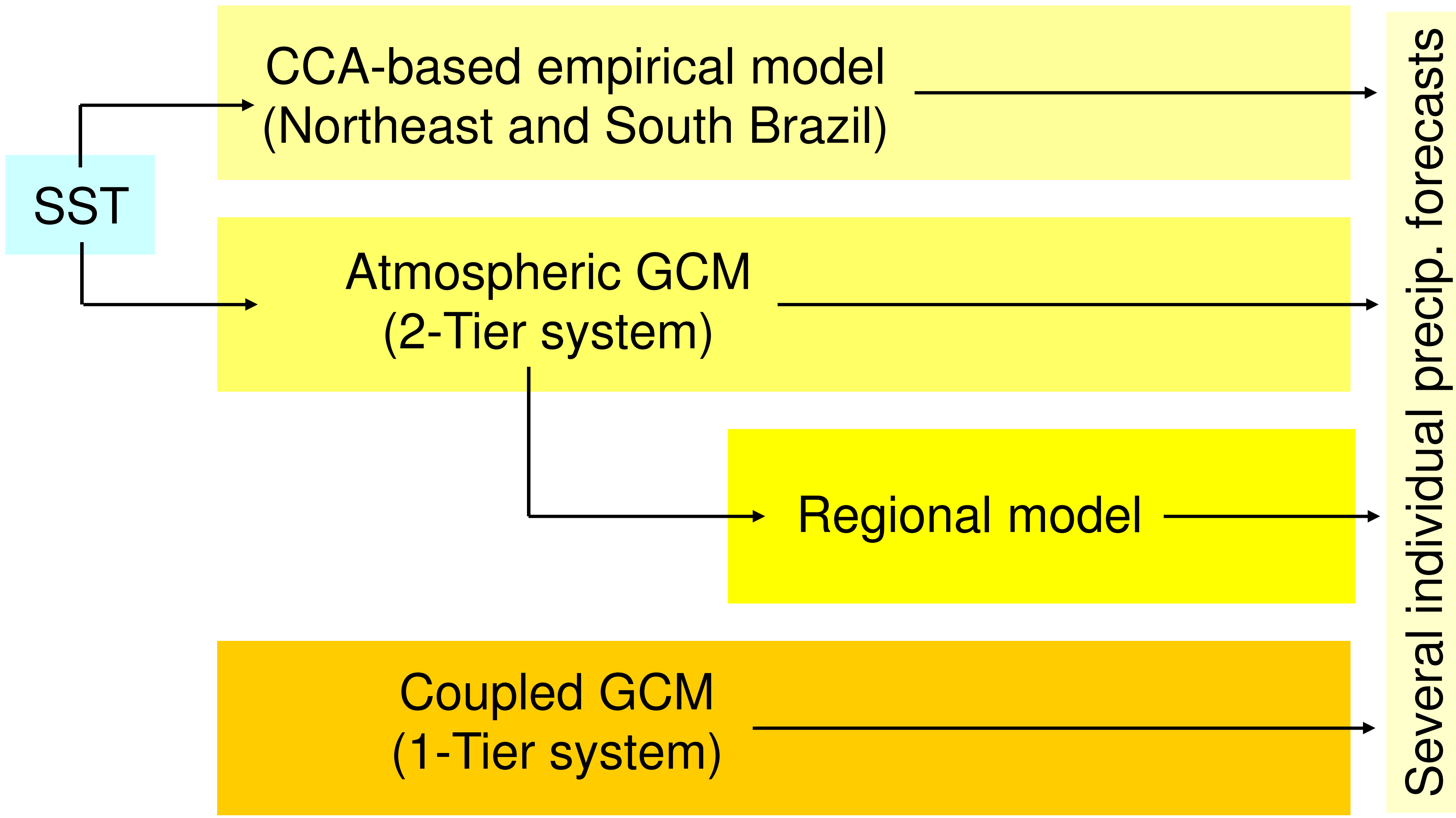


Real-time forecast and verification products

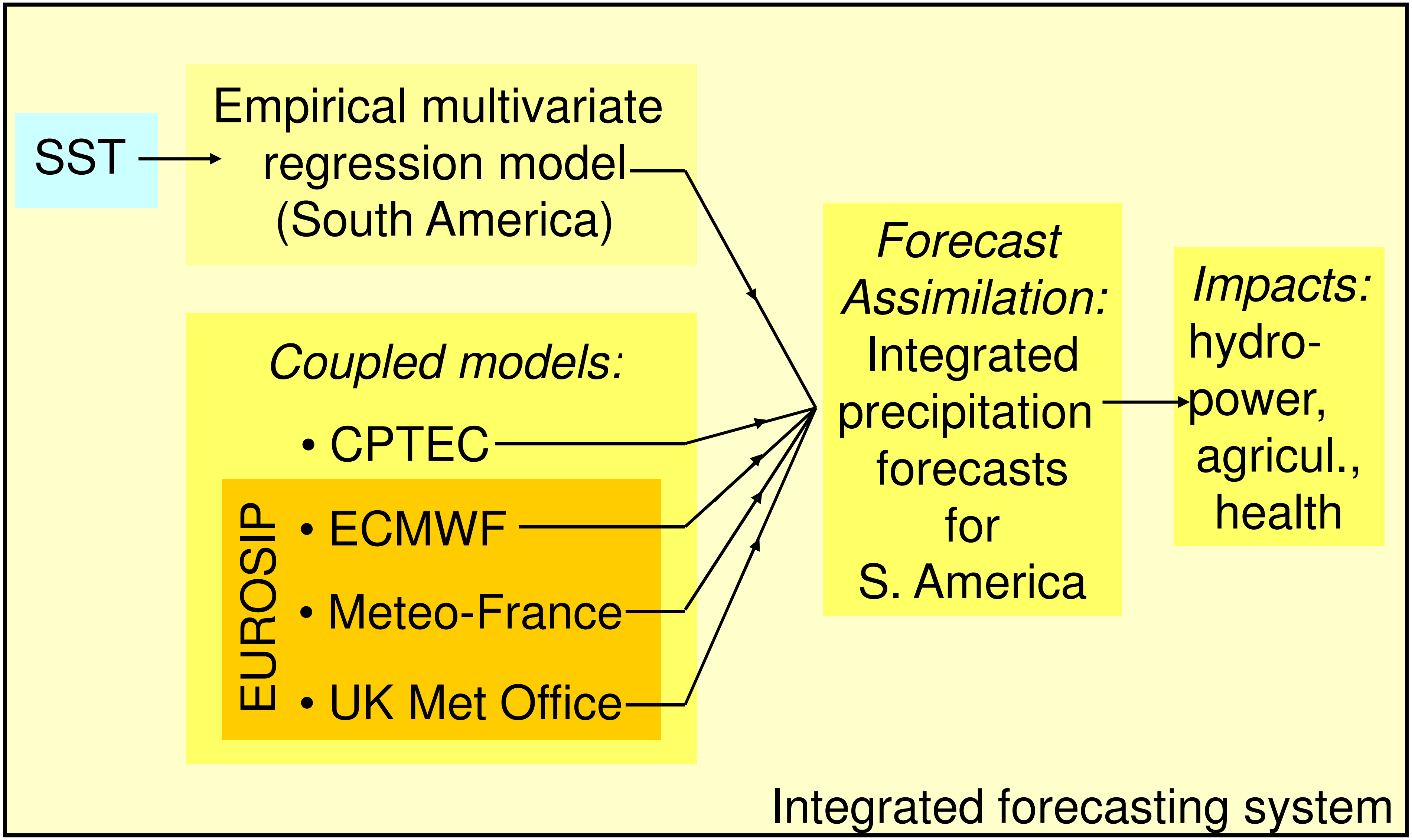
Hybrid (empirical-dynamical) multi-model ensemble system for South America

How has EUROBRISA contributed for improving seasonal forecasting practice in S. America?

Seasonal forecasting system before EUROBRISA

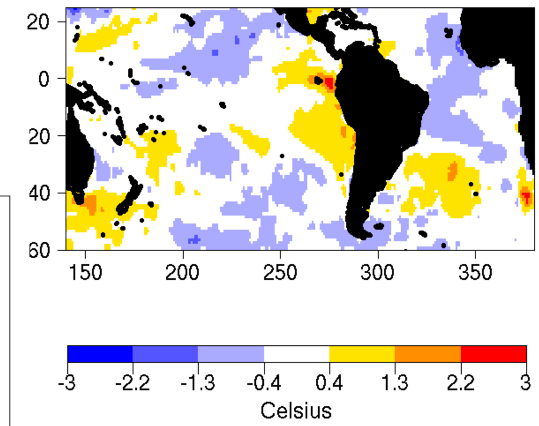


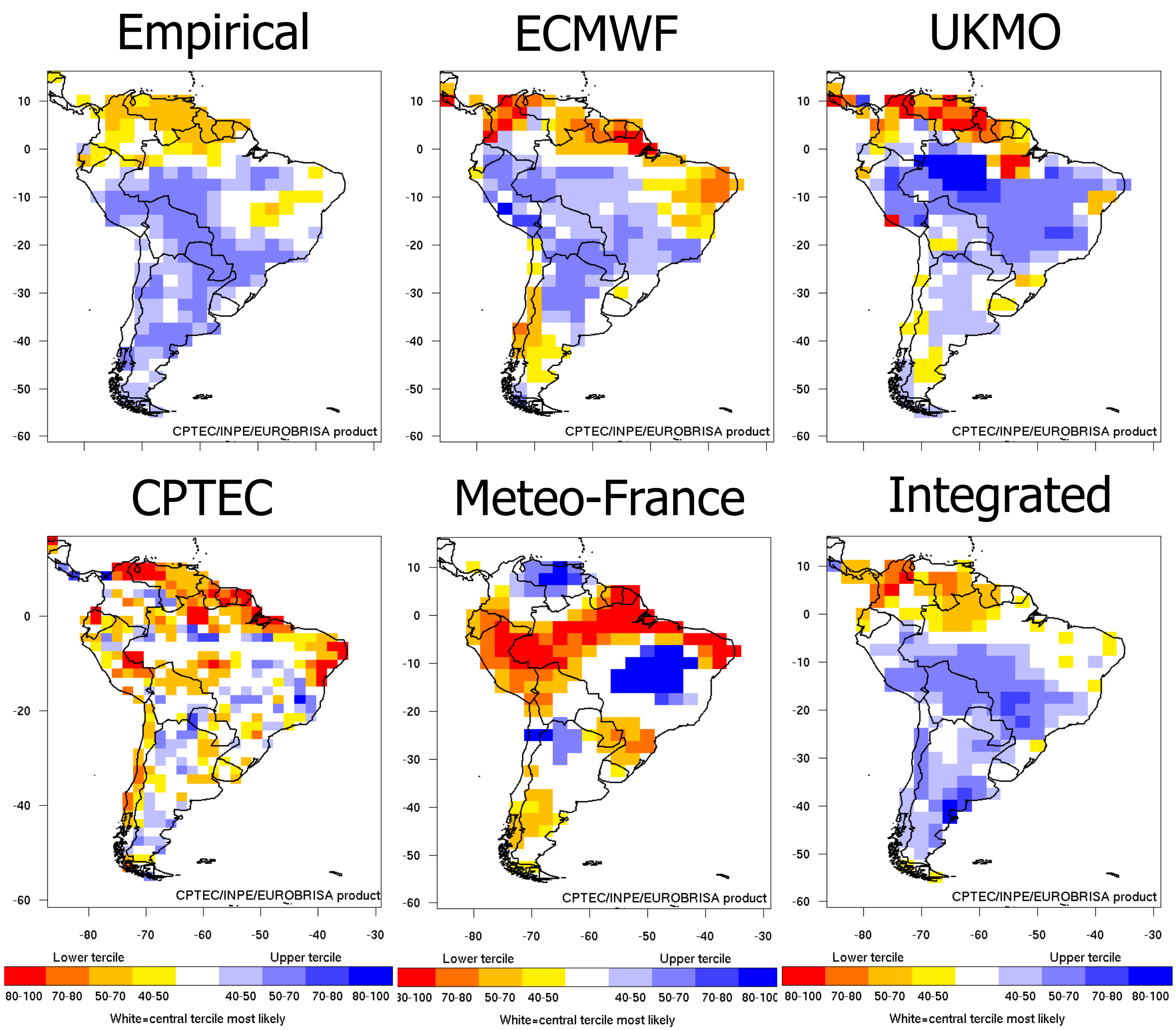
After EUROBRISA



Most recent EUROBRISA integrated fcst for JJA 2012

Obs. SST anomaly Apr 2012





Prob. of most likely precipitation tercile (%)

Issued: May 2012

Summary: EUROBRISA

- Successful initiative bringing together expertise on coupled ocean-atmosphere seasonal forecasting and statistical calibration and combination of multi-model ensemble forecasts
- Developed novel integrated precipitation seasonal forecasting system for South America
- Helped improve and advance seasonal forecasting practice in South America by objectively combining empirical and dynamical model seasonal forecasts
- Integrated forecasting system has shown reasonable performance since its implementation in 2007
- Neutral ENSO phase: EUROBRISA forecast for JJA 2012 is for below normal precipitation in northern South America and above normal precipitation in central and south South America

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Available at http://eurobrisa.cptec.inpe.br/publications.shtml

EUROBRISA articles: impact studies

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Balmaseda M.A., Y. Fujii, O. Alves, T. Lee, M. Rienecker, T. Rosati, D. Stammer, Y. Xue, H. Freeland, M. J. McPhaden, L. Goddard and C.A.S. Coelho, 2009: "Role of the ocean observing system in an end-to-end seasonal forecasting system." OceanObs'09 Conference.

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