# *Climate monitoring and prediction at sub-seasonal to seasonal time scales*

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Acknowledgments: Mari Firpo (CPTEC), Maria Skansi (SMN)
Tony Barnston, Simon Mason and Andy Robertson (IRI)

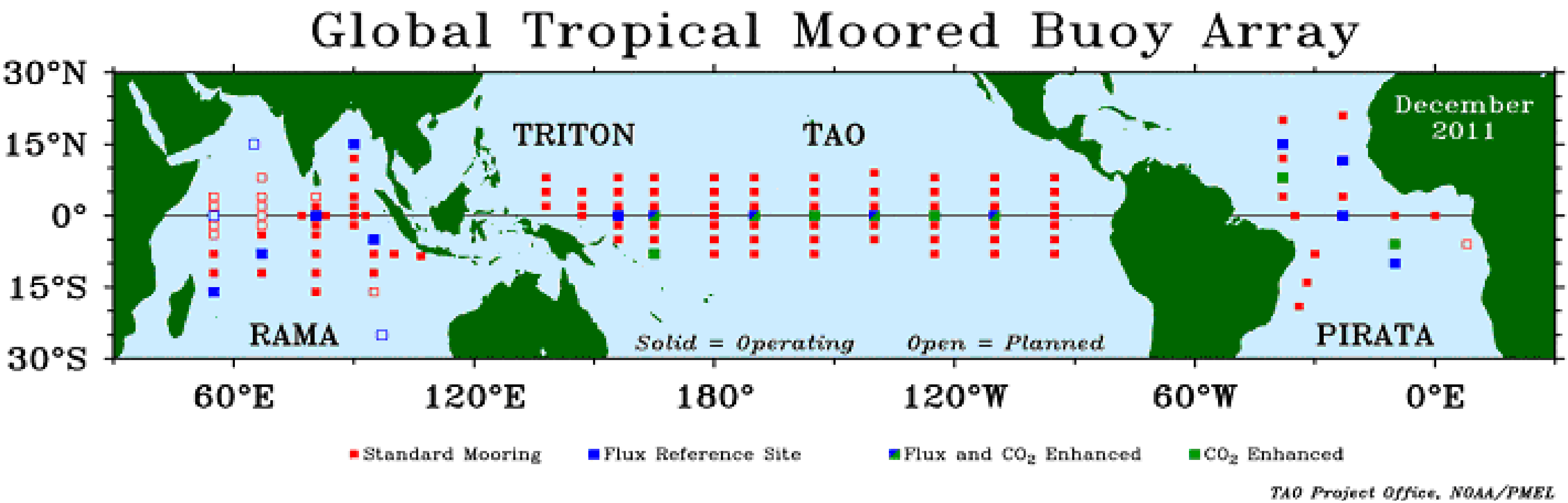
**PLAN OF TALK**

1. Brief introduction to climate monitoring and prediction: tropical oceans
2. Multi-model ensemble seasonal precipitation prediction systems
3. Regional climate prediction activities in Southeast South America
4. Examples of modern seasonal prediction practice
5. The need for improved practices: climate monitoring, prediction and verification
6. The need for improved transition of climate monitoring and prediction research to operations
7. Final remarks

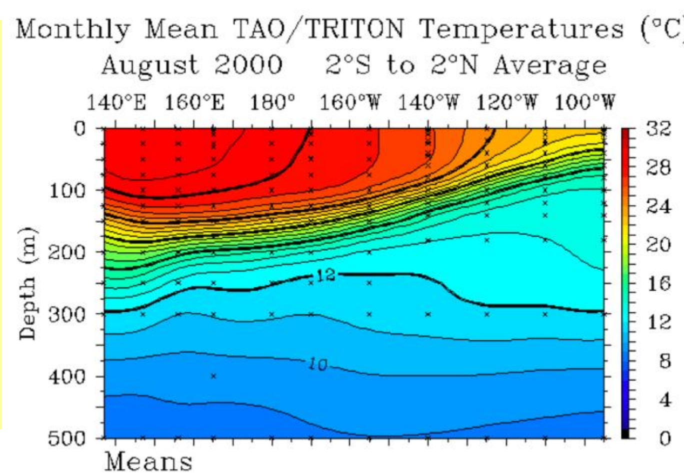
*WCRP Conference for Latin America and the Caribbean:*
*Developing, linking and applying climate knowledge*
*Montevideo, Uruguay, 17-21 March 2014*

# Introduction

- The implementation of the Tropical Atmosphere Ocean (TAO) array in the tropical Pacific Ocean in the 80's was a major achievement for improved climate monitoring and prediction activities



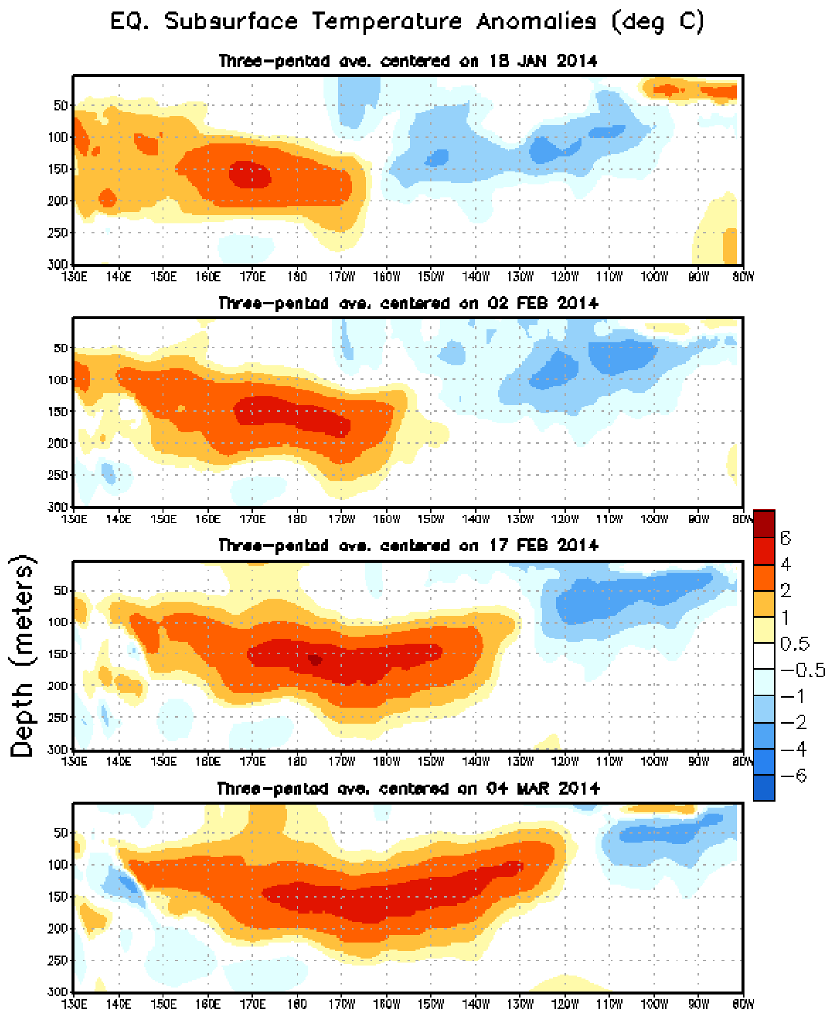

- Since then surface and subsurface tropical Pacific Ocean conditions started to be better recorded, helping to increase our knowledge about the El Niño-Southern Oscillation (ENSO) phenomenon – a major climate system driver – and its global impacts



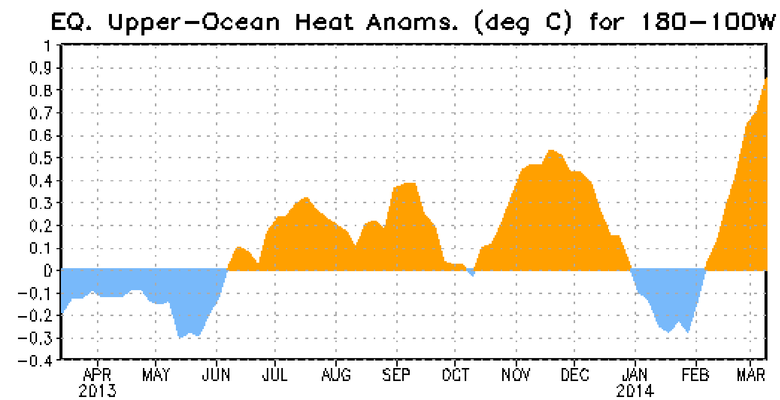
# Current Sub-Surface Temperature Conditions (ºC) in the Equatorial Pacific

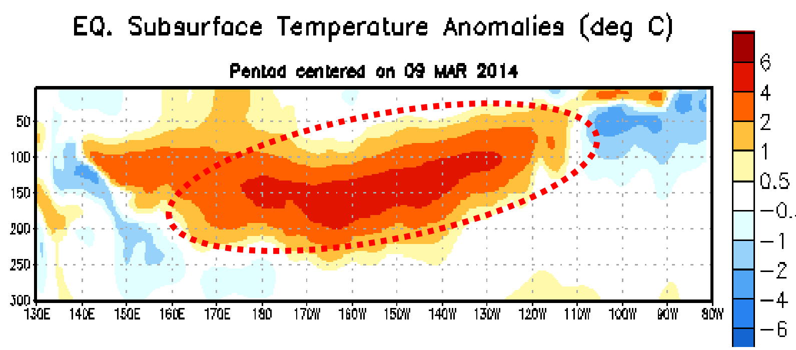
**Source: CPC/NOAA**

**Time**



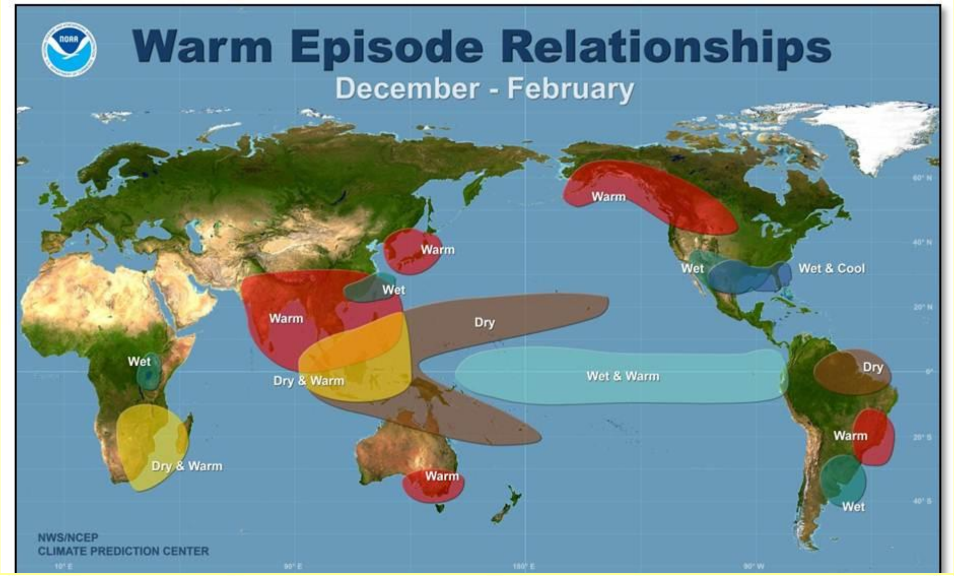

**Longitude**




**Most recent pentad analysis**

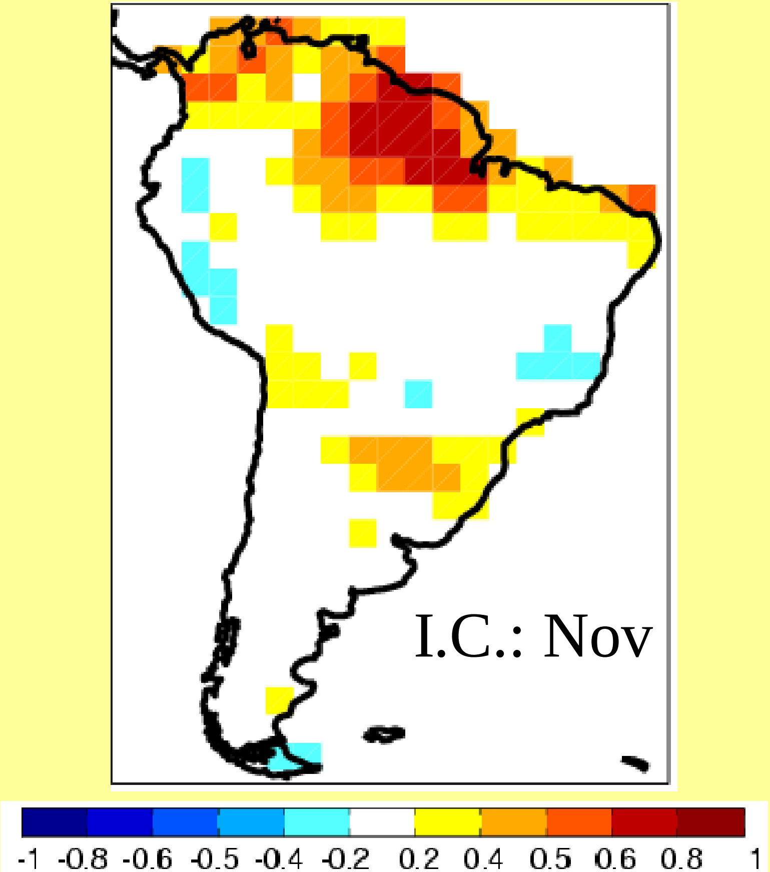
# Global ENOS impacts





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

Skill map
DJF precipitation
forecasts




Pos. values: moderate/good skill

# ENSO predictions with climate models

- Following the successful ENSO simulations in mid-eighties with Zebiak-Cane model, in the mid-nineties the first experimental climate predictions started to be produced with global dynamical coupled climate models

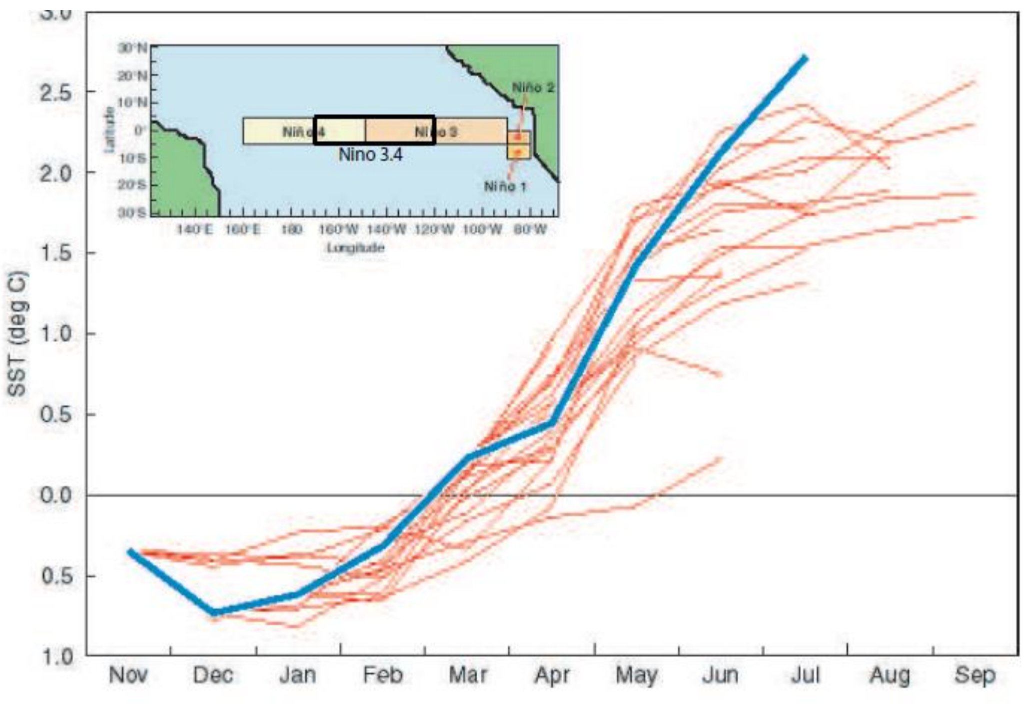
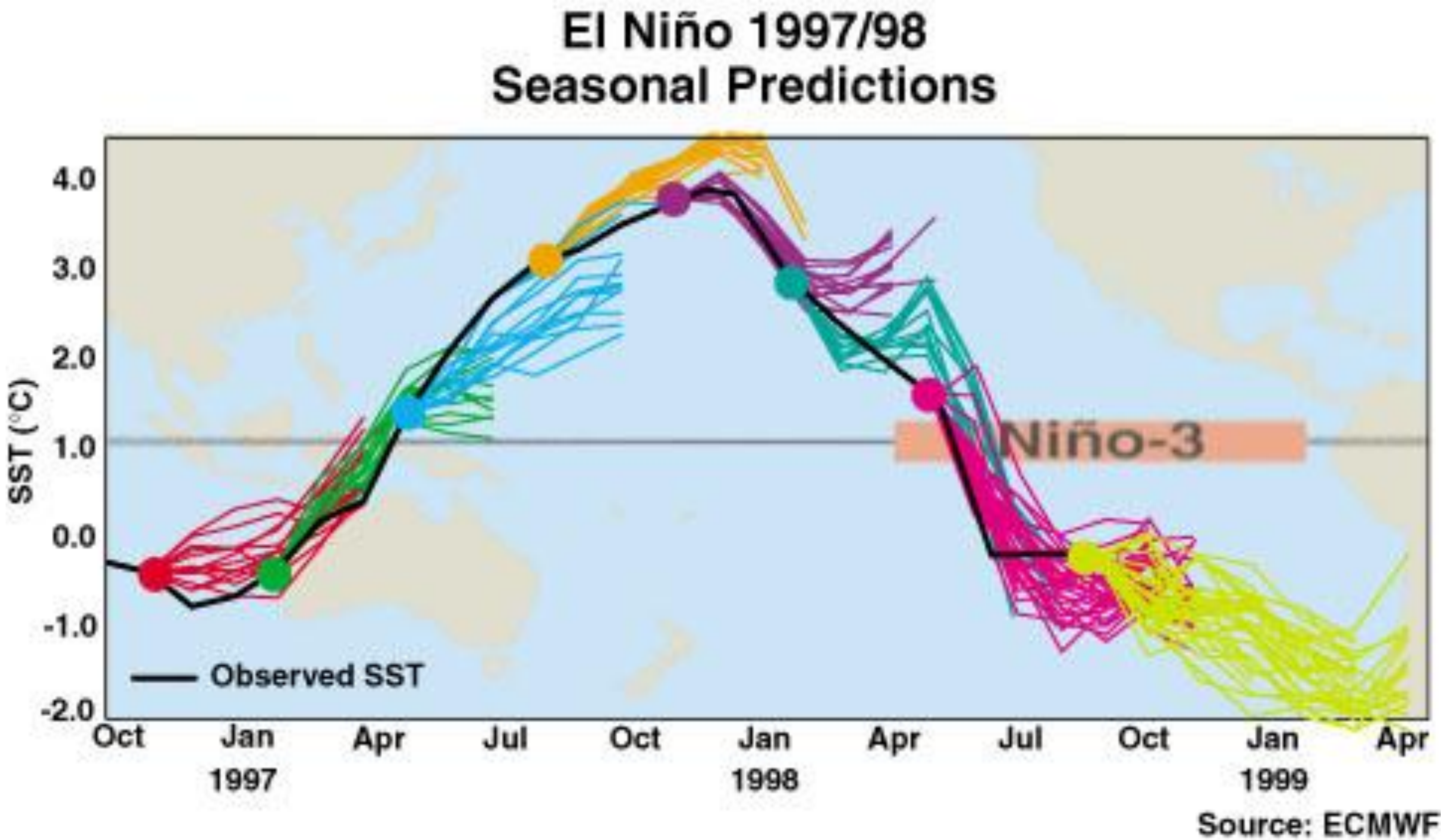



Figure 2.2: ECMWF coupled model Niño-3 SST anomaly forecasts (red plumes) made at weekly intervals from November 1996. Each forecast is for 6 months . The thick dark blue line shows the observed SST anomalies. See text for further information. Source: ECMWF web page (http://www.ecmwf.int, 2004).

# El Niño 1997/98 seasonal predictions



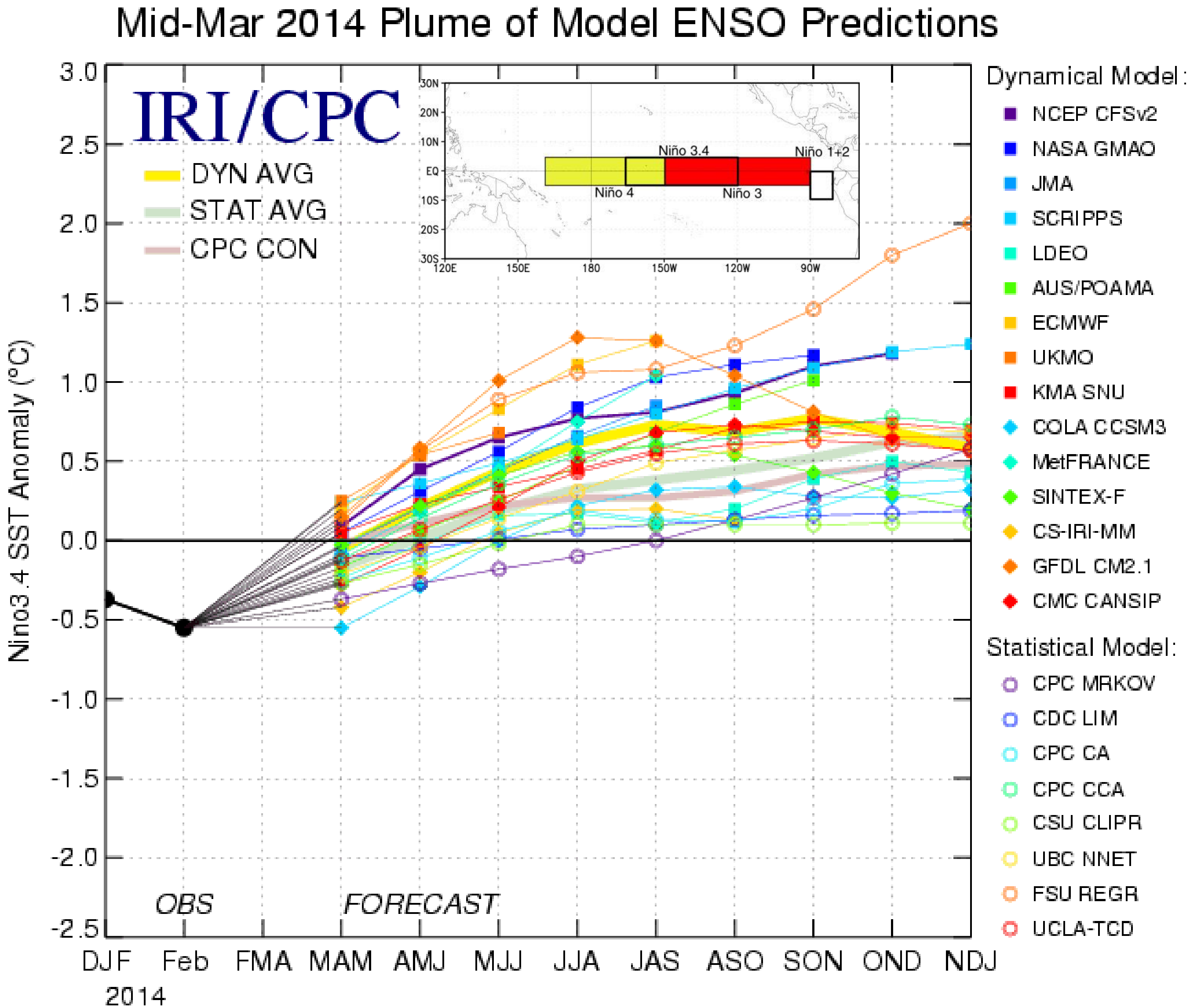

Seasonal climate model was able to predict the time evolution of the most intense El Niño event of 20th century

# Evolution towards multi-model ensemble systems

- During 80’s and 90’s several operational centers and research institutions developed different climate model versions

- Nowadays climate predictions for the forthcoming seasons are produced every month using multi-model ensemble systems

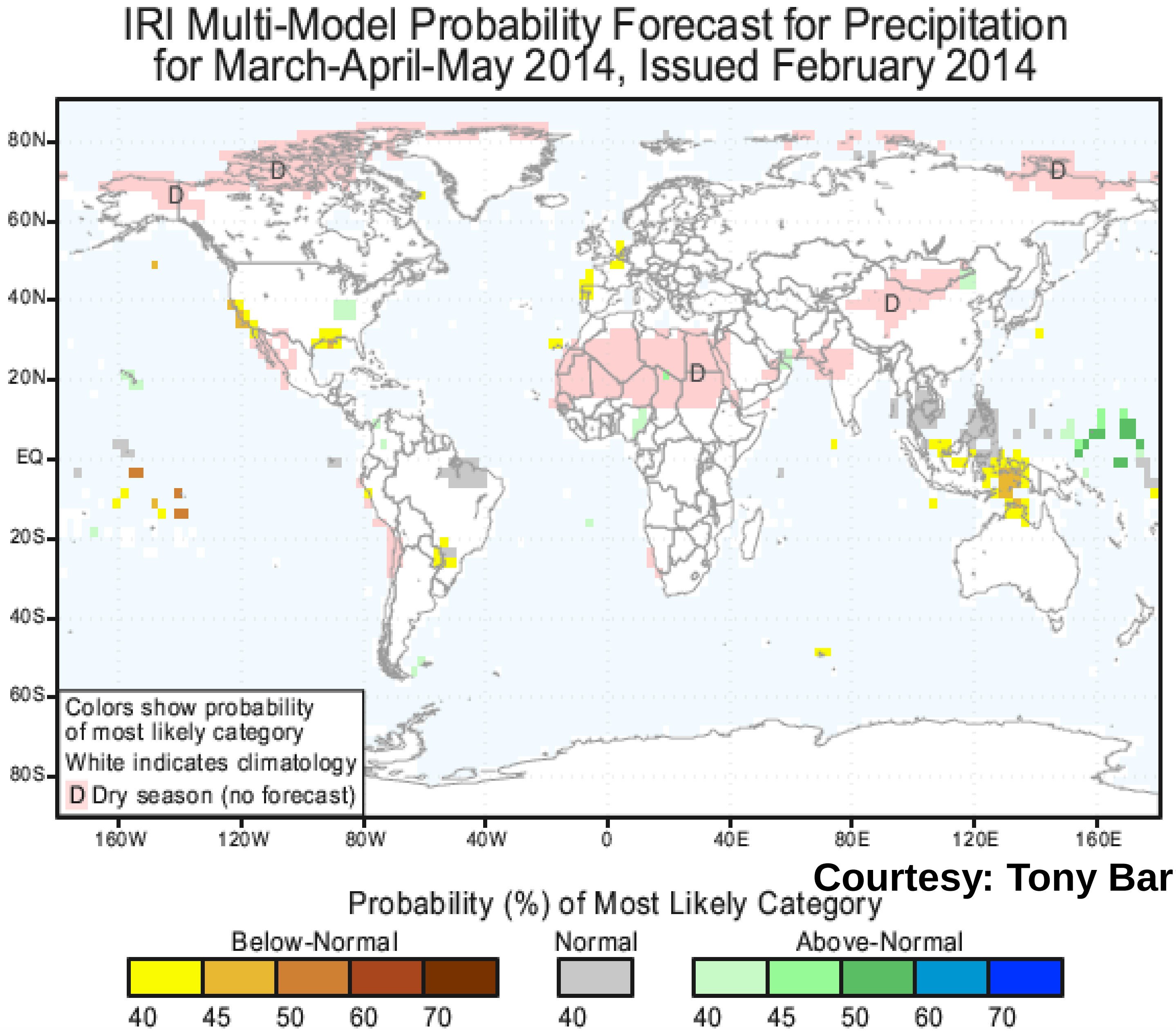
# Most recent multi-model ensemble Niño-3.4 predictions




**Courtesy: Tony Barnston (IRI)**

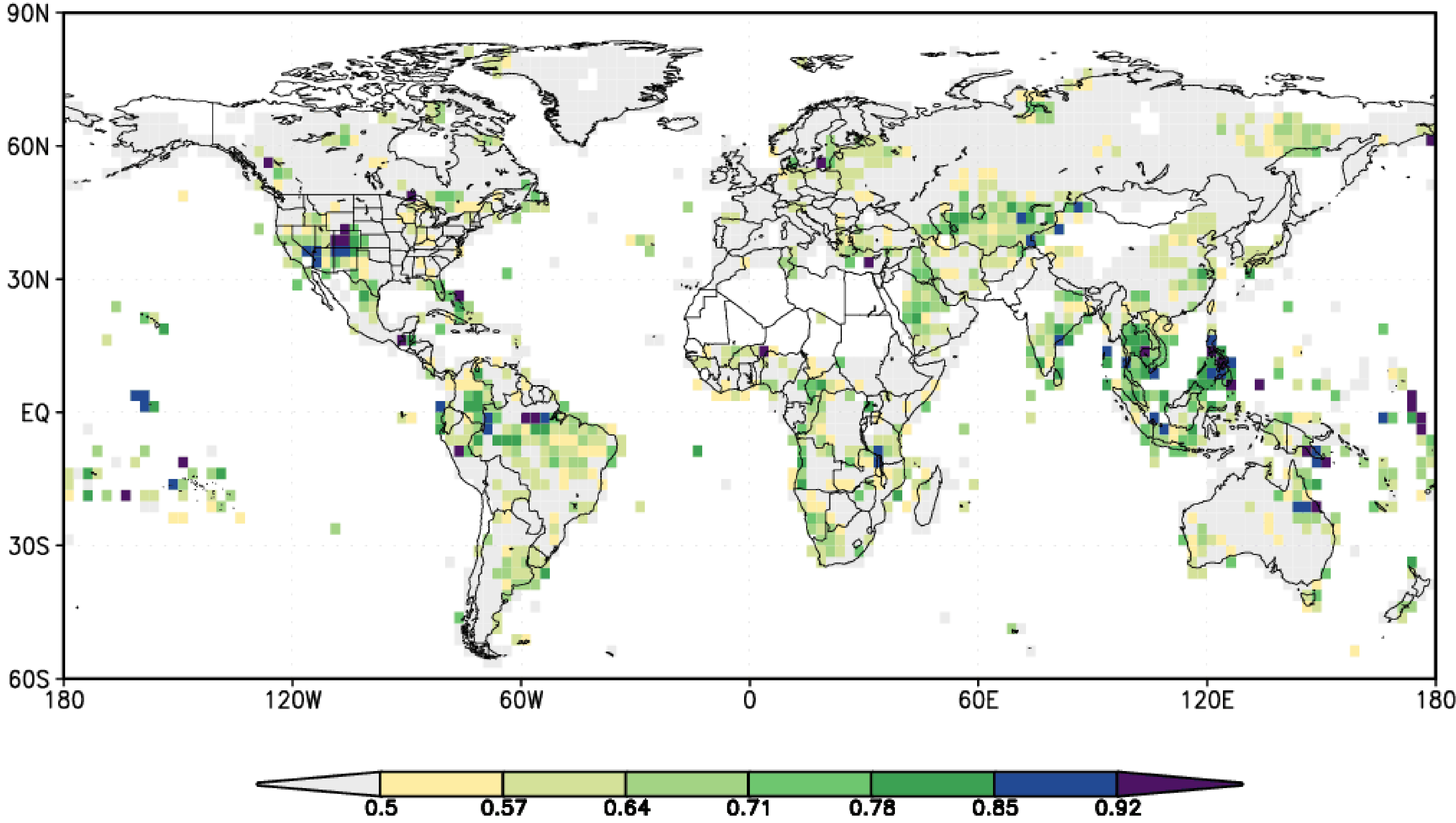
# Multi-model ensemble precip. seasonal prediction systems

# IRI multi-model global forecast system



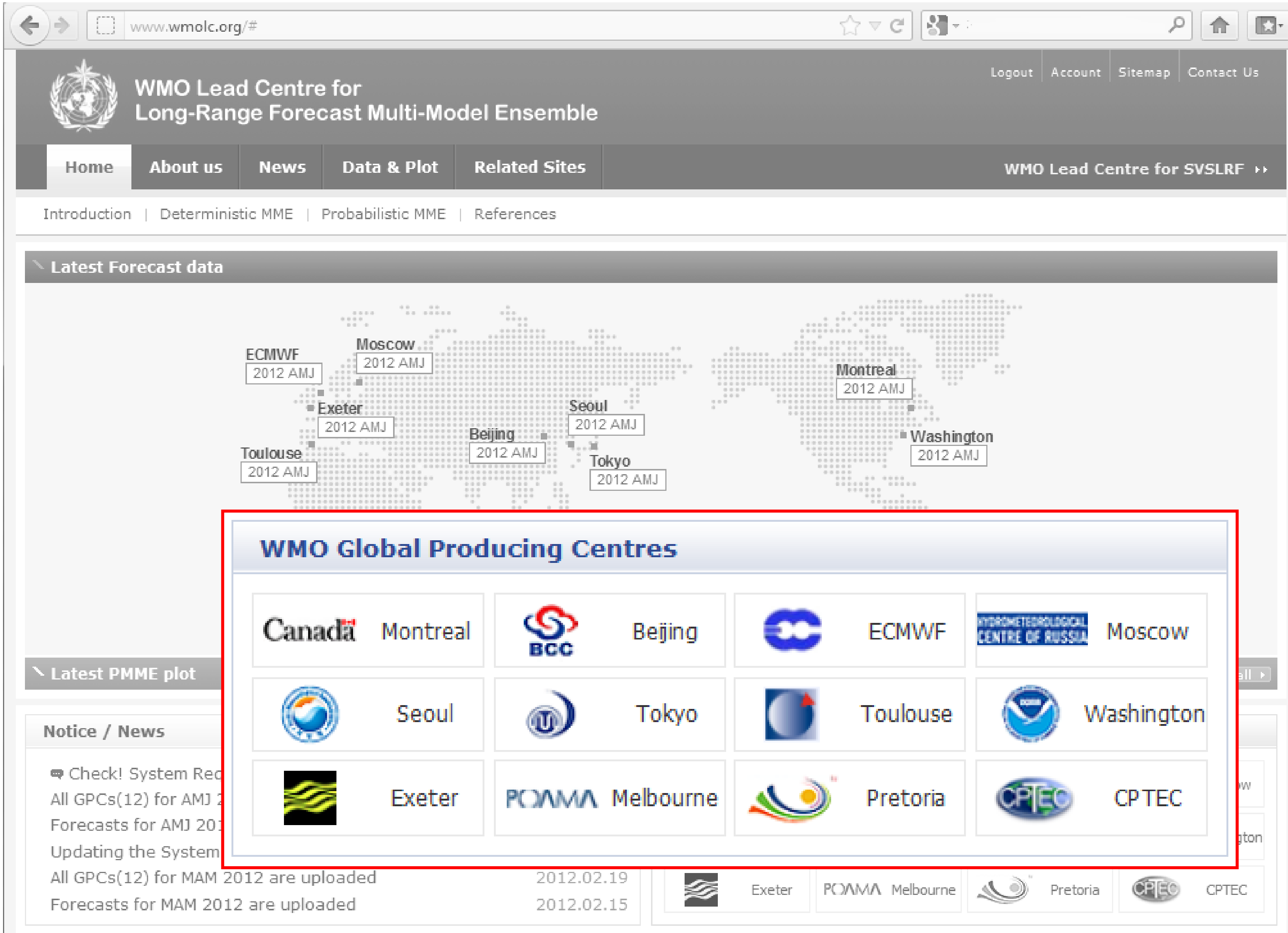

**Courtesy: Tony Barnston (IRI)**

# IRI multi-model system skill for MAM

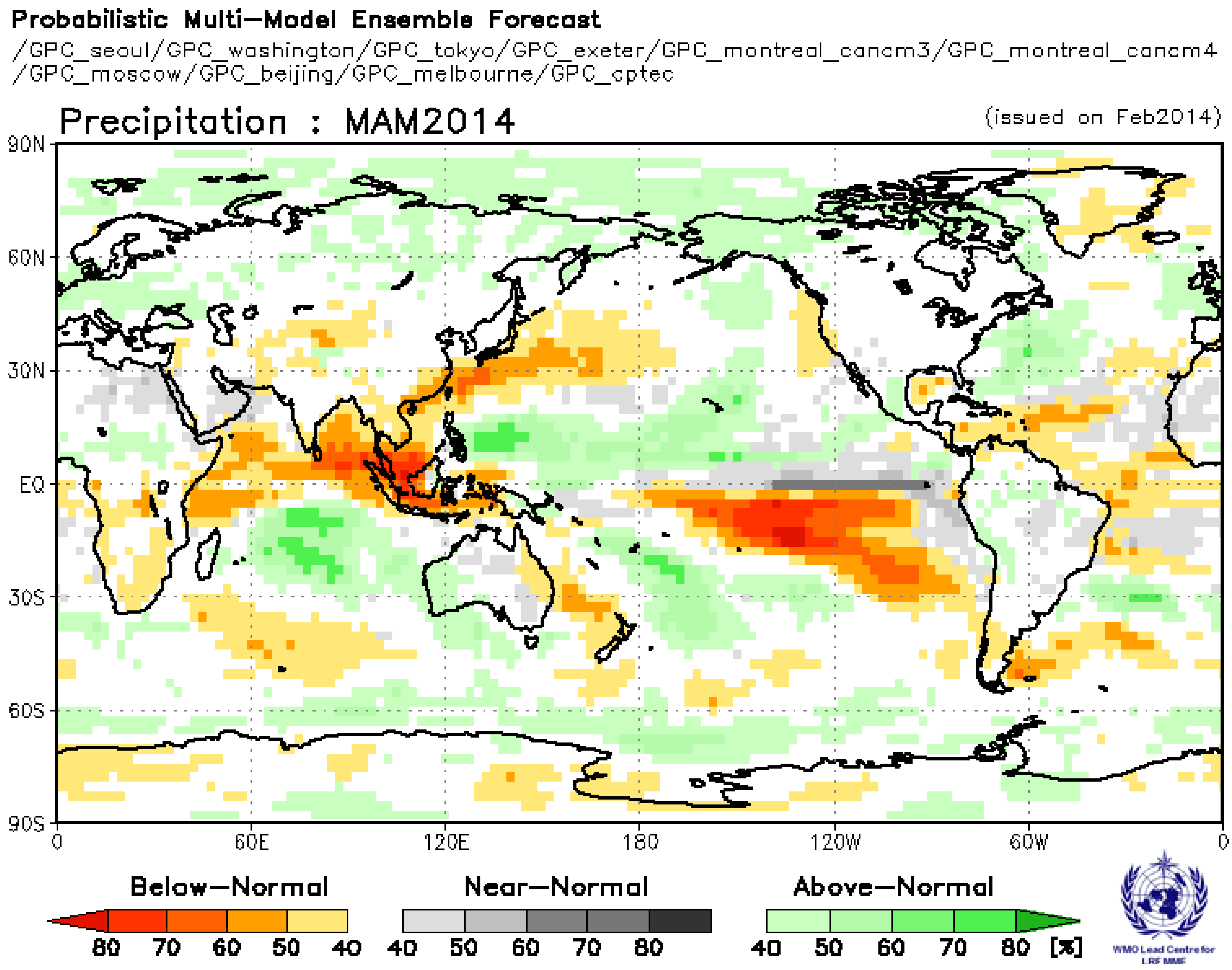


# WMO Lead Centre for Long-Range Forecast Multi-Model Ensemble

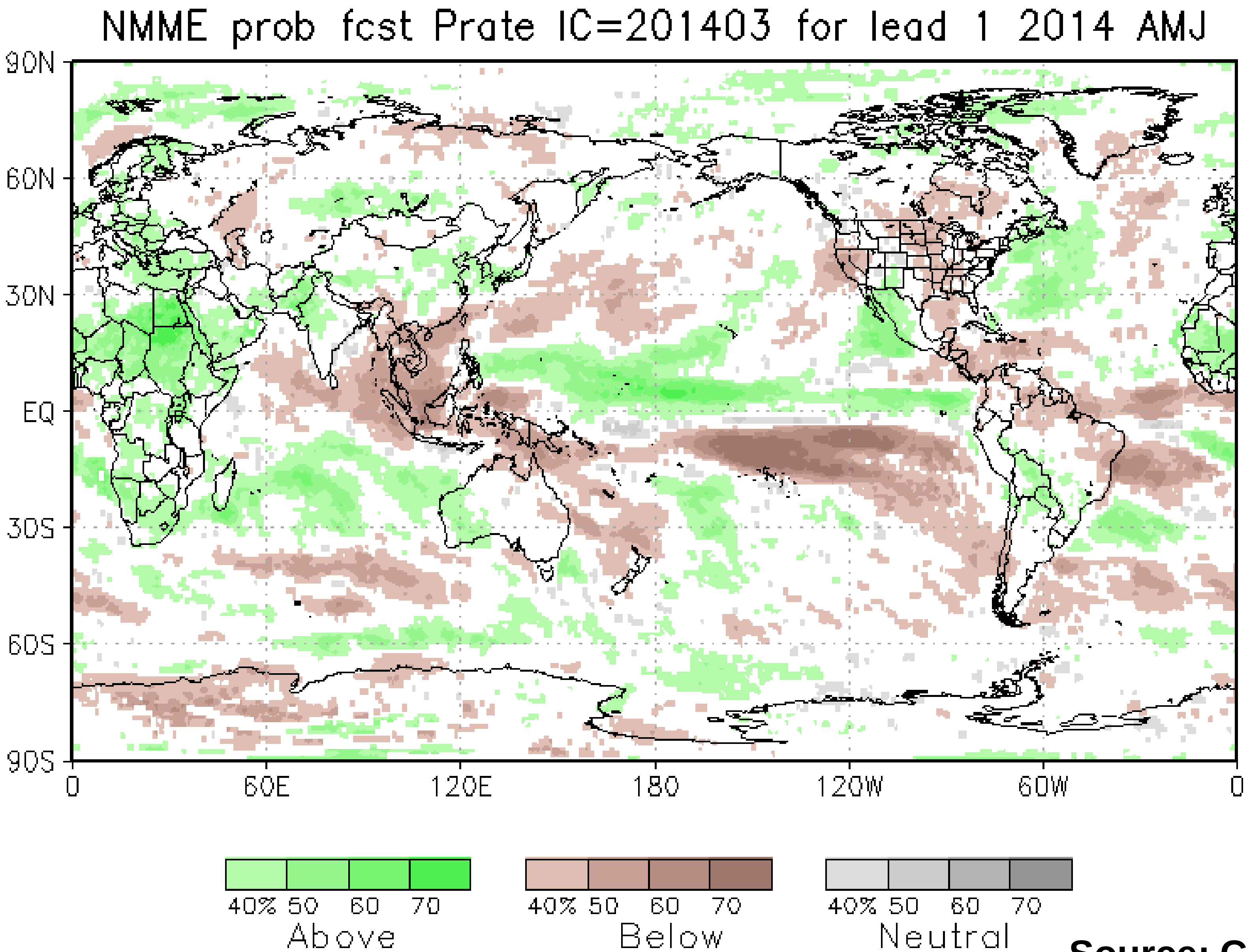
# 12 designated WMO Global Producing Centres (GPCs) of Long-Range forecasts



# WMO Multi-model ensemble probabilistic forecast



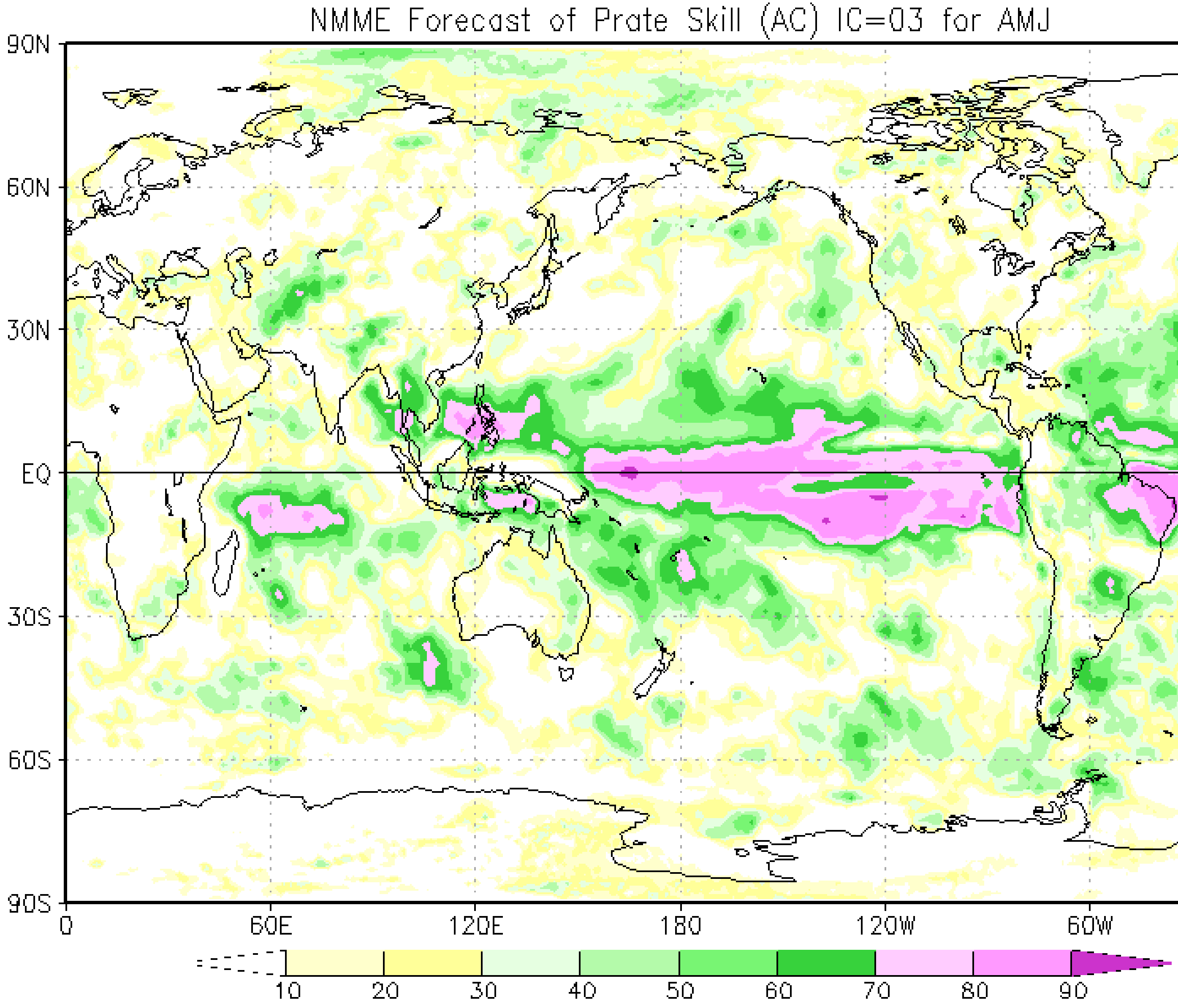
# North America Multi-Model Ensemble



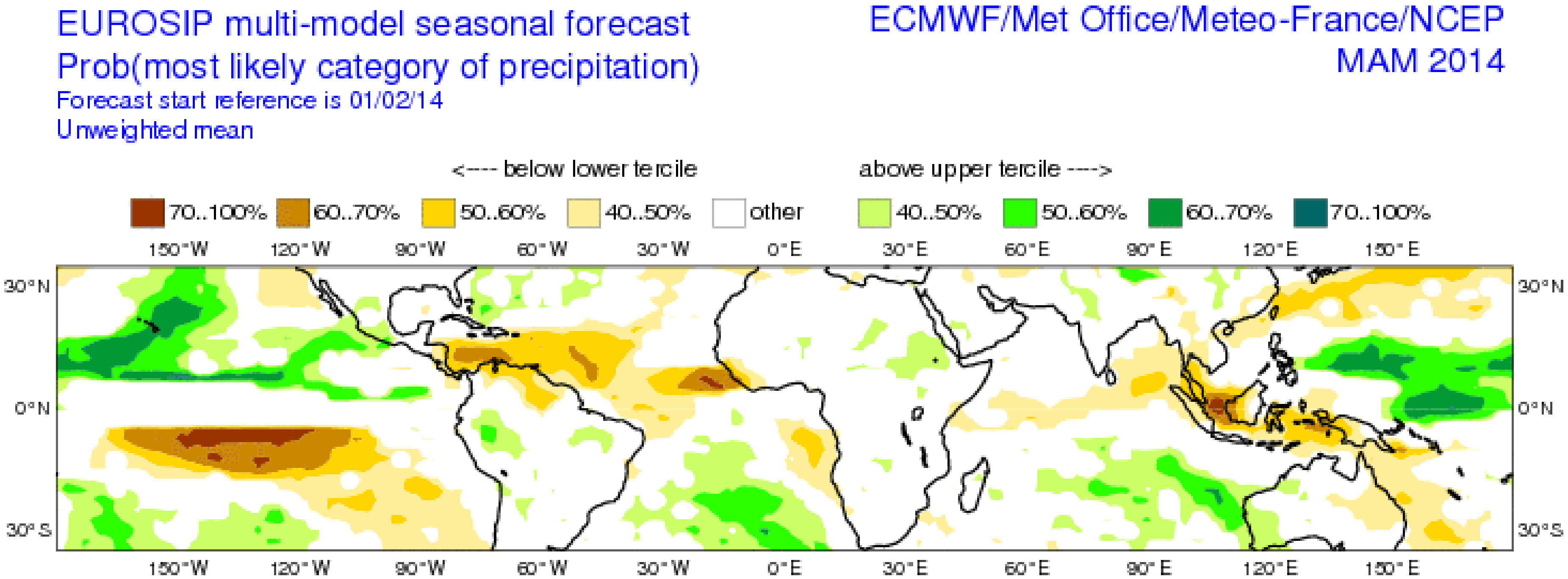

**CFS v2**
**CMC (2)**
**GFDL (3)**
**NASA**
**NCAR**

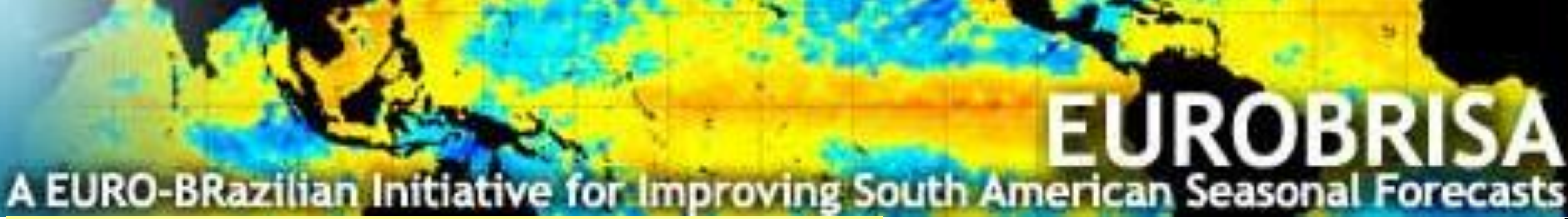
**Source: CPC/NOAA**

# North America Multi-Model Ensemble skill for AMJ



# EUROSIP Multi-Model System



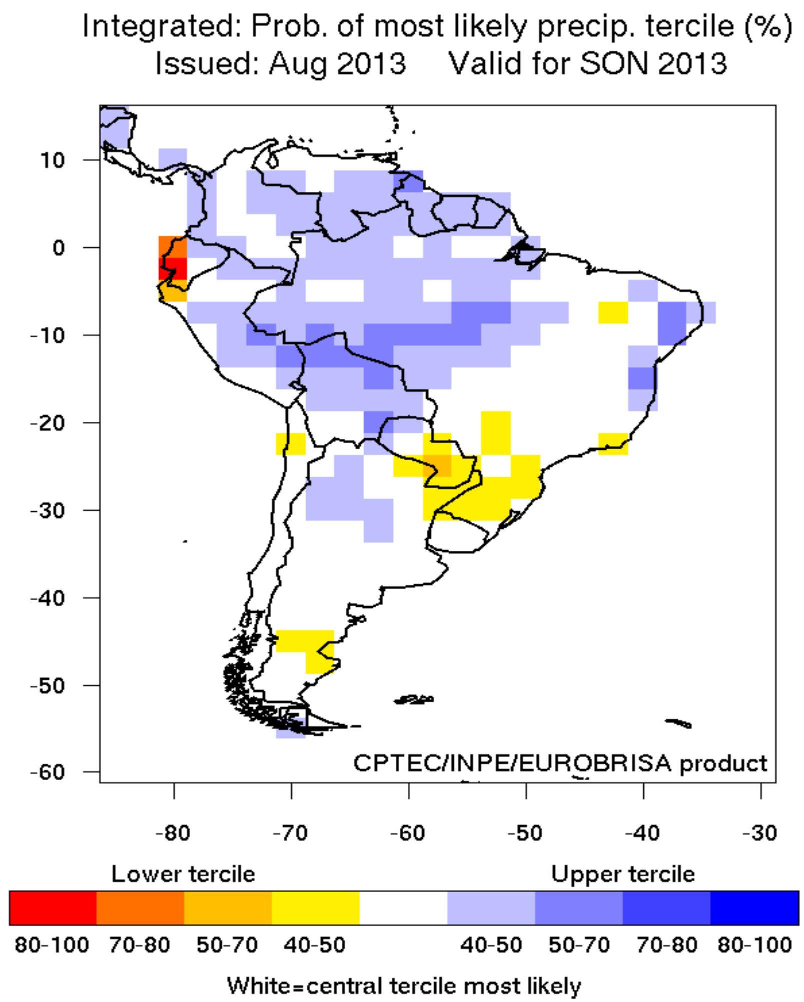



EUROBRISA Integrated (empirical-dynamical combined and calibrated) precipitation seasonal forecasting system for South America

Collaborative effort:
INPE/CPTEC, Univ. Exeter, ECMWF, UK Met Office, Météo-France, UFPR, USP and INMET

Previously supported by:
FAPESP   The Leverhulme Trust

Currently supported by: SPECS Seasonal-to-decadal climate Prediction for the improvement of European Climate Services




http://eurobrisa.cptec.inpe.br

Key idea: Why not combining all available state-of-the-art forecast information for improving seasonal forecasts in South America - a region where the forecasts have skill and useful value

# Updated 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 | International |
| UKMO GloSea 5 | U.K. **(NEW)** |
| Meteo-France Sys 4 | France **(NEW)** |

*Integrated forecast*

Updated empirical model **(NEW)**
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

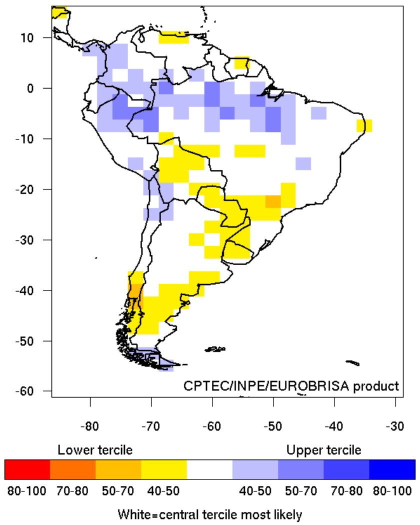
Hindcast period: 1981-2010

Implemented in Jul 2013

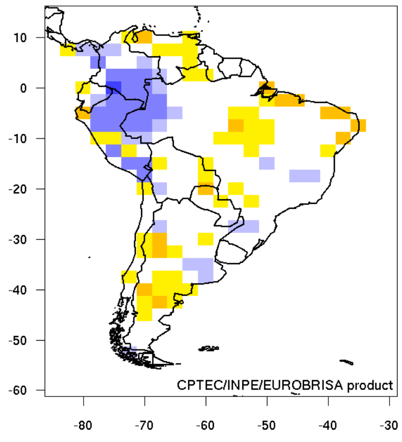
Both forecast and verification products available at http://eurobrisa.cptec.inpe.br

# EUROBRISA integrated fcst for MAM 2014 issued in February

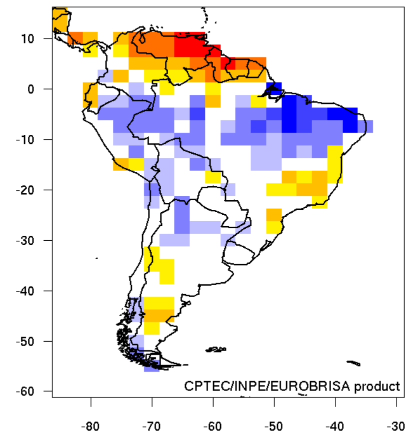
## Empirical



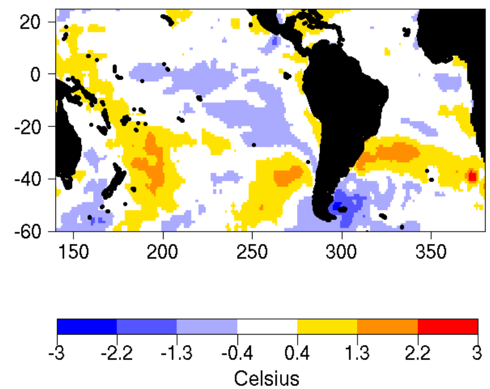

## ECMWF




## UKMO



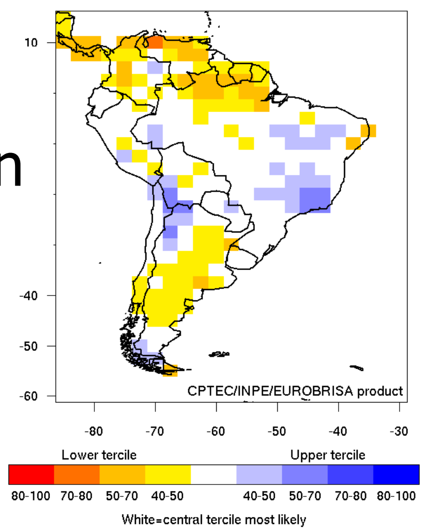

## Obs. SST anomaly Jan 2014



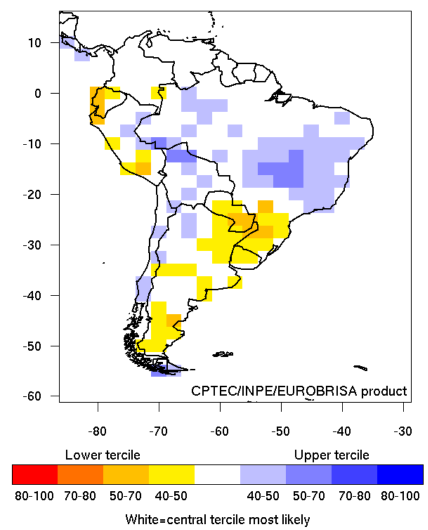

Prob. of most likely precipitation tercile (%)

Issued: Feb 2014

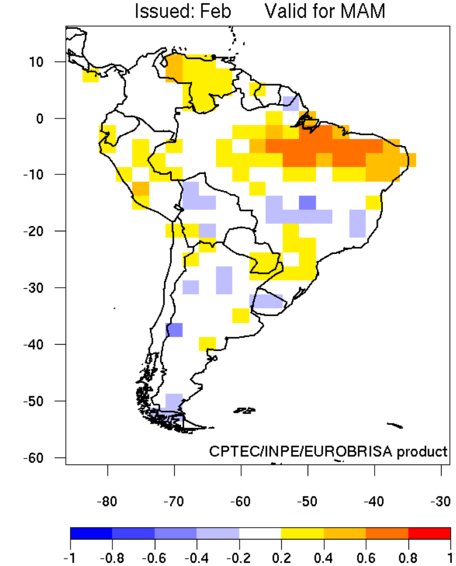
## Meteo-France




## Integrated



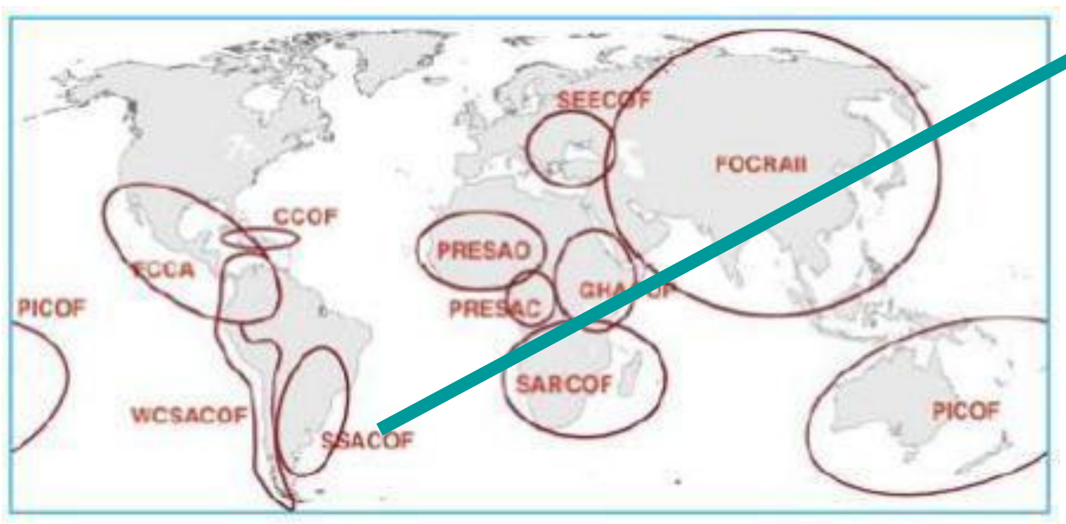

Gerrity Score (tercile categories)
Integrated: Precipitation (1981-2010)
Issued: Feb Valid for MAM

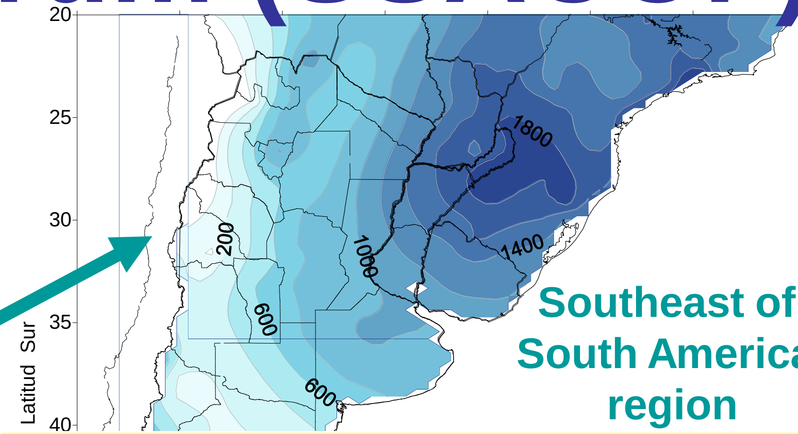


# Regional climate prediction activities

# Southeast of South America Climate Outlook Forum (SSACOF)

**Aim: Produce seasonal forecast for Southeast South America region for the upcoming season**

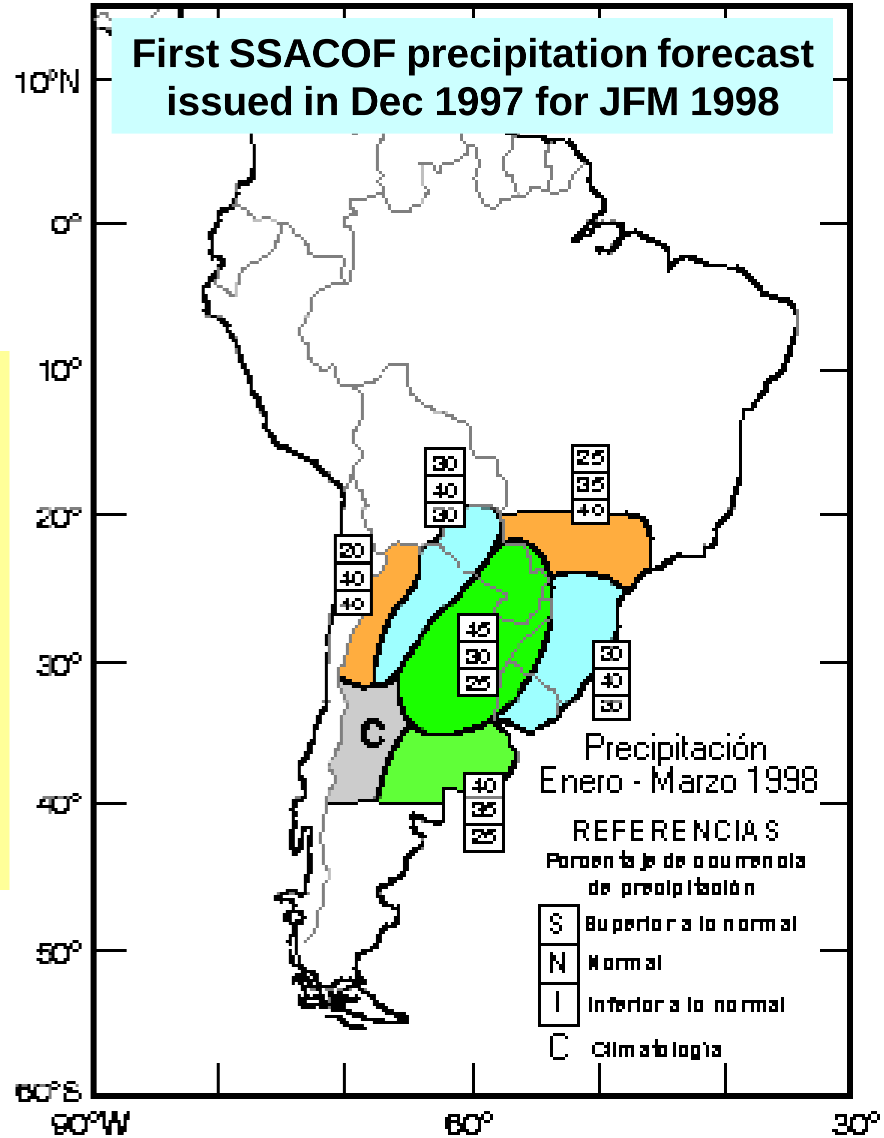



- Region between 20ºS and 40ºS east of Andes Mountains
- Main features:
  - La Plata Basin / Dams
  - One of main cereal and oilseed producing regions in the world

- In late 90’s WMO encouraged establishment of Regional Climate Outlook Forums (RCOFs)
- Both operational and research climate communities acquired important experience in terms of oceanic and atmospheric climate monitoring (at global and regional scales) and seasonal forecasting practice

# Brief history of SSACOF




- SSACOF started in December 1997.
  First forum was held in Montevideo, Uruguay
- A total of 36 forums have been organized by Argentina, Brazil, Uruguay and Paraguay (9 in each country)
- Experts from the National Meteorological Services, Universities and other institutes from these 4 countries participated

Predictions are of probabilistic nature in recognition of the uncertainties involved in their formulation process

# SSACOF methodology

- Component 1: Global and regional climate **diagnostics** of previous months including ENSO status (ENSO quick look - IRI, ENSO diagnostic discussion - CPC/NOAA, Wrap up BOM/Australia)

- Component 2: **Forecasting tools** including Niño plumes, sea surface temperature, precipitation and near surface temperature [Statistical (~30%) and dynamical (~70%) models]

- After all presentations including diagnostic and forecasts, all participants contribute to the final discussion for elaborating the upcoming seasonal forecast by **consensus agreement** among climate experts attending the COF

- **The forecast is expressed in 3 categories** (terciles probabilities) for both temperature and precipitation

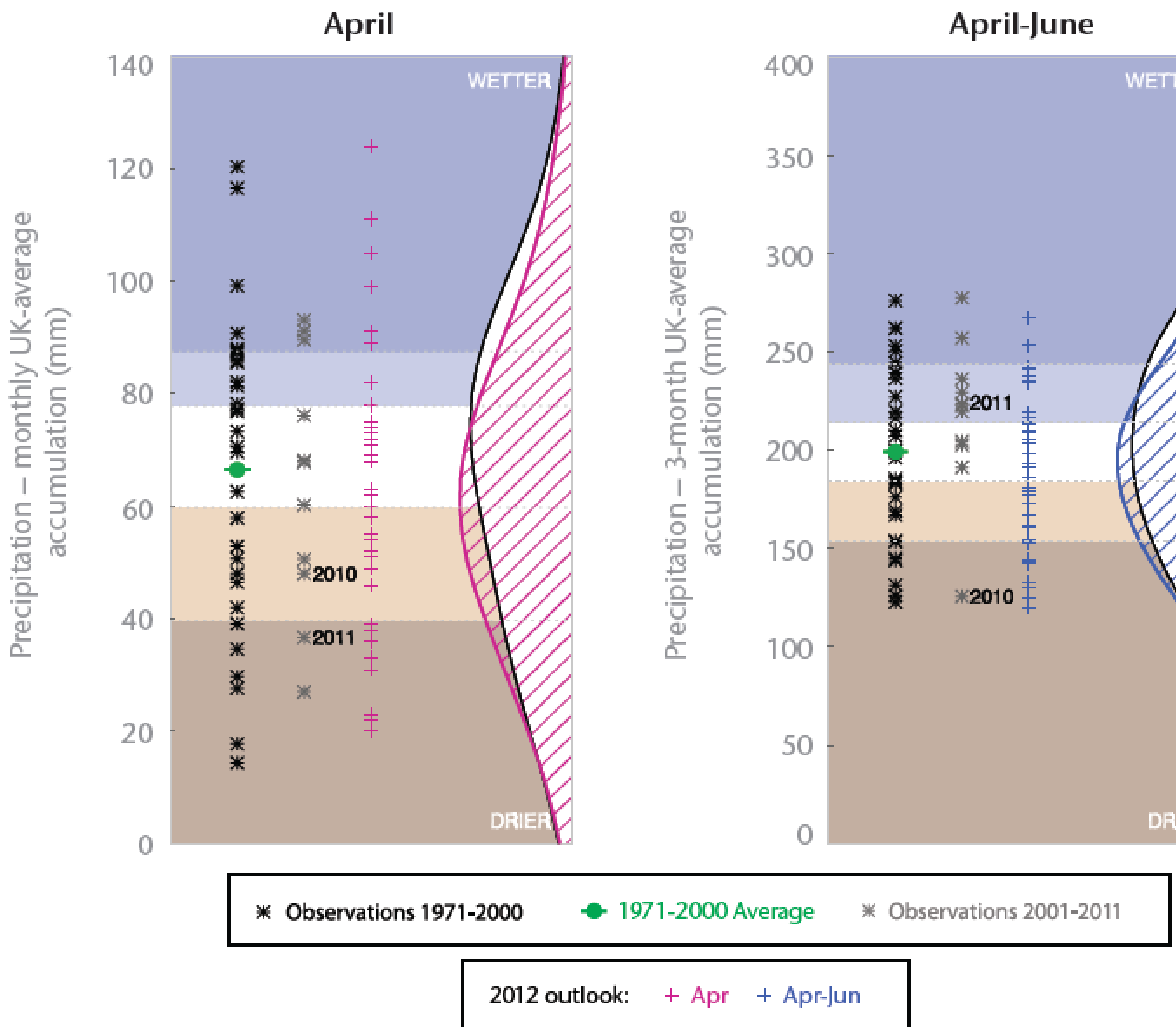
- **Probabilities are assigned subjectively**. The most likely category is generally less than 45%

# Advances in seasonal forecast practice

- Current scientific knowledge allows use of modern techniques for issuing seasonal forecasts using multi-model ensemble systems, sometimes aggregating dynamical and empirical (statistical) predictions
- Use of a set of several models rather than a single model allows sampling uncertainty due to different model formulations
- By running each model with a distinct set of initial conditions it is possible to sample uncertainties in the used initial conditions
- By producing retrospective seasonal forecasts for each forecasting system for a number of years (~ last two to three decades) it is possible to access the ability of these systems to reproduce the observed seasonal climate (i.e. the skill of these forecasting systems)
- When a new multi-model ensemble forecast is produced for a future season these retrospective forecasts are then used to calibrate the new forecast taking into account the retrospective performance of the multi-model ensemble system when compared to the observed climate
- Mathematical models/procedures are currently available for this calibration purpose for generating numerically probabilistic seasonal forecasts

# Examples of modern seasonal forecast practice

# 1- month and 3-month UK precipitation outlook in the context of the observed climatology




**Source: UK Met Office**

# Canada

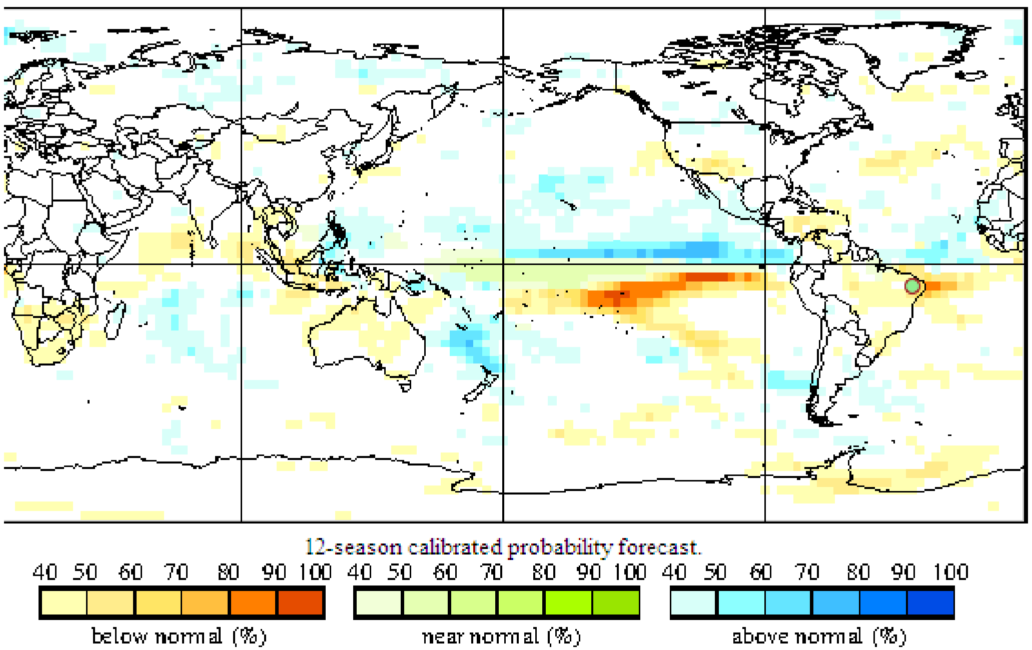
CMC/CCCma (Environment Canada) CanSIPS Experimental Seasonal Forecasts/Hindcasts

CanSIPS forecasts issued daily (contact: slava.kharin@ec.gc.ca)

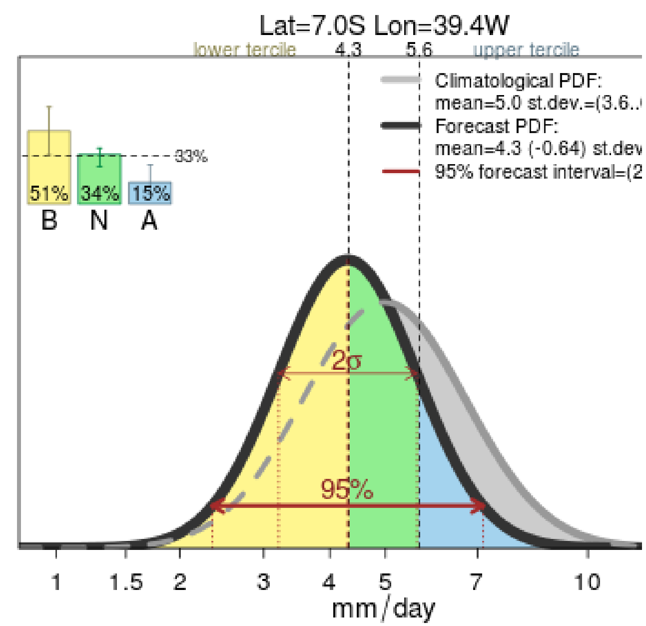
| Variable | Time avg. | Time lead | Prev./Next | | First year/month | | Version |
|---|---|---|---|---|---|---|---|
| Precip.(gamma) | Seasonal | 1-month | << | >> | 2014 | Jan | cmc(d+e) |

| Region | Forecast Type | Observ. Type | Show PDF/Obs. | Calibration/Observations | |
|---|---|---|---|---|---|
| Globe(0..360) | Probabilistic | N/A | Show PDF | Calibrated(constant) | gpcp22 |

Precip.(gamma), 3-category Probabilistic Forecast
year=2014, FMA, 1-month lead

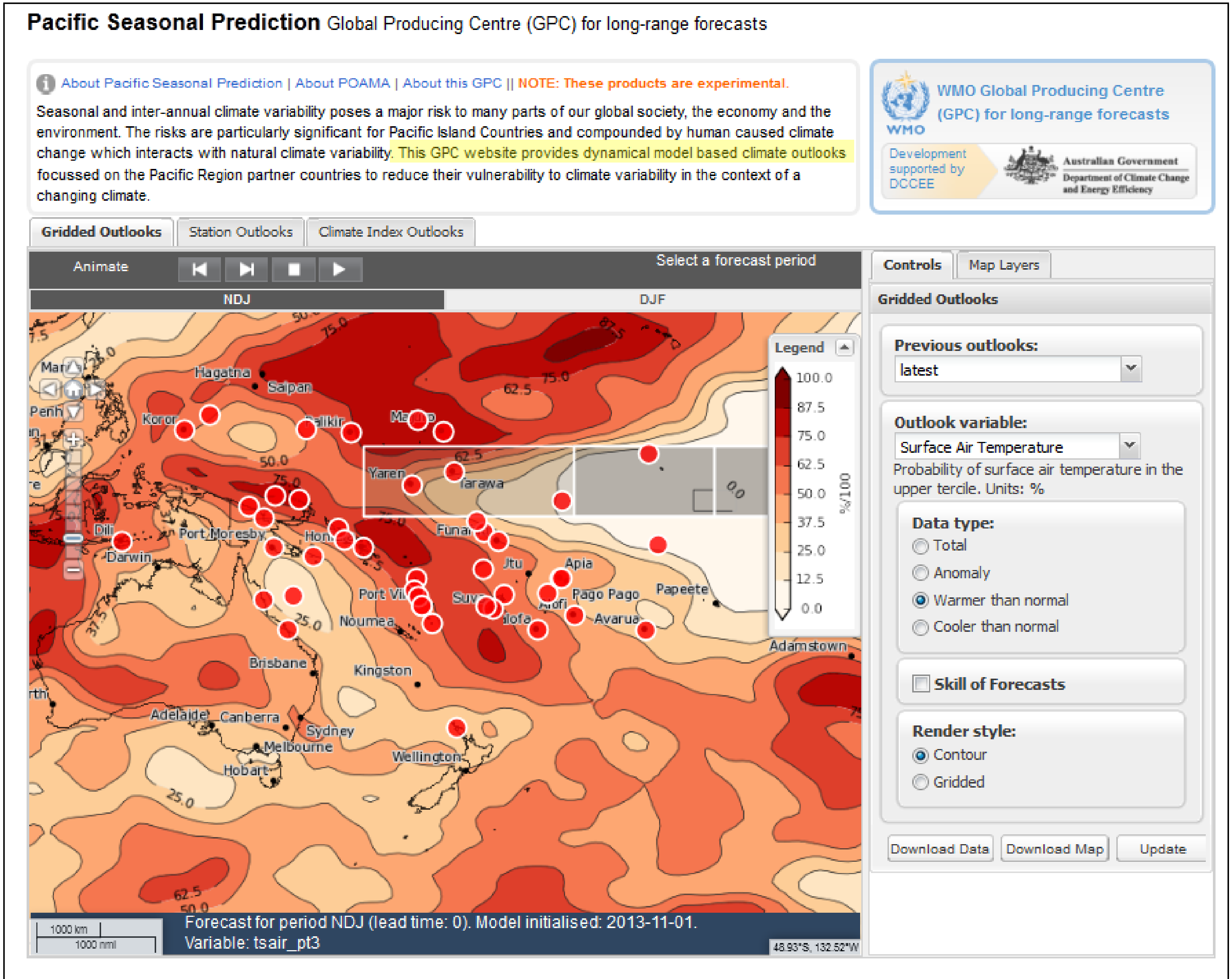



Local probability forecast

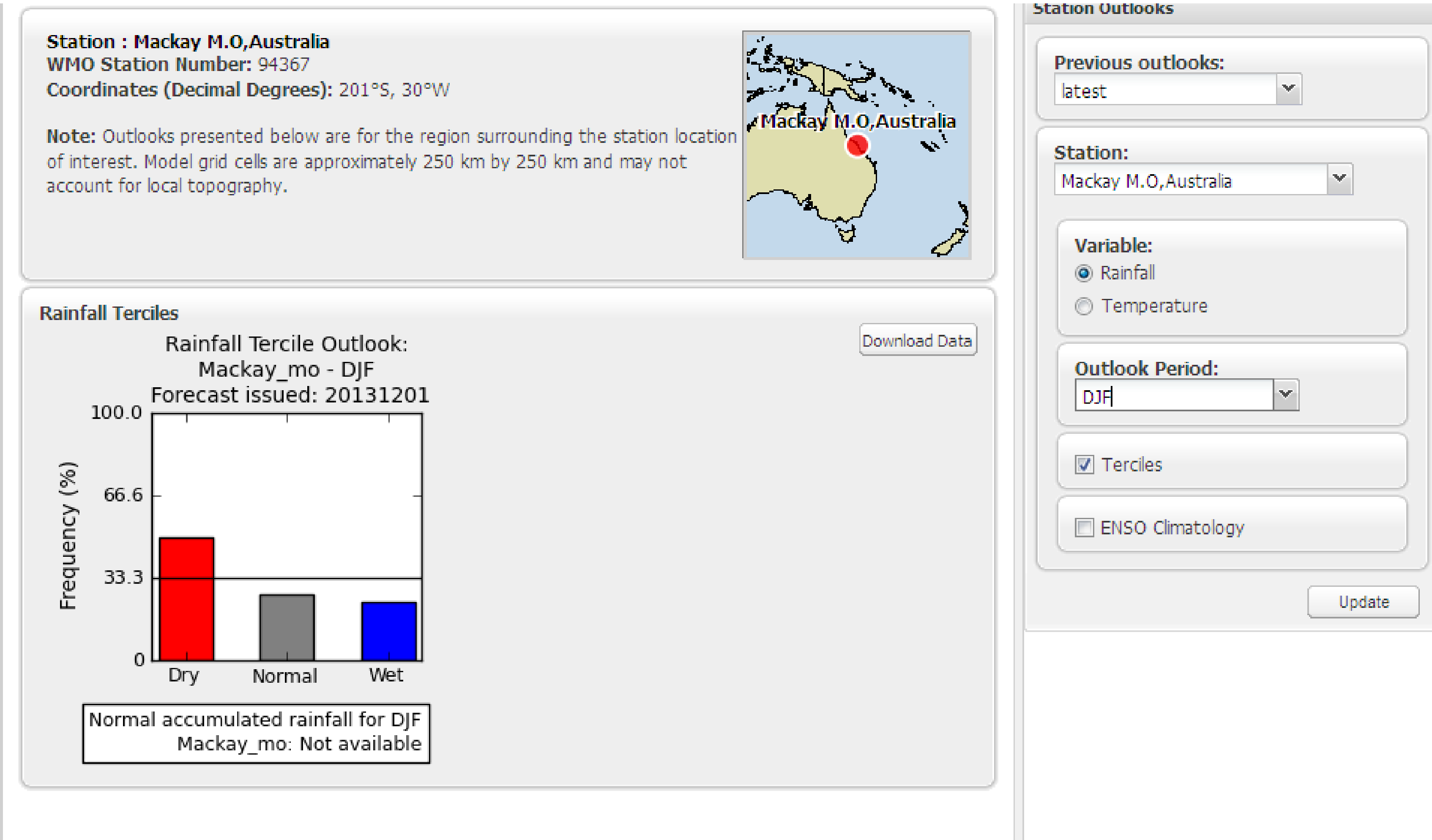



**Probabilistic forecast produced from an ensemble of 2 coupled models**

# Australian coast and Pacific Islands



# Australian coast



# Brazilian multi-model seasonal forecast system

**CPTEC/AGCM:**
Boundary conditions: persisted and predicted SST anomalies
Convective parameterization schemes: Kuo, RAS, Grell
90 ensemble members

**CPT/IRI:**
Predictors (SST, Geopotential 500hPa, vertical velocity 850 hPa)
**Time series models:**
Holt-Winters
Arima

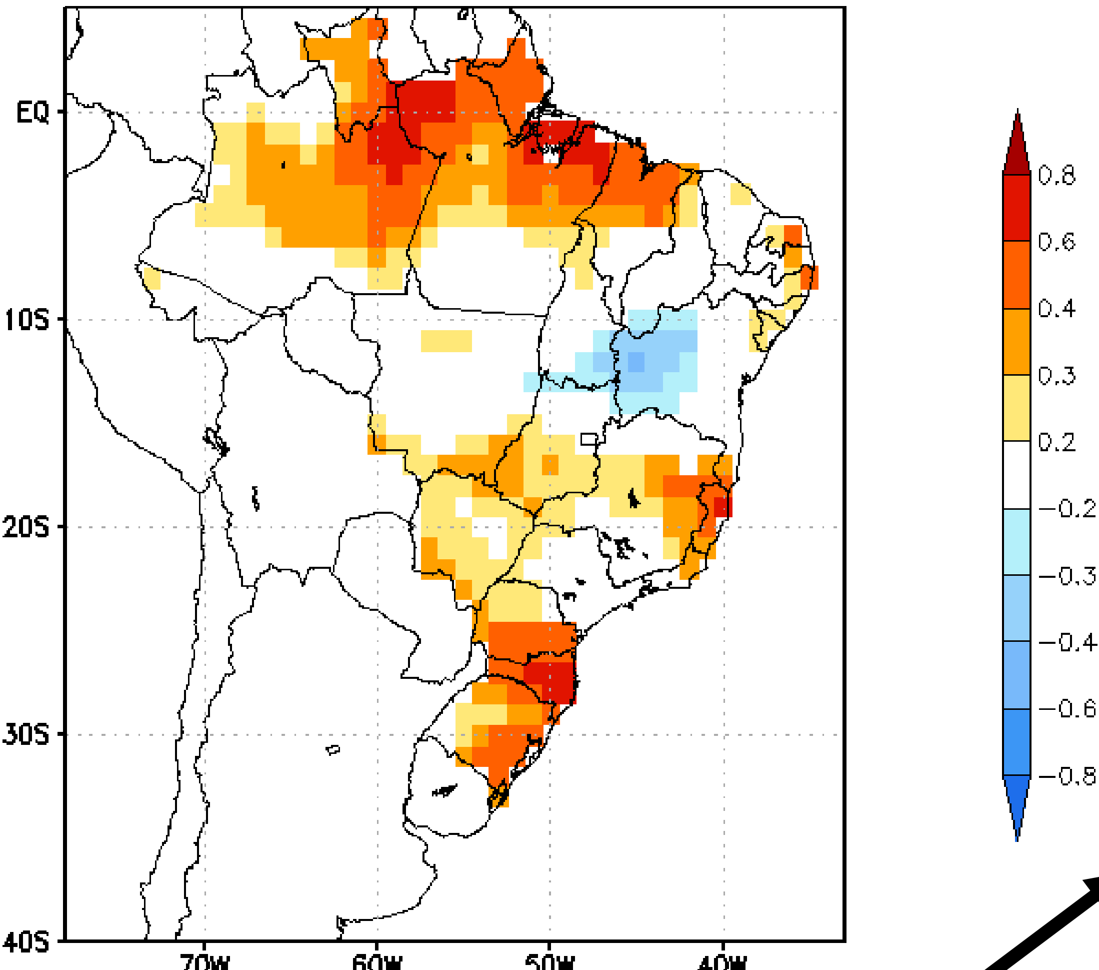
**ECHAM4.6/AGCM:**
Boundary conditions: persisted SST anomalies
20 ensemble members

All models produced retrospective forecasts (hindcasts) for the period 1989-2008 using exactly the same procedure used in real-time forecasting

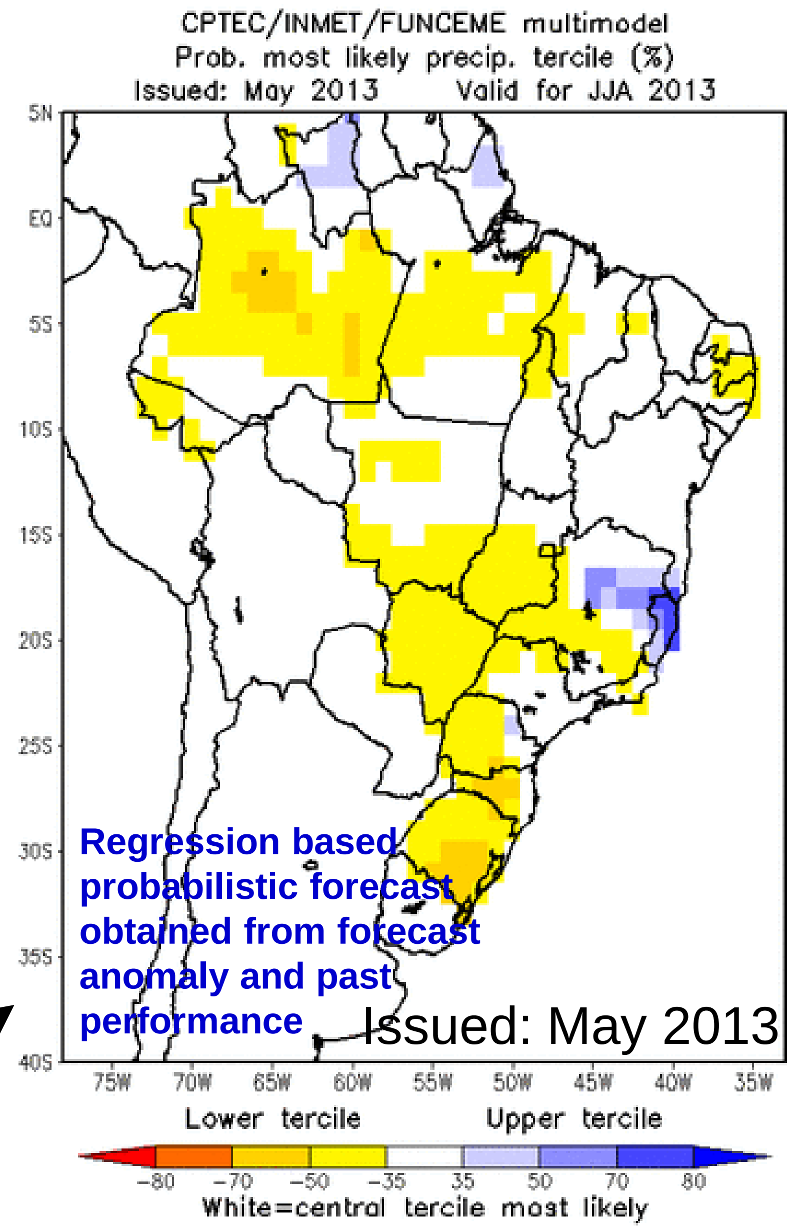
Joint effort: CPTEC/INPE, INMET and FUNCEME

# CPTEC/INMET/FUNCEME
# Multi-model probabilistic forecast

**Precipitation anomaly forecast skill: 1989-2008 correlation**




Forecast probabilities determined objectively




Regression based probabilistic forecast obtained from forecast anomaly and past performance

Issued: May 2013

# The need for improved practices in climate monitoring and prediction

Despite important advances in climate monitoring and prediction activities over the years there is still scope for improvements

Research areas in need of priority:

**1) Monitoring and prediction of sub-seasonal climate events** of great relevance for a number of application sector (e.g. water resources and agriculture) are in early development stages

- E.g. monitoring and prediction of a) onset and demise dates of rainy seasons in monsoon regions, b) wet and dry spells duration, and c) the number of wet and dry days within a given season

- There is therefore scope for advancing the research for creating new monitoring and prediction tools for generating sub-seasonal climate information. Investigation of past observed records can help answer a number of questions.

# Rainy season monitoring

Ministério da Ciência e Tecnologia

CENTRO DE PREVISÃO DE TEMPO E ESTUDOS CLIMÁTICOS

Buscar:

| Tempo | Clima | Previsão Numérica | Assimilação de Dados | Satélite | Ondas | Energia | Dados Obs. | Qualidade do Ar | Mudanças Climáticas | P & D

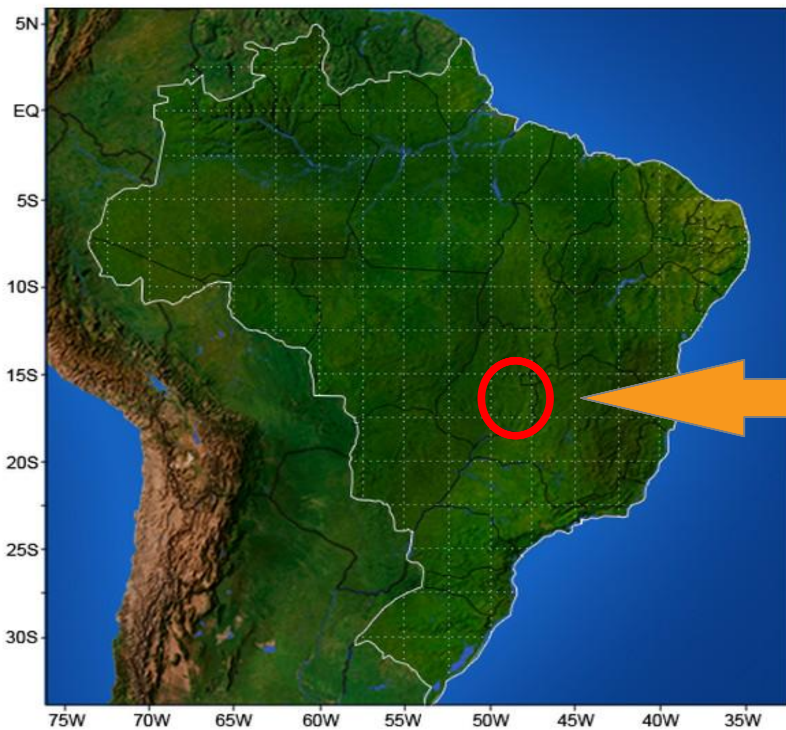
Quarta-Feira
04 Setembro 2013
12:05:46 AM

Previsão Climática

BOLETINS — Escolha uma opção

**ESTAÇÃO CHUVOSA**

Clique sobre a região de interesse




**MOTIVAÇÃO**

O conhecimento prévio das características da estação chuvosa (por exemplo, a estimativa de quando a mesma terá seu início, fim e consequentemente sua duração) em uma determinada região é uma demanda importante da sociedade, visto que diversos setores tais como o agrícola, o energético, os de segurança e saúde pública, entre outros, necessitam dessas informações para seus planejamentos.

Os produtos dessa página visam suprir parte dessa demanda através da disponibilização de gráficos construídos para facilitar o monitoramento das características da estação chuvosa para o Brasil, incluindo curvas de precipitação diária acumulada e distribuições de probabilidade das datas de início e final da estação chuvosa.

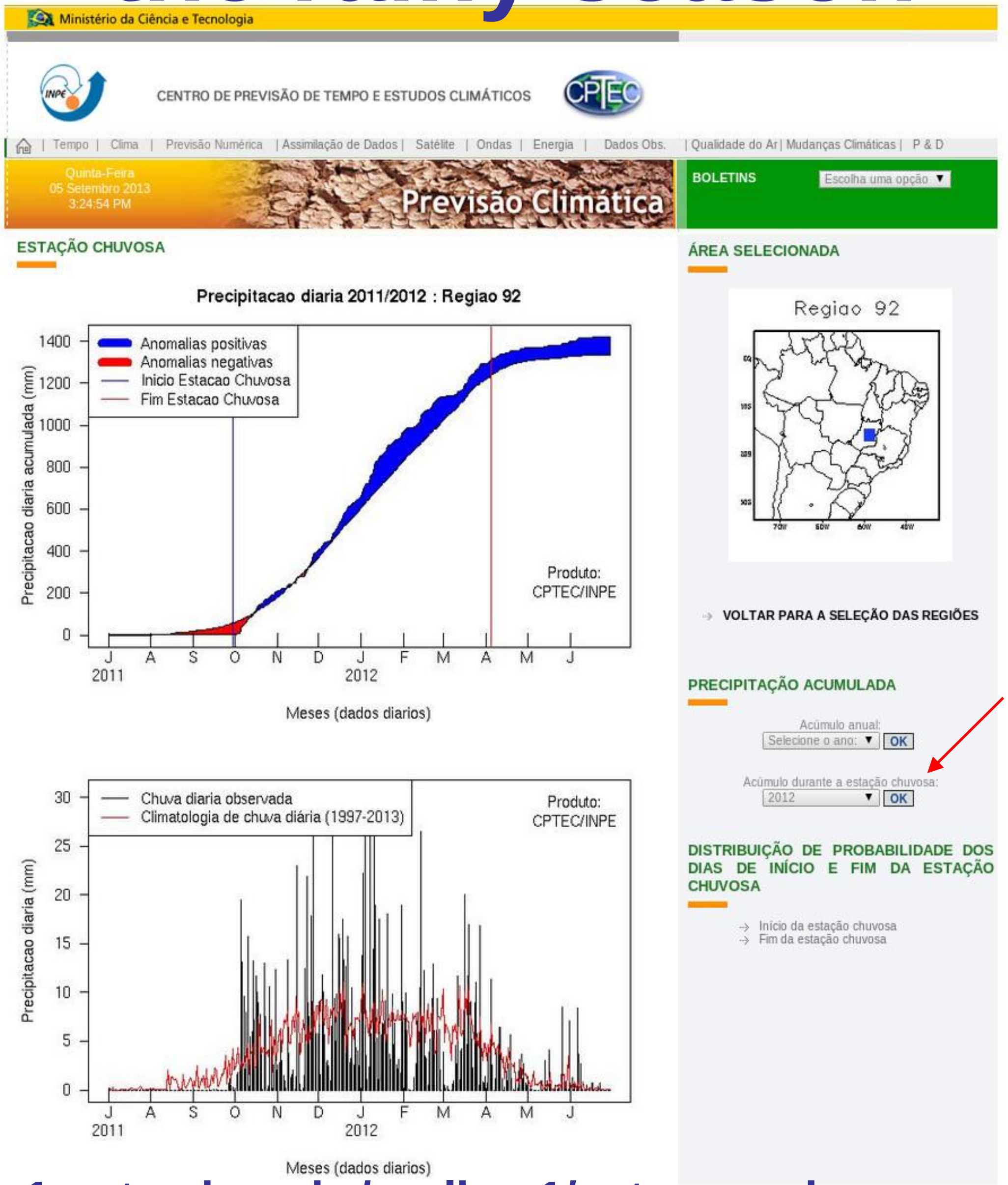
**DOCUMENTAÇÃO**

→ Descrição de produtos

**124 boxes over Brazil**

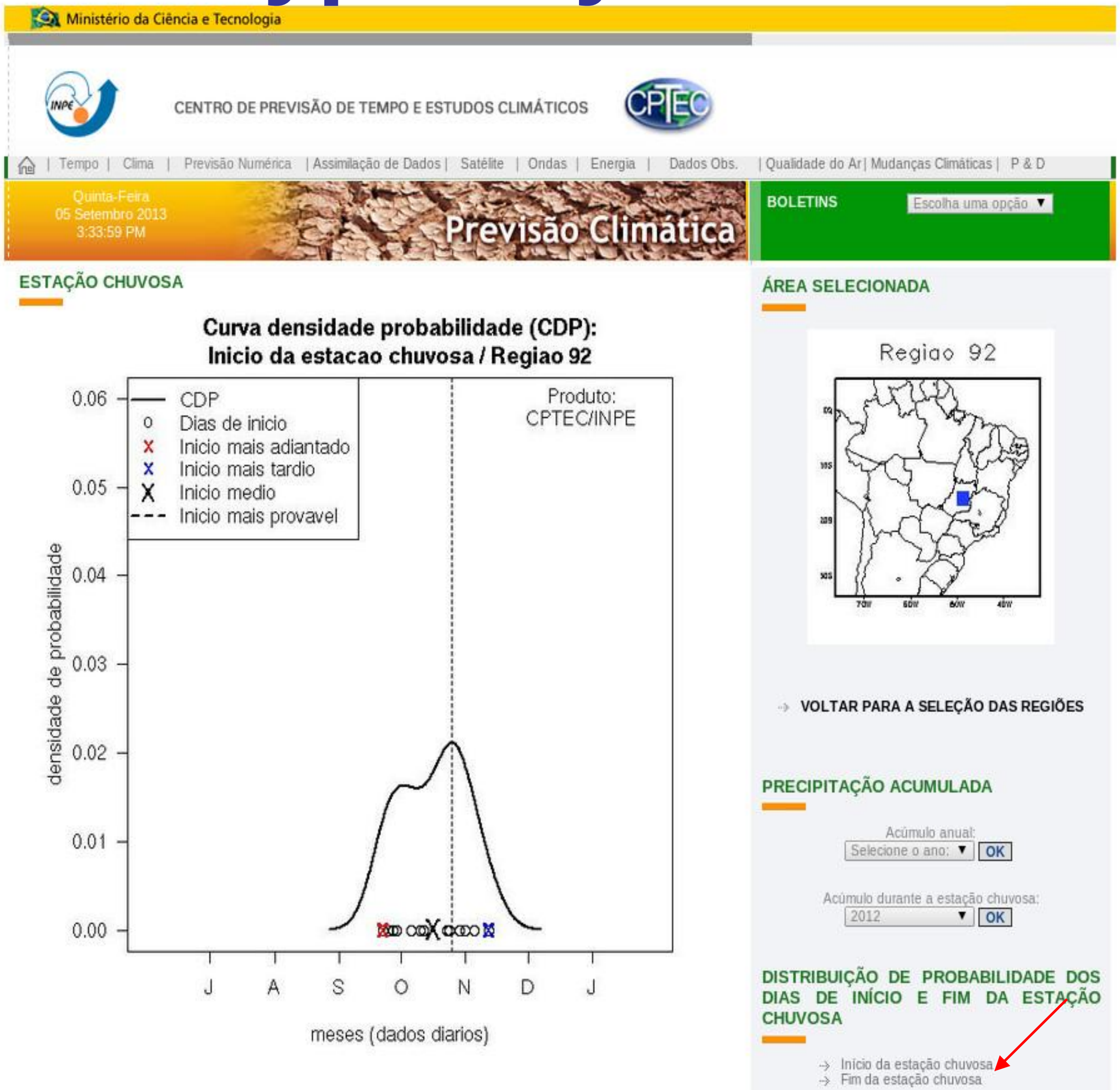
**http://clima1.cptec.inpe.br/~rclima1/estacao_chuvosa.shtml**

# Daily rainfall monitoring during the rainy season




http://clima1.cptec.inpe.br/~rclima1/estacao_chuvosa.shtml

# When does the rainy season typically start?

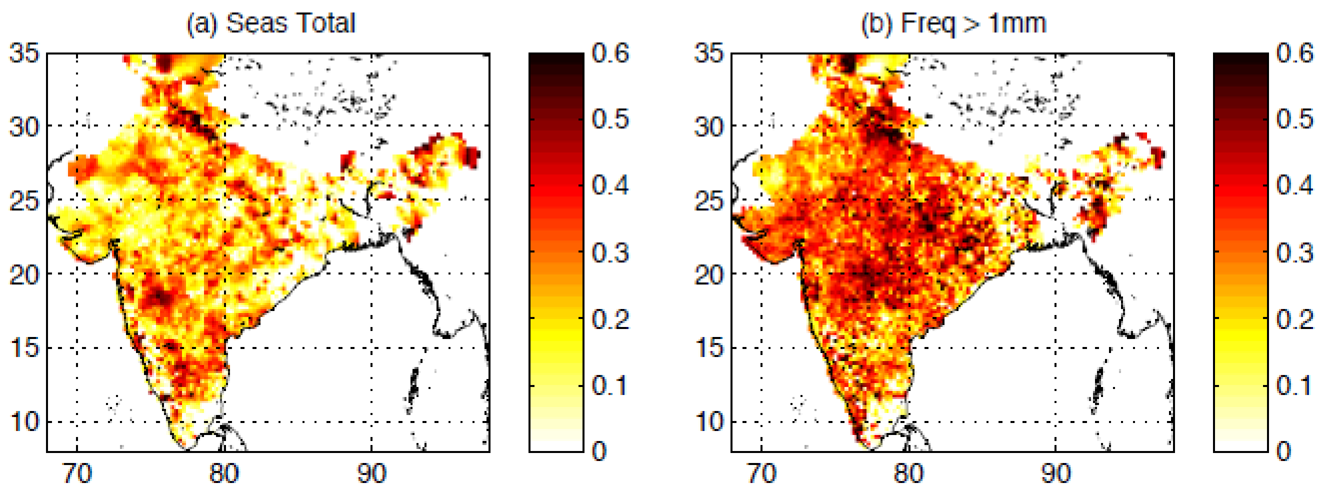


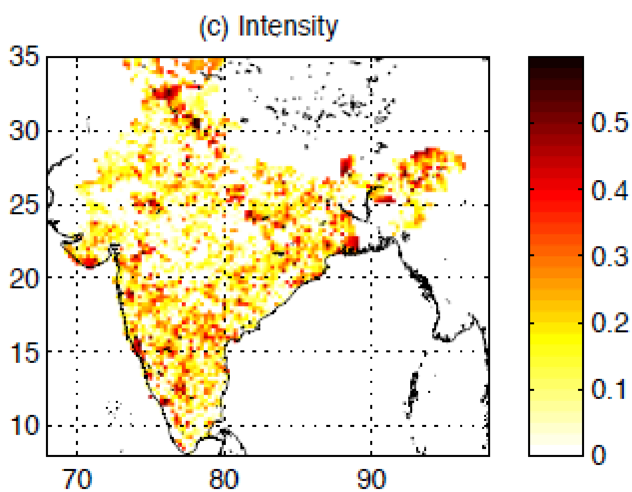

**http://clima1.cptec.inpe.br/~rclima1/estacao_chuvosa.shtml**

# How predictable are some characteristics of the rainy season?

## Potential predictability of JJAS Rainfall from SST

Cross-validated CCA with contemporaneous SST [40°-290°E, 30°N-30°S],1901–2004




**Seasonal Total =**
**(No. of Wet Days) x (Mean Wet-Day Intensity)**

IMD 0.25-degree
daily rainfall data



**Courtesy: Andy Robertson (IRI)**

# The need for improved practices in climate monitoring and prediction

Research area in need of priority:

**2) Communicating forecast uncertainty**: The communication of probabilistic forecasts to decision makers and the general public is an area that deserves particular attention

- Research on how decision makers and the general public interpret probabilistic forecasts is still much in need

- Understanding how these actors interpret probabilistic forecasts is likely to help devising new ways of presenting these forecasts

# The need for improved practices in climate monitoring and prediction

Research area in need of priority:

**3) Seasonal forecast presentation:** Traditional three category format deserves revisiting.

- For a number of end-users this format may be of little or null utility because they cannot be easily integrated in the decision making process

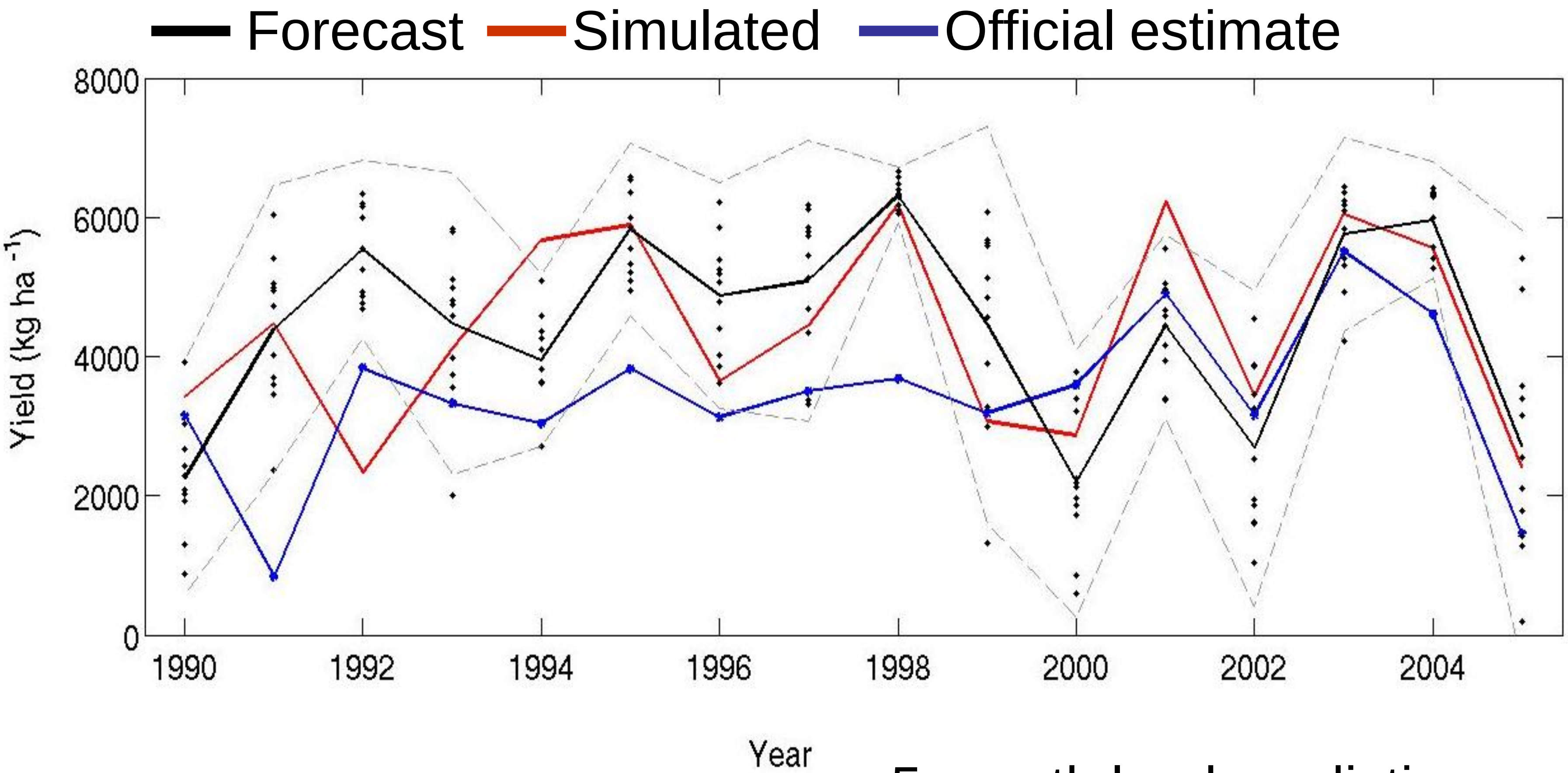
- Applied research on integrating seasonal climate forecasts in user applications is therefore much needed

- E. g. Hydrological and agricultural models generally require high frequency (daily) information at increased spatial scales for the forthcoming months to estimate the expected river flow or crop in the next season

- Research on how best to produce such high frequency and increased spatial scale climate information, based on the available seasonal forecast information, to feed application models should be performed

# Grain yield prediction

ECMWF (bias corrected) forecasts, 11 ensemble members issued in Sep (valid for Sep, Oct, Nov, Dec, Jan, Feb)




5-month lead predictions

# The need for more demonstrations

- Seasonal climate forecasts are produced at various climate prediction centers around the world
- These forecasts are rarely objectively integrated in application models to help the end user decision-making process (challenges)
- The success of integrating seasonal climate forecasts in user applications can only be achieved if the entire chain of challenges is thoroughly resolved
- Need more demonstrations to make users aware of current potential for use of climate forecasts in application areas to help the end user decision-making process

# The need for improved practices in forecast verification

- In addition to monitoring and forecasting, forecast verification is another area that deserves new research and developments to adequately assess and communicate the skill level of the forecast products generate in Latin America

- **Verification of seasonal forecasts:** What is the current level of seasonal forecasts produced in Latin America?

- **Verification of sub-seasonal forecasts:** What is the skill level of the emerging sub-seasonal prediction products for Latin America?

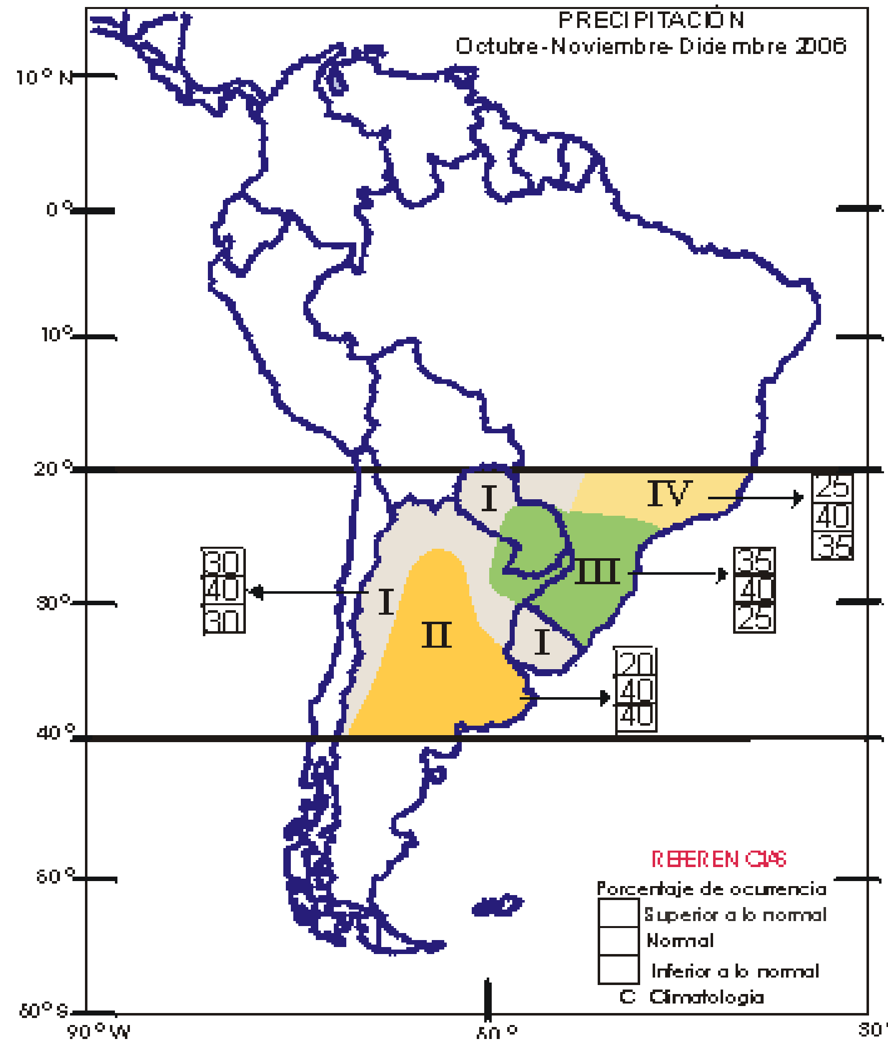
# Are these consistent forecasts?

All regions have highest probability on the normal category.

Did we genuinely think that normal was the most likely category everywhere, or did we think it was the safest forecast everywhere?

70 – 80% of all the African RCOF forecasts have highest probability on normal.

Are we really forecasting what we think, or are we playing safe?




**Courtesy: Simon Mason (IRI)**

# The need for improved transition of climate monitoring and forecasting research to operations

**Improvements needed in the way climate monitoring and prediction research are transferred to operations for practical use**

- There is generally a long time gap between the research conclusion and the implementation of new operational products incorporating the acquired research knowledge

- Should not expect research knowledge generated in academic institutions is quickly transferred to operations for practical use

- Mechanisms encouraging and facilitating faster operational implementation of recently developed research should be identified in order to put more effectively in practice the most recently generated scientific knowledge

- Operational institutions have a rich environment for smoothly performing this transition but research activities need to be closely linked with operational implementation plans: Need for applied research in operational environment

# Final remarks

Important progress in climate monitoring and prediction over the years, but there is still scope for improvements in a number of areas:

- Monitoring and prediction of sub-seasonal climate events: E. g. explore predictability of rainy season characteristics (link with S2S project)
- Communication of uncertainty and interpretation of climate prediction information: need for interdisciplinary research with social areas (e.g. anthropology)
- Seasonal forecast format: moving beyond thee category forecasts

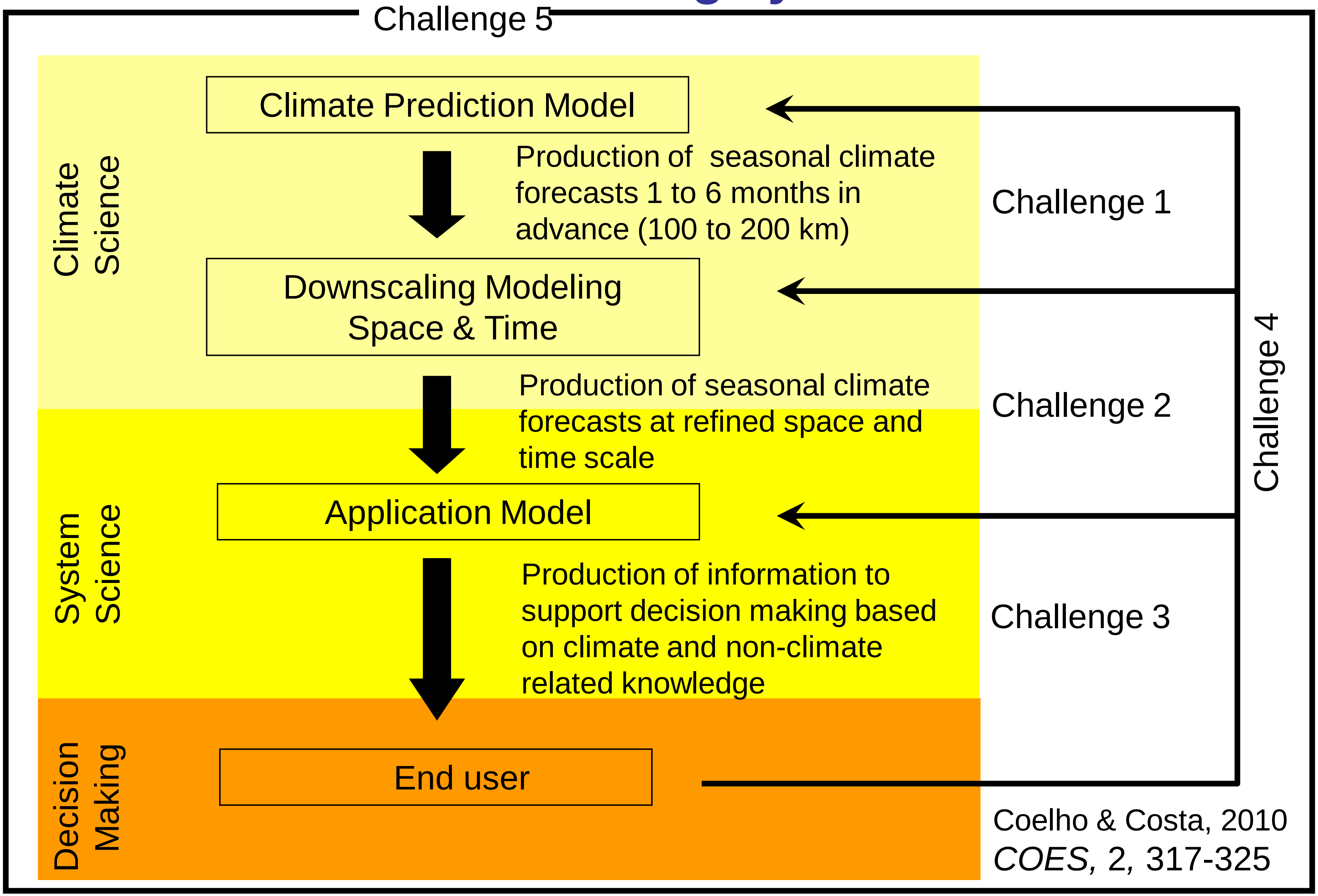
  - need for more initiatives/demonstrations for integrating forecasts into the decision making process (this requires interdisciplinary applied research in health, agriculture, hydrology, etc),

  - need for improved consistency in climate information dissemination across climate science, system science and decision making

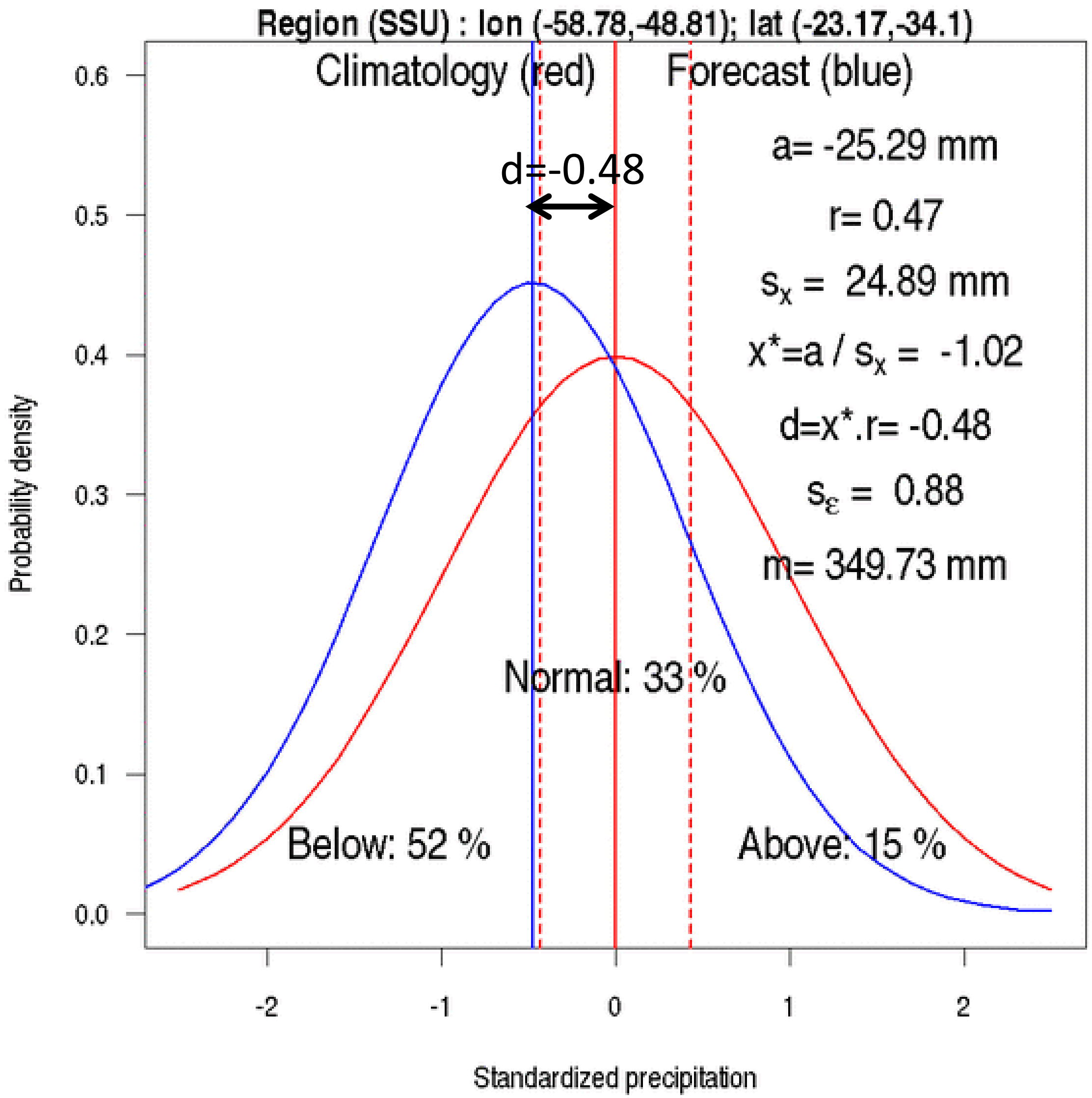
  - coordinated sub-seasonal to seasonal downscaling assessment?
- Verification of produced seasonal and emerging sub-seasonal forecasts (link with S2S project)
- Mechanisms for transition of research to operations (e.g. NOAA's Climate test bed?)
- Need for increased human resources working on near term climate monitoring, prediction and interfaces (applications areas)

**Thank you all for your attention!**

# A simplified framework for an end-to-end forecasting system



# Example of tercile probability rainfall seasonal forecast for South Brazil: JJA 2013

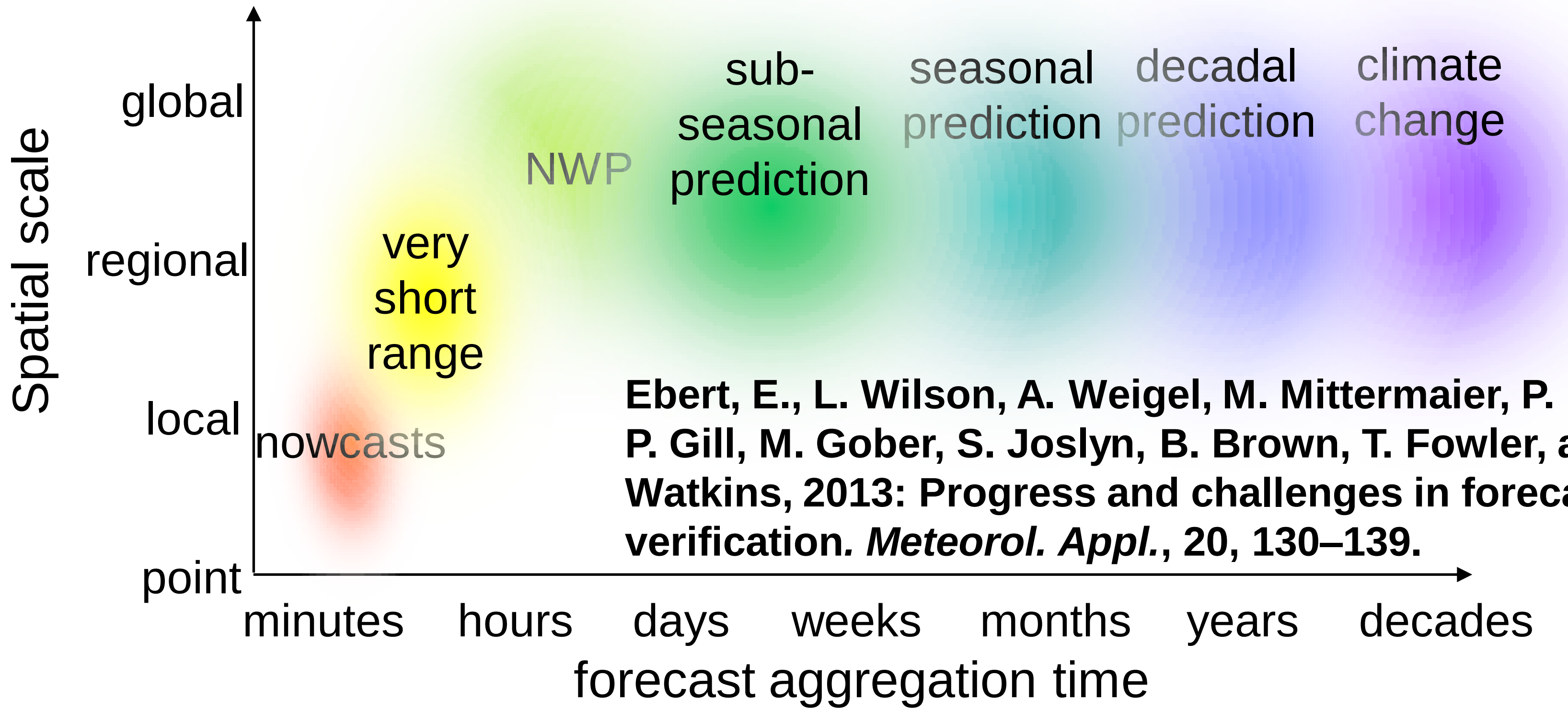


# Seamless verification

Seamless forecasts - consistent across space/time scales

single modelling system or blended

probabilistic / ensemble




**Ebert, E., L. Wilson, A. Weigel, M. Mittermaier, P. Nurmi, P. Gill, M. Gober, S. Joslyn, B. Brown, T. Fowler, and A. Watkins, 2013: Progress and challenges in forecast verification. *Meteorol. Appl.*, 20, 130–139.**