The Abdus Salam
International Centre for Theoretical Physics

United Nations
Educational, Scientific and
Cultural Organization

IAEA

1934-2

Fourth ICTP Workshop on the Theory and Use of Regional Climate Models: Applying RCMs to Developing Nations in Support of Climate Change Assessment and Extended-Range Prediction

3 - 14 March 2008

Regional Climate Modeling in Seasonal Climate Prediction: Advances and Future Directions

SUN Liqiang

International Research Institute for Climate and Society
61 Route 9W, Monell Building
Columbia University, Lamont Campus
Palisades 10964-8000 NY
UNITED STATES OF AMERICA

Regional Climate Modeling in Seasonal Climate Prediction: Advances and Future Directions

Liqiang Sun

International Research Institute for Climate and Society (IRI)

4th ICTP Workshop on the Theory & Use of REGional Climate Models

'Applying RCMs to Developing Nations in Support of Climate Change Assessment & Extended-Range Prediction'

March 3-14, 2008

Regional Climate Modeling

LAMs for climate studies

- Giorgi and Bates (1989) – one-month simulation
- Jones *et al.* (1995) – continuous multiyear simulations

RCM Reviews

- McGregor (1997)
- Giorgi and Mearns (1999)
- Giorgi *et al.* (IPCC 2001)
- Leung *et al.* (2003)
- Laprise (2006)

History of Climate Prediction

Predictions based on scientific schemes:

- Prediction for Indian Monsoon Rainfall (Blanford 1884)

Predictions based, at least in part, on ***Dynamical Climate Models****:*

- U.K. Met Office since 1988
- Climate Prediction Center since 1994
- Canadian Met Centre since 1995
- CPTEC since 1995
- Australia's Bureau of Met since 1997
- IRI since 1997

History of Climate Prediction

Predictions based, at least in part, on ***Regional Climate Models****:*

- IRI since 1997
- ECPC since 1997
- NR&M (Queensland)/IRI 1998
- FUNCEME/IRI since 2001
- NCEP since 2002
- CWB/IRI since 2003
- ICPAC/IRI since 2005
- SAWS/IRI since 2006
- ECPC/NTU,HKO, BIU since 2003
- Downscaling DEMETER Hindcasts

Challenges

- Scientific issues related to predictability at smaller scales
- Technical issues for regional climate modeling
- Computational constrains

Outline

- Motivation
- Values added by RCMs
- Seasonal climate forecasts using RCMs
- Future Directions

1. Motivation

RCMs for Seasonal Prediction (Dynamical Downscaling Prediction)

- Enhance the scale and relevance of seasonal climate forecasts and creating information to better support decisions
- Advance our understanding of physical processes that contain predictability at smaller spatial and temporal scales
- Advance our understanding of interactions between large and small scales and provide the physical evidence for statistical downscaling
- Parameterization testbed for GCMs

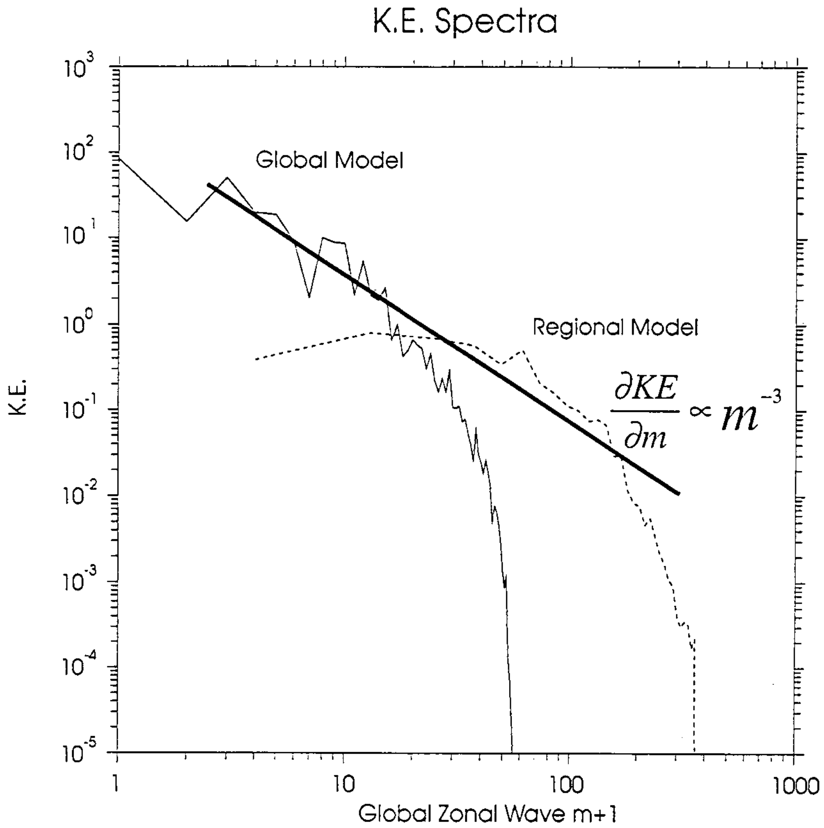
2. Values Added by RCMs

On **Seasonal** Time Scale

- Improvement of Spatial Patterns and Temporal Distribution
- Predictability at Smaller Spatial and Temporal Scales
- Representation of Climate Uncertainty

It is widely accepted that dynamical downscaling improves spatial patterns and climatologies as compared to the coarse resolution GCMs.

Typical spectral distributions of the global model and the regional model

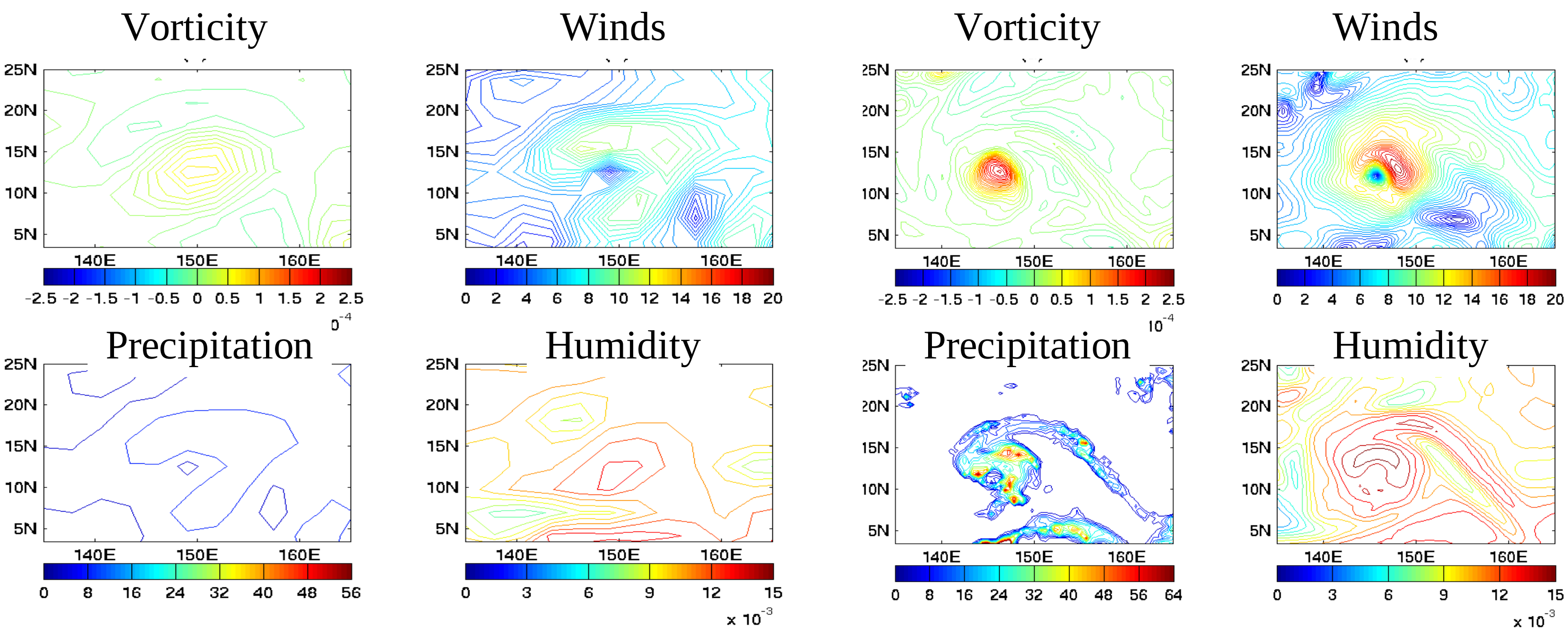


Chen *et al.* (1999)

A Typical Tropical Cyclone Simulated by Climate Models

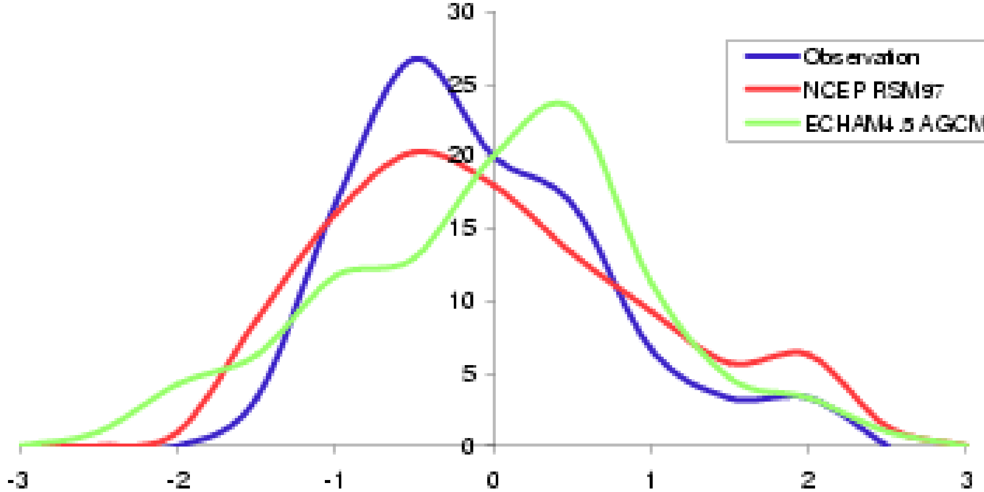
ECHAM4.5 AGCM(T42)

RSM (50km)



Carmago, Li and Sun (2007)

Climatological precipitation PDF for the period February-March-April 1971-2000 in Ceará. The unit for zonal axis is one standard deviation, and the unit for the vertical axis is percentage.



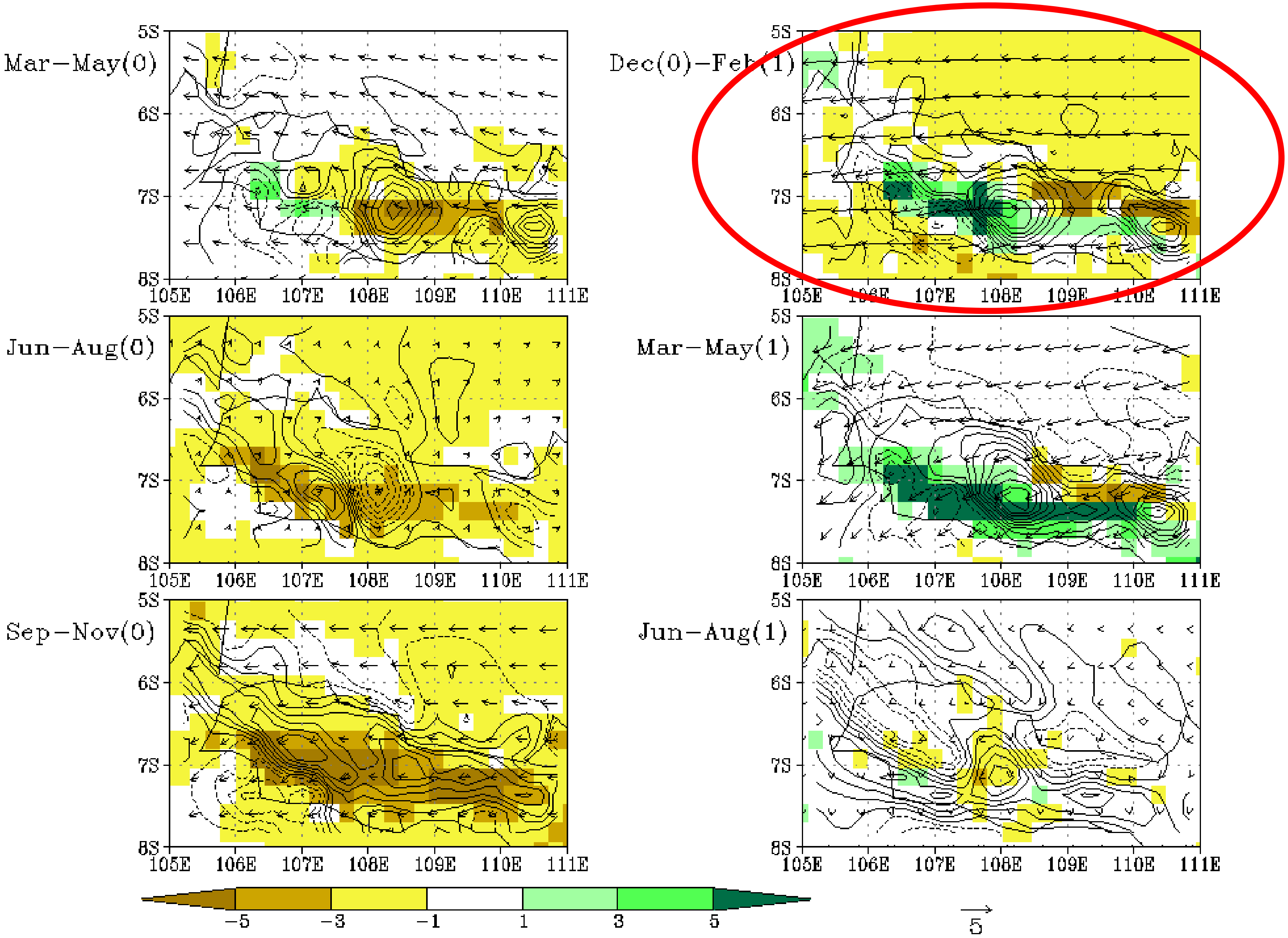
Sun *et al.* (2005)

Predictability at smaller spatial and temporal scales

Diagnosis of the added benefit of dynamical downscaling

Is the local information *skillful*? Or is it just noise on top of the large-scale signal?

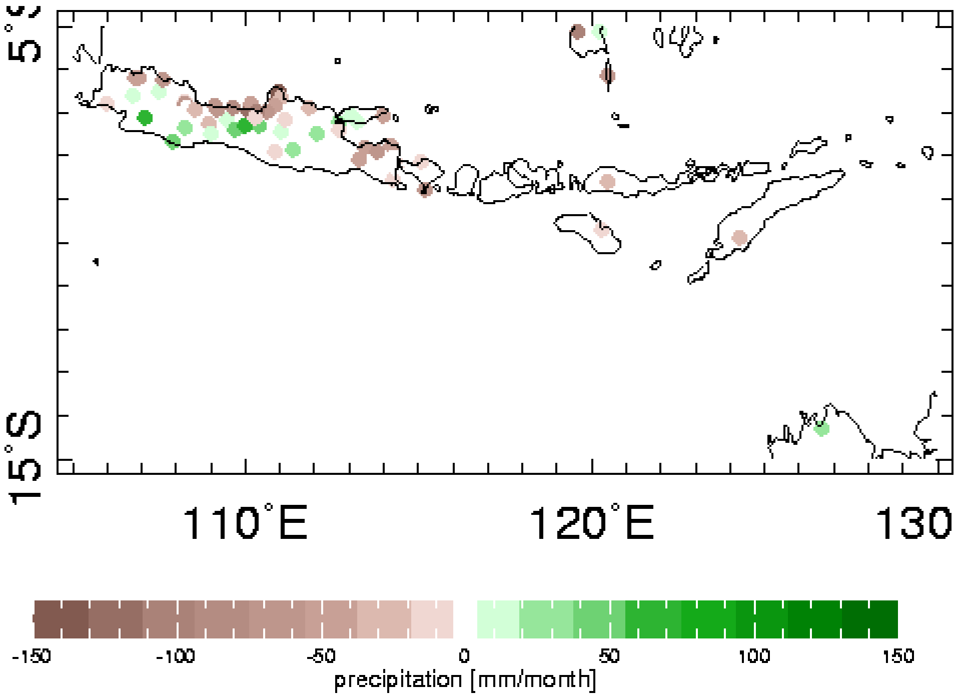
Is the *temporal* character improved?



(El Nino – La Nina) Composite of ECHAM–driving RegCM3 Seasonal Precipitation (mm/day; shaded), Winds (m/s, vector) and Divergence (contour) at σ=0.865.
(Res: 25km; El Nino years: 72/73, 82/83, 86/87, 91/92, 94/95, 97/98)
(La Nina years: 73/74, 75/76, 84/85, 88/89, 98/99, 99/00)

Qian *et al.* (2006)

Observation: Dec(0)-Feb(1)



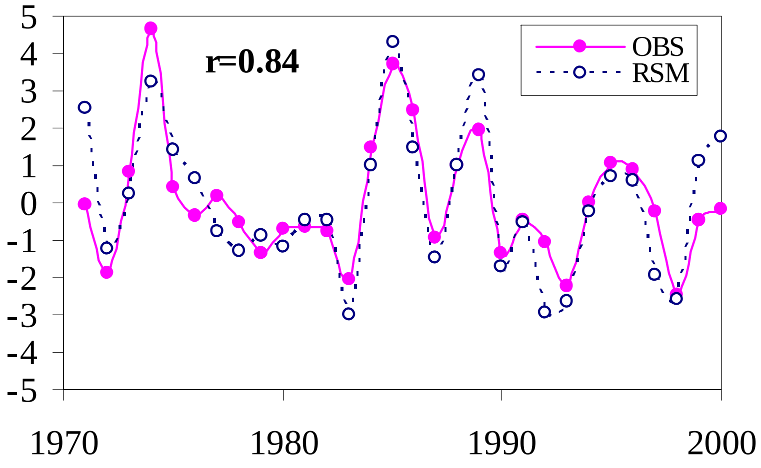
Qian *et al.* (2006)

Predictability of "weather within the climate"

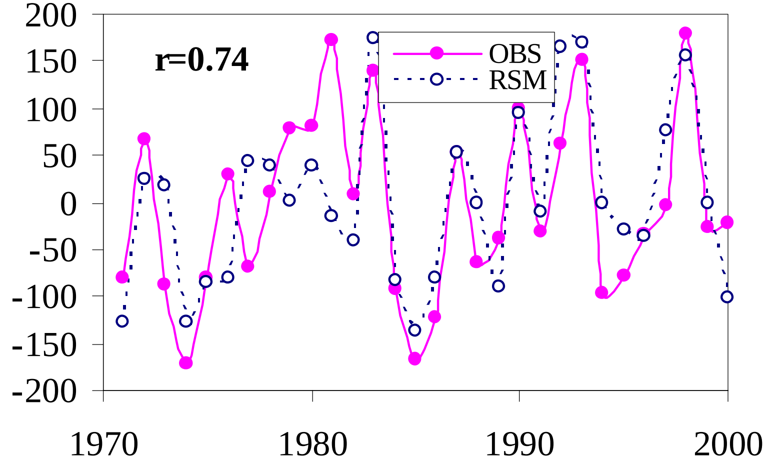
At **seasonal** lead times, there is **no usable skill** in forecasting on **which day** a locality will have precipitation, storms, temperature extremes, frontal passages, and so forth. However, there is nonetheless some skill in predicting **weather statistics** in the season.

RSM Hindcast Validation

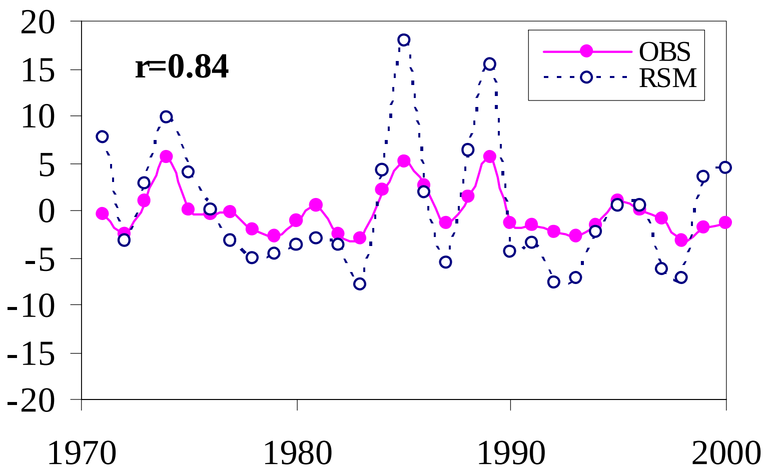
FMAM Rainfal Anomalies



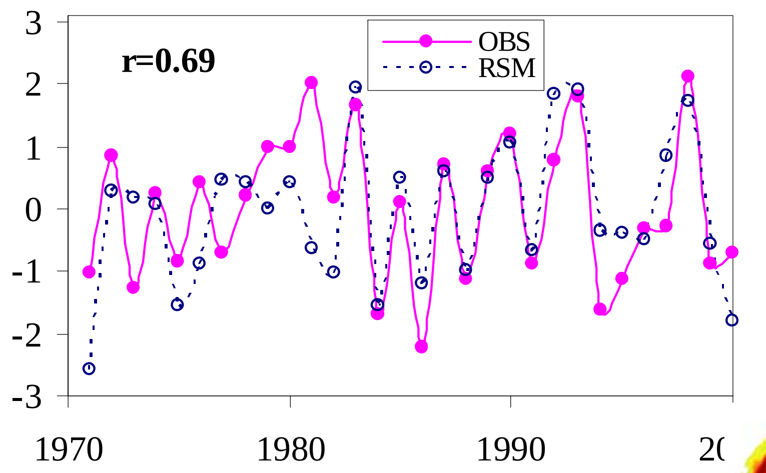
FMAM Drought Index



FMAM Flooding Index

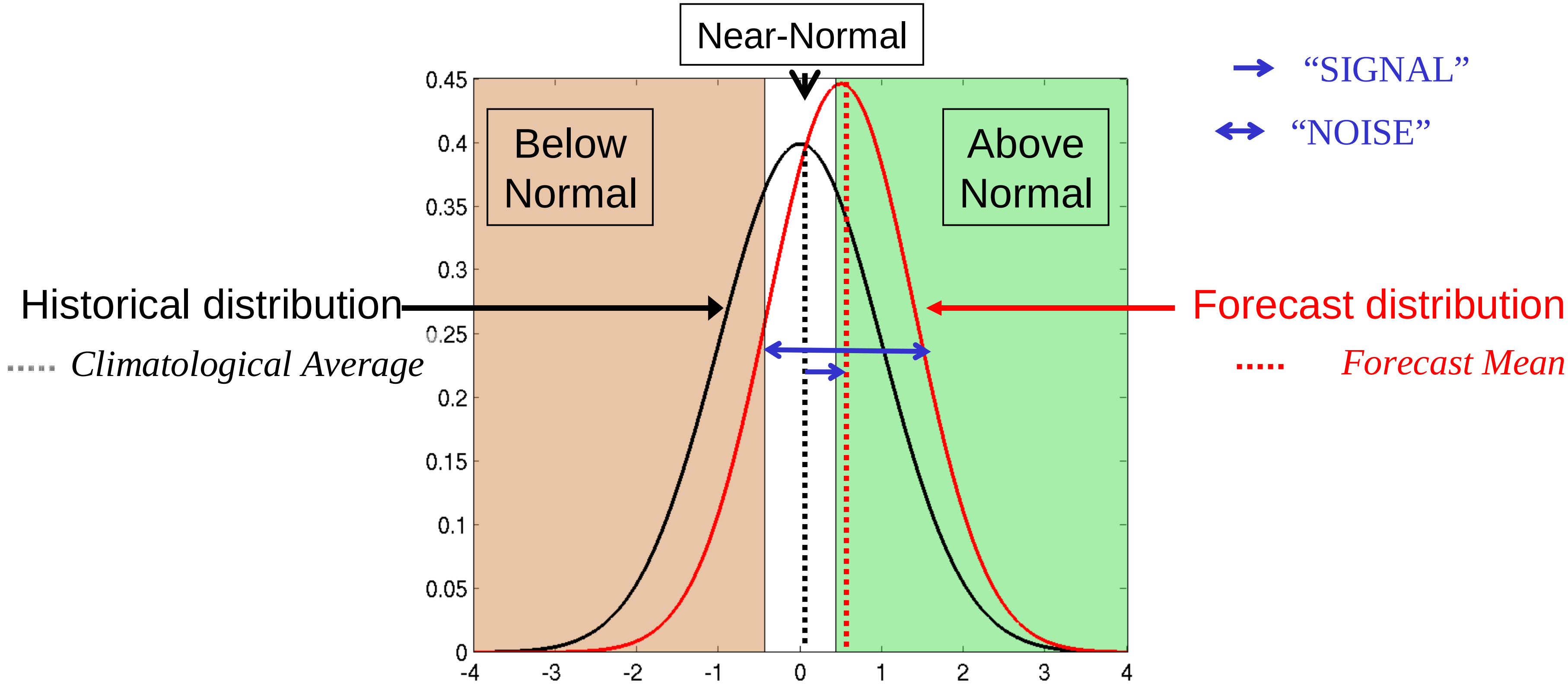


FMAM Weather Index



Sun *et al.* (2007)

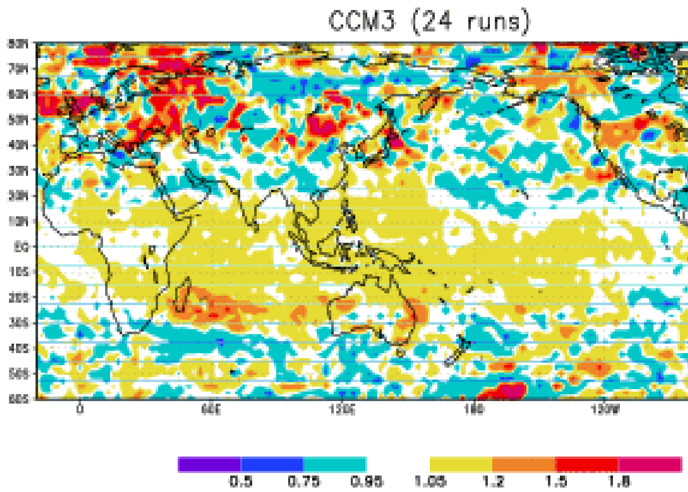
Climate Forecast: Signal + Uncertainty

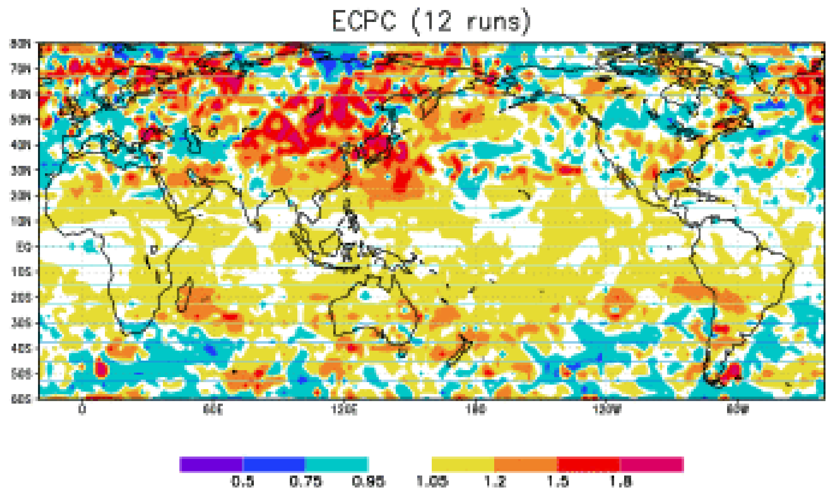


The **SIGNAL** represents the 'most likely' outcome.

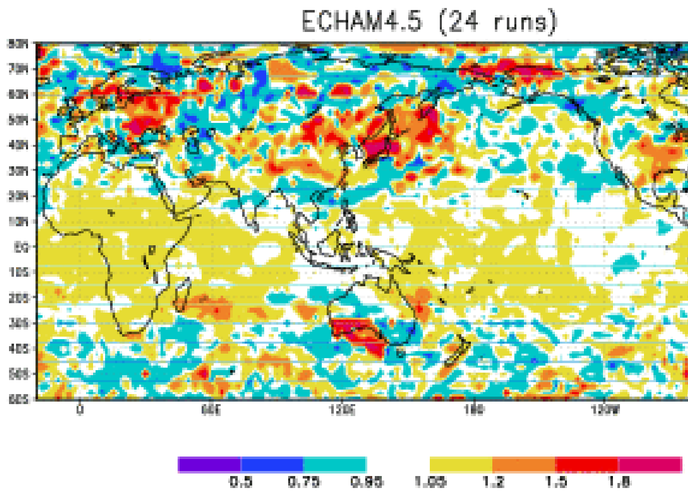
The **NOISE** represents internal atmospheric chaos, *uncertainties* in the boundary conditions, and random errors in the models.

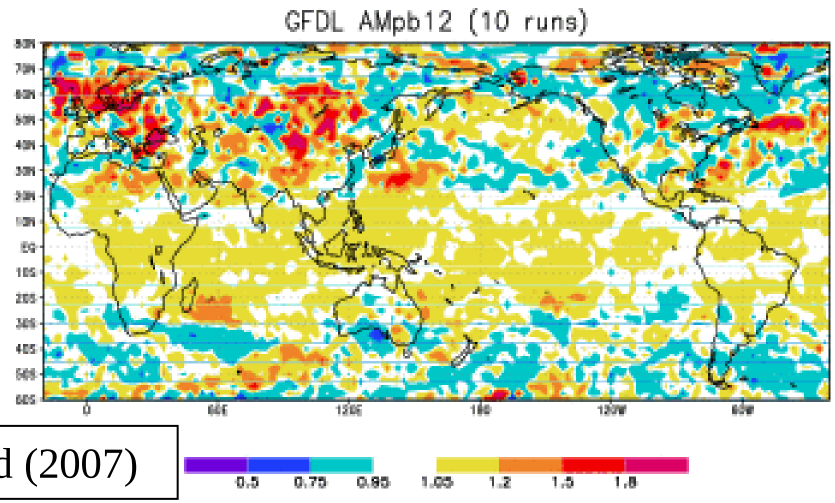
Scaling Factor for Ensemble Spread





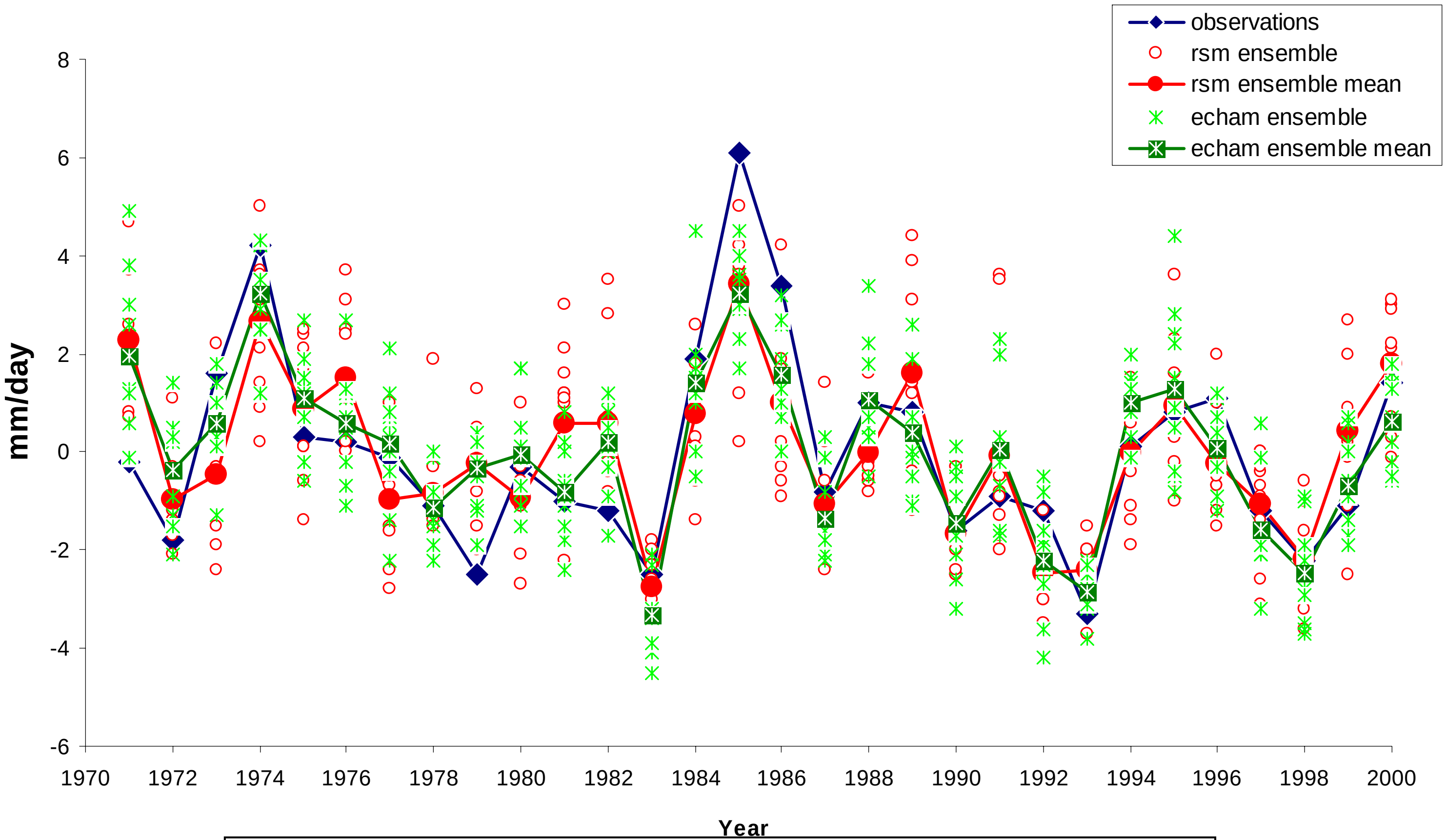
Model spread is too small in tropics too large in parts of the extra-tropics





Goddard (2007)

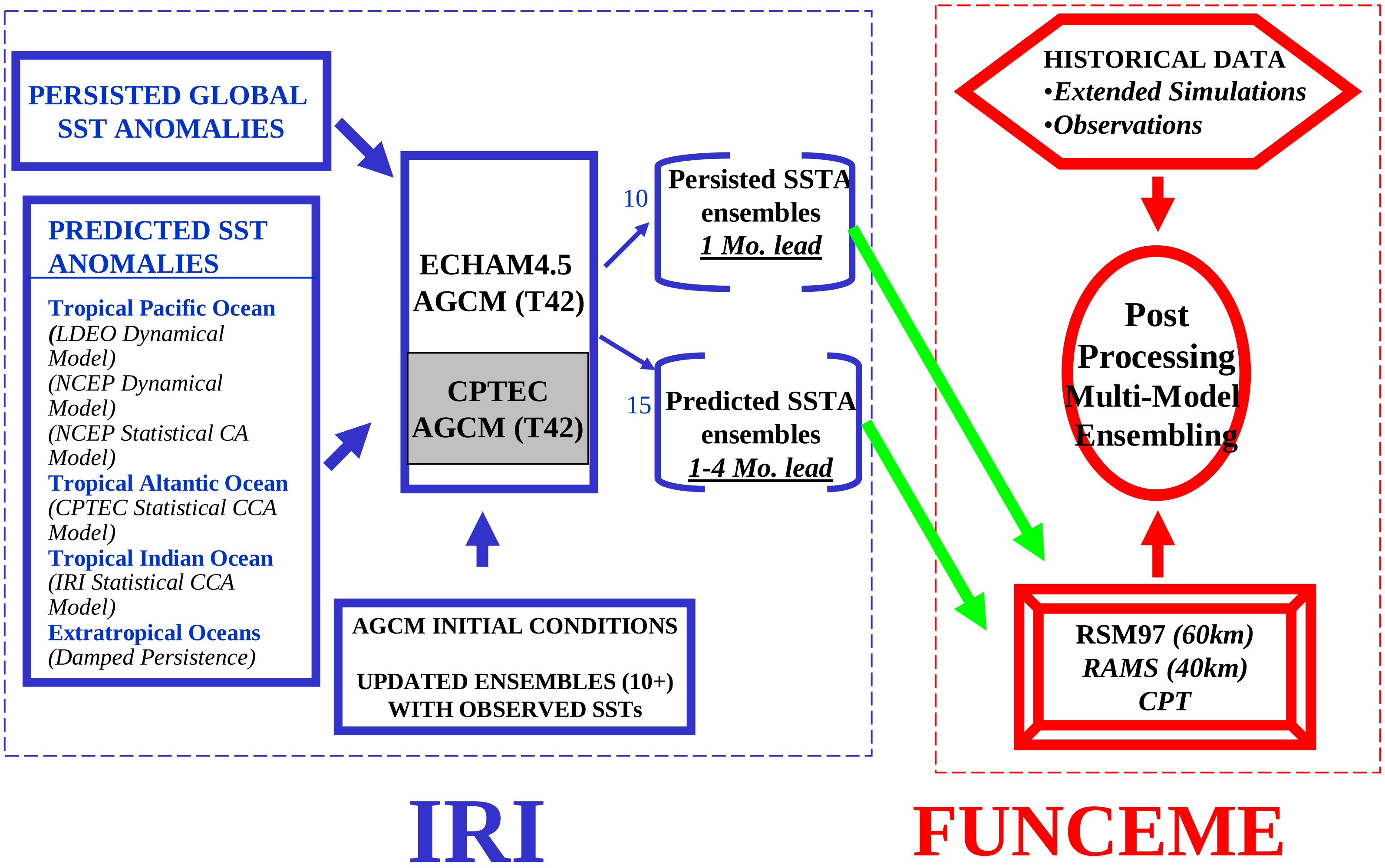
FMA Precipitation anomaly distribution over Ceara. Unit is mm/day.



	ECHAM	RSM
Ensemble Spread	1.9	2.4
Signal	2.8	3.1

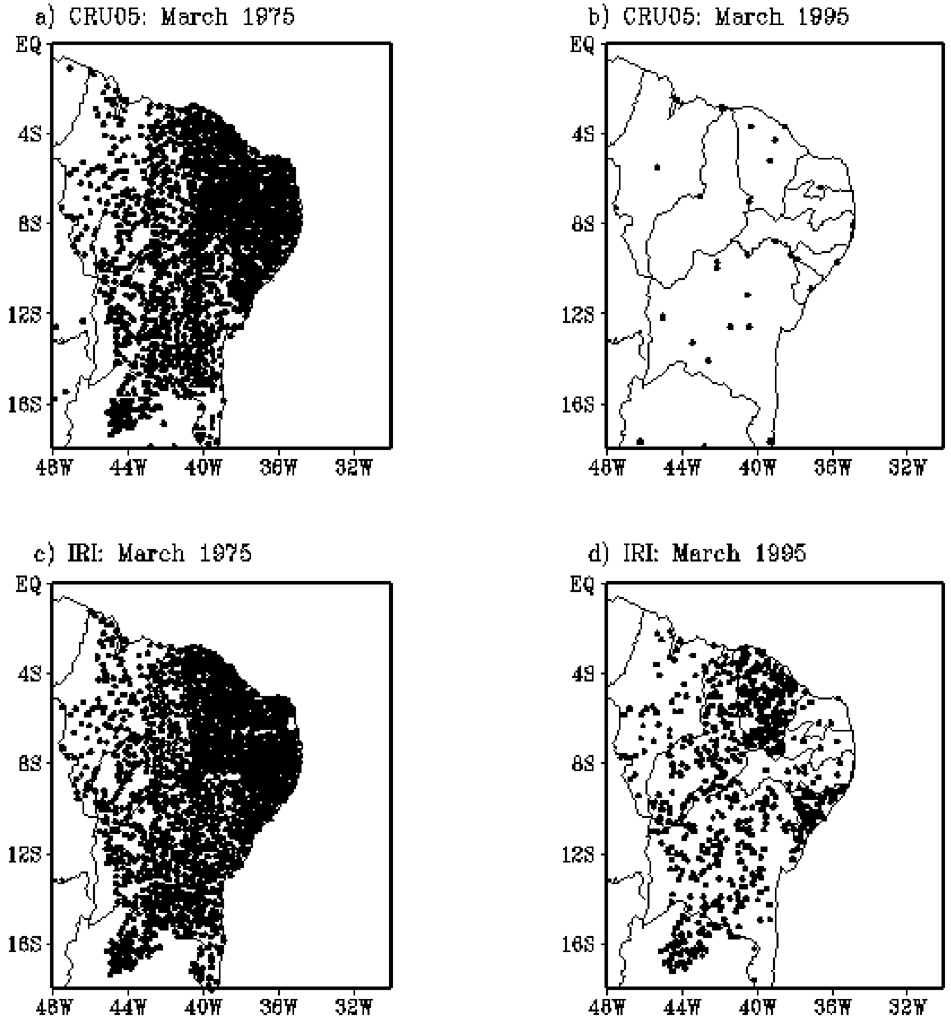
Seasonal Climate Forecasts Using RCMs
- Examples from Northeast Brazil

CLIMATE DYNAMICAL DOWNSCALING FORECAST SYSTEM FOR NORDESTE

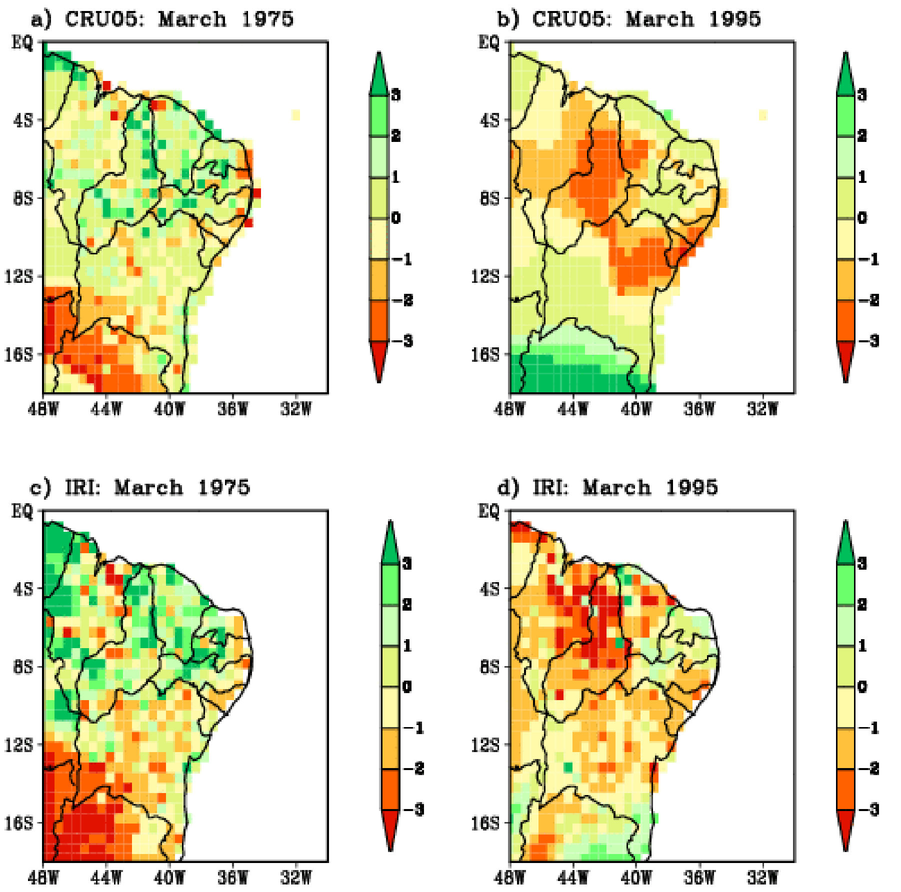


Sun *et al.* (2006)

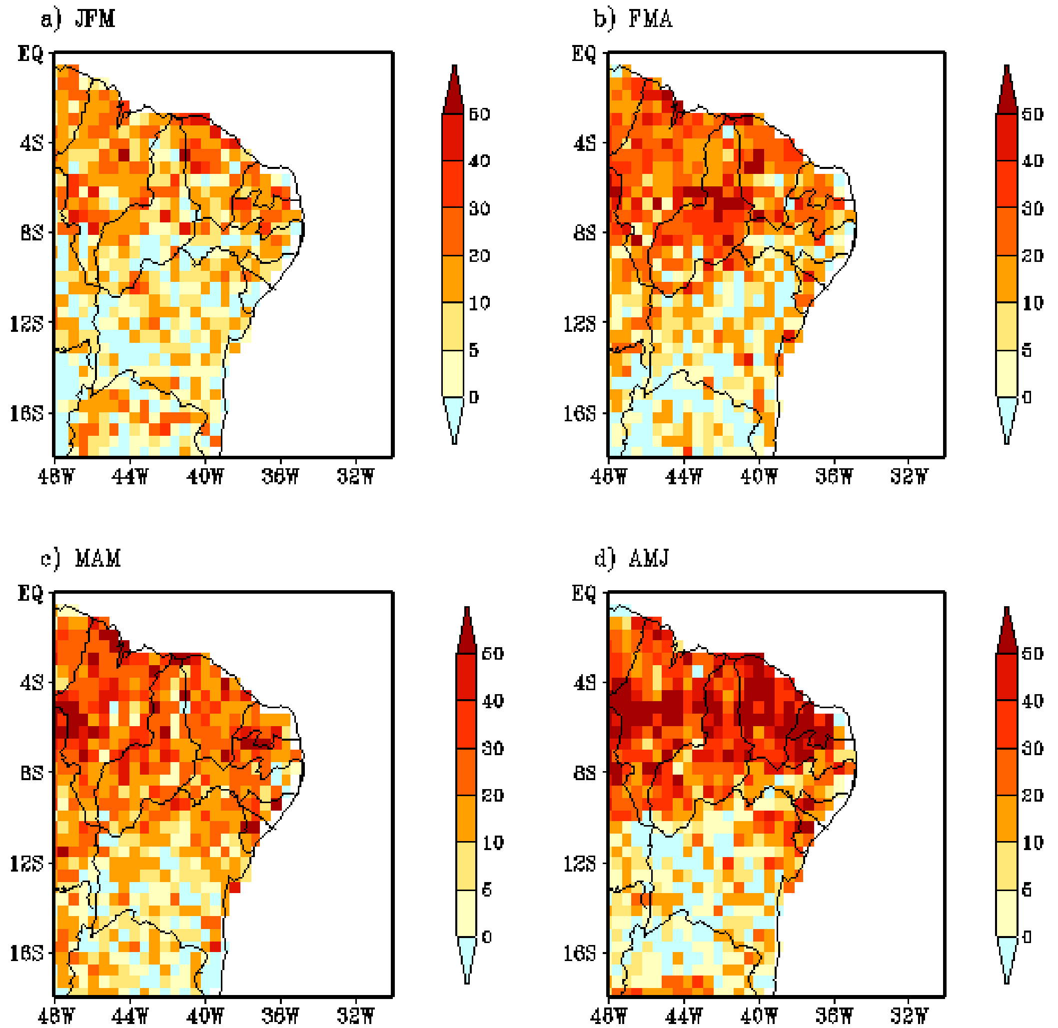
Network of Rainfall Stations



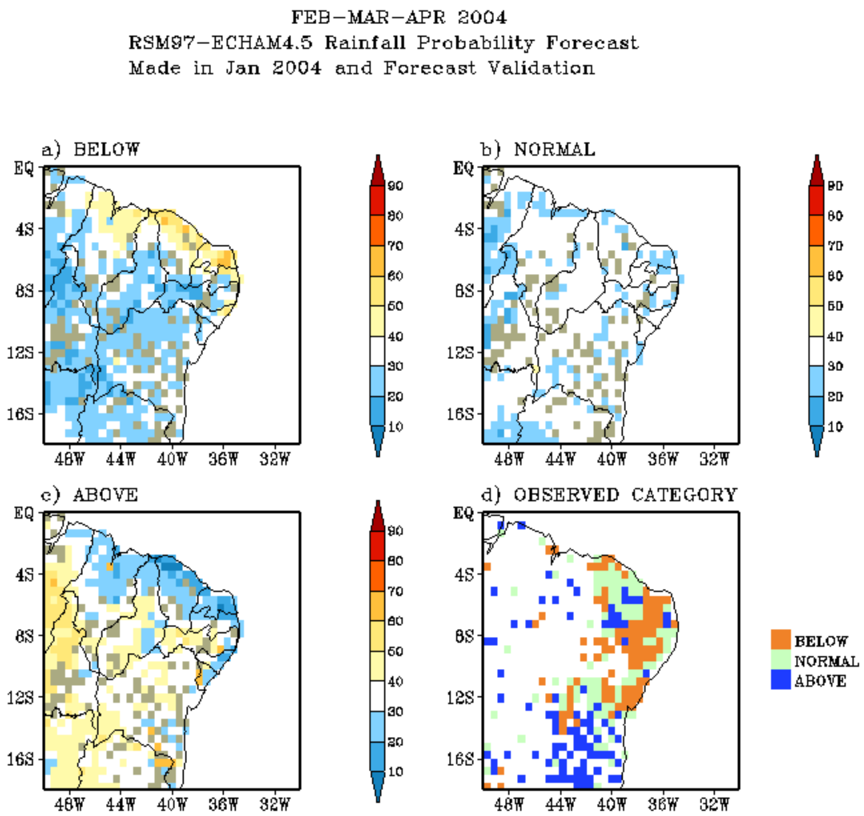
Rainfall Anomalies (mm/day)



Geographical distribution of RPSS (%) for the *hindcasts* averaged over the period of 1971-2000

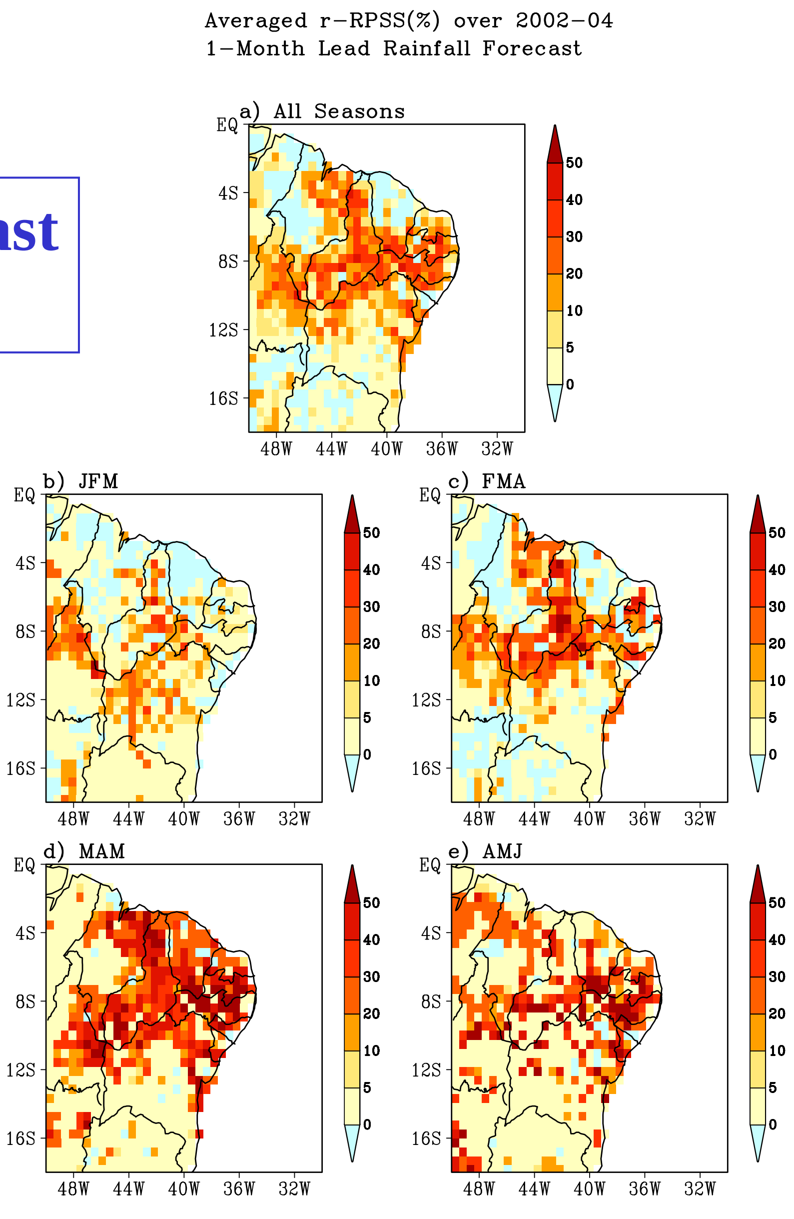


RCM Forecast



http://www.funceme.br/DEMET/index.htm

Real-Time Forecast Validation



A Major Goal of Probabilistic Forecasts - *Reliability!*
Forecasts should "mean what they say"

Confidence Level

40%

	B_o	N_o	A_o
B_f	46	41	13
N_f	48	36	16
A_f	37	27	36

50%

	B_o	N_o	A_o
B_f	49	41	10
N_f			
A_f	25	27	48

60%

	B_o	N_o	A_o
B_f	45	48	15
N_f			
A_f	31	24	45

Skill comparison between the driving ECHAM forecasts and the nested RSM forecasts. The RPSS (%) was aggregated for the whole Nordeste region.

	JFM		**FMA**		**MAM**		**AMJ**	
	ECHAM	*RSM*	*ECHAM*	*RSM*	*ECHAM*	*RSM*	*ECHAM*	*RSM*
2002	7.1	4.5	5.2	10.1	14.9	23.5	1.2	14.1
2003	-6.1	-3.2	-2.6	7.2	9.4	15.3	5.4	12.1
2004	25.7	-7.4	0.8	0.4	-5.7	28.6	5.8	16.4

Summary

- RCMs are capable of producing observed local climate variability over many regions. The possibility exists to enhance information to higher spatial and temporal scales
  - ***requires research! Results are often region and season specific.***

- Downscaled forecasts using RCMs demonstrate good skill over the Nordeste. Predictability varies with seasons and geographical regions. Downscaling prediction system has been developed for other regions and forecast evaluations are in the process.

Future Directions

- *Atmosphere-ocean coupling and parameterizations*
- *Land physics and initialization*
- *Nesting strategy*
- *Multi-Model Ensembling*
- *Changing climate*
- *Linking prediction and application*

Air-Sea Coupling and Parameterization

Coupled RCMs – better representation of the **feedbacks** between the SST and convection (case studies over the Indian Ocean, Southern Atlantic Ocean, Mediterranean Sea, etc.)

Parameterizations are based on a spectral **gap** between the scales being parameterized and those being resolved on the grid. Therefore, parameterizations are model resolution dependent.

C*umulus parameterization*

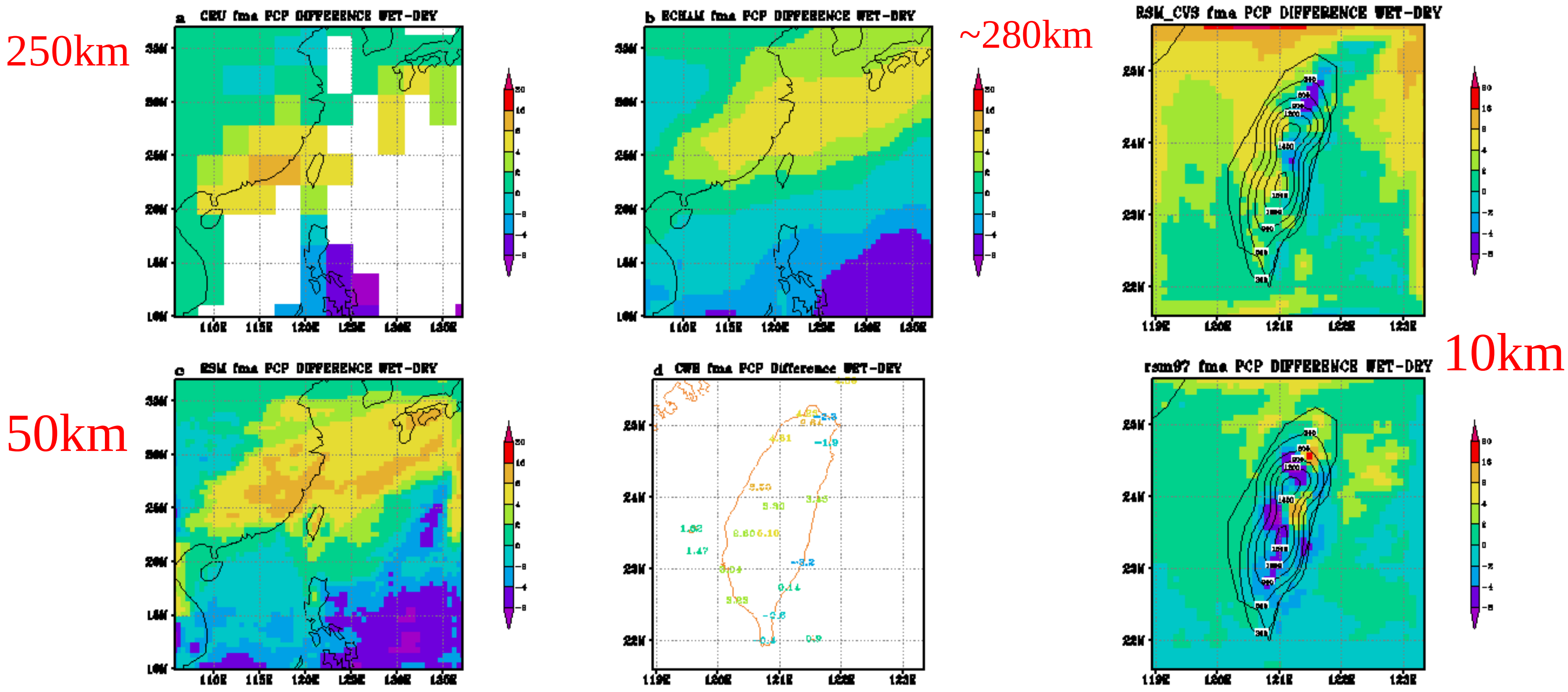
Grid Spacing (KM)

5 20 50

________|_________|_________________|_________

explicit **???** hybrid GCMs

Case Study: Rainfall Diff:1983-1971



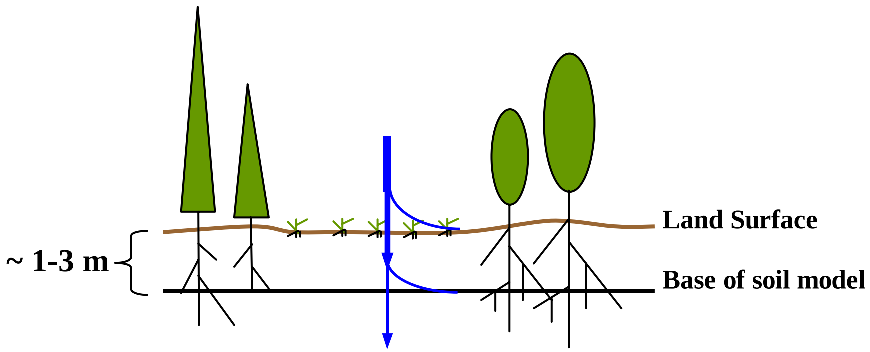
Sensitivity Tests: Model resolution & Model physics

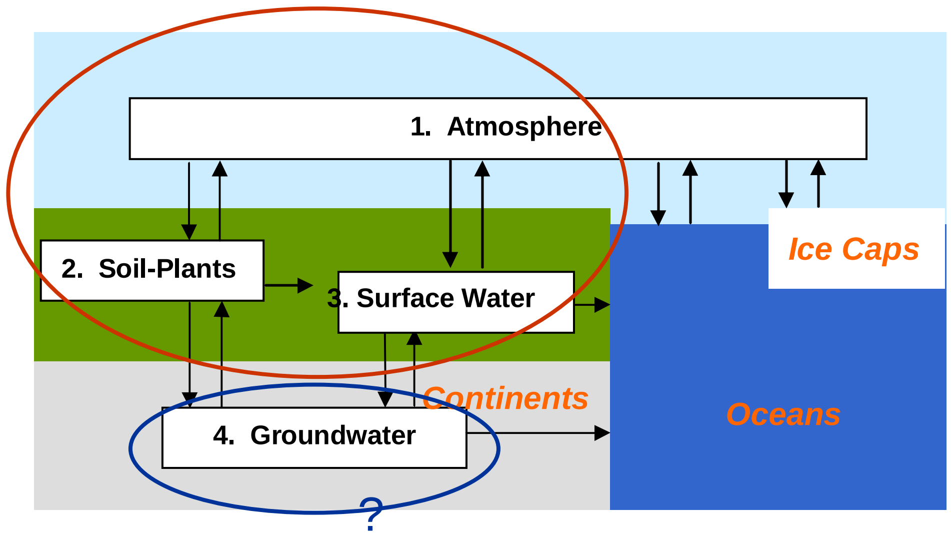
Hu and Sun (2002)

Land Process

Treatment of Groundwater Reservoir in climate models

Present (Regional) climate Models



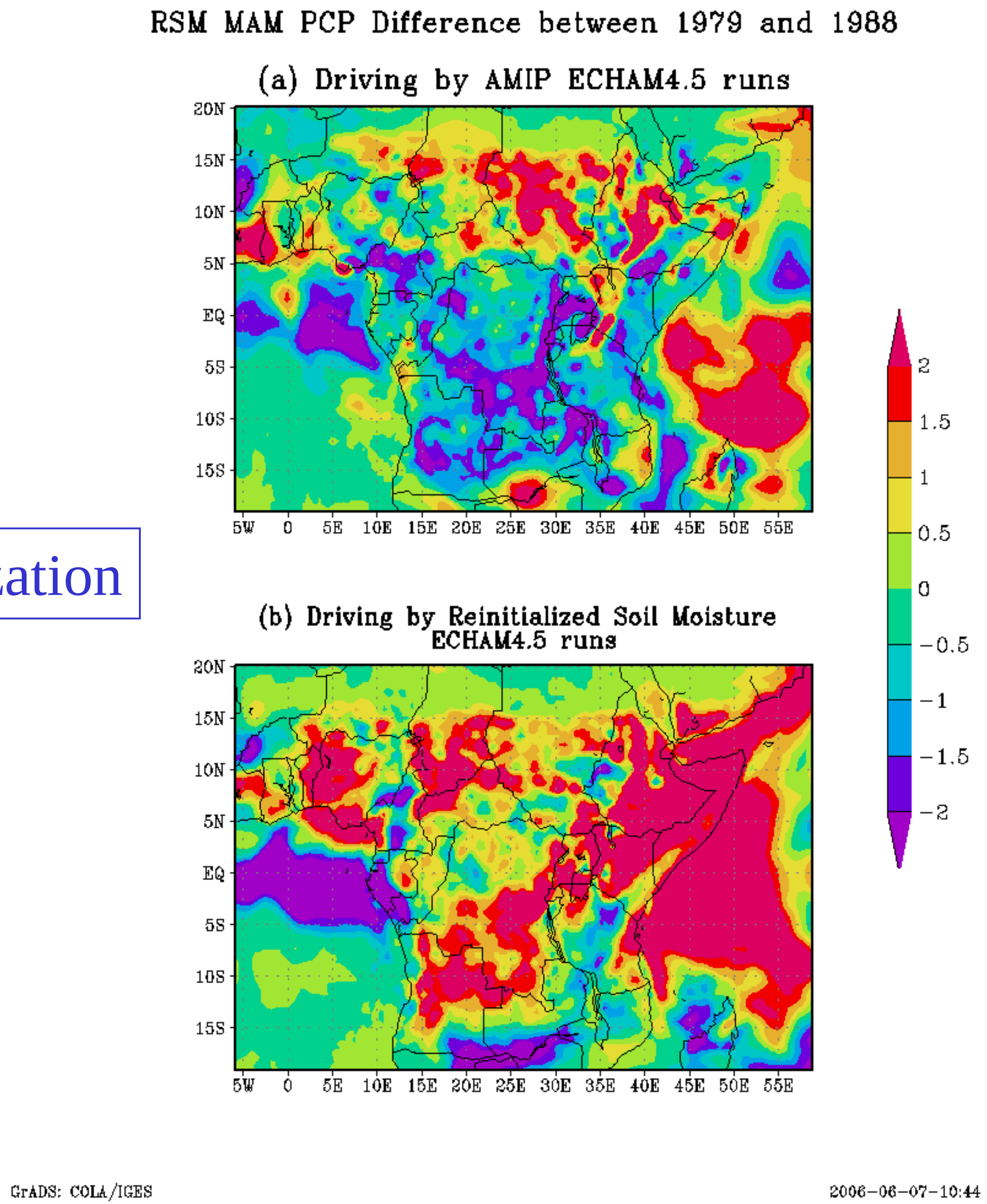


• Soil water reaching the soil-model base through gravitational flow freely drains out

• That water is no longer available for evapotranspiration even during times of water stress

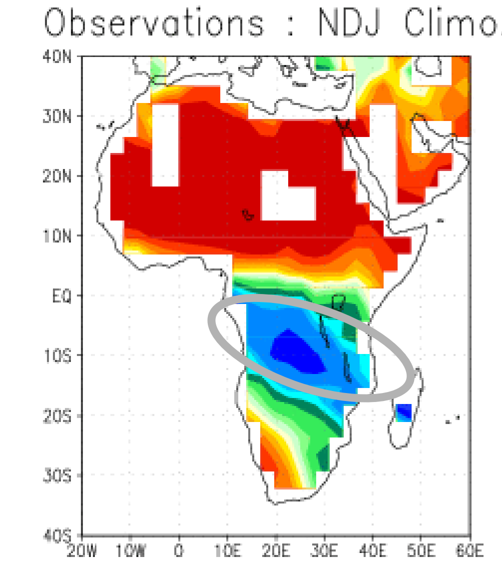
Miguez-Macho *et al.* (2007)

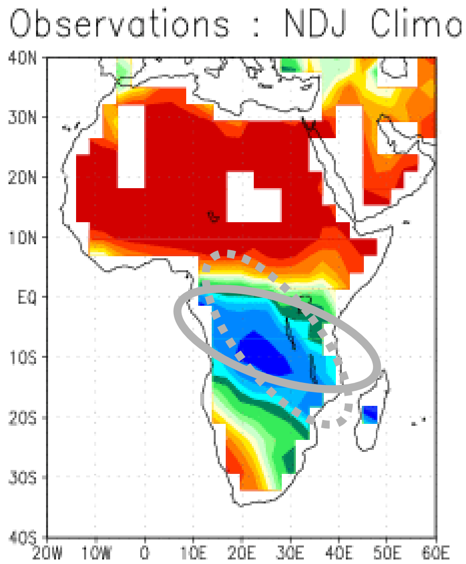
Land initialization

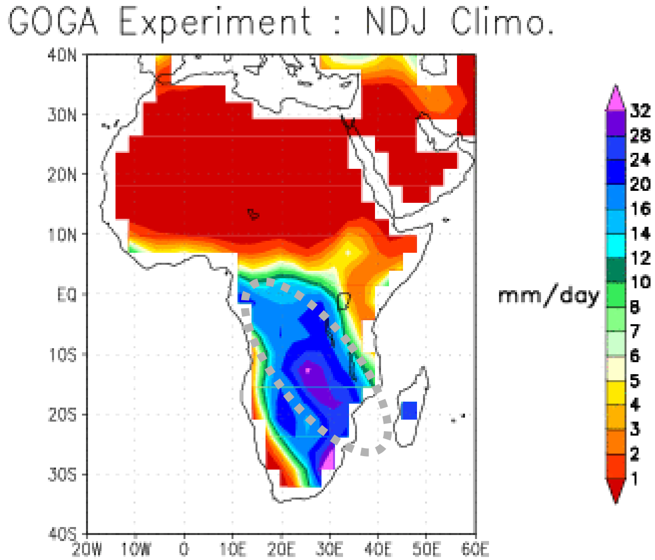


New Nesting Strategy

Anomaly Nesting
Misra and Kanamitsu (2004)



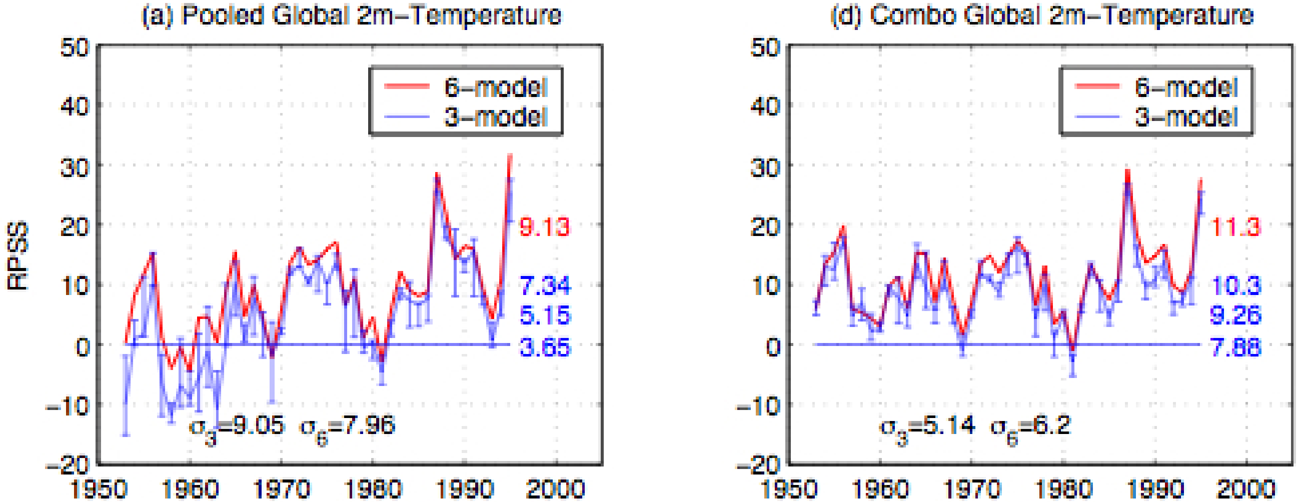




Multi-Model Ensembling

Climate Forecasts
- **be probabilistic**
- **be reliable**
- **address relevant scales and quantities**

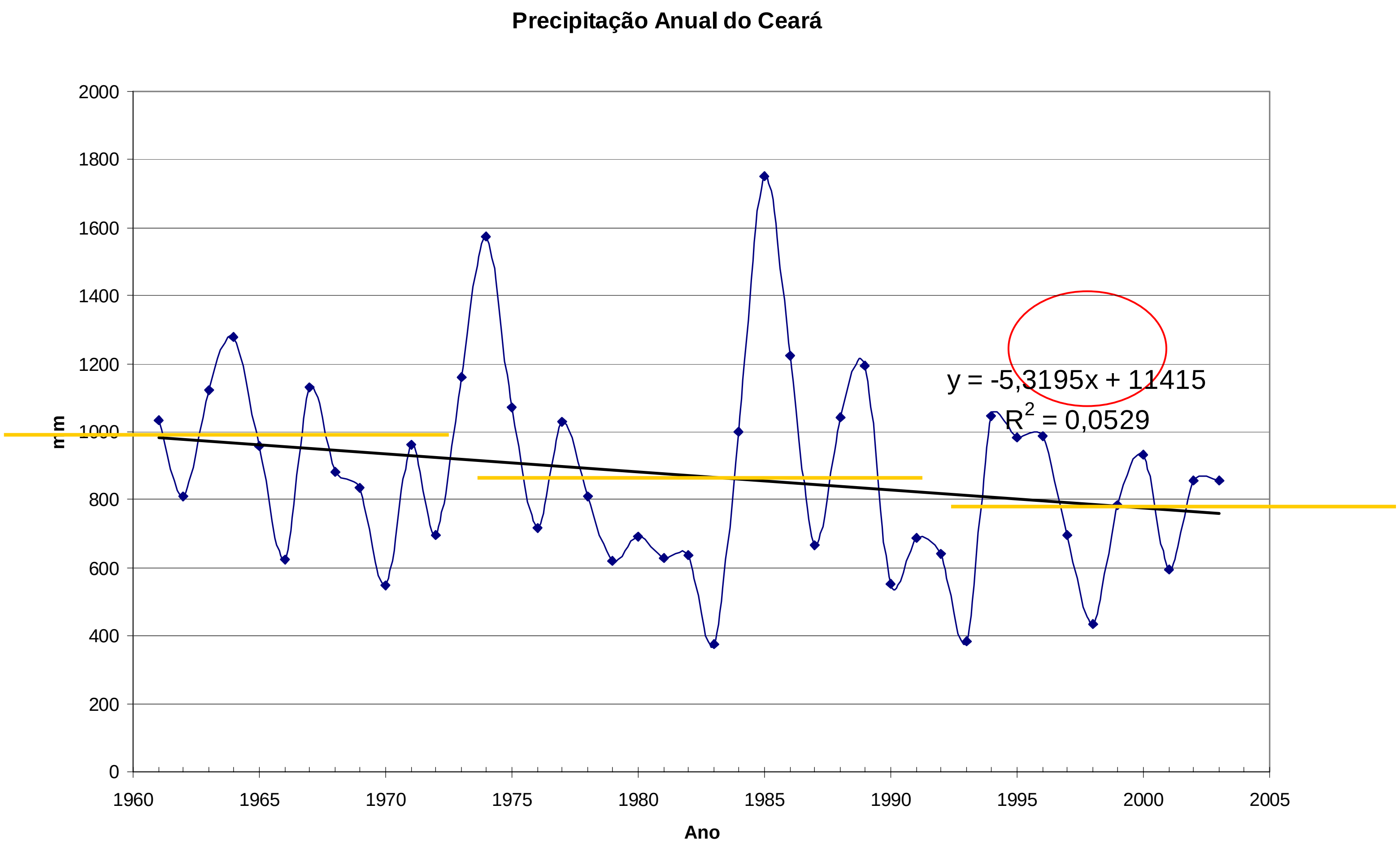
JAS Temperature



Robertson *et al.* (2004)

Benefit of Increasing Number of AGCMs in Multi-Model Combination

Changing Climate

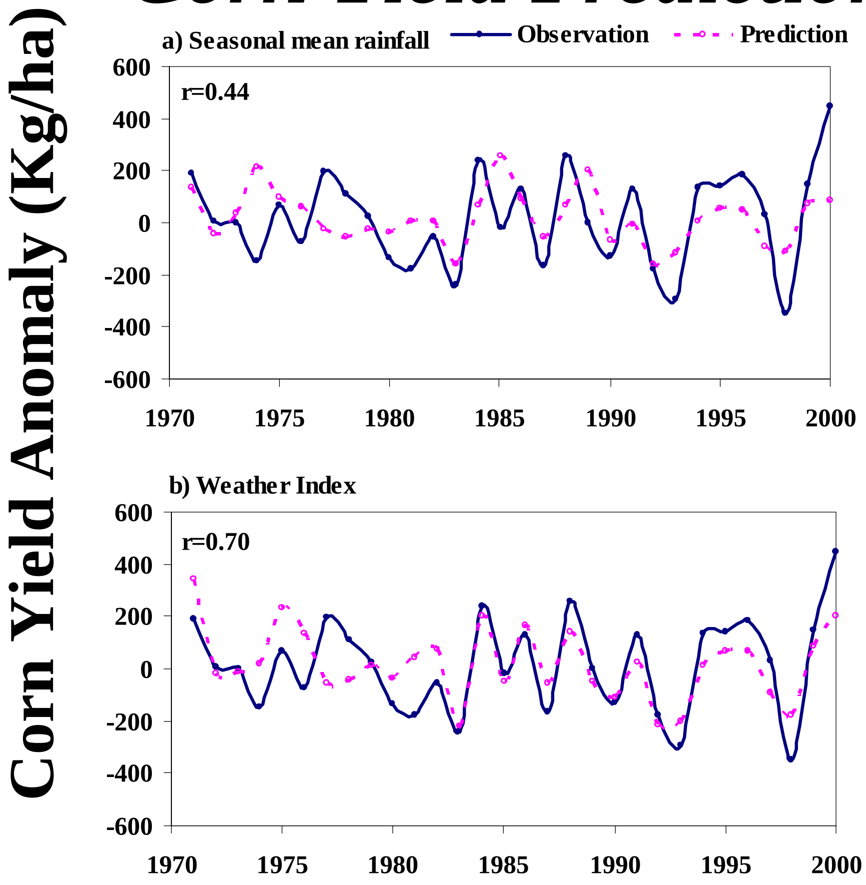


Moncunill and Sun (2008)

Os parâmetros calculados neste modelo tem um nível de significancia de 0,1% no teste t de student.

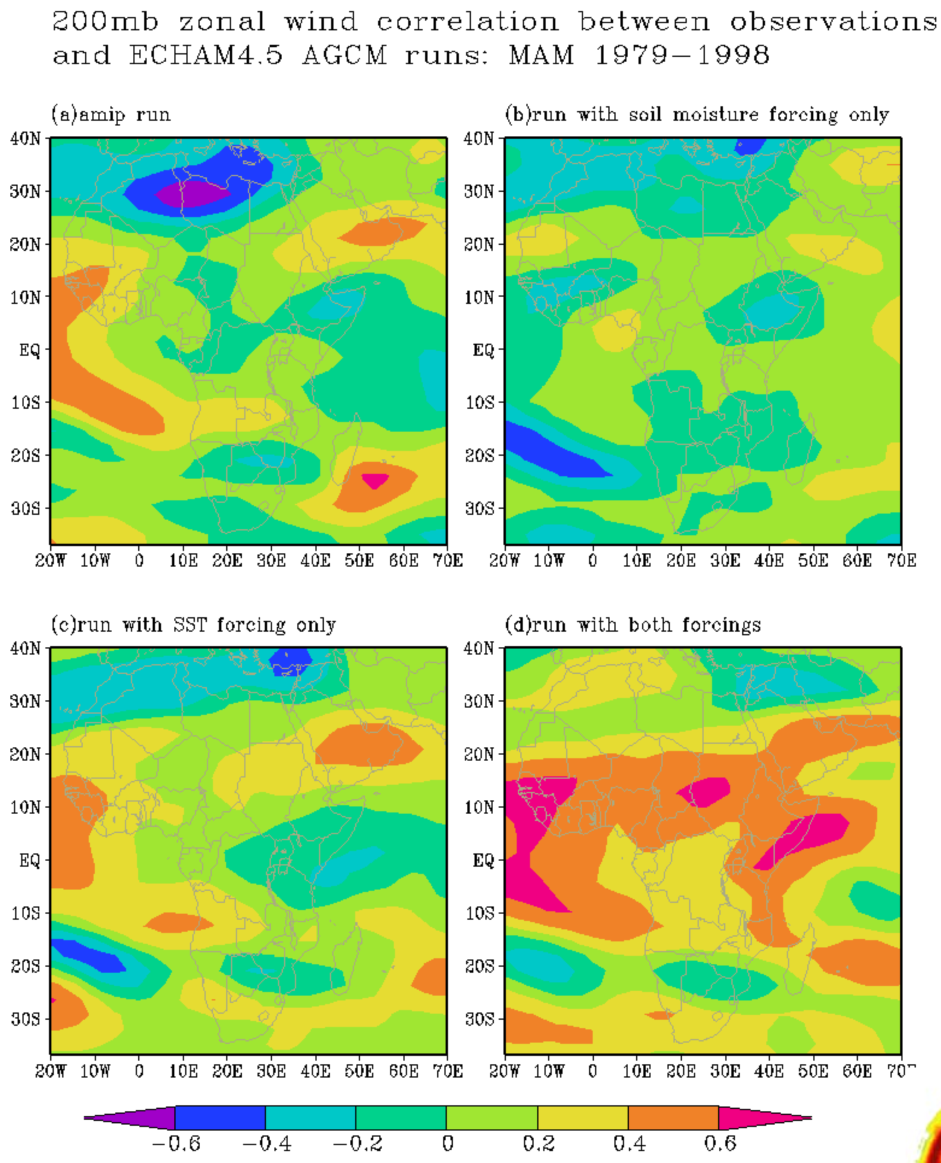
Linking prediction and application - Climate Risk Management (CRM)

Corn Yield Prediction



Sun *et al.* (2007)

Land initialization

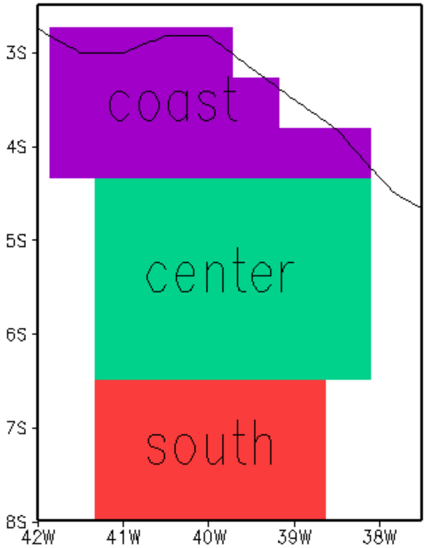


Sun *et al.* (2008)

Spatial scale separation

$$P = P_{LS} + P_{RS}$$

homogeneous subregions



Sun and Ward (2007)

Contingency tables for 3 subregions of Ceara State at **local scales** (FMA 1971-2000)

OBS (columns) / RSM (rows)

Coast	B	N	A
B	5	3	2
N	3	4	3
A	2	3	5

Central	B	N	A
B	5	2	3
N	4	5	1
A	1	3	6

Southern	B	N	A
B	4	3	3
N	3	5	2
A	3	2	5