

Brazilian Earth System Model BESM

History, Challenges, Status

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CONCLIMA, 9 September 2013



1a Conferência Nacional de Mudanças Climáticas
Globais São Paulo
09 a 13/09/2013 - FAPESP - São Paulo



FAPESP
MUDANÇAS
CLIMÁTICAS



Ministério da
Ciência, Tecnologia
e Inovação



BESM Financial Support:

- Rede CLIMA – Rede Brasileira de Pesquisa sobre Mudanças Climáticas Globais
- INCT-MC – Instituto Nacional de Ciência e Tecnologia em Mudanças Climáticas
- PFPMCG – Programa FAPESP de Pesquisa em Mudanças Climáticas Globais

BESM Science Team

- **Principal Investigator:** C. A. Nobre
- **General Coordinator:** P. Nobre
- **Atmosphere:**
 - J. P. Bonatti, J. P. Fernandez, S. N. Figuereroa, P. Kubota, F. Pesquero, E. Ramirez, G. Luzia, T. Tarasova, O. Moraes
- **Ocean:**
 - P. Nobre, E. Giarolla, L. Siqueira, M. Malagutti; M. J. Bottino; G. Marcondes, M. Baptista
- **Surface:**
 - M. H. Costa, G. Sampaio, M. Cardoso, M. Sanches, A. Luz, F. Murta,
- **Chemistry:**
 - S. Correa, D. Alvin, D. Enoré, V. Capistrano

BESM Core Institutions

- **Coordination:** INPE
- **Atmosphere:**
 - INPE/CPTEC, USP, UFSM, UFCG
- **Ocean:**
 - INPE/CPTEC, USP, UFPE, IISc, NASA/GISS, NOAA/GFDL
- **Surface:**
 - INPE/CCST, USP, UFV, UFSM, WHRC, EMBRAPA
- **Chemistry:**
 - UERJ, INPE, NCAR, MPI, IITM, CSRI



Global Climate Change

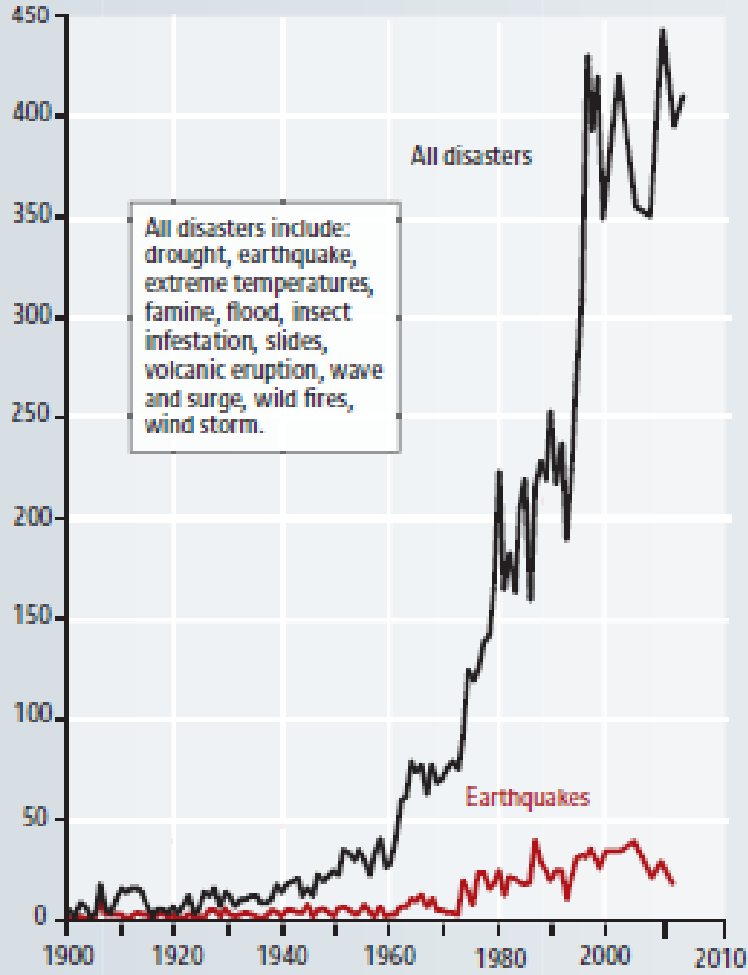
Extreme Events Fast Growth

Hurricane Catarina (2004)



Hadley Centre, UK

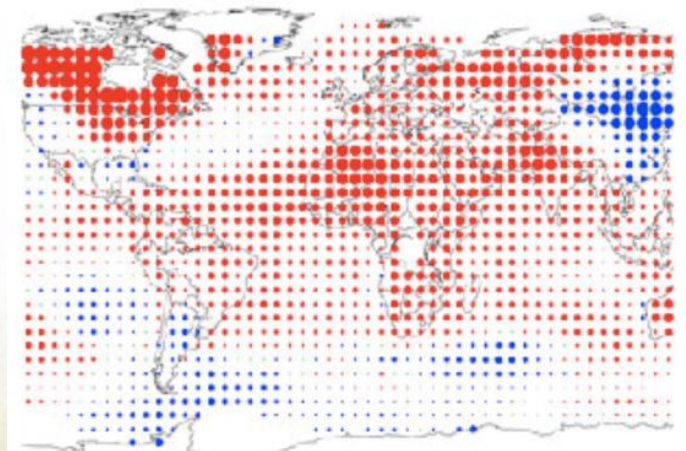
Number of disasters per year



Source: CRED Annual Disaster Statistical Review 2006, 2007.

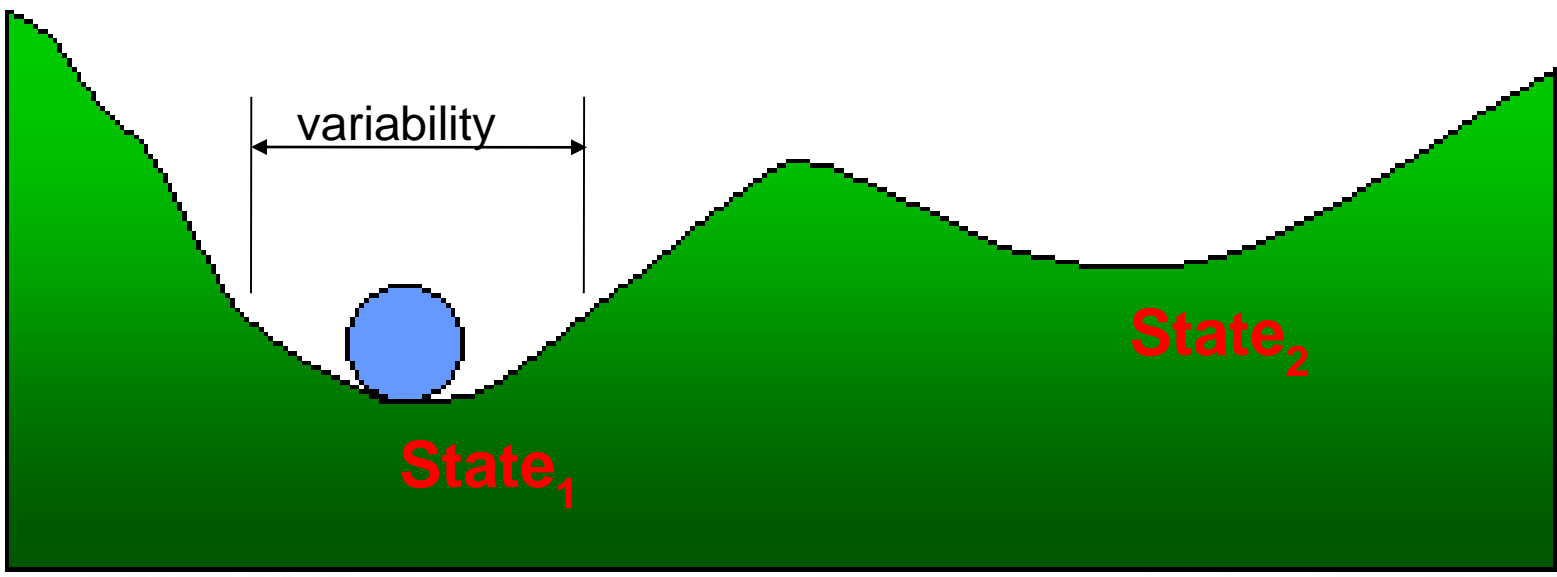
The Blue Carbon Report - UNEP

JFMA 2010: Hottest Period on Record



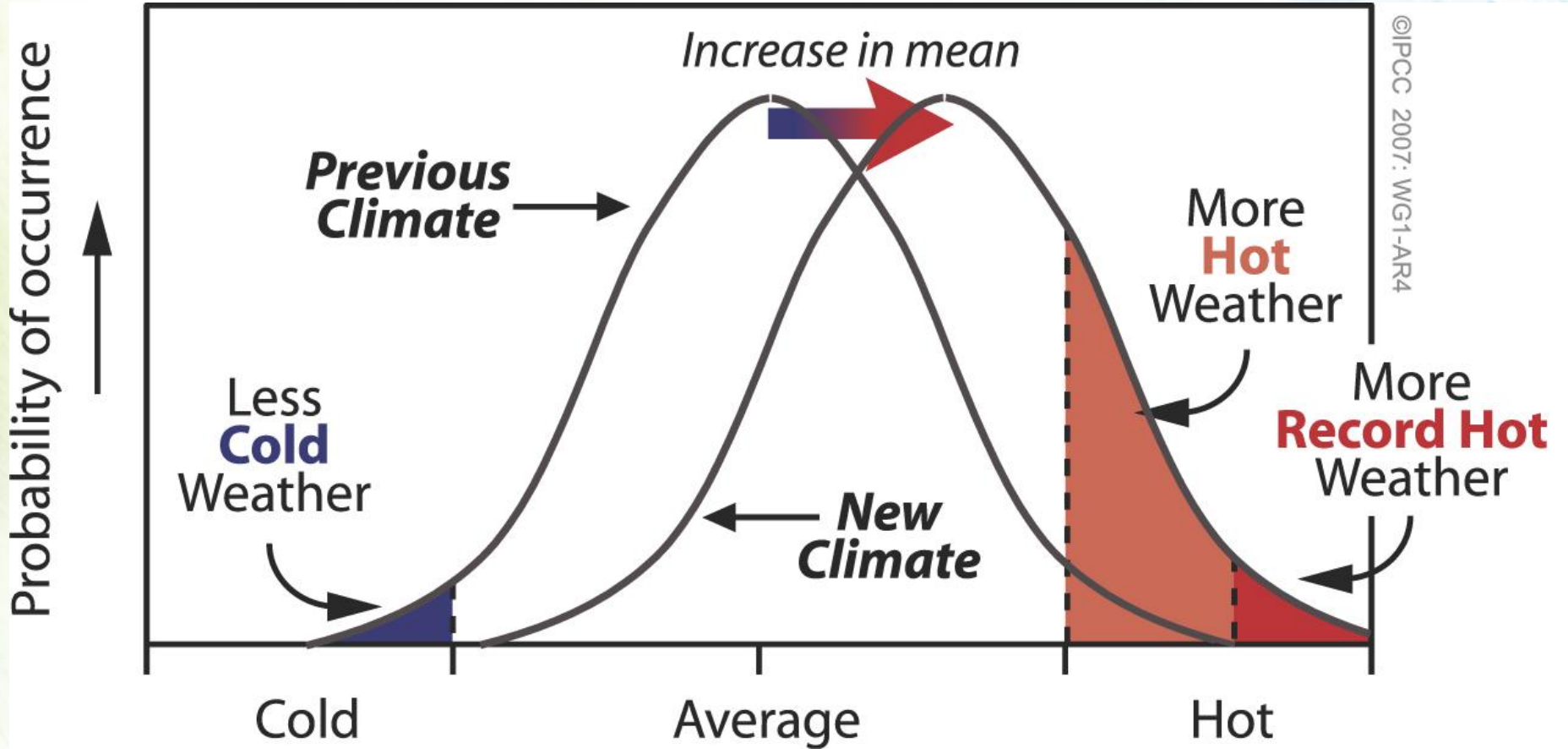
Source: NOAA (2010)

Climate Variability x Change

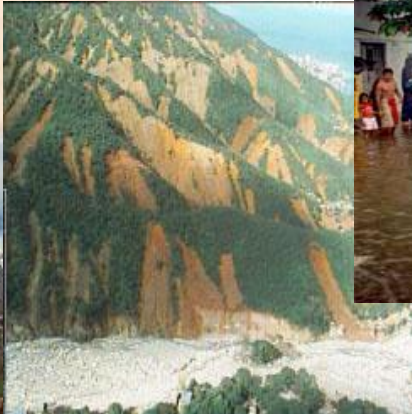


$$T_1 < T_2$$

Change of Frequency of Extremes



Extreme Events Impact on Peoples Lives



Floods

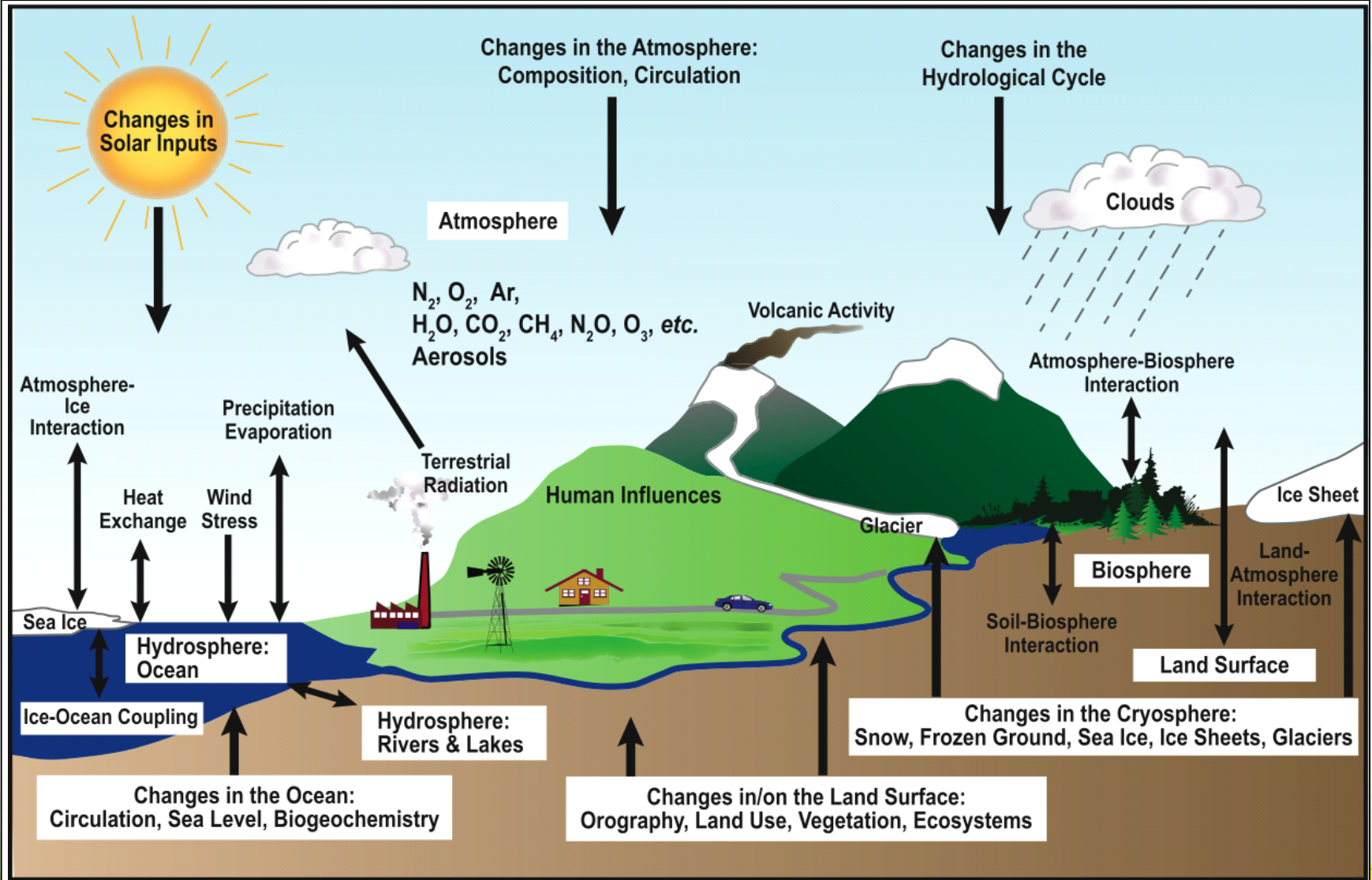
Governador Valadares, MG, 2011



Our Challenge:

- ***To build an Earth System Model in Brazil, from state of the art component models in the nation and abroad:***
 1. To incorporate expert knowledge (e.g. the LBA program) about ocean-ice-atmosphere-biosphere interactions of relevance to Brazil;
 2. To provide the scientific foundations of global climate change scenarios for mitigation and adaptation policies to climate change in Brazil;
 3. To contribute to form a new generation of modeling-capable earth system scientists in the nation.

The Global Climate System



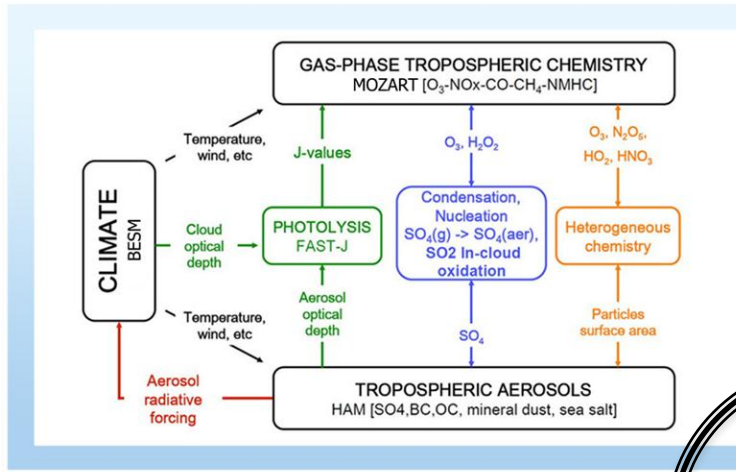
BESM DEVELOPMENT STRATEGY

- (i) full use of CPTEC's experience and sub-models
- (ii) collaboration with advanced climate change centers abroad
 - Take CPTEC Global Coupled Ocean-Atmosphere Model as the structuring building-block
 - Use GFDL/FMS coupler to add components:
 - Dynamic vegetation with carbon cycle;
 - Continental hydrology-ocean coupling;
 - Ocean carbon cycle;
 - Enhanced sea ice and pack ice;
 - Atmospheric chemistry.

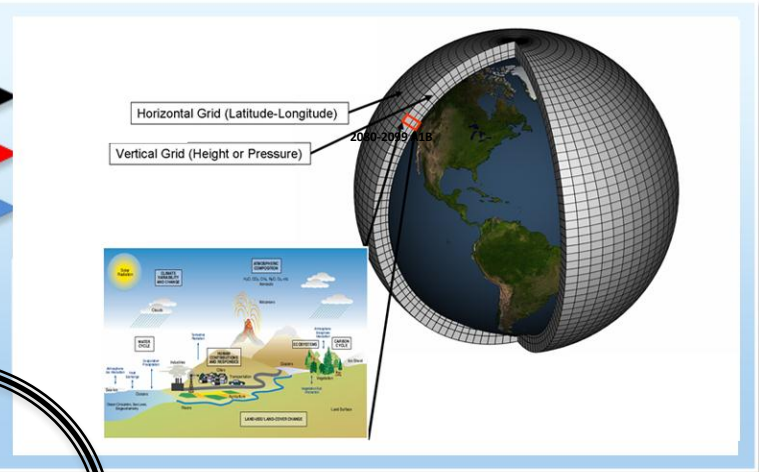
BESM Component Models

September 2013

ATMOS CHEMISTRY (HAMMOZ - MPI)

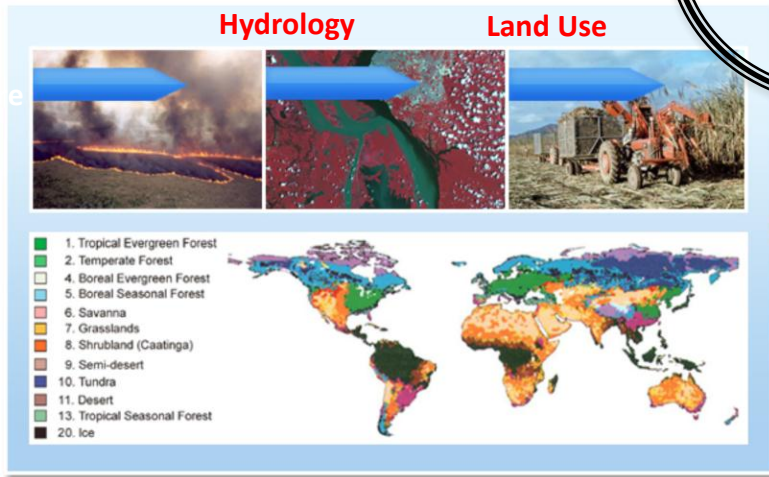


ATMOSPHERE (INPE/CPTEC)

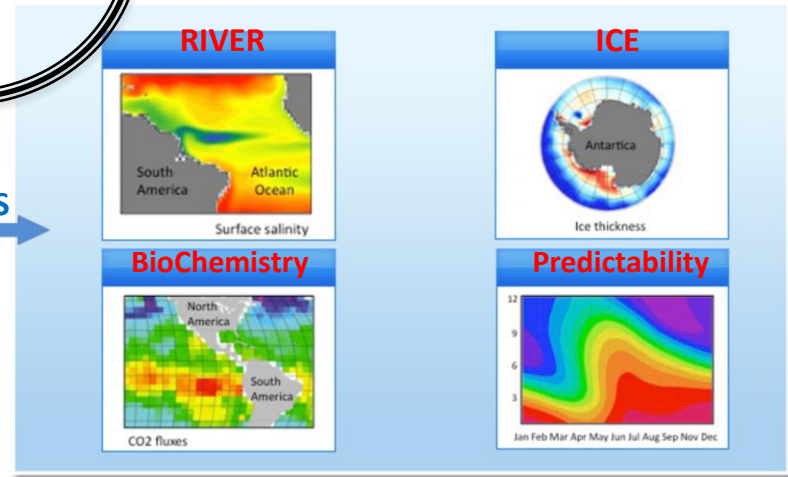


**FMS
 COUPLER**

LAND (IBIS – INPE/CCST)

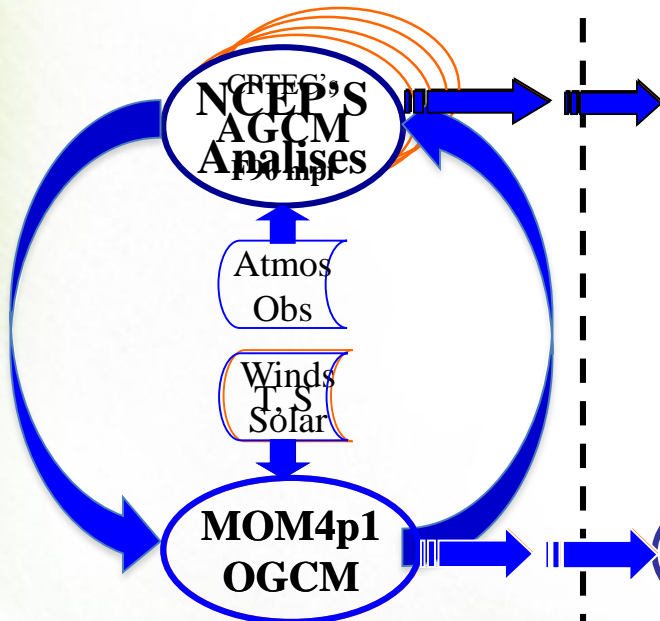


OCEAN (MOM4 – NOAA/GFDL)

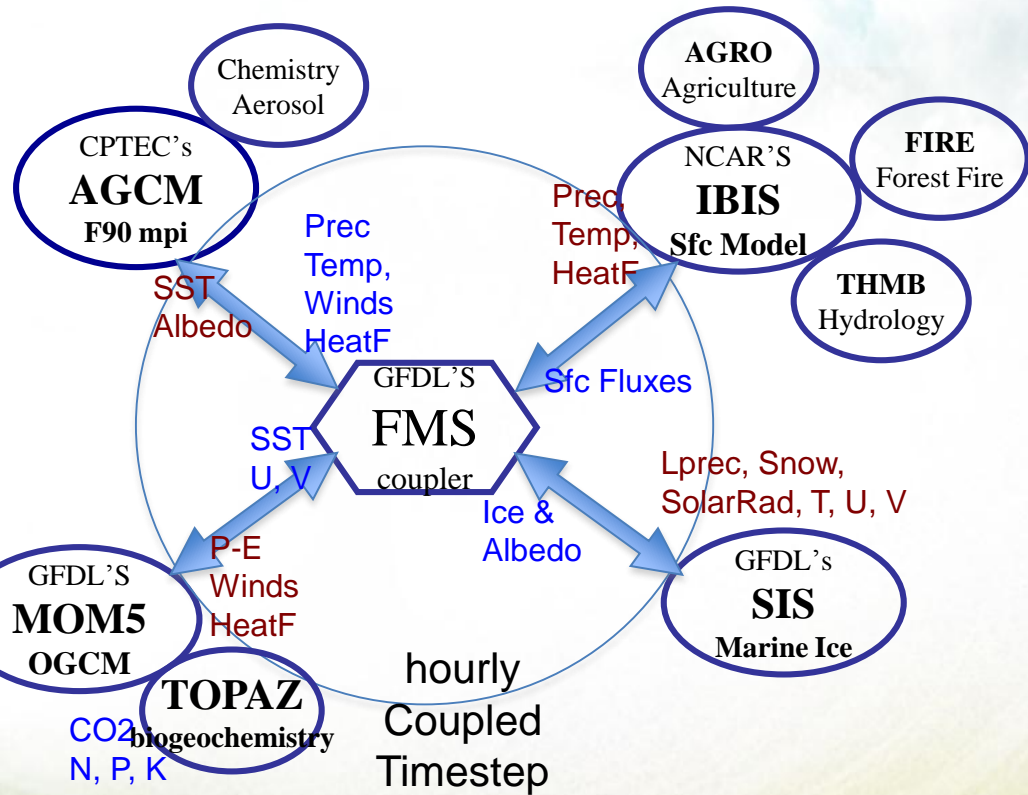


BESM System goal

Coupled Initialization



Coupled Forecast



IC

BESM SCIENTIFIC RESULTS

September 2013

- Amazon Deforestation and Climate Change
 - Nobre et al (2009) [J.Climate](#) [BESM-OA1.0 Global Tropics]
- Summer School on Global Climate Modeling
 - Nobre et al (2011) [FAPESP](#) São Paulo School on Advanced Studies
- Summer rainfall over South America
 - Nobre et al (2012) [J.Climate](#) [BESM-OA2.3]
- Oceanic CO2 modeling
 - De Farias et al (2012) [IJGS](#) [BESM-OA2.3_Topaz]
- IPCC-AR5 Atmospheric CO2 induced global warming
 - Nobre et al (2013) [J.Climate](#) [BESM-OA2.3]

- Under the hood:
 - The new version of BESM-OA2.4_Ibis

BESM Development Status

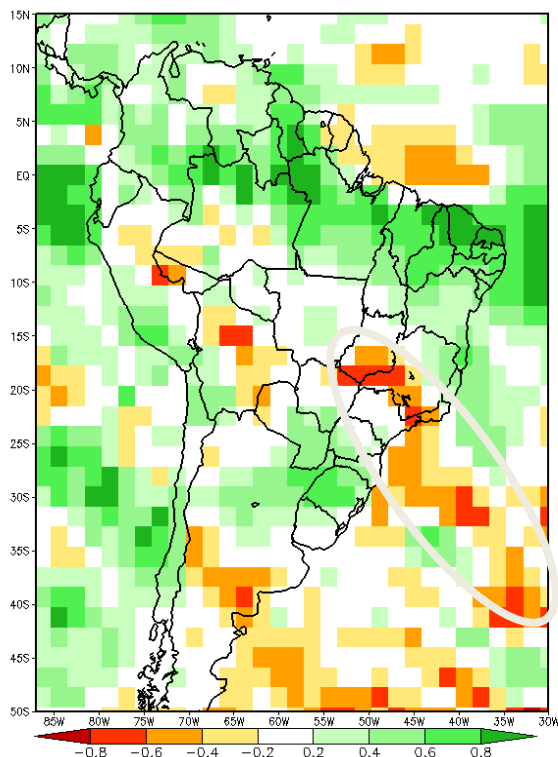
September 2013

- ✓ **BESM-OA2.3.0 (SSIB, Mauna Loa)**
 - ✓ CMIP5: 2,500 years decadal scenarios 1960-2100
 - ✓ Nobre et al (2013) J. Climate
- ✓ **BESM-OA2.3.1 (SSiB, Mauna Loa, RCPs):**
 - 3 articles in preparation
 - 2000-2100: RCP4.5 & RCP8.5;
 - 1875-2000: obs CO2, solar;
- ✓ **BESM-Ibis2.4.0 (IBIS, Mauna Loa, RCPs):**
 - Promising first results;
 - First experiments with Ibis dynamical vegetation;
 - Land use change;
- **BESM-Hammoz2.5.0 (Atmos Aerosol & Chemistry):**
 - Echam-HAMMOZ: implemented at Tupã Supercomputer, in tests.

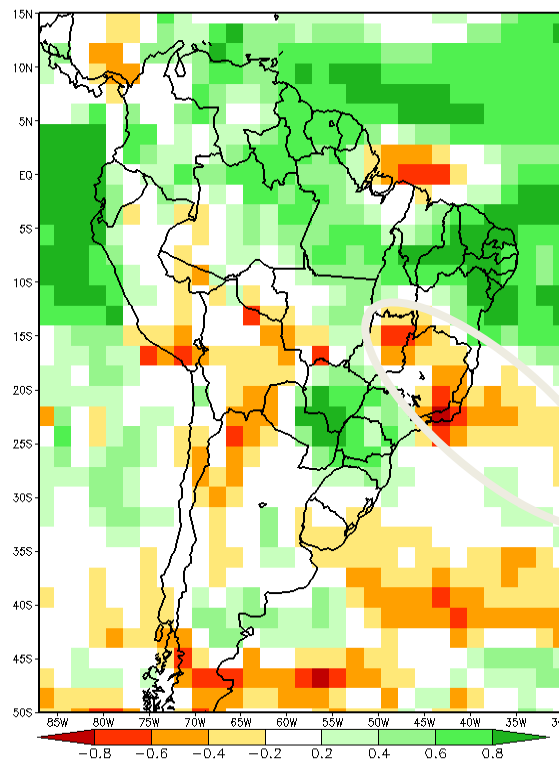
SACZ Signature, not captured by AGCM

Increased Rainfall over **WARM** Waters

DJF



MAM



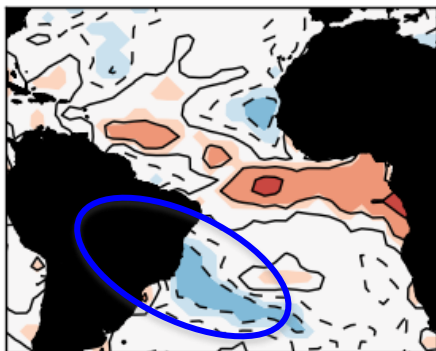
CPTEC AGCM, 50 years, 10 Member Ensemble, Kuo, T062L28, Obs SST

SACZ Signature, Represented by BESM

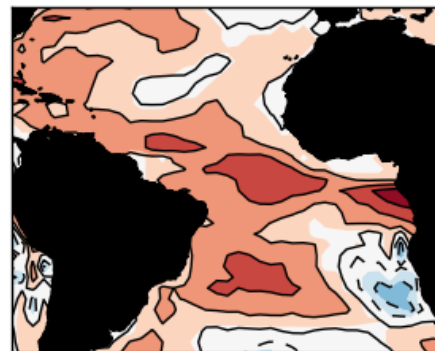
Increased Rainfall over Cold Waters

ACC (SST, precipitation)

OBSERVATIONS

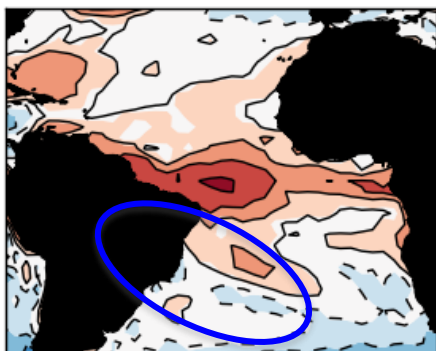


observations

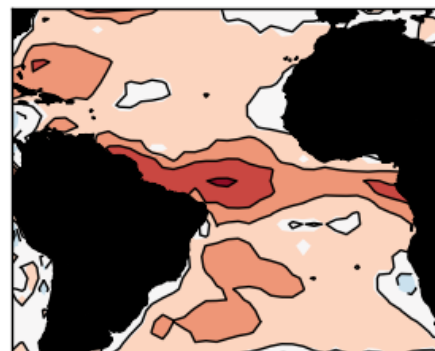


AGCM ← OISST

BESM-OA2.3

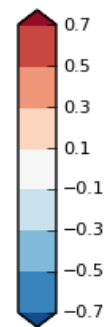


CGCM



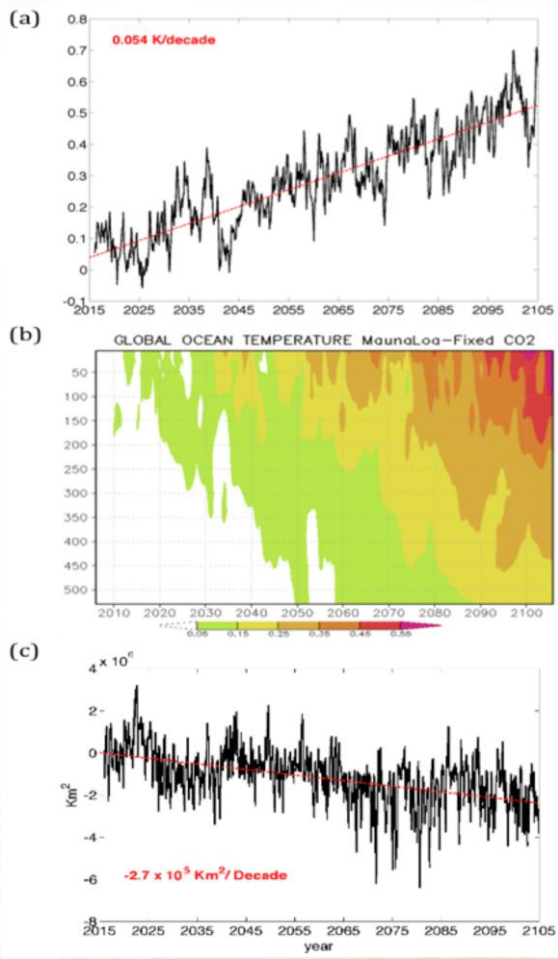
AGCM ← CGCM SST

AGCM, Obs SST

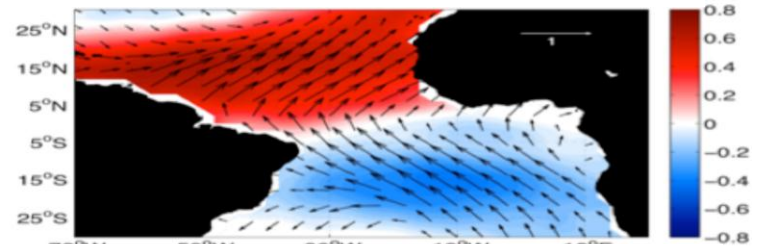


AGCM, BESM SST

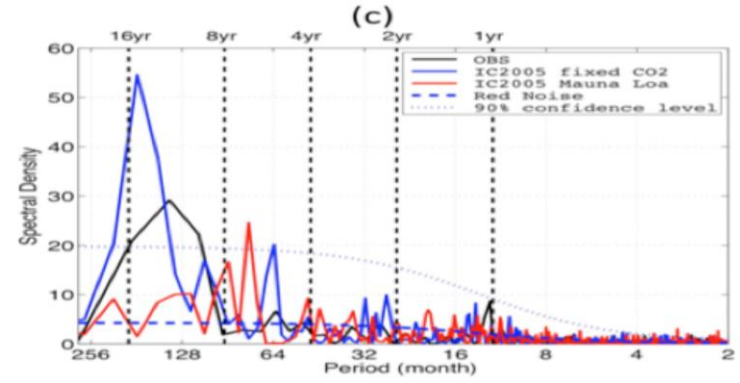
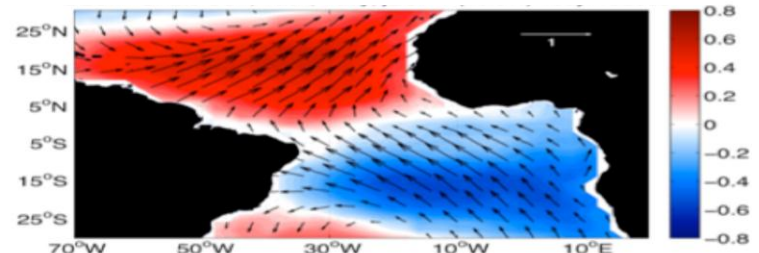
BESM-OA2.3 CMIP5 RESULTS



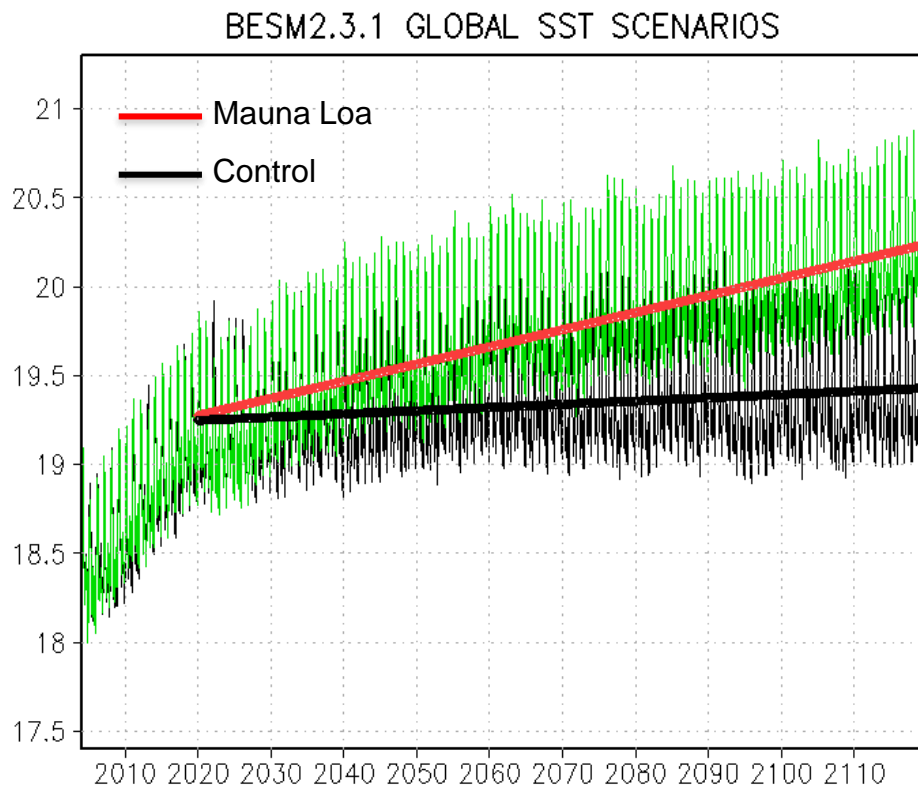
ERSST JEOF1 (12.5%) 1960-2010



BESM2.3 JEOF1 (12.5%) 2005-2105



BESM2.3.1 Centennial Runs

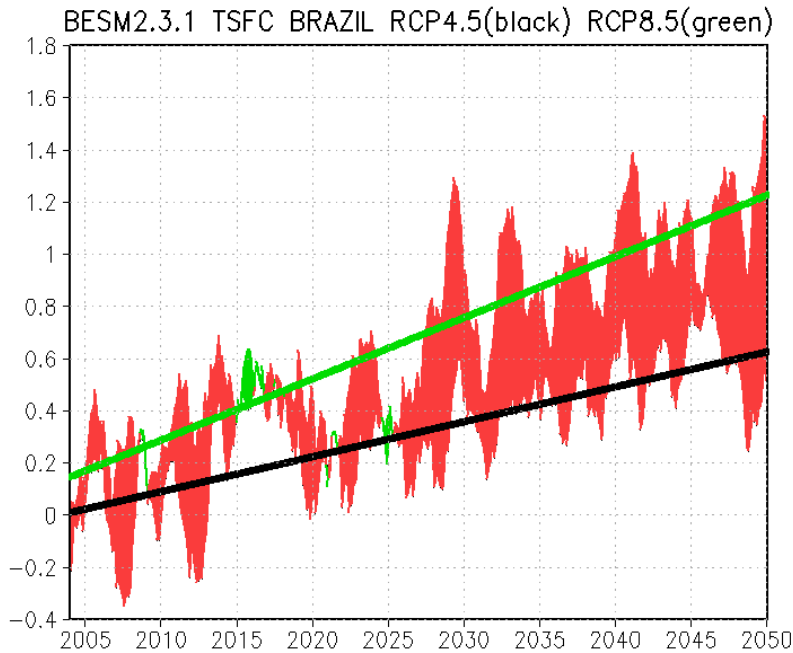


GRADS: COLA/IGES

- Cenários BESM (Mauna Loa): aquecimento dos oceanos e da atmosfera global devido ao aumento da concentração de CO₂ atmosférico.
- 10.000+ anos de integrações do BESM em modo de conjuntos já realizados no supercomputador Tupã no INPE.

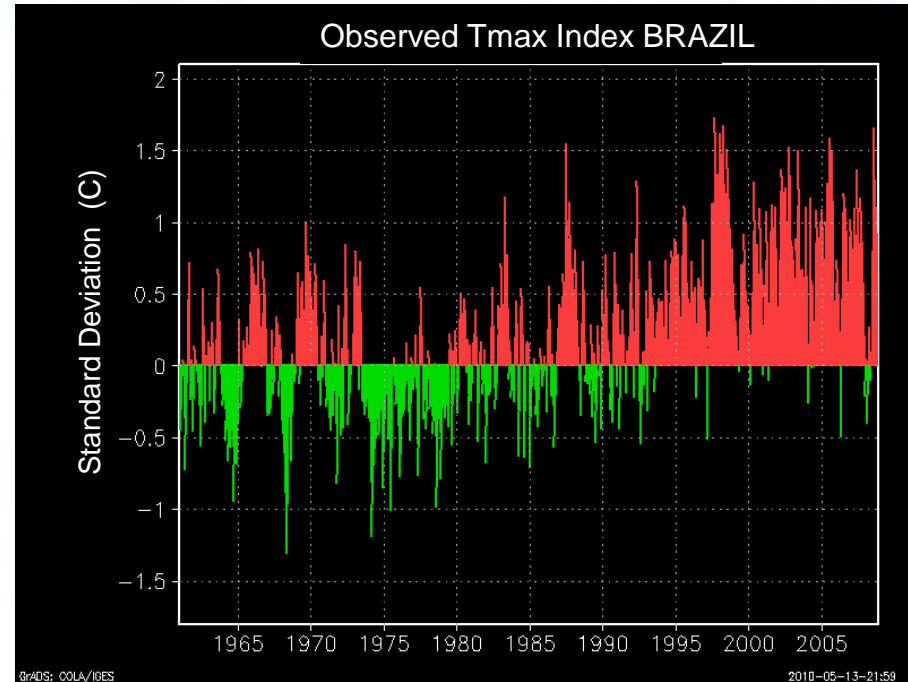
CMIP5 BESM2.3.1 RCPs Scenarios

Surface Temperature over Brazil



GrADS: COLA/IGES

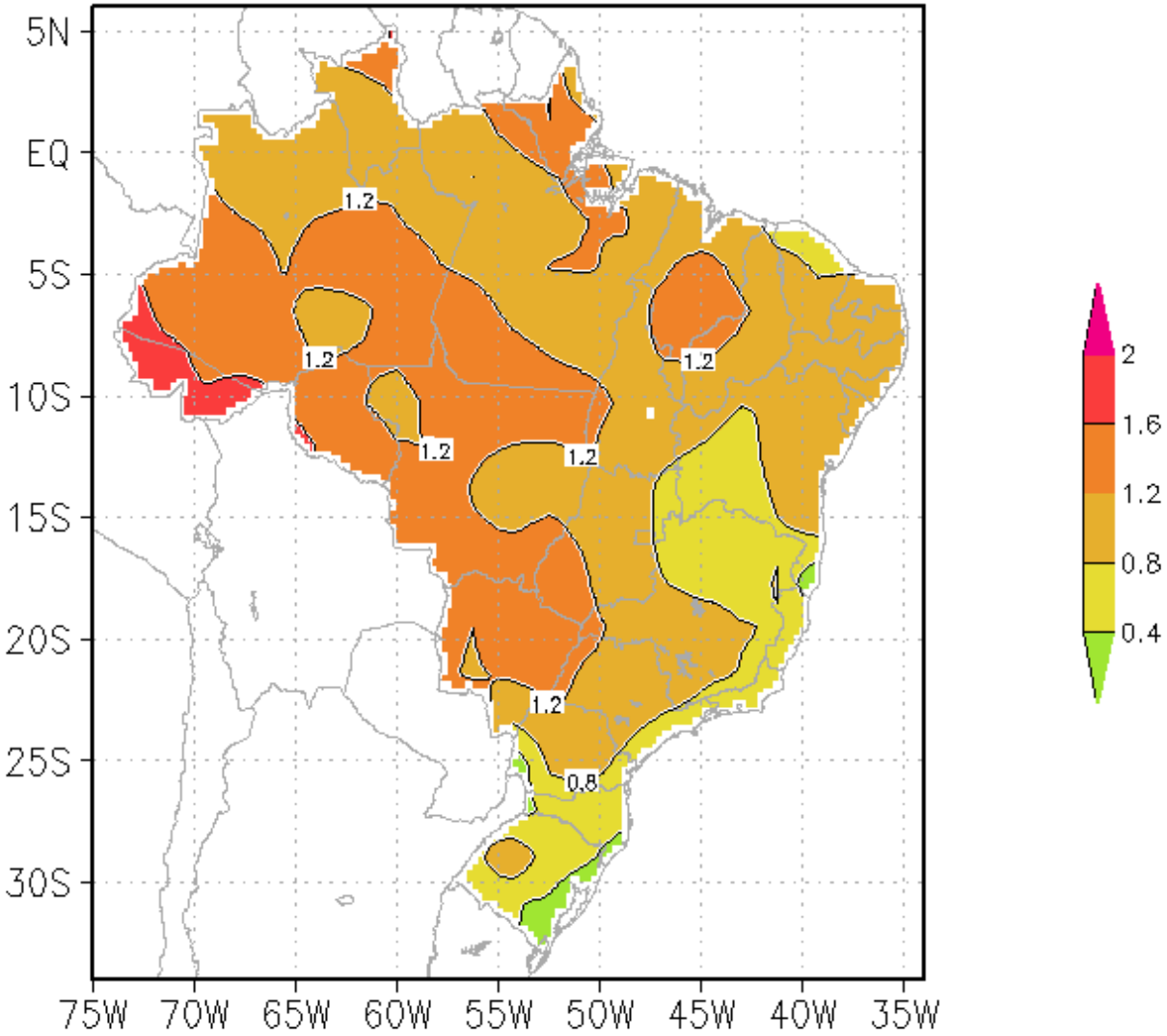
- RCP 8.5: 0.235 C/decade
- RCP 4.5: 0.134 C/decade



GrADS: COLA/IGES

2010-05-13-21:58

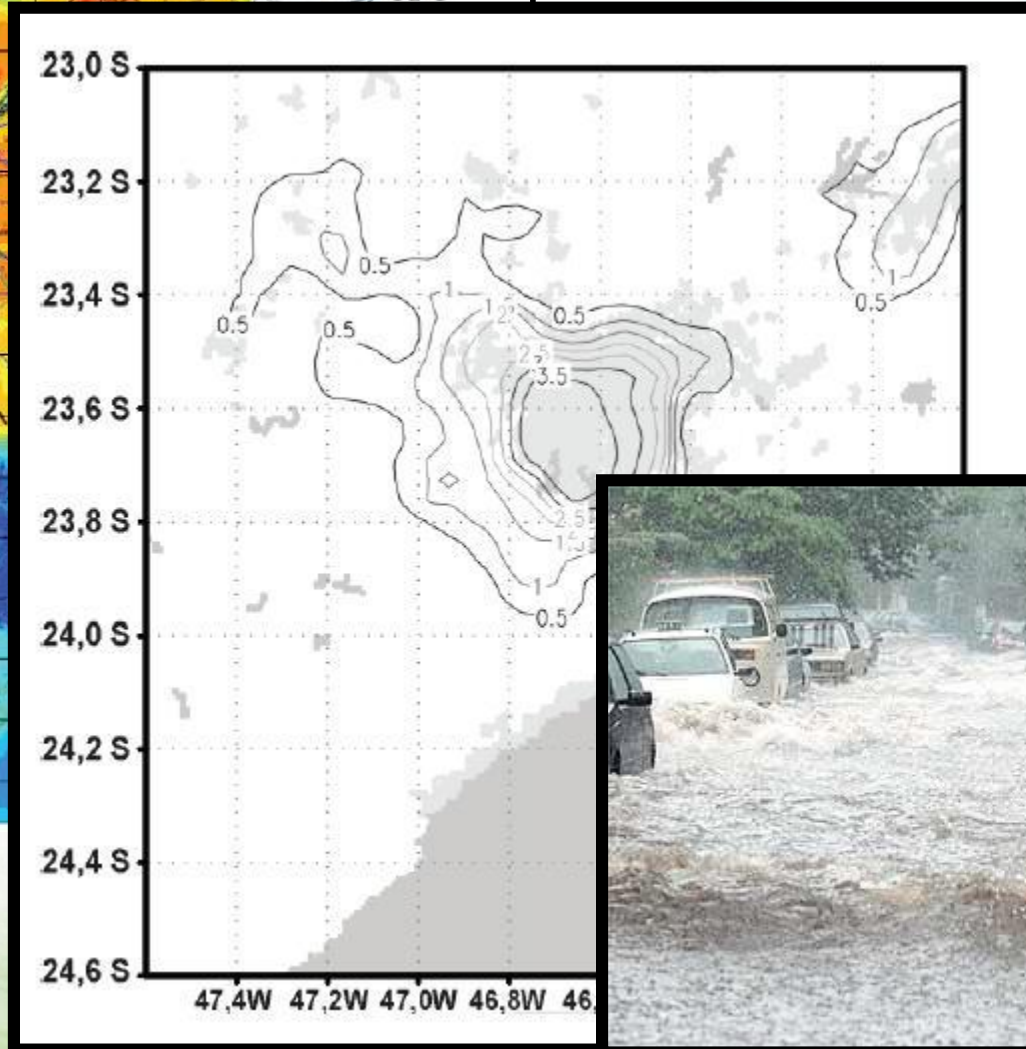
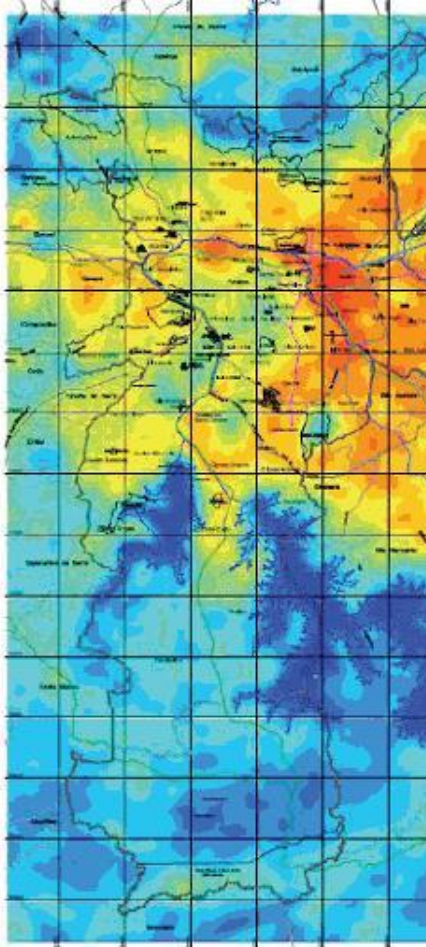
BESM-0A2.3.1 2050 TSFC CHANGE: RCP 8.5



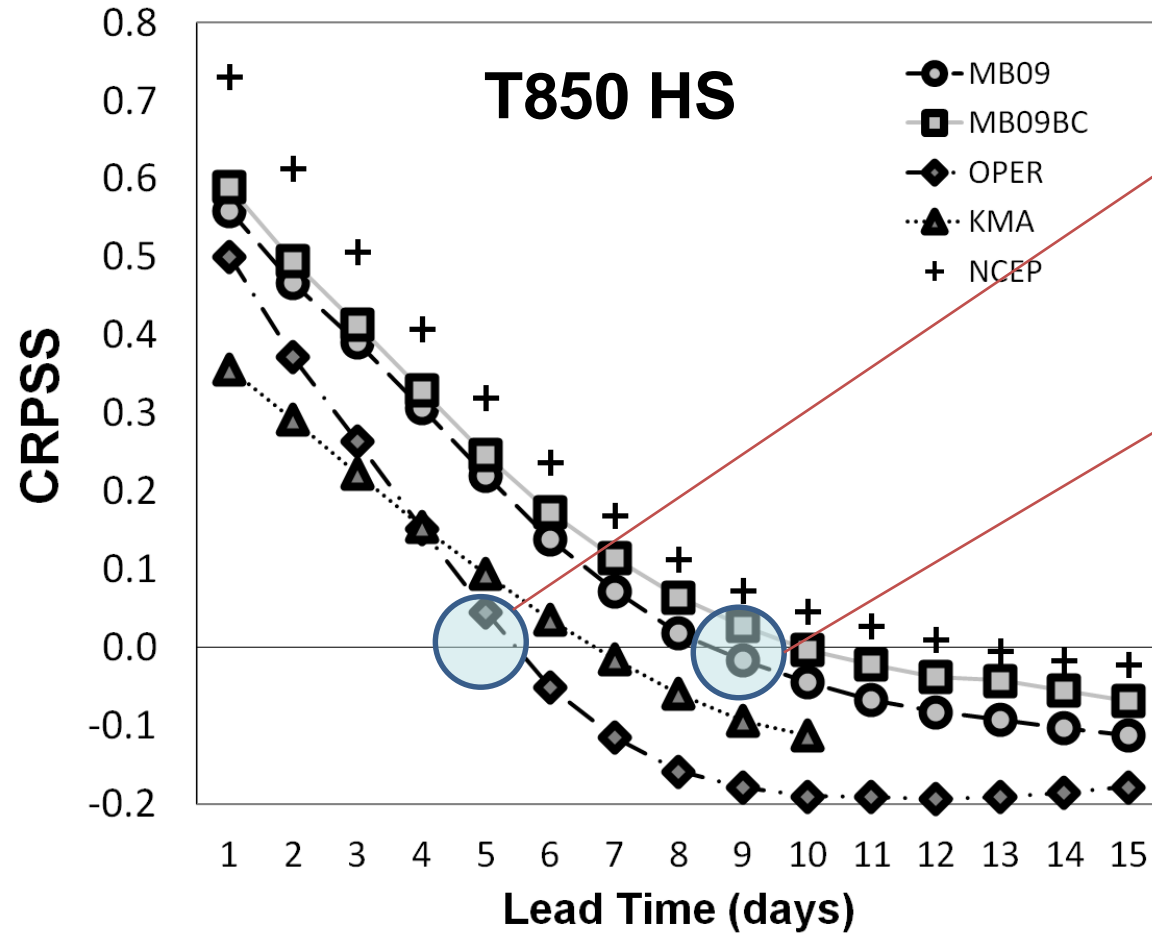
Global Climate Change and the Mega-Cities

São Paulo Heat Island

Heat Island Impact on Rainfall



CPTEC AGCM Version 2012 Improvements

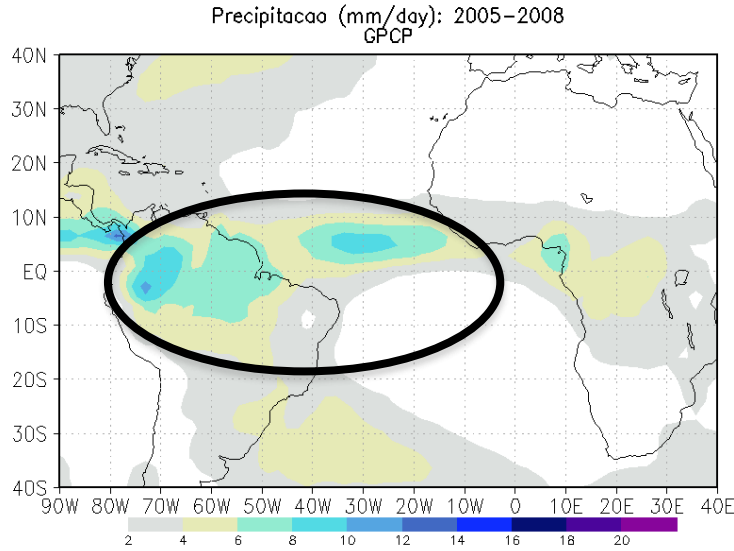


Previous version 5th day usable forecast skill

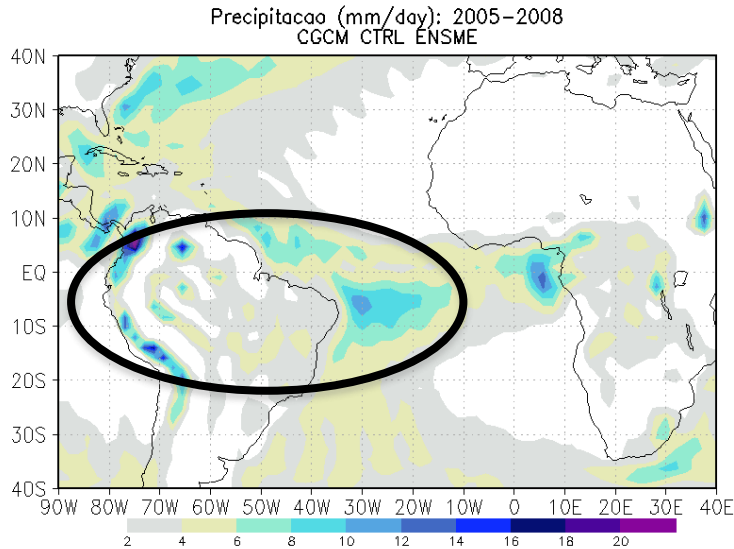
MB09BC's 9th day usable forecast skill

BESM Rainfall over the Amazon

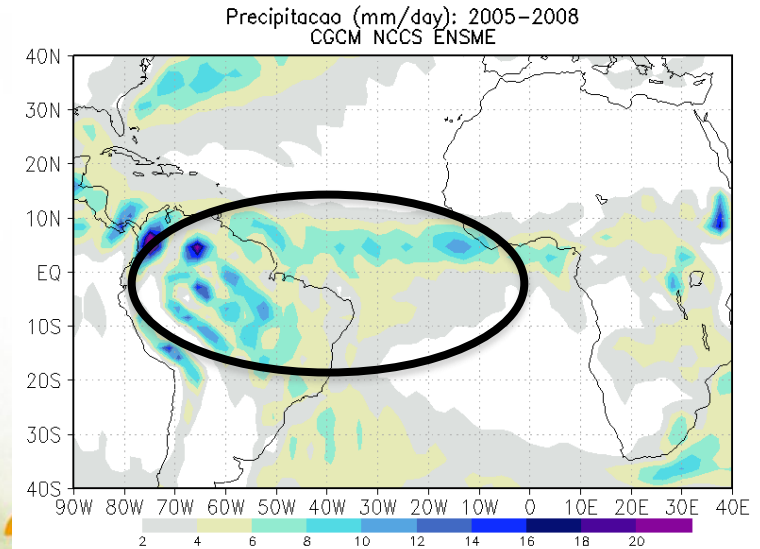
GPCP



BESM 2.3



BESM 2.3.1

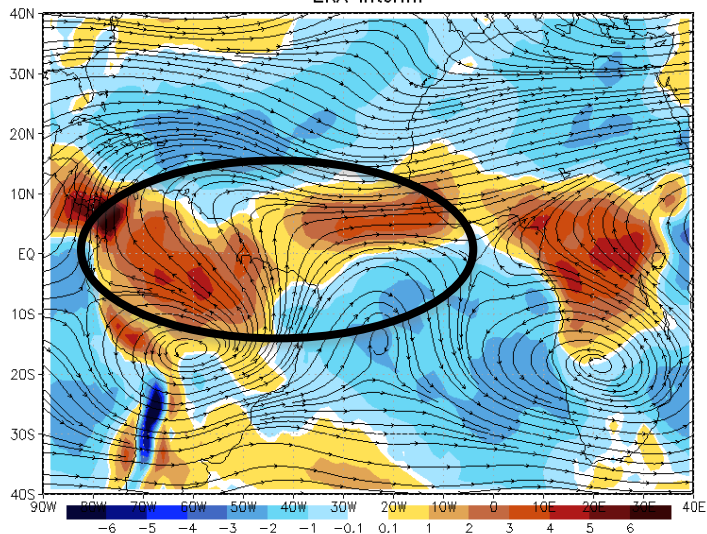




BESM Upper Air Divergence

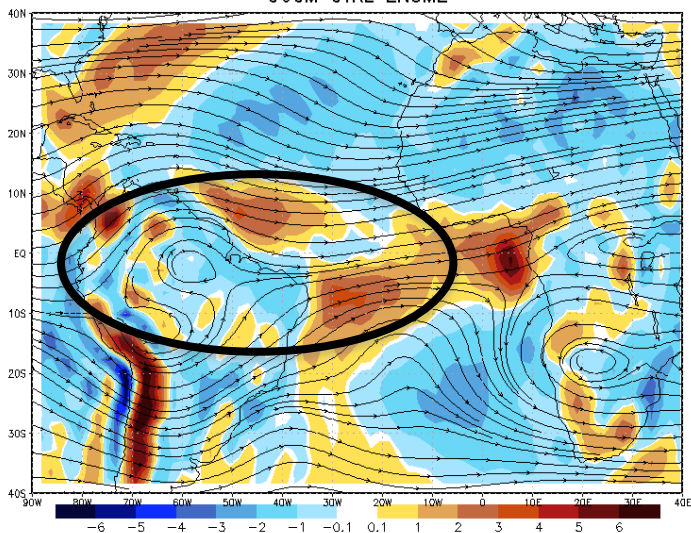
Reanalysis ERA interim

Divergência do Vento a 200hPa ($10e-6 s^{-1}$) : 2005-2008
ERA interim



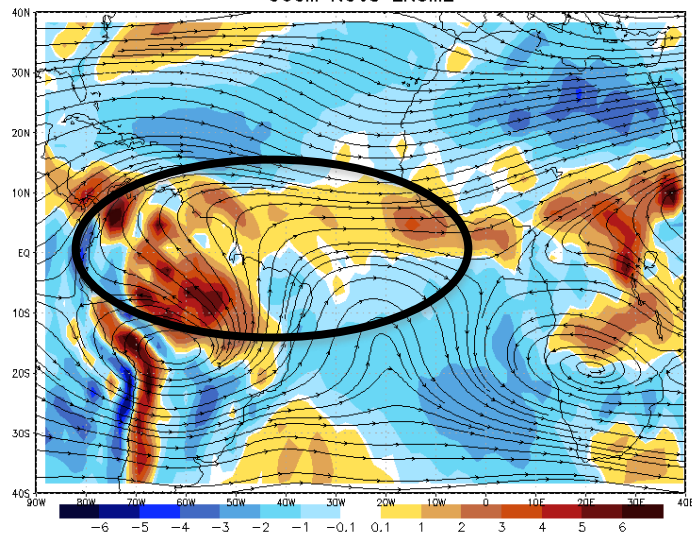
BESM 2.3

Divergência do Vento a 200hPa ($10e-6 s^{-1}$) : 2005-2008
CGCM CTRL ENSME



BESM 2.3.1

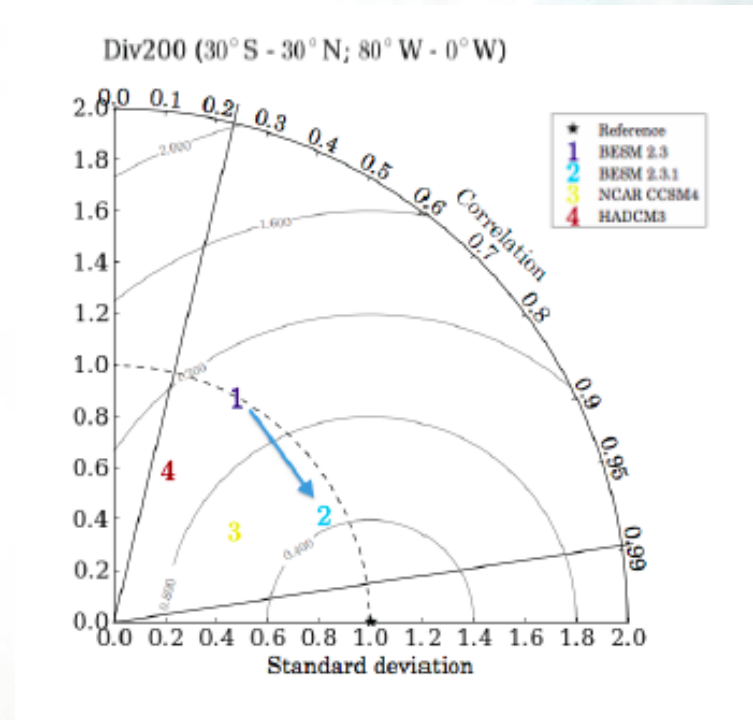
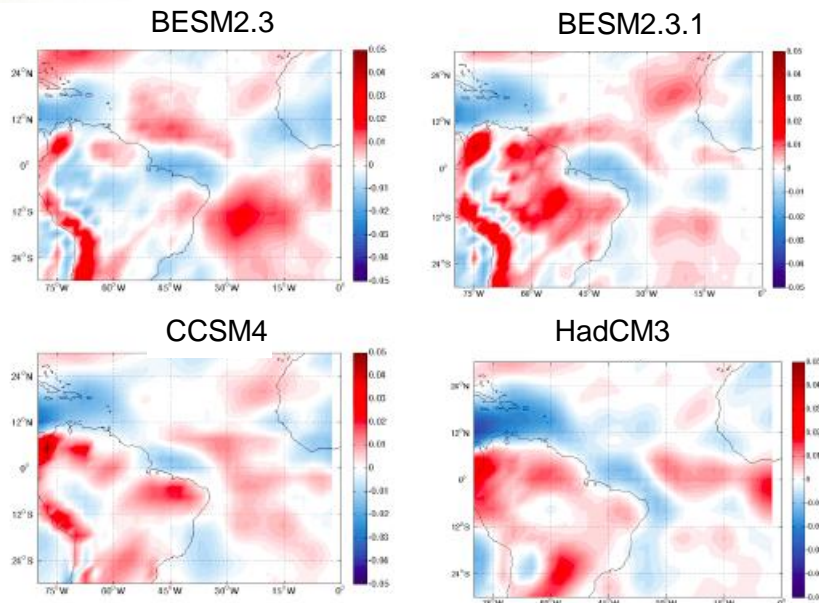
Divergência do Vento a 200hPa ($10e-6 s^{-1}$) : 2005-2008
CGCM NCCS ENSME



Upper Level Divergence CMIP5 Models Intercomparison

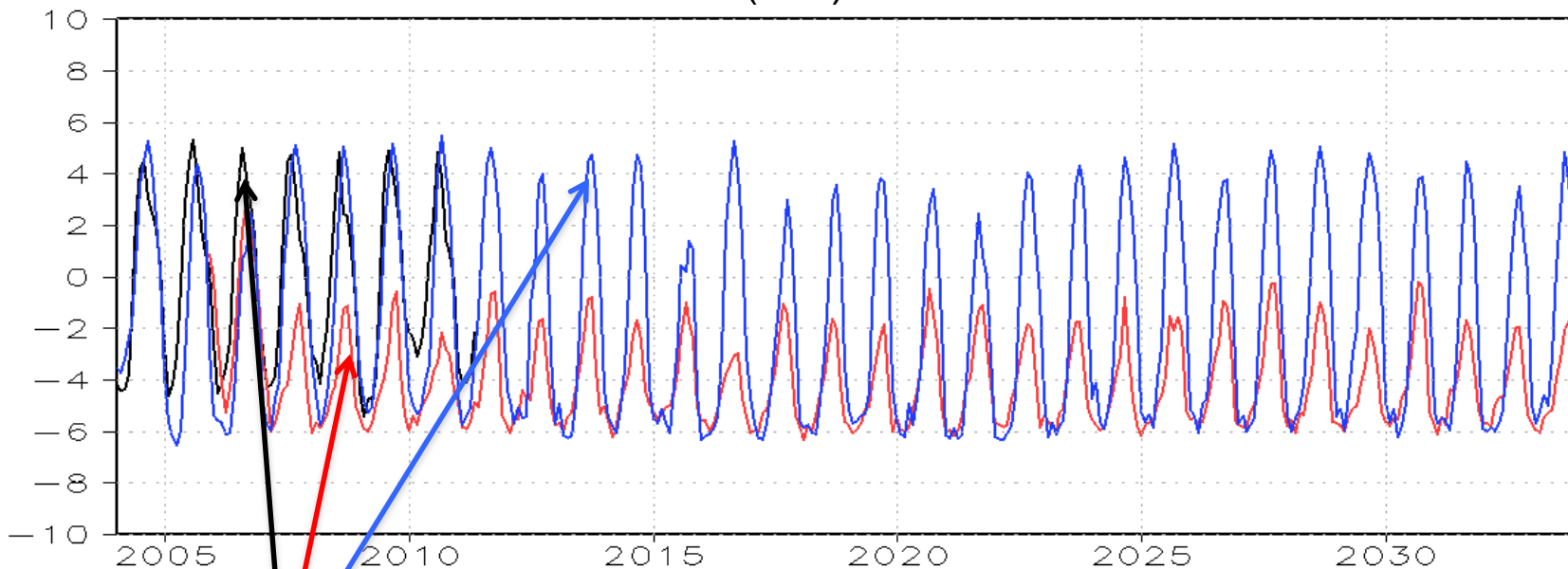
PRECIP BIAS

CLIMO SKILL



BESM-OA2.3.1 Atlantic ITCZ North-South Migration

V at 10 m (m/s): 5N 30W +/- 2

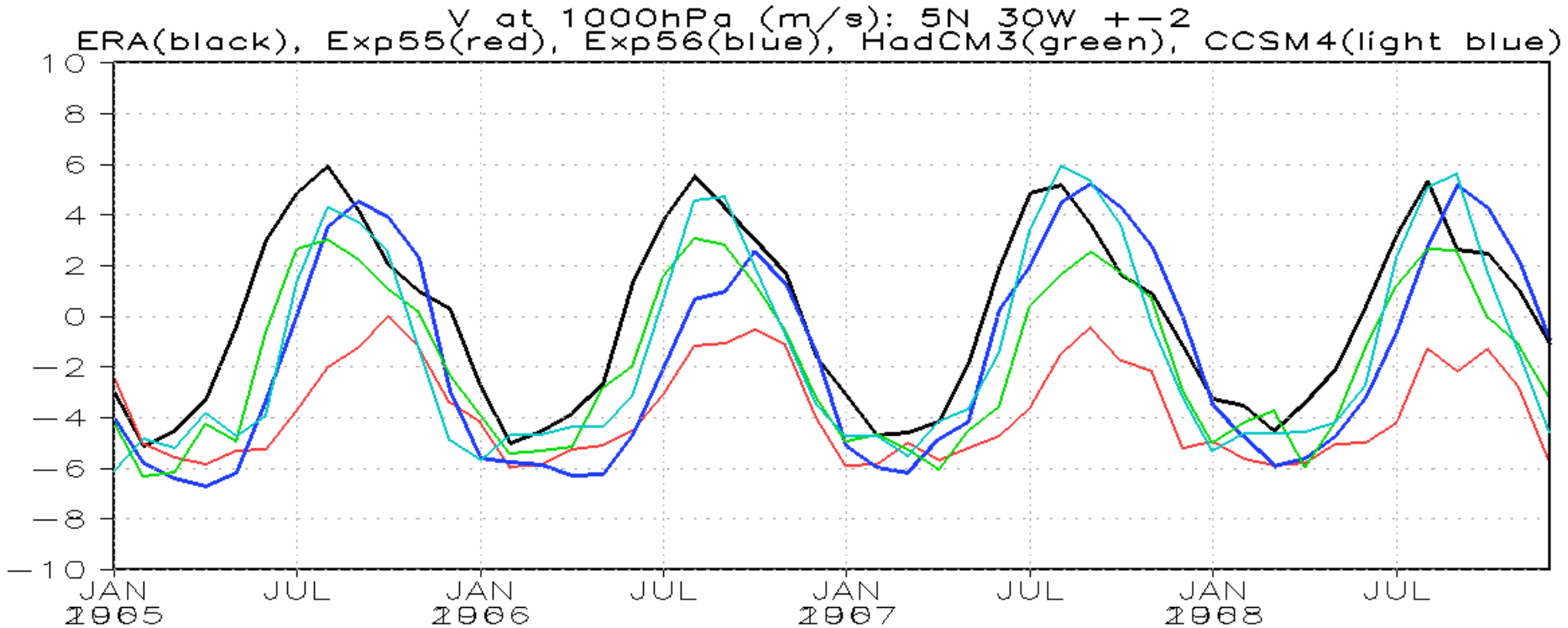


Representação da migração sazonal
Norte-Sul da ZCIT

— Reanalysis Era Interim
— BESM2.3 (bias = -4.38; rmse = 5.11)

BESM-OA2.3.1

Atlantic ITCZ North-South Migration

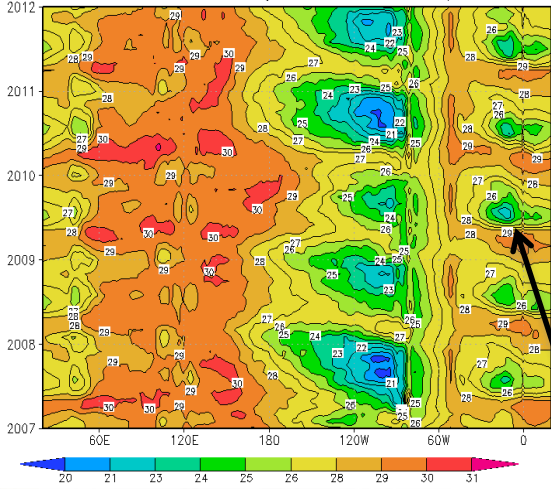


BESM-Ibis2.4

Equatorial Atlantic Cold Tongue

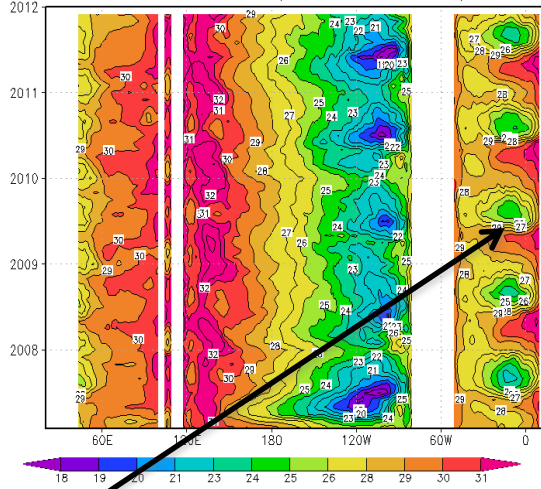
OBSERVATION

OISSTv2 SST (lat 0N, 2007–2011)



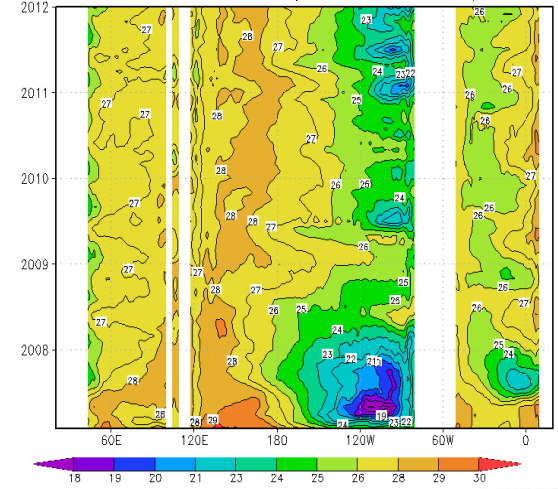
BESM-IBIS2.4

CGCM IBIS SST (lat 0N, 2007–2011)



BESM-OA2.3 (CMIP5)

CGCM CMIP5 SST (lat 0N, 2007–2011)



COLD TONGUE

Vegetação Simulada pelo BESM

Florestas Tropicais e Deserto

- O modelo simula bem as áreas de florestas tropicais na Amazônia, Trópicos e em todo o Globo.
- Subestima a área de desertos globais.

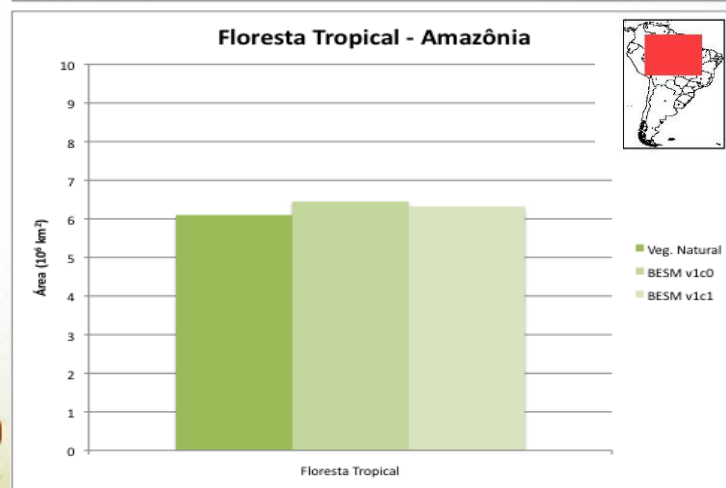
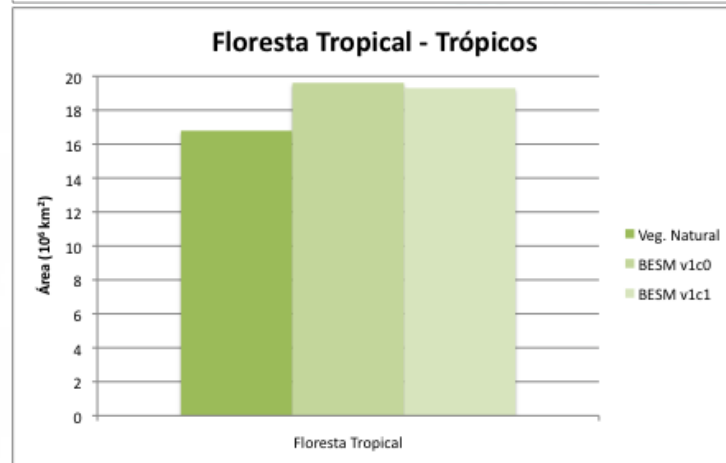
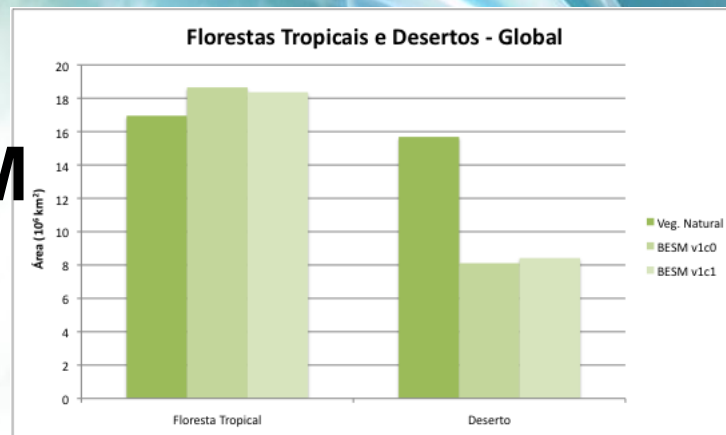
Experimentos:

1. BESM v1c0:

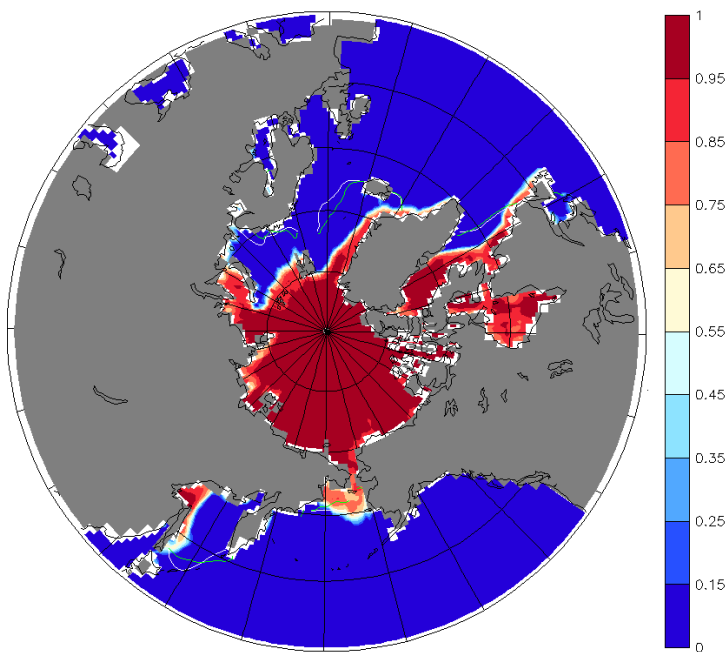
- Período de simulação: 1961-2007
- CO₂: fixo em 370 ppmv
- Dinâmica da vegetação: on

2. BESM v1c1:

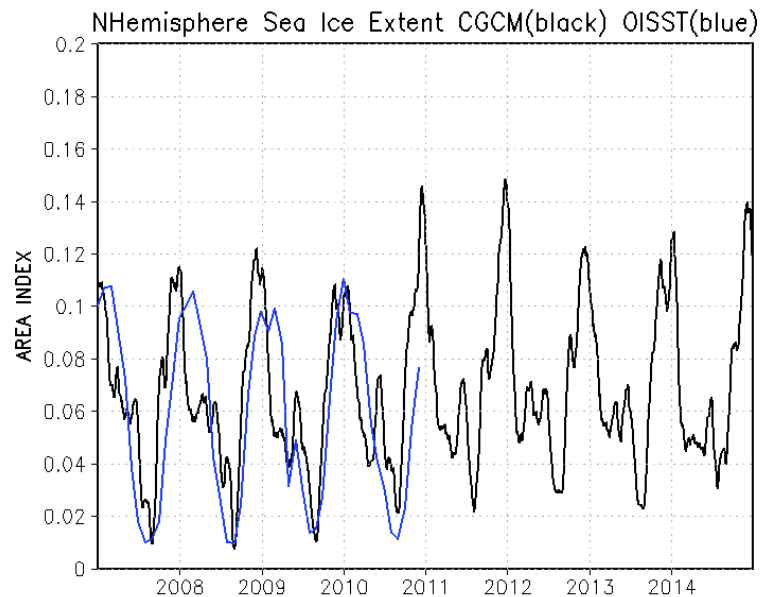
- Período de simulação: 1961-2007
- CO₂: Mauna Loa – variável
- Dinâmica da vegetação: on



Northern Hemisphere Ice Fraction

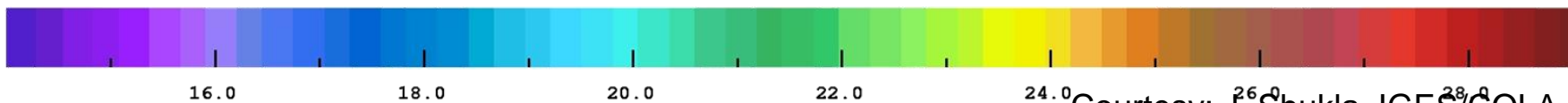
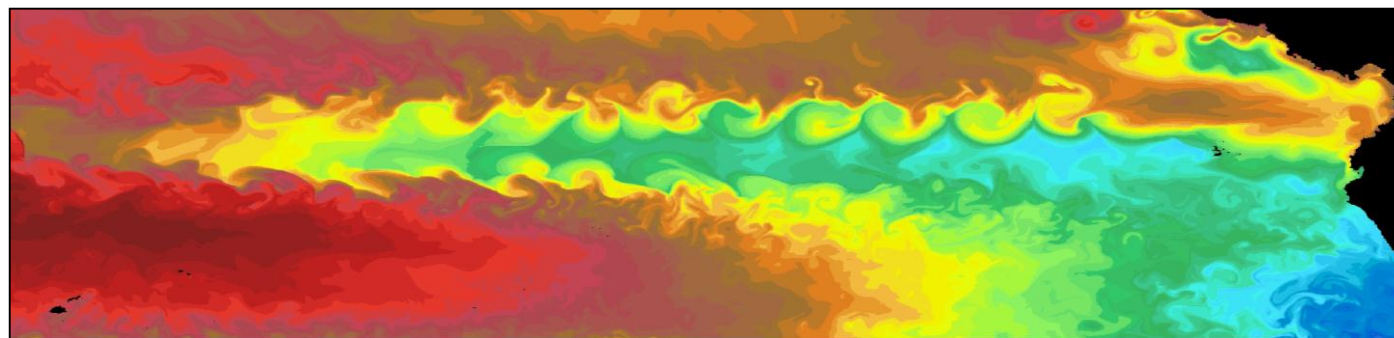
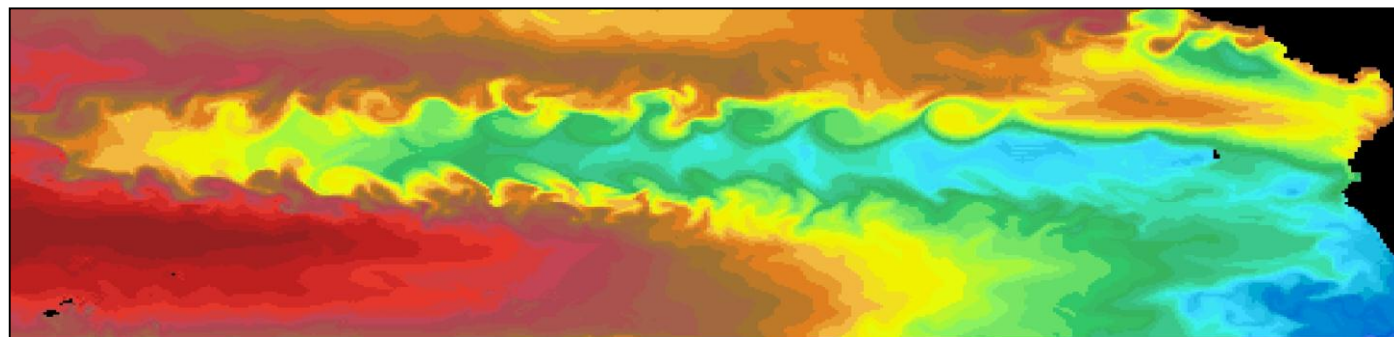
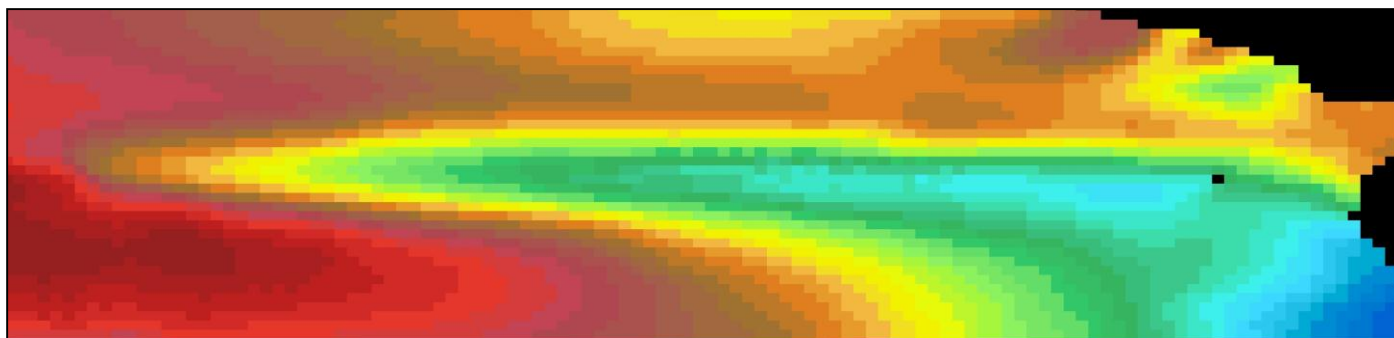


Ice Fraction (percent) – CGCM2.1(lines) vs OBS(colors)
APR 2007



GRADS: COLA/IGES

Equatorial Pacific sea surface temperatures (°C) from UK Ocean Model

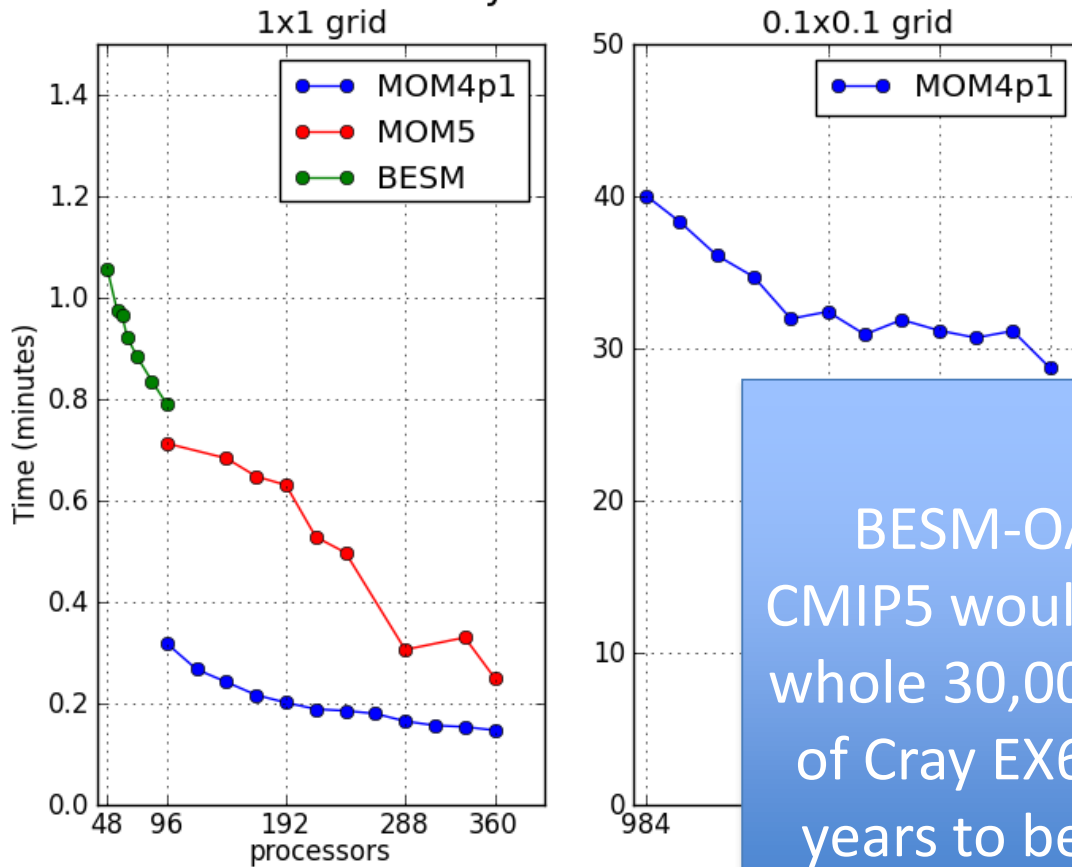


Courtesy: J. Shukla, IGES/COLA

BESM

Supercomputer Performance

1 day simulations



BESM-OA2.3HiRes
 CMIP5 would require the
 whole 30,000 processors
 of Cray EX6 during two
 years to be completed

BESM Version Releases Plan

2009: Start

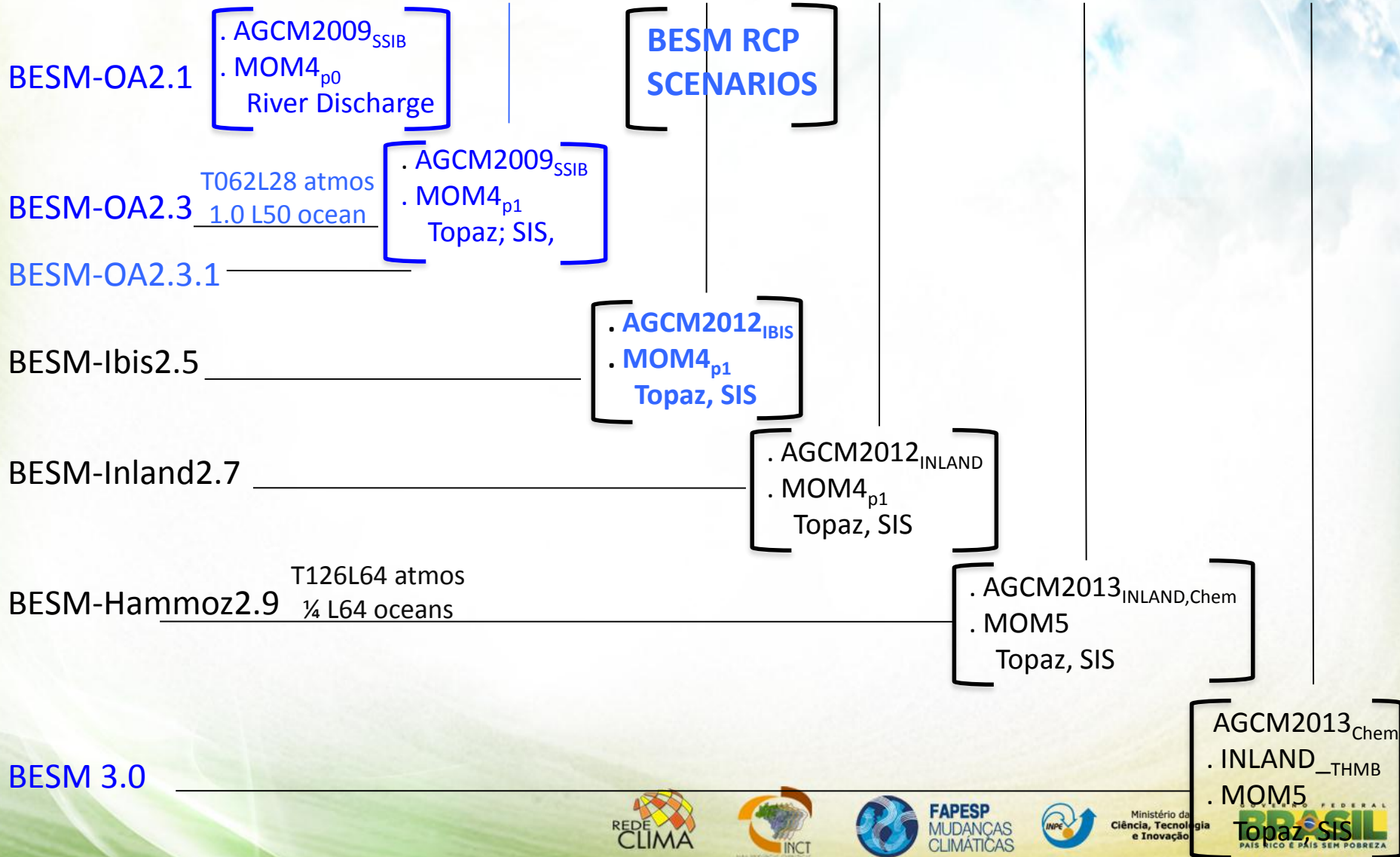
2010

2012

2013

2014

2015



The greatest Challenge: 'Peopleware'

Model Component	Present*	In 5 years*	In 10 years*
Atmosphere	8 + 10	15 + 15	30 + 30
Land	10 + 20	20 + 30	40 + 60
Chemistry	4 + 4	10 + 15	20 + 30
Ocean	8 + 6	15 + 20	30 + 40
TOTAL	30 + 40	60 + 80	120 + 160

* Researchers + Students/Collaborators

- Long term research programs: FAPESP Research Program on Global Climate Change; Rede CLIMA; INCT for Climate Change
- 10 Doctoral programs supporting capacity building in Earth System Modeling
- “International Summer Schools” will engage some 40 doctoral students/post-docs from S. America, S. Africa and India fellows per School.

Concluding Remarks

- BESM-OA model has been completed, allowing Brazil to inaugurate its participation in the CMIP5/IPCC AR5 global climate change scenarios.
- BESM-Ibis/Inland is under construction with first runs showing promising results.
- Next steps: Full ESM with dynamical vegetation, continental hydrology and the incorporation of the Atmos Chemistry component.

Challenges Ahead

- Building a truly interactive science-policy making-private sectors network that is capable to understand and use the scenarios and forecasts of **BESM** for decision making;
- Bringing the whole of the scientific community, professors & students, in Brazil and other countries to cooperate for that end.