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INSTITUTO NACIONAL DE PESQUISAS ESPACIAIS

MONAN
Model for Ocean-laNd-Atmosphere predictioN

A new paradigm for advancing the
weather, climate, and environmental prediction in Brazil

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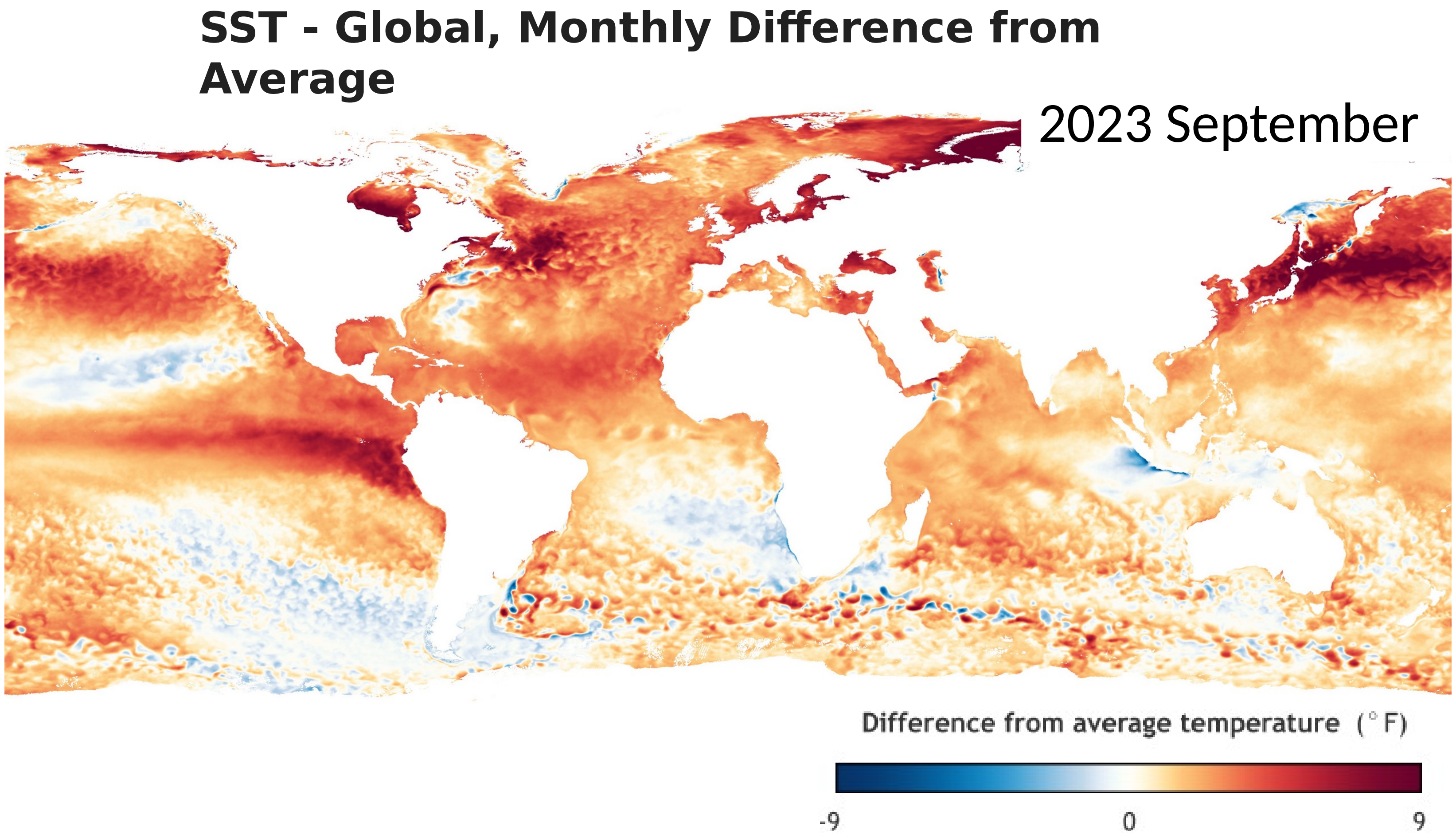
Outline

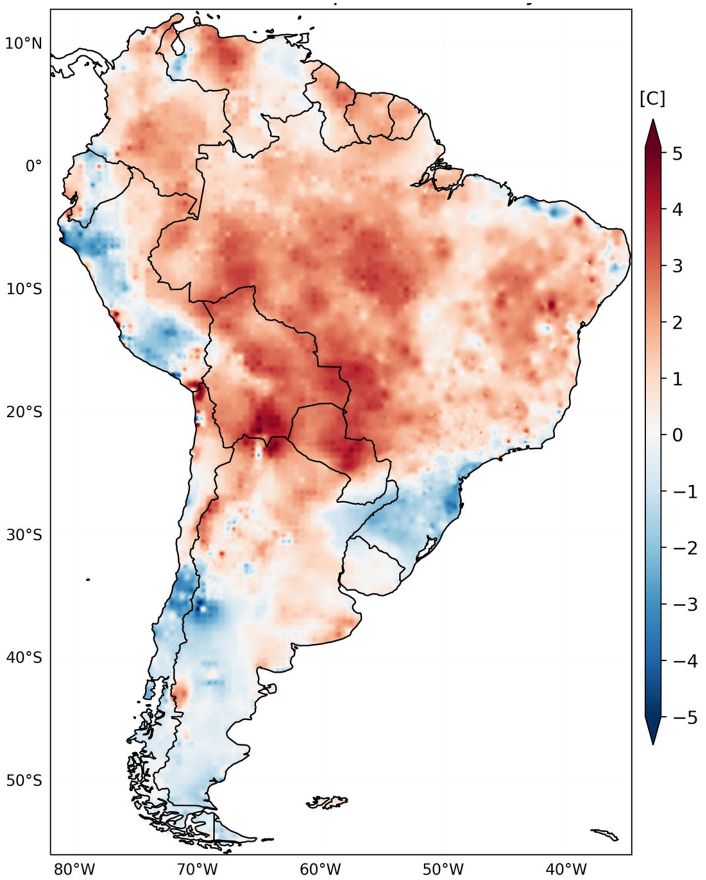
- Climate change and the associated adverse phenomena in South America
- Brief overview of Brazilian modeling efforts
- The MONAN proposal and ways to go forward.

El Niño in 1997 and 2023

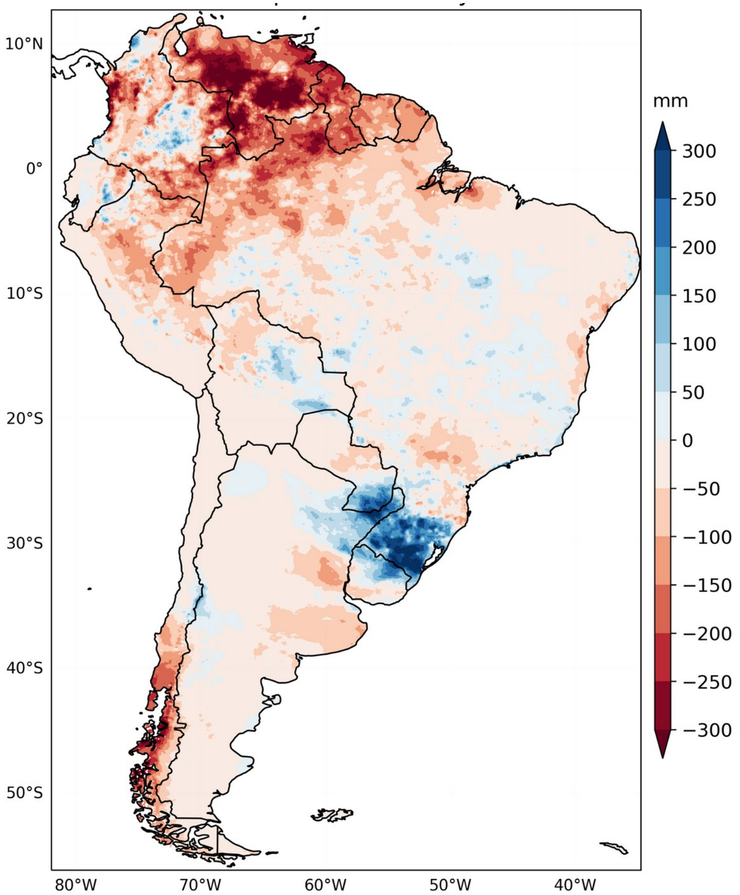


The synergy between El Niño in 2023 and the global warming

Daily Maximum Temp Anomaly [C]



Precipitation Anomaly [mm]



Reference data: 2000-2022

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Data provided by J. Rozante (2023) DIPTC/INPE

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The synergy between El Niño in 2023 and the global warming

Drought on the Rio Negro

Drought Fuels Wildfires in the

https://earthobservatory.nasa.gov/

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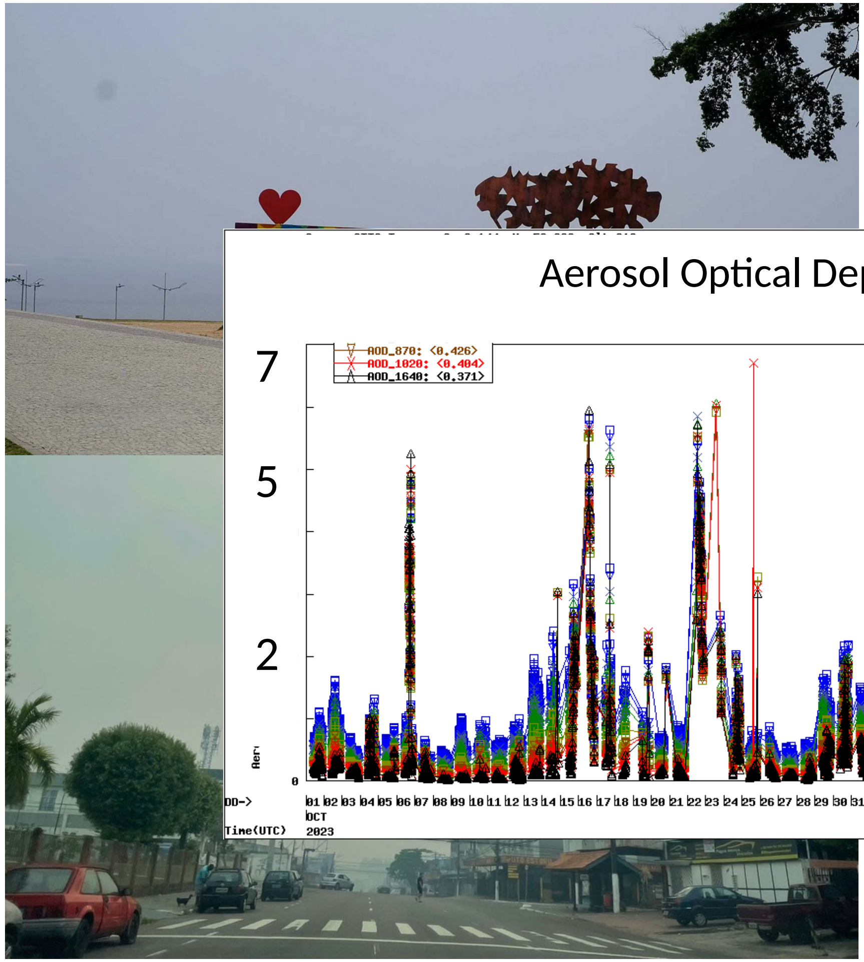
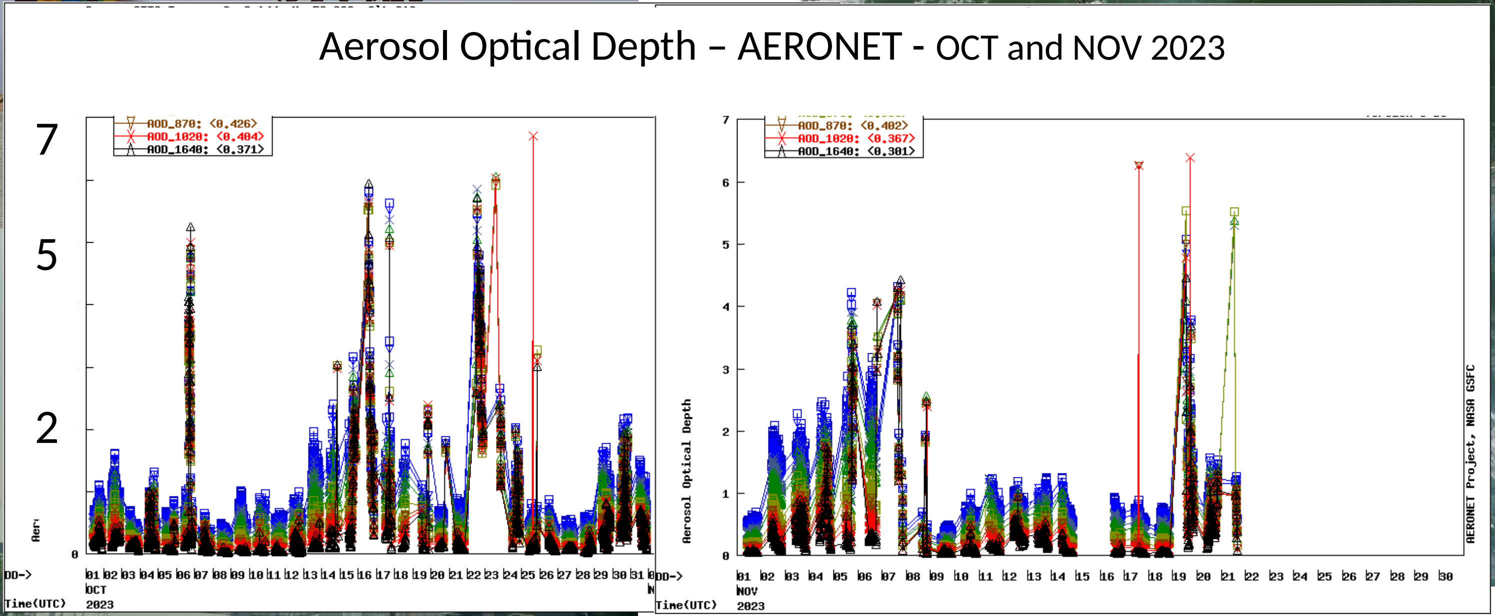
Biomass Burning Smoke invades Manaus City in Amazonia





https://earthobservatory.nasa.gov/images/151965/drought-fuels-wildfires-in-the-amazon

Onda de fumaça que encontra Manaus se torna mais densa. — Foto: Matheus Castro/g1

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The Inequity of the Extreme Events

Divergent situations at the extremes,

but, mostly converging to penalize the poorest populations!

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Modeling Activities in Brazil

Modeling Activities in Brazil (*)

Models	Type – Time scales	Institution
MCGA - BAM	Global Atmospheric model medium range - subseasonal - seasonal	INPE/CPTEC
BRAMS	Regional Atmos + Chem + Aer + CarbCycle medium range	INPE/CPTEC, Universities, Regional NWP centers
Eta	Regional Atmospheric medium range – seasonal	INPE/CPTEC and Universities
WRF	Regional Atmospheric medium range	INPE/CPTEC, Universities, Regional NWP centers
COSMO	Regional Atmospheric medium range	INMET (Brazilian National Inst of Meteorology)
ROMS+WRF	Regional O-A Coupled Only for research	INPE/DIOTG
BAM+MOM5 (BESM)	Global O-A Coupled seasonal	INPE/CPTEC

(*) not exhaustive

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CPTEC/INPE - Global Circulation Model (32-yr development)

1988	1992	1994	1995	1996	1998
Origem (COLA)	**Origem** (COLA)	MCGA CPTEC/COLA	MCGA CPTEC/COLA	MCGA CPTEC/COLA	MCGA CPTEC/COLA
COLA (Center for Ocean-Land-Atmosphere Studies). ***Versão 1.7 Romboidal*** (R40L18 - Baseado no MRF 1988 do NCEP, então NMC). Sem paralelismo	**COLA (Center for Ocean-Land-Atmosphere Studies).** ***Versão 1.12 Romboidal*** (R40L18 - Baseado no MRF 1988 do NCEP, então NMC). Sem paralelismo • Sem paralelismo **Convecção Profunda** RAS (Moorthi e Suarez, 1992).	**Versão CPTEC:** ***Versão 1.0 Triangular*** (COLA Versão 1.12 + Modificações no CPTEC/INPE). Versátil para resoluções Horizontais e Verticais. • Sem paralelismo Dinâmica: 1994, NEC/SX-3: **T_Q0062L028 (210 km), CPTEC-COLA, Euleriano, Difusão explicita, Δt = 1200 seg, sequencial**	**Versão CPTEC:** ***Versão 1.0 Triangular*** Dinâmica: 1994, NEC/SX-3: **T_Q0062L028 (210 km), CPTEC-COLA, Euleriano, Difusão explicita, Δt = 1200 seg, sequencial** Melhoramento da Difusão para controle de CFL: Local (COLA/CPTEC,1995). Sem paralelismo	**Versão CPTEC:** ***Versão 1.0 Triangular*** Dinâmica: 1994, NEC/SX-3: **T_Q0062L028 (210 km), CPTEC-COLA, Euleriano, Difusão explicita, Δt = 1200 seg, sequencial** Melhoramento da Difusão para controle de CFL: Espectral Aumentada (ECMWF,1996) Sem paralelismo	**Versão CPTEC:** ***Versão 2.0 Triangular*** Dinâmica: 1998, NEC/SX-4: T_Q0062L028 (210 km), CPTEC-COLA, **Euleriano,** Δt = 1200 seg, paralelismo openMP, paralelo até 8 processadores, primitivas NEC Com paralelismo OpenMP (primitivas NEC)

Slide provided by Paulo Kubota/Paulo Bonatti (2023) DIMNT/INPE

CPTEC/INPE - Global Circulation Model (32-yr development)

1999

Versão CPTEC:

Versão 2.0 Triangular

Dinâmica: 1999, NEC/SX-4: T_Q0062L028 (210 km), CPTEC-COLA, **Euleriano,** Δt = 1200 seg, paralelismo openMP, paralelo até 8 processadores, primitivas NEC

Física: Convecção Rasa: implementação do esquema de convecção rasa de Souza, 1999, ajustada para o AGCM.

2000

Versão CPTEC:

Versão 2.0 Triangular

Operacionalização

Dinâmica: 2000, NEC/SX-4: T_Q0126L028 (105 km), CPTEC-COLA, **Euleriano,** Δt = 1200 seg, paralelismo openMP, paralelo até 8 processadores, primitivas NEC

2002

Versão CPTEC:

Versão 2.0 Triangular

Dinâmica: T_Q0126L028 (105 km), CPTEC-COLA, Δt = 600 seg, paralelo até 8 processadores, primitivas NEC

implementação: Difusão Horizontal 2n-harmônica: Implícita (CPTEC, 2002).

2005

Versão : MCGA/CPTEC

Dinâmica: 2005, NEC/SX6: T_Q0213L042 (63 km), CPTEC/INPE-OMP, Δt = 400 seg, paralelo até 8 processadores, portável

Códigos:

Modelo, Pré e Pós:

FORTRAN 90/95 com Módulos.

Resoluções Definidas Dinamicamente.

Modelo:

OpenMP

Pós:

MPI em andamento

Portabilidade: Rodam no SX6, Tupay e Una.

2007

Versão : MCGA/CPTEC

Dinâmica: 2007, NEC/SX6: T_Q0299L064 (45 km), CPTEC/INPE-MPI, Δt = 240 seg, paralelo até 32 processadores, portável.

Código: paralelismo massivo (MPI sobre OpenMP)

Dinâmica: euleriana ou semi-lagrangeana.

Grade: quadrática ou linear; completa ou reduzida

Fisica: Radiação: CLIRAD: Chou e Suarez (1999) modificado por Tarasova e Fomin (2007).

2008

Versão : MCGA/CPTEC

Dinâmica: 2000, NEC/SX6: T_Q0062L028 (200 km), CPTEC-COLA, Δt = 1200 seg

Fisica: Implementação do esquema de convecção profunda: GRELL (Grell e Devenyi, 2002), ajustada para o **MCGA/CPTEC**.

CPTEC/INPE - Global Circulation Model (32-yr development)

2009	2010	2012	2016	2019	2021
MCGA CPTEC	MCGA CPTEC	MCGA CPTEC	BAM BRAZILIAN ATMOSPHERIC MODEL	BAM BRAZILIAN ATMOSPHERIC MODEL	BAM BRAZILIAN ATMOSPHERIC MODEL
MCGA/CPTEC Nova versão do global MPI-OMP massivamente paralela Grade: Novas formas de decomposição de domínio na malha computacional, decomposições na vertical no espaço Espectral e de Fourier, e decomposições espectral para parte semi-implicita e NNMI, com granularidade mais fina. Radiação: Inclusão da radiação do UKMetOffice (Henrique Barbosa)	**MCGA/CPTEC** **Dinâmica**. Modificação da difusão de umidade especifica no espaço espectral **Física:** Acoplamento atmosfera-continente: codificação de uma interface de acoplamento entre a atmosfera e continente para o acoplamento de diferentes modelos de superfície continental. Implementação do esquemas de camada limite de Holtslag And Boville (1993)	**MCGA/CPTEC** **Dinâmica:** Advecção de humidade usando o esquema semi-lagrangiano **Física:** a) **Implementação dos esquemas de superfície IBIS e SIB2.5** b) **Implementação dos esquemas de microfísica de nuvens** Ferrier, B., 1994 **e** Morrison, H., J. Curry, and V. Khvorostyanov (2005).	**Versão (1.0) BAM** **Dinâmica:** 2016, CRAY/TUPAN: T_Q0666L064 (20 km), CPTEC/INPE-MPI_OMP, Semi-Lagrangiano, Δt = 180 seg, paralelo até n cores, portável **Códigos**: Modelo, Pré e Pós:revisados **Dinâmica**: Semi-lagrangiano totalmente testado e validado para a resolução de 20km. **Física**: Implementação do estado da arte da parametrizações físicas.	**Versão do BAM** –**Versões consolidadas:** •**BAM_V0.0.0**: Cavalcanti et al. (2019); •**BAM_V1.0.0**: Figueroa et al. (2016); •**BAM_V1.1.0**: código operacional em 2017; •**BAM_V1.2.0**: código usado em Guimarães et al. (2019), AMIP (Coelho et al 2020), teses e dissertações, operacional em 2018; –Versão operacional: •**BAM_V1.2.0**: código operacional (2018-2020);	**–Versões** BAM **:** • **BAM_V1.2.0_MC-KPP:** (2019-2020); • **BAM_V1.3.0**: (2019); • **BAM_V1.3.1**: revisão, desenvolvimento(2019); **–Versões BAM : em coordenada Híbrida** • **BAM_V2.0.0**: versão em coordenada híbrida (2019), • **BAM_V2.1.0: versão em coordenada híbrida operacional**

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Eta @INPE
27-yr development

1996: **Bucket, SEQ, 40km, 60-h forecast, South America domain**

1998: OSU, new DSP, 72h

2002: Seasonal Forecasts, 5 members

2005: a. NOAH, **MPI,** 11-day forecast
b. Ensemble forecast, 5 member, 40-km
c. NEB setup, 10-km

2006: Non hydro, 5 km, SE, 72h

2009: Climate change version, 40 km, 4 members

2011: **Finite Volume**(**FV**), 15 km, sloping topography (**cut-cells**)

2012: Ensemble forecast, 8 members, 40 km, FV, cut-cell, 11-day fcst

2013: a. Ensemble Forecast, 5 members, 5 km, **FV**, Non-hydro
b. Seasonal Forecast, 5 members, **FV**, cut-cells
c. **Paleoclimate version**

2014: a. **Climate change version**(Eta CC), **20 km**, **8** members, **FV, cut-cell**
b. **Climate change version**, **5 km**, 2 members, FV, **Non-hydro, Urban vegetation**
c. Subseasonal, Eta-BESM, 10 members, 40 km, 60-day forecast.
d. Non-hydro, **1 km**, 72h, SP-RJ

2015: a. Eta CC, Eta/**NOAH-MP version**, 1-km resolution, 6-year run
b.Eta CC, **Eta/Dynamic Vegetation (Inland scheme)**
c. Weather version, Eta/**RRTMG,** replacing GFDL scheme

2017: a. Eta CC, **Eta/coffee crop model**
b. **Eta modules** version
c. Global Eta version – **GEF** seasonal version, **25 km**

2018: Global Eta version **– GEF** weather version, **8 km**

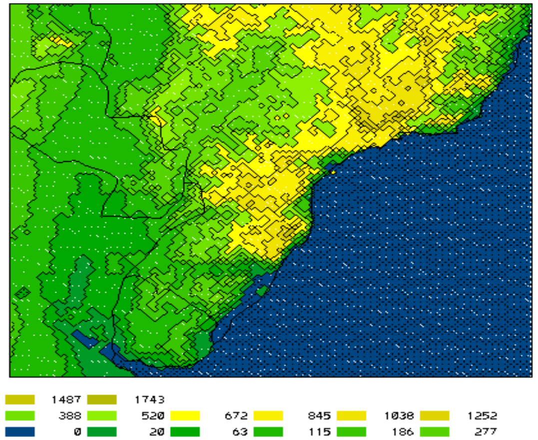
2020: a. Eta + parameterizations **Lightning** + **Nox chemistry**
b. **GEF,** top **1hPa, restart** capability

2021: a. Eta CC, **RRTMG-convection coupled**
b. Eta **deeper soil, + Brazilian biomes**
c. Eta **restart function**

biomes **2022: Eta unified – all scales**

2023: albedo revised. turbulence scheme under revision

2024: **Eta/MOM6 coupled, Eta/Flake coupled, …**



1996 2002 2005 2010 2015 2020

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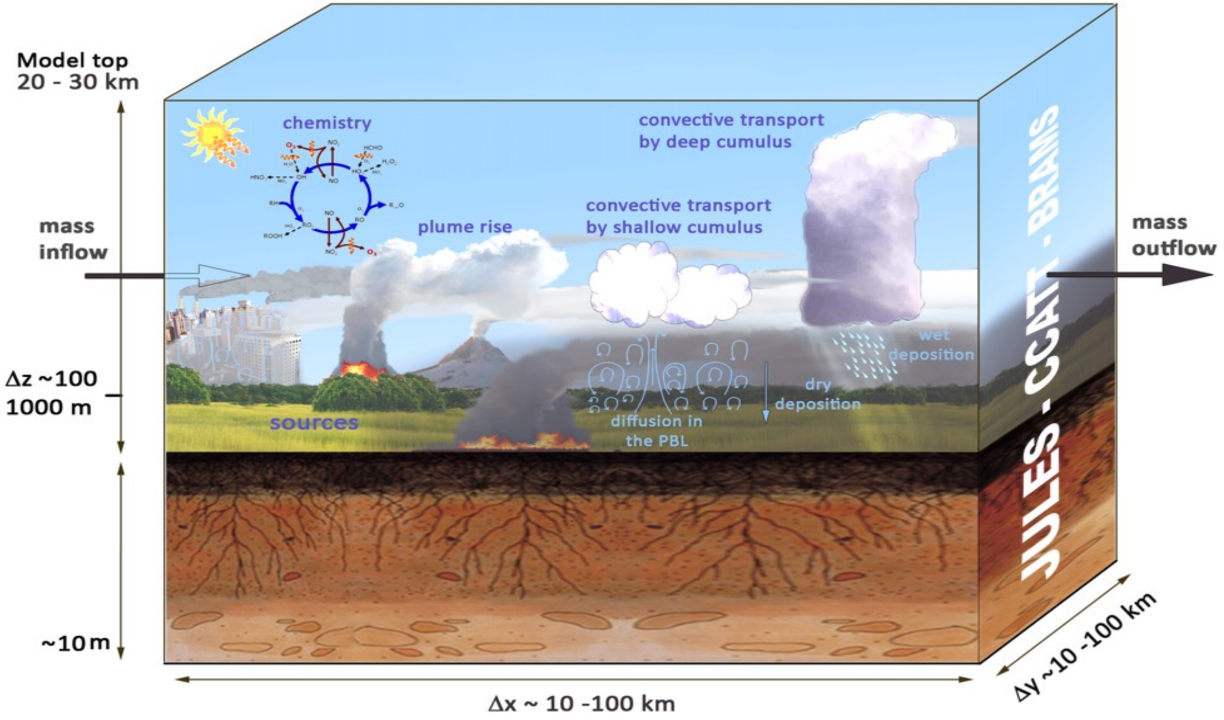
CPTEC/INPE developments on integrated atmospheric modeling tuned for tropical region



Brazilian developments on the
Regional Atmospheric Modeling System

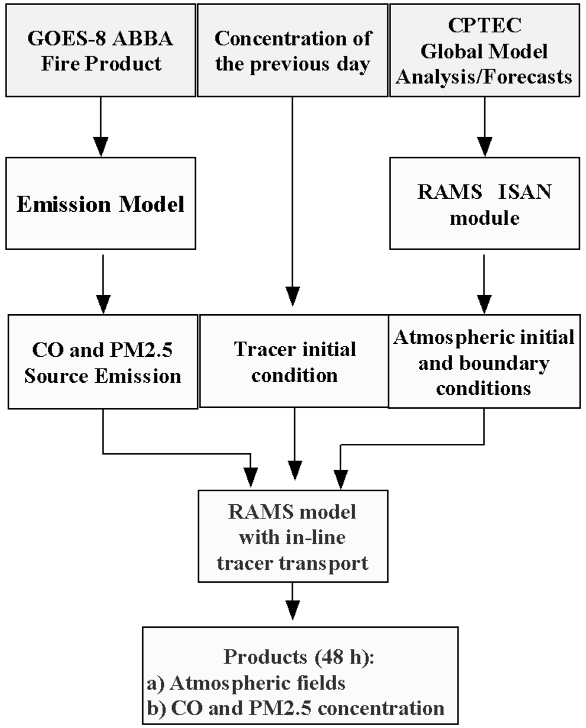
www.brams.cptec.inpe.br

Dynamics, Physics and Chemistry formulations of the BRAMS 6.0

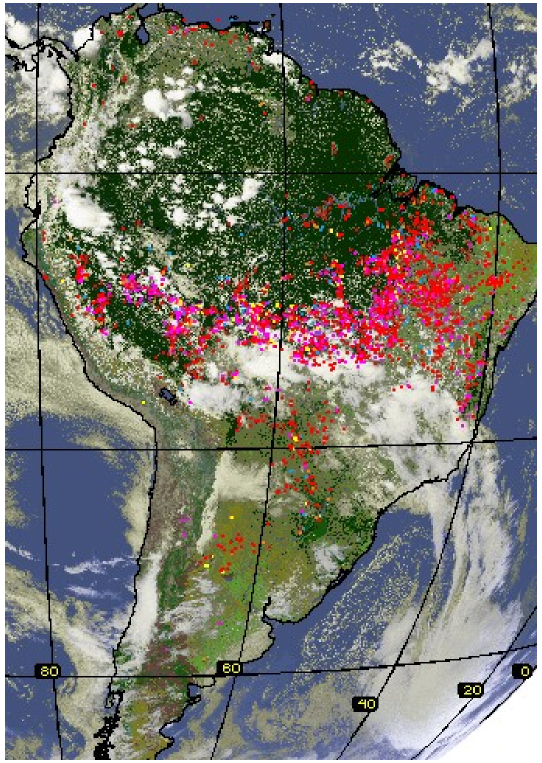
1. Dynamics
   1. Time integration with Runge-Kutta (RK3, Wicker and Skamarock, 2002; Baldauf, 2008, 2010)
   2. The polynomial flux specification (Wicker and Skamarock, 2002,) with 3rd and 5th order of spatial approximations. Additionally, the Flux Correct Transport (FCT, Skamarock, 2006).
   3. Monotonic advection scheme for scalars (Freitas et al, 2011)
2. Physical Parameterizations
   1. Radiation: RRTMG 5.0 schemes for long- and short-wave, including aerosols effects and coupled with microphysics and convection schemes.
   2. Microphysics:
      - Thompson double-moment in cloud liquid water and aerosol aware (Thompson and Eidhammer, 2014).
      - GFDL single-moment six microphysics species: water vapor, cloud water, cloud ice, rain, snow, and hail/graupel.
   3. Convection scheme: Grell and Freitas (2020) scale and aerosol aware, trimodal formulation, revised numerics, convective transport and wet removal of tracers
   4. PBL Turbulence: M&Y 2.5, Nakanishi & Nino(200X)
   5. Surface Scheme: JULES 6.0 with carbon cycle, biogenic VOCs, aerosol effects
3. Chemistry and Aerosol processes
   1. SPACK – preprocessor for any chemical mechanism
   2. Simple – monodisperse aerosol model for the main sources
   3. Comprehensive emissions preprocessor
   4. Biomass burning emission model with smoke plume rise mechanism
4. Initialization
   1. Incremental Analysis Update (IAU) from the GEOS-5 GCM.
   2. 4DDA for GCM boundary condition (GFS, ERA-5)
   3. Soil moisture and temperature from JULES off-line, GFS, GEOS-5 and ERA-5

Real time monitoring of the transport of biomass burning emissions in South America.

- *Operational* implementation in 2001 at the Lab. Master IAG/USP
- Applied for flight planning of the LBA SMOCC/RACCI 2002 Field Campaign.



General flow of the real time monitoring the transport of biomass burning emissions in South America. Vegetation map: 1 km IGBP 2.0. RAMS grid 40 Km.

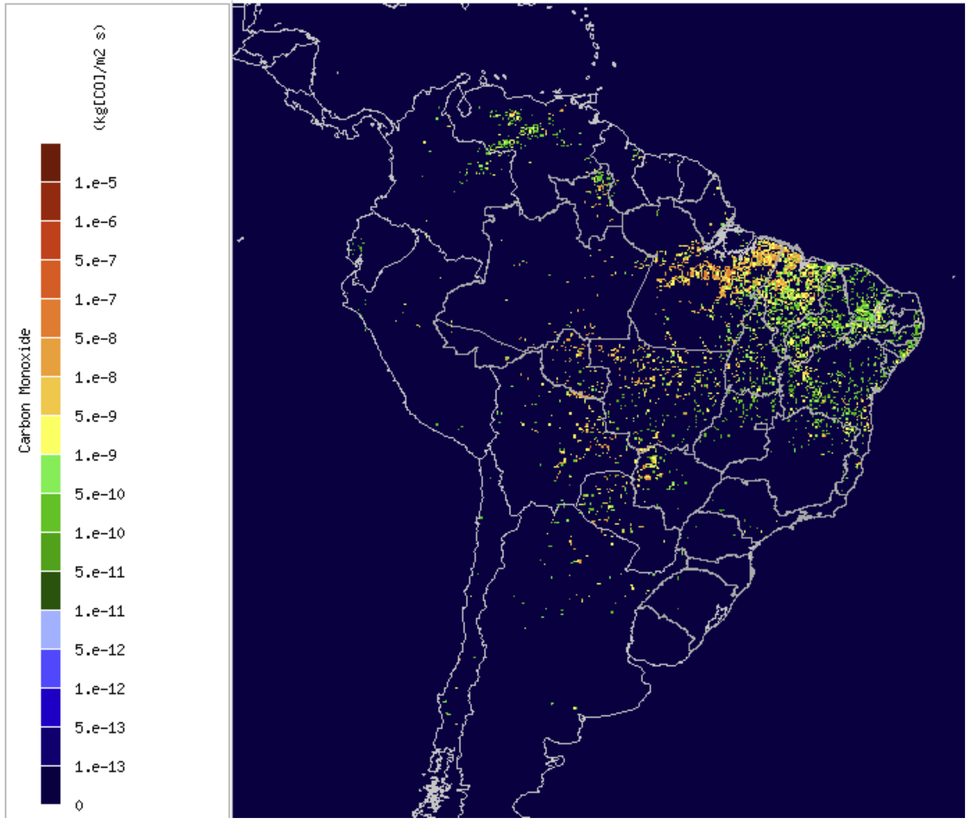


The GOES-8 ABBA Fire Product on 1745Z September 7, 2002, depicting the vegetation fires on South America. GOES resolution is 1 Km in the visible channel, 7 and 14 Km for infrared.

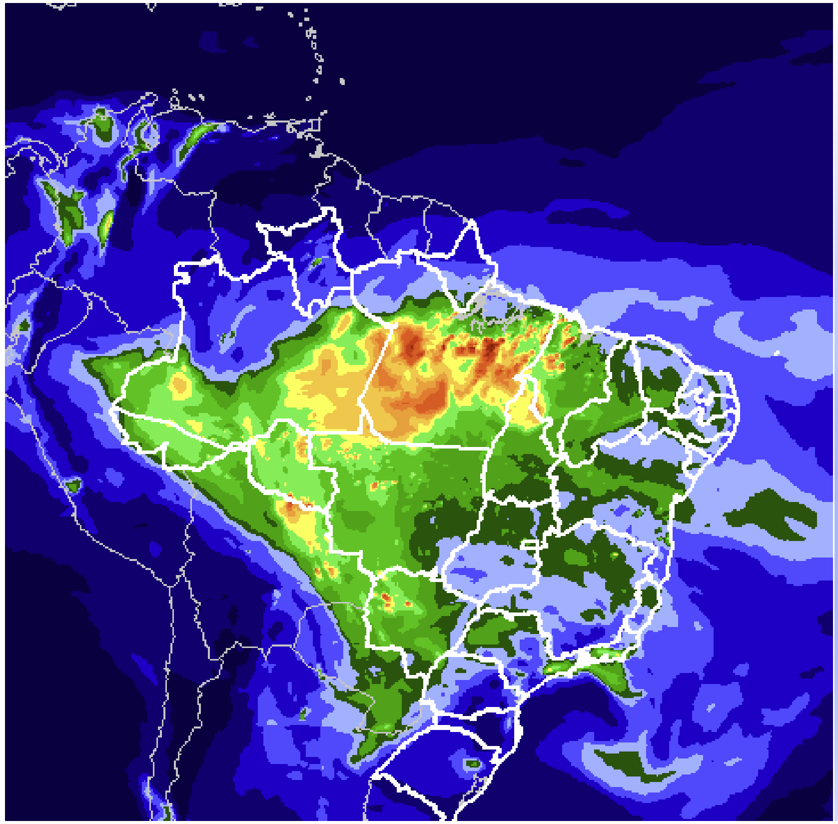
Freitas et al. (1999, 2005)

CPTEC/INPE Weather + Air Quality Forecasts with the BRAMS model

Real-time fire emissions
30 Nov 2023



Smoke Forecast for 18UTC 20 NOV 2023
AOD @ 550 nm



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How to effectively advance in the numerical forecast of the atmosphere and its interfaces?

How to effectively advance in the numerical forecast of the atmosphere and its interfaces?

We need focus in all three directions:

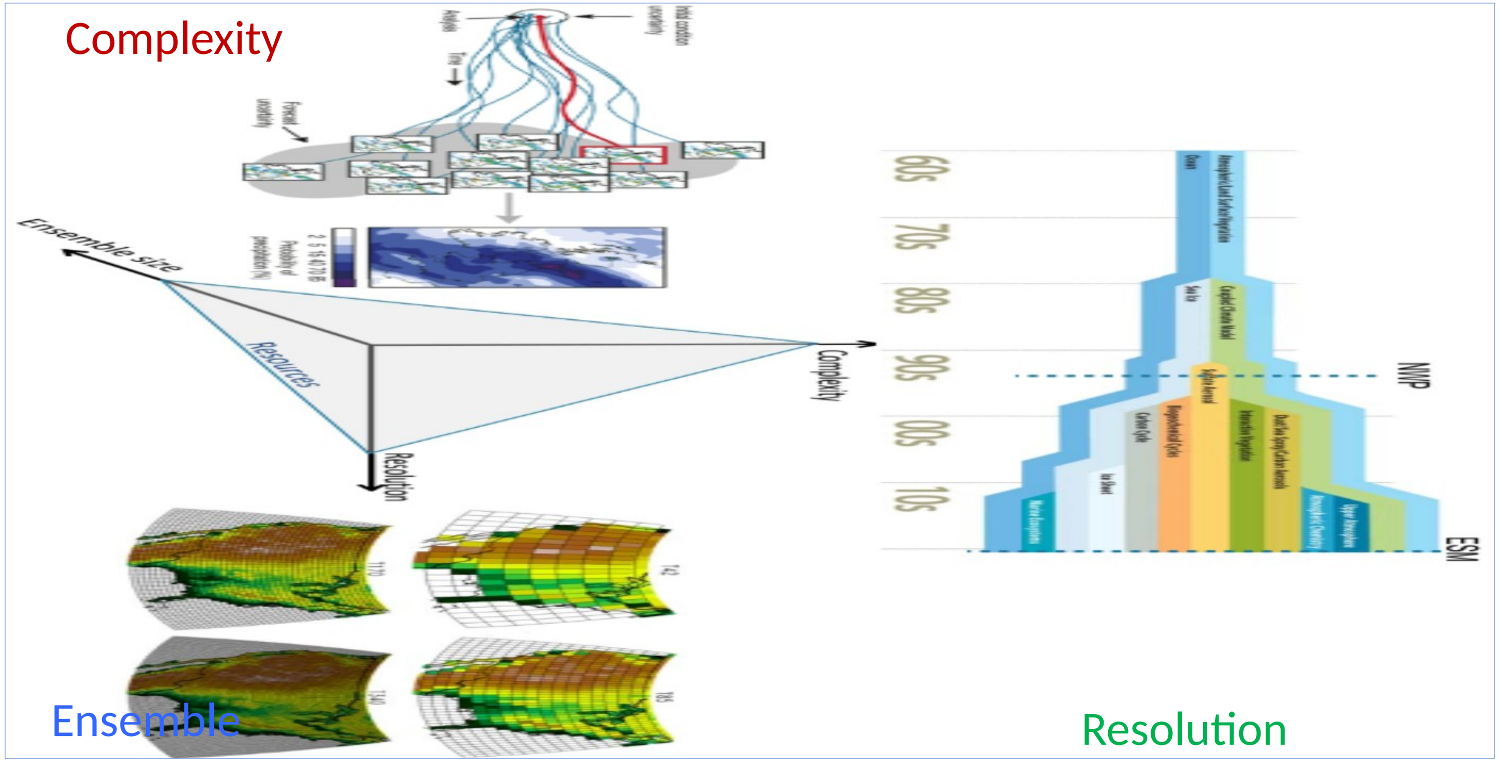

Figure adapted from J.-F. Lamarque (NCAR)

This entire framework assisted by:

- Access, treatment and storage of observational data;
- Data assimilation at different levels of complexity;
- High-performance computing service, management of complex software (millions of code lines);
- Analysis and quantitative evaluation of model results;
- Post-processing, use of IA, interpretation, publication of forecasts;
- Methodologic management of activities, processes and routines,
- Efficient and transparent communication with society and stake-holders

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What was proposed in 2021, and what are we working on?

A new paradigm of focus and organization for advancing the numerical weather, climate, and environment forecasting in Brazil.

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In the MONAN **project,** Brazil adopt a unified and community Earth System model
Everyone work on a single modeling system, a single computational code

1. **It involves the most relevant Earth System components:**
   a) Atmosphere, biosphere and continental soils, cryosphere, oceans, upper space.
   b) Anthropogenic disturbances relevant to the dynamics of the natural system (anthroposphere).
2. **Unified:**
   a) Suitable for spatial scales of atmospheric phenomena on the order of 10^2 m to 10^3 km.
   b) Suitable for temporal scales of nowcasting, weather, sub-seasonal, seasonal and climate change.
3. **Accurate:**
   a) Reduced number of approximations and use of state-of-the-art numerical methods for solving differential equations in supercomputers.
   b) Anchored in a robust Data Assimilation System using remote sensing and local observations.
   c) Enhanced with Artificial Intelligence/Machine Learning techniques.
4. **Community model:**
   a) Open source with free and public access.
   b) Workshops and training for the community.
5. Multi-Institutional Governance:
   a) Scientific steering committee formed by representatives of operational and research centers, academy and stakeholders.

How do we organize ourselves for this project?

Scientific Committee of the Earth System Community Model

- Created on April 8, 2021 by the Director of INPE
- Participating Institutions: INPE, INMET, LNCC, INPA, CENSIPAM, DECEA, Army Forces and several Universities

Current Members of SC

Membros internos ao INPE:
1. Saulo R. Freitas
2. Antonio Ocimar Manzi
3. Caio Coelho
4. Carlos Bastarz
5. Chou Sin Chan
6. Renato Galante
7. Haroldo Fraga de Campos Velho
8. João Gerd
9. Joaquim Eduardo Rezende Costa
10. Jorge Luis Gomes
11. Karla Longo
12. Luciano Pezzi
13. Luiz Flávio Rodrigues
14. Paulo Kubota
15. Ronald Buss de Souza
16. Celso Luiz Mendes

Membros externos:
1. Pedro Dias (IAG/USP) _
2. Afonso Paiva (COPPE-UFRJ)
3. Enio Pereira de Souza (UFCG)
4. Flávia Rodrigues Pinheiro (Marinha do Brasil)
5. Gilberto Bonatti (INMET)
6. Hélio Abreu Nogueira (FAB)
7. Ivan Saraiva (CENSIPAM)
8. Julia Cohen (UFPA)
9. Luiz Cândido (INPA)
10. Luiz Cláudio Oliveira Andrade (Exército)
11. Marcia Yamasoe (IAG/USP)
12. Fabrício Harter (UFPel)
13. Pedro Peixoto (IME/USP) _
14. Ricardo de Camargo (IAG/USP)
15. Roberto P. Souto (LNCC) _
16. Vinícius Capistrano (UFMS)
17. Francisco C. Vasconcelos Jr (FUNCEME)
18. Yanina Skabar (SMN Argentina)

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How do we organize ourselves for this project?

The sub-committees

Committee members collect and document the community's requirements, demands, and counterparts.

1. Integrated Modeling System: Pedro Dias/USP
2. Atmosphere: Saulo Freitas/INPE
3. Continental surface and soils: Antonio Manzi/INPE
4. Oceans and Continental and Maritime Ice: Ronald Buss/INPE
5. Space weather: Joaquim Costa/INPE
6. High Performance Processing and Code Quality : Luiz Flávio Rodrigues/INPE
7. Data Assimilation (DA) of the Earth System: João Gerd/INPE
8. Advanced DA methods and application of artificial intelligence (AI): Haroldo Campos Velho/INPE
9. Pre- and post-processing methods of weather and climate forecasts: Caio Coelho e Carlos Bastarz/INPE

11. Northern Universities : Júlia Cohen/UFPA
12. Northeast Universities: Ênio Sousa/UFCG
13. Southeast Universities and Research Institutes: Márcia Yamasoe/USP
14. Southern Universities: Otávio Acevedo/UFSM
15. Midwest Universities : Vinícius Capistrano/UFMS
16. CENSIPAM: Ivan Saraiva
17. INMET: Gilberto Bonatti
18. Brazillian Navy: Flávia Rodrigues (CHM)
19. Brazilian Air Force : Hélio Abreu Nogueira - Ten Cel Esp Met
20. Brazilian Army : Luiz Cláudio Oliveira Andrade – Army Major
21. Surface and subsurface hydrology – ASD/Funceme/IPH

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Who is already working with us?

INPE
UNIDADE DE PESQUISA DO MCTI

CPTEC

EMBRACE
Estudo e Monitoramento BRAsileiro do Clima Espacial

Laboratório Associado de Computação e Matemática Aplicada

LOA · OBT · INPE

INMET

CENSIPAM
Centro Gestor e Operacional do Sistema de Proteção da Amazônia

Laboratório Nacional de Computação Científica
UNIDADE DE PESQUISA DO MCTI

INPA
INSTITUTO NACIONAL DE PESQUISAS DA AMAZÔNIA

Centro de Hidrografia da Marinha
MARINHA DO BRASIL

DECEA
Departamento de Controle do Espaço Aéreo

ICEA

USP
Universidade de São Paulo

IME
INSTITUTO DE MATEMÁTICA E ESTATÍSTICA

IAG
INSTITUTO DE ASTRONOMIA, GEOFÍSICA E CIÊNCIAS ATMOSFÉRICAS

IO
Instituto Oceanográfico

COPPE UFRJ
Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia

UNIFESP
UNIVERSIDADE FEDERAL DE SÃO PAULO
1933

UNIVERSIDADE FEDERAL DO PARÁ

UFMS

UFCG
Universidade Federal de Campina Grande

unesp
UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"

UFG
UNIVERSIDADE FEDERAL DE GOIÁS

UFRN
UNIVERSIDADE FEDERAL DO RIO GRANDE DO NORTE

UNIVERSIDADE FEDERAL DE PELOTAS
RS-BRASIL

Universidade Federal de Santa Maria
1960

FUNCEME
FUNCEME - FUNDAÇÃO CEARENSE DE METEOROLOGIA E RECURSOS HÍDRICOS

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Servicio Meteorológico Nacional
Argentina

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With whom are we negotiating collaboration?

NCAR
NATIONAL CENTER FOR ATMOSPHERIC RESEARCH

WORLD METEOROLOGICAL ORGANIZATION

NASA Goddard SPACE FLIGHT CENTER

NATIONAL OCEANIC AND ATMOSPHERIC ADMINISTRATION
NOAA
U.S. DEPARTMENT OF COMMERCE

ECMWF
European Centre for Medium-Range Weather Forecasts

Funding and Resources for MONAN’s Development and Operational Implementation

MONAN was approved as a

- Strategic Program by the Brazilian Minister of Science and Technology
- 10-year Work Plan (2022-2031)
- Annual budget ~ US$ 250,000 (under approval)

RISC – MONAN Proposal (2023-2026)

- Funded by FINEP Brazilian Agency with ~ US$ 40 million over four years
  - US$ 24 million for the next supercomputer
  - US$ 5 million for the model and software infrastructure development
  - US$ 11 million for solar energy power plant, maintenance, etc.

CAPES Brazilian Funding Agency ~ US$ 280,000 (2024-2026)

- Scholarships for PostDoc in NCAR/USA
- Training workshops for the Brazilian community

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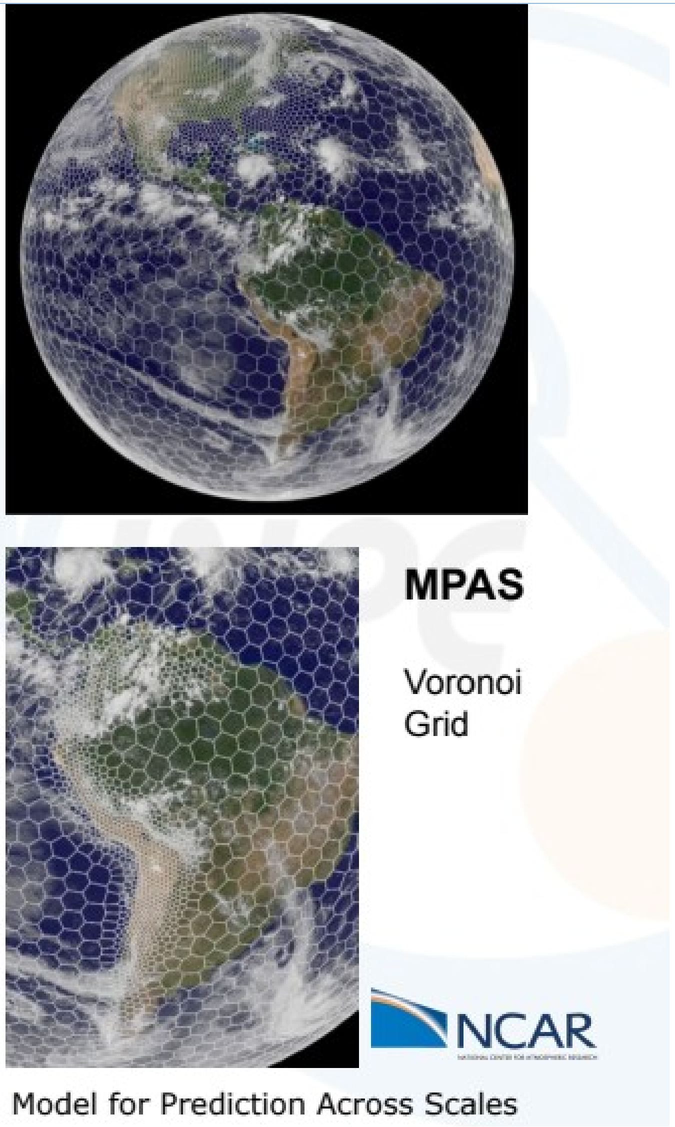
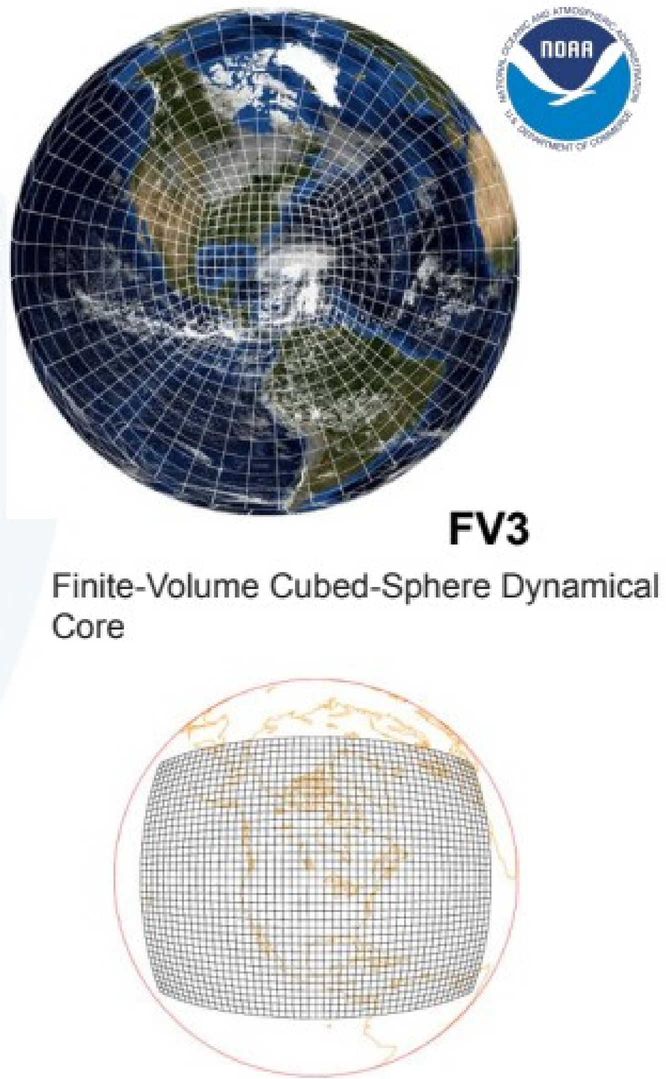
The candidates for the basis of the next-generation GCM (MONAN) in Brazil: MPAS and SHiELD





Experimental Design with MPAS and SHiELD

	MPAS	SHiELD
Grid spacing	15 km	13 km
Forecast length	10 days (240 h), starting at 00:00 UTC	
Period	06/01/2021 to 06/01/2022 -> selection of intervals (every 5 days)	
Temporal resolution	6h	
IC	ERA5	

Output interpolated to 0.25 x 0.25 degree (ERA5)
Post-processed variables:

2D: msl, T2m, q2m, u10m, v10m, rain
3D: T, u, v, Z (925, 850, 500 and 250 hPa)

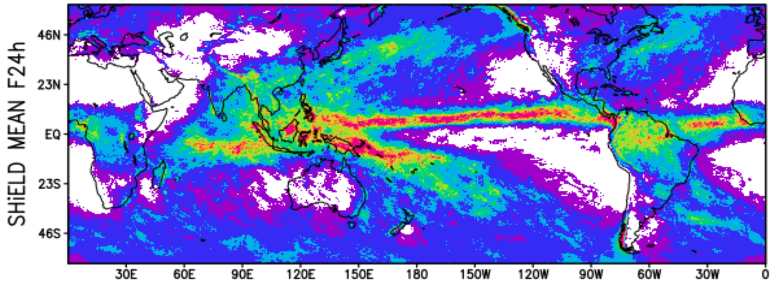
Experimental Design with MPAS and SHiELD

Physics parametrization	SHiELD	MPAS
Radiation	RTMG	RTMG
Land-surface	NOAH	NOAH
Cloud microphysics	GFDL	WSM6
Deep and shallow convection	SAS	GF & Tiedtke
PBL	EDMF	YSU
GWD	GWD	YSU

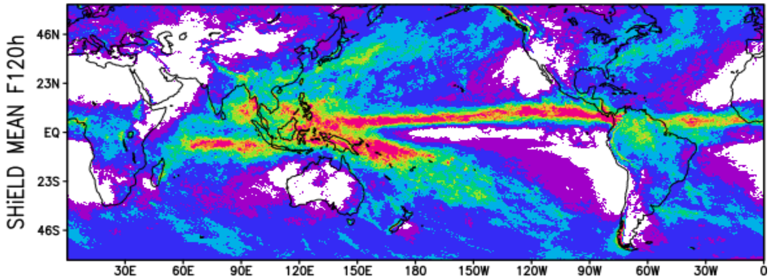
Mean Global Precipitation

mm/day

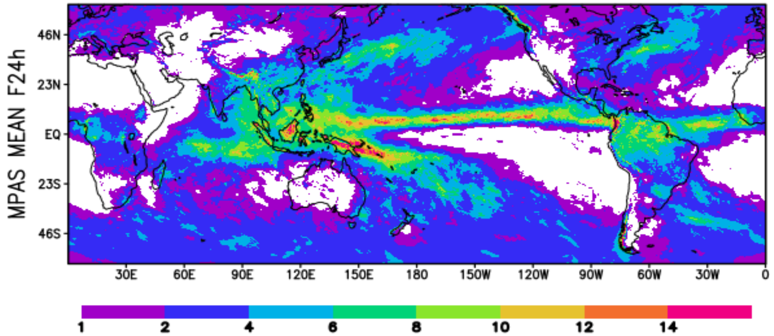
SHiELD 24h



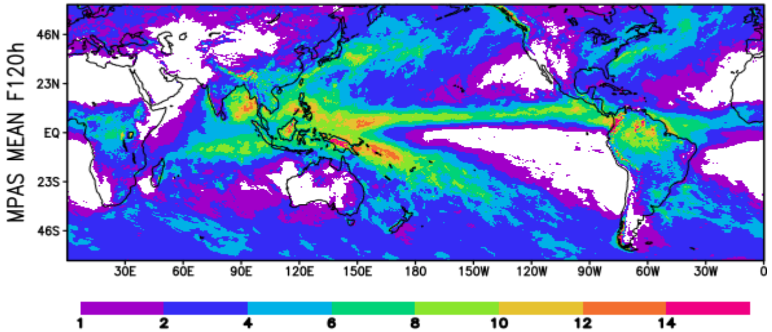
SHiELD 120h



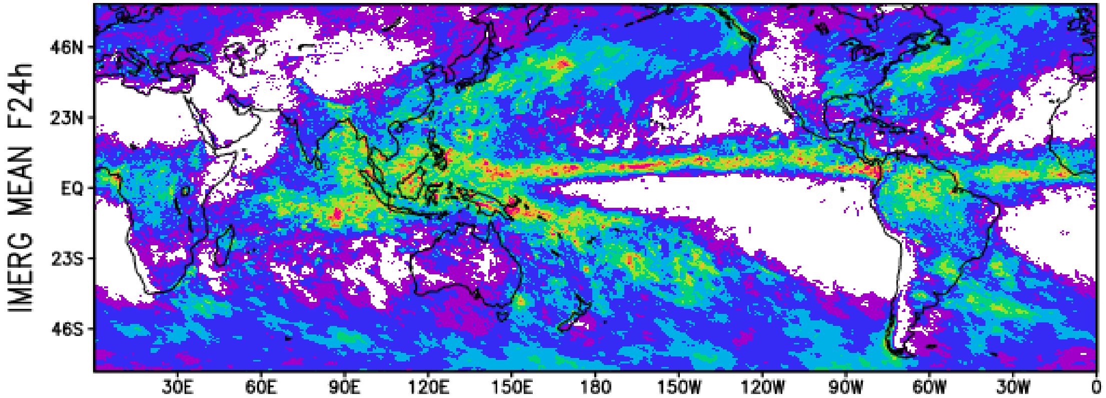
MPAS 24h



MPAS 120h



GPM-IMERG



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Modeling Evaluation Group /DIMT/INPE

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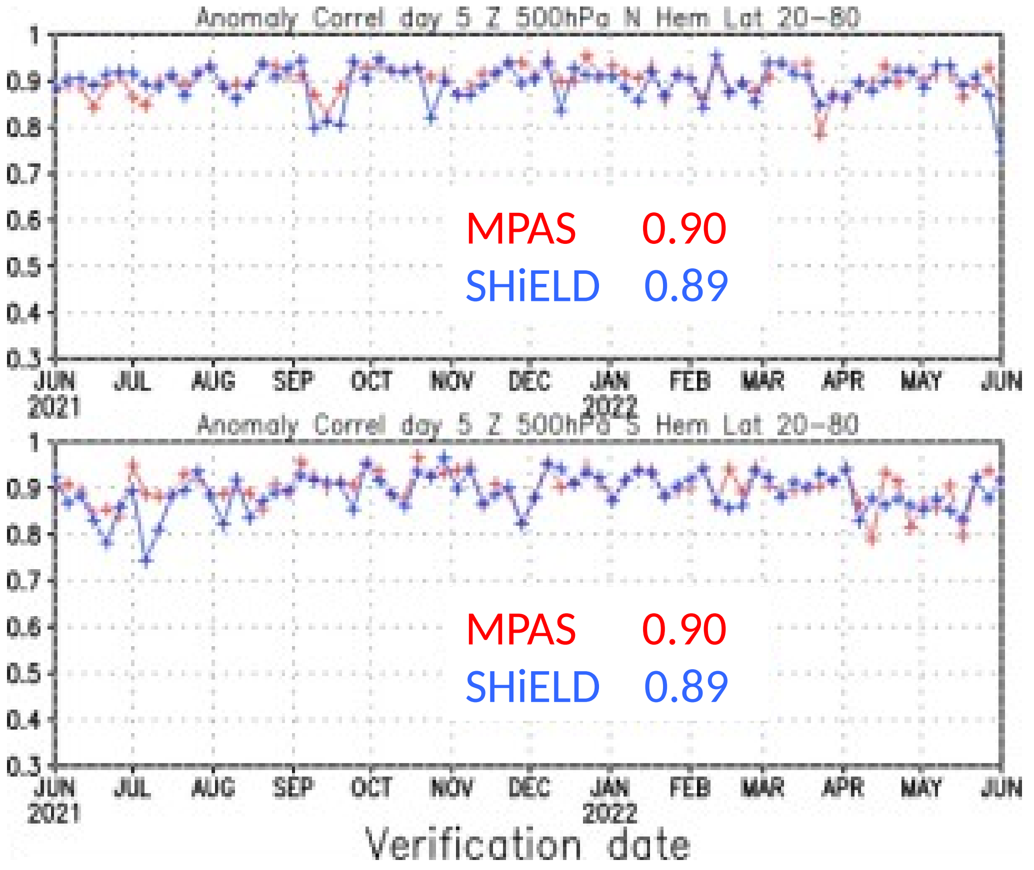
Mean Global Precipitation

Time integration	IMERG	MPAS	ShiELD	Diff perc. MPAS (%)	Diff perc. ShiELD (%)
36h	3,20	3,10	3,47	-3,2	8,5
60h	3,20	3,18	3,52	-0,8	10,0
84h	3,20	3,24	3,61	1,2	13,0
108h	3,19	3,27	3,67	3,0	15,0
132h	3,21	3,31	3,69	3,2	15,0
156h	3,20	3,34	3,72	4,3	16,2
180h	3,21	3,35	3,76	4,6	17,2
204h	3,20	3,38	3,78	5,6	18,0
228h	3,18	3,38	3,81	6,3	19,9

Geopotential Height Anomaly Correlation @ 500 hPa Forecast Day 5 (74 cases)



N. Hem.

S. Hem.

Our target:
Weather prediction on a global scale, but with focus on South America

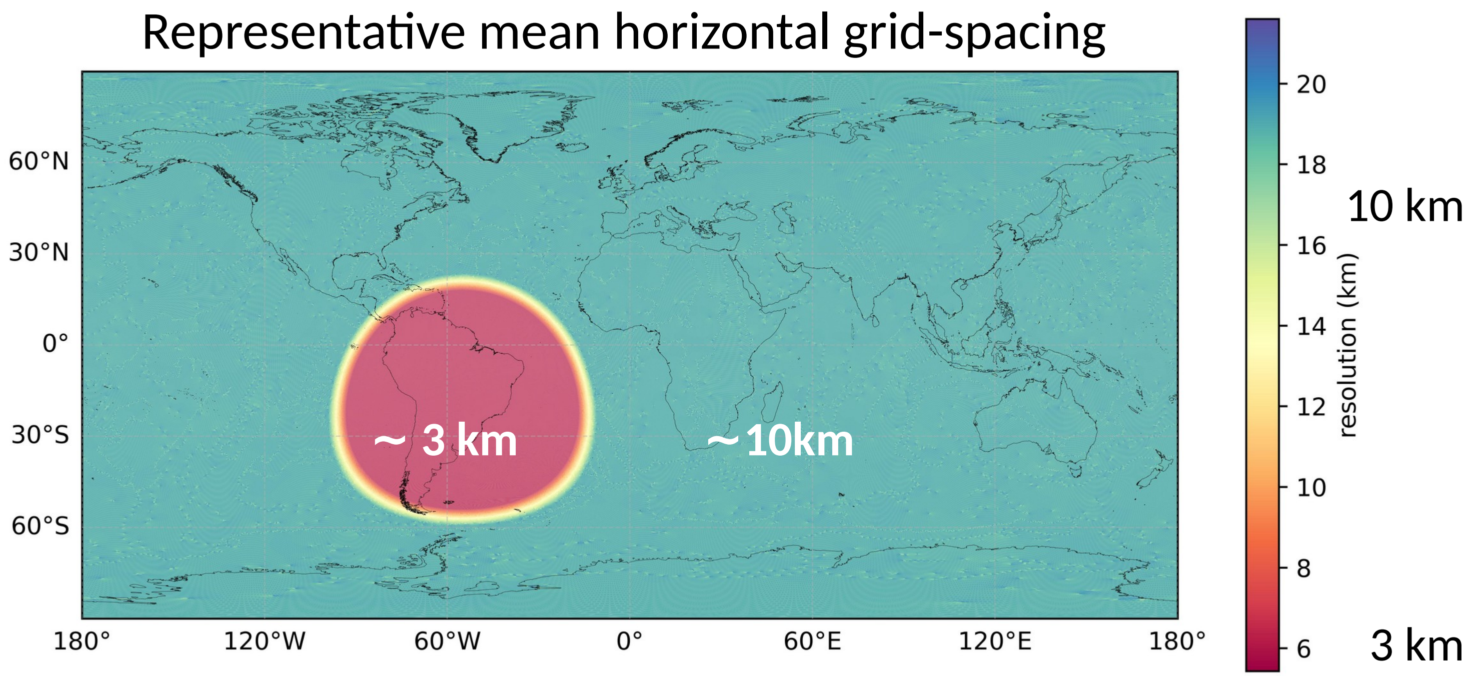


Figure provided by P. Peixoto (2023) IME/USP

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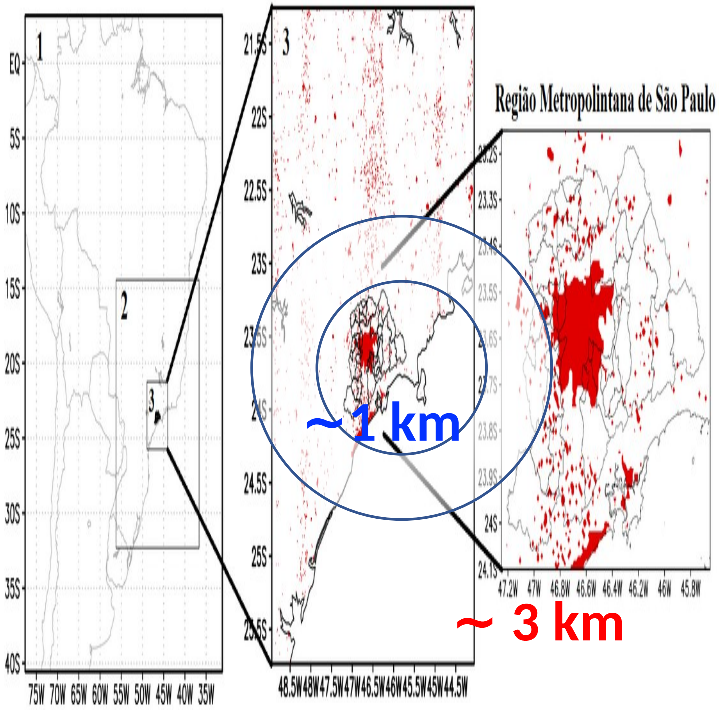
Interlocution with the National Meteorology Network and Regional Centers (operational and academic)

Environmental Prediction on a Regional/Local Scale



Example for the Metropolitan Region of São Pa
for implementation by regional centers

- Methods:
  - Initial and boundary conditions with analysis/forecasts produced with CPTEC/INPE's global **MONAN**;
  - Addition of weather radar data assimilation for nowcasting with the regional configuration of **MONAN**.

- Products:
  - Weather products (including severe weather);
  - Air quality and public health;
  - Biometeorology (thermal comfort indicators, heat waves, UV radiation);
  - Forecast of energy production (solar, wind);
  - Ocean waves;
  - ?

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The acronym and symbol of MONAN

Monan is a Tupi-Guarani’s (originary peoples of S. America) word that means ”land without evils", where they live with their ancestors and Gods, witho starvation, or any human diseases.

Thanks for your attention!
Questions?

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