39th Session of the
Working Group on Numerical Experimentation (WGNE)
04-08 November 2024
Toulouse, France

Model development overview at INPE/CPTEC

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Contents

INPE produces Numerical Weather, Climate and Environmental prediction

Current modelling systems

Computer system
Cray XC50 4160 cores (2018) - operation only
Cluster DELL to research
Current numerical models
Limited-area models

- BRAMS (since 2003) - AQ and NWP
- Eta (since 1996) - NWP, Clim, Reg Proj
- WRF (since 2018) – NWP

Global model

- BAM – NWP, Subseasonal and *Seasonal forecasting* (GPC)

A new paradigm for the environmental modeling over Brazil and South America

Model for Ocean-laNd-Atmosphere predictioN

An unified/community Earth System model: Everyone works on a single modeling system, a single computer code

Community: Open and free source, maintained by a group of HPC experts; workshops and training for the community

MONAN's dynamical core

MPAS Model for Prediction Across Scales

Future plans: **Monan** - in Tupi-Guarani language means "the land without evils" or **Ybymarã-e'yma**

- Atmosphere-land components operational for NWP in 2024 (initial conditions coming from our GFS); - Atmosphere-land components with data assimilation operational for NWP between 2024-2025;
- Atmosphere-land-ocean components to subseasonal to seasonal timescales between 2025-2026 (pending on the new supercomputer);
- Atmosphere-land-ocean-cryosphere components to subseasonal to seasonal timescales in 2027 (pending on the new supercomputer).

Allows local refinement: a single model for regional and global scales

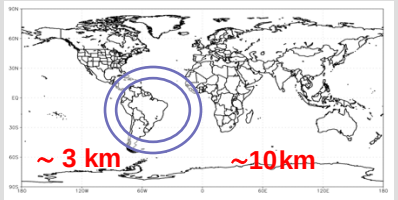


Table 6.3: Possible options for individual physics parameterizations. Namelist variables should be added to the &physics namelist record.

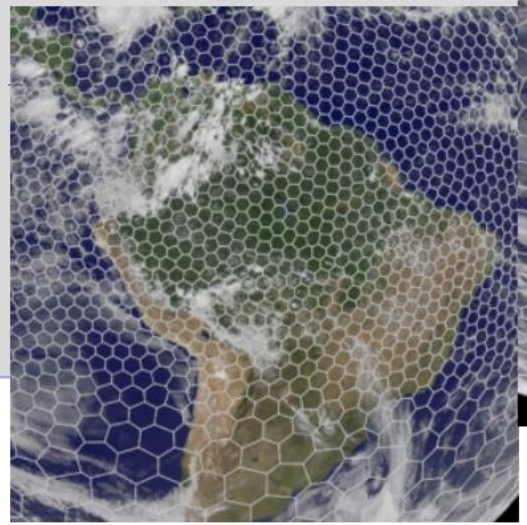
Parameterization	Namelist variable	Possible options	Details
Convection	config_convection_scheme	cu_tiedtke	Tiedtke (WRF 3.8.1)
		cu_ntiedtke	New Tiedtke (WRF 4.5)
		cu_grell_freitas	Modified version of scale-aware Grell-Freitas (WRF 3.6.1)
		cu_kain_fritsch	Kain-Fritsch (WRF 3.2.1)
Microphysics	config_microp_scheme	mp_wsm6	WSM 6-class (WRF 4.5)
		mp_thompson	Thompson non-aerosol aware (WRF 3.8.1)
		mp_kessler	Kessler
Land surface	config_lsm_scheme	noah	Noah (WRF 4.5)
Boundary layer	config_pbl_scheme	bl_ysu	YSU (WRF 4.5)
		bl_mynn	MYNN (WRF 3.6.1)
Surface layer	config_sfclayer_scheme	sf_monin_obukhov	Monin-Obukhov (WRF 4.5
		sf_mynn	MYNN (WRF 3.6.1)
Radiation, LW	config_radt_lw_scheme	rrtmg_lw	RRTMG (WRF 3.8.1)
		cam_lw	CAM (WRF 3.3.1)
Radiation, SW	config_radt_sw_scheme	rrtmg_sw	RRTMG (WRF 3.8.1)
		cam_sw	CAM (WRF 3.3.1)
Cloud fraction for radiation	config_radt_cld_scheme	cld_fraction	Xu and Randall (1996)
		cld_incidence	0/1 cloud fraction depending on $q_c + q_i$
Gravity wave drag by orography	config_gwdo_scheme	bl_ysu_gwdo	YSU (WRF 4.5)

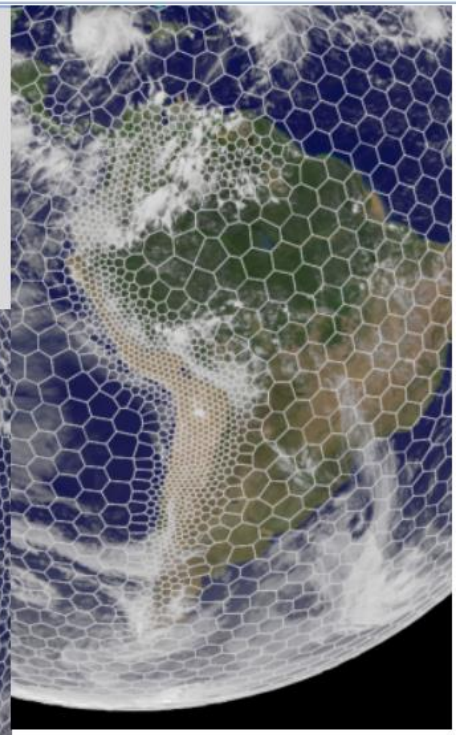
The Atmospheric Component of MONAN

The MPAS-A was officially recommended by the working group at INPE, mostly due to

- ✓Software design with modern Fortran features.
- ✓Portability for GPU.
- ✓The WRF legacy 1: the most successful regional model developed in the world.
- ✓The WRF legacy 2: applied by a large part of
- ✓Successful application in convection-allowing scales.

On 03 August 2023, the Scientific Committee of MONAN approved the recommendation.





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Model for Ocean-laNd-Atmosphere predictioN

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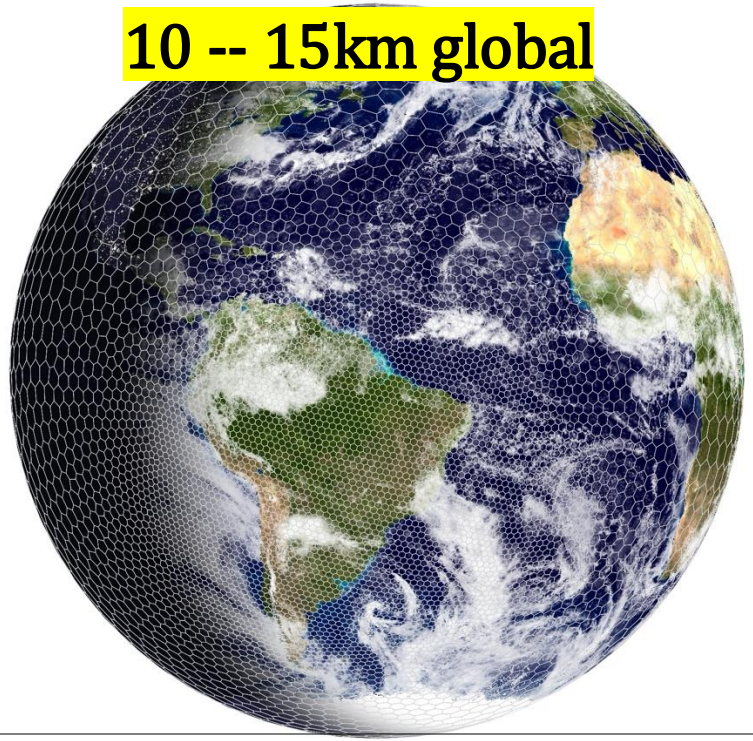
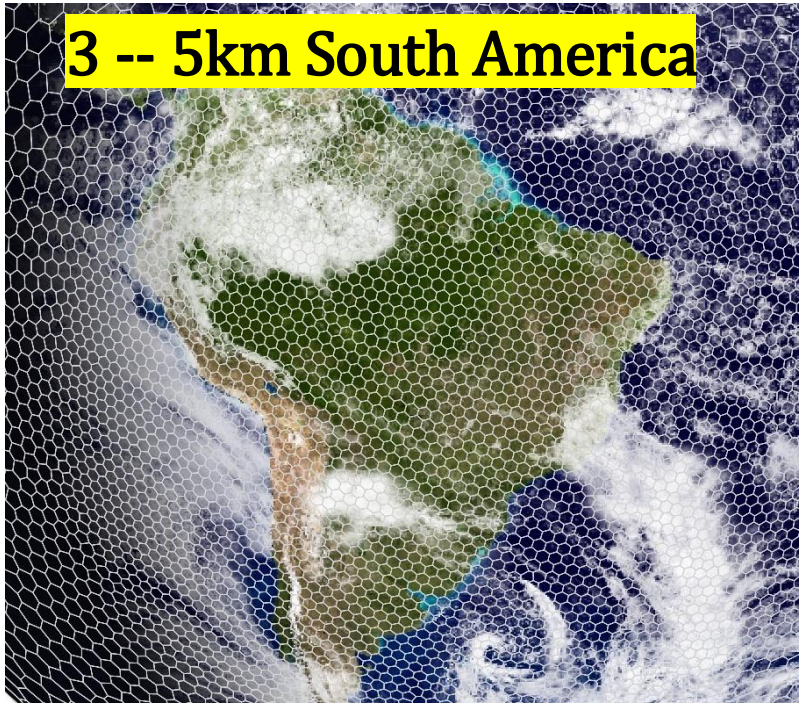
Modeling in non-structured computational meshes.





Allow local refinement: a single model for regional and global scales

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1st MONAN training for the South American Community

12-16 de Agosto 2024
CPTEC/INPE de Cachoeira Paulista

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1st MONAN training for the South American Community

Participaram do treinamento 30 pesquisadores, professores ou tecnologistas:

- MCTI, USP, UFRJ, CEMPA, UFRN, UFBA, UNESP, UFCG, UFPel, Marinha Brasileira, FUNCEME, UFMS, FURG, CENSIPAM, Força Aérea Brasileira, UFAL, UNIFESP, UFPA e LNCC.
- Instituto de Geofísica e SENAMHI do Peru
- Serviço Meteorológico da Argentina

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NCAR
Operated by UCAR

INPE

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MONAN – Atmos+Land
Latest version 1.1.0

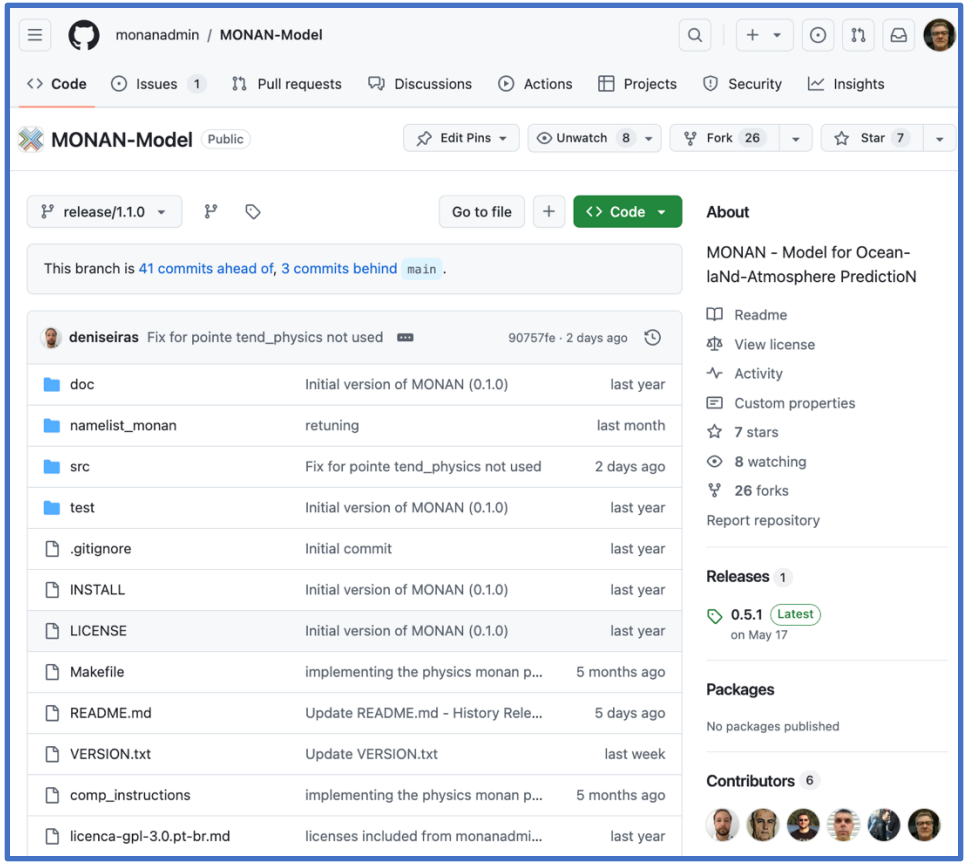
https://github.com/monanadmin/MONAN-Model

This version is being tested as a candidate for the next medium-range global forecast at INPE:

- IC from GFS-FV3 at 00 UTC
- Deterministic
- 15 – days
- 24 km horizontal uniform resolution (10 km after the new supercomputer is installed)
- 55 vertical levels (top @ ~ 10 – 15 Pa)

```
----- Setting up physics suite 'mesoscale_reference_monan' -----

    config_microp_scheme        = mp_wsm6
    config_convection_scheme    = cu_gf_monan
    config_pbl_scheme           = bl_mynn
    config_gwdo_scheme          = bl_ysu_gwdo
    config_radt_cld_scheme      = cld_fraction_monan
    config_radt_lw_scheme       = rrtmg_lw
    config_radt_sw_scheme       = rrtmg_sw
    config_sfclayer_scheme      = sf_mynn
    config_lsm_scheme           = sf_noah
```



(*) in-house developments

Prognostic equation for the Buoyancy-Excess

A sub-grid parameterization to account for effects of cold-pools in further triggering convection

Bx is a new prognostic variable which are advected by the 3-d wind as a scalar

Cold-pools are destroyed by surface fluxes and mixing with the environment air. We will not try to explicitly include those processes

They will all be represented by an 'sink term' in terms of the exponential decay with a prescribed lifetime

Definition of Buoyancy-Excess (B_x)

$$B_x = -(H_d - \tilde{H}), \text{ where } \begin{cases} H_d \text{ downdraft MSE} \\ \tilde{H} \text{ environment MSE} \end{cases}$$

Prognostic Equation: $$\frac{\partial B_x}{\partial t} = adv(B_x) + diff(B_x) + S + R$$

source term $S = \delta_d B_x$, where δ_d is the downdraft detrainment mass flux

sink term $R = -\frac{B_x}{\tau}$, τ is the cold pool lifetime ~ 10^3 - 10^4 seconds

adv and diff are the grid-scale advection and diffusion operators.

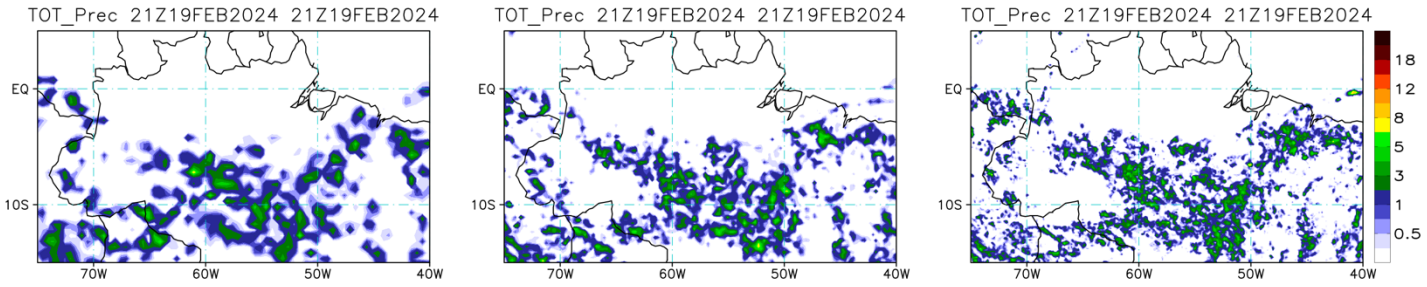
An attempt: as a boundary condition for the MSE of the updraft in the propagation direction, serving as an additional source of buoyancy for the convecting air parcels

Courtesy: Saulo Freitas

Helps organization in low resolution GCM configuration

60 km 30 km 15 km

Control



TOT_Prec Domain ave/min/max: 0.41 0 7.14 mm/hour
EN62_DC0_CNV0_EDT30_x1.163842

TOT_Prec Domain ave/min/max: 0.40 0 7.22 mm/hour
EN62_DC0_CNV0_EDT30_x1.655362

TOT_Prec Domain ave/min/max: 0.42 0 12.8 mm/hour
EN62_DC0_CNV0_EDT30_x1.2621442

Cold Pool

TOT_Prec Domain ave/min/max: 0.56 0 8.42 mm/hour
EN62_DC1_CNV1M222CW2TR2MXB20_EDT30_x1.163842

TOT_Prec Domain ave/min/max: 0.68 0 16.5 mm/hour
EN62_DC1_CNV1M222CW2TR2MXB20_EDT30_x1.655362

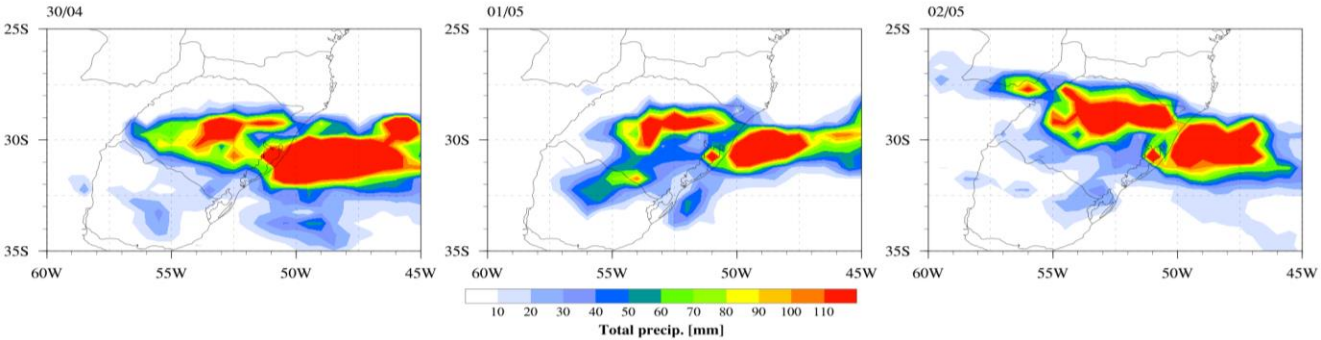
TOT_Prec Domain ave/min/max: 0.84 0 27.2 mm/hour
EN62_DC1_CNV1M222CW2TR2MXB20_EDT30_x1.2621442

MPAS
Model for Prediction Across Scales

Catastrophic Flooding in Rio Grande do Sul

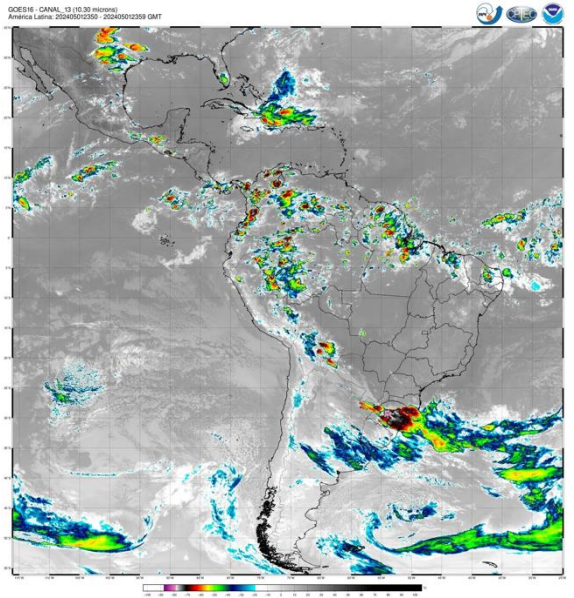
- One of the most significant environmental tragedies experienced in Brazil
- Affected 96% of the state's municipalities
- 2.3 million individuals affected
- 640,000 people losing their homes
- **~ 180** confirmed deaths with a further **~40** people unaccounted
- Average accumulation of 420 mm between April 24 and May 4
- **Most intense precipitation occured between 30 April – 02 May**

Total precipitation (24h) – combined satellite precipitation estimates and rain gauges MERGE/CPTEC



GOES16 Satellite

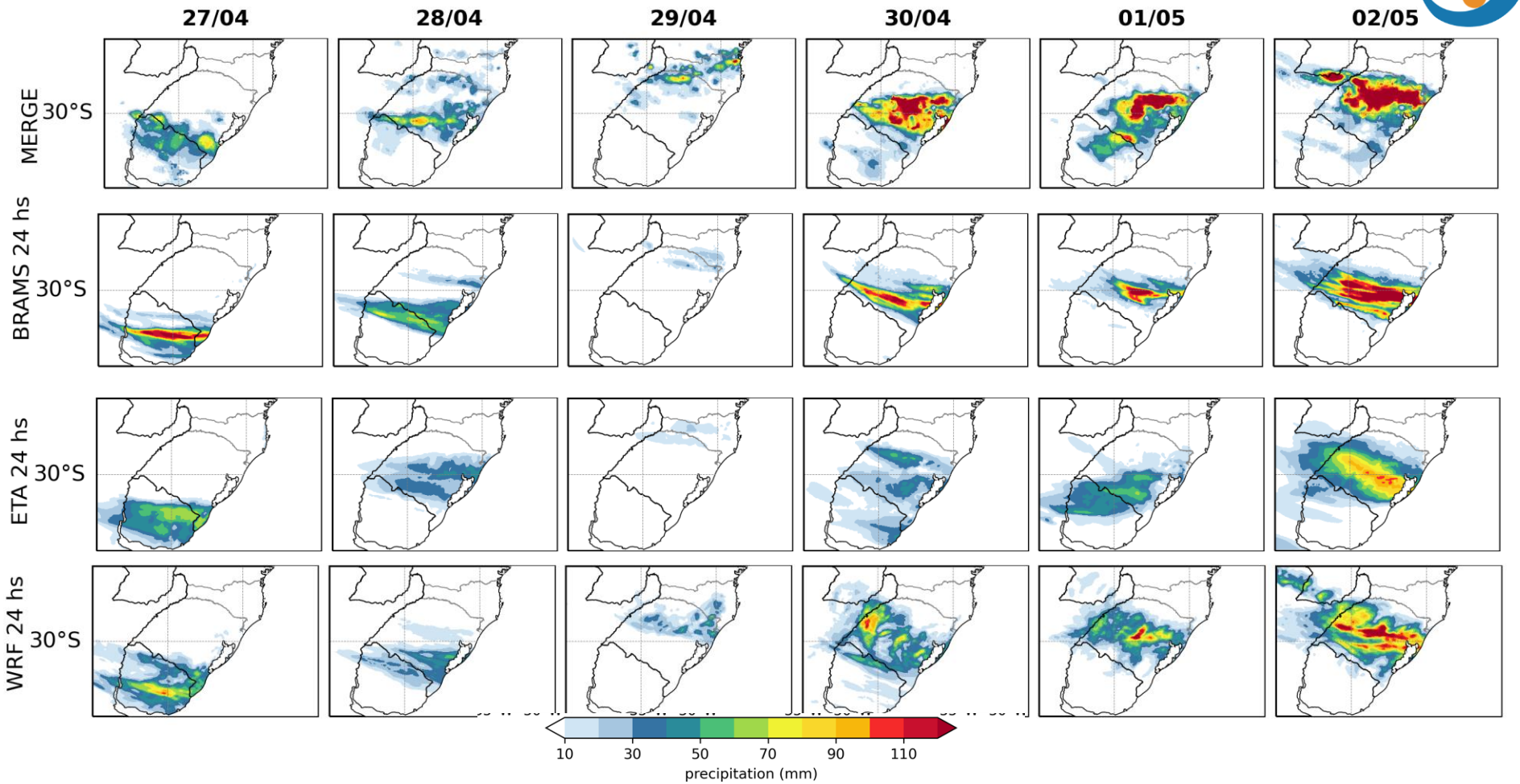
20240501 23:59

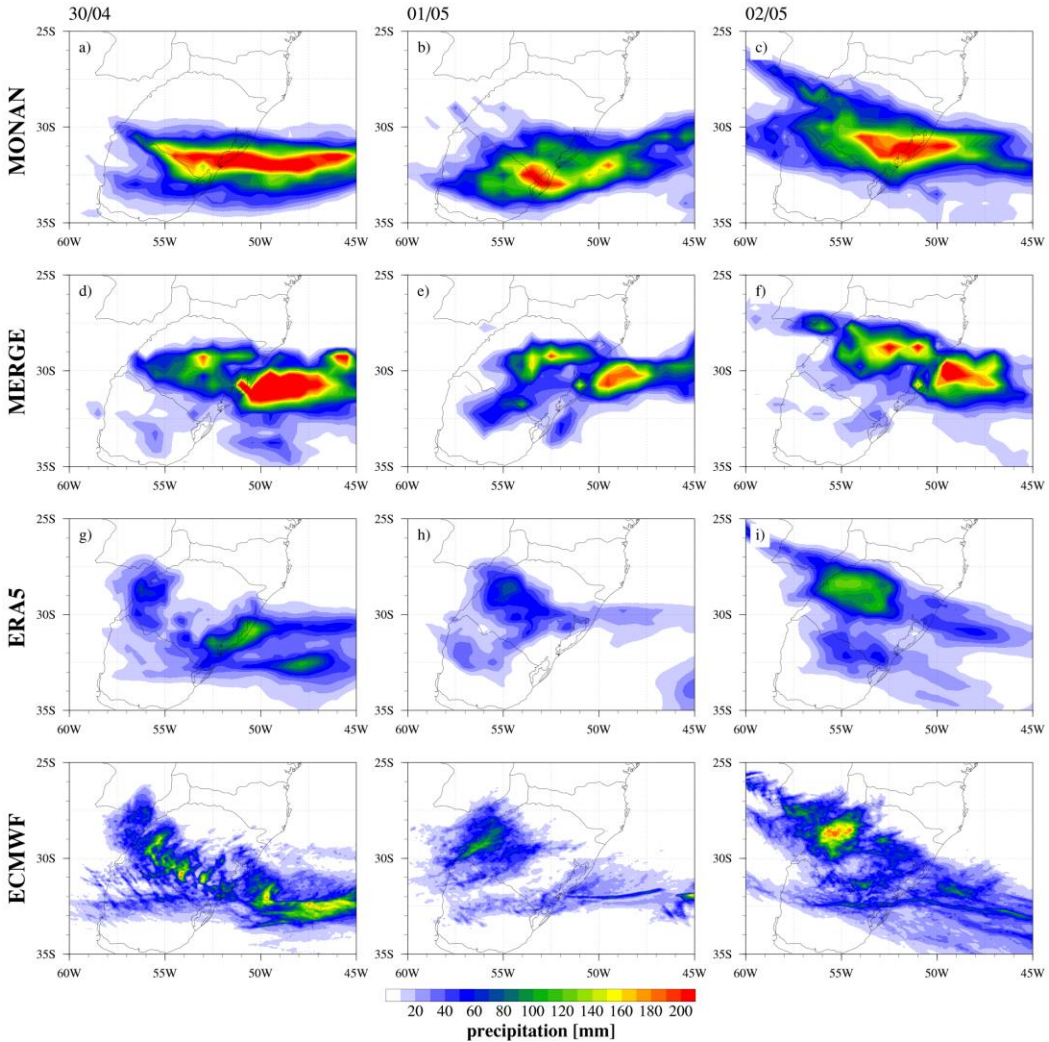


Most critical period of rain in Rio Grande do Sul - April 30 and May 02

Highest accumulations were concentrated in the central-northern and northeastern regions of the state, with values between 240mm and 480mm, according to MERGE datasets – combined weather stations and satellite estimates

Precipitation forecasts – INPE/CPTEC regional models (5km h. resolution)





24h Precipitation forecasts for total precipitation

24-hour rainfall accumulations for April 30 to May 2, 2024

Precipitation was more concentrated in the central regions of Rio Grande do Sul, particularly in the Guaíba basin

The ERA5 data showed rainfall concentrated more in the central-southern part of the state, with higher accumulations over Lagoa dos Patos and the far west of Rio Grande do Sul

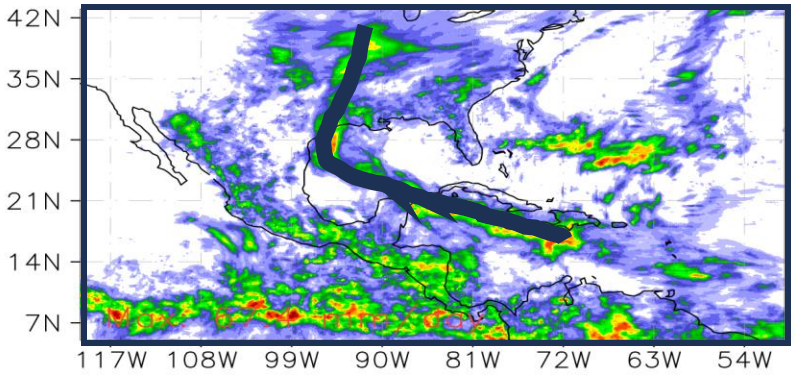
The MONAN model focused rainfall primarily in the southern part of the state, but with accumulation levels consistent with observations (>200 mm), which were considerably higher than those in the ECMWF model

MERGE - combined GPM and raingauges

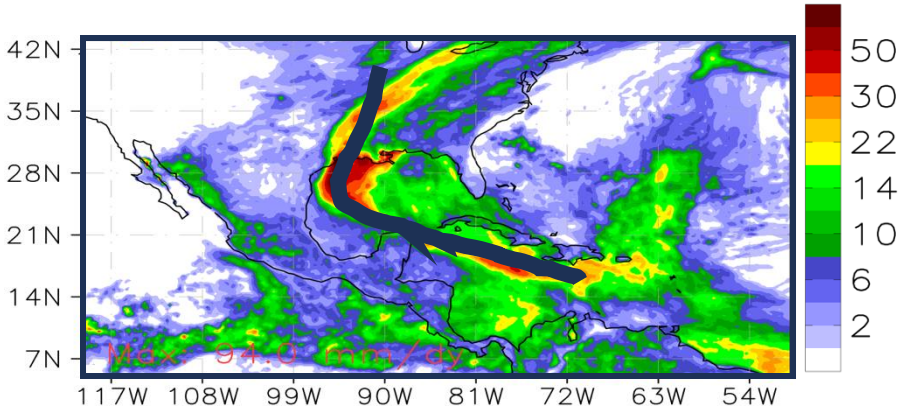
ECMWF – 4km resolution

The forecasted path of Beryl

GPM IMERG 7
00Z03 – 00Z10 JUL 2024



MONAN mean precipitation rate (mm/day)
00Z03 – 00Z10 JUL 2024



Horizontal Resolution: x1.655362 (~ 30km)
7 days forecast starting with GFS @ 00Z03JUL

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What are we doing/planning for the Atmos/Physics component?

1. A new scare-aware formulation for the GF convection parameterization (3d lateral subsidence spread): S. Freitas + G. Grell
2. WSM6 as the microphysics replacement for the current oversimplified scheme in the GF convection parameterization: S. Freitas
3. PBL dry/moist schemes:
   - Taylor's Theory: Haroldo Campos Velho, P. Kubota
   - SHOC+MF: Guilherme Machado (PGMET), S. Freitas, P. Kubota
4. EC – Radiation: P. Kubota, R. Souto (LNCC)
5. Ocean Mixed Layer as in NASA GEOS-5: S. Freitas
6. **Biomass Burning + smoke plume rise model: Jaqueline Pereira (PGMET): INPE + NCAR**
7. **Soil dust aerosols: N. Rosário (UNIFESP), K. Longo (INPE),...**
8. Cloud organization + MJO studies: Bianca Fusinato PGMET/ S. Freitas
9. Evaluating the cloud microphysics options in MPAS: Enver
10. Implementing the METplus for model evaluation: Ariane, J. Pablo, Marcelo (INPE)
11. Updating the surface characterization and evaluating surface fluxes over the land: A. Manzi, P. Kubota, J. Gerd
12. Implementing output in GRIB2/3 format: S. Henrique (INPE) F. Li (ECMWF)

MONAN
Subsequent Deliverables

- Coupling with DA using the JEDI Framework (2025-2026)
  a. Ensemble forecast for medium range (up to 15 days)
  b. Nowcasting for severe storms (up to 6 hours)
  c. Air pollution forecasting (up to 7 days)
- Coupling with oceanic and cryosphere models (2025-2028)
  a. Sub-seasonal prediction (up to 30 days)
  b. Seasonal prediction (3-month ahead)
- Coupling with the anthroposphere (2028-2030)
- Climate change scenarios (2030-2031)
- Fully developed **MONAN** South America, Earth System Community Model (2031)

Thanks!

Questions?