38th Session of the
Working Group on Numerical Experimentation (WGNE)
27-01 November 2023
São José dos Campos, SP, Brazil

Model development overview at INPE/CPTEC

Ariane Frassoni
Thanks to S. Freitas and MONAN groups
Brazilian National Institute for Space Research,
Center for Weather Forecasting and Climate Studies
Cacheira Paulista, SP, Brazil
ariane.frassoni@inpe.br
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Contents

1. INPE’s current numerical modelling setup & future plans

2. MONAN’s dynamical core choice

3. Physics to be adopted in the first oper version

INPE produces Numerical Weather, Climate and Environmental prediction

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

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)

Model for Ocean-laNd-Atmosphere predictioN

MONAN's dynamical core

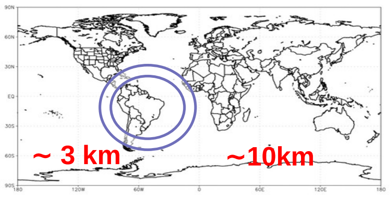
MPAS
Model for Prediction Across Scales

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

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 current global model); - 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



Partners

Model for Ocean-laNd-

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

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CPTEC

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UNIVERSIDADE FEDERAL DE SÃO PAULO
1933

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Laboratório Nacional de Computação Científica
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Centro de Hidrografia da Marinha
MARINHA DO BRASIL

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Departamento de Controle do Espaço Aéreo

ICEA

MPAS
Model for Prediction Across Scales

Servicio Meteorológico Nacional

WMO
IMO-WMO
150
1873 2023

Partners

Model for Ocean-laNd-

Towards a consortium of SA institutions

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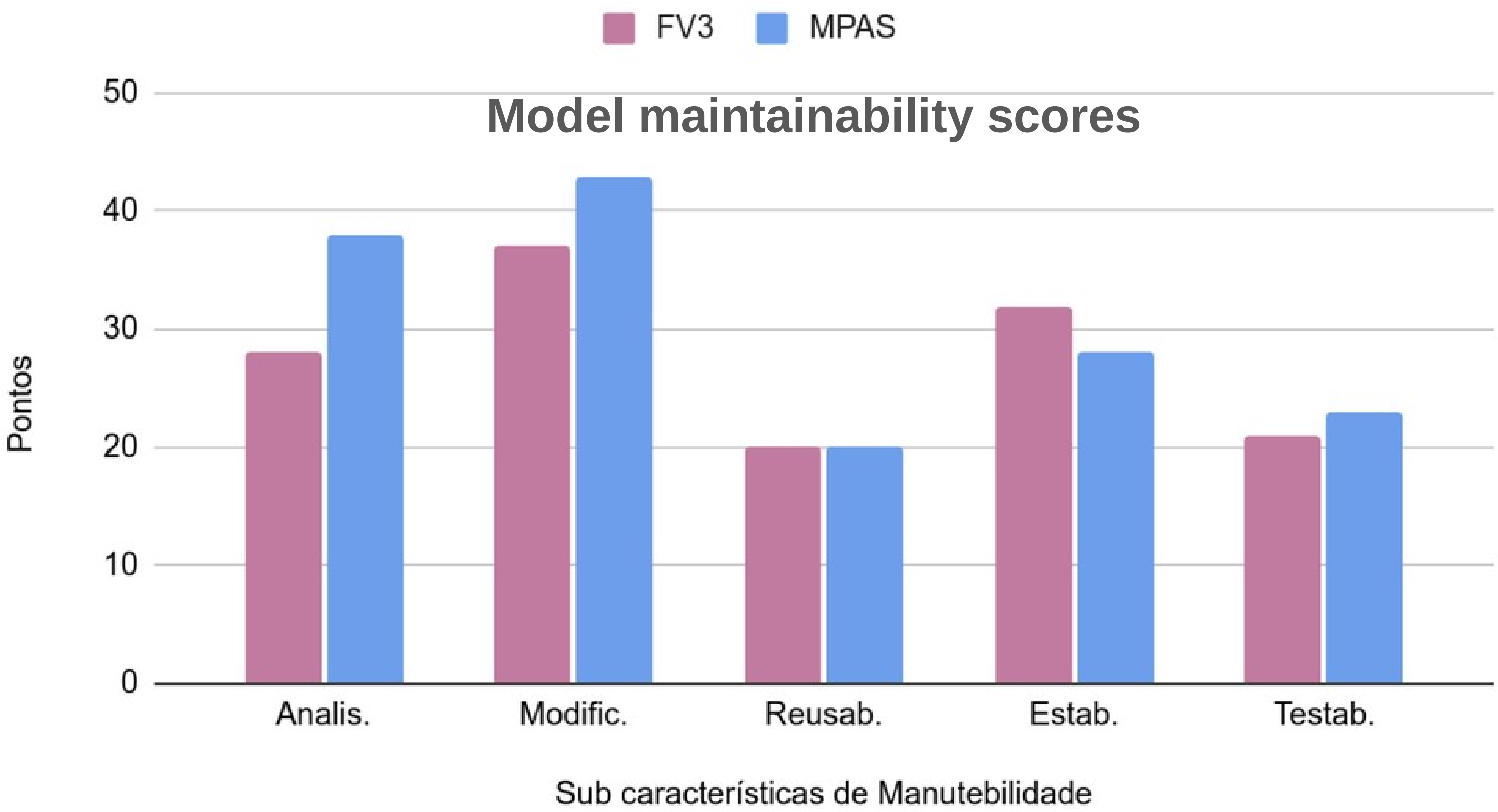
MPAS
Model for Prediction Across Scales

WMO
IMO-WMO

Quality of software evaluation

Model maintainability scores



Characteristics of maintainability

Courtesy: GCC/MONAN

Model verification: Experiments design

	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 (ERA5)

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

Model verification

Experiments design

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

Grid point assessment

Statistical metrics recommended by the WMO

Continuous Variable Forecasts

- Anomaly Correlation - ACC
- Bias
- Root Mean Square Error - RMSE
- Scatterplot

Predictions of dichotomous variables

- Frequency Bias
- Equitable Threat Score (ETS)
- Probability of Detection (POD)
- Critical Success Index (CSI)
- False Alarm Ratio (FAR)

Mahalanobis Distance

$$D_M(x) = \sqrt{(x-\mu)^T S^{-1} (x-\mu)}.$$

$\mu = (\mu_1, \mu_2, \mu_3, \ldots, \mu_p)^T$ and covariance matrix S to a multivariated vector $x = (x_1, x_2, x_3, \ldots, x_p)$ T

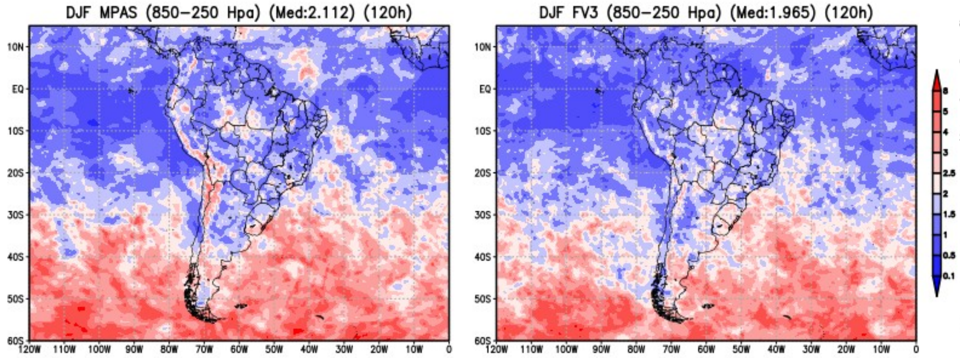
Variables used: u, v and T in the post-processed vertical levels

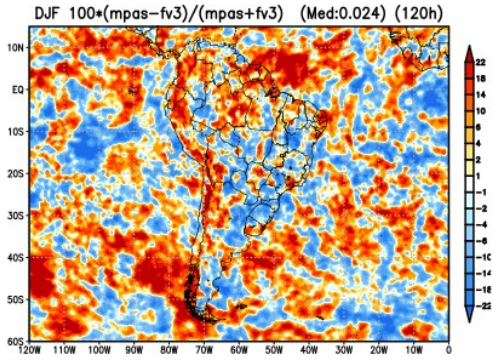
Reference: ERA5

Courtesy: Marcelo Barbio

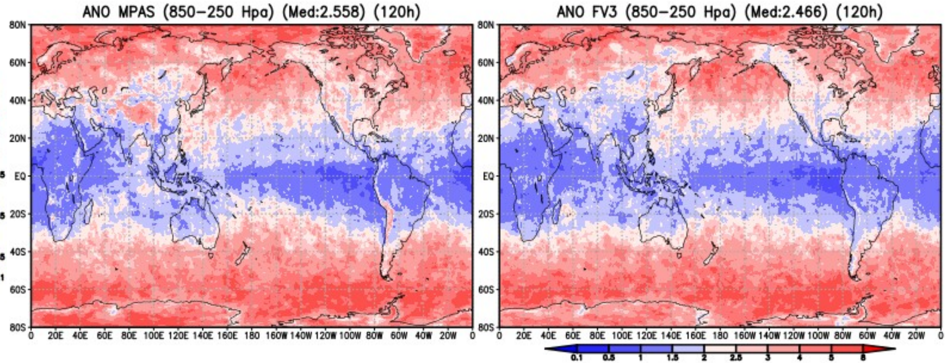
Mahalanobis distance

South America 120h - DJF

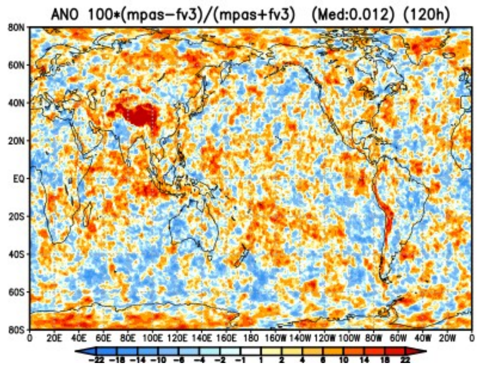




Global 120h - Annual



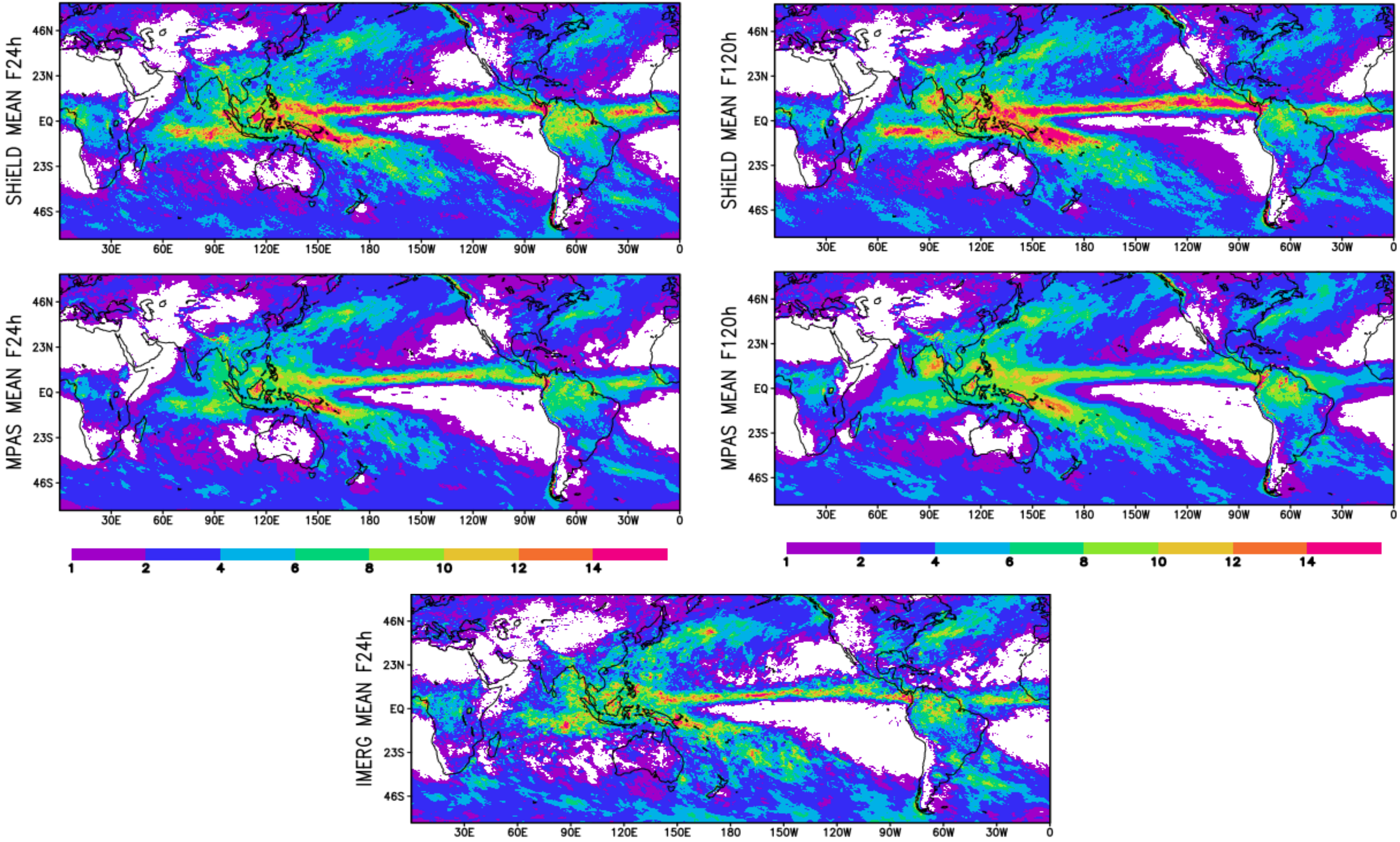
Orange-red shaded MPAS has less relation with ERA5



Mean precipitation over the global domain, in mm/day

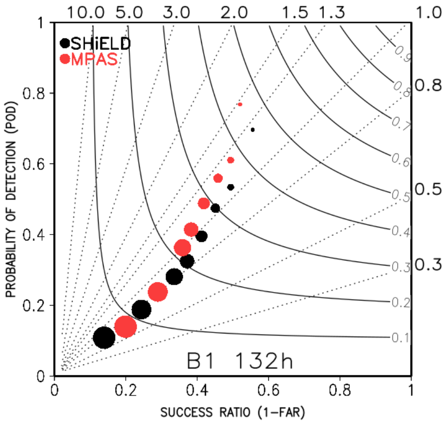
24h

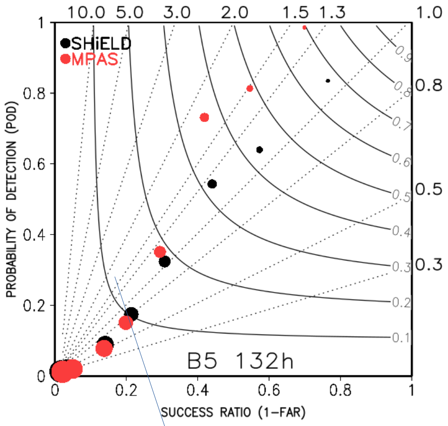
120h

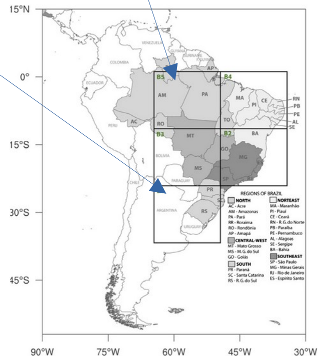


Performance diagram

Precipitation

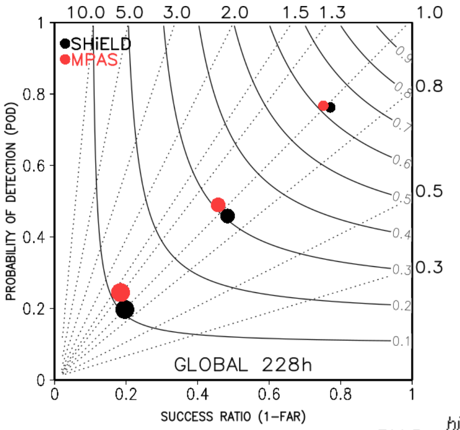






Thresholds: Circles from smallest to largest -> light to heavy rain
0.5 2 5 10 15 20 25 50 mm

10-m wind (m/s)



Thresholds: Circles from smallest to largest -> light to strong winds 5 10 15 m/s

$$BIAS = \frac{hits + false\ alarms}{hits + misses}$$

$$POD = \frac{hits}{hits + misses}$$

$$TS = \frac{hits}{hits + misses + false\ alarms}$$

$$SR = \frac{hits}{hits + false\ alarms}$$

Precip mean intensity computed over the global domain, in mm/day

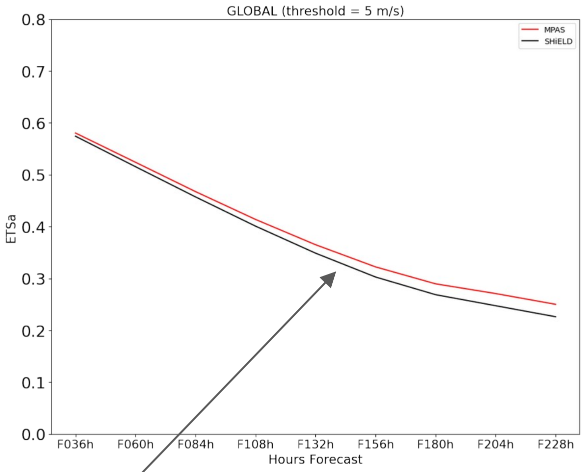
Time integration	IMERG	MPAS	ShiELD	Diff MPAS	Diff ShiELD	Diff perc. MPAS (%)	Diff perc. ShiELD (%)
36h	3,19928	3,09617	3,47084	-0,10311	0,27156	-3,223	8,488
60h	3,20317	3,17713	3,52475	-0,02604	0,32158	-0,813	10,039
84h	3,19727	3,23611	3,61322	0,03884	0,41595	1,215	13,010
108h	3,17839	3,27442	3,65614	0,09603	0,47775	3,021	15,031
132h	3,20712	3,31056	3,68918	0,10344	0,48206	3,225	15,031
156h	3,20342	3,34213	3,72282	0,13871	0,5194	4,330	16,214
180h	3,20599	3,35401	3,75819	0,14802	0,5522	4,617	17,224
204h	3,20136	3,37975	3,77914	0,17839	0,57778	5,572	18,048
228h	3,18150	3,38142	3,81426	0,19992	0,63276	6,284	19,889

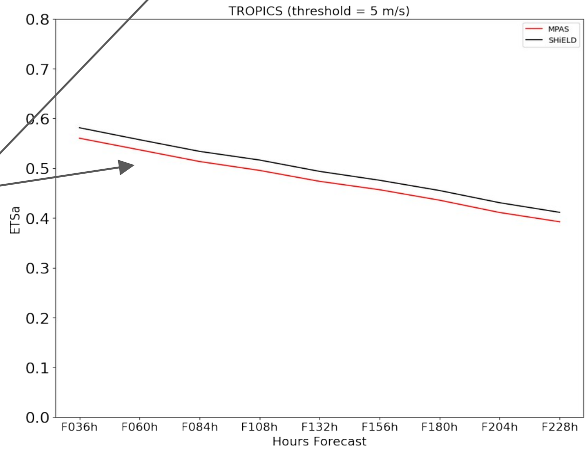
ETSa
10-meter wind (m/s)

Bias of the models were removed to compute ETS (ETSa)

MPAS performs better for light winds

Differences between MPAS and SHiELD increase with forecast length





Similar results were found for SA and for stronger wind thresholds

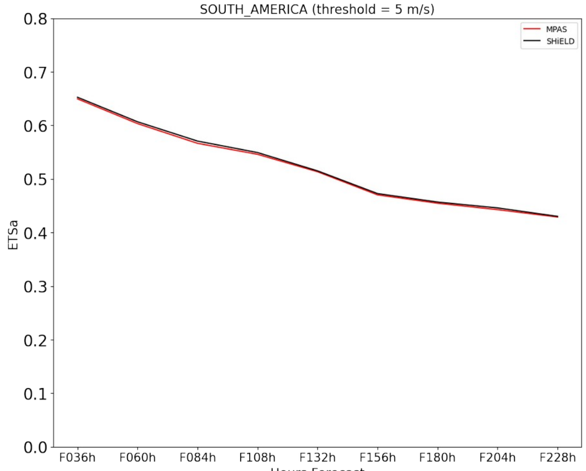


Table 6.3: Possible options for individual physics parameterizations. Namelist variables should be added to the &physics namelist record.

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)

Thanks!

Questions?