Systematic Error of Parameterization Schemes in the MM5 Model

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Motivation: To estimate systematic errors of the MM5 model while using different parameterization schemes for microphysics, cumulus, radiance and PBL and to select the optimal set.

The major topics are addressed to:

- the model error growth rate;
- evolution of model error all the way from the short range to the medium range and beyond;
- a spatial structure of model error over the Northern Atlantic – Europe region;
- a vertical distribution of model error at the standard surfaces and for different atmospheric variables;

Model domain:

Northern Atlantic – Europe
75 x 139 grids, 81 km resolution,
33 vertical levels
BC-IC: ERA40

Parameterization scheme description:

MCBR (Microphysics, Cumulus, Boundary layer, Radiation)

Microphysics:

- Mixed phase Reisner (5)
- Goddard (6)
- Schultz (8)

Cumulus:

- Anthes-Kuo (2)
- Arakawa-Schubert (4)
- Kain-Fritsch (6)

PBL:

- Eta BPL by Mellor-Yamada (4)
- MRF PBL by Hong-Pan (5)

Radiation:

- CCM2 (3)
- RRTM (4)

Diagnostics:

- Average systematic differences between forecasts and estimates of the true state

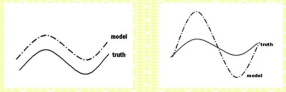
$$dif = d(era40_t) - d(mm5_t)$$

- As above but for absolute values of differences

$$std = \left| d(era40_t) - d(mm5_t) \right|$$

- Horizontal and vertical distributions of the diagnostics
- Power spectra

The advantages and shortness of the *dif* and *std* (simplified examples)



The same amplitudes but there is the bias in the mean values

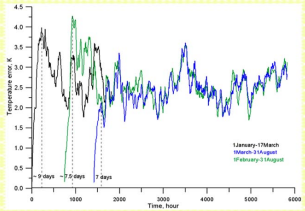
The same mean values but the amplitude of the model process is wrong

std is smaller
dif is larger

dif is smaller
std is larger

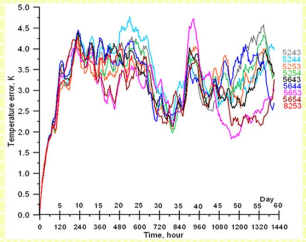
Evolution of model error

T-500 std - diagnostic



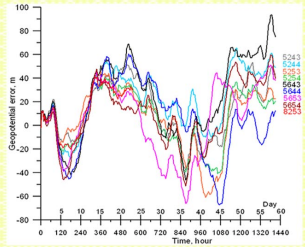
Evolution of model error from the different start moments but for the same BC and with the same parameterization schemes (5653). Model error grows more or less linearly during the first 7-10 days. Thereafter, its growth saturates and deviates with a smaller magnitude presumably due to changes in the atmospheric flow.

T-700 std - diagnostic



Evolution of the std diagnostic of model error with different parameterization schemes (the BC and IC are the same). The discrepancy between schemes is remarkable after 5-th day and varies depending on a synoptical pattern (to be studied further).

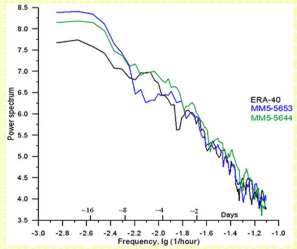
H-500 dif - diagnostic



As above but for the dif diagnostic. This diagnostic allows for the compensation of model error during its evolution.

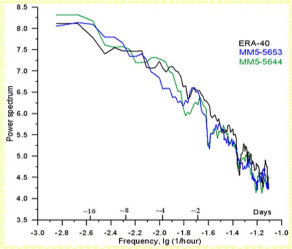
Power spectra

Europe



Over the continent region, the model processes are more powerful in the low-frequency band.

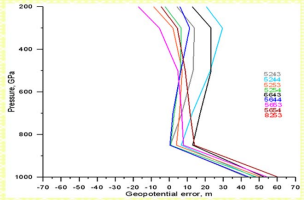
Atlantic



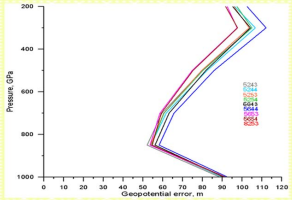
Over the ocean region, the model spectrum sharper shows synoptical scales.

Vertical profiles of model error

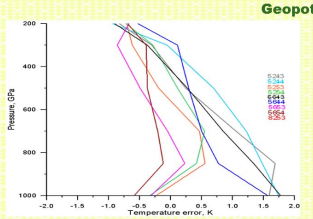
DIF

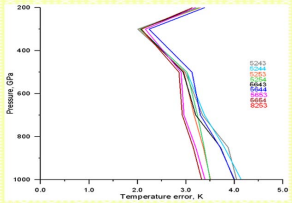


STD

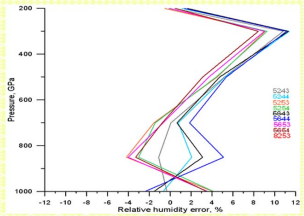


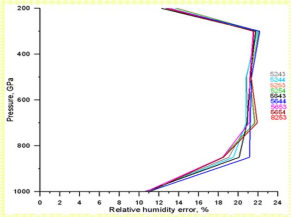
Geopotential





Temperature

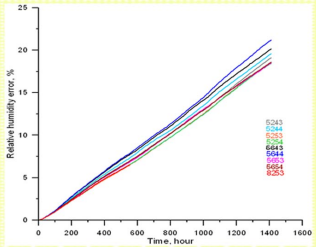




Relative humidity

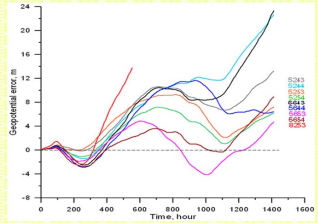
Accumulated model error

RH-850 std - diagnostic



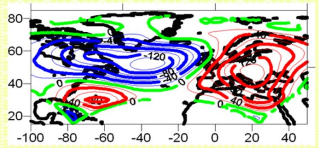
Model error linearly accumulates at a different rate for different parameterization schemes.

H-500 dif - diagnostic



Some parameterization schemes stabilize the accumulated dif diagnostic, while the others lead to breaking it down.

Spatial structure of model error over the domain



Mean difference of H500 between the ERA-40 reanalysis data and MM5-5653 model for January-February 2002 period. The model overestimates geopotential height over the Northern Atlantic region and underestimates it over the Europe continent and the warm Atlantic area.

The gain table for parameterization schemes

Sum of weights (0.00 is the best, 1.00 is the worse, grey color means the value is in the best quarter)

			5243	5244	5253	5254	5643	5644	5653	5654
std	H	1001	0.00	0.30	0.45	0.48	0.55	1.00	0.7	0.78
		850	0.00	0.30	0.25	0.32	0.65	1.00	0.22	0.40
		700	0.16	0.44	0.29	0.30	0.66	1.00	0.00	0.10
		500	0.45	0.68	0.42	0.48	0.69	1.00	0.00	0.03
		300	0.50	0.62	0.41	0.51	0.45	1.00	0.00	0.01
		200	0.53	0.42	0.39	0.53	0.33	1.00	0.07	0.00
	Sum for H		1.64	2.76	2.21	2.60	3.24	6.00	0.99	1.32
	T	1001	0.88	1.00	0.22	0.21	0.82	0.83	0.09	0.00
		850	1.00	0.89	0.29	0.29	0.78	0.78	0.07	0.00
		700	0.89	1.00	0.51	0.68	0.60	0.81	0.00	0.00
		500	0.52	0.63	0.37	0.63	0.33	1.00	0.10	0.00
		300	0.00	0.18	0.14	0.14	0.27	1.00	0.64	0.32
		200	0.32	0.24	0.64	0.52	0.24	1.00	0.28	0.00
	Sum for T		3.61	3.94	2.17	2.47	3.04	5.42	1.33	0.32
	RH	1001	0.50	0.50	0.83	1.00	0.00	0.67	0.33	0.67
		850	0.25	0.43	0.04	0.00	0.64	1.00	0.04	0.07
		700	0.18	0.00	0.52	0.32	0.09	0.36	0.27	1.00
		500	0.17	0.00	0.67	0.67	1.00	0.67	0.67	0.83
		300	0.63	0.75	0.88	0.75	0.50	1.00	0.00	0.25
		200	0.63	0.38	1.00	0.94	0.00	0.44	0.50	0.31
	Sum for RH		2.36	2.06	4.24	4.18	1.90	4.47	2.81	3.13
	Sum std		7.61	8.76	8.62	9.25	8.18	15.89	4.13	4.77
dif	H	1001	0.00	0.27	0.46	0.32	0.57	0.07	0.66	1.00
		850	0.01	0.45	0.26	0.04	0.93	0.00	0.56	1.00
		700	0.31	0.71	0.24	0.04	1.00	0.00	0.32	0.62
		500	0.46	0.97	0.14	0.08	1.00	0.00	0.00	0.23
		300	0.43	1.00	0.00	0.17	0.77	0.33	0.14	0.08
		200	0.00	1.00	0.35	0.00	0.57	0.19	0.83	0.11
	Sum for H		1.30	4.40	1.45	0.65	4.84	0.60	2.51	3.04
	T	1001	0.88	0.97	0.00	0.07	1.00	0.86	0.06	0.23
		850	1.00	0.87	0.28	0.10	0.78	0.41	0.07	0.00
		700	0.85	1.00	0.35	0.43	0.68	0.38	0.00	0.14
		500	0.22	1.00	0.14	0.00	0.28	0.31	0.66	0.47
		300	0.30	0.00	0.70	0.28	0.40	0.06	1.00	0.41
		200	0.71	1.00	0.44	0.46	0.90	0.00	0.34	0.39
	Sum for T		3.96	4.84	1.91	1.45	4.04	2.02	2.13	1.64
	RH	1001	0.00	0.00	0.99	1.00	0.53	0.56	0.85	0.93
		850	0.00	0.23	0.78	0.49	0.50	1.00	0.74	0.56
		700	0.00	0.42	0.86	0.81	0.33	1.00	0.37	0.41
		500	0.93	0.94	0.61	0.58	0.72	1.00	0.25	0.00
		300	0.77	1.00	0.23	0.30	0.97	0.90	0.20	0.00
		200	0.21	0.64	0.30	0.04	1.00	0.82	0.00	0.24
	Sum for RH		1.91	3.33	3.77	3.22	3.84	5.28	2.41	2.04
	Sum dif		7.17	12.57	7.13	5.30	12.72	7.98	7.05	6.72
	Total sum		14.78	21.33	15.75	14.55	20.90	23.87		11.49
	Sum H		1.94	7.16	3.66	3.25	8.08	6.68	3.50	4.36
	Sum T		7.57	8.78	4.08	3.90	7.08	7.44	3.46	1.96
	Sum RH		4.27	5.39	8.01	7.40	5.74	9.75	5.25	5.17

Conclusions

In general, the most optimal parameterization scheme sets for the coarse resolution forecasts are 5653 and 5654, which include the mixed-phase microphysics, Kain-Fritsch cumulus, MRF PBL by Hong-Pan and both the CCM2 or RRTM schemes for radiation. Even with the best parameterizations, the model mostly underestimates the geopotential and temperature fields over the continent and overestimate them over the ocean. Also, the model redistributes temperature from the low troposphere towards the middle and upper troposphere, and humidity in the counterwise versa. The model and reanalysis spectra have differences in the low band over the continent and on synopticul scales over the ocean.

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