Thermal evolution of terrestrial planets with 2D and 3D geometries

Fleury Aymeric, Plesa Ana-Catalina, Hüttig Christian, 2021

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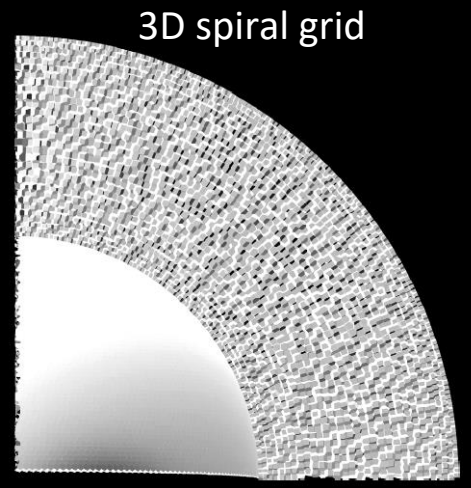
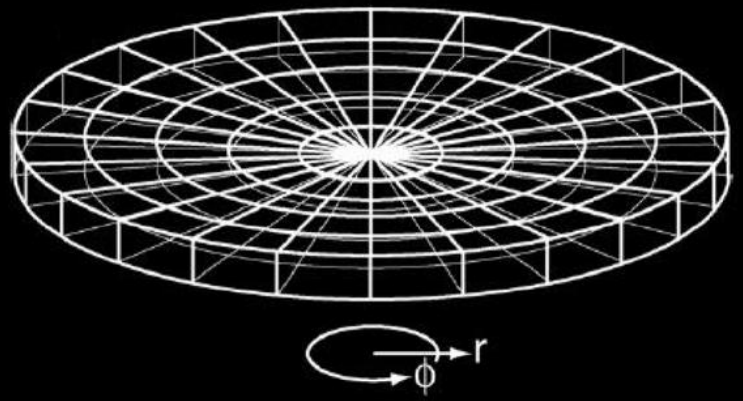
Spherical annulus geometry

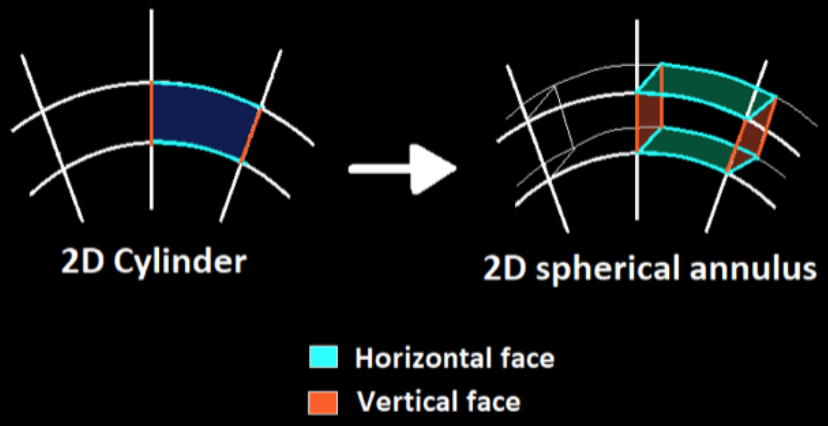
- Addition of a dimension to an initial 2D geometry
- Better approximation of the 3D geometries
- Faster computing time enabling coverage of a broader range of parameters
- High resolution that would be to expensive in 3D simulations



Hüttig et al., 2013



Hernlund & Tackley 2008



This study

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Benchmarking with StagYY and the CHIC code

- Steady states simulations
- Boussinesq approximation
- Purely basal or alternatively purely internal heating

Ra	RMS velocity			Nusselt number		
	CHIC*	STAGYY**	Gaia	CHIC*	STAGYY**	Gaia
1e 4	39,87	37,7	42,26	4,39	4,18	4,5
1e 5	174,1	160	158	7,61	7,39	8,67
1e 6	719,3	640	680	16,53	14,4	14,6
Ra / H	**RMS velocity**			**Average mantle temperature**		
1e4 / 3,4	25,09	23,5	22,36	0,295	0,308	0,275
1e5 / 6,6	97	78,5	87,8	0,369	0,349	0,341
1e6 / 14	340	265	283,9	0,385	0,35	0,351

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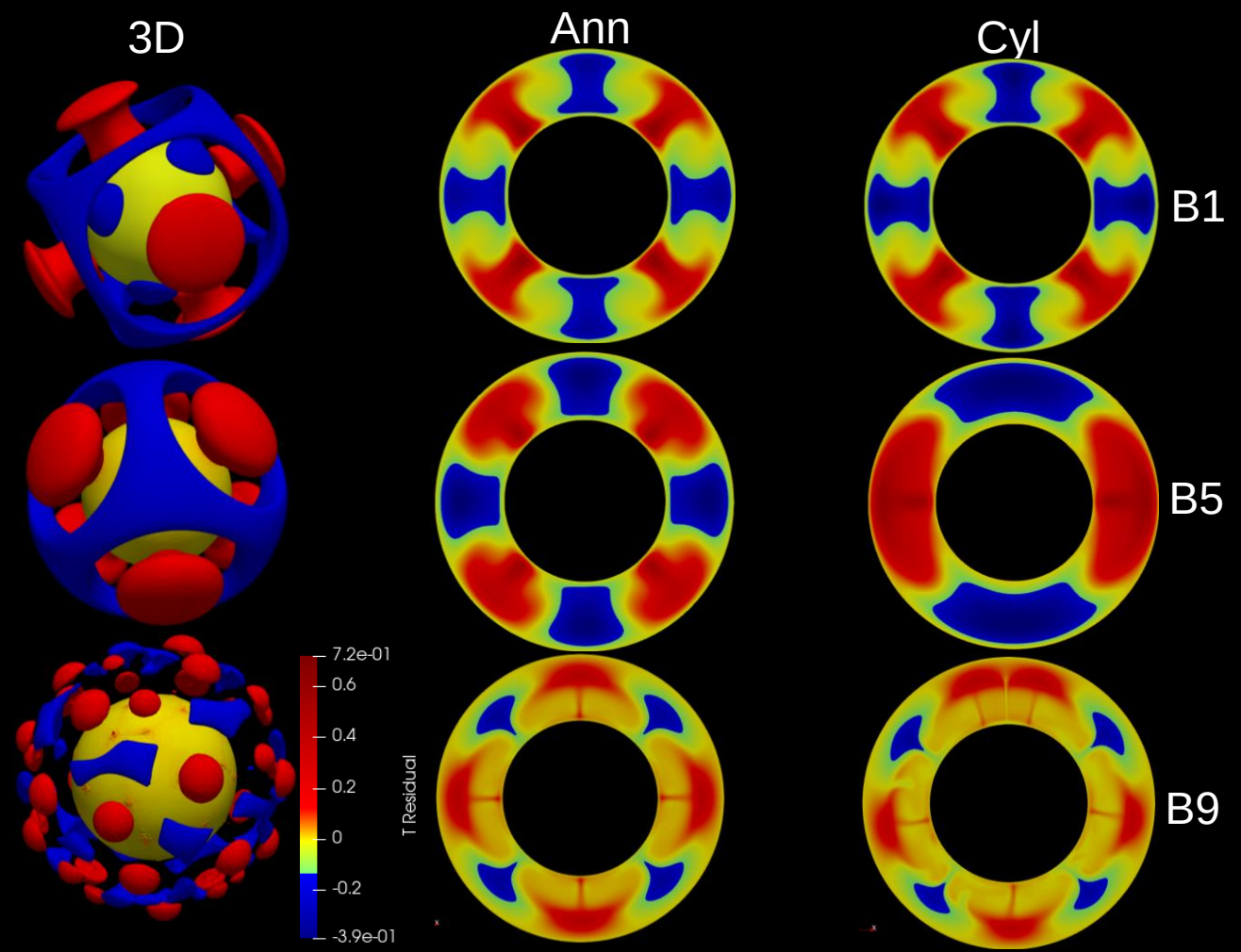
*Noack et al., 2015

** Hernlund and Tackley., 2008

Benchmark cases of Zhong et al., (2008)

- Comparison of 3D, 2D spherical annulus, and 2D cylinder geometry using the benchmark cases form Zhong et al., (2008).

		3D Zhong 2008 values	values study	Annulus	Cylinder
B1 case	T mean	0,22	0,22	0,26	0,38
	Vrms	31,09	31,06	31,95	36,22
	Nu top	3,63	3,60	4,06	4,15
	Nu bot	3,60	3,60	4,10	4,15
B5 case	T mean	0,33	0,29	0,37	0,41
	Vrms	22,29	22,08	20,77	32,88
	Nu top	2,68	2,79	3,34	2,93
	Nu bot	2,66	2,79	3,38	2,92
B9 case	T mean	0,59	0,58	0,57	0,41
	Vrms	158,70	139,82	142,40	32,83
	Nu top	3,48	3,38	2,98	2,93
	Nu bot	3,52	3,39	3,01	2,92



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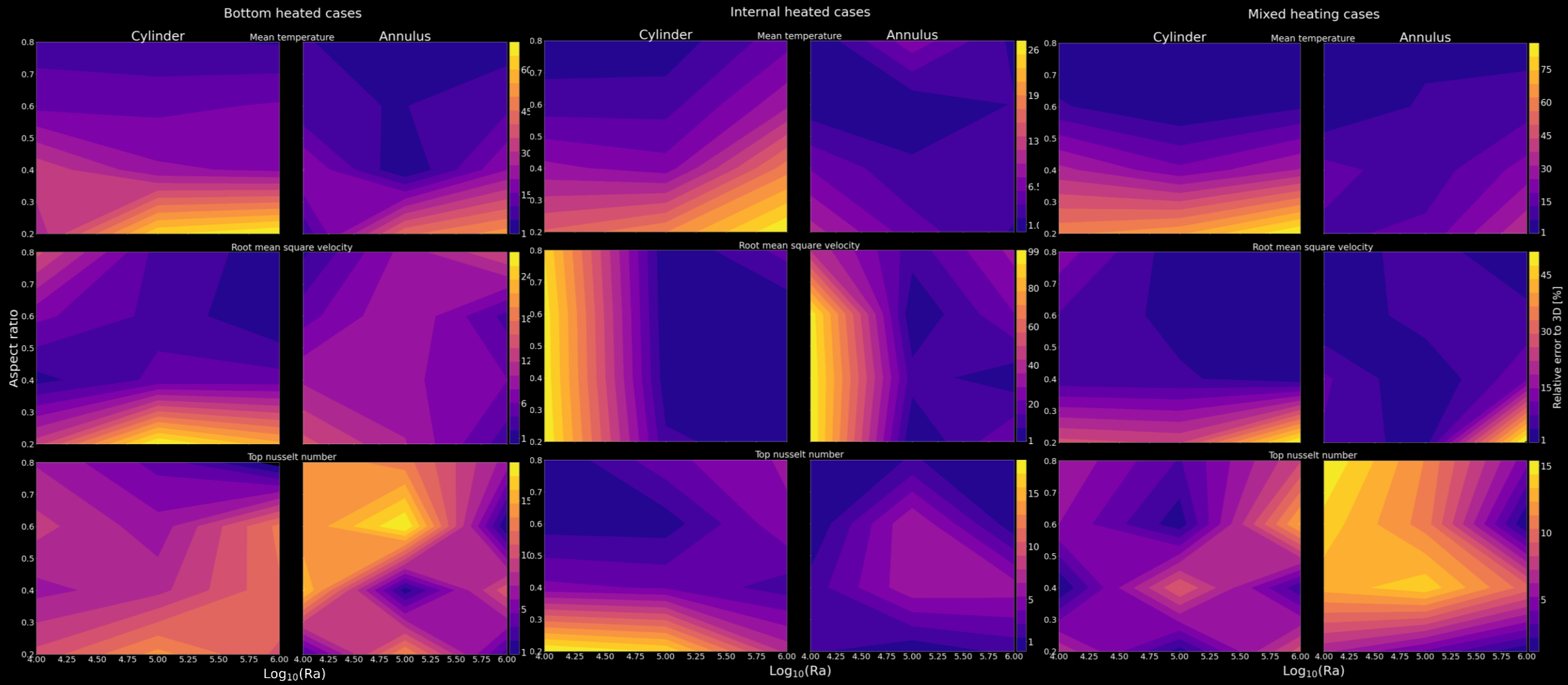
Comparison of 3D and 2D geometries

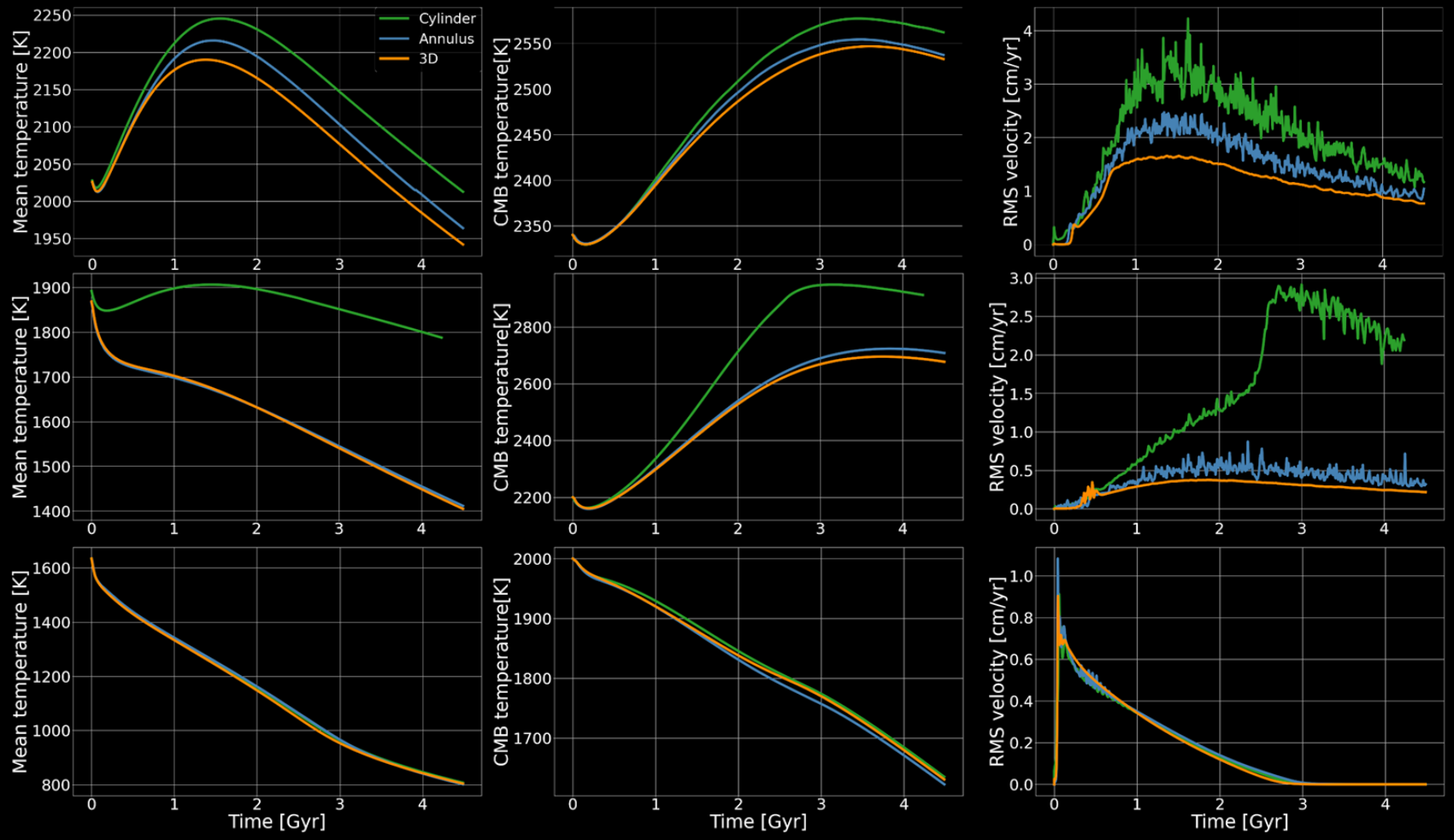
- Systematic comparison between 2D geometries and 3D cases for various Rayleigh numbers, aspect ratios, as well as heating modes



Thermal evolution of Mars, Mercury and the Moon

- Thermal evolution models using a temperature dependent viscosity, EBA, mixed heating, decay of radioactive heat producing elements, and core cooling.

- Mars
- Moon
- Mercury



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Conclusion

- The implemented spherical annulus geometry enables us to better approximate the 3D simulations
- Reproducing closely the results of previous studies within specific benchmarking (Hernlund and Tackley., 2008 & Noack et al., 2015 & Zhong et al., 2008)
- The annulus fares better than the cylinder; especially for the low aspect ratio/high Ra configurations
- The annulus geometry is reproducing more accurately the thermal evolution of a 3D-planet than a cylindrical one

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