Quantifying Uncertainties and Enhancing the Speed of climate model Tuning

Climate change is a central problem for humanity with important ramifications for policy and decision making. Robust and cost-efficient policies on mitigation and adaptation require assessments of current and future risks for natural and human systems. Those assessments rely on numerical simulations performed with state-of-the-art global climate models. These simulations are coordinated at an international level within the Coupled Model Intercomparison Project (CMIP) which provides the bedrock for a large fraction of the publications synthesized in the Intergovernmental Panel on Climate Change (IPCC) reports. These exercises are fundamentally documenting the large uncertainty in the projections that come from the choices made by the ~30 teams that develop CMIP-class models. The latest version, CMIP6, is now in the production phase. The first analysis suggests that several models are more alarming in terms of global mean temperature increase than previous versions, as quantified by the Equilibrium Climate Sensitivity (ECS). Another outcome of CMIP exercises is that the improvements in the performances of climate models are slow, especially when facing the emergency of the climate change. The derivation of the IPSL coupled model for CMIP6 (IPSL-CM6) was an unprecedented coordinated effort during which key processes and parameters for climate sensitivity were identified both in the atmosphere and in the ocean. The present project proposes an ambitious plan to **quantify the uncertainties associated with this choice of free parameters in a systematic way using the latest version of the IPSL climate model with two major targets: i) speed up and improve the calibration of the future higher resolution version of IPSL-CM and ii) estimate the associated errors in present-day climate representation (i.e. mean state and variability) and uncertainty in the ECS**. The improvements in the future version will target in particular oceanic processes in high latitudes and the potential benefit associated with a significant increase of the grid resolution, the reduction of the classical large patterns of sea surface temperature biases, and an improvement of the rainfall variability in the tropics. For both tuning and uncertainty quantification purposes, **the parameter space will be sampled by applying, for the first time in climate change simulations, state- of-the art machine learning approaches developed by the Uncertainty Quantification community**. The idea is to replace a long (3 actual years for CMIP6) calibration process for which 15 model configurations were re-adjusted based on typically 20 to 40 sensitivity experiments done by varying one parameter at once, by an automatic random Latin Hypercube sampling of the full parameter domain. First promising tests done since the first submission of the proposal suggest that the approach requires 3 waves of typically 200 few-years-long simulations of the stand alone atmospheric component for 20 parameters. **This project will take on the additional challenge of extending this to the calibration of slower ocean and coupled atmosphere-ocean processes.**

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	cores	CPU h/10 yr	**requested CPU hours**	equivalent in simulated years
IPSL-CM6-LR	960	18000	**16,155,000**	8,975
IPSL-CM6-MR1	1800	32000	**8,040,000**	2,513
IPSL-CM6-MR025	4600	100300	**12,036,000**	1,200
LMDZ6-LR-tuning	284	5000	**5,000,000**	10,000
LMDZ6-MR-tuning	512	25000	**3,125,000**	1,250
total			**44,356,000**	
allocated by PRACE			**45,000,000**	

October - December	January - March	April - June	July - September
4k cores : sensitivity exp. LR	**4k cores : sensitivity exp. LR**	**1k cores : sensitivity exp. LR**	
4k cores : UQ atm LR and MR sub-sample	**3k cores : LR & MR1 retuning (coupled)**	**1k cores : LR ad hoc retuning**	
3k cores : MR025 ad hoc	**3k cores : MR1 ad hoc and from UQ**	**3k cores : MR025 from UQ**	**5k cores : MR025 & MR1 +4xCO2**

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WP1 Physical tuning of ocean parameters **IPSL-CM6-LR**

1.1 blue ocean parameters		
inter-comparing with UK GC3.1	MM	2,700,000
1.2 Sea ice parameters		
Nudging of SIC	GG & AS	270,000
Modified albedo / conductivity	GG & AS	540,000
Modified LW	GG & AS	540,000
sea ice dynamics	MV	2,385,000
primary production & seasonality	MV	2,385,000
1.3 Impact of GrIS melting on oceanic circulation		
Reconstruction of the past climate inc. GrIS melting	DS & MD	1,035,000
Impact of GrIS on predictablilty	DS & MD	1,800,000
1.4 Impact of persistent atmopsheric conditions on decadal variablity		
Constrained experiments NAO + predictiability	YRR	1,440,000
TOTAL		**13,095,000**

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WP2 Automatic tuning of atmospheric parameters

IPSL-CM6-LR

IPSL-CM6-MR1

LMDZ6-LR-tuning

LMDZ6-MR-tuning

UQ sample, LR (3*amip +1*+4K)	FH + LF	2,000,000
UQ sub-sample, MR, atm	FH	625,000
UQ sub-sample, MR1, coupled	FH	1,280,000
pdControl - slight retuning of LR	JD et FH	2,700,000
Tuning - VAGUE 1		1,500,000
Tuning - VAGUE 2		1,500,000
Tuning		2,500,000
TOTAL		**12,105,000**

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IPSL-CM6-LR

WP3 Combining WP1 and WP2 to tune MR1 and MR025

IPSL-CM6-MR1

IPSL-CM6-MR025

pdControl - tuning from UQ LR et MR1	4,800,000
pdControl - tuning au fil de l'eau, ad hoc	1,600,000
pdControl - tuning from UQ LR et MR1	5,015,000
pdControl - tuning au fil de l'eau, ad hoc	5,015,000
+4CO2	360,000
+4CO2	360,000
+4CO2	2,006,000
TOTAL	**19,156,000**

Quantifying Uncertainties and Enhancing the Speed of climate model Tuning

collaborator	WP1	WP2	WP3
Dr Julie Deshayes	X	X	X
Ms Marie-Alice Foujols	X	X	X
Dr Laurent Fairhead	X	X	X
Dr Marion Devilliers	X		
Dr Martin Vancoppenolle	X		
Mr Nicolas Lebas	X	X	X
Dr Claire Levy			X
Mr Renaud Person			X
Dr Guillaume Gastineau	X		
Mrs Josefine Ghattas	X		
Dr Matthew Menary	X		
Dr Didier Swingedouw	X		
Dr Juliette Mignot	X	X	X
Dr Frederic Hourdin	X	X	X
Mrs Simona Flavoni	X		
Mr Arnaud Caubel	X	X	X
Dr Olivier Marti			X
Dr Frederique Cheruy	X		
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collaborator	WP1	WP2	WP3
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Dr Yohan Ruprich-Robert	X		

(bold = initials mentioned in WP)

+ anyone else interested !