EURO-CORDEX driving CMIP5 models' simulation of the large-scale European climate - a literature review

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Abstract

Information about the future climate is necessary for climate change adaptation. Future climate projections are created using climate model simulations. Since different models produce different but plausible simulations of climate, to account for model uncertainty, climate projections should be based on a probabilistic interpretation of an ensemble consisting of multiple model simulations.

For regional climate projections in Europe, EURO-CORDEX provides high resolution regional climate model simulations. Over 50 simulations are available from 10 regional climate models. The EURO-CORDEX regional models are driven by six of CMIP5 global models: CNRM-CM5, EC-EARTH, HadGEM2-ES, IPSL-CM5A-MR, MPI-ESM-LR and NorESM1-M.

Many research articles have compared the ability of individual CMIP5 models to simulate different aspects of the large-scale European climate, such as geopotential, upper layer wind and sea level pressure fields, storm tracks, blocking, NAO, ocean circulation, and also surface temperature and precipitation fields. The results of this research pertaining to the six EURO-CORDEX driving CMIP5 models are relevant to the choice of EURO-CORDEX simulations (or simulation weights) to be used for probabilistic ensemble projections. With the aim to ease the access to this information, this review provides a summary of findings from 30 research articles. The summary also includes basic information about the six CMIP5 models, such as their effective climate sensitivity and model complexity.

The review shows that two of the six considered CMIP5 models (IPSL-CM5A-MR and NorESM1-M) show relatively poor performance of most evaluated large-scale climate features compared to the rest of the models. The same claim cannot be made based only on research articles evaluating the models by comparing observed and simulated surface temperature and precipitation fields. As model evaluation involving only surface variables is common practice for regional climate projection purposes, this review may provide valuable additional insight regarding the EURO-CORDEX driving CMIP5 models' ability to simulate large-scale climate features.

Description of inter-comparison

The table on the right compares six EURO-CORDEX driving CMIP5 models based on available literature. Section **A** describes basic model properties. Section **B** compares the model's ability to simulate the energy budget. Sections **C** and **D** compare the models' representation of the general atmospheric and oceanic circulation, and the observed circulation types respectively. Finally section **E** compares the models' ability to simulate surface temperature and precipitation. Unless specified otherwise, model performance was evaluated over Europe and the adjacent North Atlantic Ocean.

Each row of the table represents an evaluated climate aspect. The corresponding literature source is denoted by a number in square brackets [ ]. Within each row green/red indicate relatively better/worse performance among models, grey indicates average performance among models, while white specifies that the particular model did not participate in the research study. Also within each row, if one or more models are considered among the best/worst of all models evaluated in the study, this is denoted by (^) and (!) respectively. It should be noted that the research studies evaluated different subsets of the CMIP5 ensemble, with the number of evaluated models ranging from 7 to 47. Values and comments relevant to the comparison were also included in the table, if available.

Discussion

Results of comparison for sections C and D suggest that models IPSL-CM5A-MR and NorESM1-M represent the observed circulation and circulation types relatively poorly compared to the other models. Although this does not establish a causal relationship, these two models have the lowest resolution among the six models. In contrast, NorESM1-M shows better representation of the energy budget compared to the other models (section B).

Results of comparison for surface temperature and precipitation evaluation (section E) are inconclusive.

Inter-comparison of the six CMIP5 models

	CNRM-CM5	EC-EARTH	HadGEM2-ES	IPSL-CM5A-MR	MPI-ESM-LR	NorESM1-M
A						
[1][2][29] effective climate sensitivity (ECS)	3.25 °C	3.34 °C	4.61 °C	4.12 °C	3.63 °C	2.80 °C
[6] temp. increase over continental Europe 1979-2008 to 2070-2099 (RCP8.5) winter	4.5 °C (140% ECS)	3.5 °C (105% ECS)	5.5 °C (120% ECS)	5 °C (120% ECS)	4 °C (110% ECS)	3.75 °C (135% ECS)
[6] temp. increase over continental Europe 1979-2008 to 2070-2099 (RCP8.5) summer	4.5 °C (140% ECS)	4 °C (120% ECS)	7.5 °C (160% ECS)	6.25 °C (150% ECS)	4.5 °C (125% ECS)	4.25 °C (150% ECS)
[4] model complexity (full representation - interactive w/ feedback; partial representation - externally prescribed/ semi-interactive/interactive w/o feedback)	full - atmosphere, land surface, ocean, sea ice partial - vegetation properties, aerosols, atmospheric chemistry	full - atmosphere, land surface, ocean, sea ice partial - aerosols	full - atmosphere, land surface, ocean, sea ice, vegetation properties, terrestrial carbon cycle, aerosols, atmospheric chemistry, ocean biogeochemistry	full - atmosphere, land surface, ocean, sea ice, vegetation properties, terrestrial carbon cycle partial - aerosols, atmospheric chemistry, ocean biogeochemistry	full - atmosphere, land surface, ocean, sea ice, vegetation properties, terrestrial carbon cycle, ocean biogeochemistry	full - atmosphere, land surface, ocean, sea ice, terrestrial carbon cycle, aerosols partial - vegetation properties
[4] atmospheric model (num. of lon. x lat. grid boxes, num. of vertical levels)	ARPEGE-Climat v5.2.1 256 × 128, 31 lv	IFS (modif. cy31R1) 320 × 160, 62 lv	HadGAM2, 192 × 145, 38 lv	LMDZ4 v5, 144 × 143, 39 lv	ECHAM6, 192 × 96, 47 lv	CAM4-Oslo, 144 × 96, 26 lv
[7][12] model lid height if above stratosphere (1hPa) = high top	low top [10 hPa]	low top [5hPa]	low top [40 km]	high top [0.04 hPa]	high top [0.01 hPa]	low top [3.54 hPa]
[4] ocean model (num. of lon. x lat. grid boxes, num. of vertical levels)	NEMO3.2-ORCA1, 42 lv	Modif. NEMO2-ORCA1, 42 lv	HadGOM2, 360 × 216, 40 lv	NEMO3.2-ORCA2, 31 lv	MPIOM, 256 × 220, 40 lv	MICOM-noresm-ver1-gx1v6, 384 × 320, 53 lv
B						
[27] surface downward shortwave radiation, global land, bias BSRN, bias GEBA, [W/m2]	[+7], [+8]		[+16], [+15]	[+17], [+23]	[+6, +2]	[+1], [+3]
[27] surface downward longwave radiation, global land, bias BSRN, [W/m2]	[-8]		[-5]	[-13]	[0]	[-5]
[30] surface latent heat flux over different vegetation types		(^)		(^)		(^)
[26] precip.- soil moisture- temp. feedback, summer (expressed as hottest day correlation between temp. and precip.)	outside of observational constraints		outside of observ. constraints (corelation too strong)	outside of observ. constraints (corelation too strong)		within observational constraints
C						
[16] winter blocking	not represented correctly	location realistic, frequency underestimated		not represented correctly		not represented correctly
[16] summer blocking		(^) frequency realistic				
[21] stratospheric heat flux extremes					(^) low bias	
[9] NAO	represented	represented		misrepresented	represented	misrepresented
[11] AMO	well represented			well represented	misrepresented spatial variability	
[15] global teleconnections						(!)
[22] Artctic sea ice coverage						
[13] deep convection, North Atlantic	(^)		(^)			
[19] sea level, North Atlantic	(^)				(^)	(^)
[28] SLP mean abs. error, Europe + N. Atlantic		(^)	(^)		(^)	
[3] SLP winter				overly strong meridional SLP gradient	overly strong meridional SLP gradient	overly strong meridional SLP gradient
[3] SLP summer	overestimated SLP over extratropical N. Atlantic		overestimated SLP over extratropical N. Atlantic	overestimated SLP over extratropical N. Atlantic		overestimated SLP over extratropical N. Atlantic
[3] SLP higher order errors			(^) no errors		in summer errors over the Mediterranean	in summer errors over the Mediterranean
[28] geopotential 500hPa, mean abs. error, Europe + N. Atlantic			(^)		(^)	
[3] specific humidity 850hPa, winter				too moist over Europe	too moist over Europe	too moist over Europe
[3] zonal wind 850hPa, winter	too strong westerlies			(!) too strong westerlies (high bias)	too strong westerlies	too strong westerlies
[17] winter circulation 850hPa						flow too westerly
[17] summer circulation 850hPa						
[17] storm tracks						
[8] storm tracks west. N. Atlantic + east coast N. America		(^)				
[20] explosive cyclone frequency, N. Atlantic, rel. bias	[-40%]		[-30%]	[-30%]	[-20%]	[-50%]
[20] explosive cyclone intensity, N. Atlantic	underestimation <10%		underestimation <10%	underestimation <10%	underestimation <10%	underestimation 10-20%
[3] circulation along lateral boundaries of EURO-CORDEX area						
[14] upper air parameters (ta, hus, ua, va at 850, 700, 500, 300 hPa) at lateral EURO-CORDEX area boundaries						
D						
[23] circulation type frequency, persistence, N. Atlantic + Europe, rel. error	[20%], [7.5%]	[30%], [10%]	[20%], [10%]	[35%], [10%]	[25%], [10%]	[50%], [15%]
[23] circulation type frequency, persistence, Central Europe, rel. error	[20%], [7.5%]	[30%], [7.5%]	[15%], [7.5%]	[50%], [10%]	[25%], [7.5%]	[50%], [10%]
[4] Lamb Weather Typing frequency		(^) low bias	(^) low bias	(!) high bias		(!) high bias (esp. winter)
[10] Lamb Weather Typing frequency		(^) low bias	(^) low bias			(!) high bias
[10] Lamb Weather Typing transition probabilities		(^) low bias	(^) low bias			
[5] circulation type (CCA, MRT) frequency		(^)	(^)			(!)
[5] circulation type (CCA, MRT) persistence		(^)				(!)
[18] K-means circulation type frequency & interannual variability eastern N. Atlantic + western Europe		(^)	(^)			
[6] K-means circulation type freq., winter						
[6] K-means circulation type freq., summer	(!)					(^)
E						
[14] surface parameters (tas, pr, SLP) within EURO-CORDEX area						
[6] temp. over continen. Europe, summer bias	[+0.5 °C]	[-1 °C]	[1.5 °C]	[+1 °C]	[under -0.5 °C]	[under +0.5 °C]
[6] temp. over continen. Europe, winter bias	[-2 °C]	[+0.5 °C]	[-1 °C]	[-0.5 °C]	[+1 °C]	[2 °C]
[24] distribution of monthly tasmax maxima, summer				(^)		
[24] distribution of monthly tasmin minima, winter				(^)		
[25] temperature RMSE, central Europe					(^)	
[25] precipitation RMSE, central Europe	(!)		(^)			
[17] annual cycle of temp. and precip.	satisfactory	satisfactory	satisfactory	precip. poorly represented in most regions	satisfactory	satisfactory

Literature used for the review

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