Climate Change in the Storm Tracks:

Are projected changes about to change?

Adam Scaife

T. Spangehl, D. Fereday, U. Cubasch, U. Langematz, H. Akiyoshi, S. Bekki, P. Braesicke, N. Butchart, M. Chipperfield, A. Gettelman, S. Hardiman, M. Michou, E. Rozanov and T.G. Shepherd

Changes in European winter climate?

Poleward shift of extra-tropical storm tracks
IPCC, SPM, p8

storm tracks are projected to move poleward with consequent changes in wind, precipitation and temperature patterns
AR4 synthesis report, p48

Sea level pressure is expected to increase over the subtropics and mid-latitudes…..

…decreased numbers of mid-latitude storms…
AR4, WG1 report, p751, p789

Is this sensitive to model resolution?

Shindell et al 1999
Positive AO response in strat-trop model only

Gillett et al 2002
No sensitivity to stratospheric resolution

Sigmond et al 2008
Positive AO response, sensitive to GW parametrization

Huebener et al 2007
Stronger Atlantic storm track into Europe

Models and Experiments

Control SST, Sea-Ice and CO_2
or
$4xCO_2$ SST, Sea-Ice and CO_2

CTL L38
$4xCO_2$ L38

CTL L60
$4xCO_2$ L60

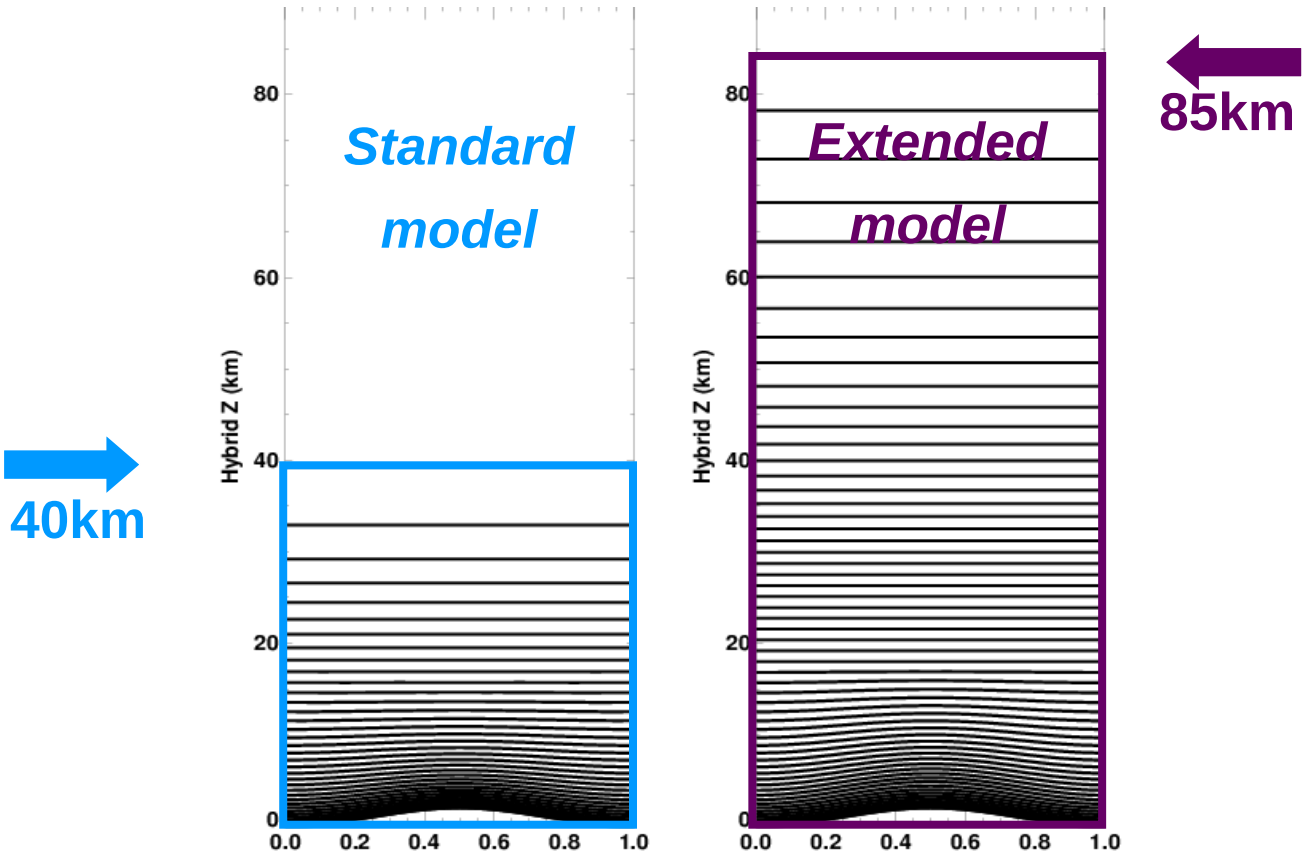
Standard Model

Resolution: L38 N96
Lid: ~40km

Extended Model

Resolution: L60 N96
Lid: ~85km

Extended and Standard Models



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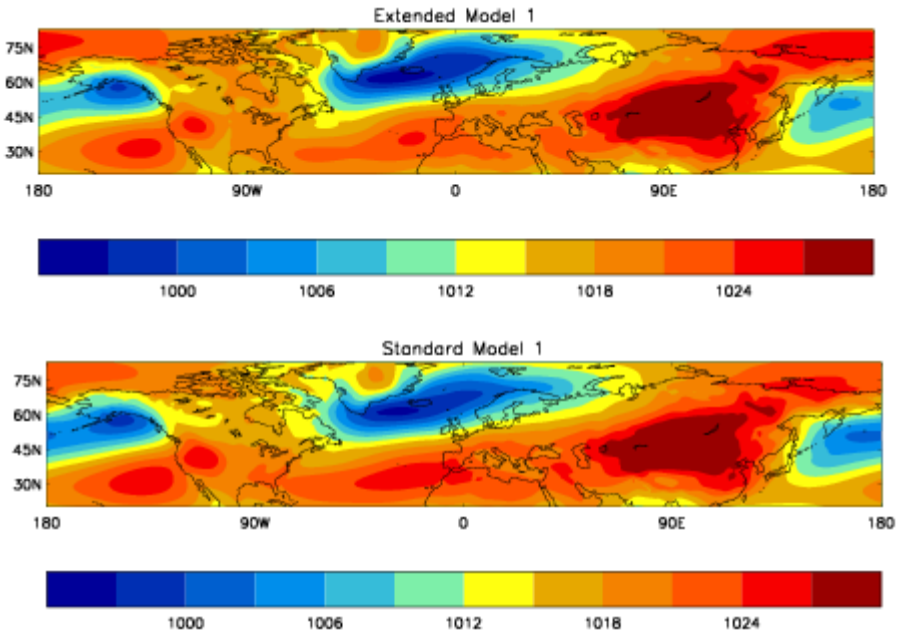
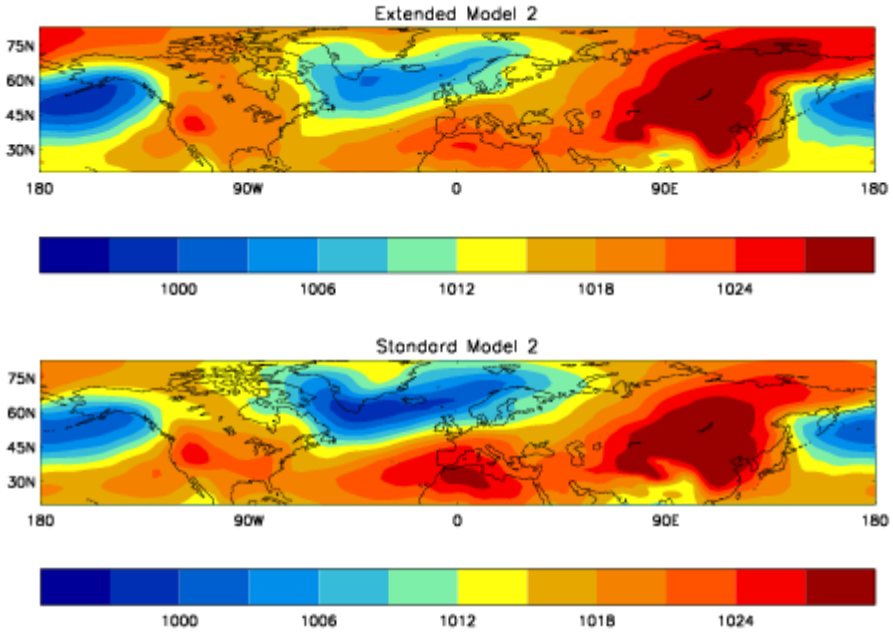
Tropospheric climatology in Extended and Standard Models (Met Office and F.U.B.)

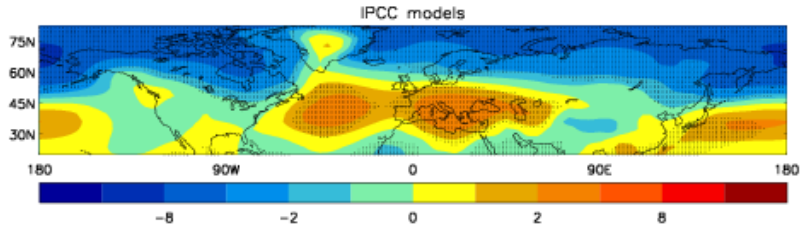




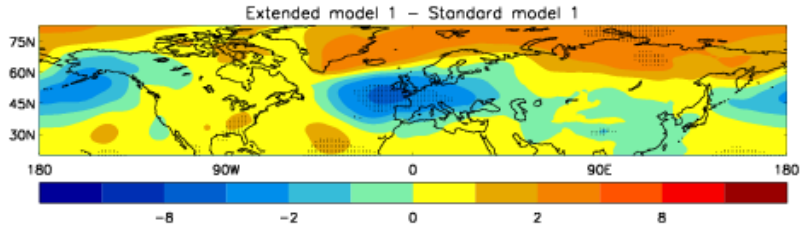
Tropospheric simulation similar in extended and standard models

Intermodel differences can be seen

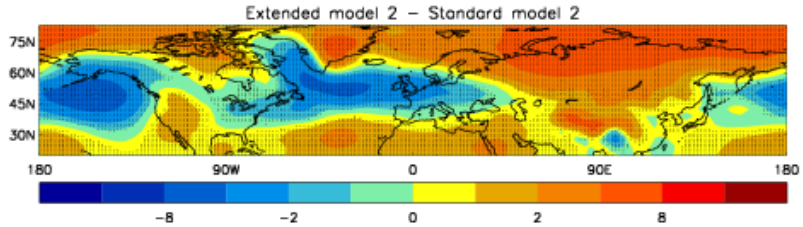
Sea Level Pressure Changes



IPCC AR4 Models



Extended – Standard (Met Office)

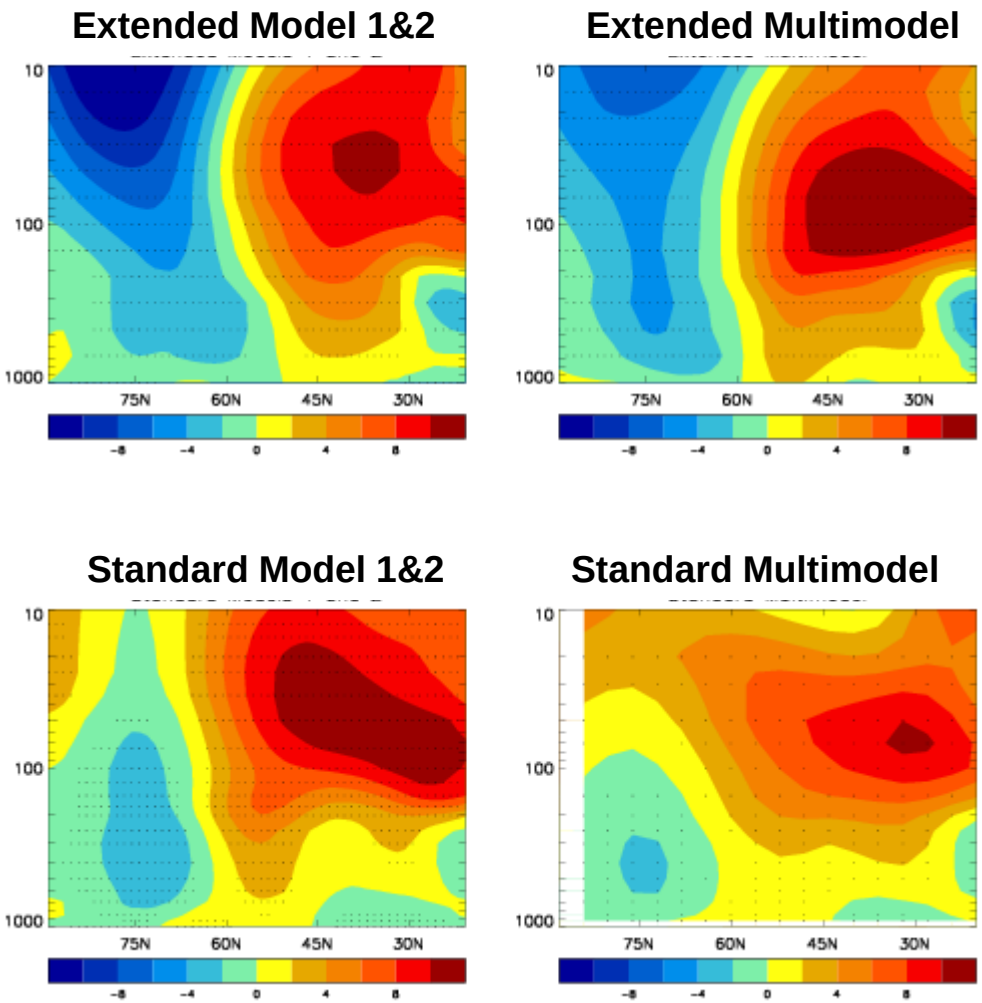


Extended – Standard (F.U.B.)

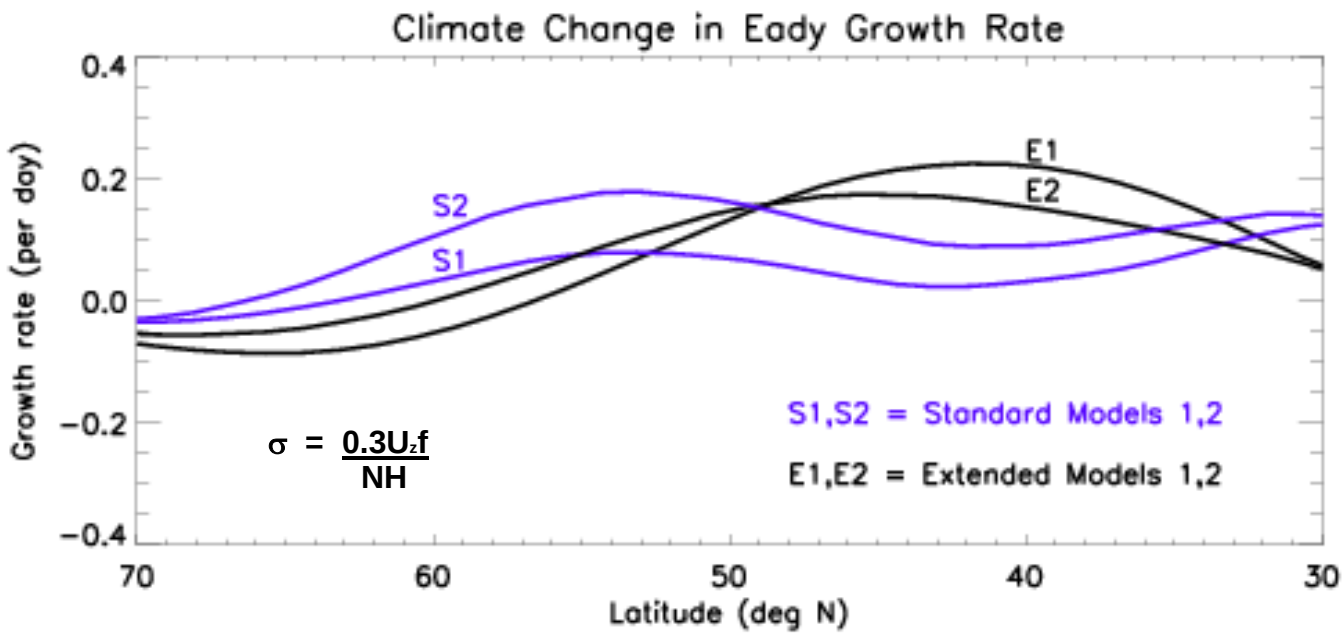
Climate Change

Increase in meridional winds and the Brewer-Dobson circulation => Dipole in zonal wind

Extends into troposphere



Eady (linear) Baroclinic Eddy Growth Rate

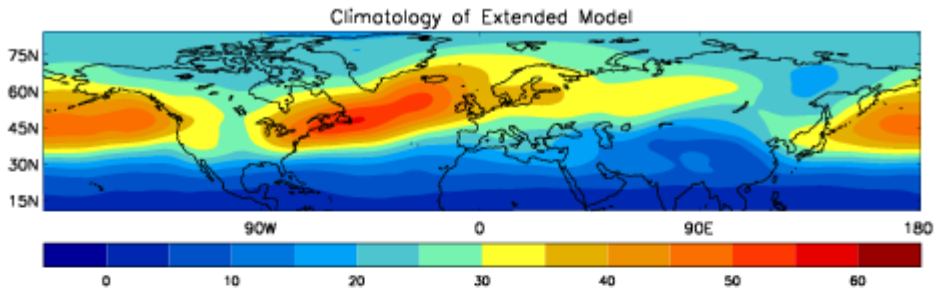


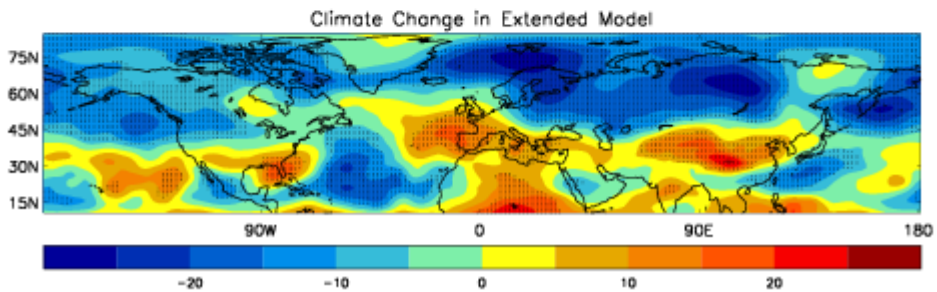
Increased growth rate at high latitudes in standard models from increased vertical shear

Occurs at mid latitudes rather than high latitudes in extended models

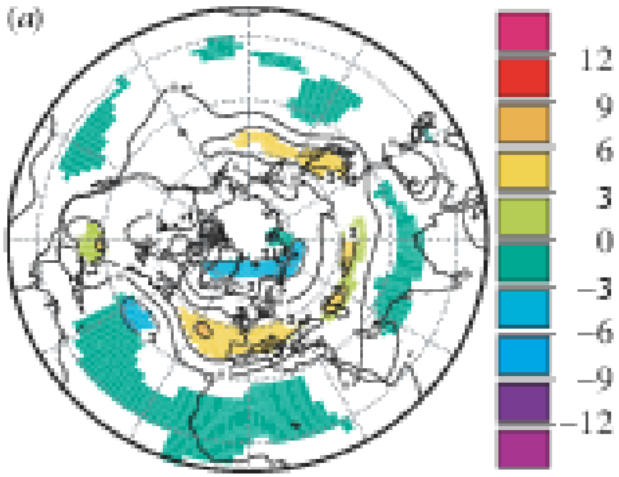
Storm Track Changes

Fractional change in 500hPa eddy activity





c.f. Huebener et al. 2007



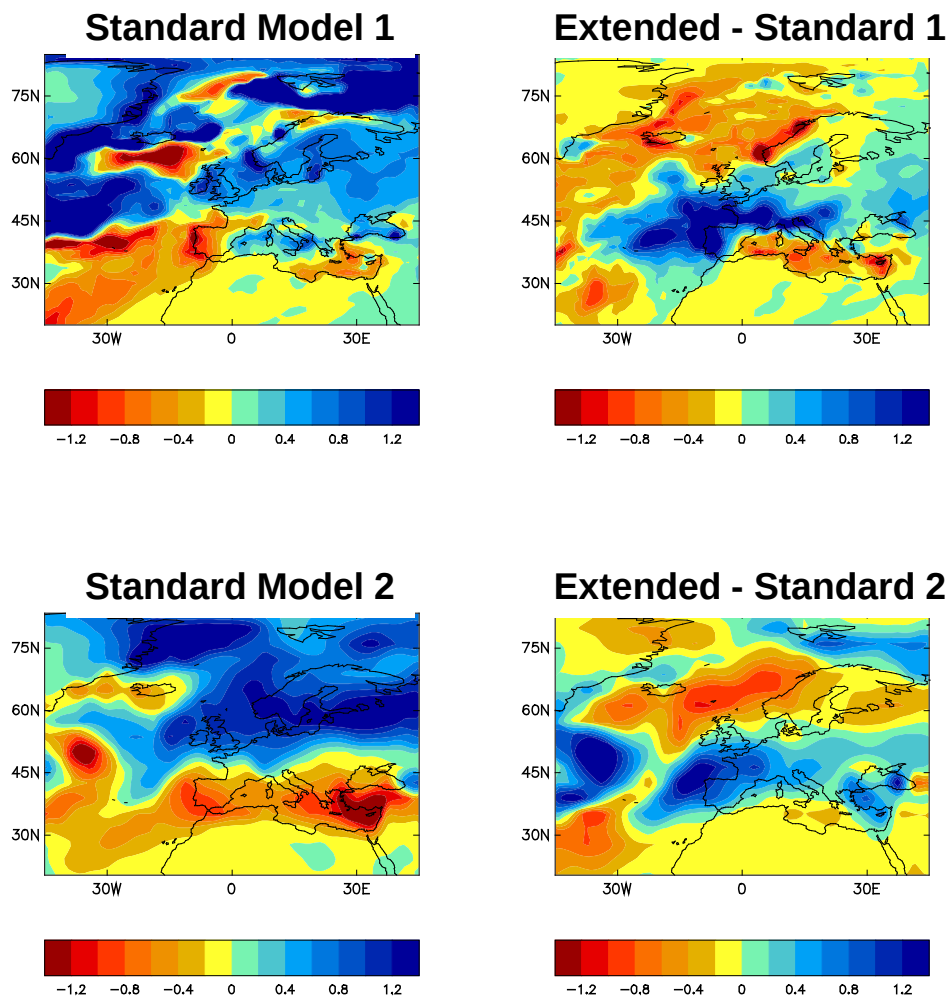
Rainfall Impacts

Standard (IPCC) models are wetter in winter in N Europe

Vertical resolution makes a *robust* difference

Error is similar size to original signal!

European climate prediction requires extended models



Extreme Rainfall

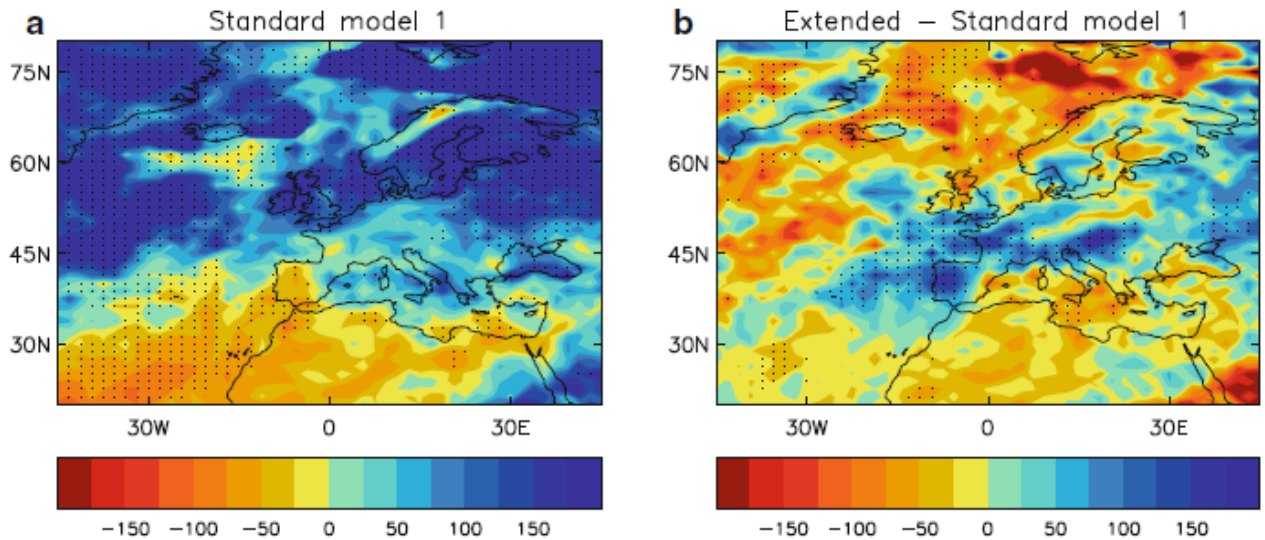


Fig. 7 Percentage change in the frequency of extreme rainfall in extended model 1 (daily data for model 2 were not available for this calculation. The very marked similarity between mean rainfall changes and rainfall extremes is easily seen by comparison with Fig. 6 for model 1). Extremes here are defined as 98th percentile daily totals at each model grid point. Climate change in standard model 1 (**a**) and the difference between extended and standard model 1 (**b**). Hatching shows where the change in mean rainfall is statistically significant at the 95% level according to a *t* test and has the same sign as the change in extreme rainfall frequency

Large increase in frequency of extreme rainfall in western and central Europe

Extra increase as big as, and in some regions outweighs, the original signal e.g. Spain

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Summary of Mechanism

Increased GHG forcing

=> Increased wave drag on the zonal circulation

=> Increased meridional circulation

=> Equatorward shifted upper level jet

=> Increased vertical wind shear through troposphere

=> Greater eddy growth, storminess and rainfall

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CMIP5 extended models……

Institute	Model	Atm Res'n	Scenario	Contact
Hadley / NCAS	HadGEM2	192x145xL60 top=85km	RCP4.5 to 2100	neal.butchart@metoffice.gov.uk
MPI	ECHAM6/MPIOM	~360x180xL95 top=0.01hPa	RCP4.5,2.6,8.5	marco.giorgetta@zmaw.de
GFDL	CM2	~200kmxL48 top=0.017hPa	?	john.austin@noaa.gov
NCAR	CCSM: WACCM + POP2	95x144xL66 top=$6x10^{-6}$hPa~135km	RCP4.5 to 2050	rgarcia@ucar.edu marsh@ucar.edu
CMCC	ECHAM5+OPA	T63xL95 top=0.01hPa	RCP4.5 to 2030	elisa.manzini@cmcc.it chiara.cagnazzo@cmcc.it
GISS	GISS-E	90x144xL40 top=0.1hPa	All 4 RCPs	dshindell@giss.nasa.gov
DMI	EC_Earth	T159xL91 top=0.01hPa	RCP4.5 to 2100	shuting@dmi.dk boc@dmi.dk
IPSL	IPSL-CM5	96x95xL35 top=65km	RCP4.5	Francois.lott@lmd.jussieu.fr
MRI	MRI-CGCM3 MRI-ESM1	TL159L60 (320x160) top=0.01hPa	RCP4.5, 8.5 to 2100 RCP8.5 to 2100	kshibata@mri-jma.go.jp

SUMMARY

An additional climate change mechanism operates in high vertical resolution climate models compared to traditional “low-lid” models

This changes winter winds and storm tracks and radically alters the regional climate change signal and extreme events

The mechanism is broadly understood and similar results in 2 climate models are backed up with a number (~10) of high-top models

CMIP5 (and therefore AR5) will include models which have the required resolution to capture these effects for the first time in IPCC reporting

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Climate Change Projections and Stratosphere-Troposphere Interaction

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Climate Dynamics, 2011.