

# Uncertainty in the response of sudden stratospheric warmings and stratosphere-troposphere coupling to quadrupled CO<sub>2</sub> concentrations in CMIP6 models

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# Introduction & data

## Summary

- Major sudden stratospheric warmings (SSWs), vortex formation and final breakdown dates are key highlight points of the stratospheric polar vortex.
- There is not a consensus on which projected changes to the polar vortex are robust.
- Possible limitations of previous model intercomparison studies: short data record or moderate CO<sub>2</sub> forcing.
- New CMIP6 simulations with the long daily data requirements of the DynVarMIP project allow us to revisit this topic by overcoming previous limitations.

**Goal of the analysis:** To analyze this new model output to document the change in vortex interannual variability under 4xCO<sub>2</sub> forcing.

Model top below 10hPa

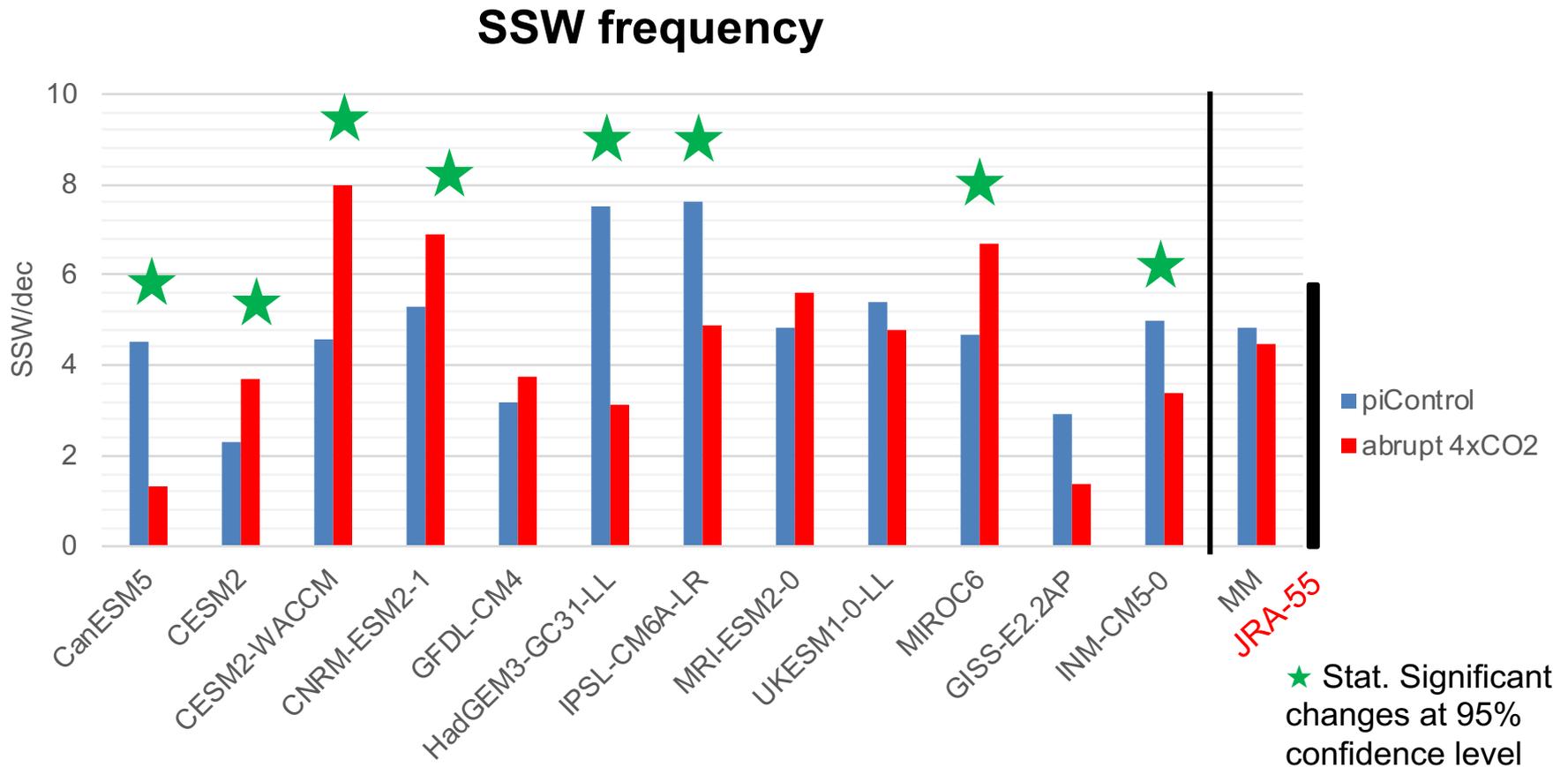
Model top below 0.1hPa

High-top model

DynVarMIP models	
CanESM5	CESM2
CESM2-WACCM	CNRM-ESM2-1
GFDL-CM4	GISS-E2.2AP
HadGEM3-GC31-LL	INM-CM5-0
IPSL-CM6A-LR	MIROC6
MRI-ESM2-0	UKESM1-0-LL

DECK Simulations	Nr. of years
PiControl	At least 150 yrs except GISS-E2.2AP
Historical	1850-2014
1pctCO2	150 yrs
Abrupt 4xCO2	At least 150yrs except GISS-E2.2AP

# SSW frequency: total changes



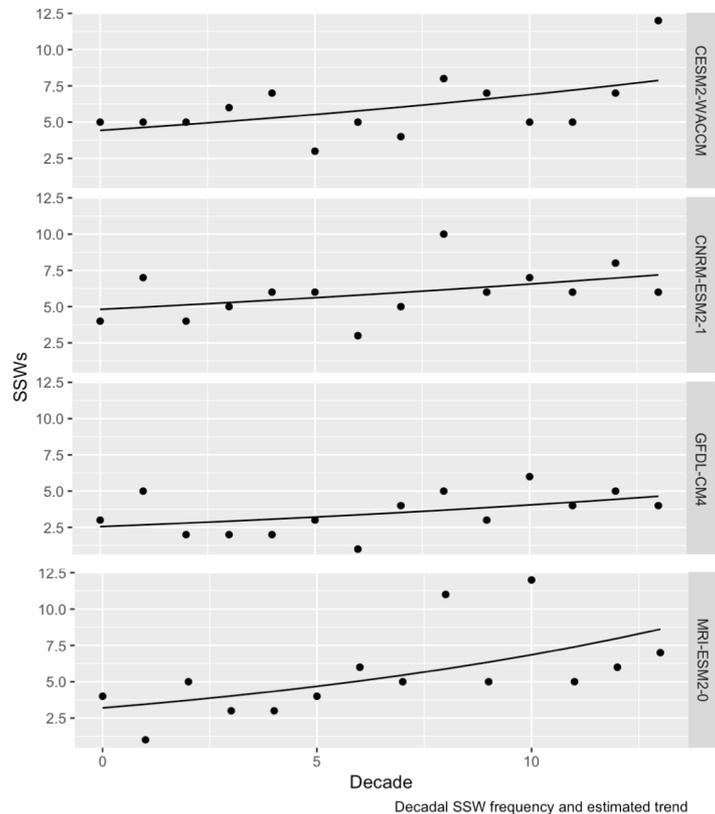
More than half of the models show stat. significant changes but there is **no consensus** on the sign of the changes in SSW frequency :

4 show an increase vs 4 show a decrease.

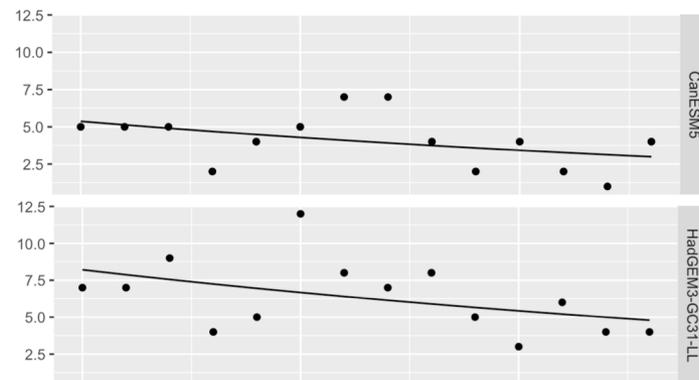
# SSW frequency: time of emergence

## 1pctCO<sub>2</sub> simulation

### Models with positive signif. trend



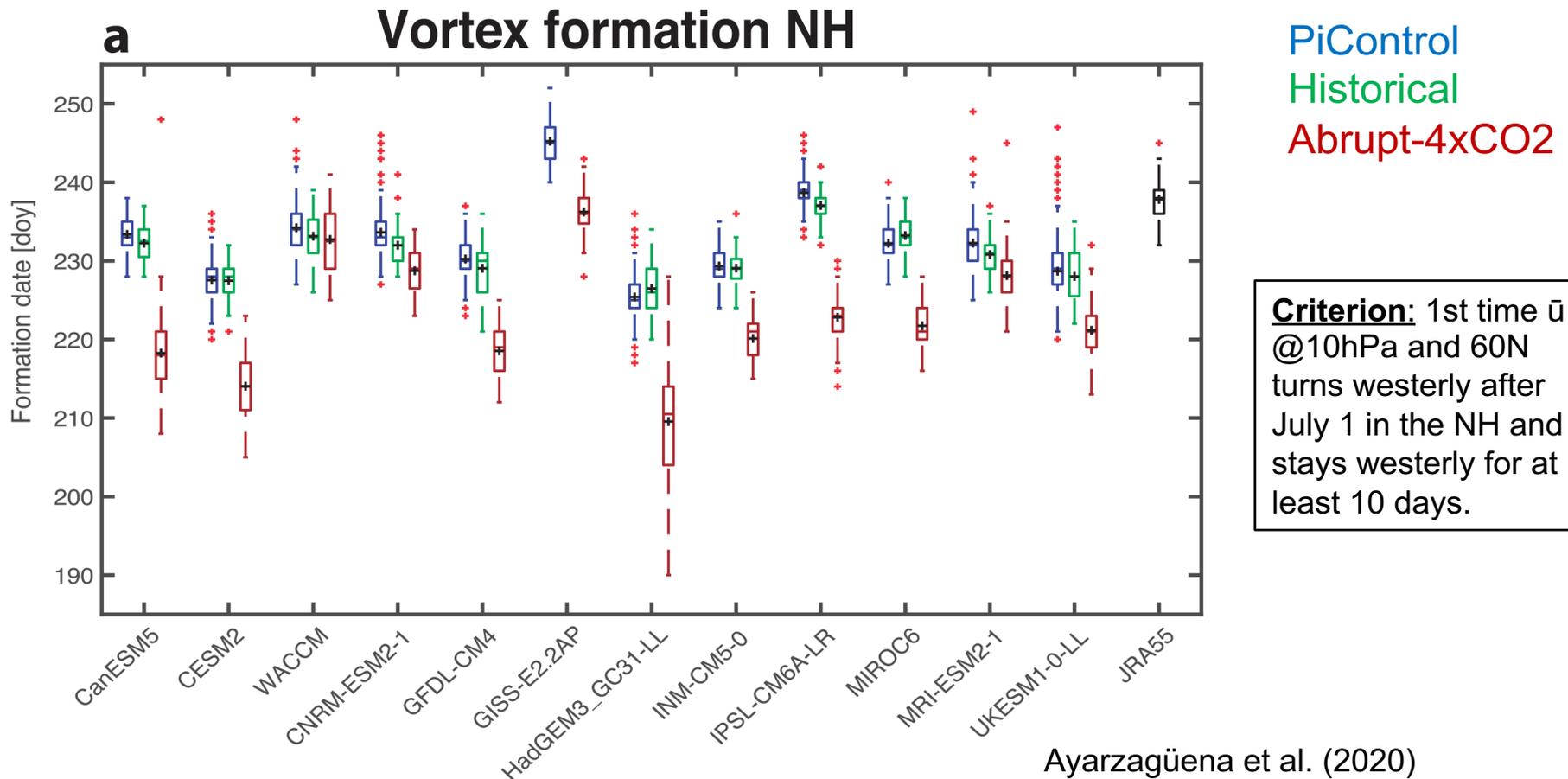
### Models with negative signif. trend



Model	Decade of emergence
MRI-ESM2-0	4.93
CESM2-WACCM	8.67
GFDL-CM4	9.66
HadGEM3-GC31-LL	11.00
CNRM-ESM2-1	11.70
CanESM5	14.10

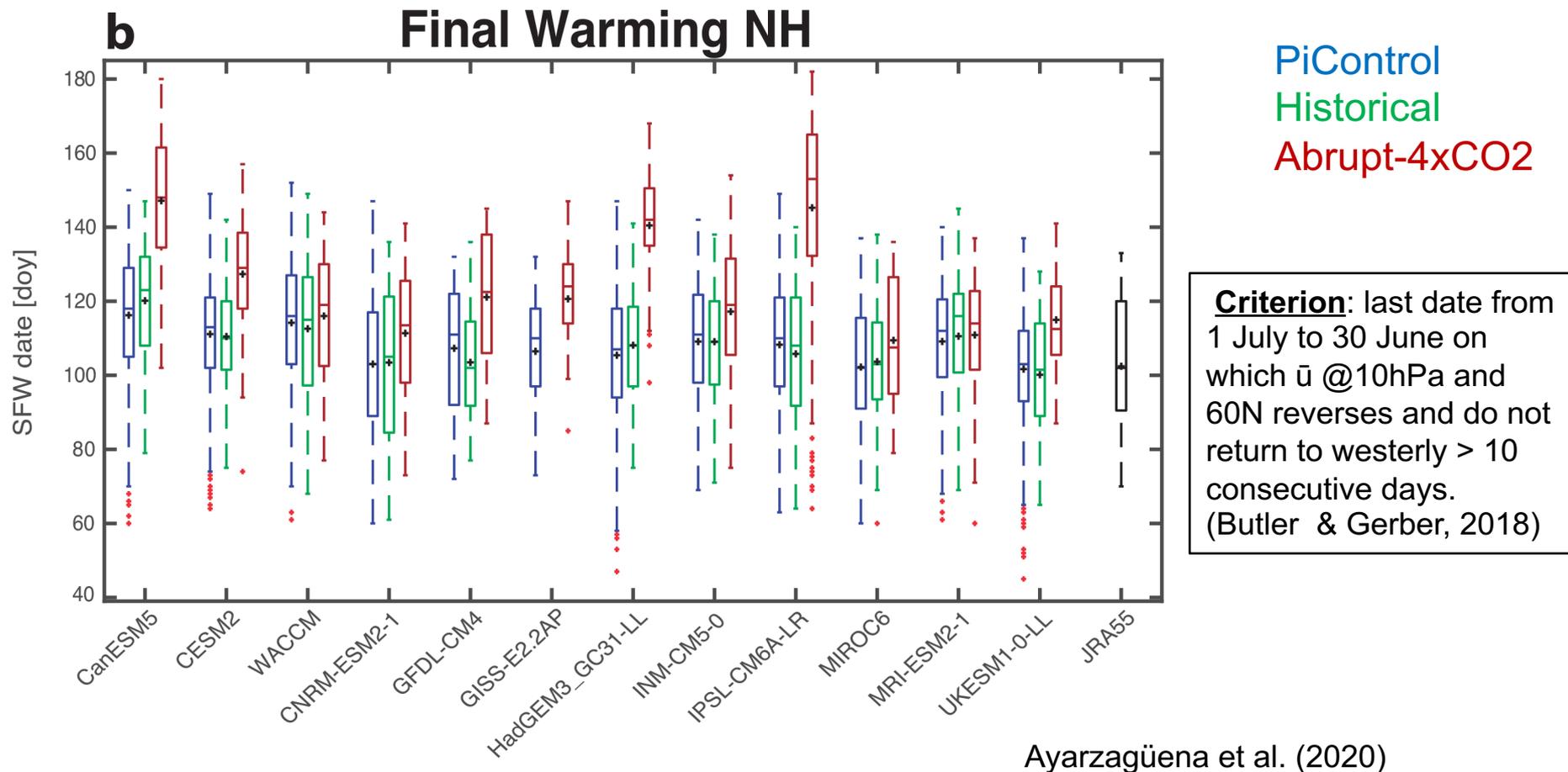
Wide variation in the prediction of time of emergence, but in most cases after CO<sub>2</sub> doubling (6-7 decade).

# Autumn vortex formation



- Earlier formation of polar vortex in Autumn in models than reanalysis.
- Vortex forms in similar dates in pre-industrial and historical conditions.
- Polar vortex tend to form earlier under 4xCO2 conditions.

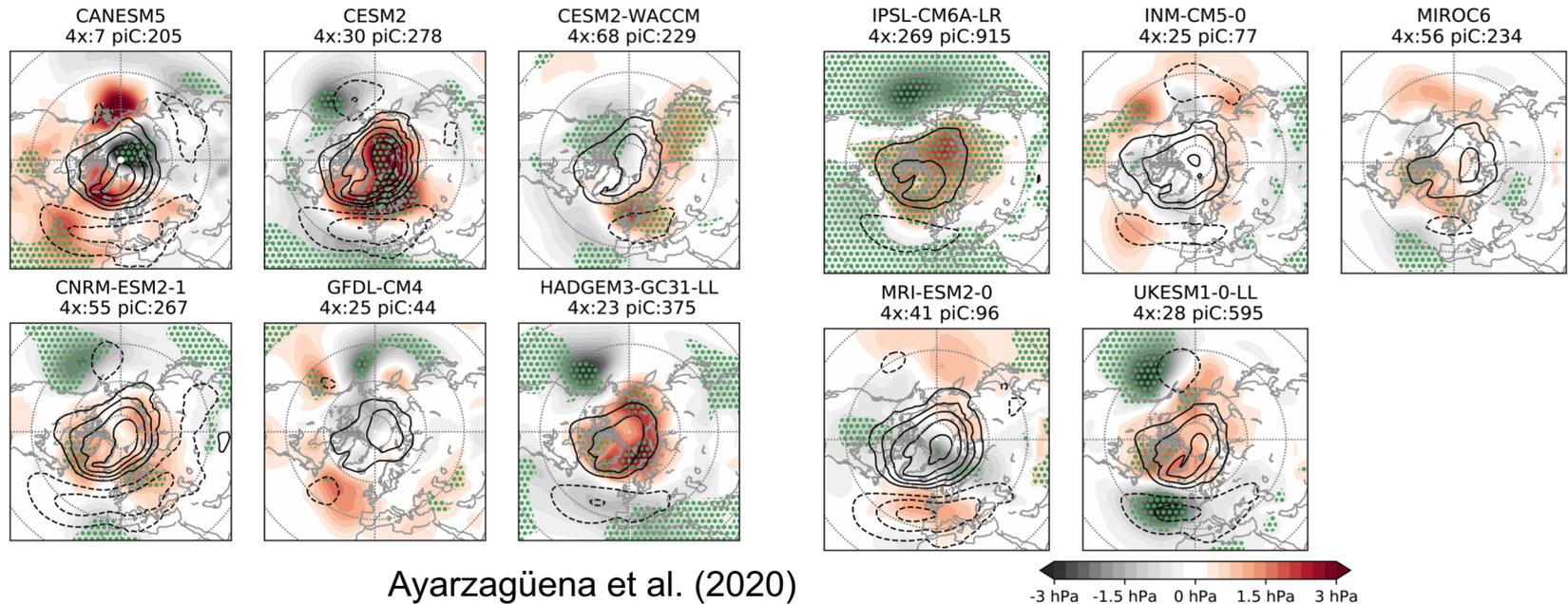
# Stratospheric final warming: final breakdown of vortex



- Models reproduce well SFW date in average.
- Almost no differences in SFW dates between pre-industrial and historical runs.
- Polar vortex tend to persist longer under 4xCO2 conditions in some models.

# Stratosphere-troposphere coupling during SSWs

## SLP +15/+60 days following SSWs



- In general, no change to the impact of SSW events in the North Atlantic between the abrupt4xCO<sub>2</sub> and piControl simulations.
- In the North Pacific, there is some indication that under large CO<sub>2</sub> forcing, there will be a larger mean response to SSWs.

Contours: piControl  
Shading: abrupt4xCO<sub>2</sub>-minus-piControl differences  
Stippling: stat. signif. differences abrupt4xCO<sub>2</sub>-minus-piControl at 95% conf. level

# Take home message

- High uncertainty in changes of SSW frequency under  $4xCO_2$  forcing, although some single models show the rate to be significantly halved or doubled.
- Longer season of stratosphere-troposphere coupling: the boreal polar vortex will form earlier and disappear later under increased  $CO_2$ .
- The tropospheric signal of SSWs in the North Atlantic does not change under  $4xCO_2$  forcing.