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Future changes in Major Stratospheric Warmings in CCMI models

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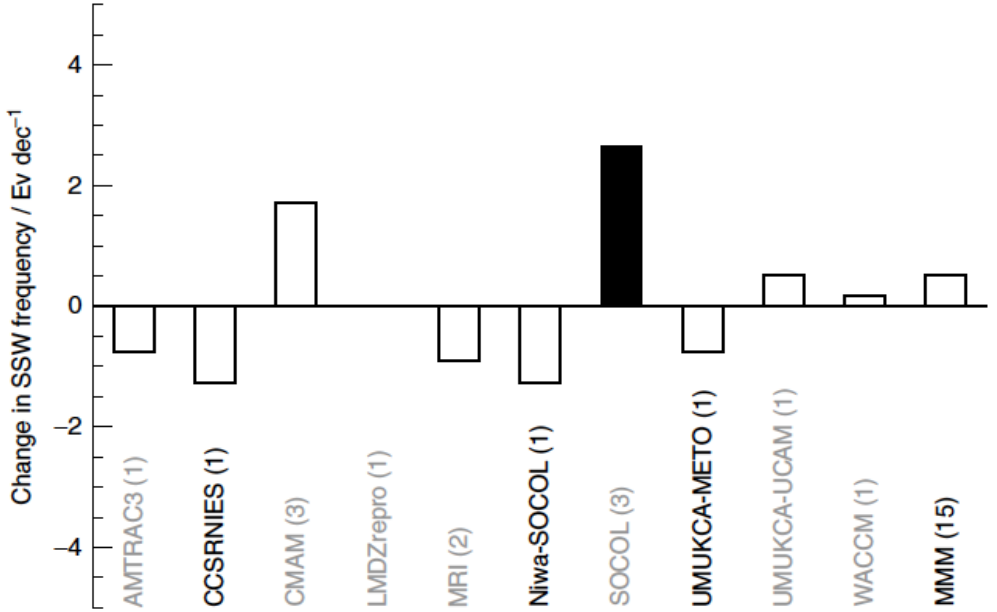
Motivation

Major Stratospheric Warmings (MSWs) in the future

- No clear consensus among recent studies about a possible impact of climate change on MSWs by analyzing chemistry climate models (CCM) simulations [*Butchart et al. 2010; Mitchell et al. 2012*].

Change in SSW freq. (1960 -2000 vs 2040-2080) in REF-B2 run



[Mitchell et al., 2012]

Possible reason for the uncertainty: competition of different forcings and sensitivity of models to these forcings.

Goal of the study

What are the results for the new CCMI runs?

Data & models

REF-C2: transient run from 1960-2100 under RCP6.0 scenario (GHGs) and A1 scenario (ODS, WMO 2010)

CCMI models	Model resolution	QBO	Solar variability	SSTs
GEOS-CCM	2.5° x 2°, L72 (top:0.01hPa)	Internally generated	No	Prescribed (CESM1)
CNRM-CCM	T42L60 (top: 0.07 hPa)	Internally generated	Yes	Prescribed (CNRM)
NIWA-UKCA	3.75° x 2.5°, L60 (top: 84 km)	Internally generated	No	Coupled to ocean model
CCSRNIES-MIROC 3.2	T42L34 (top: 0.012 hPa)	Nudged	Yes	Prescribed (MIROC 3.2)
EMAC-O	T42L39 (top: 0.01hPa)	Nudged	Yes	Coupled to ocean model
ACCESS	3.75° x 2.5°, L60 (top: 84 km)	Internally generated	No	Prescribed (HadGEM-ES2)

Mean frequency of MSWs (I)

Periods of study: **PAST** (first 40 winters) and **FUTURE** (last 40 winters)

Model	Past (MSWs/dec)	Future (MSWs/dec)
CCSRNIES-MIROC3.2	2.3	3.0
NIWA-UKCA	0.8 (!)	3.3
GEOS-CCM	1.8	1.8
CNRM-CCM	7.5	7.5
EMAC-O	9.3	7.5
ACCESS	10.0	9.3
NCEP/NCAR rean. (1960-2000)	5.5	

Criterion for MSW identification

- Simultaneous reversal of $\bar{u}$ at 60°N and 10 hPa & ΔT (90°N-60°N) at 10 hPa
- 10 consecutive days of westerly winds after the central date

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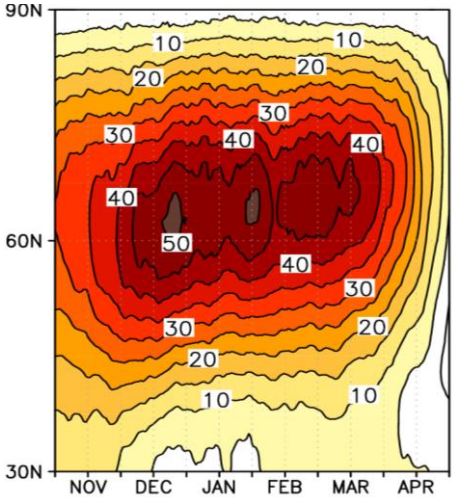
ū @ 10 hPa
NIWA-UKCA



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Criterion for MSW identification

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No statistically significant future changes in the mean frequency of MSWs are found except for NIWA-UKCA

Mean frequency of MSWs (II): Sensitivity of results to different SSW diagnostics

U6090: Reversal of ū averaged from 60°-90°N (Butler et al., under review)

Model	Past (MSWs/dec)	Future (MSWs/dec)
CCSRNIES-MIROC3.2	4.0	5.3
NIWA-UKCA	2.8	3.5
GEOS-CCM	5.5	5.5
CNRM-CCM	10.3	11.8
EMAC-O	8.0	7.3
ACCESS	12.5	11.5
NCEP/NCAR rean.	7.0	

ZPOL: Polar-cap averaged 10-hPa Z anomalies exceed +3 std (Butler et al. under review)

Model	Past (MSWs/dec)	Future (MSWs/dec)
CCSRNIES-MIROC3.2	3.5	4.0
NIWA-UKCA	4.3	4.5
GEOS-CCM	4.3	5.0
CNRM-CCM	4.0	4.0
EMAC-O	4.8	4.3
ACCESS	3.8	3.8
NCEP/NCAR rean.	6.8	

The lack of statistically significant future changes is confirmed when using other criteria for the identification of MSWs.

Type of events: split/displacement MSWs

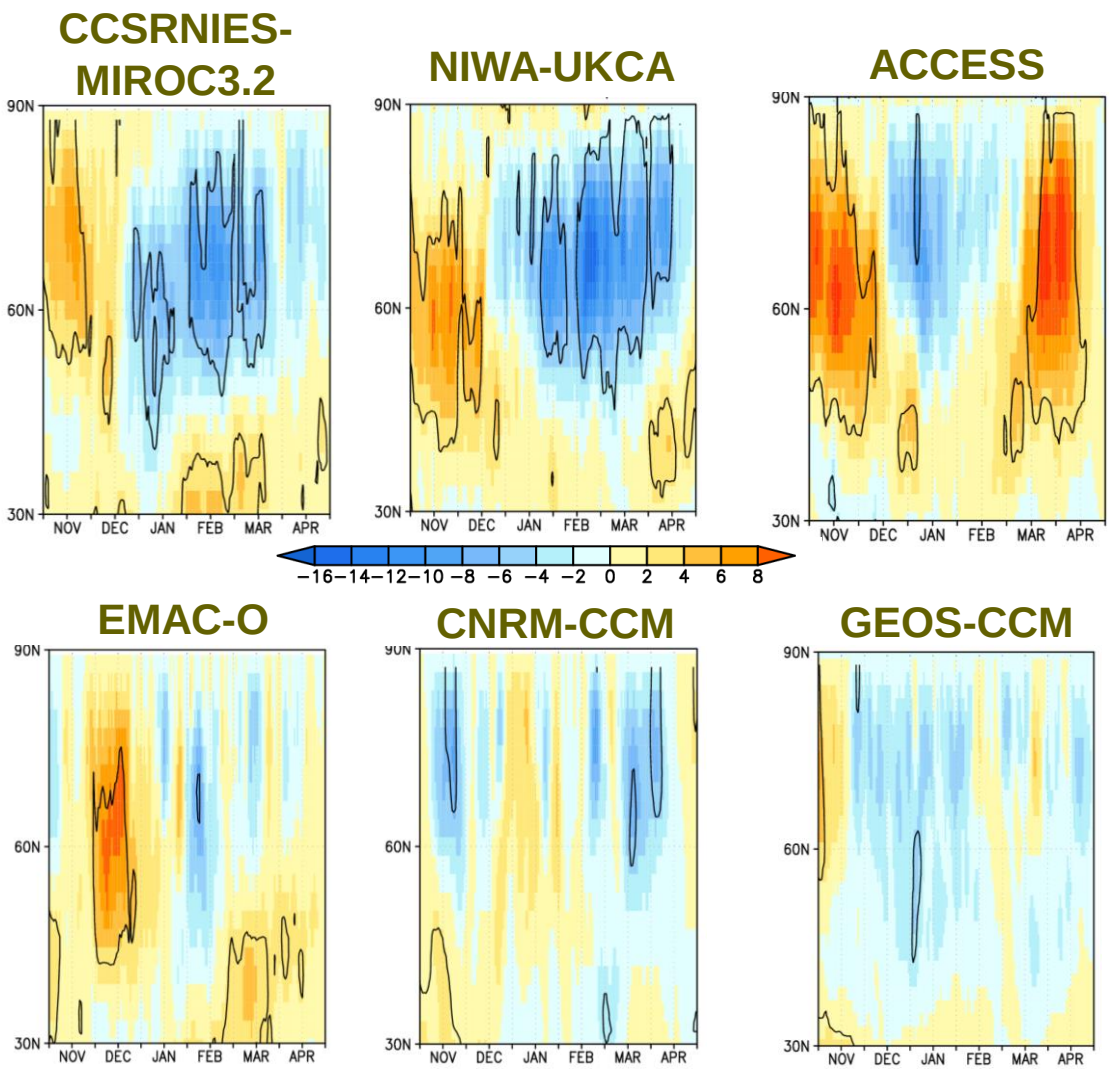
Criterion based on the calculation of area-weighted rotation around the occurrence of MSWs (algorithm developed by K. Shibata).

Model	Past (S/D ratio)	Future (S/D ratio)
CCSRNIES-MIROC3.2	0.13	0.33
NIWA-UKCA	0.50	0.00
GEOS-CCM	0.17	0.40
CNRM-CCM	0.20	0.11
EMAC-O	0.23	0.16
ACCESS	0.21	0.27
NCEP/NCAR rean.	0.77	

- CCMI models show in general a very low number of vortex split MSWs.
- **Future**: no significant changes are found.

Future seasonal changes in the intensity of PNJ

Daily ū@10 hPa (m/s)
Future-minus-past



- No stat. signif. changes in GEOS-CCM and CNRM-CCM

- Changes in other 4 models:
  - Early winter: stat. signif stronger future PNJ.
  - Midwinter: weaker future PNJ (only stat. signif. in 2 of them).

Contours enclose areas with statistically significant values at a 95% conf. level

Conclusions

- **No** statistically significant future changes in the mean frequency of MSWs are found in general in the analyzed CCMI models.
- Other characteristics of MSWs do not show stat. significant changes in the future either.
- Two groups of models are found in terms of future seasonal changes in the intensity of the PNJ:
  1. Models that do not show any statistically significant changes of the polar vortex in the future (GEOS-CCM & CNRM-CCM).
  2. Models with a future weakening (strengthening) in midwinter (early winter) (CCSRIES-MIROC3.2, NIWA-UKCA, ACCESS & EMAC-O).

Thank you for your attention!