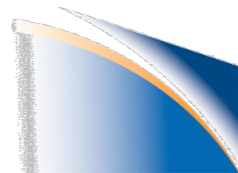


Influence of El Nino and the QBO on the frequency of Sudden Stratospheric Warmings

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Thanks:
Chris Fischer



NCAR

Introduction:

- **Sudden Stratospheric Warming (SSW)**: event where winter polar stratosphere warms abruptly and the polar vortex slows down or reverses direction
- **Major SSW**: temperature gradient between 60 N and 90 N at 10 hPa is positive for at least 5 days and the zonal mean wind at 60 N at 10 hPa is easterly during that time.
- **Minor SSW**: temperature gradient between 60 N and 90 N at 10 hPa is positive for at least 5 days, but there is no reversal of circulation at 10 hPa

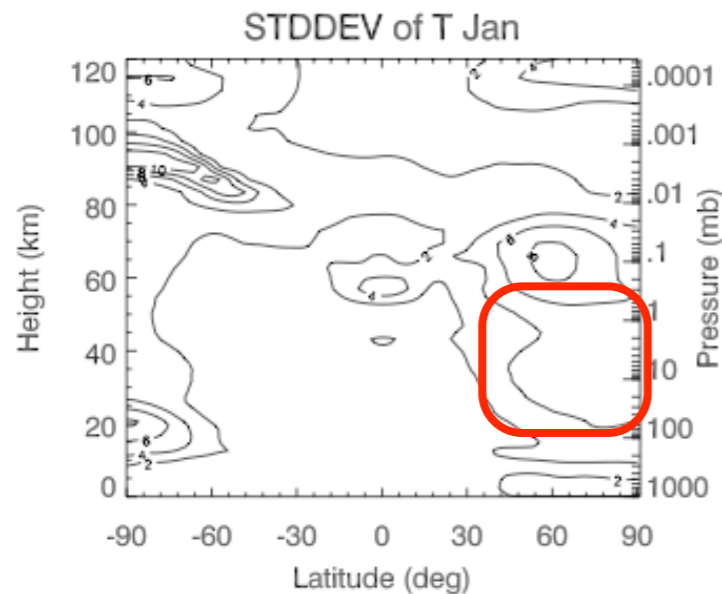
Introduction

- GCMs have trouble reproducing SSWs (Charlton et al. 2007):

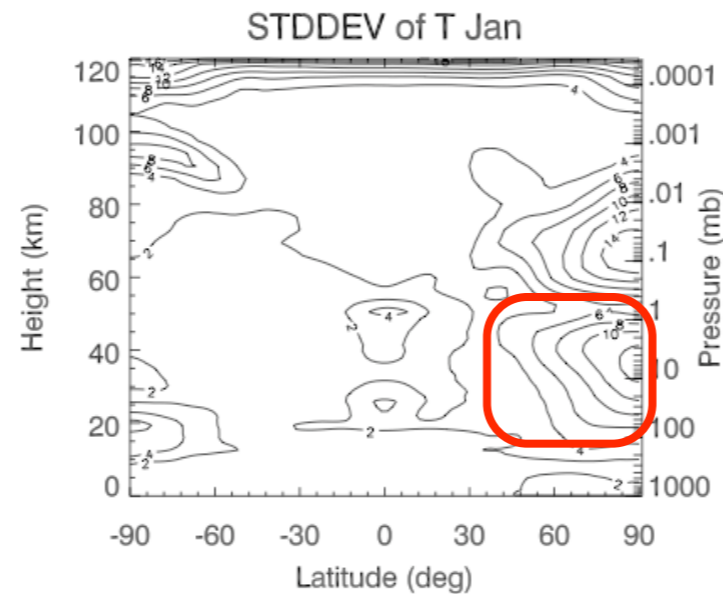
GCM	Run length/winters	SSWs	Frequency/ events yr ⁻¹
FVGCM	49	23	0.47
GISSL53	47	37	0.79
GISSL23	46	12	0.26
WACCM	50	5	0.10
MAECHAM	29	15	0.52
MRIJMA	60	14	0.23
NCEP-NCAR	45	27	0.60

SSWs in WACCM:

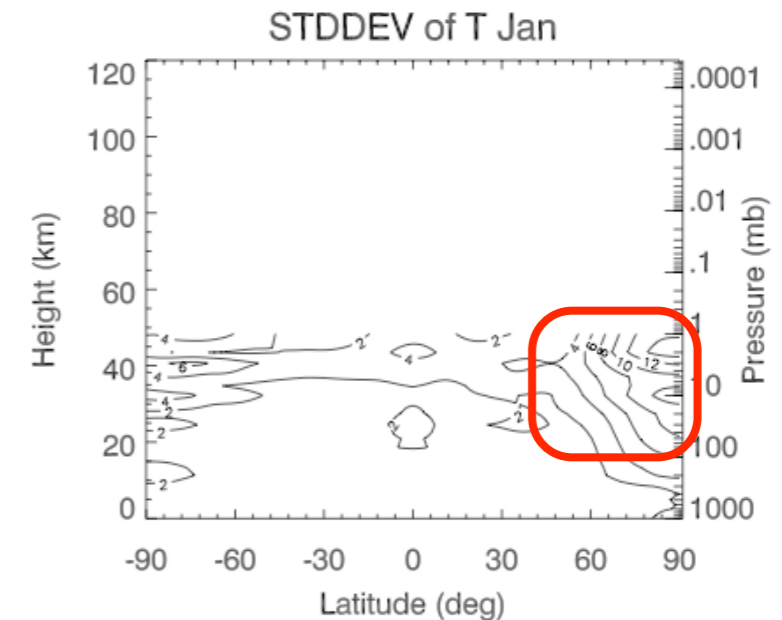
WACCM 3



WACCM 3.5



ERA 40



Frequency of Sudden Stratospheric Warmings:
(Nov - March)

WACCM 3

.13

WACCM 3.5

.66

ERA 40

.6

How do ENSO and QBO influence SSWs?

Previous Work:

- Observational studies:
 - van Loon and Labitzke (1987): more warmings during ENSO events;
 - Camp and Tung (2007): warmer polar stratosphere during ENSO events
 - Holton and Tan (1982): East QBO: warm and weak vortex
- Modeling studies focused on Temperature response of different warmings: never looked at SSW counts:
 - Sassi et al 2004: warmer polar stratosphere / weaker vortex during warm ENSO: no solar cycle (smin conditions), no QBO
 - Calvo et al 2007: East QBO: warm and weak vortex (no solar, no ENSO)
 - Calvo et al 2009: response to ENSO and QBO (no solar):
nonlinear interaction: QBOE+El Nino: no additional warming

When do SSWs happen?

ERA40: 1958 - 2004

TOTAL SSWs:	29
SSWs QBOE:	15
SSWs QBOW:	6
SSWs ELNINO:	12
SSWs LANINA:	8
SSWs SMAX:	10
SSWs SMIN:	6
SSWs NEUTRAL:	0

SSW counts: (double categories)

SSWs QBOE/ELNINO:	5
SSWs QBOE/LANINA:	5
SSWs QBOW/ELNINO:	2
SSWs QBOW/LANINA:	2
SSWs QBOE/SMAX:	3
SSWs QBOE/SMIN:	4
SSWs QBOW/SMAX:	4
SSWs QBOW/SMIN:	0
SSWs ELNINO/SMAX:	1
SSWs ELNINO/SMIN:	4
SSWs LANINA/SMAX:	2
SSWs LANINA/SMIN:	1

REFBI: 1958 - 2004

TOTAL SSWs:	29
SSWs QBOE:	12
SSWs QBOW:	8
SSWs ELNINO:	11
SSWs LANINA:	5
SSWs SMAX:	5
SSWs SMIN:	11
SSWs NEUTRAL:	4

SSW counts: (double categories)

SSWs QBOE/ELNINO:	4
SSWs QBOE/LANINA:	3
SSWs QBOW/ELNINO:	3
SSWs QBOW/LANINA:	1
SSWs QBOE/SMAX:	3
SSWs QBOE/SMIN:	4
SSWs QBOW/SMAX:	2
SSWs QBOW/SMIN:	3
SSWs ELNINO/SMAX:	0
SSWs ELNINO/SMIN:	6
SSWs LANINA/SMAX:	0
SSWs LANINA/SMIN:	4

When do SSWs happen?

ERA40: 1975 - 2004

REFBI: 1975 - 2004

TOTAL SSWs:	17
SSWs QBOE:	7
SSWs QBOW:	3
SSWs ELNINO:	5
SSWs LANINA:	7
SSWs SMAX:	8
SSWs SMIN:	3
SSWs NEUTRAL:	0

TOTAL SSWs:	19
SSWs QBOE:	7
SSWs QBOW:	3
SSWs ELNINO:	5
SSWs LANINA:	4
SSWs SMAX:	5
SSWs SMIN:	7
SSWs NEUTRAL:	4

SSW counts: (double categories)

SSWs QBOE/ELNINO:	0
SSWs QBOE/LANINA:	3
SSWs QBOW/ELNINO:	0
SSWs QBOW/LANINA:	2
SSWs QBOE/SMAX:	3
SSWs QBOE/SMIN:	1
SSWs QBOW/SMAX:	3
SSWs QBOW/SMIN:	0
SSWs ELNINO/SMAX:	1
SSWs ELNINO/SMIN:	2
SSWs LANINA/SMAX:	3
SSWs LANINA/SMIN:	1

SSW counts: (double categories)

SSWs QBOE/ELNINO:	0
SSWs QBOE/LANINA:	3
SSWs QBOW/ELNINO:	1
SSWs QBOW/LANINA:	0
SSWs QBOE/SMAX:	3
SSWs QBOE/SMIN:	2
SSWs QBOW/SMAX:	2
SSWs QBOW/SMIN:	1
SSWs ELNINO/SMAX:	0
SSWs ELNINO/SMIN:	4
SSWs LANINA/SMAX:	0
SSWs LANINA/SMIN:	3

Experiments:

- 30 year simulations (1975 - 2004)
- All simulations have observed solar and volcanic emissions
 - **refb I**: observed SSTs (**ENSO**) & relaxation to observed **QBO**
 - **refb I_fixedsst**: climatological cycle of SSTs (no ENSO) + **QBO**
 - **refb I_noqbo**: observed SSTs (**ENSO**) but NO QBO
 - **refb I_noqbo_fixedsst**: no ENSO and NO QBO

Results: Warmings Nov - March:

Sim Name	# Major SSWs / Frequency		# Minor SSWs / Frequency	
refb I: QBO+ENSO	19 / 0.63			
refb I_fixedsst: QBO	15 / 0.5	-20%		
refb I_noqbo: ENSO	16 / 0.53	-18%		
refb I_noqbo_fixedsst	4 / 0.13	-80%		

Results: Warmings Nov - March:

Sim Name	# Major SSWs / Frequency		# Minor SSWs / Frequency	
refb I: QBO+ENSO	19 / 0.63		41 / 1.37	
refb I_fixedsst: QBO	15 / 0.5	-20%	43 / 1.43	+ 0.05%
refb I_noqbo: ENSO	16 / 0.53	-18%	37 / 1.23	-1%
refb I_noqbo_fixedsst	4 / 0.13	-80%	49 / 1.63	+20 %

Tssw-Tmean:

Nov

Dec

Jan

Feb

Mar

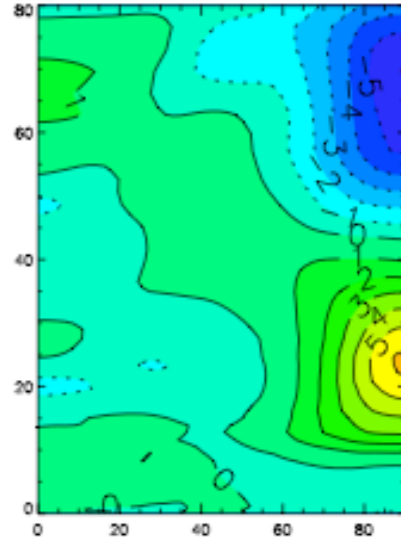
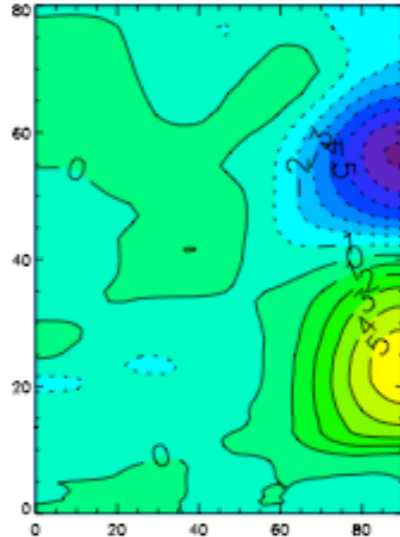
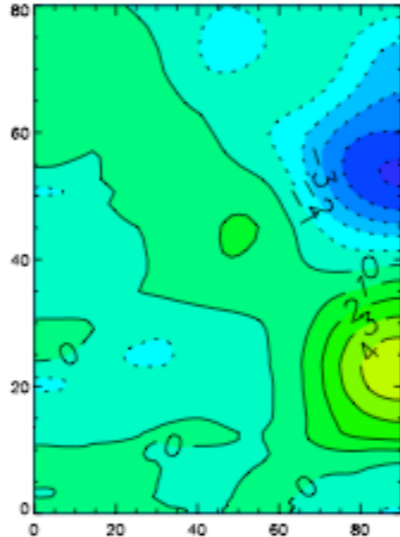
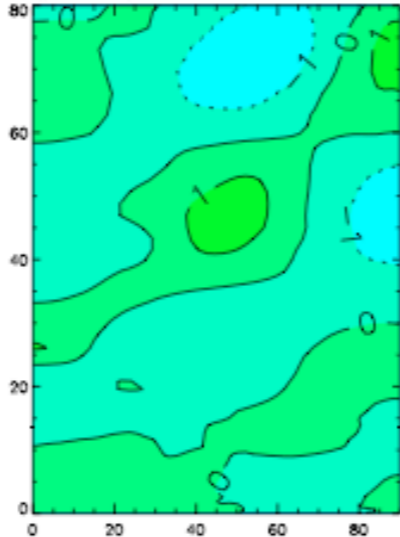
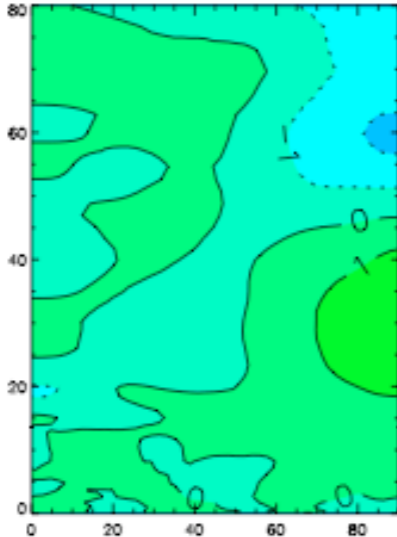
T SSW - Mean T Nov wa3548_2x_refb1.1

T SSW - Mean T Dec wa3548_2x_refb1.1

T SSW - Mean T Jan wa3548_2x_refb1.1

T SSW - Mean T Feb wa3548_2x_refb1.1

T SSW - Mean T Mar wa3548_2x_refb1.1



Refb1

QBO+ENSO

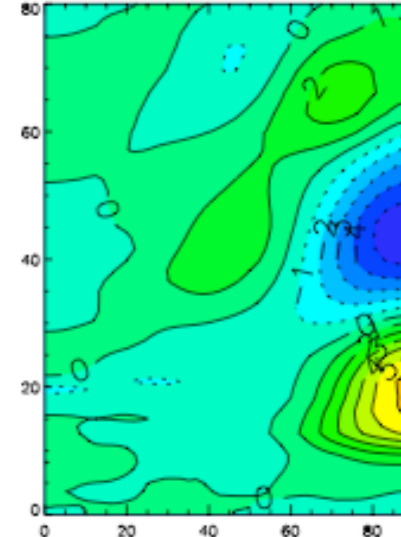
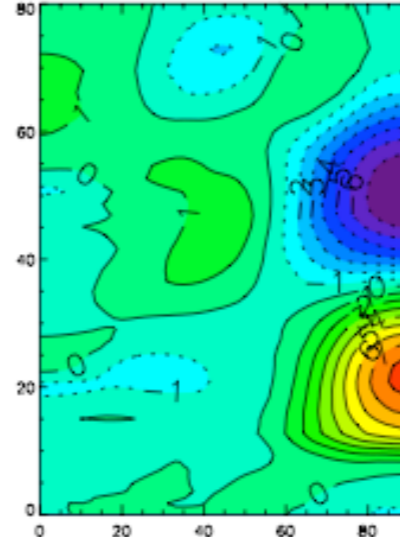
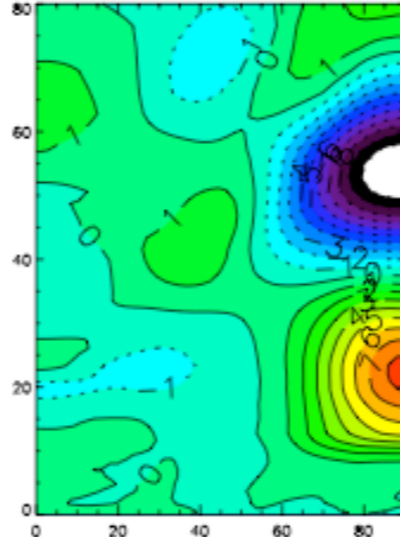
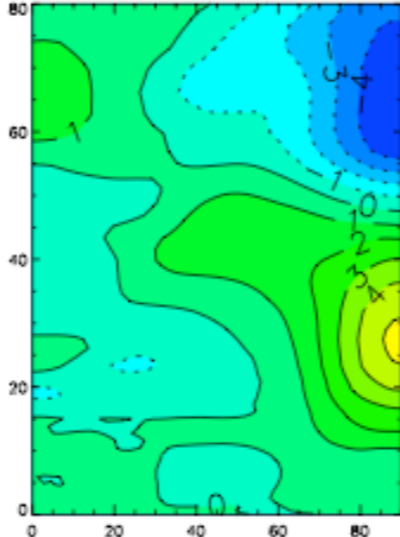
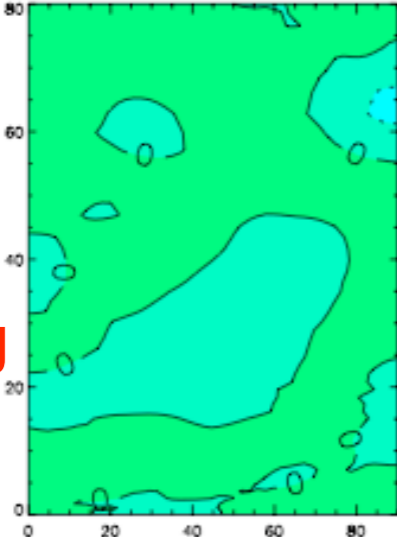
T SSW - Mean T Nov wa3548_2x_refb1.1_fixedsst

T SSW - Mean T Dec wa3548_2x_refb1.1_fixedsst

T SSW - Mean T Jan wa3548_2x_refb1.1_fixedsst

T SSW - Mean T Feb wa3548_2x_refb1.1_fixedsst

T SSW - Mean T Mar wa3548_2x_refb1.1_fixedsst



Refb1

_fixedsst

QBO forcing

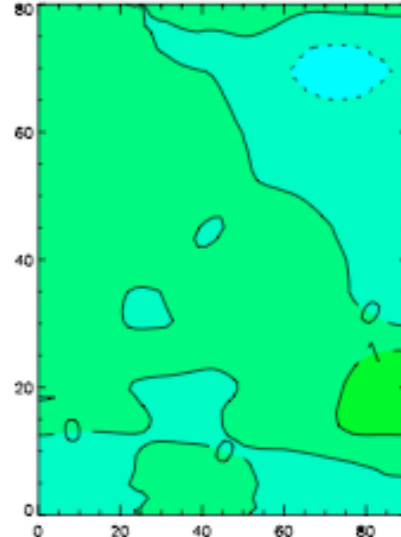
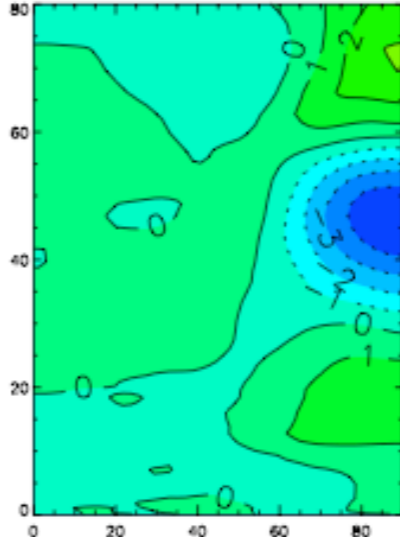
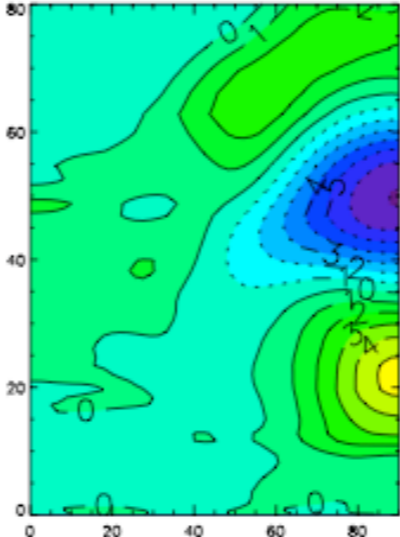
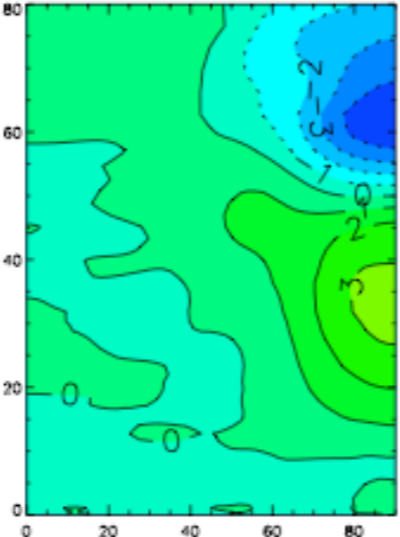
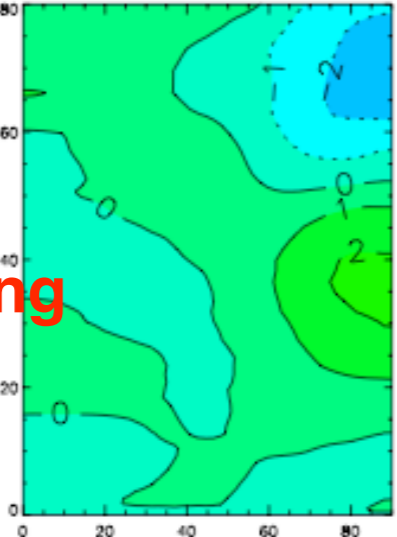
T SSW - Mean T Nov wa3548_2x_refb1.1_noqbo

T SSW - Mean T Dec wa3548_2x_refb1.1_noqbo

T SSW - Mean T Jan wa3548_2x_refb1.1_noqbo

T SSW - Mean T Feb wa3548_2x_refb1.1_noqbo

T SSW - Mean T Mar wa3548_2x_refb1.1_noqbo



Refb1

_noqbo

ENSO forcing

When do SSWs happen?

ERA40: 1975 - 2004

REFBI: 1975 - 2004

TOTAL SSWs:	17
SSWs QBOE:	7
SSWs QBOW:	3
SSWs ELNINO:	5
SSWs LANINA:	7
SSWs SMAX:	8
SSWs SMIN:	3
SSWs NEUTRAL:	0

TOTAL SSWs:	19
SSWs QBOE:	7
SSWs QBOW:	3
SSWs ELNINO:	5
SSWs LANINA:	4
SSWs SMAX:	5
SSWs SMIN:	7
SSWs NEUTRAL:	4

SSW counts: (double categories)

SSWs QBOE/ELNINO:	0
SSWs QBOE/LANINA:	3
SSWs QBOW/ELNINO:	0
SSWs QBOW/LANINA:	2
SSWs QBOE/SMAX:	3
SSWs QBOE/SMIN:	1
SSWs QBOW/SMAX:	3
SSWs QBOW/SMIN:	0
SSWs ELNINO/SMAX:	1
SSWs ELNINO/SMIN:	2
SSWs LANINA/SMAX:	3
SSWs LANINA/SMIN:	1

SSW counts: (double categories)

SSWs QBOE/ELNINO:	0
SSWs QBOE/LANINA:	3
SSWs QBOW/ELNINO:	1
SSWs QBOW/LANINA:	0
SSWs QBOE/SMAX:	3
SSWs QBOE/SMIN:	2
SSWs QBOW/SMAX:	2
SSWs QBOW/SMIN:	1
SSWs ELNINO/SMAX:	0
SSWs ELNINO/SMIN:	4
SSWs LANINA/SMAX:	0
SSWs LANINA/SMIN:	3

When do SSWs happen?

ERA40: 1975 - 2004

REFBI: 1975 - 2004

TOTAL SSWs:	17
SSWs QBOE:	7
SSWs QBOW:	3
SSWs ELNINO:	5
SSWs LANINA:	7
SSWs SMAX:	8
SSWs SMIN:	3
SSWs NEUTRAL:	0

SSW counts: (double categories)

SSWs QBOE/ELNINO:	0
SSWs QBOE/LANINA:	3
SSWs QBOW/ELNINO:	0
SSWs QBOW/LANINA:	2
SSWs QBOE/SMAX:	3
SSWs QBOE/SMIN:	1
SSWs QBOW/SMAX:	3
SSWs QBOW/SMIN:	0
SSWs ELNINO/SMAX:	1
SSWs ELNINO/SMIN:	2
SSWs LANINA/SMAX:	3
SSWs LANINA/SMIN:	1

TOTAL SSWs:	19
SSWs QBOE:	7
SSWs QBOW:	3
SSWs ELNINO:	5
SSWs LANINA:	4
SSWs SMAX:	5
SSWs SMIN:	7
SSWs NEUTRAL:	4

SSW counts: (double categories)

SSWs QBOE/ELNINO:	0
SSWs QBOE/LANINA:	3
SSWs QBOW/ELNINO:	1
SSWs QBOW/LANINA:	0
SSWs QBOE/SMAX:	3
SSWs QBOE/SMIN:	2
SSWs QBOW/SMAX:	2
SSWs QBOW/SMIN:	1
SSWs ELNINO/SMAX:	0
SSWs ELNINO/SMIN:	4
SSWs LANINA/SMAX:	0
SSWs LANINA/SMIN:	3

When do SSWs happen?

refb1_noqbo_fixedsst: 1975 - 2004

SSW counts: (single categories)

TOTAL SSWs:	4
SSWs QBOE:	0
SSWs QBOW:	0
SSWs ELNINO:	0
SSWs LANINA:	0
SSWs SMAX:	1
SSWs SMIN:	2
SSWs NEUTRAL:	1

SSW counts: (double categories)

SSWs QBOE/ELNINO:	0
SSWs QBOE/LANINA:	0
SSWs QBOW/ELNINO:	0
SSWs QBOW/LANINA:	0
SSWs QBOE/SMAX:	0
SSWs QBOE/SMIN:	0
SSWs QBOW/SMAX:	0
SSWs QBOW/SMIN:	0
SSWs ELNINO/SMAX:	0
SSWs ELNINO/SMIN:	0
SSWs LANINA/SMAX:	0
SSWs LANINA/SMIN:	0

Summary:

- WACCM3.5 reproduces SSW statistics reasonably well when consider total # of warmings, relationship with QBO and ENSO phases, however WACCM3.5 produces more warmings during SMIN years (unlike in OBS)
- Removal of ENSO or QBO reduces the number of SSWs by ~ 20% whereas removal of both forcings reduces SSWs by 80%
- Removal of one of the forcings (QBO or ENSO) changes how the solar signal interacts with the other forcing to produce SSWs. In the simulations with either ENSO or QBO forcing, the observed relationship between more SSWs during SMAX is reproduced