An analysis of SSW & elevated stratopauses generated in WACCM

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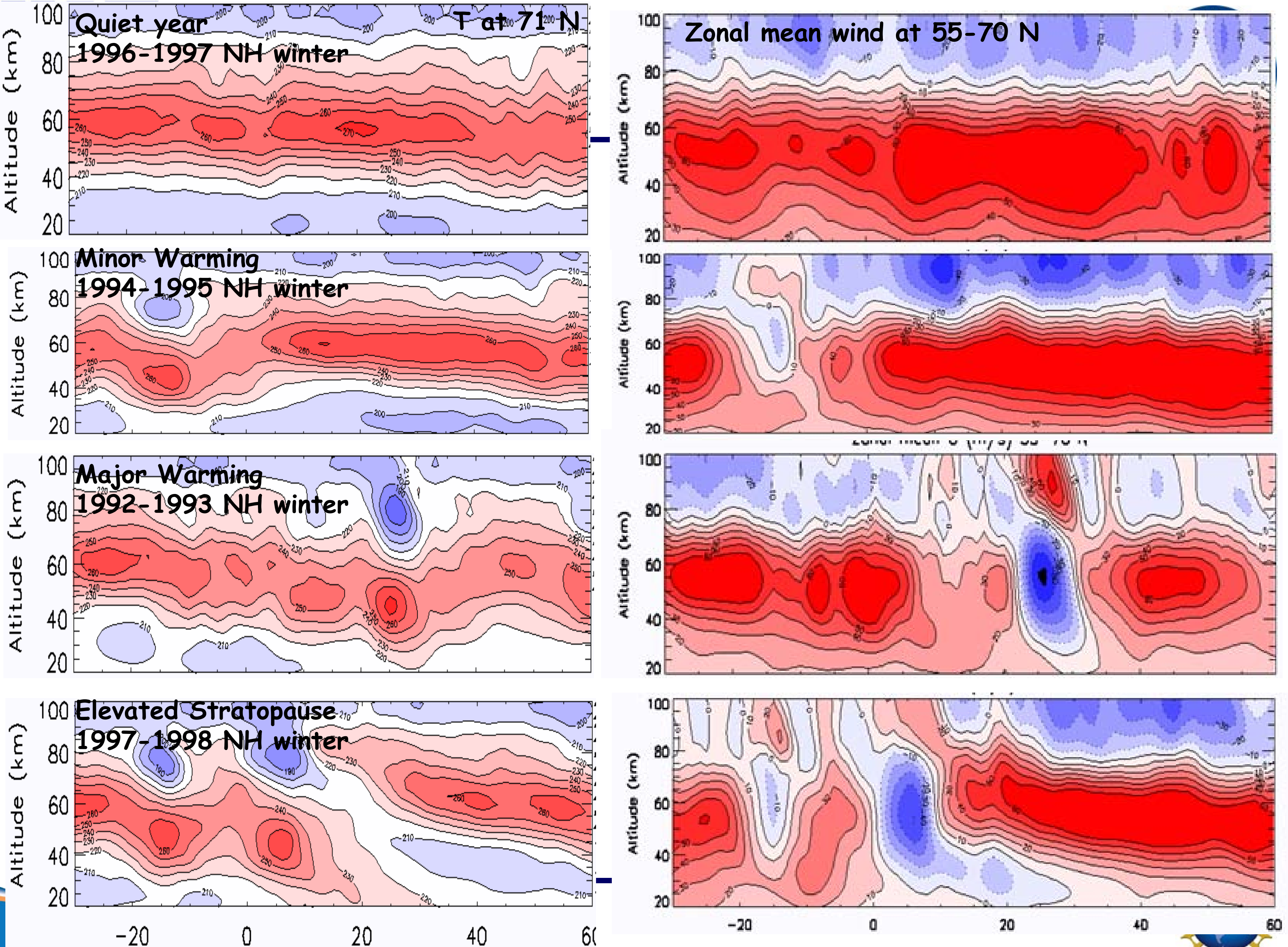
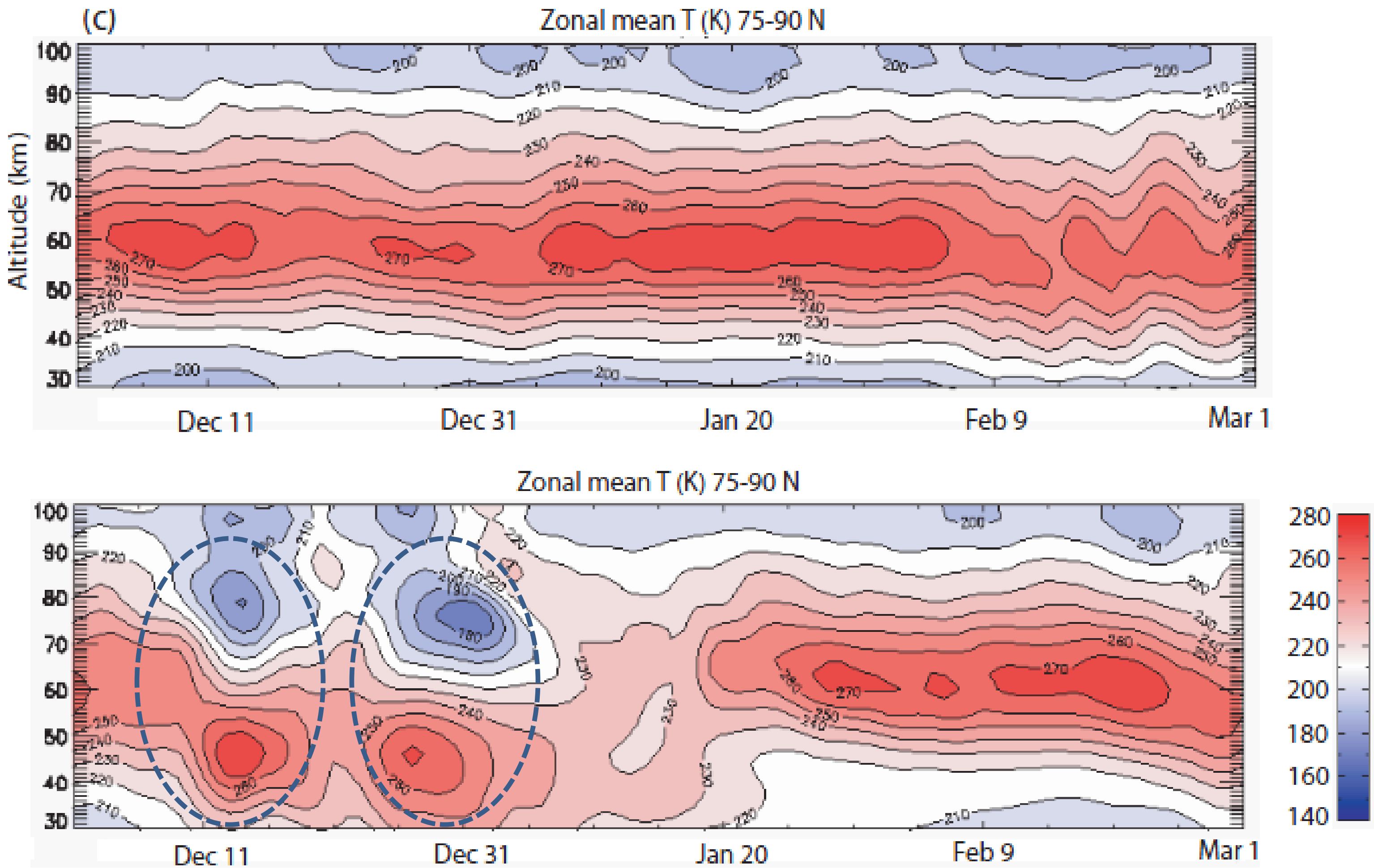
SSW in WACCM

- Multiple WACCM 3.5 simulations have been analyzed for SSW events (Two 50 year and one 150 year runs).

- Arctic winters have been classified into 4 basic types:
  - Quiet (undisturbed) winters
  - Minor SSW winters – Poleward temperature gradient becomes positive but zonal mean wind at 10 hPa remains eastward.
  - Major SSW winters - Poleward temperature gradient becomes positive with reversal in zonal mean wind at 10 hPa.
  - Major SSW with elevated stratopause winters

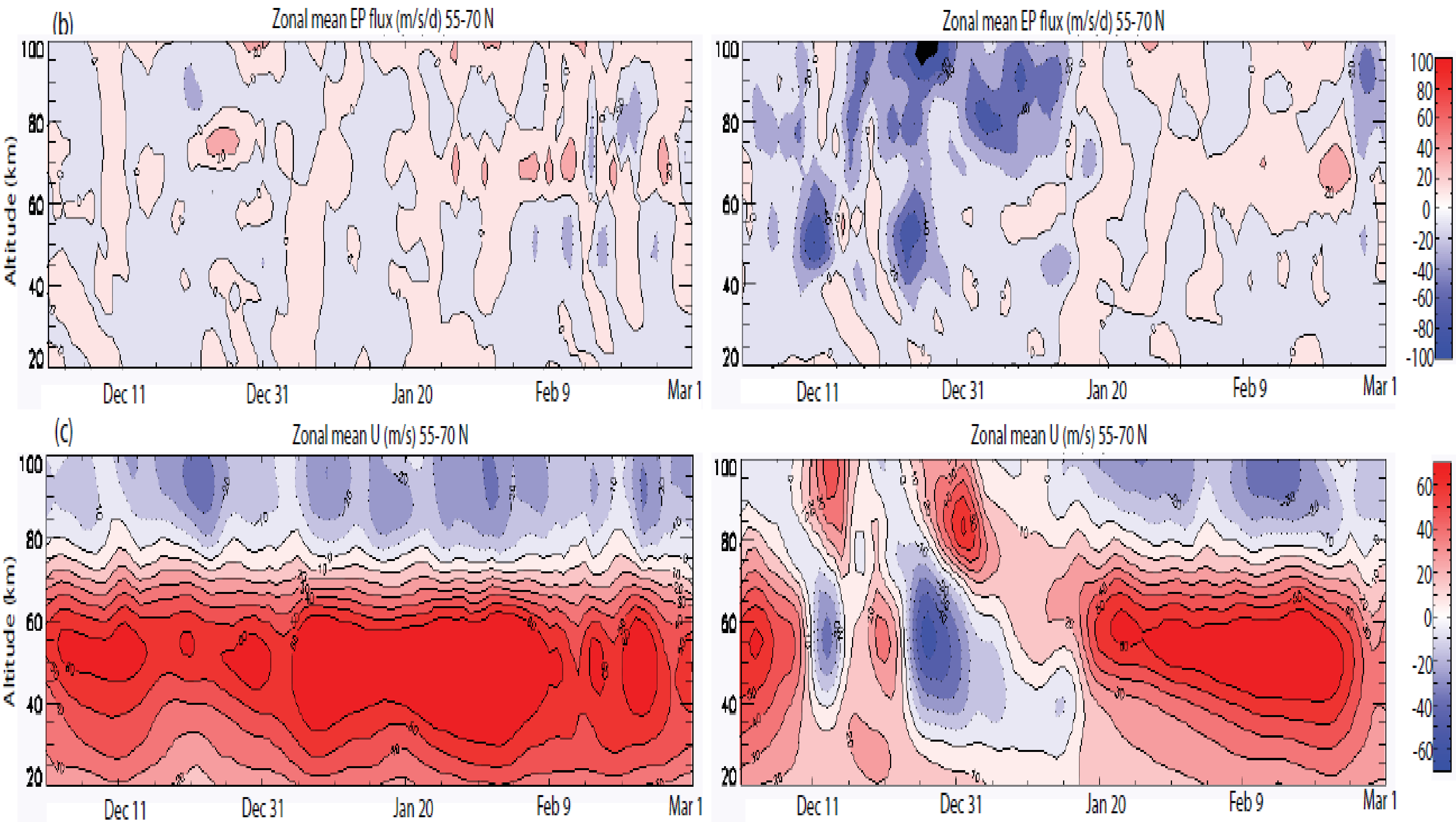

Quiet year
1996-1997 NH winter
T at 71 N
Minor Warming
1994-1995 NH winter
Major Warming
1992-1993 NH winter
Elevated Stratopause
1997-1998 NH winter
Zonal mean wind at 55-70 N
Altitude (km)
-20
0
20
40
60

Elevated stratopause in WACCM



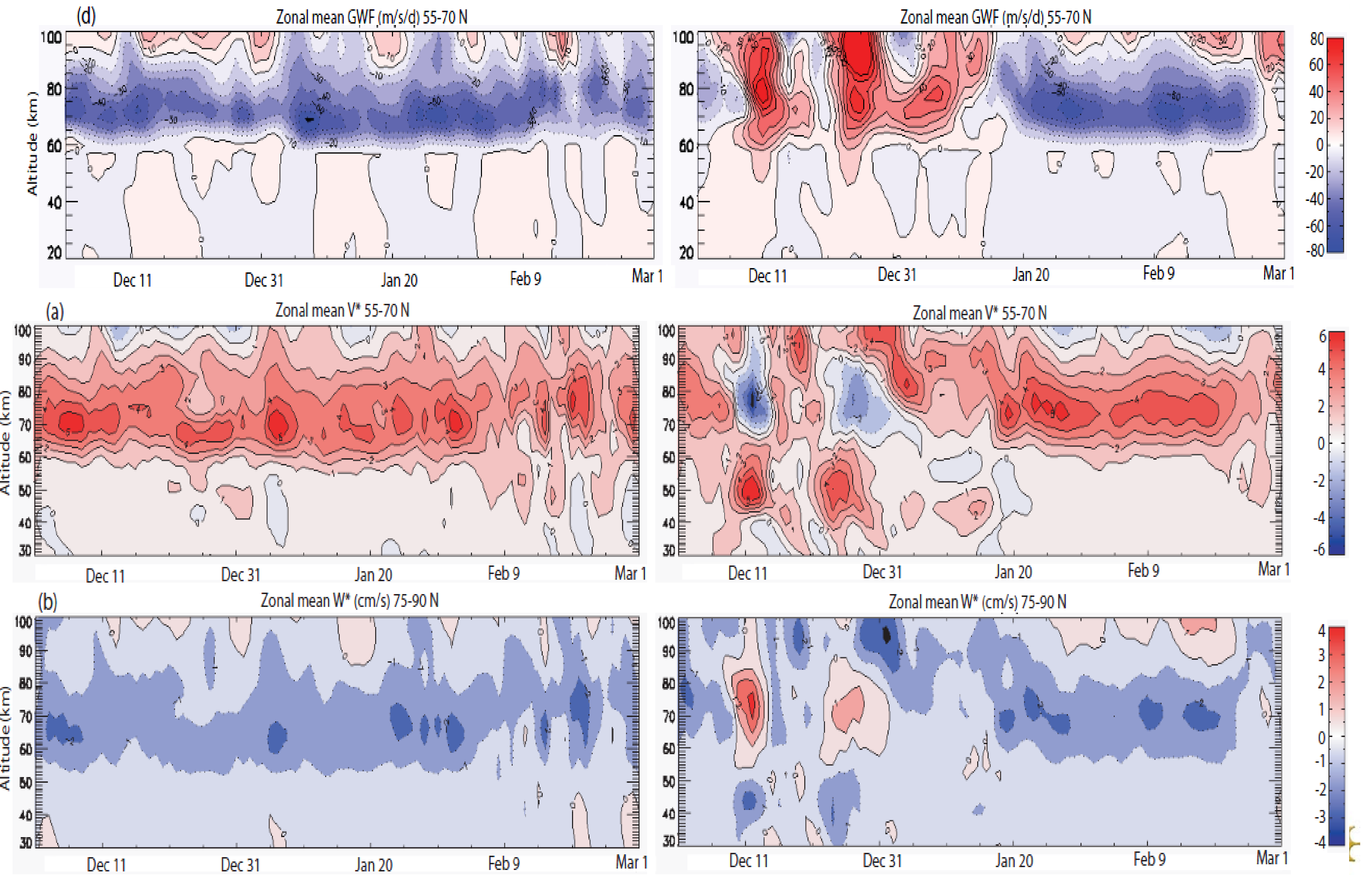
Chandran et al. GRL, 2011

Elevated stratopause in WACCM

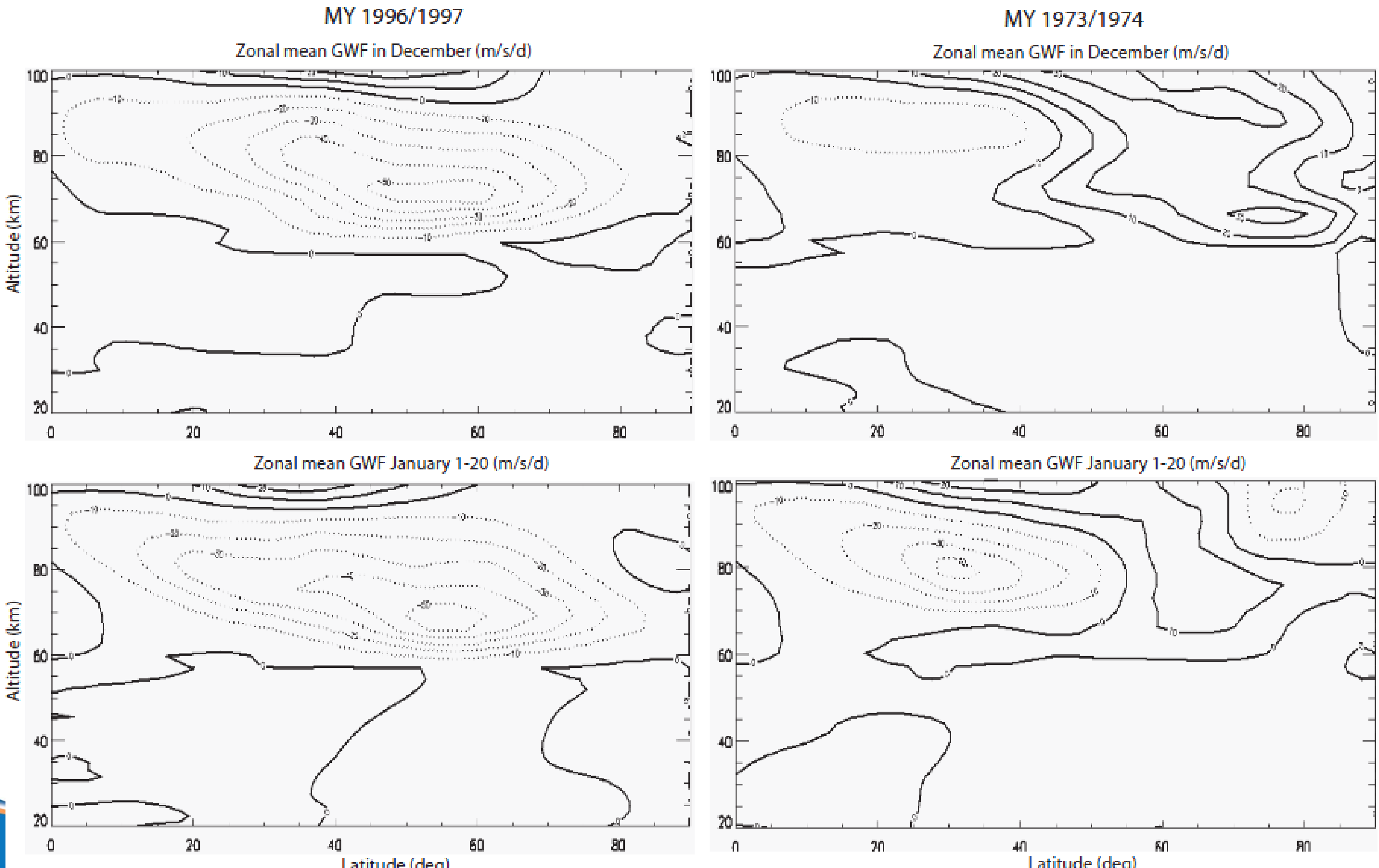


WAWG meeting, Boulder, 02/17/2011

Elevated stratopause in WACCM

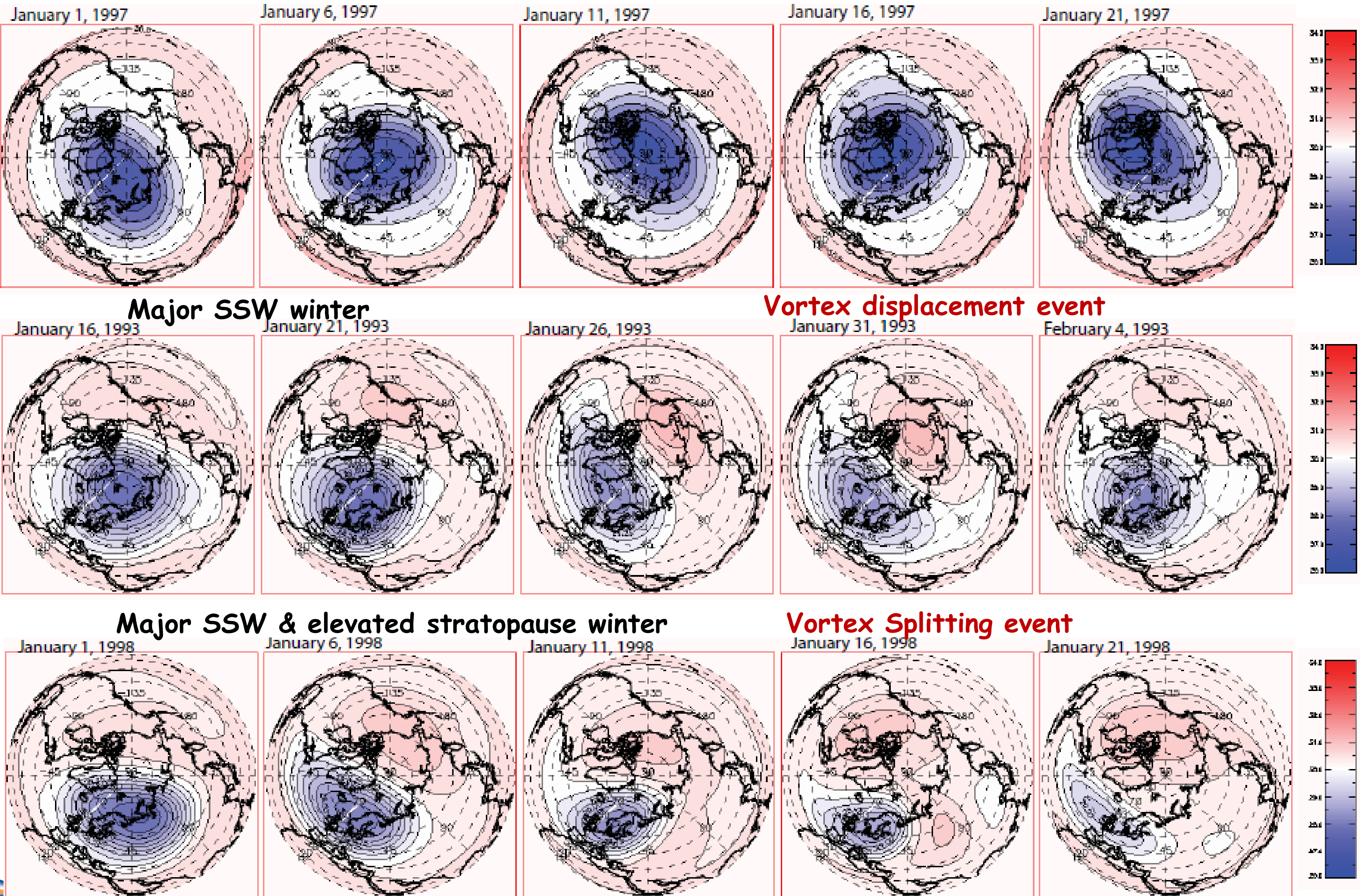


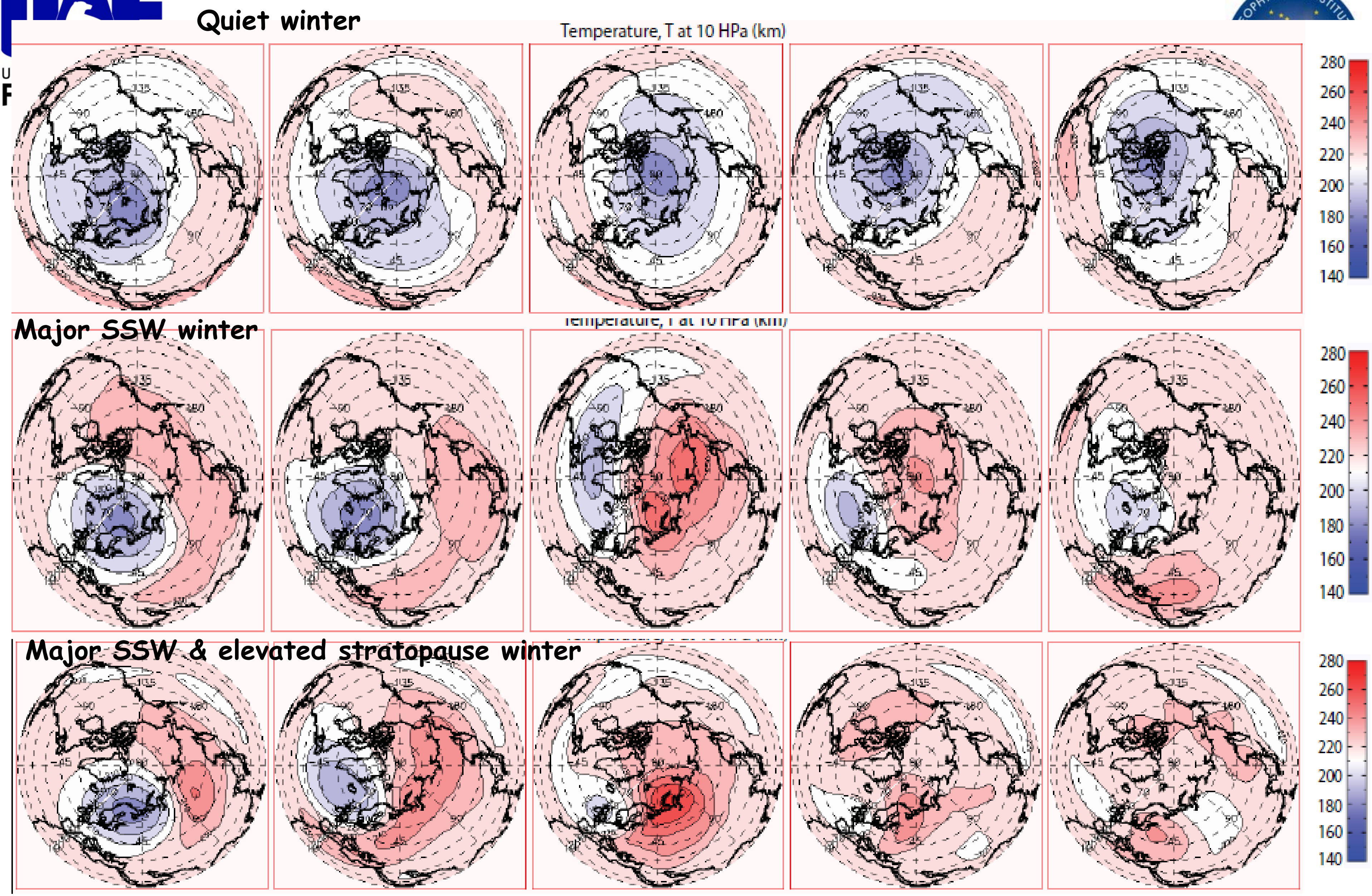
Elevated stratopause in WACCM



Quiet winter

Geopotential Height at 10 HPa (km)




Quiet winter
Temperature, T at 10 HPa (km)
Major SSW winter
Major SSW & elevated stratopause winter
280
260
240
220
200
180
160
140

Climatology of SSW in WACCM

Refb 1.1 climatology - 1953-2003

Type of SSW	1953-1963	1963-1973	1973-1983	1983-1993	1993-2003	Total
Quiet Year	(0)	67-68, (1)	(0)	88-89 (1)	96-97 (1)	3
Minor SSW	58-59,59-60,60-61 (3)	68-69,70-71,71-72, (3)	(0)	83-84,85-86,87-88 (3)	94-95,00-01,01-02 (3)	12
Major SSW	54-55,55-56,56-57,57-58,61-62,62-63 (6)	64-65,66-67,72-73 (3)	75-76,76-77,77-78,80-81,81-82,82-83 (6)	86-87,89-90,90-91,91-92,92-93 (5)	93-94,99-00 (2)	22
Major SSW with elevated stratopause	53-54 (1)	63-64,65-66, 69-70, (3)	73-74,74-75,78-79,79-80 (4)	84-85 (1)	95-96,97-98,98-99,02-03 (4)	13

Occurrence frequency of :

(1) quiet year - 0.06
(2) Minor SSW winter – 0.24
(3) Major SSW – 0.44
(4) Elevated stratopause – 0.26

Climatology of SSW in WACCM

Type of SSW	Realization		
	Refb 1.1 (1953-06)	Refb 1.4 (1953-06)	Refb 2.3 (1953-2100)
Quiet Year	0.06	0.08	0.08
Minor SSW	0.24	0.2	0.27
Major SSW	0.44	0.46	0.45
Major SSW with elevated stratopause	0.26	0.26	0.2
Quiet or minor SSW winter	0.3	0.28	0.35
Major SSW & elevated stratopause winter	0.7	0.72	0.65

Charlton & Polvani 2007 analyzed the NCEP–NCAR and 40-yr ECMWF Re-Analysis (ERA-40) datasets and identified SSWs based on the zonal mean zonal wind at 60°N and 10 hPa, and classified them into events that do and do not split the stratospheric polar vortex.

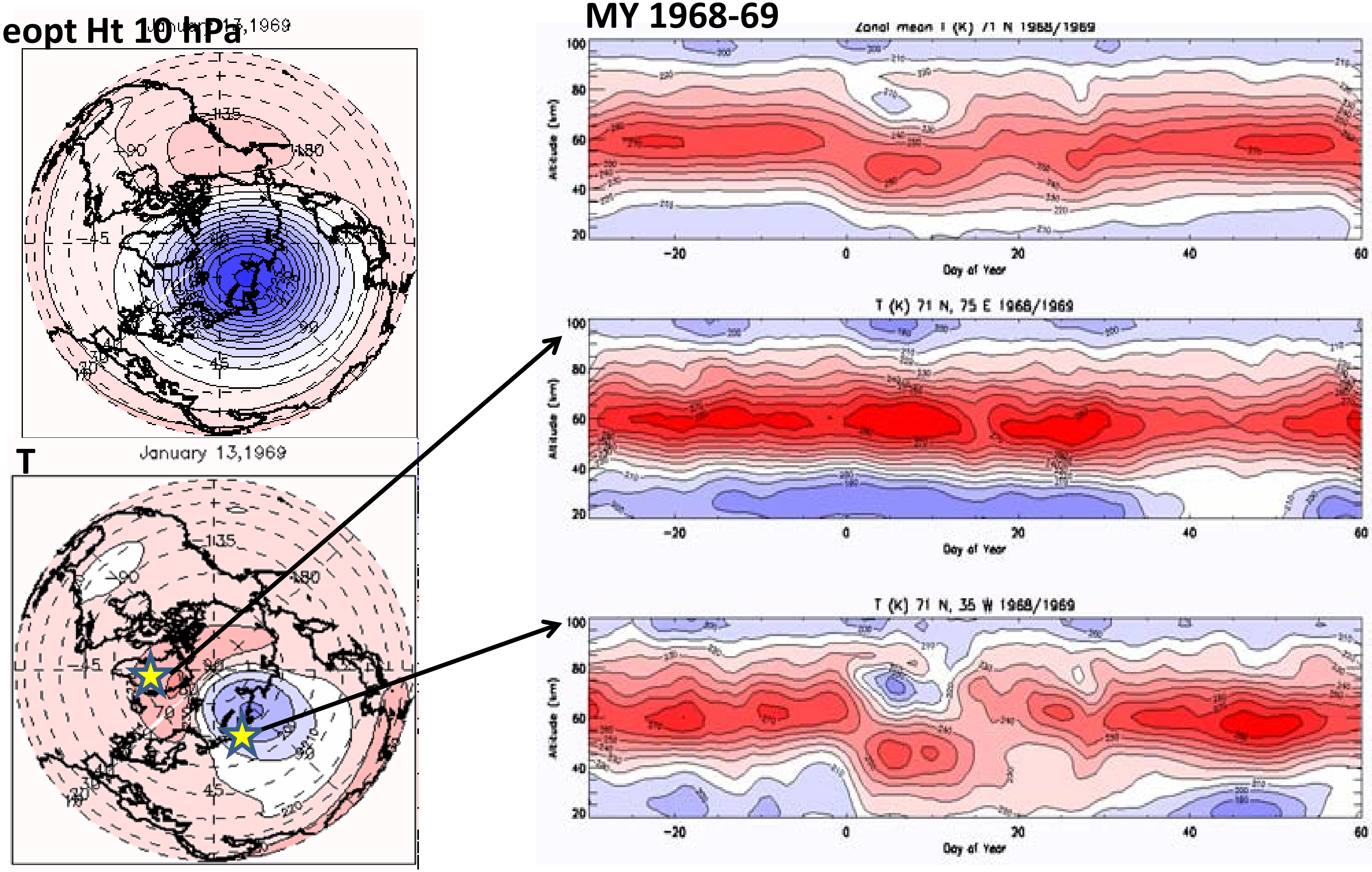
Benchmark	All SSWs	Vortex displacement	Vortex splitting
1) Frequency (SSWs yr^{-1})	0.60 (0.10)	0.33 (0.07)	0.27 (0.07)

Longitudinal Variability

Geopt Ht 10 hPa

MY 1968-69

T



Summary & Conclusions

- WACCM with the new GW parameterization produces SSW at a realistic occurrence frequency (w.r.t. observations).
- WACCM produces elevated stratopauses with characteristics similar to recently recorded events in the Arctic.
- WACCM produces both vortex displacement and vortex splitting events.
- Some of the vortex splitting events are associated with the formation of an elevated stratopause.
- During a vortex displacement event, there are vast longitudinal variability in the temperature structure and different ground based locations might observe vastly different winters.
- This study shows that during undisturbed winters the dominant GWF is westward in the mesosphere between 40-65 N. However, during an SSW event, the dominant GWF becomes eastward poleward of 60 N

The End !! Thank you !!

Summary & Conclusions - II

- The triggering mechanism for SSW events were strong persistent westward planetary wave forcing in the stratosphere which results in a reversal of the eastward stratospheric jet.
- This reversal of the stratospheric jet then results in a change in GWF from westward to eastward in the mesosphere driven by non-orographic waves as the orographic gravity waves are filtered out at the zero wind line.
- The residual circulation shows strong down-welling in the stratosphere leading to adiabatic warming and upwelling in the upper stratosphere and mesosphere leading to adiabatic cooling of the mesopause region during the SSW event.
- The net forcing in the upper mesosphere becomes eastward due to the eastward GWs which reverses the westward jet and helps in the formation of the elevated stratopause.
- After the formation of the elevated stratopause, the eastward stratospheric jet, meridional circulation and GWF are all much more robust than before the onset of the SSW.