Stratospheric Sudden Warmings and blocking in WACCM

Rolando Garcia
NCAR/ACD

Outline

- Model description
- Turbulent mountain stress (TMS)
- SSW climatology
- SSW and blocking
- Blocking and TMS
- Summary

Whole Atmosphere Community Climate Model

Model Framework	Dynamics	Tracer Advection	Resolution	Chemistry	Other Processes
Based upon NCAR Community Atmosphere Model, CAM4 Part of the NCAR Community Earth System Model, v.1	Finite Volume Dynamical Core (Lin, 2004) Fully-interactive, i.e., consistent with model-derived, radiatively active gases: O_3, CO_2, CH_4, N_2O, H_2O, CFC11, CFC12, O_2, NO QBO may be specified from observations Coupled to full ocean model (NCAR POP)	Flux-form Finite Volume (Lin, 2004)	Horizontal: 1.9° x 2.5° or 4.0° x 5.0° (lat x lon) Vertical: 66 levels 0-140km < 1.0km in UTLS 1-2 km in stratosphere 3 km in MLT	Middle Atmosphere Mechanism 57 Species including Ox, HOx, NOx, BrOx, and ClOx No NMHCs Includes het. chemistry on LBS, STS, NAT, ICE E-region Ion Chemistry	Gravity-wave parametrization (for unresolved, mesoscale gravity waves) Molecular diffusion (Banks and Kockarts, 1973) Auroral processes, including ion drag, and Joule heating Longwave, shortwave, and chemical potential heating

TMS parameterization

A convenient and practical way to implement the effective roughness is to calculate an additional surface stress, expressed as

$$\tau = \rho C_d |\mathbf{V}|\mathbf{V}, \qquad (1)$$

where ρ is the density, $\mathbf{V}$ is the horizontal wind vector in the bottom atmospheric layer, and C_d is the drag coefficient. calculated as

$$C_d = \frac{f(R_i)k^2}{\ln^2[(z + z_0)/z_0]}, \qquad (2)$$

where k is the von Kármán constant, z is the height of orography above the surface, and z_0 is an effective roughness length that represents unresolved topography and is estimated from the following:

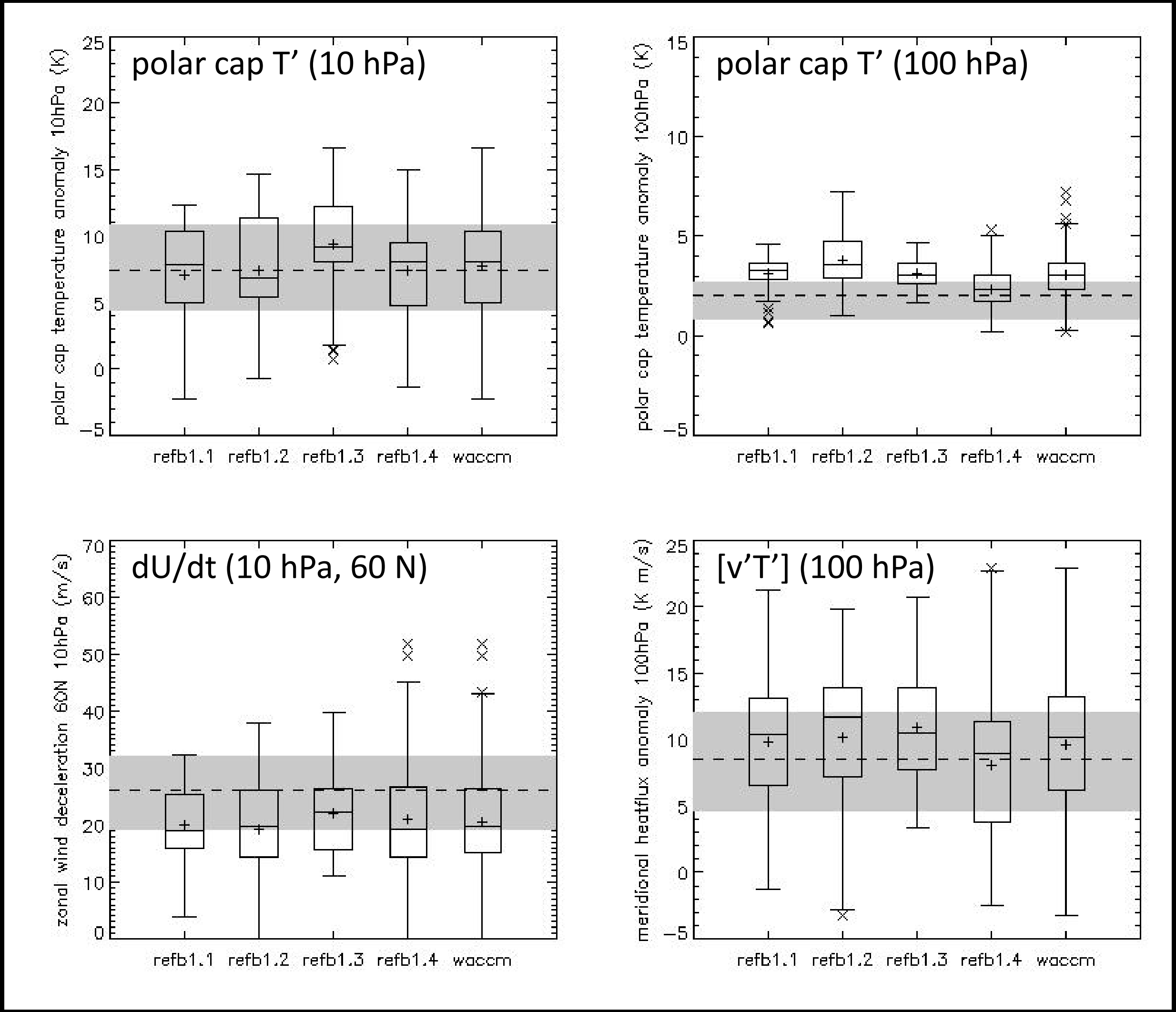
$$z_0 = \min(0.1\sigma, 100). \qquad (3)$$

In the above, σ is the standard deviation of subgrid orography, expressed in meters. In (2), $f(R_i)$ is a function of the Richardson number ($R_i = gT_z/(T\,|\mathbf{V}_z|^2)$: $f(R_i) = 1$ if $R_i < 0$; $f(R_i) = 0$ if $R_i > 1$; and $f(R_i) = 1 - R_i$ if $0 < R_i < 1$.

Richter et al. (*JAS*, 2010)

- TMS: “turbulent mountain stress”
- The parameterization is intended to account for the effect of unresolved topography
- Uses a von Kármán frictional boundary layer formulation where the roughness length is dependent on the s.d. of sub-grid scale topography

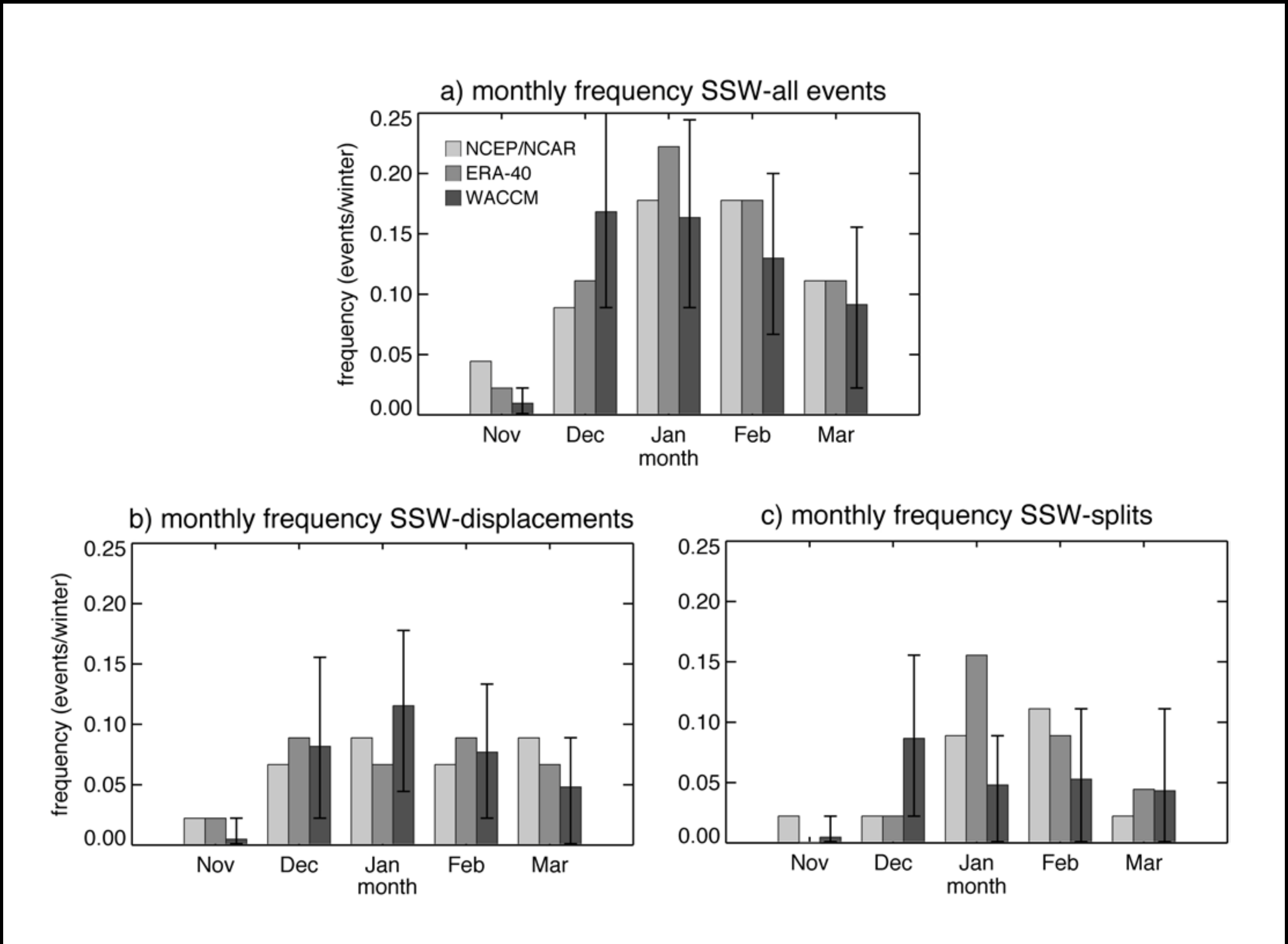
SSW "benchmarks" for refb1



de la Torre et al. (*JGR*, 2012, in press)

- results for CCMVal-2 refb1 simulations (de la Torre et al., 2012)
- boxes show the inter-quartile range
- bars show the extremes of the distribution
- gray-shadowed area shows results from observations (Charlton et al., 2007)

WACCM SSW frequency vs. Observations



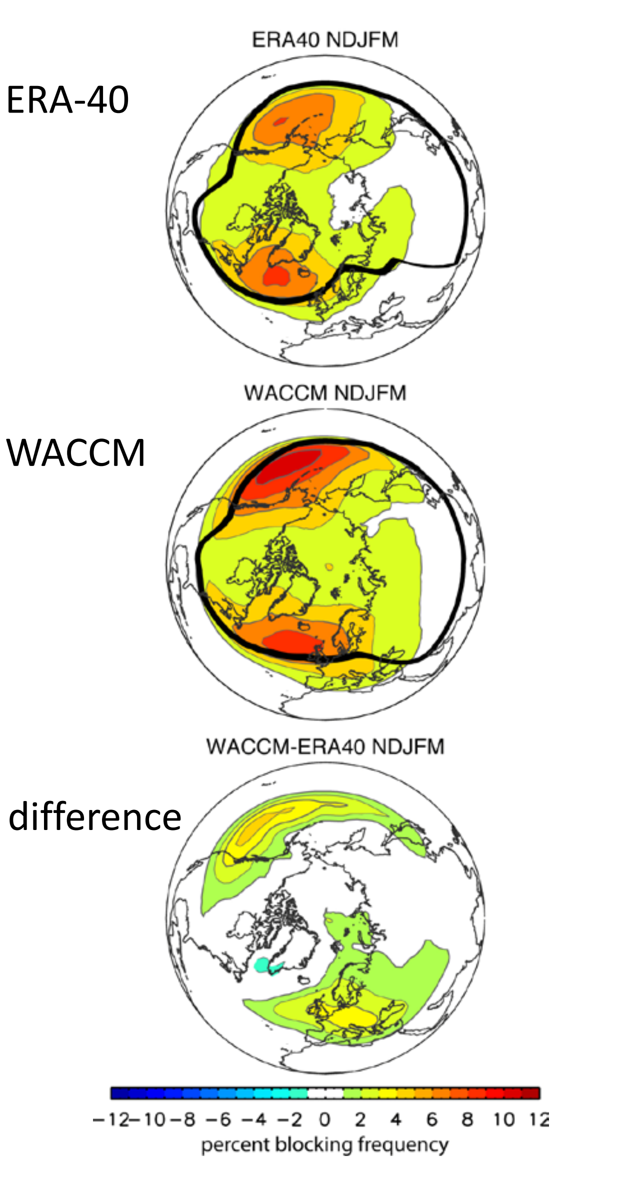
de la Torre et al. (*JGR*, 2012, in press)

- WACCM results for CCMVal-2 refb1 simulations (de la Torre et al., 2012)
- observational results from Charlton et al. (2007)
- error bars in WACCM results comprise 90% of Monte Carlo test distribution
- “displacements” are dominated by wave-1, “splits” are dominated by wave-2

SSW frequency across WACCM runs

case	SSW/year	remarks
refb1.1	0.69	CCMVal-2, 1953-2005
refb1.2	0.45	CCMVal-2, 1953-2005
refb1.3	0.49	CCMVal-2, 1953-2005
refb1.4	0.67	CCMVal-2, 1953-2005
refb2.1	0.58 / 0.62	CCMVal-2, 2000-2049 / 2050-2099
refb2.2	0.66 / 0.52	CCMVal-2, 2000-2049 / 2050-2099
refb2.3	0.78 / 0.58	CCMVal-2, 2000-2049 / 2050-2099
ar5.1	0.50	coupled ocean, 1955-2005
ar5.2	0.37	coupled ocean, 1955-2005
ar5.3	0.52	coupled ocean, 1955-2005
ar5 no TMS	0.22	coupled ocean, 1955-2005, TMS off

WACCM blocking climatology



- blocking frequency computed from the block detection algorithm of Castanheira and Barriopedro (2010); based on PV anomalies
- WACCM reproduces reasonably well the observed frequency of blocking, but has high biases with respect to ERA-40 in the N. Pacific and Eurasia

de la Torre et al. (*JGR*, 2012, in press)

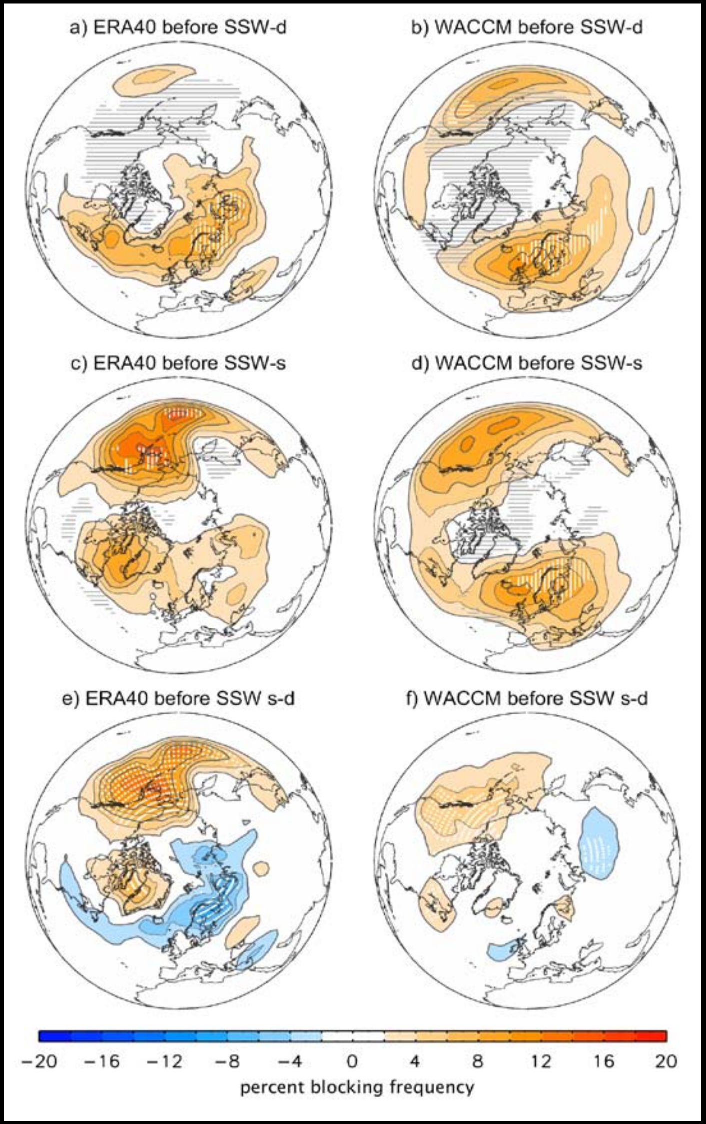
SSW and blocking

ERA-40 WACCM

displacements

splits

difference



- WACCM reproduces the increase in Pacific blocking preceding split SSW
- Pacific blocking preceding displacement SSW is larger than in ERA-40
- difference split - displacement is consistent with observations, but weaker

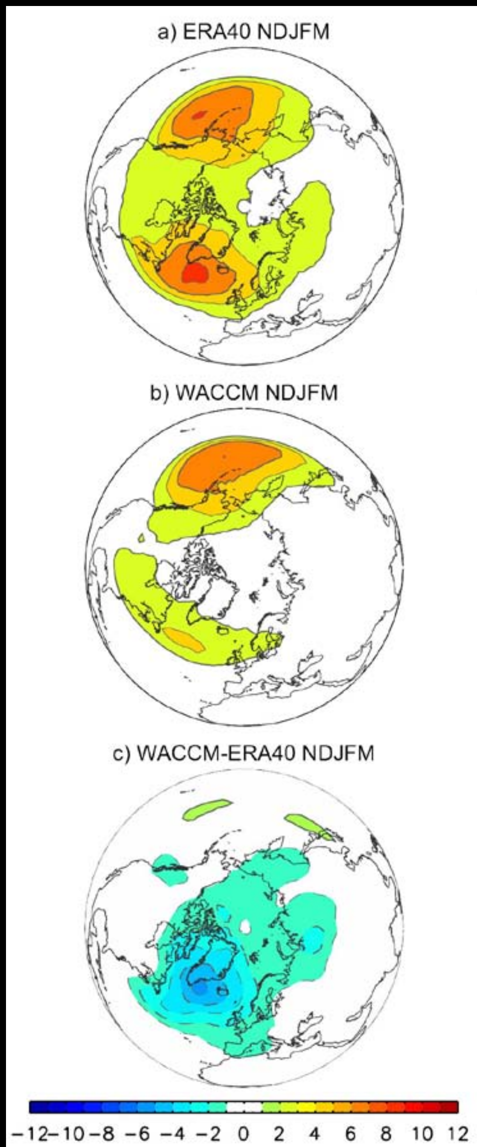
de la Torre et al. (*JGR*, 2012, in press)

TMS parameterization and blocking

ERA-40

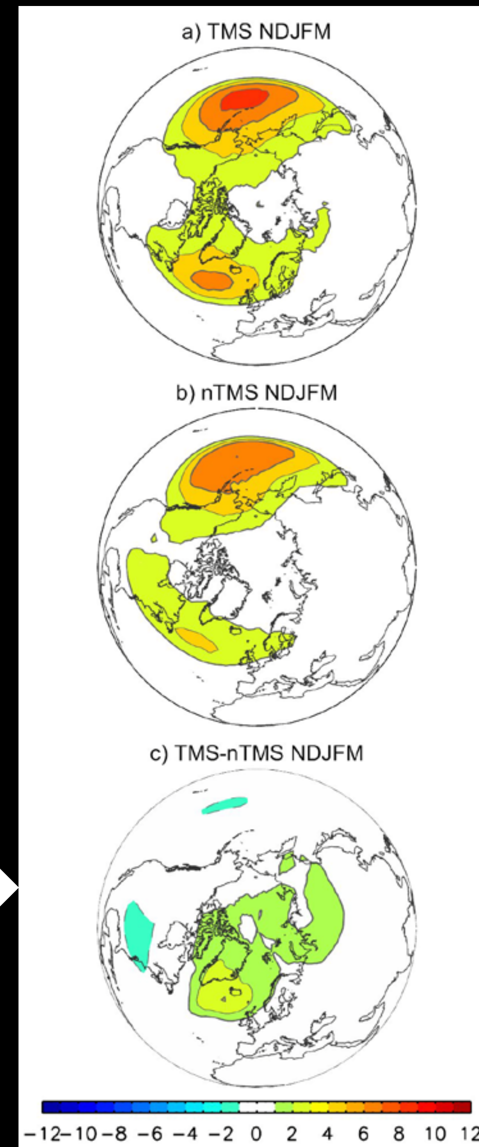
WACCM, no TMS

difference



WACCM with no TMS has a large deficit of North Atlantic blocking compared to ERA-40

addition of TMS increases sharply the frequency of North Atlantic blocking



WACCM

WACCM, no TMS

difference

Summary

- WACCM version 3.5 and later simulates well the observed climatology of SSW
- It also simulates the main features of tropospheric blocking and the association between blocking and SSW
- Improvement in SSW and blocking frequencies is due in large part to the use of a TMS parameterization to model the effects of unresolved topography