Whole Atmosphere Community Climate Model (WACCM) and Its Thermosphere/Ionosphere Extension (WACCM-X)

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Scientific Objectives of WACCM

- Solar impacts on the Earth System.
- Understand and quantify couplings between atmospheric layers through chemical, physical and dynamical processes.
- Implications of the couplings to climate (downward coupling) and to near space environment (upward coupling).

CESM Atmosphere Components

HAO/ACD/CGD WACCMX is WACCM with additional physics and further upward extended vertical range through thermosphere/ionosphere (~500km)

ACD/CGD Whole Atmosphere Community Climate Model (WACCM) is CAM with additional chemistry/physics and upward extended vertical range into lower thermosphere/ionosphere (~140km)

CGD Community Atmosphere Model (CAM) is atmospheric component of CESM

NCAR CGD Community Earth System Model (CESM)

Major WACCM/WACCM-X Components

| Model Framework	Chemistry	Physics	Physics	Resolution
Extension of the NCAR Community Atmosphere Model (CAM) Finite Volume Dynamical Core	MOZART+ Ion Chemistry (~60 species) Fully-interactive with dynamics.	Long wave/short wave/EUV RRTMG IR cooling (LTE/non-LTE) Modal Aerosal CARMA Parameterized GW Major/minor species diffusion (+UBC) Molecular viscosity and thermal conductivity (+UBC) Species dependent Cp, R, m.	Parameterized electric field at high, mid, low latitudes. IGRF geomagnetic field. Auroral processes, ion drag and Joule heating Ion/electron energy equations Ambipolar diffusion Ion/electron transport due to Lorentz force Ionospheric dynamo Coupling with plasmasphere/magnetosphere	Horizontal: 1.9° x 2.5° (lat x lon configurable as needed) Vertical: 66 levels (0-140km) 81/125 levels 0-~500km • < 1.0km in Upper Troposphere/ Lower Stratosphere • 1-2 km in strat. • 0.5 scale height in mesosphere/ thermosphere (0.25 scale height in mesosphere/thermosphere with 125 levels)

Development Updates

- Model development:
  - WACCM5-FV test (25-year run completed)
  - WACCM4-SE (ne30) test (5-year run completed)
  - WACCM/DART
  - WACCM/WACCM-X with specified dynamics (SD)
  - WACCM with Specified Chemistry (SC-WACCM)
  - WACCM Component Set with reduced complexity/reduced resolution above the mesosphere (Discussion).

- Science modules:
  - WACCM Chemistry updates.
  - Ionosphere module development.
  - Global electric circuit.
  - Lunar gravitational tide.
  - Inertial gravity wave parameterization.

Assessment/Production Simulations

- CMIP5: CCSM4/WACCM4 (data released)
- Stratosphere Processes and their Role in Climate (SPARC)
  - SD-WACCM/MERRA (back to 1979): Polar stratosphere and UTLS studies.
  - CCMI: ozone depletion and recovery trend.
  - SOLARIS: Sensitivity to solar spectral irradiance.
  - APSiC: Stratosphere aerosals and climate
- Geo-engineering: GeoMIP.
- Large-ensemble runs (1900-2100).
- Paleoclimate runs (last Millennium).

Some Research Highlights
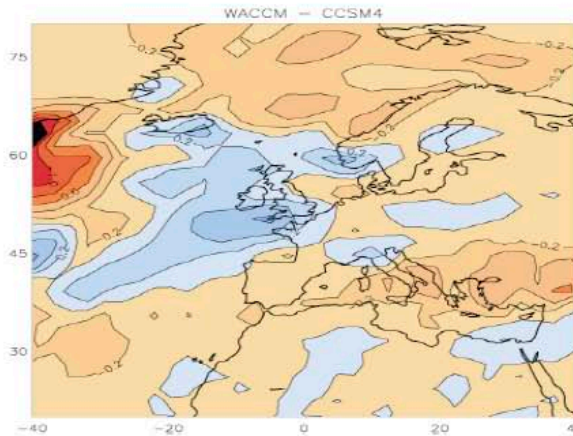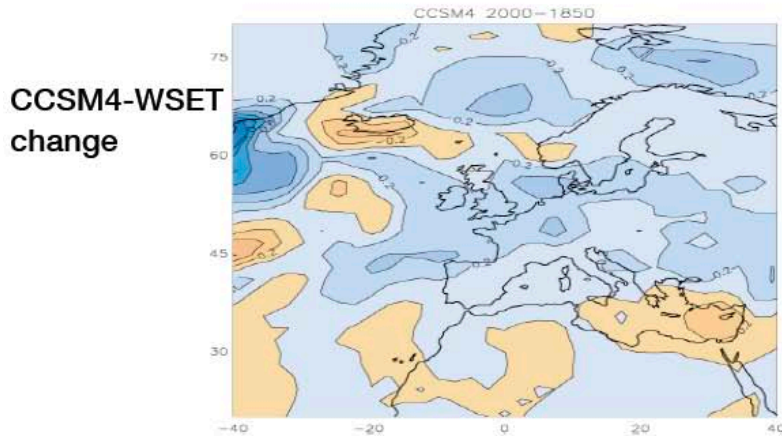
Turbulence Mountain Stress, SSW and Blocking
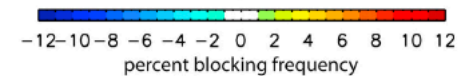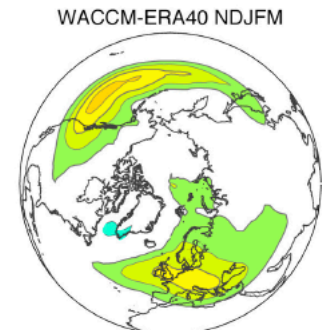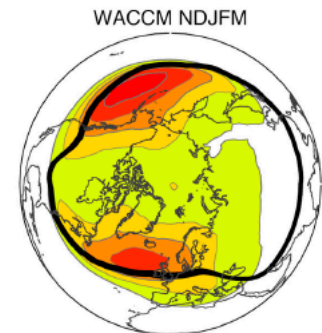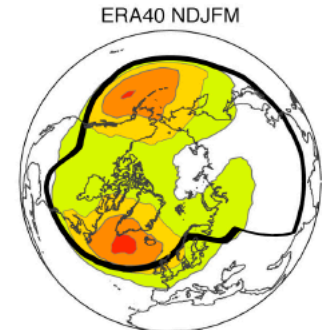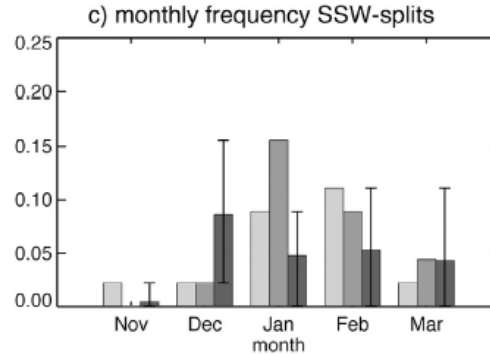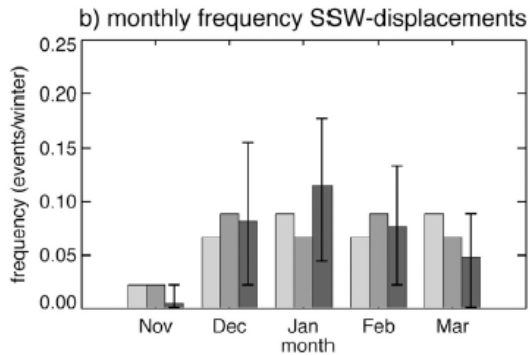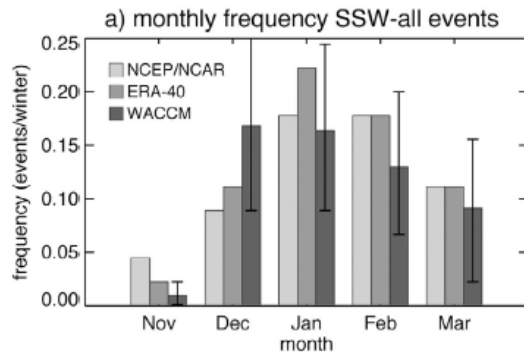
De la Torre et al. (2012)

CMIP5: WACCM4 vs CCSM4
Impact of Stratosphere-Troposphere Coupling on Regional Climate Change?

Change in winter mean rainfall (mm/day)
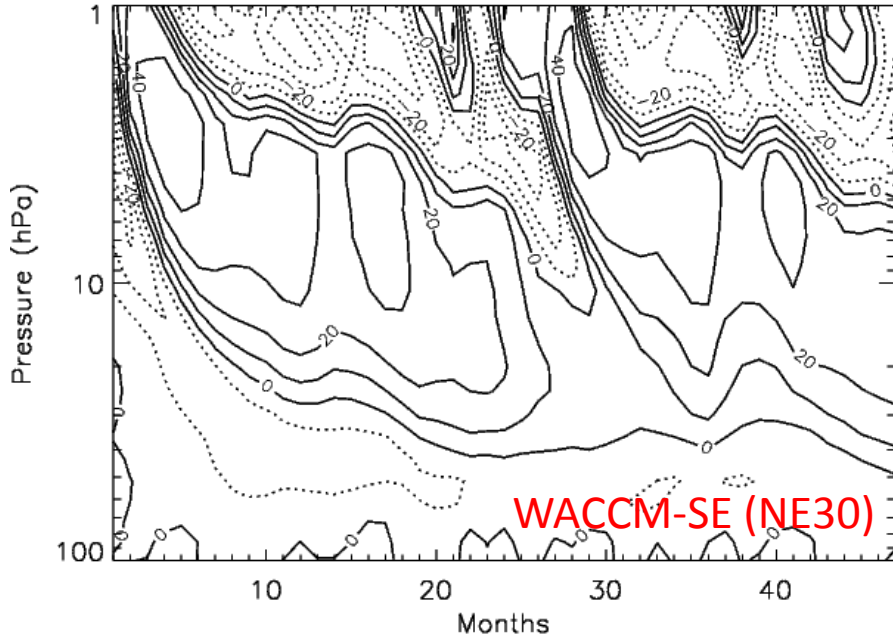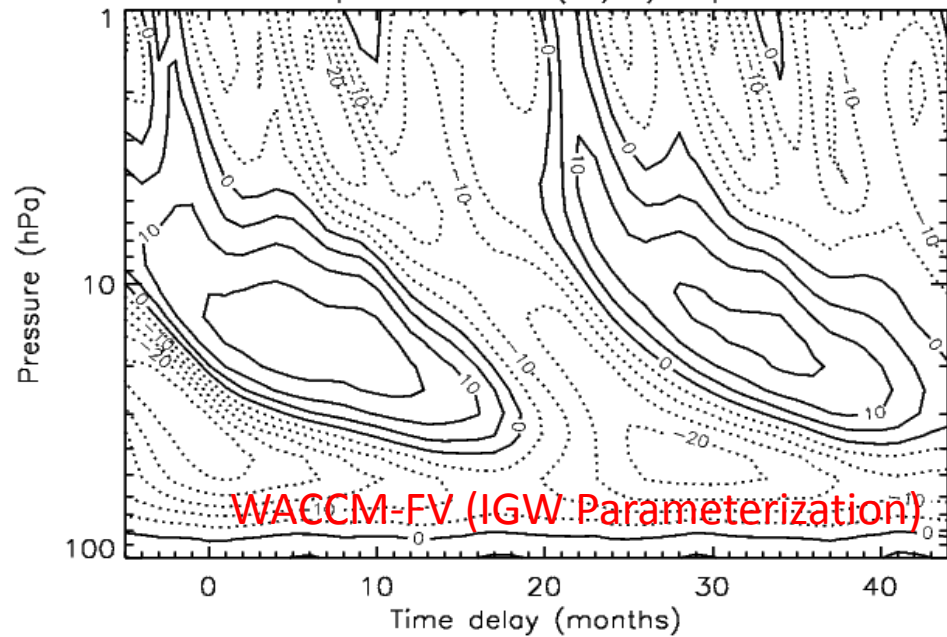

CCSM4-WSET change

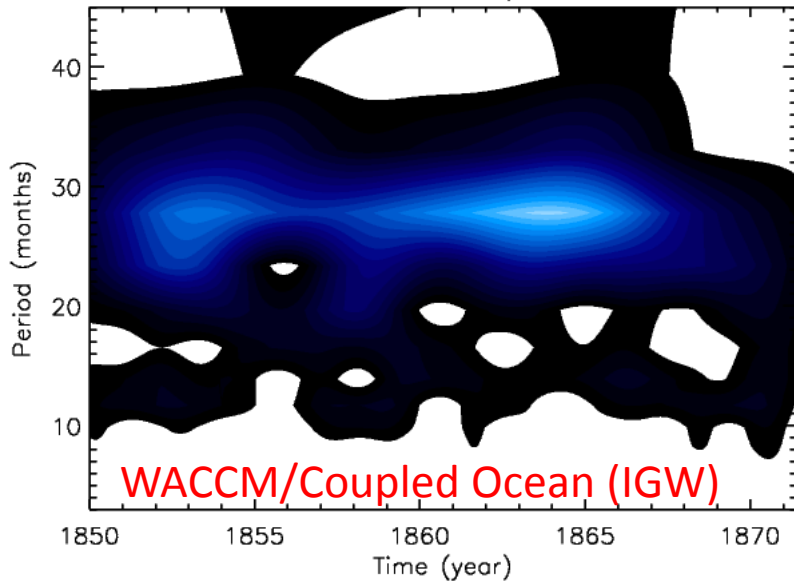WACCM - CCSM4-WSET

Courtesy of Dan Marsh

Zonal Mean U: Equator

Ubar at equator, WACCM-SC-SE

WACCM-SE (NE30)

composite ubar (m/s) equator

WACCM-FV (IGW Parameterization)

Wavelet Power Spectrum

WACCM/Coupled Ocean (IGW)

Wavelet Power Spectrum

WACCM/SST (IGW)
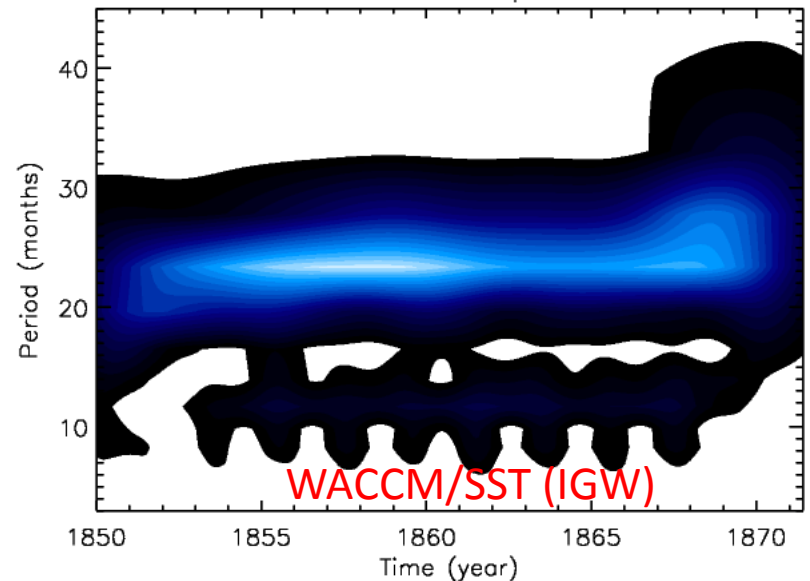
Cold Pole Bias: Missing Gravity Wave Forcing

Tan et al (in preparation)
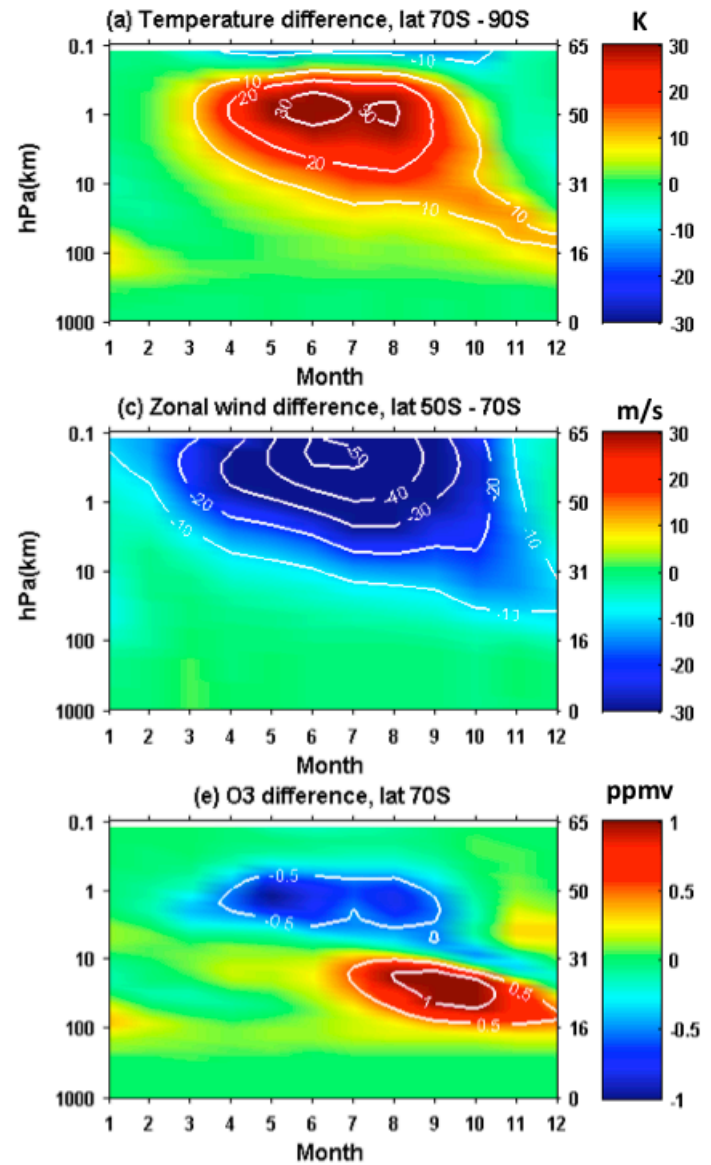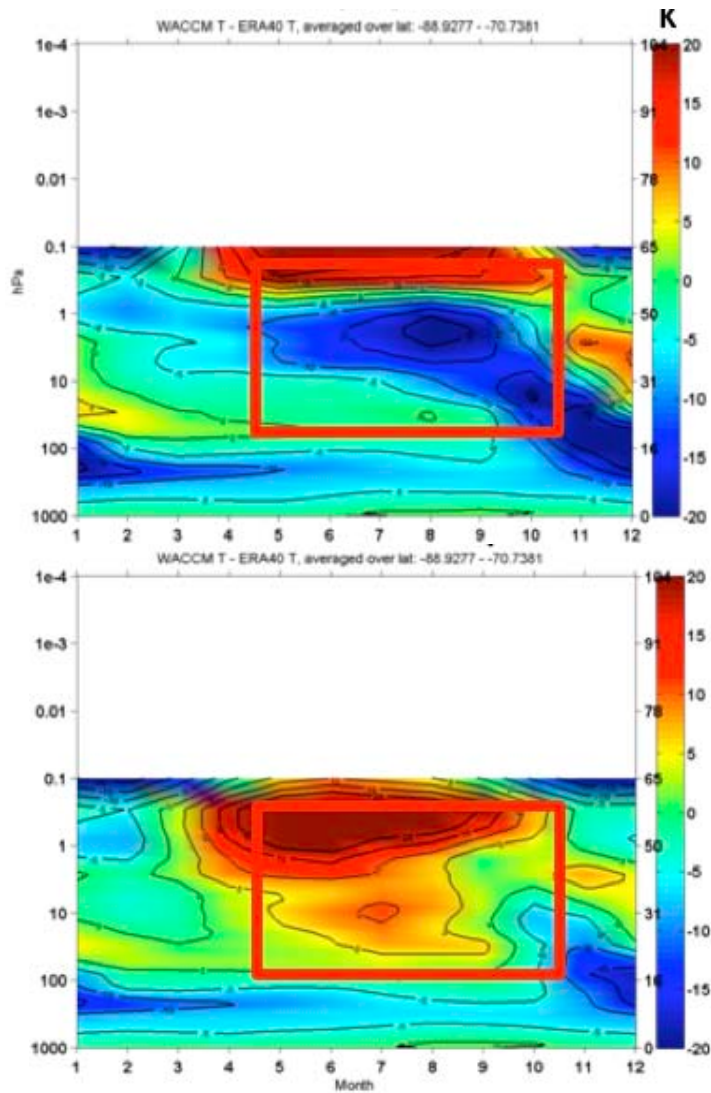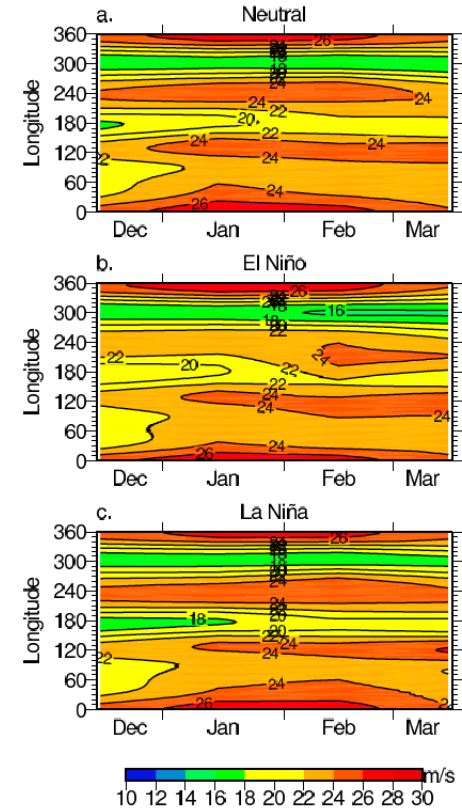
ENSO Impacts on Upper Atmosphere
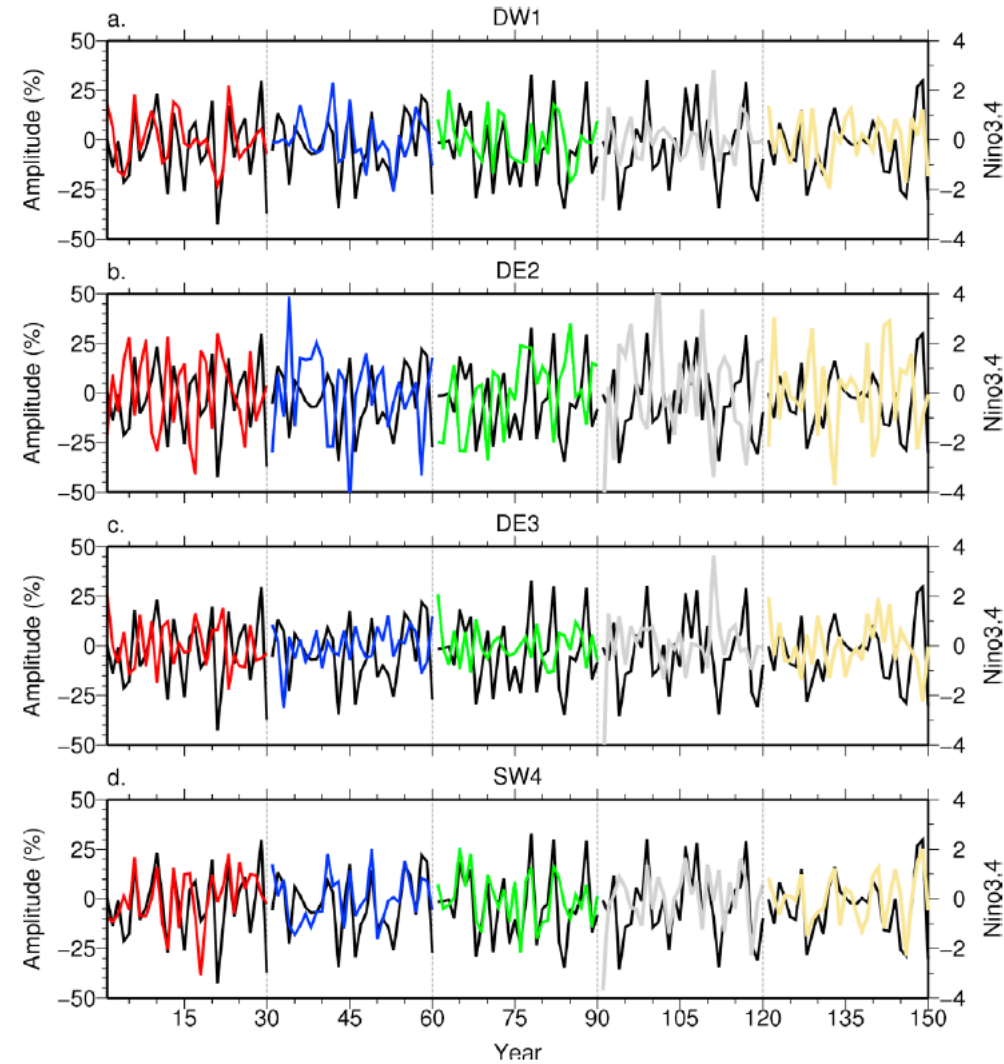
Pedatella and Liu, 2012

Figure 8. TIME-GCM vertical E x B drift velocity at the magnetic equator and 300 km for (a) neutral, (b) El Niño, and (c) La Niña time periods. The results are for 11 local time.

Pedatella and Liu, 2013

System Coupling (and associated biases)

- Possible role of middle atmosphere on regional climate.
- Turbulent mountain stress (TMS) and statistics of SSW and troposphere blocking.
- Heating/cooling caused by volcano eruption.
- Absence/bias in resolving QBO.
- Cold pole bias in the polar stratosphere (especially SH).
- Bias in mesopause/lower thermosphere temperature and winds: mean structure, variability and tides.
- Thermosphere/ionosphere variability: ENSO, QBO, SSW/planetary waves, and day-to-day scales.