Application of the pseudo-global warming methodology to extreme tornadic storm events

R. J. Trapp and K. H. Hoogewind
University of Illinois at Urbana-Champaign

ILLINOIS

jtrapp@illinois.edu

Introduction

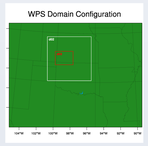
Consistent with previous research, the latest (CMIP5) simulations of future climate under enhanced radiative forcing indicate that the number of days supportive of severe thunderstorms in the U.S. will continue to increase during the 21st Century (Diffenbaugh et al. 2013, PNAS).

An open question, however, is whether the environmental change will lead to a change in the specific frequencies and intensities of the individual severe-thunderstorm phenomena. Of particular interest here is the effect of anthropogenic climate change on tornadoes and tornado-bearing storms, particularly supercellular storms. Here we ask: ***Will the (tornadic) supercells of yesterday and today be the (nontornadic) squall lines of tomorrow?***

We attempt to address this question by simulating current-day events as if they occurred under a globally warmed climate. This "pseudo-global-warming" (PGW) approach has been used most recently by Lackman (2013, 2015). Here (see Trapp and Hoogewind 2016, JCLIM), we use it to examine the realization of three high-end tornado events.

Methods

1. *Using the Weather Research and Forecasting (WRF) model, perform a control simulation of the tornado event. Notable model details are as follows:*
   - *initial/boundary conditions (ic/bc) from six-hourly NAM-Analysis (NAM-ANL)*
   - *doubly nested domain, with 3 km (d01) – 1 km (d02) grid lengths*
   - *70 vertical levels*
   - *Morrison double moment microphysical parameterization (with hail)*



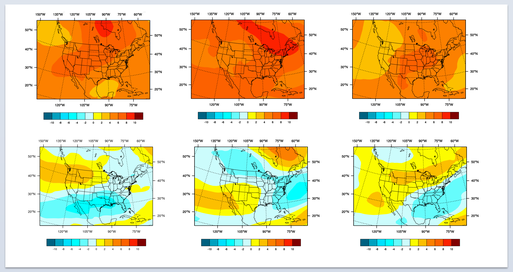
2. *Perform pseudo-global warming simulations, using NAM-ANL conditions modified by a climate change Δ from CMIP5 simulations: e.g., for the temperature (T) ic/bc, we let*

$$T_{ic/bc}(x,y,z,t) = T_{ic/bc}(x,y,z,t) + \Delta T$$

where

$$\Delta T = \overline{T(x,y,z)}_{future} - \overline{T(x,y,z)}_{past}$$

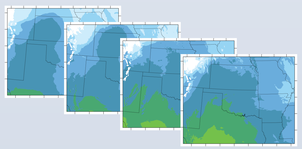
Here, the overbars indicate (monthly; May) averages over a future and past period of 2090-2099 and 1990-1999, respectively. The MIROC5, GFDL-CM3, and NCAR-CCSM4 contributions to CMIP5 were used to create separate Δ's that were then used for three separate simulations.



MIROC5 GFDL-CM3 NCAR-CCSM4

Δ's

+ time-dependent forcing of an event



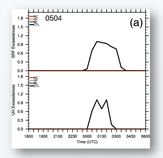
= PGW modified state

Results

Three high-end tornado events were chosen:

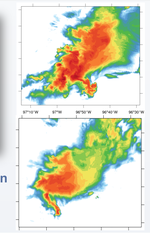
EF-5 Greensburg, Kansas tornado of 4 May 2007
EF-5 Norman, Oklahoma tornado of 10 May 2010
EF-4 Shawnee, Oklahoma tornado of 19 May 2013

We used time series of updraft helicity (UH) (>150 m^2/s^2) and reflectivity (>40 dBZ) counts to confirm supercellular mode in the PGW experiments.



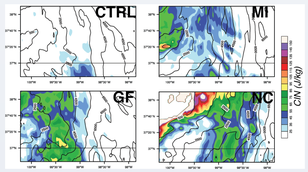
none of the 0504 PGW runs initiated significant deep convective storms

a change in convective morphology did not occur in any of the PGW experiments with significant convective storminess



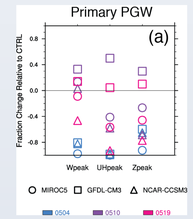
The convective inhibition (CIN) was larger in all of the PGW runs in the 0504 case. However, it was the combined effects of increased CIN and decreased parcel lifting under PGW that led to a failure of convection initiation in each of the PGW runs in the 0504 case (as well as in runs in the 0510 and 0519 cases).

The convective available potential energy (CAPE) was also larger in all of the PGW runs.



Summary of peak values in the PGW experiments:

- 3 of the 4 PGW runs with supercells had more intense updrafts than CTRL
- Of these, the GFDL-PGW runs were most likely to have more intense updrafts, with stronger rotation (larger updraft helicity)
- These GFDL-PGW runs also had higher peak vertical vorticity
  - **PGW led to more intense supercells, with stronger rotation**

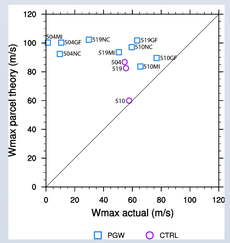


Discussion

On storm intensity:

If supercellular convection was generated under PGW, it was associated with strong updrafts, but these updrafts tended to *realize relatively less parcel buoyancy* than those of CTRL. We determined that this was due to enhanced precipitation loading in the PGW storms.

From parcel theory:
$w_{max} = (2xCAPE)^{1/2}$



Main Conclusions

Will the supercells of yesterday and today be the squall lines of tomorrow?

For this limited sample, the answer is no. In these significant events, the reduction of vertical wind shear (in two of the CMIP5 members) was insufficient to cause a change in the convective mode.

Will the supercells of yesterday and today be more intense in the tomorrow?

The answer depends on whether the supercell storm can even form. But if they can, they will generally have stronger updrafts. The strength will not, however, be in proportion to the projected higher levels of CAPE under PGW.