An Overview of the NARCCAP WRF Simulations

L. Ruby Leung, James Correia*, Yun Qian

Pacific Northwest National Laboratory

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What is WRF

- WRF is a supported "community model" that stands for Weather Research and Forecasting model – a free and shared resource with distributed development (NCAR, NOAA, AFWA, FAA, NRL, …) and centralized support (NCAR)
- Since version 2.1 (2005), WRF has two dynamical cores: ARW and NMM – both non-hydrostatic, Eulerian mass, with terrain following vertical coordinates
- The NARCCAP WRF simulations are based on WRFV2.0.1 (ARW dynamical core) (also used in the NRCM tropical channel simulations)
- Features added to WRFV2.0.1 (now mostly available in WRFV3.1+):
  - CAM3 radiation (prescribed spatially uniform aerosol concentrations and monthly/latitudinally varying ozone concentration)
  - Background surface albedo changes between summer/winter seasons
  - Prescribed seasonal changes in vegetation cover
  - Updating SST and sea ice in the lower boundary condition
  - Cloud fraction following Xu and Randall (1996) instead of 0/1

What is WRF

- Features added to WRFV2.0.1 (cont'd):
  - Output accumulated instead of instantaneous fluxes for budget analysis (plus added clear sky / total sky fluxes)
  - Prognostic deep soil temperature based on Salathé et al. (2008), where α = 0.6 and n = 140

$$T_{soil} = \alpha \langle T_{skin} \rangle_{365} + (1-\alpha) \langle T_{skin} \rangle_{n}$$

  - Use of linear-exponential functional form for the nudging coefficients in the relaxation boundary conditions with a 10-grid point wide buffer zone
  - CO_2 concentration temporally interpolated from time series of annual mean CO_2 concentration based on the GCM scenarios
  - For downscaling CCSM – used 365 day calendar
- Most "climate" implementations are incorporated in the standard WRFV3

WRF configurations:

- Physics options:
  - Radiation: CAM3 for both shortwave and longwave
  - Boundary layer turbulence: A nonlocal scheme based on YSU
  - Cloud microphysics: mixed phase (wsm4) – water, ice, snow, rain
  - Cumulus convection: Grell-Devenyi scheme (WRFG)
    - Also used Kain-Fritsch for a simulation driven by reanalysis (WRFP)
    - For consistency with the GCM downscaled runs, WRFG should be used as the “standard”
  - Land surface model: Noah LSM; No lake model
    - Lake surface temperature prescribed based on reanalysis/GCM SST linearly interpolated from coast to coast to the locations of lakes
    - In the CCSM driven future climate run, lake temperature was inadvertently prescribed based on skin temperature from CCSM, which is only representative of temperature of larger lakes simulated by CLM
- Grid resolution: 50 km (155x130); vertical levels: 35
- Time step: Between 120s and 150s

WRF initialization:

- For the reanalysis driven runs:
  - Initial atmospheric and land surface conditions are based on global reanalysis
  - Simulations were initialized on 9/1/1979 (only 3 months of model spinup)
  - Lateral and lower boundary (SST and sea ice) conditions are updated every 6 hours based on the global reanalysis
- For GCM driven runs:
  - Initial atmospheric conditions are based on GCMs; initial land surface conditions are based on global reanalysis
  - Lateral and lower boundary conditions updated every 6 hours based on GCMs
  - Allow 2 years of model spinup (e.g., 1/1/1968 – 12/31/1969)

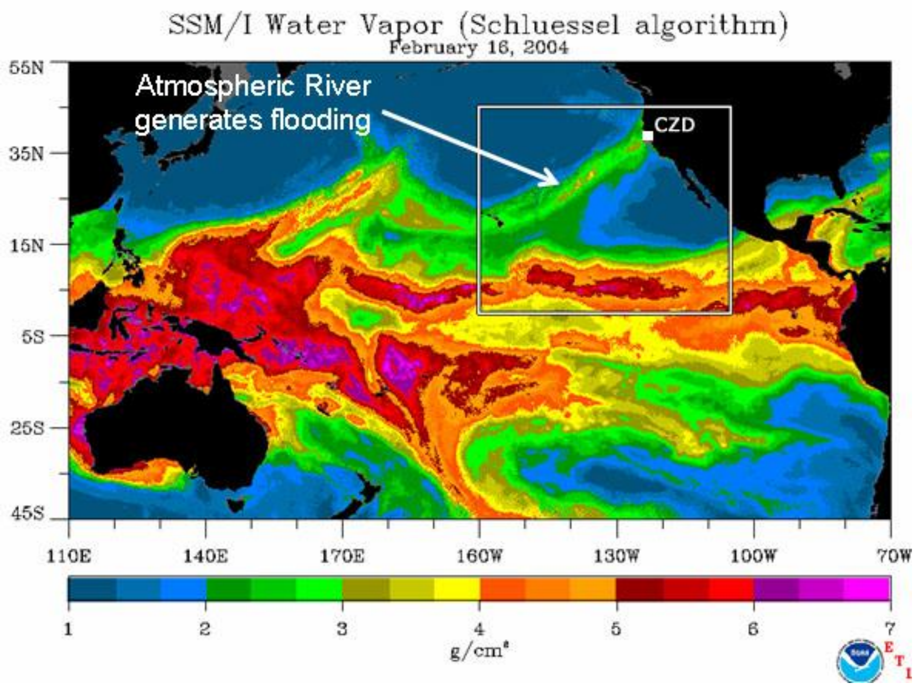
WRF Simulations:

- Completed two simulations driven by NCEP/DOE global reanalysis for 1979/9/1 – 2004/12/31 using GD (WRFG) and KF (WRFP)
- Completed two simulations driven by the CCSM control (1968/1/1 – 1999/12/31) and future (2038/1/1 – 2069/12/31) using GD
- Completed two simulations driven by the CGCM control (1968/1/1 – 2000/12/31) and future (2038/1/1 – 2070/12/31) using GD
- WRF writes two kinds of model outputs:
  - The standard wrfout* files are written every 3 hours (include both 2D and 3D fields) (~ 600 MB/day)
  - Auxiliary output files (aux*) are written every hour (include only some 2D fields) (~ 28 MB/day)
- Model outputs have been postprocessed to generate data for the various NARCCAP tables – data that have undergone checking for missing/bad values are posted on ESG
- Additional variables added to Table 3 for April – September (e.g., CAPE, wind shear, LLJ cat (Bonner), u/v moisture transport, virtual potential temp, pbl mixing ratio)

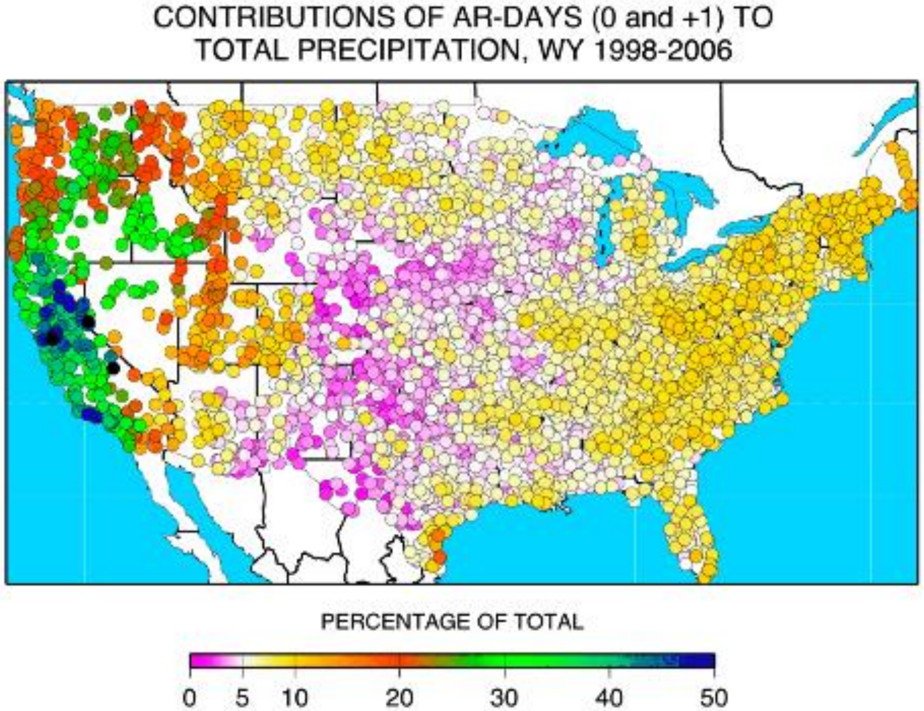
Analysis of WRF simulations

- Atmospheric river induced heavy precipitation and flooding in the western US

Leung, L.R., and Y. Qian, 2009: Atmospheric rivers induced heavy precipitation and flooding in the western U.S. simulated by the WRF regional climate model. *Geophys. Res. Lett*., 36, L03820, doi:10.1029/2008GL036445

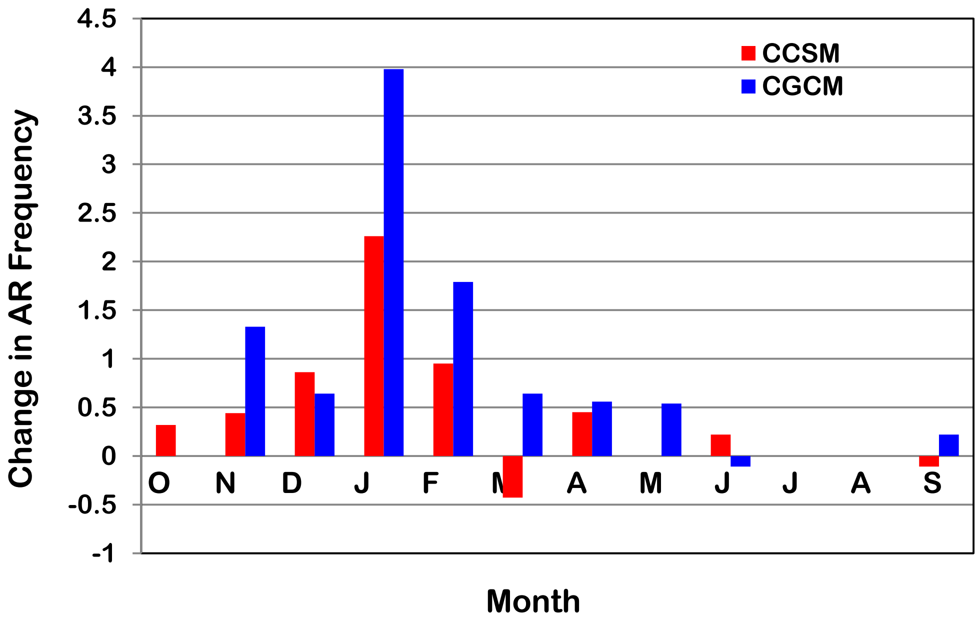


Ralph et al. (2005)



Source: Neiman et al. 2008

GCM simulated AR changes in the future climate



- The number of AR days increases by 27% and 132%, respectively, based on the CCSM and CGCM simulations of current (1970-1999) and future (2040-2069) climate
- CCSM projected larger increase in AR frequency in the north compared to CGCM
- There is a 7 – 12% increase in column water vapor and water vapor flux, with little change in wind speed

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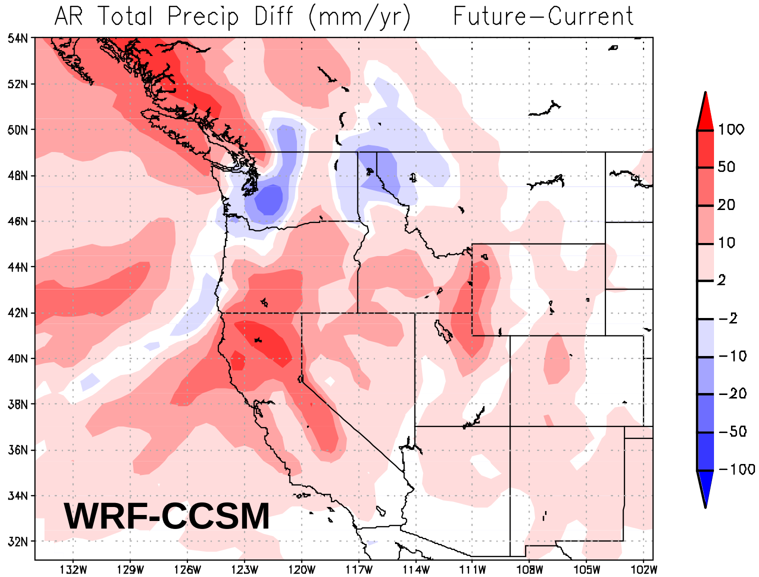
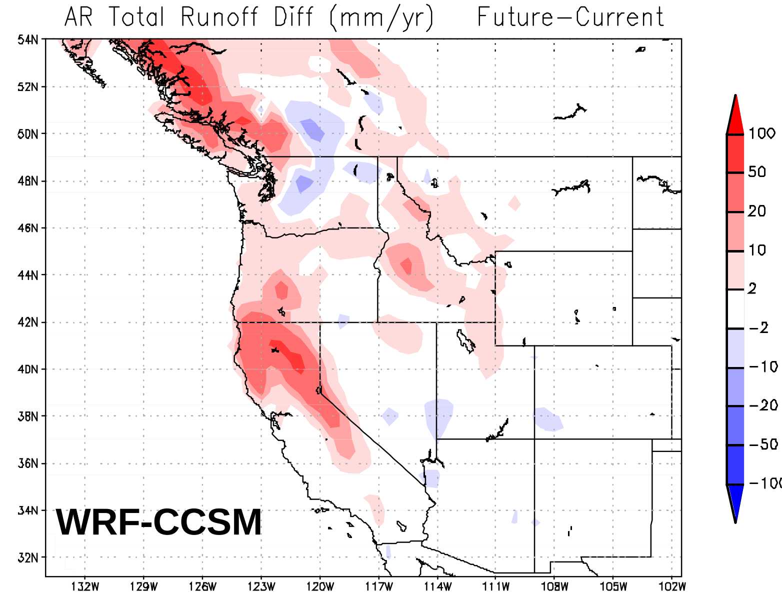
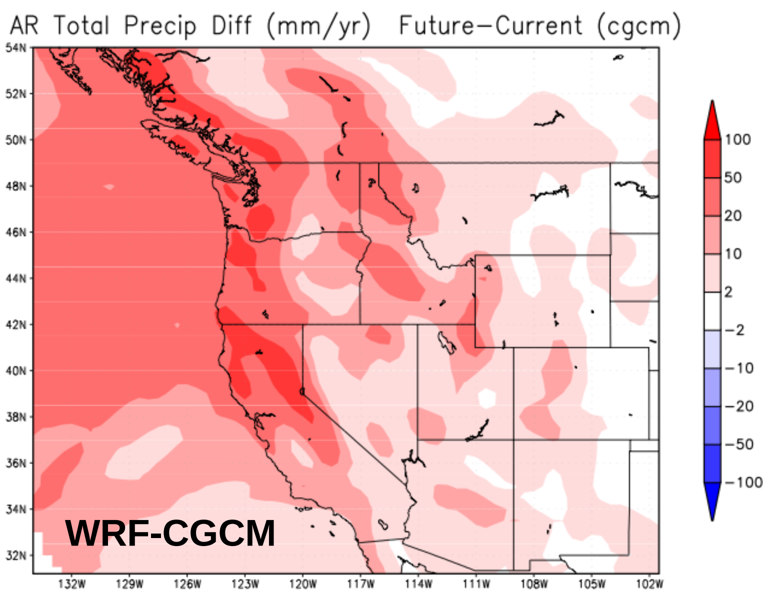
Changes in AR precipitation and runoff

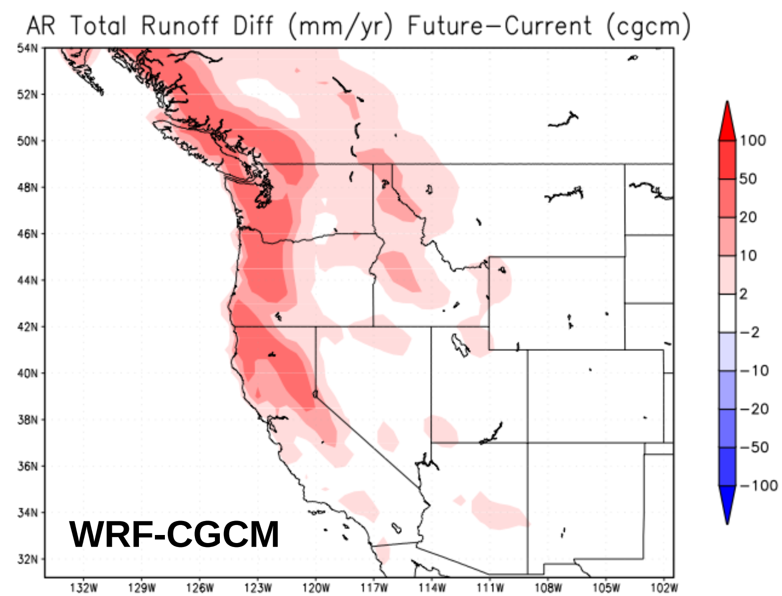
Change in total AR precip



Change in total AR runoff

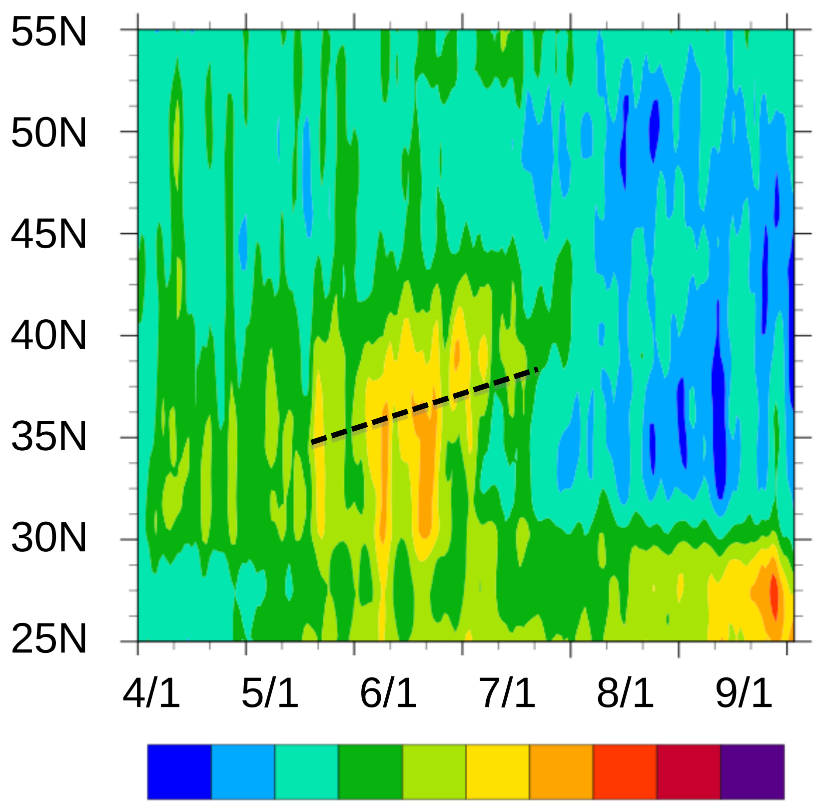




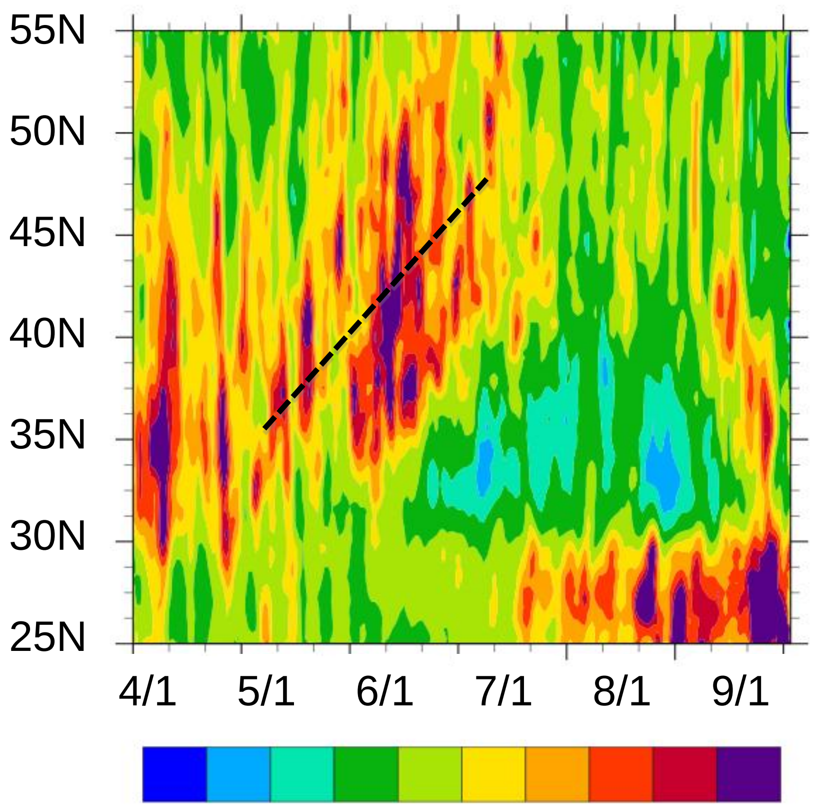


Analysis of WRF simulations

- Correia, J. Jr., and L.R. Leung, 2011: Central US severe weather environment projected under climate change. *J. Clim.*, to be submitted.
- The northward seasonal migration of precipitation from the southern Great Plains to the Midwest is well captured in WRF, but not CCSM, which provided the large-scale boundary conditions for the WRF simulation



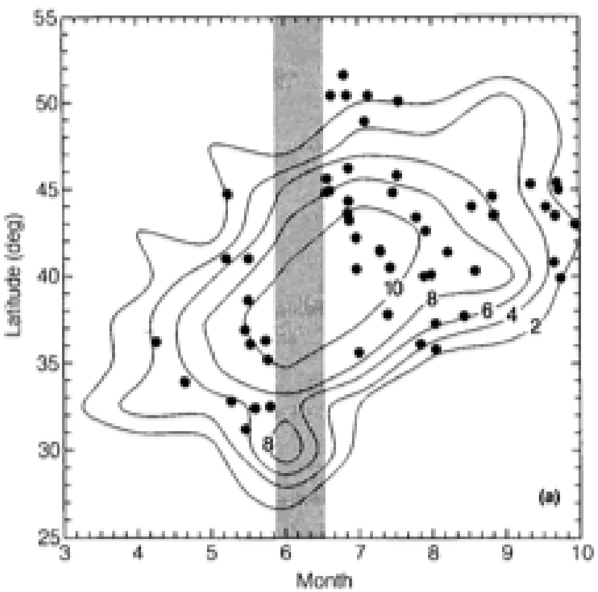
CCSM



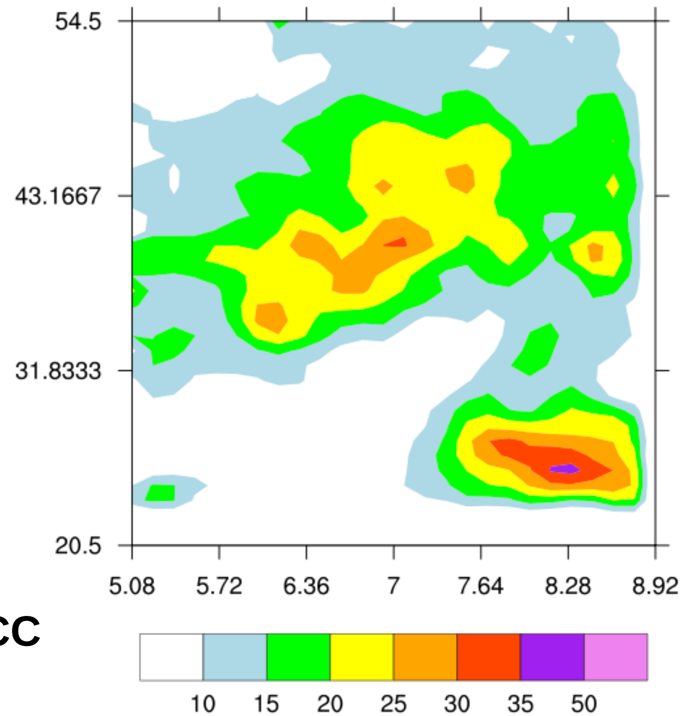
WRF driven by CCSM

Changes in severe weather environment under climate change

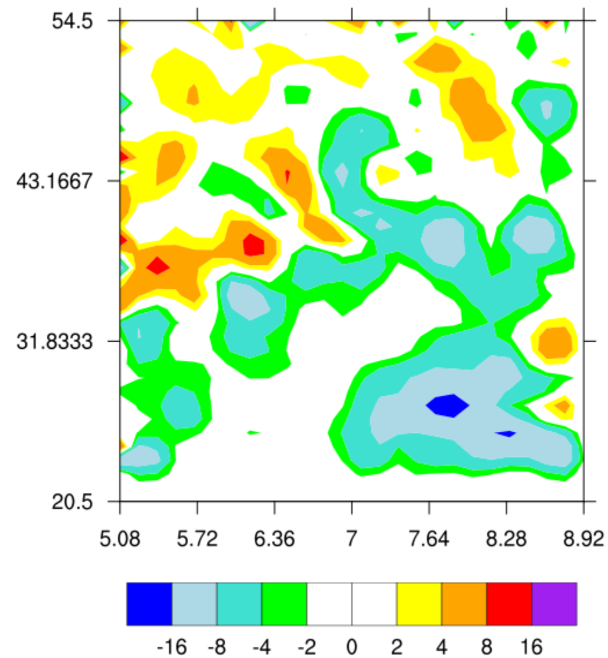
- The northward seasonal migration of mesoscale convective complex (MCC) (and the associated severe weather) is reproduced in the simulation
- The model simulated a general increase in the north and reduction in the south for severe weather environment



Frequency distribution of MCC between 1978 – 1985 (Augustine and Howard 1991)



WRF simulated frequency of MCC-like precipitation objects



WRF simulated changes in frequency of MCC-like precipitation objects between 2040-2070 and 1970-2000