Prediction of Future North American Air Quality

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Outline

- Objectives
- Model Setup
- Model Inputs
- Preliminary Results

Supported by:

NSF EASM - Developing a Next-Generation Approach to Regional Climate Prediction at High Resolution (PI Greg Holland)

NCAR ASD - Accelerated Scientific Discovery Proposal 2012 (PI Gabriele Pfister)

Objectives

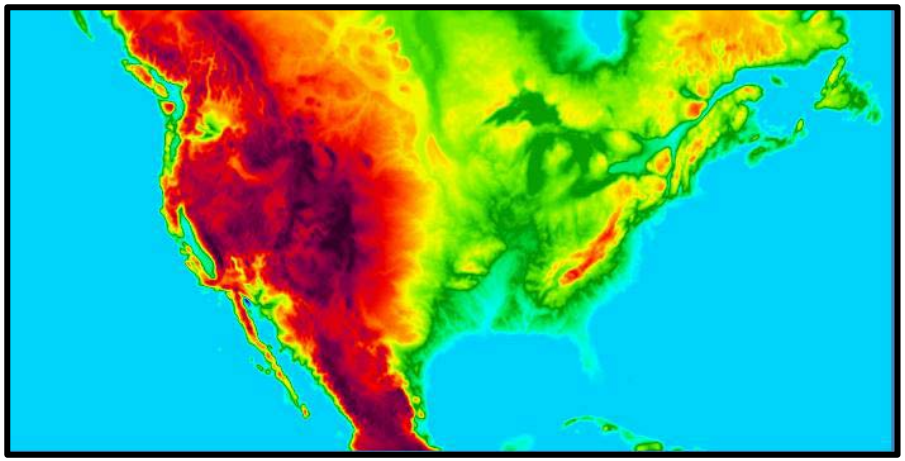
"There is growing recognition that development of optimal control strategies for key pollutants like ozone and PM2.5 requires assessment of potential future climate conditions and their influence on the attainment of air quality (AQ) objectives"

- Changes in weather and air quality over North America between present-day and future.
- Effects of changing emissions and changing climate on AQ

- **Investigate the feedbacks between chemistry and climate**
- **Explore differences in climate metrics when downscaling from global or larger scale simulations with differing physics**

Model Setup

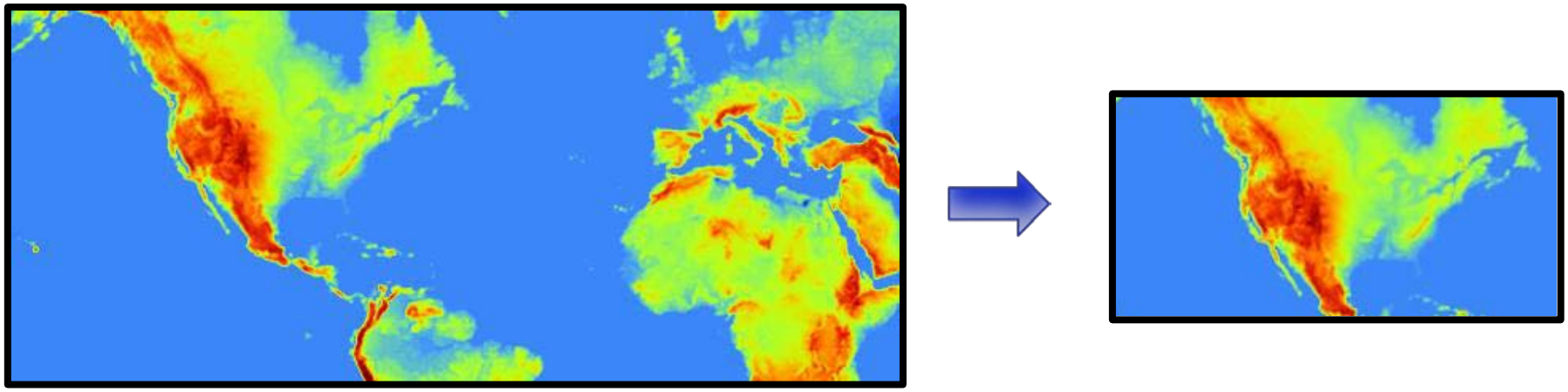
- **NRCM-Chem -- WRF with Chemistry**
  - 10 years present (1996-2005) and future (2046-2055) RCP8.5
  - Season: 1 April – 1 Oct
  - 12 x 12 km^2 (697 x 394); 51 vertical levels (up to 10 hPA)



  - Gas-Phase Scheme: Reduced Hydrocarbon Scheme
  - Aerosols: Modal Aerosol Model (MAM-3); direct and indirect effects
  - CAM-5 microphysics and PBL Scheme

Model Setup

- **Meteorological IC & BC**
  - Downscale from NRCM-met simulation 36 x 36 km^2 [Done et al., 1012]



- NRCM-Met:
  - Global climate from CCSM 3; A2 scenario (CMIP3, Meehl et al. 2007).
  - Bias Correction of CCSM data prior to simulation
  - *"Regional climate physical processes and thus predictions are highly dependent on the domain size, location and resolution of the limited area model"*

Done et al. (2012): Modeling high-impact weather and climate: Lessons from a tropical cyclone perspective. NCAR/TN-490+STR, 28pp.

Model Setup

- **Chemical IC & BC**
  - CAM-Chem RCP8.5, 1.9° x 2.5° [Lamarque et al., 2011]
  - Monthly means for 2000 and 2050

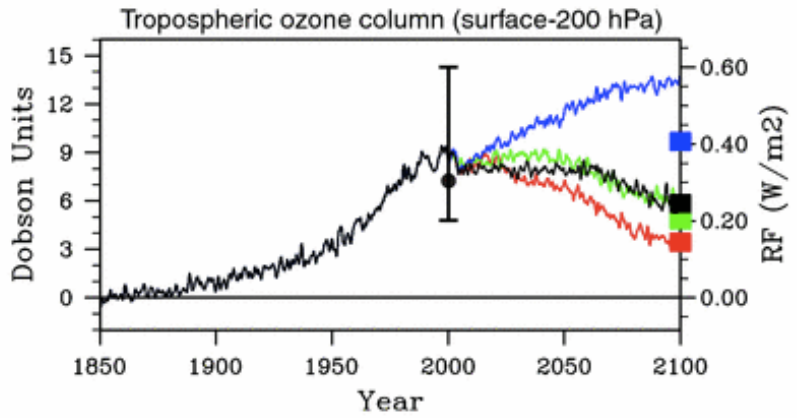


Fig. 4 Time evolution of the globally averaged tropospheric ozone column (and associated radiative forcing), shown as the departure from the 1850 mean. Red curve: RCP2.6. Green curve: RCP4.5. Black curve: RCP6. Blue curve: RCP8.5. Filled squares at year 2100 indicate the MAGICC estimated radiative forcing for each corresponding RCP. In addition, the AR4 mean and range estimates of the tropospheric ozone forcing are added (black line). Note that the AR4 and MAGICC estimates have been corrected by -0.05 W/m^2 to take into account the radiative forcing between 1750 and 1850

  - Upper boundary conditions for O_3, N_2O, ... (present & future)

Lamarque et al.,(2011), Global and regional evolution of short-lived radiatively-active gases and aerosols in the Representative Concentration Pathways, *Climatic Change*, *109*(1-2), 191-212, doi:10.1007/s10584-011-0155-0.

Emissions - Anthropogenic

- IPCC RCP 8.5 Scenario

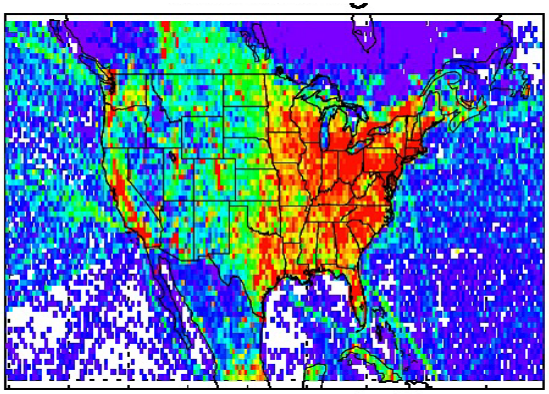
  {NO_x emissions over domain -50%, globally -10%}

- Start with global 0.5° IPCC emissions used in CAM-Chem

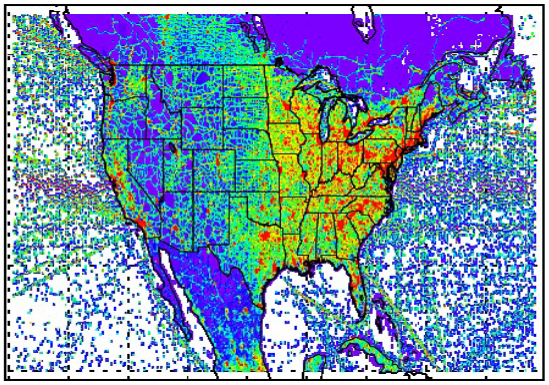
  ➔ re-grid in 2° x 2° segments to 0.1° using EDGAR-4.1[#] spatial distr.

  ➔ mass-conserving mapping to NRCM-Chem domain

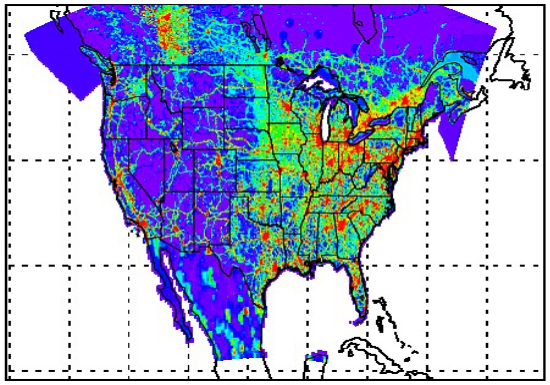
Global Emissions 0.5°



NRCM-Chem 12 km



EPA NEI 2005 4km->12km



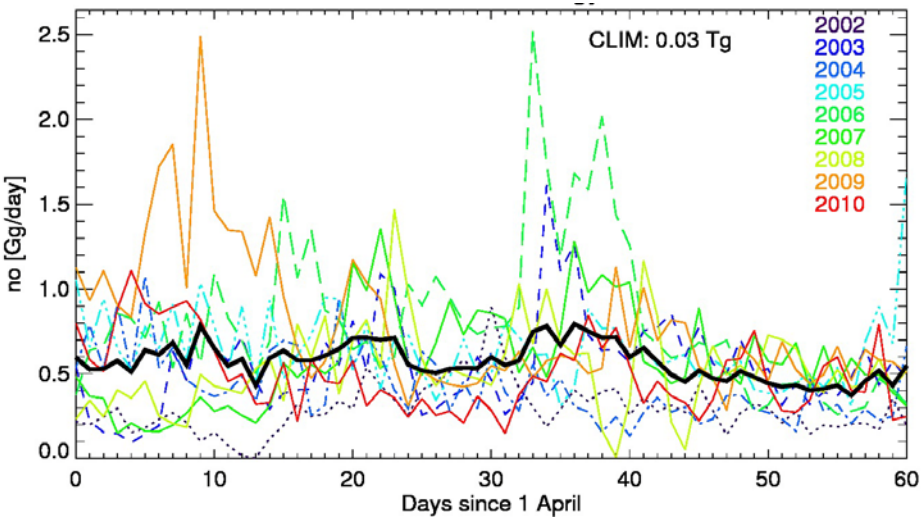
NO Emissions (moles/km2/hr]

[#] http://edgar.jrc.ec.europa.eu

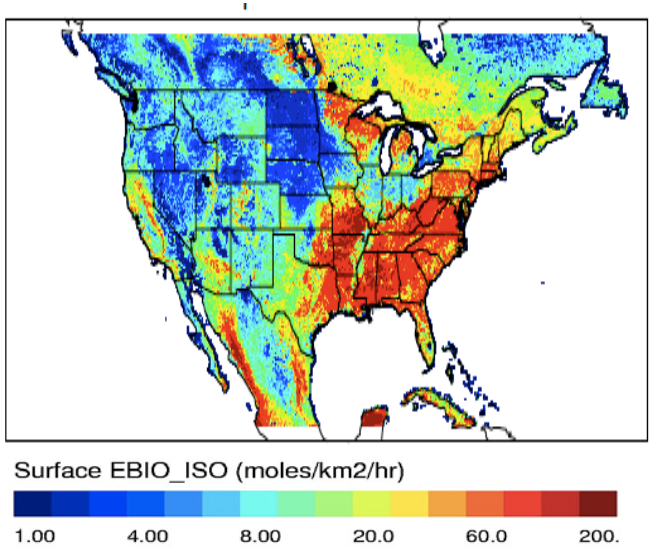
Emissions - Natural

- Fires: NCAR Fire Model FINN
  - 10-year climatology
  - same for present & future

NO Fire Emissions - Time Series



Isoprene Emissions, July present



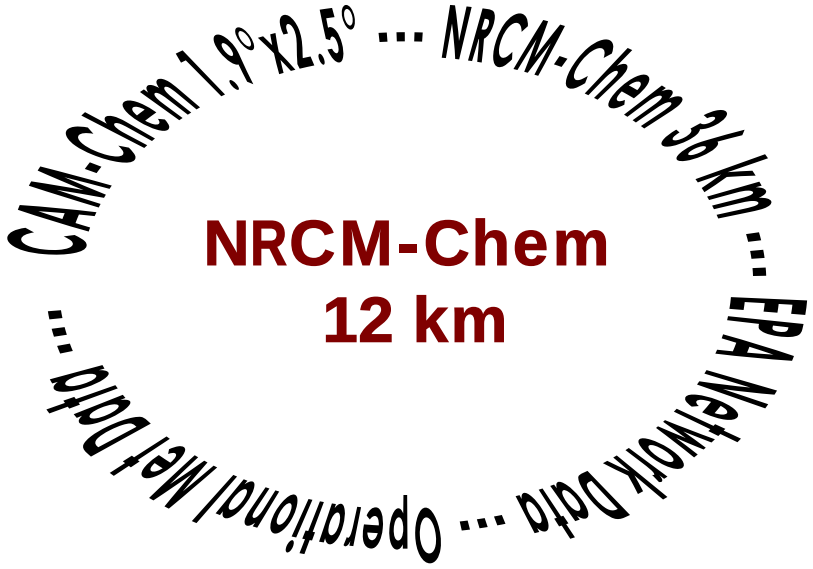
- Biogenic: online MEGAN
  - no change in land cover/use
  - dependence on radiation and temperature
  - LAI, TS and PAR climatology for plant history

Data Analysis

- **Outputs:**
  - 6-hourly Met Statistics output
  - 3-hourly 3D output: Met, Chem, passive tracers
  - 1-hourly 2D output: Surface AQ, temp, wind, humidity

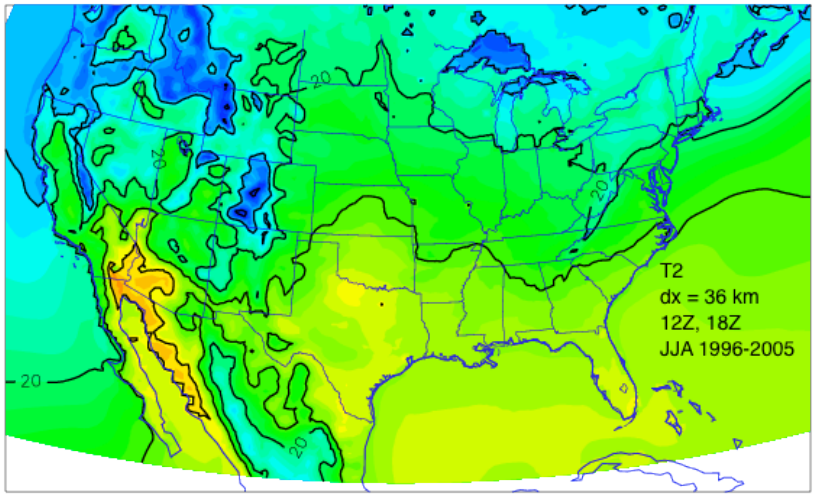
    => 18.5 GB/day ~34TB/10-year period

- **Analysis**

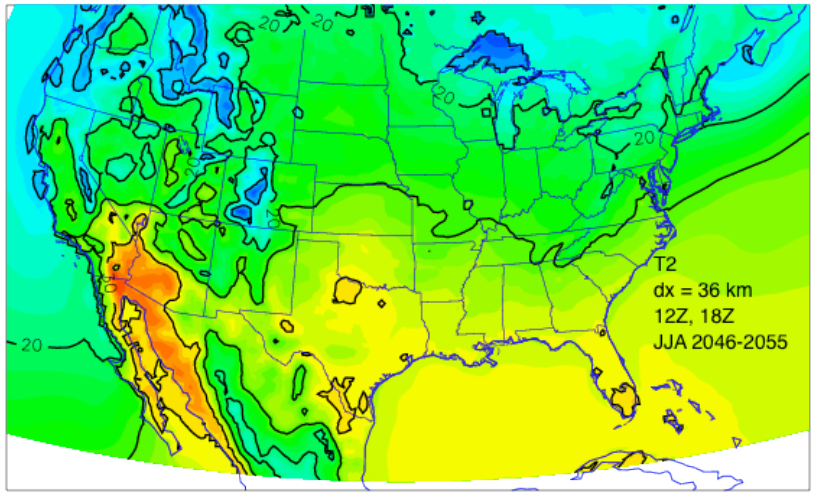


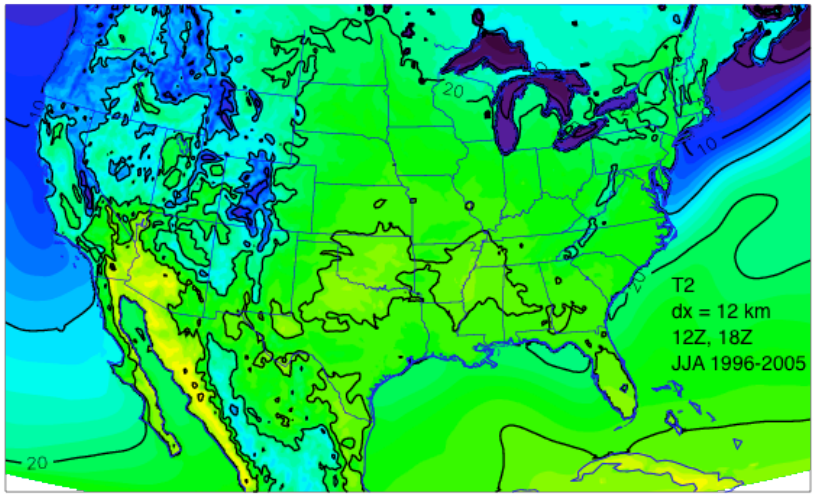
NRCM-Chem vs NRCM-Met

Present **JJA T @ 2 m [K]** **Future**

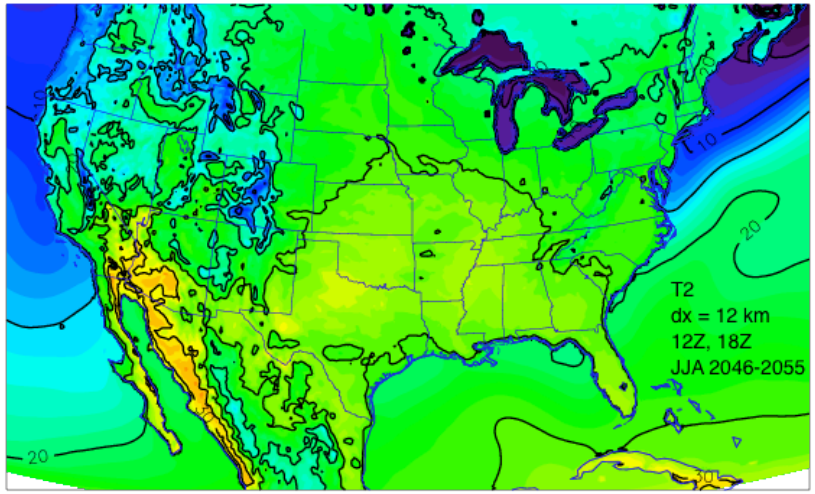


36 km

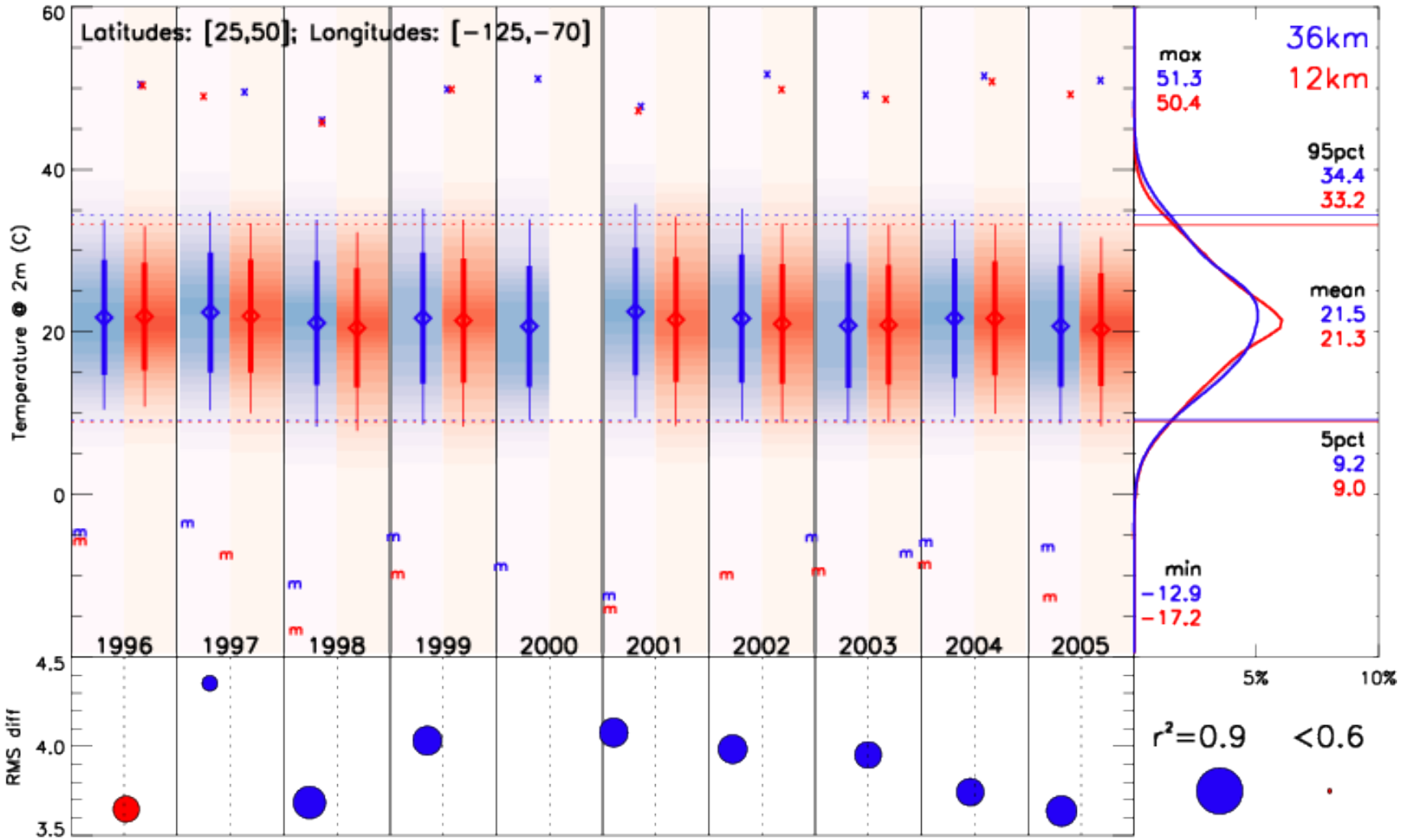




12 km

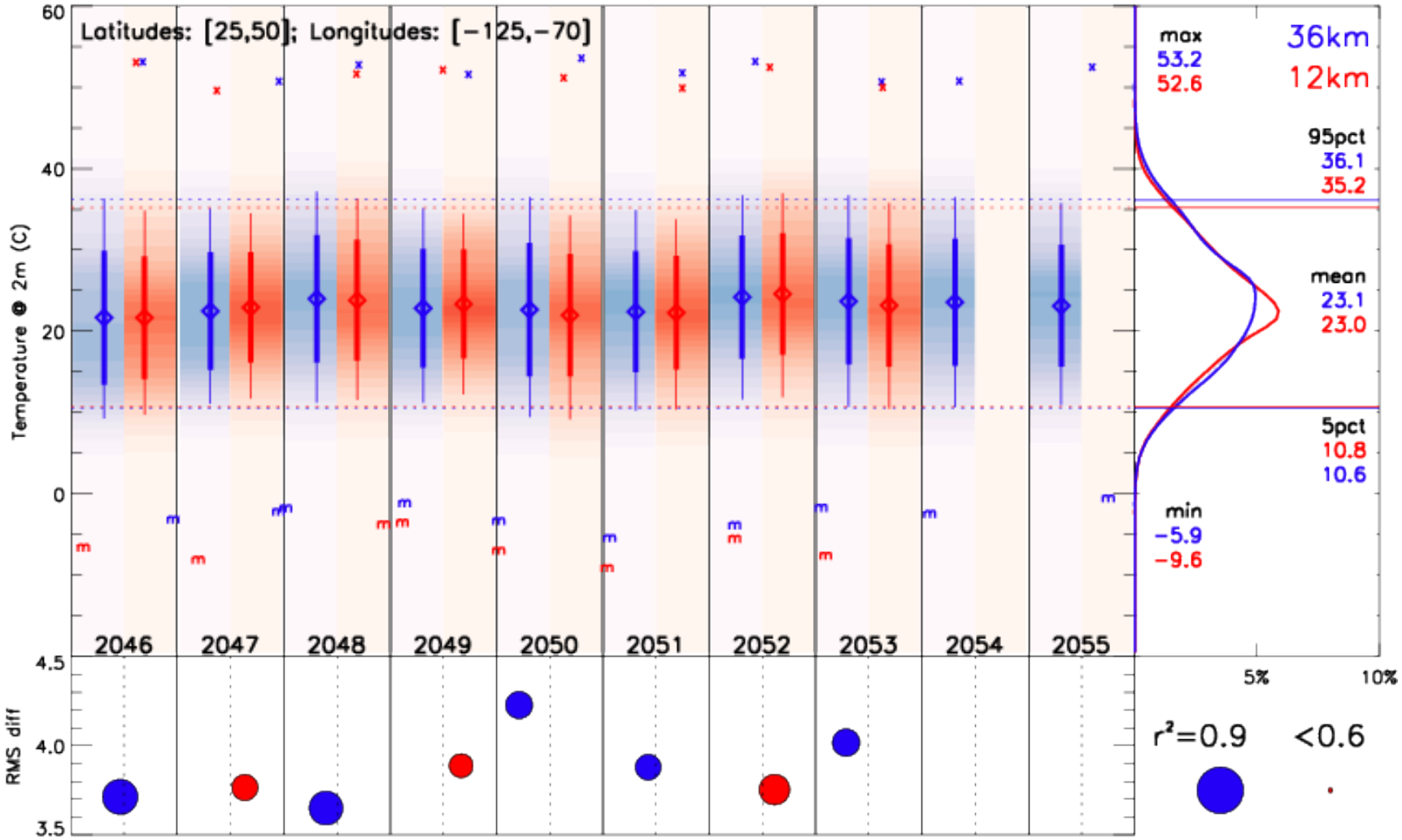


NRCM-Chem vs NRCM-Met T2 Present



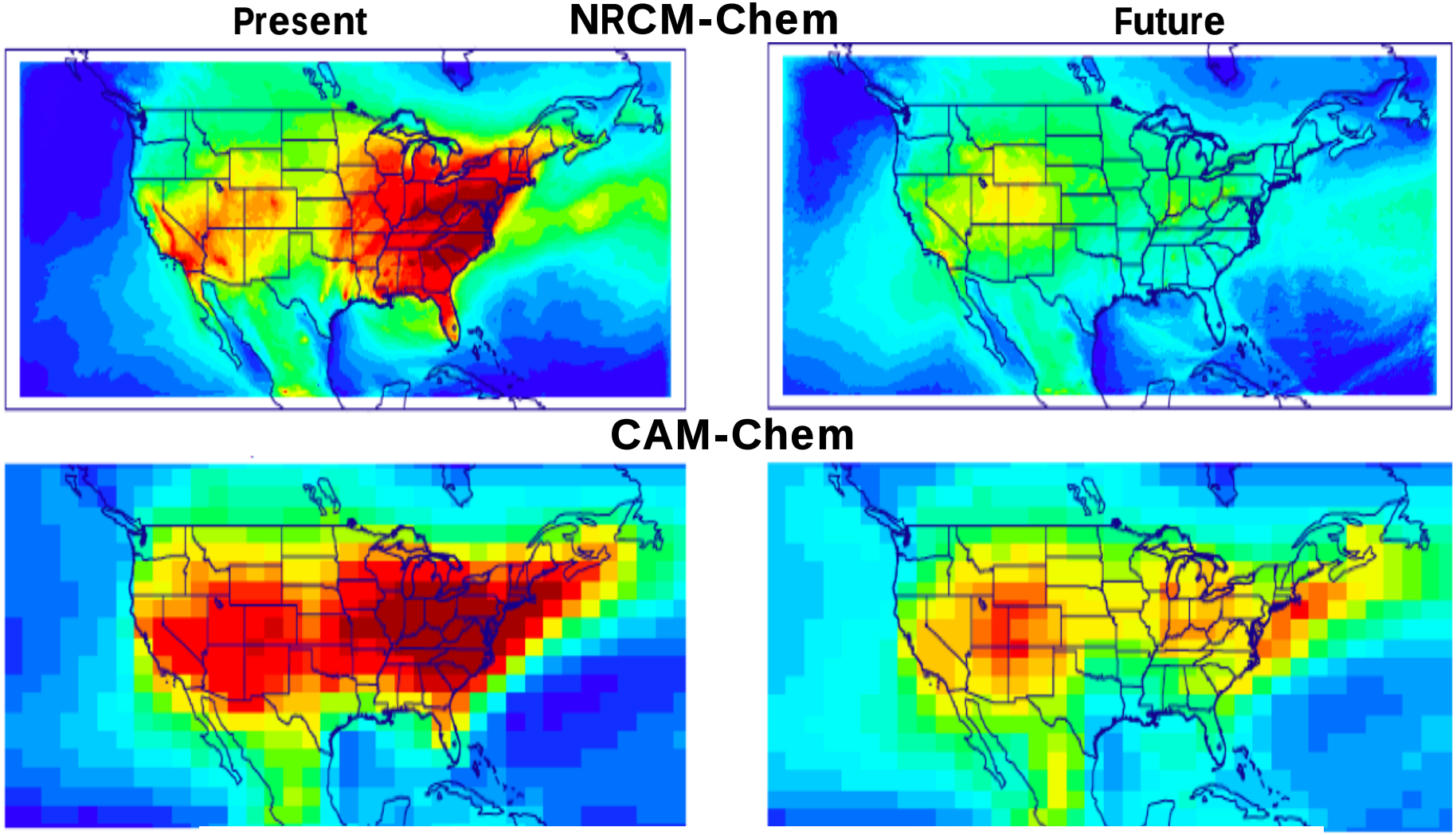
Land only

NRCM-Chem vs NRCM-Met T2 Future



Land only

NRCM-Chem vs CAM-Chem July

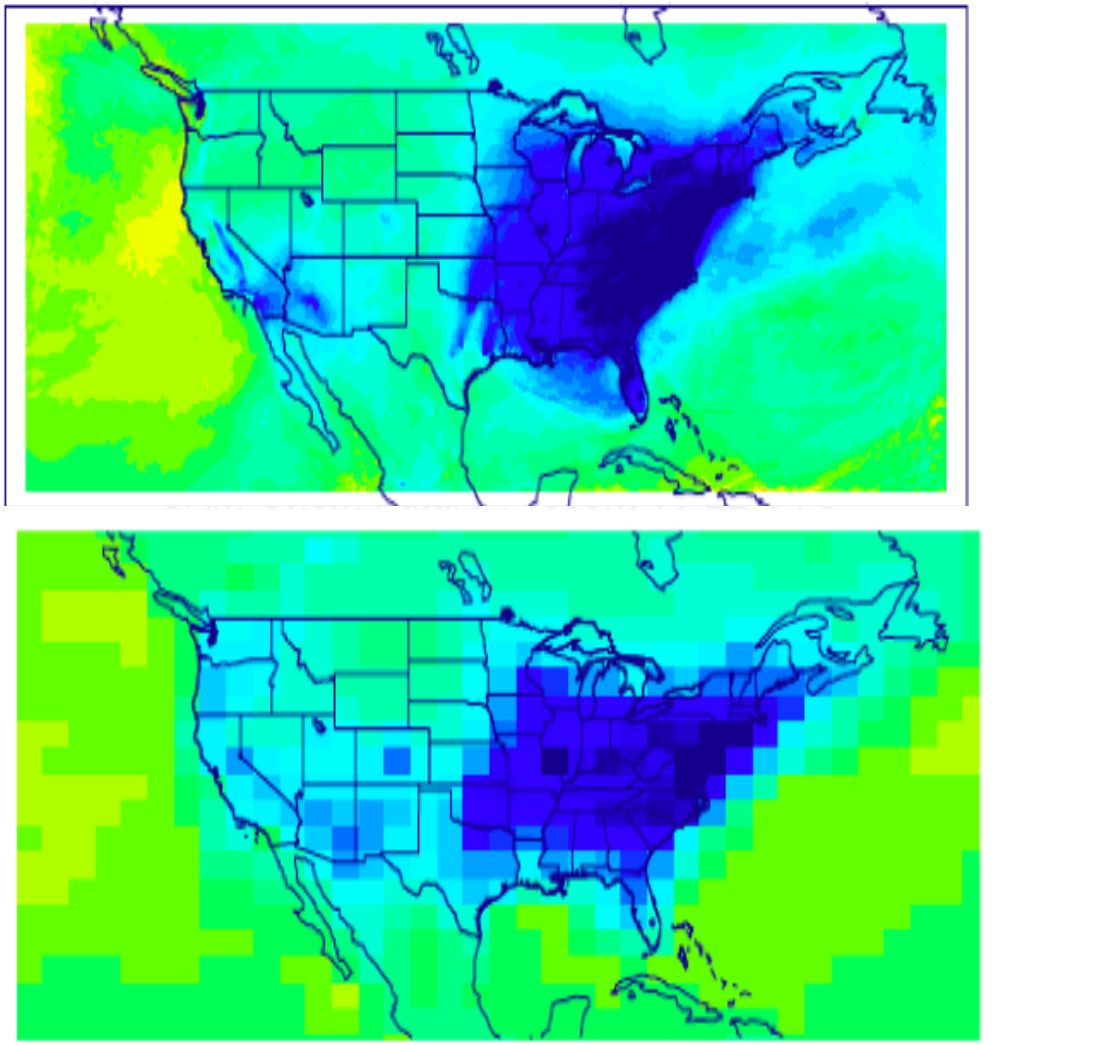


NRCM-Chem vs CAM-Chem July

NRCM-Chem

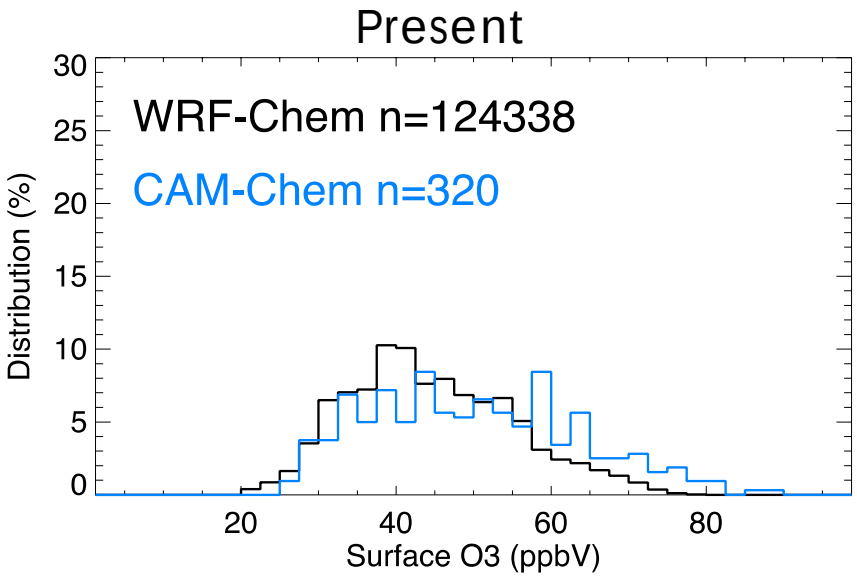
(Future-Present)

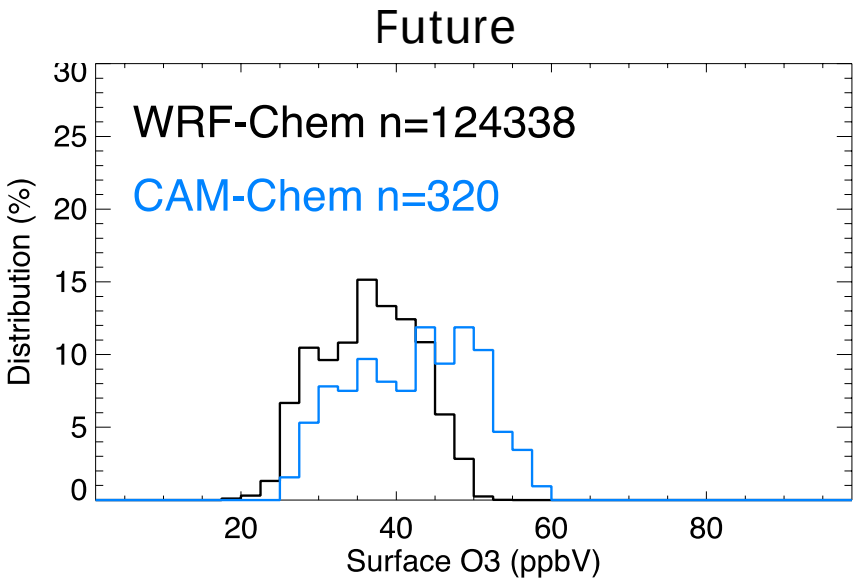
CAM-Chem

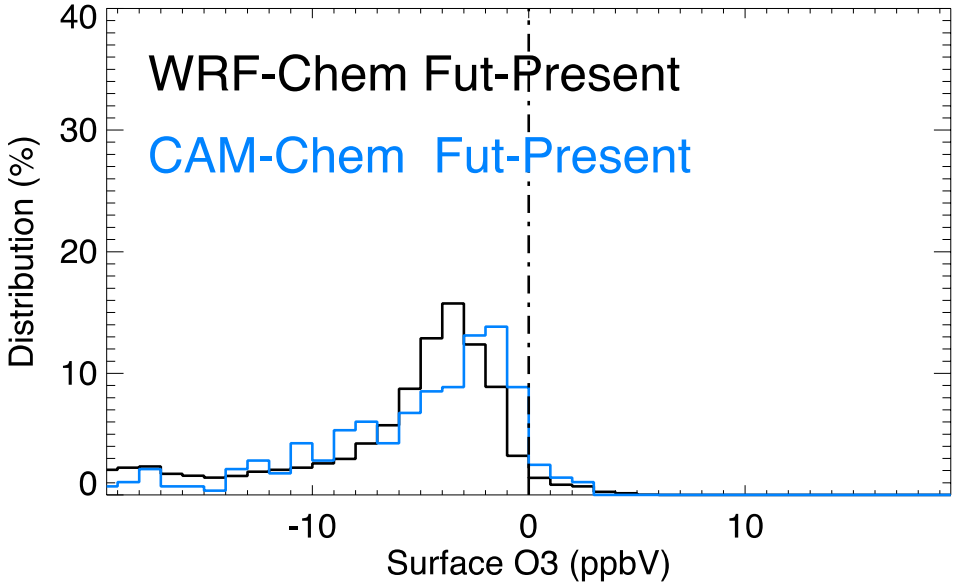


16-22 UTC

NRCM-Chem vs CAM-Chem July

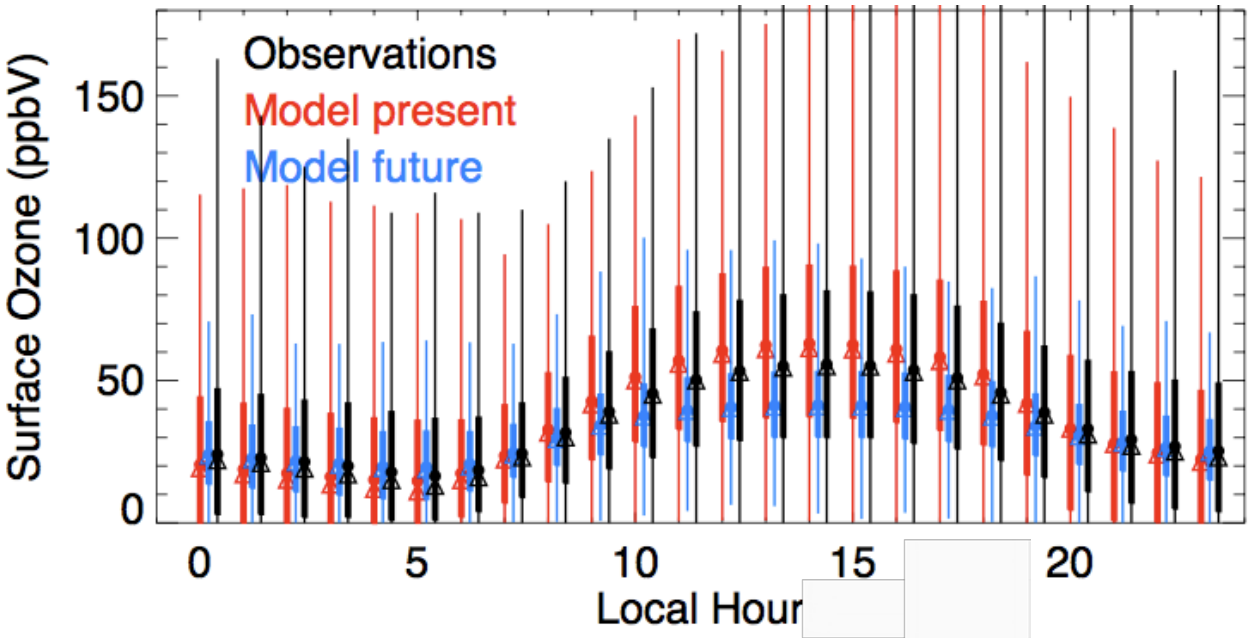




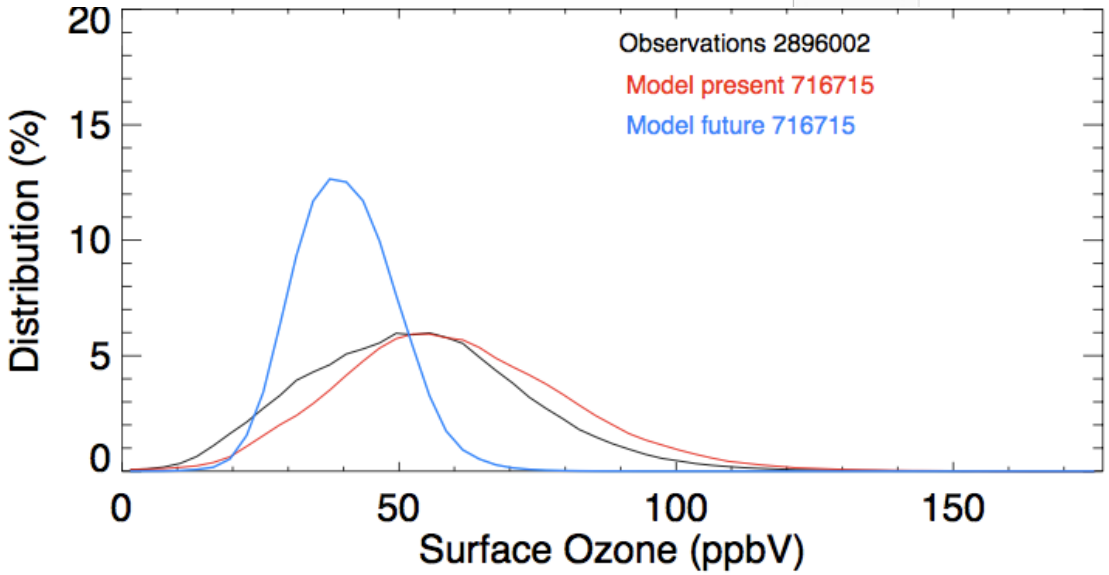


16-22 UTC; Land only

NRCM-Chem vs EPA O_3 data

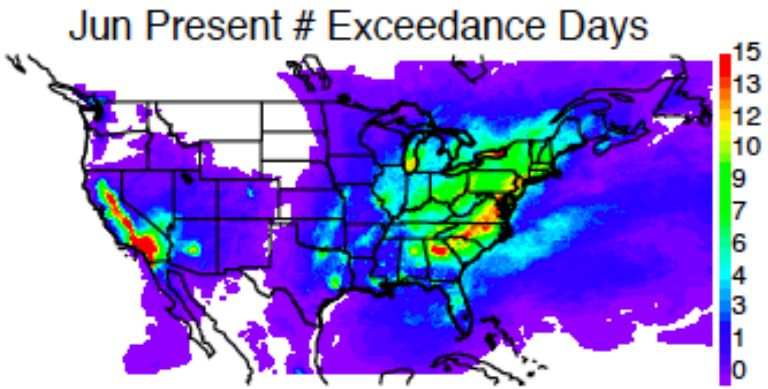


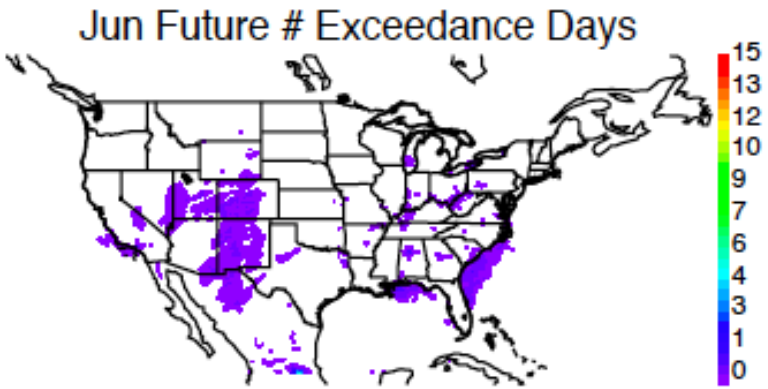
EPA: 1998-2002

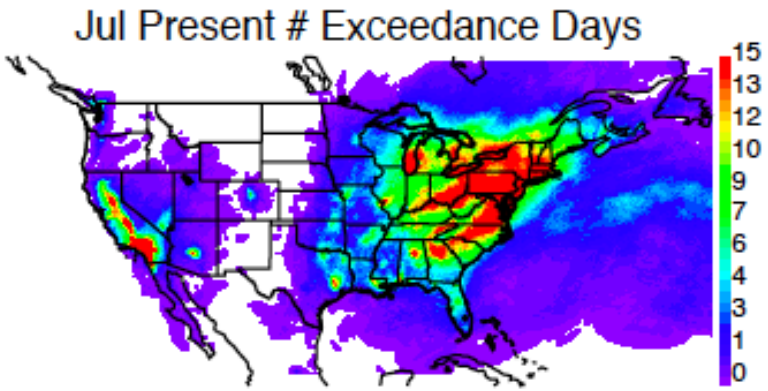


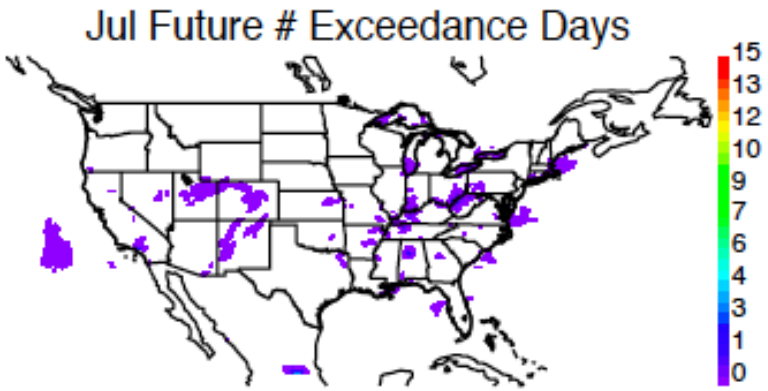
Local Afternoon

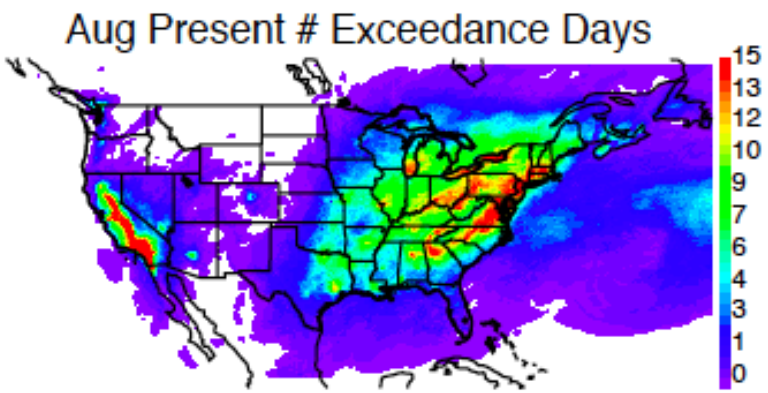
Ozone Exceedances 75 ppbV NAAQS

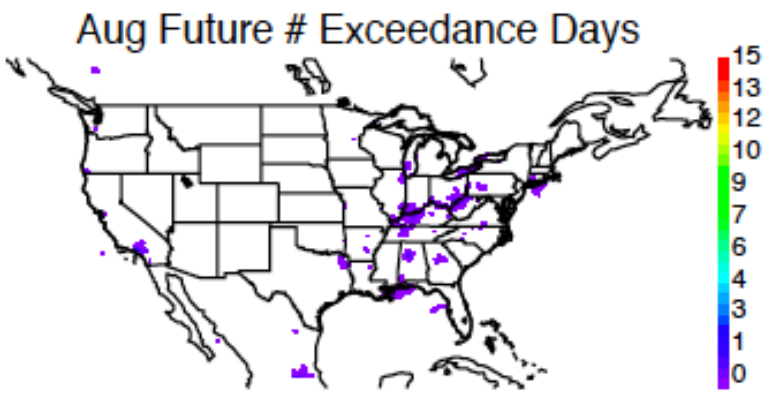




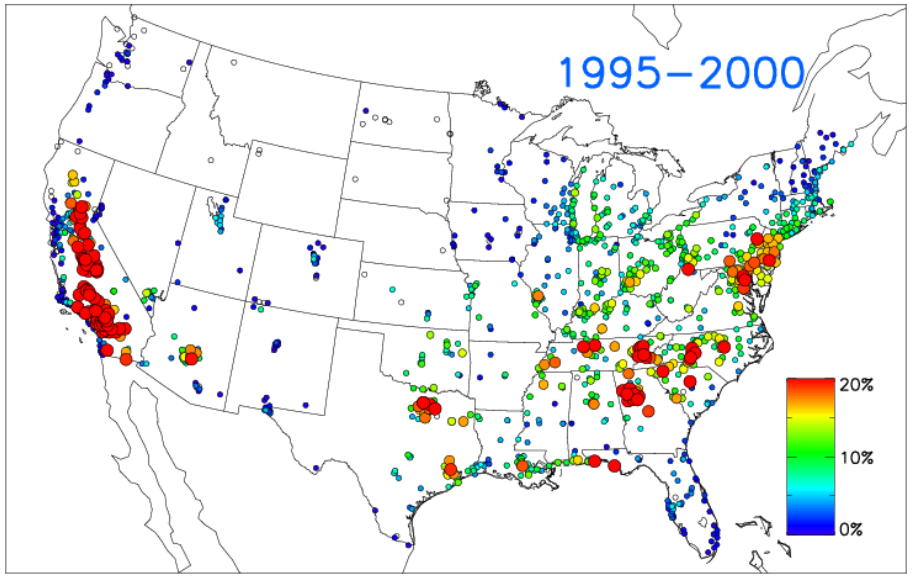


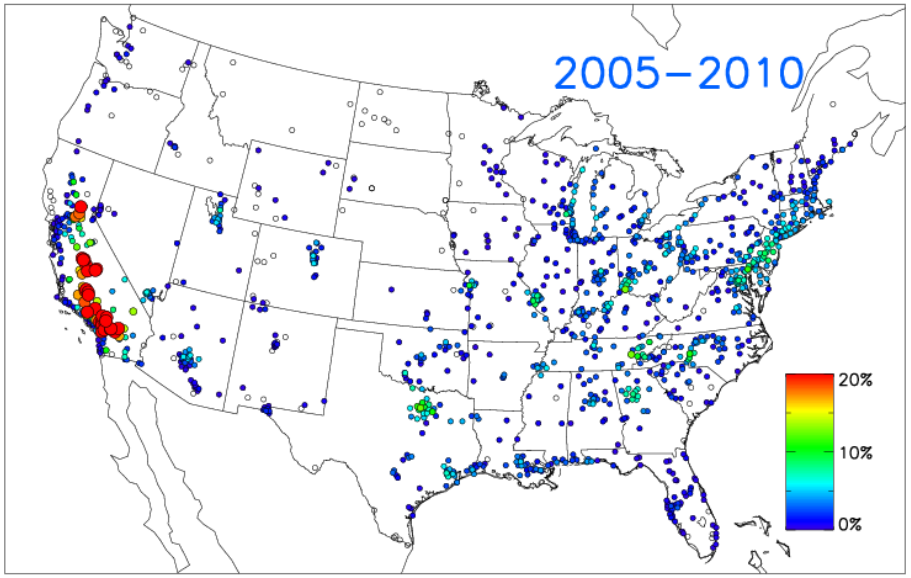






Ozone Exceedances 75 ppbV NAAQS





Average number of days (%) during May-Sep 1995-2000 and 2005-2010 when the 8-hour ozone NAAQS of 75 ppbV was exceeded.

Outlook

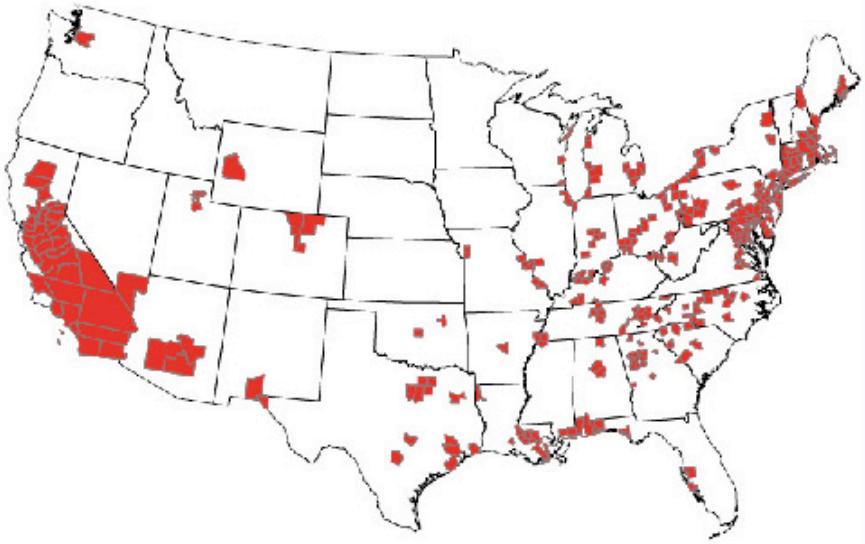
- Sensitivity Simulations:
  - NRCM (no chemistry)
  - Future 2050-Period with present time emissions
  - Computing resource dependent:
    - *2026-2035 time period*
    - *Turn off aerosol indirect effects*
    - *Different RCP scenario*
    - *Sensitivity of ozone chemistry to methane*
    - *Others?*
- Analysis ……

Additional Slides

Ozone Exceedances

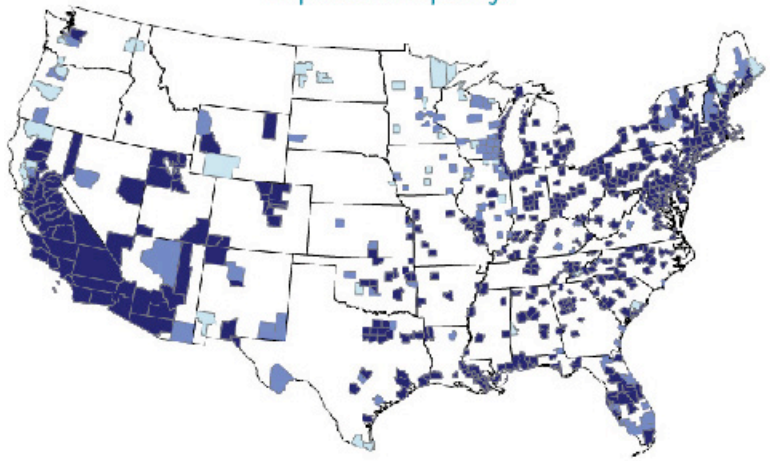
Counties with Monitors Violating the March 2008 Ozone Standard of 0.075 parts per million

(Based on 2006 - 2008 Air Quality Data)



Counties with Monitors Violating the Proposed Primary 8-hour Ozone Standards

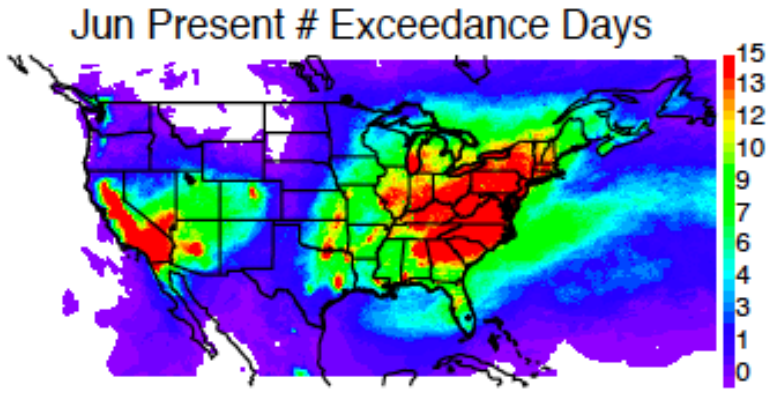
(Based on 2006 - 2008 Air Quality Data)
EPA **will not** designate areas as nonattainment on these data, but likely on 2008 - 2010 data which are expected to show improved air quality.

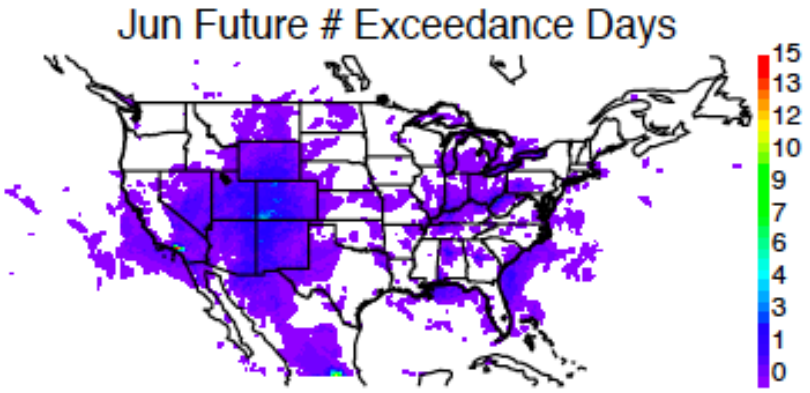


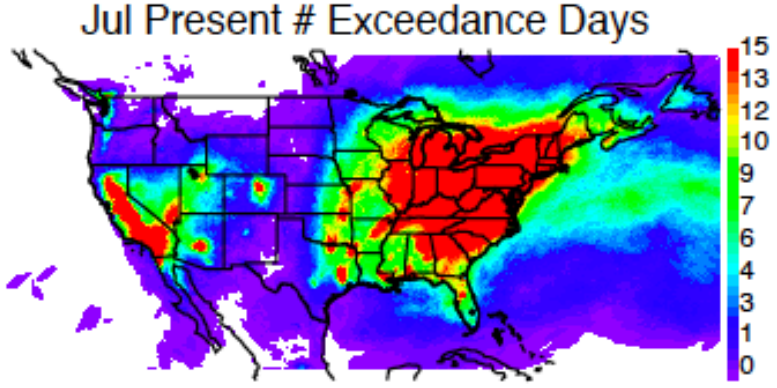
- 515 counties violate 0.070 ppm
- 93 additional counties violate 0.065 ppm
- 42 additional counties violate 0.060 ppm, for a total of 650

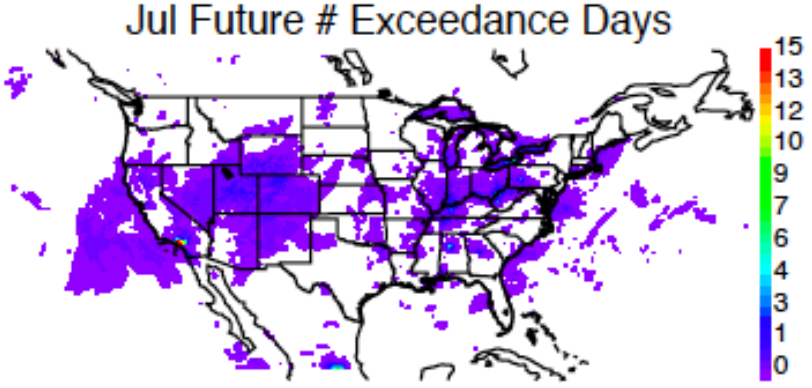
Source: www.epa.gov/air/ozonepollution/pdfs/20100104maps.pdf

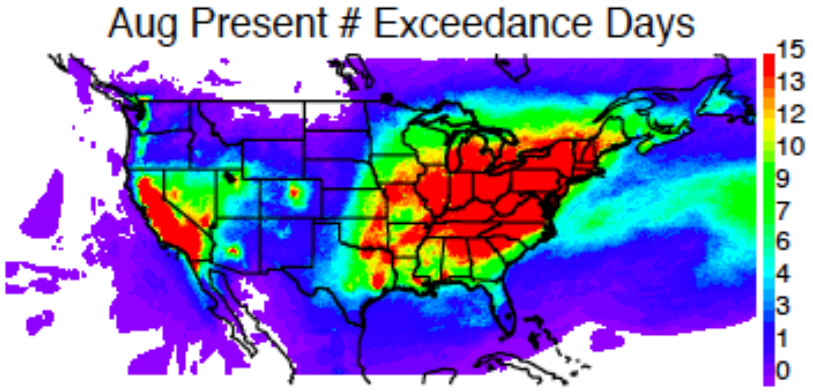
Ozone Exceedances 65 ppbV NAAQS

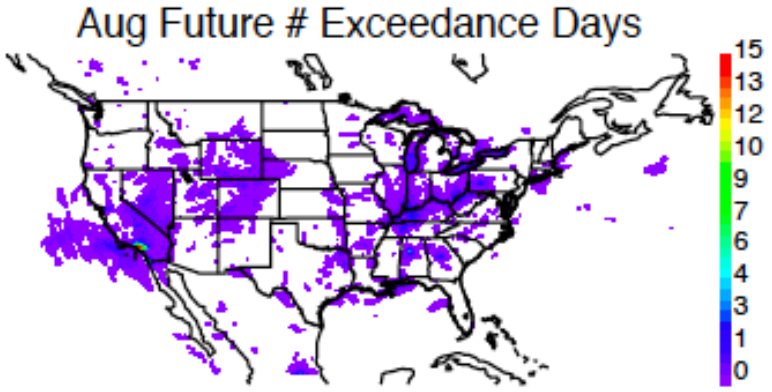












- Some notes:
  - CH4 present 1.8 ppm -> future 2.7 ppm