Prediction of Future North American Air Quality

Gabriele Pfister, Stacy Walters, Mary Barth,
Jean-Francois Lamarque, John Wong
Atmospheric Chemistry Division, NESL/NCAR

Greg Holland, James Done, Cindy Bruyere
Meteorological Mesoscale Division, NESL/NCAR

Jerome Fast, Po-Lun Ma
Pacific Northwest Laboratory, PNNL

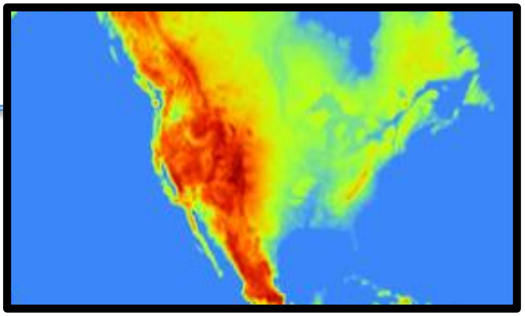
Objectives

“There is growing recognition that development of optimal control strategies for key pollutants like O_3 and PM2.5 requires assessment of potential future climate conditions and their influence on the attainment of air quality objectives”

- Future changes in weather and air quality over North America
- Effects of changing emissions and changing climate on AQ
- Feedbacks between chemistry and climate
- Differences in climate metrics when downscaling from global or larger scale simulations with different physics
- Sensitivity of predictions to initial conditions

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)

WRF-Chem Setup as NRCM-Chem



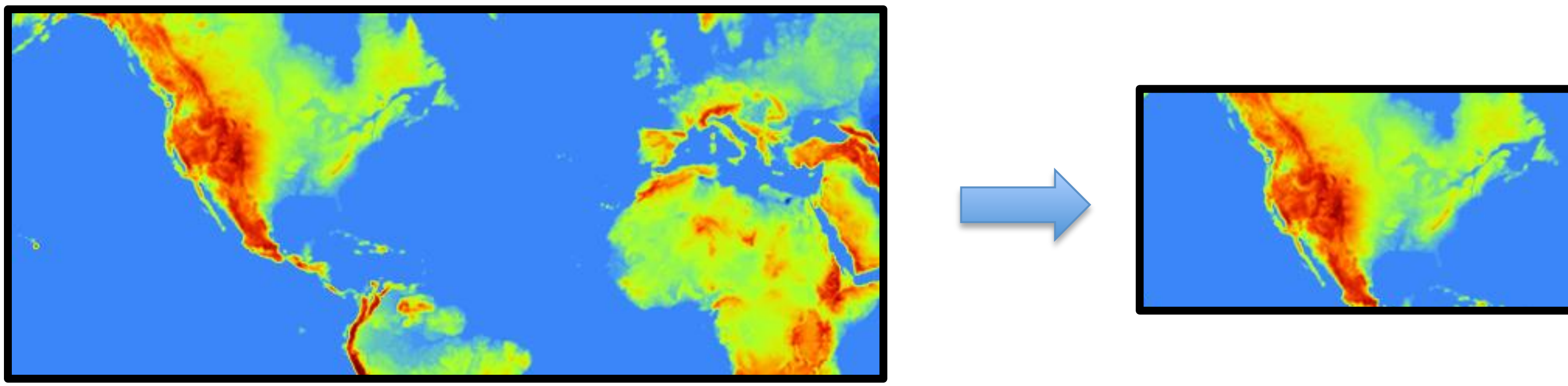
- 13 years present (1996-2007) and future (2046-2057)
- Season: 1 April – 1 Oct
- 12 x 12 km^2 (697 x 394); 51 vertical levels (up to 10 hPA)
- Gas-Phase Scheme: Reduced Hydrocarbon Scheme (40 species)
- Aerosols: Modal Aerosol Model (MAM; 33 species, +SOA)
- Direct/indirect aerosol effects
- CAM-5 microphysics and PBL Scheme
- IPCC A2 Climate Scenario, RCP8.5 Emission Scenario

Simulation	Period	Climate	Emissions	IC & BC	Chemistry
SIM^{PRES}	Present	Present	2000	Present	REDHC/MAM
SIM^{FUT}	Future	Future	2050	Future	REDHC/MAM
SIM^{FUT_EMIS}	Future	Future	2000	Future	REDHC/MAM
SIM^{MET}	Future	Future	-	Future	-

10 years + 3 years/simulation with initial start date changed

WRF-Chem Setup as NRCM-Chem

- **Meteorological IC & BC**
  - Downscaled from NRCM-Met @ 36 x 36 km^2 [*Done et al., 2012*]



- **Chemical IC & BC**
  - CAM-Chem RCP 8.5 [*Lamarque et al., 2011*]
  - Monthly means for 2000 and 2050
- **Upper Chemical Boundary Conditions for O_3, N_2O, ...**

Done et al. (2012): Modeling high-impact weather and climate, NCAR/TN-490+STR, 28pp.
Lamarque et al.,(2011), *Climatic Change*, *109*(1-2), 191-212, doi:10.1007/s10584-011-0155-0.

WRF-Chem Setup as NRCM-Chem - Emissions

- IPCC RCP 8.5 Scenario:

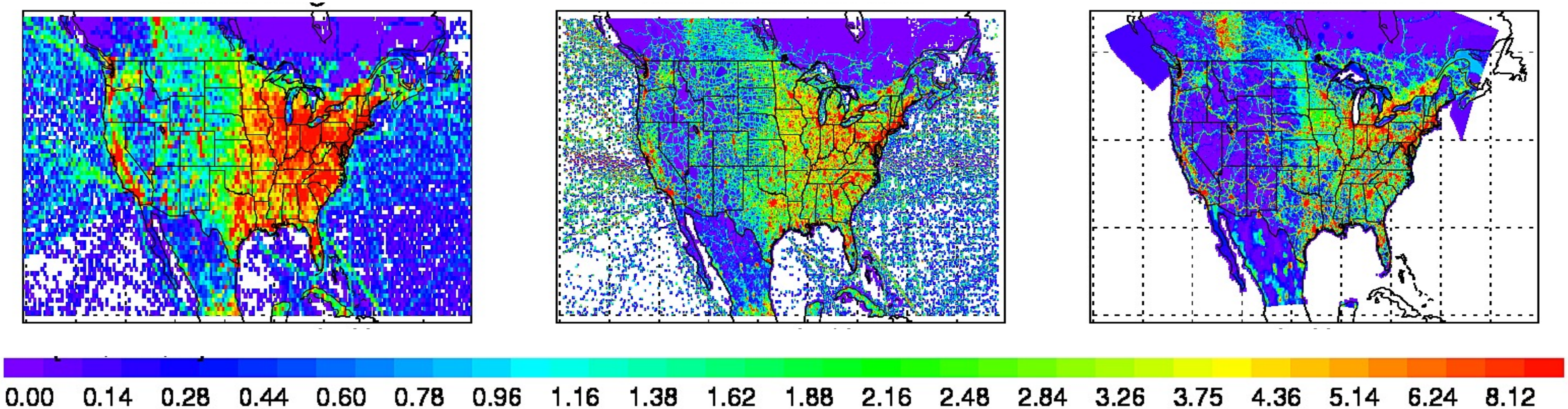
  NO_x emissions reduced by -60% over domain (-10% globally) by 2050

- 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 distribution

  ⇨ mass-conserving mapping to NRCM-Chem domain

Global Emissions 0.5° | NRCM-Chem 12 km | EPA NEI 2005 4km->12km



http://edgar.jrc.ec.europa.eu

WRF-Chem Setup as NRCM-Chem - Emissions

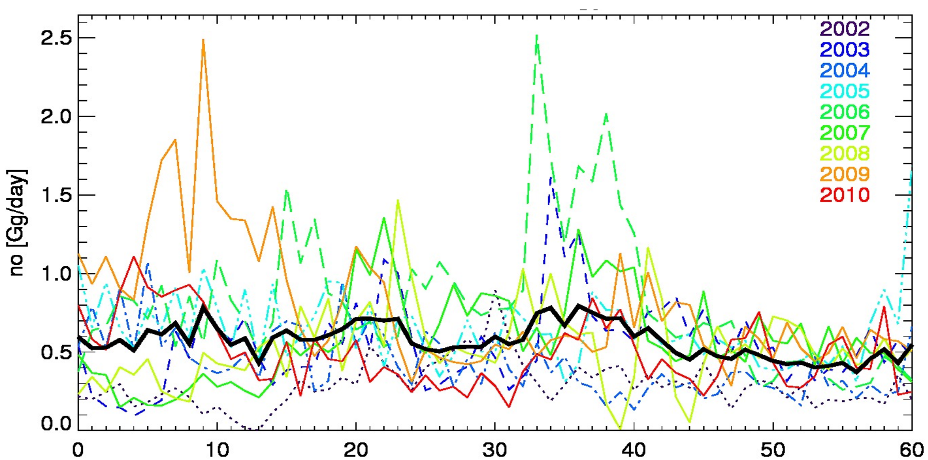
Fires:

- NCAR Fire Model FINN
  - 10-year Climatology
  - Same for Present & Future

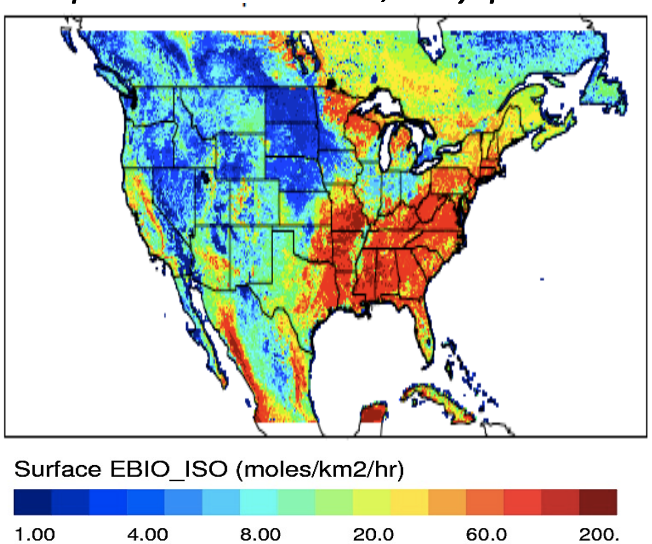
Biogenic:

- Online MEGAN
  - No change in land cover/use
  - Radiation and T dependence
  - LAI, TS and PAR climatology for plant history

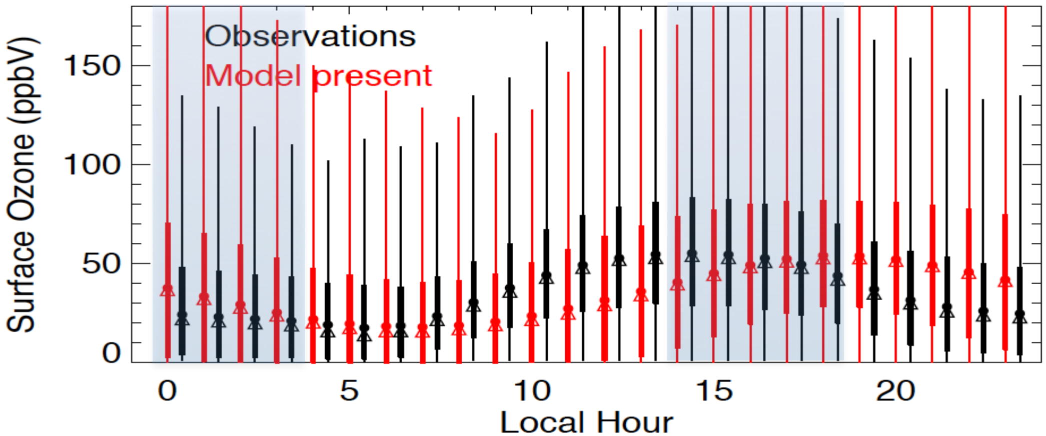
NO Fire Emissions - Time Series



Isoprene Emissions, July present

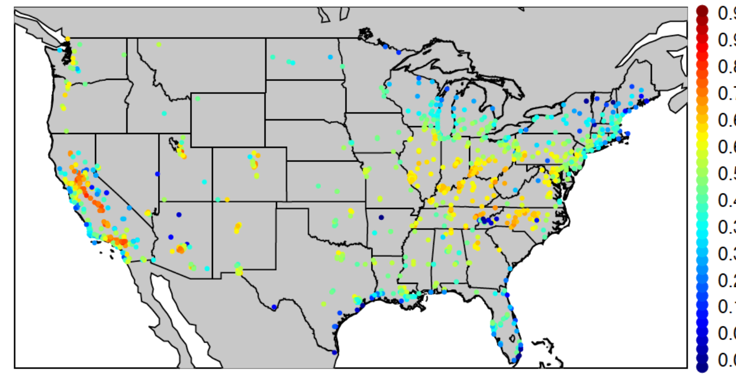


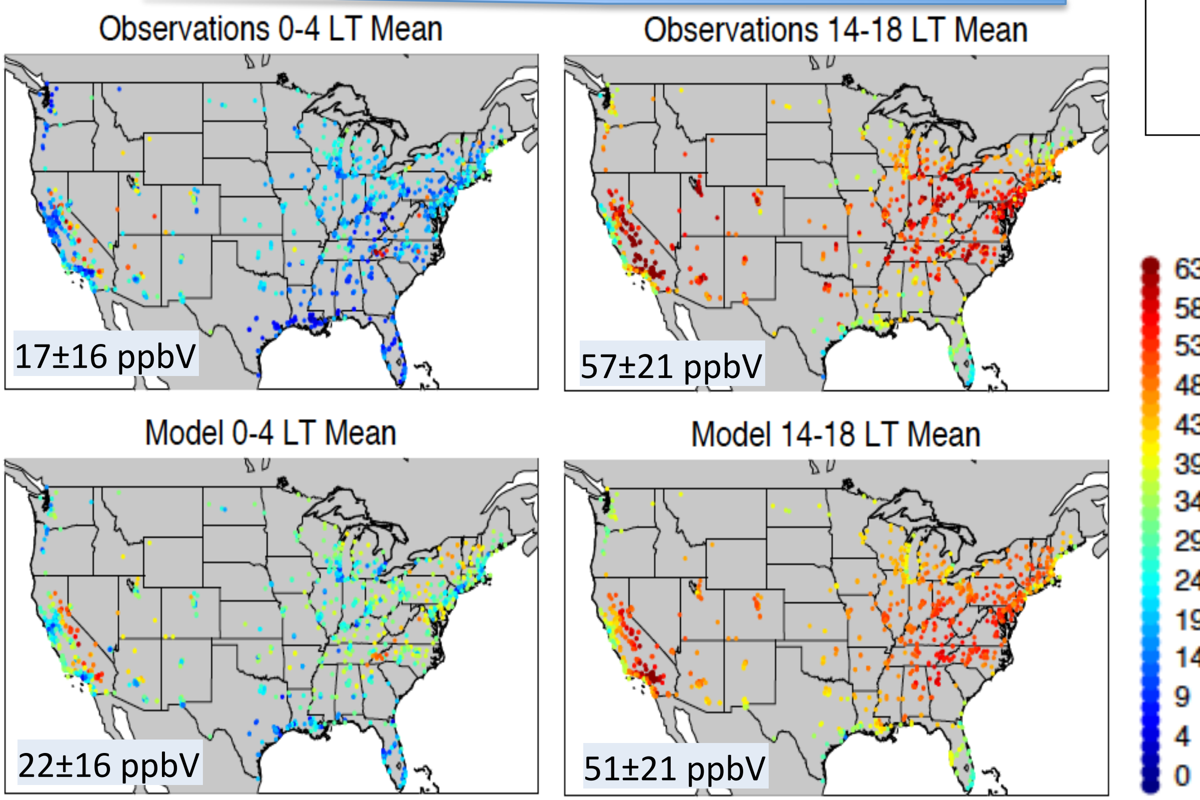
Present Time Surface Ozone – Obs and Model



⇦ Average Diurnal Cycle

Correlation



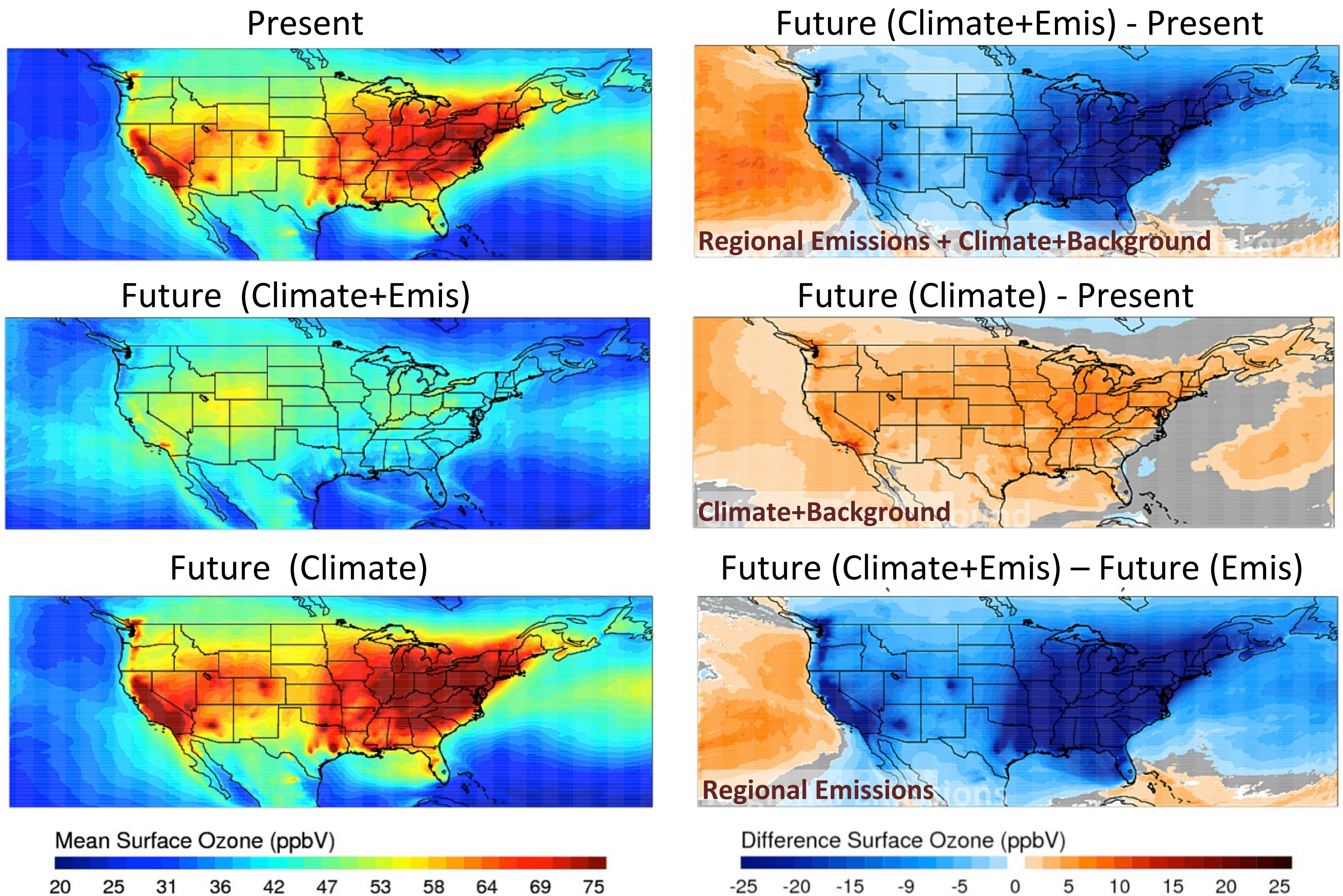


⇦ Mean for
12-18 LT & 0-4 LT

EPA Data: 1996-2005

Prediction of Future Surface Ozone

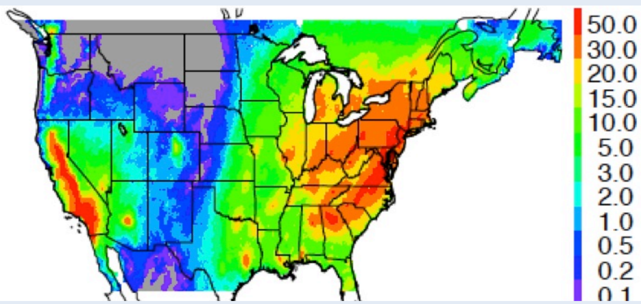
DAILY MAXIMUM HOURLY SURFACE OZONE FOR JJA

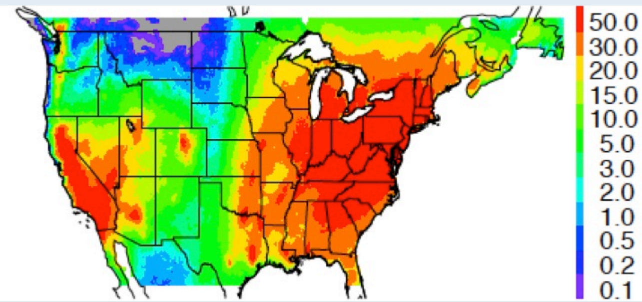


Average #Days with 8-hr Ozone Exceedance

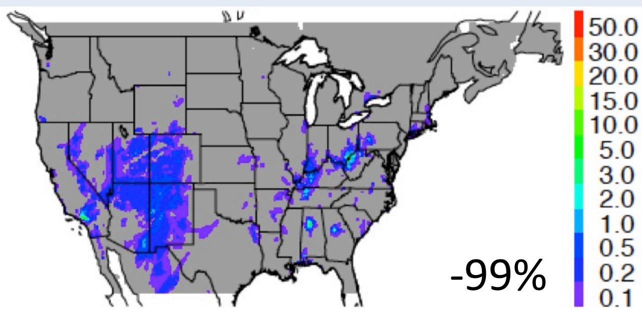
75 ppbV	65 ppbV

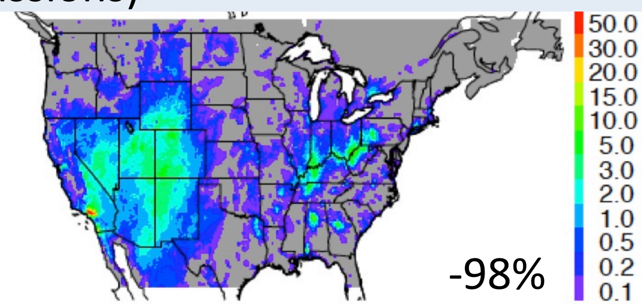
Present



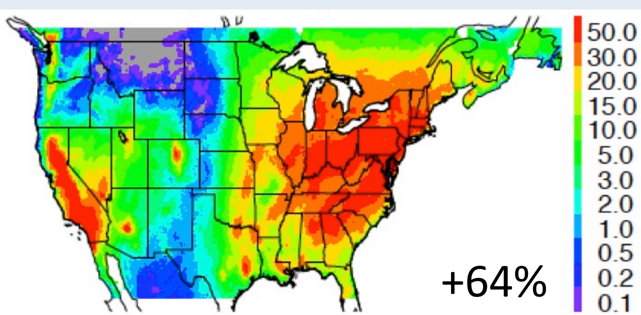


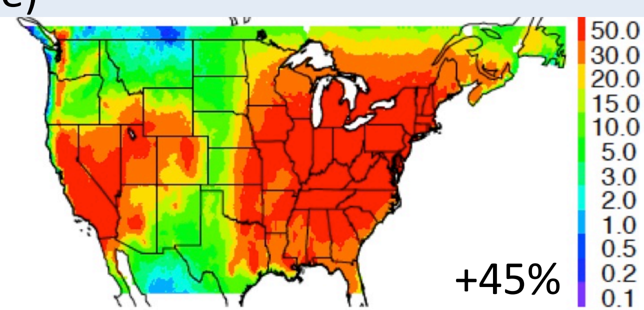
Future (Climate + Emissions)





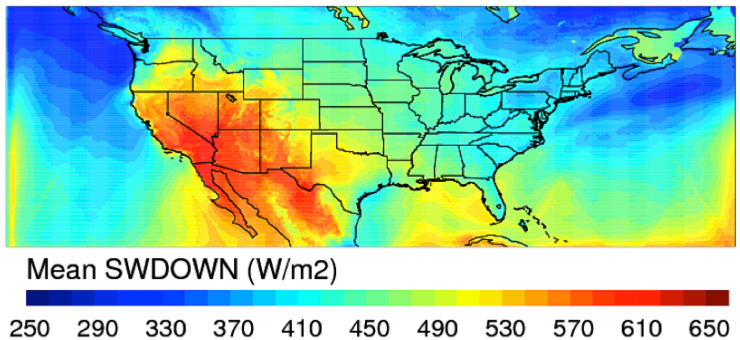
Future (Climate)

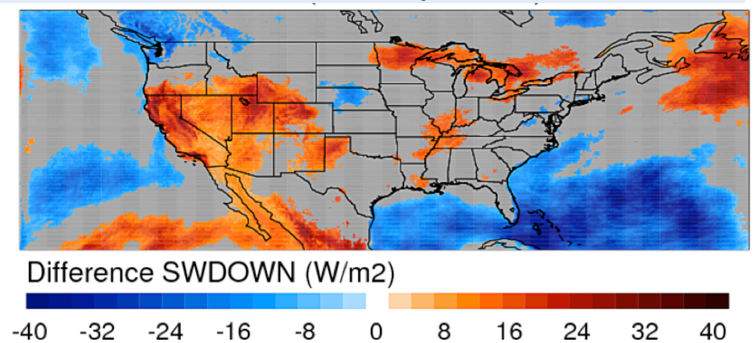




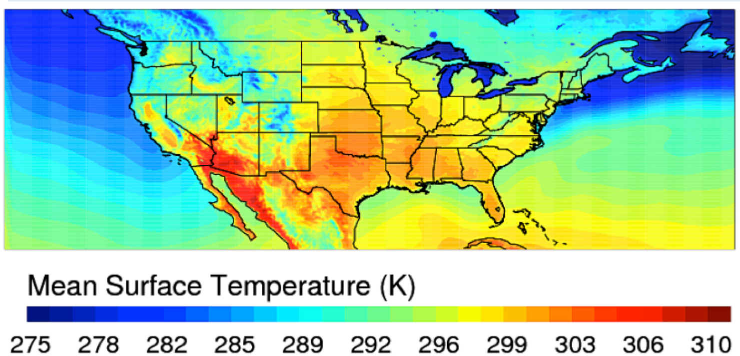
Meteorological Drivers of Ozone Change

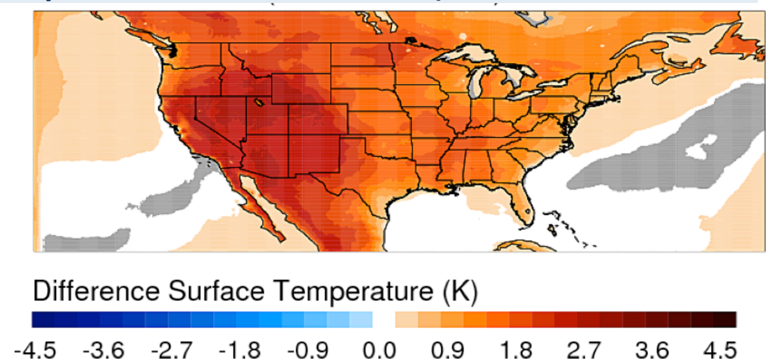
(Present) *SW Downward Radiation* (Future-Present)



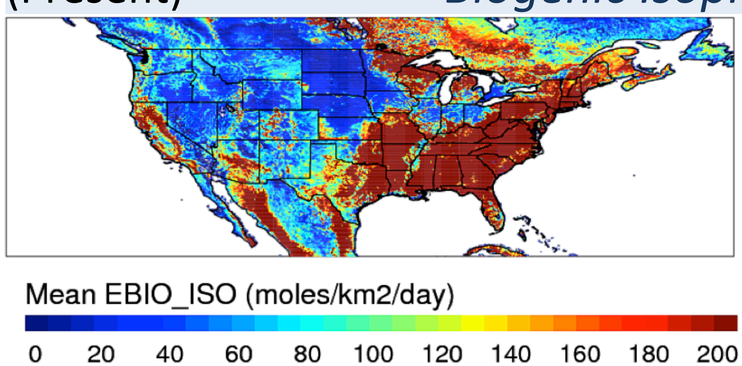


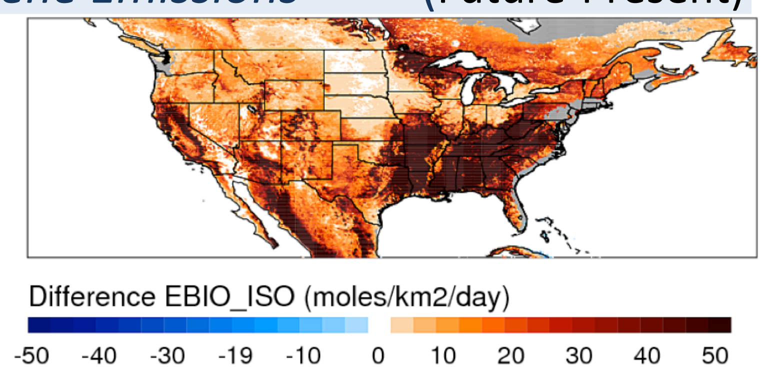
(Present) *Surface Temperature* (Future-Present)





(Present) *Biogenic Isoprene Emissions* (Future-Present)

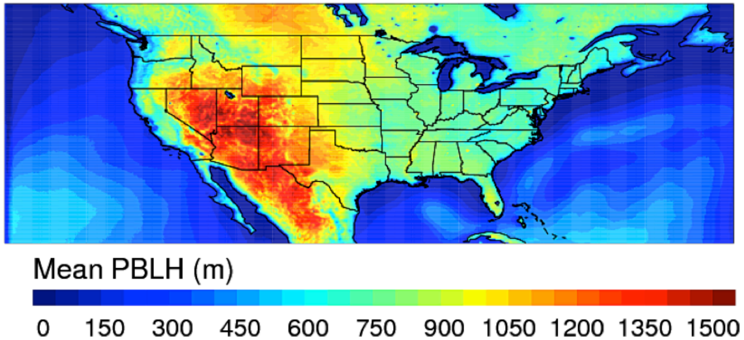


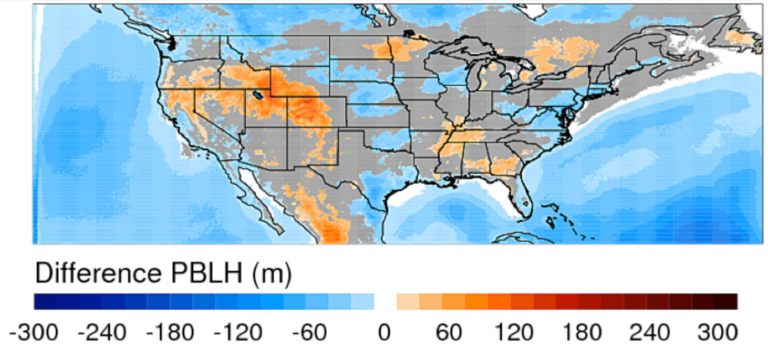


16.4 ⇨ 18.7 TgC

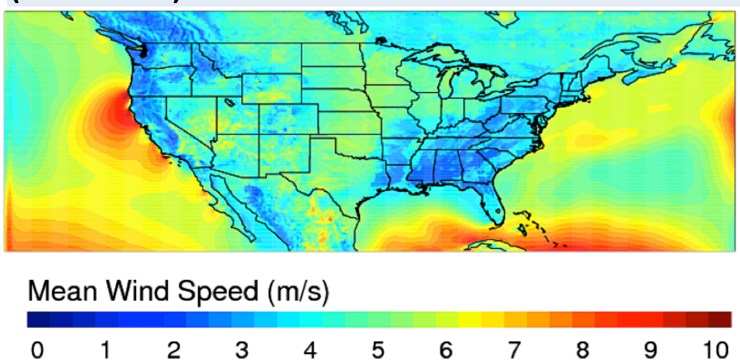
Meteorological Drivers of Ozone Change

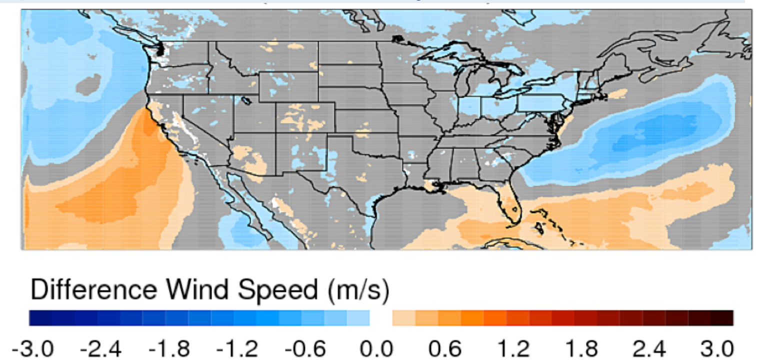
(Present) *Boundary Layer Height* (Future-Present)



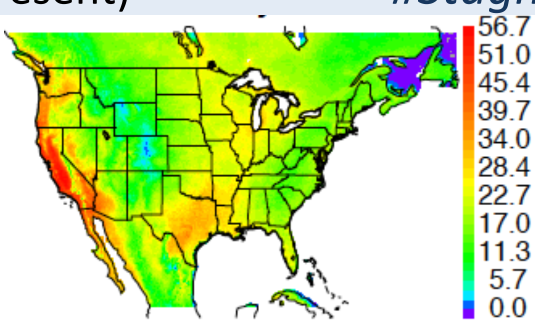


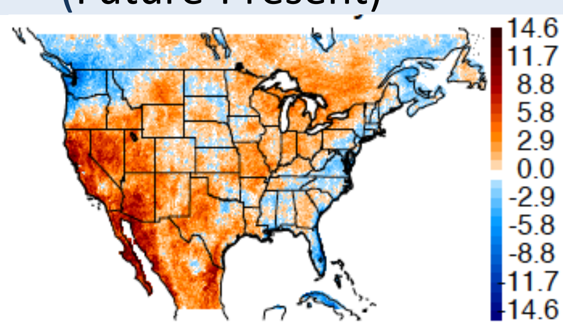
(Present) *Wind Speed* (Future-Present)





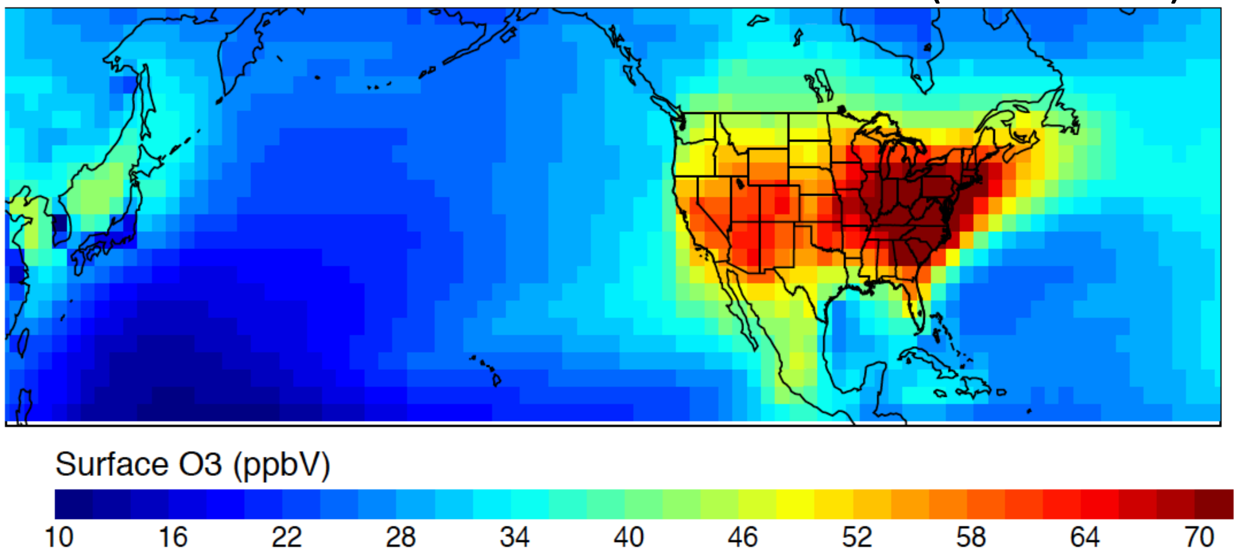
(Present) *#Stagnation Days* (Future-Present)



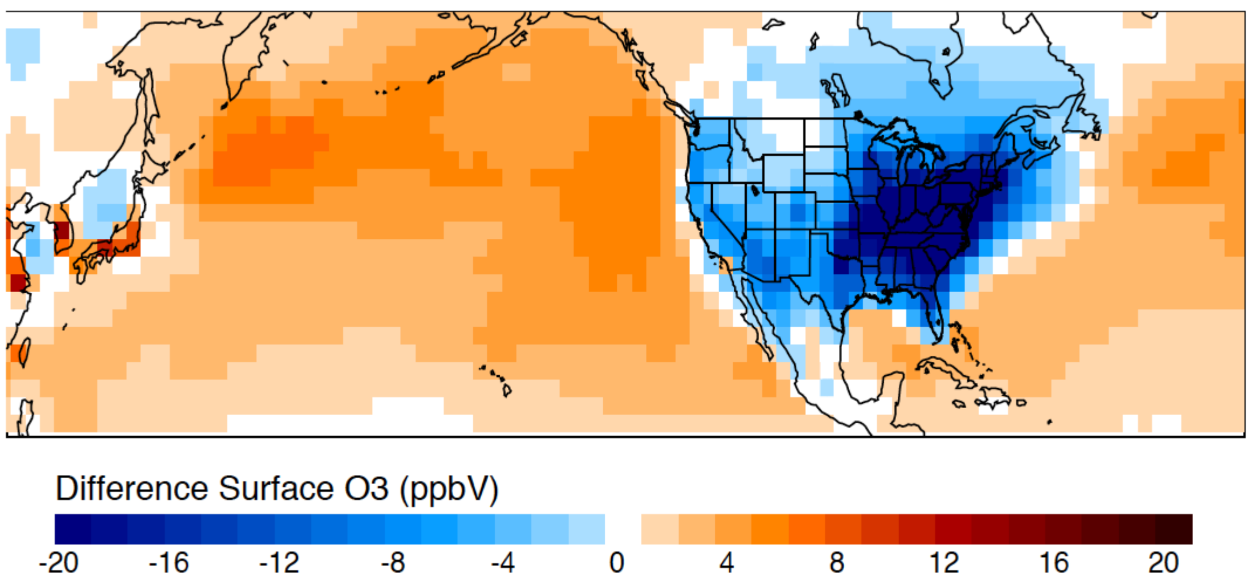


Long Range Transport and Background Ozone

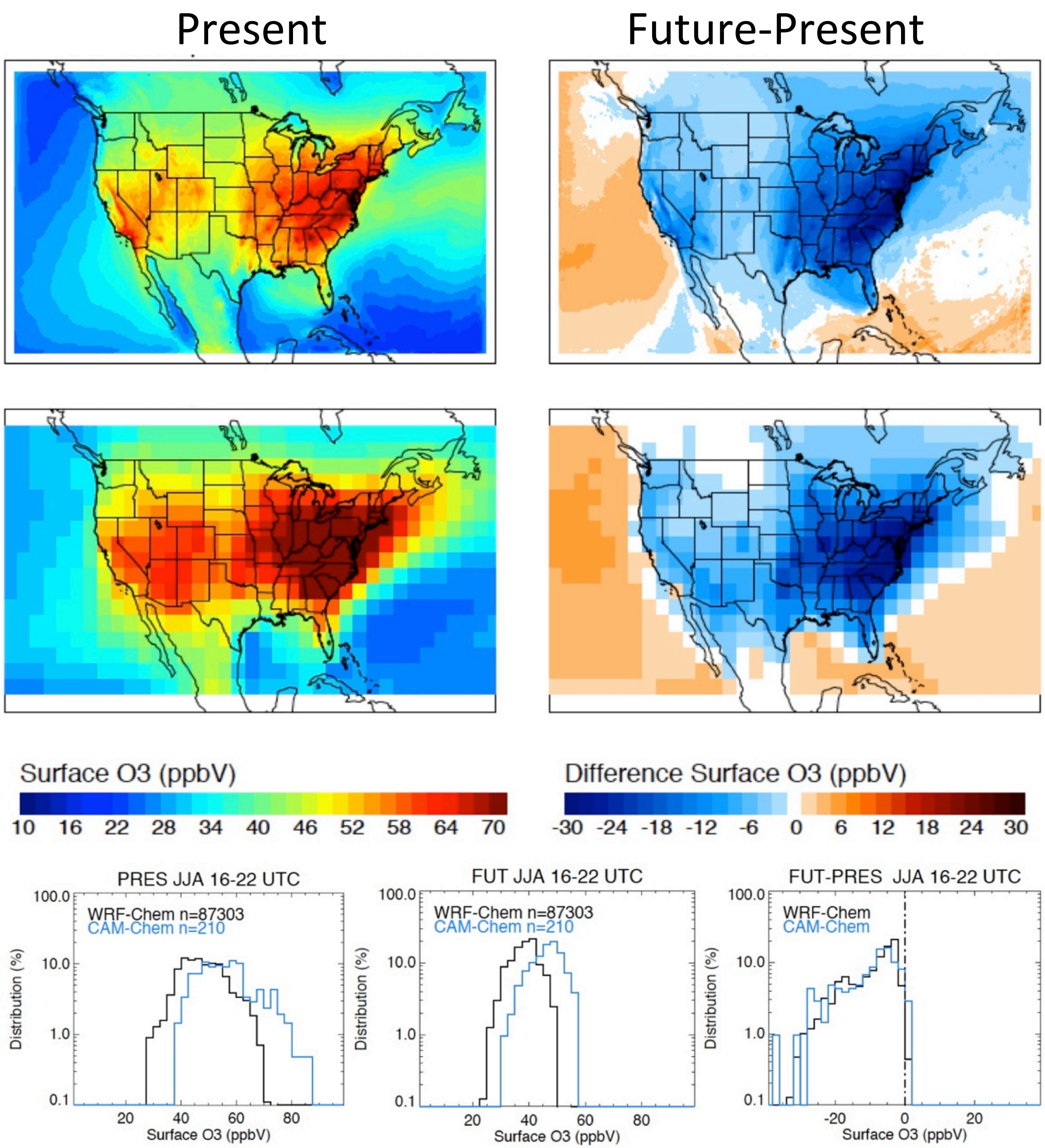
CAM-Chem Present Time Surface Ozone (16-22 UTC)



Future - Present



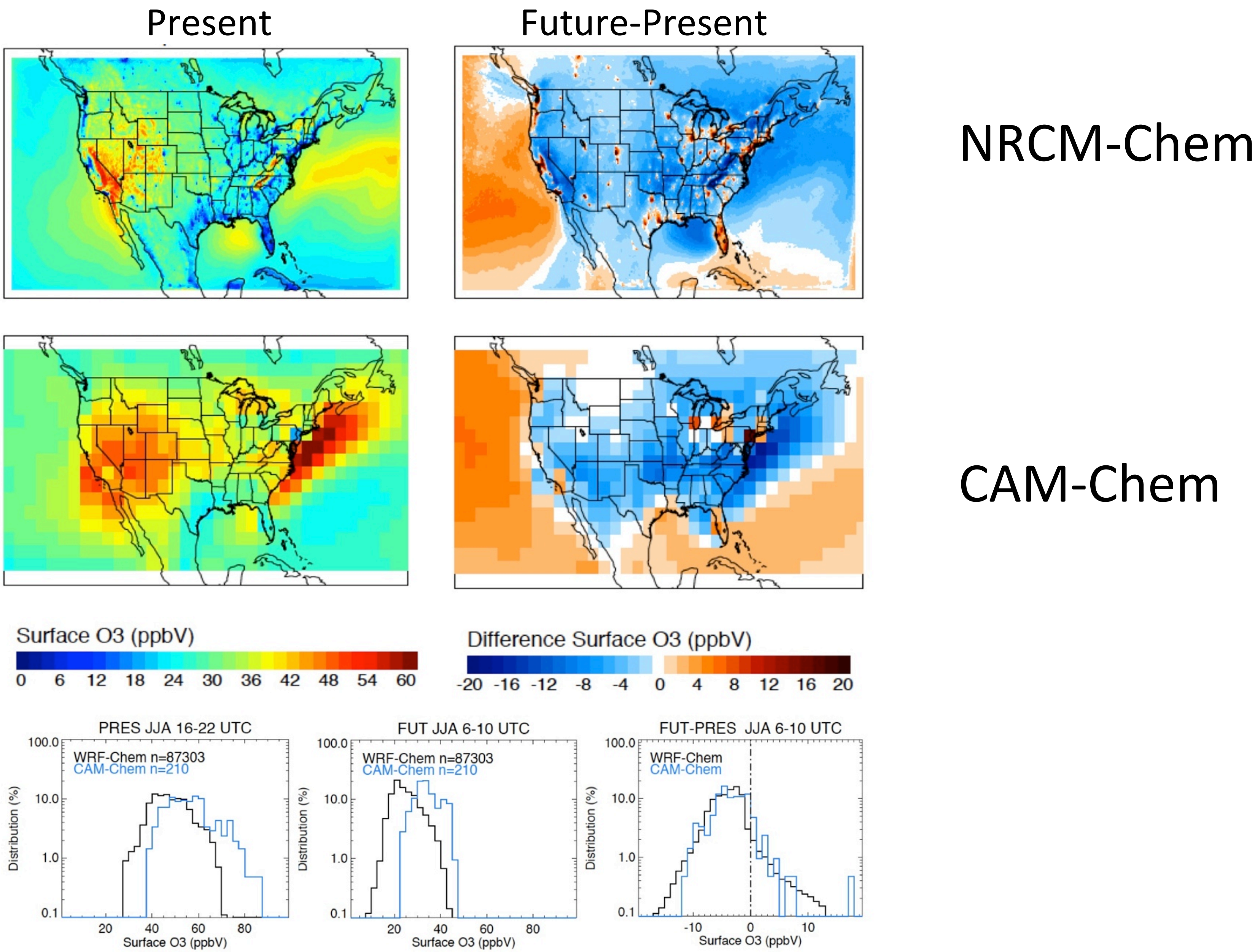
Global and Regional Predictions



NRCM-Chem

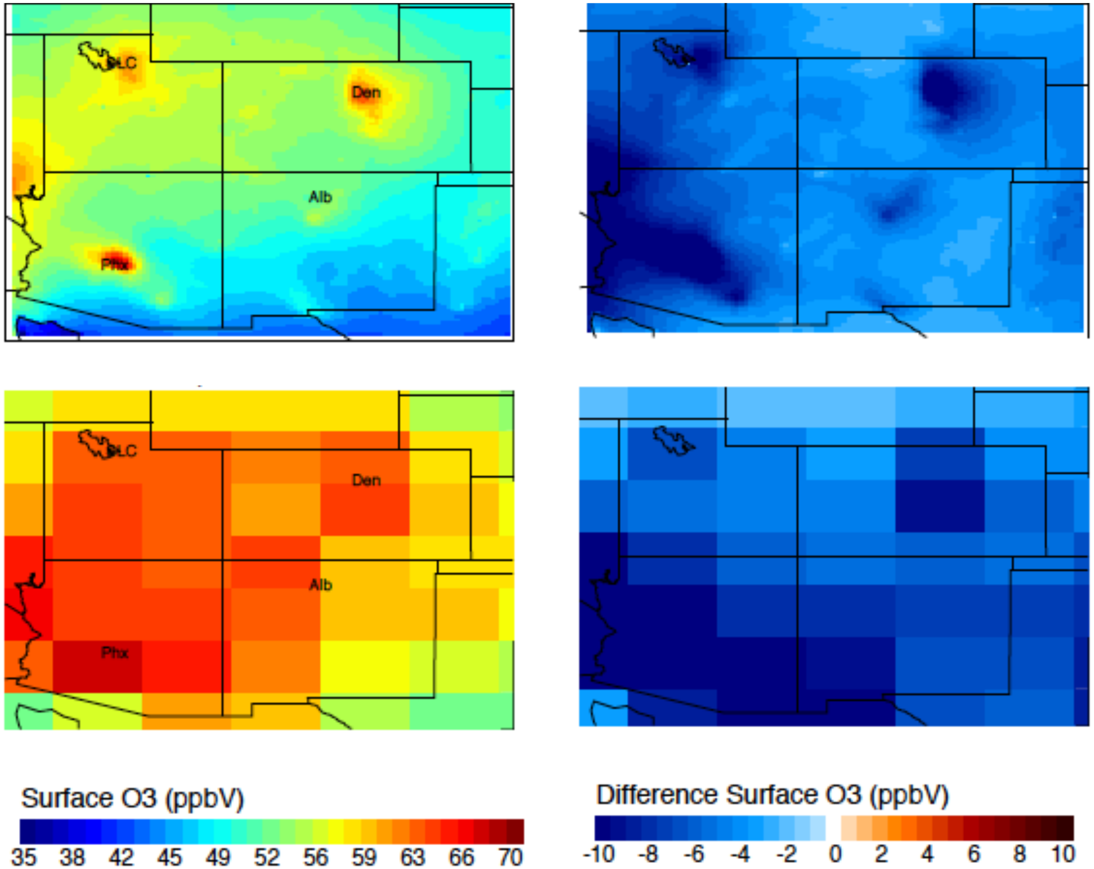
CAM-Chem

Global and Regional Predictions



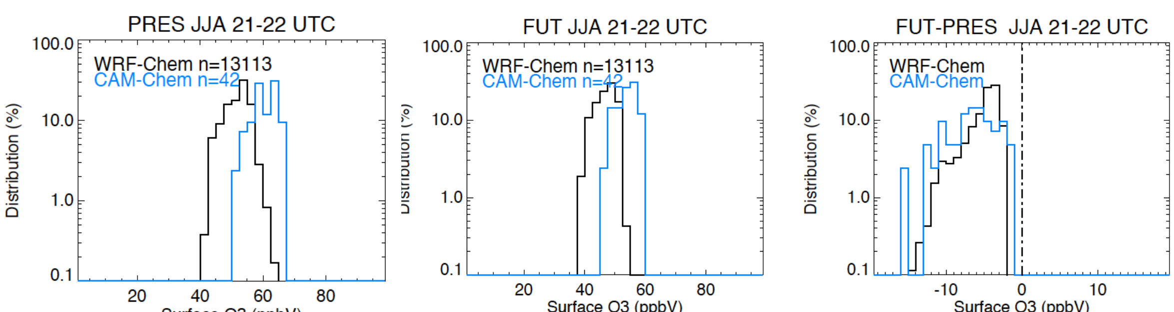
Global and Regional Predictions

Present | Future-Present



NRCM-Chem

CAM-Chem



Summary & Outlook

Simulations address range of interesting science topics:

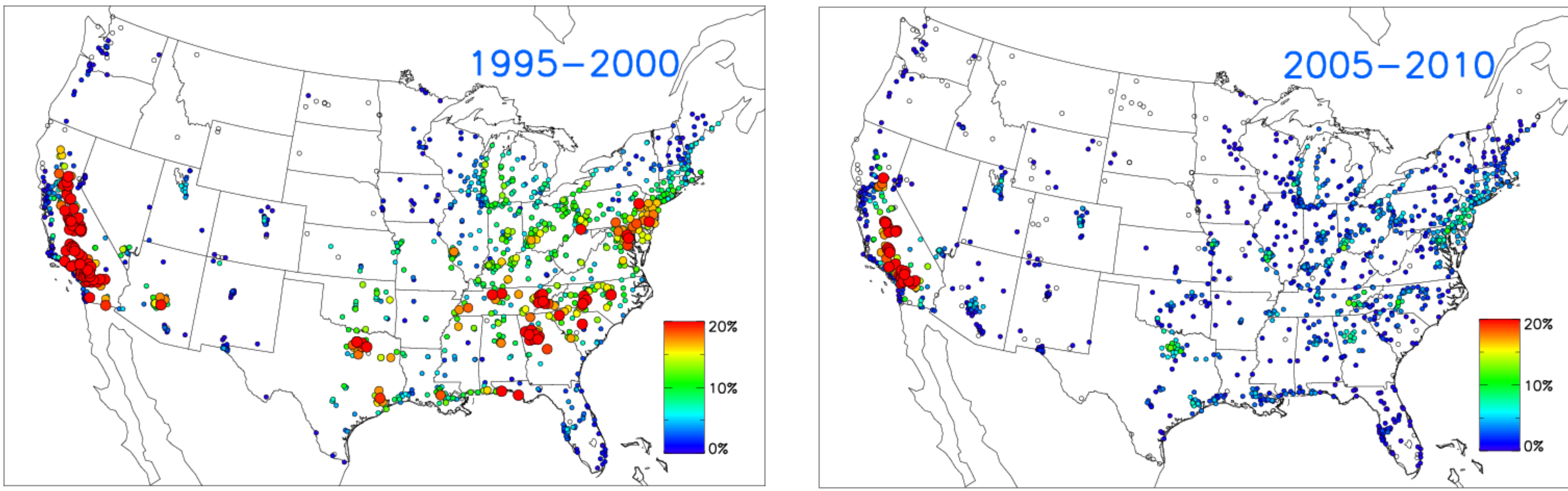
- Future Changes in Air Quality – Impacts of Climate and Emissions
- Future Changes in Climate
- Dynamical Downscaling of Meteorology and Chemistry
- Chemistry-Climate Feedbacks
- Sensitivity to Initial Conditions
- etc. etc. etc.

First Analysis:

Reducing surface Ozone over the U.S. can be achieved by strong emission reductions, while the impacts of climate act to increase surface ozone by 2050 in parts due to increased temperature, solar radiation and stagnation events and higher background levels.

Objectives

"There is growing recognition that development of optimal control strategies for key pollutants like O_3 and PM2.5 requires assessment of potential future climate conditions and their influence on the attainment of air quality objectives"



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