Impact of climate change on air quality

**WSU**: YUNHA LEE, Serena Chung, Brian Lamb, Von Walden, Joe Vaughan, and Jeremy Avis

**UC Irvine**: Alex Guenther

**PNNL**: Rahul Zaveri and Jerome Fast

LAR CEE
Washington State University

2016 NW-AIRQUEST meeting
Climate scenarios: CMIP5 four Representative Concentration Pathways (RCPs)
How can we project future air quality in “affordable way”?

Global-scale or US-regional air quality models are EXPENSIVE!

Number of processors used to compute CMAQ (4km x 4km) and how long does it take to run 10 years of summer

- **Lagrangian air quality box model**
  - Computationally affordable
  - Prescribe air trajectory
  - Like CMAQ, it requires reasonable initial and background concentrations
Model for Simulating Aerosol Interactions and Chemistry (MOSAIC)

- Photochemistry (CBM-Z)
- Aerosol thermodynamics, chemistry, microphysics
- RH, Temp, Pressure, PBL height
- Source emissions
- Free troposphere entrainment
- Air trajectory
Goal

to improve our understanding of the effects of global change on future PM levels in the western US.

Objectives:
1) to develop and apply a novel application of Lagrangian box modeling using an ensemble of high resolution and bias corrected downscaled climate conditions
2) to use the modeling approach to provide comprehensive descriptions of PM changes due to various global change factors.

End Products
1) The end products will be an extensive set of simulations explicitly addressing the effects of climate change, emission changes and land cover changes upon PM and ozone for key air quality issues and locations in the western US.
2) A special effort will be made to summarize the full range of results in terms accessible and useful for air quality managers.
**Time period:** Present, 2030s and 2050s

**Anthropogenic Emissions:**
- MARKAL Scenario 2 projections
  - US anthropogenic emissions
  - background conc. changes

**Land Use Changes:**
- CLM/MEGAN
  - Wildfire emissions
  - BVOC emissions
  - Other land use changes

**Meteorology:**
- daily, high resolution CMIP5 downscaled data (MACA method)
  - Climate change

- Wintertime stagnation
- Urban-rural transport
- Wildfire impacts

**MOSAIC gas and aerosol phase chemistry and dynamics**

**Evaluations against field campaign data**
Use master shell script to take air trajectory (time, lat, lon, alt) and read emis/met data along the trajectory. Convert emissions species (saprac07t) to mosaic tracers (CMB-Z).

Framework to link MOSAIC with gridded emis/met

Air trajectory

- CARES evaluation: assume straight line trajectory between T0 and T1 sites
- Obtain air trajectory using the weather analog used by John’s group in U of Idaho (32 km resolution)

Initial and boundary concentrations

- CARES evaluation: use WRF-Chem output
- Explore a few options: CMIP5 runs (NASA GISS), CMAQ runs, simple calculations
- Convert model species to mosaic tracers (CBM-Z)
Modeling Framework

Air trajectory ➔ Emissions / Met ➔ MOSAIC

- Read a pre-defined air trajectory
- Emissions along the air trajectory
- MACA or WRF meteorology along the air trajectory
- Initial and background concentrations along the trajectory

Compute air pollution with along the air trajectory
What affects MOSAIC species concentrations?

• MOSAIC chemistry/dynamics

• Air trajectory
  Emissions
  Dilution with free troposphere concentrations:
  \((\ln(PBL_{\text{new}}/PBL_{\text{old}})/\text{time}_\text{step})\)

• Initial concentrations
CARES (Carbonaceous Aerosol and Radiative Effects Study)

June 2010 in Central Valley, CA (Centered in Sacramento)
- "TO" site in Sacramento
  (lat: 38.65, lon: -121.35, alt: ~ 30 m)
- "T1" site in Cool, CA
  (lat: 38.87, lon: ~121.02, alt: ~450 m)
- Three aircraft measurements: DOE G1 aircraft, NASA B200 aircraft and NOAA Twin Otter aircraft

Investigate the evolution of secondary organic and black carbon aerosols and their climate-related properties in the Sacramento urban plume, which is routinely transported into the Sierra Nevada forest area
back trajectory from T0 site on June 15, 2010 at 17:00:00 UTC using HYSPLIT with WRF-Chem outputs
Air quality along the back trajectories**

** Some trajectories are out of emission domain, so it is not included.
Air quality along the back trajectories**

** Some trajectories are out of emission domain, so it is not included.
T0 site: SO$_4^-$, EC and OC
T0 site: NO, NO₂ and O₃
Representative climate change for current decade, 2030’s 2050’s

MACA (Multivariate Adaptive Constructed Analogue) 4 km gridded downscaled climate conditions (Abatzoglou and Brown, 2011)

- bias-corrected data for CMIP5 4 RCP scenarios: RH, Temp, Winds, Precip, etc
- Historical MACA data exist from 1950 to 2005
- Future RCP projections extend from 2006 to 2100 for each CMIP5 model

** How to obtain representative simulations for each case and each period
** How to define representative trajectories using downscaled climate MACCA data
<table>
<thead>
<tr>
<th>Potential Sites</th>
<th>Field Study for Model Evaluation</th>
<th>Category</th>
<th>Attribution Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sacramento/San Francisco</td>
<td>CARES</td>
<td>Summertime</td>
<td>Climate</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Urban to Rural</td>
<td>BVOC</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Wild Fires</td>
<td>Land Use</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Winter-time</td>
<td>Anthro. Emissions</td>
</tr>
<tr>
<td>San Joaquin Valley</td>
<td>Discover AQ</td>
<td></td>
<td>Back-ground Conc.</td>
</tr>
<tr>
<td>Southern CA</td>
<td>CALNEX</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phoenix, AZ</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Denver Front Range</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seattle, WA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Portland, OR</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>central ID fires</td>
<td>BBOP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yakima Valley, WA</td>
<td>YAWNS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Boise, ID</td>
<td>Treasure Valley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt Lake City, UT</td>
<td>PCAP</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Northern CA fires</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>New Mexico fires</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Next Steps

• Continue to develop the gridded framework as the basis for linking MOSAIC to CLM and to gridded emissions

• Work on definition of representative trajectories using downscaled climate MACCA data

• Define time frames and protocols for running MOSAIC to capture current and future global change conditions

• Link our model outputs to AQ regulations (e.g., 24hr PM concentrations, 8hr Max O$_3$)