AIRPACT-Fire for enhanced communication of human health risk with improved wildfire smoke modeling

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Presentation Overview:

- Fires in the Pacific Northwest (PNW)
- Overview of the AIRPACT Forecast System for the PNW
  - Fire Emissions Framework
  - Model Evaluation
- Planned upgrade
  - WRF-SFIRE
- Summary
Current Ongoing Wildfire Season

MODIS Image
August 23, 2015
Wildland Fires in the Pacific Northwest during 2012-2014

From GEOMAC: http://www.geomac.gov/viewer/viewer.shtml
AIRPACT Regional Air Quality Forecasting System:

- Pacific Northwest domain
- Operational since 2001
- ~7 years of online archive
- AIRPACT-4
  - 48-hour forecasts posted to the web daily by ~5 am Pacific Time
  - 4-km x 4-km grid cells
    (285 columns x 258 rows)
AIRPACT-4 Modeling Framework

- **WRF-ARW v3.5.1**
  - Daily forecasts from Univ. of Washington
- **CMAQ v4.7.1**
  - SAPRC99 gas-phase mechanism
  - AERO5 aerosol module
- **MOZART-4**
  - Daily forecasts for chemical boundary conditions

Components of AIRPACT-4
Fire Emissions Framework:

- **Within CMAQ domain:**
  - SMARTFIRE2 for fire activity (locations and sizes)
  - BlueSky 3.5.1 for emission and heat flux
  - Emissions for Canada are obtained from the BlueSky Canada system: [http://firesmoke.ca/data/emissions/sf2](http://firesmoke.ca/data/emissions/sf2)
  - SMOKE for plume-rise speciation of VOC and PM$_{2.5}$

- **Chemical Boundary Conditions**
  - MOZART-4 (Emmons et al., 2010) includes fire emissions from FINN (Wiedinmyer et al. 2011), which is based on MODIS Rapid Response fire counts
SMARTFIRE2:

- Reconciles data streams:
  - NOAA’s Hazard Mapping System (HMS)
  - (Infrared fires perimeter from GEOMAC)
  - (Incident Command Information from IRWIN)

- Provides fire locations and sizes (areas)
  - Fire sizes scaled by number of HMS detects

- Due to timing, forecast system is using fire locations and sizes from “yesterday”

- Reference: Larkin and Raffuse, 2012
Fire Emission Modeling:

- BlueSky v3.5.1 options selected:
  - FCCSv2 fuels map (Prichard et al. 2011)
  - CONSUMEv3 for combustion completeness (Prichard et al. 2006)
  - FEPS for emissions (Anderson et al 2004)
  - BlueSky options not used: plume rise, dispersion, time rate

- BlueSky Output
  - Daily emissions of CO, NOx, NH₃, VOC, PM₂.5
  - Daily heat flux

- SMOKE v3.5.1
  - Speciates NOx, VOC, PM₂.5
  - Temporal profile for time rate
  - Converts heat flux to buoyant flux to calculate plume rise using Brigg’s algorithm
Online output – Hourly Concentrations
(http://lar.wsu.edu/airpact)
Online output – Daily Fire Locations
(http://lar.wsu.edu/airpact)
Online output – Individual Fire Information
(http://lar.wsu.edu/airpact)
SMARTFIRE2 Information

(http://128.208.123.111/smartfire/events/5554c709-3134-4fb8-a7ad-6d2f823082a5/)
Near-Real Time Evaluation
(http://lar.wsu.edu/airpact)
AIRPACT-3 Performance
(reanalysis, 12-km, BlueSky 3.1, CMAQ 4.6)

- AIRPACT-3 forecasts of PM$_{2.5}$ downwind (+100 km) of fires are generally too low, in contrast to CO
  - Uncertainty in primary PM emission
  - Low VOC emissions
  - Low SOA
    - VOC speciation
    - Missing semi- and intermediate-volatile VOC in emission
Comparison of Plume Rise methods
(AIRPACT-3 reanalysis 12-km, BlueSky 3.1, CMAQ 4.6)

- Model underpredicts PM$_{2.5}$ when CO performs well
- Treatment of plume rise makes a big difference

Herron-Thorpe et al. 2014
Comparison of Plume Rise methods (AIRPACT-3 reanalysis: 12-km, BlueSky 3.1, CMAQ 4.6)

Herron-Thorpe et al. 2014
Some Weaknesses in the Current Framework:

- **Persistence Assumption:**
  - Tomorrow’s area burned will be the same as that from yesterday’s or two days ago

- Fixed diurnal profile

- Plume rise
  - Based on algorithm for power plants

- Constant fuel moisture of “dry”
New Framework with WRF-SFIRE:

- WRF-SFIRE is a two-way coupled atmosphere and fire model (Mandel et al. 2011)
  - WRF – ARW for meteorology
  - Rothermel (1972) semi-empirical fire spread model – fire spread depends on wind speed and terrain slope
  - Heat and moisture released by the fire feedback to atmosphere dynamics
WRF-SFIRE: coupled atmosphere-fire model

- **METEO INPUT**
  - Large scale weather data from NWP models: initial conditions and boundary conditions
  - Static data:
    - High-resolution topography
    - Land Use and Soil Data

- **FIRE INPUT**
  - High resolution fuel data:
    - 30m-resolution fuel description
    - 30m-resolution elevation data
    - times and locations of ignitions or fire perimeters
    - Initial fuel moisture

- **WRF SFiRE**
  - WRF framework (atmosphere):
    - ARW atmospheric core
    - WPS preprocessing system

- **FIRE-GENERATED HEAT AND MOISTURE**
  - Fuel Moisture Model (Van Wagner and Pickett)
    - Drying and wetting due to changes in T and RH
    - Wetting due to rain
    - Explicit treatment of different fuel classes

- **FIRE-AFFECTED WINDS**

- **METEO OUTPUT**
  - High-resolution forecast including Plume height

- **AIRPACT**
  - Regional air quality forecast

- **FIRE OUTPUT**
  - High-resolution fire forecast including:
    - fire area
    - fire heat flux
WRF-SFIRE Reanalysis Case Study: 2007 Witch Fire

3125 x 2625 ($\Delta x = 20$ m)
fire mesh at within the smallest WRF Domain

Domain D04, $\Delta x = 500$m

Kochanski et al. 2013
WRF-SFIRE Case Study: 2007 Witch Fire

• The plume rise is resolved by the dynamics based on the amount of the fire-generated heat and meteorological conditions
• Emissions are computed based on FINN
• Smoke may be represented as a passive tracer (fast), or as chemical fluxes integrated with WRF-Chem (slow)
WRF-SFIRE Case Study: 2007 Witch Fire

Kochanski et al. 2013

Observed (white) vs. simulated (red) fire perimeter at 17 PDT on October 23 2007 (60 hours into simulation)
Summary

- AIRPACT is a widely used tool for federal, state and local agencies in the PNW in managing air quality concerns.
- In retrospective mode (when fire activity is more certain), AIRPACT generally models smoke location well but PM$_{2.5}$ concentrations are under-predicted due a combination of primary emissions being too low and not enough SOA.
- Future work includes:
  - Use WRF-SFIRE for dynamic fire area and plume rise
  - Update emission factors and speciation for VOC
  - Update SOA chemistry mechanism
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- **NIST**
- **Joint Fire Science Program**
WRF-SFIRE Case Study: 2007 Witch Fire

Kochanski et al. 2013