Forecasting Wildfire Smoke PM2.5 using the AIRPACT5 Air-Quality Forecasting System: recent experience, emerging approaches and a near-term application.

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Refinery and Chemical Industry Emissions Symposium
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Air-quality Indicator Reporting for Public Access and Community Tracking: AIRPACT

• Forecasting AQ in WA state since 2001
• AIRPACT5 forecasts highly resolved AQ:
  • Nightly run forecasts the next two days (48 hours)
  • Spatial scale of 4-km grid covers WA, ID, & OR.
  • Criteria pollutants: PM2.5, O3, CO, NO2, SO2, & related precursors and products
• Supported by NW-AIRQUEST consortium: EPA, WA Ecology, OR DEQ, ID DEQ, Local & Tribal agencies, Env. CAN.
Tour of AIRPACT5 at: http://lar.wsu.edu/airpact/

- Forecasts (Imagery)
- Monitoring Sites
- Performance Charts/
- Boundary Conditions
- Curtain Plots
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10 timestep animation, every 6 hours
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Anthropogenic emissions based on the 2011 NEI
- Updates to major point sources (2014)
- Reductions in Residential Wood Combustion (Urban Areas)
- 2014 MOVES and NONROAD
  - MOVES static lookup tables:
    - increases processing speed
    - speeds forecast completion
    - but is year-specific.
- Area Fugitive Dust
  only used on ‘dry-side’,
east of the Cascades

Fire emissions - modified BlueSky approach
- Rx Fire, Ag Fire, and WF from NEI are not used.

Biogenic emissions - MEGAN 2.1
- Parallel mode (increases speed)
- MODIS Land Cover & Land Use

Canada Emissions from 2010
AIRPACT Anthropogenic Emissions Update

EPA 2014 NEI v2 used as basis for AIRPACT-6 Emissions Inventory
• Updates to Point Sources by states (2017)
• MOVES and NONROAD projected to 2019
  • Large reductions in vehicle CO/NOx/VOCs and Road Dust
  • Large reductions in ship SO2 in SECA

Transition from SMOKE v3.5.1 to SMOKE v4.5 in progress
• Requires (as distributed) Intel nodes
• Fixed width format no longer used for inputs or profiles
• New version of SMOKE-MOVES (includes hotelling and new SCCs)
• Continuing to use CB-05 speciation; CB-06 not supported yet in current forecasting implementation of SMOKE-MOVES (i.e. in static lookup tables)
SMARTFIRE-2 is queried at 10 pm PDT for USA fire locations and sizes
  - NOAA HMS fire-detects and Infrared fire perimeters from GEOMAC
  - “Spin-up” (24-hrs) look back and “persistence” assumption used for
    - Fire locations detected 1-2 days prior to the forecast date.
  - All fire acres divided by 3 to correct for HMS double counting.
  - Rx fire assumed if October – June, and treated as pile burn.
    - Rx Fires not fuel specific (assumes ~100 tons fuel burned per HMS detect)
    - Avoids very large over-estimates in cold months

FCCS fuels map from BlueSky 3.5.1 is queried
  - Fire emissions and heat flux looked up from BlueSky sensitivity analysis
    - Emissions scale linearly
    - Heat flux scales non-linearly
    - Allows fire emissions to be processed in less than 5 minutes, even when there are 1000s of fire locations

Canadian fire emissions come directly from BlueSky Canada
  - BlueSky Canada does not assume large acreage per HMS detect, so no Rx fire replacement or size adjustment is needed.
AIRPACT-5 Fire Plume Rise

- Original BlueSky approach specified Plume Top, Plume Bottom, and Smoldering Fraction based on Briggs (no PBL considered)
  - Used until 2014
- Improved SMOKE approach used WRF Planetary Boundary Layer height (meters a.g.l) to constrain plume rise
  - Used until 2018
- Note: SMARTFIRE aggregates HMS hot-spots locations, which directly impacts BlueSky heat and plume rise calculation.
  - Plume rise is modeled individually for each aggregate location.
  - Total heat release is used rather than heat/area. This is too much!
AIRPACT-5 Fire Plume Rise Update

New Modified Plume Rise Approach developed by Wei Zhang (IDEQ) addresses plume rise problems in the SMOKE approach:

1. Smoldering fraction is too low:
   Change implements new smoldering fraction by plume class based on the literature (WRAP/ DEASCO3)
   - SMOKE calculates smoldering fraction using area burned.
     - New “virtual fire area” provided to SMOKE

2. Plume rise was too high for large fires:
   Change assumes multiple fronts for big fires and reduces the heat flux which drives plume rise
   - SMOKE calculates plume rise as a function of heat
     - New lower “virtual heat” provided to SMOKE
Artificial Intelligence / Machine Learning for improved forecasts:

Random Forest and Multiple Linear Regression Daily Max 8-hr Ozone. (Fan, Dhammapala, & Lee)

- Predicts high ozone events at Kennewick, WA.
- Models used:
  - multiple linear regression,
  - generalized additive model, and
  - random forest model

WRF met in Kennewick (PBL, P, Temp, U, V, RH) + month + weekday + hour + previous day 8-hr avg. O₃

Tri-Cities Ozone Forecast is now featured on the AIRPACT5 Home Page!
Artificial Intelligence / Machine Learning for improved forecasts:

Kalman Filter Bias Correction for 24-hr (average) PM2.5 forecast, in development.

• Compute Kalman Filter Bias at each monitoring site for 24-hr PM2.5 using preceding four days, and Apply Correction:
  • Grid-applied method:
    • Interpolate the Bias over grid w/ cubic-spline and correct gridded forecast.
  • Site-applied method:
    • Apply Bias as correction to forecast at monitor grid-cell, and interpolate w/ cubic-spline.

Grid-Applied for 20170903.

Site-Applied for 20170903.
CENSE: CARDIOPULMONARY EVENTS FROM SMOKE ESTIMATOR

• CRFs: Concentration Response Functions for 7 conditions (asthma, COPD, Myocardial Infarction, etc.) from WA ECY Matt Kadlec’s review of biomass burning smoke PM$_{2.5}$ epidemiological literature.

• Relative Risk [excess %]: $RR = F(\text{cardiopulmonary cond.}, \text{age}, 24$-hr PM$_{2.5}$)

• Relative Risk map = $F(\text{AP5 bias-corrected PM2.5 forecast map}, RR(...))$

• Smart Phone App & website to serve Relative Risk forecast for users by: latitude/longitude, smart phone location, or user’s zipcode.

• Covered under HIPPA?

• Funding:
  • Joint Fire Science Program,
  • Amazon Catalyst-WSU,
  • AI for Earth Microsoft Azure Compute Grant.

• In progress...
Thank you!

Questions?