UAFSmoke - A WRF/Chem Wildfire Smoke Forecasting System for Alaska

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10th WRF Users' Workshop
OUTLINE

- BACKGROUND
- SMOKE FORECAST SYSTEM
- SYSTEM MODULES/METHODS
- NEAR-REAL TIME SMOKE FORECASTS
- EVALUATION DATA
- SUMMARY, FUTURE CHALLENGES
Fire Situation Report:
Statewide total area burnt in 2009: 275,326 acres
Number of fires: 285
Cause: Human 193
(prescribed 10)
Lightning 92

For comparison:
6.6 Mio acres burnt in 2004
Smoke Dispersion System

1. **Wildfire** source data: => ‘exact’ location and area
2. What is burning (type of surface)
3. Status of wildfire: => flaming or smoldering
4. For forecasting: fire spreading
5. Accurate quantification of pollutants emitted from wildfires
6. Smoke plume estimate: => how high, what concentration?
7. Meteorological feedback at appropriate scales
Alaska WRF/Chem ‘UAFSmoke’ Dispersion System

FIRE DETECTION & BURN AREA FROM REMOTE SENSING AND ON-SITE

FIRE EMISSIONS

Static Fuel Data Emission Factors

BACKGROUND EMISSIONS

WRF-CHEM WITH INLINE PLUME

WRF-Chem netCDF

POSTPROCESSING
Emitted tracer mass $E$ for a certain fire species $i$ from biomass burning is estimated according to:

$$E_i = a \cdot b \cdot CE \cdot e_i$$

- $a$: burning area
- $b$: fuel loading
- $CE$: combustion efficiency (above-ground biomass available for burning)
- $e_i$: emission factor


- Andrae and Merlet’s (2001) comprised necessary emission factors in order to relate various fuel-load types involved in **biomass burning to emissions**.

Saulo Freitas and Karla Longo from the Center for Weather Forecasting and Climate Studies (CPTEC/INPE) in Sao Paulo developed an emission data generator package, which has been made compatible with WRF/Chem.
PREP_CHEM_SOURCES

Emission data generator package
Gridded emission fluxes (kg/m²).

Biomass burning / wildfire emissions
- Brazilian Biomass Burning Emission Model (Freitas et al. 2005; Longo et al., 2007)
- Emission Factors from Andrae and Merlet, 2001
- 110 chemical species, 6 types of biomass burned
- GFEDv2: Global Fire Emissions Database (van der Werf et al., 2006): 8 days/monthly - 1º x 1º

Anthropogenic sources
- RETRO: REanalysis of the TROpospheric chemical composition over the past 40 years, global, 0.5º x 0.5º, monthly
- EDGAR: Emission Database for Global Atmospheric Research, global, 1º x 1º, annually

Biogenic sources
- GEIA: Global Emissions Inventory Activity, 1º x 1º

GOCART: Goddard Chemistry Aerosol Radiation and Transport model, 1º x 1.25º, monthly, anthropogenic and natural sources

by Saulo Freitas and Karla Longo, Brazil Center for Weather Forecasting and Climate Studies
Hybrid fire products as wildfire source:

1: Geostationary Operational Environmental Satellite - Wildfire Automated Biomass Burning Algorithm (GOES WF_ABBA) product (Prins et al., 1998).

2: University of Alaska Geographic Information Network of Alaska (GINA) Source: Fire Detection and Burn Area MODIS satellite thermal and reflectance bands are used as source for detection of Hot Spots and Burned Areas.

- **MOD 14** algorithm: MODIS Thermal Anomalies detection during day and nighttime at 1 kilometer resolution. => MODIS hotspots ~ 6 scenes/day
  (algorithm uses 3.9 μm and 11 μm channels, and additional 1.65- and 2.15 μm channels during night).
- => Combination of hotspots and burned area is used to specify areas of active fires.
- Data availability via UAF Geographic Information Network of Alaska (GINA). Received in real-time by the satellite reception ground station at the University of Alaska Fairbanks.
The three fire products databases may be combined using a filter algorithm to avoid double count of the same fire, by eliminating additional fires within a circle of 1 km radius. The fire detection maps are merged with 1 km resolution fuel load to provide the associated emission factor, combustion factor and carbon density.
inline in **WRF/Chem Version 3**: PLUMP => one-dimensional plume model including parameterized cloud physics has been implemented **inline** in **WRF/Chem**.

Inaccuracies are avoided due to otherwise necessary parameterization because of the small scale characteristics of the plume rise.

The one-dimensional fire plume rise model (PLUMP, Latham, 1994) estimates the vertical displacement of fire emissions mainly due to the heat emitted from fires.

$$\Delta h = \left( \frac{3r_0^2x^2}{4\beta^2F^2K^2} \right) + \left( \frac{r_0}{\beta}\right)^3 - \frac{r_0}{\beta}$$

\[F = \left( \frac{w_0^2\rho_a}{2\Delta \rho g} \right)^{\frac{1}{2}}\]

\[w_0 = \frac{8.8 \times 10^{-6} Q_h T_P}{g(T_P - T_a)r_p^2}\]

\[T_P, T_a: \text{temperature of plume and ambient respectively, K}\]

\[r_p: \text{the radius of fire, m}\]

\[Q_h: \text{the heat release rate, J/s}\]
ALASKA daily smoke forecasts

⇒ **48 hour** Smoke WX
⇒ GFS meteorological initial and boundary conditions
⇒ **daily** during the fire season
⇒ Forecast graphics at [http://smoke.arsc.edu](http://smoke.arsc.edu)

⇒ Chemistry: GOCART simple aerosol scheme, no O3
⇒ WSM 5-class scheme microphysics
⇒ RRTM longwave
⇒ Dudhia shortwave
⇒ YSU boundary layer scheme
2004: PM 2.5
Animation
Model Verification

**Data available:**

- with ground based reference data: PM measurement data from State and Local Air Monitoring Stations (SLAMS) and Special Purpose Monitoring Stations (SPM) are available.
- GINA maintains a MODIS and Landsat5 database including fire related products.
- LIDAR (UAF)
- DRUM aerosol measurements
- Sun photometer and aerosol measurement data from the DOE Atmospheric Radiation Measurement (ARM) program.
- Multiangle imaging spectroradiometer (MISR) data & additional satellite remote sensing data are available for model comparison.

Source: J. Conner, Fairbanks North Star Borough
2008: Forecast Comparison for Particulate Matter (PM2.5)

Measurement Source: James Conner, Fairbanks North Star Borough
Summary

• Alaska UAFSmoke **WRF/Chem system** has been developed.

• Daily smoke forecast runs are performed at the **Arctic Region Supercomputing Center (ARSC)**. Experimental products are available at [http://smoke.arsc.edu/](http://smoke.arsc.edu/).

• Fire source data are used from the Alaska Interagency Coordination Center (AICC). In synergy we use **MODIS** fire hotspots and image products from UA Geographic Information Network of Alaska (GINA), and **GOES WF_ABBA fire products**. MODIS data are received typically within 40 minutes of reception. MODIS products are compared to AICC data and optionally serve as direct input to the smoke model system.

• Alaska fuel load was derived from land cover classification.

• Gridded daily wildfire emission fluxes (kg/m²), anthropogenic and biogenic sources are derived using the Prep_sources_chem emission data generator package.

• Fire Plume Rise inline in WRF/Chem accounts for the vertical displacement of fire emissions due to the heat emitted from fires.

• Fire spread and diurnal cycles are neglected during the forecast period.

• Test runs during the fire season show good results. The timing of smoke episodes in Fairbanks has been well predicted.