The Impact of New BlueSky Smoke Emission on the NWS Operational HYSPLIT smoke Forecasting

Ho-Chun Huang[1,2], Susan O'Neill[3], Barbara Stunder[4], Perry Shafran[1,2], Jeff McQueen[2], Mark Ruminski [5], Shobha Kondragunta[5]
Jerry Gorline[6], Jianping Huang[1,2], Ariel Stein[4], Robert Solomon[3], Ivanka Stajner[7], Sikchya Upadhayay[7,8], Narasimhan Larkin[3]

[1] I.M. Systems Group, Inc. [2] NOAA NWS/National Centers for Environmental Prediction [3] US Forest Service, PNW Research Station [4] NOAA Air Resources Laboratory (ARL) [5] NOAA National Environmental Satellite, Data, and Information Service (NESDIS) [6] NOAA Meteorological Development Laboratory (MDL) [7] NOAA NWS/Office of Science and Technology Integration [8] Syneren Technologies

NWS/HYSPLIT Smoke Forecasting System

- The particulates matter (PM) generated from forest fires often severely impact the air quality and human health in the nearby and downstream areas. Wildfires occur randomly and the intensity and location of fire can change with time. it is extremely difficult to model the fire smoke particulate both in spatial and temporal scale.
- The National Weather Service uses the HYSPLIT smoke forecasting system (***NWS/HYSPLIT smoke***) to forecast the smoke concentration resulting from fire (Figure 1). It consists of the NOAA National Environmental Satellite, Data, and Information Service (NESDIS) Hazard Mapping System (***HMS***) fire and smoke detection system, the emission module of the US Forest Service BlueSky Smoke Modeling Framework (***BlueSky***), and The Hybrid Single Particle Lagrangian Integrated Trajectory (***HYSPLIT***) model.
- *NWS/HYSPLIT smoke* is in operational production since 2007. Since then it has been updated regularly to include more advance scientific findings and newly available tools. The latest update (in progress) is the newer version of the ***BlueSky***.
- In this study, we will examine the impact of updated BlueSky smoke emissions module on the *NWS/HYSPLIT smoke*.

Model Components

- ***HYSPLIT*** is used to calculate the transport, dispersion, and deposition of the emitted fire smoke PM (http://www.arl.noaa.gov/HYSPLIT_info.php). A fix number of particle (a computational mass representing a pollutant) is used to track smoke dispersion that are moved by the mean wind field and spread by a turbulent component.
- The NOAA NESDIS's ***HMS*** fire and smoke detection system (http://www.ospo.noaa.gov/Products/land/hms.html) provides the locations and extents of fires. Experienced analysts inspect satellite imagery (two GOES, five NOAA-AVHRR and NASA EOS Aqua and Terra), identify the location, size and duration of smoke emissions.
- The emissions module of ***BlueSky*** (http://www.airfire.org/bluesky) provides the PM emissions and heat from fire smokes based on HMS's fire locations. In addition, the BlueSky also provides fire gases and PM information to the National Air Quality Forecasting Capability (NAQFC) that uses the Community Multiscale Air Quality (CMAQ) to provide air quality guidance available to state and local air quality forecasters for their daily operation.

  NWS/HYSPLIT smoke is being updated to use a newer version (v3.5.1) of the BlueSky. The updated BlueSky incorporates the Fuel Characteristic Classification System version 2 (FCCS2) over the continental US (CONUS) and *Alaska*, which includes a more detailed description of the fuel loadings with additional plant type categories. The updated BlueSky also uses an improved fuel consumption model and fire emission production system (FEPS).

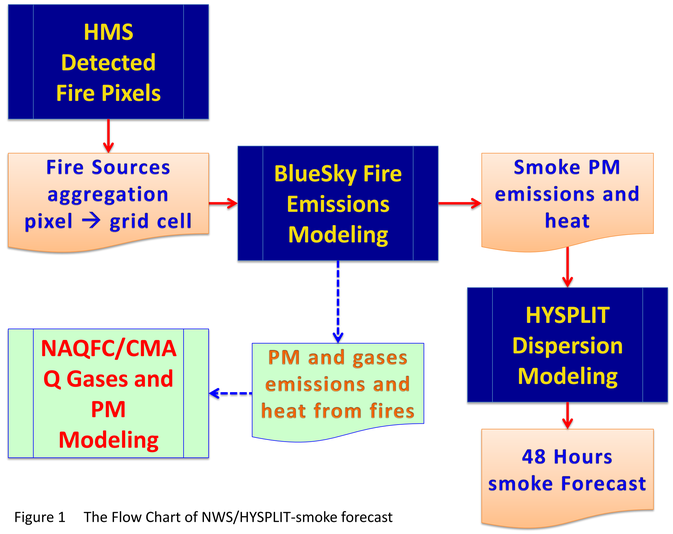

Figure 1 The Flow Chart of NWS/HYSPLIT-smoke forecast

Impact on Alaska Smoke Forecasting

Table 1 The fuel load types used in some selected fire sources in Alaska on June 25 2015. The operational HYSPLIT-smoke (PROD) use default type "Quartz Complex" while update BlueSky prescribed explicit fuel load type.

Latitude	Longitude	PROD Vegetation	EMC DEV Vegetation (FCCS2)
60.3	-159.9	Quartz Complex	Willow - Birch shrubland
61.3	-159.9	Quartz Complex	Willow -- mountain alder shrubland
64.9	-159.9	Quartz Complex	Black spruce / sphagnum moss forest
61.5	-159.7	Quartz Complex	Black spruce / feathermoss forest
61.7	-159.7	Quartz Complex	Cottongrass grassland
63.9	-159.7	Quartz Complex	Willow -- mountain alder shrubland
64.1	-159.7	Quartz Complex	Black spruce / sphagnum moss forest
61.7	-159.5	Quartz Complex	Paper birch - quaking aspen - white spruce forest
61.9	-159.5	Quartz Complex	Water
63.9	-159.5	Quartz Complex	Black spruce / sphagnum moss forest
64.1	-159.5	Quartz Complex	White spruce forest
61.7	-159.3	Quartz Complex	Cottongrass grassland
65.7	-159.3	Quartz Complex	White spruce forest
61.9	-159.1	Quartz Complex	Black spruce / cottonsedge woodland
65.7	-159.1	Quartz Complex	Willow -- mountain alder shrubland
61.9	-158.9	Quartz Complex	White spruce forest
62.3	-158.7	Quartz Complex	Black spruce / sphagnum moss forest
65.9	-158.7	Quartz Complex	White spruce forest
62.3	-158.5	Quartz Complex	Cottongrass grassland
62.5	-158.5	Quartz Complex	Black spruce / cottonsedge woodland
59.5	-158.3	Quartz Complex	Paper birch - quaking aspen - white spruce forest
59.7	-158.3	Quartz Complex	White spruce - paper birch forest
60.1	-158.3	Quartz Complex	Paper birch - quaking aspen - white spruce forest
60.3	-158.3	Quartz Complex	Willow - Birch shrubland
60.9	-158.3	Quartz Complex	Paper birch - quaking aspen forest
61.7	-158.3	Quartz Complex	Paper birch - quaking aspen forest
61.9	-158.3	Quartz Complex	Black spruce / sphagnum moss forest
62.3	-158.3	Quartz Complex	Cottongrass grassland
62.5	-158.3	Quartz Complex	Black spruce / sphagnum moss forest

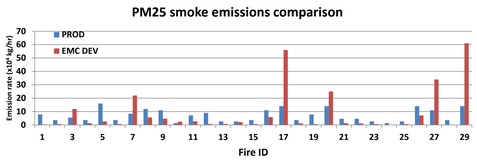

Figure 2 The PM25 smoke emission rate for operational BlueSky (PROD) and updated BlueSky (EMC DEV) for selected fires in Table 1

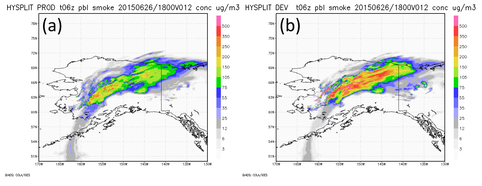

Figure 3 The Column mean (1-5000m) PM25 smoke concentration for HYSPLIT-smoke with (a) operational BlueSky and (b) updated BlueSky at forecast hours 12 valid on 18Z August 26 2015, respectively.

- Current operational BlueSky does not have explicit fuel load map for Alaska region. It uses default fuel load type "Quartz Complex" based on historical Quartz Complex fire in Canada.
- The updated BlueSky provides an explicit description of fuel load in Alaska (Table 1). Combined with more fuel load categories and updated emission processing, figure 2 shows the comparison of PM25 emission rates of the fires listed in Table 1 between using operational and updated BlueSky. The explicit fuel load type used by updated BlueSky leads to more realistic PM25 emissions than a single default fuel load type used by the operational BlueSky, i.e., a more heterogeneous strength of fire.
- The results of *NWS/HYSPLIT smoke* simulations on June 26 2015 show a larger column mean smoke PM25 concentration from using updated BlueSky than operational BlueSky (figure 3).

Model Performances

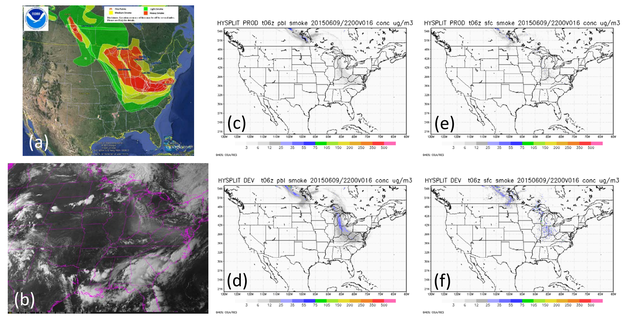

Figure 4 The Canadian fire smoke impacts on the US air quality on June 9. Both NOAA/NESDIS HMS expert analysis (a) and GOES RGB image (b) indicate the smoke plume been transported from Canada to the upper Midwest and Northeast US (courtesy of Mark Ruminski). Both operational *NWS/HYSPLIT smoke* (PROD; c and e) and *NWS/HYSPLIT smoke* with updated BlueSky (EMC DEV; d and f) agree well with the observations and expert analysis both for the column (0-5000m; c and d) and surface layer (0-100m; e and f) mean PM25 concentration. *NWS/HYSPLIT smoke* with updated BlueSky leads to higher smoke concentration in the US than that of operational *NWS/HYSPLIT smoke*.

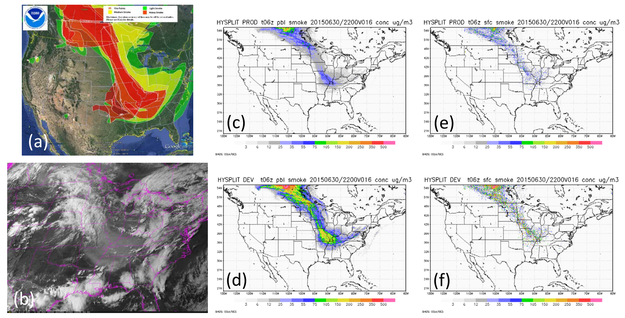

Figure 5 Similar to figure 3 except for June 30 2015, but a mush stronger smoke intrusion case.

Figures 4 and 5 show *NWS/HYSPLIT smoke* simulations on June 9 and June 30, 2015. As compared to the NOAA NESDIS HMS expert analysis and GOES satellite image, both the *NWS/HYSPLIT smoke* simulations with operational and updated BlueSky realistically capture the intrusion of Canadian fire smoke to the US. However, stronger smoke PM25 concentrations were found in column and surface layer for simulations with the updated BlueSky. Quantitatively comparisons are shown below over the CONUS.

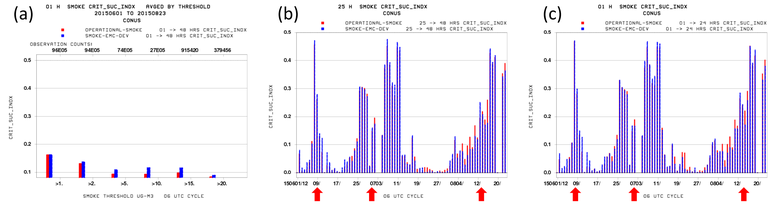

Figure 6 The performance verification of *NWS/HYSPLIT smoke* forecasting over the CONUS using operational (PROD) and updated (EMC DEV) BlueSky. Figure (6a) is the critical successful index (CSI) of various thresholds over the simulation period. Figures 6b-6c show the daily CSI score of threshold > 1 μg/m³ for 1st and 2nd day forecasts, respectively.

Figures 6a-6c show statistical evaluations of *NWS/HYSPLIT smoke* predicted column mean concentration as compared to the NOAA NEDSIS GOES atmospheric smoke detection algorithm product (GOES ASDA). Results show the *NWS/HYSPLIT smoke* with updated BlueSky emissions leads to an improved performance across the CONUS over the period of June 1 - August 23 2015.