



HRRR-SMOKE

NOAA's high-resolution weather model that forecasts smoke transport, visibility and smoke-weather interactions



Woolsey fire (California)
November, 2018

San Francisco skyline



San Francisco skyline during the Camp fire, November 2018

There is an increasing demand for high resolution, frequently updated smoke forecasts over the US for:

- Smoke/air quality alerts (health, outdoor activities)
- Visibility forecasts (transportation)
- Smoke impact on meteorology and weather forecasting
- Solar energy production
- Land-use management



Latimes.com

<http://weatherwest.com>

Fatal accident caused by wildfire smoke on Interstate 40 in Arizona, October, 2016



Wildfiretoday.com

RAP & HRRR: NOAA's Hourly Updating Weather Forecast Suite

Rapid Refresh (RAPv4)
13-km grid
forecasts to 39h (July 2018)

**Initial & Lateral
Boundary
Conditions**

**High-Resolution Rapid
Refresh (HRRRv3)**
3-km grid
– to 36h (July 2018)

**Initial & Lateral
Boundary
Conditions**

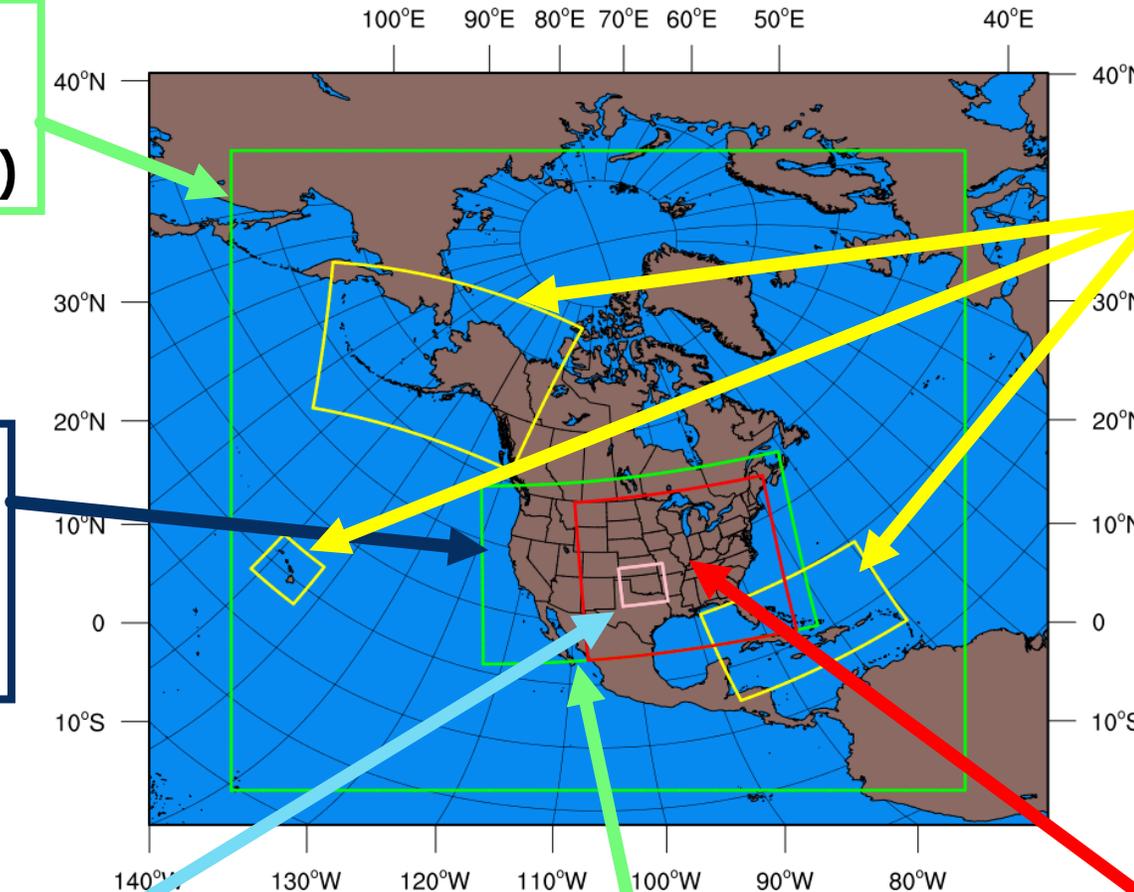
750-m grid HRRR nest
Experimental

**3-km High-Resolution Time Lagged
Ensemble (HRRR-TLE)**

3-km HRRR-Smoke (VIIRS fire data)

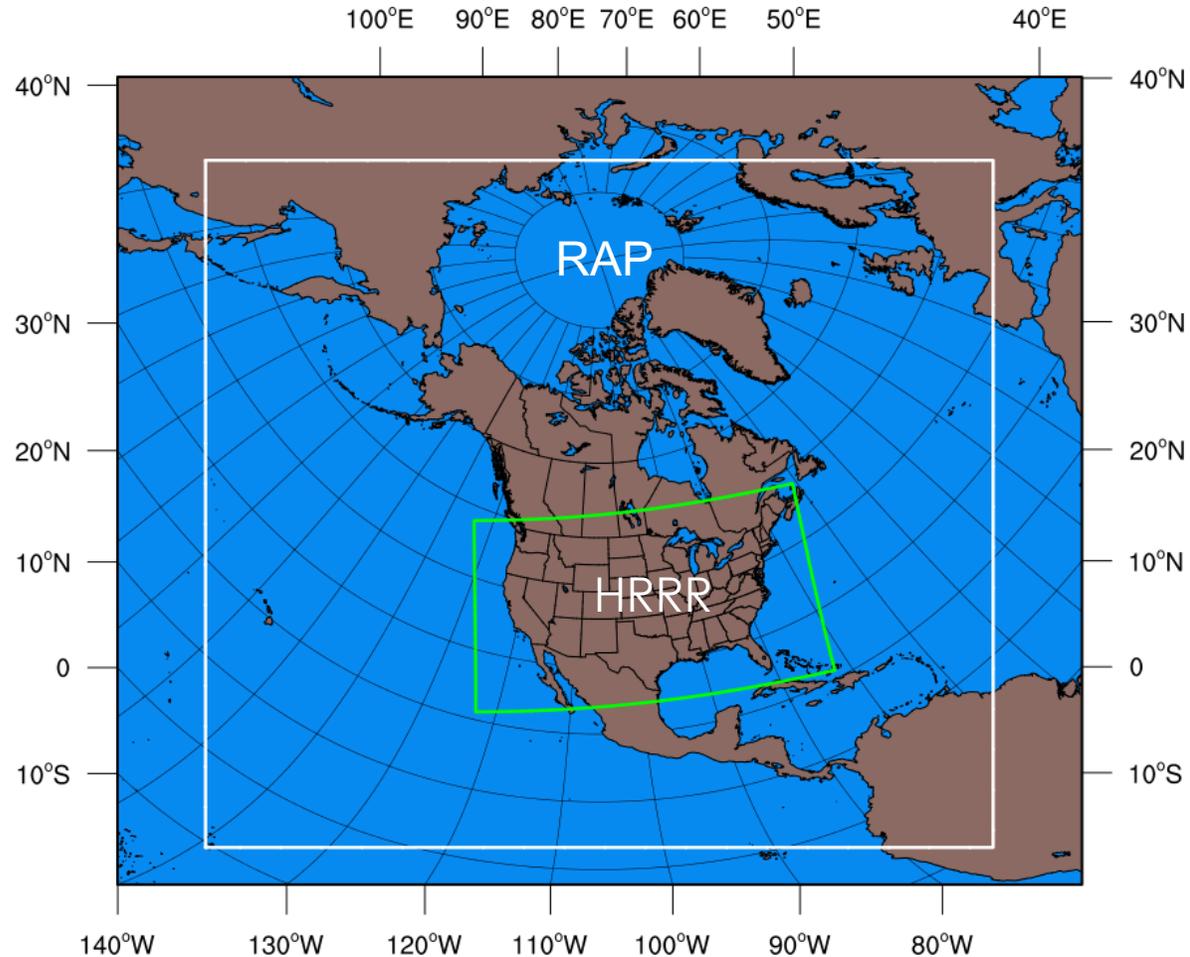
**High-Resolution Rapid
Refresh Alaska, Hawaii
and Puerto Rico**
3-km grid
Experimental

**HRRR Storm-Scale
Ensemble Analysis and
Forecast (HRRRE)**
3-km grid
Experimental



RAP/HRRR-Smoke models

- HRRR-Smoke builds on the operational HRRR by adding a **single tracer (smoke)** to NOAA's experimental RAP and HRRR weather forecasting models (based on the Weather Research and Forecasting model - WRF).
- RAP-Smoke enables forecasting smoke from all fires in North America. It provides boundary conditions for smoke to HRRR-Smoke.
- HRRR-Smoke runs on a high spatial resolution, 3-kilometer grid, to simulate mesoscale flows and smoke dispersion over complex terrain.
- **Full coupling between meteorology and smoke:** RAP/HRRR-Smoke predict the impact of smoke on radiation, thereby improving weather forecasts. The coupling improves visibility forecasts.
- HRRR-Smoke predicts biomass burning emissions and inline plume rise parameterization based on Fire Radiative Power data obtained from satellite retrievals.
- A rapidly updating data assimilation cycle for meteorology.
- Every hour, a new HRRR-Smoke forecast starts by ingesting the satellite FRP data obtained within 24 hours prior to the forecast start time. HRRR-Smoke forecasts out to 36 hours.



Operational weather forecast models at NCEP:
RAP - 13km resolution
HRRR, 3km resolution

<https://rapidrefresh.noaa.gov/>

Ingesting the real-time VIIRS and MODIS FRP data to the HRRR-Smoke model

The clustering procedure performs a combination of all **fire radiative power (FRP)** data from **VIIRS** and **MODIS** according to the model spatial resolution and grid configuration.

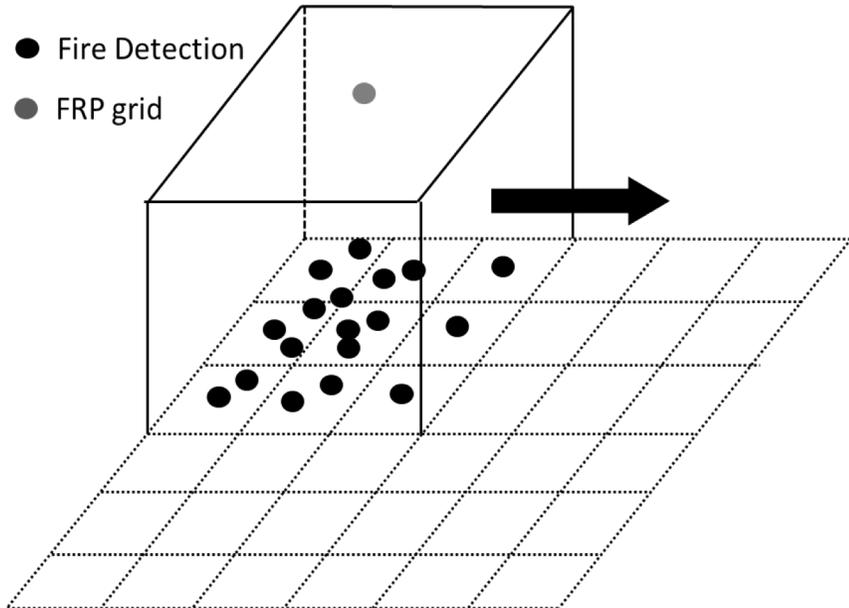
Biomass burning emissions are estimated as follows:

$$FRE = FRP \times \text{time (fire duration)}$$

$$M^{[\epsilon]} = FRE_{grid(lon,lat)} \cdot \gamma \cdot EF^{[\epsilon]}$$



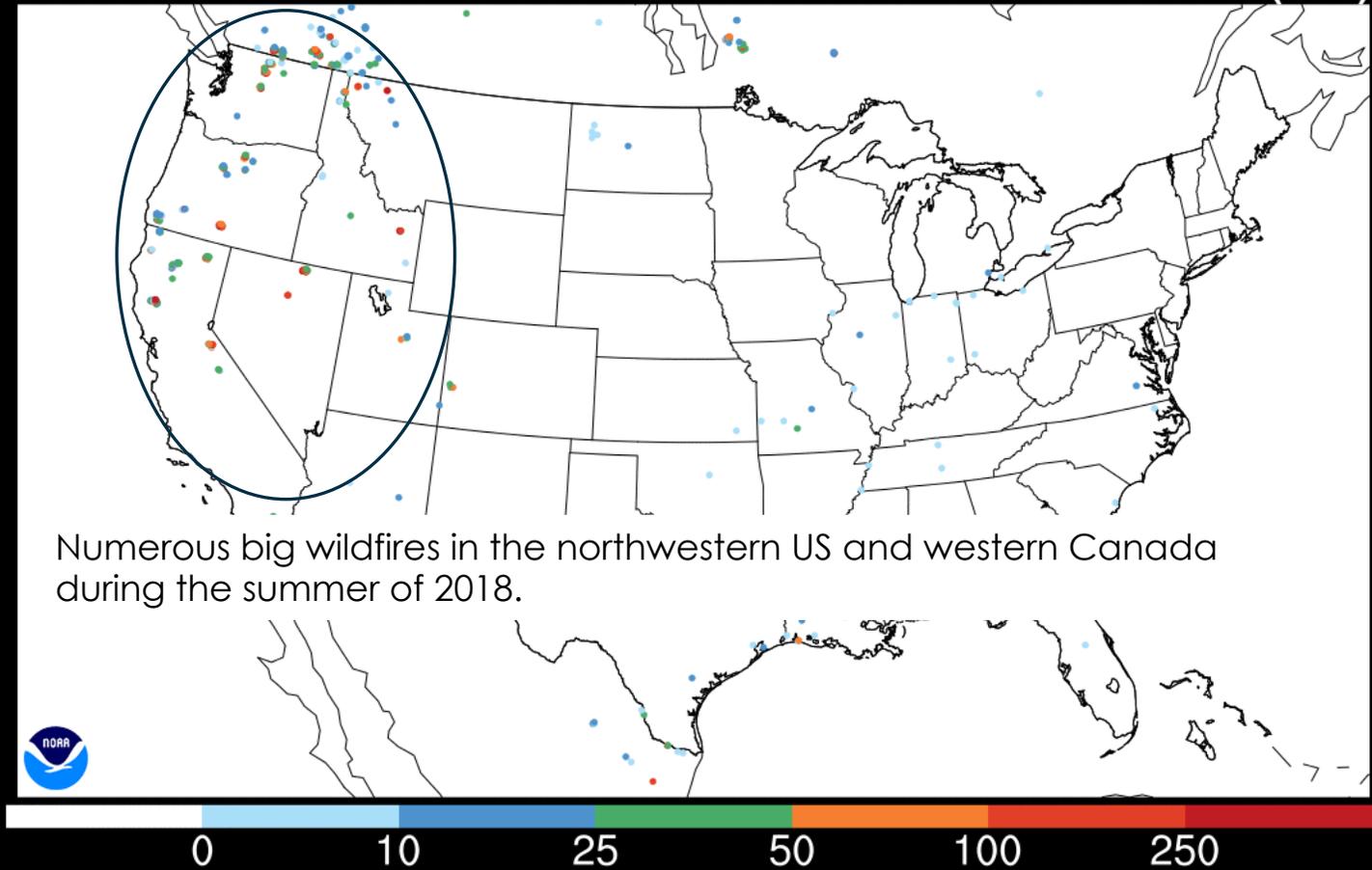
- Fire Detection
- FRP grid



Averaged satellite FRP data (24 hours), mapped over 3x3km HRRR CONUS grid pixels for August 19, 2018

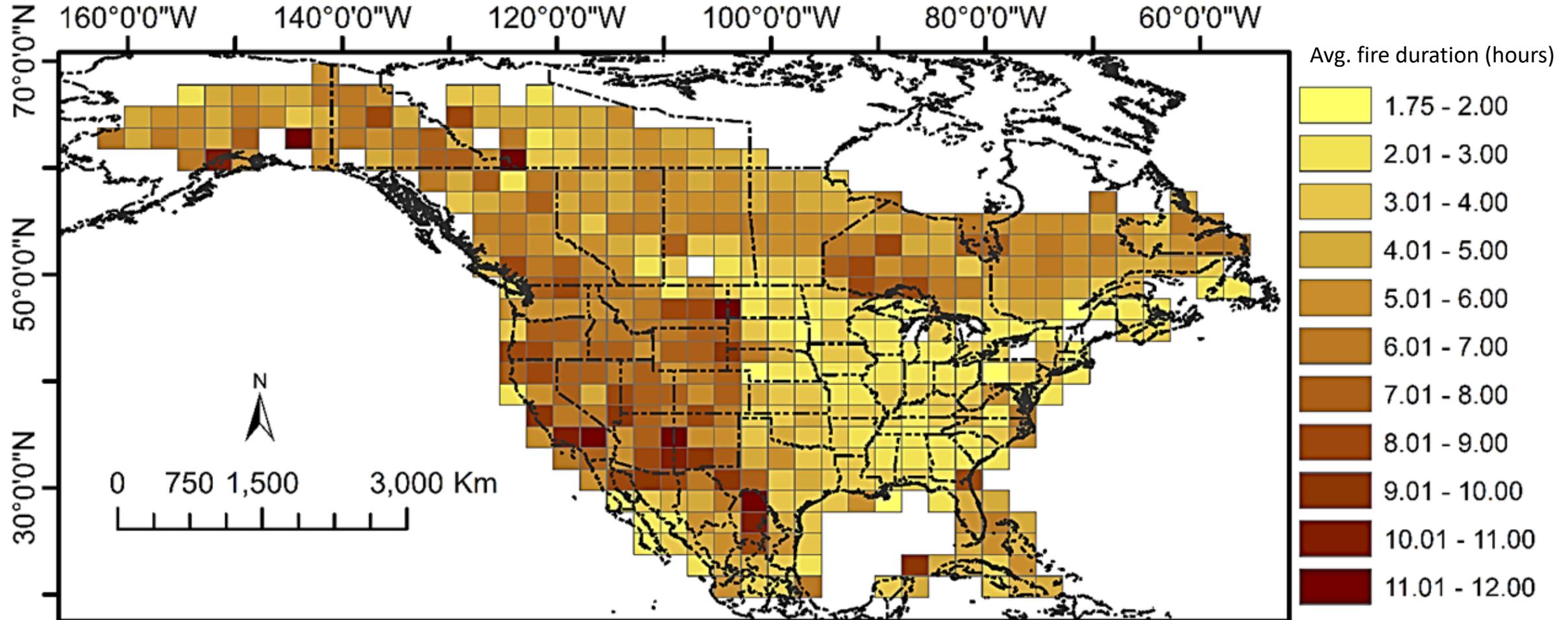
HRRR-SMOKE 2018-08-19 00 UTC - EXPERIMENTAL

Fire Radiative Power (MW)



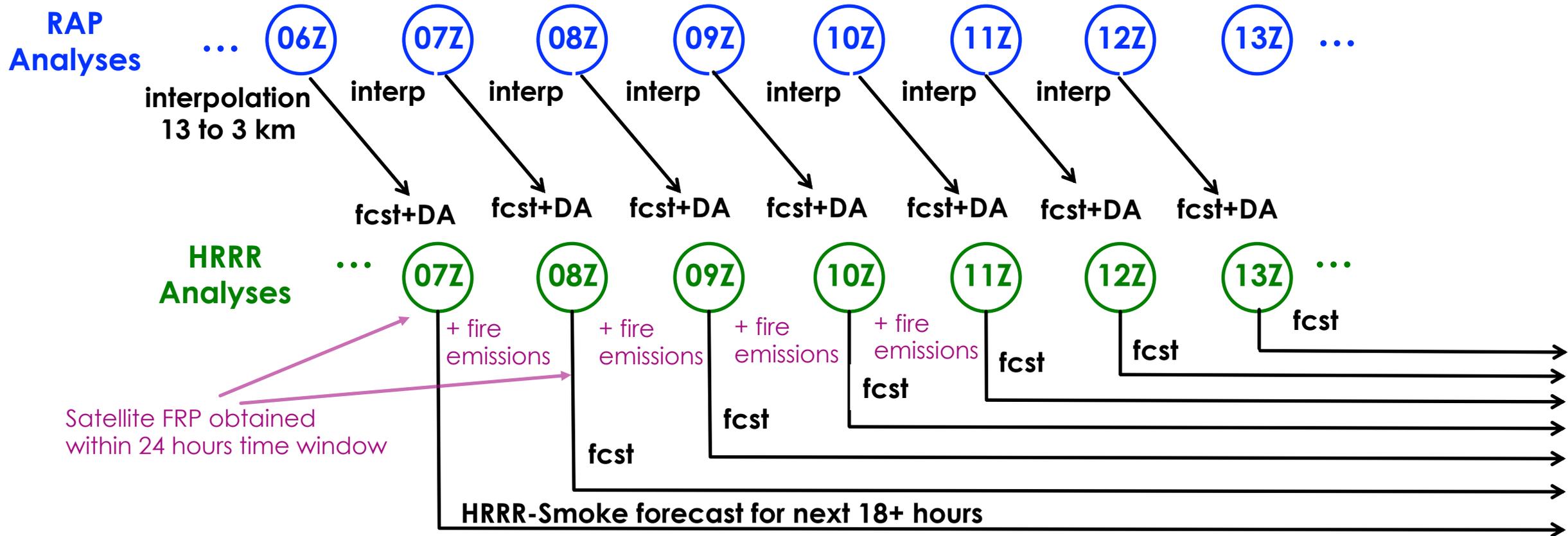
GOES-East/West satellite fire data analysis (2016)

In HRRR-Smoke, the duration of fires is estimated by using this climatology, unless there are multiple detections of a fire by satellites within 24 hours time period.



Hourly cycle of HRRR: 1-h spin-up for each forecast

New weather and smoke forecasts are produced 24 times a day

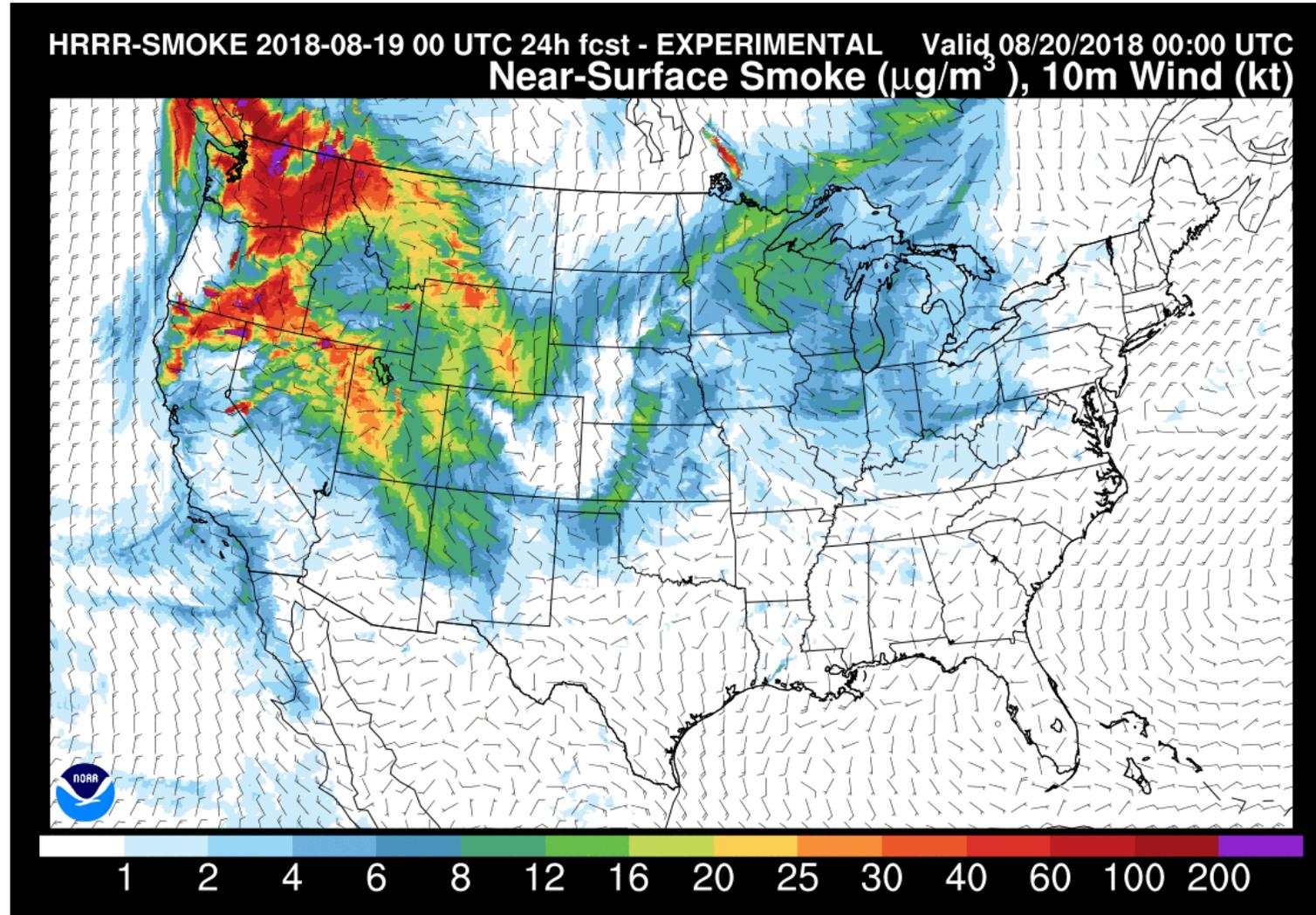


- Each HRRR analysis starts with previous hour's RAP analysis
- 1-h model integration w/ 15-min radar DA, followed by DA for conventional weather observations and non-variational cloud and hydrometeor analysis
- Simulated 3D smoke fields are cycled between the consecutive HRRR-Smoke forecasts.

HRRR-Smoke: Near-surface smoke forecast for August 19, 2018

This is the HRRR-Smoke forecast of the near-surface fire smoke for August 19, 6pm EDT over the US simulated fine particulate matter (PM2.5 or fire smoke) concentrations and wind at approximately 8m above ground. The HRRR uses a 3-km grid.

This forecast is based on the model simulation of 24 hours from 6pm EDT, August 18, 2018. (rapidrefresh.noaa.gov/hrrr/HRRRsmoke/)



RAP-Smoke

Forecast for August 21, 2018

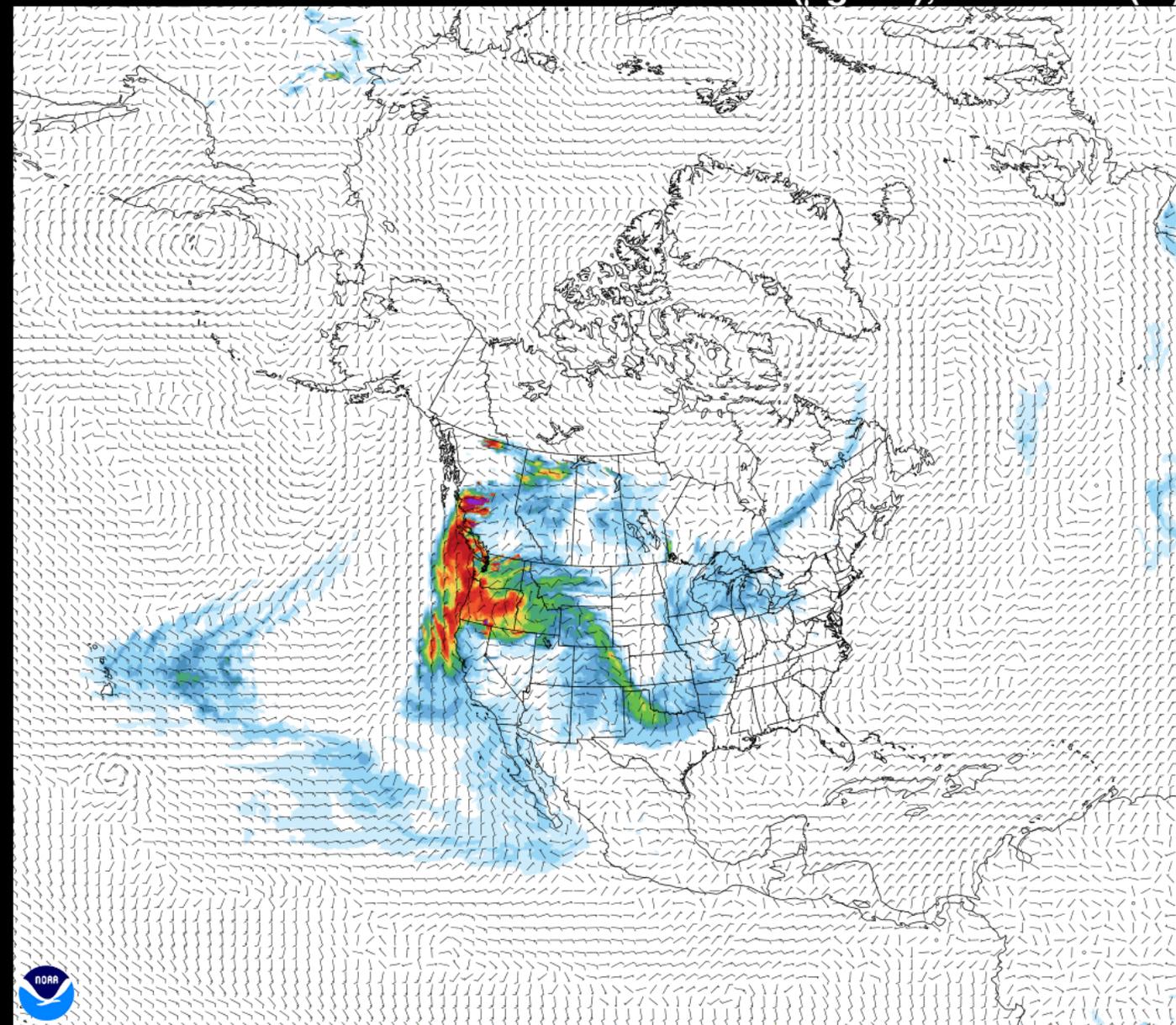
- RAP covers all of North America. The products can be used for Canada, Alaska and other regions.
- RAP uses a 13-km grid
- The same meteorology as RAPX;
- Taking advantage of the global satellite data coverage by VIIRS and MODIS;
- Feeds boundary conditions for smoke to the HRRR-Smoke over the CONUS domain;
- Enables capturing smoke transport from Canada and Mexico to CONUS;
- Forecast lead time is up to 39 hours. A new forecast starts every hour.
- The experimental smoke forecast products are displayed at:

<https://rapidrefresh.noaa.gov/RAPsmoke/>

RAP-SMOKE 2018-08-19 00 UTC 48h fcst - Experimental

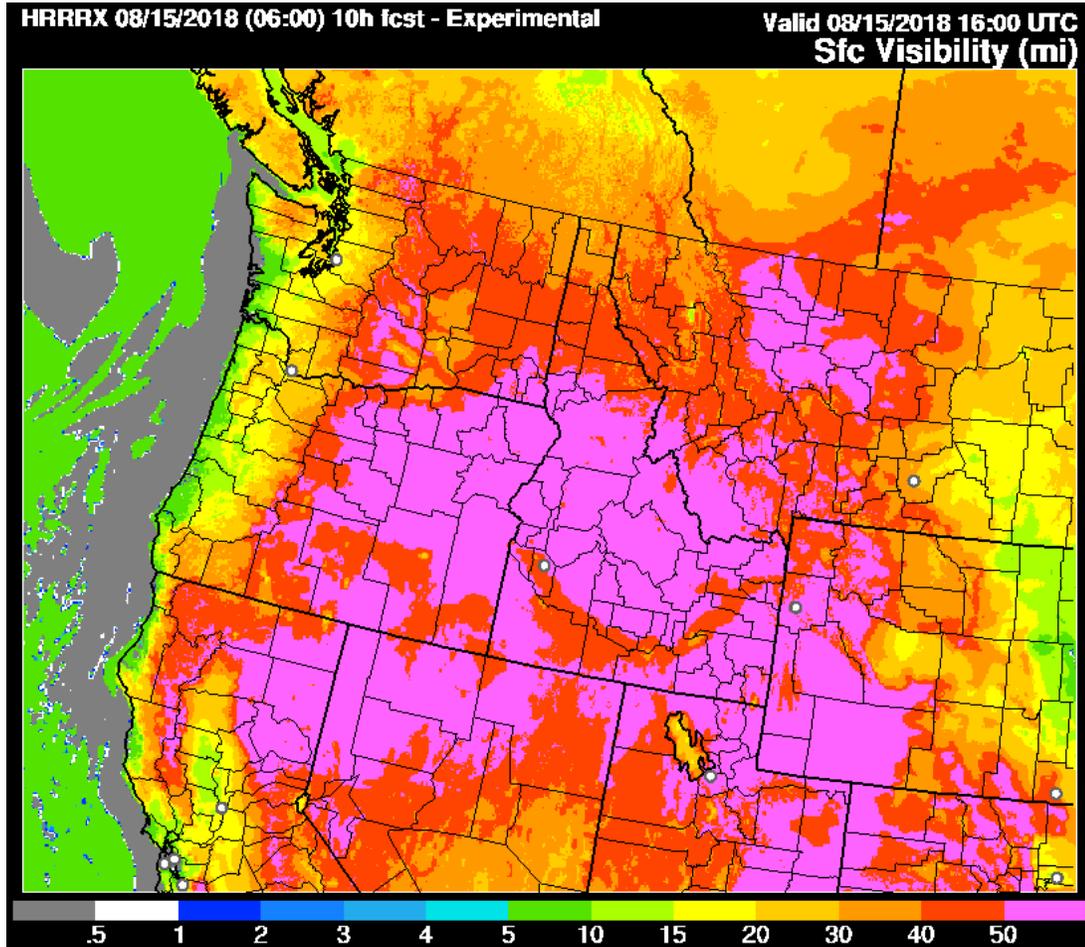
Valid 08/21/2018 00:00 UTC

Near-Surface Smoke ($\mu\text{g}/\text{m}^3$), 10m Wind (kt)

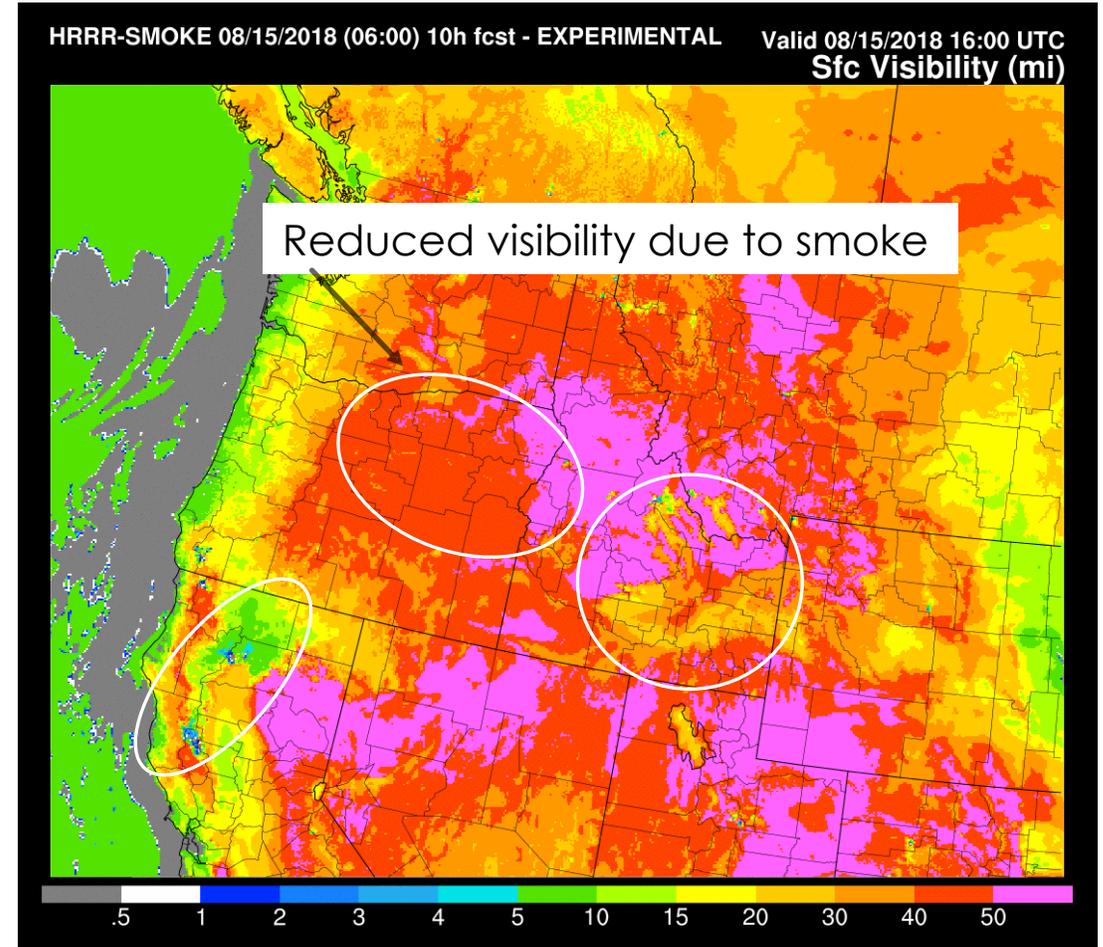


1 2 4 6 8 12 16 20 25 30 40 60 100 200

HRRR-Smoke Surface visibility forecasts for August 15, 2018



HRRR forecast without smoke effect



HRRR-Smoke forecast

Visibility is an important forecast product, widely used in the weather community (e.g. ground transportation and aviation)

Advancing HRRR-Smoke

- The frequently updated high-resolution HRRR-Smoke forecasting system allows better representation of the temporal and spatial variability of smoke distribution over the western US.
- The simulation of smoke helps to significantly improve the visibility forecasts by HRRR.
- Including the direct feedback of smoke in the model results in the improvement of weather and visibility forecasting.

Research goals

- *Ingest the high-frequency GOES-16/17 Fire Radiative Power data into HRRR-Smoke*
- *Use the FIREX lab studies to improve the parameterization of the smoldering and flaming phases of the BB emissions; Develop new parameterizations for forecasting weather dependence of the BB emissions*
- *Verify HRRR-Smoke outputs using the aircraft measurements (FIREX-AQ, WE-CAN, BBFLUX)*
- *Apply the HRRR-Smoke framework to simulate full gas/aerosol chemistry from fires*
- *Study the effect of indirect feedback in HRRR-Smoke forecasts*

Transition HRRR-Smoke into operations at NWS/NCEP