



# 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



<http://weatherwest.com>

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



# 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

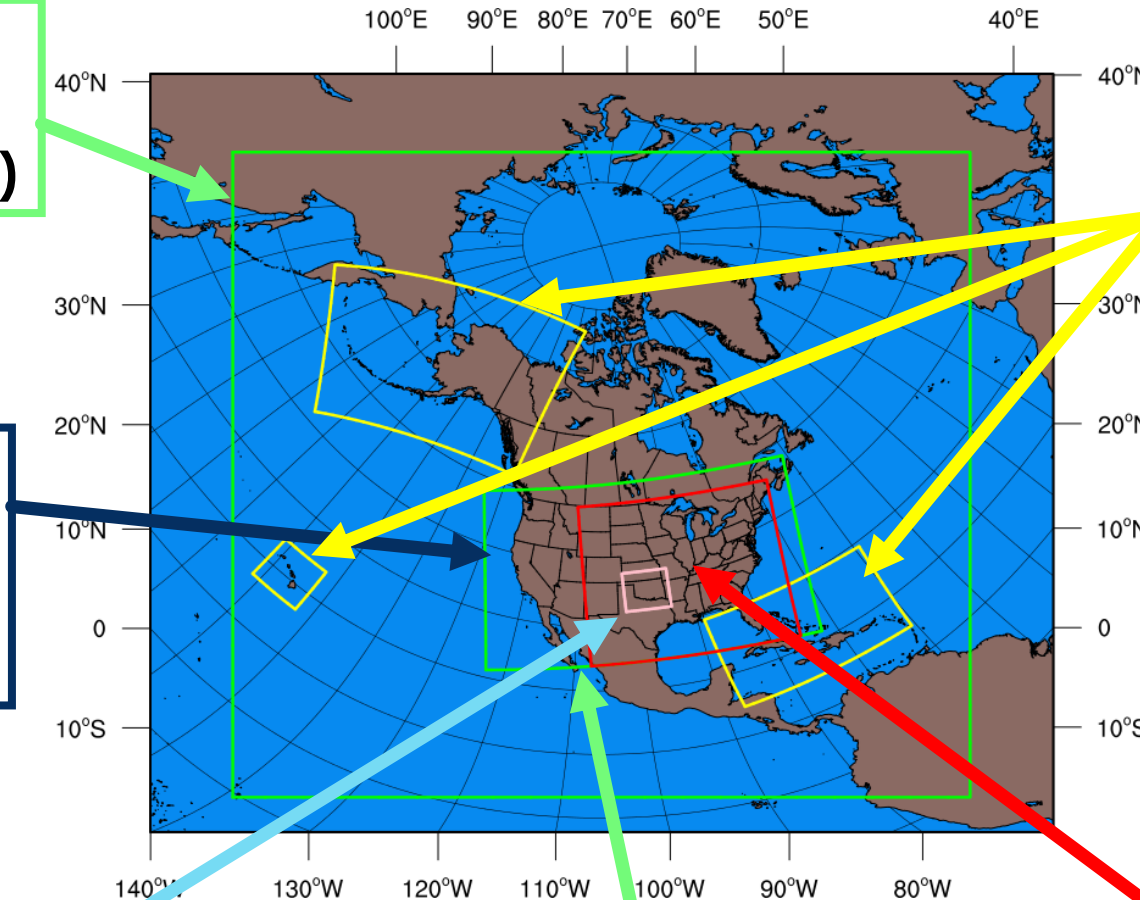
750-m grid HRRR nest  
Experimental

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

**3-km HRRR-Smoke (VIIRS fire data)**

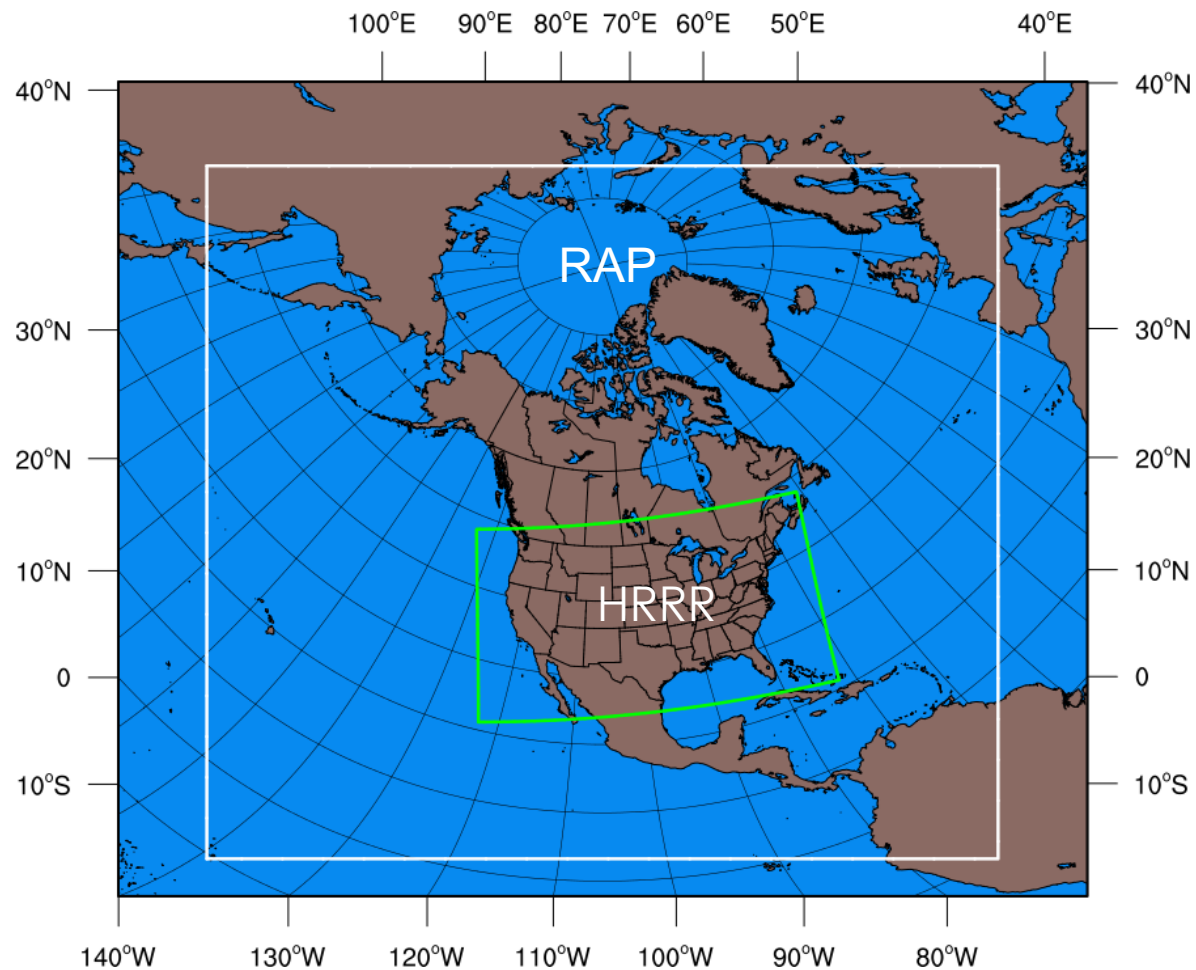
High-Resolution Rapid  
Refresh Alaska, Hawaii  
and Puerto Rico  
3-km grid  
Experimental

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.

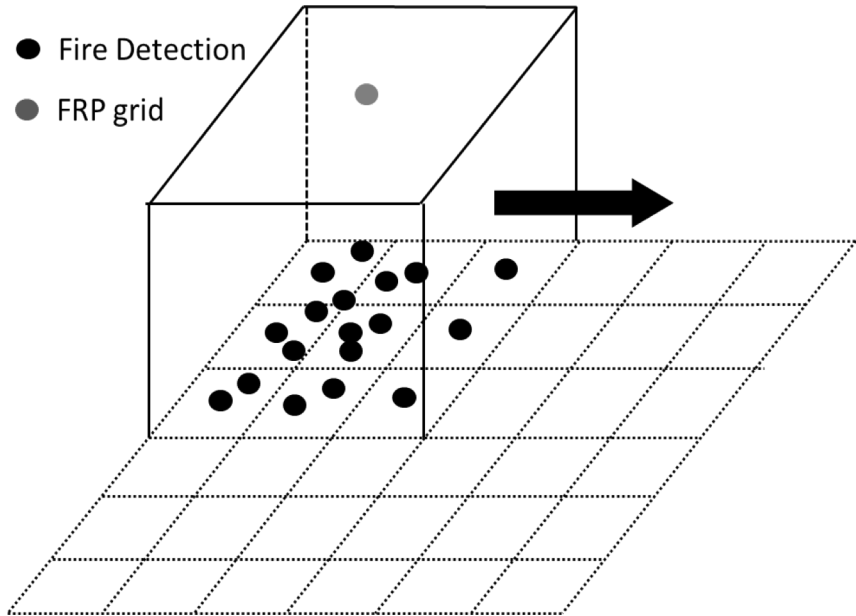
Biomass burning emissions are estimated as follows:

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

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



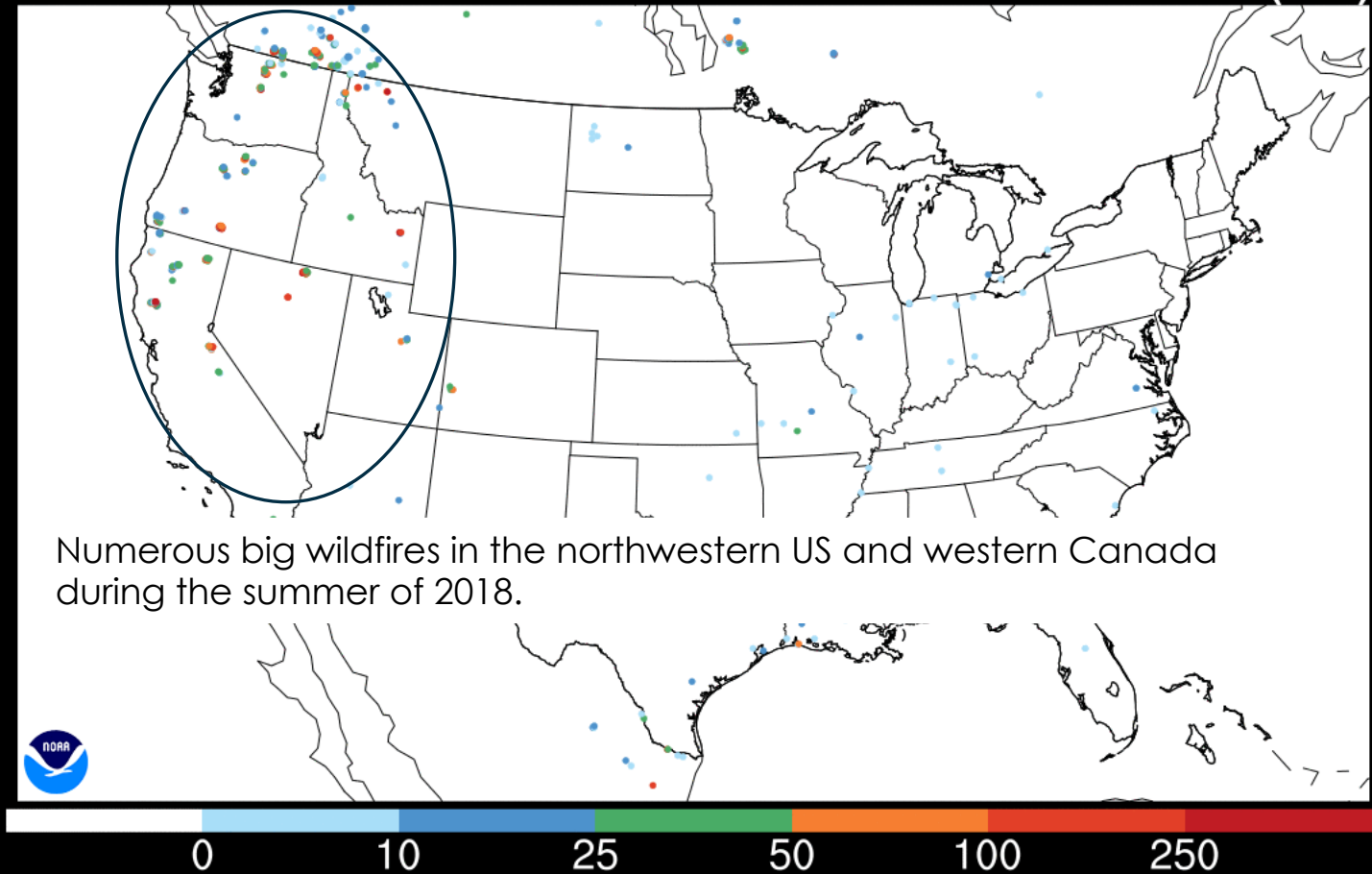
- Fire Detection
- FRP grid



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

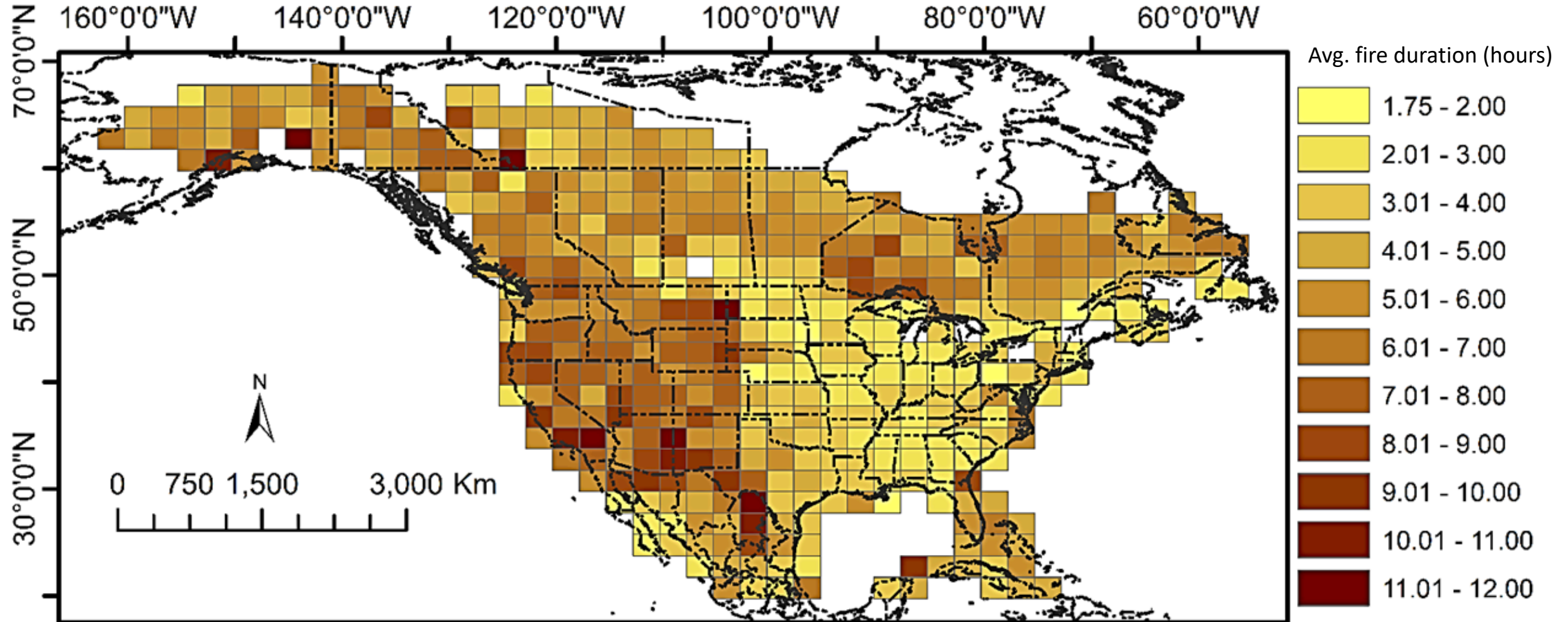
HRRR-SMOKE 2018-08-19 00 UTC - EXPERIMENTAL

Fire Radiative Power (MW)

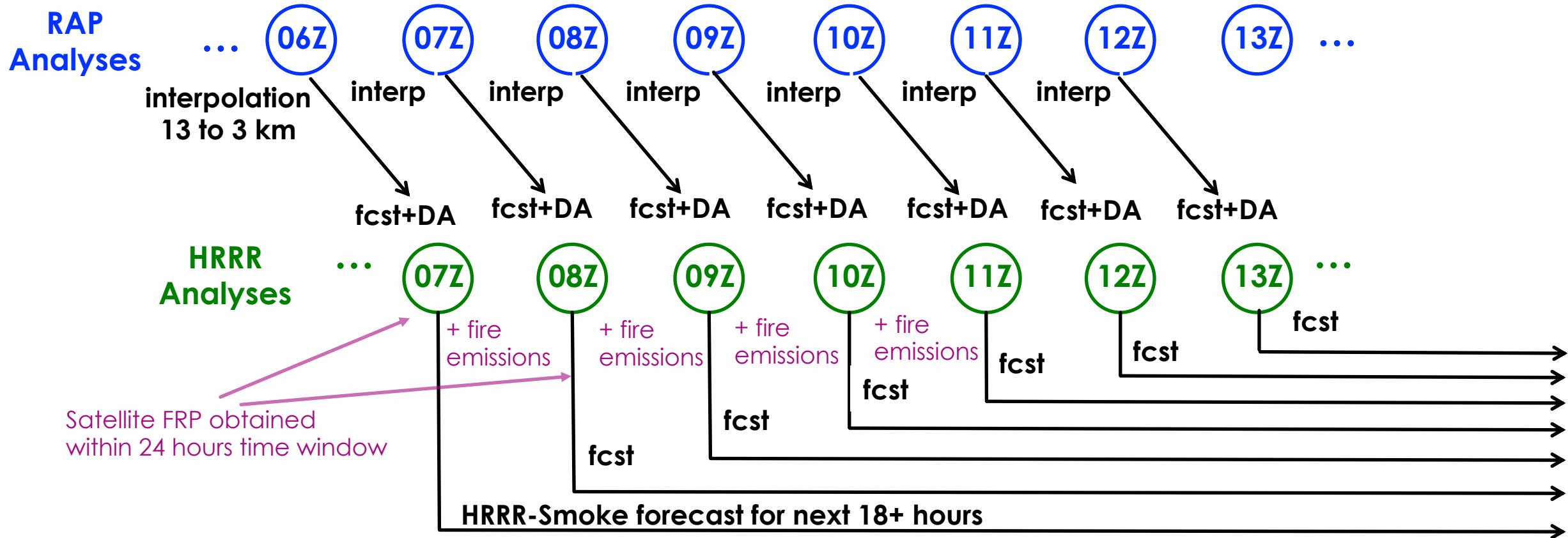


# GOES-East/West satellite fire data analysis (2016)

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

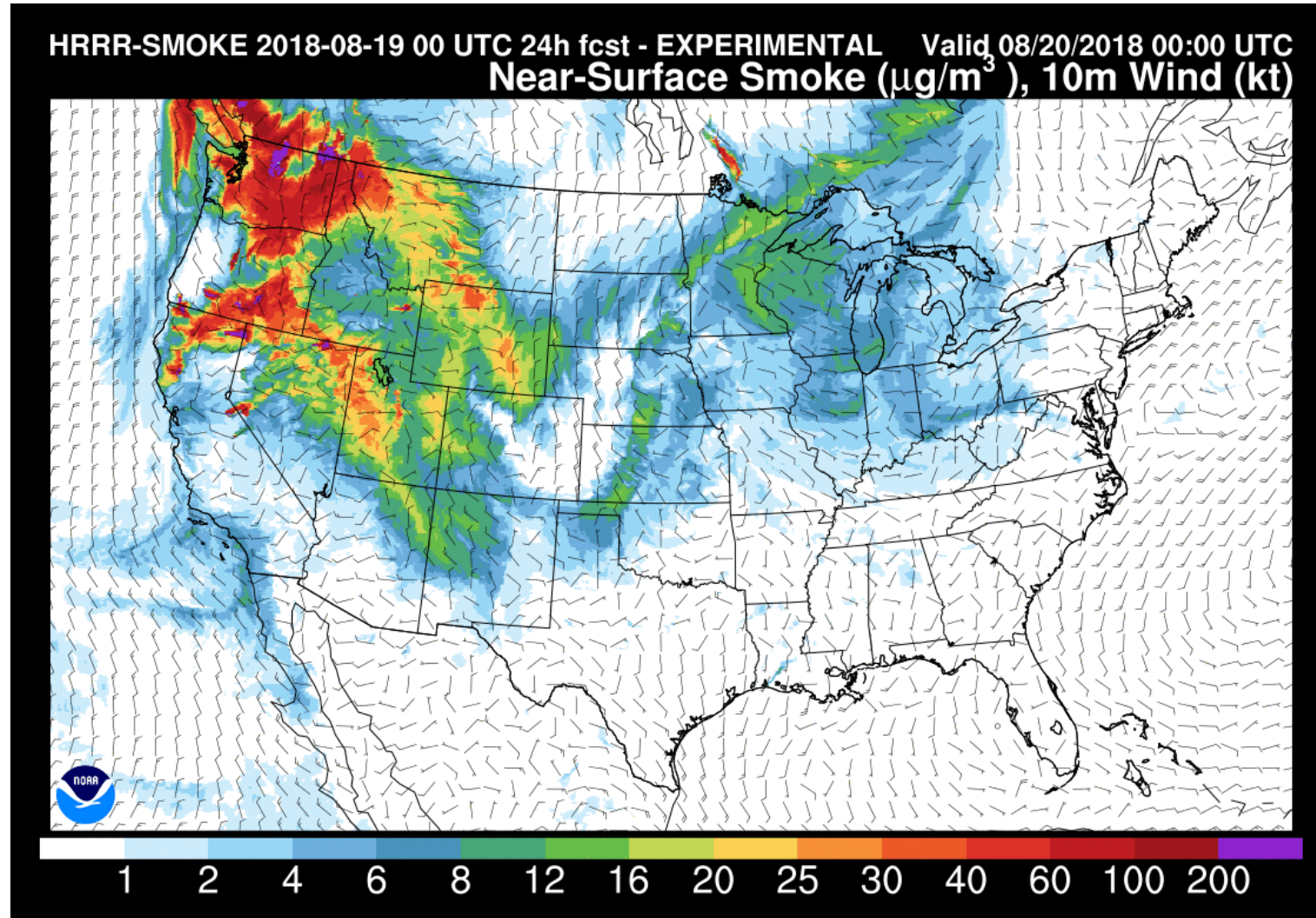


- Each HRRR analysis starts with previous hour's RAP analysis
- 1-h model integration w/ 15-min radar DA, followed by DA for conventional weather observations and non-variational cloud and hydrometeor analysis
- Simulated 3D smoke fields are cycled between the consecutive HRRR-Smoke forecasts.

## 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/](https://rapidrefresh.noaa.gov/hrrr/HRRRsmoke/))





# RAP-Smoke

## Forecast for August 21, 2018

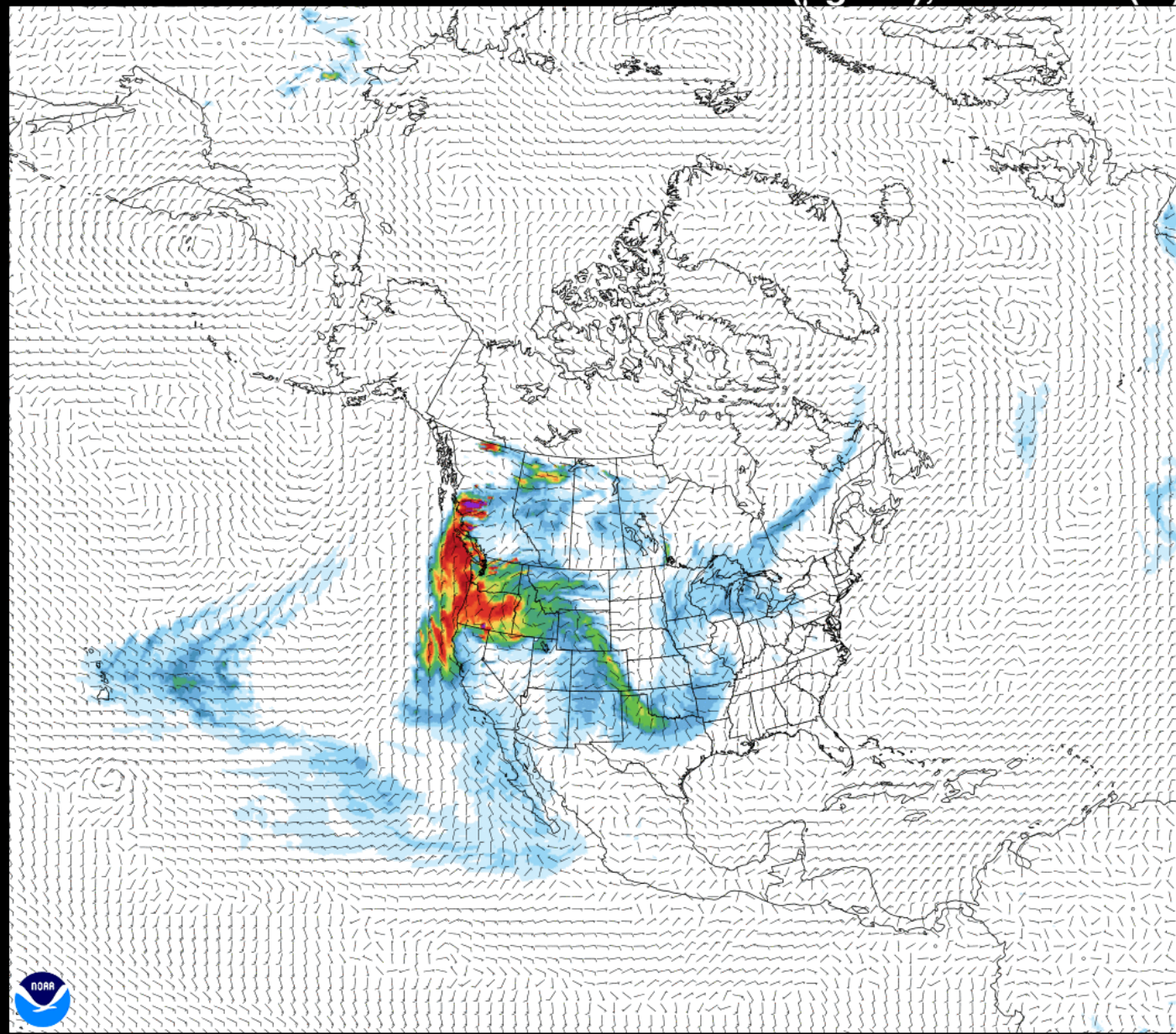
- RAP covers all of North America. The products can be used for Canada, Alaska and other regions.
- RAP uses a 13-km grid
- The same meteorology as RAPX;
- Taking advantage of the global satellite data coverage by VIIRS and MODIS;
- Feeds boundary conditions for smoke to the HRRR-Smoke over the CONUS 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

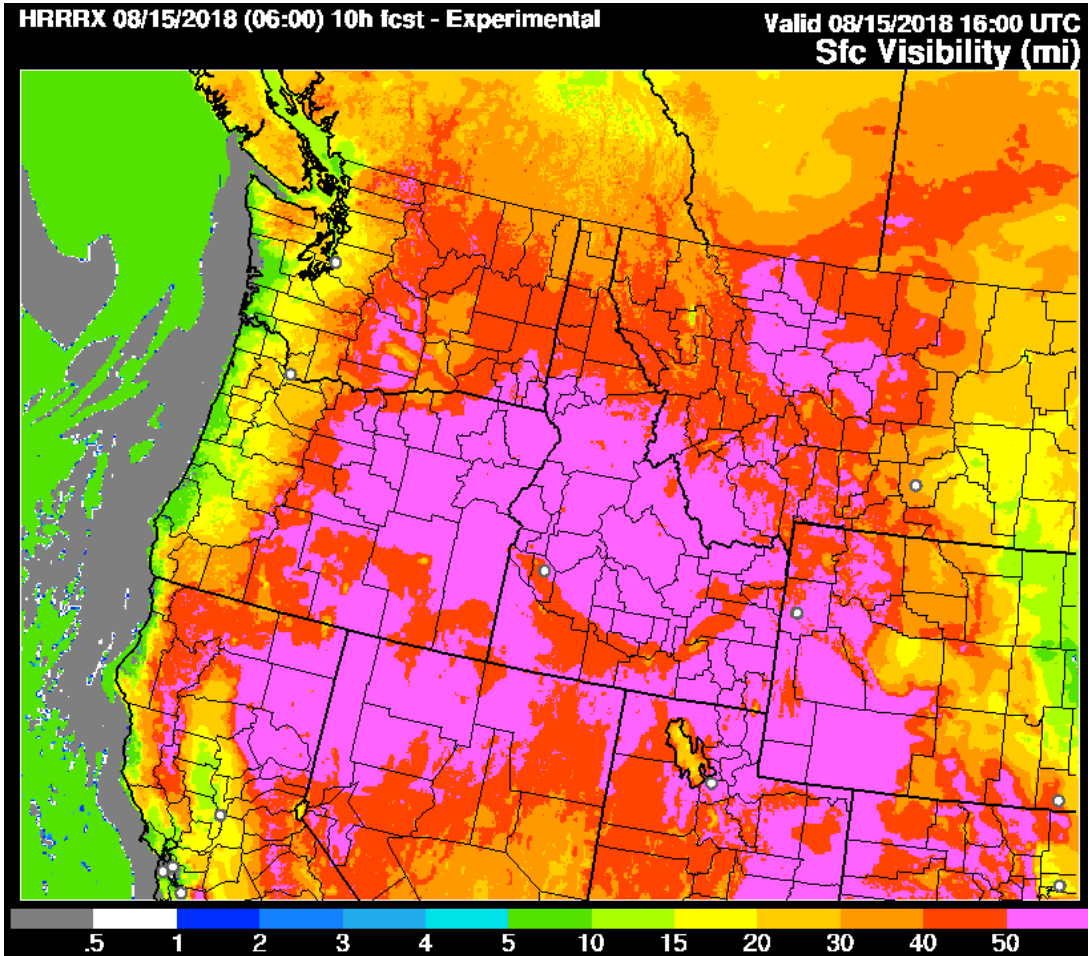
Valid 08/21/2018 00:00 UTC

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

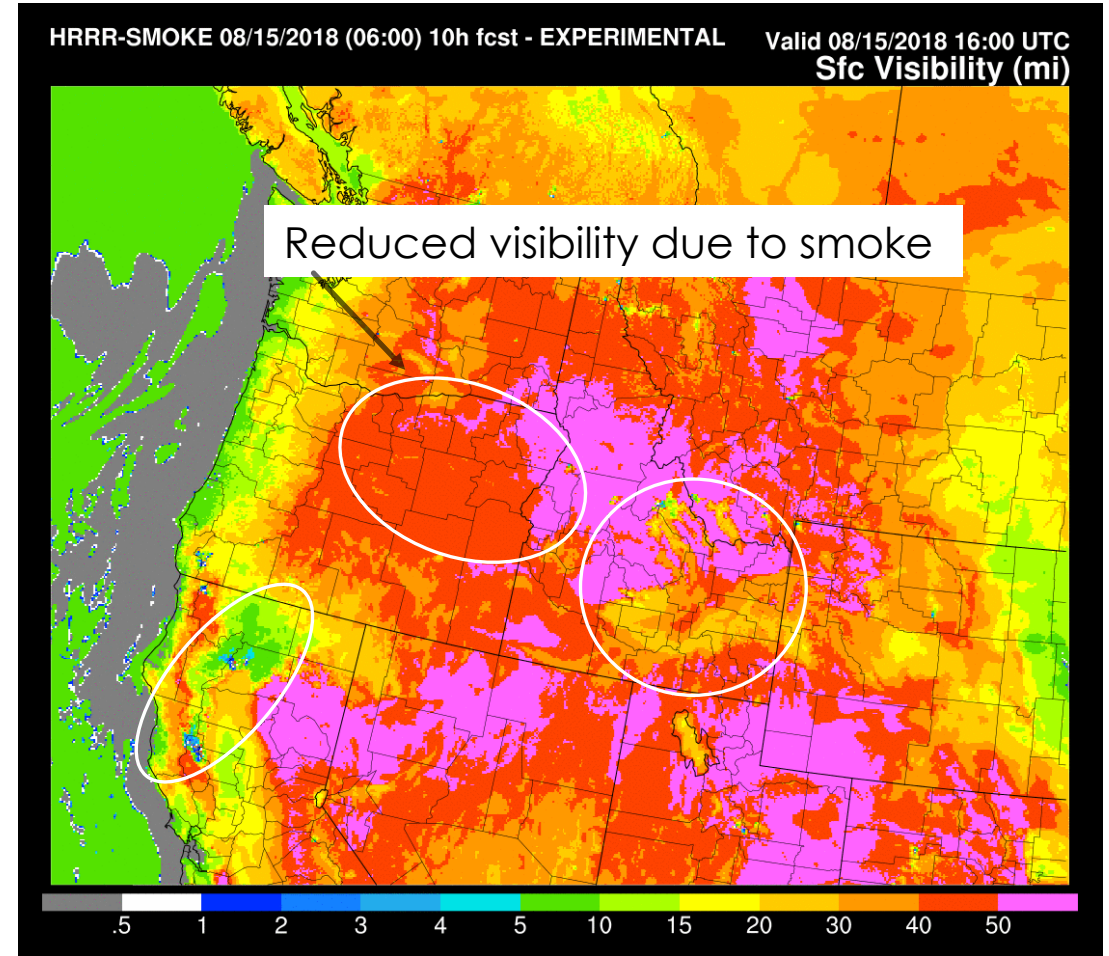


1 2 4 6 8 12 16 20 25 30 40 60 100 200

# 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*