Using VIIRS and GOES-16 ABI Aerosol Data to Evaluate NAQFC Models

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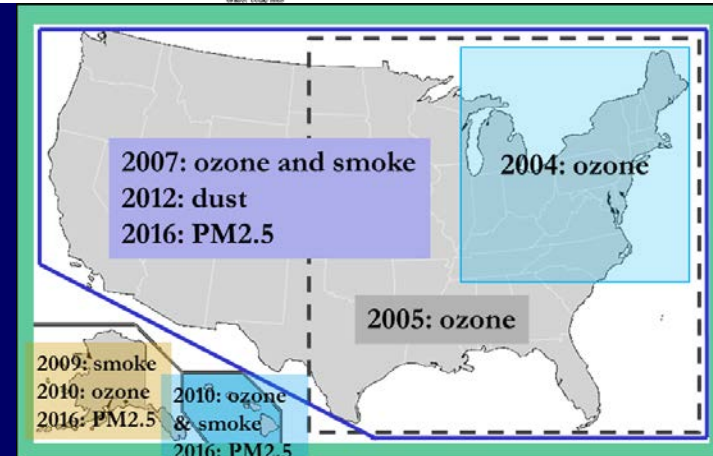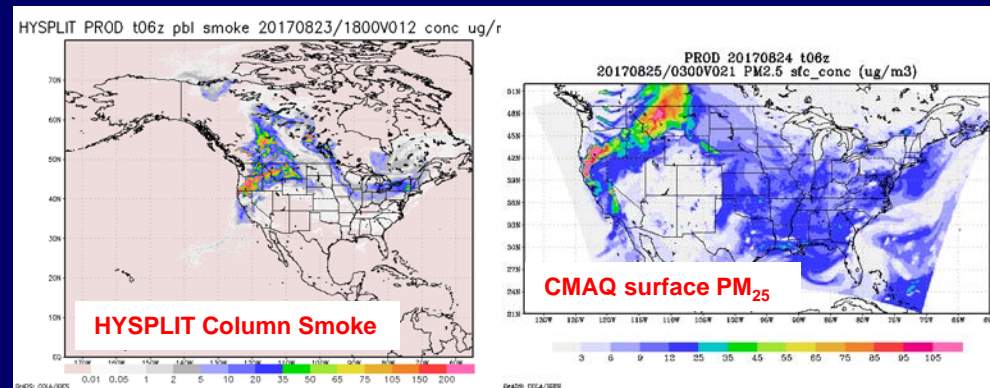
Outline

- The NWS National Air Quality Forecast Capability (NAQFC)

- NAQFC applications using NESDIS satellite aerosol products at the NCEP

- NAQFC model evaluation/verification with the NCEP FVS and METplus

- The wildfire smoke PM_{25} case study in August 2018

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The NWS National Air Quality Forecast Capability (NAQFC)

- The NAQFC missions are
  - **to provide general public air quality information in their neighborhood (http://airquality.weather.gov/)**
  - **to provide guidance for state and local air quality forecasters who issue health warnings when the public is at risk due to deteriorated air quality**

- The NAQFC forecasting systems
  - **the regional AQM based on U.S. EPA Community Multi-scale Air Quality Modeling System (*CMAQ* v.5.0.2; Stajner et al. 2012; Lee et al, 2017), and**
  - **The Hybrid Single Particle Lagrangian Integrated Trajectory (*HYSPLIT*; Rolph et al 2009).**

- The CMAQ has provided ozone-prediction guidance since 2004 and PM$_{25}$ guidance since 2016. HYSPLIT has provided smoke guidance since 2007 and dust guidance since 2012.

HYSPLIT Column Smoke

CMAQ surface PM$_{25}$

2007: ozone and smoke
2012: dust
2016: PM2.5

2004: ozone

2005: ozone

2009: smoke
2010: ozone
2016: PM2.5

2010: ozone & smoke

2016: PM2.5

Courtesy of Ivanka Stajner

NESDIS Satellite Aerosol Products for NAQFC Applications at the NCEP

- Source functions for NAQFC
  - Fire detections of GOES, SNPP, and JPSS
    - HMS quality control → USFS BlueSky → PM_{25} fire emission → HYSPLIT/Smoke and CMAQ/PM_{25}
    - NESDIS GBBEPx (FRP; Fire PM emissions) → NGAC and FV3GFS-CHEM (global and regional)
- Data assimilation
  - VIIRS AOD
    - NEMS GFS Aerosol Component (NGAC) global aerosol forecast system (Sarah Lu)
    - FV3GFS-CHEM global aerosol forecast system (in progress)
- NCEP near-real-time verification
  - VIIRS AOD
  - MODIS AOD
  - GOES-16 CONUS AOD and ADP (Beta)
- Air Quality case study
  - VIIRS AOD, Smoke/Dusk Mask, fire product, and cloud (IDEA; eIDEA)
  - MODIS AOD and cloud (IDEA)
  - GOES AOD, Smoke/Dusk mask, fire product, and cloud (IDEA; eIDEA; AerosolWatch)

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NAQFC model evaluation – NCEP Near-real-time Verification

- NCEP FVS (operational) and NCAR METplus (in development)
  - EPA AirNow surface observations
    - Ozone and PM_{25}
    - NAQFC PM forecast of CMAQ and future FV3GFS-CHEM global and regional
  - Satellite aerosol products
    - VIIRS AOD
      - NAQFC PM forecast of NGAC, CMAQ, and future FV3GFS-CHEM global and regional
    - MODIS AOD
      - NGAC PM forecast
    - GOES-16 CONUS AOD and ADP
      - HYSPLIT Column Integrated Smoke Concentration
      - NAQFC PM forecast of CMAQ and future FV3GFS-CHEM global and regional .

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METplus Aerosol Verification Development at the NCEP

- METplus is developed by NCAR DTC https://dtcenter.org/met/users/index.php.

- Unified verification tools for both meteorological, oceanic, and air quality variables at the NCEP.

- METviewer (accompany tool) displays and generates skill scores and presentation quality figure.

- Aerosol and chemical gases verification capability are in progress.

- Capability of GOES-16 AOD (using beta test data) ingestion has been built. NCEP is working on the verification script template of CMAQ AOD and HYSPLIT/Smoke concentration verification.

- Capability of VIIRS AOD ingestion is in development.

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NCEP AQ verification web site – http://www.emc.ncep.noaa.gov/mmb/aq/
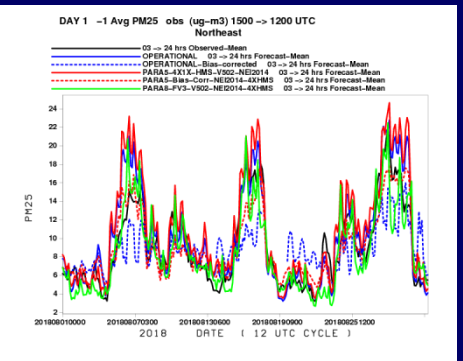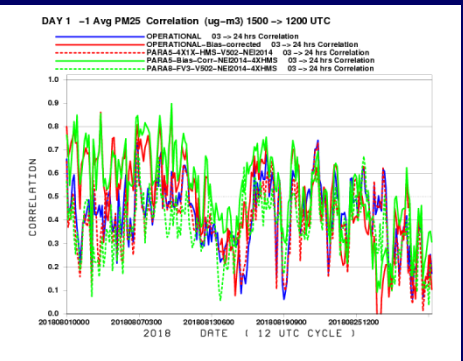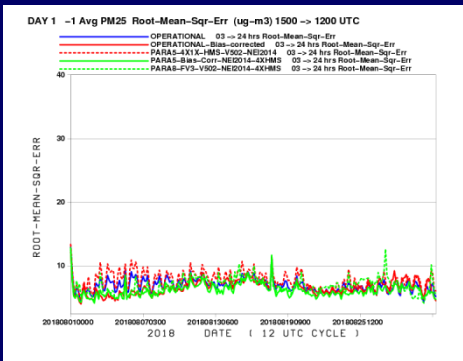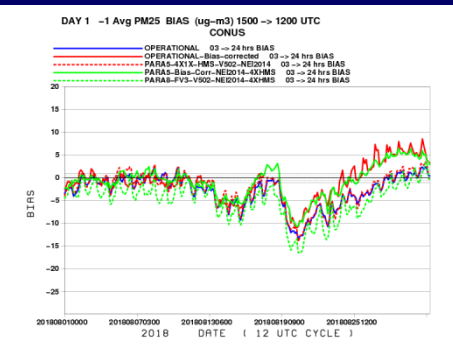
Example of NCEP FVS Products for Model Evaluation

Standard Verification Statistics

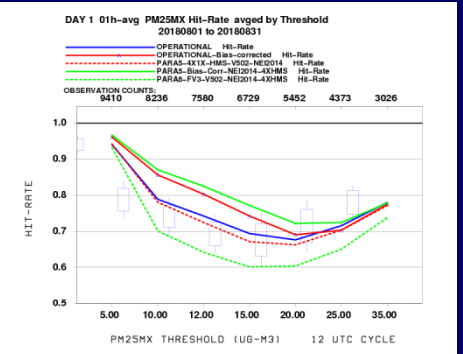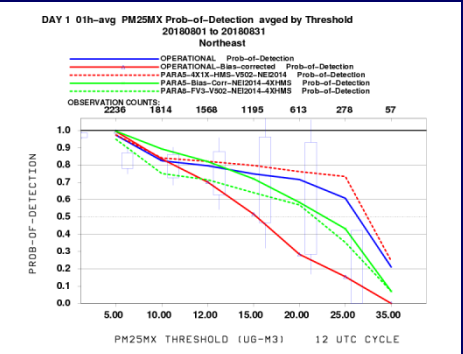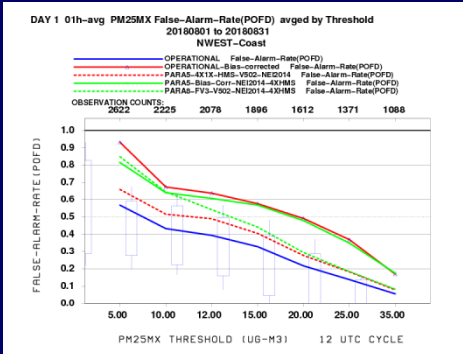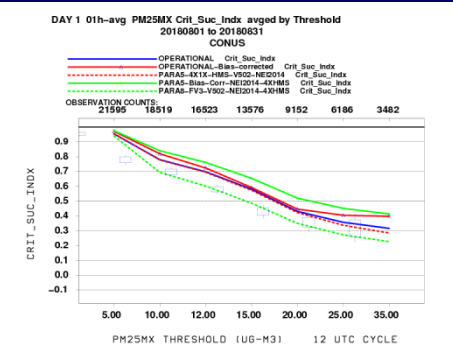| Bias	RMSE	Correlation	Obs vs Forecast Mean

Threshold Verification Statistics

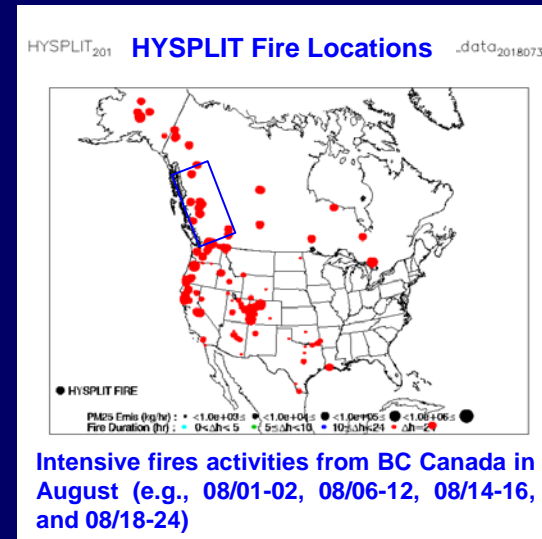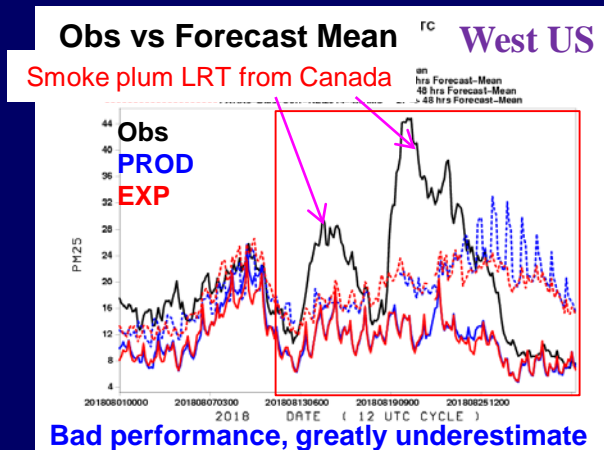| Critical Success Index	Probability of Detection	False Alarm Rate	Hit Rate

METplus will provide similar FVS products and more, such as Taylor's diagram 8

NAQFC model evaluation – Air Quality Case Study

- Performance statistics sometime may not reveal the true problem of NAQFC models

Obs vs Forecast Mean **West US**
Smoke plum LRT from Canada
Obs
PROD
EXP
Bad performance, greatly underestimate

HYSPLIT Fire Locations

Intensive fires activities from BC Canada in August (e.g., 08/01-02, 08/06-12, 08/14-16, and 08/18-24)

- Air Quality Case Study

  – VIIRS AOD, Smoke/Dusk Mask, fire product, and Cloud (IDEA; eIDEA)

  – MODIS AOD and Cloud (IDEA)

  – GOES AOD, Smoke/Dusk Mask, fire product, and Cloud (IDEA; eIDEA; AerosolWatch)

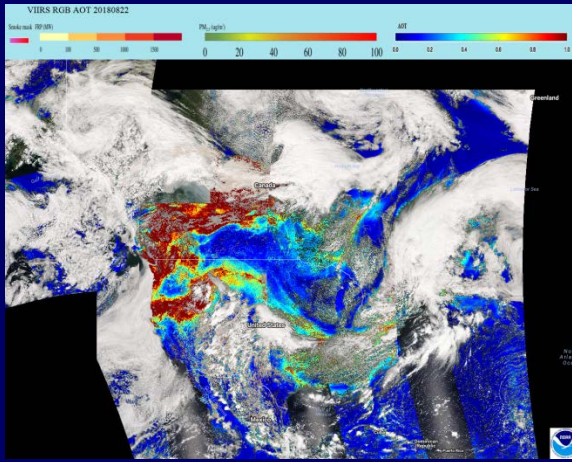 – Different aerosol models

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- RGB product is used to identify heavy aerosol events and the timing of cloud presence.
- RGB animation is used to identify the source and *transport* of heavy aerosol, e.g., smoke and dust.
- AOD product is used to estimate the magnitude of events, and
- Smoke/Dust mask is used to distinguish the type of aerosols.
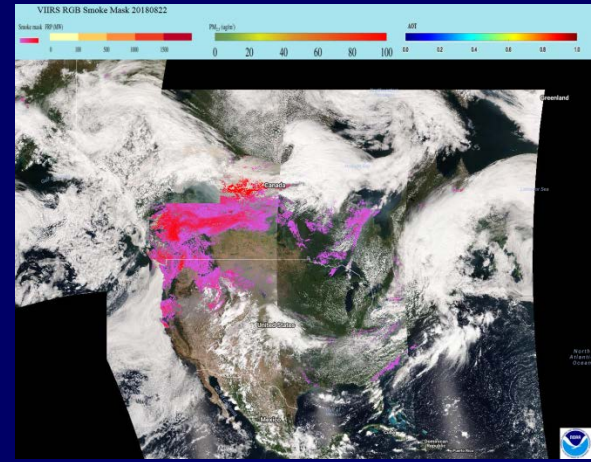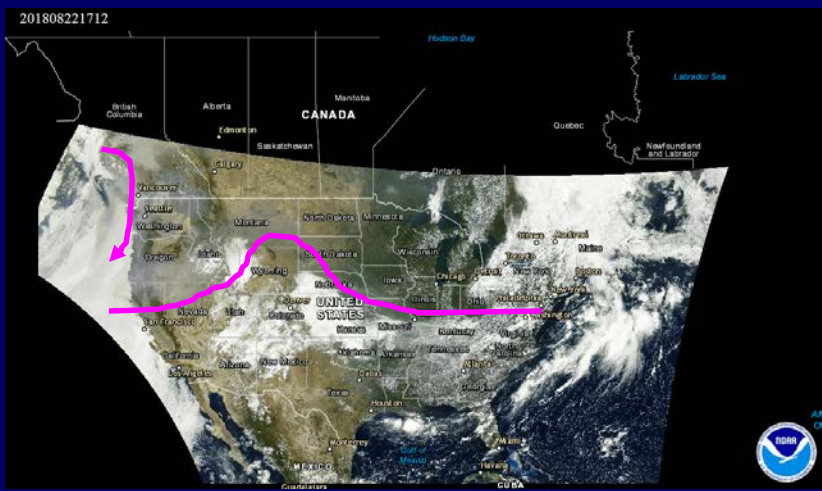
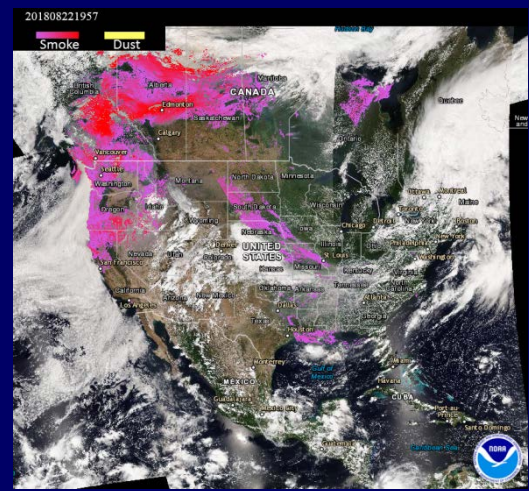### VIIRS RGB
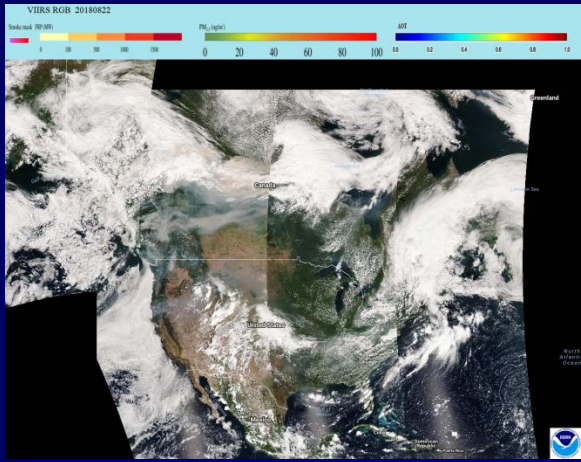
VIIRS AOD

VIIRS Smoke/Dust Mask

GOES-16 true color animation

NOAA-20 Smoke Mask (no AOD)

AerosolWatch contains both GOES-16, SNPP and NOAA-20 data.
- Can not display Fire RGB, AOD Composite, and Fire product
- Can not save image of Dust RGB and AOD products

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- Observed smoke plume from fires in Canada and N California moving eastward along Canadian border and toward Northern Plain and NE US.
- Observed Canadian smoke plume moves toward the NW US

CMAQ PM25 Column Total
PROD 20180816 t12z
20180817/1200V024 PM25 Column Total (mg/m2)
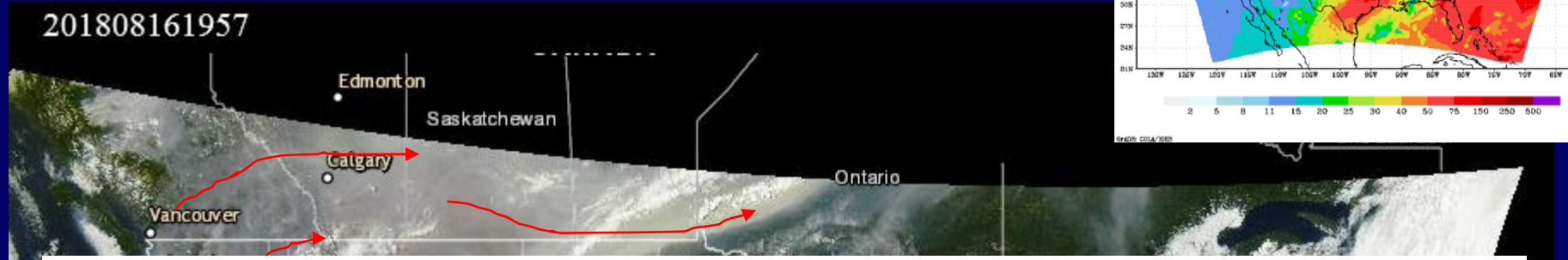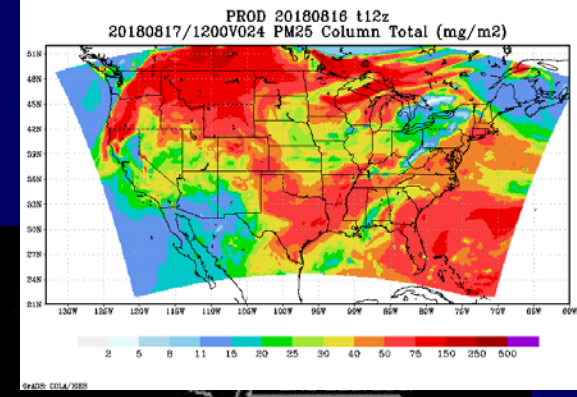
- Note all column integrated products may reveal the transport of smoke plume but can not tell you whether it reach the surface or not (no vertical profile information).
- Coupled with PM$_{25}$ concentration time series of surface station can tell you when does upper air smoke plume reach the surface, e.g., downward motion behind frontal passage.

Courtesy of NOAA NESDIS AerosolWatch

https://www.star.nesdis.noaa.gov/smcd/spb/aq/AerosolWatch/

- Observed smoke plume from Canada moves eastward along Canadian border, with southward intrusion to Northern Plain
- Smoke plume from Canada moves southward toward the NW US
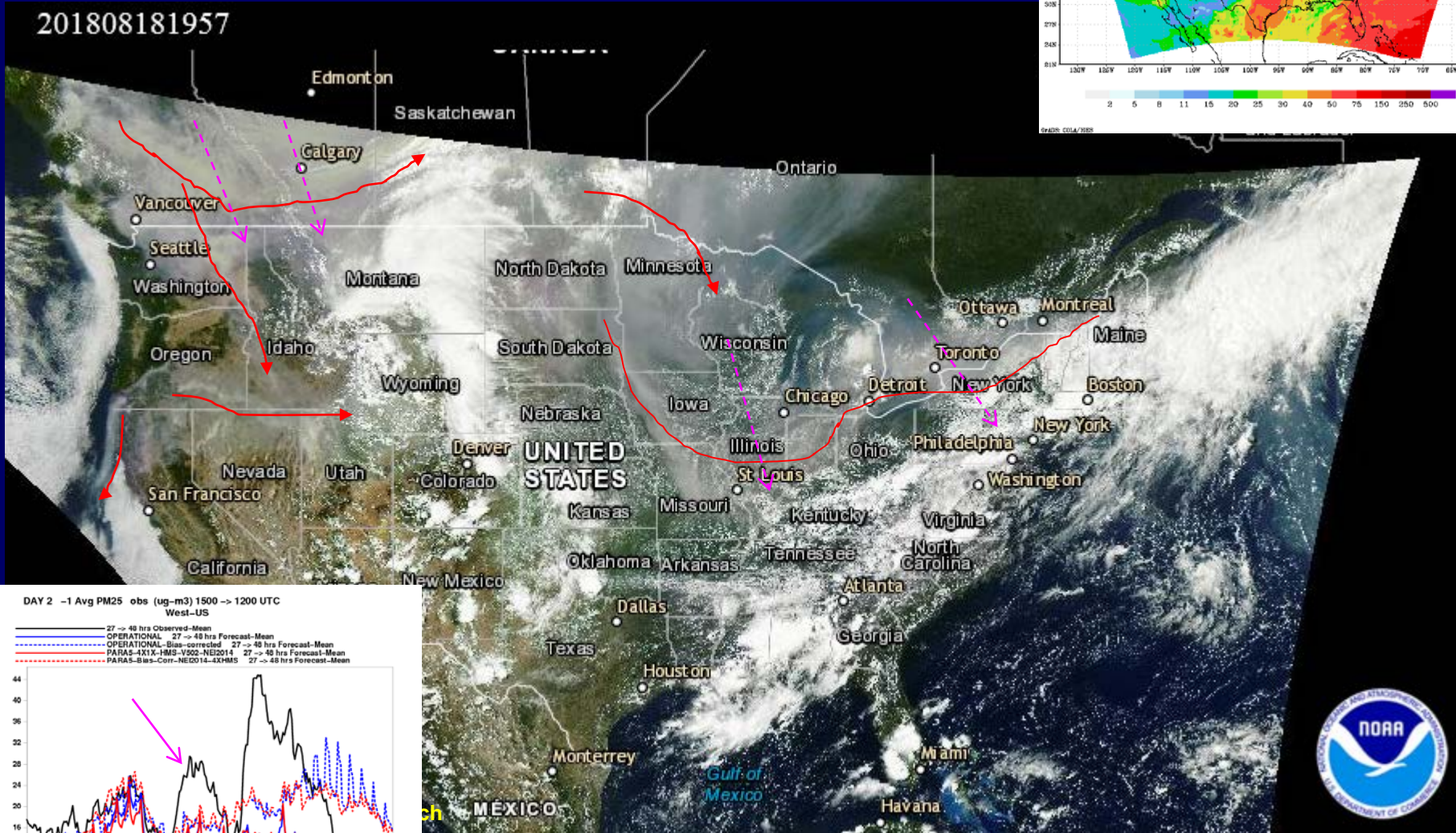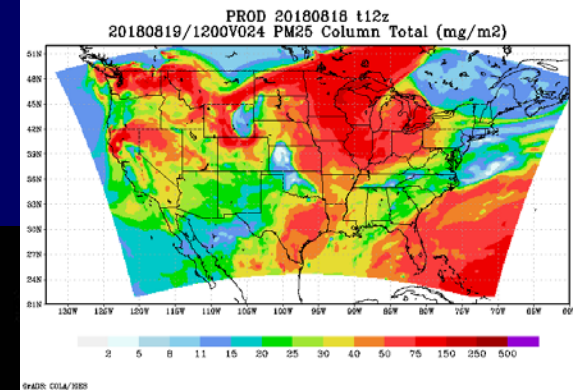- Observed smoke plume from N California moves eastward to the Northern Plain

PROD 20180817 t12z
20180818/1200V024 PM25 Column Total (mg/m2)

201808171957
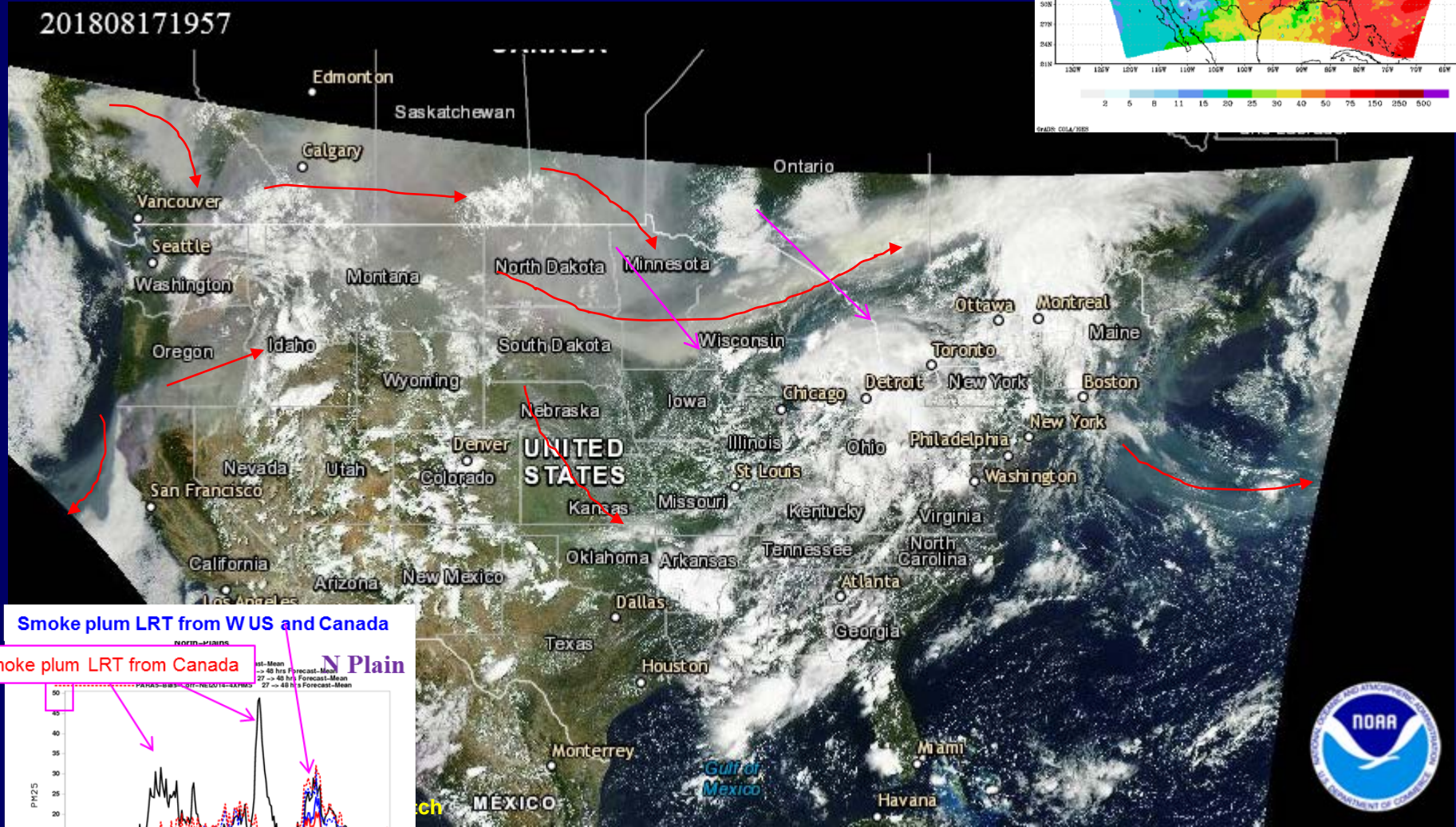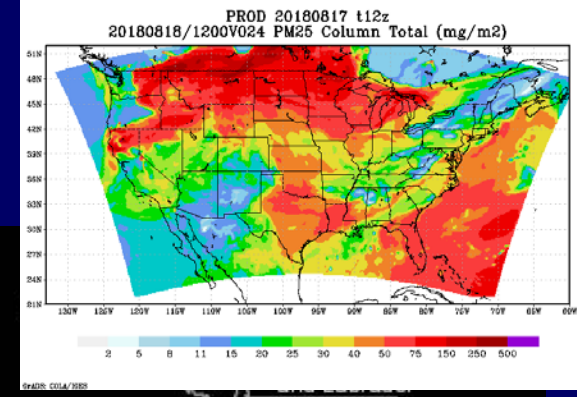
Smoke plum LRT from W US and Canada
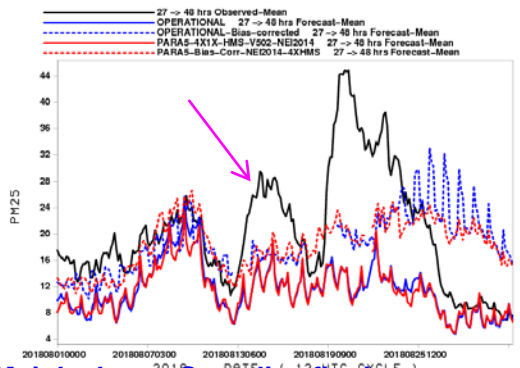
Smoke plum LRT from Canada
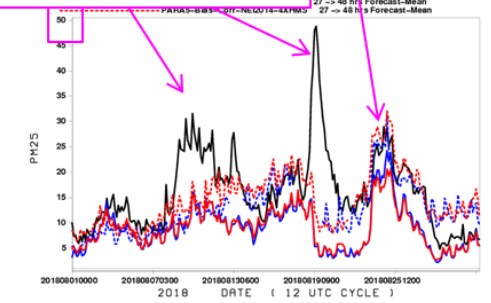
N Plain

- Observed smoke plume from Canada moves southward and eastward toward the NW US, Northern Plain, and NE US
- Observed smoke plume from Oregon fires moves toward the Norther Plain

CMAQ PM25 Column Total

PROD 20180818 t12z
20180819/1200V024 PM25 Column Total (mg/m2)

201808181957

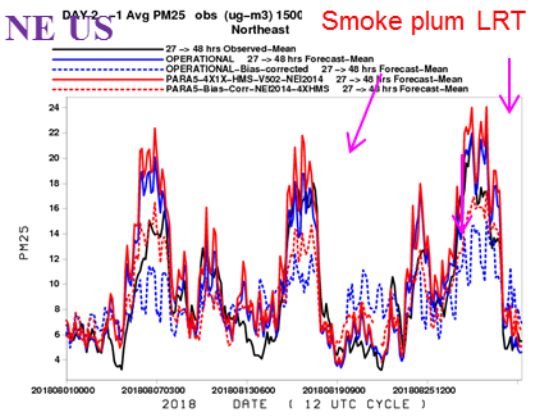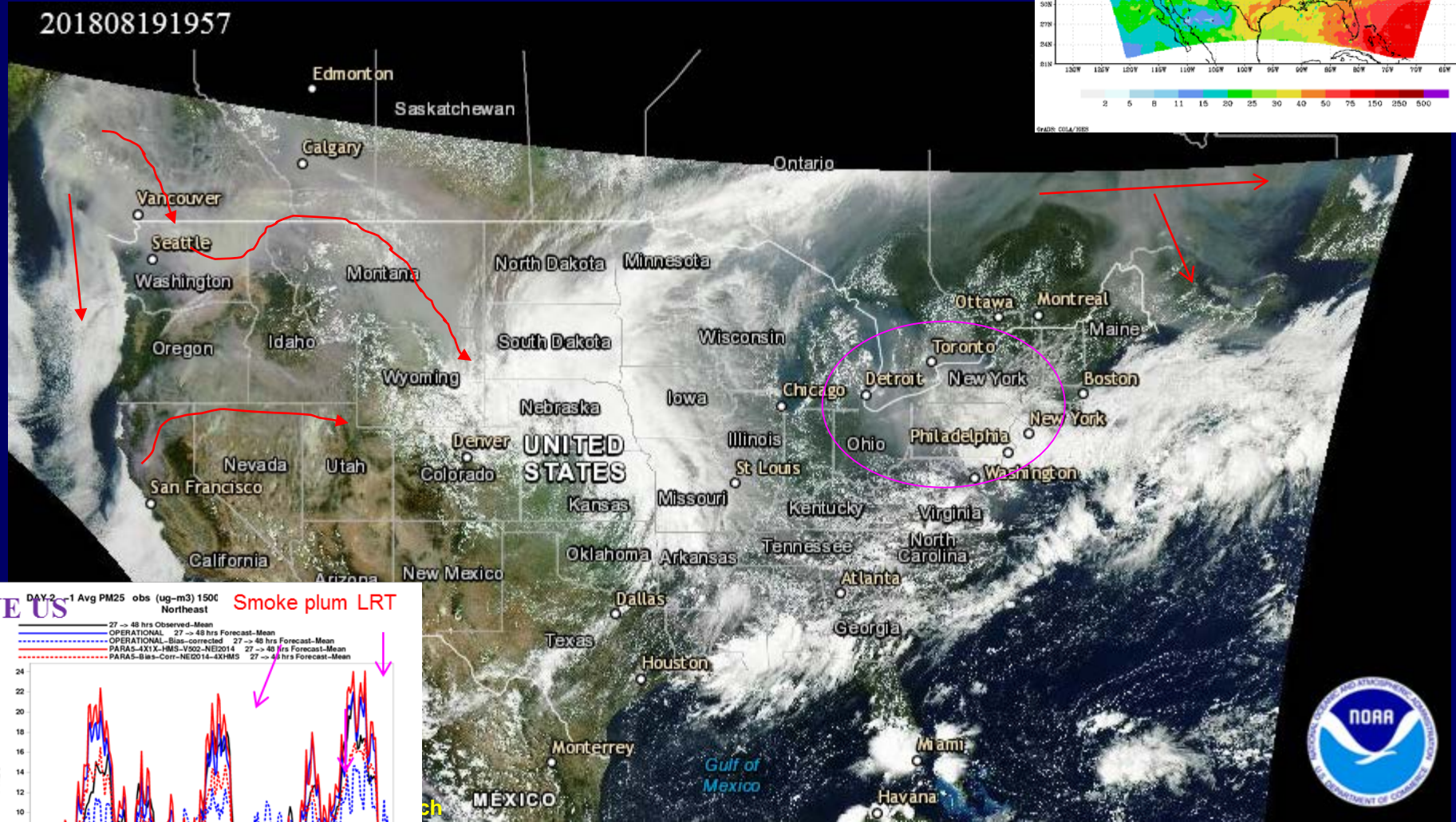DAY 2 −1 Avg PM25 obs (ug-m3) 1500 -> 1200 UTC
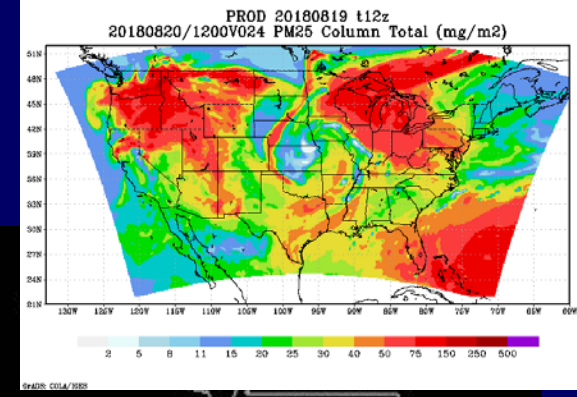West-US

Mainly due to Canadian fire impact   hop - 25-26 September 2018
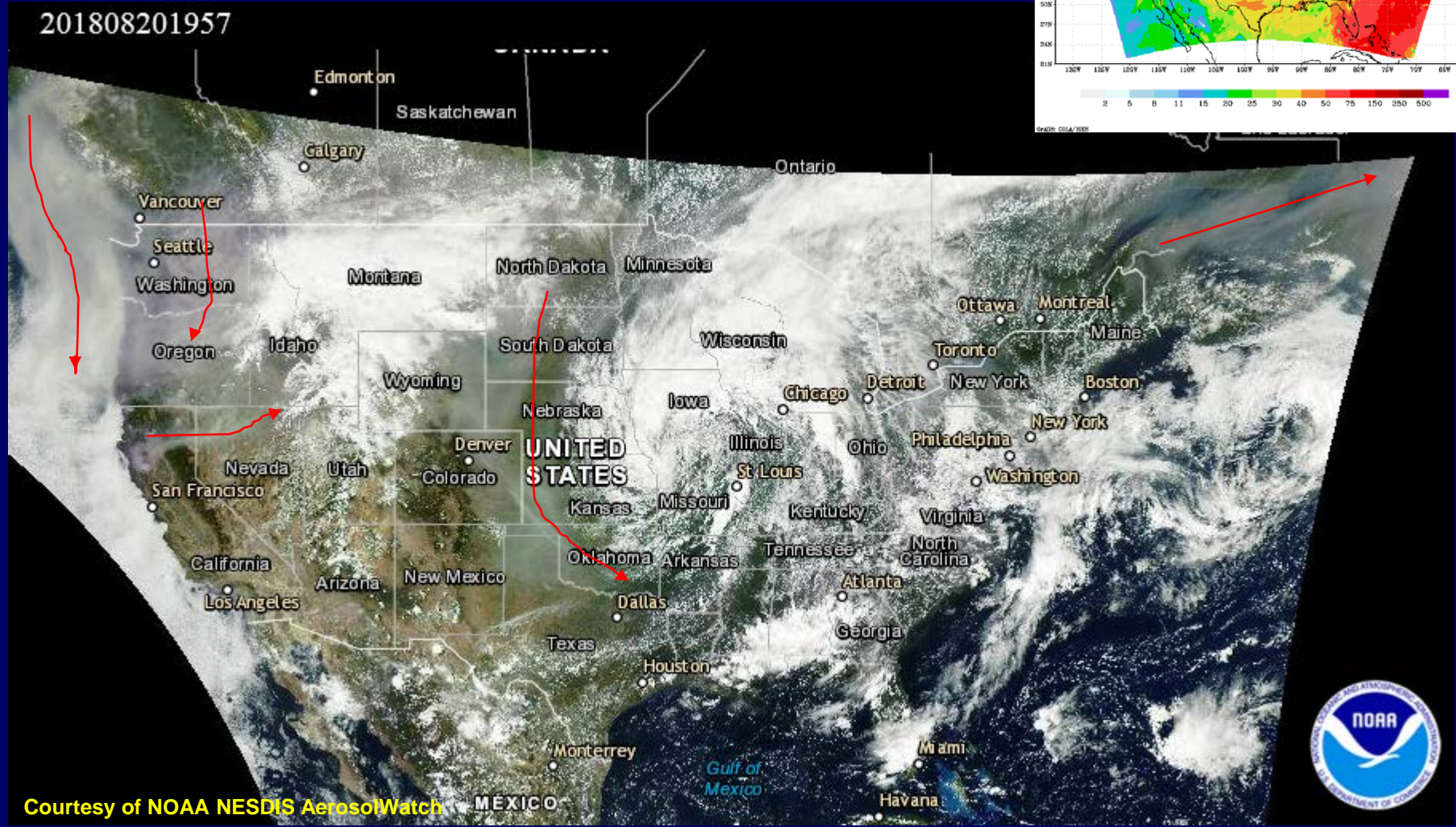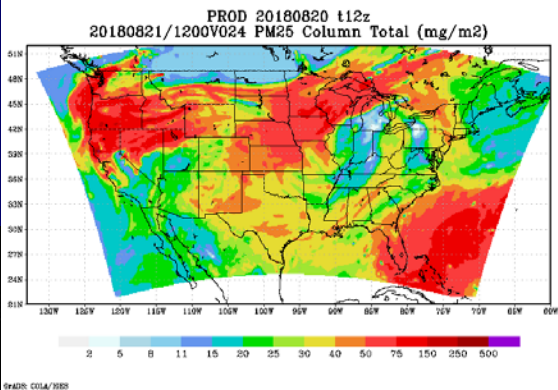
- Observed smoke plume from Canada moves southward toward the NW US and Northern Plain
- Eastward movement of smoke plume from N. California and Oregon fires
- The NE US is impacted by LRT smoke plume (W US, Canada)

CMAQ PM25 Column Total

PROD 20180819 t12z
20180820/1200V024 PM25 Column Total (mg/m2)

201808191957

Smoke plum LRT

NE US

DAY-2 1 Avg PM25 obs (ug-m3) 1500
Northeast

- Observed Canadian smoke plume movs southward along coastal area and toward the NW US.
- Observed smoke plume moved southward in Northern Plain
- Eastward movement of smoke plume from N Californian fires

CMAQ PM25 Column Total

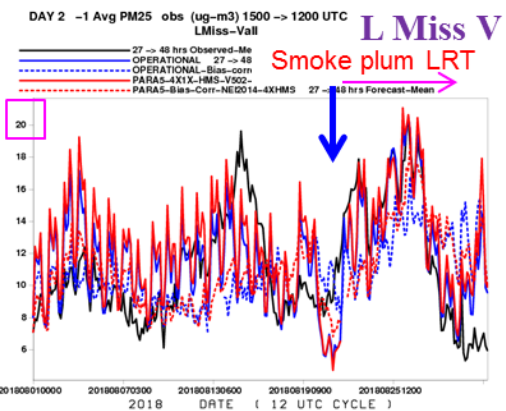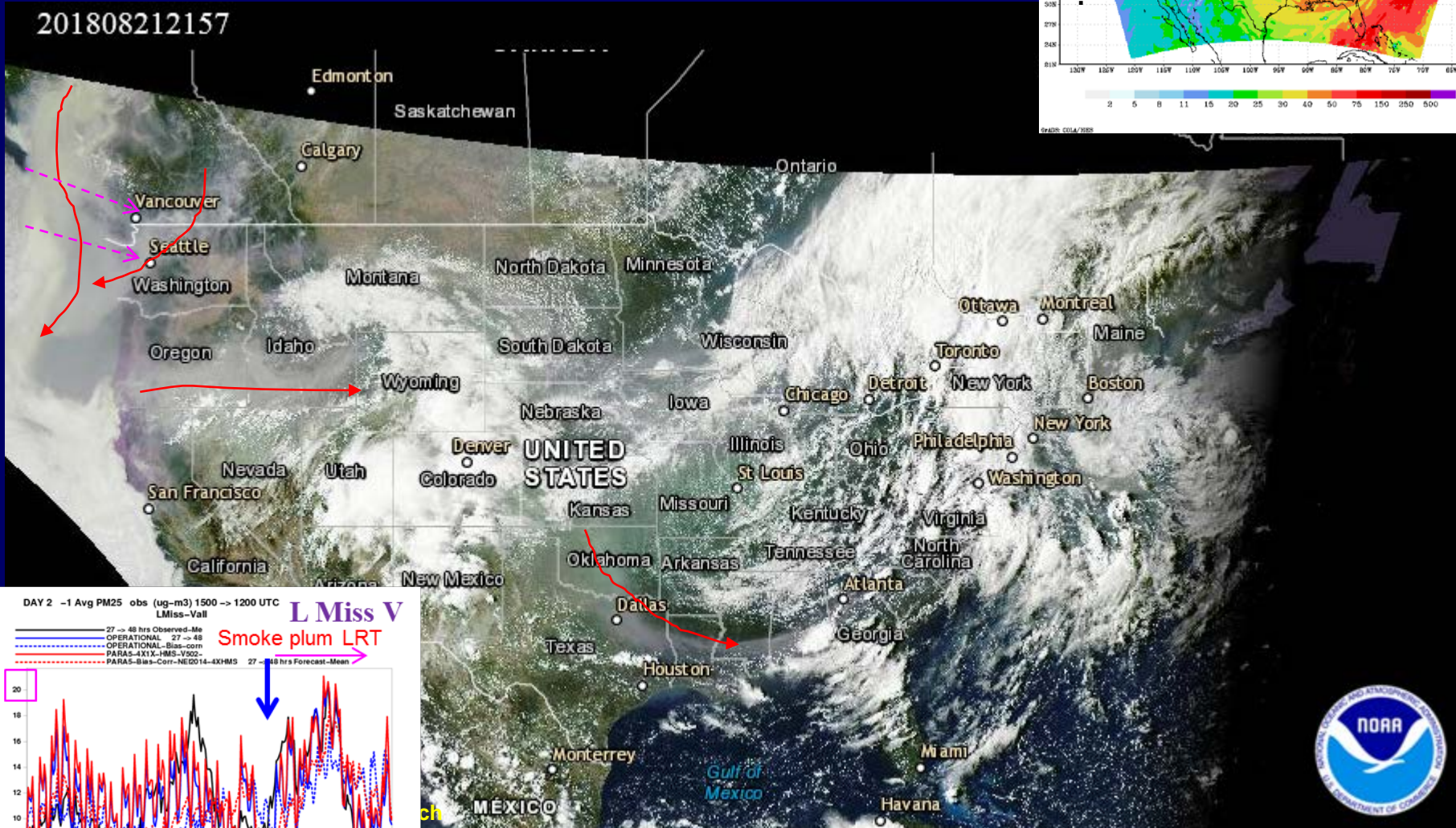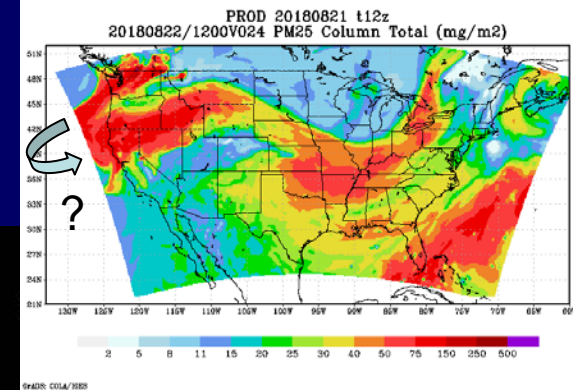PROD 20180820 t12z
20180821/1200V024 PM25 Column Total (mg/m2)

201808201957

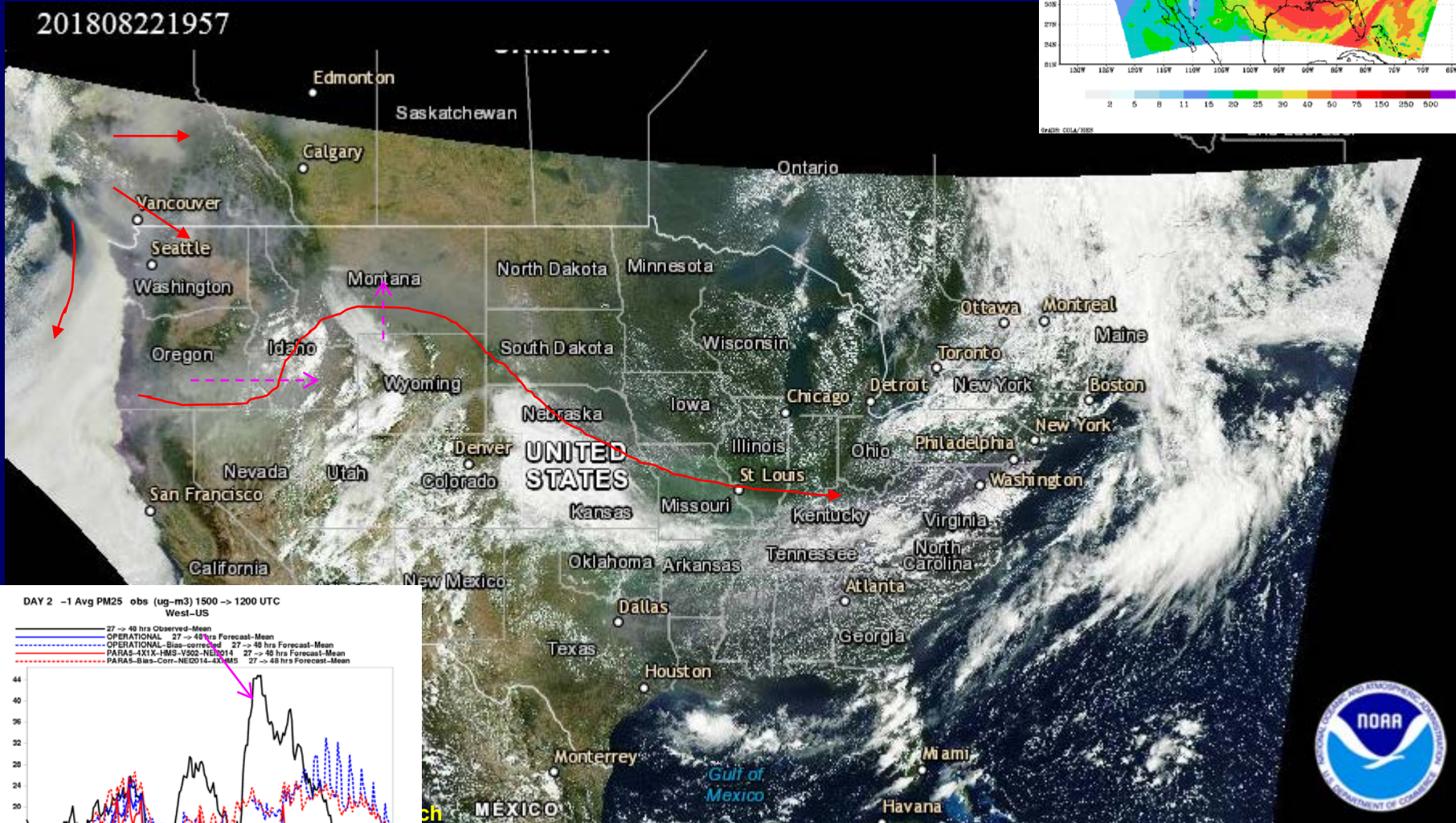Courtesy of NOAA NESDIS AerosolWatch

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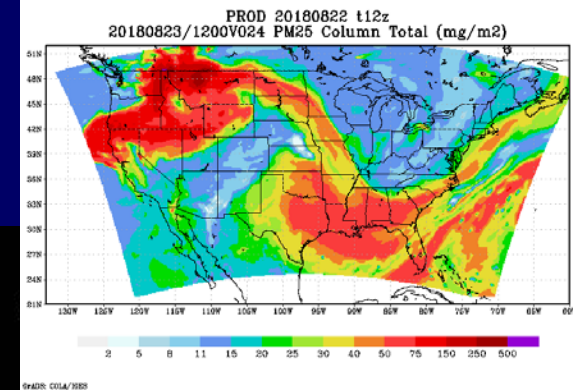- Observed Canadian smoke plume moves southward along coastal area and toward NW US.
- Observed smoke plume from N California and Oregon fires move eastward (may join-force with Canadian smoke plume) to Lower Mississippi Valley

CMAQ PM25 Column Total

PROD 20180821 t12z
20180822/1200V024 PM25 Column Total (mg/m2)

201808212157

DAY 2 −1 Avg PM25 obs (ug−m3) 1500 −> 1200 UTC
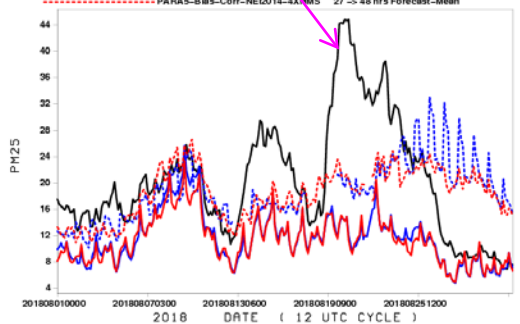LMiss−VaII

L Miss V
Smoke plum LRT

- Observed Canadian smoke plume move southward along coastal area and southeastward toward the NW US.
- Observed smoke plume from N Californian and Oregon move eastward to the Central US and Lower Mississippi Valley
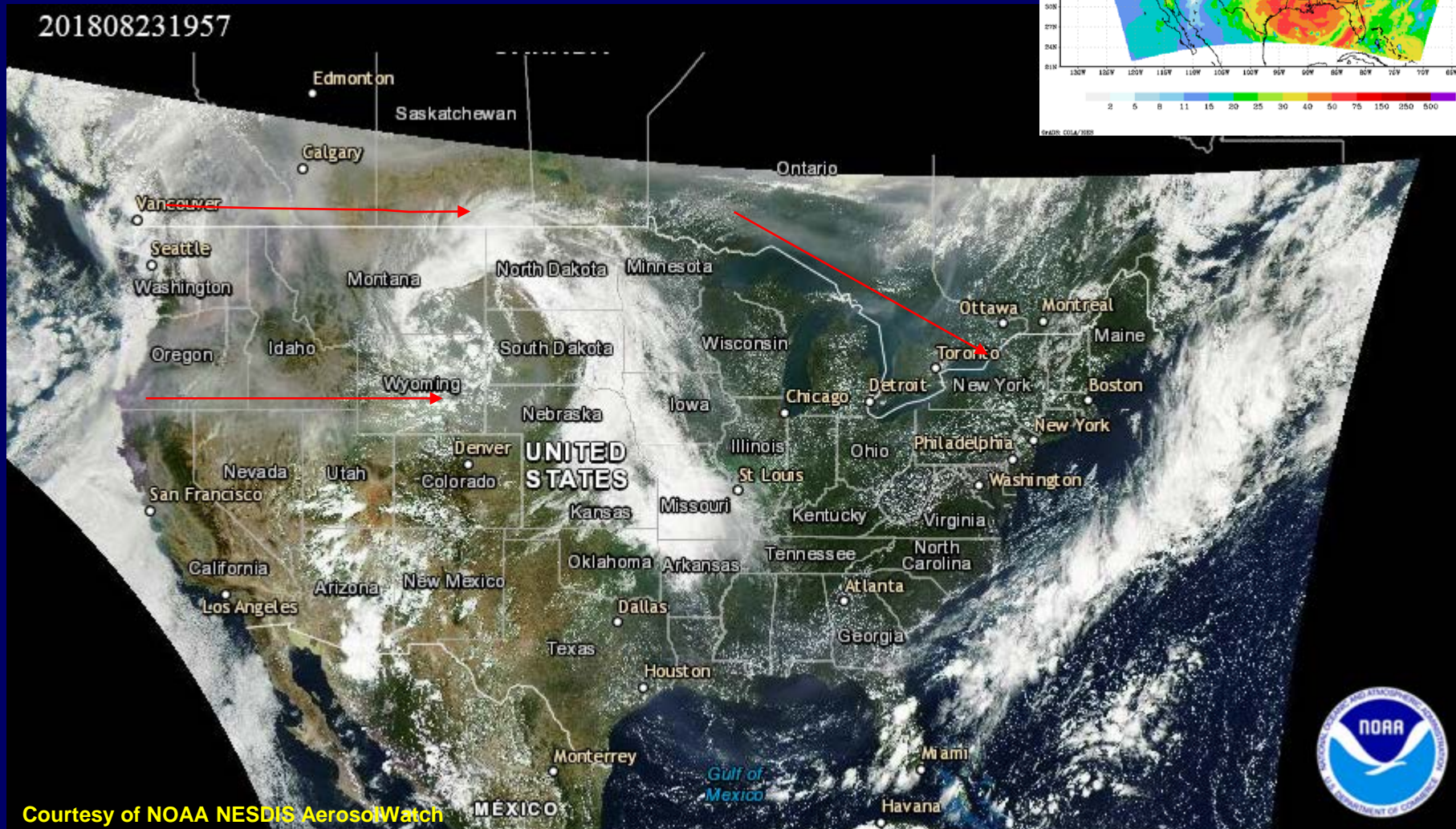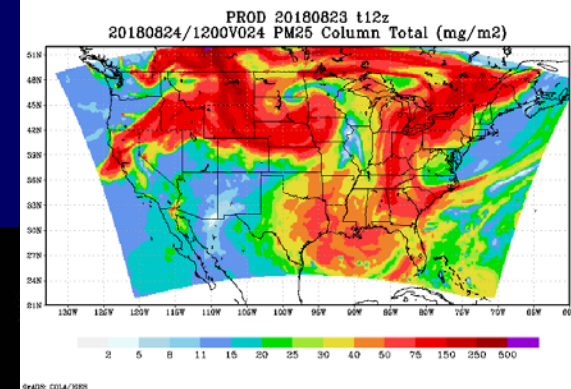

CMAQ PM25 Column Total

PROD 20180822 t12z
20180823/1200V024 PM25 Column Total (mg/m2)

201808221957


DAY 2 −1 Avg PM25 obs (ug-m3) 1500 -> 1200 UTC
West-US

- Observed Canadian smoke plume moves along Canadian border and toward NE US.
- Observed smoke plume from Oregon and N Californian fires move eastward to Northern Plain
- The NE US is impacted by LRT smoke plume (W US, Canada)

CMAQ PM25 Column Total

201808231957

Courtesy of NOAA NESDIS AerosolWatch

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- Observed Canadian smoke plume move southward to NW US
- Observed smoke plume from N Californian fires moves eastward to Canada and the Northern Plain
- The NE US is impacted by LRT smoke plume (W US & Canada)
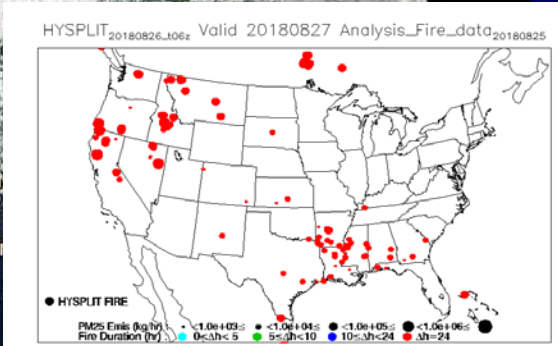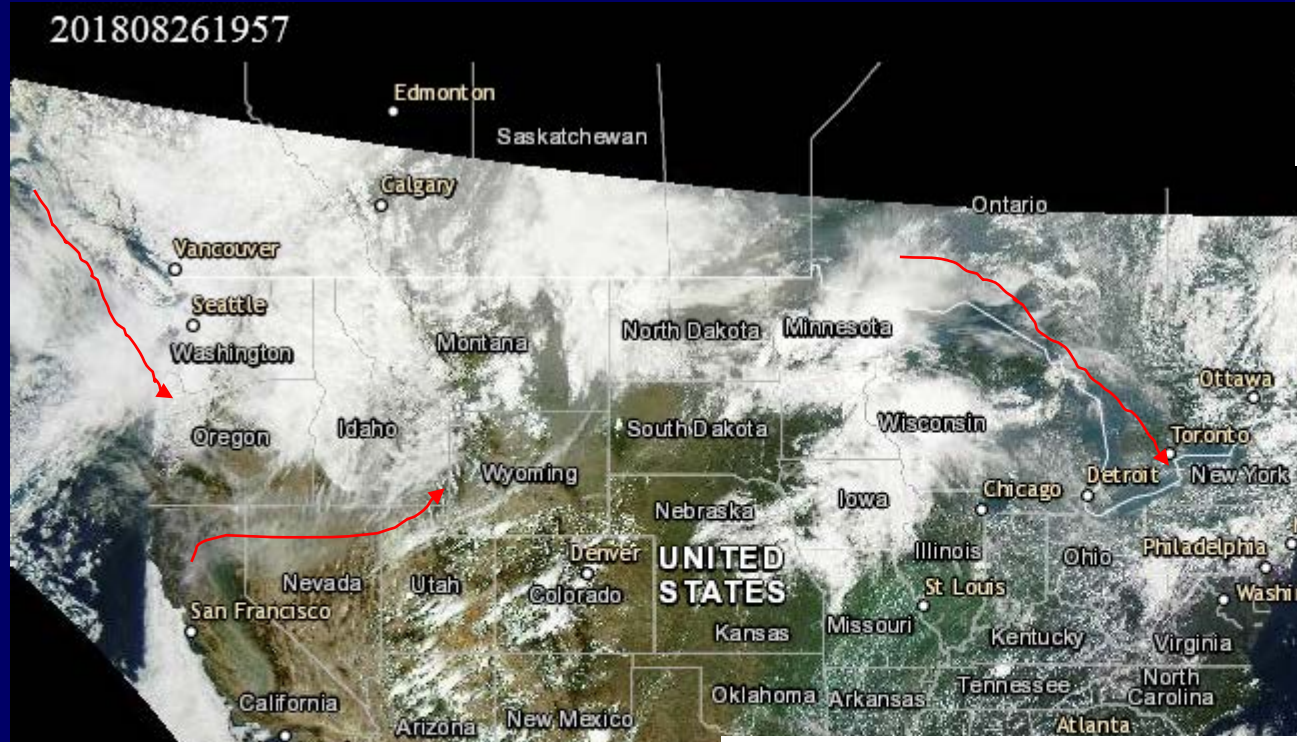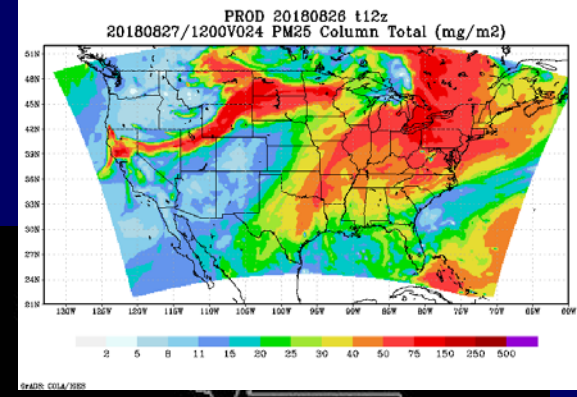
CMAQ PM25 Column Total

PROD 20180824 t12z
20180825/1200V024 PM25 Column Total (mg/m2)

201808241957
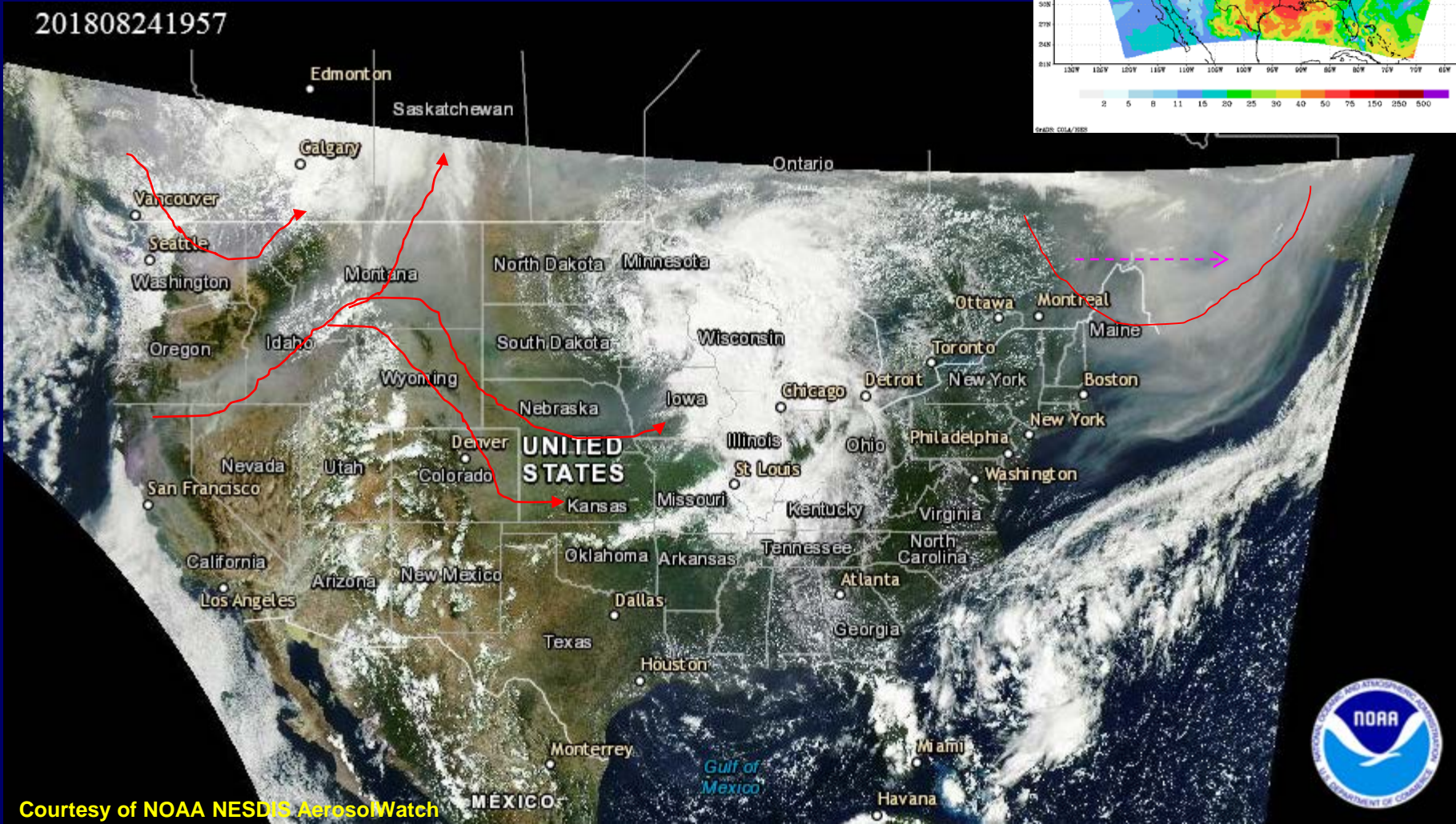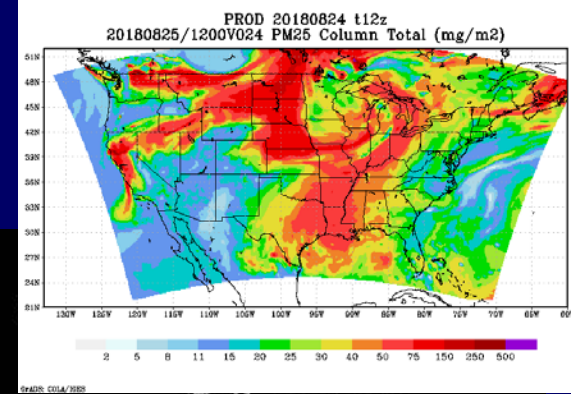
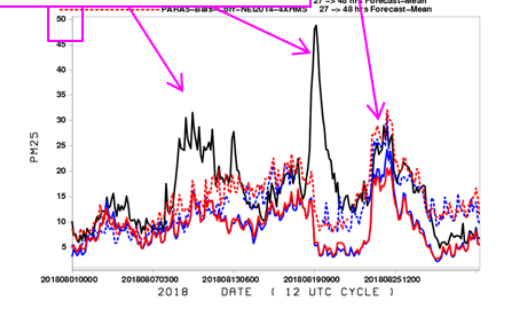**Courtesy of NOAA NESDIS AerosolWatch**

- Observed Canadian smoke plume moves south toward the NW US.
- Observed smoke plume from N Californian move eastward to the Northern Plain
- Observed Canadian smoke plume move to the NE US through Great Lake
- HYSPLIT dispersion transport indicates the impact to the western US from Canadian fires outside CMAQ domain
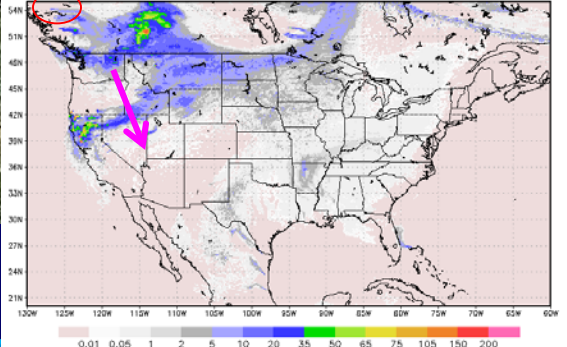
CMAQ PM25 Column Total

PROD 20180826 t12z
20180827/1200V024 PM25 Column Total (mg/m2)

201808261957

HYSPLIT 20180826_t06z Valid 20180827 Analysis_Fire_data 20180825

● HYSPLIT FIRE
PM25 Emis (kg/hr)   <1.0e+03≤   <1.0e+04≤   <1.0e+05≤   <1.0e+06≤
Fire Duration (hr)   0<Δh< 5   5≤Δh<10   10≤Δh<24   Δh=24

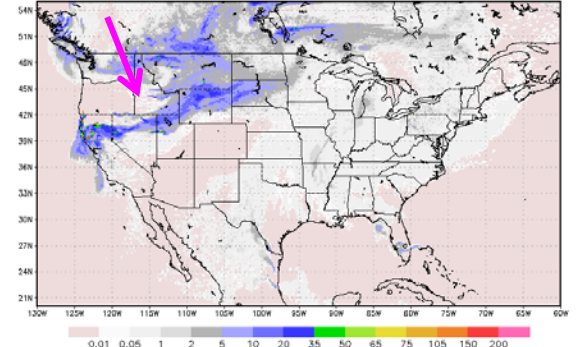Smoke plum LRT from W US and Canada

Smoke plum LRT from Canada

N Plain

HYSPLIT/Smoke indicate additional Canadian influence to the Northern Plain

HYSPLIT PROD t06z pbl smoke 20180826/0700V001 conc ug/m3   HYSPLIT PROD t06z pbl smoke 20180827/0900V027 conc ug/m3

0.01 0.05 1 2 5 10 20 35 50 75 105 150 200   0.01 0.05 1 2 5 10 20 35 50 75 105 150 200

Summary

- NESDIS satellite aerosol products are critical to operational NAQFC simulations conducted at the NCEP.

- Model evaluations performed at the NCEP are critical to provide better NAQFC AQ guidance to state AQ forecasters.

- Advance instruments such as VIIRS and ABI provide better spatial coverage and more accurate aerosol characteristics

- Collaboration with NESDIS/STAR aerosol group are in progress to incorporate GOES-16 and VIIRS aerosol data to METplus aerosol verification.

http://www.emc.ncep.noaa.gov/mmb/hchuang/web/html/cmaq_pm25_column.html

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