Update of the NCEP EMC Atmospheric Composition Modeling Projects

Jeff McQueen, Jianping Huang, Ho-Chun Huang, Li Pan, Perry Shafran, Jack Kain, Partha B., Jun Wang, Sarah Lu, Binyu Wang
&
OAR/ARL (Pius Lee) , ESRL/PSD (Jim Wilczak) ,
ESRL/GSD (Georg Grell) et al.
09/27/2018

CMAQ Current Development/Testing

FY19Q1 implementation

- **NEI 2014 V2 Anthropogenic Emissions Update (ARL)**

- **Wild-Fire Smoke Emissions update (Ho-Chun Huang)**
  - Update to NESDIS Hazards Mapping System Fire locations (8/1/18 into operations)
  - Inclusion of diurnal smoke temporal emissions
  - tests with emission strength, biomass area burned, diurnal profiles

- **Unified Bias Correction (ESRL/PSD, Jianping Huang)**
  - Rare event adjustments
  - PM2.5 operational, Ozone experimental (12/26/18

Possible FY19Q4 Updates

- **FV3 met driver tests (Jianping Huang, para8 running)**
  - Also used for 72 hr extension
  - Underprediction of PM2.5
    - Related to late onset of PBL in AM and overmixing in afternoon ?
      - (C. Bernier, E. Yang summer student evaluations

- **Improved LBCs from NGAC/GEOS-Chem (ARL)**

- **Improved Emissions**
  - Anthropogenic (ARL)
  - Smoke: NESDIS fused GBBEPx emissions

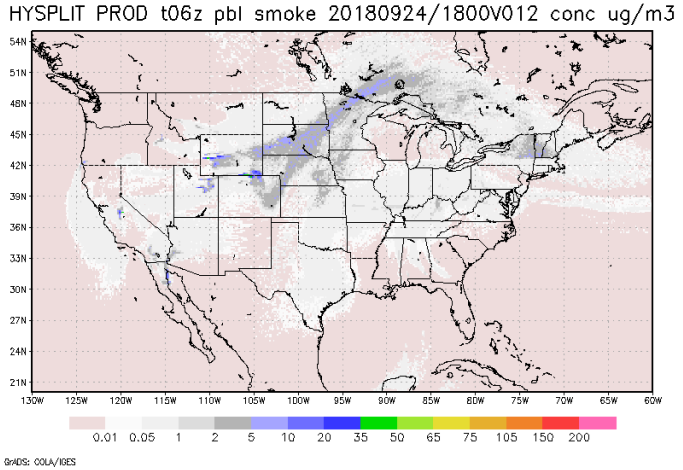
HYSPLIT Developments

- Real-time daily smoke/dust predictions:
  - Wild fire smoke (06 UTC, CONUS, AK, HI) and dust (CONUS, 00/12 UTC)

- V7.5 by Nov. 11, 2018
  - Radiological/Chemical Dispersion (RSMC/SDM): ¼ degree GFS, native grids, FV3 coupling
  - DHS/HLS: HRRR 3 km driver for events
  - Comprehensive Test Ban Treaty Org (CTBTO) Source Term: ½ degree GFS
  - Volcanic Ash (VAAC) : ¼ GFS, native grids FV3 coupling

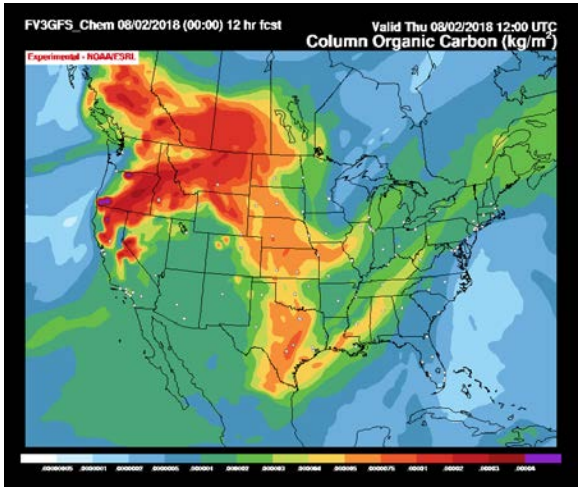
- Transfer Coefficients Matrix technique (G. Rolph, ARL)
  - Allows quick update of source term (eg: Fukushima: numerous updates during multi-month event)

- Dispersion Ensembles
  - Volcanic Ash/Radiological, based on SREF
  - Test GEFS C384, CAM ensemble when ready



NGAC V3 (FY20)

- FV3GFS-GSDChem (Li Pan, Jun Wang, Partha B. & GSD)
  - One member of GEFS Q2FY20
  - NRT runs at GSD: C384L64 (25 km) to 7 days
  - WRF-Chem version of GOCART
    - Sea salt algorithm to be updated to latest NASA 3 bin system
    - Update emission to use NESDIS GBBEPxV2 algorithm with FRP for plume rise
    - ARL dust scheme to be tested
  - Community Emissions Database System (CEDS) for anthropogenic SO2/SO4
  - Issues with too much vertical mixing with high concentrations aloft



FV3GFS-GSDChem C384
~ 25 km total integrated
https://fim.noaa.gov/FV3chem/

Current Experimental web sites

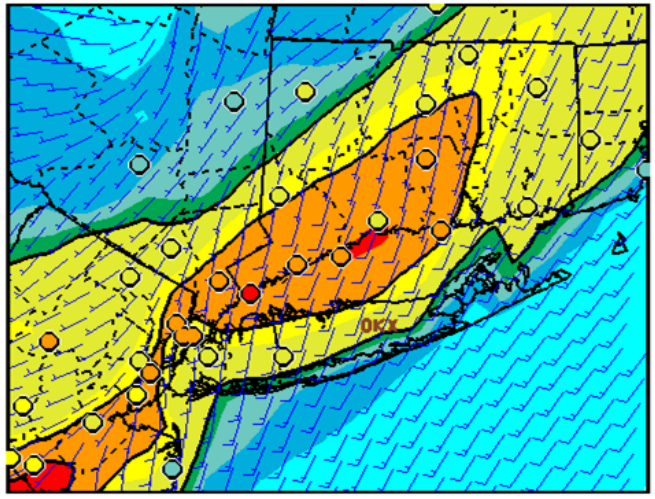
Model	
CMAQ V5 Prod vs PARA5	http://www.emc.ncep.noaa.gov/mmb/aq/cmaq/web/html/
CMAQ total column PM	http://www.emc.ncep.noaa.gov/mmb/hchuang/web/html/cmaq_pm25_column.html
PROD vs PROD PM Bias corrected	http://www.emc.ncep.noaa.gov/mmb/aq/cmaqbc/web/html
PARA5 vs PARA5 O3/PM Bias corrected	http://www.emc.ncep.noaa.gov/mmb/aq/cmaqparabc/web/html
PARA5 vs FV3-CMAQ PARA8	http://www.emc.ncep.noaa.gov/mmb/aq/cmaqpara8/web/html
Verification	http://www.emc.ncep.noaa.gov/mmb/aq/fvs/web/html/regular.html
Text files	http://www.emc.ncep.noaa.gov/mmb/aq/sv/grib
Met comparisons NAM vs Nest, FV3	http://www.emc.ncep.noaa.gov/mmb/aq/smart/web/html/nam.html
fv3gfs evaluations	http://www.emc.ncep.noaa.gov/users/Alicia.Bentley/fv3gfs

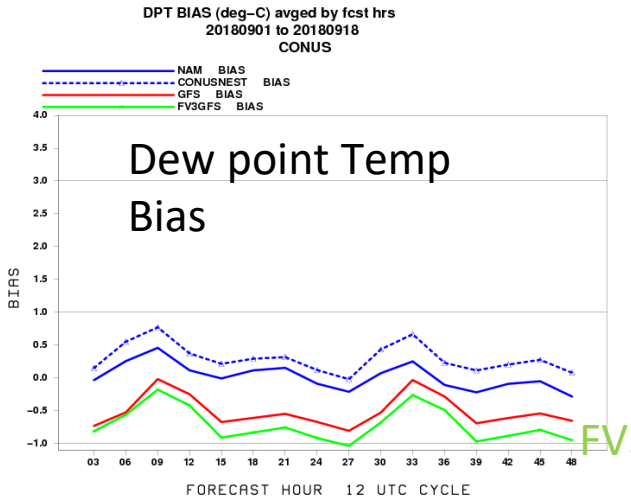
Regional/Global Verification

- Current
  - CMAQ Ozone/PM2.5 : AIRNOW sfc Obs
    - 1h, daily max avg: std + threshold
    - Overlay maps
  - HYSPLIT: NESDIS satellite smoke/dust products
  - NGAC (Partha B.)
    - AERONET AOD pointstat
    - MODIS/MERRA2 AOD gridstat
  - Meteorology: NAM, Nest, FV3, HRRR

- Transition to METPlus and/or MONET
  - Add GOES 16/17, VIIRS AOD
  - NO2/SO2, Aerosol species (IMPROVE, CASTNET…)
  - Ozonesondes/ lidar profiles
  - PBLH from Ceilometers, lidars
  - Continued analyses from forecaster

http://www.emc.ncep.noaa.gov/mmb/aq/

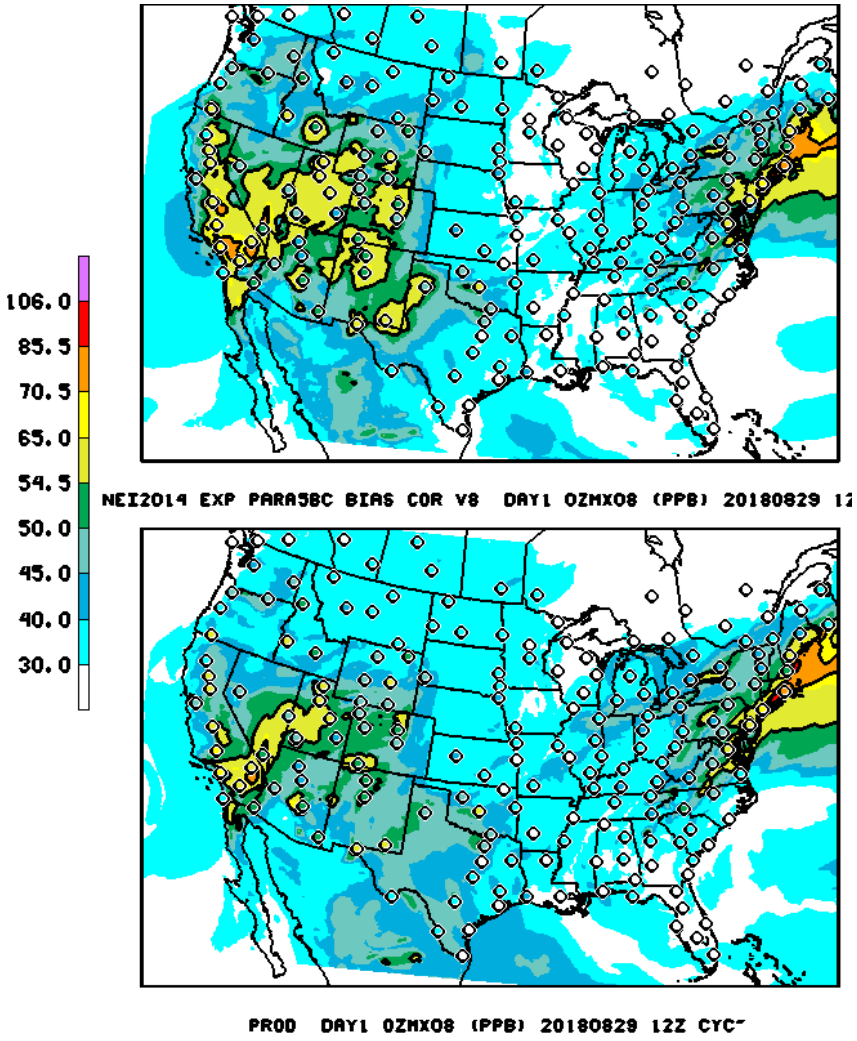


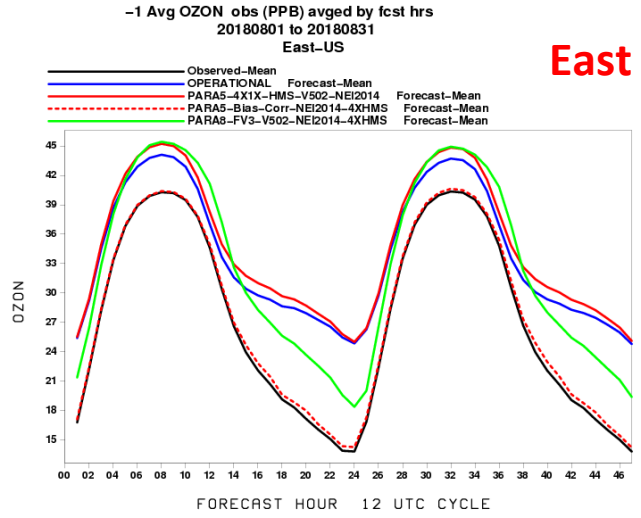


FV3

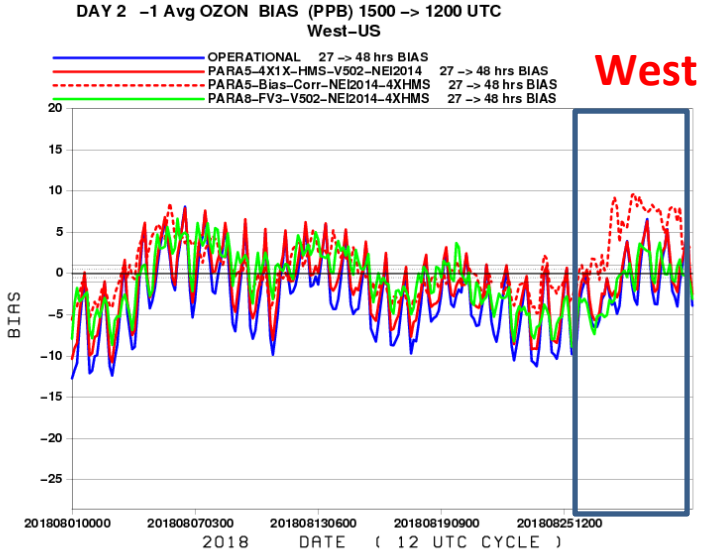
O_3 bias correction evaluation

August, 2018





East

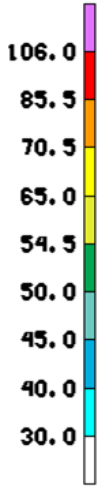


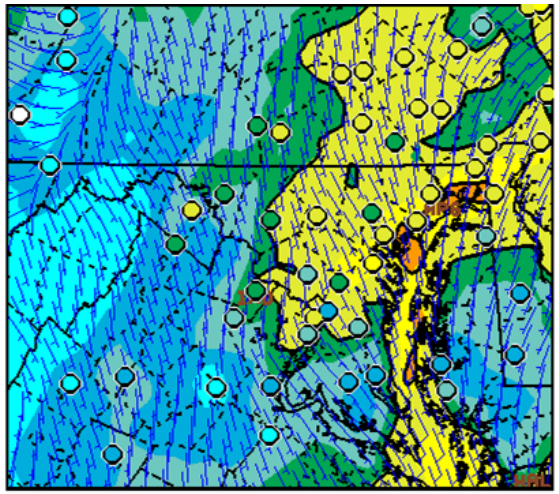
West

NEI2014V2 emissions: Slightly hotter over East, improved west

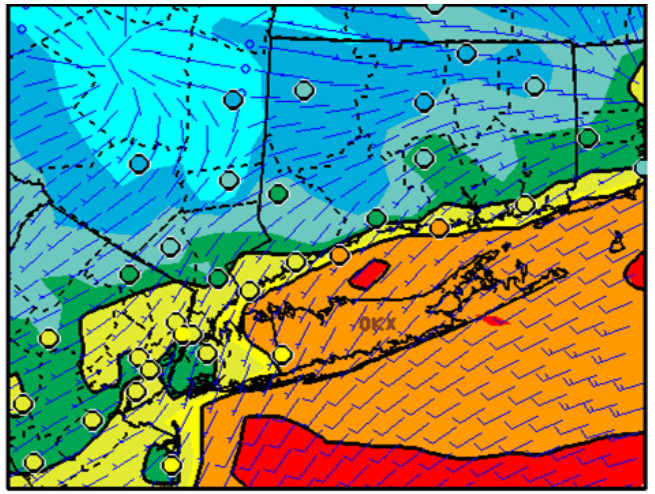
ESRL bias correction: removes overall biases but overshoot after smoke event

August 16, 2018 Day 1: O_3 8 h daily Max

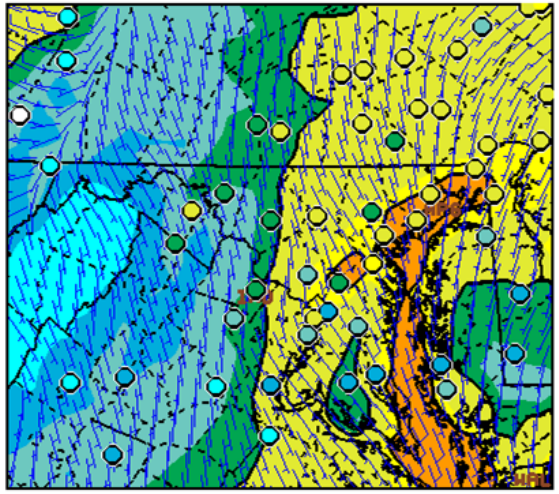




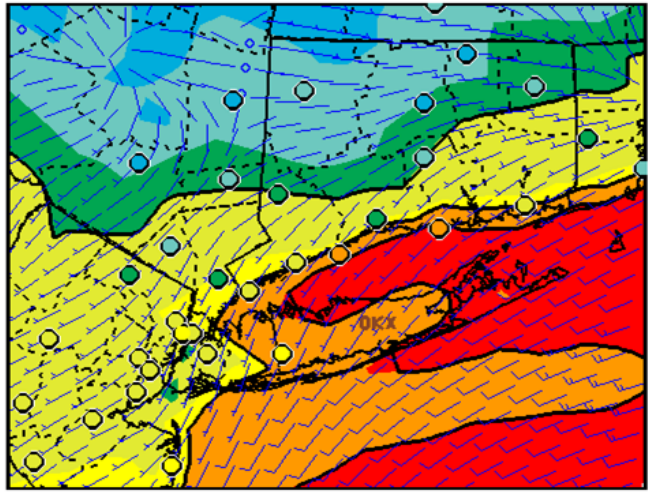
PROD BIAS COR V8 DAY1 OZMX08 (PPB) 20180816 12Z



PROD BIAS COR V8 DAY1 OZMX08 (PPB) 20180816 12Z CYC



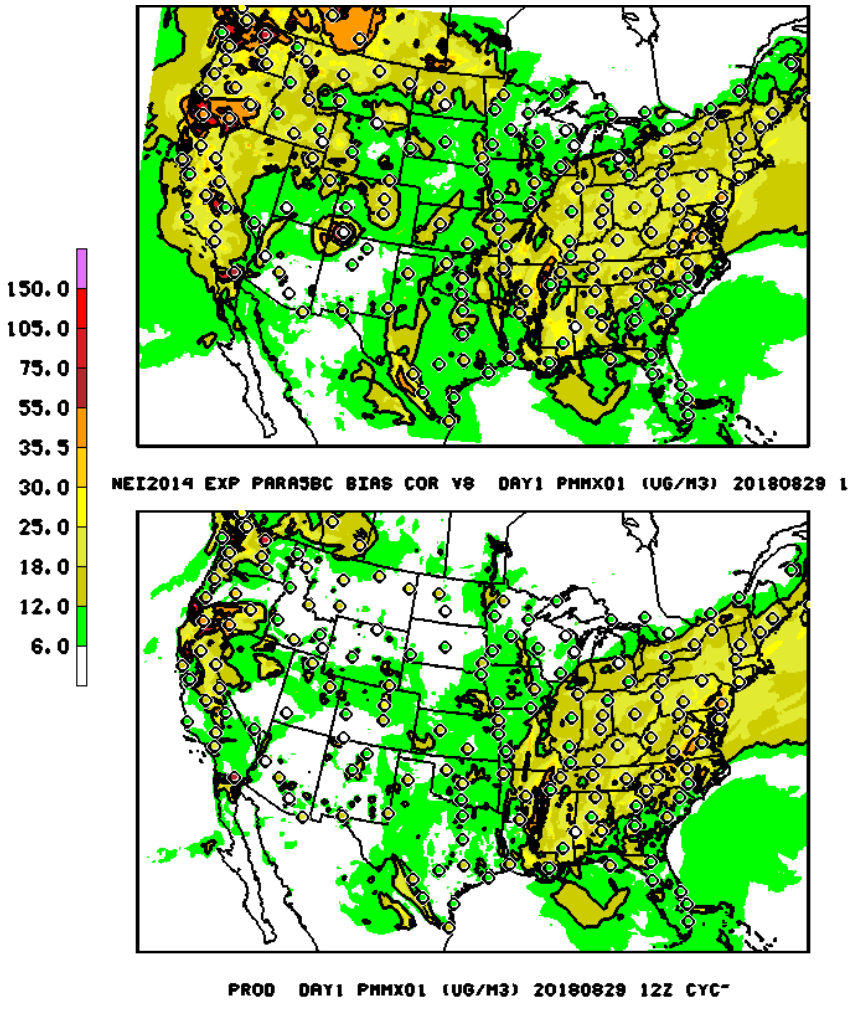
PROD DAY1 OZMX08 (PPB) 20180816 12Z CYC-

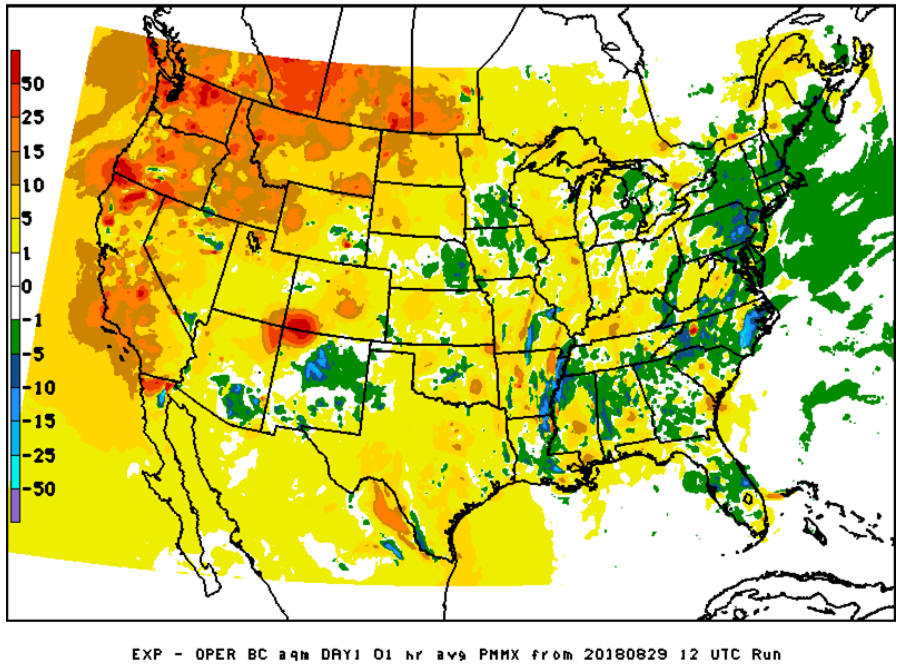


PROD DAY1 OZMX08 (PPB) 20180816 12Z CYC-

Bias correction Improved false alarm over NE Maryland
Bias correction Improved overprediction over LIS, even though smoke

PM2.5 1h daily Max
Day 1 Valid August 29 2018





Bias correction can struggle around episodic Events (eg : wild-fire smoke)

Near-term plans

Q1FY19 CMAQ implementation : Dec 26, 2018 or sooner

- For CONUS domain run:
- Include NEI 2014v2 emissions
- Include diurnal temporal smoke emissions
- Implement unified bias correction for ozone/PM w/ rare events correction

- AK/HI domain:
- Update AK/HI domains to current CMAQ version (V5.0.2)

Current Challenges

- Transition from manual to HMS fire information hurt predictions
  - Information on source strength/duration lost

  Recommend: use Global Biomass Burning Emission Product with FRP for strength & plume rise
- Inclusion of smoke from outside CMAQ domain needed.

  Recommend: Test FV3GFS-GOCART as boundary conditions

- FV3GFS over-mixing :
  - Examine PBLH, Td bias in FV3→cause of FV3CMAQ PM error (over-mixing) ?

- Begin evaluation of FV3GFS-GOCART C384 runs w/ various configurations:
  - ARL dust scheme, SAS conv. Mass mixing, use GBBEPx smoke emissions, NASA Sea salt
  - Transition to METPlus (include satellite AOD, AERONET for CMAQ)

NWS Strategic Implementation Plan

Implementation Plan for FV3-Chem (FY2018-2021)

FV3Chem	FY18				FY19				FY20				FY21			
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
FV3GFS-Chem Development	NEMS coupler and GOCART component					Develop initial 2 way cpling to GFS physics; upd. emissions										
FV3GFS-Chem Configuration	Test FV3GFS-Chem, resolution, 1-way coupling,increase 25km							Test various 2-way cpling/smoke emissions opts								
FV3-Chem DA			Test, eval; transition VIIRS, other AOD DA to Op GSI													
FV3GFS-Chem Evaluation				Final FV3GFS-Chem V1 configuration* & perform retros and real-time runs							Final glbl config (2-way cpl to rad and/or microphys), fire plume rise					
FV3GFS- Chem T2O							V1: Implem. FV3GFS-Chem								V2: AOD DA; 2-way coupling	
FV3SAR-Chem				Dev. new coupler for CB-VI chem			Configure/test adv. chem (CB-VI, Aero) w/ FV3SAR				Retros & RT runs		Optimize FV 3SAR Chem		Implem. FV3SAR -Chem	
Advance-ment of FV3-Chem											Develop, couple to adv. Physics, Transition to JEDI, Inline regional tests					

* Proposed changes for FV3GFS-Chem: 1) Couple with updated FV3-GFS physics/dynamics; 2) Increase horizontal resolution to 25 km; and 3) Assimilate VIIRS AOD

* Proposed changes for Reg FV3SAR-Chem(CB-VI): (1) Couple with advanced physics & reg. stand-alone FV3; (2) Test inline and offline approaches; (3) Update emissions to current year

3 Year Plan

- Strategic Implementation Plan for Atmospheric Composition → FV3-Chem
  - FV3GFS-GOCART (online, C384): Q2FY20
    - Coordination with GSD on updated version of GOCART
      - Biomass Burning Emissions: GBBEPx vs GSD FRP
      - Dust, Sea-salt processes
    - Coordination with Aerosol DA project
  - FV3SAR-CMAQ (online ?, ~10 km) : >FY21
    - At least 5X increase in compute resources (> 100 nodes)
    - CB-VI gas-phase chemistry

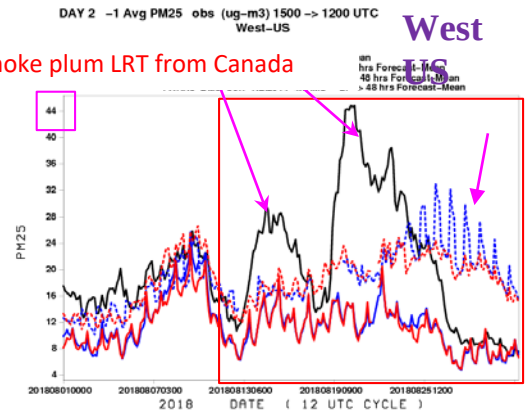
Performance of CMAQ PM_{25} Simulation based on new HMS Fire Processing Routine

Ho-Chun Huang, Jeff McQueen, Jianping Huang, Perry Shafran, Li Pan, Jack Kain, Youhua Tang, Pius Lee, Ivanka Stajner, and Jose Tirado-Delgado

Why updating fire emissions code?

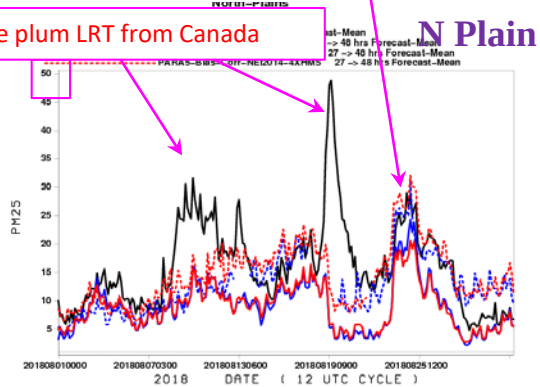
- Interim NESDIS HMS processed fire information system (w/ GOES-16)
  - Used operationally from April 11-July 31, 2018.
  - NESDIS HMS group discontinues the manual inspection of HMS fire detections because of increase number of fire detection from GOES-16 observation.
    - Can not remove false positive and add false negative
    - Does not have fire duration information
    - Can not increase fire strength (based on the smoke comparison between fires)
  - Interim solution only has manual inspection to west of 102W in the CONUS domain.
  - All fires in a 10 km^2 gridded area are represented with only one HMS fire information.
    - Will greatly reduce HYSPLIT fire intensity that depends on the number of HMS fire enclosed in each HYSPLIT grids
- New HYSPLIT/BlueSky fire processing based on HMS fire detections (w/ GOES-16)
  - New automated system is used operationally on August 1 2018.
  - Aggregate all satellite fire detections, all geostationary and orbital, in a 0.01°x0.01° grid.
    - Treat multiple/duplicate fires as a single fire If HMS fire detections are close enough
  - Identify HMS fire and starting time of each grids with more than one detection.
  - Assume 24 hour fire duration
    - Current fire detection information does not have adequate data to determine fire duration
  - Change burn-area per HMS fire from 10% to 8% of 1km^2 HMS fire resolution

Smoke plum LRT from W US and Canada



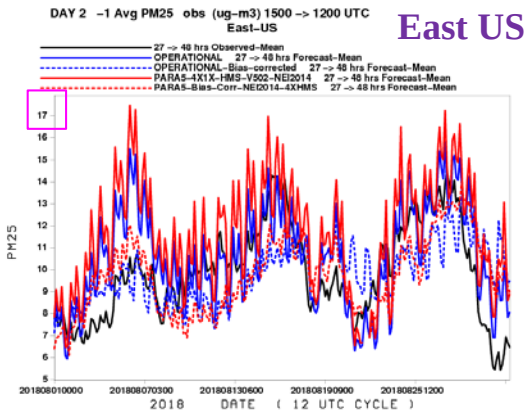
West US

Smoke plum LRT from Canada



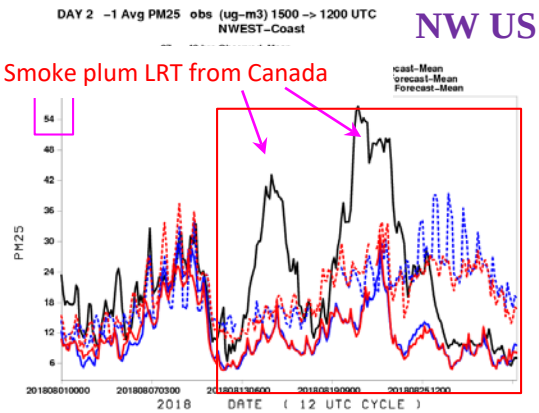
N Plain

Smoke plum LRT from Canada



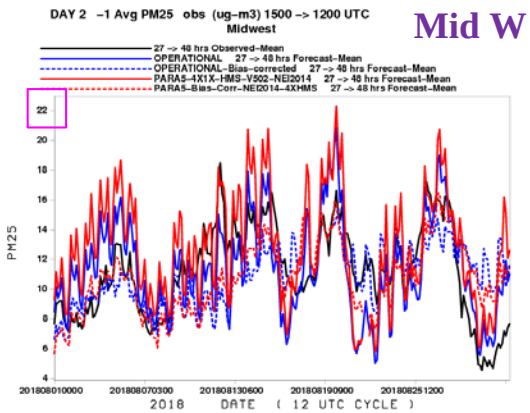
East US

Added NGAC LBC will improve raw model but not solving the problem (Jianping)

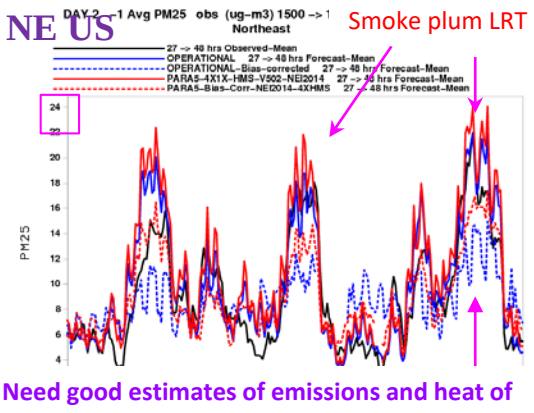


NW US

Smoke plum LRT from Canada



Mid W



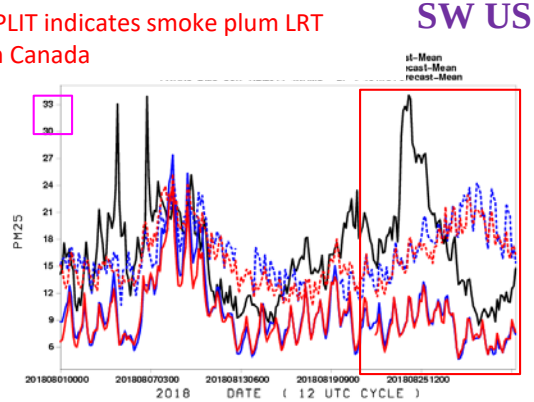
NE US

Smoke plum LRT

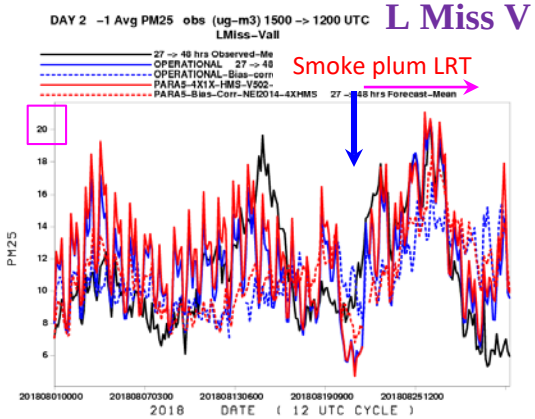
Need good estimates of emissions and heat of remote fires

Added NGAC LBC will make it worse (Jianping)

HYSPLIT indicates smoke plum LRT from Canada



SW US



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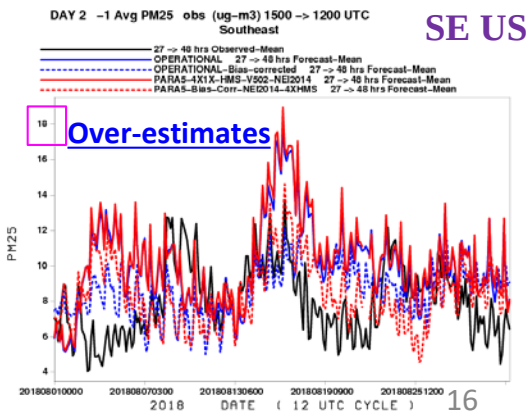
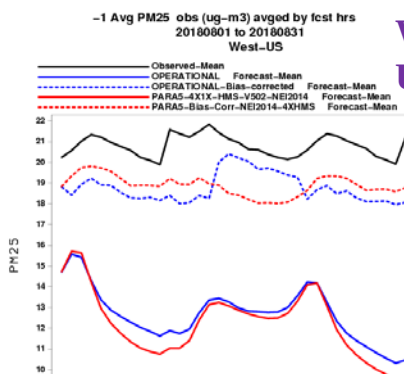
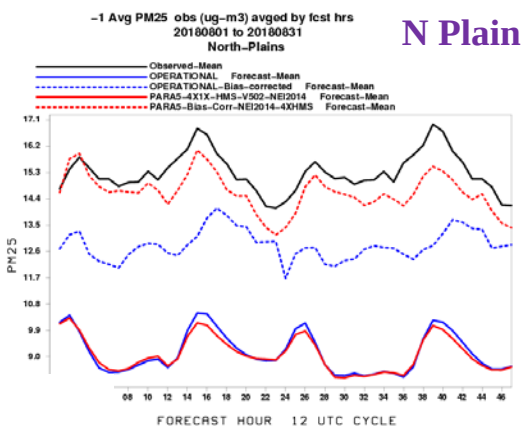


SE US

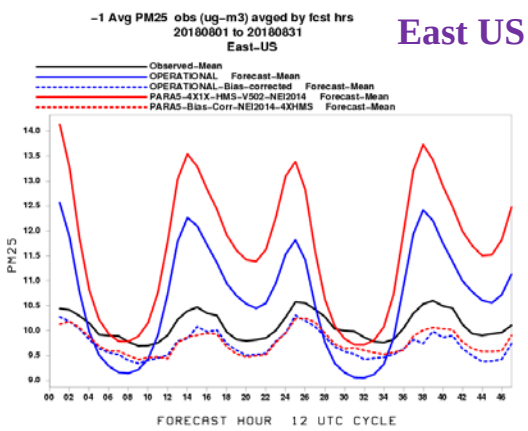
OBS PROD PROD_BC FY19 FY19_BC



West US

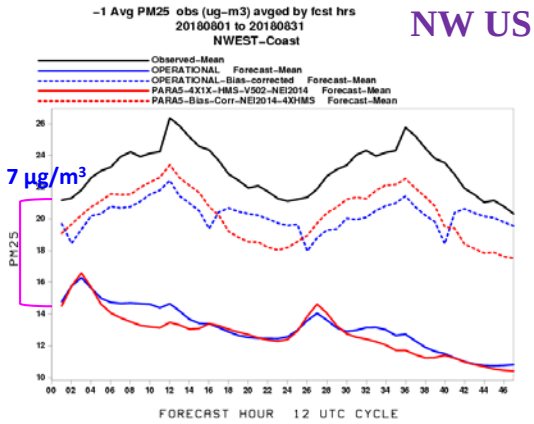


N Plain



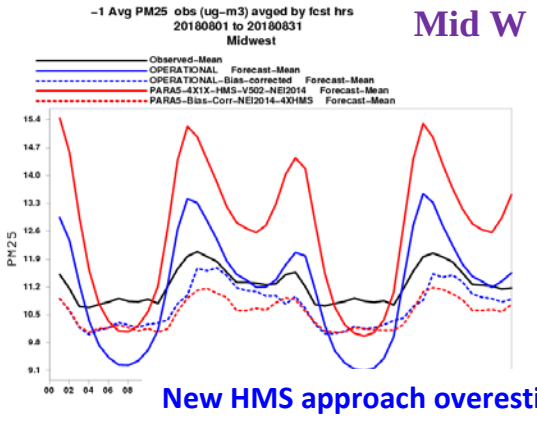
East US

New HMS approach underestimates the PM_{25} emission in the northern Plain and western US

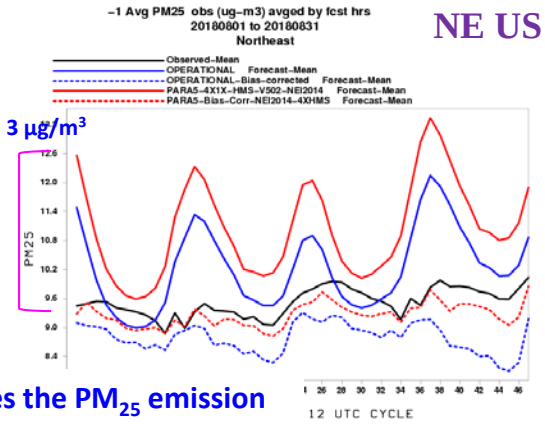


NW US

7 µg/m³



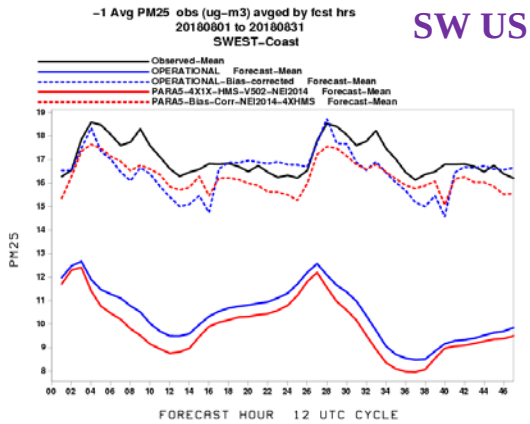
Mid W



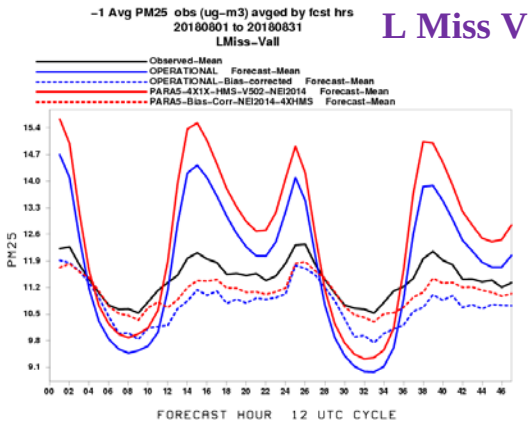
NE US

3 µg/m³

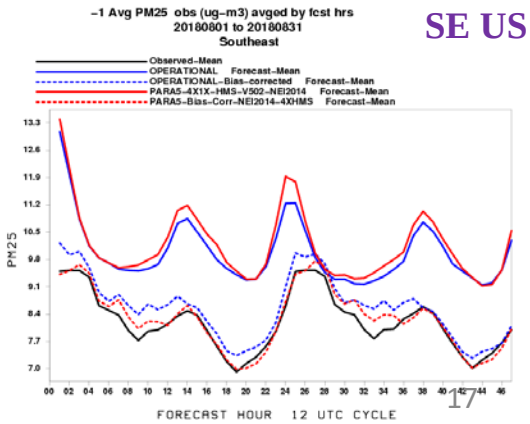
New HMS approach overestimates the PM_{25} emission in the Mid- and eastern US



SW US



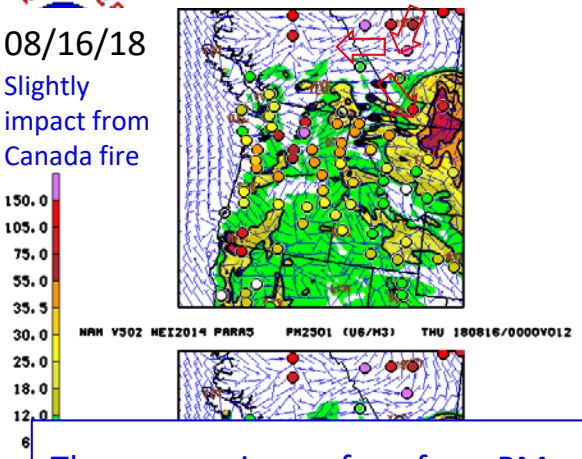
L Miss V



SE US

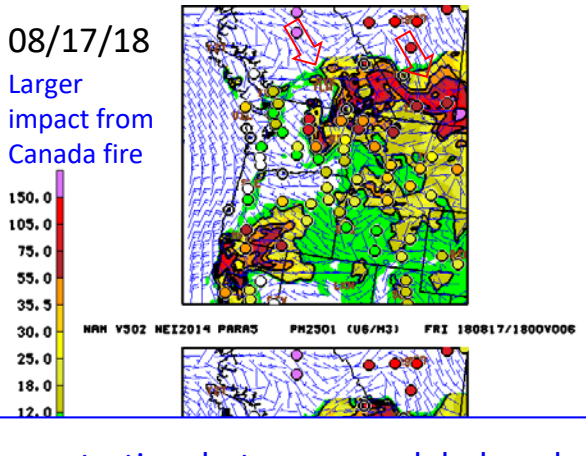
08/16/18

Slightly impact from Canada fire



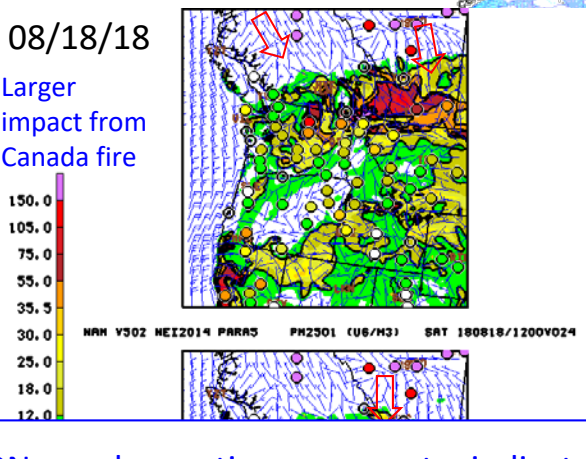
08/17/18

Larger impact from Canada fire



08/18/18

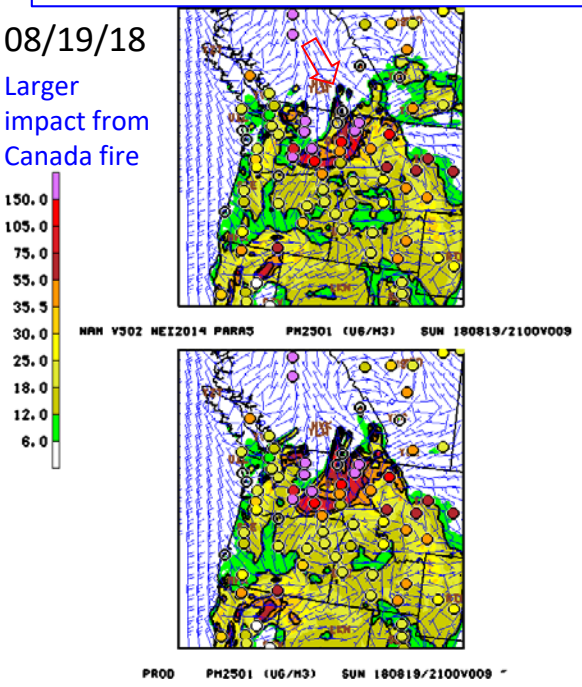
Larger impact from Canada fire



The comparison of surface PM_{25} concentration between modeled and AIRNow observations seems to indicate **weaker** PM_{25} emissions from wildfire. However, the NW US was frequently influenced by the smoke plume from British Columbia, Canada (as seen in GOES-16 images) during this period. Majority of the underestimates may come from missing smoke PM_{25} LBC.

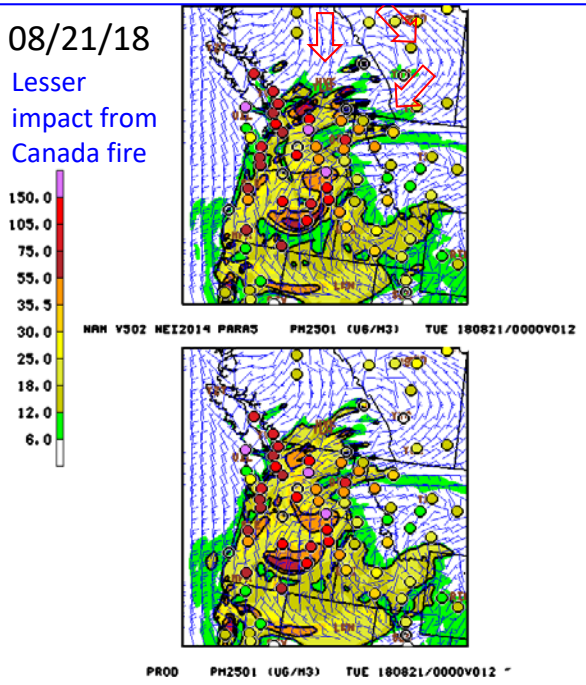
08/19/18

Larger impact from Canada fire



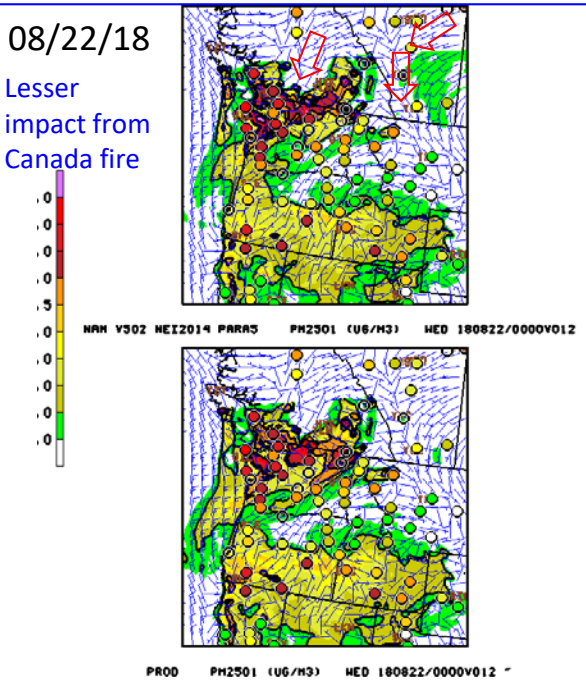
08/21/18

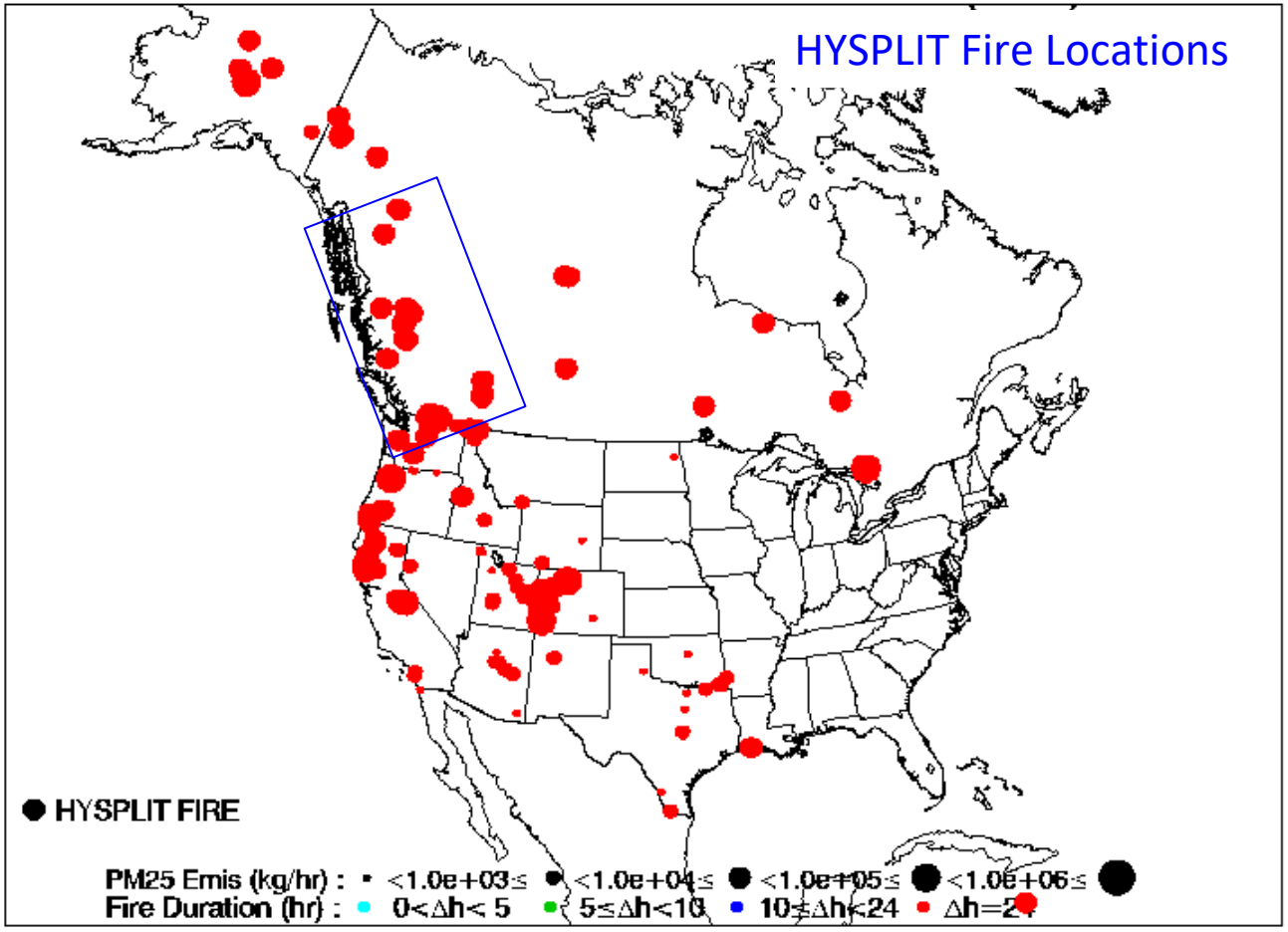
Lesser impact from Canada fire



08/22/18

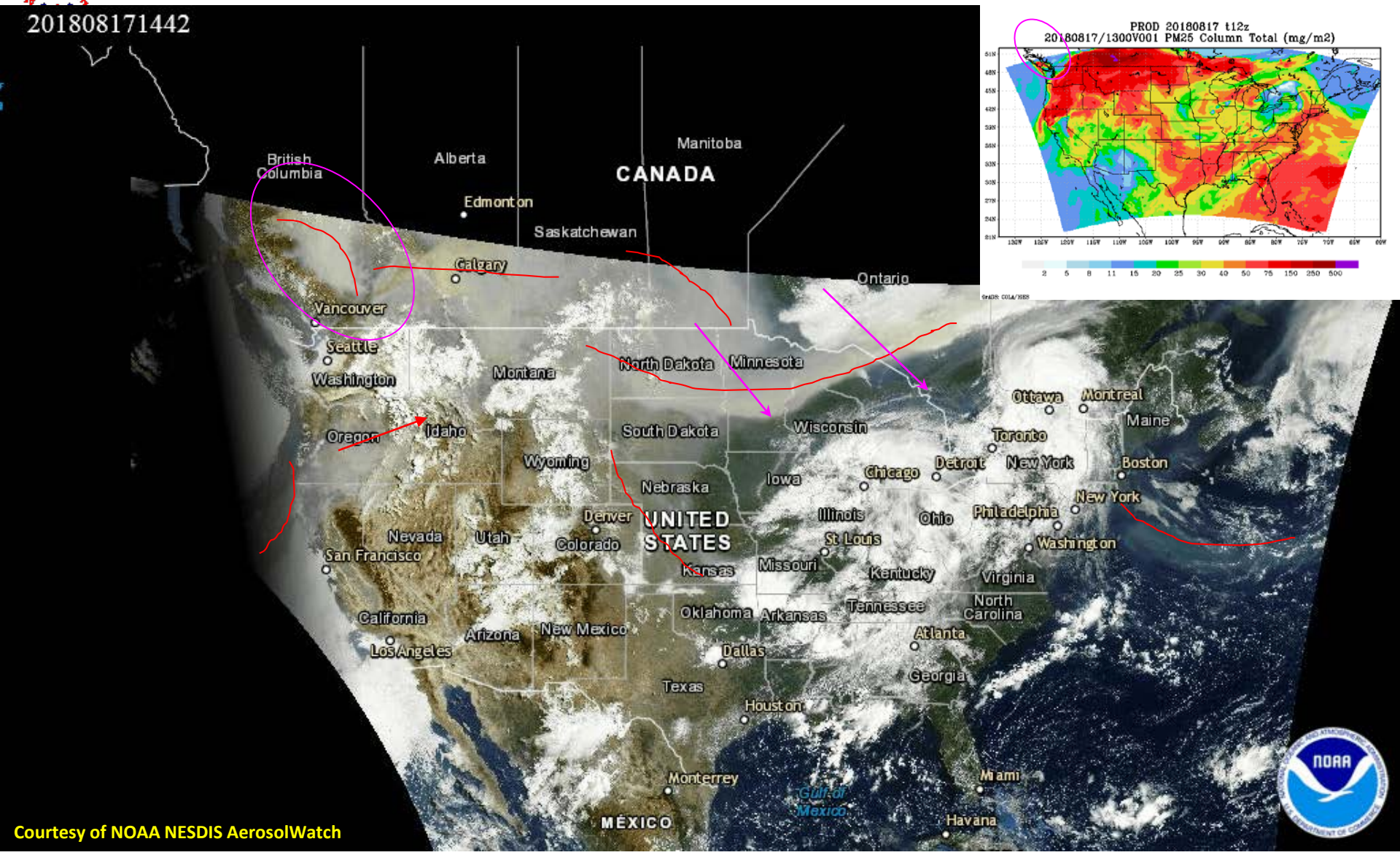
Lesser impact from Canada fire





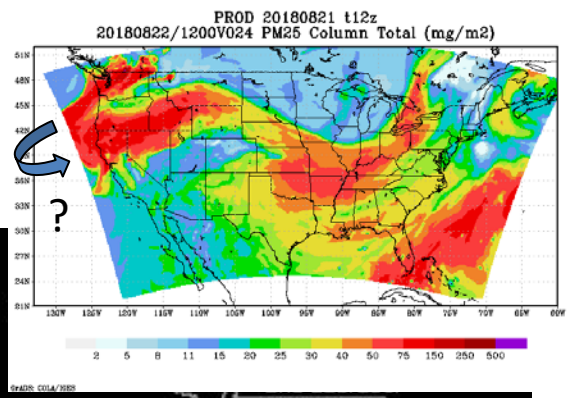
Intensive fires activities from BC Canada in August (e.g., 08/01-02, 08/06-12, 08/14-16, and 08/18-24)

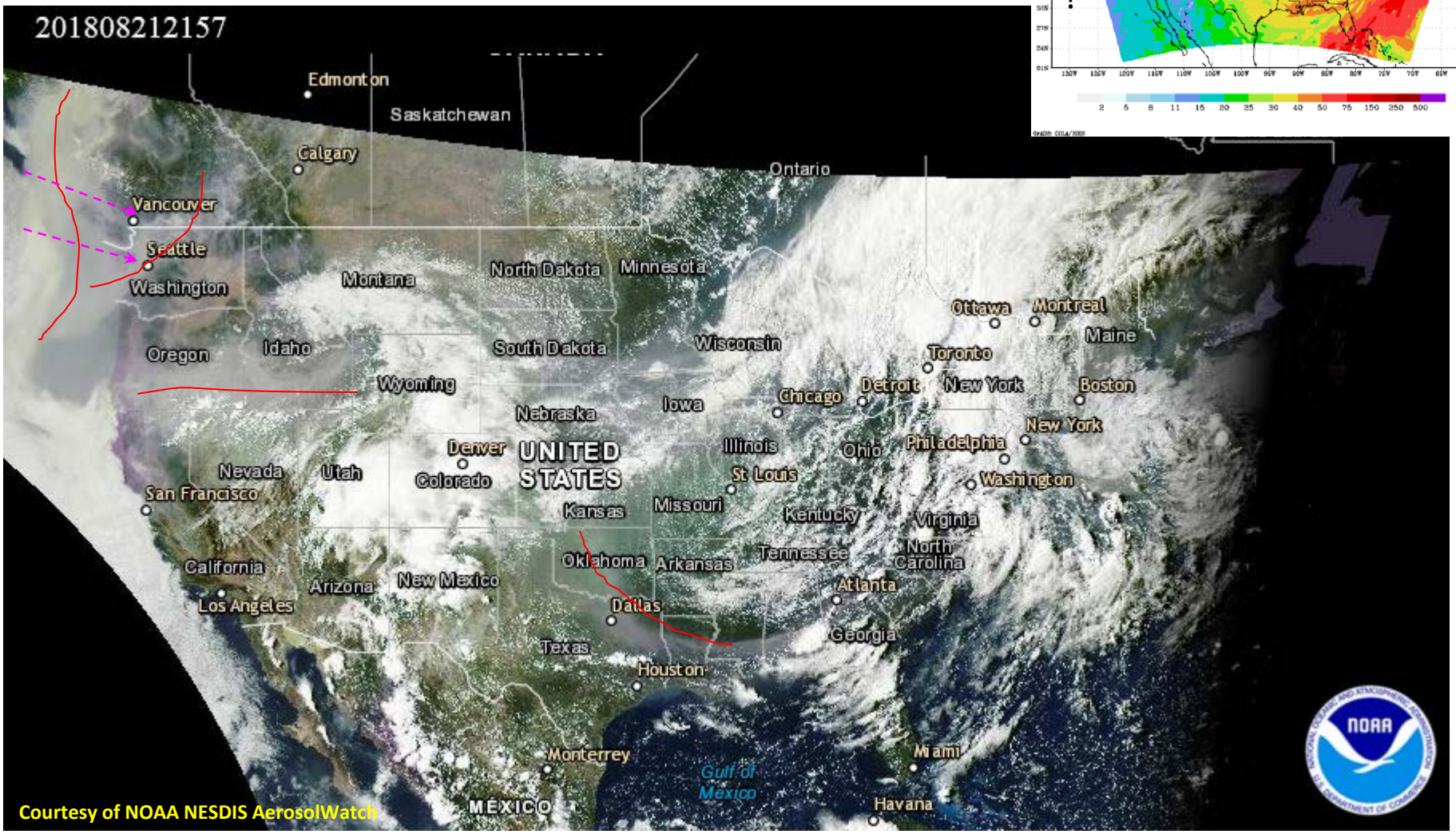
Using GOES-16 RGB animation to find the source and transport of fire smoke



The RGB is a column integrated product and can not reveal the height of smoke plume traveled.

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



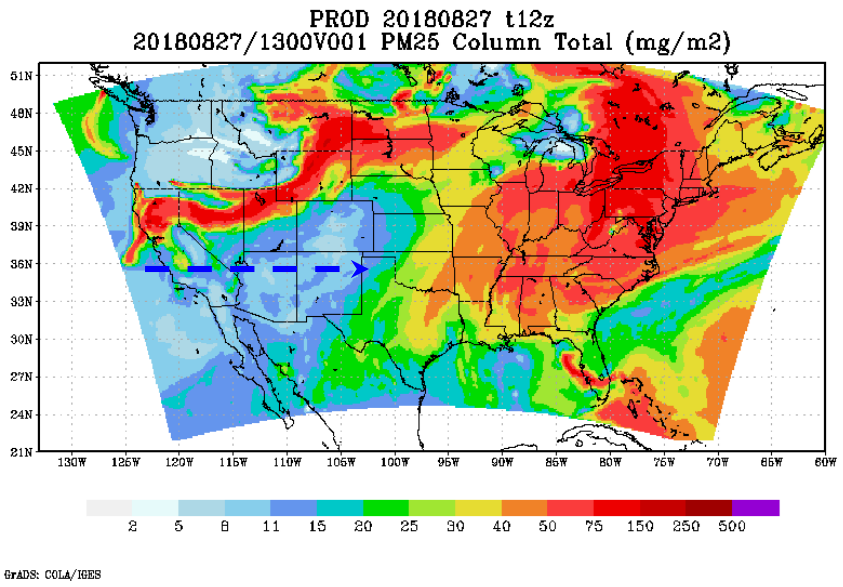


- Use CMAQ column integrated PM_{25} map to diagnosis the transport of fire smoke plume originated inside CMAQ domain

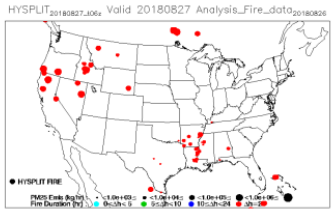
  http://www.emc.ncep.noaa.gov/mmb/hchuang/web/html/cmaq_pm25_column.html

- Use HYSPLIT/Smoke particle model to diagnosis potential transboundary impact of smoke plume from Canada

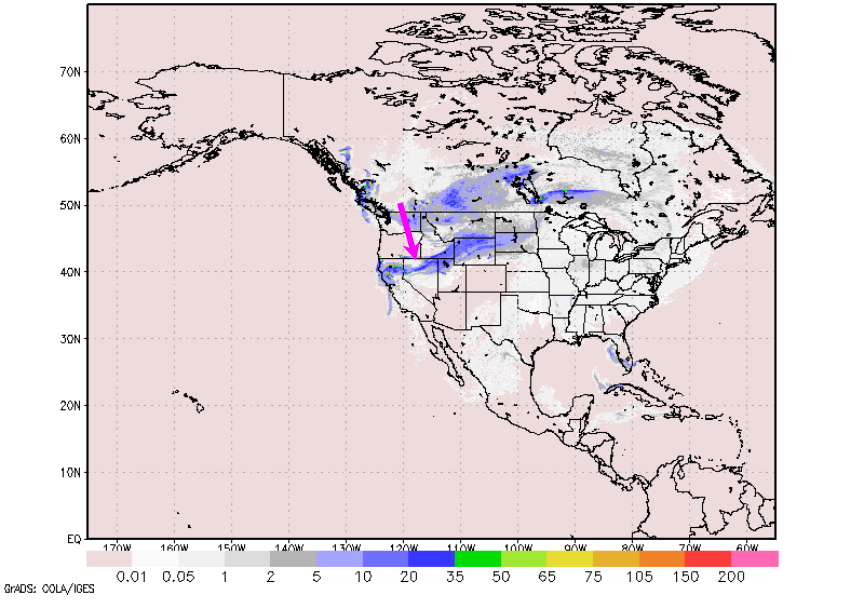
CMAQ PM25 Column Total



the major source of the PM25 in the Northern Plains



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

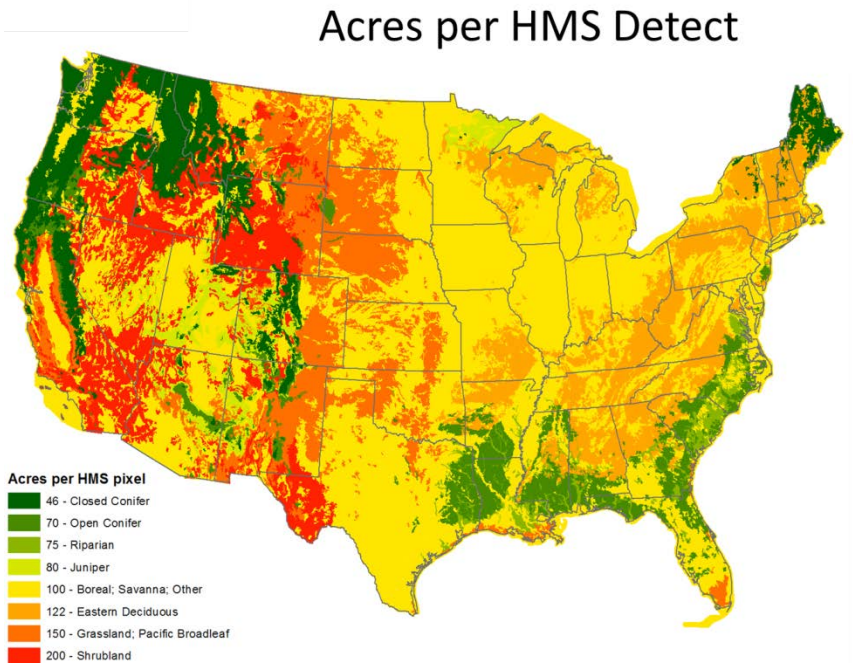


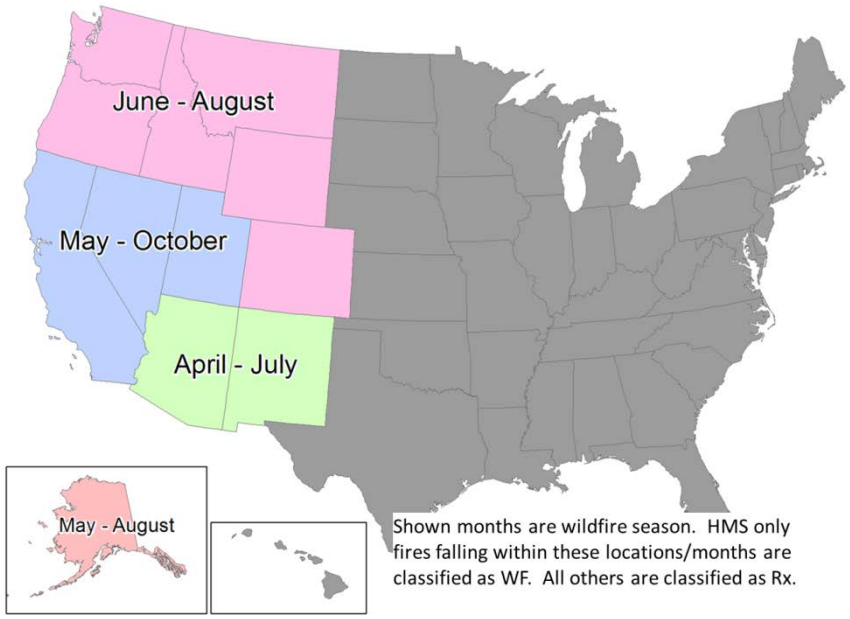
Identify the PM_{25} source from Canada that impacts the NW and the northern Plains, which can not be picked up by CMAQ results.

CMAQ PM_{25} Performance in August 2018

- From satellite images and CMAQ verification, trans-boundary transport of smoke PM_{25} from Canada was shown to be important to the Western, Midwest, and Northeastern US and Northern Plain. Occasionally, it also impacted the Lower-Mississippi Valley area.
- Considering the missing trans-boundary impact from Canadian smoke plume in CMAQ, CMAQ PM_{25} simulations are doing surprisingly well showing fire smoke PM_{25} impact in the Northern Plain and NE US.
- Need to study more on the SW US underestimate other than Canadian smoke plum impact such as local emissions.
- Need to fix consistent over-estimation in the SE US.
- Bias-correction results remains to have problem in biomass burning events (except third events in the Northern Plain).

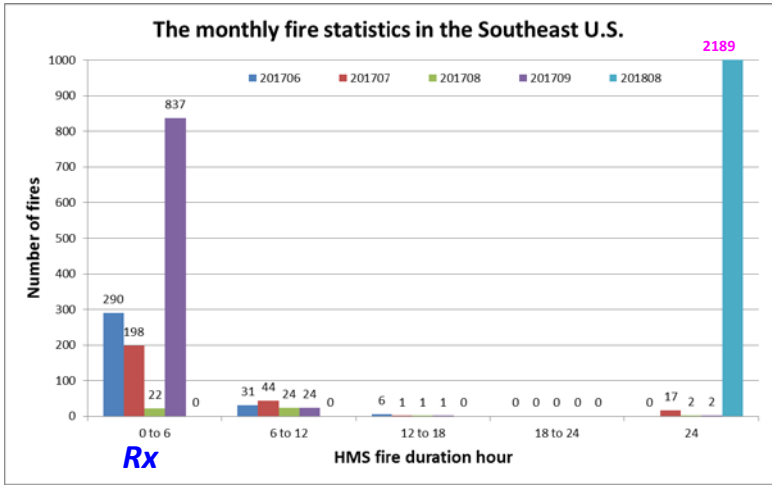
USFS burn-area and fire type Maps





Applying USFS data for future improvement

- "Burn-area per HMS Pixel" as a function of 8 selected biomass types should help to improve the problem of single value burn-area percentage (8%) currently incorporated in operational HYSPLIT.
- To assign eastern US fires as prescribed/agriculture fire
- To test the NESDIS aerosol group's GBBEPx tailored for CMAQ model, i.e., PM25 emission and FRP (for plume rise computation).



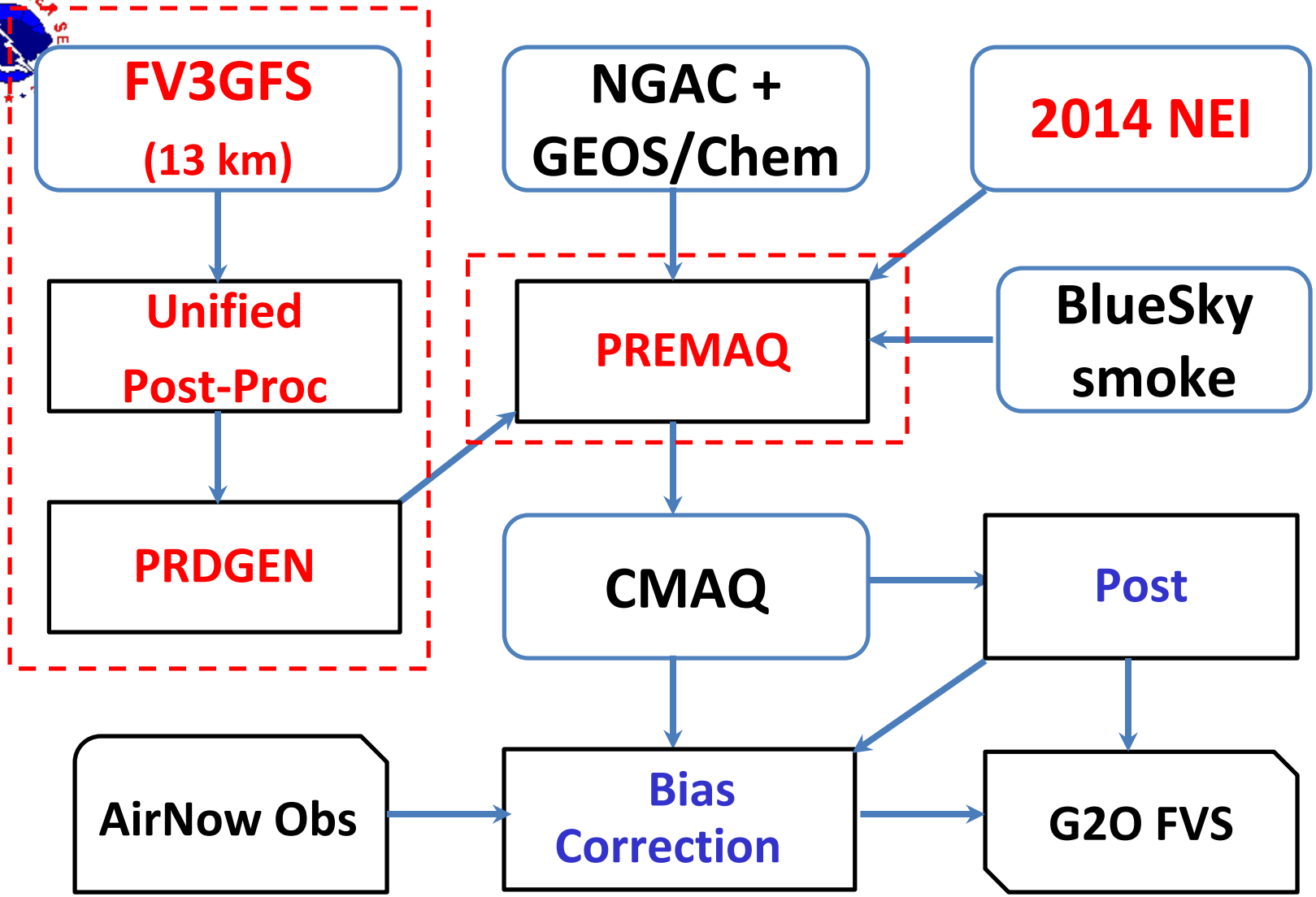
Development and Testing of Off-line Coupling for FV3GFS/CMAQ

Jianping Huang, Jeff McQueen, Ho-Chun Huang, Perry Shafran,Youhua Tang, Pius Lee, Jack Kain, Binyu Wang, Ivanka Stajner, and Jose Tirado-Delgado

Sept. 27, 2018

Motivation

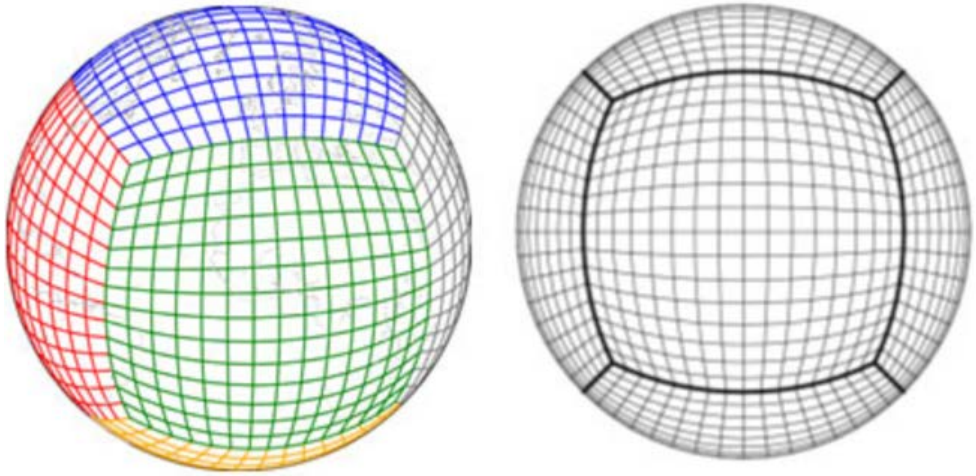
- Current North American Model (NAM, 12 km) will retire in the near future. A new GFS model built up on the GFDL Finite-Volume Cubed-Sphere (FV3) dynamical core is available for driving regional air quality model;
- To evaluate impact of meteorological inputs on air quality predictions;
- Used for a baseline to verify the inline coupling system FV3CMAQ which is under development;
- Used for a backup in case the online system can not meet the operational time requirement.

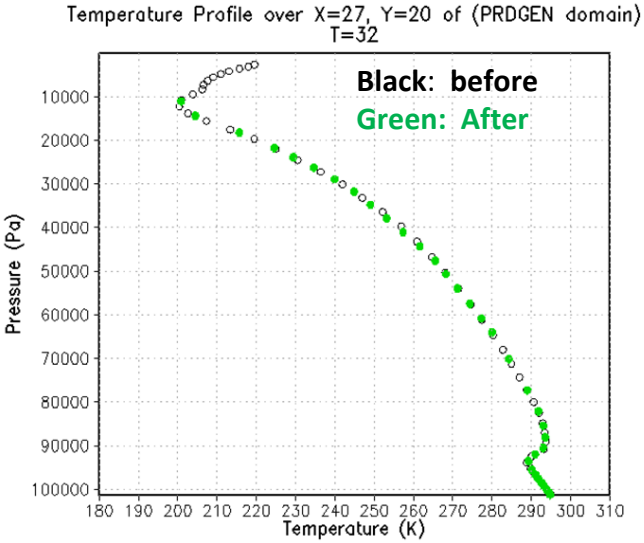


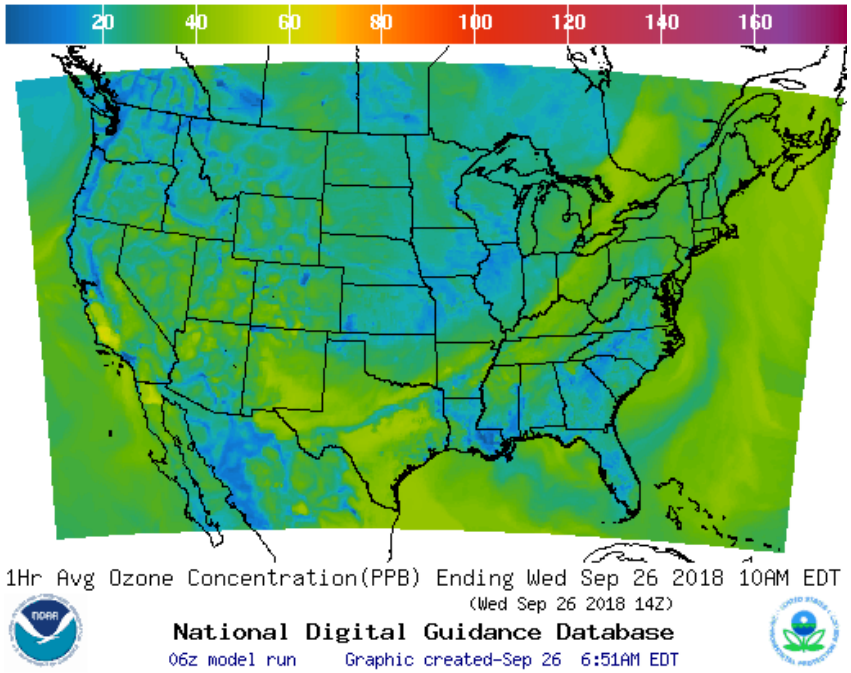
A flow-chart of the FV3GFS-CMAQ system

(new Changes as indicated by the red dashed boxes)

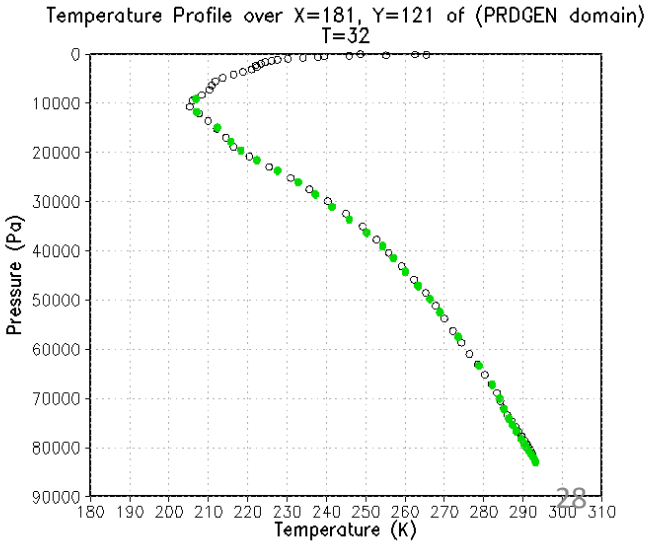
Offline coupling of FV3GFS/CMAQ







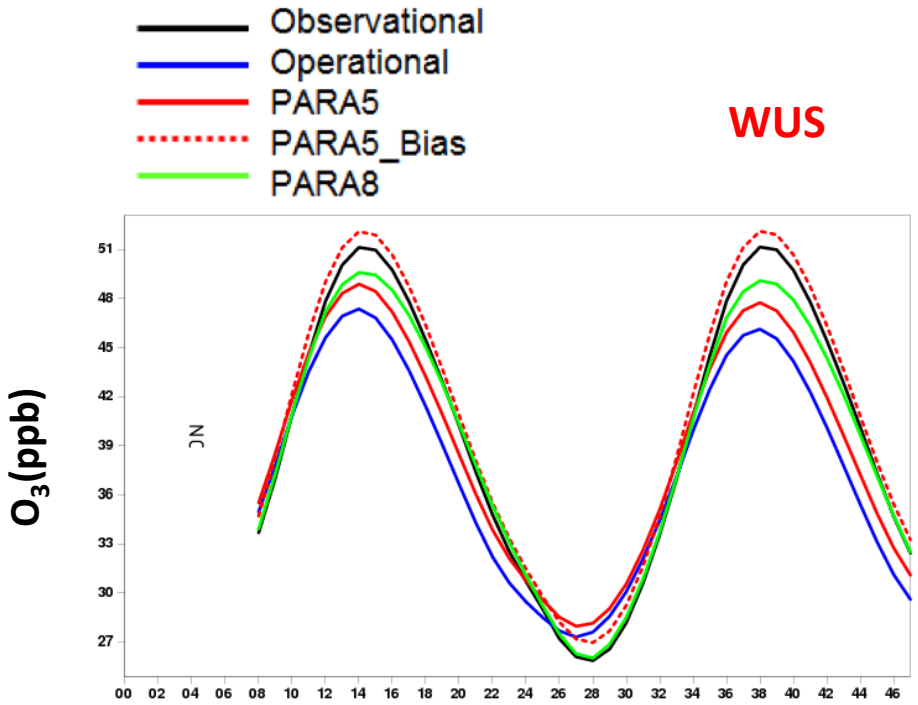
05 UTC on Aug. 15, 2018

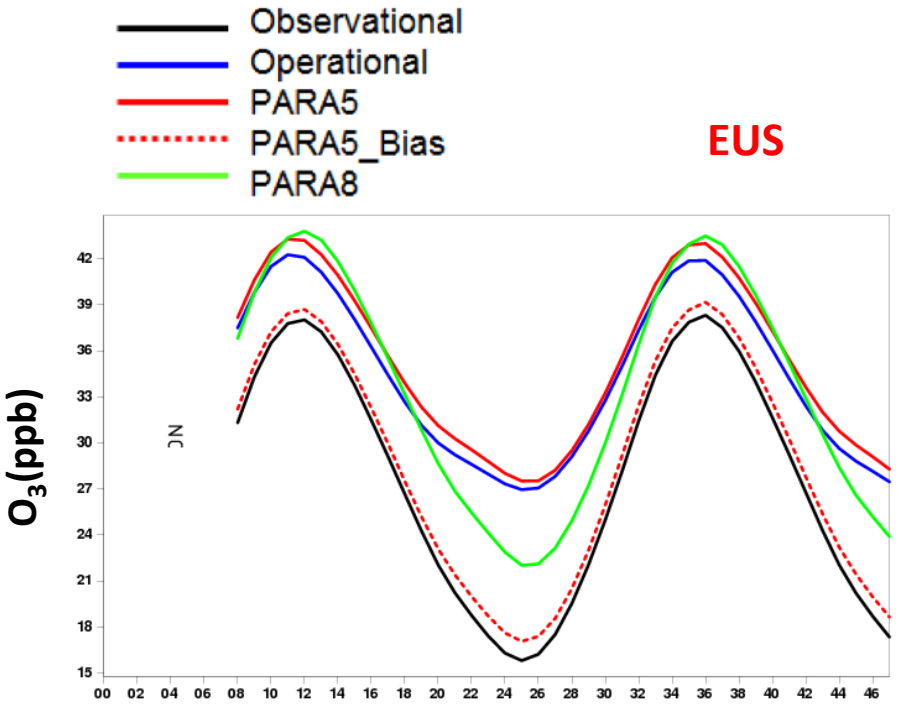


A summary of compared cases

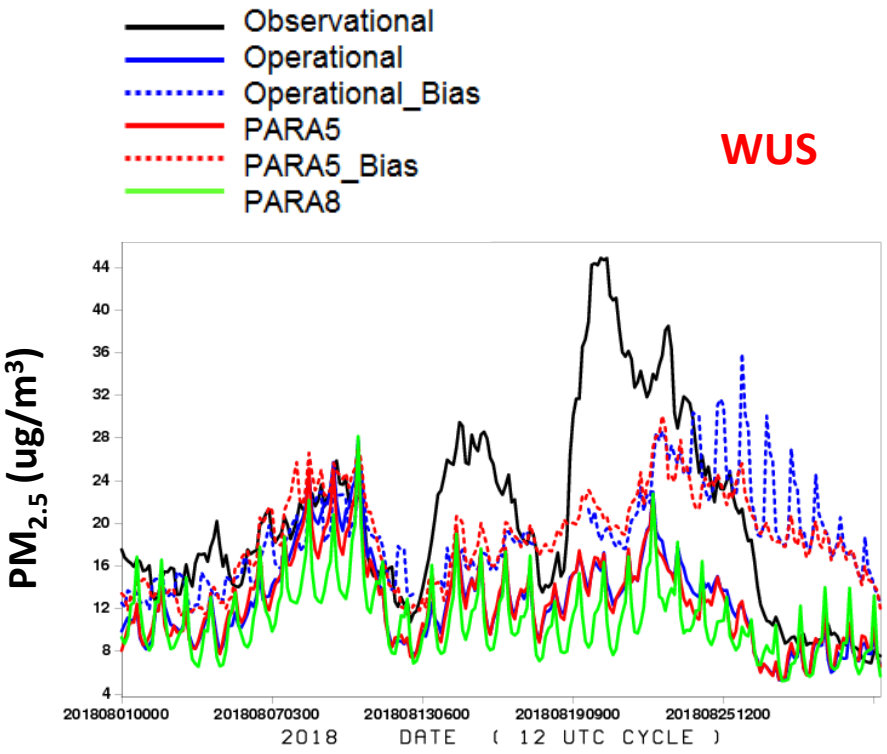
Cases	Met driver	Emissions	LBC for PM
Operational	NMMB (12km)	NEI2005/NEI2011	NGAC without smoke
Operational_Bias			
PARA5	NMMB(12km)	NEI2014	NGAC without smoke
PARA5_Bias			
PARA8	FV3GFS(13km)	NEI2014	NGAC without smoke
PARA82	FV3GFS(13km)	NEI2014	NGAC with smoke

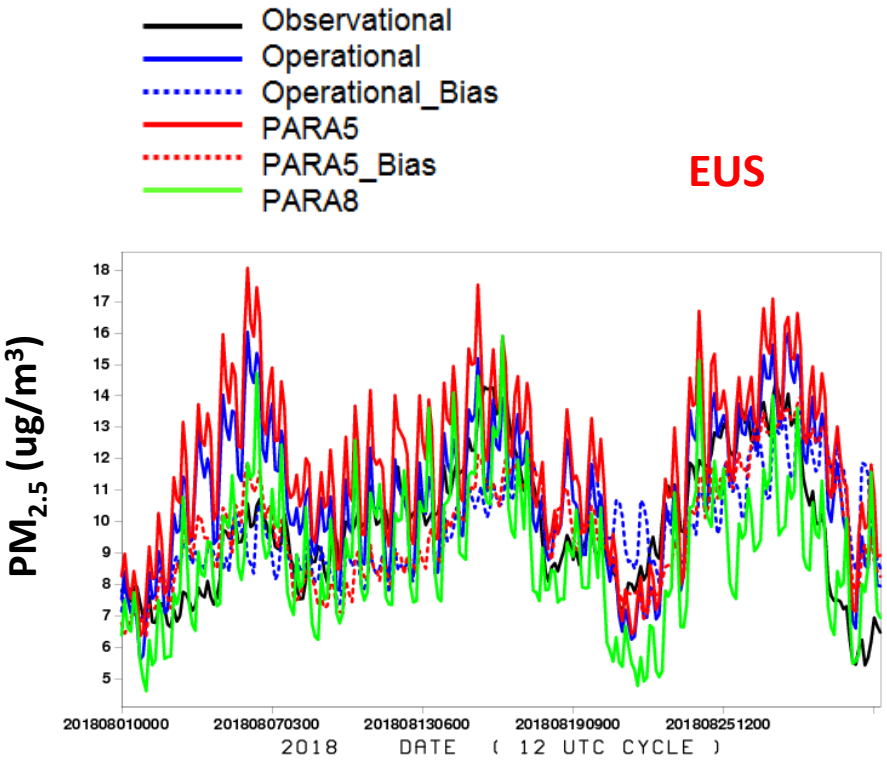
Evaluations of predicted Surface O_3 (Aug. 2018)





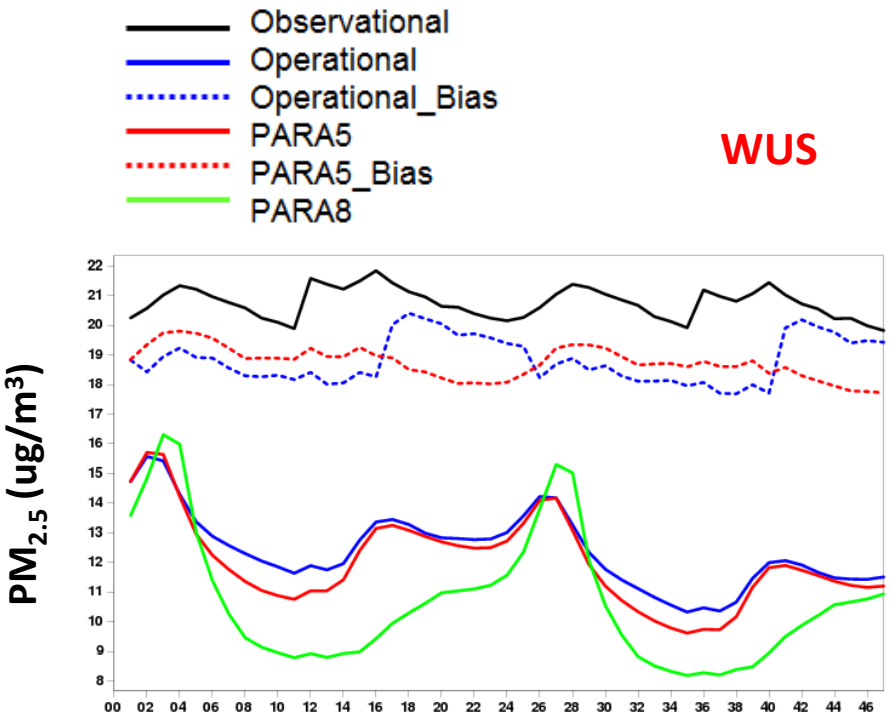
Evaluation of predicted $PM_{2.5}$ (Aug. 2018)

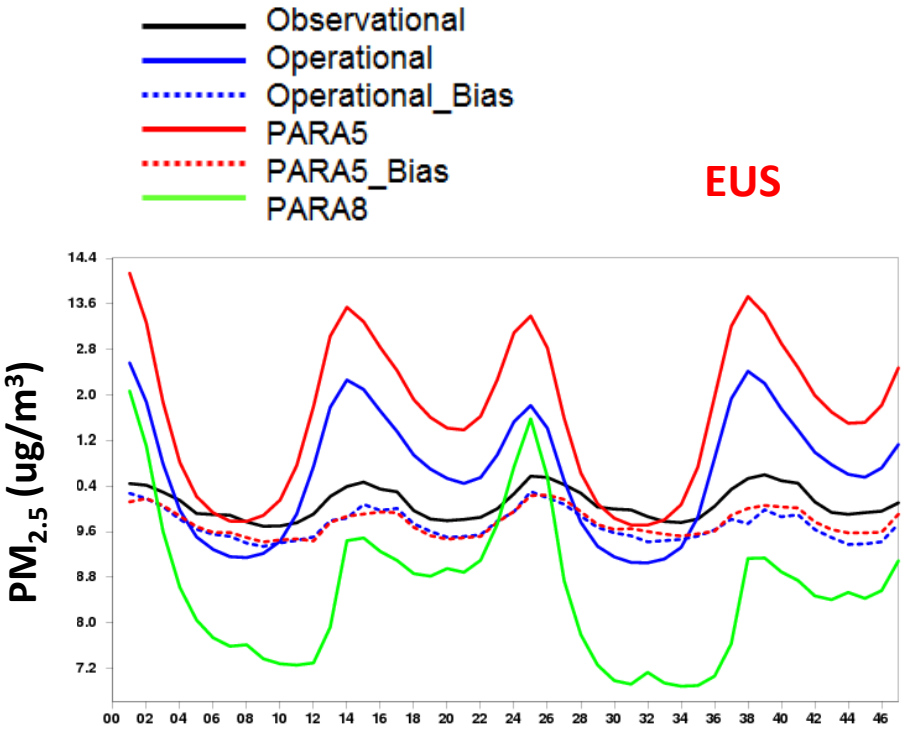




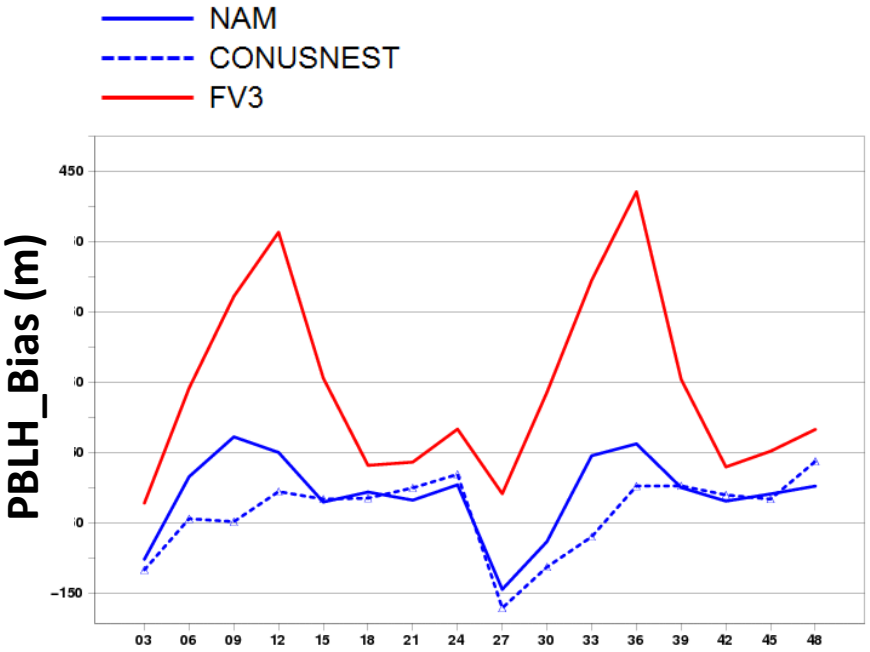
$PM_{2.5}$ under-predicted on those wildfire days over WUS and better agreement over EUS

Evaluation of predicted $PM_{2.5}$ (Aug. 2018)



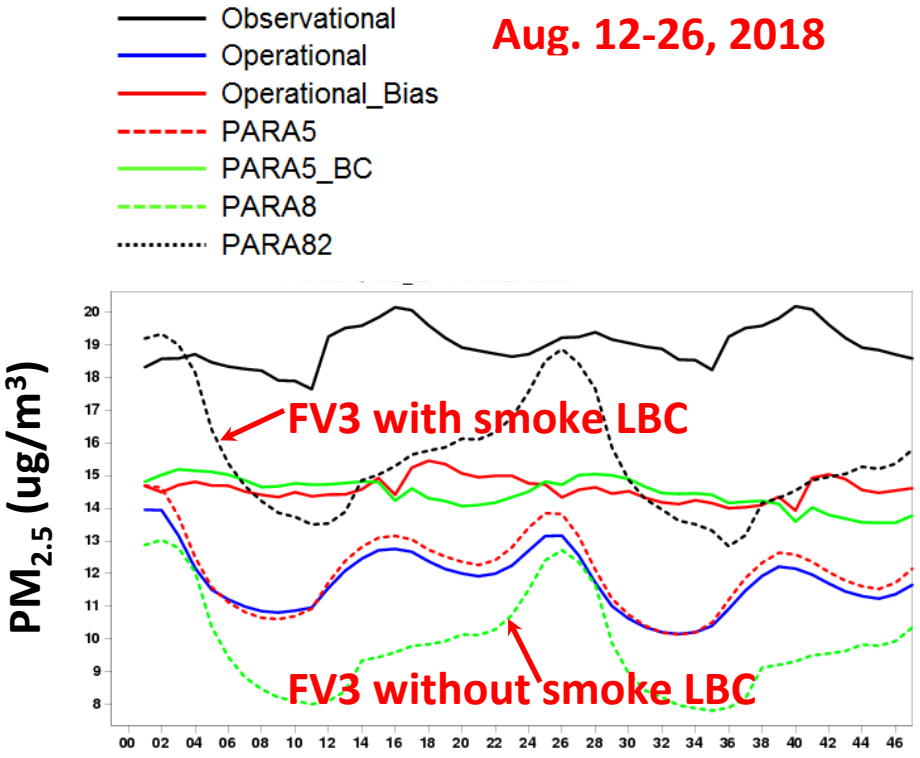


Factors causing $PM_{2.5}$ underpredictions



FCST HR 12 UTC Cycle

Over-predicted PBL heights by FV3GFS



FCST HR 12 UTC Cycle

Under-predicted by excluding smoke LBCs

Summary

- Ozone predictions
  - Improve over WUS but slightly over-predicted over EUS
  - Overall is competitive
- $PM_{2.5}$ predictions
  - Under-predicted during daytime and a sharp increase during the morning transition hours
  - Over-predicted PBL heights and excluding smoke import from Canada are the two main factors causing the under-predictions
  - Too much mixing by FV3GFS EDMF PBL scheme??