What's New in SMOKE 4.9 and 5.0?

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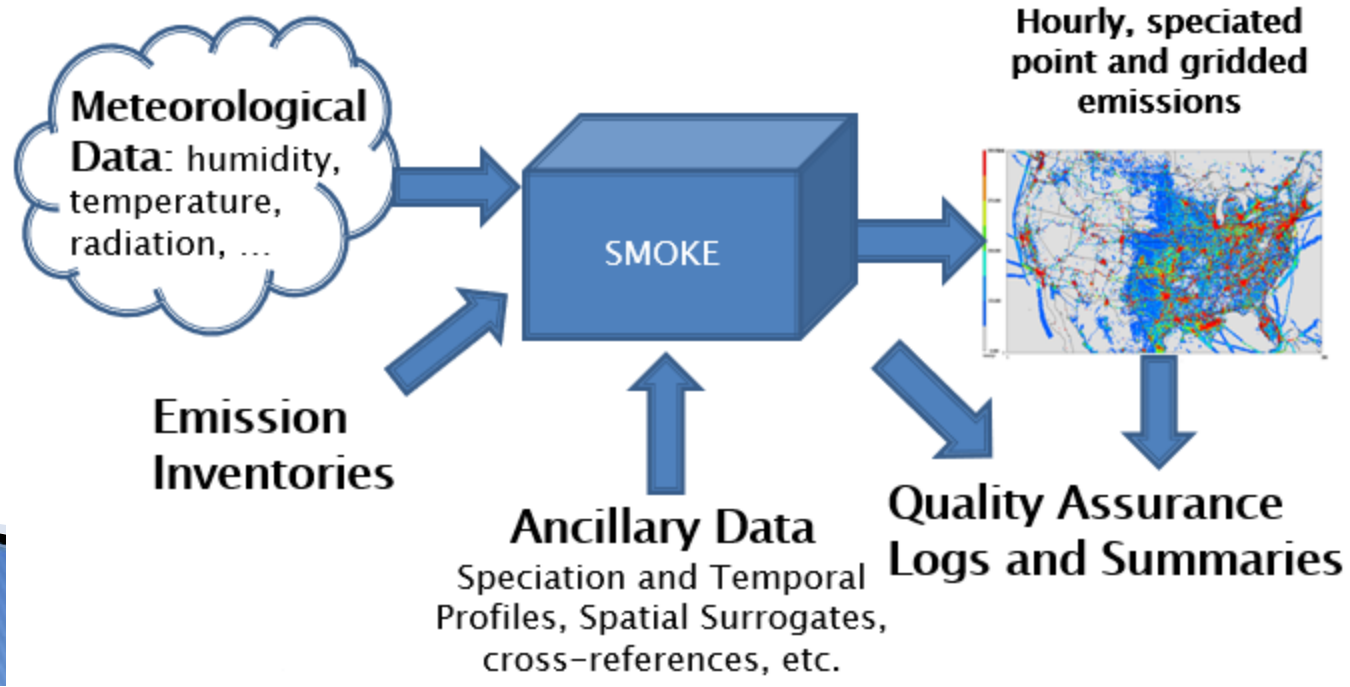
Overview

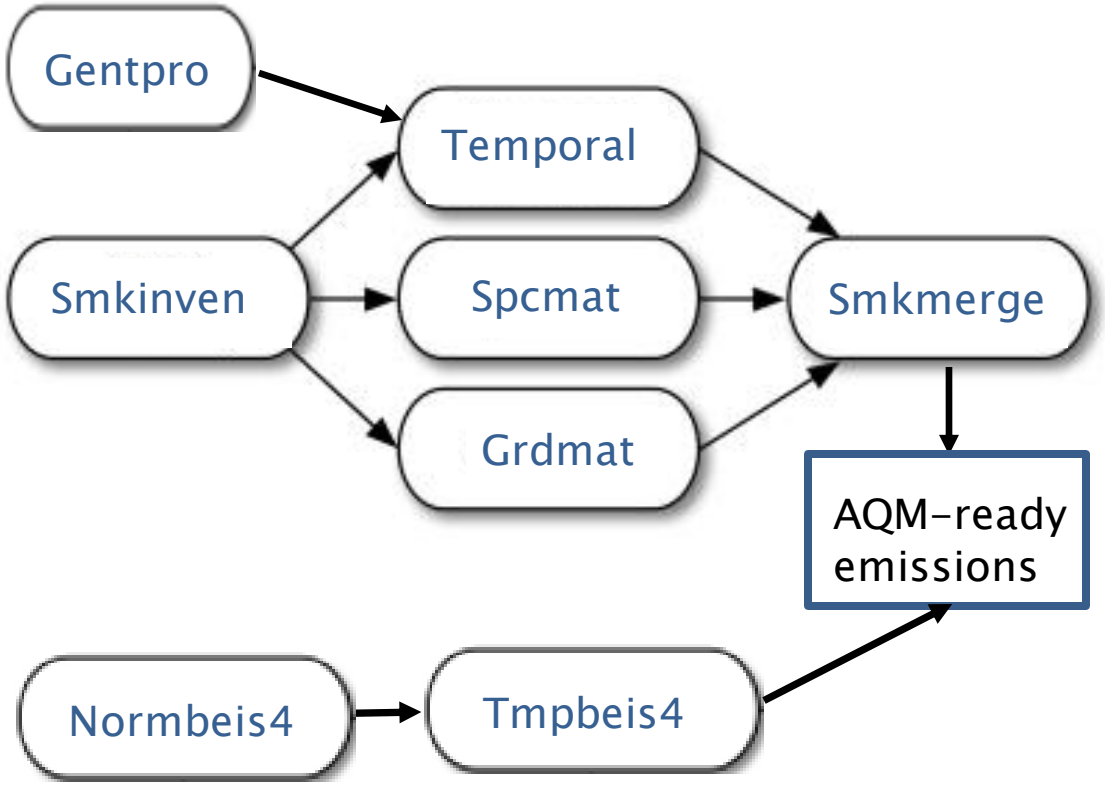
- The Sparse Matrix Operator Kernel Emissions modeling system is used to prepare emissions data for air quality models
- The CMAS Center released version 4.9 in August 2022 and version 5.0 in June 2023

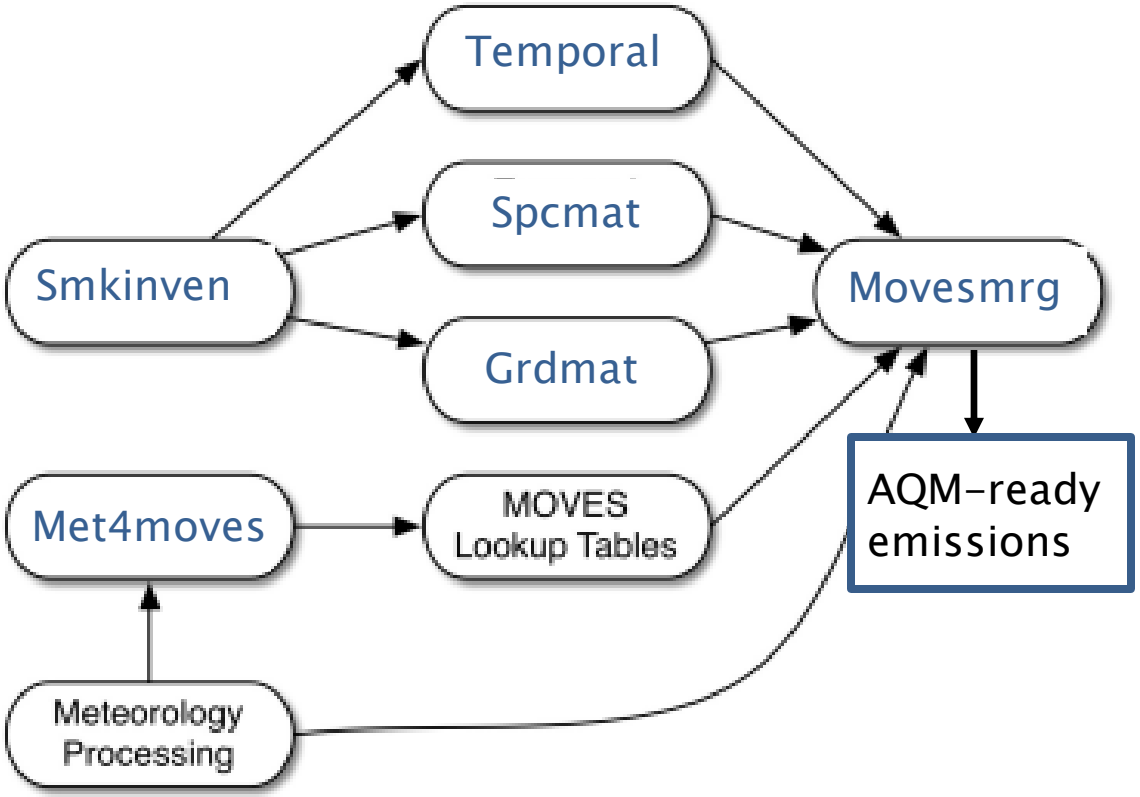


FUN FACT:
The SMOKE prototype was released in 1998, which makes 2023 the *25th anniversary* of SMOKE!

https://www.cmascenter.org/download/release_calendar.cfm

Flow of SMOKE and SMOKE-MOVES Programs





Postprocessors

Smkreport Mrggrid

SMOKE-MOVES programs are run for six groups of MOVES processes that use different activity data (e.g, VMT->RPD, hoteling hours->RPH)

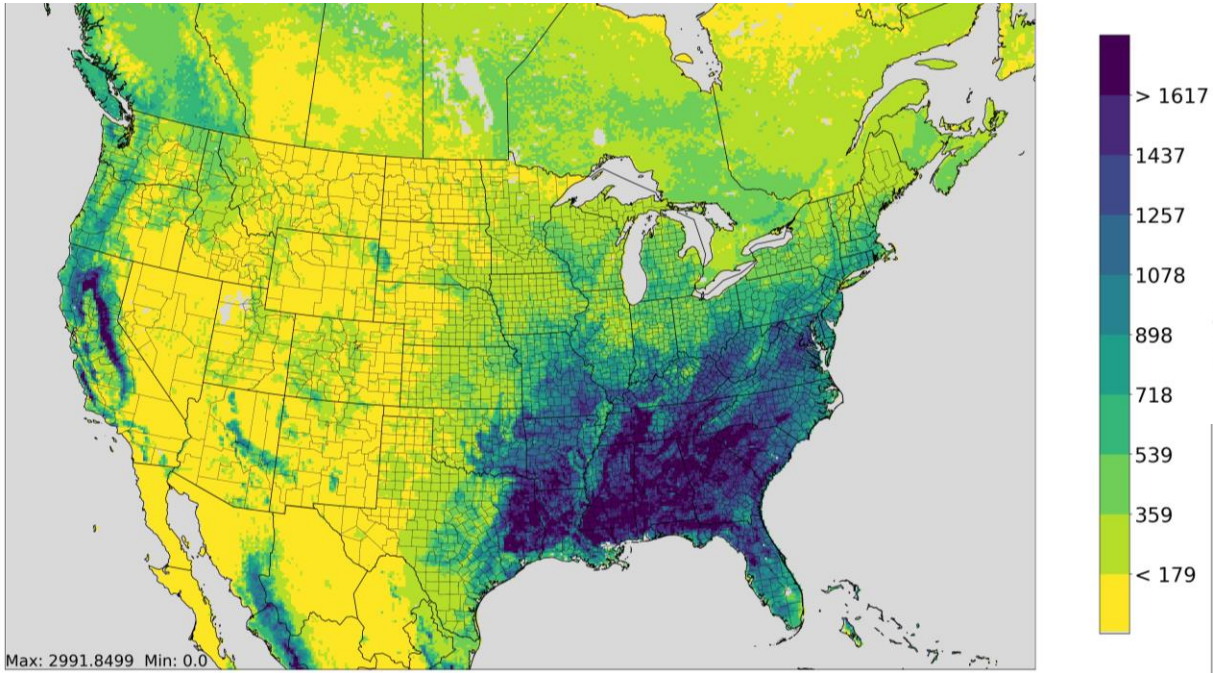
SMOKE 4.9 Updates

- Released August 2022 and was used for EPA's 2020 modeling platform
- Movesmrg (used to generate onroad mobile emissions):
  - Humidity adjustments are now applied to all NOx species ending in INV
  - Corrected issue that resulted in empty subsectors (e.g., gas, diesel)
- Added Biogenic Emissions Information System (BEIS4) support with Normbeis4 and Tmpbeis4 programs
- Smkreport updates (used to generate summaries)
  - Column headers for point sources use updated terminology
  - New options for "BY FACILITY" and "BY BOILER"
  - Applied IOAPI sphere when AERMOD processing is performed
- Other bug fixes in the programs Elevpoint, Gentpro, Normbeis3, Smkmerge, and Temporal
- Restructured SMOKE test case to be based on NEI platform package

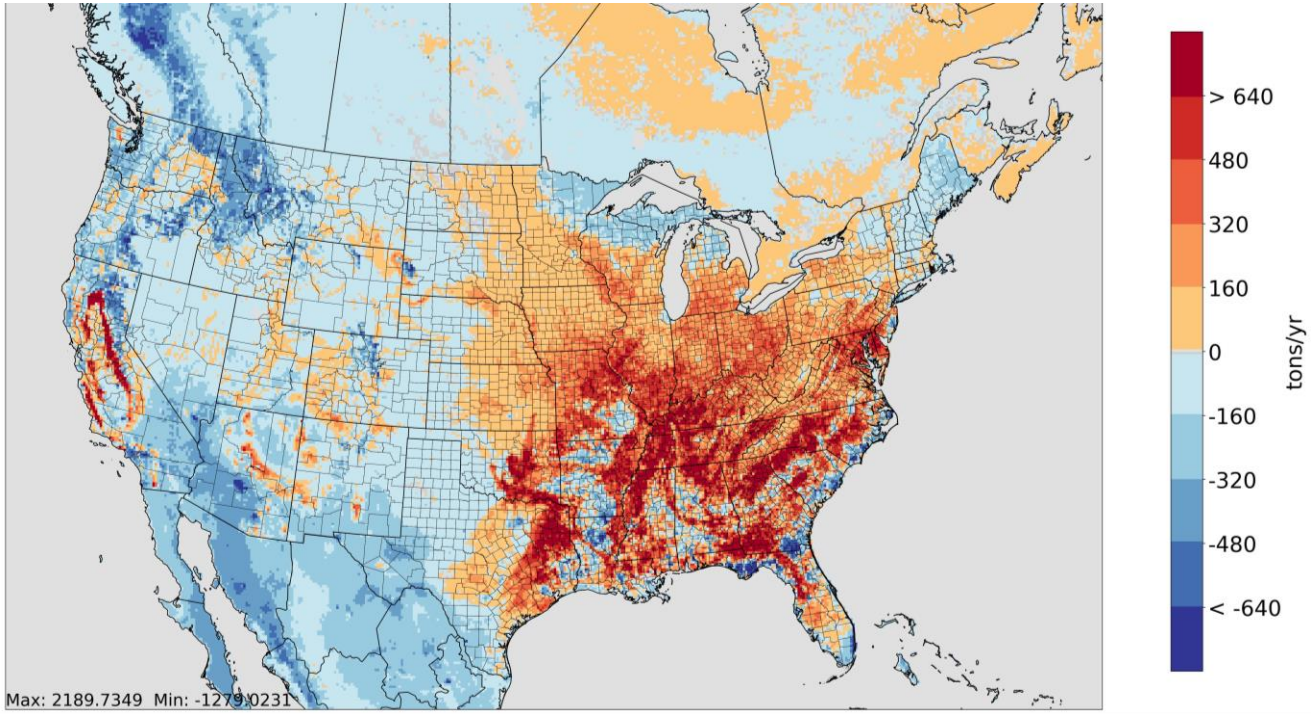
Biogenic Emission Inventory System version 4 (BEIS4)

- Used to produce emissions for the 2020 National Emissions Inventory (2020 NEI)
- Uses Biogenic Emissions Landuse Database (BELD) version 6
  - Utilizes high resolution tree species and biomass data from Wilson et al.
  - **Biomass data now a gridded input as well as the landuse**
  - Includes USDA Cropscape for agricultural landuse data
- Treatment of seasons is improved and the previously used BIOSEASON file is now optional
- Leaf Area Indices (LAI) are now based on WRF-MCIP data
- Nitric Oxide calculation from soils (both fertilized and non-fertilized) are the same as used in BEIS3
- Includes updates to solar radiation treatment and isoprene emissions

Annual VOC emissions (tons) for 2016 using BEIS4



BEIS4 – BEIS3 annual VOC (tons)



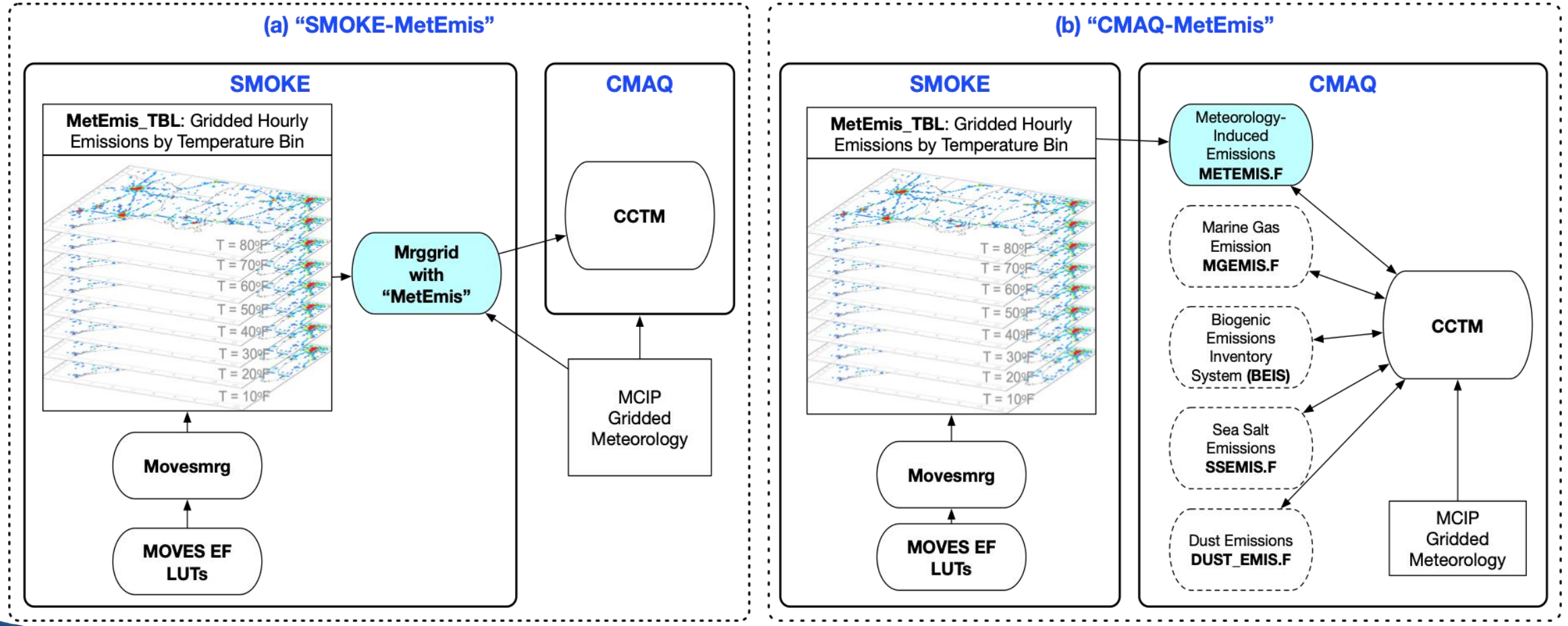
SMOKE Test Case

- We said goodbye to the NC Tox test case (which existed for almost 20 years)
- The new test case is based on EPA's 2018 Emissions Modeling Platform
- Example run scripts for the sectors np_oilgas, pt_oilgas, and beis4 are included
- See https://github.com/CEMPD/SMOKE-TestCase/

SMOKE 5.0 Updates

- Released June 2023
- New option using Movesmrg to generate temperature-bin-specific pregridded hourly emissions for use in Mrggrid ("Met-emis")
- Added option to use the MOVES4 NOx humidity correction equation for onroad emissions
- Updates to Gentpro to prepare met. data for the Farm Emissions Model (FEM) and temporal profiles for recreational wood combustion
- Updates to support new format for Continuous Emissions Monitoring System (CEMS) data in Smkinven
- New BY UNIT report option in Smkreport
- Other bug fixes and enhancements

Met-sensitive Emissions Dynamic Coupler (MetEmis) Diagram



* LUT = lookup table

See:[CMAQ-MetEmis](#) (Baek, et al., GMD,2023)

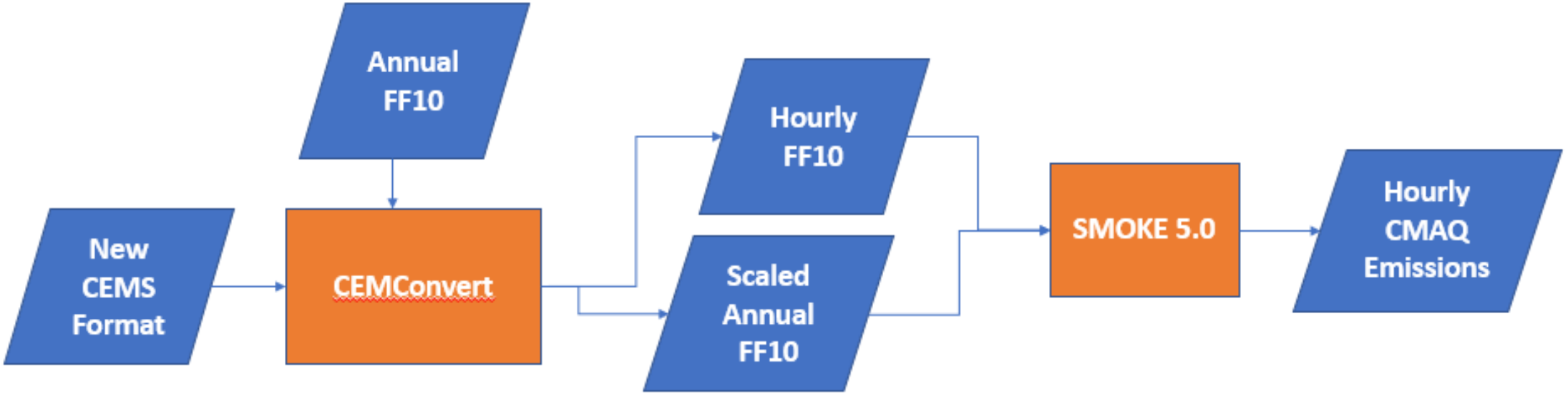
MetEmis Features

- **MetEmis_TBL**: Pseudo-layered Temperature-bin Gridded Hourly Emissions
- Mrggrid in SMOKE and MetEmis.F in CMAQ coupler that can interpolate the emissions between the gridded emissions and between the temperature bins
- Produces the exact same gridded emissions when compared to the ones from current offline SMOKE-MOVES integration tool approaches
- MetEmis_TBL from RPD, RPV, RPH, RPS, and RPHO [all but rate-per-profile (RPP)] can be merged into a single MetEmis_TBL file.
- MetEmis_TBL is portable and can replace the current MOVES EF tables
  - MWDSS MetEmis_TBL by fuel month can replace up to 700 MOVES LUT files/sectors
  - ~4GB size of MetEmis_TBL file per fuel month with 10F temperature increment
- Small computational burden for SMOKE and CMAQ to process MetEmis_TBL
  - < 1 minute of Mrggrid to compute 12km CONUS domain
  - A few seconds for CMAQ, which makes it preferable for air quality forecasting
  - Main downside is reduced reporting / summary capabilities

Support for New CEMS Data Format

- Hourly EGU CEMS data are available at https://campd.epa.gov/data
  - The data are in an updated format that contains more information
- CEMConvert reads the new format and converts the data into an Flat File 2010 (FF10) hourly point inventory file and scales annual FF10 inventory file to match the total of the CEMS data
  - https://github.com/USEPA/CEMConvert
  - The output hourly FF10 file includes the NO_x, SO_2, and CO_2 emissions along with "HOURACT" that reflects the heat input for each emissions unit
- Smkinven uses the data in the hourly point file directly for NO_x, SO_2, and CO_2 and temporally allocates emissions for other pollutants (e.g., PM) based on values of HOURACT
- CEMConvert can also process future year EGU emissions and to remove unmeasured spikes in emissions

Processing CEMS Data in New Format



- FF10 hourly and annual formats are consistent with other emissions sectors
- CEMS to FF10 unit mapping done by CEMConvert and reflected in hourly and annual FF10s
- NO_X, SO_2, and CO_2 CEMS summed annual values **replace** annual FF10 unit values where units are matched to CEMS; HOURACT variable represents hourly activity (i.e., heat input) **IMPORTANT: add HOURACT to the INVTABLE for temporal allocation of other pollutants**
- Quality assurance is simpler and more reliable because annual FF10 values match post-SMOKE model ready emissions values

Point source summaries at different levels

- Updated column headers and Smkreport instructions match FF10 conventions (instead of the older plant, point, stack, segment)

#Date	Source ID	Region	SCC	SIC	Facility ID	Unit ID	Rel Point ID	Process ID	ORIS	BUTADIE	ACROLEI
09/19/2016	1	1001	20100201	0	560011	48133813	45686112	61566714	55271	0.00E+00	3.58E-05
09/19/2016	2	1001	20100201	0	560011	48133913	45686212	61566614	55271	0.00E+00	2.52E-05

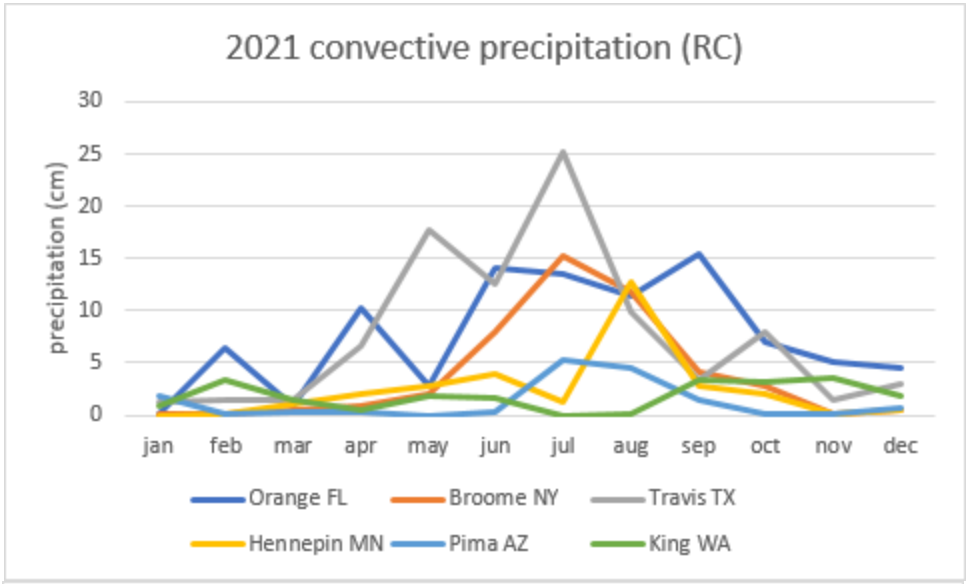
- Summarizing emissions BY UNIT and BY BOILER helps with QA

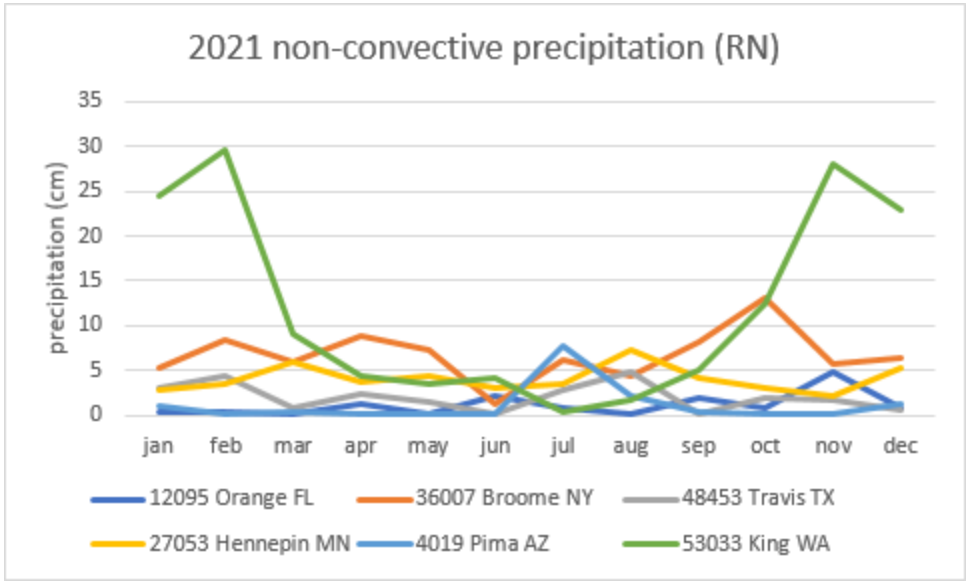
#Date	Facility ID	Unit ID	ORIS	Boiler	BUTADIE	ACROLEI	HCL	CHLORINE	CO	HOURACT	NH3
01/01/2016	560011	48133813	55271	CT1	0.00E+00	4.11E-06	0.00E+00	0.00E+00	3.58E-02	1.96E+04	2.01E-03
01/01/2016	560011	48133913	55271	CT2	0.00E+00	2.74E-06	0.00E+00	0.00E+00	1.75E-02	1.79E+04	1.81E-03

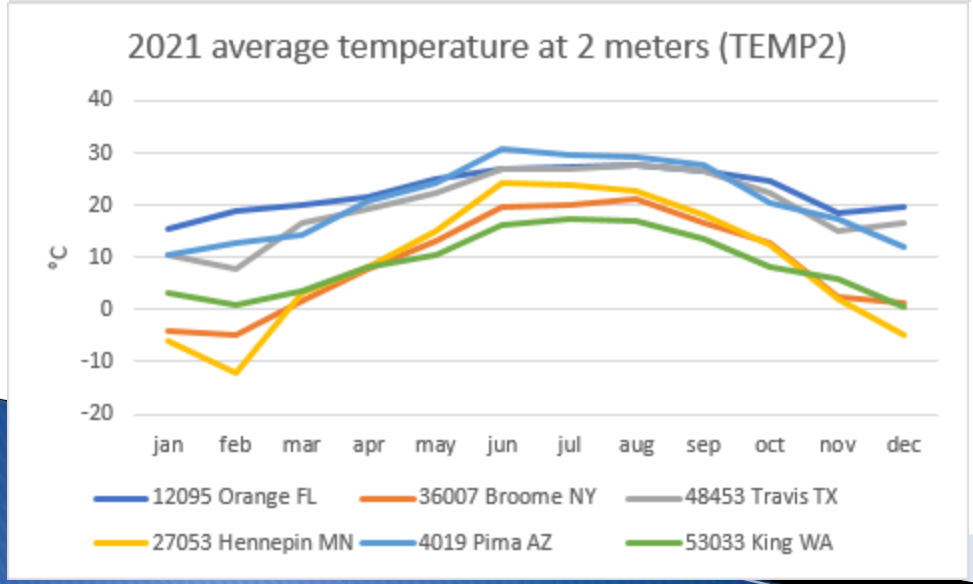
Updates to Gentpro

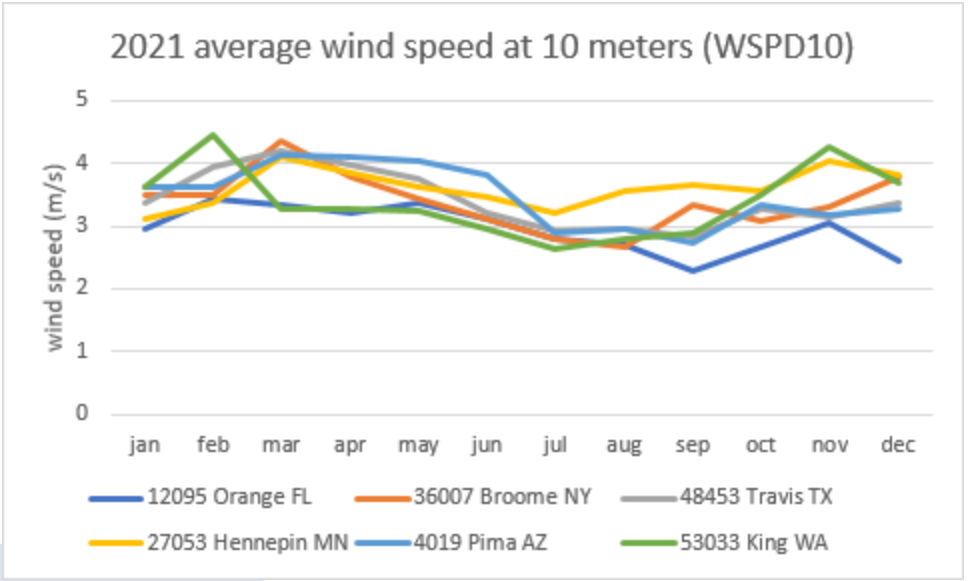
- Gentpro has *historically* been used to create temporal profiles for use by SMOKE based on other data such as meteorological data
  - Annual to day temporal profiles for many types of residential wood combustion emissions
  - Month to hour temporal profiles for agricultural fertilizer and livestock emissions
- Gentpro *can now* generate county-specific profiles for recreational residential wood combustion sources such as fire pits
  - Emissions are allocated to days with the temperature between 50F and 80F at some point during the day – presuming you are not enjoying a firepit in very hot or very cold weather
- Gentpro now prepares meteorological data for the Farm Emissions Model (FEM)
  - FEM needs county-level daily average temperature and wind speed plus daily total precip
  - Now GenTpro can compute these as and average or sum of met. values using the variables
    - Set AVG_RAW_OUTPUT_YN to Y for temperature and wind speed, SUM_RAW_OUTPUT_YN to Y for precipitation
    - Also set PROFILE_METHOD to "MET" (as opposed to AGNH3 or RWC) and set TEMP_VAR to the met variable you want to process, e.g. WSPD10).

FEM meteorology examples from Gentpro

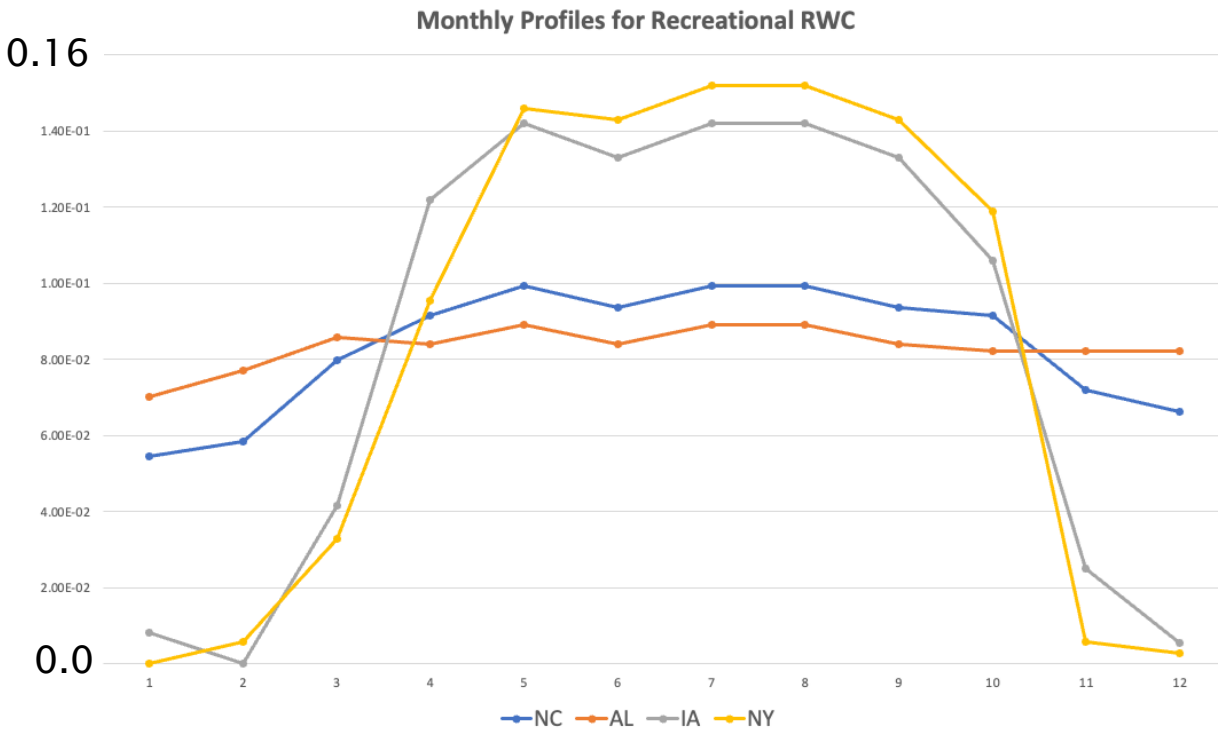




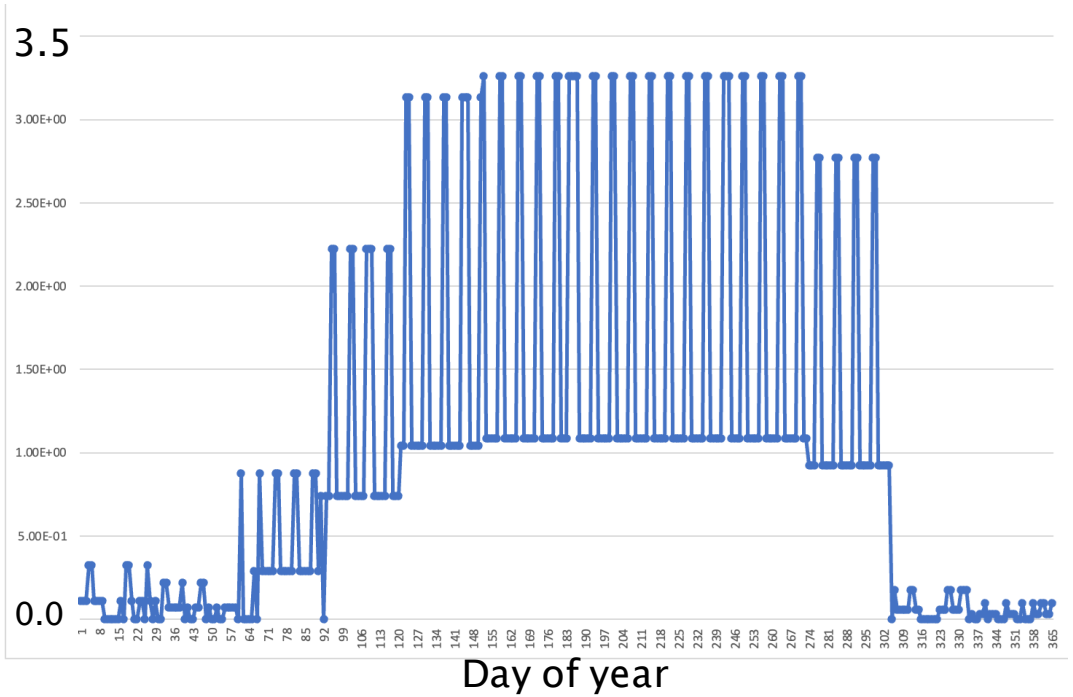




Recreational Wood Burning Profiles



Annual to day output based on meteorology



Northern states now have more emissions in the warmer months
All profiles are county-specific and incorporate day-of-week variations with higher emissions on weekends (33% each weekend day)

SMOKE Training

- The SMOKE training offered by the CMAS Center has been updated to be more modular and is based on EPA's 2018 Emissions Modeling Platform
- The training introduces emissions processing through SMOKE for nonpoint, point, biogenic, and onroad mobile emissions
- Video lectures that introduce and explain topics
- Hands-on exercises for running SMOKE, examining inputs and outputs, and visualizing results are available on a cloud platform
- Live question and answer sessions are available
- Next course offerings:
  - October 10 – October 13, 2023; Spring 2024 dates TBA
  - See https://www.cmascenter.org/training/classes/online-smoke-class.cfm

SMOKE Support and Acknowledgments

- You can submit questions on using SMOKE to forum.cmascenter.org and you can even set up a watch for SMOKE-related issues to see questions from others
- SMOKE continues to evolve to support community and EPA needs – with priorities set in part based on your questions
- SMOKE code and open issues for the software can be found at https://github.com/CEMPD/SMOKE
- Special thanks to James Beidler, formerly of GDIT, for his many contributions to testing SMOKE and for developing related tools including CEMConvert

Conclusions and Next Steps

- SMOKE 5.0 has some helpful new features and will be used for upcoming emissions modeling for base years 2021 and 2022
- SMOKE is running well on Redhat Enterprise Linux 8 so far
- The training will be updated based on feedback from October class
- The SMOKE test case will be enhanced in the coming months
- SMOKE will be further updated as functional needs arise
- EPA's Air Emissions Modeling Website at provides input data for and scripts to run SMOKE, plus detailed Technical Support Documents for EPA platforms
  - https://www.epa.gov/air-emissions-modeling/emissions-modeling-platforms